CHAPTER II
CLASSIFICATION OF PHYLUM ARTHROPODA UPTO CLASSES

que "Study of Highly species of organism called Insect."

Insect comes under the kingdom Animalia which initially gets classified into 15 phylums out of which phylum Arthropoda (Arthro-Jointed, poda- Appendages) is the largest phylum comprising of more than 78% of the known species surviving on the earth.

Characters of the Phylum Arthropoda:

i. Body is segmented and made up of series of rings.
ii. Body segments bear jointed appendages.
iii. Segments are grouped into 2 or 3 regions known as Tagmosis.
iv. Posses renewable chitinous exoskeleton.
v. Development of growth is by moulting.
vi. Body is bilateral symmetry
vii. Dorsal brain with ganglionated type of nervous system.
viii. Body cavity filled with blood known as haemocoel
ix. Respiratory system is tracheal.
x. Alimentary canal is tubular which starts with mouth cavity and ends with anus.
xi. Heart is located at dorsal side alongwith ostia .
xii. Nephridia or cilia absent.
xiii. Sexes are separate.

Classification:

Phylum Arthropoda gets classified into sub-phylum **Uniramia** under which 7 classes are developed which are;

1. **Onychophora** (claw bearing) e.g. Peripatus
2. **Arachnida** (Arachne - spider) e.g. Mite, Spider, Scorpion, Tick
3. **Diplopoda** (Diplo - two; poda- - appendage) e.g. Millipede (Thousand legged)
4. **Chilopoda** (Chilo - lip; poda - appendage) e.g. Centipedes (Hundred legged)
5. **Crustacea** (Crusta - shell) e.g. Prawn, Crab, Lobsters
6. **Trilobita** (an extinct group).
7. **Hexapoda** or **Insecta** e.g. All insects.

Relationship of Class Insecta with other classes of Arthropods.

CHAPTER III
INSECT DOMINANCE

More than 85% of living organisms known to science under animal kingdom belong to insect group. The existence of insect was nearly 350-500 million years ago on the earth. As on today total number of known insects are 13 lakhs to 15 lakhs but still its true that millions of undiscovered insect species are still hidden in different canopies of the ecosystem. Whereas large number of individuals are also found in single species e.g., Locust swarm comprises of 10^9 number of individuals. Insects have a phenomenal nature about acquiring several structural, physiological, developmental and behavioural perfections. This have very quickly helped insects to dominate position in animal kingdom due to following characteristic features;

1) **Chitinous exoskeleton:** is one of the important characteristic of insect made up of cuticular protein known as chitin. It lightens the weight and gives strength, rigidity and flexibility to the insect body and act as external armour. It provides large area for attachment of muscles, protects insects from mechanical injury alongwith desiccation. Exoskeleton appendages also act as good tools for preying and digging apparatus.

2) **Flying capacity:** Insects are the only invertebrates possessing pair of wings which are the lateral thoracic extension of exoskeleton. The capacity of insect flight increased the chances of their survival as they started moving for feeding, breeding, finding mate, escaping from their natural enemies and unfavourable conditions by migrating to longer distances. Bees can migrate @ 9 km/hour and hawk moth migrate @ 17 km/hour while locust can migrate thousands of miles in single flight.

3) **Hexapod movement:** Insect leg modification has reached to an ideal stage of evolution. Insect bears six legs of which three legs make a tripod helping them to balance the body and while remaining three legs are in moving state maintain the speed.

4) **Small size:** Maximum insects due to their smaller size exploit physiological and ecological advantages as requirement of less space, food, time and energy for development, reducing food competition even in shortages and helping to sustaining life even in adverse climatic conditions. Also helping the chances of variability and mutation. Smaller size leads easy escape from enemies with greater efficiency.

5) **Universal adaptability:** Insects are found in virtually every terrestrial and fresh-water environment of the earth starting from mountain tops in the himalayas, tide pools at the seashore and even on the polar ice caps with wide climatic range from -50°C to 60°C. Some insects such as petroleum fly (*Helaeomyia petrolei*) develops in wells of crude oil while brine fly (*Ephydra cinera*) thrives in Great Salt Lakes.

6) **Scattered sense organs:** In insects except compound eyes all other sense organs are scattered. Hearing organ situated in antenna; taste and smell organs located on antenna,

mouth parts, even on tarsi, cerci etc., which are advantageous to the insects on being injured.

7) **Decentralized Nervous System:** helps the insect to survive even when injured. A brainless insect can artificially stimulate to walk, fly or even feed. Cut silk moth female abdomen can be fertilized by male and on stimulation can lay eggs. Thus decentralized nervous system is helpful in preservation of insect.

8) **Tracheal Respiratory System:** in insects ensures direct transfer of adequate oxygen through minute spiracles and network of trachae alongwith tracheoles to actively breathing tissues. The spiracles with their closing mechanism only make passage for entry of air and restrict water loss.

9) **Higher fecundity and reproduction rate:** The female insect has the capacity of laying large number of eggs at very protective site with quick rate of development making them more prolific. In an average moth lays 200 eggs within two months whereas termite queen rapidly lays 6500-7500 eggs per day as long as 15 years of their life cycle.

In insect special type of reproduction other than oviparity and viviparity make them more prolific breeders. For e.g., Chalcids and Wasp female have capacity to develop several females from single eggs (polyembroyony) while females of aphid reproduce in absence of male or without fertilization (parthenogenesis). In certain cases of gall midges reproduction takes place in immature stages (paedogenesis).

10) **Developmental characters:** of more than 80% of insect groups are unique in animal kingdom which undergo complete i.e., holometamorphosis comprising of four well defined stages as egg, larva, pupa and adult. Only larva and adult stages are feeding but mostly differ in structure and food habitat due to which competition between parent and offspring for food and shelter are completely eliminated.

11) **Feeding specificity:** Insect have vast diversity pertaining to food habits by feeding on almost all parts of the plant like stem, leaves, root, fruit etc. Few are very specific towards food preference while others are polyphageous having wide range of feeding hosts which help to avoid inter-specific food competition.

12) **Protective adaptations:** against several adverse biotic and climatic stress is essential for insect existence. To overcome the effect of extremities following group of defense mechanisms are adopted by insects;

   a) **Behavioural:** Some insects undergo dormant stages like aestivation or hibernation or some beetles during their life cycle pretends as if dead (**Thanatosis**).

   b) **Structural:** Insects adopt different structural changes on exoskeleton for e.g., elytra forewings which protect the beetles from predation of birds. Development of spines and hairs on legs, wings and body e.g., moth and butterfly. Mimicry changes made by stick insect, leaf insect, blister beetle etc. for escaping from the enemies.

CHAPTER IV

ECONOMIC IMPORTANCE OF INSECTS: HARMFUL, BENEFICIAL AND PRODUCTIVE INSECTS

After man left nomadic habits and began raising crops with tending live stock, good number of insects came in contact and then the struggle of existence started. We generally think that man has conquered the nature but insects have thoroughly mastered the nature. No doubts all insects are not harmful to man and his agricultural commodities; some are beneficial and productive while others are harming the human interest. Hence to maintain properly everybodies population in the nature the only principle remains is **"Live and let others live"**. Based on economic aspects the insects can be grouped into following categories:

A) **Harmful Insects:** These are the group of insects causing damage to almost all the produce developed by the cultivator known as pests which can be classified as below:

I) **Direct feeding effect on plants** by insect pest is done in following ways:

a) **Injuries by Chewing and Biting mouth parts** : insect pests which feed upon following parts of the plants and cause damage;

1) **Plants growing point:** e.g., Grape vine flea beetle
2) **Leaf defoliation:** e.g., Groundnut red hairy caterpillar
3) **Notching edges of leaves:** e.g., Cotton grasshopper
4) **Rolling of leaves:** e.g., Paddy leaf roller
5) **Riddle large holes of regular shape ans size:** e.g., Cabbage semilooper
6) **Damage of inflorence parts:** e.g., Red gram blister beetle
7) **Cut tender parts of seedlings:** e.g., Cotton weevil
8) **Nibbling of earheads:** e.g., Rice grasshopper
9) **Bark attack:** e.g., Mango bark eating caterpillar

b) **Injuries by Piercing and Sucking mouth parts:** insect pests by sucking cell sap from different parts of the plant due to which following symptoms are observed:

1) **Hopper burn patch on leaves:** e.g., Cotton leaf hopper
2) **Leaf curling:** e.g., Chilli aphids, Chilli thrips
3) **Premature shedding of leaves:** e.g., Citrus fruit sucking moth
4) **Plant chlorosis:** e.g., Papaya aphids
5) **Silvery leaf surface:** e.g., Onion thrips
6) **Shoot drying:** e.g., Scale insect, Mealy bugs

7) **Faint yellow speckling of leaves:** e.g., Castor whitefly

c) **Injuries by internal feeder insect pests:** on their feeding habit and symptoms caused can be grouped as:

1) **Borer: Stem borer:** e.g., Jowar stem borer; **Shoot fly:** e.g., Jowar shootfly

2) **Stone:** e.g., Mango stone weevil

3) **Worms: Boll worms:** e.g., Cotton bollworm; **Fruit worms:** e.g., Brinjal fruit and shoot borer

4) **Galls:** e.g., Paddy gall fly

d) **Injuries caused by subterranean insect pests:** which damage to the underground parts of the plant such as roots, tubers, galls etc. e.g., Potato sweet weevil, Termite, White grub, Gall insect.

e) **Injuries caused by store grain insect pests:**

1) **Primary store grain pest:** mostly damage on healthy grains and further classified into;

Internal grain feeder pest: e.g., Rice weevil, Pulse beetle etc.

External grain feeder pest: e.g., Rice moth, Red rust flour beetle etc.

2) **Secondary store grain pest:** attack on already damaged grains by primary store grain pest e.g., Saw toothed grain beetle, Long headed flour beetle etc.

II) Indirect effect of insect feeding on plants:

1) **Detoriate produce quality and cause malnutrition:** by showing different symptoms on produce such as injury scars, rotten patches e.g., Shoot and Fruit borer (Brinjal, Tomato, Bhendi), Mango fruit fly etc.

2) **Heavy incidence of insect pests:** makes harvesting more difficult e.g., Cotton bollworm, Cabbage aphids.

3) **Disseminate plant diseases:** Insect act as a major vector to carry different pathogens as virus, fungi, bacteria, protozoa due to which more than 275 diseases are transmitted in plant causing a severe economical losses at present to agricultural produce.

4) **Destroy useful household articles:** There are some insects who have the habit to destroy different household articles as stored food, clothings, drugs, furniture, museum, papers, books eg., housefly, termite, ant, silverfish etc.

III) Effect on man and his domestic animals:

Insects act as carrier of different human diseases as Rickettesial- e.g., Human louse, Plague- e.g., Rat flea, Chikun Gunia and Malaria- e.g., Mosquito, Sleeping sickness- e.g., Testse fly, Cholera, Typhoid- Housefly etc.

Also some insects suck the blood of the domestic animals and cause harm to them e,g., Biting lice, sucking lice, fleas etc.

B) Beneficial and Productive Insects:

1) **Some insect produce valuable commodities of commercial importance:**
   a) Silkmoth larva produces silk.
   b) Honeybee produces honey,
   c) Lac insect produces lac.
2) **Some insect produce commodities of medicinal importance:** Maggots of certain flies are used for healing wounds, honey produced from honeybee used in several ayurvedic medicine; Cricket and earwing are used to cure ulcer disease.
3) **Many insects act as an important bioagents:** such as;
   a) **Predators:** Preying mantid- prey on small flying insects, Lady bird beetle- feed on aphids, Blister beetle- larva feed on eggs of grasshopper etc.
   b) **Parasite:** *Trichogramma* spps.- act as egg and larval parasite of borer, *Apanteles* spps- act as bollworm parasite etc.
4) **Some insects are used to control weeds:** Mexican beetle- feed on cogress grass, Cochineal insect- used for control of cactus etc.
5) **Insects as pollinators:** on crop like sunflower, melon, pumpkin etc mostly depends upon honey bee, wasp, few butterfly for pollination.
6) **Insects act as scavangers:** Few insect have the capacity of decaying plant and animal matters e.g., some beetles, maggots.
7) **Insects used as food:** Insects are not only been used as food by animals, fishes, pigs, poultry etc. but also by human being e.g., caterpillar, grasshopper, ants are used by human being in China, Thailand, Turkey, Iran and Iraq.
8) **Insects have aesthetic value:** Several insects such as butterflies, moths, beetles, dragonflies, mantids have been used for beautification purpose which naturally adds to pleasure.
9) **Insects have scientific value:** Insect like drosophilla is used for research purposes.
10) **Insects role in soil structure:** Insects play an important role in building up the properties of soil e.g., dead bodies of insects add to increase in soil fertility.
11) Some insects such as gall insects are used in preparation of dyes, inks and colours

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CHAPTER VI
INSECT INTEGUMENT: STRUCTURE AND FUNCTION

Insect integument is also known as Exoskeleton or Body wall of insect. It is ectodermal in origin and not only act as external cover over the body but also helps for muscle attachment, as water-tight barrier against desiccation and a sensory interface with the environment. The structure of insect integument consists of three functional regions: cuticle, epidermis, and basement membrane.

I) **Cuticle:** Insects are boneless individuals which are externally covered with durable, flexible exoskeleton known as cuticle. It is the outermost complex non-cellular layer secreted by the epidermis made up of non living material and undergoes the process of sclerotization by distinguishing them into two main layers:

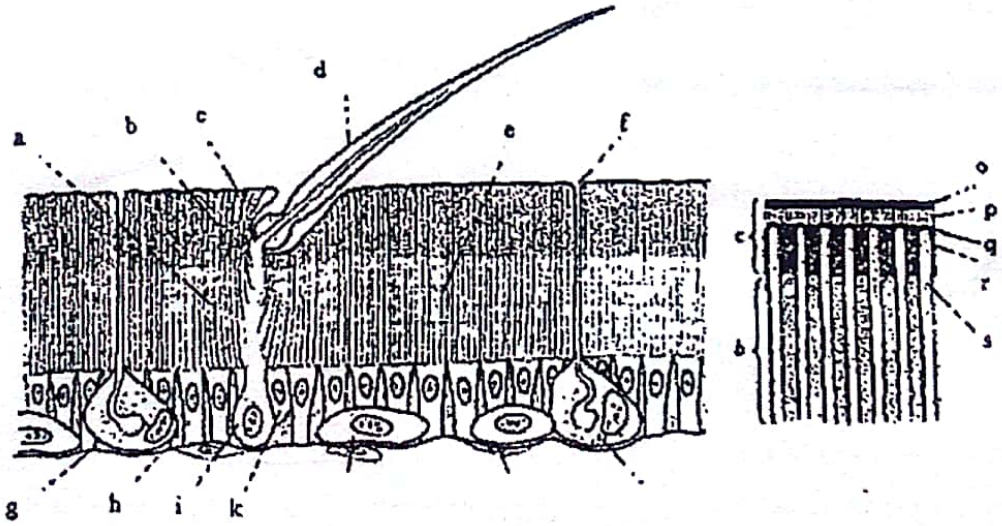
a) **Epicuticle:** is external thin layer about 0.03 to 0.04 μ in thickness and comprises of four superimposed layers;

i) **Cement layer:** contain lipoprotein formed by lipid and tanned protein.

ii) **Wax layer:** due to compact wax molecules prevents desiccation

iii) **Polyphenol layer:** responsible for tanning prosess.

iv) **Cuticulin layer:** contain non-chitinous polymerised lipoprotein.



a- laminated endocuticle; b- exocuticle; c- epicuticle; d- bristle; e- pore-canals; f- duct of dermal glands; g- basement membrane; h- epidermal cell; I- trichogen cell; k- tormogen cell; o- cement layer; p- wax layer; q- polyphenol layer; r- cuticulin layer; s- pore canal

b) **Procuticle:** is inner multilaminar layer secreted by epidermal cells having 0.2 to 10 μ thickness running parallel to its surface and pierced by pore canals.

Pore canals: are flat, ribbon like fine ducts less than 1 μ diameter containing cytoplasmic extension of epidermal cells and concerned with transport of cuticular materials used to repair wound to the epicuticle.

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Sclerotization: is the process of hardening of the sclerites which is carried in procuticle region dividing it into two layers;

i) **Exocuticle:** is outer hard, dark and sclerotized portion of the procuticle. It obtains dark colour largely due to composition of tanned protein known as chitin and sclerotin.

ii) **Endocuticle:** is inner soft, flexible and colourless portion of the procuticle made up of chitin and arthropodin.

Composition of cuticle

i. **Chitin:** is nitrogenous polysacharide which accounts 25% to 60% of dry weight of cuticle and on hydrolysis yields acetic acid and glucosamine. It is insoluble in water, dilute acids, alkalies but soluble in concentrated mineral acid and NaHCl.

ii. **Protein:**

1) Water soluble untanned cuticular protein known as **Arthropodin.**
2) Water insoluble tanned cuticular protein known as **Sclerotin.**
3) Rubber like elastic cuticular protein responsible for the flexibility of sclerites known as **Resilin.**

Functions of cuticle:

flexible exoskeleton

1) Protect internal organs from mechanical injury
2) Determine form and shape of insects.
3) Resistant to solution and corrosion.
4) Provides attachment to the muscles.
5) Reduce loss of water content in the body i.e., desiccation.
6) Concerned with storage excretion.
7) Cuticular sensory organs helps in sensing the environment.

II) **Epidermis/Hypodermis:** forms continuous unicellular layer of hypodermal cells resting on basement membrane alongwith tormogen and trichogen cells carrying following function;

1) Secret new cuticle cells.
2) Produce moulting fluids which dissolves old endocuticle before immature insect moults.
3) Absorb digestive products of old cuticle.
4) Repair wounds.

CHAPTER VIII
BODY SEGMENTATION- STRUCTURE OF HEAD

Body Segmentation:

The insect body consists of jointed structure called segmentation which divides into series of successive rings known as **segments** or **somites** or **metameres.** The flexible cuticle portion between adjacent segments is termed as **intersegmental membrane** which allows freedom for body movements.

Segmental Body Division:

Insect body segments are divided into definite sclerotized regions differentiated into separate sclerites and adjacently detached by intersegmental plates.

Body Segment	Sclerotic Region	Sclerites	Intersegments
1. Dorsal region	Tergum (Notum)	Tergites	Intertergites
2. Ventral region	Sternum	Sternites	Intersternites
3. Lateral region	Pleuron	Pleurites	Interpleurites

Insect Body Division:

The total regions of the insect body is collectively called as **tagmata** whereas grouping of body segments into definite regions is known as **tagmosis.** In general body of insect divides into three regions: Head, Thorax and Abdomen.

Insect Head:

Insect head is a compact compartment that houses the brain, a mouth opening, mouthparts used for ingestion of food, and major sense organs (including antennae, compound eyes, and ocelli). According to embryological evidence insect head comprises of neuromeres, pair of coelom sac, paires appendages been fused by first six or seven body segments as below:

Segments	Appendages
1. Pre-antennary	Absent
2. Antennary	Paired antenna
3. Ocular	Pair of compound eyes
4. Intercalary	Unpaired labrum
5. Mandibular	Paired mandibles
6. Maxillary	Paired maxillae
7. Labial	Labium

The head exoskeleton comprises of several sclerites more or less fused or welded together to form a hard compact case known as **head capsule or cranium**. The attachment of the head to the thorax is through the neck known as **cervix.**

1) **Insect Head Areas:**

a) **Epicarnium:** is dorsal region of head capsule between pair of compound eyes which extends upto the neck.

b) **Vertex:** is portion of epicranium behind the frons and between pair of compound eyes.

c) **Ociput:** is hinder part of epicranium between vertex and neck.

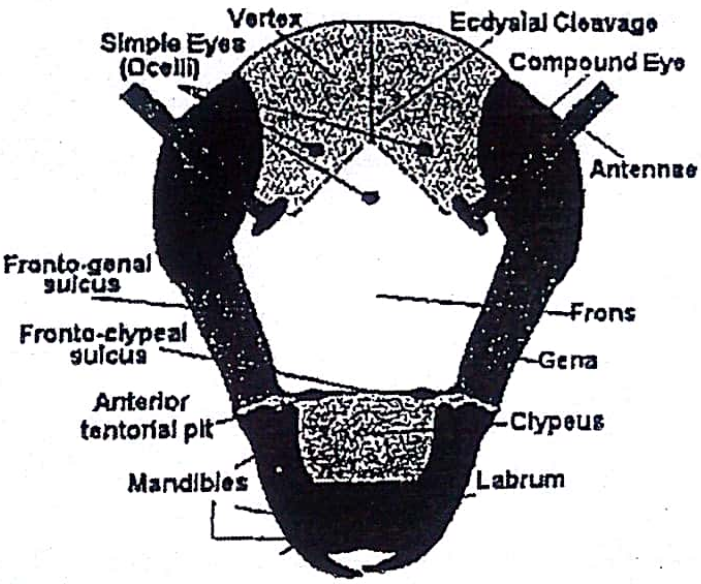
d) **Frons:** is unpaired upper facial triangular part of the head which lies between arms of epicranial suture bearing median ocellus.

e) **Gena:** form whole of the lateral area below and behind the compound eyes.

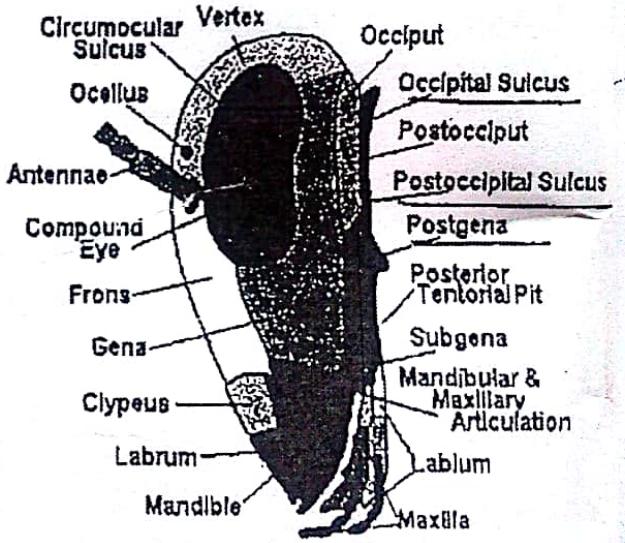
f) **Clypeus:** lies immediately below the frons to which labrum is attached.

g) **Labrum:** is unpaired movable sclerite articulated with the clypeus

The Insect Head (Frontal)



The Insect Head (Side View)



2) **Insect Head Sutures:** are thin impressed lines which separates sclerites from each other.

a) **Epicarnial suture:** is inverted 'Y' shaped suture which divides vertex with frons. The stem of epicarnial suture is called as median while two lateral arms are called frontal sutures. The insect break down first during moulting at epicranial suture hence called as ecdysial cleavage line.

b) **Occipital suture:** lies between vertex and occiput.

c) **Post-genal suture:** is lateral part of occipital suture.

d) **Post- occipital suture:** lies in between occiput and neck region.

e) **Clypeo-frontal suture:** lies in between clypeus and frons region.

f) **Fronto- genal suture:** lies in between frons and gena on either side.

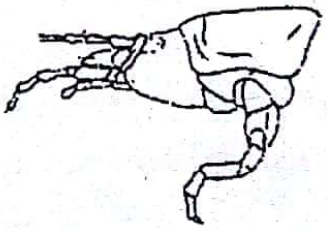
g) **Circum- ocular suture:** is suture surrounding compound eyes.

h) **Circum-antennal suture:** is external grooves of antennal socket.

Occipital foramen is posterior opening of the cranium through which aorta, foregut, ventral nerve cord and neck muscles passes. **Tentorium** is a space for attachment of muscles of antenna and mouthparts created by endoskeleton of insect cuticle.

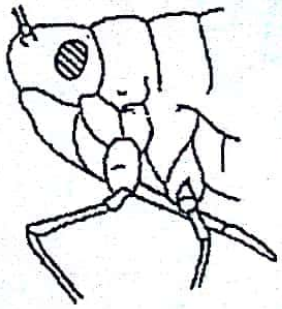
Insecst Head Position:

On basis of inclination of longer axis of head alongwith position of mouth parts insect head gets classified into following three types:



1) **Prognathous (Pro- infront; gnathous- jaw):** Whenever long axis of the head is in horizontal position and mouth parts projected forward and lying anteriorly found in termites soldier caste, beetles, caterpillar etc.

2) **Hypognathous (Hypo- below; gnathous- jaw):** Whenever long axis of the head is in vertical position and mouth parts downward mastly noticed in orthopteroid such as cockroach, grasshopper etc.



3) **Opisthognathous (Opistho- behind; gnathous- jaw):** head position is somewhat similar to hypognathous type in which mouth parts slightly diverted downward and backward so as to held in between the fore-legs mostly found in hemipteroid such as red cotton bugs, aphids, jassids etc.

Type and Example(s)	Structure	Appearance
Pilose (Whorl like) e.g., Female Culex Mosquitoes	Only base of each segments having whorl of hairs.	
Aristate (Bristle like) e.g., House flies	Upper side of third segment enlarges and bears a conspicuous dorsal bristle like structure called as arista.	
Stylate e.g., Robber fly, Jassid	Bristle like structure present at tip of antenna called as styli.	

Functions of Antennae:

1. They are usually covered with olfactory receptors that can detect odour molecules in the air (sense of smell) e.g housefly.
2. Many insects also use their antennae as humidity sensors, to detect changes in the concentration of water vapor.
3. Male mosquitoes, Paper wasp detect sounds with their antennae.
4. Many flies use theirs antenna to gauge air speed while they are in flight.
5. To detect danger.
6. To find food.
7. To serve as secondary sexual character e.g., Culex mosquito.
8. Clothed antenna with hydrofuse hairs facilitate formation of air funnel e.g., water beetle.
9. To communicate with each other e.g., ants.
10. To hold opposite sex at the time of mating e.g., flea, spring tail.

Insect Mouth Parts

Insect mouth parts are organs concerned with feeding which are in detail needed to be studied because majority of insecticidal control measures are broadly based on feeding habits of insects. Among insects of different orders on basis of mouth part modifications insect can be briefly classified into two main functional groups: mandibulate and haustellate. Mandibulate (chewing) mouthparts are used for biting and grinding solid foods. Examples: dragonflies and damselflies (Order: Odonata), termites (Order: Isoptera), adult lacewings (Order: Neuroptera),

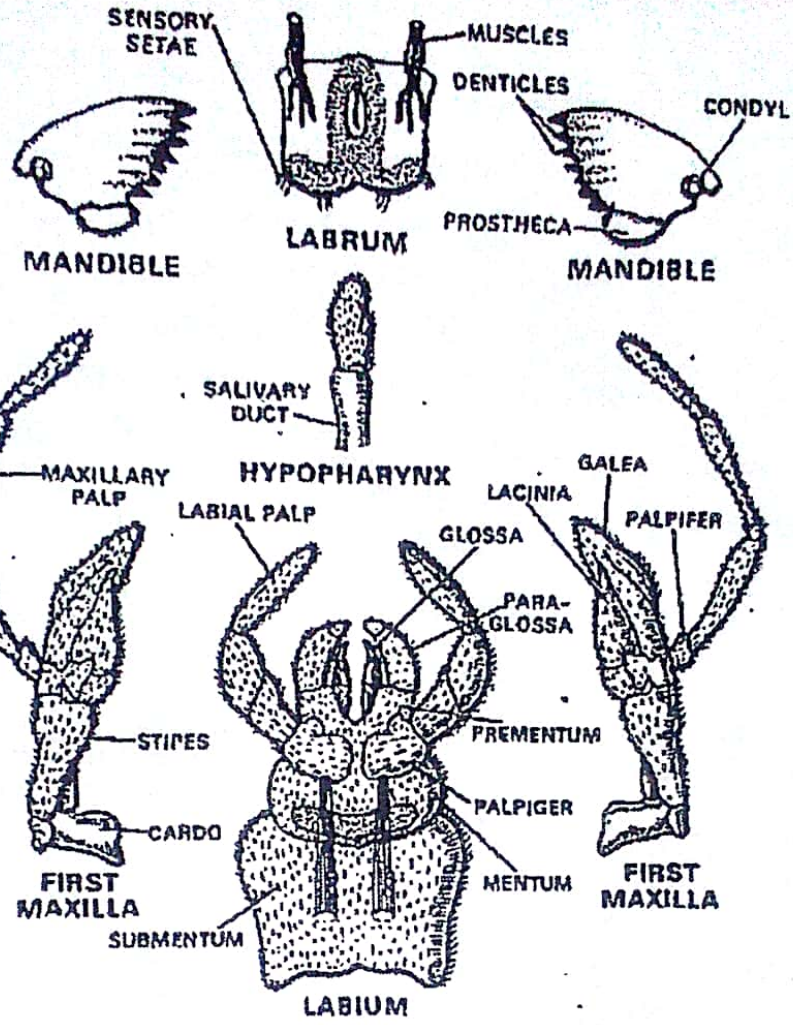
beetles (Order: Coleoptera), ants (Order: Hymenoptera), cockroaches (Order: Blattaria), grasshoppers, crickets and katydids (Order: Orthoptera), caterpillars (Order: Lepidoptera).

I) MANDIBULATE TYPE OF MOUTH PARTS

A) Chewing & Biting Type of Mouth Parts:

This is one of the most primitive and generalized type of mouth parts present in insects such as cockroaches, grasshoppers, beetles which consist of five major basic components;

1. **Labrum:** is broad, transverse, bilobed plate attached to clypeus by clypeo-labral suture allowing limited up and down movement. It is usually been used to hold and guide food into the mouth. While in grasshoppers 'V' shape notch been provided to hold leaf blade while feeding.
2. **Epipharynx:** is a swollen inner membranous lining of the labrum which act as organ of taste.
3. **Mandibles (Upper Jaw):** present behind labrum which is a solid sclerotised piece articulated with head by ginglymus at clypeus and condyl at gena region. Inner margins are toothed distal incisor teeths used for cutting while moral teeth for crushing solid food material. Each jaw moves horizontally by abductor (outer) and adductor (inner) muscles.
4. **Maxillae (Lower Jaw):** present just beneath the mandibles composed of following parts;
   a) **Cardo:** is basal triangular segment attached to the head at lower side of postgena.
   b) **Stipes:** is rectangular piece forming the body of maxilla which is articulated with cardo.
   c) **Palpifer:** is small lateral sclerite on stipes to which maxillary palp is attached.
   d) **Maxillary Palp:** is sensory appendage attached to stipes with palpifer having 7 segments and bear sensory (tactile) hairs for smelling or tasting.
   e) **Lacinia:** is inner lobe articulated with distal margin of stipes helping mandibles to hold food material while feeding.
5. **Labium:** is called as second maxilla and consist of following parts;
   i) **Postmentum:** is proximal broad plate attached to the head and further divided into submentum and mentum in case of some insects (e.g., cockroach).



ii) **Prementum:** is distal plate attached to post-mentum. Labial sulcus exist between post-mentum and prementum in case of cockroach.

iii) **Palpiger:** is small sclerite on lateral base of prementum to which labial palp is articulated.

iv) **Labial Palp:** is 3 segmented sensory appendages articulating with palpiger.

v) **Paraglossae:** are outer lobe arising from distal margin of prementum.

vi) **Glossae:** are inner lobes arising fron distal margin of prementum. In grasshopper paraglossae and glossae are fused together to form a single median lobe called as **ligula.**

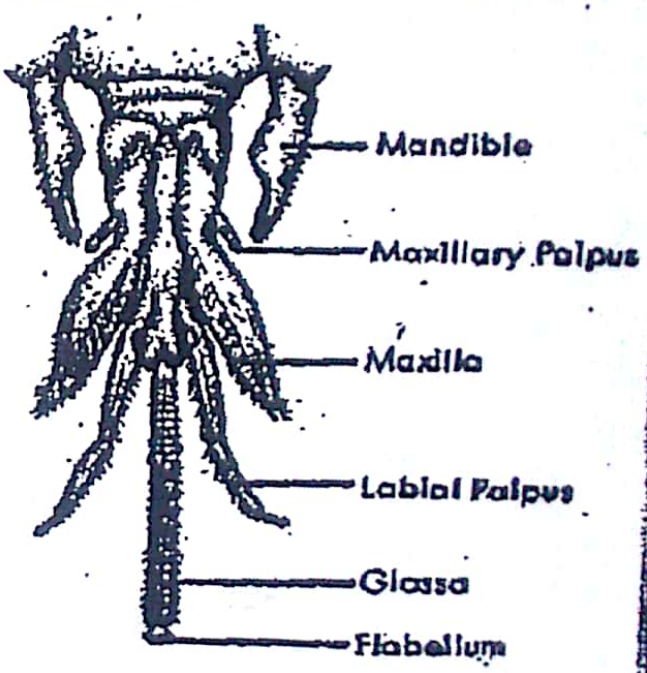
Feeding Mechanism:

Initially the maxillae hold the food material and later on mandibles cut off and grind solid food material. Maxillae and labium push the food into the oesophagus by mixing the saliva from the salivary glands.

B) Chewing and Lapping Type of Mouth Parts:

The labrum and mandibles remain more or less the same as that of chewing and biting type whereas labium and maxillae are fused together to form maxilo- labial complex suitable for lapping the liquid substances (nector) and consisting of following components e.g., honeybee;

1) **Labrum:** is narrow and quite simple plate attached with clypeus.
2) **Mandibles:** are two blunt and dumbbell shaped structure not used for feeding but for moulding wax while constructing the comb and also for cleaning the cells of the comb.
3) **Maxillae:** are complex structure greatly modified and comprising of following parts;
   i. **Cardo:** is elongated and rod like sclerite attached to the head at postgena.
   ii. **Stipes:** is elongated or oval sclerite attached to cardo.
   iii. **Maxillary Palp:** is peg like structure articulated with stipes.
   iv. **Galea:** is long blade like structure articulating with the distal extremity of the stipes.
   v. **Lacinia:** is small and highly reduced structure.



4) **Labium:** is also called as **proboscis** comprising of following parts;
   a) **Submentum:** is also known as lorum having 'V' shaped sclerite of which two extremities articulate with cardines.
   b) **Mentum:** is rectangular in shape articulated proximally with submentum and distally with prementum.
   c) **Prementum:** is well developed, elongate, rectangular sclerite which articulated with mentum.
   d) **Labial palp:** is elongated, 4 segmented and articulated with prementum.
   e) **Paraglossae:** are two cup like structures situated at the base of glossa.
   f) **Glossa:** is modified into elongated, hairy and flexible tongue like structure having spoon like apperence at the apex, known as **flabellum.**

Feeding Mechanism:

The galea fit tightly lengthwise against the elongated labial palp and make a roof over the elongated glossa (tongue) to form a temporary food channel. According to G .E. King, glossa (tongue) is trusted into the flower which get smeared with the nectar. It is then retracted between labial palps and galea, during which the nectar is squeezed by the galea and is deposited within the cup like structure formed by two paraglossae. Accumulated nector is later sucked into the oesophagpus by the action of pharyngeal pump.

II) HAUSTELLATE TYPE OF MOUTH PARTS

Haustellate mouthparts are primarily used for sucking liquids and can be broken down into two subgroups: those that possess stylets and those that do not. Stylets are needle-like projections used to penetrate plant and animal tissue. The modified mandibles, maxilla, and hypopharynx form the stylets and the feeding tube. After piercing solid tissue, insects use the modified mouthparts to suck liquids from the host. Some haustellate mouthparts lack stylets. Unable to pierce tissues, these insects must rely on easily accessible food sources such as nectar at the base of a flower. One example of non-stylate mouthparts are the long siphoning proboscis of butterflies and moths (Lepidoptera). Although the method of liquid transport differs from that of the a Lepidopteran proboscis, the rasping-sucking rostrum of some flies are also considered to be haustellate without stylets.

A) Piercing and Sucking Type of Mouth Parts:

Piercing-sucking mouthparts are used to penetrate solid tissue and then suck up liquid food. Examples: Red cotton bug, jassid, whiteflies, aphids, and other bugs (Order: Hemiptera), sucking lice (Order: Phthiraptera), stable flies and mosquitoes (Order: Diptera). The head position is mostly opisthognathous. These mouth parts consist of following parts;

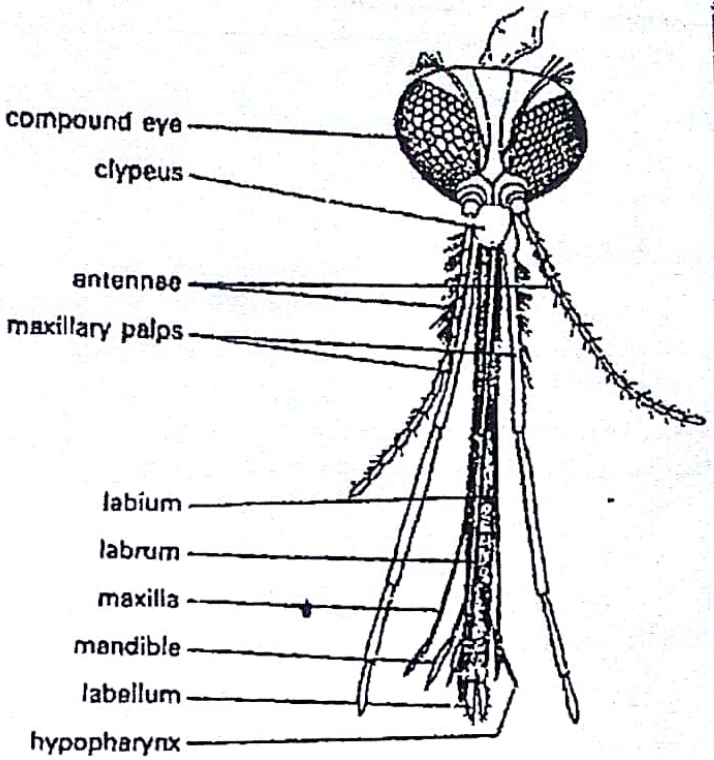
1) **Labrum:** is short triangular flap like structure which covers labial beak at its base.
2) **Mandibles:** are two extremely modified slender, sharp and chitinised needle called as stylets. Each mandible fits closely against the opposed maxillary stylet moving up and down during piercing.
3) **Maxillae:** Maxillary palps are absent which gets modified into maxillary stylet having double grooves along its inner sides. They fit together during feeding and form two microscopic tubes. The dorsal tube is suctorial tube or food channel which communicates with cibarial sucking pump while the ventral tube is salivary channel for ejecting the saliva.

All four stylets cling together appearing like single bristle which pierce the plant tissues. Each mandibular stylet and maxillary stylets

alternatively move upward and downward for the purpose of piercing due to retractor and protractor muscles attached to them.

4) **Hypopharynx:** forms the floor of the cibarial sucking pumps which is provided by strong dilator muscles arising from the clypeus.

5) **Labium:** also called as rostrum or proboscis which is a long 4 segmented beak with an open groove throughout its length at dorsal side. The four stylets dung together in this groove at rest. The sensory hairs are present at its apex to sample the food and locate the spot of piercing. The labial palps are absent. Labium dose not take part in piercing the tissue or in sucking the cell sap.



Feeding Mechanism:

At rest proboscis are always held parallel or directed backward to vertical side of insect body. When insect is about to feed, the proboscis are extended and inclined downwards and the stylets pierce the leaf tissue. The mandibular stylets pushing first followed by maxillary stylets alternately and at a rapid rate, trust themselves into the epidermis till they reach the cell sap. Later the saliva is poured through the salivary channel to dissolve the cell wall and to predigest the starch. The sap is sucked by the action of cibarial pump due to capillary action and turgor pressure playing role in ascending of the liquid which is passed towards the oesophagus.

B) Sponging Type of Mouth Parts:

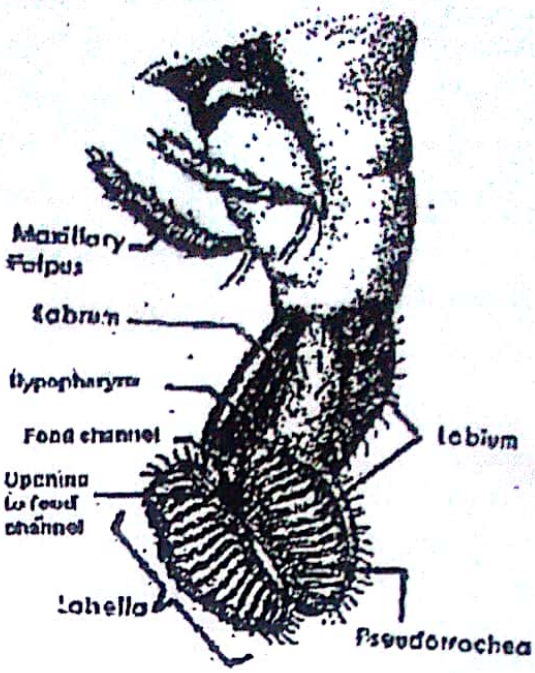
Insect having sponging type of mouth parts feed on exposed liquid food material such as nector or milk or may dissolve solid food material like sugar crystals in their saliva, hence the mouth parts are modified accordingly. Such type of mouth parts are present in house flies and blow flies consisting of following parts;

1) **Labrum:** is modified into stylet like structure which is represented by labrum, epipharynx and borne on the anterior face of the haustellum.

2) **Mandibles:** are totally absent.

3) **Maxillae:** may be absent but if present are only represented by one pair of maxillary palps.

4) **Labium:** forms a fleshy, elbowed and retractile proboscis attached in elbow-like form of elongated head which divide into two regions, basal is **rostrum** and distal is **haustellum**. At the apex of the labium their is a chair of fleshy lobe known as **labella**. It is a sponge like organ and consists of number of half opened small tubes (food channels) known as **Pseudotrachae**. The posterior sclerotised microscopic plate at the base of the labella is the prementum.



Feeding Mechanism:

Housefly often spit enzyme containing saliva on to solid foods to liquefy them and then sponge up the mixture. When the labellum is pressed against the exposed liquid food material, pseudotrachae absorb it by capillary attraction. The liquid material is collected at a point on labella where these tiny channels unit. From this point the liquid is further drawn up through the food channels by the stylet formed in between the labrum, epipharynx and hypopharynx.

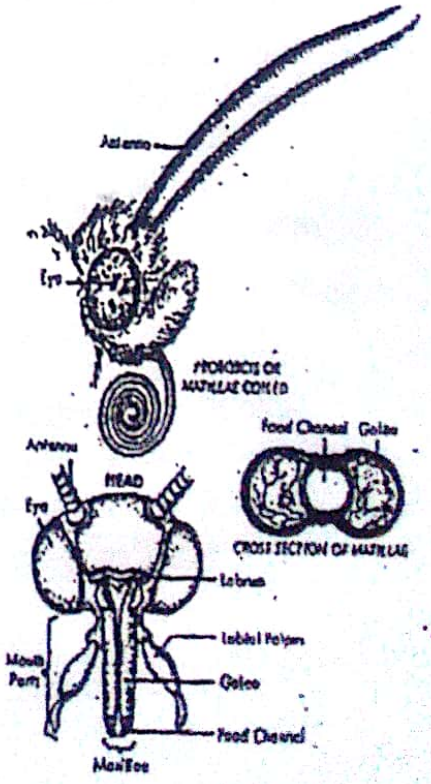
C) Siphoning Type of Mouth Parts:

These are specially modified type of mouth parts present in adults of moths and butterflies utilized for taking nectar from the flower and having following parts;

1) **Labrum:** is a small transverse band with extremely narrow reduced plate.

2) **Mandibles:** are totally absent.

3) **Maxillae:** The galea of maxilla form into a slender, hollow, tubular structure which remains as an elongated coiled proboscis underneath the head during non feeding. The proboscis composed of immense number of sclerotized and incomplete rings. Two halves of proboscis form a suctorial tube through which nector is sucked while lacina are atrophied or mostly absent. The proboscis are extended by means of blood pressure created in stipes of each maxillae.



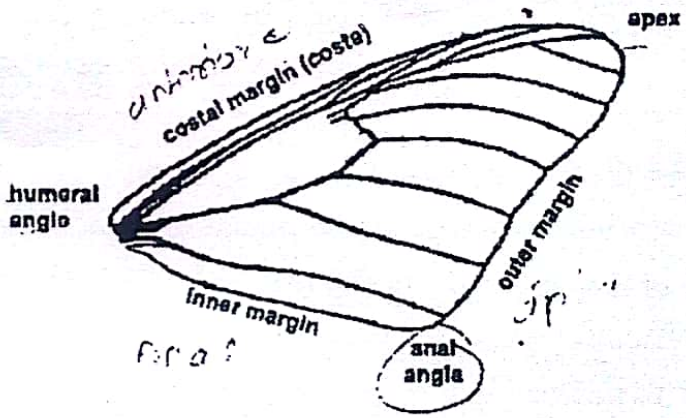
Structure and Modification of Insect Wings

Insects are the only invertebrates that can fly. Insect wings are boneless, thin evaginations ut growth) composed of upper and lower parchments of membranous cuticle during rphogenesis and become fully functional only during adult stage of an insect's life cycle. stly insects have two pairs of wings - first pair attached to mesothorax while second pair to tathorax (but never on the prothorax).

ings Margin:

Insect wings are usually triangular in shape and possessing three margins;

1) **Costal margin:** is anterior margin strengthened by the costa.
2) **Apical margin:** is outer or lateral margin of insect wing.
3) **Anal margin:** is inner or posterior margin of insect wing.



Vings Angle:

1) **Humeral angle:** is angle created at base of costa by which wing is attached to thorax.
2) **Apical angle:** is angle between costal and apical margins.
3) **Anal angle:** is angle between apical and anal margins.

Wing shape, texture and venation are quite distinctive among the insect taxa and therefore hly useful as aids for identification.

ing Venation:

The name been given to a hypothetical scheme of wing venation proposed for first winged ct is known as **archedictyon**. The anterior area of wing supported by veins is usually ed **remigium.** The systematic arrangement of longitudinal veins alongwith cross veins on wings is called **wing venation.** These are network of veins running throughout the wing ıe and are extensions of the body's circulatory system filled with hemolymph containing a heal tube and a nerve which provides strength, reinforcement during flight.

Longitudinal veins: As per current dogma, insect contains 6-8 longitudinal veins which run parallel to wing margin. Positive "+" and Negative "-" veins indicate convex and concave veins, respectively. These veins with their branches are named according to a

system devised by John Comstock and George Needham known as **Comstock-Needham System:**

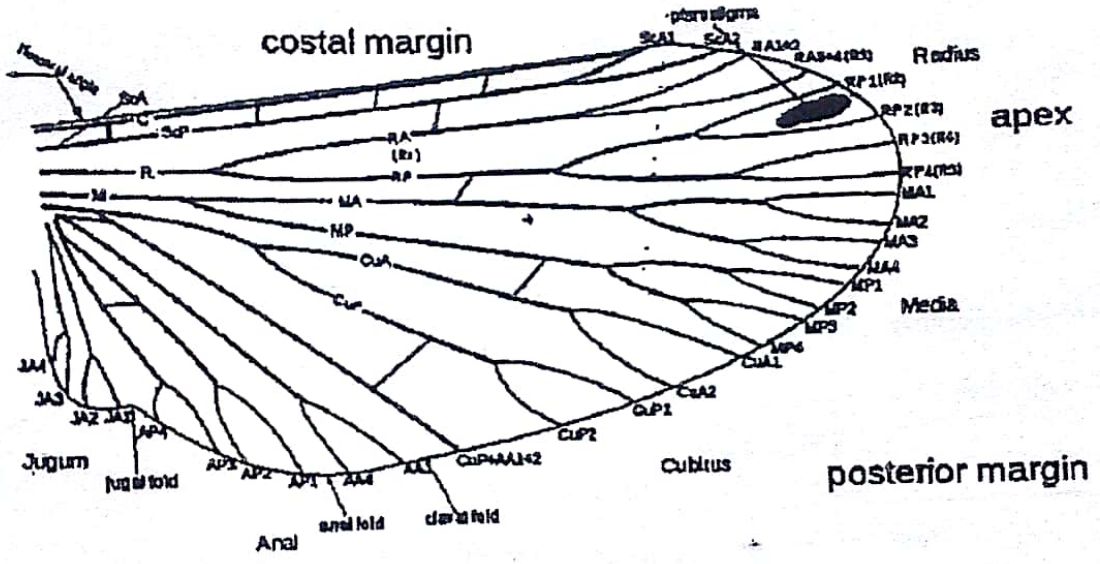
A) **Costa (C) "+"** : unbranched and forms thick margin of wing.

B) **Sub-costa (Sc) "-"** : run behind the costa, typically branched as ScA_1 and ScA_2

C) **Radius (R) "+"**: five branched, strongly convex:

i) **R_1 "+"**: reach the wing margin.

ii) **Radial sector (R_s)"-"**: divides into four sub branches R_2, R_3, R_4 and R_5.



D) **Media (M) "-"** : divides into four branches:

i) **Media Anterior (MA) "+"**: sub- branches MA_1 and MA_2.

ii) **Media Posterior (MP) "-"**: sub-branches four i.e., MP_1, MP_2, MP_3 and MP_4.

E) **Cubitus (Cu) "-"**: two branches

i) **Cu "+"**: sub-branches two CuA_1 and CuA_2 (anterior) alongwith CuP_1 and CuP_2 (posterior).

ii) **Cu "-"** : concave and unbranched.

F) **Anal veins "+"(AA_3, AA_4, and AP_1, AP_2, AP_3, AP_4)** : branched veins behind the cubitus.

II) **Cross veins:** are small veins often found inter connecting the longitudinal veins:

A) **Humeral (h)**- extend from sub-costa to costa near humeral angle of wing.

B) **Radial (r)**- run between R_1 and R_5.

C) **Radio-medial (r-m)**- run between the radius and media.

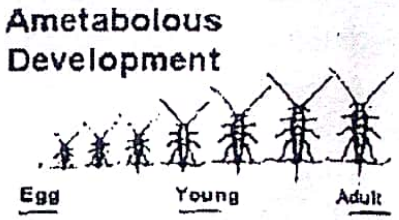
D) **Medial (m)**- between MP_2 and MP_3.

E) **Media- Cubital (m-cu)**- run between the media and cubitus.

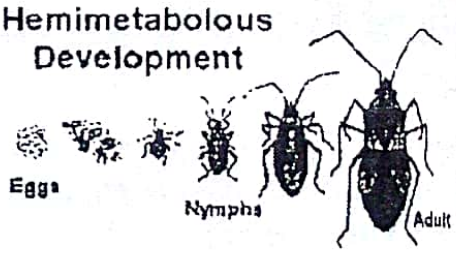
CHAPTER XII
INSECT METAMORPHOSIS AND DIAPAUSE

The conspicuous changes which occur in form and appearance of insect in between egg stage till they become adult is known as **insect metamorphosis.** Each time an insect moults, it gets a little larger. It may also change physically depending on its type of metamorphosis such as:

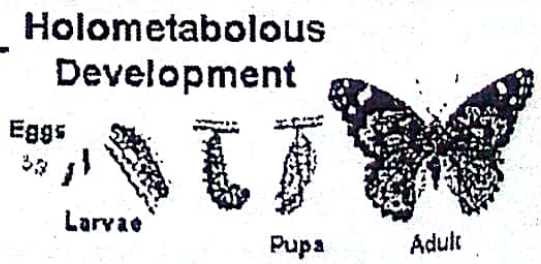
1) **Ametabolous :** undergo little or no structural change as they grow older. Immature ones are called young; they are physically similar to adults in every way except size and sexual maturity. Other than size, there is no external manifestation of their age or reproductive state e.g., Silverfish.



2) **Incomplete / Hemimetabolous :** exhibit gradual changes in body form during morphogenesis. Immature ones are called **nymphs** or if aquatic called as **naiads.** Maturation of wings, external genitalia, and other adult structures occurs in small steps from molt to molt. Wings may be completely absent during the first instar and appear in the second or third instar as short wing buds and grow with each molt until they are fully developed and functional in the adult stage. Developmental changes that occur during gradual metamorphosis are usually visible externally as the insect grows but adults retain the same organs and appendages as nymphs (eyes, legs, mouthparts, etc.) e.g., Grasshopper, Red cotton bug.



3) **Complete / Holometabolous:** have immature forms (larvae) that are very different from adults. Larvae are "feeding machines" adapted mostly for consuming food and growing in size. They become larger at each molt but do not acquire any adult-like characteristics. When fully grown, larvae molt to an immobile pupal stage and undergo a complete transformation. Larval organs and appendages are broken down (digested internally) and replaced with new adult structures that grow from imaginal discs, clusters of undifferentiated (embryonic) tissue that form during embryogenesis but remain dormant throughout the larval instars. The adult stage, which usually bears wings, is mainly adapted for dispersal and reproduction. e.g., Butterfly, Beetles, Housefly.



Anamorphosis: In insect like Protura, first instar larva has only 8 abdominal segments with terminal telson. The remaining three segments are added in subsequent molts. Telson remains at terminal end.

Hypermetamorphosis: In insects like blister beetle the larva passes through totally different instars hence called as hypermetamorphosis.

Epimorphosis: In which segments and legs are not added at molts e.g. Myriopods.

gnificance:

) Reducing competition of food and space.

) Helps taxonomist in classifying insects into different groups.

) Helps in changing size, shape and structure of insect body by periodical shedding of their old cuticle and by formation of new cuticle.

4) Help to overcome the unfavourable climatic conditions by entering into hibernation or aestivation or diapause stage.

5) Helps insect as a protective adaptation by way of camouflaged/ mimicry i.e., resemblance to the nature.

Insect Diapause

Period of arrested or suspended development of growth in an insect to suvive predictable nfavourable environmental conditions is called as **diapause**. This may occur in ay stage of life ycle viz., embryonic, larval, nymphal, pupal or adult. The period may last for few hours, few ays, few months to an year or even more. Insect diapauses can be classified into two types:

Facultative diapauses: mostly been induced by environmental conditions effecting some insect species in a generation resulting into several generations in a year i.e., multivoltine.

Obligate diapause: now a days has become common in life cycle. Each individual in every generation enters obligate diapause which results in a single generation during the year i.e., univoltine.

iapause Phases:

Insects diapause consists of several distinct phases characterized by particular sets of etabolic processes and responsiveness of the insect to certain environmental stimuli. Reduced xygen consumption is typical as is reduced movement and feeding. In *Polistes exclamans* nly queen is said to be able to undergo diapause.

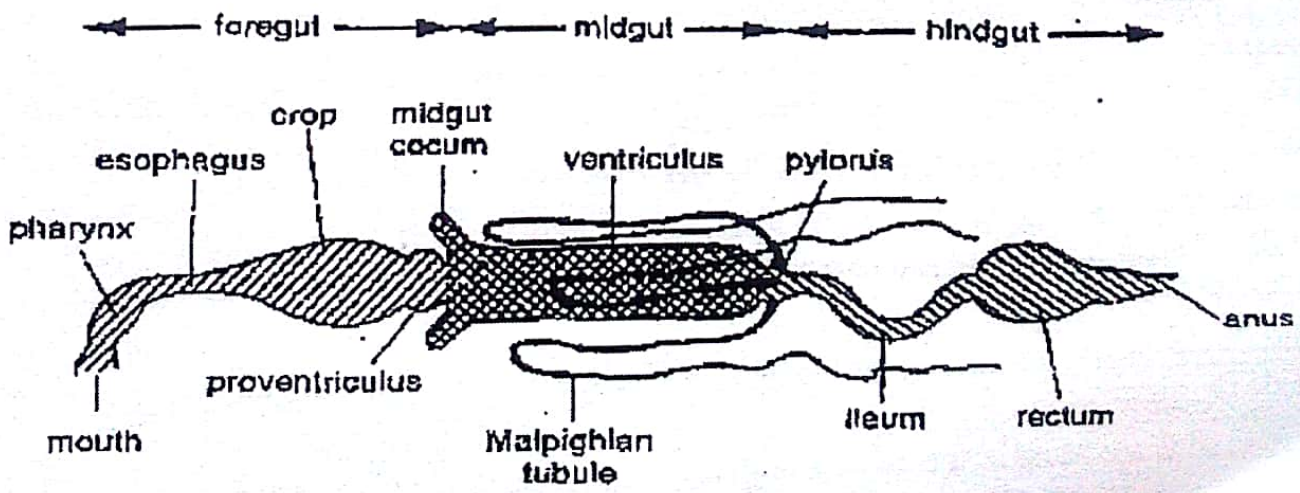
CHAPTER XV
INSECT ANATOMICAL STRUCTURES AND FUNCTIONS

Digestive System

An insect uses its digestive system to extract nutrients and other substances from the food which within a tube-like enclosure known as **alimentary canal** which running lengthwise through the body from mouth to anus. As per anatomist a complete digestive system is an evolutionary improvement over an incomplete digestive system due to development of specialized functional parts for adapting various functions of food digestion, nutrient absorption and waste excretion. In most of the insects, the alimentary canal is divisible into three primary regions: foregut (stomodeum), midgut (mesenteron) and hindgut (proctodeum).

I. Foregut (Stomodeum): is anterior most invagination with ectodermal origin which starts from mouth till gizzard.

1) **Mouth:** also known as pre-oral cavity made up of two lobes i.e., dorsal lies between epipharynx and hypopharynx is called as **cibarium** while ventral lies between hypopharynx and salivary duct is called as **salivarium**. It is an opening through which the food is been temporary stored and then injected into the body.
2) **Pharynx:** is a well musculated organ located behind the mouth helping to push the food into oesophagous and also acts as a **sucking pump** in sap feeders.
3) **Oesophagous:** is a simple, straight, narrow tube running through forepart of thorax having inner walls longitudinally folded which help to pass food material from pharynx to crop.
4) **Crop:** is expansion of dilated distal part of oesophagus which constitute major portion of fore gut and act as temporary reservoir of food.



5) **Gizzard (Proventriculus):** is muscular posterior part of foregut mostly found in solid feeders which modifies the internal cuticular layer into teeth-like structures in cockroach helping to grind food, plate- like structures in honey bee to separate pollen grains from nectar or spine-like structures in flea to break the blood corpuscles.

The **cardiac valve or oesophageal valve** are formed to regulate food flow by invagination of foregut and anterior part of midgut.

II. Midgut (Mesenteron): is an intermediate region marked anteriorly with gastric caecae and posteriorly by malpighain tubules lying between foregut and hindgut. It is endodermal in origin been made up of three different epithelial cells as secretory cells (columnar cells); goblet cells (aged secretory cells); regenerative cells which later replaces secretory cells. Midgut may be saclike, coiled or tubular and marked by important structures such as:

a) **Gastric caecae (Enteric caecae or Hepatic caecae):** are blind finger like tubes mostly 8 in cockroach which helps to increase the functional area of midgut and also shelter symbiotic bacteria in some insects.

b) **Peritrophic membrane:** is midguts internal lining secreted by anterior layer of epithelial cells present mostly in solid feeders and functions as lubricant to facilitate food movement; act as food envelops to protect damage of midgut epithelial cells; act as barrier to microflora to prevent infection.

c) **Filter chamber:** is a complex modification with anterior portion of hindgut attached to midgut which are enclosed in a sac been useful to remove excess water from liquid food in homopteran insects. It also helps in preventing dilution of haemolymph by osmoregulation.

d) **Pyloric valve (Proctodeal valve):** is sphincter muscular opening that regulate flow of food material from the mesenteron to the proctodeum.

III. Hindgut (Proctodeum): is posterior ectodermal invagination with internal cuticular lining which start from insertion of malpighain tubules till anus.

a) **Malpighain tubules:** are yellowish tubules which are 80 to 100 in number arranged in 8 to 10 groups behind midgut and are excretory in function.

b) **Illum:** is anterior pouch like structure been developed by wood eating termites containing protozoan symbiots which help in cellulose digestion.

c) **Colon:** is corrugated middle portion providing passage for food towards rectum.

d) **Rectum:** is enlarges globular terminal portion containing variable number of rectal pads (papillae) which helps in reabsorption of water and essential ions from faeces and urine hence acts as fermentation chamber.

e) **Anus:** is last posterior opening from which waste, undigested food material is released outside the insect body.

IV. Digestion of food: Most of this food is ingested in the form of macromolecules and other complex substances such as proteins, polysaccharides, fats, nucleic acids, etc. which must

be broken down by catabolic reactions into smaller molecules i.e., amino acids, simple sugars, etc. before being used by cells of the body for energy, growth or reproduction. This break-down process is known as **digestion.**

V. **Physiology of gut:** works on digestion of ingested food for absorption of the metabolites by enhancing the enzymes and microbes produced by digestive glands and special cells.

A. Digestive glands:

(a) **Salivary glands:** are pair of glandular structures (acini) and pair of reservoirs present on sides of the crop. Each gland has separate duct which further unit into common duct at the base of hypopharynx.

Functions of saliva:

(i) To moisten, lubricate and dissolve food.

(ii) In ant saliva secrete formic acids which causes irritation.

(iii) In silkworm larvae saliva is used to produce silk for the purpose of construction of silken cocoons.

(iv) In cockroach saliva contains amylase used for starch digestion.

(v) In honey bee saliva contains invertase which helps in sucrose digestion

(vi) In jassid saliva contains toxins producing tissue necrosis and phytotoxemia on plant parts and also contains lipase and protease which helps in lipids and protein digestion

(vii) In plant bug saliva contains pectinase which helps the stylet for penetration with extra intestinal digestion.

(viii) In mosquito, bed bug and testse fly saliva contains anticoagulin which prevents clotting of blood.

(ix) Gall midge produces galls on plant parts due to saliva containing Indole Acetic Acid (IAA).

(x) The saliva of disease transmitting insects act as vectors making way for the entry of pathogens.

(b) **Hepatic caecae and midgut epithelial cells:** secretes digestive juices in which holocrine epithelial cells disintegrate in the process of enzyme secretion while merocrin enzyme secretion occurs without cell break down.

B. Enzymes of Digestion:

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

These enzymes help for breakdown of complex substances into simpler easily acceptable rm such as carbohydrates into monosaccharides; proteins broken into polypeptides; fats often oken down into fatty acids and glycerol.

Nervous System

An nervous system is a network of specialized cells called neurons that serve as an nformation highway" within the body. These cells generate electrical impulses that travel waves of depolarization along the cell membrane. Every neuron has a nerve cell body d filament-like processes called as dendrites, axons or collaterals that propagate always idirectional signal transmission.

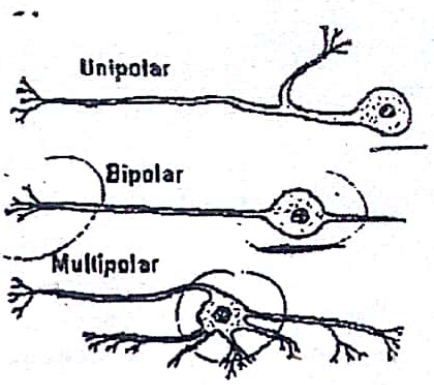
Neurons are usually divided into two categories depending on their structure and function rformed within the nervous system:

Functional basis:

1. **Afferent (sensory) neurons:** are bipolar or multipolar cells of which one axon attaches to sense organs and other to central nervous system to convey the information.
2. **Efferent (motor) neurons:** are unipolar cells present on ganglions of central nervous system that stimulate signals to the muscles, glands or effector organs.
3. **Internuncial (association) neurons:** are unipolar cells located on the ganglions that help to connect sensory and motor neurons which conduct signals within the central nervous system.

) **Structural basis:**

1. **Unipolar:** neuron having single axon.
2. **Bipolar:** neuron with proximal axon and long distal dendrite.
3. **Multipolar:** neuron with proximal axon and many distal dendrite.



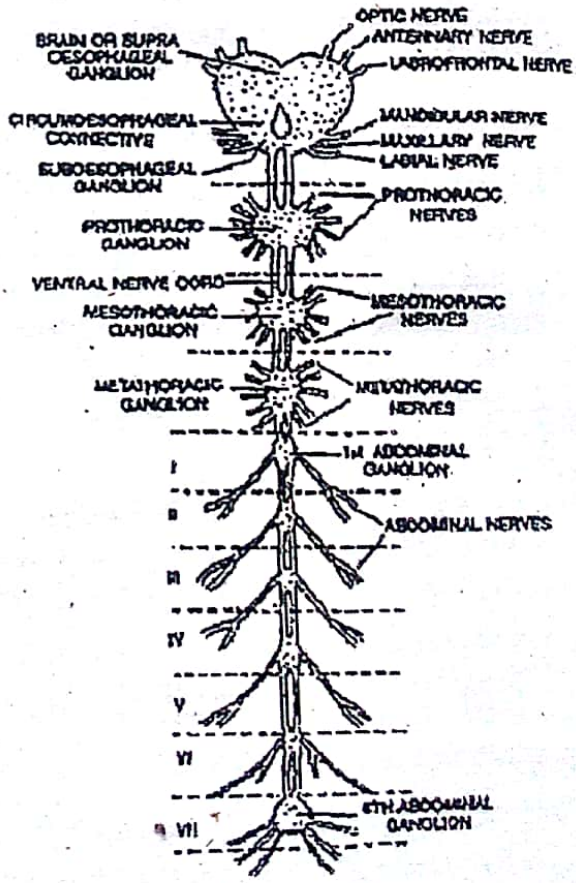
Individual nerve cells connect with one another through special junctions called **synapses.** When a nerve impulse reaches the synapse, it releases a chemical messenger known as **neurotransmitter** such as Acetylcholine, 5-hydroxytryptamine, dopamine and noradrenaline that diffuses across the synapse and triggers a new impulse in the dendrite(s) of one or more connecting neurons.

Nerve cells are typically found cells which are mostly grouped in bundles. A **nerve** is simply a bundle of dendrites or axons that serve the same part of the body. A **ganglion** is a dense cluster of interconnected neurons that process sensory information or control motor outputs.

Nervous system is anatomically divided into three types which are interconnected with each other as follows:

A) Central Nervous System:

Insects have relatively simple central nervous system with a dorsal brain linked to ventral nerve cord that consists of double series of ganglia joined together by longitudinal nerve fibers known as **connectives** and transverse nerve fibers known as **commissure.**



I) Brain or Supra Oesophageal ganglion: also known as dorsal ganglionic center of the head lies just above the oesophagus and contain entirely association neurons. It is a complex fusion of first three pairs of embryonic ganglia termed as:

i) **Protocerebrum:** is first fused paired ganglia of pre-antennary segment which innervate impulses to the compound eyes and ocelli.

ii) **Deutocerebrum:** is second fused pair of ganglia of antennary segment innervating impulses to the antenna .

iii) **Tritocerebrum:** forms ganglia of intercalary segment of head contain two separate lobes attached to deutocerebrum by post-oesophageal commissures and contain para- oesophageal connectives which unite brain with sub-oesophageal ganglion and rest of the ventral nerve cord alongwith stomodeal nervous system that controls the internal organs. It also contains labro-frontal nerves which pass through labrum and form root of frontal ganglion.

II) **Sub-oesophageal ganglion:** is ventral ganglionic center of the head located just below the brain and oesophagus. It is a complex fusion of three embryonic ganglia present on third segment of head region innervating impulses not only to mandibles, maxillae and labium but also to hypopharynx, salivary glands and neck muscles.

III) **Ventral Nerve cord:** consist of series of ganglion lying on the floor of thorax i.e., three pairs of thoracic ganglia innervating impulses to legs, wings for controlling locomotion and abdomen i.e., first abdominal ganglion fused with metathorax while last abdominal ganglia is formed by fusion of last three pairs of ganglion forming a large caudal ganglion. The abdominal ganglia control movements of abdominal muscles whereas terminal abdominal ganglia innervate impulses to anus, internal and external genitalia and sensory receptors such as cerci. Spiracles in both the thorax and abdomen are controlled by a pair of lateral nerves that arise from each segmental ganglion.

B) Visceral Nervous System:

The visceral nervous system gets divided into following three subsystems:

(i) **Oesophageal Sympathetic or Stomatogastric Nervous System:** is dorsal in position and directly connected with the brain. It innervates impulses to fore intestine, mid intestine, heart and several endocrine organs as corpora cardiaca been attached with it is one non-nerve known as corpora allata which is responsible for secretion of harmones. In front of the brain above the oesophagus lies triangular frontal ganglion.

(ii) **Ventral Sympathetic Nervous System:** consist of a part of transverse nerves on each ganglion of ventral nerve cord which passes impulses to the spiracles of their segment and control its opening and closing.

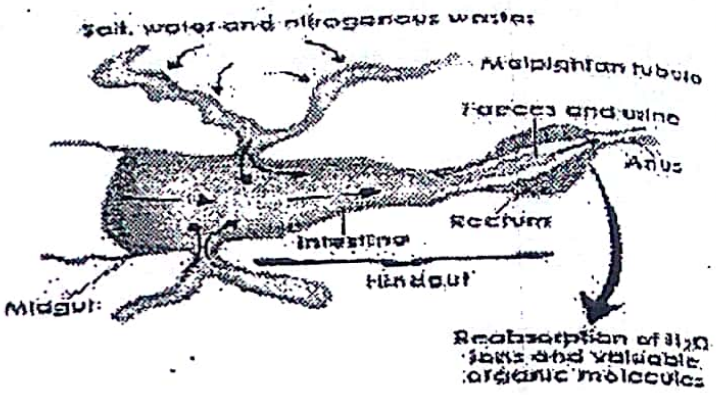
(iii) **Caudal Sympathetic Nervous System:** is originated from posterior ganglion and supplies nerve impulses to the reproductive systems, hindgut and cerci.

C) Peripheral Nervous System:

The peripheral nervous system consists of all the motor neurone axons from the central nervous system and visceral nervous system which are applied to the integument, gut walls and

Physiology of Excretion and Osmoregulation:

The insect excreta produced may be liquid urine or solid pellets which are results of two processes known as **excretion and osmoregulation.** To performed such functions insect use largely the malpighian tubules and hindgut. The hindgut produces special cells called as **chloride cells** which are capable of absorbing inorganic ions from the dilute solutions e.g., dragonfly and damselfly naids.



Whereas malpighian tubules produces a isosmotic filtrate which is high in K^+ and low in Na^+ with Cl^- as major anion for active transport of ions especially K^+ into the tubule lumen by generating an osmotic pressure gradiant for the passive flow of water.

Reproductive System

In insects reproductive organs are mostly similar in structure and function where male testes produce sperms and female ovaries produce eggs. Most insects reproduce bisexually which classifies on functional basis into two different types such as:

Male Reproductive System

The male reproductive system consists of following organs located near the back of the abdomen.

1) Testes:

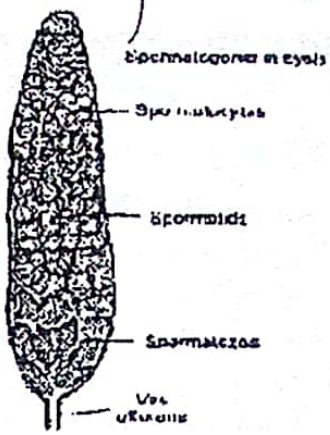
Testes are pair of faint whitish gonads consisting of 30-40 small rounded functional units called **sperm tubes (follicles)** in which sperm are actually produced. They may be placed dorsally or ventrally at sides of gut maintaining their position by surrounding fat bodies and tracheas.

A typical testis may contain hundreds of testicular follicle which are lined inner by layer of epithelium and covered with coat of connective tissues. Each follicle contains series of zones with presence of sex cells. The zones are as follows:

a) **Germanium zone:** contain spermatogonia which undergo multiplication.

b) **Zone of growth:** Spermatogonia increases in size by undergoing mitosis dividing to form **spermatocytes.**

c) **Zone of division and reduction:** These spermatocytes migrate toward basal end of the follicle and undergoes meiosis division yielding four haploid **spermatids** which develop into mature **spermatozoa or sperms** by moving further along the follicle.



Spermatogenesis: (occurs inside sperm tube)

mitosis

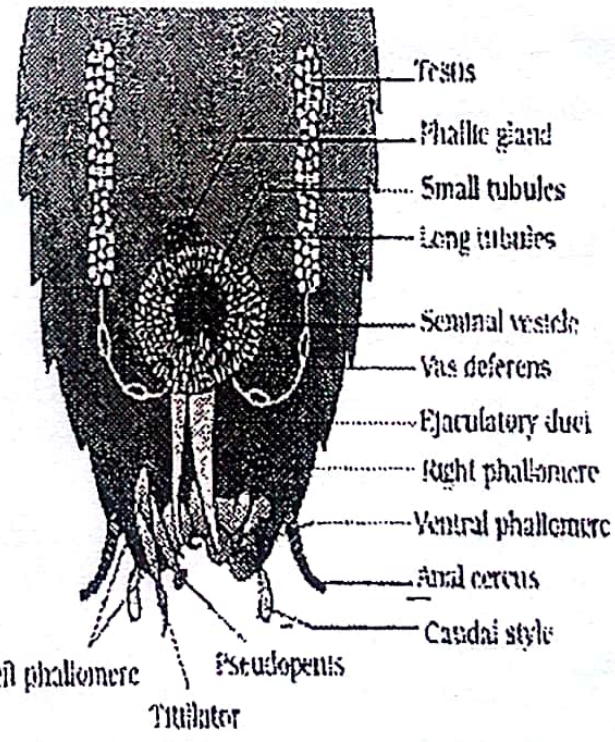
meiosis

Spermatogonia----------> Primary spermatocytes (2n) ----------> Secondary spermatocytes (n) --------> Spermatids (n) ------> Spermiogenesis-------> **Sperms/ Spermatozoa (n)**

mitosis meiosis

) Vasa deferentia:

A pair of very thin whitish tube arises from testes and posteriorly running beneath the ectum is called vasa deferentia. They vary in ength and enlarges during their course to form ac-like structure known as **seminal vesicles** which spermatozoa are retained or stored hile passing through the ejaculatory duct.



) Ejaculatory duct:

It is a common duct of vasa deferentia rovided with powerful muscles below which the layer of epithelial cells that leads out of he body through genital opening of aedeagus.

) Aedeagus:

Terminal section of ejaculatory ducts nclosed in a finger like evagination at the ventral body wall which forms the males copulatory organ called an aedeagus. The genital opening lies behind 9th abdominal sternum known as penis while on either side contains two parameres.

5) Accessory glands:

They are tubular sac-like structures found in one or three pairs of accessory glands which are usually associated with reproduction. They manufacture a seminal fluid which nourishes mature sperm present in the males genital system. It comprises of:

a) **Mushroom gland:** consists of numerous whitish tubules and normally lie above ejaculatory duct.

b) **Conglobate gland:** is large elongated sac like structure beneath the mushroom gland and ejaculatory duct which opens by the sides of male gonopore.

There secretions are mixed with spermatozoa concerned with production of **spermatophores** which encase the sperm and protect them while delivered to the females body during copulation.

Female Reproductive System

When female insects are actively reproducing, these organs swell with developing eggs and may nearly fill the abdomen. The female reproductive system consists of following organs:

1) Ovaries:

They are more or less compact pale yellowish gonads which lies in the body cavity on either side of median line been embedded with fat bodies in between 4th to 6th abdominal segments known as ovaries. In each ovariole, there are group of germ cells known as **oogonia** with mitosis division increase the size to form **oocytes.** Later these oocytes migrate toward the basal end of the ovariole undergoes meiosis division yielding four cells i.e., one egg and three polar bodies. The polar bodies may disintegrate or they may accompany the egg as nurse cells.

Oogenesis : (occurs inside egg tube)

Oogonia ---(mitosis)---> Primary oocytes(2n) ---(meiosis)---> Secondary oocytes (n)---(mitosis)--->

Oocytes (n) ---> Oogenesis ---> Ovum (n)

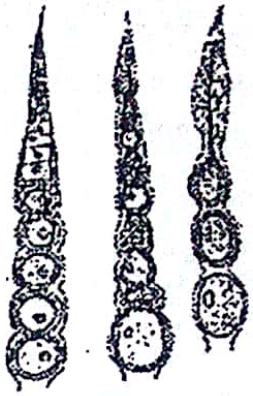
2) Ovariole:

Each ovary is composed of variable number of functional egg tubes called as ovarioles. Ovariole is an elongated egg-tube in which developing eggs or ova are placed in a linear series of progressive stages of maturation, giving the appearance of a "chain of beads". By the time an egg reaches the base of the ovariole it is been often grown upto 100,000 times larger than the original oocyte. The inner wall of ovariole contains epithelium layer while outer side is surrounded by coat of connective tissues. They development of egg within ovariole takes place in following three zones as:

a) **Terminal filament:** are thread like prolongations at apex and unit to opposite sides to form a median ligament which helps in maintaining the ovarioles in position by attaching to the fat bodies.

b) **Germarium:** forms apex of ovariole below the terminal filament and consists of mass of germ cells differentiated into primordial germ cells and nutritive cells.

c) **Vitellarium:** constitute major portion of ovariole where the development of eggs or ova takes place.

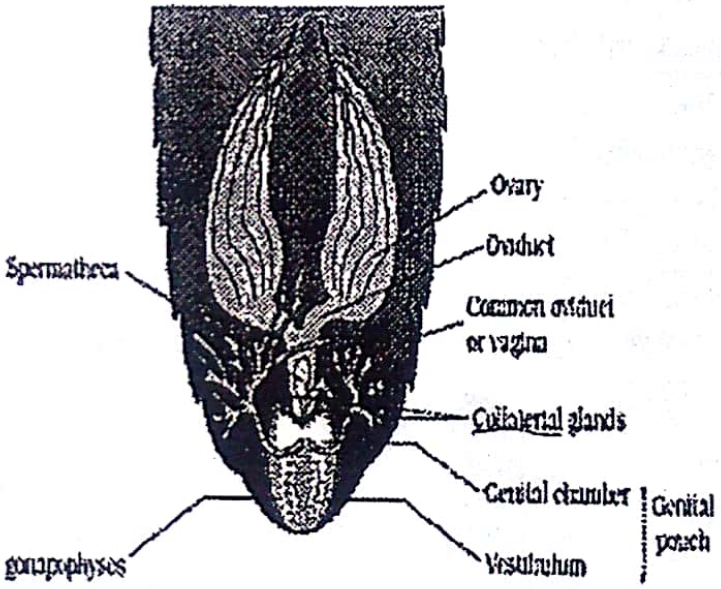


3) Lateral oviducts:

These are pair of short but wide ducts each arising from an ovary been mesodermal in origin helping matured eggs to leave the ovaries and move towards common oviduct.

4) Common oviduct:

The lateral oviducts units posteriorly at 7th abdominal sternum to form a common oviduct which elongated and opens into a genital chamber called the bursa copulatrix (vagina) at 8th abdominal sternum.



5) Spermatheca:

Spermatheca is a sac or pouch like structure made-up of two slender, spirally coiled tubules of unequal size united to form a short stalk which opens into the dorsal wall of bursa copulatrix (vagina). The male during copulation deposits their spermatophore by peristaltic contractions force into females spermatheca which produces enzymes (for digesting the protein coat of the spermatophore) and nutrients (for sustaining the sperm while they are in storage). Sperm can remain viable in the spermatheca for a weeks, months or even years.

6) Accessory glands/ Collateral glands:

These are two asymmetrically branched, tubular, opaque, white to colourless transparent glands which usually open into distal portion of bursa copulatrix i.e., vagina. It secretes a protein-rich material which form a dark and hard covering of ootheca or egg pod.

CHAPTER XVIII
BINOMIAL NOMENCLATURE

Almost all exiting well-known living things have common names creating more confusion and difficulties for taxanomists to differentiate between them due to which later on every species were given a unique scientific name.

A) Common Name:

1) These are inaccurate names which varies from one place to other causing lots of confusion between same insect species. For e.g., locust names as cicada in Europe.
2) Whenever same name is give to two different types of insects such naming pattern is known as **homonym** e.g., bollworm have five different insect species.
3) But in certain insects, a single insect is deen named by several names known as **synonym.** e.g., American bollworm, Gram pod borer.

B) Scientific Name: is a formal, accurate, universally accepted naming system denoted by two words known as **Binomial Nomenclature** was first uniformly used by Carl Linnaeus.

The important rules regarding scientifically naming the insects must be followed to keep all binomial names standardized which were first enforced by **International Code for Zoological Nomenclature (ICZN)** which are as follows:

1) The first word of a scientific name called as genus i.e., the name for a small group of closely related organisms.
2) The second word of a scientific name is the specific epithet used to identify a particular species as separate from others belonging to the same genus.
3) The entire scientific name must be written in italics or been underlined when handwritten.
4) The genus name must always be written in capitalized form.
5) While the specific epithet i.e., species name should be denoted in small letters.

But recently in certain insects the taxa are been furtherly reclassified and placed into another group. Such type of naming of the insects alongwith the generic name i.e., third word is called as **Trinomial Nomenclature or Trival Name.**

These trival names may be given either to differentiate sub-species for e.g.,

Head louse: *Pediculus humanus captis*

Body louse: *Pediculus humanus corporis*

Trival names also sometimes denotes the taxonomist (authority) name who have studied certain news characters helping them to reclassify the taxa and place it in another group.

QUESTION BANK

Q.1. Give structure and composition of insect integument with it's functions.

Q.2. Describe with suitable diagram the areas and sutures of insect head capsule.

Q.3. Define metamorphosis. Describe different types of metamorphosis with suitable examples.

Q.4. Define Entomology. How insects are related (beneficial/ harmful) to man giving suitable examples.

Q.5. Enlist the important characters of Phylum Arthropoda and state its classes with one example each.

Q.6. Describe with well labeled diagram following mouth parts and explain its feeding mechanism.

a) Chewing & Biting/ Mandibulate type e.g., Cockroach

b) Chewing & Lapping type e.g., Honeybee

c) Sponging type e.g., Housefly

d) Siphoning type e.g., Butterfly

Q.7. Describe with well labeled diagram the mouth parts of Red cotton bug/ Mosquito (Peircing and Sucking) and explain its feeding mechanism.

Q.8. Describe with well labeled diagram Male or Female Reproductive System of cockroach.

Q.9. Describe with well labeled diagram Digestive or Nervous System in insects & explain how digestion takes place.

Q.10. Describe in brief structure of insect legs & state modifications with one example each.

Q.11. Write short notes on-

a) Wing venation

b) Types of larva or pupae

c) Blood circulation in insects

d) Insect dominance

e) Insect antenna

f) Endocrine glands

g) Respiration in aquatic insects

h) Modes/ Types of Reproduction
i) Sound Producing organs in insects
j) Segmentation of Insect head
k) Position of Insect head
l) Types of wings
m) Wing coupling apparatus
n) Insect Sense organs
o) Photoreceptors in insects

Q.12. Differentiate between:
a) Exopterygota & Endopterygota
b) Moth & Butterfly
c) Homoptera & Heteroptera
d) Insecta & Arachnida
e) Solitary phase & Gregarious phase in locust

Q.13. Describe distinguishing characters alongwith families of following orders:
a) Orthoptera
b) Hymenoptera
c) Hemiptera
d) Coleoptera
e) Isoptera
f) Lepidoptera
g) Dictyoptera

Q.14. What is bionomial nomenclature? State its general rules for classification of insects.

Q.15. What is sclerotization? Explain moulting process in insects. State the cuticular appendages and processes with examples.

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