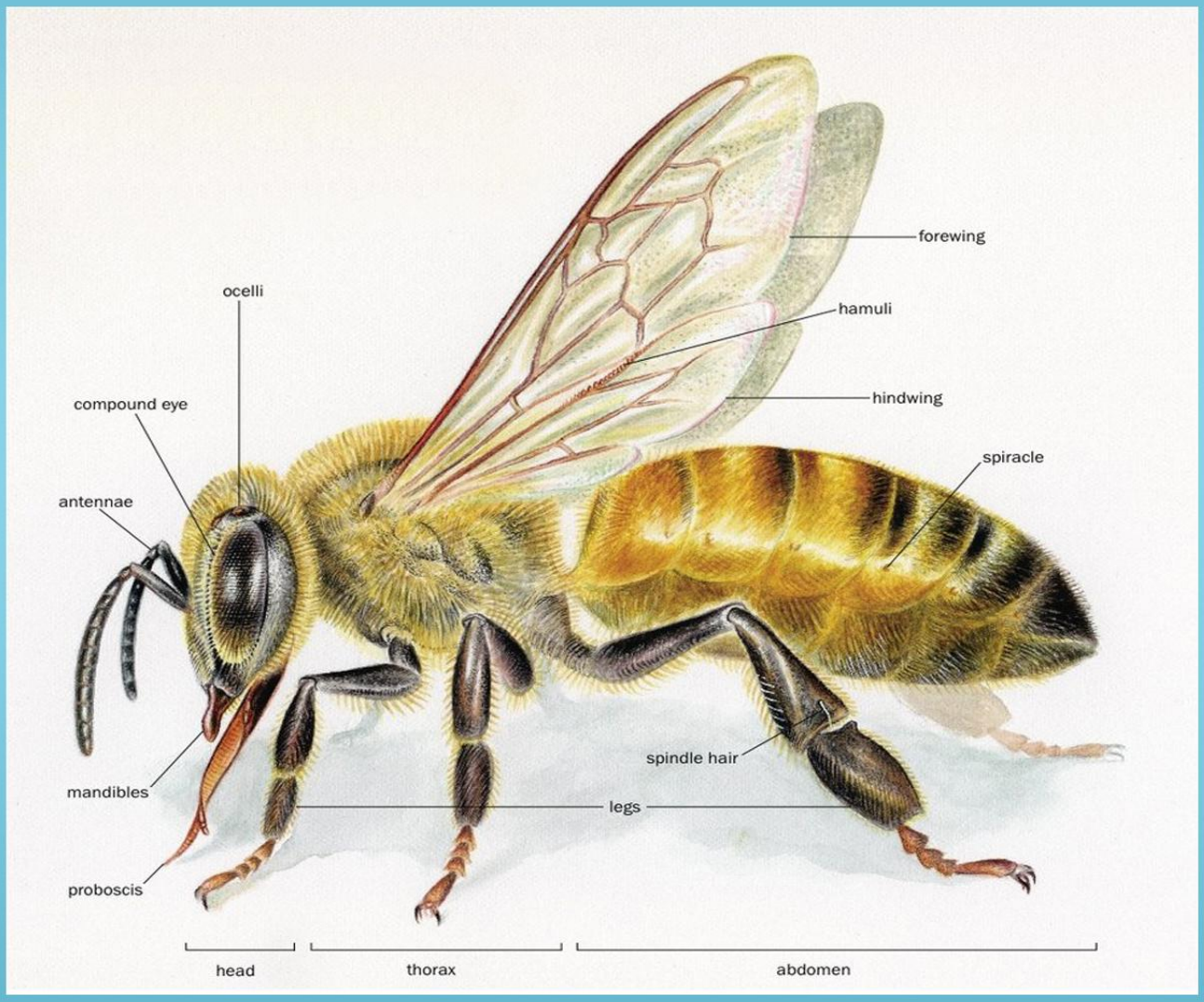
Development of e-Courses for B.Sc.(Agriculture) Degree Program



ENTO-231
Insect Morphology and Systematics

Insect Morphology and Systematics

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INDEX

HISTORY OF ENTOMOLOGY IN INDIA AND POSITION OF INSECTS IN ANIMAL KINGDOM AND ITS RELATIONSHIP WITH OTHER ARTHROPODA

History of Entomology in India

1758 - 10th edition of Systema Naturae Linnaeus with only **12 Indian insects** which was the earliest record.

1779 - Dr. J.G. Koenig - Medical Officer initiated the **work on** Indian insects on **scientific lines**. He also published a special account of the **termites** of Thanjavur District.

1782 - Dr. Kerr Published on account of **lac insect**.

1785 - **Asiatic Society of Bengal** started in Calcutta and **many papers** were published in the Societys publications.

1790 - Roxburgh (Botanist) published a **detailed** account of **lac insect**.

1791 - Dr. J. Anderson issued a **monograph** on **Cochineal scale insects**

1800 - Buchanan (Traveller) wrote on the **cultivation of lac** in India and on **sericulture** in some parts of South India. Denovan published Natural **History of Insects** which was the first contribution on the insects of Asia and was **revised in 1842** by West Wood.

1875 - Foundation of the **Indian Museum** at Calcutta

1883 - **Bombay Natural History Society** was started. After the foundation of these two organisations scientific studies received greater attention in India. Numerous contributions of Indian insects were published in the **Journal of the Bombay Natural History**.

1892 - Hampson issued four volumes on **months of India**

1893 - Rothney published on **Indian Ants** (earliest record of **biological pest control** in India) i.e. **White ants** attach on **stationary items** was kept free by **red ants**.

Government of India commenced the publication of the **Fauna of British India** series

1897 - Bingham's issued volumes on **"Hymenoptera'** (Ants, bees and wasps). Since than **volumes on other groups** of insects like Coleoptera (beetles), Hemiptera (bugs), Odonata (dragenfly and damselfly), etc., were published.

1889 - Indian Museum, Calcutta published the **Indian Museum Notes** in five volumes.

1903 - which contributed much on **economic entomology** and **applied entomology** in India. 19th Century marks the major progress and expansions in the field of applied entomology.

1901 - (Lionel de Nicevelle) posting of the **first entomologist** to the Government of India.

1905 - Establishment of **Imperial Agricultural Research Institute** at Pusa (Bihar). Subsequently this Institute was shifted to New Delhi as **Indian Agricultural Research Institute**.

1906 - “Indian Insect Pests” & “Indian Insect Life” Books by Professor Maxwell. Lefroy, Head, Division of Entomology, IARI, New Delhi. Subsequently **State Governments** also took up entomological work. **Madras, Punjab and Uthar Pradesh** appointed their first Government Entomologists in **1912, 1919 and 1922** respectively.

1914 - T.B. Fletcher, the first Government Entomologist of Madras State, published his book "Some South Indian Insects".

1916 - The **Natural History Section** of the Indian Museum was formed as the **Zoological Survey of India**.

1921 - Indian Central Cotton Committee to investigate on pests of cotton.

1925 - Indian Lac Research Institute

1940 - Dr. T.V. Ramakrishna Ayyar published the book "Handbook of Economic Entomology" which met the long felt need of the students of Agriculture and agricultural scientists as well.

1968 - Dr. M.S. Mani's "General Entomology"

1969 - Dr. H.s. Pruth's "Textbook of Agricultural Entomology". Dr. Pradhan's "Insect Pests of Crops"

1946 - Government of India started the **"Directorate of plant protection"**.

1960 - "The Desert Locust in India" monograph by Y.R. Rao.

1969 - "The monograph on Indian Thysanoptera" by Dr. T.N. Ananthakrishnan

FACTORS FOR INSECTS ABUNDANCE

Measures of dominance

1. **More number of species:** In the animal kingdom more than 85 per cent of the species belongs to insect group. Total number of insects described so far is more than 9 lakhs.

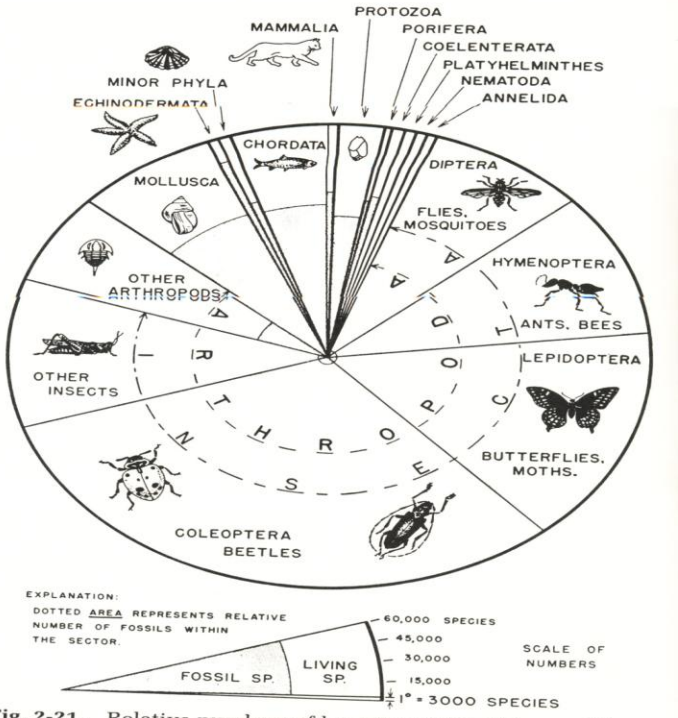


Fig. 2-21. Relative numbers of known species, living and fossil, of various phyla. (From Muller and Campbell, 1954, with permission of *Systematic Zoology*).

2. **Large number of individuals in a single species:**

   e.g., Locust swarm comprising of 10^9 number of individuals, occupying large area.

3. **Great variety of habitats:** Insects thrive well under varied conditions.

4. **Long geological history:** Insects were known to occupy this earth for more than 350 million years, which is a good track record. This has given the insects great variety of adoptions under different conditions.

Reasons for dominance

1. Capacity for flight: Insects posess wings, which is the lateral extension of exoskeleton. Insects are the earliest animals and the only flying invertebrates. Flight is used for the following purpose.

i. To seek food, mate, shelter and oviposition sites

ii. To colonize in a new habitat and also to exchange habitat.

iii. To escape from enemies and unfavourable conditions.

iv. To migrate (i.e. for long distance travel e.g. Locusts)

2. Adaptability or Universality: Insects are the earliest groups to make their life on the earth and to occupy vast habitats of soil and water.

i. Found in wide range of climatic conditions, from -50°C to 40°C.

ii. ***Psilopa petroli*** found in crude petroleum well.

iii. ***Ephydra*** fly living in great salt lake.

iv. Every flowering plant providing food for one or many **Phytophagous** insects.

v. Even the decomposing materials serving as food for many **Saprophagous** insects.

vi. Many **Carnivorous** insects are parasitic on other animals and insects.

3. Size: Majority of insects are small conferring the following physiological and ecological advantages.

i. Exploitation of numerous ecological niches inaccessible for other animals.

ii. Less **space, food, time and energy** requirements for development and sustaining life.

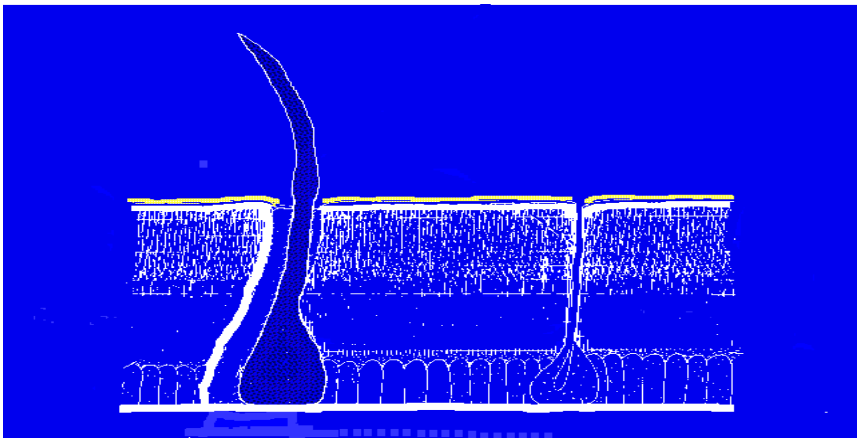
iii. Energy Utilization maximum.

iv. Less gravitational effect.

v. Muscular action and tracheal respiration more effective.

vi. Easy escape from enemies.

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



EXOSKELETON CROSS SECTION

Uses: i.Act as external armour

Ii.Provides space for muscle attachment

Iii.Prevents water loss

5. Resistance to desiccation: Insects minimise the water loss from their body surface through the following processes.

I. **Prevention of water loss:**

i. Lipids and polyphenols present in the **Epicuticle** acts as water proofing.

ii. **Was layer** with closely packed wax molecules prevents escape of water.

iii. **Spiracles** are closed to prevent water loss.

iv. In the egg stage **shell development** prevents water loss and desication of inner embryos.

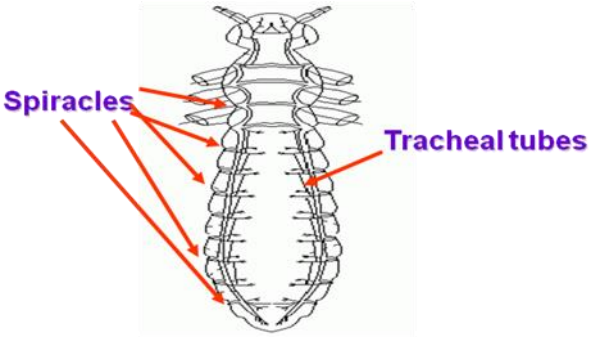
II. Conservation of water

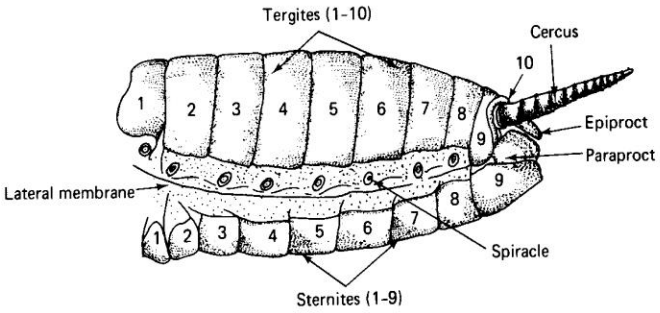
i. Capable of utilizing **metabolic water**

ii. **Rectal resorption** of water from faeces.

iii. Terrestrial insects use less quantity of water to remove the nitrogenous waste (**Uric acid**) which is water insoluble.

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





7. Reproductive potential: Reproductive potential of insect is high due to the following reasons:

i Egg laying capacity (**fecundity**) is high. e.g., Queen termite lays 6000 - 7000 eggs per day for 15 long years.

ii. Development period is short. e.g., Corn aphid produces 16 nymphs per female which reaches the adulthood within 16 days. There by one generation is completed within a short period of 16 days, which favours greater genetic changes in the insect population, like quicker development of insecticide resistant strains.

iii. Careful selection of egg lying sites and protection of eggs.

iv. Exhibits parental care like **progressive provisioning** (e.g. bees) and **mass provisioning** (e.g. Wasps)

v. Presence of special types of reproduction other than oviparity and viviparity.

* **Polyembryony:** Development of many individuals from a single egg. e.g. parasitic wasps.

* **Parthenogenesis:** Reproduction without male or without fertilization, e.g. aphids

* **Paedogenesis:** Reproduction by immature stages. e.g. certain flies.

8. Complete metamorphosis: More than 82 per cent of insects undergo complete metamorphosis (**Holometabolous insects**) with the following four stages.

i. **Egg:** Inactive, inexpensive, inconspicuous and embryo develops inside.

ii. **Larva:** Active, feeds, digests, grows and store food.

iii. **Pupa:** Inactive, internal reorganisation and resist adverse conditions.

iv. **Adult:** Active, reproduce and disperse

As the larval and adult food sources are different, competition for food is less.

9. Defense mechanisms: By using the following defense mechanisms, insects escape from the enemies to increase their survival rate.

i. **Behavioural:** Thanatosis - insects pretends as if dead. e.g. some beetles.

ii. **Structural** e.g. hardened forewings of beetles known as **elytra** protect the beetles from predation of birds.

iii. **Colourational:** Presence of protective colours. e.g.Stick insects

iv. **Chemical:** Presence of defensive chemicals. e.g. Bees producing venom

10. Hexapod locomotion: Insects uses 3 legs at a time during locomotion, while the remaining 3 legs are static, which gives greater stability.




CLASSIFICATION OF PHYLUM ARTHROPODA UPTO CLASSES & POSITION OF INSECTS IN ANIMAL KINGDOM AND ITS RELATIONSHIP WITH OTHER ARTHROPODA

Insects are invertebrates grouped in the phylum Arthropoda (Subphylum : Uniramia)

Characters of the Phylum Arthropoda: (Arthro-joint, poda-foot)

i. Segmented body

ii. Segments grouped into 2 or 3 regions known as Tagmosis

iii. Renewable chitinous exoskeleton

iv. Grow by moulting

v. Bilateral symmetry

vi. Body cavity filled with blood-Haemocoel

vii. Tubular alimentary canal with mouth and anus

viii. Dorsal heart with ostia

ix. Dorsal brain with ventral nerve cord

x. Striated muscles

xi. No cilia

xii. Paired segmented appendages

Classification: 7 classes.

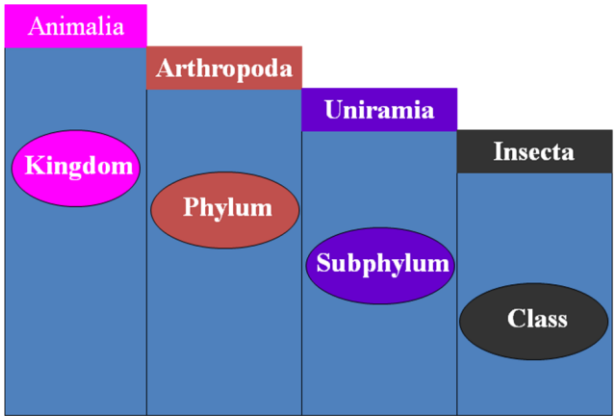
Phylum : Arthropoda

Classes :

1. Onychophora (claw bearing)e.g. Peripatus
2. Crustacea (Crusta - shell)e.g. Prawn, crab, wood louse
3. Arachnida (Arachne - spider)e.g. Scorpion, spider, tick, mite
4. Chilopoda (Chilo - lip; poda - appendage)e.g. Centipedes
5. Diplopoda (Diplo - two; poda- - appendage)e.g. Millipede
6. Trilobita (an extinct group)

7. Hexapoda or Insectae.g. Insects.

POSITION OF INSECTS IN ANIMAL KINGDOM



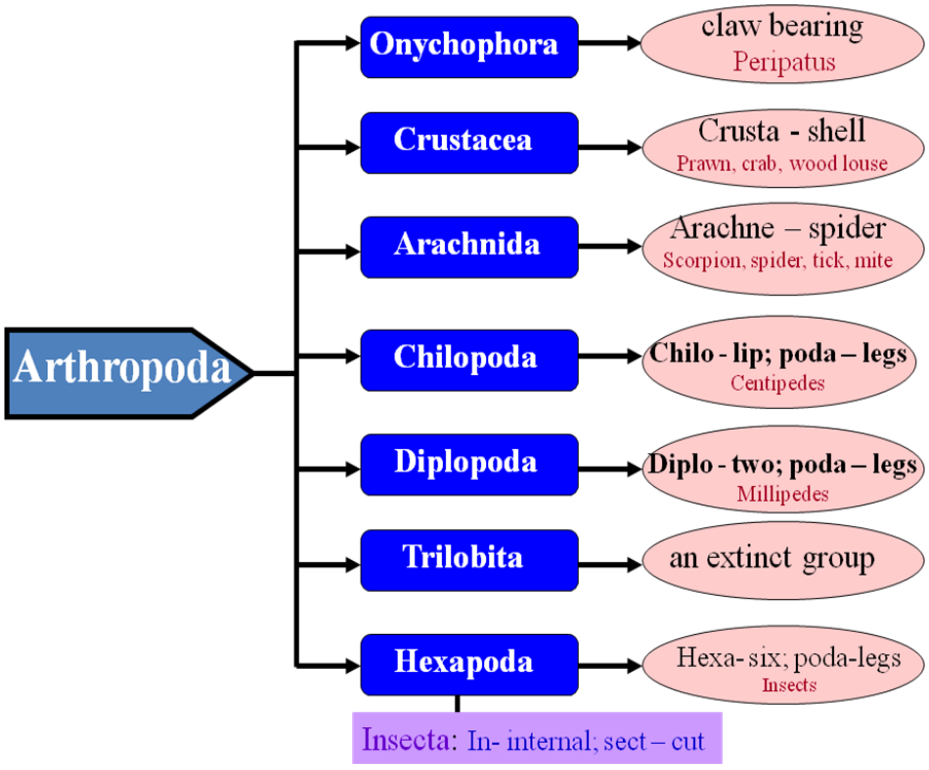


Table 1. Relationship of Insects with other Arthropods

Characters		Onychophora	Crustacea	Arachnida	Chilopoda	Diplopoda	Insects (Hexapoda)
1.	**Habit**	Terrestrial	Aquatic and few terrestrial	Terrestrial	Terrestrial	Terrestrial	Many terrestrial and very few aquatic
2.	**Body regions**	Not distinct	Two-Cephalothorax and abdomen	Three-Pro, meso and Metasoma eg. Scorpion Two-Pro and Opisthosoma eg. Spider	Two-Head and multisegmented trunk	Two-Head and multisegmented trunk	Three-Head, thorax and abdomen
3.	**Antenna**	1 pair	2 pair - Antennule and Antenna	No antenna	One pair	One pair	One pair
4.	**Visual organs**	Not distinct	One pair-Stalked compound eyes	One pair-simple eyes	One pair-simple eyes	One pair-simple eyes	Both simple eyes and compound eyes (one pair)
5.	**Locamotor organs**	Many pairs of unjointed legs	Minimum five pairs of biramous legs	Four pairs	One pair per segment (First pair of legs modified as poison claws)	Two pair per segment (No poison claws)	Three pairs of legs on three thoracic segments and two pairs of wings on meso and metathorax

6.	**Mouth parts**	Non mandibulate	Mandibulate (1 pair)	Non mandibulate, but possess chelicerae	Mandibulate - 1 pair	Mandibulate - 1 pair	Mandibulate - 1 pair
7.	**Respiration**	Cutaneous	Gill breathing	Book lungs (Scorpion) and tracheal (spiders)	Tracheal	Tracheal	Tracheal
8.	**Body fluid**	Haemolymph	Haemolymph	Haemolymph	Haemolymph	Haemolymph	Haemolymph
9.	**Circulatory system**	Heart with ostia	Heart with ostia	Heart with ostia	Heart with ostia	Heart with ostia	Heart with ostia
10.	**Development**	Anamorphosis	Anamorphosis	Metamorphosis absent-Scorpion; Metamorphosis present-mites	Metamorphosis	Metamorphosis	Metamorphosis
11.	**Habit**	Feed on organic matter	Herbivorus and Carnivorous	Phytophagous and predators	Carnivorous	Herbivorous	Phytophagous, predators and parasitoides
12.	**Special features**	Link between Annelida and Arthropoda	Calsification strengthens exoskeleton	Life cycle; Egg-larva-numph-adult larva with 3 paris of legs	Opisthogenital-gonopore present in the terminal	Progogenital-gonopore in 3rd segment	Genital structures on 8th and 9th abdominal segments. Brain with **proto,**

				and Nymph with 4 pairs of legs	segment		**deuto** and **tritocerebrum**

STRUCTURE AND FUNCTIONS OF INSECT CUTICLE AND MOULTING

Insect body wall is called as **Integument** or **Exoskeleton.** It is the external covering of the body which is ectodermal in origin. It is rigid, flexible, lighter, stronger and variously modified in different body parts to suit different modes of life.

Structure

Body wall consists of an inner cellular layer (**Epidermis**) and an outer non cellular part (**Cuticle**).

Epidermis

It is an inner unicellular layer resting on basement membrane with the following function.

i. Cuticle secretion

ii. Digestion and absorption of old cuticle

iii. Wound repairing

iv. Gives surface look

Cuticle

It is an outer non cellular layer comprising of three sub layers.

i. Endocuticle

Compared to others it is the inner and thickest layer. This layer is made up of **Chitin** and **arthropodin**. This layer is colourless, soft and flexible.

ii.**Exocuticle**

Outer layer, much thicker with the composition of **Chitin** and **sclerotin**. This layer is dark in colour and rigid.

iii. **Epicuticle:** Outer most layer which is very thin. Pore canals present in the exocuticle helps in the deposition of epiculticle. This layer is differentiated into the following layers.

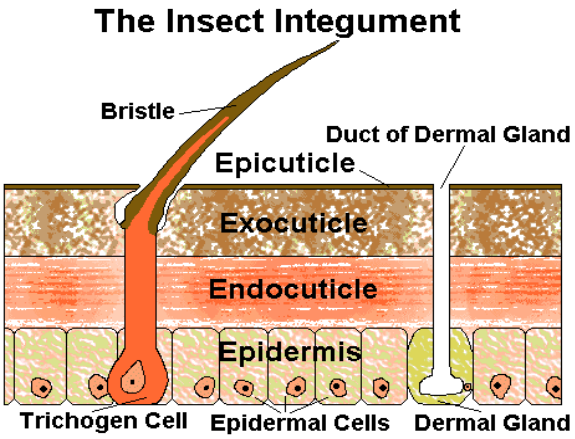
a. Inner epicuticle: It contains **wax filaments**

b. Outer epicuticle: It makes the contact with **cuticulin**

c. Cuticulin : Non chitinous polymerised lipoprotein layer.

d. Wax layer: It contains closely packed wax molecules which prevents desiccation.

e. Cement layer: Outer most layer formed by lipid and tanned protein. It protects wax layer.



Composition of cuticle

i.**Chitin:** It is the main constituent of cuticle, which is Nitrogenous polysacharide and polymer of **N-acetylglucosamine**. It is water insoluble but soluble in dilute acids, alkalies and organic solvents.

ii.**Arthropodin:** An untanned cuticular protein, which is water soluble.

iii.**Sclerotin:** Tanned cuticular protein, which is water insoluble.

iv.**Resilin:** An elastic cuticular protein responsible for the flexibility of sclerites, e.g., wing articulatory 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.

ii.**Apophysis:** Solid invagination of body wall.

CUTICULAR APPENDAGES

Non-cellular: Non-cellular appendages have no epidermal association, but rigidly attached. e.g. minute hairs and thorns.

Cellular: Cellular appendages have eipdermal association.

Unicellular

a. Clothing hairs, plumose hairs. e.g. Honey bee. Bristles. e.g. flies.

b. Scales - flattened out growth of body wall e.g. Moths and butterflies

c. Glandular seta. et. caterpillar

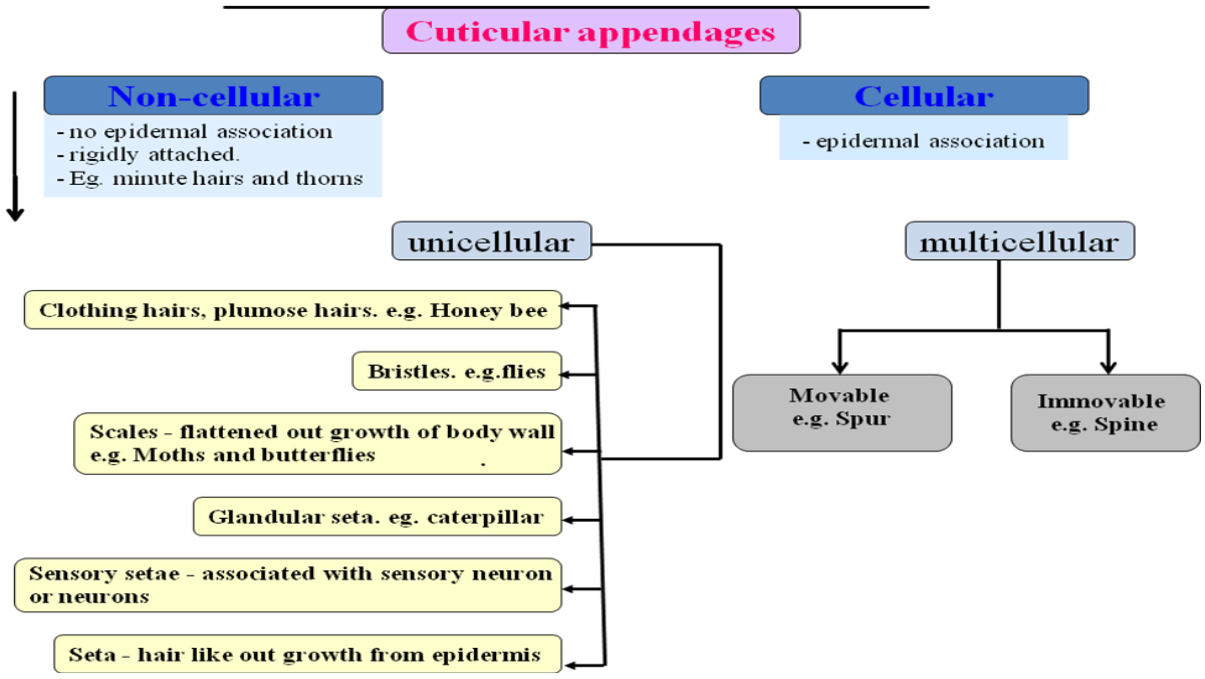
d. Sensory setae - associated with sensory neuron or neurons

e. Seta - hair like out growth (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**).

Multicellular

e.g. Spur - movable structure

Spine- Immovable structure



GLANDS

Cuticular glands are either unicellular or multicellular. Following are some of the examples.

i. Wax gland - e.g. Honey bee and mealy bug

ii. Lac gland - e.g. Lac insects

iii. Moulting gland secreting moulting fluid.

iv. Androconia or scent scale - e.g.moth

v. Poison gland - e.g. slug caterpillar

Functions of Body wall

i. Acts as **external armour** and strengthen external organs like jaws and ovipositor

ii. Protects the organs against physical aberation, injurious chemicals, parasites, predators and pathogen.

iii. Internally protects the vital organs, foregut, hindgut and trachea.

iv. Provides space for muscle attachment and gives shape to the body.

v. Prevents water loss from the body.

vi. Cuticular sensory organs helps in sensing the environment.

vii. Cuticular pigments give colour.

MOULTING (**Ecdysis**)

Ecdysis

Periodical process of shedding the old cuticle accompanied by the formation of new cuticle is known as **moulting** or **ecdysis**. The cuticular parts discarded during moulting is known as **Exuvia**. Moulting occurs many times in an insect during the immatured stages before attaining the adult-hood. The time interval between the two subsequent moulting is called as **Stadium** and the form assumed by the insect in any stadium is called as **Instar**.

Steps in moulting

1. Behaviroual changes: Larva stops feeding and become inactive.

2. Changes in epidermis: In the epidermis cell size, its activity, protein content and enzyme level increases. Cells divide miotically and increases the tension, which results in loosening of cells of cuticle.

3. Aolysis: **Detachment of cuticle** from epidermis

4. Formation of **Sub cuticular space**

5. Secretion of **moulting gel** in the sub cuticular space which is rich with chitinase and protease.

6. New epicuticle formation: Lipoprotein layer (cuticulin) is laid over the epidermis.

7. Procuticle formation: Procuticle is formed below the epicuticle.

8. Activation of moulting gel: Moulting gel is converted into moulting fluid rich in enzymes. This activates endocuticle digestion and absorption.

9. Wax layer formation: Wax threads of pore canals secrete wax layer.

10. Cement layer formation : Dermal glands secretes cement layer (Tectocuticle).

11. **Moulting:** This involves two steps

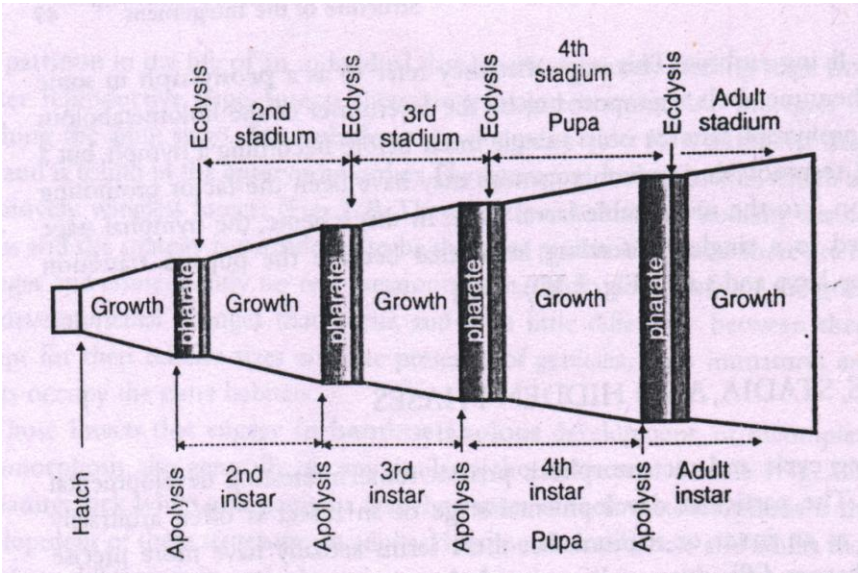
i. **Rupturing of old cuticle:** Insect increases its body volume through intake of air or water which enhances the blood flow to head and thorax. There by the old cuticle ruptures along prede-termined line of weakness known as **ecdysial line**

ii. **Removal of old cuticle:** Peristaltic movement of body and lubricant action of moulting fluid helps in the removal of old cuticle. During each moulting the cuticular coverings discarded are the cuticular of legs, internal linings of foregut and hindgut and trachea.

12. Formation of exocuticle: The upper layer of procuticle develops as exocuticle through addition of protein and tanning by phenolic substance.

13. Formation of endocuticle: The lower layer of procuticle develops as endocuticle through addition of chitin and protein. This layer increases in thickness.

Control of Moulting: It is controlled by endocrine gland like prothoracic gland which secrete moulting hormone. Endocrine glands are activated by prothoracico-tropic hormones produced by neurosecretory cells of brain.



BODY SEGMENTATION - STRUCTURE AND MODIFICATIONS OF INSECT ANTENNAE, MOUTH PARTS AND LEGS, WING VENATION, MODIFICATIONS AND WING COUPLING APPARATUS & SENSORY ORGANS

Insect body is differentiated into three distinct regions called head, thorax and abdomen (grouping of body segments into distinct regions is known as **tagmosis** and the body regions are called as **tagmata**).

I. HEAD

First anterior tagma formed by the fusion of six segments namely preantennary, antennary, intercalary, mandibular, maxillary and labial segments. Head is attached or articulated to the thorax through neck or **Cervix.** Head capsule is sclerotized and the head capsule excluding appendages formed by the fusion of several sclerites is known as **Cranium**.

Sclerites of Head

i. **Vertex**: Summit of the head between compound eyes.

ii. **Frons**: Facial area below the vertex and above clypeus.

iii. **Clypeus**: Cranial area below the frons to which labrum is attached.

iv. **Gena**: Lateral cranial area behind the compound eyes.

v. **Occiput** : Cranial area between occipital an post occipital suture.

Sutures of Head

i. **Epicranial suture**: (Ecdysial line) Inverted `Y' shaped suture found medially on the top of head, with a median suture (coronal suture) and lateral suture (frontal suture).

ii. **Epistomal suture**: (Fronto clypeal suture) found between frons and clypeus.

iii. **Clypeo labral suture**: Found between clypeus and labrum.

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

Posterior opening of the cranium through which aorta, foregut, ventral nerve cord and neck muscles passes is known as **Occipital foramen**. **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

TYPES OF INSECT HEADS

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

1) HYPOGNATHOUS (Hypo – below; gnathous – jaw)

This type is also called orthopteroid type. The long axis of the head is vertical. It is at right angles to the long axis of the body. Mouth parts are ventrally placed and project downwards.

2) PROGNATHOUS (Pro- infront ; gnathous – jaw)

This type is also called coleopteroid type. The long axis of the head is horizontal. It is in line with the long axis of the body. Mouth parts are directed foreward. Eg: groung beetles.

3) OPISTHOGNATHOUS (Opistho – behind ; gnathous – jaw)

This type is also called hemipteroid type or opisthorhychous. Head is deflexed. Mouth parts are directed backwards and held in between the fore legs. Eg: Stink bug.

II. THORAX

Second and middle tagma which is three segmented, namely prothorax, mesothorax and metathorax. Meso and metathorax with wing are called as **Pterothorax**. Thorax is made up of three scleritic plates namely, dorsal body plate (**Tergum** or **Nota**, ventral body plate (**Sterna**) and lateral plate (**Pleura**).

Thoracic nota: Dorsal body plate of each thoracic segments are called as pronotum, mesonotum and metanotum respectively.

Pronotum: this sclerite is undivided and **Saddle** shaped in grass hopper, **Shield** like in cockroach.

Pterothoracic notum: Have 3 transverse **sutures** (Antecostal, Pre scutal and Scuto-scutellar) and 5 **tergites**(Acrotergite, Prescutum, Scutum, Scutellum and Post-scutellum)

Thoracic sterna: Vental body plate of each thoracic segments are called as prosternum, mesosternum and metasternum. Thoracic sterna is made up of a segmental plate called **Eusternun** and a intersternite called **Spinasternum**. Eusternum is made up of three sclerites viz., presternum, basisternum and sternellum.

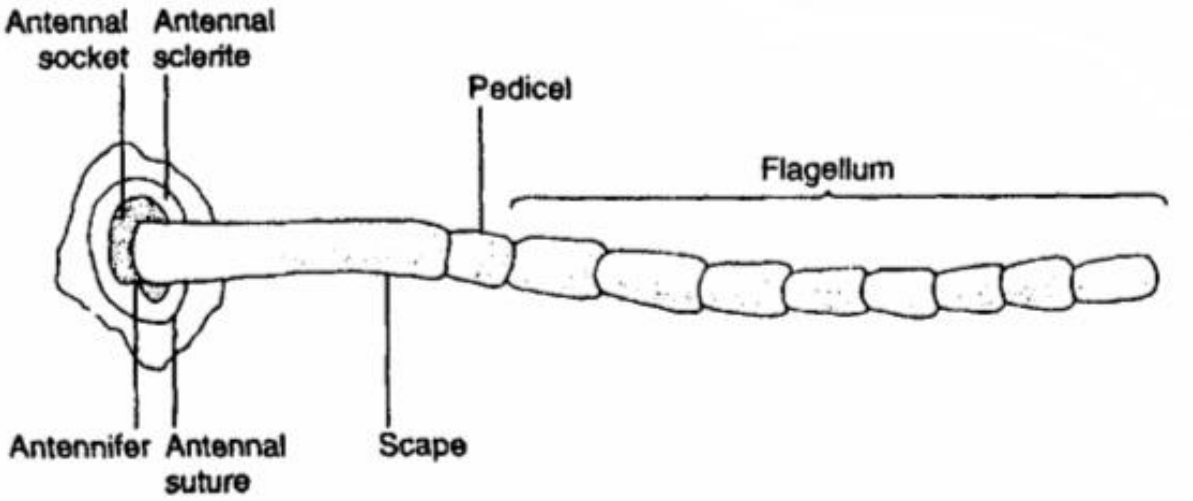
Thoracic pleura: Lateral body wall of thoracic segment between notum and sternum. Selerites of pleuron is called as pleurites and they fuse to form **Pleural plate**. Pleural plate is divided into **anterior episternum** and **posterior epimeron** by **Pleural suture**. Pterothoracic pleuron provides space for articulation of wing and le.g. Thoracic appendages are three pairs of legs and two pairs of wings. Two pairs of spiracles are also present in the mesopleuron and metapleuron.

Functions of thorax: Mainly concerned with locomotion.

III. ABDOMEN

Third and posterior tagma. This tagma is made up of 9-11 Uromeres (segments) and is highly flexible. abdominal segments are telescopic in nature and are interconnected by a membrane called conjunctiva. Each abdominal segment is made up of only two sclerite namely dorsal body plate (**tergum**) and ventral body plate (**sternum**). Eight pairs of spiracles are present

in the first eight abdominal segments, in addition to a pair of **tympanum** in the first abdominal



segment. Eight and ninth abdominal segments contains the female genital structure and ninth segment with male genital structure. Abdominal appendages are genital organs and cerci.

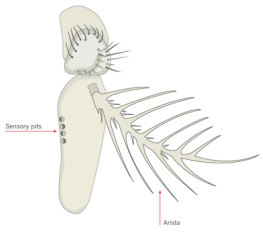
Function: Concerned with reproduction and metabolism.

STRUCTURE OF INSECT ANTENNAE

Antennae function almost exclusively in sensory perception. Some of the information that can be detected by insect antennae includes: **motion and orientation, odour, sound, humidity, and a variety of chemical cues.** Antennae vary greatly among insects, but all follow a basic plan: segments 1 and 2 are termed the scape and pedicel, respectively. The remaining antennal segments (flagellomeres) are jointly called the flagellum.

MODIFICATIONS OF INSECT ANTENNAE

1. ARISTATE



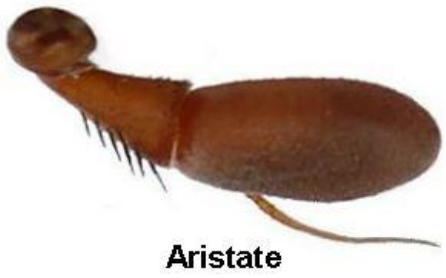
Aristate antennae are pouch-like with a lateral bristle.

Examples: House and shore flies (order Diptera).

The antennae are important sensory structures used to detect air movement and odors.

Among the olfactory receptors are sensilla located in several pits which lie ventrally on the basal one-third of the third segment of the antenna. The antenna is three-segmented with a

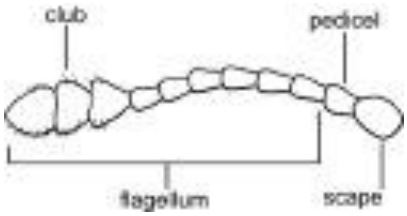
branched arista projecting dorsally from the third segment. A U-shaped groove around the lateral and dorsal part of the depression housing the pair of antennae is the frontal lunule (the suture through which the ptilinum was everted as the fly emerged from the puparium).



Aristate

2. CAPITATE

Capitate antennae are abruptly clubbed at the end. Examples: Butterflies (order Lepidoptera).



Capitate

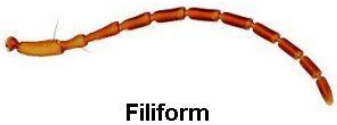
3. CLAVATE

Clavate antennae are gradually clubbed at the end. Examples: Carrion beetles (order Coleoptera). Adult carrion beetles feed on decaying animal matter or maggots.

Clavate

4. FILIFORM

Filiform antennae have a thread-like shape. Examples: Ground and longhorned beetles (order Coleoptera), cockroaches (order Blattaria).



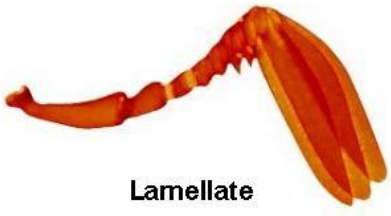
Filiform

5. GENICULATE

Geniculate antennae are hinged or bent like an elbow. Examples: Bees and ants (order Hymenoptera).

6. LAMELLATE

Lamellate or clubbed antennae end in nested plates. Examples: Scarab beetles (order Coleoptera).



7. MONILIFORM

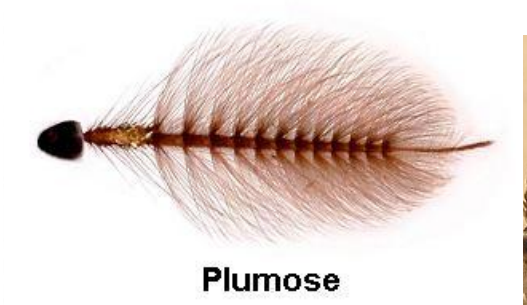
Moniliform have a beadlike shape. Examples: Termites (order Isoptera).

8. PECTINATE

Pectinate antennae have a comb-like shape. Examples: Fire-colored beetles and fireflies (order Coleoptera).

9. PLUMOSE

Plumose antennae have a feather-like shape. Examples: Moths (order Lepidoptera) and mosquitoes (order Diptera).



Plumose

10. SERRATE

Serrate antennae have a saw-toothed shape. Examples: Click beetles (order Coleoptera).

Serrate

11. SETACEOUS

Setaceous antennae have a bristle-like shape. Examples: Dragonflies and damselflies (order Odonata).

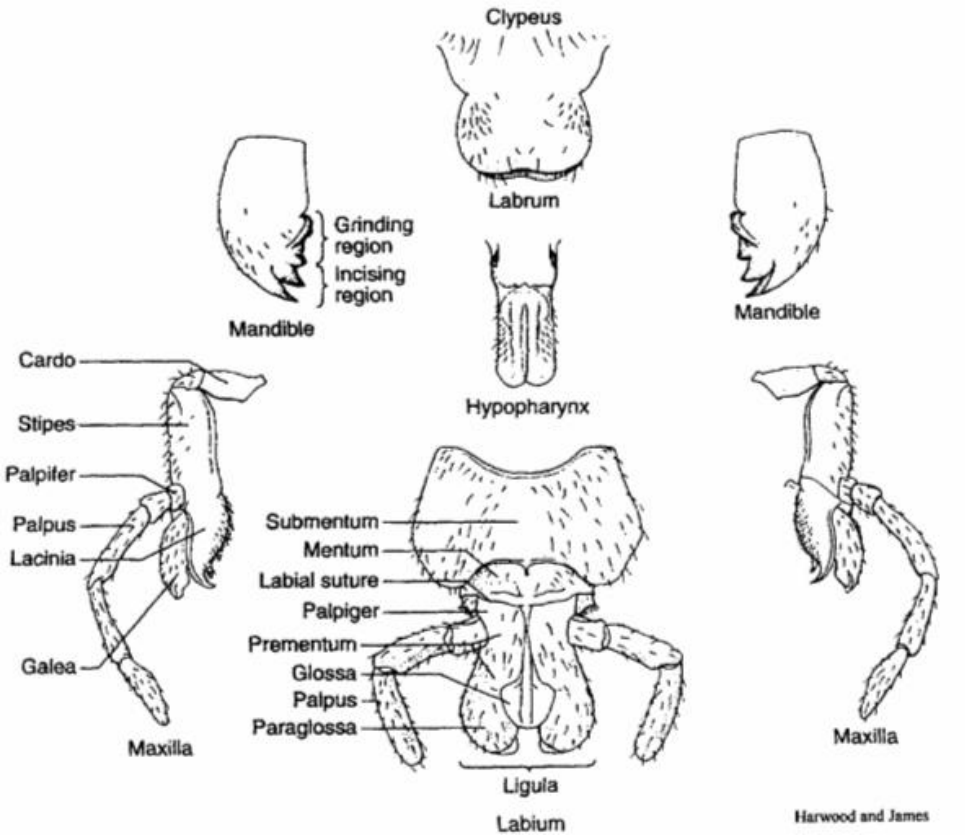
Setaceous

MOUTH PARTS

The 4 main mouthparts are the **labrum, mandibles, maxillae (plural maxilla) and labium.** The labrum is a simple fused sclerite, often called the upper lip, and moves longitudinally. It is hinged to the clypeus. The mandibles, or jaws, are highly sclerotized paired structures that move at right angles to the body. They are used for biting, chewing and severing food. The maxillae are paired structures that can move at right angles to the body and possess segmented palps. The labium (often called the lower lip), is a fused structure that moves longitudinally and possesses a pair of segmented palps.

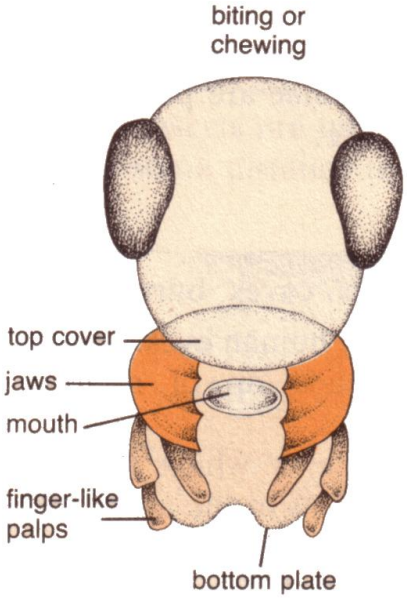
MODIFICATIONS

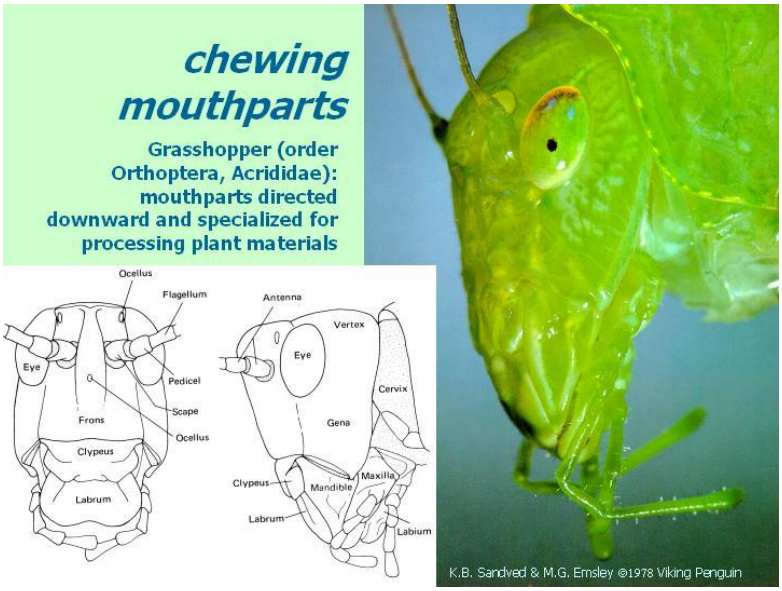
Mouthparts very greatly among insects of different orders but there are two main functional groups: **mandibulate and haustellate**. Haustellate mouthparts can be further classified as **piercing-sucking, sponging, and siphoning.**



MANDIBULATE MOUTH PART

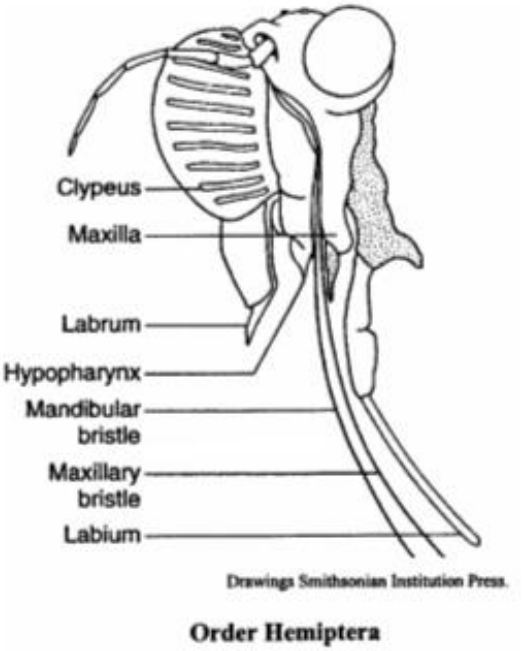
Mandibulate (chewing) mouthparts are used for biting and grinding solid foods. Examples: Dragonflies and damselflies (order Odonata), termites (order Isoptera), adult lacewings (order Neuroptera), beetles (order Coleoptera), ants (order Hymenoptera), cockroaches (order Blattaria), grasshoppers, crickets and katydids (order Orthoptera), caterpillars (order Lepidoptera). Adult Lepidoptera have siphoning mouthparts.



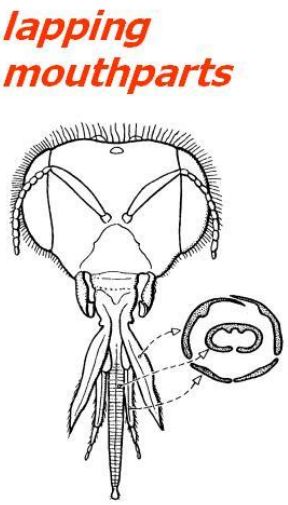


HAUSTELLATE MOUTH PARTS

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 nonstylate 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.



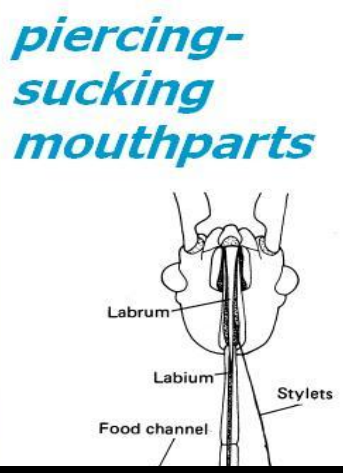
Order Hemiptera

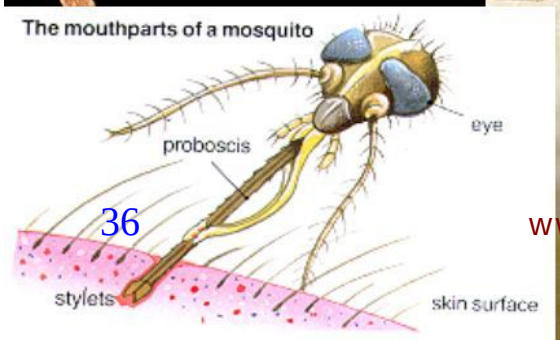


1. Piercing-sucking mouthparts

Piercing-sucking mouthparts are used to penetrate solid tissue and then suck up liquid food.

Examples: Cicadas, aphids, and other bugs (order Hemiptera), sucking lice (order Phthiraptera), stable flies and mosquitoes (order Diptera).

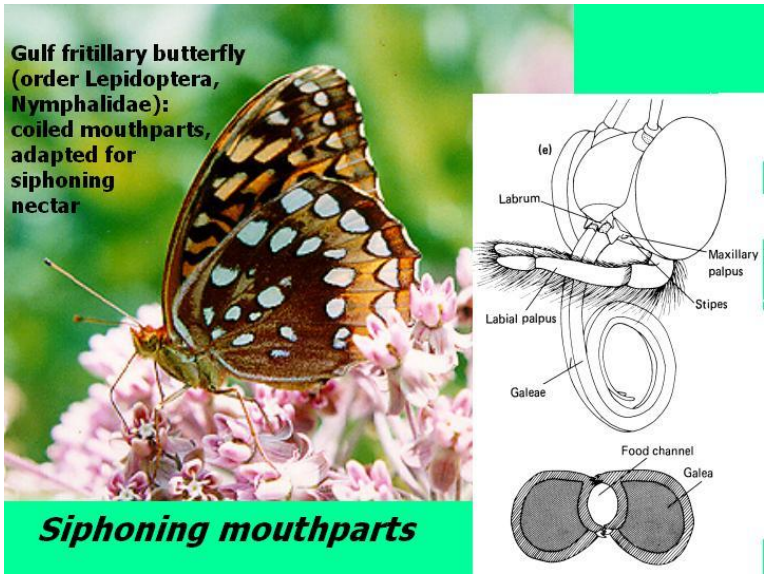




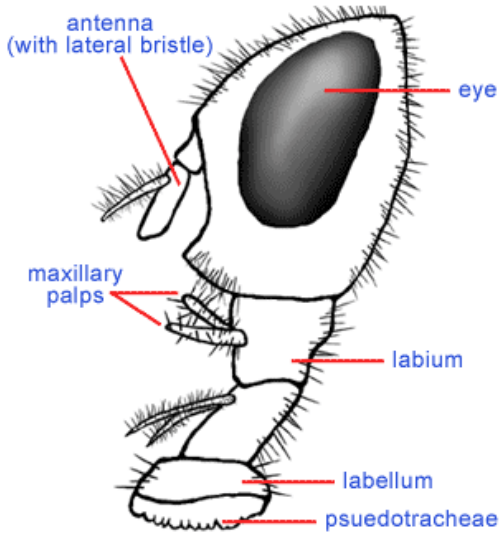
2. Siphoning mouthparts

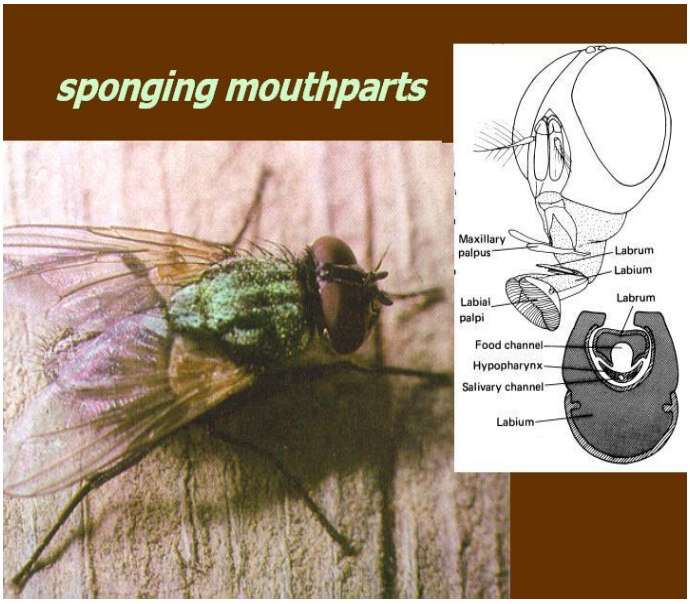
Siphoning mouthparts lack stylets and are used to suck liquids. Examples: Butterflies, moths and skippers (order Lepidoptera), bees (order Hymenoptera). Larval Lepidoptera have chewing mouthparts.

3. Sponging mouthparts



Sponging mouthparts are used to sponge and suck liquids. Examples: House flies and blow flies (order Diptera).





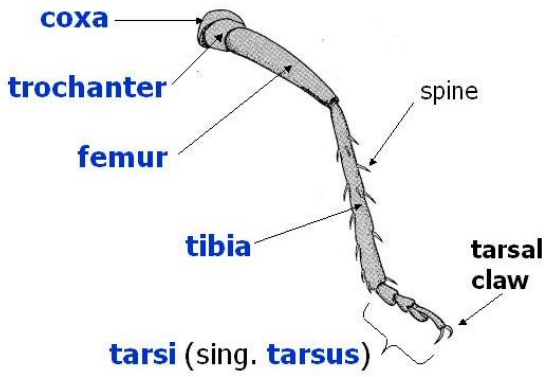
LEGS AND THEIR MODIFICATION

LEGS

The **fore-legs** are located on the prothorax, the **mid-legs** on the mesothorax, and **the hind legs** on the metathorax. Each leg has six major components, listed here from proximal to distal: **coxa** (plural coxae), **trochanter**, **femur** (plural femora), **tibia** (plural tibiae), **tarsus** (plural tarsi), **pretarsus**. The femur and tibia may be modified with spines. The tarsus appears to be divided into one to five "pseudosegments" called **tarsomeres**. The term **pretarsus** refers to the terminal segment of the tarsus and any other structures attached to it, including:

- ungues -- a pair of claws
- arolium -- a lobe or adhesive pad between the claws
- empodium -- a large bristle (or lobe) between the claws
- pulvilli -- a pair of adhesive pads

Like the mouthparts and antennae, insect legs are highly modified for different functions, depending on the environment and lifestyle of an insect.



LEG MODIFICATIONS

- Saltatorial -- jumping
- Raptorial -- seizing
- Fossorial -- digging

- Natatorial -- swimming
- Cursorial – running
- Ambulatory- walking

1. Ambulatory legs

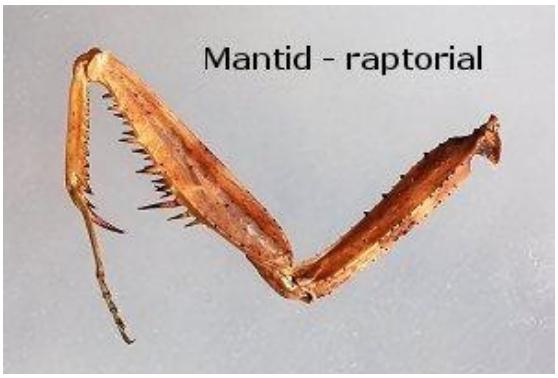
Ambulatory legs are used for walking. The structure is similar to cursorial (running) legs. Examples: Bugs (order Hemiptera), leaf beetles beetles (Corder oleoptera).

2. Saltatorial legs

Saltatorial hind legs adapted for jumping. These legs are characterized by an elongated femur and tibia. Examples: Grasshoppers, crickets and katydids (order Orthoptera).

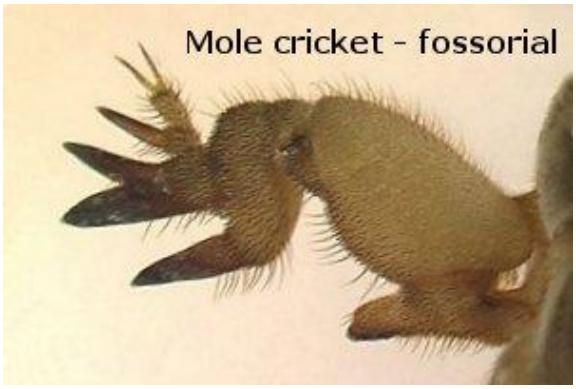
3. Raptorial legs

Raptorial fore legs modified for grasping (catching prey). Examples: Mantids (order Mantodea), ambush bugs, giant water bugs and water scorpions (order Hemiptera).



4. Fossorial legs

Fossorial fore legs are modified for digging. Examples: Ground dwelling insects; mole crickets (order Orthoptera) and cicada nymphs (order Hemiptera).

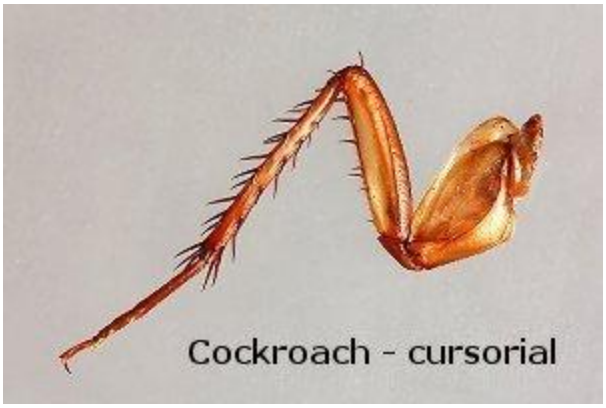


5. Natatorial legs

Natorial legs are modified for swimming. These legs have long setae on the tarsi. Examples: Aquatic beetes (order Coleoptera) and bugs (order Hemiptera).

6. Cursorial legs

Cursorial legs are modified for running. Note the long, thin leg segments. Examples: Cockroaches (order Blattaria), ground and tiger beetles (order Coleoptera).



WINGS VENATION AND MODIFICATION

WINGS VENATION

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

Wing is flattened double layered expansion of body wall with a dorsal and ventral lamina having the same structure as the integument. Both dorsal and ventral laminae grow, meet and fuse except along certain lines. Thus a series of tracheae, nerves and blood. Wing is nourished by blood circulating through veins. Later the walls of these channels become thickened to form veins or nervures. The arrangement of veins on the iwngs is called venation which is extensively used in insect classification. The principal longitudinal veins arranged in order form the anterior margin are costa (C) , sub costa (Sc), radius ®, median (M), cubitus (Cu) and anal veins (A). Small veins often found inter connecting the longitudinal veins are called cross veins. Due to the presence of longitudinal veins and cross veins, the wing surface gets divided into a number of enclosed spaces rermed cells. In insects like dragon fly and damselfly, there is an opaque spot near the coastal margin of the wing called pterostigma.

Margins and Angles

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

WING REGIONS

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

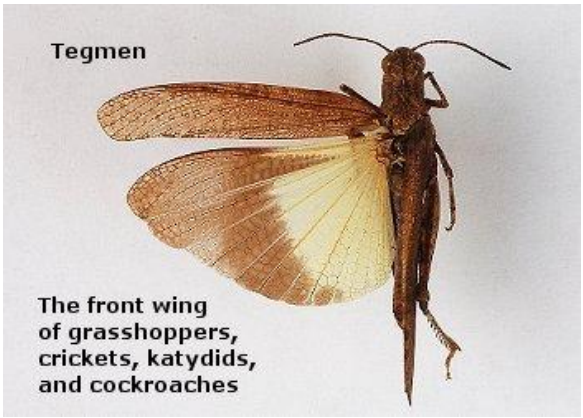
Insects have evolved many variations of the wings, and an individual insect may posess more than one type of wing. Wing venation is a commonly used taxonomic character, especially at the family and species level.

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

MODIFICATION

1. TEGMINA

Tegmina (singular tegmen) are the leathery forewings of insects in the orders Orthoptera, Blattaria, and Mantodea. Like the elytra on beetles and the hemelytra on bugs, the tegmina help protect the delicate hind wings. Examples: Grasshoppers, crickets and katydids (order Orthoptera), Cockroaches (order Blattaria), Mantids (order Mantodea).



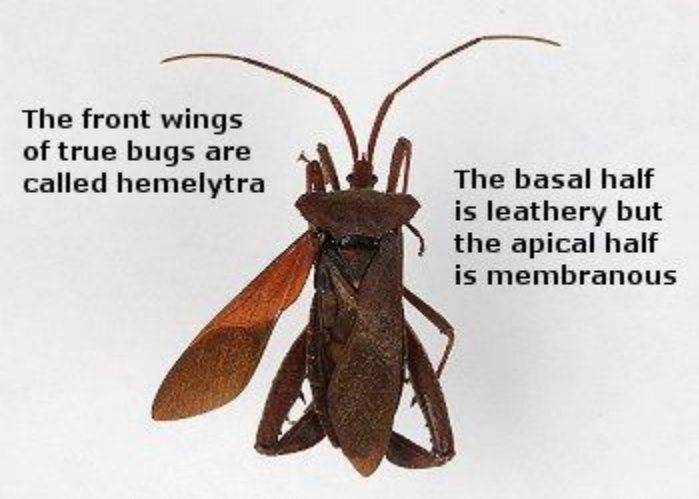
2. ELYTRA

Elytra (singular elytron) are the hardened, heavily sclerotized forewings of beetles and are modified to protect the hind wings when at rest. Examples: All beetles (order Coleoptera).

3. HEMELYTRA

A variation of the elytra is the **hemelytra**. The forewings of Hemipterans are said to be hemelytrous because they are hardened throughout the proximal two-thirds, while the distal portion is membranous. Unlike elytra, hemelytra function primarily as flight wings.

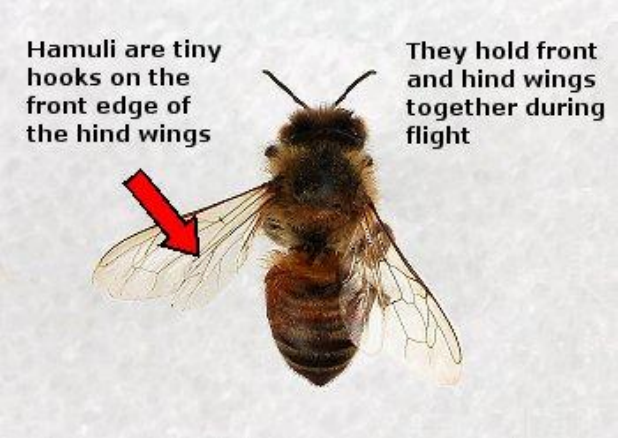
Examples: Bugs (order Hemiptera).



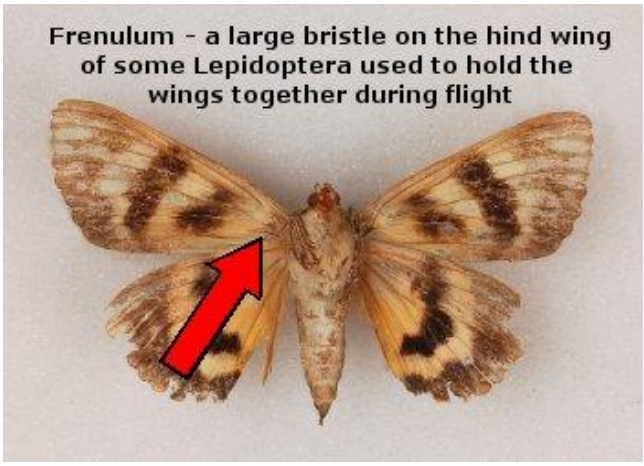
4. HALTERES

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

5. HAMULI



6. FRENULUM



7. MEMBRANOUS WINGS

Membranous wings are thin and more or less transparent, but some are darkened. Examples: Dragonfiles and damselflies (order Odonata), lacewings (order Neuroptera), flies (order Diptera), bees and wasps (order Hymenoptera), termites (order Isoptera). Note the paleopterous wing conditions of the damselflies and dragonfly to the right and below and the neopterous wing conditions of the other insects.

8. SCALES

Some insect wings are covered with **scales**. The scales make the wings colorful. Examples: Butterflies, moths and skippers (order Lepidoptera), caddisflies (order Trichoptera).

WING COUPLING

Higher pterygotes have attained virtual dipterism by co ordinate wing movements. Such insects have devices for hooking fore and hind wings together so both the pairs move synchronously. By coupling the wings the insects become functionally two winged.

TYPES OF WING COUPLING

1. Hamulate: A row of small hooks is present on the costal margin of the hindwing which is known as hamuli. These engage the folded posterior edge of fore wing. Eg: Bees.

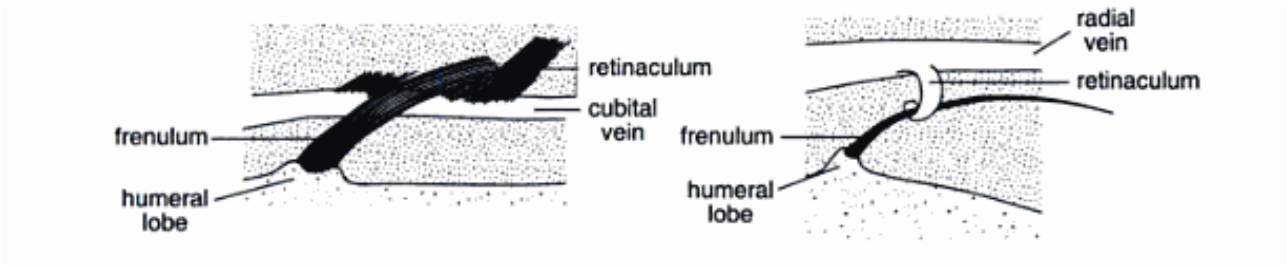
2. Amplexiform: It is the simplest form of wing coupling. A linking structure is absent. Coupling is achieved by broad overlapping of adjacent margins. Eg: Butterflies.

3. Frenate: There are two sub types. Eg: Fruit sucking moth.

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

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

Frenate coupling - female **Frenate coupling - male**



METAMORPHOSIS AND DIAPAUSE IN INSECTS

Although all insects molt and change body shape through their life, some of them undergo only minor changes while most undergo extreme changes in structure and function. Juvenile insects molt frequently during their journey to adulthood. A few insects exhibit no change in body part proportions or modification of the body after molting, but most insects accompany these molts with simple or dramatic alterations of body form called metamorphosis. These changes may be accompanied by addition and/or subtraction of body parts, or they may simply be alterations of body proportions.

No Metamorphosis

A few insects are ametamorphic and do not exhibit any metamorphic changes. The aphids (Homoptera) are prime examples of this. An aphid is produced when an unfertilized egg hatches inside the mother, grows to a young female that looks exactly like her mother except in size, and the offspring emerges onto the host plant the mother is feeding on. After eating for about a day, the young aphid has molted one or more times, and begins to produce her own offspring – even before she has reached full size or has finished molting. This mode of reproduction is so efficient that under favorable conditions, an aphid colony can multiply to ten times their numbers (1000%) in three days.

Gradual Metamorphosis

The simplest form of metamorphosis is a gradual change in body form that occurs between molts. The juvenile stages of these insects closely resemble the adult stages and only trained entomologists (insect scientists) can distinguish the several stages of their life history. A newly hatched praying mantis (*Mantis religiosa*) or grasshopper looks very much like an adult without wings. It has six legs, of which the front pair are modified to capture food just as in the adult mantis. Antennae, mouth parts, and abdomen are the same as in the adult but their relative proportions differ.

The proportion of the head gradually becomes smaller and that of the abdomen longer with each molt. The reproductive organs and wings of the adult remain inactive as imaginal discs for several molts. When wings begin to develop during the last two molts before the adult molt, they appear first as small external buds, become about one third the adult size with the next molt, and finally reach adult size and function after the last molt at which time, the insect is also reproductively mature.

Incomplete Metamorphosis

A more extensive form of metamorphosis is termed incomplete or abrupt metamorphosis. Insects that use this mode of development pass through several nymphal stages before the nymph molts to the winged adult. These insects are usually aquatic with external gills. At the beginning of life, insects that undergo incomplete metamorphosis, such as aquatic dragonfly and damselfly (Orthopterans) nymphs, called naiads, go through a molting process similar to gradual metamorphosis. These insects have six legs, a head with compound eyes and antennae, and a small abdomen with gills at the posterior end. The head becomes proportionately smaller and the abdomen larger with successive molts. As they approach adulthood, wings appear on the back, much as they do if the animal were to undergo gradual metamorphosis.

As these insects metamorphose, the insect abruptly changes its body form. The gills are lost and wings develop. But the changes in leg form, head shape, abdominal morphology, development of spiracles for air breathing, and reduction in the size of mouth parts, drastically alter the appearance of the insect. Looking at the penultimate naiad and the adult, most naive observers would not guess they were related – never mind being the same individual.

Complete Metamorphosis

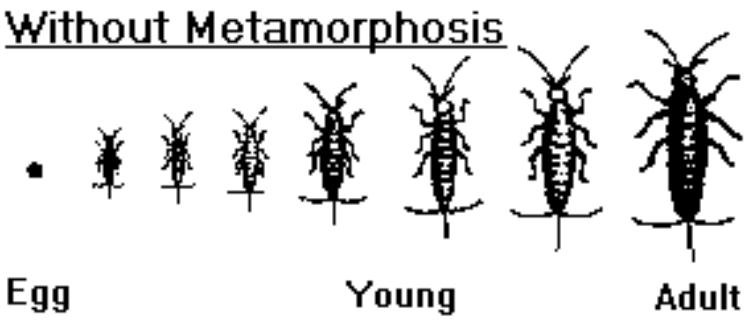
The complete form of metamorphosis involves three very different life stages once the insect hatches from the egg: larva, pupa or chrysalis, and adult or imago. If these insects are aquatic, they may or may not have gills. Those without gills must rise to the surface of the water

to breathe. The larval forms of most insects exhibiting complete metamorphosis is more worm-like than insect-like with tiny or no legs, and often use a worm-like wriggling movement to move. Except for the caterpillars of butterflies and moths and the grubs of some beetles, these larvae usually have a reduced or even absent head definition, often have no eyes or antennae, and sometimes appear to be mostly abdomen with a mouth at one end and anus at the other.

At some point in their development, these insects molt to form a “resting” stage called a pupa or chrysalis. This is a stage incapable of coordinate locomotion. Feet, antennae, and wings (when present) are closely attached to the animal's outer surface and, although appearing for the first time, are nonfunctional.

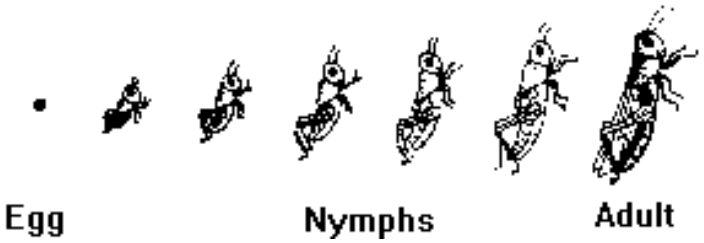
The metamorphosis from the pupa to the imago is sometimes as dramatic as the metamorphosis of an insect with incomplete metamorphosis. The relatively inactive pupal shell splits and the adult draws itself out of the pupal shell. The adult then, as in those with incomplete metamorphosis, pumps body fluids and air into its extremities, causing them to swell and transform to the adult form. After a period of hardening, when the antennae are capable of supporting themselves and the wings and legs can support the insect in flight and walking, the insect walks or flies off to feed, find a mate or mates, and reproduce.

Metamorphosis of Various Insects



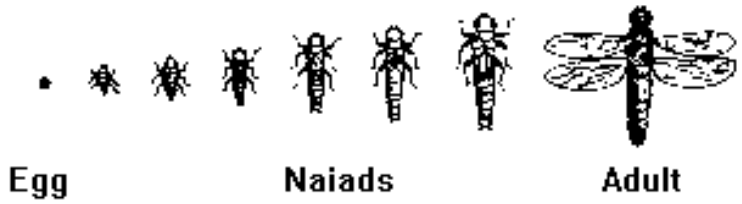
Examples	Orders
Silverfish	Collembola
Springtail	Collembola
Chewing Lice	Mallophaga
Sucking Lice	Anoplura

Gradual Metamorphosis



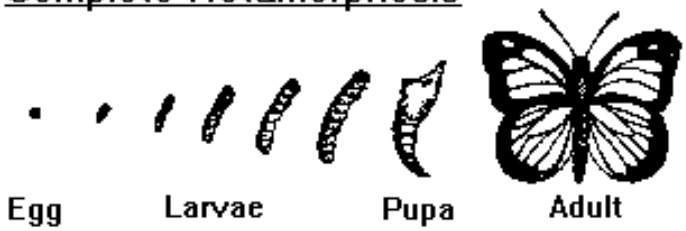
Examples	Orders
Grasshoppers	Orthoptera
Termites	Isoptera
Booklice	Psocoptera (Corrodentia)
Thrips	Thysanoptera
True Bugs	Hemiptera
Aphids	Homoptera
Earwigs	Dermaptera

Incomplete Metamorphosis



Examples	Orders
Mayflies	Ephemeroptera
Dragonflies	Odonata
Stoneflies	Plecoptera

Complete Metamorphosis



Examples	Orders
Lacewing	Neuroptera
Beetles	Coleoptera
Scorpionfly	Mecoptera
Coddisfly	Trichoptera
Moths, Butterflies	Lepidoptera
Flies	Diptera
Fleas	Siphonaptera
Wasps, Bees	Hymenoptera

TYPES OF LARVAE AND PUPAE

EGGS

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

Types of eggs

a) Singly laid

1) Sculptured egg: Chorion with reticulate markings and ridges. Eg: castor butterfly

2) Elongate egg: Eggs are cigar shaped. Eg: Sorghum shoot fly.

3) Rounded egg: Eggs are either spherical or globular. Eg: Citrus butterfly.

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

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

b) LAID IN GROUPS

1) Pedicellate eggs: Eggs are laid in silken stalks of about 1.25 mm length in on groups plants. Eg: Green lace wing fly.

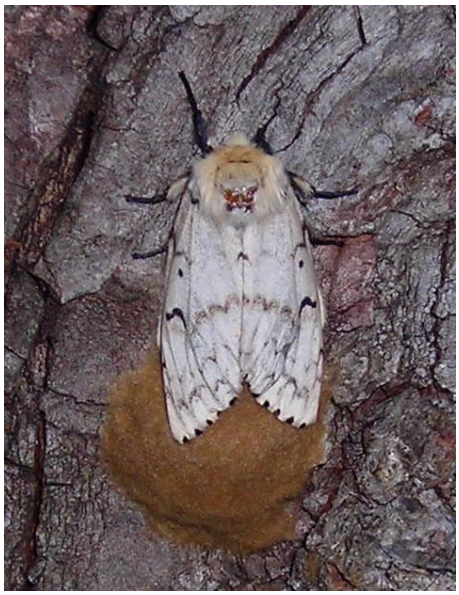
2) Barrel shaped eggs: Eggs are barrel shaped. They look like miniature batteries. They are deposited in compactly arranged masses. Eg: Stink bug.

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

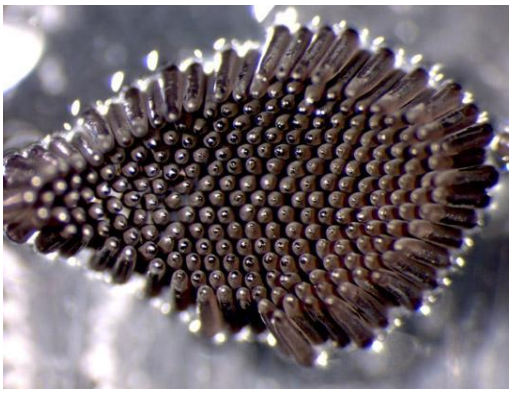
4) Egg pod: Grass hoppers secrete a frothy material that encases an egg mass which is deposited in the ground. The egg mass lacks a definite covering. On the top of the egg, the frothy substance hardens to form a plug which prevents the drying of eggs.

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

6) Egg mass: Moths lay eggs in groups in a mass of its body hairs. Anal tuft of hairs found at the end of the abdomen is mainly used for this purpose. Eg: Rice stem borer. Female silk worm moth under captivity lays eggs on egg card. Each egg mass is called a dfl (disease free laying).



7) Egg raft: In culex mosquitoes, the eggs are laid in a compact mass consisting of 200 – 300 eggs are called egg raft in water.



II) LARVAE

There are three main types of insects larvae namely oligopod, polypod and apodous.

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

a) Campodeiform: They are so called from their resemblance to the dipluran genus campodea. Body is elongate, depressed dorso ventrally and well sclerotised. Head is prognathous. Thoracic legs are long. A pair of abdominal cerci or caudal processes is usually present. Larvae are generally predators and are very active. Eg: grub of ant lion or grub of lady bird beetle.

b) Scarabaeiform: Body is 'C' shaped, stout and subcylindrical. Head is well developed. Thoracic legsa re short. Caudal processes are absent. Larva is sluggish, burrowing into wood or soil. Eg: grub of rhinocerous beetle.

2) POLYPOD OR ERUCIFORM: The body consists of an elongate trunk with large sclerotised head capsule. Head bears a pair of powerful mandibles which tear up vegetation. Two groups of single lensed eyes found on either side of the head constitute the visual organs. The antenna is short. Three pairs of thoracic legs and upto five pairs of unjointed abdominal legs or prologs are present. Thoracic legs are segmented and they end in claws which are used for holding typically bears rows or circlet of short hooked spines or crochets which are useful in clinging to the

exposed surface of vegetation and walking. Abdominal segments three to six and ten typically bear prologs. Eg: caterpillar (larvae of moths and butterflies).

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

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

c) Semilooper: either three or four pairs of prologs are present. Prologs are either wanting or rudimentaly in either third or third and fourth abdominal segments. Eg: Castor semilooper.

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

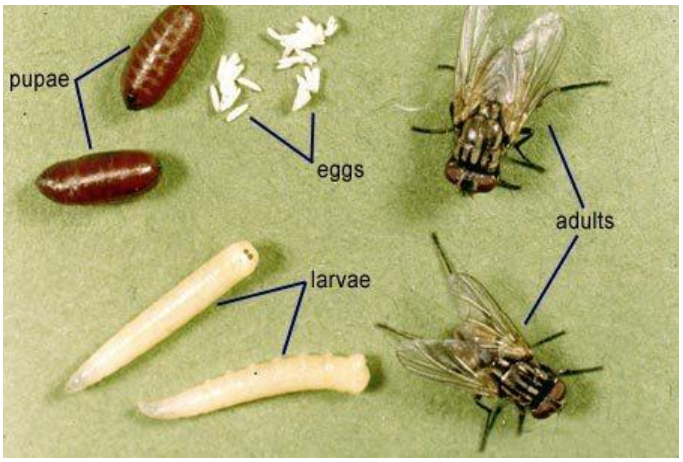
3) APODOUS

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

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

b) Hemicephalous: Head capsule is reduced and can be with drawn into thorax. Mandibles act vertically. Eg: Larva of horse fly and robber fly.

c) Acephalous: Head capsule is absent. Mouth parts consists of a pair of protrusible curved mouth hooks and associated internal sclerites. They are also called vermiform larvae. Eg: maggot (larva of housefly)



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

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

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

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

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

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

PUPAL PROTECTION

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

S.No	Types of cocoon	Materials used	Example
1.	Silken cocoon	silk	silkworm
2.	Earthern cocoon	Soil + saliva	Gram pod borer
3.	Hairy cocoon	Body hairs	Wolly bear
4.	Frassy cocoon	Frass + saliva	Coconut black headed caterpillar
5.	Fibrous cocoon	Fibres	Red palm weevil
6.	Puparium	Hardened last larval skin	House fly

STRUCTURE AND FUNCTIONS OF DIGESTIVE SYSTEM

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

I. FOREGUT

Foregut is ectodermal in origin. Anterior invagination of ectoderm forms foregut (**Stomodeum**). Internal cuticular lining is present. Terminal mouth parts leads into a **preoralcavity**. Preoralcavity between epipharynx and hypopharynx is called as **Cibarium**. Preoralcavity between hypopharynx and salivary duct is **Salivarium**. Behind the mouth a well musculated organ called **Pharynx** is present which pushes the food into oesophagous. Pharynx acts as a **sucking pump** in sap feeders. **Oesophagous** is a narrow tube which conducts food into crop. **Crop** is the dilated distal part of oesophagus acting as food reservoir. In bees crop is called as honey stomach where nectar conversion occurs. **Proventriculus or Gizzard** is the posterior part of foregut and is musculated. It is found in solid feeders and absent in fluid feeders or sap feeders. The internal cuticle of gizzard is variously modified as follows.

i. Teeth like in cockroach to grind and strain food.

ii. Plate like in honey bee to separate pollen grains from nectar

iii. Spine like in flea to break the blood corpuscles

Food flow from foregut to midgut is regulated through **Cardiac valve or Oesophageal valve**.

II. MIDGUT

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

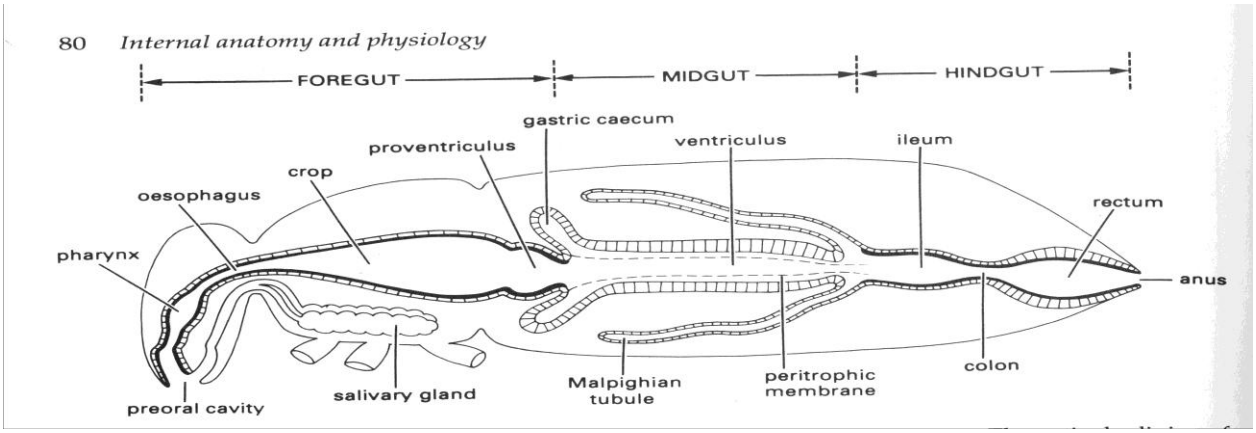
Important structures present in midgut are as follows:

(i) **Peritrophic membrane**

It is the internal lining of midgut, secreted by anterior or entire layer of midgut epithelial cells. Present in solid feeders and absent in sap feeders. This layer is semipermeable in nature to digestive juices and digestion products. Its functions are

(a) Lubricate and facilitate food movement

(b) Envelops the food and protects the midgut epithelial cells against harder food particles.



(ii) **Gastric caecae:** (Enteric caecae or Hepatic caecae)

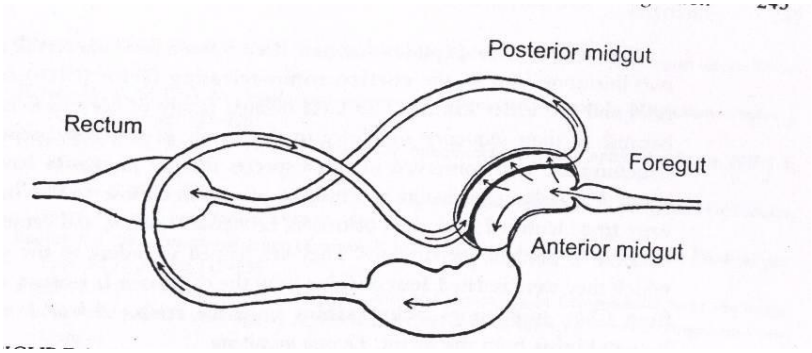
Finger like outgrowths found in anterior or posterior ends of midgut. This structure increases the functional area of midgut and shelter symbiotic bacteria in some insects.

(iii) **Pyloric valve:** (Proctodeal valve)

Midgut opens into hindgut through pyloric valve, which regulate food flow. In certain immature stages of insects midgut is not connected to hindgut till pupation. e.g. Honey bee grub.

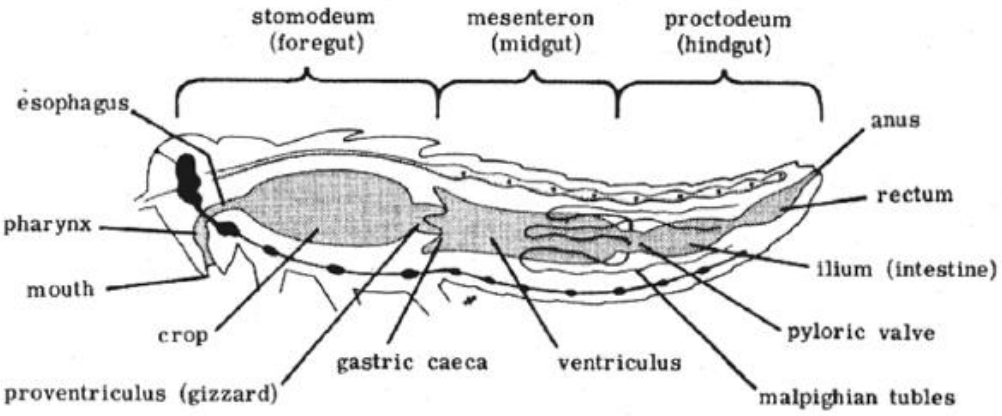
(iv) **Filter chamber:**

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



III. HINDGUT

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



The "generalized" digestive system of insects.

IV. GUT PHYSIOLOGY: Primary functions of the gut is to digest the ingested food and to absorb the metabolites. The digestion process is enhanced with the help of enzymes and microbes which were produced by digestive glands and special cells.

A. Digestive glands

(a)Salivary glands

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

Functions of saliva

(i) To moisten and to dissolve food

(ii) To lubricate mouthparts

(iii) To add flavour to gustatory receptors

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

(v) In honey bee saliva contains invertase for sucrosedigestion

(vi) In Jassid saliva contains lipase and protease for lipids and protein digestion. Jassid saliva also contains toxins which produces tissue necrosis and phytotoxemia on the plant parts.

(vii) In plant bug saliva contains pectinase which helps in stylet penetration and extra intestinal digestion.

(viii) In mosquito, saliva contains anticoagulin which prevents blood clotting.

(ix) In gall midge saliva contains Indole Acetic Acid (IAA) which produces galls on plant parts.

(x) In disease transmitting insects (vectors) the salivapaves way for the entry of pathogens.

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

(i) **Holocrine :** Epithelial cells disintegrate in the process of enzyme secretion.

(ii) **Merocrine :** Enzyme secretion occurs without cell break down.

B. Digestive enzymes

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

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

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

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

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

These microbes were transmitted between individuals through food exchange (mouth to mouth feeding) called **trophallaxis** and through egg called as **transovarial** transmission.

In plant bug and ant lion grub partial digestion occurs in the host body prior to food ingestion called as **extra intestinal digestion**. In most of the insects digestion occurs in mid gut.

Absorption

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

Alimentary system of cockroach

The alimentary canal is a long tube (Holotrophic) extending from mouth to anus. It is convoluted in the posterior end. It is mainly divided into three regions viz., foregut or stomodaeum, midgut or mesenteron or ventriculus and hindgut or proctodaeum. Mouth leads into pharynx which leads immediately into a narrow tube called oesophagus. The distal end of the oesophagus enlarges into a large sac like structure called crop which is useful to store the food prior to digestion. The posterior part of the crop narrows down to a small sac, the gizzard or proventriculus. Inside the gizzard, six chitinous cuticular teeth are present which help in pulverizing the food. Midgut is the main site of digestion and assimilation. Hindgut is differentiated into a narrow ileum, wider colon and sac like rectum. Salivary glands and hepatic caecae are digestive glands associated with alimentary tract. Salivary apparatus consists of two pairs of salivary glands and a pair of salivary reservoirs. Hepatic caecae are finger like projections found at the junction of foregut and midgut, which serve as enzyme source for digestion. Associated with the alimentary tract at the junction of midgut and hindgut are many yellowish, hair like structures called malpighian tubules which eliminate nitrogenous waste from blood.

STRUCTURE AND FUNCTIONS OF CIRCULATORY SYSTEM

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

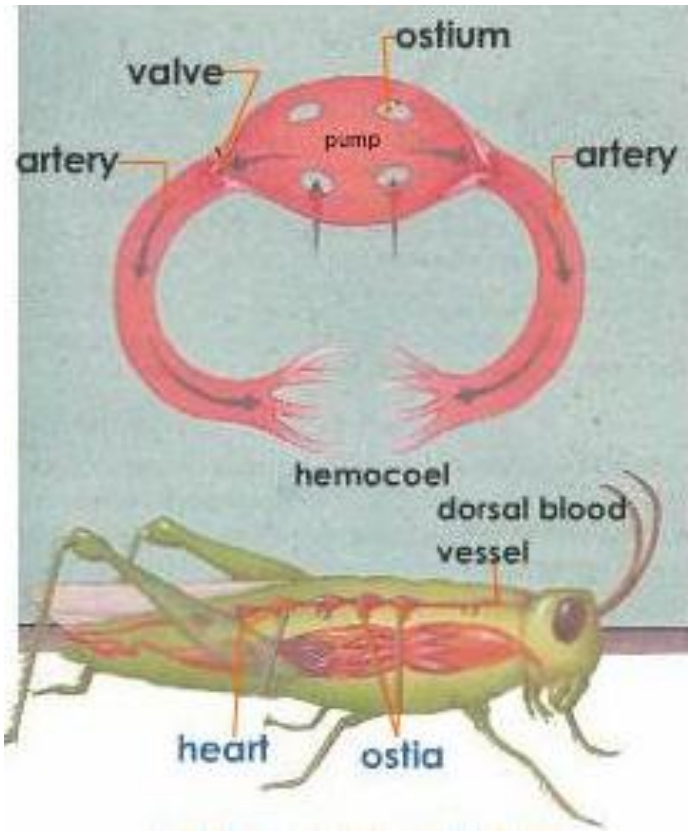
Haemolymph enters the periocardial sinus via segmental openings in the diaphragm and then moves into the dorsal vessel via the ostia during a muscular relaxation phase. Waves of contraction start at the posterior end of the body, pump the haemolymph forward in the dorsal vessel and out via the aorta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

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

Haemolymph is generally circulated to appendages unidirectionally by various tubes, septa, valves and pumps. The muscular pumps are termed accessory pulsatile organs and occur

at the base of the antennae and legs. Antennal pulsatile organs releases neurohormones that are carried to the antennal lumen to influence the sensory neurones. Circulation occurs in the wings of young adult. In wing circulation is sustained by influxes of air into the wing veins, rather than any pulsatile organs. Pulses of air in the fine tracheal tubes of the veins push the haemolymph through the enclosed space of the veins.

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



HAEMOLYMPH AND ITS FUNCTIONS

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

(respiration).Haemolymph contains a fluid portion called **plasma** and cellular fractions called **haemocytes**.

I. PLASMA

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

II. HAEMOCYTES

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

1. Prohaemocyte - Smallest of all cells with largest nucleus.
2. Plasmatocyte - (Phagocyte) aids in phagocytocis
3. Granular heamocyte - Contains large number of cytoplasmic inclusions
4. Spherule cell - Cytoplasmic inclusions obscure the nucleus
5. Cystocyte - (Coagulocyte) Role in blood coagulation and plasma precipitation.
6. Oenocytoids - Large cells with ecentric nucleus
7. Adipo haemocytes - Round or avoid with distinct fat droplets
8. Podocyte - Large flattened cells with number of protoplasmic projections.
9. Vermiform cells - Rare type, long thread like.

Functions of haemolymph

1. Lubricant

Haemolymph keeps the internal cells moist and the movement of internal organs is also made easy.

2. Hydraulic medium

Hydrostatis pressure developed due to blood pumping is useful in the following processes.

i. Ecdysis (moulting)

ii. Wing expansion in adults

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

iv. Eversion of penis in male insects

v. Eversion of osmeteria in papilionid larvae

vi. Eversion of mask in naiad of dragonfly

vii. Maintenance of body shape in soft bodied catepillars.

3. Transport and storage

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

4. Protection

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

5. Heat transfer

Haemolymph through its movement in the circulatory system regulate the body heat (Thermoregulation)

6. Maintenance of osmotic pressure

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

7. Reflex bleeding

Exudation of heamolymph through slit, pore etc repels natural enemies. e.g. Aphids.

8. Haemolymph

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

STRUCTURE AND FUNCTIONS OF EXCRETORY SYSTEM

Different types and their functional mechanisms

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

1. Malpighian tubules

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

2. Nephrocytes

Cells that sieve the haemolmph for products that they metabolize (pericardial cells).

3. Fat bodies

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

4. Oenocytes

The cells of haemocoel, epidermis or fat body with many functions.

5. Integument

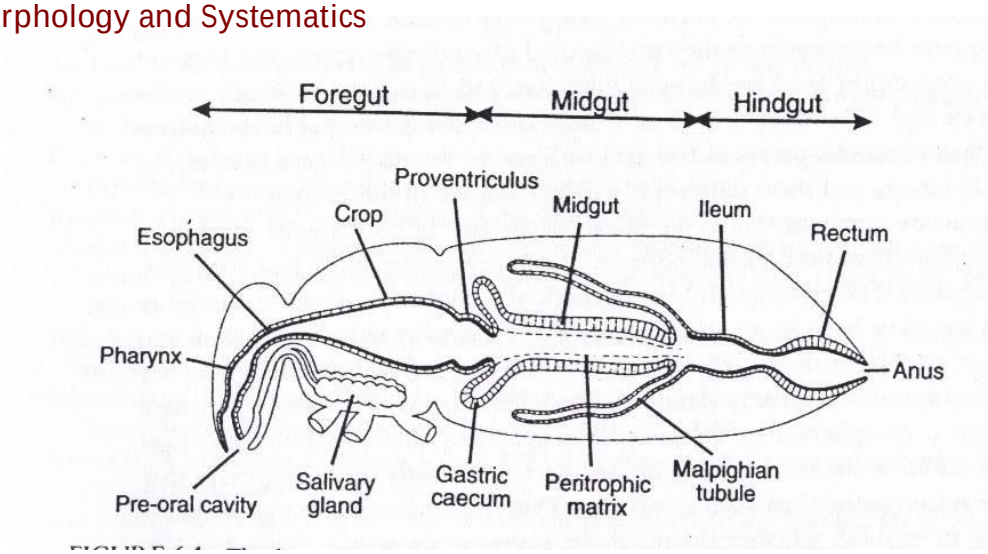
The outer covering of the living tissues of an insect.

6.Tracheal system

The insect gas exchange system, comprising tracheae and tracheoles.

7. Rectum

The posterior part of hind gut. Among the above organs, malpighian tubules are the major organ of excretion.

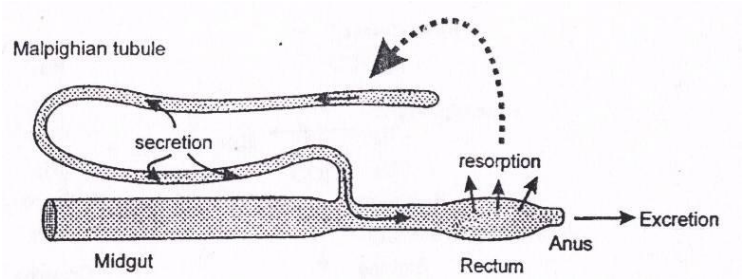


Excretion and Osmoregulation

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

Malpighian Tubules

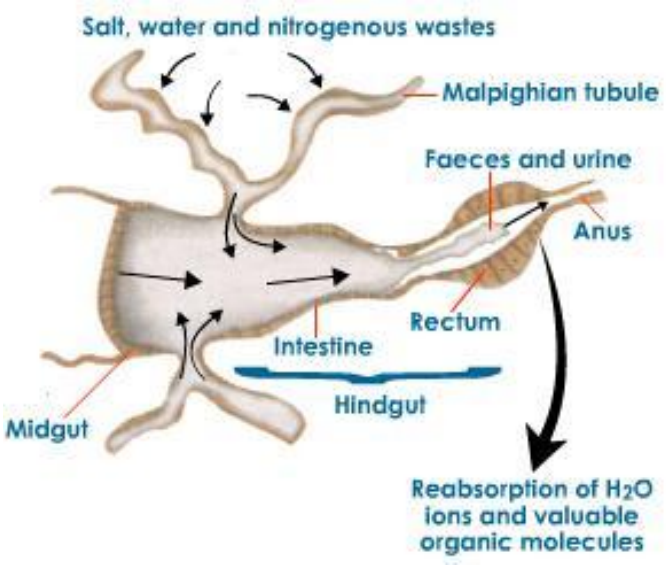
The main organ of excretion and osmoregulation in insects are the malpighian tubules, acting in association with rectum or ileum. Malpighian tubules are outgrowths of the alimentary canal and consist of long thin tubles formed of a **single layer of cells** surrounding a blind-ending **lumen,** they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

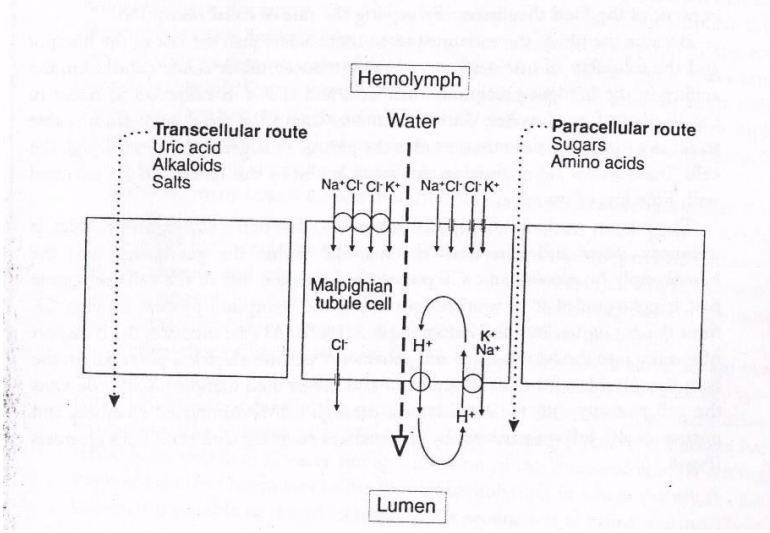


Physiology

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

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



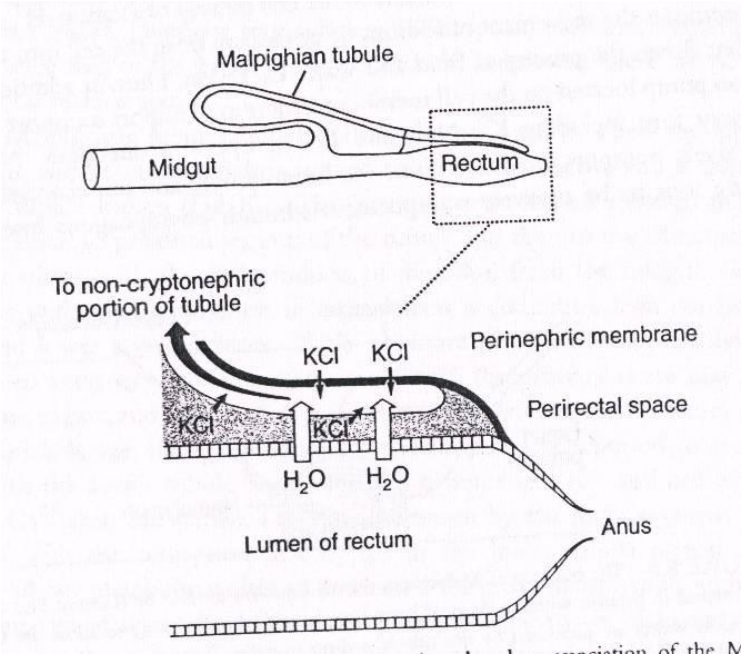


Nitrogen excretion

Terrestrial insects excrete waste products as uric acid or certain of its salts called urates, which were water insoluble and requires less amount of water for waste product removal. This type of excretion is known as **uricotelism**. In aquatic insects ammonia is the excretory product, which is freely soluble in water and requires more amount of water for waste product removal. This type of excretion is known as **ammonotelism**.

Cryptonephry

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



Functions of malphighian tubule

Excretory in function, mainly concerned with removal of nitrogenous wastes. The other accessory functions are as follows:

1. Spittle secretion in spittle bug
2. Light production in **Bolitophila**
3. Silk production in larval neuroptera

Storage Excretion

The excretory waste materials are retained within the body in different sites.

Uric acid is stored as urates in the **cells of fat body** e.g., American cockroach.

Uric acid is stored in the **body wall**, giving white colour, e.g., Red cotton bug.

Uric acid is stored in the **male accessory glands** to produce the outer coat of spermatophore, which is excreted during copulation.

Uric acid is stored in the **wing scales** giving white colour. e.g., Pierid butterflies.

Waste products of pupal metabolism (**meconium**) is stored and released during adult emergence.

STRUCTURE AND FUNCTIONS OF RESPIRATORY SYSTEM

Similar to aerobic animals, insects must obtain oxygen from their environment and eliminate carbon dioxide respired by their cells. This is **gas exchange** through series of gas filled tubes providing surface area for gaseous exchange (Respiration strictly refers to oxygen-consuming, cellular metabolic processes). Air is supplied directly to the tissue and no haemolymph (blood) is involved in the respiratory role. Gas exchange occurs by means of internal air-filled **tracheae**. These tubes branch and ramify through the body. The finest branches called **tracheloe** contact all internal organs and tissues and are numerous in tissues with high oxygen requirements. Air usually enters the tracheae via **spiracular openings** positioned laterally on the body. No insect has more than ten pairs (two thoracic and eight abdominal).

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

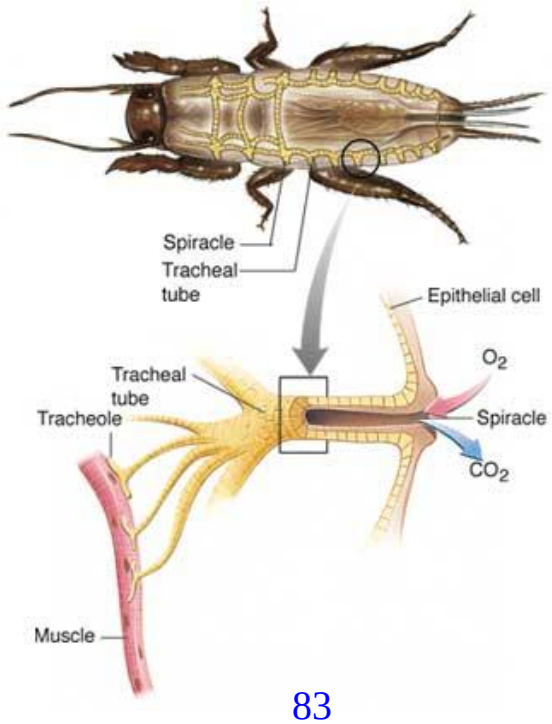
1.	Holopneustic	10 pairs, 2 in thorax and 8 in abdomen. e.g. grasshopper
2.	Hemipneustic	Out of 10 pairs, one or two non functional
3.	Peripneustic	9 pairs - 1 in thorax 8 in abdomen. e.g. Caterpillar
4.	Amphipneustic	2 pairs - One anterior, one posterior, e.g. maggot
5.	Propneustic	1 pair -anterior pair e.g. Puparium
6.	Metapneustic	1 pair - posterior pair e.g.Wriggler
7.	Hypopneustic	10 pairs - 7 functional (1 thorax + 6 abdominal), 3 non functional. e.g. head louse
8.	Apneustic	All spiracles closed, closed tracheal system e.g. naiad of may fly.

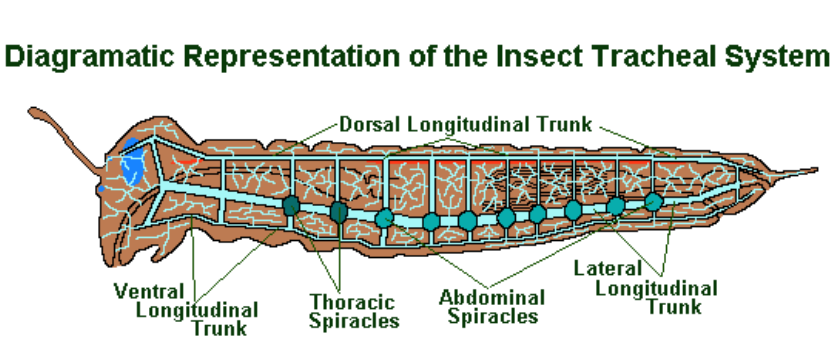
ORGANS OF RESPIRATION

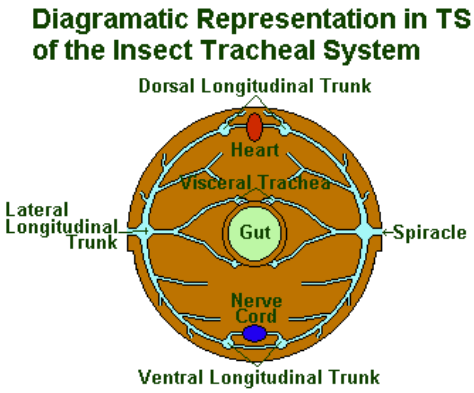
SPIRACLES

Spiracles have a chamber or **atrium** with a opening and closing mechanism called **valve**. This regulates air passage and minimise water loss. Each spiracle is set in a sclerotized cuticular plate called a **peritreme**. Tracheae are invaginations of the epidermis and thus their lining is continuous with the body cuticle. The ringed appearance of the tracheae is due to the spiral ridges called **taenidia**. This allows the tracheae to be flexible but resist compression. The cuticular linings of the tracheae are shed when the insect moults, but not the linings of tracheoles.

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







Mechanism of respiration

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

Respiration in aquatic insects

1. **Closed tracheal system**

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

Lamellate gills - mayfly naiad

Filamentous gills - damselfly naiad

Rectal gills - dragonfly naiad

2. **Open tracheal system**

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

   ii. Respiratory siphon - e.g. Wriggler

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

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

STRUCTURE AND FUNCTIONS OF NERVOUS SYSTEMS

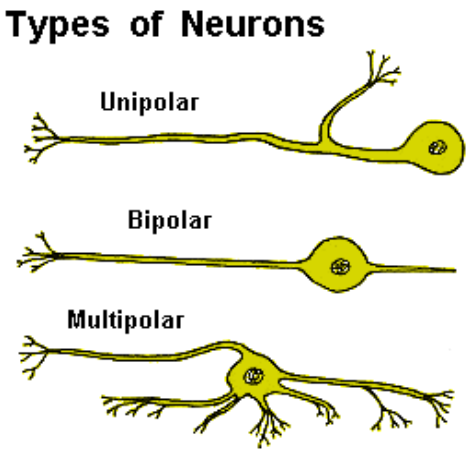
The basic component in the nervous system is the nerve cell or neuron, composed of a cell body with two projections (fibres) - the dendrite that receives stimuli and the **axon** that transmits information, either to another neuron or to an effector organ such as a muscle. Axon may have lateral branches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

A. Structural basis

i. Monopolar : neurone with a single axon

ii. Bipolar : neurone with a proximal axon and a long distal dendrite.

iii. Multipolar : neurone with a proximal axon and many distal dendrites.



B. Functional basis

i. Sensory neurone: It conducts impulse from sense organs to cennervoussystem(CNS).

ii. Motor neurones: It conducts impulse from CNS to effector organs

iii. Inter neurones:(association neurone: It interlinks sensory and motor neurones.

The cell bodies of interneurones and motor neurones are aggregated with the fibres inter connecting all types of nerve cells to form nerve centres called ganglia.

Mechanism of impulse conduction

Impulses are conducted by the neurones by two means.

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

B. Synaptic conduction: Neuro chemical transmitters are involved in the impulse conduction through the synaptic gap. Neuro transmitters and the type of reactions helping in the impulse conduction is as follows.

Acetyl CO-A + Choline (choline acetylase) → Acetyl choline

Acetyl choline + Water (Acetyl choline esterase) → Choline + Acetic acid

NERVOUS SYSTEM

i. Central nervous system (CNS)

ii. Visceral nervous system (VNS)

iii. Peripheral nervous system (PNS)

I. Central nervous system

It contains double series of nerve centres (ganglia). These nerve centres (ganglia) are connected by longitudinal tracts of nerve fibres called **connectives** and transverse tracts of nerve fibres called **commissures**. Central nervous system is made up of the following.

(i).Brain: Formed by the fusion of first three cephalic neuromeres.

Protocerebrum : Large, innervate compound eyes and ocelli.

Deutocerebrum : Found beneath protocerebrum, innervate antennae.

Tritocerebrum : Bilobed, innervate labrum.

Functions: i. Main sensory centre controls insect behaviour.

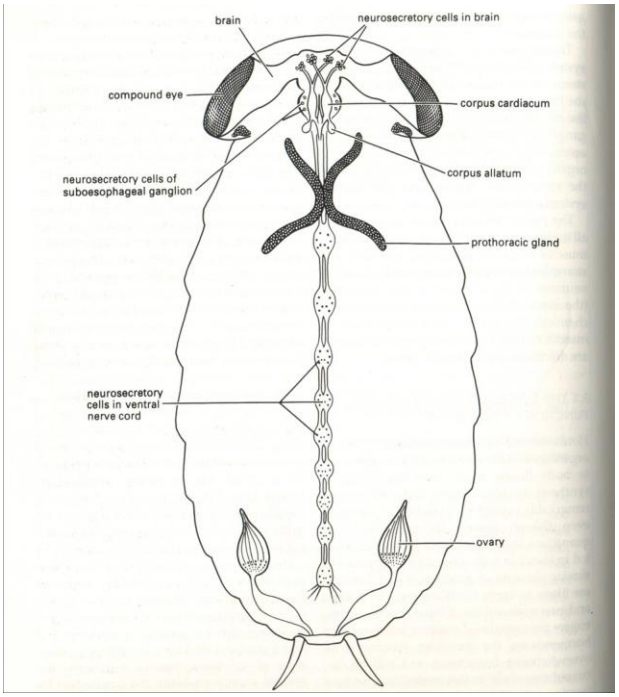
ii. Ventral nerve cord: Median chain of segmental ganglia beneath oesophagus.

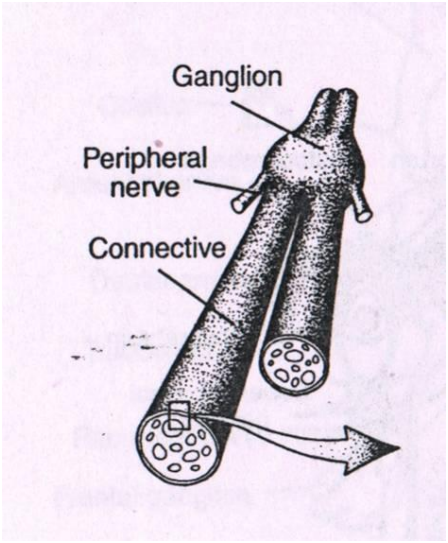
iii. Sub esophageal ganglia: Formed by the last three cephalic neuromeres. Innervates mandible, maxillae and labium.

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

v. Abdominal ganglia: 8 pairs, number varies due to fusion of ganglia, innervate spiracles.

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



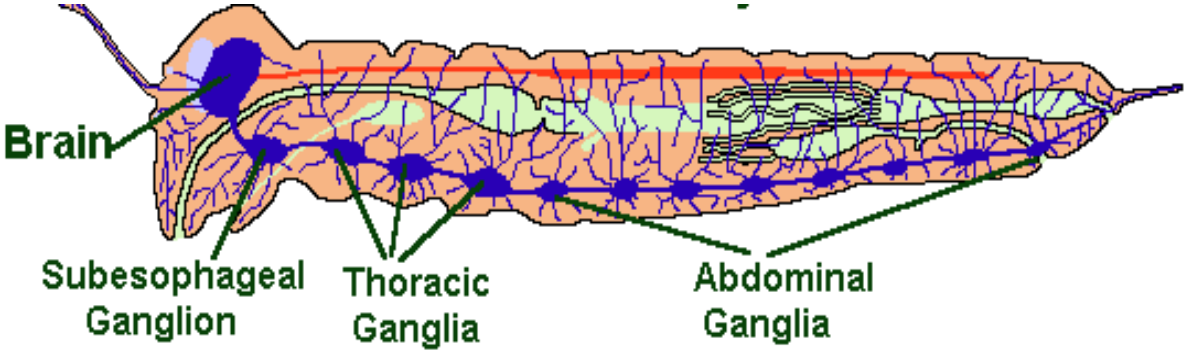


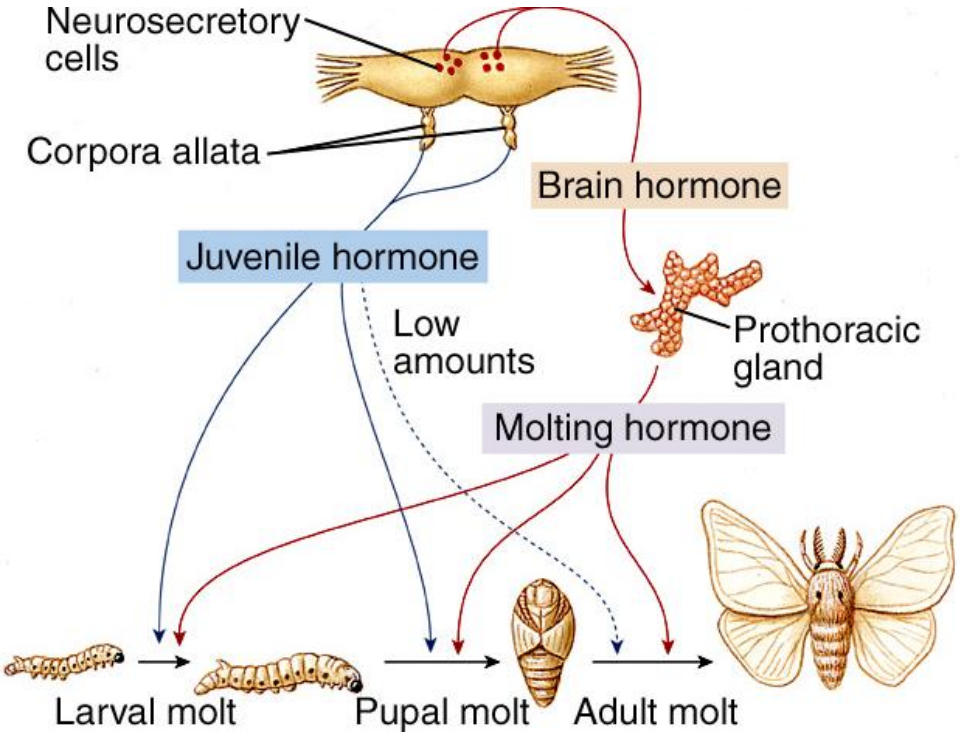
II. Visceral nervous system

The **Visceral** (**sympathetic**) nervous system consists of three subsystems: (i) the **stomodeal** or **stomatogastric**, which includes the frontal ganglion; (ii) **Ventral visceral** and (iii) the **caudal visceral**. Together the nerves and ganglia of these subsystems innervate the anterior and posterior gut, several endocrine organs (Corpora cardiaca and Corpora allata), the reproductive organs, and the tracheal system including the spiracles.

III. Peripheral nervous system

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





REPRODUCTIVE SYSTEM

In insects male and female sexes are mostly separate. Sexual dimorphism is common where the male differ from the female morphologically. e.g. bee, mosquito and cockroach. The other types are

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

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

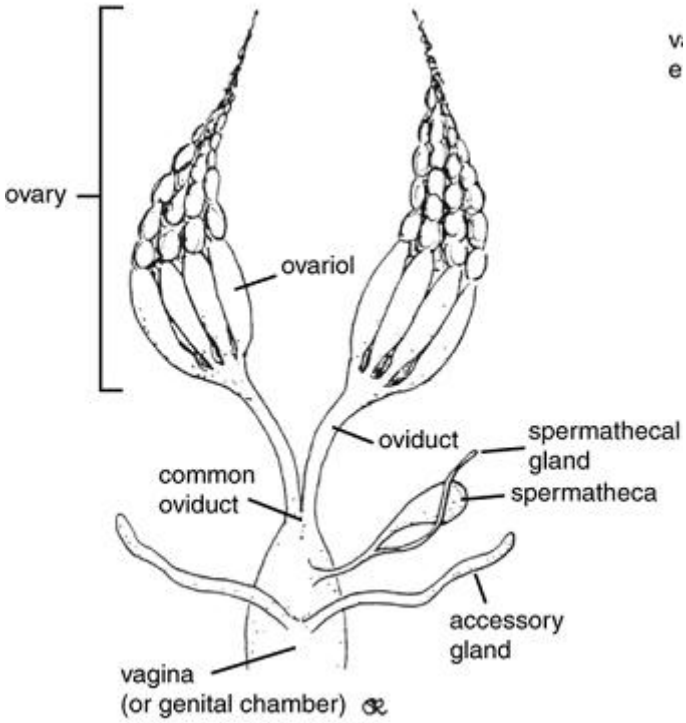
FEMALE REPRODUCTIVE SYSTEM

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

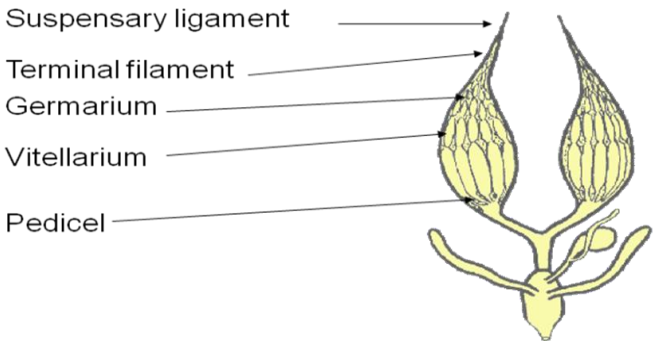
Two types of ectodermal glands open into the genital chamber. The first is the **spermatheca** which stores **spermatoza** until they are needed for egg fertilization. The epermatheca is single and sac-like with a slender duct, and often has a diverticulum that forms a tubular **spermathecal gland**. The gland or glandular cells within the storage part of the spermatheca provide nourishment to the contained spermatozoa.

The second type of ectodermal gland, known collectively as **accessory glands**, opens more posteriorly in the genital chamber.

Each ovary is composed of a cluster of egg or ovarian tubes, the **ovarioles,** each consisting of a **terminal filament**, a **germarium** (in which mitosis gives rise to primary oocytes), a **vitellarium** (in which oocytes grow by deposition of yolk in a process known as vitellogenesis) and a **pedicel**. An ovariole contains a series of developing oocytes each surrounded by a layer of follicle cells forming an epithelium (the oocyte with its epithelium is termed a follicle), the youngest oocytes occur near the apical germarium and the most mature near the pedicel.



The different types of ovariole is based on the manner in which the oocytes are nourished.



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

Ovarioles of the other two contains trophocytes (nurse cells) that contribute to the nutrition of the developing oocytes.

(ii)Telotrophic ovariole: (**Acrotrophic**) The trophocytes are confined to the germarium and remain connected to the oocytes by cytoplasmic strands as the oocytes move down the ovariole, e.g. bugs.

(iii) Polytrophic ovariole: A number of trophocytes are connected to each oocyte and move down the ovariole with it, providing nutrients until depleted, thus individual oocytes alternate with groups of smaller trophocytes. e.g. moths and flies.

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

Structure of egg

Chorion

Vitelline membrane

Micropyle

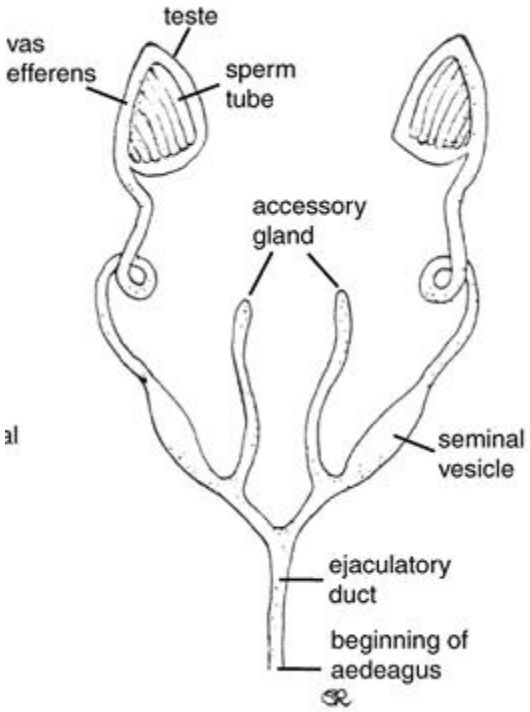
Periplasm with yolk

MALE REPRODUCTIVE SYSTEM

The main functions of the male reproductive system are the **production and storage** of spermatozoa and their transport in a viable state to the reproductive tract of the female. Morphologically, the male tract consists of paired **testes**, each containing a series of testicular tubes or follicles (in which spermatozoa are produced) which open separately into the mesodermally derived sperm duct or **Vas deferens** which expands posteriorly to form a sperm

storage organ or **seminal vesicle**. Tubular paired **accessory glands** are formed as diverticula of the vasa deferentia. Sometimes the vasa deferentia themselves are glandular and fulfil the functions of accessory glands. The paired vasa deferentia unite where they lead into the ectodermally derived **ejaculatory duct** (the tube that transports the semen or the sperm to the gonopore).

Accessory glands are 1-3 pair, either mesodermal of ectodermal in origin and associated with vasa deferentia or ejaculatory duct. Its function is to produce seminal fluid and spermatophores (sperm containing capsule).



TYPES OF REPRODUCTION IN INSECTS

PHYSIOLOGY OF REPRODUCTION

1. Spermatogenesis: (occurs inside sperm tube)

mitosis

Spermatogonia --------> Primary spermatocytes (2n) Meiosis

mitosis

Spermatids (n) <------- Secondary spermatocytes (n)

Spermiogenesis----------> Sperms (n)

2. Oogenesis : (occurs inside egg tube)

Mitosis Meiosis

Oogonia ---------> Primaryoocytes(2n) -------> Secondary oocytes (n)

Oogenesis Mitosis

Ovum (n) <---------- Oocytes (n) <---------

3. Sperm transfer

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

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

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

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

TYPES OF REPRODUCTION

1. OVIPARITY

Majority of female insects are oviparous that is, they lay eggs. Embryonic development occurs after oviposition by utilizing the yolk, e.g. Head louse moths.

2. VIVIPARITY

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

i. OVOVIVIPARITY

Fertilized eggs containing yolk are incubated inside the reproductive tract of the female and hatching of egg occur just prior to or soon after oviposition e.g. Thysanoptera, some cockroaches, few beetles, and some flies-(fleshfly). Fecundity of this group is low.

ii. PESEUDOPLACENTAL VIVIPARITY

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

ii. HAEMOCOELOUS VIVIPARITY

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

v. ADENOTROPHIC VIVIPARITY

This occurs when a poorly developed larva hatches and feeds orally from accessory (milk) gland secretion within the uterus of the mother's reproductive system. The full grown larva is deposited and **pupariates** immediately (eg) tsetse flies, louse or wallaby flies, bat flies.

3. PARTHENOGENESIS

Reproduction without fertilization is called parthenogenesis. Different types of parthenogenesis are as follows

I. BASED ON OCCURRENCE

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

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

iii. Cyclic or spordic : alternation of gamic and agamic population, e.g. aphid.

II. BASED ON SEX PRODUCED

i. Arrhenotoky: Produce male e.g. bee

ii. Thelytoky: produce female e.g. aphids

iii. Amphitoky or deuterotoky: produce both male and female e.g. cynipid wasp.

III. BASED ON MEIOSIS

i. Apodictic : no meiosis occurs

ii. Automictic: meiosis occurs, but diploidy is maintained

4.POLYEMBRYONY

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

5.PAEDOGENESIS

Some insect cut short their life cycles by loss of adult and pupal stages. In this precocious stage gonads develop and give birth to young one by parthenogenesis.

i. Larval paedogenesis - e.g. gall midges

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

TAXONOMY – IMPORTANCE, HISTORY AND DEVELOPMENT AND BINOMIAL NOMENCLATURE - DEFINITIONS OF BIOTYPE, SUB-SPECIES, SPECIES, GENUS, FAMILY AND ORDER

Taxonomy is the process of identifying and classifying living organisms. Taxonomists study organisms and identify them based on their characteristics. These characteristics might be visible morphological characteristics or genetic differences.

The binomial naming system is the system used to name species. Each species is given a name that consists of two parts. The first part is the Genus to which the species belongs and the second part is the species name.

For example, *Apis mellifera* (the honey bee). The honey bee belongs to the Genus *Apis* and has a scientific name of *Apis mellifera*.

The binomial naming system was first uniformly used by Carl Linnaeus.

Other names for (or types of) *Binomial naming system* include:

- Binominal nomenclature

Biological classification

Biological classification is the process by which scientists group living organisms. Organisms are classified based on how similar they are. Historically, similarity was determined by examining the physical characteristics of an organism but modern classification uses a variety of techniques including genetic analysis.

Organisms are classified according to a system of seven ranks:

1. Kingdom
2. Phylum
3. Class
4. Order
5. Family
6. Genus

7. Species

For example, the honey bee (*Apis mellifera*) would be classified in the following way:

1. Kingdom = Animalia
2. Phylum = Arthropoda
3. Class = Insecta
4. Order = Hymenoptera
5. Family = Apidae
6. Genus = *Apis*
7. Species = *Apis mellifera*

   Species names are always written including the Genus in either full or abbreviated, for example, *Apis mellifera* or *A. mellifera* respectively.

BIOTYPE

A group of organisms having the same or nearly the same genotype, such as a particular strain of an insect species.

SUB-SPECIES

A sub-division of a species, usually inhabiting a particular area: visibly different from other populations of the same species but still able to interbreed with them.

A subspecies is further division of a species based on minor but constant differences in structure, appearance or biology. Individuals in different subspecies will be morphologically or genetically different from one another but still capable of interbreeding and producing viable offspring.

SPECIES

The basic unit of living things, consisting of a group of individuals which all look more or less alike and which can all breed with each other to produce another generation of similar creatures.

Species is one of the seven taxonomic ranks used to classify living organisms. A species can be defined as a group of organisms that can breed and produce fertile offspring.

Historically speaking, species are described by taxonomists and what's called a *Type specimen* is catalogued and kept in a museum or other collection where scientists can access it. The *Type specimen* can be compared with other specimens to determine if they belong to the same species.

In modern taxonomy scientists now consider a species to be a group of evolving organisms and have moved away from the idea of a historical *Type specimen* representing the form of a species.

GENUS

A group of closely related species (plural: genera). The name of the genus is incorporated into the scientific names of all the member species: *Pieris napi* and *Pieris rapae*, for example, both belong to the genus *Pieris*

Genus is one of the seven taxonomic ranks used to classify living organisms. Genus is positioned after Family and before Species.

1. Kingdom
2. Phylum
3. Class
4. Order
5. Family
6. **Genus**
7. Species

FAMILY

A taxonomic subdivision of an order, suborder, or superfamily that contains a group of related subfamilies, tribes and genera. Family names always end in -idae.

ORDER

A subdivision of a class or subclass containing a group of related families.

Order is one of the seven taxonomic ranks used to classify living organisms. Order is positioned after Class and before Family.

1. Kingdom
2. Phylum
3. Class
4. Order
5. Family
6. Genus
7. Species

There are 29 insect Orders although, like much of biological classification, this is still being discussed and changed by scientists.

CLASSIFICATION OF CLASS INSECTA UPTO ORDERS

Insect is a six legged arthropod. Taxonomist **A.D. Imms** proposed a classification of insect.

Phylum : Arthropoda (with several classes)

Class: Insecta (Hexapoda)

Characters of class Insecta

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

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

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

The subclass Apterygota has 4 orders namely

1. Thysanura - Silverfish (Thysan-fringed, Ura-tail)

2. Collembola- Springtail or snowflea (coll-glue; embol-peg)

3. Protura - Proturans or Telsontail (Pro-first, Ura-tail)

4. Diplura - Diplurans or Japygids (Di-two; Ura-tail)

The sub-class Pterygota has **two division**, namely **Exopterygota** and **Endopterygota** based on the wing development.

	Character	**Exopterygota**	**Endopterygota**
1.	Wing development	External	Internal
2.	Type of metamorphosis	Incomplete(Hemimetabola) or gradual (Pau- rametabola)	Complete (Holome- tabola)
3.	Pupal stage	Absent	Present
4.	Immature stage	Naiad or Nymph	Larva
5.	No. of orders	16	9

The class Insecta has 29 orders (4 in Apterygota and 25 in Pterygota)

EXOPTERYGOTA **GROUPS**

01. Ephemeroptera - Mayflies **Group I. Paleopteran orders** (1,2)

02. Odonata-Dragonfly, Damselfly

03. Plecoptera - Stonefly **Group II**. **Orthopteroid orders**(3-11)

04. Grlloblatodia - Rock crawlers

05. Orthoptera-Grasshopper, locust, cricket, mole cricket

06. Phasmida-stick insect, leaf insect

07. Dermaptera-Earwigs

08. Embioptera-Webspinners/Embids

09. Dictyoptera-cockroach, preying mantis

10. Isoptera - Termites

11. Zoraptera - Zorapterans

12. Psocoptera - Book lice

Group III. **Hemipteroid orders**(12-16)

13. Mallophaga - Bird lice

14. Siphonculata - Head and body louse

15. Hemiptera - Bugs

16. Thysanoptera - Thrips

ENDOPTERYGOTA

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

02. Mecoptera - Scorpionflies.

Group IV. Panorpoid complex (1-6)

03. Lepidoptera - Butterflies and moths.

04. Trichoptera - Caddisfly.

05. Diptera - True fly.

06. Siphonaptera - Fleas.

07. Hymenoptera - Bees, wasps, ants.

08. Coleoptera - Beetles and weevils.

09. Strepsiptera - Stylopids.

ORDER - ORTHOPTERA FAMILY – ACRIDIDAE

ORTHOPTERA

Synonyms: Saltatoria, Saltatoptera

Etymology: Ortno - straight; ptera-wings.

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

Characters

- ✓ They are medium to large sized insects.
- ✓ Antenna is filiform.
- ✓ Mouthparts are mandibulate.
- ✓ Prothorax is large. Pronotum is curved, ventrally covering the pleural region.
- ✓ Hindlegs are saltatorial
- ✓ Forewings are leathery, thickened and known as tegmina.
- ✓ They are capable of bending without breaking.
- ✓ Hindwings are membranous with large anal area. They are folded by longitudinal pleats between veins and kept beneath the tegmina.
- ✓ Cerci are short and unsegmented.
- ✓ Ovipositor is well developed in female.
- ✓ Metamorphosis is gradual. In many Orthopterans the newly hatched frist instar nymphs are covered by loose cuticle and are called pronymphs. Wing pads of nymphs undergo reversal during development.
- ✓ Specialized stridulatory (sound-producing) and auditory (hearing) organs are present.

Classification

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

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

I. Sub order: Caelifera

1. Acrididae: (Locusts, Grasshoppers)

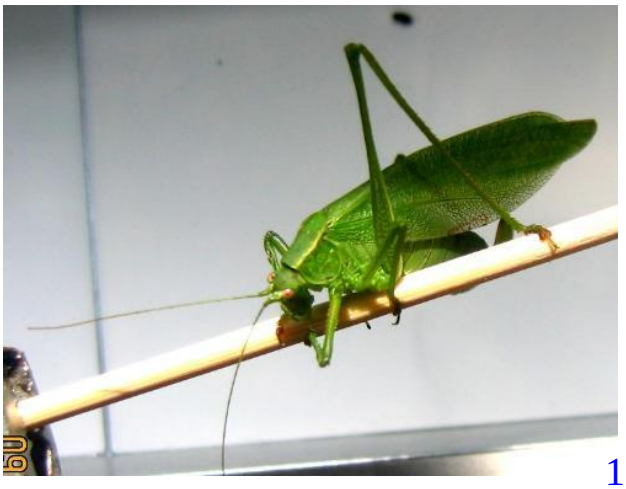
- ✓ Antenna is short
- ✓ Tarsus is three segmented
- ✓ Ovipositor is short and horny
- ✓ Tympanum is located one on either side of the first abdominal segment.
- ✓ Sound is produced by **femoro-alary** mechanism. A row of **peg** like projections found on the innerside of each hindfemur is rubbed against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

II. Sub order : Ensifera

1.Tettigonidae : (Katydids, Long horned grasshoppers)

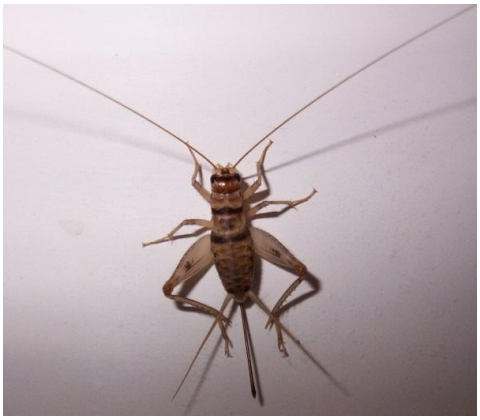
- ✓ Antenna is long, slender as long as or longer than the body.
- ✓ Tarsus is four segmented.
- ✓ Ovipositor is sword like.
- ✓ Auditory organs are found in foretibiae. In each foretibia a pair of tympanum is present. The outer tympanum is larger than the inner.

Sound production is **alary type**. A thick region on the hind margin of the forewing (**scraper**) is rubbed against a row of teeth on the stridulatory vein (**file**) present on the ventral side of another forewing which throws the resonant area on the wing (**mirrors**) into vibrations to produce sound.



2. Gryllidae (Cricket)

- ✓ Antenna is long.
- ✓ Tarsus is four segmented.
- ✓ Ovipositor is slender and needle like.
- ✓ Forewings are abruptly bent down to cover the sides of the body
- ✓ Hindwings are acuminate. They are produced into a pair of long processes which project beyond the abdomen.
- ✓ Cerci are long and unsegmented
- ✓ Auditory organs and stridulatory organs are similar to long horned grasshopper. Males stridulate during night. They produce a shrill chirping noise.
- ✓ *Gryllus sp*. It is household pest.
- ✓



3. Gryllotalpidae : (Mole crickets)

- ✓ They are brown coloured insects found inside the burrows. Eyes are reduced.
- ✓ Pronotum is elongate, ovate and rounded posteriorly.
- ✓ Forelegs are fossorial. Tibiae are expanded and digitate.
- ✓ Hindwings are extended beyond the tegima as a pair of processes
- ✓ Special stridilatory structures are absent. A humming sound is produced by rubbing the forewings.

- ✓ A pair of tympanum is found on the order surface of the tibiae.
- ✓ Ovipositor is vestigeal.
- ✓ Mole crickets burrow into the soil and feed on tender roots of growing plants. *Gryllotalpa africana* is a pest on stored potatoes.

MOLE CRICKET

DICTYOPTERA – MANTIDAE

DICTYOPTERA

Synonyms : Oothecaria, Blattiformia

Etymology : Dictyon - net work; ptera - wings

Common names : Cockroaches and preying mantids.

Characters

- ✓ Head is hypognathous.
- ✓ Antenna is filiform.
- ✓ Mouthparts are chewing type.
- ✓ Tarsus is five segmented.
- ✓ Forewings are more on less thickened, leathery with a marginal costal vein. They are called tegmina.
- ✓ Hindwings are large, membranous and folded fanlike and kept beneath the forewings.
- ✓ Cerci are short and many segmented.
- ✓ Eggs are contained in an ootheca.

Classification

Dictyoptera is divided into two suborders viz., **Blattaria** (cockroaches) and **Mantodea** (preying mantids). There are two important families viz., **Blattidae** and **Mantidae**

	Blattidae	**Mantidae**
1.	Head is not mobile in all directions	Head is mobile in all directions
2.	Head is hidden by the pronotum	Pronotum does not cover the head
3.	Two fenestrae (dagenerated ocelli sensitive to light) occur in the place of ocelli	Three ocelli are present
4.	Pronotum is shield like	Pronotum is elongate

5.	Legs are cursorial and are adapted for running	Forelegs are raptorial middle and hindlegs suited for walking
6.	Gizzard is powerfully armed with chitinous teeth to grind food	Chitinous teeth are absent in gizzard
7.	Female does not devour the male during mating	Often (but not always) devours the male during mating
8.	Eggs are laid inside a chitinous ootheca	Eggs are enclosed in filled solidfied foam Ootheca is not chitinous.
9.	Nymphs are not cannibalistic	Nymphs are cannibalistic
10	No mimicry is found	Mimic leaves and flowers
11.	Omnivorous	Carnivorous
12.	Found in household, dead wood, litter etc.	Found mostly outdoors
13.	Economic importance: They feed on food stuff, clothes and paper. They impart a foul smell to the food by contaminating with excreta. Hence they are harmful.	Economic importance: They are predators on moths, flies, grasshoppers, cater- pillars, etc. Hence they are beneficial.
14.	Important species: American cockroach *Periplanata americana*	Important species: *Mantis religiosa*
		

ODONATA

Etymology : Odon - tooth

Common names : Dragonflies and damselflies

Characters

- ✓ Medium to large sized insects
- ✓ They are attractively coloured
- ✓ Head is globular and constricted behind into a petiolate neck.
- ✓ Compound eyes are large.
- ✓ Three ocelli are present
- ✓ Mouthparts are adapted for biting. Mandibles are strongly toothed Lacinia and galea are fused to form mala which is also toothed.
- ✓ Wings are either equal or sub equal, membraneous; venation is net work like with many cross veins. Wings have a dark pterostigma towards the costal apex. Sub costa ends in nodus. Wing flexing mechanism is absent.
- ✓ Legs are anteroventrally placed. They are suited for grasping, holding and conveying the prey to the mouth. Spinose femora and tibiae are useful for holding the prey. Forward shift of leg attachments allow easy transfer of prey items to mouth in flight. Legs are held in such a way that a basket is formed into which the food is scooped.
- ✓ Abdomen is long and slender. In male gonopore is present on ninth abdominal segment. But the functional copulatory organ is present on the second abdominal sternite. Before mating sperms are transferred to the functional penis. Cercus is one segmented.
- ✓ Metamorphosis is incomplete with three life stages. The naiad is aquatic. Labium is greatly elongated, jointed and bears two hooks at apex. It is called mask. It is useful to capture the prey.

Importance

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

Classification

There are two sub-orders. Dragonflies are classified under **Anisoptera** and damselflies are grouped under **Zygoptera.**

	ANISOPTERA (Dragonflies)	**ZYGOPTERA (Damselflies)**
	ADULTS	
1.	Strong fliers	Weak Fliers
2.	Wings are unequal, Hindwings are basally broader than forewings	Equal
3.	Wings are broadly attached to the abdomen	Wings are petiolated and narrowly attached
4.	**Venation is not similar in both forewings and hindwings.**	**Venation is identical in both the wings**.
5.	Wings are spread laterally at rest	Wings are held at an angle above the abdomen
6.	Compound eyes are large and meet mid dorsally (**holoptic**)	Compound eyes are button like, wide apart (**dichoptic**)
7.	Male has three abdominal appendages. Two superior and appendages (cerci) and one inferior	Four terminal abdominal appendages are present. A pair of superior anal appendages (cerci) and a pair of inferior anal appendages

	anal appendage (epi- proct) are present.	(paraprocts) are present.
8.	Oviposition is exophytic	Oviposition is endophytic
		
	NAIAD	
1.	Stout and robust	Slender and fragile
2.	Gills are internal and found associated with rectum	Three caudal gills are present which are visible axternally.
3.	Able to propel themselves by forcibily ejecting water through anus from rectum	Lack jet propulsion mechanism
		

ISOPTERA-TERMITIDAE

ETYMOLOGY: "*iso*" meaning equal and "*ptera*" meaning wings

COMMON NAME: Termites

Characters

- ✓ Pale, elongate bodies, and are sometimes called “white ants.”
- ✓ Reproductive individuals have two pairs of membranous wings, all of equal length.
- ✓ Termites shed their wings after mating.
- ✓ Have chewing mouthparts.
- ✓ Antennae are roughly the length of their heads.

Classification

Hemimetabola - incomplete development (egg, nymph, adult)

Orthopteroid - closely related to Blattodea and Mantodea

Major Families

Rhinotermitidae (Subterranean termites) -- These insects build nests in the soil and generally infest wood that is in contact with the ground.

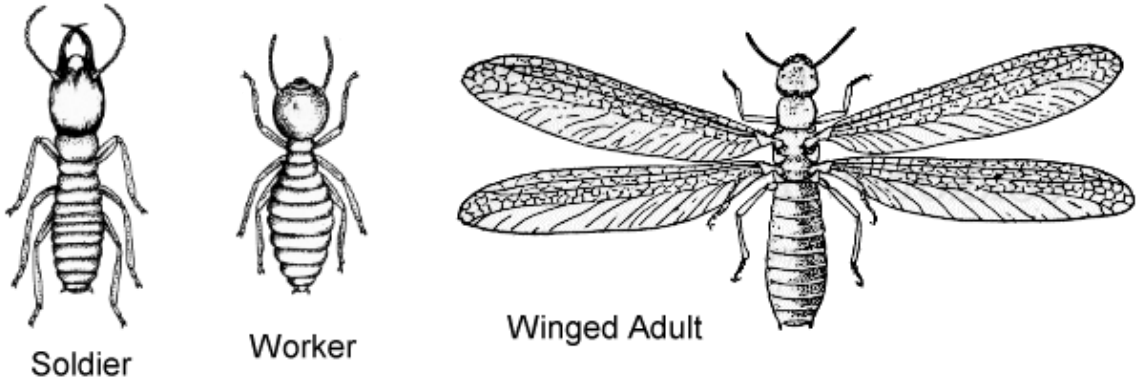
Hodotermitidae (Rottenwood termites) -- Generally found inhabiting moist wood. Contact with the soil is not a requirement.

Kalotermitidae (Drywood and dampwood termites) -- These insects nest in the wood itself and do not require contact with the soil.

Termitidae -- This is the largest family of termites worldwide.

Termitidae

Physical Features



	Immatures (Workers & Soldiers)	**Adults (Reproductives)**
1.	Body pale in color, somewhat ant-like in appearance but with a broader junction between thorax and abdomen	Body may be darkly pigmented
2.	Compound eyes small or absent	Compound eyes present
3.	Head large and cylindrical or small and round	Head well-developed, with chewing mouthparts and beaded antennae
4.	Antennae beaded	Two pairs of membranous wings, all similar in shape and size; wings are shed after mating
5.	Mouthparts chewing; sometimes with large mandibles	



THYSANOPTERA-THRIPIDAE

THYSANOPTERA

Synonyms : Physopoda

Etymology : Thysano - fringe; ptera - wings

Common name : Thrips.

Characters

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

Classification: This order is subdivided into two suborders.

1. TEREBRANTIA: Female with an appendicular ovipositor. Wing venation is present.

2. TUBULIFERA: Ovipositor is absent. The abdomen is tubular. Wing venation is absent.

Importance

They suck the plant sap. Some are vectors of plant diseases. Few are predators.

e.g. Rice thrips: *Stenchaetothrips biformis* is a pest in rice nursery.

HEMIPTERA - PENTATOMIDAE, COREIDAE, PYRRHOCORIDAE, LYGAEIDAE

Synonym : Rhynchota

Etymology :Hemi - half; ptera - wing

Common name :True bugs

General characters

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

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

	Heteroptera **(Hetero-different;ptera-wing)**	**Homoptera** **(Homo-uniform; ptera-wing)**
1.	Head is porrect or horizontal	Head is deflexed
2.	Bases of the forelegs do not touch the head	Bases of the forelegs touch the head
3.	Beak arises from the anterior part of the	Beak arises from the posterior part of the

	head	head
4.	Gular region of the head(midventral sclerotised part between labium and foramen magnum) well defined.	Gular region not clearly defined
5.	Pronotum usually greatly enlarged.	Pronotum is almost alway small and collar-like.
6.	Scutellum (triangular plate found between the wing bases) well developed	Scutellum not well developed.
7.	Forewings heavily sclerotized at the base and the apical half is membranous (Hemelytra)	Forewings are of uniform texture. They are frequently harder than hind pair.
8.	Wings are held flat over the the back at rest and the left and right side overlap on the abdomen.	Wings are held roof-like over the back and wings do not over lap.
9.	Honey dew secretion uncommon	Honey dew secretion common
10	Repungnatorial or odori- ferous or scent glands present.	Wax glands usually present.
11.	Both terrestrial and aquatic	Terrestrial.
12.	Herbivorous, predaceous or blood sucking.	Herbivorous.

IMPORTANT FAMILIES OF HETEROPTERA

1. GERRIDAE: (Jesus bugs, Water striders, or Pond skater) Slender, elongate insects.

- ✓ Forelegs are short, raptrorial and suited for capturing prey.
- ✓ Middle legs are long and useful in pushing.

- ✓ Hindlegs are long and useful in steering. Hind femur is very long and extends beyond the abdomen.
- ✓ Legs are fitted with fine non wetting hairs.
- ✓ They skate on water surface.
- ✓ They feed on insects falling on water surface.

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

- ✓ Head is narrow and elongate, constricted behind the eye forming a neck.
- ✓ Beak is short, three segmented and fits into a groove in the pro-sternum.
- ✓ Abdomen is widened in the middle.
- ✓ Lateral margins of the abdominal segments are exposed beyond the wing
- ✓ Many are predaceous on other isects. eg. *Platymeris leavicollis* is a predator on coconut rhinoceros beetle. *Triatoma sp and Rhodnius prolixus* are the vectors of chagas disease caused by *Trypanasoma cruzi* which causes human trypanasomiasis.

3. CIMICIDAE (Bed bugs)

- ✓ Body is dorsoventrally flattened so that they can hide in cracks and crevices. Body is oval in outline.
- ✓ It is dull reddish brown incolour.
- ✓ Thorax is deeply notched in front to receive the short head upto bulging eyes.
- ✓ Hemelytra short and reduced to scale like pads.
- ✓ Hindwings are completely atrophied.
- ✓ Stink glands are located in the dorsal surface of first three abdominal segments.
- ✓ Male bed bugs pierce the integument of the female and inject the sperm into the haemocoel during copulation (**Haemocoelic** or **traumatic insemination**).
- ✓ Beg bugs hide in crevices of beds, furniture, etc., during theday and emerge at night to seek a blood meal.They are blood sucking ectoparasites on birds and mammals. They are known for their irritating bite. *Cimex lectularis and Cimex hemipterus* are two important species affecting man in temperate and tropical conditions respectively.

4. TINGIDAE (Lacewing bugs)

- ✓ Pronotum has lateral expansions with lace like sculpturing. Scutellum is concealed by pronotum.
- ✓ Forewings have elaborate lace like markings due to densely reticulate, raised wing venation.
- ✓ Nymphs differ consideraly from adults. They are usually spiny and lack lace like markings.

- ✓ Both nymphs and adults are found on the undersurface of the leaves in groups, suck the sap and produce white spotted apperance on the leaf.
- ✓ They secrete honey dew. e.g. Banana lecewing bug *Stephanitis typicus*.

5. MIRIDAE : (Plant bugs or Leaf bugs).

- ✓ Beak and antennae are four segmented.
- ✓ Hemelytra with distinct **corium**, **clavus** and **cuneus** (a triangular apical piece of the basal part of forewing). Forewings are tilted at the distinct angle posterior to abdomen. Loop veins are found in membrane. Wings are tilted downwards.
- ✓ Nymphs and adults feed on plant juice and some species cause phytotoxemia due to the injection of toxic saliva. A few are also predaceous. e.g. Tea musquito bug *Helopeltis antonii* causes cankerous wart like growth on guava fruits.

6. LYGAEIDAE (Seed bugs or Chinch bugs)

- ✓ Cuneus is absent in hemelytra.
- ✓ Membrane has a few irregular veins (4-5 veins) arising from a transverse basal vein.

e.g. Dusky cotton bug *Oxycarenus hyalinipennis* nymphs and adults suck the sap from seeds of injured or already opened bolls and reduce the seed quality.

7. PYRRHOCORIDAE (Red bugs or Stainers)

- ✓ They are elongate oval bugs.
- ✓ They show warning colouration. They are brightly marked with red and black.
- ✓ Membrane is with more branched veins and cells. e.g. Cotton stainer *Dysdercus cingulatus*.
- ✓ Feeding injury caused by these bugs leads to the contamination by the fungus *Nematospora* resulting in yellowish brown discolouration of the lint.

8. COREIDAE (Squash bugs or leaf footed bugs)

- ✓ Membrane with many branching veins arising from a transverse basal vein.
- ✓ Stink glands are found inside the metathorax and glands openings are found on the sides of the thorax between middle and hind coxae. They emit a bad odour.
- ✓ Hind tibia and tarsi are expanded and leaf like.
- ✓ The edge of the abdomen is raised and wings lie in a distinct depression.e.g. Pod bug, *Riptortus pedestris* nymphs and adults suck the sap from pods of pulses.

9. PENTATOMIDAE (Stink bugs or Shield bugs)

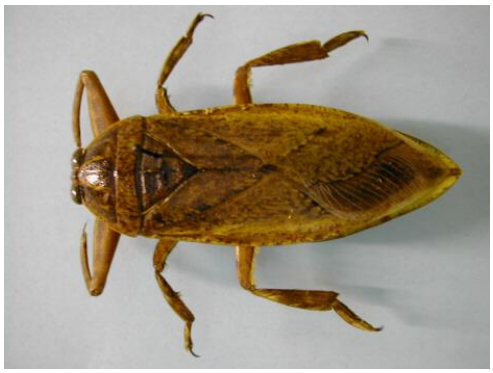
- ✓ Antenna is five segmented.
- ✓ Scutellum is prominent and shield like.
- ✓ Adults and nymphs produce a disagreeable odour from stink glands located in metathorax and abdomen respectively.
- ✓ Some are phytophagous and some are predaceous. e.g. Green stink bug *Nezara viridula* is a pest on millets.

10. NEPIDAE(Water scorpions)

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

11. BELOSTOMATIDAE(Giant water bugs or electric light bugs)

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



IMPORTANT FAMILIES OF HOMOPTERA

1. CICADIDAE (Cicadas)

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

2. MEMBRACIDAE(Tree hoppers or Cowbugs)

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

3. CICADELLIDAE (Leaf hoppers or Jassids)

- ✓ Elongate insects with a wedge shaped body.
- ✓ Attractively coloured.
- ✓ Hind tibiae have a double row of spines.
- ✓ Ovipositor is well suited for lacerating the plant tissue.
- ✓ Nymphs and adults have the habit of running sidewise.

- ✓ They suck the plant sap and transmit diseases. eg. Green leaf hopper *Nephotettix virescens* transmits tungro disease in rice.

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

- ✓ Adults resemble tiny frogs.
- ✓ Hind tibiae with one or two lateral spines and a crown short spines at the tip.
- ✓ Nymphs are soft, whitish and live inside the forth.
- ✓ Froth comes from liquid freed from alimentary canal and from a mucilagenous substance created from the epidermal glands on the seventh and eight abdominal segments. These are beaten into froth by means of the caudal appendages of the insect. Spittle serves both as a protective device and a means of reducing evaporation.

5. DELPHACIDE (Plant hoppers)

- ✓ Large mobile flattened spur is present at the apex of hind tibia
- ✓ eg. Brown plant hopper *Nilaparvata lugens* causes hopper burn, transmits viral diseaes in rice.

6. LOPHOPIDAE

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

7. PSYLLIDAE (Jumping plant lice)

- ✓ Small active insect
- ✓ They resemble minute cicadas
- ✓ They move actively by leaping and flying.

- ✓ Hindleg is more muscular and suited for jumping.
- ✓ There is a prominent basal vein in the forewing formed by the fusion of radius, median and cubitus.
- ✓ Nymphs are sluggish. e.g. Subabul psyllid *Heteropsylla cubana* is a serious pest on subabul.

8. ALEYRODIDAE (Whiteflies)

- ✓ Minute insects which superficially resemble tiny moths.
- ✓ Wings are opaque and dusted with mealy white powdery wax. Wing venation is much reduced.
- ✓ Vasiform orifice is present in the last abdominal tergite. It is a conspicuous opening provided with an operculum. Beneath the operculum there is a tongue-like organ termed lingula. The anus opens at the base of the lingula through which honey dew is excreated in large amount.
- ✓ Immature instars are sessile, scale like, with waxy covering.
- ✓ Metamorphosis approaches the homometabolus type due to the presence of a quiescent stage prior to the emergence of adults.
- ✓ e.g. Cotton whitefly *Bemisia tabaci* transmits vein clearing disease in bhendi.

9. APHIDIDAE (Aphids or Plant lice or Greenflies)

- ✓ Body is pear shaped
- ✓ Both apterous and alate forms are found.
- ✓ A pair of cornicles or siphonculi or wax tubes is present in the dorsum of fifth or sixth abdominal segments which secretes wax like substance.
- ✓ They excrete copious amount of honey dew on which ants feed and sooty mould fungus grows.
- ✓ Aphids are known for their extraordinary fecundity, short life cycle and parthenogenitic reproduction. Life cycle is highly complex and it involve alternation of generation.
- ✓ They feed on plant sap and disseminate plant diseases.
- ✓ e.g. Cotton aphid *Aphis gossypii*.



10. COCCIDAE (Scale insects or Soft scales)

- ✓ Sexual dimorphism is present.
- ✓ **Male** : They are gnat like, with long antennae, lateral eye and vestigeal mouth parts.

- ✓ Mesothorax is enlarged bearing one pair of wings with on or two veins. Hind wings are reduced to halteres. A quiescent stage is present in the life history.
- ✓ **Female** : Body segmentation is indistinct. Body wall naked and covered with a waxy coating. They are wingless, legless and suck the plant sap.
- ✓ The first instar nymph is active and is known as crawler which moults and becomes legless. e.g. Coffee green scale *Coccus viridis*.

11. DIASPIDIDAE (Armoured scale)

- ✓ Adult female lacks antennae, legs, and wings.
- ✓ The body is covered by a hard, waxy, shell like substance
- ✓ e.g. Coconut scale *Aspidiotus destructor*.

12. KERRIDAE (Lac insect)

- ✓ Females are highly degenerate without legs, wings and antennae.
- ✓ The body is irregularly globular.
- ✓ Body is enclosed in a thick resinous cell.
- ✓ e.g. Lac insect *Laccifer lacca*. Dermal gland secretions of this insect provides the sticklac.

13. PSEUDOCOCCIDAE (Mealy bugs)

- ✓ Body is elongate oval in shape.
- ✓ Body segmentation is distinct.
- ✓ Body is covered by long radiating thread of mealy secretion.

- ✓ Functional legs are present in all instars.
- ✓ Wings are absent.
- ✓ e.g. Coconut mealy bug, *Pseudococcus longispinus*.
- ✓ Nymphs and adults suck the sap and affect the growth of spindle leaf.

NEUROPTERA – CHRYSOPIDAE

NEUROPTERA

Etymology : Neuro-nerve; ptera - wings.

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

Characters

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

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

Sub order: PLANIPENNIA

1. CHRYSOPIDAE (Green lacewings, Goldeneyes, Stinkflies, Aphid lions)

- ✓ Body is pale green in colour.
- ✓ Eyes are golden yellow in colour.
- ✓ Eggs are mounted on stalks to avoid predation and cannibalism.
- ✓ Larvae preys on soft bodied insects, especially on aphids. It often carries a layer of debris on its body which provides camouflage.
- ✓ They emit a stinking fluid when alarmed, from prothoracie stink gland.
- ✓ They are mass multiplied and released in fields for controlling aphids.

2. MANTISPIDAE (Mantispid flies).

- ✓ They resemble preying mantids.
- ✓ Prothorax is elongated.
- ✓ Forelegs are raptorial. Femur is armed with powerful spines.
- ✓ Larva preys on spiderlings in the nests of ground spiders.
- ✓ Development involves hypermetamorphosis.

3. MYRMELEONTIDAE (Ant lions)

- ✓ Adult resembles a damselfly.
- ✓ The antenna is long a clubbed.
- ✓ They are weak fliers.
- ✓ Grubs construct conical pits for capturing prey.
- ✓ Larval mandibles are sickle-like with one or more internal teeth.

- ✓ They have dolichasters (Lateral segmental processes fringed with setae).

4. ASCALAPHIDAE (Owlflies)

- ✓ Adult resembles a dragonfly.
- ✓ Antenna is long, conspicuous and clubbed
- ✓ Hypostigmal cell is present in the wings
- ✓ Larvae do not construct pits to capture the prey
- ✓ Adults are aerial predators like dragonflies.

LEPIDOPTERA - NOCTUIDAE, SPHINGIDAE, PYRALIDAE, GELECHIIDAE, ARCTIIDAE

LEPIDOPTERA

Synonym : Glossata

Etymology : Lepido - scale; ptera - wings.

Common names : Moths, Butterflies, Skippers

Characters

- ✓ Body, wings, appendages, are densely clothed with overlapping scales, which give colour, rigidity and strength. They insulate the body and smoothen air flow over the body.
- ✓ Mouthparts in adults are of **siphoning** type. Mandibles are absent. The galeae of maxillae are greatly elongated and are held together by interlocking hooks and spines. The suctorial proboscis is coiled up like a watch spring and kept beneath the head when not in use.
- ✓ Wings are membranous and are covered with overlapping pigmented scales. Forewings are larger than hind wings. Cross veins are few. Wings are coupled by either **frenate** or **amplexiform** type of wing coupling.
- ✓ Larvae are **polypod-eruciform** type. Mouthparts are adapted for chewing with strong mandibles. A group of lateral ocelli is found on either side of the head. The antenna is short and three segmented. There are three pairs of five segmented thoracic legs ending in claws. Two to five pairs of fleshy unsegmented **prolegs** are found in the abdomen. At the bottom of the proleg, **crochets** are present.
- ✓ Pupa is generally **obtect**. It is either naked or enclosed in a cocoon made out of soil, frass, silk or larval hairs.

Classification

Majority of Lepidopteran insects (97%) are grouped under the suborder **Ditrysia** in which the female insects have two pores. The copulatory pore is located in eighth abdominal sternite

and the egg pore in ninth abdominal sternite. Ramaining insects are grouped under the suborder **Monotrysia** in which the female insects have one pore.

BUTTERFLY FAMILIES

1. NYMPHALIDAE (Brush footed or four footed butterflies)

- ✓ Forelegs are short, functionless, hairy and folded on thorax.
- ✓ Foretibia is short and covered with long hairs.
- ✓ Larva is with many processes or spines on the body.
- ✓ e.g. Castor butterfly : Ergolis merione. It is a defoliator.

2. LYCAENIDAE (Blues, Coppers, Hair streaks)

- ✓ Compound eyes are white rimmed.
- ✓ Antennae are with white rings.
- ✓ Upper wing surface is either metallic blue or coppery.Lower wing surface is lighter in colour.
- ✓ Hindwings is often with delicate hair like prolongations and two or three black spots.
- ✓ Larvae are flattened with retractile head.
- ✓ e.g. Pomegranate fruit borer : *Virachola isocrates*.

3. PAPILIONIDAE (Swallow tails)

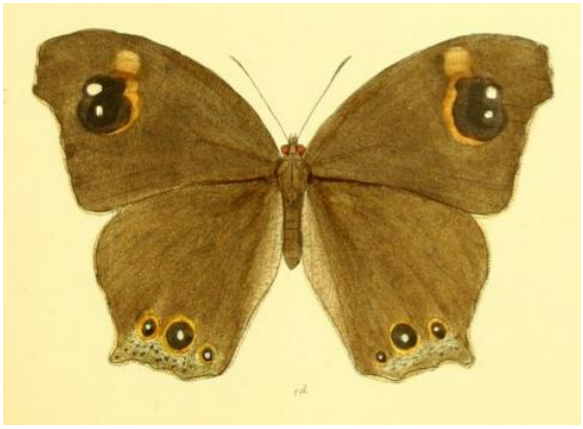
- ✓ They are often large and brightly coloured**.**
- ✓ Prothoracic legs have tibial epiphysis.
- ✓ In ma ny species hindwings has tail like prolongation**.**
- ✓ **Amplexiform** type of wing coupling is present.
- ✓ Larval body is either smooth or with tubercles.
- ✓ Retractile **osmeteria** are present on the prothoracic tergum of the caterpillar
- ✓ e.g. Citrus butterfly , *Papilio demoleus*.

4. PIERIDAE (whites or Sulphurs)

- ✓ They are white or yellow or orange coloured with black markings.
- ✓ Larva is green, elongate and covered with find hairs.
- ✓ Larval body segments have annulets.
- ✓ e.g. Daincha caterpillar, *Eurema hecabe*.

5. SATYRIDAE (Browns, Meadow - browns)

- ✓ They are dull brown or blackish in colour.
- ✓ Wings are with eye like spots both on the upper and lower surface.
- ✓ e.g. Rice horned caterpillar, *Melanitis ismene*.



MOTH FAMILIES

6. ARCTIIDAE (Tiger moths)

- ✓ Wings are conspicuously spotted or banded.
- ✓ They are nocturnal and attracted to light**.**
- ✓ Larva is either sparsely hairy or densely hairy (wooly bear).
- ✓ e.g. Black hairy caterpillar, *Estigmene lactinea*.

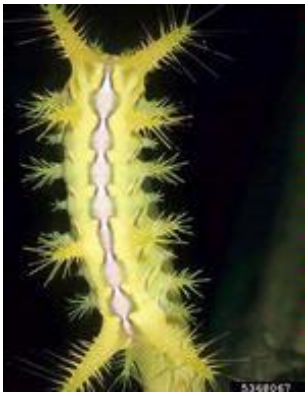
7. BOMBYCIDAE (Silk worm moths)

- ✓ Antenna is bipectinate.

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

8. COCHLIDIDAE (Slug caterpillar)

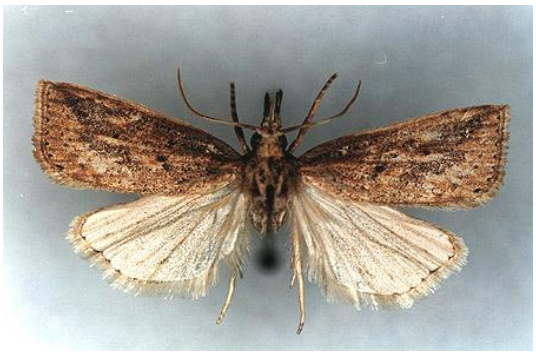
- ✓ They are medium sized moths with stoutly built body.
- ✓ Larva resembles the slug. Larva is thick, short, fleshy and stout. Larval head is small and retractile. Thorocic legs are minute. Abdominal segmentation is indistinct.
- ✓ Prolegs are absent. Poisonous urticating hairs are present on the body.
- ✓ Pupal cocoon is hemispherical with urticating hairs.
- ✓ e.g. Castor slug caterpillar *Latoia lepida*.



9. CRAMBIDAE (Grass moths)

- ✓ Labial palps are extended.
- ✓ Forewings are narrow and elongated. At rest they are wrapped around the body.

- ✓ Larva bores into root, stem or crown of graminaceous plants.
- ✓ e.g. Sorghum stem borer, *Chilo partellus*.



10. GELECHIIDAE

- ✓ Forewings trapezoidal and narrower than hindwings.
- ✓ Caterpillars bore into the seeds, tubers, and leaves.
- ✓ e.g. Cotton pink boll worm, *Pectinophora gossypiella*.

11. GEOMETRIDAE (Loopers)

- ✓ Both pairs of wings are angular and thin.
- ✓ Larva is naked and elongate. It shows protective resemblance to twings or stems. Only two pairs of prolegs are present in sixth and tenth abdominal segments. It walks by drawing the posterior part of the body close to the thorax, the body forming a loop. It is also called inch worm, measuring worm and earth measurer.
- ✓ e.g. Tea looper, *Biston suppressaria.*

12. LYMANTRIDAE (Tussock moths)

- ✓ Antenna is bipectinate
- ✓ Legs are clothed with wooly hairs.
- ✓ Female is provided with a tuft of anal hairs.
- ✓ Larvae is densely hairy.
- ✓ e.g. Castor hairy caterpillar, *Euproctis fraterna.*

13. NOCTUIDAE (Noctua moths)

- ✓ They are medium sized, stoutly built moths.
- ✓ They are nocturnal and attracted to light.
- ✓ Labial palp is well developed.
- ✓ Crochets on the larval prolegs are all of one size and arranged in semi-circle.
- ✓ Some larvae are semiloopers. They have either three or four pairs of prolegs.

- ✓ Larvae attack the plants during night. Larvae of some species remain concealed beneath the surface of the ground or litter on the surface during day and feed on plants during night. They often cut small seedlings close to the ground and hence they are called cut worms.
- ✓ e.g. Tobocco cut worm, *Spodoptera litura*.

14. PTEROPHORIDAE (Plume moths)

- ✓ They are small lightly built months
- ✓ Forewings are elongate with two to four clefts or fissures.
- ✓ Hindwings have three divisions
- ✓ Legs are long, slender and armed with prominent tibial spurs.
- ✓ e.g. Redgram plume moth, *Exelastis atomosa*.

15. PYRAUSTIDAE

- ✓ Proboscis is vestigial in many species.
- ✓ Libial palp is snout like.

- ✓ Larval habit varies. It may live among aquatic plants and bore into the stem or remain in silken web among spun up plants parts. Some larvae are aquatic and gill breathing.
- ✓ e.g. Rice stem borer, *Scirpophaga incertulas*.

16. SATURNIIDAE (Moon months, giant silk worm moths)

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

17. SPHINGIDAE (Hawk moths, Sphinx moths, Horn worms)

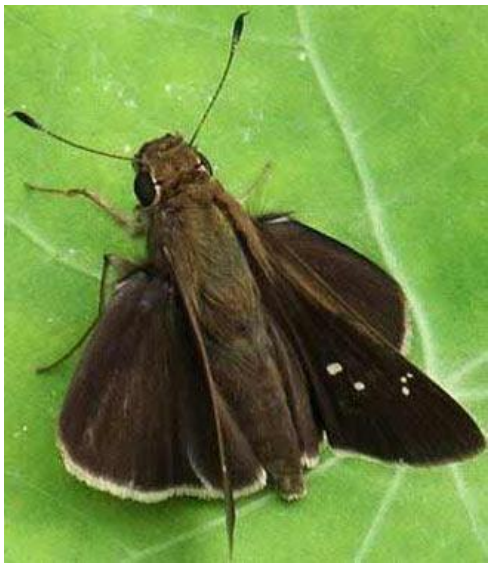
- ✓ They are large sized stoutly built moths.
- ✓ Antenna is thick towards middle and hooked at the tip.
- ✓ Proboscis is very long.
- ✓ Forewings are elongated and pointed with very oblique outer margin.
- ✓ Hindwings are reduced in width fitting into the indendted margin of forewings. They are powerful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

SKIPPER FAMILY

18. HESPERIIDAE (Skipper)

- ✓ Antennae are widely separated at the base. They are dialated apically to form a gradual club. Each antenna is apically prolonged beyond the club into a hook or small recurved point.

- ✓ Wings are comparatively small. They are often held partly open at rest. Flight is erratic and darting.
- ✓ Larval head is large. There is a constriction beyond the head. Larva tapers towards both extremities. Larvae are often concealed in the host foliage.
- ✓ e.g. rice skipper, *Pelopidas mathias*.



COLEOPTERA - COCCINELLIDAE, CHRYSOMELIDAE, CERAMBYCIDAE, CURCULIONIDAE, BRUCHIDAE, SCARABAEIDAE

COLEOPTERA

Synonym : Elytroptera

Etymology : Coleo - Sheath ; ptera-wing

Common names : Beetles, Weevils

Characters

- ✓ They are minute to large sized insects.
- ✓ Antenna is usualy 11 segmented.
- ✓ Mouthparts are chewing type. Mandibles are short with blunt teeth at the mesal face in phytophagous group. In predators the mandibles are long, sharply pointed with blade like inner ridge. In pollen feeders teeth are absent and the mandibles are covered with stiff hairs.
- ✓ Prothorax is large, distinct and mobile.
- ✓ Mesothorax and metathorax are fused with the first abdominal segment.
- ✓ Forewings are heavily sclerotised, veinless and hardened. They are called elytra. Forewings do not overlap and meet mid-dorsally to form a mid-dorsal line. It is not used for flight. They serve as a pair of convex shields to cover the hindwings and delicate tergites of abdomen.
- ✓ Hindwings are membranous with few veins and are useful in flight. At rest they are folded transversely and kept beneath the elytra. In some weevils and ground beetles the forewings are fused and hindwings are atrophied.
- ✓ A small part of the mesothorax known as scutellum remains exposed as a little triangle between the bases of elytra.
- ✓ Cerci and a distinct ovipositor are absent.
- ✓ Metamorphosis is complete. Larva are often called grubs.

- ✓ Pupae are usually exarate and rarely found in cocoons.

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

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

FAMILIES OF PREDATORS

1. CICINDELIDAE (Tiger beetles)

- ✓ Head is usually wider than prothorax.
- ✓ Eyes are fairly larger and they have very keen vision.
- ✓ Mandibles are sharply pointed, sickle shaped and acutely toothed for capturing the prey.
- ✓ Legs are long and tarsi slender which enable to run fast.
- ✓ Elytra have spots and stripes.
- ✓ Larva excavates vertical pits for prey capture.
- ✓ Both grubs and adults are active predators.

2. CARABIDAE (Ground beetles)

- ✓ Adults are often black in colour and some brightly spotted.
- ✓ Some cannot fly because they have fused elytra and atrophied hindwings.
- ✓ Legs are suited for running.

- ✓ Larvae have caliper like mandibles, well developed legs and terminal cerci like structures called urogomphi.
- ✓ They are nocturnal. Ground beetles are voracious predators both as adults and larvae.
- ✓ They feed on soft bodied caterpillars and other insects.
- ✓ Six spotted carabid : *Anthia sexguttata*

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

- ✓ Body is long, oval, smooth and shiny.
- ✓ Head, thorax and abdomen are compactly joined.
- ✓ Antenna is filiform.
- ✓ In some male beetles the foretarsi are provided with cup like suckers which are useful in clasping the mate.
- ✓ Hindlegs are flattened, fringed with hairs and suited for swimming.
- ✓ Air is stored beneath the elytra.
- ✓ Adults and larvae are aquatic predators

4. GYRINIDAE (Whirlinig beetles)

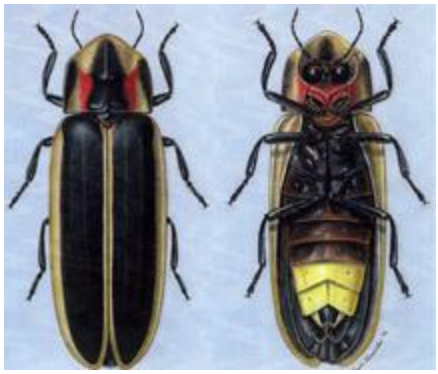
- ✓ They swim in erratic paths on water surface and exhibit gyrating moton.
- ✓ Compound eyes are completely divided by the front margin of the head into an upper and lower half so that the beetle appear to have two pairs of compound eyes. The dorsal pair is suited for aerial vision and the ventral pair is for aquatic vision.
- ✓ Forelegs are prehensile and long.
- ✓ Middle legs and hindlegs are **natatorial**.
- ✓ They are predators.

5. COCCINELLIDAE (Lady bird beetles)

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

6. LAMPYRIDAE (Fireflies, Glow worms)

- ✓ They show sexual dimorphism.
- ✓ **Male** : head is concealed by the semicircular pronotum.
- ✓ Eyes are well developed and contiguous.
- ✓ Forewings are soft and flexible. They do not fully cover the abdomen.
- ✓ Photogenic organ is found in sixth and seventh abdominal segments.
- ✓ **Female** : Head is hidden by pronotum.
- ✓ Eyes are very much reduced.
- ✓ Wings are absent and is larviform.
- ✓ Photogenic organ is present in seventh abdominal segment.
- ✓ Larvae are with sickle like mandibles. They are carnivorous and feed on snails. Extra intestinal digestion is common in larvae.
- ✓ All life stages are luminous to varying degree. The luminescence is produced by the oxidation of a substance luciferin in the presence of an enzyme luciferase. The function of luminescence is to bring the sexes together.



FAMILIES OF SCAVENGERS

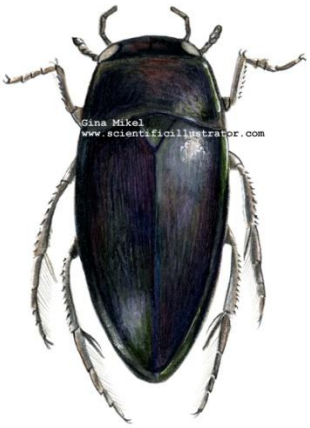
1. SCARABAEIDAE (Scarabs, Dung beetles)

- ✓ Head is broad and flat.
- ✓ Mandibles are membranous and incapable of chewing.

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

2. HYDROPHILIDAE (Water scavenger beetles)

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



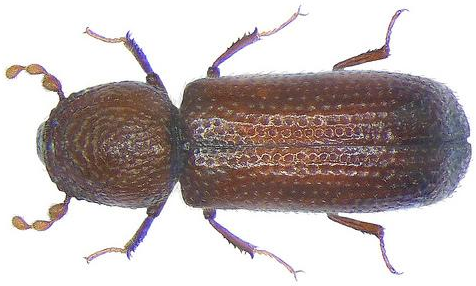
FAMILIES OF STORED PRODUCT PESTS

1. ANOBIIDAE (Wood worms, Wood borers)

- ✓ Body is oval shaped or cylindrical.
- ✓ Head is concealed by pronotum which is helmet like.
- ✓ Grub is fleshy with larger abdominal segments.
- ✓ Cigarette beetle : *Lasioderma serricorne* is the most serious pest of tobacco in factories and cigar stores.

2.BOSTRYCHIDAE

- ✓ They are small, elongate and cylindrical beetles.
- ✓ Head is concealed by the pronotum which is hood like.
- ✓ Antenna is either smooth or sculptured.
- ✓ Lesser grain borer : *Rhizopertha dominica* larvae bore in to the stored grains and eat the inner contents completely.



3. BRUCHIDAE (Pulse beetles, Seed beetles)

- ✓ They are small, short beetles.
- ✓ Head is small and the snout is blunt.
- ✓ Antenna is serrate.
- ✓ Hind femur is thick.
- ✓ Elytra are short and do not cover the abdomen fully.
- ✓ Eggs are whitish, scale like and glued to the pods or seeds by a glutinous secretion. Grubs feed exclusively on seed legumes. Pupation occurs within the seed. Adult emerges by cutting a circular exit hole. Development is similar to hypermetamorphosis. Pulse beetle : *Callosobruchus chinensis*. It is a serious pest on stored pulses.

4. TENEBRIONIDAE(Meal worms)

- ✓ Body is flat and elongate.
- ✓ Elytra is often sculptured.
- ✓ Legs are heteromerous with a tarsal formula of 5-5-4.
- ✓ Larvae are called meal worms.

- ✓ Red flour beetle : *Tribolium castaneum*. It is an important pest of milled products.

FAMILIES OF CROP PESTS

1. APIONIDAE:

- ✓ Head is produced into a snout
- ✓ Antenna is not elbowed.
- ✓ Grubs are apodous.
- ✓ Sweet potato weevil : *Cylas formicarius*. It attacks sweet potato both in fields and in storage.

2. BUPRESTIDAE (Jewel beetles, Metallic wood borers)

- ✓ They are often elongate hard bodied insects.
- ✓ Body regions have a metaliic lusture
- ✓ Antenna is serrate.

- ✓ Larvae are called flat headed borers. Larval head is small and is entirely withdrawn into thorax. Prothorax is greatly expanded. Legs are absent. They tunnel beneath the bark or bore into stems or roots.
- ✓ Groundnut stem borer : *Sphenoptera perotetti*. The larva tunnels into the main root and kills the plants.



4. CASSIDIDAE (Tortoise beetles)

- ✓ Adults look like a small tortoise
- ✓ Head is concealed under the prothorax.
- ✓ Head is inferior in position.
- ✓ Prothorax and elytra are convex, wider and form a shell.
- ✓ Leg tips alone are exposed outside the shell.
- ✓ Larva is dorsally spiny to which excreta and exuviae are attached forming a faecal shield.
- ✓ Sweet potato beetle : *Aspidiomorpha miliaris*. They primarily feed on sweet potato.

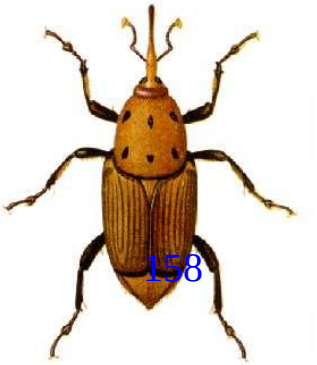
5. CERAMBYCIDAE (Longicorn beetles)

- ✓ Body is cylindrical.

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

6. CURCULIONIDAE (Weevils, snout beetles)

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



7. DYNASTIDAE (Unicorn beetles, Rhinoceros beetles)

- ✓ Mandibles are bent, expanded, leaf like and visible from above.
- ✓ Horns are usually present in male in the head and thorax.
- ✓ Coconut rhinoceros beetle: *Oryctes rhinoceros*. Cephalic horns are found in both the sexes. In male the horn is longer and recurved. In female it is shorter and straight. Adults are injurious to coconut and grubs are found in dying palms and manure pits.

8. ELATERIDAE(Click beetles, Wire worms)

- ✓ Body is elongate and cylindrical.
- ✓ Pronotum is rounded anteriorly and its posterior corners are sharply pointed.
- ✓ Adult is able to jump and land upon its feet while lying on its back. Each jump is accompanied by an audible clicking sound. Movement of prothorax makes the prosternal spine to slip into the mesosternal cavity. This causes the elytra to press against the surface and propel the beetle into air.
- ✓ Eggs are laid in soil.Grubs are long,

cylindrical and tough skinned and called wireworms. They feed on roots.

9. GALERUCIDAE(Pumpkin beetles)

- ✓ Antennae are closely approximated.
- ✓ Third tarsomere is deeply bilobed.
- ✓ Larvae are root feeders.
- ✓ Adults bite holes on leaves.
- ✓ Red pumpkin beetles : *Raphidopalpa foveicollis*.

10. MELOIDAE(Blister beetles, Oil beetles)

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

Banded blister beetle : *Mylabris pustulata*

11. MELOLONTHIDAE (Chafer beetles, June beetles, White grubs)

- ✓ They are stout beetles with glossy surface.
- ✓ Head is small.
- ✓ Labrum is well sclerotised.
- ✓ Adults are attracted to light. They feed on tree foliage during night and hide in soil during day time.
- ✓ Larvae are scarabaeiform and root feeders.
- ✓ Groundnut white grub: *Holotrichia consanguinea*. It is a serious pest on groundnut under rainfed condition.

HYMENOPTERA

Etymology : Hymen - membrane; ptera - wings.

Hymeno - god of marriage; ptera - wings,

(Marriage on the wings)

(union of fore and hindwings by hamuli)

Common names :Ichneumonflies, Ants, Bees, Wasps.

Characters

- ✓ Mouthparts are primarily adapted for chewing. Mandibles are very well developed. In bees both labium and maxillae are integrated to form the **lapping tongue**.
- ✓ Thorax is modified for efficient flight. Pronotum is collar like. Mesothorax is enlarged. Metathorax is small. Both prothorax and metathorax are fused with mesothorax.
- ✓ Wings are stiff and membranous. Forewings are larger than hindwings. Wing venation is reduced. Both forwings and hindwings are coupled by a row of hooklets (**hamuli**) present on the leading edge of the hindwing.
- ✓ Abdomen is basally constricted. The first abdominal segment is called **propodeum**. It is fused with metathorax. The first pair of abdominal spiracles is located in the propodeum. The second segment is known as **pedicel** which connects the thorax and abdomen. Abdomen beyond the pedicel is called **gaster** or **metasoma**.
- ✓ Ovipositor is always present in females. It is variously modified for oviposition or stinging or sawing or piercing plant tissue.
- ✓ Metamorphosis is complete. Often the grub is apodous and eucephalous. Larva is rarely eruciform. Pupa is exarate and frequently enclosed in a silken cocoon secreted from labial glands.
- ✓ Sex is determined by the fertilization of the eggs. Fertilized eggs develop into females and males are produced from unfertilized eggs. Males are haploid and females diploid.

Classification

This order is subdivided into two suborders.

	SYMPHYTA (Chalastogastra)	APOCRITA (Clistogastra)
1.	Abdomen is broadly joined to the the thorax.	Abdomen is petiolated.
2.	Larva is a caterpillar and belongs to eruciform type	Larva is a grub and it belongs to apodous eucephalous type
3.	Stemmata are present	Stemmata are absent.
4.	Both thoracic and abdominal legs are present	Legs are absent
5.	Ovipositor is saw like and suited for piercing the plant tissue	Ovipositor is not saw like and is suited for piercing in para sitic groups or for stinging in other groups
6.	Behavioural sophistication is less	Behavioural sophistication is more.
7.	They are phytophagous	They are generally parasitic

I.Suborder : SYMPHYTA

1. TENTHREDINIDAE (Sawflies)

- ✓ They are wasp like insects.
- ✓ Abdomen is broadly joined to the thorax.
- ✓ The ovipositor is saw toothed and suited for slicing the plant tissue.
- ✓ Larvae is eruciform. It resembles a lepidopteran caterpiller. It has one pair of ocelli, papillae (reduced antenna) three pair of thoracic legs and 6-8 pairs of abdominal legs.

Prolegs lack crochets. They are external feeders on foliage. Larvae while feeding usually have posterior part of the body coiled over the edge of the leaf.

Mustard sawfly : *Athalia lugens proxima* is a defoliator of mustard and cruciferous vegetables.

II. Suborder : APOCRITA

2. ICHNEUMONIDAE (Ichneumonflies)

- ✓ Adults are diurnal and visit flowers.
- ✓ Trochanter is two segmented. Hind femur is with **trochantellus**
- ✓ Forewing has two recurrent veins.
- ✓ Petiole is curved and expanded at the apex.
- ✓ Sternites of the gaster are membranous
- ✓ Ovipositor is arising anterior to the tip of abdomen. It is often longer than the body and exerted out permanently.
- ✓ Larvae are mostly parasites and less frequently hyperparasites. They are solitary parasites. They spin cocoons in or outside the host. *Eriborus trochanteratus* is an exotic larval parasite of coconut black headed caterpillar.

3. BRACONIDAE (Braconid wasps)

- ✓ They are small, stout bodied insects
- ✓ Forewing has one recurrent vein.
- ✓ Petiole is neither curved nor expanded at the apex.
- ✓ Gaster is sessile or subsessile.
- ✓ Sternites of the gaster are partly membranous.
- ✓ Abdomen is as long as the head and thorax together
- ✓ They parasitize lepidopteran larvae commonly.
- ✓ They are gregarious parasites.
- ✓ In many species polyembryony is observed.
- ✓ Pupation occurs in silken cocoons either externally on the host or away from the host in groups. *Bracon brevicornis* is mass multiplied and released for the control of coconut black headed caterpillar.

4. BETHYLIDAE

They are ant like, black coloured wasps.

Females of many species are wingless.

Parasierola nephantidis is a specific larval parasite on coconut black headed caterpillar.

5. CHALCIDIDAE

- ✓ They are small to medium sized insects.
- ✓ Hind coxae are five to six times larger than forecoxae.
- ✓ Hind tibial spurs are larger than mid tibial spurs.
- ✓ Hind femora are larger with a row of short-teeth beneath.
- ✓ Wing venation is reduced to a single anterior vein.
- ✓ Ovipositor is short and straight.
- ✓ *Brachymeria sp* is a pupal parasite on coconut black headed caterpillar.

6. EULOPHIDAE

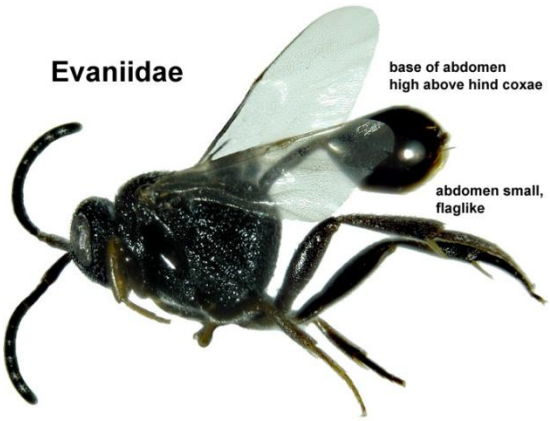
- ✓ They are minute pupal parasites.
- ✓ Forewing is narrower with pubascence on the wing lamina.
- ✓ Hairs are not arranged in rows.
- ✓ Ovipositor is present almost at the tip of the abdomen.
- ✓ *Tetrastichus israelli* is a gregarious pupal parasite commonly used for the control of coconut black headed caterpillar.

7. TRICHOGRAMMATIDAE

- ✓ They are very tiny insects (0.3 to 1.0 mm long)
- ✓ Tarsus is three segmented.
- ✓ Forewing is broad with pubascence (Microscopic hairs) in rows.
- ✓ Hindwing is reduced and fringed with hairs along the margins.
- ✓ They are mainly egg parasites on Lepidopteran insects.
- ✓ *Trichogramma sp*. is extensively used in the biological control of sugarcane moth borers.

8. EVANIIDAE (Ensign wasps)

- ✓ Petiole is long and abrupt.
- ✓ Gaster is short, compressed and attached to the propodeum by the slender petiole. It is carried almost like a flag.
- ✓ They are parasitic on the **ootheca** of cockroaches.



9. AGAONIDAE (Fig wasps)

- ✓ Male is apterous.
- ✓ Female is winged.
- ✓ Female has a logn ovipositor
- ✓ Forelegs and hindlegs are stout.
- ✓ Middle legs are slender**.**

- ✓ They live inside fig receptacles and pollinate and fractify the flowers.

Blastophaga pesenes develops in the capri fig (wild) and pollinates symyrna fig (edible cultivated fig).

10. VESPIDAE (Yellow jackets, Hornets)

- ✓ Lateral extensions of the pronotum reach the point of insertion of wings and do not form rounded lobes**.**
- ✓ Abdomen is conical
- ✓ They construct nest with `wasp paper', a substance made from fragments of chewed wood mixed with saliva.
- ✓ They are either solitary or social wasps.
- ✓ They are generally predaceous on Lepidopteran caterpillars. Many paralysed caterpillars are stored in the cells of their nests. Eggs are suspended by a filament from the top of the nest and the cell is sealed.
- ✓ Yellow banded wasp *Vespa cincta* is a bee enemy.

11. SPHECIDAE (Thread waisted wasp, Digger wasp, Mud dauber)

- ✓ Lateral extensions of the pronotum form rounded lobes
- ✓ Petiole is slender.
- ✓ Nests are constructed by using mud or dug out in ground. They use insects and spiders to provision their nests. Eggs are laid on the paralysed or killed host.

12. FORMICIDAE (Ants)

- ✓ They are common widespread insects.
- ✓ Antennae are geniculate.
- ✓ Mandibles are well developed.
- ✓ Wings are present only in sexually mature forms.
- ✓ Petiole may have one or two spines.
- ✓ They are social insects with three castes viz., queen, males and workers. Workers are sterile females and they form the bulk of the colony. Exchange of food materials between adults and immature insects is common. After a mating flight queen alone finds a suitable nesting site. Wings break near the abscission suture near the base are nipped off by mandibles. Egg laying is started after divesting the wings. Usually the queen does not forage for food. During the initial phase of nest building it lives entirely on fat body reserves and products of wing muscle degeneration.
- ✓ Many species have established symbiotic relationship with homopteran insects.

13. APIDAE (Honey bees)

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

Indian honey bee *Apis indica* is a productive insect.

Apis indica

Apis dorsata

Apis florea

14. MEGACHILIDAE (Leaf cutter bees)

- ✓ They are solitary bees.
- ✓ Mandibles are sharp and scissors like.
- ✓ Pollen gathering hairs (scopa) are present on the venter of the abdomen.
- ✓ They cut circular or crescent shaped pieces of leaves of rose, redgram, guava etc. The cut pieces of leaves are used for preparing leaf lined cells. The provision for the brood consists of a mixture of pollen mixed with honey.
- ✓ Rose leaf cutter bee: *Megachile anthracena* is a pest on rose, redgram and guava.

15. XYLOCOPIDAE (Carpenter bees)

- ✓ They are large, robust bees.
- ✓ Dorsum of the abdomen is bare.
- ✓ Pollen baskets are absent in hindlegs. But brushes of hairs are present on hinglegs.
- ✓ They build nests in dead logs and in live branches. They tunnel in all directions. They do not feed on wood. The tunnel is partitioned into several cells, separated by cemented wood chips. Pollen and nectar are placed in each cell together with one egg. The larvae hatch, feed, grow and pupate inside.
- ✓ Adults are not aggressive and do not sting. They visit flowers and take nectar often by simply biting through the base of the flower instead of sipping from the top.

DIPTERA - CECIDOMYIIDAE, TRYPETIDAE, TACHINIDAE, AGROMYZIIDAE.

DIPTERA

Etymology : Di-two; ptera-wing

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

Characters

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

Classification

This order is sub divided in to three suborders.

I. NMATOCERA (Thread-horn)

- ✓ Antenna is long and many segmented in adult.
- ✓ Larval head is well developed.

- ✓ Larval mandibles act horizontally.
- ✓ Pupa is weakly obtect.
- ✓ Adult emergence is through a straight split in the thoracic region.

II. BRACHYCERA (Short-horn)

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

CYCLORRHAPHA: (Circular-crack)

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

Sub order: NEMATOCERA

1. CULICIDAE (Mosquitoes)

- ✓ They are delicate, fragile, slender insects
- ✓ Females have piercing and sucking type of mouthparts with six stylets.
- ✓ Antenna is plumose (bushy) in male and pilose (less hairy) in female.
- ✓ Legs are slender, delicate and long.
- ✓ Wings are fringed with hairs and scales on hind margin and on some veins.
- ✓ Males are short lived and feed on nectar or decaying fruits.
- ✓ Females live long and are blood feeders.

- ✓ Larvae are called **wrigglers**. Larval head is large with chewing mouthparts and mouth brush aiding in filter feeding. Thorax is large without legs. Respiratory siphon is located in the penultimate abdominal segment. Anal gills are present at the terminal end of the abdomen.
- ✓ Pupa is known as **tumbler**. It is very active. It has a pair of prothoracic horns which houses the anterior pair of spiracles. A pair of anal paddles is present at the terminal end aids in swimming.

Malarial mosquite

Anopheles sp transmits malaria

Filarial mosquito .

Culex sp transmits filariasis

Mosquito larvae wriggler

Mosquito pupa tumbler

2. CECIDOMYIIDAE (Gall midges)

- ✓ They are minute delicate, mosquito like flies.
- ✓ Antennae and legs are long
- ✓ Wing venation is reduced. Wings are covered with long hairs.
- ✓ A dark sclerotised area is present midventrally on the prothorax in the larva called `chest bone'.

Rice gall midge : *Orseolia oryzae - maggot* feeding produces galls.

Sub order: BRACHYCERA

3. ASILIDAE (Robber flies)

- ✓ They are elongate bristly flies.
- ✓ Head is broad and hollowed out in between the compound eyes
- ✓ Compound eyes are protuberant. A prominent tuft of hairs is found on the head forming the mouth-beard. The proboscis is thick and stout.
- ✓ Legs are stout, hairy and suited for catching the prey.
- ✓ Abdomen is tapering and has a pair of large claspers at the tip of the male and a horny ovipositor in female.
- ✓ They are most active, non selective predators.

4. TABANIDAE (Horse flies)

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

Sub order: CYCLORRHAPHA

5. SYRPHIDAE (Hover flies, Flower flies)

- ✓ They are birghtly coloured and brilliantly striped. A vein like thickening (spurious vein) is present in between the radius and median in the forewing.

- ✓ Abdomen has distinct black and yellow markings.
- ✓ Maggots prey on soft bodied insects especially aphids.
- ✓ Abdults are excellent flies. They hover over flowers. They feed on pollen and nectar. They aid in pollination.

Hover flies

Flower flies

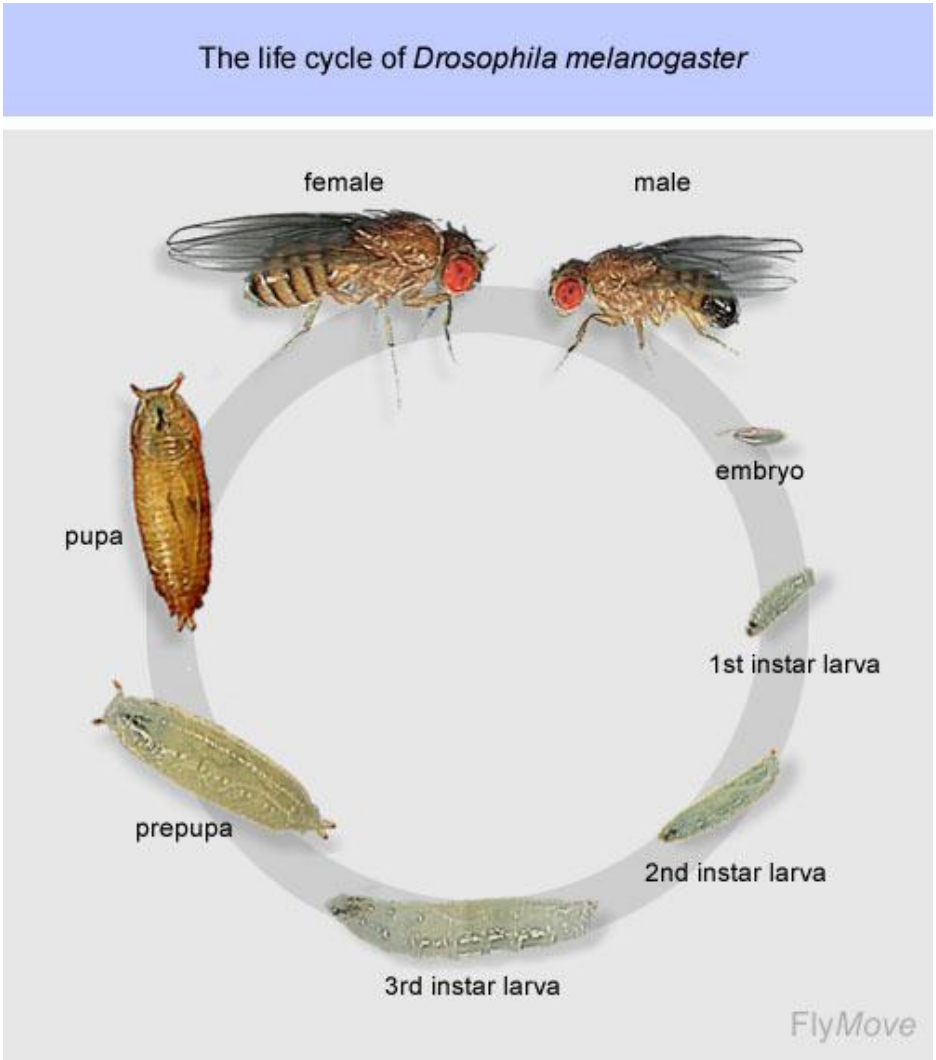
6. TEPHRITIDAE (Fruit flies)

- ✓ Sub costa bends apically and fades out.
- ✓ Wings are spotted or banded.
- ✓ Female has a sharp and projecting ovipositor.
- ✓ Maggots can hop. They are highly destructive to fruits and vegetables.
- ✓ Curcurbit fruit fly : *Dacus cucurbitae*

7. DROSOPHILIDAE (Vinegar gnats, Pomace flies)

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

Pomace fly : *Drosophila melanogaster*. They are extensively used in the study of animal genetics.



8. TACHINIDAE (Tachinid flies)

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

- ✓ They are non specific endoparasites on the larvae and pupae of Orthoptera, Hemiptera, Lepidoptera and Coleoptera.

9. MUSCIDAE(House fly)

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

Common house fly: *Musca domestica*

10. HIPPOBOSCIDAE

- ✓ Body is flat and leathery.
- ✓ Legs are short, strong and useful for clinging to the host.
- ✓ Wings are present or absent.
- ✓ They are viviparous. They give birth to mature larvae which are glued to the hairs of the host. The young larva is retained in a special uterine pouch and nourished by special nutritive glands. Larva once laid never feeds. It pupates immediately.
- ✓ They are blood sucking ectoparasites on cattle and dogs. *Hippobosca maculata* is associated with cattle and *H. capensis* is parasitic on dogs.

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