SECOND SEMESTER,
THIRD YEAR, FOURTH YEAR

INTRODUCTORY OF ENTOMMOLOGY

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)	1-3
2	Contributory factors for abundance of insects – structural characters, developmental characters and protective characters (morphological, physiological, behavioral and construction of protected niches)	4-6
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	7-13
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	14-20
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);	21-25
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	26-27
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PRACTICALS:

1 Methods of collection and preservation of insects including immature stages
2. Methods of collection and preservation of insects including immature stages
3 External features of grasshopper/ blister beetle
4 Study of insect deferent types of antenna
5 Study of insect deferent types of legs
6 Study of types of mouthparts – biting and chewing, sucking,

sponging and siphoning

7 Study of types of mouthparts – biting and chewing, sucking, sponging and siphoning

8 Study of wing venation, types of wings and wing coupling organs

9 Study of different types of insect larvae and pupae

10 Dissection of digestive system in insects

11 Dissection of female and male reproductive systems in insects

12 Nematodes- Extraction of nematodes from soil and roots- temporary/ permanent slides.

13 Nematodes- Identification of different types of Nematodes.

14 Mites- Identification of different mite species

15 Rodents- Identification of different non-insect pests – bards – rodents- crabs-snails - veterinary and house hold pests.

16 Non insect pest including house hold and veterinary insect pests

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

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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 la nd was donated by Mr.Phiffs of USA after whom the place was named as Pusa	Pusa, Bihar
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		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

ent	Direct	Indirect	Direct except	Direct	Direct	Direct	Direct or indire
	Onycophora	**Crustacea**	**Arachnida** in mites and	**Diplopoda**	**Chilopoda**	**Symphyla**	**Insecta**
	Head is	Cephalothor	Cephalothorax	Head, trunk	Head,	Head,	Head, thorax
	Terrestrial with the body	Mostly aquatic in	Mostly terrestrial	Terrestrial	Terrestrial	Terrestrial	Aquatic or terrestrial
	1pair	2 pairs	no antenna	1 pair	1 pair	1 pair	1 pair
ts	Mouth parts are	Mouth parts	Mouth parts	1 pair of	1 pair of	Mandibles,	Labrum ,a pair
	Paired jaws or oral papillae	Mandibles, two pairs of maxillae with maxillary pads	Chelicerae and pedipalpi	Mandibles and 1 pair of maxillae	One pair of mandibles and 2 pairs of maxillae	One pair of mandibles and labium	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	1 pair / segment. 1st pair of leg is modified to form poison claws	1 pair / segment	3 pairs
	Cutaneous	Gills	Book lungs	Trachea	Trachea	Trachea	Trachea
f 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

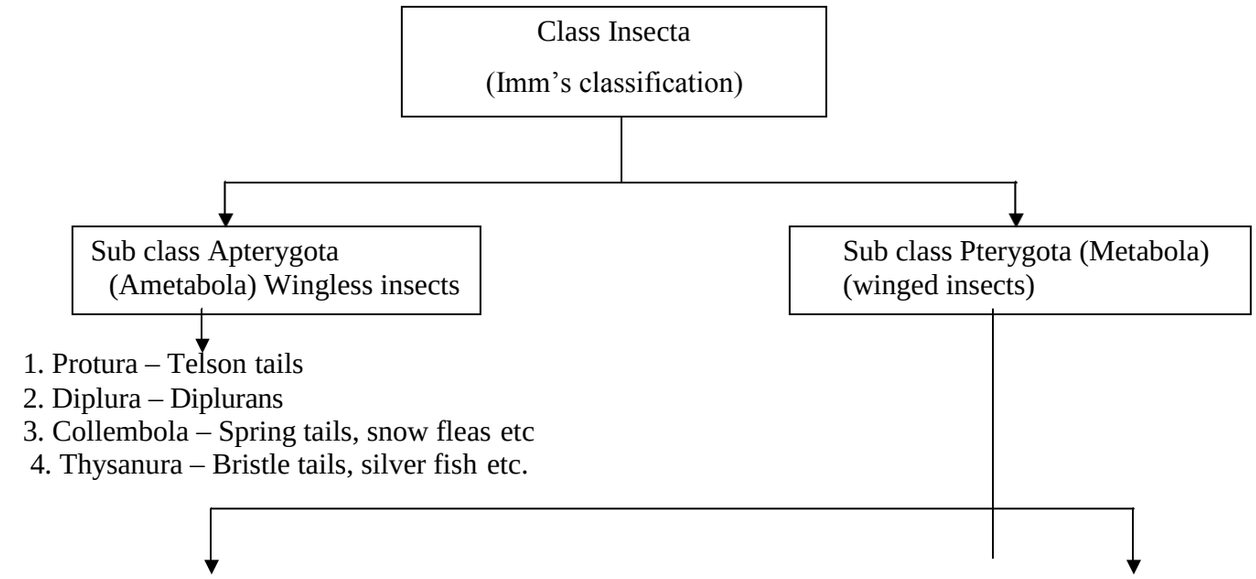
Characters of class insecta (Hexapoda ; Hexa-six, poda-legs

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



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

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 - Booklice
17. Mallophaga - Bird lice
18. Siphunculata - Sucking lice (Anoplura)
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 deve lop 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. <u>Basement membrane</u>: 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. <u>Epidermis</u>: 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.

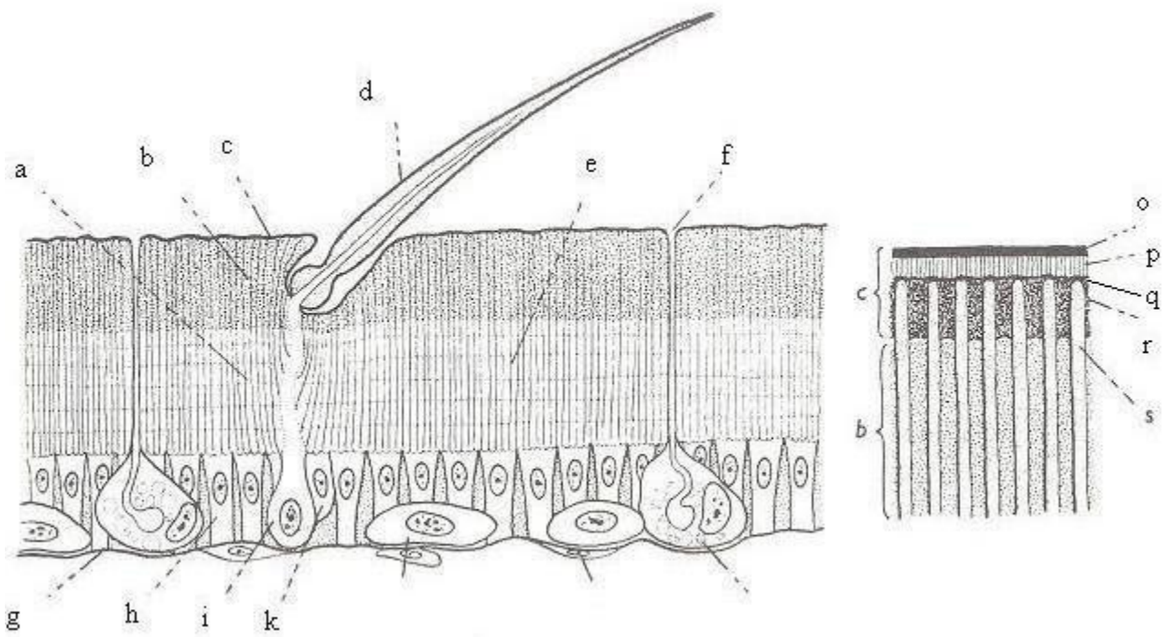


Fig. 1. A typical insect cuticle

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 **ß-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)

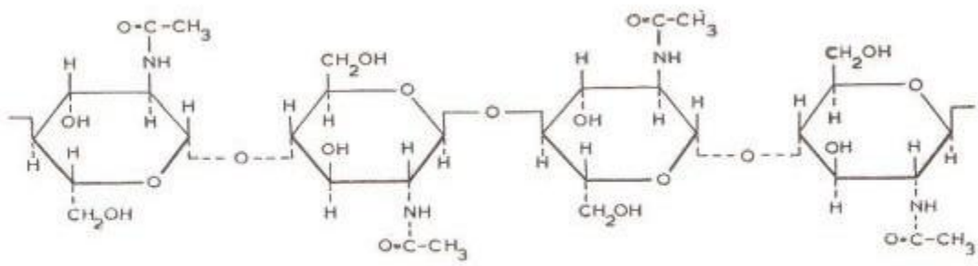


Fig. 2.

(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

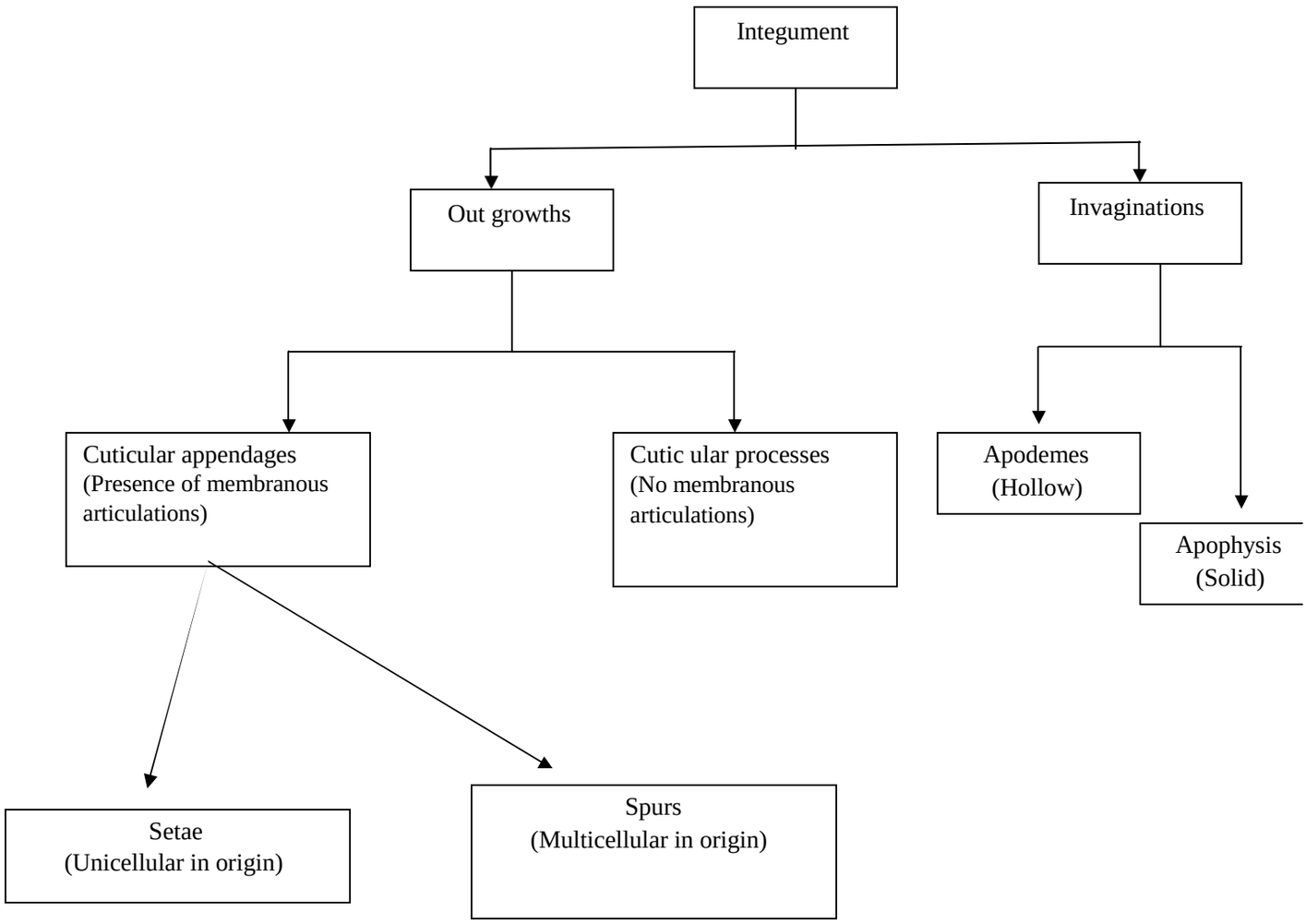
(a) Arthropodin: It is soft water soluble protein present in endocuticle. The conversion of arthopodin in to sclerotin is known as **sclerotization or tanning.**

(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 into 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.

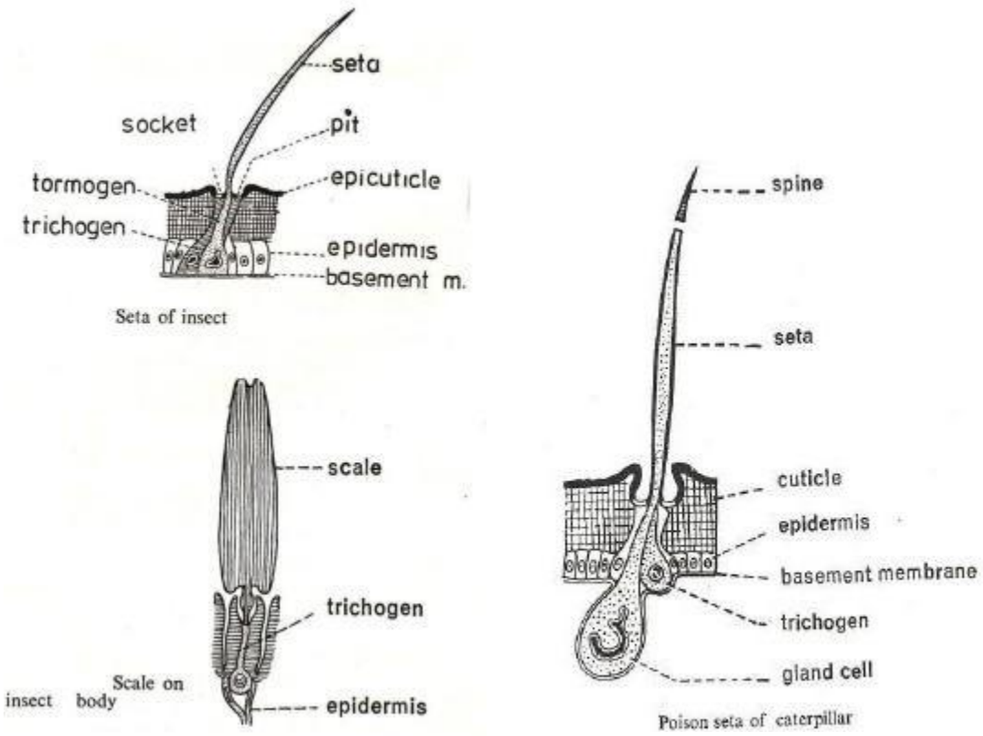


Fig. 3 Cuticular outgrowths

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 polypheno l 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.

3) 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)**

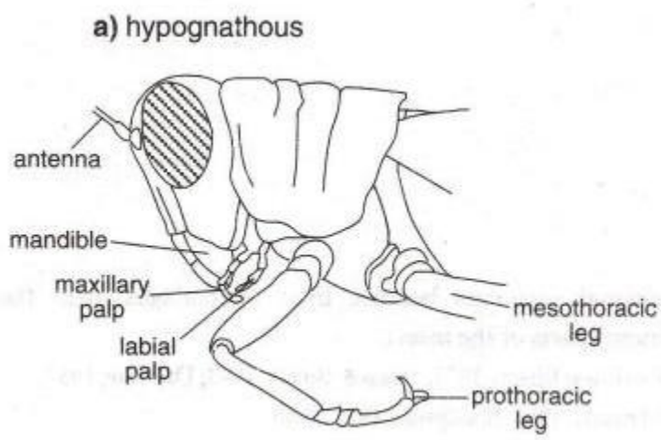
The head remains in the same axis to body and mouth parts are projected forward.. This is also kwown as **Coleopteroid** type..

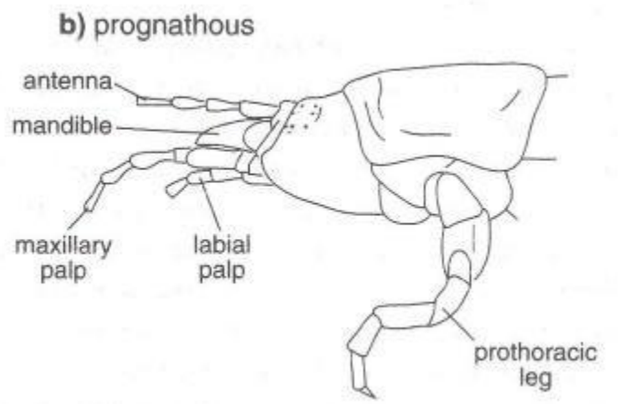
Eg: beetles

(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





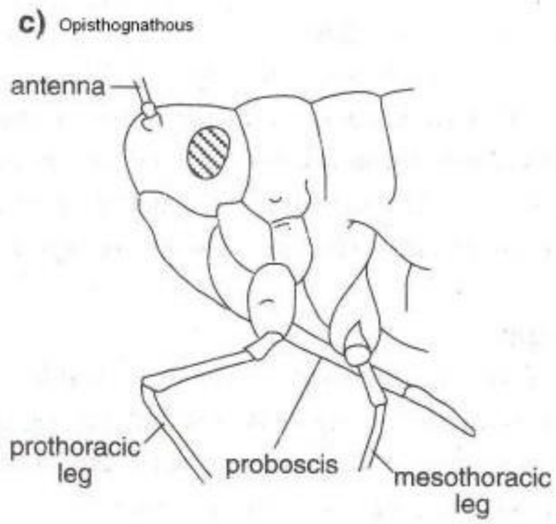


Fig. 4. Types of insect head

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.

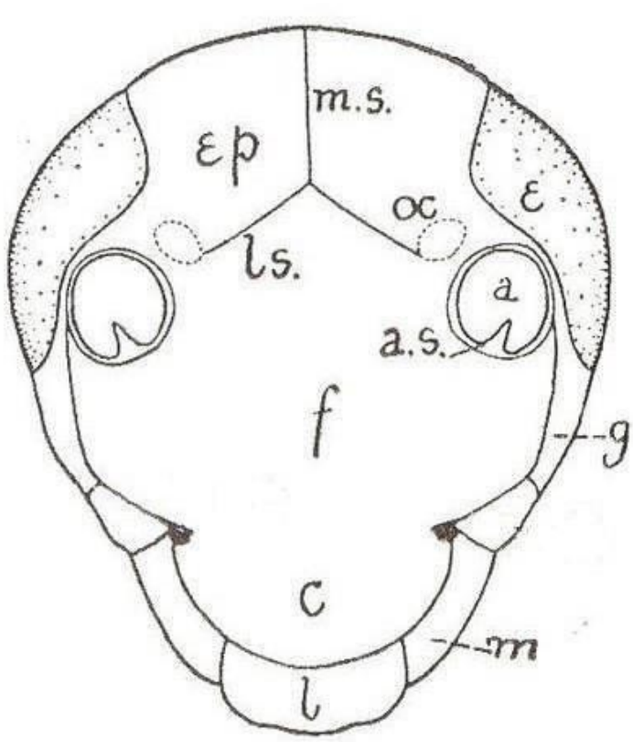


Fig 5. Front view of head of cockroach

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.

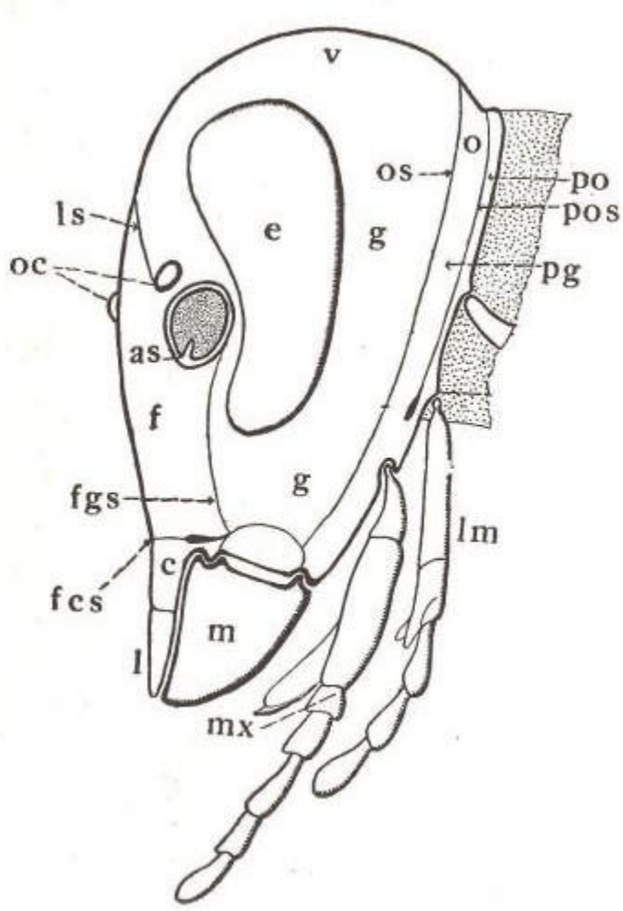


Fig. 6. Lateral view of head of Orthopterous insect
as, antennary sclerite; c, clypeus; e, compound eye; f, frons; fcs, fronto-clypeal suture; fgs, fronto-genal suture; g, gena; l, labrum; lm, labium; ls, lateral arm of epicranial suture; m, mandible; mx, maxillae; o, occiput; oc, ocelli; os, occipital 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 10th segment in general forms the **supra anal plate** and 11th 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 5th and 6th 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 **1st abdominal** segment get fused to metathorax forming **propodeum** whereas **2nd abdominal** segment forms a narrow **pedicel or petiole** followed by enlarged **gaster** (rest of the abdominal segments) in **hymenoptera.**

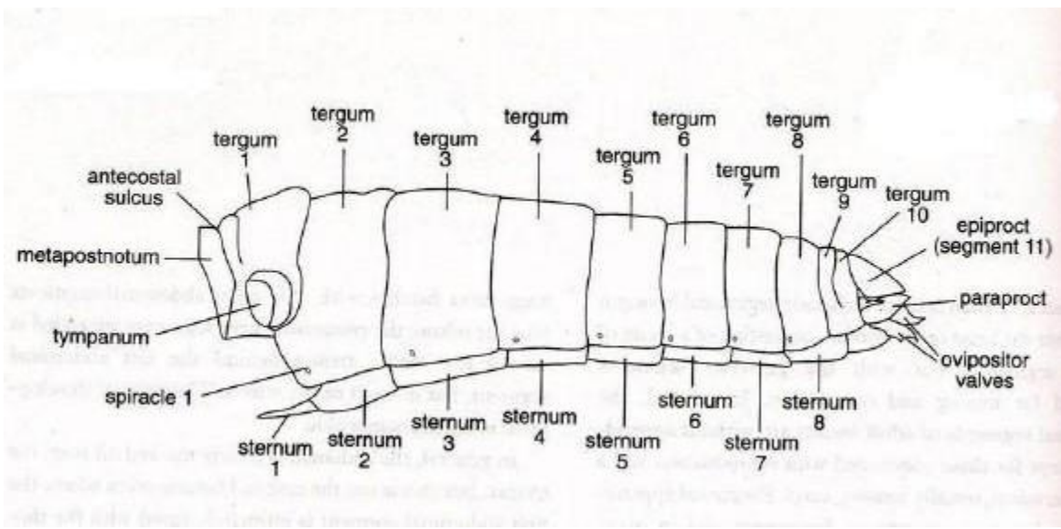


Fig. 7. Thoracic segments

(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.

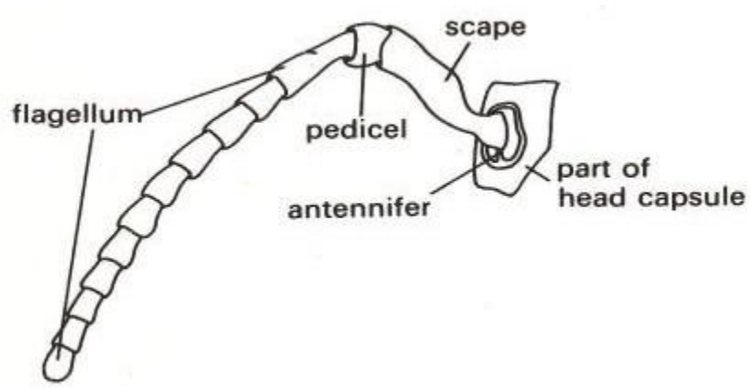


Fig. 8. A typical antennae of pterygote insect
(Source: Taken from The Insects- Structure and Function, 4th Edition, 1998) – R.F. Chapman. Cambridge University Press.)

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.

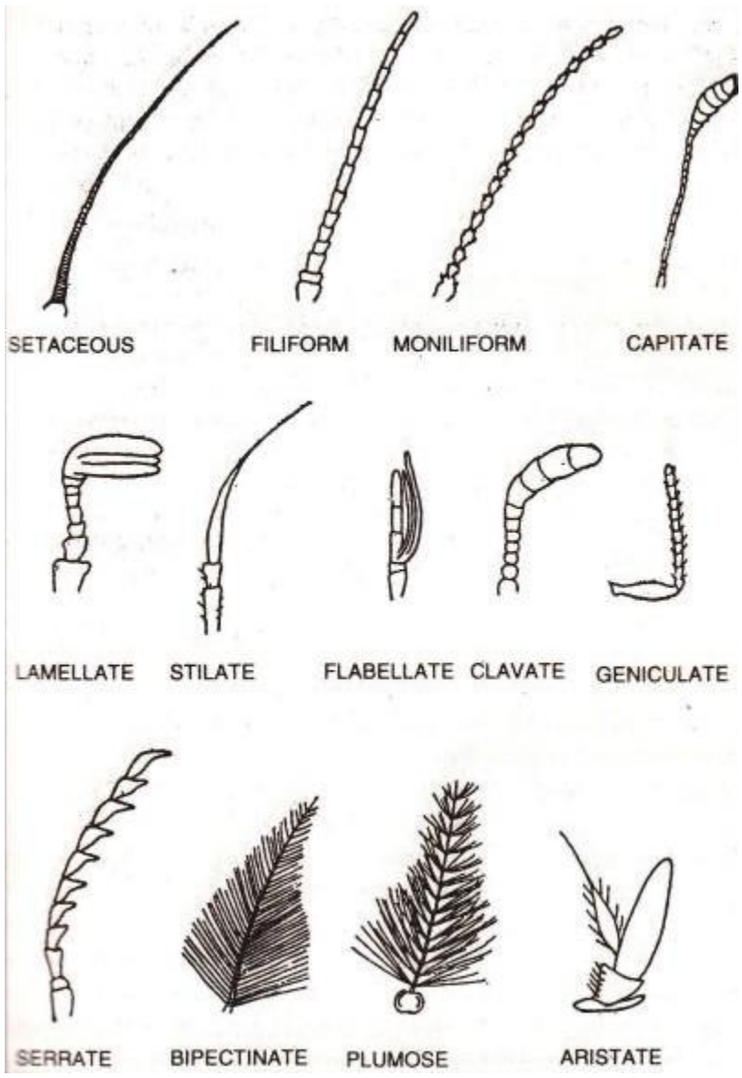


Fig. 9. Different types of antennae

(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.

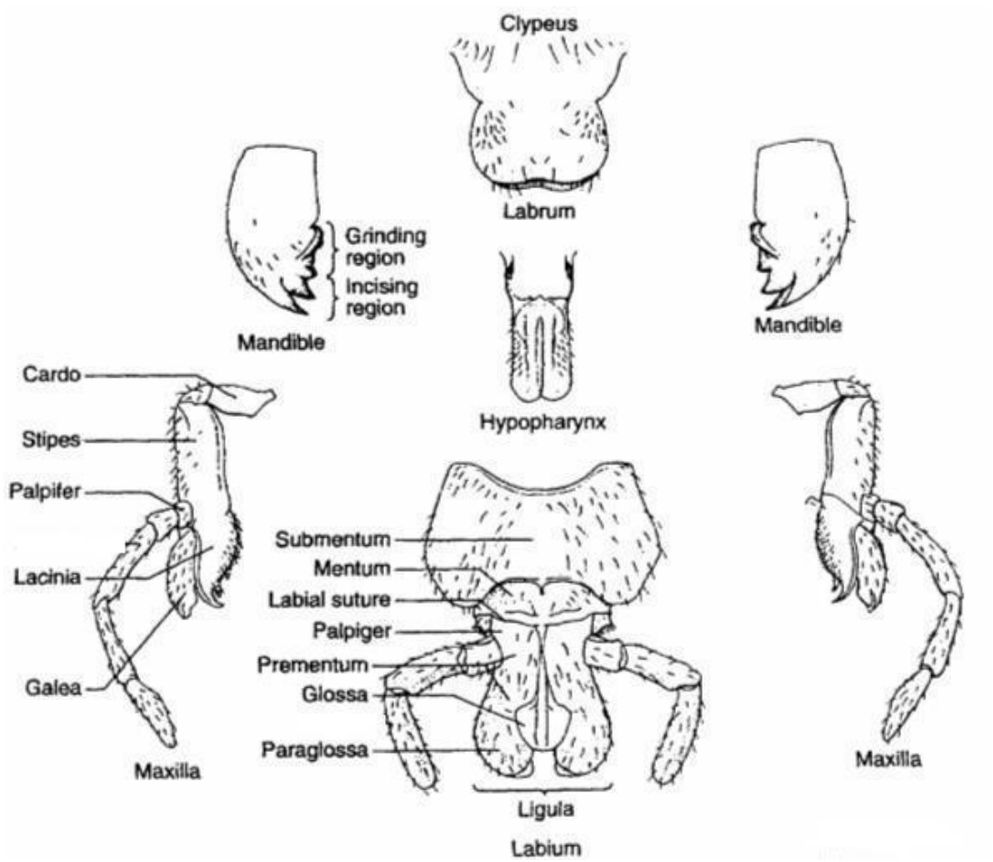


Fig. 10. Biting and chewing type of mouthparts

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.

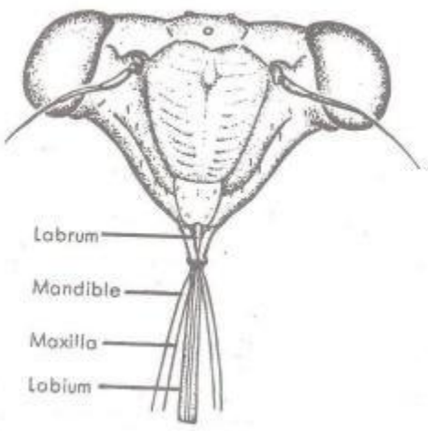
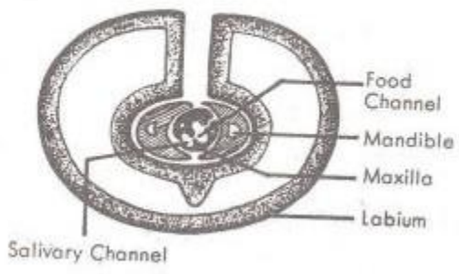


Fig. 11. Piercing and sucking mouthparts

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

Fig. 12. Cross section



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.

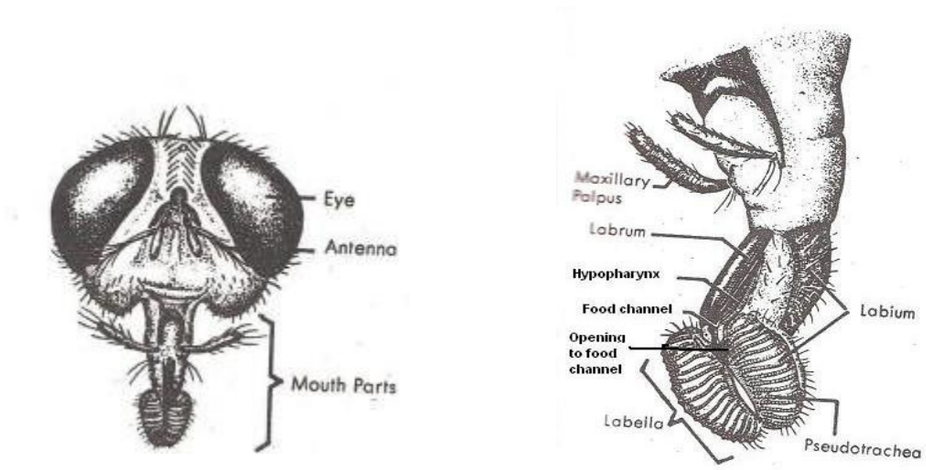


Fig. 13. Sponging type of mouthparts

(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.

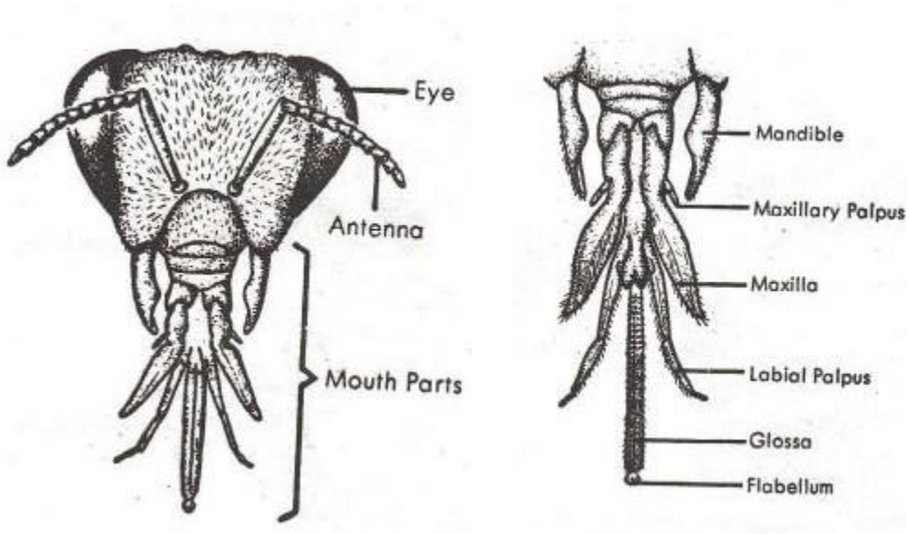


Fig. 14. Chewing and lapping type of mouthparts

(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.

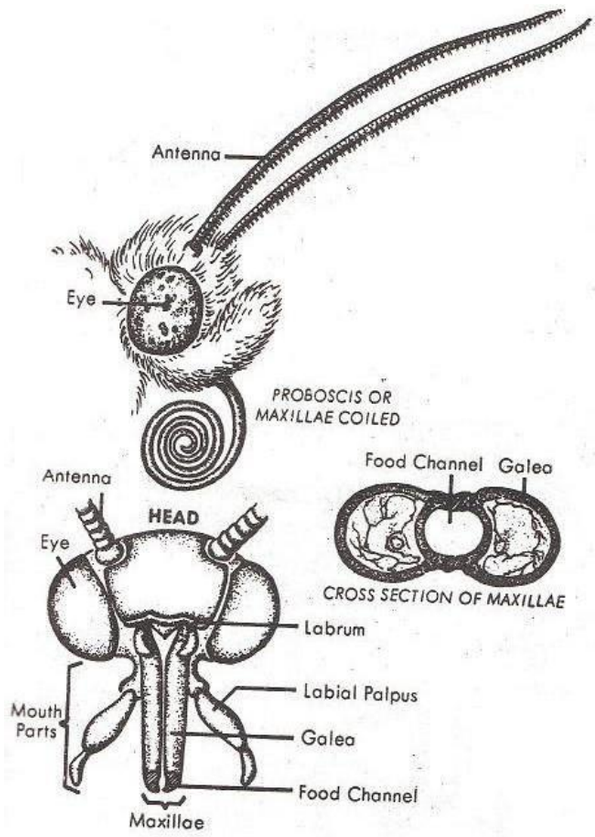


Fig. 15. Siphoning type of mouthparts

(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**.

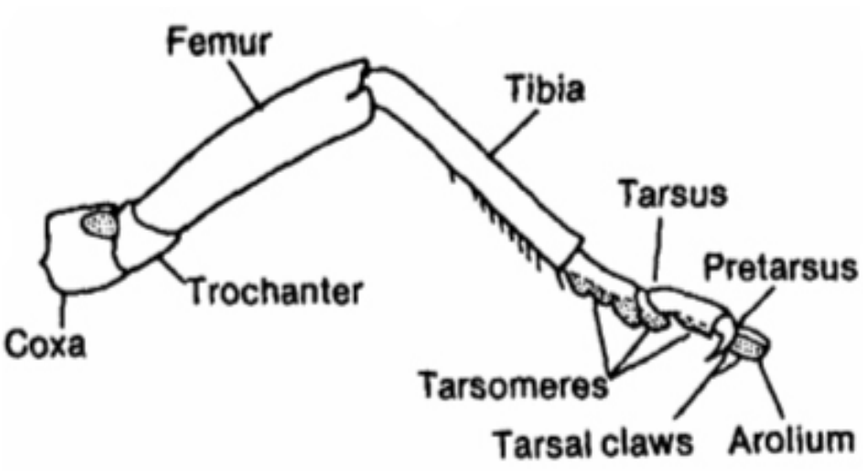


Fig 16.Structure of typical insect leg

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	Front legs	Honey bee	For cleaning	Tibia possess a movable spine, and the first tarsal

legs			antennae	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 cleaning the body	Inner surface of large tibia has a groove and is used as pollen basket or 'Corbicula' 'for temporary storage of pollen grains. First tarsal segment enlarged and possess short stiff hairs 'Pecten' all over the surface called pollen brush.

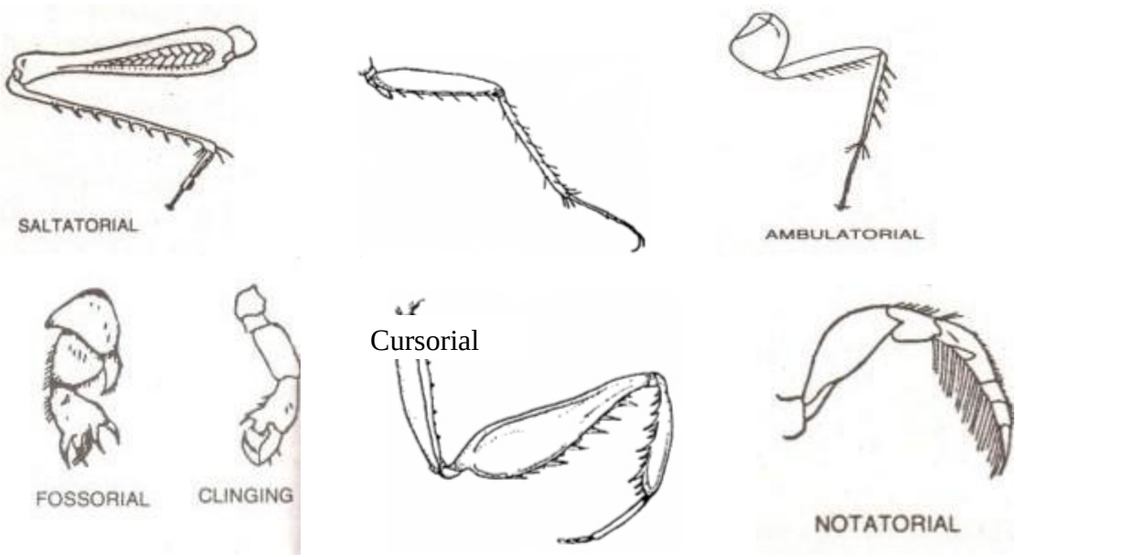
10. **Legs of immature stages:**

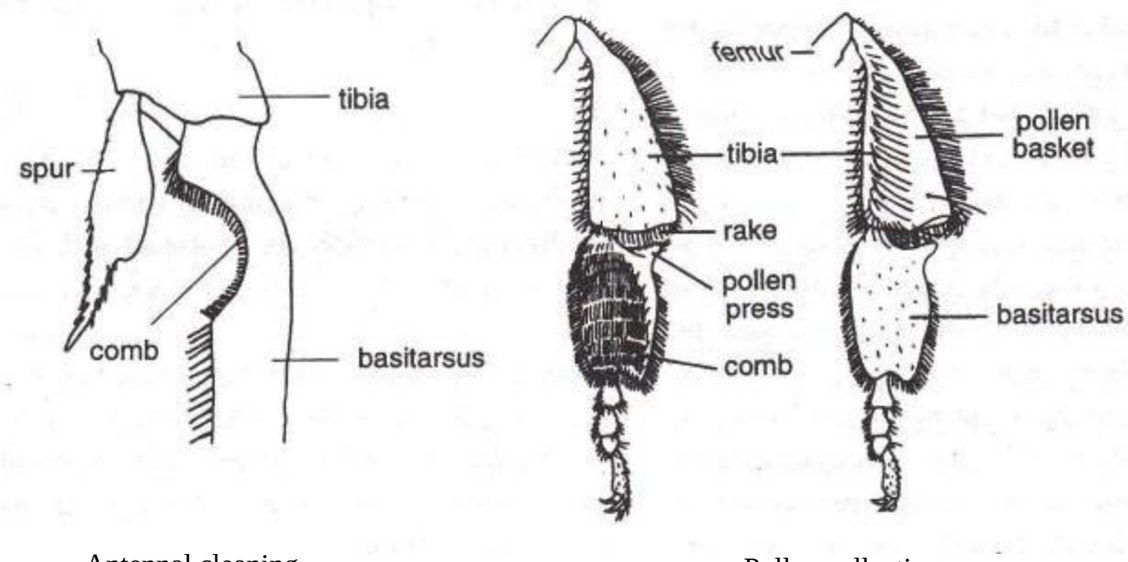
The immature stage of **exopterygotes** i.e. nymph consist of only thoracic legs similar to its adult where as that of **endopterygote** i.e. larva possess two types of legs.

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 3rd, 4th, 5th, 6th and 10th 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** .

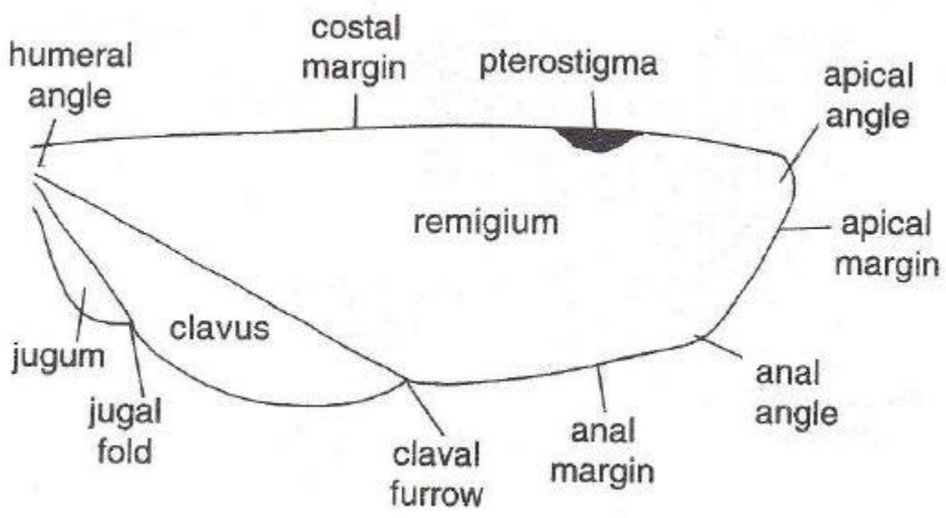


Fig. 18. Insect wing areas

(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 wi ng to the margin. They may be convex (n) 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 Sc_1 and 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 R_1 and **Rs** (Radial sector). R_1 goes directly towards apical margin and is convex; **Rs** is concave and divided in to 4 branches, 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 **MA_1** and **MA_2**. Median posterior is again divided in to **MP_1, MP_2, MP_3, MP_4**.

5. Cubitus (Cu): It articulates with median auxillary sclerite. Cubitus is divided into convex **CU_1** and concave **CU_2**. CU_1 is again divided into **CU_{1a}** and **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

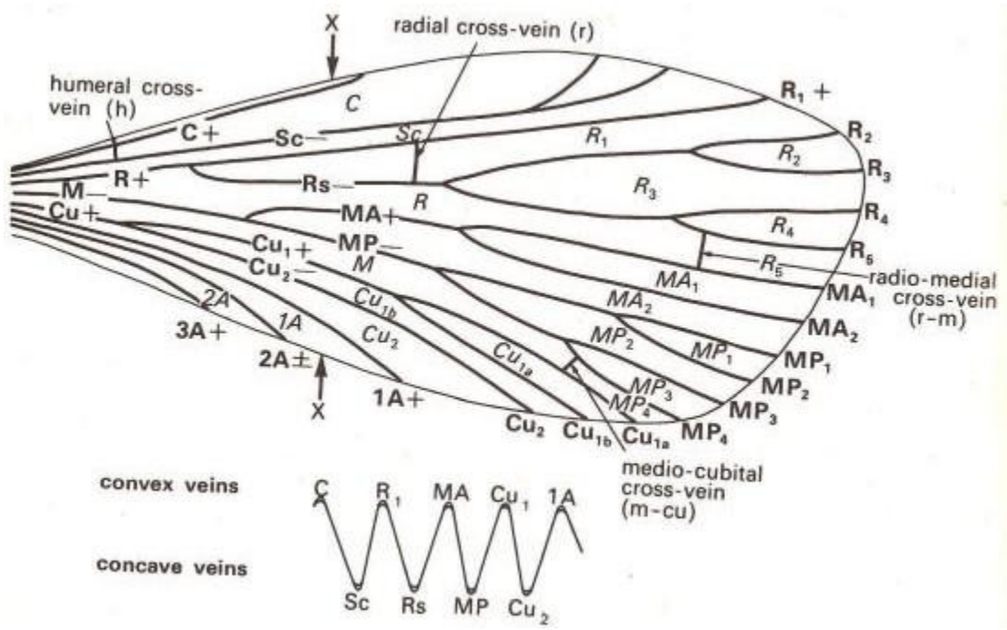


Fig. 19. Hypothetical wing venation

(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.

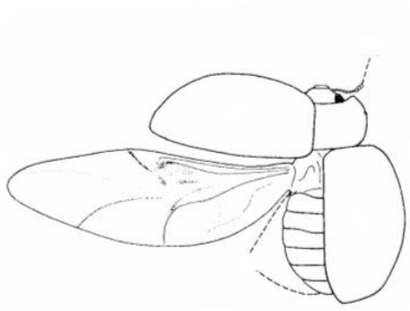
e.g.: Both the wings of plume moth

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.

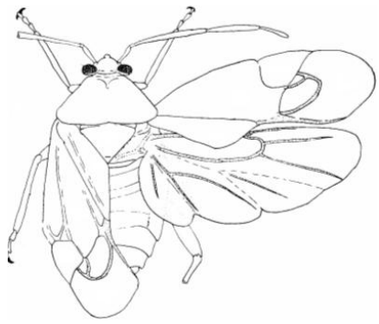
eg. Hind wings housefly and front wings of male stylopids

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

Eg: Front wings of Strepsiptera

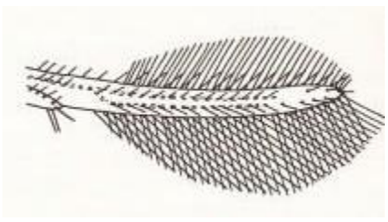


Elytra

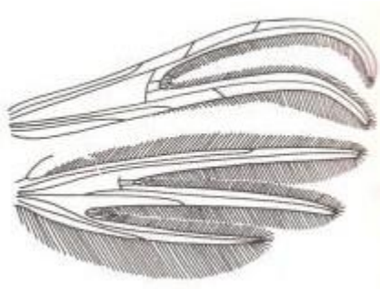


Hemelytra

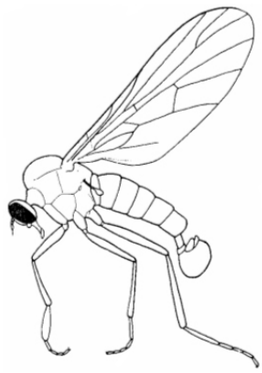
Membranous wings



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..

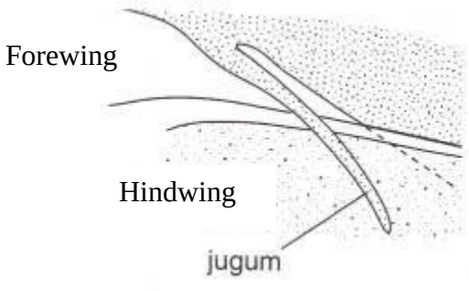
e.g.: moths

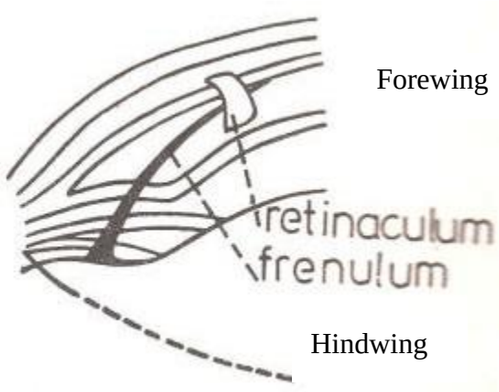
3. Amplexiform Costal margin of hind wing and anal margin of forewing overlap one above the other

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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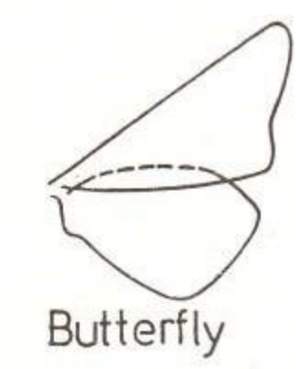
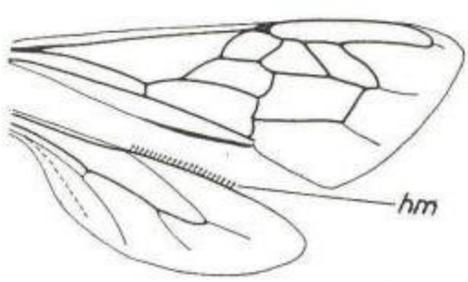




3 **4**

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.

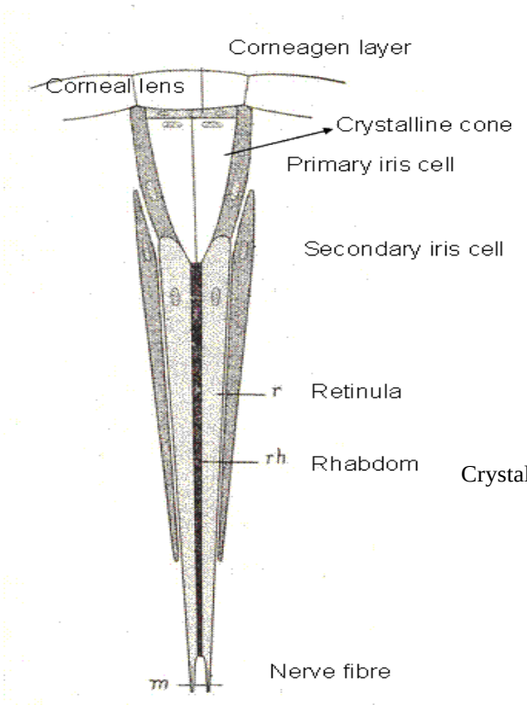
II. Simple eyes (or) ocelli:

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.



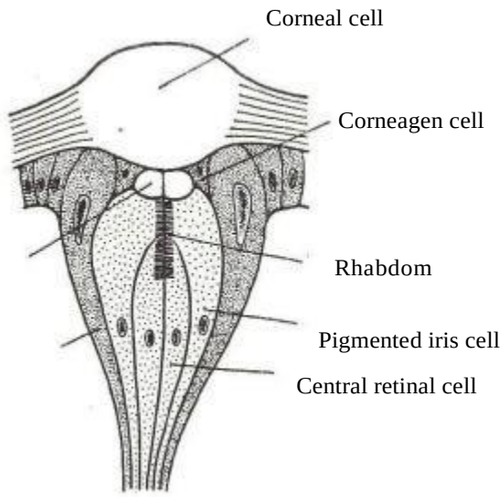


Fig. 22a Ommatadium of compound eye

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.

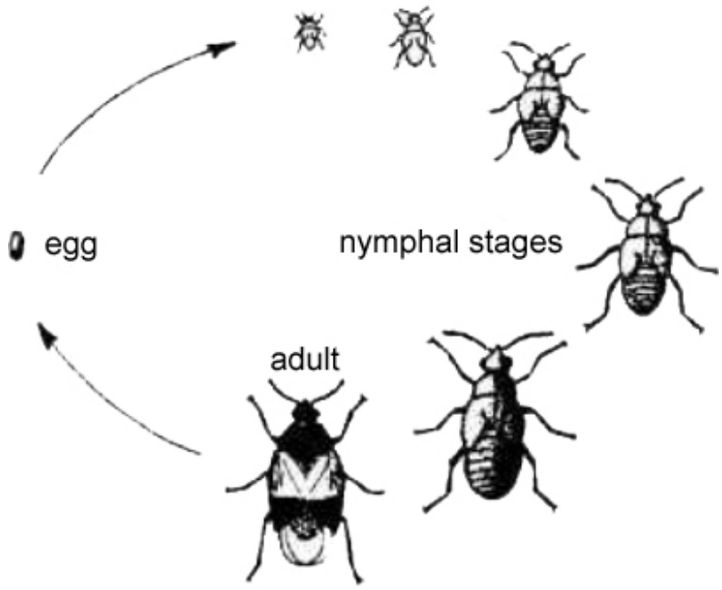


Fig. 23. Incomplete metamorphosis

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.**

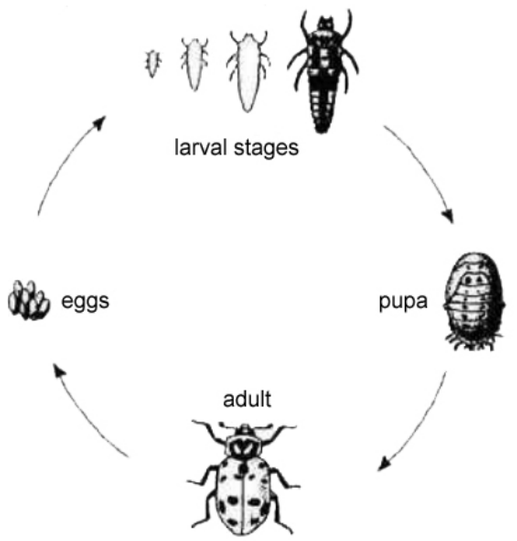


Fig. 24. Complete metamorphosis

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} abdomina l 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.

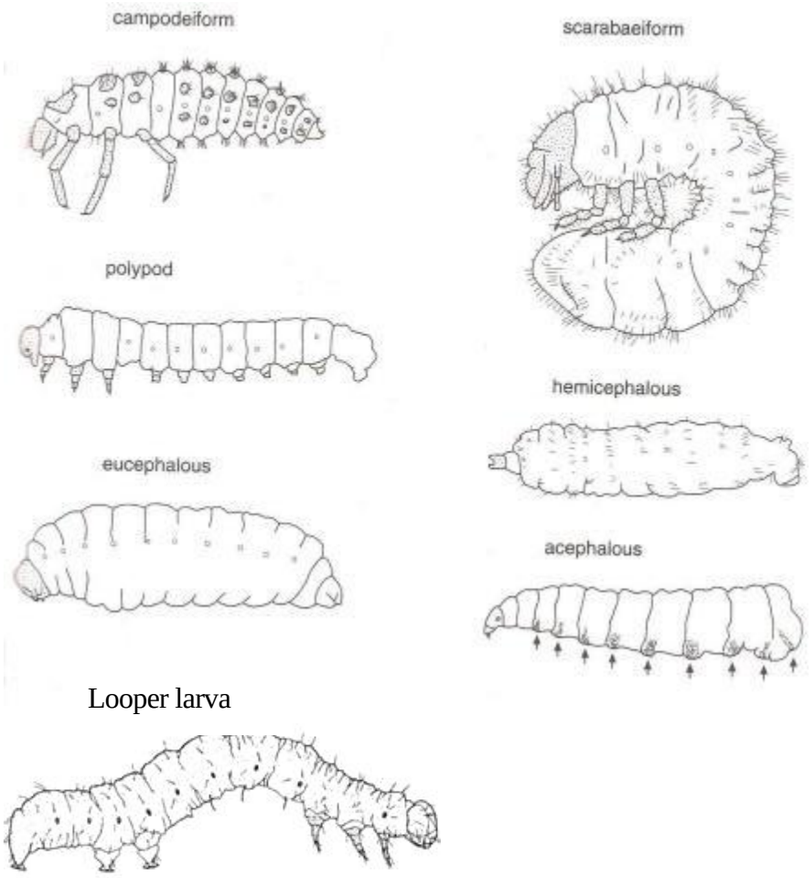


Fig. 25. Types insect larvae

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 of** 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**

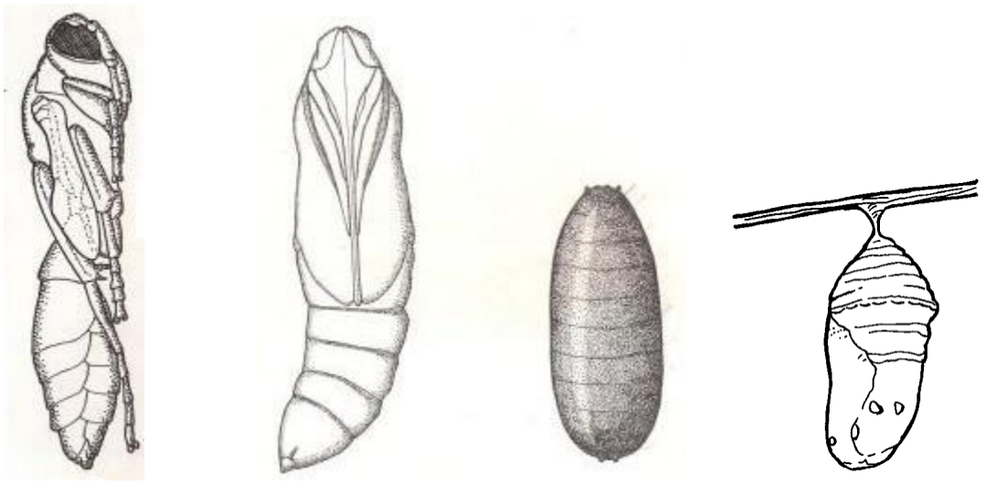
2. **Obtect** pupa eg: Lepidoptera (moths)

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 **ectodermal** 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

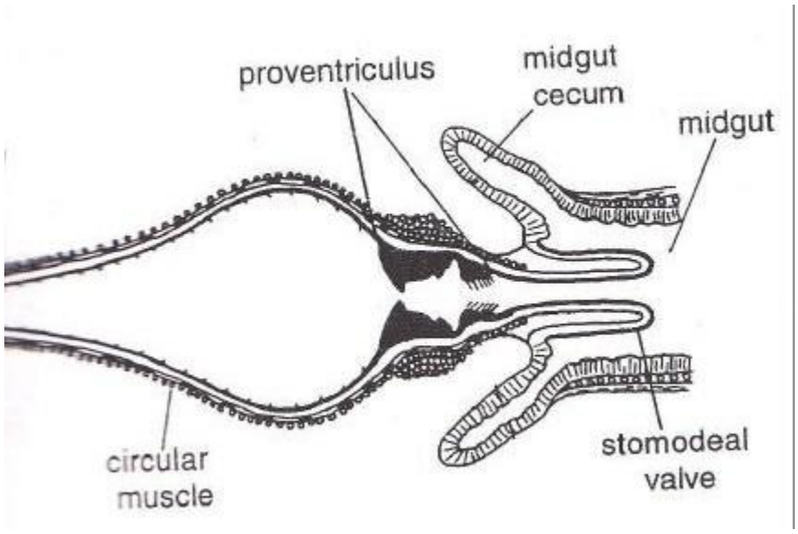


Fig. 27 Proventriculus (Foregut)

(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.**

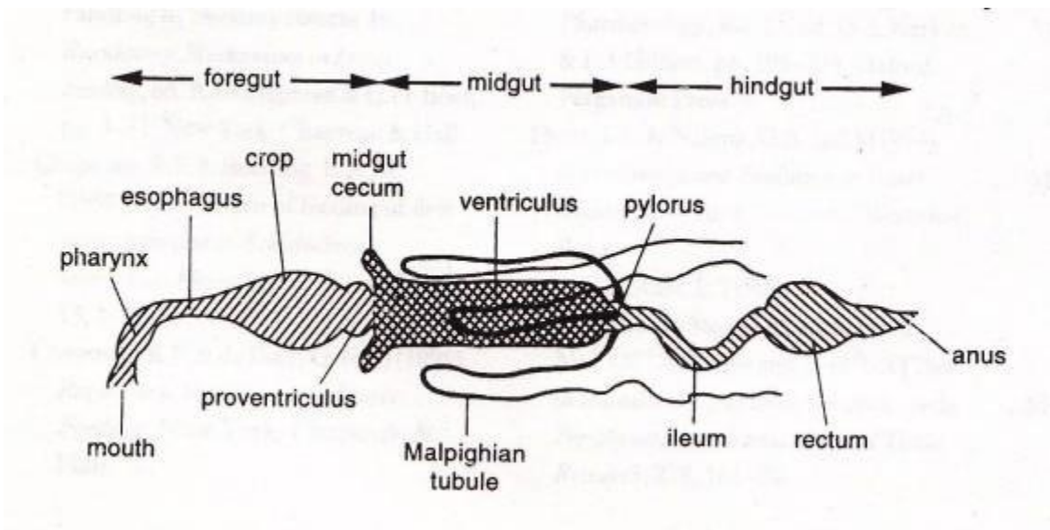


Fig. 28 Structure of alimentary canal

(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.

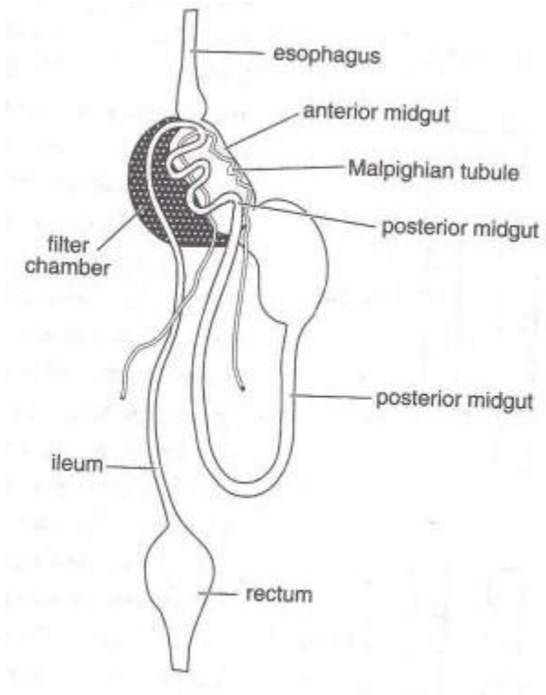


Fig. 29. Filter chamber

(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**.

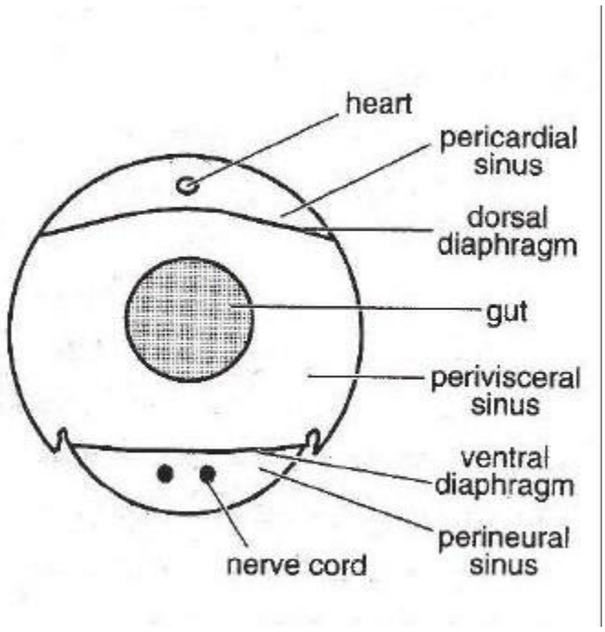


Fig. 30. Main sinuses of hemocoel

(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 .

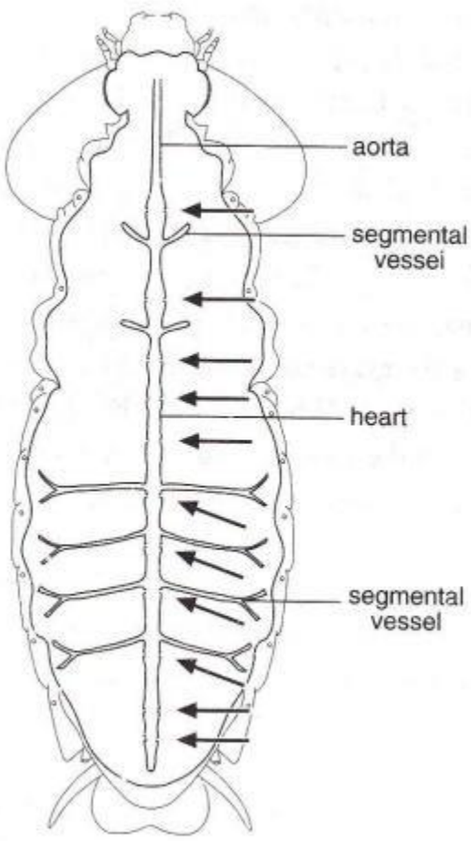


Fig. 31 Circulatory system

(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 struc tures 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.

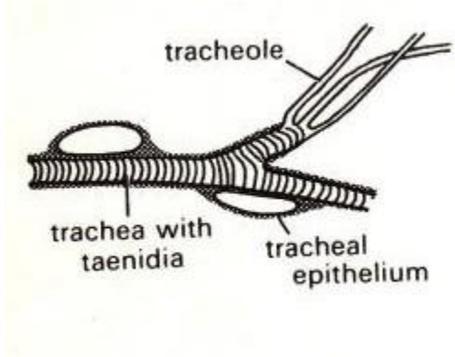


Fig. 32 Structure of trachea

(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.

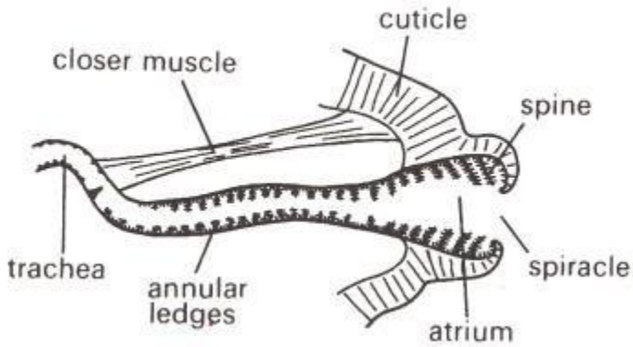


Fig. 34. Structure of spiracle

(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.

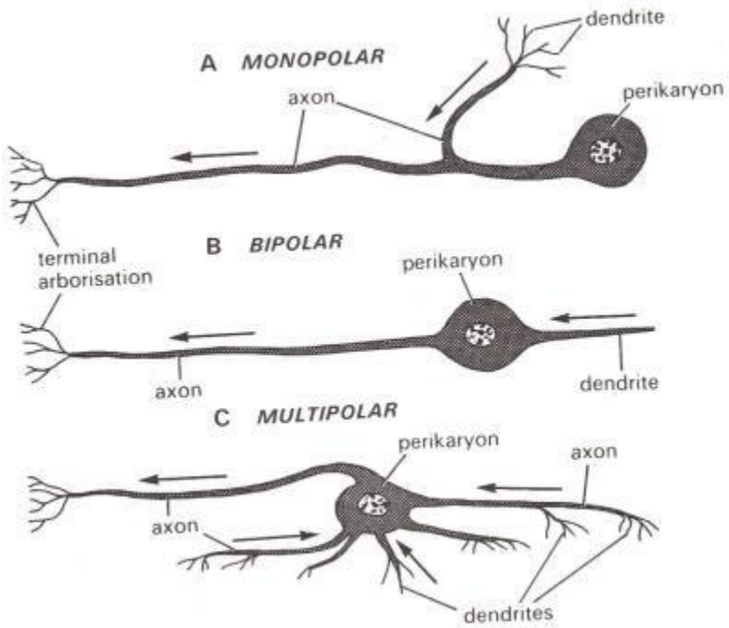


Fig. 35 Structural types of neurons

(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

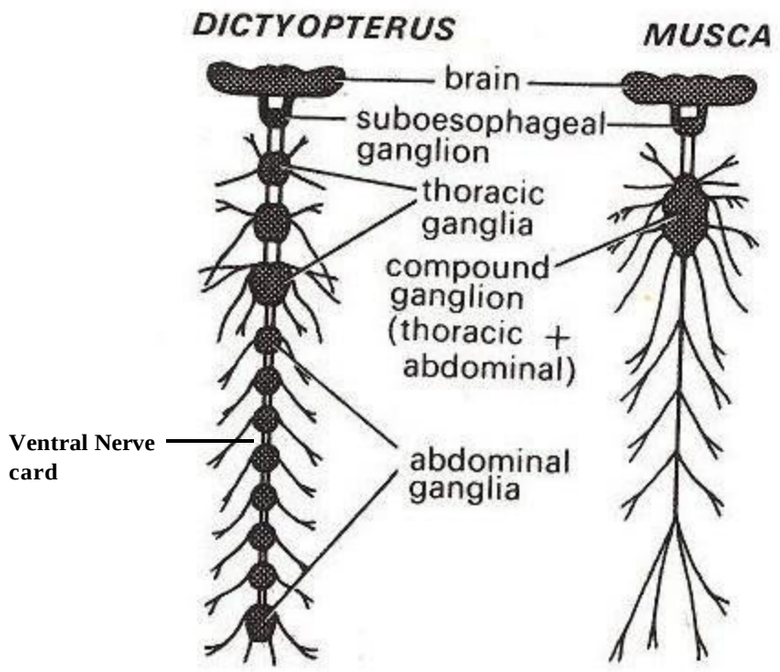


Fig. 36. Central nervous system

(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).

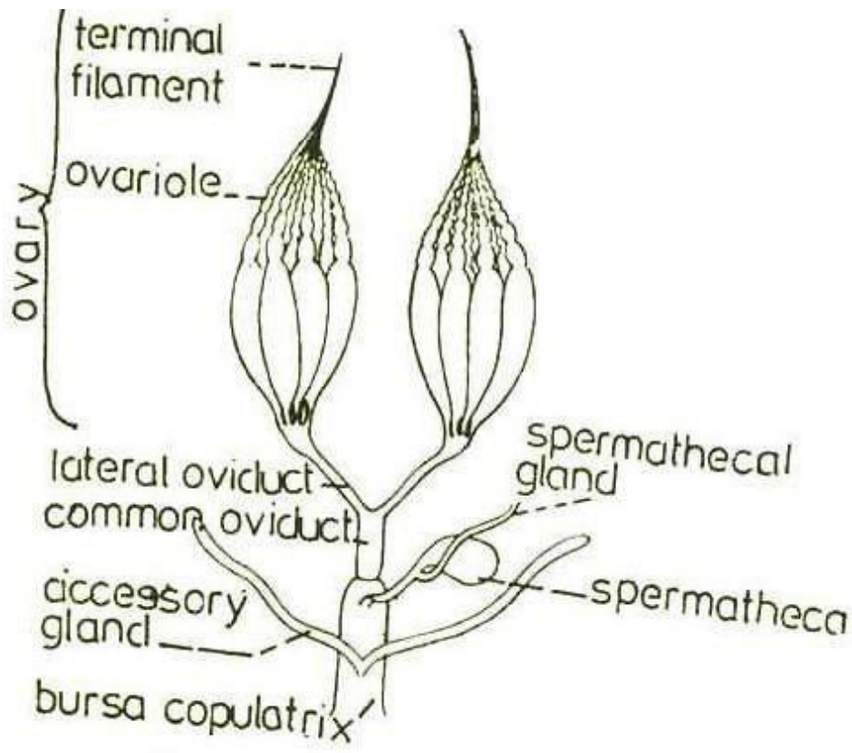


Fig. 38 Female reproductive system

(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.

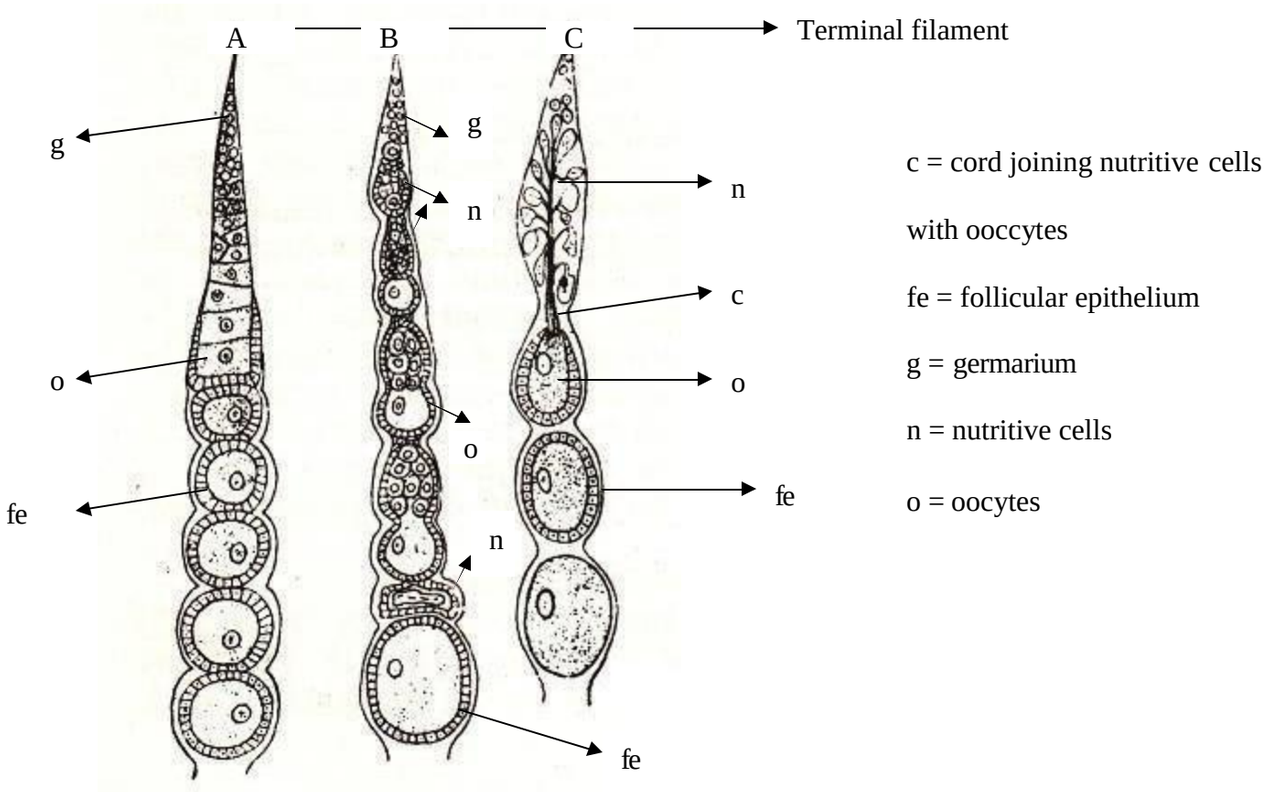
Based on the position of trophocytes **Meriostic** ovarioles are classified into

(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.

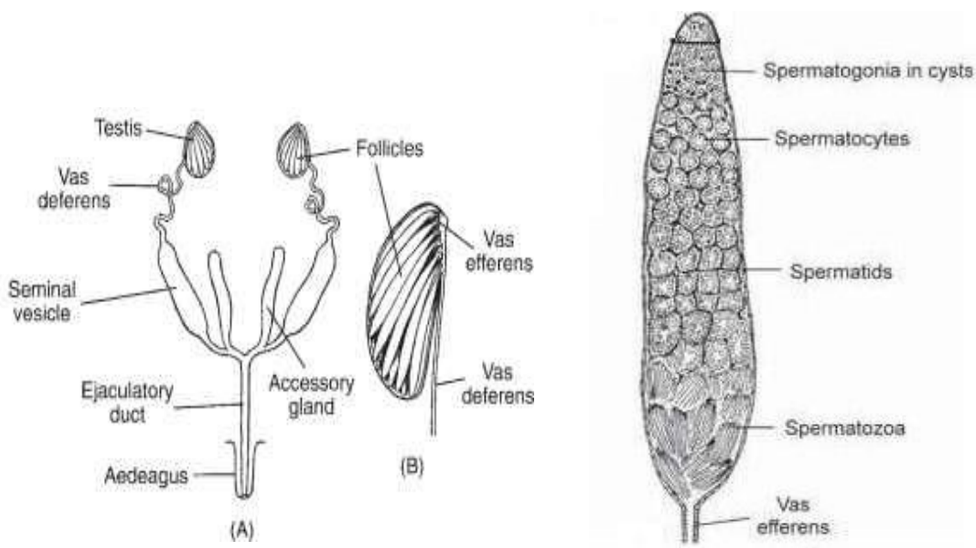


Fig. 37. Male reproductive system

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 : History of nematology, economic importance in Agriculture- Classification of Nematihelmenthes – General characters of plant parasitic nematodes

History of nematology:

The guinea worm, *Dracunculus medinensis* and round worms, *Ascaris lumbricoides* were known to Egyptians as early as 1553-1500 B.C as parasites of man.

William Shakesphere mentioned about plant parasitic nematodes in 1594 in his book" **Loves Labours Lost"** where he wrote the line " Sowed the ear cockle nematodes and called them "Vibrios".

In 1743, Needham discovered the Ear cockle nematode, *Vibrio tritici* (*Anguina tritici*) as the causal agent of "Cockles" in Wheat.

Later in 1858, Berkely reported root knot nematode from the roots of green house cucumber.

In 1857, Khun reported "Vibrios" *Anguillula dipsaci*, *Ditylenchus dipsaci* infesting the heads of teasel, *Dipsacus fullonum*.

In 1859, Schacht reported the sugarbeet cyst nematode, which was named as *Heterodera sachachtii* in 1871 from Germeny

In 1884 - **De Man** - Taxonomic monograph of soil and fresh water nematodes and

De Maris formula for measurement .

1891 - Ritzemaboss - First report of foliar nematode, *Aphelenchoides frageriae* on strawberry.

1889-1937 - Flipjer - Manual of Agril. Helminthology.

1910 - Helminthological society of Washington

1953 - Mc Beth - Nematological property of DBCP (DiBromo chloro picrin)

1957 - Hewitt, Raski & Goheen - Transmission of fan leaf virus of grapes by *Xiphinema index.*

These discoveries are considered to be the milestones of Nematology.

Important events in the field of Nematology is furnished below.

1837-1915 – **Bastian H.C,** published a monograph of "Anguillidae" in 1866 which marked the beginning of science of Nematology.

He was considered as "**Father of Nematology**".

1871 - **Kuhn** experimented with CS_2 as fumigant for control of sugarbeet Nematodes, *Heterodera schachtii*

1913 - **N.A.Cobb** published

"contributions to a science of Nematology"

lab manual "For estimating the nematodes population of soil" and

developed Sieving method for nematode extraction from soil.

He was considered as Father of American Nematology.

1941 - Discovery of potato cyst nematode, *Globodera rostochiensis* in Long Islands, USA.

1943 - **Carter** - Discovered the nematicidal properties of DD (dichloropropane-dichloropropene)

1945 - **Christie** discovered the nematicidal properties of EDB (ethylene dibromide)

1950 – **B.C. Chitwood** and **M.B. Chitwood** – publication of book "An introduction to nematology".

1955 – Founded European society of Nematologists

1956 – Publication of First Journal for plant parasitic nematodes "**Nematologica**".

1970 - Edward, J.C.& Misra,S.L.- First text book on Nematology, " An introduction to plant Nematology"

History of Nemotology in India:

"1901 - **Barber** reported - first ever report of a plant parasitic nematode from India "root-knot nematode infecting tea in south India"

1913 - **Butler** reported **Urfa disease** of rice from Bengal

1917 - Hutchinson - First report of Tundu disease of wheat, *Anguina tritici.*

1919 - **Milne** recorded seed gall nematode of wheat in Punjab

1926-34. **Ayyr** discovered root-knot nematode on vegetables and other crops in south India

1936 - **Dastur** reported **White tip** disease of rice caused by *Aphelenchoides besseyi*

1956 - Thirumala Rao - First report of root-knot nematode on citrus.

1958 - **Vasudeva** reported **Molya disease** of wheat and barley in Rajasthan

1959 - Prasad Mathur and Sehgal - First report of *Heterodera avenae*

1959-61 - **Siddiqi** discovered plant parasitic nematodes from Uttar Pradesh including citrus nematode on citrus

1961 - **Jones** reported Golden nematode of potato from Nilagiri hills in Tamil nadu

1966 - **Nair, Das and Menon** reported burrowing nematode, *Radopholus similis* on banana in Kerala

1966 - Establishment of **Division of Nematology** at Indian Agricultural Research Institute, New Delhi

1969 - Founded Nematological society of India .

First All-India Nematology symposium held at the IARI, New Delhi

1971 - Commencement of publication of Indian Journal of Nematology

1977 - Establishment of All-India Co-ordinated Research Project on Nematode pests of crops and their control at New Delhi

1979 – All India nematology workshop and symposium at OUAT, Bhubaneswar

1986 – National conference on Nematology at IARI, New Delhi

1992 – Silver jubilee celebration of division of Nematology, IARI, New Delhi

2001 – Centenary celebration of Nematology held at Division of Nematology, IARI, New Delhi.

Economic importance of Nematodes in Agriculture

The science that deals with study of nematodes is known as Nematology.
The branch of nematology that deals with animal parasites is known as **Helminthology**.
The branch of nematology that deals with plant parasites is known as **Phytonematology.**

Nematodes occur in soil and water and are ubiquitous in nature. In agricultural soils, plant parasitic species are known to occur to a depth of at least 17 feet. One gram of soil has 101 nematodes. There are about 30,000 described species, of which 50% are marine,25% free living (found in soil and water), 15% are animal parasites and 10% are **plant parasitic**. Some are **entomopathogenic** with insect killing ability through parasitism.Eg: *Heterorabditis* sp and *Steinernematidis* sp

Plant parasitic nematodes present in soil are the most difficult pest problems encountered in our country. The damage of nematodes to a crop may be to roots, stems, crowns, leaves, buds or developing seeds. The degree of damage depends upon the crop/ cultivar, nematode species, level of soil infestation and environment. Damage result in affecting plant growth resulting in low yields and poor quality.

Annual loss due to namatodes in the world has been estimated to the tune of 1000 billion dollars . Annual loss due to seed gall nematode *Anguina tritici* responsible for Ear Cockle Disease in North India is about 10000 tonnes of Wheat costing more than 70 million rupees. The golden cyst nematode of potato *Globodera rostochinensis* is a serious problem in about 3050 hectares in Nilgiri Hills and 200 hectares in Kodaikanal hills. The annual loss to Indian Coffee due to root lesion nematode *Pratylenchus coffeae* is estimated to be about 40 million rupees. AICRP on nematodes has reported an yield loss in vegetables varying from 6 to 90 %.

The groundnut yield in Rayalaseema particularly in Chittor district has been significantly reduced due to" Kalahasti Melody" for which nematodes are responsible.

Classification of Nematihelmenthis :

The nematodes have bee placed with in the kingdom –Animalia , sub-kingdom-Invertebrata and phylum – Nematihelmenthis

The concept that nematodes belong to phylum Nemata or Nematoda was first proposed by N.A.Cobb (1919) and later supported by Maggenti (1971 & 1981).

Nematodes are cylindrical, bilaterally symmetrical, unsegmented, pseudo coelomic (body cavity without epithelium), triploblastic (ie having three germ layers) , microscopic organisms with well developed digestive, excretory and reproductive systems and no respiratory and circulatory systems.

The word 'Nematode'' is derived from the Greek word, '**nema**' means threads and '**oides'** means resembling or like.

Nematodes are called as either eel worms or nemas or round worms .

Phylum Nematoda is divided in to two classes viz.,

Secernentea (Phasmida) and

Adenophorea (Aphasmida)

Characters of nematodae classes

Character	**Secernentea**	**Adenophorea**
Orders	Tylenchida, Aphelenchida	Dorylaimida
Habitat	Exclusively terrestrial, rarely fresh water or marine	Marine, fresh water and terrestrial
Amphids open on	Head near lip region	Behind head ie post labial
Oesophagous divided in to	Procarpus, isthmus and glandular terminal bulb with or without median bulb	It is cylindrical with an enlarged glandular base

Caudal glands (Three elongated cells in or near the tail)	absent	present
Male tail	Have caudal alae (bursa)	Lack bursa but possess genital papillae
Excretory system	Possess a transverse duct with lateral canals	Lacks lateral canals and excretory duct ends in a cell

Class **Secernentea** is divided in to three sub classes namely

Rhabditia – Entomopathogenic nematodes

Diplogasteria – Entomopathogenic and plant parasitic nematodes

Tylenchia (Spirulia)- Parasitic on birds, Ascaris and Fish

Class **Adenophorea** is divided in to two sub classes namely

Chromadoria -

Enopila –

Orders under different sub classes:

Rhabditia	**Diplogasteria**	**Tylenchia (Spirulia)**	**Chromadoria**	**Enopila**
Rhabditida	Diplogastrida	Tylenchida	Araiolamida	Enoplida
Oxiurida	Drylonematida	Aphelenchida	Menohysterida	Dorylaimida
Stronglida			Desmodarina	Monochida
			Chromodorina	Mermithida
			Desmoscolaicida	

Plant parasitic nematodes belong to three orders namely

Tylenchida, Dorylaimida and Aphelenchida

Characters of Plant parasitic nematode orders:

Character	**Tylenchida**	**Aphelenchida**	**Dorylaimida**
Stoma	Has protrusible stomato stylet	--	Is with mural tooth/an axial spear called as odanto or onchio stylet
Oesophagus	Has three parts	Dorsal oesophagal gland opens with in median bulb of oesophagus	Two parts- anterior part slender , posterior part expanded with 3 to 5 gland nuclei
Caudal alae	Not provided by ribs	Males with out caudal alae except Aphelencha and Metaaphelencha	
Cuticle	With distinct annulation		
Median bulb		Angular and occupy entire body diameter	
Amphids			Variable in size

The plant parasitic nematodes are classified it two groups based on plant part damaged.

I. Above ground feeders:

1. Seed gall nematodes (*Anguina tritici*)
2. Leaf and bud nematode (*Aphelenchoides* spp.)
3. Stem and bunematode (*Ditylenchus* sp.)

II.Below ground feeders :

Based on mode of feeding , they can be divided in to three groups

i) Endoparasites

a) Sedentery:

Root knot nematode (*Meloidogyne* spp)

Cyst forming nematodes (Heterodera and Globodera)

b) Migratory:

Lesion nematode (*Pratylenchus* sp)

Burrowing nematode (Radopholus similis)

Rice root nematode (*Hirschmaniella* sp)

ii) Semi Endoparasites :

a) Sedentery:

Citrus nematode: (*Tylenchulus semipenetrans*)

Reniform nematode (*Rotylenchulus reniformis*)

b) Migratory:

Spiral nematode (*Helicotylenchus*, *Rotylenchus*)

Lance nematode (*Hoplolaimus* sp.)

Stunt nematode (*Tylenchorynchus*, *Microlinus*)

iii) Ectoparasites :

a) Sedentery:

Ring nematode (*Criconema* sp, *Cricuneroides* sp)

Shead nematode (*Hemicriconemoides* sp , *Hemicycliophora* sp)

Pin nematode (*Pratylenchus* sp)

b) Migratory:

Needle nematode (*Longidorus* sp)

Dagger nematode (*Xiphinema* sp)

Stubby nematode (*Trichodorus* sp)

General Characters of Plant Parasitic Nematodes :

Nematodes are cylindrical , bilaterally symmetrical , unsegmented, pseudo coelomic (body cavity without epithelium), triploblastic (ie having three germ layers) , microscopic organisms with well developed digestive, excretory and reproductive systems and no respiratory and circulatory systems.

In general nematodes are **dioecious** (males and females are separate).

For sucking the food material from the plant parts the plant parasitic nematodes possess protrusible piercing **sphere/ stylet** (ie Stomato stylet (Axial holosphere) in Tylenchida and Aphelenchida , **Odonto stylet** in Dorylaimida , **Onchio stylet** (Solid stylet) in Trichodorida).

All Plant Parasitic Nematodes prefer sandy loam soils. Due to their microscopic nature and passive mode of life, their role in Agricultural Production remained underestimated.

Lecture - 22 : Different Functional Systems of Nematodes

Morphology

Body shape & size

Sexual dimorphism occur in some members of Tylenchida, where females become swollen and males are vermiform.

Eg. *Anguina, Meloidogyne, Heterodera, Rotylenchulus* and *Tylenchulus* etc.

Size vary from 0.2mm (*Pratylenchus*) to about 11mm (*Paralongidorus maximus*) averaging about 1.0mm in length. Width range from 0.01 to 0.5mm. The nematode parasitising whale fish is about 27 feet long.

Body Posture:

Nematode, when relaxed by gentle heat, remain straight (*Pratylenchus)*, Slightly curved ventrally (*Hoplolaimus),* curved dorsally into 'C' shape(*Dorsalla)* Curved i nto 'e' shape (*Tylenchorhynchus)* or spiral (*Helicotylenchus).*

Body is not segmented. However, body appears segmented as annulations of cuticle as in *Criconema.* Body show radial symmetry in the anterior region and asymmetry in intestine, excretory and reproductive systems.

Body at the anterior region has **mouth**, **lips** and **stoma** forming the head position. Behind the head and base of Oesophagous is the neck, from anus and extending to the posterior extremity is the tail.

Body longitudinally can be divided into four zones, ventral side having the natural openings i.e. excretory, anus and vulva. Side opposite to ventral is dorsal.

Head or lip region:

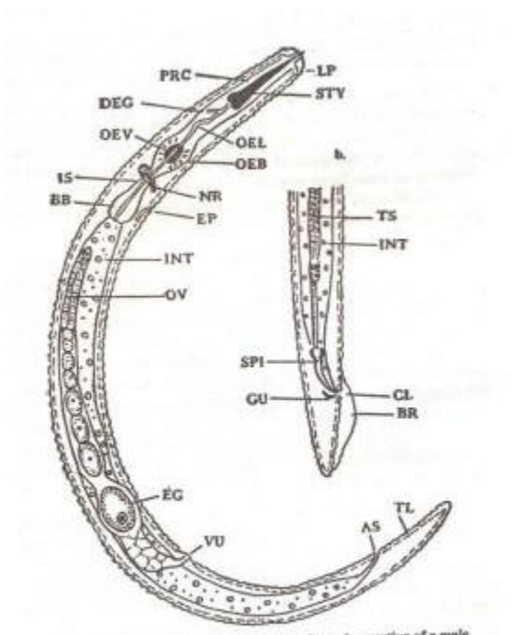
In some nematodes (*Ecphyadiphora)* head in merged with body or it may be truncates (*Duotylenchus*)or it may be distinctly set off (*Dolichodorus)*.

Around the lip region, number of **annules** formed by transverse striae are present. However, longitudinal striations are also found in lip region of *Hoplolaimes* that gives **tick like** appearance.

Tail:

Present in male, female and larva. Tail vary in shape and size. Sometimes it may be different in larva and adult or it may be present in larva but reduced or absent in adult as in *Heterodera* and *Globodera.*

Tail is a **locomotory** organ useful for **swimming** in aquatic nematodes. Other structures present at tail region include **caudal alae**, **bursa** and **genital papillae** that help in reproduction. Tail tip may be filiform, conoid, hooked short bluntly conoid, hemi-spheroid or clavate type.



A typical female nematode, b. Posterior portion of a male nematode, AS, Anus; BB, basal bulb; BR, Bursa; CL, Cloaca; DEG, dorsal oesophageal gland opening; EG, egg; EP, excretory pore; GV, Gubernaculum; INT, intestine; IS, isthmus; LP,lip; NR,nerve ring; OEB,median oesophageal bulb; OEL, oesophageal lumen; OEV, oesophageal valve, OV, ovary, PRC, procorpus, SPI, spicule, STY, Stylet, TL,Tail; TS, testis, VU, vulva.

General structure of Nematode:

Body is tubular and divided into three regions

1. Outer body tube or body wall.
2. Inner body tube or alimentary canal.
3. Body cavity or Pseudocoelom in which excretory, nervous and reproductive system are present.

1. Outer body tube:

Consists of three layers; the cuticle, epidermis(hypodermis) and somatic muscle layer.

Cuticle: is the outermost layer non cellular secreted by epidermal cells derived from ectoderm serves as exoskeleton and protect the inner soft body tissues.

Cuticle has three layers

1. Outer cortical - has keratin and collagen disulphide group – give resistance nature.
2. Matrix - Consists of protein resembling collagen. It is not metabolically active layer.
3. Fibre Layer - protect nematode from environment.

Hypodermis / Epidermis : It lies between cuticle and somatic layer. It is responsible for formation of cuticle. In higher nematodes it is rich in lipids and glycogen which serve as source of reserve energy .

Somatic muscle layer:

These are arranged longitudinally beneath the hypodermis in the interchordal zones.

Based on arrangement the following types of cells are present

1. Holomyarian - Have 2 muscle cell in each zone.
2. Meromyarian - 2 or 5 muscle cells in each zone.
3. Polymyarian - More than 5 muscle cells per zone

Based shape of cells they are grouped in to –

1. Platymyarian - flat type of muscle cell
2. Coclomyarian - 'U' shaped cell muscle fibre are adjacent and perpendicular to epidermis
3. Circomyarian` - Muscle fibre completely surround the cytoplasm

Nematode muscles are unusual, in that muscle sends branches to nerves rather than nerves send branches to muscle.

Inner body tube or digestive system:

It is divided in to **stomodeum** (foregut), **mesenteron** (Midgut) and **proctodeum** (Hindgut). Foregut and hindgut are **lined with cuticle**. Proctodeum is small and includes the **rectum** in females and **cloaca** in males, Midgut is **endodermal** in origin.

Stomodeum: It includes mouth and lips, the stoma and the oesophagus. Six lips surround the mouth.

Mouth cavity is called **stoma or buccal cavity** forming the feeding apparatus.

In the order Tylenchida, stoma has protrusible hollow stylet, formed by the fusion of stomal walls, hence called **stomatostylet.**

In the order, Dorylaimida, stylet is formed from oesophagial wall, hence called **Odontostylet**

It is a replaceable stylet, it is also called **Odontostyle or Ononio stylet**

Phaynx or Oesophagus : It is found between stoma and intestine. Serves to pump food from stoma into intestine. Oesophagus may be simple consisting of cylindrical muscular tube as in Monenchida.

In Dorylaimida, it is bottle shaped and with narrow anterior and broad posterior part.

In Tylenchida, cylindrical oesophagus has 3 parts i.e. **corpus**, **isthumus** and **basal bulb**. Corpus is further divided into anterior cylindrical **procorpus** and swollen **metacarpus.**

Mesenteron : It is divided into 3 distinct regions (1) anterior ventricular region, (2) mid intestinal region and (3) posterior or pro rectal region. Inside, plasma membrane is thrown in to finger like projection called **microvilli ,** which are **secretary and absorptive** in nature.

Proctodeum : Rectum is a narrow tube connecting intestine in the slit like anus in females and cloaca in males.

In Dorylaimida, a distinct region known as **prerectum** is found between intestine and rectum.

In some nematodes, rectal glands which are 3 in females and 6 in males are present, which are responsible for production of gelatinous matrix in which eggs are laid.

Body Cavity:

Body cavity is devoid of **mesoderma**l lining,hence, it is called **pseudocoelom**.. Externally it has somatic muscle cells and internally cells of alimentary canal. Pseudocoelom is filled with fluid which is rich in proteins and bathes all internal organs and functions as part of the **turgor pressure** system on the exoskeleton.

The pseudocoelom is also linked with a network of fenestrated membrane that support visceral organs.

Excretory system:

Different types of excretory systems are found in Nematodes, **Vonlinstow**, 1909 classified nematodes into **4** groups based on excretory system viz:

1. Secerentes 2. Resorbents 3. Pleuromyarli 4. Adenophori.

Now secerentes are synonymous to resorbants; Pleuromyarli with Adenophori.

Morphologically excretory system is of two types

(1) **Renette type** has large cell in the pseudo coelomic cavity known as renette or ventral gland, which is connected to the excretory pore by a duct Eg. Adenophorea

(2) **Tubular** or **Canalicular** type : Eg. Secernentea

Tubular type that may be

(a) simple H shaped (Oxyuroid type)

(b) Rhabditoid type

(c) Ascaridid type 3 Nuclei (Invented U shape)

(d) Asymmetrical type or uni nucleate system.

In tylenchida, the terminal duct points the lateral canal and there are (2) nuclei,

The excretory system also plays important role in osmoregulation, in addition to excretion so it is called as excretory secretory sytem.

Reproductive system:

Nematodes are **dioceous or amphigonus** having separate males and females within a species. Generally males are less in number than females or may be absent completely, indicating reproduction by hermaphroditism or parthenogenesis.

Hermaphroditism: -an individual function both as male and female. It may be

1. **Syngonic Hermaphroditism:** gonads first produce sperms that are stored and fertilize eggs produced later .

Eg. *Caeonoshabditis briggsae*.

2. **Digonic Hermaphroditism** : Both sperms and ova are produced simultaneously by different parts of same gonad.

Eg. *Helicotylenchus sp.*

Parthenogenesis: If males are not found or less in number , eggs can reproduce without fertilization.

Eg. *Meloidogyne, Heterodera, Tylenchulus*.

Intersexes are found in some genera like *Meloidogyne* and *Ditylenchus* – it is an individual that show blending of both male and female characters usually females showing male characters of pseudo coelomic fluid. The nervous, excretory and reproductive system are present in pseudocoelom.

Male reproductive system:

Nematode may consists of one or two testes ,If it is only one testes – it is called **monarchic,** Two testes – **diarchic.**

In diarchic forms testes may be outstretched i.e directed opposite to each other except in *Meloidogyne* where they are in parallel position. Males have testes, seminal vesicle and vasa difference.

Male nematodes ha ve a pair of **copulatory spicules** which are lodged in the spicular pouches formed as out growths of dorsal wall of the rectum.

Spicules are tubular structures covered by sclerotized cuticle. It functions to open the vulva for transfer of sperms during copulation.

Spicule is divided into 3 parts:

1. Head known as **capitulum.**
2. Shaft known as **corpus or calomus**.
3. The blade or **lamina** that tapers to tip.

Gubernaculum : Sclerotized plate like structure located dorsal to the spicules.

Eg. *Tylenchorhynehus , Ditylenchus.*

Sexual dimorphism is very common among females of ***Meloidogyne ,*** where they are swollen and males are slender, worm like

Female Reproductive :**system**

The female has a single ovary, it is called as **monodelphic**. If at anterior to vulva, monodelphix or **prodelphic ,** posterior **– opisthodelphic**, two ovaries – **didelphic;** among the two, if one is towards anterior other is towards posterior end of the body, it is called **didelphic**, **amphidelphic**. However, in *Meloidogyne* and *Heterodera* , both the gonads are directed towards the anterior end of the body with reflexed ovaries, it is called didelphic, prodelphic.

Female reproductive system consists of an ovary, oviduct, uterus, vagina and vulva,

Eggs have outer protein layer, chitinous layer, a vitelline or lipid membrane

Gelatinous matrix is secreted by rectal glands in which eggs are deposited. If eggs are laid outside the body – it is called **exotoky.**

Eggs deposited with the body of female – **endotoky**

Nervous system:

It is not well studied in nematodes particularly in Tylenchida due to its small size. The central nervous system has nerve ring, associated ganglia and the ventral nerve. The nerve ring is broad, flat present around the oesophagus.

In Tylenchida, it encircles the middle part of the oesophagm.

In Dorylaimida, it is present around the narrow anterior part of oesophagus.

Ventral nerve is a chain of ganglia. The first and largest ganglia is known as Retro – vesicular ganglia

Sensory organs

Amphids : lateral pair of sensory organs or chemoreceptors present in the cephalic region of the nematode. They are larger in males than females.

Phasmids: Paired lateral sense organs usually one on each side of tail.

Deirids: paired papillae present in the oesophageal mid region of the body opposite to the excretory pore. Do not open outside Also called as **Cervical papillae** function as mechanoreceptors.

Hemizonids and Hemizonion : Highly refractive biconvex structure forming a semi-circle on the ventral side of the body and ending at the lateral fields. Hemizonion is a small nerve commisure.

Cephalids: Highly refractive band like structure present in the cuticle dorsally.

Caudalids: small nerve commissure in caudal region slightly posterior to anus.

Lecture - 23 : Biology and Ecology of nematodes-types of parasitism-complex diseases caused by nematodes:

Biology :

The plant parasitic nematodes have 6 stages in their life cycle. They are

1. Egg , 2. First stage larva/juvenile (J_1)

3. Second stage larva/juvenile (J_2), 4. Third stage larva/juvenile (J_3)

5. Fourth stage larva/juvenile (J_4) and 6. Adult

The first stage juvenile undergo molting with in the egg after hatching and second stage juveniles will be released into the soil, which is the infective stage. Larva or juvenile undergo moulting thrice and then develops into adult.

The female lays eggs in the soil or plant tissue either singly or in masses that hatch into larvae which are almost similar to adults in appearance. The first moulting usually occurs before hatching when the larvae is within the egg shell. The larva undergoes series of four moults. The period of growth between moults are called juvenile stages.

The first larval stage is ended by the first moult, the 2^{nd} stage by second moult. After 4^{th} moult the adult is formed. In case of *Xiphinema index* the larvae emerge from the egg before the first moult. The larval cuticle is shed after each moult.

The average number of eggs laid by nematode may be 200-500. The total lifecycle will be completed in 20-40 days.

NATURE OF DAMAGE:

Majority of phytophagous nematodes are polyphagous infecting wide range of hosts among which a few may be more favourable than others. These nematodes feed on plant tissues by sucking sap from the host cell with the oral stylet that is used as a hypodermic needle to puncture the host cell. Nematodes usually cause damage by

Mechanical injury – by penetration and movement through plant tissues causing cellular changes like necrosis – death of cells and causes some

Physiological changes in the host by interruption in uptake of nutrients and water from roots as vascular bundles get damaged.

Provide avenue for **entry of other microorganisms**

Interaction with other **disease causing organisms**

Transmission of disease causing organisms and

Increase susceptibility to **environment stress**

Classification of Nematodes (based on plant part damaged).

I. Above ground feeders:

1. Seed gall nematodes (*Anguina tritici*)
2. Leaf and bud nematode (*Aphelenchoides* spp.)
3. Stem and bunematode (*Ditylenchus* sp.)

II. **Below ground feeders :**

Based on mode of feeding , they can be divided in to three groups

i) Endoparasites: remain inside the host and feed

a) **Sedentery:** enter in to the root and settle at one place for feeding

Root knot nematode (*Meloidogyne* spp)

Cyst forming nematodes (Heterodera and Globodera)

b) **Migratory:** enter in to the root system and feed from cells as they migrate

Lesion nematode (*Pratylenchus* sp)

Burrowing nematode (Radopholus similis)

Rice root nematode (*Hirschmaniella* sp)

ii) Semi Endoparasites : half of the body remain outside and half inside the plant tissue

a) **Sedentery:** only anterior portion will be inserted in to plant tissue and settle at one feeding site.

Citrus nematode: (*Tylenchulus semipenetrans*)

Reniform nematode (*Rotylenchulus reniformis*)

b) **Migratory:** only anterior portion will be inserted in to plant tissue and move from one site to other feeding site

Spiral nematode (*Helicotylenchus*, *Rotylenchus*)

Lance nematode (*Hoplolaimus* sp.)

Stunt nematode (*Tylenchorynchus*, *Microlinus*)

iii) Ectoparasites : nematode remain outside the host and suck the sap

a) **Sedentery:** remain outside the host throughout its life and settle at place for feeding

Ring nematode (*Criconema* sp, *Cricuneroides* sp)

Shead nematode (*Hemicriconemoides* sp, *Hemicycliophora* sp)

Pin nematode (*Pratylenchus* sp)

b) **Migratory:** remain outside and move from one feeding site to the other

Needle nematode (*Longidorus* sp), Dagger nematode (*Xiphinema* sp)

Stubby nematode (*Trichodorus* sp)

Symptoms of nematode infection:

Nematode infected plant lack vigour and have reduced ability to withstand drought and adverse conditions. Various types of symptoms due to nematode infection are furnished below

A. Above ground symptoms:

1. **Distorted and abnormal growth**: *Anguina tritici* larvae feed on the growing point of wheat seedlings without killing it. The affected plant show twisted and crinkled leaves. *Aphelenchoides* spp. associated with straw berry disease known as

'spring crimp' & 'summer crimp' , here the leaves become crinckled abnormally dark in colour & brittle.

2. **Leaf galls:** some spps of *Anguina* produces galls on leaf surface.

   Eg: *A. tumifaciens* produces galls on *Cynodon transvalenses & A. graminis* on *Festuca ovina & F. rubra.*

3. **Seed galls:** Eg: *A. tritici* on wheat. The nematode larvae feed on floral primodia & seeds gall become green & soft in initial stage & later on turned into black – brown hard structure. and *A.agrostis* on *Agrostis tenuis*.

4. **Stem galls:** A number of spp of *Anguina* forms galls on *Cyanodon transvalensis.* These galls may be greenish or reddish in colour.

5. **Necrosis & discolouration of foliage & stem:** Discolouration of stem & foliage may range from light to dark shades & these symptoms are not very specific. Eg: *Aphelenchoides ritzembosi* causes interveinal discolouration in Chrysanthemum & strawberry and a similar symptom is produced by *Ditylenchus dipsaci* on aster leaves. On coconut, *Rhadinaphelenchus cocophilus* produces a band of necrotic tissues in the lower part of the stem & which turns reddish in colour due to death of cells.

6. **Lesion & spots:** The foliar nematodes causes destruction of leaf parenchyma which may appear in the form of spots or lesions. The spots first appear on the lower side of leaf surface as small yellowish areas, which later turned to brown & finally black in colour. These spots may coalesce together & the entire leaf is destroyed.

   Eg: *Aphelenchoides ritzembosi* on chrysanthemum *& A. fragariae* on Begonia.

7. **Devitalised buds:** This type of symptom may result in killing buds or growing points & stopping further growth of the affected tissues. *A.besseyi & A. fragariae* may cause this type of injury on strawberry.

B. Below ground symptoms:

Nematode produces a wide range of symptoms on under ground parts of the plants which may be specific or non specific types.

1. **Root galls & cysts:** Galling of roots is the most characteristic symptom produced by root knot nematodes. Small root galls can be produced by *Hemicycliophora arenaria* on citrus, by *Xiphinema diversicaudatum* on roses. The size & number of galls may vary with host crops & nematode spp. . In cyst nematodes the presence of white to brown cyst projecting on root surface is seen.

2. **Root proliferation:** Some spp of nematodes do not cause generally decay of roots. But due to injury plants grow more roots in cluster, especially behind the damaged portion. *Heteroderous sp., Globodera rostochinensis , Trichodorous christei & Meloidogyne* sp. produce such type of symptoms.

3. **Lesions & necrosis:** Typical lesions are produced by the lesion nematodes, *Pratylenchus sp.,* burrowing nematode, *Radopholus similis* & rice root

nematode, *Hirschmaniella sp*. Ectoparasitic nematodes may cause superficial discolouration & injury due to killing of cells over large area. Eg: *Xiphinema sp., Tylenchulus semipenitrans & Aphelenchoides sp.*

4. **Devitalised root tips:** Many nematodes penetrate roots just behind the root tip resulting in stoppage of further growth & a situation arises when the root system appears to be composed of cluster of stubby roots. Eg : *Trichodorous & Belomolaimus sp*. Sudden halt in growth of lateral roots just as they are emerging from main roots.

5. **Root rots:** Many nematodes parasitizing fleshy roots serve to initiate & increases the activity of many other micro organisms. Once the nematodes have started the damage of root system, other secondary micro organisms enter through the injuries causing extensive tissue destruction. Eg : Infection of potato by *Ditylenchus destructor*.

Association of nematodes (as vectors) with other plant pathogens:

A. Nematode- bacterium Association :

1. Tundu Disease/Yellow slime/ear rot of wheat :

Nematode, *Anguina tritici* acts as a vector carrying the bacterium *Corynebacterium tritici* causing above disease.

2. Bacterial wilt in Cotton:

Nematode , Ditylenchus dipsaci

3. Bacterial wilt in potato and tomato:

Nematode , *Helicotylenchus naunm* transmits the bacteria *Pseudomonas solanacearum*

B. Nematode –Virus Association :

1. Tomato Mosaic viral Disease:

Transmitted by nematode *Meloidogyne javanica*

2. Tomato Leaf curl viral Disease :

Transmitted by nematode *Meloidogyne incognita*

3. Cow pea mosaic viral Disease :

Transmitted by nematode *Meloidogyne incognita*

4. Fan leaf disease of Grape (NEPO) :

Transmitted by nematode *Xiphinema index*

NEPO : Nematode Transmitted Polyhedra Viruses

NETU: Nematode Transmitted Tubular Viruses

C. Nematode –Fungus Association :

1. Wilt Diseases :

Nematode , *Meloidogyne incognita* predisposes plants like cotton, tomato, tobacco, chickpea to the attack of wilt causing fungi ie., *Fusarium, Phytophthora, Pythium, Rhizoctonia, Sclerotium, Verticilium* sp etc.

2. Root Decay in Citrus:

Citrus root nematode aggravate the above disease by transmission of *Fusarium solani*

3. **Wilt in Maize :**

Haplolaimus indicus (Lance nematode) & *Fusarium moniliformae* show maximum wilt symptoms in Maize.

Lecture - 24 : Different types of nematodes

1. **Seed gall nematode: *Anguina tritici***

Host Range: Wheat

First plant parasitic nematode identified . Nematode larvae revived even after 28 years of storage.

- Obligate plant parasites with obese body.
- Female spiral in form and immobile.
- Males usually shorter than females.
- Infective stage: **juvenile stage (J2).**
- The juveniles moult thrice in quick succession within 3-5 days after invasion of flower primordia and change into adult males and females.

Symptoms:

- Nematode infected seedlings show slight enlargement of basal portion of the stem after about 20-25 days of germination.
- Leaves emerging from the seedling are twisted and crinkled, often folded with their tips held near the growing point.
- Infested plants generally show profuse tillering.
- Glumes may be loosely arranged and **galls** replace the seeds.
- Conversion of all or few grains in the ear into **cockles**.

2. **Stem and bulb nematode: *Ditylenchus sp.***

Host Range: Paddy , potato, mushroom (*D.myceliophagus*) and Onion

Important pest during storage.

- Rarely striated head, lip region is without dovious annuls.
- Oesophageal glands may overlap intestine slightly.
- Female with monodelphic, prodelphic ovary.
- Male with one testis.

- Infective stage - **juvenile stage (J4)**
- **Symptoms:**
- The leaves may become slightly thinner and more flaccid and sometimes chlorosis may be observed.
- The chlorotic portion of leaves becomes brown to dark brown.
- Twisting of leaf and leaf sheath.
- Panicles do not emerge and are enclosed completely within the flag leaf sheath.

3. **Leaf and bud nematode: *Aphelenchoid sp.***

Host Range: Rice, mushroom ,strawberry and chrysanthemum

- Cuticle is marked by fine transverse striae.
- Lip region is not striated.
- Spear is with thickening at the base but without well developed knobs
- Female with single ovary out stretched. Vulva posterior,
- The nematode is carried beneath the hull of the rice kernel in quiescent, immature, usually preadult stage.
- These nematodes do not survive in the soil after harvesting and are not transmitted through seeds.
- Infective stage - **juvenile stage (J2)**

Symptoms:

- White tip of seedlings.
- Initially the seedling growth is stunted and germination is delayed.
- Turning of 3-5cm of leaf tip into pale yellow to white colour at the tillering stage.
- The emerged panicles are generally short and flower becomes sterile.
- Glumes of affected spikelets are white and do not change in shape and size.

4.*Red ring nematode: *Rhadinaphelenchus cocophilus

Host Range: Coconut

Very slender body, massive sclerotization of the labial arches, elongated medium bulb , wide vulvar flap, curved vagina, speculum form and sclerotized spade like extension of male tail.

- Transfer of nematodes is purely mechanical through palm weevil *Rhynchophorus palmarum*

Symptoms:

- Yellowing and browning of the leaves begin at the base of the tree and progress upward till the leaves die, break and hang down.
- A cross section shows 1-2 inches **red ring** that extends from the base of the trunk to a height of 4 feet or more.
- Infested roots show discoloured tissues.

5.*Root knot nematode: *Meloidogyne sp.

Polyphagous

Host Range:Tomato, brinjal, bhendi, chilli, cowpea, greengram and tobacco

Female:

- The cuticle is transcuscent and glistening giving the white , pearly appearance to the nematode.
- the posterior end of the females possess distinctive arrangements of striae about the vulva- anus areas(perineal area).
- The excretory pore is infront of the muscular bulb of the oesophagus and close behind the stylet base.

Male:

- Vermiform, having blunt tail and slightly tapering neck region.
- Spicules simple, curved and gubernaculum is small.
- Caudal alae absent.

Symptoms:

- The infected plants usually exhibit yellowing of foliage, reduced unthrifty growth, smaller foliage, poor and fewer fruits and a tendency to wilt during warmer parts of the day.
- Poor emergence and death of young seedlings .
- Early poor fruiting for a relatively shorter period .
- Wilting and drying of crop in the field in patches.

- Presence of **galls or knots** on roots is the important diagnostic symptom

6. **Cyst nematode: *Heterodera sp. and Globodera sp.***

Host Range: Wheat, Barley. Rie, Oats, Pulses and Potato etc

- **Heterodera:**
- the mature cyst is **lemon shaped** with a short neck and terminal cone
- Male vermiform, stylet and oesophagus we ll developed, tail end twisted, spicules robust with out bursa.
- **Infective stage :** juvenile stage(J2)

Globodera:

The mature cyst **spheroidal** (round) with a short projecting neck, terminal region not forming a cone.

- Vulval fenestra circumfenstrate, no anal fenestra.

Infective stage : juvenile stage(J2)

Symptoms of potato cyst nematode:

- The disease usually occurs in patches under severe infection

- Stunted growth, general necrosis, in severe infection

- The newly formed tubers are few in no. and considerably reduced in size.

Symptoms of *Heterodera avenae*:

The effected fields usually give patchy appearance during initial stages of infection.

- Stunted growth, general necrosis, in severe infection, there may not be any grain formation.

- Infected roots are short, with multiple branches giving a bunchy appearance.

7. **Root lesion nematode(*Pratylenchus sp.)***

The head is relitively broad and continuos with body. Tail blunty rounded.

Symptoms:

In infected plants exhibit thin stem, leaves are small ,chlorotic ,crinkled and diseased plants are stunted ,become prematurely old.

The roots of diseased plants show discreate elliptical lesions in the intial stage which are yellow, brown or black in colour.

The infected plants can be easily pulled out from the ground.

The wounds caused by nematode are invaded by secondary pathogens like fungi and bacteria.

8. Rice root nematode*(Hirschmanniella sp.*)

It is migratory, endoparasitic aquatic nematode. Spear shape well developed.Tail is abruptly conoid with a mucro at the terminous.

Sympotoms:

Damage to roots, retardation of growth ,stunting of plants chlorosis and reduction in tillers can be observed .

In case of severe infection, flowering is delayed by about 12 to 15 days resulting in late maturation of crop.

Infected root exhibits necrosis and browning and too much vaculation in the cortex.

9. **Burrowing nematode(R*adopholus sp.*)**

Host Range: Wheat, Barley. Rie, Oats, Pulses and Potato etc

Both adult female and male are vermiform .In female, the lip region rounded, marked by striae.

Tail is concoid to blunt with rounded terminus.in adult males, lip region is subspherical with or without striae.

Infective stage: Juvenile (J3) and adult Female

Symptoms:

Spreading decline of citrus: (*R.citrophilus)*

Infection results in stunted plants with sparce foliage, small fruits and retarded terminal growth.

Trees possess large number of drying branches. Typical lesions are found on new roots

Root and rhizome rot banana:

Leaf chlorosis, dwarfing, thin pseudostem, small bunches and premature lodging of plants occur due to nematode infection.

Yellow disease of pepper:

Infection results in increase in the number of yellow leaves , arrests growth of veins, leading to severe die back and death of the plants

10. **False root knot nematode (*Nacobbus sp.)***

Female body is swollen and irregularly shaped . While male is typical filiform with short tail enveloped by a narrow bursa.

Large galls frequently contains no living female and only masses of darkened tissues are found . Cell wall collapses and enlarged cells are formed due to coalesion of adjacent cells .

11. Citrus nematode (*Tylenchulus semipenetrans*)

Females long with variable saccate body, stylet short , blunt tail.

Male: Slender, vermiform, stylet and oesophagus degenerated

Symptoms:

Infection results in reduced terminal growth, chlorosis and shedding of leaves, dieback of branches, and reduction in size and number of fruits. Infected fibrous roots show irregular thickening and exhibit extensive necrosis which give them a rust brown colour.

12.* Reniform nematode (*Rotylenchulus sp.)

It is kidney shaped. Female irregular shaped, reniform, tail concoid with rounded terminus. In case of male tail is pointed; spicules are curved.

Infective Stage: Immature Female

Symptoms: Stunted growth of plants, premature decay and loss of secondary roots

Cotton: Browning and necrosis of epidermal cells are found on infected roots.

Castor: Infection results in reduction in growth, shedding of leaves, early flowers malformation and discolouration of seeds ultimately leading to dieback symptoms

Vegetables: Infection destroys the epidermal cells causing necrosis and browning of surrounding cells.

13. Lance nematode *(Hoplolaimus sp.*):

Yellowish in colour spear robust with prominent tulip shaped knobs. Vulva near middle of body, tail with rounded terminus

Symptoms:

H.indicus stunting of upper internodes ;drooping of leaves ;withering leaf tips the infected roots exhibit gallaries. young lateral roots developed reddish brown it is important in inducing the wilt fungi *fusarium monoliformae* .

14. Spiral nematodes *(Helicotylenchus sp.and Rotylenchus sp.*)

Spiral or helical shape, pore like tiny phasmids.

Rotylenchus is migratory ectoparasite of roots

Helicotylenchus dihystera: Roots attacked by the nematode are blunt, malformed and much reduced in volume

15. **Sheath nematode (H*emicycliophora sp.)***

Ovary is prodelphic and outstretched tail elongated, pointed and rounded. Inmales spicules are variously shaped, almoststright, slightlycurved, sicklelike. Due to feeding on root tips, galls are caused growth of hoots stop

16. **Pin nematode (P*ratylenchus sp.):***

Usually they lie immobile in semi circularposition. Head is conical or rounded .tail is conical to various shaped point.

Though the nematode have long styletsbut generally feed only upon epidermal tissues or roothairs.

17. Dagger nematode(*xiphinema sp.*)

Long, sword like stylet and given the common name “dagger nematodes” stylet very long hypodermal needle like. Tail short rounded to filiform.

X. index is a vector for NEPO virus transmitting the **fan leaf virus of grape**

18. **Needle nematode*(Longidorus sp.):***

Longidorus are known to transmit polyhedral viruses.

Eg*: L. elongates* transmits **raspberry ring spot viruses** and

L. attenuates transmits **tobacco black ring viruses**.

19.Stubby root nematodes (*Trichodorus and Paratrichodorus*):

Stylet with hair like mural tooth.

The nematodes with blunt rounded tails and thick cuticle. Transmit soil borne plant viruses

Feeding is confined to root tips causing ,stunted growth of roots hence, the name “stubby root” It is a vector of NETU virus.

Lecture - 25 : Integrated Nematode Management – Host plant resistance-cultural, mechanical methods

Several species of nematodes cause damage to crops. One or more of them occur in soil and cause damage. Careful integration of all available and suitable techniques is necessary for reducing the economic loss due to nematodes.

In the management of nematode problem, prevention is always better than control where nematode problems may be observed throughout the cultivated area and can spread either through plant or soil.

Preventing spread of nematodes can be done by

1. Use of certified planting material
2. Use soil less graving media in green houses
3. Clean the equipment from soil before moving between the fields
4. Prevent animal movement from infested field to uninfested.
5. Removal of weeds from the field.

MANAGEMENT:

HOST PLANT RESISTANCE:

Nematode resistant varieties:

Rice - TKM-9 - *Hirshemanielia oryzae*
RNR-877, WGL-47969, Badami, neel,
Palghar-1, KAU 28-1-1,bhanja - *M. graminicola*
Barley - DL 349,DL-375,DL-379, Raj kiran, BP-263, BP-264 - *H. avenae*
Tomato – nematex, PAU-15, SL-120 – *M.incognita*
Atkins HIsarlaht – *M.javanica*
LP3 - *M. javanica*
N 10- M.incognita
NDTR-1 - *M. arenaria*

Potato – kuifri swarna- *G. rostochinensis*
Pea- Co-50, A-70, B-58- *M. incognita*
Chickpea- selection no 501- *M. incognita*
Ground nut – Ambali 4018- *M. javanica*
Virginia runner group Ah-18- *M. arenaria*
TMV-10, Jb-182, DS-99- *M. arenaria*
Coffee- *C. robusta – M. incognita*
C. Arabica- M. javanica
Grape- Hur, Calcutta- *M. incognita*

Cultural practices:

a) **Crop rotation:** effective against nematodes that show a strong food preference

Eg: cereals followed by vegetables and *vice versa* reduces *Heterodera avenae* and *Meloidogyne incognita*

b) **Crop root destruction:** After the crop season uproot the roots and destroy or burn on the soil surface.

Eg: *Hoplolaimus, Helicotylenchus, Xiphinema longidorus, Tylenchorhynchus sp.*

c) **Flooding and fallowing:** Due to flooding , oxygen content of soil is decreased and nematodes are killed by asphyxiation.

d) **Healthy plnating material:** Use of nematode free planting material to avoid further spread especially in the case of Onion, garlic, flower buds (*D. dipsavi*) Strawberry and chrysanthemum (*Aphelenchoides)*, citrus (*T. semipenetrans*) and Banana (*R. similis*).

e) **Summer ploughing:** Two to three deep ploughings during hot summer months suppresses weeds, insects, soil fungi along with nematodes.

f) **Solarisation of soil:** Exposure of soil covered with polythene cover during April- June will effectively reduce nematode population in soil.

g) **Application of organic amendments or green manuring:** soil application of oil cakes of Neem, Pongamia, Mahua, Castor etc. has (with nematicidal action) @15 tonnes per ha reduce nematodes in soil.

h) **Adjustment of sowing/ planting dates or season.** As nematode activity depends upon the soil temperature that vary with the season. Planting at unfavourable temperature or moisture condition of soil affect the nematode activity.

i) **Growing trap crops/antagonistic crops.** Trap crops should be grown in nematode infested soil where the second stage juveniles of nematodes enter in to the root but unable to reproduce affecting their population.

Eg: Crotolaria, Chrysanthimum, cowpea, sweet potato cv. Shree Bhadra can be used as trap crops.

Antagonistic crops are those which affect the nematode development in soil due to the chemicals released by them with nematicidal activity

Eg: *Tagetes erecta, T. patula,* mustard neem – release ferthinyl and bithinyl compounds

marigold – isothiocyanate

Pangola grass – Pyrocatechol compounds

Allelopathic cover crops: produce allelochemicals that function as nematode-antagonistic compounds such as triterpenoids, phenolics, glycosides, alkaloids

Eg: oil radish as a green manure reduce *Trichodorus* and *Pratylelchus* in potato

Rape seed a nd mustard in straw berry fields

j) **Sanitation:** Removal of weeds, destruction of crop residues and disinfestation of farm equipment

k) Nutrition and general care of plants:

Proper nutrition and timely irrigation should be provided to maintain the health of the plants.

Mechanical Methods:

Sieving : Simple sieving or winnowing or floatation in plain water or brine (5-10% salt solution) avoid nematodes in infested wheat seed with *Anguiana tritici*

Lecture - 26 : Integrated nematode management- Physical- biological- quarantine- chemical methods

Physical methods:

a) **Barriers:** Plastic bags of 100 cm^3 should be placed on boards while rising seedlings to avoid infestation from soil due to small breaks

b) **Heat and solarisation :** Sending steam through pipes in glass houses and seed beds and bins.

c) **Hot water treatment:** Dipping of seeds, tubers, bulbs, suckers, rhizomes, rooted cuttings and often planting material in hot water at 50^0c will help in reducing the nematodes

d) **Use of nematode free stock:** Helps to reduce the infection by wheat gall nematode, stem nematode in garlic and onion seed, flower bulbs, leaf nematode in strawberry and chrysanthemum,Citrus nematode in citrus seedlings

e) **Irradiation;** Expose potato infected with *Globodera* to 20,000 gamma rays affect the eggs.

Biological control:

1. Nematophagous fungi :

A) Endoparasitic fungi – *Nematophthora*

2. **Predaceous fungi** :

Eg: *Arthrobotrys conoids*

Oligospora

Dactylella doedycoides

Dactylaria candida

3. **Oppurtunistic fungi-** Colonize nematodes

Eg: *Paecilomyces lilacinus*

Verticillium or Pochorria clamydosporus

Hirsutella sps

4. Mycorrhiza

Eg: *Glorris fasiciculatum*

5. Bacteria:

Eg: Pastenria penetrans - *Pseudomonas flourescens*

Parasitic protozoa - *Duboscquia penetrans*

Predaceous nematodes – *Mononchus, Diplogaster vorax, Aphelenchoides*

Quarantine methods*:*

It is originated from Latin word **quarantum** meaning **forty** , originally it was applied to the period of detention for ships arriving from the countries having epidemic diseases .Later on the term was also applied to regulatory methods aimed at keeping out the exotic pests and pathogens associated with plants.

Plant quarantine regulations in India :

The Destructive Insects and Pests Act (DIP Act) was enacted in1914 to regulate the import of certain plant or plant materials from other countries (International Quarantine) and from one state to other within the country(Domestic Quarantine) **Eg:** Domestic quarantine is in vogue in Tamil Nadu against Goldent Cyst Nematode - *Globodera rostochiensis and G pallida* due to the enactment of Madras Agricultural pests and Diseases Act 1919

Chemicals / Nematicides:

Nematicides which are in commercial use may be grouped in to two types namely

a) Fumigants (Compounds belonging to halogenated hydrogen and isothiocyanate group) and

b) Non Fumigants (include organophosphates and carbamates)

Halogenated Hydrogen Group:

DD Mixture (1-3 Dichloro propene and 1-2 , Dichloro propane in 2:1 ratio)
Used @ 400-500 lts per ha as pre platn soil fumigant .

EDB (Ethylene Dibromide)

Chloropicrin

Methylbromide

Organophosphates and Carbamates:

Parathion , Phorate , Carbofuran and Methomyl

Factors affecting the efficacy of Nematicides:

The following factors influence the efficacy of soil nematicides

1. **Temperature:** Chemcials with boiling point between 150-200 ^{O}c are more effective at soil temperature of 27 ^{O}c or more, and almost ineffective at 10 ^{O}c.
2. **Soil Moisture:** In sandy loam or clay loam soils moisture content prolongs gas retention and retards diffusion
3. **Soil Type:** Heavy clay soils are unsuitable for fumigation owing to absorption on the increased active surface area of the soil particles and blocking of pore spaces by soil moisture.
4. **Compactness of Soil :** Fumigant gas tends to move upwards in most porous top layers of the soil henc, soils must be cultivated deeply before treatment.
5. **Sorption capacity of Soil:** The chemicals are absorbed more in dry soil than moist soils**.**

Lecture - 27 : Mites –Importance of mites –morphology and biology of mites

Importance of Mites : Mites are very tiny creatures capable of infesting and causing severe loss to a variety of **agricultural and horticultural crops** particularly under dry situations.

In addition to direct damage to crops they also cause in direct damage by acting as **vectors** of important viral diseases .

Some of the mites harbour in carpets, sofa etc furniture in the houses and cause **serious allergies** in human beings.

Some of the mites even cause loss to the **stored produce**

Not only they cause damage to crops they are also harmful to **productive insects** like honeybees acting as parasites.

On the other side, some of the mites (predatory mites) are very useful in **biological control** of some insect pests and mites.

Phytophagous mites:

The mites that feed on plants are called **phytophagous** mites which mainly belong to families namely

Eriophyidae (Erenium or gall or itch or rust mites), Tetranychidae (spider mites),

Tenuipalpidae (Broad mites) and

Tarsonemidae (False spider mites).

Mites as Vectors:

Some of the eriophid mites act as vectors of some important viral diseases

Eg: *Aceria cajani* transmit redgram sterility mosaic disease

Aceria tulipae transmit wheat streak mosaic disease

Mites as Parasites :

Ecto Parasite on honey bee : *Tropilaelaps clariae*

Varroa jacobsoni

Endo Parasite*:* *Acarapis woodi(Tarsonemidae)*

(Tracheal mite on honey bee)

Locustacarus buchneri (Poapolidae) on bumble bees

Predatoy Mites: (Phytoseiids)

Phytoseilus persimilis

Amblyseius fallacies

House Dust Mite: ***Dermatophagoides farina***

Stored grain mite*:* ***Acarus siro***

Mites belong to the class, Arachnida and Order Acarina. They are found in a variety of habitats ie., aquatic (lakes or ponds) or terrestrial (plants, mammals, on birds and insects).

Mites can be distinguished from their insect relatives by the presence of two body regions (cephalothorax and abdomen, in some these two are fused), four pairs of legs(only two pairs in Eriophyidae) , sucking mouth parts and lack of antennae and wings

Mites possess chelicerae as mouth parts which are needle like useful for sucking sap from plants. Adults vary in body shape and possess 2 or 4 pairs of legs. The life cycle consists of an egg, larva , proto nymph, deuto nymph, trito nymph and adult stages. Oval shaped eggs are laid on leaves. Incubation Period is 6-13 days. The no.of nymphal instars vary among the families.

Example: Eriophyid mite has only 2 nymphal instars and Tetranychid mite has 3 nymphal instars. The nymphs are active and nymphal period vary from 1-3 weeks. The total life cycle in summer extend from 3-6 weeks .

MORPHOLOGY:

Body is vermiform, divided into cephalothorax and abdomen in family Eriophyidae . It contains 2 pairs of legs.

In Tetranychidae, body is divided into **Gnathosoma** and **Idiosoma**. Gnathosoma contains mouth parts like Chelicerae and Pedipalpi that cover the mouth cavity.Above the mouth cavity there is a **capitulum or tectum** dorsally.

Gnathosoma consists of 3 segments where the second segment has chelicerae and 3rd segment has pedipalpi. The Idiosoma is further divided into **Podosoma** and **Opisthosoma**. Podosoma has legs that is further divided into **Propodosoma** and **Metapodosoma**. Propodosoma has 2 pairs of legs and Metapodosoma has 2 pairs of legs. Opisthosoma is the posterior part of the body having anal opening.

Eyes may be present or absent. In some mites if eyes are absent body surface act as photo sensitive organ.

Mouthparts are Chelicerae , 3 segmented, modified into stylet like piercing organs.

Pedipalpi are present on dorso-ventral surface of Gnathosoma resembling the legs. These are modified as piercing or grasping organs.

Legs may be 2 or 4 pairs. Each leg consists of coxa, trochanter, femur, Genu, tibia and tarsus

Differences between Eriophyid and Tetranychid mites

Character	**Eriophyid mite**	**Tetranychid mite**
Size	Very minute	Bigger
Body	Vermiform	Flat or oval
Segmentation	Body is divisible into Cephalothorax and long tapering abdomen	Body unsegmented and not divided into cephalothorax and abdomen
Legs	2 pairs of legs(situated near the anterior end of the body) both in the adult and nymphal stages	4 pairs of legs in the adult and also nymphal stages. The larva (1st nymphal stage) has only 3 pairs of legs (mites living enclosed with in plant tissues have vestigial legs)
Life Cycle	2 nymphal instars (protonymph and duetonymph) which are almost similar to adults	3 nymphal stages(protonymph, duetonymph, tritonymph) and an adult stage.
Symptoms	Gall formation is the main symptom	Formation of the red spot is the main symptom
Examples	Eg: Gall mite, blister mite, rust mite & bud mite	Eg: spider mite

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Lecture - 28 : Mites –Classification- characters of important families Tetranychidae, Tenuipalpidae, Tarsonemidae, Eriophidae- host range

Family: Tetranychidae(spider mites)

Characters:

1. Body colour is red, green, yellow, brown etc.
2. Body is 0.2 -0.8 mm long
3. Body is flat, oval.
4. Body is not divided into divisions
5. Not segmented.
6. Body of male tapers posteriorly
7. Chelicerae are fused to form a stylopore and the movable segment of chelicerae forms a flagellate stylet.
8. Threre is no mitotic division in larval stage.
9. Most of the species are having narrow host range
10. Palpal thumb claws are present.

Life cycle includes

Egg,
Larva (3 pairs of legs),
Protonymph (4 pairs of legs),
Deutonymph(4 pairs of legs),
Tritonymph(4 pairs of legs) and
Adults (4 pairs of legs)

Examples:

1. Red spider mite on okra, cotton, citrus, tomato, grape, papaya, jasmine, pumpkin. *Tetranychus macfarlani*(telarius) results in Browning of leaves, fruits and hairy out growth on both.
2. Jowar mite (greyish green colour): *Oligonychus indicus*, lower side of leaf becomes wet, red spots appear in patches on leaf.
3. Vegetable mite, *Tetranychus cucurbitae*

Family:Tenuipalpidae (false spider mites)

Characters:

1. Same as Tetranychidae, but without thumb claws.
2. Three types of setae namely hysterosomal, dorsocentral and mediolateral are present.

3. The true tarsal claw is hooked or pad like and with tenent hairs.

Examples:

Citrus flat mite *Brevipalpus lewisi*

Brevipalpus californicus- It causes serious injury to a wide variety of ornamental and agricultural crops.

Lecture - 29 : Mites –Classification- characters of important families Tetranychidae, Tenupalpidae, Tarsonemidae, Eriophidae- host range

Family: Tarsonemidae (Broad mites)

Characters:

1. Body is elliptical (ovoid)
2. Body measures 0.1-0.3 mm long
3. Body is divided in to three parts Capitulum, Propodosoma and Prohysterosoma (the later two parts together known as Idiosoma)
4. Mouth parts are contained in a distinct capsular head known as Capitulum
5. Females are bigger than males.
6. Body colour is opaque white, light green, pinkish
7. Adult integument is hard and shiny.
8. Few hairs, spines are present on body.
9. Chelicerae are needle like
10. Egg – larvae – adult

Examples:

Yellow mite on chilli- *Palyphagotarsonymus latus*

Paddy panicle mite - *Stenotarsonemus spinki*

Family: Eriophyidae (Blister, rust, gall mites)

Characters:

1. Body is minute measuring 0.08 – 0.2 mm long.
2. Body is 2 types:
   a) Elongate (vermiform), worm like, soft body
   b) Wedge shaped, hard body
3. Body is segmented

4. Body is divided into cephalothorax and tapering abdomen.

5. Abdomen is finely striated with long setae.

6. Two pairs of legs on anterior end of body (in all the life stages)

7. Pedipalpi or chelicerae are capable of making some independent movements and form a telescope or fold base. No thrusting stylopore.

8. Egg, Protonymph (2 pairs of legs),Deuteronymph (2 pairs of legs)

Adult (2 pairs of legs)

Examples:

1. Citrus rust mite- *Phyllocoptruta oleivora*

(Pinkish brown blotches on fruits).

2. Jasmine mite - *Aceria jasmini*

3. Mango gall mite- *Aceria mangiferae*

4. coconut mite- *Eriophyes guerreronis*

Nature and symptoms of Mite damage :

Both nymphs and adults suck sap from plant parts like leaves, terminal or axillary shoots, fruits etc with their needle like chelicerae .

They cause symptoms like

1) Formation of white blotches on leaves in vegetables
2) Characteristic red spots that enlarge and coalese making whole leaf reddish
3) Drying of leaves and stems in sugarcane
4) Formation of galls on leaves in pongamia
5) Production of felt like growth on leaves in jasmine
6) Formation of crowded buds ,crumpled shoots in mango
7) Formation of pinkish blotches on fruits of citrus
8) Curling of leaves upwards in chillies
9) Formation of warts and longitudinal tissues on nuts of coconut
10) Act as vectors by transmitting viral diseases
11) Spin delicate webs on the lower surface of the leaf and live inside the web and suck sap from leaves

Mites of Agricultural Importance :

1. Jowar mite : *Oligonychus indicus* - Tetranychidae
2. Red spider mite : *Tetranychus neocaledonicus*
   T. telarius - Tetranychidae
3. Citrus rust mite :*Phyllocoptruta oleivora* – Eriophyidae
4. Citrus leaf mite : *Eutetranychus banski* - Tetranychidae
5. Sugarcane mite : *Schizotetranychus andropogonii* Tetranychidae
6. Coconut eriophyid mite :Aceria guerreronis
7. Jasmine mite (felt mite) : *Aceria jasmini* – Eriophyidae
8. Sweet potato rust mite :*Oxpleurites convolvuli* –Eriophyidae
9. scarlet mite of tea :*Brevipalpus anstralis* – Tetranychidae
10. Chilli mite :*Tarsonemus transluscens*
    Polyphagotarsonemus latus - Termipalpidae
11. Sugarcane mite :*Tarsonemus spinipes*
12. Coffee mites :*Oligonychus coffeae* –Tetranychidae

Management of mites:

1. Removal of alternate hosts in the field .
2. Spraying of sulphur @ 3 gm/ Dimethoate 30 EC @ 2 ml/lt/

   Methyldemeton 25 EC @ 2 ml /lt / kelthane (Dicofol) 5 ml /lt /

   Ethion @ 1 ml/lt
3. Fungal pathogen, *Hirsutella thompsoni* reported to be effective against coconut eriophid mite
4. Predaceous insects on mites

   Ex. *Scolothrips indicus*

   Scymnus gracilis

Lecture - 30 : Rodents

Rodents are of two type namely Commensel rodents and Field rodents

COMMENSEL RODENTS

Family: Muridae; Order: Rodentia; Class : Mammalia

House mouse - *Mus musculus*

House rat or black rat – *Rattus rattus*

Common Indian field mouse - *Mus musculus booduga*

Brown rat - *Rattus norvegicus*;

1. House mouse (*Mus musculus*)

It is quick, tends to nibble and run rather than stay longer at food source. They can pass through a hole slightly less than 1.25 cm. They live mostly in houses. They produce 6-10 litter per year with 6-10 young ones per litter. They can climb easily and also can swim when necessary. They are distributed all over India and are omnivorous. Total length including tail is 8-22 cm with pointed snout. They are brownish grey above and whitish to light grey on belly.

2. House rat (*Rattus rattus*)

Lives in close association with human beings. Excellent climber and good swimmer. 4-6 litters / year and tail length 31-43 cm with pointed snout. Dark brownish above (dorsal) and dirty white on belly.

3. Common Indian field mouse (*Mus musculus booduga*)

The body of Indian field mouse is about 5 to 8 cm long with 5 cm long tail. It is brown in color with a white belly. It burrows in field bunds causing extensive damage to bunds and wastage of water. It produces 3 to 9 young ones per litter.

4. Brown rat or Norway rat (*Rattus norvegicus*)

Closely associated with the activity of man. Good climber and swimmer. Prefers wet or damp locations. Do not close the burrow openings. Length from nose to tail 35-41 cm with blunt snout. Brownish above, white on belly.

The above three species are known as **commensal** rodents. They contaminate 20 times the material actually they eat. A rat winates 15-25 ml/day and 25-150 pellet droppings per day / rat. They regularly shed hairs @ 100-200 hair fragments per day/rat. They bite some times human beings. They spread disease. They are social animal. They share same food source and common run way. They live closely to one another. They are most active at dusk and during calm period.

Rats become conditioned to eating a particular food and are suspicious in nature. Taste the food cautiously and develop bait shyness. House mouse is not suspicious of new food. Eagerly tastes all. In single night mice tastes and feed on many different foods, hence difficult to get them to take a lethal dose of poisoned bait. Mice readily accept water baits.

Management of commensal rodents

Killing rats by sticks

Trapping the rats using traps.

Snap neck trap kills the rat instantly.

Live catch traps trap the rats alive Eg. Single rat trap, wonder trap.

Chemicals

Chemicals are of two types

Acute poison: That are used in single dose

Anticoagulants : That are used in multiple doses

1. Acute poison

Zinc phosphide: To be used only in fields not in houses

Commonly used acute rodenticide in India

Recommended at 2.5% technical grade in bait material

Broken cereal could be used as bait material with vegetable oil as binding medium

Pre-baiting is compulsory for effective results

95% flour + 1 to 2% Zinc phosphide + 2% groundnut oil + 1% sugar

Prebaiting 2-3 days without Zinc phosphide and then bait is mixed with zinc Phosphide

2. Anticoagulants

1st generation anticoagulants

Warfarin, Fumarin, Toumarin, Recumin

These poisons are lethal when consumed for several days. They prevent blood clotting and break cell wall of blood capillaries leading to **haemorrhage**. Rats normally die in aerated areas. House rat and house mouse die after 2-5 days of continuous feeding.

Solid base – Rodafarin C

1 part of Rodafarin C + 1 part of granulated sugar + 1 part of vegetable oil + 17 parts of crushed grian or corn meal

Liquid base –Rodafarin C

Antidote- Vitamin k-1

2nd generation anticoagulants

Bromadiolone is only registered

Recommended @ 0.005% ai in cereal baits to be used in pulsed baiting technique (Exposing the bait at weekly interval)

Fumigants :

Aluminium phosphide (CP) solid.

Ethelen dibromide (EDB)

Ethelene dichloride carbontetrachloride (EDCT)

Natural enemies

Cats, dogs, owl, hawks and snakes

Field rodents

1. Soft furred field rat or grass rat (*Millardia meltada*)

It occurs in irrigated fields but observed in pastures also. It is nocturnal and lives in simple burrows. It breeds through out the year with litter size of 2-10 young ones. It is small and slender. Adult weight is 100 gm. Total length including tail is 19-29 cm, tail length is 9-14 cm either equal or little shorter than head and body, moderately to poorly haired. The tail is dark above and pale below.

2. Indian Mole Rat or Lesser Bandicoot Rat (*Bandicota bengalensis*)

It is an excellent swimmer, often living in flooded rice fields and bunds. Also occurs in the wheat crop fields and godowns. It is nocturnal and fossorial. They hoard large amounts of food in its burrows. Breeds commonly twice a year with 8-10 young ones in each litter.

Adult weight is 325 gm. Length from nose to tip of tail is 36-48 cm. Tail is18-20 cm; less than or some times equal to length of head and body together, 160-170 rings clearly seen on scaly tail. Ear 2.5 to 2.6 cm in length, thick and opaque. Snout – short, stumpy, pig like. Fur and colour – thick, short and harsh, spines present, dark brown, pale brown or reddish above.

Nature and Symptoms of damage

Rodents attack rice at all stages of growth from planting to harvest and if there is opportunity, even they will continue to attack the grain in store. Freshly sown seed may be dug up and the seed eaten. On young rice plants, rodents attack the heart of the stem discarding the leaves. The rodents make the rice stems fall by gnawing 5-15 cm above ground level. Some rodent species may store grain in their burrows. Large rodents, besides feeding on the crop may cause serious damage to the bunds.

Management of Rodents:

Rodent management should be taken up on community basis well before sowing of the crop. The rodent burrows should be marked and the burrow opening is closed with moist soil. The burrows opened out on the next day are active burrows. Then pre baiting has to be done on the 1st and 3rd day. On 5th day 2% zinc phosphide is added and baits distributed in the field. 70-80% kill of rodent population can be secured by the operation.

The remaining population can be controlled by fumigating the burrows. On 6th day in those reopened burrows, aluminium phosphide @ 1.5 gm/ should be placed in the active burrow and this will take care of residue rodent population.

Lecture - 31 : Other non insect pests

1. Important birds causing damage to agricultural crops

A number of birds feed upon grains from earheads of field crops; fruits and vegetables. They actually consume very little quantity but often cause more damage than what they actually eat.

Major bird species affecting different crops are as follows

1. Crow *Corvus* spp. – Damage wheat, cobs of maize, ripe fruits of fig, mulberry
2. The parrot *Psittacula cyanocephalus* cuts and feeds on maize, jowar, bajra, what, barley grains and fruits such as guava, fig, mango, pomegranate etc., (both semi ripened and ripened fruits are cut and eat leading to fruit drop)
3. The house sparrow – *Passer domesticus* damages the earheads of jowar, maize, bajra and soft and fleshy fruits such as mulberry and fig
4. The blue rock pigeon *Columba livia* eats maize, pulses and groundnut
5. The yellow throated sparrow causes havey damage to wheat and barley

Many species of birds are found throughout India, out of which some birds are considered harmful to agricultural crops. Some of them are as following:
(i) **Crow:** (*Corvus Splendens* Vieillot): Crows cause considerable damage to ripe fruits in orchards and also ripening grains of maize and fruits. The crows are particularly attracted to the grains when they are exposed on a cob. They may prove a menace to the successful growth of field crops as well as harvest of fruits. They are often seen in flocks in maize and other fields.
(ii) **Sparrow :** (*Passer domesticus*): The flocks of sparrows is a great menace to various field crops like Jowar, bajra, wheat, maize, etc. mainly in the seed setting stage. They also threaten mulberry and many other small sized juicy fruits and fruit buds.They visit the ripening fruit fields, particularly those of wheat in the spring season, and cause much damage both by feeding and causing the grains to shed.

Damage by House sparrows

House sparrows consume grains in fields and in storage. They do not move long distances into grain fields, preferring to stay close to the shelter of hedge rows. Localized damage can be considerable since sparrows often feed in large numbers over a small area. Sparrows damage crops by pecking seeds, seedlings, buds, flowers, vegetables, and maturing fruits. They interfere with the production of livestock, particularly poultry by consuming and contaminating feed. In grain storage facilities, fecal contamination probably results in as much monetary loss as does the actual consumption of grain.

(iii) **Parrot:** (*Psittacula* spp.): About eight species of parrots have been recorded in India. Out of these species, Large Indian parakeet (*P. eupatria*) is very common in Maharashtra. This species causes heavy damage to orchards by eating fruits and also spoiling the fruits by cutting it with beak. The parakeets are among the most wasteful a destructive birds. They gnaw at and cut into bits all sorts of near-ripe fruits such as guava, ber, mango, plums, peaches, etc. In sunflower when the seeds are soft the parrots cause extensive damage by feeding on the seed thus reducing the yield

Management of Birds

Various methods are employed which include covering by nets, using scaring devices, reducing their population by shooting, trapping and use of chemicals.

(a) Trapping the birds in nets or catching them with the help of sticky substance '**Lassa**'.

(b) A piece of Chapatti dipped in 0.04% parathion and placed on the top of roof is a good bait for crows.

(c) Parrots and sparrows are repelled by spraying 0.6% **thiurun**' on wheat crops at milk stage.

(d) Scaring devices using mechanical, acoustic and visual means are normally employed, i.e. Beating of drums to produce sounds is still in vogue in many parts of the country particularly during harvesting.

(e) Fire crackers placed at regular intervals along a cotton rope. The rope burns from one end and ignites the crackers at regular interval which produce sounds and scare away the birds.

(f) Loud sounds due to the burning of **acetylene gas** produced at intervals are utilized to scare away birds and small animals.

(g) Birds may be scared by display of scare crows, dead birds and visually attractive flags etc.

2. Crab damage

The rice **field crab** *Paratelphusa hydrodromus* (Decapoda; Crustacea). The crab has an oval body with an abdomen tucked beneath the thoracic region. Crabs live in holes made in the sides of field bunds, irrigation channels and field corners, where water does not stand. The holes are protected by heaping soil around their openings. Crabs multiply mainly during dry period, April to June. A single female lays about 200 eggs which are carried by the mother in a pouch like abdominal flap on her ventral side.

Crab Damage :

Young seedlings in nurseries and newly transplanted fields are damaged. The seedlings are cut at ground level in to small bits which are carried to the holes for feeding. In older plants, outer sheaths are cut open and the tender inner portions are consumed. In an attacked field, bits of leaves and stems can be seen floating in water. In severely affected fields patches of damage can be seen. Crabs are active mostly after dusk and at nights. In addition to damage to plants, the carb holes made in bunds lead to braches and water losses.

Management:

1. They are naturally controlled by rats and **pond heron** *Ardeloa grayi*.
2. They can be trapped in wide-mouthed pots buried with their rim at about the water level; inside the pots, moistened rice bran in lumps are kept as bait.
3. Poison baiting with warfarin 0.0025 per cent in popped rice mixed with fried onions and fish can be used
4. Fumigation with cyno gas though effective is costly

3. Snail damage

The giant African snail – *Achatina fulica*, which is a foreign pest got introduced in India and is now wide spread.

Slugs and snails are legless creatures that glide along on a path of mucus. This mucus dries out and can be seen in the daytime as a shiny trail over leaves, fruit and soil. The detection of these "**slime trails**" may be the only way of determining their presence, as slugs and snails generally feed at night. When trails and damage are observed, the slugs and snails can often be found on the ground near the injured plants, hiding under decaying plant debris, stones, clods of soil, or logs.

They feed on the lower leaves of many plants especially in the areas between the veins. Immature slugs and snails damage plants by rasping away the surface tissue, while adults eat holes through the leaves, nip off tender shoots or cause complete destruction of seedlings. Damaged leaves break, due to wind and shed or in the case of grass and corn, split lengthwise. Litter heaps, compost piles, drain pipes, greenhouses, well walls and uncultivated areas with dense plant growth, provide ideal sites in which the gray garden slug, gray field slug and snails are capable of overwintering in all developmental stages.

Management:

1. During rainy season, moist gunny sacks or leaves can be heaped near the cropped area and the snails collected near them can be killed on following day.
2. Among chemicals, metaldehyde is the most effective molluscicide which are available as 5 % pellets.

Chapter : 32 - House hold and live stock insect pests

Domestic insect pest

1. Ants

House ants viz., *Monomorium criniceps* (small brown ant) and *M. destructor* (small red ant) is a problem in household carrying bits and pieces of food material. They cause annoyance and also sting people causing disturbances. They can be controlled by keeping the house clean and tidy. Chemical control can be done with dusting of carbaryl 10 per cent (not advisable if infants live in the houses)

2. Termites

Termites feed on wood, paper, wood products, dried plant and animal products etc.,

To prevent infestation by subterranean termites, avoid construction of any wood material 40 cm from ground surface. A thin sheet of metal or good concrete between foundation and timber of the house will prevent infestation. Termite proofing of wood can be done by pressure impregnation with coal tar, zinc chloride, chlorpyrifos etc., Soil termite attack can be controlled by spraying of chlorpyrifos 20 EC @ 50 ml/ liter of water.

3. Silver fish *Ctenolepisma* spp. (Lepismatidae; Thysanura)

This insect is found commonly in neglected places on walls, starched clothes, fabrics, bindings of books, papers on which paste or glue is used. The insect is wingless, 8-13 mm long, silvery greenish grey or brownish, lives in warm places and avoids light.

This insect can be controlled by application of propoxur (Baygon) 0.5 %.

4.Cockroach *Periplanata Americana*; German cockroach *Periplanata germanica* (Blattidae; Dictyoptera)

Well known insect in all households. They are active in nights mostly in places which are damp and dark and avoid light. They cause nuisance in the household with their foul smelling excreta. The female cockroach produces ootheca containing 14 to 16 eggs and about 15 to 90 oothecae may be laid by a female.

These insects can be controlled by application of propoxur (Baygon) 0.5 %. Aerosols containing propoxur 0.75 % + cyfluthrin 0.025%

5. Cricket *Gryllus* spp. (Gryllidae; Orthoptera)

These insects live in cracks and crevices in the houses and causes annoyance by making chirping noise at nights. With proper ventilation and lighting, these insects can be controlled.

6. Powder post beetles

The furniture beetle *Sinoxylon sudanicum* (Bostrychidae; Coleoptera) and other species Anobiidae, Bostrychidae etc destroy wood items in households. The grubs of these insects cut the hard and dry wood and tunnels downwards until the wood becomes powdered. Small shot holes can be seen externally on affected wood.

These insects can be controlled by painting the wood with varnish, paint, tar etc., of fumigation with methyl bromide can be done.

7. Carpet beetle *Anthrena pimpinella* (Dermistidae; Coleoptera); Cloth moths *Trichophaga abruptella* (Tinaeidae; Lepidoptera)

The larva and adults of the beetle and the moth, bite holes in fabrics like wigs, clothing, interior padding of furniture etc., which contains wool, fur, feathers and hairs. They also attack cotton goods, insect specimens, dried meat etc.,

These insects can be controlled by cleaning the household premises regularly and also fumigation with naphthalene balls or paradichloro benzene crystals.

Veterinary Entomology

Cattle Pests:

1. The horse fly *Tanbanus striatus* (Tabanidae; Diptera)

It resembles the housefly but is larger and stouter, has three rows of white spots on the abdomen and prominent compound eyes. The fly breeds in marshy places. Eggs are black, elongate and are laid on aquatic plants. The grubs are carnivorous and feed on small aquatic organisms. The female fly pierces the skin of the animal and sucks the blood, causing wounds.

2. The stable fly *Stomoxys calcitrans* (Muscidae; Diptera)

This fly is cosmopolitan and is smaller than housefly, long proboscis and presence of seven spots on the abdomen. It breeds in moist straw, grass and other material in the cattle shed. Both male and female sucks the blood from the animals.

3. The cattle fly *Hippobosca maculate* (Hippoboscidae; Diptera)

It is a flat fly with a leathery thick-set body and strong tarsal claws. It can be always seen on cattle clinging mostly at sides of the neck region. It feeds on the blood contneously and produces seed-like puparia direcly without egg and grub stage.

All the above three flies can be controlled by use fenitrothion 50% EC @ 10 ml/liter of water or deltamethrin 2.8% EC @ 2ml/liter of water. The animals can be sprayed individually taking care to treat the tip and under portion of tail; inside

the ear and folds of legs. The animals should not be washed immediately. Spraying may be repeated at an interval of 4 to 5 weeks.

4. The blood sucking fly *Siphona exigua* (Muscidae; Diptera)

It is a common blood-sucking fly in India, which attacks cattle, buffalo and dog. It is attracted by the odour, warmth and sweat of its host.

5. The eye fly *Siphunculina funicola* (Chloropidae; Diptera)

They are shining black in colour and cling in clusters. They hover in front of the eyes and feed on upon the secretions from the eye.

II. Fowl

1. The shaft louse *Menopon gallinae* (Menoponidae; Mallophaga)

It is a permanent ectoparasite of fowl found on their feather feeding by nibbling on the dry scales of the skin and chewing the feathers.The louse spends its entire life cycle on the host bird itself. Badly infested birds can be seen rubbing their bodies in soil or ash pits to get rid of the louse.

2. The body or vent louse *Menacanthus stramineus* (Menoponidae; Mallophaga)

It is one of the common ectoparasite of poultry. It congregates on the skin just below the vent and in case of severe infestation can be seen on ventral side of wings.

3. The chicken flea *Echidnophaga gallinacean* (Tungidae; Siphonaptera)

The flea infests the face, comb, wattles and area around the eyes of fowl in clusters. It is a minute, flat, dark brown insect remaining attached to the host with its head embedded in to the skin.

Control of poultry lice and chicken flea can be done by spraying fenitrothion 0.25 % on batches of 10-12 birds at a time. The spray should be repeated at an interval of three months.

III. Sheep and goat

1. The head maggot of sheep *Oestrus ovis* (Oestridae; Diptera)

This larviparous fly deposits the maggots in the nostrils of sheep. The maggots move to frontal sinuses resulting in constant nasal discharge and sometimes obstruction of air passage.

2. The sheep ked *Melophagus ovinus* (Hippoboscidae; Diptera)

It is a wingless, leathery, hairy fly which attacks the sheep. The female glues its larvae to the wool of sheep. The adults live among the wool and suck blood causing intense irritation prompting the sheep to bite the area thus damaging the wool. Spraying with 0.01% diazinon or deltamethrin will eliminate this insect.

3. The biting louse *Bovicola caprae* (Trichodectidae; Mallophaga)

Commonly occurs in goats and sheep (*B. ovis*). Dips containing 0.01 % diazinon or deltamethrin 2.8% EC @ 3 ml/liter of water.
