B.Sc. FISHERY SCIENCE LAB MANUAL

2nd Semester

Prepared By
Biological Science Dept.
Fishery Science

MIDNAPORE CITY COLLEGE

Morphometry of lakes, ponds and streams. Determination of physical characteristics of lentic water bodies. Determination of chemical characteristics of lentic water bodies. Determination of physical characteristics of lotic water bodies. Determination of chemical characteristics of lotic water bodies. Collection and identification of freshwater phytoplankton. Enumeration and biomass estimation of freshwater phytoplankton. Estimation of primary productivity in fresh water bodies. Collection and identification of freshwater zooplankton. Enumeration and biomass estimation of fresh water zooplankton. Collection and identification of benthos from lakes and ponds, streams and canals. Collection and identification of nekton/aquatic insects from freshwater bodies. Collection and identification of aquatic plants from different fresh water bodies. Field visit to lotic and lentic water bodies.

BFSC-202: Aquatic Ecology and Biodiversity

Collection of species of fishes and other organisms and studying the assemblages of organisms of rocky, sandy and muddy shores, lentic and lotic habitats. Field visits to mangroves, marine parks, sanctuaries, coral reefs, rivers, hills, streams, lakes and reservoirs. Working out biodiversity indices.

BFSC-203: Freshwater Aquaculture

Preparation and management of nursery, rearing and grow-out ponds. Study on effect of liming, manuring and fertilization on hydrobiology of ponds and growth of fish and shellfishes. Collection, identification and control of aquatic weeds, insects, predatory fishes, weed fishes and eggs and larval forms of fishes. Algal blooms and their control. Estimation of plankton and benthic biomass. Study of contribution of natural and supplementary feed to growth. Workout of economics of different culture practices.

Estimation of live stock requirement / Unit in integrated aquaculture Design of paddy plot for paddy-cum-fish culture. Design of Fish and Shrimp Culture, livestock shed on pond embankment, Economics of different integrated farming systems.

BFSC-204: Aquaculture in Reservoir

Preparation of charts on the present situation of reservoirs fisheries productivity; detailed case studies of selected reservoirs on the changing trends in capture fisheries profile; drawing inferences from the analysis of data; suggestions for the sustainable development of reservoirs fisheries. Case studies on cage and pen culture; field visit to cage and pen culture site to acquaint with construction details and operation.

BFSC-205: Statistical Methods

Construction of questionnaires and schedules. Diagrams and frequency graphs. Calculation of arithmetic mean, median, mode, range, mean deviation, variance, Standard Deviation. Exercises on probability, Binomial and Poisson distributions, Area of normal curve ,confidence interval for population mean, Test of hypothesis based on normal, t, and chisquare. Computation of Simple correlation and regression. Fitting of length - weight relationship in fishes.

BFSC-206: Anatomy and Biology of Finfish

Study of internal organs – digestive, respiratory, circulatory, urino-genital system, nervous, skeletal systems and endocrine system. Study of food and feeding habits. Analysis of gut contents. Estimation of age and growth by direct and indirect methods. Classification of maturity stages. Estimation of fecundity. Study of developmental stages. Tagging and marking.

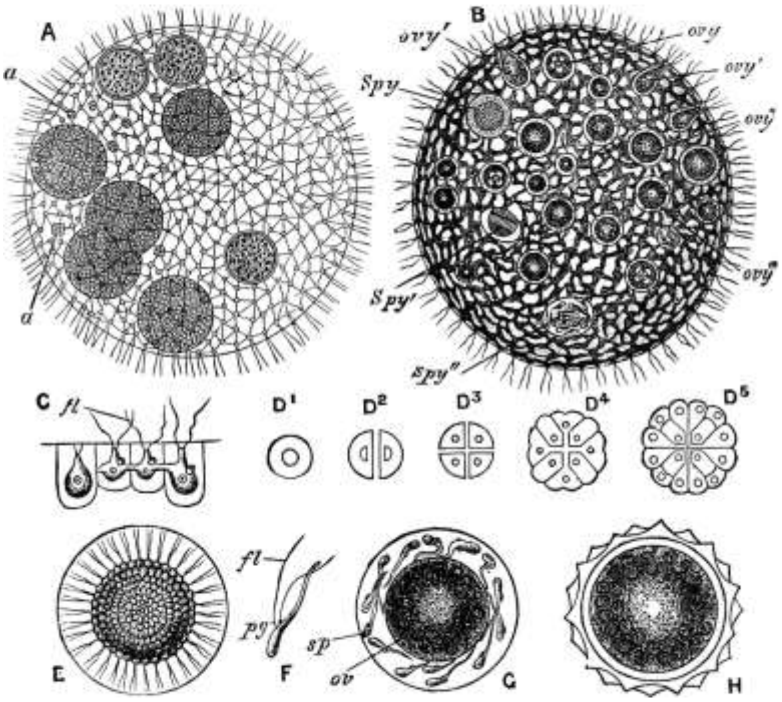
BFSC-207: Anatomy and Biology of Shellfish

Study of Internal Organs commercially important crustaceans and mollusks. Study of Digestive, respiratory, circulatory, nervous and reproductive systems. Study of food and feeding habits - analysis of gut contents, age and growth, length - weight relationship and condition. Reproductive biology: maturity stages, spawning periodicity, fecundity and larval stages.

BFSC-208: Food Chemistry

Estimation of moisture, crude protein, fat, ash (including acid soluble) in fish sample. Determination of energy value of fish. Estimation of glucose and salt content in foods. Colorimetric method of estimation of proteins and carbohydrates. Use of pH meter. Estimation of freshness quality indices such as TVBN, TMA, alpha-amino nitrogen, PV, FFA, TBA value of fish. Estimation of fibre in foods.

BFSC-201: Limnology



A, entire colony, enclosing several daughter-colonies; B, the same during sexual maturity; C, fourzooids in optical section; D1-D5, asexual formation of daughter-colony; E, zooid which has become converted into a mass of microgametes; F, microgamete; G, mega gamete surrounded bymicrogametes; H, zygote; a, early stages in the formation of daughter-colonies; fl, flagellum; ov, ovy, megagametes; pg, pigment spot; spy, zooids containing microgametes

SYSTEMATIC POSITION

Class: Chlorophyceae
Order: Volvocales
Family: Sphaerellaceae
Genus: *Volvox*

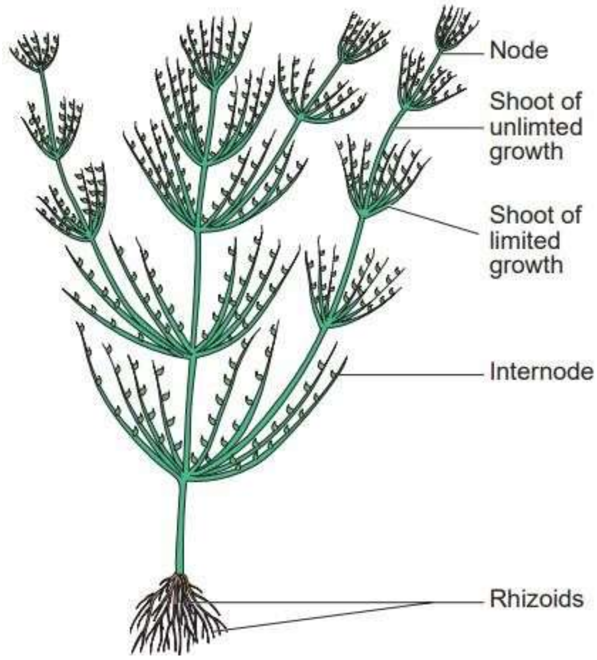
IDENTIFYING CHARACTER –

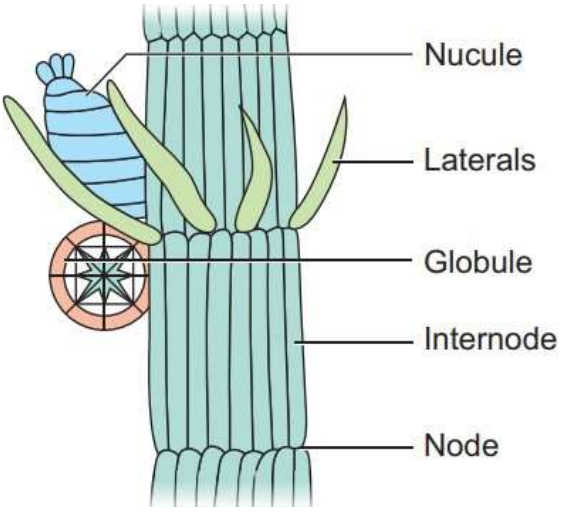
1) Chloroplasts green, storage product starch.
2) Cells spherical with interconnecting mucilaginous strands and are situated around theperiphery of the colony.
3) Mucilaginous strands do not radiate from the center of the colony.
4) Each cell with two equal length flagella.

Hence the specimen is *Volvox* sp.

COMMENTS –

1) Volvox colonies are large and spherical, composed of hundreds or thousands of cells.
2) May produce a fishy odor in drinking water.
3) Used as food for aquatic organisms.





A. Chara B. Sex Organ

Chara sp.

SYSTEMATIC POSITION –

Class: Charophyceae
Order: Charales
Family: Characeae
Genus: *Chara*

IDENTIFYING CHARACTER –

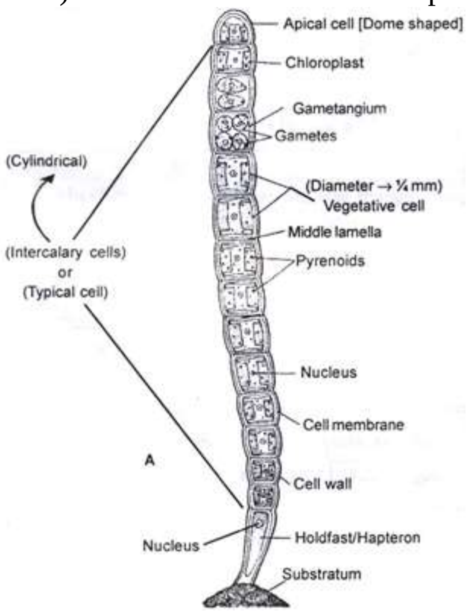
1) The branching system of *Chara* species is complex with branches derived from apical cellswhich cut off segments at the base to form nodal and internodal cells alternately.
2) The main axes bear whorls of branches in a superficial resemblance to Equisetum (avascular plant).

3) They are typically anchored to the littoral substrate by means of branching undergroundrhizoids.
4) Chara plants are rough to the touch because of deposited calcium salts on the cell wall.
5) The metabolic processes associated with this deposition often give Chara plants a distinctive and unpleasant smell of hydrogen sulfide.

Hence the specimen is *Chara* sp.

COMMENTS –

1) This is a phytoplankton and commonly used as fish food.
2) The common name of the plant is Stonewort.



Ulothrix sp.

SYSTEMATIC POSITION –

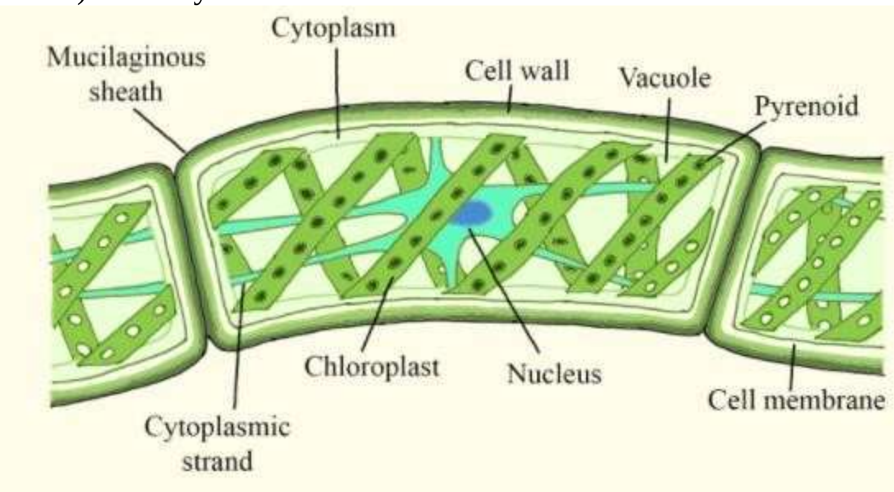
Class: Ulvophyceae
Order: Ulotrichales
Family: Ulotrichaceae
Genus: *Ulothrix*

IDENTIFYING CHARACTER –

1) Chloroplast saddle-shaped extending more than half way around the circumference of thecell
2) The plant body consists of unbranched, uniseriate filaments.
3) The cells of the filaments are arranged end to end.
4) They are cylindrical or barrel-shaped.
5) The apical cell is somewhat rounded at its terminal end whereas the basal cell is elongated. It is also called the basal holdfast, which attaches the filament to the substratum. The cell wall is composed of propectin and cellulose and it lacks mucilage.
6) Each cell has a single girdle-like and parietal chloroplast and two to many pyrenoids are present in each chloroplast

COMMENTS –

1) *Ulothrix* is a genus of non-branching filamentous green algae, generally found in fresh andmarine water.
2) Usually used as common fish food in freshwater.



Spirogyra sp.

SYSTEMATIC POSITION –

Class:
Zygnematophyceae
Order: Zygnematales
Family: Zygnemataceae
Genus: *Spirogyra*

IDENTIFYING CHARACTER –

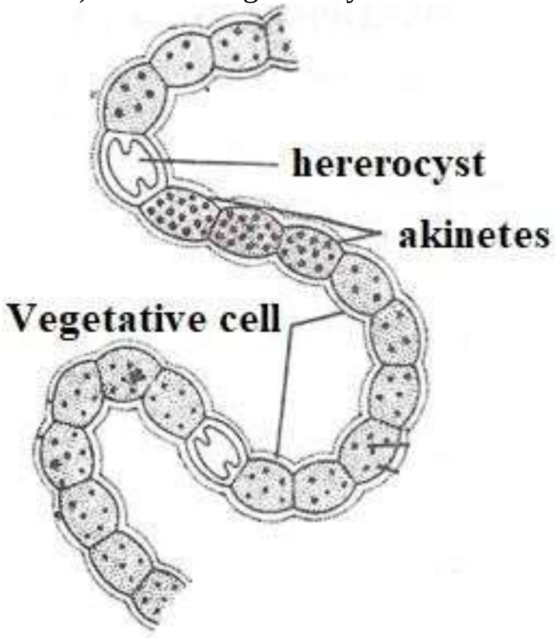
1) Chloroplasts form a distinct spiral band within the cell.
2) Spirogyra has cylindrical cells that are joined end to end to form an unbranched filament.
3) The cell walls are firm and have a thin film of mucilage on the outside, giving them a slimyfeel.
4) Chloroplasts have a helical shape and there can be up to 15 per cell. Numerous pyrenoidsare present.
5) The nucleus, often visible in live material, is in the center of the cell. Cells may be between10 and 160 µm in diameter and up to 590 µm long.
6) Filaments fragment easily at the cross walls, each fragment growing into a new filament.
7) Sexual reproduction in Spirogyra involves conjugation between cells of different filamentsand results in the production of a resistant zygote.
8) It is widely distributed in shallow ponds and ditches where it can form dense green

masses.Hence the specimen is *Ulothrix* sp.

COMMENTS –

1) Very important phytoplankton and plant consumed by zooplankton and herbivorous fishes.

2) These are generally found in the margin of stagnant water body.



Nostoc sp.

SYSTEMATIC POSITION –

Class: Cyanophyceae
Order: Nostocales
Family: Nostocaceae
Genus: *Nostoc*

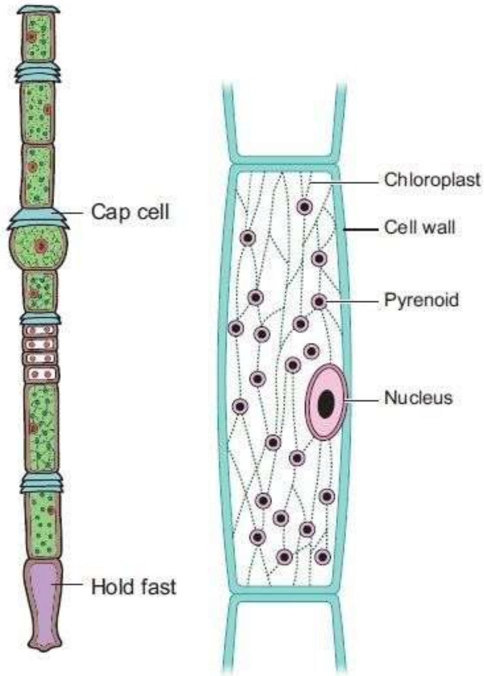
IDENTIFYING CHARACTER –

1) Trichromes embedded in obvious and extensive firm mucilage.
2) Cells of *Nostoc* are similar to *Anabaena* but they are embedded in firm, extensive, mucilagewhich may be leathery in texture and colored straw or brown.
3) In older colonies the trichomes tend to be situated towards the edge.
4) Akinetes may occur in older parts of the colony and are produced between heterocysts(unlike in Anabaena).
5) Hormogonia may be occasionally produced.
6) The cells are approximately spherical to barrel-shaped 3–6 µm wide.

Hence the specimen is *Nostoc* sp.

COMMENTS –

1) Grows on damp or wet surfaces, shallow waters. Can be free floating or attached.
2) It occurs in rice paddies where it is used to contribute nitrogen to the rice crop.
3) Nostoc can produce toxins in freshwaters, e.g. microcystins and lipopolysaccharides.



Oedogonium sp.

SYSTEMATIC POSITION –

Class: Chlorophyceae
Order: Oedogoniales
Family: Oedogoniaceae
Genus: *Oedogonium*

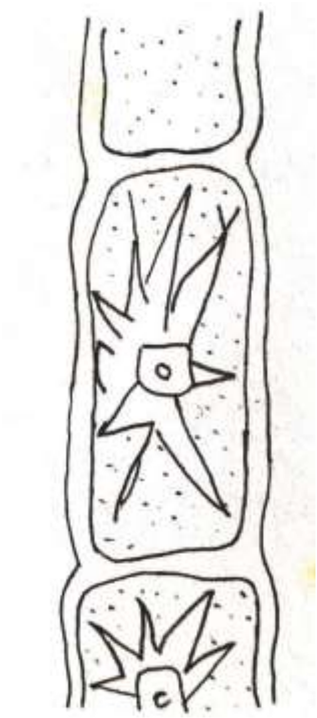
IDENTIFYING CHARACTER –

1) Cells form long, unbranched, filaments.
2) Cells cylindrical, sometimes slightly swollen at one end.
3) The chloroplast is parietal and netlike.
4) Cell wall firm but not very robust.
5) Filaments unbranched. Some cells along the filament will have ring-like transverse lines atthe swollen end (cap cells).
6) Cells 10–40 µm wide and 2–5 times as long as broad.

Hence the specimen is *Oedogonium* sp.

COMMENTS –

1) *Oedogonium* is a genus of filamentous, free-living green algae.
2) *Oedogonium* has been found to be important in the fixation of heavy metals in freshwaterecosystems.
3) Common fish food for zooplanktons and herbivorous fish.



Zygnema sp.

SYSTEMATIC POSITION –

Class:
Zygnematophyceae
Order: Zygnematales
Family: Zygnemataceae
Genus: *Zygnema*

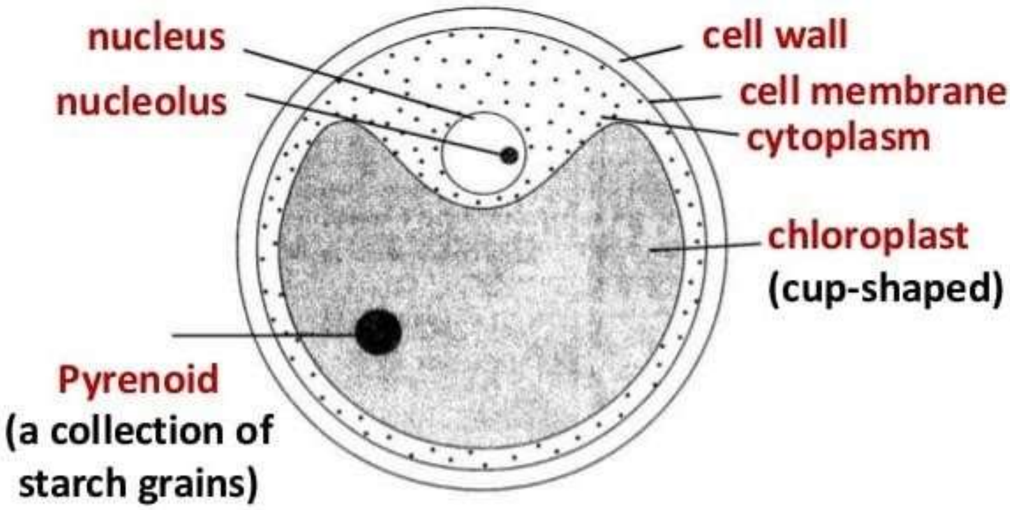
IDENTIFYING CHARACTER –

1) Cells of *Zygnema* are cylindrical and have two, characteristic, star-shaped chloroplastsseparated by a clear area.
2) Each chloroplast has a pyrenoid.
3) The filaments usually have a soft mucilage sheath, are unbranched and not very long.
4) They may be attached to a substrate by means of rhizoids.
5) Cells 16–50 µm in diameter and 2 to 3 times long as broad.

Hence the specimen is *Zygnema* sp.

COMMENTS –

1) As members of the Chlorophyta they store starch and used as food for zooplankton andaquatic organisms.
2) Common in shallow waters where it can form luxuriant growths.
3) Excess growth may cause bloom and oxygen depletion in pond water. Huge growth maycause fish death.



Chlorella sp.

SYSTEMATIC POSITION

Class:
Trebouxiophyceae
Order: Chlorellales
Family: Chlorellaceae
Genus: *Chlorella*

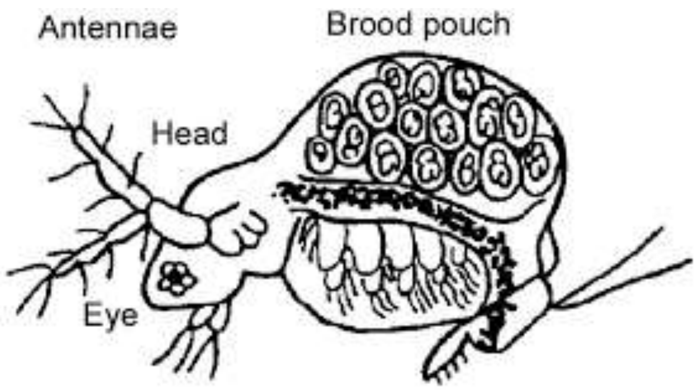
IDENTIFYING CHARACTER –

1) *Chlorella* cells are spherical to sub spherical with a single parietal chloroplast which nearlyfills the cell.
2) A single pyrenoid is present.
3) Cells 2–10 µm in diameter.

Hence the specimen is *Chlorella* sp.

COMMENTS –

1) Common in nutrient-rich waters but easily overlooked because of their small size. Its smallsize can also mean that it can pass through traditional water treatment sand filters giving rise to color problems in the treated water.
2) *Chlorella* is a food source because it is high in protein and other essential nutrients; whendried, it is about 45% protein, 20% fat, 20% carbohydrate, 5% fiber, and 10% minerals andvitamins.



SYSTEMATIC POSITION –

Phylum: Arthropoda
Subphylum: Crustacea
Class: Branchiopoda
Order: Anomopoda
Family: Moinidae
Genus: *Moina*

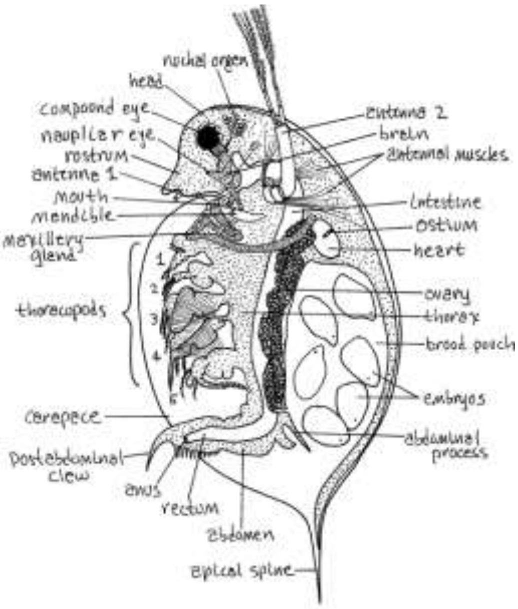
IDENTIFYING CHARACTER –

1) Body is more or less oval shaped.
2) Presence of pointed appendages
3) Presence of 2 pairs of antennules.
4) Presence of distinctly visible eyes.
5) Presence of abdominal scales
6) Cephalic region is more or less conical in shape.
7) Posterior part of the body more or less conical in shape.

Hence, the specimen is *Moina* sp.

COMMENTS –

1) This genus demonstrates the ability to survive in waters containing low oxygen levels, highsalinity, and other impurities, including salt pans, and commonly eutrophication.
2) Very important fish food organisms.



Daphnia sp.

SYSTEMATIC POSITION –

Phylum: Arthropoda
Subphylum: Crustacea
Class: Branchiopoda
Order: Anomopoda
Family: Daphniidae
Genus: *Daphnia* sp.

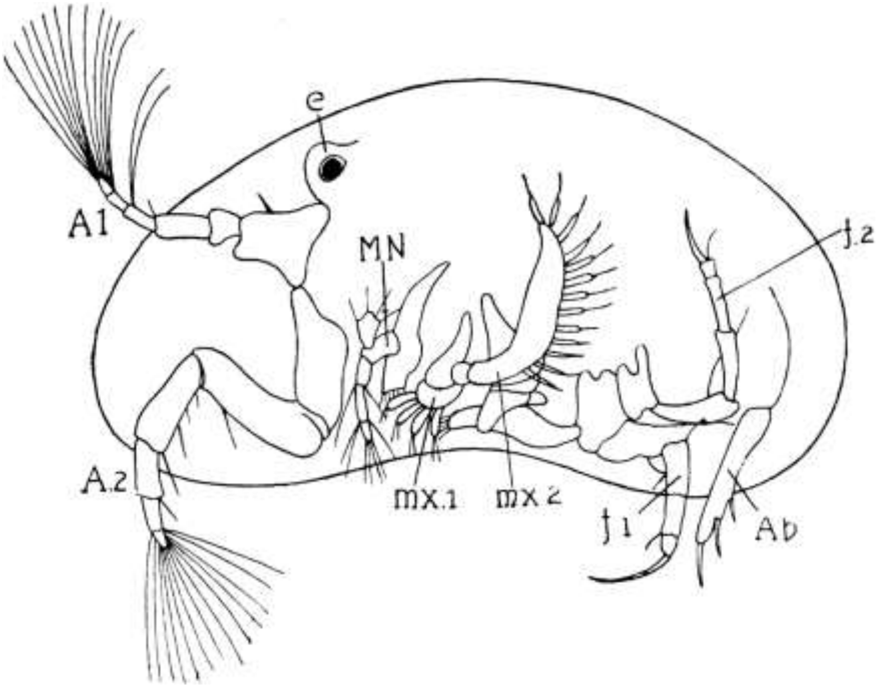
IDENTIFYING CHARACTER –

1) The body of a Daphnia species is usually 1–5 mm (0.039–0.197 in) long, and is divided into segments, although this division is not visible.
2) The head is fused, and is generally bent down towards the body with a visible notch separating the two. In most species, the rest of the body is covered by a carapace, with a ventral gap in which the five or six pairs of legs lie.
3) The most prominent features are the compound eyes, the second antennae, and a pair of abdominal setae.
4) In many species, the carapace is translucent or nearly.

Hence, the specimen is *Daphnia* sp.

COMMENTS –

1) *Daphnia* spp. are a popular live food in tropical and marine fish keeping.
2) *Daphnia* spp. is used in certain environments to test the effects of toxins on an ecosystem.
3) Because of their thin membranes, which allow drugs to be absorbed, they are used tomonitor the effects of certain drugs, such as adrenaline or capsaicin.



Cypris, side view, after removal of one valve. e., Eye; A.1, first antennae; A.2, second antennae; MN., mandibles; mx.1, first maxilla; mx.2, second maxilla; f.1, f.2, thoracic legs; Ab., rudimentaryabdomen

SYSTEMATIC POSITION –

Phylum: Arthropoda
Subphylum: Crustacea
Class: Ostracoda
Order: Podocopida
Family: Cyprididae
Genus: *Cypris*

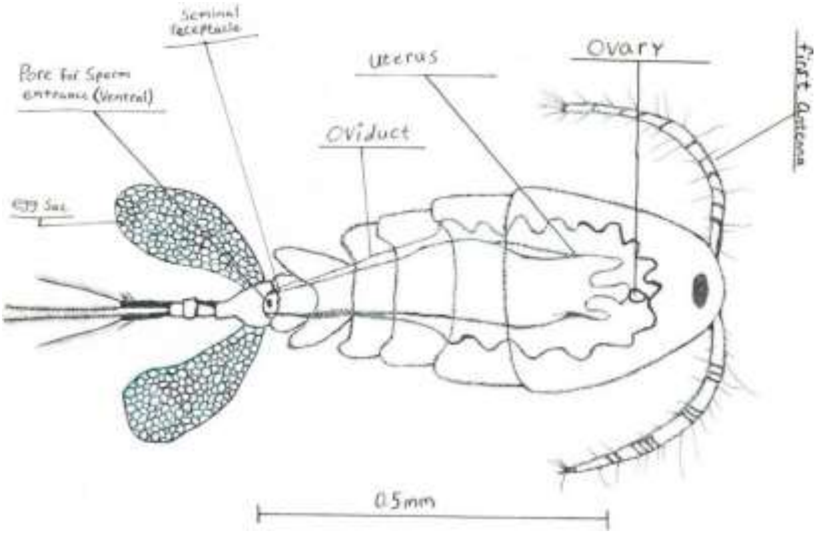
IDENTIFYING CHARACTER –

1) Carapace nearly pea-shaped, valves asymmetric, right valve overlaps left one.
2) Furca with short terminal claw, distal and proximal setae unequal in length.
3) Presence of distinctly visible eyes.
4) Body is covered with soft gel like covering.
5) Presence of jointed appendages at the posterior part of the body.

Hence the specimen is *Cypris* sp.

COMMENTS –

1) Primary consumers of tropic level.
2) These are nutritious food for aquatic organisms.



Cyclops sp.

SYSTEMATIC POSITION –

Phylum: Arthropoda
Subphylum: Crustacea
Class: Hexanauplia
Order: Cyclopoida
Family: Cyclopidae
Genus: *Cyclops* sp.

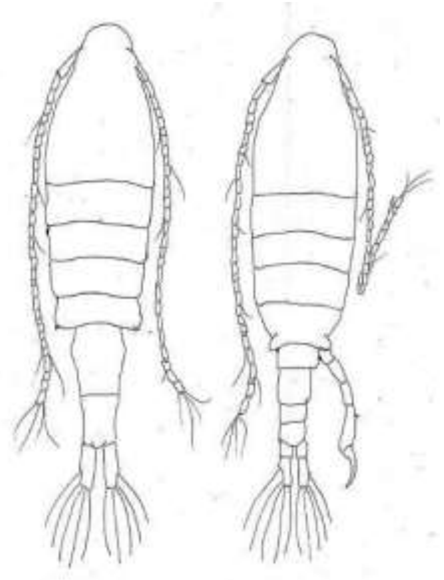
IDENTIFYING CHARACTER –

1) Cyclops individuals may range from ½–5 mm long and are clearly divided into two sections.
2) The broadly oval front section comprises the head and the first five thoracic segments. Thehind part is considerably slimmer and is made up of the sixth thoracic segment and the fourlegless pleonic segments.
3) Two caudal appendages project from the rear. Although they may be difficult to observe, Cyclops has 5 pairs of legs.
4) The long first antennae, 2 in number, are used by the males for gripping the females duringmating.
5) Afterwards, the female carries the eggs in two small sacs on her body. The larvae, or nauplii, are free-swimming and unsegmented.

Hence, the specimen is *Cyclops* sp.

COMMENTS –

1) Cyclops is intermediate host of dracunculiasis (guinea-worm disease) and fish tapeworm(*Diphyllobothrium latum*) infection.
2) Primary consumer of the trophic level, nutritious food for aquatic organisms.



Female & Male

SYSTEMATIC POSITION –

Phylum: Arthropoda
Subphylum: Crustacea
Class: Maxillopoda
Order: Calanoida
Family: Diaptomidae
Genus: *Leptodiaptomus*

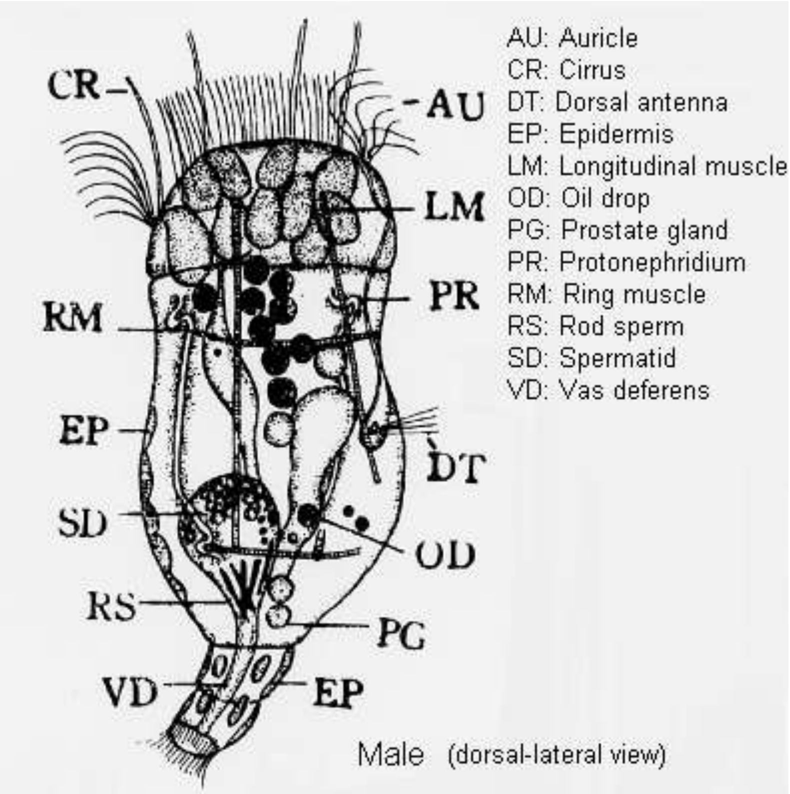
IDENTIFYING CHARACTER –

1) *Leptodiaptomus* adult females are characterized by a two-segmented urosome, metasomalwings that are nearly symmetrical and rounded, and endopods of leg 5 are greatly reducedin size.
2) In adult males, the small lateral spine on the terminal segment of leg 5 is located in the proximal third of the segment, and the right (geniculate) antennule has a slender process on the third to the last segment.
3) The right antennule on the male has a long, slender process coming off the terminal end ofthe third segment from the distal end and the metasomal wings are expanded and triangularin shape.

Hence, the specimen is *Leptodiaptomus* sp.

COMMENTS –

1) *Leptodiaptomus* is a prey animal for aquatic organisms. This zooplankton is nutritious foodfor fish and other aquatic organisms.



SYSTEMATIC POSITION –

Phylum: Rotifera
Class: Monogononta
Order: Ploima
Family: Brachionidae
Genus: *Keratella* sp.

IDENTIFYING CHARACTER –

2) Keratella has an oval lorica, a shell-like protective outer cuticle.
3) At the anterior end are three pairs of spines.
4) The central pair curve towards the ventral surface, the next pair diverge slightly and theouter pair converge.
5) There is a single red eye.
6) There is also a central funnel-shaped mouth and on either side of this are rings of ciliawhich twirl and help waft food particles into the mouth.

Hence, the specimen is *Leptodiaptomus* sp.

COMMENTS –

1) *Keratella* is found worldwide in marine, brackish and freshwater habitats.
2) Keratella is a rotifer and very important fish food organism.

Table of Contents

Title

Experiment #01

To find the pH value of a given solution.

Objective/Significance:

It represents the acidity or basicity of

water sample.PH scale ranges from 0-14.

1

2

3 Acidity increases (H^+ ions are more)

4 Basicity decreases

(OH^- ions are less)5

6

7 Neutral point (at

temperature 25 ^{0}C)8

9

10 Basicity increases (OH^- ions are more)

11 Acidity decrease

(H^+ ions are less)12

13

14

pH is important because biological and chemical reactions take place in very narrow range ofpH. If pH is not appropriate, animals and plants will be harmed.

Apparatus: pH meter, Beaker, Distill water. (Buffer Solution)

Reagent: No reagent is used.

Procedure: Dip the pH meter probe in sample, stir it and note the reading until stable.

Title

Experiment #02

To find out the Alkalinity of the given solution.

Objective/Significance:

Alkalinity is a measure of water's ability to neutralize acids or it shows buffering capacity of water.

Alkalinity is mainly due to:

- Carbonate ion CO_3^{-2}
- Bi-Carbonate ion HCO_3^{-1}
- Hydroxyl ion OH^{-1}

Alkalinity determination is needed for calculating the coagulant dose and lime and soda ashrequirements in water softening process. Alkalinity is total concentration of base in water.

Apparatus:

Burette, Pipettes, Titration flask, Measuring cylinder, beakers.

Reagents:

Phenolphthalein Indicator, Methyl Orange Indicator, H_2SO_4(0.02N) Titrant.

Procedure:

Take 50 ml of water sample in titration flask. Add few drops (2-5) of phenolphthalein indicator. If water becomes pink, titrate it by H_2SO_4 until pink color disappears. Measure the amount of H_2SO_4 used. Then add few drops (3-5) of methyl orange in the sample. The solution will become yellow. Titrate it by H_2SO_4 until yellow color changes into orange or pinkish orange. Measure the H_2SO_4 used. Sum up the volumes of H_2SO_4 used in both titrations and calculate total alkalinity by this formula.

$$\text{Total Alkalinity (in mg/lit)} = \frac{(\text{ml of titrant}) \times (N) \times (50) \times (1000)}{\text{Sample vol. in ml}}$$

Where, N= Normality of H_2SO_4 i.e. (0.02).

Note: If phenolphthalein does not change the color of water to pink, directly go for methyl orange alkalinity

Title

Experiment# 03

To find out the Acidity of the given solution

Objective/Significance:

It is measure of the acids present in water sample. In natural unpolluted waters, acidity is due to CO_2 which reacts with H_2O to form carbonic Acid. In polluted water some acidity is due to acetic or organic acids. If acidity is more (i.e. pH low) then it harmful for giving organisms in water and for drinking purpose.

Apparatus:

Burette, Pipettes, Titration Flask, Measuring cylinder, Beakers.

Reagents:

Sodium Hydroxide (NaOH)0.02N solution, phenolphthalein indicator.

Procedure:

Take 100 ml of water sample in titration flask. Add 2 drops of a phenolphthalein indicator and Titrate it with sodium hydroxide solution till light pink color appears.

Calculate acidity by following formula:

$$\text{Total Acidity} = \frac{(\text{ml of titrant}) \times (N) \times (50) \times (1000)}{\text{Sample vol. in ml}} \text{(in mg/lit)}$$

Where

N = Normality of NaOH i.e. (0.02).

OBSERVATION AND CALCULATIONS:

No. of Observations	Initial reading	Final reading	Actual volume used	Mean
1				
2				
3				

Result:...
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Title

Experiment #04

To find out the dissolved oxygen of a given sample.

Objective/Significance:

Dissolved oxygen (DO) in water comes from air and also produced by plants living in water. DO is required for respiration by all living organisms of water. If DO is less or absent the living organism may not be survive. High temperature, more dissolved solids and organisms matter cause decrease in DO levels.

Apparatus:

. Burette, Pipettes, Measuring Cylinder, Titration flask, beaker, Stirrer

Reagents:

$MnSO_4$ (Manganese sulphate), Alkali iodide Azide, $Na_2S_2O_3$(Sodium Thio-sulphate 0.025N).Conc. H_2SO_4.Starch Indicator.

Procedure:

Take 300 ml water sample in titration flask. Add 2 ml $MnSO_4$ and 2 ml alkali iodide Azide into asimple. Shake very well and settle the contents for 3 minutes. Add 2 ml H_2SO_4 and Shake. Take 200 ml of the bottle content in a flask. Titrate against $Na_2S_2O_3$until a pale straw color (pale yellow color) appears. Now add 3 drops of starch indicator. The solution becomes blue. Now titrate it with 0.025N Na_2So_3 until blue color disappears.

Calculate dissolved oxygen by formula:

$$\text{Dissolved Oxygen (In mg/lit)} = \frac{(\text{ml of titrant}) \times (8) \times (0.025) \times (1000)}{\text{Sample vol. In ml}}$$

Observations and Calculations:

No. of Observations	Initial reading	Final reading	Actual volume used	Mean
1				
2				
3				

Result:...
.

....

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Title

Experiment #05

To find out the Carbon Dioxide in a given sample.

Objective/Significance:

It comes from air and is also produced by all living organisms. CO_2 is necessary for food production in plants. If it is not present, plants will die. So, all organisms will be harmed. If CO_2 is more, it will increase acidity which is harmful.

Apparatus:

Burette, Pipettes, Measuring Cylinder, Titration Flask and Beaker.

Reagents:

Na_2CO_3(sodium carbonate, 0.045N), Phenolphthalein indicator.

Procedure:

Take 50ml water sample in titration flask. Add 4 drops of phenolphthalein indicator. If sample become pink, then there is no free CO_2.Do not titrate it. If Sample is colorless, it means that free $CO_2$is present. Titrate it with Na_2CO_3 (0.045N). When very light pink color appears, it meansthat it is end point. Note the ml of titrant used and calculate free CO_2 by the following formula:

$$C0_2 \text{ (In mg/lit)} = \frac{(\text{ml of titrant}) \times (0.045) \times (22) \times (1000)}{\text{Sample vol. in ml.}}$$

Observations and Calculations:

No. of Observations	Initial reading	Final reading	Actual volume used	Mean
1				
2				
3				

Result:

……
……

……
……

……………………………………………………………

Title

Aim:

Experiment #06

To find out the Total hardness in a given sample.

To estimate the amount of total hardness in the collected sample of water.

Principle:

Hardness in water is due to the presence of dissolved salts of calcium and Magnesium. It is unfit for drinking, bathing, washing and it also forms scales in boilers. Hence it is necessary to estimate the amount of hardness producing substances present in the water sample. Once it is estimated, the amount of chemicals required for the treatment of water can be calculated.

The estimation of hardness is based on complexometric titration. Hardness of water is determined by titrating with a standard solution of ethylene diamine tetra acetic acid (EDTA) which is a complexing agent.

Total hardness:

Total hardness is due to the presence of bicarbonates, chlorides and sulphates of calcium andmagnesium ions.

Apparatus:

Burette, Pipettes, Measuring Cylinder, Titration flask, Beakers, Conical flask.

Reagents:

Ethylene diamine tetra acid (EDTA)0.01M Erichrome Black-T, Buffer solution (pH

9.5)1 ml of 0.01M EDTA solution =1.00mg of $CaCO_3$

Procedure:

- Take 50 ml water sample in titration flask.
- Add 5 ml of Ammonia buffer and 2 drops of Erichrome Black-T indicator.
- Titrate it against 0.01M EDTA until the blue color is appeared.
- Note the ml of titrant used and calculate the hardness of the sample by the followingformula:

$$\text{Hardness as mg/l } CaCO_3 = \frac{\text{Vol. of EDTA used for titration} \times 1000}{\text{Sample vol.in ml.}}$$

Observations and Calculations:

No. of Observations	Initial reading	Final reading	Actual volume used	Mean
1				
2				
3				

Result:

....
......
....
......
....

Title

Experiment #07

To find out the permanent hardness in a given sample.

Permanent hardness:

Permanent hardness is due to the presence of chlorides and sulphates of calcium and magnesiumions. This type of hardness cannot be removed by boiling**.**

Apparatus:

Burette, Pipettes, Measuring Cylinder, Titration Flask, Beaker, Conical Flask.

Reagents:

EDTA0.01M Erichrome Black-T, Buffer solution (pH 9.5).

Procedure:

Take 100 ml of water sample in titration flask. Boil it for 20 minutes and then cool it. Add 5ml ofAmmonia buffer and 2 drops of Erichrome Black-T indicator. Titration it against 0.01M EDTA until the light blue color is appeared. Note the ml of titrant used and calculate the permanent hardness of the sample by the following formula:

$M_1V_1 = M_2V_2$

Observations and Calculations:

No. of Observations	Initial reading	Final reading	Actual volume used	Mean
1				
2				
3				

Result:

....
....
....
....
....

Title

Experiment #8

To find out the total suspended solids in the given sample:

Objectives/Significance:

Environmental waters may contain a variety of solid or dissolved impurities. In quantifying levels of these impurities, suspended solids are the term used to describe particles in the water column. Practically, they are defined as particles large enough to not pass through the filter used to separate them from the water. Smaller particles, along with ionic species, are referred to as dissolved solids. In considering waters for human consumption or other uses, it is important to know the concentrations of both suspended and dissolved solids. The most common pollutant in the world is “dirt” in the form of TSS.

TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.

Total

Apparatus:

Crucibles (Evaporating dish), Measuring Cylinder, oven. Furnace, Desiccators balance.

Reagents:

No reagent is used.

Procedure:

- Note down the initial dry weight of filter paper.
- Filter 50ml of the field water sample using whattman filter paper
- Take the filter paper and place it on the evaporating dish
- Place the evaporating dish inside the oven at 103°C
- After drying in the oven cool to room temperature inside desiccator
- Note down the final dry weight of the filter paper

Calculations:

Weight of filter paper W_1= ....g

Weight of filter paper + residue (W_2) = ...g

Total solids =

(W_2

-W_1) ×1000(in mg/lit)

Sa

mple vol. in ml

Title:

Aim:

Experiment #09

To find out the volatile solids in a given solution

To determine total organic (Volatile Solids) and inorganic (Fixed Solids) solids in the givenwater sample.

Introduction:

The term total volatile solids refer to materials that are completely volatilized from water at higher temperature (550ºC). These solids are often referred to the organic content of the water, and the term total fixed solids can be referred to materials which are not volatilized from water athigher temperature (550ºC). These solids are often referred to the inorganic content of the water.

Apparatus:

Crucibles (Evaporating dish), Measuring Cylinder, Oven Furnace, Desiccators and Balance

Reagents:

No reagent is used.

Procedure:

- To measure the total volatile solids, take a clean silica crucible which has been washedand dried in a hot air oven at 105º C for one hour and ignited at 550ºC to remove all organic materials present in it.
- Now weigh the empty silica crucible in analytical balance. Let's denote the weightmeasured as W1.
- Using pipette transfer 75ml of unfiltered sample in porcelain dish.
- Switch on the oven and allowed to reach 105ºC
- Place the silica crucible in the hot air oven and care should be taken to prevent ofsplattering of sample during evaporating or boiling
- Dry the sample to get the constant mass
- Cool the container in desiccator.
- Note the weight with residue as W_2.
- Switch on the furnace and allow it to reach 550ºC
- Place the silica crucible in the furnace
- Note the weight as W_3 .

Calculations:

Initial weight of the evaporating dish + sample **(W_1)** **=…............ g**

Final weight of the evaporating dish + sample after drying at 103°C **(W_2) = ...g**

Final weight of the evaporating dish + sample after drying at 550°C **(W_3) = ...g**

Weight of Volatile Substance = W_2-W_3

Total volatile solids = $\frac{(W_2-W_3)\times 1000}{\text{Sample vol.in ml}}$ (in mg/lit)

Title:

Experiment #10

To find out settle-able solids in a given solution.

Objective:

The settle able solids test is the measurement of the volume of solids in one liter of sample that will settle to the bottom of an Imhoff cone during a specific time. The test indicates the volume of solids removed by settling in sedimentation tanks, clarifiers, or ponds. The settle able solids test indicates whether the primary and secondary processes are functioning properly.

Apparatus:

Imhoff Cone, Measuring Cylinder, Beaker.

Reagents:

No reagent is used

Procedure:

- Mix the waster sample and pour 1000ml into Imhoff cone.
- Place the cone in the support rack allow the sample to settle for 45 minutes.
- Spain the cone and allow the sample to settle for another 15 minutes.
- Record the volume of settle-able matter (ml/lit which has accumulated in the bottom ofthe cone.

Title

Aim:

Experiment #11

To find out the total solids in the given solution.

To determine the total solids in the given water sample

Introduction:

The term "solids" is generally used when referring to any material suspended or dissolved in water or wastewater that can be physically isolated either through filtration or through evaporation.

Solids can be classified as either filterable or non-filterable. Filterable solids may either be settleable or non-settleable. Solids can also be classified as organic or inorganic.

Total solids in term applied to the material residue left in the vessel after evaporation of a sampleand its subsequent drying out in an oven at a defined temperature. Dissolved solids may lead to scaling in boiler, corrosion and degraded quality of the product. Estimation of total dissolved solids is useful to determine whether the water is suitable for drinking purpose, agriculture and industrial purpose.

Measurement of solids can be made in different water samples (industrial, domestic and drinkingwater) and it is defined as residue upon evaporation of free water.

Environmental Significance:

Total Solids measurements can be useful as an indicator of the effects of runoff from construction, agriculture practices, logging activities, sewage treatment plant discharge and othersources.

Total solids also affect water clarity. Higher solids decrease the passage of light through water. Water will heat up affect aquatic life that has adapted to a lower temperature regime.

As with turbidity, concentration often increases sharply during rainfall. Especially in developed watersheds.

Apparatus:

Crucible (Evaporating dish), Measuring Cylinder, Oven Furnace, Desiccators, Balance

Reagents:

No reagent is used.

Procedure:

- Put the crucible in furnace at 103^{0}C temperature for 30 minutes.
- Cool the crucible in desiccator.
- Weigh the crucible. This is represented by D.
- Now add a measured amount of water sample in crucible.
- Place the crucible inside the oven at 103^{0}C for 60 minutes.
- After this take crucible out and cool it in desiccator.
- After cooling, weigh the crucible with solids.
- This weight is represented by R.
- Calculate the total solids by the following formula:

$$\text{Total solids} = \frac{(R - D) \times 1000}{\text{Sample vol. in ml}} \text{ (in mg/lit)}$$

Precautions:

- Water or wastewater samples which contain high concentrations of calcium, chloride, magnesium or sulphate can readily absorb moisture from the air. Such samples may needto be dried for a longer period of time, cooled under proper desiccation and weighed rapidly in order to achieve a reasonable constant weight.
- Non representative particles such as leaves, sticks etc. should be excluded from thesample.

Course outlines

Part – I

History of Entomology in India, Major points related to dominance of Insecta in Animal kingdom. Classification of phylum Arthropoda up to classes. Relationship of class Insecta with other classes of Arthropoda. Morphology: Structure and functions of insect cuticle and molting. Body segmentation. Structure of Head, thorax and abdomen. Structure and modifications of insect antennae, mouth parts, legs, Wing venation, modifications and wing coupling apparatus. Structure of male and female genital organ. Metamorphosis and diapause in insects. Types of larvae and pupae. Structure and functions of digestive,

circulatory, excretory, respiratory, nervous, secretary (Endocrine) and reproductive system, in insects. Types of reproduction in insects. Major sensory organs like simple and compound eyes, chemoreceptor.

Part-II

Insect Ecology: Introduction, Environment and its components. Effect of abiotic factors– temperature, moisture, humidity, rainfall, light, atmospheric pressure and air currents. Effect of biotic factors – food competition, natural and environmental resistance.

Part III

Categories of pests. Concept of IPM, Practices, scope and limitations of IPM. Classification of insecticides, toxicity of insecticides and formulations of insecticides. Chemical control- importance, hazards and limitations. Recent methods of pest control, repellents, antifeedants, hormones, attractants, gamma radiation. Insecticides Act 1968- Important provisions. Application techniques of spray fluids. Symptoms of poisoning, first aid and antidotes.

Part – IV

Systematics: Taxonomy –importance, history and development and binomial nomenclature. Definitions of Biotype, Sub-species, Species, Genus, Family and Order. Classification of class Insecta up to Orders, basic groups of present day insects with special emphasis to orders and families of Agricultural importance like Orthoptera: Acrididae,Tettigonidae, Gryllidae, Gryllotalpidae; Dictyoptera: Mantidae, Blattidae; Odonata; Isoptera: Termitidae; Thysanoptera: Thripidae; Hemiptera: Pentatomidae, Coreidae, Cimicidae, Pyrrhocoridae, Lygaeidae, Cicadellidae, Delphacidae, Aphididae, Coccidae, Lophophidae,

Aleurodidae, Pseudococcidae; Neuroptera: Chrysopidae; Lepidoptera: Pieridae, Papiloinidae, Noctuidae, Sphingidae, Pyralidae, Gelechiidae, Arctiidae, Saturnidae, Bombycidae; Coleoptera: Coccinellidae, Chrysomelidae, Cerambycidae, Curculionidae, Bruchidae, Scarabaeidae; Hymenoptera: Tenthridinidae, Apidae. Trichogrammatidae, Ichneumonidae, Braconidae, Chalcididae; Diptera: Cecidomyiidae, Tachinidae, Agromyziidae, Culicidae,Muscidae, Tephritidae.

Syllabus for Practicals

1. Methods of collection and preservation of insects including immature stages
2. External features of Grasshopper/Blister beetle
3. Types of insect antennae, mouthparts and legs
4. Wing venation, types of wings and wing coupling apparatus.
5. Types of insect larvae and pupae
6. Dissection of digestive system in insects (Grasshopper)
7. Dissection of male and female reproductive systems in insects (Grasshopper)
8. Study of characters of orders Orthoptera, Dictyoptera, Odonata,
9. Isoptera, Thysanoptera,
10. Hemiptera,
11. Lepidoptera,
12. Neuroptera,
13. Coleoptera,
14. Hymenoptera
15. Diptera and their families of agricultural importance.
16. Insecticides and their formulations.
17. Pesticide appliances and their maintenance.
18. Sampling techniques for estimation of insect population and damage.

Practical-1:To study the methods of collection and preservation of insects including immature stages

Insect collection is a source of recreation for many people and may be a hobby for thosewho are interested in studying insects. Methods of collection and preservation of insects arethe pre-requisite to study the insects and their various internal and external organs. Aftercollection, it becomes imperative to keep and preserve the insect specimens intact and safefor longer time to further study the characters or to develop the insect collection museum.Let‘s have a look and do the different types methods of collection, devices used for collectionand preservation of insects including immature stages in this practical session.

Nature of insect collection

A good Zoological collection should consist of at least four (4) individual representativeof each of the order of insects. So that the collection comprises the great diversity and itshould reflect thedifferent forms occurs in insect fauna in a certain ecosystem.

Places of insect collection

Insects are omnipresent and abound anywhere and everywhere. A good place to startcollecting insects is a flowering hedgerow or garden where insects can be found on thedifferent parts of plants like flowers, leaves and stems. Besides these, we can also probe thesmall insects in the soil or near the roots of plants, aquatic insects can be collected in water,ponds, streams, rivers, lakes etc. and even do the indoors collection year round.They can be collected from- **Air (**flying insects), **Wate**r (dragonflies, mayflies andstoneflies that hover over water, aquatic insects and sea shore insects), **Home** (fromfurniture, boxes, bookshelves (fleas, bugs, flies, and mosquitoes), flower, fruits andvegetables brought in), **Debris and animal dung** (which acts as food source for manyinsects), and from **domestic animals and birds** (ecto and endo- parasites).

Catching insects: Aerial insects can be caught during flight or after they have alighted bysweeping a net through the air or foliage or by beating the foliage and holding the netbelow.

- The aerial/ sweep nets can catch aerial insects.
- Net forceps, dippers and dredge, can catch aquatic insects.
- Separator and Berlese funnel can catch soil dwelling insects.

Methods of insect collection

1. Hand picking

This method is suitable for catching the large insects like beetles and grasshoppers. It isvery tedious (hard working) method and not suitable for catching the biting and stingingnatured insects.

2. Aerial net or Butterfly net

It is light in weight, useful for catching activefliers like butterflies, moths, dragonflies,wasp, fliesetc. The net consists of three partsviz., loop or frame; handle and porous muslinclothe bags. The diameter of hoop and thedepth of the bag should be in the proportionof 1:2.

3. Sweep net

It is heavier than the aerial net. It consists ofshort handle, a large loop and dense clothbag. This is suitable for collectingleafhoppers, grasshoppers and other smallinsects. The net is swept over vegetation.

4. Beating tray

This method is suitable for collectingcrawling insects and those, which rest onbranches. A beating tray is held under abranch, which is then hit sharply with a stick.

5. Aspirator/Potters/Suction tube

It is the device to collect small insects intoglass vials with no damage to the specimens.It is employed to suck in through a rubbertube small and minute insect that is alreadycollected in the net or sitting on wall orfoliage and on the bark of the tree. Usually itis meant for catching more active insects. Toprevent entry of insect in to mouth, a smallcloth piece is kept in between the glass andrubber tube.

6. Berlese (Tullgren) funnel

Soil arthropods can be sorted out by thismethods. Debris including soil arthropodscan be collected by using the light as thesource of heat in berlese funnel method.

7. Traps- Trapping is a method of collecting insects in the absence of collector. This is themost common methods or techniques used by growers in Integrated pest managementprogramme to catch the insects. There are many different types of traps used for collectionof insects. They are pheromone traps or sleeve traps, fruit fly trap, sticky traps, delta traps,water or Wota traps, pitfall trap, wind pan trap, malaise trap and light traps.

Pheromone traps

Synthetic sex pheromones are placed in the traps to attract male moths. The rubberizedsepta containing the pheromone lure are kept in the traps designed especially for thispurpose and used in monitoring, mass trapping and mating disruption programmes. Stickytarps, Water pan traps and funnel type models are available for use in pheromone basedinsect-pest control programmes.**Yellow sticky traps:** Aphids, whiteflies, thrips prefer yellow colour. Yellow colour is paintedon tin boxes and sticky material like castor oil/vaseline is smeared on the sticky material.

Probe trap: It is used by keeping them under grain surface to trap stored product pests.

Pitfall traps: Containers such as small plastic buckets, plant pots, glass jars or jam tins aresunk into the ground to trap flightless, ground-living insects and arachnids, especiallybeetles (ground beetles), cockroaches, crickets, spiders, harvestmen and mites. The containershould be placed ina hole with the upper rim flush with the ground surface. A killing agentand preservative, such as ethylene glycol, should be placed in traps that are not emptieddaily. Radiating vanes, such as wooden planks, placed in the substrate will increase theeffective area of the trap. A bait can be added to the trap to increase its effectiveness.

Thetype of bait will depend on the specimens one wishes to catch.

Light traps: Light traps are mainly used for attracting moths & other night flying insectswhich are attracted towards the light. The insects are actively caught or encouraged to entera trap. The simplest light trap consists of a light on a cable hanging out in the field forattracting the pests during nights. However, besides a number of species of moths, beetles,flies, and other insects, most of which are not pests, are also attracted to artificial light. Soidentification of pests and beneficial insects is of prime importance before any controloperation is executed.

Mercury vapour lamp light trap: This trap is the basic model designed by Robinson (1952).This trap produces ultravoilet, blue and green radiation with little red. This is currently usedtowards a wide range of noctuids and other nocturnal flying insects. a mercury lamp (125W)is fixed at the top of a funnel shaped (or) trapezoid galvanized iron cone terminating in a jarcontaining dichlorvos soaked in cotton as insecticide to kill the insect.

Killing insects

Killing should be immediately after capture. Potassium cyanide (KCN), ethyl acetate,carbon tetrachloride and chloroform are commonly used for killing insects. KCN kills theinsects quicklybut deadly poisonous and must be handled with extreme care. Ethyl acetatekills the insects slowly and does not last long. But the dead insects remain in relaxedcondition for a longer time without becoming brittle and stiff.

Pinching- In this method, thorax is pressedbetween thumb and index finger swiftly andwith jerk.It needs constant practice. e.g.butterfly, grasshopper.

Injecting- Hypodermic injection of fluids.

Drowning- Larvae and insects without scales, hairs or powdery covering can be killed bysubmerging them in water. They die of Auto toxicity when excessive CO_2 unable to escapesfrom spiracles and collects in trachea and tissues.

How to prepare Killing Bottle/ Cyanide Bottle?

Steps involved in preparing the killing bottles are given below -

- Take a wide mouthed strong bottle or vial with a tight fitting lid.
- Place a layer of potassium cyanidegranules/pellets (1/4-inch thickness) atthe bottom ofbottle.
- Cover it with a layer of dry plaster ofParis (1/4 -inch thickness)
- Mix plaster of Paris with enoughwater so that it will pour off from theend of spoon. Pour1/2-inch layer ofwet plaster of Paris over the dry layer.
- Tap the bottle lightly on the table toeliminate any bubble in the bottle.
- Leave the lid off for a day to let theplaster dry in a well-ventilated room,completely awayfrom direct sunlight.
- Keep a circular piece of filter orblotting paper on the top of plaster ofParis and avoidcondensation of water droplets on the side of bottom (to check thesweating process).
- Lastly, the bottle should be tightly corked and labeled with the word –Poison‖.
- In place of KCN, now a day‘s Ethyl acetate is being used as the replacement inkillingbottle.

Insect Collection Box

Storage of insects is done in the insect boxes,which is made up of wood (top and bottomcould beof plywood) and lined on one(bottom) or both (roof also) sides with corksheets covered with white paper. It is light inweight, moisture proof and airtight. General(common) size of insect collection box is45x30x15 cm.

Labeling

Specimen collected should be uniform in size and labeled properly on stiff paper orreferencecard. Labeling consists of following notes i.e., **Host, Date, collector and Location.**

Setting or stretching boards

Setting is the method that wings antennaeand Occasionally (Hymenopterans) spread legsin full display of their features. This methodneeds a setting or stretching board which havetwo side‘s boards separated by groove. Bothboard and grooves are lined with thin sheet ofcork. The widthof groove varies according to thewidth of insect body.

Methods of preservation

Protection of Insect specimens

Collected Insects can be protected for longer time in insect collection box by puttingthenephathalene balls on the corner side of box.

Preservation of insects

a) Temporary preservation

b) Permanent preservation: Insects can be permanently preserved either dry, in fluid, oron microscope slides. Arachnids are always preserved in liquid or on microscope slides. Themethodof preservation depends on the type of arthropods. It can be done by the followingmethods-

- **Dry preservation-** Insects that are to be preserved dry are best mounted in ways thatfacilitate study and permanent storage. Specimens should be mounted soonafterkilling, if possible while still soft.
- **Liquid preservation-** It is done in 70 % ethyl alcohol + 4 % formaline solution. **Softscale insects and mealybugs** can be preserved in mixture of 4 parts 90 % ethanol and 1part glacial acetic acid whereas, **thrips** can be preserved in a mixture of 9 parts 60

%ethanol and 1 part glacial acetic acid. It is very important to periodically check and topup containers of a liquid collection.

- **Mounting on a microscopic slide-** Small specimens have to be mounted on microscopeslides so that they can be studied under a compound microscope. Theseinclude groupssuch as thrips, aphids, parasitic wasps, scale insects, booklice, lice and mites. Insect andspider body parts (e.g. mouthparts and genitalia), and larvae often haveto be slidemounted.Microscope slide mounts may be temporary or permanent, but specimensmaintained in collections require permanent mounts.

Bringing the specimen home or the laboratory Materials

required

Butterflies and other large-wingedinsects can be stored in folded protectivepaper envelopes. Most arthropod specimenscan be conveniently stored between layers ofabsorbent paper. Paper envelops(Newspaper, waxpaper) can be used to keepthe specimen and brought it to homeorlaboratory (having good absorbent quality)Cellophane and transparent plastics can alsobe used for this purpose.

Relaxing container/Jar

Relaxing is the method / process of re-softening the insects. Relaxing container/Jar –contains a layer of sand (5 cm thick) or any other absorbent materials (basal wood, pith,synthetic sponge) and few drops of formaline or carbolic acid is added to prevent mould/fungal growth and then covered with filter paper. Cleaning- Dust, pollens and dirt can beremoved with a camel hairbrushdipped in water mixed with detergent.

Preparing insects for the insect collection box

Insects longer than about 8 mm are usually mounted on pins pushed through thethorax. Insect pins are longer than ordinary pins, and are made of stainless steel that doesnot rust. A No. 2 or No. 3 entomological pin is suitable for most insects, although those withdelicate bodies may require a size No. 0 or No. 1.

Entomological pins-There is three general series of pins viz.,**English pins:** Sold by weight, range of 18-30 mm in length and stout, used to pinlepidopteran insects, which lies or kept low in the box.

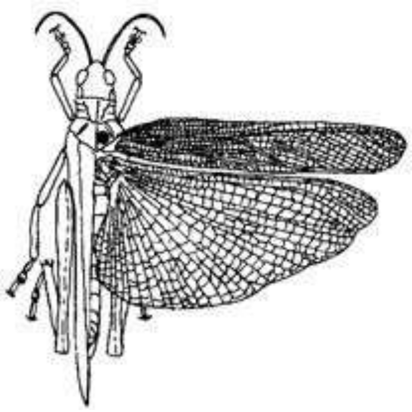
Continental pins: Sold by 100s, Range 35 mm in length,(000,00,0 & 1-7 Nos.), No. 2 & 3 areuseful for general purpose, 38 mm(No. 8-10), 50 mm(No. 11-12), 000 is the thinnest pin andNo. 12 is the thickest pin.

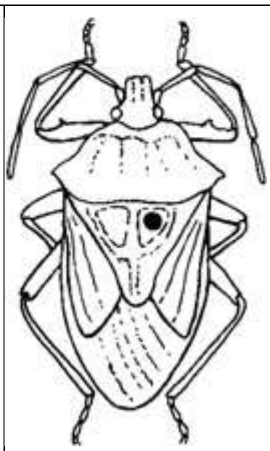
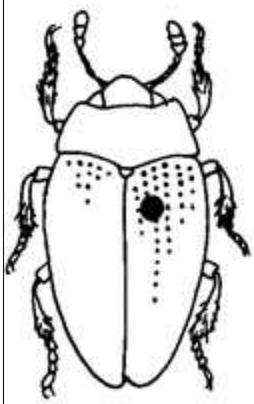
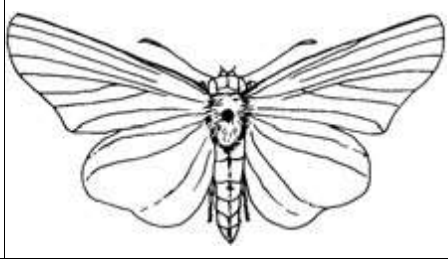
Minute pin: Minutest and finest pins, used for pinning the insects meant to stage, forminute, softest and fragile insects.

Pinning

It is the best and common method to preserve hard bodied insects. They will dry andremain in perfect condition on the pins for long time without any further treatment. Theyare pinnedvertically through the body. Depending upon the size of insect‘s pins has to beselected accordingly. Exact place of insertion of the pin varies among different groups ofinsects.

Insect groups Sketch diagram Pinning region

Insect groups	Sketch diagram	Pinning region
Grasshopper, crickets, Preying mantids and cockroaches		Pronotum

Bugs (most of the Hemipterans)		Scutellum
Beetles and weevils (Colepterans)		Right elytra
Dragonfly, damselfly, antlion, green lace wing fly, Moths, butterfly bees, wasp, ants and true flies etc.		Thorax

Double mounting

Pinning is troublesome in smallerinsects. Very small insects cannot be pinnedbecause most ofthe body parts of the insectsare lost during pinning. For such insectsdouble mounting can be followed.

Staging

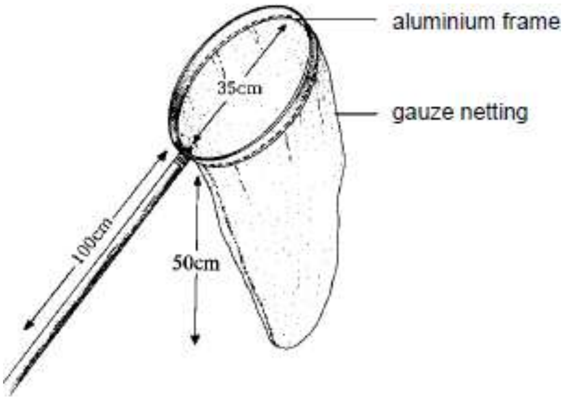
The stage is narrow rectangular piece ofcork or pith. The small insect is pinnedcorrectly with amicro pin to the stage. Laterthe stage is pinned in the insect store boxwith a bigger pin.

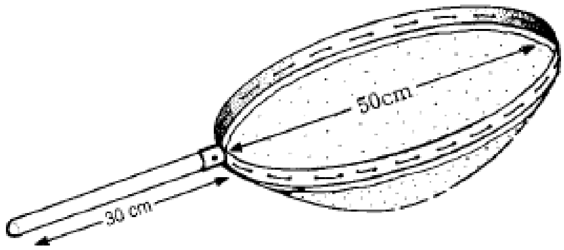
Carding

A rectangular white card (**5**x**8 or 5**x**12mm**) may be used as stage. On stage insteadof pinning, the insect specimen is stuck on itby **using glue or adhesive**. After mountingthe insect, card is pinned in the box with alarge pin.

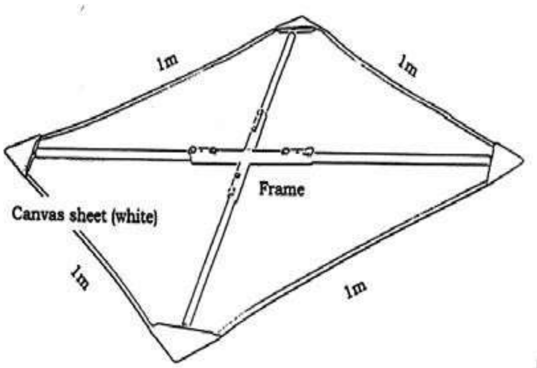
Pointing / gumming

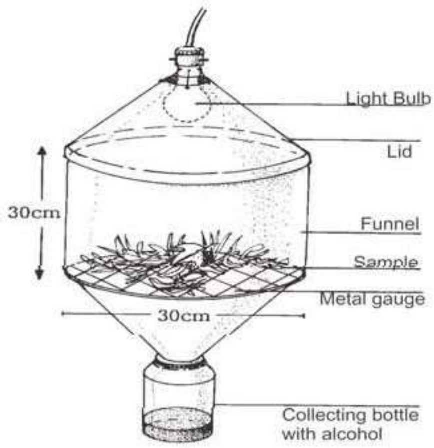
The insect specimen is glued to a cardcut into a triangle of 10 mm height and 5 mmbase. Bend down the tip of card to form asmall surface to which the insect is stuck.Apply a drop of glue or adhesive bytouching the point to the glue and to thethorax of the insects to be mounted.



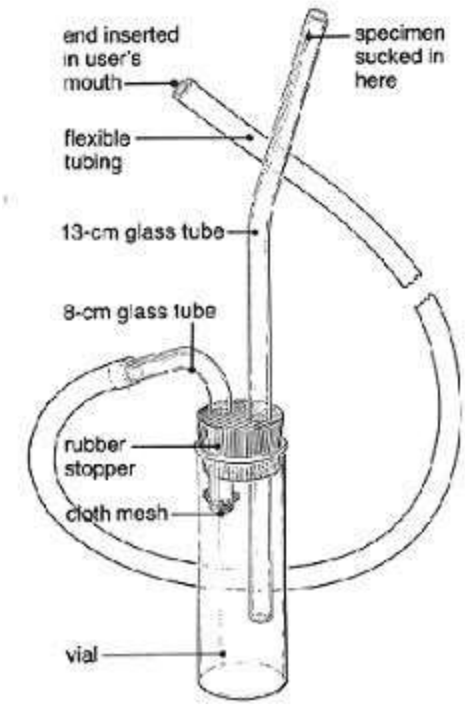


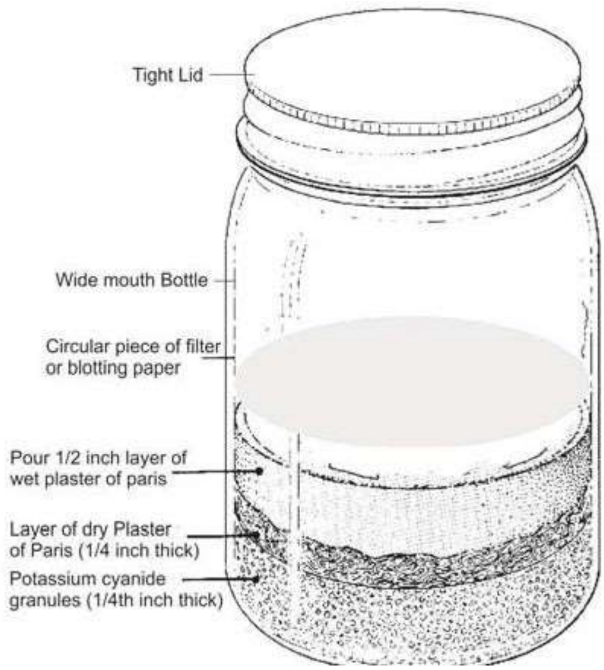
Sweep netAerial/Butterfly net



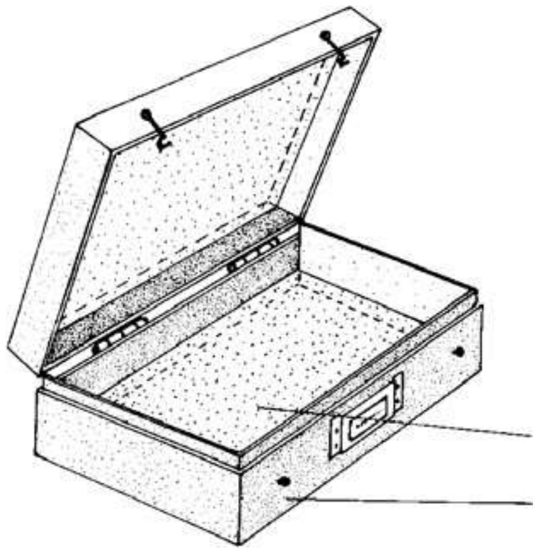


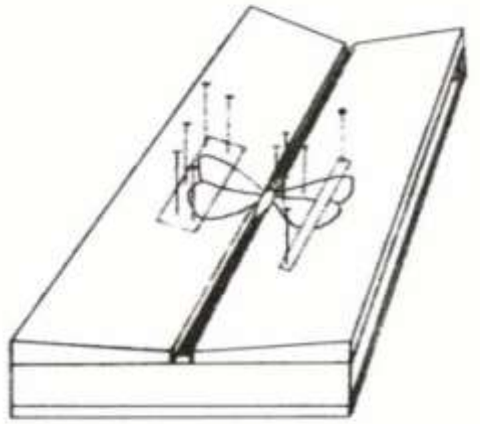
Beating tray Berlese funnel





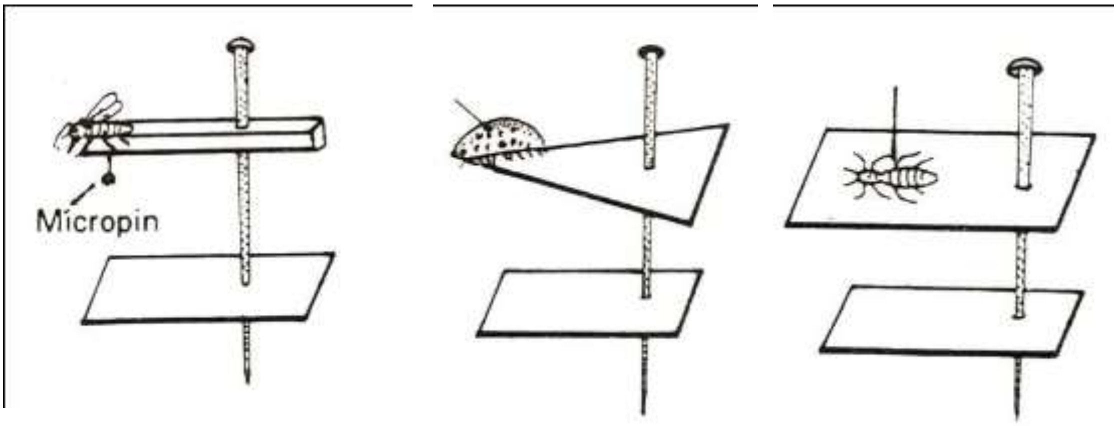
Aspirator/Potters/Suction tube **Insect killing box**



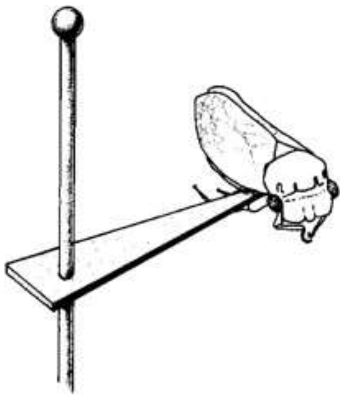


Insect collecting box **Setting/Stretching box**

Double Mounting



Gumming



Practical – 2To study the External features of Grasshopper

The grasshoppers are widely distributed throughout the country and may be seen inabundance during monsson season. For the generalized morphological description, thisinsect has beenconsidered as the most suitable representative of class insects because itsstructural details are notmuch variable. Apart from this, being larger insize, it can bestudied easily.

The generalized insect body is divided into 3 distinct body regions: a head, a thorax andan abdomen. Grouping of body segments into distinct regions is known as **tagmosis** and thebody regions are called as **tagmata**.

The Head

This is an anterior part of the body formed by the fusion of six segments viz., ocellary,antennal, intercalary, mandibular, maxillary and labial. All these segments are closelyamalgamated to forma hard case or head capsule, the cranium that bears the antennae, eyesand mouthparts. The headis attached to the thorax by means of a flexible membranous neck(cervix) that allows its movement. Head capsule is sclerotized and the head capsuleexcluding appendages formed by thefusion of several sclerites is known as **cranium**.

Sclerites of Head

i. **Vertex**: Summit of the head between compound eyes.
ii. **Frons**: Facial area below the vertex and above clypeus.
iii. **Clypeus**: Cranial area below the frons to which labrum is attached.
iv. **Gena**: Lateral cranial area behind the compound eyes.
v. **Occiput** : Cranial area between occipital and post occipital suture.

Sutures of Head: The linear invaginations of the exoskeleton between two sclerites arecalled assuture (sometimes referred as sulcus).

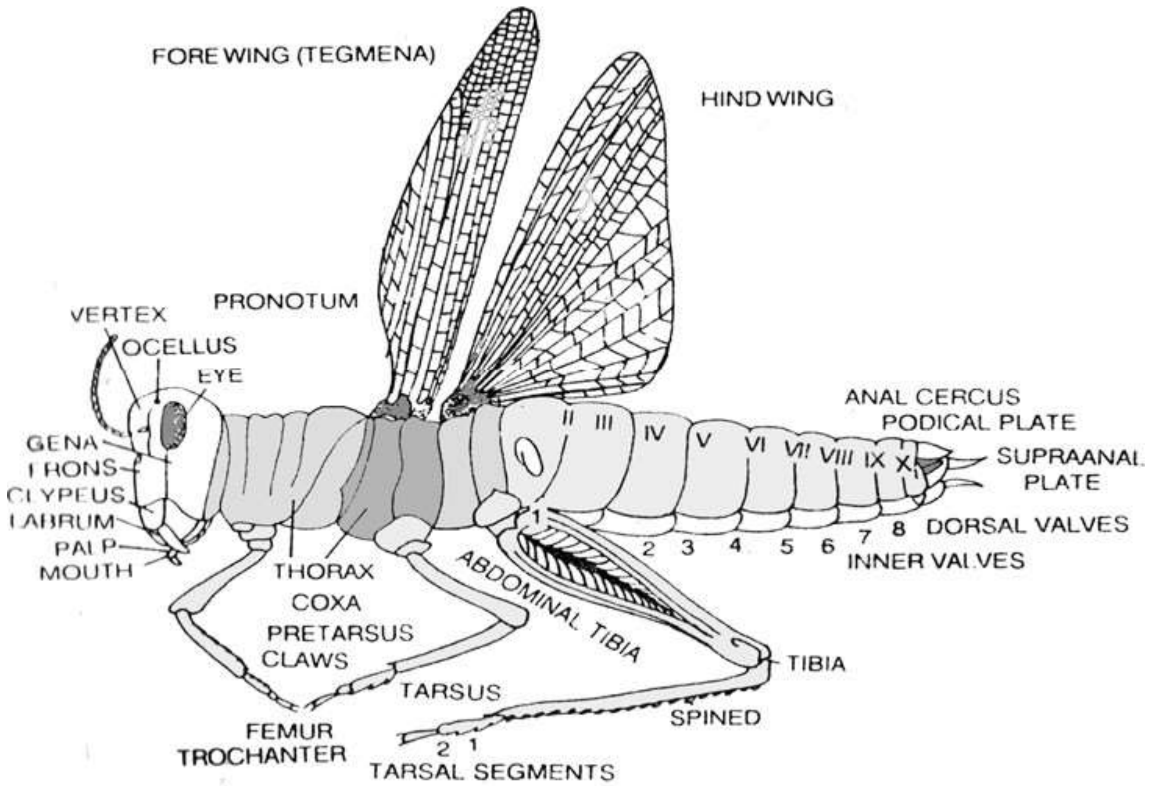
i. **Epicranial suture/ ecdysial line**: Inverted `Y' shaped suture found medially on the topof head,with a median suture (coronal suture) and lateral sutures (frontal suture).
ii. **Epistomal suture/ Fronto clypeal suture**: Found between frons and clypeus. (epi –above;stoma- mouth parts)
iii. **Clypeo-labral suture**: Found between clypeus and labrum (upper lip).
iv. **Postoccipital suture**: Groove bordering occipital foramen. Line indicating the fusionofmaxillary and labial segment.

The Thorax: It is a body region situated between head and abdomen. The insect thorax is composedof three segments: an anterior prothorax, a middle mesothorax, and a posterior metathorax.Each segment bears a pair of legs. The last two segments often called as pterothorax maybear wings. Meso and metathorax which bear wings are called as **Pterothorax**.Thoracicsegments are made up of three sclerites namely, dorsal body plate **tergum or nota**, ventralbody plate **sternum** and lateral plate **pleuron**

Functions of thorax: Site of locomotion.

Abdomen: Abdominal segments are telescopic in nature, highly flexible and are interconnected bya membrane called **conjunctiva**. Each abdominal segment is made up of only two scleritesnamely dorsal body plate (tergum) and ventral body plate (sternum). In grass hopper eightpairs of spiracles are present in the first eight segments, in addition to a pair of tympanum inthe first segment. Eight and ninth abdominal segments bears the female genital structureand ninth segment bears male genital structure. Abdominal appendages in adult insects aregenital organs and cerci.

Function: Site of metabolism and reproduction.


FORE WING (TEGMENA)
HIND WING
PRONOTUM
VERTEX
OCELLUS
EYE
GENA
FRONS
CLYPEUS
LABRUM
PALP
MOUTH
THORAX
COXA
PRETARSUS
CLAWS
TARSUS
FEMUR
TROCHANTER
ABDOMINAL TIBIA
TIBIA
SPINED
TARSAL SEGMENTS
ANAL CERCUS
PODICAL PLATE
SUPRAANAL PLATE
DORSAL VALVES
INNER VALVES

Practical -3To study the types of insect antennae

The collected insect samples can be inspected in laboratory after detaching the antennaand put them under the microscope. They can also be studied through the permanent slidesof different types of antennae by the help of microscope.

Antennae are mobile sensory segmented appendages of the head. They articulate with headinfront or between the eyes and arise from antennal socket. The size and shape ofantennae varies indifferent insects. They used for sensory perception whi ch includesmotion and orientation, odor, sound, humidity, and a variety of chemical cues. Sensilla onantenna acts as tactile, olfaction, carbon dioxide, temperature, wind, humidity, andsound receptors.

Structure of Antenna: Antennae consist of **three parts**:

a) **Scape-** It is first basal segment of antenna by which the antennae is attached to thehead. It is often distinctly larger than the other succeeding joints. It articulates withthe antennal ridge.

b) **Pedicel-** The joint immediately followed the scape is pedicel. It is usually smalland contains aspecial sensory structure known as **Johnston's organ**, which is absentin Diplura, Collembola.

c) **Flagellum-** It is also known as **clavola**, and is the remaining part of theantenna. Flagellum segments (flagellomeres) increase in number in certain insects. Itis modified according to the surroundings and habits of the insects.

Types of antennae:

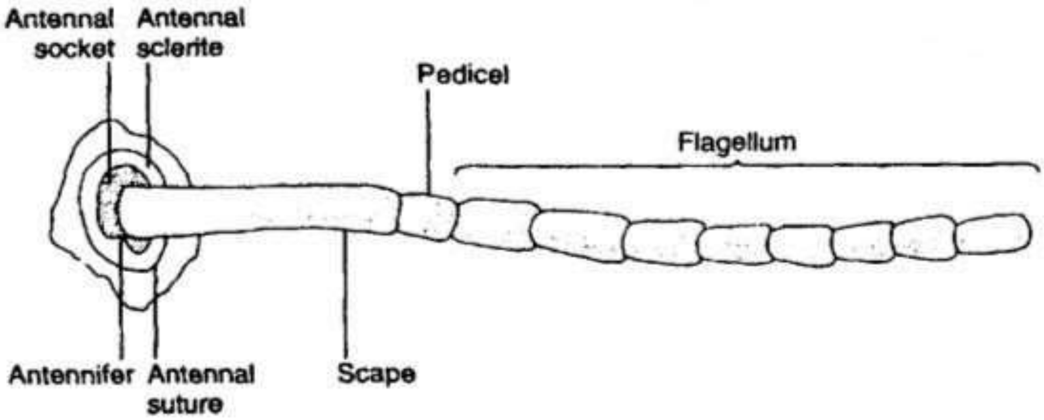
1. **Setaceous**: (Bristle like) Size of the segments decreases from base to apex. e.g.Leafhopper,Dragonfly, Damselfly.
2. **Filiform**: (Thread like) Segments are usually cylindrical. Thickness of segments remainssamethroughout. e.g. Grasshopper.
3. **Moniliform**: (Beaded) Segments are either globular or spherical with prominentconstriction inbetween e.g. Termite.
4. **Serrate**: (Saw like) Segments have short triangular projections on one side. e.g.Longicornbettle
5. **Pectinate**: (Comb like) Segments with long slender processes on one side e.g. Sawfly
6. **Bipectinate**: (Double comb like) Segments with long slender lateral processes on boththesides e.g. Silkworm moth
7. **Clavate**: (Clubbed) Antenna enlarges gradually towards the tip. e.g. Blister beetle
8. **Capitate**: (Knobbed) Terminal segments become enlarged suddenly e.g. butterfly
9. **Lamellate**: (Plate like) Antennal tip is expanded laterally on one side to form flat platese.g.lamellicorn beetle
10. **Aristate**: The terminal segment is enlarged. It bears a conspicuous dorsal bristle calledarista

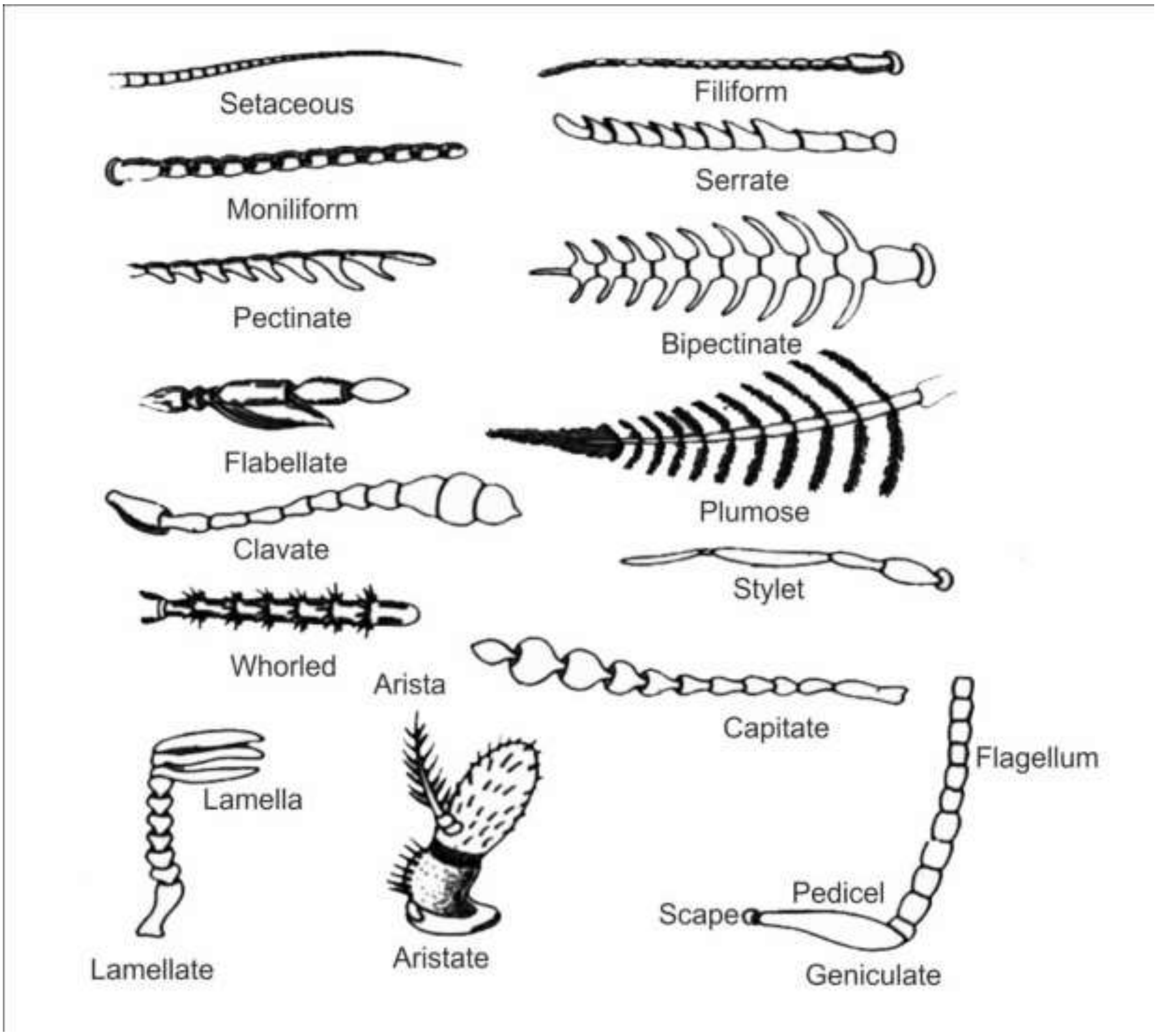
e.g. House fly

11. **Stylate**: Terminal segment bear a style like process eg. Horse fly, Robber fly.
12. **Plumose**: (Feathery) Segments with long whorls of hairs e.g. male mosquito
13. **Pilose**: (Hairy) Antenna is less feathery with few hairs at the junction of flagellomeres.e.g.Female mosquito.

14. Geniculate: (Elbowed) Scape is long remaining segments are small and are arranged atanangle to the first resembling an elbow joint. e.g. Ant, weevil and honey bee.

Structure of Typical Antenna





Practical- 4To study the different types of mouthparts and their modifications Mouthparts of insects vary among insects of different groups depending upon theirfeedinghabits. They are mainly of two types viz., Mandibulate (feeding mainly on solidfood) andhaustellate (feeding mainly on liquid food). Insect mouthparts have becomemodified in variousgroups to perform the ingestion of different types of food and bydifferent methods. Indeed themodifications in the mouthparts to ingest almost all kinds ofthe food material, are one of thefactors for the success of the group.

1. Biting and chewing type: e.g. Cockroach & grasshopper.

It is the primitive type of mouth part and consists of the following parts.

i. **Labrum : (Upper lip)** It is flap like, bilobed and attached to the clypeus by an articularmembrane. It is movable. It covers the mouth cavity from above. It helps to pull thefood into the mouth. It holds the food in position so that mandibles can act on it. Itforms the roof ofthe pre oral food cavity.

ii. **Labrum-epipharynx:** Inner surface of the labrum is referred to as epipharynx. It isfrequently membranous and continuous with the dorsal wall of pharnyx. It is an organof taste.

iii. **Mandibles:** There is a pair of mandibles. They are the first pair of jaws. They are alsocalled as primary jaws or true jaws. Mandibles articulate with the cranium at twopoints. They are heavily sclerotised. They are toothed on their inner border. There aretwo types of teeth. Distalare sharply pointed and are called incisor or cutting teeth andproximal teeth are called molar or grinding teeth. They act transversely to bite andgrind the food into small fragments.

iv. **Maxillae:** They are paired and more complicated than mandibles. They are calledsecondary jaws or accessory jaws. At proximal end the first sclerite cardo joins themaxilla to head. The second sclerite is called stipes which articulates with cardo. Stipescarries a lateral sclerite called palpifer which bears a five segmented antenna likemaxillary palp. On the distal end of the stipes, there are two lobes. The outer lobe iscalled galea and inner lobe is lacinia which is toothed. Maxille direct the food into themouth. They hold the food in place when the mandibles are in action. They act asauxillary jaws and assist in mastication of food. Sense organs connected with theperception of touch, smell and taste are abundantly found in palpi.

v. **Hypopharynx :** It is a tongue like organ. It is located centrally in the preoral cavity.Salivary gland duct opens through it.

vi. **Labium /lower lip:** It is a composite structure formed by the fusion of two primitivesegmented appendages. It bounds the mouth cavity from below or behind. It forms thebase of the preoral cavity. It consists of three median sclerites viz., submentum(largebasalsclerite), mentum (middle sclerite) and prementum (apical sclerite). On the lateralside of the prementum there are two small lateral sclerites called palpiger bearing threesegmented labial palpi. Distally prementum bears two pairs of lobes. The other pair oflobes is called paraglossae and inner pair of lobes, glossae. Both pairs when fused arecalled ligula.

2. Piercing and sucking / hemipterous /bug type e.g. Plant bugs.

Labium projects downwards from theanterior part of the head like a beak. Beak isfour segmentedand grooved throughoutits entire length. At the base of the labiumthere is a triangular flap like structurecalled labrum. Labium is neither involvedin piercing nor sucking. It functions as aprotective covering for the four stylets(fascicle) found within the groove.Both mandibles and maxillae are modified into long slender sclerotized hair likestructure called stylets. They arelying close together and suited for piercing and sucking.The tips of the stylets may have minute teeth for piercing the plant tissue. The innermaxillary stylets are doubly grooved on their inner faces. When these are closely opposedthey form two canals viz., food canal and salivary canal through sap and saliva areconducted respectively. Saliva contains enzymes or toxins that can distort plant cell wall topermit the stylets to penetrate down and reach phloem for suking the sap. Both palps areabsent.

3. Piercing and sucking / dipterous /mosquito type : e.g. Female mosquito
Mouthparts of female mosquito consistsof an elongate labium which is groovedforming a gutter which encloses six stylets.The stylets are composed of labrum -epipharynx (enclosing the food canal), thehyphophrynx (containing the salivary canal),two maxillae and two mandibles. Both theends of maxillary stylets and mandibularstylets are saw like and suited piercing flesh.The stylets are inserted into host's skin by a strong downward and forward thrust ofbody. Both mandibles and maxillae are reduced in male and they feed on plant nectar andjuices of decaying fruits. Female pierces the skin of human beings into which it injects salivacontaining an anticoagulant (to keep the blood flowing without clotting) and an anesthetic(to keep the victim unaware of the bite) and sucks up the blood. Labium does not pierce butfolds up or back as stylets pierce. Maxillary palpi are present.

4. Chewing and lapping type : e.g.honey bee
Labrum and mandibles are as inbiting and chewing type of mouth parts.But mandibles are bluntand not toothed.They are useful to crush and shape waxfor comb building; ingest pollen grains and other manipulative functions.Maxillolabial structures are modified toform the lappingtongue.The tongue unit consists of two galea of maxillae, two labial palpi and elongatedflexiblehairy glossa of labium. The glossa terminates into a small circular spoon shaped lobecalledspoon or bouton or flabellum which is useful to lick the nectar.

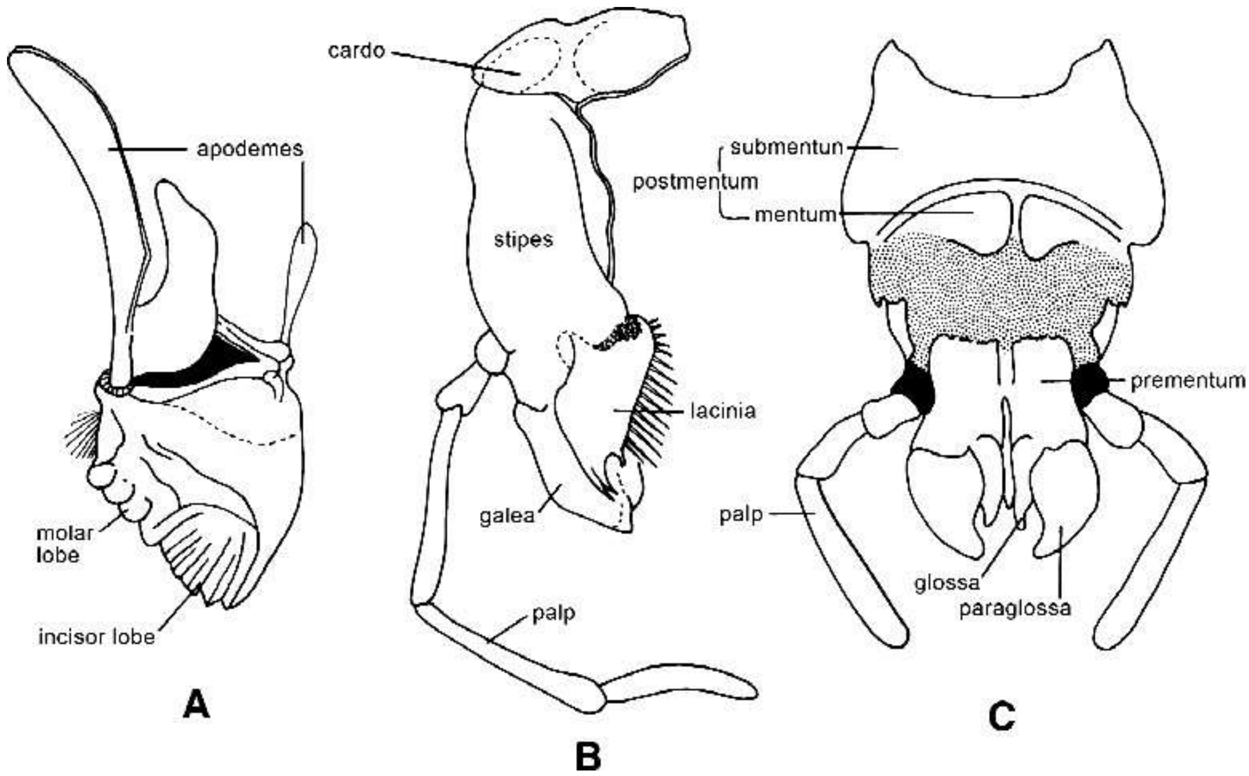
5. Rasping and sucking : e.g. Thrip
Mouth cone consists of labrum, labiumand maxillae. There are three stylets derivedfrom two maxillae and left mandible. Rightmandible is absent. Stylets are useful tolacerate the plant tissue and the oozing sap issucked up by the mouth cone. Bothmaxillary palpi and labial palpi are present.

6. Sponging type : e.g. House fly
The proboscis is fleshy, elbowed,retractile and projects downwards fromhead. The proboscis canbe differentiatedinto basal rostrum and distal haustellum.The proboscis consists of labium which isgrooved on its anterior surface. Within thisgroove lie the labrum-epiphraynx (enclosing

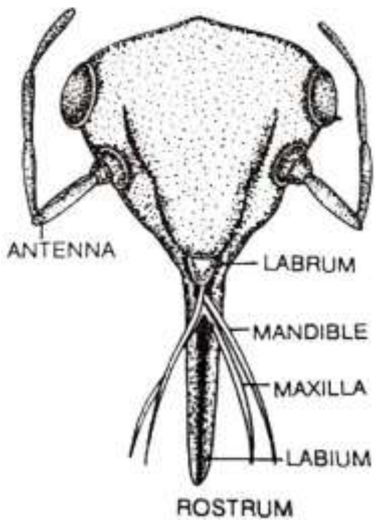
the food canal) and slender hypopharynx(containing the salivary canal).Mandibles are absent. Maxillae are represented by single segmented maxillary palpi.The end of the proboscis is enlarged, sponge like and two lobed which acts as suction pads.They are called oral discs or labella. The surfaces of labella are transvered by capillarycanals called pseudotracheae which collect the liquid food and convey it to the canal. Labellafunction as sponging organs and are capable of taking exposed fluids. These insects oftenspit enzyme containing saliva onto solid foods to liquify them.

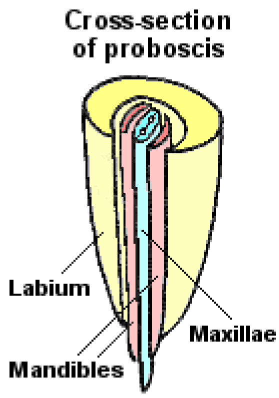
7. Siphoning type : **e.g. Moths andbutterflies**

Mouth parts consists of elongate sucking tube or proboscis. It is formed by two greatlyelongated galeae of maxillae which are zippered together by interlocking spines and hooks.Galeae are grooved on their inner surface and when they are fitting together closely theyform a suctorial food canal through which the nectar is sucked up. The proboscis is coiled uplike watch springand kept beneath the head when it is not in use. By pumping of blood intogaleae, the proboscis is extended. The other mouth parts are reduced or absent except thelabial palpi and smaller maxillary palpi.



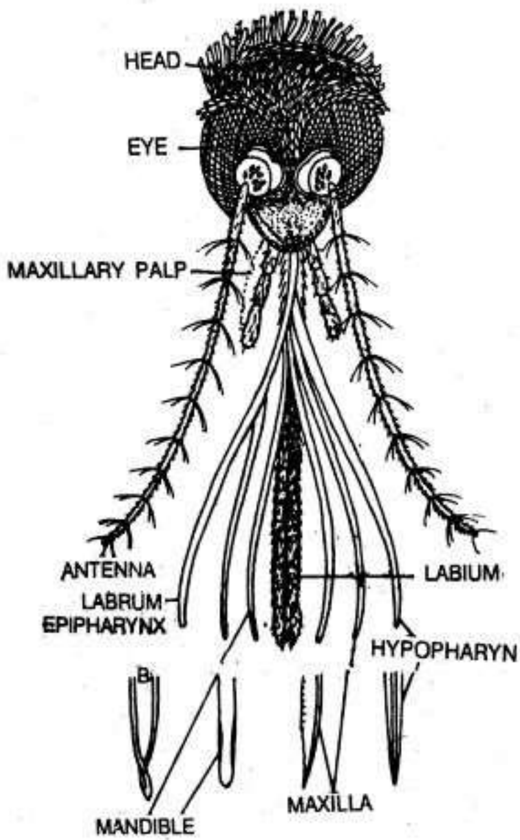
Structure of (A) mandible, (B) maxilla, and (C) labium of a typical chewing insect.

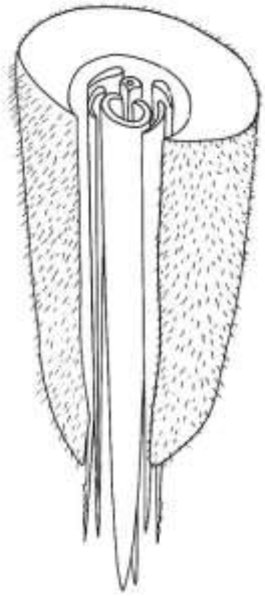




Piercing and sucking type – Bug

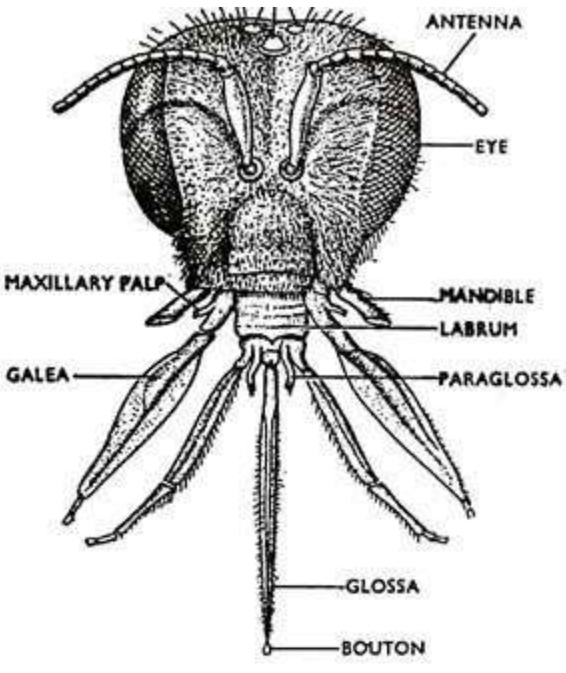
Piercing and sucking type – Mosquito

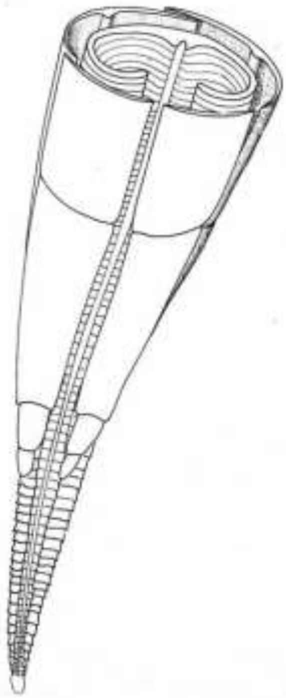




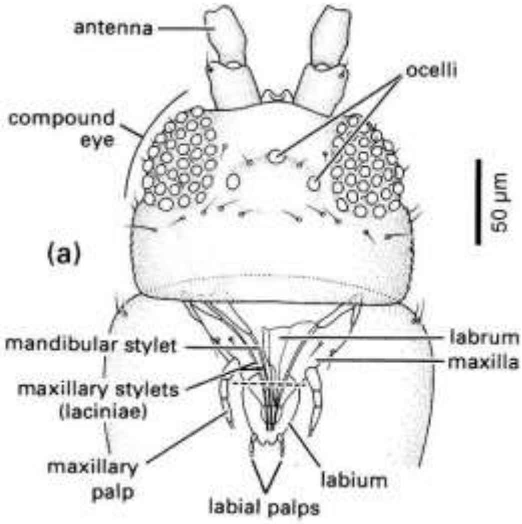
Cross

Chewing and Lapping type: Honey bee

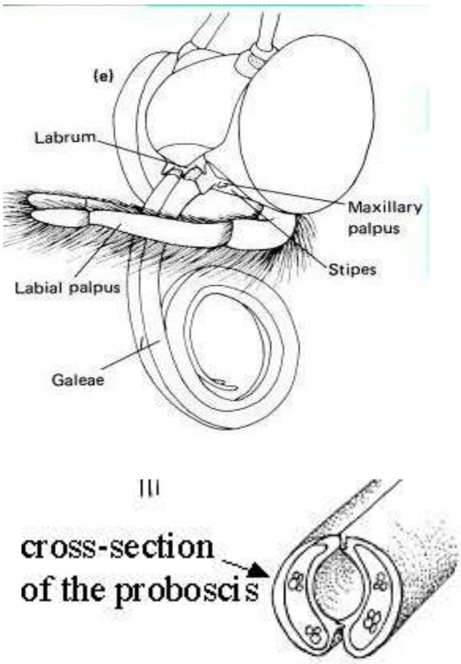




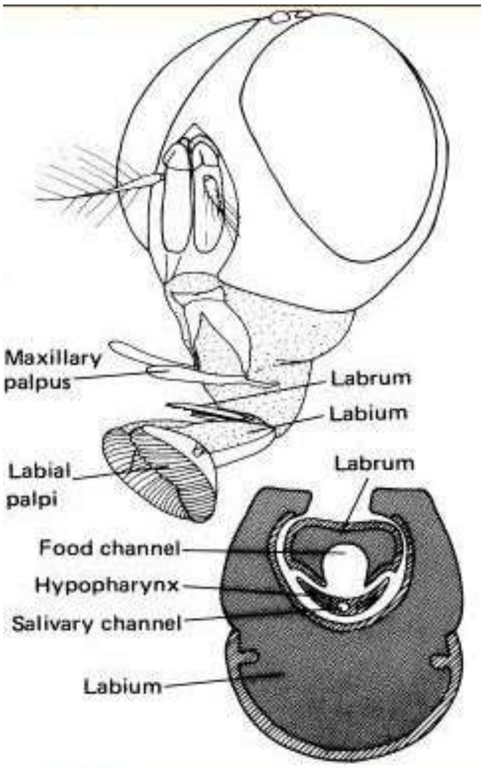
Rasping and sucking type mouth parts

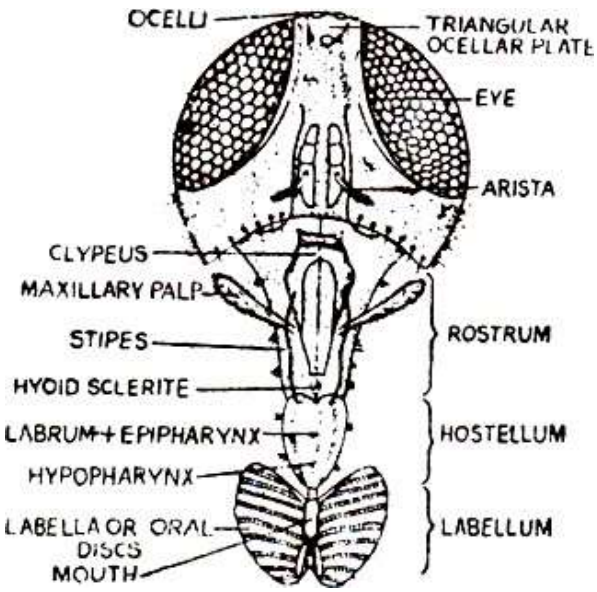


Siphoning type of mouth parts



Sponging type of mouth parts





Practical -5To study the legs and their modifications

The typical thoracic leg consists of six parts, basal coxa that articulates with the thoraxin the pleural region, small trochanter, femur, tibia, segmented tarsus, and pretarsus. Thecoxa is often divided into two parts, the posterior and the anterior (usually the larger part)being called the meron. The trochanter articulates with the coxa, but usually forms animmovable attachment with the femur. The femur and tibia are typically the longest legsegments. The tarsus, which is derived from a single segment, - is usually sub-divided intoindividual tarsomeres. The pretarsus may consist of a single claw, but it is usually composedof a pair of moveable claws and one or more pads or bristles.Legs are usually lookedupon as the principal organs ofterrestrial locomotion. Theyhave undergone manymodifications and have beenadapted to a wide variety offunctions including swimming,prey capture, pollen collectionand digging.

Ambulatorial (Ambulate - to walk;Walking leg) e.g. Fore leg and middle legof grasshopper. Femur and tibia are long.Legs are suited for walking.

Cursorial: (Cursorial = adapted forrunning : Running leg) e. g. All the threepairs of legs of cockroach. Legs are suitedfor running. Femur is not swollen.

Saltatorial: (Salatorial = Leaping: JumpingLeg) e.g. hind leg of grasshopper.

Fossorial: (Forrorial =Digging; Burrowingleg) e.g. Fore legs of mole cricket.

Natatorial: (Natatorial = pertaining toswimming; Swimming leg) e.g. hing legsof water bug and water beetle.

Raptorial: (Raptorial=predatory; Graspingleg) e.g. Forelegs of preying mantids.

Scansorial: (Scansorial = Climbing;climbing or clinging leg) e.g. all the threepairs of legs of head louse.

Foragial leg: (Forage = to collect foodmaterial) e.g. Legs of honey bee.

i. **Forelegs** : The foreleg has threeimportant structures (Eye brush, Antennacleaner or strigillis and Pollen brush)

ii. **Middle legs**: It has two importantstructures.

(a.) **Pollen brush**: Stiff hairs onbasitarsus form pollen brush which isuseful to collect pollen from middle part oftheir body.

(b.) **Tibial spar**: At the distalend of the tibia, a movable spur is presentwhich is useful to loosen the pellets ofpollen from the pollen basket of hind legsand to clean wings and spiracles.

iii. **Hind legs**: It has three importantstructures viz., pollen basket, pollenpacker and pollen comb. (a.) **Pollenbasket**: It is also called corbicula. Theouter surface of the hind tibia contains ashallowcavity. The edges of the cavity arefringed with long hairs. The pollen basketenables the bee tocarry a larger load ofpollen and propolis from the field to thehive.

(b.) **Pollen packer**: It is also calledpollen press. It consists of pecten andauricle. Pecten is a rowof stout bristles atthe distal end of tibia. Auricle is a smallplate

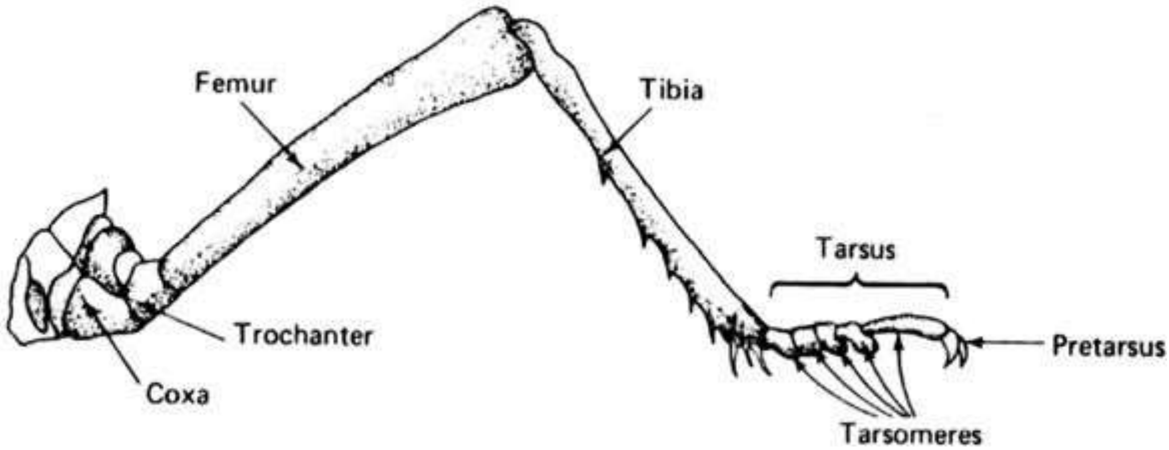
Climbing or Sticking leg: e.g. all the threepairs of legs of house fly.

Clasping leg: e.g. Forelegs of male waterbeetle.

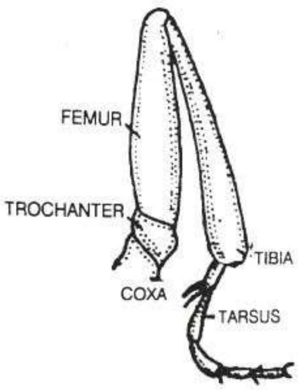
Prolegs: Caterpillars' posses' three pairs of thoracic legs (true-legs) and five pairs of abdominal legs (pro-legs) on 3rd, 4th, 5th, 6th, and last abdomenal segments. In some, semi-loopers larvae, prologs on 3rd and 4th abomenal segments absent, and hence while movement, it looks like semiloop, in some, looppers, prologs present only on 6th and last abdominal segments, and hence while movement, it looks like loop.

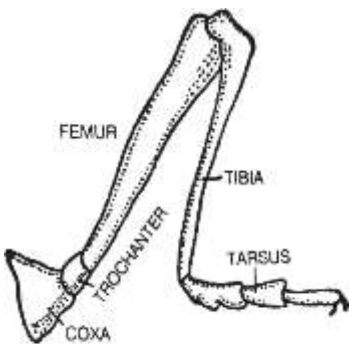
- Thoracic legs are also called the true legs, which are typically jointed and sclerotized.
- Abdominal legs are called prolegs. These are unjointed, short, fleshy with a flat surface at thebottom called planta.
- A number of hooks like structures called crochets are seen arranged in circular or semicuticular form on the surface of the plants.
- In sawflies of Hymenoptera, the larvae have 3 pairs of true legs in thorax, and 6 or >6 pairs ofprologs in abdomen. This is the unique feature of sawfly larva, but these prologs do not bear crochets, unlike lepidopteran larva.

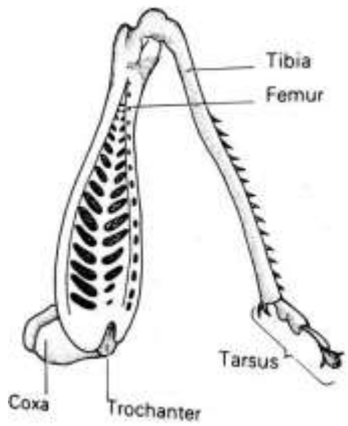
Structure of a typical leg



Ambulatorial leg **Cursorial leg** **Saltatorial leg**

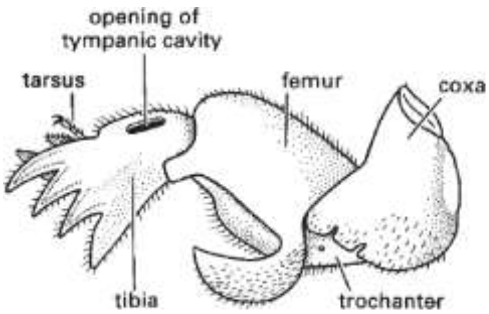


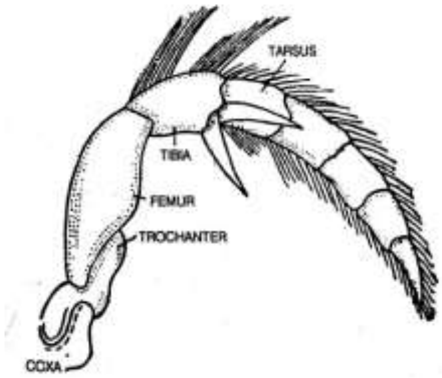




Fossorial leg

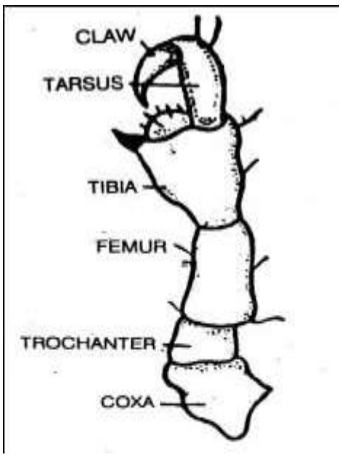
Natatorial leg

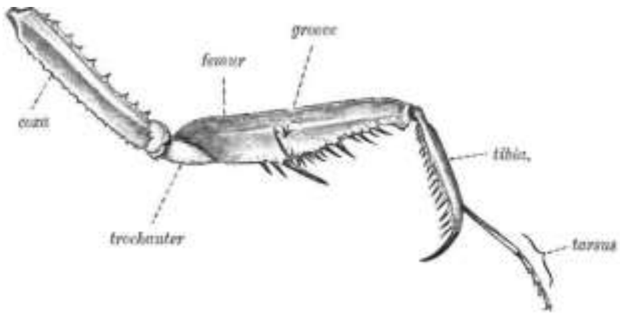




Scansorial leg

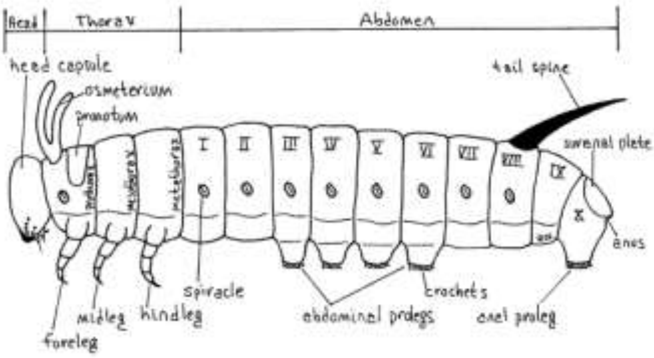
Rap torial leg

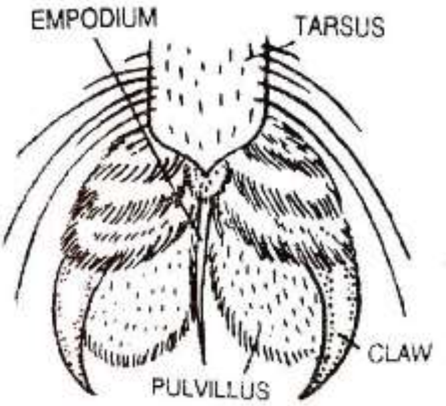




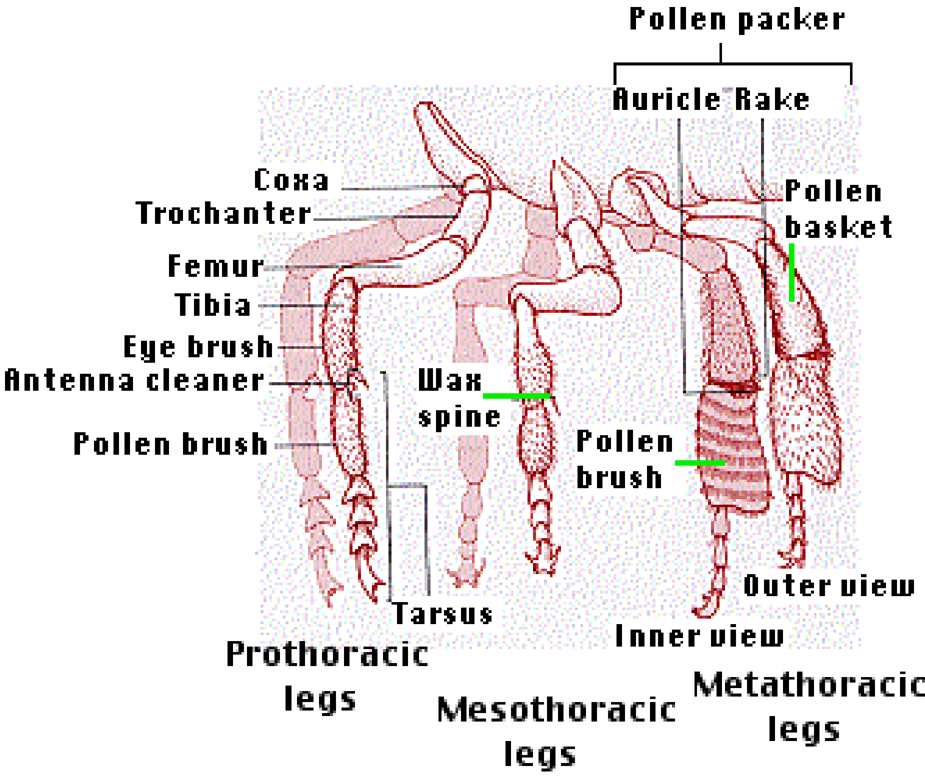
Sticking leg

Prolegs



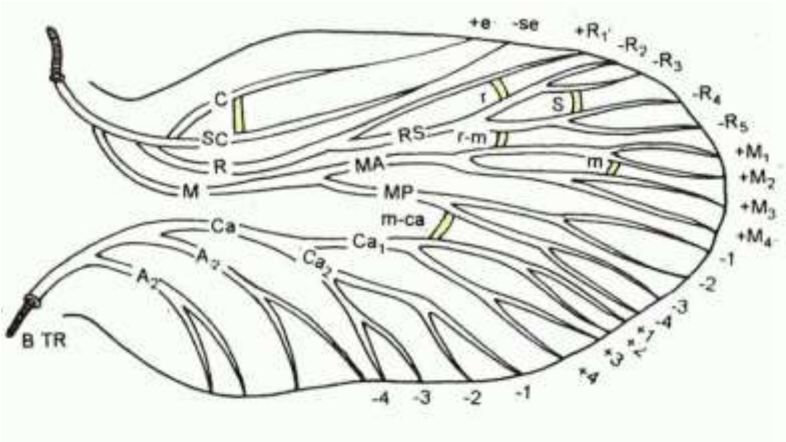

EMPODIUM
TARSUS
CLAW
PULVILLUS

F


Pollen packer
Auricle
Rake
Coxa
Trochanter
Femur
Tibia
Eye brush
Antenna cleaner
Pollen brush
Wax spine
Pollen brush
Pollen basket
Outer view
Inner view
Tarsus
Prothoracic legs
Mesothoracic legs
Metathoracic legs

Practical- 6To study about the Wing venation, types of wings and wing coupling apparatus.

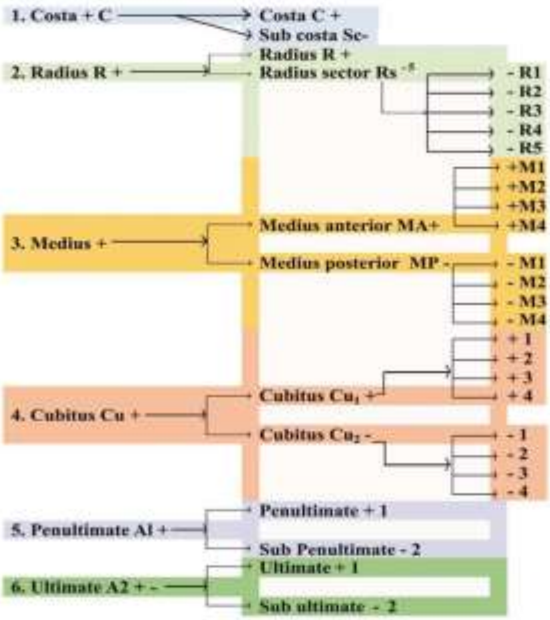
The complete system of veins of a wing is termed as venation or neuration. Generally inall the insects there is some similarity in wing venation and therefore, it is presumed that alltypes of wing venation have developed from the common base or the same ancestor. Bymeans of an extensive study of wing venation in different groups of insects, **Comstock andNeedham** constructed a hypothetical type of wing venation from which all other types havepresumely been derived. According to them the primitive wing venation has developedfrom two tracheae which are situated on the anterior and the posterior basal margins ofwings and their branches are spreadall over he wing. Each main trachea give rise to threeprincipal veins, thereby forming 6 principal veins



namely costa, radius, medius, cubitus,penultimate and ultimate. Each principal vein gives rise to a sub-vein near its base.

Wing venation of a hypothetical wing

The **principal veins are represented by + sign** whereas the **sub veins by - sign**. Thus thewhole wing venation system is represented **by + and the - signs** in alternate as shown in thefigure. The branching of principal veins is represented in the following manner:


1. Costa + C
Costa C +
Sub costa Sc-
Radius R +
2. Radius R +
Radius sector Rs
- R1
- R2
- R3
- R4
- R5
+M1
+M2
+M3
+M4
3. Medius +
Medius anterior MA+
Medius posterior MP -
- M1
- M2
- M3
- M4
+ 1
+ 2
+ 3
+ 4
4. Cubitus Cu +
Cubitus Cu1 +
Cubitus Cu2 -
- 1
- 2
- 3
- 4
5. Penultimate Al +
Penultimate + 1
Sub Penultimate - 2
6. Ultimate A2 + -
Ultimate + 1
Sub ultimate - 2

Such type of hypothetical wing ventaion is never met in any insect as one or the othervein is invariably found lacking for example the medius vein is absent in order Hemipteraand Ephimereda and submedius is missing in Odonata. Some of the scientists considerprecosta, costa, subcosta, radius, medius, cubitus and anal as the principal veins of the insectwing.

Cross veins

The veins joining the two longitudinal veins are known as cross veins. The importantcross veins along with their symbols are given below :

(i) **Humeral cross vein (h)-** It extends fromcosta to sub-costa near the humeral angle andvein.

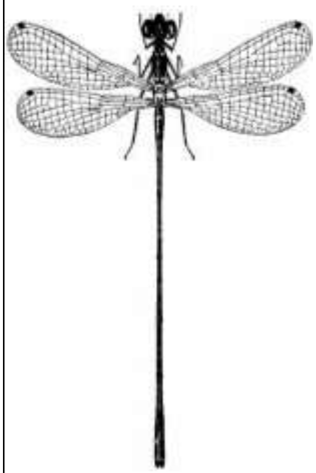
(ii) **Radio-medial cross vein (rm)-** It joins the sub radius and the medius veins.

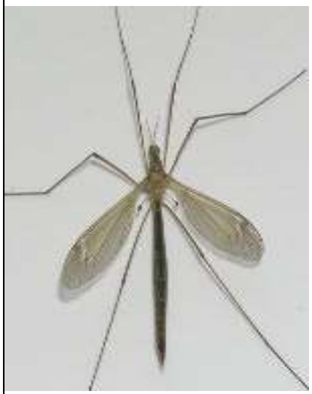
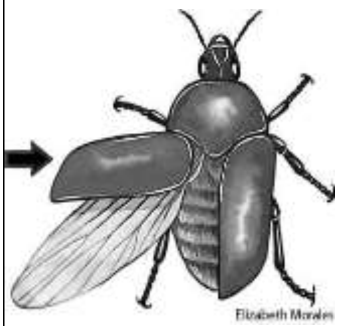
(iii) **Medial cross vein (m)** -The vein joining the m2 and m3 branches of medius is termedasmedial cross vein.

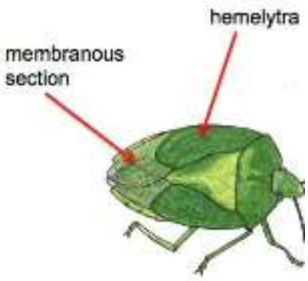
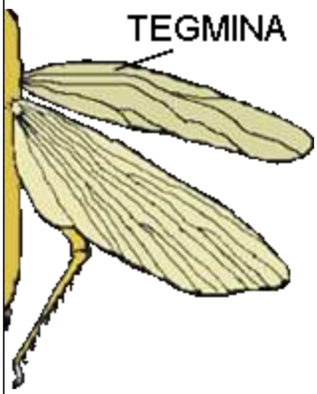
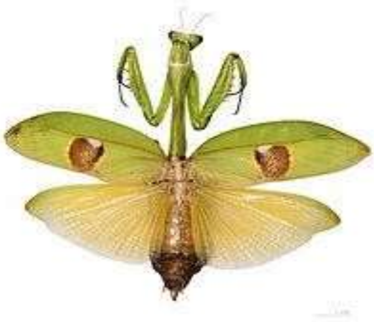
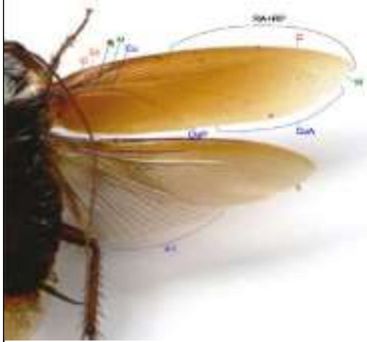
(iv) **Medio-cubital cross vein (m-cu)** - It joins the medius and the cubitus longitudinalveins.

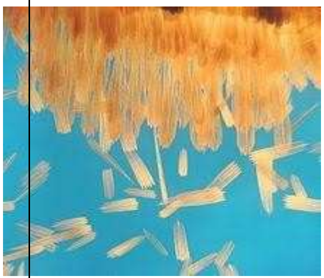
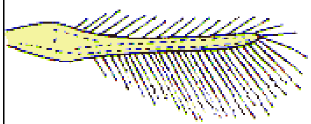
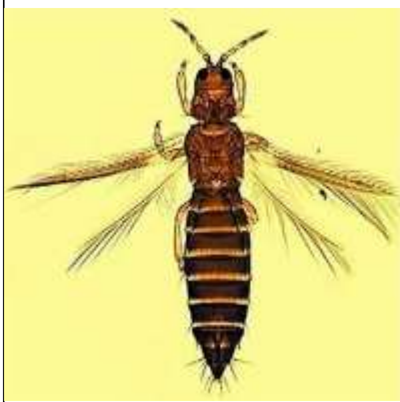
(v) **Radial cross vein (r)** -It extends from R1 to R2

Wing Adaptations and Modifications:

Wing Type	**Photos**	**Modifications and Examples**
Membranous 		• Membranous wings are thin & more or less transparent, but some are darkened. • These wings are with highly developed venation. • They are useful for flight. Examples: Hind wings of Grasshopper, Dragonfiles and damselflies (order: Odonata), lacewings (order: Neuroptera), flies (order: Diptera), bees and wasps (order Hymenoptera), termites (order Isoptera)

Halteres 		• Halteres are an extreme modification among the order Diptera (true flies), in which the hind wings are reduced to mere nubs. • Used for balance and direction during flight (gyroscopic stabilizers). • It is divided into three regions-scabellum, pedicel and capitalum. Examples: All flies (Diptera).
Elytra 	 	• Elytra (singular elytron) are the hardened, heavily sclerotized forewings of beetles (horny sheet without venation). • Modified to protect the hind wings when at rest. • Examples: All beetles (order Coleoptera).

Hemi Elytra 	 	• A variation of the elytra is the hemelytra. • The forewings of Hemipterans are said to be hemelytrous because they are hardened throughout the proximal two-thirds,while the distal portion is membranous. • Unlike elytra, hemelytra function primarily as flight wings. • Examples: Bugs(Hemiptera)
Tegmina 	 	• Tegmina (singular tegmen) are the leathery forewings of insects in the orders Orthoptera, Dictyoptera • Like the elytra on beetles the tegmina help protect the delicate hind wings, and also used for flight sometimes. • Examples: Grasshoppers, crickets and katydids (Orthoptera), Cockroaches, Mantids (Dictyoptera)

Scaly Wings  	 	• Scaly wings-thin and membranous front and hind wings covered over surface with flattened unicellular setae (scales). • The scales make the wings colorful and used for taxonomic studies. • They are useful for flight. • Examples: Butterflies, moths and skippers (order Lepidoptera), caddisflies (order: Trichoptera).
Fringed Wings 		• Fringed wings-slender front and hind wings with long fringes of marginal hairs, giving a feather like appearance. • The wings are highly reduced with reduced venation. • They are useful for flight. • Example: Thrips (Thysanoptera)
Clefted Wings (Fissured Wings)		• Front wing is longitudinally divided forming a fork-like structure. • The hind wing is divided twice, forming two forks with three arms. • All forks possess small marginal hairs. • They are useful for flight.

		• Example: Both wings of Plume Moth

Wing coupling apparatus

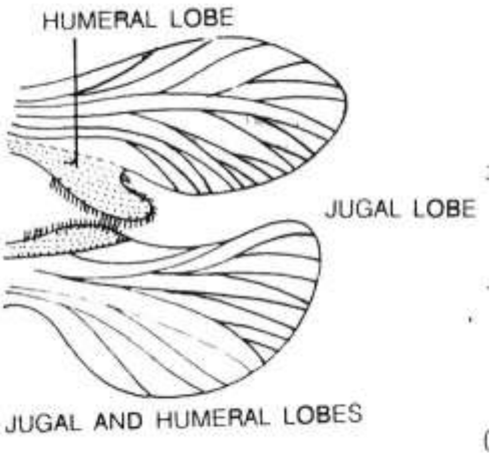
In certain insects special structures have been developed to fasten together the twowings of each side so that it may bring more synchronus action of the fore and hind wings,thereby enabling the insects to fly more swiftly. This action in many insects is ensuredsimply by fore wing overlapping the hind wing. The important coupling device developedin insects' wing for adding more efficiency in flying are described below-

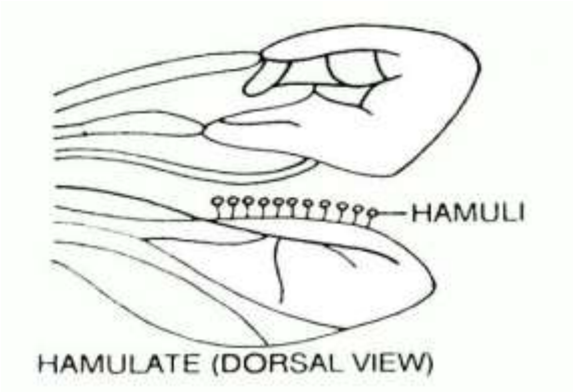
(i) Jugal and humeral lobe- This couplingdevice is commonly found in Lepidoptera,Thchopteraand Mecoptera wherein thewing bases are highly modified. Theposterior end of the fore wing is modifiedinto slender finger like organ which isstiffened by a branch of IIIrd anal vein isknown as the jugal lobe; whereas theanterior margin of the hind wings ismodified in to a small humeral lobe. Thelobes of fore and the hind wings arecoupled with each other during flight.

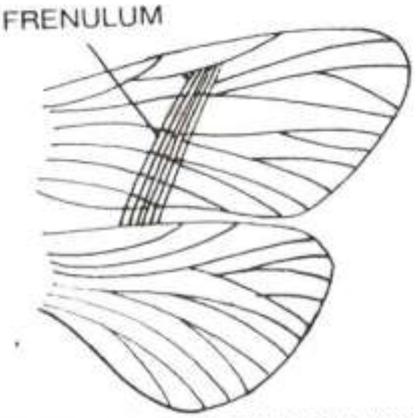
(ii) Frenulum and Retinaculum -This type ofcoupling apparatus is well illustrated in higherLepidoptera wherein the jugum is lostand the frenulum assumes more importance. In femalebutterflies a number of stoutbristle arise beneath the extended fore wing known as frenulum which engages in aretinaculum from a patch of hair near the cubitus of a hind wing. However, inmales thefrenulum bristles are fused into a single stout structure and is held by a curved process from the sub-costal vein of the fore-wing.

(iii) Hamuli -In this modification the costal margin of the hind wings bears a row of smallhooks known as hamuli. These hooks get attached into a fold on the inner margin of thefore-wings. Such coupling apparatus is generally met in Hymenoptera.

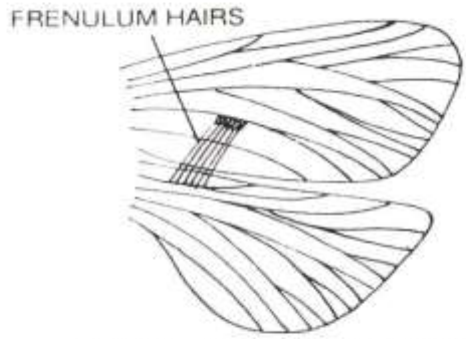
(iv) Amplexiform - This example is commonly met in the insects belonging to familypapilionidac and bombycidae of order Lepidoptera. In this case the wings are coupledsimply by overlapping basally to each other.


HUMERAL LOBE
JUGAL LOBE
JUGAL AND HUMERAL LOBES

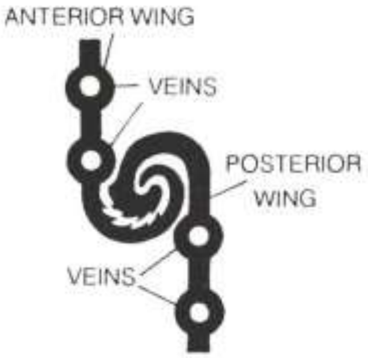

HAMULI
HAMULATE (DORSAL VIEW)



FENULUM AND RETINACULUM
(MALE BUTTERFLY)



FRENULUM AND RETINACULUM
(FEMALE BUTTERFLY)



AMPLEXIFORM (VERTICAL SECTION)

HOOK AND CHANNEL

Practical- 7To study the types of insect larvae and pupae Metamorphosis and immature stages

The change in growth and development (form) of an insect during its life cycle frombirth to maturity is called metamorphosis. There are four basic types of metamorphosis ininsects.

Ametabola: (No metamorphosis) e.g. Silver fish.

These insects have only 3 stages in their life cycle namely egg, young ones and adults. It ismost primitive type metamorphosis. The hatching insects resemble the adult in all respectsexcept for the size and called as juveniles. Moulting continues throughout the life.

Hemi-metabola: (Incomplete metamorphosis) e.g. Dragonfly, damselfly and may fly.

These insects also have 3 stages in their life namely egg, young ones and adults. Theyoung ones are aquatic and are called **naiads**. They are different from adults in habits andhabitat. They breathe by means of tracheal gills. In dragonfly naiad, the lower lip (labium) iscalled **mask** which is hinged and provided with hooks for capturing prey. After final moult,

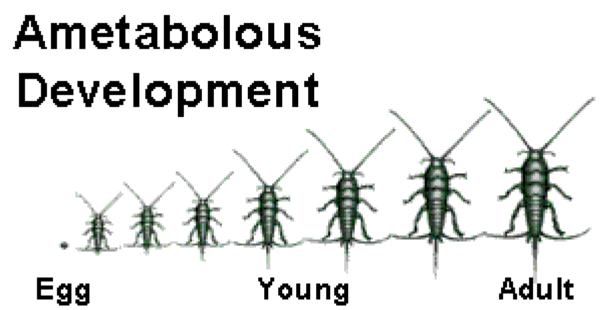
the insects have fully developed wings suited for aerial life.

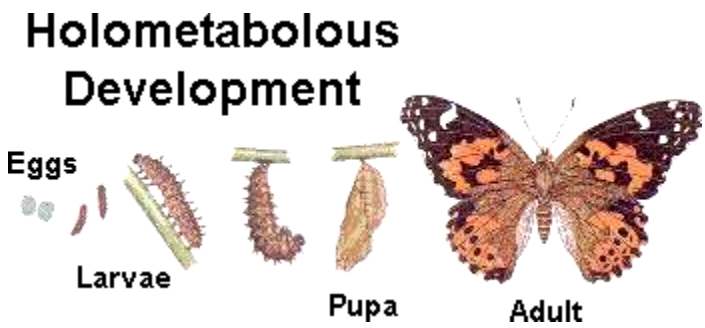
Pauro-metabola: (Gradual metamorphosis) e.g. Cockroach, grasshopper, bugs.

The young ones are called nymphs. They are terrestrial and resembles the adults ingeneral body form except the wing and external genitalia. Their compound eyes and mouthparts are similar to that of adults. Both nymphs and adults share the same habitat. Wingbuds externally appear in later instars. The genitalia development is gradual. Later instarsnymphs closely resemble the adult with successive moults.

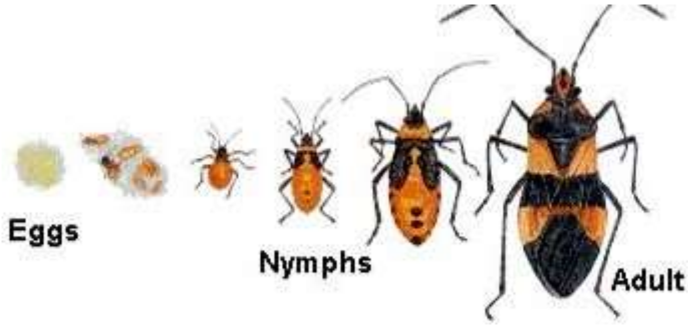
Holo-metabola: (Complete metamorphosis) e.g. Butterflies, moths, fly and bees.

These insects have 4 stages namely egg, larva, pupa and adult. Majority of the insectsundergo complete metamorphosis. Larvae of butterfly is called caterpillar. Larva differsgreatly in form from adult. Compound eyes are absent in larva. Lateral ocelli or stemmataare the visual organs. Their mouth parts and food habits differ from adults. Wingdevelopment is internal. When the larval growth completed it transforms into pupa. It isthe resting and non feeding stage in which the larval tissues disintegrate and adult organsare built up.

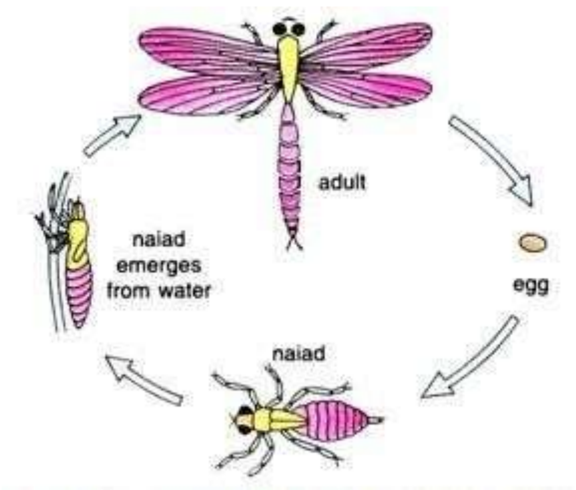



Holometabolous
Development
Eggs
Larvae
Pupa
Adult

Paura-metabola



Hemi-metabola

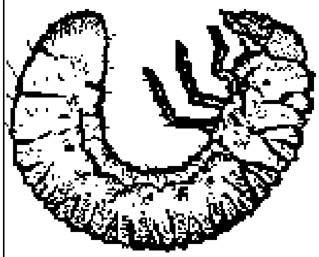


Immature stages in insects

Larva: Larval stage is the active growing and immature stage between the egg and pupalstage ofan insect having complete metamorphosis. This stage differs radically from theadults.

Types of larvae:

Type of larva	Photo	Modification
I. **Oligopod:** Thoracic legs are well developed. Abdominal legs are absent.		
i. **Campodeiform** 		They are similar with diplurans genus Campodea. Body is elongate, depressed dorsoventrally and well sclerotized. Head is prognathous. Thoracic legs are long. A pair of abdominal or caudalprocesses is usually

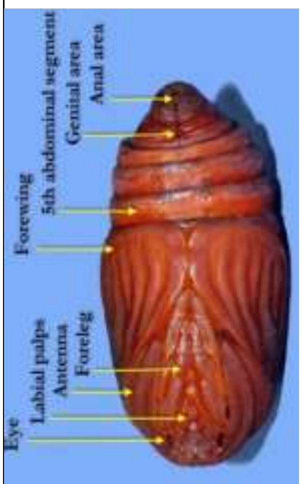
<table>
<tr><td></td><td>present. Larvae aregenerally predators and are very active. E.g. grub of antlion or grub of lady bird beetle.</td></tr>
<tr><td>ii. Scarabaeiform

</td><td>Body is “C” shaped, stout and sub-cylindrical. Head is well developed. Thoraciclegs are short. Caudal processes are absent. Larva is sluggish, burrowing into wood or soil. e.g. grub of rhinoceros beetle.
Body is “C” shaped, stout and sub-cylindrical. Head is well developed. Thoraciclegs are short. Caudal processes are absent. Larva is sluggish, burrowing into wood or soil. e.g. grub of rhinoceros beetle.</td></tr>
<tr><td colspan="2">II. Polypod or Eruciform: The body consists of an elongate trunk with large sclerotized head capsule. Head bears powerful mandibles which tear up vegetation. Two groups of single lensed eyes Stemmata found on either side of the head constitute the visual organs. The antenna is short. 3 pairs of thoracic legs and up to 5 pairs of unsegmentedabdominal legs or prolegs or pseudolegs are present. e.g. Caterpillar (larva of moth and butterfly).</td></tr>
<tr><td>i. Hairy caterpillar
</td><td>The body hairs may be dense, sparse or arranged in tufts. Hairs may cause irritation, when touched.
e.g. red hairy caterpillar.</td></tr>
</table>

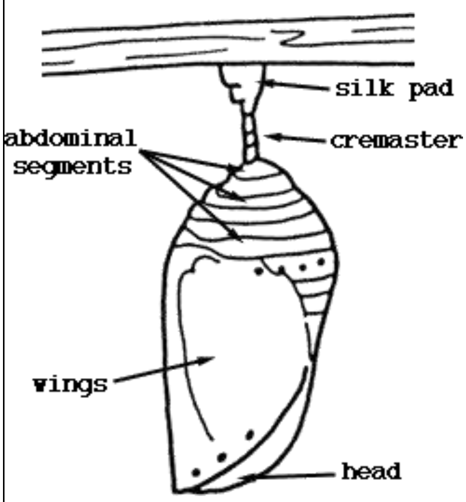
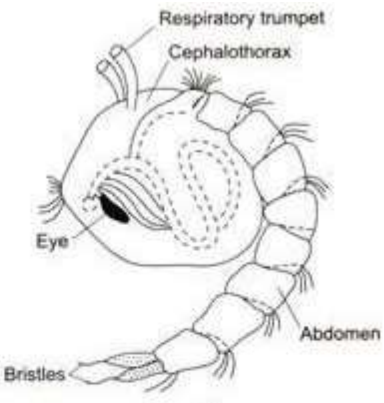
ii. Slug caterpillar 	Larva is thick, short, stout and fleshy. Larval head is small and retractile.
iii. Semilooper 	either 3 or 4 pairs of prolegs are present. e.g castor semilooper.
iv. Looper 	They are also called measuring worm or inch worm. In this type, only 2 pairs of prolegs are present in 6th and 10th abdominal segments. e.g. Dhaincha looper.
III. Apod: They are larvae without appendages for locomotion. Based on the degree of development and sclerotization of head capsule.	
i. Eucephalous 	Larva with well developed head capsule with functional mandibles, maxillae, stemmata and antennae. Mandibles act transversely. e.g. Wriggler (larva of mosquito) and grub of red palm weevil.

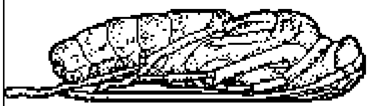
ii. Hemicephalous 	Head capsule is reduced and can be withdrawn into thorax. Mandibles act vertically. e.g larva ofhouse fly and robber fly.
iii. Acephalous 	Head capsule is absent.Mouth parts consists of a pair of protrusiblecurved mouth hooks and associated internal sclerites. They are also called vermiform larvae. e.g. Maggot (larva of house fly)

Pupa: It is the resting and inactive stage in all holometabolous insects. During this stage, theinsect is incapable of feeding and is quiescent. During the transitional stage, the larvalcharacters are destroyed and new adult characters are created.

Types of pupae

Type of pupae	Photo	Modification
Obtect 		Various appendages of pupa viz. Antennae, legs and wing pads areglued to the body by a secretion produced during the last larval moult. Exposed surfaces of the appendages are more heavily sclerotized than the inner surface. e.g. moth pupa.

Chrysali 		It is naked obtect type of butterfly. It is angular and attractive coloured. The pupa is attached to the substratum by **hooks** present at the terminal end of the abdomen called **Cremaste**r. The body of chrysalis is attached to the substratum by 2 strong silken threads called **gridle**.
Tumbler 		Pupa of mosquito is called tumbler. It is an obtect type pupa. It is comma shaped with rudimentary appendages. Breathing trumpets are present in the cephalic end and anal paddles are present at the end ofthe abdomen. Abdomen is capable of jerky movements which are produced by the anal paddles. The pupa is **very active**.

Exarate 		Various appendages viz. antennae, legs and wing pads are not glued to the body. They are free. All oligopod larvae will turn into exarate pupae. The pupa is soft and pale. e.g. pupa of rhinoceros beetle.
Coarctate 		the last larval skin is changed into a pupal case and the pupa is actually an exarate pupa. The pupal case is dark brown, barrel shaped, smooth with no apparent appendages and called as **puparium**. e.g. fly pupa

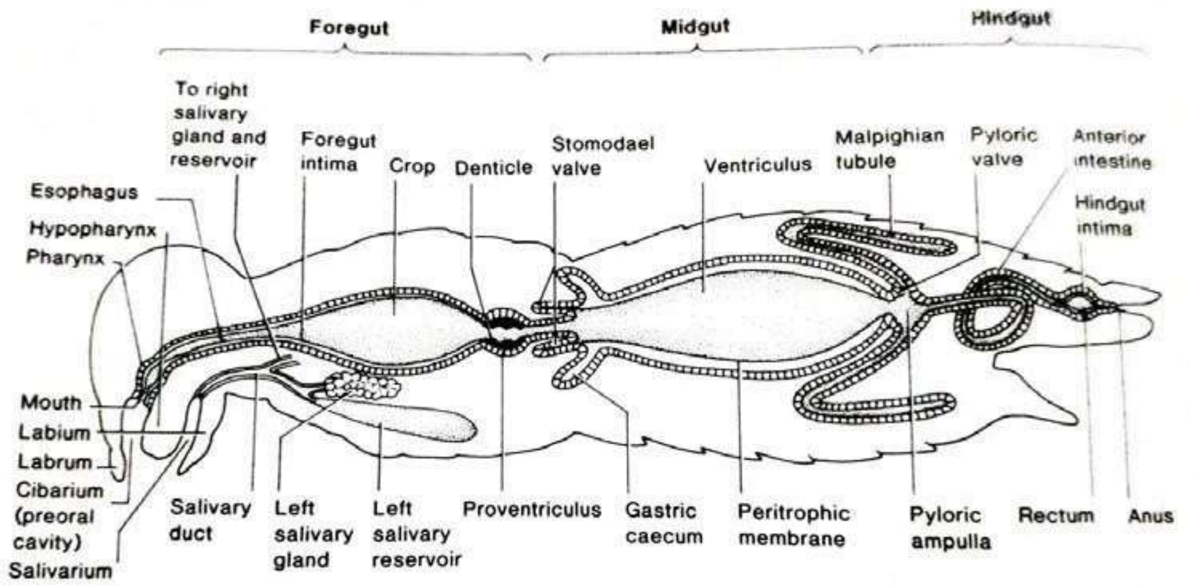
Practical -8To study the dissection of alimentary canal/nervous system in insects (Grasshopper/Cockroach)

The best learning situation requires one specimen and set of tools per two students forstudies. Students working in pairs have ample opportunity to fully participate in thedissection and to carefully examine the specimen. They are also able to share and discusstheir observations during and after the dissection.

Materials required for dissecting Cockroach

Dissection Kit includes- Surgical scissors, Iris scissors, Tissue forceps, Scalpel, handle,Scalpel blades, Probe with angled tip, Dissection needles, Dropping pipette, Blow pipes,Dissection tray, Dissecting pins, Rigid metal ruler, And case Camel hair brush etc

Diagram of Alimentary canal showing the major subdivisions in a generalized GrasshopperInsect



Digestive system

It includes the organs of ingestion (alimentary canal and its associated glands) and thephysiologyof digestion. The organs of ingestion are located in the head and are meant forthe intake of food. The preoral cavity is enclosed by the mouth parts and is divided into twoparts by the hypopharynx, the anterior region in which the alimentary canal opens is termedas cibarium andin which the salivary duct opens is known as salivarium. In the suckingInsects the cibarium is modified into a sucking pump while salivarium serves as the salivarysyringe.

Alimentary canal

The alimentary canal of grasshopper/cockroach is a simple, hollow and tubular instructure whichruns from the buccal cavity to anus. It is distinctly divided into thefollowing three primary regions

1. Foregut or stomodaeum.

2. Mid gut or mesenteron or ventriculus.
3. Hind gut or proctodaeum.

1. Foregut or Stomodaeum

It constitutes the anterior region of the alimentary canal which is primarily an organ ofingestionand shows as a site for storing food. It consists of the following paris

(i) Pre-oral food cavity-It has been described previously and indeed it is not a part ofalimentary canal.

(ii) Pharynx-It is situated in between the pie-oral cavity and the oesophagous and isprovided by the dilateral muscles. These muscles are highly developed in those thoseinsects which pharynx helps in forming the suking pump.

(iii) Oesophagous-It is simple straight tube which runs from the posterior region of thehead to thorax and joins with the crop.

(iv) Crop- It is simple bag like structure and serves as a storage reservoir for the food.Apparently it is a dilated portion of the oesophagous but differs histologically by thepresence of sclerotized ridges which are arranged transversely in the crop. Since itserves as a reservoir for food hence its walls are thin and the muscles are poorlydeveloped.

(e) Gizzard-It is situated in the posterior region of the crop which cannot be apparentlydistinguished from crop but differs internally by having the longitudinal folds into thelumen in which cuticular teeth are attached. Its posterior part is concentric in the internallayer of six 'V' shaped processes are attached which form the cardiac valve with the folds ofgizzard. Its major function is to regulate the passage of food into the mid gut.Histologically, the following layers may be distinguished in the walls of the stomodaeum

(1) Intima - The inner most layer of chitin found in continuation of body cuticle.
(2) Epithelial layer-It is a thin layer secreting the intima.
(3) Basement membrane- Bounding the outer most surface of the epithelium.
(4) Longitudinal muscles—These muscles are less developed than circulatory muscles.
(5) Circulatory muscles - These are well developed.
(6) Peritoneal membrane - It is often difficult to detect and consists of apparentlystructurelessconnective tissue.

2. Mid Gut or Mesenteron

It is relatively a short tube or elongated sac with uniform diameter extends from hepaticcaecae or cardiac valve to Malpighian tubes or pyloric valve. Histologically, the inner wall ofmesentcronor stomach is not made up of chitin, but consists of following layers

(i) Peritrophic membrane (ii) Enteric epithelium
(iii) Basement membrane (iv) circular muscles
(v) Longitudinal muscles (vi) Peritoneal membrane

The enteric epithelium is made up of three types of cells:

(i) The columnar cells whichsecret the enzymes and absorb the digested food,

(ii) the regenerative cells which renew thedestroyed and dead epithelial cells throughsecretion or in the process of degeneration and

(iii) the goblet cells which are of uncertain functions.

Thus, there are following five major function of enteric epithelium:

(i) to make digestiveenzymes
(ii) to absorb the digested food
(iii) to produce new cells
(iv) to absorb the water
(v) to excrete the waste material outside the body.

The inner surface of midgut is sometime lined by a thin membrane known asperitrophic membrane which protects the epithelial cells from the direct contact of foodparticles. This membrane is absent in Lepidopterans and hemipterans.

3. Hind Gut or Proctodaeum

It extends from the posterior end of midgut to the anus and is also an invagination ofthe body wall. The hind gut consists of the some layers as the fore gut except that thecircular muscles of its are developed both inside and outside the layer of longitudinalmuscles. The hind gut is externally marked by the insertion of the Malpighian tubes andinternally by the pyloric valve. It may be divided into three distinct regions(i) Ileum or small intestine (ii) Colon or large intestine

(iii) Rectum.

Ileum- It is a small tube which has many folds in its inner wall.

Colon- It is situated on the 5th and 6th segments of the abdomen and is a slender tubewhich, cannot be easily distinguished from the ileum. In some insects it is just like 'S' instructure.

Rectum- Both the ends of the rectum are comparatively slender while the middle portion isthick and large which consists of six rectal papillae internally and six ridges of longitudinalmuscles externally. The rectum opens to exterior through the anus which is situated at thecaudal end ofthe abdomen.

Salivary Glands - The labial glands which are associated with the gnathal appendages arethe salivary glands. A pair of salivary glands is found in the grasshopper which generally liein the thorax and are convoluted tubes often branched and racemose. Both the ducts ofsalivary glands unite together beneath the oesophagous to form a common salivary ductwhich opens into the salivarium.

Physiology of digestion

The grasshopper is phytophagous and eats the leaves and soft parts of the plants whichare holdby the maxillae and, they bring the food near to mandibles where it is broken intosmall particles. These small food particles are sent to the buccal cavity with the help oflabrum and labium. On entering the buccal cavity, it is subjected to the action of salivawhich contains the amaylase enzyme. It acts on the carbohydrates present in the food andchange them into simple sugar i.e., glucose which is absorbed in the crop. Saliva is alsohelpful in moistening the food. This food passes onward to the crop where the secretions ofthe midgut and the hepatic 'caecae mix with it. These secretions are weakly acidic or alkalineand contain maltase, invertase, lactase, protease, lipase, peptidase, erypsin and trypsinenzymes which act on the food. Due to the action of these eyzymes the starch is convertedinto sugars, protein into amino acids and fat into fatty acids. After this the food comes togizzard where it is again masticated then it passes through thecardiac valve intomesenteron where further digestion of the food takes place. The digested foodis absorbedby the spongy and thick walls of mesenteron. The undigested food passes to the hind gut(proctodaeum) through pyloric valve where the absorption of water takes place and thenwaste and undigested food expelled out through anus in the form of excreta. The absorbedfood is utilized for the following purposes

(i) In the form of energy required for different life activites
(ii) Some part is consumed in theformation of muscles etc.
(iii) The rest is stored in the fat bodies which are used in emergency.

Filter Chamber:

• A number of cicadids and cercopids suck sap from xylem, which contains amino acidsin very dilute solution and relatively higher concentration of salts.

• This solution has to be concentrated before absorption so as to avoid excessive dilutionof haemolymph.

• In these insects removal of excessive water is done with the help of –the filterchamber‖.

• The filter chamber consists of an expanded thin walled bladder-like anterior midgut,which lies in close association with (or surrounds) the posterior midgut (interior) andproximal ends of the Malpighian tubules (interior) or anterior part of the hindgut.

• The chamber formed within the folds of the anterior gut is called the filter chamber. Itis suggested that the Malpighian tubules produce a hypertonic fluid, which is rich inK+. This establishes an osmotic gradient from the anterior midgut to the filter chamberthen to the Malpighian tubules, so that water passes almost directly to the hindgut andabsorption of nutrientstakes place in the more central region of the midgut. Filterchamber of the coccids has parts of midgut invaginated into the rectum.

Practical- 9To study the male and female reproductive systems in insects (Grasshopper)MALE REPRODUCTIVE ORGANS

The male reproductive organs consist of the followings- (i) A pair of testes (ii) A pair ofvasa deferentia (iii) Seminal vesicles (iv) Ejaculatory duct (v) Penis or Aedeagus (vi)Accessoryglands (vii) Male genital atrium

The Testes-They are located above the midgut and held in position by the surrounding fatbodies and tracheae. Each testis is a more or less ovoid body partly or completely dividedinto a variable number of follicles or lobes which are cylindrical in shape. Each follicle isconnected with vas deferens by a relatively well developed slender tube known as vaseffcrens. The peritoneal investment of the follicle is developed to the extent of envelopingthe testis as a whole in a common coat known as scrotum. the presence of the sex cells indifferent stages of development.

These zones are as follows

(i) The germarium - It is the region having primordial genii cells or spermatogonia whichundergo multiplication.

(ii) The zone of growth – In this zone the spermatogonia increase in size and undergorepeated mitotic division and develop into spermatocytes.

(iii) The zone of division and reduction-Here the spermatocytes undergo meiosis andproduce spermatids.

(iv) The zone of transformation - The spermatids are transformed into spermatozoa.The massesof spermatozoa are generally enclosed in the testicular cyst cells from whichthey are released in the vas deferens. In addition, the testes contain large elements knownverson's cells or apical cells.

Vas deferens- These are the paired canals leading from the testes which are partly or whollymesodermal in origin.

Seminal Vesicles- The Vas deferens vary greatly in length in the majority of insects. EachVas deferens becomes enlarged along its course to form a sac known as seminal vesicle inwhich spermatic fluid is collected.

Ejaculatory duct -Posteriorly, the vasa deferentia unite to form a short common canal whichis continuous with a median ectodermal tube known as ejaculatory duct. The terminal endofejaculatory duct opens in the male genital atrium.

Aedeagus- The terminal end of the ejaculatory duct is enclosed in a finger-like evaginationof theventral body wall which forms the male intromittent organ known as aedeagus. It issituated on9th abdominal sternum of the grasshopper on the conjunctival membrane of theposterior margin. **Accessory glands-** These are one to three pairs in number and usually present in relationwith the genital ducts opening into seminal vesicle. These are tubular or sac-like in structure.In most ofthe cases their secretions mix with spermatozoa and in some insects glands aredirectly concernedwith the formation of the spermatophores.

THE FEMALE REPRODUCTIVE ORGANS

The female reproductive system consists of the following organs- (i) A pair of ovaries(ii) A pair of lateral oviducts (iii) Spermatheca (iv) Vagina and genital chamber (v) Accessoryglands(Collaterial glands)

The ovaries-These are typically more or less compact bodies lying in the body cavity of theabdomen on either side of the alimentary canal. Each ovary is about 2 cm long andcomposed of a variable number of ovarioles and open into the oviduct. A typical ovariole isan elongated tube in which the developing eggs are disposed one after the other in a singlechain. The oldest oocyte is situated nearer the union with the oviduct. The wall of anovariole is made of follicular epithelium whose cells rest upon a basement membraneknown as tunica propria. Each ovariole may be differentiated into three zones:

(i) **Terminal filament-** It is the slender thread like apical prolongation of the peritoneallayer. The filaments of the ovary combine to form a common thread termed as terminalfilament. The terminal filament of one ovary units with the filament of the other ovaryto form a median ligament. It aids in maintaining the ovaries in the position and isattached to the dorsal diaphragm.

(ii) **The germarium**- It is situated below the terminal filament and forms the apex of anovariole. It consists of a mass of cells which are differentiated from the primordial germcells.

(iii) **The region of growth**- It is also called as vitellarium which constitutes the majorportion ofan ovariole. The vitellarium contains the developing eggs (oocytes). Theepithelial layer of thewall of vitellarium grows inwards to enclose each oocyte in adefinite sac known as follicle. Thecells of the follicle secrete the chorion of the egg andin some cases serve to nourish the oocytes. Three types of ovarioles may be recognized on the basis of presence or absence ofnutritive cells.

(a) Panoistic type– Nutritive cells are absent e.g., grasshopper and other insects ofOrthopteraand Isoptera.

(b) Polytrophic type-Nutritive cells are present and arranged inalternate with the oocytes e.g.,Hymenoptera**.**

(c) Acrotrophic type-Nutritive cells arepresent and situated at the apices of the ovarioles e.g.,Hemiptera.

The oviducts– The lateral oviducts are paired canals leading from the ovaries and areformed from the mesoderm. These lateral oviducts form the common oviduct which opensinto thevagina. Each oviduct is an enlarged pouch which stores eggs. The vagina is greatlyenlarged to form a chamber, known as uterus, for the reception of developing eggs.

The Spermatheca– This is a pouch or sac for the reception and storage of the spermatozoa(seminal fluid) and is also known as receptaculum seminis. It generally opens by a duct intothe dorsal wall of the vagina which is known as sperm duct. In many insects pairing takesplace only once and since the maturation of eggs may extend after the union of the sexes, theprovision of spermatheca allows for their fertilization from time to time. A specialspermathecal gland opens into the duct of spermatheca and secretes a fluid which lengthensthe life of sperms.

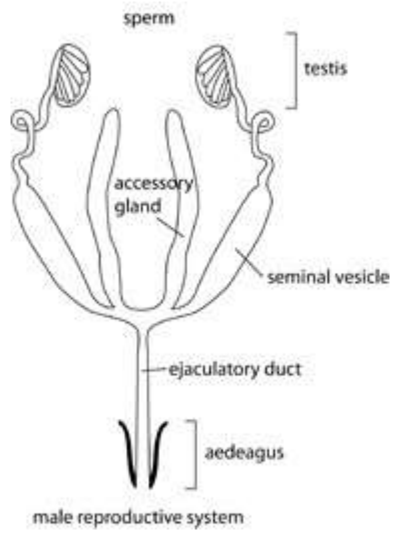
Genital chamber– The vagina opens into the genital chamber on 9th sternum and thischamber iscalled bursa copulatrix which helps in copulation.

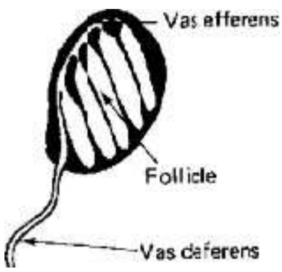
Accessory glands– These are paired structures opening into the distal portion of the vagina.These glands provide material for the formation of egg pod or ootheca.

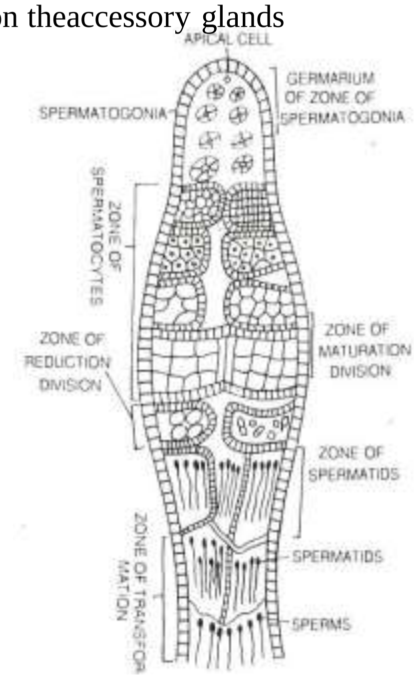
Fertilization– After copulation; the spermatic fluid is received in the spermatheca. The eggcomes down from the oviduct to the vagina which has an opening (micropyle) into its shellfor the entrance of male germ cell (spermatzoan). One or two spermatozoa enter the eggthrough micropyle and only one succeeds in fertilizing the egg. After fertilization theaccessory glands secrete a fluid around the egg which hardens it.

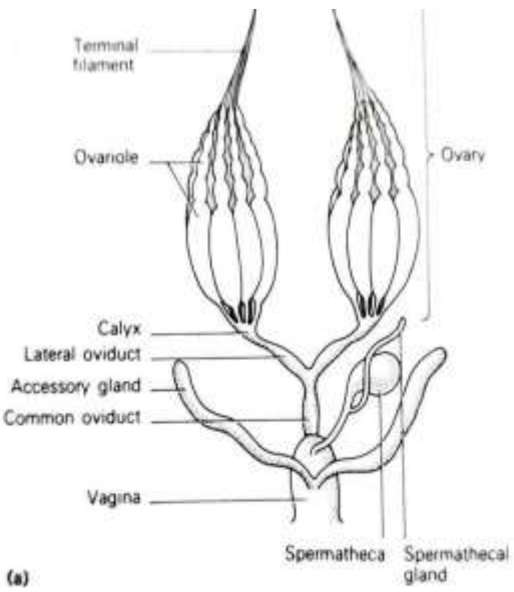
Male reproductive organ

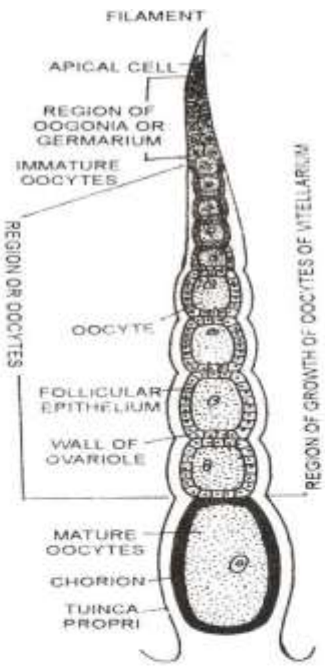
L. S. of Testicular follicle









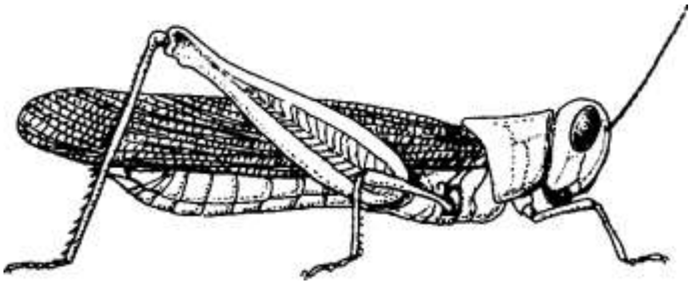


Female reproductive organ **L.S. of an Ovariole**

Practical -10To study the characters of orders Orthoptera, Dictyoptera, Odonata,Neuroptera, Isoptera,Thysanoptera and their families

Order- Orthoptera(Ortho- straight; ptera - wing)

Synonyms : Saltatoria, Saltatoptera, Orthopteroid
Common names : Grasshoppers, Locust, Katydid, Cricket, Mole cricket



Characters
Distribution : Worldwide
but mainly in tropicsBody :
Medium to large sized
Mouthparts : Chewing and biting type
Eyes : Well developed compound eyes; ocelli 2or 3
Antenna : variable, filiform in most of the insects
Thorax : Large prothorax with shield in many of the insects
Wings : Forewings are called **tegmina** (hard and lathery in texture),Hind wingsare **membranous**
Legs : Hind legs is usually adopted for jumping (saltatorial)
Cerci : Short and unsegmented
Ovipositor : Long and well developed
Specializedorgans : Stridulatory (sound producing) organ and auditory (hearing) organpresentMetamorphosis : Gradual / Paurometabola type

Sub-orders : Caelifera and Ensifera

Family:

Acrididae

(Caelifera)

Characters

Antenna : shorter than the body length

Legs : Hind legs are long and meant for jumping with the help of **levatormuscles**

Tarsus : three segmented

Ovipositor : Short and horny

Sound production : Tympanum is located on either side of the 1st abdominal segment.Sound is produced by **femoro-alary mechanism** (a row of peg likeprojections found on the innerside of each hind femur which arerubbed against hard radial vein of the tegmen)Examples(Short hornedGrasshopper andLocusts)Dhan ka tidda – *Hieroglyphus banian*

Kharif ka tidda – *H. nigrorepletus*

Ghas ki tiddi – *Chrotogonus sp.*

Locust – *Schistocerca gregaria*

Family:

Tettigonidae

(Ensifera)

Characters

Antenna : Long as long as body or larger

Tarsus : Four segmented

Ovipositor : Sword like

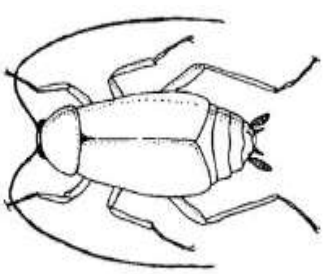
Sound production : Alary type (a thick region on the hind margin of forewing (scraper)is rubbed against a row of teeth on the stridulatory vein (file)present on the ventral side of another forewing which throws theredonant areas on the wing (mirror) into vibrations to producesound)Examples : (Long horned grasshoppers, Katydids and bush crickets)

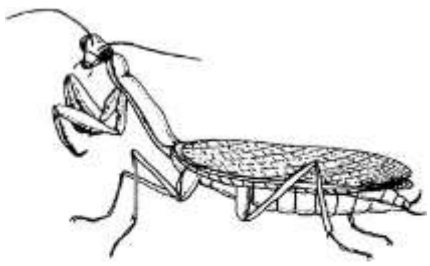
Order-Dictyoptera(Dictyon = network; ptera=wings)

Synonyms : Oothecaria,

Blattiformia Common names :

Cockroaches and preying mantids





Characters

Body : Medium to large sized

Head : Hypognathous

Antenna : Filiform or setaceous

Mouthparts : Chewing type

Thorax : Prothorax usually larger than meso and meta thorax

Wings : Forewings thickened, leathery with a marginal costal vein calledtegmina, Hindwings membranous and folded fanlike
Tarsi : 5 segmented
Cerci : Short and many segmented
Eggs :
Contained in Ootheca
Metamorphosis :
Gradual/paurometabola
Sub-orders : Blattaria (Cockroach) and Mantodea (Preying mantids)

Important Families of Dictyoptera

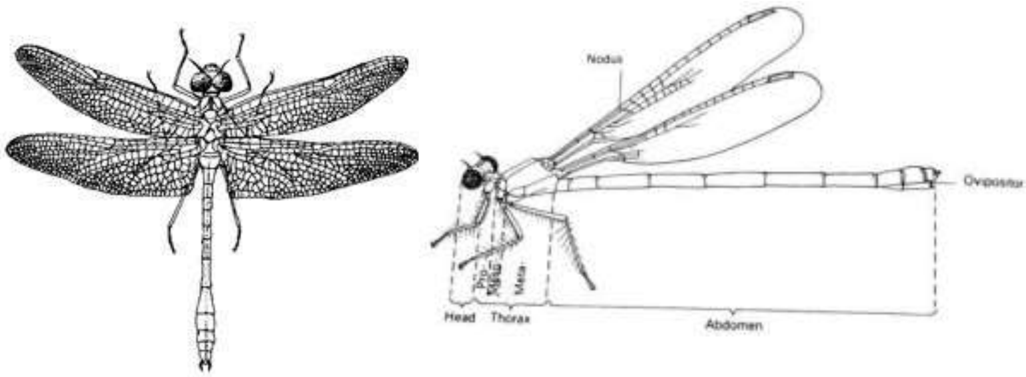
Characters	**Blattidae**	**Mantidae**
Head	Not mobile in all directions	Mobile
in all directions Pronotum		Shield
like and cover the head	Elongated, do not cover headOcelli	
	Degenerated- 2 called as fenestra	Three
Body	Flattened, dark coclored	Elongated
sometimescylindrical Legs	Cursorial running type	Forelegs are
raptorial, middleand		
hind legs are ambulatorialGizzard		
	Powerfully armed with chitinous	
	NoChitinous teeth	
teeth		
Mating behaviour	Do not devour male during mating	
	Often (but not always)Ootheca	
	Chitinous	
	Not chitinous	
Nymphal charcter	Not cannibalistic	Cannibalistic
Mimicry	Absent	Mimic leaves and flowers
Habitat	Omnivorous	Mostly outdoors
Economic importance	Household pest	Predators on crop pest
Examples	American Cockroach	Preying mantids

Order- Odonata

(Odon = tooth; strong mandibules)

Common names : Dragonflies and damselflies

Characters



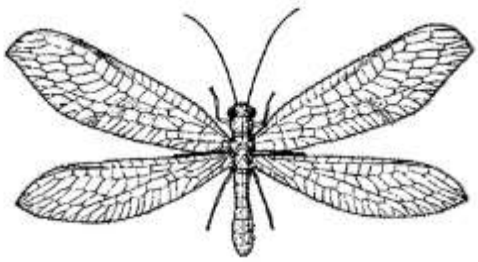
Body : Long, cylindrical, medium to large sized, attractively colouredHead : Globular and constricted behind into a petiolate neck

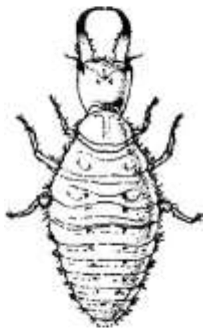
Antenna : Very short, bristle like, setaceous
Eyes : Compound eyes are large. Ocelli- Three
Mouthparts : Adapted for biting, Mandibles are strongly toothed Lacinia andgalea are fused to form mala which is also toothed
Wings : Membraneous, venation is net work with many cross veins. Wingshave a dark pterostigma towards the costal apex. Sub costa ends innodus. Wing flexing mechanism is absent.
Legs :Basket type arrangement, 3 segmented tarsi, They are suited forgrasping, holding and conveying the prey to the mouth.
Abdomen :Abdomen is long and slender, In male gonopore is present on 9thabdominal segment. But the functional copulatory organ is presenton the 2nd abdominal sternite. Before mating sperms are transferredto the functional penis. Female have gonopore on 8th segment.
Metamorphosis : Incomplete with three life stages. The Nymphs (called naiad) isaquatic. Labium is greatly elongated, jointed and bears two hooks atapex. It is called mask. It is useful to capture the prey.
Sub-orders : Anisoptera (Dragonfly) and Zygoptera (damselfly)
Importance : Adults are aerial predators. They are able to catch, hold and devourthe prey in flight. Naiads are aquatic predators. Dragonflies anddamselflies can be collected with an aerial net near streams andponds especially on a sunny day. Naiads can be collected fromshallow fresh water ponds and rice fields.

Order- Neuroptera (Neuro=nerve; ptera=wing)

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

Characters





Body : Soft bodied insects
Antenna : Filiform, with or without a terminal club
Mouthparts : Chewing type in adults
Wings : Wings are equal, membranous with many cross veins, held in a roof-likemanner over the abdomen, weak fliers
Larva : Campodeiform with mandibulo-suctorial mouthparts

Pupa : Exarate, Pupation takes place in a silken cocoon, Six out of eightMalpighian tubules are modified as silk glands. They spin thecocoonsthrough anal spinnerets.

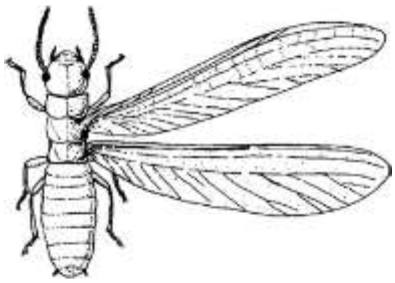
Sub-orders : Megaloptera and Planipennia

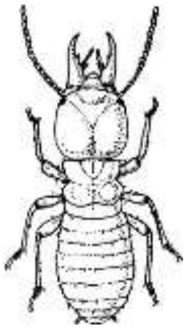
Planipennia : **Families**

1. **Chrysopidae:** Body pale green in colour, eyes are golden yellowin colour, pedicellate/stalked eggs to avoid cannibalism andpredation, larvae prey on soft bodied insects especially on aphids,exhibits camouflage with debris, biocontrol agents, mass multipliedeasily for pest control in field. (e.g. Green lacewings, Goldeneyes,Stinkflies, Aphid lions)
2. **Mantispidae:** Resemble preying mantids, larvae predaceous(e.g.Mantispidflies).
3. **Myrmeleontidae:** Resemble damselfly (Ant lions)
4. **Ascalaphidae:** resemble dragonfly (Owlflies)

Order- Isoptera (Iso=equal; ptera=wing)

Synonyms : Termitina / termitida / SocialiaCommon names : Termites, White ants **Characters**





Body : Minute to large sized and soft

Head : Prognathus, characteristic depression **"Fontanella"** is present onthedorsum of head

Mouthparts : Biting and chewing type

Eyes : Compound eyes present in the winged form; in apterous form itmay ormay not be present; Ocelli 0 – 2

Antenna : Short and moniliform

Wings : Identical in size, form and venation, two pairs, membranous andsemi transparent. Wings are extended beyond abdomen and flexedover abdomen when at rest.

Abdomen : Broadly joined to the thorax without constrictionCerci : Short

Genital organs : Externally lacking in both sexes

Specialities : They are ancient polymorphic, **social insects** living in coloniesExamples Termites- *Odontotermusobesus*, *Eutermusheimi*, *Microtermesanandi*

Caste system is existing in isopteran.

Termite castes

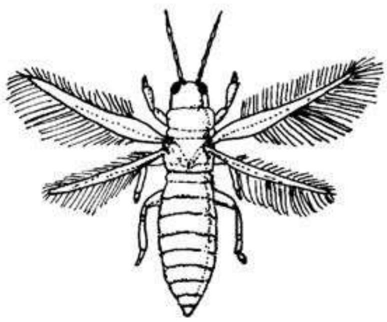
1. Reproductives	**2. Non-reproductives (sterile)**
King	**Workers** (dominate the colony, usually blind and apterous)
Queen	**Soldiers**- (a) mandibulate (b) Nasute (defend the colony)

Order: Thysanoptera (Thysano-fringe; ptera- wing)

Synonyms : Physopoda

Common names : Thrips

Characters



Body : Minute, slender, soft bodied insects

Mouthparts : Rasping and sucking type, Mouth cone is formed by the labrum andlabium together with basal segments of maxilla. There are threestylets derived from 2 maxillae and left mandibles. **Right mandibleis absent**. Hence mouth parts are asymmetrical.

Antenna : Moniliform

Eyes : Compound eyes well developed, ocelli present in alate form

Wings : Either present or absent, when present very narrow and **fringedwith hairs** which increase the surface area, weak fliers and passiveflight in wind is common

Legs : Ambulatorial, Tarsus is with one or two segments, At the apex ofeach tarsus a protrusible vesicle is present.

Abdomen : 11 segmented, pointed. An appendicular ovipositor may be presentor absent

Cerci : absent

Metamophosis : Paurometabola/gradual, Nymphal stage is followed by prepupaland pupalstages which are analogous to the pupae ofendopterygote insects.

Sub-orders : Terebrantia (Important family is **Thripidae**) and tubulifera(ovipositor absent, tubular abdomen, Wing venation is absent)

EconomicImportance : Most of the thrips species belong to the family Thripidae and arephytophagous. They suck the plant sap. Some are vectors of plantdiseases. Few are predators.

Examples : Rice thrips, *Stenchaetothripsbiformis*and Onion thrips, *Thripstabaci*

Practical -11To study of characters of order Hemiptera and its familiesOrder –Hemiptera

(Hemi - half; ptera – wings)

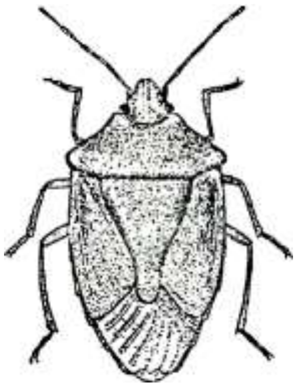
Synonyms

: Rhynchota

Common names

: True bugs

Characters



Body : Minute to large sized

Head : Opisthognathous

Mouthparts : Piercing and sucking type, 2 pairs of bristle like stylets which are the modified mandibles and maxilla are present. Stylets rest in thegrooved labium or rostrum

Antenna : Mostly with 4 or 5 segments

Thorax : Mesothorax is represented dorsally by scutellum.

Wings : Forewings are mostly hemelytra basally coriaceous anddistallymembranous

Cerci : Always absent

Metamorphosis : Usually gradual, rarely complete

Alimentary canal Modified into **filter chamber** to regulate liquid food

Sub-orders : Heteroptera (Hetero -different; ptera - wing) andHomoptera (Homo -uniform; ptera - wing)

Characters	**Heteroptera**	**Homoptera**
Forewings	heavily sclerotized at the base, hemelytra	Uniformly textured
Wings at rest	Held flat over the abdomen	held roof like over the back

Head porrect or
horizontal deflexedBases of forelegs do not
touch the headtouch the head

Habitat Both terrestrial and aquatic Only terrestrial (Herbivorous)(Herbivorous, predaceous or bloodsucking)
Glands Odoriferous or scent glandsWax glands usually present present

Honeydew secretion	uncommon	Common
Scutellum (Triangular plate found Betweenthe wing bases)	well developed	Not well developed
Antenna	Relatively long	Short
Ocelli	Dorsal ocelli 0 or 2	2 or 3

Families of Hetroptera sub-order

Family: Coreidae (Squash bugs / Leaf footed bugs)

Members with many branching veins arising from a transverse basal vein. Stink glandsare found inside the metathorax and glands opening are found on the sidesof the thoraxbetween middle andhind coxae. They emits disagreeable / foul pungent odour. Hind tibiaand tarsi are expanded and leaf like. Nymphs and adult suck the sap from the panicles orpods of pulses.

e.g. Rice gundhi bug- *Leptocorisaacuta*, Pod bug- *Riptortuspedestris*

Family: Pyrrhocoridae (Red bug or Stainer)

They are elongate oval bugs. They show warning colouration. They are brightly markedwith red and black. Feeding injury caused by these bugs leads to the contamination by thefungus Nematospora resulting in yellowish brown discolouration of the lint.

e.g. Red cotton bug- *Dysdercuscingulatus*

Family: Reduviidae (Assassin bugs or Kissing bugs)

Predaceous insects, Head is narrow elongated and beak like. The portion behind thecompound eyes is narrow and resembles a beak. The rostrum is short and three segmentedantenna is filiform. Abdomen is broad in the middle. The lateral margins of the abdomen areexposedbeyond the margin of the wings. e.g. *Rhynocorismarginatus*- predators on bees andother pests.

Families of Homoptera sub-order

Family: Jassidae or Cicadellidae (Leaf hoppers and Jassids)

Insects have wedge shaped body with attractive colour. Hind tibiae have a double rowof spines. Ovipositor is modified for lacerating plant tissue. Nymphs and adults have thehabits of running sidewise. They suck the plant sap and also transmit the viral disease.e.g. Green leaf hopper- *Nephotettixvirescence*transmits the Rice tungro virus disease.

Family: Delphacidae (Plant hoppers)

Large mobile flattened spur is present at the apex of hind tibia. It causes hopper burn,transmits viral disease in rice. e.g. Brown plant hopper- *Nilaparvatalugens*

Family: Lophopidae (Aeroplane bugs)

Head is produced into snout. Hind trochanter is directed backward. Hind basitarsus ismoderately long. Both nymph and adult suck the sap and reduce the quality and quantity ofcane juice. e.g. Sugarcane leaf hopper- *Pyrillapurpusilla*

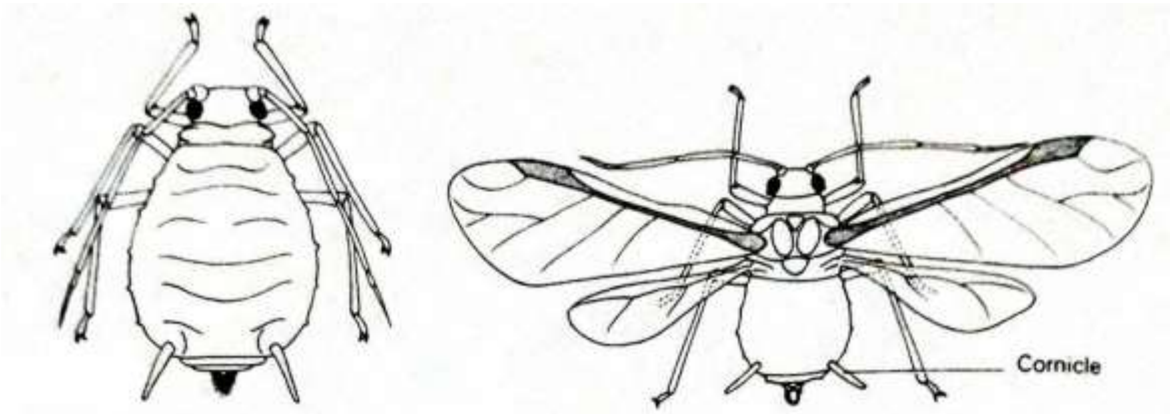
Family: Aleyrodidae (Whiteflies)

Minute insects, which superficially resemble like tiny moths. Wings are opaque anddusted with mealy white powder wax. Wing venation is much reduced. Vasiform orifice ispresent in the last abdominal tergite. It is conspicuous opening provided with an operculum.Beneath the operculumthere is a tongue-like organ termed ligula. The anus opens at thebase of the ligula through which the honey dew is excreted in large amount. Immatureinstars are sessile, scale like, with wax covering. Metamorphosis approaches theholometabolous type due to the presence of a quiescent stage prior to the emergence ofadults. It transmits vein clearing/mosaic disease in Bhendi (Okra).

e.g. Cotton whitefly-*Bemisiatabaci*

Family: Aphididae (Aphids or Plant Lice)

Body is pear shaped. Both apterous and alate forms are found. A pair of cornicles orsiphonculi orwax tube or honey tube is present in the dorsum of 5th or 6th abdominalsegments which secretes wax like substance. The chief constituents are being Myristic acid,sugars and water. Theyexcrete copious amount of honey dew on which ants feed and sootymould fungus grows. Aphids are known for their extraordinary fecundity, short life cycleand parthenogenitic reproduction. Life cycle is highly complex and it involves alteration ofgeneration. They feed on plant sap and disseminate plant diseases. e.g. Cotton aphid –*Aphisgossypii*



Family: Kerridae or Lacciferidae (Lac Insect)

Females are highly degenerate without legs, wings and antennae. The body is irregularglobular. Body is enclosed in a thick resinous cell. Dermal glands secretion of this insectprovides the stick lac. e.g. Lac insect – *Lacciferlacca*

Family: Pseudococcidae (Mealy bug)

Body is elongate, oval in shape. Body segmentation is distinct. Body is covered by longradiating thread of mealy secretion. Functional legs are present in all instars. Wings areabsent. Nymph andadults suck the sap and affect the growth of spindle leaf. e.g. Coconutmealy bug-*Pseudococcuslongispinus*.

Family: Cicadidae (Cicadas)

Males have sound producing organs at the base of the abdomen. Sound producingorgans consistsof a pair of large plates, the opercula covering the cavity containingstructures producing sound.

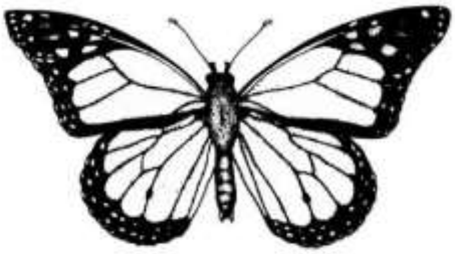
In the anterior part of the cavity beneath each operculum is ayellowish membrane. A shining mirror is located in the posterior part of the cavity. In thelateral wall of the cavity is an oval shaped ribbed structure, the tymbal. These are vibratedby strong muscles to produce sound. Each species has a characteristics song. Tympanum ispresent in both the sexes. Wings are transparent. Eggs are inserted into the tree twigs by thefemale. Nymphs drop to the ground, enter the soil and feed on root sap. Anterior femurs ofthe nymph are thickened with spines beneath and are suited for digging the soil. Life cycleof periodical cicada lasts for 13- 17 years.

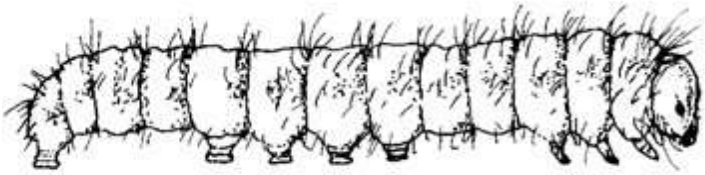
Practical- 12To study of characters of order Lepidoptera and its familiesOrder: Lepidoptera
(Lepido- scale; ptera- wings)

Synonyms : Glossata

Commonnames : Butterflies, moths and skippers

Characters





Body : Body, wings and appendages are densely clothed with overlappingscales,which give colour, rigidity and strength. They insulate the bodyand smoothen air flow over the body.

Mouthparts : Mouthparts in adults are of **siphoning type**. Mandibles are absent. The**galeae of maxillae are greatly elongated** and are held together byinterlocking hooks and spines. The suctorial proboscis is coiled up likeawatch spring and kept beneath the head when not in use.

Wings : Wings are membranous and are covered with overlapping **pigmentedscales**. Forewings are larger than hind wings. Wings are coupled byeither frenate or amplexiform type of wing coupling.

Larvae : Larvae are **polypod-eruciform** type. Mouthparts are adapted forchewingwith strong mandibles.There are three pairs of five segmented thoracic legs ending in claws.Two to five pairs of fleshy unsegmented **prolegs** are found in theabdomen. At the bottom of the proleg, **crochets** are present.

Pupae : Pupa is generally **obtect**. It is either naked or enclosed in a cocoonmade out of soil, frass, silk or larval hairs.

Sub-orders : **Ditrysia and Monotrysia**

Most of the lepidoptern insects **(97 %)** are grouped under the **suborder Ditrysia** in which thefemale insects have **two pores i.e., the copulatory pore** is located in the **8th** abdominalsternite and the egg pore in the **9th** abdominal sternite. Remaining insects are grouped underthe **suborder Monotrysia** in which the female insects have **one pore.**

Butterfly Family

1. **Papilionidae (Swallotail Butterfly)**

They are often large and brightly coloured (Fig. on cover page). Prothoracic legs havetibial epiphysis. In many species hind wings has tail like prolongation. Amplexiform type ofwing coupling is present. Larval body is either smooth or with tubercles. RetractileOsmeteria are present on the prothoracic tergum of the caterpillar. e.g. Citrus butterfly,*Papiliodemoleus*

2. **Pieridae (Whites and sulphurs)**

They are white or yellow or orange coloured with black markings. Larva is green,elongate and covered with fine hairs. Larval body segments have annulets. e.g. Cabbagewhite butterfly,*Pierisbrassicae*

Moth Family

1. **Arctidae (Tiger moth)**

Wings are conspicuously spotted or banded. They are nocturnal and attracted to light.Larva is either sparsely hairy or densely hairy (wooly bear). e.g. Spotted boll worm, *Eariasvitella*, Sunhemp caterpillar, *Utetheisapulchella*

2. **Bombycidae (Silk worm moths)**

Antenna is bipectinate. Larva is either with tuft of hairs or glabrous with medio dorsalhorn on8th abdominal segment. Pupation occurs in dense silken cocoon. e.g. Mulberry silkworm, *Bombyxmori*

3. **Gelichidae (Paddy moths)**

Forewings trapezoidal and narrower than hind wing. Caterpillars bore into the seedstubers and leaves. e.g. Cotton pink boll worm, Pectinophora gossypiella, Angumous grainmoth, *Sitotrogacerealella*, Potato tuber moth, *Pthoremeaoperculella*

4. **Noctuidae (Noctua moths)**

They are medium sized, stoutly built moths. They are nocturnal and attracted to lights.Labial palpi is well developed. All crochets on the larval prolegs are of same size andarranged in semi circle. Some larvae are semiloopers. They have either 3 or 4 pairs ofprolegs. Larvae attack the plants during night. Larvae of some species remain concealedbeneath the surface of the ground or litter during day and feed on plants during night. Theyoften cut small seedlings close to the ground and hence they are called cut worms. e.g.Tobacco cut worm, *Spodopteralitura*

5. **Pyraustidae/ Pyralidae**

Proboscis is vestigial in many species. Labial palp is snout like. Larval habit varies. Itmay live among aquatic plants and bore into the stem or remain in silken web among spunup plants parts. Some larvae are aquatic and gill breathing. e.g. Rice stem borer, *Scirpophagaincertullus*

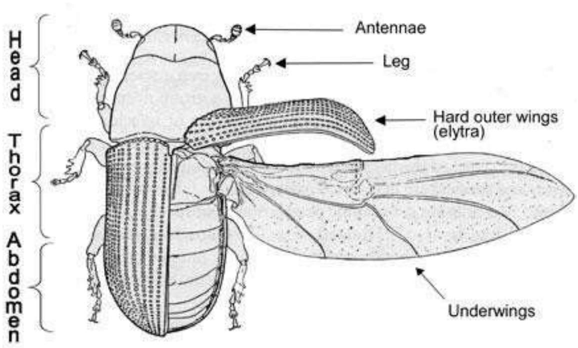
6. Saturniidae (Moon moth, giant silk worm moth)

They are large sized moths. Antenna is bipectinate. Transparent eye spots are presentnear the centre of each wing. The spots are either circular or crescent shaped. Larva is stoutand smooth with scoli. Cocoon is dense and firm.e.g. Tusor silk worm, *Anthereapaphia*,which yields silk.

Practical- 13To study the characters of order Coleoptera and its familiesOrder: Coleoptera (Coleo-Sheath; petra- wing)

Synonyms : Elytroptera
Common names : Beetles, Weevils

Characters



Body : Minute to large sized insects
Antenna : 11 segmented
Mouthparts : **Chewing and biting** type, Mandibles are short with blunt teeth atthe mesal face in phytophagous group, In predators the mandiblesare long, sharply pointed with blade like inner ridge. In pollenfeeders teeth are absent and the mandibles are covered with stiffhairs.

Thorax : Prothorax is large, distinct and mobile. Mesothorax and metathoraxare **fused** with the first abdominal segment. Forewings are heavilysclerotized, veinless, hardened and called **elytra**.

Wings : Forewings are heavily sclerotised, veinless and hardened. They arecalled elytra. Forewings do not overlap and meet mid-dorsally toform a mid-dorsal line. It is not used for flight. They serve as a pairof convex shields to cover the hind wings and delicate tergites ofabdomen. Hind wings are membranous with few veins and areuseful in flight. At rest they are folded transversely and keptbeneath the elytra. In some weevils and ground beetles theforewings are fused and hind wings are atrophied.

Abdomen : Cerci and a distinct ovipositor are absent.

Development : Metamorphosis is complete. Larvae are often called grubs. Pupae are usually exarate and rarely found in cocoons.

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

Sub-orders : **Adephaga (predators/ devourers) and Polyphaga (eaters of manythings).**

Families of predators **:**Cicindelidae (Tiger beetle), Carabidae (Ground beetle), Dytiscidae(True water beetle), Gyrinidae (whirligig beetle), Coccinellidae (Lady bird beetle),Lampyridae (Firefly, glow worm)

Families of scavengers **:**Scarabaeidae (Scarabs, dung beetle), Hydrophilidae (waterscavenger beetle)

Families of stored product pests:

Anobiidae (Wood worm/ wood borer) e.g. Cigrette beetle- *Lasiodermaserricorne*Bostrychidae (Grain borer) e.g. Lesser grain borer -*Rhizoperthadominica* **Families of crop pests:**

1. **Apionidae** e.g. Sweet potato weevil, *Cylasformicarius*, a pest both in the field and instorage.Head is produced into snout. Antennae are not elbowed. Grubs are apodous.
2. **Cerambycidae (Longicorn beetles/ Longhorn beetles)**

e.g. Mango stem borer, *Batocerarufomaculata*

3. **Curculionidae (Weevils/ snout beetles)**

Minute to large sized insects. Frons and vertex of the head produced into snout, which iscylindrical and in some species larger than the beetle itself. Mouthparts (mandible andmaxilla) are present at the tip of the snout, It is useful to feed on internal tissues of the plantand provide a place for egg laying. Antenna is geniculate and usually found in the middle ofthe snout. Grubsare apodous and acephalous. Weevils are important crop pests during bothin field and in storage. e.g. Coconut red palm weevil, *Rhynchophorusferrugineus*

4. **Galerucidae / Chrysomelidae (Pumpkin beetle)**

Antenna are closely approximated. Third tarsomere is deeply bilobed. Larvae are rootfeeders. Adults bite holes on plants.Red pumpkin beetles, *Raphidopalpafoevicollis*

5. **Melolonthidae (Chaffer beetle, June beetle, White grub)**

They are stout beetles with glossy surface. Head is small. Labrum is well sclerotized.Adults are attracted to lights. They feed on tree foliage during night and hide in soil duringday time. Larvae are scarabaeiform and root feeders. e.g. Groundnut white grub, *Holotrichiaconsanguinea*, a serious pest under rainfed conditions.

Families of Predators:

1. **Coccinellidae (Lady bird beetle)**

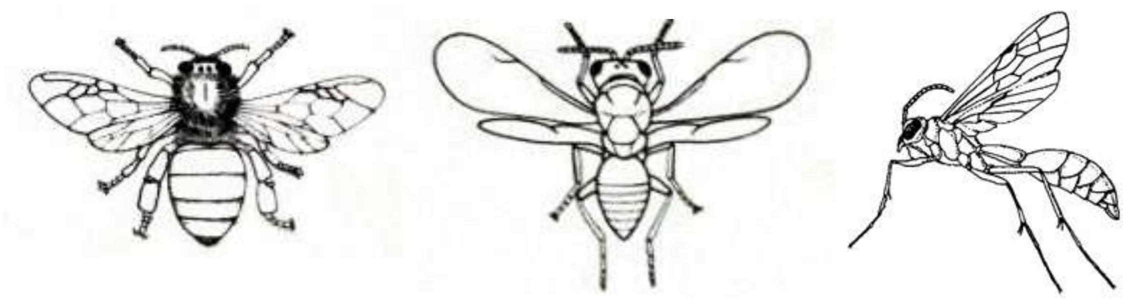
They are hemispherical insects. The body is convex above and flat below. The bodyappearance resembles like a split pea, head is small, turned down ward and received into aprominent notchof prothorax. Elytra is strongly convex, brightly coloured and variouslyspotted. Grubs are campodeiform and spiny. The last larval skin either covers the pupa andgets attached to its anal end. Except the genus Epilachna others are predators on aphids,scales, mites and whiteflies. e.g. *Coccinellaseptupunctata*, *Coccinellavigintioctopunctata*

Practical- 14To study the characters of order Hymenoptera and Diptera and their familiesOrder: Hymenoptera

(Hymen- membrane; ptera- wings), (Marriage on wings)

Common names : Sawflies, ants, bees, and wasps

Characters



Mouthparts : Primarily adapted for chewing, Mandibles are very well developed.In bees both labium and maxillae are integrated to form the **lappingtongue**.

Thorax : Modified for efficient flight. Pronotum is collar like. Mesothorax isenlarged. Metathorax is small. Both prothorax and metathorax arefused with mesothorax.

Wings :Stiff and membranous. Forewings are larger than hindwings. Wingvenation is reduced. Both forwings and hindwings are coupled by arow of hooklets (**hamuli**) present on the leading edge of thehindwing.

Abdomen :Basally constricted, The first abdominal segment is called**propodeum**. It is fused with metathorax. The first pair of abdominalspiracles is located in the propodeum. The second segment is knownas **pedicel** which connects the thorax and abdomen. Abdomenbeyond the pedicel is called **gaster** or **metasoma**.

Ovipositor :Always present in females. It is variously modified for oviposition orstinging or sawing or piercing plant tissue.

Metamorphosis : Complete

Larva :Often the grub is apodous and eucephalous. Larva is rarely eruciform.

Pupa : Exarate and frequently enclosed in a silken cocoon secreted fromlabial glands

Sex determination : Fertilized eggs develop into females and males are produced from unfertilized eggs.

Importance : Productive and beneficial insectsSub-orders : **Symphyta and Apocrita**

Suborder Symphyta- Abdomen is broadly joined with thorax, stemmata present, ovipositorissaw like and suited for piercing plant tissues, habits are phytophagous ,e.g. sawflies andhorntails **Family: Tenthrinidae (Saw flies)**

They are wasp like insects. Abdomen is broadly joined to the thorax. Ovipositor is sawtoothed and suited for slicing the plant tissue. Larva is eruciform. It resembles a lepidopterncaterpillar. It has 1 pair od ocelli, papillae (reduced antanna), 3 pairs of thoracic legs and6-8pairs of abdominallegs.Prolegs lack chrochets. They are external feeder on the foliage.Larvae while feeding usually have posterior part of the body coiled over the edge of the leaf.(Mustard Sawfly, Athlia lugens proxima is a defoliator of mustard and cruciferous vegetables.

Suborder Apocrita– Abdomen is petiolated, Stemmata are absent, Legs are absent,ovipositor is not saw like and Suited for piercing or stinging,they are generally parasitic.

Family:Apidae (Honey bee)

Body is covered with branching or plumose hairs. Mouth parts are chewing andlapping type. Mandibles are suited for crushing and shaping wax for building combs. Legsare specialized for pollen collection. Scopa (pollen basket) is present on hind tibia. They aresocial insects with 3 castes viz. Queen, drone and workers.Division oflabour is noticedamong honey bees. Indian honey bee, *Apisindica*

Formicidae (Ants)

They are common widespread insects. Antennae are geniculate. Mandibles are welldeveloped. Wings are present only in sexually mature forms.Petiole may have 1 or 2 spines.They are social insects with 3 castes viz. Queen, males and workers. Workers are the sterilefemales and theyform the bulk of the colony. Exchange of food materials between adultsand immature insects is common. After a mating flight queen alone finds a suitable nestingsite.Many species have associated symbiotic relationship with homopteran insects.

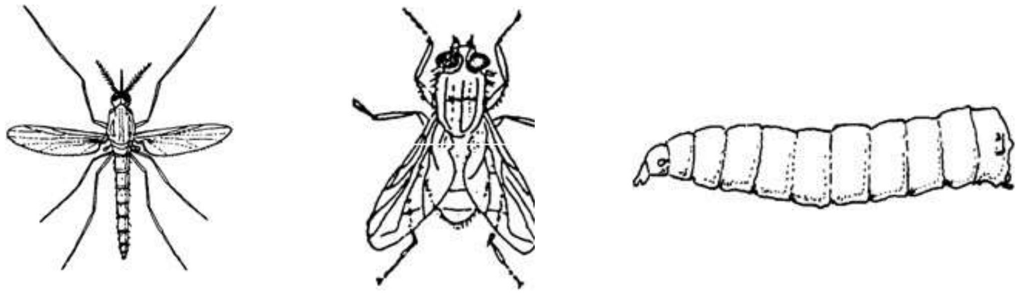
Braconidae (Braconid wasp)

They are small, stout bodied insects. Fore wing has one recurrent vein. Petiole is neithercurved nor expanded at the apex. Gaster is sessile or subsessile. Abdomen is as long as headand thorax together. They parasitize lepidoptern larvae commonly. They are gregariousparasites. In many species, Polyembryony is observed. Bracon brevicornis is mass multipliedand released for the control of black headed coconut caterpillar.

Order- Diptera (Di-two;ptera-wings)

Common names : True flies,Mosquitoes,midges,gnats

Characters



Body : Small to medium sized, soft bodied insects

Antenna : Often hemispherical and attached to the thorax by a slender neck

Mouthparts : Sucking type

Thorax :Fused together. The thoracic mass is largely made up ofmesothorax.

Wings : Single pair of wings. Forewings are larger, membranous andusedfor flight. Hind wings are highly reduced, knobbed at the end andare called **halteres**

Metamorphosis : Complete

Larvae : Larvae of more common forms are known as maggots. They are**apodous** and **acephalous**.

Pupa : Pupa is generally with free appendages, often enclosed in thehardened last larval skin called **puparium**. Pupa belongs to thecoarctate type.

Sub-orders : **Nematocera (Thread-horn), Brachycera (Short-horn) andCyclorrhapha(Circular-crack)**

Families of agricultural Importance:

Syrphidae (Horse flies, Flower flies)

They are brightly coloured and brilliantly stripped. A vein like thickening is present inbetween the radius and median in the forewing. Abdomen has distinct black and yellowmarkings. Maggots prey on soft bodied insects especially aphids. Adults are excellent fliers.They hoverover flowers. They feed on pollen and nectar. They aid in pollination.

Tephritidae (Fruit flies)

Sub costa bends apically and fades out. Wings are spotted or banded. Female has asharp and projecting ovipositor. Maggots can hop. They are highly destructive to fruits andvegetables. Cucurbit fruit fly, *Dacuscucurbitae*.

Tachinidae (Tachinid flies)

Arista is completely bare. Abdomen is stout with severalnoticeable bristles.They arenon specificendoparasite on the larvae and pupae of Orthoptera, Hemiptera, Lepidopteraand Coleoptera.

Practical- 15To study the Insecticides and their formulations.

Insecticide formulations

After an insecticide is manufactured in a relatively pure form (technical grade), it mustbeformulated before it can be applied. Formulation is the processing of the technical gradeby various methods which is done to make the product safer, more effective and moreconvenient to use. Formulation is the final physical condition in which the insecticide is soldcommercially. In aformulation, there are one or more chemicals (formulants) which are theactive ingredients (a.i.) and other ingredients which have no pesticide action (inertingredients). There are mainly three types of pesticide formulations (liquid, solid and gas).
A single pesticide may be sold in more than one formulation. Formulation type depends onseveral factors:

- toxicology of the active ingredient,
- chemistry of the active ingredient,
- how effective the product is against the pest,
- the effect of the product on the environment (plant, animal or surface etc.),
- how the product will be applied and the equipment needed the application rate.

Characteristics of an Appropriate Insecticides Formulation

- Highly toxic to target insects.
- Not repellent or irritant to target insects
- Long-lasting
- Safe to humans and domestic animals
- Stable during storage and transportation
- Cost-effective

TYPE OF FORMULATIONS

Emulsifiable Concentrates (EC)

- It consists of a technical grade material, organic solvent and a emulsifier.
- Emulsifier makes the water insoluble toxicant to water soluble
- When an emulsifiable concentrate is added to water and agitated (i.e., stirredvigorously), the emulsifier causes the oil to disperse uniformly throughout the carrier(i.e., water) producing an opaque liquid (oil in Water suspension).
- A few formulations are Water in oil suspension. These are opaque and thick, employedas herbicide formulations, because they result in little drift.
- These are easy to transport and store, and require little agitation in the tank. However,care must be exercised in handling the toxic concentrates.
- Shelf life approximately 3 years
- More than 75% of all insecticides formulations are applied as sprays.
- Examples : Quinalphos 25EC, Dimethoate 30EC, Chlorpyriphos 20EC.

Dusts (D)

- Simplest of all formulations and the easiest to apply.
- The technical material (active ingredient) is mixed with an inert diluents carrier suchasclay, organic flour, pulverised minerals.
- In a formulated dust, the following two types of mixtures are usually found :

Undiluted toxic agent, e.g., sulfur dust used for control of mites and powdery mildew and**Toxic** a.i. plus an inert diluent. This is the most common dust formulation sold as 2%,5%, or 10% a.i dust.

- Concentration of dust formulation ranged between 0.1% to 25%
- Particle size of dust particles 1-40 µ pass through 325 mesh sieve.
- Least effective and cause wind drift leading to poor deposit on surface. It has beencalculated that not more than 10-15% of the applied material is retained on the surface.
- Highly toxic to beneficial insects.
- Example : Carbryl 5 D, Malathion 5D.

Granules (G)

- The chemical is in the form of small granules of inert material, either as a coating onthesurface of the inert granules, or as an impregnated toxicant in the granules.
- Consist of small pellets of the active ingredients sprayed on to clay and allowingsolventsto evaporate
- Size: 0.25 – 0.38 mm (20-80 mesh or 30-60 mesh i.e (i.e., the number of grits(granules)per inch of the sieve through which they have to pass).)
- The amount of active ingredient varies from 2-10 per cent.
- Used mainly as systemic insecticides and can be applied on to the soil, or may beplacedin the whorl of leaves depending on the nature of pest control required.
- Granular insecticides may be more economic since precise applications are possiblewiththem.
- Much safer to apply than dusts and are generally less harmful to beneficial insects suchasbees.
- Example : Carbofuran 3G, Phorate 10G, Cratap 4G.

Wettable Powders (WP)

- Concentrated dusts containing a inert diluents (50-75% talc or clay) and a wetting agenttofacilitate mixing the powder with water before spraying.
- Much more concentrated than dusts, containing 15 to 95 per cent active ingredient.
- Do not dissolve washers and rubber hoses;do not damage materials sensitive toorganicsolvents
- Leave effective residues in cracks and crevices and are not phytotoxic.
- Require frequent agitation and cause corrosion of valves, nozzles and pumps andsprayers

- Should never be used without dilution.
- These are easy to carry, store, measure, and mix. However, care must be taken toprotectagainst inhalation during handling.
- Example: Carbaryl 50WP, Sulfur 80WP, Bacillus thurnigiensis var. kurstaki 5WP.

Soluble Powders (SP or WSP)

- Contain a finely ground water soluble solid which dissolves readily upon the additionofwater forming true solution.
- Do not require constant agitation and forms no precipitate.
- The amount of active ingredient in soluble powder ranges from 15-95% by weight; itisusually not more than 50%.
- Soluble powder have all the advantages of wettable powders except the inhalationhazardduring mixing.
- Example: Cartap hydrochloride 50SP, Acephate 75SP.

Water Dispersible Granules (WDG)

- Water dispersible granules, or dry flowables is a relatively new type of formulation andbeing developed as safer and more commercially attractive alternatives to wettablepowders and suspension concentrates formulations.
- They are becoming more popular because of convenience in packaging and use, nondusty,free-flowing granules which should disperse quickly when added to water in thespray tank.
- They therefore represent a technological improvement over wettable powders. Thedispersion time in water is a very important property and to ensure that no problemsshould occur during mixing in the spray tank.
- It is necessary for all the granules to disperse completely within two minutes in varyingdegrees of water temperature and hardness.
- Example: Endosulfan 50 WG, Cypermethrin 40 WG, Thiamethaxam 25 WG,Deltamethrin 25 WG.

Suspension Concentrates (SC)

- Pesticide particles maybe suspended in an oil phase, but it is much more usualforsuspension concentrates to be dispersed in water.
- A stable suspension of solid pesticide(s) in a fluid usually intended for dilution withwaterbefore use. Ideally, the suspension should be stable (i.e. not settle out).
- The active ingredient range between 0.1-60%.
- A.I. must be water insoluble with friable crystals, Easy to tankmix (very compatible) -

A.I. tends to settle out over time.

- Farmers generally prefer suspension concentrates to wettable powders because theyarenon-dusty and easy to measure and pour into the spray tank.

- Example: Fipronil 5 SC, Sulphur 52 SC.

Microencapsulation/Capsule Suspensions (CS)

- The polymer membrane, or microencapsulation technique, has become popular inrecent years.
- These are particles of pesticide, either solid or liquid encapsulated by polymericcoatings. Microcapsule solids are suspended in water as a concentrate and dilutedproduct (1:100 to 1:1000) is applied in spray solution to soil or foliar canopy.
- The rate of release of the active ingredient can be controlled by adjusting themicrocapsule/droplet size, the thickness of the polymer membrane and the degree ofcross-linking or porosity of the polymer.
- Example: Lambda Cyhalothrin 10 CS, Lambda Cyhalothrin 25 CS etc

O/W Emulsions (EW)

- Oil-in-water emulsions are now receiving considerable attention reduced or eliminatedvolatile organic compounds (VOCs) for safer handling.
- They are water based, oil-in-water emulsions can have significant advantages overemulsifiable concentrates in terms of cost and safety in manufacture, transportation anduse.
- The active ingredient must have very low water solubility to avoid crystallizationissues.
- Example: Butachlor 50 EW, Cyfluthrin 5 EW, Tricontanol 0.1 EW etc

Flowable Suspension (FS)

- Flowable suspensions are concentrated 40% to 70% w/w suspensions of micronizedinsoluble active pesticide in water.
- FSs must be formulated for low viscosity and good fluidity, so that transfer to the spraytank is easy and complete. This requires an effective wetting agent and an efficientdispersing agent to ensure adequate dispersion of the pesticide in the water. Since theactive ingredients in FSs are insoluble, good suspension stability is essential.
- If the suspension settles and leaves sediment at the bottom of the container, theapplication of the pesticide may be too weak to be effective.
- A combination of smectite clay (bentonite) and xanthan gum works synergistically toprovide excellent long term suspension stability at low viscosity and at low cost.
- Example: Thiram 40 FS, Thiamethoxam 30 FS, Tebuconazole 5.36 FS

Microemulsions (ME)

- Microemulsions are thermodynamically stable transparent dispersions of twoimmiscibleliquids and are stable over a wide temperature range.
- Involves the incorporation of the insecticide in a permeable covering, microcapsulesorsmall spheres with diameter ranging from

1-50 μ.

- The total concentration of surfactants for a microemulsion can be as high as 10–30%ormore, compared with about 5% for a typical o/w emulsion.
- The insecticides escape through the small sphere wall at a slow rate over anextendedperiod of time.
- Microemulsions have relatively low active ingredient concentrations, but the highsurfactant content and solubilisation of the active ingredient may give rise to enhancedbiological activity.
- Example: Neemazal 30 MEC, Pyrithiobac Na 5.4 + Quizalofop-P-Ethyl 10.6 ME.

Oil Dispersion Formulations

- One of the latest formulation types is oil dispersions (ODs). This technology allows veryefficient and environmentally friendly agrochemical formulations.
- In ODs the solid active ingredient is dispersed in the oil phase, making it especiallysuitable for water-sensitive or non-soluble active ingredients.
- The oil-phase can comprise different oils such as mineral oils, vegetable oils or esters ofvegetable oils.
- Special attention is needed with the auxiliaries in ODs: suitable oil-compatibledispersing agents and emulsifiers adjusted to the type of oil which forms a stableemulsion after dilution with water.

ZW Formulation of CS & EW

- A mixed formulation of CS and EW is a stable suspension of microcapsules of the activeingredient and fine droplets of active ingredient(s) in fluid, normally intended fordilution with water before use.
- In the case of microcapsules, the active ingredient is present inside discrete,inert,polymeric microcapsules.
- The formulation is intended for dilution into water prior to spray application. Mixturesof active ingredients one of which is encapsulated are used to provide a broaderspectrum of pest control.
- Formulating the active ingredients together eliminates the need for tank mixing (whichcan lead to incompatibilities).
- Example: Lambda Cyhalothrin-25.0 CS + Chloropyriphos-10.0 EW

Flowable Powder (FP)

- The technical material is wet milled with a clay diluent and water with a suspendingagent, a thickener and anti freeze compound forming a thick creamy pudding likemixture which mixes well with water.
- Needs constant agitation to prevent the insecticide from coming out of suspension andsettling.

Oil solutions

- Formulated by dissolving the insecticides in an organic solvents for direct use in insectcontrol

- Rarely used on crops as they cause severe burning of foliage.
- Effective on livestock, as weeds sprays along roadsides, in standing pools formosquito's larvae control, and in fogging machines for adult mosquito control.

Aerosols

- Most common of all formulations for home use
- Consists of toxicant (2%), solvent (10%), knockdown agent (2%) and propellant (86%).
- The active ingredients soluble in volatile petroleum oil is kept under pressure providedbypropellant gas
- When solvent is atomized, it evaporates quickly leaving behind small droplets oftheinsecticides suspended in air
- The toxicant is suspended as minute particle (0.1 - 50 w/w) in air as a fog or mist.
- Used for the knockdown and control of flying insects and cockroaches, but theyprovideno residual effect.
- Caution must be taken when used as they produce droplets well below 10 μ,readilyabsorbed by alveolar tissues in the lungs.

Ultra low volume concentrates (ULV)

- Technical ingredient is dissolved in minimum amount of solvent 0.6 litre to 5.0 litre/hainvery small droplets of 1-15μ.
- Small droplets can better penetrate thick vegetation and other barriers
- Used for insect control in large areas where high volume of water constitutes atechnicaldifficulty.

Fumigants

- Gases or low volatile liquids of low molecular weight which readily penetrate thematerialto be protected
- Used for the control of insects in stored products, for soil sterilization.
- Most of the fumigants are liquid and are mixtures of two or more gases.

Fogging concentrates

- Used in control of adult flies and mosquitoes for public health.
- Fogging machines generate droplets of 1-10μ.

Smoke generators

- They are used in the form of coil like strips containing pyrethrum, oxidant and wooddustfor the control of mosquitoes. When ignited, these coils release vapours.

Impregnating materials

- Used in the treatment of woollens for moth proofing and timbers against wooddestroyingorganisms.

Poison bait

- Contains low level of toxicant incorporated in to material such as food stuffs,sugars,molasses etc. that are attractive to target pest.

LABEL INFORMATION

Every pesticide container has a label affixed on it with a leaflet. The label givesinformation of the pesticide in the container. The leaflet contains information on directionsto use warnings, disposal and storage. Both the lable and leaflet are statutorily requiredunder the Insecticide Act, 1968. The following information must be furnished on the label.

- Name of the pesticide (Brand name, Trade name, Common name), Name ofthemanufacturer and address, Registration number, Kind and name of active ingredientand their percentage, Types of formulation, Net content by weight, Batchnumber(assigned by manufacturer), Date of manufacture, Expiry date, Antidote statement
- Warming symbols and signal (warming symbol is of diamond shaped consisting oftwotriangles with a colour in the lower triangle and a signal in the upper triangle).

Practical -16To study the Pesticide appliances and their maintenancePlant Protection Equipments
SPRAYERS

Sprayer is a machine used to apply liquid chemicals on plants to control pest anddiseases. It can also be used to apply herbicides to control weeds and to spray micronutrientsto enhance plant growth. The main functions of a sprayer are

- Breaking the chemical solution in to fine droplets of effective size.
- Distributing the droplets uniformly over the plants.
- Applying the chemicals with sufficient pressure for positive reaching the plants
- Regulating the amount of liquid applied on plants to avoid excessive application.

A variety of high volume sprayers are available in the market. Almost all types of highvolume sprayers have some kind of pump to supply pressurised spray liquid to thehydraulic nozzle whichbreaks the liquid into spray droplets and throws the spray awayfrom it. The high volume sprayersare both manually operated or power operated type.

Principle: The function of sparyer is to atomize the spary fluid in to small droplets and ejectit with some force.

Parts of sprayers: The important parts are tank, agitator, pressure gauge, valves, filters,pressure chamber, hose, spray lance, cut off device, boom and nozzle.

Fig.1. Sprayer components

Nozzle body: It is the main component on which other component of a nozzle fit (Fig. 1a).

Swirl plate: It is the part of a cone nozzle which imparts rotation to the liquid passingthrough it(Fig. 1b).

Spray gun: It is a lance from which spray is readily adjustable during the operation.

Spray boom: It is a spray lance with spray nozzles fitted to a head, mounted at right anglesto thelance (Fig. 1d).

Filter: It is a component to remove suspended matter larger than a predetermined size fromfluid. **Over-flow pipe**: It is a conduit through which excess fluid from a pump is by-passed bytheaction of a relief valve or pressure regulator.

Relief valve: It is an automatic device to control the pressure of fluid or gas within rangeapredetermined value.

Pressure regulator: It is an automatic device to control the pressure of fluid or gas withinarange of settings.

Cut-off valve: It is a mechanism between the pump and the nozzle to control the flow ofliquidfrom the sprayer. This is operated by hand.
Nozzle disc: It is component containing the final orifice of a nozzle usually acone nozzle. **Nozzle boss**: It is a lug on spray boom or spray lance to which a nozzlebody or cap is screwed.**Nozzle tip**: It is component containing the final orifice of a nozzle usually afan nozzle.
Spray lance: A hand-held pipe through which the liquid reaches thenozzle mounted at the free end.
TYPES OF NOZZLE: The three common types of nozzle

a. **Hollow cone nozzle:** This liquid is fed into a whirl chamber through atangential entry or through a fixed spiral passage to give a rotatingmotion. The liquid comes out in the form of a harrow conical sheetwhich then breaks up into small drops. This is used for insecticide andfungicide spraying.

b. **Solid cone nozzle:** This nozzle covers the entire area at small range.The construction is similar to hollow cone nozzle with the addition ofan internal jet which strikes the rotating liquid just within the orifice ofdischarge. The breaking of drop is mainly due to impact. This is usedfor herbicide spraying.

c. **Fan nozzle:** It is a nozzle which forms narrow elliptical spray pattern. In this type theliquid is forced to come out as a flat fan shaped sheet which is then broken intodroplets. This nozzle is mostly used for low pressure



spraying.

a. Hollow cone nozzle b. Solid cone nozzle c. Fan nozzle

TYPES OF SPRAYERS:

A. **Manually Operated Hydraulic Sprayers-** In this type, the hydraulic pump directly actson the spray fluids and discharge it.

a. Hand syringe

It is a single acting pump working on the principle of cycle pump. it consists of cylinderin to which the spray fluid is drawn during the suction stroke and delivered during thepressure stroke and discharge through nozzle. It is useful to operate only a small area.

b. Hand Sprayers

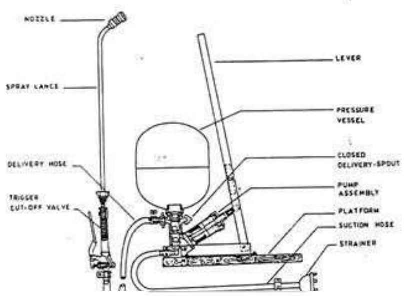
This is a simple sprayer. It creates hydraulic pressure by forcing spray solution to anozzle by the direct action of hand pumping. The spray solution is filled in a plastic can (5-10 L) which is usually shoulder slung. A dip-tube draws liquid from the tank due to handactuation of the plunger. Held by both the hands the piston pump is worked by slidingaction. The capacity of thissprayer is about 0.5 acre per day. It is useful for small scalespraying in nursery or kitchen gardens and pot plants.

c. Bucket or Stirrup Pump Sprayer:

It consist either of a double acting pump with two cylinders or a single acting pumpwith one cylinder. The other parts of the sprayer are the plunger assembly, foot valueassembly, hose, lanceand nozzle, a stirrup and an adjustable foot rest. The suction part ofthe pump is immersed in the spray solution kept on floor in a bucket. The pump is operatedby hand by one person while the other person holding the delivery line, trigger cut-offdevice and lance nozzle sprays pesticide. This sprayer is used both for public healthspraying and agricultural spraying purposes. This type of sprayer is useful for sprayingsmall trees. Area covered per day is 0.5 to 0.8 ha.

d. Knapsack Sprayer

The sprayer is mounded on the back of operator with help of a pair of mounting straps.The pumpof the sprayer is actuated by working a hand lever up and down by one hand ofthe operator and the other hand holds the cut off device for spraying purpose. This sprayerconsists of liquid tank, hydraulic pump, operating lever, pressure chamber, agitator,delivery hose, spray lance and nozzle. A bean shaped plastic tank of 14-16 liters capacity iscommonly used. It is necessary to operate the hand lever continuously at the rate of 15-20strokes per minute. The normal working pressure is 40 psi. It is user for spraying field cropsvegetables and nurseries. The area covered per day is 0.8 to 1 ha.



e. Rocker Sprayer

It is very much similar to thefoot sprayer.The main differenceis the operation ofpump. Thepump actuation is done by hand of the operator. The sprayer pumpmountedon wooden platform iskept on ground and the spraysolution is kept in a separate tank or container. It can develop highpressure 10 kg/cm2. For sprayingtall trees, an extension bamboolance can be fitted. The adjustabletype hydraulic nozzle (TripleAction Nozzle) is normally used. It can be used for spraying trees and tall fieldcrops. Itcovers about 1.5 to 2 hectares of areain a day.

f. Foot Sprayer or Pedal Pump:

The pump of the sprayer isworked by operating a pedal lever bythe foot of the operator. The sprayliquid is kept in bucket or containerand it is sucked by a suction hosethrougha filter (strainer) due to pistonmovement. A suitable ball valve isprovided in the piston assembly toserve as suction valve. The liquid fromthe pump cylinder is then deliveredinto a pressure chamber where fromthe pressurized liquid reacheshydraulic nozzle. Minimum two person team is required to work on this machine.Hydraulic pressure of 10 kg/cm2 can be achieved which is necessary to project the jet ofspray to tall trees simultaneously from two spray nozzles. The foot operated sprayer isbasically for orchard and tree spraying. The design is strong and sturdy. An adjustable typehydraulic nozzle (Tripple Action Nozzle) is generally used which can generate differenttypes of spray patterns viz., fine spray (hollow cone), medium spray and coarse spray (jet).

The fine and medium spray are suited for low height orchards, jet spray are necessary fortree spraying. The spray jet can reach height of 15 - 20 feet. For spraying taller trees an extraextension like bamboo lance may be used to gain additional height by 8 - 10 feet. It isdifficult to treat field crops by foot sprayers because the sprayer is kept on ground andpesticide solution tank is also kept on ground separately and so movement of the longdelivery hose becomes very difficult. About 1 to 1.5 ha area can be sprayed in a day.

B. Manually Operated air compression Sprayers

These are also known as pneumatic sprayersbecause air pressure is employed for forcing theliquid though the nozzle for atomization. Thecontainers of these sprayers should not be filledcompletely with the spray fluid. A part of thecontainer is kept empty so that adequate air pressurecan be developed over the spray fluid in the tank.They do not have agitators and hence are not usefulspraying materials which settle down quickly.

a. Pneumatic Hand Sprayer

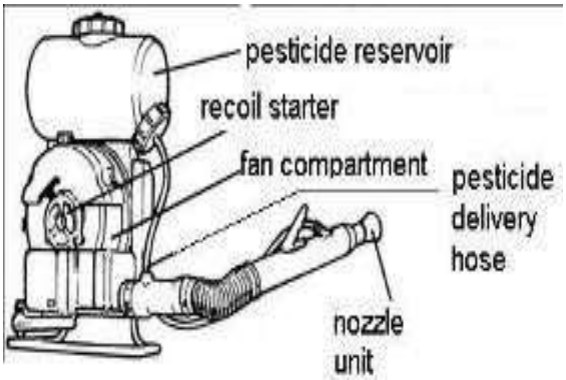
The container for the spray fluid also acts as thepressure chamber. An air pump attached to thechamber inside. The inner end of the discharge pipe runs down to the bottom of thecontainer and its outlet terminates in a nozzle is filled about 3/4th of it and the pump isworked force air into the space to build sufficient pressure upon the spray fluid. Thesesprayers are used extensively in kitchen gardens, in glasshouses and in doors againsthousehold insects. The capacity of tank is up to one liter, if used in field it can cover an areaof 0.1 ha in a day.

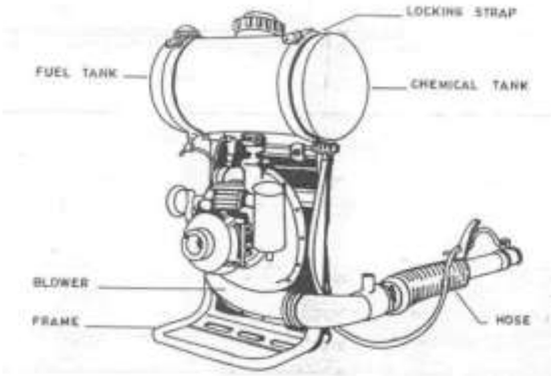
b. Pneumatic Knapsack Sprayer

This is similar to compresssion hand sprayer but are used for spraying large quantitiesof liquids (9-10 Litres). It comprises a tank for holding the spray as well as compressed air, avertical air pump with a handle, filling hole with a strainer, spray lance with nozzle andrelease and shut-off devices. The tank is provided a convenient rest with the back of theoperator and has shoulder straps that allow it to be carried by him. These sprayers are usedagainst agricultural pests and mosquito control operations. This pump covers an area ofabout 0.8 to 1.2 ha in a day.

C. Power Sprayer (Mist blowers cum Duster**)**

Here the spray fluid is blown out by an air produced in the machine. It consists ofchemical tank, fuel tank, carburator, spark plug, engine, blower assembly, delivery system,nozzle system and starter pulley. The power operated spraying system can be converted into a dusting unit by changing certain components. The tank in these is made of a thickpolyethylene and has a capacity of 10 liters. The fuel tank capacity is 1.0 to 1.5 liters. It isprovided with 1.2 to 3.0 hp petrol engine. This can also be used for dusting providedsuitable accessories. The area coveredby these sprayers is about 2 ha in a day.

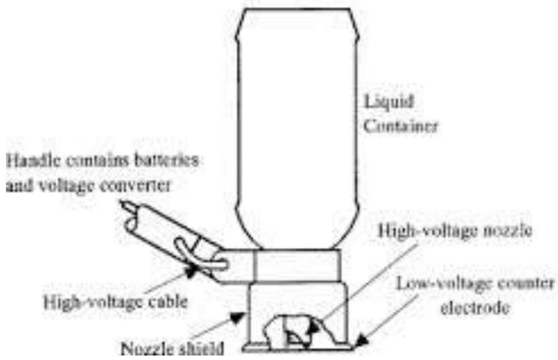




Mist blower **Motorized Knapsack sprayer**

D. Hand carried, battery operated spinning disc sprayer (Ultra Low Volume Sprayer)

The pesticides are applied assuch or with less than 5 litres sprayfluid produces fine droplets (80µm).These are light weight sprayers(<3kg) have a rotaryatomizer(spinning disc) powered by anenclosed DC motor with a plasticspray head, a liquid reservoir, ahandle and a power supply unit.



Liquid is gravity fed frompolyethenecontainer screwed in to the sprayhead moulding and the liquid isflung off by centrifugal force.

E. Electrodyn Sprayers (EDS)

It is new system of spraying for the controlled droplet application of chemicals (CDA).EDS puts more of active chemical on the target than any other spraying system since thecharged particles are attracted to target crop which ensure coverage on the underside ofleaves where many pests feed and also there is minimal drift to non target areas. The EDSconsists of a spray stick and an unique combination of bottle plus nozzle the bozzle. Thespray stick consists of the batteries anda solid state high voltage generator. The bozzlecontains ready formulated chemical for immediate application to crops. The pesticide inULV formulation is used undiluted at a quantity less than 6 liters/ha and usually at 0.5 to2.0 liters/ha for field crops. The droplet size varies from 20-150 micron with ground sprayingequipment for ULV spray an area of 5 ha can be covered ina day.

DUSTERS

The dusting powders are low concentration ready to use type, dry formulationscontaining 2 to 10% pesticide. The inert material or dry diluents is talc, soapstone,attapulgite, etc., and it is non toxic. The sulphur dust is not diluted with inert material. Thedusts are applied at 20 - 50 kg/ha. It should be noted that the application is done in highlyconcentrated form, as compared to high volume or low volume spraying technique.Therefore, adequate precautions must be taken in handling the dust and during theapplication in field. The dusters are available both manually operated and power operatedmodels. All dusters consist essentially of a hopper which usually contains an agitator, anadjustable orifice and delivery tubes. A rotary fan or a bellows provides the conveying air.

A. Manually operated dusters

a. Plunger duster

They are very simple, low cost machines and useful in a limited way. It consists of adust chamber, a cylinder with a piston or plunger, a rod and a handle. The field applicationcapacity is low. They hold 200 to 400 g of dust in a chamber into which air is pushed by anadjoining piston type air pump operated by hand. The dust cloud is issued from thedischarge outlet. It is useful forsmall scale use in kitchen garden and in household.

b. Bellows duster

This is also a simple design low cost dusting machine. A collapsible bellows pushes airinto a dust hopper of 1-2 kg capacity and dust is discharged from the nozzle outlet.

c. Rotary duster:

This type of duster makes use of a fan or blower to flow large volume of air at highspeed. The dust powder is fed into the stream of air and blown from the outlet tube. The fanor blower rotatesat high speed by hand cranking handle, which is geared to it. The highergear-ratio and better blower design provide easy cranking and good volume of air isemitted. The dust hoppers are generally cylindrical and are provided with agitator, feedersand dust metering mechanism.Such rotary dusters are either shoulder slung type or belley mounted type. Theshoulder-slung models are better balanced when the dust hoppers are filled. But it becomesinconvenient to operate in crops like sugarcane and cotton. The belley mounted type can beused in such situations. A hand rotary duster can discharge dust powder from 0 – 150 g/minand displace air about one m3/min at35 RPM. Such machine can treat 1 to 1.5 ha /day.

d. Power Duster

These are bigger machines run with the help of engine or electrical motor. Some powerdusters are tractor mounted type and are driven by tractor P.T.O. The equipment ismounted on ironframe (stretcher) and can be carried by 2-3 men. The engine/motor drives acentrifugal fan usually via V-belt drive. The engine is petrol/ diesel run and 3 - 5 H.P. Thefan displaces 20 m3 air/min or more at 100-250 km/hr air velocity. These dusters are good forlarge area treatment andsuitable for application on tall trees. In this type of duster design,usually the dust powder is not rotated in the fan-case but dust powder is aspirated in thedelivery channel by air blast. The dust hopper capacity is 10- 20 kg and dust can bedischarged at a rate of 1 to 8 kg/min. A power dustercan cover about 10 ha/day.

e. KNAPSACK DUSTER

The motorised knapsack sprayer can be converted to a duster by replacing some plasticfittings inside the hopper. Almost all mist blowers have provision of converting them fromspraying unit to dusting unit. The two stroke petrol engine runs a blower fan and deliversthe air through a hosepipe system. The dust is agitated and lifted by the blast of air in thehopper (2-5kg capacity) and itis fed into the main air hose or a long dusting hose (40-50 ftlong polythene perforated hose) can also be attached to knapsack duster. Such anattachment is very good for large area treatment in less time. The dust output can beadjusted from 0 to 1.5 kg/min. The motorised knapsack sprayer-cum-duster unit is thereforeuseful for both low volume spraying and dusting operation.

Soil Injector

It is also known as soil gun, which consists of a cylindrical tank for the liquid fumigant,a pump barrel and plunger assembly, injector nozzle, thrust handle and injection handle.The hand operated soil injectors have a capacity of 1 to 3 liters and they can cover about 0.5ha in a day. They are used to apply liquid nematicides to kill soil nematodes.

Granule Applicators:

They are used to apply granular formulations of pesticides uniformly. These are twotypes of granular applicators.

i. There is a plastic hopper 1 liter capacity from which the granules flow by gravity to anozzle.
ii. It is a knapsack type with hopper of 10 liters capacity.

Bird Scarer

It produce loud noise at regular interval and used to scare away the birds. It has threeessential chambers, a chamber to hold calcium carbide, a smaller chamber placed inside theformer to hold water and combustion chamber attached to the main chamber. Water actswith calcium carbide and generates acetylene which explodes producing the noise. Thefrequency of flow of water into calcium carbide chamber. One kg of calcium carbide issufficient for working a machine for 24 hours. One bird scarer is sufficient to cover 1 to 2 ha.

Rat Traps:

Several types of mechanical devices for trapping rats and mice are used in India. Inthese traps baits like dry fish are used for attracting these rats. The cage type wooden boxwith a door closingdevice and spring board types are the more common ones used in thehouses.

Practical- 17To study about the Sampling techniques for estimation of insect population and damage

Sampling population estimates of insect pests are the fundamental activity in ecologicalentomology. Regular monitoring can answer several important questions such as- Whatkinds of pests are present? Are the pest numbers great enough to do damage and towarrantcontrol? Are bio-agents or natural control present and working? When is the right time tobegin control? and have management efforts successfully reduced the number of pests? Pest monitoring is the pre-requisite for any successful pest management programwherein, no control measure should be undertaken for a pest unless it is known that- thepest is activelypresent and it is present in sufficient numbers to cause an economic loss.

How to count or measure a species/damage caused in plant, soil or other habitat ?

The sampling method should be: suitable for all key pests, rapid and simple to use, easyintegration into current sampling program, sampling equipment readily available and easyto carry and sampling procedure be simple to understand and conduct.

Sample unit: Single plant, clusters, plants/hill, plant/m2 etc.

Sampling Size: In preliminary studies: sample size will be small and 10% of the mean errorshallbe acceptable. Number of samples depends on degree of precision required and chosento minimize the variance and cost..

Types of Sampling

Random sampling: The sample is taken at random with good field coverage to determineinsectnumbers or damage per samples unit. For this purpose, use of random numbers ismade.

Stratified random sampling: It involves the division of population in to different stratabased ondistribution of population.

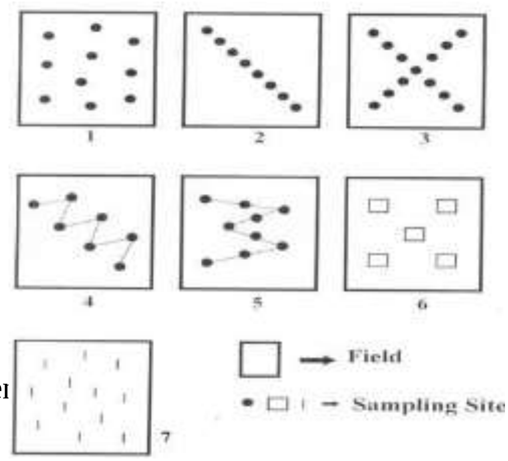
Sequential sampling: It requires continuous sampling until a pre established upper or lowerinfestation level is found.

Trap sampling: This refers to using light, suction, sticky or sex pheromone traps to detectthepresence of insects in an area.

Systematic sampling: It involves sampling ofpopulation at fixed intervals.

Selection of Sampling Site

1. Random
2. Along one diagonal
3. Along two diagonals
4. Zig-zag diagonally
5. Along alphabet ‗W‘
6. In micro-plots of 1m2
7. Meter row length



Important Sampling Methods

Absolute methods: This method is used to estimateden Differenttypes of absolute sampling are denoted by **n.**

Unit of habitat method

- **In situ or direct counts**: e.g. Leafhoppers
- **Knock down:** removing insects form the habitats-drop sheet method e.g. *Helicoverpa*

spp.brushing, washing etc.

- **Netting:** for highly mobile insects
- **Trapping:** Use of different types of traps. Phermone traps, Light traps, suction traps etc.
- **Extraction from soil:** From a fixed volume of soil insects can be counted. e.g. whitegrubs, cutworms, pupae of several lepidopterous larvae.
- **Indirect techniques:** By taking crop samples for example, **dead hearts** in case ofsugarcane shoot borer, **number of plants cut** e.g cutworms, **per cent defoliation** e.g.foliage feeders, **root damage** e.g. termites, root weevils; **shoot damage** e.g. spottedbollworms, **per cent fruiting bodies damaged** e.g. bollworms of cotton, pod borers,**stubble infestation** e.g. in sugarcane.

Absolute sampling method are desirable because they are accurate, however, these methodsare time consuming, often difficult to conduct and are usually expensive compared torelative methods. Relative methods are more economical in terms of time, labour andequipments.

Relative methods: This method provides an identification of insect pests abundance ordamage relative to other times or location. Different types of relative methods are as followsvisualsearches, use of various traps, plant damage etc.

Remote sensing: Acquiring information through the satellite about pest damage withoutcoming into physical contact. It can be useful in monitoring of certain pests. A radar canmonitor height, speed and direction of insects like locusts, aphids etc.

Components of Remote Sensing

1. **Platform**
   - The vehicle/device on which sensors are mounted
   - Carriers or vehicles for the sensors
2. **Sensor System**
   - The device which senses the energy reflected/emitted by the target object
3. **Data Products**
   - Information received from the sensor Packaged as per user requirement

OTHER METHODS

Beat bucket: Requires 20-25 litre capacity plastic bucket (white or light coloured); similar toshake cloth/drop sheet method; top 25 cm of a single plant is bent into the bucket andshaken vigorously (12-15 times during 4-5 seconds); plant is quickly removed andinsects/predators and spiders are counted. It is more effective than shake cloth method;reduces variability due to field scouts.

Vacuum sampling: Sucks into bags most everything from on and around a single plant orplant part; impractical for regular use in sampling and the samples are too messy to process.Further improvements could be made by better initial planning and involvement of thestatistician with the biologists.

Sampling techniques for major insect pests on Paddy crops

Crop	Pest	Economic threshold level	Method of sampling
Paddy	**Green leafhopper**		
	a) At earing stage	5-15 insects/hill	Select 5 micro-plots of 1m2 each in a field and shake vigorously plants in 5 hills/plot or shake vigorously 25 random plants and count leafhopper fallen on water.
	b) At flowering stage	10-15 insects/hill	Same as above
	Stem borer	5-10% plants with dead-hearts or 2% white ears or one egg mass or moth/m^2.	Count infested and healthy tillers in 25 random plants.
	Leaf-folder	2 damaged leaves/ plant or one larva/hill	Count infested and healthy plants among 25 random plants or count
	Rice gundhi bug	1-2 insects/hill	Count the insect on 25 random
Gram	**Gram pod borer**	One larva/meter row length	Count larvae in one meter row length from 10-20 random sites in a field.
Okra	**Leafhopper**	2-5 nymphs/leaf	Count leafhopper nymphs from underside of three fully developed leaves in the upper canopy of each of 20 random plants or count leaves showing yellowing and curling from margins and healthy leaves of 20 random plants in a field
	Whitefly	6-8 adults/leaf	Count whitefly adults as above.
	Spotted bollworm	10% drooping shoots or 5-10% infested fruiting bodies	Count drooping shoots and healthy shoots of 25 random plants or examine all green fruiting bodies of the above

			plants for spotted bollworm induced holes or damage.
Tomato	**Fruit borer**	One larva/m2	Count larvae in 1 m_2 micro plot from 10 random sites in a field

Course outlines

Part – I

History of Entomology in India, Major points related to dominance of Insecta in Animal kingdom. Classification of phylum Arthropoda up to classes. Relationship of class Insecta with other classes of Arthropoda. Morphology: Structure and functions of insect cuticle and molting. Body segmentation. Structure of Head, thorax and abdomen. Structure and modifications of insect antennae, mouth parts, legs, Wing venation, modifications and wing coupling apparatus. Structure of male and female genital organ. Metamorphosis and diapause in insects. Types of larvae and pupae. Structure and functions of digestive,

circulatory, excretory, respiratory, nervous, secretary (Endocrine) and reproductive system, in insects. Types of reproduction in insects. Major sensory organs like simple and compound eyes, chemoreceptor.

Part-II

Insect Ecology: Introduction, Environment and its components. Effect of abiotic factors– temperature, moisture, humidity, rainfall, light, atmospheric pressure and air currents. Effect of biotic factors – food competition, natural and environmental resistance.

Part III

Categories of pests. Concept of IPM, Practices, scope and limitations of IPM. Classification of insecticides, toxicity of insecticides and formulations of insecticides. Chemical control- importance, hazards and limitations. Recent methods of pest control, repellents, antifeedants, hormones, attractants, gamma radiation. Insecticides Act 1968- Important provisions. Application techniques of spray fluids. Symptoms of poisoning, first aid and antidotes.

Part – IV

Systematics: Taxonomy –importance, history and development and binomial nomenclature. Definitions of Biotype, Sub-species, Species, Genus, Family and Order. Classification of class Insecta up to Orders, basic groups of present day insects with special emphasis to orders and families of Agricultural importance like Orthoptera: Acrididae,Tettigonidae, Gryllidae, Gryllotalpidae; Dictyoptera: Mantidae, Blattidae; Odonata; Isoptera: Termitidae; Thysanoptera: Thripidae; Hemiptera: Pentatomidae, Coreidae, Cimicidae, Pyrrhocoridae, Lygaeidae, Cicadellidae, Delphacidae, Aphididae, Coccidae, Lophophidae,

Aleurodidae, Pseudococcidae; Neuroptera: Chrysopidae; Lepidoptera: Pieridae, Papiloinidae, Noctuidae, Sphingidae, Pyralidae, Gelechiidae, Arctiidae, Saturnidae, Bombycidae; Coleoptera: Coccinellidae, Chrysomelidae, Cerambycidae, Curculionidae, Bruchidae, Scarabaeidae; Hymenoptera: Tenthridinidae, Apidae. Trichogrammatidae, Ichneumonidae, Braconidae, Chalcididae; Diptera: Cecidomyiidae, Tachinidae, Agromyziidae, Culicidae,Muscidae, Tephritidae.

Syllabus for Practicals

19. Methods of collection and preservation of insects including immature stages
20. External features of Grasshopper/Blister beetle
21. Types of insect antennae, mouthparts and legs
22. Wing venation, types of wings and wing coupling apparatus.
23. Types of insect larvae and pupae
24. Dissection of digestive system in insects (Grasshopper)
25. Dissection of male and female reproductive systems in insects (Grasshopper)
26. Study of characters of orders Orthoptera, Dictyoptera, Odonata,
27. Isoptera, Thysanoptera,
28. Hemiptera,
29. Lepidoptera,
30. Neuroptera,
31. Coleoptera,
32. Hymenoptera
33. Diptera and their families of agricultural importance.
34. Insecticides and their formulations.
35. Pesticide appliances and their maintenance.
36. Sampling techniques for estimation of insect population and damage.

Practical-1:To study the methods of collection and preservation of insects including immature stages

Insect collection is a source of recreation for many people and may be a hobby for thosewho are interested in studying insects. Methods of collection and preservation of insects arethe pre-requisite to study the insects and their various internal and external organs. Aftercollection, it becomes imperative to keep and preserve the insect specimens intact and safefor longer time to further study the characters or to develop the insect collection museum.Let‘s have a look and do the different types methods of collection, devices used for collectionand preservation of insects including immature stages in this practical session.

Nature of insect collection

A good Zoological collection should consist of at least four (4) individual representativeof each of the order of insects. So that the collection comprises the great diversity and itshould reflect thedifferent forms occurs in insect fauna in a certain ecosystem.

Places of insect collection

Insects are omnipresent and abound anywhere and everywhere. A good place to startcollecting insects is a flowering hedgerow or garden where insects can be found on thedifferent parts of plants like flowers, leaves and stems. Besides these, we can also probe thesmall insects in the soil or near the roots of plants, aquatic insects can be collected in water,ponds, streams, rivers, lakes etc. and even do the indoors collection year round.They can be collected from- **Air (**flying insects), **Wate**r (dragonflies, mayflies andstoneflies that hover over water, aquatic insects and sea shore insects), **Home** (fromfurniture, boxes, bookshelves (fleas, bugs, flies, and mosquitoes), flower, fruits andvegetables brought in), **Debris and animal dung** (which acts as food source for manyinsects), and from **domestic animals and birds** (ecto and endo- parasites).

Catching insects: Aerial insects can be caught during flight or after they have alighted bysweeping a net through the air or foliage or by beating the foliage and holding the netbelow.

- The aerial/ sweep nets can catch aerial insects.
- Net forceps, dippers and dredge, can catch aquatic insects.
- Separator and Berlese funnel can catch soil dwelling insects.

Methods of insect collection

8. Hand picking

This method is suitable for catching the large insects like beetles and grasshoppers. It isvery tedious (hard working) method and not suitable for catching the biting and stingingnatured insects.

9. Aerial net or Butterfly net

It is light in weight, useful for catching activefliers like butterflies, moths, dragonflies,wasp, fliesetc. The net consists of three partsviz., loop or frame; handle and porous muslinclothe bags. The diameter of hoop and thedepth of the bag should be in the proportionof 1:2.

10. Sweep net

It is heavier than the aerial net. It consists ofshort handle, a large loop and dense clothbag. This is suitable for collectingleafhoppers, grasshoppers and other smallinsects. The net is swept over vegetation.

11. Beating tray

This method is suitable for collectingcrawling insects and those, which rest onbranches. A beating tray is held under abranch, which is then hit sharply with a stick.

12. Aspirator/Potters/Suction tube

It is the device to collect small insects intoglass vials with no damage to the specimens.It is employed to suck in through a rubbertube small and minute insect that is alreadycollected in the net or sitting on wall orfoliage and on the bark of the tree. Usually itis meant for catching more active insects. Toprevent entry of insect in to mouth, a smallcloth piece is kept in between the glass andrubber tube.

13. Berlese (Tullgren) funnel

Soil arthropods can be sorted out by thismethods. Debris including soil arthropodscan be collected by using the light as thesource of heat in berlese funnel method.

14. **Traps-** Trapping is a method of collecting insects in the absence of collector. This is themost common methods or techniques used by growers in Integrated pest managementprogramme to catch the insects. There are many different types of traps used for collectionof insects. They are pheromone traps or sleeve traps, fruit fly trap, sticky traps, delta traps,water or Wota traps, pitfall trap, wind pan trap, malaise trap and light traps.

Pheromone traps

Synthetic sex pheromones are placed in the traps to attract male moths. The rubberizedsepta containing the pheromone lure are kept in the traps designed especially for thispurpose and used in monitoring, mass trapping and mating disruption programmes. Stickytarps, Water pan traps and funnel type models are available for use in pheromone basedinsect-pest control programmes.**Yellow sticky traps:** Aphids, whiteflies, thrips prefer yellow colour. Yellow colour is paintedon tin boxes and sticky material like castor oil/vaseline is smeared on the sticky material.

Probe trap: It is used by keeping them under grain surface to trap stored product pests.

Pitfall traps: Containers such as small plastic buckets, plant pots, glass jars or jam tins aresunk into the ground to trap flightless, ground-living insects and arachnids, especiallybeetles (ground beetles), cockroaches, crickets, spiders, harvestmen and mites. The containershould be placed ina hole with the upper rim flush with the ground surface. A killing agentand preservative, such as ethylene glycol, should be placed in traps that are not emptieddaily. Radiating vanes, such as wooden planks, placed in the substrate will increase theeffective area of the trap. A bait can be added to the trap to increase its effectiveness.

Thetype of bait will depend on the specimens one wishes to catch.

Light traps: Light traps are mainly used for attracting moths & other night flying insectswhich are attracted towards the light. The insects are actively caught or encouraged to entera trap. The simplest light trap consists of a light on a cable hanging out in the field forattracting the pests during nights. However, besides a number of species of moths, beetles,flies, and other insects, most of which are not pests, are also attracted to artificial light. Soidentification of pests and beneficial insects is of prime importance before any controloperation is executed.

Mercury vapour lamp light trap: This trap is the basic model designed by Robinson (1952).This trap produces ultravoilet, blue and green radiation with little red. This is currently usedtowards a wide range of noctuids and other nocturnal flying insects. a mercury lamp (125W)is fixed at the top of a funnel shaped (or) trapezoid galvanized iron cone terminating in a jarcontaining dichlorvos soaked in cotton as insecticide to kill the insect.

Killing insects

Killing should be immediately after capture. Potassium cyanide (KCN), ethyl acetate,carbon tetrachloride and chloroform are commonly used for killing insects. KCN kills theinsects quicklybut deadly poisonous and must be handled with extreme care. Ethyl acetatekills the insects slowly and does not last long. But the dead insects remain in relaxedcondition for a longer time without becoming brittle and stiff.

Pinching- In this method, thorax is pressedbetween thumb and index finger swiftly andwith jerk.It needs constant practice. e.g.butterfly, grasshopper.

Injecting- Hypodermic injection of fluids.

Drowning- Larvae and insects without scales, hairs or powdery covering can be killed bysubmerging them in water. They die of Auto toxicity when excessive CO2 unable to escapesfrom spiracles and collects in trachea and tissues.

How to prepare Killing Bottle/ Cyanide Bottle?

Steps involved in preparing the killing bottles are given below -

- Take a wide mouthed strong bottle or vial with a tight fitting lid.
- Place a layer of potassium cyanidegranules/pellets (1/4-inch thickness) atthe bottom ofbottle.
- Cover it with a layer of dry plaster ofParis (1/4 -inch thickness)
- Mix plaster of Paris with enoughwater so that it will pour off from theend of spoon. Pour1/2-inch layer ofwet plaster of Paris over the dry layer.
- Tap the bottle lightly on the table toeliminate any bubble in the bottle.
- Leave the lid off for a day to let theplaster dry in a well-ventilated room,completely awayfrom direct sunlight.
- Keep a circular piece of filter orblotting paper on the top of plaster ofParis and avoidcondensation of water droplets on the side of bottom (to check thesweating process).
- Lastly, the bottle should be tightly corked and labeled with the word –Poison‖.
- In place of KCN, now a day‘s Ethyl acetate is being used as the replacement inkillingbottle.

Insect Collection Box

Storage of insects is done in the insect boxes,which is made up of wood (top and bottomcould beof plywood) and lined on one(bottom) or both (roof also) sides with corksheets covered with white paper. It is light inweight, moisture proof and airtight. General(common) size of insect collection box is45x30x15 cm.

Labeling

Specimen collected should be uniform in size and labeled properly on stiff paper orreferencecard. Labeling consists of following notes i.e., **Host, Date, collector and Location.**

Setting or stretching boards

Setting is the method that wings antennaeand Occasionally (Hymenopterans) spread legsin full display of their features. This methodneeds a setting or stretching board which havetwo side‘s boards separated by groove. Bothboard and grooves are lined with thin sheet ofcork. The widthof groove varies according to thewidth of insect body.

Methods of preservation

Protection of Insect specimens

Collected Insects can be protected for longer time in insect collection box by puttingthenephathalene balls on the corner side of box.

Preservation of insects

c) Temporary preservation

d) Permanent preservation: Insects can be permanently preserved either dry, in fluid, oron microscope slides. Arachnids are always preserved in liquid or on microscope slides. Themethodof preservation depends on the type of arthropods. It can be done by the followingmethods-

- **Dry preservation-** Insects that are to be preserved dry are best mounted in ways thatfacilitate study and permanent storage. Specimens should be mounted soonafterkilling, if possible while still soft.
- **Liquid preservation-** It is done in 70 % ethyl alcohol + 4 % formaline solution. **Softscale insects and mealybugs** can be preserved in mixture of 4 parts 90 % ethanol and 1part glacial acetic acid whereas, **thrips** can be preserved in a mixture of 9 parts 60

%ethanol and 1 part glacial acetic acid. It is very important to periodically check and topup containers of a liquid collection.

- **Mounting on a microscopic slide-** Small specimens have to be mounted on microscopeslides so that they can be studied under a compound microscope. Theseinclude groupssuch as thrips, aphids, parasitic wasps, scale insects, booklice, lice and mites. Insect andspider body parts (e.g. mouthparts and genitalia), and larvae often haveto be slidemounted.Microscope slide mounts may be temporary or permanent, but specimensmaintained in collections require permanent mounts.

Bringing the specimen home or the laboratory Materials

required

Butterflies and other large-wingedinsects can be stored in folded protectivepaper envelopes. Most arthropod specimenscan be conveniently stored between layers ofabsorbent paper. Paper envelops(Newspaper, waxpaper) can be used to keepthe specimen and brought it to homeorlaboratory (having good absorbent quality)Cellophane and transparent plastics can alsobe used for this purpose.

Relaxing container/Jar

Relaxing is the method / process of re-softening the insects. Relaxing container/Jar –contains a layer of sand (5 cm thick) or any other absorbent materials (basal wood, pith,synthetic sponge) and few drops of formaline or carbolic acid is added to prevent mould/fungal growth and then covered with filter paper. Cleaning- Dust, pollens and dirt can beremoved with a camel hairbrushdipped in water mixed with detergent.

Preparing insects for the insect collection box

Insects longer than about 8 mm are usually mounted on pins pushed through thethorax. Insect pins are longer than ordinary pins, and are made of stainless steel that doesnot rust. A No. 2 or No. 3 entomological pin is suitable for most insects, although those withdelicate bodies may require a size No. 0 or No. 1.

Entomological pins-There is three general series of pins viz.,**English pins:** Sold by weight, range of 18-30 mm in length and stout, used to pinlepidopteran insects, which lies or kept low in the box.

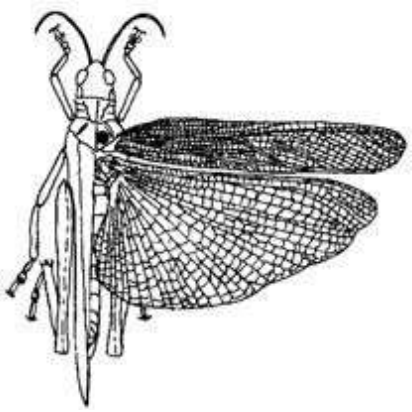
Continental pins: Sold by 100s, Range 35 mm in length,(000,00,0 & 1-7 Nos.), No. 2 & 3 areuseful for general purpose, 38 mm(No. 8-10), 50 mm(No. 11-12), 000 is the thinnest pin andNo. 12 is the thickest pin.

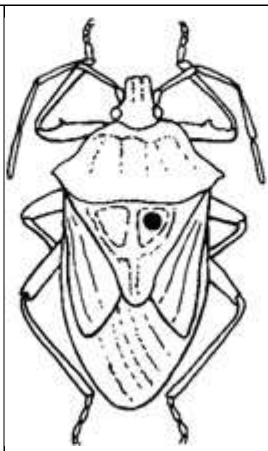
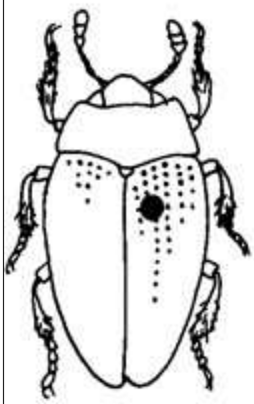
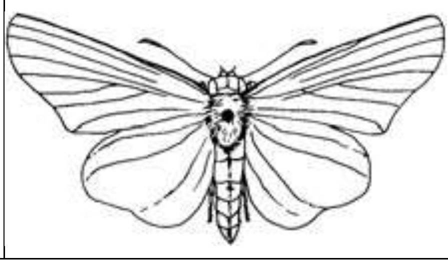
Minute pin: Minutest and finest pins, used for pinning the insects meant to stage, forminute, softest and fragile insects.

Pinning

It is the best and common method to preserve hard bodied insects. They will dry andremain in perfect condition on the pins for long time without any further treatment. Theyare pinnedvertically through the body. Depending upon the size of insect‘s pins has to beselected accordingly. Exact place of insertion of the pin varies among different groups ofinsects.

Insect groups Sketch diagram Pinning region

Insect groups	**Sketch diagram**	**Pinning region**
Grasshopper, crickets, Preying mantids and cockroaches		Pronotum

Bugs (most of the Hemipterans)		Scutellum
Beetles and weevils (Colepterans)		Right elytra
Dragonfly, damselfly, antlion, green lace wing fly, Moths, butterfly bees, wasp, ants and true flies etc.		Thorax

Double mounting

Pinning is troublesome in smallerinsects. Very small insects cannot be pinnedbecause most ofthe body parts of the insectsare lost during pinning. For such insectsdouble mounting can be followed.

Staging

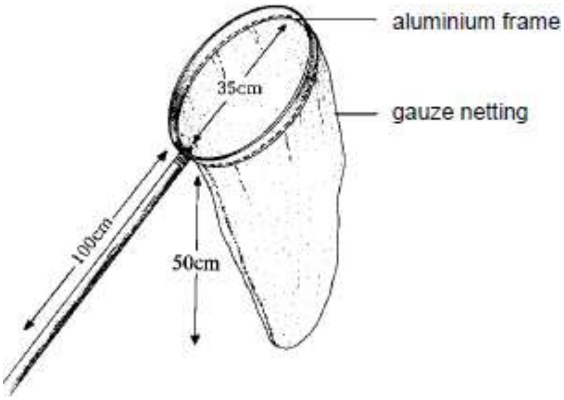
The stage is narrow rectangular piece ofcork or pith. The small insect is pinnedcorrectly with amicro pin to the stage. Laterthe stage is pinned in the insect store boxwith a bigger pin.

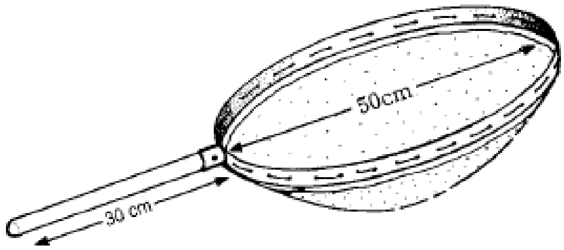
Carding

A rectangular white card (**5**x**8 or 5**x**12mm**) may be used as stage. On stage insteadof pinning, the insect specimen is stuck on itby **using glue or adhesive**. After mountingthe insect, card is pinned in the box with alarge pin.

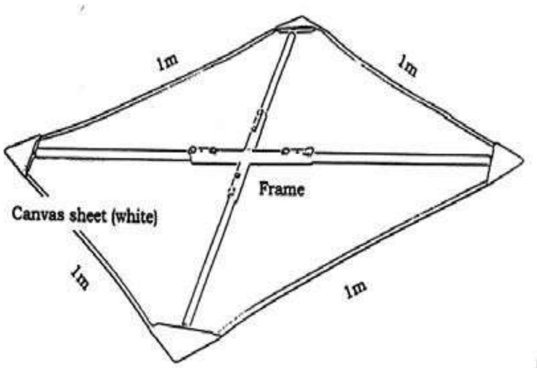
Pointing / gumming

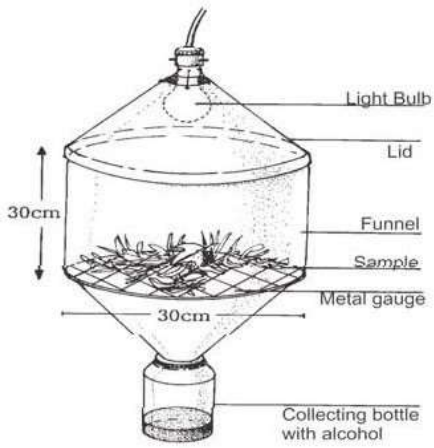
The insect specimen is glued to a cardcut into a triangle of 10 mm height and 5 mmbase. Bend down the tip of card to form asmall surface to which the insect is stuck.Apply a drop of glue or adhesive bytouching the point to the glue and to thethorax of the insects to be mounted.



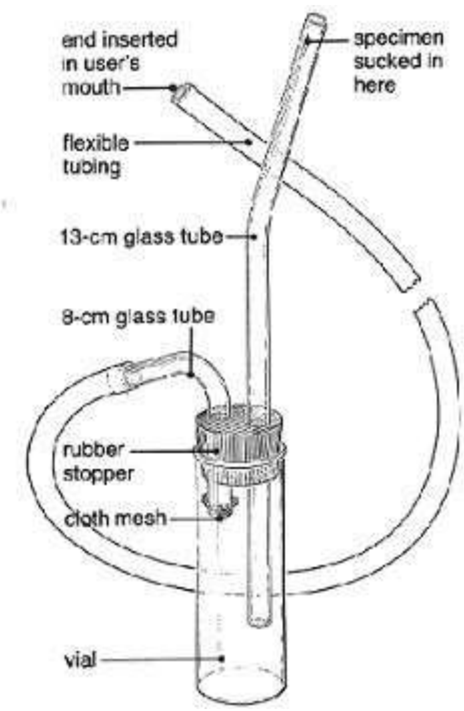


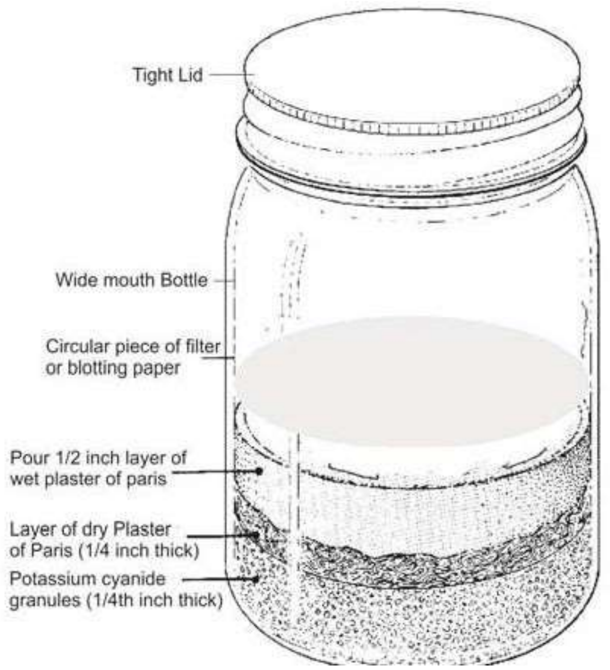
Sweep netAerial/Butterfly net



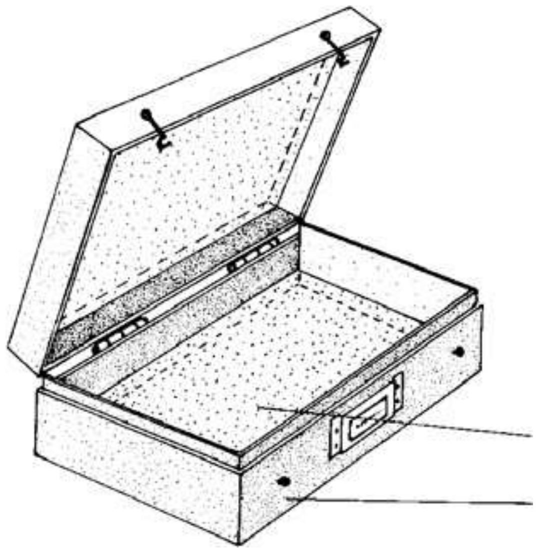


Beating tray **Berlese funnel**

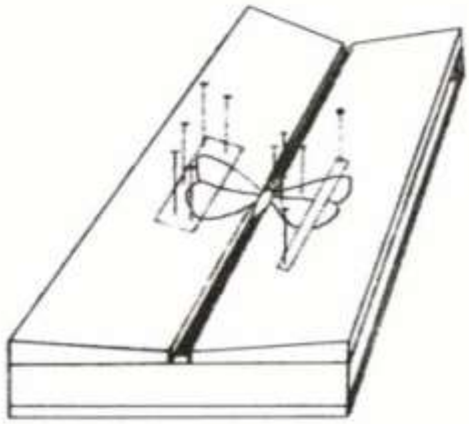




Aspirator/Potters/Suction tube **Insect killing box**

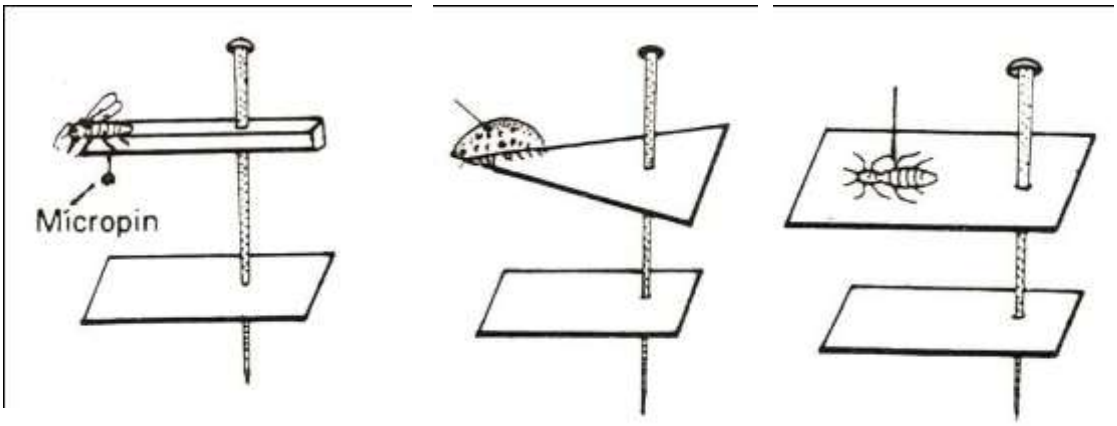


Insect collecting box

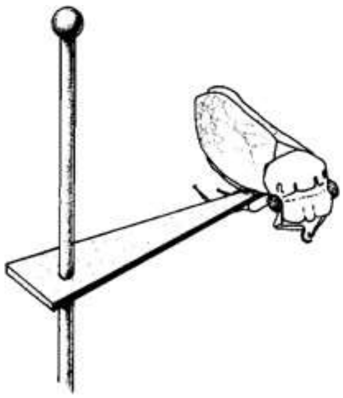


Setting/Stretching box

Double Mounting



Gumming



Practical – 2To study the External features of Grasshopper

The grasshoppers are widely distributed throughout the country and may be seen inabundance during monsson season. For the generalized morphological description, thisinsect has beenconsidered as the most suitable representative of class insects because itsstructural details are notmuch variable. Apart from this, being larger insize, it can bestudied easily.

The generalized insect body is divided into 3 distinct body regions: a head, a thorax andan abdomen. Grouping of body segments into distinct regions is known as **tagmosis** and thebody regions are called as **tagmata**.

The Head

This is an anterior part of the body formed by the fusion of six segments viz., ocellary,antennal, intercalary, mandibular, maxillary and labial. All these segments are closelyamalgamated to forma hard case or head capsule, the cranium that bears the antennae, eyesand mouthparts. The headis attached to the thorax by means of a flexible membranous neck(cervix) that allows its movement. Head capsule is sclerotized and the head capsuleexcluding appendages formed by thefusion of several sclerites is known as **cranium**.

Sclerites of Head

vi. **Vertex**: Summit of the head between compound eyes.
vii. **Frons**: Facial area below the vertex and above clypeus.
viii. **Clypeus**: Cranial area below the frons to which labrum is attached.
ix. **Gena**: Lateral cranial area behind the compound eyes.
x. **Occiput** : Cranial area between occipital and post occipital suture.

Sutures of Head: The linear invaginations of the exoskeleton between two sclerites arecalled assuture (sometimes referred as sulcus).

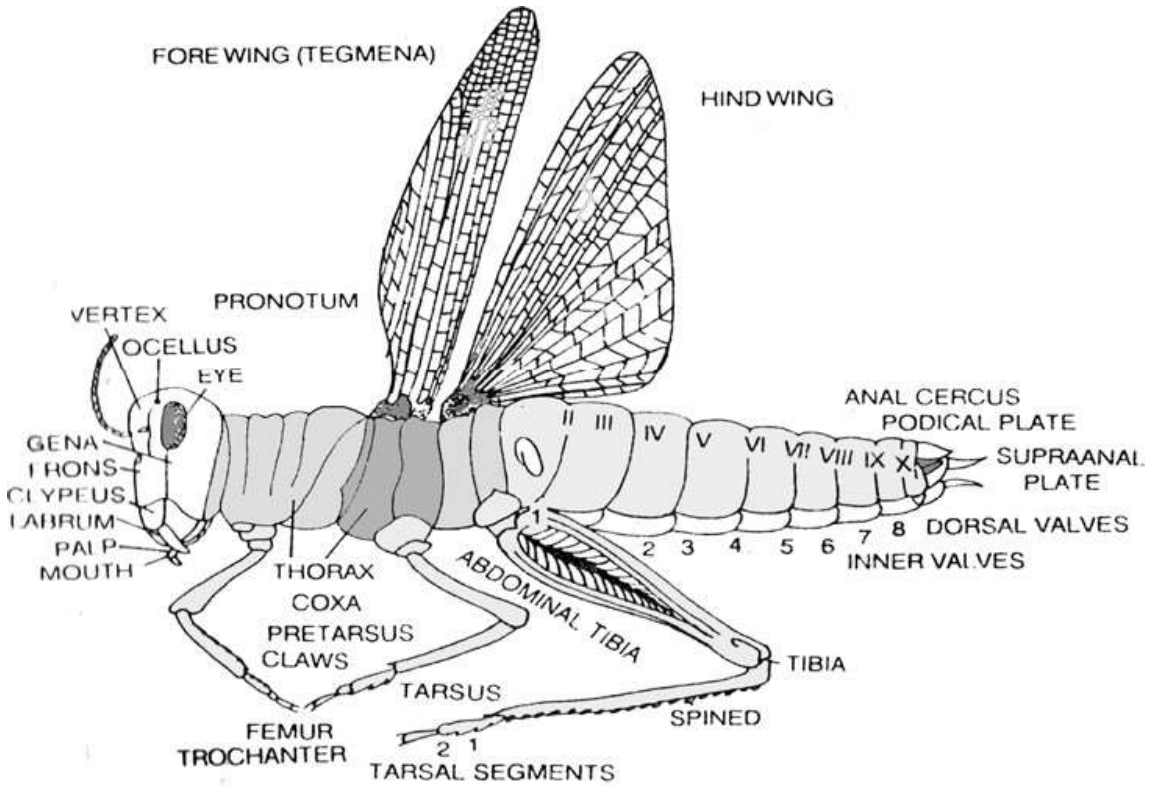
v. **Epicranial suture/ ecdysial line**: Inverted `Y' shaped suture found medially on the topof head,with a median suture (coronal suture) and lateral sutures (frontal suture).
vi. **Epistomal suture/ Fronto clypeal suture**: Found between frons and clypeus. (epi –above;stoma- mouth parts)
vii. **Clypeo-labral suture**: Found between clypeus and labrum (upper lip).
viii. **Postoccipital suture**: Groove bordering occipital foramen. Line indicating the fusionofmaxillary and labial segment.

The Thorax: It is a body region situated between head and abdomen. The insect thorax is composedof three segments: an anterior prothorax, a middle mesothorax, and a posterior metathorax.Each segment bears a pair of legs. The last two segments often called as pterothorax maybear wings. Meso and metathorax which bear wings are called as **Pterothorax**.Thoracicsegments are made up of three sclerites namely, dorsal body plate **tergum or nota**, ventralbody plate **sternum** and lateral plate **pleuron**

Functions of thorax: Site of locomotion.

Abdomen: Abdominal segments are telescopic in nature, highly flexible and are interconnected bya membrane called **conjunctiva**. Each abdominal segment is made up of only two scleritesnamely dorsal body plate (tergum) and ventral body plate (sternum). In grass hopper

eightpairs of spiracles are present in the first eight segments, in addition to a pair of tympanum inthe first segment. Eight and ninth abdominal segments bears the female genital structureand ninth segment bears male genital structure. Abdominal appendages in adult insects aregenital organs and cerci.
Function: Site of metabolism and reproduction.


FORE WING (TEGMENA)
HIND WING
PRONOTUM
VERTEX
OCELLUS
EYE
GENA
FRONS
CLYPEUS
LABRUM
PALP
MOUTH
THORAX
COXA
PRETARSUS
CLAWS
TARSUS
FEMUR
TROCHANTER
TARSAL SEGMENTS
ABDOMINAL TIBIA
TIBIA
SPINED
ANAL CERCUS
PODICAL PLATE
SUPRAANAL PLATE
DORSAL VALVES
INNER VALVES
II III IV V VI VII VIII IX X
1 2 3 4 5 6 7 8

Practical -3To study the types of insect antennae

The collected insect samples can be inspected in laboratory after detaching the antennaand put them under the microscope. They can also be studied through the permanent slidesof different types of antennae by the help of microscope.

Antennae are mobile sensory segmented appendages of the head. They articulate with headinfront or between the eyes and arise from antennal socket. The size and shape ofantennae varies indifferent insects. They used for sensory perception whi ch includesmotion and orientation, odor, sound, humidity, and a variety of chemical cues. Sensilla onantenna acts as tactile, olfaction, carbon dioxide, temperature, wind, humidity, andsound receptors.

Structure of Antenna: Antennae consist of **three parts**:

d) **Scape-** It is first basal segment of antenna by which the antennae is attached to thehead. It is often distinctly larger than the other succeeding joints. It articulates withthe antennal ridge.

e) **Pedicel-** The joint immediately followed the scape is pedicel. It is usually smalland contains aspecial sensory structure known as **Johnston's organ**, which is absentin Diplura, Collembola.

f) **Flagellum-** It is also known as **clavola**, and is the remaining part of theantenna. Flagellum segments (flagellomeres) increase in number in certain insects. Itis modified according to the surroundings and habits of the insects.

Types of antennae:

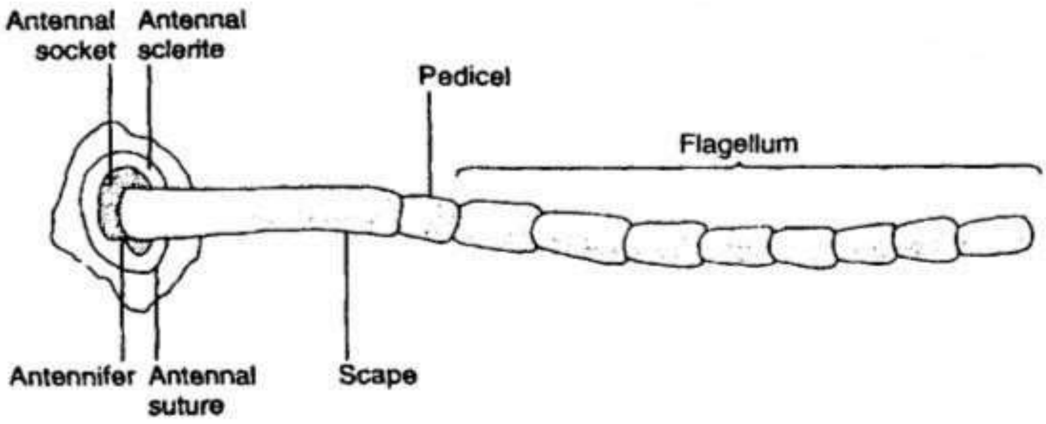
15. **Setaceous**: (Bristle like) Size of the segments decreases from base to apex. e.g.Leafhopper,Dragonfly, Damselfly.
16. **Filiform**: (Thread like) Segments are usually cylindrical. Thickness of segments remainssamethroughout. e.g. Grasshopper.
17. **Moniliform**: (Beaded) Segments are either globular or spherical with prominentconstriction inbetween e.g. Termite.
18. **Serrate**: (Saw like) Segments have short triangular projections on one side. e.g.Longicornbettle
19. **Pectinate**: (Comb like) Segments with long slender processes on one side e.g. Sawfly
20. **Bipectinate**: (Double comb like) Segments with long slender lateral processes on boththesides e.g. Silkworm moth
21. **Clavate**: (Clubbed) Antenna enlarges gradually towards the tip. e.g. Blister beetle
22. **Capitate**: (Knobbed) Terminal segments become enlarged suddenly e.g. butterfly
23. **Lamellate**: (Plate like) Antennal tip is expanded laterally on one side to form flat platese.g.lamellicorn beetle
24. **Aristate**: The terminal segment is enlarged. It bears a conspicuous dorsal bristle calledarista

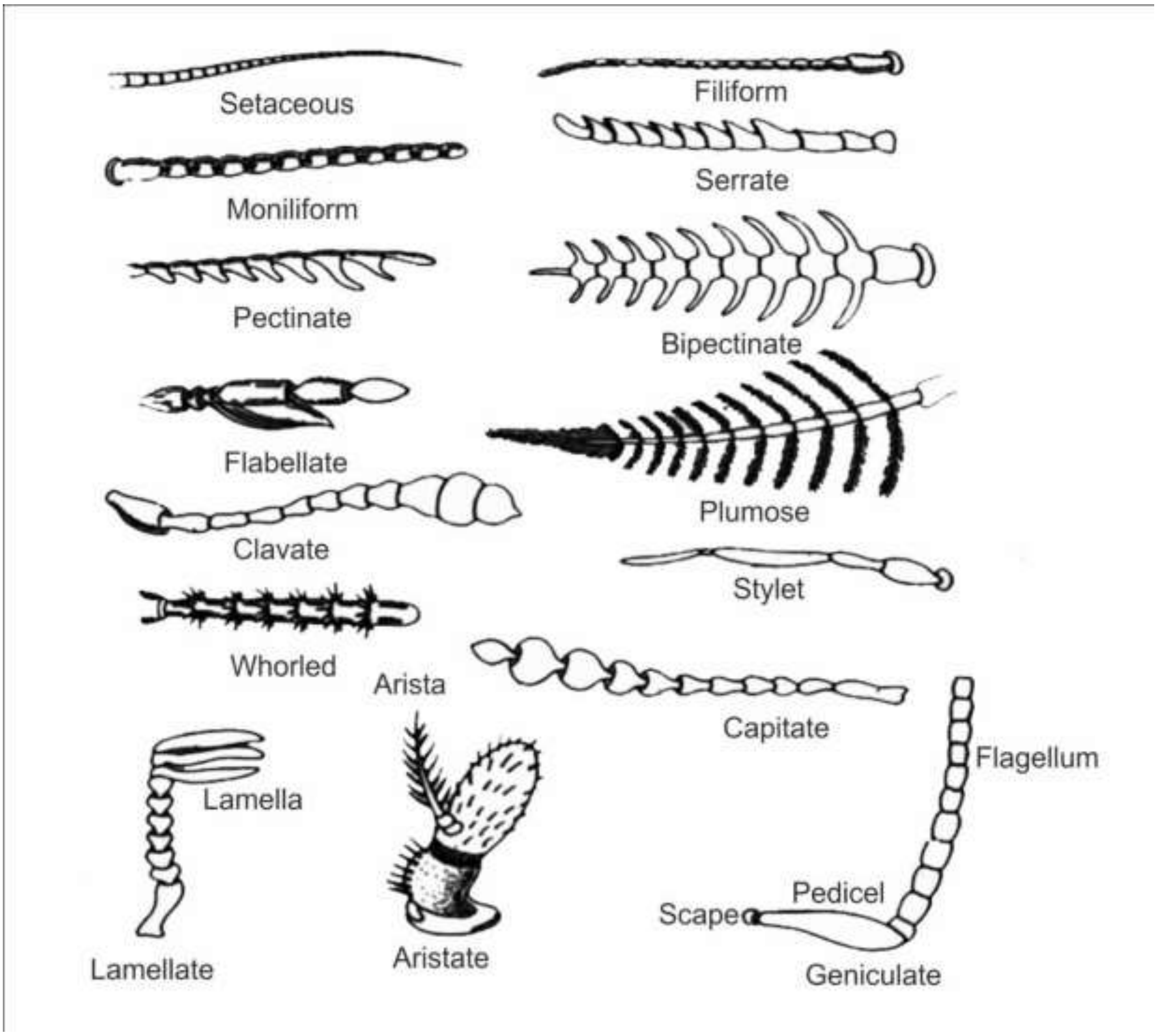
e.g. House fly

25. **Stylate**: Terminal segment bear a style like process eg. Horse fly, Robber fly.
26. **Plumose**: (Feathery) Segments with long whorls of hairs e.g. male mosquito
27. **Pilose**: (Hairy) Antenna is less feathery with few hairs at the junction of flagellomeres.e.g.Female mosquito.

28. Geniculate: (Elbowed) Scape is long remaining segments are small and are arranged atanangle to the first resembling an elbow joint. e.g. Ant, weevil and honey bee.

Structure of Typical Antenna





Practical- 4To study the different types of mouthparts and their modifications Mouthparts of insects vary among insects of different groups depending upon theirfeedinghabits. They are mainly of two types viz., Mandibulate (feeding mainly on solidfood) andhaustellate (feeding mainly on liquid food). Insect mouthparts have becomemodified in variousgroups to perform the ingestion of different types of food and bydifferent methods. Indeed themodifications in the mouthparts to ingest almost all kinds ofthe food material, are one of thefactors for the success of the group.

8. **Biting and chewing type**: e.g. Cockroach & grasshopper.

It is the primitive type of mouth part and consists of the following parts.

i. **Labrum : (Upper lip)** It is flap like, bilobed and attached to the clypeus by an articularmembrane. It is movable. It covers the mouth cavity from above. It helps to pull thefood into the mouth. It holds the food in position so that mandibles can act on it. Itforms the roof ofthe pre oral food cavity.

ii. **Labrum-epipharynx:** Inner surface of the labrum is referred to as epipharynx. It isfrequently membranous and continuous with the dorsal wall of pharnyx. It is an organof taste.

iii. **Mandibles:** There is a pair of mandibles. They are the first pair of jaws. They are alsocalled as primary jaws or true jaws. Mandibles articulate with the cranium at twopoints. They are heavily sclerotised. They are toothed on their inner border. There aretwo types of teeth. Distalare sharply pointed and are called incisor or cutting teeth andproximal teeth are called molar or grinding teeth. They act transversely to bite andgrind the food into small fragments.

iv. **Maxillae:** They are paired and more complicated than mandibles. They are calledsecondary jaws or accessory jaws. At proximal end the first sclerite cardo joins themaxilla to head. The second sclerite is called stipes which articulates with cardo. Stipescarries a lateral sclerite called palpifer which bears a five segmented antenna likemaxillary palp. On the distal end of the stipes, there are two lobes. The outer lobe iscalled galea and inner lobe is lacinia which is toothed. Maxille direct the food into themouth. They hold the food in place when the mandibles are in action. They act asauxillary jaws and assist in mastication of food. Sense organs connected with theperception of touch, smell and taste are abundantly found in palpi.

v. **Hypopharynx :** It is a tongue like organ. It is located centrally in the preoral cavity.Salivary gland duct opens through it.

vi. **Labium /lower lip:** It is a composite structure formed by the fusion of two primitivesegmented appendages. It bounds the mouth cavity from below or behind. It forms thebase of the preoral cavity. It consists of three median sclerites viz., submentum(largebasalsclerite), mentum (middle sclerite) and prementum (apical sclerite). On the lateralside of the prementum there are two small lateral sclerites called palpiger bearing threesegmented labial palpi. Distally prementum bears two pairs of lobes. The other pair oflobes is called paraglossae and inner pair of lobes, glossae. Both pairs when fused arecalled ligula.

9. Piercing and sucking / hemipterous /bug type e.g. Plant bugs.

Labium projects downwards from theanterior part of the head like a beak. Beak isfour segmentedand grooved throughoutits entire length. At the base of the labiumthere is a triangular flap like structurecalled labrum. Labium is neither involvedin piercing nor sucking. It functions as aprotective covering for the four stylets(fascicle) found within the groove.Both mandibles and maxillae are modified into long slender sclerotized hair likestructure called stylets. They arelying close together and suited for piercing and sucking.The tips of the stylets may have minute teeth for piercing the plant tissue. The innermaxillary stylets are doubly grooved on their inner faces. When these are closely opposedthey form two canals viz., food canal and salivary canal through sap and saliva areconducted respectively. Saliva contains enzymes or toxins that can distort plant cell wall topermit the stylets to penetrate down and reach phloem for suking the sap. Both palps areabsent.

10. **Piercing and sucking / dipterous /mosquito type** : e.g. Female mosquito

Mouthparts of female mosquito consistsof an elongate labium which is groovedforming a gutter which encloses six stylets.The stylets are composed of labrum -epipharynx (enclosing the food canal), thehyphophrynx (containing the salivary canal),two maxillae and two mandibles. Both theends of maxillary stylets and mandibularstylets are saw like and suited piercing flesh.The stylets are inserted into host's skin by a strong downward and forward thrust ofbody. Both mandibles and maxillae are reduced in male and they feed on plant nectar andjuices of decaying fruits. Female pierces the skin of human beings into which it injects salivacontaining an anticoagulant (to keep the blood flowing without clotting) and an anesthetic(to keep the victim unaware of the bite) and sucks up the blood. Labium does not pierce butfolds up or back as stylets pierce. Maxillary palpi are present.

11. **Chewing and lapping type : e.g.honey bee**

Labrum and mandibles are as inbiting and chewing type of mouth parts.But mandibles are bluntand not toothed.They are useful to crush and shape waxfor comb building; ingest pollen grains and other manipulative functions.Maxillolabial structures are modified toform the lappingtongue.The tongue unit consists of two galea of maxillae, two labial palpi and elongatedflexiblehairy glossa of labium. The glossa terminates into a small circular spoon shaped lobecalledspoon or bouton or flabellum which is useful to lick the nectar.

12. **Rasping and sucking : e.g. Thrip**

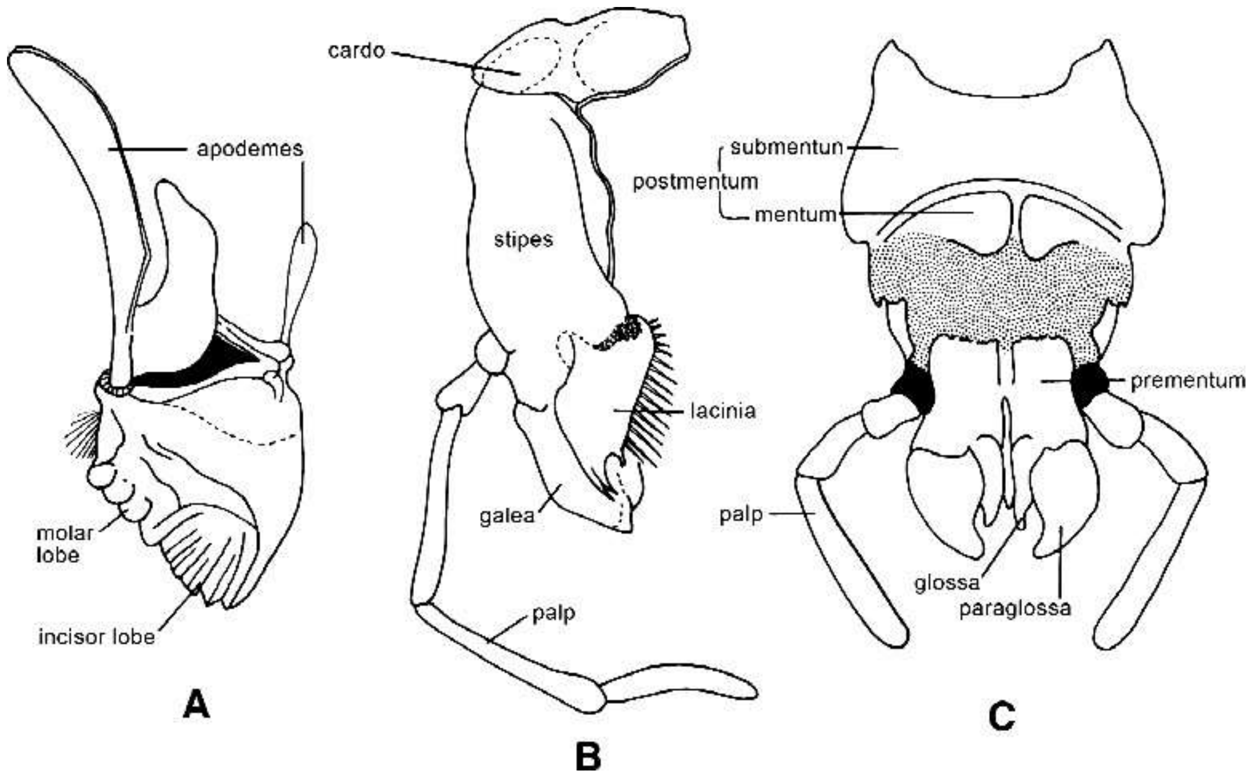
Mouth cone consists of labrum, labiumand maxillae. There are three stylets derivedfrom two maxillae and left mandible. Rightmandible is absent. Stylets are useful tolacerate the plant tissue and the oozing sap issucked up by the mouth cone. Bothmaxillary palpi and labial palpi are present.

13. **Sponging type : e.g. House fly**

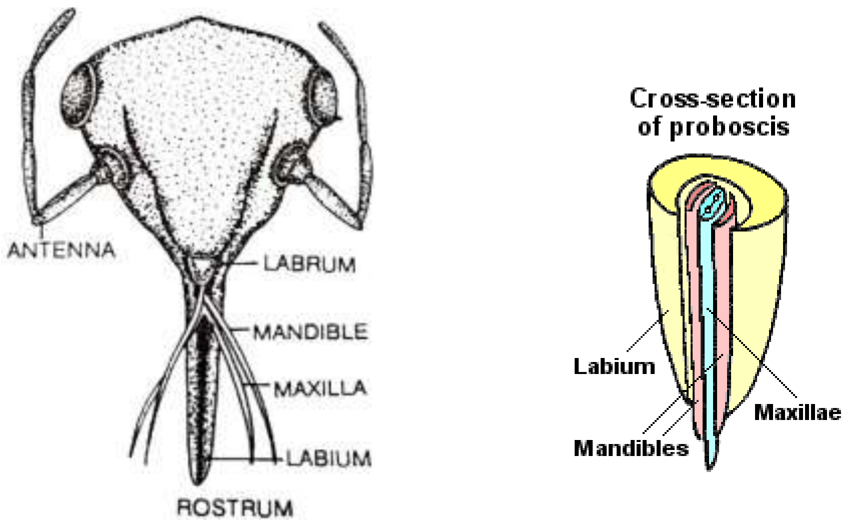
The proboscis is fleshy, elbowed,retractile and projects downwards fromhead. The proboscis canbe differentiatedinto basal rostrum and distal haustellum.The proboscis consists of labium which isgrooved on its anterior surface. Within thisgroove lie the labrum-epiphraynx (enclosing the food canal) and slender hypopharynx(containing the salivary canal).Mandibles are absent. Maxillae are represented by single segmented maxillary palpi.The end of the proboscis is enlarged, sponge like and two lobed which acts as suction pads.They are called oral discs or labella. The surfaces of labella are transvered by capillarycanals called pseudotracheae which collect the liquid food and convey it to the canal. Labellafunction as sponging organs and are capable of taking exposed fluids. These insects oftenspit enzyme containing saliva onto solid foods to liquify them.

14. Siphoning type : **e.g. Moths andbutterflies**

Mouth parts consists of elongate sucking tube or proboscis. It is formed by two greatlyelongated galeae of maxillae which are zippered together by interlocking spines and hooks.Galeae are grooved on their inner surface and when they are fitting together closely theyform a suctorial food canal through which the nectar is sucked up. The proboscis is coiled uplike watch springand kept beneath the head when it is not in use. By pumping of blood intogaleae, the proboscis is extended. The other mouth parts are reduced or absent except thelabial palpi and smaller maxillary palpi.

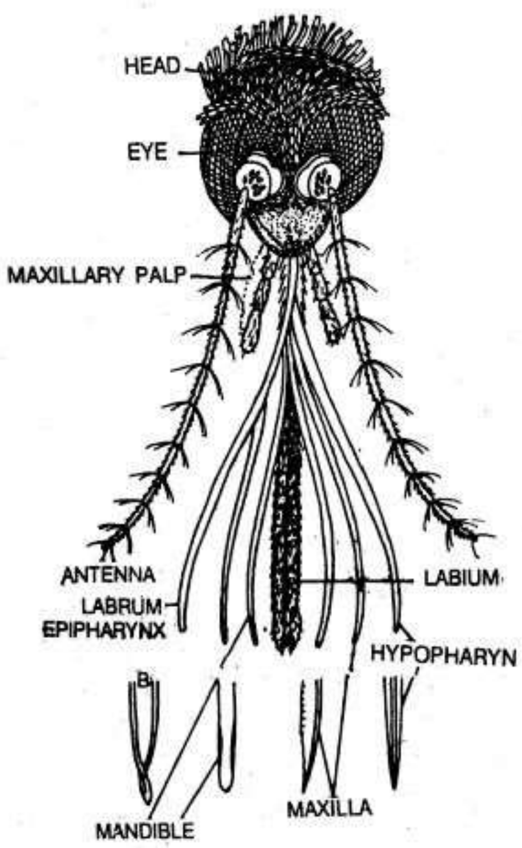


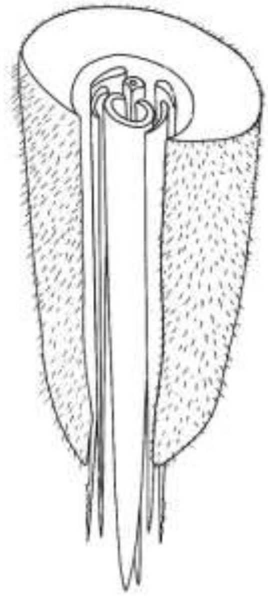
Structure of (A) mandible, (B) maxilla, and (C) labium of a typical chewing insect.



Piercing and sucking type – Bug

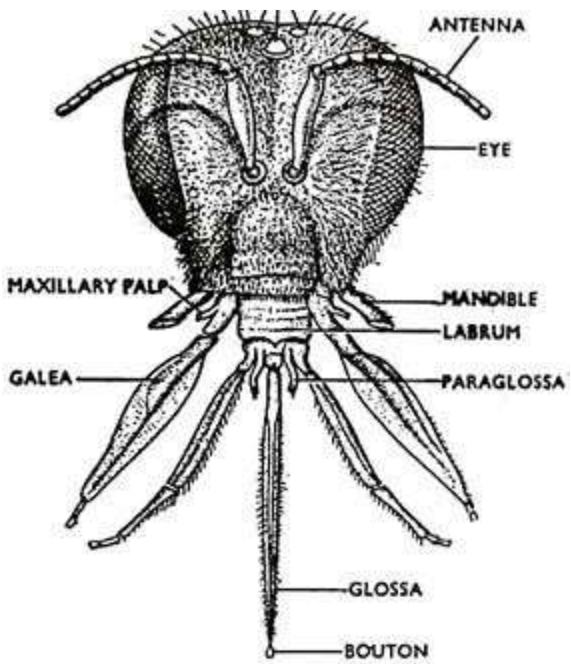
Piercing and sucking type – Mosquito

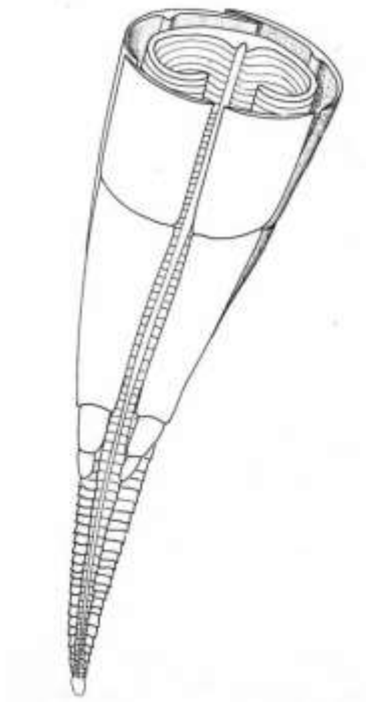




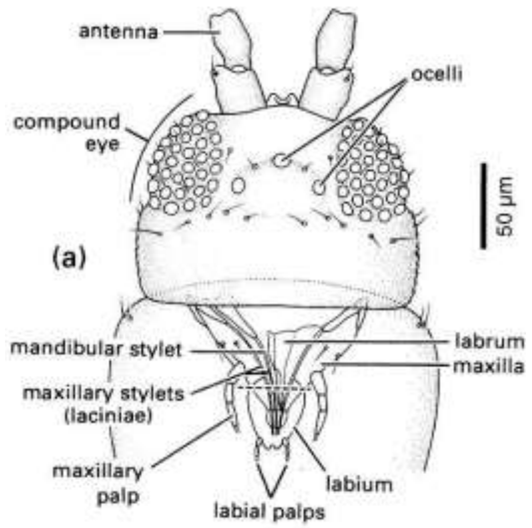
Cross

Chewing and Lapping type: Honey bee

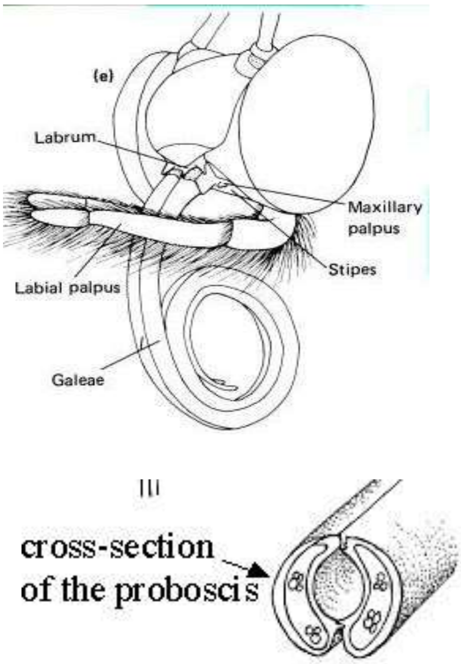




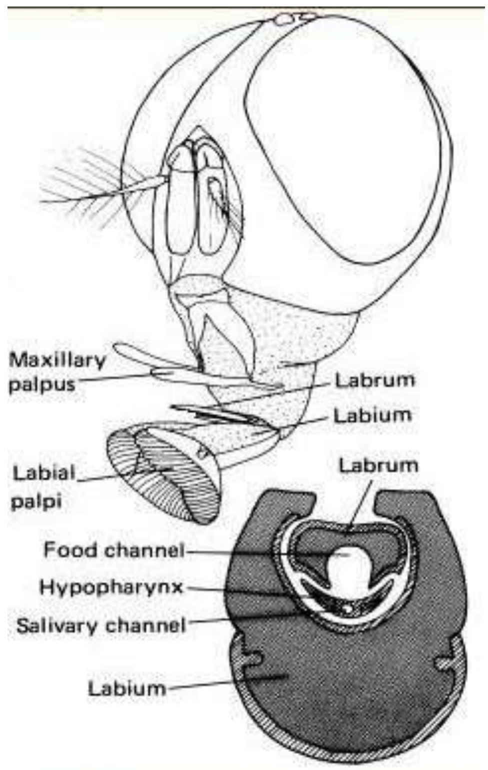
Rasping and sucking type mouth parts

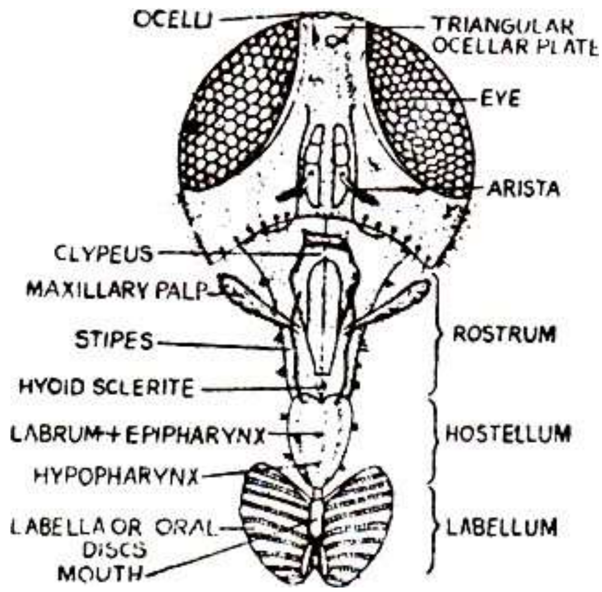


Siphoning type of mouth parts



Sponging type of mouth parts





Practical -5To study the legs and their modifications

The typical thoracic leg consists of six parts, basal coxa that articulates with the thoraxin the pleural region, small trochanter, femur, tibia, segmented tarsus, and pretarsus. Thecoxa is often divided into two parts, the posterior and the anterior (usually the larger part)being called the meron. The trochanter articulates with the coxa, but usually forms animmovable attachment with the femur. The femur and tibia are typically the longest legsegments. The tarsus, which is derived from a single segment, - is usually sub-divided intoindividual tarsomeres. The pretarsus may consist of a single claw, but it is usually composedof a pair of moveable claws and one or more pads or bristles.Legs are usually lookedupon as the principal organs ofterrestrial locomotion. Theyhave undergone manymodifications and have beenadapted to a wide variety offunctions including swimming,prey capture, pollen collectionand digging.

Ambulatorial (Ambulate - to walk;Walking leg) e.g. Fore leg and middle legof grasshopper. Femur and tibia are long.Legs are suited for walking.

Cursorial: (Cursorial = adapted forrunning : Running leg) e. g. All the threepairs of legs of cockroach. Legs are suitedfor running. Femur is not swollen.

Saltatorial: (Salatorial = Leaping: JumpingLeg) e.g. hind leg of grasshopper.

Fossorial: (Forrorial =Digging; Burrowingleg) e.g. Fore legs of mole cricket.

Natatorial: (Natatorial = pertaining toswimming; Swimming leg) e.g. hing legsof water bug and water beetle.

Raptorial: (Raptorial=predatory; Graspingleg) e.g. Forelegs of preying mantids.

Scansorial: (Scansorial = Climbing;climbing or clinging leg) e.g. all the threepairs of legs of head louse.

Foragial leg: (Forage = to collect foodmaterial) e.g. Legs of honey bee.

i. **Forelegs** : The foreleg has threeimportant structures (Eye brush, Antennacleaner or strigillis and Pollen brush)

ii. **Middle legs**: It has two importantstructures.

(a.) **Pollen brush**: Stiff hairs onbasitarsus form pollen brush which isuseful to collect pollen from middle part oftheir body.

(b.) **Tibial spar**: At the distalend of the tibia, a movable spur is presentwhich is useful to loosen the pellets ofpollen from the pollen basket of hind legsand to clean wings and spiracles.

iii. **Hind legs**: It has three importantstructures viz., pollen basket, pollenpacker and pollen comb. (a.) **Pollenbasket**: It is also called corbicula. Theouter surface of the hind tibia contains ashallowcavity. The edges of the cavity arefringed with long hairs. The pollen basketenables the bee tocarry a larger load ofpollen and propolis from the field to thehive.

(b.) **Pollen packer**: It is also calledpollen press. It consists of pecten andauricle. Pecten is a rowof stout bristles atthe distal end of tibia. Auricle is a smallplate

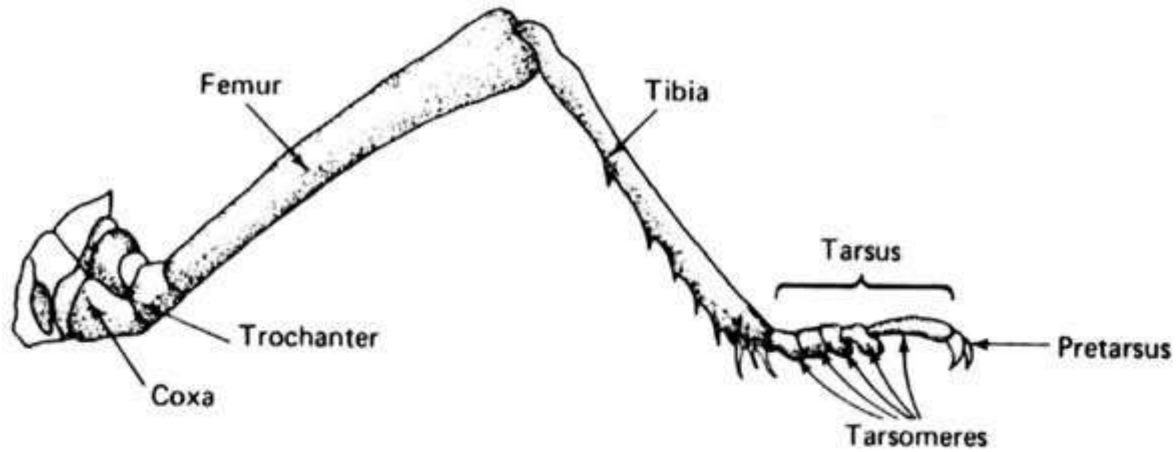
Climbing or Sticking leg: e.g. all the threepairs of legs of house fly.

Clasping leg: e.g. Forelegs of male waterbeetle.

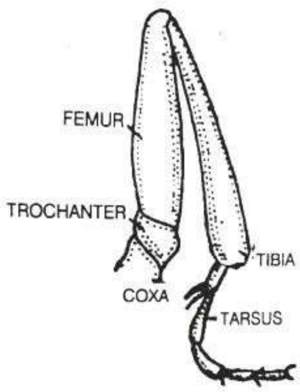
Prolegs: Caterpillars' posses' three pairs of thoracic legs (true-legs) and five pairs of abdominal legs (pro-legs) on 3rd, 4th, 5th, 6th, and last abdomenal segments. In some, semi-loopers larvae, prologs on 3rd and 4th abomenal segments absent, and hence while movement, it looks like semiloop, in some, looppers, prologs present only on 6th and last abdominal segments, and hence while movement, it looks like loop.

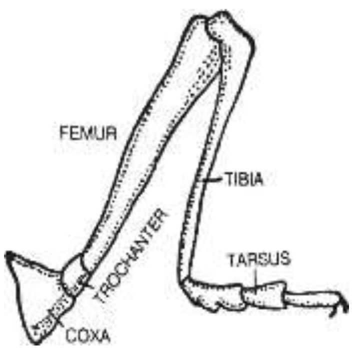
- Thoracic legs are also called the true legs, which are typically jointed and sclerotized.
- Abdominal legs are called prolegs. These are unjointed, short, fleshy with a flat surface at thebottom called planta.
- A number of hooks like structures called crochets are seen arranged in circular or semicuticular form on the surface of the plants.
- In sawflies of Hymenoptera, the larvae have 3 pairs of true legs in thorax, and 6 or >6 pairs ofprologs in abdomen. This is the unique feature of sawfly larva, but these prologs do not bear crochets, unlike lepidopteran larva.

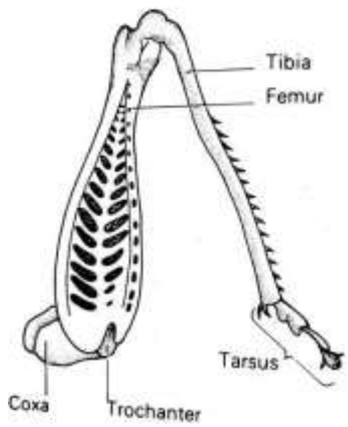
Structure of a typical leg



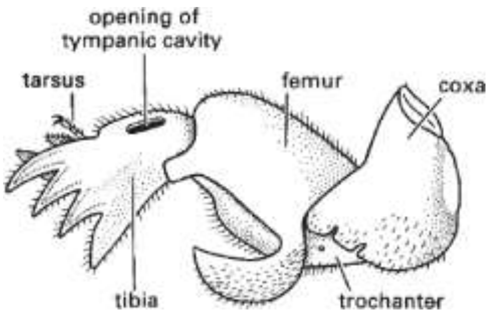
Ambulatorial leg **Cursorial leg** **Saltatorial leg**

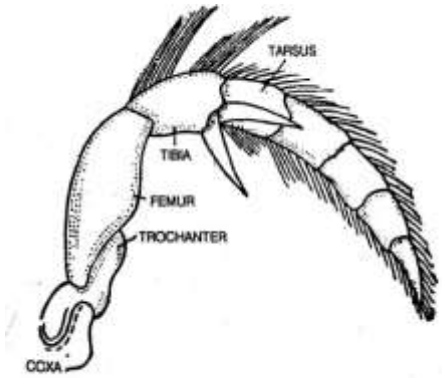




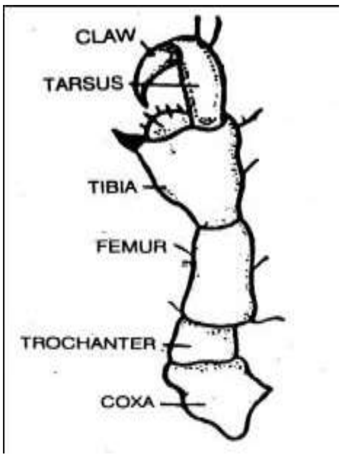


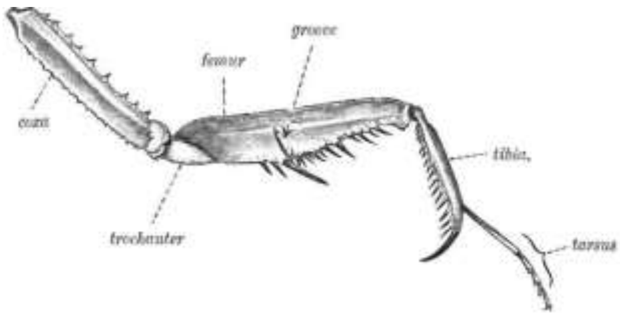
Fossorial leg **Natatorial leg**



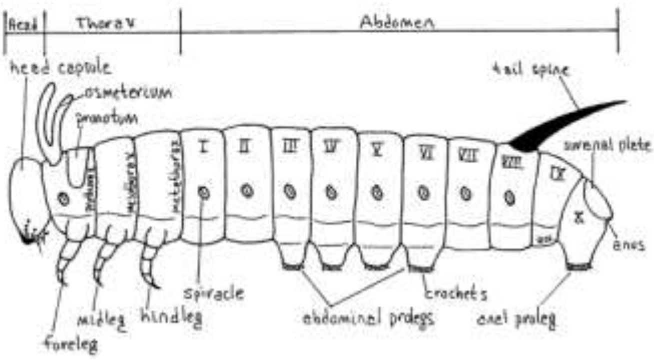


Scansorial leg
**Rap
torial leg**





Sticking leg
Prolegs



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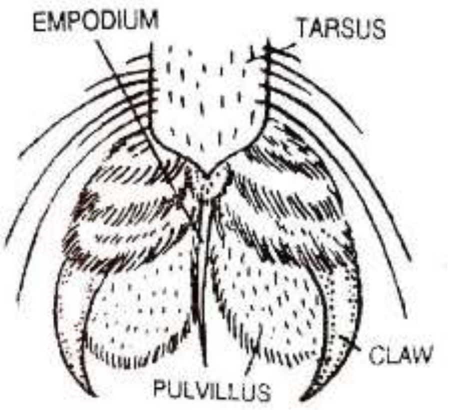
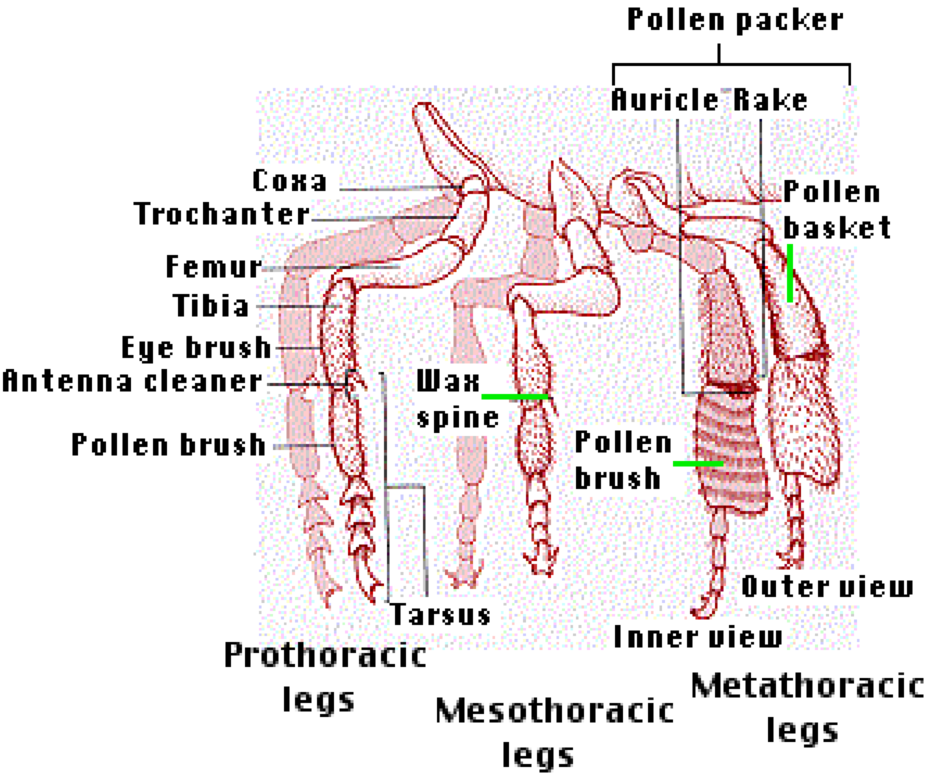
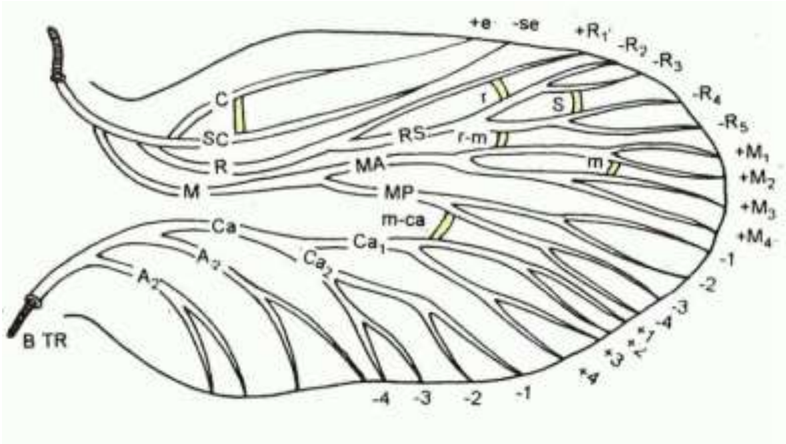

EMPODIUM
TARSUS
CLAW
PULVILLUS


Pollen packer
Auricle
Rake
Coxa
Trochanter
Femur
Tibia
Eye brush
Antenna cleaner
Pollen brush
Wax spine
Pollen brush
Pollen basket
Outer view
Inner view
Tarsus
Prothoracic legs
Mesothoracic legs
Metathoracic legs

Practical- 6To study about the Wing venation, types of wings and wing coupling apparatus.

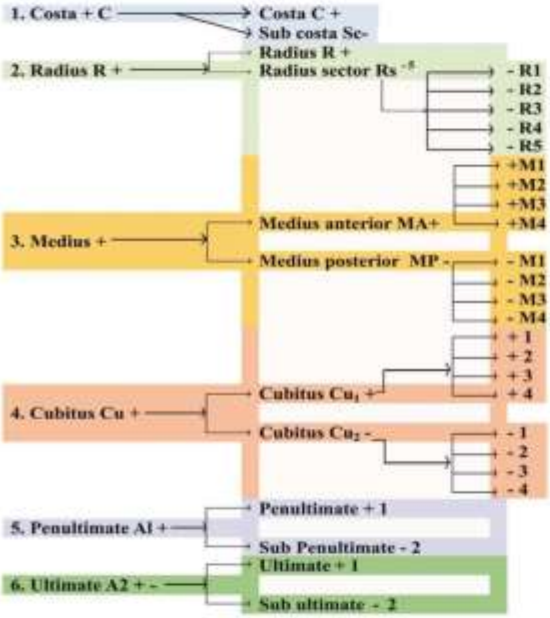
The complete system of veins of a wing is termed as venation or neuration. Generally inall the insects there is some similarity in wing venation and therefore, it is presumed that alltypes of wing venation have developed from the common base or the same ancestor. Bymeans of an extensive study of wing venation in different groups of insects, **Comstock andNeedham** constructed a hypothetical type of wing venation from which all other types havepresumely been derived. According to them the primitive wing venation has developedfrom two tracheae which are situated on the anterior and the posterior basal margins ofwings and their branches are spreadall over he wing. Each main trachea give rise to threeprincipal veins, thereby forming 6 principal veins



namely costa, radius, medius, cubitus,penultimate and ultimate. Each principal vein gives rise to a sub-vein near its base.

Wing venation of a hypothetical wing

The **principal veins are represented by + sign** whereas the **sub veins by - sign**. Thus thewhole wing venation system is represented **by + and the - signs** in alternate as shown in thefigure. The branching of principal veins is represented in the following manner:


1. Costa + C
Costa C +
Sub costa Sc-
2. Radius R +
Radius R +
Radius sector Rs -5
- R1
- R2
- R3
- R4
- R5
3. Medius +
Medius anterior MA+
+M1
+M2
+M3
+M4
Medius posterior MP -
- M1
- M2
- M3
- M4
4. Cubitus Cu +
Cubitus Cu1 +
+ 1
+ 2
+ 3
+ 4
Cubitus Cu2 -
- 1
- 2
- 3
- 4
5. Penultimate Al +
Penultimate + 1
Sub Penultimate - 2
6. Ultimate A2 + -
Ultimate + 1
Sub ultimate - 2

Such type of hypothetical wing ventaion is never met in any insect as one or the othervein is invariably found lacking for example the medius vein is absent in order Hemipteraand Ephimereda and submedius is missing in Odonata. Some of the scientists considerprecosta, costa, subcosta, radius, medius, cubitus and anal as the principal veins of the insectwing.

Cross veins

The veins joining the two longitudinal veins are known as cross veins. The importantcross veins along with their symbols are given below :

(vi) **Humeral cross vein (h)-** It extends fromcosta to sub-costa near the humeral angle andvein.

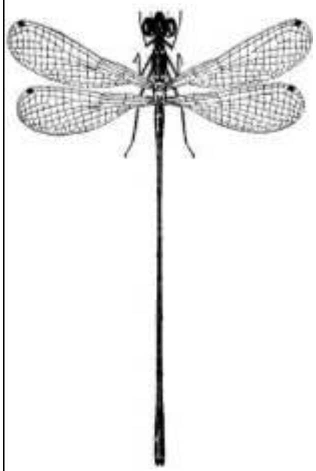
(vii) **Radio-medial cross vein (rm)-** It joins the sub radius and the medius veins.

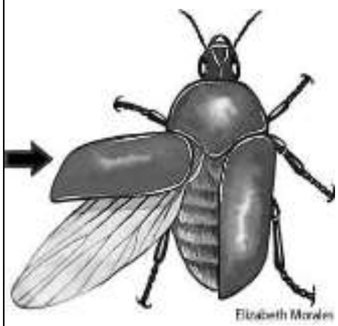
(viii) **Medial cross vein (m)** -The vein joining the m2 and m3 branches of medius is termedasmedial cross vein.

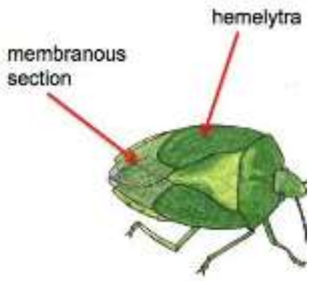
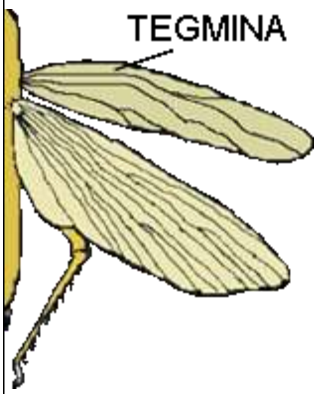
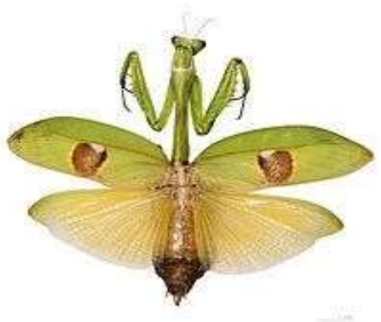
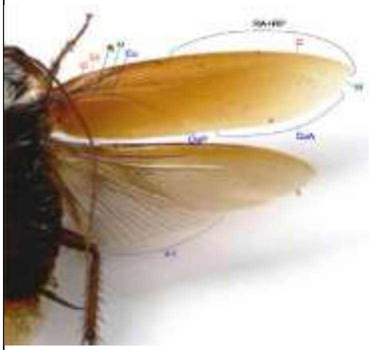
(ix) **Medio-cubital cross vein (m-cu)** - It joins the medius and the cubitus longitudinalveins.

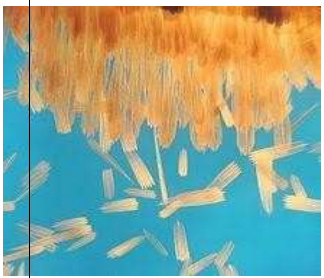
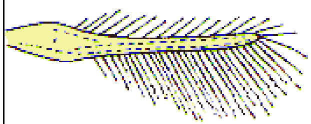
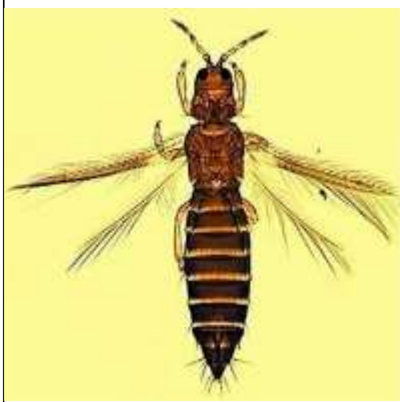
(x) **Radial cross vein (r)** -It extends from R1 to R2

Wing Adaptations and Modifications:

Wing Type	**Photos**	**Modifications and Examples**
Membranous 		• Membranous wings are thin & more or less transparent, but some are darkened. • These wings are with highly developed venation. • They are useful for flight. Examples: Hind wings of Grasshopper, Dragonfiles and damselflies (order: Odonata), lacewings (order: Neuroptera), flies (order: Diptera), bees and wasps (order Hymenoptera), termites (order Isoptera)

Halteres 		• Halteres are an extreme modification among the order Diptera (true flies), in which the hind wings are reduced to mere nubs. • Used for balance and direction during flight (gyroscopic stabilizers). • It is divided into three regions-scabellum, pedicel and capitalum. Examples: All flies (Diptera).
Elytra 	 	• Elytra (singular elytron) are the hardened, heavily sclerotized forewings of beetles (horny sheet without venation). • Modified to protect the hind wings when at rest. • Examples: All beetles (order Coleoptera).

Hemi Elytra 	 	• A variation of the elytra is the hemelytra. • The forewings of Hemipterans are said to be hemelytrous because they are hardened throughout the proximal two-thirds,while the distal portion is membranous. • Unlike elytra, hemelytra function primarily as flight wings. • Examples: Bugs(Hemiptera)
Tegmina 	 	• Tegmina (singular tegmen) are the leathery forewings of insects in the orders Orthoptera, Dictyoptera • Like the elytra on beetles the tegmina help protect the delicate hind wings, and also used for flight sometimes. • Examples: Grasshoppers, crickets and katydids (Orthoptera), Cockroaches, Mantids (Dictyoptera)

Scaly Wings  	 	• Scaly wings-thin and membranous front and hind wings covered over surface with flattened unicellular setae (scales). • The scales make the wings colorful and used for taxonomic studies. • They are useful for flight. • Examples: Butterflies, moths and skippers (order Lepidoptera), caddisflies (order: Trichoptera).
Fringed Wings 		• Fringed wings-slender front and hind wings with long fringes of marginal hairs, giving a feather like appearance. • The wings are highly reduced with reduced venation. • They are useful for flight. • Example: Thrips (Thysanoptera)
Clefted Wings (Fissured Wings)		• Front wing is longitudinally divided forming a fork-like structure. • The hind wing is divided twice, forming two forks with three arms. • All forks possess small marginal hairs. • They are useful for flight.

		• Example: Both wings of Plume Moth

Wing coupling apparatus

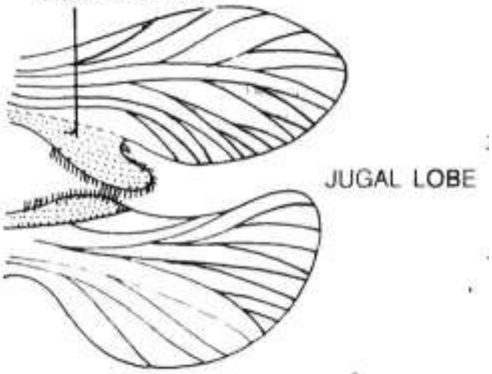
In certain insects special structures have been developed to fasten together the twowings of each side so that it may bring more synchronus action of the fore and hind wings,thereby enabling the insects to fly more swiftly. This action in many insects is ensuredsimply by fore wing overlapping the hind wing. The important coupling device developedin insects‘ wing for adding more efficiency in flying are described below-

(v) Jugal and humeral lobe- This couplingdevice is commonly found in Lepidoptera,Thchopteraand Mecoptera wherein thewing bases are highly modified. Theposterior end of the fore wing is modifiedinto slender finger like organ which isstiffened by a branch of IIIrd anal vein isknown as the jugal lobe; whereas theanterior margin of the hind wings ismodified in to a small humeral lobe. Thelobes of fore and the hind wings arecoupled with each other during flight.

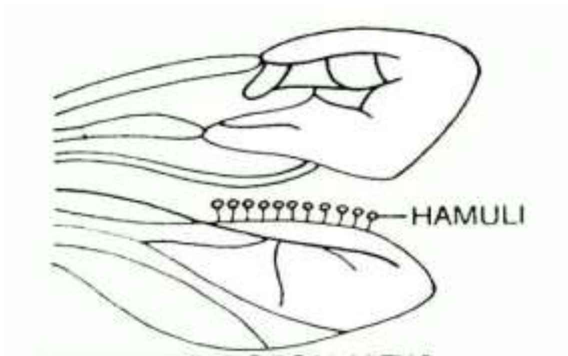
(vi) Frenulum and Retinaculum -This type ofcoupling apparatus is well illustrated in higherLepidoptera wherein the jugum is lostand the frenulum assumes more importance. In femalebutterflies a number of stoutbristle arise beneath the extended fore wing known as frenulum which engages in aretinaculum from a patch of hair near the cubitus of a hind wing. However, inmales thefrenulum bristles are fused into a single stout structure and is held by a curved process from the sub-costal vein of the fore-wing.

(vii) Hamuli -In this modification the costal margin of the hind wings bears a row of smallhooks known as hamuli. These hooks get attached into a fold on the inner margin of thefore-wings. Such coupling apparatus is generally met in Hymenoptera.

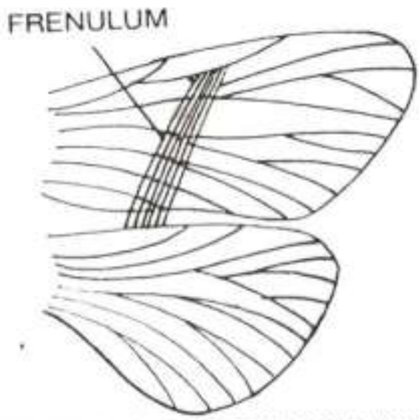
(viii) Amplexiform - This example is commonly met in the insects belonging to familypapilionidac and bombycidae of order Lepidoptera. In this case the wings are coupledsimply by overlapping basally to each other.



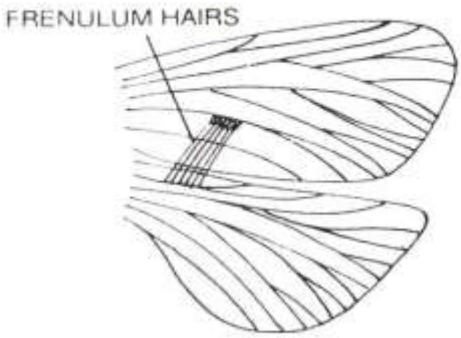
JUGAL AND HUMERAL LOBES



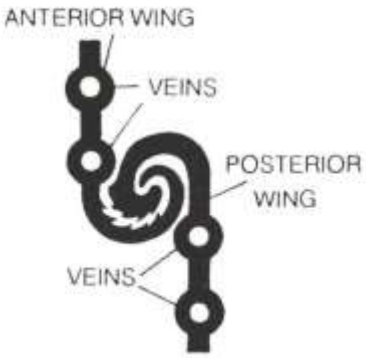
HAMULATE (DORSAL VIEW)



FENULUM AND RETINACULUM
(MALE BUTTERFLY)



FRENULUM AND RETINACULUM
(FEMALE BUTTERFLY)



AMPLEXIFORM (VERTICAL SECTION)

HOOK AND CHANNEL

Practical- 7To study the types of insect larvae and pupae Metamorphosis and immature stages

The change in growth and development (form) of an insect during its life cycle frombirth to maturity is called metamorphosis. There are four basic types of metamorphosis ininsects.

Ametabola: (No metamorphosis) e.g. Silver fish.

These insects have only 3 stages in their life cycle namely egg, young ones and adults. It ismost primitive type metamorphosis. The hatching insects resemble the adult in all respectsexcept for the size and called as juveniles. Moulting continues throughout the life.

Hemi-metabola: (Incomplete metamorphosis) e.g. Dragonfly, damselfly and may fly.

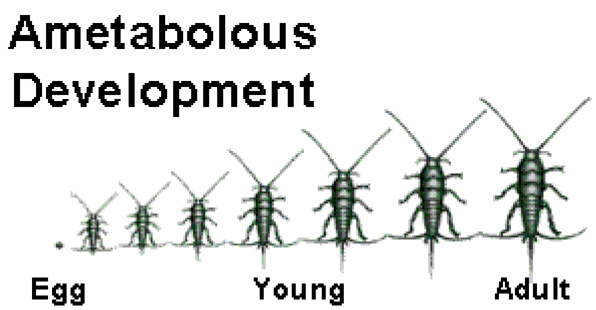
These insects also have 3 stages in their life namely egg, young ones and adults. Theyoung ones are aquatic and are called **naiads**. They are different from adults in habits andhabitat. They breathe by means of tracheal gills. In dragonfly naiad, the lower lip (labium) iscalled **mask** which is hinged and provided with hooks for capturing prey. After final moult,
the insects have fully developed wings suited for aerial life.

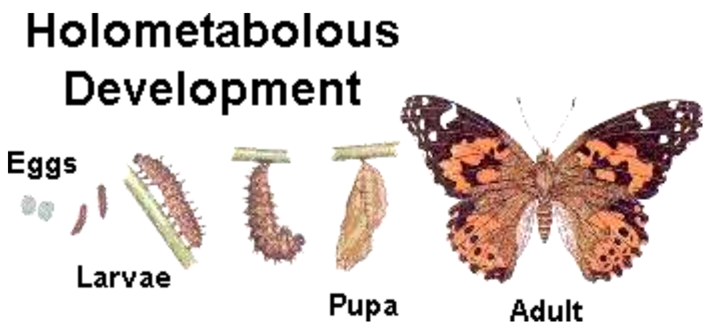
Pauro-metabola: (Gradual metamorphosis) e.g. Cockroach, grasshopper, bugs.

The young ones are called nymphs. They are terrestrial and resembles the adults ingeneral body form except the wing and external genitalia. Their compound eyes and mouthparts are similar to that of adults. Both nymphs and adults share the same habitat. Wingbuds externally appear in later instars. The genitalia development is gradual. Later instarsnymphs closely resemble the adult with successive moults.

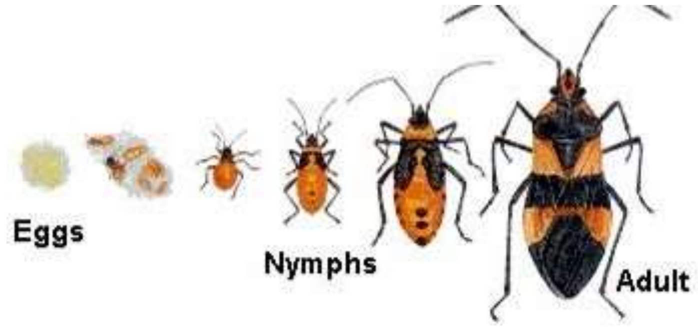
Holo-metabola: (Complete metamorphosis) e.g. Butterflies, moths, fly and bees.

These insects have 4 stages namely egg, larva, pupa and adult. Majority of the insectsundergo complete metamorphosis. Larvae of butterfly is called caterpillar. Larva differsgreatly in form from adult. Compound eyes are absent in larva. Lateral ocelli or stemmataare the visual organs. Their mouth parts and food habits differ from adults. Wingdevelopment is internal. When the larval growth completed it transforms into pupa. It isthe resting and non feeding stage in which the larval tissues disintegrate and adult organsare built up.

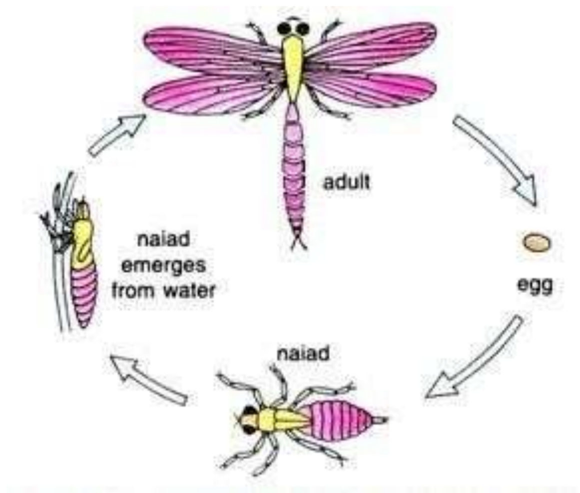




Paura-metabola



Hemi-metabola

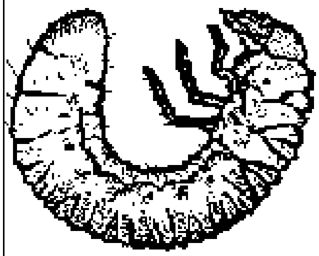


Immature stages in insects

Larva: Larval stage is the active growing and immature stage between the egg and pupalstage ofan insect having complete metamorphosis. This stage differs radically from theadults.

Types of larvae:

Type of larva	Photo	Modification
I. **Oligopod:** Thoracic legs are well developed. Abdominal legs are absent.		

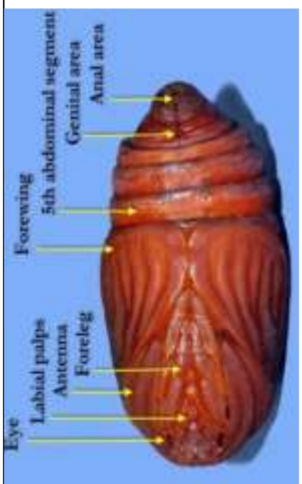
i. Campodeiform  	They are similar with diplurans genus Campodea. Body is elongate, depressed dorsoventrally and well sclerotized. Head is prognathous. Thoracic legs are long. A pair of abdominal or caudalprocesses is usually
	present. Larvae aregenerally predators and are very active. E.g. grub of antlion or grub of lady bird beetle.
ii. Scarabaeiform  	Body is **"C" shaped**, stout and sub-cylindrical. Head is well developed. Thoraciclegs are short. Caudal processes are absent. Larva is sluggish, burrowing into wood or soil. e.g. grub of rhinoceros beetle. Body is **"C" shaped**, stout and sub-cylindrical. Head is well developed. Thoraciclegs are short. Caudal processes are absent. Larva is sluggish, burrowing into wood or soil. e.g. grub of rhinoceros beetle.
II. Polypod or Eruciform: The body consists of an elongate trunk with large sclerotized head capsule. Head bears powerful mandibles which tear up vegetation. Two groups of single lensed eyes Stemmata found on either side of the head constitute the visual organs. The antenna is short. 3 pairs of thoracic legs and up to 5 pairs of unsegmentedabdominal legs or prolegs or pseudolegs are present. e.g. Caterpillar (larva of moth and butterfly).	

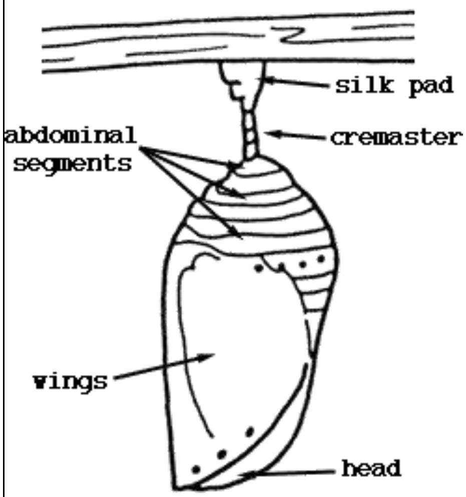
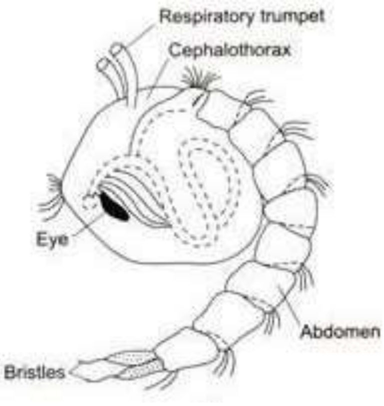
i. Hairy caterpillar 	The body hairs may be dense, sparse or arranged in tufts. Hairs may cause irritation, when touched. e.g. red hairy caterpillar.
ii. Slug caterpillar 	Larva is thick, short, stout and fleshy. Larval head is small and retractile.
iii. Semilooper 	either 3 or 4 pairs of prolegs are present. e.g castor semilooper.
iv. Looper 	They are also called measuring worm or inch worm. In this type, only 2 pairs of prolegs are present in 6th and 10th abdominal segments. e.g. Dhaincha looper.
III. Apod: They are larvae without appendages for locomotion. Based on the degree of development and sclerotization of head capsule.	
i. Eucephalous 	Larva with well developed head capsule with functional mandibles, maxillae, stemmata and antennae. Mandibles act transversely. e.g. Wriggler (larva of mosquito) and grub of red palm weevil.

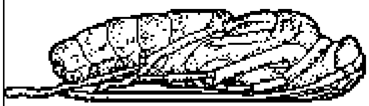
ii. Hemicephalous 	Head capsule is reduced and can be withdrawn into thorax. Mandibles act vertically. e.g larva ofhouse fly and robber fly.
iii. Acephalous 	Head capsule is absent.Mouth parts consists of a pair of protrusiblecurved mouth hooks and associated internal sclerites. They are also called vermiform larvae. e.g. Maggot (larva of house fly)

Pupa: It is the resting and inactive stage in all holometabolous insects. During this stage, theinsect is incapable of feeding and is quiescent. During the transitional stage, the larvalcharacters are destroyed and new adult characters are created.

Types of pupae

Type of pupae	**Photo**	**Modification**
Obtect 		Various appendages of pupa viz. Antennae, legs and wing pads areglued to the body by a secretion produced during the last larval moult. Exposed surfaces of the appendages are more heavily sclerotized than the inner surface. e.g. moth pupa.

Chrysali 		It is naked obtect type of butterfly. It is angular and attractive coloured. The pupa is attached to the substratum by **hooks** present at the terminal end of the abdomen called **Cremaste**r. The body of chrysalis is attached to the substratum by 2 strong silken threads called **gridle**.
Tumbler 		Pupa of mosquito is called tumbler. It is an obtect type pupa. It is comma shaped with rudimentary appendages. Breathing trumpets are present in the cephalic end and anal paddles are present at the end ofthe abdomen. Abdomen is capable of jerky movements which are produced by the anal paddles. The pupa is **very active**.

Exarate 		Various appendages viz. antennae, legs and wing pads are not glued to the body. They are free. All oligopod larvae will turn into exarate pupae. The pupa is soft and pale. e.g. pupa of rhinoceros beetle.
Coarctate 		the last larval skin is changed into a pupal case and the pupa is actually an exarate pupa. The pupal case is dark brown, barrel shaped, smooth with no apparent appendages and called as **puparium**. e.g. fly pupa

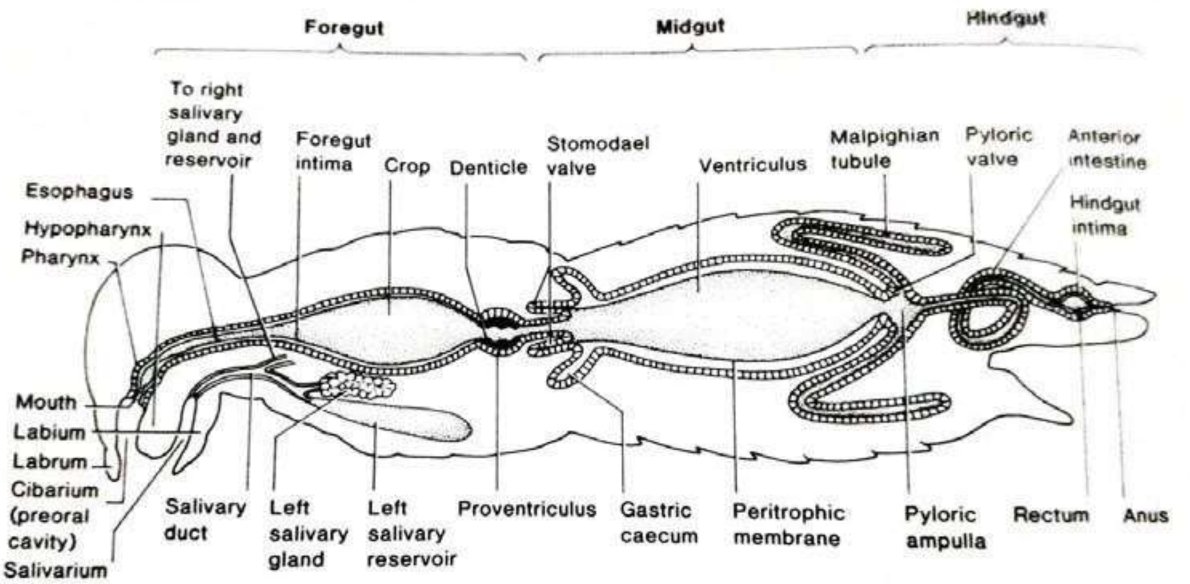
Practical -8To study the dissection of alimentary canal/nervous system in insects (Grasshopper/Cockroach)

The best learning situation requires one specimen and set of tools per two students forstudies. Students working in pairs have ample opportunity to fully participate in thedissection and to carefully examine the specimen. They are also able to share and discusstheir observations during and after the dissection.

Materials required for dissecting Cockroach

Dissection Kit includes- Surgical scissors, Iris scissors, Tissue forceps, Scalpel, handle,Scalpel blades, Probe with angled tip, Dissection needles, Dropping pipette, Blow pipes,Dissection tray, Dissecting pins, Rigid metal ruler, And case Camel hair brush etc

Diagram of Alimentary canal showing the major subdivisions in a generalized GrasshopperInsect



Digestive system

It includes the organs of ingestion (alimentary canal and its associated glands) and thephysiologyof digestion. The organs of ingestion are located in the head and are meant forthe intake of food. The preoral cavity is enclosed by the mouth parts and is divided into twoparts by the hypopharynx, the anterior region in which the alimentary canal opens is termedas cibarium andin which the salivary duct opens is known as salivarium. In the suckingInsects the cibarium is modified into a sucking pump while salivarium serves as the salivarysyringe.

Alimentary canal

The alimentary canal of grasshopper/cockroach is a simple, hollow and tubular instructure whichruns from the buccal cavity to anus. It is distinctly divided into thefollowing three primary regions

4. Foregut or stomodaeum.

5. Mid gut or mesenteron or ventriculus.
6. Hind gut or proctodaeum.

4. Foregut or Stomodaeum

It constitutes the anterior region of the alimentary canal which is primarily an organ ofingestionand shows as a site for storing food. It consists of the following paris

(v) Pre-oral food cavity-It has been described previously and indeed it is not a part ofalimentary canal.

(vi) Pharynx-It is situated in between the pie-oral cavity and the oesophagous and isprovided by the dilateral muscles. These muscles are highly developed in those thoseinsects which pharynx helps in forming the suking pump.

(vii) Oesophagous-It is simple straight tube which runs from the posterior region of thehead to thorax and joins with the crop.

(viii) Crop- It is simple bag like structure and serves as a storage reservoir for the food.Apparently it is a dilated portion of the oesophagous but differs histologically by thepresence of sclerotized ridges which are arranged transversely in the crop. Since itserves as a reservoir for food hence its walls are thin and the muscles are poorlydeveloped.

(e) Gizzard-It is situated in the posterior region of the crop which cannot be apparentlydistinguished from crop but differs internally by having the longitudinal folds into thelumen in which cuticular teeth are attached. Its posterior part is concentric in the internallayer of six 'V' shaped processes are attached which form the cardiac valve with the folds ofgizzard. Its major function is to regulate the passage of food into the mid gut.Histologically, the following layers may be distinguished in the walls of the stomodaeum

(7) Intima - The inner most layer of chitin found in continuation of body cuticle.
(8) Epithelial layer-It is a thin layer secreting the intima.
(9) Basement membrane- Bounding the outer most surface of the epithelium.
(10) Longitudinal muscles—These muscles are less developed than circulatory muscles.
(11) Circulatory muscles - These are well developed.
(12) Peritoneal membrane - It is often difficult to detect and consists of apparentlystructurelessconnective tissue.

5. Mid Gut or Mesenteron

It is relatively a short tube or elongated sac with uniform diameter extends from hepaticcaecae or cardiac valve to Malpighian tubes or pyloric valve. Histologically, the inner wall ofmesentcronor stomach is not made up of chitin, but consists of following layers

(i) Peritrophic membrane (ii) Enteric epithelium
(iii) Basement membrane (iv) circular muscles
(vi)Longitudinal muscles (vi) Peritoneal membrane

The enteric epithelium is made up of three types of cells:

(i) The columnar cells whichsecret the enzymes and absorb the digested food,

(ii) the regenerative cells which renew thedestroyed and dead epithelial cells throughsecretion or in the process of degeneration and

(iii) the goblet cells which are of uncertain functions.

Thus, there are following five major function of enteric epithelium:

(vi) to make digestiveenzymes
(vii) to absorb the digested food
(viii) to produce new cells
(ix) to absorb the water
(x) to excrete the waste material outside the body.

The inner surface of midgut is sometime lined by a thin membrane known asperitrophic membrane which protects the epithelial cells from the direct contact of foodparticles. This membrane is absent in Lepidopterans and hemipterans.

6. Hind Gut or Proctodaeum

It extends from the posterior end of midgut to the anus and is also an invagination ofthe body wall. The hind gut consists of the some layers as the fore gut except that thecircular muscles of its are developed both inside and outside the layer of longitudinalmuscles. The hind gut is externally marked by the insertion of the Malpighian tubes andinternally by the pyloric valve. It may be divided into three distinct regions(i) Ileum or small intestine (ii) Colon or large intestine

(iv) Rectum.

Ileum- It is a small tube which has many folds in its inner wall.

Colon- It is situated on the 5th and 6th segments of the abdomen and is a slender tubewhich, cannot be easily distinguished from the ileum. In some insects it is just like 'S' instructure.

Rectum- Both the ends of the rectum are comparatively slender while the middle portion isthick and large which consists of six rectal papillae internally and six ridges of longitudinalmuscles externally. The rectum opens to exterior through the anus which is situated at thecaudal end ofthe abdomen.

Salivary Glands - The labial glands which are associated with the gnathal appendages arethe salivary glands. A pair of salivary glands is found in the grasshopper which generally liein the thorax and are convoluted tubes often branched and racemose. Both the ducts ofsalivary glands unite together beneath the oesophagous to form a common salivary ductwhich opens into the salivarium.

Physiology of digestion

The grasshopper is phytophagous and eats the leaves and soft parts of the plants whichare holdby the maxillae and, they bring the food near to mandibles where it is broken intosmall particles. These small food particles are sent to the buccal cavity with the help oflabrum and labium. On entering the buccal cavity, it is subjected to the action of salivawhich contains the amaylase enzyme. It acts on the carbohydrates present in the food andchange them into simple sugar i.e., glucose which is absorbed in the crop. Saliva is alsohelpful in moistening the food. This food passes onward to the crop where the secretions ofthe midgut and the hepatic 'caecae mix with it. These secretions are weakly acidic or alkalineand contain maltase, invertase, lactase, protease, lipase, peptidase, erypsin and trypsinenzymes which act on the food. Due to the action of these eyzymes the starch is convertedinto sugars, protein into amino acids and fat into fatty acids. After this the food comes togizzard where it is again masticated then it passes through thecardiac valve intomesenteron where further digestion of the food takes place. The digested foodis absorbedby the spongy and thick walls of mesenteron. The undigested food passes to the hind gut(proctodaeum) through pyloric valve where the absorption of water takes place and thenwaste and undigested food expelled out through anus in the form of excreta. The absorbedfood is utilized for the following purposes

(i) In the form of energy required for different life activites
(ii) Some part is consumed in theformation of muscles etc.
(iii) The rest is stored in the fat bodies which are used in emergency.

Filter Chamber:

- A number of cicadids and cercopids suck sap from xylem, which contains amino acidsin very dilute solution and relatively higher concentration of salts.
- This solution has to be concentrated before absorption so as to avoid excessive dilutionof haemolymph.
  - In these insects removal of excessive water is done with the help of –the filterchamber‖.
- The filter chamber consists of an expanded thin walled bladder-like anterior midgut,which lies in close association with (or surrounds) the posterior midgut (interior) andproximal ends of the Malpighian tubules (interior) or anterior part of the hindgut.
- The chamber formed within the folds of the anterior gut is called the filter chamber. Itis suggested that the Malpighian tubules produce a hypertonic fluid, which is rich inK^+. This establishes an osmotic gradient from the anterior midgut to the filter chamberthen to the Malpighian tubules, so that water passes almost directly to the hindgut andabsorption of nutrientstakes place in the more central region of the midgut. Filterchamber of the coccids has parts of midgut invaginated into the rectum.

Practical- 9To study the male and female reproductive systems in insects (Grasshopper)MALE REPRODUCTIVE ORGANS

The male reproductive organs consist of the followings- (i) A pair of testes (ii) A pair ofvasa deferentia (iii) Seminal vesicles (iv) Ejaculatory duct (v) Penis or Aedeagus (vi)Accessoryglands (vii) Male genital atrium

The Testes-They are located above the midgut and held in position by the surrounding fatbodies and tracheae. Each testis is a more or less ovoid body partly or completely dividedinto a variable number of follicles or lobes which are cylindrical in shape. Each follicle isconnected with vas deferens by a relatively well developed slender tube known as vaseffcrens. The peritoneal investment of the follicle is developed to the extent of envelopingthe testis as a whole in a common coat known as scrotum. the presence of the sex cells indifferent stages of development.

These zones are as follows

(v) The germarium - It is the region having primordial genii cells or spermatogonia whichundergo multiplication.

(vi) The zone of growth – In this zone the spermatogonia increase in size and undergorepeated mitotic division and develop into spermatocytes.

(vii) The zone of division and reduction-Here the spermatocytes undergo meiosis andproduce spermatids.

(viii) The zone of transformation - The spermatids are transformed into spermatozoa.The massesof spermatozoa are generally enclosed in the testicular cyst cells from whichthey are released in the vas deferens. In addition, the testes contain large elements knownverson's cells or apical cells.

Vas deferens- These are the paired canals leading from the testes which are partly or whollymesodermal in origin.

Seminal Vesicles- The Vas deferens vary greatly in length in the majority of insects. EachVas deferens becomes enlarged along its course to form a sac known as seminal vesicle inwhich spermatic fluid is collected.

Ejaculatory duct -Posteriorly, the vasa deferentia unite to form a short common canal whichis continuous with a median ectodermal tube known as ejaculatory duct. The terminal endofejaculatory duct opens in the male genital atrium.

Aedeagus- The terminal end of the ejaculatory duct is enclosed in a finger-like evaginationof theventral body wall which forms the male intromittent organ known as aedeagus. It issituated on9th abdominal sternum of the grasshopper on the conjunctival membrane of theposterior margin. **Accessory glands-** These are one to three pairs in number and usually present in relationwith the genital ducts opening into seminal vesicle. These are tubular or sac-like in structure.In most ofthe cases their secretions mix with spermatozoa and in some insects glands aredirectly concernedwith the formation of the spermatophores.

THE FEMALE REPRODUCTIVE ORGANS

The female reproductive system consists of the following organs- (i) A pair of ovaries(ii) A pair of lateral oviducts (iii) Spermatheca (iv) Vagina and genital chamber (v) Accessoryglands(Collaterial glands)

The ovaries-These are typically more or less compact bodies lying in the body cavity of theabdomen on either side of the alimentary canal. Each ovary is about 2 cm long andcomposed of a variable number of ovarioles and open into the oviduct. A typical ovariole isan elongated tube in which the developing eggs are disposed one after the other in a singlechain. The oldest oocyte is situated nearer the union with the oviduct. The wall of anovariole is made of follicular epithelium whose cells rest upon a basement membraneknown as tunica propria. Each ovariole may be differentiated into three zones:

(iv) **Terminal filament-** It is the slender thread like apical prolongation of the peritoneallayer. The filaments of the ovary combine to form a common thread termed as terminalfilament. The terminal filament of one ovary units with the filament of the other ovaryto form a median ligament. It aids in maintaining the ovaries in the position and isattached to the dorsal diaphragm.

(v) **The germarium**- It is situated below the terminal filament and forms the apex of anovariole. It consists of a mass of cells which are differentiated from the primordial germcells.

(vi) **The region of growth**- It is also called as vitellarium which constitutes the majorportion ofan ovariole. The vitellarium contains the developing eggs (oocytes). Theepithelial layer of thewall of vitellarium grows inwards to enclose each oocyte in adefinite sac known as follicle. Thecells of the follicle secrete the chorion of the egg andin some cases serve to nourish the oocytes. Three types of ovarioles may be recognized on the basis of presence or absence ofnutritive cells.

(d) Panoistic type– Nutritive cells are absent e.g., grasshopper and other insects ofOrthopteraand Isoptera.

(e) Polytrophic type-Nutritive cells are present and arranged inalternate with the oocytes e.g.,Hymenoptera**.**

(f) Acrotrophic type-Nutritive cells arepresent and situated at the apices of the ovarioles e.g.,Hemiptera.

The oviducts– The lateral oviducts are paired canals leading from the ovaries and areformed from the mesoderm. These lateral oviducts form the common oviduct which opensinto thevagina. Each oviduct is an enlarged pouch which stores eggs. The vagina is greatlyenlarged to form a chamber, known as uterus, for the reception of developing eggs.

The Spermatheca– This is a pouch or sac for the reception and storage of the spermatozoa(seminal fluid) and is also known as receptaculum seminis. It generally opens by a duct intothe dorsal wall of the vagina which is known as sperm duct. In many insects pairing takesplace only once and since the maturation of eggs may extend after the union of the sexes, theprovision of spermatheca allows for their fertilization from time to time. A specialspermathecal gland opens into the duct of spermatheca and secretes a fluid which lengthensthe life of sperms.

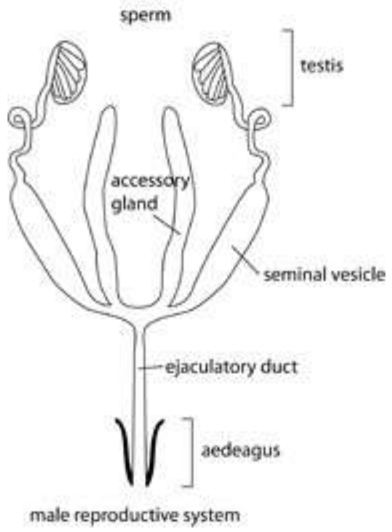
Genital chamber– The vagina opens into the genital chamber on 9th sternum and thischamber iscalled bursa copulatrix which helps in copulation.

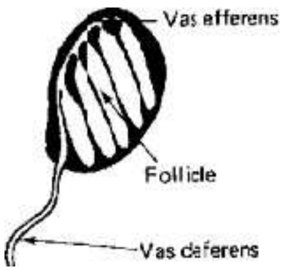
Accessory glands– These are paired structures opening into the distal portion of the vagina.These glands provide material for the formation of egg pod or ootheca.

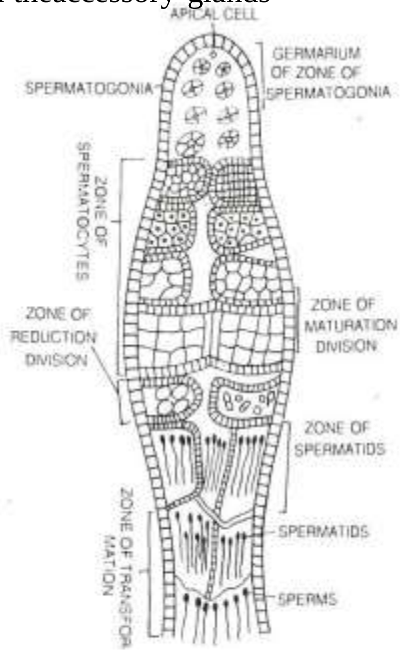
Fertilization– After copulation; the spermatic fluid is received in the spermatheca. The eggcomes down from the oviduct to the vagina which has an opening (micropyle) into its shellfor the entrance of male germ cell (spermatzoan). One or two spermatozoa enter the eggthrough micropyle and only one succeeds in fertilizing the egg. After fertilization theaccessory glands secrete a fluid around the egg which hardens it.

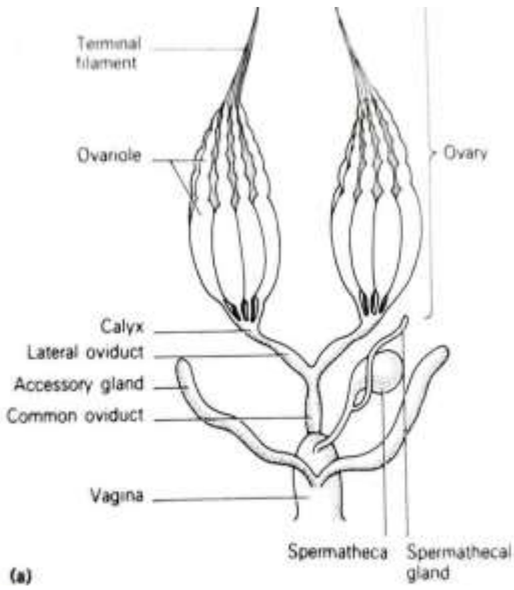
Male reproductive organ

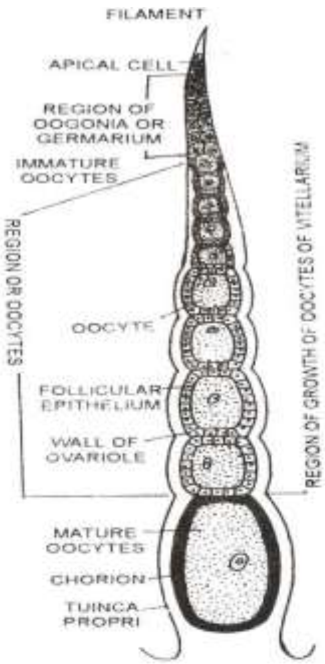
L. S. of Testicular follicle









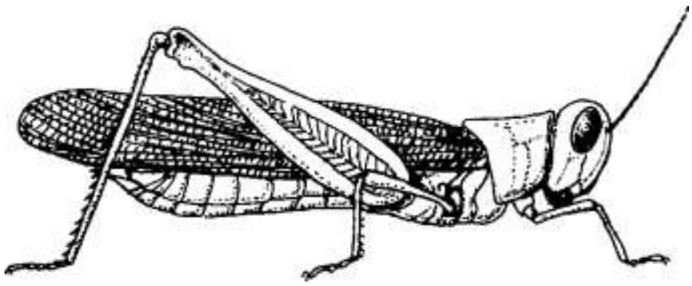


Female reproductive organ **L.S. of an Ovariole**

Practical -10To study the characters of orders Orthoptera, Dictyoptera, Odonata,Neuroptera, Isoptera,Thysanoptera and their families

Order- Orthoptera(Ortho- straight; ptera - wing)

Synonyms : Saltatoria, Saltatoptera, Orthopteroid
Common names : Grasshoppers, Locust, Katydid, Cricket, Mole cricket



Characters
Distribution : Worldwide
but mainly in tropicsBody :
Medium to large sized
Mouthparts : Chewing and biting type
Eyes : Well developed compound eyes; ocelli 2or 3
Antenna : variable, filiform in most of the insects
Thorax : Large prothorax with shield in many of the insects
Wings : Forewings are called **tegmina** (hard and lathery in texture),Hind wingsare **membranous**
Legs : Hind legs is usually adopted for jumping (saltatorial)
Cerci : Short and unsegmented
Ovipositor : Long and well developed
Specializedorgans : Stridulatory (sound producing) organ and auditory (hearing) organpresentMetamorphosis : Gradual / Paurometabola type

Sub-orders : Caelifera and Ensifera

Family:

Acrididae

(Caelifera)

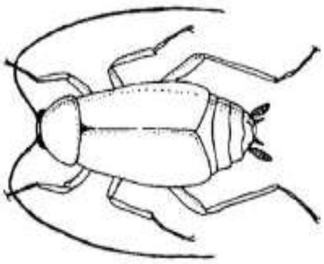
Characters
Antenna : shorter than the body length
Legs : Hind legs are long and meant for jumping with the

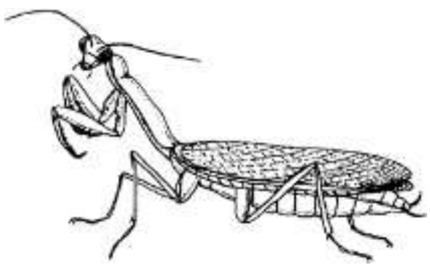
help of
levatormuscles
Tarsus : three segmented
Ovipositor : Short and horny
Sound production : Tympanum is located on either side of the 1st abdominal segment.Sound is produced by **femoro-alary mechanism** (a row of peg likeprojections found on the innerside of each hind femur which arerubbed against hard radial vein of the tegmen)Examples(Short hornedGrasshopper andLocusts)Dhan ka tidda – *Hieroglyphus banian*
Kharif ka tidda – *H. nigrorepletus*
Ghas ki tiddi – *Chrotogonus sp.*
Locust – *Schistocerca gregaria*

Family:
Tettigonidae
(Ensifera)
Characters

Antenna : Long as long as body or larger
Tarsus : Four segmented
Ovipositor : Sword like
Sound production : Alary type (a thick region on the hind margin of forewing (scraper)is rubbed against a row of teeth on the stridulatory vein (file)present on the ventral side of another forewing which throws theredonant areas on the wing (mirror) into vibrations to producesound)Examples : (Long horned grasshoppers, Katydids and bush crickets)

Order-Dictyoptera(Dictyon = network; ptera=wings)
Synonyms : Oothecaria,
Blattiformia Common names :
Cockroaches and preying mantids





Characters

Body : Medium to large sized
Head : Hypognathous
Antenna : Filiform or setaceous
Mouthparts : Chewing type
Thorax : Prothorax usually larger than meso and meta thorax
Wings : Forewings thickened, leathery with a marginal

costal vein calledtegmina, Hindwings membranous and folded fanlike

Tarsi	: 5 segmented
Cerci	: Short and many segmented
Eggs	:
Contained in Ootheca	
Metamorphosis	:
Gradual/paurometabola	
Sub-orders	: Blattaria (Cockroach) and Mantodea (Preying mantids)

Important Families of Dictyoptera

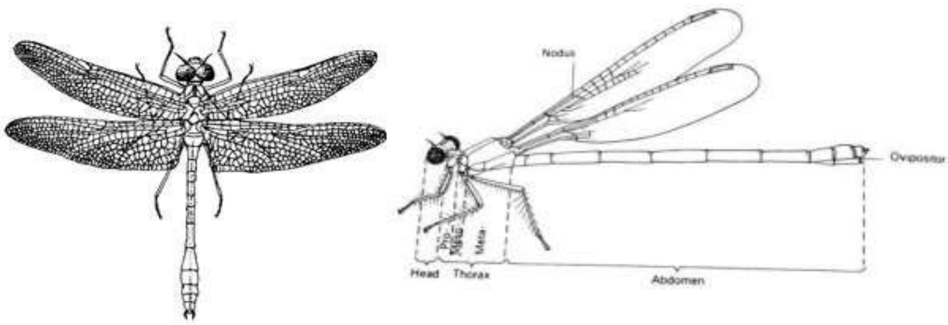
Characters	**Blattidae**	**Mantidae**
Head	Not mobile in all directions	Mobile
in all directions Pronotum		Shield
like and cover the head	Elongated, do not cover headOcelli	
	Degenerated- 2 called as fenestra	Three
Body	Flattened, dark coclored	Elongated
sometimescylindrical Legs	Cursorial running type	Forelegs are
raptorial, middleand		
hind legs are ambulatorialGizzard		
	Powerfully armed with chitinous	
	NoChitinous teeth	
teeth		
Mating behaviour	Do not devour male during mating	
	Often (but not always)Ootheca	
	Chitinous	
	Not chitinous	
Nymphal charcter	Not cannibalistic	Cannibalistic
Mimicry	Absent	Mimic leaves and flowers
Habitat	Omnivorous	Mostly outdoors
Economic importance	Household pest	Predators on crop pest
Examples	American Cockroach	Preying mantids

Order- Odonata

(Odon = tooth; strong mandibules)

Common names : Dragonflies and damselflies

Characters



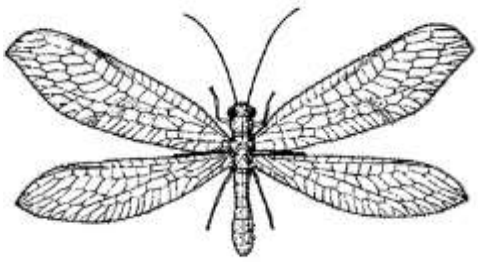
Body : Long, cylindrical, medium to large sized, attractively colouredHead : Globular and constricted behind into a petiolate neck

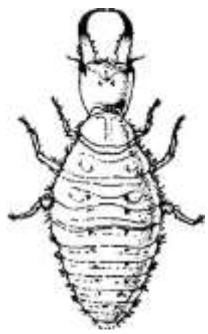
Antenna : Very short, bristle like, setaceous
Eyes : Compound eyes are large. Ocelli- Three
Mouthparts : Adapted for biting, Mandibles are strongly toothed Lacinia andgalea are fused to form mala which is also toothed
Wings : Membraneous, venation is net work with many cross veins. Wingshave a dark pterostigma towards the costal apex. Sub costa ends innodus. Wing flexing mechanism is absent.
Legs :Basket type arrangement, 3 segmented tarsi, They are suited forgrasping, holding and conveying the prey to the mouth.
Abdomen :Abdomen is long and slender, In male gonopore is present on 9^{th}abdominal segment. But the functional copulatory organ is presenton the 2nd abdominal sternite. Before mating sperms are transferredto the functional penis. Female have gonopore on 8th segment.
Metamorphosis : Incomplete with three life stages. The Nymphs (called naiad) isaquatic. Labium is greatly elongated, jointed and bears two hooks atapex. It is called mask. It is useful to capture the prey.
Sub-orders : Anisoptera (Dragonfly) and Zygoptera (damselfly)
Importance : Adults are aerial predators. They are able to catch, hold and devourthe prey in flight. Naiads are aquatic predators. Dragonflies anddamselflies can be collected with an aerial net near streams andponds especially on a sunny day. Naiads can be collected fromshallow fresh water ponds and rice fields.

Order- Neuroptera (Neuro=nerve; ptera=wing)

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

Characters





Body : Soft bodied insects
Antenna : Filiform, with or without a terminal club
Mouthparts : Chewing type in adults
Wings : Wings are equal, membranous with many cross veins, held in a roof-likemanner over the abdomen, weak fliers
Larva : Campodeiform with mandibulo-suctorial mouthparts

Pupa : Exarate, Pupation takes place in a silken cocoon, Six out of eightMalpighian tubules are modified as silk glands. They spin thecocoonsthrough anal spinnerets.

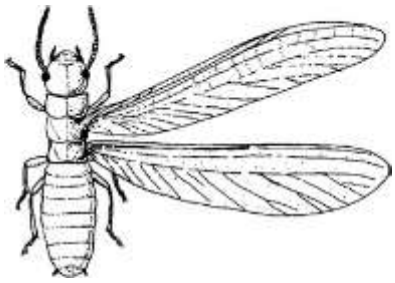
Sub-orders : Megaloptera and Planipennia

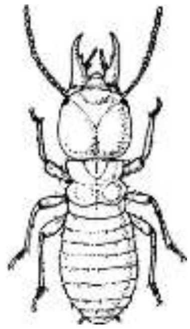
Planipennia : **Families**

1. **Chrysopidae:** Body pale green in colour, eyes are golden yellowin colour, pedicellate/stalked eggs to avoid cannibalism andpredation, larvae prey on soft bodied insects especially on aphids,exhibits camouflage with debris, biocontrol agents, mass multipliedeasily for pest control in field. (e.g. Green lacewings, Goldeneyes,Stinkflies, Aphid lions)
2. **Mantispidae:** Resemble preying mantids, larvae predaceous(e.g.Mantispidflies).
3. **Myrmeleontidae:** Resemble damselfly (Ant lions)
4. **Ascalaphidae:** resemble dragonfly (Owlflies)

Order- Isoptera (Iso=equal; ptera=wing)

Synonyms : Termitina / termitida / SocialiaCommon names : Termites, White ants **Characters**





Body : Minute to large sized and soft

Head : Prognathus, characteristic depression **"Fontanella"** is present onthedorsum of head

Mouthparts : Biting and chewing type

Eyes : Compound eyes present in the winged form; in apterous form itmay ormay not be present; Ocelli 0 – 2

Antenna : Short and moniliform

Wings : Identical in size, form and venation, two pairs, membranous andsemi transparent. Wings are extended beyond abdomen and flexedover abdomen when at rest.

Abdomen : Broadly joined to the thorax without constrictionCerci : Short

Genital organs : Externally lacking in both sexes

Specialities : They are ancient polymorphic, **social insects** living in coloniesExamples Termites- *Odontotermusobesus*, *Eutermusheimi*, *Microtermesanandi*

Caste system is existing in isopteran.

Termite castes

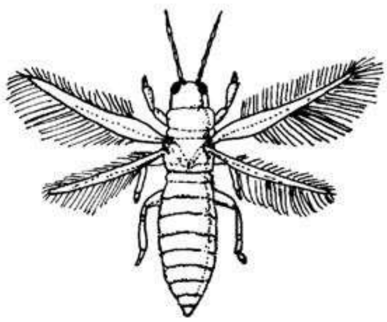
1. Reproductives	**2. Non-reproductives (sterile)**
King	**Workers** (dominate the colony, usually blind and apterous)
Queen	**Soldiers**- (a) mandibulate (b) Nasute (defend the colony)

Order: Thysanoptera (Thysano-fringe; ptera- wing)

Synonyms : Physopoda

Common names : Thrips

Characters



Body : Minute, slender, soft bodied insects

Mouthparts : Rasping and sucking type, Mouth cone is formed by the labrum andlabium together with basal segments of maxilla. There are threestylets derived from 2 maxillae and left mandibles. **Right mandibleis absent**. Hence mouth parts are asymmetrical.

Antenna : Moniliform

Eyes : Compound eyes well developed, ocelli present in alate form

Wings : Either present or absent, when present very narrow and **fringedwith hairs** which increase the surface area, weak fliers and passiveflight in wind is common

Legs : Ambulatorial, Tarsus is with one or two segments, At the apex ofeach tarsus a protrusible vesicle is present.

Abdomen : 11 segmented, pointed. An appendicular ovipositor may be presentor absent

Cerci : absent

Metamophosis : Paurometabola/gradual, Nymphal stage is followed by prepupaland pupalstages which are analogous to the pupae ofendopterygote insects.

Sub-orders : Terebrantia (Important family is **Thripidae**) and tubulifera(ovipositor absent, tubular abdomen, Wing venation is absent)

EconomicImportance : Most of the thrips species belong to the family Thripidae and arephytophagous. They suck the plant sap. Some are vectors of plantdiseases. Few are predators.

Examples : Rice thrips, *Stenchaetothripsbiformis*and Onion thrips, *Thripstabaci*

Practical -11To study of characters of order Hemiptera and its familiesOrder –Hemiptera
(Hemi - half; ptera – wings)

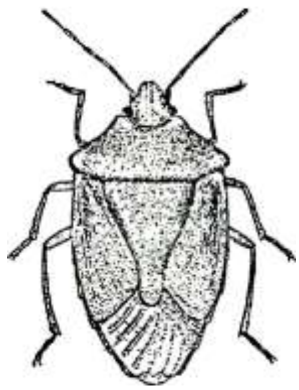
Synonyms

: Rhynchota

Common names

: True bugs

Characters



Body : Minute to large sized

Head : Opisthognathous

Mouthparts : Piercing and sucking type, 2 pairs of bristle like stylets which are the modified mandibles and maxilla are present. Stylets rest in thegrooved labium or rostrum

Antenna : Mostly with 4 or 5 segments

Thorax : Mesothorax is represented dorsally by scutellum.

Wings : Forewings are mostly hemelytra basally coriaceous anddistallymembranous

Cerci : Always absent

Metamorphosis : Usually gradual, rarely complete

Alimentary canal Modified into **filter chamber** to regulate liquid food

Sub-orders : Heteroptera (Hetero -different; ptera - wing) andHomoptera (Homo -uniform; ptera - wing)

Characters	**Heteroptera**	**Homoptera**
Forewings	heavily sclerotized at the base, hemelytra	Uniformly textured
Wings at rest	Held flat over the abdomen	held roof like over the back

Head porrect or
horizontal deflexedBases of forelegs do not
touch the headtouch the head

Habitat Both terrestrial and aquatic Only
terrestrial (Herbivorous)(Herbivorous, predaceous or bloodsucking)
Glands Odoriferous or scent glandsWax glands usually present
present

Honeydew secretion	uncommon	Common
Scutellum (Triangular plate found Betweenthe wing bases)	well developed	Not well developed
Antenna	Relatively long	Short
Ocelli	Dorsal ocelli 0 or 2	2 or 3

Families of Hetroptera sub-order

Family: Coreidae (Squash bugs / Leaf footed bugs)

Members with many branching veins arising from a transverse basal vein. Stink glandsare found inside the metathorax and glands opening are found on the sidesof the thoraxbetween middle andhind coxae. They emits disagreeable / foul pungent odour. Hind tibiaand tarsi are expanded and leaf like. Nymphs and adult suck the sap from the panicles orpods of pulses.

e.g. Rice gundhi bug- *Leptocorisaacuta*, Pod bug- *Riptortuspedestris*

Family: Pyrrhocoridae (Red bug or Stainer)

They are elongate oval bugs. They show warning colouration. They are brightly markedwith red and black. Feeding injury caused by these bugs leads to the contamination by thefungus Nematospora resulting in yellowish brown discolouration of the lint.

e.g. Red cotton bug- *Dysdercuscingulatus*

Family: Reduviidae (Assassin bugs or Kissing bugs)

Predaceous insects, Head is narrow elongated and beak like. The portion behind thecompound eyes is narrow and resembles a beak. The rostrum is short and three segmentedantenna is filiform. Abdomen is broad in the middle. The lateral margins of the abdomen areexposedbeyond the margin of the wings. e.g. *Rhynocorismarginatus*- predators on bees andother pests.

Families of Homoptera sub-order

Family: Jassidae or Cicadellidae (Leaf hoppers and Jassids)

Insects have wedge shaped body with attractive colour. Hind tibiae have a double rowof spines. Ovipositor is modified for lacerating plant tissue. Nymphs and adults have thehabits of running sidewise. They suck the plant sap and also transmit the viral disease.e.g. Green leaf hopper- *Nephotettixvirescence*transmits the Rice tungro virus disease.

Family: Delphacidae (Plant hoppers)

Large mobile flattened spur is present at the apex of hind tibia. It causes hopper burn,transmits viral disease in rice. e.g. Brown plant hopper- *Nilaparvatalugens*

Family: Lophopidae (Aeroplane bugs)

Head is produced into snout. Hind trochanter is directed backward. Hind basitarsus ismoderately long. Both nymph and adult suck the sap and reduce the quality and quantity ofcane juice. e.g. Sugarcane leaf hopper- *Pyrillapurpusilla*

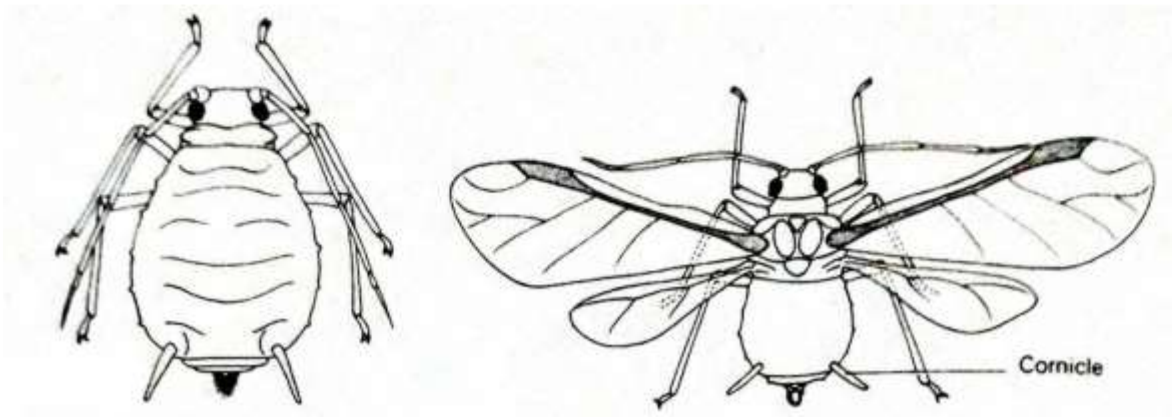
Family: Aleyrodidae (Whiteflies)

Minute insects, which superficially resemble like tiny moths. Wings are opaque anddusted with mealy white powder wax. Wing venation is much reduced. Vasiform orifice ispresent in the last abdominal tergite. It is conspicuous opening provided with an operculum.Beneath the operculumthere is a tongue-like organ termed ligula. The anus opens at thebase of the ligula through which the honey dew is excreted in large amount. Immatureinstars are sessile, scale like, with wax covering. Metamorphosis approaches theholometabolous type due to the presence of a quiescent stage prior to the emergence ofadults. It transmits vein clearing/mosaic disease in Bhendi (Okra).

e.g. Cotton whitefly-*Bemisiatabaci*

Family: Aphididae (Aphids or Plant Lice)

Body is pear shaped. Both apterous and alate forms are found. A pair of cornicles orsiphonculi orwax tube or honey tube is present in the dorsum of 5th or 6th abdominalsegments which secretes wax like substance. The chief constituents are being Myristic acid,sugars and water. Theyexcrete copious amount of honey dew on which ants feed and sootymould fungus grows. Aphids are known for their extraordinary fecundity, short life cycleand parthenogenitic reproduction. Life cycle is highly complex and it involves alteration ofgeneration. They feed on plant sap and disseminate plant diseases. e.g. Cotton aphid –*Aphisgossypii*



Family: Kerridae or Lacciferidae (Lac Insect)

Females are highly degenerate without legs, wings and antennae. The body is irregularglobular. Body is enclosed in a thick resinous cell. Dermal glands secretion of this insectprovides the stick lac. e.g. Lac insect – *Lacciferlacca*

Family: Pseudococcidae (Mealy bug)

Body is elongate, oval in shape. Body segmentation is distinct. Body is covered by longradiating thread of mealy secretion. Functional legs are present in all instars. Wings areabsent. Nymph andadults suck the sap and affect the growth of spindle leaf. e.g. Coconutmealy bug-*Pseudococcuslongispinus*.

Family: Cicadidae (Cicadas)

Males have sound producing organs at the base of the abdomen. Sound producingorgans consistsof a pair of large plates, the opercula covering the cavity containingstructures producing sound.

In the anterior part of the cavity beneath each operculum is ayellowish membrane. A shining mirror is located in the posterior part of the cavity. In thelateral wall of the cavity is an oval shaped ribbed structure, the tymbal. These are vibratedby strong muscles to produce sound. Each species has a characteristics song. Tympanum ispresent in both the sexes. Wings are transparent. Eggs are inserted into the tree twigs by thefemale. Nymphs drop to the ground, enter the soil and feed on root sap. Anterior femurs ofthe nymph are thickened with spines beneath and are suited for digging the soil. Life cycleof periodical cicada lasts for 13- 17 years.

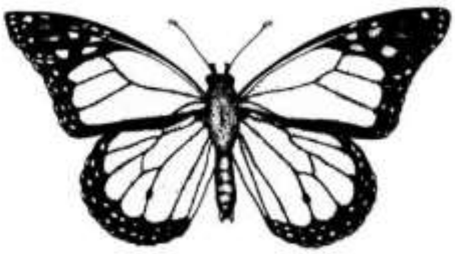
Practical- 12To study of characters of order Lepidoptera and its familiesOrder: Lepidoptera

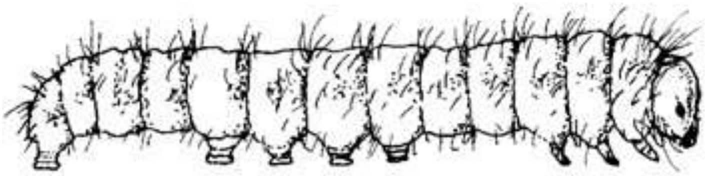
(Lepido- scale; ptera- wings)

Synonyms : Glossata

Commonnames : Butterflies, moths and skippers

Characters





Body : Body, wings and appendages are densely clothed with overlappingscales,which give colour, rigidity and strength. They insulate the bodyand smoothen air flow over the body.

Mouthparts : Mouthparts in adults are of **siphoning type**. Mandibles are absent. The**galeae of maxillae are greatly elongated** and are held together byinterlocking hooks and spines. The suctorial proboscis is coiled up likeawatch spring and kept beneath the head when not in use.

Wings : Wings are membranous and are covered with overlapping **pigmentedscales**. Forewings are larger than hind wings. Wings are coupled byeither frenate or amplexiform type of wing coupling.

Larvae : Larvae are **polypod-eruciform** type. Mouthparts are adapted forchewingwith strong mandibles.There are three pairs of five segmented thoracic legs ending in claws.Two to five pairs of fleshy unsegmented **prolegs** are found in theabdomen. At the bottom of the proleg, **crochets** are present.

Pupae : Pupa is generally **obtect**. It is either naked or enclosed in a cocoonmade out of soil, frass, silk or larval hairs.

Sub-orders : **Ditrysia and Monotrysia**

Most of the lepidoptern insects **(97 %)** are grouped under the **suborder Ditrysia** in which thefemale insects have **two pores i.e., the copulatory pore** is located in the **8th** abdominalsternite and the egg pore in the **9th** abdominal sternite. Remaining insects are grouped underthe **suborder Monotrysia** in which the female insects have **one pore.**

Butterfly Family

3. Papilionidae (Swallotail Butterfly)

They are often large and brightly coloured (Fig. on cover page). Prothoracic legs havetibial epiphysis. In many species hind wings has tail like prolongation. Amplexiform type ofwing coupling is present. Larval body is either smooth or with tubercles. RetractileOsmeteria are present on the prothoracic tergum of the caterpillar. e.g. Citrus butterfly,*Papiliodemoleus*

4. Pieridae (Whites and sulphurs)

They are white or yellow or orange coloured with black markings. Larva is green,elongate and covered with fine hairs. Larval body segments have annulets. e.g. Cabbagewhite butterfly,*Pierisbrassicae*

Moth Family

7. Arctidae (Tiger moth)

Wings are conspicuously spotted or banded. They are nocturnal and attracted to light.Larva is either sparsely hairy or densely hairy (wooly bear). e.g. Spotted boll worm, *Eariasvitella*, Sunhemp caterpillar, *Utetheisapulchella*

8. Bombycidae (Silk worm moths)

Antenna is bipectinate. Larva is either with tuft of hairs or glabrous with medio dorsalhorn on8th abdominal segment. Pupation occurs in dense silken cocoon. e.g. Mulberry silkworm, *Bombyxmori*

9. Gelichidae (Paddy moths)

Forewings trapezoidal and narrower than hind wing. Caterpillars bore into the seedstubers and leaves. e.g. Cotton pink boll worm, Pectinophora gossypiella, Angumous grainmoth, *Sitotrogacerealella*, Potato tuber moth, *Pthoremeaoperculella*

10. Noctuidae (Noctua moths)

They are medium sized, stoutly built moths. They are nocturnal and attracted to lights.Labial palpi is well developed. All crochets on the larval prolegs are of same size andarranged in semi circle. Some larvae are semiloopers. They have either 3 or 4 pairs ofprolegs. Larvae attack the plants during night. Larvae of some species remain concealedbeneath the surface of the ground or litter during day and feed on plants during night. Theyoften cut small seedlings close to the ground and hence they are called cut worms. e.g.Tobacco cut worm, *Spodopteralitura*

11. Pyraustidae/ Pyralidae

Proboscis is vestigial in many species. Labial palp is snout like. Larval habit varies. Itmay live among aquatic plants and bore into the stem or remain in silken web among spunup plants parts. Some larvae are aquatic and gill breathing. e.g. Rice stem borer, *Scirpophagaincertullus*

12. Saturniidae (Moon moth, giant silk worm moth)

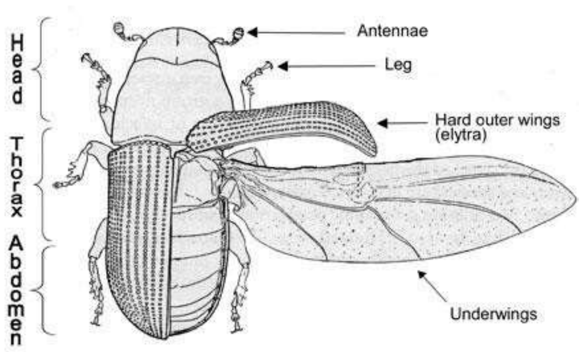
They are large sized moths. Antenna is bipectinate. Transparent eye spots are presentnear the centre of each wing. The spots are either circular or crescent shaped. Larva is stoutand smooth with scoli. Cocoon is dense and firm.e.g. Tusor silk worm, *Anthereapaphia*,which yields silk.

Practical- 13To study the characters of order Coleoptera and its familiesOrder: Coleoptera
(Coleo-Sheath; petra- wing)

Synonyms : Elytroptera

Common names : Beetles, Weevils

Characters



Body : Minute to large sized insects

Antenna : 11 segmented

Mouthparts : **Chewing and biting** type, Mandibles are short with blunt teeth atthe mesal face in phytophagous group, In predators the mandiblesare long, sharply pointed with blade like inner ridge. In pollenfeeders teeth are absent and the mandibles are covered with stiffhairs.

Thorax : Prothorax is large, distinct and mobile. Mesothorax and metathoraxare **fused** with the first abdominal segment. Forewings are heavilysclerotized, veinless, hardened and called **elytra**.

Wings : Forewings are heavily sclerotised, veinless and hardened. They arecalled elytra. Forewings do not overlap and meet mid-dorsally toform a mid-dorsal line. It is not used for flight. They serve as a pairof convex shields to cover the hind wings and delicate tergites ofabdomen. Hind wings are membranous with few veins and areuseful in flight. At rest they are folded transversely and keptbeneath the elytra. In some weevils and ground beetles theforewings are fused and hind wings are atrophied.

Abdomen : Cerci and a distinct ovipositor are absent.

Development : Metamorphosis is complete. Larvae are often called grubs. Pupae are usually exarate and rarely found in cocoons.

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

Sub-orders : **Adephaga (predators/ devourers) and Polyphaga (eaters of manythings).**

Families of predators : Cicindelidae (Tiger beetle), Carabidae (Ground beetle), Dytiscidae(True water beetle), Gyrinidae (whirligig beetle), Coccinellidae (Lady bird beetle),Lampyridae (Firefly, glow worm)

Families of scavengers : Scarabaeidae (Scarabs, dung beetle), Hydrophilidae (waterscavenger beetle)

Families of stored product pests:

Anobiidae (Wood worm/ wood borer) e.g. Cigrette beetle- *Lasiodermaserricorne*Bostrychidae (Grain borer) e.g. Lesser grain borer -*Rhizoperthadominica* **Families of crop pests:**

6. **Apionidae** e.g. Sweet potato weevil, *Cylasformicarius*, a pest both in the field and instorage.Head is produced into snout. Antennae are not elbowed. Grubs are apodous.

7. Cerambycidae (Longicorn beetles/ Longhorn beetles)

e.g. Mango stem borer, *Batocerarufomaculata*

8. Curculionidae (Weevils/ snout beetles)

Minute to large sized insects. Frons and vertex of the head produced into snout, which iscylindrical and in some species larger than the beetle itself. Mouthparts (mandible andmaxilla) are present at the tip of the snout, It is useful to feed on internal tissues of the plantand provide a place for egg laying. Antenna is geniculate and usually found in the middle ofthe snout. Grubsare apodous and acephalous. Weevils are important crop pests during bothin field and in storage. e.g. Coconut red palm weevil, *Rhynchophorusferrugineus*

9. Galerucidae / Chrysomelidae (Pumpkin beetle)

Antenna are closely approximated. Third tarsomere is deeply bilobed. Larvae are rootfeeders. Adults bite holes on plants.Red pumpkin beetles, *Raphidopalpafoevicollis*

10. Melolonthidae (Chaffer beetle, June beetle, White grub)

They are stout beetles with glossy surface. Head is small. Labrum is well sclerotized.Adults are attracted to lights. They feed on tree foliage during night and hide in soil duringday time. Larvae are scarabaeiform and root feeders. e.g. Groundnut white grub, *Holotrichiaconsanguinea*, a serious pest under rainfed conditions.

Families of Predators:

2. Coccinellidae (Lady bird beetle)

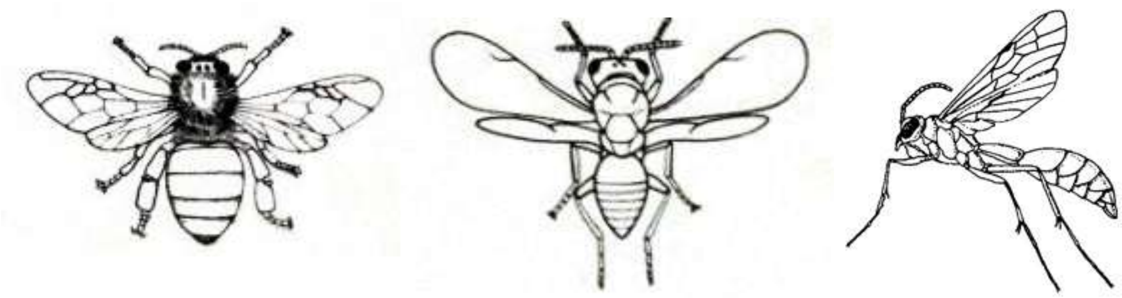
They are hemispherical insects. The body is convex above and flat below. The bodyappearance resembles like a split pea, head is small, turned down ward and received into aprominent notchof prothorax. Elytra is strongly convex, brightly coloured and variouslyspotted. Grubs are campodeiform and spiny. The last larval skin either covers the pupa andgets attached to its anal end. Except the genus Epilachna others are predators on aphids,scales, mites and whiteflies. e.g. *Coccinellaseptupunctata, Coccinellavigintioctopunctata*

Practical- 14To study the characters of order Hymenoptera and Diptera and their familiesOrder: Hymenoptera

(Hymen- membrane; ptera- wings), (Marriage on wings)

Common names : Sawflies, ants, bees, and wasps

Characters



Mouthparts : Primarily adapted for chewing, Mandibles are very well

developed.In bees both labium and maxillae are integrated to form the **lappingtongue**.

Thorax : Modified for efficient flight. Pronotum is collar like. Mesothorax isenlarged. Metathorax is small. Both prothorax and metathorax arefused with mesothorax.

Wings :Stiff and membranous. Forewings are larger than hindwings. Wingvenation is reduced. Both forwings and hindwings are coupled by arow of hooklets (**hamuli**) present on the leading edge of thehindwing.

Abdomen :Basally constricted, The first abdominal segment is called**propodeum**. It is fused with metathorax. The first pair of abdominalspiracles is located in the propodeum. The second segment is knownas **pedicel** which connects the thorax and abdomen. Abdomenbeyond the pedicel is called **gaster** or **metasoma**.

Ovipositor :Always present in females. It is variously modified for oviposition

orstinging or sawing or piercing plant tissue.

Metamorphosis : Complete

Larva :Often the grub is apodous and eucephalous.

Larva is rarely eruciform.

Pupa : Exarate and frequently enclosed in a silken

cocoon secreted fromlabial glands
Sex determination : Fertilized eggs develop into females and males are produced from
unfertilized eggs.
Importance : Productive and beneficial insectsSub-orders : **Symphyta and Apocrita**

Suborder Symphyta- Abdomen is broadly joined with thorax, stemmata present, ovipositorissaw like and suited for piercing plant tissues, habits are phytophagous ,e.g. sawflies andhorntails **Family: Tenthrinidae (Saw flies)**
They are wasp like insects. Abdomen is broadly joined to the thorax. Ovipositor is sawtoothed and suited for slicing the plant tissue. Larva is eruciform. It resembles a lepidopterncaterpillar. It has 1 pair od ocelli, papillae (reduced antanna), 3 pairs of thoracic legs and6-8pairs of abdominallegs.Prolegs lack chrochets. They are external feeder on the foliage.Larvae while feeding usually have posterior part of the body coiled over the edge of the leaf.(Mustard Sawfly, Athlia lugens proxima is a defoliator of mustard and cruciferous vegetables.

Suborder Apocrita– Abdomen is petiolated, Stemmata are absent, Legs are absent,ovipositor is not saw like and Suited for piercing or stinging,they are generally parasitic.

Family:Apidae (Honey bee)

Body is covered with branching or plumose hairs. Mouth parts are chewing andlapping type. Mandibles are suited for crushing and shaping wax for building combs. Legsare specialized for pollen collection. Scopa (pollen basket) is present on hind tibia. They aresocial insects with 3 castes viz. Queen, drone and workers.Division oflabour is noticedamong honey bees. Indian honey bee, *Apisindica*

Formicidae (Ants)

They are common widespread insects. Antennae are geniculate. Mandibles are welldeveloped. Wings are present only in sexually mature forms.Petiole may have 1 or 2 spines.They are social insects with 3 castes viz. Queen, males and workers. Workers are the sterilefemales and theyform the bulk of the colony. Exchange of food materials between adultsand immature insects is common. After a mating flight queen alone finds a suitable nestingsite.Many species have associated symbiotic relationship with homopteran insects.

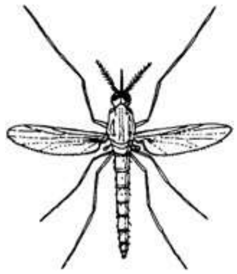
Braconidae (Braconid wasp)

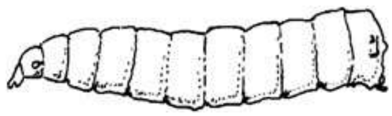
They are small, stout bodied insects. Fore wing has one recurrent vein. Petiole is neithercurved nor expanded at the apex. Gaster is sessile or subsessile. Abdomen is as long as headand thorax together. They parasitize lepidoptern larvae commonly. They are gregariousparasites. In many species, Polyembryony is observed. Bracon brevicornis is mass multipliedand released for the control of black headed coconut caterpillar.

Order- Diptera (Di-two;ptera-wings)

Common names : True flies,Mosquitoes,midges,gnats

Characters





Body : Small to medium sized, soft bodied insects

Antenna : Often hemispherical and attached to the thorax by a slender neck

Mouthparts : Sucking type

Thorax :Fused together. The thoracic mass is largely made up ofmesothorax.

Wings : Single pair of wings. Forewings are larger, membranous andusedfor flight. Hind wings are highly reduced, knobbed at the end andare called **halteres**

Metamorphosis : Complete

Larvae : Larvae of more common forms are known as maggots. They are**apodous** and **acephalous**.

Pupa : Pupa is generally with free appendages, often enclosed in thehardened last larval skin called **puparium**. Pupa belongs to thecoarctate type.

Sub-orders : **Nematocera (Thread-horn), Brachycera (Short-horn) andCyclorrhapha(Circular-crack)**

Families of agricultural Importance:

Syrphidae (Horse flies, Flower flies)

They are brightly coloured and brilliantly stripped. A vein like thickening is present inbetween the radius and median in the forewing. Abdomen has distinct black and yellowmarkings. Maggots prey on soft bodied insects especially aphids. Adults are excellent fliers.They hoverover flowers. They feed on pollen and nectar. They aid in pollination.

Tephritidae (Fruit flies)

Sub costa bends apically and fades out. Wings are spotted or banded. Female has asharp and projecting ovipositor. Maggots can hop. They are highly destructive to fruits andvegetables. Cucurbit fruit fly, *Dacuscucurbitae*.

Tachinidae (Tachinid flies)

Arista is completely bare. Abdomen is stout with severalnoticeable bristles.They arenon specificendoparasite on the larvae and pupae of Orthoptera, Hemiptera, Lepidopteraand Coleoptera.

Practical- 15To study the Insecticides and their formulations.

Insecticide formulations

After an insecticide is manufactured in a relatively pure form (technical grade), it mustbeformulated before it can be applied. Formulation is the processing of the technical gradeby various methods which is done to make the product safer, more effective and moreconvenient to use. Formulation is the final physical condition in which the insecticide is soldcommercially. In aformulation, there are one or more chemicals (formulants) which are theactive ingredients (a.i.) and other ingredients which have no pesticide action (inertingredients). There are mainly three types of pesticide formulations (liquid, solid and gas).
A single pesticide may be sold in more than one formulation. Formulation type depends onseveral factors:

- toxicology of the active ingredient,
- chemistry of the active ingredient,
- how effective the product is against the pest,
- the effect of the product on the environment (plant, animal or surface etc.),
- how the product will be applied and the equipment needed the application rate.

Characteristics of an Appropriate Insecticides Formulation

- Highly toxic to target insects.
- Not repellent or irritant to target insects
- Long-lasting
- Safe to humans and domestic animals
- Stable during storage and transportation
- Cost-effective

TYPE OF FORMULATIONS

Emulsifiable Concentrates (EC)

- It consists of a technical grade material, organic solvent and a emulsifier.
- Emulsifier makes the water insoluble toxicant to water soluble
- When an emulsifiable concentrate is added to water and agitated (i.e., stirredvigorously), the emulsifier causes the oil to disperse uniformly throughout the carrier(i.e., water) producing an opaque liquid (oil in Water suspension).
- A few formulations are Water in oil suspension. These are opaque and thick, employedas herbicide formulations, because they result in little drift.
- These are easy to transport and store, and require little agitation in the tank. However,care must be exercised in handling the toxic concentrates.

- Shelf life approximately 3 years
- More than 75% of all insecticides formulations are applied as sprays.
- Examples : Quinalphos 25EC, Dimethoate 30EC, Chlorpyriphos 20EC.

Dusts (D)

- Simplest of all formulations and the easiest to apply.
- The technical material (active ingredient) is mixed with an inert diluents carrier suchasclay, organic flour, pulverised minerals.
- In a formulated dust, the following two types of mixtures are usually found :

Undiluted toxic agent, e.g., sulfur dust used for control of mites and powdery mildew and**Toxic** a.i. plus an inert diluent. This is the most common dust formulation sold as 2%,5%, or 10% a.i dust.

- Concentration of dust formulation ranged between 0.1% to 25%
- Particle size of dust particles 1-40 μ pass through 325 mesh sieve.
- Least effective and cause wind drift leading to poor deposit on surface. It has beencalculated that not more than 10-15% of the applied material is retained on the surface.
- Highly toxic to beneficial insects.
- Example : Carbryl 5 D, Malathion 5D.

Granules (G)

- The chemical is in the form of small granules of inert material, either as a coating onthesurface of the inert granules, or as an impregnated toxicant in the granules.
- Consist of small pellets of the active ingredients sprayed on to clay and allowingsolventsto evaporate
- Size: 0.25 – 0.38 mm (20-80 mesh or 30-60 mesh i.e (i.e., the number of grits(granules)per inch of the sieve through which they have to pass).)
- The amount of active ingredient varies from 2-10 per cent.
- Used mainly as systemic insecticides and can be applied on to the soil, or may beplacedin the whorl of leaves depending on the nature of pest control required.
- Granular insecticides may be more economic since precise applications are possiblewiththem.
- Much safer to apply than dusts and are generally less harmful to beneficial insects suchasbees.
- Example : Carbofuran 3G, Phorate 10G, Cratap 4G.

Wettable Powders (WP)

- Concentrated dusts containing a inert diluents (50-75% talc or clay) and a wetting agenttofacilitate mixing the powder with water before spraying.
- Much more concentrated than dusts, containing 15 to 95 per cent active ingredient.
- Do not dissolve washers and rubber hoses;do not damage materials sensitive toorganicsolvents

- Leave effective residues in cracks and crevices and are not phytotoxic.
- Require frequent agitation and cause corrosion of valves, nozzles and pumps andsprayers
- Should never be used without dilution.
- These are easy to carry, store, measure, and mix. However, care must be taken toprotectagainst inhalation during handling.
- Example: Carbaryl 50WP, Sulfur 80WP, Bacillus thurnigiensis var. kurstaki 5WP.

Soluble Powders (SP or WSP)

- Contain a finely ground water soluble solid which dissolves readily upon the additionofwater forming true solution.
- Do not require constant agitation and forms no precipitate.
- The amount of active ingredient in soluble powder ranges from 15-95% by weight; itisusually not more than 50%.
- Soluble powder have all the advantages of wettable powders except the inhalationhazardduring mixing.
- Example: Cartap hydrochloride 50SP, Acephate 75SP.

Water Dispersible Granules (WDG)

- Water dispersible granules, or dry flowables is a relatively new type of formulation andbeing developed as safer and more commercially attractive alternatives to wettablepowders and suspension concentrates formulations.
- They are becoming more popular because of convenience in packaging and use, nondusty,free-flowing granules which should disperse quickly when added to water in thespray tank.
- They therefore represent a technological improvement over wettable powders. Thedispersion time in water is a very important property and to ensure that no problemsshould occur during mixing in the spray tank.
- It is necessary for all the granules to disperse completely within two minutes in varyingdegrees of water temperature and hardness.
- Example: Endosulfan 50 WG, Cypermethrin 40 WG, Thiamethaxam 25 WG,Deltamethrin 25 WG.

Suspension Concentrates (SC)

- Pesticide particles maybe suspended in an oil phase, but it is much more usualforsuspension concentrates to be dispersed in water.
- A stable suspension of solid pesticide(s) in a fluid usually intended for dilution withwaterbefore use. Ideally, the suspension should be stable (i.e. not settle out).
- The active ingredient range between 0.1-60%.
- A.I. must be water insoluble with friable crystals, Easy to tankmix (very compatible) -

A.I. tends to settle out over time.

- Farmers generally prefer suspension concentrates to wettable powders because theyarenon-dusty and easy to measure and pour into the spray tank.
- Example: Fipronil 5 SC, Sulphur 52 SC.

Microencapsulation/Capsule Suspensions (CS)

- The polymer membrane, or microencapsulation technique, has become popular inrecent years.
- These are particles of pesticide, either solid or liquid encapsulated by polymericcoatings. Microcapsule solids are suspended in water as a concentrate and dilutedproduct (1:100 to 1:1000) is applied in spray solution to soil or foliar canopy.
- The rate of release of the active ingredient can be controlled by adjusting themicrocapsule/droplet size, the thickness of the polymer membrane and the degree ofcross-linking or porosity of the polymer.
- Example: Lambda Cyhalothrin 10 CS, Lambda Cyhalothrin 25 CS etc

O/W Emulsions (EW)

- Oil-in-water emulsions are now receiving considerable attention reduced or eliminatedvolatile organic compounds (VOCs) for safer handling.
- They are water based, oil-in-water emulsions can have significant advantages overemulsifiable concentrates in terms of cost and safety in manufacture, transportation anduse.
- The active ingredient must have very low water solubility to avoid crystallizationissues.
- Example: Butachlor 50 EW, Cyfluthrin 5 EW, Tricontanol 0.1 EW etc

Flowable Suspension (FS)

- Flowable suspensions are concentrated 40% to 70% w/w suspensions of micronizedinsoluble active pesticide in water.
- FSs must be formulated for low viscosity and good fluidity, so that transfer to the spraytank is easy and complete. This requires an effective wetting agent and an efficientdispersing agent to ensure adequate dispersion of the pesticide in the water. Since theactive ingredients in FSs are insoluble, good suspension stability is essential.
- If the suspension settles and leaves sediment at the bottom of the container, theapplication of the pesticide may be too weak to be effective.
- A combination of smectite clay (bentonite) and xanthan gum works synergistically toprovide excellent long term suspension stability at low viscosity and at low cost.
- Example: Thiram 40 FS, Thiamethoxam 30 FS, Tebuconazole 5.36 FS

Microemulsions (ME)

- Microemulsions are thermodynamically stable transparent dispersions of twoimmiscibleliquids and are stable over a wide temperature range.

- Involves the incorporation of the insecticide in a permeable covering, microcapsulesorsmall spheres with diameter ranging from 1-50 μ.
- The total concentration of surfactants for a microemulsion can be as high as 10–30%ormore, compared with about 5% for a typical o/w emulsion.
- The insecticides escape through the small sphere wall at a slow rate over anextendedperiod of time.
- Microemulsions have relatively low active ingredient concentrations, but the highsurfactant content and solubilisation of the active ingredient may give rise to enhancedbiological activity.
- Example: Neemazal 30 MEC, Pyrithiobac Na 5.4 + Quizalofop-P-Ethyl 10.6 ME.

Oil Dispersion Formulations

- One of the latest formulation types is oil dispersions (ODs). This technology allows veryefficient and environmentally friendly agrochemical formulations.
- In ODs the solid active ingredient is dispersed in the oil phase, making it especiallysuitable for water-sensitive or non-soluble active ingredients.
- The oil-phase can comprise different oils such as mineral oils, vegetable oils or esters ofvegetable oils.
- Special attention is needed with the auxiliaries in ODs: suitable oil-compatibledispersing agents and emulsifiers adjusted to the type of oil which forms a stableemulsion after dilution with water.

ZW Formulation of CS & EW

- A mixed formulation of CS and EW is a stable suspension of microcapsules of the activeingredient and fine droplets of active ingredient(s) in fluid, normally intended fordilution with water before use.
- In the case of microcapsules, the active ingredient is present inside discrete,inert,polymeric microcapsules.
- The formulation is intended for dilution into water prior to spray application. Mixturesof active ingredients one of which is encapsulated are used to provide a broaderspectrum of pest control.
- Formulating the active ingredients together eliminates the need for tank mixing (whichcan lead to incompatibilities).
- Example: Lambda Cyhalothrin-25.0 CS + Chloropyriphos-10.0 EW

Flowable Powder (FP)

- The technical material is wet milled with a clay diluent and water with a suspendingagent, a thickener and anti freeze compound forming a thick creamy pudding likemixture which mixes well with water.
- Needs constant agitation to prevent the insecticide from coming out

of suspension andsettling.

Oil solutions

- Formulated by dissolving the insecticides in an organic solvents for direct use in insectcontrol
- Rarely used on crops as they cause severe burning of foliage.
- Effective on livestock, as weeds sprays along roadsides, in standing pools formosquito‘s larvae control, and in fogging machines for adult mosquito control.

Aerosols

- Most common of all formulations for home use
- Consists of toxicant (2%), solvent (10%), knockdown agent (2%) and propellant (86%).
- The active ingredients soluble in volatile petroleum oil is kept under pressure providedbypropellant gas
- When solvent is atomized, it evaporates quickly leaving behind small droplets oftheinsecticides suspended in air
- The toxicant is suspended as minute particle (0.1 - 50 w/w) in air as a fog or mist.
- Used for the knockdown and control of flying insects and cockroaches, but theyprovideno residual effect.
- Caution must be taken when used as they produce droplets well below 10 μ,readilyabsorbed by alveolar tissues in the lungs.

Ultra low volume concentrates (ULV)

- Technical ingredient is dissolved in minimum amount of solvent 0.6 litre to 5.0 litre/hainvery small droplets of 1-15μ.
- Small droplets can better penetrate thick vegetation and other barriers
- Used for insect control in large areas where high volume of water constitutes atechnicaldifficulty.

Fumigants

- Gases or low volatile liquids of low molecular weight which readily penetrate thematerialto be protected
- Used for the control of insects in stored products, for soil sterilization.
- Most of the fumigants are liquid and are mixtures of two or more gases.

Fogging concentrates

- Used in control of adult flies and mosquitoes for public health.
- Fogging machines generate droplets of 1-10μ.

Smoke generators

- They are used in the form of coil like strips containing pyrethrum, oxidant and wooddustfor the control of mosquitoes. When ignited, these coils release vapours.

Impregnating materials

- Used in the treatment of woollens for moth proofing and timbers against wooddestroyingorganisms.

Poison bait

- Contains low level of toxicant incorporated in to material such as food stuffs,sugars,molasses etc. that are attractive to target pest.

LABEL INFORMATION

Every pesticide container has a label affixed on it with a leaflet. The label givesinformation of the pesticide in the container. The leaflet contains information on directionsto use warnings, disposal and storage. Both the lable and leaflet are statutorily requiredunder the Insecticide Act, 1968. The following information must be furnished on the label.

- Name of the pesticide (Brand name, Trade name, Common name), Name ofthemanufacturer and address, Registration number, Kind and name of active ingredientand their percentage, Types of formulation, Net content by weight, Batchnumber(assigned by manufacturer), Date of manufacture, Expiry date, Antidote statement
- Warming symbols and signal (warming symbol is of diamond shaped consisting oftwotriangles with a colour in the lower triangle and a signal in the upper triangle).

Practical -16To study the Pesticide appliances and their maintenancePlant Protection Equipments

SPRAYERS

Sprayer is a machine used to apply liquid chemicals on plants to control pest anddiseases. It can also be used to apply herbicides to control weeds and to spray micronutrientsto enhance plant growth. The main functions of a sprayer are

- Breaking the chemical solution in to fine droplets of effective size.
- Distributing the droplets uniformly over the plants.
- Applying the chemicals with sufficient pressure for positive reaching the plants
- Regulating the amount of liquid applied on plants to avoid excessive application.

A variety of high volume sprayers are available in the market. Almost all types of highvolume sprayers have some kind of pump to supply pressurised spray liquid to thehydraulic nozzle whichbreaks the liquid into spray droplets and throws the spray awayfrom it. The high volume sprayersare both manually operated or power operated type.

Principle: The function of sparyer is to atomize the spary fluid in to small droplets and ejectit with some force.

Parts of sprayers: The important parts are tank, agitator, pressure gauge, valves, filters,pressure chamber, hose, spray lance, cut off device, boom and nozzle.

Fig.1. Sprayer components

Nozzle body: It is the main component on which other component of a nozzle fit (Fig. 1a).
Swirl plate: It is the part of a cone nozzle which imparts rotation to the liquid passingthrough it(Fig. 1b).
Spray gun: It is a lance from which spray is readily adjustable during the operation.
Spray boom: It is a spray lance with spray nozzles fitted to a head, mounted at right anglesto thelance (Fig. 1d).
Filter: It is a component to remove suspended matter larger than a predetermined size fromfluid. **Over-flow pipe**: It is a conduit through which excess fluid from a pump is by-passed bytheaction of a relief valve or pressure regulator.
Relief valve: It is an automatic device to control the pressure of fluid or gas within rangeapredetermined value.
Pressure regulator: It is an automatic device to control the pressure of fluid or gas withinarange of settings.

Cut-off valve: It is a mechanism between the pump and the nozzle to control the flow ofliquidfrom the sprayer. This is operated by hand.
Nozzle disc: It is component containing the final orifice of a nozzle usually acone nozzle. **Nozzle boss**: It is a lug on spray boom or spray lance to which a nozzlebody or cap is screwed.**Nozzle tip**: It is component containing the final orifice of a nozzle usually afan nozzle.
Spray lance: A hand-held pipe through which the liquid reaches thenozzle mounted at the free end.
TYPES OF NOZZLE: The three common types of nozzle

d. **Hollow cone nozzle:** This liquid is fed into a whirl chamber through atangential entry or through a fixed spiral passage to give a rotatingmotion. The liquid comes out in the form of a harrow conical sheetwhich then breaks up into small drops. This is used for insecticide andfungicide spraying.
e. **Solid cone nozzle:** This nozzle covers the entire area at small range.The construction is similar to hollow cone nozzle with the addition ofan internal jet which strikes the rotating liquid just within the orifice ofdischarge. The breaking of drop is mainly due to impact. This is usedfor herbicide spraying.
f. **Fan nozzle:** It is a nozzle which forms narrow elliptical spray pattern. In this type theliquid is forced to come out as a flat fan shaped sheet which is then broken intodroplets. This nozzle is mostly used for low pressure

spraying.

a. Hollow cone nozzle b. Solid cone nozzle c. Fan nozzle

TYPES OF SPRAYERS:

F. Manually Operated Hydraulic Sprayers- In this type, the hydraulic pump directly actson the spray fluids and discharge it.

g. Hand syringe

It is a single acting pump working on the principle of cycle pump. it consists of cylinderin to which the spray fluid is drawn during the suction stroke and delivered during thepressure stroke and discharge through nozzle. It is useful to operate only a small area.

h. Hand Sprayers

This is a simple sprayer. It creates hydraulic pressure by forcing spray solution to anozzle by the direct action of hand pumping. The spray solution is filled in a plastic can (5-10 L) which is usually shoulder slung. A dip-tube draws liquid from the tank due to handactuation of the plunger. Held by both the hands the piston pump is worked by slidingaction. The capacity of thissprayer is about 0.5 acre per day. It is useful for small scalespraying in nursery or kitchen gardens and pot plants.

i. Bucket or Stirrup Pump Sprayer:

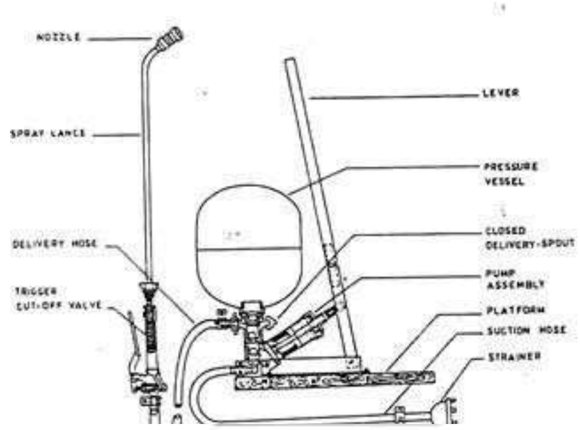
It consist either of a double acting pump with two cylinders or a single acting pumpwith one cylinder. The other parts of the sprayer are the plunger assembly, foot valueassembly, hose, lanceand nozzle, a stirrup and an adjustable foot rest. The suction part ofthe pump is immersed in the spray solution kept on floor in a bucket. The pump is operatedby hand by one person while the other person holding the delivery line, trigger cut-offdevice and lance nozzle sprays pesticide. This sprayer is used both for public healthspraying and agricultural spraying purposes. This type of sprayer is useful for sprayingsmall trees. Area covered per day is 0.5 to 0.8 ha.

j. Knapsack Sprayer

The sprayer is mounded on the back of operator with help of a pair of mounting straps.The pumpof the sprayer is actuated by working a hand lever up and down by one hand ofthe operator and the other hand holds the cut off device for spraying purpose. This sprayerconsists of liquid tank, hydraulic pump, operating lever, pressure chamber, agitator,delivery hose, spray lance and nozzle. A bean shaped plastic tank of 14-16 liters capacity iscommonly used. It is necessary to operate the hand lever continuously at the rate of 15-20strokes per minute. The normal working pressure is 40 psi. It is user for spraying field cropsvegetables and nurseries. The area covered per day is 0.8 to 1 ha.

k. Rocker Sprayer

It is very much similar to thefoot sprayer.The main differenceis the operation ofpump. Thepump actuation is done by hand of the operator. The sprayer pumpmountedon wooden platform iskept on ground andthe spraysolution is kept in a separate tank or container. It can develop highpressure 10 kg/cm2. For sprayingtall trees, an extension bamboolance can be fitted. The adjustabletype hydraulic nozzle (TripleAction Nozzle) is normally used. It can be used for spraying trees and tall fieldcrops. Itcovers about 1.5 to 2 hectares of areain a day.



l. Foot Sprayer or Pedal Pump:

The pump of the sprayer isworked by operating a pedal lever bythe foot of the operator. The sprayliquid is kept in bucket or containerand it is sucked by a suction hosethrougha filter (strainer) due to pistonmovement. A suitable ball valve isprovided in the piston assembly toserve as suction valve. The liquid fromthe pump cylinder is then deliveredinto a pressure chamber where fromthe pressurized liquid reacheshydraulic nozzle. Minimum two person team is required to work on this machine.Hydraulic pressure of 10 kg/cm2 can be achieved which is necessary to project the jet ofspray to tall trees simultaneously from two spray nozzles. The foot operated sprayer isbasically for orchard and tree spraying. The design is strong and sturdy. An adjustable typehydraulic nozzle (Tripple Action Nozzle) is generally used which can generate differenttypes of spray patterns viz., fine spray (hollow cone), medium spray and coarse spray (jet).

The fine and medium spray are suited for low height orchards, jet spray are necessary fortree spraying. The spray jet can reach height of 15 - 20 feet. For spraying taller trees an extraextension like bamboo lance may be used to gain additional height by 8 - 10 feet. It isdifficult to treat field crops by foot sprayers because the sprayer is kept on ground andpesticide solution tank is also kept on ground separately and so movement of the longdelivery hose becomes very difficult. About 1 to 1.5 ha area can be sprayed in a day.

G. Manually Operated air compression Sprayers

These are also known as pneumatic sprayersbecause air pressure is employed for forcing theliquid though the nozzle for atomization. Thecontainers of these sprayers should not be filledcompletely with the spray fluid. A part of thecontainer is kept empty so that adequate air pressurecan be developed over the spray fluid in the tank.They do not have agitators and hence are not usefulspraying materials which settle down quickly.

a. Pneumatic Hand Sprayer

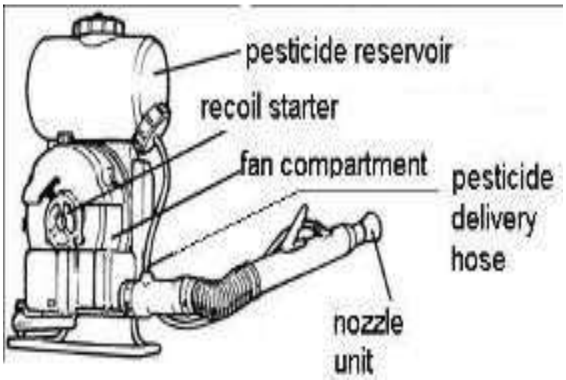
The container for the spray fluid also acts as thepressure chamber. An air pump attached to thechamber inside. The inner end of the discharge pipe runs down to the bottom of thecontainer and its outlet terminates in a nozzle is filled about 3/4th of it and the pump isworked force air into the space to build sufficient pressure upon the spray fluid. Thesesprayers are used extensively in kitchen gardens, in glasshouses and in doors againsthousehold insects. The capacity of tank is up to one liter, if used in field it can cover an areaof 0.1 ha in a day.

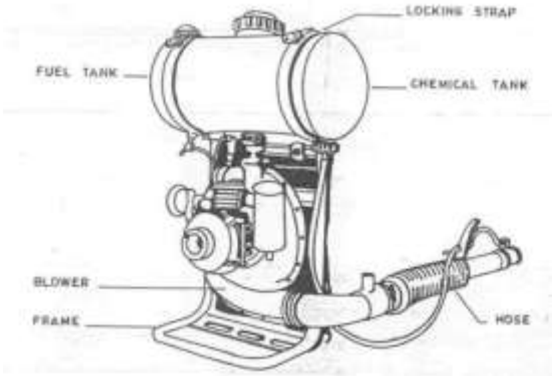
b. Pneumatic Knapsack Sprayer

This is similar to compresssion hand sprayer but are used for spraying large quantitiesof liquids (9-10 Litres). It comprises a tank for holding the spray as well as compressed air, avertical air pump with a handle, filling hole with a strainer, spray lance with nozzle andrelease and shut-off devices. The tank is provided a convenient rest with the back of theoperator and has shoulder straps that allow it to be carried by him. These sprayers are usedagainst agricultural pests and mosquito control operations. This pump covers an area ofabout 0.8 to 1.2 ha in a day.

H. Power Sprayer (Mist blowers cum Duster**)**

Here the spray fluid is blown out by an air produced in the machine. It consists ofchemical tank, fuel tank, carburator, spark plug, engine, blower assembly, delivery system,nozzle system and starter pulley. The power operated spraying system can be converted into a dusting unit by changing certain components. The tank in these is made of a thickpolyethylene and has a capacity of 10 liters. The fuel tank capacity is 1.0 to 1.5 liters. It isprovided with 1.2 to 3.0 hp petrol engine. This can also be used for dusting providedsuitable accessories. The area coveredby these sprayers is about 2 ha in a day.



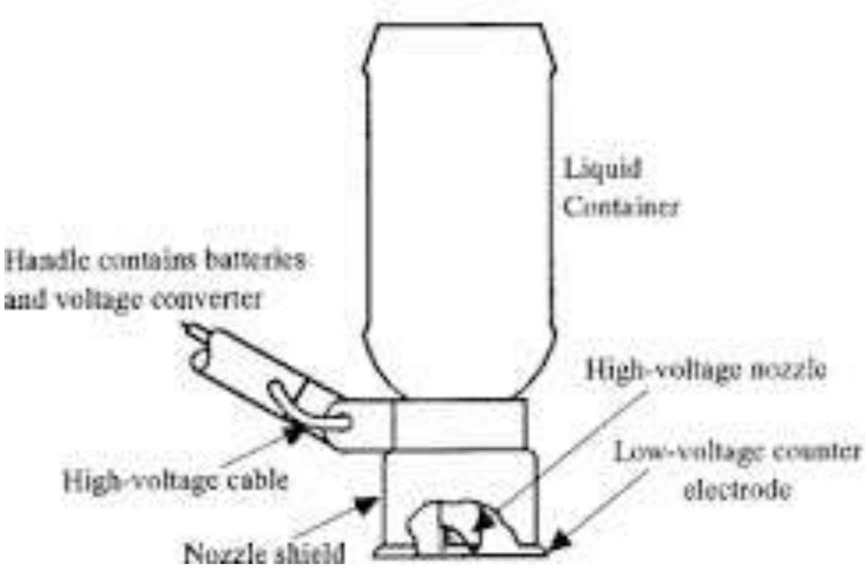


Mist blower **Motorized Knapsack sprayer**

I. Hand carried, battery operated spinning disc sprayer (Ultra Low Volume Sprayer)

The pesticides are applied assuch or with less than 5 litres sprayfluid produces fine droplets (80µm).These are light weight sprayers(<3kg) have a rotary atomizer(spinning disc) powered by anenclosed DC motor with a plasticspray head, a liquid reservoir, ahandle and a power supply unit.

Liquid is gravity fed from polyethenecontainer screwed in to the sprayhead moulding and the liquid isflung off by centrifugal force.



J. Electrodyn Sprayers (EDS)

It is new system of spraying for the controlled droplet application of chemicals (CDA).EDS puts more of active chemical on the target than any other spraying system since thecharged particles are attracted to target crop which ensure coverage on the underside ofleaves where many pests feed and also there is minimal drift to non target areas. The EDSconsists of a spray stick and an unique combination of bottle plus nozzle the bozzle. Thespray stick consists of the batteries anda solid state high voltage generator. The bozzlecontains ready formulated chemical for immediate application to crops. The pesticide inULV formulation is used undiluted at a quantity less than 6 liters/ha and usually at 0.5 to2.0 liters/ha for field crops. The droplet size varies from 20-150 micron with ground sprayingequipment for ULV spray an area of 5 ha can be covered ina day.

DUSTERS

The dusting powders are low concentration ready to use type, dry formulationscontaining 2 to 10% pesticide. The inert material or dry diluents is talc, soapstone,attapulgite, etc., and it is non toxic. The sulphur dust is not diluted with inert material. Thedusts are applied at 20 - 50 kg/ha. It should be noted that the application is done in highlyconcentrated form, as compared to high volume or low volume spraying technique.Therefore, adequate precautions must be taken in handling the dust and during theapplication in field. The dusters are available both manually operated and power operatedmodels. All dusters consist essentially of a hopper which usually contains an agitator, anadjustable orifice and delivery tubes. A rotary fan or a bellows provides the conveying air.

A. Manually operated dusters

f. Plunger duster

They are very simple, low cost machines and useful in a limited way. It consists of adust chamber, a cylinder with a piston or plunger, a rod and a handle. The field applicationcapacity is low. They hold 200 to 400 g of dust in a chamber into which air is pushed by anadjoining piston type air pump operated by hand. The dust cloud is issued from thedischarge outlet. It is useful forsmall scale use in kitchen garden and in household.

g. Bellows duster

This is also a simple design low cost dusting machine. A collapsible bellows pushes airinto a dust hopper of 1-2 kg capacity and dust is discharged from the nozzle outlet.

h. Rotary duster:

This type of duster makes use of a fan or blower to flow large volume of air at highspeed. The dust powder is fed into the stream of air and blown from the outlet tube. The fanor blower rotatesat high speed by hand cranking handle, which is geared to it. The highergear-ratio and better blower design provide easy cranking and good volume of air isemitted. The dust hoppers are generally cylindrical and are provided with agitator, feedersand dust metering mechanism.Such rotary dusters are either shoulder slung type or belley mounted type. Theshoulder-slung models are better balanced when the dust hoppers are filled. But it becomesinconvenient to operate in crops like sugarcane and cotton. The belley mounted type can beused in such situations. A hand rotary duster can discharge dust powder from 0 – 150 g/minand displace air about one m3/min at 35 RPM. Such machine can treat 1 to 1.5 ha /day.

i. Power Duster

These are bigger machines run with the help of engine or electrical motor. Some powerdusters are tractor mounted type and are driven by tractor P.T.O. The equipment ismounted on ironframe (stretcher) and can be carried by 2-3 men. The engine/motor drives acentrifugal fan usually via V-belt drive. The engine is petrol/ diesel run and 3 - 5 H.P. Thefan displaces 20 m3 air/min or more at 100-250 km/hr air velocity. These dusters are good forlarge area treatment and suitable for application on tall trees. In this type of duster design,usually the dust powder is not rotated in the fan-case but dust powder is aspirated in thedelivery channel by air blast. The dust hopper capacity is 10- 20 kg and dust can bedischarged at a rate of 1 to 8 kg/min. A power dustercan cover about 10 ha/day.

j. KNAPSACK DUSTER

The motorised knapsack sprayer can be converted to a duster by replacing some plasticfittings inside the hopper. Almost all mist blowers have provision of converting them fromspraying unit to dusting unit. The two stroke petrol engine runs a blower fan and deliversthe air through a hosepipe system. The dust is agitated and lifted by the blast of air in thehopper (2-5kg capacity) and itis fed into the main air hose or a long dusting hose (40-50 ftlong polythene perforated hose) can also be attached to knapsack duster. Such anattachment is very good for large area treatment in less time. The dust output can beadjusted from 0 to 1.5 kg/min. The motorised knapsack sprayer-cum-duster unit is thereforeuseful for both low volume spraying and dusting operation.

Soil Injector

It is also known as soil gun, which consists of a cylindrical tank for the liquid fumigant,a pump barrel and plunger assembly, injector nozzle, thrust handle and injection handle.The hand operated soil injectors have a capacity of 1 to 3 liters and they can cover about 0.5ha in a day. They are used to apply liquid nematicides to kill soil nematodes.

Granule Applicators:

They are used to apply granular formulations of pesticides
uniformly. These are twotypes of granular applicators.

iii. There is a plastic hopper 1 liter capacity from which the granules flow by gravity to anozzle.

iv. It is a knapsack type with hopper of 10 liters capacity.

Bird Scarer

It produce loud noise at regular interval and used to scare away the birds. It has threeessential chambers, a chamber to hold calcium carbide, a smaller chamber placed inside theformer to hold water and combustion chamber attached to the main chamber. Water actswith calcium carbide and generates acetylene which explodes producing the noise. Thefrequency of flow of water into calcium carbide chamber. One kg of calcium carbide issufficient for working a machine for 24 hours. One bird scarer is sufficient to cover 1 to 2 ha.

Rat Traps:

Several types of mechanical devices for trapping rats and mice are used in India. Inthese traps baits like dry fish are used for attracting these rats. The cage type wooden boxwith a door closingdevice and spring board types are the more common ones used in thehouses.

Practical- 17To study about the Sampling techniques for estimation of insect population and damage

Sampling population estimates of insect pests are the fundamental activity in ecologicalentomology. Regular monitoring can answer several important questions such as-Whatkinds of pests are present? Are the pest numbers great enough to do damage and towarrantcontrol? Are bio-agents or natural control present and working? When is the right time tobegin control? and have management efforts successfully reduced the number of pests?

Pest monitoring is the pre-requisite for any successful pest management programwherein, no control measure should be undertaken for a pest unless it is known that- thepest is activelypresent and it is present in sufficient numbers to cause an economic loss.

How to count or measure a species/damage caused in plant, soil or other habitat ?

The sampling method should be: suitable for all key pests, rapid and simple to use, easyintegration into current sampling program, sampling equipment readily available and easyto carry and sampling procedure be simple to understand and conduct.

Sample unit: Single plant, clusters, plants/hill, plant/m2 etc.

Sampling Size: In preliminary studies: sample size will be small and 10% of the mean errorshallbe acceptable. Number of samples depends on degree of precision required and chosento minimize the variance and cost..

Types of Sampling

Random sampling: The sample is taken at random with good field coverage to determineinsectnumbers or damage per samples unit. For this purpose, use of random numbers ismade.

Stratified random sampling: It involves the division of population in to different stratabased ondistribution of population.

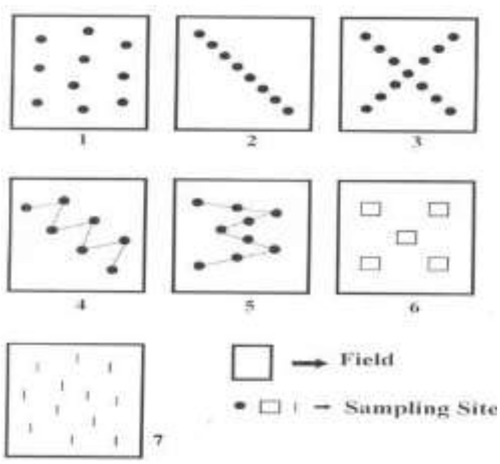
Sequential sampling: It requires continuous sampling until a pre established upper orlowerinfestation level is found.

Trap sampling: This refers to using light, suction, sticky or sex pheromone traps to detectthepresence of insects in an area.

Systematic sampling: It involves sampling ofpopulation at fixed intervals.

Selection of Sampling Site

1. Random
2. Along one diagonal
3. Along two diagonals
4. Zig-zag diagonally
5. Along alphabet ‗W‘
6. In micro-plots of 1m2
7. Meter row length



Important Sampling Methods

Absolute methods: This method is used to estimatedensity of insects

per unit area.
Differenttypes of absolute sampling are denoted by **n.**

Unit of habitat method

- **In situ or direct counts**: e.g. Leafhoppers
- **Knock down:** removing insects form the habitats-drop sheet method e.g. *Helicoverpa*

spp.brushing, washing etc.

- **Netting:** for highly mobile insects
- **Trapping:** Use of different types of traps. Phermone traps, Light traps, suction traps etc.
- **Extraction from soil:** From a fixed volume of soil insects can be counted. e.g. whitegrubs, cutworms, pupae of several lepidopterous larvae.
- **Indirect techniques:** By taking crop samples for example, **dead hearts** in case ofsugarcane shoot borer, **number of plants cut** e.g cutworms, **per cent defoliation** e.g.foliage feeders, **root damage** e.g. termites, root weevils; **shoot damage** e.g. spottedbollworms, **per cent fruiting bodies damaged** e.g. bollworms of cotton, pod borers,**stubble infestation** e.g. in sugarcane.

Absolute sampling method are desirable because they are accurate, however, these methodsare time consuming, often difficult to conduct and are usually expensive compared torelative methods. Relative methods are more economical in terms of time, labour andequipments.

Relative methods: This method provides an identification of insect pests abundance ordamage relative to other times or location. Different types of relative methods are as followsvisualsearches, use of various traps, plant damage etc.

Remote sensing: Acquiring information through the satellite about pest damage withoutcoming into physical contact. It can be useful in monitoring of certain pests. A radar canmonitor height, speed and direction of insects like locusts, aphids etc.

Components of Remote Sensing

4. **Platform**
   - The vehicle/device on which sensors are mounted
   - Carriers or vehicles for the sensors
5. **Sensor System**
   - The device which senses the energy reflected/emitted by the target object
6. **Data Products**
   - Information received from the sensor Packaged as per user requirement

OTHER METHODS

Beat bucket: Requires 20-25 litre capacity plastic bucket (white or light coloured); similar toshake cloth/drop sheet method; top 25 cm of a single plant is bent into the bucket andshaken vigorously (12-15 times during 4-5 seconds);

plant is quickly removed andinsects/predators and spiders are counted. It is more effective than shake cloth method;reduces variability due to field scouts.

Vacuum sampling: Sucks into bags most everything from on and around a single plant orplant part; impractical for regular use in sampling and the samples are too messy to process.Further improvements could be made by better initial planning and involvement of thestatistician with the biologists.

Sampling techniques for major insect pests on Paddy crops

Crop	**Pest**	**Economic threshold level**	**Method of sampling**
Paddy	**Green leafhopper**		
	a) At earing stage	5-15 insects/hill	Select 5 micro-plots of 1m2 each in a field and shake vigorously plants in 5 hills/plot or shake vigorously 25 random plants and count leafhopper fallen on water.
	b) At flowering stage	10-15 insects/hill	Same as above
	Stem borer	5-10% plants with dead-hearts or 2% white ears or one egg mass or moth/m^2.	Count infested and healthy tillers in 25 random plants.
	Leaf-folder	2 damaged leaves/ plant or one larva/hill	Count infested and healthy plants among 25 random plants or count
	Rice gundhi bug	1-2 insects/hill	Count the insect on 25 random
Gram	**Gram pod borer**	One larva/meter row length	Count larvae in one meter row length from 10-20 random sites in a field.
Okra	**Leafhopper**	2-5 nymphs/leaf	Count leafhopper nymphs from underside of three fully developed leaves in the upper canopy of each of 20 random plants or count leaves showing yellowing and curling from margins and healthy leaves of 20 random plants in a field
	Whitefly	6-8 adults/leaf	Count whitefly adults as above.

	Spotted bollworm	10% drooping shoots or 5-10% infested fruiting bodies	Count drooping shoots and healthy shoots of 25 random plants or examine all green fruiting bodies of the above
			plants for spotted bollworm induced holes or damage.
Tomato	**Fruit borer**	One larva/m2	Count larvae in 1 m^2 micro plot from 10 random sites in a field

BFSC-202: Aquatic Ecology and Biodiversity

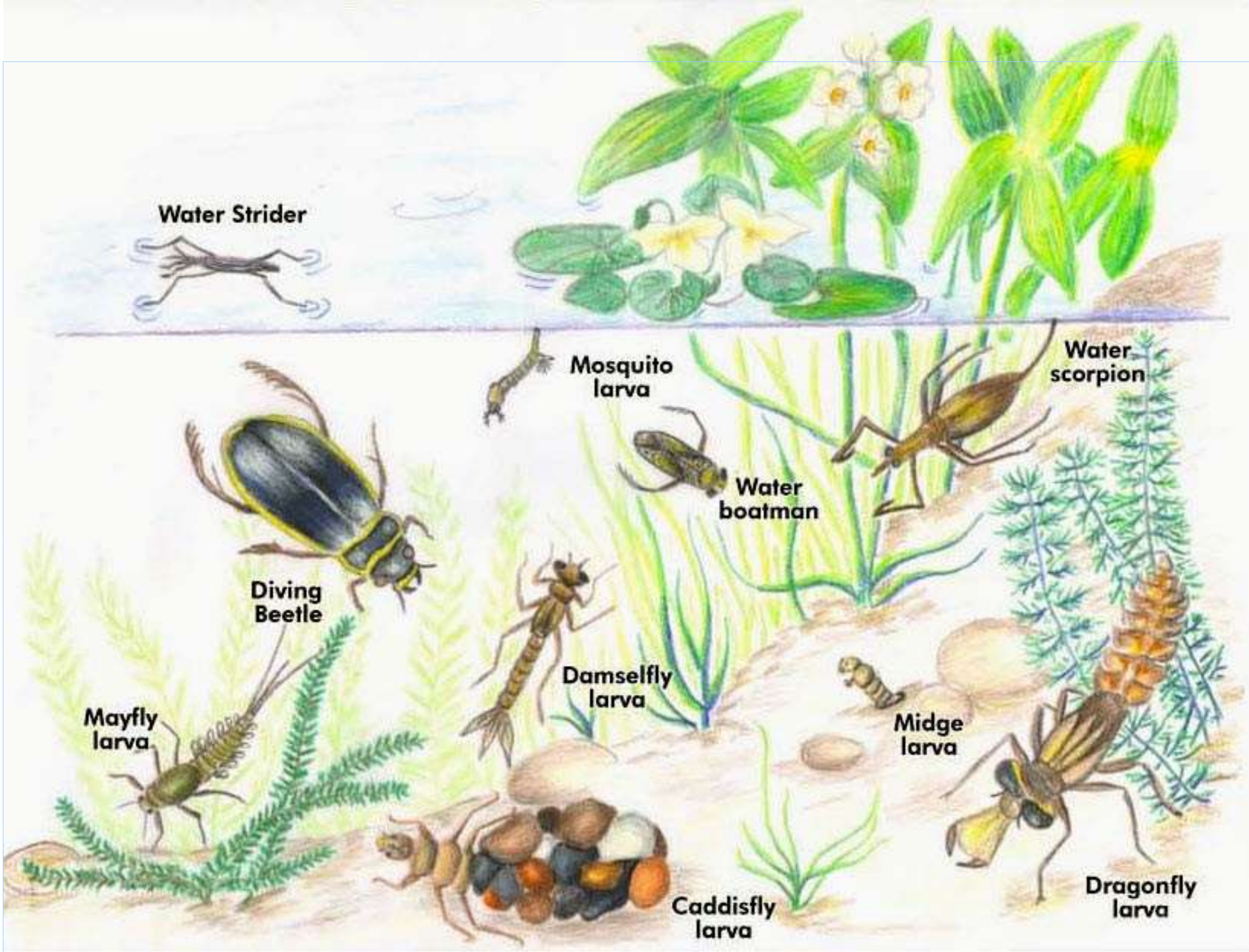


Illustration by Moriya Rufer

Aquatic insects play a major role in the aquatic ecosystem. They help break down and decompose the dead material at the bottom of the lake such as leaves, dead fish, and otherorganisms. They are also a major food source for fish, frogs, birds and other animals. Without insects in the lake or stream, it wouldn't be a very nice place to fish or swim!

A Waterbug's Life

Dragonflies, mosquitoes, midges, mayflies and many more insects live in the water during their immature life stage (nymphs and larvae) and fly on land in their adult life stage. You can think of the immature life stage and adult life stage as the equivalent of a caterpillar andbutterfly. Aquatic insects that live in the lake as larvae (caterpillars) often spend a year or more in the water eating and growing before they are ready to fly away as adults. Whirligigbeetles, water boatmen, and water striders use the lake all their lives.

Dragonflies, for example, live in the water during their nymph life stage. They scoot aroundon the bottom of the pond, eating minnows and other insects. Some of them become a tastymeal to fish, frogs and birds. Those that survive crawl on land to molt into an adult Dragonfly. When they molt, they leave their shed skins on vegetation, buildings and rocks. The adult then flies away to begin its new life on land.

Dragonfly nymph

Dragonfly shed skin

Dragonfly adult

Mayflies (Ephemeroptera)

Mayfly nymphs **Mayfly adults**

Mayfly nymphs have hairy looking gills attached to their abdomen. This is how they breathe under water. They also have 2 to 3 long tails extending from their back end. The nymphs eat detritus and decomposing things at the bottom of lakes and streams. They arealso a favorite food for fish.

Mayfly adults have 2-3 tails extending from their back end as well. The two long limbs sticking out the front are actually their front legs, not antennae. The male uses these legs tohug the female. Mayfly adults also don’t have any mouths. They only live for one or twodays, so they don't need to eat anything!

Damselflies and Dragonflies (Odonata)

Damselflies and Dragonflies are related to each other like cousins. They are both predatorsand eat minnows, worms and other aquatic insects. They're mouth has an extension that shoots out and catches minnows swimming by!

Damselfly nymphs

Damselfly adults

Damselflies have long skinny bodies with gills that look like feathers coming out the backend. This is how they breathe underwater.

The adults are very common flying around lakes and ponds. The adults look like they're flying in crazy patterns because they actually catch and eat other bugs like mosquitoes whileflying in the air!

Dragonfly nymphs **Dragonfly adults**

Dragonflies have shorter, stouter bodies with no visible gills. They breathe by sucking waterinto their back end, absorbing the oxygen out of it, and then shooting the water back out their back end. When they shoot water out their back end, it scoots them forward.

The adults are very common flying around lakes and ponds. The adults look like they're flying in crazy patterns because they actually catch and eat other bugs like mosquitoes whileflying in the air!

Backswimmers and Water Boatmen

Backswimmers and water boatmen look very similar to each other. The main difference isthat backswimmers swim on their back and water boatmen swim on their front.

Backswimmmers (Notonectidae)
Backswimmers do just that – they swim on their back! Their third pair of legs are much longer than their front and middle legs. They use their back legs like oars to swim throughthe water.

Water Boatmen (Corixidae)
Water boatmen look similar to backswimmers, but they swim on their front side. Theirsecond and third pair of legs are similar in length, and their back has pretty stripes and speckled patterns.

Giant Waterbug (Belostomatidae)

Giant water bugs can be very big - 1 to 3 inches long! They are voracious predators, andbite their prey with a sharp beak. They have even been seen attacking minnows.

They are called toe-biters, because if you accidentally step on them in a pond they may biteyour toe. They usually stay away from humans in lakes though, so they shouldn't bother you while swimming.

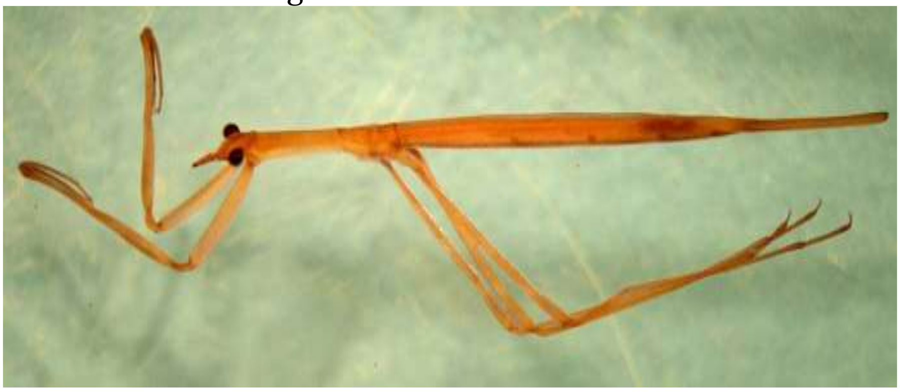
Water Striders and Water Scorpians

Water Striders (Gerridae)
Water striders walk on top of the water. They have little hairs on their feet that repel waterand keep them on top of the surface. If soap or oil is added to the water, it makes the surface of the water soft and the water strider is not able to stay on top anymore. It will fallinto the water and drown. This is why we should not bathe and shampoo our hair in the lake.



Water Scorpians (Nepidae)
Water scorpions are vicious predators. They catch bugs, minnows and worms with their long arms. They have a long, beak-like mouth to eat their prey. The long tube that sticks out from their back end is their breathing tube. You can think of it like a straw. They hangupside down in the water with the tube at the top of the water and

breathe in air in throughit. When they dive down deeper into the water, they close the tube so no water gets in it.



Water Beetles

Water beetles live in the water their whole life. They start out as a larva, and then molt intoan adult like butterflies do. The adults breathe in a unique way. They have a little air bubble stuck to their belly that they breathe from. They come up to the top of the water every few minutes to get more air into their bubble and then they dive back down underwater.

Whirligig beetle adults have eyes both on top of their head and on the underneath part of their head! This allows them to see both above and below water when they're floating on top. Whirligig beetles swim in fast little circles at the top of the water.

Predacious diving beetle (Dytiscidae)
larvae adult

Whirligig beetle (Gyrinidae)
larvae adult

Water scavenger beetle (Hydrophilidae)
larvae adult

Caddisflies (Trichoptera)

Caddisfly larvae **Caddisfly adults**

Caddisfly larvae build little houses for themselves out of sticks and stones. They use theirsaliva as glue to hold their houses together. The houses give them protection from predators.

Caddisfly adults look similar to moths, but their wings are usually held back over their bodyinstead of to the sides. If you see what you think are a bunch of tiny moths swarming around on rocks by a lake, they're most likely caddisflies, not moths.

Caddisfly houses

Aquatic Flies (Diptera)

Non-biting Midges (Chironomidae)

larvae adult

Non-biting midges look a lot like mosquitoes as adults, but they do not bite. They don't have a long tube-like mouth attached their face for sucking blood.

Mosquitoes (Culicidae)

larvae adult

Most people are familiar with mosquitoes, but not everyone knows that they live in water aslarvae. The larvae like to live in stagnant water like ponds, puddles, and bird baths. They have a long tube extending from their back end to breath air from the water's surface.

As adults, the females are the only ones that suck our blood. They need the blood for nutrients for growing eggs. The males do not bite us, they drink nectar from plants.

Horse Flies (Tabanidae)

larvae adult

Horseflies can leave a nasty bite. Most people don't know that they live in the water as larvae too. That is why you're most likely to get bit by a horsefly when you're in a boat ornear a lake.

Collection and identification of aquatic plants from different freshwater bodies

The plants vary greatly in the degree to which they have become truly aquatic and present in an interesting series of gradations from those which are little more than amphibious, living at the edge of the water in very moist or water saturated soil. Aquatic plants are those unwanted and undesirable vegetation which reproduce and grow in water and if left unchecked may choke the entire body of water posing a serious menace to pisciculture. Another definition is that the surplus growth of a plant that influences adverse physical, chemical and biological effects on a water body with its resultant economic and aesthetic losses.

Collection of Aquatic plants

The aquatic plants can be collected using a long handled hook, nets or by hand. For quantification of sample in a given area the floating or sinking type of quadrates of known size namely (1m x 1m or 0.5m x 0.5m) made up of PVC pipes or wood are used. These quadrates are placed to mark the area from which sample is to be taken. After collection, these plants are brought to the laboratory for identification. Before identification of these plants, they must be classified based on their habitat into the following classifications, they are :

i. Floating macrophytes

ii. Marginal macrophytes

iii. Submerged macrophytes

iv. Emergent macrophytes

Identified of plants using the following keys :

i. Floating macrophytes

1. Eichhornia sp (Water hayacinth or blue devil)

Class : Angiosperm

Family : Pontederiacea

It is native of Brazil, accidentally brought to India and released in West Bengal, one of the most damaging aquatic weeds, inhabits stagnant and slow moving rivers.

Leaves broad with swollen stalks filled with air to enable them to float on water surface, dense leathery roots, flower pinkish in colour, multiplication by vegetative propagation, dries off in winter and spourts during summer.

2. Salvinia (water fern velvet)

Family : Salviniaceae

This plant has got rhizome, stalk or stem is delicate, oblong or hemispherical leaves, actual roots absent, leaves sessile with short stalk, leaves in two or more whorls, second whorl is either lateral and floating, third one submerged in water which looks like roots, lateral leaves sometimes filled with air which aids in floating.

3. Pistia (water lettuce)

Family : Araceae

A free floating perennial plant, plant body comprise a shell like rosette of tongue shaped leaves, reduced stem, sessile leaves and numerous branching roots, leaves form common cup shaped structure, leaves ovate and surrounded at the base by membranous sheath.

4. Lemna (duck weed)

Light green in colour, occurs in group of one to three, no distinct stem, leaves have flattened, minute leaf-like fronds, vegetative reproduction is rapid, often forming a scum over the surface, flowers are rare and so small that they are invisible to naked eye, appear as small weeds.

5. Azolla (water velvet)

Family : Azollaceae

Smaller plant, found in stagnant water bodies, leaves lobed, scale like, thick and about 0.5 mm in length, the entire plant is 1.5 – 2.0 cms in length, impart reddish green colour to water surface by covering it, it fixes atmospheric nitrogen.

ii. Marginal macrophytes

1. Colocasia

Family : Araceae

This plant covers large areas of the water body, leaves ovate, 6-20 inches long and 3-12 inches wide, leaf margin dark green in colour, base of stem triangular, petiole long up to 3-4 inches, colour of petiole green, violet or purple.

2. Typha (Cat tail or Elephant grass)

Family : Typhaceae

Common in margins of ponds, lakes, rivers and canals, perennial, creeping rhizome with leaves growing up to 2 m height and leaves have sheath at the base. Leaves bi-serrate, thick and spongy, secreting organ present at the leaf base, flower numerous and cylindrical.

3. Marsilea (water shamrock)

Family : Marsiliaceae

It inhabits ponds, rooted in shallow and stagnant waters, roots slender, stalks slender and thin, roots burrowed into the ground, petiole long with four cloves like or sharp pointed leaflets.

4. Scirpus (Bullrush)

Family : Cyperaceae

Annual herb, triangular in cross section, stem bears sheath at the base but sometimes leafy and naked, spiklets numerous with one or more long leaves from the base of branch, spiklets are usually with more flowers.

5. Cyperus (Flat sedges)

Family : Cyperaceae

Perennial herb with a single stem, cylindrical in cross section and hallow. The stem has sheath at the base and with one or more leaves on top forming a cluster, flowers or spikltes are present at the top.

iii. Submerged macrophytes (Rooted)

1. Hydrilla

Family : Hydrocharitacea

It is found to occur in almost all water bodies in India like ponds, lakes tanks etc. Leaves linearly arranged in whorls while stem is slender, grows up to 45 cms, has got fibrous roots, multiplies very rapidly by spores and vegetative propagation, infestation density is 20-30 kg per square meter, broken parts of this plant develops into a new plant by attaching themselves with the help of roots, provides shelter to young fish in aquaria offer a substrate for attachment of spawn of common carp.

2. Chara (stonewort)

Occurs in all types of freshwater bodies, stem has got erect branches and are gregarious in habit, nodes and internodes can be easily distinguished, grow up to 15 – 30 cm in length, remains unattached to the bottom, plant is rough to touch.

3. Vallisneria (eel grass / tape grass)

Plant with long ribbon like leaves measuring 0.5 – 1 m width, female flowers are long, thread like, twisted and appear at stalks, propagation is by offshoots, it can tolerate temperature of 25 – 30oC and medium water hardness.

4. Ceratophyllum (Horn wort) - (Non-rooted)

It has got a fragile algal like structure, grows to about 80 cms in length, roots are lacking, leaf branches are sometimes modified into rhizoids, lower part of stem serves as an anchore and helps in the absorption of nutrients, leaves are set in whorls, repeatedly forked with minute teeth on the side of the segment.

5. Cobamba (Fan wort)

Leaves are opposite, cut into thread like regions, stem slender with a gelatinous lining; plant provides shade and shelter for small organisms and forms a beautiful aquarium plant.

iv. Emergent macrophytes

1. Nymphaea (Water lily / Nilkamal)

Found in ponds, lakes, canals and also in water up to 1.5 m depth, perennial herb, petiole with lower end of leaflet, leaf round, veins radiating from the centre, leaves float on the surface of water, flower white or pink and solitary.

2. Nelumbo (Lotus)

Perennial herb, inhabiting tanks, ponds, lakes and other stagnant water bodies, leaves almost brown and are raised well above the water surface when mature, petiole attached to the centre of leaf, veins prominently radiate from the centre, flower large pinkish red leaf diameter ranging from 30 to 90 cms.

3. Trapa (Water chestnut / Singhara)

A perennial herb, occurs commonly in wild waters, leaves floating, solitary, branched or rhomboidal in shape, petiole with spongy swelling, flowers are solitary projecting over water surface, nuts with two or four sharp spines.

4. Myriophyllum (Parrot head / Water milfoil)

Found in stagnant and slow moving waters especially in places which are sheltered from wind, plants with slender, sparingly branched floating system mostly rooting freely at lower nodes, leaves opposite or whorled, the emergent leaves are horn like, flowers are very small and sessile and found in the axis of upper, emergent leaves grows to moderate height.

Other emergent type of plants are Nymphoides (Floating or Tringed water lily), Nuphar (Yellow lily or Cow lily) etc.

COMMUNITY STRUCTURE

n t s

4.1 Introduction

Communities are recurrent organized system of organisms respondingin a related manner to changes in the environment (Legendre and Legendre 1978). Due to concomitant and continuous interaction taking place betweenindividuals of different species and between the individuals and the environmental factors, the community remains dynamic. The changes occurring in the biodiversity is a gauge of structure of the community, whereas the changes in production reflect its function. For aquatic ecosystems, indices of diversity are basically an approach to assess biological quality, through the structure of the community (Ismael and Dorgham 2003).

The community structure of periphytic algae in N. Paravoor and Vypeen Island backwaters have not been investigated so far. Periphytic algaehave a major role in the productivity of the aquatic system. A variety of studies have appeared concerning the structure and function of periphyton indifferent ecosystems. Efforts were also made to relate the changes in the periphyton community structure with the level of pollutants using introducedsubstrata (Cooper and Wilhm 1975; Singh and Gaur 1989). Many studies have conducted in different ecosystems by various workers about the factorsinfluencing periphyton accrual. The macronutrients, nitrogen and phosphorusare commonly the major limiting resources for periphyton growth in freshwater streams. Streams draining agricultural watersheds of the midwest characteristically have elevated levels of both nitrogen and phosphorus, andhighly variable N: P ratios (Kilkus *et al*. 1975).

4.2 Materials and Methods

Periphyton grown on glass slides for the quantitative and qualitative analysis was collected from 10 different stations of N. Paravoor andVypeen Island wetlands (Fig. 2.1). Details of collection methods (APHA 1998.) and identification were described in chapter 3. Hydrological parameters such as dissolved oxygen, pH, salinity, temperature and nutrients like nitrite, nitrate, silicate and phosphate were determined by standard methods and given in the chapter 2.

4.2.1 Biological Diversity

Biological diversity can be quantified in many different ways. The two main factors taken into account when measuring diversity are richness and evenness. Richness is a measure of the number of different kinds of organisms in a particular area. Evenness compares the similarity of population size of each of the species present.

4.2.2 Richness

The number of species per sample is a measure of richness. Themore species present in a sample, the ‘richer’ the sample. Species richnessas a measure on its own takes no account of the number of individuals of each species present. It gives as much weight to those species which have very few individuals as to those species which have many individuals. Species richness was calculated to Margalef's (1958) formula.

4.2.3 Evenness

Evenness is a measure of the relative abundance of the different species making up the richness of an area.

4.2.4 Margalef's index

There are several simple species richness indices that attempt to compensate for sampling effects by dividing richness, *S*, the number of species recorded, by *N*, the total number of individuals in the sample. One of the best known of these is Margalef's index (Magurran 2004). This index is weighted towards species richness and is the measure of the total number of species for a given number of individuals.

$$R = (S\text{-}1)/ \ln N$$

Where,

R = Species richness

S = Total number of species in the community

N = Total number of individuals in the community

4.2.5 Simpson's index

The Simpson's index is one of the most meaningful and robustdiversity measures available. It captures the variance of the species abundance distribution (Magurran 2004). Simpson's diversity index is measures of diversity which take into account both richness and evenness.Simpson's index (D) is calculated by the following equation:-

$$D = \sum \left(\frac{\Sigma n_i [n_i - 1]}{N [N - 1]} \right)$$

Where n_1= the number of individuals in the *i*th species; and N= the totalnumber of individuals.

4.2.6 Simpson's measure of evenness

Although Simpson's diversity measure emphasizes the dominance,as opposed to richness, component of diversity strictly speaking, it is a pure evenness measure. A separate measure of evenness can, however,be calculated by dividing the reciprocal form of Simpson's index by the number of species in the sample (Smith and Wilson, 1996; Krebs, 1999).

Where,
$E_{1/D} = (1/D)S$

$E_{1/D}$ = Simpson's measure of evennessD = Simpson's index and

S = Number of the species

4.2.7 Similarity index

Similarity index is a simple and elegant measure of comparing stations for obtaining an integrated picture of the biotopes and calculated using Sorensen's (1948) equation:

$$S = \frac{2c \times 100}{a + b}$$

where 'c' = the number of the species common at both stations and 'a' is the number of species at one station and 'b' is the species at the other station. S is the index of similarity.

4.2.8 Shannon Wiener index (H')

It is important to note that while the energy flow in the community depends to a large extent on the dominant species, the species diversity depends on the total number of species particularly those of less importance or rare species. Species diversity decreases in system controlled by strong physico-chemical limiting factors while the diversity of species increases in biologically controlled communities and is directly proportional to the stability of the system. The diversity in the community can be determined by Shannon index of general diversity. The higher the value the greater the diversity. Commutationof species diversity in periphytic algae was made using Shannon index (Pielou 1975).

where

H' = $-\sum p_i \ln p_i$

H' = Diversity index

p_i = Proportion of individuals found in the *i*th speciesln =

Natural logarithm

4.3 Results and discussion.

4.3.1 Environmental parameters

Environmental parameters such as dissolved oxygen, temperature, pH, salinity and nutrients such as nitrite, nitrate, silicate and phosphate of the study area were analyzed (Table 4.1). The monthly mean value of salinity of the backwaters during the study period showed a variation from

1.4×10^{-3} during September to 23.75×10^{-3} during February. Salinity of station 6, Cherai *kayal* showed higher values (Table 2.5) in all months except July, August and September (Monsoon). This station is close to Arabian Sea and it is permanently connected by Azhikode estuary. This may be the reason for remaining higher salinity values. Other stations which showed higher salinity values are located close to the Vembanad *kayal*. Stations distantly located to Arabian Sea and Vembanad *kayal*showed lesser values of salinity.

Dissolved oxygen of N. Paravoor and Vypeen Island backwaters showed a variation from 4.51 to 10.8 ml L^{-1} and recorded an yearlyaverage of 6.393 ± 2.644 ml L^{-1}. Monsoon season showed the highest values of dissolved oxygen. Dissolved oxygen values of pre-monsoon, monsoon and post-monsoon were 6.690 ± 2.454, 7.748 ± 2.772 and

4.741 ± 1.690 ml L^{-1} respectively.

Temperature ranged from 28.8 to 32.25^0 C in the backwaters during the period of study. The pH of the backwaters showed a variation from

6.21 to 7.18 during the study period. During monsoon and post- monsoon, the backwaters showed a slight acidic nature and during the pre-monsoon, the backwaters showed the pH values just above the neutral.

The silicate concentration of the study area showed (Table 4.1) higher values during all months of study. The values ranged from 36.96 to

114.64 µg at L^{-1}. Monsoon and post-monsoon seasons showed higher values of silicate than pre-monsoon. The concentration of nitrite-N varied from 0.14 to 0.83 µg at L^{-1}. The lowest value was reported during January and the highest value during September. Greenwood and Lowe (2006) have reported that the low silicate in water column potentially a limiting factor to diatom growth.

The average monthly nitrate-N showed a variation from 0.07 during March to 3.7 µg at L^{-1} during September (Table 4.1). The annual meanwas 0.949 ± 1.803 µg at L^{-1}. The phosphate concentration of the backwaters varied from 0.99 to 3.17 µg at L^{-1} and showed an annual meanof 2.112 ± 1.834 µg at L^{-1}.

Two way ANOVA of salinity (Table 4.2) showed a significant variation between stations and between seasons, ($p< 0.01$). Dissolvedoxygen (Table 4.7) showed significant variation between stations andbetween seasons ($p< 0.01$).

Two way ANOVA analysis of temperature (Table 4.3) showed significant variation between stations and no variation between seasons. The pH (Table 4.4) varied significantly between seasons and stations($p < 0.01$). Silicate (Table 4.5) showed season wise significant variation($p < 0.01$). Nitrate (Table 4.6) and nitrite (Table 4.8) also showed significant seasonal variation ($p<0.01$). Analysis of phosphate with two way ANOVA showed (Table 4.9) significant variation between season, stations and station to season ($p<0.01$).

Pearson correlation analysis (Table 4.10) showed that the salinitywas negatively correlated to NO_3-N, silicate, and phosphate and positively correlated to pH. Dissolved oxygen was found positively correlated to phosphate and temperature. Temperature was found positively correlated to dissolved oxygen only. pH showed positive correlation to salinity.Silicate was positively correlated to NO_3, PO_4 and negatively correlated tosalinity. NO_2 had positive correlation to NO_3 and PO_4. NO_3 was positively correlated to NO_2, SiO_3 and negatively correlated to salinity. Phosphate was found positively correlated to dissolved oxygen, nitrite and silicate and negatively correlated to salinity.

Pearson correlation analysis revealed that there was no correlation between the nutrient concentration and algal growth. Algal numbers showed a negative correlation ($p<0.05$) to dissolved oxygen and a positive correlation to salinity ($p<0.01$). Munn *et al*. (1989) had noticed that the periphyton growing in agricultural streams of central Illinois did not respond to nutrients examined. Previous studies on agricultural streams have also found lack of correlation between periphyton standing crop and increase in either nitrate or phosphate (Kilkus *et al*. 1975; Moore 1977; Patrick 1966; Wiley *et al*. 1987). Rier and Stevenson (2006) also have reported the lack of correlation between nitrogen and phosphorus concentrations in periphyton growth. Sreekumar (1998) in his studies withperiphytic algae on Cochin estuary has also noticed no correlation with nutrients such as nitrite and phosphate with periphyton standing crop. The results of this study are consistent with the above observations.

Scholten *et al*. 2005 has reported that phosphates is one of theessential nutrients for algal growth and is considered to be the prime limiting element determining the biological productivity.

O' Reilly (2006) with his studies of seasonal dynamics of periphytonin a large tropical lake in Zambia, and reported that the nutrients remain the primary factor limiting algal growth throughout the year in the shallowwaters. Becares, *et al*. (2008) have reported that periphyton chl-*a* often significantly related to nutrient loading.

Correlation analysis has shown that temperature is positively correlated to primary productivity. Even though the temperature is not considered as a resource, it does interact with other variables to enhance primary production (Munn *et al*. 1989). Kilkus *et al*. (1975) reported that water temperature was a major driving variable for periphyton in agricultural streams in Iowa.

4.3.2 Margalef's richness index

Various seasonal mean community indices are shown in Table 4.11. The highest value of Margalef's index recorded during pre monsoon was
3.552 at station 5 and the lowest was 2.654 recorded from station 1. The mean value of the season was 3.015. The maximum and minimum range during the monsoon season was 3.803 (station 5) and 2.105 (station 2) andthe mean value was 2.945. During post monsoon the highest value recorded was 3.822 at station 5 and the lowest 2.520 at station 7 and meanof the seasons was 3.129. Almost all stations showed high values ofspecies richness.

Stn. 5 showed the highest species diversity in all seasons. Stn. 5 is a pokkali paddy tract.

Species richness values were higher during post monsoon. This indicate that the environmental conditions prevailed during the seasonwas most favorable for species abundance. This observation agrees with that of Sreekumar (1998); Paniadima *et al*. (2006) and Vaheeda (2008).

4.3.3 Shannon Wiener index H'

The pattern of seasonal Shannon-Weiner index is given in Table 4.11.During pre-monsoon Stn. 10 showed the highest value (2.567) and the lowest value was recorded at station 6 (1.969). During monsoon the highestvalue noticed was 2.658 at station 5 and the least 1.594 at station 2. The maximum value recorded during post monsoon was 2.661 at station 5 and minimum was 2.068 at station 1. The mean values of Shannon index for pre-monsoon, monsoon and post-monsoon were 2.235, 2.167 and 2.361 respectively. Post monsoon recorded the highest mean H' value.

4.3.4 Simpson's Index (D)

Simpson (1949) gave the probability of any two individuals drawn atrandom from an infinitely large community belonging to the same species. As the Simpson's index (D) increases, the diversity decreases. The value ranges from 0 to 1. With this index, 0 represents infinite diversity and 1, denotes the least diversity.

The seasonal mean values of Simpson's index of the study area are given in Table 4.11. During pre-monsoon station 6 reported the highest D value (0.268) and the lowest recorded was at station 10 (0.130). The highest value reported during monsoon was at station 2 (0.360) and the lowest at station 5 (0.127). The maximum D value shown during post- monsoon season was 0.253 at station 9 and the minimum at station 5 (0.118). The average D values recorded during pre-monsoon, monsoon and post- monsoon were 0.203, 0.243 and 0.171 respectively. The post- monsoon season recorded the minimum D value. Station 6, Cherai *kayal* recorded a higher value of D indicated its low species diversity. This station reported during December the highest algal numbers in the present study. This was due to the occurrence of *Navicula cincta* and *Nitzschia clausii* in enormous quantity in December. Blooming of these two species might have occurred during this period.

4.3.5 Simpson's measure of evenness ($E_{1/D}$)

The measure ranges from 0 to 1 and is not sensitive to speciesrichness. It is usually termed $E_{1/D}$ to denote the use of the reciprocal form ofthe index (Magurran 2004). Seasonal evenness value is given in Table 4.11.The pre monsoon maximum value was recorded at station 10 (0.252) and the minimum at station 6 (0.140) .During monsoon the highest value recorded was 0.339 at station 9 and the lowest was 0.162 at station 2. Station 4 recorded the highest value during post monsoon (0.266) and the least at station 6 (0.135). Average $E_{1/D}$ values of pre monsoon, monsoon and post monsoon were 0.194, 0.243 and 0.221 respectively.

Analysis of the results of different indices indicated that the post monsoon was the most favorable season for species diversity. More evenness showed during pre monsoon. The high species diversity during post monsoon showed that this season was the most suitable for periphyton growth, offering the most favorable saline regime.

Station 5 which showed the highest H' value during post monsoon and comparatively higher value during monsoon is a pokkali paddy tract. Due to the peculiar cultural practices, substantial paddy stubbles are left in the field after harvest. They act as additional substrata for periphyton growth. The high species diversity can be explained in this direction. Station 5 also recorded the least D values.

The observation of maximum diversity during the post-monsoon agreesto the reports of De *et al*. (1994) from Hubli estuary, Ilangovan (1987), Vareethiath and Haniffa (1997) from Vellar estuary, Sreekumar (1998) fromCochin estuary, Krishnakumay and John (2003) and Vaheeda (2008).

Studies of phytoplankton diversity is an important contribution to theunderstanding of the ecosystem dynamics (Hillebrand and Sommer 2000).The species diversity is typically measured by the species count (richness)and sometimes with an evenness index. However, it may also be measuredby proportional statistics like Shannon-Wiener index (H' Shannon and Weaver 1949) that combine both measures which is one of the most widelyused diversity indices for measuring diversity (Gao and Song 2005).

Species diversity within the aquatic communities is closely related withthe trophic state of the water body. If it is accurately identified and measured on the unified basis, variability (or stability) of structural and functional parameters such as Shannon-Wiener index of plankton communities in theestuaries and coastal waters, can serve as an indicator for the modification of ecosystems under the eutrophication/pollution stress (Telesh 2004).

Shannon-Wiener diversity index is a suitable indicator for water quality. Hendley (1977) used Shannon-Wiener diversity index as pollution index of microalgal communities, especially diatoms and put forward the following scale; 0-1 for high pollution, 1-2 for moderate pollution, 2-3 for small scale pollution, and 3-4 for incipient pollution.

The value of diversity index of a community in less polluted waters would be higher (Margalef 1967; Gao and Song 2005). These observations agreed with the results obtained from this study. Station 10 during June recorded the least standing crop and its Shannon-Wienerindex was 1.75. Hence it is perceived that all the stations studied except stations 2 and 7 are not polluted.

4.3.6 Floral similarity

Floral similarity of periphytic flora of the study area was analyzed withSorensen's similarity index and 'trellis diagram' (Fig. 4.1). The study showed that a high similarity between stations. Abundance of *Achnanthes brevipes, A. coarctata, A. longipes, Amphora coffeaeformis, A. coffeaeformis* var. *borealis, A. holsatica, Bacillaria paradoxa, Cocconeis placentula var*.

euglypta, C. scutellum. Cymbella cistula, C. hustedtii, C. japonica, C. marina, C. minuta, C. spicula, Diploneis puella, Epithemea musculus, Fragilaria oceanica, Grammatophora undulata, Gyrosigma nodiferum, G. scalproides, Hantzschia amphioxys, Melosira nummuloides,Navicula cincta, N. exigua, N. longa, N. radiosa, N. salinarum, Nitzschia clausii, N. closterium, N. linearis, N. longissima, N. palea, N. paleaecea, N. panduriformis, N. sigma, N. singma, N. sigma var. *rigida, N. sigma* var.*rigidula, Pinnularia braunii, Pleurosigma angulatum, P. elongatum, Synedra ulna, Thalassionema nitzschiodes, Oscillatoria limnetica, O. raoi, O. tenuis, Mougetia adnata, Oedogonium rufescens, Stigeoclonium flagelliferum* and*Ulothrix tenerrima* at the stations studied contributed the similarity betweenstations.

4.3.7 Species Composition

Pokkali and prawn fields of N. Paravoor and Vypeen Island composedof 185 species of Bacillariophyceae, 34 species of Myxophyceae 24 speciesof Chlorophyceae and two species of Euglenineae. The stations exhibited ahigh variation in the number of species reported. The maximum number ofspecies 119 was recorded from station 5 while the minimum number 96 species were reported from the stations 1 and 6 (Table 4.12). Species of Nitzschia and Navicula showed high species diversity. 21 species of Nitzschia have been reported from station 3.

4.3.8 Population Density

Annual and monthly occurrences of abundance of periphyton standing crop at 10 different stations are shown in Fig 4.2 and Fig 4.3. The monthly average periphyton cell numbers in the study area varied from $4.4x10^3$ to $6.4x10^4$ cells cm^{-2}. The highest cell numbers recorded was$3x10^5$ from station 6 during December and the lowest, $9.7x10^2$ cells cm^{-2} from station 10 during July.

Achnanthes brevipes, A. longipes, Amphora coffeaeformis, Cocconeis placentula var. *euglipta, C. scuttellum, Cymbella japonica,Epithemia musculus, Fragilaria oceanica, Hantzschia amphioxys, Navicula cincta, N. exigua, N. longa, N. salinarum, Nitzschia clausii,*
N. closterium, N. palea, N. sigma ,N. sigma var. *rigida, Pinnularia braunii, Thalassionema nitzschioides, Oscillatoria spp., Mougeotia adnata, Oedogonium rufescens and Stigeoclonium flagelliferum* were dominant through out the year in all stations studied. Irrespective of the variations of the study area the common occurrence of these speciesthrough out the year indicted that they are typically euryhaline species.

Climacosphenia moniligera, Coscinodiscus radiatus, Fragilaria construens, Gomphonema gracile, Gyrosigma littorale, Licmophora abbreviata, Nitzschia capitellata, Nitzschia sigma var. *rigida, Microspora pachyderma* and *Monoraphidium dybowskii* were *recorded only during post* *monsoon season* and *Achnanthes coarctata, Diploneis puella, Encyonema prostratum, Melosira dubia, Thalassiosira subtilis, Oscillatoria angustissima, O. chlorina, O. formosa, O. laete-virens* var. *minimus, O. raoi,* and *Spirulinasubsala* were recorded only during pre monsoon. As these forms were seenonly during high salinity they are true saline species.

The presence of *Cymbella tumida, Gyrosigma nodiferum, Navicula rhynchocephala* var. *grunowii, N. hasta, Pleurosigma aestuarii, Tabellaria flocculosa, Oscillatoria agardhii,* and *Ulothrix cylindricum*only during monsoon indicted that they are true fresh water forms.

Periphytic floral composition of the pokkali and prawn fields of N. Paravoor and Vypeen Island (Table 3.1) showed that out of the 71 genera identified, 45 belonged to Bacillariophyceae, 9 Myxophyceae, 16 Chlorophyceae and 1 Euglenineae. 185 species of diatoms formed the dominant group of periphytic flora of the study area. Among diatoms pennate forms were dominant. Out of 185 diatoms reported 162 species were pennales and only 23 species belonged to 8 genera of centrales.

4.4 Summary

The monthly average periphyton cell numbers in the study areavaried from $4.4x10^3$ to $6.4x\ 10^4$ cells cm^{-2}. The highest cell numberrecorded was $3x\ 10^5$ from station 6 during December and the lowest $9.7\ x\ 10^2$ cells cm^{-2} at station 10 during July. The two way ANOVA analysis of salinity showed a significant variation between stations and between seasons ($p<0.05$). The algal number of the study area showed a positive correlation to salinity ($p<0.01$). Thus the standing crop at different stations exhibited considerable variation with salinity. Analysis showed thatthere was no correlation between nutrient concentration and algal cell number. Margalef's index of richness was higher during monsoon indicating the favourable environmental conditions prevailed during the season.

The highest Shannon Weiner index of diversity was noticed during post-monsoon. Likewise the least Simpson's index value was recorded during post-monsoon suggesting that more species diversity was shown during post monsoon. The lowest value of Simpson's measure of evennessrecorded during monsoon indicated the high evenness during monsoon.

The similarity of the flora was analysed by studying Sorenson's similarity index. The study revealed that the flora showed high similarity. In six stations the floral similarity was higher than 70%.

The flora of pokkali and prawn fields of N. Paravoor and Vypeen Island composed with 71 genera and 245 species. Out of that 45 genera and185 species of diatoms, 9 genera and 34 species of Myxophyceae, 16 generaand 24 species of Chlorophyceae and 1 genus and 2 species of Euglenineae. Among the Diatoms 37 genera and constituted by pennales and 8 genera by centrals.

Table 4.1 Monthly mean values of environmental parameters

Month	Salinity ($x10^{-3}$)	Dis. Oxygen(ml/L)	Temp.^{0}C	pH	Silicate	NO_2-N	NO_3-N	PO_4
Feb.	23.75	5.22	29.58	7.08	42.64	0.55	0.23	0.99
Mar.	23.10	5.98	30.00	7.05	36.96	0.62	0.07	1.55
Apr.	20.05	7.65	32.25	7.18	47.21	0.33	0.54	1.98
May	13.90	9.34	30.93	6.94	46.52	0.45	0.21	2.07
Jun.	9.80	9.93	29.95	6.87	52.91	0.48	0.83	2.47
Jul.	1.60	8.47	29.35	6.93	82.54	0.61	0.76	3.17
Aug.	3.38	6.87	31.16	6.21	89.43	0.41	1.83	2.79
Sep.	1.40	10.80	32.20	6.81	102.45	0.83	3.70	2.90
Oct.	6.63	4.62	30.68	6.71	114.64	0.19	0.79	1.84
Nov.	6.75	4.88	30.30	6.99	108.52	0.34	0.99	2.31
Dec.	11.00	4.94	31.75	6.91	85.52	0.28	0.75	1.87
Jan.	22.35	4.51	28.78	6.99	50.99	0.14	0.70	1.41
Average	**11.98**	**6.93**	**30.58**	**6.89**	**71.69**	**0.44**	**0.95**	**2.112**

Table 4.2 ANOVA of seasonal variations ($p<0.05$) of salinity atdifferent stations

Source of Variation	DF	SS	MS	F
Station	9	1284.956	142.773	4.063
Season	2	5225.666	2612.833	74.355
Station x Season	18	253.334	14.074	0.401
Residual	90	3162.594	35.14	
Total	119	9926.55	83.416	

Table 4.3 ANOVA of seasonal variations of Temperature(p<0.05) at different stations

Source of Variation	DF	SS	MS	F
Station	9	98.82	10.98	4.242
Season	2	2.43	1.215	0.469
Station x Season	18	59.057	3.281	1.268
Residual	90	232.968	2.589	
Total	119	393.275	3.305	

Table 4.4 ANOVA of seasonal variations of pH (p<0.05) atdifferent stations

Source of Variation	DF	SS	MS	F
Station	9	5.195	0.577	5.68
Season	2	2.575	1.287	12.667
Station x Season	18	1.368	0.076	0.748
Residual	90	9.147	0.102	
Total	119	18.285	0.154	

Table 4.5 ANOVA of seasonal variations of Silicate (p<0.05)at different stations

Source of Variation	DF	SS	MS	F
Station	9	19098.2	2122.022	2.124
Season	2	49585.14	24792.57	24.821
Station x Season	18	16807.68	933.76	0.935
Residual	90	89897.7	998.863	
Total	119	175388.7	1473.855	

Table 4.6 ANOVA of seasonal variations of Nitrate ($p<0.05$) atdifferent stations

Source of Variation	DF	SS	MS	F
Station	9	32.995	3.666	1.401
Season	2	47.252	23.626	9.031
Station x Season	18	71.188	3.955	1.512
Residual	90	235.447	2.616	
Total	119	386.882	3.251	

Table 4.7 ANOVA of seasonal variations of Dissolved oxygen($p<0.05$) at different stations

Source of Variation	DF	SS	MS	F
Station	9	176.176	19.575	4.978
Season	2	186.197	93.099	23.676
Station x Season	18	115.837	6.435	1.637
Residual	90	353.89	3.932	
Total	119	832.1	6.992	

Table 4.8 ANOVA of seasonal variations of Nitrite ($p<0.05$) atdifferent stations

Source of Variation	DF	SS	MS	F
Station	9	2.212	0.246	2.866
Season	2	2.525	1.263	14.725
Station x Season	18	1.587	0.0882	1.028
Residual	90	7.718	0.0858	
Total	119	14.042	0.118	

Table 4.9 ANOVA of seasonal variations of Phosphate ($p<0.05$)at different stations

Source of Variation	DF	SS	MS	F
Station	9	118.499	13.167	7.896
Season	2	32.111	16.056	9.629
Station x Season	18	99.555	5.531	3.317
Residual	90	150.068	1.667	
Total	119	400.234	3.363	

Table 4.10 Correlation matrix of standing crop and environmentalparameters

	Dissolved Oxygen	NO_3-N	NO_2-N	SiO_3	PO_4	pH	Temperature	Salinity	Algal Number
Dissolved Oxygen	1								
NO_3-N	.253**	1							
NO_2-N	.169	.313**	1						
SiO_3	-.156	.208*	.011	1					
PO_4	.182*	.054	.247**	.362**	1				
pH	-.046	-.146	.126	-.154	.126	1			
Temperature	.433**	.156	.123	.047	.159	.015	1		
Salinity	-.091	-.311**	-.126	-.645**	-.319**	.318**	-.046	1	
Algal Number	-.188*	-.092	-.112	-.085	-.144	.168	.104	.289**	1

** Significant at 0.01 level (2 tailed)
* Significant at 0.05 level (2tailed)

Table 4.11 Diversity indices of species richness (R), diversity (H'), Simpson's (D) and Simpson's measure of evenness $E_{1/D}$

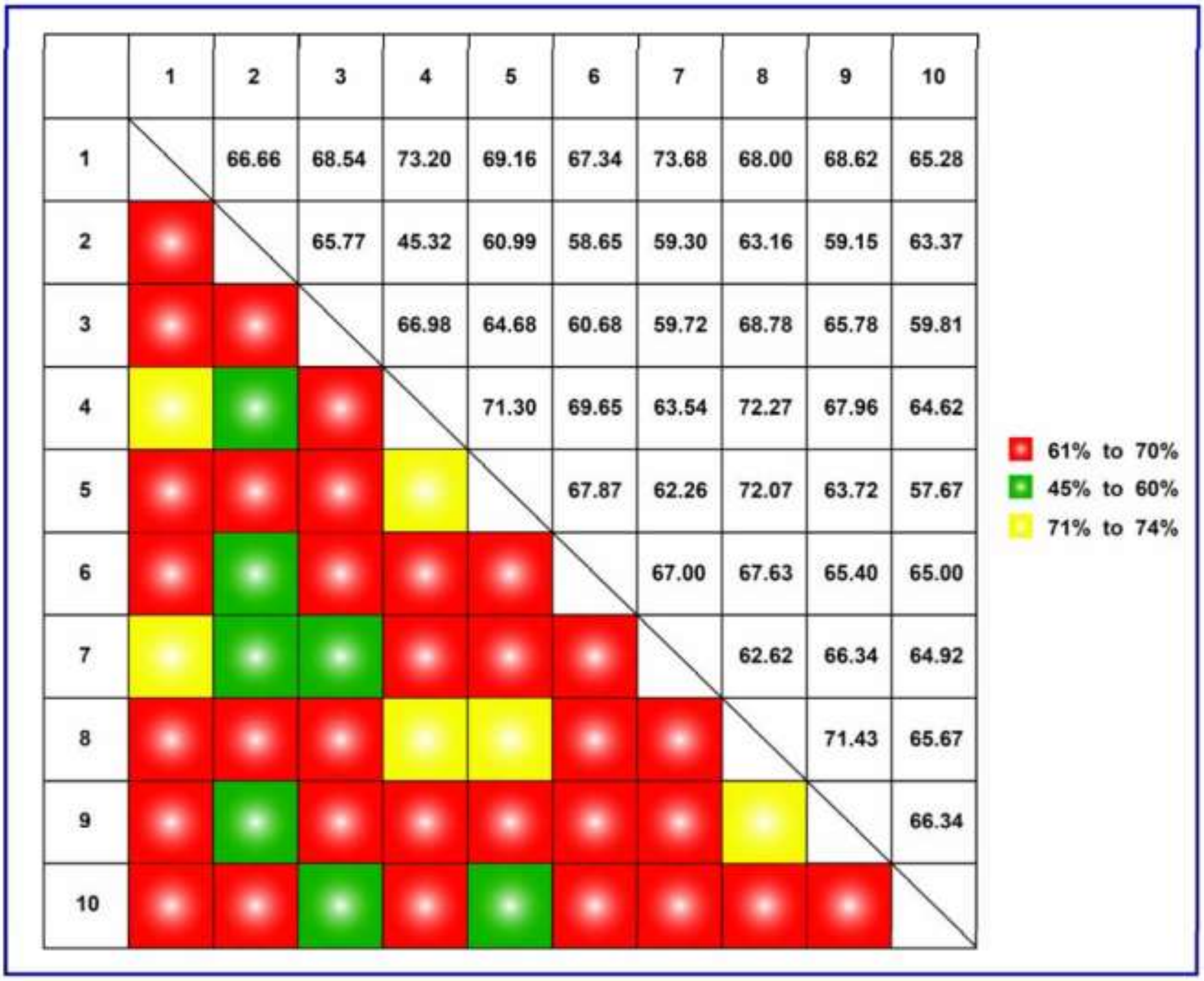
Station	Pre-monsoon				Monsoon				Post-monsoon			
	R	H'	D	$E_{1/D}$	R	H'	D	$E_{1/D}$	R	H'	D	$E_{1/D}$
1	2.654	2.201	0.176	0.235	2.830	2.247	0.175	0.228	2.981	2.068	0.230	0.138
2	2.730	2.099	0.241	0.200	2.105	1.594	0.360	0.162	3.047	2.475	0.140	0.265
3	3.179	2.112	0.218	0.154	3.263	2.343	0.151	0.267	3.170	2.387	0.159	0.198
4	3.037	2.418	0.161	0.248	2.256	2.196	0.200	0.26	3.327	2.616	0.121	0.266
5	3.552	2.294	0.198	0.146	3.803	2.658	0.127	0.256	3.822	2.661	0.118	0.224
6	2.812	1.969	0.268	0.140	3.544	2.178	0.238	0.167	3.154	2.103	0.251	0.135
7	3.154	2.148	0.223	0.173	2.561	1.795	0.327	0.236	2.520	2.349	0.149	0.311
8	3.009	2.443	0.172	0.236	3.560	2.473	0.144	0.245	3.274	2.513	0.127	0.257
9	2.898	2.096	0.239	0.155	2.839	2.466	0.152	0.339	3.075	2.075	0.253	0.162
10	3.121	2.567	0.130	0.252	2.691	2.218	0.191	0.269	2.920	2.362	0.164	0.256
Average	**3.015**	**2.235**	**0.203**	**0.194**	**2.945**	**2.217**	**0.207**	**0.243**	**3.129**	**2.361**	**0.171**	**0.221**

Table 4.12 List of periphytic algal genera reported in the study area

Number of genera at 10 different stations										
Algal genera	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Bacillariophyceae									
Achnanthes	3	2	3	3	3	4	3	3	3	2
Amphiprora	0	1	0	0	2	1	0	1	1	1
Amphora	5	5	5	5	7	4	5	9	5	6
Anomoeoneis	0	0	0	0	0	0	1	2	0	0
Bacillaria	1	1	1	1	1	0	1	1	1	1
Biddulphia	0	1	3	1	1	0	0	1	1	1
Caloneis	2	1	1	2	2	4	1	2	1	1
Campylodiscus	1	1	0	0	2	1	0	0	0	0
Climacosphenia	0	1	0	0	0	0	1	0	0	0
Cocconeis	3	3	3	3	3	2	2	3	3	2
Coscinodiscus	2	2	2	2	4	3	2	1	0	2
Cyclotella	2	0	0	0	1	1	1	0	1	1
Cymbella	6	7	7	6	7	7	7	7	7	7
Diatoma	0	0	0	0	0	0	0	0	0	1
Diploneis	2	3	4	3	3	2	2	2	2	2
Donkinia	0	0	1	0	0	0	0	0	1	0
Encyonema	1	0	0	1	1	0	1	0	1	0
Epithemia	1	1	1	1	1	1	1	1	1	1
Eunotia	1	1	1	1	0	0	0	0	1	1
Fragilaria	1	1	1	1	2	2	1	1	1	1
Frustulia	0	1	0	0	0	0	0	0	0	1
Gomphonema	2	2	2	1	1	1	1	1	1	1
Grammatophora	1	1	1	1	1	1	1	1	1	1
Gyrosigma	4	3	3	4	6	5	1	3	4	3

Hantzschia	1	1	1	1	1	1	1	1	1	1
Licmophora	1	1	1	0	1	1	1	1	1	1
Mastogloia	1	1	0	2	0	1	1	1	0	0
Melosira	1	0	2	1	1	3	0	2	2	1
Navicula	13	16	12	17	13	12	11	11	13	11
Nitzschia	16	16	21	14	20	15	16	14	20	15
Pinnularia	1	2	1	1	1	1	1	1	1	1
Pleurosigma	2	3	4	3	3	3	4	4	3	7
Podosira	0	0	0	1	1	0	0	1	0	0
Rhaphoneis	0	0	0	1	1	0	1	0	1	0
Rhoicosphenia	0	1	0	0	0	0	0	0	0	0
Rhopalodia	0	0	0	0	0	0	0	1	0	0
Stephanodiscus	0	0	0	0	0	0	0	0	1	0
Surirella	0	2	2	0	3	1	2	2	2	1
Synedra	2	3	2	2	2	2	2	2	2	2
Tabellaria	1	0	1	1	0	1	0	0	0	0
Thalassionema	1	1	1	1	1	1	1	1	1	1
Thalassiosira .	0	0	0	1	1	1	1	0	0	0
Thallassiothrix	0	0	1	0	0	0	0	0	0	0
Triceratium	0	0	0	0	0	0	0	1	0	1
Tropidoneis	0	0	1	0	0	0	1	1	0	1
Myxophyceae										
Anabaena	0	0	0	1	1	1	0	1	0	0
Aphanocapsa	1	2	2	1	1	1	1	1	1	1
Arthospira	0	0	0	0	0	1	1	0	0	1
Calothrix	1	1	1	1	0	0	0	0	1	0
Lyngbya	1	4	3	1	1	1	3	2	3	1

Merismopedia	0	1	1	0	1	0	0	1	1	0
Nostoc	1	0	1	1	1	0	1	1	0	0
Oscillatoria	3	5	4	3	5	8	3	4	5	5
Spirulina	0	0	1	0	1	2	1	0	0	0
Chlorophyceae										
Chaetophora	0	0	1	0	0	0	0	0	0	0
Chlorella	1	1	1	0	1	1	1	1	1	1
Cladophora	1	0	1	0	0	0	1	1	1	0
Closterium	0	1	0	0	0	0	0	0	0	0
Enteromorpha	1	1	1	1	1	0	0	0	1	1
Microspora	1	0	0	0	0	0	1	0	1	0
Monoraphidium	0	0	1	1	0	1	1	0	0	1
Mougeotia	1	1	1	1	1	0	0	1	1	1
Oedogonium	1	2	2	1	1	1	1	2	1	1
Parsonella	0	0	0	0	1	0	0	0	0	0
Schizomeris	0	1	0	0	0	0	0	0	0	0
Schroederiella	0	0	0	0	1	0	0	1	0	0
Spirogyra	0	3	1	0	1	0	0	1	1	0
Stigeoclonium	2	2	2	1	2	1	2	2	2	2
Ulothrix	2	0	1	1	1	1	1	1	2	1
Uronema	0	0	0	0	0	0	0	0	1	0
Euglenineae										
Euglena	1	2	1	1	1	1	1	1	1	1
Total	**96**	**112**	**115**	**97**	**119**	**102**	**94**	**104**	**108**	**96**



155

Fig. 4.1 Trellis diagram showing floral similarity at 10 different stations

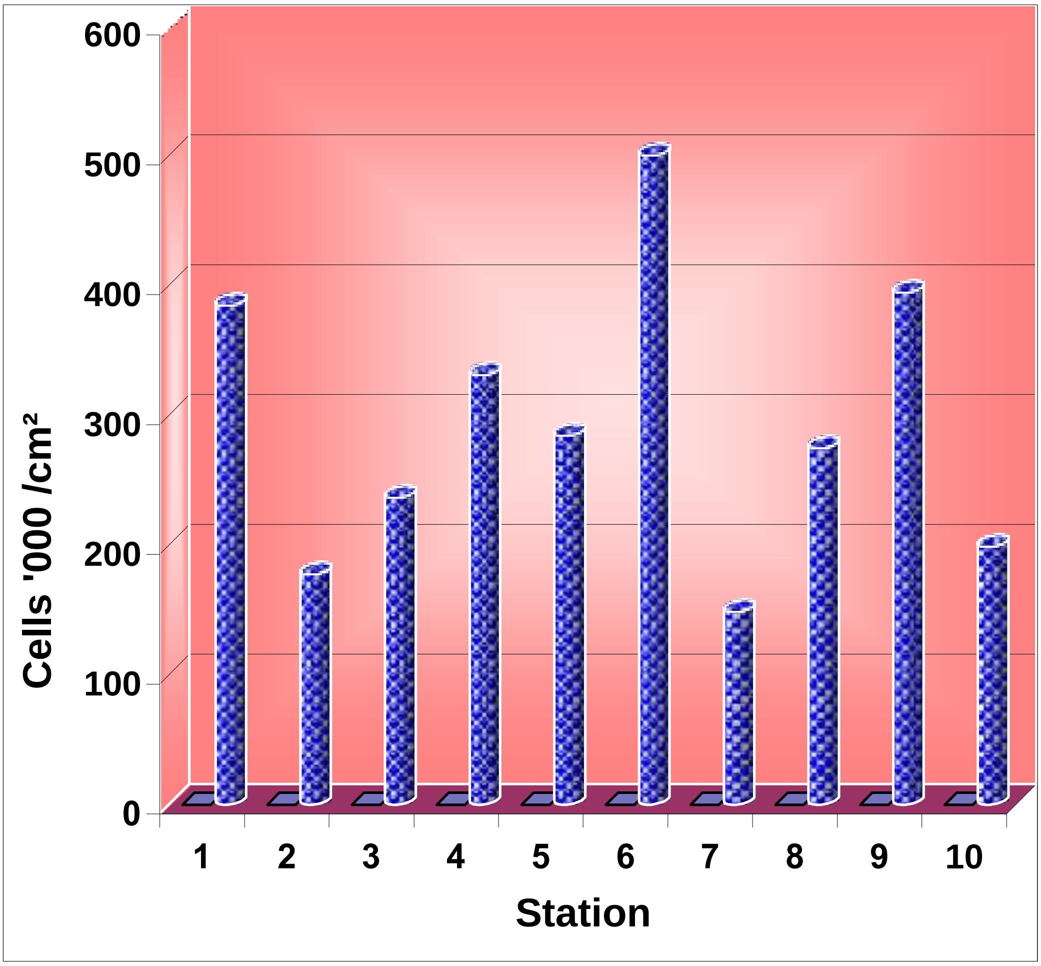


Fig.4.2 Annual mean algal numbers at stations1-10

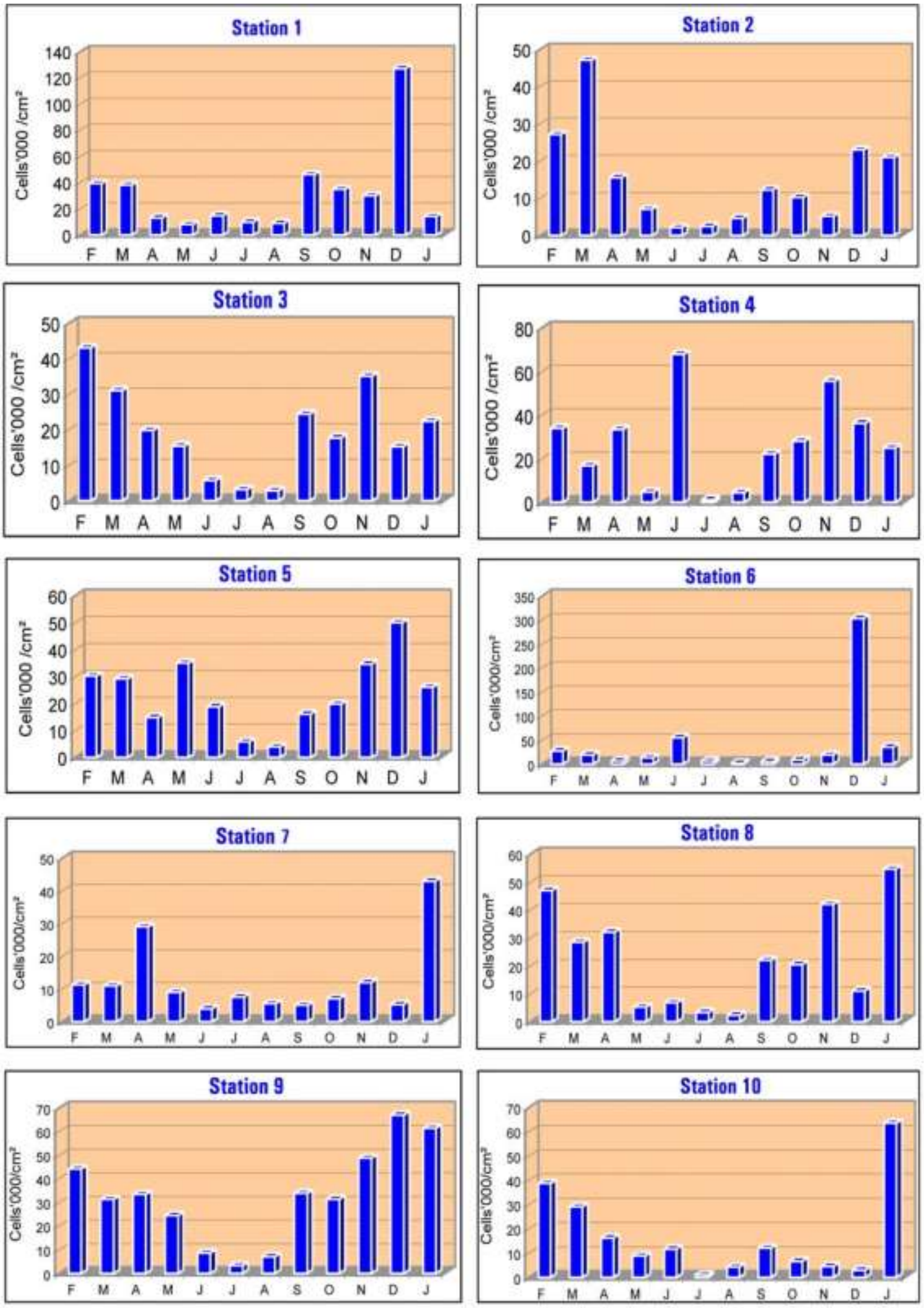


Fig. 4.3 Monthly mean periphytic cell numbers at stations 1-10

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BFSC-203: Freshwater Aquaculture

Pond Management

A. Nursery Pond:

The total fry (fish seeds above 8mm. and up to 40mm. in length) requirements for the presently cultivated waters have been estimated over 165.18 crores. If all existing readily available water areas for nursery production are to adequately stocked, the total requirements to meet the above demand would be 219.66 crores and this requirement will further increase the production of fish culture in our country.

The available sources of fry production in the country are

a) From riverine collection (contributes 5.90% of total seed production in country)
b) Production in different hatcheries

Nursery pond management is based on the principle of bringing suitable and proper ecological, physico-chemical and biological conditions in pond, where by protection from harmful external factors and promotion of optimum growth and survivality of the fry, will be ensure in natural conditions or through human manipulation.

Factors responsible for mortality of fish larvae in nurseries are –

a) Damage and injury to spawn collection and during transport.
b) Wide fluctuation of physico-chemical parameters of the container carrying the fry and pond water.
c) Defective method of fish seed stocking in pond.
d) Presence of unwanted organisms in nursery pond.
e) Macro and micro weed infestation.
f) Lack of sufficient natural food.
g) Rearing duration.
h) Improper feeding management and schedule.
i) Deterioration of soil and water quality in pond.

Nursey ponds are small, shallow ponds, perennial or seasonal, to rear the fishes from spawn to fry stage. In some larger production ponds may be large in size, though, generally, these types of ponds having 0.02-0.04 ha in size, 3-3.5 feet in depth. Cement riveted, stone, brick and even fiberglass tanks can also be used as nursery rearing tank with different management protocols than earthen pond. Culture period in nursery ponds is about 12-16 days.

The ecological condition – the inter-relationship of primary productivity, plant and animal life, which complete with each other and complete the food chain in a nursery environment bears great significance in successful nursery management in earthen ponds. Ecological factors such as, abundance of macro-vegetations and higher animal life in the form of fish, insects and amphibian population hardly play any important and useful role in the rearing of the fry. An alternation of natural ecology through human agency is necessary to make a nursery is, there, to be limited to short cycle ending with zooplankton organism.

Time of the pond preparation: April to May.

Type of the pond: Seasonal (Dry type) and Perennial (Nevertheless, seasonal types are most common).

Pre-stocking Operation in Dry/Seasonal Pond:

1. Drying the pond still the cracks appear on the bottom.
2. Repair the dykes, berm, and bottom of the pond.
3. Ploughing of the pond bottom with raw cow dung and green manure by exposing the sub soil to the atmosphere to speeding up the oxidation process and release the nutrients.
4. Applications of small volume water to the pond just to moist the pond bottom.
5. Application of manure – raw cow dung @ 1000 kg/bigha; single super phosphate @ 10 kg/ha.
6. Raking of pond soil after 7 days of manuring.
7. Application of lime @ 30 kg/ha.
8. Filling of pond with sufficient water inlet.
9. Testing of water parameters after 2 to 7 days. (The optimal condition should be like as follows)
    a) Colour of the water – turbid brown, light green, red,
    b) pH => 7.8 to 8.2
    c) Alkalinity => 120-170 ppm.
    d) Dissolved oxygen content => 5 to 8 ppm.
    e) Alkalinity – 70 to 150 ppm.
    f) Free ammonia – Nil.
    g) Phosphate => 0.2 to 0.4 ppm.
    h) Nitrite => 0.06 to 0.1 ppm.
10. Measurement of zooplankton density, when the density is found optimum, the pond is ready to be stocked.
11. Twenty-four hours before stoking, all the aquatic insects should be killed by using soap and oil emulsion, generally kerosene is used.

Pre-stocking Operation in Perennial Pond:

1. **Control of predatory and weed fishes -** In perennial pond predatory and weed fauna in the water body is to be eradicated by netting or using fish toxicants. The common fish toxicants are –
    a) Mohua oil cake - Mahua oil cake at 200-250 ppm is applied 15 days before stocking and pond effectively kills in predatory fishes. Mahua oils cake containing -6% saponin enters the blood stream of fishes causing haemolysis and subsequent mortality. The application of mahua oil cake has gained wide popularly due to its fertilizing effect after toxic effect.
    b) Derris root powder – It is a contact poisons with 5% rotenone, damages the respiratory system of the fishes and a connection of 4 ppm is effective against all forage fishes. The required quantity of derris root powder is applied 12 days prior to stocking. It is mixed thoroughly with water and sprayed over the water surface.
    c) Chlorinated hydrocarbons –

i. Endrin (Tafadrin 20)
ii. Organophosphate (Thiometon DDVP, Phosphamidon)

2. **Control of aquatic weeds** - Perennial water bodies is used for nursery operations may contain luxurious growths of various aquatic weeds which should be removed by following ways –
   a) Manual control – Nursery ponds are small and labours are cheap in India. Most of the ponds are cleared manually by hand pickling of aquatic weeds. Small floating weeds like *Lemna* and other algae can be removed by straw rope dragging towards the corner of the pond.
   b) Mechanical control – some weed cutting machine can be used for relatively large pond for larger production. But in nursery pond, mechanical weed cutters are hardly used.
   c) Chemical control **-** The manual removal of weeds from heavily infested large water bodies is difficult and time consuming. Under such conditions certain commercially available chemicals (herbicides) can provide an efficient means of eradication of undesirable aquatic plants. The common herbicide used in pond clearance is 2-4D (12 kg/ha). Water lettuce which often causes a serious problem in fish ponds can be controlled with 0.1–0.2 kg of paraquat/ha. This infestation could also be controlled by foliar spray of aqueous ammonia (1%) at the rate of 50–75 kg/ha along with 0.2 % of any commercially available detergent as a wetting agent.
   d) Biological control – biological control of aquatic weeds is not common in nursery pond. Grass carp is the most effective biological control agent against most of the submerged and floating weeds except the water ferns. Grass carp normally consumes some aquatic weeds, at least 50% of their body weight in a day.
3. **Fertilization** - Fertilization schedule involving both organic and inorganic fertilizers starts 10–15 days prior to stocking and is prepared on the basis of nutrient status and chemical environment of the pond soil and water.
   a) Organic fertiliser – Raw cow dung @ 1000 kg/bigha
   b) Inorganic fertiliser – single super phosphate @ 10 kg/bigha; urea @ 5 kg/ha.
   c) Maharashtra schedule of manuring consist of the following steps:
      i. **Stage-1:** Organic RCD @ 700kg/ha. and oilcake @ 700kg/ha, with inorganic superphosphate 150kg/ha, triple phosphate 80kg. /ha. the day before the expected date of stocking spawn.
      ii. **Stage-2:** Organic RCD @ 88kg/ha and peanut oil cake @ 350kg/ha on the day following the date of stocking.
      iii. **Stage-3:** Organic RCD 44kg/ha, peanut oil cake @ 175kg/ha on the second day following the date of stocking.
      iv. **Stage-4:** Organic RCD 22kg/ha, peanut oil cake @ 88kg/ha from 3rd day to 10th day following the date of stocking.
4. **Liming** - This is the first steps in the fertilization of a nursery pond. The quantity of lime to be applied depends on the pH of the soil. Liming is important to enhance the effect of organic fertilisers in pond. It can also disinfect the pond water and eliminates some harmful pathogens. It also maintains the optimum pH condition of water and soil.

PH range	Quantity of Lime kq/ha
4 - 4.5	1,000
4.5 - 5.5	700
5.5 - 6.5	500
6.5 - 7.5	200

5. **Control of aquatic insect** – A high survival in nursery pond can be expected only if the insect population is completely eradicated which otherwise will prey upon with spawn in addition to being competitors for the food. Among the insect beetles back swimmers water bugs, water scorpions, dragonfly nymphs cause considerable harm to the span in nursery ponds.
   a) Repeated drag netting using a fine method (1/16) on the previous day of commissioning the one can eradicate the insect population in nursery pond in to a considerable extends.
   b) Most of aquatic insects utilize the atmospheric oxygen for respiration which if cut off from the water column will lead to its mortality by suffocation. This is achieved through. 'Oil emulsion' by producing and uniform oil firm over the water surface. For making soap-oil emulsion, the soap is mixed with oil and gently heated for some time with vigorous stirring. These emulsions are applied by spraying over the pond surface about 12–24 hours prior to stocking of spawn. It is the film of the emulsion which is important and hence care is taken not to disturb the film for a few hours. Windy days should be avoided as it will break the film.
   c) Malathion application in nursery ponds also controls the predatory insects' population and hence subsequent treatment for control of insect is not required. However, if swarms of these predatory insects are seen in the nursery pond, treatment should be applied immediately.
6. **Water quality test** – (same as dry pond preparation mentioned above).
7. **Assessment of Food in Nurseries** – The quantitative and qualitative nature of standing crop of plankton following fertilization od nurseries is to be ascertained at short intervals by filtering 45 litres of pond water through plankton collection net made of No. 21 bolting silk. A rich production and dominance of Phyto-planktonic organisms in the nursery at the time of stocking suggests its immediate unsuitability for stocking and sediment volume of about 1.0ml. of zooplankters, consisting of rotifers, copepod nauplii and Cladocera is to be regarded as a good food reserve for the hatchlings.

Stocking of Nursery Pond:

Complete detoxification of the piscicide applied earlier should be ensured before stocking the nursery, rearing and stocking ponds. One or two days prior to stocking, a hapa should be fixed in the pond and some stocking materials should be put inside the hapa. Absence of distress and mortality after 24 hours confirm complete detoxification and the pond should be regarded as ready for stocking.

Carp spawn requires natural feed immediately after stocking and hence it is essential to have a minimum plankton value of 30–40 ml/m^3 in case of stocking at a moderate rate (1.5–2.5 million/ha). When a higher stocking rate is to be adopted, plankton population is also required to be increased accordingly. In case the stocking density is over 5 million/ha, the plankton volume should be around 100 ml/m^3. Self-produced or procured 3–4 days old spawn should be stocked in the morning at the rate of 4–6 million/ha. The stocking density must be according to the condition of the pond and the amount of fish food organisms available. The rate of stocking in a well-prepared nursery pond with adequate fish food organisms can be as high as 10 million/ha.

Post-stocking Operation Nursery Pond:

1. **Feeding** - Soon after the entry into the pond the spawn starts voracious feeding on the plankton. Within a couple of days, the plankton population gets depleted. Hence a supplementary diet is resorted so as to keep up the plankton biomass. Nursery ponds are fed with rice bran and finely powdered ground nut oil cake in 1:1 by weight. The following feeding schedule is more economical and gives better survival. For better utilization half of the feed is given during the morning hours and half during the evening hours in every day.
    - ✓ First 5 days - Equal to the initial body wt. of spawn stocked.
    - ✓ Second 5 days - Double the initial body wt. of the spawn stocked.
    - ✓ Third 5 days - Thrice the initial body wt. of the spawn stocked.

    The nursery feeds for higher stocking densities to get best survival rates should have the following qualities –

    a) Ready acceptability to early fry,
    b) Easy digestibility and
    c) Higher conversion value

    The daily ratio is estimated on the basis of fry population and their advancing growth with the approximate initial weight of each spawn as 0.0014 g. The total quantity to be fed as; first 5 days of stocking – double the weight, second 5 days of stocking – three times the weight, and third 5 days of stocking – four times the weight.

    Broadcasting of feed on the surface water is the normal procedure. All the food broadcasted is not utilised by the early spawn and fry to full extent. A large quantity of feed drops down at the bottom of the pond, decomposed and forms organic manure.

    Mixture of dry finely powdered notonecta, small shrimps and cheap pulses in the ratio of 5:3:2 is also used as artificial feed at the same rate as that of grain barn and vegetable oil cake.

2. Harvesting - After 15 days of rearing the fry attains a size of 20-25 mms and the stock is ready for harvesting. Using 1/16 mesh cotton drag net pond is harvested repeated netting the survival range would be 60-85% with an average of 75%. The harvested fry required to be transferred to larger rearing ponds. Survival rates in nurseries have been

registered as high as 88% and an average of about 50% with size of fry ranging between 20 and 30 mm.

B. Rearing Pond:

Rearing of the 15 days old fry (25 to 30 mm) to the fingerlings (100-150mm) size in a large pond with in shortest period of 3 months' time is called rearing pond management. A rearing pond should have an area of 0.8 to 0.1 ha preferably rectangular in shape with water depth ranging from 1.5 to 2 metres. The utility of the rearing pond culture is to provide more space to fry reducing stocking density and at the same time providing a larger pond than the nursery pond for their proper growth and development. On the other hand, the 15 days old fry are reared in the same small nursery pond, their growth will be retarded and hence production will be hampered. The time of rearing in rearing pond is normally 2-3 months and sometimes up to 6 months.

Pre-Stocking management –

1. **Eradication of Aquatic Weeds -** Being somewhat deeper and longer than nursery ponds, rearing ponds are more liable to get infested with weeds. Am overgrowth of weeds deprived the pond soil of nutritive elements, restrict movement of fish interferes with netting operations and harbours predatory and weed fishes and insects.
   a) Manual control - Floating weeds like *Eichhornia* and *Pistia* are best removed by manual labour.
   b) Chemical control - Chemicals like 2,4-D are quite effective and economical against *Eichhornia*. When mixed with common domestic detergent 2,4-D effectively against weeds like Pistia *Nymphaea* and *Nelumbo*. Taficide 80, at a dose of 2.2kg/ha is also effective against *Eichhornia*.
   c) Mechanical control - Marginal weeds like *Typha*, grasses, sedges, *Ipomoea*, *Sagittaria* and *Colocasia* are effectively controlled by ploughing and burning during dry season or repeated cutting by weed cutter.
   d) Biological control - Some of the better-known fishes that are used for biological control of weeds are the grass carp, *Ctenopharyngodon idella* and *Puntius javanicus*. Grass carp feeds most of the weeds like *Otelia valliharia*, *Utricularia*, *Trapa* and *Myriophyllum*.

2. **Eradication of Predatory and weed fishes -** Weed fishes (e.g. *Puntius* spp. *Amblypharyngodon mola, E. danricus etc.)* are those which compete with the culturable species of fishes for food, space and oxygen and causing serious problem to fish culture. Predatory fishes (e.g. *Channa* spp., *Clarias* sp., *Wallago attu* etc.) are those causing the above-mentioned problems and also directly prey upon the fry and fingerlings of the culturable species.
   a) These fishes may be controlled by repeated drag netting or by complete dewatering of the ponds.
   b) However, when this is not possible and effective the unwanted fishes may be killed by the application of Mahua oil cake an effective fish toxicant a 2000-2500 kg/ha (at 1-meter water) to 200-250ppm/ Which kills toxicant fishes of the pond within 4-6 hours. The effect of the toxicant lasts for about 21 days after which it acts as 5% rotenone content at a dose of 4.20 mg/1 is perhaps the commonest pond toxicant used.

3. **Fertilisation -** The next step in rearing pond preparation is fertilization, the objective of which is to have sustained production of adequate quantities of zooplankton which forms the natural food of carp fry.

a) Organic manuring: Organic manures raw cattle dung is generally used as 10,000 organic manure raw cattle before the anticipated of stocking.
b) Inorganic Fertilization: Inorganic manures such as super phosphate can be used @ 250 kg/ha before stocking.

4. **Liming -** The advantage of liming pond is numerous enhances pond productivity and improves its sanitation. The commonly available lime for pond application are calcium carbonate, calcium hydroxide, calcium oxide and calcium sulphate. Lime can be applied to the pond bottom 200-250 kg/ha-added to water at inlets or uniformly broadcast on the water surface depending on the form of lime used.

Stocking Management:

In rearing ponds, the fry of IMC and Chinese are stocked in various combination at densities ranging from 2-3 lakhs/ha in the following rations.

Species Ratio - Some of the possible combinations are - catla, rohu, mrigal, common carp (3:4:1:3); silver carp, grass carp (1:1); silver carp, grass carp, common carp (4:3:3); catla, rohu, mrigal, grass carp (4:3:1.5); silver carp, grass carp, common carp, rohu (3:1.5:2.5:3), etc. Combination of too many species should be avoided as it invites excessive handling at the time of harvesting for species segregation. Fry are reared in ponds for about 3 months when they usually attain 100–150 mm in length and 15–40 g in weight. For healthy fry rearing it is recommended that the size of the fry at the time of stocking in the rearing pond should be as uniform as possible. This can be done by size grading at the time of fry harvesting from nursery ponds. Prior to stocking the rearing ponds, the pond waters must have a plankton level of about 30–50 ml/m^3.

Post stocking management –

1. **Feeding -** Supplementary feeding consisting of a mixture of ground nut /. Mustard oil cake and rice brain at 1: 1 ratio by weight in powders form broadcast every day in the pond during morning hours from the first day of stocking. The feeding schedule as shown below may be followed for 3 months rearing period.

Period	Quantity of Feed day/Lakh of Fry
First Month	6 kgs
Second Month	10 kg
Third Month	15 kg.

2. **Manuring -** During the culture period both organic and inorganic manures should be applied at 15 days interval in order to enhance zooplankton and phytoplankton respectively.
   a) Organic manure – 1000 kg/ha/month.
   b) Inorganic manure - 40kg/ha/ month.

3. **Liming -** During the culture period liming should be done 25kg/ha/ month liming should be followed on bright days and should be avoided on cloudy or rainy days.

4. **Netting Operations and Harvesting of fingerlings -** Netting should be done regularly at least once a month, the more the netting in a pond the better will be the yield of good sized fingerlings in pond. After 3 months the fingerlings can be harvested by which time they attain an average weight of 150-20gms. Supplementary feeding should be stopped a day before, harvesting. Harvesting should be done during cool morning hours.

C. Stoking Pond

Raising of fingerlings to table sized fish in large ponds (0.25-10.0 ha area and 0.8-3.0 depth) is referred to as the stocking pond management. Most of the following activities in the stocking pond management are similar to those of nursery and rearing ponds. To get maximum production of fish utmost care should be taken through the most economic management measures. The principles in the rational management of stocking ponds are increasing the carrying capacity or the maximum standing crop.

A pond can support a fish biomass up to only certain level or limit. This limit is called the carrying capacity or the maximum standing crop. Carrying capacity of ponds are increasing by fertilization and supplementary increasing by fertilization and supplementary feeding, optimum utilization of ecological riches in the pond by good management of water quality, the culture of first growing species and fish health monitoring. The management of stocking pond is broadly discussed in three stage as in rearing ponds.

Pre-stocking Management:

New ponds, pre-stocking operations starts with liming and filling of the pond with water. The first step for existing pond requiring development deals with clearing the unwanted weeds and fishes either by manual, mechanical or chemical means from the pond. Different methods are employed for this.

1. **Control of aquatic weeds -** Removal of weeds by Manual/Mechanical, Chemical or biological means.
   i. Manual/Mechanical – Clearance of weeds by means of hand pickling, mechanical cutter, burning etc.
   ii. Chemical means – herbicides like 2,4-D (2,4-dichlorophenoxy acetic acid), Paraquat or aqueous ammonia and Diuron/Karmex,
   iii. Biological means- introduction of Grass carp, Tilapia, Common carp, Pearl spot, Giant gourami

2. **Removal of unwanted and predatory fishes and other animals –** by repeated netting or using mahua oil cake @ 2500 kg/ha meters or by sun drying the pond bed. Other toxicants include tea seed cake with a dose of 15 ppm. in salinity less than 15ppt, tamarind seed powder with a dose of 175-200 ppm.

3. **Liming -** The soils/ tanks which are acidic in nature are less productive than alkaline ponds. Lime is used to bring the pH to the desired level. In addition, lime also has the following effects
   a) Increases the pH.
   b) Acts as buffer and avoids fluctuations of pH.
   c) It increases the resistance of soil to parasites.
   d) Its toxic effect kills the parasites.
   e) It hastens organic decomposition.

   The normal doses of the lime desired ranges from 200 to 250 Kg/ha. However, the actual dose has to be calculated based on pH of the soil and water as follows:

SoilpH	Nature	Lime(kg/ha)
4.0-4.5	Highly acidic	1000
4.5-5.5	Medium acidic	700
5.5-6.5	Slightly acidic	500
6.5-7.5	Near acidic	200
7.5-8.5	Alkaline	Nil

Liming materials- calcium carbonate, calcium oxide, calcium hydroxide etc**.**

4. **Fertilisation/ Manuring -** Fertilisation of the pond is an important means for intensifying fish culture by increasing the natural productivity of the pond. The fertilisation schedule has to be prepared after studying the quality of the pond soil. A combination of both Organic and Inorganic fertilisers also be used. The fertiliser programme has to be suitably modified depending on the growth of the fish, available food reserve in the pond, physicochemical conditions of the pond and climatic conditions.

   a) Organic - Farm yard manure (FYM)- Cow dung @ 5000 kg/ha, Poultry, sheep manure.
   b) Crop by-products - cotton seed meal, mustard oil cake.
   c) Inorganic - Inorganic fertilisation to be undertaken after 15 days of organic manuring. Requirement of nitrogenous and phosphate fertilisers would vary as per the nature of the soil fertility indicated below. However, any one of the nitrogen and phosphate fertilisers could be used as per given rate.

Inorganic Fertiliser Application (kg/ha/month)

Soil fertility status	Ammonium sulphate	Urea
1. Nitrogen (mg/100 g soil)		
i) High (51-75)	70	30
ii) Medium (26-50)	90	40
iii) Low (upto 25)	140	60
2. Phosphorus (mg/100 gm soil)	**Single super phosphate**	**Triple super Phosphate**
i) High (7-12)	40	15
ii) Medium (4-6)	50	20
iii) Low (upto 3)	70	30

Stocking:

After proper preparation, the pond should be stocked with 100–150 mm long fingerlings of desired carp species. In case the fingerlings are not available, the pond can also be stocked with advanced fry or early fingerlings in absolutely predator-free ponds. The stocking rate depends primarily upon the volume of water and on the oxygen balance of the pond. Quality of available natural fish food in the pond and the capacity of the farmer to provide supplementary feed, are also matters for consideration. Usually a pond having average water depth of 1.5–2.5 m should be stocked at the rate of 5 000 fingerlings/ha. The volume of water available for fish in an undrainable pond should not be less than 2 m^3/fish if there is no provision of artificial aeration. In composite fish culture, rearing of six species of carps, viz. catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), silver carp

(*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*) is considered to be the ideal combination. However, depending on the availability of quality fingerlings of these carp species, three or four species combinations can also be taken up.

Species	3-species	4-species	6-species
Catla	4.0	3.0	1.5
Rohu	3.0	3.0	2.0
Mrigal	3.0	2.0	1.5
Silver Carp	-	-	1.5

Post stocking:

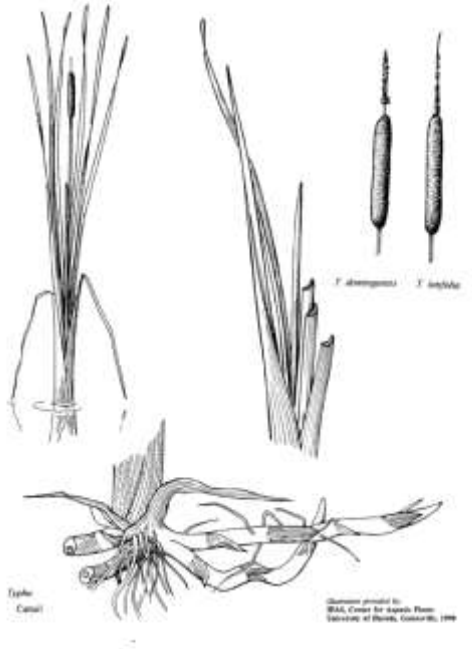
1. **Supplementary feeding -** Fishes need much more food than what is available naturally in the pond. Fishes can be fed with a mixture of rice bran and oilcakes in the ratio 4:1. Due to the high cost of Ground Nut Oil Cake (GOC) alternate sources like Cotton seed oil cake which is comparatively cheaper than GOC. GOC and cotton seed oil cake can be mixed in equal proportions and fed to the fish and is reported to give almost the same growth rate as that of GOC. The feed should be placed on a feeding tray or in feeding bags and lowered to the pond bottom or it can be dispersed at the corners of the pond. After some time, the fishes will get used to this type of feeding and aggregate at the same place at particular time for regular feeding thereby reducing the feed losses. The recommended feeding rate is 5 - 6 % of the body weight up to 500gm size of fish and then reduce to 3.5% of body weight from 500-1000gm size. The feeding is supplementary in nature.

2. **Manuring -**
   a) Organic manuring may be done in monthly instalments @ 1000 kg/ha.
   b) Inorganic fertilisation may be done at monthly intervals alternating with organic manuring. However, the monthly rate of fertilisation will depend on pond productivity and the growth of the fishes. It should be ensured that excess fertilisation does not take place which may result in eutrophication.

3. **Harvesting -** Harvesting is generally done at the end of first year, when the fishes attain average weight of 800 gm to 1.25 kg. With Proper management a production of 4 to 5 tons/ha can be obtained in a year. Harvesting is done by partial dewatering and repeated netting. In some cases, complete dewatering of ponds is resorted to. Some farmers resort to partial harvesting also depending on the season and demand for fish.

Identification of Aquatic Weeds

Specimen - 1



Systematic Position

Kingdom – Plantae

Order - Poales

Family - Typhaceae

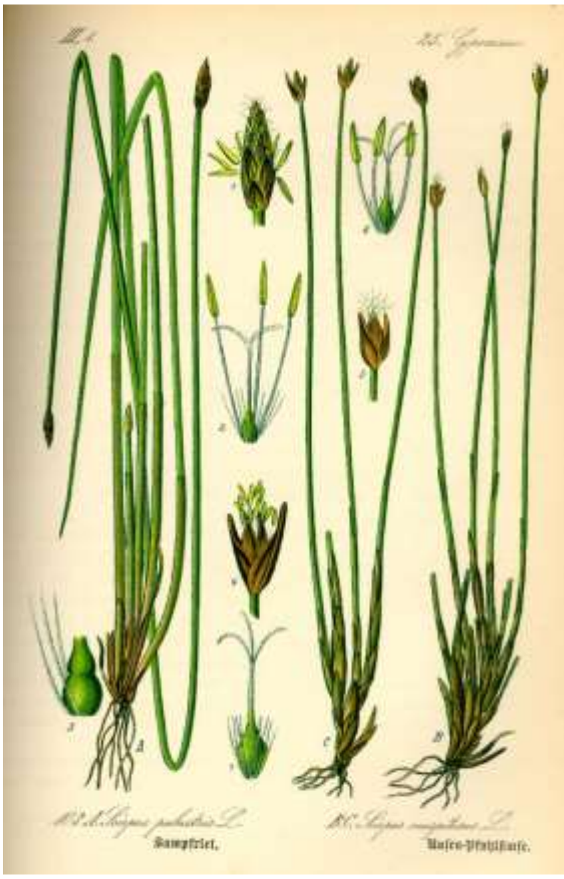
Genus – Typha

Identifying Character

1. *Typha* leaves are alternate and mostly basal on a simple, joint less stem that bears the flowering spikes.
2. The plants are monoecious, with unisexual flowers that develop in dense racemes.
3. The numerous male flowers form a narrow spike at the top of the vertical stem. Each male (staminate) flower is reduced to a pair of stamens and hairs, and withers once the pollen is shed. Large numbers of tiny female flowers form a dense, sausage-shaped spike on the stem below the male spike.

4. In larger species this can be up to 30 centimeters (12 in) long and 1 to 4 centimeters (0.39 to 1.57 in) thick.

Specimen - 2



Kingdom - Plantae

Order - Poales

Family - Cyperaceae

Genus – *Eleocharis*

Identifying Character

1. *Eleocharis* species have photosynthetic tube-shaped, leafless green stems but no green leaves (the leaves have been reduced to sheaths surrounding the base of the stems).
2. *Eleocharis* is an erect, rhizomatous, semi aquatic or aquatic, perennial herb.
3. Vegetative reproduction occurs through an extensive rhizome system and is responsible for the maintenance and expansion of existing stands. Sexual

reproduction via seed dispersal and seedling establishment is responsible for invasion of new areas.

4. Flower develop singly in axil of glumes, unisexual or bisexual.

Specimen - 3

Kingdom: Plantae

Order: Alismatales

Family: Araceae

Subfamily: Lemnoideae

Tribe: Lemneae

Genus: *Lemna*

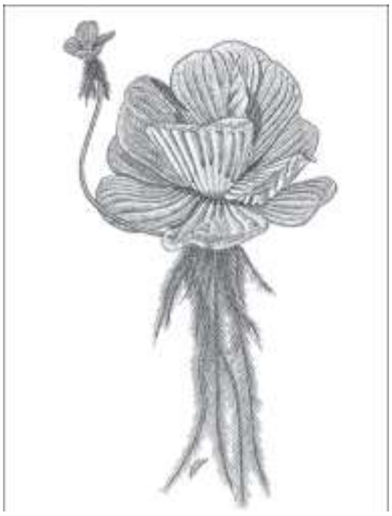
Specimen: *Lemna minor*

Identifying Character:

1. It is a floating freshwater aquatic plant, with one, two or three leaves each with a single root hanging in the water; as more leaves grow, the plants divide and become separate individuals.
2. The root is 1-2 cm long. The leaves are oval, 1-8 mm long and 0.6-5 mm broad, light green, with three (rarely five) veins, and small air spaces to assist flotation.

3. It propagates mainly by division, and flowers are rarely produced; when produced, they are about 1 mm diameter, with a cup-shaped membranous scale containing a single ovule and two stamens. The seed is 1 mm long, ribbed with 8-15 ribs.

Specimen – 4:



Kingdom: Plantae

Order: Alismatales

Family: Araceae

Subfamily: Aroideae

Tribe: Pistieae

Genus: *Pistia*

Identifying Character:

1. It is a perennial monocotyledon with thick, soft leaves that form a rosette.
2. It floats on the surface of the water, its roots hanging submersed beneath floating leaves.
3. The leaves can be up to 14 cm long and have no stem. They are light green, with parallel veins, wavy margins and are covered in short hairs which form basket-like structures which trap air bubbles, increasing the plant's buoyancy.
4. The flowers are dioecious, and are hidden in the middle of the plant amongst the leaves.

5. Small green berries form after successful fertilization. The plant can also undergo asexual reproduction. Mother and daughter plants are connected by a short stolon, forming dense mats.

Specimen - 5

Kingdom: Plantae

Order: Solanales

Family: Convolvulaceae

Tribe: Ipomoeeae

Genus: *Ipomoea*

Identifying Character:

1. It grows in water or on moist soil. Its stems are 2–3 metres (7–10 ft) or more long, rooting at the nodes, and they are hollow and can float.
2. The leaves vary from typically sagittate (arrow head-shaped) to lanceolate, 5–15 cm (2–6 in) long and 2–8 cm (0.8–3 in) broad.
3. The flowers are trumpet-shaped, 3–5 cm (1–2 in) in diameter, and usually white in colour with a mauve centre.

4. Propagation is either by planting cuttings of the stem shoots that will root along nodes or planting the seeds from flowers that produce seed pods

Specimen – 6

Kingdom: Plantae

Order: Commelinales

Family: Pontederiaceae

Genus: Eichhornia

Species: E. crassipes

Identifying Character:

1. Water hyacinth is a free-floating perennial aquatic plant (or hydrophyte) native to tropical and sub-tropical South America.
2. With broad, thick, glossy, ovate leaves, water hyacinth may rise above the surface of the water as much as 1 meter in height. The leaves are 10–20 cm across, and float above the water surface. They have long, spongy and bulbous stalks.

3. The feathery, freely hanging roots are purple-black. An erect stalk supports a single spike of 8-15 conspicuously attractive flowers, mostly lavender to pink in colour with six petals. When not in bloom, water hyacinth may be mistaken for frog's-bit (Limnobium spongia).
4. One of the fastest growing plants known, water hyacinth reproduces primarily by way of runners or stolons, which eventually form daughter plants. Each plant can produce thousands of seeds each year, and these seeds can remain viable for more than 28 years.

Algal Bloom

An algal bloom is a rapid increase or accumulation in the population of algae (typically microscopic) in a water system. Cyanobacteria blooms are often called blue-green algae. Algal blooms may occur in freshwater as well as marine environments. Typically, only one or a small number of phytoplankton species are involved, and some blooms may be recognized by discoloration of the water resulting from the high density of pigmented cells.

Problems of algal bloom

1. Produce extremely dangerous toxins that can sicken or kill people and animals.
2. Absorbs nutrients from water
3. Sudden death of algal bloom increase the BOD and COD level in water bodies.
4. Create dead zones in the water
5. Raise treatment costs for water
6. Harmful algal blooms negatively impact the food web by decreasing the amount of nutritious, edible phytoplankton that zooplankton and other primary consumers need to survive. These organisms may then starve, leading to decreased food for secondary and higher order consumers.
7. Increased cell concentration can block sunlight from primary producers under the water’s surface as well, leading to decreased food and oxygen levels. When

the cells in the bloom begin to die it can also lead to decreased dissolved oxygen levels that can be lethal to other aquatic organisms and cause fish kills. Low dissolved oxygen can be made worse by overcast days and warmer temperatures.

Chemical control of Aquatic Weeds:

Herbicides (plant poisons) are commonly used to manage land and water plants. Herbicides are relatively easy to apply and may be the only practical method of control in some situations. 2,4-D, carfentrazone ethyl, copper, diquat, endothall, fluridone, glyphosate, imazapyr, sodium carbonate peroxyhydrate compounds, and triclopyr can be used safely in ponds to control the aquatic weeds.

Biological control of Aquatic Weeds:

Biological Controls (Grass Carp)

Introducing animals and plants that eat or compete with waterweeds represents another control method. Herbivorous animals (those that eat plants) include a wide variety of insects, snails, crayfish, tadpoles, turtles, fish, ducks, geese, and swans which can be stocked in ponds to consume aquatic plants.

Fish - Of these, the triploid (sterile fish with 50% more chromosomes than normal) Chinese grass carp (*Ctenopharyngodon idella*) is a plant-eating fish that can be stocked in ponds to provide effective, economical plant control. The recommended stocking rate is about 12 fish (stock large fish 9-12 inches in length) per surface acre. Ponds with very dense weeds may require more fish and those with less, fewer fish. These fish will try to migrate up or downstream out of your pond, so block fish passage out of the pond. Most states require a permit from the fish and game agency to import and stock these non-native fish.

Insects - Two insects are also being used as a biological control. Adults and larvae of the South American weevil *Neohydronomous affinis* feed on *Pistia* leaves, and the larvae of moth *Spodoptera pectinicornis* from Thailand. Both are proving to be useful tools in the management of Pistia. Another natural antagonist of the *Pistia* is the freshwater turtle.

BFSC-204: Aquaculture in Reservoir

P-1: Make a chart on physicochemical feature of the Indian reservoirs and comment on it.

Parameter	Overall	Productivity		
		Low	Medium	High
Water				
pH	6.5–9.2	<6.0	6.0–8.5	>8.5
Alkalinity (mg 1^{-1})	40–240	<40.0	40–90	>90.0

Nitrates (mg 1^{-1})	Tr.-0.93	Negligible	Up to 0.2	0.2–0.5
Phosphates (mg 1^{-1})	Tr.-0.36	Negligible	Up to 0.1	0.1–0.2
Specific conductivity (µmhos)	76–474		Up to 200	>200
Temperature (°C)	12.0–31.0	18	18–22	>22
		(with minimal stratification : i.e.,>5°C)		
Soil				
pH	6.0–8.8	<6.5	6.5–7.5	>7.5
Available P (mg/100 g)	0.47–6.2	<3.0	3.0–6.0	>6.0
Available N (mg/100 g)	13.0–65.0	<25.0	25–60	>60.0
Organic carbon (%)	0.6–3.2	<0.5	0.5–1.5	1.5–2.5

In India, majority of the reservoirs fall under low productivity, which has the water quality parameters pH is less than 6.0, alkalinity is less than 40mg/l. The soil parameters such as the pH are less than 6.5, available nitrogen is less than 3.0mg/100g, and available nitrogen is less than 25mg/100g and organic carbon is less than 0.5%. The total dissolved solids and specific conductivity directly influence the productivity of the reservoirs.

The soil pH is one of the important parameter, which regulates the productivity of the water bodies. If the pH value is less than 6 then it is a low productivity reservoir, 6.5 - 7.5 is termed medium productivity and more than pH 7.5 is termed a high productivity reservoir.

P-2: Make a chart on Fish production of reservoirs in India

	Small reservoir			Medium reservoir			Larger reservoir			Pooled reservoir		
	Number	Production (t)	Yield (kg ha^{-1})	Number	Production (t)	Yield (kg ha^{-1})	Number	Production (t)	Yield (kg ha^{-1})	Number	Production (t)	Yield (kg ha^{-1})
Tamil Nadu	52	760	48.5	8	269	13.74	2	294	12.66	62	1323	22.63

Uttar Pradesh	31	168	14.6	13	156	7.17	1	50	1.07	45	374	4.68
Andhra Pradesh	37	2224	188	29	306	22	3	800	16.8	69	4330	36.48
Maharashtra	6	72	21.09	12	313.5	11.83	4	794	9.28	22	1179.6	10.21
Rajasthan	78	970	46.43	17	599.7	24.47	2	120	5.3	97	1690	24.89
Kerala	7	118	53.5	2	17.3	4.8	-	-	-	9	135	23.37
Bihar	25	22	3.91	3	7.2	1.9	1	0.8	0.11	28	30	0.054
Madhya Pradesh	2	24	47.26	20	624.9	12.02	3	1184	14.53	25	1833.1	13.68
Himachal Pradesh	-	-	-	-	-	-	2	1453	35.55	2	1453	35.55
Odisha	53	349	25.85	6	163	12.76	3	925	7.62	62	1437	9.72
Total	291			110			21			422		
Average			49.9			12.3			11.43			20.13

P-3: Make a chart on Reservoir potential of the Indian reservoirs

Category	Yield (kg ha^{-1})	Area (ha)	Present Production	Potential Production
Small	49.90	1485557	74129	148556
Medium	12.30	527541	6488	39565
Large	11.43	1140268	13033	57013
Total		3153366	93650	245134

P-4: Make a chart on present pollution of different reservoirs of India:

Reservoir	Name of river	Sources of pollution
Getalsud	Subarnarekha	Heavy engineering, chemicals and sewage.
Gandhisagar	Chambal	Textile, chemicals, trade effluents from Indore, Ujjain and Kota.
Tungabhadra	Tungabhadra	Paper, iron and steel, rayon, chemicals and sewage.
G.B.Pantsagar	Rend	Thermal power plant, coal washery, chemicals.
Bhavanisagar	Bhavani	Viscose factory effluent.
Hussainsagar	Musa	Trade effluents and sewage from Hyderabad city.

Hirakud	Mahanadi	Paper mill
Byramangala	Vrishabhavati	Industrial effluents and city sewage
Sandynulla	-	Animal products

P-6: Make case study on

Status of heavy metals in Byramangala reservoir			
Metal	**Concentration**		
	Water ***(µg l*** $^{-1}$	**Sediment** ***(µg*** ^{1}	**Plant** ***µg g-*** ^{1} ***dry wt.)***
Zn	87–130	50–197	76.5–207.8
Cu	28–52	38–64	33–143
Cd	nd-15	32–106	1.4–2.1
Cr	nd	0.88–1.32	0.42–0.7
Pb	16–22	53.4–101.2	5.3–9.0
Hg	0.08–0.12	0.14–0.4	0.29–0.63

P-7: Cage and Pen Culture in Reservoirs

Cage and pen culture

The unconventional production systems, such as cage and pen cultures have not become very popular in India, although they have a definite role to play in augmenting fish production from open water, especially the reservoirs. It is now widely accepted that the pen enclosures erected in the reservoir margins can be used as nurseries to raise stocking material to obviate the necessity for constructing concrete nursery farms which are cost-intensive. Similarly, the rearing of fish in cages and pens up to marketable size enables easier stock manipulation and total harvesting. However, non-standardization of farm practices and the materials to be used in the operation still acts as a major retardant for large-scale adoption of these culture systems in Indian reservoirs.

Species selection

Main criteria for the choice of candidate species for cage and pen culture are:

1. *fast growth rate,*
2. *adaptability to the stresses in enclosures due to crowded conditions,*
3. *ready acceptance of artificial feeds consisting mainly of cheap agricultural byproducts,*
4. *high feed conversion rates,*
5. *resistance to diseases, and*
6. *good market demand.*

The candidate species should preferably not breed in the cages and upset the population balance. Under the Indian conditions, the Gangetic major carps*(C. catla, L. rohita, C. mrigala)*, the chinese carps *(Hypophthalmichtys molitrix, Ctenopharyngodon idella)*, common carps *(Cyprinus carpio)*, the magur *(Clarias batrachus)* and tilapias satisfy these requirements to a great extent. Murrels *(Channa spp.)* also can be cultured in maritime States, where marine trash fish is available at a discount. Selection of species, however, is mainly dictated by the local demands and availability of quality seed and other inputs in adequate quantities.

Site selection

Appropriate site selection is important for successful enclosure aquaculture. Sheltered, weed-free, shallow bays are the ideal locations for installing pens and cages. The sites should have adequate circulation of water, with wind and wave action within moderate limits. Excessive turbulence may lead to wastage of fish energy for stabilizing themselves and loss of feed. The other major considerations are that the water should be pollution-free, availability of seed in the vicinity, easy accessibility to the site and a ready market for fish. Flowing waters with a slow current of 1.0 to 9.0 m per minute are considered ideal for cage siting. It is desirable to install cages a little away from the shore to prevent poaching and crab menace.

Water level fluctuation is the most important consideration in site selection for the pen culture operations in reservoirs. A scrutiny of the contour map and the monthly fluctuation patterns of reservoir levels will enable the location of suitable sites, which retain sufficient water for the required period of time. Sites which dry out during summer will be ideal, as it is easier to erect pens on dry land, to be inundated later as the water level increases. Similarly, some bays of the reservoir retaining water for sufficient period can be identified and cordoned off by erecting barricades.

Cage culture

Experiments on cage culture conducted in India have been exploratory in nature and the yields obtained, so far, are not impressive. The supplemental feeds given are oilcakes, ricebran, soy bean flour and silkworm pupae, which have great demand in cattle, poultry, pig rearing and other animal husbandry practices and hence command a good price in the market. The food quotient obtained in the cage culture of various species has not been high, except in the case of tilapia, making conventional supplemental feeding unremunerative. The low production and feed conversion rates are mainly due to the relatively low stocking density and many deficiencies in the feed. The feed is often not in a water–stable form and nutritionally balanced to promote growth. There is need for evolving suitable complete feeds for individual species of fish from the locally available raw materials, by experimentation.

One of the major constraints of the cage culture system is the lack of suitable cage designs to withstand severe wave action, common in Indian reservoirs. Mukherjee (1990) suggested a number of flexible, floating barriers, sheet barriers and rigid floats to protect the cage structures from wave action. The floats dampen the wave thrust and absorb the wave energy before the wave can propagate and strike the cage and cause damage. Kumaraiah and Parameswaran (1985) proposed a circular cage that could be used in reservoir with moderate wave action for culture of carps, tilapia and air breathing fishes. The cages can float at the surface, remain just submerged or rest at the bottom. Floating cages are considered to be most appropriate for Indian conditions and all the experiments conducted so far in the country for seed rearing, growout, nutrition and biomonitoring have been in such enclosures.

Cage materials

Floating fish cages can be constructed out of a variety of materials including metal, wood, bamboo and netting. Fairly fine-meshed nylon netting is used for nursery purposes. Cages made of monofilament woven material of 1.0 to 3.0 mm mesh size are light and easy to handle but last only for six months to one year, depending on their thickness. Knotless nylon webbing of 3 to 6 mm mesh size and knotted nylon webbing of 7 to 15 mm mesh have been found to be very durable as cage material. A battery of cages can be buoyed up within a bamboo catwalk which will serve as a working platform, floated by sealed empty barrels. Circular and boxlike cages of varying diamensions on conduit pipe structures which can be easily assembled, and suitable flotation systems have been designed in India. Similarly, self–floating cage with HDPP pipe structure has also been experimented with succesfully.

In Jari tank near Allahabad, nylon cages (20 mesh cm^{-1}; size 2.2×1.6×1.45 m) were stocked at a density of 8500 hatchlings m^{-2} (size 6.5 to 7.8 mm). These grew in 21 to 28 days to 30.2 to 45.6 mm with a survival of about 25% (Anon., 1979). In fry rearing, the stocking rate in the cages (mesh size 3 mm) was 700 to 2 500 m^{-2} and within 90 days they attained a size of 103.6 to 121.8 mm. The feed given was powdered soybean, groundnut cake and rice bran in equal proportions. Rearing of carp fry was done in Getalsud reservoir, where they (10 to 31 mm in size) were stocked in 2.4 × 1.5 × 1.5 m cages at the rate of 300 to 700 m^{-2}. The growth rate per month was 17, 25 and 20 mm in mrigal, catla and rohu respectively. The stock was fed with mustard and groundnut cake and rice bran in the ratio 3:1:1 at 30% of the body weight (bw) of the stock for 4 days and thereafter at 20% for the rest of the period. Summary of cage culture experiments conducted is presented in Table 1.13.

A series of cage culture trials have been reported from a 12 ha impoundment in Bangalore (Parameswaran, 1993). In an experiment conducted with monofilament cloth cages of size 10.5 m^{-2}, common carp and silver carp fry were reared at a ratio of 40:1 at a stocking density of 225 m^{-2}. Put ona diet of powered rice bran, defatted silkworm pupae, groundnut cake and soya flour in 12:5:2:1 ratio at 10 to 20% bw day^{-1}, the survival obtained at the end of 4 months rearing was 97.5% in common carp and 88% in silver carp. The stock attained average final weight of 20 and 8.6 g respectively. However, experiments conducted on catla gave erratic results with survival rate varying from 9 to 71.4%. In another trial, 30 000 spawn obtained from cage grown common carp parents were reared in 4.5 m^3 auto-floating (PVC frame) monofilament cloth (mesh: 15 cm^{-1}) cages. In 35 days, the fry attained a size of 25.4 mm with 38% survival. Restocked in 3.5 m^3, 8 mm mesh knotless nylon netting cages, at a density of 475 m^{-3}, they grew to 54.8 mm/4.9 in 75 days with a survival rate of 88.5%.

In a cage culture experiment reported from Tamil Nadu (Parameswaran, 1993), 10 days old fry (size 10 mm) stocked at a density of 500 m^{-2} were raised to a size of 50 to 60 mm in 40 days, with survival rates ranging from 45 to 85%. Department of Fisheries in Tamil Nadu has been undertaking rearing of spawn and fry of major carps in floating cages during July to September every year. However, data on the stocking density, nutrition, growth and survival are not available.

Rearing of the fry of Indian major carps was tried in Tungabhadra reservoirs in the year 1984–85 (Singit et al., 1985). Four floating cages, made of 16-P velon screen fitted on rectangular bamboo frame of 10×4×1 m, were stocked with rohu and mrigal. Although survival rates ranging from 37.5 to 87.5% were obtained at the end of the 3 months rearing period, the experiment was vitiated due to the destruction of cages due to heavy winds. At stocking densities ranging from 2 to 5 million ha-1, growth of about 100 mm (33 g) was obtained.

Dependent on the type of management input, fish production rates obtained for growout in cages vary greatly. Unlike the hi–tech system of saturated stocking and feeding on enriched formulated diets, the production recorded in cage culture of common carp is 35, 37.5 and 25 kg m^{-3} $month^{-1}$ respectively in Japan, Germany and the Netherlands. In Asia, in general, only semi–intensive and low cost technologies are adopted, mainly due to economic considerations. In India, the growing season is almost year round, except for December–January in northern parts, where the temperature is low during these winter months.

Table 1.13 Summary of growout experiments conducted in cages in India

Species cultured	**Cage volume (m^3)**	**Stocking**		**Mean harvest size (g)**	**Culture period (months)**	**Production (kg m^{-2} $month^{-1}$)**	**Feed**	**Feeding rate (%bw**	**FCR**	**Reference**
		density (m^{-2})	**size (g)**							
Cyprinus carpio	15.75	30–38	40–50	325	6	1.55–2.22S	WP, GNC, RB (8:9:3)	10–20	8.3–10.4	Govind(MS.) 1983
Catla catla	15.0–15.75	13–49	8–50	544–772	6–8	0.83–1.30	GNC,RB(1:1)	5–10	5.6–6.6	Govind*et al.*, 1988
Hypoph- thalmichthys molitrix	10	15	61	472	10	0.7	SWP,RB, GNC (1:2:3)	3–5	3.1	Kumaraiah *et al.*, 1991
Labeo calbasu	10	5	16.5	208	8	0.1	GNC, RB(1:1)	2	2.9	Kumaraiah *et al.*, (unpublished)
Ctenopharyngodon idella	3	33–67	7–10	350–400	6	2.0–3.3	Lemna, Hydrilla	80	-	Bandopadhyay *et al.*, 1991
Oreochromis mossambicus	5–10	100–200	6.0–7.6	32–62	2–5	09–1.6	RB, GNC, CFP (1:1:1)	3–5	1.8–2.3	Kumaraiah et al.,1986
Channa marulius	5	40	25.8	177	5.3	0.8	Trash fish	10–12	2.5	Kumaraiah Parameswaran; and (unpublished)
Clarias *batrachus*	2	100	7.4	36.9	3	1	-	-	-	Murugesan and Kumaraiah; 1972

SWP=Silkoworm pupae;

GNC= Groundnut cake;

RB=rice bran;

CFP=cattle feed pellets;

FCRfood conservation ratio

Pen culture

Pen culture has a special relevance in reservoir management, since it has been widely recognised as a means to rear, *in situ*, the fingerlings for stocking. The number of fingerlings required for stocking the reservoirs in the country is so enormous that it is impossible to raise all of them in land-based nursery farms which makes pen nurseries *sine qua non* for reservoir management. Nevertheless, pen culture on a regular basis has not been practised anywhere in India except at Tungabhadra reservoir. The factors that hamper the standardisation of pen culture technique are:

1. the steep level fluctuations,
2. wind and wave action,
3. lack of suitable pen materials,
4. weed infestation and the related harvesting problems, and
5. nonsynchronisation of suitable water levels and the spawn availability.

The water retention time is important, since the rearing has to be completed before the water level in the pen goes down the critical limit. In reservoirs with high drawdown, the water retention time is very limited. Sometimes the filling takes place so late that no spawn of desirable carps will be available when the water level attains the desirable limit. The pen walls limiting the water circulation to some extent, the accumulated feed and fertilizers case eutrophication leading to weed infestation fouling of water and fish kills.

Pen culture in Tungabhadra reservoir

Despite all the limitations, pen nurseries are used with remarkable success in Tungabhadra reservoir for the last 12 years. During 1992–93, 21 pens were erected in Ladakanabhavi, 25 km away from the dam site, covering a total enclosure of 3.3 ha. The pen site is situated at an elevation of 496 m above MSL and the installation was completed in the month of July, when the site was still exposed. Later, when the water level increased, the pen got inundated.

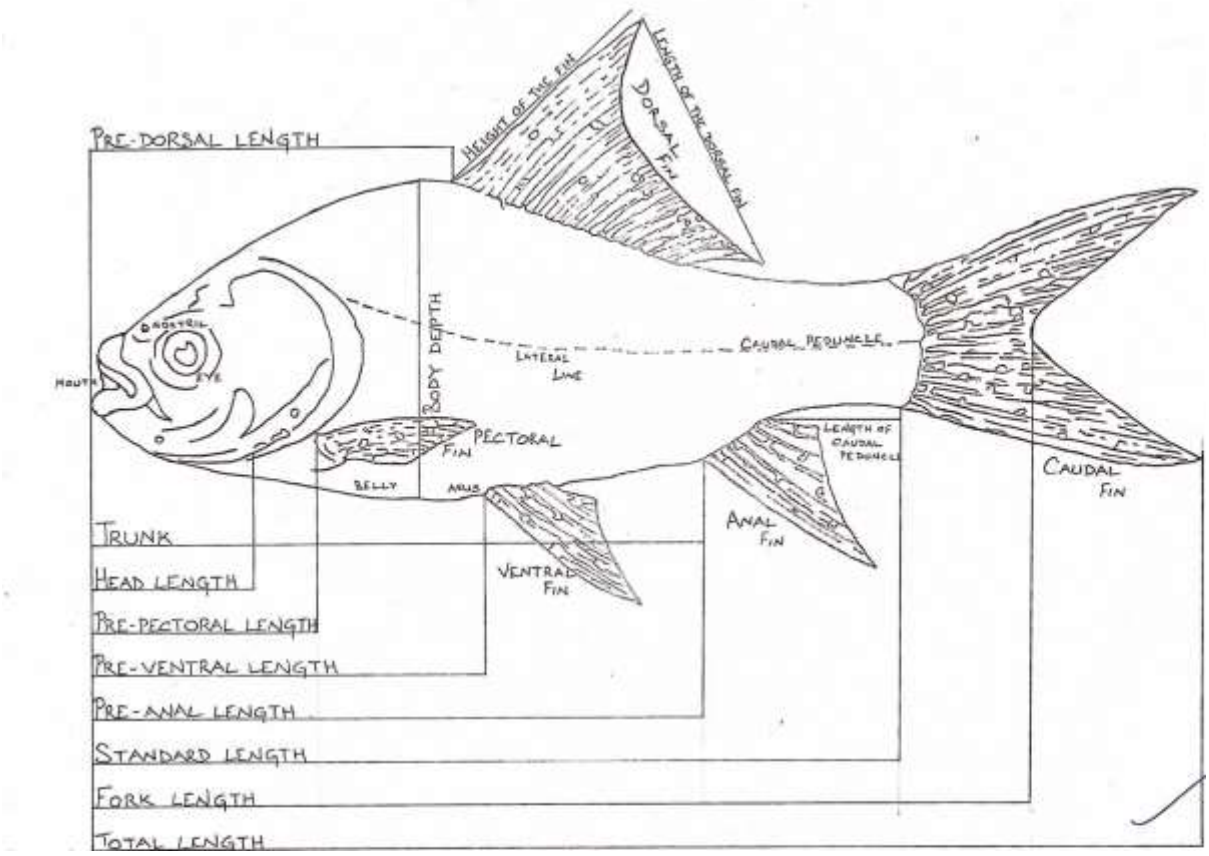
The pen area was pre-treated with organic manure that resulted in a rich growth of plankton after the filling. A total of 15 million spawn were stocked in the pens, comprising 6.75 million *Labeo rohita*, and 8.25 million *Cirrhinus mrigala*. After a rearing period of 90 days, 2. 41 million fingerlings were collected from the pen and released into the reservoir. This included 1. 085 million *L. rohita* and 1. 325 million *C. mrigala*, worth Rs. 495 875. Pen culture operations on similar lines are being in Kyrdemkulai and Nongmahir reservoirs of the northeast (see Chapter on the Northeast).

Seed rearing experiments were conducted in a split bamboo pen enclosure of 247 .5 m^2 reinforced with a nylon netting in Punjar swamp, adjoining the Bhavanisagar reservoir (Abraham, 1980a). The pen was stocked with the spawn of *C. mrigala* (size 7 mm) and *L. fimbriatus* (size 5 mm) at the rate of 4.6 million ha^{-1} and usual farm practices were followed. In 30 days, mrigal attained a size of 38 mm and L. fimbriatus, 28 mm. At the time of conclusion of the study after 3 months, the former had attained a size of 88 mm and the latter, 75 mm. The overall survival obtained was 27.8%.

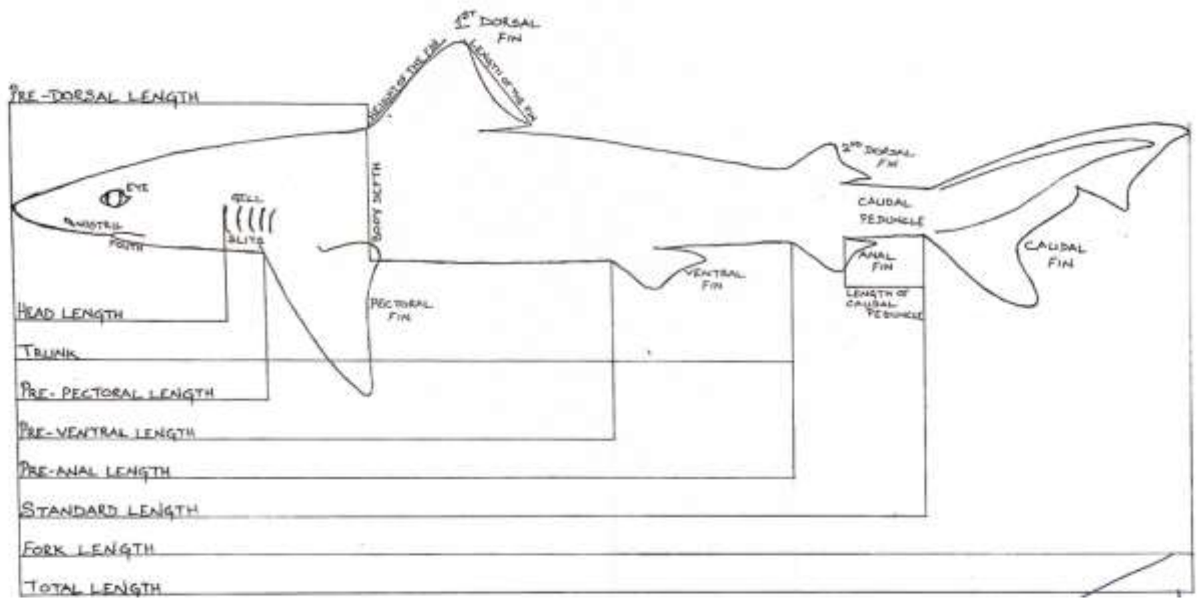
A pen culture experiment for raising catla and rohu in Manika maun, a floodplan lake in Gandak basin yielded a (computed) production of 4 t fish ha^{-1} in six months. The experiment was conducted in a bamboo screen pen (1000 m^2) and the stock was fed with mixture of rice bran and mustard cake, apart from a feed formulated from the aquatic the weeds collected from the lake.

BFSC-206: Anatomy and Biology of Finfish

Anatomy of a Typical Freshwater Fish



Anatomy of a Typical Elasmobranch



MORPHOMETRIC MEASUREMENTS OF *Tilapia mossambica*

1. Standard length — 15 cm
2. Total length — 19 cm
3. Fork length — 15.5 cm
4. Snout length — 1 cm
5. Post orbital length — 1.8 cm
6. Length of the upper jaw — 1.5 cm
7. Length of the lower jaw — 1.2 cm
8. Pre dorsal length — 7 cm
9. Girth length — 3.5 cm
10. Pre pectoral length — 4 cm
11. Pre anal length — 11.8 cm
12. Length of caudal peduncle — 2 cm
13. Isthmus — 1.7 cm

MORPHOMETRIC MEASUREMENTS OF *Cirrhinus mrigala*

1. Standard length	—	13.6cm
2. Total length	—	16.5cm
3. Fork length	—	15.0cm
4. Snout length	—	1.5cm
5. Post orbital length	—	1.7cm
6. Length of the upper jaw	—	0.5cm
7. Length of the lower jaw	—	0.9cm
8. Pre dorsal length	—	6.1cm
9. Girth length	—	3.5cm
10. Pre pectoral length	—	3.2cm
11. Pre anal length	—	10.5cm
12. Length of caudal peduncle	—	2.5cm
13. Isthmus	—	1.1cm

STUDY OF BUCCOPHARYNX, GUT CONTENT, FEEDING HABIT & RELATIVE GUT LENGTH OF FISH

INTRODUCTION– In order to study the feeding habits of fishes the study of buccopharynx and alimentary canal is very important. The structural pattern of buccal mass and pharynx varies from fish to fish depending upon different feeding habits along with structural variants of alimentary canal.

OBJECTIVE– To manipulate the production in water body, the knowledge about feeding habits of fish is necessary. In fish culture it must be known whether the fish is carnivorous, herbivorous or omnivorous to occupy the possible ecological niches by minimising the complication among themselves.

PROCEDURE– The fish is dissected and the buccopharynx and entire viscera is exposed after noting the weight of the fish and the total length of the fish. After that the length of the intestine, body-weight relationship, condition factor Ga.S.I., Go.S.I. etc are studied. The content of the stomach is observed under the microscope and from these observations the feeding habits of the fish will be known to us.

COMMENT– The following features are important from which the following remarks may be made.

i) TEETH: When teeth are present in the jaw it indicates the fish is carnivorous in feeding habit. The teeth helps in grasping of food, also indicates that the food is large and able to escape. When the teeth is present on pharynx or ~~plate~~ palate then it helps in crushing of food.

ii) GILL RAKERS: Well developed gill rakers indicate that the fish is plankton feeder.

iii) INTESTINE: Long intestine indicates generally herbivorous type while the short intestine indicates that the fish is carnivorous. Many folds of the intestine shows increased efficiency of digestion.

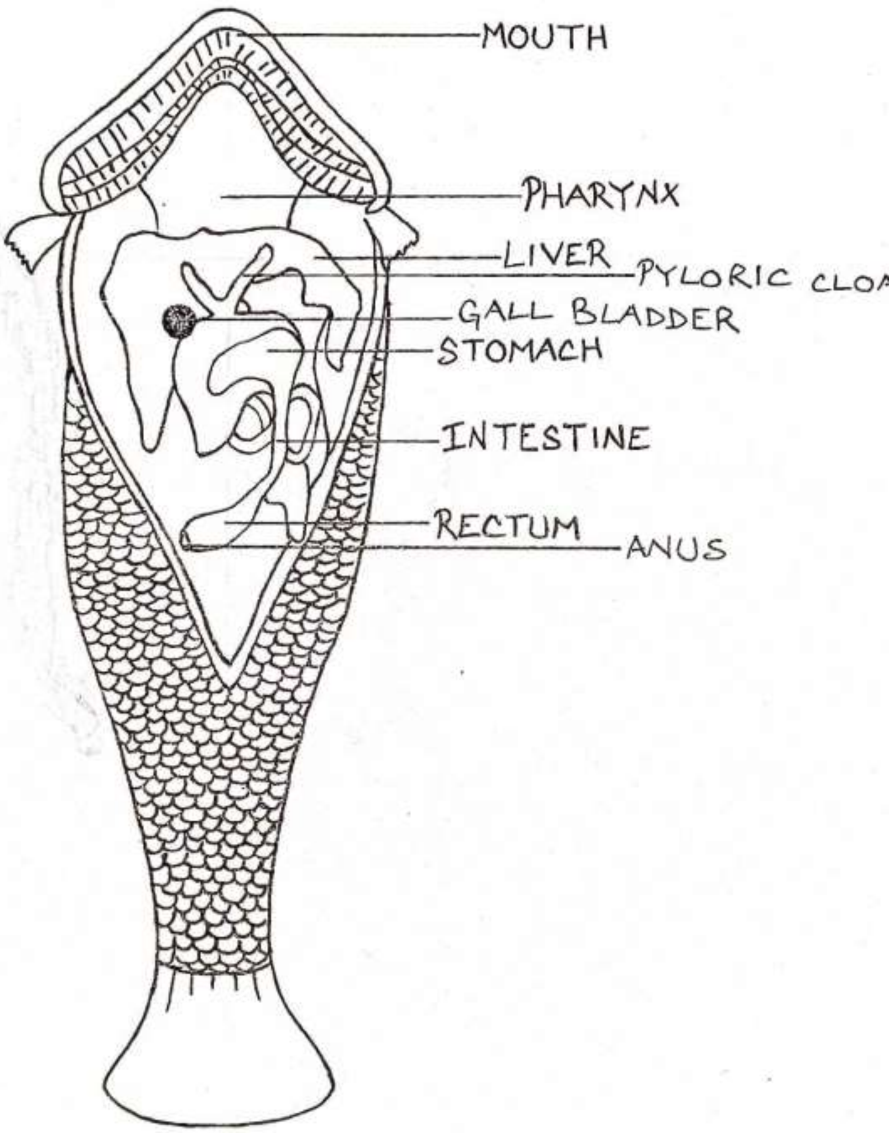
iv) STOMACH: Well developed stomach indicates further crushing of food.

v) CONDITION FACTOR: $K = \frac{W}{L^3} \times 100$

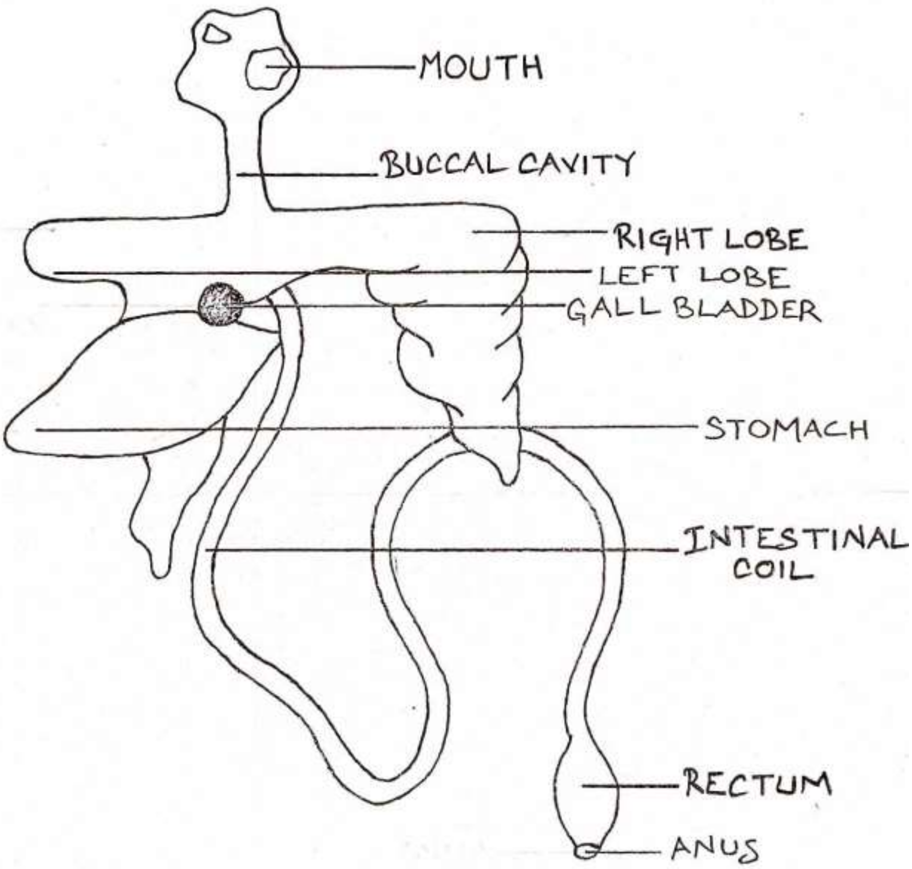
K = Condition factor
W = Body weight of the fish
L = Total length of the fish

$$Ga.S.I. = \frac{\text{Total length of gut}}{\text{Total length of body}} \times 100$$

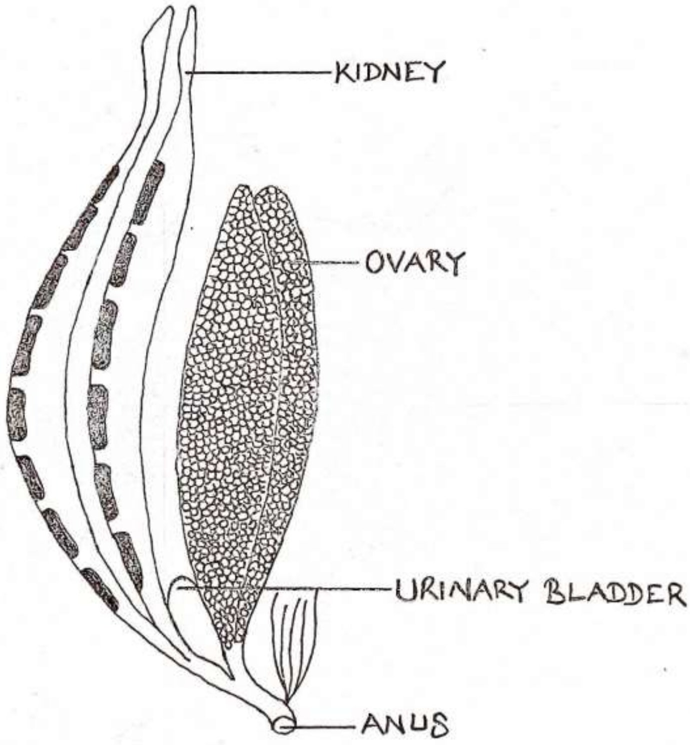
$$R.L.G. = \frac{\text{Gut length}}{\text{Body length}}$$



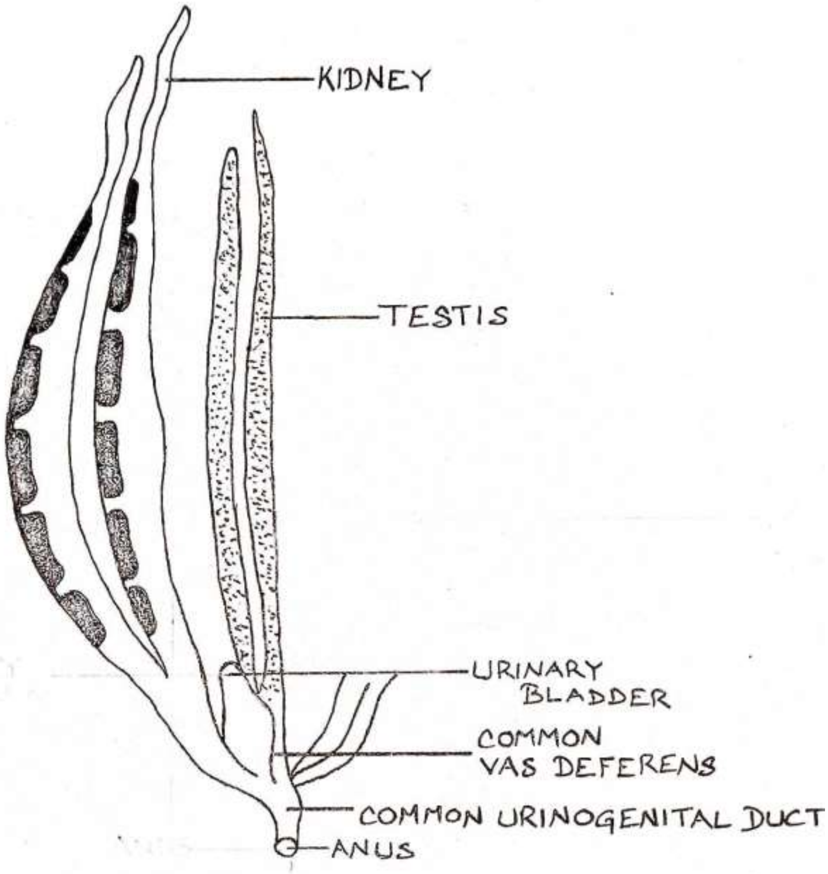
Digestive system of Channa punctatus



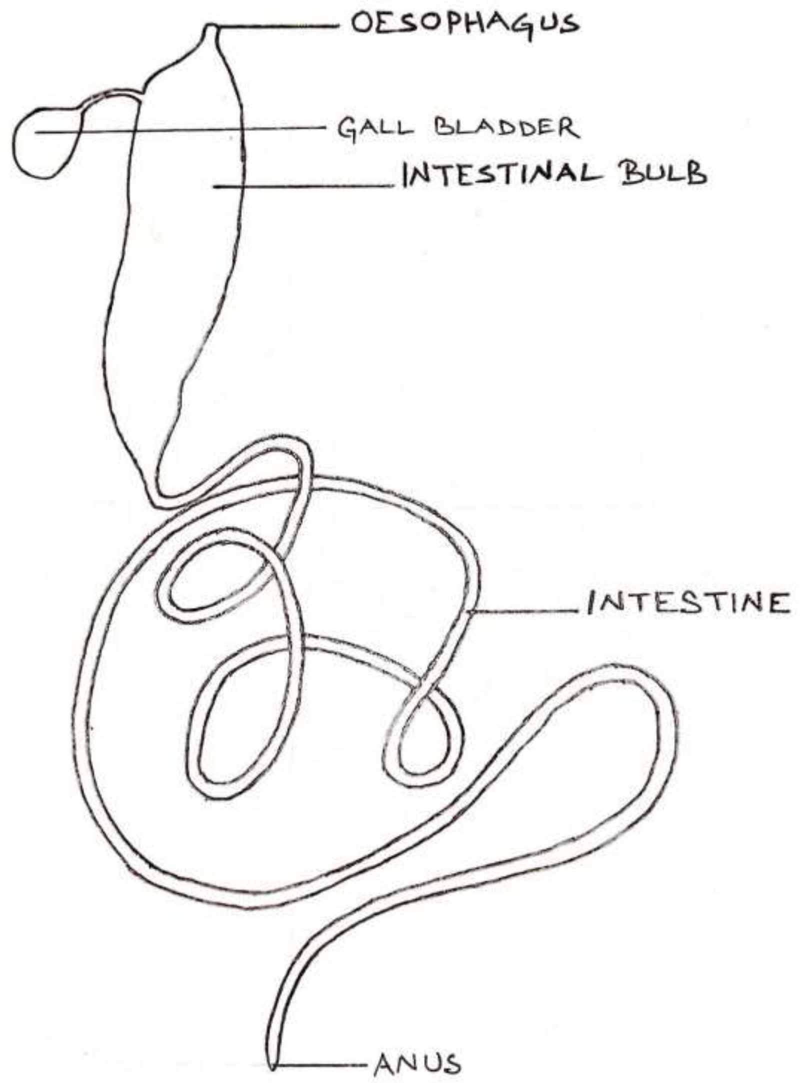
Digestive system of *Tilapia mossambica*



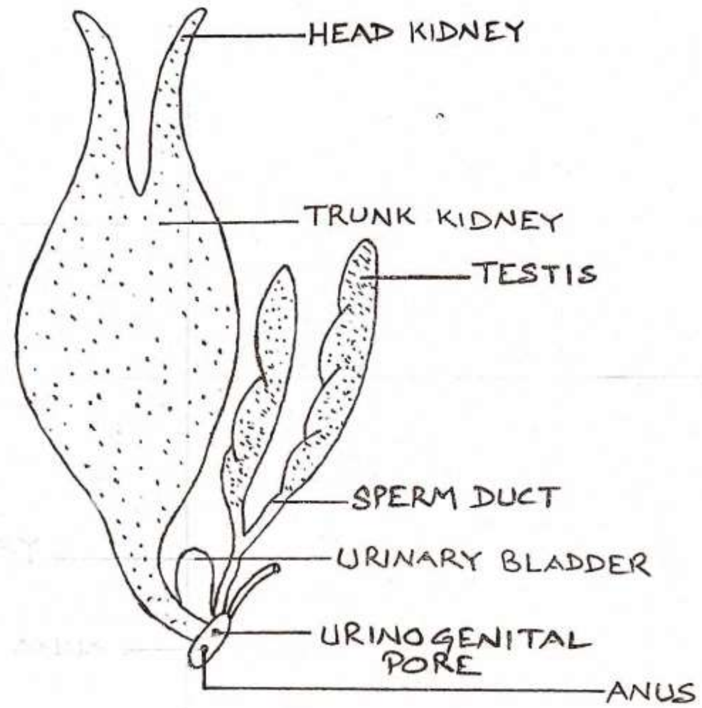
Urinogenital system of *Tilapia mossambica*



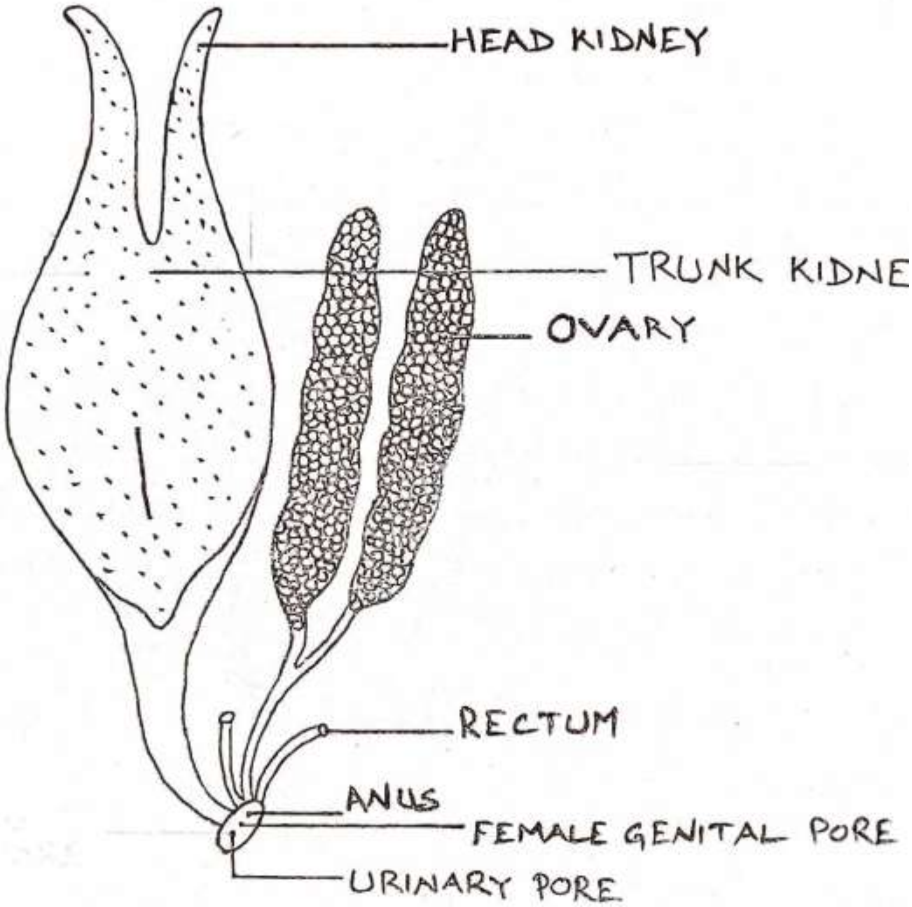
Urinogenital system of *Tilapia mossambica*



Digestive system of *Cirrhinus mrigala*



Urinogenital system of Cirrhinius mrigala



Urinogenital system of Cirrhinius mrigala

Draw and Label a Typical Fish

Fecundity Estimation

Fecundity Estimation:

Fecundity derived from the word fecund, generally refers to the ability to reproduce. In biology, fecundity is the potential reproductive capacity of an organisms or population, measured by the number of gametes (eggs), seed set or sexual propagates. Fecundity can be defined as the number of ova that are likely to be laid by a fish during the spawning season. Or, the fecundity is the measurement of reproductive capacity of female fish.

Methods of Estimation:

- Volumetric Method:
  - Total number of the ovary is measured
  - Ovaries are cut into small pieces and random samples are taken from anterior, middle and posterior part of the ovaries.
  - The number of ova from each sample is counted along with the volume.
  - The total number of the ova and total volume of the ovary is then calculated.
- Gravimetric Method:
  - The formalin preserved ovaries are used.
  - The weight of the ovary is measured
  - The ovary is cut into three samples of 100mg each by assumption from anterior, middle and posterior part.
  - The number of ova from each sample is counted along with the weight.
  - Total number of ova is then calculated by following formula:
    $F = (S \times OW)/100$
    Where, F = Fecundity
    S = Average number of ova obtained from three samples of 100mg each.
    OW = Total weight of the Ovary
- Quantitative method:
  - By this method the fecundity is estimated after fertilization only.
  - Fertilization was performed by mixing the eggs and the sperm adding water and shaking the petri-dish by hand.
  - Excess sperms are removed and the fertilized eggs are left for 10 minutes to get water hardened.
  - After being fertilized the after hardened eggs are photocopied and a piece of thick white paper was used to cover the petri-dish while eggs after photocopied.
  - White circles were counted and recorded as viable eggs, and dark dots counted as dead eggs.

- Scanned Image Method
    - The ovaries are collected and kept on ice until they could be weighed and gravimetric subsamples could be dissected.
    - Each sub samples was then preserved in Gilson's Fluid (0.015l nitric acid, 0.008l glacial acetic acid, 0.1l 60% ethyl alcohol, 0.877l distilled water for 1l of fluid) to promote the breakdown of ovarian tissues.
    - After exposure of four to six weeks, the eggs are rinsed and dewatered using a 333-am square mesh screen and low vacuum suction.
    - Eggs are then dispersed in petri dish and any large clumps are gently separated. We used 100 mm diameter plastic (round) petri-dish, which are tended to produce low optical aliases when scanned.
    - Concentration of the eggs alongside of the dish is to be avoided by using melted agarose gel mixed with 15l of water.
    - After the agarose hardened, an image of the dish was taken by placing the dish directly on flatbed scanner. The cover of the petri-dish is painted black which can produce high resolution images of the eggs on black background.
    - The image was saved as gray-scale at a pixel resolution of (600×600 dpi).
    - Scans were then examined using image processing and the eggs are counted.

The number of the eggs produced by a female fish or the fecundity of the fish entirely depends upon the length weight and the age of the fish. Or we can say the fecundity is proportional to the length and weight of the fish.

Estimation of Fecundity is Important in respect of fisheries science due to the following:

1. This is important in the field of population ecology. Fecundity can be increased or decreased in a population according to the current conditions and certain regulating factors. For instance, in times of hardship for a population such as a lack of food, juvenile and eventually adult fecundity has been shown to decrease.
2. The estimation is important to know the relation between the length and weight of the fish. In fish farming, the estimation helps to understand which size group would be economical and profitable for maximum production of new offspring.

Fins of fishes:

Fins are the most distinctive features of fish. They are either composed of bony spines protruding from the body with skin covering them and joining them together, either in a webbed fashion as seen in most bony fish, or are similar to a flipper, as seen in sharks. Apart from the tail or caudal fin, fins have no direct connection with the spine and are supported by muscles only. Their principal function is to help the fish swim. Fins can also be used for gliding or crawling, as seen in the flying fish and frogfish. Fins located in different places on the fish serve different purposes, such as moving forward, turning, and keeping an upright position. For every fin, there are a number of fish species in which this particular fin has been lost during evolution.

Types of fins:

Dorsal fins are located on the back. Most fishes have one dorsal fin, but some fishes have two or three. The dorsal fins serve to protect the fish against rolling, and assist in sudden turns and stops. In anglerfish, the anterior of the dorsal fin is modified into an illicium and esca, a biological equivalent to a fishing rod and lure. The bones that support the dorsal fin are called Pterygiophore. There are two to three of them: "proximal", "middle", and "distal". In spinous fins the distal is often fused to the middle, or not present at all.

The caudal fin is the tail fin, located at the end of the caudal peduncle and is used for propulsion. The caudal peduncle is the narrow part of the fish's body to which the caudal or tail fin is attached. The hypural joint is the joint between the caudal fin and the last of the vertebrae. The hypural is often fan-shaped. The tail is called:

- Heterocercal if the vertebrae extend into the upper lobe of the tail, making it longer (as in sharks)
- Reversed heterocercal if the vertebrae extend into the lower lobe of the tail, making it longer (as in the Anaspida)
- Protocercal if the vertebrae extend to the tip of the tail and the tail is symmetrical but not expanded (as in amphioxus)
- Diphycercal if the vertebrae extend to the tip of the tail and the tail is symmetrical and expanded (as in the bichir, lungfish, lamprey and coelacanth. Most Palaeozoic fishes had a diphycercal heterocercal tail.)
- Most fish have a homocercal tail, where the fin appears superficially symmetric but the vertebrae extend for a very short distance into the upper lobe of the fin. This can be expressed in a variety of shapes. The tail fin can be:
    - Rounded at the end

- Truncated: or end in a more-or-less vertical edge, such as in salmon
- Forked: or end in two prongs
- Emarginated: or with a slight inward curve.
- Continuous: with dorsal, caudal and anal fins attached, such as in eels

The anal fin is located on the ventral surface behind the anus. This fin is used to stabilize the fish while swimming.

The paired pectoral fins are located on each side, usually just behind the operculum, and are homologous to the forelimbs of tetrapods. A peculiar function of pectoral fins, highly developed in some fish, is the creation of the dynamic lifting force that assists some fish, such as sharks, in maintaining depth and also enables the "flight" for flying fish. In many fish, the pectoral fins aid in walking, especially in the lobe-like fins of some anglerfish and in the mudskipper. Certain rays of the pectoral fins may be adapted into finger-like projections, such as in sea robins and flying gurnards. The "horns" of manta rays and their relatives are called cephalic fins; this is actually a modification of the anterior portion of the pectoral fin.

The paired pelvic or ventral fins are located ventrally below the pectoral fins. They are homologous to the hindlimbs of tetrapods. The pelvic fin assists the fish in going up or down through the water, turning sharply, and stopping quickly. In gobies, the pelvic fins are often fused into a single sucker disk. This can be used to attach to objects.

The adipose fin is a soft, fleshy fin found on the back behind the dorsal fin and just forward of the caudal fin. It is absent in many fish families, but is found in Salmonidae, characins and catfishes. Its function has remained a mystery, and is frequently clipped off to mark hatchery-raised fish, though data from 2005 showed that trout with their adipose fin removed have an 8% higher tailbeat frequency.[15] Additional research published in 2011 has suggested that the fin may be vital for the detection of and response to stimuli such as touch, sound and changes in pressure. Canadian researchers identified a neural network in the fin, indicating that it likely has a sensory function, but are still not sure exactly what the consequences of removing it are.[16]

Some types of fast-swimming fish have a horizontal caudal keel just forward of the tail fin. Much like the keel of a ship, this is a lateral ridge on the caudal peduncle, usually composed of scutes (see below), that provides stability and support to the caudal fin. There may be a single paired keel, one on each side, or two pairs above and below.

Finlets are small fins, generally behind the dorsal and anal fins (in bichirs, there are only finlets on the dorsal surface and no dorsal fin). In some fish such as tuna or sauries, they are rayless, non-retractable, and found between the last dorsal and/or anal fin and the caudal fin.

Scales of Fishes:

The skin of most bony and cartilaginous fishes is covered by scales. Scales vary enormously in size, shape, structure, and extent, ranging from rigid armour plates in fishes such as shrimpfishes and boxfishes, to microscopic or absent in fishes such as eels and anglerfishes. The morphology of a scale can be used to identify the species of fish it came from.

The principal types of scales are the cycloid scales of salmon and carp, the ctenoid scales of perch, the placoid scales of sharks and rays, the ganoid scales of sturgeons and gars. Fish scales are produced from the mesoderm layer of the dermis, which distinguishes them from reptile scales. The same genes involved in tooth and hair development in mammals are also involved in scale development.

Fish, along with reptiles, have hard protective scales on their skin for protection. The outer body of many fish is covered with scales, which are part of the fish's integumentary system. The scales originate from the mesoderm (skin). It has been suggested that they are similar in structure to teeth, but they probably originate from different tissue. Some species are covered instead by scutes. Others have no outer covering on the skin. Most fish are covered in a protective layer of slime (mucus).

Types of Scales:

Leptoid scales/Bony Ridge Scale:

Leptoid scales are found on higher-order bony fish, the teleosts (the more derived clade of ray-finned fishes). As they grow they add concentric layers. They are arranged so as to overlap in a head-to-tail direction, like roof tiles, allowing a smoother flow of water over the body and therefore reducing drag. Leptoid scales come in two forms: cycloid and ctenoid.

- Cycloid scales have a smooth outer edge or margin, and are most common on fish with soft fin rays, such as salmon, banded killifish, and carp.
- Ctenoid scales have a toothed outer or posterior edge, with tiny teeth called ctenii that give them a rough texture. They are usually

found on fish with spiny fin rays, such as the perch-like fishes. These scales contain almost no bone, being composed of a surface layer containing hydroxyapatite and calcium carbonate, and a deeper layer composed of mostly collagen. The enamel of the other scale types is reduced to superficial ridges and ctenii.

Ctenoid scales can be further subdivided into three types:

- Crenate scales: where the margin of the scale bears indentations and projections.
- Spinoid scales: where the scale bears spines that are continuous with the scale itself.
- True ctenoid scales: where the spines on the scale are distinct structures.

Both cycloid and ctenoid scales are overlapping, making them more flexible than cosmoid and ganoid scales. They grow in size through additions to the margin, creating bands of uneven seasonal growth called annuli (singluar annulus). These bands can be used to age the fish.

Most ray-finned fishes have ctenoid scales. In flatfishes, some species have ctenoid scales on the eyed side and cycloid scales on the blind side, while other species have ctenoid scales in males and cycloid scales in females.

Placoid scales

Placoid scales are found in the cartilaginous fishes: sharks, rays, and chimaeras. They are also called dermal denticles, Placoid scales are structurally homologous with vertebrate teeth ("denticle" translates to "small tooth"), having a central pulp cavity supplied with blood vessels, surrounded by a conical layer of dentine, all of which sits on top of a rectangular basal plate that rests on the dermis. The outermost layer is composed of vitrodentine, a largely inorganic enamel-like substance. Placoid scales cannot grow in size, but rather more scales are added as the fish increases in size.

Similar scales can also be found under the head of the denticle herring.

Sharks are entirely covered by placoid scales. This is what we think of as "shark skin". Studies have found that the scales create tiny vortices that reduce drag, which makes swimming more efficient, as well as quieter compared to bony fishes. The amount of scale coverage is much lesser in rays and chimaeras. The rough, sandpaper-like texture of shark and ray skin, coupled with its toughness, has led it to be valued as a source of rawhide leather, called shagreen. One of the many historical applications of shark shagreen was in making hand-grips for swords.

Unlike bony fish, sharks have a complex dermal corset made of flexible collagenous fibers and arranged as a helical network surrounding their body. This works as an outer skeleton, providing attachment for their swimming muscles and thus saving energy. Their dermal teeth give them hydrodynamic advantages as they reduce turbulence when swimming.

Elasmoid scales

Elasmoid scales are thin, imbricated scales composed of a layer of dense, lamellar bone called isopedine, above which is a layer of tubercles usually composed of bone, as in Eusthenopteron. The layer of dentine that was present in the first sarcopterygians is usually reduced, as in the extant coelacanth, or entirely absent, as in extant lungfish and in the Devonian Eusthenopteron. Elasmoid scales appeared several times. They are present in some lobe-finned fishes: coelacanths, all extant and some extinct lungfishes, some tetrapodomorphs like Eusthenopteron, amiids, and teleosts, whose cycloid and ctenoid scales represent the least mineralized elasmoid scales.

Cosmoid scales

Cosmoid scales are found in several ancient lobe-finned fishes, including some of the earliest lungfishes, and were probably derived from a fusion of placoid scales. They are composed of a layer of dense, lamellar bone called isopedine, above which is a layer of spongy bone supplied with blood vessels. The bone layers are covered by a complex dentine layer called cosmine and a superficial outer coating of vitrodentine. Cosmoid scales increase in size through the growth of the lamellar bone layer.

Ganoid scales

Ganoid scales are found in the sturgeons, paddlefishes, gars, bowfin, and bichirs. They are derived from cosmoid scales, with a layer of dentine in the place of cosmine, and a layer of inorganic bone salt called ganoine in place of vitrodentine. Most are diamond-shaped and connected by peg-and-socket joints. In sturgeons, the scales are greatly enlarged into armour plates along the sides and back, while in the bowfin the scales are greatly reduced in thickness to resemble cycloid scales.

Scutes

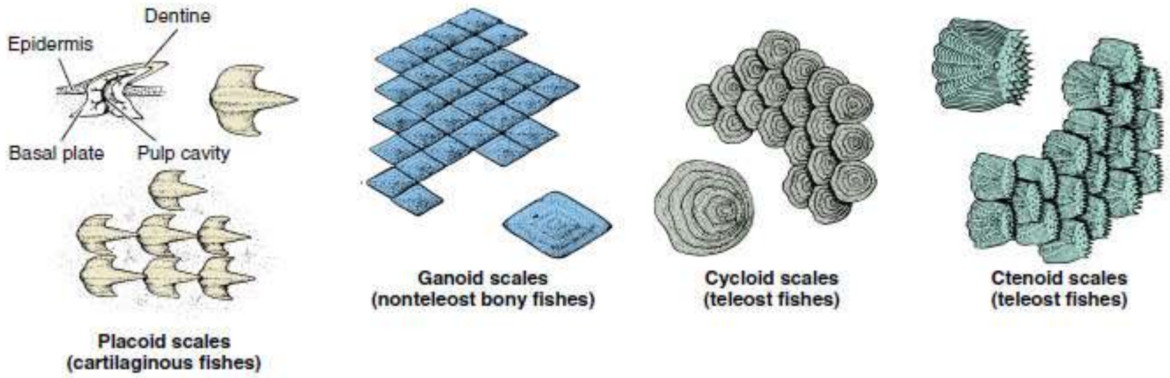
A scute is another, less common, type of scale. Scute comes from Latin for shield, and can take the form of:

- an external shield-like bony plate, or
- a modified, thickened scale that often is keeled or spiny, or
- a projecting, modified (rough and strongly ridged) scale, usually associated with the lateral line, or on the caudal peduncle forming caudal keels, or along the ventral profile.

Some fish, such as pinecone fish, are completely or partially covered in scutes. River herrings and threadfins have an abdominal row of scutes, which are scales with raised, sharp points that are used for protection. Some jacks have a row of scutes following the lateral line on either side.

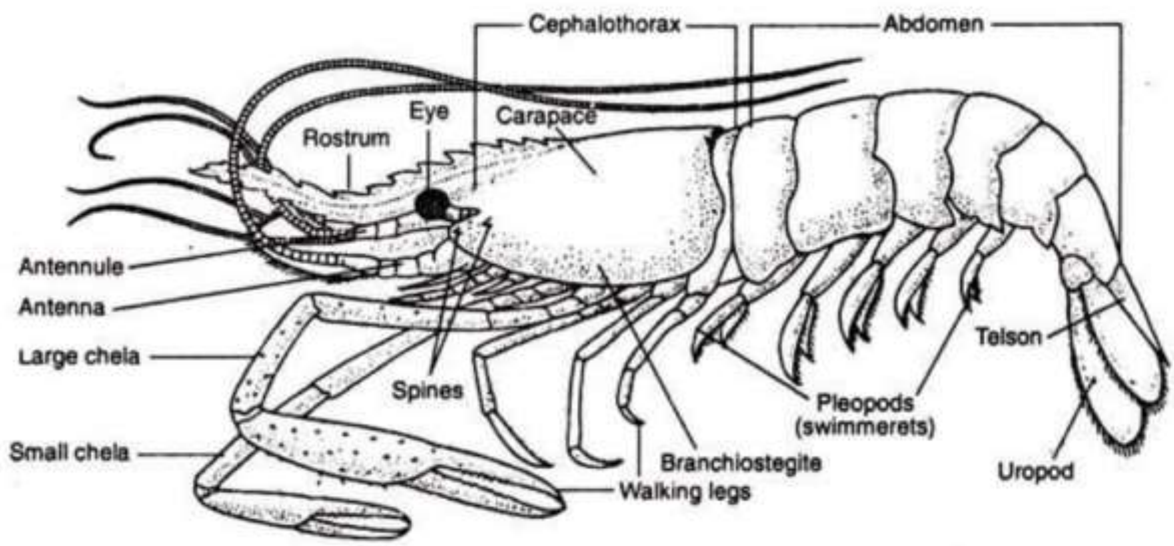
Thelodont scales

The bony scales of thelodonts, the most abundant form of fossil fish, are well understood. The scales were formed and shed throughout the organisms' lifetimes, and quickly separated after their death.



BFSC-207: Anatomy and Biology of Shellfish

P-1: Draw and Label the Diagram of a typical prawn anatomy



Lateral View of Freshwater Prawn

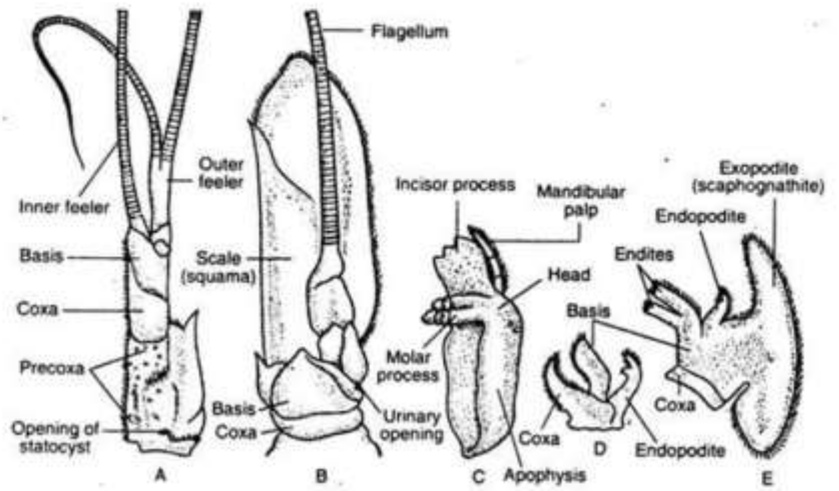
P-2: Dissect and Display the Cephalic Appendages of Prawn

Cephalothorax is the broad, un-segmented and cylindrical anterior part. It is formed by the fusion of head and thorax. In fact, during the development of prawn, one pre-segmental region and first fourteen segments fuse to form cephalothorax. The pre-segmental region remains in adult and carries the stalked eye and the first segment disappears during the process of transformation.

A continuous shield-like exoskeletal covering, called carapace, encloses the cephalothorax. On both the ventrolateral sides, the carapace-hangs freely over the gill-chamber as gill-cover or branchiostegite. The branchiostegite is raised and lowered by a thin membrane, branchiostegal membrane. Ventrally, the carapace is covered by several hard sternal plates.

Following structures are present on the cephalothoracic region:

1) Rostrum: On the dorsal and median surface, the carapace is drawn into a long-serrated projection towards the anterior end. This is defensive in function.
2) Eye: Near the base of the rostrum and on each side of the carapace is placed an eye. Each eye is black and hemispherical and made up of several visual elements. It is thus called compound eye and it is mounted on a movable and jointed stalk. It is responsible for detecting light.
3) Spines: These are small pointed structures, present in pairs on each lateral side of the carapace and posterior to each eye. The anterior pair is known as antennal spines and the short posterior pair is the hepatic spines.
4) Appendages: Thirteen pairs of appendages are present on the ventral side of prawn. The close apposition of these appendages speaks about the fusion of cephalothoracic segments. The first five pairs, i.e. First antenna or Antennule, second antenna, Mandible, first maxilla or Maxillula and Second maxilla are known as cephalic appendages. The remaining eight pairs are called thoracic appendages or pereopods, which include three pairs of Maxillipeds and five pairs of walking legs.
   a) First antenna: First antenna is also known as antennule. It is placed near the base of the eye stalk. Its protopodite carries an additional segment, a spiny precoxa. The basis is longer than coxa and probably its exo and endopodites are modified as feelers or flagella. The outer feeler has two branches and the smaller branch carries olfactory setae, probably for determining smell. The precoxa carries the balancing organ, called statocyst and the coxa is beset with many sensory hairs.
   b) Second antenna: It is situated immediately after the first antenna. The coxa contains a specialized organ, called green gland, or antennal gland (or maxillary gland), which serves as excretory organ. The exopodite is modified as a leaf-like squama or scale with setae along its inner margin. The scale serves as a balancer during swimming. The endopodite has become a long many-jointed flagellum and carries numerous tactile setae.



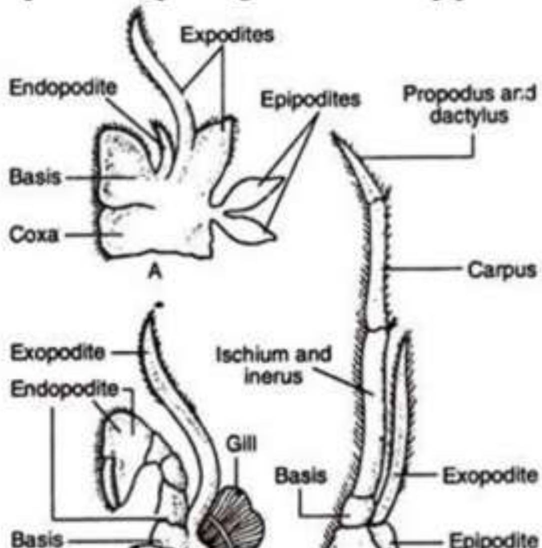
Cephalic appendages of prawn (Palaemonid). A. Antennule or First Antenna; B. Second Antenna; C. Mandible; D. First maxilla; E. Second maxilla.

c) Mandible: It is placed on the outer side of the mouth and is responsible for crushing the food. In its protopodite, the coxa is modified to form as spoon-shaped proximal apophysis and solid distal part called head. The head contains stout molar process with five to six yellow teeth and thin incisor process with three closely set white teeth. The basis portion of protopodite and the endopodite form a three- jointed mandibular palp, which remains in front of the head of the mandible and carries sensory setae. The exopodite is absent.

d) First maxilla or Maxillula: This crown-shaped smallest appendage is placed slightly posterior to the mouth. It consists of three small leaf-like plates carrying sensory setae in their margins. Two to these plates (formed by coxa and basis) are projected inwards and are called jaws or gnathobases or endites. The remaining plate is endopodite and is directed outwards. The exopodite is absent. The first maxilla is responsible for pushing the food inside the mouth.

e) Second maxilla: It is fan-shaped and placed immediately after the first maxilla. The coxa is much reduced and the basis is bifurcated and directed inwards to form endites or jaws. The exopodite is large, fan-shaped and known as scaphognathite. The endopodite is small and placed between the basis and exopodite. The second maxilla serves double functions jaws are for food-getting and the scaphognathite is for producing constant water current within the gill chambers.

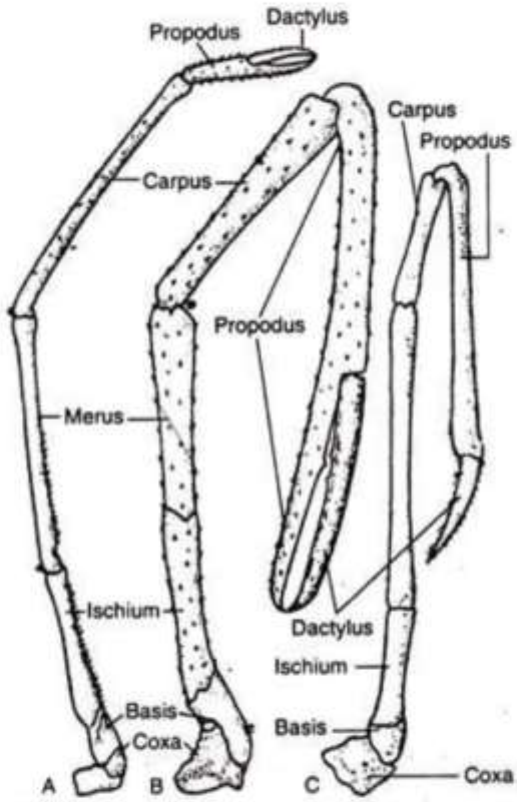
f) First maxilliped: The coxa and basis of the protopodite are flattened to become jaws and bear stiff setae on their inner margins. In addition to short endopodite and long exopodite, the coxa bears a bilobed epipodite. The exo and endopodite parts of coxa together with basis help in the in-pushing of food. The epipodites help in respiration.



Three Maxillipeds of freshwater prawn

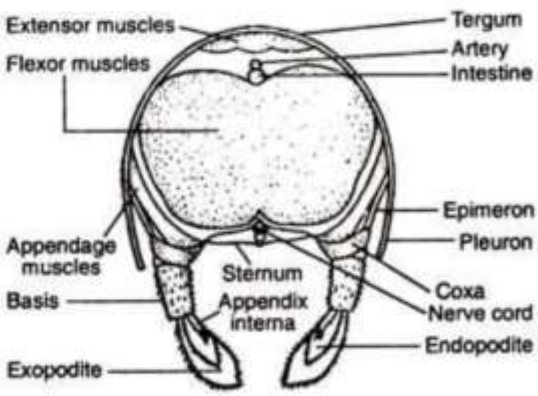
A. First Maxilliped; B. Second Maxilliped; C. Third Maxilliped

g) Second maxilliped: Here the short coxa carries on its outer margin a small epipodite and a gill. The inner margin is lined with numerous setae. The exopodite is long and un-jointed but the endopodite is made up of five segments - ischium, merus; carpus, propodus and dactylus. The last two segments are curved backwards to form a knife-like structure.
h) Third maxilliped: This appendage is leg-like and its coxa carries a thin epipodite on the outer side. The exopodite is thin and un-jointed but the endopodite has three segments - proximal, middle and distal. The proximal segment is formed by the fusion of ischium and merus, middle is carpus and the distal segment is formed by the fusion of propodus with dactylus.
i) Walking legs: There are five pairs of walking legs for crawling. Each leg has a short protopodite with distinct coxa and basis and a prominent five segmented endopodite. These endopodite segments are ischium, merus, carpus, propodus, and dactylus. The epi and exopodites are absent. The first and second legs possess pincers formed by the attachment of dactylus on propodus and are called chelate legs, while the rest are known as non-chelate legs. The second walking leg being the largest is known as large chela and the first walking leg is called small chela.



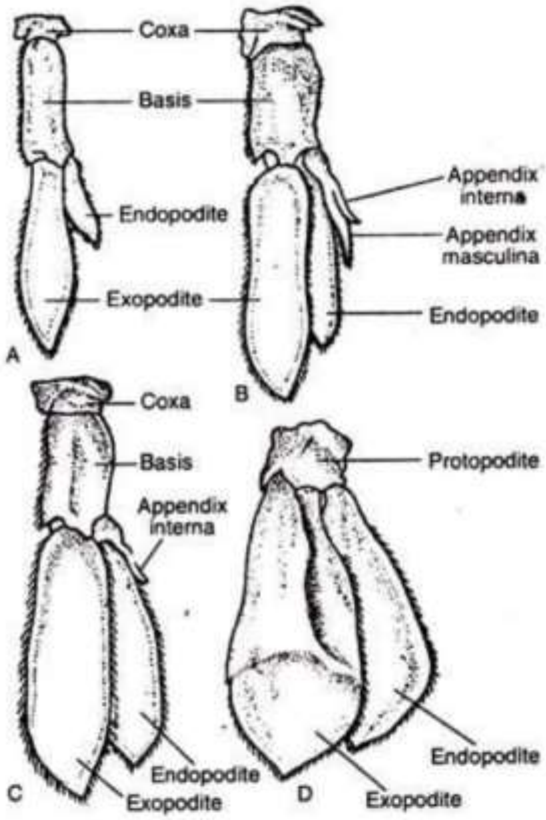
A. First walking legs; B. Second walking legs; C. Third walking legs;

5) Different apertures in cephalothorax:
    a) Mouth: The mouth is a slit-like unpaired and median aperture on the ventral side of the cephalothorax and is situated in between third and fourth segments. It is encircled by mandibles, maxillae and first maxillipeds. It is concerned with the ingestion of food.
    b) Renal apertures: It is present as a minute opening on a raised papilla near the base of each second antenna. It serves as an outlet of excretory duct from the excretory organ, green gland.
    c) Gonopores: The position of these paired openings depends upon the sex of the individual. In males, the gonopores are seen on the inner sides of the coxae of fifth walking legs and in females these are in similar positions on the third walking legs.
    d) Statocyst openings: Tine statocysts or the balancing organs of prawn communicate with the exterior through minute pores. There are two statocysts situated one on the base of each first antenna.
6) Abdomen: The abdomen is composed of six distinct segments and a posterior-most triangular telson. Each abdominal segment is laterally compressed and is bounded by a ring-like exoskeletal piece, called the sclerite. The sclerite of one segment covers the sclerite of the following segment. Such imbricately arranged sclerites are united with each other by thin un-calcified arthrodial membrane. Each sclerite consists of a ventral plate-like sternum and a dorsal arch-shaped tergum. The tergum suspends freely on the lateral sides as pleuron. The pleuron is connected with the appendage of the corresponding side by a small plate-like epimeron. The imbricate arrangement of the sclerites and its hinge-like joints (marked by orange spots) permit free vertical movements of the abdomen. Each abdominal segment carries a pair of appendages on its ventral sides. These appendages are called pleopods and the last pair is modified and known as uropods.



Transverse section of a prawn passing through abdominal region.

a) Pleopods or Swimmerets: One pair of pleopods is present in each of the first five abdominal segments. In each pleopod the protopodite has a longer basis than the coxa. The exopodite is longer than the endopodite. Both the exo and endopodites bear tactile setae but the former is larger. An additional hook-like process, appendix interna is present on the inner sides of the endopodites of 2nd, 3rd, 4th and 5th pleopods. These processes of both the sides in females unite to form a basket for carrying eggs. The second pleopods of the male prawn have an additional process which is known as appendix masculina. The pleopods are primarily meant for swimming.

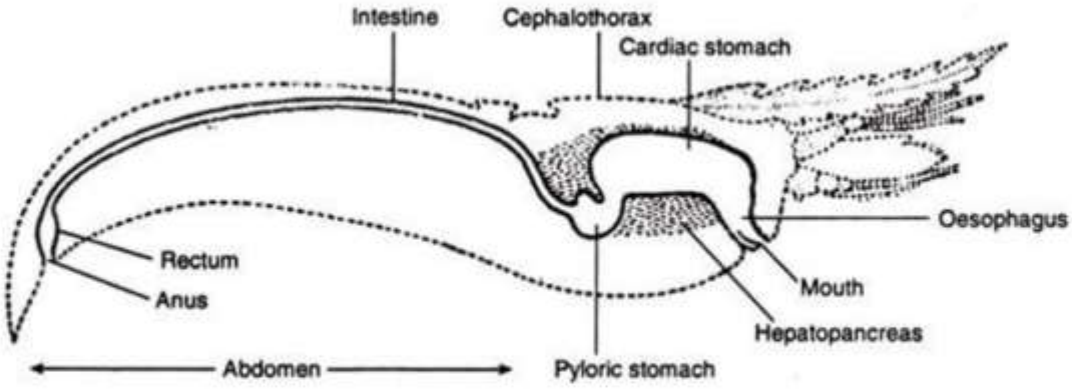


A. First swimmeret; B. Second swimmeret; C. Third swimmeret

b) Uropod: One pair of uropods is present in the last segment, one on each side of the telson. The protopodite is one segmented but the exo- and endopodites are large and fan-shaped. The exopodite is divided by a fine suture but the endopodite is not sutured. The tactile setae are arranged at the margin of both the exo- and endopodites. The uropods are used for changing direction and also for leaping backwards. Only one aperture called anus is present near the base of the telson on its ventral side. This is the opening of alimentary canal for the purpose of egestion.

P-3: Digestive System of Prawn

The digestive system of Prawn consists of (A) Alimentary canal and (B) Digestive glands.



Lateral view of alimentary system in freshwater prawn. The outline of the body is drawn to indicate the position of the different parts of alimentary canal.

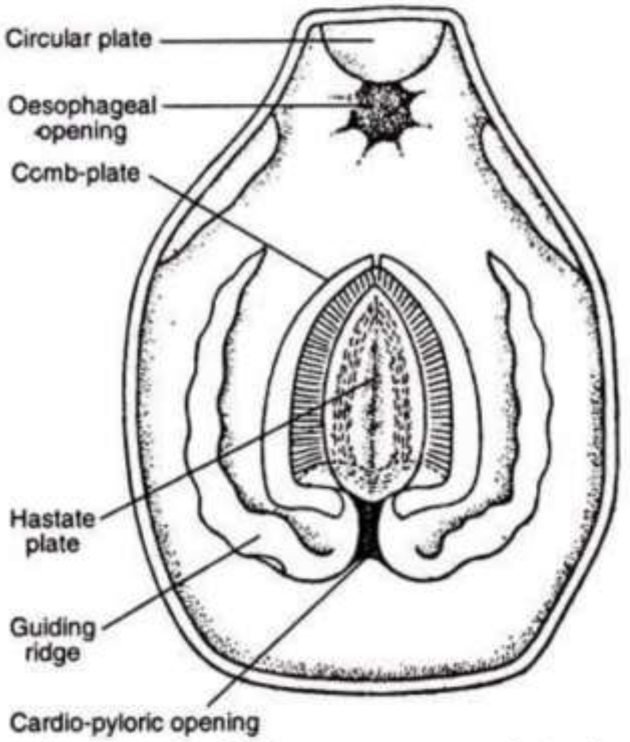
(A) Alimentary canal:

The alimentary canal of Prawn is distinctly divisible into three parts - fore gut, mid gut and hind gut.

1) **Fore gut:** It is internally lined by thick cuticle and consists of following parts:
   (a) **Mouth:** It is a broad opening on the ventral side of the cephalothorax between the third and fourth segments. It is bordered anteriorly by shield-like labrum, posteriorly by two-lobed labium and laterally by the incisor processes of the mandibles.
   (b) **Buccal cavity:** A small anterio-posteriorly flattened chamber between the mouth and esophagus. It has an irregularly folded lining of cuticle.
   (c) **Esophagus:** It runs vertically upwards as a broad tube from the buccal cavity and leads to the stomach. The inner lining is muscular and has one anterior, two lateral and one posterior folds.
   (d) **Stomach:** This is the longest part of the fore gut which is placed longitudinally within the cephalothorax. It also divided into two parts –

      (i) **Cardiac stomach:** It is large, spacious and bag-like anterior part of the stomach. Its inner cuticular wall is provided with ridges having minute bristles. Following plates support its wall - circular plate in the anterior part, lanceolate plate on the dorsal side of the posterior part and a shield-shaped hastate plate in the mid-ventral region. The posterior part of the hastate plate is depressed and reaches up to the cardio-pyloric opening.

      The upper part is slightly convex and gradually slopes towards the two lateral sides from a distinct median ridge in the middle. Both the upper and posterior surfaces have delicate setae. On each lateral side of the hastate plate lies an elongated lateral groove. A cuticular supporting rod and a ridged plate of similar nature, bound the inner and outer sides respectively of each lateral groove.



Floor of the cardiac stomach of freshwater prawn seen in longitudinal section

The inner side of each ridged plate is provided with rows of comb-like setae, which are known as comb-plate. The bristles of the comb-plate partially cover the lateral side of the hastate plate. The comb-plates of two sides unite at the anterior end but remain free at the posterior end just near the cardio- pyloric opening.

The inner wall of the cardiac stomach on the side of each comb-plate is folded to form a longitudinal channel, called the guiding ridge. The two guiding ridges posteriorly form the border of the cardio-pyloric opening.

(ii) **Pyloric stomach:** The cardiac stomach opens within th6 next part, pyloric stomach through a narrow, X-shaped cardio-pyloric opening. The opening is guarded by one anterior, one posterior and two lateral valves. The anterior valve is the posterior extension of hastate plate, posterior one is the fold of stomach wall and the two lateral valves are the projections of the guiding ridges.

The pyloric stomach is much smaller and narrower than cardiac stomach. Its lateral muscular wall is incompletely divided by folds into a small dorsal chamber and large ventral chamber. The ventral chamber receives the duct from the digestive gland, hepatopancreas and is divided into two lateral compartments.

The floor of the ventral chamber has a rectangular filter plate having alternate ridges and grooves. This filter plate together with the bristles on the lateral wall of ventral chamber, acts as pyloric filtering apparatus. This filter permits only liquid food to enter into the intestine.

2) **Mid gut:** It is the narrow and elongated part of the' intestine, which begins from the dorsal chamber of pyloric stomach and runs along the mid-dorsal line up to the sixth abdominal segment. Its internal epithelial lining at the posterior part is folded. Thus, the space within the tube is reduced.
3) **Hind gut:** It is also lined by thick cuticle and consists of following parts:
   (a) **Rectum**: It is the swollen muscular region of the last part of intestine having number as internal folds.
   (b) **Anus**: This is the aperture through which the alimentary canal opens to the exterior. It is a ventrally placed longitudinal slit-like opening, present near the base of the telson on a raised papilla.

(B) Digestive gland:

Only one digestive gland, hepatopancreas, is present. It is an orange-yellow colored, loosely arranged bilobed organ which encircles completely the pyloric stomach, part of the intestine and partly the cardiac stomach. One hepatopancreatic duct originates from each lobe independently and opens separately within the pyloric stomach, immediately after the pyloric filter plate.

The hepato-pancreas in its role as digestive gland serves as liver, pancreas and intestine of higher animals. In addition, it absorbs digested food and can store it for future use. Thus, this organ serves double functions - digestion and storage.

Mechanism of Nutrition:

The process of nutrition involves three stages—ingestion, digestion and egestion.

Ingestion: Prawn is omnivorous, i.e., eats all kinds of foods. It feeds actively at dusk and in the morning on algae, decaying vegetables and small insects. Food is procured by the chelate legs and brought near the mouth cavity by following appendages— maxillipeds, maxillulae and maxillae.

Mandibles help to fragment the food into smaller bits and the molar processes of the mandibles inside the buccal cavity crush the food. Entrance of food within the cardiac stomach is assisted by the peristaltic motion of the esophageal wall.

Digestion: Within the cardiac stomach the food is churned by the action of cuticular plates on the inner wall, finer particles of food filtered by the complete come within lateral grooves from where it is guided into the ventral chamber of pyloric stomach.

Digestion takes place within the pyloric stomach by the action of digestive juices which come from the hepatopancreas. All the enzymes for the breakdown of carbohydrate, protein and lipid are present in the juice.

The digested liquid food is strained by the filtering apparatus in the ventral chamber of pyloric stomach and enters within dorsal chamber and then to the hepatopancreas. The residual part of the food passes within the mid gut. After certain amount of absorption, the residual matter enters within dorsal chamber and then to the hepatopancreas. The residual part of the food passes within the hind gut.

Egestion: From intestine the residual part of the food enters within the rectum and is temporarily stored there for some-time. Finally, it is ejected through the anus.

P-4: Dissect and Display the Circulatory System of Prawn

C. True blood vessels: These are the vessels which possess definite walls. As all of them originate from the heart to supply blood to different parts of the body, they are better called arteries. From the heart of prawn six large vessels originate.

They are:

a) Single ophthalmic artery: The single ophthalmic or cephalic artery originates from the apex of the heart and runs anteriorly along the mid-dorsal line up to the base of the rostrum and unites with the branches of two antennary arteries

b) Paired antennary arteries: Each antennary artery originates from the heart and from the sides of the ophthalmic artery. It runs anteriorly along the outer border of the mandibular muscle.

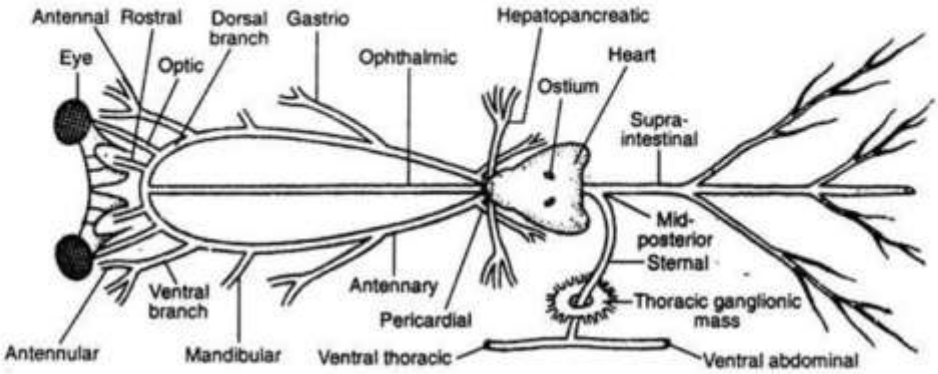
   Each antennary artery sends the following branches on its own side:

   i) Pericardial branch to supply blood to the pericardial wall
   ii) Gastric branch to supply blood to the cardiac stomach
   iii) Mandibular artery to the muscle of the mandible. Each antennary artery then splits into –
      - A ventral branch - The ventral branch supplies vessels to the first and second antennae.
      - A dorsal branch - The dorsal branch sends an optic artery to the eye and then the two dorsal branches of the two antennaries unite with the median ophthalmic artery to run within the rostrum as paired rostral arteries

c) Paired hepatopancreatic arteries: The hepatopancreatic or hepatic artery of each side originates from the posterio-median end of the heart and runs transversely to enter within the hepatopancreas

d) A single mid-posterior artery - The mid-posterior artery immediately after originating from the posterio-median end of the heart divides into:
   - Supra-intestinal artery - The supra-intestinal which is also known as dorsal abdominal artery runs posteriorly along the mid-dorsal line up to the hind gut. It supplies the alimentary canal and the muscles on the dorsal sides.
   - Sternal artery - The sternal artery runs transversely towards the ventral side. It pierces the thoracic ganglion mass and bifurcates into an anteriorly directed ventral thoracic and a posteriorly directed ventral abdominal arteries.

e) The ventral thoracic artery - supplies blood to the different parts on the ventral side of the cephalothorax and ventral abdominal sends branches to the ventral side of the abdomen.



Heart and principal arteries of freshwater prawn. Ventral arteries are partially drawn.

All the arteries ultimately break up into finer branches and open within the haemocoelomic spaces. Thus, the Circulatory system of prawn lacks network of capillaries.

D. Haemocoelomic spaces: Small haemocoelomic spaces are called lacunae. These lacunae open into larger spaces, called sinuses. The passages connecting lacunae and sinus or two sinuses are known as haemocoelomic channels.

Blood after flowing through different small haemocoelomic spaces or lacunae is collected in a pair of common elongated space, called ventral sinus. These are placed beneath the hepatopancreas and continued up to certain length within the abdomen. The two ventral sinuses are interconnected by several small slender channels.

From the ventral sinus six afferent branchial channel take the deoxygenated blood to the gills. First afferent branchial channel supplies blood to the podobranch and arthrobranchs while the remaining five vessels supply to the five pleurobranches.

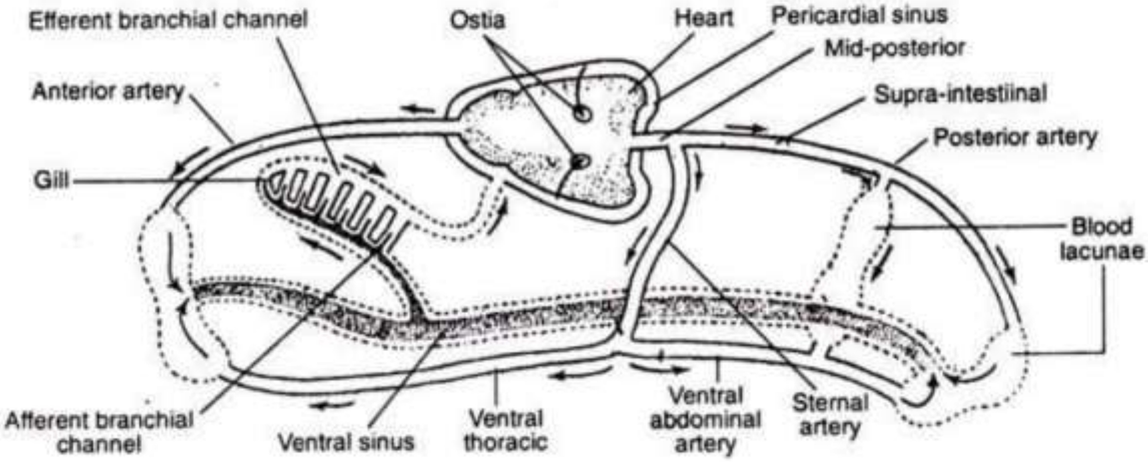
From gills oxygenated blood is collected by six pairs of efferent branchial channels and is finally drained into dorsal or pericardial sinus.

Mechanism of blood flow:

The heart contracts to drive the oxygenated blood to the different parts of the body through arteries. These arteries instead of forming capillary network open directly within haemocoelomic spaces. From different haemocoelomic lacune deoxygenated blood is collected within paired ventral sinuses.

From these large spaces, blood is sent for oxidation to the respiratory organs through the afferent branchial channels. From gills the blood returns to the pericardial sinus through efferent branchial channels.

When the pericardial sinus is full its wall starts to contract and forces the blood to enter within the heart through ostia. When heart contracts the lip-like borders of the ostia close and thus blood is permitted to travel only through arteries.



Schematic route of blood flow in Freshwater Prawn

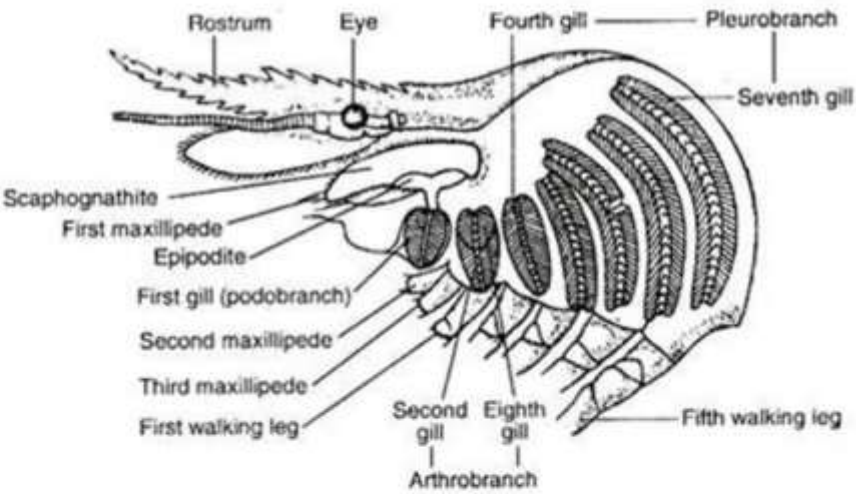
P-5: Dissect and Display the Respiratory System of Prawn

Prawn respires in the aquatic medium and it carries three sets of organs for the purpose - lining of the branchiostegite, epipodites and gills. All these organs are enclosed within a special chamber on each side of the cephalothorax, which is called gill chamber. The gill-chamber is covered by the lateral extension of carapace, called gill- cover or branchiostegite. Each gill-chamber is thus open ventrally, anteriorly and posteriorly.

Lining of the branchiostegite: The richly vascularized membrane of the branchiostegite serves as respiratory surface, through which gaseous exchange takes place.

Epipodites: These are small highly vascularized leaf-like membranous structures, one on the coxal segment of each maxilliped. These epipodites being present in the anterior part of the gill-chamber carry out respiratory functions.

Gills: Among the three sets of respiratory organs, the gills are regarded as primary respiratory organs. On each lateral side of the cephalothorax and beneath the branchiostegite, there are eight gills, each attached with the thoracic wall by a gill-root. Seven of these eight gills are serially arranged, while the eighth gill remains concealed under the second gill.



Respiratory organs (Gills) of freshwater prawn. Note that the branchiostegite of one side has been removed to expose the gill-chamber.

Structure:

The gills are crescent-shaped and their sizes increase gradually from anterior to posterior direction. Each gill consists of a slender axis or base on which double rows of rhomboidal leaf-like gill-plates are arranged like the pages of a book.

According to their position and mode of attachment, the gills are of three types:

(i) Podobranch - attached with the coxa of the second maxilliped.
(ii) Arthrobranch - attached with the arthrodial membrane of third maxilliped.

(iii) Pleurobranch - attached with the outer border of the thorax and over the articulating surface of the walking legs.

In prawn, the first gill is podobranch, second and eighth gills are Arthrobranch and remaining five gills are pleurobranches.

Histology: Histological structure of the gill shows that gill base has following layers - the outermost cuticle, inner epidermis and innermost connective tissue mass. Each gill- plate is formed by monolayer of cells, sand- witched between two layers of cuticle. The cellular layer includes two alternately arranged cell types - pigmented and transparent.

Blood supply: Two lateral and one median longitudinal blood channels pass throughout the length of gill-base. The two lateral channels are interconnected by numerous transverse channels.

From each lateral channel a slender marginal channel is given to each plate. After covering the entire margin of the plate, the marginal channel opens within the median channel. The gill receives deoxygenated blood through afferent branchial channels.

Each branch of afferent channels opens within the transverse channels. From transverse channels the blood passes to the lateral longitudinal channels and is distributed subsequently within the gill-plates through the marginal channels. After oxidation, the blood from marginal channel returns to the median channel and then to the efferent branchial vessels, which convey it to the heart.

The course of circulation of blood through the gill is given below:

Afferent branchial channels → Transverse channels → Lateral longitudinal channels → Marginal channels → Median longitudinal channels → Efferent branchial channels → Heart

Mechanism of Respiration:

The scaphognathites of maxillae and exopodites of maxillipeds are responsible for forcing the water to rush inside the gill- chamber through posterior and lateral sides. This water passes out through the anterior end.

During the flow of water, the vascularized surface of the branchiostegite, gills and epipodites are bathed and gaseous ex-change occurs through these areas when dissolved oxygen is taken in and carbon dioxide passes from the body to the exterior.

P-5: Dissect and Display the Nervous System of Prawn

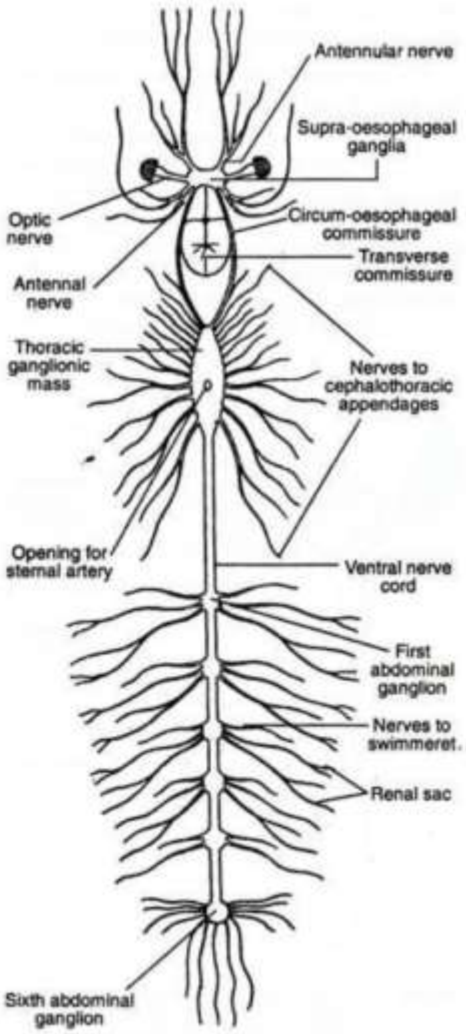
Nervous system resembles the annelidan pattern but shows considerable advancement.

It is divisible into:

A. Central nervous system,
B. Peripheral nervous system and
C. Autonomic nervous system.

It also includes several sense organs to permit the entry of different messages from outside.

A. Central nervous system: The central nervous system runs from anterior to posterior end and contains following structures:



Nervous system of Freshwater Prawn

1) **Brain:** It is made up of a pair of supraoesophageal ganglia which are placed dorsally and near the base of the rostrum. It sends a number of peripheral nerves to the different organs at the anterior end of the cephalothorax.
2) **Circumoesophageal connectives:** These are a paired cord, each of which begins from the supraoesophageal ganglion of one side and runs posteriorly along the ventro-lateral wall of the cephalothoracic cavity. A small ganglion is present in each commissure to supply nerve to the mandibles. The two cords are connected by a thin nerve, called transverse loop, which is present immediately after the esophagus. The two connectives ultimately unite at the floor of the thoracic cavity with a large ganglion, called the thoracic ganglionic mass.
3) **Thoracic ganglionic mass:** A large ventral elongated mass is formed by the fusion of eleven pairs of ganglia. Two circumoesophageal connectives are united with it at the anterior end. This ganglionic mass is pierced by the sternal artery. It sends eleven pairs of peripheral nerves.
4) **Ventral nerve cord:** From the posterior end of the thoracic ganglionic mass originates ventral nerve cord which runs up to the posterior-most segment. The cord appears to be single but in reality, it is formed by the fusion of two separate cords. The ventral nerve cord along its course bears a ganglion in each segment. The last ganglion or 6th ganglion is the largest of all the abdominal ganglia and known as stellate ganglion.

B. Peripheral nervous system: The peripheral nerves are given off from the different parts of the central nervous system. Each peripheral nerve contains two kinds of fibers — motor and sensory. The motor fibers carry instructions from the central nervous system to different parts and the sensory fibers are meant for bringing messages from different corners of the body.

Following peripheral nerves are seen in prawn:

1) **Optic nerve:** From each lobe of brain, an optic nerve enters within the eye to inner-vate the retinal layer.
2) **Antennular nerve:** From each lobe of brain an antennular nerve is given within the first antenna or antennule to supply statocyst and various other structures present in the first antenna.
3) **Antennary nerve:** From the posterior side of each lobe of brain, antennary nerve originates and runs posteriorly to take a quick turn towards the anterior dissection to supply the various parts within second antenna including green gland.
4) **Cephalothoracic nerves:** Eleven pairs of cephalothoracic nerves originate from the thoracic ganglionic mass to supply different muscles and appendages in that region.
5) **Abdominal nerves:** From each abdominal ganglion two ‘pairs of peripheral nerves are given off to the corresponding segments to supply muscles and appendages. The stellate ganglion in addition to these two pairs sends several more branches to telson, rectum and other adjoining structures.

C. Autonomic nervous system: It includes a few minute ganglia and slender nerves which are present over the cardiac stomach to supply involuntary parts of the body.

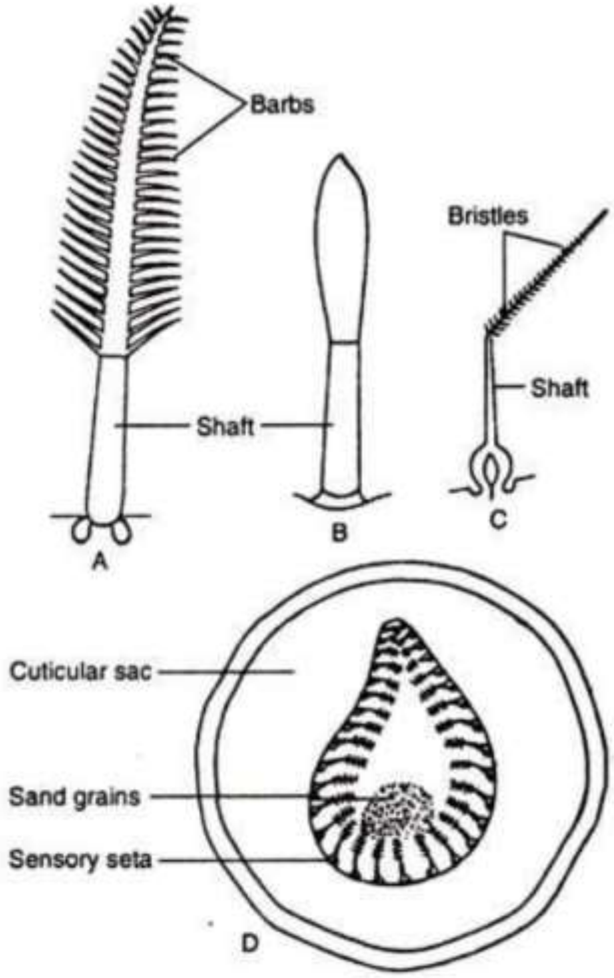
D. Sense organs: Following sense organs are present in prawn to receive different stimuli—tactile organs, olfactory setae, statocyst and eye.

1) **Tactile organs:** These sense organs are present along the margin of antenna and other appendages.

A typical tactile seta consists of:

a) Swollen base or shaft and
b) Pointed plumose with double rows of barbs.

These are responsible for the sensation of touch.



A-C. Different sensory setae of freshwater prawn; A. Tactile seta; B. Olfactory seta; C. Statocystic seta; D. Statocyst of *Macrobrachium* (sectional view) – note the arrangement of sensory setae

2) **Olfactory setae:** These organs are present on the small inner branch of the outer feeler of the first antenna. These organs differ from tactile setae in the absence of the barbs in the plumose part. These are responsible for smell.
3) **Statocyst:** Inside the base (pre-coxa) of each antennule, the statocyst is present as a small, white and spherical cuticular sac. In the central part of the sac, elongated and slender sensory setae are elliptically arranged.

   Each seta consists of a pointed bristled end, called shaft, which is directed inwards and an outer swollen base which is connected with a fine branch of statocyst nerve. In the area surrounded by the setae there are minute sand grains.

   When the prawn moves, these inner sand grains are displaced at each change of position. These displaced sand particles press against the sensory setae. Finer branches of statocyst nerve carry the information from each seta to the brain and the animal corrects its loss of equilibrium.
4) **Eye:** Each movable and stalked eye is compound in nature, i.e., made up of several simple visual units. Each unit is called an ommatidium or ocellus.

   a) **Structure of an ommatidium:** Each ommatidium is divisible into two parts—outer dioptrical region for focusing the light rays falling from the object and inner retinal part or receptor region for receiving light stimuli and serves to form the image. The dioptrical region consists of cornea, corneagen cells, crystalline cone and cone cells. The receptor region includes rhabdome, retinular cells and pigment sheath.

      These two portions (dioptrical region and receptor gerion) in each ommatidium contain following parts from outer to inner sides:

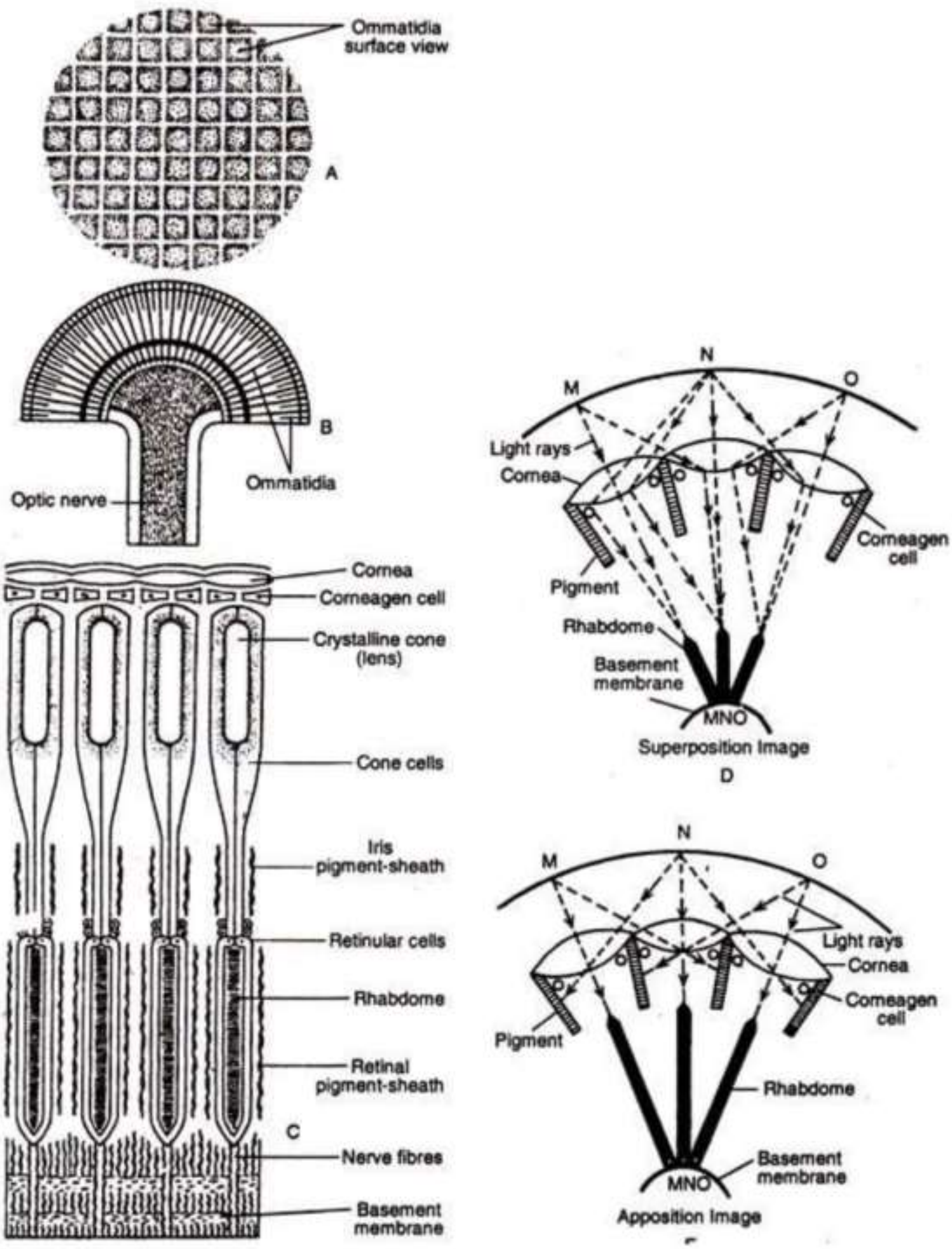
      i) **Cornea:** It is the outermost transparent cuticular layer. The cornea of all the ommatidia gives the outermost part of the eye a graph paper-like appearance and each square is called a facet. The cornea acts as a lens
      ii) **Corneagen cells:** Immediately beneath the cornea pair of corneagen cells is present which are responsible for the replacement of cornea.
      iii) **Crystalline cone:** This is an elongated transparent body, placed beneath the corneagen cells and works as a second lens.
      iv) **Cone cells or Vitrellae:** These cells are four in number and they encircle the cone or lens to provide nourishment.
      v) **Rhabdome:** Elongated transversely striated body which is situated immediately beneath the cone cells.
      vi) **Retinular cells:** These are elongated sickle-shaped cells. Seven such cells secrete the rhabdome and encircle it to provide its nutrition.

vii) **Pigment sheath:** Two separate sheaths containing chromatophores are responsible for separating one ommatidium from the other. The group of pigment sheath which is present around cone and cone cells is called iris sheath, while the other group around rhabdome and retinular cells is called retinal sheath. Pigment sheaths are able to contract and relax, which depends upon the intensity of light.

b) **Mechanism of image formation:** The ommatidia of a compound eye may work singly or collectively. Several adjacent ommatidia take part in the formation of an image and each ommatidium produces a separate image of a part of the object. Therefore, the whole image which is produced by the compound eye is made up several pieces of images. So, the vision produced by the compound eye is known as mosaic vision.

During bright light both the pigment sheaths extend and completely separate the ommatidia, which result in the formation of a large number of images. These images are called apposition images. This type of vision is also called mosaic vision.

When light is dim, ommatidia work together to form a single but blurred image. Such image is called superposition image and the kind of vision is known as superposition image. Prawn can move its eye considerably and has nearly 360° vision.



A. Compound Eye of freshwater prawn (Surface view); B. Compound eye of freshwater prawn (longitudinal section, diagrammatic); C. Histological structure of four ommatidia (longitudinal section, diagrammatic). D. Diagrammatic representation of the formation of superposition image by a compound eye. E. Formation of an apposition image.