DON BOSCO COLLEGE OF AGRICULTURE, SULCORNA

(Affiliated to GOA University)

B.Sc. (Hons.) Agriculture

Fundamentals of Entomology

ENTO-121

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INSECT MORPHOLOGY & ANATOMY

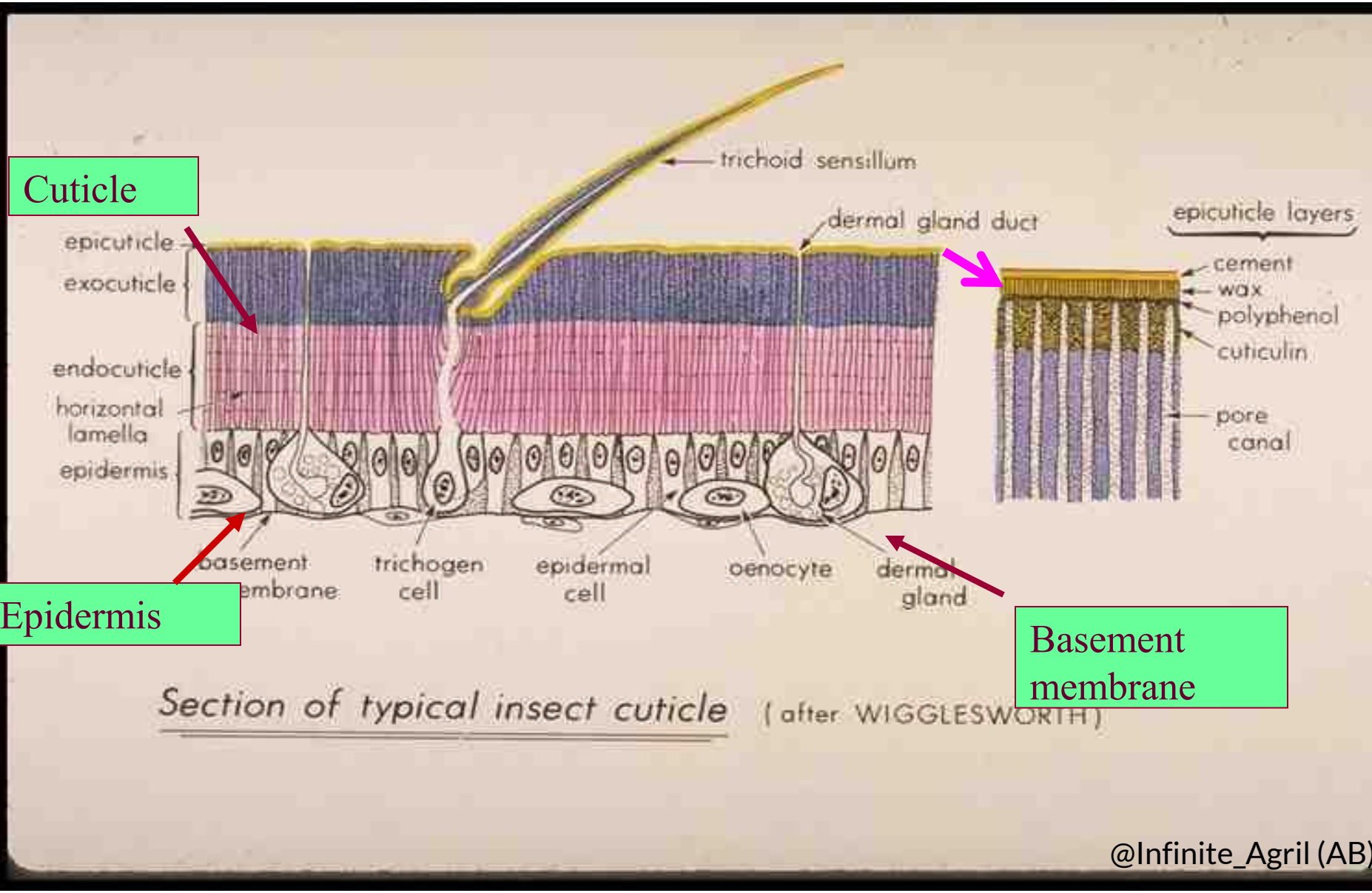
Lecture -4 INSECT INTEGUMENT

- Integument is c/as Insect body wall or Exoskeleton.
- It is **ectodermal** in origin.
- **Sclerotisation** –Hard and dark
- Provides lining for tracheal system, some glands, parts of alimentary canal & reproductive tract
- Cuticle not only covers the entire insect body from outside, but also the **foregut and the hindgut (ectodermal in origin) and the tracheae.**
- Insect cuticle can be further differentiated into two major parts, **the non-chitinous epicuticle and the chitinous procuticle.**

- **Constituents of cuticle :Chitin, Lipids & Polyphenols**

Body wall or Integument

Insect integument consists of three distinct layers



Cuticle:

- **Cuticle: It is an outer non cellular layer comprising of three sub layers.**

i. Endocuticle:

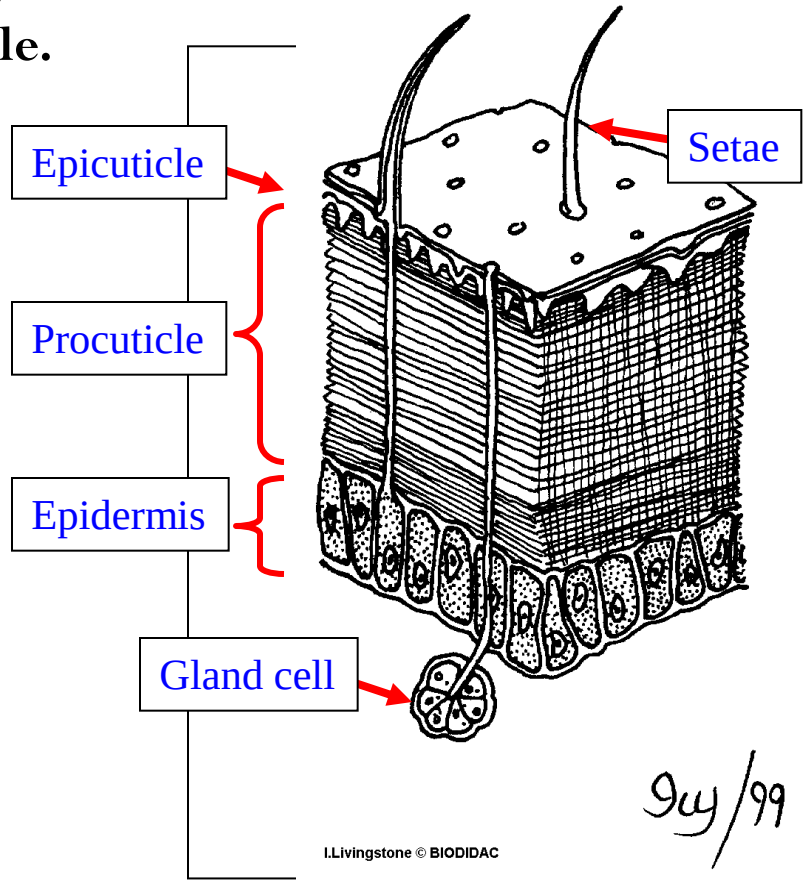
It is the innermost and thickest layer. Chitin and arthropodin. Soft and flexible.

ii. Exocuticle:

Outer layer, much thicker . Chitin and sclerotin. Dark in colour and rigid.

Endocuticle+exocuticle =Procuticle

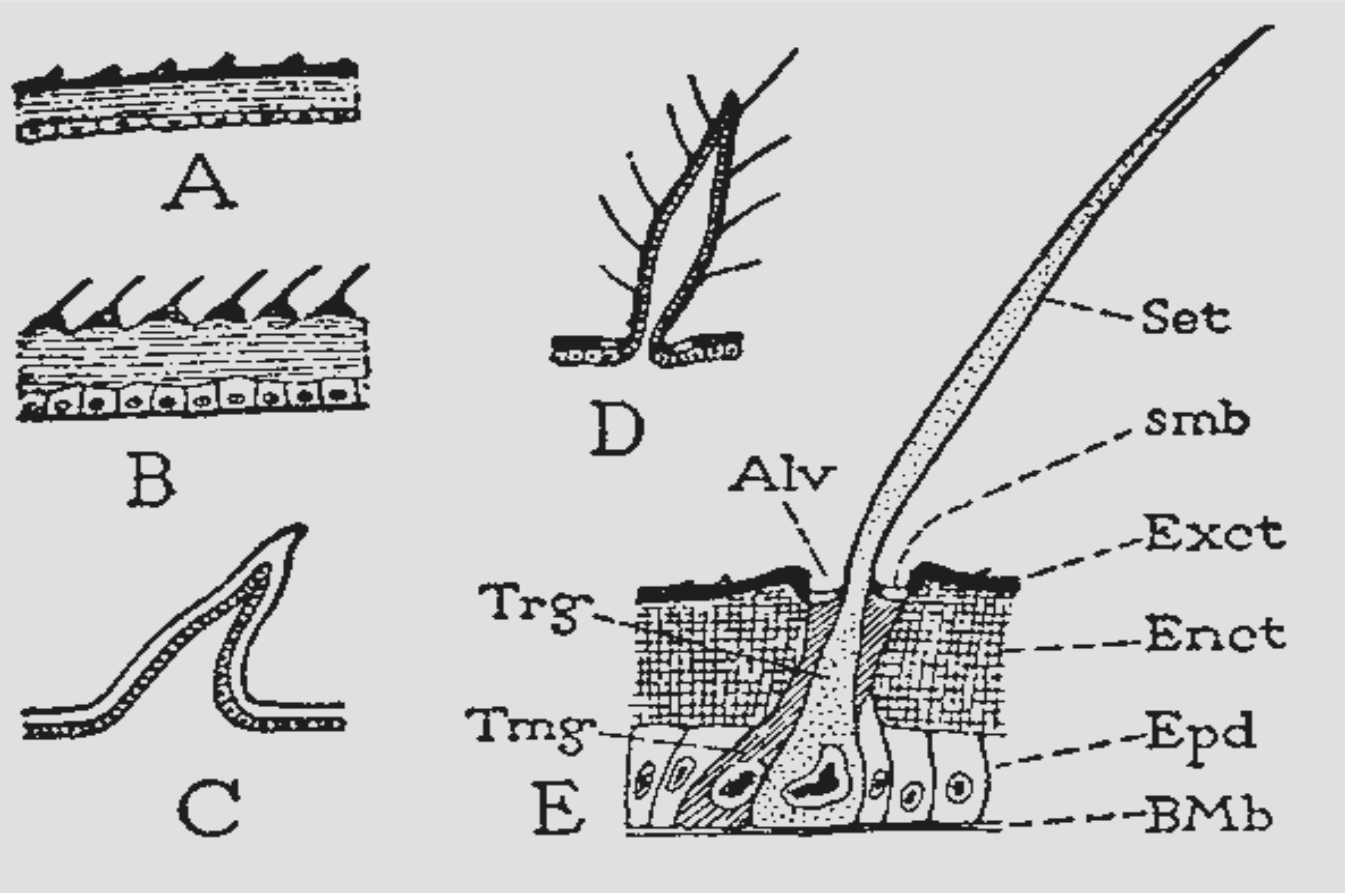
– **Procuticle**
  - Thick
  - Provides strength and hardness



Cuticular appendages:

- **Non-cellular**: Eg. **minute hairs and thorns.**
- **Cellular**: unicellular, multicellular.
- i. **Unicellular** structures:
- a. **Clothing hairs**, **plumose hairs**. e.g. Honey bee.
- b. **Bristles**. e.g.flies.
- c .**Scales** - flattened out growth of body wall e.g. Moths and butterflies
- d. **Glandular seta**. et. caterpillar
- e. Sensory setae - associated with sensory neuron or neurons
- f. **Seta** - hair like out growth from epidermis. Epidermal cell generating seta is known as **Trichogen**, while the socket forming cell housing trichogen is known as **Tormogen**. Study of arrangement of seta is known as **Chaetotaxy**.
- ii. **Multicellular** structures: e.g. **Spur** – movable ; **Spine-** immovable.

External processes of the body wall



A, B – Non-cellular processs ; C, D – Multi-cellular processs;

E – a typical uni-cellular process or seta

Alv - setal socket or alveolus; Set- seta; Smb - setal membrane,

Tmg- tormogen or socket forming cell, Trg - trichogen or seta forming cell

[Ref: Snodgross, Principles of insect morphology]

• Composition of cuticle:

- **i.Chitin**: It is the main constituent of cuticle, which is nitrogenous polysaccharide and polymer of N-acetylglucosamine. It is water insoluble but soluble in dilute acids, alkalies and organic solvents.
- **ii.Arthropodin**: An untanned protein, which is water soluble.
- **iii.Sclerotin**: Tanned protein, which is water insoluble.
- **iv.Resilin**: An elastic protein responsible for the flexibility of wing sclerites.
- **Endoskeleton** : **Cuticular in growth of body wall** providing space for muscle attachment is known as endoskeleton. There are two types
- i. **Apodeme**: **Hollow** invagination of body wall (**ridge** like).
- ii. **Apophysis**: **Solid** invagination of body wall (**spine** like).

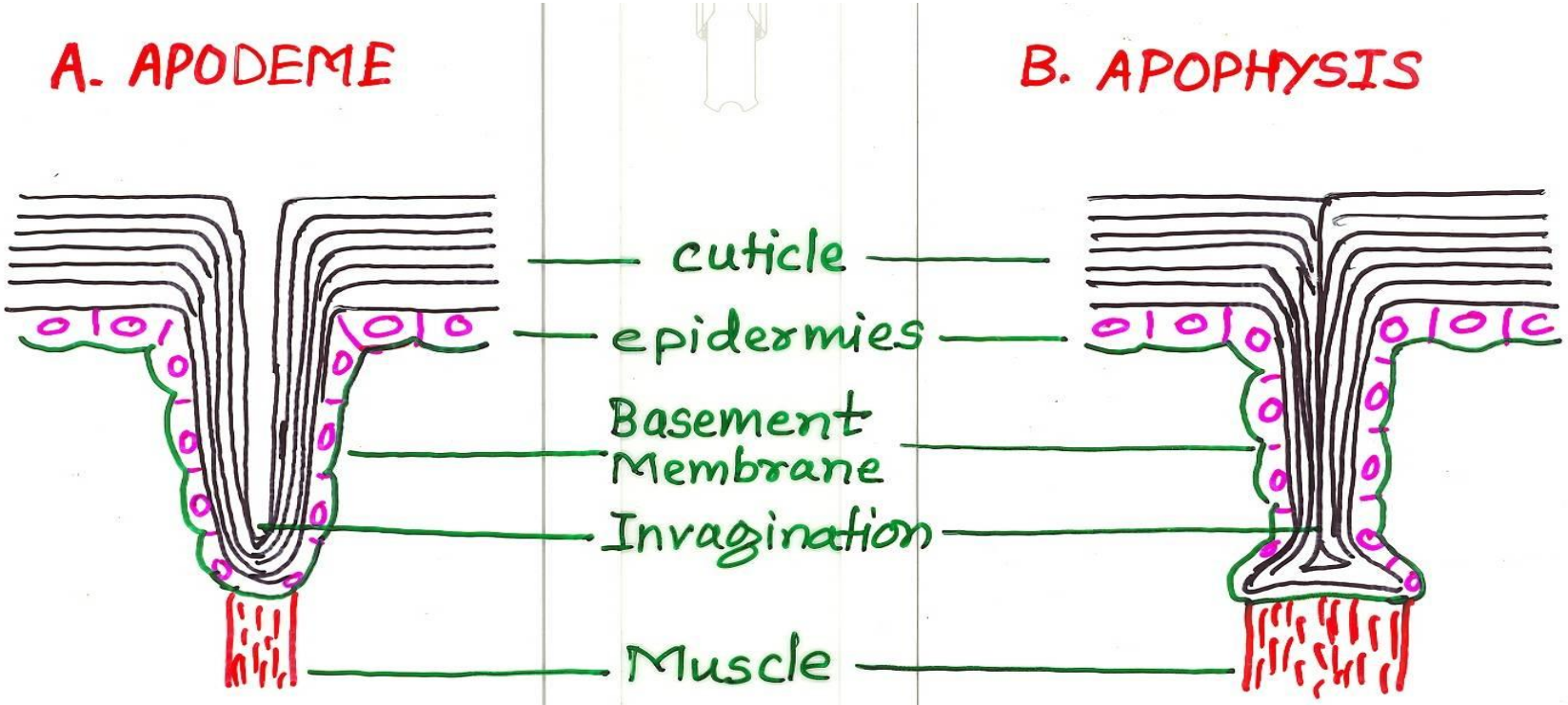
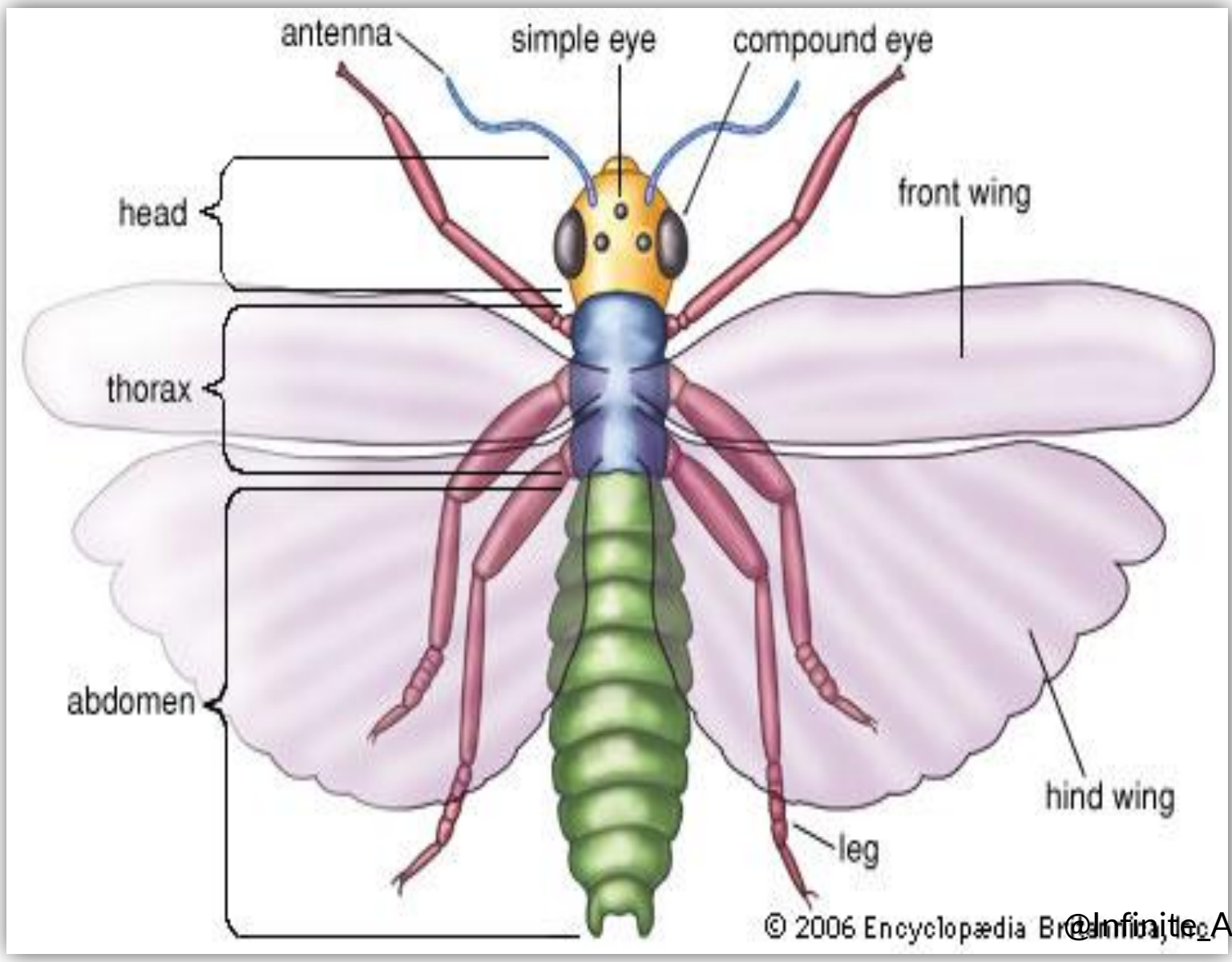


Diagram of a cuticular invaginations formings
A. Apodeme B. Apophysis

(Chapman- 431)

Lecture-5 Insect body consists of **20 segments** which are grouped together to form three distinct functional regions



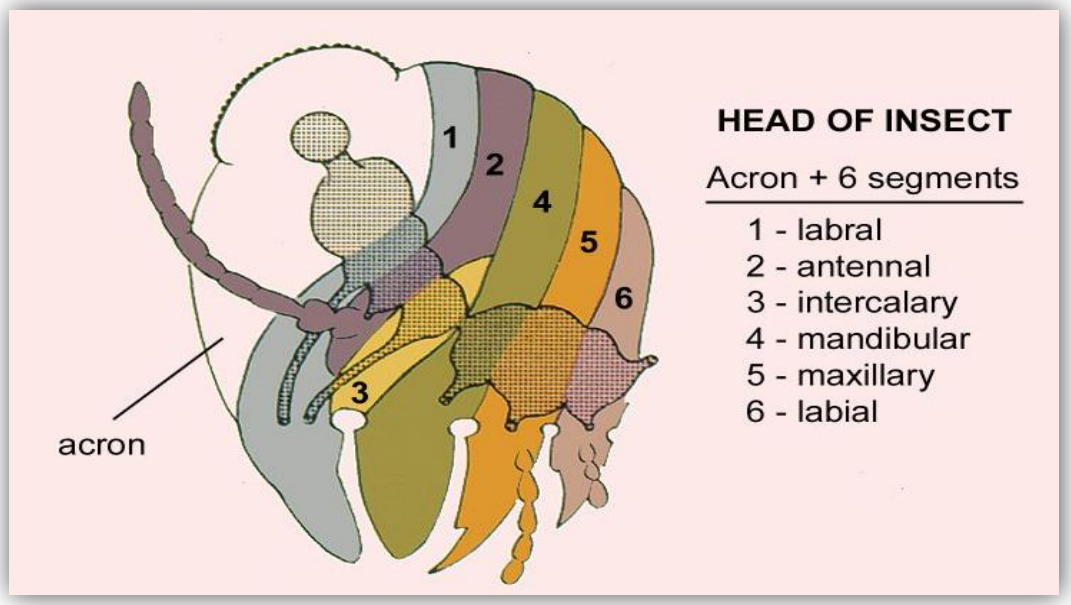
Head

- The appendages of head are
  mouthparts,
  pair of **antennae**,
  pair of **compound eyes**
  three **ocelli.**

- The head is formed due to fusion of six segments plus acron.

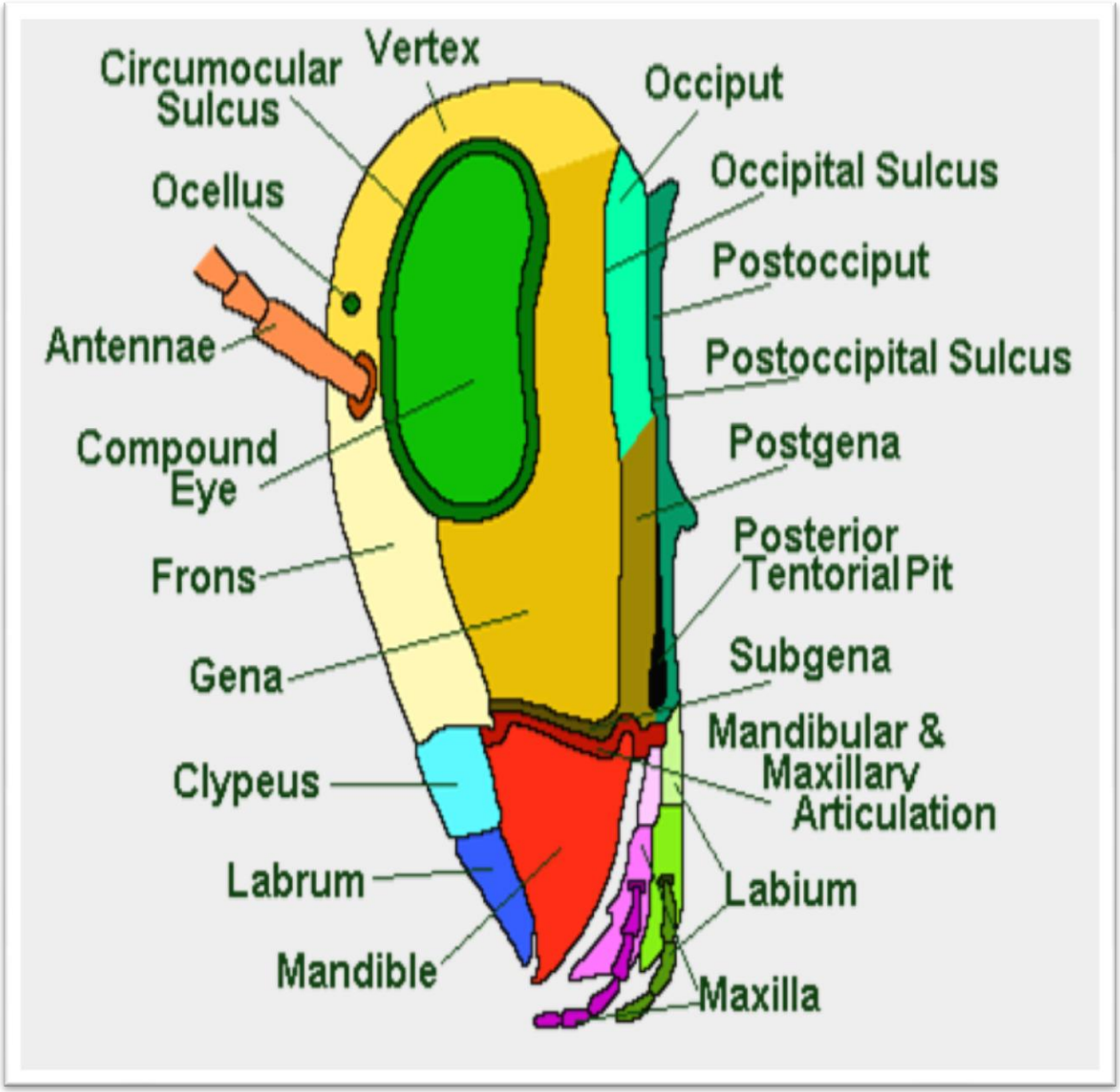
- Head capsule is sclerotized and the head capsule excluding appendages formed by the fusion of several sclerites is known as **cranium**.

Head Segments



Pre antennary	Labrum
Antennary	Antennae
Intercalary	No appendages
Mandibular	Mandibles
Maxillary	Maxillae
Labial	Labium

Sclerites in the Head Capsule

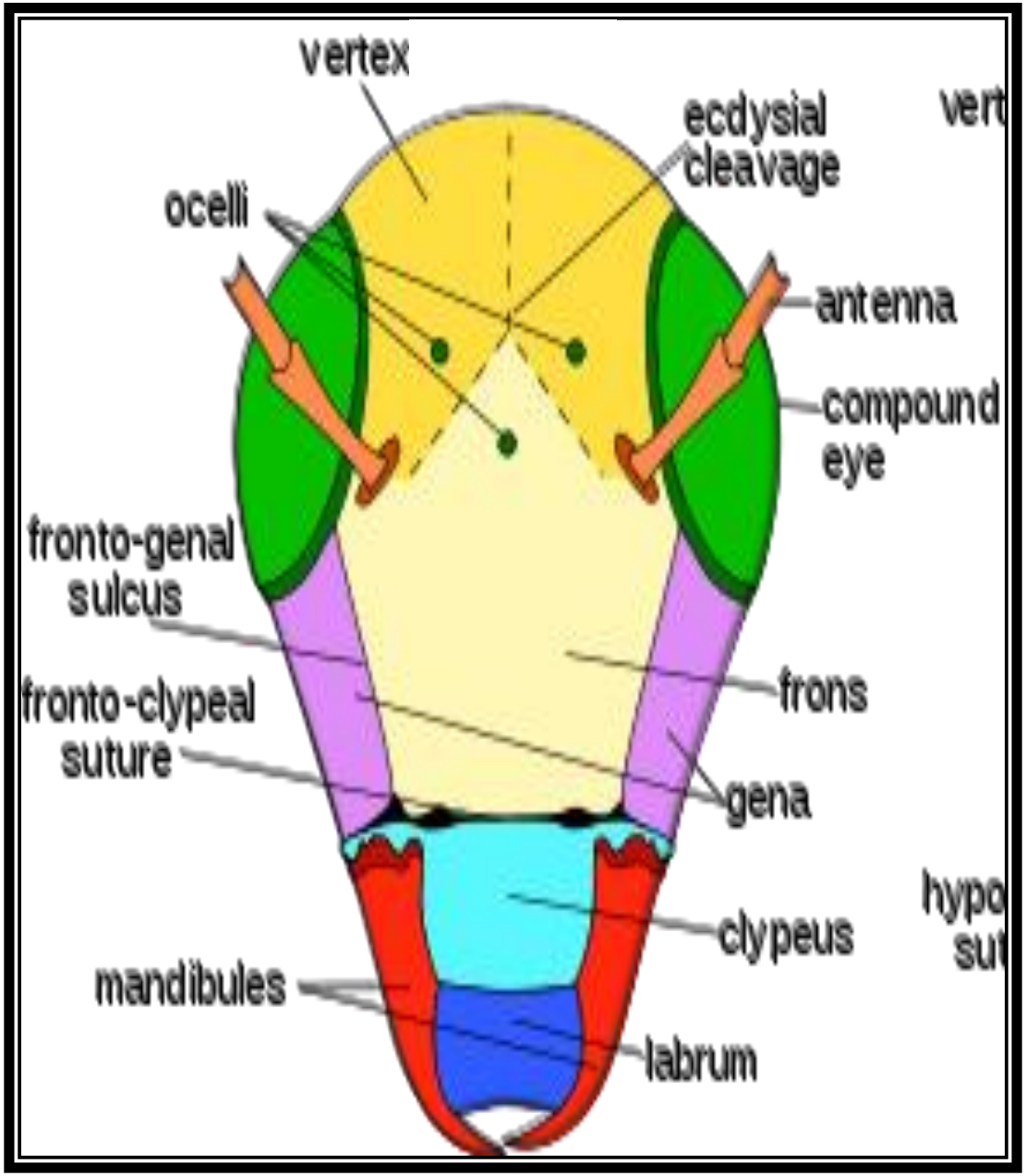


- Vertex
- Frons
- Clypeus
- Labrum
- Gena
- Occiput
- Post occiput

Sclerites in the Head Capsule

- **Vertex (Epicranium):** It is the **top or dorsal side** of the head .It posses Ocelli & antennae.
- **Frons:** It is present on the **anterior face. The median ocellus is located on it.**
- **Clypeus:** Tip like structure attached to frons.
- **Labrum:** It is called **upper lip.**
- **Gena (lateral sides):** It is the lower part of the head **beneath the eyes**
- **Occiput:** It is the area comprising most of the back of the head. The occipital suture divides it from the vertex and genae.
- **Post occiput:** It forms the **margin of the occipital foramen** and narrow ring like in shape. The post-occipital suture divides it from occiput.

Sutures in Head Capsule



- **Epicranial suture**
- **Fronto-clypeal suture**
- **Clypeo-labral suture**
- **Genal suture**
- **Sub-genal suture**
- **Occipital suture**
- **Post-occipital suture**

Sutures in Head Capsule

The linear invaginations of the exoskeleton between two sclerites are called as **suture** (some times referred as sulcus).

i. Epicranial suture (Ecdysial suture): Inverted 'Y' shaped suture separating vertex and frons, with a median suture (coronal suture) and lateral sutures (frontal suture).

ii. **Epistomal suture/ Fronto clypeal suture**: Found between frons and clypeus. (epi –above; stoma- mouth parts).

iii. **Clypeo-labral suture**: Found between clypeus and labrum (upper lip).

iv. **Postoccipital suture**: Groove bordering occipital foramen. Line indicating the fusion of maxillary and labial segment.

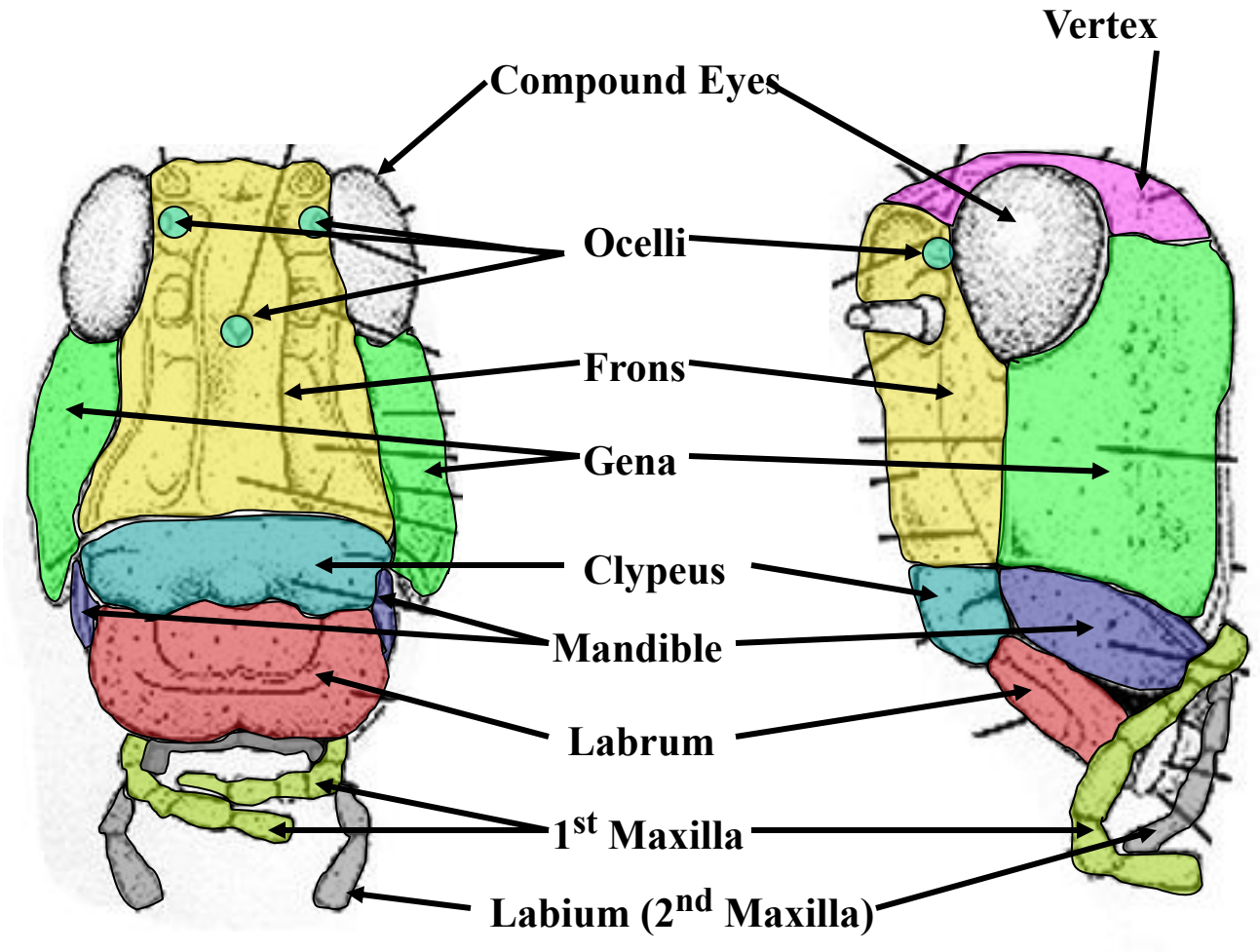
Endoskeleton of insect cuticle provides space for attachment of muscles of antenna and mouthparts, called as **tentorium**.

The appendages like a pair of compound eyes, 0-3 ocelli, a pair of antenna and mouth parts are called as cephalic appendages.

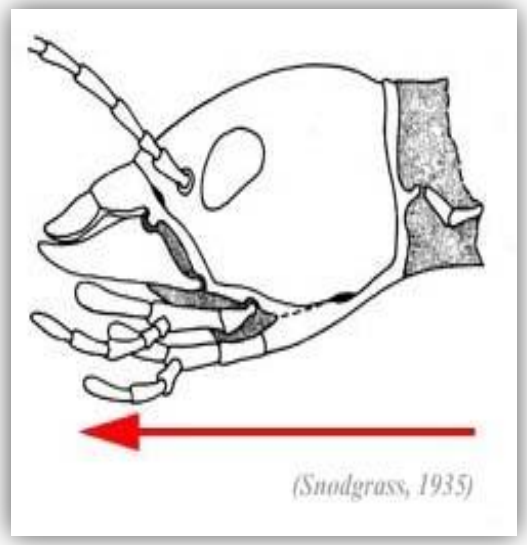
Functions of Head

i. Food ingestion
ii. Sensory perception
iii. Coordination of bodily activities
iv. Protection of the coordinating centers

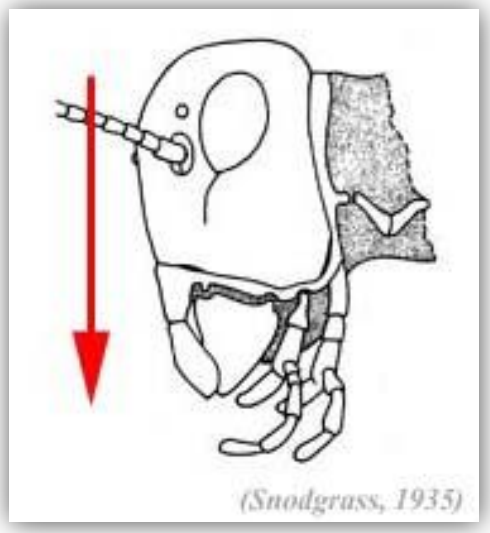
Insect Head



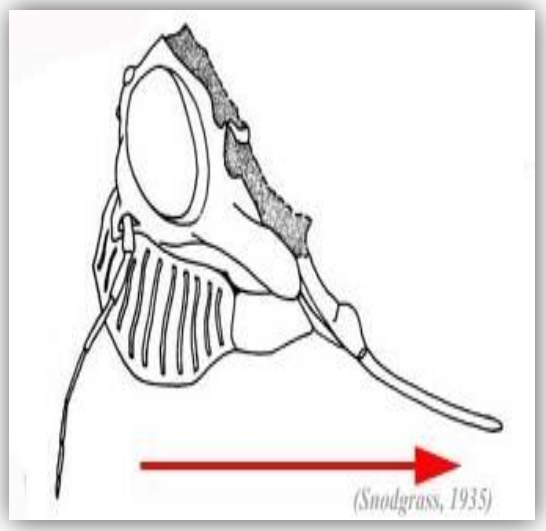
HEAD POSITIONS



Prognathous



Hypognathous



Opisthorhynchous

- Hypognathous : Mouthparts directed below : **Grasshopper, Cockroach**
- Prognathous : Mouthparts directed forward : **Beetles, Larvae, Termites**
- Opisthognathous : Mouthparts run backward between legs : **Red cotton bug**

Lecture 6 & 7TYPES OF MOUTHPARTS:

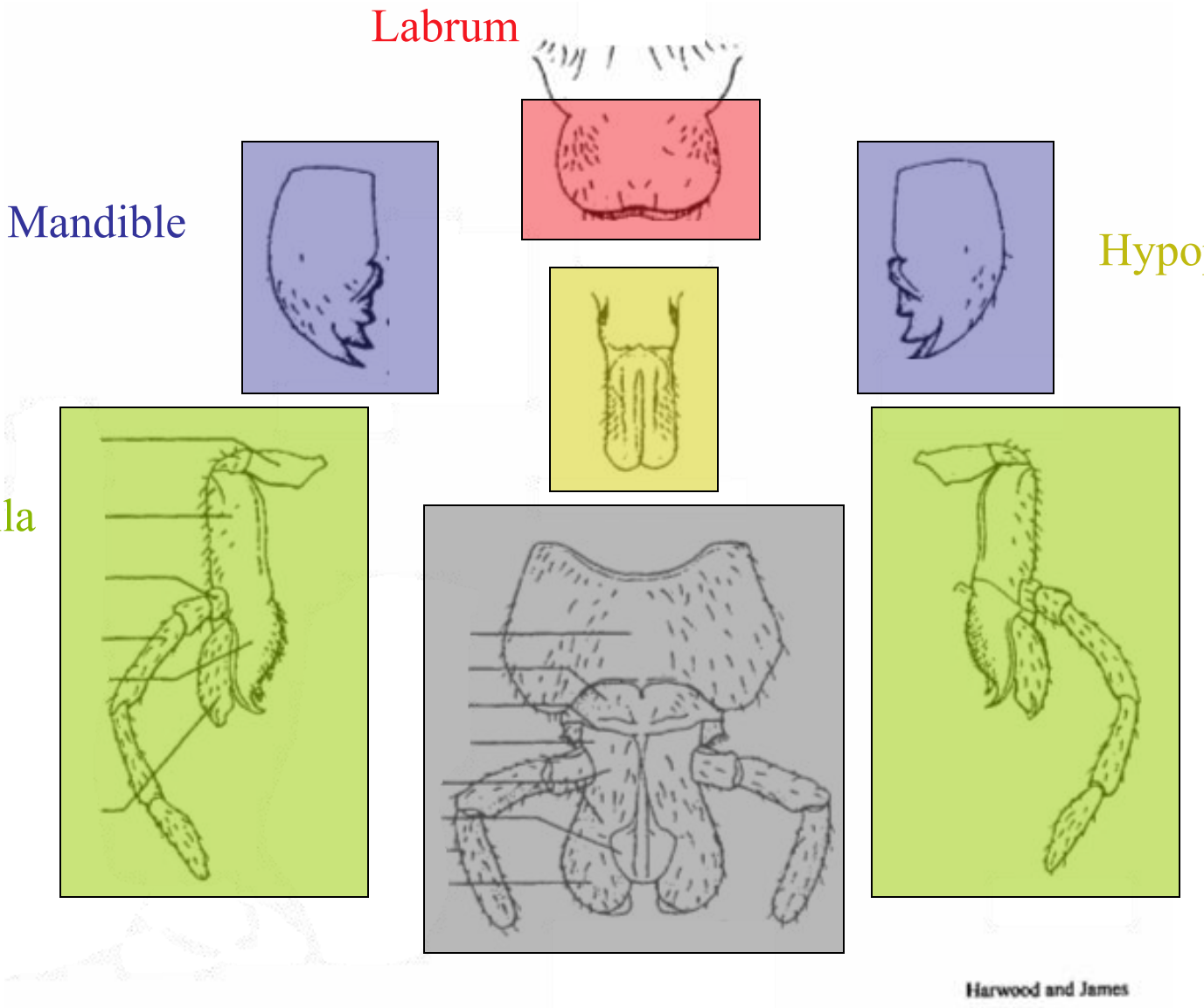
Two main functional groups: **mandibulate and haustellate**.

•**Mandibulate (chewing)**

Examples: Dragonflies and damselflies (**Odonata**), termites (**Isoptera**), adult lacewings (**Neuroptera**), beetles (**Coleoptera**), **ants** (Hymenoptera), cockroaches (**Blattaria**), grasshoppers, crickets and katydids (**Orthoptera**), and **caterpillars** (Lepidoptera).

•**Haustellate** mouthparts are primarily used for **sucking liquids** and can be broken down into two subgroups: **stylet and without stylet.**

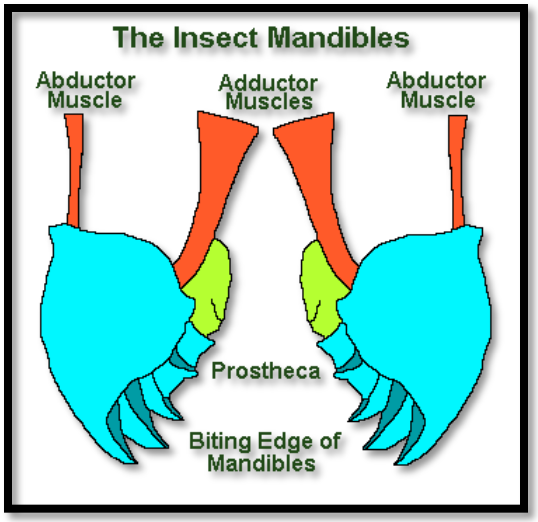
Insect Mouthparts

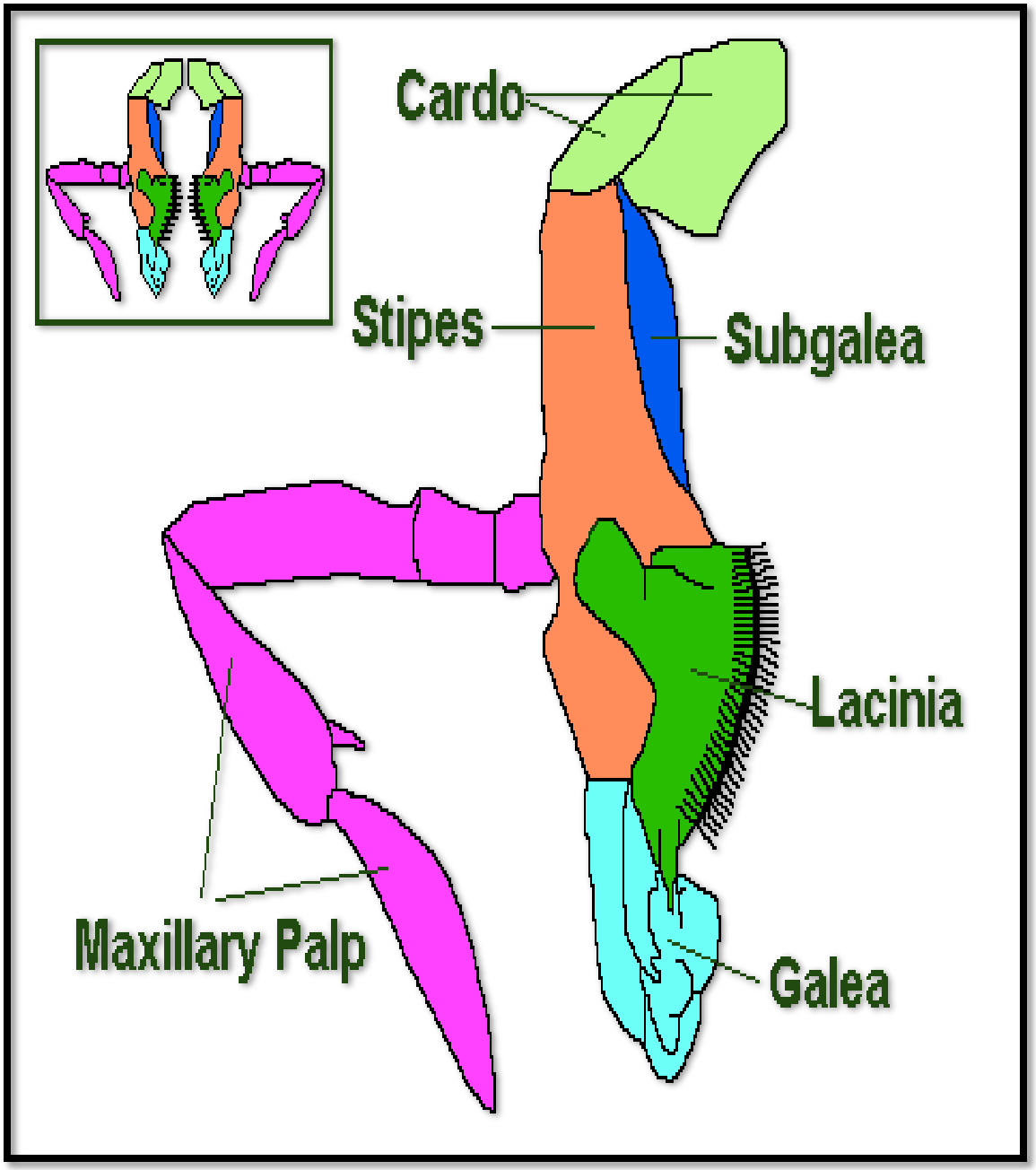


Labium (2nd maxilla)

Hypopharynx

- **Hypopharynx or tongue** is found behind the mouth, and has the salivary ducts at its base, in **most Diptera and Hemiptera it has become highly modified.**

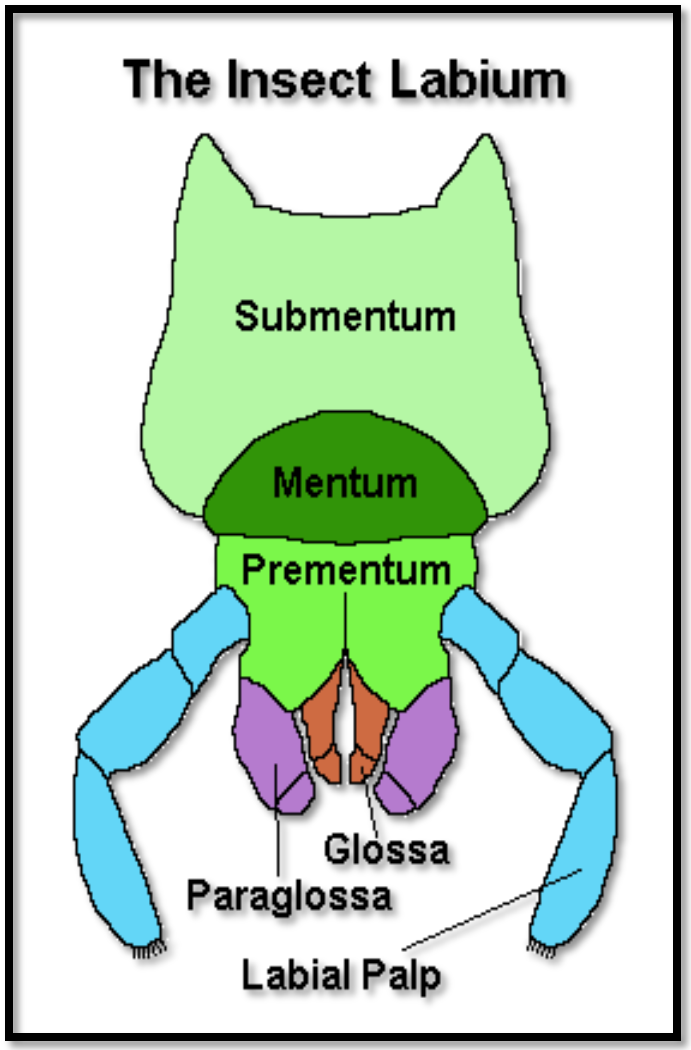




Insect Maxillae

- Cardo
- Stypes
- Palpifer,
- Maxilliary palp
- Lacinia
- Galea
- Subgalea

Labium

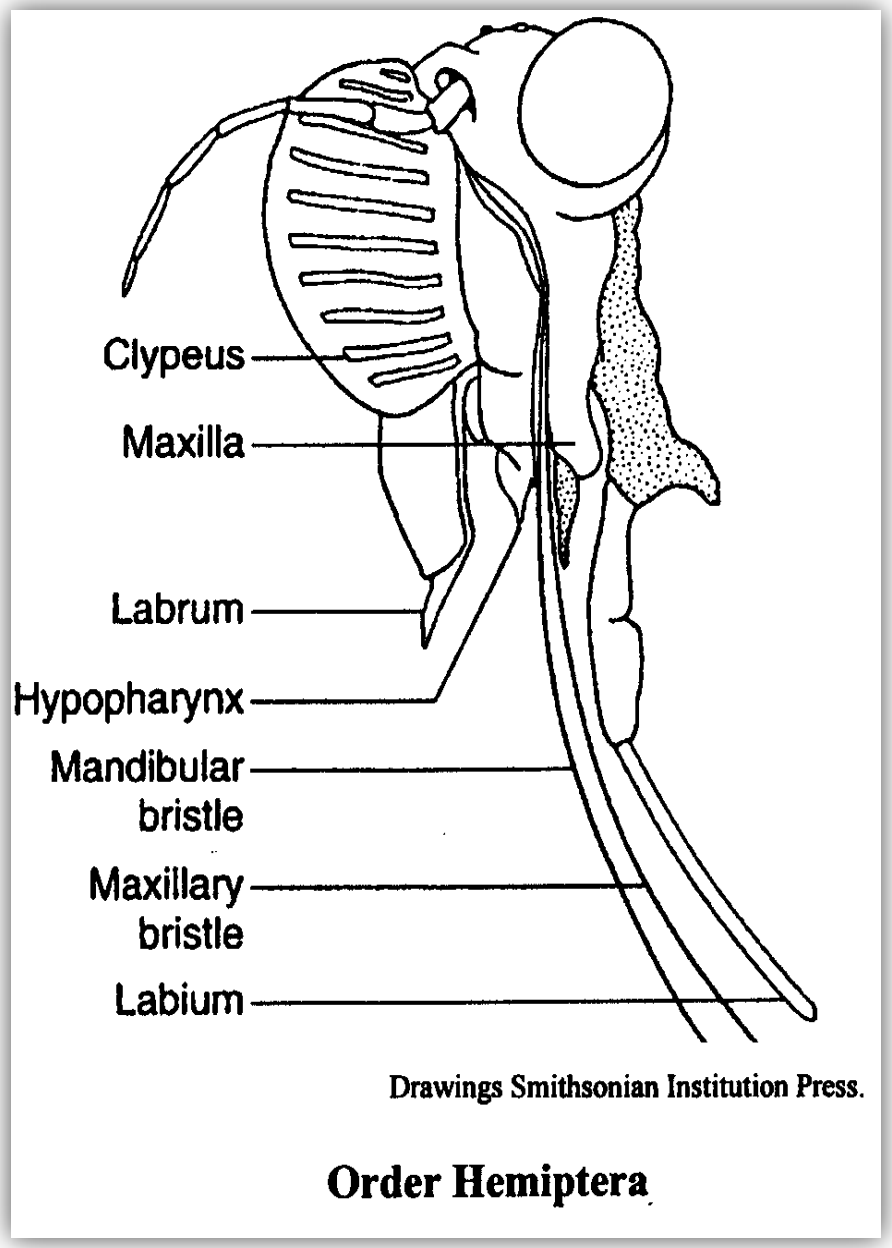


•The **glossae and paraglossae may be fused**, with one or the other considerably reduced, in which case the whole thing is known as the **'ligula'.**

Types of mouthparts

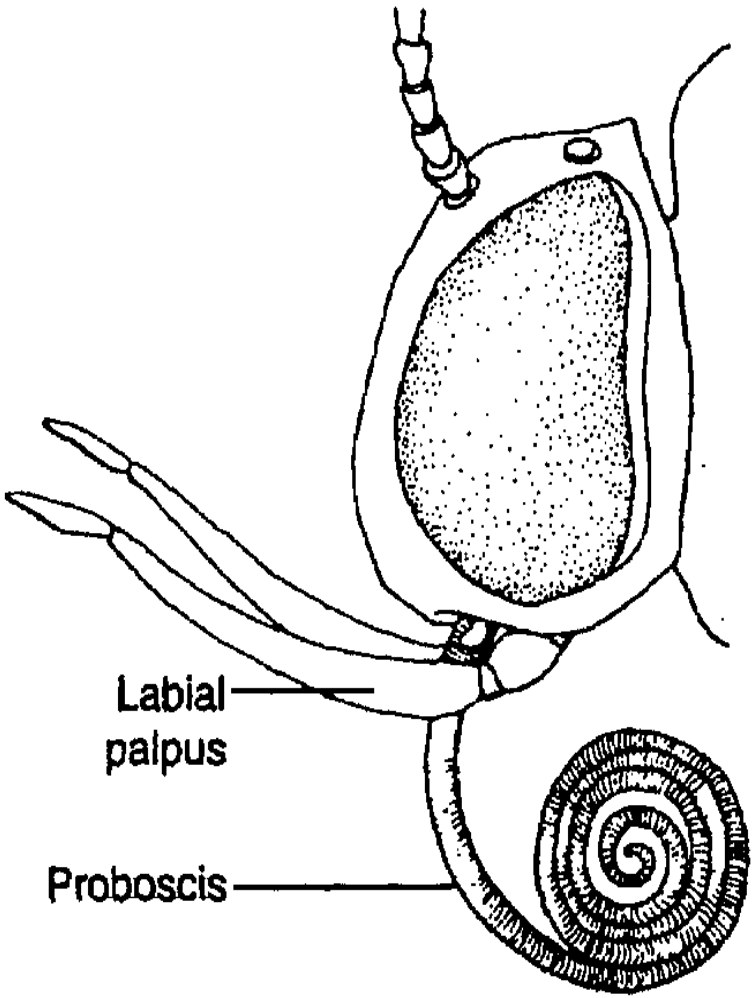
Basically the mouthparts may be divided into two groups: Biting and chewing type (considered as primitive), and Sucking type- these may modified in different ways.

1. Chewing and biting type: E.g. **Grasshoppers, cockroach**
2. Piercing and sucking type: E.g. **Plant bugs, mosquito**
3. **Rasping and sucking** or : E.g. **Thrips.**
4. Sponging or lapping and sucking type: E.g. **House fly**
5. Chewing and lapping type mouthparts: E.g. **Honey bees**
6. Siphoning type: E.g. **Butterflies and moths.**
7. Mask type: E.g. **Naiad of dragonfly.**
8. Degenerate type: E.g. **Dipteran maggots**



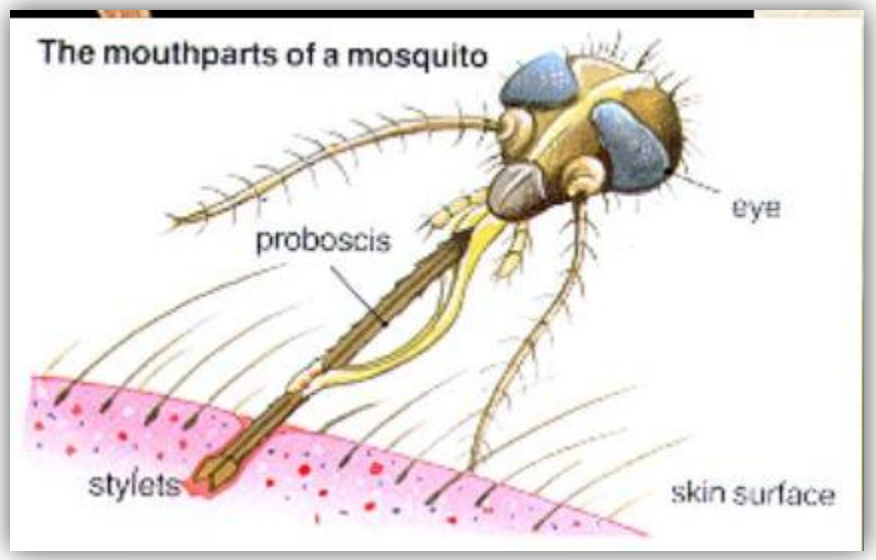
Drawings Smithsonian Institution Press.

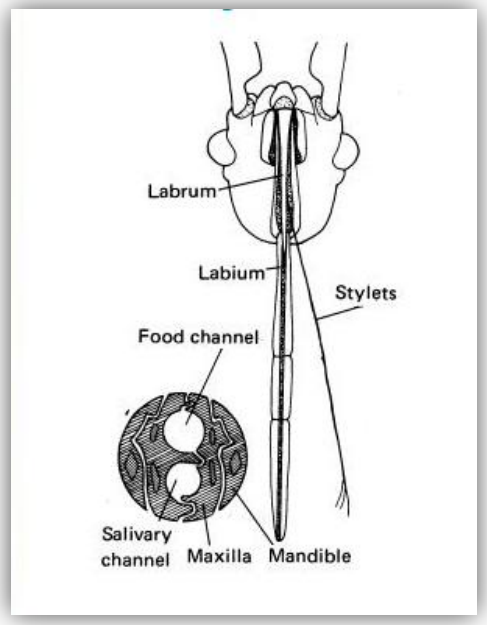
Order Hemiptera



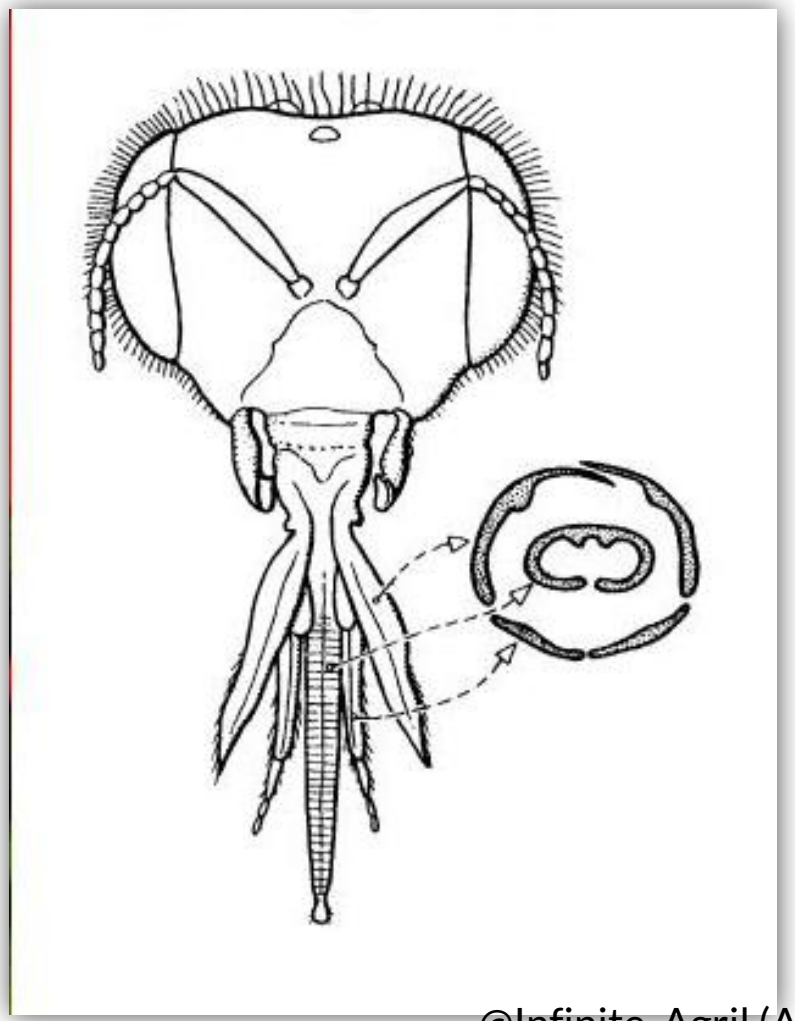
Moth (Order Lepidoptera)

Piercing and sucking Mouthparts



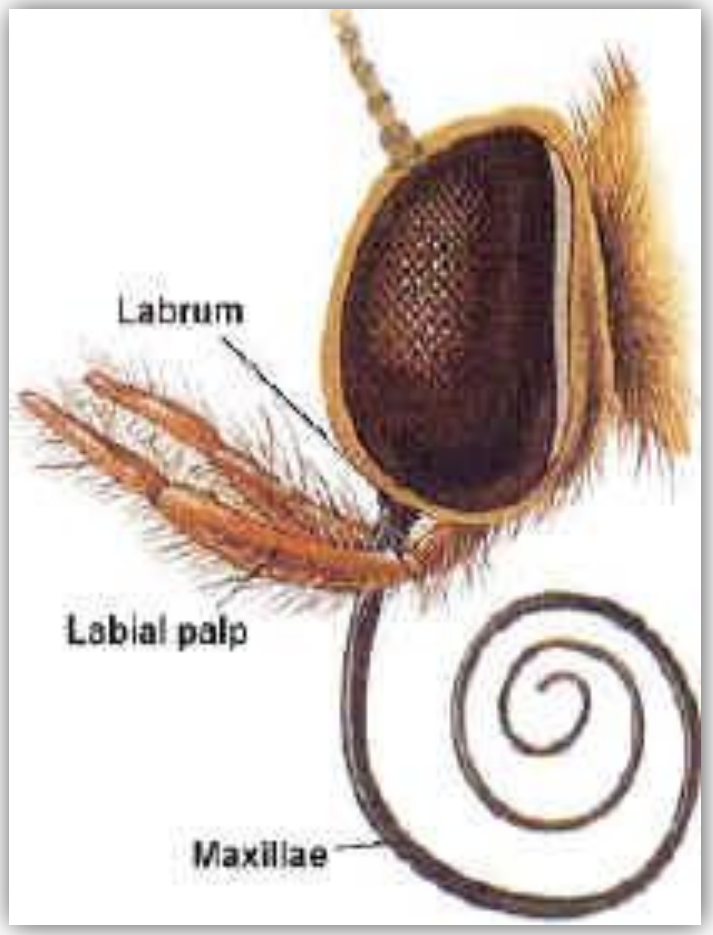


Lapping Mouthparts



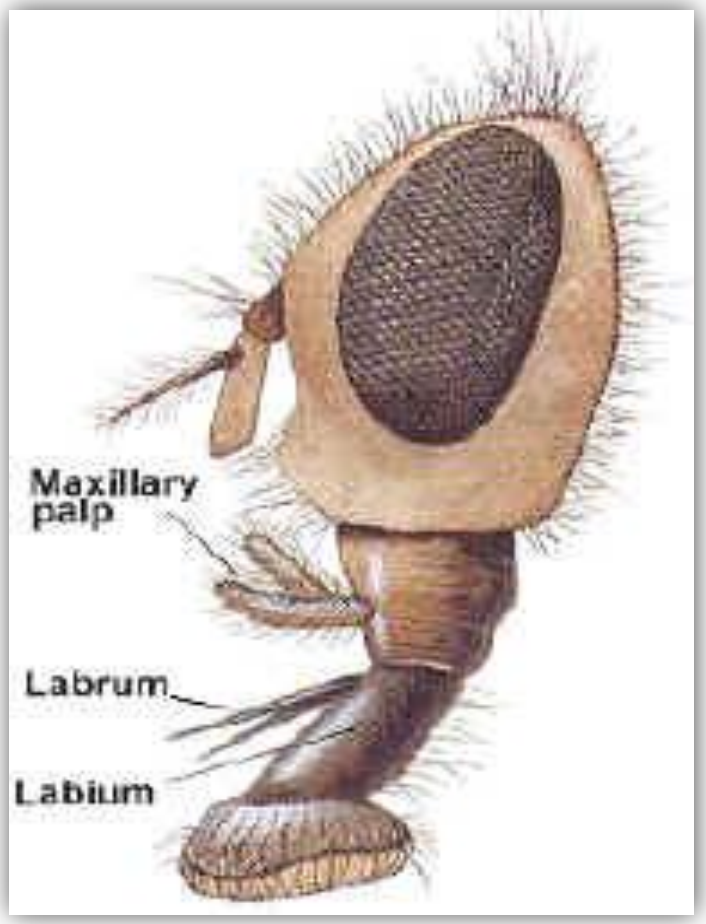
Modifications of Mouthparts

Siphoning



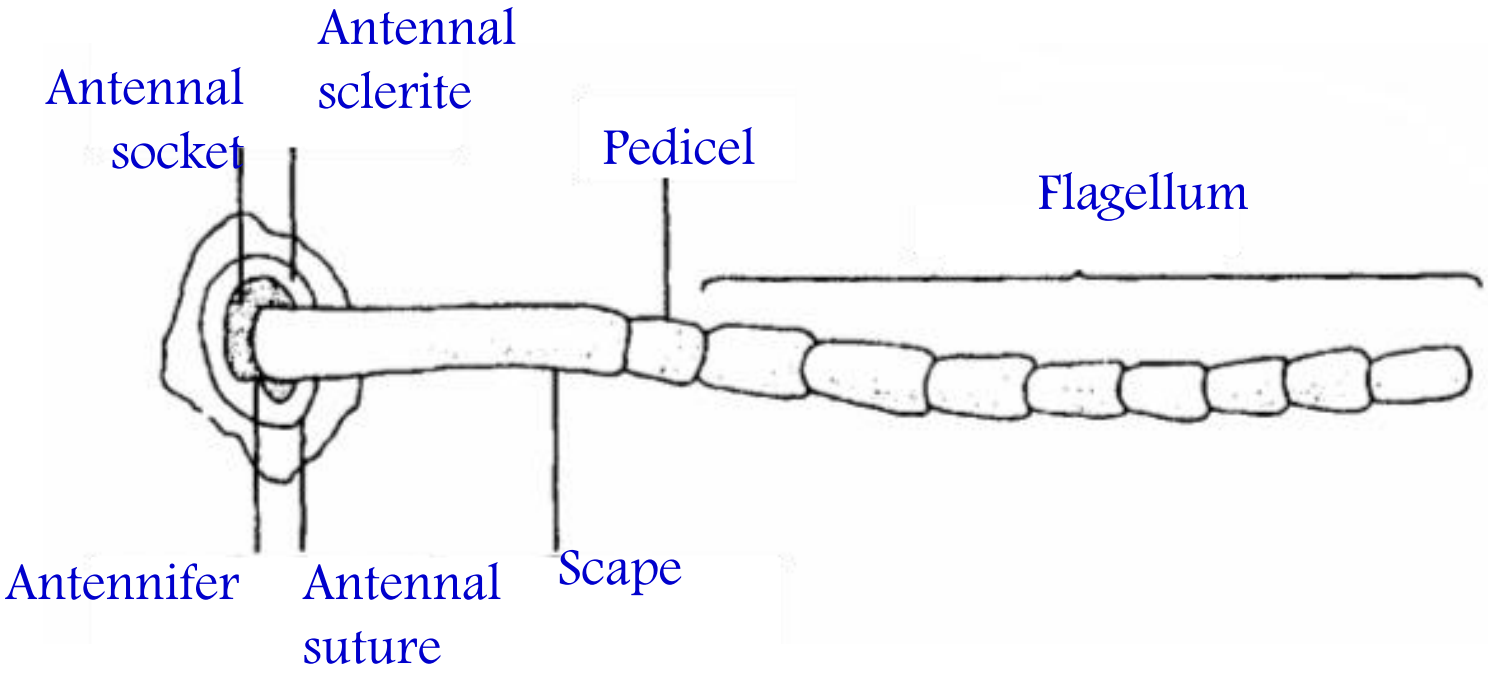
e.g. butterfly

Sponging



e.g. housefly

Lecture-8 Insect Antenna



The rim of the antennal socket associated with the cranium characteristically contains an **articular point,** the '**antennifer'**. It is set in a grove called **antennal socket.**

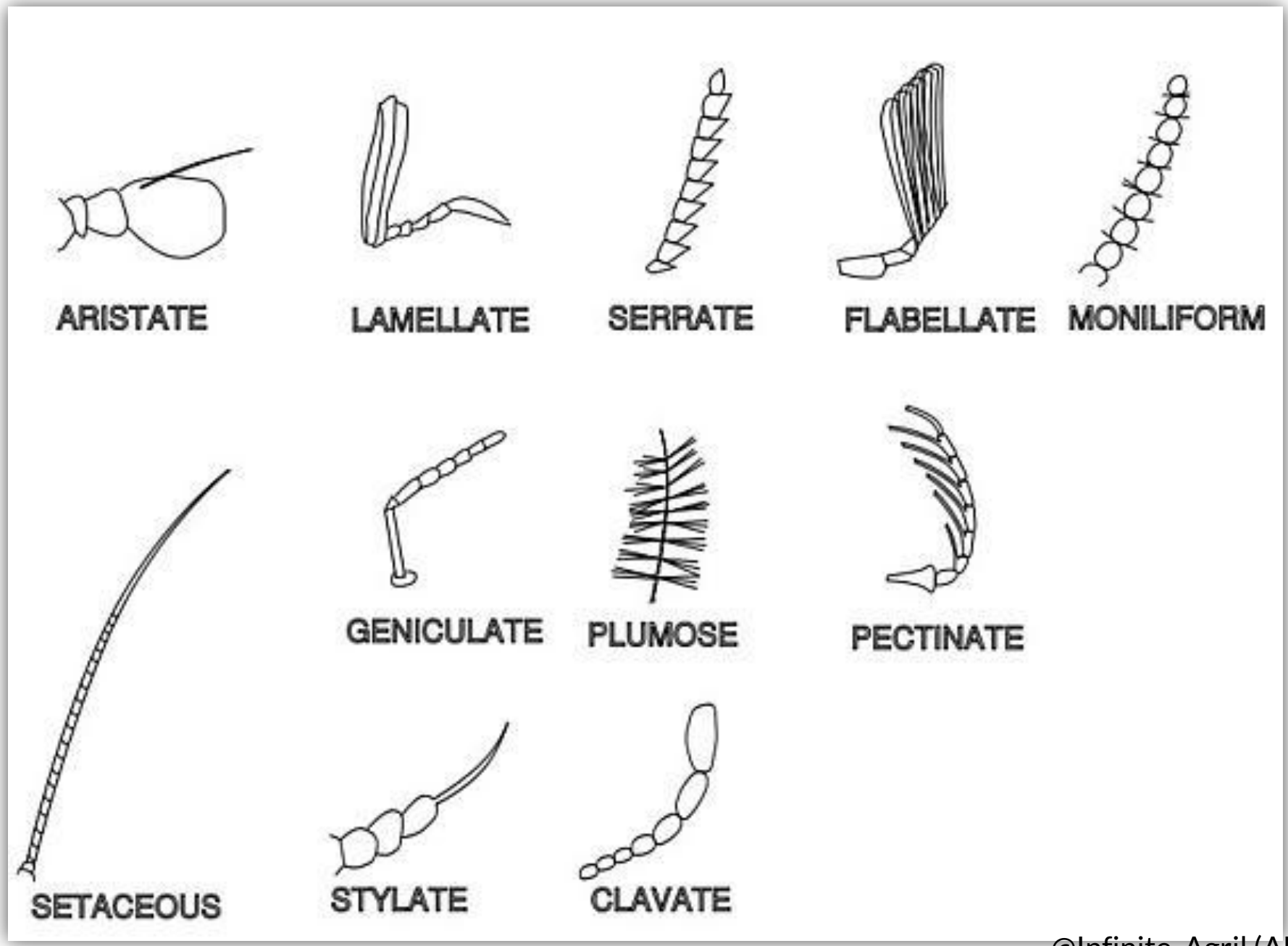
Sclerite at the base of antennae and present around the scape is known as **Antennal sclerites.**

The marginal depressed ring around the antennal socket is known as **antennal suture.**

TYPES OF ANTENNAE:

Antennae are of many shapes. Various types can be noticed in insects.

1. **Filiform (thread like):** E.g. Grasshopper
2. **Setaceous (Whip like or bristle like)**: E.g. Cockroach, dragonfly
3. **Moniliform (like string of beads):** E.g. Termites
4. **Pectinate (comb like):** E.g. Female arctiid moth.
5. **Bipectinate (double comb like)**: E.g. Mulberry silk moth.
6. **Serrate (saw like)**: E.g. Pulse beetle, Jewel beetle.
7. **Clavate (clubbed):** E.g. Butterflies.
8. **Clavate with hook (clubbed antennae with hook):** E.g. Skipper butterflies.
9. **Capitate (clubbed with knob):** E.g. Red flour beetle, Blister beetles.
10. **Geniculate (elbowed):** E.g. Ants, honeybees.
11. **Lamellate:** E.g. Rhinoceros beetle, Dung rollers, Chaffer beetle.
12. **Flabellate (Plate like):** E.g. Stylopids.
13. **Plumose (brush like with dense hairs):** E.g. Male mosquito.
14. **Pilose (brush like with sparse hairs):** E.g. Female mosquito.
15. **Aristate (antennae with arista):** E.g. Housefly.
16. **Stylate (antennae with style):** E.g. Robberfly.



COMPOUND EYES

- Compound eyes individual facets or lenses called **ommatidia** which can visualize colours**.** Coumpound eyes are **absent in majority of larvae** of insects that undergo complete metamorphosis and also **in primitive wingless insects.**

SIMPLE EYES

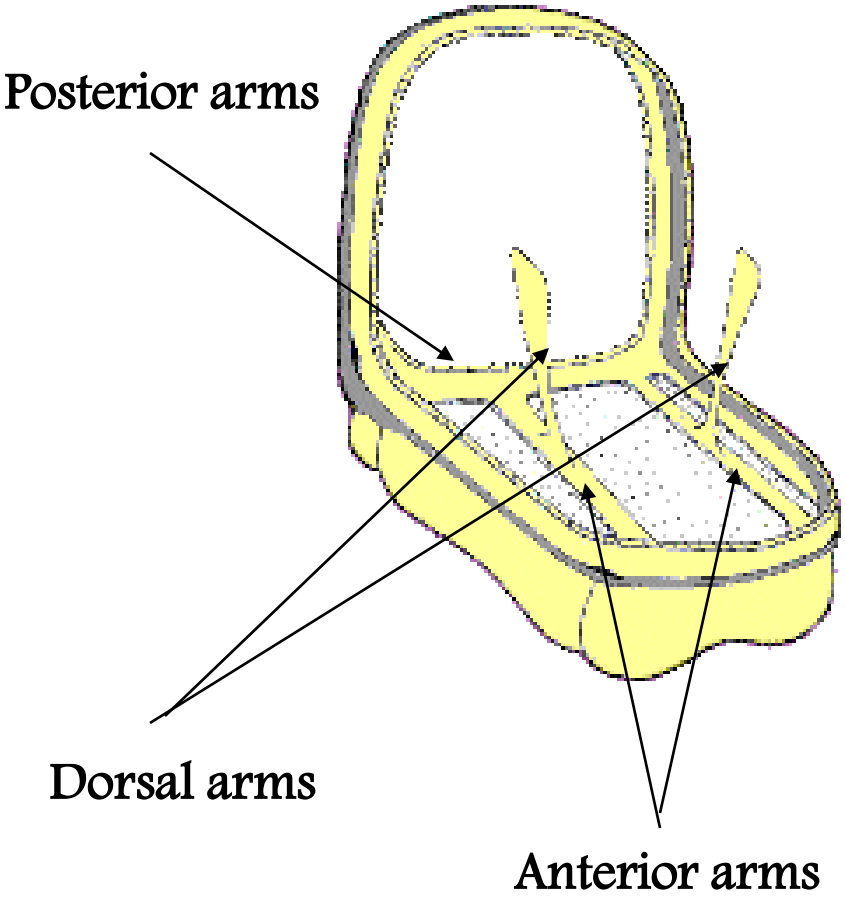
The **dorsal ocelli, or simple eyes**, are commonly three in number.
Two different forms of ocelli have been described for insects, **Dorsal ocelli and Lateral ocelli**.
Dorsal ocelli occur mostly in adult insects and are situated on the front of the insects face in the area of the 'frons' and or the 'epicranium'.

Lateral ocelli generally occur on the sides of the insect head and are the form of eye most common in **larval forms**.

Cockroach-**Fenestrae**-Reduced ocelli

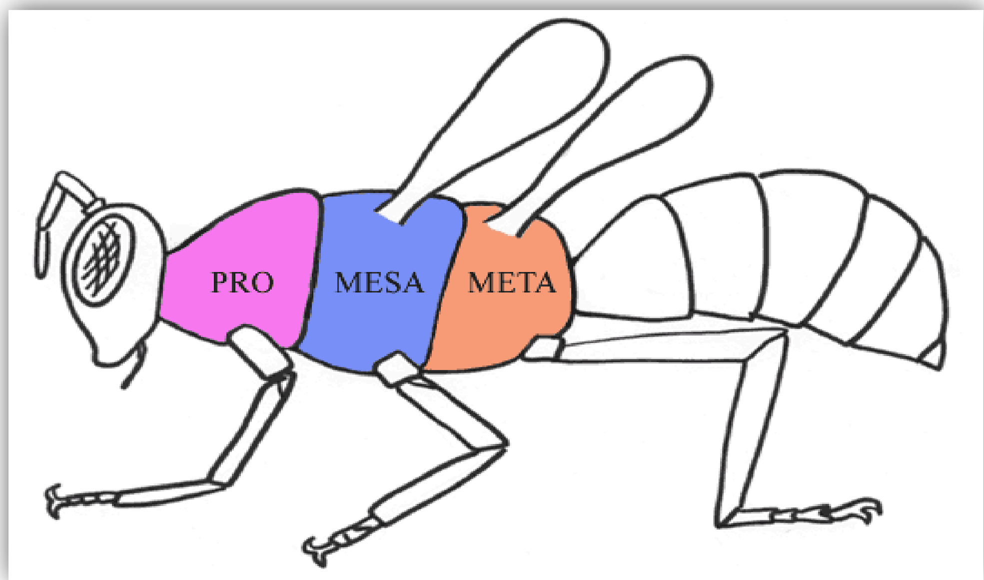
Tentorium:

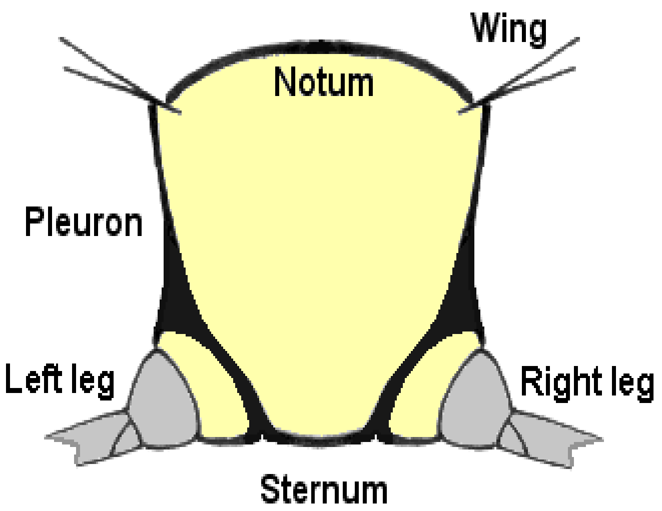
- At each of four points on the cranium the cuticle forms an arm like inflection. Internally these inflections join, **forming a framework.** This **internal framework**, the '**tentorium'** affords many points for muscle attachment.
- It contributes appreciably to the **rigidity of the head capsule**, and provides support for the brain and the part of the foregut that passes through the head.



Lecture-9 Insect Thorax

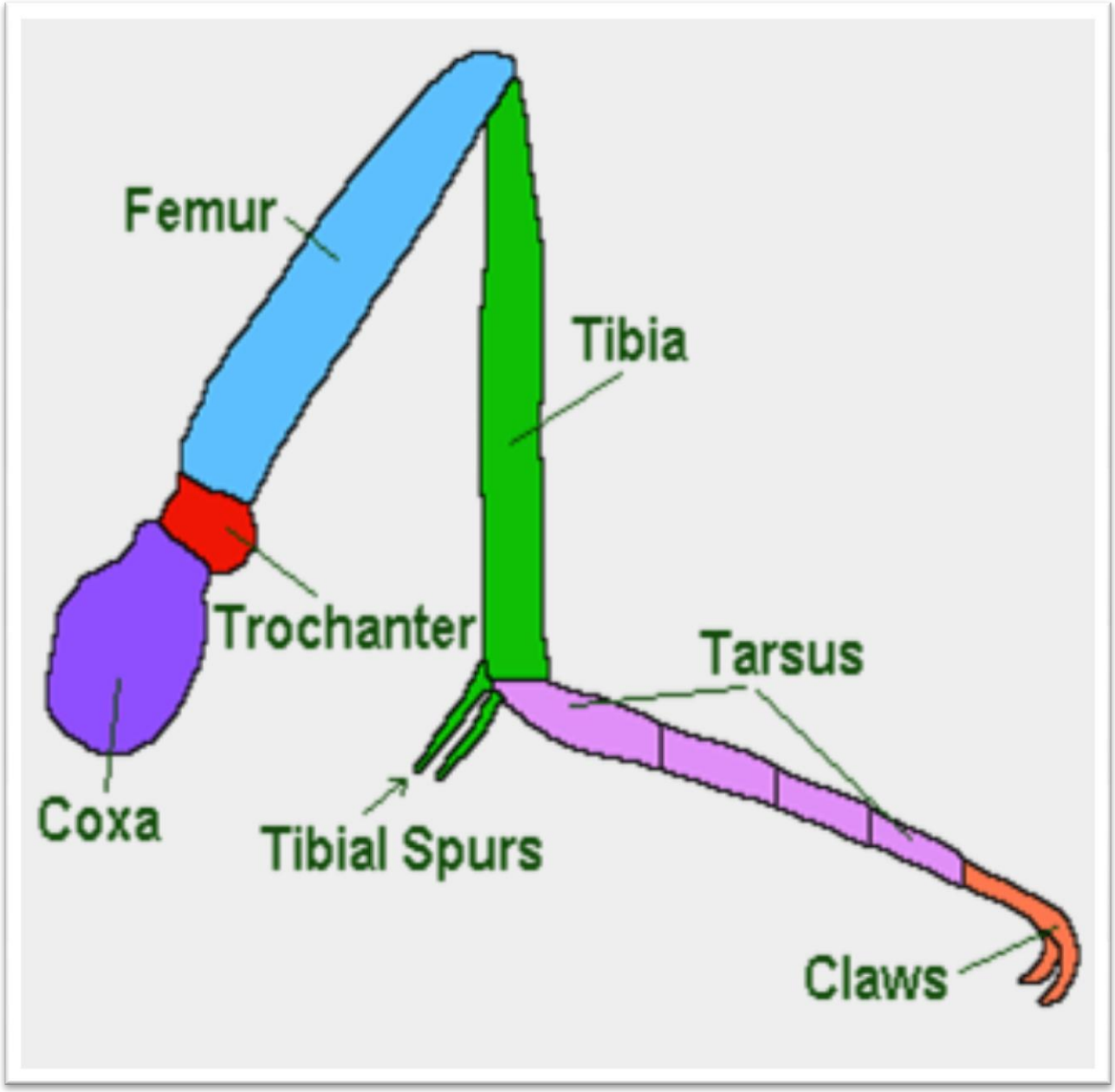
- Structurally, the thorax is composed of three body segments: prothorax, mesothorax, and metathorax.
- Each segment has a dorsal sclerite, the **tergum**. The ventral sclerite of each segment is the **sternum**. The side of each segment is called the **pleuron** .





Each of the three thoracic segments contains one pair of legs.

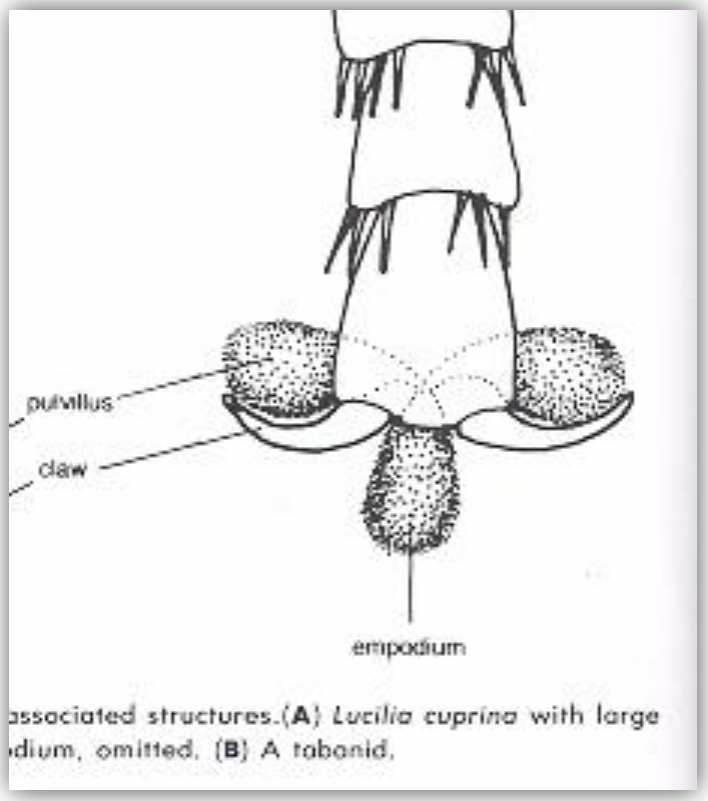
Wings are found only on the meso- and metathoracic segments.



Insect Legs

- Coxa:
- Trochanter:
- Femur:
- Tibia:
- Tarsus:

At the **apex of the tarsus**, a group of small structures called pre-tarsus are present. These are:



associated structures.(A) *Lucilia cuprina* with large odium, omitted. (B) A tabanid.

In simplest form it is prolonged into a single claw- E.g. **Collembola, Protura**.

Ventral side pretarsus expands into a medium lobe or "**Arolium**".

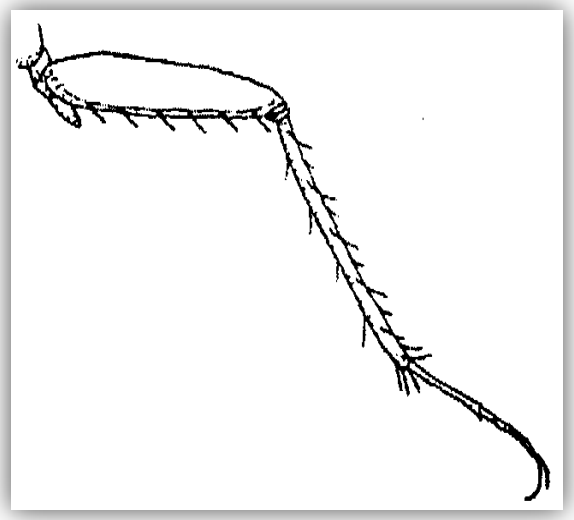
In Diptera, there are two lobes or "**Pulvilli**" lying below the claws often with an Arolium between them. Eg. **Housefly.**

In place of **arolium, pretarsus is some times prolonged into a medium bristle** called "**Empodium**". Eg. **Housefly.**

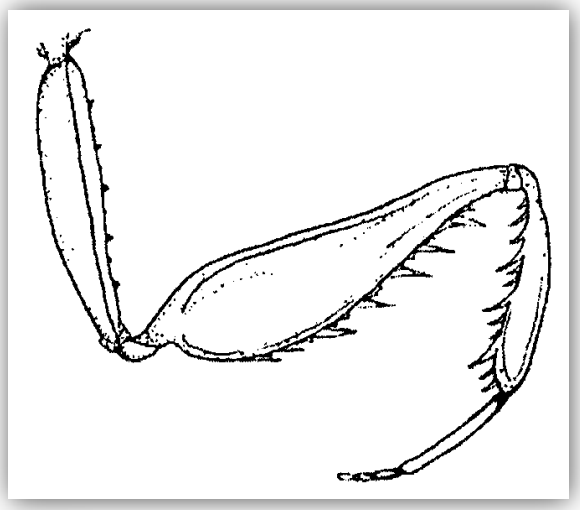
TYPES OF LEGS:

1. **Ambulatory** (ambulare=to walk) : Grasshoppers
2. **Cursorial** (cursor= a runner):Blister beetle, Cockroach
3. **Saltatorial** (saltare= to jump) :Hind legs of Grasshopper
4. **Raptorial type** (raptore= to seize) :Preying mantis
5. **Fossorial** (fossor= to dig) : Mole cricket, Rhinoceros beetle
6. **Scansorial type** (scansum= to climb): Head louse
7. **Natatorial (**natare= to swim) :Water beetles, water bugs
8. **Prehensile or Basket forming legs :** Dragon flies
9. **Antennal cleaning :** First pair legs of honeybee
10. **Wax picking type :** Second pair of legs in honeybee
11. **Pollen collecting type :** Hind legs of honeybee

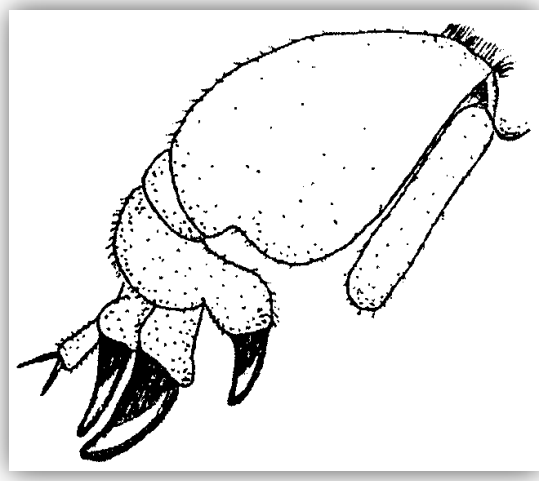
Types of legs



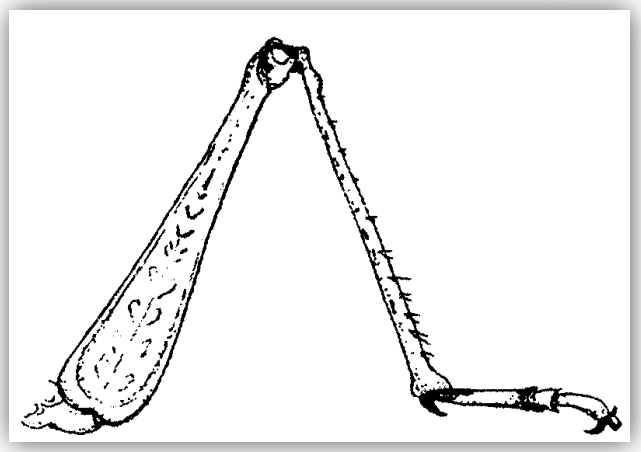
Cursorial



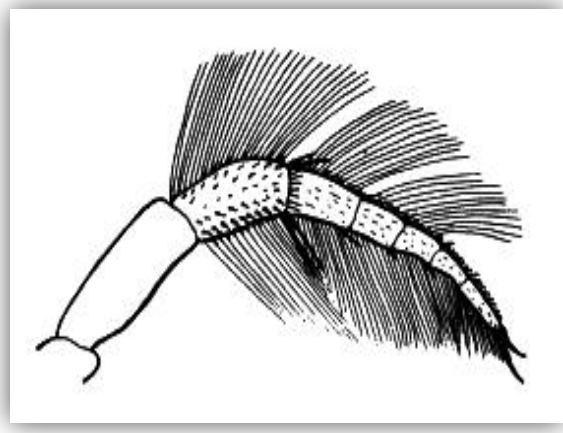
Raptorial



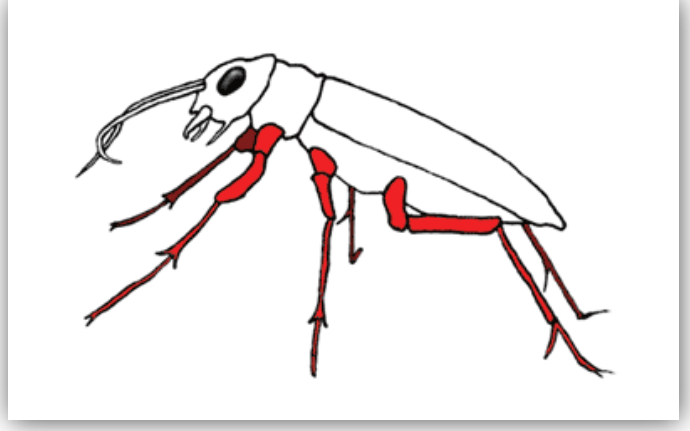
Fossorial

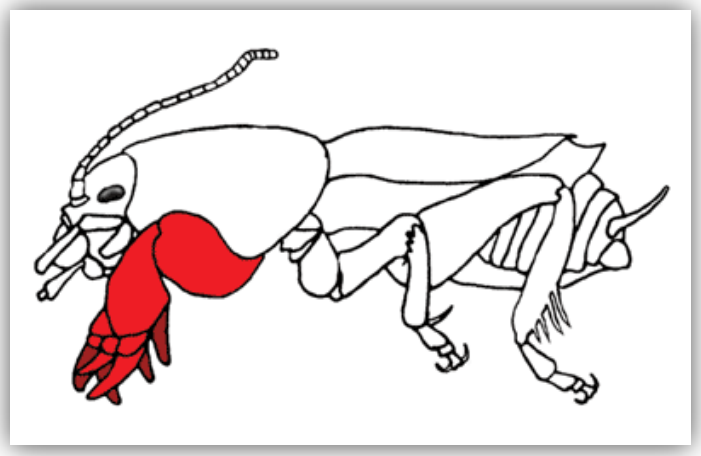


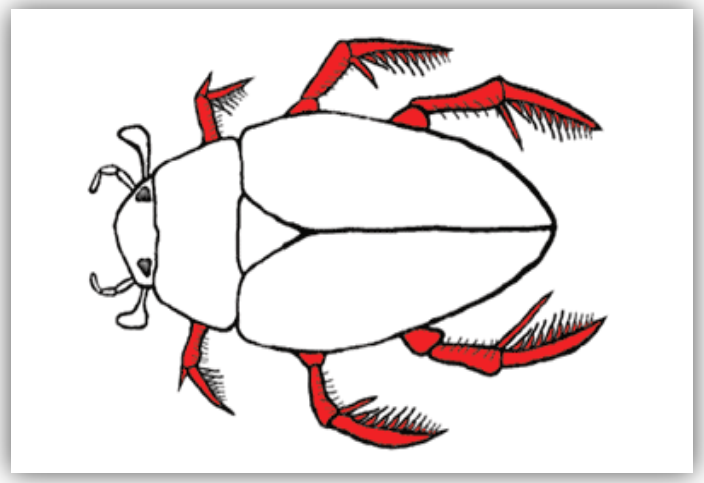
Saltatorial

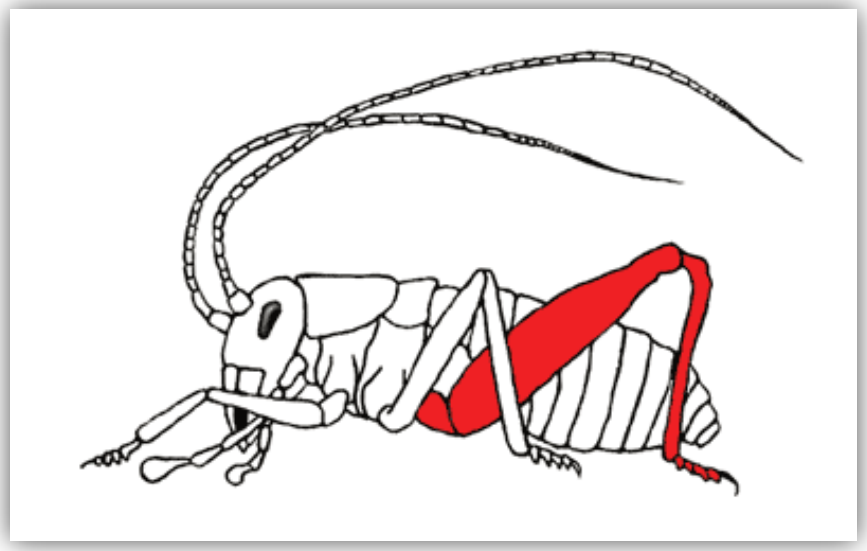


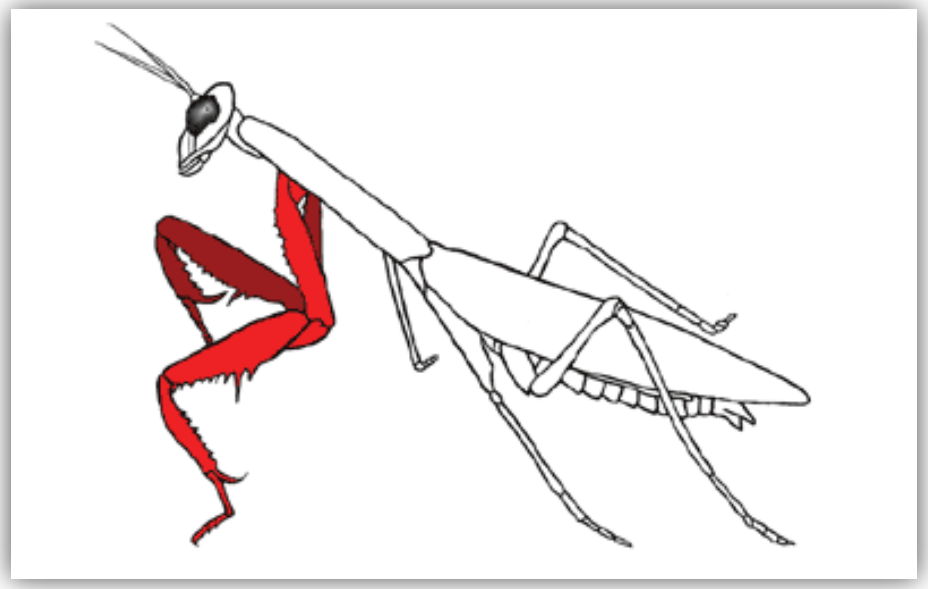
Natatorial











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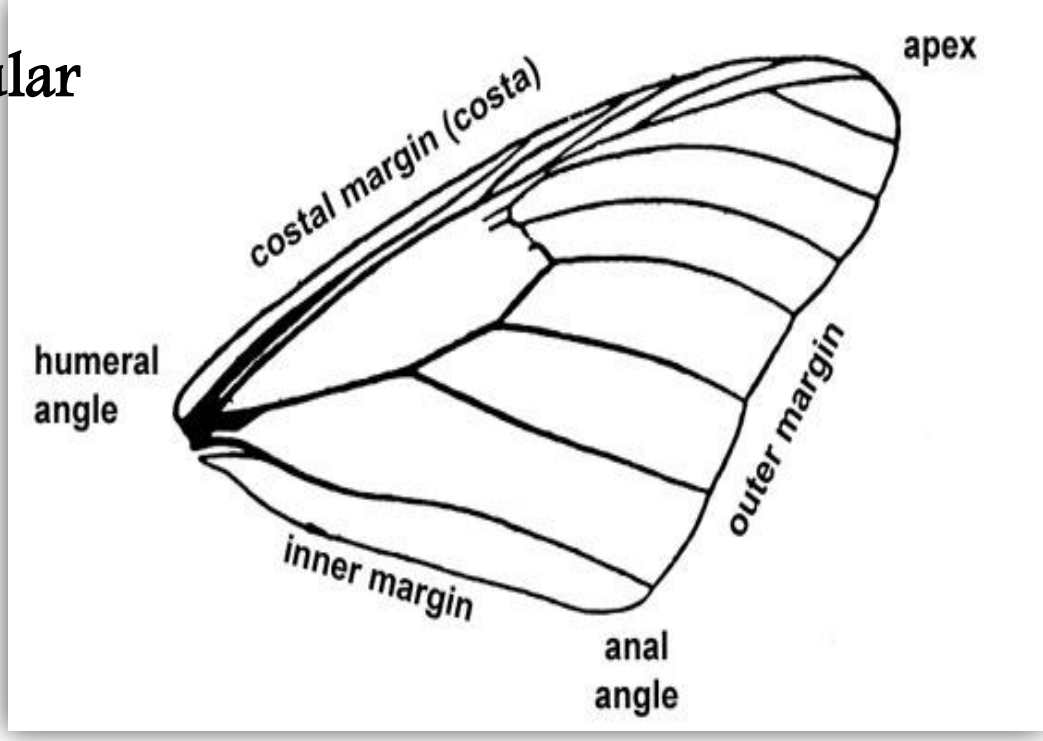
Lec-10 Wing is somewhat triangular in shape

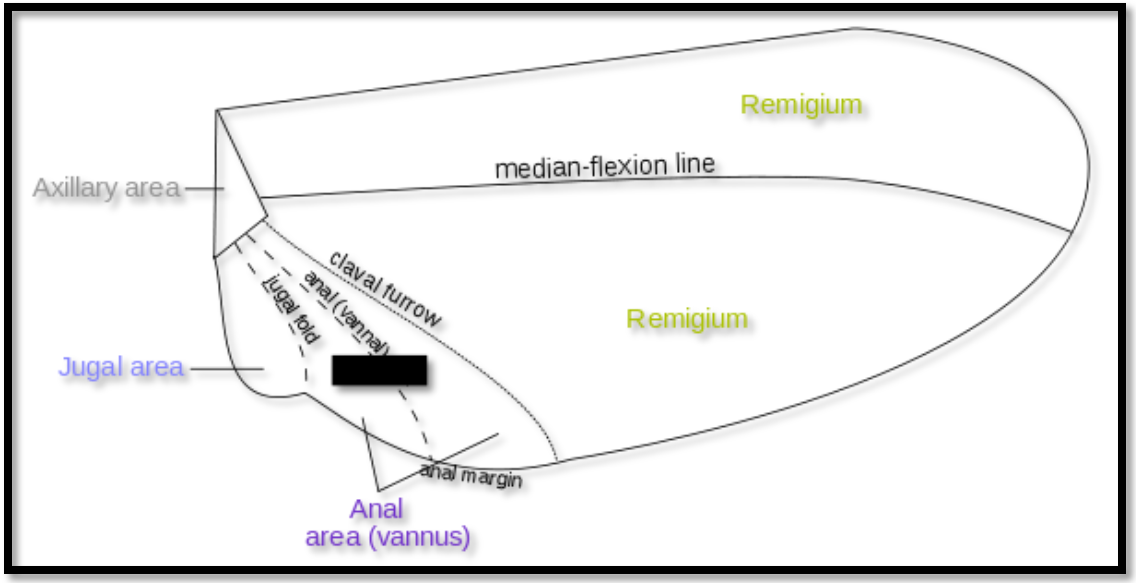


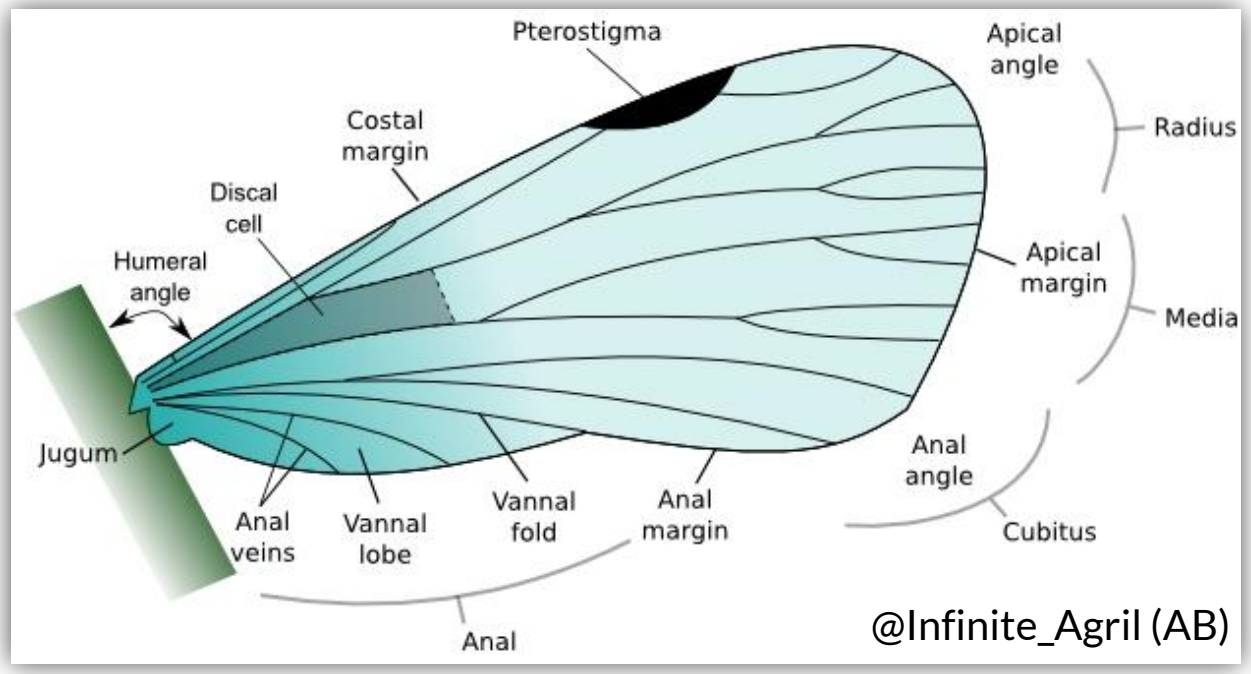
Wing margin :

1. Anterior - costal margin
2. Outer - apical margin.
3. Inner- anal margin.

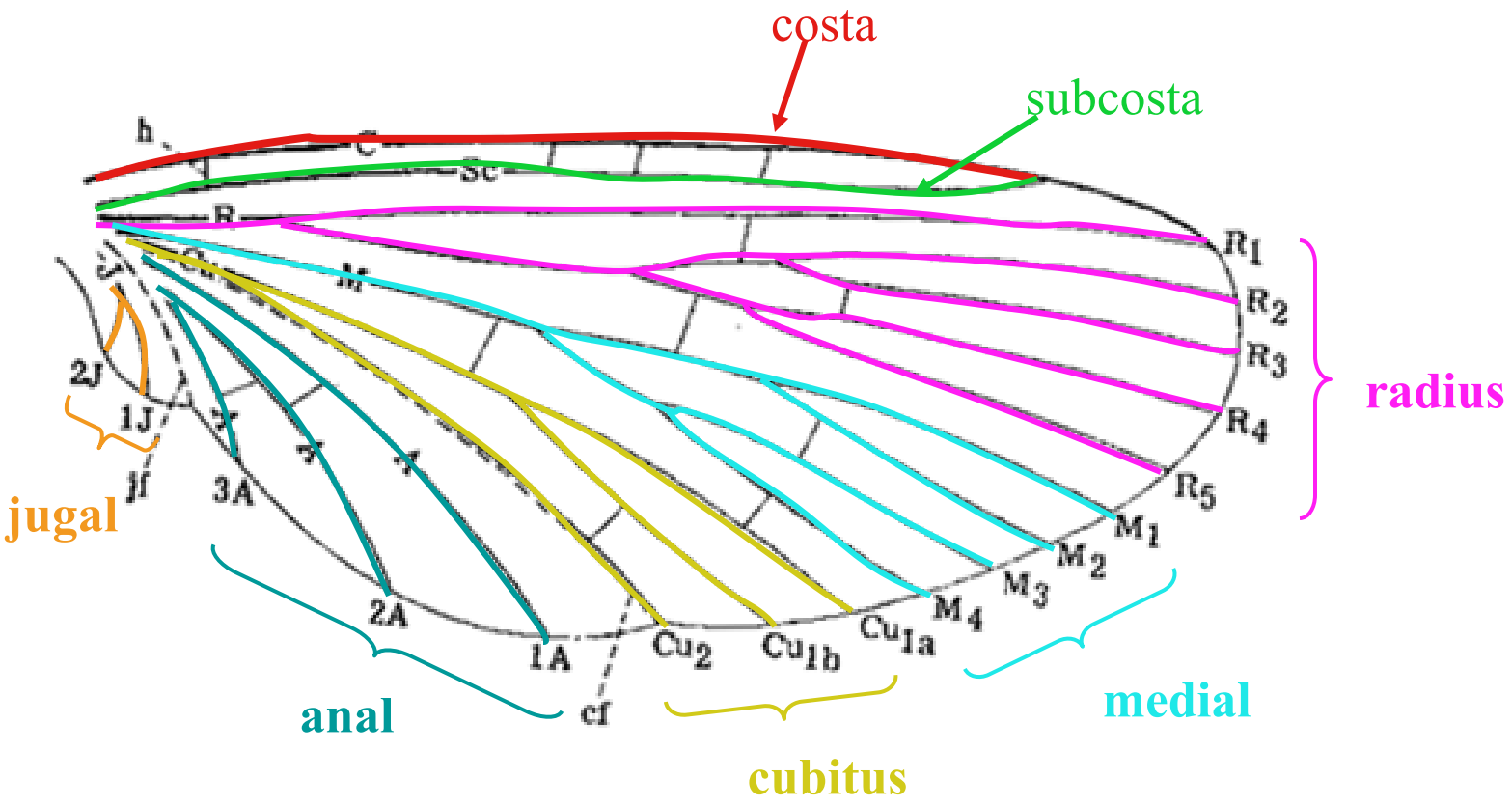
Angles of the wings:

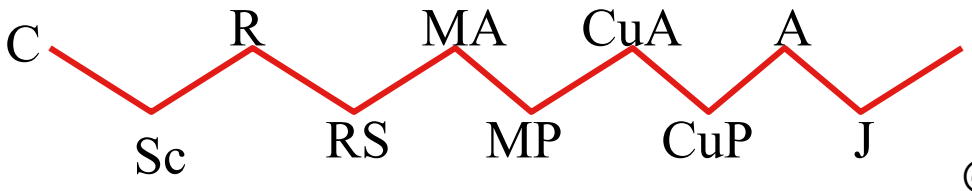
1. Humeral angle: At the base of wing
2. Apical angle: Between costal margin and apical margin.
3. **Anal angle or Tornus** :Between apical margin & anal margin


Remigium
median-flexion line
Axillary area
claval furrow
anal (vannal)
jugal fold
Remigium
Jugal area
anal margin
Anal
area (vannus)

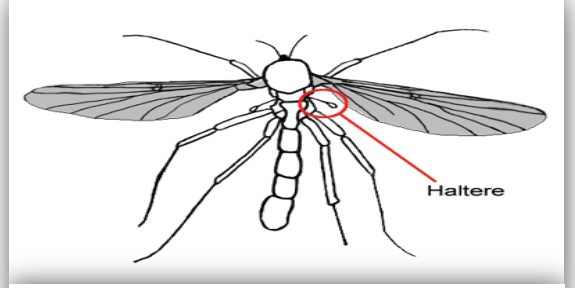

Pterostigma
Apical
angle
Radius
Costal
margin
Discal
cell
Humeral
angle
Apical
margin
Media
Jugum
Anal
angle
Cubitus
Anal
veins
Vannal
lobe
Vannal
fold
Anal
margin
Anal
@Infinite_Agril (AB)

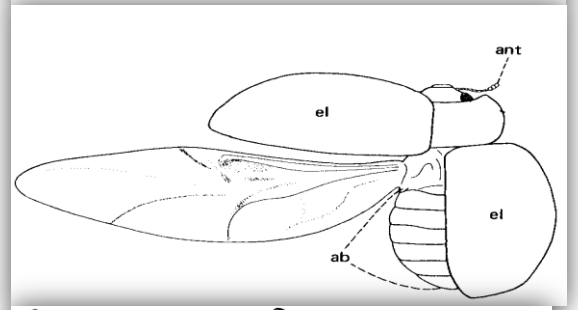
The Insect Wing

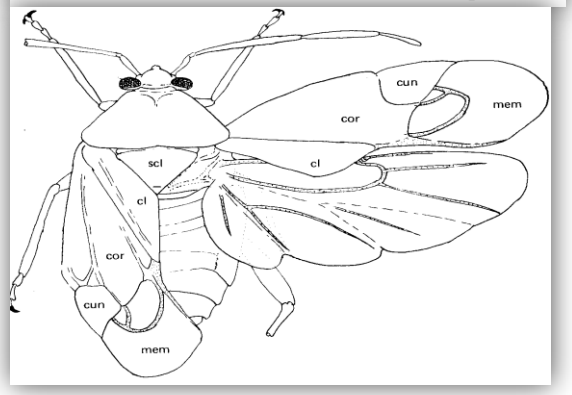




1. **Halteres-Diptera (true flies),** in which the **hind wings are reduced -balance and direction during flight.**
2. **Elytra-**heavily sclerotized **forewings** of beetles (Order Coleoptera)-**protect the hind wings when at rest.**
3. **Hemelytra**. The **forewings** of Hemipterans**hardened throughout the proximal two-thirds** (approximately), while the distal portion is membranous.
4. **Tegmina:** In this type the fore wings are **hard and with leathery consistency**.The forewings protect the hind wings when the Insect is resting. E.g. **Cockroach, Grasshopper .**







4. Fissured or Clefted wings: fork-like structure.
E.g. **both the wings of plume moth.**

5. Fringed wings: **reduced venation.** The wings are fringed with long **marginal hairs**, giving a **feather-like appearance**. E.g. **both the wings of thrips**.

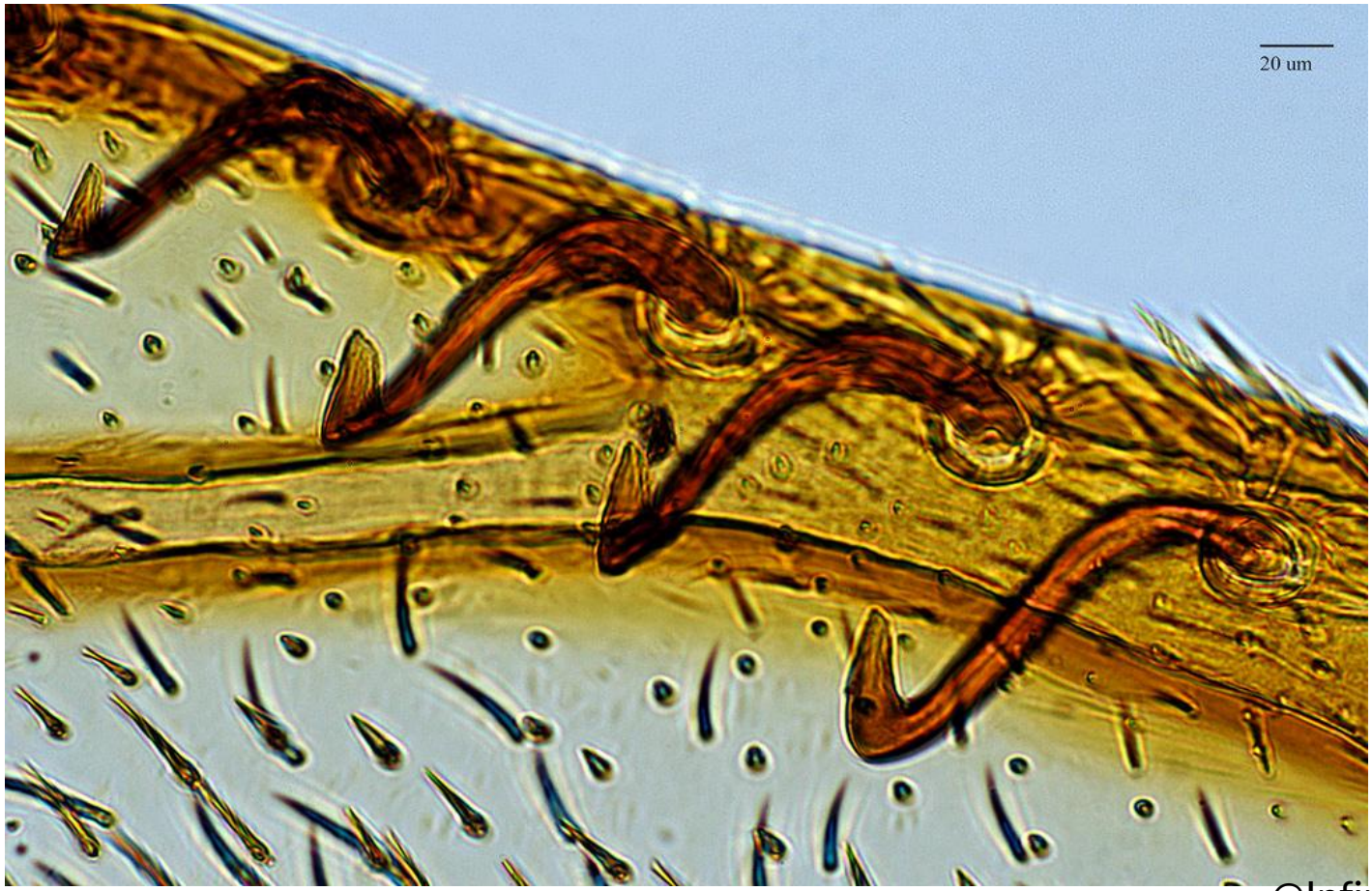
6.Membranous wings: highly developed venation. E.g. Both the wings of **Dragonflies, wasps and bees. Hind wings of grasshopper, cockroach and beetles.**

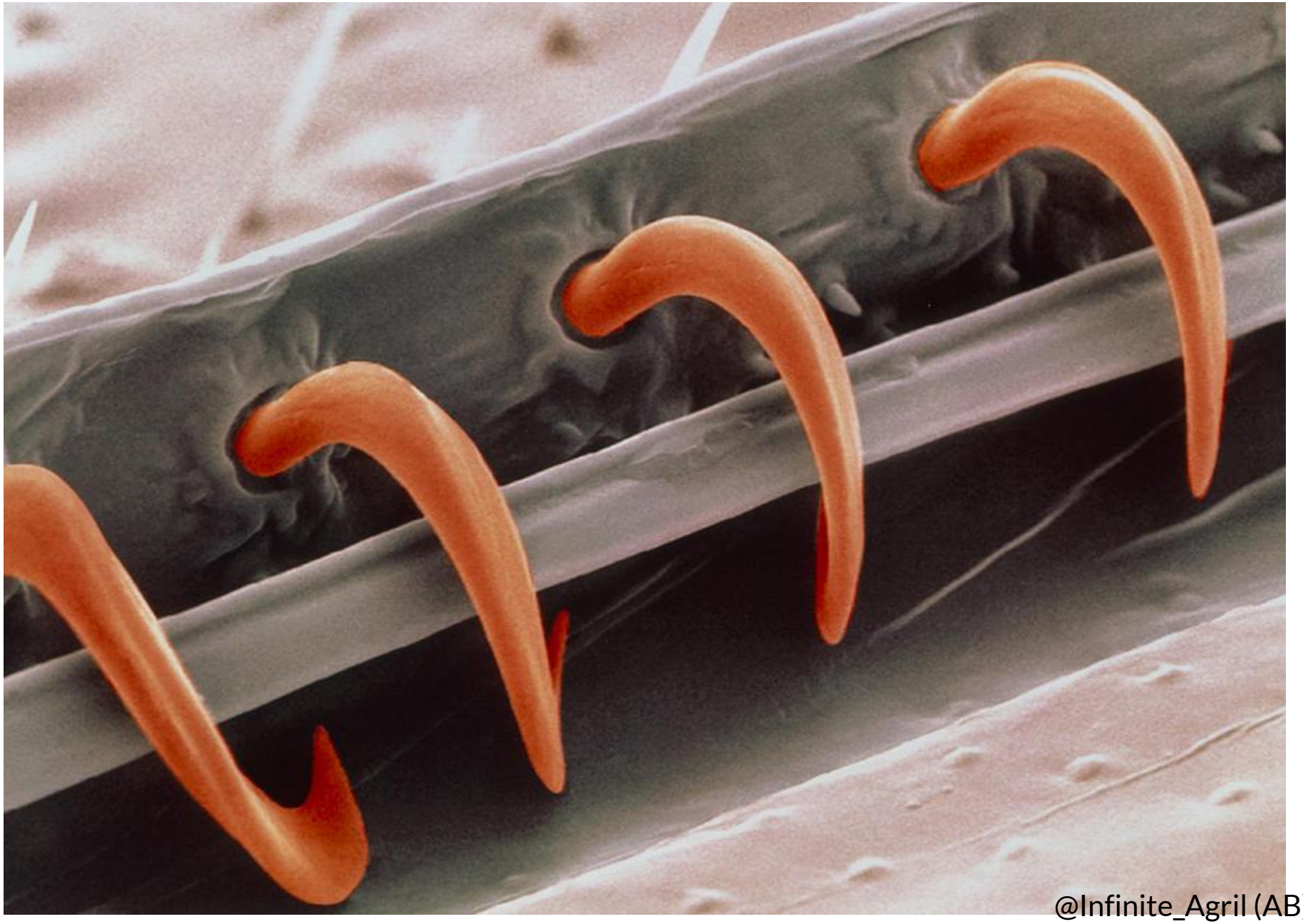
7.Scaly wings: unicellular scales all over the surface,
E.g. both the wings of **butterflies & moth.**

WING COUPLING APPARATUS:

No wing coupling

Hamuli type: E.g. **Wasps and Bees. Costal margin of hind wings** posses a row of hooks called Hamuli. Which engage the folded posterior edge of fore wing.

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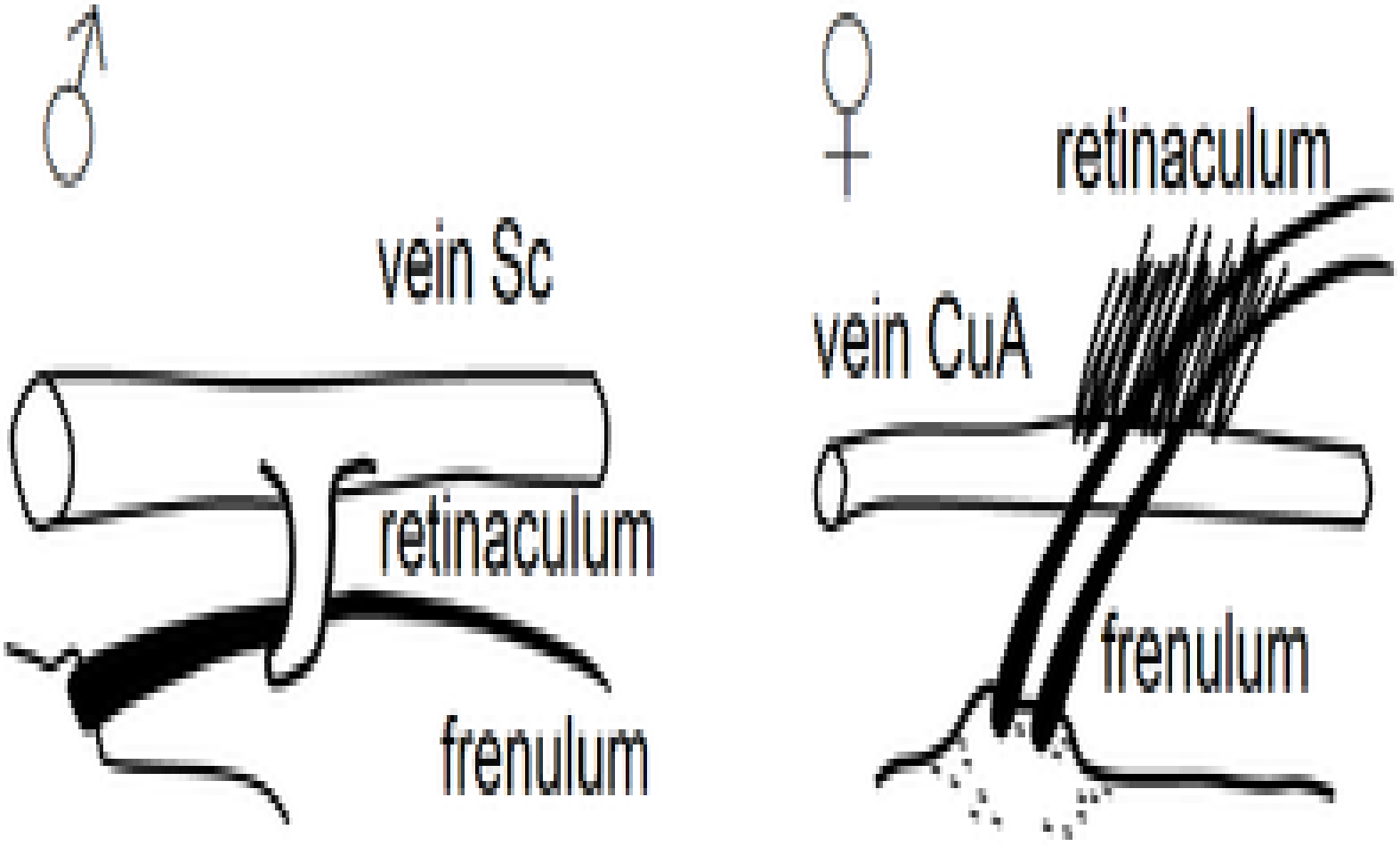
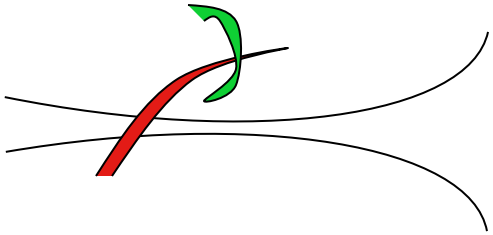
Prenulum or Frenulum and Retinaculum type:

Eg. **citrus fruit sucking moth**

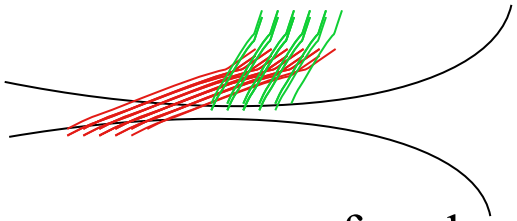


Wing Coupling

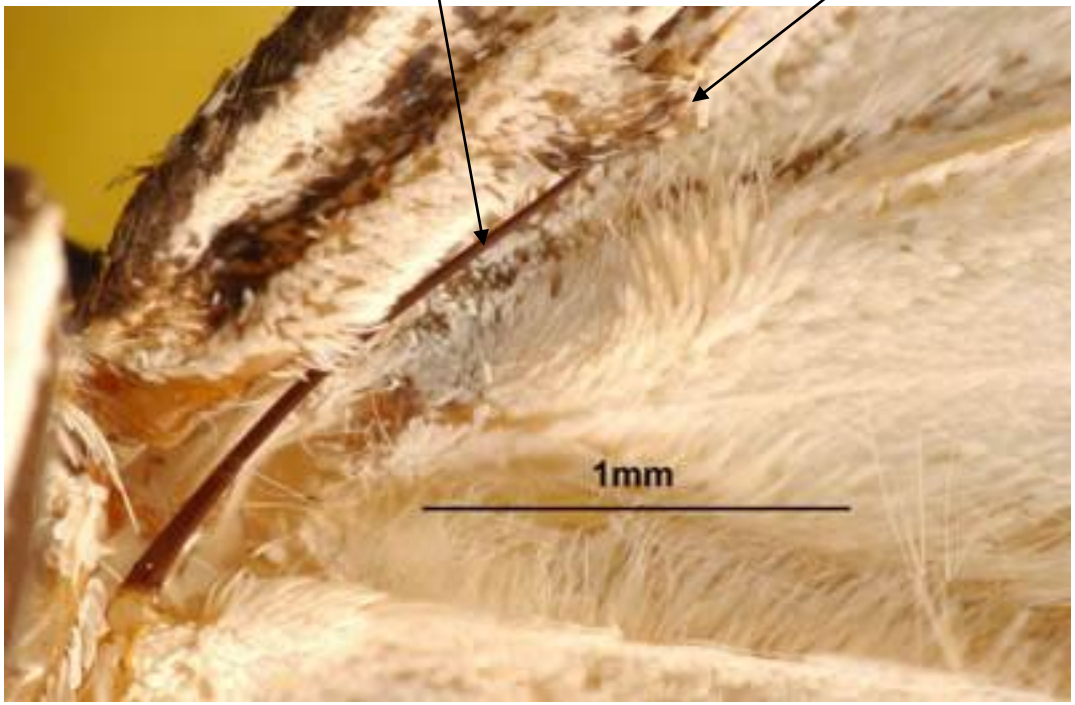
Frenate (Lepidoptera)



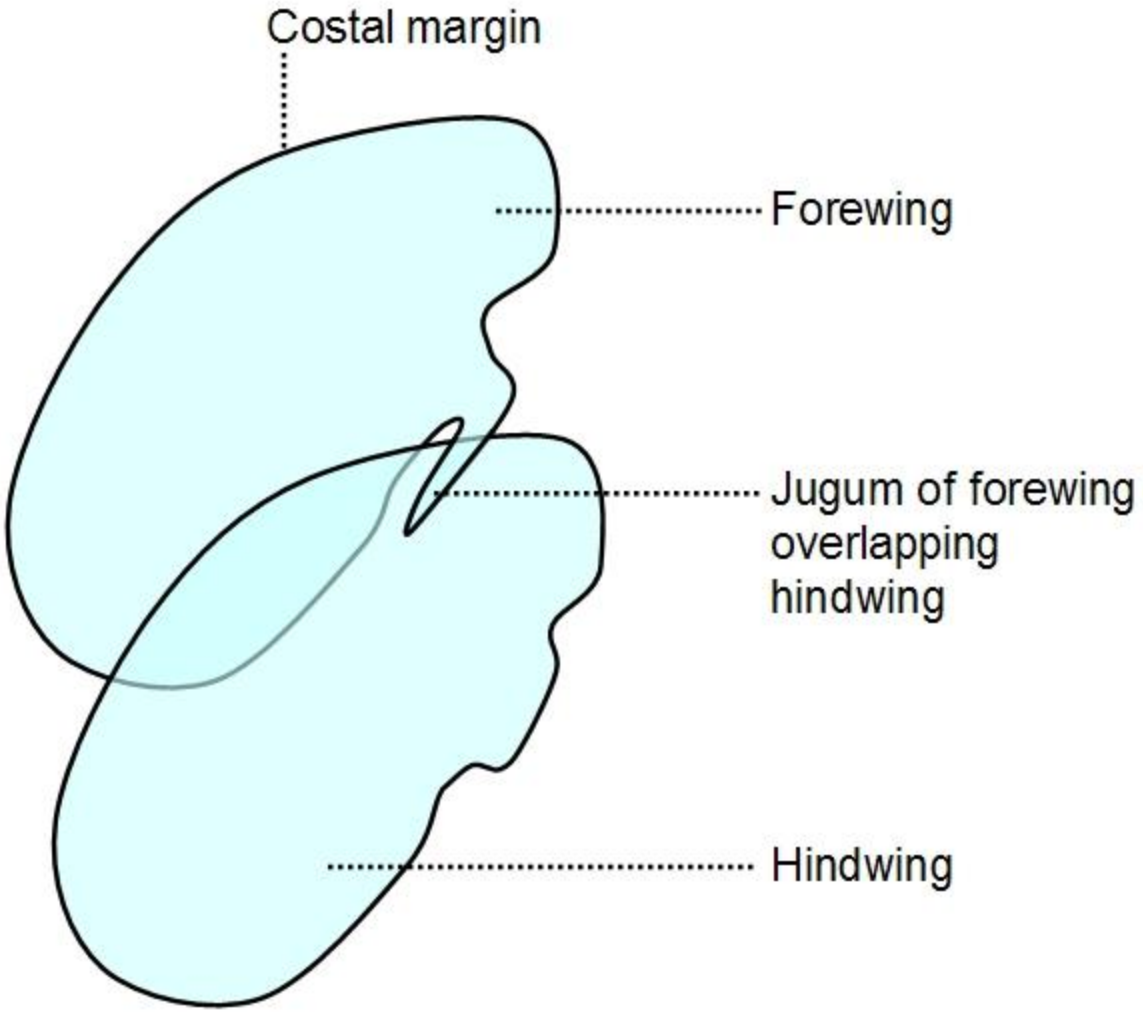
male



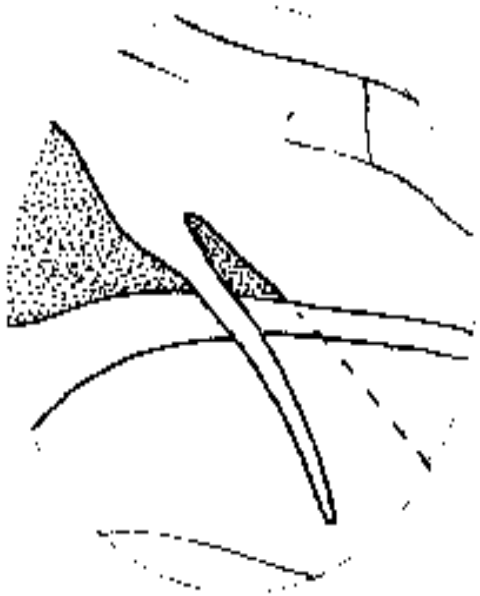
female



Wing Coupling- **Primitive Lepidopterous Insects.** Hepialid moths and Strepsiptera



Jugal coupling



1.JUGATE TYPE

- Costal margin of front wing possess a small lobe at its base called fibula, which rest on the surface of the hind wings.

Amplexiform type: E.g. **Butterflies. over lapping both the wings** are kept together.


Thank you
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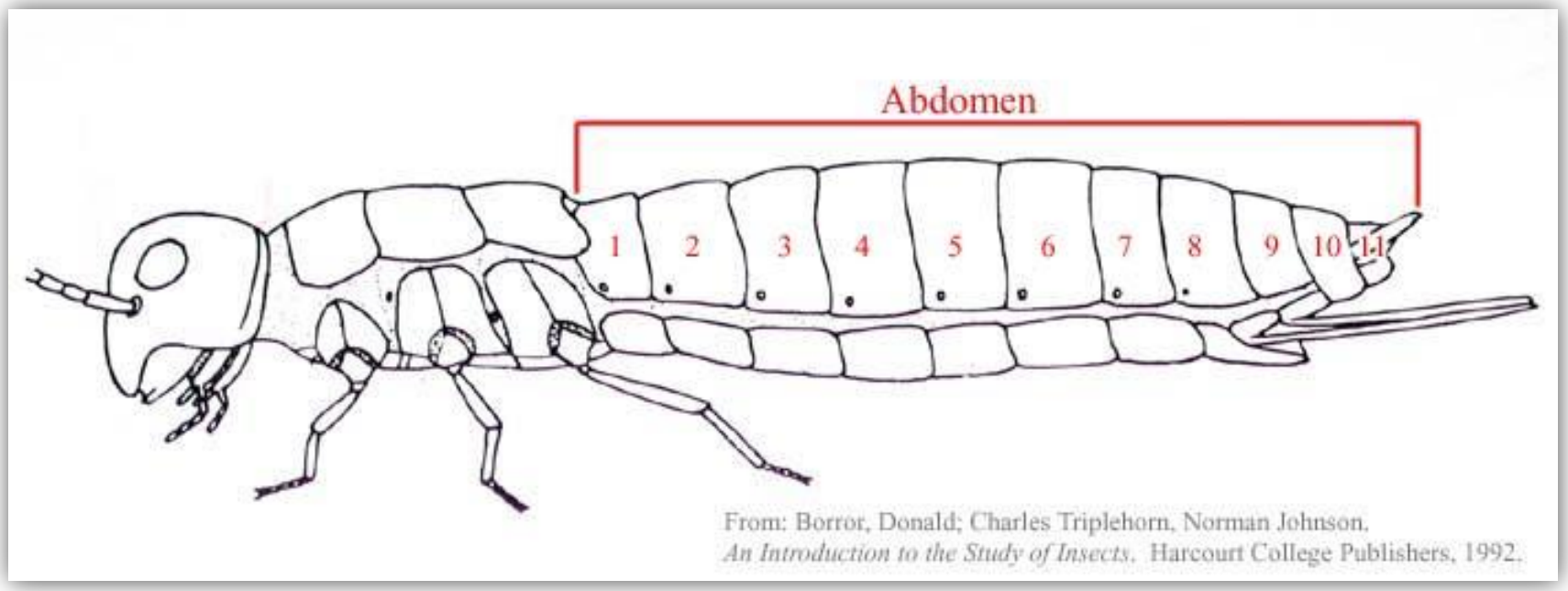
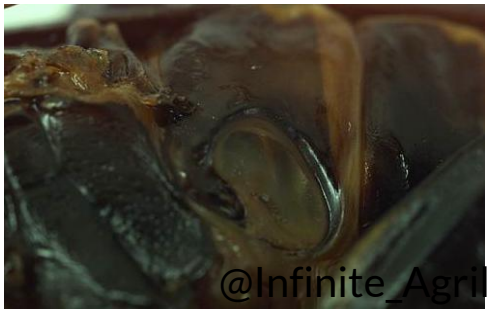
Lecture-10 Abdomen



- In a typical insect, abdomen consists of eleven segments.
- However, in **Collembola** it is **six segmented.**
- Abdominal segments are divided into three categories.
  - Segments 1 – 7 are **pre-genital segments**
  - Segments 8 – 9 are **genital** segments
  - Segments 10 – 11 are **post-genital** segments

- **Anal cerci** are the post- genital appendages attached **to 11th segment.**
- **Pseudo-ovipositor-**In **Diptera** the terminal segments of the abdomen are **telescoped into one another** and the segments come out at the time of oviposition, hence called **pseudo-ovipositor.**
- **Cornicles :** In Homoptera (aphids) a pair of tubes called **"cornicles" is present on the 5th or 6th abdominal terga.**
- **Tympanum-**In grasshopper : **1st abdominal segment is fused with metathoracic segment** and it bears **Tympanum** (auditory organ).



- **Pincers** -- In **Dermaptera (earwigs),** the cerci are heavily sclerotized and forceps-like.

- **Median caudal filament** -- a thread-like projection arising from the center of the last abdominal segment (between the cerci). (e.g. **Diplura, Thysanura, and Ephemeroptera**).
- **Abdominal prolegs** - locomotory appendages found only in the larvae of certain orders (notably **Lepidoptera, Mecoptera and some Hymenoptera**).
- **Sting** - a modified ovipositor, **females of aculeate Hymenoptera** (ants, bees, and predatory wasps).
- **Ovipositor**-Cricket-needle like
- **Abdominal gills** -- respiratory organs found **(naiads)** In **Ephemeroptera** (mayflies), **Odonata** (damselflies)
- **Furcula**
- **Collophore**.

Termites and certain insects break off or tear off their wings after a single **nuptial flight** and before beginning their life in soil.

Tagmosis:

In adult arthropods some of the segments are more or less united into groups forming distinct trunk sections or tagmata. This type of grouping of segments into body regions is called **tagmosis** and each region is called **tagma** (Head, Thorax, and Abdomen).

Insect Physiology

Lect.11-15

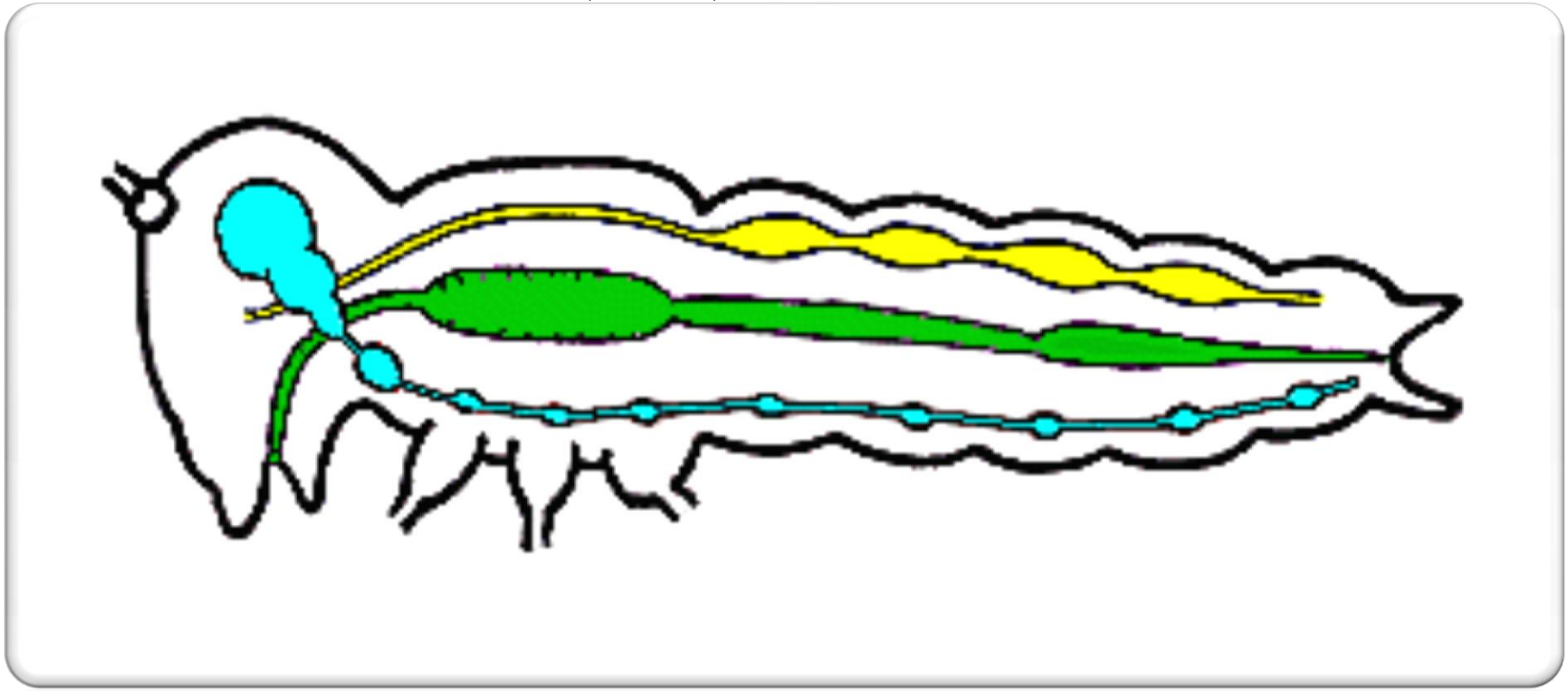
Physiology is the science of the *function* of living systems. This includes how organisms, organ systems, organs, cells, and bio-molecules carry out the chemical or physical functions that exist in a living system.

OUTLINE

- Nervous system
- Digestive System
- Excretory System
- Circulatory System
- Respiratory System
- Endocrine System
- Reproductive System

INSECT SYSTEMS

Side view of body showing relative position of circulatory (yellow), digestive (green), and nervous (blue) systems.



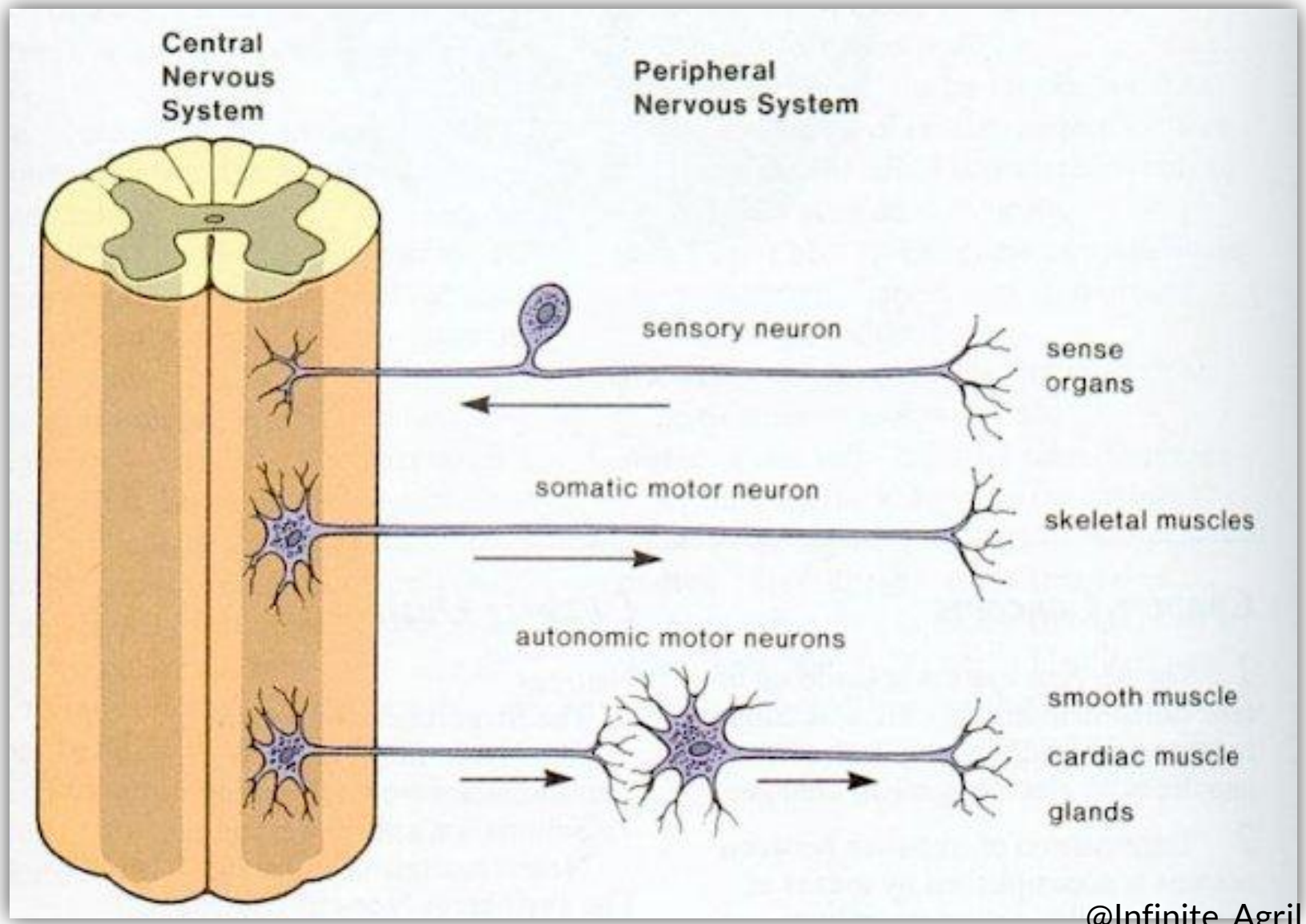
INSECT NERVOUS SYSTEM

Introduction

The nervous system functions as a fast acting means of transmitting important information throughout the body. There are two types of nervous systems in insect.

A. **Central Nervous system**
B. **Sympathatic Nervous system**
C. **Peripheral Nervous System**

Nervous System



NEURON

A **neuron** is a single nerve cell. The group of neurons is called ganglion.

Nerve cell or Neuron is ectodermal cell. It has following parts:

Cell body : It contains the nucleus, mitochondria and other organelles typical of eukaryotic cells. Two types of cytoplasmic processes extend from the cell body.

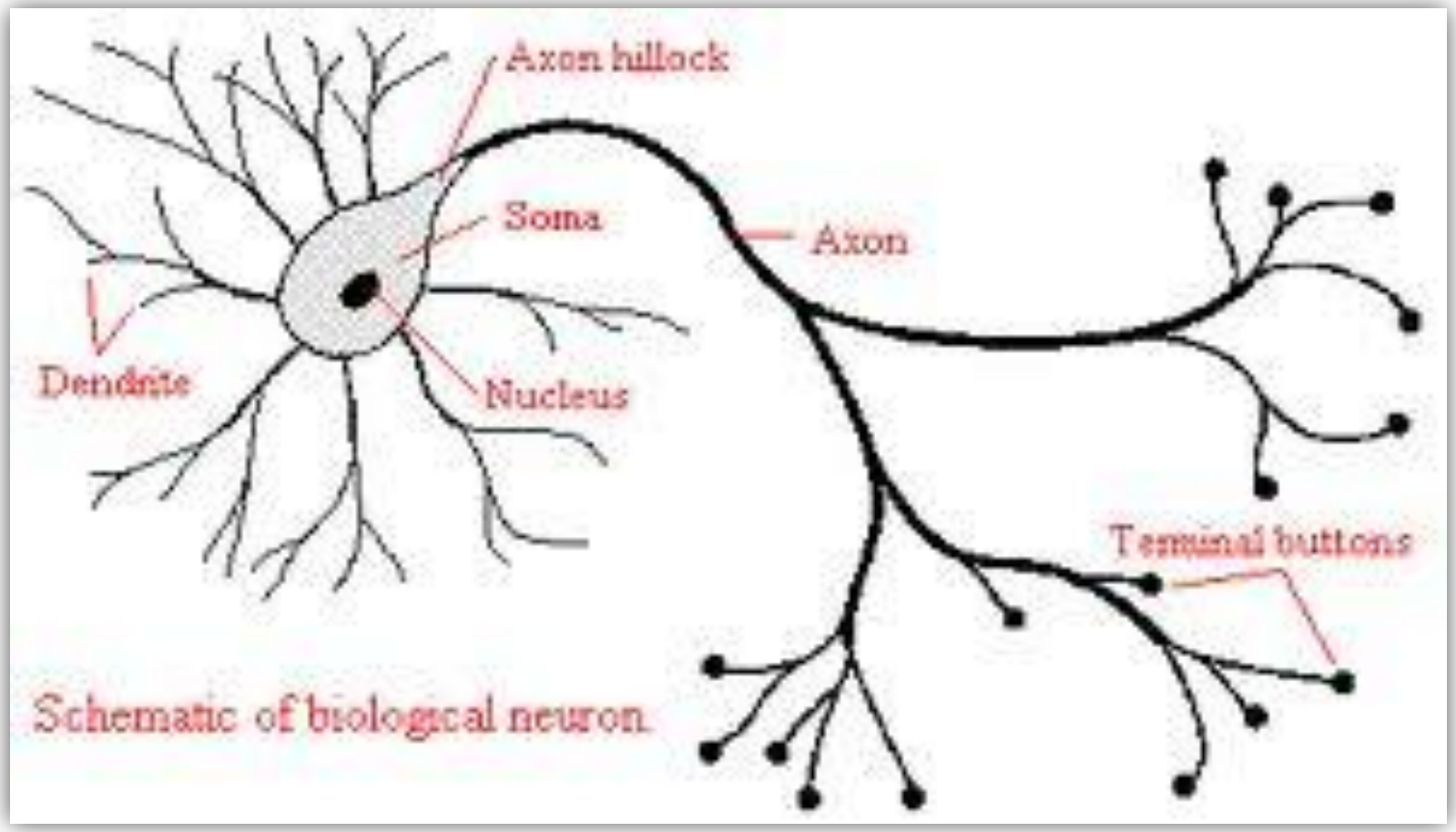
Dendrites bring signals in **to the** cell body. Often highly branched.

Axons carry signals **away from** the cell body.

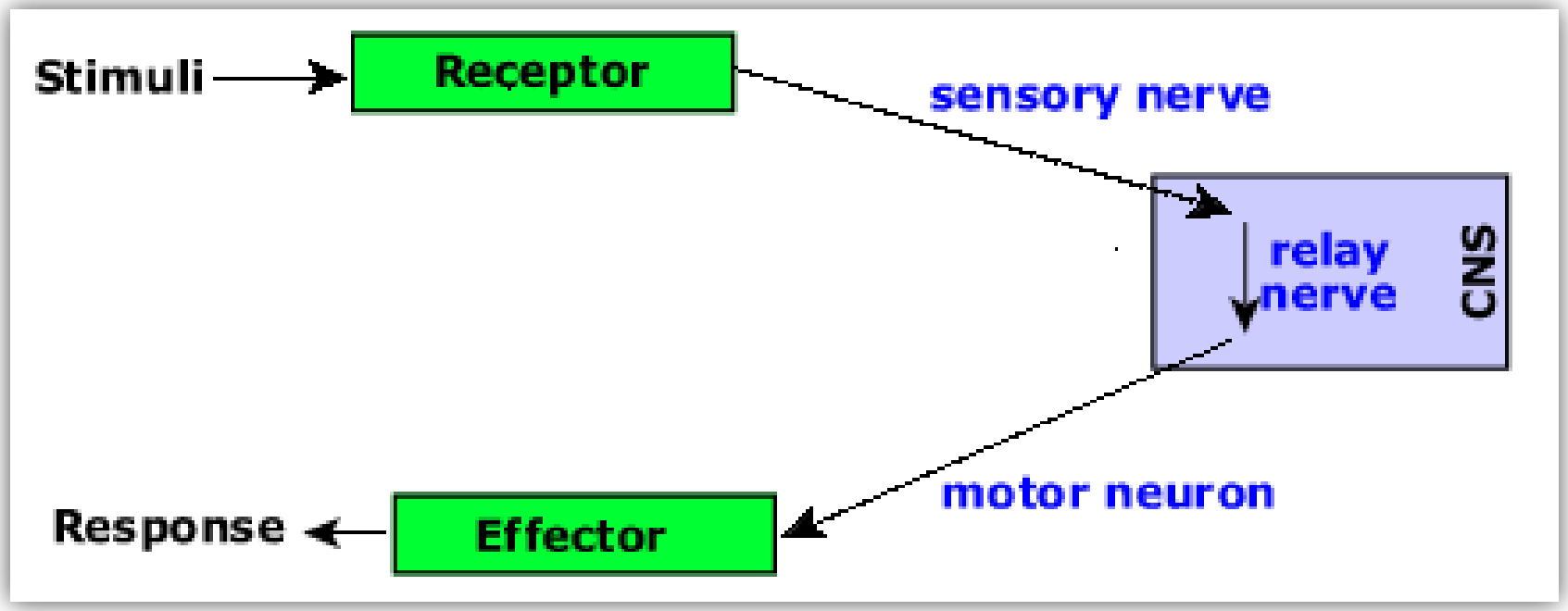
Group of neurons is called ganglia, each with central mass being called a **neuropile** where most of the synapses occurs.

One or more cells form an envelope around each neuron, these are called **glial cells**.

Nerve cell or Neuron



Types of Neurons

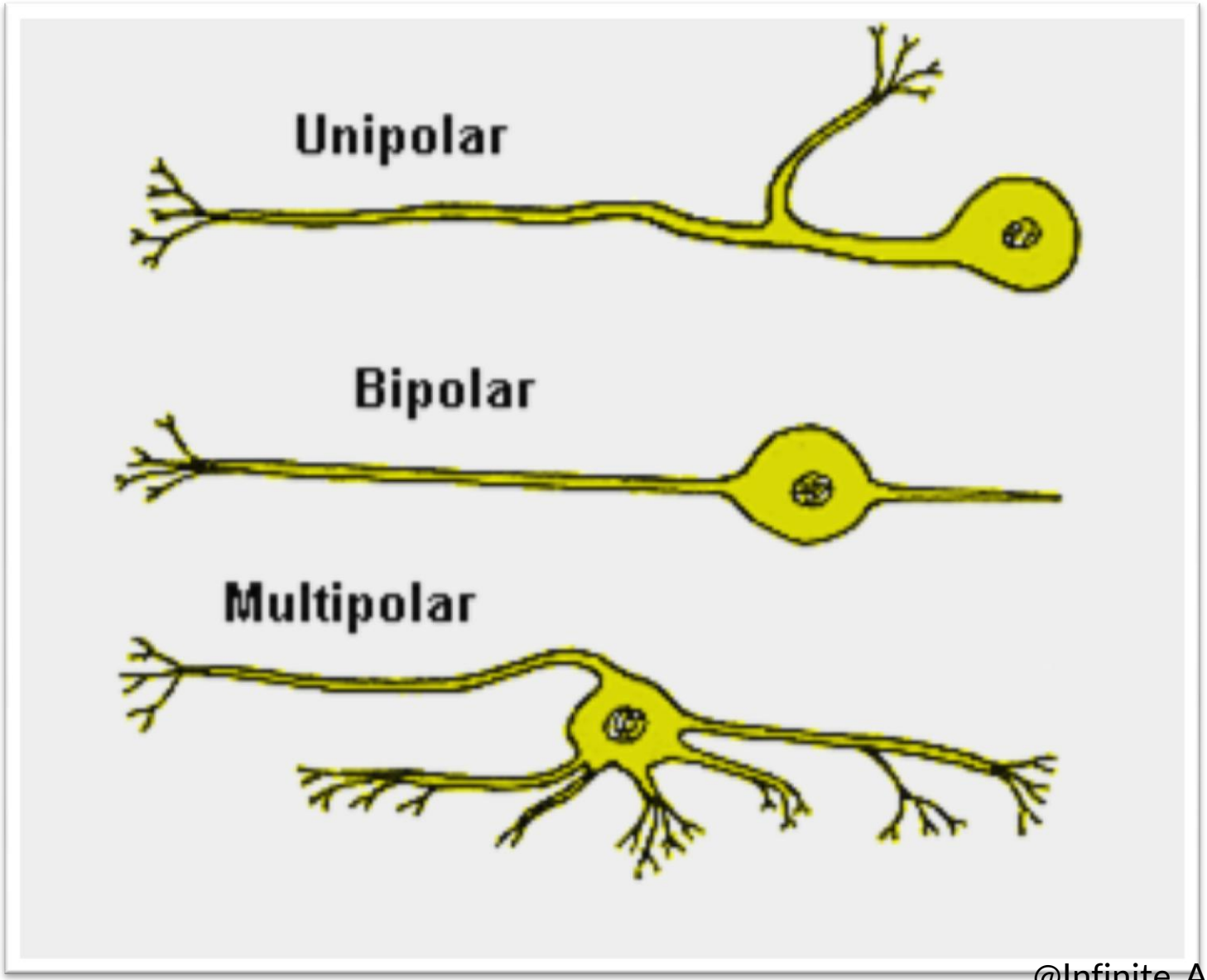


I. **Sensory neurons** transmit nerve impulses from sensory receptors all over the body to the CNS.

II. **Motor neurons** transmit nerve impulses from the CNS to effectors (muscles and glands) all over the body.

III. **Interneurones** (connector neurons or relay neurons) are usually much smaller cells, with many interconnections.

Types of Neurons



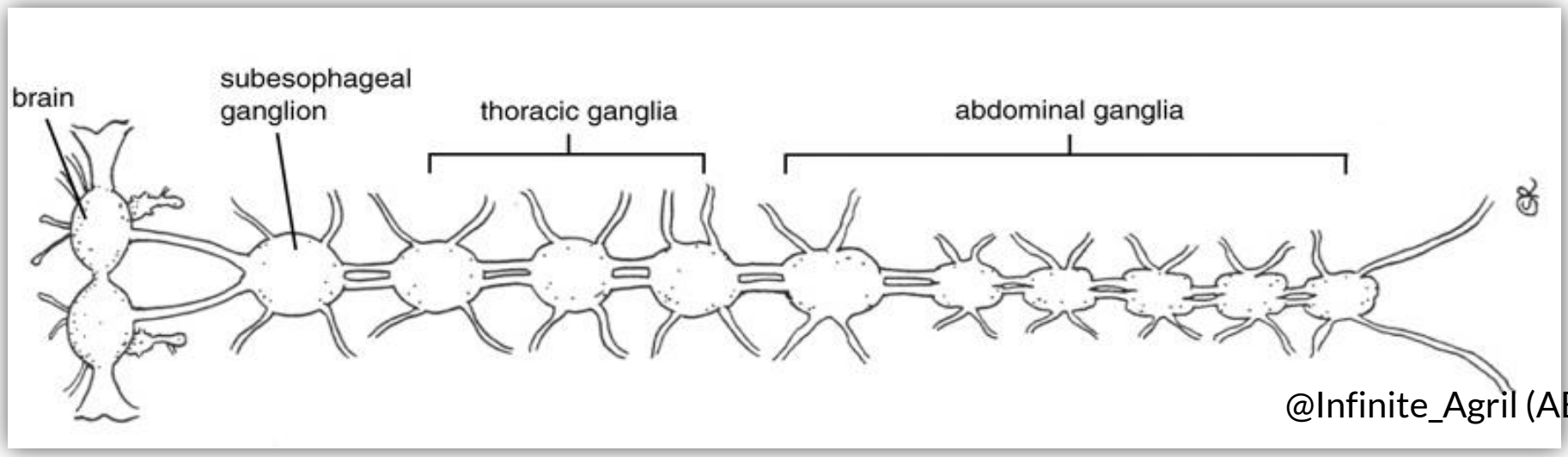
Structure of Central nervous system

Being the principal division of the nervous system, The insect nervous system consists primarily of

Brain

Subesophageal ganglion

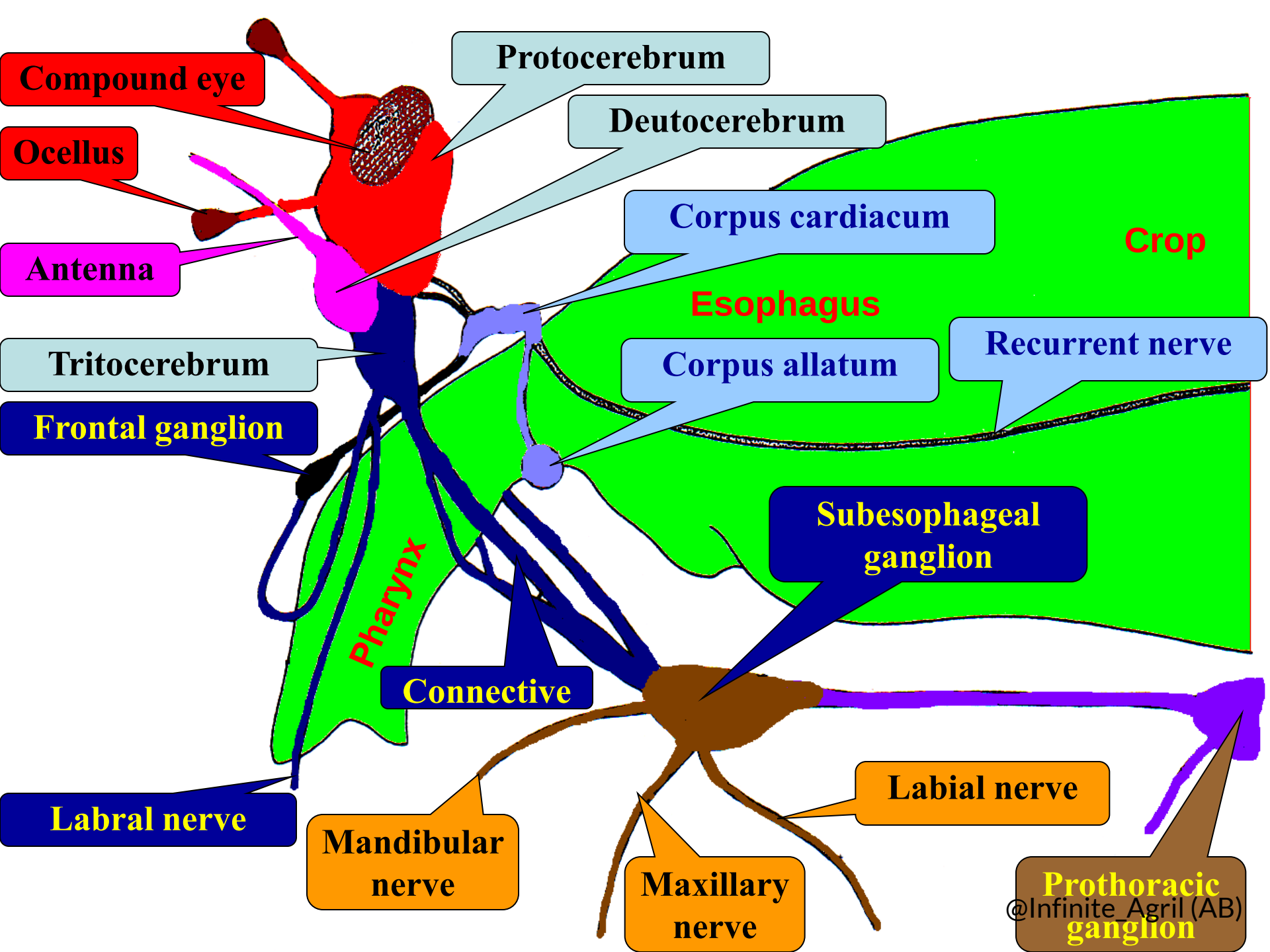
Ventral Nerve Cord



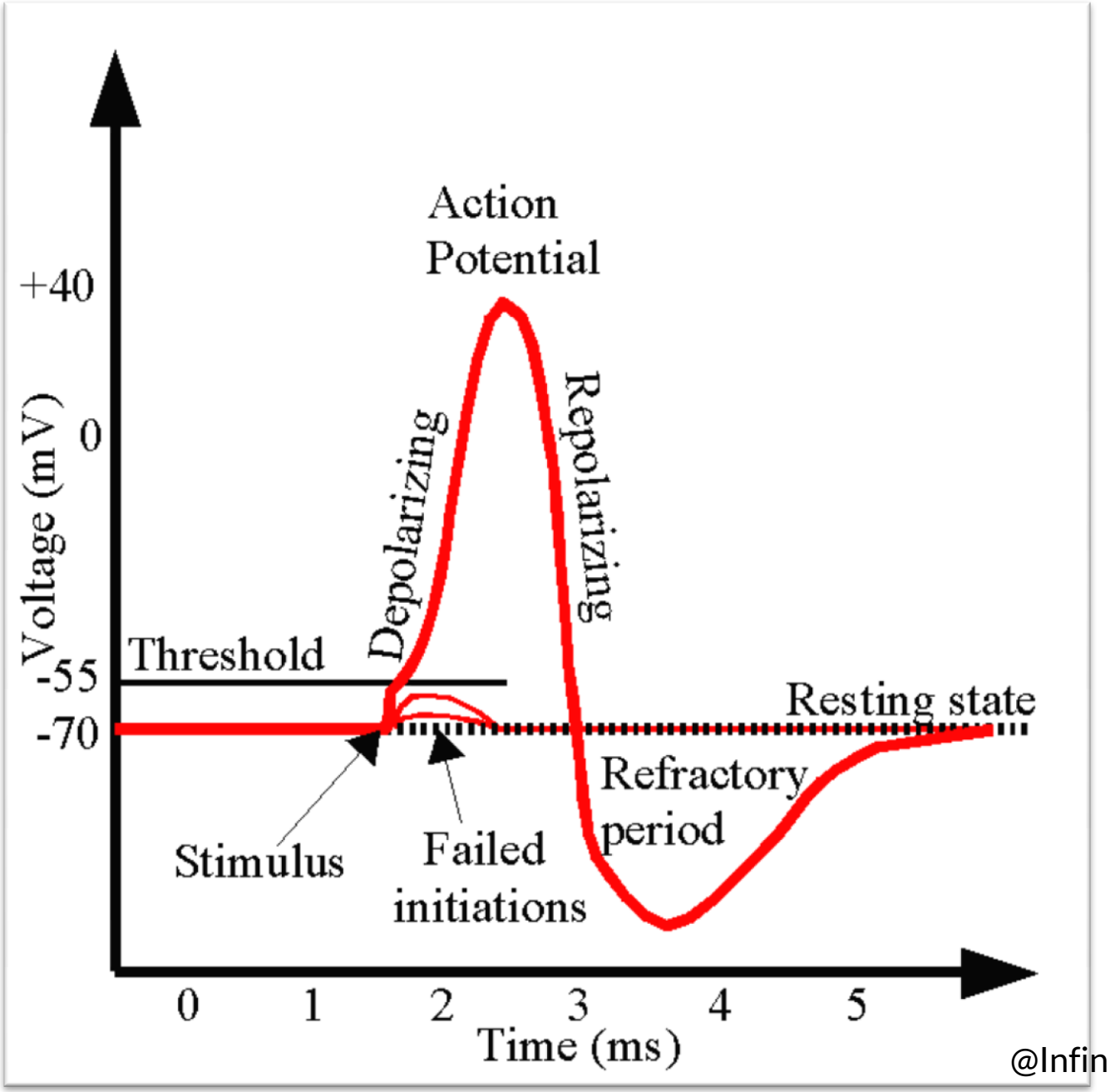
Insect brain (supraesophageal ganglion)

The **brain** which is pre-oral and is positioned dorsally in the head above the foregut. It is a fusion of three pairs of ganglia, each supplying nerves for specific functions.

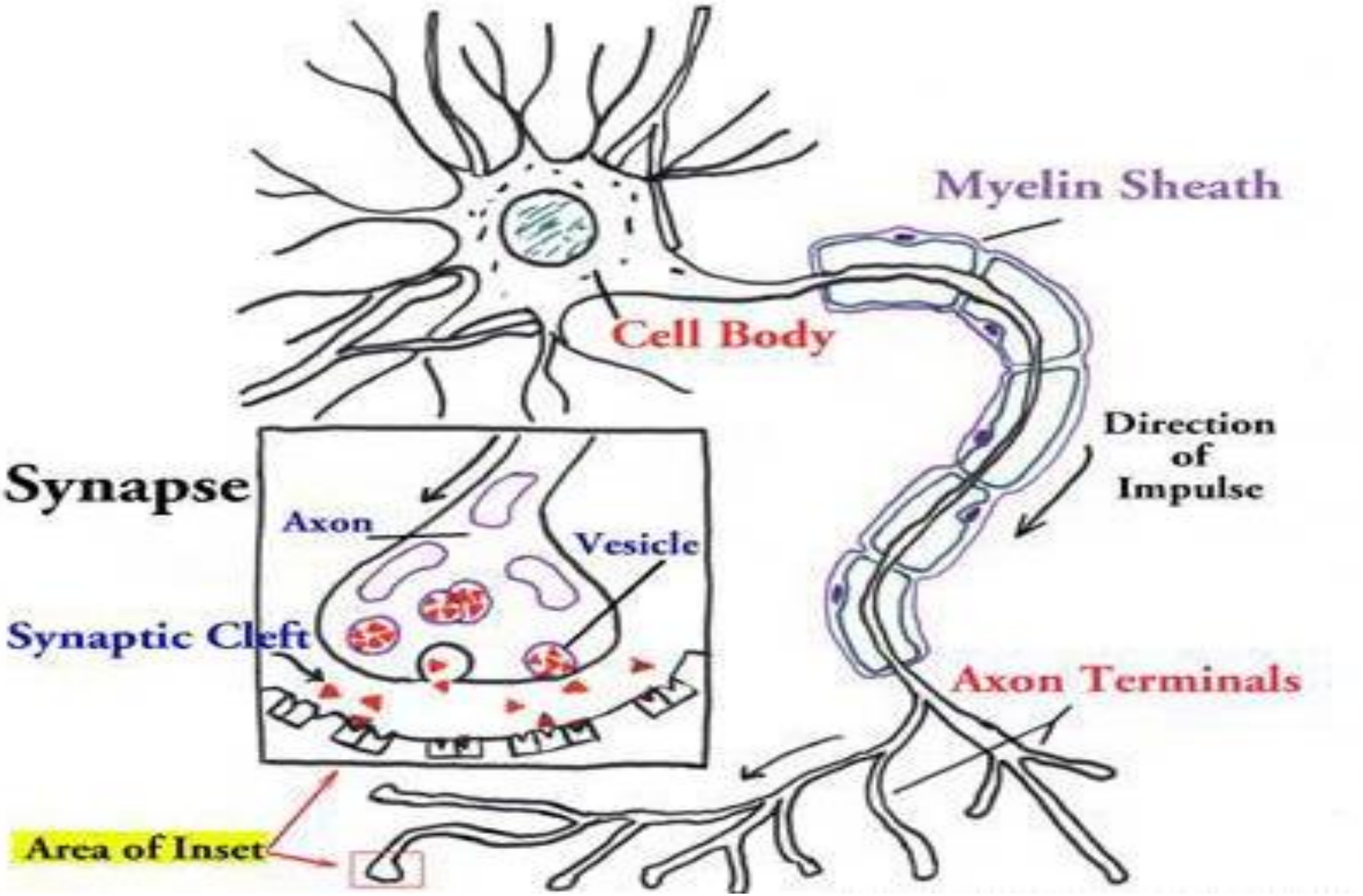
1. Protocerebrum receives nerves from:
    a. Compound eyes
    b. Ocelli
2. Deutocerebrum receives nerves from:
    a. Antennae
3. Tritocerebrum receives nerves from:
    a. Frontal ganglion
    b. Labrum
    c. Subesophageal ganglion



In the **cockroach** there are **3 thoracic** and only **6 abdominal** ganglia. In common **house fly** all the abdominal and thoracic ganglia have become **fused** into a single compound body-ganglion.



Acetylcholine – Example Neurotransmitter



Kinds of Synapses

- There are many types of neurotransmitters, each recognized by certain receptor proteins.
- **Excitatory synapse**
- **Inhibitory synapse**
- The size of the resting potential varies, but in excitable cells runs about -70 millivolts (mv).

Digestive system

- Macromolecules- catabolic reactions- smaller molecules (i.e. amino acids, simple sugars, etc.)
- Digestion is the process by which the food is broken down hydrolytically into simpler components, which can be absorbed or assimilated by the animal.
- **Alimentary canal.**
- The canal has 2 openings:
    - Mouth anteriorly and Anus posteriorly
- Alimentary canal is divided into three main regions:

1. Foregut (stomodeum) of ectodermal origin.
2. Midgut (mesentron) of endodermal origin.
3. Hindgut (proctodeum) of ectodermal origin.

Alimentary Canal

Foregut

Pharynx

Esophagus

Crop

Proventriculus

Midgut

Gastric cacae

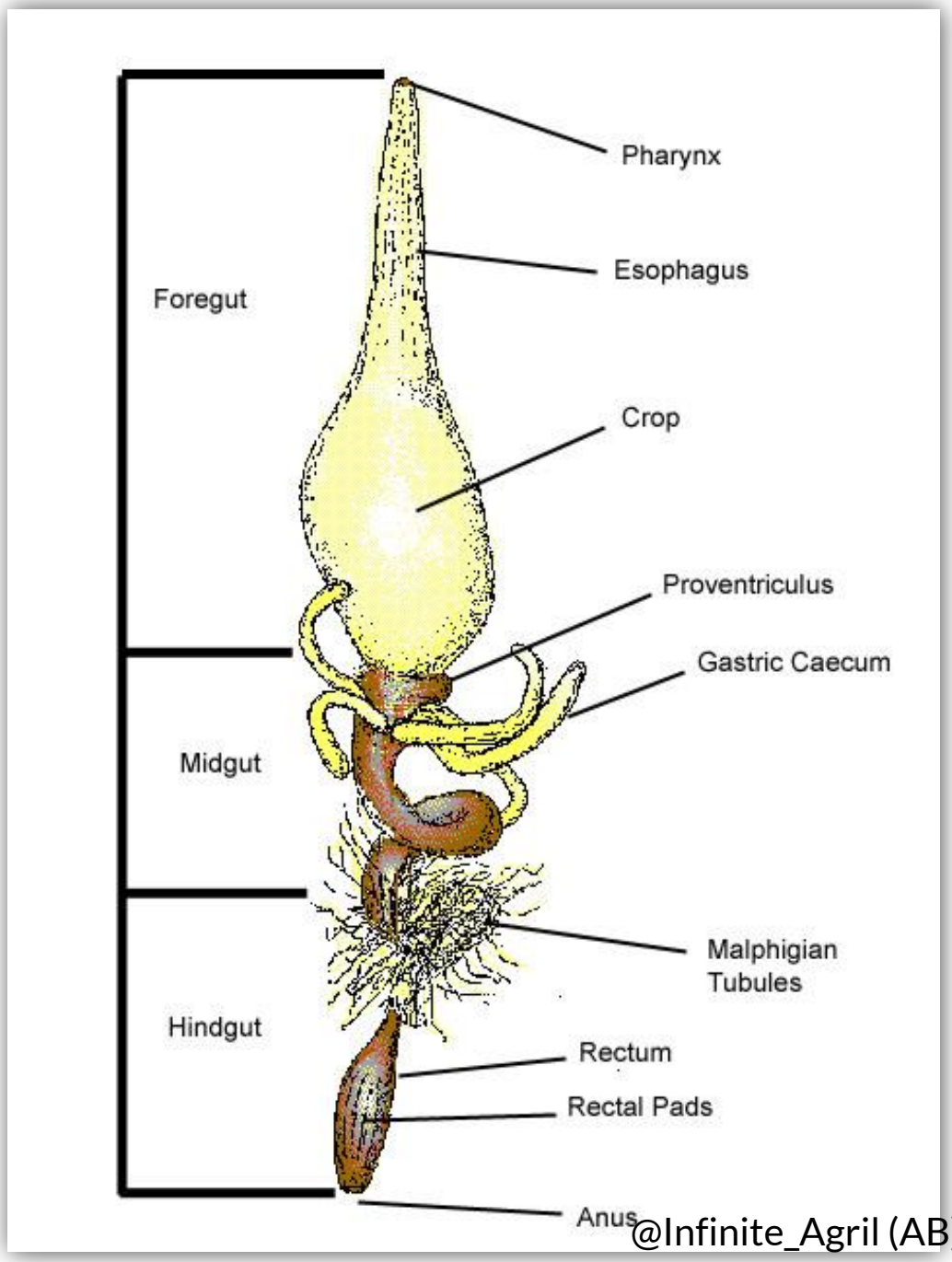
Malpighian Tubules

Hindgut

Ileum

Colon

Rectum



Midgut Enzymes

Insect	Diet	Protease	Lipase	Amylase	Invertase	Maltase
Cockroach	omnivorous	√	√	√	√	√
Carausius	phytophagous	√	√	√	√	√
Lepidoptera larvae	phytophagous	√	√	√	√	√
adults	nectar				√	
adults	Non-feeding					
Lucilia	meat	√	√			
Glossina	blood	√				

- **Peritrophic membrane : It protects the delicate digestive cells. Present in solid feeders.**
- **Foregut: Breakdown** of large non-absorbable organic compounds
- **Midgut: Absorbing** the small absorbable-sized molecules.
- **Hindgut: Defecate** not digested materials.

1. **Ingestion** - getting food into the GI tract (eating)
2. **Propulsion** - moving food along the tract
3. **Mechanical digestion** - the physical grinding and churning of foodstuffs to breakdown
4. **Chemical digestion** - breakdown of larger molecules into absorbable parts by enzymatic action
5. **Absorption** - transport of digested molecules, vitamins, minerals, water, into blood
6. **Defecation** - elimination of unused foodstuff (faeces)

Filter chamber

Insects-fluid diet, the connection between the mid and hindgut is occluded.

Many **homopterans (aphids, mealy bugs, scales)**

Preventing excessive **dilution of haemolymph**, **enzymes** and facilitate better enzyme activity.

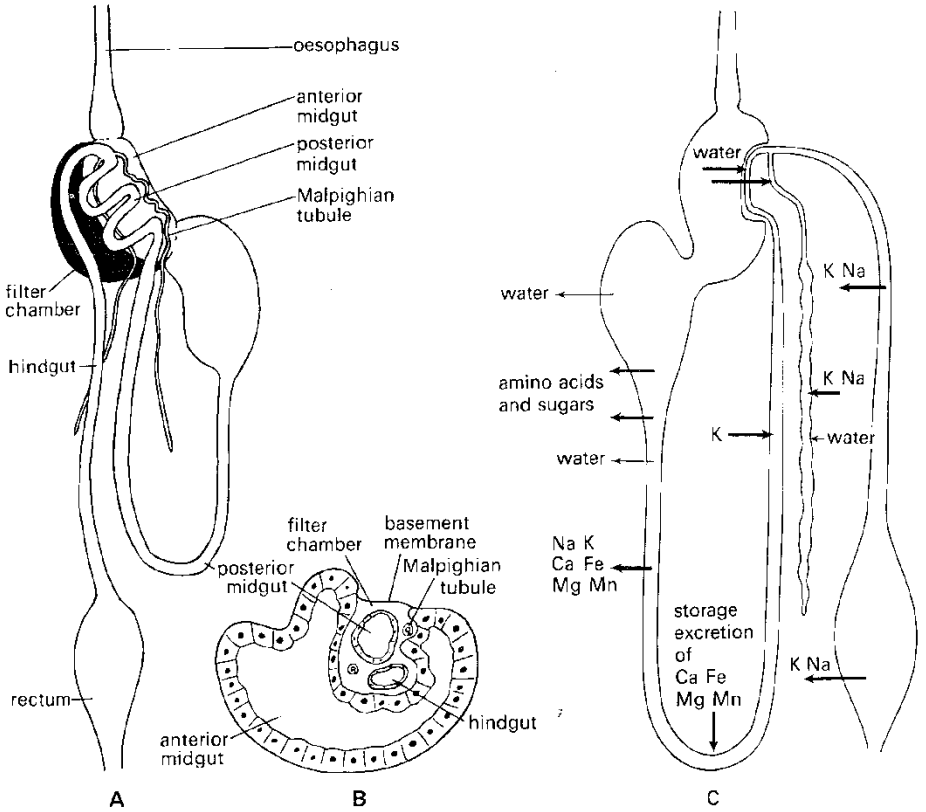


Fig. 39 Diagrams of the gut of a cercopid A General arrangement showing the filter chamber B Transverse section of the filter chamber C Postulated movements of water and solutes across the wall of the gut (after Snodgrass, 1935; Imms, 1957; Cheung and Marshall, 1973)

EXCRETORY SYSTEM

a. Elimination of excess or unwanted materials either toxic or not useful is known as **excretion**.

b. The organs involved in the **elimination of excess or unwanted** materials are together known as **excretory system**.

c. These toxic materials are **nitrogenous** products of metabolism (mainly ammonia). The principal excretory product in gaseous form is **CO2**, liquid form is **honey dew**, solid form is **urea/uric acid** and semi solid form is **allantoin.**

Organs involved in excretion

1. Malpighian tubules
2. Integument or body wall
3. Tracheal system
4. Alimentary canal
5. Nephrocytes
6. Urate cells
7. Oenocytes
8. Labial glands and
9. Chloride cells

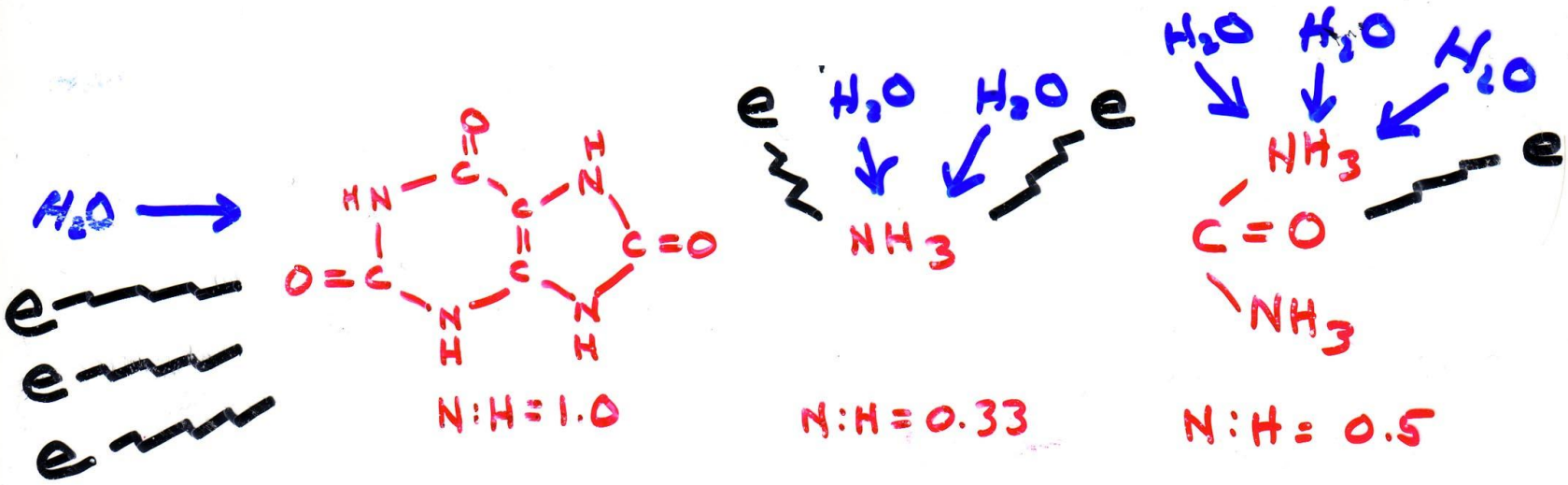
Malpighian tubules:

- **Marcello Malpighi** in **1669**, named after him by **Heckel** in 1820.
- In between midgut and hindgut
- 2-250 (**coccids-2**; **locust- 250**).
- **Absent** in **aphids** and **Collembola.**
- '**Cryptonephridial condition'- caterpillars** and **coleopterans**, **distal ends of MT** get reattached to the alimentary canal by opening in to the rectum of hindgut. **Reabsorption of water from rectum.**
- Waste products from the hemolymph diffuse into the Malpighian tubules, -converted to uric acid.

- This function allows insects **to survive and thrive** in even the most arid climates.

more water

more energy

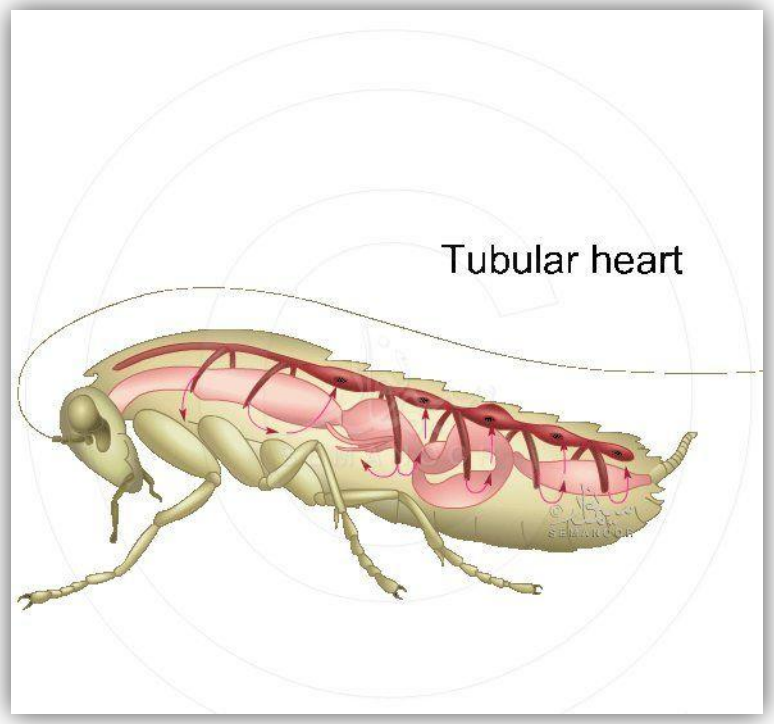


uric acid — most insects

ammonia — aquatic insects

urea — vertebrates

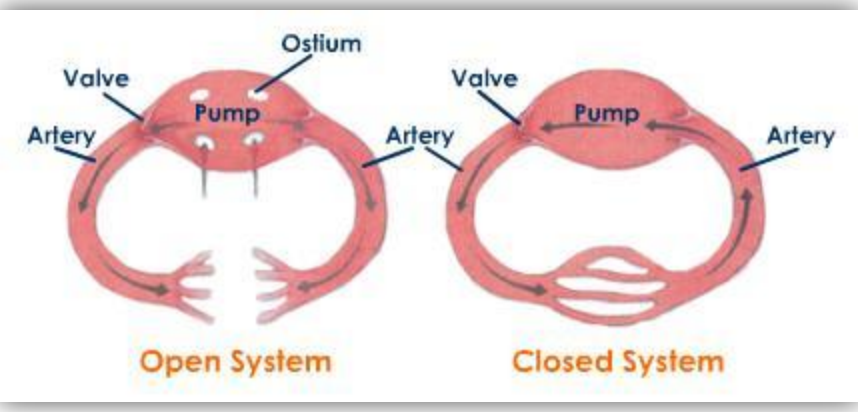
CIRCULATORY SYSTEM



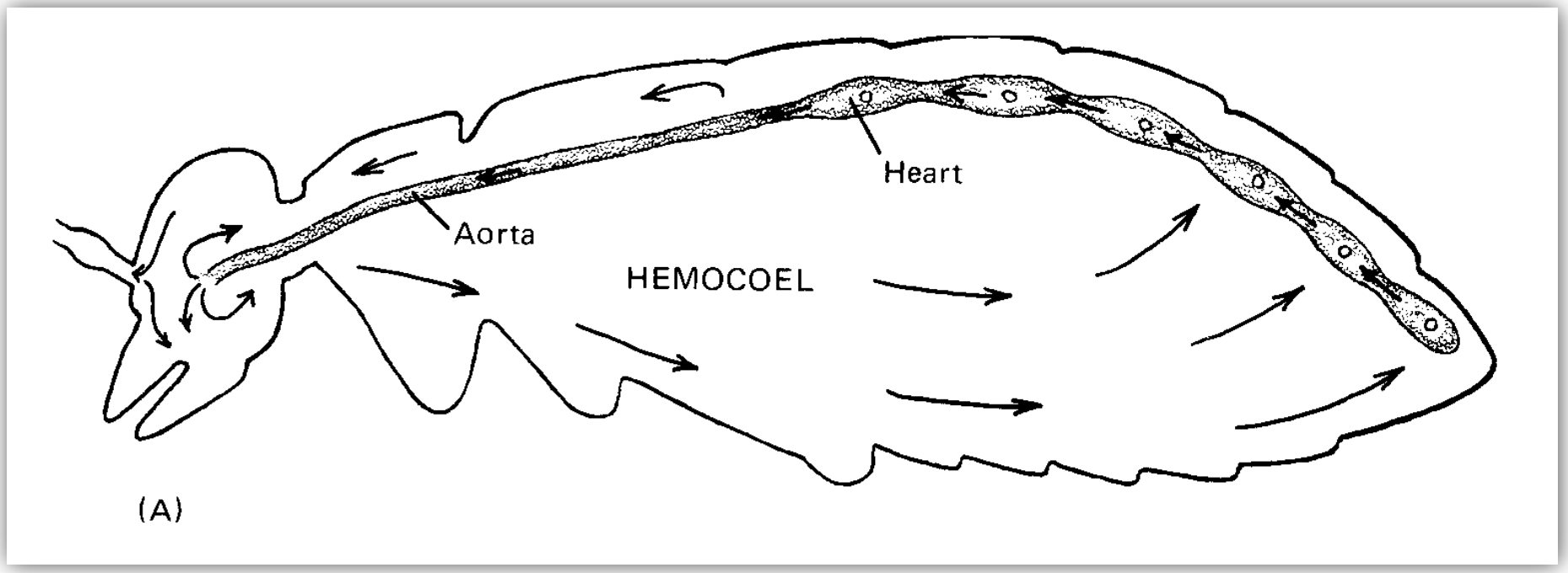
Open Circulatory System
Closed Circulatory System

In a closed system, blood is always contained within vessels (arteries, veins, capillaries, or the heart itself).

In open system blood (usually called **hemolymph**) flow freely within body cavity (haemocoel) where it makes direct contact with all internal tissues and organs.



Introduction



Haemolymph in insect body circulates mechanically in a **posterior to anterior direction** by the action of a **pulsatile organ , the dorsal vessel.**

Dorsal Blood Vessel

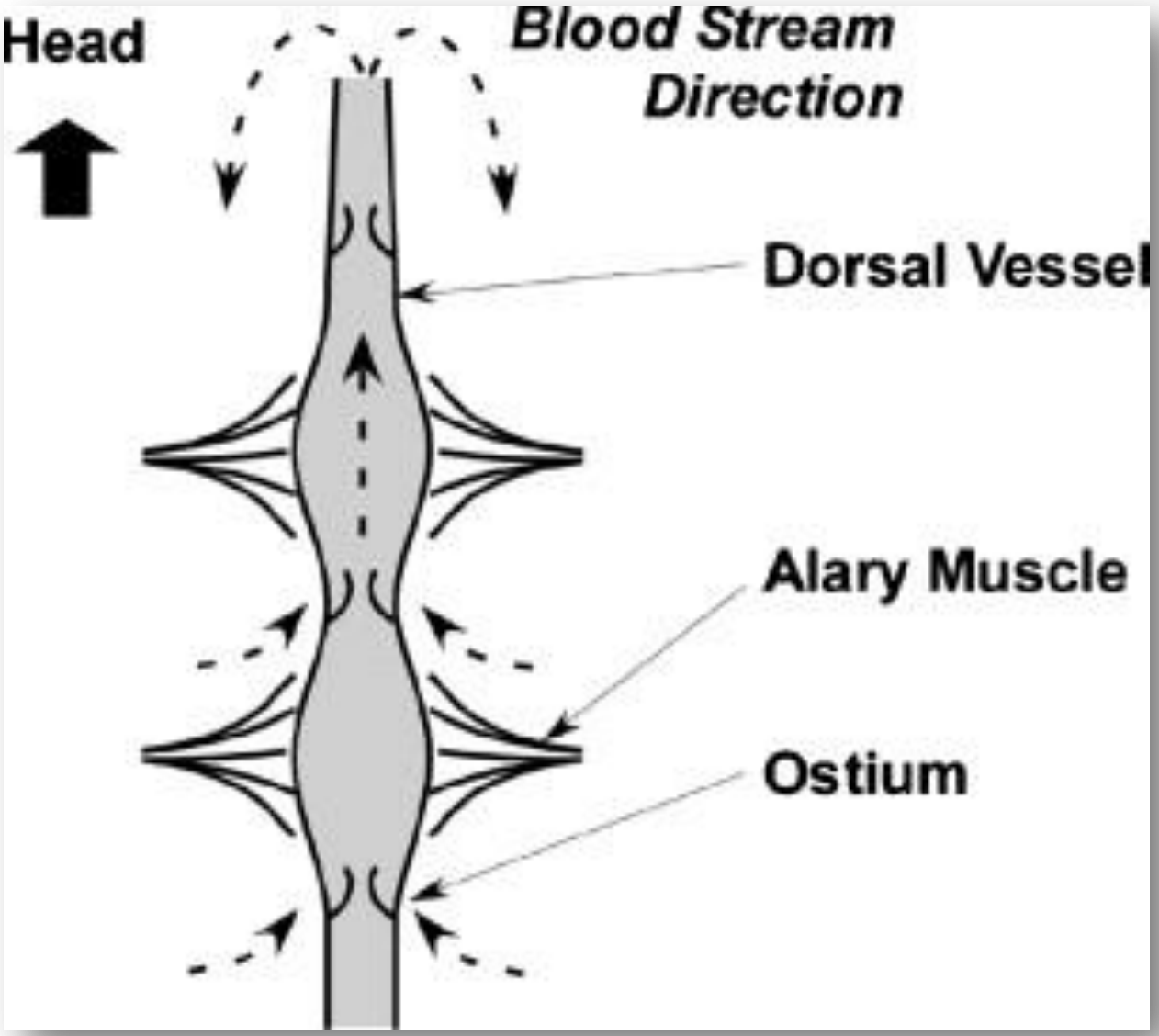
Differentiated into Anterior **Aorta** and posterior **Heart.**

1. **Heart** act as pumping organ- (may extend forwards as the **prothorax in cockroach.)**

Ostia one on each side through which blood enters the heart. (Most Blattodea and Mantodea have no excurrent ostia, but have segmental vessels)

2. **Aorta** act as conducting vessel. Principal artery.

- **Aortic valve**.



Process of blood circulation

Posterior end to the anterior end in a forward direction.

Two phases:

Diastole: During which expansion of heart takes place

Systole: during which **c**ontraction of heart takes place.

In between diastole and systole there will be a short period of rest which is known as **diastasis.**

Properties of blood:

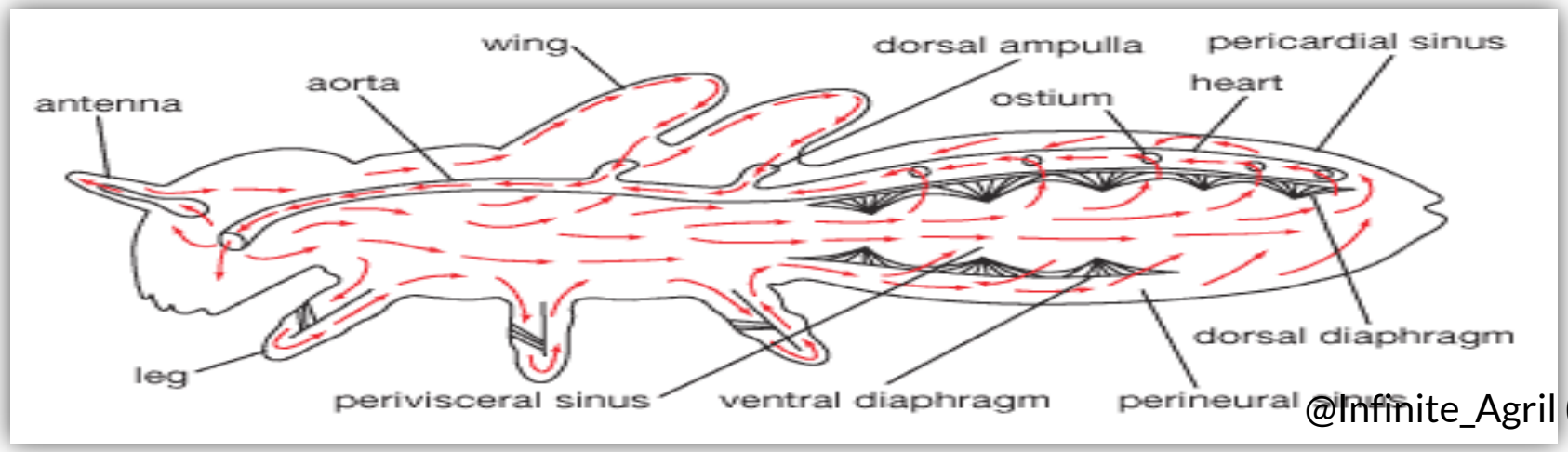
a. Blood is **colourless** (or) green (or) yellowish.
b. Green colour-chlorophyll-insectoverdin
c. Red colour -haemoglobin in *Chironomus* midge
d. 5 – 40% of the total body. **pH : 6-7.**
e. Phytophagous -rich in **'K' ,carnivores** -rich in '**Na'**
f. The blood sugar –**trehalose,** lacks vitamin **'K'**

Functions of blood

I. Transport of minerals.
II. Encapsulation:
III. Phagocytosis :
IV. Immunity:
V. Wound healing (or) coagulation:
VI. Detoxification:
VII. **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.

Accessory pulsatile organs

- **Circulation through the appendages.**
- Accessory pulsatile organs-at the base of the antennae or wings and sometimes in the legs.
- Oxygen is delivered by the tracheal system
- About 90% of insect hemolymph is **plasma**
- **Glycerol** in the plasma to prevent it from freezing during the **coldest** winters
- 10% haemocytes-cell types (collectively known as **haemocytes**);



Sinus

Two diaphragms, known as **dorsal** and **ventral diaphragms** forming three compartments.

I. **Dorsal or Pericardial Sinus :** Area in between the **tergum and dorsal diaphragm.** It contains **heart**.
II. **Ventral or Perineural Sinus:** Area in between the **sternum and ventral diaphragm.** It contains **nerve cord.**
III. **Visceral Sinus:** Area in between **dorsal and ventral diaphragms.** It contains **alimentary canal and gonads.**

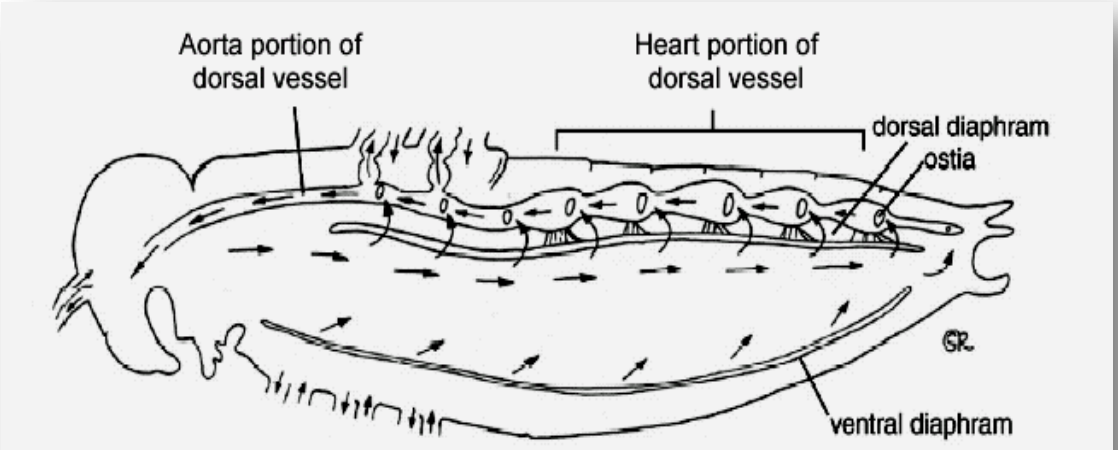


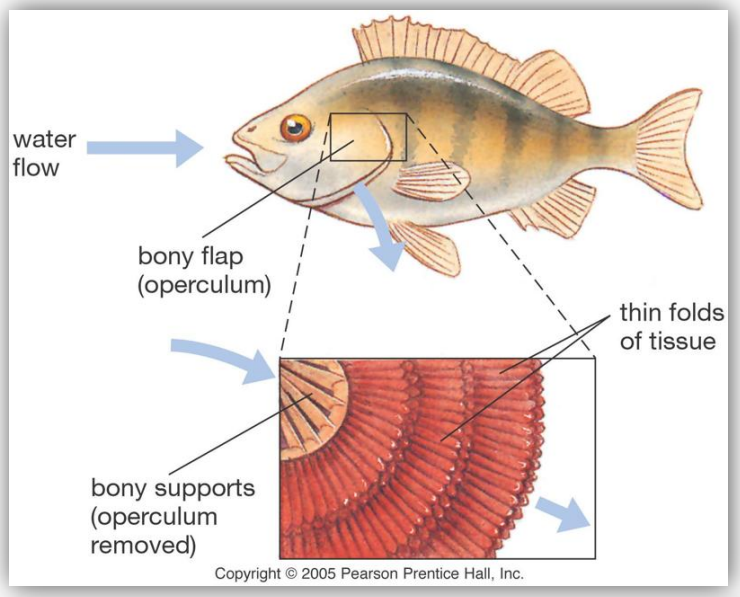
Figure 8-2. Circulatory system. Arrows indicate direction of flow of hemolymph.

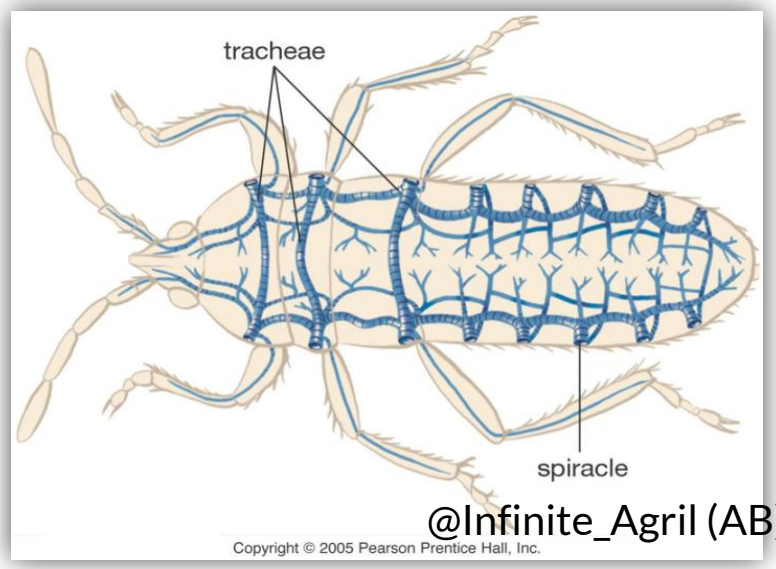
Respiratory Systems

- *Respiratory systems* are the organs in animals that exchange gases with the environment
- Respiratory systems allow animals to move oxygen (needed for cellular respiration) into body tissues and remove carbon dioxide (waste product of cellular respiration) from cells.

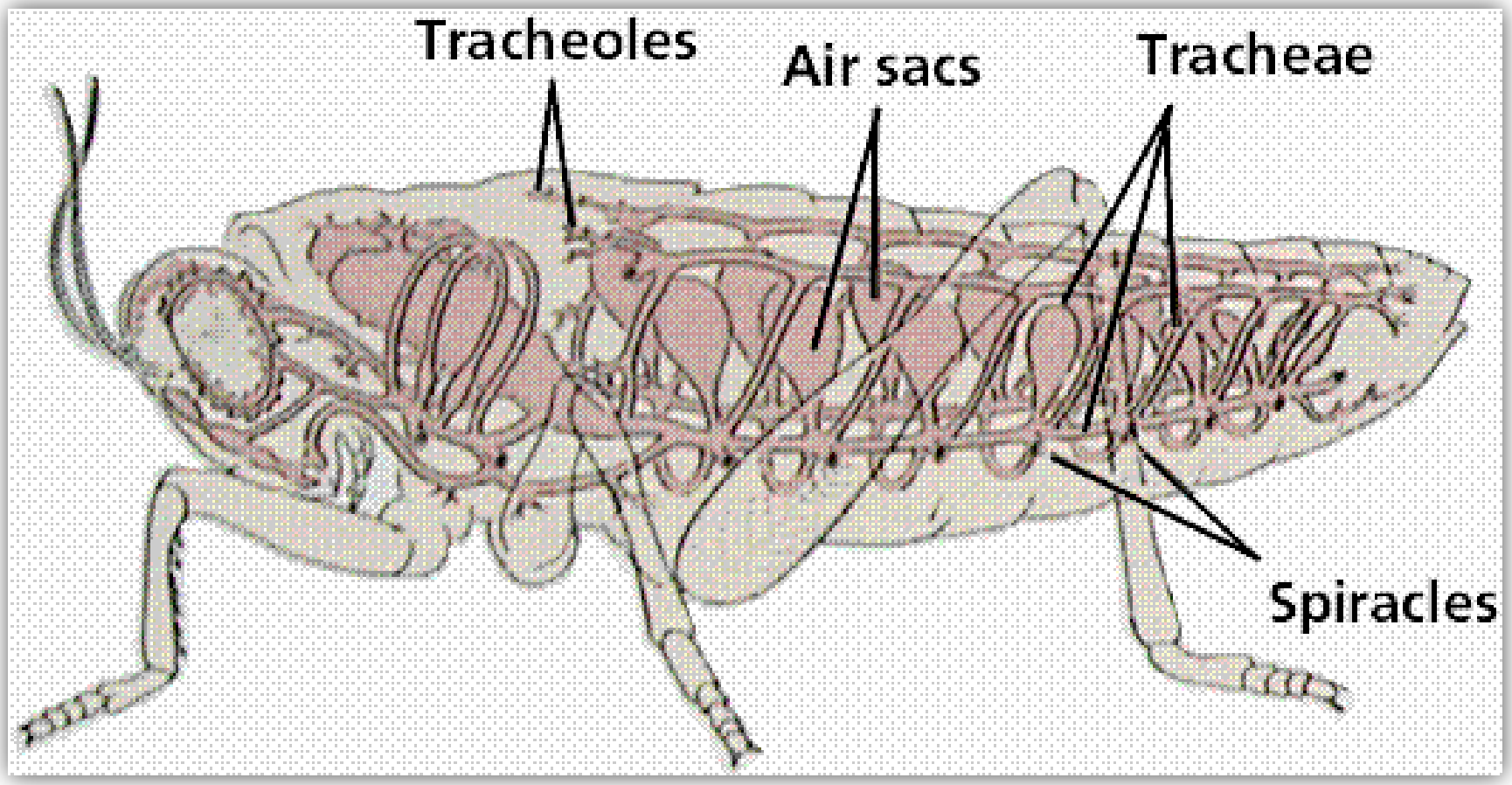
Specialized structures

- Structures specialized for gas exchange include:
  - gills (aquatic animals)
  - spiracles (terrestrial insects)
  - lungs (most terrestrial vertebrates)





The Insect Gas Exchange System



Tracheal system

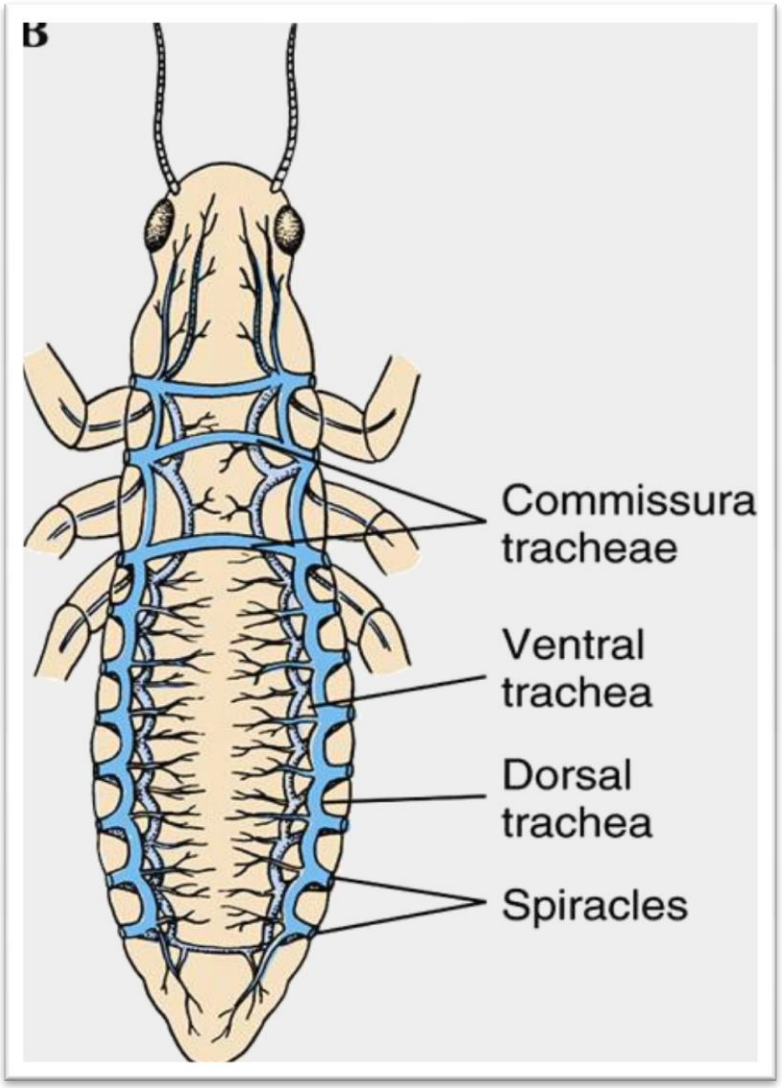
It is separate from the circulatory system.
It is a complex network of tubes (called a tracheal system) that delivers O_2-containing air to every cell of the body.

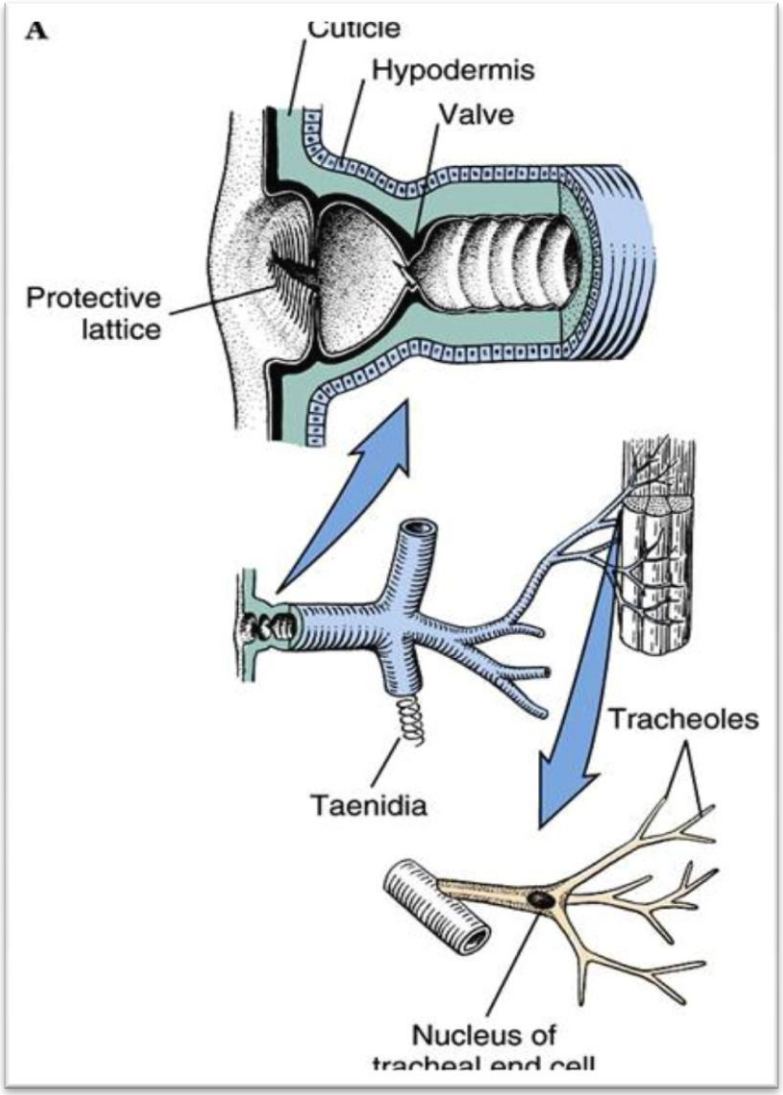
Tracheae - carry air directly to cells for gas exchange.

Spiracles -Air enters the insect's body through valve-like along the thorax and abdomen of most insects -- usually one pair of spiracles per body segment.
The **hydrophobic** nature -**peristigmatic glands** which secrete a hydrophobe material preventing the wetting.

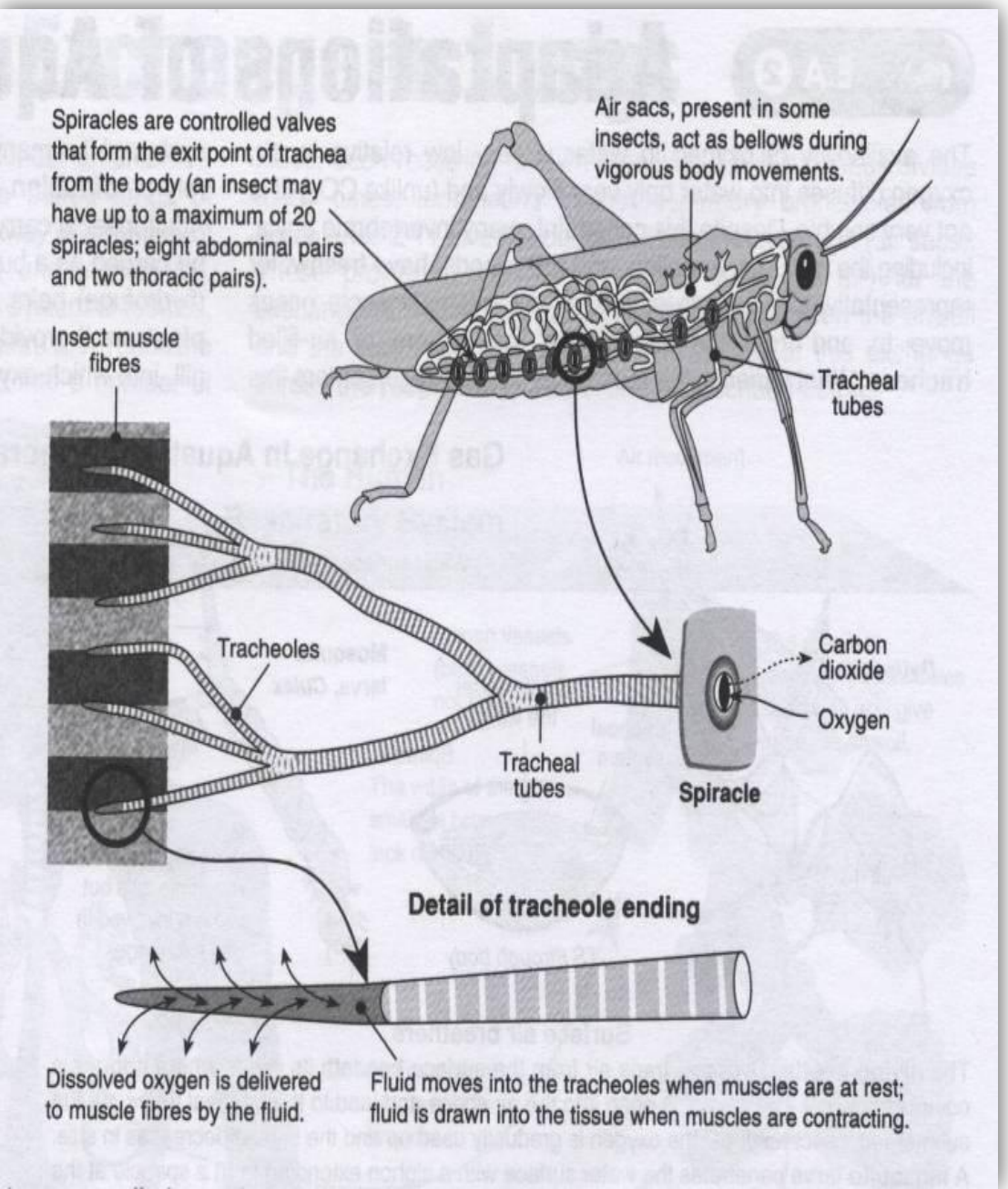
Trachea- **ectodermal** in origin. The spiral thickenings are known as **'taenidia'** which give support to the trachea without being **collapsed** when there is no air.

Insect Respiratory System





Tracheal System



Outside air

↓

spiracles (openings)

↓

Tracheae

↓

Tracheoles

Classification of tracheal system based on number and arrangement of functional spiracles

- **Holopneustic:** 2 pairs of spiracles on thorax & 8 pairs on abdomen. All are functional. 1 + 1 + 8.e.g. **dragonflies, grasshoppers and cockroach**
- **Hemipneustic:** One or more pairs of spiracles become non-functional. They are
  - **Peripneustic:** Metathoracic spiracle is closed. 1 + 0 + 8.
    e.g.: **larvae of Lepidoptera, Hymenoptera, and Coleoptera.**
  - **Amphipneustic** : Only mesothoracic and last pair of abdominal spiracles are open. 1 + 0 + 1. e.g: larva of **cyclorrhaphan Diptera**.
  - **Propneustic :** Only one pair i.e. mesothoracic spiracles are open, 1 + 0 +0
    e.g.: **mosquito pupa-tumbler**
  - **Metapneustic :** Only last pair of abdominal spiracles are open. 0 + 0 + 1.
    e.g.: **mosquito larvae-wriggler**
  - **Apneustic:** No functional spiracles. e.g: **mayfly larva, nymph of Odonata**
  - **Hypopneustic :** 1 or 2 pairs of spiracles may completely disappear or absent
    e.g.: **Siphunculata, Mallophaga**
  - **Hyperpneustic:** More than 10 pairs of spiracles are present e.g.: ***Japyx* sps. (dipluran**)

Other types of respiration

1. Cutaneous respiration: e.g.: **Protura, Collembola**
2. Tracheal gills: e.g.: larva of **Trichoptera**,
3. Spiracular gills : In some **aquatic pupae**,
4. Blood gills: **Chironomid** larvae
5. Rectal gills: In dragonfly nymphs (**naids**),
6. Air sacs: Many winged insects
7. Plastron respiration: e.g.: **aquatic beetles.**

Endocrine Organs in Insects

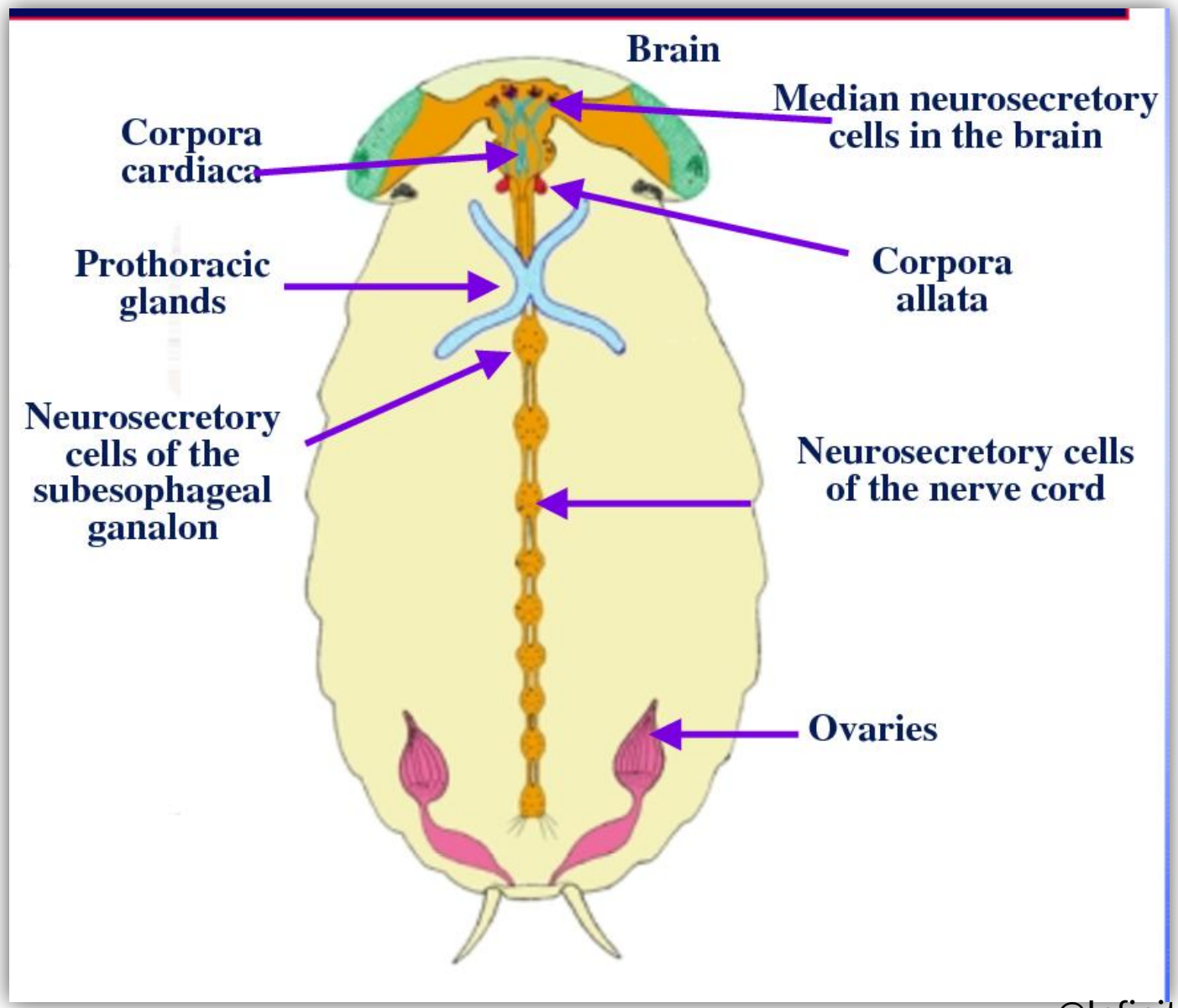
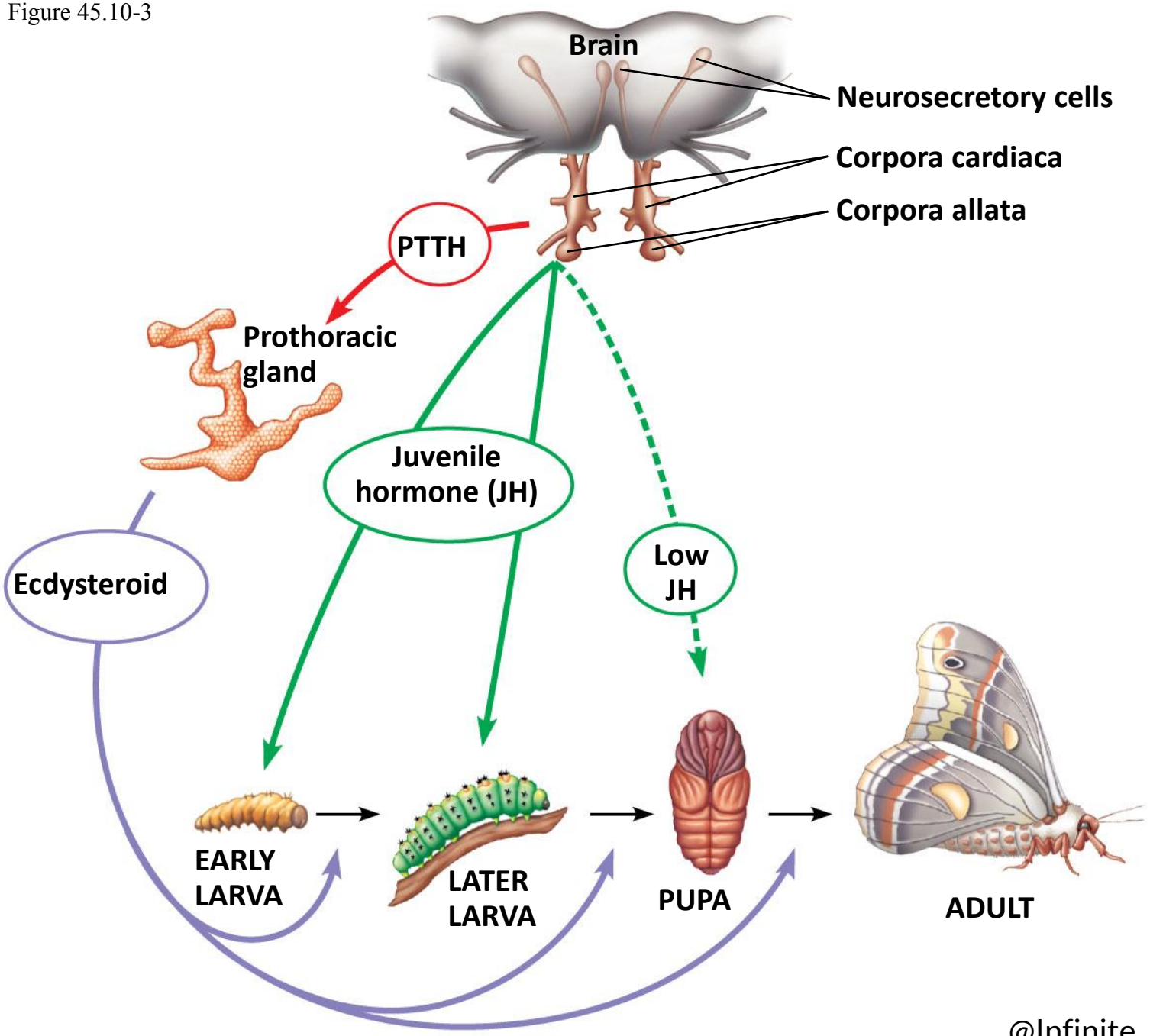


Figure 45.10-3



Types of Hormones in Insects

- **Steroid** hormone
  - **ecdysteroids**
- **Sesquiterpenes**
  - **juvenile hormones**
- **Peptide** hormones
  - prothoracicotropic hormone (**PTTH**)
  - many others

REPRODUCTIVE SYSTEM

Functions of Reproductive System

Female

Egg production

Egg fertilization

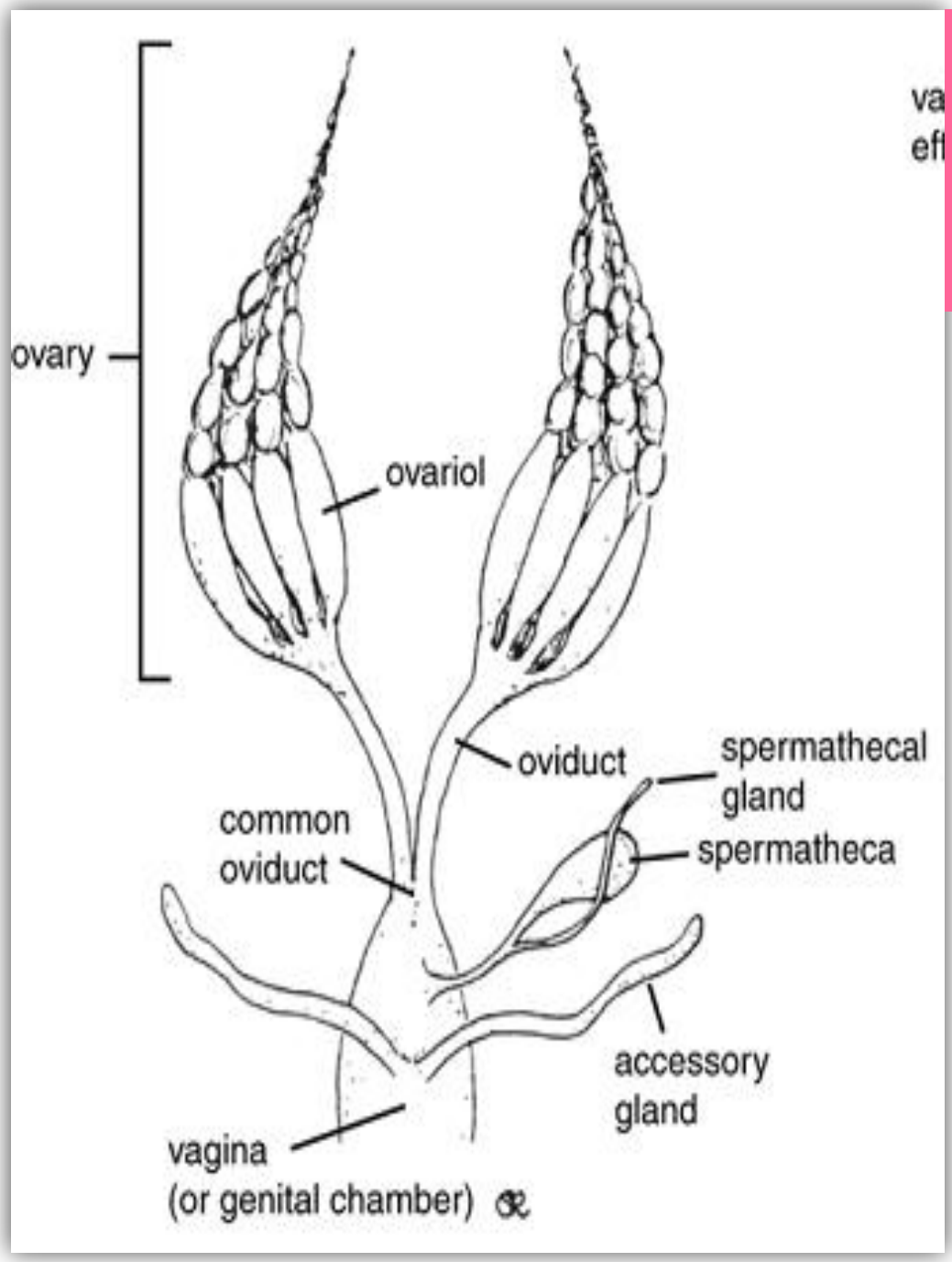
Egg placement

Male

Sperm production

Sperm transfer

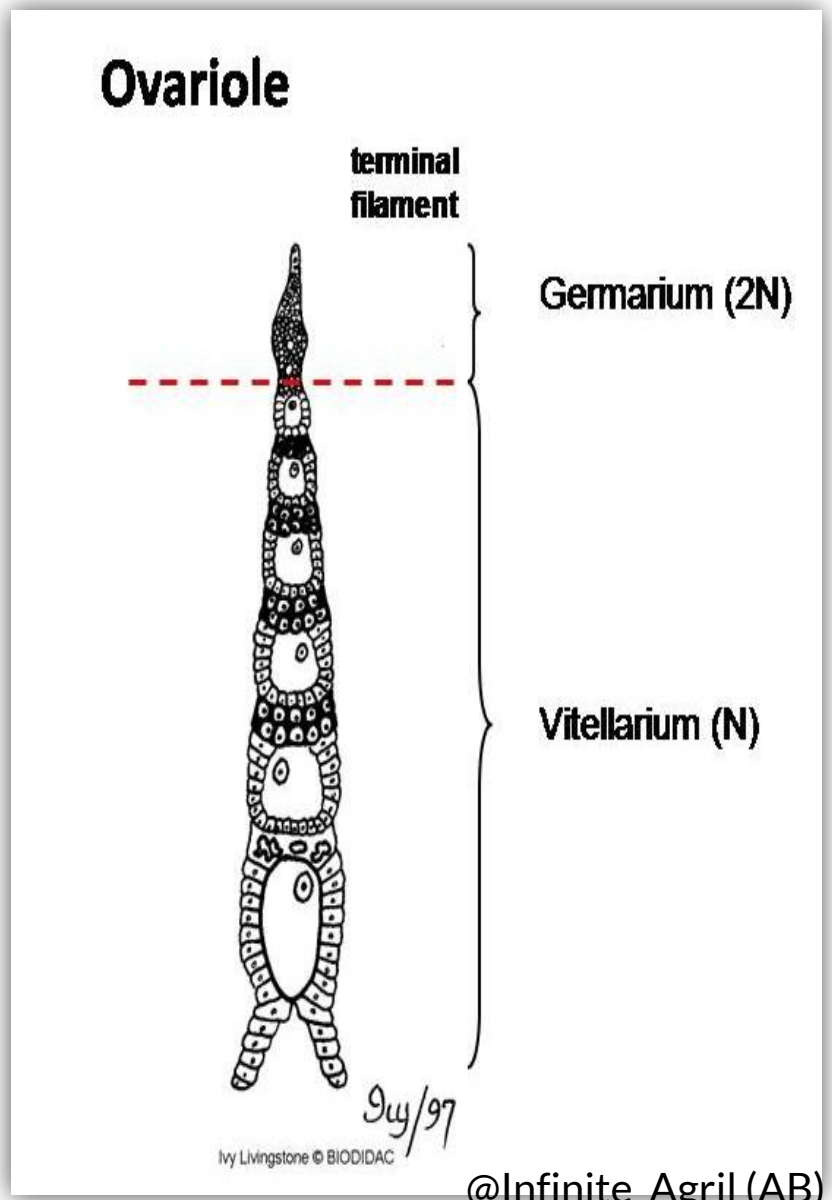
FEMALE REPRODUCTIVE SYSTEM



1. Pair of ovaries,
2. Two lateral oviducts,
3. Median oviduct,
4. Accessory glands,
5. Spermatheca,
6. Bursa copulatrix.

Female ovary

Functional chambers -ovarioles.
Each ovarioles -Terminal Filament, Germarium, Vitellarium and Pedicel. Egg production takes place in the ovarioles. Eggs are then released into the oviduct.



Ovary Types

A. Panoistic ovarioles: In these, the nutritive cells are absent.
e.g.: Odonata, Dictyoptera, Orthoptera and Ephemeroptera

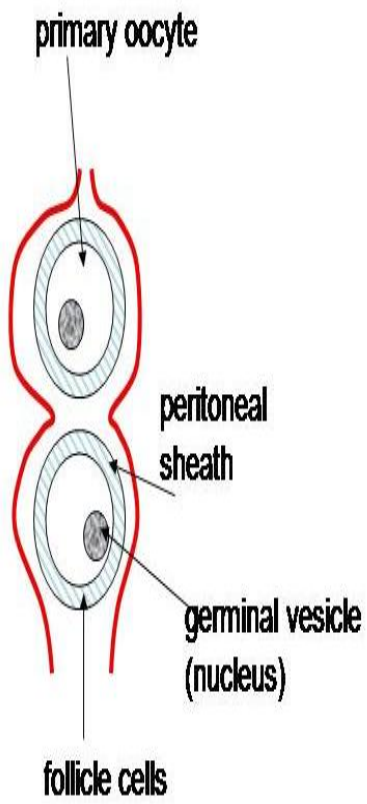
B. Meriostic ovarioles: They contain trophocytes / nutritive cells which vary in their position.

B1. Polytrophic ovarioles: where developing oocyte and trophocytes arranged alternatively within the vitellarium.
e.g.: Mecoptera, Dermaptera, Psocoptera

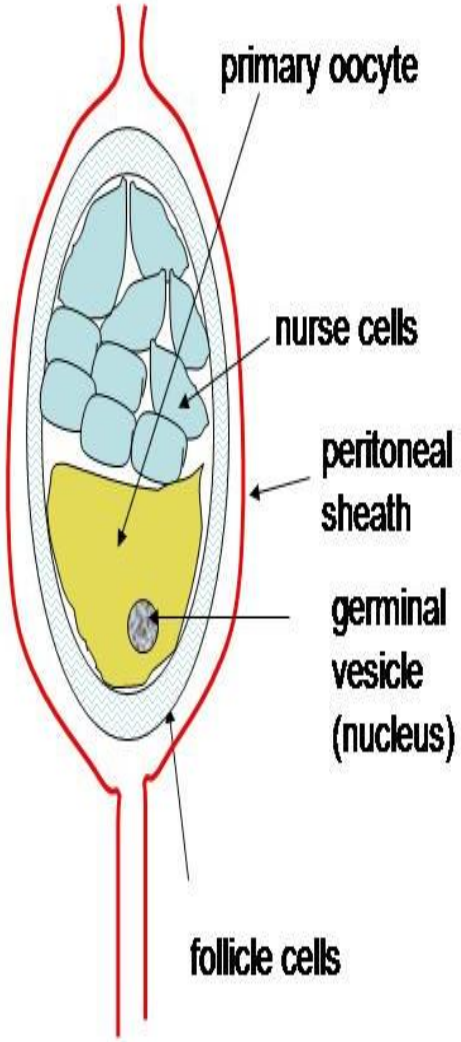
B2. Acrotrophic ovarioles: Also called **teletrophic** ovarioles where the trophocytes are present in the germarium (apex) e.g.: Hemiptera and Coleoptera.

Ovary Types

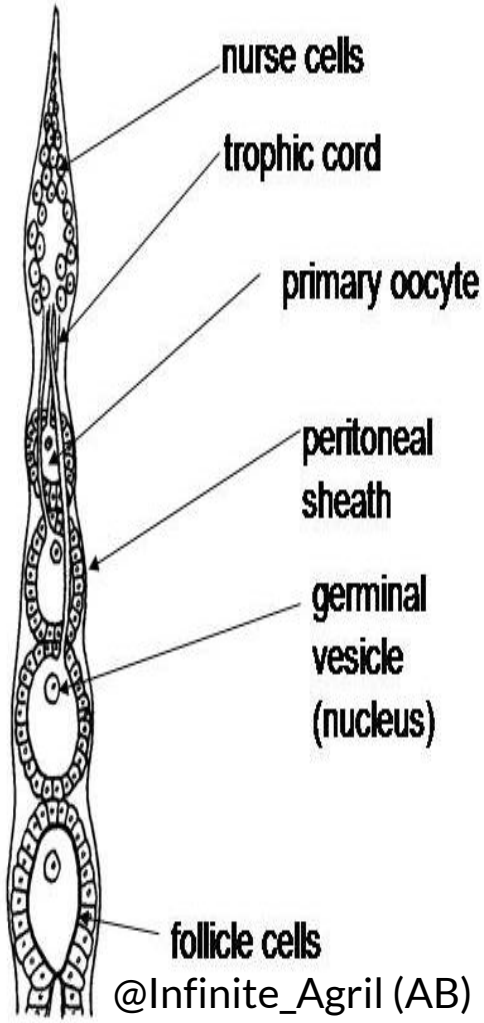
Panoistic Overy



Meroistic Overy: a. Polytrophic

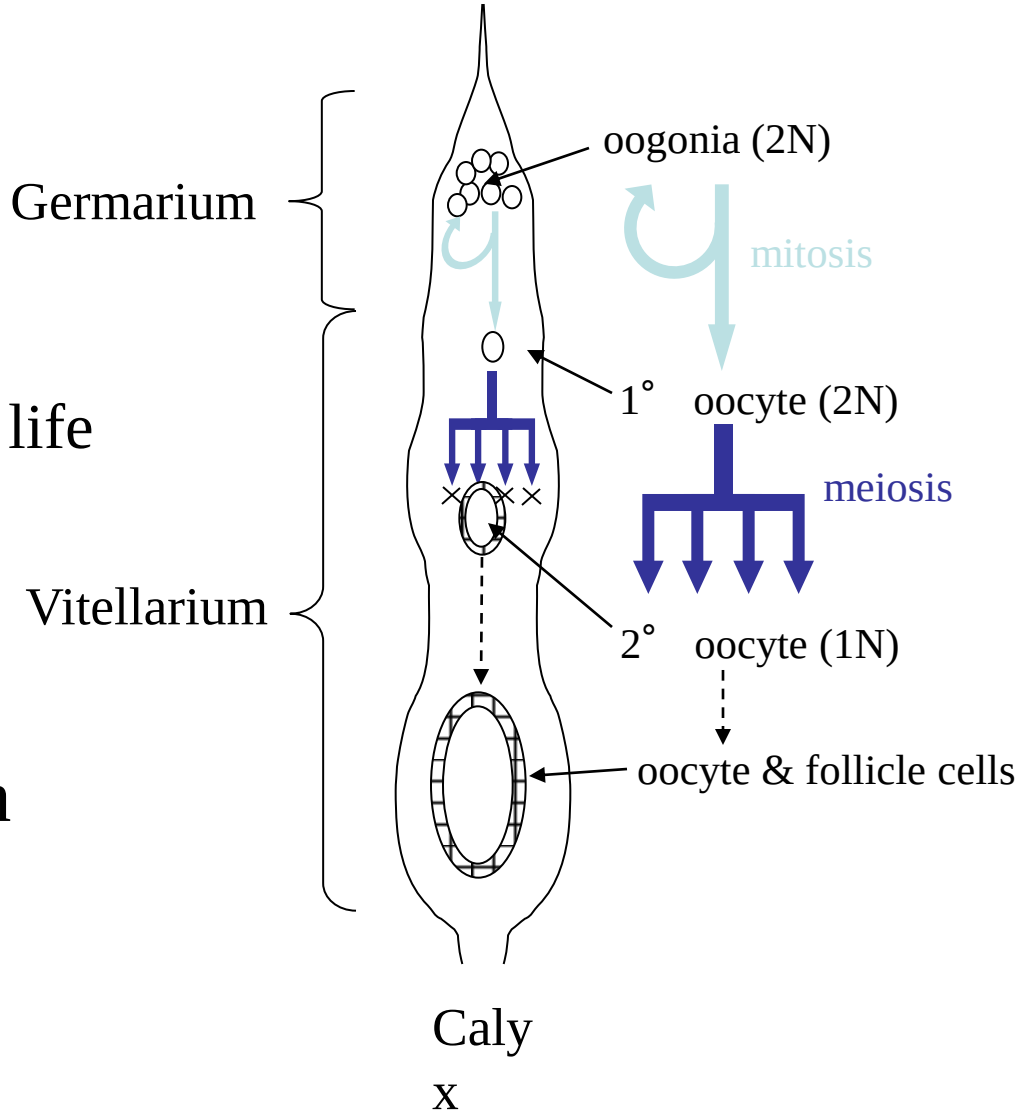


Meroistic Overy : b. Telotrophic



Oogenesis & Ovulation

- Oogenesis occurs in ovariole
  - May be continuous process
  - May occur once in the life cycle
- Mature oocyte exits ovariole - ovulation
- Oocyte passes through oviducts
- Fertilization in genital chamber

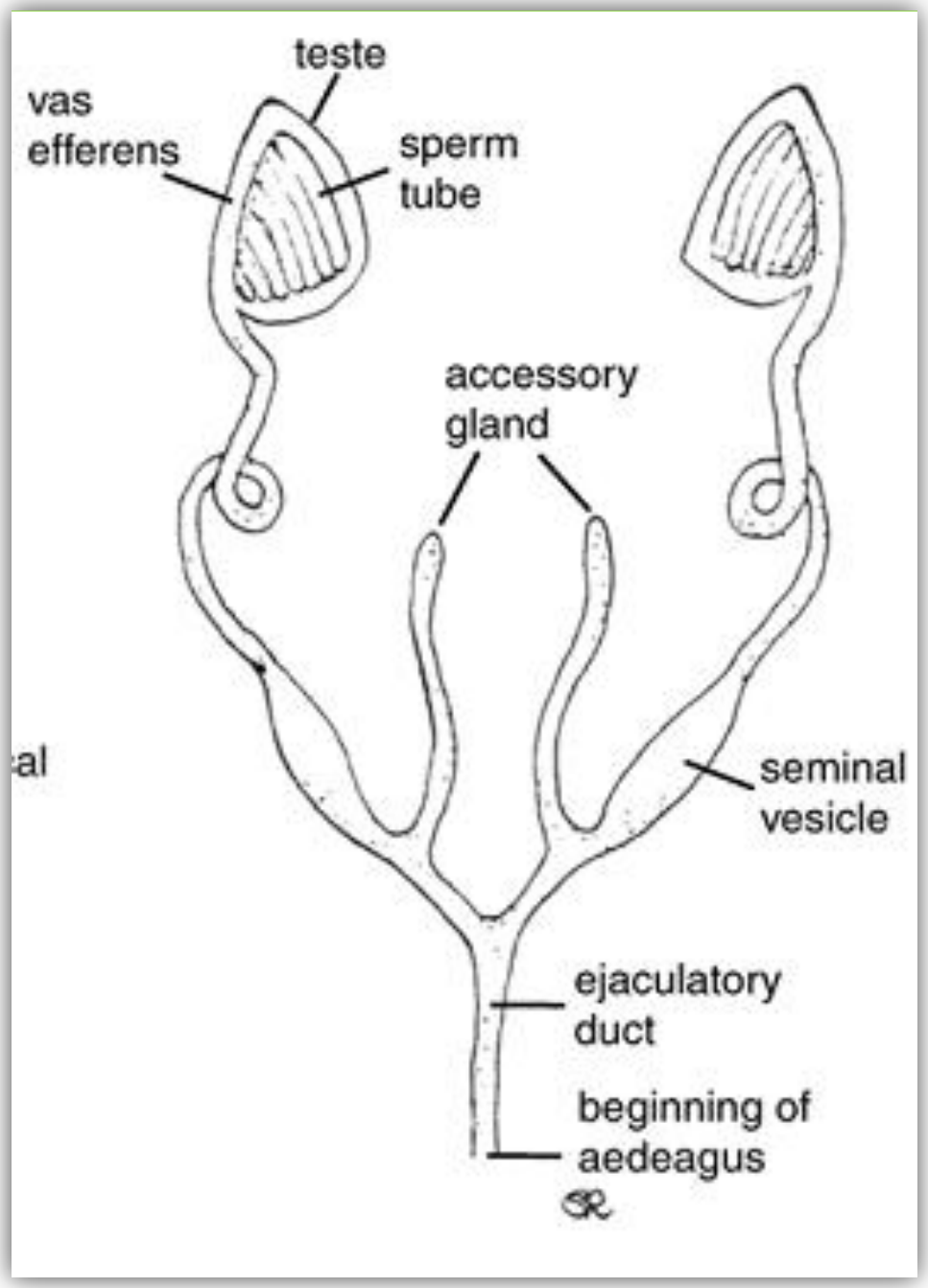


- Frequently the vagina is developed to form a pouch, the **bursa copulatrix** which receive the penis.
- Usually there are two lateral oviducts joining a median oviduct which is lined with cuticle.
- The median oviduct open at the gonopore or into a genital chamber invaginated above sternum of segment 8.
- **Spermatheca :** are attached with vagina. The function of spermatheca is to store and nourish the spermatozoa, until these can fertilize the eggs.
- The number of spermatheca varies from 2 -3.
- The spermatheca is ectodermal in oregin, so lined with cuticle.

Accessory glands

- **Accessory or Collateral glands** secrete an adhesive substance that aid in oviposition.
- The glands often produce substances for attaching the eggs to the substratum during oviposition and hence are called **colleterial (glue) glands**.
- In some insects they produce an **ootheca** that protect the eggs after oviposition.
- Glands associated with the genitalia, which are modified to form a **sting**, perform a variety of functions in female Hymenoptera.

MALE REPRODUCTIV E SYSTEM



1. **Pair of testes,**
2. **Vas deferens,**
3. **Seminal vesicle,**
4. **Median ejaculatory duct**
5. **Accessory glands.**

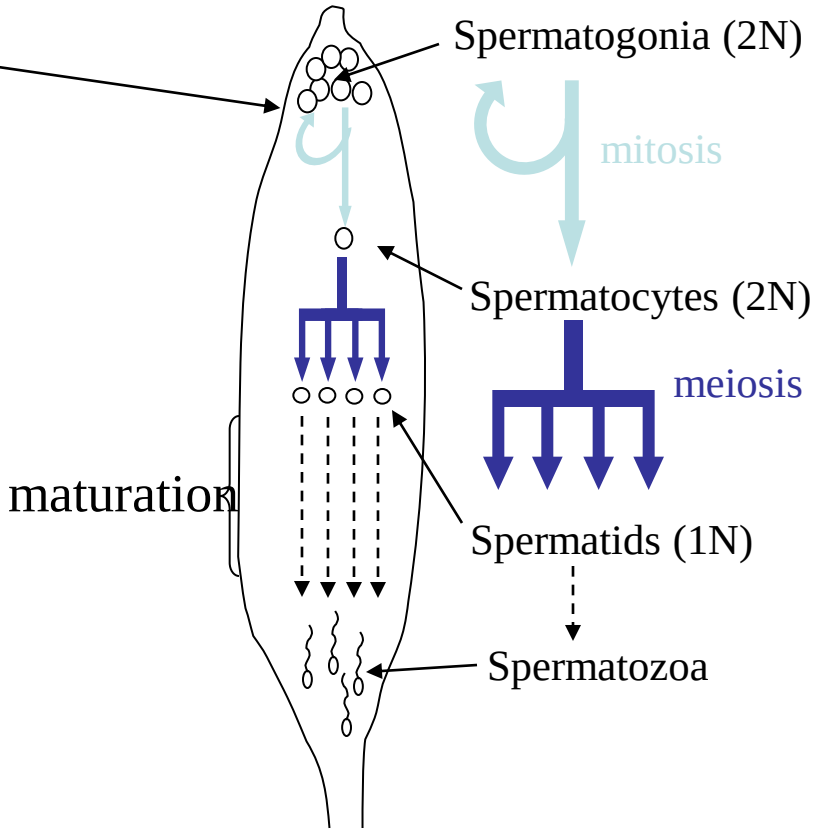
- Usually each testis consists of a series of testis tubes or follicles ranging in number from **one in Coleoptera to over 100 in grasshoppers.**

- The **accessory glands** become functional in adult insects, their secretions are involved in producing the **spermatophore.**

- **Mushroom glands in cockroaches and mantids**

Spermatogenesis

- Occurs in sperm tubes
  - May be continuous process
  - May occur once in the life cycle
- Spermatozoa exit sperm tubes
- Stored in seminal vesicles

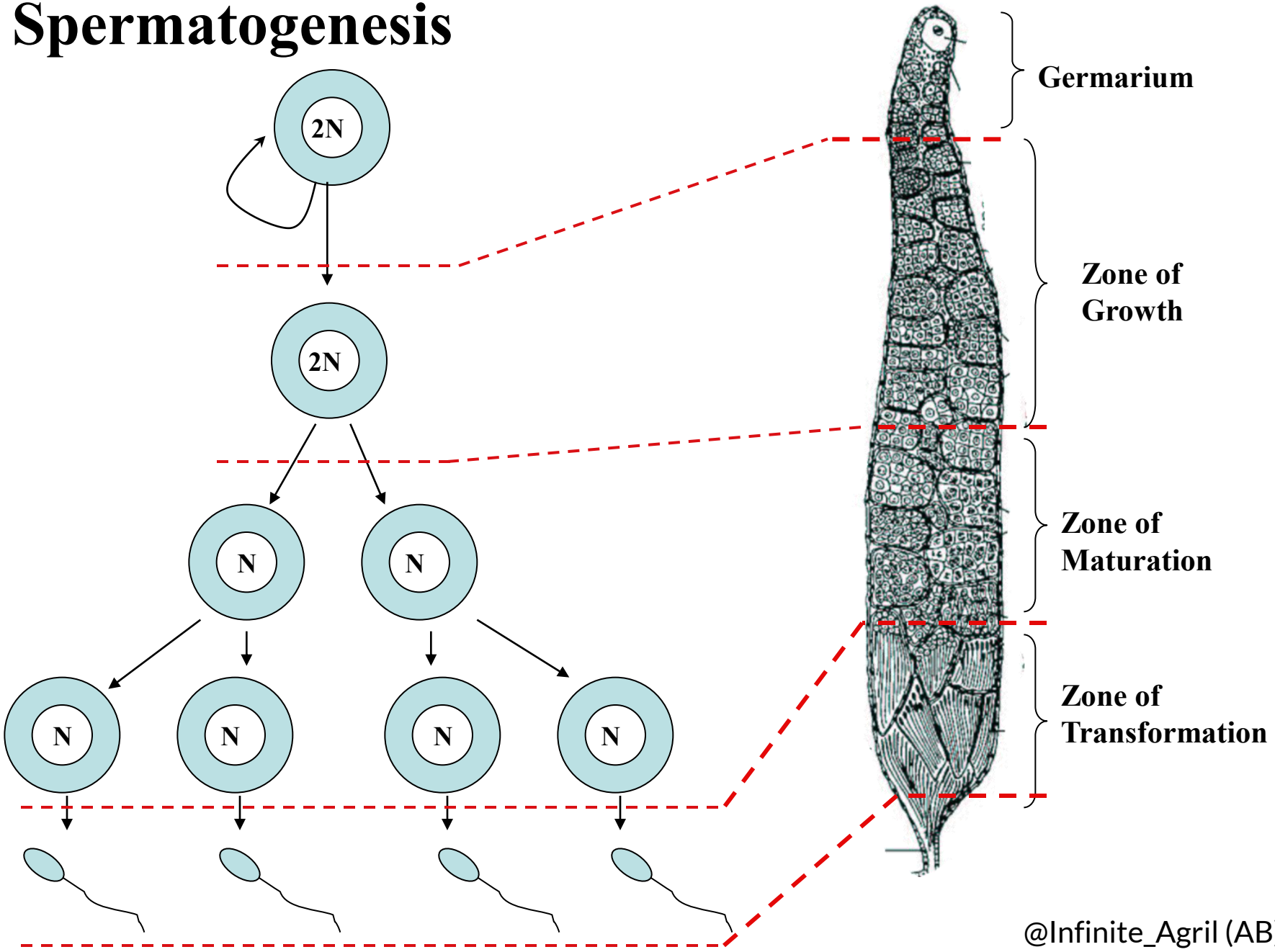


Sperm Transfer

- **Most Apterygota**:
  - **Indirect sperm transfer**
  - Requires spermatophore and generally humid conditions
- Pterygota generally:
  - Direct transfer
  - Requires copulatory structures
- Exception: traumatic insemination
  - Cimicidae
  - Penis inserted through body wall
  - Sperm delivered into hemolymph

Packages the sperm in a spermatophore

Spermatogenesis



Reproductive Strategies-I : “To Lay Eggs or Not To Lay Eggs”

- Oviparity
- Ovoviviparity
- Viviparity

Types of Reproduction :

1. **Oviparity** : Insects reproduce by laying eggs e.g.: **moths and butterflies.**

2. **Viviparity** : It is the phenomenon of reproduction where the female gives birth to the young ones instead of laying eggs.

(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**

ii) Adenotrophic viviparity : 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 which contains milk that have lipids and proteins.
Eg.**Tsetse fly**

iii) Pseudoplacental viviparity: Little (or) no yolk.
Nourishment- pseudoplacenta
e.g.: Psocoptera, Dermaptera, **aphids** etc.,

iv) Haemocoelous viviparity: Eggs are retained within the haemocoel e.g: **strepsipterans** & some larvae of **cecidomyids** (Diptera)

Reproductive Strategies -II : Who Reproduces?”

- Paedogenesis
  - Reproduction by larval insects
- Parthenogenesis
  - Development without fertilization
  - Unfertilized eggs produce:
    - Males (arrhenotoky) in Hymenoptera
    - Females (thelytoky) in acridids in aphids
    - Both (amphitoky), some wasps
- Polyembryony

Parthenogenesis: It is the ability of the females to reproduce without fertilization / copulation with males.

Sporadic : occurs occasionally e.g.: silkworm.

- **Constant** : occurs regularly. e.g.: thrips
- **Cyclic** :alternation of generations where parthenogenesis occur in alternation with the sexual reproduction. e.g.: aphids.

Paedogenesis (or) Neoteny: 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.

Larval paedogenesis : Gall midges

Pupal paedogenesis : Blister beetle, *Miaster* sp.

Polyembryony : Found in some endoparasitic groups only Single egg results in 2 to 'several thousand' larvae eg. ***Platygaster oryzae***

- **Hermaphroditism** : Both male and female gonads are present in the same individual.

  Functional hermaphroditism - *Icerya purchsi* .

  Non functional -stonefly, *Perla marginata*

- **Gynandromorphs (genetic mosaics)**
  - **Intersexes** (genetically uniform, result from unstable development)
  - Eg. **Mutant Drosophila**

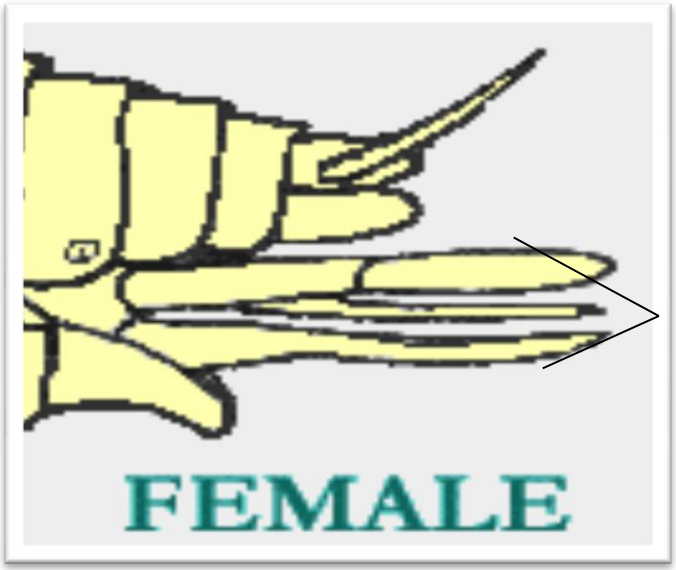
- Normal development in some **scale insects**
  - Female scales have both male and female gonads
  - Eggs are self-fertilized
  - In some scale insect species, **males are rare**

1. Epimorphic development: The young one after hatching from the egg consists of **definite number of segments and the same number** is maintained throughout.

2. Anamorphic development: The young one hatches with only **8 segments and the rest of the segments** are added during post embryonic development.
e.g. **Protura.**

Haplodiploidy-Honey bee

clasper



ovipositor

Classification of insects

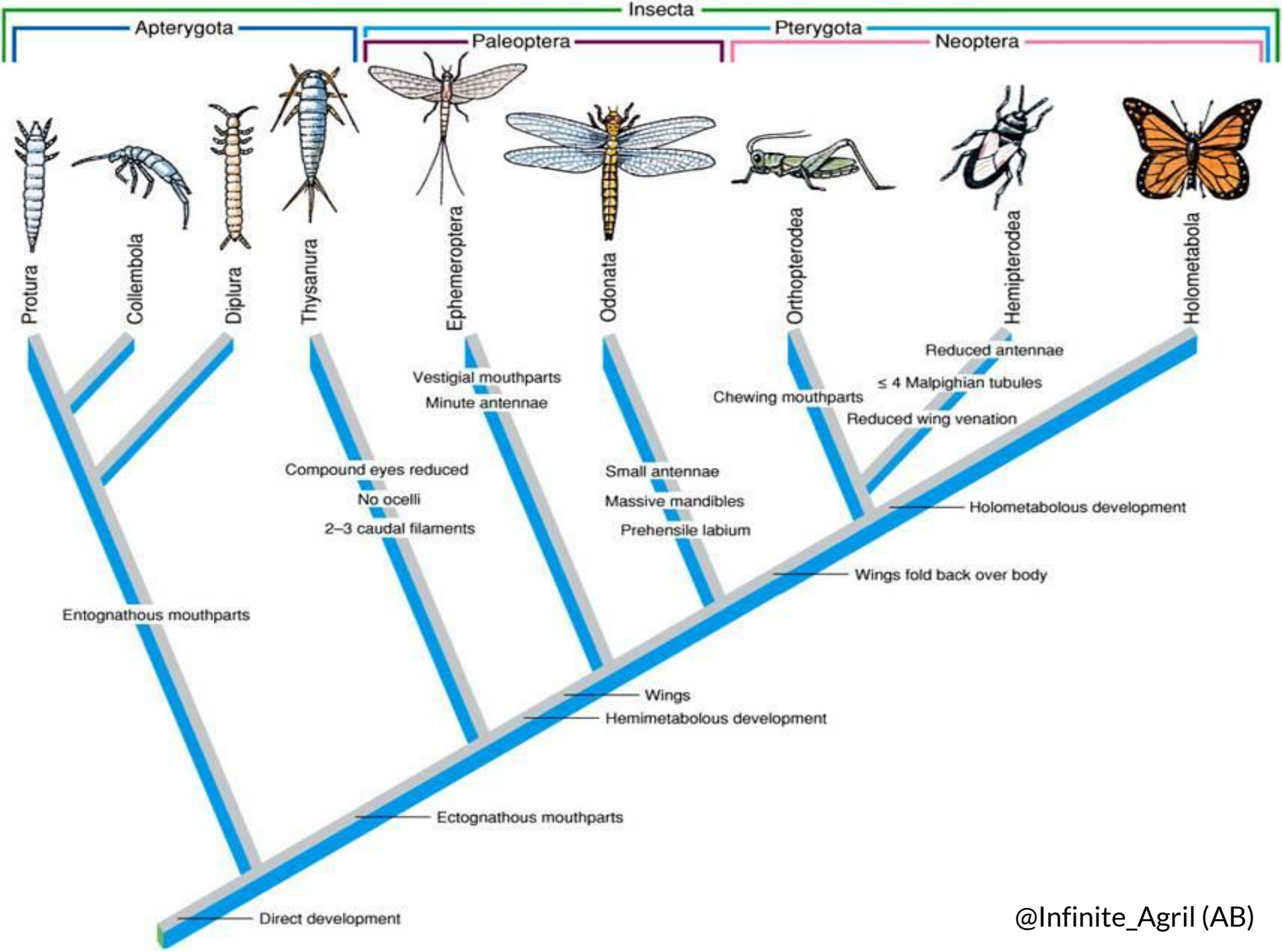
Lecture 15-20

- **<u>Characters of Class insecta</u> :**

1. Head, thorax and abdomen
2. 3pairs of legs, hence the name **Hexapoda**
3. 1 or 2pairs of wings
4. A pair of antennae
5. Respiration -**trachea**
6. Genital opening situated at the posterior end
7. Presence of metamorphosis
8. Possess **exoskeleton**
9. Excretion is mainly by **malpighian tubules**

Characters of Sub Classes:

Apterygota(Ametabola)	Pterygota(Metabola)
Primarily wingless	**Winged and secondarily wingless**
Monocondyle	Dicondyle
Not	Malphigian tubules are present
Adults have pregenital abdominal appendages	Not
Abdominal segments are more in number (11 or 12)	Abdominal segments are secondarily reduced (8 to 10)
Adults moult several times	Adults donot moult



Characters of divisions of Sub class Pterygota :

Exopterygota (Hemimetabola) 17	Endopterygota (Holometabola) 9
Wings develop externally	**internally**
Metamorphosis simple and incomplete	Complete and complex
Immature stages (nymphs) resemble adults in structure and habits	Immature stages (lava) differ adults in structure and habits
No pupal instar	**Pupal instar present**

Relationships among Hexapoda

Collembola

Protura

Diplura

Entognatha

Hexapoda

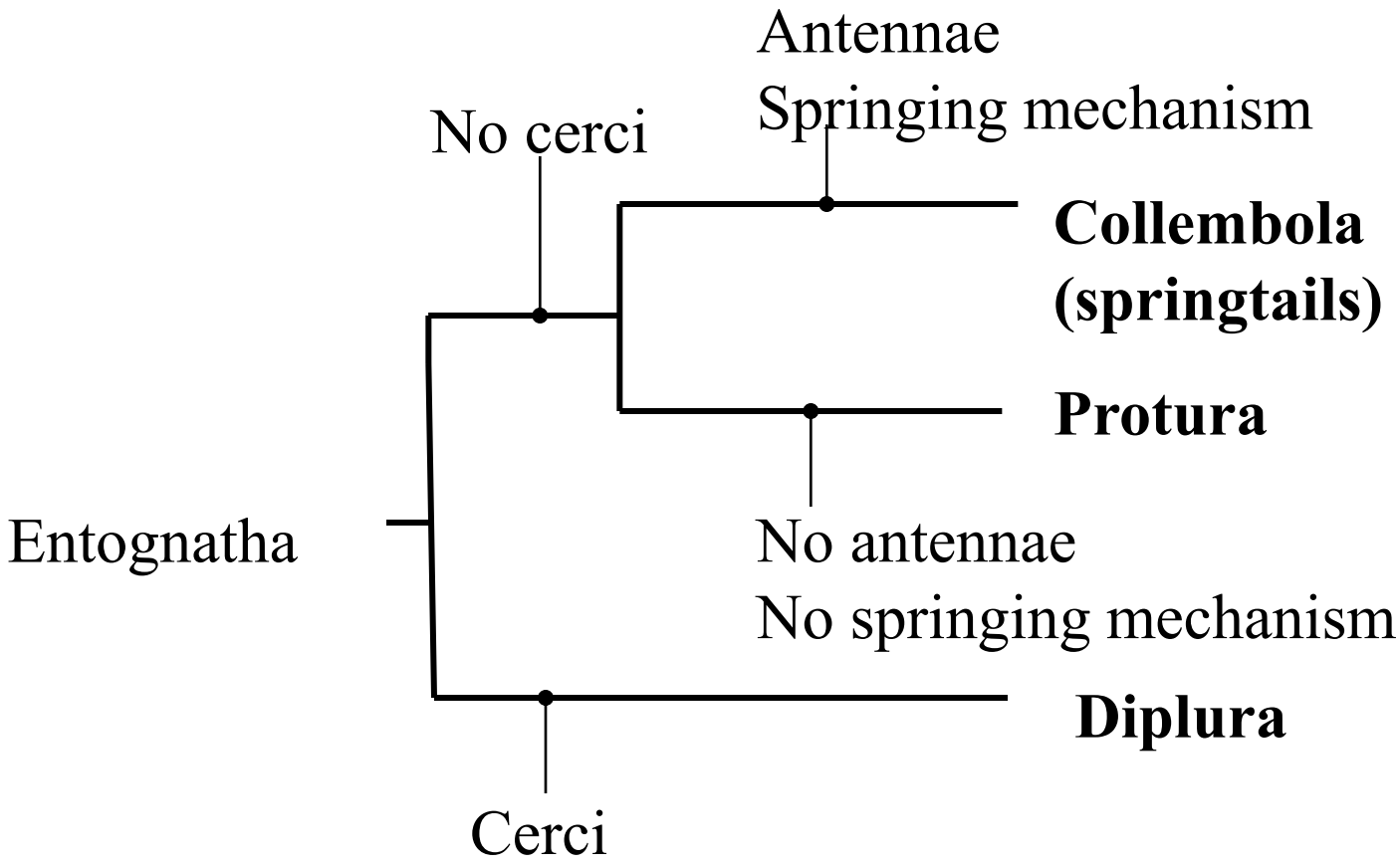
Insecta

Archaeognatha

Thysanura

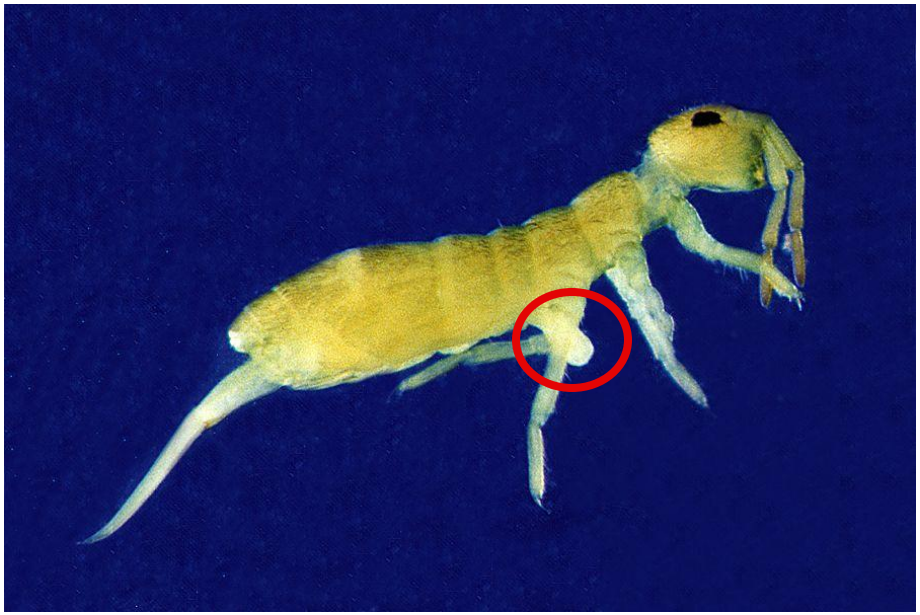
Pterygota

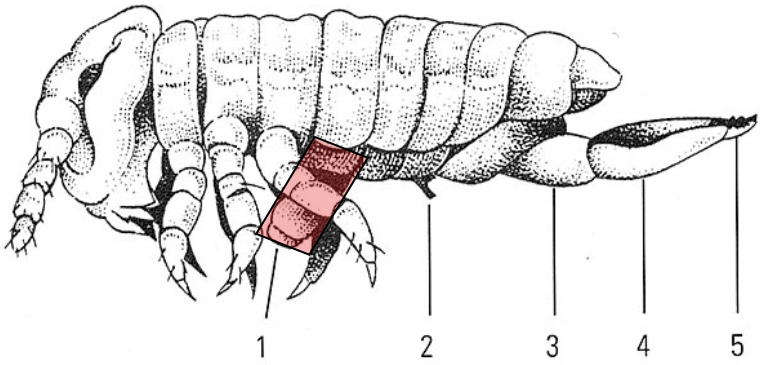
Phylogeny of the Entognatha



Collembola - Features

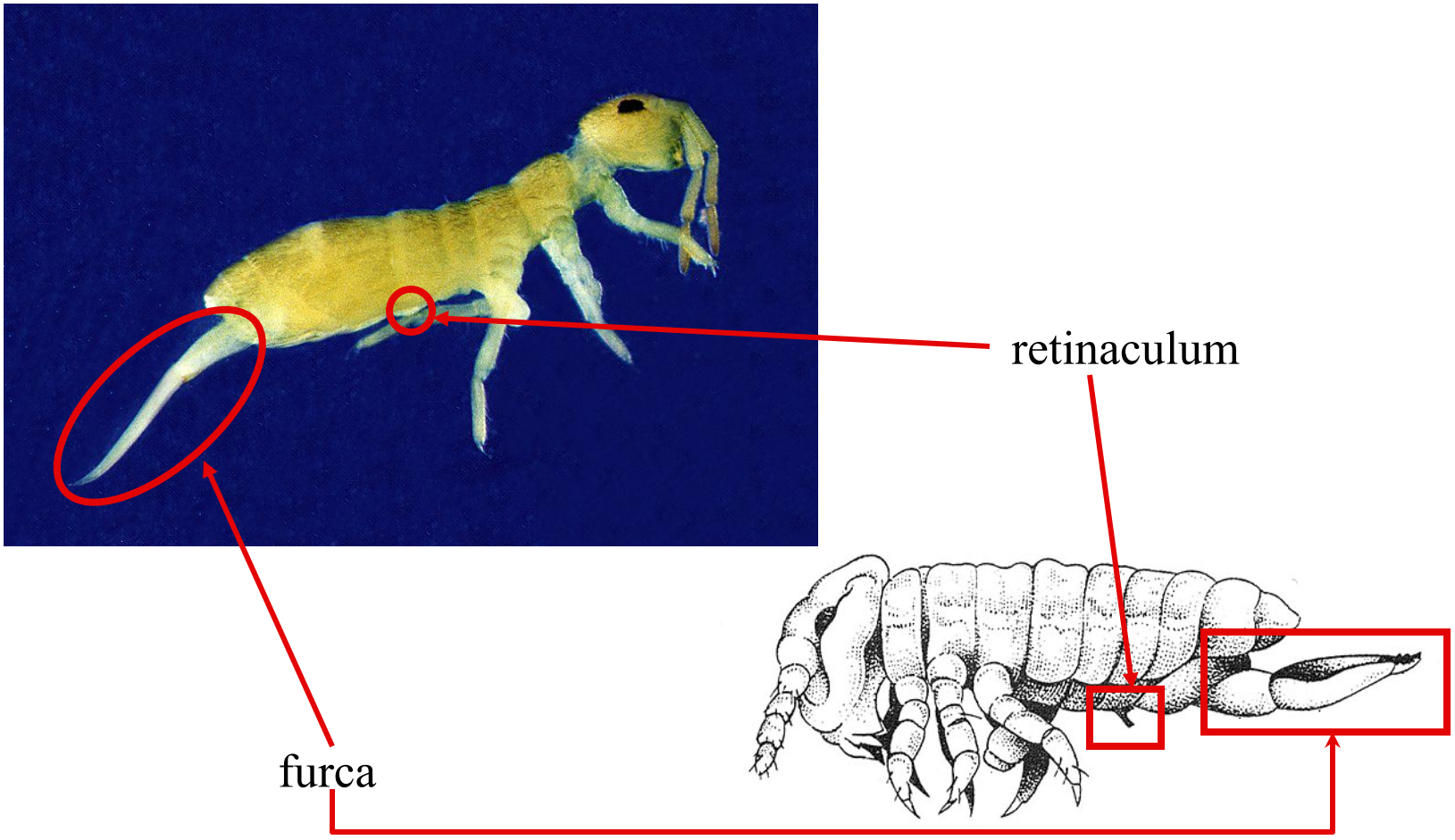
Collophore





Collembola - Features

Spring - Jumping Mechanism



CLASSIFICATION CATEGORIES

Kingdom: Animal

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Scolytidae

Genus: *Dendroctonus*

Species: *frontalis*

** Order Ephemeroptera - Mayflies, Shadflies, Dayflies

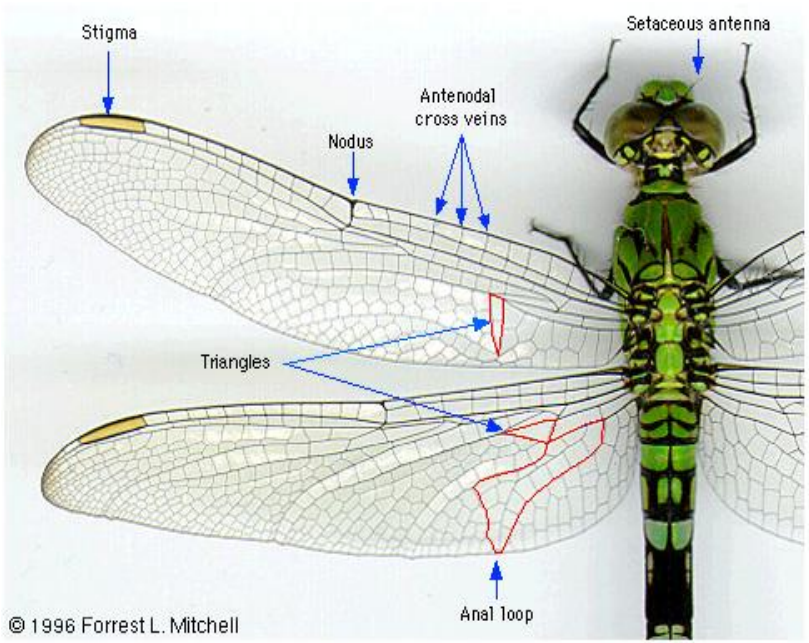
Ephemero-living for day ptera- wing

Sub-imago

Naiad-aquatic predators

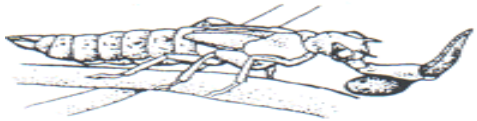
** Order Odonata-Dragonflies and Damselflies

Odon-tooth



Lacinea and Galea fused together – **Mala**

-Naiad(aquatic predators)-Labium with two hooks at apex-**mask**-useful to capture the prey



Suborders :

Ansioptera	**Zygoptera**
Strong fliers	Weak fliers
Dragonflies	**Damselflies**

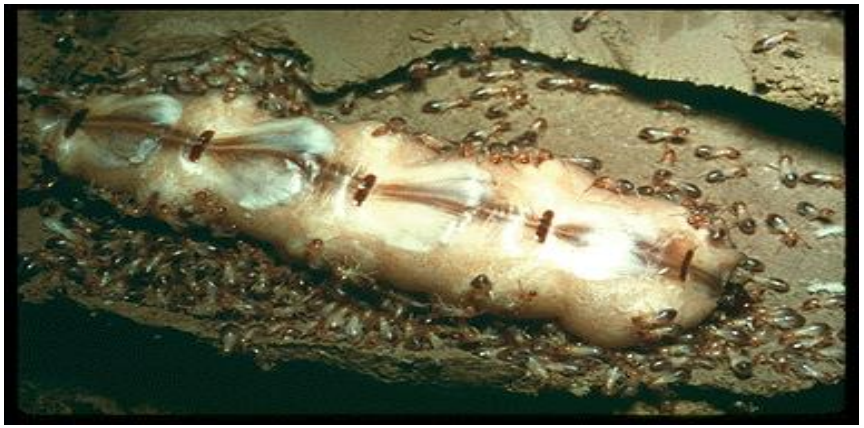
Order Plecoptera - stoneflies

** Order Dictyoptera: Cockroaches, praying mantids

Dictyon-network

Sub orders : Blattaria **Mantodea**

** Order ISOPTERA :TERMITES Iso-equal



Termite workers and damage to wooden structure

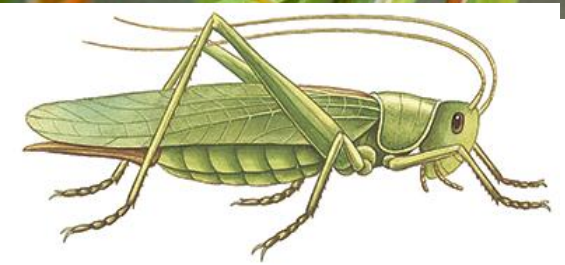
Castes: King, queen, workers, soliders

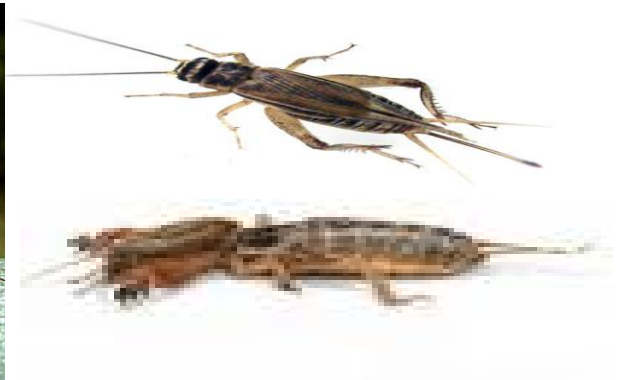
- ❖Termitaria: Place of living
- ❖Royal cell, Fungal garden, Forage tunnel
- ❖Termitophiles: Other organisms in termitarium

Obesity: Physiogastery

Colony multiplication : Swarming, Budding, Sociatomy

Trophallaxis-Mutual exchange of alimentary fluid Oral and anal





**** Order Orthoptera: Ortho- Stright Grasshoppers**

Sub orders:

Caelifera,	**Ensiefera**
Acrididae	**Tettigonidae**
Short horned Grasshoppers, **Locust**	Long horned Grasshoppers, Katydids and Bush crickets
Femoro-alary type	Alary type

Gryllidae

Crickets

Gryllotalpidae

Mole crickets

Order Dermaptera: earwigs Derma-Skin

**** Order Hemiptera:** **Hemi-half**

These are the true bugs, Cicadas, aphids, scales and spittlebugs

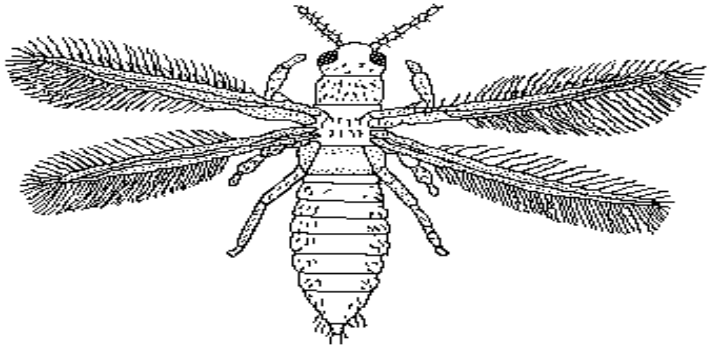
Sub orders :

Sternorrhyncha

Heteroptera

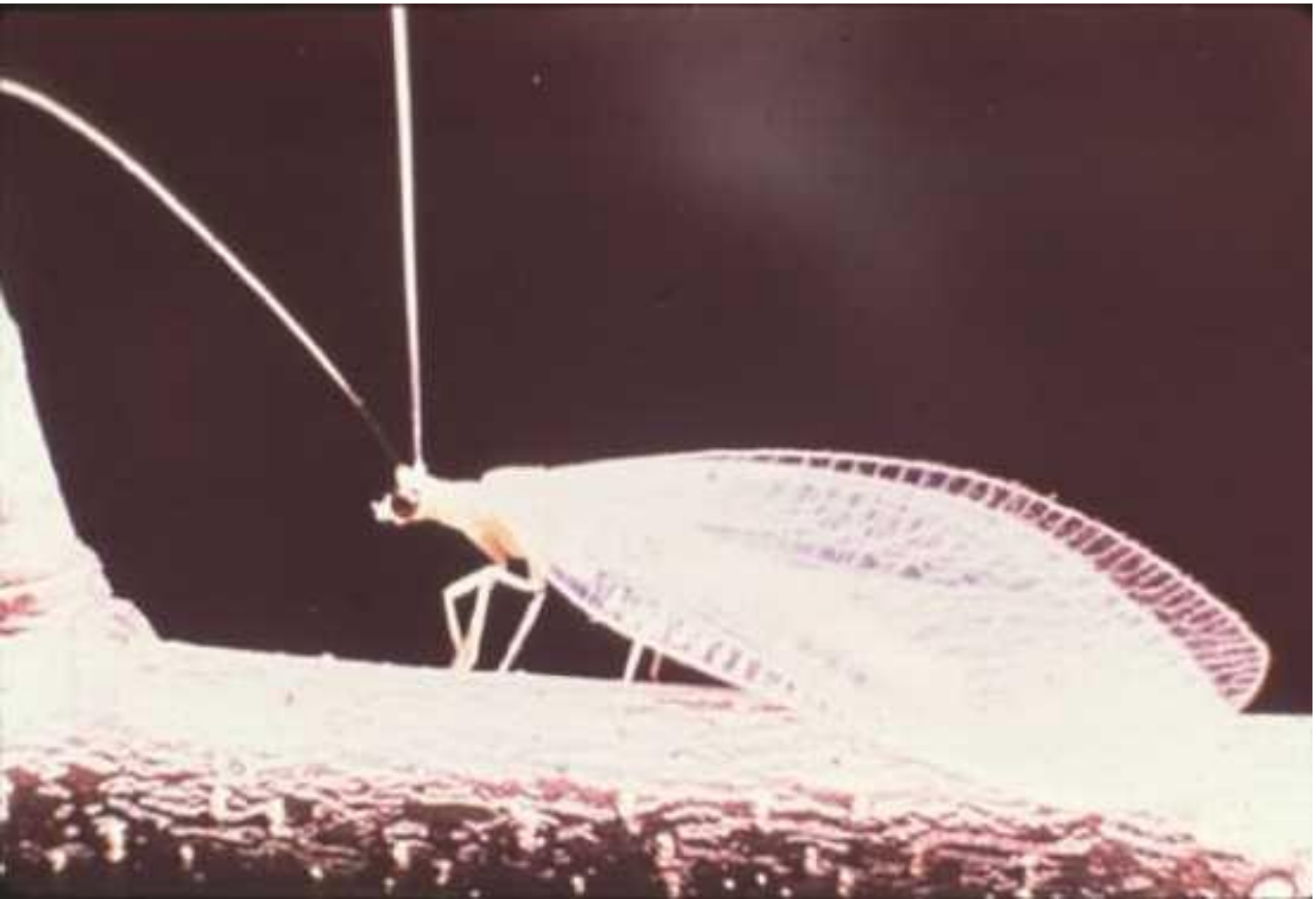
Auchenorrhyncha

Order Thysanoptera: Thrips
"fringe wing"



Suborders:
Terebrantia and Tubulifera

Order Neuroptera: Lacewings
“nerve wing”



@Infinite_Agril (AB)

** Order Coleoptera: Beetles Coleo-sheath

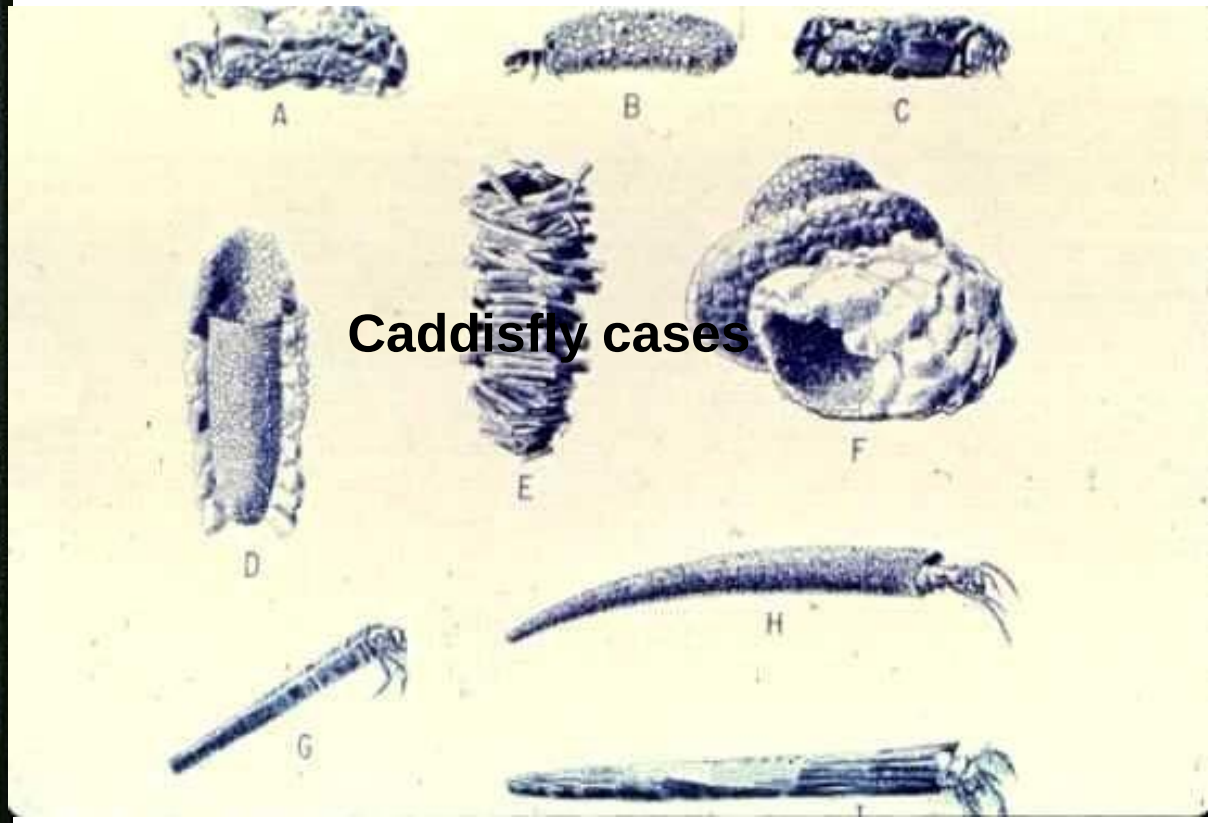
Sub orders : Adephaga and Polyphaga

Goliath beetles

Order Mecoptera: Scorpionflies
“long wing”

@Infinite_Agril (AB)

Order Trichoptera: Caddisflies Tricho-hair



Caddisfly cases

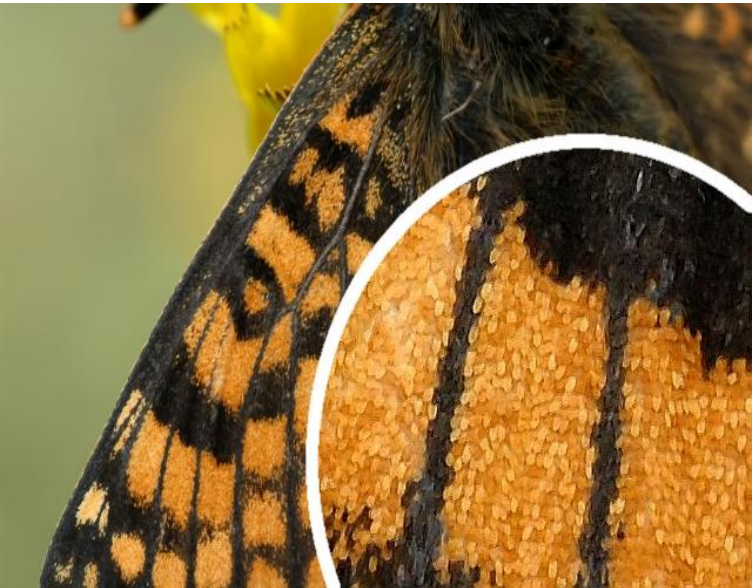
** Order Lepidoptera: Moths & Butterflies

Lepido-scale

Sub orders

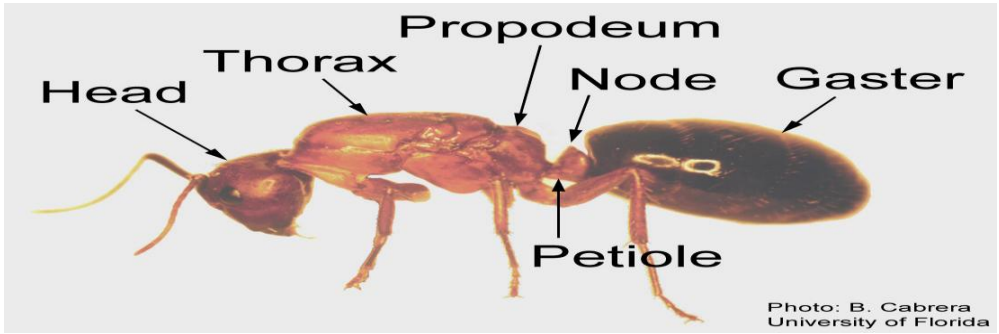
Ditrysia (Female insect have two pores- copulatory pore on 8 and egg pore on 9)

Monotrysia –Female insect only one pore



Butterflies - Nymphalidae (fritillaries)

** Order Hymenoptera: Bees, Wasps, Ants & Sawflies
"membrane wing"

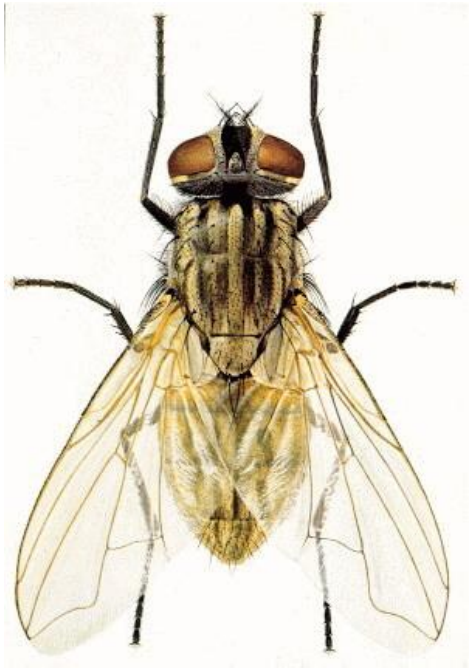


Suborders :

Symphyta	**Apocrita**
No waist	Waist
Sawflies	**Aculeata (stinging forms)**
	Parasitica (piercing forms)

** Order Diptera: True Flies

Di-Two



Sub orders

Nematocera –Mosquitoes, gall midges

Brachycera-

Robber flies, Horse flies

Cyclorrhapha-

House fly,

Hover flies, Fruit flies, Dog fly

Exopterygota (Insects having simple metamorphosis)

1. Ephemeroptera (May flies)
2. Odonata (Dragon flies & damsel flies)
3. Plecoptera (Stone flies)
4. Grylloblattodea (Grylloblattids)
5. Mantophasmotodea : (Gladiator,….)
6. Orthoptera (Locusts and grass hoppers)
7. Phasmida (Walking sticks, leaf insects & stick insects)
8. Dermaptera (Ear wigs)
9. Embioptera (Web spinners)
10. Dictyoptera (Cockroaches and mantids)
11. Isoptera (White ants or termites)
12. Zoraptera (Zorapterans)

13. Psocoptera (Psocids, book lice)
14. Mallophaga (Bird lice)
15. Siphunculata or Anoplura (sucking lice)
16. Hemiptera (Plant bugs)
17. Thysanoptera (Thrips)

Endopterygota (Insects having complex metamorphosis)

1. Neuroptera (Ant lions and lace wings)
2. Coleoptera (Beetles, weevils)
3. Strepsiptera (Stylopids)
4. Mecoptera (Scorpion flies)
5. Siphonoptera (Fleas)
6. Diptera (Flies, midges, mosquitoes)
7. Lepidoptera (Moths and butterflies)
8. Trichoptera (Caddis flies)
9. Hymenoptera (Ants ,bees, wasps)

Mantophasmatodea

Hemimetabola

- incomplete development (egg, nymph, adult)

Orthopteroid

- closely related to Grylloblattodea

Distribution: Rare. Found only in Tanzania, Namibia, and the southwestern corner of South Africa.

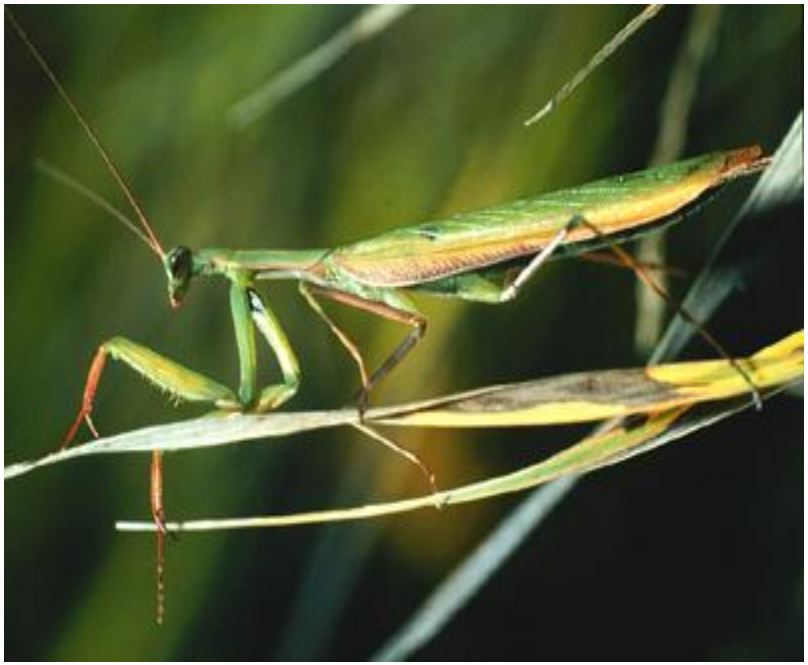
•Life History & Ecology

These insects are nocturnal predators. They live within rock crevices where they hide in clumps of grass and prey on spiders and other insects.

•Classification & Distribution

	North America	*Worldwide*
Number of Families	**0**	**1**
Number of Species	**0**	**6-8**

- The name Mantophasmatodea is an amalgamation of the order names for **praying mantids (Mantodea) and walking sticks (Phasmatodea**).
- It reflects the blend of physical and ecological characteristics found in these insects.



- Antennae slender, filiform
- Mouthparts mandibulate, hypognathous
- Body cylindrical
- Tarsi 5-segmented
- Secondarily wingless

Cerci short, one-segmented

MEGALOPTERA

- Originally the Alderflies and Dobsonflies were part of the Order Neuroptera. However, entomologists have now split the Order Neuroptera into three Orders:

- Megaloptera - Alderflies, Dobsonflies & Fishflies

- Neuroptera - Lacewings, Antlions & Mantidflies

- Raphidioptera - Snakeflies

Tarachoptera

•Apomorphic characters of Trichoptera and Lepidoptera could not be disclosed which suggests an independent origin and evolution from an amphiesmenopteran ancestor which was not the ancestor of the Trichoptera-Lepidoptera clade.

• The new order Tarachoptera is placed in the superorder Amphiesmenoptera

Economic importance of insects :

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

This classification is according to **TVR Ayyar**.

Insects of no economic importance:-

Insects of economic importance

A. Injurious insects

a) Pests of cultivated plants (crop pests)

(eg) cotton bollworm, Rice stem bores.

b) Storage pests

Insects feed on stored products and cause economic loss. (eg) Rice weevil, Pulse beetle.

c) Pest attacking cattle and domestic animals

Horse fly, Fleshfly, Flea and Lice.

d) House hold and disease carrying insects

Mosquitoes, houseflies, bed bugs, fleas

B. Beneficial insects

a) Productive insects

Silk worm, Honey bee, Lac insects

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

(a) As medicine eg.

Sting of honey bees- remedy for **rhenmatism and arthritis**

Canthridin - extracted from **blister beetle** –useful as **hair tonic.**

(b) **As food** - for animals and human being.

For animals- aquatic insects used as fish food. **Grass hoppers, 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 an hobby

(d) **Scientific research: Drosophila** and **mosquitoes** are useful in **genetic** and **toxicological** studies respectively.

Nutritional studies-Cockroach

(II) Helpful insects

Parasites, Predators, Pollinators ,Weed killers, Soil builders,Scavengers

d) House hold and disease carrying insects

i) Cockroaches, furniture beetle, sliver fish etc.

ii) Wasps, bees sting us. Hairy caterpillar nettling hairs are poisonous. Mosquitoes, bugs bite, piece and suck blood from us.

iii) Disease causing Mosquito- Malaria, Filariasis ,dengue fever.