ACHARYA N G RANGA AGRICULTURAL UNIVERSITY

Rajendranagar, Hyderabad – 500 030

Study Material for Course No: Ento 131

Insect Morphology and Systematics (2+1)

(2011-12)

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Objectives and Lecture Out-lines

General Objective : To impart knowledge to the students on morphology and classification of insects

Specific Objectives :

a) Theory

By the end of the course, the students will be able to

i. understand morphology of the insects
ii. understand taxonomic characters of insects

b) Practical

By the end of the practical exercises, the students will be able to

i. get training in collection and preservation of insects
ii. observe external features of insects
iii. study the mouthparts, digestive system and reproductive system of insects by dissection and observation
iv. identification of different insects of some important families

Theory Lecture Outlines

Lecture No	Topic	Pages
1	History of Entomology in India – Arthropoda – mention of insects in scripts – contributions of Fabricius, Carolus Linnaeus, Rothney , L De Niceville, H.M Lefroy, T.B.Fletcher, T.V. Ramakrishna Ayyar, B.V.David, Ronald Ross, H.S. Pruthi, M.R.G.K. Nair and S. Pradhan; Locations and year of establishment of Zoological Survey of India (ZSI), Directorate of Plant Protection, Quarantine and Storage (DPPQS), Indian Institute of Natural Resins and Gums (IINRG), National Bureau of Agriculturally Important Insects (NBAII), National Institute of Plant Health Management (NIPHM), National Centre for Integrated Pest Management (NCIPM) and Forest Research Institute (FRI)	7-9
2	Contributory factors for abundance of insects – structural characters, developmental characters and protective characters (morphological, physiological, behavioral and construction of protected niches)	10-13
3	Classification of Phylum Arthropoda upto Orders – different Classes of Arthropoda and comparison of characters of Class Insecta with Arachnida, Crustacea, Symphyla, Chilopoda, Diplopoda and Onychophora; Subphyla Apterygota and Pterygota – names of Orders of Apterygota and Pterygota with examples and characters of Class Insecta – economic classification of insects	14-21
4	Structure and functions of body wall – different layers, chemical composition, functions and cuticular appendages – cuticular processes and cuticular invaginations – chaetotaxy – moulting – apolysis, ecdysis and sclerotization	22-30
5	Body segmentation of the insects – head – procephalon and gnathocephalon, types of head, sclerites and sutures of insect head; Thorax – segments and appendages (wings and legs);	31-38
6	Abdomen – segments and appendages (furcula, cornicles, tracheal gills and pseudoovipositor in Diptera, propodeum, petiole and gaster in Hymenoptera); Epimorphic and anamorphic development in insects	39-40

PRACTICALS:

1 Methods of collection and preservation of insects including immature stages
2. Study of different types of insect antennae and legs
3 Study of types of mouthparts – biting and chewing, piercing and , rasping and sucking
4 Study of types of mouthparts – chewing and lapping, sponging and sucking and siphoning
5 Study of wing venation, types of wings and wing coupling organs
6 Study of different types of insect larvae and pupae
7 Dissection of digestive system in insects
8 Dissection of female and male reproductive systems in insects
9 Study of characters of Orders Orthoptera and Dictyoptera and its families
10 Study of characters of Orders Isoptera and Thysanoptera and its families
11 Study of characters of Orders Hemiptera and its sub order Heteroptera and its families
12 Study of characters of Sub Order Homoptera and its families
13 Study of characters of Order Lepidoptera and its families
14 Study of characters of Order Coleoptera and its families
15 Study of characters of Order Hymenoptera and its families
16 Study of characters of Order Diptera and its families

Note: Submission of well maintained insect specimens during the final practical examination is compulsory

References

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Richards, O.W. and Davies, R.G. 1977. *Imm's General Text Book of Entomology* (Vol. I and II). Chapman and Hall, London.

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Lecture - 1 : History of Entomology

- **Entomology** (Entomon = Insect; Logos = Study) is the branch of science that deals with the study of insects.

  The word insect is derived from **insecare** which means "to cut in to".

- Insects belong to the Phylum **Arthropoda** which is the biggest phylum of Animal kingdom. Insects appeared 350 million years ago, much earlier than human beings who appeared on earth only 150 000 years ago. They are initially aquatic and later became terrestrial .
- There is much variation in size, shape of the insects
- Insects are distributed every where from cooler parts to hottest tropics. They live in water, land, air, deserts, high mountains etc.
- They can be seen in crop plants, gardens, libraries, museums, stores etc.,
- In ancient scripts like Ramayana and Mahabharata, some of the terms used were related to insects. They are
- Pipilika – Ant,
- Pathanga – grasshoppers,
- Madhumakshika – honey bees,
- Umbakapalika - termite queen
- The reference to insects were found in Sanskrit dictionary, 'Amarakosa' and in books like Artha Sastra, Chanakya Sutra etc.
- **Aristotle** made investigation about flies, honey bees, ants etc.
- 1745- 1808 : **"J.C. Fabricius"** made an extensive study of Indian insects for the first time and classified insects into 3 orders based on the type of mouth parts.
- 1758 : The beginning of the modern Indian entomology with the publication of 10th edition of 'Systema Naturae' by '**Carolus Linnaeus'** where only 12 Indian insects were included and it forms the first record
- 1767-1779: **"J.G. Koenig**" initiated the first regular scientific work on Indian insects and supplied the insect specimens to systematists like **Linnaeus, Fabricius, Cramer** and **Dury**
- 1782: "**Dr. Kerr"** published an account of Lac insects
- 1840: "**Rev Hope"** published a paper "Entomology of the Himalayas and India"
- 1893: "**Dr. Rothney"** published the book 'Indian ants' (Earliest record of biological pest control in India ie white ants attack on stationery items kept free by red ants.)
- 1897: **Sir Ronald Ross** , an IMS officer, incharge of a Madras regiment stationed in Begumpet (Secunderabad) made the discovery of the malarial parasite in a dissected *Anopheles* mosquito.

- 1901 : "**Lionel de Niceville"** was appointed as first entomologist to Govt. of India.
- 1903 : "**Maxwell Lefroy"** succeeded as the second entomologist.
- 1906 publication of 'Indian insect pests' by "Maxwell Lefroy"
- 1909 publication of Indian insect life' by "Maxwell Lefroy"
- 1914 : "**T.B Fletcher"** , the first Govt Entomologist of Madras state wrote a book 'Some South Indian insects'.
- 1914 : **E.P.Stebbing,** the first imperial forest entomologist published "Indian forest insects of economic importance :coleoptera
- 1937 : A laboratory for storage pests was started at Hapur, U.P.
- 1937: Entomology division was started in IARI, New Delhi
- 1939-establishment of locust warning organization after the locust plague during 1926-32
- 1940: **T.V. Rama Krishna Ayyar,** wrote a book 'Hand book of Economic Entomology for South India'
- 1953: National Malaria eradication programme was launched
- 1960-"The desert locust in India" monograph by **Y.Ramachandra Rao**
- 1963: 'Text book of Agricultural Entomology' - **H S Pruthi**
- 1968: 'General Entomology' **– M S Mani**
- 1969: 'Insect Pests of Crops'- **S Pradhan**

1975: 'Elements of Economic Entomology' - **B. Vasantharaj David** and **T.Kumara Swami**

- 1975: Insects and Mites of crops in India- **M R G K Nair**
- 1976: 'General and applied Entomology'- **K.K. Nayar, N. Ananthakrishnan** and **B. Vasantharaj David.**

Definitions

- Study and use of insects in crime investigations is known as **Forensic Entomology**
- Study of insects related to live stock and veterinary animals is known as **Veterinary Entomology**
- Study of insects in relation to Human beings is known as **Medical Entomology**

Establishment of entomological institutes

S.no	Year	Institute	Location
1	1905	Establishment of "Agricultural research institute" by lord Curzon. The land was donated by	Pusa, Bihar

		Mr.Phiffs of USA after whom the place was named as Pusa	
2	1906	Forest research institute	Dehradun
3	1911	“Agricultural research institute” Pusa renamed as Imperial Agricultural Research Institute	Pusa, Bihar
4	1914	Zoological survey of India	Kolkata
5	1925	Indian institute of natural resins and gums(IINRG) formerly known as Indian lac research research institute	Numkam,Ranchi
6	1936	Imperial Agricultural Research Institute , Pusa shifted to New Delhi	New Delhi
7	1937	Establishment of Entomology division at IARI	New Delhi
8	1946	Directorate of plant protection Quarantine and storage(DPPQS)	Faridabad
9	1946	National institute of plant health management (formerly known as central plant protection training institute, later national plant protection training institute	Hyderabad
10	1947	Imperial Agricultural Research Institute, renamed as Indian Agricultural Research Institute	New Delhi
11	2009	National bureau of agricultural important insects (NBAII) (formerly known as Project Directorate on Biological Control)	Bangalore
12		National institute of Integrated Pest Management	New Delhi

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Lecture - 2 : Contributory factors for the abundance of insects.

Insects occupy around 70 per cent of all known species of animal kingdom. The most diverse order of insects is C**oleoptera** followed by **Lepidoptera**, **Hymenoptera** and **Diptera.** The structural, developmental and protective characters acquired by insects made them dominant in the animal kingdom.

Factors responsible for abundance of insects :

I. Structural perfections:-

1) **Exoskeleton**: The insect body has an outer exoskeleton or body wall made up of cuticular protein called as chitin. This is light in weight and gives strength, rigidity and flexibility to the insect body. It is responsible for protection from

Desiccation or water loss from the body

Physical or mechanical injuries and to maintain

shape and size of the body,

Providing area for muscle attachment,

Giving strength to the body appendages

2. Small size: It helps the insects to exploit different ecological niches inaccessible for other animals. Insects, due to their small size, require less space (for shelter), food and energy for their survival and can easily escape from their natural enemies.

2) **Quicker speciation**: Because of hard exoskeleton, smaller size and short life cycle there is a chance of quicker species formation (more number of species at a faster rate). Changes that occur during the process of evolution through variation in their habitat or habits will be maintained or continued to several generations resulting in the development of more species from a genus.

3) **Functional wings**: Two pairs of wings that are present on meso and meta thoracic segments are mainly helpful for taking flight from one place to another in search of food, shelter or to find a mate, to oviposit or to get protection from their natural enemies.

4) **Hexapod locomotion**: Because of the presence of six legs on the three thoracic segments, though a pair of legs are lost, the insect will have equilibrium during all the phases of it's locomotion.

5) **Compound eyes**: Most of the adult insects and nymphs consists of compound eyes as visual organs which possess number of hexagonal units known as ommatidia, corresponding to the cornea of an individual eye or lens. Because of presence of number of ommatidia in the compound eyes, even if some or few ommatidia get damaged, the insect does not loose the power of vision

6) **Scattered sense organs**: The sense organs viz., visual organs, gustatory organs, organs of touch etc. are distributed on different parts of the body such as antennae, eyes, mouth parts in the head, legs with claws on thorax, tympanum, cerci in the abdomen etc. This scatteredness on all parts of the body prevents the chance of all being damaged.

7) **Decentralized nervous system**: The nervous system is so decentralized that insects can be artificially stimulated to walk, fly, feed, mate or oviposit even if some parts of the body are removed or damaged.

8) **Direct respiration**: Insects respire by means of thin elastic air tubes known as trachea which open outside, on the body surface through spiracles. Presence of these trachea allows free supply of oxygen to the insect and make it to be an efficient terrestrial or aerial arthropod

9) **Enteronephric excretion**: In insects, excretion is mainly by means of malpighian tubules which open in between midgut and hindgut. This arrangement is well suited for water conservation as well as for the absorption of unwanted waste metabolites at a quicker rate.

II. Developmental characters:-

1) High fecundity: Fecundity is defined as the egg laying capacity of a female insects. It helps to increase the population at faster rate.

2) Method of reproduction: Insects can reproduce both sexually as well as parthenogenitically. This parthenogenitic reproduction coupled with high fecundity help insects to increase their populations to large numbers, when all the biotic and abiotic factors are favourable.

3) Controlled reproduction: Though insects posses high fecundity, there is also high degree of control over reproduction by reducing the number of females that can lay eggs. This character is mostly seen in social insects such as honey bees and termites.

4) Short life cycle: Most of insects have very short life cycle i.e. 2 to 4 weeks which help insects to complete more number of generations in a definite period of time.

5) Specificity of food: There is diversity in food habits among different species of insects. As they differ in their preference for particular type of food, there will not be any competition among themselves. Less competition for food increases their chances of survival and further multiplication.

6) Zenith of evolution: During the process of evolution, insects have shown a high degree of specialization to the extent that there is division of labour, polymorphism etc., that make them to be efficient in their struggle for existence.

III. Protective adaptations and devices:-

For protecting themselves from adverse environmental conditions or natural enemies, insects have developed or attained some adaptations including

1) Morphological adaptations: The body color and shape of some insects make them look like part of the plant, thereby protecting themselves from natural enemies
eg: **stick insects** and **leaf insects**

2) Physiological adaptations: Some insects produce or release poisonous or unpleasant odors from their body or possess warning coloration by imitating certain distasteful insects.
Eg: **Stink bugs** have specialized exocrine glands located in the thorax or abdomen that produce foul smelling hydrocarbons.

Larvae of **swallow tail butterflies** have eversible glands called **osmeteria** , located just behind the head when disturbed they release repellent volatile and waves their body back and forth to ward of intruders

Some **blister beetles** (Meloidae) produce **cantharidin**, a strong irritant and blistering agent.

3) Behavioral adaptations: It is a defense strategy adopted by some insects through feigning death or imitating the voice of dangerous insects or mimicry.
Eg: **Colarado potato beetles** when disturbed , draw their legs beneath and drop to the ground and pretend as if dead.

Hairy caterpillars

4) Construction of protective structures: Some insects construct shelter with the available plant material for protecting themselves from adverse conditions , natural enemies and to store food material for use during the period of scarcity.

Eg: Cases / Bags in case of **case worms/bag worms**

Termatoria in case of **termites**,

Honey comb in case of **honey bees**

Lecture - 3 : Classification of phylum Arthropoda

(Arthro-Joint, Poda –Foot)

The arthropods possess

a. The segmented body

b. Bilateral symmetry

c. Paired jointed appendages usually terminates in a class

d. Chitinous exoskeleton

e. Ventral nervous system and

f. Dorsal heart.

g. Haemocoelic body cavity

h. Muscles are composed of striated fibres, ciliated epithelium absent

i. Open type of circulatory system

It is the largest phylum in the animal kingdom. Besides insects, many creatures like crayfish, crabs, lobsters, centipedes, millipedes, spiders, mites, ticks, scorpions etc come under this category.

Phylum arthropoda is classified into 7 classes viz

1 .Onychophora (claw bearing): eg: peripatus

2. Crustacea (crusta-shell): eg: prawns, crabs, wood louse

3.Arachnida (Arachine-spider): eg:scorpion, spider, ticks, mites

4.Chilopoda (chilo-lip,poda-legs): eg:centipedes

5.Diplopoda (diplo-two,poda-legs):eg:millipedes

6.Trilobita (an extinct group)

7.Hexopoda (hexa-Six; poda-legs) eg.insects

Insecta (in-internal ;sect-cut)

Phylum Arthropoda is divided into 11 classes, of which the following are important

r	Onycophora	Crustacea	Arachnida	Diplopoda	Chilopoda	Symphyla	Insecta
	Head is continuous with the body	Cephalothorax, abdomen	Cephalothorax, abdomen	Head, trunk	Head, trunk	Head, trunk	Head, thorax and abdomen
	1pair	2 pairs	no antenna	1 pair	1 pair	1 pair	1 pair
ts	Mouth parts are called jaws or oral papillae	One pair of Mandibles, two pairs of maxillae with maxillary pads	Mouth parts are Chelicerae and pedipalpi	1 pair of mandible and 1 pair of maxillae	1 pair of mandible and 2 pairs of maxillae	Mandibles, maxillae and labium	Labrum ,a pai Mandibles,a p of Maxillae ,labiu And hypopharnyx
	Legs are short, stumpy and one pair per segment	5 pairs	2 or 4 pairs	2 pairs / segment	1pair / segment. 1^{st} pair of leg is modified to form poison	1 pair / segment	3 pairs

					claws		
ry	Cutaneous	Gills	Book lungs	Trachea	Trachea	Trachea	Trachea
of the tive	Open at posterior or caudal end	Open anteriorly on 9th post oral segment	Open at the base of the abdomen anteriorly	Open at behind the 2nd pair of legs	Open at penultimate segment of abdomen	Open after 4th cephalic segment	Opening at th anal End of the abdomen
	coelomoducts	Coelomoducts or green glands	Malpighian tubules	Malpighian tubules	Maligning tubules	Maligning tubules	Maligning tubules
nent	Direct	Indirect	Direct except in mites and ticks	Direct	Direct	Direct	Direct or indire
	Terrestrial	Mostly aquatic in salt and fresh water	Mostly terrestrial	Terrestrial	Terrestrial	Terrestrial	Aquatic or terrestrial
	Peripatus	Crabs, shrimps, lobsters	Scorpions, mites, ticks, spiders	Millipedes	Centipedes, behind the head have poison gland	Garden centipedes	Insects

Characters of class insecta (Hexapoda ; Hexa-six, poda-legs

Insects occupy 2/3rd of total population of Phylum Arthropoda and belongs to sub phylum mandibulata.

Insects are **tracheate arthropods** whose body is divided in to three regions namely **head, thorax** and **abdomen** possessing two pairs of **wings** and three pairs of **legs** in thoracic region , genital organs towards posterior end of the body and with decentralized nervous system.

Characters of Class insecta :

1. Body divided in to head, thorax and abdomen
2. Possess three pairs of legs, hence the name Hexapoda
3. Presence of one or two pairs of wings
4. A pair of antennae
5. Respiration by means of internal air tubes known as trachea
6. Genital opening situated at the posterior end of the body
7. Presence of metamorphosis(incomplete/complete) during development
8. Possess exoskeleton made up of hard cuticle which plays important role for survival.
9. Excretion is mainly by malpighian tubules which help in maintaining ionic balance

Class Insecta

(Imm's classification)

Sub class Apterygota (Ametabola) Wingless

1. Protura – Telson tails
2. Diplura – Diplurans
3. Collembola – Spring tails, snow fleas etc
4. Thysanura –Bristle tails,Silver fish etc

Sub class Pterygota (Metabola)

(winged insects)

Division: Exopterygota (Hemi metabloa)

(wings develop externally)

5. Ephemeroptera - May flies
6. **Odonata - Dragon flies and Damsel flies**
7. **Plecoptera - Stone flies**
8. **Dictyoptera - Cockroaches and mantids**
8. **Grylloblattodea - Grylloblattids**
9. **Orthoptera - Grasshoppers, locusts,** Crickets , mole crickets etc.
10. Phasmida - Stick insects
11. Dermaptera - Earwigs
12. Embioptera - Web spinners
14. Isoptera - Termites
15. Zoraptera - Zorapterans
16. Psocoptera - Book lice
17. Mallophaga - Bird lice
18. Siphunculata (Anoplura) - Sucking lice
19. Hemiptera - Plant bugs
20. Thysanoptera - Thrips

Division-Endopterygota (Holo metabola

(wings develop

21. Neuroptera - Ant lions and lace wings
22. **Mecoptera - Scorpion flies**
23. **Trichoptera - Caddis flies**
24. **Lepidoptera - Moths and butteflies**
25. **Diptera - Flies, mosquitoes**
26. **Siphanoptera - Fleas**
27. **Hymenoptera –Ants, bees , wasps**
28. **Coleoptera- Beetles, weevils**
29. **Strepsiptera-Stylopids**

Characters of Sub Classes:

Apterygota(Ametabola)	Pterygota(Metabola)
Small and primitive insects	Developed insects
Primarily wingless	Winged and secondarily wingless
Mouth parts are hidden in the head	Mouthparts are exposed
Mandibles articulate with head at single point -Monocondyle	Mandibles articulate with head at two points -Dicondyle
Malphigian tubules are absent or rudimentary	Malphigian tubules are present
Adults have pregenital abdominal appendages	Adults without pregenital abdominal appendages
Pleural suture in thorax is absent	Pleural suture divides thoracic pleuron into episternum and epimeron
Metamorphosis is simple or absent	Metamorphosis is present and variable
Abdominal segments are more in number (11 or 12)	Abdominal segments are secondarily reduced (8 to 10)
Adults moult several times	Adults donot moult

Characters of divisions of Sub class Pterygota

Exopterygota(Hemimetabola)	Endopterygota(Holometabola)
Wings develop externally	internally

Metamorphosis simple and incomplete	Complete and complex
Immature stages (nymphs) resemble adults in structure and habits	Immature stages (lava) differ adults in structure and habits
No pupal instar	Pupal instar present

ECONOMIC CLASSIFICATION OF INSECTS

INSECTS

1. **Possessing Economic importance (Economic Entomology)**
2. **Possessing of no economic importance (Harmless insects)**

ECONOMIC ENTOMOLOGY	
Harmful Insects	**Beneficial Insects**
A. Pest of crops and plants (Agricultural Entomology and Forest trees (Forest Entomology)	A. Productive Insects
Damage caused by feeding, oviposition, using plant parts for construction of nests *etc.,* transporting other pest species to other hosts, disseminating organisms of plant diseases and aiding in cross fertilization of certain rusts.	1. Products from secretion of insects - silk (silk worms) - Bee wax (Honey bee) - Shellac (lac insect) - Illumination (Giant firefly) 2. Bodies useful as or contain substances such as : - Dye (cochineal insect) - Cantharidin (Blister beetle) - Fish bait (stonefly nymph)

	3. Collect, elaborate and store Plant product. - Honey (nectar collected by bee) 4. Products from plant galls Caused by insects. - Tannic acid, Inks, Dyes 5. Insects as food for fishes, birds, hogs, certain animals and human beings.
B. Pests of stored products (Storage Entomology)	B. Helpful Insects
By feeding, contaminating with their excretions, seeking protection or building nests or tunnels and necessitating frequent sorting, packing and preserving of material. C. Inimical to man (Medical entomology) & Animals (Veterinary entomology by causing annoyance, applying venoms, disseminating the diseases, feeding` extra.	- Aid in pollination - Parasites and predators of injurious insects - Destroy weeds - Improve soil fertility (Agricultural Entomology) - As scavengers - Insects and their products useful in medicine (Medical Entomology) - Certain species are ideal materials in scientific investigations. - Have aesthetic and entertaining values

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Lecture - 4 : Structure and functions of Insect Integument

The body wall or integument of insects forms an exoskeletal covering of the insect body. It forms a composite structure which forms the skeleton of the insect body. It provides area for muscle attachment; protection from desiccation, physical / mechanical injuries and shape, strength to the body and its appendages.

Integument consists of 3 layers (Fig. 1.)

1. Inner basement membrane
2. Middle epidermis (or) hypodermis
3. Cuticle

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

2. **Epidermis**: It is an unicellular layer formed from polygonal cells which modifies in to cuboidal or columnar during the process of moulting. These cells consists of well developed nucleus and other cytoplasmic contents. Adjacent epidermal cells are held together by means of certain cytoplasmic processes which are known as **desmosomes.**

All the epidermal cells are glandular and secrete cuticle and the enzymes involved in production and digestion of old cuticle during moulting. The epidermal cells get differentiated in to following types based on the function they perform and may modify in to

a) **dermal glands** producing cement layer

b) **trichogen cell** producing hair like seta or trichome.

c) **moulting glands** secreting moulting fluid which digests the old cuticle

d) **peristigmatic glands** around the spiracles in case of Dipteran larvae

3. **<u>Cuticle</u>**: It is outermost thick layer of integument secreted by epidermis. It is divided in to two regions

A) Upper **epicuticle** B) Inner **procuticle**

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

1. **Cement layer** : It is secreted by dermal glands and is composed of lipoprotein It protects the body from external damage.

2. **Wax layer:** It is prominent layer , 0.25µ in thickness, consisting of long chain hydrocarbons, esters of fatty acids and alcohols.
It serves as water proof layer preventing water loss from the body

3. **Polyphenol layer:** It is a non-static layer containing various types of phenols which are mainly used in the formation of the proteins
It is resistant to acids and organic solvents

4. **Cuticulin layer:** It is an amber coloured thin layer over the surface of the epidermis which is strengthened by outer polyphenol layer.
It serves the purpose of permeability and also acts as growth barrier.

B. Procuticle: It is differentiated in to **exo** and **endocuticle** after sclerotization process.

Exocuticle is darkly pigmented, hard and sclerotized. It offers rigidity to the cuticle and consists mainly chitin and a hard protein called **sclerotin**.

Endocuticle is soft, light coloured and unsclerotized. It contains more chitin but lacks hard protein sclerotin

Pore canals: These are numerous fine vertical channels traversing both exo and endocuticle measuring **< 1µ (0.1 – 0.15µ)** in diameter. They run perpendicularly from epicuticle through out the length of the cuticle. They are useful in transportation of cuticular material and enzymes to the outer pro and epicuticle parts.

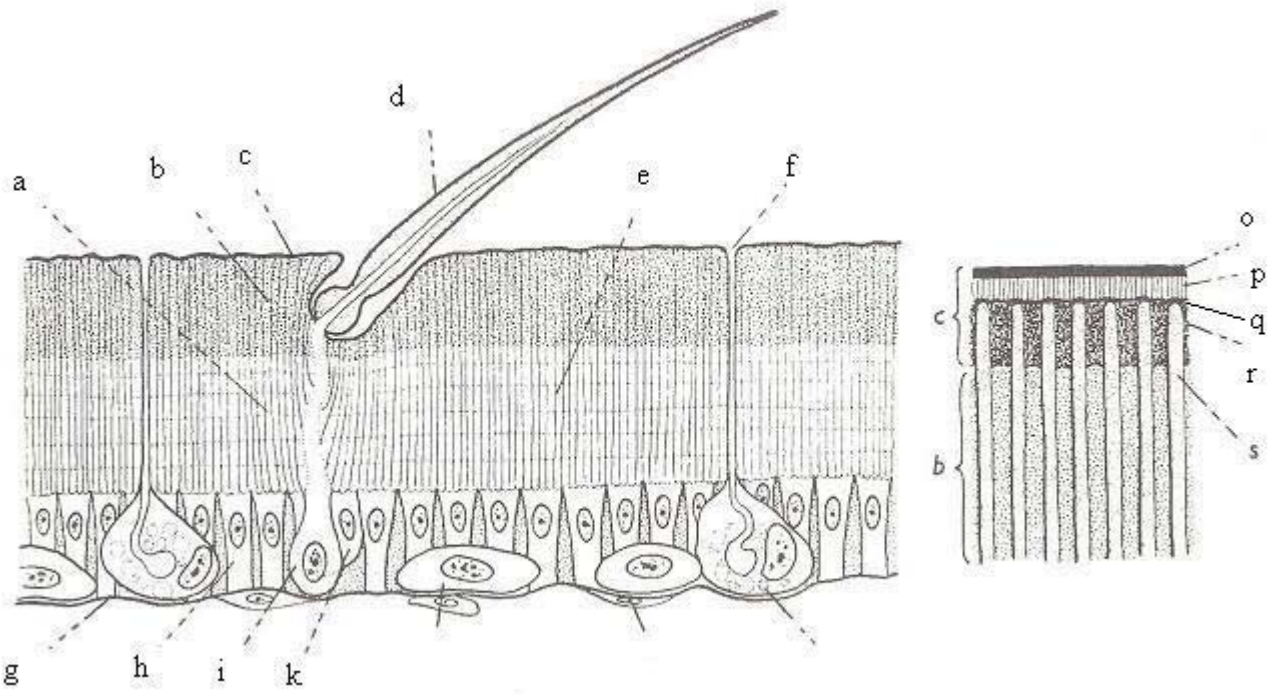


Fig. 1. A typical insect cuticle

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

(Source: Taken from A General Textbook of Entomology (1960) – A.D. Imms (Revised by Professor O.W. Richards and R.G. Davies, 9th Edition) (Butler & Tanner Ltd., Frome and London))

Two major components of insect cuticle are

i) **Chitin** ii) **Proteins**

i). Chitin : It is a **nitrogenous polysaccharide.** $(C_8H_{13}O_6N)_x$. It accounts for 25-60 per cent of the dry weight of the cuticle. It is named by Odier in 1834.

It consists of high molecular weight polymer of anhydro-**N-acetyl glucosamine** residues joined by **β-glycosidic linkages** (Fig. 2.) . It is embedded with proteins in the procuticle to form glycoproteins. It is insoluble in water, alcohol, organic solvents, dilute acids and concentrated alkalies, but **soluble** only in **concentrated mineral acids** and **sodium hypochlorite**. Its specific gravity is 1.4 (wt/vol)

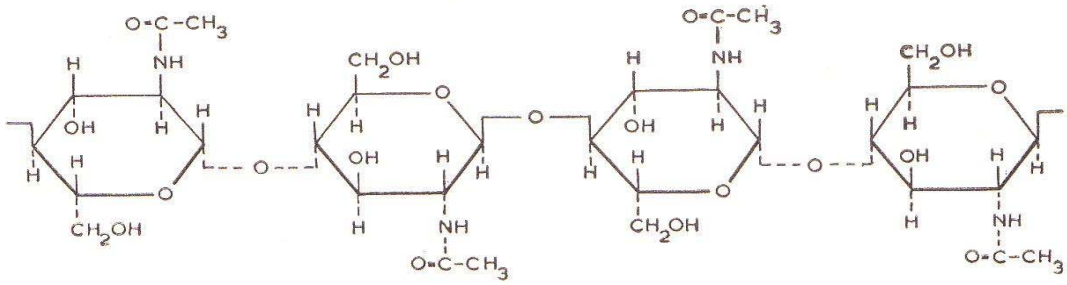


Fig. 2.

(Source: Taken from A General Textbook of Entomology (1960) – A.D. Imms (Revised by Professor O.W. Richards and R.G. Davies, 9th Edition) (Butler & Tanner Ltd., Frome and London))

ii). Proteins: Cuticle has 3 types of proteins

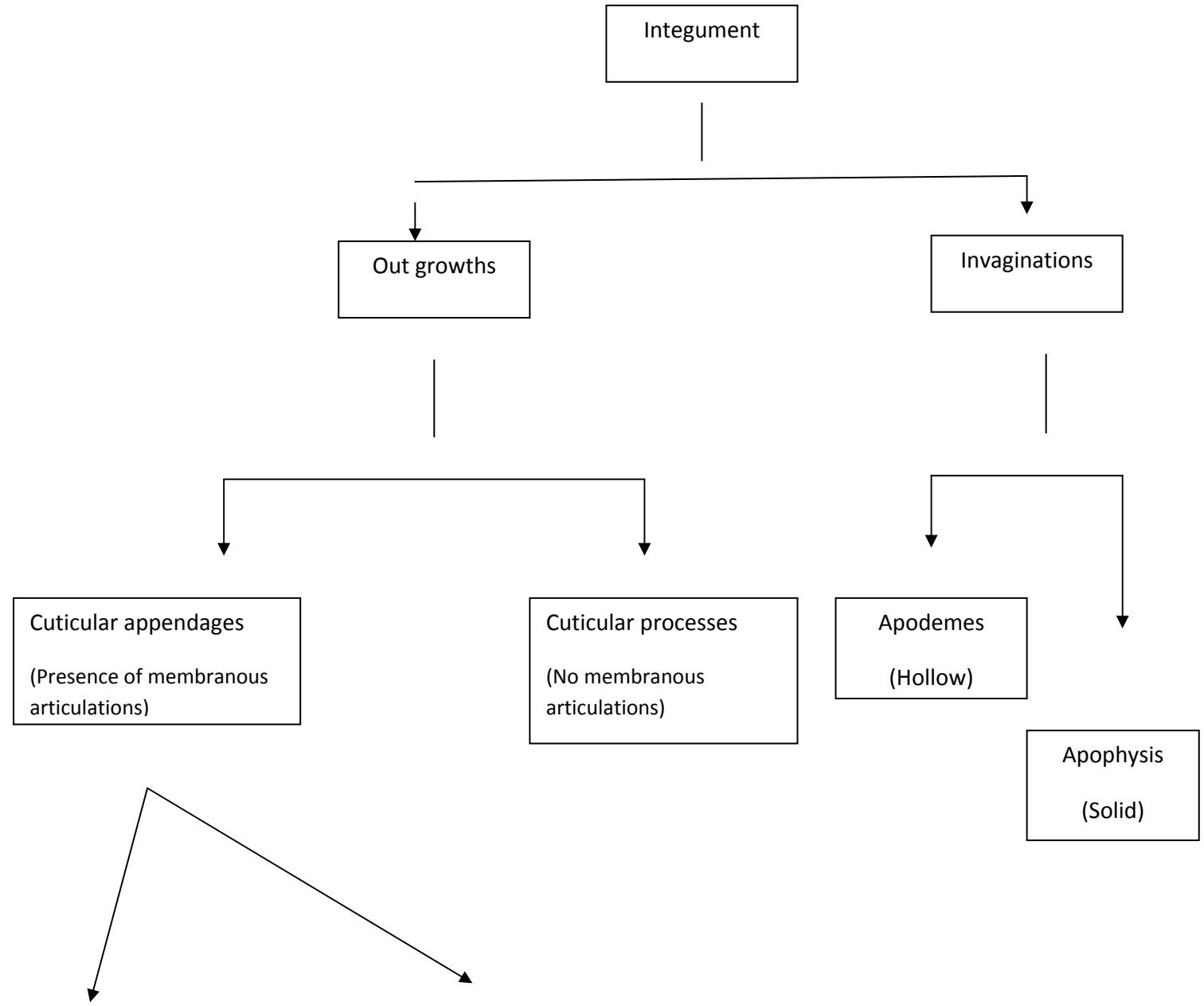
(a) Arthropodin: It is soft water soluble protein present in endocuticle. The conversion of arthopodin in to sclerotin is known as **sclerotization or tanning.**

(b) **Sclerotin:** It is also called **tanned protein** which is **amber** coloured and present only in exocuticle.

(c) **Resilin :** It is a rubber like elastic protein which is **colourless** and present in joints such as wing hinge ligaments, leg joints, clypeolabral joints or suture and tergosternal joints.

Cuticular/ Integumental modifications

Cuticle/Integument is modified in to external outgrowths or internal invaginations.



A. Cuticular Out growths: They are divided into **cuticular appendages** and **cuticular processes** depending on the presence or absence of membranous articulations.

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

(1) **Seta/ Macrotrichia:** Commonly known as hairs and arise from a cup like alveolus or pit.

Setae are hollow structures developed as extension of exocuticle and are produced by a single enlarged hypodermal cell called ' **trichogen**' cell. Articular membrane is usually produced by a second hypodermal cell called '**tormogen**' cell (Fig. 3).

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

Different kinds of setae are as follows

(a) **Clothing hairs:** These are hair like structures that cover the entire body, legs and wings. Eg: honey bee

(b) **Scales:** These are varyingly pigmented plate like structures covering the body as well as wings of adult moths and butterflies (Fig. 3).

(c) **Glandular setae :** Setae that functions as outlet for the secretion of **hypodermal glands. If they are stout they are called glandular bristles as in** case of certain larvae of Lepidoptera (Fig. 3).

(d) **Sensory setae** : These are the setae or trichomes provided with sensory receptors or sensory nerve cells and respond to the external stimuli. These are present on antennae, legs and mouth parts.

(2) **Spurs :** Occur on the legs of many insects and differ from setae in being **multicellular** in origin.

II. **Cuticular processes**: They have no membranous articulation. They are of two types

(1). **Microtrichia / fixed hairs / aculei:** These are minute hair like structures found on wings of Mecoptera and certain Diptera.

(2). **Spines :** Outgrowths of the cuticle which are more or less thorn like in form.

Spurs	Spines
Cuticular appendages	Cuticular processes
Movable, multicellular structures and thick walled	These are immovable outgrowths of cuticle
Eg: present on tibia of plant hoppers and honey bees	Eg: hind tibia of grasshopper and leaf hoppers

B. Culticular invagination:

The body wall or cuticle of the body wall invaginate internally and grow in to definite structures which are of two types.

Apodemes	Apophyses
Hollow cuticular invaginations which provide area for muscle attachment	Solid invaginations of the cuticle which gives mechanical support to various organs by forming distinct skeletal structures.

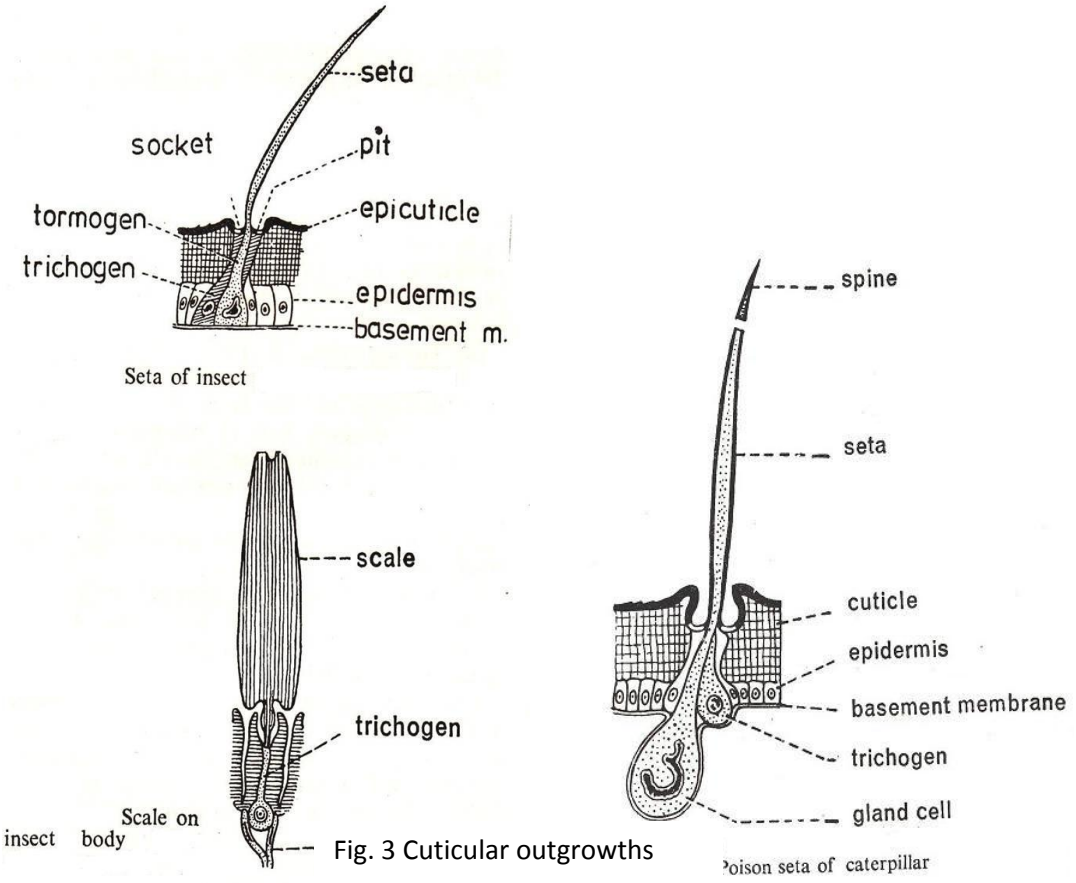


Fig. 3 Cuticular outgrowths

Source: Taken from General and Applied Entomology (10th edition1993) – K K Nayar, T.N. Ananthakrishnan and B.V. David. Tata McGraw-Hill publishing company, New Delhi., India

Moulting process

The insect cuticle is hard and forms unstretchable exoskeleton and it must be shed from time to time to permit the insects to increase their size during growth period. Before the old cuticle is shed new one has to be formed underneath it . This process is known as moulting

Moulting is a complex process which involve

1) **Apolysis** 2. **Ecdysis** 3) **Sclerotization**

1) Apolysis : [Apo = formation ; Lysis = dissolution] The dissolution of old cuticle and formation of new one is known as apolysis. Apolysis starts with repeated mitotic division of epidermal cells resulting in increase in number and size of epidermis, which becomes columnar in shape and remain closely packed. Because

of this change, the epidermal cells exerts tension on cuticular surface and as a result get separated themselves from the cuticle. Due to separation of epidermis from the cuticle a sub cuticular space is created and the epidermal cells starts producing their secretion i.e. moulting fluid and cuticular material into this space.

The moulting fluid is granular, gelatinous and contains two enzymes viz., proteinase and chitinase which can dissolve the old cuticle. As the moulting fluid digest the old cuticle, the sub cuticular space increases gradually by the same time and is occupied by the newly formed cuticular layer, the polyphenol layer, wax layer and cement layer into the deposition of definite layers of epicuticle. Procuticle get deposited beneath the epicuticle and subcuticular space is fully occupied. Though moulting fluid is capable of digesting the entire endocuticle, some undigested old exo and epicuticle portions will remain as a layer in the form of an ecdysial membrane.

2) Ecdysis : The stage where the insect has both newly formed epi and procuticle and old exo and epicuticle is known as pharate instar. The ecdysial membrane starts splitting along the line of weakness due to muscular activity of the inner developing insect and also because of swallowing of air & water resulting in the distention of the gut. The breaking at the ecdysial membrane is also due to the pumping of blood from abdomen to thorax through muscular activity. After the breakage of old cuticles which is known as exuviae, the new instar comes out bringing its head followed by thorax, abdomen and appendages.

Sclerotization : After shedding of old cuticle the new cuticle which is soft, milky white coloured becomes dark and hard through the process known as tanning (or) sclerotization. The process of hardening involves the development of cross links between protein chains which is also known as sclerotization. This tanning involves the differentiation of procuticle in to outer hard exocuticle and inner soft endocuticle.

Three types of hormones involved in the process of moulting which are as follows

JH : Juvenile Hormone :Produced from corpora allata of brain that helps the insects to be in immature stage.

MH : Moulting hormone: Produced from prothoracic glands of brain that induces the process of moulting

Eclosion Hormone: Released from neurosecretory cells in the brain that help in the process of ecdysis or eclosion.

Lecture - 5 : Body segmentation of Insect

In general, insect body is divided in to a series of segments, which in primitive arthropods are known as "**somites**" or "**metameres".** During the process of evolution, these somites gets fused with each other in different ways forming the body parts of the existing arthropods.

The type of arrangement of these body segments in **embryonic stage** is known as **primary segmentation** while in **adult insects** is known as the **secondary segmentation** which differ from primary in having a sclerotized membranous **intersegmental** region.

Insect body is divided in to three regions or **tagmata** namely head, thorax and abdomen. This grouping of body segments in to regions is known as **tagmosis.**

Head consists of mouthparts, compound eyes, simple eyes (ocelli) and a pair of antennae.

Thorax consists of 3 segments i.e. prothorax, mesothorax and metathorax, Meso and metathorax are together known as **pterothorax**. All the three thoracic segments possess a pair of legs and meso and meta thorax possess one pair of wings.

Abdomen has 7-11 segments with genital appendages on 8^{th} and 9^{th} segments.

Insect head

Insect head is a hard and highly **sclerotized** compact structure. It is the foremost part in insect body consisting of 6 segments that are fused to form a **head capsule.** The head segments can be divided in to two regions i.e. **procephalon** and **gnathocephalon** (mouth).

Six segments of head are represented as.

	Segment		**Appendages**
I	Pre antennary segment	Procephalon	No appendages
II	Antennary segment		Antennae
III	Intercalary segment	Procephalon	No appendages
IV	Mandibular segment	Gnathocephalon	Mandibles
V	First maxillary segment		Maxillae
VI	Second maxillary / labial segment		Labium

Types of head

The orientation of head with respect to the rest of the body varies. According to the position or projection of mouth parts (Fig. 4), the head of the insect can be classified as

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

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

Eg: Grass hopper, Cockroach

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

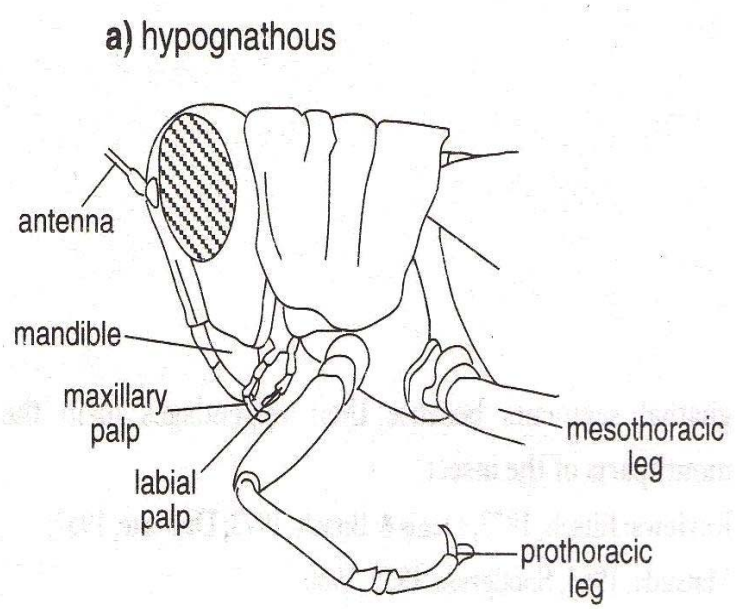
The head remains in the same axis to body and mouth parts are projected forward.. This is also kwown as **Coleopteroid** type..

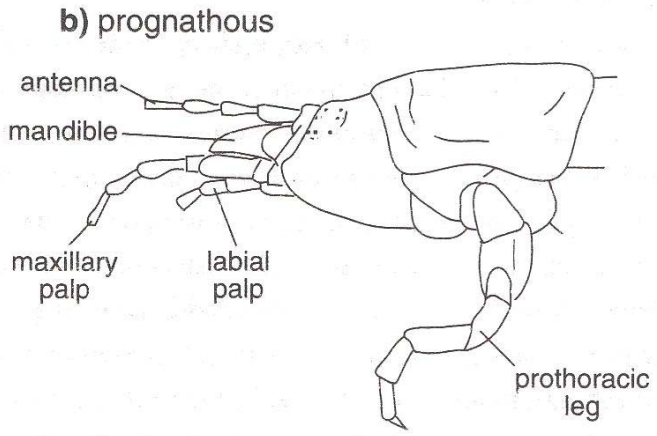
Eg: beetles

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

It is same as prognathous but mouthparts are directed back ward.and held inbetween the fore legs. .This is also kwown as **Hemipteroid or Opisthorhynchous** type..

Eg: bugs





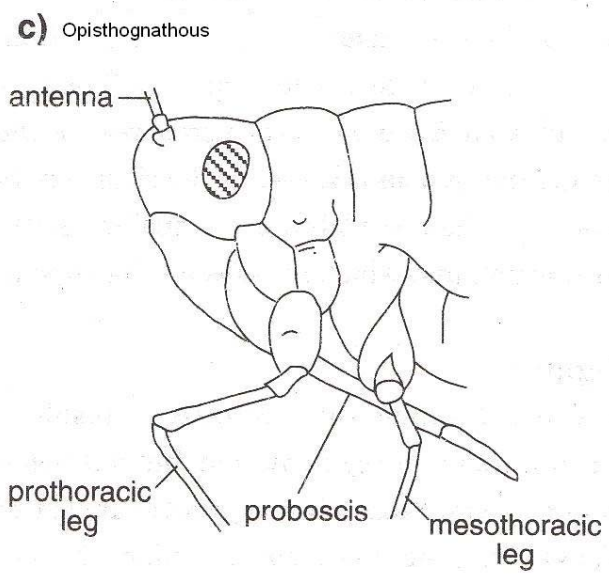


Fig. 4. Types of insect head

Source: Taken from The Insects- Structure and Function (4th Edition, 1998) – R.F. Chapman. Cambridge University Press.

Sclerites and sutures of head

The head capsule is formed by the union of number of sclerites or cuticular plates or areas which are joined together by means of cuticular lines or ridges known as **sutures** (Fig. 5).

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

A general insect posses the following sclerites.

1. **Labrum :** It is small sclerite that forms the upper lip of the mouth cavity. It is freely attached or suspended from the lower margin of the **clypeus**
2. **Clypeus:** It is situated above the labrum and is divided in to anterior **ante-clypeus** and posterior **post-clypeus.**
3. **Frons :** It is the facial part of the insect consisting of **median ocellus**.
4. **Vertex :** It is the top portion of the head behind the frons or the area between the two compound eyes.

5. **Epicraniun :** It is the upper part of the head extending from vertex to occipital suture.

6. **Occiput :** It is an inverted “U” shaped structure representing the area between the epicranium and post occiput (Fig. 6).

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

8. **Gena :** It is the area extending from below the compound eyes to just above the mandibles

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

10. **Antennal sclerites :** These form the basis for the antennae and present around the scape which are well developed in Plecoptera (stone flies)

All the above sclerites gets attached through cuticular ridges or sutures to provide the attachment for the muscles inside.

The common sutures present in head are

1) **Clypeolabral suture :** It is the suture present between clypeus and labrum. It remains in the lower margin of the clypeus from which the labrum hangs down.

2) **Clypeofrontal suture or epistomal suture:** The suture present between clypeus and frons

3) **Epicranial suture:** It is an inverted ‘Y’ shaped suture distributed above the facial region extending up to the epicranial part of the head. It consists of two arms called **frontal suture** occupying the frons and stem called as **coronal suture.**
This epicranial suture is also known as **line of weakness** or **ecdysial suture** because the exuvial membrane splits along this suture during the process of ecdysis.

4) **Occipital suture:** It is ‘U’ shaped or horseshoe shaped suture between epicranium and occiput.

5) **Post occipital suture:** It is the **only real suture** in insect head. Posterior end of the head is marked by the post occipital suture to which the sclerites are attached. As this suture separates the head from the neck, hence named as real suture.

6) **Genal suture:** It is the sutures present on the lateral side of the head i.e. gena.

7) **Occular suture:** It is circular suture present around each compound eye.

8) **Antennal suture:** It is a marginal depressed ring around the antennal socket.

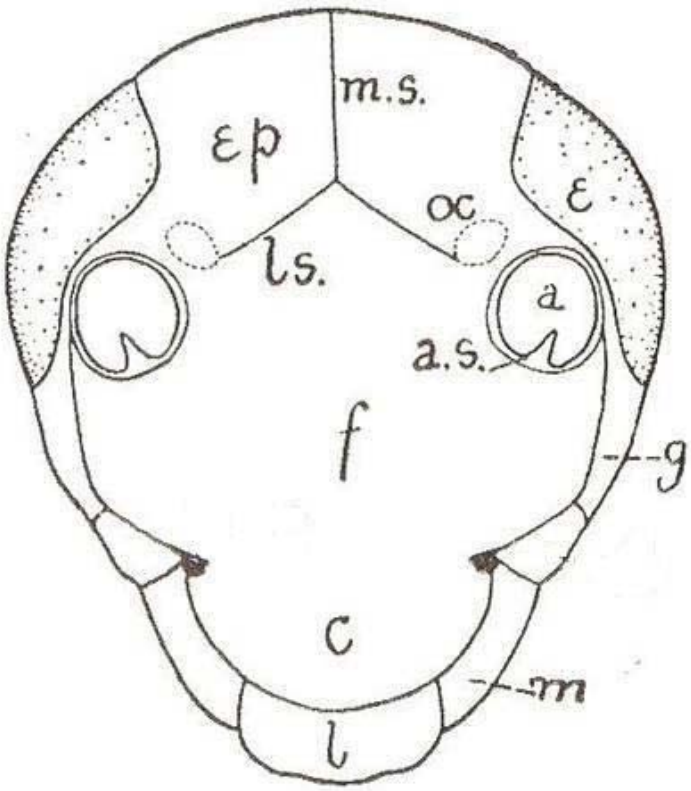


Fig 5. Front view of head of cockroach

a, antennal socket; a.s., antennal sclerite; c, clypeus; e, compound eye; Ep, epicranial plate; f, frons; g, gena; l, labrum; ls, lateral arms of epicranial suture; m, mandible; m.s., median epicranial suture; oc, ocellus;

Source: Taken from A General Textbook of Entomology (9th edition, 1960) – A.D. Imms (Revised by Professor O.W. Richards and R.G. Davies). Butler & Tanner Ltd., Frome and London.

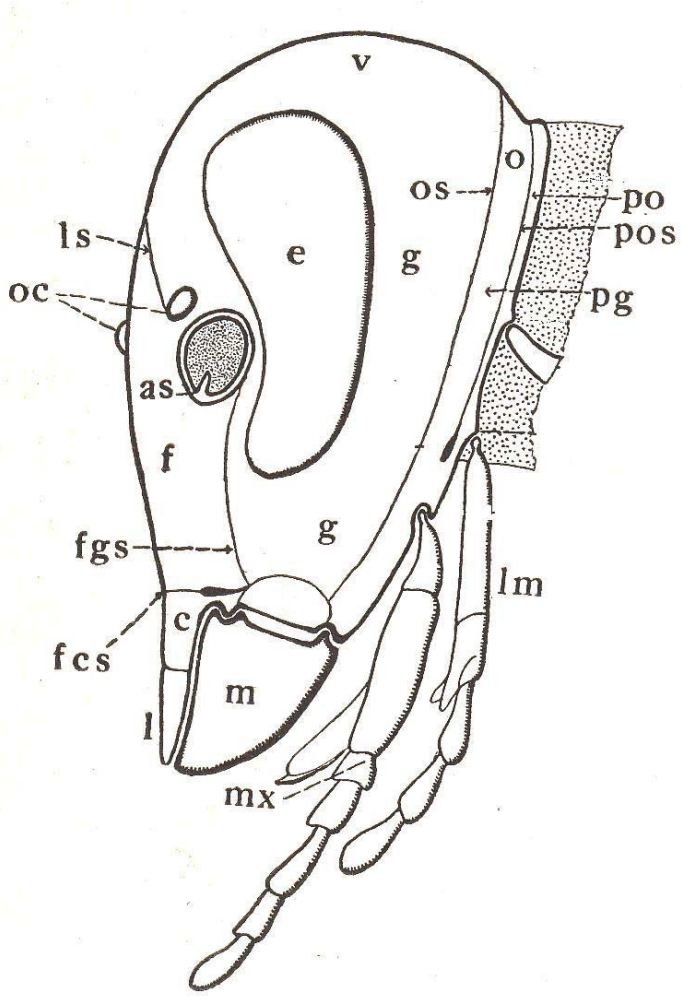


Fig. 6. Lateral view of head of Orthopterous insect

as, antennary sclerite; c, clypeus; e, compound eye; f, frons; fcs, fronto-clypeal suture; fgs, fronto-genal suture; g, gena; l, labrum; lm, labium; ls, lateral arm of epicranial suture; m, mandible; mx, maxillae; o, occiput; oc, ocelli; os, occipital suture; pg, post gena; po, post occiput; pos, post occipital suture; v, vertex.

Source: Taken from A General Textbook of Entomology (9th edition, 1960) – A.D. Imms (Revised by Professor O.W. Richards and R.G. Davies). Butler & Tanner Ltd., Frome and London.

Thorax

It is the middle part of the body consisting of three segments each possessing a pair of legs and a pair of wings on meso and meta thoracic segment. Meso and meta thoracic segments together known as **pterothorax**.

Sclerite of dorsal region of thorax is **tergum or notum** in case of winged insect, ventral region is called **sternum** and lateral region is called **pleuron**.

Lecture - 6 : Abdomen

Abdomen forms the posterior part of the insect body . Pre genital appendages are absent in pterygotes and present in Apterygotes. The abdomen in the embryo usually consists 12 segments, later the last segments degenerate and appear as 7-11 segments. Last segment is known as **telson or tail** as in case of Protura.

Abdominal Segments from 1 to 7 are **pregenital** segments, **eighth** and **ninth** are known as **genital segments** as they form genital appendages i.e. **ovipositor** in females and **aedeagus** or penis in males (Fig. 7) .Tenth and eleventh segments are known as **postgenital** segments.

The 10^{th} segment in general forms the **supra anal plate** and 11^{th} segment is represented by a pair of **anal cerci** (usually known as post- genital abdominal appendages).

Pre-genital segments are represented by

-collophore, **furcula** and **tenaculum** in **Collembola**,

-styli in **Thysanura** and

-cornicles (on dorsal side of 5^{th} and 6^{th} abdominal segments.) in aphids (family: **Aphididae**)

The **abdominal** segments consists of **tracheal gills** In **immature forms** of trichopterans, mayflies, mosquitoes etc.

The **last abdominal** segments telescope in to each other to form a

pseudo ovipositor in **diptera,.**

Tthe **1^{st} abdominal** segment get fused to metathorax forming **propodeum** whereas **2^{nd} abdominal** segment forms a narrow **pedicel or petiole** followed by enlarged **gaster** (rest of the abdominal segments) in **hymenoptera.**

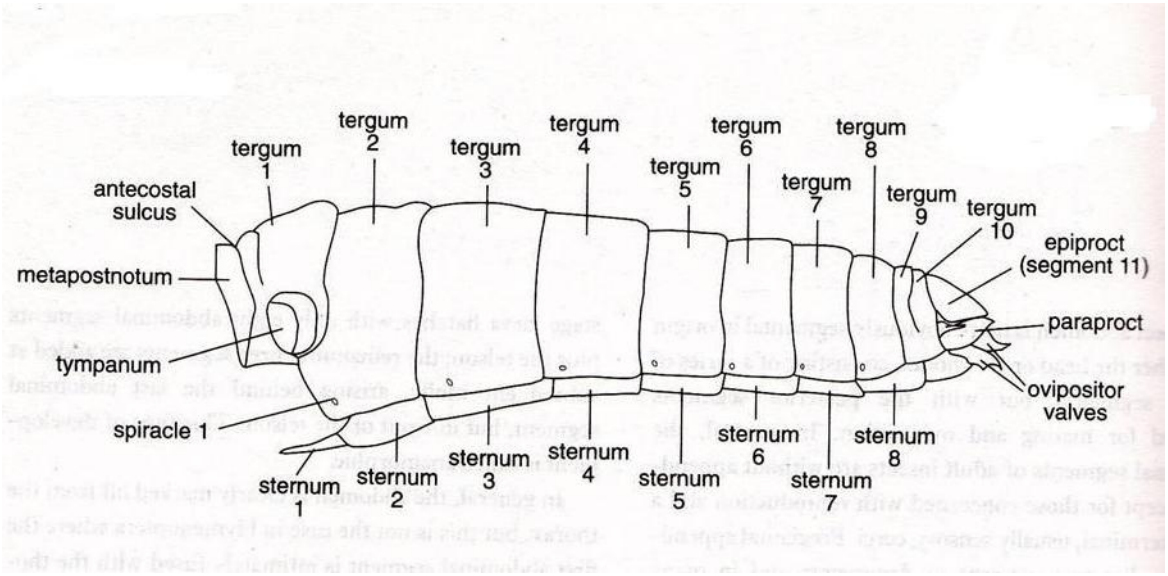


Fig. 7. Thoracic segments

(Source: Taken from The Insects- Structure and Function(4th Edition, 1998) – R.F. Chapman (Cambridge University Press))

Anamorphic development

In **protura**, the first instar larva hatch with only 8 abdominal segments and telson. the remaining 3 segments are added at subsequent moults arising behind the last abdominal segment, but in front of the telson. This type of development is called **Anamorphic development.**

Epimorphic development

In **pterygotes**, a definite number of segments are present at hatching. The differentiation of segments takes place in the embryo itself. This type of development is called epimorphic development

Definitions

- **Suture :** a line or a narrow space separating sclerotic areas of cuticle.
- **Sclerite :** Any of the large or small sclerotized areas of the body wall.
- **Notum :** Tergum of thoracic segment.

Lecture - 7 : Antennae

Antennae are a pair of sensory **preoral** appendages arising from the 2nd or antennal segment of the head possessing nerves coming from **deutocerebrum** of the brain.

They are well developed in adults and poorly developed in immature stages. Antennae are absent in order **protura** and class **Arachnida** whereas 2 pairs of antenna (antennules) are present in class **Crustacea**. These are said to be **uniramous** (unbranched), segmented and mobile structures which are basally fixed in to deep antennal socket (**antennifer**). Antennal socket is provided with an antennal suture. The base of socket is connected to the edge of the socket by an articulatory membrane. This permits free movement of antennae..

Structure of antenna.

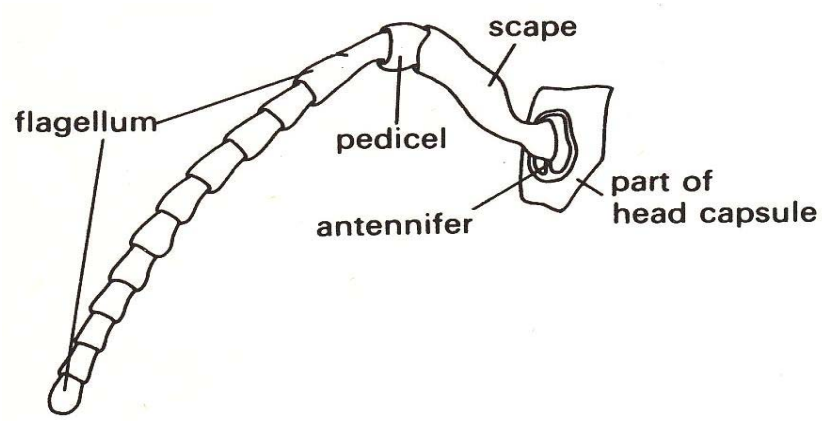


Fig. 8. A typical antennae of pterygote insect

(Source: Taken from The Insects- Structure and Function, 4th Edition, 1998) – R.F. Chapman. Cambridge University Press.)

Antenna consists of 3 parts (Fig. 8)

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

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

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

In the family **Chalcidoidea,** the flagellar segments are divided in to the basal ring segments **funicle** and terminal **club.**In general there are no muscles in the flagellum and hence the antennae are called **annulated type**.

In **collembola *and* Diplura**, the flagellar segments are muscular in nature and regarded as true segments and the antennae is known as **segmented type**. **Jhonston's organ** is absent in Collembola & Diplura.

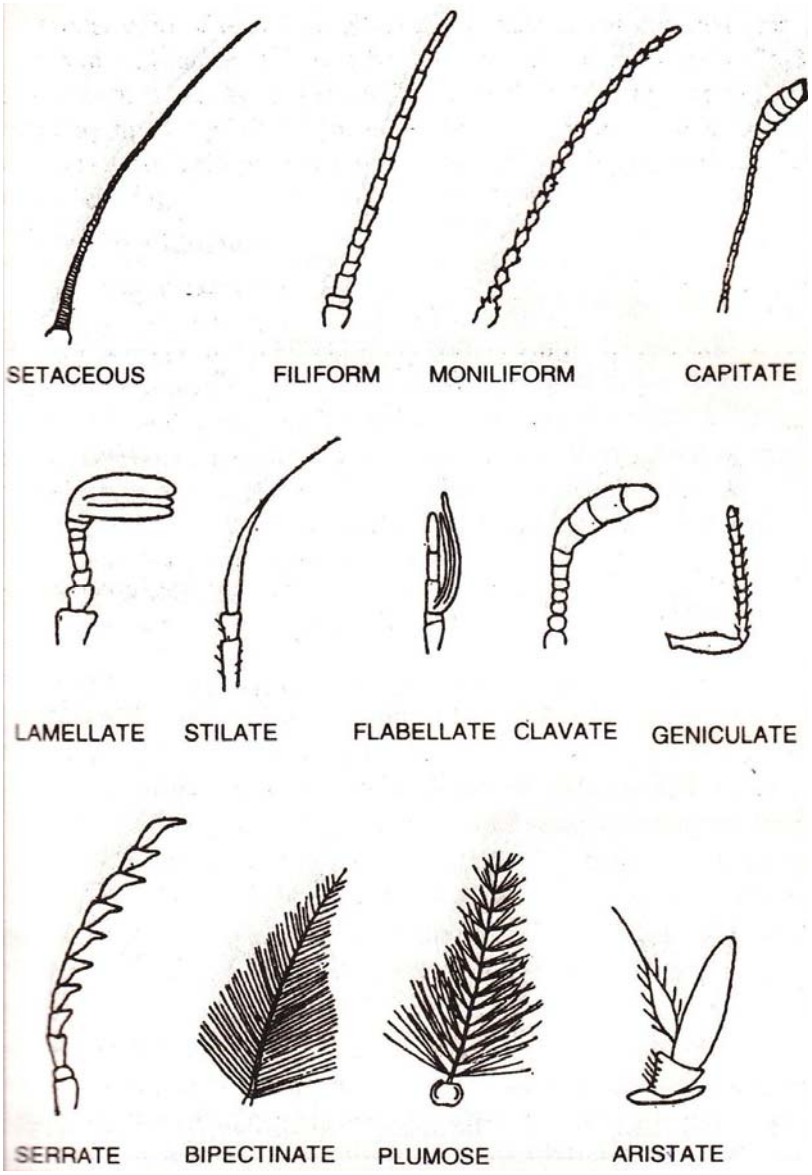


Fig. 9. Different types of antennae

(Source: Taken from The Insects (Diversity, Habits and Management) (1999) – Ramesh Arora and G.S. Dhaliwal. Kalyani Publishers., Noida, U.P., India.)

The antennae are of different form in different orders of insects.(Fig 9)

Types of Antennae:

S.No	Type of antennae	Example	Nature of modification
1	Filiform (Thread like)	Grasshopper	Segments are more or less uniform throughout from base to apex and never ends with bristle.
2	Setaceous(Whip/ bristle like)	Cockroach	Segments gradually decrease in size from base to apex presenting a whip or bristle like structure.
3	Moniliform (Like string of beads)	Termites	Segments are round or oval with well developed constrictions between segments, appearing like a string of beads.
4	Pectinate (Comb like)	Female arctid moth	Segments possess lateral processes on one side giving comb like appearance.
5	Bipectinate (Double comb)	Male Lymantrid moth, mulberry silk moth	Segments bear lateral processes on either side ,givng double comb like appearance.
6	Serrate(Saw like)	Pulse beetle, jewel beetles	Segments of flagellum are triangular with projecting points on one side giving saw like

			appearance.
7	Clavate (Clubbed)	Butterflies	Segments gradually increase in diameter from base to tip ending in a club like apical part.
8	Clavate with hook(clubbed antennae with hook)	Skipper butterflies	Segments gradually increase in diameter from base to tip and the last one ends with a small hook like structure.
9	Capitate (Clubbed with knob)	Red flour beetle	Segments gradually increase in diameter from base to apex and the terminal 3-5 segments suddenly enlarge to form a knob like structure.
10	Geniculate (Elbowed)	Ants, honey bees	The first segment (scape) is greatly elongated and flagellum always makes an angle with it
11	Lamellate (plate like)	Rhinoceros beetles, dung rollers, chaffer beetles	The terminal segments expand to one side and form broad plate or leaf like structure
12	Flabellate (feather like)	stylopids	Projections of some upper segments become long and form a feather like structure called **flabella**
13	Plumose(brush like with dense hairs)	Male mosquito	Whorls of hairs arise from each joint of the segment. Each whorl contains number of hairs
14	Pilose (brush like with sparse hairs)	Female mosquito	Looks like a plumose but each whorl contains less number of

			hairs
15	Aristate (antennae with arista)	House fly	Antennae are small, microscopic 3 segmented. 3rd segment enlarged and bears a bristle called **arista** on its dorsal side
16	Stylate (antennae with style)	Robber fly	Antennae small 3-4 segmented. Terminal segment elongate into a bristle like structure called **style**

.

Functions of antenna:

1. Mainly serve as the sense organ responding to touch, smell, odour, humidity, temperature as well as air currents or wind speed.
2. Jhonston's organ on pedicel functions as an auditory organ responding to sound and also helpful for measuring the speed of air currents.
3. Help the mandibles for holding prey and for mastication of food material
4. Helps in sexual dimorphism
5. Useful for clasping the female during copulation
6. Aid in respiration by forming an air funnel in aquatic insects.

Lecture - 8 : Mouth parts of insects

These are the organs primarily concerned with the uptake of food. Typical mouthpart of an insect consists of the following parts.

(i) Labrum (upper lip) (ii) A pair of mandibles (iii) A pair of maxillae (iv) Labium (lower lip) (v) Hypopharynx (tongue)

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

S.No	Type of Mouth parts	Examples
I	**Biting and chewing type**	Grasshoppers, cockroaches
II	**Sucking type / Haustellate type**	
	1.Piercing and sucking type	Plant Bugs and Mosquitoes
	2.Rasping and sucking type	Thrips
	3.Sponging type	Adult Houseflies
	4.Chewing and lapping type	Honey bees
	5.Siphoning type	Butterflies and moths
III	**Other types**	
	1. Mask type	Naids of Dragonflies
	2. Degenerate type	Maggots of Diptera

I.Biting and chewing type of Mouth Parts:

This type is considered as primitive and found in Orthoptera, Isoptera and Coleoptera, larvae of Lepidoptera and Neuroptera etc.

The mouth parts include following parts (Fig. 10)

a. Labrum : It is a small sclerite that forms the upper lip of the mouth cavity. It protects the mandibles and helps in closing of the mouth cavity and guide the food in to mouth.

On its inner surface, labrum consists of lobe like structure called **labrum – epipharynx** which is well developed in Hymenoptera. Labrum hangs down from the clypeus through a **clypeo-labral suture**.

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

c. Maxillae: These are paired homologous structures with basal triangular '**cardo',** middle rectangular '**stipes'** and the lateral '**palpifer'** bearing maxillary palpi and lobe like inner '**lacinia'** and outer '**galea**'.

Maxillary palps possess **olfactory** and **gustatory** sense receptors and function as **sensory** organs . These. Galea and lacinia helps in holding the food material along with the mandibles.

d. Labium: It is known as lower lip and is also called as second maxillae. It closes the mouth cavity from below.

It is divided in to proximal **prementum**. central **mentum** and distal submentum Near the base of pre mentum, on either side lobe like 'palpiger' is present which bears labial palps. Prementum has four terminal lobes. The median pair is '**glossae'** and outer **'paraglossae'** together called **ligula** that function mainly as **gustatory** sense organs.

e. Hypopharynx : It is a tongue like structure situated between labrum and labium and ducts of salivary glands open on or near its base.

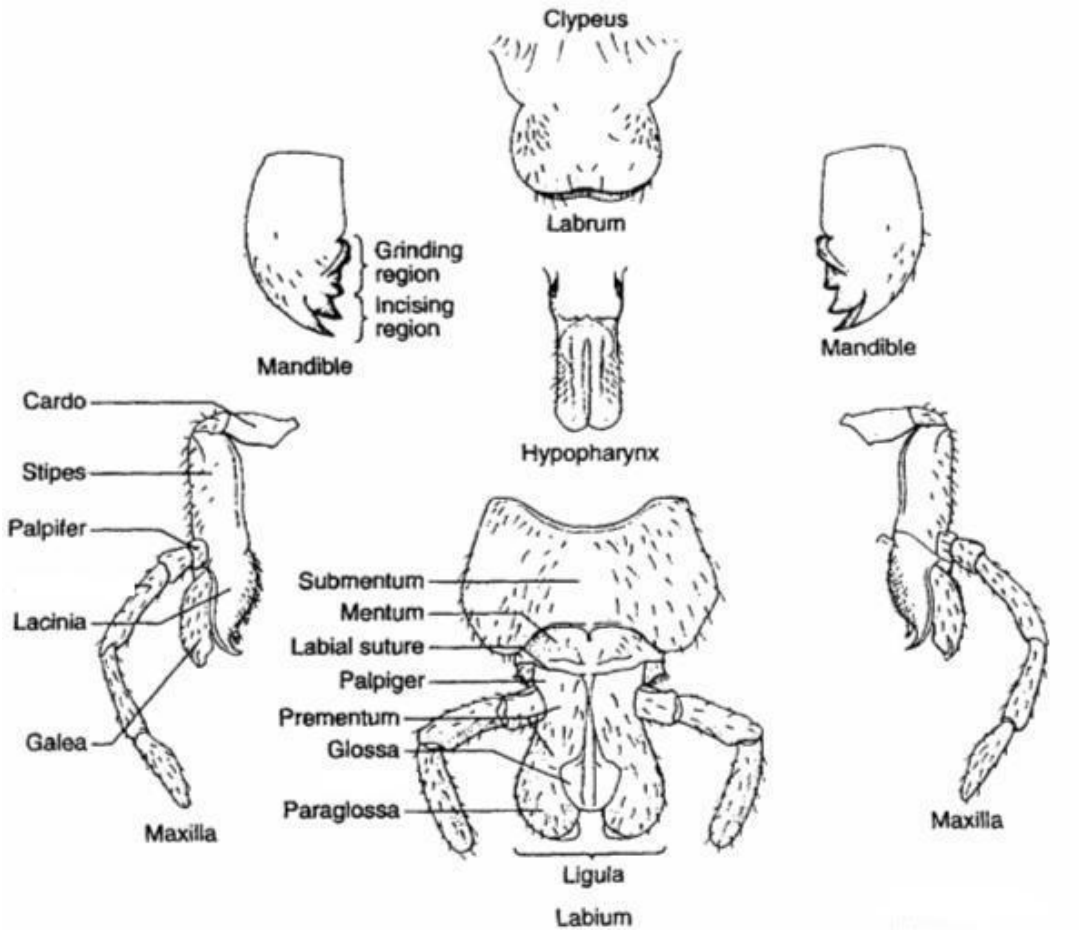


Fig. 10. Biting and chewing type of mouthparts

II. Sucking type of Mouth Parts:

This is considered as advanced type where the oral appendages get modified differently.

1. Piercing and sucking type e.g.: plant bugs, mosquitoes

They are mainly adopted for piercing the tissues and sucking either plant sap or the nectar or blood from the host.

Mouth parts are represented by **rostrum/beak** which is a modification of **Labium** . It acts as a pouch for protecting the **mandibular** and **maxillary** stylets.

Mandibles and maxillae are modified in to sharp needle like stylets (Fig. 11). The mandibular stylets form the outer pair and possess serrated margins at their tip. The maxillary stylets forms the inner pair having smooth curved tips and combine together enclosing a **food channel**.

The food channel is divided in to an upper **cibarium** and lower **salivarium** with the help of the grooves present inside the maxillary stylets (Fig. 12). Salivarium is used for **releasing the saliva** and cibarium is used for **sucking the sap**.

The hypopharynx is modified in to a **pharyngeal pump** and is situated at the tip of the food channel. Llabrum is modified into a small **flap like** structure at the base of rostrum.

Insects with these type of mouthparts pierce the tissues with the mandibular stylets and suck the contents (sap/ blood / nectar) through cibarium with the action of pharyngeal and cibarial muscles.

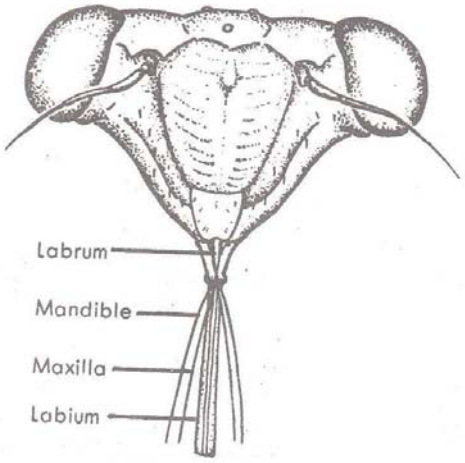


Fig. 12. Cross section

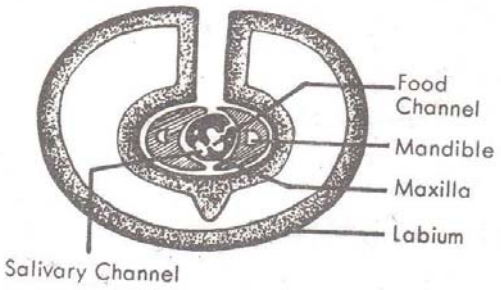


Fig. 11. Piercing and sucking mouthparts

(Source: Taken from Entomology – Pramod Kumar (2001). Published by IVY Publishing house, New Delhi., India)

2. Rasping and sucking type of Mouth Parts : e.g. thrips

These are called asymmetrical type , since **right mandible** is rudimentary . They are in between the biting – chewing type; and piercing - sucking type. Mouth parts are represented by **mouth cone** which is formed by the labrum and clypeus above and labium below.

With in the beak/mouth cone **hypopharynx** and **left mandible** is present. Right mandible is absent where as the left mandible is modified in to a mandibular stylet.

Maxillae are modified in to maxillary stylets which are mainly useful for sucking the sap that is released outside due to the rasping of tissues by the left mandible.

3. Sponging type of Mouth Parts: eg: housefly

These mouthparts are represented by **proboscis** formed from the **labium**.

The proboscis is divided into a basal **rostrum**, middle **haustellum** and a distal **labellum.**

The labellum is a sponge like structure. It is traversed by a number of narrow transverse channels called **pseudotrachea** which converge at one point in the centre of the labellum. From this point, the food enters in to food channel which is formed by the **labrum- epipharynx** and **hypopharynx**.

Mandibles are absent (reduced) maxillary palpi are 1-3 segmented (Fig. 13).

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

The **pseudo trachea** gets filled with the food material by the **capillary** action and is sucked up from the central point in to the oesophagus.

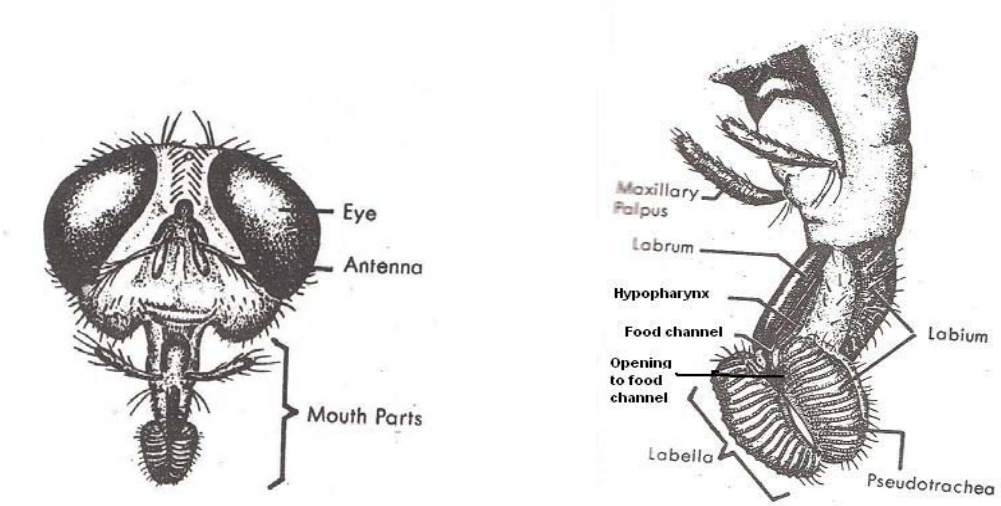


Fig. 13. Sponging type of mouthparts

(Source: Taken from Entomology – Pramod Kumar (2001). Published by IVY Publishing house, New Delhi., India)

4. Chewing and lapping type of Mouth Parts : e.g**.** : honey bees

The labrum and mandibles are **biting type** whereas maxillae, labium and hypopharynx combine together to form a sucking **proboscis** . The mandibles are dumbbell shaped, non-trophic and industrial in function . The cardo of maxillae unite with submentum of labium forming an inverted "V" shaped **lorum**. The maxillary palpi are very small or reduced. Galea and lacinia of maxillae remain suspended from the cranial wall and attached at the lorum. Labial palpi are conspicuous and 4-segmented. Elongated central organ of the proboscis is the glossa and at the base of glossae are two small concealed lobes are paraglossae (Fig. 14).

Glossae is provided with long hairs and a small spoon shaped lobe, called **flabellum** or **bouton** at its apex. The side walls of glossae are inclined downwards and inwards until they almost meet along the mid ventral line and form the boundaries of a central cavity.

At rest, mouth parts are folded beneath the head against stipes and mentum. During feeding they are straightened with labial palpi closely applied to glossa and partly embraced by the ensheathing of galea and lacinia.

Glossa is very active while food is being imbibed retracting and protruding from the base of mentum. The liquid food (nectar) ascends by means of capillary action in to the central channel of glossae and enters in to the space between paraglossae and in to the mouth cavity.

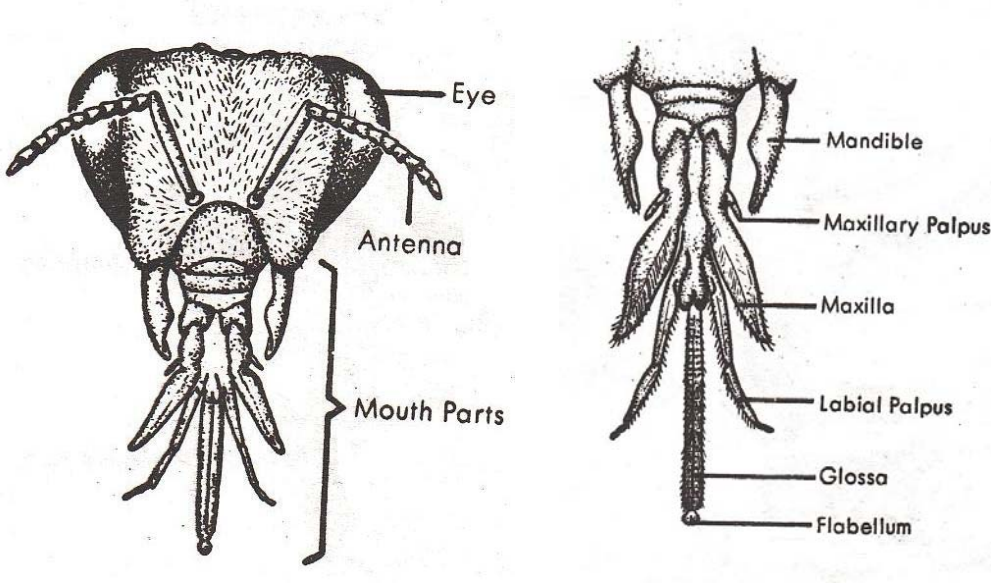


Fig. 14. Chewing and lapping type of mouthparts

(Source: Taken from Entomology – Pramod Kumar (2001). Published by IVY Publishing house, New Delhi., India)

5. Siphoning type of Mouth parts : eg: butterflies

These are specially modified for taking nectar from the flowers. The galea of maxilla form into a slender, hollow, tubular structure which remains as an elongated coiled proboscis underneath the head during non feeding (Fig. 15). Mandibles are totally absent. The labrum and maxilla palpi are reduced. Labium is modified in to a small basal plate possessing a 3 segmented labial palpi. The food channel is formed by the fusion of both the galea . The nectar will be sucked from the flowers through muscular action.

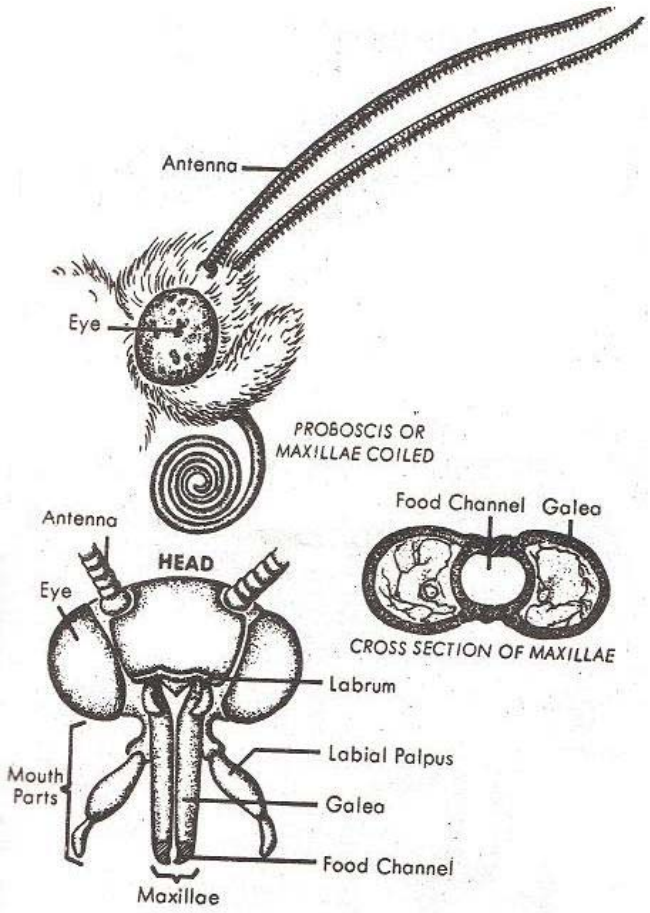


Fig. 15. Siphoning type of mouthparts

(Source: Taken from Entomology – Pramod Kumar (2001). Published by IVY Publishing house, New Delhi., India)

III. Other types

1. Mask type of Mouth Parts : e.g. Naids of dragon flies.

Mainly useful for catching the prey. **Labium** is modified in to a mask where the prementum and post mentum forms in to an elongated structure with a joint. The labial palpi are represented as teeth like structures / spines at the tip of the labium that are helpful for catching the prey. All other parts remain rudimentary (reduced). During resting period, when the insect is not feeding, the mouthparts cover a part of the head. Hence it is called mask type.

2. Degenerate type of Mouth Parts : e.g.:Maggots of Diptera.

In apodous maggots a definite head is absent and mouth parts are highly reduced and represented by a mouth hooks/ Spines .

Lecture - 9 : Insect legs

All the three thoracic segments of an insect possess a pair of legs as locomotory organs giving the name hexapods and the class insecta as **hexapoda**.

Insect leg mainly consists of 5 parts viz.

Coxa , Trochanter, Femur , Tibia and. Tarsus.

In primitive insects, a small sclerite known as **subcoxa** occur before the coxa which form the true basal segment. In the process of evolution, this sub coxa is reduced or modified.

Structure of leg (Fig. 16)

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

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

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

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

5. Tarsus : it is the largest segment of the leg and usually devided into sub segments tarsomeres. The number of tarsomeres vary from 1-5 and are movable one on the other. Among the 5 segments, 1st segment is large, big or broad in size known as basitarsus.

The tarsus at it's end consists of pretarsus which is in the form of a pair of claws and cushion like **pulvilli**. In between the claws, if there is lobe like structure, it is known as "**aroleum**" as in Orthoptera (grass hopper) and if it is bristle like structure, it is called "**embodium**" as in Diptera. In some insects, the ventral surface of pretarsus consist of a median circular plate between the claws known as **unguitractor** where as the claws are known as **ungues**.

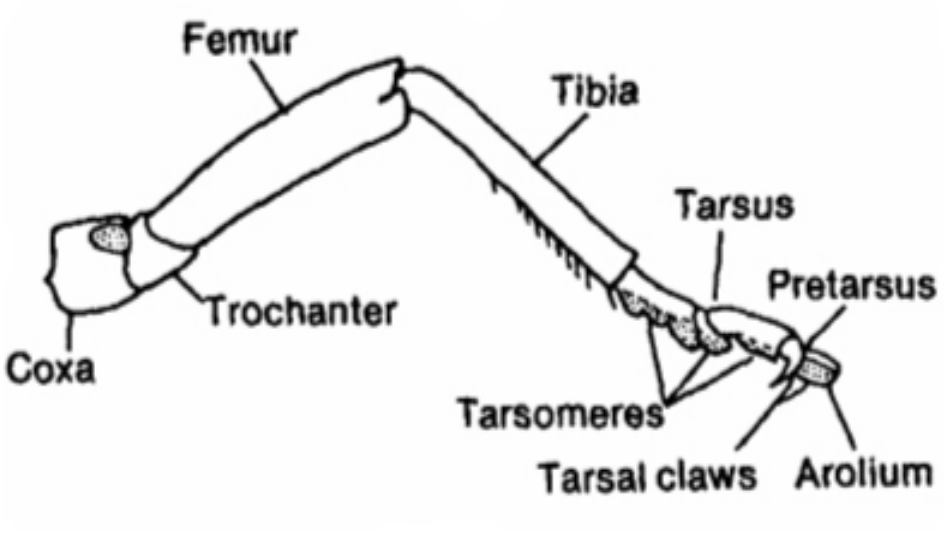


Fig 16.Structure of typical insect leg

MODIFICATIONS OF LEGS IN DIFFERENT INSECTS

Type	Leg modified	Example	purpose	Modification
Cursorial	All legs	Blister beetle, wasp	Walking	All the legs uniformly well developed without any special modification
Ambulatory	All legs	Cockroach	Running	All legs are normal. coxa widely separated
Saltatorial	Hind legs	Grasshopper , gryllids	Leaping and jumping	Femur and tibia elongated
Fossorial	Front legs	Mole crickets, dung rollers	Digging	Tibia and tarsus short and broad with teeth like projections
Raptorial	Front legs	Preying mantids	Preying (grasping)	femur spinose and possess a central longitudinal groove. Tibia narrow, blade like spinose and fits into the

				groove of femur
Natatorial	Hind legs	Water beetle, water bugs	Swimming	Hind legs pad like. Tibia and tarsus short and broad having dense long marginal hairs.
Scansorial	All legs	Head louse	clinging	Tibia possess tibial thumb. Tarsus single segmented and pretarsus with a single long curved claw
Prehensile	All legs together	Dragon flies	Catching prey, basket forming type	Thoracic segments obliquely arranged . Tergal platea are pulled backwards and Sternal plates pushed forward, resulting that all the legs pushed forward and seen below the head, together from a basket like structure useful for catching the prey even in flight
Antennal cleaning legs	Front legs	Honey bee	For cleaning antennae	Tibia possess a movable spine, and the first tarsal segment with a semicircular notch
Wax pick type	Middle legs	Honey bee	For picking wax plates	Tibia possess a spine called wax pick for removing the wax plates from the ventral side of the abdomen
Pollen basket and brush type	Hind legs	Honey bee	For collecting pollen and	Inner surface of large tibia has a groove and is used as pollen basket or ‘Corbicula’

			cleaning the body	'for temporary storage of pollen grains. First tarsal segment enlarged and possess short stiff hairs 'Pecten' all over the surface called pollen brush.

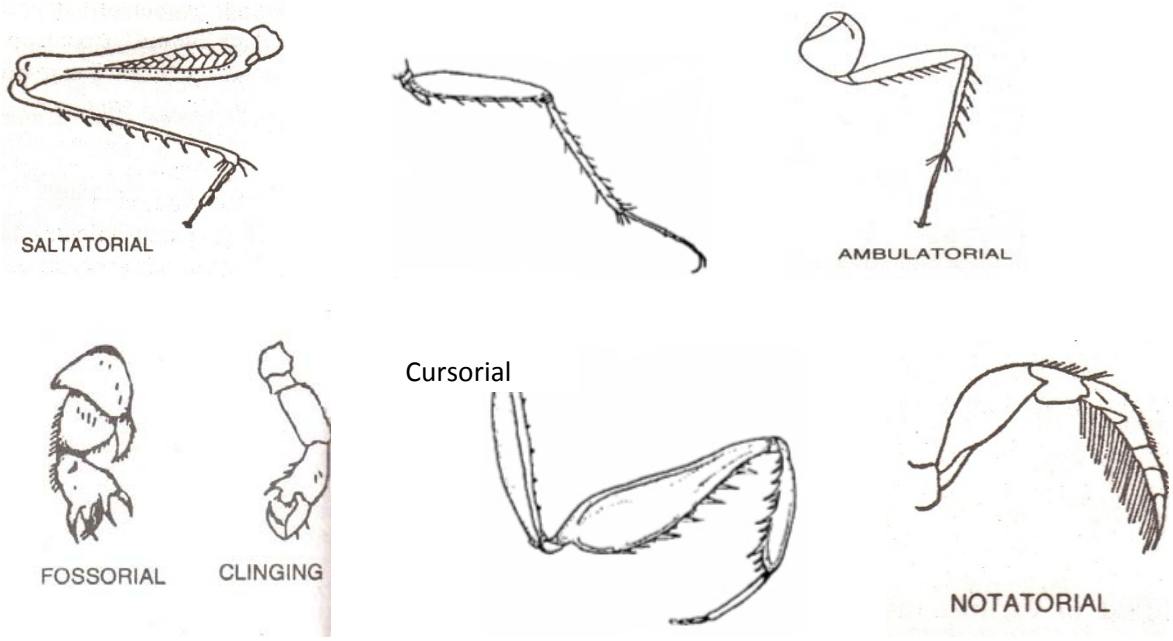
10. **Legs of immature stages:**

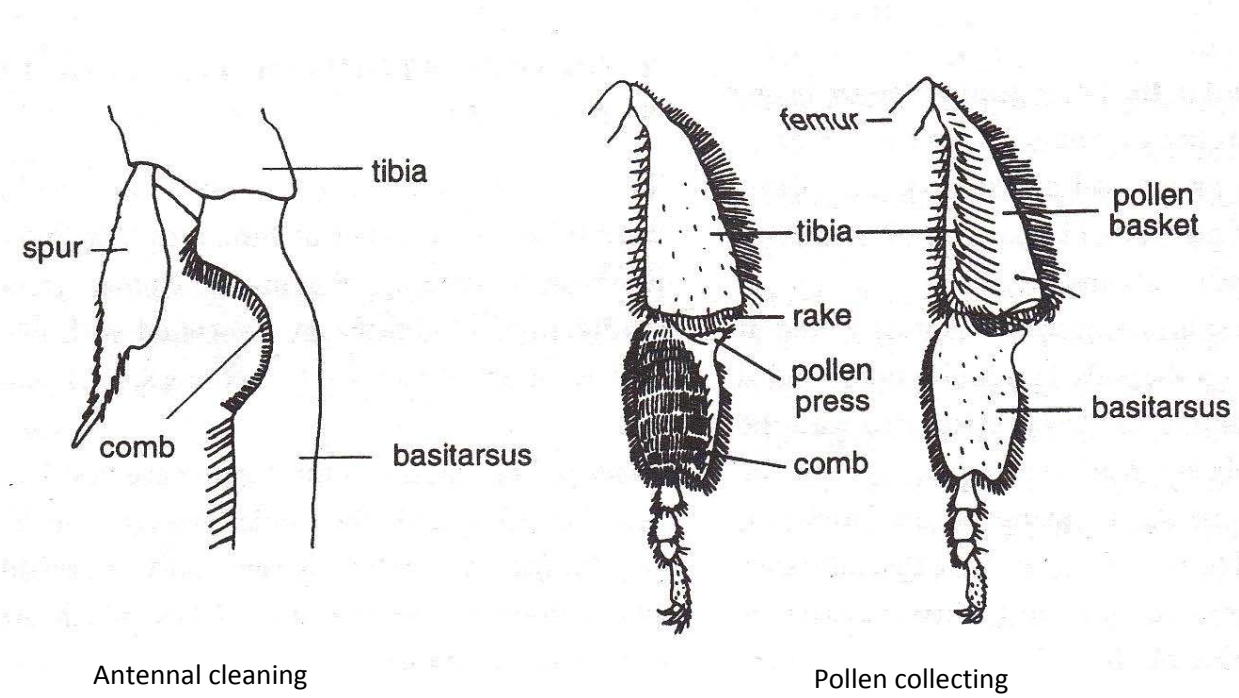
The immature stage of **exopterygotes** i.e. nymph consist of only thoracic legs similar to its adult where as that of **endopterygote** i.e. larva possess two types of legs.

i. Thoracic legs or **true legs**: Jointed, present on all the 3 thoracic segments.

ii. Abdominal legs or **prolegs**: Unjointed sucker like legs, having flat, fleshy surface at its tip known as **planta**. The planta consists of hook like structures known as **crochets** which are used for clinging to the substrate. The number of prolegs vary from 1-5 pairs which are distributed on 3^{rd}, 4^{th}, 5^{th}, 6^{th} and 10^{th} abdominal segments. For example, sawfly larva has 6-8 pairs of abdominal prolegs.

In some insects leg are degenerated e.g.: Coccidae; Endoparasitic hymenopterans.





Antennal cleaning

Pollen collecting

Fig. 17 Modification of insect legs

Lecture - 10 : Insect wings

Insects are the only invertebrates possessing wings and capable of true flight Based on the presence or absence of wings, class insecta is divided into two subclasses. 1. **Apterygota** 2**. Pterygota**.

The primitive **apterygotes** are **wingless**. Eg: Silver fish and Spring tails

Among the pterygotes, wings arises from meso and meta thoracic segments. Front pair of wings are known as forewings and back pair of wings are known as hind wings. Sometimes wings may be reduced among pterygotes e.g.. Mallophaga and Siphunculata . In coccids, only males are winged; and aphids may or may not have the wings.

Based on the degree of development of wings the insects may be classified into three forms **Macropterous, Brachypterous** and **Apterous.**

A typical insect wing is triangular with **three margins** and **three angles**.

Three margins are

costal or anterior,

Apical or outer and

Anal or inner

Three angles are (Fig. 18)

Humeral angle :
between body wall and costal margin

Apical or outer angle : between costal and apical margin

Anal angle or **tornus** : between apical and anal margin

The surface area of typical insect wing is divided in to two portions .ie **Remegium** and **Vannal Area**

The anterior (upper) part of the wing towards coastal margin where more no of longitudinal veins are present is called **remigium**.

The posterior part of the wing where veins are sparsely distributed is known as **Vannal Area,** which is called as **clavus** in forewings and **vanus** in hindwings. **Jugum** is the inner most portion of the wing that is cutoff from the main wing by **jugal fold**.

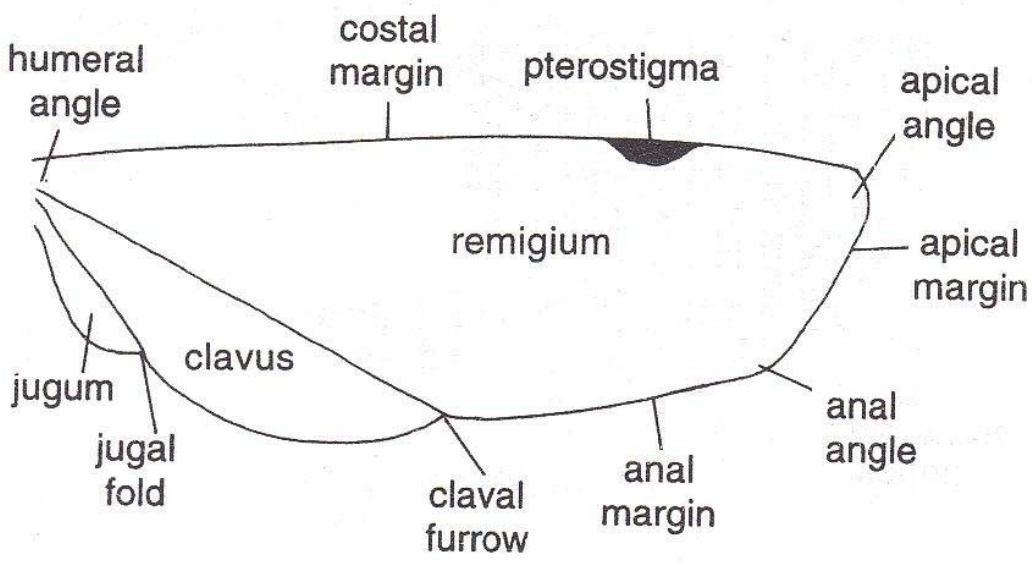


Fig. 18. Insect wing areas

(Source: Taken from The Insects- Structure and Function (4th Edition, 1998) – R.F. Chapman (Cambridge University Press))

Wings are very thin broad leaf like structures strengthened by a number of hollow narrow tubular structures called **veins**. Arrangement of veins on wing surface is known as **Wing venation,** which consists of two types of veins

1. **Longitudinal** veins : Extend from base of the wing to the margin. They may be convex (∩) or concave (U)
2. **Cross** veins : That interlink the longitudinal veins

The insect wings may some times possess some **pigmented spot** near coastal margin known as **pterostigma** or **stigma** as in Odonata (dragon flies and damsel flies)

Hypothetical wing venation (Fig.19)

1. **Costa (C) :** It forms the thickened anterior margin of the wing (costal) and is un-branched. and is convex
2. **Sub costa (Sc) :** It runs immediately below the costa always in the bottom of a trough between **C** and **R** . It is forked distally .The two branches of **SC** are $\mathbf{Sc_1}$ and $\mathbf{Sc_2}$ and is concave
3. **Radial vein (R):** It is the next main vein , stout and connects at the base with second auxillary sclerite , it divided in to two branches $\mathbf{R_1}$ and **Rs** (Radial sector). $\mathbf{R_1}$ goes directly towards apical margin and is convex; **Rs** is concave and divided in to 4 branches, $\mathbf{R_2, R_3, R_4, R_5}$.
4. **Media (M)** It is one of the two veins articulating with some of the small median seclerites. It is divided in two branches 1. **Media anterior** (MA) which is convex and 2.**Media posterior**(MP) and is concave.

Media anterior is again divided into $\mathbf{MA_1}$ and $\mathbf{MA_2}$. Median posterior is again divided in to $\mathbf{MP_1, MP_2, MP_3, MP_4}$.

5. **Cubitus (Cu):** It articulates with median auxillary sclerite. Cubitus is divided into convex $\mathbf{CU_1}$ and concave $\mathbf{CU_2}$. CU_1 is again divided into $\mathbf{CU_{1a}}$ and $\mathbf{CU_{1b}}$.
6. **Anal veins (A) :** These veins are convex. They are individual un-branched, 1-3 in number.

1 or 2 jugal veins (unbranched) are present in the jugal lobe of the forewing

Cross veins

Humeral cross vein (h) : between costa and subcosta

Radial cross vein (r) : between radius and radial sector

Sectorial cross veins (s): between sub branches of radial sector

Radio medial cross vein (r-m): between radius and media

Medical cross veins : between branches of media

Medio-cubital veins : between media and cubitus

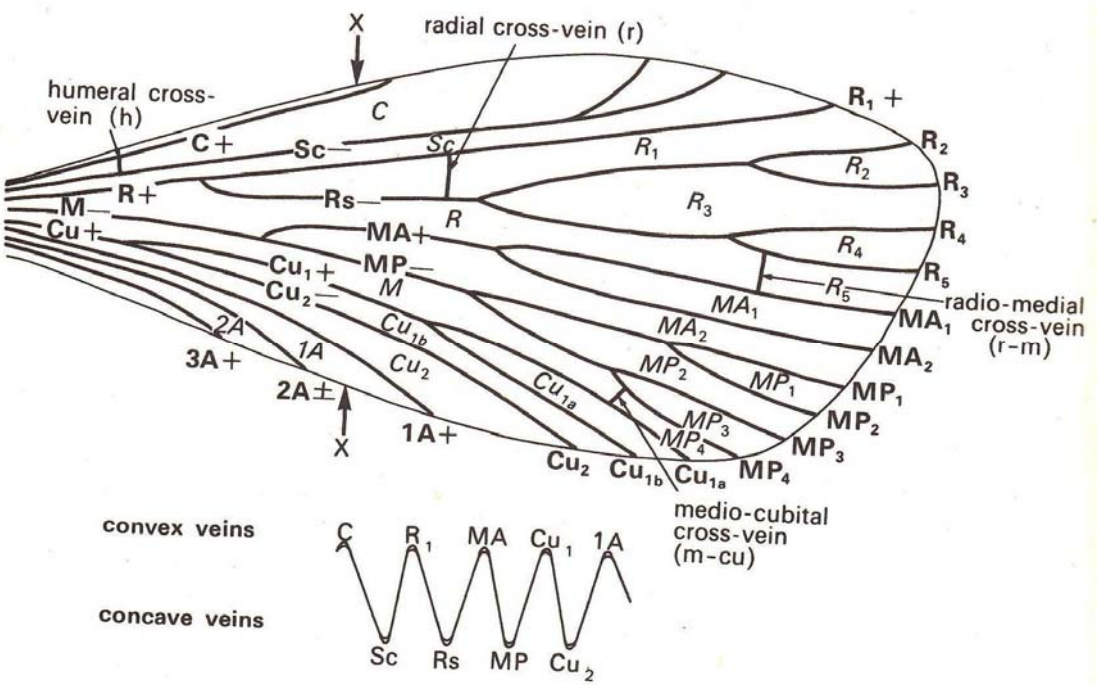


Fig. 19. Hypothetical wing venation

(Source: Taken from The Insects- Structure and Function(3rd Edition, 1971) – R.F. Chapman (Cambridge University Press))

Different types of wings (Fig. 20)

1. **Tegmina :** Forewings are leathery and tough . They protect the membranous hindwings.

e.g.: forewings wings of cockroach, grasshopper

2. **Elytra :** Hard, shell like without clear venation. They form horny sheet and protect the membranous hind wings and abdomen.

e.g. Forewings beetles

3. **Hemelytra :** The base of the wing is thick like elytra and the remaining half is membranous. This thickened portion is divided in to corium, clavus cuneus and embolium. They are useful of protection and flight

e.g.Forewings bugs

4. **Membranous :** Naked thin with clear venation. Always useful of flight

e.g.: Both the wings of Dragonflies, bees and wasps,

Hind wings of grasshopper, beetles etc.

5. **Scaly wings :** Wings thin , membranous but covered with unicellular scales all over the surface .They are useful for flight

e.g.: Both the wings of moths and butterflies.

6. **Fringed wings :** Wings are highly reduced with reduced venation. The wings are fringed with long marginal hairs giving a feather like appearance

e.g.:Both the wings of thrips

7. **Fissured wings :** Forewings are longitudinally divided twice forming a fork like structure whereas hindwings are divided twice in to three arms. All the forks possess small marginal hairs . They are useful for flight.

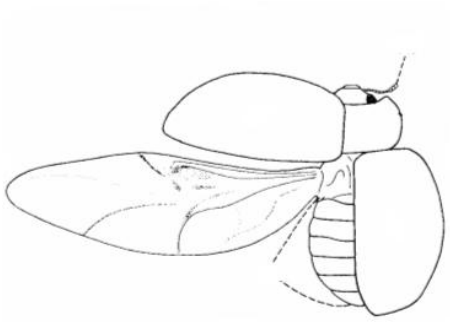
e.g.: Both the wings of plume moth

8. **Halteres :** The hind wings of houseflies are modified in to small microscopic structures called halteres and are divided in to three regions namely **scabellum** ,**pedicel** and **capitellum**.They act as balancers.

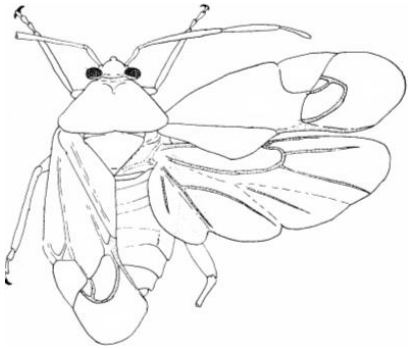
eg. Hind wings housefly and front wings of male stylopids

9. **Pseudohalteres** : They are short and modified in to pseudohalteres which are dumbbell shaped.

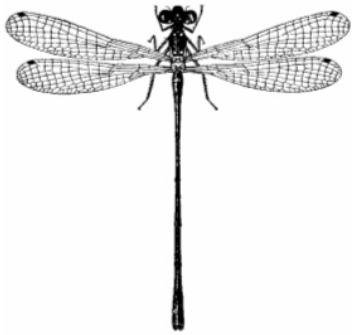
Eg: Front wings of Strepsiptera



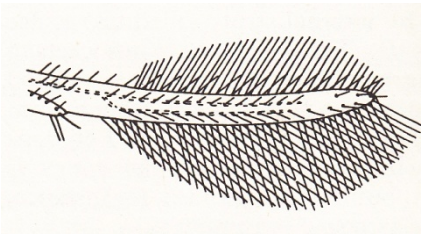
Elytra



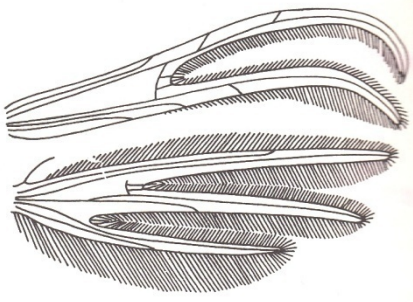
Hemelytra



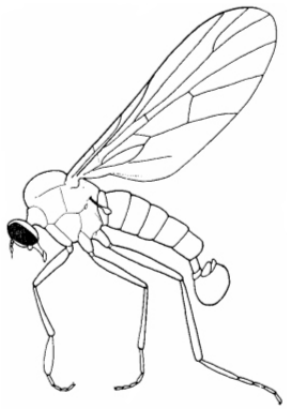
Membranous wings



Fringed wings



Fissured wings



Halteres

Fig. 20. Different types of wings

Wing coupling apparatus/Organs/Mechnisms:

For taking flight, insect need to keep both the fore and hindwings together as a single unit. The structures in the form of lobes , bristles, hairs or spines that help the wings to be together are known as wing coupling organs

1. Jugate type or jugum type :

The costal margin of the front wing possess a small lobe at ite base called **fibula**

Which rest on the surface of the hind wing or sometimes engages with spines present on the upper surface of hind wings .

e.g.: primitive lepidopterans of the family Hepialidae

2. Frenulum and retinaculum type The hind wings posses bristle or spine like structure or group of hairs known as **frenulum**.The forewings possess hook like r**etinaculum** on anal side. During flight the frenulum passes beneath the retinaculum and thus the both the wings are kept together..

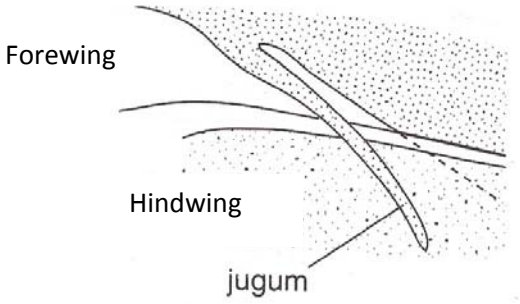
e.g.: moths

3. Amplexiform Costal margin of hind wing and anal margin of forewing overlap one above the other

e.g.: butterfly

4. Hamuli : Small curved hook like structures present on the costal margin of the hind wing known as **Hamuli** that fit into the upward fold of the anal margin of the forewing .

e.g.: hymenopterans(wasps and bees)



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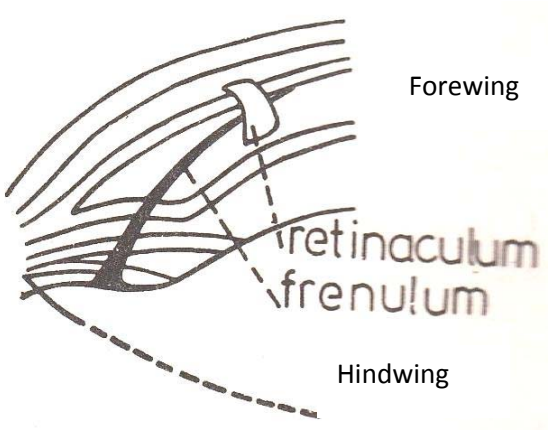

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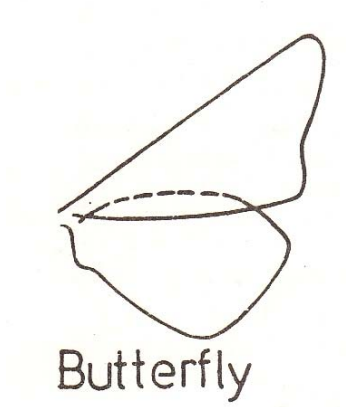

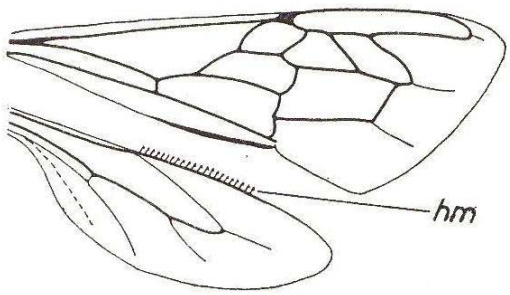

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Fig. 21. Different types of wing coupling mechanisms

(Source: Taken from A General Textbook of Entomology (1960) – A.D. Imms (Revised by Professor O.W. Richards and R.G. Davies, 9th Edition) (Butler & Tanner Ltd., Frome and London)

Lecture - 11 : Insect Sense Organs

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

The sense organs may be classified as

1. Visual organs (or) photoreceptors
2. Auditory organs (or) organs of hearing
3. Chemoreceptors which respond to chemicals
4. Tacticle receptors which respond to touch
5. Gustatory receptors which respond to taste.

1. Visual organs or photoreceptors

These are two types I. **Compound eyes** and II. **Simple eyes**

I. Compound eyes.

These organs possess the ability to perceive light energy and able to produce a nerve impulse. The compound eyes may be completely absent in insects like **Protura** or they may remain reduced in endoparasitic **Hymenoptera, Siphunculata, Siphonaptera, female coccids** etc. The compound eyes are present on either side of the head capsule of an adult insect and also in the nymphs of Exopterygota. These are a pair and consists of number of individual units (or) facets called **ommatidia**. The number of ommatidia varies from 1 in the worker of ant, *Ponera punctatissima* to over 10,000 in the eyes of **dragonflies.** The shape of compound eye vary based on number of ommatidia. If the number of ommatidia is more they remain closely packed and they attain a **hexagonal** shape. If they are few, they remain loosely packed and they attain **circular** shape.

Structure of ommatidium: Ommatidium consists of 2 parts.

1. Dioptic apparatus : Acts as lens
2. Receptor apparatus : Forms the image

1. The **dioptic apparatus** has (Fig. 22a)

a) **Cornea :** It is a cuticular transparent colourless layer that remains continuous with the integument. It forms a biconvex lens receiving the light.

b) **Corneagen cells:** These are the modified epidermal cells which secrete the cornea and are two in number.

c) **Crystalline cone cells :** These cells remain just beneath the cornea and corneagen cells and are four in number, forming the crystalline cone and consists of a translucent material.

d) Primary pigment cells (or) Iris pigment cells:

These are darkly pigmented cells, commonly two in number, present around the crystalline cone which are mainly useful for separating the ommatidia from one another and also restrict the movement of light passing from the neighboring ommatidia.

2. The **receptor apparatus** consists of

e) **Retinular cells:** These are commonly eight in number which are arranged and contribute to the formation of a centrally located rod like **rhabdom** (with the rhabdomeres (microtubules) which are formed with the inner side margins of retinular cells) on which the image is formed. The rhabdom contains a light absorbing pigment called **rhodopsin**. The retinular cells continue with the axons that pass through the basement membrane forming an optic nerve which remain connected to the optic lobes of the brain.

f) Secondary pigment cells: The rhabdom is surrounded by secondary pigment cells that help to separate the ommatidia. They surround the retinular and primary pigment cells. These are numerous in number.

II. Simple eyes (or) ocelli:

These are of two types

1) **Dorsal ocelli :** Seen in nymphs and adults of **Hemimetabolous insects** and adults of **Holometabola.** They vary from 3-4 in numbers which are arranged in a triangular fashion between the compound eyes with a median ocellus.

The dorsal ocelli consists of a single cornea secreted by the corneagen cells, below which are a group of retinular cells forming the rhabdom. These ocelli function as stimulatory organs to improve the sensitivity of the compound eyes. Dorsal ocelli are represented by **fenestrae** in cockroach.

2) **Lateral ocelli (Fig. 22b):** Also known as **stemmata**. These are present on the lateral sides of the head of Endopterygote larva. They vary from 1-6 in number and some times 7 on each side. Lateral ocelli consist of cornea, a crystalline cone body and retinular cells forming the rhabdom. The main function of these ocelli are responding to light, perception of moving objects, colour, form and distance.

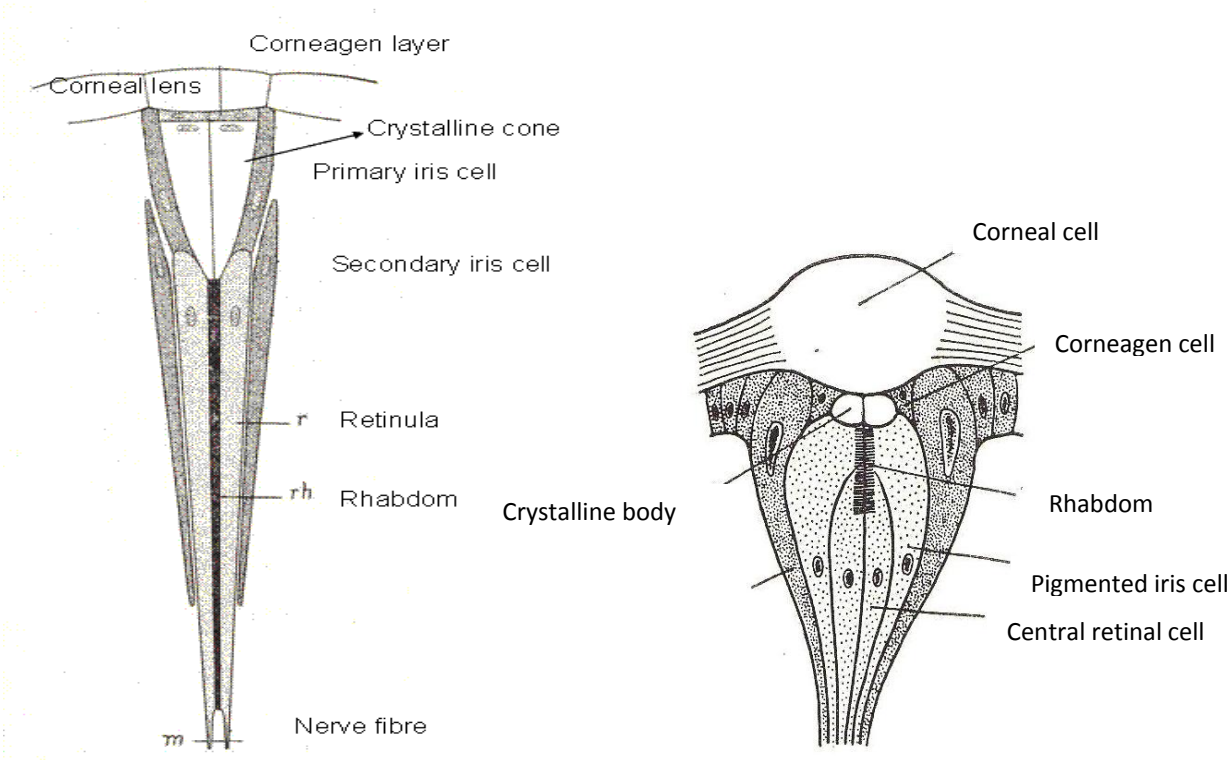


Fig. 22a Ommatadium of compound eye

Fig. 22b Simple eye (lateral ocelli)

(Source: Taken from A General Textbook of Entomology (1960) – A.D. Imms (Revised by Professor O.W. Richards and R.G. Davies, 9th Edition) (Butler & Tanner Ltd., Frome and London))

Classification of Compound eyes based on image formation.

	Apposition eyes	Superposition eyes
1.	These are active during day time (**diurnal** insects)	These are active during evening and night time (**crepuscular** and **nocturnal** insects)
2	The light received by the cornea of **single** ommatidium passes through the central portion and forms the image on the rhabdom of the same ommatidium	The light received by **many** ommatidia (or) the neighboring ommatidia forms the image on a single rhabdom
3	The pigment cells remain in the extended position completely surrounding the ommatidium so that they separate the individual ommatidia, and do not allow the light to pass from the neighboring ommatidia	The pigment cells are constructed such that they allow the light to pass on to a rhabdom from neighboring ommatidia. Primary pigment cells are absent allowing the light to pass between the adjascent ommatidia
4	Image formed is distinct	Image is not clear where only general features of objects are formed.
	Eg: butterflies	Eg: moths

2. Auditory organs

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

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

2. Tympanal organ : This is a delicate organ (or) structure seen in the form of a cuticular membrane which internally consists of a '**mullers**' organ. Tympanum is present one on either side of the **1st abdominal segment** of short horned grasshoppers , on the base of **foretibia** in long horned grasshoppers and crickets, and on **thorax or abdomen** in Lepidoptera.

3. Jhonston's organ : It is present on the **pedicel** of antennae and functions as an auditory organ responding to air (or) water currents. They are absent in **Collembola**.

4. Pilifer of hawk moths (sphingid moths) : An unique auditory organ, sensitive to ultrasonic frequencies is found in the head of several species of Sphingidae.

Lecture - 12 : Metamorphosis and diapause

Series of changes that takes place during the development of an insect from egg to adult are collectively known as **metamorphosis**.

Metamorphosis is derived from Greek word **'Meta'** = Change, **'morph'** = form or structure.

Metamorphosis include three developmental processes namely **growth, differentiation** and **reproduction** which takes place in larval, pupal and adult stages respectively.

The presence of hard exoskeleton on the body prevents the growth of larva. The series of moults during larval stage allow them to increase their body size/growth. The number of moults in general may vary from 5-6.

Instar: It is the form of the body during two inter moults. The larva is known as first instar, immediately after hatching from egg, and as second instar after first moult and so on

Stadium : The interval or time period between two moults is known as stadium.

Exuviae : The skin shed during moulting process is known as exuviae.

Imago (or) Adult : It is the final stage of insect with well developed organs for reproduction, which emerges out from pupal body.

Sub-imago: It is a pre adult stage with fully developed wings but without reproductive organs .Eg: mayflies (**Ephemeroptera**)

Types of metamorphosis:

1. Ametamorphosis
2. Incomplete metamorphosis
3. Complete metamorphosis
4. Intermediate metamorphosis
5. Hyer metamorphosis

1. Ametamorphosis :

Insects do not undergo any metamorphosis. When the insect hatches from the egg, it resembles the adult in all the characters except the small body size, which later increases, until they reach sexual maturity with well developed reproductive organs.

e.g.: Apterygotes e.g.: silver fish, springtails.

2. Incomplete metamorphosis or hemimetamorphosis or direct development or simple metamorphosis

The life cycle includes egg, nymph and adult stages. The nymph resembles the adult in all the characters except wings. Nymphs possess wing buds which transform in to fully developed wings in adult stage. (Fig. 23). In these insects, wings develop externally and hence are also called as **Exopterygota**. Pupal stage is absent hence, development is said to be direct and simple.

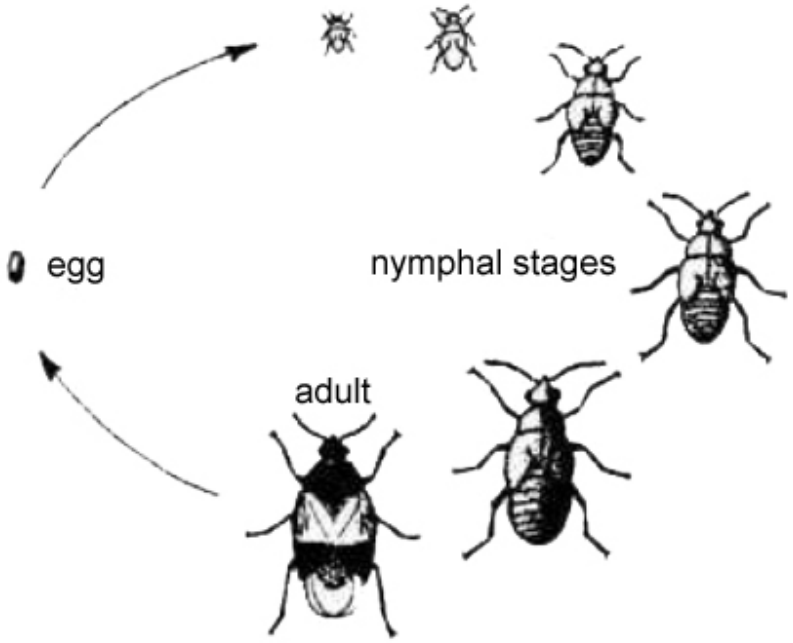


Fig. 23. Incomplete metamorphosis

3. Complete (or) holometamorphosis or indirect development

The life cycle includes four stages; egg. larva, pupa and adult. Larva differs from the adult both in body structure and habits. Larva has both thoracic and

abdominal legs, sometimes legs may be absent in larva, where as adult has only thoracic legs.

Compound eyes are absent in larva . Larva undergoes moulting to enter in to pupal stage from which the adult insect emerges. Wings develop **internally** during the pupal stage and hence, they are called **Endoptreygotes.**

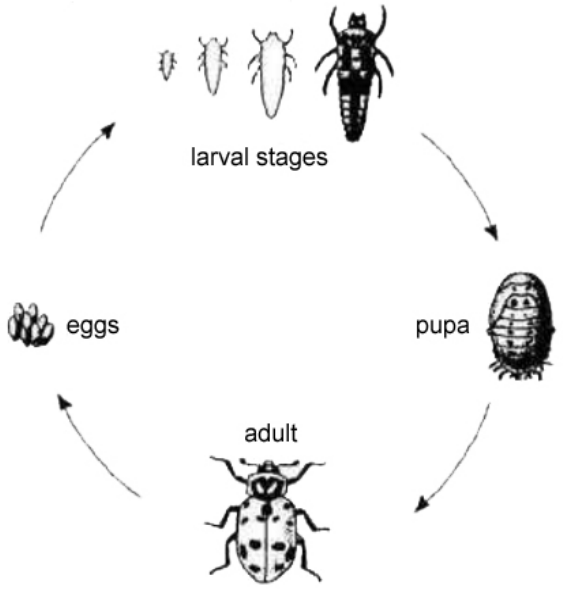


Fig. 24. Complete metamorphosis

4. Intermediate metamorphosis: In this case, insects may undergo either

hemi or **holometamorphosis**. If they undergo holometamorphosis, there is a short pupal stage. e.g.: coccids, thrips etc.

5. Hypermetamorphosis:

This is a peculiar type of development which consists of two or more types or forms of larvae in the life cycle of insects. In majority of the cases the first larval instar is **campodeiform** and the subsequent larval forms depends on type and mode of life of the larva.

E.g.: In blister beetle (Meloidae; Coleoptera), the first larval instar is **campodeiform** followed by **scarabeiform** larval type.

Diapause

It is the period of arrested growth or development in the life cycle of the insects during which the physiological processes like **differentiation** and **reproduction** are suspended. Diapause is represented by low rate of metabolism, low O_2 consumption, low body weight, low body water content and vitamin deficiency in the blood. Diapause may occur in **egg, larva, nymph, pupa** or **adult** stage.

For example:

Egg diapause - *Bombyx* mori;

Larval diapause- *Euproctis* sp., *Pectinophora gossypiella*;

Pupal diapause- Redhairy Caterpillar (*Amsacta albistriga*) and

Adult diapause- Mango nut weevil (*Sternochaetus mangiferae*)

Diapause is of two types:

1. **Obligatory diapause**: It refers to the stage of suspended activity of the insect which is a hereditary character controlled by genes and is species specific.
   e.g. egg diapause in silkworm

2. **Facultative diapause**: It is the stage of suspended activity of the insect due to unfavourable conditions and with the onset of favourable condition, the insect regains its original activity.
   e.g. Cotton pink bollworm *Pectinophora gossypiella*.

The unfavourable conditions may be biotic or abiotic. Biotic conditions are natural enemies, population density etc. Whereas abiotic conditions are temperature, rainfall, humidity, photoperiod, type of food material etc.

The occurrence of diapause during summer due to high temperatures is known as **"aestivation**" where as the period of inactivity during winter due to low temperatures known as "**hibernation**".

Lecture - 13 : Types of larvae and pupae

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

Differences between larva and nymph

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

Types of larva (Fig. 25):

1. Protopod larva: Eg: endoparasitic Hymenoptera.

The larva emerge (hatch)from egg which is still in an early embryonic phase as the egg contain **less yolk material**. The larvae are partially developed. They possess well developed head and thoracic segments but **lack segmentation** in the abdomen. They possess **rudimentary cephalic** and **thoracic appendages** but no abdominal appendages. They have **partially** developed digestive system and **underdeveloped** respiratory and nervous systems.

2. Oligopod larva : These are characterized by the presence of well developed thoracic legs, head capsule and **without** any abdominal legs.

These are classified in to two types viz., **campodeiform** and **scarabaeiform.**

Differences between Campodeiform and Scarabaeiform

S. No.	Campodeiform	Scarabaeiform
1	The body is long and fusiform in shape	Body is 'C' shaped
2	Body is dorso-ventrally compressed with sclerotized cuticle	Body is cylindrical or sub cylindrical, stout and fleshy in nature
3	Prognathous type of head	Hypognathous type of head
4	Long thoracic legs	Short thoracic legs
5	A pair of terminal abdominal processes (anal cerci) are present	Absent
6	These are active	Inactive
7	Predatory in nature	Phytophagous
	Ex: Neuroptera, Trichoptera	e.g.: Scarabidae of Coleoptera

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

Different types of polypod larvae:

A. **Hairy caterpillar** Larval body is fully covered with hairs

Eg: Redhairy caterpillar (*Amsacta albistriga*), Castor hairy caterpillar (*Pericalia ricini*).

B. **Sphingid caterpillar / larva** The larva consists of a horn (or) hook on the dorsal surface of 8^{th} abdominal segment.

Eg: *Acherontia styx* (Gingelly death's head moth)

C. **Looper :** Only two pairs of abdominal legs present on 6^{th} and last abdominal segment .During walking the insect body forms a complete loop like structure hence, the name looper.

Eg: Mango looper, *Thalassodes quadraria*

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

Eg:Castor semilooper *Achoea janata*

4. Apodous larva : These are characterized by the absence of trunk appendages (or) legs.They possess 3 pairs of sensory papillae in the place of thoracic legs. They are usually derived from Oligopqd type.

Based on the **degree of development** of the head capsule and its appendages,, these larva are divided in to **3 types**.

a. **Eucephalous** : e.g.: Sub order Nematocera of Diptera, Mosquito (Culcidae)

The larva consists of a well sclerotized head capsule.

b. **Hemicephalous.** e.g.: Brachycera of Diptera, robberflies (Asilidae)

Larva possess partially developed head capsule

C. **Acephalous** e.g.: Cyclorrhapa of Diptera, Muscidae (houseflies)

The larva are characterized by the absence of head capsule and mouth parts are represented by mouth hooks.

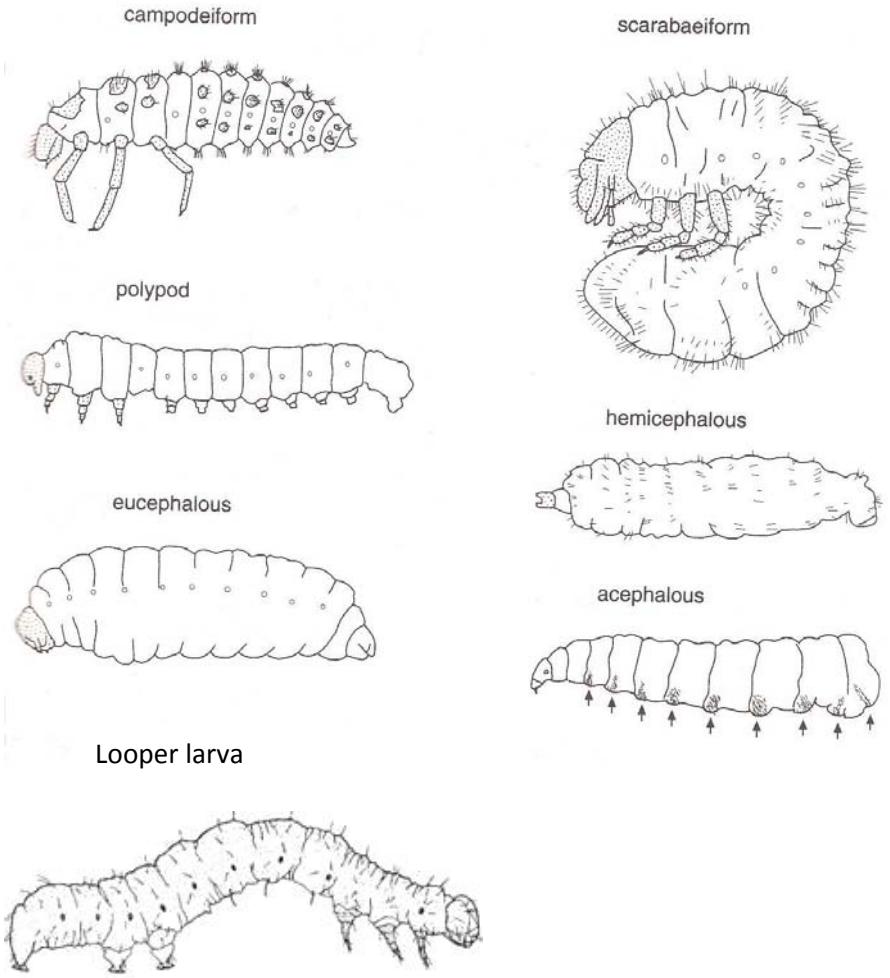


Fig. 25. Types insect larvae

Types of Pupa

It is resting, inactive stage of the holometabolous insects anf transitional phase during which the wings are developed and the insect attain matured sexual organs. The pupa is incapable of feeding, locomotion except in some cases where they crawl (Neuroptera) (Aphid lion), can swim e.g.: mosquitoes. Pupa represents a

pharate adult stage and later it emerges as adult, pupation may takes place either in soil, or on the plant surface or within the webs.

Pupae is divided on the following bases

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

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

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

1. **Exarate** pupa: e.g.: most of the Coleoptera

The pupae have appendages which are free without any secondary attachment to the **body**

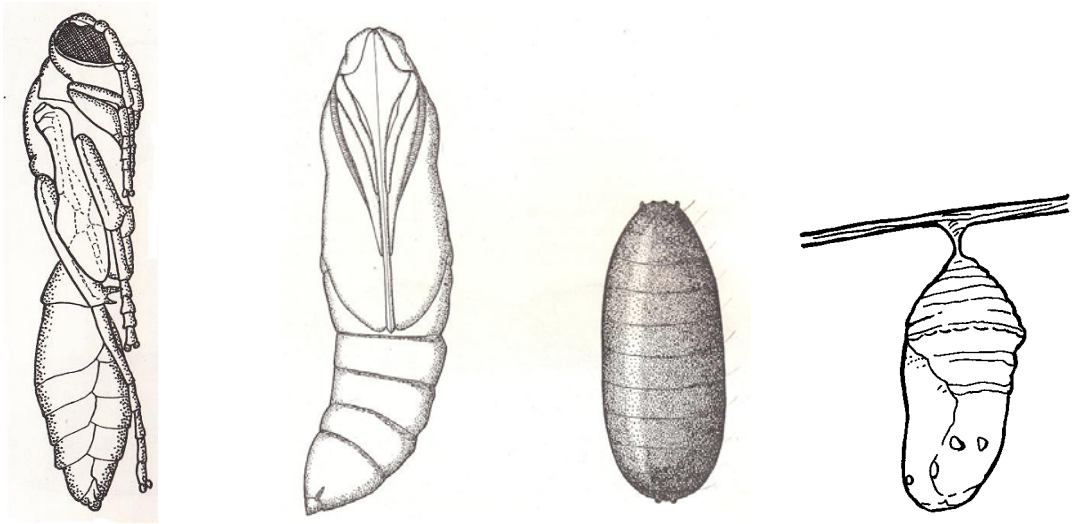
2. Obtect pupa eg: Lepidoptera (moths)

The pupae have appendages which are **firmly pressed against the body** and the pupa is highly **chitinized.**

3. **Coarctate** : e.g.: Cyclorrhapha of Diptera (housefly)

The pupa remain enclosed in a **puparium** formed by the last larval skin and the pupa looks like a capsule or barrel.

4. **Chrysalis**: It is an obtect type of pupa which has golden colouration and a stalk eg: butterflies.



Exarate pupa Obtecta pupa Coarctate pupa Chrysalis

Fig. 26. Type of insect pupa

Lecture - 14 : Digestive system

Insects may be phytophagous, entomophagous, wood borers, wool feeders (or) saprophytic, mainly feeding on the solid food material which may be a plant part (or) host tissue (or) wood etc.

- If the food ingested in a liquid form, it may be a **plant sap** (or) **nectar** (or) **blood**
- Based on the food material ingested, there are **structural modifications** in the digestive system of insects.
- Insects having the habit of feeding on the **solid food** material, possess the **biting** and **chewing** type of mouth parts where as **sap feeding** ones have **sucking** type. Sap suckers possess a **filter chamber** and solid feeders have well developed **gizzard**.
- The alimentary canal in insects extends from mouth to anus which is divided in to an anterior **stomodaeum** (foregut), middle **midgut** (**mesenteron** or stomach or **ventriculus**) and posterior hindgut **(proctodaeum**).
- The foregut and hindgut are **ectoderma**l in origin where as the midgut is **endodermal** in origin.
- Compared to the carnivores (or) sap suckers, the phytophagous solid feeders possess longer alimentary canal.

Alimentary canal is divided into 3 parts.

1) Foregut

It is the anterior part of the alimentary canal which starts with the **mouth cavity** and ends with the **gizzard** (or) **proventriculus**. It is divided in to **pharynx**, **oesophagus, crop** and **gizzard** (Fig. 28). The mouth cavity is formed by the **labrum** as upper lip, **labium** as lower lip with **mandibles** and **maxillae** laterally and **hypopharynx** at the centre. At the base of the hypopharynx, salivary glands open into the mouth cavity.

Pharynx: It is the region between the mouth and oesophagus.

Oesophagus: it is a narrow part of the foregut through which the food get transported from pharynx into the crop.

Crop : It is a sac like structure which is a dilated form and mainly serves the purpose of storage of food material.

Gizzard : It is a small constricted part of the alimentary canal which consists of the cuticular **intima layer** modified in to a teeth like denticles that help for **grinding** the food material. In some insects such as honey bees, the gizzard functions as honey stopper (or) stainer separating the **pollen** from the **nectar.** After gizzard the foregut forms into a stomodeal valve which is surrounded by **gastric** (or) **hepatic caecae**, which may vary from 5-6 in number (Fig. 27).

Internally foregut consists of the following layers.

(i) Inner most intima layer
(ii) Epithelial cells
(iii) Basement membrane
(iv) Longitudinal muscles
(v) Circular muscles

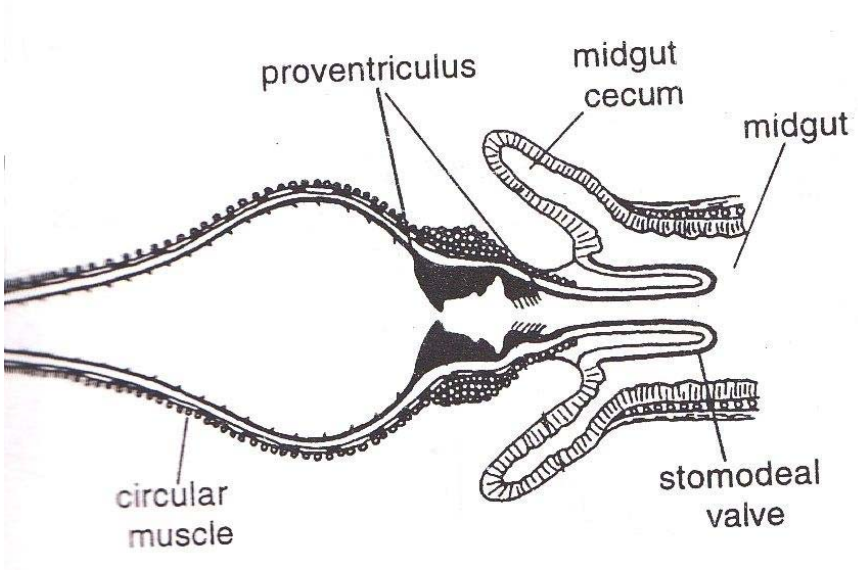


Fig. 27 Proventriculus (Foregut)

(Source: Taken from The Insects- Structure and Function(4th Edition, 1998) – R.F. Chapman (Cambridge University Press))

2) Midgut

It is also known as **mesenteron** or stomach. Foregut opens in to midgut through **stomodae**l / **cardiac** valve. Midgut is a short, straight tube in case of primitive insects or a **sac** or may be **pyriform** or **fusiform** in shape in caterpillars.. In some insects midgut appears as a completely separated sac like structure that gets connected with the hindgut. Structurally midgut consists of

(i) Inner peritrophic membrane
(ii) A layer of epithelial cells
(iii) Basement membrane
(iv) Circular muscles
(v) Longitudinal muscles

Midgut consists of an inner delicate layer called **peritrophic membrane** secreted by the epithelial cells . The peritrophic membrane **protects** the tender **epithelial cells** of the midgut from abrasion by hard food particles as no mucous is secreted in insects that feed on the solid food material. The peritrophic membrane forms a coat over the food particles and no damage will occur to epithelial cells of midgut. This layer is said to be **permeable** to the digestive enzymes and the products of digestion. It is **absent** in case of sap sucking insects.

The epithelial layer of midgut consists of 3 types of cells

1) Columnar cells: These are columnar in shape, vary in size and **release enzymes** through a series of microvilli arranged in a **brush border** (or) **honey comb border .**

2) Regenerative cells: These epithelial cells are involved in the **production** (or) **formation** of new cells to replace the whole columnar cells involved in holocrine secretion of **enzymes.** These regenerative cells may be arranged either in groups (or) may remain scattered (or) sometimes singly. If they are arranged in groups (or) clusters they are called **Nidhi.**

3) **Goblet cells**: Mainly serve for **storage** and **excretion.**

3. Hindgut

It is also known as **proctodaeum** which is lined inside by **intima**. It is more **permeable** than that of the foregut. Anterior end of the hindgut can be marked by the presence of a set of **malpighian tubules** and a **pyloric valve**. Internally hindgut has same structure as that of the foregut.

Hindgut is divided into 3 regions namely **ileum, colon** and **rectum** (Fig. 28). Ileum is a small intestine (or) tube like structure and appears as a pouch in scarabids. Colon may (or) may not be present and if present, it leads to rectum. The epithelial cells of the rectum may sometimes get differentiated into **rectal papillae** (or) **pads** which vary in number from 3-6. These are involved in

reabsorption of water, salts from the faecal matter.

Salivary glands: These are a pair of glands involved in the secretion of salivary juices. These glands open at the base of the **hypopharynx** through small salivary ducts. The secretion of the glands contain the enzymes such as **amylases, lipases, proteases**, but never **cellulase**.

In case of **silkworm** (or) lepidopteran larvae, the salivary glands produce silk which contains two proteins **fibroin** and **sericin** and **anti coagulants** in blood suckers like **mosquitoes.**

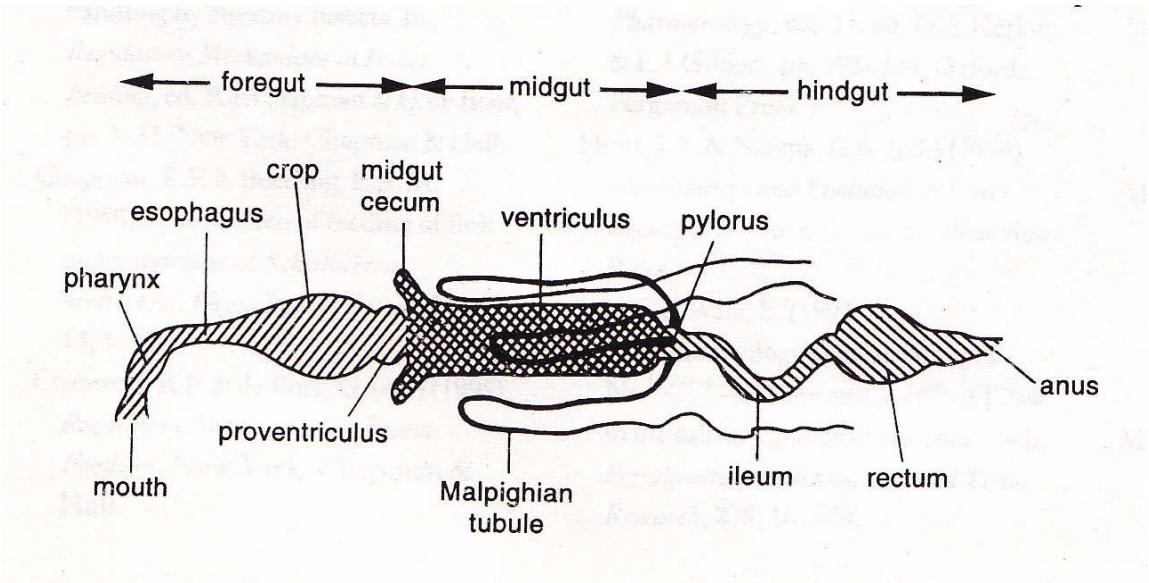


Fig. 28 Structure of alimentary canal

(Source: Taken from The Insects- Structure and Function(4th Edition, 1998) – R.F. Chapman (Cambridge University Press)

Filter chamber:

This is a characteristic arrangement of the **midgut** in hemipteran insects (**fluid feeders**). Anterior part of midgut forms a **thin-walled bladder** i.e **filter chamber** which is closely bound to either posterior part of midgut or the anterior hindgut and Malpighian tubules (Fig. 29). Filter chamber enables the **excess fluids** including sugar in the food to **pass directly** from the anterior part of the midgut to the hindgut without passing through the middle portion of midgut thus preventing excessive **dilution of haemolymph**, **enzymes** and facilitate better enzyme activity. In aphids, the **honey dew** (rich in sugars) is the substance that is being excreted after passing through the filter chamber.

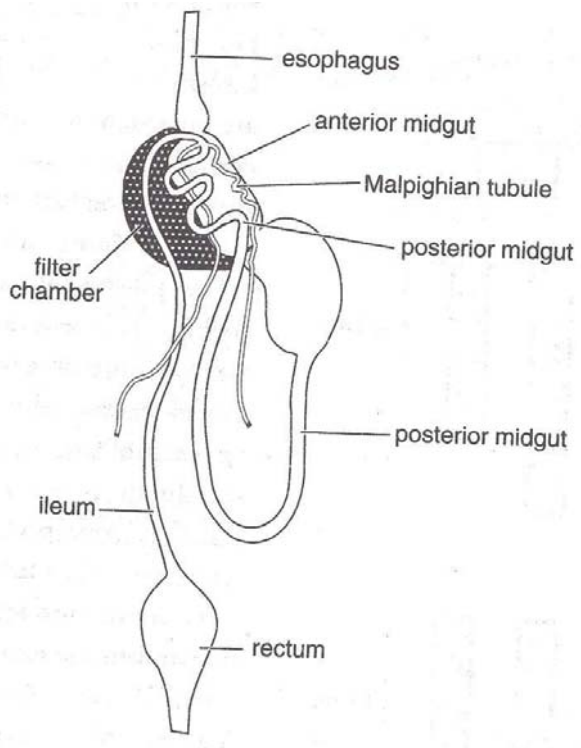


Fig. 29. Filter chamber

(Source: Taken from The Insects- Structure and Function(4th Edition, 1998) – R.F. Chapman (Cambridge University Press))

Process of digestion

The food ingested by the insects through the mouth cavity enters into the alimentary canal, get digested and the undigested waste material is excreted through anus. During this process, food material is broken down into small particles (or) in to a form that can be readily absorbed by the cells of the midgut and hindgut.

Digestion mainly takes place in 5 steps.

1. Ingestion : Food is partially digested in the oral cavity with the help of salivary enzymes. In insects like fluid feeders, carnivorous hemiptera, blowfly larvae etc, digestion occurs outside the intestine by a process called **extra intestinal (or) extra oral digestion** .

2. Transportation : The food material entered in to the oesophagus is transported in to the crop by muscular activity i.e. by **peristatic movements**. Food moves continuously from oesophagus in to the crop where it is stored. From the crop, food enters in to the gizzard where it is still broken in to very minute particles with the help of **denticles** or the cuticular teeth.

3. Digestion: From the gizzard through the stomodeal valve, food passes in to the midgut where actually digestion starts. The epithelial cells produce enzymes i.e. **proteases** which break proteins in to aminoacids, **carbohydrases** breaking carbohydrates in to **mono** & **disaccharides**, **lipases** breaking lipids in to **fatty acids** and **glycerol**.

In termites, digestion takes place in colon of hindgut where **mycetomes** (group of cells which harbour the micro organisms like protozoans) secrete the enzyme **cellulase** which can digest the wood material rich in cellulose.

In scarabid beetle larvae, **bacteria** are involved in digestion. In wood feeders, **keratin** digestion is facilitated by **alkaline p^H** of midgut. In *Tineola* (cloths moth) , **keratinase** secreted by protozoans.

4. Absorption: Midgut epithelial cells absorb the nutrients from the digested food and pass on the faecal matter and undigested food material in to the hindgut.

The Malpighian tubules maintain **ionic balance** by absorbing **Na** and **K** salts from the blood. The cells of the hindgut are also involved in the **re absorption** of water, salts and other metabolites from the faecal matter.

5. Egestion: The waste food material is discharged through the anus due to the action of the anal muscles.

Lecture - 15 : Circulatory system

There are two types of circulatory systems in the animal kingdom. In many animals , the blood travels through vessels like arteries, capillaries and veins. This is known as **closed type** of circulatory system. In insects the blood flows through the body cavity(ie, **heamocoel**) irrigating various tissues and organs. It is known as **open type** of circulatory system**.**

Haemocoel of the insects is divided into **3 sinuses** (or) regions due to the presence of **two** fibro muscular septa (or) **diaphragms** composed of connective tissues (Fig. 30).

Dorsal or Pericardial Sinus: The area lying in between the **tergum** and dorsal diaphragm . It contains **heart**.

Ventral or Perineural Sinus: The area lying in between the **sternum** and ventral diaphragm .It contains **nerve cord.**

Visceral Sinus: The area in between dorsal and ventral diaphragms . It harbour the visceral organs like **alimentary canal** and **gonads**.

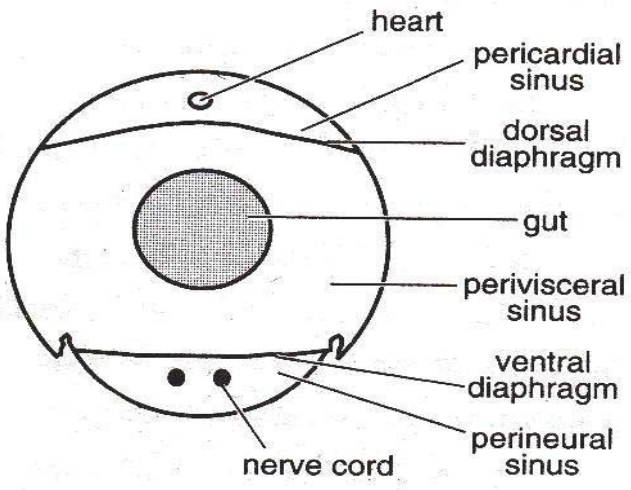


Fig. 30. Main sinuses of haemocoel

(Source: Taken from The Insects- Structure and Function(4th Edition, 1998) – R.F. Chapman (Cambridge University Press))

Dorsal blood vessel.

It is the principal blood **conducting organ** in insects which remain closed at the posterior end and opens anteriorly in to the head. It is divided into an anterior **aorta** and posterior **heart** extending throughout the length of the body (Fig. 31).

1. Aorta: It is the anterior part of the dorsal blood vessel and functions as **principal artery**. It is present in the thoracic region and opens in to the head near the brain. Its attachment with the heart posteriorly is marked by a aortic valve. Anteriorly sometimes it gets divided into 2 (or) more **cephalic arteries** in the head .

2. Heart: It is the posterior part of dorsal blood vessel extending up to the terminal end of the abdomen. Heart remains in position with the help of alary muscles that are attached to the tergum of the abdomen on one side and to the dorsal diaphragm on other side. These **alary muscles** appear to be distributed fan like over the heart.

Heart consists of number of chambers marked by constrictions and the presence of the opening called the **incurrent 'ostia'** which allow the entry of blood from pericardial sinus in to the heart. The number of ostia depends upon the number of heart chambers which will be usually 9. The walls of heart also consists of muscles. Heart mainly functions as the **pumping organ**. in to the aorta .

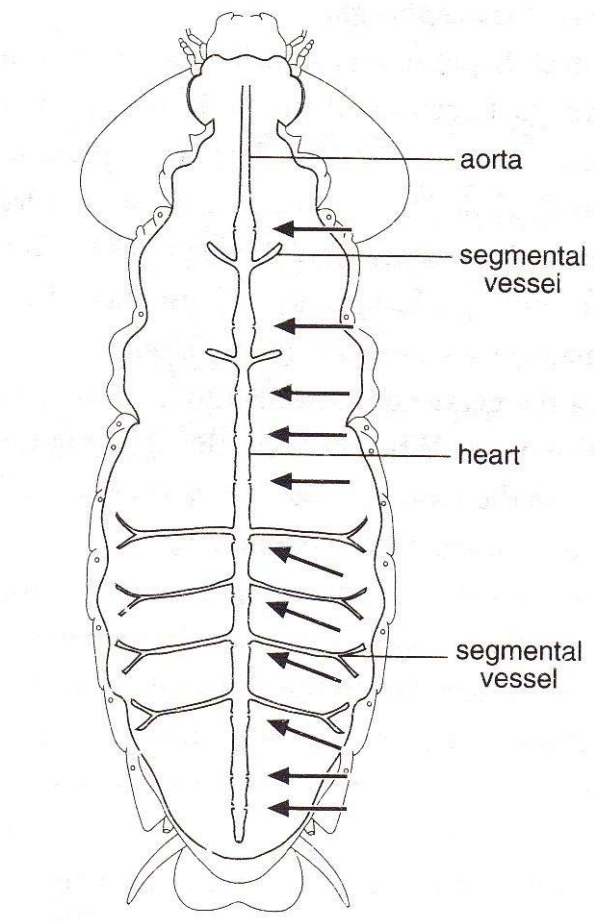


Fig. 31 Circulatory system

(Source: Taken from The Insects- Structure and Function(4th Edition, 1998) – R.F. Chapman (Cambridge University Press))

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

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

The two phases are

1. **Diastole**: During which expansion of heart takes place.
2. **Systole** : Contraction of heart takes place.

1. Diastole: Expansion of heart (diastole) occurs, when the alary muscles that are spread fan like over the heart and connected to the tergum get contracted. It results in **increase of volume** of heart and **decrease in the area** of pericardial sinus. This creates a pressure on the blood in pericardial sinus forcing the blood to enter into the heart through the incurrent ostia. These incurrent ostia allow only the entry of blood from the sinus in to the heart and prevents its backflow from the heart to the sinus.

2. Systole : Contraction of heart (systole), is brought about by the **expansion** of the alary muscles as well as contraction of the muscles of the heart wall. This **creates pressure** on the blood within the heart leading to its **forward movement** in to the aorta. From the aorta blood enters in to the head and flows back bathing the visceral organs in the visceral sinus and neural cord in the perineural sinus.

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

During the process of backward flow of blood, after entering in to the visceral and perineural sinuses, blood flow to the posterior part of the body and in to the pericardial sinus, due to the **undulating movements** of the dorsal and ventral diaphragms. During the process of circulation throughout the body some part of the blood flows into the accessory **pulsatile organ** that are present at the base of appendages like legs, wings and antennae.

The rate of **heart beat** (diastole) generally vary with the **body temperature** and **physiological conditions** of the body which in turn differs between species (or) between stages of the insects.

Properties of blood:

1. Blood is **colourless** (or) green (or) yellowish with different types of haemocytes and plasma.

Green colour is due to chlorophyll dissolved in the plasma and red colour is due to haemoglobin in *Chironomus* midge

2. Blood covers up **5 – 40%** of the total body weight that vary with the **sex** and **stag**e (or) age of the insect.

3. Insect blood contain proteins, lipids, sugars, organic acids, phosphates, pigments, uric acid etc.

4. The insect blood of **phytophagous** insect is **rich** in **'K'** where as that of **carnivores** is rich in '**Na'**

5. Specific gravity of the blood varies from **1.01 to 1.06**.

6. **p^H** of the blood generally varies from **6-7.**

7. The blood sugar of insects is **trehalose.**

8. Blood lacks vitamin **'K'**

Functions of blood :

1. **Transport of minerals** or food materials: blood transports minerals, digested products, hormones to different parts of the body.

2. Blood stores water for the tissues.

3. Helps during the process of moulting for splitting up of the old cuticle.

4**. Encapsulation** : to protect from the large metazoan parasites, the haemocytes of blood, become aggregated around the foreign body forming a capsule of 2-3 layers. This leads to the death of the foreign bodies due to lack of O_2 supply.

5. **Phagocytosis** : to get protection from micro organisms like bacteria, viruses and fungi, the haemocytes completely engulf the foreign body and gets autolysed (this is the principal function of haemocytes)

6. **Immunity**: blood gives immunity by producing antibodies to restrict further infections.

7.**Connective tissue formation :** blood provides lipoproteins that are necessary for the formation of the connective tissue.

8. **Wound healing** (or) **coagulation** : haemocytes extend **pseudopodia** which forms a cellular network over the wounded site (or) **plasmtocytes** coagulate forming a plug over the wound (or) **haemocytes** are arranged in to multi layered sheaths over the wounded site, thus helping in wound healing.

9. **Detoxification** : as the haemocytes are capable of detoxifying the **toxic chemicals**, insects get the **ability to resist** the toxic effects of chemicals.

10**. Reflex bleeding**: it is a phenomenon where **emission of blood** occurs through the pores (or) slits of the cuticle which mainly helps the insects for getting **protection** from their **natural enemies**.

Lecture - 16 : Excretory system

The organs of insect body , involved in the **elimination of excess** or unwanted materials either toxic or not useful, are together known as **excretory system**. These toxic materials are **nitrogenous** products of metabolism (mainly ammonia), pigments, salts etc. For the efficient maintenance of water and the ionic balance in the haemolymph, the waste products of the metabolism are to be removed or eliminated. These waste material may be in solid, semisolid, liquid or gaseous form. The principal excretory product in gaseous form is **CO_2**, liquid form is **honey dew**, solid form is **urea/uric acid** and semi solid form is **allantoin.**

The organs that are involved in the process of excretion are

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

1. Malpighian tubules: These are discovered by an Italian scientist, **Marcello Malpighi** in the year **1669**, which were named after him by **Heckel** in 1820.

The Malpighian tubules long, tubular structures which open proximally in between midgut and hindgut and closed distally, floating freely in the haemolymph. Malpighian tubules vary in their **shape** and **size**. They may be simple or branched. Their number varies from 2-250 (in coccids – 2; in locust – 250). The shape of tubules may be sac like, papillae like or branched. Malpighian tubules are **absent** in **aphids** and **Collembola.**

In some of the insects such as caterpillars and coleopterans, the distal ends of the Malpighian tubules get reattached to the alimentary canal by opening in to the rectum of hindgut. This condition is called '**cryptonephridial condition'**. The cryptonephridial arrangement is concerned with re absorption of water from rectum. The cells of Malpighian tubules also produce enzymes, acid and alkaline phosphatases, dehydrogenase (succinic), lipases, vitamins like thiamine, ascorbic acid etc.

Functions of Malpighian tubules:

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

2. In case of glow worms, the distal ends of tubules **produces light energy**.

3. Also helps in the **storage of Ca** necessary for the processes such as hardening of puparium.

4. In case of aphid lion (chrysoperla), the secretions of the tubules **produce stalked eggs**.

5. In case of spittle bugs spittle around the immature stages is also a MT secretion.

2. Integument: Through the process of moulting, insects remove the waste nitrogenous products, i.e. they are deposited in the form of **exuviae**. In some insects, where respiration occurs through body wall, **CO_2** is removed through integument as waste product (**cutaneous respiration**).

3. Tracheal system: The respiratory tubes, the trachea which are distributed throughout the body, function in **elimination of CO_2** through spiracles.

4. Alimentary canal : The gut of the insects also play a major role **in excretion** by removing the unwanted material, dead cells formed during enzyme secretion (**holocrine**) and intima layer during moulting. Rectum plays an important role in excretion by reabsorbing the water from faeces.

5. Nephrocytes: These are the special cells that are distributed in the body cavity and scattered. Nephrocytes are cells that take up **foreign chemicals** of relatively **high molecular weight** which Malpighian tubules may be incapable of dealing with. They are of two types

1. **Dorsal** or **pericardial** nephrocytes on **either side of the heart** in pericardial sinus, present in immature and adult stages of most of the insects.

2. **Ventral** nephrocytes, arranged as a **chain below the foregut** and attached by its two ends to the salivary glands. e.g.: dipterous larvae.

Nephrocytes helps in the **removal of ammonia**, **chlorides**, **dyes**, **colloidal particles** etc.

6. Oenocytes: These are large cells and are usually present near the **abdominal spiracles**. They arise from the ectoderm or hypodermis. These cells are thought to secrete **cuticulin** layer of the **epicuticle** and in cockroach, surface grease which covers the integument is believed to be involved in **excretion.**

7. Urate cells: Some of the fat body cells which store urea or uric acid in the form of granules are known as **urate cells**. Preserved uric acid can be utilized subsequently. These are present when Malpighian tubules are absent or may become nonfunctional. In some of the insects such as cockroach, the waste material in the form of urea or uric acid is stored throughout its life in the fat body cells without any

harmful effect. This phenomenon of storage of urea / uric acid in the fat body cells is called '**storage excretion'** which is useful for supply of nitrogen, when insect feeds on nitrogen deficient food.

8. Labial glands: These are seen in Collembola, Diplura, Thysanura. They consists of a sac like structures called **ampulla** that leads to a long coiled labyrinth that open at the base of labium in the head. These glands helps to remove **ammonia**.

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

Lecture - 17 : Respiratory system

Tracheal system

In insects, exchange of gases takes place through tubular structures, called **trachea.** They are distributed throughout the body collectively forming tracheal system. These trachea open outside on the body wall through small openings called spiracles. Spiracles occur on the **pleural** surfaces of the body, one on either side of each segment.

The trachea are divided in to very fine branches known as **tracheoles.** They supply **oxygen** to the body tissues.

The tracheal system with functional spiracles is called the **open tracheal system** and with non-functional spiracles is called **closed tracheal system**.

Trachea are fine elastic tubular structures which are **ectodermal** in origin. They consist of cuticle, epidermis, basement membrane as in case of general body wall but arranged in reverse manner, i.e. basement membrane forms the outermost coat of trachea. The inner cuticular lining forms the i**ntima** inside.

Trachea are **circular** or **elliptical** in their cross section.

The cuticular lining (intima)appear as a spiral thickening throughout the length of the tube of trachea. These spiral thickenings are known as **'taenidia'** which give support to the trachea without being **collapsed** when there is no air. It consists of **chitin**, **resilin** in protein-chitin matrix.

The trachea ramify into very fine branches known as **'tracheoles'** which are about 0.1 – 1 µm in diameter (Fig. 32). These tracheoles are formed in to cells called **'tracheoblast'** or tracheolar end cell, which are derived from epidermal cells, lining the trachea. Tracheoles form a network over the visceral organs including the alimentary canal as well as the gonads (ovaries, testis) and penetrate in to the tissues of the organs and become **intracellular** and supply **oxygen** directly to the tissues.

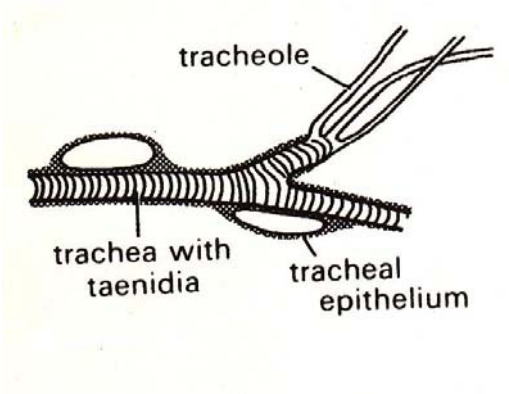


Fig. 32 Structure of trachea

(Source: Taken from The Insects- Structure and Function(4th Edition, 1998) – R.F. Chapman (Cambridge University Press)

Differences between trachea and tracheoles:

	Trachea	**Tracheoles**
1	These are large tubes running from spiracles	Fine tubes arising **distally** from trachea
2	Taenidia **present**	**Absent**
3	Intima layer is **shed** during moulting	Intima layer is **retained, unchanged** during moulting
4	Never become intracellular	Intracellular
5	The intima layer consist of protein – chitin matrix **with resilin**	Chitin – protein matrix present, **resilin absent**

Tracheal trunks

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

All these in total form into **dorsal trunk**, **lateral trunks** which are **two** in number and **one ventral trunk** (Fig. 33). The dorsal trunk **supply oxygen** to proximal part of the body as well as to heart where as the ventral supplies to the central nervous system. The two lateral longitudinal trunks spreads tracheoles to alimentary canal, legs, gonads and wings.

As the head do not contain spiracles, **air** is supplied through the first pair spiracles by means of two main branches of the dorsal longitudinal trunk, where one branch supply O_2 to eyes, antenna, brain; other branch to mouthparts and muscles of the head.

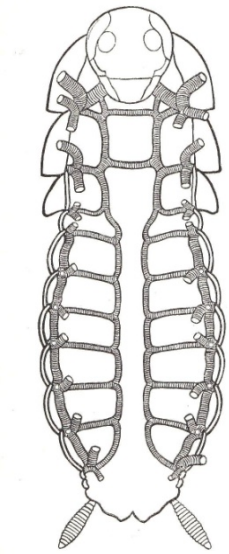


Fig. 33 Tracheal system (dorsal tracheal trunks)

(Source: Taken from A General Textbook of Entomology (1960) – A.D. Imms (Revised by Professor O.W. Richards and R.G. Davies, 9th Edition) (Butler & Tanner Ltd., Frome and London))

Spiracles: They are the **openings** of the internal tubular trachea. Except in **Diplura**, in all the orders, spiracles are **absent** in prothorax and distributed in meso, metathorax and abdomen.

A total of **10** pairs are present in general, 2 pairs in thorax and 8 pairs in abdomen.

Spiracles are situated on **pleural** surface. They consists of a small ring like sclerite at opening called '**peritreme'** leading to a cavity known as **'atrium'** (Fig. 34). The closing and opening of spiracles is accompanied by **atrial valve** lined with

fibrous processes and form so called **felt chamber** which reduces water loss in the absence of closing mechanism.

In some dipterans, coleopterans, lepidopterans, spiracles consists of **sieve plate** containing large number of small apertures through which **gas** exchange takes place. This modification is to **prevent entry of water** especially in **acquatic** forms.

In most of the **terrestrial** insects, water loss through spiracles is controlled by the **closing mechanism** which consists of one or two valves or a constriction from the trachea or by muscular activity. The **hydrophobic** nature of spiracles is also due to the presence of modified epidermal glands known as **peristigmatic glands** which secrete a hydrophobe material preventing the wetting of these organs.

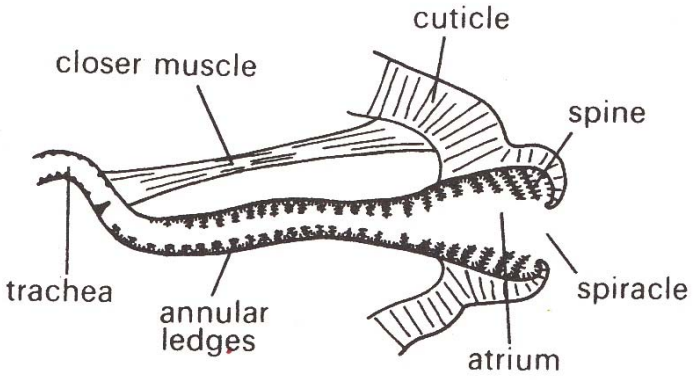


Fig. 34. Structure of spiracle

(Source: Taken from A General Textbook of Entomology (1960) – A.D. Imms (Revised by Professor O.W. Richards and R.G. Davies, 9th Edition) (Butler & Tanner Ltd., Frome and London)

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

In most of the insects, 10 pairs of spiracles are present. Some of the modifications are as follows

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

e.g. **dragonflies, grasshoppers and cockroach**

II. **Hemipneustic** : One or more pairs of spiracles become non-functional. They are

a) **Peripneustic** : Metathoracic spiracle is closed. 1 + 0 + 8.
e.g.: **larvae of Lepidoptera, Hymenoptera, Coleoptera.**

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

c) **Propneustic :** Only one pair i.e. mesothoracic spiracles are open, 1 + 0 +0
e.g.: **mosquito pupa**

d) **Metapneustic :** Only last pair of abdominal spiracles are open. 0 + 0 + 1.
e.g.: **mosquito larvae**

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

III. **Hypopneustic :** 1 or 2 pairs of spiracles may completely disappear or absent
e.g.: **Siphunculata, Mallophaga**

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

Other types of respiration

1. Cutaneous respiration : e.g.: **Protura, Collembola** and **endoparasitic** insects.

When the spiracles are absent, respiration occurs through body wall which forms main source for gaseous exchange.

2. Tracheal gills: e.g.: **larva** of **Trichoptera, nymphs** of **Ephemeroptera**

Also called as **abdominal gills** which occur as the outgrowths of the trachea in the form of gills distributed on the lateral sides of the body. They are useful for **absorption of dissolved oxygen**. They may vary in shape as **lamellate** or **filamentous.**

3. Spiracular gills : In some **aquatic pupae**,

Peritreme or atrium of spiracles is drawn out in to a long filament like structure known as **spiracular gills.** These gills are adapted for both **aquatic** and **aerial** respiration, enabling the insect to live in air and moist places or completely in water or at the edges of water structures.

4. Blood gills: These are tubular or digitiform or eversible structures present at the anal end of body ranging from 4-6 in **larva of Trichoptera**. In chironomid larva of Diptera, 2 pairs of blood gills are present on penultimate segment and a group of 4 shorter anal gills are present. These are called **blood gills** as they contain blood but some times have trachea. Function of these structures is the **absorption** of **water** and inorganic ions **rather than respiration**.

5. Rectal gills: In dragonfly **nymphs (naids**), the rectum modifies in to a barrel like chamber where the rectal wall forms in to basal thick pads and distal gill filaments which are richly supplied with tracheoles. They help in **respiration**.

6. Air sacs: In many winged insects, the trachea get dilated at some points to form thin walled air sacs which do not contain the taenidia. These can be seen as glistening sac like structures mainly function as storage structures of air which change their volume with respiratory movement.

7. Plastron respiration: e.g.: **aquatic beetles**.

The plastron is a special type of air store in the form of a thin film held by a system of hydrofuge hairs, scales or other cuticular processes whose volume remains constant. If there is adequate oxygen dissolved in water, the plastron can act as a **permanent physical gill.** The trachea opens in to plastron.

Lecture - 18 : Nervous system

Insects show co-ordination in behaviour, memory and possess intelligence due to well distributed nervous system. The nervous system functions as a link between the **sense organs** which respond to various external and internal stimuli and the **effector organs** such as muscles, glands etc, The sense organs include the structures with various sensilla that respond to sounds, weather factors, smell etc.

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

Structure of a neuron

The nerve cells are called neurons which are derived from **ectoderm**. Each neuron consists of a prominent nucleated cell body known as **perikaryon** (or) **soma** and an elongated cytoplasmic thin fibre called the '**axon'** and group of small branches called the '**dendrites'**. The axon gives lateral branches called **collaterals.** Both the axon and collaterals end in fine fibrils known as **terminal arborizations**. The neurons get connected with each other by having a link between the terminal arborizations of the axon of one neuron and dendrites of the soma of other neuron through a '**synapse'.**

Classification of neurons

I. Based on their structure (Fig. 35):

1. **Unipolar** / **monopolar** : Have a single axon without collaterals and dendrites
2. **Biopolar** : Have either collaterals and dendrites in addition to axon
3. **Multipolar** : Neurons have an axon with several collaterals and dendrites.

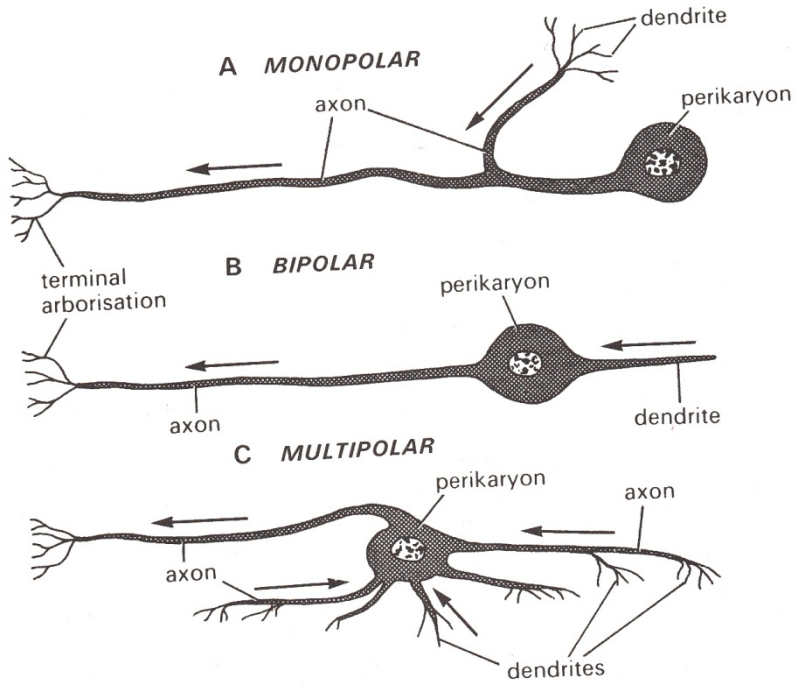


Fig. 35 Structural types of neurons

(Source: Taken from The Insects (structure and function) – R.F. Chapman (3rd edition, 1971). Published by American Elsevier publishing company, INC., New York)

II. **Based on function: 3 kinds of neurons**.

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

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

3. **Association / internuntial neurons** : Associated in between sensory and motor neurons, usually present in ganglia, consists of axons of sensory neurons and soma of motor neurons. The transverse commissures are also formed with these neurons.

The points at which neurons receive information from or convey to another neuron is known as **synapse.** Synaptic gap is approximately **100^0A**

Nervous system can be grouped in to three

1. Central nervous system (CNS)

2. Visceral or sympathetic nervous system:

3. Peripheral nervous system :

Central nervous system consist of brain, sub-oesophageal ganglion and ventral nerve cord.

Brain

It is the dorsal ganglionic centre of the head supported by the **tentorium.** It is formed by the union of the ganglia of first 3 segments of the head. Brain is divided into protocerebrum, deutocerebrum and tritocerebrum.

Protocerebrum: It is formed by the union of the ganglia of pre-antennary segment and forms the greater part of the brain. It gives nerve connection to the compound eyes and ocelli.

Deutocerebrum: It is formed from the ganglia of antennary segment and innervates antenna.

Tritocerebrum : It is formed by the union of ganglia of third / intercalary segment and is relatively small. The lobes of it are attached anteriorly to **deutocerebrum** and posteriorly to **suboesophageal ganglion**.

Sub-oesophageal ganglion: It is the ventral ganglionic centre of the head formed by the union of ganglia of the gnathocephalic segments (Fig. 36). It gives nerves to mandibular, maxillary, labial segment, labrum, salivary ducts, part of cervical muscles in the neck region and corpora allata.

Aggregation of neurons is called **ganglion**.

Ventral nerve card (VNC)

Ventral nerve card consists of a chain of segmented ganglia connected by means of **longitudinal connectives** and **transverse commissures**.

In thorax, there are 3 ganglia, with nerve connections for legs, wings and general muscles. In the abdomen, there are about 8 ganglia . The first abdominal ganglia remain closed with that of the metathoracic ganglia and those ganglia from 9^{th}, 10^{th}, & 11^{th} abdominal segment form a composite ganglion. The abdominal ganglia gives

off nerves to the muscles of its segment. The ultimate ganglia also passes nerves to anal cerci and ovipositor

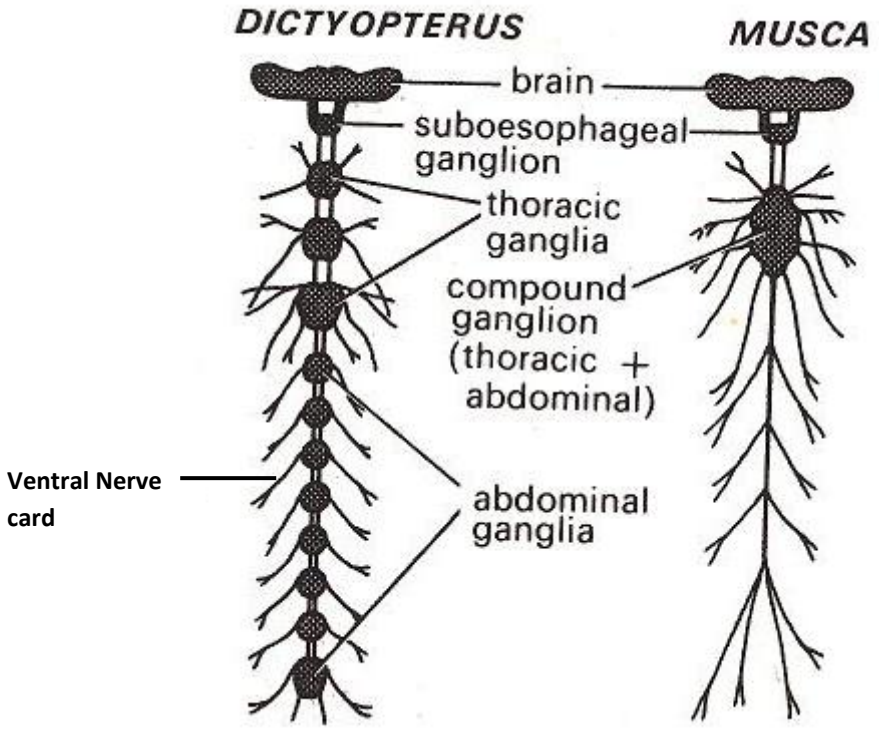


Fig. 36. Central nervous system

(Source: Taken from The Insects (structure and function) – R.F. Chapman (3rd edition, 1971). Published by American Elsevier publishing company, INC., New York)

2. Visceral / sympathetic nervous system :

It is divided in to three systems

(i) **Oesophageal sympathetic / stomatogastric** nervous system :- It is directly connected with the brain which supplies nerves for the anterior part of the alimentary canal (foregut and midgut), heart and certain other parts. It is dorsal in position.

(ii) **Ventral sympathetic** nervous system :- Consist of a pair of transverse nerves that are connected with each ganglia of VNC. The transverse nerves pass to the spiracles of that particular segment.

(iii) **Caudal sympathetic** nervous system : Some additional nerves arises from posterior compound ganglion of VNC which supply nerves for the posterior part of the gut and the reproductive system.

3. Peripheral NS:

It includes all the nerves coming from the ganglia of CNS and that of the visceral nervous system.

Synapse: The neurons are not continuous with each other. The branched terminations of axon of one neuron come in intimate association with dendrites, the cells body or terminal arborisation of the collateral or the axon of another neuron to form a synapse.

The terminal arborisation of sensory axon ends up into a tiny swelling called synaptic knob. The synaptic gap is around 100^0A distance.

Lecture - 19 : Reproduction in insects

Usually Insects are bisexual. But sometimes reproduction also occurs by **Parthenogenesis** and **hermaphroditism**.

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

Female reproductive system:

It consists of

a pair of **ovaries** which possess number of ovarioles,

a pair of **oviducts**,

common oviduct / **Median** oviduct ,

spermatheca ,

a pair of **accessory glands** and

Bursa copulatrix or copulatory pouch or genital chamber or vagina

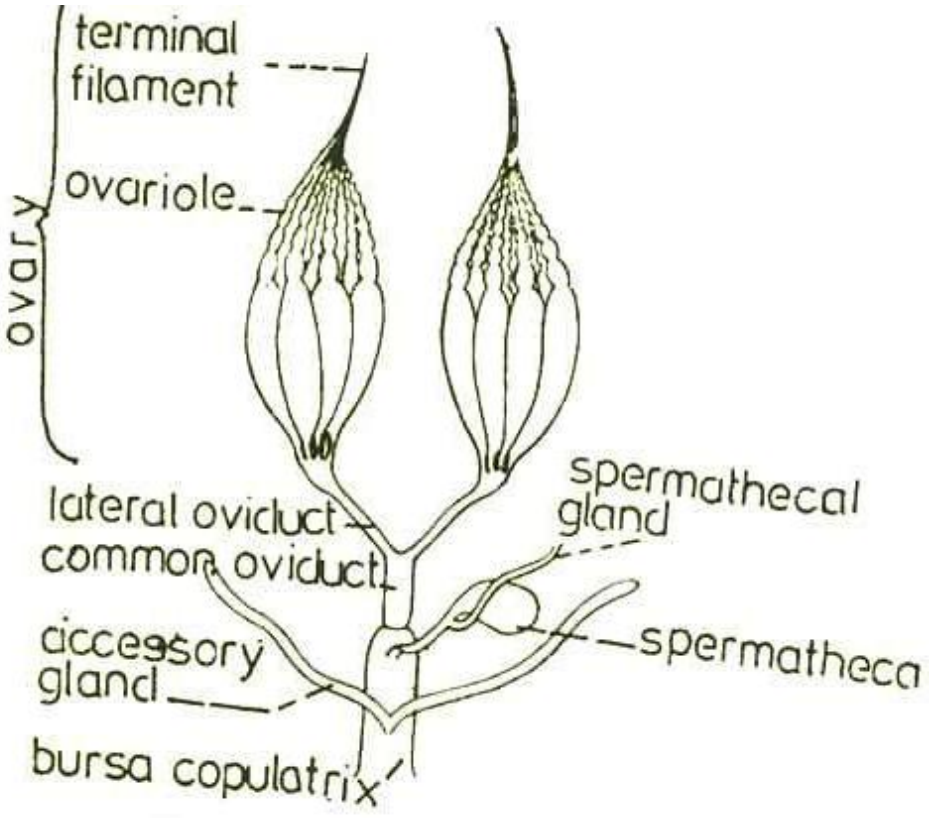


Fig. 38 Female reproductive system

(Source: Taken from General and apllied Entomology – K.K. Nayar, T.N. Ananthakrishnan and B.V. David (10th edition, 1993). Tata McGraw-Hill Publishing Company Ltd., New Delhi., India.)

1. Ovaries : These are the prominent visceral organs present on the either side of alimentary canal. Anteriorly the ovaries get connected with the body wall by means of thread like suspensory ligaments. The ovaries are covered with fat body and are richly covered with trachea. Each ovary consists of a no of **ovarioles** or **egg tubes**.

Ovarioles: Each ovariole is enveloped by a double layered cellular wall . The outer wall is called **ovarial sheath** which has an abundant supply of tracheae. The inner layer called **tunica propria** is elastic in nature. Each ovariole at its terminal has a filament which unites with other filaments to form a **suspensary ligament** .The ligament is attached to the body wall or dorsal diaphragm and thus helps the ovaries to remain suspended at a proper place . The eggs are discharged in to the lateral oviducts .

Lateral oviducts: Proximal end of the ovarioles of each ovary join to form a lateral oviduct on each side .The wall of oviduct is glandular and muscular

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

Vagina: In most of the insects median oviduct doesnot open directly to outside. It opens in to a tubular genital chamber or vagina formed by invagination of bodywall from VIII segment . The vagina opens outside and the opening is called vulva. Vulva serves both purposes of receiving the sperms and discharging the eggs.

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

Eg: Lepidoptera and water beetles

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

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

Each ovariole in insects consists of a group of tapering units called **ovarioles**. The number of ovarioles in an ovary varies greatly in different insects , usually 4 to 8. In Isoptera more than 2000

Typical ovariole or egg tube consists of 3 parts namely

1.Terminal filament

2.Egg tube

3.Supporting stalk or pedicel

Terminal filament: of all the ovarioles in a ovary unite distally with one another in a suspensory ligament. The ligaments from the two ovaries are combined in a single median ligament which is attached to the tergal plated of thorax.

The Egg tube is divided in to two parts

1.Egg chamber or Germarium

2.Zone of growth or vitellarium

Germarium : Also called as egg chamber which contain the primordial germ cells or undifferentiated cells. These cells give rise to three types of cells . 1.Germ cells developing in to oogonia and dinally oocytes

2.Nutritive cells or nurse cells **trophocytes.**

3.Follicle cells

(i) **Vitellarium or Zone of growth** : It occupies the major part of the ovariole and contains large number of **oocytes** and eggs in different stages of development
The egg cells grow and attain their mature stage. In the anterior region of vitellarium the nurse cells and oocytes remain mixed up and assume the central position while follicle cells take peripheral position. In posterior end oocytes are enclosed by follicle cells to form follicular layer. The nurse cells absorb nutrients

From haemolymph through follicular cells and transmit them to oocytes. In some case follicle cells provide nutrients to the oocytes where nurse cells are absent.

Types of ovarioles :

Based on the presence or absence of nutritive cells and their location ovarioles are categorized in to two (Fig. 39).

1. **Panoistic** ovarioles: In these, the nutritive cells are absent and the development of oocytes takes place with the help of follicular epithelial cells
e.g.: Odonata, Dictyoptera, Orthoptera and Ephemeroptera

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

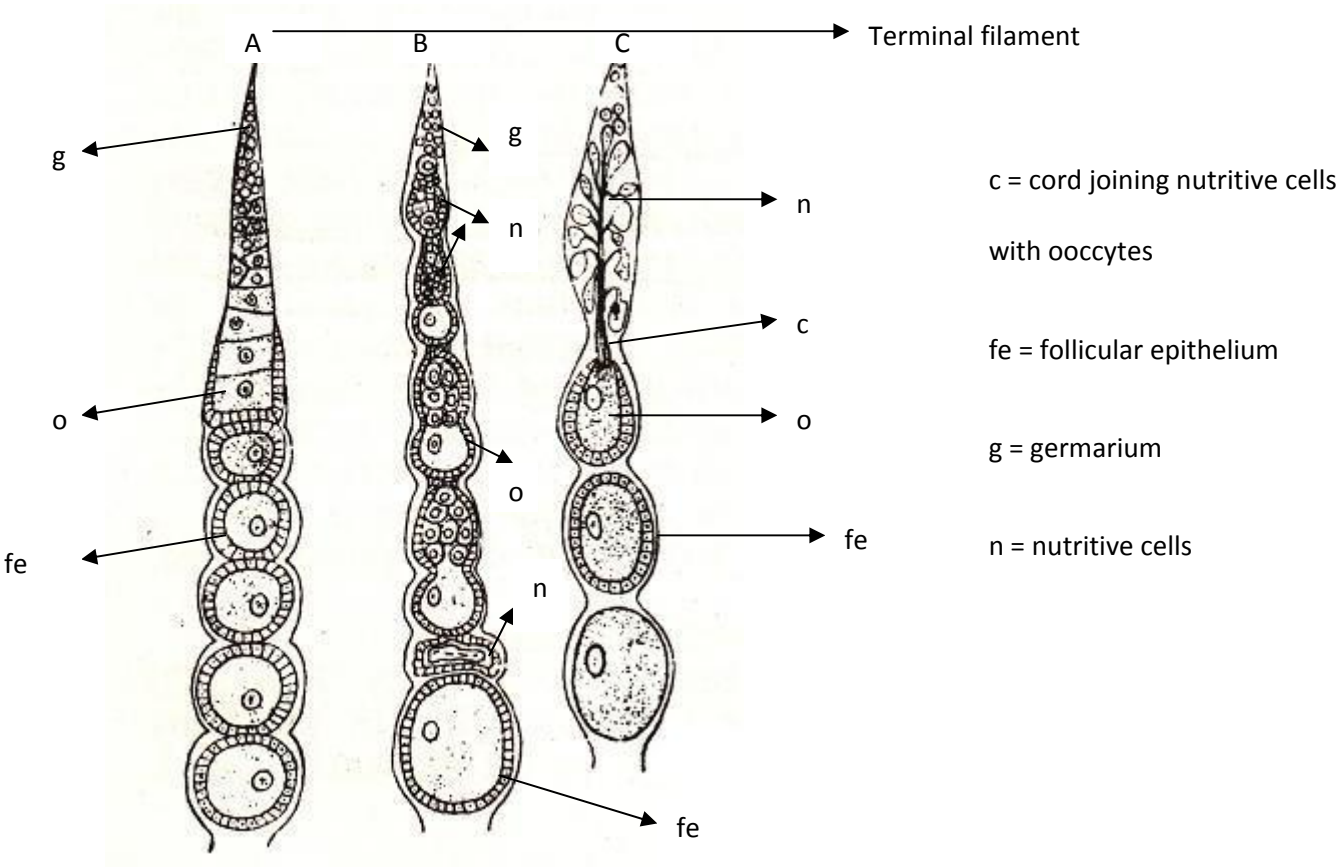
Based on the position of trophocytes **Meriostic** ovarioles are classified into

(i) **Polytrophic** ovarioles: where developing oocyte and trophocytes arranged alternatively within the vitellarium.

e.g.: Mecoptera, Dermaptera, Psocoptera

(ii) **Acrotrophic** ovarioles: Also called **teletrophic** ovarioles where the trophocytes are present in the germarium (apex) and are connected with the growing or developing oocytes by cytoplasmic strands.

e.g.: Hemiptera and Coleoptera



A = Panoistic; B = Polytrophic; C = Acrotrophic

Fig. 39 **Types of Ovarioles**

(Source: Taken from General and apllied Entomology – K.K. Nayar, T.N. Ananthakrishnan and B.V. David (10th edition, 1993). Tata McGraw-Hill Publishing Company Ltd., New Delhi., India.)

Male reproductive system

Internal male reproductive organs consists of

-a pair of **testis ,**

-a pair of **vasa deferens,**

-seminal vesicle

-ejaculatory duct

-accessory glands a) mesodenia b) ectodenia and

-Genitalia

Testis : The size of testis is practically same as that of ovaries in Apterygota and very much smaller in Pterygota . They lie in visceral cavity above the alimentary canal and are connected to the body wall through translucent ducts and are well supplied with trachea and fat body tissues.

Each testis consists of number of oval shaped structures known as **follicles or sperm tubes**. Each follicle has a layer of epithelial cells. The entire follicle is covered by a peritoneal membrane where as the testis is completely enveloped within a coat known as **scrotum.**

Structure of follicle

Each individual follicle is divided into a series of zones (or) areas characterized by the presence of the sex cells i.e. sperms in different stages of development. These zones are zone of germarium, zone of growth , zone of division and reduction and zone of transformation.

(i) Germarium : It is the region containing primordial germ cells or spermatogonia which undergo multiplication. (Zone of spermatogonia)

(ii) Zone of **growth**: It is the area where spermatogonia increase in size, undergo repeated mitosis and develop in to spermatocytes.(Zone of spermatocytes)

(iii) Zone of **division and reduction** : It is the area where spermatocytes undergo meiosis and give rise to spermatids (Zone of spermatids)

(iv) Zone of **transformation** : It is the area where spermatids get transformed in to spermatozoa.(Zone of spermatozoa)

Spermatozoa are a group of cells which are enclosed in testicular cyst cells from which they are released in to **vasa efferens**, the tubular connections of the follicles which combine together to form the vasa deferens.

2. Vasa deferens : These are the long tubes formed by the union of vasa efferens which receives the sperms from testis and allow their transport to the ejaculatory duct (Fig. 37).

4. Seminal vesicles: Each vasa deferens become enlarged posteriorly to form a sac like structure called seminal vesicle for **storage of spermatozoa** for some time.

4. Ejaculatory duct: Both the vasa deferens of the two testis unite posteriorly to form a common median ejaculatory duct. The terminal section of ejaculatory duct is enclosed in a finger like evagination of body wall , male copulatory organ or aedeagus or penis.

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

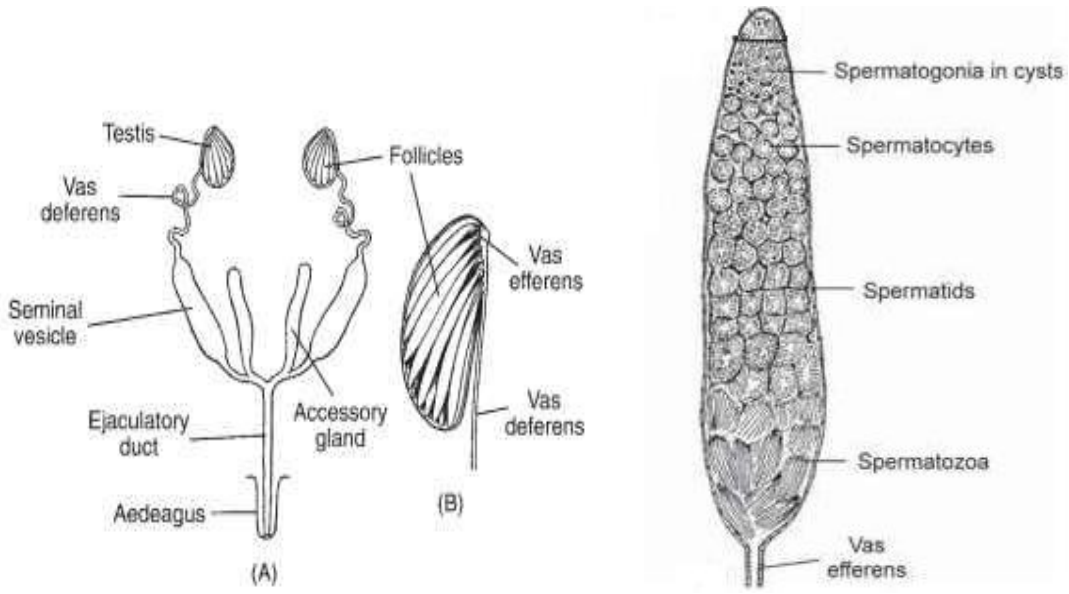


Fig. 37. Male reproductive system

Types of Reproduction.

Insects are bisexual, they can undergo sexual reproduction for producing either the eggs (or) the young ones. However they also reproduce by other means. Different types of reproduction in insects are:

1. Oviparity : Insects reproduce by laying eggs by the female on any substrate either singly (or) in mass (or) in groups which later hatch and produce the young ones.

e.g.: moths and butterflies.

2. Viviparity : It is the phenomenon of reproduction where the female gives birth to the young ones instead of laying eggs. Embryonic development is completed within the female and the embryo gets nourishment from the mother and produce the larva/young ones within the haemocoel. These young ones after some time emerges out from the mother, based on the source of nourishment. Viviparity is classified in to 4 types.

(i) **Ovo-viviparity**: Insects retain the eggs within the genital track until the eggs are ready to hatch (or) giving birth to young ones. However immediately after hatching , the young ones will be released outside. Hence, no special structures are developed for nourishment. e.g.: Thysanoptera

(ii) **Adenoparous viviparity** : It is a type of viviparity where the eggs have sufficient yolk, complete their embryonic development and retain in the uterus. Eggs hatch and the young ones get nourishment from special nourishment glands called milk glands which contains milk that have lipids and proteins. When young ones are fully developed, it emerges from the mother and forms in to a pupa within short time and no feeding phase is seen. e.g.: *Glossina pupipara* of Diptera.

(iii) **Pseudoplacental viviparity** : It is a phenomenon where insect have eggs with little (or) no yolk. Hatching takes place within the mother and the nourishment

for the young one is received through embryonic maternal structure called pseudoplacenta
e.g.: Psocoptera, Dermaptera, aphids etc.,

(iv) **Haemocoelous viviparity**: It is a type of reproduction where the eggs are retained within the haemocoel and the embryonic development as well as the nourishment of young one takes place through the transfer of nutrients from the haemolymph of mother. After development, young one comes out either through genital canal or by the rupture in the walls of the parent. Eggs have no chorion but become surrounded from an early stage by a trophic membrane through which nutrient material are supplied from the maternal tissues. e.g: strepsipterans & some larvae of cecidomyids (Diptera)

3. Parthenogenesis : It is the ability of the females to reproduce without fertilization / copulation with males. This usually occurs due to the genetic characters, due to heredity, failure in finding a mate, hormonal changes within the body and weather factors. This parthenogenesis is classified as

(i) **Sporadic** parthenogenesis : occurs occasionally e.g.: silkworm.
(ii) **Constant** parthenogenesis : occurs regularly. e.g.: thrips
(iii) **Cyclic** parthenogenesis : it is nothing but the alternation of generations where parthenogenesis occur in alternation with the sexual reproduction. e.g.: aphids.

II. Based on the **sexes of the off springs produced**, parthenogenesis can be

(i) **Arrhenotoky** : only males are produced e.g.: Hymenoptera
(ii) **Thelytoky** : only females are produced e.g.: acridids
(iii) **Amphytoky** : both females and males are produced e.g.: hymenopterans

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

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

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

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

8. Alternation of generation : Insects reproduce by parthenogenesis and bisexual reproduction by alteration of generations. e.g.: aphids which reproduce by parthenogenesis in summer and undergo sexual reproduction. in winter.

Lecture - 20 : Endocrine system

Insect endocrine system is structurally and functionally integrated with nervous system

1. They secrete **harmones** which travel in the blood to various organs of the body coordinating their long term activities.

2. Endocrine organs are of two types.

a) **Neuro-secretory cells** in the central nervous system

b) specialized **endocrine glands** such as

i) Corpora cardiaca

ii) Corpora allata

iii) Prothoracic glands

1. Neurosecretory cells

These are typical neurons with secretory activity. They produce **harmones** which act directly on **effector organs** or they may act on other **endocrine glands** which in turn are stimulated to secrete harmones.

They occur in the mid region of brain and central nervous system. Their axons lead out from the brain, posteriorly, most often cross each other and emerge out of the brain to enter in to or lie apposed to the corpora cardiaca. The secretions of neurosecretory cells are called **brain hormone** or **activator hormones.**

Large number of neuro-secretory cells may be present in the nervous system and are three types.

A. Median NSC of the brain (PTTH harmone)

B. Lateral NSC of the brain

They Promote function of prothoracic glands

Stimulate protein synthesis

possibly control water loss and

Oocyte development and activity and

C. Ventral NSC of the other ganglia (ventral nerve cord): these secretions are known to concern with activity, water regulation.

2. Corpora cardiaca

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

3. Corpora allata

They are glandular bodies, usually situated one on either side of the Oesophagous. They may be fused to a single median organ as in higher Diptera. Each is connected with Corpus cardiac of the same side by a nerve which carries fibres from NSC. Under the influence of brain hormone, corpora allata secretes Juvenile hormone (JH) or **neotenin** which regulates metamorphosis on yolk deposition on eggs.**.** JH helps to keep the insect in young stage only.

4. Prothoracic glands

They are two in number and placed mostly in thoracic region. Prothoracic glands secrete **moulting hormone (MH), called Ecdysone** under the influence of brain hormone. Moulting hormone, helps in insects in the initiation and process of moulting.

Except in Thysanura (which moult as adults) and solitary locusts, the prothoracic glands break down soon after final moult to adults, so they are seen only in immature forms but not in adults.

Lecture - 21 : INSECT TAXONOMY

Scientific Nomenculture

Caroles Linnaeus (1707 – 1778) in his tenth edition of systema nature published in 1758 used the binomial system of nomenclatuture for the first time for both plants and animals. This double naming in latin one for the genus and the second for the species has been universally accepted and followed subsequently but before such an universal acceptance, several scientists started their own codes of nomenclature.

In 1842,Strickland published a code of nomenclature in English and it was called Strickland code. Another code called 'Dall code" was evolved by the Americans in 1877. Similarly some more codes of nomenclature were evolved in France and Germany. In order to promote stability and universality in the scientific names of animals, an international code of zoological nomenclature was evolved in 1901 at Berlin. At the 16^{th} session of International congress of Zoology in Washington, the latest international code of Zoological nomenclature was approved and the same was revised and published in 1964.

According to it, the descriptions of unrecorded species should be based on a single specimen whether it be a male or female and the specimen is to be referred as 'holotype'.

The opposite sex specimen which is described along with the holotype is termed as allotype. The other specimens of the species kept along with the holotype and allotype are called paratypes. The names are to be given in Latin. The authors name in full should be written at the end of species name without any punctuation.

The generic name has to be a simple or compound word. The supraspecific categories like tribe, sub family, family and superfamily are denoted by the endings -ni, -inae, -idea and –oides respectively.

The underlying principle of International code of Zoological nomenclature is law of priority. i.e the first published name remains in official records while all the

subsequently published names go as synonyms. If the same name is given by the different scientists to the different organisms, it is called Homonymy. All such cases are referred to International commission on Zoological nomenclature which settles such confusion.

The following is the classification given by Imms which is being followed by most of the taxonomists

Class – Insecta

Sub class 1. Apterygota

Order 1. Thysanura (Bristle tails, Silverfish, firebrats)

Order 2.Diplura (Diplurans)

Order 3: Protura (Telson tails)

Order 4: Collembola (Spring tails, snow fleas)

Sub class 2: Pterygota

Exopterygota (Insects having simple metamorphosis)

Order 5. Ephemeroptera (May flies)

Order 6: Odonata (Dragon flies & damsel flies)

Order 7: Plecoptera (Stone flies)

Order 8: Grylloblattodea (Grylloblattids)

Order 9: Orthoptera (Locusts and grass hoppers)

Order 10: Phasmida (Walking sticks, leaf insects & stick insects)

Order 11: Dermaptera (Ear wigs)

Order 12: Embioptera (Web spinners)

Order 13 Dictyoptera (Cockroaches and mantids)

Order 14: Isoptera (White ants or termites)

Order 15: Zoraptera (Zorapterans)

Order 16: Psocoptera (Psocids, book lice)

Order 17: Mallophaga (Bird lice)

Order 18: Siphunculata or Anoplura (sucking lice)

Order 19: Hemiptera (Plant bugs)

Order 20: Thysanoptera (Thrips)

Endopterygota (Insects having complex metamorphosis)

Order 21: Neuroptera (Ant lions and lace wings)

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

Hemiptera was divied in to two suborders - homoptera and heteroptera but recent workers are treating homoptera as a separate order due to definite characters by which it is differing from hemiptera. Thus the study of insects comes to 30 orders.

Classification of insects:

The basic biological unit in the classification is species.

Species: These are a group of individuals which are similar in their structure, capable of interbreeding and producing fertile off spring, but at the same time reproductively isolated from other groups.

Subspecies: is an aggregate of phenotypically similar populations of a species, inhabiting a geographic subdivision of the range of a species and differing taxonomically from other populations of the species.

Genus : A group of species having some definite similar characters or relationships is called a geneus

Subfamily is a group of allied genera to form a subfamily

Family is a taxonomic category containing a single genus or a group of genera of common phylogenetic origin which is separated from related families by a decided gap. Such families showing similar characters form order.

The classification of animals was first started by Aristotle (384-322BC). Later by Linnaeus who is considered as the father of the classification of animals and plants, classified insects into only seven orders *viz* Coleoptera, Hemiptera, Lepidoptera, Neuroptera, Diptera, Hymenoptera and Aptera.

Jeannel recognized 40 orders

Brues, Melander and carpenter recognized 27 orders

Imms and pruthi gave 29 orders

Essig and Mani listed 33 orders

Ross 28 orders

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

Sub Class: Apterygota

These are primitive wingless insects with pregenital abdominal appendages with no or slight metamorphosis. Mandibles articulate with head capsule at a single point. The malpighian tubules are rudimentary. There is no pleural suture in the thoraccic region.

Sub class pterygota: These are insects with developed wings and showing definite metamorphosis. The pregenital appendages are absent in these insects. A pleural suture divides the thoracic pleura in to episternum and epimeron. The mandibles articulate at two points with the head capsule.

Division 1: Exopterygota (Hemimetabola). Metamorphosis simple, wings develop externally. Immatue stages (nymphs) usually resemble adults in structure and habits

Division 2: Endopterygota (Holometabola). Metamorphosis complex accompanied by a pupal instar, wings develop internally. Immature stages (larvae) differ from adult in structure and habit.

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Lecture - 22 : ORDER: ORTHOPTERA

Orthos = straight

Pteron = wings

Straight winged insects eg. Crickets, grasshoppers, locusts etc.

1) Usually medium or large sized insects with elongated body.
2) Head is hypognathous or prognathous with long (suborder – ensifera) or short (caelifera) usually filiform antennae.
3) Biting and chewing mouth parts with well developed mandibles.
4) Prothorax large and its notum extends laterally to conceal a great deal of propleurons. Meso and metathorax closely associated to form pterothorax and its notum is divided into prescutum, scutum and scutellum.
5) Winged or wingless. If winged, the wings are straight, front wings are long and narrow, many veined, some what thickened and are known as tegmina (in tetiigidae, the front wings are reduced to scale like, structures). Hind wings are membranous, broad, many veined and when at rest folded fanwise beneath the forewings. Well developed anal vein is present in hindwings.
6) Specialized stridulatory organs are present. Usually males alone can produce sound. Two types of stridulation is present. Alary type and femoroalary type. In alary type (cricket sound is produced by rubbing a sharp edge (scraper) at the base of one forewing along a file like ridge (file) on the ventral side of the other forewing. The bases of forewings at rest lie one above the other. Both the forewings possess the file and the scraper. But the file is longer in upper wing and scraper is better developed in lower wing. The forewings are elevated at about 45^0 when the sound is produced. In femoro alary type, the femur of hind legs is rubbed against the tegmina.
7) Auditory or tympanal organs are also well developed and are located on either side of the first abdominal segment or at the base of fore tibiae.
8) Legs normally developed, or fore legs modified for digging (fossorial) as in molecrickets or hind legs modified for jumping (saltatorial) as in grasshopper. Tarsi 3 or 4 segmented.
9) Male genitalia concealed by the boat shaped 9^{th} abdominal sternum.

10) Females with well developed ovipositor with 3 pairs of valves which are useful for inserting the eggs in soil.
11) Anal cerci well developed, usually short and unsegmented.
12) Metamorphosis simple or incomplete

Family: Acrididae (Short horned grasshopper)

1. .Antennae filiform shorter than the body with less than 30 segments

2 .Pronotum saddle shaped
3 .Auditory or tympanal organs situated one on either side of 1st abdominal segment
4. Stridulation femoro – alary type. The ridge on inner side of hind femur with Peg likeprojections (acting like a file) is rubbed against the hardend radial vein of Tegmina
5. Hind legs modified for jumping. Tarsus 3 segmented.
6. Ovipositor short and well develpped. Its valves are short and curved.
7. These are plant feeders and are often very destructive.

Eg: Rice grasshopper -*Hieroglyphus banian*
Rice small grasshopper - *Oxya chinensis*
Cotton grass hopper - *Cyrtacanthacris ranacea*
Calotropis grasshopper - *Poecilocerus pictus*

Family: Tettigonidae (Long horned grasshopper& Katydids)

1. Cryptic colouration
2. Antenna as long as or longer than the body
3. Tarsus 4 segmented
4. Stridulation - alary type
5. Mainly herbivorous but some carnivorous
   Eg : Surface grasshopper – *Conocephalus indicus*

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Lecture - 23 : ORDER: DICTYOPTERA

Dictyo: Net and Pteron: wings

Cockroaches, Mantids

Though cockroaches and mantids were included in orthoptera earlier, they are kept in a separate order, dictyoptera, in the present day classification

Characters of Dictyoptera

1. Head is usually hypognathous
2. Mouth parts mandibulate
3. Antennae filiform, invariable
4. Forewings modified into tegmina with marginal costal vein. Hind wings have a Large anal lobe in a fan like fashion.
5. Tarsus – 5 segmented
6. A pair of many segmented cerci are present
7. Specialized stridulatory and auditory organs are absent.
8. Eggs are laid in ootheca

Family: Mantidae

This contains the family mantidae that include the praying mantids. They are well characterized by possessing front pair of raptorial legs with tibiae and femora bearing prominent spines. Head is triangular and deflexed with filiform antennae. Prothorax greatly elongated meso and matathoracic segments short, abdomen flattended, cerci short and segmented. The mantids exhibit cryptic colouration thus simulating well with the background. The eggs are laid in water tight egg cases which are fixed to the plants. The case is prepared from a frothy gum, secreted by the female. After exposure to air, the case hardens and nymphs resembling ants emerge from them. The nymphs and adults are predators on other insects, small animals and even scorpions.

Eg: *Gongylus* sp.,

Mantis religiosa

Lecture - 24 : ORDERS: ISOPTERA AND THYSANOPTERA

Order: Isoptera

Iso – Similar; Pteron – wings

Similar winged insects; Termites or white ants

1. These are small to medium sized social living and polymorphic insects with well developed caste system
2. Antennae are moniliform (some times filiform also)
3. Compound eyes present in winged forms, median ocillus wanting.
4. Mouth parts typical biting type with powerful mandibles.
5. Apterous, brachypterous or winged. In winged forms, the front and hind wings are similar in size, shape and venation, when at rest the wings are held flat over the body and extend beyond the tip of abdomen. Wings are membranous with some what reduced venation and are capable of being shed by means of basal structures.
6. Legs short and stout. Tarsus usually 4 segmented
7. Frontal gland is a characteristic termite organ which attains its greatest Developmentin soldiers.It is formed by a group of hypodermal cells in the median line of frons. It is sac like gland which communicate to the exterior by frontalpore, which opens in a shallow depression, on the surface of the head where the cuticle is pale, which is known as frontanella. It appears to have defensive functions
8. Anal cerci short or very short.
9. Metamorphosis simple or incomplete
10. Caste system : Following are the difference castes that are usually seen in a termite colony.

A) Reproductives or Pirmary reproductives: (King& Queen)

These are the highly developed individuals sexually. They have fully developed wings and compound eyes and are usually heavily pigmented. The males are often small. Queens sometimes live for several years. The kings and queens are usually produced in large numbers at certain seasons. They leave the colony in a swarm, mate and individual pairs establish new colonies, wings are shed after

mating leaving remanents called stubs. The queen termite attains enormous size after mating and the obesity is known as physogastry.

B) Supplementary reproductives:

They have short wings and less heavily pigmented, usually have smaller eyes. They sometimes carry on extensive reproduction in the colony and supplement the queen in building the colony.

C. Workers:

These are sterile wingless adults. They are pale in colour, lack compound eyes. Mandibles relatively small. They collect food and feed queens, soldiers and newly hatched young ones. They build up nests, passage ways, tunnels and galleries. They form the bulk of the colony.

D. Soldiers:

These are also sterile wingless adults with greatly enlarged head and mandibles. Slightly larger than workers, may or may not have compound eyes. They protect the colony. Two types of soldiers may be seen. (1) Mandibulate type (2) Nasute type (Nasuti). In nasute type, the individuals have the head prolonged anteriorly into a narrow snout through which a sticky secretion is exuded. Mandibles are reduced in these.

The food of termites is the cast skins and feaceses of other individuals, dead individuals and plant materials such as wood and wood products. Termites frequently groom each other with their mouth parts as a result of the attraction of some secretions available on the body (trophallaxis – Mutual exchange of food i.e secretions on the body).

Family: Termitidae

Included about 2/3rd of recent isopterns

1 Frontanella present

2. Pronotum of workers is narrow with a raised anterior lobe, saddle shaped

3. The scale or stub of the front wing is shorter than pronotum. Wing margin is more or less hairy. R_S Reduced / absent.

4. Cerci with 1 or 2 semented
5. These are all ground dwelling with wide range of food habits.
   Eg: *Odontotermes obesus*, *Microtermes obesi*.

Order: Thysanoptera

Thysano: Fringed and pteron: wing

Eg. Thrips (fringed wings)

1. Small to minute slender bodied terrestrial insects
2. Antennae short moniliform, 6-10 segmented, usually with sense cones or sensoria on 3rd or 4th segments
3. Compound eyes conspicuous with 3 ocelli in winged forms
4. Mouth parts asymenetrical, right mandible is rudimentary, lacerating and sucking or rasping and sucking type with three stylets. Mouth cone is formed by the labrum, labium and the maxillae which extend ventrally between the front coxae.
5. Winged or wingless. wings when fully developed are long and narrow with highly reduced venation (with few no veins). The wings are fringed with long hairs on the margins.
6. Legs short, tarsi 1 or 2 segmented with 1 or 2 claws, with a bladder like terminal protrusable vesicle (hence known as Physopods previously) which at rest is retracted and invisible. When walking, it is exerted out by means of blood pressure and enable the insect to walk on any kind of surface.
7. Abdomen is elongate with 10-11 segments, usually tapering posteriorly
8. Cerci absent
9. Metamorphosis is accompanied by one or two inactive pupal instars i.e intermediary between simple and complete.
10. Parthenogenetic type of reproduction is very common and in many species males are rarely seen.

Family: Thripidae

1. This is the largest and most important injurious family in thrips.
2. Antennae 6-9 segments not conical with sense cones. Antennae ends in 1 or segmented apical style. 4th segment usually enlarged.
3. Winged / wingless. If winged, the wings are narrow and pointed at the tip and fringed with long hairs on the margins.
4. Ovipositor normally well developed and down curved
5. Tarsi sometimes with claw like appendages at apex of 1st or 2nd segment.
   Eg: Onion thrips -*Thrips tabaci*
   Chilli thrips - *Scirtothrips dorsalis*

Lecture - 25 : ORDER: HEMIPTERA

Hemi: Half; Pteron: Wings

Suborder: Heteroptera includes true bugs

1. Small to large mostlty terrestrial, some are acquatic
2. Antennae fairly long, 4 or 5 segmented compound eyes well develpped. Ocelli when present are two in number
3. Mothparts piercing and sucking type and with slender segmented beak (modified labium) that arises from the front part of the head and usually extends back along the ventral side, some times as far as the bases of hind coxae. The beak and rostrum serves as a sheath for the four piercing stylets, two outer mandibular and two inner maxillary stylets. The inner maxillary stylets fit very close together with central ridge in the groove and form dorsal food channel and ventral salivary channel. There are no palpi.
4. Pronotum large, the mesonotum exhibits five fold division, among which scutellum is very prominent
5. Winged and wingless.When winged, the fore wings are basally thickened and membranous apically and are known as Hemelytra. The hemelytron is composed mainly of regions (corium, clavus and membrane). In some insects, a narrow strip of corium along the costal margin is set off from the reminder of corium by a suture and is called embolium. In a few hemiptera, a cuneus is set off by a suture from the apical part of corium. Hind wings are entirely membranous and are slightly shorter than forewings. At rest the wings are held flat on the body. Alary polymorphism is seen.
6. Odoriferous glands or repugnatorial glands or scent glands or stink glands are present which open near hind coxae on the sides by ventral pores giving out unplesant odour
7. Ovipositor small with two pairs of valves or well developed for inserting their eggs in plant tissues.
8. Anal cerci absent
9. Metamorphosis simple

Family: Pentatomidae (Stink bugs or shield bugs)

Medium to large insects, most common and abundant of bugs that produce disagreeable odour.Broad shield like.

1. Head with lateral margins concealing bases of antennae
2. Antennae usually 5 – segmented. Ocelli almost always present
3. The pronotum broad and shield shaped. Scutellum large triangular some times extends posteriorly to the extent of covering the wings entirely.
4. In hemelytron, corium large extending to anal margin. Membrane with many longitudinal veins, arising from a vein which is nearly paralelled to the apical margin of corium.
5. Four pairs of odoriferous glands are present on dorsum of abdomen of the nymphs
6. The eggs are usually barrel shapped with spines on the upper end.

Eg: Green (stink) bug – *Nezara viridula*,
Red pumpkin bug *-Aspongopus janus*
Cabbage painted bug – *Bagrada cruciferarum*

Family: Lygaeidae Seed bugs or Chinch bugs
Small bugs, hard bodied

1. Antennae 4 segmented inserted down on the sides of the head, apical segment is larger
2. Compound eyes and ocelli are well developed
3. 4 to 5 unbranched simple veins in the membrane of hemelytra. Cuneus is lacking, clavus is elongate
4. Metathoracic gland openings are present.
5. In some, the front femora moderately swollen with 2 rows of teeth beneath
6. Coxa rotator, tarsi 3 segmented, pulvulli present

Eg. Dusky cotton bug – *Oxycarenushyalinipennis*
Groundnut pod bug –*Aphanussoridiidus*

Family: Miridae (Capscidae) Mirid bugs

1. Medium or small, usually delicate insects
2. Ocelli absent
3. Rostrum is 4 segmented
4. Cuneus is present
5. Empodium is indistinct. Tarsi almost invariably 3 segmented
6. Majority live on plant juices, some prey on small arthropods

   Eg. Tea mosquito bug - *Helopeltis antonii*

   Predator on rice BPH - *Cyrtorhinos liwidipennis*

Family: Pyrrhocoreidae (Pyrrhocoreids), red cotton bugs or cotton strainers

1. They exhibit red and black colourations
2. Ocelli absent
3. More branched veins and ceels present in hemelytra
4. Coxa is rotatory and tarsi 3 segmented with pulvilli

   Eg.*Dysdercus cingulatus* – red cotton bug

Family : Coreidae Leaf footed bugs
Medium to large, long and narrow bugs

1. Antennae 4 segmented sitiuated well upon the sides of the head above a line drawn from the eyes to the base of the beak. Ocelli present.
2. Head narrower, shorter than pronoutm, scutellum smaller.
3. In hemelytra, richly branched veins are present.
4. In most of the species, either or both the hind femora and tibiae may have conspicuous enlargements or leaf like dilations and hence the name leaf footedbugs.
5. Tarsi – 3 segmented pulvilli present.
6. Metathoraccic gland openings present

   Eg Rice gundhi bug- *Leptocorisa varicornis*

   Pod bugs :*Clavigralla gibbosa* on pulses

Lecture - 26 : ORDER:HEMIPTERA

Sub-order: Homoptera. Homo: Alike; Pteron: Wings (uniform wings)

Jassids, Aphids, mealy bugs, whiteflies etc

Differences between heteroptera and homoptera

	Heteroptera	**Homoptera**
1	Pronotum usually large	Pronotum small and collar like
2	Gular region present and it is sclerotized (the maxillary plates meet and fuse ventrally to form gula)	Gular region absent or very small and membranous
3	Forewings hemelytra	Forweings uniform in consistency
4	Wings fold flat over the body at rest	Wings held roof like over the body
5	Beak or rostrum arise from the front part of the head and base of the rostrum not touching anterior coxae	Beak or rostrum arise from the posterior part of the head and base of rostrum extending between anterior coxae
6	Tarsi – 3 segmented antennae 4-5 segmented, odoriferous glands are present	Tarsi 1-3 segmented antenna 3-10 segmented, wax glands are present.

Characters of the suborder: Homoptera

This suborder contains a large and diversified group of insects and is closely related to the hemiptera.

1. These are minute to small insects and are distributed widely

2. Head is deflexed and not generally constricted behind to form a neck.
3. Compound eyes well developed, ocelli absent in apterous form but 2 to 3 in winged forms
4. Antennae well developed and usually 3 to 10 segmented
5. Mouth parts piercing and sucking type, stylets often exceedingly long, retractile, rostrum arising from the back of the head, in some cases appearing to arisebetween anterior coxae. In some adults like male coccids the mouth parts are vestigial or absent
6. Thoracic segments generally fused together and not distinguishable from abdomen in wingless forms. Pronotum small and collar like.

7. Winged or wingless when winged the four wings are uniform in consistency and the wings are held roof like over the body at rest. Alary polymorphism is prevalent. In male coccids only one pair i.e forewings are present.
8. Wax glands or honey tubes usually well developd in most of the members of this order.
9. In most of the species, the life history is very complex involving sexual and parthenogenetic generations winged and wingless individuals.
10. Usually undergo simple metamorphosis. In some species, the last nymphal instar Is quiescent and pupalike.

Family Cicadellidae : (Jassidae) : Jassids or leaf hoppers

1. Slender, usually tapering, posteriorly, wedge shaped insects usually rest in a position ready for jumping. When disturbed they leap often several feet.
2. Antennae minute, bristle like, 3 segmented
3. One or two rows of small spines are present on hind tibia which is most important feature
4. Both young ones and adults have the characteristic habit of running sideward or diagonally
5. These are very important vectors of viral diseases.
6. Ovipositor well developed and adopted for lacerating plant tissues for egg laying.
7. Many excrete honeydew through anus.

8. Forewings are somewhat thickened and often brightly coloured
9. Anal veins 1A and 2A do not unite to form 'Y' shaped vein.
   Eg: Cotton leafhopper - *Amrasca biguttula biguttula*
   Paddy leafhopper - *Nephotettix virescens* –
   Mango hoppers - *Amritodes atkinsoni,Ideoscopus clypealis* s

Family: Delphacide Plant hoppers

This is the largest family among the plant hoppers

1. Most of the species are small with reduced wings
2. The characteristic feature of this family is the presence of large mobile apical spur on hind tibiae
3. Costal cell is absent in the winged forms
4. Alary polymorphism is very common winged, wingless and brachypterous forms occur in the some species.
   Eg Brown plant hopper of paddy (BPH)- *Nilaparvata lugens*

   White backed plant hopper on rice (WBPH) -*Sogatella furcifera*

Family: Aphididae Aphids or plant lice

This family constitute a large group of small soft bodied, pear shaped, fragile phytophagous insects that are frequently found in large numbers sucking the sap from various parts of plants

1. Antennae fairly long
2. Rostrum usually long and well developed
3. The characteristic feature of aphids is the presence of a pair of cornicles on the dorsal surface of 5^{th} or 6^{th} abdominal segments (It is believed that they produce waxy substances)
4. Winged / Wingless. Alary polymorphism is prevalent. When winged, hind wings are much smaller with fewer veins. At rest the wings are generally held vertically above the body.
5. Tarsus – 3 segmened with a pair of claws
6. Nine pairs of lateral spiracles present

7. Excrete honeydew through anus (honey dew consists of excess sap, excess sugars and waste materials) to which ants are attracted,
8. Associated phenomenon in reproduction are parthenogenesis, oviparity and viviparity
9. Occurrence of alternation of generations. The sexes are unequally developed, males often being rare. Eg: *Myzus persicae* – Tobacco aphid, *Aphis gossypi* – Cotton aphid, *Aphis craccivora* – Groundnut aphid

Family: Pseudococcidae Mealy bugs

1. Females are wingless, elongate oval with distinct segmentation. Body covered with powdery wax or filamentous waxy secreations.
2. Legs well developed. No instar is sessile. All the insect stages are able to move because of legs
3. Eggs are placed in a loose cottony waxy material

   Eg: Brinjal mealy bug – *Planococcus insolitus*

   Citrus mealy bug - *Planococcus citri*

   Sugarcane mealy bug - *Saccharicoccus sacchari*

Family: Coccidae Scale insects (Soft scales)

1. The females in this group are flattened, elongate oval insects with obscure segmentation and hard smooth exoskeleton or covered with wax or tough scales. They are wingless, legs present or absent and the antennae absent or much reduced.
2. Males are active, 1st pair of wings well developed, 2nd pair reduced to halters.
3. Tarsus if present 1 – segmented with a single claw.
4. Metamorphosis complex. 1st instar nymph has legs & antennae and active known as crawlers after 1stmoult, become sessile a waxy or scale like covering is secreted. In males last instar preceeding adult is queicent and called pupa. Females have one less instar than males.
5. Oviparous, ovoviviparous
6. Excrete honey dew like aphids

   Eg: *Pulvinaria psidi* – Guava scale, *Icerya purchasi* - cottony cushion scale

Family: Aleurodidae White flies

1. These are minute insects 1 to 3 mm in length and resemble tiny moths with opaque body
2. The adults have the wings covered by a fine whitish dust or powdery wax giving white colour
3. Antennae well developed usually 7 segmented
4. Adults of both sexes are winged and the wing venation is highly reduced
5. Tarsi with two equal segmented with paired claws
6. The characteristic feature of this family is the presence of vasiform orifice which opens on the basal surface of the last abdominal segment in both nymphs and adults. The opening is provided with an operculum and beneath it a tongue shaped organ known as linguae is present. The anus opens within the orifice at the base of the linguae. Honey dew is excreted through this orifice
7. Honey dew is excreted in large quantities particularly by larvae through anus
8. Compound eyes well developed and ocelli two in number
9. Metamorphosis is complex. The 1st instar young ones are active but subsequent immature stages are sessile and look like scales. The scale like covering is a waxy secretion of the insect. The wings develop internally during metamorphosis and the early instars are called larvae. The next to the last instar is quiescent and is called pupa. The wings are given out at the moult of last larval instar.
10. The eggs are very charcaterstic being provided with a pedicel, which sometimes exceeds the length of the egg.

Eg: Sugarcane whitefly – *Aleurolobus barodensis*

Cotton whitefly - *Bemisia tabaci*

Castor whitefly - *Trialeurodes ricini*

ENDOPTERYGOTA

Lecture - 27 : ORDER: LEPIDOPTERA

(Lepido = Scales; Pteron = wing) scaly winged insects

Butterflies and Moths

One of the largest orders. Small to large insects with flat overlapping scales and hairs on the body, wings and other appendages giving various beautiful colours to the insects

1) Head relatively small free with small neck. Compound eyes are relatively large, two ocelli present one on each side close to the margins of compound eyes.
2) Mouthparts siphoning type represented by a long coiled proboscis formed by the galeae of maxillae. Maxillary palpi small or acking.Mandibles nearly always lacking except in one family micropterygidae. A few species have vestigial mouth parts and do not feed in adult stage. Labial palpi usually well developed.
3) Forewings usually large. In males of various insects, groups of more specialized scales known as androconia occur on the upper surface of wings serving as outlets of odoriferous glands. These are fringed distally with each tip finely divided.
4) Larvae are called caterpillars usually eruciform. Most of the larval stages are phytophagous and are very serious pests of crops. Caterpillars are with well developed head and cylindrical body consisting 13 segments (3 thoracic and 10 adbominal). Head bear 2 ocelli on each side and very short bristle like antennae. Mouth parts mandibulate with well developed mandibles. Labium with a spinneret, a median process for spinning silk. Each of the thoracic segments bears a pair of legs which end in a point. Abdominal segment 3 to 6 and 10^{th} usually bear a pair of prolegs which are fleshy and broad bearing a number of tiny hooks known as crochets at their end. Caterpillars have well developed silk glands and are usually peripneustic.

5) Pupae are usually obtect and generally enclosed in a cocoon. Butterflies do not Make a cocoon and their pupae are called chrysalis.
6) Adults are harmless except fruit sucking moths.
7) Natural silk is a product of this order
8) Undergo complete metamorphosis.

Differences between moths and butterflies

Character	**Moths**	**Butterflies**
Behaviour	Nocturnal	Diurnal
Antennae	Pectinate, plumose	Clavate
Ocelli	Present	Absent
Mandibles	Present	Absent
Frenulum	Present	Absent
Humeral lobe of hindwings	Undeveloped	Greatly developed
Wings at rest	Held roof like over body	Folded vertically upward
Cu_2 vein of forewing	Present	Absent
Abdomen	Large and stout	Comparatively small and slender
Pupa	Obtect pupa within a cocoon	Obtect pupa without cocoon. It is a naked pupa brightly coloured and supported by silken girdles,called as chrysalis

Family : Noctuidae

Noctuid moths, army worms, cutworms etc

1. This is the largest family in the order comprising medium size nocturnal, moths attracted to light and sugar mixture
2. Antennae generally filiform, maxillary palpi normally vestigial and labial palpi long and ocelli present

3. The forewings cryptic and some are coloured similarly with the surrounding
4. In forewing M_2 arises close to M_3 than to M_1. Cubitus appears four branched. In hind wings Sc and R fuse for very short distance at the base of the discal cell.
5. In the larvae, only primary setae are present and the crochets are generally in a uniordinal series. Usually 5 pairs of abdominal legs are present but in some 1^{st} or 1^{st} and 2^{nd} pairs may be aborted and the larvae are semiloopers. Most of them are highly polyphagous and nocturnal. They are called army worms / cut worms by their habits. Majority feed on foliage and some are stem borers
6. Pupation is in an earth cell in the soil and some pupae are characterized by the presence of labial palpi and maxillae extending to the caudal margin of the wings
7. Adults have a pair of well developed tympanal organs at the base of abdomen

Eg: Climbing cutworm of paddy - *Mythimna separata*

Redgram podborer - *Helicoverpa armigera*

Tobacco cutworm- *Spodoptera litura*

Fruit sucking moth of citrus - *Othereis fullonica*

Family: Lymantriidae

Tussock moths and gypsy moths

1. Medium sized, dull coloured, nocturnal moths with females of most species having only rudimentary wings (*Notolophus* sp) proboscis is atrophied
2. Ocelli absent. Antennae bipectinate in males and pectinate or plumose in females – sexual dimorphism
3. Wing venation resembles the Noctuidae. Sc and R fused to some extend and basal areole is larger in some species in hind wings
4. The caudal extremity of females is often provided with the large tuft of anal hairs which are ddeposited as a covering on egg masses
5. Caterpillars are densly hairy, often with thick compact dorsal tufts on certain segments
6. Osmeteria are frequently present on 6^{th} and 7^{th} abdominal segments. Some are provided with urticating hairs which cause irritation
7. Pupation takes lace in a cocoon above ground and are charecterized by specific evident setae

Eg. Yellow hairy caterpillar on Paddy – *Psalis recuris*

Hairy caterpillar on fruit trees, pulses and castor – *Euproctis fraternal* and *E.Scintillans*

Casuarina hairy caterpillar – *Lymantria incerta*

Family: Sphingidae

Sphinx or hawk moths or horn worms

1) Medium to large sized, heavy bodied powerfully flying moths with spindle shaped body tapering and pointed both anteriorly and posteriorly.
2) Antennae are thickened in the middle or towards the tip and hooked at tips
3) The proboscis is very long in most of the species and attains its greatest length in the family and usually the adults produce sound by forcing air through proboscis.
4) The forewings are elongate (long and narrow) with oblique outer margin. Hind wings small and usually brightly coloured. Sc and Rs in wings connected by a cross vein near middle of discal cell.
5) Larvae of most species have a conspicuous horn on the dorsal surface of 8th abdominal segment which is relatively longer in 1st instar and hence the name horn worms.
6) Pupation occurs freely in a cell in the ground or in a very loose cocoon on the surface among leaves. In some genera the proboscis projects from the body resembling the handle of a pitcher.

Eg: Gingelly deaths head (robs honey from honey comb)- *Acherontia styx*

Sweet potato sphinx - *Herse convolvuli*

Lecture - 28 : ORDER: LEPIDOPTERA (contd.)

Family: Pyralidae

Snout moths

1. These are small and delicate moths with well developed antennae and ocelli present
2. Labial palpi well developed and projected forward appearing as a snout infront of the head and hence are called snout moths.
3. Forewings elongate or triangular with cubitus appearing four branched. Hind wings are usually broad with SC and R usually close together, fused or closely parallel for a short distance beyond discal cell.
4. Larvae are naked, prolegs variable but always present in VI segment. Generally internal feeders.
5. Adult females are generally provided with a tuft of anal hairs at the caudal extremity which are deposited as a covering on the egg masses

Eg: Paddy stem borer-*Scirpophaga incertulas*,
Jowar stem borer-*Chilo partellus* –
Brinjal shoot and fruit borer-*Leucinodes orbonalis*

Family: Gelechiidae

Small to minute moths, usually cryptic coloured

1. Labial palpi are long and curved, the terminal segment is long and pointed
2. The venis R4 and R5 in the forewings are stalked at the base. Forewings are trapezoidal and narrower than the hind wings
3. Hindwings usually have the outer margin, curved and RS and M1 stalked.

Eg: Angoumois grain moth -*Sitotroga cerealella,*
Cotton pink boll worm - *Pectinophora gossypiella*
Groundnut leafminer – *Aproaerema modicella*

Family: Lycaenidae blues, coppers and hair streaks

1. Medium sized butterflies with upper surface of wings being metallic blue or coppery, dark brown or orange and under surface more sombre with delicate streakings or dark centered eye spots. Hind wings are procided with delicate tail like prolongations
2. The sexes frequently exhibit great differences in colouration, the male is pale shining blue and the female is irridiscent brown
3. Each compound eye is surrounded by a rim of white scales and the antennae ringed with white
4. Legs are normal except fore legs of males which may possess more or less shortened tarsi and may be wanting in one or both claws
5. Larvae are characteristically onisciform with both ends tapering end with broad projecting sides concealing the legs
6. Pupa is attached to the surface by its anal end and is held by a central grith of silk, rarely it is subterranean
7. Larvae are voracious feeders, some species are carnivorous
   Eg.*Virachola isocrates* – Pomegranate fruit borer or Anar butterfly
   Lampides beoticus and *catechrysops cnejus* – Red gram blue butterfly

Family: Arctiidae

Tiger moths or wooly bears

1. Stout bodied, medium sized conspicuously and brightly spotted or banded nocturnal moths.
2. Sc and Rs in hind wings are usually fused near or beyond the middle of the discal cell.
3. Caterpillars are usually densely hairy and some are called as wooly bears since they curl into a compact mass when disturbed.
4. Many species are capable of producing sound.
5. Pupation in a cocoon and the cocoons are made of silk and larval body hairs.

Eg: Red hairy caterpillar - *Amsacta albistriga*

Black hairycaterpillar -*Pericallia ricini*

Sunhemp hairy caterpillar -*Utetheisia pulchella*

Family: Papilionidae

Swallow tail butterfly

1. Medium sized to large butterflies , most of which have tail like prolongation in the hindwings
2. Cubitus in the forewings appears 4 branched.
3. Larva is smooth with a series of fleshly dorsal tubercles or occasionally a raised prominence on the 4^{th} segment
4. Pupa, characteristic in having two lateral cephalic projections

Eg: *Papilio demoleus, Papilio polytes* -Citrus butterflies

Lecture - 29 : ORDER: COLEOPTERA.

Coleo = sheath, pteron= wing

Beetles and weevils

Elytra are sheath like (fore wings)

1. This is the largest order in class insecta comprising about 1/3rd or 40% of the known insect species.
2. Minute to large sized with leathery or horny integument.
3. Head highly sclerotized free, normal or prolonged in to a snout as in weevils. Ocelli usually absent.
4. Antennae variable usually 11 segmented
5. Mouth parts are chewing type with well developed mandibles. The mandibles attain their greatest length in the males of many of the stag beetles (Lycanidae)
6. Prothorax large and freely movable, mesothorax much reduced and fused with metathorax and the tergum of these segments is divisible in to prescutum, scutum and scutellum.
7. Two pairs of wings present. Forewings are horny or leathery known as elytra which atleast always meet to form a straight mid dorsal suture. Hindwings membranous. The wings are highly reduced in few beetles.
8. Legs well developed for walking, running and tarsal segments are variable.
9. Abdomen usually 10 segmented. First tergum membranous and one or more of the sterna from the first to third are aborted in many species, the terminal abdominal segments are refractile and tubular, thus functioning as an ovipositor (eg: cerambycidae).
10. The larvae are known as grubs and generally thoracic legs are present.
11. Pupa exarate, pale coloured and are invested by a thin soft cuticle.
12. Most of the adults possess stridulatory organs and these are variable.
13. Metamorphosis is complete and complex.

Family: Coccinellidae

Lady bird beetles or Coccinellid beetles.

1. Beetles of moderate size, oval, convex dorsally and horizontal ventrally, brightly coloured or spotted.
2. Head partly concealed from above by the pronotum.
3. Antennae usually clavate, short and partly concealed.
4. The legs are short and hidden under the body. Tarsi 4 segmented but appear to be 3 segmented since this 3rd segment is small and concealed in the deeply bilobed second segment. Tarsal formula is 4:4:4. Tarsal claws are teethed at the base.
5. Grubs are usually covered with minute tubercles or spines known as setose or rugose and are usually flattened.
6. Elytra coveres the abdomen completely.
7. Both adults and grubs of most of the species are highly predacious feeding on aphids, coccids, mites, psyllids and other soft bodied insects.
8. Genus epilachna are phytophagous

Eg.Predator on aphids – *Menochilus sexomaculata*

Predator on cottony cushion scale-*Rodalia cardinalis*

Lady bird beetle on brinjal -*Henosepilachna vigintioctopunctata*

Family: Bruchidae

Pulse beetles or seed beetles

1. Short, stout bodied beetles with the body narrowed anteriorly
2. The head is produced anteriorly in to a short and broad snout
3. Antennae serrate or pectinate
4. Prothorax prominent, somewhat triangular wider than long and its notum is greatly narrowed anteriorly
5. Elytra shortened, never cover the tip of abdomen, abdominal tip bluntly rounded

6. Legs short, tarsi, 5-segmented hind femur more or less thickened and toothed beneath. Tarsal formula is 5:5:5
7. Larvae usually undergo hypermetamorphosis. First instar with well developed legs and possess spined or toothed thoracic plates to aid in entering smooth and hard seeds. After first moult it becomes partially / wholly apodous.

Eg. Pulse beetles : C*allsobruchus chinensis*,

Callosobruchus maculatus

Lecture - 30 : ORDER: COLEOPTERA (contd.)

Family : Scarabaeidae

Chafer beetles, horn beetles, dung rollers, root grubs

1. These are heavy bodied oval or elongate usually convex beetles.
2. Head often slender, recurved, sometimes toothed or bilobed frontal horn.
3. Antennae 8-11 segmented and lamellate type.
4. Prothorax large simple or with horny structure.
5. Elytra not usually completely covering the abdomen
6. Tarsi 5 segmented, tarsal formula 5:5:5, the hind tibiae more or less dilated with the outer edge toothed.
7. Adults usually feed on foliage. Grubs typically scraboid and feed on roots known as root grubs which are very serious pests of most of the crops, while some feed on organic matter living in manure pits.
8. The grubs are sluggish, stout and usually white in colour and called as white grubs.

   Eg.*Oryctes rhinoceros* – Rhinoceros bettle on coconut

   Holotrichia serrata – Root grub on sugarcane

   Anomalavarians – Chafer beetles on fruit trees.

Family: Chrysomelidae

Flea beetles, leaf beetles

1. Usually small to medium, oval or spherical beetles with the upper surface of the body generally bare and shining, frequently with metallic colouration
2. Antennae short or of moderate length usually with 11 segments and except in this they resemble to cerambycids
3. Legs short, hind femora enlarged for jumping in many forms. Tarsi 5 segmented, but appear to be 4 segmented since the 4^{th} segment is small and concealed in the notch of the bilobed 3^{rd} segment. Tarsal formula is 5:5:5, tibial spurs absent usually.

4. Adults generally feed on leaves causing numerous holes and also on flowers. Some grubs feed on foliage, some act as leaf miners and some feed on roots and stems also
5. Abdomen short with 5 visible sternites

Eg: Sweet potato tortoise beetle - *Metriona circumdata*

Rice hispa - *Dicladispa armigera*

Pumpkin beetles - *Raphidopalpa foveicollis*.

Family: Cerambycidae

Longicorn beetles

1. These are elongate and cylindrical beetles with very long filiform / serrate antennae atleast two thirds as long as the body, capable of being flexed backwards and usually inserted on prominent tubercles.
2. Prothorax is narrow or as wide as mesothorax usually spined or tuberculate
3. Elytra usually cover the body but sometimes may leave the posterior one or two segments exposed in few cases.
4. Legs well developed tarsi 5 segmented but appear to be 4 segmented since the 4^{th} segment is small and concealed in the notch of the bilobed 3^{rd} segment. All tibiae with two well developed spurs. Tarsal formula is 5:5:5
5. Most of the grubs are tree borers. Few are confined to roots with powerful mandibles boring into deep and hardwood also and are highly destructive.
6. Most of the adults feed on flowers and some of them produce squeaking sound when picked up.

Eg.Mango stem borer - *Batocera rufomaculata*

Grapevine stem gridler - *Sthenias grisator*

Longicorn beetles on cucurbits - *Apomycyna pertigera*

Family: Apionidae

1. Antennae clavate, rarely geniculate
2. Trochanter elongated.
3. Ventral surface of mentum without projecting setae
4. In the larvae, the abdominal segments have only two dorsal folds and the frontal sulci extended to the mandibular articulation.

Eg. Sweet potato weevil – *Cylas formicarius*

Family: Curculionidae

Weevils, snout beetles.

1. Minute to large species characterized by the head prolonged to form a pronounced snout or rostrum of variable length and shape. In many species, it exhibits sexual dimorphism being better developed in females acting as a boring instrument for placing the eggs.
2. Antennae geniculate and clubbed arising about the middle of the snout
3. Palpi reduced and rigid, mouth parts small and arranged at the end of the snout
4. Legs are short or very long, tarsi 5-segmented 4^{th} one ofter small.
5. Wings well developed rudimentary or absent
6. Abdomen with 5 visible sternites
7. Adults and larvae are phytophagous and stored grain pests.
8. Larvae usually apodous, curved with developed head.

Eg: Red palm weevil - *Rhynchophorus ferrugenius*

Sweet potato weevil-*Cylas formicarius*

Rice weevil - *Sitophilus oryzae*

Lecture - 31 : ORDER: HYMENOPTERA

Hymen = Membranous; pteron = wing (Naked membranous wings)

Wasps, bees, ants, sawflies *etc*

1) This is the most beneficial order in the class insecta comprising of parasites, predators and bees involved in poliination and honey production. Most of them are social living.
2) Varied in size and shape. Head prominent remarkably free with small neck.
3) Compound eyes well developed and ocelli usually 3 or absent.
4) Antennae variable usually exhibit sexual dimorphism being longer in males
5) Mouth parts primarily adopted for biting and often for lapping and sucking also. mandibles always present
6) Usually two pairs of naked membranous wings are present with reduced venation. Hind wings are smaller and have a row of tiny hooks on their anterior
   margin by which they attach to the front wings. Usually stigma is present in the
   forewings along the costal margin near the apex.
7) Legs slender, trochanter 1 or 2 segmented
8) Abdomen usually basally constricted to form pedicel or petiole. The 1st abdominal segment fused with metathorax and known as propodaeum. Second segment forms pedicel. The remaining region of the abdomen is bulged one known as gaster.
9) Ovipositor very well developed and modified for sawing, boring, piercing, stingingetc.
10) Larvae are known as grubs with well developed head and usually apodous
11) Pupa exarate and a cocoon is generally present
12) Metamorphosis complete and complex also

Family : Tenthredinidae

Sawflies

1. Stout wasp like insects without abdominal pedicel. Adults feed on flowers, foliage or while some feed on small insects (carnivorous). Medium sized and brightlycoloured insects.
2. Antennae 3 to 6 or 8 to 11 segmeted, filiform or setaceous
3. Trochanter 2 –segmented, front tibia posses 2 apical spurs.
4. ovipositor well developed with 2 pairs of flattended plates
5. In many species, the two sexes are different coloured. Parthenogenesis is very common
6. Larvae are eruciform, exclusively phytophagous. The body segments are usually subdivided by transverse folds in to annulets. Resemble to those of lepidopteran larvae but are provided with 6 to 8 pairs of abdominal legs which are devoid of crochets. Many larvae are provided with glands resembling osmoteria which open on the sternum of each of the first seven abdominal segments.
7. Pupation takes place in an elongated oval silken cocoon or in an earthern cell

Eg: Mustard sawfly - *Athalia lugens proxima*

Family: Ichneumonidae

1. One of the largest families in the entire class – insecta. They are slender wasp like insects.
2. Antennae longer with more than 16 segmentes and filiform
3. Trochanter 2 segmented. Legs are provided with conspicuous tibial spurs and strong claws, tarsus 4 segmented
4. In forewings, the costal cell is wanting and have two recurrent veins while braconids have one or none
5. Abdomen long and slender, petiolate, petiole usually curved and expanded apically.
6. Ovipositor very long often longer than the body arising anterior to the tip of abdomen

7. Most of the members are endoparasites and undergo complete metramorphosis i.e. hypermetamophosis. Caudal prolongation of tail is present, in 1st instar larvae

   Eg: Larval parasite on jowar stem borer - *Xanthopimpla stemmator* –
   Larval parasite on stem borers of paddy and
   sugarcane top borer - *Isotima javensis*

Family: Branconidae Braconids

1. Closely related to Ichneumonids
2. Minute to small parasitic insects
3. Abdomen sessile or sub sessile or petiolate
4. Costal cell is wanting in forewings with one recurrent vein
5. Ovipositor well developed
6. Unlike Ichneumonids, many of these pupate in silken cocoons on the outside of the body of the host
7. Poly embryony occurs in a few species of this family

   Eg: Larval parasite on jower stem borer - *Apanteles flavipes*
   Larval parasite on black headed caterpillar of coconut, *Bracon hebator*

Family: Trichogrammatidae

1. Minute insects with three tarsal segments
2. Microscopic hairs on wings arranged in rows
3. Egg parasitoids on lepidopterans

   Eg: *Trichogramma minutum, T. Chilonis, T. Japonicum*

Lecture - 32 : ORDER: DIPTERA

Dis = Twice, pteron = wings

Flies and mosquitoes (two winged insects or true flies)

1. These are small and soft bodied insects with prominent head and small neck
2. Eyes large : usually larger in males, holoptic / dichoptic
3. Ptilinum or frontal sac is characteristic feature of cyclorrhapha indicated by the frontal or ptilinal suture. It is a retractile bladder like organ employed to break open the puparium
4. Antennae mostly 3 segmented (except in Nematocera) and aristate
5. Mouth parts sucking type usually forming a proboscis. In many they are piercing and sucking and in others they are sponging (lapping) with labium distally expanded in to a pair of fleshy lobes.
6. Mesothorax large supporting the functional wings, pro and metathoracic segments small and fused with mesothorax
7. Only front pair of wings present. Hind pair modified into halters which act as balancers
8. Legs well developed, tarsus usually 5 segmented pulvilli and an empodium Usuallypresent
9. Metamorphosis is complete
10. Larvae eruciform and apodous known as maggots mostly amphipneustic
11. Pupa either free or enclosed in the hardened larval cuticle known as puparium (coarctate pupa)

Family: Cecidomyiidae

Gall midges; gall flies

1. Minute to small delicate flies, somewhat hairy with small head.
2. Antennae long, moniliform with whorls of hairs. Legs long resembling mosquitoes, tibiae without spurs.
3. Wings broad with few longitudinal veins (3 to 5) for the most part unbranched with no obvious cross veins

4. Larvae live in plants forming galls, some occur under bark, in decaying vegetation and a few are predacious or parasitic on aphids / scales etc., The head is greatly reduced without mandibles. In the last larval instar most of the species possess a sternal spatula or breast bone on the ventral side of the prothorax.
5. Paedogenesis is seen in some members of this family
   Eg: Rice gall midge -*Orseolia oryzae*
   Hessian fly on wheat -*Phytophaga destructor*

Family: Tephritidae (Trypetidae)

1. Small to medium flies, slightly hairy / bristly
2. Head large broad with small neck
3. Wings large mostly pictured. Sub Costa bends apically formed at almost a right angle and then fade out without reaching the margin
4. Middle legs tarsi with spurs
5. Ovipositor very well developed horny and flattened and usually 3 segmented
6. Adults are visitors of flowers, fruits and foliage
7. Larvae phytophagous, Amphipneustic (1st's last pair of spiracle functional)
   Eg: Fruit fly on cucurbit- *Dacus cucurbitae*
   Fruit fly on guava- *Chaetodacus incisus*

Family: Agromyzidae

Leaf miner flies

1. These are small blackish or yellowish flies
2. Femora of the legs bristled
3. Wings by hyaline or pictured
4. Vibriosae are generally present (a pair of stout bristles on each side of the face just above the oral margin longer than other bristles on the vibrissal ridge)
5. Most of the larvae are phytophagous, mine in the leaves producing characteristic blotches

Eg: Redgram podfly- *Melanagromyza obtusa*

Pea leaf miner -*Phytomyza atricornis*

Family: Tachinidae

Tachinid flies (Parasitic flies)

1. Small to medium, conspicuously bristly or hairy, active flies
2. Head is large and free. Arista on antennae often bare
3. Pteropleural bristles are present. Post scutellum is prominent
4. Wings are large , rarely mottled, Rs cell narrowed or closed apically
5. Abdominal sternite usually overlapped by the tergites on the sides. Abdomen clothed with long, conspicuous marginal, dorsal and apical bristles
6. Larvae mostly parasitoids. Few are saprophagous. Metapneustic in first instar and amphipneustic subsequently. Distinctly segmented
   Eg.*Sturmiabimaculata* – parasitoid on Spodopteera and other caterpillars
   Stomatomiabezziana- parasitoid on black heade caterpillar on coconut
   Exorista civiloides – parasitoid on many caterpillars

Family: Muscidae

Flower flies, root maggots, shoot flies, house flies

1. Small to medium dark coloured flies
2. Fine erect hairs are present on the under surface of scutellum (mesothorax portion) and have more than one stero pleural bristles.
3. Abdomen bristly with somewhat constricted base usually 4-5 segmented
4. Vein Cu2 + 2A is short and do not reach the wing margin
5. Larvae cylindrical and truncate posteriorly some are phytophagous, some are saprophagous while a few are parasitic.
   Eg: Jowar shootfly-*Atherigona soccata* .
