Course No. : **ENTO-121**

Course Credit: **2(1+1)**

Course Title: Fundamentals of Entomology

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- **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 / insecure* which means 'cut into'.
- Insects came into earth 350-500 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.
- **Entomology: -**Greek word-(Entomon = Insect; Logos = Study) It is the branch of zoology or biological science that deals with the study of insects.
- **Insect: -**The insects are the tracheate arthropods in which the body is divided in to head, thorax and abdomen possessing two pairs of **wings** and three pairs of **legs** and single pair of **antennae**.

- **Branches of Entomology:-**

1.) Study and use of insects in crime investigations is known as **Forensic Entomology.**

2.) Study of insects related to live stock and veterinary animals is known as **Veterinary Entomology.**

3.) Study of insects in relation to Human beings is known as **Medical Entomology.**

HISTORY OF ENTOMOLOGY

- In ancient scripts like Ramayana and Mahabharata, some of the terms used were related to insects. They are;

- Pipilika – **Ant,**
- Pathanga – **grasshoppers,**
- Madhumakshika – **honey bees,**
- Umbakapalika - **termite queen**

References of Insects in Ancient Indian Literature

- **Mahabharta :** (1424 – 1366 BC) Mentions about silk, honey and lac
- The Famous story of "Lakshgruha" i.e. House of Lac build by Kauravas to burn their cousins live, Pandavas.
- Amarkosha Sanskrit dictionary provide references like Patanga and Bhramar of flies , Moths, beetles and Glow worms
- **Sushruta :** Surgeon (100 - 200 AD) : Classified ants (Pipilika), Mosquitoes and Flies
- **Umaswati :** Physician (0 - 100 AD) : Classified the Bees

❖ **Pests of national importance** –

- E.g. Locust, termite and white grub.

Contribution of scientist: -

- **Aristotle (384-322 B.C.) –**
  - He was the **Father of biological classification.**
  - First person grouped insects in Mandibulate and Haustellate types and winged and wing less groups.
  - He gave the terms like Coleoptera and Diptera
- **Carolus Linnaeus (1758**) –
  - **Father of Taxonomy**
  - In his publication **"Systema Naturae"** 1758 includes 28 Indian insect species.
- **J. C. Fabricius (1745- 1808) –**
  - Danish Entomologist described over 10,000 insect species.
  - Published **"Philosophia Entomologia"** in 1778.
  - **World's first Text Book in Entomology.**
  - The first entomologist who made any extensive study of Indian Insects.
  - Classified the insects in to 13 orders based on type of mouth parts.
- **J.G. Koenig (1767-1779) –**
  - J.G Koenig was the first to collect number of insects from Coromandel and Southern India.
  - For his memory Red cotton bug is named as *Dysdercus koenigi*
- **Snodgrass R. E. (1875) –**
  - Great Insect Morphologist referred as a Father of Insect **Morphology.**
  - He wrote book - **Principles of InsectMorphology**
- **Lionel de Nicevelle (1901) –**
  - Was appointed as the first entomologist to the Government of India.
- **Maxwell Lefroy (1903) –**
  - Was appointed as the second entomologist to the Government of India.
  - **First Imperial Entomologist**
  - 1906 publication of 'Indian insect pests'P
  - 1909 publication of Indian insect life'
- **Mithan Lal Runwal (1908) -**

- Outstanding work on Termites / White ants
- Contributions to ecology, embryology and Locust study are noteworthy

- **Sir Vincent B. Wigglesworth**–
  - Insect physiologist, work on blood sucking bug, **Bed Bug.**
  - **Father of Insect Physiology**
- **T.B Fletcher (1914) –**
  - The first Govt. Entomologist of Madras state.
  - Wrote a book 'Some South Indian insects'.
  - **Second Imperial Entomologist.**
- **T.V. Rama Krishna Ayyar (1940) –**
  - Wrote a book 'Hand book of Economic Entomology for South India'
- **H S Pruthi (1963)**–
  - 1934 - First Indian, Imperial Entomologist of Independent India
  - 1963 - He become first Plant Protection Advisor to Government of India
  - 'Wrote a Text book of Agricultural Entomology'
- **Dr. M.S. Mani's (1968)**–
  - Wrote a "General Entomology"
- **Dr. S. Pradhan(1969) -**
  - Wrote a "Insect Pests of Crops" and **Father of ModernApplied Entomology in India**
- **B. Vasantharaj David and T.Kumara Swami (1975) –**
  - Wrote a'Elements of Economic Entomology'
- **M R G K Nair (1975) –**
  - Wrote a'Insects and Mites of crops in India'.
- **K.K. Nayar, N. Ananthakrishnan and B. Vasantharaj David(1976) –**
  - Wrote a'General and applied Entomology'
- **1912-** Plant Quarantine Act was enforced.
- **1914-** Destructive Insects and Pests Act was enforced. (DIPA)
- **1916 -** Imperial Forest Research Institute Established at Dehradun (Uttarakhanda)
- **1925 –** Indian Lac Research Institute started at Ranchi, Bihar
- **1937 -** A laboratory for storage pests was started at Hapur, U.P.
- **1937 -**Entomology division was started in IARI, New Delhi
- **1939 –** Locust Warning Organization established
- **1946-** 'Directorate of Plant Protection, Quarantine and Storage' of GOI started.
- **1968-** The Govt. of India enacted 'Central Insecticide Act' which came into force from 1st January, 1971.

<u>Establishment of entomological institutes</u>

- **IOBC,West Indies(Trinidad)-** (International Organization for Biological and Integrated Control of Noxious animals and Plants)
- **ICIPE,Kenya** – International Centre of Insect Physiology and Ecology
- **NCIPM,New Delhi -** (National Centre for Integrated Pest Management - 1988)
- **PDBC, Bangalore -** (Project Directorate of Biological Control -1993), and thenPDBC

are **(NBAII)** i.e. National Bureau of Agriculturally Important Insects(2009)&nowareNBAIR -National Bureau of Agricultural Insect Resources.

- **CIB, Faridabad –** Central Insecticide Board
- **NPPTI, Hyderabad –** National Plant Protection Training Institute - 1966
- **IGSI, Hapur U.P.** - Indian Grain Storage Institute
- **1946** Directorate of plant protection Quarantine and storage(DPPQS), Faridabad
- **1937** Establishment of Entomology division at IARI New Delhi
- **CABI, UK –** Commonwealth Agricultural Bureau International

★ CLASSIFICATION OF INSECT

- ✓ 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 ofbody.
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) e.g. Trilobite
7. Hexapoda (Hexa- six; poda-legs) or Insecta (In- internal; sect – cut) e.g. Insects.

1. Class : Onychophora

- ♠ Animals forms the connecting link between the phylum **Annelida & Arthropoda**
- ♠ Animals are terrestrial and worm like
- ♠ Body is unsegmented, externally with numerous pairs of unjointed legs

2. Class : Trilobita

- ♠ Animals are marine forms with 3 lobed molded body, Unsegmented head (Cephalon), flexible trunk (Thorax) and (Pygidium) unsegmented tail
- ♠ Head possesses single pair of antennae
- ♠ Body is unsegmented, externally with numerous pairs of unjointed limbs

3. Class: Crustacea

- ♠ Animals are predominantly marine
- ♠ Body is divided in to Cephalothorax & Abdomen
- ♠ **Animals possess five pairs of legs and two pairs of antennae**
- ♠ Respiration by means of **gills**

4. **Class : Arachnida**

♠ The body is divided into cephalothorax and abdomen.
♠ Bears **four pair of legs**
♠ Instead antennae Chelicerae & Pedipalpi present
♠ Respiration by lung books and tracheae

5. **Class : Myriapoda**

♠ The body is divided into head and trunk
♠ Bears single pair of antennae
♠ Each body segment bears appendages
♠ Respiration by lung books and tracheae

Sub Class: Diplopoda

♠ Animals with two pair of legs to each segment

Sub Class: Chilopoda

6. **Class : Insecta**

♠ The body is divided into distinct regions, i.e. Head, Thorax and Abdomen.

♠ Single pair of antennae on head.

♠ Three pairs of legs on thorax.

♠ Two pairs of wings on thorax.
♠ The genital opening are situated on 8^{th} and 9^{th} abdominal segments

♠ Respiration by means of tracheae

♠ Undergo Metamorphosis

♠ Possess exoskeleton made up of hard cuticle which plays important role for survival
♠ Excretion is mainly by malpighian tubules which help in maintaining ionic balance.

★ INSECT DOMINANCE

❖ **Measures of dominance:**

1. More number of species.
2. Large number of individuals in a single species: e.g. Locust swarm comprising of 10 numbers 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 smaller size**: Majority of insects are small in their size conferring the following physiological and ecological advantages.
3. **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.
4. **Resistance to desiccation**: Insects minimize 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, reabsorption of water from fecal matter, use less quantity of water to remove the nitrogenous waste)
5. **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.
6. **Higher reproductive potential**: Reproductive potential of insect is high e.g. 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.
7. **Presence of complete metamorphosis**: More than 82 per cent of insects undergo complete metamorphosis (holometabolous insects) with four stages. As the larval and adult food sources are different, competition for food is less.
8. **Presence of defense mechanisms**: By different defense mechanisms, insects escape from the enemies to increase their survival rate.
9. **Hexapod locomotion**: Insects uses 3 legs at a time during locomotion, while the remaining 3 legs are static, which gives greater stability.

★ ECONOMIC IMPORTANCE OF INSECTS

The field of entomology may be divided into 2 major aspects.

1. Fundamental Entomology or General Entomology
2. Applied Entomology or Economic Entomology

❖ ***Fundamental Entomology:-***

- ✓ It deals with the basic or academic aspects of the Science of Entomology.
- ✓ It includes morphology, anatomy, physiology and taxonomy of the insects.
- ✓ In this case we study the subject for gaining knowledge on Entomology irrespective of whether it is useful or harmful.

❖ ***Applied Entomology or Economic Entomology:-***

- ✓ It deals with the usefulness of the Science of Entomology for the benefit of mankind.
- ✓ Applied entomology covers the study of insects which are either beneficial or harmful to human beings.

- ✓ It deals with the ways in which beneficial insects like predators, parasitoids, pollinators or productive insects like honey bees, silkworm and lac insect can be best exploited for our welfare.
- ✓ Applied entomology also studies the methods in which harmful insects or pests can be managed without causing significant damage or loss to us.

Economic classification of insects

- ➢ Insects can be classified as follows based on their economic importance.

1. Insects of no economic importance:-

There are many insects found in forests, and agricultural lands which neither cause harm nor benefit us.

2. Insects of economic importance:-

A. Injurious insects

a) Pests of cultivated plants (crop pests)

Each cultivated plant damage by many insect pests which feed on them reduces the yield of the crop. E.g. cotton bollworm, Rice stem bores.

b) Storage pests

Insects feed on stored products and cause economic loss. E.g. Rice weevil, Pulse beetle.

c) Pest attacking cattle and domestic animals

Cattle are affected by pests like Horse fly, Flesh fly, Fleas and Lice. They suck blood and sometimes eat the flash.

d) House hold and disease carrying insects

House hold pests include cockroach, ants, etc. Disease carrying insects are like mosquitoes, houseflies, bed bugs, fleas etc.

B. Beneficial insects

I) Productive insects

i) **Silk worm: -** The silk worm filament secreted from the salivary gland of the larva helps us in producing silk.

ii) **Honey bee: -** Provides us with honey and many other byproducts like bees wax and royal jelly.

iii) **Lac insects**: - The secretion from the body of these scale insects is called lac. Useful in making vanishes and polishes.

iv) **Insects useful as drugs, food, ornaments** etc.,

(a) As medicine e.g. Sting of honey bees- remedy for rheumatism and arthritis Eanthoridin - extracted from blister beetle –useful as hair tonic.

(b) As food - for animals and human being. For animals- aquatic insects used as fish food. Grasshoppers, termites, pupae of moths. They have been used as food by human beings in different parts of the world.

(c) Ornaments, entertainers

-Artists and designers copy colour of butterflies.

- Beetles worm as necklace.

- Insect collection is a hobby.

(d) Scientific research

Drosophila and mosquitoes are useful in genetic and toxicological studies respectively.

(II) Helpful insects

(i) **Parasites:** These are small insects which feed and live on harmful insects by completing their life cycle in a host and kill the host insect. E.g. egg, larval and pupal parasitoids

(ii) **Predators:** These are large insects which capture and devour harmful insects.E.g. Coccinellids and Preying Mantid.

(iii) **Pollinators:** Many cross pollinated plants depend on insects for pollination and fruit set. E.g. Honey bees, aid in pollination of sunflower crop.

(iv) **Weed killers:** Insects which feed on weeds kill them thereby killers. E.g. Mexican beetle eats on Parthenium (Gajar gavat). Cochineal insect feeds in *Opuntia dillenii.*

(v) **Soil builders:** soil insects such as ants, beetles, larval of cutworms, crickets, collombola, make tunnels in soil and facilitate aeration in soil. They become good manure after death and enrich soil.

(vi) **Scavengers:** Insects which feed on dead and decaying matter are called scavengers.They important for maintaining hygiene in the surroundings.E.g. Carrion beetles, Rove beetles feed on dead animals and plants.

d) House hold and disease carrying insects

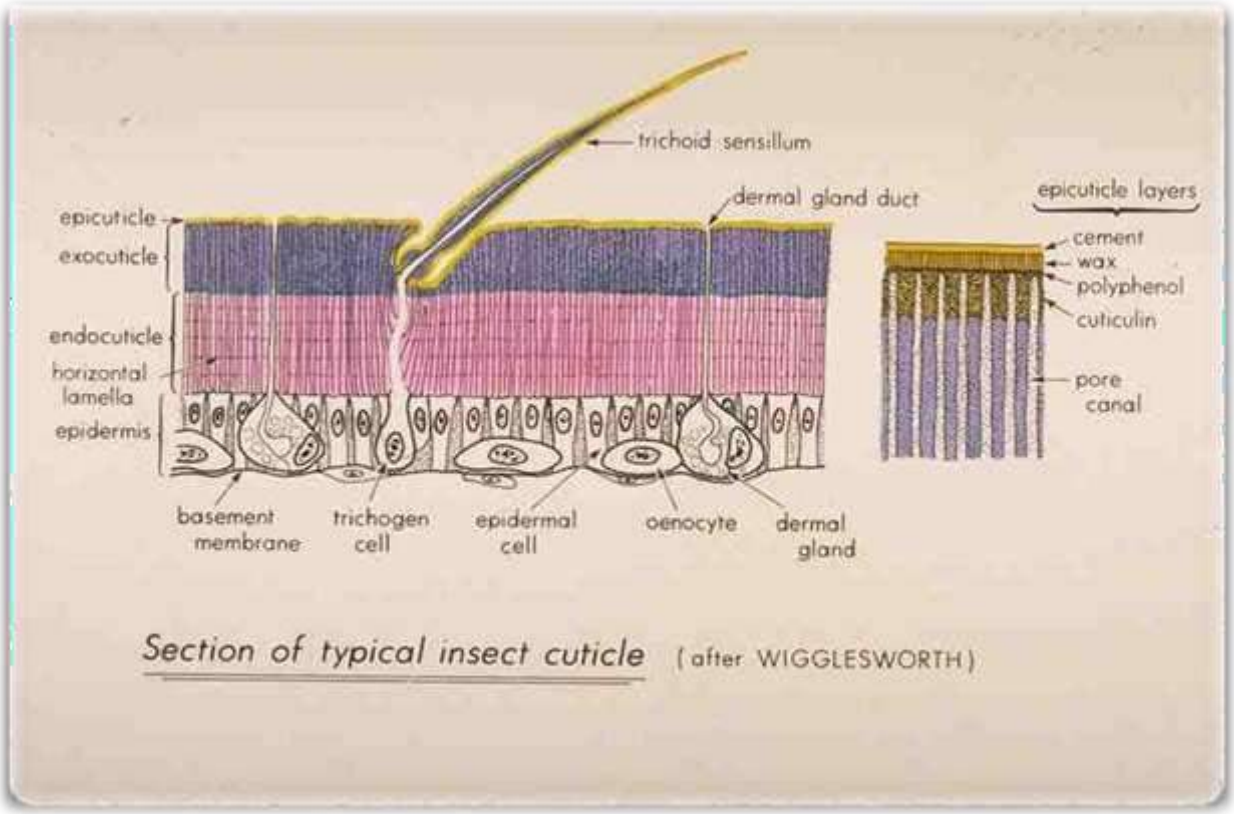
ii) Pests which cause damage to belongings of human being like furniture, wool, paper etc. E.g. Cockroaches, furniture beetle, sliver fish etc.

iii) Pests which cause painful bite, inject venoms. E.g. Wasps, bees sting us. Hairy caterpillar nettling hairs are poisonous. Mosquitoes, bugs bite, piece and suck blood from us.

iv) Disease causing Mosquito- Malaria, Filariasis, dengue fever. Housefly- Typhoid, Cholera, Leprosy, Anthrax.

★ INSECT INTEGUMENT

- The vertebrates have internal skeleton known as **endoskeleton**while in insects it is located outside the body forming exoskeleton.
- Insect cuticle provides space for attachment of muscles of antenna and mouthparts, called as **tentorium**.
- Insect body wall iscalled as **Integument or Exoskeleton.** It is the external covering of the body which is ectodermal in origin. It is rigid, flexible, lighter, stronger and variously modified in different body parts to suit different modes of life.
- Integument consists of 3 layers:-
  1) **Cuticle** (Upper)
  2) **Epidermis (or) hypodermis**(Middle)
  3) **basement membrane (**Inner)



1. Cuticle:-

- ✓ It is outermost thick layer of integument secreted by epidermis.
- ✓ It is non-cellular.
- ✓ It is divided in to two regions:-**Epicuticle** (Upper) and **Procuticle**(Inner)

A. Epicuticle:

- ✓ It is a thin outermost layer varying in thickness from 1-4µ. **Chitin is absent in epicuticle.**It consists of the following **4** layers

- **Cement layer:**It is secreted by dermal glands and is composed of lipoprotein.It protects the body from external damage.
- **Wax layer:** Itconsisting of long chain hydrocarbons, esters of fatty acids and alcohols. It serves as water proof layer preventing water loss from the body
- **Polyphenol layer:** It is a non-static layer containing various types of phenols which are mainly used in the formation of the proteins.It is resistant to acids and organic solvents.
- **Cuticulin layer:** It is an amber coloured thin layer over the surface of the epidermis which is strengthened by outer polyphenol layer.It serves the purpose of permeability and also acts as growth barrier.

B. Procuticle:

- ❑ It is differentiated in to **exo** and **endocuticle.**
- ✓ **Exocuticle:** It is darkly pigmented, hard and sclerotized. **This layer is made up of chitin and sclerotin.**
- ✓ **Endocuticle:** It is soft, light coloured and unsclerotized. **This layer is made up of chitin and arthropodin.**

- **Pore canals:** These are numerous fine vertical channels traversing both exo and endocuticle. Pore canals present in the exocuticle helps in the deposition of epicuticle. They are useful in transportation of cuticular material and enzymes to the outer pro and epicuticle parts.

❖ **Composition of cuticle:**

♣ Two major components of insect cuticle are; i) **Chitin**,ii) **Proteins.**

i) Chitin:

- ✓ It is a **nitrogenous polysaccharide.**
- ✓ It consists of high molecular weight polymer of **anhydro-N-acetyl glucosamine** residues joined by **β-glycosidic linkages.**It is water insoluble but soluble in dilute acids, alkalies and organic solvents.

ii) Proteins: Cuticle has 3 types of proteins

- ✓ **Arthropodin:**An untanned protein means it is soft water soluble protein present in endocuticle. The conversion of arthopodin in to sclerotin is known as sclerotization or tanning.
- ✓ **Sclerotin:**It is also called tanned protein which is amber coloured and present only in exocuticle.This is water insoluble.
- ✓ **Resilin:**It is a rubber like elastic protein which is colourless and present in joints such as wing hinge ligaments, leg joints, clypeolabral joints or suture and tergosternal joints.

2. Epidermis (or) hypodermis:

- ✓ It is an inner unicellular layer resting on basement membrane with the following function.
  i. Cuticle secretion
  ii. Digestion and absorption of old cuticle
  iii. Wound repairing
  iv. Gives surface look
- ✓ Adjacent epidermal cells are held together by means of certain cytoplasmic processes which are known as **desmosomes**.
- ✓ All the epidermal cells are glandular and secrete cuticle and the enzymes involved in production and digestion of old cuticle during moulting.
- ✓ The epidermal cells get differentiated in to following types based on the function they perform and may modify in to;
  a) **Dermal glands** producing cement layer
  b) **Trichogen cell** producing hair like seta or trichome.
  c) **Moulting glands** secreting moulting fluid which digests the old cuticle
  d) **Peristigmatic glands** around the spiracles in case of Dipteran larvae

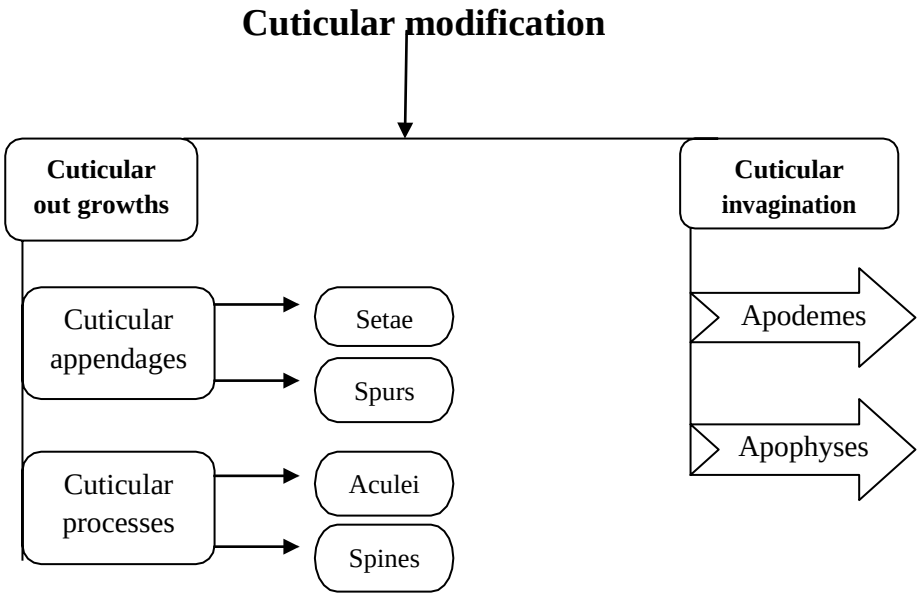
3. Basement membrane:

- ✓ It is the basal part of the body wall formed from degenerated epidermal cells and appears as non-living amorphous (shapeless) granular layer of integument.
- ✓ It is about 0.5µ in thickness and consists of fibrous protein, glycosaminoglycans which are polymers of disaccharides.
- ✓ The basement membrane forms a continuous sheet beneath the epidermis, where muscles are attached and become continuous with sarcolemma of the muscles.

Functions of Insect Integument

- o It provides protection to the internal organs enclosed by it.
- o It gives shape and size to the insects.
- o It provides surface for the attachment of muscles.
- o It conserves moisture and prevents desiccation.
- o It prevents entry of pathogens and insecticides.
- o It forms sense organ.
- o It contains pigments to make insects attractive.

★ CUTICULAR/ INTEGUMENTAL MODIFICATIONS:



A. Cuticular out growths:

✓ They are divided into **cuticular appendages** and **cuticular processes** depending on the **presence or absence of membranous articulations.**

I. Cuticular appendages:

- These are the outgrowths of the cuticle / integument connected with it by means of a membranous joint. They arise from modified epidermal cells. These are classified in to **setae and spurs.**

(1) Seta/ Macrotrichia:

♣ Commonly known as **hairs** and arise from a cup like alveolus or pit. Setae are hollow structures developed as extension of exocuticle and are produced by a single enlarged hypodermal cell called **' trichogen' cell**. Articular membrane is usually produced by a second hypodermal cell called '**tormogen' cell.**

♣ Setae have role of taxonomic importance and vary with species to species. *Study of arrangement of setae is known as* '**chaetotaxy'.**

(2) Spurs:

♣ Occur on the **legs** of many insects and differ from setae in beingmulticellular in origin.

II. Cuticular processes:

- They have **no membranous articulation**; They are of two types

(1) Microtrichia / fixed hairs / aculei:

♣ These are minute hair like structures found on wings of Mecoptera and certain Diptera.

(2) Spines:

♣ Outgrowths of the cuticle which are more or less thorn like in form**.**

Sr. No.	Spurs	Spines
1	Cuticular appendages	Cuticular processes
2	Movable, multicellular structures and thick walled	These are immovable outgrowths of cuticle
3	E.g.: present on tibia of plant hoppers and honey bees	E.g.: hind tibia of grasshopper and leaf hoppers

B. Cuticular invagination:

- The body wall or cuticle of the body wall invaginate internally and grow in to definite structures which are of two types.
- **Apodemes-** Hollow cuticular invaginations whichprovide area for muscle attachment
- **Apophyses**- Solid invaginations of the cuticle which gives mechanical support to various organs by forming distinct skeletal structures.

★ MOULTING PROCESS

- Process of periodical shedding of old cuticle and formation of new cuticle this process is known as **moulting.** It is a complex process which involves: - Apolysis, Ecdysis and Sclerotization.

Apolysis : [Apo = formation ; Lysis = dissolution]

- The dissolution of old cuticle and formation of new one is known as apolysis.
- It starts with repeated mitotic division of epidermal cells resulting in increase in number and size of epidermis, Because of this change, the epidermal cells exert tension on cuticular surface and as a result get separated them from the cuticle.
- Due to separation of epidermis from the cuticle a sub cuticular space is created and the epidermal cells starts producing their secretion i.e. moulting fluid and cuticular material into this space.

Ecdysis :

- The stage where the insect has both newly formed epi and procuticle.
- The ecdysial membrane starts splitting along the line of weakness due to muscular activity of the inner developing insect and also because of swallowing of air & water resulting in the distention of the gut and also due to the pumping of blood from abdomen to thorax through muscular activity.
- After the breakage of old cuticles, the new instar comes out bringing its head followed by thorax, abdomen and appendages.

Sclerotization :

- After shedding of old cuticle the new cuticle which is soft, milky white coloured becomes dark and hard through the process known as tanning (or) sclerotization.
- **Three** types of **hormones** involved in the process of moulting which are as follows-
- **JH: Juvenile Hormone: Produced** from corpora allata of brain that helps the insects to be in immature stage.
- **MH: Moulting hormone:** Produced from prothoracic glands of brain that induces the process of moulting.
- **Eclosion Hormone:** Released from neurosecretory cells in the brain that help in the process of ecdysis or eclosion.

★ BODY SEGMENTATION OF INSECT

- Cockroach, *Periplanata americana* is a typical insect as it possesses all important characters of class insect.
- In general, insect body is divided in to a series of rings or segments are known as "**somites" or "metameres".**
- During the process ofevolution, these somites get fused with each other in different ways forming the body parts of the existing arthropods.
- The type of arrangement of these body segments in embryonic stage is known as **primary segmentation** while in adult insects is known as the **secondary segmentation.**
- Insect body is divided in to three **regions** or **tagmata** namely head, thorax and abdomen. This grouping of body segments in to regions is known as **tagmosis.**
    - **Head** consists of 6 segmentspossessesmouthparts, compound eyes, simple eyes (ocelli) and a pair of antennae.
    - **Thorax** consists of 3 segments i.e. prothorax, mesothorax and metathorax, Meso and metathorax are together known as pterothorax. All the three thoracic segments possess a pair of legs and meso and meta thorax possess one pair of wings.
    - **Abdomen** has 11 segments with genital appendages on 8th and 9th segments.
    - **The insect body generally consists of 20 segments.**

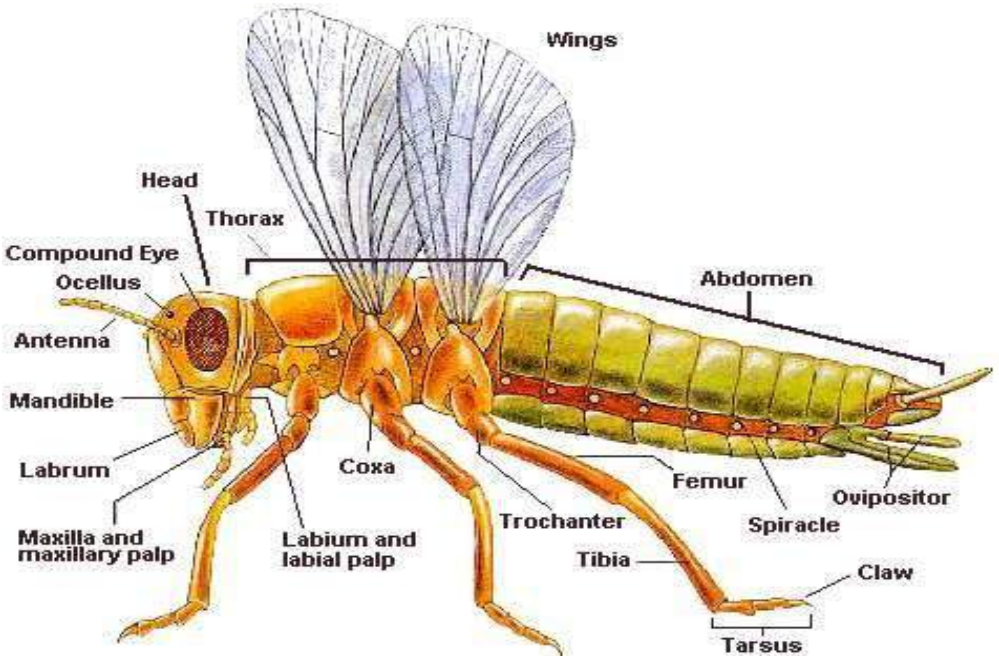


Fig. General Organization of Insect Body

INSECT HEAD

- It is the foremost part in insect body consisting of **6 segments** that are fused to form a head capsule.
- The head segments can be divided in to two regions i.e. **procephalon** and **gnathocephalon** (mouth).
- Head is attached or articulated to the thorax through neck or cervix.
- Head capsule is sclerotized and the head capsule excluding appendages formed by the fusion of several sclerites is known as cranium.
- Inside the head, an **endoskeletal** structure called the **tentorium**which give supports to the brain, and provides a rigid origin for muscles of the mandibles and other mouthparts.
- **Head is concerned with feeding and sensory perception**.

	Segment		**Appendages**
I	Pre antennary segment	Procephalon	Pair of compound eyes& three ocelli (Simple eyes)
II	Antennary segment		Pair of Antennae
III	Intercalary segment		Single labrum
IV	Mandibular segment	Gnathocephalon	Pair of Mandibles
V	Maxillary segment		Pair of Maxillae
VI	Labialsegment		Single Labium

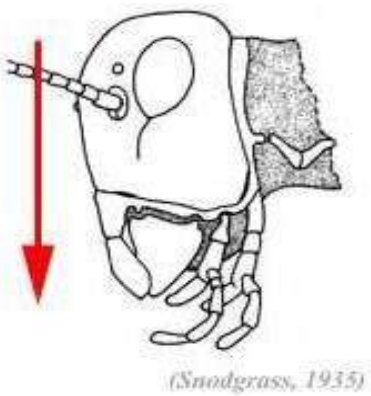
Types of head position:

The orientation of head with respect to the rest of the body varies. According to the position or projection of mouth parts the head of the insect can be classified as;

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

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

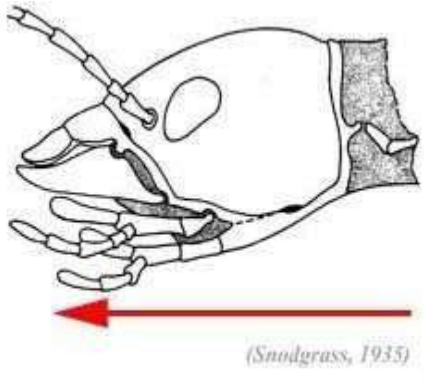
Eg: Grass hopper, Cockroach.




CockroachGrass hopper

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

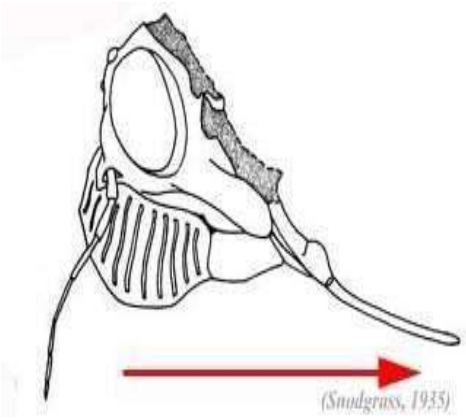
The head remains in the same axis to body and mouth parts are projected forward. This is also known as Coleopteroid type.Eg: beetles



Beetles

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

It is same as prognathous but mouthparts are directed backward and held inbetween the fore legs. .This is also kwown as Hemipteroid or Opisthorhynchous type.Eg: bugs



Mosquito Red cotton bug

SCLERITES AND SUTURES OF HEAD

The head capsule is formed by the union of number of sclerites or cuticular plates or areas which are joined together by means of cuticular lines or ridges known as **sutures** or any of the large or small sclerotized/harden areas of the body wall.

These sutures provide **mechanical support** to the cranial wall.

Suture: The sclerites separated from each other by means of thin impressed line called suture.(Sometimes referred as a sulcus).

General insect possess the following sclerites-

1. **Labrum:**It is small sclerite that forms the upper lip of the mouth cavity. It isfreely attached clypeus by means of clypolabral suture.

2. **Clypeus:**It is situated above the labrum, separated by fronto-clypeal suture & also separated from gena by clypogenal suture.

3. **Frons:** It is unpaired, facial part of the head capsule lying between the arms of epicranial suture.

4. **Gena:** It is the area extending from below the compound eyes to just above the mandibles. It is separated from frons by frontoganal suture and from clypeus clypogenal suture.

5. **Epicraniun:** It forms the upper part of the head extending from frons to the neck.

6. Vertex: It is the top portion of epicranium which lies behind the frons or the area between the two compound eyes.

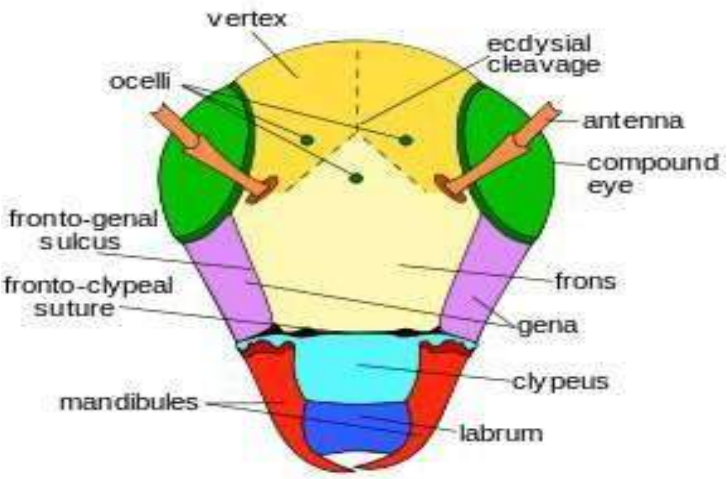
7. Epicranial Suture: Starting from the dorsal portion of the epicranium is an inverted Y shape suture known as epicranial suture or ecdysial line. The head capsule breaks open along this line at the time of moulting.

8. Occiput: It is an inverted "U" shaped structure representing the area between the epicranium and post occiput.

9. Post occiput: It is the extreme posterior part of the insect head that remains before the neck region.

10. Occular sclerites: These are cuticular ring like structures present around each compound eye.

11. Antennal sclerites: These form the basis for the antennae and present around the scape.

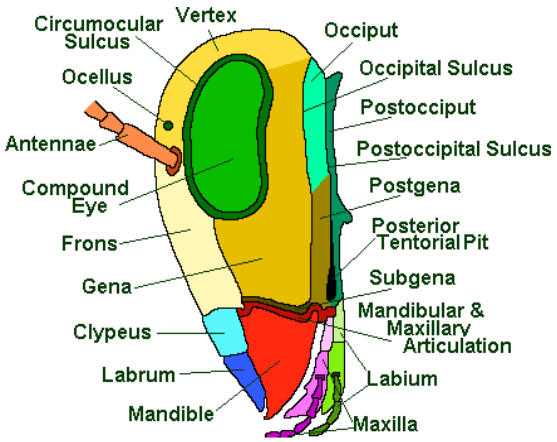


Anterior view or face view

The common sutures present in head are:

1. **Clypeolabral suture:**It is the suture present between clypeus and labrum.
2. **Clypeofrontal suture or epistomal suture:** The suture present betweenclypeus and frons.
3. **Epicranial suture:** It is an inverted 'Y' shaped suture distributed above thefacial region extending up to the epicranial part of the head. It consists of two arms called **frontal suture** occupying the frons and stem called as **coronal suture.** This epicranial suture is also known as **line of weakness or ecdysial suture** because the exuvial membrane splits along this suture during the process of ecdysis.
4. **Occipital suture:** It is 'U' shaped or horseshoe shaped suture between epicranium and occiput.

5. **Post occipital suture:** It is the only **real suture in insect head.** Posterior end of the head is marked by the post occipital suture to which the sclerites are attached. As this suture separates the head from the neck, hence named as real suture.
6. **Genal suture:** It is the sutures present on the lateral side of the head i.e. gena.
7. **Occular suture:** It is circular suture present around each compound eye.
8. **Antennal suture:** It is a marginal depressed ring around the antennal socket.

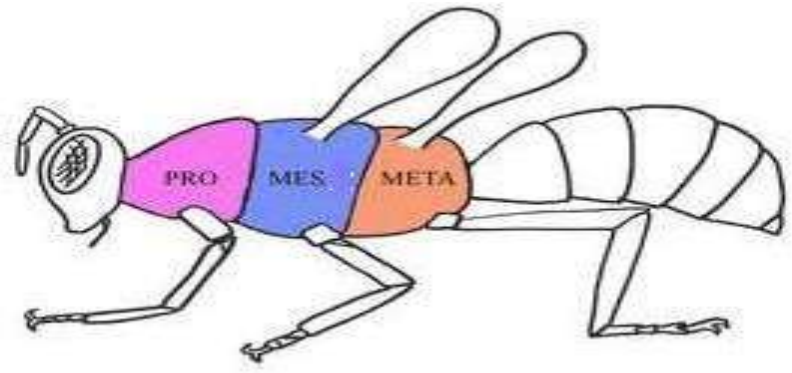


The Insect Head (Side View)

INSECT THORAX

- It is the middle part of the body consisting of **3segments**such as prothorax, mesothorax and metathorax, each possessing a pair of legs and a pair of wings on meso and meta thoracic segment. Meso and meta thoracic segments bear a pair of wings each together known as **pterothorax** (Ptera = wings).

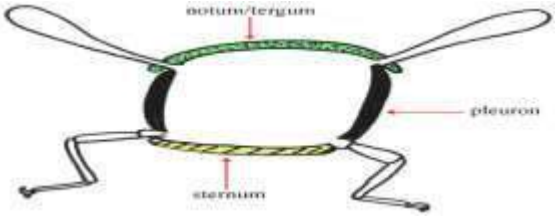
- **Thorax generally concerned with locomotion.**



- The body wall of a typical insect is divided into four regions;
  - The dorsal (Upper) region is called **dorsum or tergum/notum.**
  - |The ventral (Lower) region is called as **venter or sternum.**
  - The two lateral regions are known as **pleurae/pleuron.**
- **Sclerites–**The cuticle hardens at localized areas form sclerites.

- **Sutures –** The sclerites are separated from each other by means of thin impressesd lines called as sutures.
- Sclerites forming these regions are called as tergites, sternites and pleurites, respectively.

- **Sclerites of thoracic segments:-**
    1. **Sclerites of tergum (tergites) -** The dorsal sclerites consists of three segmental plates (nota) called pro-notum, meso-notum and meta-notum. Each notum is again divided into three parts i.e pre-scutum, scutum and scutellum.
    2. **Sclerites of pleuron (pleurites) –**it is fully developed in winged insects. It is divided into two parts, anterior episternum and posterior epimeron. It is absent in prothorax.
    3. **Sclerites of sternum (sternites)**–It is divided into eusternum and spinasternum.

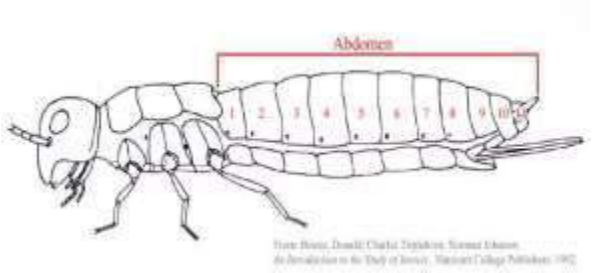


INSECT ABDOMEN

- The abdomen in the embryo usually consists 11 segments.
- The abdominal segments are sometimes designated as uromeres.
- The terminal region of abdomen is called telson which bears anus.
- The 1st abdominal segment gets fused to metathorax forming propodeum. (In ants, bees and wasps).
- The first eight abdominal segments carry a pair of spiracles each.
- **Thorax generally concerned with reproduction and metabolic activity.**
- **Appendages of abdomen–**
    1. **Non reproductive appendages –**
        a) **Cerci –**They are present on 11^{th} segment in most of the insects. It is present inmale cockroach, silverfish, grasshopperCerciusuallyact as tactile organ or sound receptors in grasshopper. They become a part of male genitalia in caddis fly. In earwigs, cerci are modified into defensive organ.
        b) **Prolegs in insect larvae-** The larvae of Lepidoptera bear five pairs of abdominal legs called **Prolegs** on 3^{rd} 4^{th} 5^{th} 6^{th} and 10^{th} segments. These Prolegs bear spines like structures called **crochets**, on terminal ends to grip the plant surfaces. In case of larvae of sawfly there are eight pairs of Prolegs but are without crochets.
        c) **Abdominal gills-**
        It is present in aquatic insects for respiration. eg. Nymph of odonata.
        d) **Cornicles:** Aphids have a pair of short tubes known as cornicles or siphonculi projecting from dorsum of fifth or sixth abdominal segment.

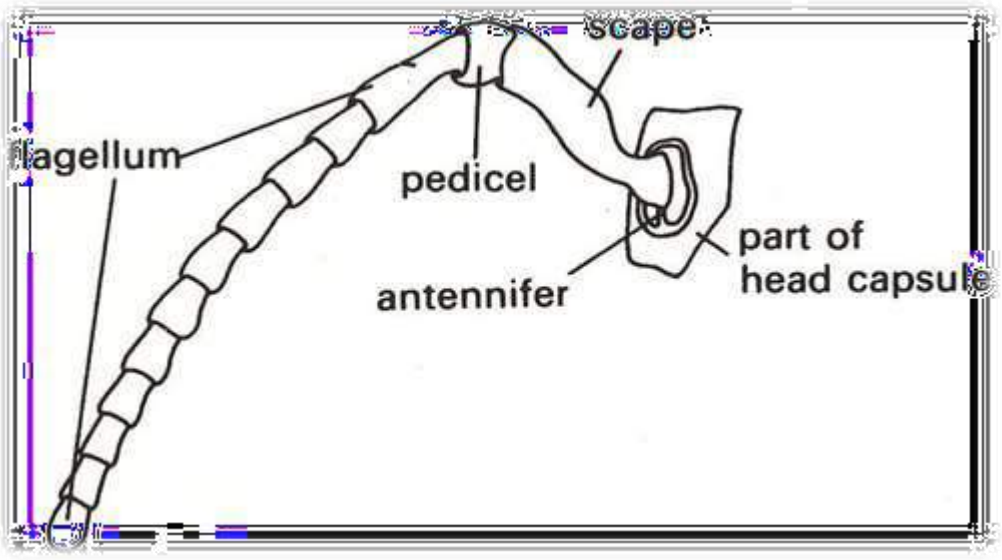
They permit the escape of waxy fluid which perhaps serves for protection against predators.

2. **Reproductive appendages –**
    - ❖ It includes abdominal Segments from 1 to 7 are **pregenital segments**, 8^{th} and 9^{th} are known as **genital segments** as they form genital appendages i.e. ovipositor in females and aedeagus or penis in males. 10^{th}and11^{th}segments are known as **postgenital segments.** These organs are specially concern with mating in male and deposition of eggs in females. They are collectively called as **external genitalia or gonapophysis.**
    - **Male external genitalia-**The9^{th} sternum bears two styli and pair of claspers which help to hold female during copulation. The aedeagus lies between claspers.
    - **Female external genitalia-**It has a special egg laying organs called ovipositor for egg lying on 8^{th} and 9^{th} segments.The ovipositor of house fly& fruit fly is called pseudoovipositor.



INSECT ANTENNAE

- Antennae are a pair of sensory preoral appendages arising from the 2^{nd} or antennal segment of the head possessing nerves coming from deutocerebrum of the brain.
- Antennae are also called feelers.
- They are well developed in adults and poorly developed in immature stages.
- Antennae are absent in order **protura** and class **Arachnida** whereas **2 pairs of antenna** (antennules) are present in class **Crustacea**.
- Aantennal socket (**antennifer)** is provided with an antennal suture. The base of socket is connected to the edge of the socket by an articulatory membrane. This permits free movement of antennae



- **Antenna consists of 3 parts:-**

1) Scape: It is the first segment of antenna. It articulates with the head capsule through antennifer which provides movement for the scape.

2) Pedicel: It is the 2nd or middle segment of antenna that forms a joint between scape and flagellum. It consists of the special auditory organ known as **"Jhonston's organ".**

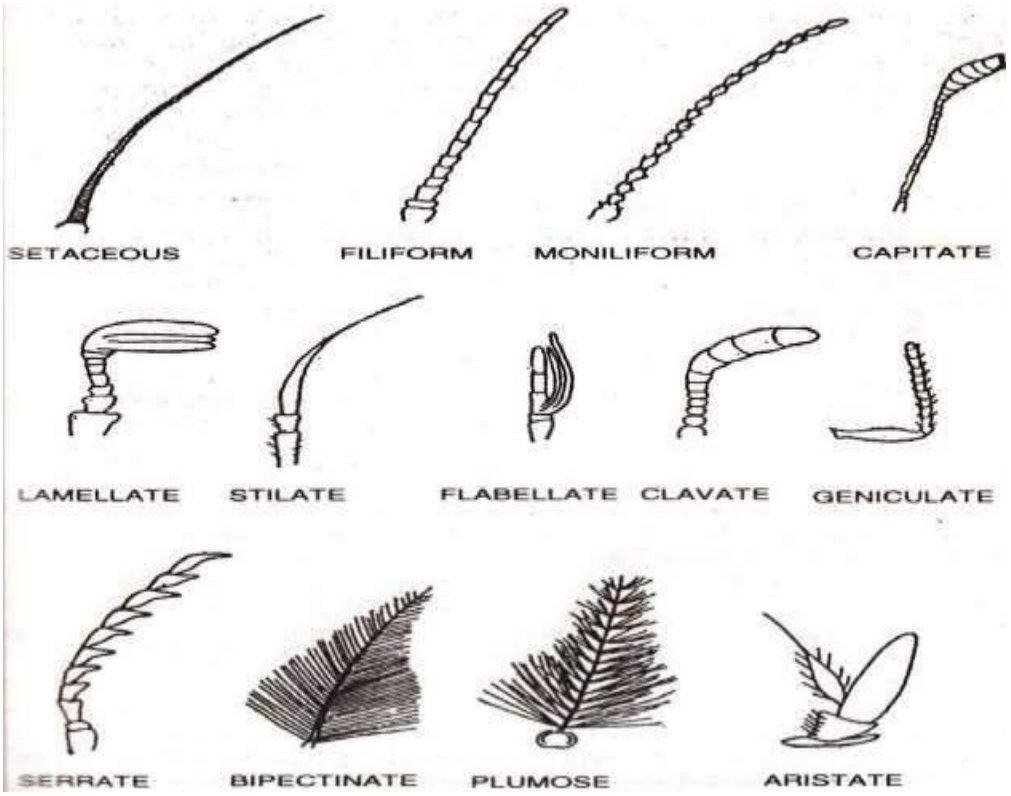
3) Flagellum: It is the last antennal segment which consists of many segments that varies in shape and size.

Types of Insect antennae

SrNo.	Type of antennae	Example
1	Filiform (Thread like)	Grasshopper
2	Setaceous(Whip/ bristle like)	Cockroach
3	Moniliform (Like string of beads)	Termites& Thrips
4	Pectinate (Comb like)	Female mulberry silk moth
5	Bipectinate (Double comb)	Male mulberry silk moth

6	Serrate(Saw like)	Pulse beetle, Mango stem borer
7	Clavate (Clubbed)	Butterflies, Moths
8	Clavate with hook	Skipper butterflies
9	Capitate (Clubbed with knob)	Red flour beetle
10	Geniculate (Elbowed)	Ants, honey bees, Wasps
11	Lamellate (plate like)	Rhinoceros beetles, dung rollers,chaffer beetles
12	Plumose(Feather like)	Male Culex mosquito, stylopids
13	Pilose (brush like hairs)	Female Culex mosquito
14	Aristate (antennae with arista)	House fly
15	Stylate (antennae with style)	Jassids, Robber fly

Term	**Mean**
1. Gustatory	Related with stimulus of taste
2. Olfactory	Related with stimulus of smell
3. Tactile	Related with stimulus of touch



Functions of Antennae

1. To feel and find the its way
2. To detect danger
3. To find food
4. To find the opposite sex
5. To communicate with each other e.g. (Ants)
6. To smell – bears olfactory organ e.g. (House fly)
7. To perceive the sound **Chorodontonal organ**e.g. (male mosquito)
8. To serve secondary sexual characters
9. It possesses hydro fuse hairs to form air funnel eg. (Water beetle)
10. Taste hairs occur on antennae e.g. (Cockroach)
11. Helps in mating by holding opposite sex eg. (Flea, Spring tails)
12. Useful for clasping the female during copulation

★ STUDY OF INSECTS MOUTH PARTS

Typical mouth part of an insect consists of the following parts.

(i) Labrum (upper lip)

(ii) A pair of mandibles (upper Jaw)

(iii) A pair of maxillae (lower Jaw)

(iv)Labium (lower lip)

(v) Hypopharynx (tongue)

- The mouth parts of insects can be basically grouped in to following types based on the type of food and method of feeding.

Type of Mouth parts

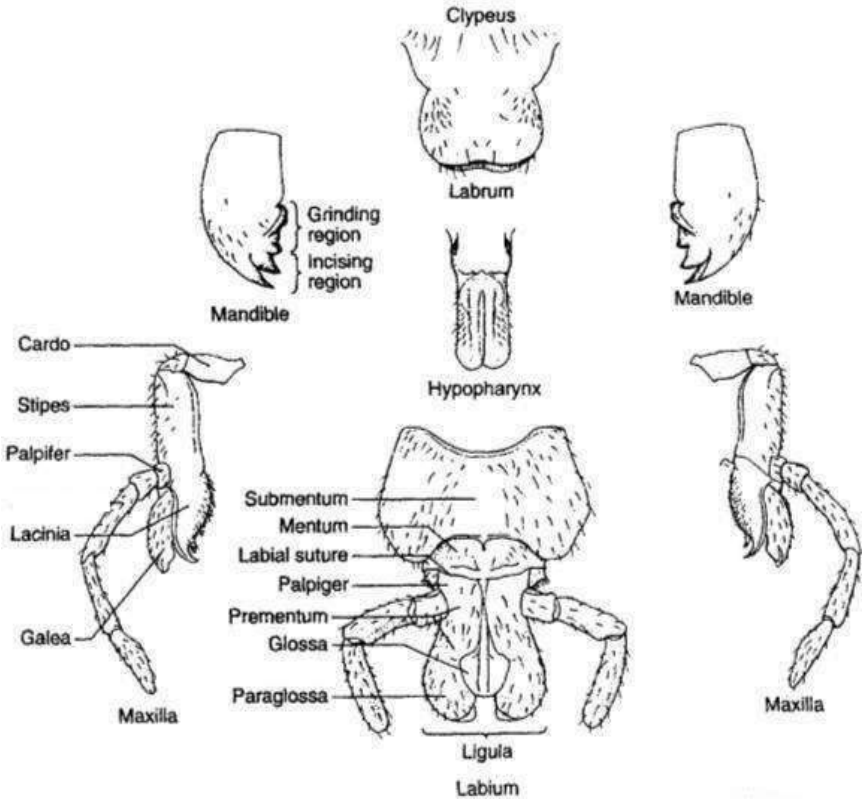
Sr. No.	Type of Mouth parts	Examples
I	**(Mandibulate type)**	**Those insects feeding on solid food material.**
	1. Chewing and Biting type	Grasshoppers, cockroachesBeetles, Lepidopterous larvae.
II	**Sucking type / Haustellate type**	**Those insects feeding on liquid food material.**
	1.Piercing and sucking type	Plant Bugs and Mosquitoes
	2.Rasping and sucking type	Thrips
	3.Sponging type	Adult Houseflies
	4.Chewing and lapping type	Honey bees
	5.Siphoning type	Butterflies and moths
III	**Other types**	
	1. Mask type	Naids of Dragonflies
	2. Degenerate type	Maggots of Diptera

MANDIBULATE TYPE OF MOUTH PARTS

- Those insects feeding on solid food material such as leaves, fruits, tree bark.

I) CHEWING AND BITING TYPE OF MOUTH PARTS

E.g. Grass hopper, Cockroach, Beetles, Lepidopterous larvae



(a) Labrum:

- It is a single unpaired that forms the upper lip of the mouth cavity.
- It protects the mandibles and helps in closing of the mouth cavity and guides the food in to mouth or hold the food material while feeding.
- Labrum hangs down from the clypeus through a clypeo-labral suture.
- The inner surface of labrum is lined by small lobe like epipharynx, which is the taste organ.

(b) Mandibles:

- These are the paired, unsegmented, and strongest and sclerotized structures calledfirst pair of jaws.
- They are attached to the head capsule by means of two joints known as ginglymus and condyle.
- They possess teeth like molars and incisors that help in the process of cutting the food material.
- Each mandible is moved by powerful Abductor and adductor muscles.

(c) Maxillae:

- These are paired and also known as second pair of jaws.
- These are homologous structures with basal triangular **'cardo'**, middle rectangular **'stipes'** and the lateral **'palpifer'** bearing maxillary palpi and lobe like inner **'lacinia'** and outer **'galea'**. **Maxillary palps** possess olfactory and gustatory sense receptors and function as sensory organs. These Galea and lacinia helps in holding the food material along with the mandibles.

(d) Labium:

- It is known as lower lip and is also called as second maxillae. It closes the mouth cavity from below.
- It is divided in to proximal **prementum**. central**mentum** and distal **submentum**Prementum has three terminal lobes.
- Near the base of pre mentum, on either side lobe like **'palpiger'** is present which bears labial palps. The median pair is **'glossae'** and outer '**paraglossae'** together called **ligula** that function mainly as gustatory sense organs.

(e) Hypopharynx:

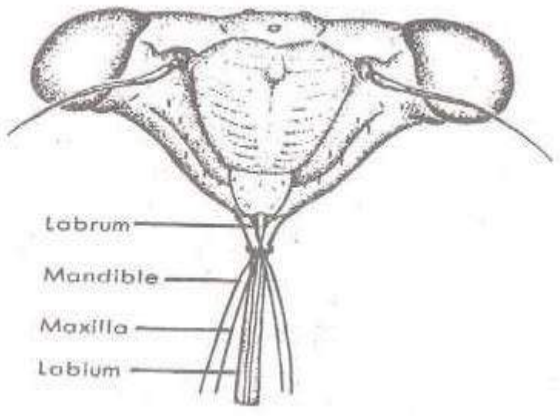
- It is a tongue like structure situated between labrum and labium and ducts of salivary glands open on or near its base. The function of hypopharynx is to mix saliva with the food material.

★ HAUSTELLATE TYPE OF MOUTH PARTS

➢ Those insects feed on liquid food material such plant sap, fruit juice, blood *etc*

1. PIERCING AND SUCKING TYPEOF MOUTH PARTS

➢ e.g.: plant bugs, mosquitoes
➢ They are mainly adopted for piercing the tissues and sucking either plant sap or the nectar or blood from the host.



a) Labrum :

- Labrum is modified into a small flap like structure at the base of rostrum.

b) Mandibles & maxillae:

- Mandibles and maxillae are modified in to sharp needle like stylets. (Four in numbers)
- The mandibular stylets form the outer pair and possess serrated margins at their tip.
- The maxillary stylets forms the inner pair having smooth curved tips and combining together enclosing a food channel.
- The food channel is divided in to an upper cibarium and lower salivarium with the help of the grooves present inside the maxillary stylets. Salivarium is used for releasing the saliva and cibarium is used for sucking the sap.

c) Labium :

- Mouth parts are represented by rostrum/beak/Proboscis which is a modification of Labium.
- It acts as a pouch for protecting the mandibular and maxillary stylets.
- Rostrum has sensory hairs at its tip for sampling the food and locating spot for piercing.

d) Hypopharynx :

- The hypopharynx is modified in to a pharyngeal pump and is situated at the tip of the food channel.

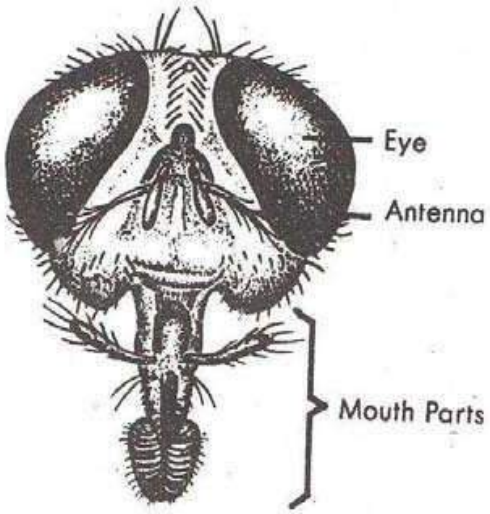
❖ **<u>Feeding Mechanism:</u>**

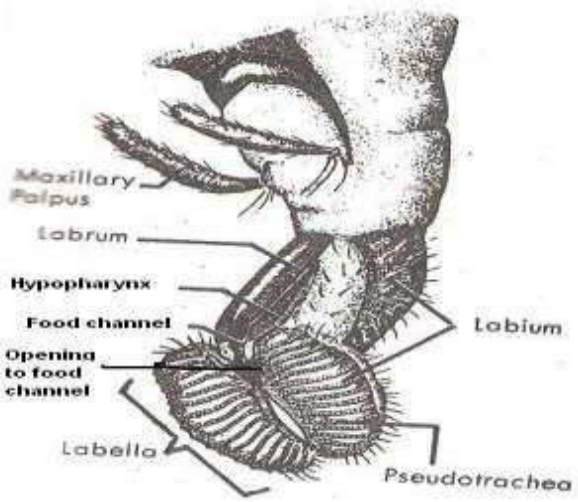
✓ At rest proboscis is always held parallel to ventral side of insect body.
✓ During feeding the rostrum shot out, stylets released and rostrum looped behind to allow the stylets to penetrate plant tissues.
✓ Mandibular stylets by their sliding movement puncture a hole in plant tissues. Then maxillary stylets are pushed inside.
✓ Saliva is injected through salivary channel to dilute the cell sap, dissolve the cell wall.
✓ Then suck the contents (sap/ blood / nectar) through cibarium with the action of pharyngeal and cibarial muscles.

2. RASPING AND SUCKING TYPE OF MOUTH PARTS E.g. Thrips

- Insect like thrips lacerate the epidermis of plant parts and suck the oozing cell sap.
- These are called asymmetrical type, since right mandible is rudimentary or reduce or absent whereas the left mandible is modified in to a mandibular stylet hence left mandible is present.
- Maxillae are modified in to maxillary stylets which are mainly useful for sucking the sap that is released outside due to the rasping of tissues by the left mandible.

3. SPONGING TYPE OF MOUTH PARTS: - e.g.: housefly





a) Labrum:
- It is represented by labrum epipharynx.
- It forms stylet.
- It is born on anterior face of haustellum.

b) Mandibles: They are entirely absent.

c) Maxillae: They are represented by a pair of maxillary palps.Maxillary palpi are 1-3 segmented

d) Labium :
- These mouthparts are represented by proboscis formed from the labium.
- The proboscis is divided into a basal rostrum, middle haustellum and adistallabellum.
- The labellum is a sponge like structure. It is traversed by a number of narrow transverse channels called **pseudotrachea** which converge at one point in the centre of the labellum. From this point, the food enters in to food channel which is formed by the labrum- epipharynx and hypopharynx.

e) Hypopharynx :
- It is also modified into stylet like structure and is present on haustellum.

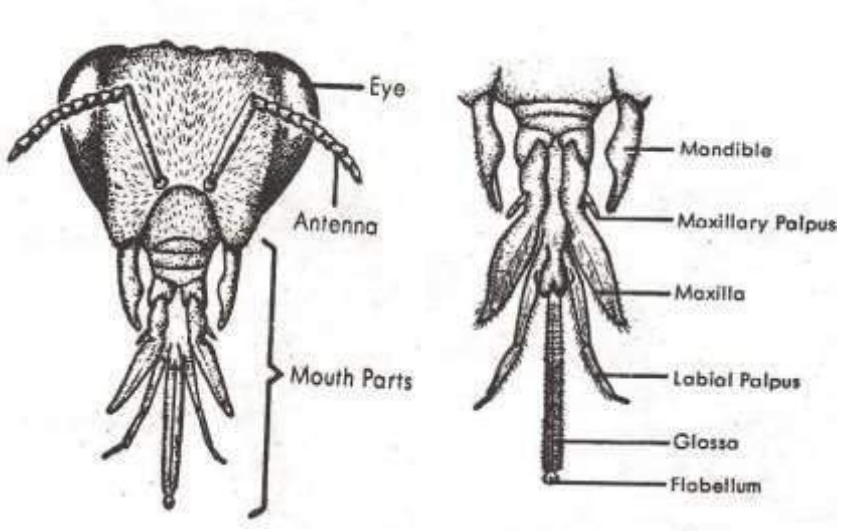
❖ **<u>Feeding Mechanism:</u>**

✓ During feeding, the proboscis is pressed over the food material.

✓ The pseudo trachea gets filled with the food material by the capillary action which converges at one point in the centre of the labellum.

✓ From this point, the food enter in to food channel which is formed by the labrum-epipharynx and hypopharynx and is sucked up from the central point in to the oesophagus.

4. CHEWING AND LAPPING TYPE OF MOUTH PARTS:e.g.: honey bees



- The labrum and mandibles are biting type whereas maxillae, labium and hypopharynx combine together to form a sucking proboscis.

a) Labrum: It is narrow plate attached to clypeus.

b) Mandibles: The mandibles are dumbbell shaped, used for molding wax and squeezing the nectar.

c) Maxillae :

- Both maxillae are modified and suspended from head.
- They are articulated through like **cardo** to which is attached **stipes**.
- The **maxillary palpi** are very small or reduced and it is peg like structure articulating with stipes.
- The cardo of maxillae unite with submentum of labium forming an inverted "V" shaped **lorum**.
- **Galea** and **lacinia** attached at the lorum.

d) Labium : It is also called as proboscis and consist of following parts;

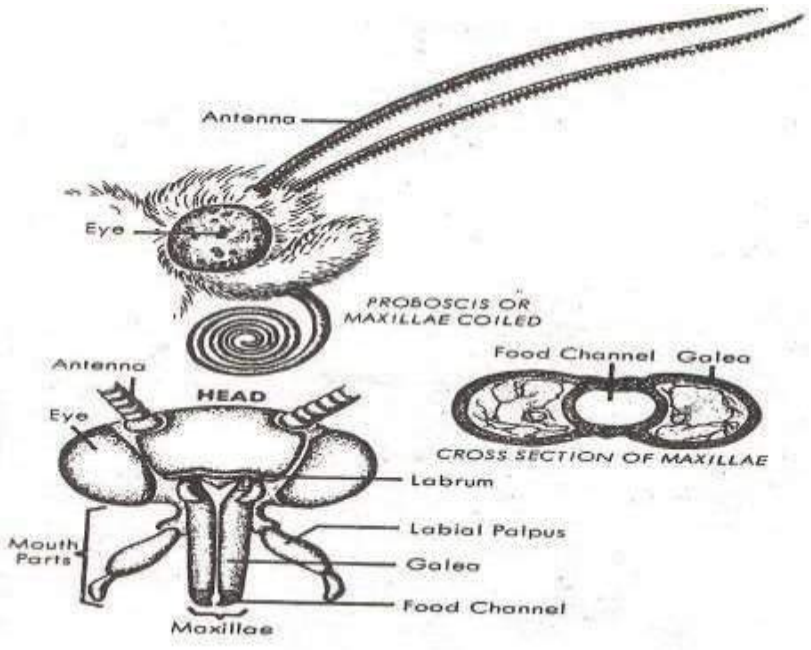
- Submentum (lorum),mentum, prementum, labial palp and glossa.
- Glossae are provided with long hairs and a small spoon shaped lobe, called **flabellum** or **bouton** at its apex.
- Two paraglossa are cup like structure situated at the base of glossa.

e) Hypopharynx: It is vestigial or reduces.

❖ **<u>Feeding Mechanism:</u>**

- ✓ When at rest the mouthparts are folded down beneath the head.
- ✓ During feeding they become straight and shot out glossae and lick the nectar with the help of flabellum.
- ✓ The glossal toung thus smeared with nectar is rapidly retracted between labial palp and galeae.
- ✓ As a result the nectar is squeezed off and deposited in a small cavity formed by paraglossae and sucked in by the capillary action of pharyngeal pump.

5. SIPHONING TYPE OF MOUTH PARTS: e.g.: Moths and Butterflies.



- ✓ These are specially modified for taking nectar from the flowers.
- ✓ The galea of maxilla form into a slender, hollow, tubular structure which remains as an elongated coiled proboscis underneath the head during non feeding.
- ✓ **Mandibles are totally absent.**
- ✓ The labrum and maxilla palpi are reduced.
- ✓ Labium is modified in to a small basal plate possessing 3 segmented labial palps.
- ✓ The food channel is formed by the fusion of both the galeae.
- ✓ The nectar will be sucked from the flowers through muscular action

★ STUDY OF INSECT LEG

- ❖ Insect legs are paired; hollow more or less cylindrical and jointed outgrowth of thoracic segments. They are the important locomotory organ.

Components of Insect Leg

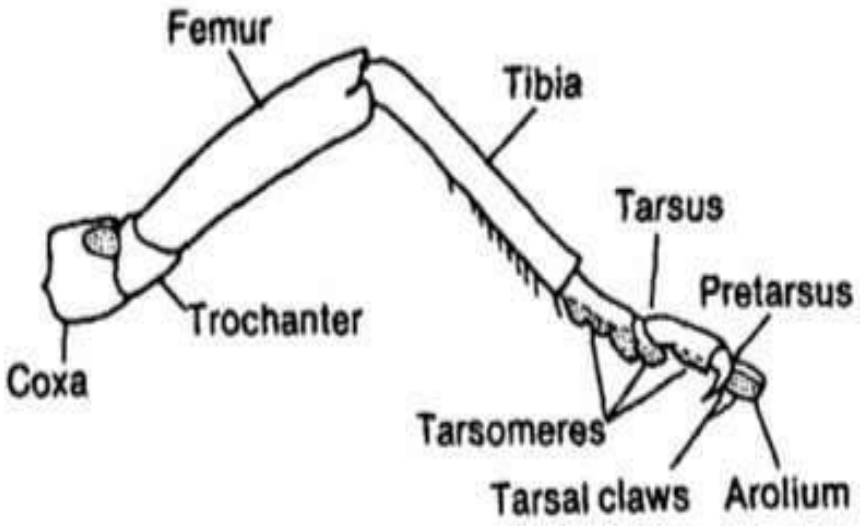


Fig. Structure of Typical Insect Leg

Insect leg mainly consists of **5** parts viz.

1. Coxa: It is the functional basal segment and it is rigidly fixed to thorax.

2. Trochanter: It is very small and the second segment. It is articulated with coxa and fixed to femur.

3. Femur: It is the largest, strongest segment and is articulated with the tibia..

4. Tibia: It is equal or more than the length of the femur, articulated with tarsus.

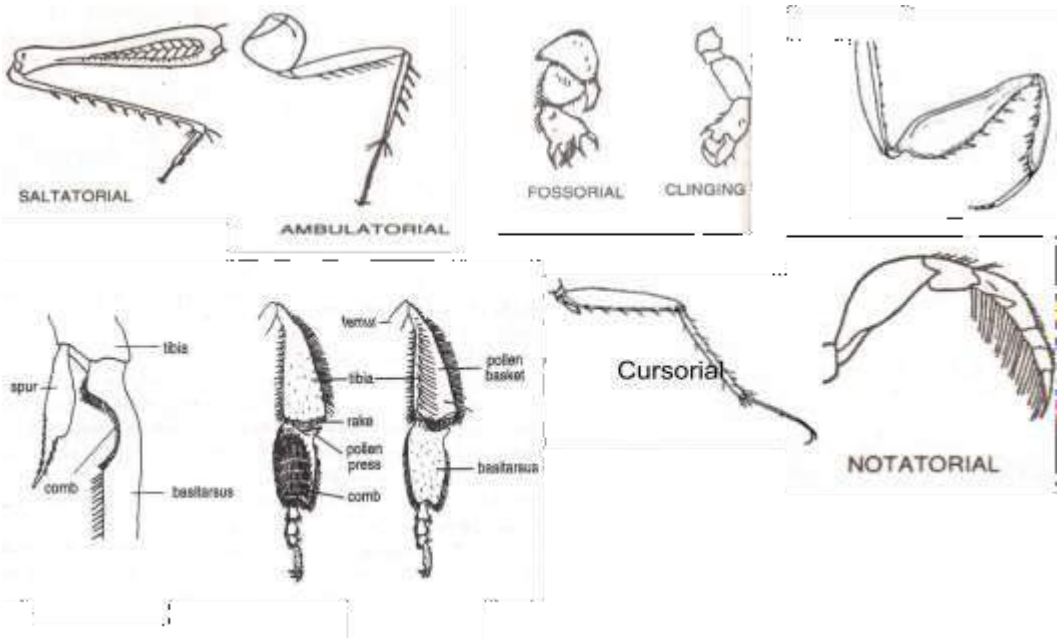
5. Tarsus: it is the largest segment of the leg and usually devided into sub segments **tarsomeres.** The number of tarsomeres vary from 1-5**.** The tarsus at its end consists of **pretarsus** which is in the form of a pair of claws and cushion like pulvilli. In between the claws, if there is lobe like structure, it is known as **"arolium"** as in Orthoptera (grass hopper) and if it is bristle like structure, it is called "**embodium**" as in Diptera.

- ❑ **Legs of Larvae: Prolegs**
  - Thoracic legs mean true legs and abdominal legs mean Pseudo legsor false leg of larvae.There are two to five pairs.
  - Abdominal legs are thick, fleshy and unsegmented and the tip (Planta) bear hooks called **crochets**, which help in cling the plant surface.

MODIFICATIONS OF LEGS IN DIFFERENT INSECTS

Type	Legs modified	Example	purpose
Cursorial	All legs	Blister beetle, wasp	Walking
Ambulatorial	All legs	Cockroach	Running
Saltatorial	Hind legs	Grasshopper , gryllids	Leaping and jumping
Fossorial	Front legs	Mole crickets, dung rollers	Digging
Raptorial	Front legs	Preying mantids	Preying (grasping)
Natatorial	Hind legs	Water beetle, water bugs	Swimming
Scansorial	All legs	Head louse	clinging
Prehensile	All legs	Dragon flies	Catching prey, basketForming type
Antennal cleaning legs	Front legs	Honey bee	For cleaningantennae
Pollen basket and brush type	Hind legs	Honey bee	For collectingpollen and cleaning the body

Fig. Modification of insect legs



★ STUDY OF INSECT WINGS

- ❖ Based on the presence or absence of wings, class insecta is divided into two subclasses; 1. **Apterygota &2. Pterygota**
  - o The primitive apterygotes are wingless**. E.g.: Silver fish and spring tails.**
  - o Secondarily wingless insects: Among pterygotes, some insects in their advanced stage of growth (Adult) shed the wings **e.g. Bed bugs, head louse.**
- ❖ Based on the degree of development of wings the insects may be classified into three forms; 1) Macropterous, 2) Brachypterous & 3) Apterous.
- ❖ The insect wings may sometimes possess some pigmented spot near coastal margin known as **pterostigma or stigma** as in Odonata (dragon flies and damsel flies).

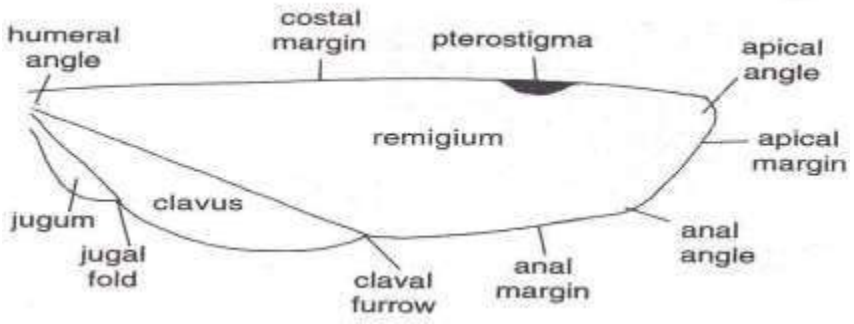


Fig. Insect wing areas

- ✓ A typical insect wing is triangular with **three margins** 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**
- ✓ Three angles are,
  - **Humeral angle:** between body wall and costal margin
  - **Apical or outer angle:** between costal and apical margin
  - **Anal angle or tornus** : between apical and anal margin
- ✓ Wings area are;
- ➢ The surface area of typical insect wing is divided in to two portionsi.e.**Remegium** and **Vannal Area.**
- ➢ The anterior (upper) part of the wing towards coastal margin where more no of longitudinal veins are present is called **remigium**.
- ➢ The posterior part of the wing where veins are sparsely distributed is known as **Vannal Area,** which is called as **clavus** in forewings and **vanus** in hindwings.
- ➢ **Jugum** is the inner most portion of the wing that is cutoff from the main wing by jugal fold.
- ❑ Wings are very thin broad leaf like structures strengthened by a number of hollow narrow tubular structures called **veins.**

- Arrangement of veins on wing surface is known as **Wing venation,** which consists of two types of veins;

1. Longitudinal veins: Extend from base of the wing to the margin. They may be convex (∩) or concave (U)

2. Cross veins: That interlinks the longitudinal veins.

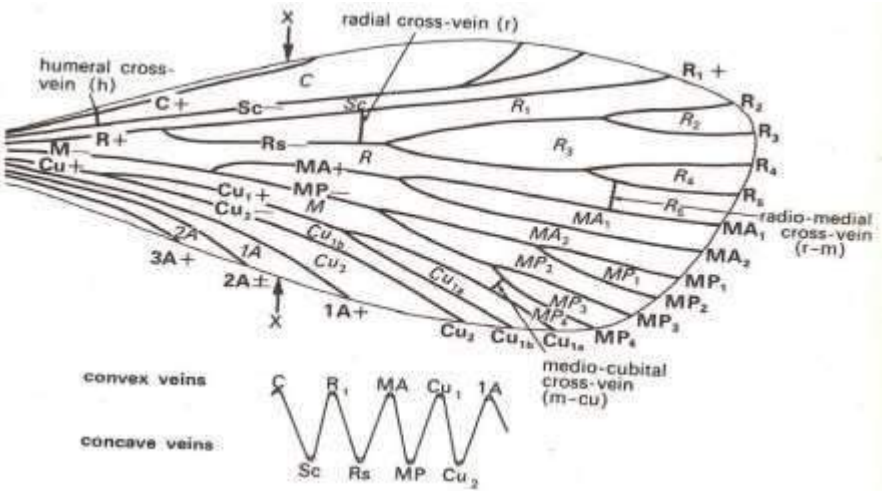


Fig. Hypothetical wing venation

Longitudinal veins:

1. Costa (C): It forms the thickened anterior margin of the wing (costal) and isun-branched and is convex

2. Sub costa (Sc): It runs immediately below the costa always in the bottom ofa trough between C and R. The two branches of SC are Sc1 and Sc2 and is concave

3. Radial vein (R): It is the next main vein, it divided in to two branches R1 and Rs (Radial sector). R1 goes directly towards apical margin and is convex; Rs is concave and divided in to 4branches, R2, R3, R4, and R5.

4. Media (M) It is divided in two branches 1. Media anterior (MA) which is convex and2. Media posterior (MP) and is concave. Media anterior is again divided into MA1 and MA2. Median posterior is again divided in to MP1, MP2, MP3, and MP4.

5. Cubitus (Cu): Cubitus is divided into convex CU1 and concave CU2. CU1 is again divided into CU1a and CU1b.

6. Anal veins (A): These veins are convex. They are individual un-branched, 1-3 in number.1 or 2 jugal veins (unbranched) are present in the jugal lobe of the forewing

Cross veins: - Small veins often found inter connecting the longitudinal veins are called cross veins.

- **Humeral cross vein (h):**between costa and subcosta.
- **Radial cross vein (r):** between radius and radial sector.
- **Sectorial cross veins (s):** between sub branches of radial sector.
- **Radio medial cross vein (r-m):** between radius and media.
- **Medical cross veins:** between branches of media.
- **Medio-cubital veins:** between media and cubitus.

DIFFERENT TYPES OF WINGS

1. Tegmina: Forewings are leathery and tough. They are protective in function. They protect the membranous hindwings. They are not used for flight.e.g.: forewings wings of cockroach, grasshopper

2.Elytra: The wing is heavily sclerotised without clear venation. Wing is tough and it is protective in function. They protect the membranous hind wings and abdomen. e.g.: Forewings beetles and weevils.

3.Hemelytra: The base of the wing is thick like elytra and the remaining half is membranous. They are not involved in flight and are protective in function. e.g.: Forewings of bugs.

4.Membranous: Naked thin with clear venation. e.g.: Both the wings of Dragonflies, bees and wasps, Hind wings of grasshopper, beetles,cockroach, both fore wings and hind wings of (wasp, bees, dragonfly and damselfly).

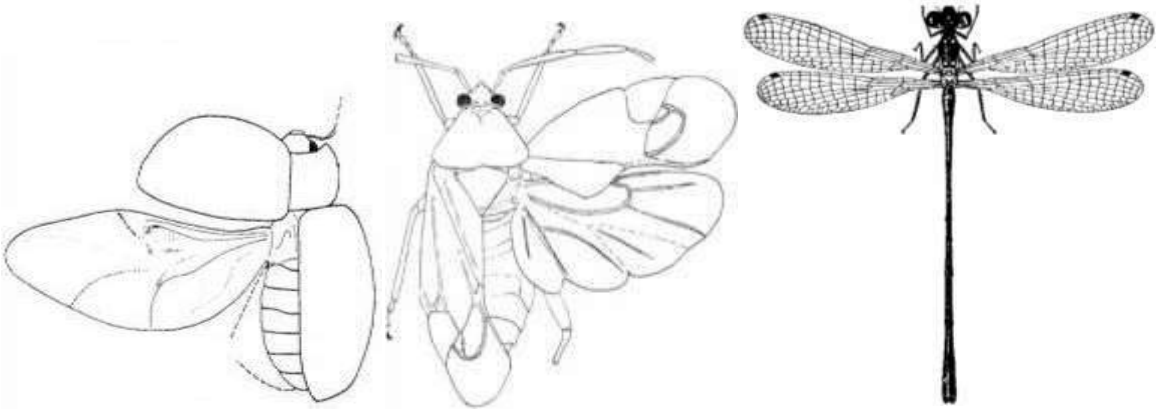
5. Scaly wings: Wings thin, membranous but covered with unicellular scales all over the surface. Scales are responsible for colour. e.g.: Both the wings of moths and butterflies.

6. Fringed wings: Wings are highly reduced with reduced venation. The wings are fringed with long marginal hairs giving a feather like appearance e.g. both the wings of thrips

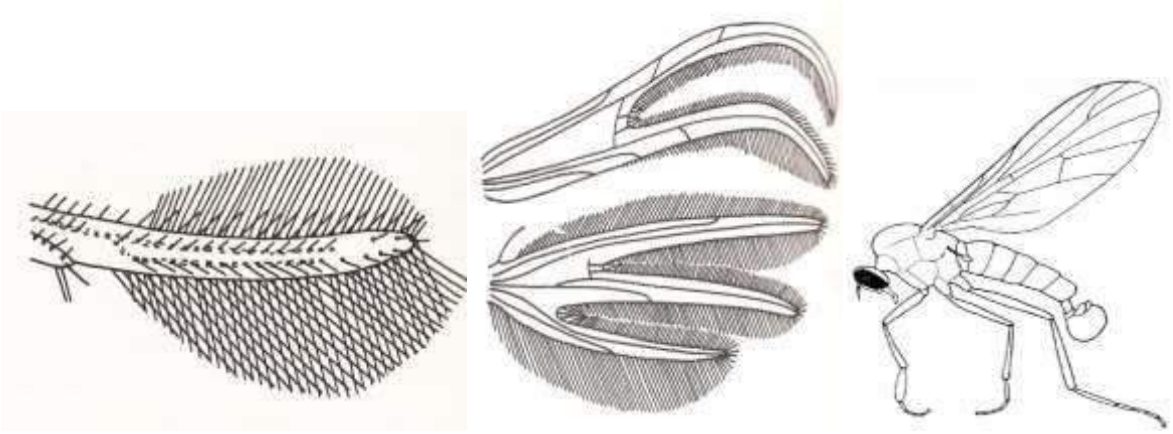
7. Fissured wings: Forewings are longitudinally divided twice forming a fork like structure whereas hindwings are divided twice in to three arms. All the forks possess small marginal hairs.e.g.: Both the wings of plume moth

8. Halteres: In houseflies the hind wings are modified into small microscopic structures/ knobbed vibrating organs called haltere**.**They are divided in to three regions namely **scabellum**, pedicel and **capitellum**. They act as balancers. E.g. Hind wings housefly and front wings, male stylopids, mosquito and male scale insect.

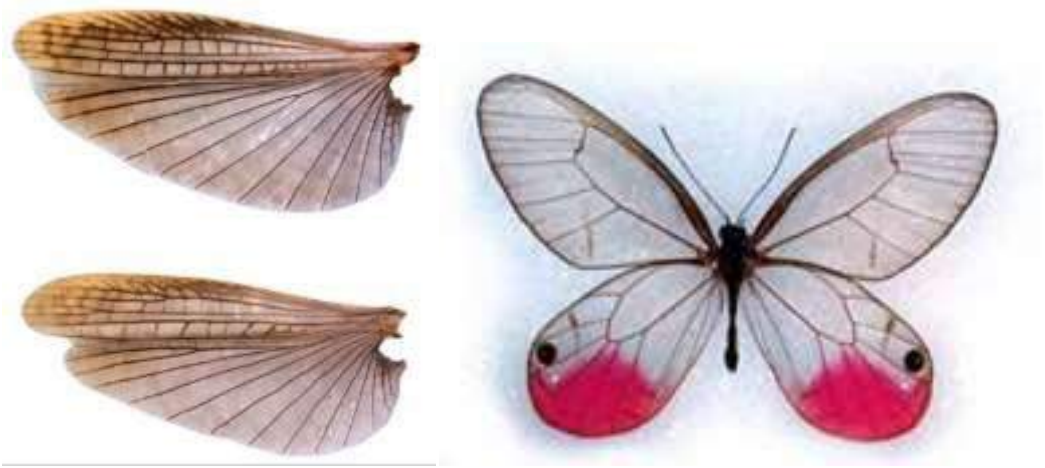
9. Pseudohalteres: They are short and modified in to pseudohalteres which are dumbbell shaped. Eg: Front wings of Strepsiptera



ElytraHemelytraMembranous wings



Fringed wingsFissured wings Halteres



Tegmina wings Scaly wings

★ WING COUPLING APPARATUS/ORGANS/MECHNISMS

- ❖ Among the insects with two pairs of wings, the wings may work separately as in the dragonflies and damselflies.
- ❖ For taking flight, insect need to keep both the fore and hind wings together as a single unit. The structures in the form of lobes, bristles, hairs or spines that help the wings to be together are known as wing coupling organs.

1. **Jugate type or jugum type:**

   The costal margin of the front wing possess a small lobe at the base called **fibula** which rest on the surface of the hind wing or sometimes engages with spines present on the upper surface of hind wings . e.g.: primitive lepidopterans of the family Hepialidae.

2. **Frenulum/Franate/retinaculum type:**

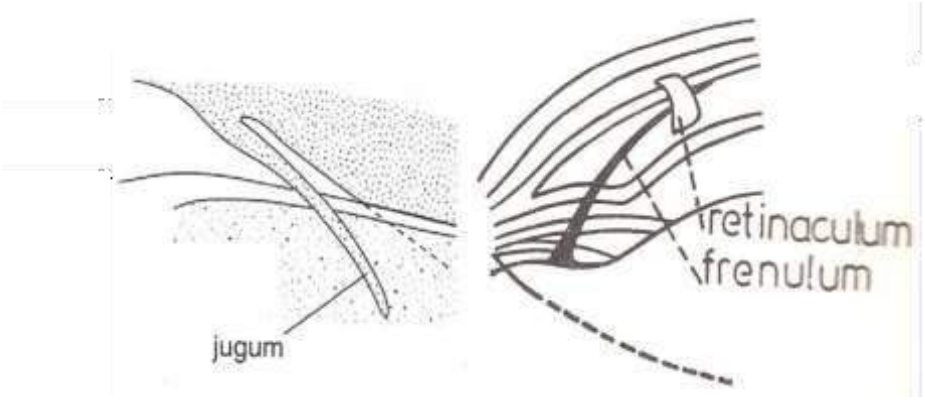
   The hind wings possess bristle or spine like structure or group of hairs known as **frenulum.**The forewings possess hook like **retinaculum** on anal side. During flight the frenulum passes beneath the retinaculum and thus the both the wings are kept together. e.g.: Fruit sucking moth.

3. **Amplexiform:**

   Costal margin of hind wing and anal margin of forewing overlap one above the other e.g.: butterfly

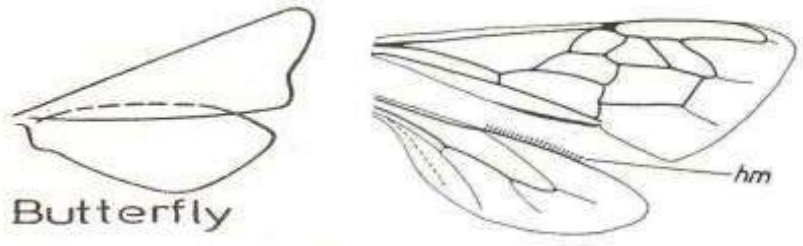
4. **Hamuli/Hamulate :**

   TheSmall curved hook like structures present on the costal margin of the hind wing known as **Hamuli** that fit into the upward fold of the anal margin of the



forewings.e.g.hymenopterans (wasps and bees)

Jugate typeFrenulum type



Amplexiform type **Hamuli type**

★ METAMORPHOSIS

- Metamorphosis is derived from Greek word 'Meta' = Change, 'morph' = form or structure.
- Series of changes that takes place during the development of an insect from egg to adult are collectively known as metamorphosis.
- Metamorphosis include **three** developmental processes namely, **growth**, **differentiation** and **reproduction** which takes place in **larval**, **pupal** and **adult** stages respectively.

- **Eclosion:** The process of hatching of eggs after fully development of embryo called eclosion.
- **Instar:** It is the forms of the body during two inter moults. The larva is known as first instar, immediately after hatching from egg, and as second instar after first moult and so on
- **Stadium:** The interval or time period between two moults is known as stadium.
- **Exuviae:** The skin shed during moulting process is known as exuviae.
- **Imago (or) Adult:** It is the final stage of insect with well-developed organs for reproduction, which emerges out from pupal body.
- **Sub-imago:** It is a pre adult stage with fully developed wings but without reproductive organs .E.g.: mayflies (Ephemeroptera)

Types of metamorphosis:

1. Ametamorphosis (Ametabolous)

2. Incomplete metamorphosis (Hemimetabolous)

3.Gradual metamorphosis: (Paurometabola)

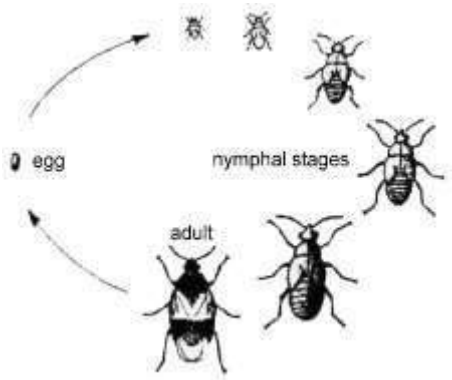
4. Complete metamorphosis/Holometabolous

5. Hyper metamorphosis

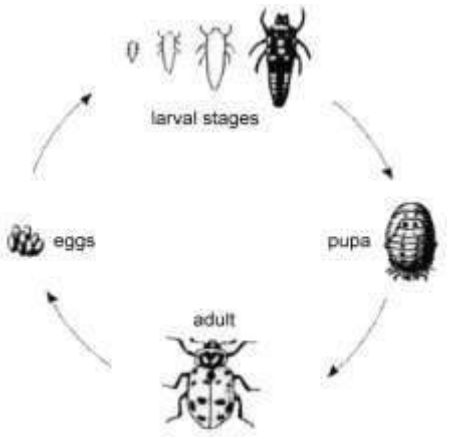
1. **Ametamorphosis:**
   - ♠ E.g.: Apterygote e.g.: silver fish, springtails.
   - ♠ Insects do not undergo any metamorphosis.
   - ♠ These insects have only three stages in their life namely **egg, young ones and adult.**
   - ♠ The hatching insect resembles the adult in all respects except for the 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, naiads and adult. Pupal stage is absent.**
    - ♠ 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. grasshoppers, cockroaches, termites, true bugs, cicadas, and hoppers.
    - ♠ It is also called as simple metamorphosis.
    - ♠ The life cycle includes **egg**, **nymph** and **adult** stages.
    - ♠ The nymph resembles the adult in all the characters except wings. Nymphs possess wing buds which transform in to fully developed wings in adult stage.
    - ♠ Both nymphs and adults share the same habitat.
    - ♠ In these insects, wings develop externally and hence are also called as **Exopterygota.**
    - ♠ **Pupal stage is absent hence,** development is said to be direct and simple.



4. **Complete or Holometamorphosis or indirect development:**
    - ♠ E.g. Butterfly, moth, Beetles, weevils, fly and bees.
    - ♠ The life cycle includes **four** stages; e**gg**, **larva**, **pupa** and **adult**.
    - ♠ Larvae of butterflies are called **caterpillar**.
    - ♠ Larva differs from the adult both in body structure and habits. Larva has both thoracic and abdominal legs, sometimes legs may be absent in larva, whereas adult has only thoracic legs.
    - ♠ Compound eyes are absent in larva.
    - ♠ Larva undergoes moulting to enter in to pupal stage from which the adult insect emerges.
    - ♠ Wings develop internally during the pupal stage and hence, they are called **Endoptreygotes.**



5. **Hypermetamorphosis:**
   - ♠ This is a peculiar type of development which consists of two or more types or forms of larvae in the life cycle of insects.
   - ♠ In majority of the cases the first larval, instar is **campodeiform** and the subsequent larval forms depends on type and mode of life of the larva. E.g.: In blister beetle (Meloidae; Coleoptera), the first larval instar is **campodeiform** followed by **scarabeiform** larval type.

SIGNIFICANCE OF METAMORPHOSIS

i. It helps the insect to tide over unfavorable climate conditions by entering into hibernation, aestivation and or diapauses.

ii. It helps the insect to accommodate growth by periodical shedding of their old cuticle and by formation of new cuticle.

iii. It helps the insect to reduce or avoid competition for food amongst themselves by either entering into inactive stage or by acquiring different feeding habits and habitats.

iv. It helps the insect as a protective adaptation by a way of mimicry. i.e. resembles to the nature.

v. It also serves as an important aspect in classification of insects.

SEASONAL ADOPTIONS

- **Diapause : -**

✓ It is the period of arrested growth or development in the life cycle of the insects during which the physiological processes like **differentiation** and **reproduction** are suspended. Diapause is represented by low rate of metabolism, low O2 consumption, low body weight, low body water content and vitamin deficiency in the blood. Diapause may occur in **egg, larva, nymph, pupa** or **adult** stage.

✓ The occurrence of diapause during summer due to high temperatures is known as **"aestivation**"

✓ Whereas the period of inactivity during winter due to low temperatures known as "**hibernation**".

★ IMMATURE STAGES OF INSECTS

- Immature stages of exopterygote insects are known as **Nymphs** and endopterygote insects are known as **Larvae.**

Differences between Larva and Nymph

Sr.No.	Larva	Nymph
1.	It is an immature stage, of Endopterygotes.	Immature stage of exopterygotes
2.	It undergoes holometamorphosis	It undergoes hemimetamorphosis
3.	Body is vermiform which differs from the adult both in structure and feeding habits	Body resembles the adult in all the characters except wings
4.	Consists of ocelli and reduced Antennae	Have compound eyes and antennae
5.	Possess both thoracic and abdominal legs	Possess only thoracic legs.
6.	The larva is different from adult in feeding habits and behaviour	Nymph resembles the adult in feeding habits and behaviour
7.	The larva enters pupal stage	No pupal stage
8.	E.g.: Lepidoptera, Coleoptera	Hemiptera, Orthoptera.

TYPES OF LARVA

1. Protopod larva: E.g.: Endoparasitic Hymenoptera.

The larvae are partially developed. They possess well developed head and thoracic segments but lack segmentation in the abdomen. They possess rudimentary cephalic and thoracic appendages but no abdominal appendages. They have partially developed digestive system and underdeveloped respiratory and nervous systems.

2. Oligopod larva:

Thoracic legs are well developed. Abdominal legs are absent. These are classified in to two types' viz., **campodeiform** and **scarabaeiform**.

Differences between Campodeiform and Scarabaeiform

Sr. No.	Campodeiform	Scarabaeiform
1	The body is long and fusiform in shape	Body is 'C' shaped
2	Body is dorso-ventrally compressed with sclerotized cuticle	Body is cylindrical or sub cylindrical, stout and fleshy in nature
3	Prognathous type of head	Hypognathous type of head
4	Long thoracic legs	Short thoracic legs
5	Apair ofterminalabdominal processes (anal cerci) are present	Absent
6	These are active	Inactive
7	Predatory in nature	Phytophagous
8	e.g. grub of antlion /grub of lady bird beetle.	e.g.: grub of rhinoceros beetle/white grub

3. Polypod larva (Eruciform larva):

The larva possess well defined segmentation of the body with three pairs of thoracic legs, 2-5 pairs of abdominal legs (3rd, 4th, 5th, 6th and 10th abdominal segment. They are phytophagous and destructive.

Different types of polypod larvae:

A. **Hairy caterpillar** larval body is fully covered with hairsE.g.: Red hairy caterpillar, *Castor hairy caterpillar*

B. **Sphingid caterpillar** / larva the larva consists of a horn (or) hook on the dorsal surface of 8th abdominal segment. E.g.: *Gingelly death's head moth*

C. Looper: Only two pairs of abdominal legs present on 6th and last abdominal segment during walking the insect body forms a complete loop like structure hence, the name looper.E.g.: Mango looper.

D. Semilooper: e.g.: Castor semilooper First two pairs of abdominal legs (on 3 rd and 4 th segments) are reduced, hence a part of the insect body forms a small loop during its movementE.g.:Castor semilooper.

4. Apodous larva:

These are characterized by the absence of trunk appendages (or) legs. They possess 3 pairs of sensory papillae in the place of thoracic legs. They are usually derived from Oligopod type.Based on the degree of development of the head capsule and its appendages, these larvas are divided in to **3** types.

a. Eucephalous: e.g.: Sub order Nematocera of Diptera, Mosquito(Culcidae) The larva consists of a well sclerotized head capsule.

b.Hemicephalous. e.g.: Brachycera of Diptera, robberflies (Asilidae) Larva possess partially developed head capsule

c. Acephalous e.g.: Cyclorrhapa of Diptera, Muscidae (houseflies)the larva are characterized by the absence of head capsule and mouth parts are represented by mouth hooks.

Appearance	Larval Type	Common Name	Description	Examples
	Eruciform	Caterpillar	Body cylindrical with short thoracic legs and 2-10 pairs of fleshy abdominal prolegs	Moths and butterflies
	Campodeiform	Crawler	Elongated, flattened body with prominent antennae and/or cerci. Thoracic legs adapted for running	Lady beetle, lacewing
	Scarabaeiform	White grub	Body robust and "C"- shaped with no abdominal prolegs and short thoracic legs	June beetle, dung beetle
	Elateriform	Wireworm	Body long, smooth, and cylindrical with hard exoskeleton and very short thoracic legs	Click beetle, Flour beetle
	Vermiform	Maggot	Body fleshy, worm-like. No head capsule or walking legs	House fly, flesh fly

TYPES OF PUPA

It is **resting**, **inactive stage** of the holometabolous insects and transitional phase during which the wings are developed and the insect attain matured sexual organs. The pupa is incapable of feeding, locomotion except in some cases where they crawl (Neuroptera) (Aphid lion), e.g.: mosquitoes. Later it emerges as adult, pupation may be takes place either in soil, or on the plant surface or within the webs.

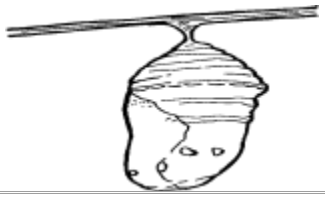
Pupae are divided on the following bases;

I. Based on the presence or absence of **powerful mandibles**

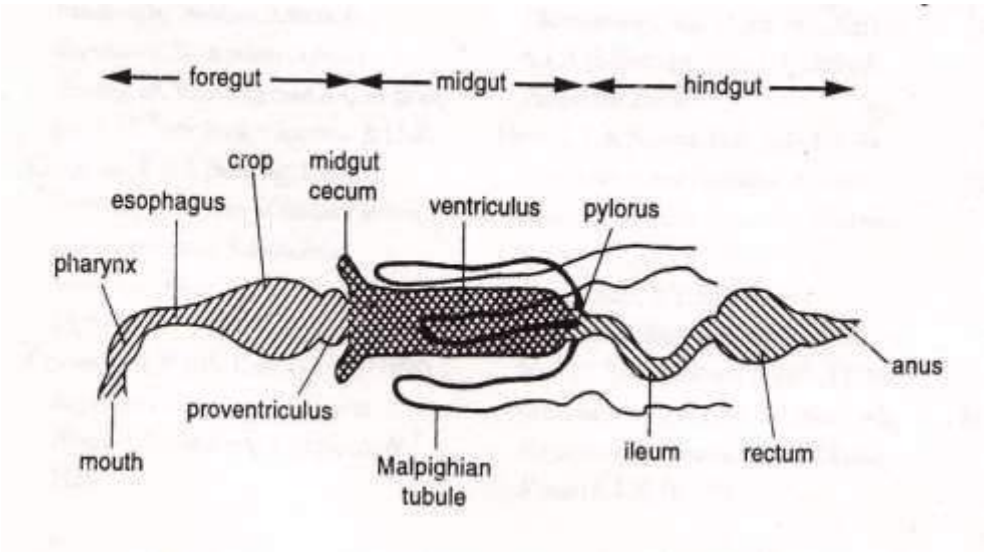
Decticous pupae	Adecticous pupae
Possess relatively **powerful** mandibles which are used for escaping of the adult from the cocoon i.e. to break the cocoon. e.g.: **Neuroptera**	Do not possess the mandibles but with the help of other appendages, adults escape from the cocoon e.g.: **Lepidoptera**, **Diptera**.

II. Based on the **attachment on the appendages** (or) **shape** of the pupae

1. **Exarate pupa:** e.g.:Coleoptera
   The pupae have appendages which are free without any secondary attachment to the body
2. **Obtect pupa** eg: Lepidoptera (moths)
   The pupae have appendages which are firmly pressed against the body and the pupa is highly **chitinized**.
3. **Coarctate:** e.g.: Diptera (housefly)
   The pupa remains enclosed in a puparium formed by the last larval skin and the pupa looks like a capsule or barrel.
4. **Chrysalis:** eg: butterflies
   It is an obtect type of pupa which has golden colouration and a stalk.

Appearance	Pupal Type	Common Name	Description	Examples
	Obtect	None	Developing appendages (antennae, wings, legs, etc.) held tightly against the body by a shell-like casing. Often found enclosed within a silken cocoon.	Butterflies and moths
	Exarate	None	All developing appendages free and visible externally	Beetles, Lacewings
	Coarctate	Puparium	Body encased within the hard exoskeleton of the next-to-last larval instar	housefly
	Chrysalis	None	It is an obtect type of pupa which has golden colouration and a stalk.	butterflies

★ STUDY OF INSECT DIGESTIVE SYSTEM



❖ Digestive system of insect consists of **Alimentary canal** and **Salivary glands.**

❑ **Alimentary canal:** It is a long, muscular and tubular structure. The alimentary canal in insects extends from mouth to anus which is divided in to three parts, **foregut, midgut** and **hindgut.**

1. Foregut (stomodaeum):

- Ectodermal in origin.
- Ectodermic Cells secretes cuticular layer called **Intima.**
- It is the anterior part of the alimentary canal which starts with the mouth cavity and ends with the gizzard (or) proventriculus**.**
- Terminal mouthparts lead into a preoralcavity. Preoralcavity between epipharynx and hypopharynx is called as**Cibarium**. Preoralcavity between hypopharynx and salivary duct is **Salivarium**.
- It is divided in to **pharynx,esophagus, crop** and **gizzard.**

  i. **Pharynx:** Behind the mouth a well musculated organ called **Pharynx** is present which pushes the food into esophagus. Pharynx also acts as a sucking pump in sap feeders. It is the region between the mouth and oesophagus.It concerned with **ingestion and back word flow of food.**

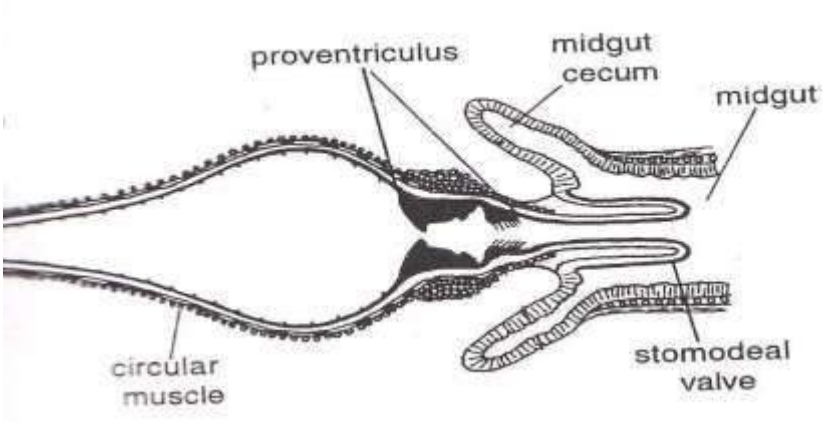
  ii. **Esophagus:** It is a narrow Simple tube of the foregut through which the foods get transported from pharynx into the crop.

  iii. **Crop:** It is a sac like structure which is a dilated form and mainly serves the purpose of **storage of food material**. In honey bees crop is called as honey stomach where nectar conversion occurs.

  iv. **Gizzard (Proventriculus):** It formsthe last portion of foregut. This consists of the cuticular intima layer modified in to teeth like denticles that **help for grinding the food material.**It is found in solid feeders and absent in fluidfeeders or sap feeders.

✓ **Stomodeal valve or cardiac valve:**

- After gizzard the foregut forms into a **stomodeal valve or cardiac valve** which is surrounded by gastric (or) hepatic caecae.
- This prevents backward movement of food. Foregut opens in to midgut through **stomodael / cardiac valve**.



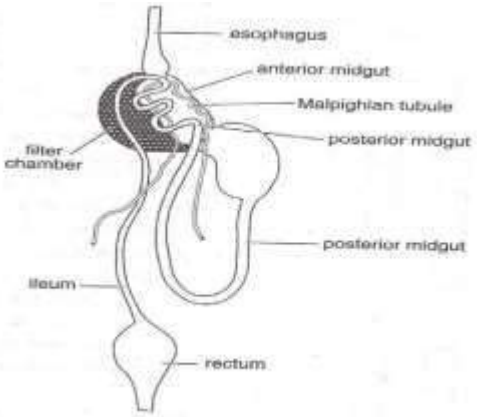
Proventriculus

2. Midgut (Ventriculus or mesenteron or stomach),(Middle)

- Endodermal in origin**.**Is concern with;
  i. Secretion of Enzymes,**ii.**Digestion of food, **iii.**Absorption of food.
- An endodermic cell does not secrete **intima** but instead of that secretes delicate membrane called **Peritrophic membrane.**
- Midgut consists of an inner delicate layer called **peritrophic membrane** secreted by the epithelial cells. The peritrophic membrane protects the tender epithelial cells of the midgut from abrasion by hard food particles. **Present in solid feeders and absent in sap feeders.**
- The midgut is a long tube it carries **eight** small blunt tubes known as **gastric or hepatic or enteric caeca.** It increase the surface area of malpighian tubules and they are secretary and absorptive in function.

❖ **Filter chamber:**

- This is a characteristic arrangement of the midgut in **hemipteran** insects (fluid feeders).
- This is closely bound to either posterior part of midgut or the anterior hindgut and Malpighian tubules.
- Filter chamber enables the excess fluids including sugar in the food to pass directly from the anterior part of the midgut to the hindgut without passing through the middle portion of midgut thus **preventing excessive dilution of haemolymph, enzymes and facilitate better enzyme activity.**



Filter chamber

✓ **Pyloric valve or proctodeal valve:** Present between midgut and hingut, which regulate food flow.

3. Hindgut (Proctodaeum) (Posterior)

- Ectodermal in origin.Intima present.
- In termites, digestion takes place in colon of hindgutwhich secretes the enzyme cellulase for digest the wood material rich in cellulose.
- Anterior end of the hindgut can be marked by the presence of a set of **malpighian tubules** which are excretory in function.
- Hindgut is divided into **3** regions namely **ileum**, **colon** and **rectum.**
  - **i.** **Ileum** is a **small intestine** (or) tube like structure.
  - **ii.** **Colon** is a **large intestine.**
  - **iii.** **Rectum -** The rectum may sometimes get differentiated into **rectal papillae (or) pads** which vary in number from 3-6. These are involved in **reabsorption of water, salts from the faecal (waste) matter.**

❑ **Salivary glands:-**

- These are a **pair** of glands involved in the secretion of salivary juices.
- These glands present either sides of esophagus which open at the base of the hypopharynx through small salivary ducts.
- In case of silkworm (or) lepidopteran larvae, the salivary glands produce silk and anti-coagulants in blood suckers like mosquitoes.
- **Digestive enzymes** such as;
  - ♠ **Amylases**–Helps for digestion of **Starch**.
  - ♠ **Lipases -**Helps for digestion of **Fats & Lipids.**
  - ♠ **Proteases**–Helps for digestion of **Protein.**
  - ♠ **Invertase –** Helps for digestion of **Sucrose.**(Present in honey bees)
  - ♠ **Maltase -** Helps for digestion of **Maltose.**
  - ♠ **Cellulase -**Helps for digestion of **Cellulose.**(Present in termites)

★ STUDY OF INSECT NERVOUS SYSTEM

- The nervous system functions as a link between the **sense organs** which respond to various external and internal **stimuli** and the **effectors organs** such as **muscles**, **glands**
- The sense organs include the structures with various **sensilla** that respond to sounds, weather factors, smell etc.

➢ Nervous system consists of elongated cells which form the physiologically functional elements that are known as **neurons**. These neurons carry the information in the form of electrical impulses. It is a unit of nervous system.

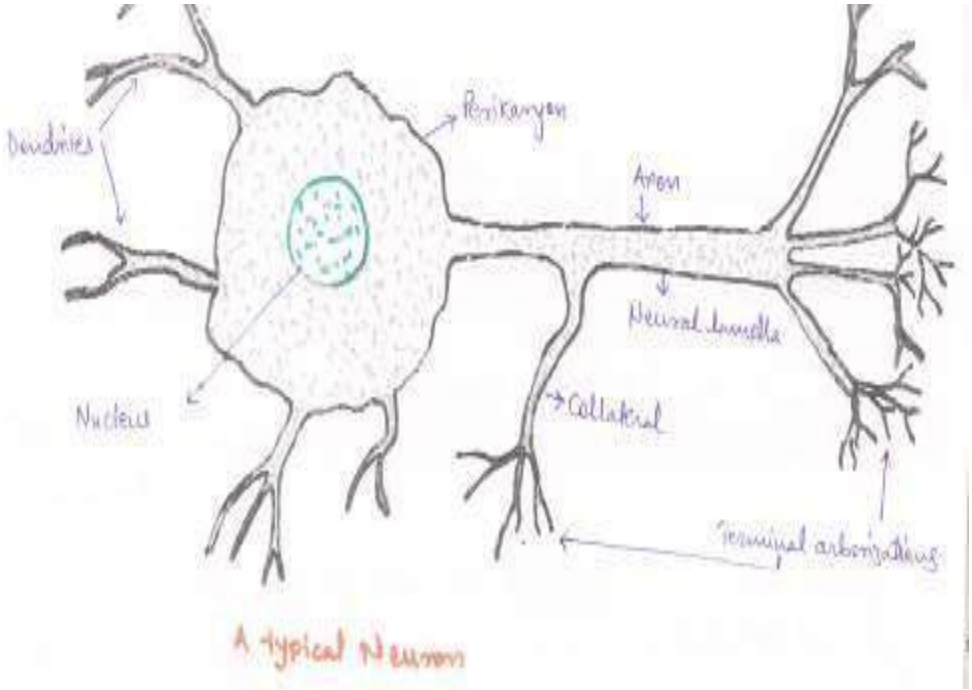
STRUCTURE OF A NEURON

❖ The **nerve cells** are called **neurons** which are derived from ectoderm.

❖ Each neuron consists of a prominent nucleated cell body known as **perikaryon (or) soma** and an elongated cytoplasmic thin fibre called the '**axon**' extends to make contact with other neurons or with effector organs, the **muscles** and group of small branches called the '**dendrites**'.

❖ The axon gives lateral branches called **collaterals**. Both the axon and collaterals end in fine fibrils known as **terminal arborizations**.

❖ The neurons get connected with each other by having a link between the terminal arborizations of the axon of one neuron and dendrites of the soma of other neuron through a '**synapse**'.



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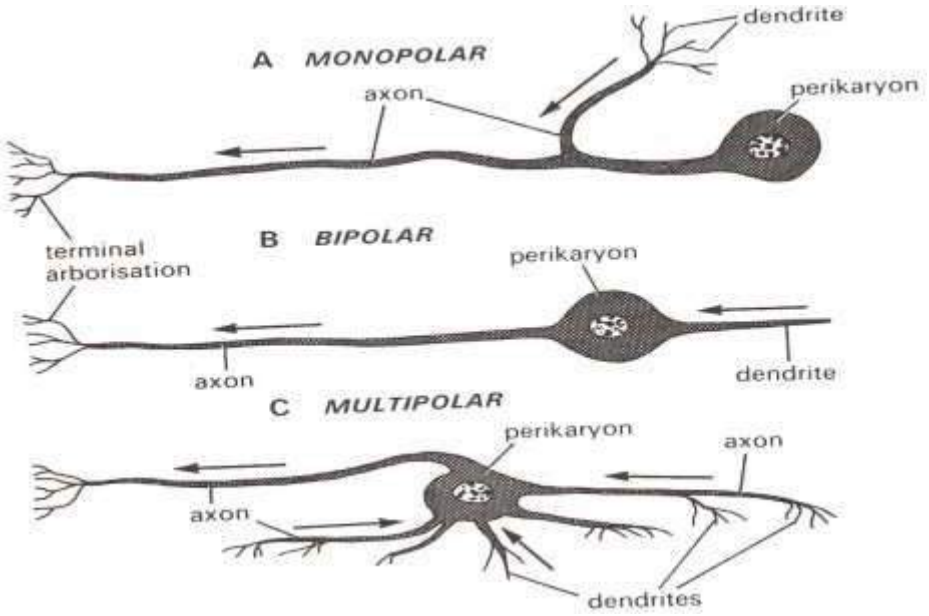
Classification of neurons:

I. Based on their structure:

1. Unipolar / monopolar: Have a single axon without collaterals and dendrites.

2. Bipolar: Have either collaterals or dendrites in addition to axon.

3. Multipolar: Neurons have an axon with several collaterals and dendrites



II. Based on function: 3 kinds of neurons.

1. Sensory / afferent: Present just beneath the integument and associated with sensory organs. **Carry impulses from sense organs to the central nervous system.**

2. Motor / efferent neurons: Always unipolar / monopolar.**Carry impulses from central nervous system to the organs.**

3. Association / internuntial neurons: Associated in between sensory and motor neurons.

- ✓ The point at which neurons receive information from or convey to another neuron is known as **synapse**. Synaptic gap is approximately 100 ^{0}A (20-25nm).

Nervous system can be grouped in to three;

1. Central nervous system (CNS)
2. Visceral or sympathetic nervous system
3. Peripheral nervous system

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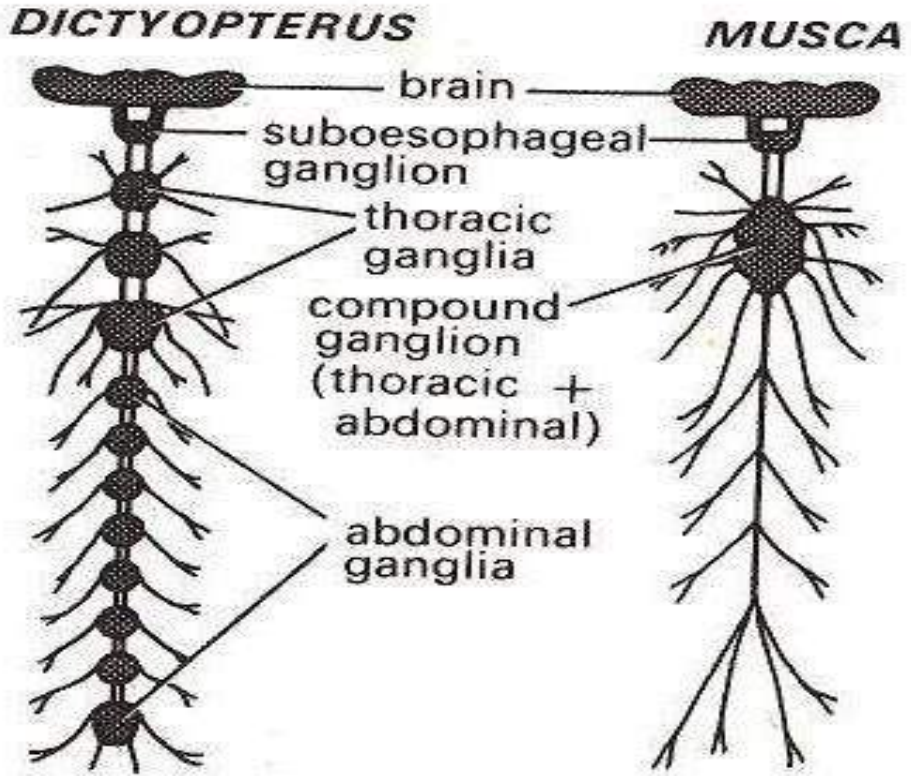
1. CENTRAL NERVOUS SYSTEM (CNS)

- Insect have a **decentralized** nervous system.
- The group of nerve cells or neurons is called **ganglion.**
- CNS consists of double series of ganglia joined together by longitudinal and transverse fibers.
- Generally each body segment possesses a pair of ganglia, so closely united as they appear to be one.
- The ganglia of adjoining segments are joined together by **longitudinal fibers** called as **connectives**.
- The ganglia of same segment unite by **transverse fibers** called as **commissures**.
- **CNS** consists of brain(supraoesophageal/cerebral ganglion), **sub-oesophagealganglion** and **ventral nervecord**.



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Brain (Supra-oesophageal ganglion):

- It is present in the head above the oesophagus in the head. It is formed by the union of the ganglia of **first 3 segments** of the head. Brain is divided into **protocerebrum, deutocerebrum and tritocerebrum.**

❖ **Protocerebrum:**

- It is also known as **fore-brain.** It is formed by the union of the ganglia of **pre-antennarysegment** and forms the **greater part of the brain**. It gives nerve connection to the **compound eyes and ocelli.** It is bilobed and continuous laterally with the optic lobes.

❖ **Deutocerebrum:**

- It is also known as **mid-brain.** It is formed from the ganglia of **antennary segment** and it gives nerve connection to the **antenna**.

❖ **Tritocerebrum :**

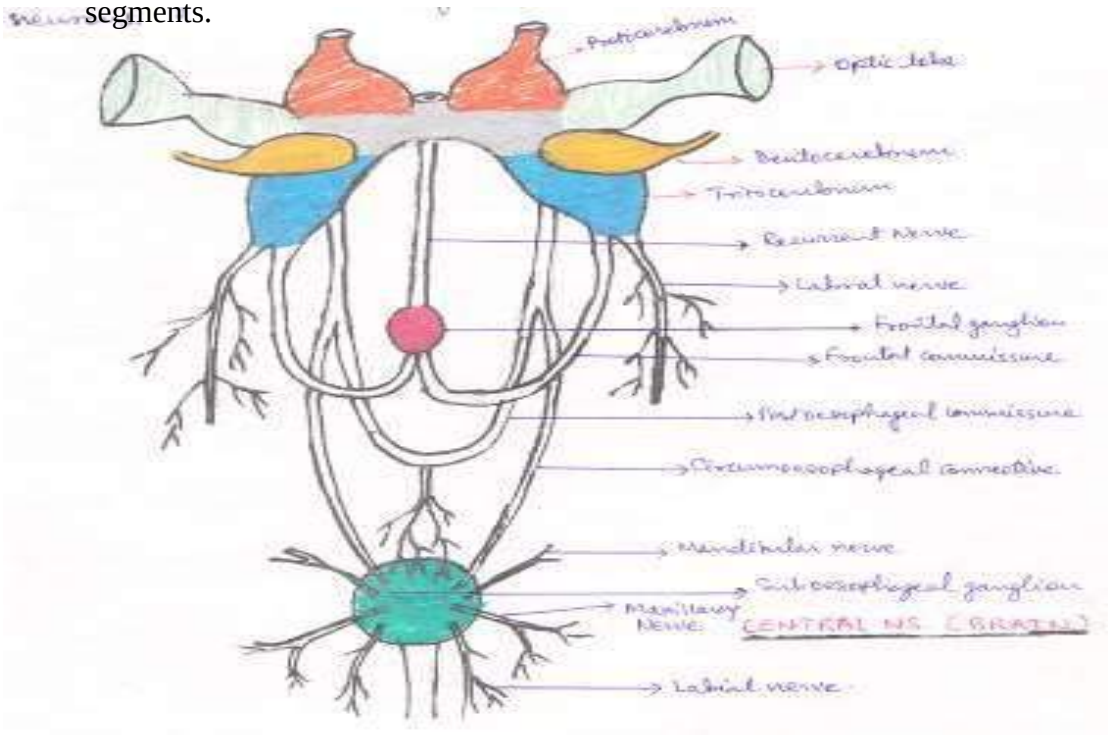
- It is also known as **hind brain**. It is formed by the union of ganglia of **intercalarysegment** and is relatively **small**. It gives nerves to the **labrum**.

Sub-oesophageal ganglion:

- It is present in the head below the oesophagus in the head. It is formed by the union of ganglia of the gnathocephalic segments. It gives nerves to **mandibular**, **maxillary**, **labialsegment**, **salivaryducts**, **part of cervical muscles in the neck region and corpora allata.**

Ventral Nerve Cord (VNC):

- Ventral nerve card consists of a chain of segmented ganglia connected by means of **longitudinal connectives and transverse commissures.**
- In **thorax**, there are **3** ganglia. It controls the locomotory organs and gives nerve connection to the legs and wings called thoracic ganglia.
- In **abdomen**, there are about **8** ganglia. Each ganglion gives off nerves to respective segments.



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Mechanism of impulse conduction

✓ Conduction of nerve impulse is mainly of two types-

1. **Axonic- Electrical conduction through Na and K ionic movement**

2. **Synaptic- Bio-Chemical transmission (Acetylcholine production)**

- In **axonic conduction** ionic composition varies between inside and outside of axon resulting in excitable conditions, which leads to impulse conduction as electrical response.
- In **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.

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

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

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★ REPRODUCTION IN INSECTS

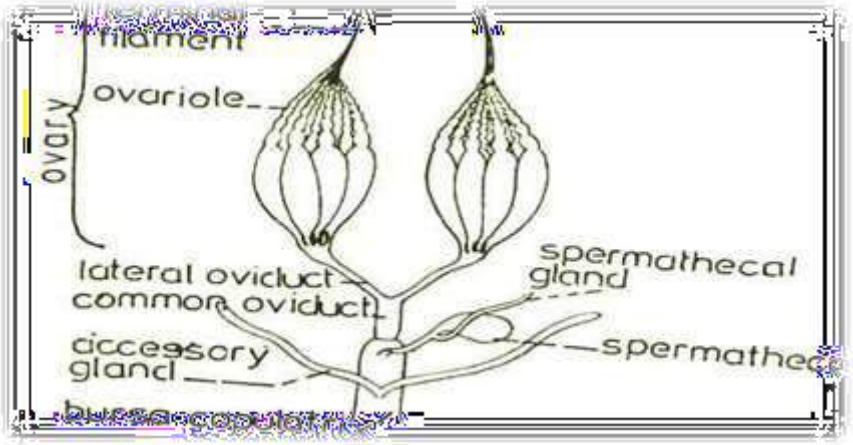
- The reproductive system is divided in to **two parts** namely, **internal genitalia** and **external genitalia.**
- The internal genitalia serve to the development of **germ cells**. The external genitalia accomplish the union of two sexes and enable the female to **deposit eggs.**

★ 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.

It consists of;

- ❖ A pair of ovaries which possess number of ovarioles,
- ❖ A pair of oviducts,
- ❖ A common oviduct / Median oviduct ,
- ❖ spermatheca ,
- ❖ A pair of accessory glands and
- ❖ Bursa copulatrix/copulatory pouch/genital chamber/vagina



1. Ovaries :

- These are the prominent visceral organs present on the either side of alimentary canal.
- These are paired in structured mainly covered with fat body and trachea.
- Each ovary consists of eight ovarioles or egg tubes. It consists of 3 parts namely; Terminal filament, Egg tube, Pedicel.
- The functions of ovary are production of eggs or ova and storage of male's spermatozoa.

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Types of ovarioles:-

- Based on the presence or absence of nutritive cells and their location ovarioles are categorized in to two;
  - **i. Panoistic -** In these, the nutritive cells are absent. e.g.: Odonata, Dictyoptera, Orthoptera and Ephemeroptera
  - **ii. Meriostic -** They contain trophocytes / nutritive cells which vary in their position. Based on the position of trophocytes Meriostic ovarioles are classified into;
    - Polytrophic - e.g.: Mecoptera, Dermaptera, Psocoptera
    - Acrotrophic (Teletrophic) - e.g.: Hemiptera and Coleoptera

2. Lateral oviducts: Proximal end of the ovarioles of each ovary join to form a lateral oviduct on each side. Function is to transfer the eggs form ovary to the median oviduct.

3. Median Oviduct: Two lateral oviducts combine to form a median oviduct.

4. Vagina: (genital chamber) Median duct opens in to a tubular **genital chamber or vagina** formed by invagination of body wall from VIII segment.

5. Bursa Copulatrix:

- In some insects the genital chamber or vagina develops a separate pouch called **Bursa Copulatrix** in to which insects have two reproductive openings
- One is **vulva for receiving the sperms** open on VIII sternum and another one is **ovipore or gonopore** on IX segment **for discharging eggs**. E.g.: Lepidoptera and water beetles.

6. Spermatheca:

- It is a sac like structure consisting of a spermathecal gland and opens in to vagina through spermathecal duct.
- This is mainly used for temporary storage of sperms.
- It also produces some fluids responsible for longevity of sperms cells for several hours.

7. Accessory glands: (collateral glands)

- These are a pair structured which open in to the distal portion of vagina.
- They secrete the sticky substance responsible for the formation of ootheca of cockroach, preying mantid and poisonous secretions in case of Hymenoptera.
- These sticky substances are useful for attachment of egg to the substrate on which they are laid.

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- **Oogenesis**-The process in which primary oocyte developed in to fully developed ova is called **oogenesis.**

Difference between male and female reproductive system

Male reproductive system	Female reproductive system
A pair of testes composed of follicles or sperm tubes.	A pair of ovaries which possess number of ovarioles.
A pair of vasa deferens.	A pair of oviducts.
Seminal vesicle.	A common oviduct / Median oviduct.
Ejaculatory duct.	A spermatheca.
Accessory glands.	A pair of accessory glands.
Genitalia. (aedeagus or penis)	Bursa copulatrix/copulatrix pouch/genital chamber/vagina.

★ 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.

A male reproductive organ consists of;

- ✓ A pair of testes composed of follicles or sperm tubes
- ✓ A pair of vasa deferens,
- ✓ seminal vesicle
- ✓ ejaculatory duct
- ✓ accessory glands
- ✓ Genitalia.

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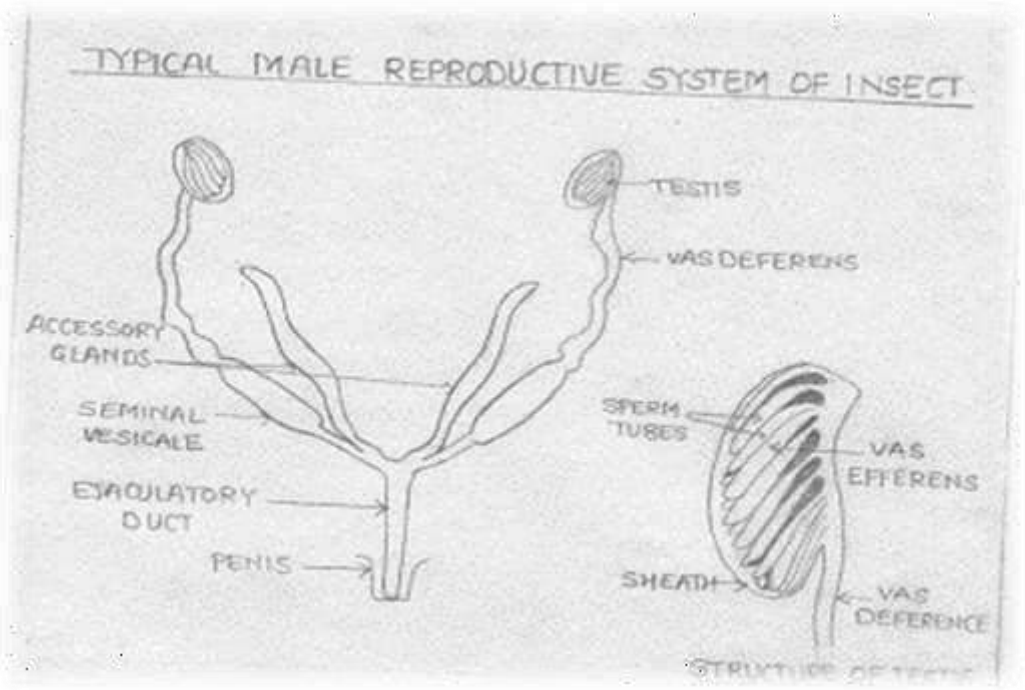

1. Testes:

- These are paired in structured &lie in visceral cavity above the alimentary canal.
- Each testes are well supplied with trachea and fat body tissues.
- Each testis consists of number of oval shaped structures known as **follicles or sperm tubes**. Each follicle has a layer of epithelial cells.
- The entire follicle is covered by a peritoneal membrane whereas the testes are completely enveloped within a coat known as **scrotum**.
- The functions of testes are production and storage of spermatozoa.

2. Vasa differentia:

- These are the long tubes formed by the union of vasa efferens which receives the sperms from testis and allow their transport to the ejaculatory duct.

3. Seminal vesicles:

- Each vasa deferens becomes enlarged posteriorly to form a sac like structure called seminal vesicle for storage of spermatozoa for some time.

4. Ejaculatory duct:

- Both the vasa deferens of the two testes unites posteriorly to form a common median ejaculatory duct.
- The terminal section of ejaculatory duct is enclosed in a finger like invagination of body wall **called male copulatory organ or aedeagus or penis.**
- The function of aedeagus is that ejaculate the spermatozoa into the female genital tract.

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5. Accessory glands:

- These are 1-3 pairs of glands which open in to the ejaculatory duct
- In most cases their secretion mix with spermatozoa. **These glands are called mushroom glands in cockroaches and mantid** because of their appearance as mushrooms.
- This secretion facilitates sperm transmission from male to female.

★ Types of Reproduction

1. Oviparity:

- Insects reproduce by **laying eggs** by the female which later hatch and produce the young ones. e.g.: **moths and butterflies.** (Higher order insect)

2. Viviparity:

- It is the phenomenon of reproduction where the **female gives birth to the young ones** instead of laying eggs.Viviparity is classified in to **4** types.

i) Ovo-viviparity:

- Insects retain the eggs within the **genital track** until the eggs are ready to hatch (or) giving birth to young ones. e.g.: **Thysanoptera** (Thrips)

(ii) Adenoparous viviparity:

- It is a type of viviparity where the eggs have sufficient yolk, complete their **embryonic development** and retain in the **uterus**. Eggs hatch and the young ones get nourishment from special nourishment glands called **milk glands.**

(iii) Pseudoplacental viviparity:

- It is a phenomenon where insect have eggs with little (or) no yolk. Hatching takes place within the mother and the nourishment for the young one is received through embryonic maternal structure called **pseudoplacenta** e.g.: **Psocoptera**, **Dermaptera**, **aphids** etc.

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(iv) Haemocoelous viviparity:

- It is a type of reproduction where the eggs are retained **within the haemocoel** and the embryonic development as well as the nourishment of young one takes place through the transfer of nutrients from the haemolymph of mother. e.g: strepsipterans & some larvae of cecidomyids (Diptera).

3. Parthenogenesis:

- It is the ability of the females to reproduce without fertilization / copulation with males. This usually occurs due to the genetic characters, due to heredity, failure in finding a mate, hormonal changes within the body and weather factors. . e.g.: **aphids**.

4. Paedogenesis (or) Neoteny:

- It is a phenomenon where the immature insects or stages give birth to young ones. This usually occurs due to the hormonal imbalance. Most of the insects which reproduce by paedogenesis also reproduce by parthenogenesis. e.g.: **cecidomyids**. (Mustad sawfly).

5. Polyembryony:

- It is a type of reproduction where insects reproduce by giving birth to two or more young ones instead of a single one, as two or more embryos are produced from a single egg. e.g.: **endoparasitic Hymenoptera like *platygaster*.**

6. Hermaphroditism:

- It is a type of reproduction where both male and female gonads are present in the same individual. It may be a functional **hermaphroditism** as in case of ***Icerya purchsi*** (scale insect)(or) nonfunctional as in case of **stonefly**, ***Perla marginata.***

7. Castration:

- It is a type of reproduction where the separation of the individuals occurs mainly due to the development of the reproductive organs. The insects with well-developed ovaries develop in to females (queens), the insects with well-developed testis develop in to males (drones) and insects with underdeveloped ovaries develop in to workers. **e.g.: social insects such as honey bees.**

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★ STUDY OF INSECT RESPIRATORY SYSTEM

- It is also called as **tracheal system**.
- In insects, exchange of gases takes place through tubular structures, called **trachea**.
- They are distributed throughout the body collectively forming **tracheal system**.
- These trachea open outside on the body wall through small openings called **spiracles**.
- Spiracles occur on the pleural surfaces of the body, one on either side of each segment.
- The tracheas are divided into very fine branches known as **tracheoles**. They supply oxygen to the body tissues. These tracheoles are formed in to cells called **'tracheoblast'**
- The tracheal system with functional spiracles is called the **open tracheal system** and with non-functional spiracles is called **closed tracheal system.**
- Tracheas are fine elastic tubular structures which are **ectodermal** in origin.
- A spiral thickening throughout the length of the tube of trachea. These spiral thickenings are known as '**taenidia**' which give support to the trachea without being collapsed when there is no air.

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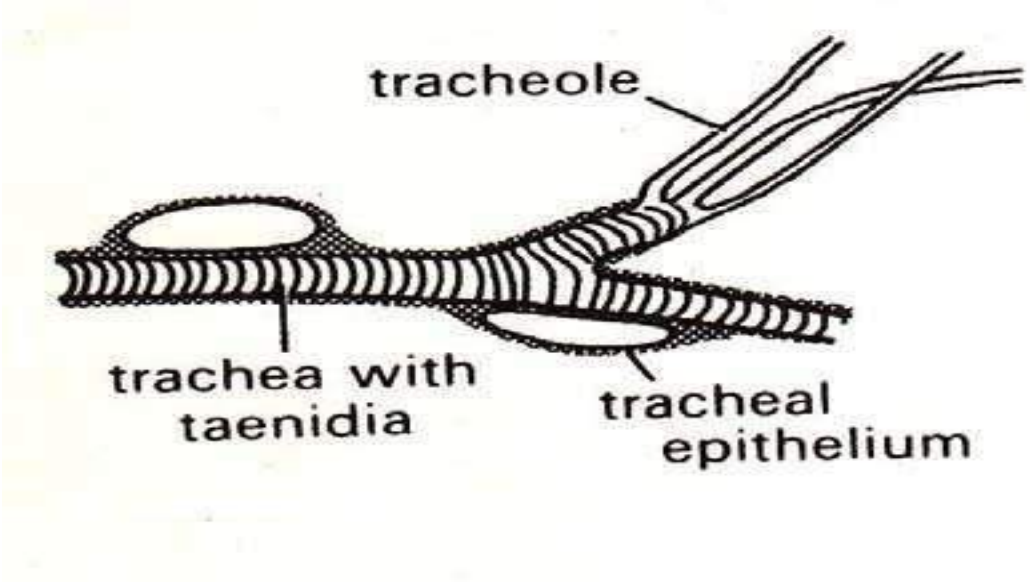

Structure of trachea

Differences between trachea and tracheoles

Trachea	Tracheoles
These arelargetubesrunningfrom spiracles.	Fine tubes arising distally from trachea.
Taenidia present.	Absent.
Intima layer isshedduringmoulting.	Intima layer is retained, unchangedduringmoulting.
Never become intracellular.	Intracellular.
Theintimalayerconsistsofprotein–chitinmatrixwithresilin.	Chitin– protein matrix present, resilinabsent.

Tracheal trunks:

- The trachea coming from spiracles throughout the body join with those of neighboring spiracles forming **'longitudinal trunks'.** Likewise, these tracheas by combining with those coming from **dorsal**, **lateral** and **ventral** sides of the body fuse to form **transverse commissures** and **longitudinal connectives**.

- All these in total form into **dorsal trunk, lateral trunks** which are two in number and one **ventral trunk.**

- The **dorsal trunk supply oxygen to proximal part of the body as well as to heart** whereas the **ventral supplies to then central nervous system.** The **two lateral** longitudinal trunks **spread tracheoles to alimentary canal, legs, gonads and wings.**

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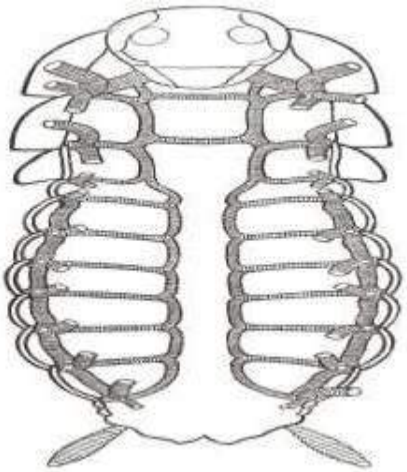
- **Head do not contain spiracles,** air is supplied through the first pair spiracles by means of two main branches of the dorsal longitudinal trunk, where one branch supply O2 to eyes, antenna, brain; other branch to mouthparts and muscles of the head.

Tracheal system (dorsal tracheal trunks)



Spiracles:

- They are the openings of the internal tubular trachea.
- Except in **Diplura**, in all the orders, **spiracles** are **absent** in **prothorax** and distributed in **meso**, **metathorax** and **abdomen**.
- A total of **10pairs** are present in general, **2** pairs in thorax and **8** pairs in abdomen.
- Spiracles are situated on pleural surface. They consist of a small ring like sclerite at opening called '**peritreme**' leading to a cavity known as **atrium.**
- The closing and opening of spiracles is accompanied by **atrial valve** lined with fibrous processes and form so called **felt** chamber which reduces water loss in the absence of closing mechanism.

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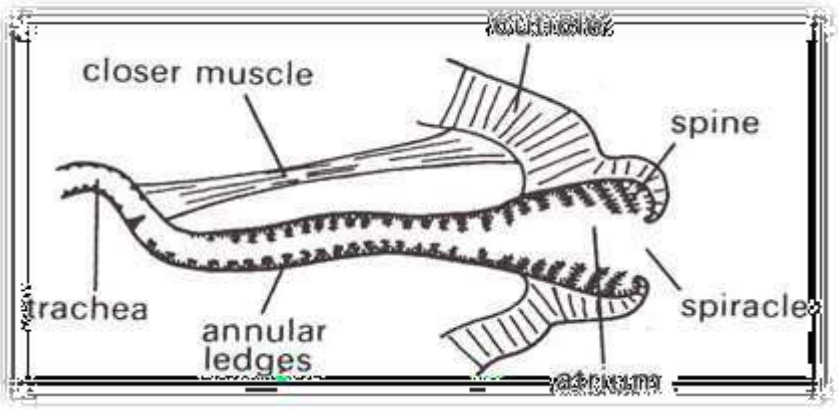
closer muscle
spine
trachea
annular ledges
spiracle

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Structure of spiracle

- **Classification of tracheal system based on number and arrangement of functional spiracles: (Types of respiration).**

1. Holopneustic:

These are primitive type with **2 pairs** of spiracles on **thorax** and **8 pairs** on **abdomen**. **All** the spiracles are **functional**. **1 + 1 + 8.**

E.g. dragonflies, grasshoppers and cockroach.

2. Hemipneustic:

One or more pairs of spiracles become **non-functional**. They are;

a) Peripneustic: Metathoracic spiracle is closed. 1+ 0 + 8.

e.g.: larvae of Lepidoptera, Hymenoptera, Coleoptera.

b) Amphipneustic: only mesothoracic and last pair of abdominal spiracles is open. 1 + 0 + 1. e.g: larva of cyclorrhaphan Diptera.

c) Propneustic: Only one pair i.e. mesothoracic spiracles are open,

1 + 0 +0 e.g.: mosquito pupa.

d) Metapneustic: only last pair of abdominal spiracles is open.

0 + 0 + 1. e.g.: mosquito larvae.

e) Apneustic: No functional spiracles. e.g: mayfly larva, nymph of Odonata

3. Hypopneustic:

1 or 2 pairs of spiracles may completely disappear or absent

e.g.: Siphunculata, Mallophaga

4. Hyperpneustic:

More than 10 pairs of spiracles are present e.g.: *Japyx sps. (dipluran)*

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★ STUDY OF INSECT CIRCULATORY SYSTEM

✓ There are **two types of circulatory systems** in the animal kingdom.

✓ In many animals, the blood travels through vessels like **arteries**, **capillaries** and **veins**. This is known as **closed type of circulatory system.**

✓ In insects the blood flows through the body cavity (i.e, **heamocoel**) irrigating various tissues and organs. It is known as **open type of circulatory system**.

Haemocoel:

❖ Haemocoel of the insects is divided into **3sinuses**(or) regions due to the presence of **two** fibro muscular septa (or) **diaphragms** composed of connective tissues.

- **Dorsal or Pericardial Sinus:**

✓ The area lying in between the **tergum** and **dorsal diaphragm.**

✓ It contains **heart**.

- **Ventral or Perineural Sinus:**

✓ The area lying in between the **sternum** and **ventral diaphragm**.

✓ It contains **nerve cord.**

- **Visceral Sinus:**

✓ The area in between **dorsal** and **ventral diaphragms**.

✓ It harbour the visceral organs like **alimentary canal and gonads.**

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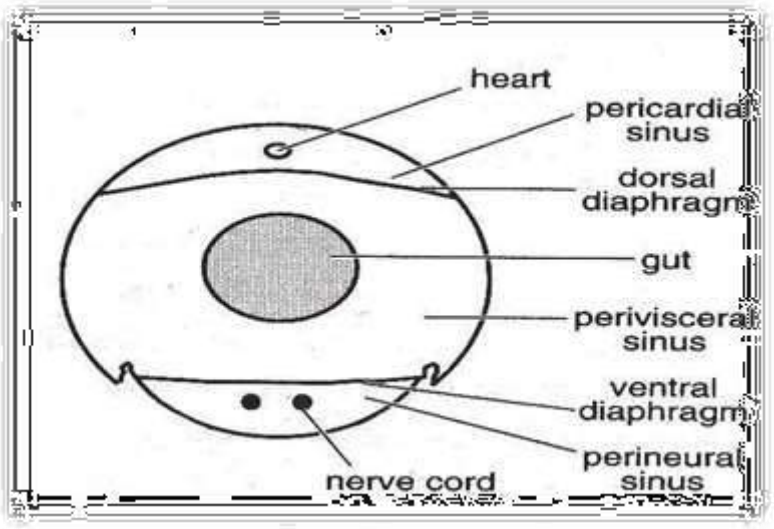

Main sinuses of haemocoel

- **Dorsal blood vessel:**
  - It is the principal **blood conducting organ** in insects which remain closed at the posterior end and opens anteriorly in to the head.
  - It is divided into an anterior **aorta** and posterior **heart**

1. Aorta:

- It is the anterior part of the dorsal blood vessel.
- Its **functions as principal artery**.
- It is present in the thoracic region and opens in to the head near the brain.
- Its attachment with the heart posteriorly is marked by an **aortic valve.**

2. Heart:

- It is the posterior part of dorsal blood vessel extending up to the terminal end of the abdomen.
- Heart remains in position with the help of alary muscles. These alary muscles appear to be distributed fan like over the heart.
- **Heart** consists of number of chambers marked by constrictions and the presence of the opening called '**ostia**' **which allow the entry of blood from pericardial sinus in to the heart.**
- The number of Ostia depends upon the number of heart chambers which will be usually **9**.
- **Heart mainly functions as the pumping organ** in to the aorta.

Accessory pulsatile organs:

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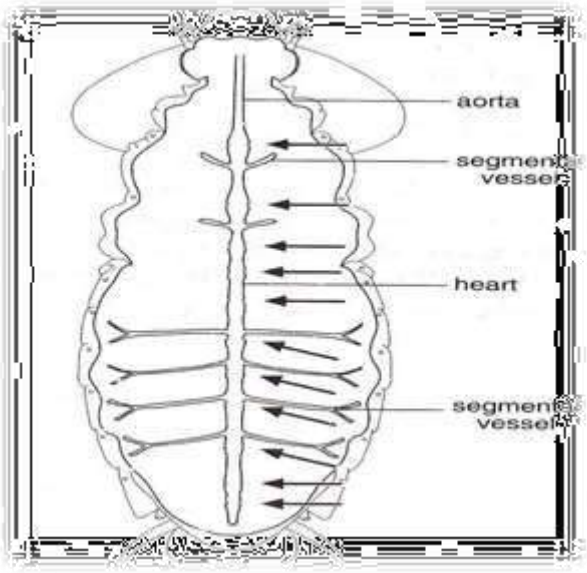
- An insect consists of sac like structures **called accessory pulsatile organs,** which are present at the base of the appendages such as wings, legs and antenna. They pulsate independently and supply adequate blood to the appendages.



Circulatory system

Process of blood circulation:

- Heart mainly function as a pulsatile organ whose expansion and contraction leads to blood circulation.
- It takes place generally in an anti-clock manner starting from posterior end to the anterior end in a forward direction.
- Circulation of blood takes place in two phases due to the action of the alary muscles as well as the muscles of the walls of the heart.

The two phases are;

1. Diastole: During which expansion of heart takes place.

2. Systole: Contraction of heart takes place.

1. Diastole:

- ✓ **Expansion of heart** (diastole) occurs, when the **alary muscles** that are spread fan like over the heart and connected to the tergum get **contracted**.
- ✓ It results in **increase of volume of heart** and **decrease in the area of pericardial sinus**.
- ✓ This creates a **pressureon** the blood in **pericardial sinus** forcing the blood to enter into the heart through the Ostia.

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- ✓ These ostia allow only the entry of blood from the sinus in to the heart and prevent its backflow from the heart to the sinus.

2. Systole:

- ✓ **Contraction of heart** (systole) is brought about by the **expansion of the alary muscles** as well as contraction of the muscles of the heart wall.
- ✓ This creates pressure on the blood within the heart leading to its forward movement in to the aorta.
- ✓ From the aorta blood enters in to the head and flows back bathing the visceral organs in the visceral sinus and neural cord in the perineural sinus.
- ✓ The short period of rest between diastole and systole called as **diastasis.**
- ✓ The rate of heart beat generally varies with the body temperature and physiological conditions of the body which in turn differs between species (or) between stages of the insects.

Properties of blood:

1. Blood is **colourless** (or) **green** (or) **yellowish** with different types of haemocytes and plasma. Green colour is due to chlorophyll dissolved in the plasma and red colour is due to haemoglobin.
2. Blood covers up **5 – 40%** of the total body weight that vary with the sex and stage (or) age of the insect.
3. Insect blood contains proteins, lipids, sugars, organic acids, phosphates, pigments, uric acid etc.
4. The insect blood of **phytophagous insect** is rich in '**K'** where as that of **carnivores** is rich in **'Na'**.
5. Specific gravity of the blood varies from 1.01 to 1.06.
6. **p^H** of the blood generally varies from **6 to 7.**
7. The **blood sugar** of insects is **trehalose**.
8. **Blood lacks vitamin 'K'**

Functions of blood:-

1. **Transport of minerals or food materials:**blood transports minerals, digested products, hormones to different parts of the body.
2. **Water storage:**Blood stores water for the tissues.
3. **Helps for moulting:**Blood helps during the process of moulting for splitting up of the old cuticle.

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4. **Encapsulation:** To protect from the large metazoan parasites, the haemocytes of blood, become aggregated around the foreign body forming a capsule of 2-3 layers. This leads to the death of the foreign bodies due to lack of O2 supply.
5. **Phagocytosis:** To get protection from microorganisms like bacteria, viruses and fungi, the haemocytes completely engulf the foreign body and gets autolyzed.**(This is the principal function of haemocytes).**
6. **Immunity:** Blood gives immunity by producing antibodies to restrict further infections.
7. **Connective tissue formation:** Blood provides lipoproteins that are necessary for the formation of the connective tissue.
8. **Wound healing (or) coagulation :**Haemocytes extend pseudopodia which forms a cellular network over the wounded site (or) plasmtocytes coagulate forming a plug over the wound (or) haemocytes are arranged in to multi layered sheaths over the wounded site, thus helping in wound healing.
9. **Detoxification:** As the haemocytes are capable of detoxifying the toxic chemicals, insects get the ability to resist the toxic effects of chemicals.
10. **Reflex bleeding:** It is a phenomenon where emission of blood occurs through the pores (or) slits of the cuticle which mainly helps the insects for getting protection from their natural enemies.

★ STUDY OF INSECT EXCRETORY SYSTEM

- ✓ **What is excretion?**
  "It is simply removal of the unwanted metabolic end products or some of the nutrients in excess form out of the body."
- ✓ **Why it is necessary?**
- ✓ A constant maintenance of level of salt and water and also osmotic pressure in the hemolymph.

- ➢ The organs of insect body, involved in the **elimination of excess or unwanted** materials either toxic or not useful, are together known as **excretory system.**

The organs that are involved in the process of excretion are;

1. Malpighian tubules
2. Integument or body wall
3. Tracheal system
4. Alimentary canal
5. Nephrocytes

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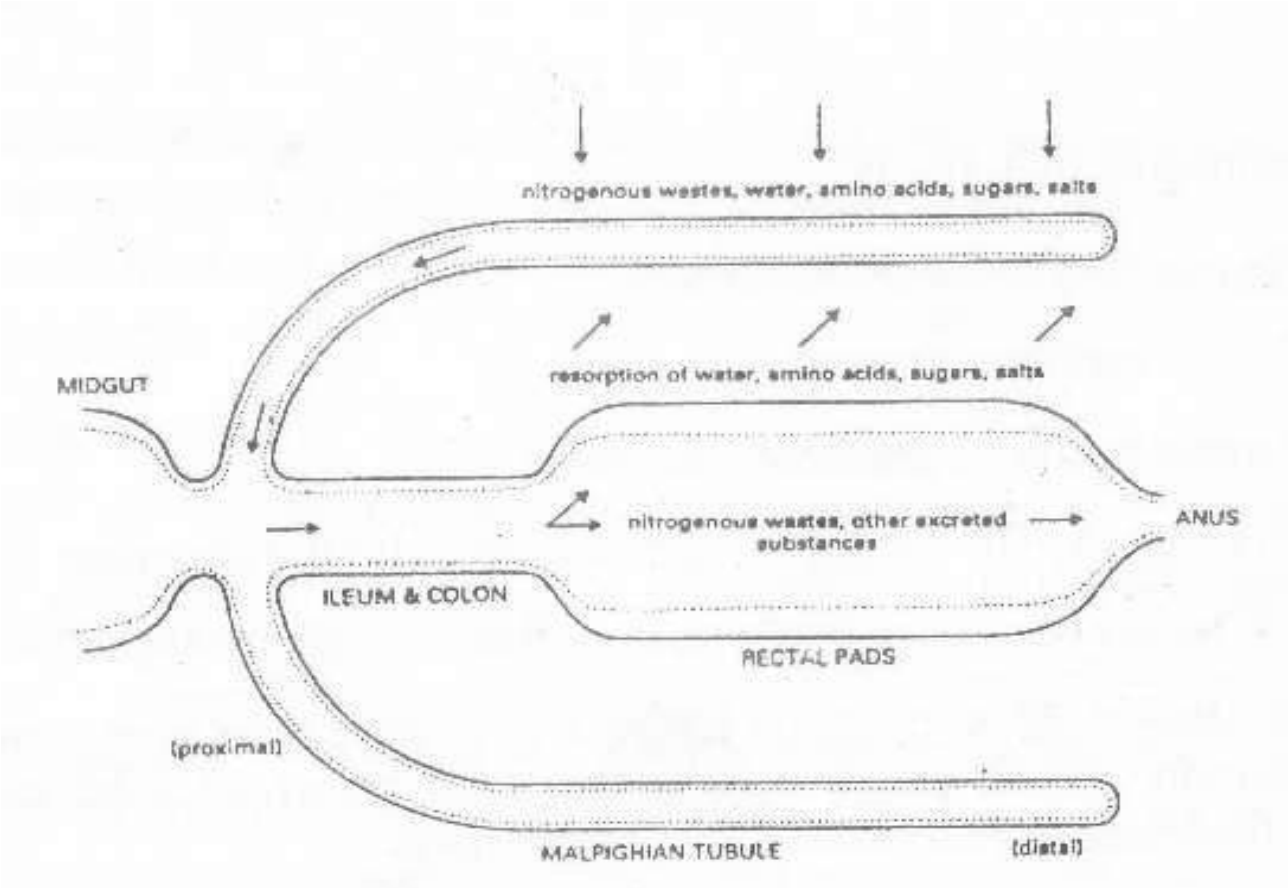
6. Urate cells
7. Oenocytes
8. Labial glands and
9. Chloride cells

1. Malpighian tubules:

- ✓ These are discovered by an Italian scientist, **Marcello Malpighi** in the year 1669, which were named after him by Heckel in 1820.
- ✓ The Malpighian tubules long, tubular structures which open proximally in between midgut and hindgut and closed distally, floating freely in the haemolymph.
- ✓ Malpighian tubules vary in their shape and size. They may be simple or branched. Their number varies from 2-250 (**2 in scale insect** and **250 in locust, 60 in cockroach,** 6 in moths and butterfly, 4 in bugs).
- ✓ Malpighian tubulesare **absent** in **aphids and Collembola.**
- ✓ In some of the insects such as **caterpillars** and **coleopterans**(Beetles & Weevils), the distal ends of the Malpighian tubules get reattached to the alimentary canal by opening in to the rectum of hindgut. This condition is called '**cryptonephridial condition'.** Thecryptonephridial arrangement is concerned with reabsorption of water from rectum.



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Functions of Malpighian tubules:

1. This is the main organ of excretion and osmoregulation. It involved in regulation of salt, water and nitrogenous waste material.

2. Helps in the process of excretion or removal of waste products in order to regulate the internal body environment by maintaining ionic and water balance.

3. In case of glow worms (Fireflies), the distal ends of tubules produces light energy.

4. It also helps in the storage of Ca necessary for the processes such as hardening of puparium.

5. In case of aphid lion the secretions of the tubules produce stalked eggs.

6. In case of spittle bugs spittle around the immature stages is also a Malpighian secretion.

3. Integument:

- ✓ Through the process of moulting, insects remove the waste nitrogenous products, i.e. they are deposited in the form of exuviae.
- ✓ In some insects, where respiration occurs through body wall, CO2 is removed through integument as waste product (cutaneous respiration).

4. Tracheal system:

- ✓ The respiratory tubes, the trachea which are distributed throughout the body, function in elimination of CO_2 through spiracles.

5. Rectum:

- ✓ Rectum plays an important role in excretion by reabsorbing the water from faeces.

Accessory organs of excretion-

6. Nephrocytes:

- ✓ These are the special cells that sieve the haemolymph and are distributed in the body cavity.
- ✓ Nephrocytes are cells that take up foreign chemicals of relatively high molecular weight which Malpighian tubules may be incapable of dealing with.

7. Oenocytes:

- ✓ These are large cells and are usually present near the abdominal spiracles. These are the specialized cells of haemocoel involve in excretion.

8. Urate cells: (Fat bodies)

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- ✓ In some of the insects body cells which store urea or uric acid in the form of granules are known as urate cells.
- ✓ Preserved uric acid can be utilized subsequently.
- ✓ These are present when Malpighian tubules are absent or may become nonfunctional.
- ✓ In some of the insects such as cockroach, the waste material in the form of urea or uric acid is stored throughout its life in the fat body cells without any harmful effect. This phenomenon of storage of urea / uric acid in the fat body cells is called **'storage excretion'** which is useful for supply of nitrogen, when insect feeds on nitrogen deficient food.

9. Labial glands:

- ✓ These are seen in Collembola, Diplura, Thysanura. They consists of a sac like structures called **ampulla** that leads to a long coiled that open at the base of labium in the head. This gland helps to remove ammonia.

10. Chloride cells:

- ✓ These are the cells distributed on the body of aquatic insects such as **larva ofmayfly or stone fly**. They absorb ions from salt water (body) and then excrete in to surrounding medium to compensate the changes in the ionic concentration of haemolymph.

★ STUDY OF INSECT ENDOCRINE SYSTEM

There are two types of secretrory structures occur in insect.

1.) Exocrine glands:

- ➢ It is a ducted glands and discharge their secretions outside the body.
- ➢ E.g. Wax glands, Lac glands, Mandibular glands, Maxillary glands, Labial glands, Silk glands, Repugnatorial glands, Attractant glands and Poison glands.

2.) Endocrine glands:

- ➢ It is a ductless glands and their secretion (harmones) usually diffusing into the blood which transports them to all parts of the body.
- ➢ Insect endocrine system is structurally and functionally integrated with nervous system**. It is also called as secretory system.**
- ➢ They secrete **harmones** which travel in the blood to various organs of the body coordinating their long term activities.
- ➢ Endocrine organs are of **two types,**

- ➢ **1. Neuro-secretory cells** in the central nervous system.
- ➢ **2.Specialized endocrine glands** such as
  i) Corpora cardiaca

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ii) Corpora allata
iii) Prothoracic glands
iv) Weismann's Ring:

2. Neurosecretory cells:

- These are typical neurons with secretory activity.
- They produce harmones which act directly on **effector organs** which in turn are stimulated to secrete harmones.
- They **occur in** the mid region of **brain** and **central nervous system.**
- The secretions of neurosecretory cells are called **brain hormone** or **activator hormones.**
- Large number of neurosecretory cellsmay be present in the nervous system and are threetypes.**a)** Median NSC of the brain (PTTH harmone), **b)** Lateral NSC of the brain:
  - They Stimulate protein synthesis, control water loss and Oocyte development and activity. And **c)** Ventral NSC of the other ganglia (ventral nerve cord):

✓ These secretions are known to concern with activity, water regulation.

3. Corpora cardiaca:

- They are **paired** structures, lying in close association with neurosecretory cells of brain.
- Each corpus cardiacum is transversed by neurosecretory axons from the brain. Neurosecretions from brain, on reaching corpus cardiacum, is stored and periodically released into the blood.

4. Corpora allata:

- They are glandular bodies, usually situated one on either side of the Oesophagous.
- Under the influence of brain hormone, corpora allata secretes **Juvenile hormone (JH) or neotenin which regulates metamorphosis or yolk deposition on eggs in insect.**
- JH helps to keep the insect in young stage only.
- It is also called as **Juvenile hormone (JH) or neotenin.**

5. Prothoracic glands:

- It is also known as **ecdysial glands.**

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- ❖ They are **twoin number** and placed mostly in prothoracic region.

- ❖ Prothoracic glands **secrete moulting hormone (MH), called Ecdysone** under the influence of brain hormone.

- ❖ Moulting hormone helps in insects in the initiation and process of moulting.

6. Weismann's Ring:

- ✓ It is found in housefly, flesh fly and blow fly.
- ✓ A Small ring like structure present behind the brain and around the aorta, supported by tracheae.
- ✓ It contains three types of glandular cells homologous with other endocrine glands.

★ SENSORY AND SOUND PRODUCING ORGANS

The sense organs in an insect body are distributed on different parts and respond to a given stimulus such as light, sound, touch, chemicals etc.

The sense organs may be classified as;

1. Photoreceptors(or) Visual organs- To detect light energy.

2. Auditory receptors (or) organs of hearing- To detect sound waves.

3. Chemoreceptor's which respond to chemicals- To detect smell and taste.

4. Mechanoreceptor/Tactile receptors which respond to touch- To detect mechanical force

5. Thermoreceptor – To detect heat.

1. **Visual organs or photoreceptors:**These are two types, Compound eyes and Simple eyes.

I. Compound eyes:These organs possess the ability to perceive light energy and able to produce a nerve impulse. The compound eyes may be completely absent in insects like Protura or they may remain reduced in endoparasitic Hymenoptera. The compound eyes are present on either side of the head capsule of an adult insect and also in the nymphs of Exopterygota.

These are a pair and consist of number of **individual units** (or) facets called **ommatidia.** Function is to gather light.

Classification of Compound eyes based on image formation;

- **Apposition eyes:**These are active during day time (**diurnal insects);**e.g.: butterflies
- **Superposition eyes:**These are active during evening and night time **(Nocturnal insects**); e.g.: moths

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II. Simple eyes (or) ocelli: These are of two types

- **Dorsal ocelli:**Seen in nymphs and adults of **Hemimetabolous insects and** adults of **Holometabola.**Dorsal ocelli are represented by **fenestrae** in cockroach. It perceive light to maintain diurnal rhythm.
- **Lateral ocelli:**Also known as **stemmata**. These are present on the lateral sides of the head of Endopterygote larva. It helps to detect form, colour and movement.

2. Auditory organs (or) organs of hearing:

Insects are provided with structures (or) organs that are able to perceive the sound waves (or) the aquatic water currents. Among the organs of hearing, the auditory hairs, tympanal organ and Jhonston's organ are important.

- **Auditory hairs :**

These are present on the body of insects such as larvae of Lepidoptera which are developed from the modified epidermal cells. These respond to the sounds of air (or) water currents mediated by the hair sensillae (or) trichoid

- **Tympanal organ :**

Tympanum is present one on either side of the 1st abdominal segment of short horned grasshoppers, on the base of foretibia in long horned grasshoppers and crickets, and on thorax or abdomen in Lepidoptera.

- **Jhonston's organ:**

It is present on the **pedicel of antennae** and functions asan auditory organ responding to air (or) water currents. They are absent in Collembola.

- **Pilifer of hawk moths (sphingid moths):**

A unique auditory organ, sensitive to ultrasonic frequencies is **found in the head** of several species of Sphingidae.

3. Mechanoreceptor: (detect mechanical force)

- **Trichoid sensilla:**Hair like sense organ. Sense cell associated with spur and seta. These cells are sensitive to touch and are located in antenna and mouthparts.
- **Campaniform / Dome sensilla:**These cells are sensitive to pressure and located in legs joints and wing bases.
- **Chordotonal organ:**The specialized sensory organs that receive vibration are subcuticular mechanoreceptors called chordotonal organ.

4. Chemoreceptors: (detect smell and taste):

It contains sensilla with one pore (uniporous) or more pores (multiporous).

- ♣ Uniporous chemoreceptors mostly detect chemicals of solid and liquid form by contact called **gustatory receptors**and located in antennae.
- ♣ Multiporous chemoreceptor's detect chemicals in vapour form at distant by smell called **olfactory receptors** and located in mouth and tarsi.

5. **Thermoreceptor** – (detect heat)
   Present in poikilothermic insects and sensitive to temperature changes. E.g. Bed bugs.

Scientific Nomenclature: -

Caroles Linnaeus (1707 – 1778) in his tenth edition of **'systema naturae'**published in 1758 used the binomial system of nomenclature for the first time for both plants and

animals. This double naming in Latin one for the genus and thesecond for the species has been universally accepted.

Taxonomy – (Taxis = arrangement & Nomus = laws) 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.

Systematic position of insect

Invertebrates

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Kingdom: Animalia

⇩

Phylum: Arthropoda

⇩

Sub-phyllum: Uniramia

⇩

Class: Insecta/Hexapoda

⇩

Sub class: Pterygota /Apterygota

⇩

Order:

⇩

Suborder:

⇩

Super family:

⇩

Family:

⇩

Subfamily

⇩

Genus:

⇩

Species

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The basic biological unit in the classification is species.

- ✓ **Species:**These are a group of individuals which are similar in their structure, capable of interbreeding and producing fertile off spring.
- ✓ **Subspecies:**It is an aggregate of phenotypically similar populations of a species and differing taxonomically from other populations of the species.
- ✓ **Genus:**A group of species having some definite similar characters or relationships is called a geneus.
- ✓ **Subfamily:**It is a group of allied genera to form a subfamily.
- ✓ **Family:**It is a taxonomic category containing a single genus or a group of genera of common phylogenetic origin which is separated from related families by a decided gap. Such families showing similar characters form order.

★ **The class insecta is divied in to two subclasses Apterygota and Pterygota.**

Class – Insecta

Sub class 1. Apterygota

Order 1: Thysanura (Bristle tails, Silverfish, firebrats)(Thysan-fringed, Ura-tail)
Order 2: Diplura (Diplurans)(Di-two; Ura-tail)
Order 3: Protura (Telson tails)(Pro-first, Ura-tail)
Order 4: Collembola (spring tails, snow fleas)(coll-glue; embol-peg)

Sub class 2: Pterygota

Exopterygota (Insects having simple metamorphosis)
Order 5: Ephemeroptera (May flies)
Order 6: Odonata (Dragon flies & damsel flies)
Order 7: Plecoptera (Stone flies)
Order 8: Grylloblattodea (Grylloblattids)
Order 9: Orthoptera (Locusts and grass hoppers)
Order 10: Phasmida (Walking sticks, leaf insects & stick insects)
Order 11: Dermaptera (Ear wigs)
Order 12: Embioptera (Web spinners)
Order 13 Dictyoptera (Cockroaches and mantids)
Order 14: Isoptera (White ants or termites)
Order 15: Zoraptera (Zorapterans)
Order 16: Psocoptera (Psocids, book lice)
Order 17: Mallophaga (Bird lice)
Order 18: Siphunculata or Anoplura (sucking lice)
Order 19: Hemiptera (Plant bugs)

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Order 20: Thysanoptera (Thrips)

Endopterygota (Insects having complex metamorphosis)

Order 21: Neuroptera (Ant lions and lace wings)
Order 22: Coleoptera (Beetles, weevils)
Order 23: Strepsiptera (Stylopids)
Order 24: Mecoptera (Scorpion flies)
Order 25: Siphonoptera (Fleas)
Order 26: Diptera (Flies, midges, mosquitoes)
Order 27: Lepidoptera (Moths and butterflies)
Order 28: Trichoptera (Caddis flies)
Order 29: Hymenoptera (Ants, bees, wasps)

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

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

Sr. No.	Apterygota	Pterygota
1	Primarily wingless insect	Winged or secondarily wingless insect
2	Metamorphosis is totally absent or slight present.	Present
3	Mandibles articulate with head capsule at a single point.	double
4	Pleural sulcus in thorax is absent.	Present
5	Pregenital abdominal appendages Absent.	present

The sub class Pterygota has **two divisions** viz.,**Exopterygota**and **Endopterygota**

Character	Exopterygota	Endopterygota
Wing development	External	Internal
Metamorphosis	Incomplete (Hemimetabola) or gradual	Complete (Holometabola)
Pupal stage	Absent	Present
Immature stage	Egg, Naiad or Nymph, Adult	Egg, Larva, Pupa, Adult
No. of orders	16	09

★ **STUDY OF INSECT ORDERS**

1. **ORDER: ORTHOPTERA**(Orthos - Straight; Ptera-wings)
   E.g.Grasshoppers, Locust, Katydids, Mole cricket, house and field cricket.

- **Economic Importance: Majority** of insects are phytophagous like grasshopper, locust some create noisy loud sound**.**

Characters:

- Antenna is filiform.

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- Mouthparts are mandibulate.
- Head position is hypognathous.
- Prothorax is large and distinct.
- Legs are saltatorial type.
- Legs normally developed, or forelegs modified for digging (fossorial) as in mole crickets or hind legs modified for jumping (saltatorial) as in grasshopper.
- Forewings are leathery, thickened and known as Tegmina and Hind wings are membranous.
- Specialized stridulatory (sound-producing) organs are present. Usually males alone can produce sound.
- Auditory or tympanal (hearing) organs are also well developed and are located on either side of the first abdominal segment or at the base of fore tibia.
- Cerci are short and unsegmented.
- Metamorphosis is gradual. (simple or incomplete)(Egg – Nymph - Adult)
- Ovipositor is well developed in female on 7 & 8thabdominal sternum.
- Male genitalia on 9th abdominal sternum.

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

Sr. No.	Caelifera	Ensifera
1	Antennae are shorter than bodyless than 30 segments	Antennae are longer than body more than 30 segments
2	Tympanum is found on the lateral side of the first abdominal segment.	Tympanum is found on the fore tibia.
3	Diurnal(Active at day)	Nocturnal(Active at night)
4	Feed on monocot plants	Feed on dicot plants
5	Eggs laid in soil.	Eggs laid in plant tissue
6	Ovipositor is short	Ovipositor is more or less elongate.
7	Stridulatory organ (Femoro-alary type)	Stridulatory organ (Tegminal)
8	**Family: Acrididae:** Short horned grasshoppers, Surface grasshoppersand locusts.	**Families:** **1. Tettigonidae:**Long horned grasshoppers, Katydids and bush crickets. **2. Gryllidae:** House and fieldCrickets. **3. Gryllotalpidae:** Mole crickets.

2. ORDER: DICTYOPTERA(Dictyon - Network; Ptera – wings)

♣ E.g. Cockroaches and Preying Mantid

- **Economic Importance :** Cockroaches are household pests and Mantid predatory in habit

Characters:

- Head is usually hypognathous.

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- Antenna is filiform/ cetaceous.
- Mouthparts are mandibulate type.
- Forewings are tegmina and Hind wings are large membranous.
- Prothorax with pronotum covering
- Cerci are short and many segmented.
- Fore legs is walking/raptorial type.
- Eggs are contained in an ootheca.
- Metamorphosis is gradual. (simple or incomplete)
- Female with reduce ovipositor on 7^{th}abdominal sternum.
- Male genitalia on 9^{th} abdominal sternum.
- Dictyoptera is divided into two suborders viz., **Blattaria** (cock-roaches) and **Mantodea** (preying mantids). The important families are **Blattidae** and **Mantidae.**

Differences between Blattaria and Mantodea

Sr. No.	Blattaria	Mantodea
1	Head is completely covered with pronotum.	Head is not covered with pronotum.
2	Two ocelli are present.	Three ocelli are present.
3	Legs cursorial (All pairs)	Fore legs is raptorial type.
4	Proventriculus with powerful teeth.	Proventriculus not powerful teeth.
5	Eggs laid in ootheca	Eggs laid in spaumaline
6	Omnivorous	Carnivorous
7	No mimicry found	Mimicry found
8	Nymph not cannibalistic	Nymph cannibalistic
	Family: Blattidae- e.g. Cockroaches	Family: Mantidae- e. g. preying mantids

3. **ORDER: ODONATA** (Odous - Tooth; anus – having), E.g. Dragonflies and damselflies.

- **Economic Importance:** Adults are aerial predators. They are able to catch, hold and devour the prey in flight. Naiads are aquatic predators. Adult predacious on mosquitoes, Houseflies etc. and nymph feed on mosquito larvae.

Characters:

- Medium to large sized insects. They are attractively coloured.
- Head is Mobile and attached to slender neck
- Compound eyes are large. Three ocelli are present.

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- Antennae is filiform
- Chewing and biting type of mouth parts
- Wings are membranous. Wings have a dark pterostigma towards the costal apex.
- Prothorax is reduced; meso and meta thorax is fused.
- Basket like legs present to catch prey in flight
- Abdomen is long and slender.
- 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.
- Respiration by means of rectal or caudal gills.
- Immature stage of Odonata is called "Naiads"
- There are three sub-orders. **Anisoptera, Zygoptera and Anisozygoptera.**

Differences between Anisoptera and Zygoptera

ANISOPTERA (Anisos = Unequal & Ptera = Wing)	**ZYGOPTERA** (Zygon = Equal & Ptera = Wing)
Adult Characters	
1. Strong fliers	1. Weak fliers
2. Compound eyes large meet each other (Holoptic)	2. Compound eyes button like, wide apart (Dichoptic)
3. Hind wings basally broader than forewings	3. Both Pair equal with identical venation
4. Wings spread laterally at rest	4. Wings held at an angle above abdomen
NYMPH (Naid) CHARACTERS	
1. Stout and robust	1. Weak and fragile
2. Rectal gills present	2. Caudal gills present
3. Jet propulsion Mechanism present	3. Absent
E. g. Dragonfly	E. g. Damselfly

4. **ORDERS: ISOPTERA**(Iso - Equal; Ptera - wing)E. g. Termites (White ants)

- **Economic 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

Characters:

- They are ancient polymorphic, social insects living in colonies
- White, soft bodied insects.
- Antennae are short and moniliform.

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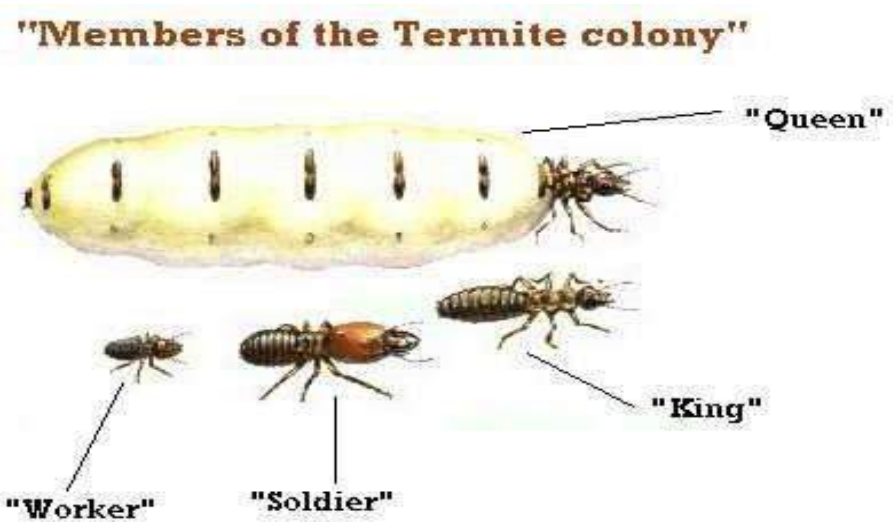
- Compound eyes present in winged forms.
- Mouthparts are adapted for biting and chewing.
- Wings are membranous. Wings are present only in sexually mature forms during swarming season.(Deciduous type)
- Tarsi are always 4 segmented
- Circi are short
- External genital organs are lacking in both the sexes.
- Metamorphosis simple or incomplete.
- Caste system: Following are the difference castes that are usually seen in atermite colony.
- Workers is the damaging caste

A) Reproductives Cast;-

a) Primaryreproductive (King& Queen)
b) Supplementary reproductive

B) Sterile Cast;-

a) Workers
b) Soldiers



- **Important families:-**
  1. Termitidae- e.g. Termes spp, Odontotermes spp.
  2. Kalotermitidae- e.g. Dry wood termites.

5. ORDER: THYSANOPTERA (Thysano: Fringed and Pteron: wing), E.g. Thrips

- **Economic 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.

Characters:

- They are minute, slender, soft bodied insects.
- Mouthparts are rasping and sucking.

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- Right mandible is absent Hence mouthparts are asymmetrical.
- Antennae short moniliform
- Fringed wings are present
- Prothorax is free and well develops.
- Abdomen is elongate with 10-11 segments, usually tapering posteriorly
- Cerci absent
- Metamorphosis is incomplete with inactive pupa like instars (Aberrant hemimetabola)
- Parthenogenetic type of reproduction is very common and in many species males are rarely seen.
- This order is subdivided into two suborders.
- **1. Terebrantia:** Important family is **Thripidae, e.g Onion Thrips**
- **2. Tubulifera:** Important family is **Phaleothripidae e.g Olive Thrips**

6. ORDER: HEMIPTERA (Hemi - half; Ptera – wing)
E.g. Bugs, Aphids, Whiteflies, Mealy bugs, Scales etc

Characters:

- Head is opisthognathous.
- Mouthparts are piercing and sucking type.
- Forewings (Hemielytra) are either uniformly thickened throughout distally membranous.
- Cerci are always absent.
- Metamorphosis usually incomplete.
- Alimentary canal is suitably modified **(filter chamber)** to handle liquid food.
- There are two suboders *viz*., Heteroptera and Homoptera

Differences between Heteroptera and Homoptera

Sr. No.	**Heteroptera** (Hetero-different; Ptera-wing)	**Homoptera** (Homo-uniform; Ptera-wing)
1	Head is porrect or horizontal	Head is deflexed
2	Pronotum usually large	Pronotum small and collar like
3	Forewings hemelytra	Forewings uniform in consistency
4	Wings fold flat over the body atrest	Wings held roof like over the body
5	Tarsi – 3 segmented antennae 4-5segmented	Tarsi 1-3 segmented antenna 3-

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		10segmented
6	odoriferous glands arepresent	wax glands are present
7	Herbivorous, predaceous orblood sucking.	Herbivorous
8	Both terrestrial and aquatic	Terrestrial
9	Honey dew secretion uncommon	Honey dew secretion common
10	**Important families of heteroptera** **1. Cimicidae:** (Bed bugs) **2. Tingidae:** (Lacewing bugs or Tingid bug) **3. Miridae:** (Plant bugs or Leaf bugs) **4. Lygaeidae:** Dusky cotton bug **5. Pyrrhocoridae:** Red cotton bug **6. Coreidae:** Rice earhead bug,Tur pod bug, **7. Pentatomidae:** (Stink bugs, Painted bug) **8. Belostomatidae:** (electric light bugs)	**Important families of homoptera** **1.Cicadellidae:** (Leaf hoppers or Jassids) **2. Delphacidae :** (Delphacids) **3. Aleyrodidae:** (Whiteflies) **4. Aphididae:** (Aphids) **5. Coccidae:** (Scale insects) **6. Kerridae:** (Lac insect) **7. Pseudococcidae:** (Mealy bugs)

7. **ORDER: NEUROPTERA**(Neuron-nerve; Ptera - wings), E. g. Green lace wings, Ant lions, Alder fly, Snake fly

- **Economic Importance:** Insects are predacious (on aphids, White flies, thrips) – beneficial, Dobson flies called hellgrammites use for fish baiting.

Characters:

- They are soft bodied insects
- Antenna is filiform
- Mouthparts are chewing type in adults.
- Two pairs of similar membranous wings in rest form roof on abdomen
- Circi absent
- Larva is carnivorous, campodeiform
- Pupa is Exarate, decticous.
- Pupation takes place in a silken cocoon.
- Malpighian tubules are modified as silk glands.
- Abdomen without cerci.
- Metamorphosis complete type (Egg – Larva – Pupa - Adult)
- **Classification:** This order is subdivided into two suborders viz., Megaloptera and Planipennia.

Sub order: Planipennia:

1. Chrysopidae: (Green lacewings, Goldeneyes, Stink flies, Aphid lions)
2. Mantispidae: (Mantispidflies).
3. Myrmeleontidae: (Ant lions)
4. Ascalaphidae: (Owlflies)

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8. ORDER: LEPIDOPTERA (Lepidos - scales; Ptera – wings)

E. g. Moths, Butterflies, Skippers

Characters:

- Head relatively small free with small neck. Compound eyes are relatively large; two ocelli present one on each side close to the margins of compound eyes.
- Mouthparts in adults are of **siphoning** type. Mandibles are absent.
- Antennae are clubbed in buterflies and filamentous in moths
- Wings are membranous and scaly.
- Wings are coupled by either **frenate** or **amplexiform** type of wing coupling.
- Larvae are called caterpillars usually **polypod-eruciform** type.
- 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 **adecticous and obtect**
- Adults are harmless except fruit sucking moths.
- Undergo complete metamorphosis.

There are three sub-orders. **Zeugloptera, Ditrysia, Monotrysia.**

Sr. No.	Zeugloptera	Monotrysia	Ditrysia
1	Adults with functional mandibles	Adults without functional sometimes with vestigial mandibles	Adults without functional mandibles
2	Female bursa copulatrix opening into common oviduct	Female with 1 or 2 genital opening behind sternite	Female with opening bursa copulatrix on sternite
3		Female insects have one pore.	Female insects have two pores.

Important familyof suborder Ditrysia:-

Family: Noctuidae - This is the largest family in this order. **E. g.** Army worms, cutworms, Spodoptera, Helicoverpa, Fruit sucking moth, Castor semilooper.

Family: Gelechidae– E. g. Potato tuber moth, Pink bollworm, Groundnut leaf miner, Angoumois grain moth.

Family: Pyralidae–E. g. Cotton leaf roller, Jowar stem borer, Wax moth

Family: Pterophoridae–E. g. Tur plume moth

Family: Arctiidae–E. g. Hairy caterpillar

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Family: Hesperiidae–E. g. Rice skipper

Family: Shingidae–E. g. Sesamum and Sweet potato leaf eating caterpillar

Family: Papilionidae–E. g. Lemon butterfly

Family: Lycanidae–E. g. Anar caterpillar

Family: Pieridae–E. g. Cabbage butterfly

Family: Bombycidae–E. g. Mulberry silk worm

Family: Saturnidae–E. g. Tasar and Erri silk worm

Differences between moths and butterflies

Sr. No.	Moths	Butterflies
1	Nocturnal in habit	Diurnal in habit
2	Antennae either Pectinate or bi Pectinate plumose type	Antennae Clavate type
3	Ocelli Present	Ocelli Absent
4	Mandibles Present	Mandibles Absent
5	Wing coupling Frenate type	Wing coupling amplexiform type
6	Abdomen Large and stout	Abdomen Comparatively small and slender
7	Obtect pupa within a cocoon	Obtect pupa without cocoon.
8	At rest, wings held roof like on body	At rest, wings held erect straight upward.

9. **ORDER: HYMENOPTERA** (Hymen - membrane; Ptera - wings.)

   E. g. Wasps, bees, ants, sawflies, Parasitoids etc

- Economic Importance: Red ant, mustard saw fly are crop pest. Many insects are beneficial parasitoids or pollinators

Characters:

- This is the most beneficial order in the class insecta comprising of parasites, predators and bees involved in poliination and honey production. Most of them are social living
- Mouth parts are biting type modified for lapping or sucking
- Wings are membranous
- Wing venation ishamuli type.
- Abdomen is basally constricted. The first abdominal segment is called propodeum. It is fused with metathorax.The second segment is known as pedicel which connects the thorax and abdomen. Abdomen beyond the pedicel is called gaster or metasoma
- Larvae are known as grubs with well developed head and usually apodous and eucephalous
- Pupa exarate and a cocoon is generally present
- Metamorphosis complete and complex also.
- Fertilized eggs develop into females and males are produced from unfertilized eggs. Males are haploid and females diploid.

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- This order is subdivided into two suborders; **Symphyta andApocrita**

Differences between Symphyta and Apocrita

Sr. No.	Symphyta	Apocrita
1	Abdomen is broadly joined to the thorax	Abdomen is petiolated
2	Larva is a caterpillar and it belongs eruciform type	Larva is a grub and it belongs apodous eucephalous type
3	Stemmata are present	Stemmata are absent.
4	Both thoracic and abdominal legs are present	Legs are absent
5	Ovipositor is saw like andsuited for piercing the plant tissues	Ovipositor is not saw like and is suited for piercing in parasitic groups or for stingingin other groups.
6	Behavioural sophistication is less.	Behavioural sophistication is more
7	They are phytophagous	They are generallyparasitic
8	**Important families:** Tenthredinidae : (Sawflies)	**Important families:** Apidae : (Honey bees) Vespidae: Wasps Megachilidae: (Leaf cutter bees) Formicidae: (Ants) Braconidae : (Braconid wasps) Trichogrammatidae: (Egg parasitoids)

10. ORDER: COLEOPTERA (Coleos - Sheath ; Ptera-wing), E. g. Beetles, Weevils

- **Economic Importance:** It is the largest order. It includes predators, scavengers and many crop pests. They also damage stored products.

Characters:

- They are minute to large sized insects.
- This is the largest order in class insecta comprising about 1/3rd or 40% of the known insect species.
- Mouthparts are chewing & biting type.
- Head position is prognathous type
- Antenna is usualy 11 segmented.
- Prothorax is large, distinct and mobile. Mesothorax and metathorax are fused with the first abdominal segment.
- Forewings are horny or leathery known as elytrait is not used for flight. Hind wings are membranous with few veins and are useful in flight.
- Legs well developed for walking, running.
- Cerci and a distinct ovipositor are absent.
- Metamorphosis is complete.
- Larvae are often called grubsit is campodeiform or eruciform.
- Pupae adecticous and Exarate.

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- This order is divided into four suborders, viz., **Adephaga** (devourers) and **Polyphaga** (eaters of many things), Archostemata (wood feeders) and Myxophaga (Found in wet places

Difference between Adephaga and Polyphaga

Sr. No.	**Adephaga**	**Polyphaga**
1	**Cicindelidae:** (Tiger beetles)	**Meloidae: (**Blister beetles, Oil beetles)
2	**Dytiscidae:** (True water beetles)	**Coccinellidae:** (Lady bird beetles, Epilachna beetle)
3	**Carabidae:** (Ground beetles)	**Scarabaeidae:** (white grub, Dung beetles)
4		**Cerambycidae:** (Mango stem borer, Grape stem girdler)
5		**Bruchidae:** (Pulse beetles, Seed beetles)
6		**Tenebrionidae:** (Rust red flour beetle)
7		**Bostrychidae:** (Lesser Grain borers)
8		**Melolonthidae:** (Chafer beetles, June beetles)
9		**Dynastidae:** (Rhinoceros beetles)
10		**Curculionidae:** (Weevils, snout beetles)
11		**Chrysomelidae :** eg. Red pumpkin beetle

Differences between Beetle and Weevil

Sr. No.	**Beetle**	**Weevil**
1	Mouthparts typically chewing type	Mouthparts chewing type but modified into snout like structure.
2	Both pairs of wings present.	Hind wing absent.
3	Antennae capitates/ serrate/ Lamellate	Antennae clavate
4	Tarsi 3 to 5 segmented	Tarsi 4 segmented
5	Larvae oligopod	Larvae apodous

11. ORDER: DIPTERA(Di-two; Ptera-wing)

E. g. Housefly, Fruit fly, Horse fly, Pod fly, Stem fly, Mosquito, Midges.Midge fly, shoot fly, gall fly

- **Economic Importance:** Considerable number of flies is predacious. some are act as a vectors for transmission of disease, fruit flies, leaf miners, stem fly and root maggots are crop pest

Characters:

- They are small to medium sized, soft bodied insects.

- Mouth parts sucking type usually forming a proboscis. In many they are piercing and sucking and in others they are sponging type
- Antennae mostly 3 segmented and Aristate type
- Forewings are larger, membranous and used for flight. Hind wings are highly reduced, knobbed at the end and are called halters.
- Prothorax and metathorax are small and fused with large mesothorax
- Metamorphosis is complete
- Larvae of more common forms are known as maggots. They are apodous and acephalous (eruciform). Maggots mostly amphipneustic
- Pupa is generally with free appendages, often enclosed in the hardened last larval skin called puparium. Pupa belongs to the coarctate type.
- Legs well developed, tarsus usually 5 segmented pulvilli and an empodium usuallypresent
- This order is sub divided in to three suborders; Nematocera (Thread-horn), Brachycera (Short-horn), Cyclorrhapha (Circular-crack

Comparative characters of these sub-orders

Sr. No.	Nematocera	Brachycera	Cyclorrhapha
1	Antenna is long and many segmented in adult.	Antenna is short and few segmented in adult.	Antenna is aristate in adult
2	Larval head is well developed.	Larval head is retractile into the thorax.	Larval head is vestigial with mouth hooks.
3	Larval mandibles act horizontally.	Larval mandibles act vertically	Larval mouth hooks act vertically.
4	Pupa is weakly obtect.	Pupa is exarate.	Pupa is coarctate.
5	Adult emergence is through a straight split in the thoracic region	Adult emergence is through a straight split in the thoracic region.	The split results due to the pressure applied by an eversible bladder ptilinum in the head.
6	Pseudotrachae absent	Pseudotrachae present	Pseudotrachae present
7	**Important families:** **Culicidae**: Mosquitoes **Cecidomyiidae** :Pady gall fly	**Important families:** **Asilidae**: Robber flies **Tabanidae**: Horse flies **Trypetidae**: Fruit flies **Agromyzidae**: Tur pod fly, Leaf miner	**Important families:** **Syrphidae**; Syrphid fly **Tachinidae**: Tachinid flies **Muscidae**: House fly