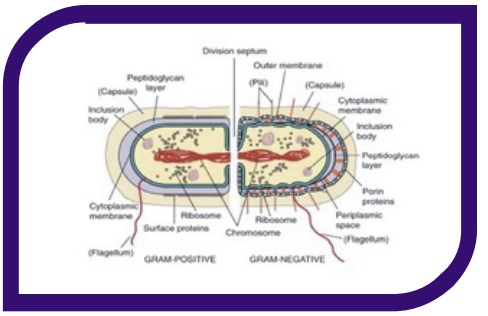
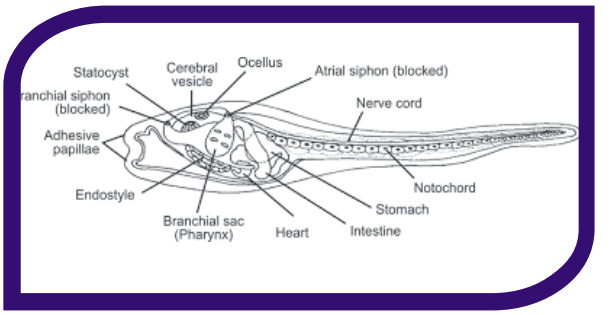
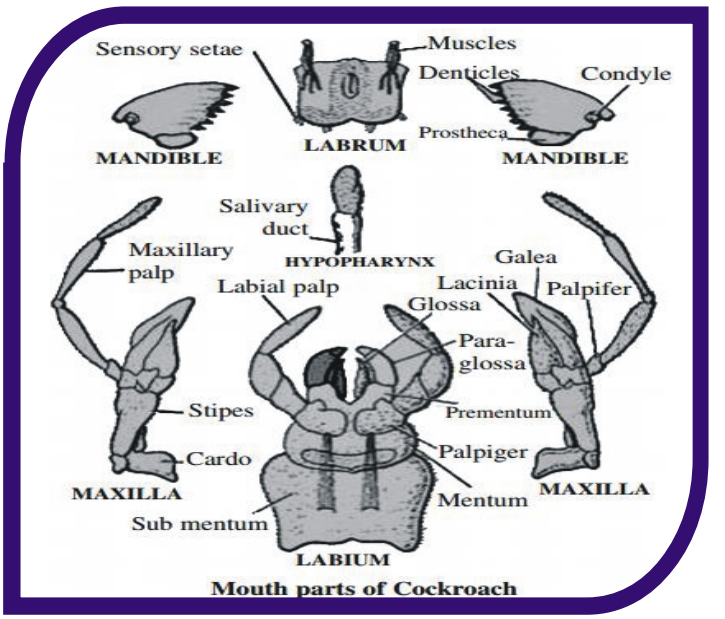
MZO-10

Vardhman Mahaveer Open University, Kota







Mouth parts of Cockroach

Practical Zoology-II

MZO-10

Vardhman Mahaveer Open University, Kota

Practical Zoology-II

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Preface

The present book entitled "**Practical Zoology-II"** has been designed so as to cover the unit-wise syllabus of MZO-10 course for M.Sc. Zoology (Final) students of Vardhman Mahaveer Open University, Kota. The basic principles and practical aspects have been explained in simple, concise and lucid manner. Adequate examples, diagrammes , photographs have also been included to enable the students to grasp the practical easily. The teachers conducting the practical are expected to give practical exposure and make the student learn the techniques involved in an exercise so that the student is able to learn the practical aspects required from a PG student of Zoology. Extensive care has been taken to eliminate misprints, omissions and errors but still in the first edition of the book there is a great possibility for having these things in the textbook. The authors would be grateful to the readers for bringing the same to our notice. The unit writers have consulted various standard books and internet as their reference on the subject and they are thankful to the authors of these reference books. The authors shall be satisfied if the book meets the needs of the students for whom it is meant. Suggestions and criticism for the further improvement of the book will be thankfully acknowledged and incorporated in further editions.

Unit -1

Museum Specimen-I

Structure of the Unit

1.6.17 *Diodon*
1.6.18 *Tetradon*
1.6.19 *Ostracion*
1.6.20 *Lophis*
1.6.21 *Syngnathus*
1.6.22 *Hippocampus*
1.6.23 *Angulla*
1.6.24 *Labeo*
1.6.25 *Ophiocephalus*

1.1 Objectives

The present unit has been designed with the objective to learn about the animals which are classified as chordates. The study of the habitat, form of life, the basic structure and the life activities of the representative chordates types would help you to have an understanding of the taxonomic concepts to a great extent.

1.2 Introduction

There is large number of animals included in each group/taxon of the animal kingdom but it is not possible to study all the animals. For each class there is a representative animal which can be best studied by preserving them in formalin /alcohol/stuffing or if such animals are not available due to legal restrictions imposed by the government, being taxonomically significant, it should be studied in a model form or through the diagram for the practical exercises.

1.3 Phylum Chordata

The name of this phylum is derived from two Greek words, the chorde meaning a string or cord, and ata meaning bearing.

Four key features present at some point in life cycle of all chordates:

1. A **notochord** (**noto** = the back; **chord** = string) is present in all embryos, and may be present or absent/reduced in adults. This is the structure for which the phylum was named.
2. A dorsal, hollow, ectodermal **nerve cord** (compare with Annelida and Arthropoda which have ventral, solid, mesodermal nerve cords) typically forms by an infolding of the ectoderm tissue, which then "pinch off" and becomes

surrounded by mesoderm. **Spinal bifida** is the failure of the nervous system to close.

3. The **pharyngeal slits** (**pharynx** = throat) originally functioned in filter feeding: water is taken into the mouth and let out via the pharyngeal slits. The slits filter out food particles and keep them in the animal's body so they can be put into the digestive tract. In fish, these have become modified as gills, and in humans as our ears and eustachian tubes.
4. A **postanal tail** (**post** = behind, after; **anal** refers to the anus) is present and extends behind the anus in many taxa, thus the anus isn't at posterior tip of body. In humans, the tail is present during embryonic development, but is subsequently resorbed.

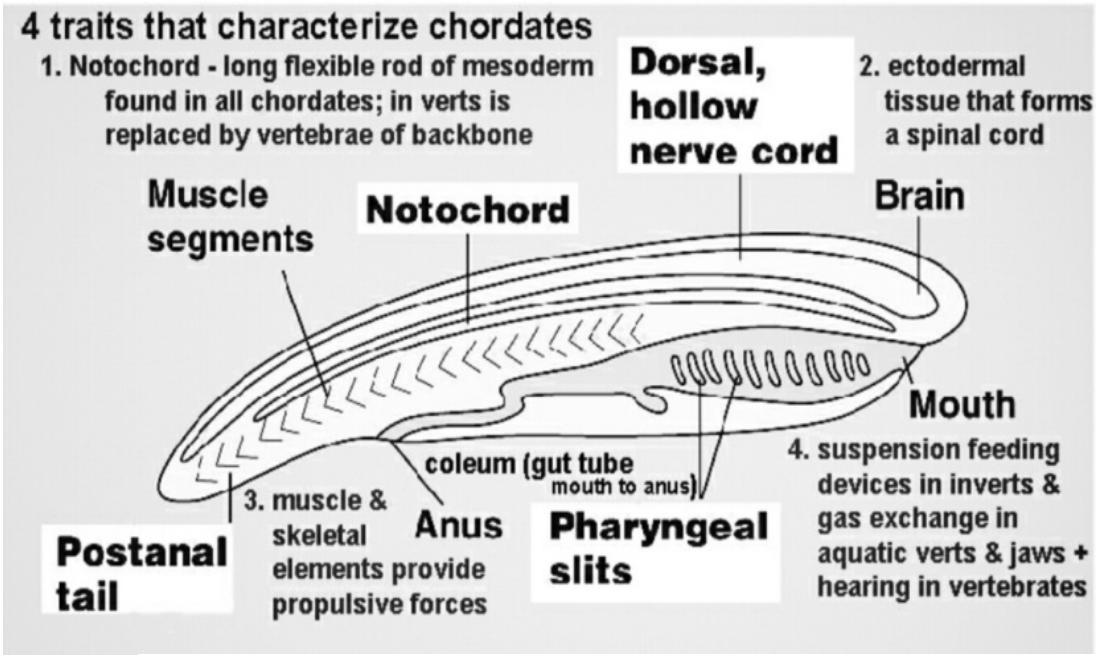


Fig – 1.1

Phylum chordata is classified as follows:

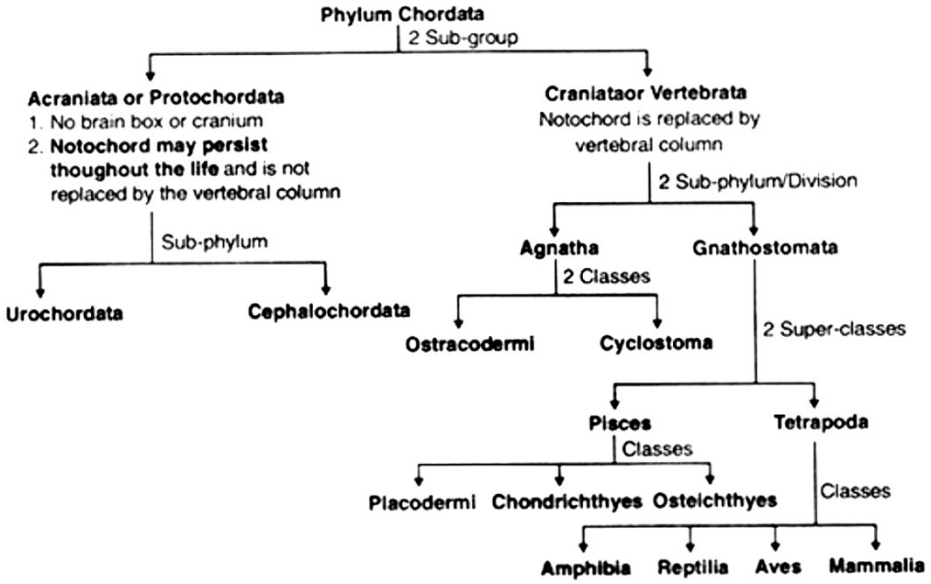


Fig – 1.2

1.4 Lower Chordates (Protochordata)

Group protochordata includes chordates without cranium, jaws, vertebrae or paired appendages.

A. Subphylum Cephalochordata (lancelets)

1. Fishlike creatures that bury selves in mud and filter feed
2. All four key chordate feature present in adults
3. Like vertebrates, muscles broken up into bands called myomeres (body segmentation)
4. Essentially no brain in adults

B. Subphylum Urochordata (sea squirts, tunicates)

1. Barrel-shaped, sessile, filter-feeders
2. Many secrete and live in a tough cellulose sac (tunic) as adults
3. Only have pharyngeal gill slits as adults, other chordate characters only present in tadpole-like larvae
4. Incurrent and excurrent siphons
5. No brain in adults

1.4.1 Salpa

Classification with identification:

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.

Group- **Acrania**-without cranium, jaws and brain.

Sub-phylum –Urochordata-Notochord and nerve cord only in larva.

Class - **Thaliacea-**Tunic permanent, transparent, with circular muscle.

Order- **Salpida** – Incomplete muscle bands, no larva.

Genus- ***Salpa***

Habit and Habitat – Salpa is a cosmopolitan, marine, and typical pelagic acidian distributed in almost all seas

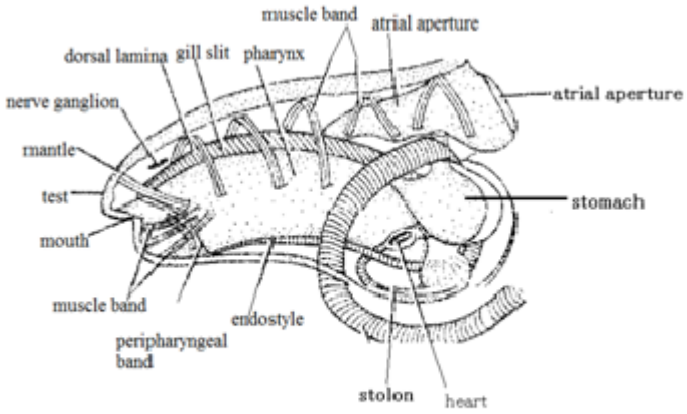
It is dimorphic exhibits alternation of generations. Its solitary phase is **asexual oozooid**, while gregaria phase is **sexual gonozooidor blastozooid**

Oozooid-

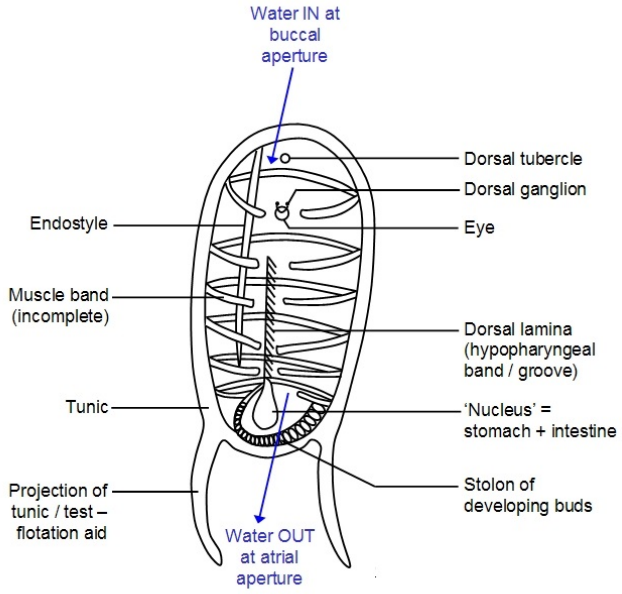
1. It is prism like bilaterally symmetrical and having branchial (mouth) and atrial (anus) apertures at opposite ends.
2. Test is thin and transparent.
3. Muscle bands are incomplete except the first and ninth muscle bands, which are complete and form sphincters.
4. The mouth, bounded by dorsal and ventral lips, leads into a large pharynx with endostyle and a dorsal lamina forming a ciliated gill bar.
5. Near the brain is a single ocellus.
6. The asexual oozooid has no gonads, but it has a stolon arising from near the endostyle.
7. The stolon elongates anmd segments into a chain of buds, these forms gonozooids.

Blastozooid-

1. Sexual blastozooid has a general structure like asexual oozooid.
2. It is smaller, asymmetrical with no test processes.
3. Number of muscle bands is fewer.
4. Gonads are present and there is no stolon.
5. Development occurs on the pharyngeal wall in a placenta which nourishes the embryo.



***Salpa* (Lateral View)**



Salpa

Fig – 1.3

1.4.2 *Doliolum* oozooida

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.

Group- **Acrania**-without cranium, jaws and brain.

Sub-phylum – Urochordata-Notochord and nerve cord only in larva.

Class - **Thaliacea-T**unic permanent, transparent, with circular muscle.

Order- **Doliolida-** muscle bands form 8 complete rings, larva present.

Genus- *Doliolum*

Habit and Habitat –Doliolum is a cosmopolitan, marine, free swimming and pelagic, thaliacean distributed in almost all seas.

1. Oozooid is a colonical asexual gregaria phase of Dolliolum.
2. It is barrel shaped, having wide branchial (mouth) and atrial (anus) aperture at opposite ends each surrounded by 10-12 lobes.
3. The mantle containing 9 muscle bands completely encircling the body and the terminal ones work as sphincters.
4. The animals move by jet propulation driving out water through atrial aperture by contraction of muscle.
5. Mouth leads into a pharynx having several stigmata only in its posterior wall it has an endostyle, but there is no dorsal lamina.

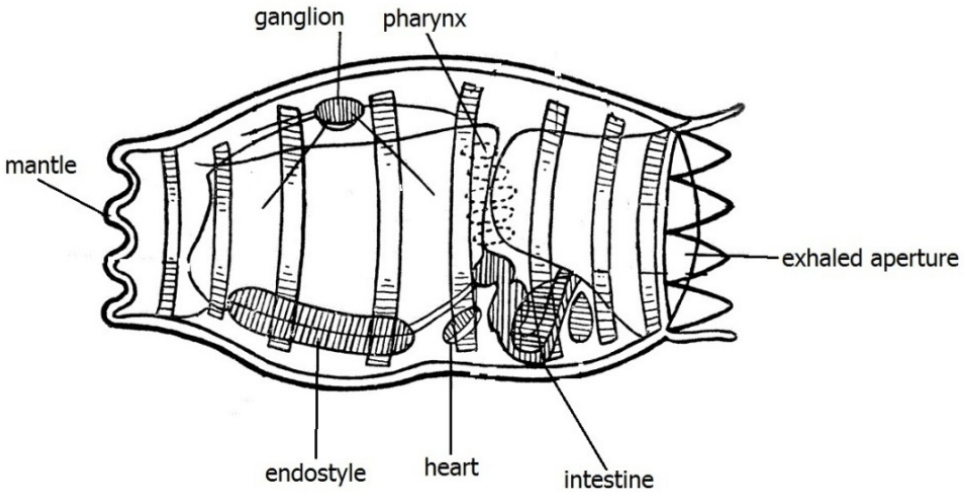


Fig – 1.4

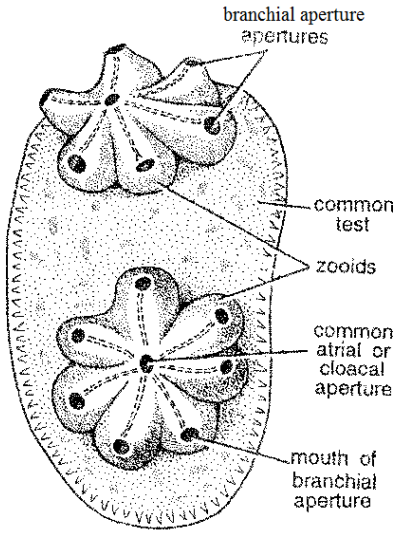
1.4.3 *Botrylus*

Classification with identification:

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.
Group- **Acrania**-without cranium, jaws and brain.
Sub-phylum – Urochordata-Notochord and nerve cord only in larva.
Class - **Ascidiacea** -Tunic with scattered muscles, many gill-slits.
Order- **Ascidiaecompositae** - fixed & colonial
Genus- ***Botrylus***

Habit and Habitat –It is sedentary, colonial marine forms, common in Atlantic and Mediterranean seas found attached to piers, ships, in shallow waters.

1. The gelatinous test of colony is flat and hard on which zooids of colony borne.
2. Groups of zooids are arranged in star –like fashion on the hard test.
3. The structure of each zooid is like that of simple ascidian.
4. The branchial apertures (mouth) of zooids are present at the ends of the arms of the star, but the atrial apertures of zooids open in centre into a common cloaca.
5. Dorsal lamina has no languets; neural gland is dorsal to the brain.
6. Its colony increases in size by sexual reproduction and also by budding. The buds remain permanently attached to the colony.
7. It is hermaphrodite having a pair of gonads.



Botrylus

Fig – 1.5

1.4.4 Herdmania

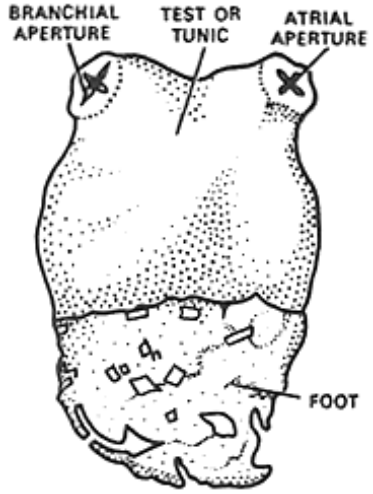
Classification with identification:

Phylum – **Chordata**-Nerve cord, notochord, and gill-slits present.
Group- **Acrania**- without cranium, jaws and brain.
Sub-phylum- **Urochordata** - Notochord and nerve cord only in larva.
Class- **Ascidiacea**-Tunic with scattered muscles, many gill-slits.
Order- **Ascidiaesimplices** -Fixed solitary, Gonad one.

Genus- ***Herdmania***

Habit and Habitat- *Herdmania* is basically marine living organism, which is commonly found in seawater.

1. It is marine, segmented and solitary animal.
2. The body look like square and enclosed in a soft transparent tunic "the test".
3. The tail is absent in adults or they are without tail.
4. The individuals are attached to substratum through "foot".
5. Alimentary canal is almost "U" shaped.
6. The mouth and cloaca open into definite chambers- the branchial and atrial siphons.
7. Pharynx is perforated with paired stigmata in young and adults both.
8. Vascular system is of open type.
9. Nervous system is represented by single ganglion in adults.
10. Dorsal tubular nerve cord is absent in adults but present in embryonic stages.
11. It is hermaphrodite and protogynous.
12. It shows retrogressive metamorphosis in which notochord, nerve cord, tail and tail fins are degenerated by the time adult is formed, all chordate character disappear.



Herdmania

Fig – 1.6

1.4.5 ***Amphioxus***

Classification with identification:

Phylum- Chordata -Nerve cord, notochord, and gill-slits present.

Sub-phylum- Cephalochordata-Notochord alongentire body length and persistent

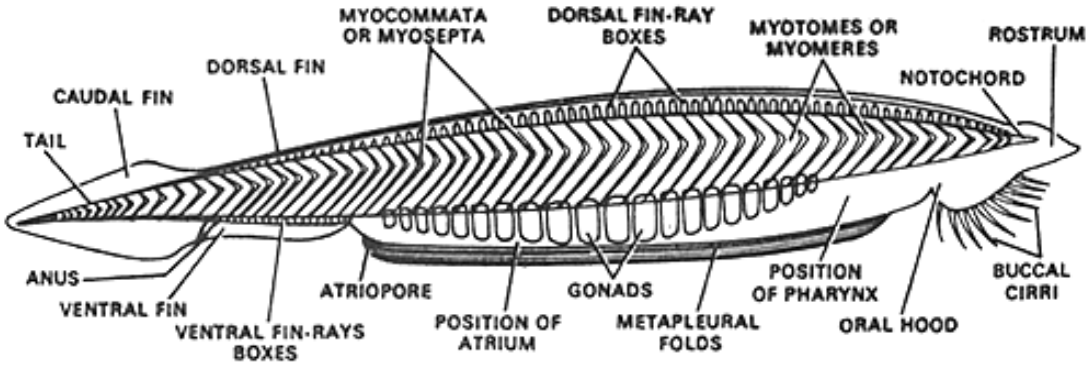
Class- **Leptocardii**-Lancets, many gill-slits

Order- **Amphioxiformes**

Genus- ***Amphioxus (Branchiostom*a)**

Habit and Habitat- They are burrowing, marine, fish-like living organism found in seawater.

1. They are generally fish-like in appearance and commonly called as **lancelet.**
2. Body is laterally compressed and has a distinct tail and a caudal fin.
3. A dorsal fin is present all along the back and the ventral fin is present in front of caudal fin.
4. Two lateral metapleural folds are present.
5. Body is divisible into trunk and tail. Head, snout and exo and endoskeleton are absent.
6. Mouth is surrounded by a ring and the oral hood is made up of 18-20 oral cirri.
7. The opening between buccal cavity and pharynx is guarded by a ring known as velum having 8 tentacles.
8. Pharynx is surrounded by atrium and is perforated by oblique gill slits (stigmata)
9. Anus is symmetrically placed on right side.
10. Gonads 26 pairs metamerically arranged on pharynx. The two sexes are separate but without sexual dimorphism.



Amphioxus

Fig – 1.7

1.5 Cyclostomata

The cyclostomata (Gr., cyklos, circular + stoma, mouth) are the living agnathans, they are primitive in many respect, but specialized in others.

1. They have round bodies with laterally compressed protocercal tail, eel like.
2. The suctorial mouth is ventral and round.
3. Gill chambers are round pouches.
4. The skin is soft and devoid of scales, paired appendages are absent, though median fins are present and supported by cartilaginous fin rays.
5. Endoskeleton cartilaginous with no bones, the vertebral column is primitive, exoskeleton lacking.
6. They have 6-14 pairs of internal gill in different species.
7. There is a single median nostril, and only one or two semicircular canals are present in each auditory organ.
8. Cyclostomata include lampreys and hag-fishes.

1.5.1 *Petromyzon*

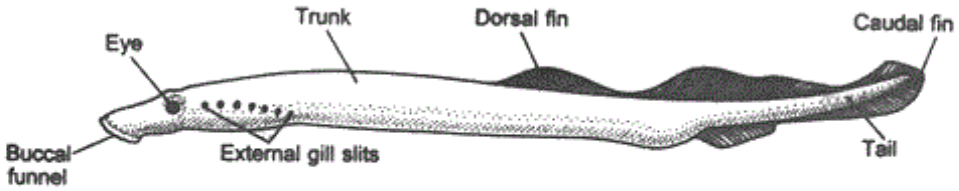
Classification with identification:

Phylum- **Chordata**- Nerve cord, notochord, and gill-slits present.
Sub-phylum- **Vertebrata**-Cranium, jaws and brain present.
Super-class- **Agnatha**- Without true jaws and appendages.
Class- **Cyclostomata**- Mouth circular, suctorial, without jaws
Order- **Petromyzontia**- Mouth with funnel, without tentacles
Genus- ***Petromyzon***

Habit and habitat- It occurs both in freshwater and seawater. It is present in coastal waters of North America, Europe and Japan.

1. Most primitive living vertebrates.
2. Body is cylindrical, slimy and eel-like with a definite head.
3. Head bears a pair of lateral eyes, a single dorsomedian nostril or nasal aperture between the eyes, and a ventral suctorialbuccal funnel.
4. The suctorialbuccal funnel is fringed with papillae, called the oral fimbriae and in the centre is the mouth, which is surrounded by cone-shaped horny teeth.

5. Just behind the head 7 pairs of gill-slits or pores on the body are laterally present.
6. Body is smooth without scales and slimy due to mucous glands on skin.
7. Body contains 2 median dorsal fins. The posterior dorsal fin is continuous with the caudal fin.
8. Paired fins or appendages are absent.
9. It is an active voracious carnivore and attaches to the side of a fish, cuts the flesh of the prey by its rasping tongue and with the suctorial action of its buccal funnel suck the flesh and the blood.



Petromyzon

Fig – 1.8

1.5.2 *Myxine*

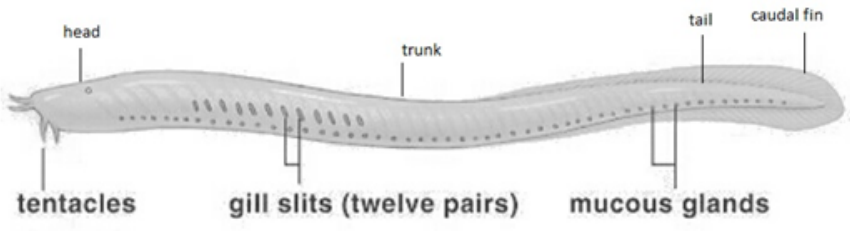
Classification with identification:

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.
Sub-phylum- **Vertebrata**-cranium, jaws and brain present
Super-class- **Agnatha**-Without true jaws and appendages.
Class- **Cyclostomata**-Mouth circular, suctorial, without jaws
Order- **Myxinoidia**-Eel like body, Vestigeal eyes
Genus- ***Myxine***

Habit and Habitat- It occurs along the coasts of America, Europe and Japan.

1. These are called hag-fishes as the skin surrounding the mouth is folded like an old hag.
2. Body is slimy, cylindrical, and eel-like and may reach a length of 45 cm.
3. Skin is smooth without scales and very slimy because of presence of slime glands on the skin.

4. Head bears a terminal suctorial mouth which has a tongue containing 2 rows of horny teeth for rasping.
5. There is a single median tooth in mouth.
6. Near the mouth 4 pairs of short sensory tentacles are present.
7. The single median nostril is terminal.
8. Eyes are degenerate and lie buried under muscles and skin.
9. Six pairs of gills are present, the ducts of which join to open to the exterior by a single pair of branchial apertures present, laterally in the anterior part of the body.
10. A single continuous caudal fin is present. The dorsal fin is absent or reduced.



Myxine

Fig – 1.9

1.6 Pisces

The superclass Pisces of the truly jawed vertebraes includes all the fishes which are essential aquatic forms with paired fins for swimming and gills for respirstion.

1. They are aquatic vertebrates that live in water. Their body is invariably stream lined and they swim with the help of tail.
2. They have paired appendages in the form of fins. Unpaired fins are also present. Fins help in balancing during swimming.
3. They have lateral line system that helps them to know the disturbances in the nearby environment. The system is a unique sense organ.
4. Their body is covered by dermal scales. The scales provide them protection. Scales of fishes arise from the dermis layer hence are deep seated.
5. Fishes have a two chambered heart and there is a single circulation of blood.

6. Respiration is typically by pharyngeal gills, varying from 5 to 7 on each side; some possess lungs.
7. Skin is generally covered by protective dermal scales; skin glandular.
8. Nasal cavity is not connected to the buccal cavity.
9. Internal skeleton is either cartilaginous or bony.
10. Sexes are separate; fertilization is external or internal.
11. Gonads and true gonoducts are present.
12. Amnion is absent.

Class Chondrichthyes (**chondro** = cartilage; **ichthys** = fish) which includes sharks and rays. They have a cartilage skeleton, not bone. They are not buoyant like other fish so they must swim or sink. Like other fish they have a **lateral line** system which detects differences in water pressure, the equivalent of our hearing. **Class Osteichthyes** (**osteo** = bone) is the bony fish. This is the most numerous of all vertebrate classes. In fish, O_2 is exchanged via the gills, which are covered by an **operculum** which helps to draw water across/through the gills. Their swim bladder is an air sac used to control buoyancy, thus unlike the sharks, bony fish can hold still at any depth and not sink.

1.6.1 *Rhinobatos*

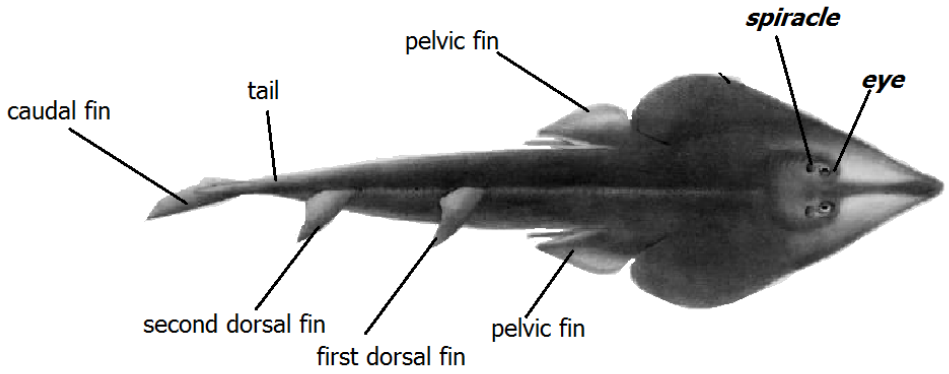
Classification with identification:

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.
Sub-phylum- **Gnathostomata**-With jaws and paired appendages.
Superclass- **Pisces**-Paired fins, gills, and skin with scales.
Class- **Chondrichthyes**-Endoskeleton cartilaginous, spiral valve in intestine.
Sub-class- **Selachii**-Sharks and rays, Cloaca present
Order- **Hypotremata**-gill-slits ventral, spiracles present.
Genus- ***Rhinobatos***

Habit and Habitat- This fish often bury themselves in sand, mud or weedy bottoms near patch reef and are believed to tolerate fresh, brackish and marine water.

1. Guitarfish have the appearance of both a shark and skate, their bodies are dorso-ventrally flattened like a skate or ray and the tail has two dorsal fins similar to most sharks.

2. The pectoral fins are fused to the head creating a heart or triangle shaped head and body.
3. A few tubercles are typically found on the tip of the snout.
4. The dorsal side of the guitar fish is gray, olive brown or chocolate brown and typically with white freckles covering the surface. The fins are usually slightly darker than the trunk of the fin and its ventral side is white to pale yellow in color.
5. The dorsal denticles are very small and set closely together with skin visible between them. They are arranged in a row along the dorsal mid line and vary greatly in shape depending upon their location on the guitarfish's body.
6. These fish reproduce via internal fertilization and give birth of live young.
7. It is an ovoviviparous fish and the young develop inside the female, obtain nourishment from their yolk sacs a first and later from uterine secretions of their mother.
8. The guitarfish is considered harmless to humans.



***Rhinobatos* –Guitar Fish**

Fig – 1.10

1.6.2 *Pristis*

Classification with identification:

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.

Sub-phylum- Gnathostomata-With jaws and paired appendages.

Superclass- **Pisces**-Paired fins, gills, and skin with scales.

Class- **Chondrichthyes**-Endoskeleton cartilaginous, spiral valve in intestine.

Sub-class- **Selachii**-Sharks and rays, Cloaca present

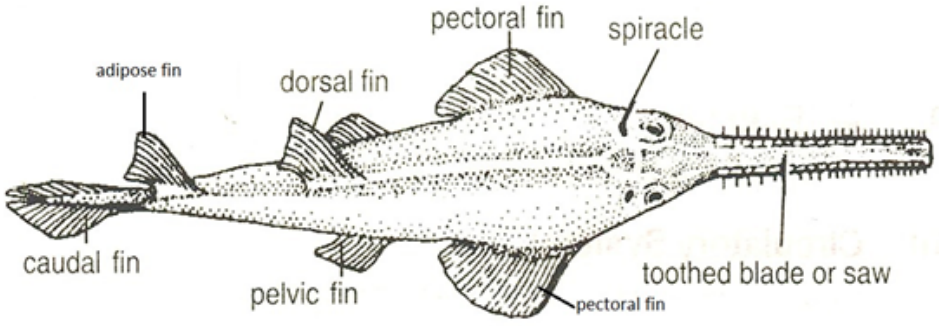
Order- **Hypotremata**-gill-slits ventral, spiracles present.

Genus- ***Pristis***

Species- ***cuspidatus***

Habit and Habitat- It is marine fish, commonly found in seawater.

1. It is commonly known as ‘ Saw-fish’
2. Body is elongated with spindle shaped.
3. Exoskeleton is made up of placoid scales.
4. Head is produced into a long, beak-like and flat rostrum having tooth-like lateral denticles to work as saw. It is used for offence, defence and food capture.
5. Median and paired fins are present and pectoral fins are small.
6. Males have paired claspers.
7. Two dorsal fins and one anal fin are present, first dorsal fin is just opposite to pelvic fin.
8. Heterocercal tail bears single lobed caudal fin.
9. It is viviparous in nature.



Pristis

Fig – 1.11

1.6.3 *Trygon*

Classification with identification:

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.

Sub-phylum- **Gnathostomata**-With jaws and paired appendages.

Superclass- **Pisces**-Paired fins, gills, and skin with scales.

Class- **Chondrichthyes**-Endoskeleton cartilaginous, spiral valve in intestine.

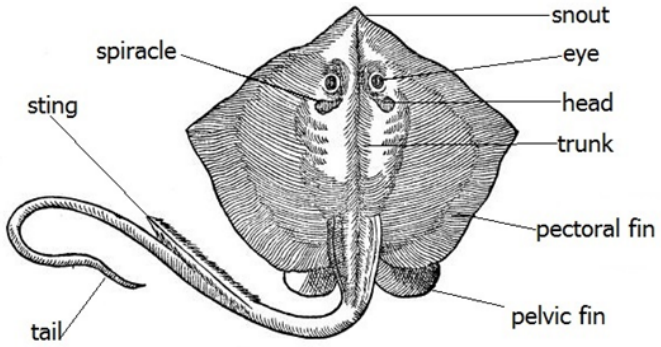
Sub-class- **Selachii**-Sharks and rays, Cloaca present

Order- **Hypotremata**-gill-slits ventral, spiracles present.

Genus- ***Trygon***

Habit and Habitat- It is bottom-dwelling fish. The predominant prey of the crustacean, molluscs, polychaete worm, and small bony fish.

1. It is commonly known as sting ray or whip tailed ray because of the presence of 3 stings or spine in tail.
2. Body divisible into head trunk and tail, it has a diamond shaped pectoral fin disc and a whip- likes tail.
3. The leading margins of the disc are almost straight and converge on a pointed, slightly protruding snout.
4. The eye are smaller than the spiracles, which are placed closely behind
5. Skin is smooth or spiny.
6. Mouth is ventral rectangular, nasofrontal flap is present in front of mouth.
7. Gill-slit 5 pairs, ventral in position.
8. It is aplacental viviparous, the embryo are initially sustained by yolk, which is later supplemented by uterine nutritive milky fluid.



Trygon

Fig – 1.12

1.6.4 *Chimaera*

Classification with identification:

Phylum- Chordata-Nerve cord, notochord, and gill-slits present.

Sub-phylum-Gnathostomata-With jaws and paired appendages.

Superclass- Pisces-Paired fins, gills, and skin with scales.

Class- Chondrichthyes-Endoskeleton cartilaginous, spiral valve in intestine
Order- Holocephalii-Adult scaleless, operculum present cloaca absent
Genus- *Chimaera*

Habit and Habitat- It is marine, found at the coastal regions of Pacific and Atlantic oceans.

1. It is commonly known as 'rat fish', monster fish, elephant fish, and queen of herrings.
2. Exoskeleton is absent in adults.
3. Median and paired fins present. Dorsal fins are two and one small anal fin is present opposite to second dorsal fin.
4. Body is about 60 cm long with a long compressed head having a blunt snout.
5. Head bears a small ventral mouth surrounded by lips and containing crushing plates instead of teeth.
6. Head also bears a pair of lateral eyes and terminal single nasal aperture.
7. Skin is smooth without scales but in certain areas placoid scales are also present.
8. Both pectoral and pelvic fins are present. The pectoral fins are very large.
9. Long and whiplike tail is surrounded by a diphycercal caudal fin in its anterior half.
10. Males have paired claspers.
11. Four pair of gills opens by single external gill-slits covered by a fleshy operculum.
12. Lateral line canals on head are open grooves.

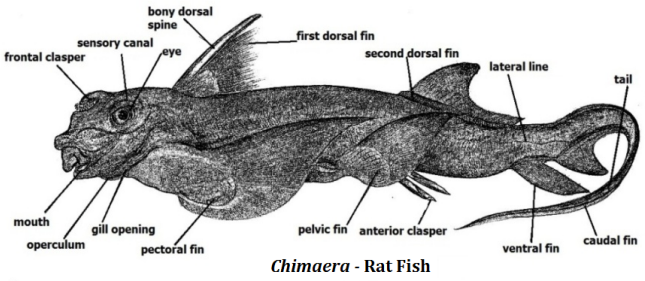


Fig – 1.13

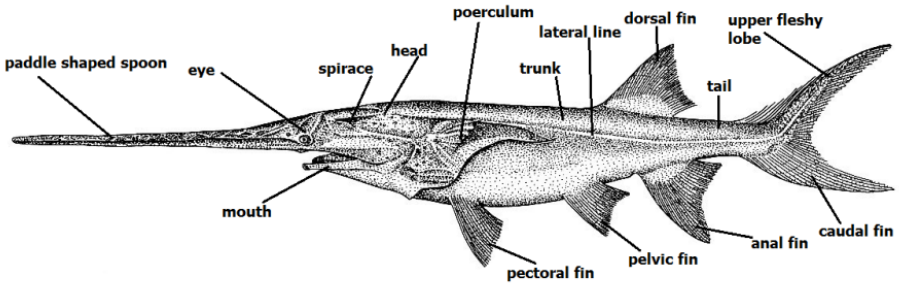
1.6.5 *Polyodon*

Phylum- Chordata-Nerve cord, notochord, and gill-slits present.
Sub-phylum- Gnathostomata-With jaws and paired appendages.

Superclass- **Pisces**-Paired fins, gills, and skin with scales.
Class – **Osteichthyes**-Bony fish
Subclass- **Palaeopterygii**- Ancient fishes
Order- **Chondrostei**- body covered with bony scutes or nacked
Genus- ***Polyodon***

Habit and Habitat-It is marine, sluggish and feed on mud with minute organism.

1. It is commonly known as paddle fish or spoon bill.
2. Head produced into a paddle shaped bill or spoon, body length 5 to 6 feet.
3. Ventral mouth, teeth minute, spiracle present.
4. Paired pelvic and pectoral fins small
5. Dorsal fin opposite to anal fin
6. A poorly developed sub operculum is present in addition to a small-rayed operculum.
7. Lateral line distinct.
8. Tail heterocercal caudal fin bilobed.



Polyodon

Fig – 1.14

1.6.6 *Acipenser*

Classification with identification:

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.
Sub-phylum- **Gnathostomata**-With jaws and paired appendages.
Superclass- **Pisces**-Paired fins, gills, and skin with scales.
Class – **Osteichthyes**-Bony fish
Subclass- **Actinopterygii**-One dorsal fin, ray finned fishes
Order- **Acipenseriformes**-Body with ganoid scales, heterocercal tail
Genus- ***Acipenser***
Species- ***struthio***

Habit and Habitat- Primitive ganoid fish which lives in the sea, but comes to the rivers of North America, North Asia and Europe for breeding.

1. It is marine, anadromous(lives in freshwater for breeding) and carnivorous fish and commonly known as " Sturgeon ".
2. Body is fusiform with the head produced into a long pointed snout having ventral barbels.
3. Head bears a ventral mouth with reduced tooth-less jaws.Head is large, it is produced into a tubular snout.
4. Exoskeleton is in the form of dermal rings.
5. Tail is heterocercal, long, and prehensile.
6. Gill slits are in the form of small rounded apertures and are covered by operculum.
7. Median and paired fins are made of dermal fin rays.
8. Paired lateral pectoral and pelvic fins and the unpaired median single dorsal, single anal and single caudal fins are present.
9. Anal fin is absent in males but present in females.
10. Nostril is one on both side and spiracles are absent.

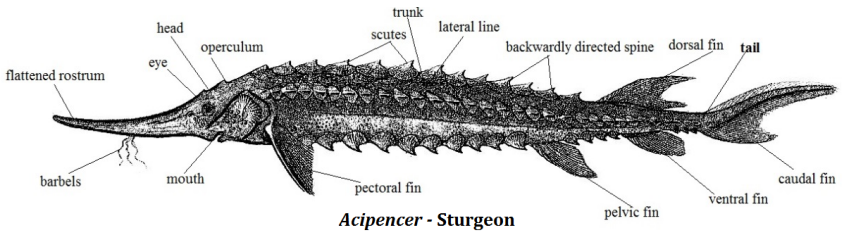


Fig – 1.15

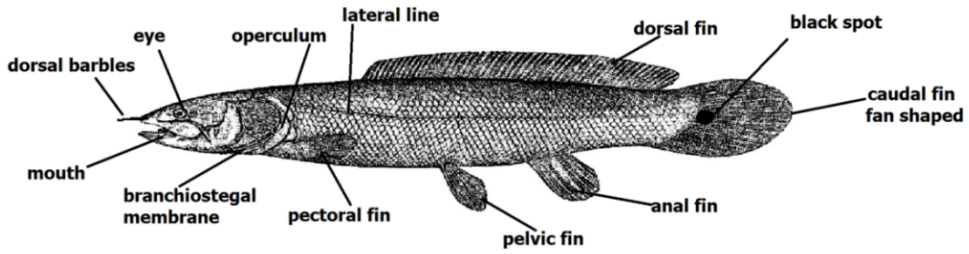
1.6.7 *Amia*

Classification with identification:

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.
Sub-phylum- **Gnathostomata**-With jaws and paired appendages.
Superclass- **Pisces**-Paired fins, gills, and skin with scales.
Class – **Osteichthyes**-Bony fish
Subclass- **Actinopterygii**-One dorsal fin, ray finned fishes
Order- **Amiiformes**-cycloid scales on trunk, ganoid scales on head
Genus- ***Amia***
Species- ***calva***

Habit and Habitat- It lives in freshwater, it is primitive ganoid fish found in rivers and lakes of North America.

1. It is commonly known as bow-fish.
2. Body is laterally compressed which measures about 60 cm in length.
3. Head has a wide terminal mouth containing teeth, a pair of lateral eyes, and dorsolateral terminal nostrils. Spiracles are absent.
4. Body scales overlap eachotherand appears cycloid type.Head bears ganoid scales.
5. Paired pectoral and pelvic fins and the unpaired median single dorsal, caudal and anal fins are present.
6. The dorsal fin is continuous long fin and hence the name "bow-fin."
7. Tail is homocercal.
8. It is carnivorous fish and exhibits parental care.



Amia calva

Fig – 1.16

1.6.8 *Lepidosteus*

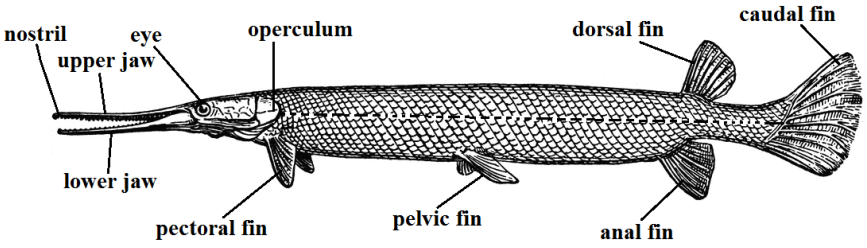
Classification with identification:

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.
Sub-phylum- **Gnathostomata**-With jaws and paired appendages.
Superclass- **Pisces**-Paired fins, gills, and skin with scales.
Class – **Osteichthyes**-Bony fish
Subclass- **Actinopterygii**-One dorsal fin, ray finned fishes
Order- **Lepidosteiiformes**-long jaws, ganoid scales on body
Genus- ***Lepidosteus***
Species- ***platystomus***

Habit and Habitat- It is freshwater primitive ganoid fish found in the rivers of North America and Cuba.

1. It is predatory fish and commonly known as "gar-pike"

2. Body is covered with thick close fitting ganoid scales which bears fused dermal denticles.
3. Exoskeleton on dorsal side is represented by five longitudinal rows of large bony scutes and spines.
4. Mouth is ventral and jaws are produced into a long snout or beak and bears sharp teeth for feeding on other fishes.
5. Median and paired fins have dermal fin rays.
6. Dorsal fin is single and lies opposite to anal fin and pelvic fin are abdominal.
7. Head is produced in front into an elongated shovel-like rostrum
8. Four sensory barbles are present on the ventral side of rostrum.
9. The gill slits are covered by operculum.
10. Tail is modified heterocercal and appershomocercal.
11. Air bladder is a respiratory lung and the fish periodically breaks the water surface to breathe air.



Lepidosteus - Garpike

Fig – 1.17

1.6.9 *Protopterus*

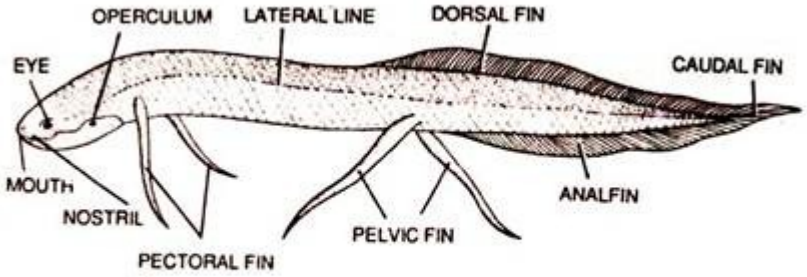
Classification with identification:

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.
Sub-phylum- **Gnathostomata**-With jaws and paired appendages.
Superclass- **Pisces**-Paired fins, gills, and skin with scales.
Class– **Osteichthyes**-Bony fish.
Subclass- **Sarcopterygii**-2 dorsal fin, fleshy or lob-finned.
Order- **Dipnoi**-Air bladder single or paired.
Genus- ***Protopterus***

Habit and habitat- It is freshwater mainly found in rivers and lakes of Western Africa.

1. Body is elongated, cylindrical and measures about 25 cm in length.

2. Head bears a terminal mouth with dental plates in place of teeth, a pair of lateral small eyes, external nostrils and internal nostrils which opens into the mouth.
3. Paired pectoral and pelvic fins are thin, long, and lobed.
4. Dorsal and anal fins are absent but sometimes dorsal fin fuses with caudal fin.
5. Tail is diphycercal having 3 lobes with the central lobe projecting out.
6. Paired gill-clefts covered with opercula behind the head.
7. It bears a pair of lungs, trachea and glottis and a blood supply of pulmonary artery and vein.
8. It depends mainly on lungs for respiration.
9. It can live without water by aestivating in muds-tubes for as long as 6 months when the rivers dry up.



Protopterus

Fig – 1.18

1.6.10 *Lepidosiren*

Classification with identification:-

Phylum- Chordata-Nerve cord, notochord, and gill-slits present.
Sub-phylum- Gnathostomata-With jaws and paired appendages.
Superclass- Pisces-Paired fins, gills, and skin with scales.
Class– Osteichthyes-Bony fish.

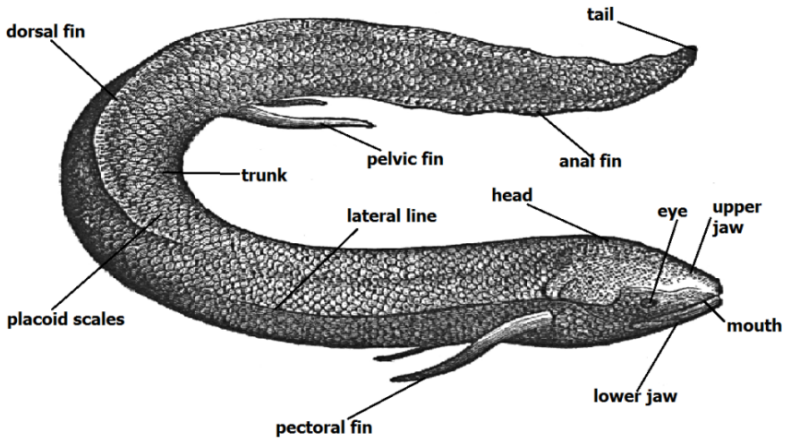
Subclass- Sarcopterygii- paired fins lobed, dorsal fin 2

Order-Dipnoi- air bladder single or paired, lung like

Genus- *Lepidosiren*

Habit and Habitat – It is distributed in Amazon and Paraguay basins and plains of South America.It inhabits swampy places,also makes a burrow lined by mucus in muddy water.

1. It is commonly known as South American lung fish.
2. Body is elongated and eel-like.
3. It measures about 3 feet in length and covered with cycloid scales.
4. Gill slits are 4 in number.
5. Eyes are very small.
6. Paired fins are reduced to slender styliform appendages formed of jointed axis.
7. At the time of breeding season, vascular filaments develop on the pelvic fins of the male.
8. Filaments are almost meant for respiration.
9. Larva posses 4 gills.
10. It has 2 lungs or air bladders.
11. Caudal fin and anal fin are continuous.
12. Lateral line is distinct.



Lepidosiren

Fig – 1.19

1.6.11 *Neoceratodus*

Classification with identification:

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.
Sub-phylum- **Gnathostomata**-With jaws and paired appendages.
Superclass- **Pisces-**Paired fins, gills, and skin with scales.
Class– **Osteichthyes**-Bony fish.

Subclass- **Sarcopterygii**-2 dorsal fin, fleshy or lob-finned.

Order- **Dipnoi**-Air bladder single or paired.

Genus- ***Neoceratodus***

Habit and Habitat- It is found in rivers of Queenland in Australia.

1. It is commonly known as "lung-fish".
2. It bears cycloid scales on the exoskeleton.
3. Body is eel like, median with paired fins.
4. Pelvic and pectoral fins are well developed with fin rays and also lobate.
5. Dorsal, anal and caudal fins are confluent.
6. Tail is diphycercal, pelvic girdle is single.
7. It has single air bladder which works as lung.
8. Mouth is small with jaws which have crushing tooth plates.
9. Eyes are reduced.
10. They aestivate during drought in summers
11. It shows parental care.

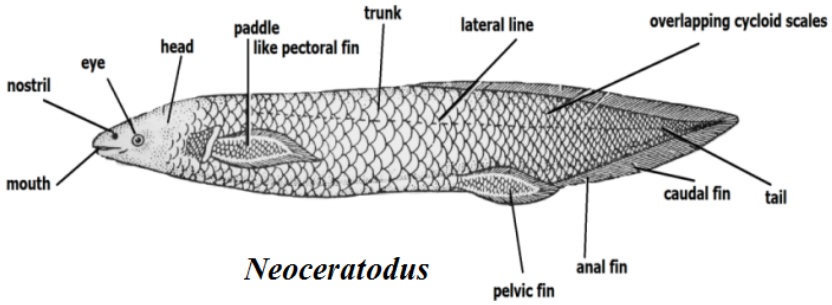


Fig – 1.20

1.6.12 *Notopterus* (Chital)

Classification with identification:-

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.

Sub-phylum- **Gnathostomata**-With jaws and paired appendages.

Superclass- **Pisces**-Paired fins, gills, and skin with scales.

Class – **Osteichthyes**-Bony fish.

Subclass- **Actinopterygii**-One dorsal fin, ray finned fishes.

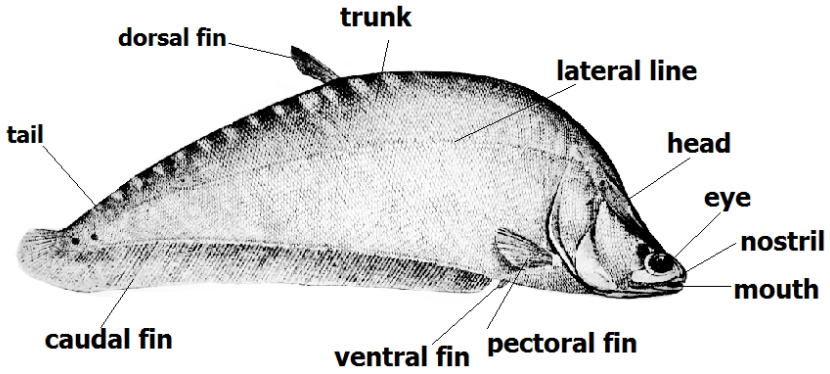
Superorder- **Teleostei**- mouth opening terminal, spiracle lost.

Order- **Clupeiformes**- scales cycloid

Genus- ***Notopterus***

Habit and Habitat- It is widely distributed in India, Burma, Malaya and West Africa.It is commonly found in lakes, freshwater.

1. *Notopterus* is commonly known as cat-fish or chital.
2. Body is strongly compressed with a short pre caudal region, it measures about 1.5 meters in length.
3. Colour is silvery dark or greenish on the back.
4. Head contains large and oblique mouth, whitish eyes and nostrils.
5. Dorsal fin is short, anal fin is very much elongated.
6. Caudal fin is reduced and varies upto 85-100.
7. Pelvic fin has 3-4 rays.
8. Air bladder is very large and divided into several compartments.
9. Teeth are homodont.
10. They bear scaly gill cover.
11. Lateral line scales are 120-180.
12. They posses ventral scutes 25-45.



Notopterus - Chitala

Fig – 1.21

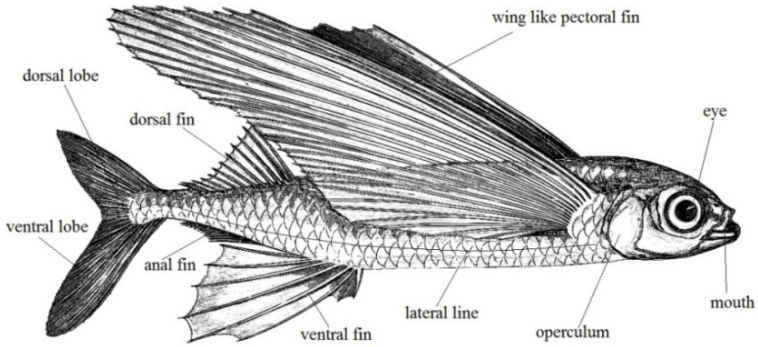
1.6.13 *Exocoetus*

Classification with identification:

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.
Sub-phylum- **Gnathostomata**-With jaws and paired appendages.
Superclass- **Pisces**-Paired fins, gills, and skin with scales.
Class – **Osteichthyes**-Bony fish.
Subclass- **Actinopterygii**-One dorsal fin, ray finned fishes.
Order- **Beloniformes**-Scales cycloid, pectoral fins large.
Genus- ***Exocoetus***

Habit and Habitat- It is marine found in Indian Ocean and tropical Atlantic Ocean. It feeds on prawns, young fishes and their eggs.

1. It is commonly known as "Flying fish"
2. Body is silvery in colour, measures about 30-40 cm and covered with large cycloid scales.
3. Head is large and blunt, but the jaws are not produced into a beak.
4. Eyes are large, nostrils are on sides mouth is wide and toothed.
5. Pectoral fin is wing like and is placed near the dorsal side.
6. The fins are used for gliding out of water .It can glide up to 400 meters , hence the name "flying-fish"
7. They are oviparous and lack claspers and spiracles.
8. The pectoral fins are as large as the body and are placed high up on the body and work as parachute.



Exocoetus

Fig – 1.22

1.6.14 *Echeneis*

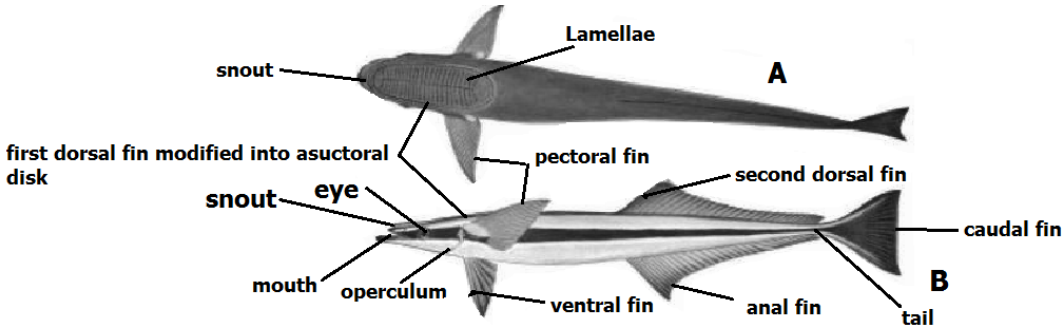
Classification with identification:

Phylum- **Chordata**-Nerve cord, notochord, and gill-slits present.
Sub-phylum- **Gnathostomata**-With jaws and paired appendages.
Superclass- **Pisces**-Paired fins, gills, and skin with scales.
Class – **Osteichthyes**-Bony fish.
Subclass- **Actinopterygii**-One dorsal fin, ray finned fishes
Order- **Echeiniformes**-Dorsal fin forms a sucker, no air bladder.
Genus- ***Echeneis***

Habit and Habitat- It is marine in form, found in tropical and sub-tropical seas.

1. It is commonly known as "sucker-fish."
2. Body is elongated measuring about 50 cm and covered with small scales.

3. Anterior part of the median dorsal fin is modified into a suctorial transversely laminated oral disc for attachment.
4. Lower jaw is large and the mouth is upturned.
5. It shows commensalism with sharks, to which it attaches by its oral disc for food and also for transport from one place to another.



Echeneis **A- Dorsal View B - Lateral View**

Fig – 1.23

1.6.15 *Pleuronectes*

Classification with identification:

Phylum- Chordata-Nerve cord, notochord, and gill-slits present.

Sub-phylum- Gnathostomata-With jaws and paired appendages.

Superclass- Pisces-Paired fins, gills, and skin with scales.

Class – Osteichthyes-Bony fish.

Subclass- Actinopterygii-One dorsal fin, ray finned fishes

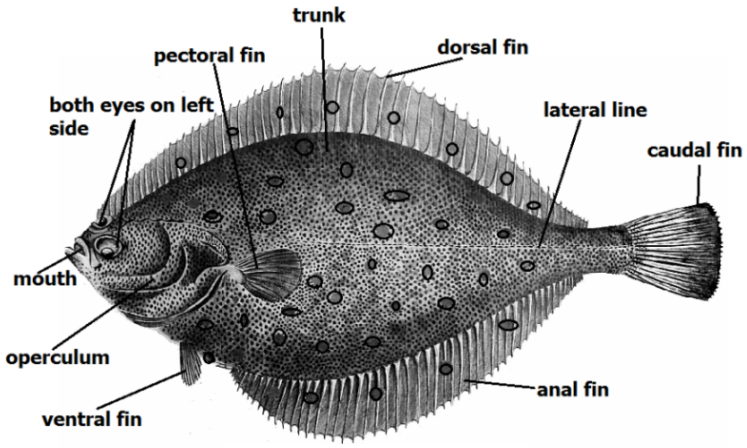
Order-Pleuronectiformes-Bottom dwellers, body flat

Genus- *Pleuronectes*

Habit and Habitat- It is marine, present on the sandy bottom of Atlantic Ocean, South America, India, Malaya.

1. It is commonly known as flat –fish.
2. Body is laterally compressed and flattened.
3. Head is asymmetrical.
4. Body is without scales with an average size of 40 cm. The fish has the remarkable property of changing colour to suit the habitat.
5. Body is asymmetrical and compressed .
6. The left upper side has bands and is pigmented whereas the lower right side is silvery white.

7. The whole body is twisted and both eyes come to lie on the upper surface.
8. Eyes can be raised and moved independently to survey the sandy bottom of the sea.
9. The spineless dorsal and anal fins are attached to dorsal and ventral side of body as a fringe and extend upto the base of caudal fin.
10. Mouth is protrusible and has sharp chisel like teeth and pharynx has flattened crushing teeth.
11. Claspers and spiracle are absent.
12. It is used as food and its main food is mollusks.



***Pleuronectus* - Flat Fish**

Fig – 1.24

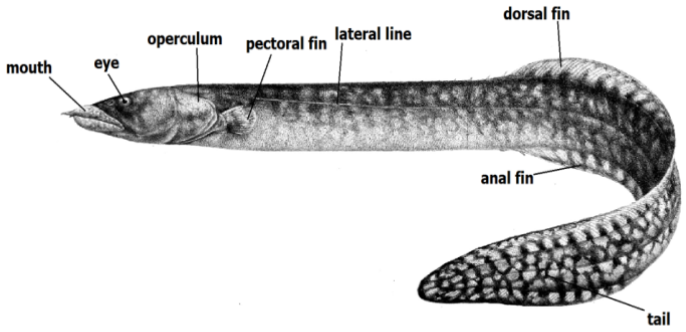
1.6.16 *Mastacembelus*

Phylum- Chordata-Nerve cord, notochord, and gill-slits present.
Sub-phylum- Gnathostomata-With jaws and paired appendages.
Superclass- Pisces-Paired fins, gills, and skin with scales.
Class – Osteichthyes-Bony fish.
Subclass- Actinopterygii-One dorsal fin, ray finned fishes
Order- Mastacembeliformes- body eel-like
Genus- *Mastacembelus*

Habit and habitat- They are native to freshwater habitats in Africa and Asia.

1. It is large elongated fish that has a snake like body.
2. Dorsal, caudal and anal fin united to form a continuous fin.
3. The dorsal fin preceded by numerous spine
4. The body colour is dull and the belly is a lighter shade of brown.
5. They are nocturnal but peaceful and shy.

6. Male and female are only distinguishable when mature



Mastacembelus

Fig – 1.25

1.6.17 *Diodon* *(Porcupine Fish)*

Classification with identification:-

Phylum- Chordata-Nerve cord, notochord, and gill-slits present.
Sub-phylum- Gnathostomata-With jaws and paired appendages.
Superclass- Pisces-Paired fins, gills, and skin with scales.
Class – Osteichthyes- Bony fish.
Subclass- Actinopterygii-One dorsal fin, ray finned fishes

Superorder-Teleostei- Bony fish proper

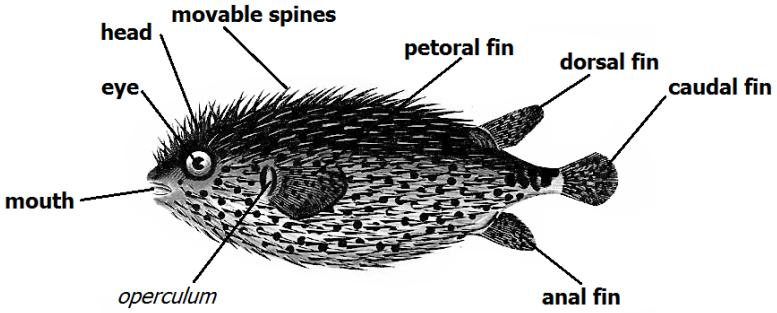
Order- Plectognathi- Strong jaws with sharp beak

Genus-*Diodon*

Habit and Habitat – It is marine fish, commonly found in tropical seas.

1. It is commonly known as Porcupine fish.
2. Body is rounded, globuse and covered with numerous flexible spines.
3. Scales present on their body are generally spiny or bony.
4. Teeth are strong incisors seems to be sharp edged beak.
5. Inter-operculum is rod like and attached to the anterior limb of sub-operculum.
6. Gills are almost three in number.
7. Vertebrae are 21-22 in number.
8. Pre-caudal vertebrae contain bifid neural spines.
9. Skin is almost leathery.

10. Anal and Dorsal fins are small, Caudal fin is curved upwards and tail is totally absent.
11. These are mainly poisonous fishes and non-edible.



Diodon - Porcupine Fish

Fig – 1.26

1.6.18 *Tetradon*

Classification with identification:-

Phylum- Chordata-Nerve cord, notochord, and gill-slits present.
Sub-phylum- Gnathostomata-With jaws and paired appendages.
Superclass- Pisces-Paired fins, gills, and skin with scales.
Class – Osteichthyes-Bony fish.
Subclass- Actinopterygii-One dorsal fin, ray finned fishes

Superorder-Teleostei- Bony fish proper

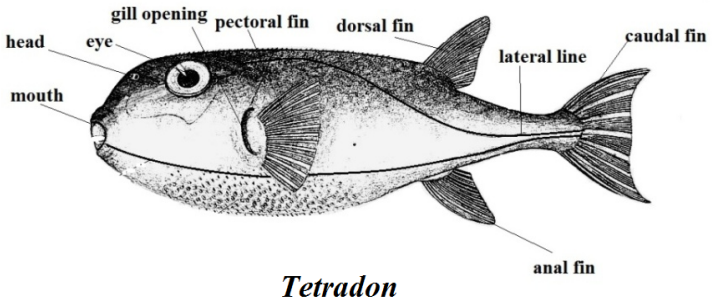
Order- Plectognathi- Strong jaws with sharp beak

Genus- *Tetradon*

Habit and Habitat – Tetradon is marine fish. It is mainly found in Tropical and sub- tropical, Atlantic and Indian sea.

1. It is commonly known as globe-fish.
2. Body is light brown from the backside and dark brown bands are found from back upto the sides.
3. Head and anterior part of body is very large and without scales.
4. Body is rounded and can adapt according to need.
5. Pre-maxillaries are united to maxillaries.
6. Teeth in each jaw are fused to form a beak but are separated by sutures.
7. There is one nasal opening on either side, found on a papilla.

8. Eyes are large.
9. Spinous dorsal fin and ventral fin are absent.
10. Air bladder is horse-shoe shaped.



Tetradon

Fig – 1.27

1.6.19 *Ostracion*

Classification with identification:-

Phylum- Chordata-Nerve cord, notochord, and gill-slits present.
Sub-phylum- Gnathostomata-With jaws and paired appendages.
Superclass- Pisces-Paired fins, gills, and skin with scales.
Class – Osteichthyes-Bony fish.
Subclass- Actinopterygii-One dorsal fin, ray finned fishes

Superorder-Teleostei- Bony fish proper

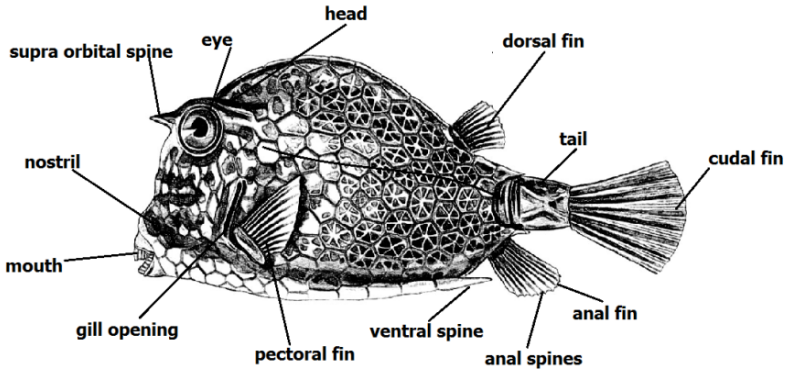
Order- Plectognathi- Strong jaws with sharp beak

Genus- *Ostracion*

Habit and Habitat - It is found in bottom of shallow sea water. It is distributed in tropical seas, Red Sea, African Sea, Indian Ocean, Atlantic and Pacific.

1. It is commonly known as Trunk fish.
2. Body is roughly triangular, composed of large, hexagonal bony plates.
3. Carapace is closed behind the anal fin.
4. It measures about 60 cm in length.
5. Body colour is olive brown with dark bands. Also a light blue spot is present in the centre of each scute or bony plate.
6. Spiny dorsal fin and ventral fin are absent.
7. Pectoral fin is enlarged and helps to form water current.
8. Caudal fin is helpful during swimming and acts as rudder.

9. They discharge a toxic substance called ostracitoxin which kill other fish in confined water.



Ostracion

Fig – 1.28

1.6.20 *Lophius*

Classification with identification:-

Phylum- Chordata

Group- Craniata

Phylum- Chordata-Nerve cord, notochord, and gill-slits present.
Sub-phylum- Gnathostomata-With jaws and paired appendages.
Superclass- Pisces-Paired fins, gills, and skin with scales.
Class – Osteichthyes-Bony fish.
Subclass- Actinopterygii-One dorsal fin, ray finned fishes

Superorder-Teleostei- Bony fish proper

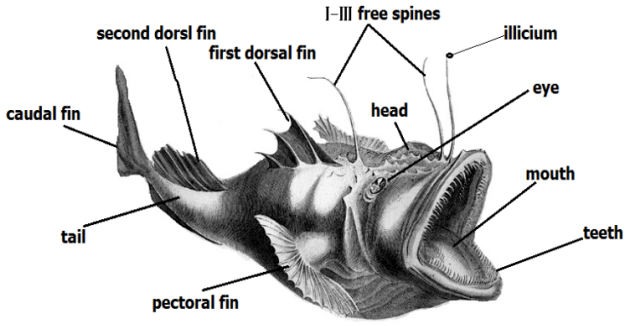
Order- Pediculati- Dorsal fin consist of flexible rays with dilated lips

Genus-*Lophius*

Habit and Habitat –it is marine fish.It is found in Atlantic, Indian and Pacific Oceans.It also occurs on the coasts of Europe and North America.

1. It is commonly known as Angler-fish.
2. Body is depressed, dorso-ventrally flattened.ugly,soft
3. It measures about 4 feet in length.
4. Head and anterior part of body is very large and without scales.

5. Mouth is large, containing strong cordiform or recurved teeth.
6. Eyes are large and lateral in position.
7. It posses small nostrils.
8. Gill opening is in lower axil of pectoral fin.
9. Pectoral and caudal fins are present.
10. Male in small in size and attached to the body of the female as ecto-parasite.



***Lophius* - Angler Fish**

Fig – 1.29

1.6.21 *Syngnathus*

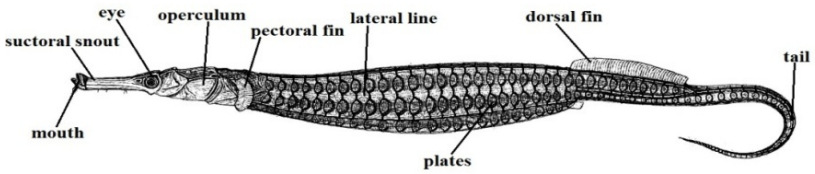
Classification with identification :

Phylum- Chordata-Nerve cord, notochord, and gill-slits present.
Sub-phylum- Gnathostomata-With jaws and paired appendages.
Superclass- Pisces-Paired fins, gills, and skin with scales.
Class – Osteichthyes-Bony fish.
Subclass- Actinopterygii-One dorsal fin, ray finned fishes
Order-Syngnathiformes-Snout tubular, brood pouch present.
Genus- *Syngnathus*
Species-*pelagicus*

Habit and Habitat- It is found almost in all seas, including Indian Ocean.

1. It is commonly known as “pipe fish”
2. Body is narrow, elongated and cylindrical.
3. Head is produced into a snout.
4. Exoskeleton is in the form of dermal plates.

5. Dorsal fin is single, pelvic fins and anal fins are absent in male and pectoral fin is small and reduced.
6. The caudal fin is small and tail is dephycercal.
7. The suctorial mouth is toothless and back is without any filaments.
8. The operculum is reduced and the gill-slits are one pair, small and round.
9. The males have brood pouch on the abdomen for carrying the eggs till they are hatched. It shows parental care.
10. They are oviparous and fertilization is external.



Syngnathus - Pipe Fish

Fig – 1.30

1.6.22 *Hippocampus*

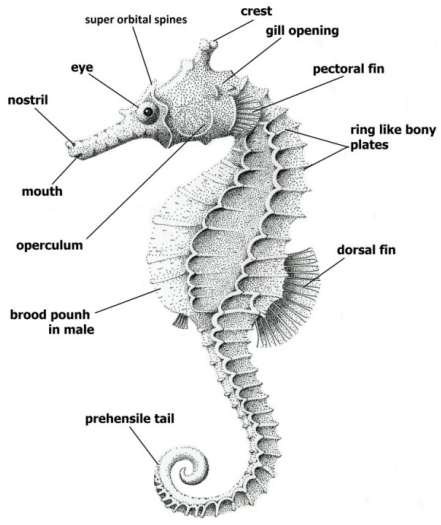
Classification with identification:

Phylum- Chordata-Nerve cord, notochord, and gill-slits present.
Sub-phylum- Gnathostomata-With jaws and paired appendages.
Superclass- Pisces-Paired fins, gills, and skin with scales.
Class – Osteichthyes-Bony fish.
Subclass- Actinopterygii-One dorsal fin, ray finned fishes
Order-Syngnathiformes-Snout tubular, brood pouch present.
Genus- *Hippocampus*

Habit and Habitat- It is marine fish, found in the Indian and Atlantic Oceans at the bottom near the coast in the sea-weeds. It is found in tropical and temperate seas.

1. It is commonly known as “sea horse” because its snout appears like a horse.
2. Body is modified extremely and is covered completely by large shield-like bony scales.
3. A Head is large and is right angles to the body. It is produced into a tubular snout.

4. Head is produced into a tooth-less snout or rostrum and resembles a horse' head.
5. Exoskeleton is in the form of dermal rings.
6. The pectoral fins are reduced and lie just behind the operculum.
7. The pelvic fins are absent.
8. Mouth is edentulous and suctorial.
9. Lopobranch gills are made of many small rounded lobes.
10. Gill-slits are in the form of small rounded apertures and are covered by operculum.
11. Median and paired fins are made of dermal fin rays.
12. Anal fins is absent in males buy present in females.
13. Tail is prehensile and curved. It is used for anchoring to the sea-weeds.
14. It shows sexual dimorphism. A brood pouch is present on the belly of males for carrying the eggs. They show parental care.



Hippocampus **- Sea Horse**

Fig – 1.31

1.6.23 *Anguilla*

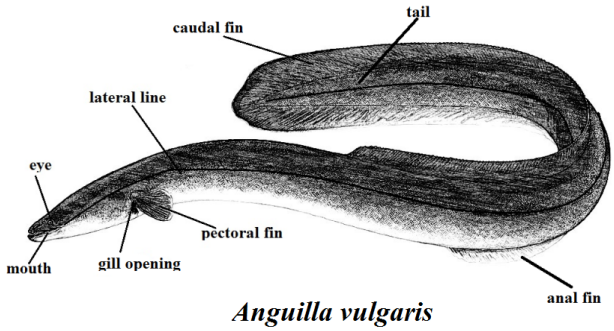
Phylum- Chordata-Nerve cord, notochord, and gill-slits present.
Sub-phylum- Gnathostomata-With jaws and paired appendages.
Superclass- Pisces-Paired fins, gills, and skin with scales.
Class – Osteichthyes-Bony fish.

Superorder-Teleostei- bony fish proper

Subclass- Actinopterygii-One dorsal fin, ray finned fishes
Order-Anguilliformes-Snake like body, scales vestigial or absent.
Genus- *Anguilla*
Species-*vulgaris*

Habit and Habitat- Anguilla Anguilla is found in the rivers, lakes and ponds of Europe and America. Anguilla bengalensis is found in India.

1. It lives in marshes and commonly known as "European Eel".
2. Body is elongated, cylindrical and eel like.
3. Body is long snake-like yellow green in colour and about 1 meter in length.
4. Skin is naked but rudimentary scales are buried in skin.
5. Paired and median fins have only branched rays.
6. Pectoral fin is reduced and pelvic is entirely absent.
7. The median fins that is dorsal, caudal, and anal fins are continuous.
8. Minute and round gill openings are present on the sides and are covered by operculum.
9. Air bladder is closed.
10. It is migratory fish. Its adults migrate to Sargasso sea in autumn to breed. After spawning in deep waters they die. Development is through delicate transparent leptocephalus larva, which feeds and grows in sea for 2-3 years, after which they return to rivers and metamorphose into adult.



Anguilla vulgaris

Fig – 1.32

1.6.24 *Labeo*

Phylum- Chordata-Nerve cord, notochord, and gill-slits present.
Sub-phylum- Gnathostomata-With jaws and paired appendages.
Superclass- Pisces-Paired fins, gills, and skin with scales.

Class – Osteichthyes-Bony fish.

Subclass- Actinopterygii-One dorsal fin, ray finned fishes

Superorder-Teleostei- bony fish proper

Order-Cypriniformes-Anterior vertebrae fused, weberian ossicles present between air bladder and ear.

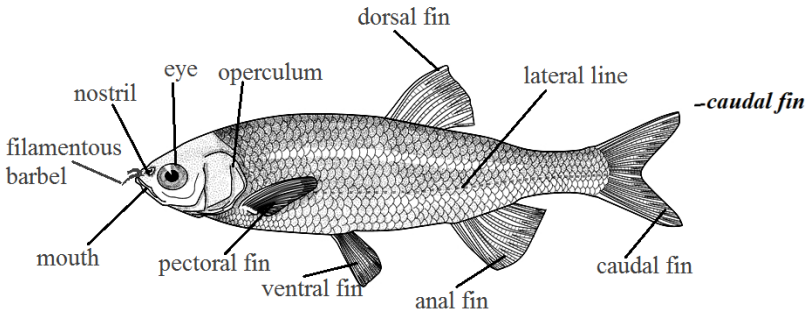
Genus-*Labeo*

Species-*rohita*

Habit and Habitat- Fresh water fish found in lakes and rivers of India.

Common species are *L.rohita* and *L.calbasu*.

1. It is commonly known as "Rohu or Indian carp"
2. It is herbivorous and bottom feeder.
3. Body is fusiform and the colour is bluish or brownish above and silvery white in below.
4. Body is laterally compressed and dorsoventrally elongated measuring upto 1 metre in length.
5. Exoskeleton is of large cycloid scales.
6. Head is produced into a short and blunt snout covered with tubercles.
7. Mouth is sub-terminal and surrounded by thick and fleshy lips.
8. The large scaleless head bears a terminal mouth, a pair of large lateral eyes, dorsolateral terminal nostrils and a pair of small maxillary barbels.
9. The trunk is covered by overlapping large transparent cycloid scales.
10. Median and paired fins have bony fin rays.
11. Four pair of gills are covered with operculum.
12. Dorsal fin is large and single, pectoral, pelvic and anal fins are present.
13. Homocercal tail is surrounded by a deeply notched caudal fin.



Labeo rohita

Fig – 1.33

1.6.25 *Ophiocephalus*

Classification with identification:-

Phylum- Chordata-Nerve cord, notochord, and gill-slits present.
Sub-phylum- Gnathostomata-With jaws and paired appendages.
Superclass- Pisces-Paired fins, gills, and skin with scales.
Class – Osteichthyes-Bony fish.
Subclass- Actinopterygii-One dorsal fin, ray finned fishes

Superorder-Teleostei- bony fish proper

Order- Ophicephaliformes- Teeth present on jaws and palate

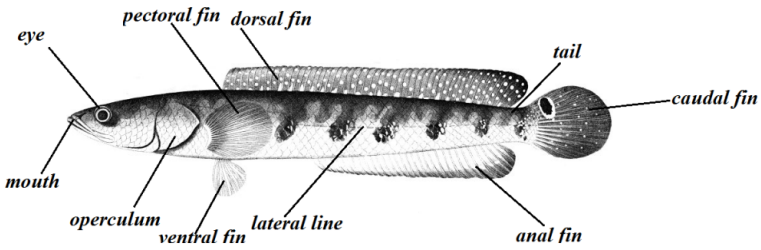
Genus- *Ophiocephalus*

Species- *punctatus*

Habit and Habitat- It is commonly found freshwater ponds. It is distributed in India, Tropical Africa and Southern Asia.

1. It is commonly called snake headed fish.
2. Its colour varies in water with greenish back, yellowish sides and striped abdomen.
3. Body is elongated and cylindrical.
4. Body is differentiated into head, trunk.
5. Head and body covered with cycloid scales.
6. Head is triangular in shape, tapers into a pointed snout.
7. Teeth present on jaws and palate.
8. Suprabranchial organ is present for breathing.
9. Dorsal and anal fins are long.

10. Pectoral fins are nearer to pelvic fins.
11. Caudal fin is rounded.
12. Lateral line is slightly curved.



Ophiocephalus

Fig – 1.34

Unit - 2

Museum Specimen-II

Structure of the Unit

2.1 Amphibia

- 2.1.1 *Ichthyophis*
- 2.1.2 *Necturus*
- 2.1.3 *Proteus*
- 2.1.4 *Ambystoma*
- 2.1.5 Axolotal
- 2.1.6 *Salamender*
- 2.1.7 *Siren*
- 2.1.8 *Alytes*
- 2.1.9 *Pipa*
- 2.1.10 *Bufo*
- 2.1.11 *Hyla*
- 2.1.12 *Rhacophorus*
- 2.1.13 *Rana*

2.2 Reptilia

- 2.2.1 *Testudo*
- 2.2.2 *Chelone*
- 2.2.3 *Sphenodone*
- 2.2.4 *Calotes*
- 2.2.5 *Hemidactylus*
- 2.2.6 *Phyrosoma*
- 2.2.7 *Draco*
- 2.2.8 *Varanus*
- 2.2.9 *Chameleon*
- 2.2.10 Cobra
- 2.2.11 *Hydrophis*
- 2.2.12 Rattle Snake
- 2.2.13 *Viper*
- 2.2.14 Pit viper

2.1 Amphibia

- Amphibious (Gr., amphi, dual + bios, life) able to live both on land and in water.
- Bony endoskeleton, variable number of vertebrae. Skull with 2 occipital condyles.

- Usually 4 limbs (tetrapod), some limbless, forelimb usually with 4-5 digits.
- Smooth skin with many glands and moist, pigment cells (chromatophore) common.
- Mouth large with homodont teeth on one or both jaws
- 2 nostrils open into buccal cavity.
- Respiration by lungs, skin, and gills.
- 3-chambered (2 auricles + 1 ventricle) heart with a double circulation through the heart.
- Predominantly oviparous, mesolecithal eggs with gelatinous.

2.1.1 *Ichthyophis*

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head. Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Amphibia (cold blooded,Scaleless glandular skin,can live in water and land.)

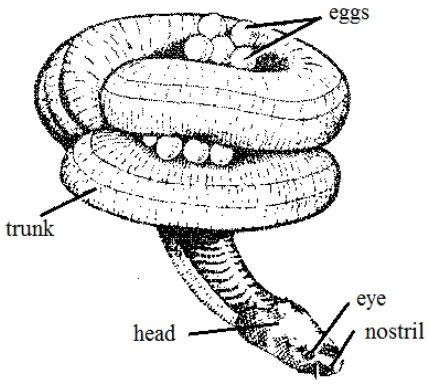
Order- Gymnophiona (Limbless, blind, worm like)

Genus- *Ichthyophis*

Habit and Habitat- Subteranean amphibians found in underground burrows in moist places. It is found near water in the Western Ghats, South Africa and South America.

1) External ring like annuli is present on body.(pseudo-metamerism).
2) Limbs , tail and neck are absent and anus is sub-terminal.
3) Eyes are reduced and concealed below skin.
4) Body is worm-like elongated and cylindrical without any trace of limbs and measures about 25 -30 cm.
5) Skin is smooth, moist and slimy and has ring-like grooves on its surface.

6) Small head is slightly dorsoventrally compressed and bears a terminal mouth, pairs of nostrils and minute non-functional vestigial eyes which is covered by the skin.
7) There is presence of sensory tentacles in pits between the eyes and nostrils.
8) Anus is present just anterior to the posterior end of the body, hence a very small post-anal tail is present.
9) Male has an eversible copulatory organ bearing hooks.
10) Fertilization is internal.
11) Females show parental care. It coils around the fertilized eggs till the aquatic larvae hatch.



Ichthyophis

Fig – 2.1

2.1.2 *Necturus* (Mud-puppy)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

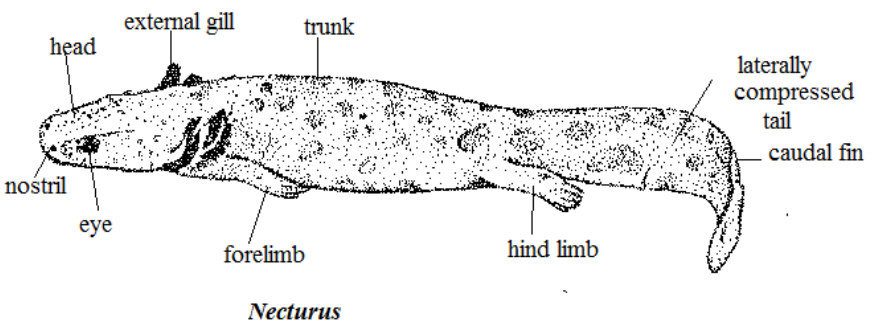
Class-Amphibia (cold blooded,Scaleless glandular skin,can live in water and land.)

Suborder-Proteidae (Adults with 3 pairs of external gills, without eyelid)

Genus- *Necturus*

Habit and Habitat- It is nocturnal, bottom dweller North American fresh water amphibian.

1) It is commonly known as “Mud puppy”.
2) It is dark brown in colour with a few black spots on its body.
3) Body is divisible into head , trunk and tail.
4) Rectangular head and elongated trunk are dorsiventrally flattened but tail is laterally compressed and has tail fin.
5) Hind and forelimbs are weak and have 4 digits.
6) External gills are of 3 pairs and two pair of gill slits are present.
7) Eyes are small and without lids.
8) Tympanum is absent.
9) Middle ear open s into pharynx.
10) Skull is dicondylic and teeth are present in jaws.
11) Lateral line system well developed.
12) Heart is mainly three chambered and kidney mesonephric.
13) It represents permanent neotenic larval stage.



Necturus

Fig – 2.2

2.1.3 *Proteus* (Cave Salamander or Olm)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Amphibia (cold blooded,Scaleless glandular skin,can live in water and land.)

Suborder- Proteidae (Adults with 3 pairs of external gills, without eyelid)

Genus- *Proteus*

Habit and Habitat-Found in water of completely dark caves of central European mountains.

1) Body is elongated and eel-like measuring about 25 cm.
2) Skin is smooth, unpigmented and whitish in colour.
3) Head is broad produced into small snout.
4) Head bears terminal mouth and nostrils, a pair of rudimentary eyes which sunk deep into the head and covered by skin.
5) External gills are of 3 pairs and two pairs of open gill-clefts.
6) Fore and hindlimbs are reduced or very small.
7) Hindlimbs are smaller and bears two digits but the larger forelimbs bears a caudal fin.
8) Tail is laterally compressed and bears caudal fins.
9) It is permanently neotenous larva as evidenced by external gills, gill clefts.

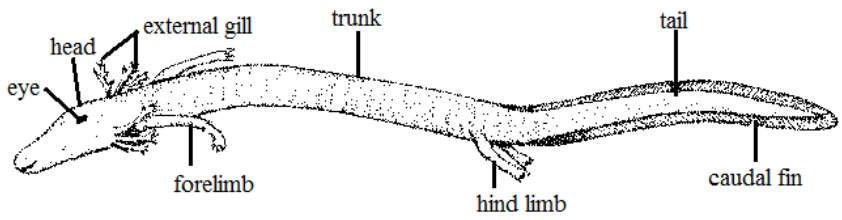


Fig – 2.3

2.1. 4 *Ambystoma* (Tiger Salamander)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Amphibia (cold blooded,Scaleless glandular skin,can live in water and land.)

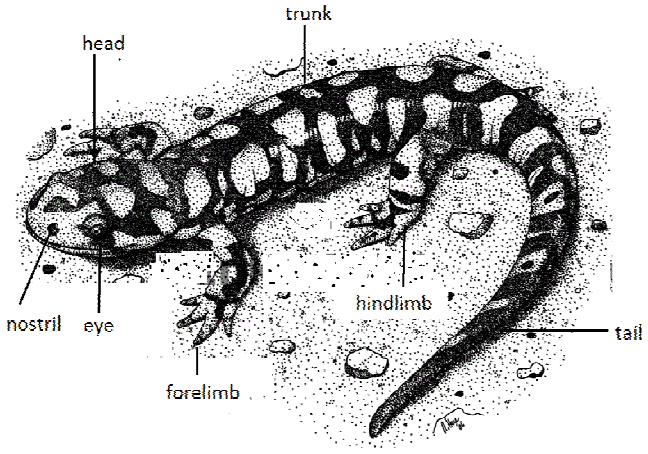
Suborder- Ambystomatoidea (Adults terrestrial with eyelid)

Genus- *Ambystoma*

Habit and Habitat- It is terrestrial and found in North America and Central Mexico.

1) It is commonly known as “Tiger Salamander”.
2) Yellow or orange patches are present on dorsal surface and lateral sides of the body.
3) Body is lizard like with smooth moist skin which is black in colour with yellow spots.
4) Body is divided into a large well developed head, neck, trunk and long slightly laterally compressed tail.
5) Head is flat and round tail is cylindrical and trunk has 12 intercoastal grooves.

6) Eyes with movable eyelids and nictitating membrane is present.
7) Fore and hind limbs are well developed with 4 or 5 digits.
8) External gills and caudal fins are absent in adults.
9) A pair of poisonous parotid glands are present behind tympanum.
10) Skull is dicondylic, jaws are toothed and vertebrae are amphicoelus.
11) A gular fold is present on the throat.
12) Sexes are separate.
13) Fertilization is internal and indirect development is through Axolotl larva which shows neotony.



Ambystoma

Fig – 2.4

2.1.5 Axolotal larva

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Amphibia (cold blooded, Scaleless glandular skin, can live in water and land.)

Order-Urodela or Caudata ((have 2 limbs, scaleless amphibia with well developed tail, gillslits present)

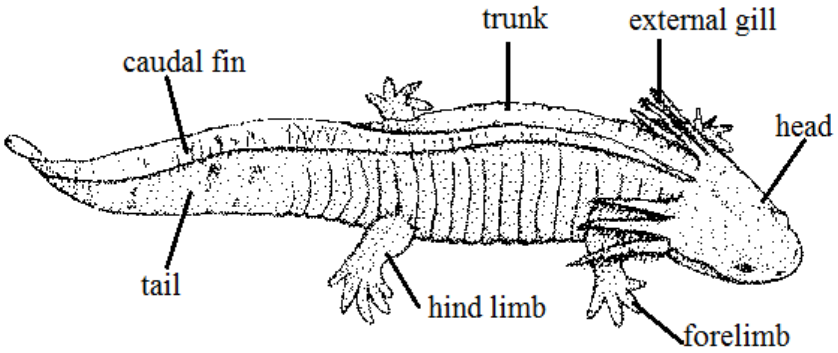
Suborder- Ambystomoidea

Family- Ambystomoidae

Genus- Axolotal Larva of *Ambystoma*

Habit and Habitat- It is larva of Ambystoma, completely aquatic and is found in mountain lakes of America and Mexico.

1. It is perennial and its body is divisible into head, trunk and laterally compressed tail fin.
2. It has 3 pairs of external gills and 4 pairs of open gill clefts.
3. Head is large, blunt and bears a wide terminal mouth and pair of nostrils and eyes.
4. Eyes are without movable eyelids.
5. Jaws are toothed and vertebrae amphicoelus.
6. Larva is perennial.
7. Body measuring about 27 cm in length.
8. Tail is laterally compressed and is provided with caudal fin.
9. Trunk bears well-developed fore and hind limbs.
10. It becomes sexually mature and lays eggs. This phenomenon is called as Neotony or Paedogenesis.
11. Axolotl larva is metamorphoses to adult. Metamorphosis can be induced by injecting thyroid injections into axolotl larva. The thyroid hormone which is necessary for metamorphosis requires iodine. Metamorphosis can be artificially brought about by increasing iodine content of water or by injections of thyroid stimulating hormone (TSH) to the larva.



Axolotal larva

Fig – 2.5

2.1.6 *Salamandra* (Fire Salamender)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Amphibia (cold blooded, Scaleless glandular skin, can live in water and land.)

Order-Urodela or Caudata ((have 2 limbs, scaleless amphibia with well developed tail, gillslits present)

Suborder- Salamandroidea

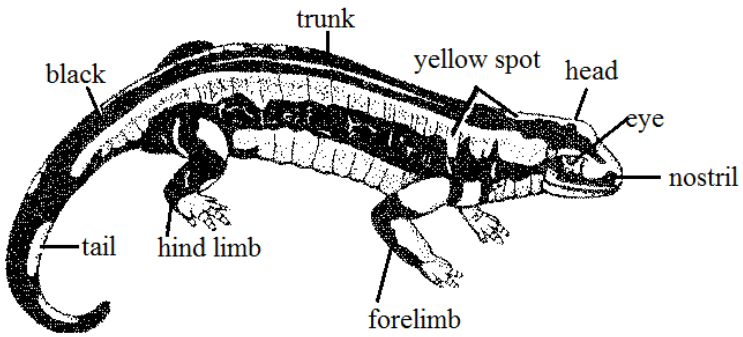
Family- Salamandridae

Genus- *Salamandra*

Habit and Habitat- It is distributed in Europe, EasternAsia and North America.It is terrestrial and inhabits under logs, stones, crevices of old walls.

1. It is commonly known as fire salamander.
2. It is lizard like in appearance.
3. Males are 12-15 cm in length. Females longer than males.

4. Body is coloured mainly black with irregular patches of yellow on back and limbs.
5. Fore and hindlimbs are well developed.
6. Head cosist of eyes and nostrils.
7. Eyes are provided with movable eyelids.
8. Large paratoid glands are present behind the head.
9. Lungs are present.
10. Gills and gill clefts are absent in adults.
11. Bertebrae opisthocoelus.
12. Tail is without tail fin.



Salamandra

Fig – 2.6

2.1.7 *Siren* (Mud-Eel)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Amphibia (cold blooded, Scaleless glandular skin, can live in water and land.)

Order-Urodela or Caudata ((have 2 limbs, scaleless amphibia with well developed tail, gillslits present)

Suborder- Meantes (slenderbody without hindlimbs, persistent gills)

Family- Sirenidae

Genus- *Siren*

Habit and Habitat- It is found in burrows, muddy ditches and ponds, mainly in North America.

1. It is commonly known as mud eel.
2. It is a permanently neotenous form.
3. Body is long, cylindrical, eel like.
4. It measures about 60-75 cm in length.
5. Body is covered with small papillae and is divided into head, trunk and tail.
6. Skin is moist, smooth, and pigmented and of blackish colour.
7. Head bears terminal mouth or conical in shape with small eyes and nostrils.
8. Eyes are without eyelids.
9. Behind the head 6 pairs of lateral external gills are present.
10. Forelimbs are small with 4 digits but hindlimbs are absent.
11. Tail is thick and provided with small caudal fin.
12. Jaws with horny covering.
13. Gill slits are of one pair.
14. Cloacal glands are absent.
15. Fertilization is totally external.

2.1.8 *Alytes* (Midwife Toad)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Amphibia (cold blooded,Scaleless glandular skin,can live in water and land)

Order- Anura or Salientia

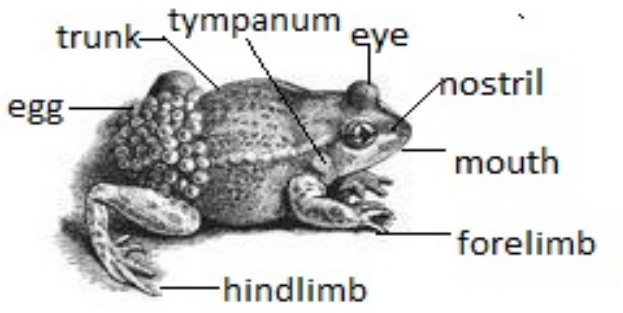
Suborder- Opisthocoeia

Family- Discoglossidae

Genus- *Alytes*

Habit and Habitat- It is found in European countries,mainly France and Italy.

1. It is commonly known as midwife toad.
2. Body is divisible into head and trunk.
3. Skin is dark mainly grey, brown, green or red colour with papillae on both the dorsal and ventral side.
4. Body is about 5-8 cm in length.
5. Head contains large tympanum and protuberant eyes.
6. Skin on dorsal surface is rough and is provided with warty outgrowths and poison glands.
7. Tongue is in the form of rounded non-protrusible disc.
8. Large triangular head joins with the large dorsally humped trunk.
9. Head bears terminal mouth and pairs of nostrils, eyes with movable eyelids.
10. Fore limbs bear 4 unwebbed digits and the long hind limbs bears 5 webbed digits.
11. External ear is absent and middle ear is represented by columella, connected with tympanum.
12. Males are without vocal sacs.
13. Larva contains median spiracle.
14. Upper jaw is toothed, lower jaw edentulous and vertebrae opisthocelous.
15. Adults have ribs, ribs are present throughout life.



***Alytes* (Midwife Toad)**

Fig – 2.7

2.1.9 *Pipa* (Surinam Toad)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Amphibia (cold blooded,Scaleless glandular skin,can live in water and land)

Order- Anura or Salientia

Suborder- Opisthocoeia

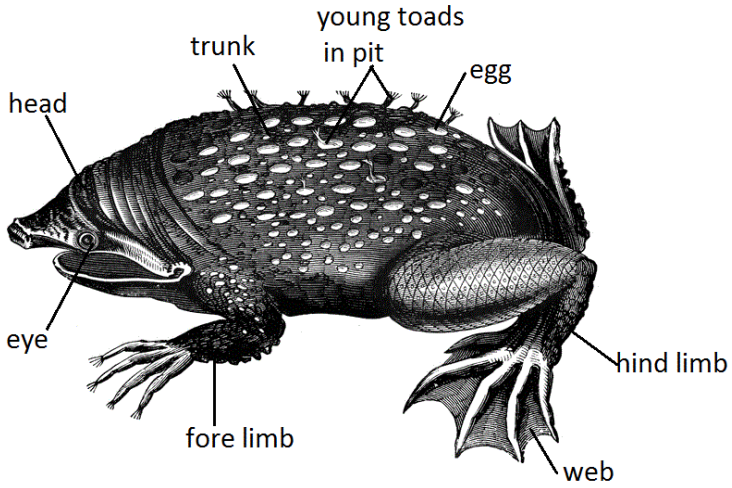
Family- Pipidae

Genus- *Pipa*

Habit and Habitat- It is totally aquatic, commonly found in Northern and South America.

1. It is commonly known as Surinam toad.
2. Head is triangular and depressed with large trunk.
3. Head contain small eyes, eyelids are absent.
4. Tongue is also absent.
5. Dermal papillae are present, star shaped.
6. Skin bears poison glands.
7. Forelimbs are small, while hindlimbs are fully webbed.

8. Upper part of snout is produced into irregular flaps and tentacles.
9. Jaws do not contain teeth, but have horny reliever.
10. Vertebrae opisthocoelous.
11. Female show parental care.
12. Gills are not formed.



***Pipa* (Surinam Toad)**

Fig – 2.8

2.1.10 *Bufo* (Common Toad)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Amphibia (cold blooded,Scaleless glandular skin,can live in water and land.)

Order- Anura or Salientia

Suborder- Procoela (Procoelous vertebrae,urostyle with double condyle)

Family- Bufonidae

Genus- *Bufo*

Species-*melanostrictus*

Habit and Habitat- It remain hidden during day and becomes activate during night.It has worldwide distribution. They are abundantly found in India,United States and Pacific state of Alaska.

1. It is terrestrial and nocturnal.
2. It is commonly known as true toad.
3. Body is divisible into head and trunk.
4. Head contains large eyes, nostrils and tympanum.
5. There is a pair of large parotid poison glands behind eyes.
6. Hind legs are much larger than the forelegs and have 4 and 5 digits respectively.
7. Web is poorly developed between hind toes.
8. Toes are provided with horny tips.
9. Liver is bilobed.
10. Skin on dorsal surface is rough and bears warty outgrowths and poison glands.
11. Eyelids are well formed and nictitating membrane is present in eyes.
12. They bears large poison secreting carotid glands behind each tympanum.
13. External ear is absent but middle ear is represented by columella oris connected with tympanum.
14. Eggs are pigmented. Young toad matures in many years.

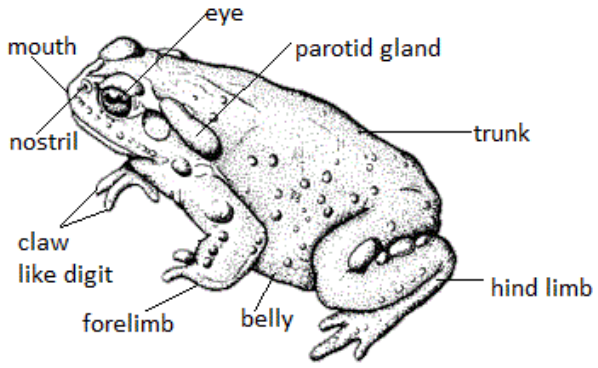


Fig – 2.9 *Bufo* (common Toad)

2.1.11 *Hyla* (Tree Frog)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Amphibia (cold blooded, Scaleless glandular skin, can live in water and land.)

Order- Anura or Salientia

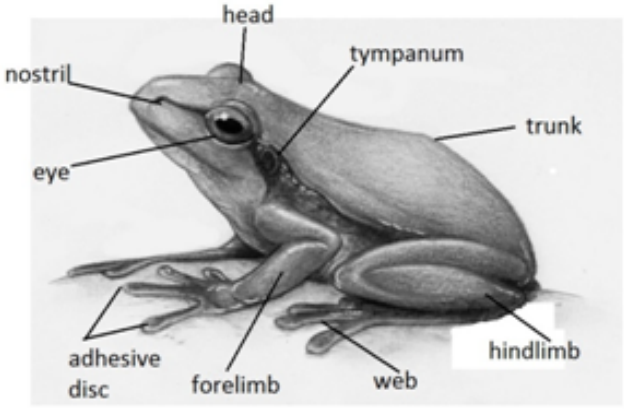
Suborder- Procoela (Procoelous vertebrae,urostyle with double condyle)

Family- Hylidae

Genus- *Hyla*

Habit and Habitat- It is found on trees in damp tropical forests of the world, including India. It is commonly distributed in India , China ,United States, Africa and Canada.

1. It is commonly known as tree frog.
2. It is arboreal in nature and measuring 3-10 cm in size.
3. Body is divided into head and trunk.
4. Skin is moist on the dorsal surface and also smooth.
5. Papilla is present on the ventral side.
6. Colour of body varies according to the species may be green.
7. Head is triangular which joins with the slender trunk.
8. Neck and tail absent.
9. Head bears terminal mouth which has teeth only on the upper jaws, and a pair each of dorso-lateral nostrils, large eyes.
10. Eyes have movable eyelids and tympanic membrane behind the eyes.
11. Skin of belly contains hygroscopic glands which help in adhering *Hyla* with leaf, twigs or stem.
12. Limbs are elongated, forelimbs are small with 4 digits without web.Hindlimbs are long with 5 digits with little web between them.
13. Upper jaw toothed, lower jaw is edentulous (without teeth).
14. Fertilization is external. Development includes tadpole larva.



***Hyla* (Tree Frog)**

Fig – 2.10

2.1.12 *Rhacophorus* (Flying Frog)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Amphibia (cold blooded, Scaleless glandular skin, can live in water and land.)

Order- Anura or Salientia

Suborder- Diplasiocoela

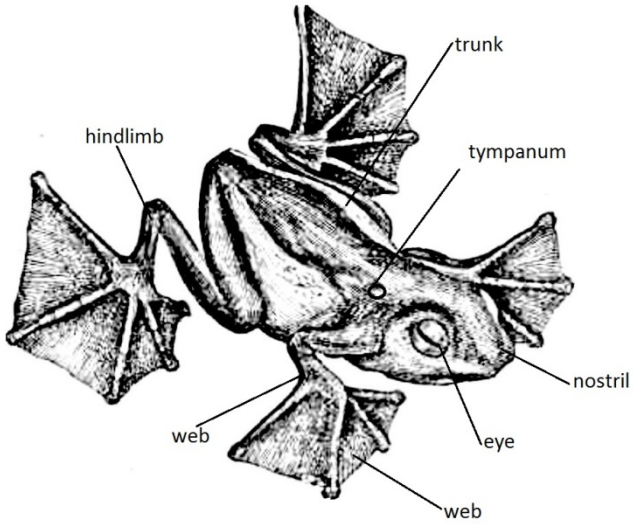
Family- Polypeditiadae

Genus- *Rhacophorus*

Habit and Habitat- It is distributed in Africa, South-eastern Asia, Japan and Madagascar. It remains under stones or on trees.

1. It is commonly known as flying frog.
2. Body is slender and divided into head and trunk.
3. Belly in narrow posteriorly.

4. Head is broad and conical.
5. Eyelids are well developed and tympanum is present behind eyes.
6. Limbs are elongated and bears well developed webs in digits.
7. Digits of hindlimbs contain intercalary cartilages.
8. When the flying frog climb on trees and walls, thw webs are spread like parachute.
9. Eggs are laid in gelatinous foam over shallow water of pools and rice fields.
10. It shows parental care.



***Rhacophorus* (Flying Frog)**

Fig – 2.11

2.1.13 *Rana* (Indian bull frog)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Amphibia (cold blooded, Scaleless glandular skin, can live in water and land.)

Order- Anura or Salientia

Genus- *Rana*

Species-*trigrina*

Habit and Habitat- It is found in lakes, freshwater ponds, rivers and streams. It distribution is worldwide. It is carnivorous and feeds on small worms, snails, slugs and insects.

1. It is commonly known as Indian bull frog.
2. Body is green with black patches along with yellow mid-rib on the dorsal surface and pale yellow on the ventral surface.
3. Head is almost triangular in shape.
4. Dorsal surface on snout bears a pair of external nostrils , one on each side of the median line.
5. Eyes are large and eyelids lying behind the nostrils.
6. A pair of tympanum is present behind the eyes.
7. Limbs pentadactyle, forelimbs with 4 digits and hindlimbs with 5 webbed toes.
8. Lower jaw is without teeth.
9. Tongue is large, muscular and forked, attached in front and free behind.
10. Vertebrae are procoelous.

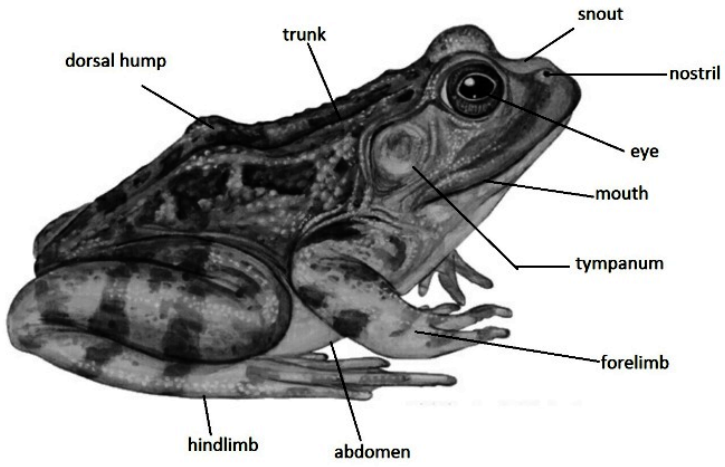


Fig – 2.12

***Rana* (Indian bull frog)**

2.2 Reptilia

Class Reptilan (L. Reptilia = Creeping) include the first class of vertebrates fully adapted few life in dry places on land. . The characters of reptiles

1. Two sets of paired limbs, pentadactyle. Digits provided with horny claws. However, limbs absent in a few lizards and all snakes.
2. The skin has a few coetaneous glands and high level of keratin, which prevents water loss through the skin.
6. Mouth terminal. Jaws bear simple conical teeth. In turtles teeth replaced by horny beaks.
7. Alimentary canal opens into a cloacal aperture.
4. Exoskeleton of horny epidermal scales, shields, plates and scutes.
8. Endoskeleton bony. Skull with one occipital condyle (monocondylar). A characteristic T-shaped interclavicle present.
9. All reptiles have 3-chambered heart, except crocodiles which have 4-chambered heart. Sinus venosus reduced. 2 systemic arches present. RBC oval and nucleated. Cold-blooded.
10. Respiration by lungs only.
11. Kidneys metanephric. Uricotelic animal.
12. Twelve pair of cranial nerve.
13. Lateral sense organs are absent. Jacobson's organs present in the roof of mouth,
15. Fertilization internal. They are the first animals with amniotic eggs that can be laid on land not in water.

2.2.1 *Testudo* (Giant Turtle)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Reptilia (Skin dry, covered by horny scales or bony plates)

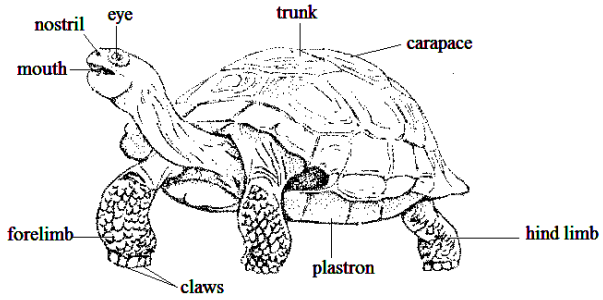
Subclass- Anapsida (Primitive reptiles with a solid scull roof)

Order-Chelonia (Body encased in a shell, limbs clawed or webbed)

Genus- *Testudo*

Habit and Habitat- It is widely distributed in Asia, Africa, Europe, Galapagos Islands, India and SriLanka. It is found in fresh water or salt water or on land. It feeds on small worms and insects. It enters water in hot weather and hibernates in winter.

1. It is commonly known as Giant turtle.
2. Body is incased in an oval shell. Over the shell is a layer of leathery skin or cornified scutes in definite pattern.
3. Carapace is about 30-40 cm in length. It is oval, high-domed and very convex.
4. Body colour is yellowish-brown with star-shaped scales on the carapace.
5. Head is mounted on retractile neck, tail, and limbs which protrude between two parts of the shell.
6. Carapace and plastron are very hard with well developed scales.
7. Head, neck, limbs and tail covered with scales.
8. Jaws lack teeth but bear stout cornified sheaths to crush their food.
9. Limbs are pentadacyle with 5 claws and modified for terrestrial locomotion.
10. Feet are stumpy. Toes end in horny claws which is useful for crawling and digging.
11. Male has an erectile penis on the ventral wall of the cloaca. They are oviparous.
12. On disturbance it withdraws completely the head, neck, tail and limbs into the carapace.



Testudo

Fig – 2.13

2.2.2 *Chelone* (Green Turtle)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata 9Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Reptilia (Skin dry, covered by horny scales or bony plates)

Subclass- Anapsida (Primitive reptiles with a solid scull roof)

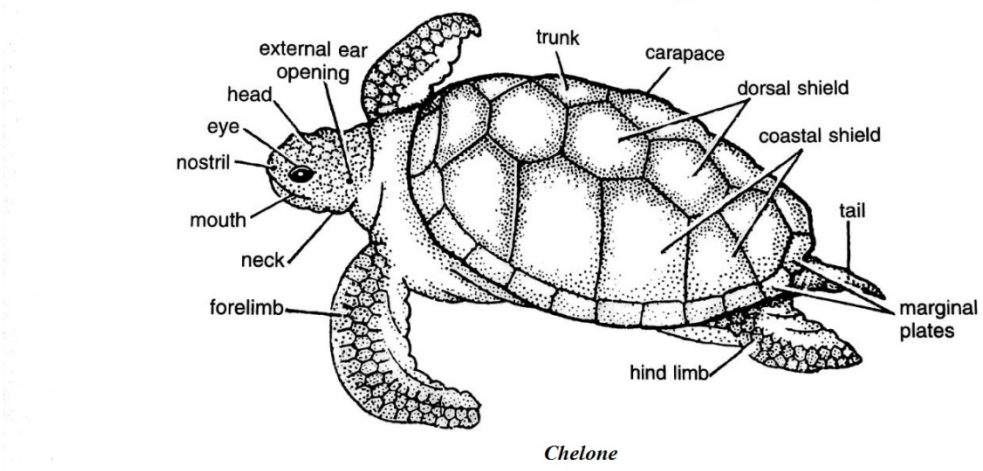
Order-Chelonia (Body encased in a shell, limbs clawed or webbed)

Genus- *Chelone*

Habit and Habitat- IT is distributed in tropical and subtropical regions and mainly found in the Indian, Pacific and Atlantic Oceans and coasts of the United States.

1. It is a marine reptile which is commonly known as green turtle.
2. It is large turtle of about 110 cm in length. Shell measures a meter in length.
3. Body case is rigid.
4. Body colour is marbled dark green above and pale yellow below.
5. Dorsal carapace is flat and heart-shaped which is covered with smooth bony shields and is attached to the ventral plastron only by ligaments.

6. Small head is attached to a long neck which is not completely retractile into a carapace.
7. Head is covered by single pair of prefrontal shields.
8. Jaws bear denticulate edges.
9. Eyes are well developed which are provided with eyelids and nictitating membrane.
10. Fore limbs are modified into paddles or flippers, which are adapted for swimming.
11. Forelimbs have single claw on the first digit. Hind limbs are unmodified but are webbed.
12. Tail is very short.
13. They lay eggs on dry beaches near the sea. A single female lays more than 200 eggs at a time.
14. They are economically important because its flesh is edible considered very delicious.



Chelone

Fig – 2.14

2.2.3 *Sphenodone*(Tuatara)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata 9Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Reptilia (Skin dry, covered by horny scales or bony plates)

Subclass- Diapsida (Scull with two temporal opening)

Order- Rhynchocephalia (Vertebrae amphicoelous, Jaws with acrodont teeth)

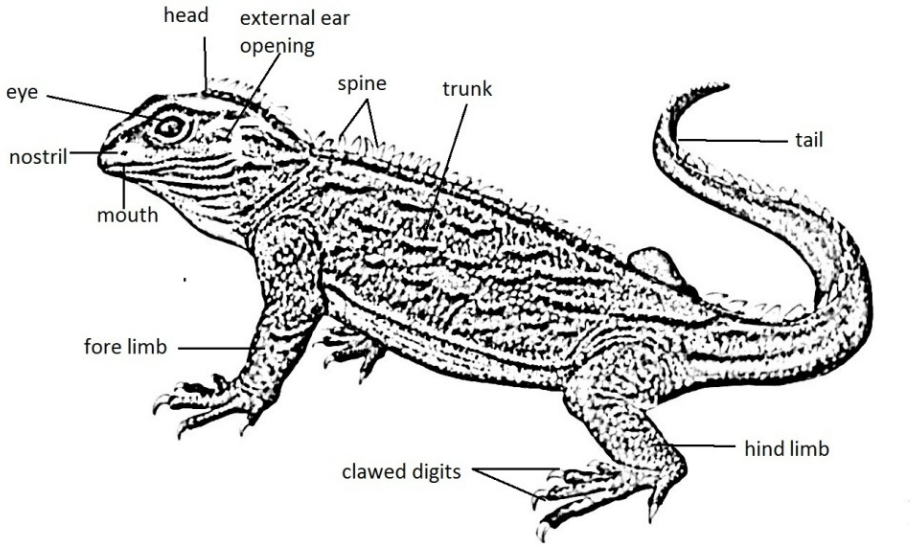
Genus- *Sphenodon*

Species- *punctatum*

Habit and Habitat- It is found in burrows and in New Zealand. It is nocturnal and insectivorous in habit.

1. *Sphendon punctatum* is the only living member of the order. It is considered as a living fossil and has remained unchanged for about 200 million years (Lower Permian)
2. It is commonly known as Tuatara.
3. It is lizard like body which has the average size of 50 -75 cm.
4. The colour of the body is dull olive -green with white and yellow spots.
5. Body is divided into head, trunk and tail.
6. It contains scaly skin, long tail and limbs are pentadactyl, adapted for walking.
7. Body is covered with granular scales which form a median row of spines that runs from head to tail, except on the neck.
8. The ventral surface of the body is covered by square plates.
9. The large head bears terminal mouth with acrodont teeth, pairs of nostrils and eyes bears a third median parietal or pineal eye which is light-sensitive.
10. Skull contains two complete fossae, quadrate is fixed, postfrontals are separate and upper jaws have beaks.
11. Mandibles jointed by ligament. There is presence of proatlas between skull and atlas.
12. Sternum present and vertebrae amphicoelous. Caudal vertebrae have chevron bones.
13. There is a presence of prominent parietal eye with retina, lens and nervous connection to brain. It is photosensitive. Pineal eye is covered with transparent scale.
14. Tail is thick and laterally compressed.

15. It is the only reptile where the male is without a copulatory organ or penis.



***Sphenodone*(Tuatara)**

Fig – 2.15

2.2.4 *Calotes*

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Reptilia (Skin dry, covered by horny scales or bony plates)

Subclass- Diapsida (Scull with two temporal opening)

Order-Squamata (Vertebrae procoelous, teeth acrodont or pleurodont)

Suborder- Sauria or Lacertillia (Limbs and girdles developed, eyelids movable)

Family- Agamidae- limb normal, teeth differentiated

Genus- *Calotes*

Habit and Habitat- It is an insectivore, adapted for arboreal life, widely distributed in Asia.

1. Commonly known as bloodsucker due to their red heads and other as garden lizard. Common name in Hindi is girgit.
2. Body covered with uniform-sized dorsal scales, and lacking a fold of skin extending between the cheek and shoulder.
3. Its body divided into four parts: head, neck, trunk and tail.
4. Total length including the tail is up to 37 cm.
5. The coloration is variable, sometimes uniform brownish or grayish-olive or yellowish.
6. Dorsal crest of spine on the neck and anterior part of the trunk.
7. Tongue short.
8. Teeth heterodont and homodont type.
9. Foelimb and hind limbs are normal. Tail elongated.

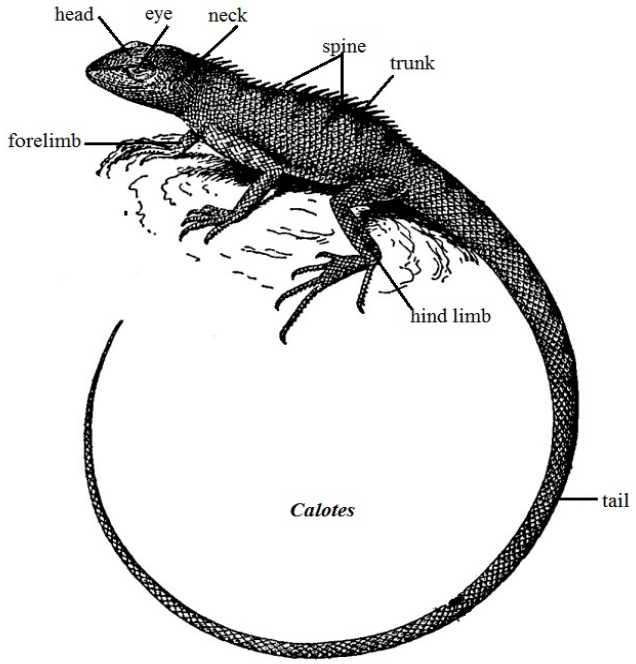


Fig – 2.16

2.2.5 *Hemidactylus* (Common House Lizard)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head. Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Reptilia (Skin dry, covered by horny scales or bony plates)

Subclass- Diapsida (Scull with two temporal opening)

Order-Squamata (Vertebrae procoelous, teeth acrodont or pleurodont)

Suborder- Sauria or Lacertillia (Limbs and girdles developed, eyelids movable)

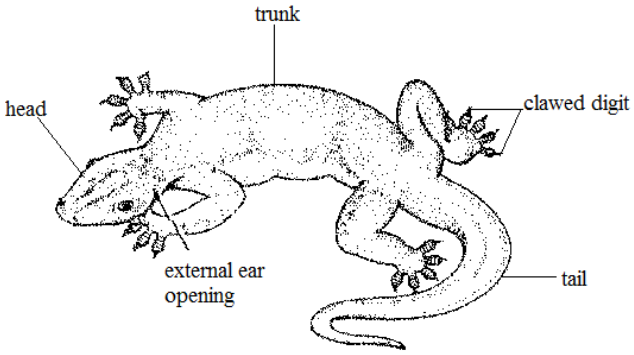
Family- Gecknoidae

Genus- *Hemidactylus*

Habit and Habitat- has worldwide distribution and mainly found in India, Europe, Asia, Africa, United States of America, SriLanka and China. It is common house lizard or wall lizard, also known as house gecko.

1. Body measures about 25 cm in length.
2. Body is slender, covered with minute small scales and is divided into head, trunk and tail.
3. Skin is soft and has poison glands along with minute scales.
4. Dorsoventrally compressed body is pale green in colour. Abdomen is yellow white.
5. Body is composed of a triangular head, neck, trunk and a long flat tail.
6. Triangular head contains a pair of eyes, nostrils.
7. Eyes lack movable eyelids. Tongue protrusible.
8. Limbs are of two pairs and pentadactyle and the clawed digits on the ventral side are swollen and pad-like bearing a double series of ridged lamellae.
9. Most of them produce sound.
10. Tail is smaller and brittle; it breaks its tail on the approach of danger and exhibits autotomy.
11. External ear opening is represented by tympanum.
12. Digits are flat and broad ventrally and bear numerous transverse lamellae arranged in two rows which help walking along vertical walls and along the ceilings.
13. Jaws bear pleurodont teeth.

14. Tongue is sticky and protrusible.
15. Skull monocondylic and has two temporal arches.
16. Quadrate bone is movable. Vertebrae amphicoelous.
17. Males with reversible double hemipenes.



Hemidactylus flaviviridis

Fig – 2.17

2.2.6 *Phyrnosoma* (Horned Toad)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata 9Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Reptilia (Skin dry, covered by horny scales or bony plates)

Subclass- Diapsida (Scull with two temporal opening)

Order-Squamata (Vertebrae procoelous, teeth acrodont or pleurodont)

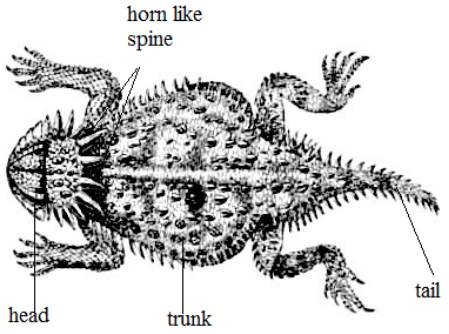
Suborder- Sauria or Lacertillia (Limbs and girdles developed, eyelids movable)

Family- Iguanidae

Genus- *Phrynosoma*

Habit and Habitat- It is terrestrial lizard present in the deserts of South-Western USA, Mexico, and Eastern Washington. It lives on sandy and dry places. It can live without water for a long time.

1. It is commonly known as horned toad.
2. Body is short and almost oblong in outline and gives the appearance of a toad.
3. Body is flat, broad, and spiny also.
4. Scales of head region are enlarged like horns while spiny scales are found all over the body. Undersurface is covered with keeled scales.
5. Skin is dry which is covered with scales and produced into spines. These spines are present in rows from the head to the tip of the tail.
6. Dorsal surface is yellowish green.
7. There is presence of pores on the undersurface of thigh in both the sexes.
8. Head contains 5 spikes on each side, one post-orbital, three temporal and one occipital. Due to presence of these spikes which look like horns and hence it is called as a horned toad.
9. Tongue is fleshy and non-protrusible.
10. Eyes bear complete eyelids.
11. Teeth are homodont or pleurodont.
12. Limbs are well developed and also covered with spiny scales.
13. Tail is short and covered with spiny scales.



Phrynosoma

Fig – 2.18

2.2.7 *Draco* (Flying Lizard)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata 9Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Reptilia (Skin dry, covered by horny scales or bony plates)

Subclass- Diapsida (Scull with two temporal opening)

Order-Squamata (Vertebrae procoelous, teeth acrodont or pleurodont)

Suborder- Sauria or Lacertillia (Limbs and girdles developed, eyelids movable)

Family- Agamidae

Genus- *Draco*

Habit and Habitat- It is arboreal in nature, found in Burma, India, Malaysia, Europe, Africa, Asia and Australia. It is found living on trees in the Indo-Malayasian tropical regions, Summatra, Java, Borneo, and forests of Kerala (India).

1. It is commonly known as flying lizard.
2. It is a brightly coloured lizard with a long tail. It is of beautiful colour like flowers of trees in which it lives.
3. Body is dorsoventrally compressed, it measures about 15-22 cm in length.
4. Body is chiefly divided into head, neck, trunk and tail.
5. Skin is covered with uniform layer of rough scales.
6. Head is triangular, which bears terminal mouth containing acrodent teeth, a pair each of nostrils and large eyes with moveable eyelids.
7. There is presence of tympanum behind the eyes.
8. Teeth are also heterodont and attached to the edges of the jaws.
9. On the ventral side of the neck 3 soft hooks are present. Below the neck there are sac-like structure known as gular pouches, which are larger in males than females and they help in copulation.
10. Tongue is thick and short.
11. Both pairs of limbs are well developed, clawed and pentadactyle.

12. Skin of lateral side of trunk expands to form parachute-like petagium or "wings", which are supported by 5 thoracic ribs. The "wings" are used for gliding from tree to tree.
13. Tail is long, slender and whip-like.

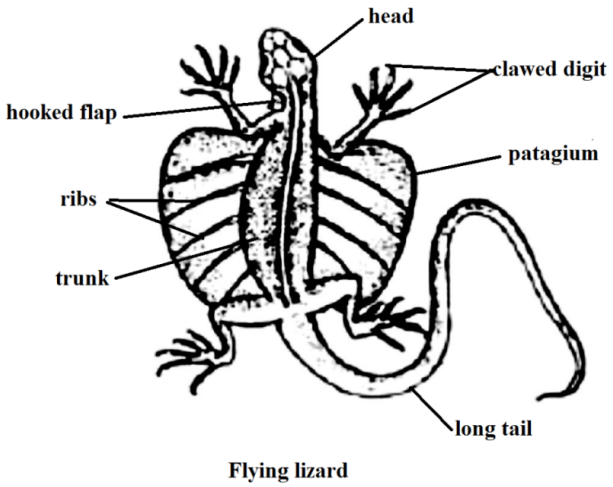


Fig – 2.19

2.2.8 *Varanus* (Monitor Lizard)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Reptilia (Skin dry, covered by horny scales or bony plates)

Subclass- Diapsida (Scull with two temporal opening)

Order-Squamata (Vertebrae procoelous, teeth acrodont or pleurodont)

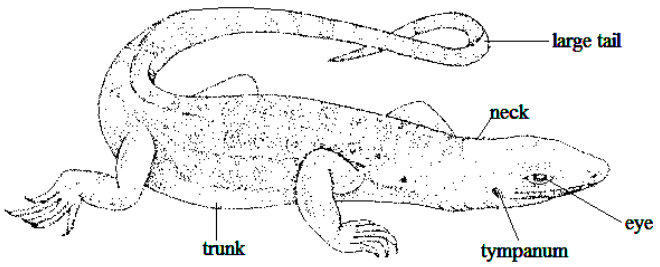
Suborder- Sauria or Lacertillia (Limbs and girdles developed, eyelids movable)

Family- Varanidae

Genus- *Varanus*

Habit and Habitat- It is distributed in Africa, Southern Asia, and South-East Islands of Australia, India, Srilanka and Malaya. It is carnivores and semiaquatic. It lives burrowing life, mostly active during night and feeds on reptiles, squirrels and dead bodies of other animal.

1. It is commonly known as monitor lizard.
2. It measures about 60-90 cm in length.
3. It is divided into head, neck, trunk and tail.
4. Body is covered with smooth, small scales having large browinish, black and orange patches, which act like warning colours.
5. Head is triangular and contains fixed eyes and nostrils.
6. The opening of external ear is present behind the head.
7. Mouth gap is wide with a long bifid smooth and protrusible tongue.
8. Teeth are pointed, large, pleurodont and dilated from the base.
9. Post orbital arch incomplete and osteoderm absent.
10. Trunk is large and stout.
11. Tail is long thickened and laterally compressed.
12. Limbs are stout and well developed.
13. Claws are very much powerful and as such the animal was used for climbing on steep walls.
14. It lays eggs in a nest on the ground.



Monitor lizard

Fig – 2.20

2.2.9 *Chameleon*

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Reptilia (Skin dry, covered by horny scales or bony plates)

Subclass- Diapsida (Scull with two temporal opening)

Order-Squamata (Vertebrae procoelous, teeth acrodont or pleurodont)

Suborder- Sauria or Lacertillia (Limbs and girdles developed, eyelids movable)

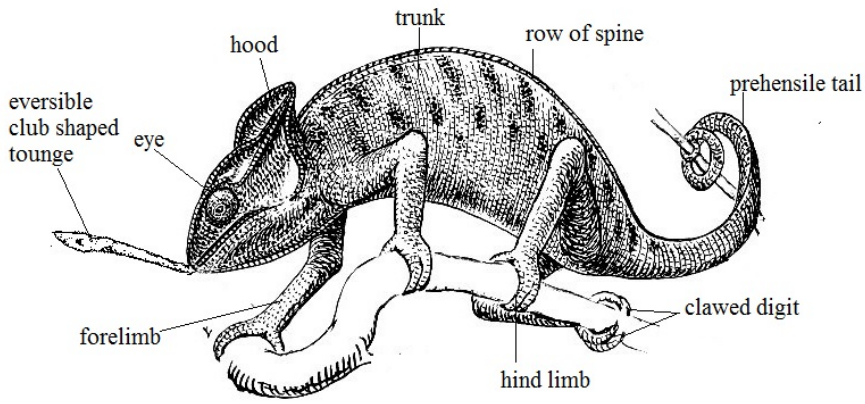
Family- Chamaeleontidae

Genus- *Chamaeleon*

Habit and Habitat- It has worldwide distribution. It is found in Africa,Madagascar, Southern Arabia, Spain, Europe, Asia, Syria, South India, Ceylon and SriLanka. It is arboreal and feeds on insects.

1. Body is laterally compressed and is about 40 cm in length.
2. Body is covered with scales which are modified into small tubercles. Its body is divided into head, neck, trunk and tail.
3. Head is produced dorsally into a helmet-like structure formed by the squamosal and occipiyal bones.
4. Head has wide mouth, large eyes, small nostrils and backwardly directed hood.
5. Mouth contains a long sticky and club shaped tongue which is swollen at the tip.
6. Skull and atlas are joined by a proatlas.
7. Eyes are large and are completely covered by the eyelids except in the centres which have small pin-hole openings. Eyes are adapted foe binocular vision; they work actively while catching the insects.
8. Acrodent teeth are found on maxillaries and mandible. Premaxillaries and palate are without teeth.
9. Two pairs of well developed clawed, and pentadactyle limbs are adapted for gasping the twigs. Its digits are zygodactyle and are opposable and arranged in groups of 3/2 in forelimbs and 2/3 in hindlimbs .This is an adaption to grasp twigs.
10. Claws are syndactylus in which digits are found in groups.

11. Tail is long and prehensile which is used for anchoring to twigs and branches of trees.
12. They are capable to change their body colour rapidly to blend with their surroundings.
13. Its lungs have air sacs.



Chamaeleon

Fig – 2.21

2.2.10 *Naja* (Cobra)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Reptilia (Skin dry, covered by horny scales or bony plates)

Subclass- Diapsida (Scull with two temporal opening)

Order-Squamata (Vertebrae procoelous, teeth acrodont or pleurodont)

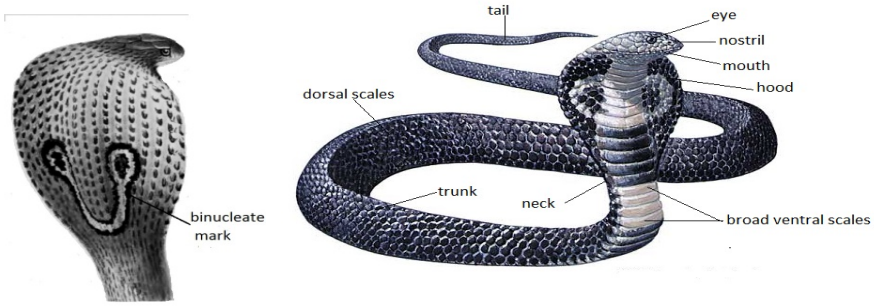
Suborder- Ophidia ((Limbs absent, eyelids fixed)

Family- Elapidae

Genus- *Naja*

Habit and Habitat- *Naja naja* is common throughout India with numerous varieties. It has worldwide distribution found in India, Africa, China, Philippines, Tsamania, Australia, and New Guinea. Naja lives in holes, under stones, mud walls, and in thick vegetation.

1. *Naja* is commonly known as cobra. In India it is known as nag.
2. The colour of the cobra varies from blackish to black and it reaches length of 2-3 metres. During hibernation colour becomes golden but on exposure to light it changes to brown.
3. Body is covered with uniform, smooth and oblique scales on the dorsal side. The ventral scales form large transverse plates.
4. Head is not well differentiated from neck.
5. Neck region is dilatable with elongated ribs and expands to form hood.
6. Small head bears a pair each of eyes with narrow pupils and nostrils.
7. The upper jaw contains a pair of sharp curved teeth or fangs which are present on the maxillae. On each side is present a poison gland which opens into the canal of each fanduct by a duct.
8. Tail shields on the undersurface of the tail in a double row.
9. Poison fangs are followed by 1-3 small teeth.
10. It is oviparous, carnivorous in nature.



Naja

Fig – 2.22

2.2.11 *Hydrophis* (Sea Snake)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Reptilia (Skin dry, covered by horny scales or bony plates)

Subclass- Diapsida (Scull with two temporal opening)

Order-Squamata (Vertebrae procoelous, teeth acrodont or pleurodont)

Suborder- Ophidia ((Limbs absent, eyelids fixed)

Family- Hydrophidae

Genus- *Hydrophis*

Habit and Habitat-*Hydrophis* is marine, found in the coastal areas of sub-tropical and tropical seas including India, along the Pacific Coast from Southern Mexico to Northern South America. It inhabits water and feeds on fishes.

1. *Hydrophis* is commonly known as sea snake.
2. Body is long, elongated, laterally compressed and may reach length of 2 meters.
3. They are pigmented dark olive green above with yellowish cross bars and whitish area below.
4. Head is indistinct and covered by large shields.
5. Body scales are small. Ventral scales are small. Loreal shield is absent
6. Maxillary teeth 14-18 behind the poison fangs.
7. Eyes small with rounded pupil.
8. Tail is laterally compressed and used for swimming.
9. Sea snakes never come out of water and thus are completely aquatic.
10. It is deadly poisonous, venom is dangerous to mankind.
11. Sea snakes are oviparous and they come out for egg laying.

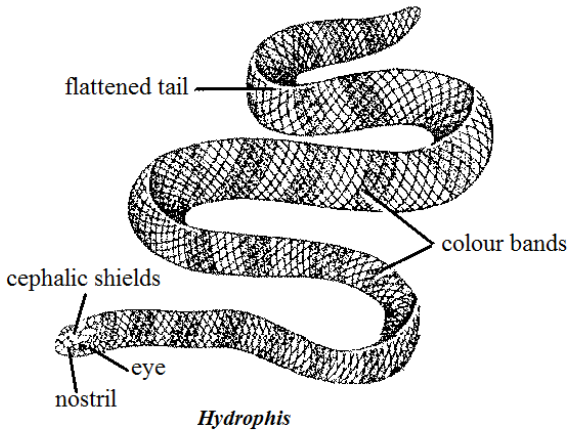


Fig – 2.23

2.2.12 *Crotalus* (Rattle Snake)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head. Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class-Reptilia (Skin dry, covered by horny scales or bony plates)

Subclass- Diapsida (Scull with two temporal opening)

Order-Squamata (Vertebrae procoelous, teeth acrodont or pleurodont)

Suborder- Ophidia ((Limbs absent, eyelids fixed)

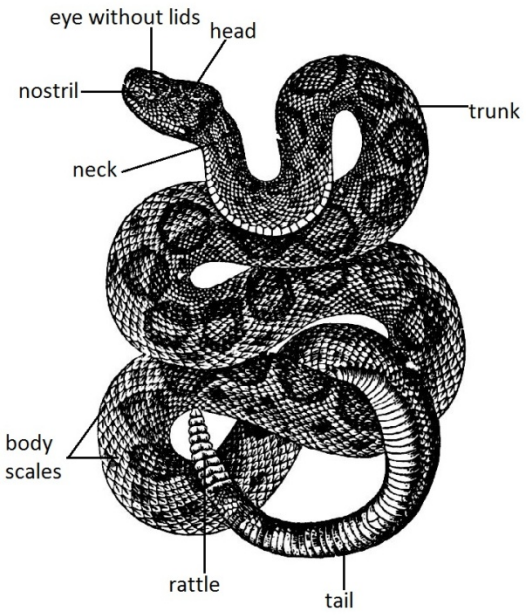
Family- Viperidae

Genus- *Crotalus*

Habit and Habitat- *Crotalus* is found in U.S.A. and Mexico. About 40 species are found in western hemisphere. It is adapted for terrestrial life.

1. *Crotalus* is commonly known as Rattle Snake.
2. Body is elongated and about 2-3 metres in length.
3. Body surface is greyish brown with dark bands and pigmentation patterns.

4. Head is triangular in shape with distinct neck.
5. Head contains small nostrils and ventral mouth.
6. Upper side of head has small scales.
7. Eyes are small, without eyelids.
8. Sensory pit is present between eye and nostril.
9. There are two erectile fangs in front of jaw, one on each maxillary bone and folded backwards when not in use.
10. Tongue bifid and protrusible.



***Crotalus* (Rattle Snake)**

Fig – 2.24

2. 2.13 *Vipera* (Pitless Viper)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class- Reptilia (Skin dry, covered by horny scales or bony plates)

Subclass- Diapsida (Scull with two temporal opening)

Order- Squamata (Vertebrae procoelous, teeth acrodont or pleurodont)

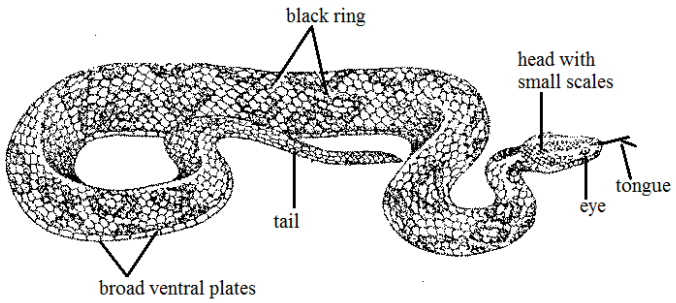
Suborder- Ophidia (Limbs absent, eyelids fixed)

Family- Viperidae

Genus- *Vipera*

Habit and Habitat- *Vipera* are commonly found from Europe, Asia, Sri lanka, Burma and India. It is found in rocky and bushy regions. It feeds on mice, rats, lizards and birds.

1. Viper is commonly known as Dobia, it is pitless viper.
2. Body measures about 1-2 meter in length. Body is covered with keeled scales.
3. Head large, flat, triangular covered with small scales.
4. Body is thick set, followed by narrow neck, a thick trunk and a short pointed tail.
5. Head bears a very wide mouth and a pair each of nostrils and eyes.
6. Colour is brownish but it varies according to the environment.
7. Facial bones movable, maxilla is small and contains long and movable poison fangs with canals.
8. Paired erectile fangs in front of upper jaws, one on each maxillary bone and folded backward.
9. Maxillaries short, thick and movable in vertical plane.
10. Absence of pit between nose and eyes.
11. Snake remain coiled with the head in the centre of the coil.



Vipera

Fig – 2.25

2.2.14 *Ancistrodon* (Pit viper)

Classification with identification:-

Phylum- **Chordata** (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Reptilia** (Skin dry, covered by horny scales or bony plates)

Subclass- **Diapsida** (Scull with two temporal opening)

Order- **Squamata** (Vertebrae procoelous, teeth acrodont or pleurodont)

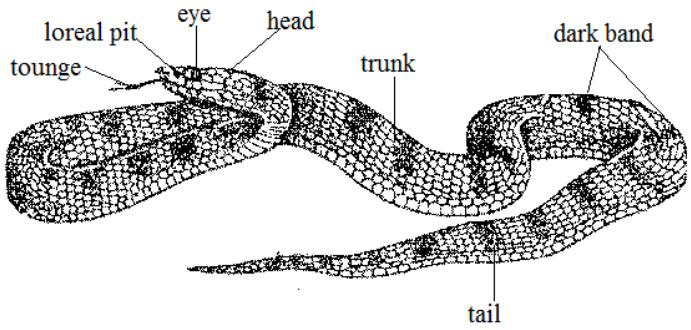
Suborder- **Ophidia** (Limbs absent, eyelids fixed)

Family- **Viperidae**

Genus- ***Ancistrodon***

Habit and Habitat- *Ancistrodon* is found in hilly areas in north and eastern parts of India and Asia.

1. It is commonly known as pit viper.
2. Body is not much elongated, measures about 1 meter in length.
3. Colour is bluish brown with black spots which appears like crossbars.
4. Head is triangular containing nostrils, eyes and mouth.
5. Loreal pit on each side of upper jaw separating eyes and nostrils.
6. Head shields are large.
7. Eyes are big with golden iris and vertical pupil.
8. It is poisonous snake having well developed, erectile poisonous and sheathed fangs.



Pit viper

Fig – 2.26

2.2.15 *Bungarus* (Krait)

Classification with identification:-

Phylum- **Chordata** (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- **Vertebrata** (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Reptilia** (Skin dry, covered by horny scales or bony plates)

Subclass- **Diapsida** (Scull with two temporal opening)

Order- **Squamata** (Vertebrae procoelous, teeth acrodont or pleurodont)

Suborder- **Ophidia** ((Limbs absent, eyelids fixed)

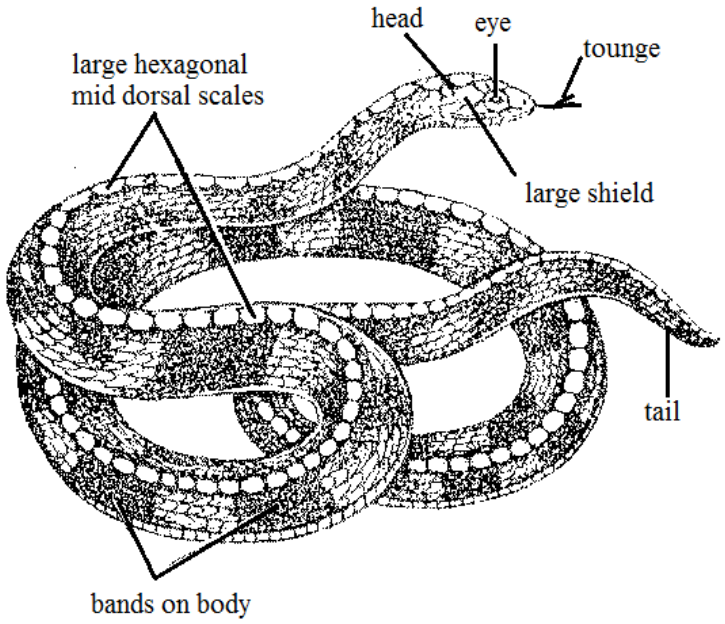
Family- **Elapidae**

Genus- ***Bungarus***

Habit and Habitat- *Bungarus* is found in South-east Asia, all over India. It is found under logs and stones. It is noctoral and feeds on smaller snakes, toads and mice.

1. *Bungarus* is commonly known as Krait.
2. Body is elongated and cylindrical, measuring 1-1.5 meter in length.

3. Colour of body is dark blue with yellow –white and black cross-bars.
4. Body scales are smooth. The dorsal scales are small while ventral scales extend fully across the ventral side.
5. Head is not differentiated from neck. Loreal absent. Fangs small.
6. The arrangement of scales on head is used for identification of kraits.
7. Scales are smooth with 13-17 rows. Ventrals are 194-234 and caudals 42-52.
8. Eyes with round pupils. Tongue bifid and protrusible.
9. Kraits are highly poisonous and have and have a pair of small immovable poison fangs on the maxillae which are connected to a pair of poison glands by means of duct.
10. The poison of krait is more potent than of cobra and untreated bites are often swiftly fatal.
11. They are oviparous in nature.
12. Females show parental care.



Bungarus

Fig – 2.27

2.2.16 *Eryx* (Rat Snake)

Classification with identification:-

Phylum- **Chordata** (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Reptilia** (Skin dry, covered by horny scales or bony plates)

Subclass- **Diapsida** (Scull with two temporal opening)

Order- **Squamata** (Vertebrae procoelous, teeth acrodont or pleurodont)

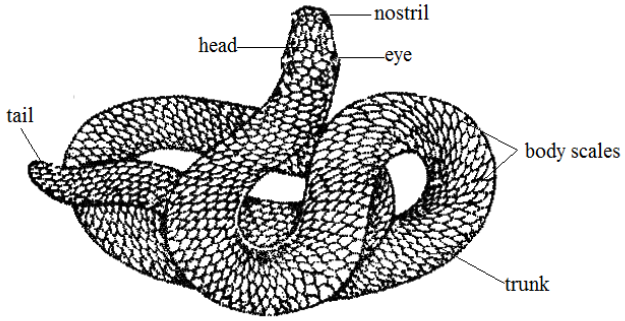
Suborder- **Ophidia** (Limbs absent, eyelids fixed)

Family- **Boidae**

Genus- ***Eryx***

Habit and Habitat- Eryx is found in sandy regions. It is present in arid and semi-arid parts of India and found living in burrows of rats and gerbils on which it also feeds. It feeds on lizards, frogs and mice.

1. *Eryx conicus* is commonly known as sand boa (Dumuhi) and common Indian species is *E.johnii*.
2. It is elongated measuring one meter in length.
3. Its dorsal surface is pinkish grey and has irregular brown patches while vertical surface is yellowish.
4. Body is thick and cylindrical, of a uniform brown colour and measures 80 cm in length, body is also covered with 40-45 rows of small scales
5. Skin is covered with dorsally with small smooth scales and ventrally by slightly large plate-like scales.
6. Head bears a terminal mouth, a pair each of nostrils and small eyes
7. Head scales are primitive and 3 scales enlarged.
8. Neck is indistinguishable.
9. Eyes are small with vertical pupil and reduced due to burrowing life.
10. Nostrils are slit-like.
11. Tympanum is absent.
12. Tail is head-like
13. It is a harmless non-poisonous sluggish snake.



Eryx

Fig – 2.28

2.2.17 *Gavialis* (Ghariyal)

Classification with identification:-

Phylum- **Chordata** (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Reptilia** (Skin dry, covered by horny scales or bony plates)

Subclass- **Diapsida** (Scull with two temporal opening)

Order- **Crocodilia** (large sized, tail long laterally compressed)

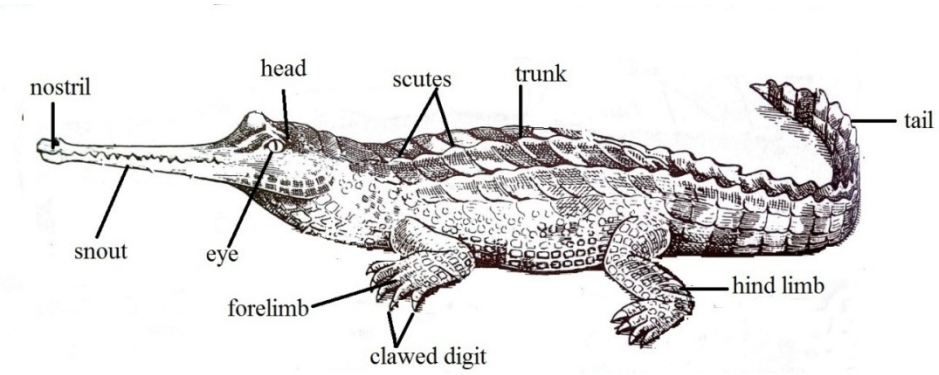
Family- **Crocodylidae**

Genus- ***Gavialis***

Habit and Habitat- *Gavialis* is found in India in Ganga River, Burma, and Malaysia.

1. *Gavialis gangeticus* is commonly known as Ghariyal.
2. It is largest of all crocodilians.
3. It is not harmful to mankind.

4. Body is covered with an exoskeleton of epidermal horny scales.
5. Body colour is dark olive green with markings.
6. Head large and produced into a long and narrow snout.
7. Jaws are powerful with conical teeth.
8. Teeth sub-equal and internal nares within the pterygoids.
9. Upper jaw contains 28 and lower jaw 25 teeth on either side.
10. Fore and hind limbs short pentadactyle and ending in clawed toes with webs between.
11. Tongue is not protrusible.
12. Heart 4 chambered with separate ventricles.
13. Tail is strong and powerful and laterally compressed.



Gavialis

Fig – 2.29

2.3. Aves

1. Body usually spindle shaped, and divisible into four distinct region: head, neck, trunk, and tail; neck disproportionately long for balancing and food gathering. Tail is short and stumpy.
2. Limbs paired. Forelimbs are modified as wings for flying. Hind limbs are large, and **variously** adapted for walking, perching, and swimming etc. Each foot with four clawed toes, of which the first or hallux is directed backwards.
3. Epidermal covering of feathers and leg scales.
4. Skin is dry and no sweat glands. Oil or preen gland at the base of tail.

5. Fully ossified skeleton with air cavities; skull bones fused with one occipital condyle; each jaw covered with a keratinized sheath, forming a beak; no teeth; ribs with strengthening, uncinate processes; posterior caudal vertebrae reduced and fused as the pygostyle; pelvic girdle a synsacrum; aerythrocytes sternum usually well developed with keel; single bone in middle ear.
6. Nervous system well developed, with 12 pairs of cranial nerves and brain with large cerebellum and optic lobes.
7. Circulatory system consists of four-chambered heart with two atria and two ventricles; completely separate pulmonary and systematic circuits; right aortic arch persisting; nucleated erythrocytes.
8. Respiration by slightly expansible lungs, with thin air sacs among the visceral organs and skeleton; syrinx (voice box) near junction of trachea and bronchi.
9. Excretory system includes metanephric kidneys; ureters open into cloaca; no bladder; semisolid urine; uric acid main nitrogenous waste.
10. Sexes separate; testes paired, with the vas deferens opening into the cloaca; females have left ovary and oviduct only; copulatory organ (penis) only in ducks, geese, paleognathids and a few athers.
11. Fertilization internal; amniotic eggs with much yolk and hard, calcareous shells; embryonic membranes in egg during development; incubation external; young active at hatching (precocial) or helpless and naked (altricial);
12. Females have left ovary and oviduct only.
13. Parental care is well developed.

2.3.1 Tailor Bird

Classification

Phylum: **Chordata** (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class: **Aves** (Bipedal, feather-clad)

Subclass- **Neornithes** (True birds, teeth absent)

Superorder- Neognathae (feather with interlocking mechanism, sternum with keel)

Order: **Passeriformes**

Family: **Cisticolidae**

Genus: ***Orthotomus***

Habit and Habitat: They occur in the old world tropics, principally in Asia.

1. These are usually brightly coloured, with green or grey upperparts and yellow white or grey under parts.
2. They often have chest nut on the head.
3. Tailorbirds have short rounded wings, short tails, strong legs and long curved bills.
4. The tail is typically held upright, like a wren.
5. They are typically found in open woodland, scrub and gardens.
6. Tailorbirds get their name from the way their nest is constructed. The edges of a large leaf are pierced and sewn together with plant fibre or spider's web to make a cradle in which the actual grass nest is built.

Tailor bird

Fig – 2.30

2.3.2 *Eudynamis scolopaceus* (Indian Koel)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class- Aves (Bipedal, feather-clad,)

Subclass- Neornithes (True birds, teeth absent)

Superorder- Neognathae (feather with interlocking mechanism, sternum with keel)

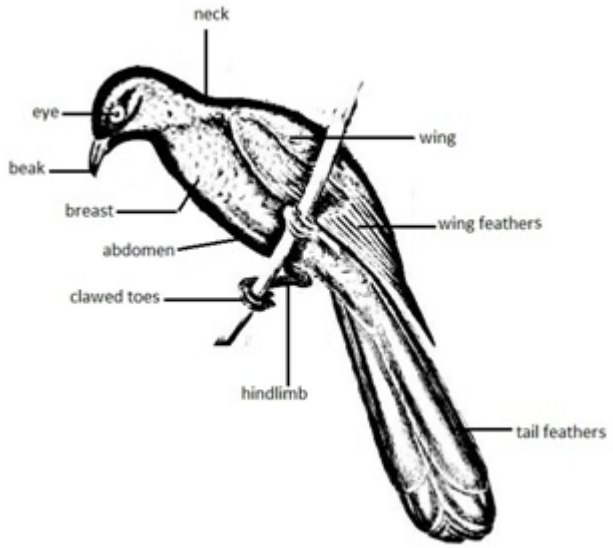
Order- Cuculiformes (toes 2 in front and 2 behind)

Genus- *Eudynamics*

Species- *scolopaceus*

Habit and Habitat- *Eudynamis scolopaceus* is commonly found in India, Pakistan, China, Philippines and Australia.

1. *Eudynamis scolopaceus* is commonly known as Koel.
2. Size is similar to crow.
3. Body is divided into head, neck and trunk.
4. Sexual dimorphism is seen. Male is black totally and having glistening metallic colour with blood red eyes and pale bill. Female is brown with white spots.
5. Beak tip pointed and curved downwards.
6. Eyes small with rounded pupil.
7. Tail is long.
8. Feet not adapted for grasping. Two toes in front, two behind.
9. Female does not sing.
10. Koel is famous for its beautiful and charming voice.



***Eudynamis scolopaceus* (Indian Koel)**

Fig – 2.31

2.3. 3 Jungle Fowl

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class- Aves (Bipedal, feather-clad,)

Order: Galliformes

Family: Phasianidae

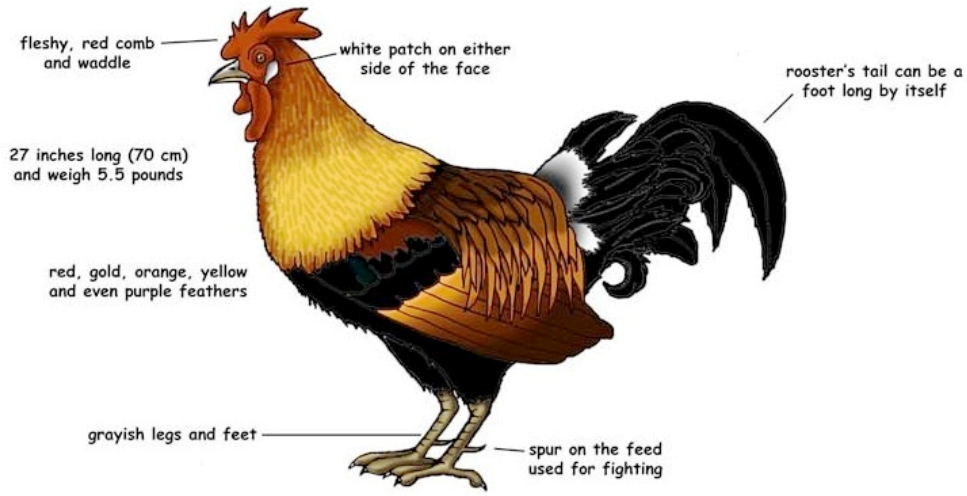
Genus: *Gallus*

Species: *gallus*

Habit and habitat: Junglefowl are the four living species of bird from the genus ***Gallus***, which occur in India, Sri Lanka and Southeast Asia.

1. These are large birds, with colourful male plumage, but are nevertheless difficult to see in the dense vegetation they inhabit.

2. As with many birds in the pheasant family, the male takes no part in the incubation of the egg or rearing of the precocial young. These duties are performed by the drab and well camouflaged female.
3. The junglefowl are seed-eaters, but insects are also taken, particularly by the young birds.
4. One of the species in this genus, the red junglefowl, is of historical importance as the likely ancestor of the domesticated chicken, although it has been suggested the grey junglefowl was also involved.



Jungle Fowl

Fig – 2.32

2.3. 4 *Pavo* (Peacock)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Aves** (Bipedal, feather-clad,)

Subclass- **Neornithes** (True birds, teeth absent)

Superorder- Neognathae (feather with interlocking mechanism, sternum with keel)

Order- Galliformes (massive scratching feet)

Genus- *Pavo*

Species- *cristatus*

Habit and Habitat- It is found in forests, jungle and various areas of India. It feeds on grains, small reptiles and insects.

1. *Pavo cristatus* is commonly known as pea-fowl or peacock in Hindi it is called Mor.
2. It is national bird of India and it is protected animal.
3. Head bears a short beak and crest of feathers on top.
4. Legs are strong and feet have sharp claws.
5. Males bear flighting spurs on the legs.
6. It is capable of flight of very short distances as the wings cannot efficiently support the heavy and large body.
7. It displays a well marked sexual dimorphism.
8. Male bird is beautifully pigmented with fans-shaped crest, brilliant metallic blue head, neck and breast.
9. Female is duller having lower neck metallic green instead of blue as in male and lacks the ornamental tail.
10. Peahen is less beautiful. It has a crest on the head, but lacks the train of beautifully ocellated feathers.
11. Feet adapted for scratching and running.
12. They live in groups or families.

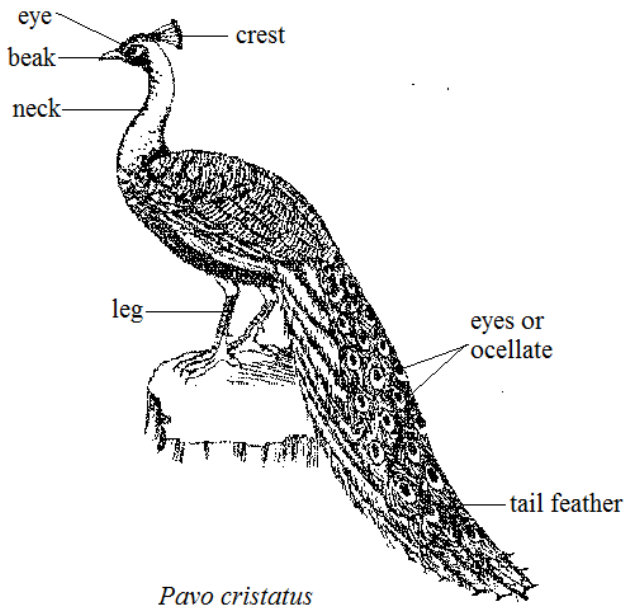


Fig – 2.33

2.3. 5 *Columba* (Pigeon)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Aves** (Bipedal, feather-clad,)

Subclass- **Neornithes** (True birds, teeth absent)

Superorder- Neognathae (feather with interlocking mechanism, sternum with keel)

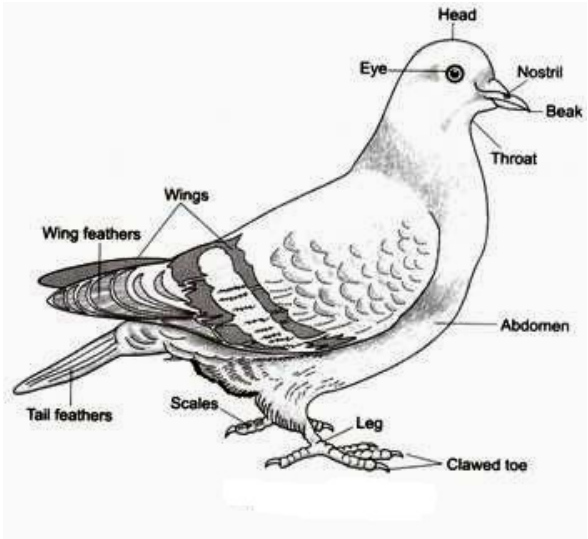
Order- **Columbiformes** (Crop producing pigeon milk for young one)

Genus- ***Columba***

Species- ***livia***

Habit and Habitat- It is most common and familiar bird found commonly in buildings, old houses etc.

1. Columba is commonly known as bvlue rock pigeon and Kabutar in hindi.
2. Body is divisible into head, trunk and tail.
3. Head contains large eyes and slit like nostrils.
4. Body colour is grey with glistening metallic green and purple on breast and neck.
5. Eyes are large and rounded with well developed nictitating membrane.
6. Forelimbs are modified into wings which contain flight feathers.
7. Feet are covered with epidermal scutes formed by fusion of several reptilian epidermal scales.
8. Hindlimbs are modified for bipedal locomotion.
9. They are known for their swift and strong flight.
10. Eggs are white and unmarked.



***Columba* (Pigeon)**

Fig – 2.34

2.3. 6 *Psittacula* (Parrot)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head. Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Aves** (Bipedal, feather-clad,)

Subclass- **Neornithes** (True birds, teeth absent)

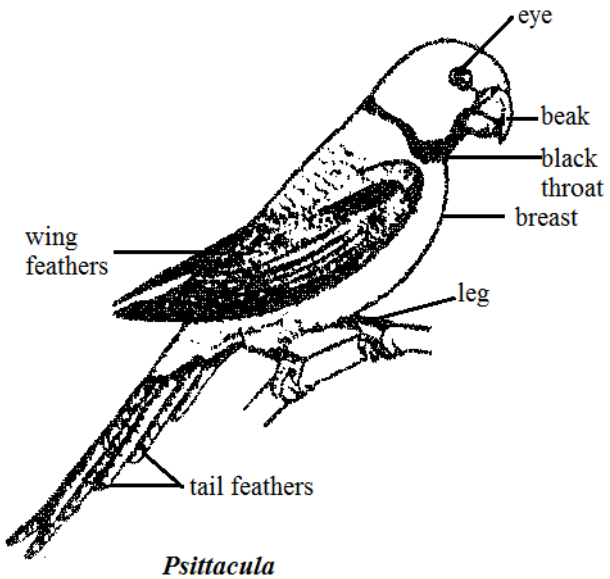
Superorder- Neognathae (feather with interlocking mechanism, sternum with keel)

Order- **Psittaciformes** (beak stout and hooked)

Genus- ***Psittacula***

Habit and Habitat- It is found in India, Pakistan, Burma, Sri Lanka and United States. It is common found on fruit trees, ripe crops and in jungles. Feeds on crops and fruits.

1. *Psttacula eupatria* is commonly known as Parrot or tota.
2. It has bright blue-green plumage with massive, deeply hooked red bill.
3. Beak stout, narrow, sharp edged and hooked at the tip.
4. Upper mandible movable on frontal bone of skull.
5. Feet adapted for grasping, holding and climbing.
6. Foot zygodactylous in which I and IV digits are directed backwards and II and III forward to provide a grip to hold the branch of the tree.
7. Tail feathers elongated.
8. Flight is graceful and voice is powerful and copied some words like man.
9. Female is green but male has a rose pink collar and a black throat.
10. Nesting season December to April.
11. It is popular domesticated cage bird found in homes.
12. It is serious agricultural pest to the cultivators.



Psittacula

Fig – 2.35

2.3. 7 *Dendrocopus mahrattensis* (Wood pecker)

Classification with identification:-

Phylum- **Chordata** (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Aves** (Bipedal, feather-clad,)

Subclass- **Neornithes** (True birds, teeth absent)

Superorder- Neognathae (feather with interlocking mechanism, sternum with keel)

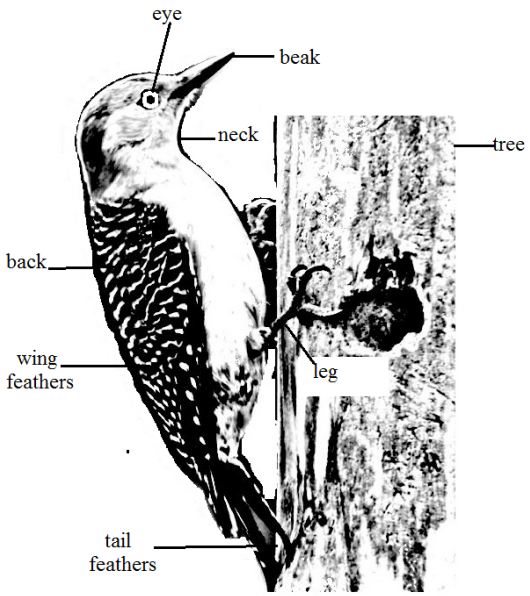
Order- **Piciformes** (Bill stout)

Genus- ***Dendrocopus***

Species- ***mahrattensis***

Habit and Habitat- It is small bird found most commonly in Forests, orchards, groves of trees. It feeds on ants.

1. It is commonly known as woodpecker.
2. Size is similar as compared with Bulbul.
3. Beak is long. Stout and pointed owl like with which they destroy wood.
4. Eyes are large.
5. Tongue roughed with barbs near the tip.
6. Toes 2 in front and 2 behind.
7. Upper plumage contains black and white spots.
8. Males have scarlet patches.
9. Tail is stiff and wedge shaped.
10. It destroys the tunics of woody trees.



Dendrocopus maharattensi

Fig – 2.36

2.3.8 *Bubo bubo* (Horned owl)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- **Vertebrata** (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Aves** (Bipedal, feather-clad,)

Subclass- **Neornithes** (True birds, teeth absent)

Superorder- Neognathae (feather with interlocking mechanism, sternum with keel)

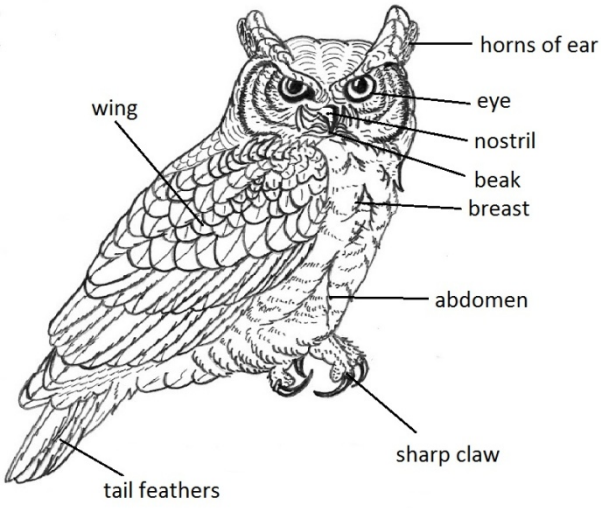
Order- **Strigiformes** (large head, powerful grasping feet feathered upto toes)

Genus- ***Bubo***

Species- ***bubo***

Habit and Habitat- *Bubo bubo* has worldwide distribution, found in India, Pakistan, and Burma. It lives in woody habitat. It feeds on small mammals, insects, birds, lizards.

1. It is commonly known as the great horned owl or Ghughu.
2. It is large in size with large rounded head, huge orange gold eyes and longhorns or ears.
3. Bird is heavily built with dark brown back mottled and spotted with buff.
4. Beak is short.
5. Eyes are large, yellow and forwardly directed each in a disk of radial feathers.
6. Ear opening large, with flip like cover.
7. Legs are fully feathered.
8. Feet adapted for grasping and claws are sharp.
9. Nesting season is November to April.
10. It hides in day time and active in night time.
11. It is of great economic value to mankind by destroying the harmful animals like rats, mice etc.



***Bubo bubo* (Horned owl)**

Fig – 2.37

2.3.9 *Archaeopteryx*

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

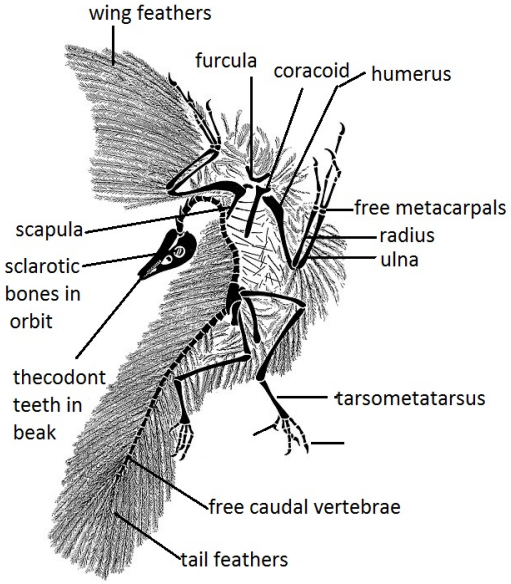
Class- Aves (Bipedal, feather-clad,)

Subclass- Archaeornithes (Extinct, teeth present, sternum without keel)

Genus- *Archaeopteryx*

1. It is oldest known fossil bird and was discovered from Upper Jurassic period in 1891 from Bavaria, Germany.
2. It forms a connecting link between reptiles and birds and exhibits many characters.
3. It was typical bird about size of crow.
4. Body was covered with feathers except the head and neck.

5. Forelimbs were typically modified as wings and were covered with flight feathers.
6. Jaws possessed small equal-sized pointed thecodont teeth.
7. Tail was long with more than 13 separate caudal vertebrae.
8. Reptilian characters posses:-
    a) Epidermal scales over body and limbs.
    b) Simple brain, cylindrical cerebral hemispheres and unexpanded cerebellum.
    c) Jaws with peg-like homodent teeth lodged in sockets.
    d) Vertebrae amphicoelous.
    e) Sternum poorly developed, without keel.
    f) Cervical vertebrae 9-10.
    g) Tail long, tapering, lizard like.
    h) Carpals and metacarpals free.
9. Avian characters posses :-
    a) Presence of feathers.
    b) Two jaws like beak.
    c) Skull monocondylic.
    d) Two clavicles fused into V shaped furcula.



Archaeopteryx

Fig – 2.38

2.3.10 *Phoenicopterus* (Flamingo)

Classification with identification:-

Phylum- **Chordata** (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Aves** (Bipedal, feather-clad,)

Subclass- **Neornithes** (True birds, teeth absent)

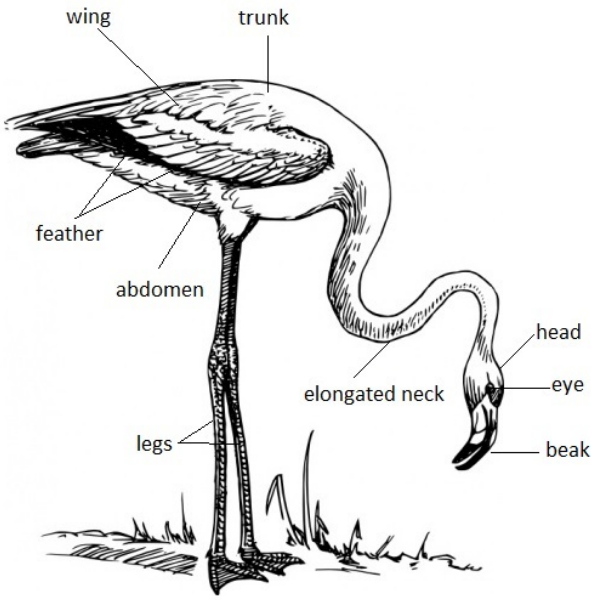
Superorder-Neognathae (feather with interlocking mechanism, sternum with keel)

Order- **Ciconiiformes** (long neck and long legged, marshy wading birds)

Genus- ***Phoenicopterus***

Habit and Habitat- It is found in East Africa, Afganistan, India, South Spain, West Siberia and Sri Lanka. It is found in flocks on ponds, lakes. They feed on small insects, worms, molluscs etc.

1) *Phoenicopterus* is Flamingo called Raj Hans.
2) It is a pale, rosy white bird with elongated pink legs and long neck.
3) It height is about 1.25 m.
4) Long neck extended during flight.
5) Head contains eyes.
6) Large pink bill is down curved.
7) Fleshy tongue works like a plunger.
8) Web present between toes.
9) It flies rapidly and can swim in water also.
10) Nests are mostly formed in colonies on mud flats in tropical brackish water.



***Phoenicopterus* (Flamingo)**

Fig – 2.39

2.4. Mammals

1. Possess hair which is made of keratin, terrestrial, warm-blooded, viviparous, tetrapod vertebrates.
2. Body with four divisions: head, neck trunk and tail.
3. Four chambered heart.
4. Skin glandular containing sweat, sebaceous and scent glands. Female Mammary glands are used to produce milk to nourish their young.
5. The diaphragm is a muscle that separates the thoracic cavity from the abdominal cavity.
6. Seven cervical vertebrae (neck bones) are present in most mammals.
7. Most are viviparous though some are oviparous. An extended gestation period uterine development is common in most placental mammals.
8. Teeth are imbedded in the jaw bone and come in a variety of forms.
9. Well developed brain.

10. Mammals are heterodontic, meaning that their teeth are different shapes, except those with no teeth at all.
11. The buccal cavity (the mouth) has a false palate as a roof, meaning that the nostrils do not lead directly into his mouth.
12. The body is maintained at a constant temperature they generate heat within their bodies metabolically and also have special cooling mechanisms.
13. Highly developed neopallium.
14. Tectum reduced to corpora quadrigemina: functions mainly as a relay center for auditory information and to control visual reflexes.
15. Corpus callosum in eutherians provides additional communication
16. Tapetum lucidum well developed in nocturnal mammals.
17. Lateral movement of jaw during mastication.
18. Viviparous except monotremes which are egg lying.
19. Parental care well developed.

2.4.1 *Orinthorhynus* (Duck-bill)

Classification with identification:-

Phylum- **Chordata** (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- **Vertebrata** (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Mammalia** (Hair clad, mammary glands present)

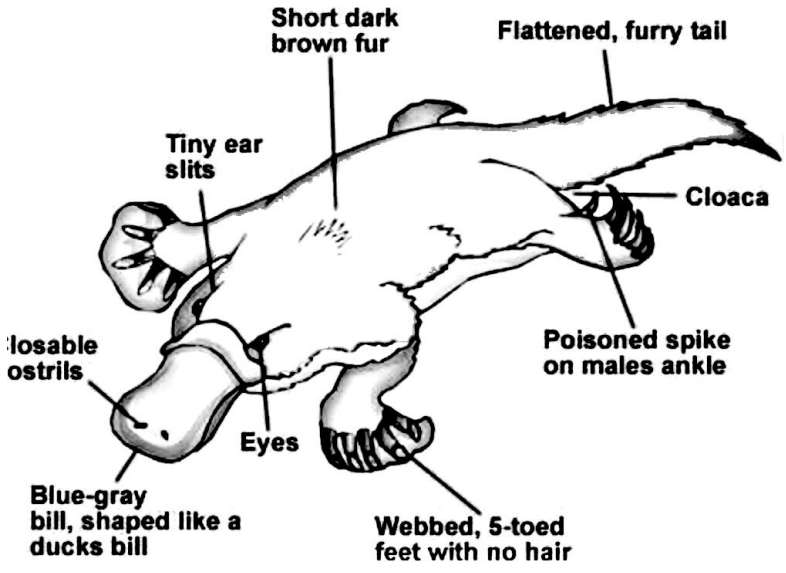
Subclas- **Prototheria** (Primitive, reptile-like, oviparous)

Order- **Monotremata** (Cloacal opening present)

Genus- ***Ornithorhynchus***

Habit and Habitat- It is found in South-eastern Australia and Tasmania. It is aquatic burrowing mammal native of rivers, freshwater lakes and ponds. It feeds on freshwater invertebrates.

1) Ornithorhynchus is commonly known as duck-billed platypus.
2) It measures about 50-70 cm in length.
3) Body is divided into head, thick trunk and tail.
4) Body is covered with short fur, dark brown colour.
5) They posses primitive reptilian characters and described as connecting link between.
6) Adults are without teeth and have a duck-bill.
7) Jaws are covered with horny plates.
8) Head bears small eyes with nictitating membrane.
9) Ear openings are without external pinnae.
10) Mammary glands without nipples.
11) Limbs have 5 clawed and webbed digits.
12) Feet are webbed and males posses a fowl like spur on heel which is connected to a poison gland.
13) Tail is flat and helps in swimming.
14) Cloaca present. Testes abdominal.
15) Penis conducts only sperms.



Orinthorhynus **(Duck-bill)**

Fig – 2.40

2.4.2 *Echidna* (Spiny anteater)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class- Mammalia (Hair clad, mammary glands present)

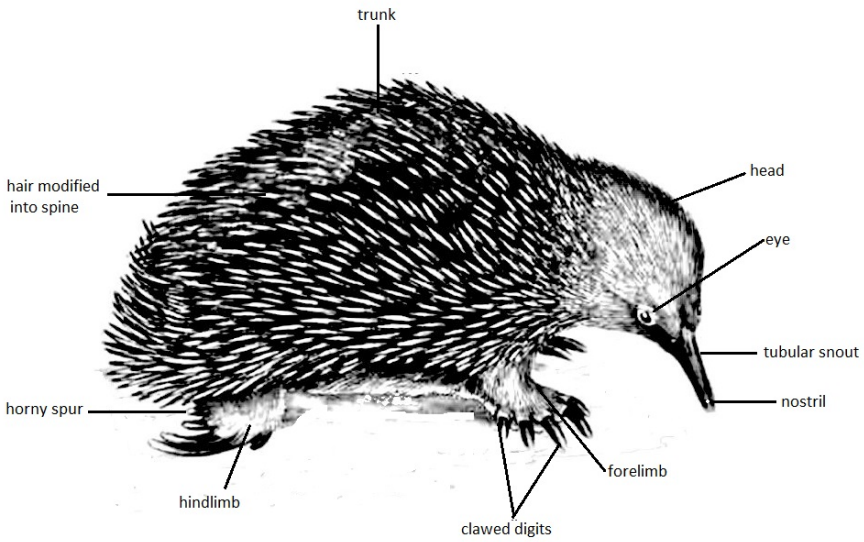
Subclas- Prototheria (Primitive, reptile-like, oviparous)

Order- Monotremata (Cloacal opening present)

Genus- *Echidna*

Habit and Habitat- It is found in Australia, Tasmania and New Guinea. It feeds on ants.

1) *Echidna* is commonly known as spiny anteater.
2) Neck and body indistinct.
3) Body is covered with strong pointed spines and hairs.
4) Head small and produced into a small tubular pointed snout.
5) Head bears an elongated cylindrical toothless beak and a pair of eyes without nictitating membrane.
6) External ears absent.
7) Limbs are short and have 3-5 digits with claws.
8) Tongue long and sticky teeth absent in adult.
9) Girdles and limbs reptile like. Feet without web.
10) Female lays one egg which is carried and incubated in a pouch or marsupium on the abdomen.
11) Male also posses mammary glands.
12) It is nocturnal and burrowing mammal.



***Echidna* (Spiny anteater)**

Fig – 2.41

2.4.3 *Macropus* (Kangroo)

Classification with identification:-

Phylum- **Chordata** (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- **Vertebrata** (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Mammalia** (Hair clad, mammary glands present)

Subclass- **Theria** (Marsupial and placental animal)

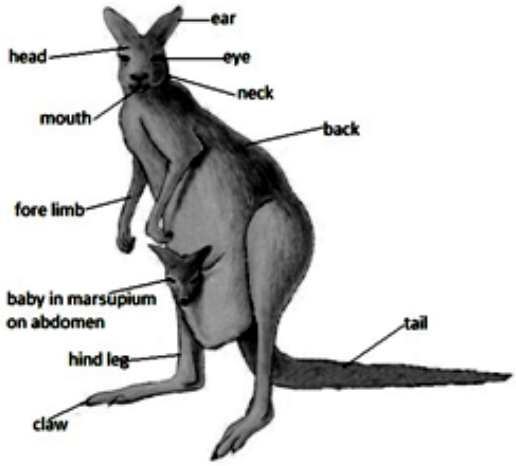
Infraclass- **Metatheria** (Pouched and viviparous)

Order- **Masupialia** (Female with marsupium)

Genus- ***Macropus***

Habit and Habitat- Kangaroo are found in Australia, New Zealand. They are terrestrial, gregarious, Herbivores animals.

1) They are commonly called as Kangaroo.
2) Kangaroo are large marsupials and reaches height upto 2 meters. Males are about 6 ft. and females are 4 ft tall.
3) Head small but ears are large.
4) Hindlegs and feet very long and powerful.
5) Forelimbs are small and do not touch the ground.
6) Hindlimbs digits 4 in number while forelimbs digits 5.
7) Tail is long, powerful, thick and used as a support when animal rests on the ground.
8) Females have an abdominal marsupial pouch in which the young one is nourished.
9) Hallux absent.



***Macropus* (Kangroo)**

Fig – 2.42

2.4.4 *Erinaceus* (Hedgehog)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Mammalia** (Hair clad, mammary glands present)

Subclass- **Theria (**Marsupial and placental animal)

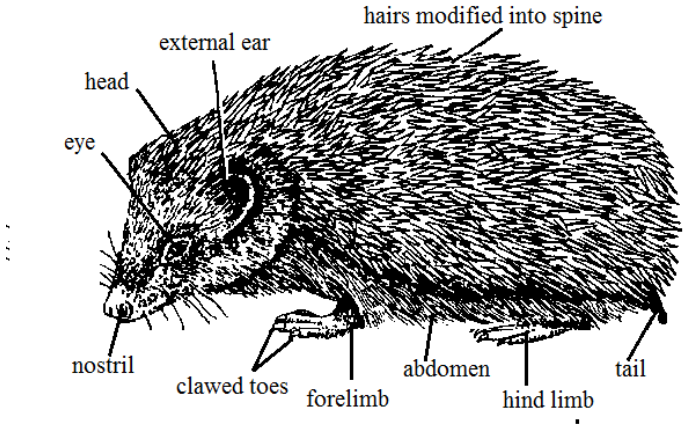
Infraclass- **Eutheria** (Placental mammals without marsupium)

Order- **Insectivora** (Snout long pointed, teeth sharp)

Genus- ***Erinaceus***

Habit and Habitat- It is found in northern hemisphere, West Indies, Africa and India. It is omnivores feeds on fruits, roots, insects and worms.

1) *Erinaceus* is commonly known as hedgehog.
2) Body is divisible into head, neck and trunk.
3) Body is covered with sharp backwardly directed spines on dorsal surface on ventral side bears soft fur.
4) Head conical and produced into a small snout bearing nostrils at the tip.
5) Mouth small bearing 36 sharp pointed teeth.
6) Eyes are small.
7) Pinnae and legs short.
8) Absence of marsupial bone or pouch.
9) Feet 5 toed with claws.
10) Vagina single, foetus develops within uterus of female attached by a placenta.



Erinaceus: Hedgehog

Fig – 2.43

2.4.5 *Manis* (Scaly anteater)

Classification with identification:-

Phylum- **Chordata** (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- **Vertebrata** (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Mammalia** (Hair clad, mammary glands present)

Subclass- **Theria** (Marsupial and placental animal)

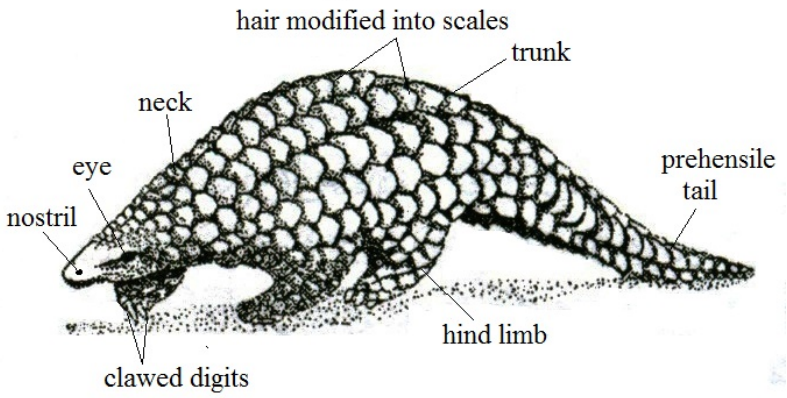
Infraclass- **Eutheria** (Placental mammals without marsupium)

Order- **Pholiodota** (Body covered by large overlapping plates)

Genus- ***Manis***

Habit and Habitat- *Manis* is found in South Africa, East Asia, India (Assam), Sikkim, Nepal. It feeds on ants and termites.

1) *Manis* is commonly known as scaly anteater.
2) Body measures about 90cm in length.
3) Body is divided into head, neck, trunk and tail.
4) Body is covered with yellow brown large horny epidermal scales or plates.
5) Between scales coarse hairs are found.
6) Head is small. Snout is pointed.
7) Teeth absent. Tongue long and glutinous.
8) Eyes and pinnae small.
9) Tail is long and broad and contains 16-17 scales in each row.
10) Each limb has 5 strongly clawed digits.
11) They are shy, nocturnal mammals.
12) During day they rest in burrows which are 2-3 meter deep from the surface.
13) On disturbance they roll up and become immobile.



Manis

Fig – 2.44

2.4.6 *Loris*

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class- Mammalia (Hair clad, mammary glands present)

Subclass- Theria (Marsupial and placental animal)

Infraclass- Eutheria (Placental mammals without marsupium)

Order- Primates (Head turns on neck, great developed brain)

Suborder- Lemuroidea (Snout elongated)

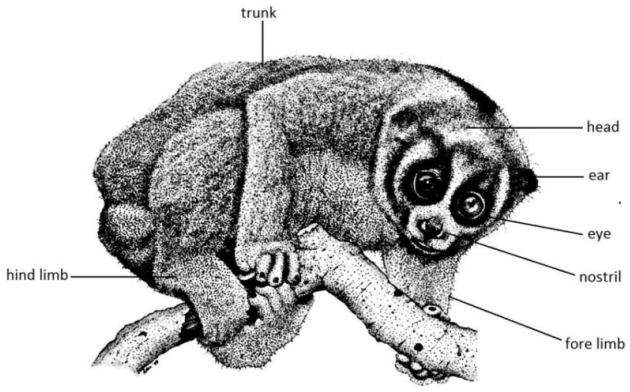
Family- Lorisidae

Genus- *Loris*

Habit and Habitat- *Loris* is found in dense tropical jungles of South India and Sri Lanka. It feeds on fresh leaves, fruits and insects.

1) Body is covered with brownish fur with silver look. Fur is thick and wooly.
2) It is small nocturnal mammal measures about 20 cm in length.
3) Head is small or flat face and produced into snout.
4) Eyes are small closely packed with small pinnae.

5) External ear or pinna is conical.
6) Nostrils are in the form of small apertures.
7) Teeth thecodont and heterodont.
8) Tail is long but non prehensile.
9) Limbs elongated. Toes clawed.
10) It is found hanging upside down on trees.



Loris

Fig – 2.45

2.4.7 *Pteropus* (Bat)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class- Mammalia (Hair clad, mammary glands present)

Subclass- Theria (Marsupial and placental animal)

Infraclass- Eutheria (Placental mammals without marsupium)

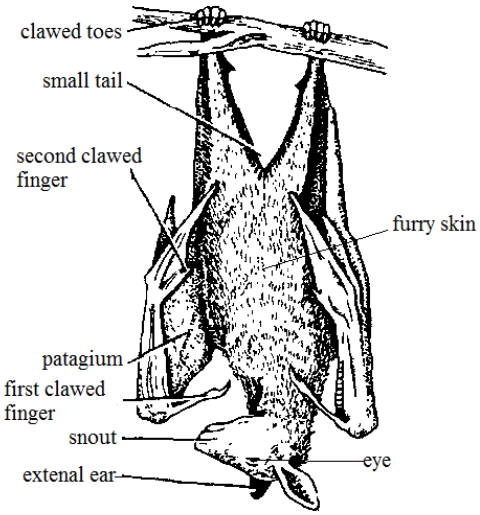
Order- Chiroptera (Forelimbs modified into wings (patagium))

Suborder- Megachiroptera (Frugivores, head foxlike)

Genus- *Pteropus*

Habit and Habitat- *Pteropus* is found in South –Eastern Asia. It feeds on fruits and damage orchards.

1) *Pteropus* is commonly known as Bat.
2) They sleep by day on trees.
3) It is nocturnal and hangs by its legs on high trees.
4) Body is dark brown coloured and shoulders are golden yellow.
5) Forelimbs are modified into wings.
6) Body measures about 60-70 cm in length and is covered with hair which is black on head.
7) Head is fox-like with a snout.
8) Head bears small external ears, large eyes, snout and small teeth.
9) Each wing formed a fold of skin or patagium supported by elongated forelimb.
10) Hindlimbs and tail also included in patagium.
11) Tail small and stumpy.



Indian fruit bat

Fig – 2.46

2.4.8 *Herpestes* (Mongoose)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- **Vertebrata** (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Mammalia** (Hair clad, mammary glands present)

Subclass- **Theria** (Marsupial and placental animal)

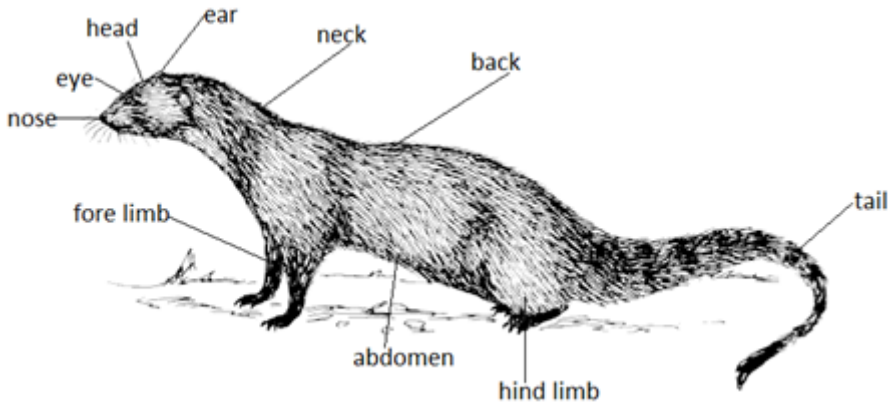
Infraclass- **Eutheria** (Placental mammals without marsupium)

Order- **Carnivora Carnivora** (Small to large predatory, flesh eating)

Genus- ***Herpestes***

Habit and Habitat- It is found in Asian and African countries. It feeds on small mammals , insects, reptiles and birds.

1) *Herpestes* is commonly known as mongoose or Neola.
2) It is small and highly modified carnivore.
3) Body is covered with greyish fur.
4) It has long skull and short legs.
5) Snout pointed, Eyes are small.
6) Pinna small and rounded.
7) Tail elongated and bushy.
8) Forelimbs and hindlimbs have 5 digits with claws.
9) Teeth thecodont and heterodont with well developed cannies.
10) It is a burrowing and nocturnal animal.



Herpestes **(Mongoose)**

Fig – 2.47

2.4.9 *Hystrix* (Porcupine)

Classification with identification:-

Phylum- Chordata (Dorsal tubular nervecord, notochord and gill slits present)

Group- Craniata (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- Gnathostomata (Jaws and paired appendages present)

Superclass- Tetrapoda (paired limbs, lungs, cornified skin and bony skeleton)

Class- Mammalia (Hair clad, mammary glands present)

Subclass- Theria (Marsupial and placental animal)

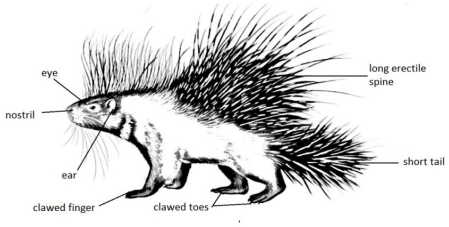
Infraclass- Eutheria (Placental mammals without marsupium)

Order- Rodentia (Chisel like incisors growing throughout life)

Genus- *Hystrix*

Habit and Habitat- It is found in India. It commonly inhabits river banks, etc.

1) *Hystrix* is commonly known as porcupine.
2) It is nocturnal and herbivore.
3) Body is about 1 meter.
4) Presence of long spines or quills which are modified hairs.
5) Snout is covered with short and stiff bristles.
6) Throat spines small.
7) Head contains a crest of black bristles.
8) Quills are mostly white, yellowish white on tail.
9) Lumber region is flat and striated.
10) It attacks on enemies by erecting its spines.



***Hystrix* (Porcupine)**

Fig – 2.48

2.4.10 *Lutra* (Otter)

Classification with identification:-

Phylum- **Chordata** (Dorsal tubular nervecord, notochord and gill slits present)

Group- **Craniata** (Definite head.Cranium with brain present)

Subphylum- Vertebrata (Vertebral column present)

Division- **Gnathostomata** (Jaws and paired appendages present)

Superclass- **Tetrapoda** (paired limbs, lungs, cornified skin and bony skeleton)

Class- **Mammalia** (Hair clad, mammary glands present)

Subclass- **Theria** (Marsupial and placental animal)

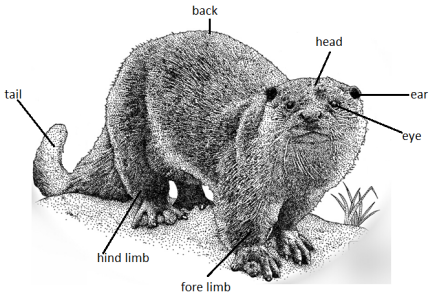
Infraclass- **Eutheria** (Placental mammals without marsupium)

Order- **Carnivora** (Small to large predatory, flesh eating)

Genus- ***Lutra***

Habit and Habitat- It is found throughout world. It is found near rivers in India. It feeds on small fishes and frogs.

1) *Lutra* is commonly known as otter or Udbilao.
2) It is terrestrial, good swimmers also.
3) It is a small carnivore with primitive characters.
4) Body is elongated and covered with short-fur.
5) Head is cat like, elongated.
6) Head bears small eyes, long hairs and small ears.
7) Feet are webbed and suited for water life.
8) Teeth thecodont with well developed cannies.



***Lutra* (Otter)**

Fig – 2.49

2.5 Viva- Voce, Question and answer

1. What are chordates?
2. What is difference between chordate and non chordate?
3. What is difference between Acrania and Craniata?
4. What is difference between Agnataha and gnathostomata?
5. How will you classify *Herdmania?*
6. What is zoological name of Sea Horse?
7. What are basic characters of Chondrichthyes?
8. What is common name of *Amphioxus*?
9. Which kind of scales found in Osteichthyes?
10. What do you mean by heterocercal caudal fin?
11. What are three basic character of cyclostomata?
12. Name any two lung fishes?
13. What is zoological name of snake head fish?
14. What are ampullae of lorenzini?
15. Can you enumerate economic importance of fish?
16. What are important characters of Pisces?
17. Name any two electric fish?
18. What are the specific characters of class Amphibia?
19. What are the specific characters of class Reptilia?
20. What are the specific characters of class Aves?
21. What are the specific characters of class Mammalia?
22. What is zoological name of our national bird?
23. What is common name of Manis?
24. Distinguish between lizard and snake?
25. Which animal is the connecting link between birds and reptilian?
26. Can you enumerate reptilian and avian characters of *Archeopteryx*?
27. Classify Amphibia into subclasses?
28. Classify mammals into subclasses?
29. What are differences between Ratitae and Carinatae?
30. What is neoteny and paedogenesis?
31. Which animal shows paedogenesis?
32. What is ornithology?
33. Which kind of bone found in birds?

34. What is difference between poisonous and non poisonous snake?
35. What are the examples of poisonous snake?

2.6 References

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Unit –3

Microscopic Slides-I

Structure of the Unit

3.0 Objectives

After going through this unit you will be able to understand the structure of tissue mounts and histology of representative lower chordates types. Structure of whole mounts; larva and sections of individuals of different subphylum and class of chordates like Urochordates, Cephalochordate, Pisces and Amphibia with specific functioning have been detailed in this unit.

3.1 Introduction

Study of histological structure helpful in to understand the specificity and functioning of particular organs. It can be used for the comparative study of organism of different phylum, class etc. It also helpful to understand the anatomical and physiological relevance of organism. To study histological structure of tissue or organ pre prepared slides are used. In this unit study of prepared slide of lower chordate subphylum, different classes of vertebrata have been detailed. For the easy understanding well labeled histological diagrams of tissue and organ have also been given.Permanent slides are used to study the internal structures of lower chordates. Through prepared slides histological, structural composition of endoskeleton and exoskeletons of animal will be learned.

3.2 Lower chordates

3.2.1.*Herdmania*

3.2.1.1. Spicules of *Herdmania*

Comments:

Spicules of herdmania are calcareous and have a definite shape. There are two types of spicules found in the body, viz; very small known as Microscleres and larger ones are known as Megascleres.

Microscleres:

1. These are found only in the test and lie scattered throughout the test.
2. Each spicule consists of a rounded knob-like head and an elongated body.
3. Head is generally smooth, rarely with few spines on its side.
4. Body bears a large number of rings of spines ranging from 5-20.
5. The spines are always pointing towards the head if spicule.
6. The average size if spicule is 50 to 80 microns.

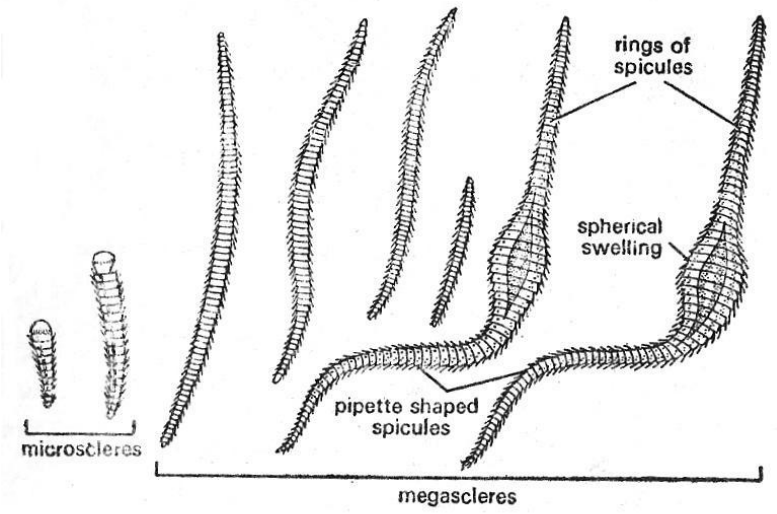

Fig. 1. Spicules of *Herdmania*

Fig – 3.1

Megascleres:

Megascleres are of two kinds, i.e.; (i) spindle-shaped and (ii) pipette-shaped.

(i) Spindle-shaped spicules:

1. These are always found enclosed in a connective tissue sheath and lie scattered throughout the body in most of its tissues.
2. Each spicule has a large number of rings of spines ranging from 20-60, all pointing in the same direction.
3. The average size is 1.5-2.5 m.

(ii)Pipette-shaped spicules:

1. These spicules are larger than those of the spindle shaped type.
2. The average size being as much as 3.5 mm.
3. The characteristic feature of each spicule is the presence of large spherical swelling in the middle.
4. They are having large number of rings of spines.

3.2.1.2. *Herdmania* Tadpole larva:

Comments:

1. Herdmania is a hermaphrodite animal.
2. The fertilized eggs undergo holoblastic unequal clevage and it develops into blastula. it shows upper micromeres and lower macromeres.
3. By invagination of the macromeres gastrulation takes place and gastrula is formed.
4. This gastrula develops into a tailed larva called Ascidian Tadpole larva.

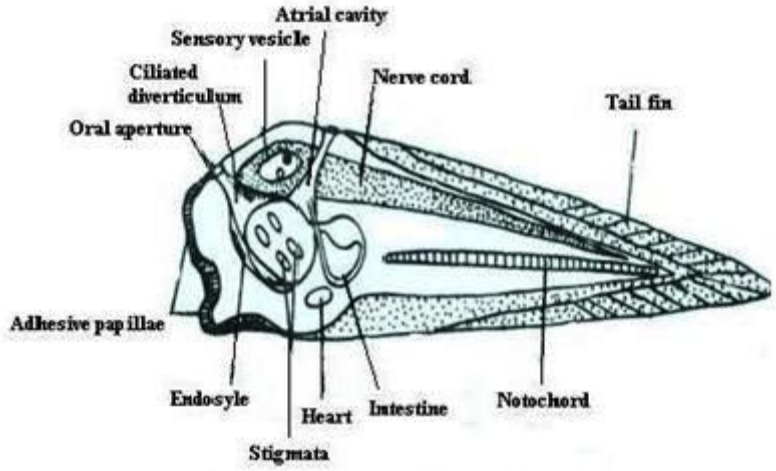

Fig.2. Tadpole larva of *Herdmania*

Fig – 3.2

5. The larva is 3 mm in length. It has short oval body and a long tail.
6. This larva shows all the chordate features.
7. The body is covered by thin test.
8. The tail is long and shows a tail fin or caudal fin.
9. The tail is supported by notochord. Hence it comes under urochordata.
10. On the dorsal side above the notochord hollow nerve cord is present. This nerve cord is enlarged at the anterior end as a cerebral vesicle. In the cerebral vesicle pigmented eye spot is present. Statocyst is also present. They work as sense organs.
11. On either side of the notochord in the tail region muscles are Present which are helpful in the locomotion.
12. On the trunk region digestive system is present. It shows large pharynx with few gills slits. They open into atrium. On the mid ventral floor of the pharynx an endostyle is present.
13. Atrium opens out through atriopore.
14. Below the pharynx on the ventral side a muscular heart is present.
15. On the anterior end of the trunk three adhesive papillae are present These are very much useful to attach the larva to the substratum
16. This larvae 'undergoes retrogressive' metamorphosis and develops into adult Herdmania.

3.2.2. *Amphioxus*

3.2.2.1. T.S. passing through oral hood

Comments:

Transverse section of Amphioxus passing through the region of oral hood shows the following details:

1. Body wall comprises single layer of epidemis.
2. On the dorsal surface dorsal fin having the dorsal fin ray is present.
3. Myotomes separated by myocommata are present on both the sides in the dorsal half portion of the section.

4. Dorsal tubular nerve cord containing ocellus lies below the dorsal fin.
5. Notochord composed of vacuolated cells, is enclosed in the notochordial sheath and lies below the nerve chord.
6. The oral hood encloses a large buccal cavity.
7. The dorsal wall of the buccal cavity has a groove called Hatscheck's which is sensory in nature.
8. In the buccal cavity several sections of the buccal cirri are seen.

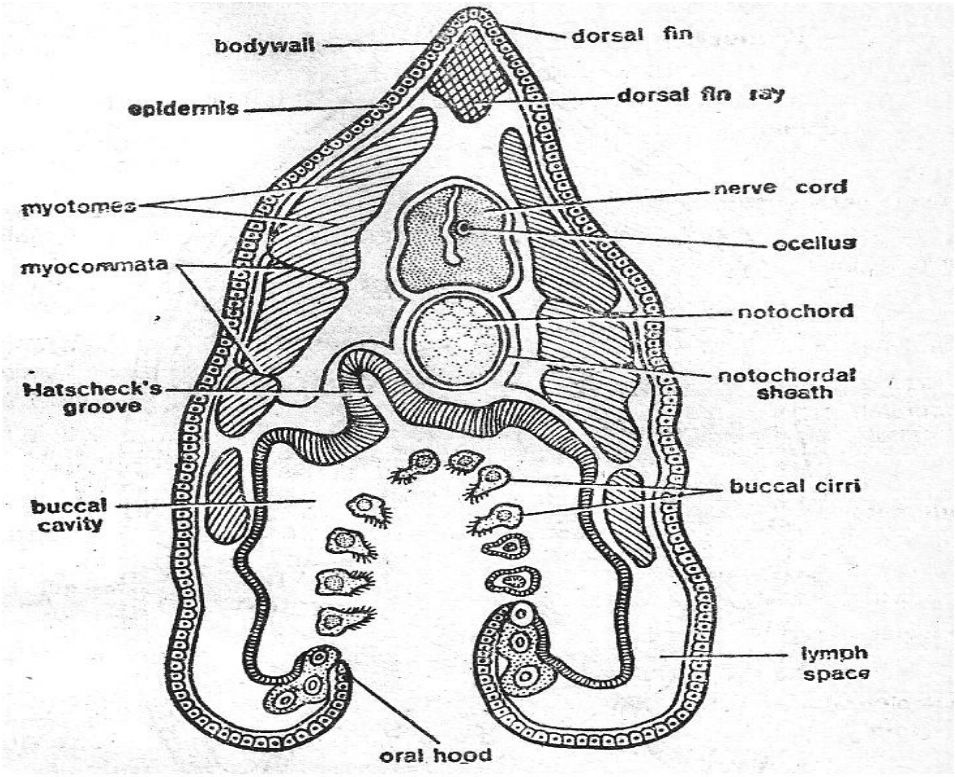

Fig.3. T.S. Passing through oral hood

Fig – 3.3

3.2.2.2. T.S. passing through pharynx

Comments:

Transverse section of Amphioxus passing through the pharynx shows the following important structures:

1. Body wall is formed of epidermis which is composed of a single layer of simple columnar epithelium.
2. Dorsal fin containing the dorsal fin ray lies at the dorsal surface.
3. Myotomes and myocommata of both the sides alternate with each other.
4. Dorsal tubular nerve cord is present below the dorsal fin.

5. Notochord comprising of vacuolated cells is surrounded by notochordial sheath and lies below the nerve cord.
6. The pharynx is quite spacious and surrounded by the atrial cavity.
7. The pharynx is perforated by numerous gill-slits which on either side separated by primary and secondary gill-bars.
8. In the mid-dorsal line of pharynx is present a ciliated epipharyngeal-groove, while in the mid-ventral line lies a glandular endostyle.
9. The dorsal aortae are present, one on the either side of the epipharyngeal groove.
10. The coelom appears as dorsal coelomic canals on either side if the epipharyngeal groove. Parts of coelom are also present in the endostyle and in metapleural folds.
11. The metapleural folds are present on the ventral side.

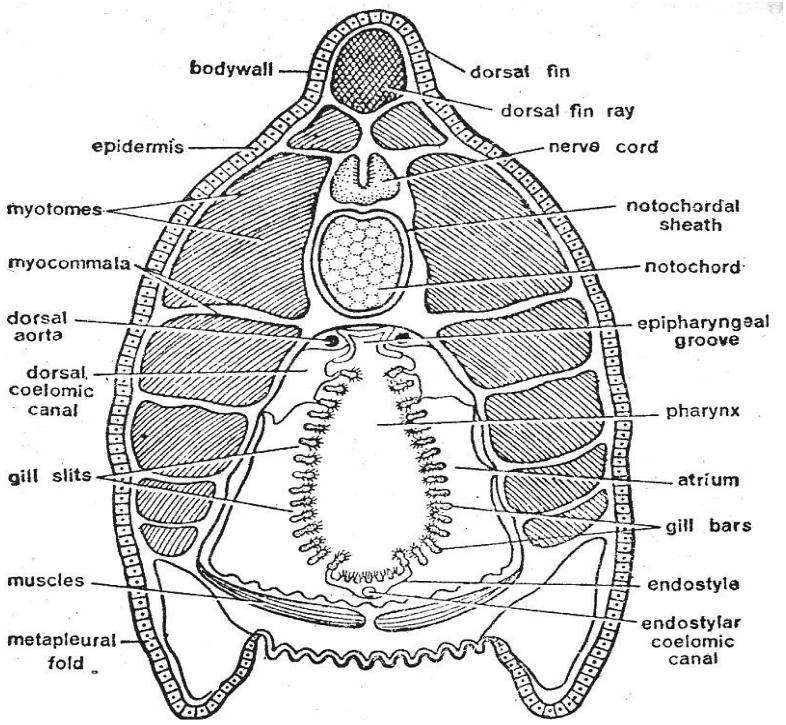

Fig. 4. T.S. passing through pharynx

Fig – 3.4

3.2.2.3. T.S. passing through testes

Comments:

Transverse section of Amphioxus through testis reveals the following structure:

1. Body wall is composed of single layer of simple columnar epithelium.
2. Dorsal fin having the dorsal fin ray is present on the dorsal surface.
3. Myotomes separated by myocommata are present on both the sides.
4. Nerve cord contains a central canal and lies below the dorsal fin ray.
5. Notochord composed of vacuolated cells and surrounded by notochordial sheath, lies below the nerve cord.
6. Pharynx is quite spacious occupying the most of the space between the notochord and the metapleural folds.
7. The pharynx is performed by numerous gill-slits.
8. In the mid-dorsal line of pharynx lies a ciliated epipharyngeal-groove, while in the mid-ventral line is present a glandular ciliated endostyle.

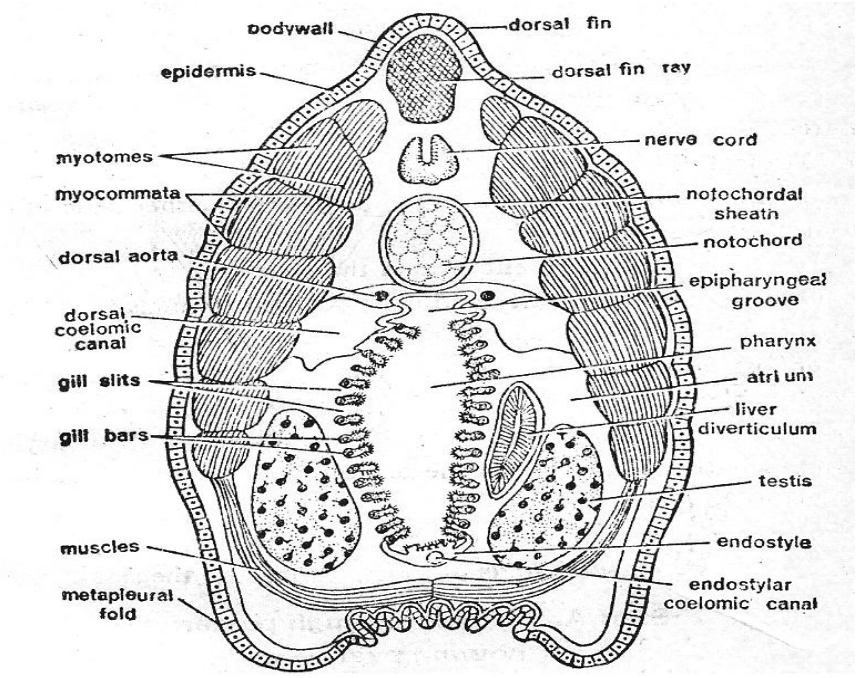

Fig. 5. T.S. passing through testes

Fig – 3.5

9. Two dorsal aortae are present, one on either side of the epipharyngeal groove.
10. The atrium is present around the pharynx.
11. The coelom appears as dorsal coelomic canals on either side of the epipharyngeal groove. Parts of coelom are also present in the endostyle, in the metapleural folds and around the liver diverticulum and gonads.

12. The testis, one pair in the section, lie in the atrium on both the sides of the pharynx.
13. The testis contains several spermatozoa.
14. Two metapleural folds are present on both the sides.

3.2.2.4. T.S. passing through ovary

Comments:

Transverse section of Amphioxus through the ovaries reveals the following structure:

1. Body wall is formed of epidermis which is composed of single layer of simple columnar epithelium.
2. Dorsal fin having the dorsal fin ray is present on the dorsal surface.
3. Myotomes separated by myocommata are present on both the sides.
4. Nerve cord contains a central canal and lies below the dorsal fin ray.
5. Notochord composed of vacuolated cells and surrounded by notochordial sheath, lies below the nerve cord.

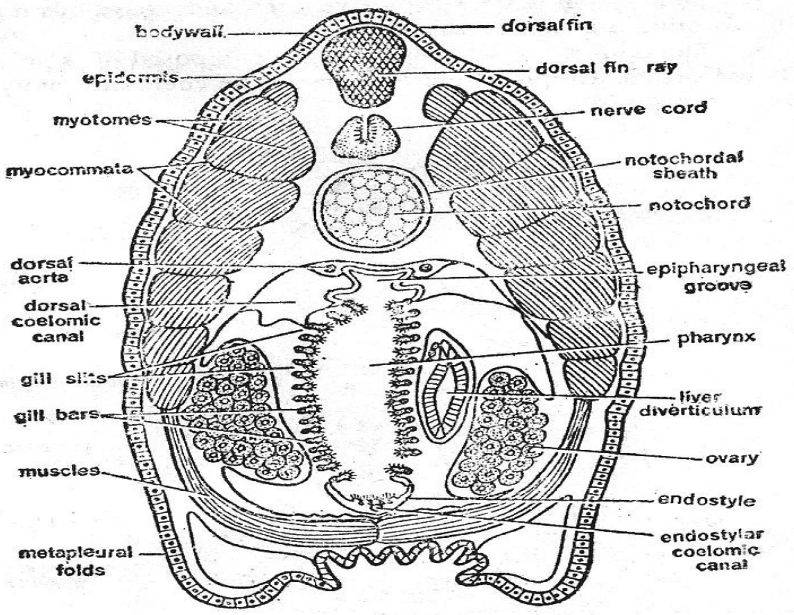

Fig. 6. T.S. passing through ovary

Fig – 3.6

6. Pharynx is quite spacious occupying the most of the space between the notochord and the metapleural folds.

7. Two dorsal aortae are present, one on either side of the epipharyngeal groove.
8. The coelom appears as dorsal coelomic canals on either side of the epipharyngeal groove. Parts of coelom are also present in the endostyle, in the metapleural folds and around the liver diverticulum and gonads.
9. The ovaries are the same as in the previous section.
10. The ovaries contain several ova.
11. Two metapleural folds are present on both the sides.

3.2.2.5. T.S. passing through intestine

Comments:

Transverse section of Amphioxus passing through mid-gut or intestine showsthe following important structures:

1. Body wall is formed of epidermis which is composed of single layer of simple columnar epithelium.
2. Dorsal fin having the dorsal fin ray lies on the dorsal surface.
3. Myotomes and myocommata of both the sides alternate with each other.
4. Nerve cord is tubular and situated below the dorsal fin ray.
5. Notochord comprising of vaculoted cells is surrounded by notochord sheath and lies below the nerve cord.
6. Single median dorsal aorta is seen ventral to the notochord.
7. The coelom is very well developed and surrounded the intestine by forming a coelomic cavity.

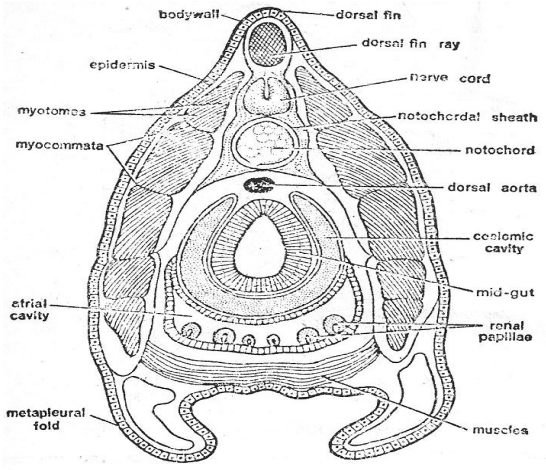

Fig. 7. T.S. passing through intestine

Fig – 3.7

8. The midgut or intestine is oval, composed of single layer of ciliated columnar epithelium and lies in the coelomic cavity in the centre of the section.
9. The atrium is well developed and forms a atrial cavity which lies ventral to the coelomic cavity.
10. The atrial cavity contains several renal papillae.
11. The metapleural folds are present on the ventral side.

3.2.2.6. T.S. passing through caudal region

Comments:

Transverse section of Amphioxus passing through the caudal region shows the following structures:

1. Body wall comprises single layer of epidermis which is composed of simple columnar epithelium.
2. Dorsal and ventral fins containing the respective fin rays are also present.
3. Myotomes separated by myocommata are present on both the sides.
4. Dorsal tubular nerve cord lies below the dorsal fin ray.
5. Notochord is surrounded by notochordal sheath and composed of vacuolated cells. It occupies the central portion of the section.
6. Dorsal aorta and sub intestinal vein lie below the notochord the dorsal aorta is dorsal to the vein.
7. The intestine, coelom and atrium are wanting.
8. Metapleural folds are also absent.

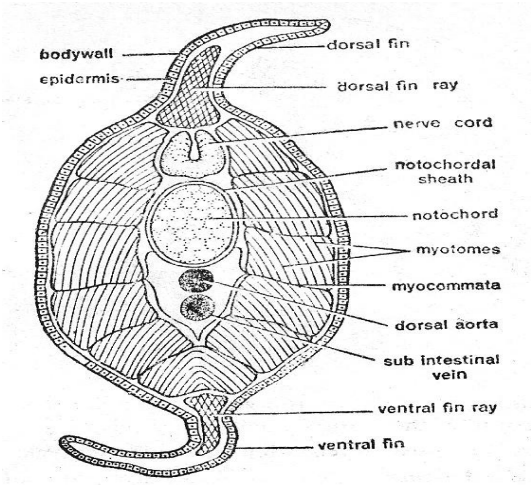

Fig. 8. T.S. passing through caudal region

Fig – 3.8

3.2.2.7. Ammocoete larva: Whole mount

Comments:

1. It is fishlike, laterally compressed, and fusiform.
2. Anteriorly there is a poorly defined head with an oral hood enclosing a preoral space known as the vestibule.
3. There is a long dorsal fin and the tail bears a caudal fin.
4. The nerve cord is a conspicuous, longitudinal, tube lying dorsally in the animal.
5. Anteriorly the cord is expanded to form a distinct brain, a feature absent in amphioxus.
6. The brain of the larva is divided into three regions, each associated with a primary sense capsule.
7. The anterior prosencephalon is associated with the olfactory sense, the middlemesencephalon with vision, and the posterior rhombencephalon with detection of balance, acceleration, and equilibrium.
8. The prosencephalon comprises an anterior telencephalon and a posterior diencephalon separated by a deep groove. The brain narrows abruptly posterior to the rhombencephalon to become the nerve cord.

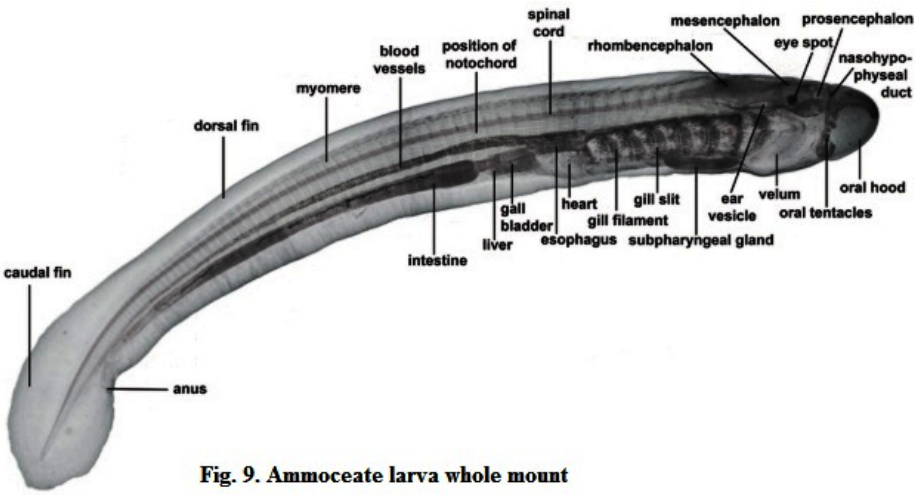

Fig. 9. Ammoceate larva whole mount

Fig – 3.9

9. A median funnel-shaped invagination of ectoderm, the nasohypophyseal pouch which contribute to the formation of the pituitary gland of the adult lamprey and is homologous to Rathke's pouch and perhaps to Hatschek 's pit (amphioxus).

10. It extends from the surface ectoderm to a position ventral to the prosencephalon. The external opening of the pouch is the nostril, on the dorsal midline.
11. Lampreys, like many early vertebrates have three eyes consisting of a pair of lateral eyes on the sides of the head and a single, unpaired median eye on top of the head.
12. The inner ear (otic vesicle) is the sense organ associated with the rhombencephalon and it can be seen as a large clear oval beside the anterior rhombencephalon. It lies just posterior to the division between the mesencephalon and rhombencephalon. During embryonic development the olfactory, optic, and otic sense organs develop as invaginations of surface ectoderm.
13. The notochord is a long thick rod lying ventral to the neural tube. It extends from the level of the inner ear posteriorly to the tip of the tail. The name "cephalochordate" for amphioxus alludes to the presence of the notochord in the entire length of the head.

3.3. Pisces

3.3.1. Placoid scale (Whole mount)

Comments:

1. The placoid scales are arranged in regular oblique rows, covering the entire surface of the body and form the exoskeleton of the shark.
2. Placoid scales are small pointed and tri radiate denticles found embedded in the dermal layer of the skin.
3. A typical placoid scale consists of a diamond shaped or rhomboidal basal plate having an opening of the pulp cavity and flat trident spine.

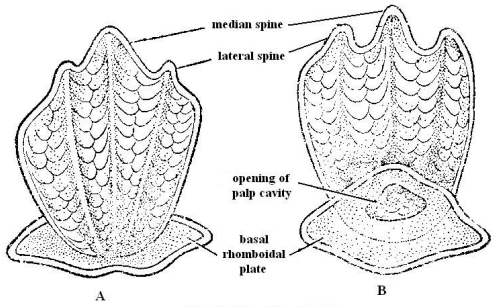

Fig. 10. Placoid scale
A- Dorsal view; B- Ventral view

Fig – 3.10

4. The basal plate is formed of a trabecular calcified tissue, the cement.
5. The spine is composed of a hard calcareous substance, the dentine which is coated externally with hard and dense enamel.
6. The pulp cavity contains the vascular connective tissue, pulp containing numerous odontoblasts, blood vessels, nerves and lymph chamber.

3.3.2. Cycloid scale (whole mount)

Comments:

1. Cycloid scales are found in teleosts and dipnoi.
2. These are soft and dermal plate s.
3. Each cycloid scale is roughly circular and flattened.
4. Each scale is composed of a central nucleus and numerous lines of growth.
5. The free or anterior border is more or less rounded and remains exposed.
6. The posterior part of the scale is having numerous longitudinal grooves for sucking the nourishment from the skin.
7. Pulp cavity and dentine are entirely absent.
8. Cycloid scales are derivatives of the ganoid scales in which ganoin and cosmine layer and bone cells are lost.

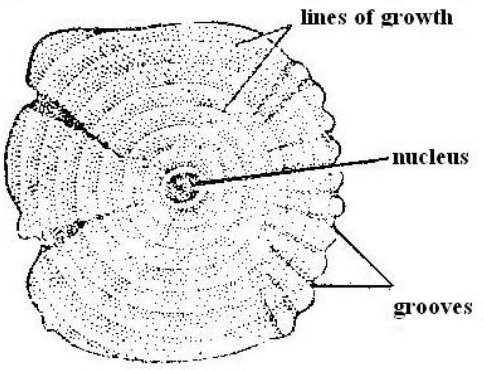

Fig. 11. Cycloid scale (whole mount)

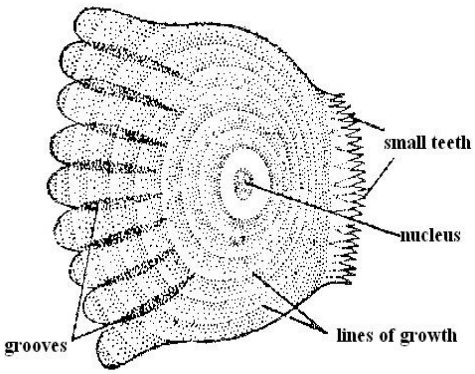

Fig. 12. Ctenoid scale (Whole mount)

Fig – 3.11

3.3.3. Ctenoid scale (whole mount)

Comments:

1. Ctenoid scales (Fig.12) commonly found in teleosts and actinopterygian fishes.
2. These are soft and dermal plates.
3. Each Ctenoid scale is flat and somewhat oval in shape.

4. Each scale is composed of central nucleous and numwerous lines of growth.
5. The anterior free border bears numerous small teeth like structures.
6. The posterior border remains embedded in the skin and slightly wavy.
7. Numerous longitudinal grooves are present on the posterior border and as such these grooves are used for sucking the nourishment from the skin.
8. Pulp cavity and dentine are entirely absent.
9. Ctenoid scales are derivatives of genoid scales in which ganoin, cosmine layers and bone cells are lost.

3.4. Amphibia

3.4.1. V.S. of skin of frog.

Comments:

Vertical section of skin of frog shows the following histological details:

1. The skin consists of two distinct layers, the outer epidermis and inner dermis.
2. The epidermis is made up of outer stratum corneum of flattened horny cells arranged in several layers which is case off as squamous epithelium and an inner layer of stratum Malpighi.
3. The dermis consists largely of connective tissue which is differentiated into two distinct layers, i.e., outer spongy layer and inner compact layer.
4. The spongy layer is composed of an areolar connective tissue and contains mucous glands, melanophores, blood vessels, nerve fibers and lymph spaces etc.
5. Mucous glands are flask shaped opening on the surface of the skin. They originate from the stratum Malpighi and their body lies in dermis.

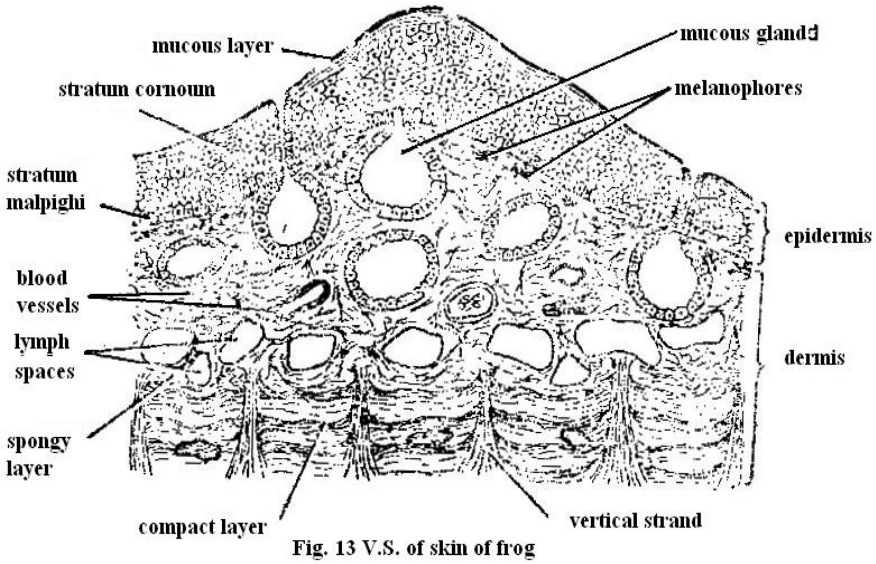

Fig. 13 V.S. of skin of frog

Fig – 3.12

6. Melanophores are colour pigments present in the dermis and imparting characteristics colour to the frog.
7. The compact layer is made up of compact fibrous connective tissue having horizontal and vertical strands.
8. The outer most covering of the skin is mucous layer which makes it slimy and slippery.
9. The skin of frog performsseveral functions as: it Protectbody, production of mucous to keep the skin moist and slippery to protect it from enemies, perform respiration, excretory and sensory.

3.4.2. T. S. passing through stomach

Comments:

Transverse section of stomach of frog showing the following histological details:

1. It is composed of five layers, i.e., serosa, subserosa,muscularis,submucosa and mucosa.
2. The serosa is thin and made up of a single layer of peritoneal cells.
3. The subserosa consists of a thin layer of connective tissue and conatins some blood vessels.

4. The muscularies consists of a thick and prominent layer of circular muscle fibres.
5. The suubmucosa lies below the circular muscle fibers and made up of loose connective tissue fibres containing blood vessels.
6. The muscularis mucosa is well developed and lies blow the submucosa. It consists of an outer longitudinal layer and inner circular layer.
7. The mucosa is the innermost layer and consists of simple columnar epithelium. It gives rise to simple and branched tubular glands.
8. The mucosa is thrown into numerous folds or villi projecting into the lumen. The villi increase the maximum absorptive surface.
9. The tubular or gastric glands open into the lumen of stomach through narrow ducts and secrete pepsin and HCl.

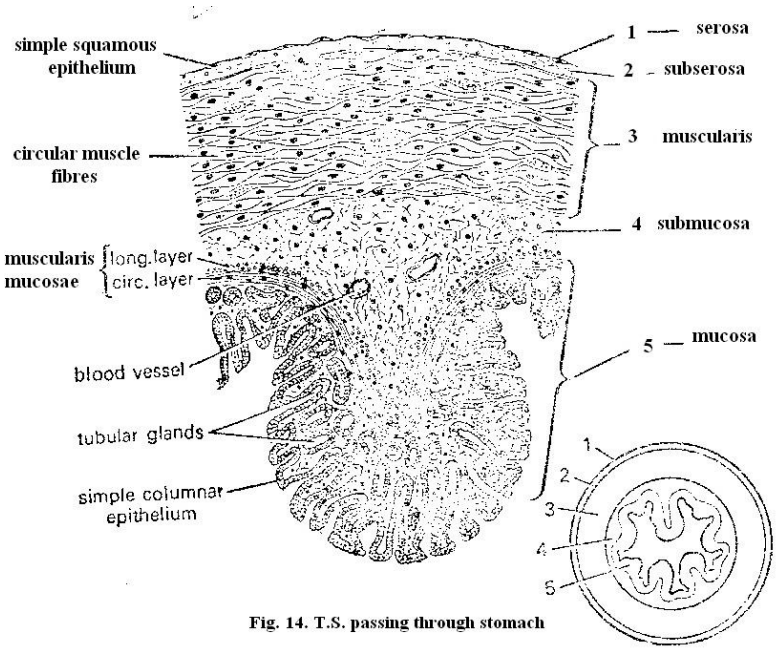

Fig. 14. T.S. passing through stomach

Fig – 3.13

3.4.3. T. S. passing through duodenum:

Comments.

Transverse section passing through duodenum shows the following feathers:

1. Histologically duodenum resembles with ileum but its mucosa is peculiar. Section shows serosa, musculature, sub- mucosa, muscularis mucosa and mucosa.

2. Serosa forms outer covering of duodenum. It is derived from the visceral peritoneum and is composed of flat squamous epithelial cells, called as mesothelium.
3. Musculature or muscular coat is composed of two layers of muscular tissue, an outer thinner longitudinal and inner thicker circular.
4. Longitudinal muscles are composed of unstriped fibers. Due to their contraction, the duodenal tube is shortened but the volume of its lumen is widened.
5. Circular muscles consist of circular fibers. By their contraction, the duodenal tube increases in size but the volume of its lumen decreases.
6. Between longitudinal and circular muscles lies a network of lymphatic vessels and nerve fibers.
7. Sub-mucosa is well developed and is composed of loose connective tissue. In it the blood vessels and lacteals ramify before entering or after leaving the mucous membrane.
8. Mucosa is thrown into irregular and branched villi.
9. Muscularis mucosa consists of inner circular and outer longitudinal layers.

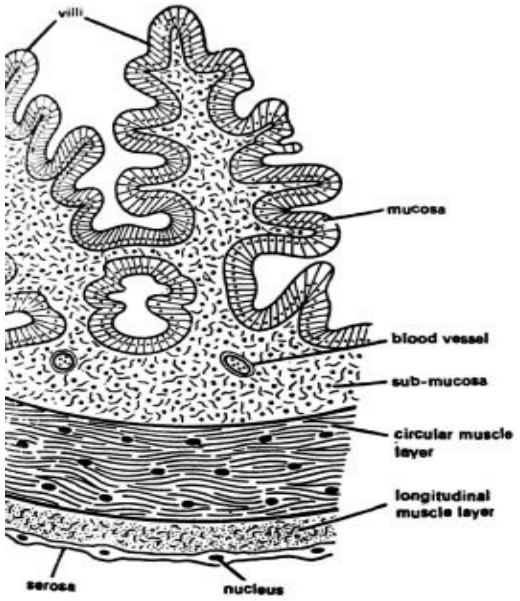

Fig. 14. T.S. passing through duodenum

Fig – 3.14

3.4.4.T.S. passing through intestine

Comments

Transverse section of intestine of frog shows the following histological details:

1. It consists of the usual four layer viz , serosa, muscularis, submucosa and mucosa.
2. The serosa is very thin and made up of single layer of peritoneal cells.
3. The muscularis consists of two layers an outer thin layer of longitudinal muscle fibers and an inner thick layer of circular muscle fibers.
4. The submucosa consists of loose connective tissue fibers and contains lymph spaces and blood vessels.
5. The mucosa is folded into numerous simple folds or villi.
6. The mucosa is made up of single layer of simple columnar epithelium which is formed of absorptive cells and goblet cells.
7. Muscularis mucosa and tubular glands are entirely absent.
8. The numerous folds or villi of mucosa increase the maximum absorptive surface.

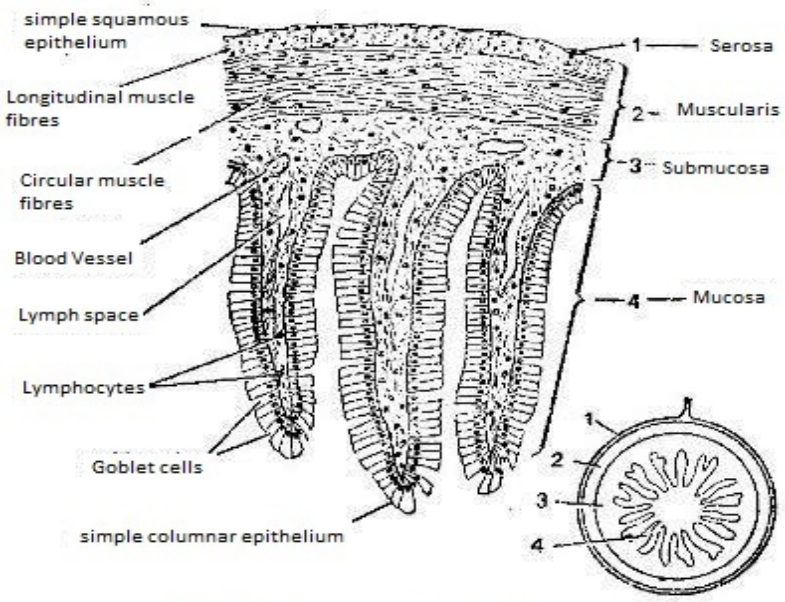

Fig. 15. T.S. passing through intestine

Fig – 3.15

3.4.5.T.S. passing throughliver

Comments:

Transverse section of liver of frog shows the following histological details:

1. It is a compound tubular gland.
2. It consists of a large number of hepatic acini which appear in section lined by hepatic cells.
3. The hepatic acini are made up of granular columnar hepatic cells surrounding bile canalicule in the centre.
4. Each hepatic cell contains a prominent nucleus and granular cytoplasm which indicate its secretary nature.
5. The bile canalicule unite to from the bile ductules and these in turn unite to form bile duct.
6. Blood capillaries and sinusoids or blood spaces are seen among the acini which are formed by the breaking down of the hepatic cells.
7. The structure of the liver helps it in taking the monosaccharides from the blood of the hepatic portal vein and in secreting the bile which is drained through the bile duct.

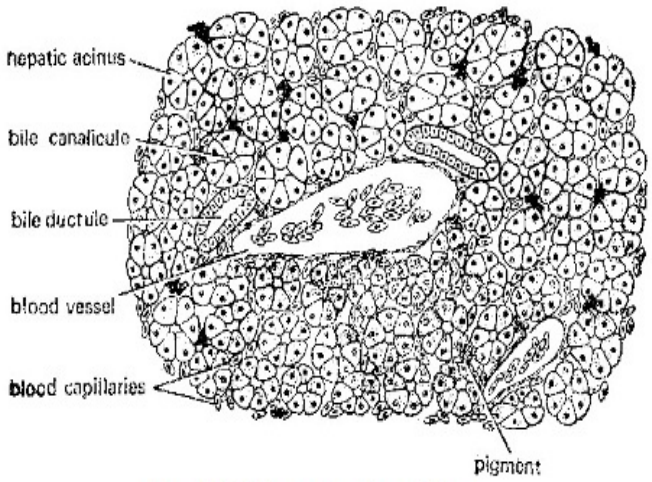

Fig. 16. T. S. passing through liver

Fig – 3.16

3.4.6. T. S. passing through pancreas

Comments:

Transverse section of pancreas of frog shows the following histological details:

1. It is a much branched and grape-bunch-like gland.
2. It consists of a series of pancreatic lobules.
3. The lobules are bounded by connective tissues.
4. Each lobule consists of a cluster of secretary cells enclosing a very narrow central lumen.
5. The cavities of adjacent lobules communicate with one another and finally discharge into the bile duct as it passes through the pancreas.
6. Between the pancreatic lobules there are scattered groups of cells which stain paler and are known as islets of Langerhans.
7. Islets of Langerhans are small prism shaped cells without lumen.
8. Blood vessels are found in and around the islets of Langerhans.
9. The function of pancreas is dual because it produces exocrine as well as endocrine secretions.
10. Pancreatic juice (exocrine secretion) contains three digestive enzymes such as amylopsin, trypsin and lipase.
11. Islets of langerhans also produce an endocrine secretion or hormone known as insulin. The function of this hormone is to store glycogen in the liver cells.

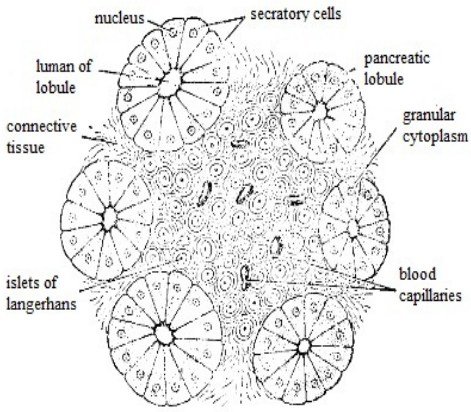

Fig. 17. T. S. passing through pancreas

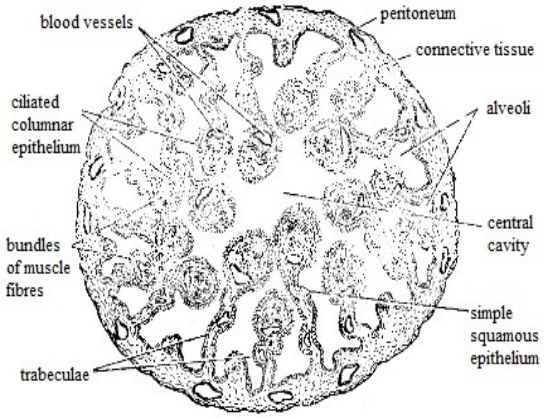

Fig. 18. T.S. passing through lungs

Fig – 3.17

3.4.7. T.S. passing through lungs

Comments:

Transverse section of lung of frog shows the following details:

1. The outer well of the lung is peritoneum consisting of connective tissue which contains some elastic fibres.

2. The peritoneum is covered externally by squamous epithelium or mesothelium.
3. The central cavity of lung is partly divided into numerous chambers or alveoli separated from each other by partitions or trabeculae.
4. The trabeculae are lined partly by a thin, flattened simple squamous epithelium and partly by a ciliated columnar epithelium on the outer edges.
5. The walls of the trabeculae are richly supplied with blood vessels and capillaries.
6. Numerous bundles of muscle fibers are present within the trabeculae.
7. The elastic fibres present in the outer wall of lung give them the remarkable power of contraction and expansion.
8. The respiratory surface is increased by the presence of trabeculae and alveoli.
9. The structure of the lung is such that the blood is separated from the air contained in the alveoli by only two thin membranes, namely the exceedingly thin epithelium of the trabeculae and the thin walls of the capillaries.

3.4.8. T.S. passing throughkidney

Comments:

Transverse section of kidney of frog shows the following histological details:

1. The outermost layer covering the kidney is peritoneum.
2. The uriniferous tubules are numerous and seen in various shapes and sizes.
3. The uriniferous tubules are lined by glandular and ciliated epithelium.
4. The bowman's capsules are cup-shaped, double walled structures.
5. There are afferent and efferent arterioles forming tufts or knots in the bowman's capsules.
6. The tuft of blood vessels, formed within the Bowman's capsule, is known as glomerulus.
7. Several collecting tubules cut in various planes are seen scattered throughout the section.
8. The sections of renal artery, renal vein and renal portal vein are also seen.

9. The Bowman's capsule leads into a uriniferous tubule which is much convoluted and ultimately opens into a collecting tubule.
10. The chief function of kidney is to remove certain nongaseous waste matter like urea, uric acid, and certain salts (phosphates and sulphates) that are brought to them from different parts of the body.

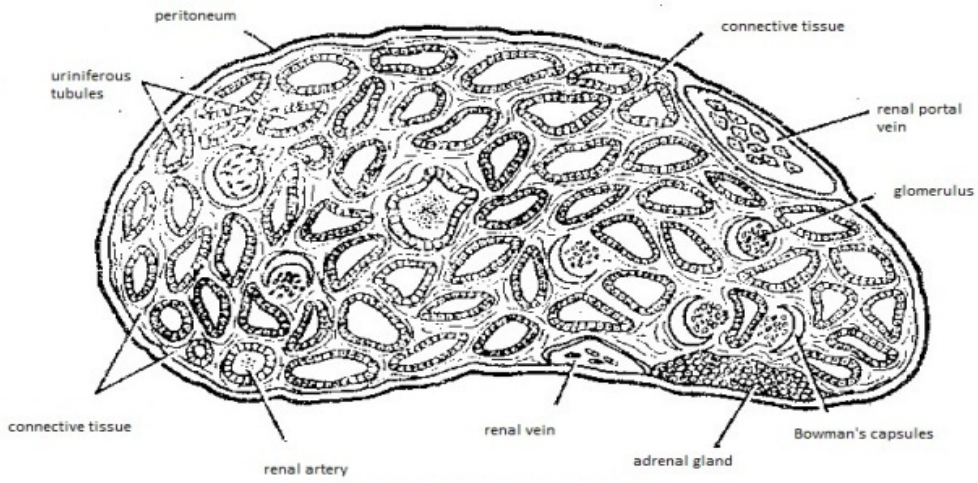

Fig. 19. T.S. passing through kidney

Fig – 3.18

3.4.9. T.S. passing through testis

Comments:

Transverse section of testis of frog shows the following structures:

1. The outer covering is the peritoneal epithelium or peritoneum.
2. Numerous seminiferous tubules are held together by the inter-tubular connective tissue.
3. Each seminiferous tubule is lined with germinal epithelium whose cells undergo spermatogenesis to produce spermatozoa.
4. Bundle of spermatozoa are seen in the lumen of the mature seminiferous tubules.
5. Spermatogonia, spermatocytes and spermatids (stages of spermatogenesis) are also seen.
6. The connective tissue contains interstitial cells which secrete hormones responsible for the appearance of the secondary sexual characters.
7. Sections of blood vessels are seen in the connective tissue.

8. Sertoli cells are absent.

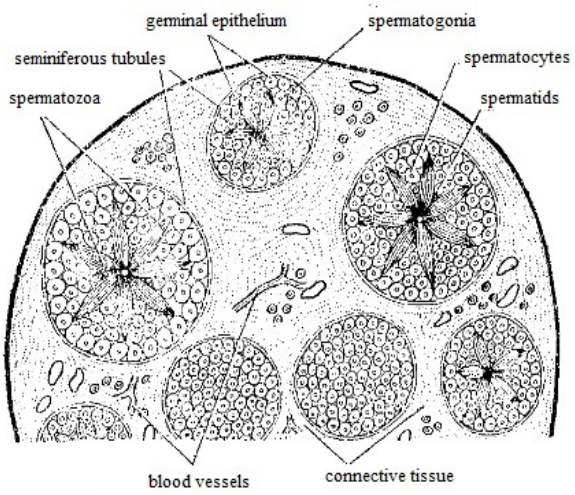

Fig. 20. T.S. passing through testis

Fig – 3.19

3.4.10. T.S. passing through ovary

Comments:

Transverse section of ovary of frog exhibits the following structures:

1. The ovary consists of a number of hollow lobes or lobules in which ova are formed.
2. Each lobule is surrounded externally by theca externa.
3. Several follicles of various sizes are connected to the theca externa.
4. Each follicle of a lobule is surrounded by theca interna which contains muscle fibres,blood vessels and nerves.
5. Each ovum has a nucleus surrounded by yolky granular cytoplasm.
6. The ovum is also surrounded by follicular cells which develop from oogonia.
7. Small patches of germinal epithelium are lying attached to the theca externa at various places.
8. The germinal epithelium undergoes oogenesis and givesrise to ova which can be seen in various stages of development.
9. Fully formed ova are shed into the coelomic cavity of ovary.
10. The theca externa, theca interna and follicular cells from the ovarian which secretes ovarian hormones.

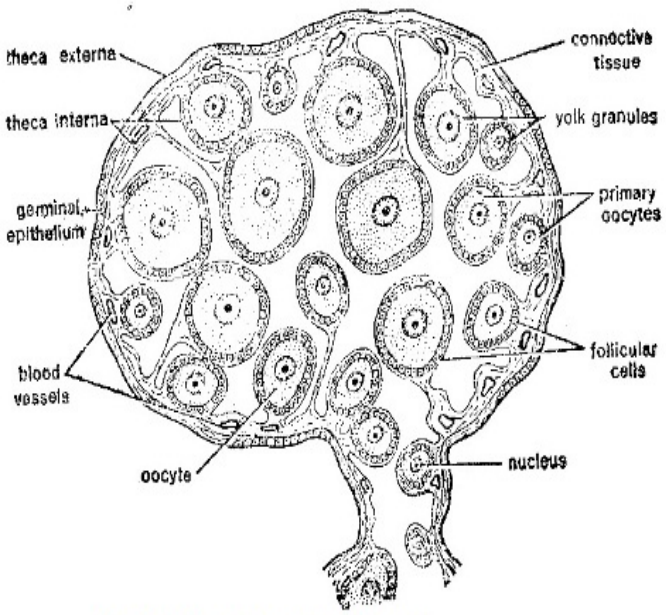

Fig. 21. T.S. passing through ovary

Fig – 3.20

3.4.11. T.S. passing through spinal cord

Comments:

Transverse section of spinal cord of frog shows the following histological structures:

1. The spinal cord is surrounded by twofibrous membranes, i.e., durameter is the thicker and the outer layer.
2. Dura meter is the thicker and the outer layer.
3. The piameter is the thinner and the inner layer.
4. The spinal cord is made up of two kinds of nervous tissues, i.e., outer layer.
5. The grey matter forms the H-Shaped area and composed of gangilion cells.
6. In the centre of grey matter there is a small canal known as central canal which is lined by single layer of epithelium. Its function is presumably to circulate the cerebo spinal fluid.
7. Surrounding the grey matter is the white matter. It consists of axons with their white myelin sheaths.
8. The grey matter gives rise to four horns (cornu). Two dorsal and two ventral.
9. The dorsal horns contain single band of nerve fibres, while the ventral horns contain numerous very slender bands of nerve fibres.

10. On its mid-dorsal side present a very slight dorsal fissure and on the mid-ventral side a slightly wide cleft, the ventral fissure.

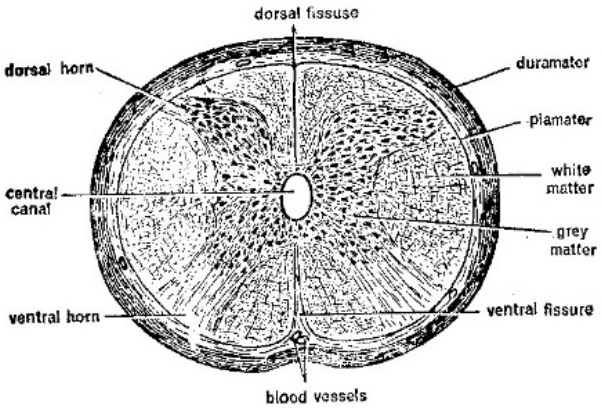

Fig. 22. T.S. passing through spinal cord

Fig – 3.21

3.4.12. T.S. passing through Bone

Comments:

Transverse section of bone of frog shows the following structures:

1. Outer most layer is Periosteum when seen under high magnification.
2. Beneath the periosteum is outer Osteoblast layer.
3. Below the outer osteoblast layer are lamellae osteocyte cells and inner osteoblast layer.
4. Innermost layer endosteum enclosed bone marrow.

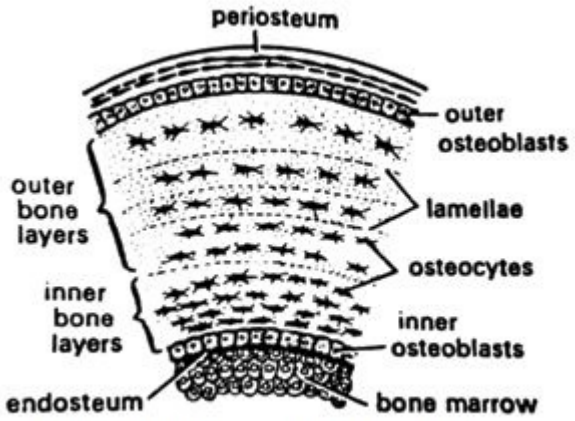

Fig. 23. T.S. passing through bone

Fig – 3.22

3.5 Self-Learning Exercise

1. Describe the characteristic features of *Herdmania* tadpole larva.
2. What is common name of *Amphioxus*?
3. What structures are seen in T.S. passing through oral hood of *Amphioxus*?
4. Describe the characters of Ammocoete larva.
5. What types of scale are present in scolidon?
6. Differentiate between placoid and cycloid scales.
7. Describe the structures seen in T.S. passing through stomach of amphibian.
8. Describe the structures seen in T.S. passing through liver of amphibian.
9. Write the comments on the following:
   i) T.S. passing through Pancreas of amphibian
   ii) T.S. passing through Testis of amphibian
   iii) T.S. passing through Spinal cord of amphibian

3.6 References

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- **Practical zoology Vertebrate**: Lal,S. S. ;Rastogi publications.
- **Vertebrate Practical Zoology:** Agarwal, S. C. and Mishra,S. P. ; Pragati Prakashan, Meerut.
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Unit-4

Microscopic slides-II

Structure of the Unit

4.0 Objectives

After going through this unit you will be able to understand the structure of tissue, organ and histology of representative class of vertebrata viz., reptiles, aves and mammal. It will be helpful to understand the histological variation in tissue of different organs. There relevance in modification and specific functioning has been detailed in this unit.

4.1 Introduction

Study of histological structure of any organism helpful in to understand the specificity and functioning of particular organs. It also helpful to understand the anatomical and physiological relevance of organism. To study histological structure of tissue or organ pre prepared slides are used. In this unit study of prepared slide of classes of vertebrata viz., Reptiles, Aves and Mammals have been given in detail. For the easy understanding well labeled histological diagrams of tissue and organ have also been given.

4.2 Reptilia

4.2.1. V.S. of Skin of Lizard

Comments:

Vertical section passing through skin of Lizard shows following structures:

1. V.S. skin of lizard shows outer epidermis and inner dermis.

2. Epidermis contains horny epidermal scales which are characteristic of reptilian skin.
3. Various layers of epidermis are stratum corneum followed by stratum germinatum or stratum malpighii from which new skin develops.
4. Below stratum germinatum in loose connective tissue, dermal papilla present.
5. Dermis is composed of fibrous connective tissue and conjunctiva tissues.
6. Dermis contains muscles, nerves, blood vessels and chromatophores.
7. Epidermal Scales are identification feature of skin of Lizard.

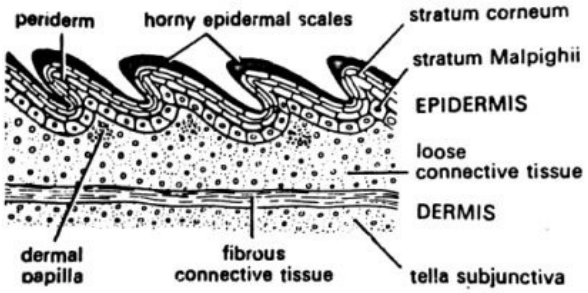


Fig. 4.2.1. V.S. of skin of Lizard

Fig – 4.1

4.3 Aves

4.3.1. V.S. of skin of a bird

Comments:

Vertical section of skin of a bird shows the following details:

1. It consists of two layers, the outer layer epidermis and inner dermis.
2. The outer epidermis is composed of several layers, i.e., epitrichium, stratum corneum and stratum malpighii.
3. The ephitichium is the outermost layer and consists of a single layer of flattened delicate cells.
4. The epitrichium is the middle layer of cells. It is horny and protective.
5. The stratum malpighii is the inner layer of epidermis and composed of large and cylindrical cells.

6. Feather papilla, calamus of down feather along with barbs is also seen in the epidermal layer.
7. The inner dermis is composed of upper vascular spongy layer and lower compact layer.
8. In the spongy layer dermal papilla of permanent feather, involuntary muscles and blood vessels are seen.
9. The innermost compact layer has patches of fat cells on its upper and lower sides.

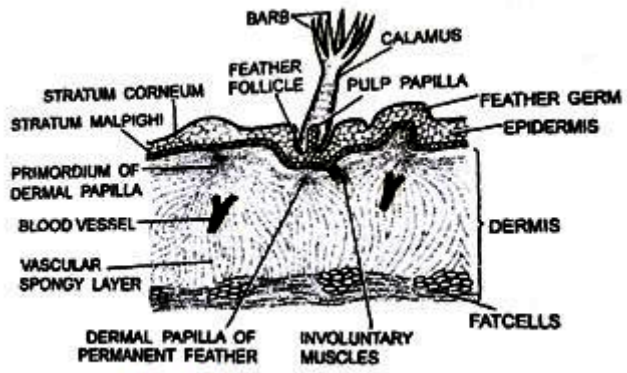


Fig. 4.3.1. V. S. Skin of a Bird.

Fig – 4.2

4.3.2. Contour feather:

Comments:

1. The contour feathers are the outermost feathers.
2. They provide the color and the shape of the bird.
3. The contour feathers tend to lie on top of each other, much like shingles on a roof. The feathers therefore tend to shed rain, keeping the body dry and well insulated.
4. Each contour feather can be controlled by a set of specialized muscles which control the position of the feathers, allowing the bird to keep the feathers in a smooth and neat condition.
5. The largest contour feathers are often the large flight feathers, which are collectively called the remiges. Since they are responsible for supporting the bird during flight, remiges are attached by ligaments or directly to the bone.

6. The outer remiges are referred to as the primaries and are the largest and strongest of the flight feathers. They are attached to the skeletal equivalent of the "hand" of the bird.
7. The inner remiges are called the secondaries and are attached to the "forearm" of the bird. They are located between the body of the bird and the primaries. The secondaries provide lift in both soaring and flapping flight.
8. Highly specialized feathers known as bristles are small contour feathers which lack barbs on the outermost part and have an especially stiff rachis.

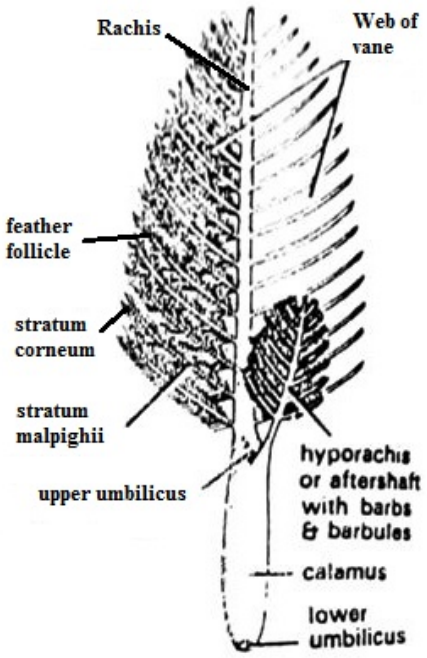


Fig. 4.3.2. Contour feather

Fig – 4.3

4.3.3. Down feather:

Comments:

1. Down feathers keeps birds warm.
2. In down feathers, the rachis is either missing completely or substantially reduced in length.
3. The barbules lack hooks, which combined with the lack of rachis, results in a very soft and fluffy feather. Without the hooks, the barbs and barbules create a puffy tangle of insulating air pockets.

4. Natal downs are typically found on well developed hatchlings that can almost immediately walk or swim independently of their parents.
5. The young of most Passerine species, such as Blue Jays, are totally helpless and virtually naked at birth. It is thought that the baby birds save energy by not producing down and are able to absorb the body heat of the parent bird more easily.

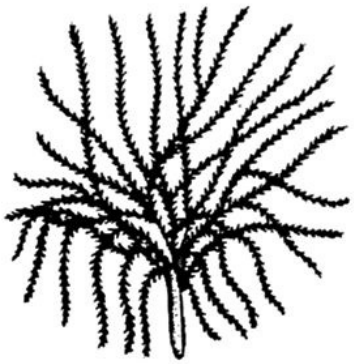


Fig. 4.3.3. Down feather of bird.

Fig – 4.4

4.4. Mammals

4.4.1. V.S. of skin of a mammal

Comments:

Vertical section of skin of a mammal shows the following histological structures:

1. The skin is composed of two layers, i.e., an outer layer epidermis and an inner layer dermis.
2. The epidermis comprises of four layers namely outer stratum corneum, next to it stratum lucidium then stratum granulosum and innermost layer is stratum germinativum.
3. Stratum corneum consists of horny cells and periodically moulted.
4. Stratum granulosum is made up of granular cells.
5. The dermis consists of dense areolar connective tissue, muscle fibres, blood vessels, nerves and glands.
6. The mammalian skin is characterized by the presence of hairs and glands.
7. The hair root is lodged in the hair follicle and hair follicle swells up at the base forming the hair bulb.

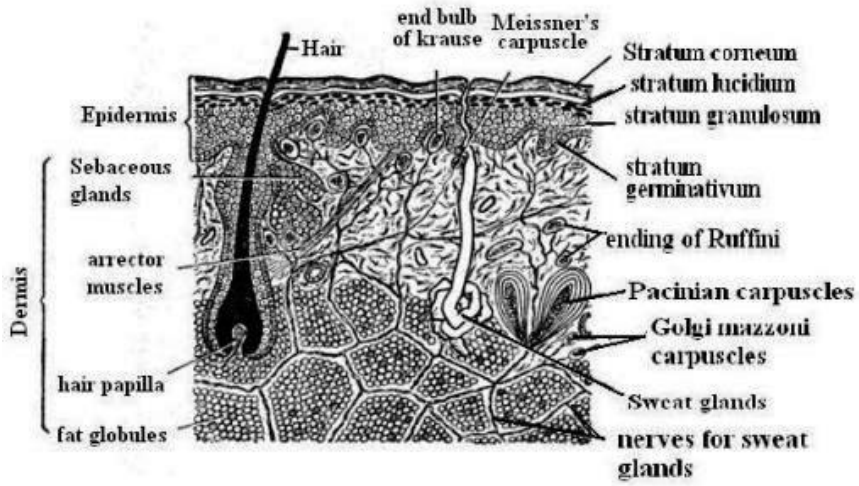


Fig. 4.4.1. V.S. of skin of mammal

Fig – 4.5

8. Blood vessels, nerves and connective tissue from the dermis project into the hair bulb forming the hair papilla.
9. Some unstriated muscle fibres connect the hair with the epidermis. These muscle fibres move the hair involuntarily and are known as arrector muscles of the hair.
10. The glands are of two types namely sebaceous glands and sweat glands.
11. The sebaceous glands are small glands of the simple branched alveolar type. Usually each gland is connected to a hair and opens by a short duct close to it.
12. The sweat glands are coiled, tubular and much longer. Each gland opens on the surface through a long coil duct.
13. The main function of sweat glands is temperature regulation of body.

4.4.2. T. S. passing through stomach

Comments:

Transverse section of a stomach of a mammal shows the following histological details:

1. The serosa is the outermost layer which is composed of simple squamous epithelium.

2. The muscularis consists of two layers; the outer layer is composed of longitudinal muscle fibers, while the inner layer is composed of circular muscle fibres.
3. The muscle fibres in both the layers are arranged in bundles which are bound together by connective tissue.
4. The submucosa is made up of connective tissue containing blood vessels, nerves and lymph in vessels.
5. Muscularis mucosae are a thin layer and its fibres are arranged in two layers.
6. Muscularis mucosae are the thickest layer. It consists of simple columnar epithelium and tubular or gastric glands.

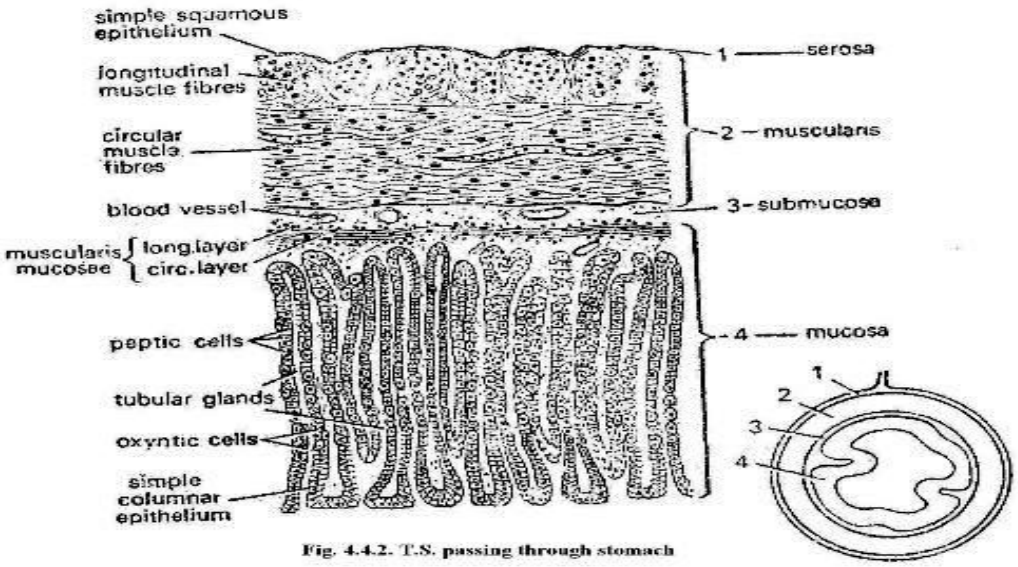


Fig. 4.4.2. T.S. passing through stomach

Fig – 4.6

7. The gastric glands are very long and arranged parallel to each other.
8. They are simple or simple branched tubular type.
9. The gastric glands composed of two types of cells namely peptic cells and oxyntic cells.
10. The peptic cells are found at the base of gastric glands.
11. These are polygonal and granular and secrete digestive enzymes.
12. The oxyntic cells (parietal cells) are found towards the luminal pat of gastric glands.
13. These are circular or oval, non-granulated and secrete HCl.

4.4.3. T. S. passing through intestine

Comments:

Transverse section of intestine of a mammal shows the following histological structures:

1. Outermost layer is serosa which is usually consists of a simple squamous epithelium
2. The muscularis consists of longitudinal muscle fibres to the outside and circular muscle fibres to the inside.
3. The submucosa consists of connective tissue holding blood vessels, nerves and lymphatic vessles.
4. The muscularis mucosaeis thin and double layered consisting of outer layer of longitudinal fibres and inner layer of circular fibres.
5. The mucosa is thrown into numerous large and small finger-like folds villi which are all covered by simple columnar epithelium with scattered goblet cells.
6. Each villus contains blood vessels, lymphocytes and a lacteal.
7. At the base between the villi are present crypts of Lieberkuhn. These are lined by columnar epithelium which contains goblet cells.
8. The crypts of Lieberkuhn into Bruner's glands.
9. The secretions of the crypts of Lieberkuhn and Bruner's glands from the intestinal juices.

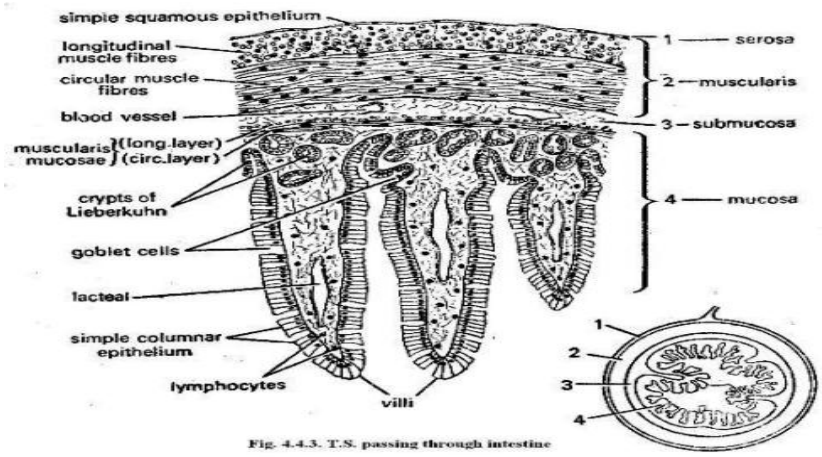


Fig. 4.4.3. T.S. passing through intestine

Fig – 4.7

4.4.4. T. S. passing through liver

Comments:

Transverse section of liver of a mammal shows the following histological structures:

1. The liver is composed of polygonal lobules containing a central vein (intra-lobular vein) in the centre and portal canals at the corners.
2. Each portal canal consists of connective tissue strand and contains a branch of portal vein (inter-lobular vein), hepatic artery, bile duct and lymph vessel.
3. The liver cells are polyhedral or rectangular and arranged in single celled long chains extending radially from the central vein to the periphery of the lobule.
4. Each liver cell has granular cytoplasm and a prominent nucleus.
5. The sinusoid are formed from branched of the hepatic portal veins and empty into central veins.
6. Liver has several functions which are as follows:
   (i) It produces bile which plays an important role in the digestion of food.
   (ii) It stores the soluble products of digestion and metabolizes them for assimilation.
   (iii) Oxidation of sugar takes place in it.
   (iv) Toxic substances are detoxicated in the liver.

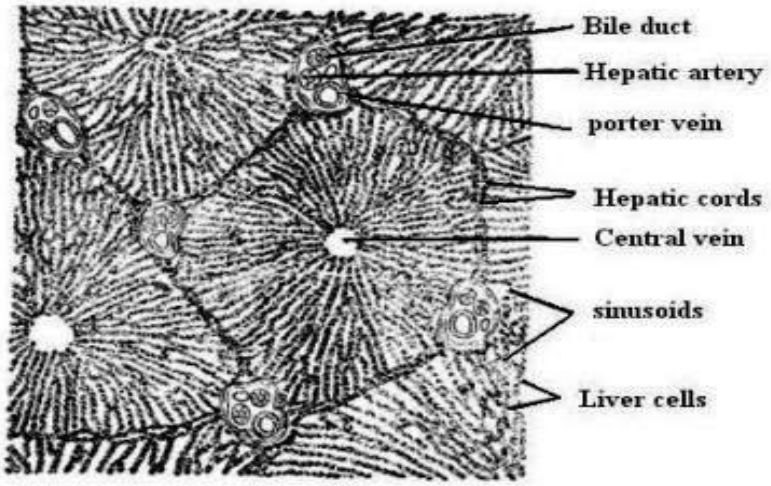


Fig. 4.4.4. T.S. passing through liver

Fig – 4.8

4.4.5. T. S. passing through pancreas

Comments:

Transverse section of liver of a mammal shows the following histological details:

1. The pancreas consists of two portions namely, exocrine portion and endocrine portion.
2. The exocrine portion consists of a series of lobules or acini.
3. The lobules or acini are bound together by loose connective tissue containing blood vessels, nerve and lymph vessels.
4. Each lobule or acini is made up of few pyramidal pancreatic cells having granular cytoplasm and prominent nuclei.
5. The lobules or acini open into small ductules which join large ducts and eventually the main pancreatic ducts.
6. The exocrine portion produces pancreatic juice which contains trypsin, amylase and lipase enzymes.

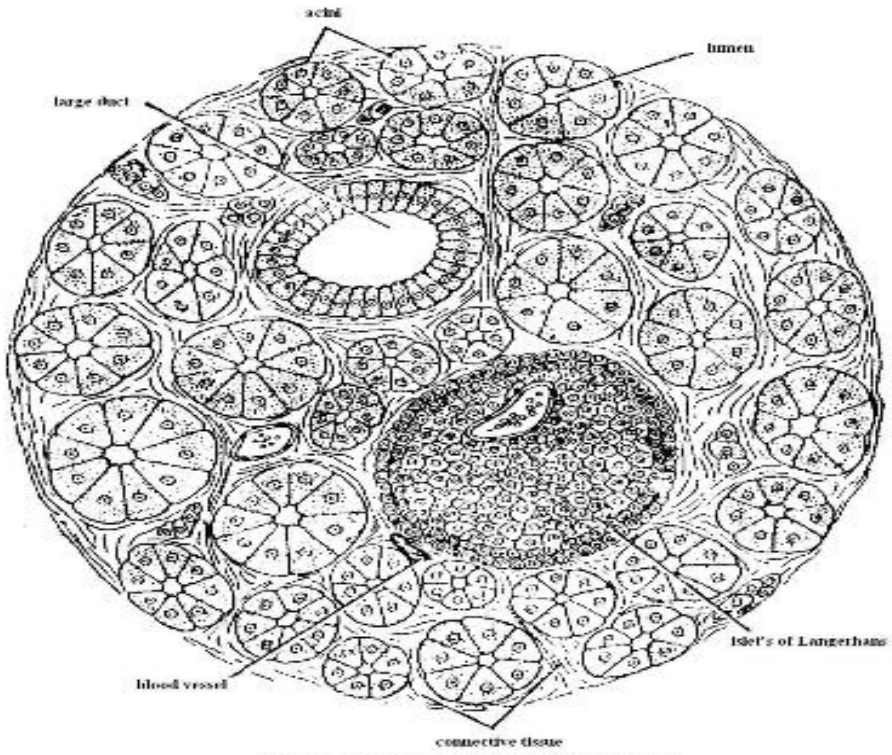


Fig. 4.4.5. T.S. passing through pancreas

Fig – 4.9

7. The endocrine portion is composed if islets of langerhans found between the acini.
8. The islets of langerhans are compact masses of cells and secrete two hormones namely insulin and glucagon.
9. The insulin is said to be produced by the beta cells of islets of langerhans. It reduces the sugar contents of the blood.
10. The glucagon is said to be produced by alpha cells. It increases the sugar contents of the blood and thus causes diabetes.
11. Pancreas acts both as an exocrine as well as endocrine gland.

4.4.6. L.S. passing through kidney

Comments:

Longitudinal section of kidney of a mammal shows the following histological details:

1. The kidney is surrounded by a capsule of dense connective tissue.
2. The glandular part of the kidney composed of outer cortex and inner medulla.
3. The cortex contains numerous uriniferous tubules, malpighian capsules having Bowman's capsules and glomerulus scattered throughout.
4. The medulla is composed of several renal pyramids, medullary rays, columns of Bertini, tubules of medulla and connective tissue.
5. The depression found in the middle of the inner concave region is known as hilus.
6. A slender muscular tube known as ureter takes its origin at the hilus and runs backwards to join the urinary bladder.
7. The renal artery and renal vein are in and out of the hilus.
8. The renul pelvis comprises uniferous tubules which include the proximal portion of ureter, major renal calyces (branches of ureters towards the renal portion) and minor renal calyces (branches of the major calyces).

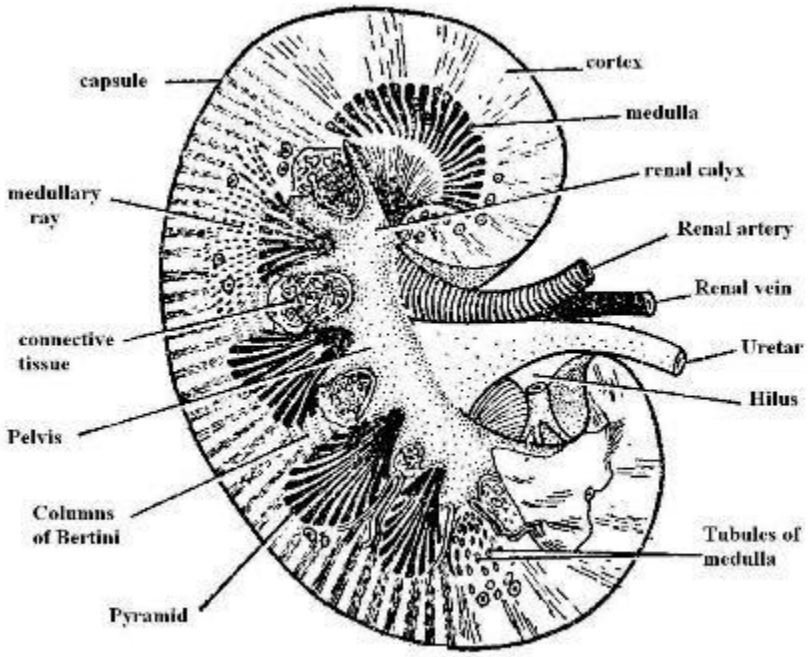


Fig. 4.4.6. L.S. passingh through kidney

Fig – 4.10

4.4.7. T.S. passing through Testis

Comments:

Transverse section of testis of a mammal shows the following details:

1. The testis is somewhat rounded or oval in shape and surrounded by peritoneum followed by a layer of fibrous connective tissue, the tunica albuginea.
2. Histologically each testis is composed of a mass of coiled seminiferous tubules.
3. The seminiferous tubules are separated from one another by intertubular tissue.
4. The intertubular tissue is formed of connective tissue which holds the tubules together and contains blood vessels and interstitial cells.
5. The interstitial cells secrete a hormone testosterone responsible for male secondary sexual characters.
6. Each seminiferous tubule appears rounded or oval in section surrounded by basement membrane and lined by germinal epithelium.

7. In between the germinal cells certain larger cells called Sertoli cells are usually seen. These cells have the role of supplying nourishment to the developing sperms.
8. The germinal epithelium gives rise to sperms which are seen in various stages of development in a seminiferous tubule as follows:
   (i) The spermatogonia lie along the periphery of the tubule and appear closely packed together.
   (ii) The spermatocytes lie just below the spermatogonia which develops into primary and secondary spermatocytes
   (iii) The spermatids aggregate in clusters below the spermatocytes.
   (iv) The spermatozoa lie in the cavity of the tubule, grouped in clusters and appear connected with Sertoli cells.
9. A spermatozoon or sperm has an elongated head and long delicate tail. Its nucleus lies in the head.

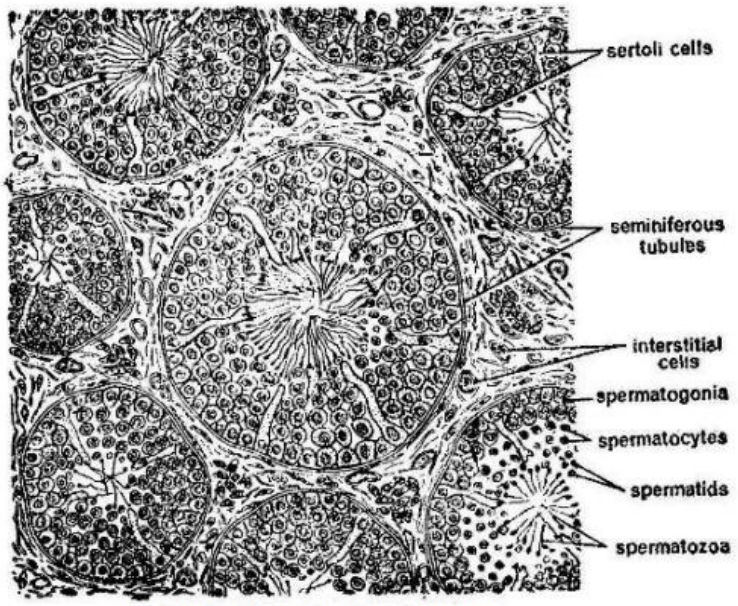


Fig. 4.4.7. T.S. passing through Testis

Fig – 4.11

4.4.8. T.S. passing through ovary

Comments:

Transverse section of ovary of a mammal shows the following important structures:

1. The ovary is lined by germinal epithelium which is bounded by the connective tissue, the tunica albuginea.
2. It consists of mass of connective tissue and spindle-shaped cells, the two together forming the stroma.
3. Lying in the stoma are egg cells in various stages of development, each surrounded by a nourishing epithelial layer, the follicle and blood vessels.
4. In the section egg nest, primary follicle approaching maturity showing antrum formation. Mature follicle, follicle approaching maturity showing antrum formation, mature follicle, ruptured follicle, young and fully formed corpus luteum and corpus albicans are seen.
5. The primary follicle arise form ingrowth of the germinal epithelium into the stroma.
6. One group of cells enlarges to form a developing ovum, while the other forming a single layer of cells the follicle around it.

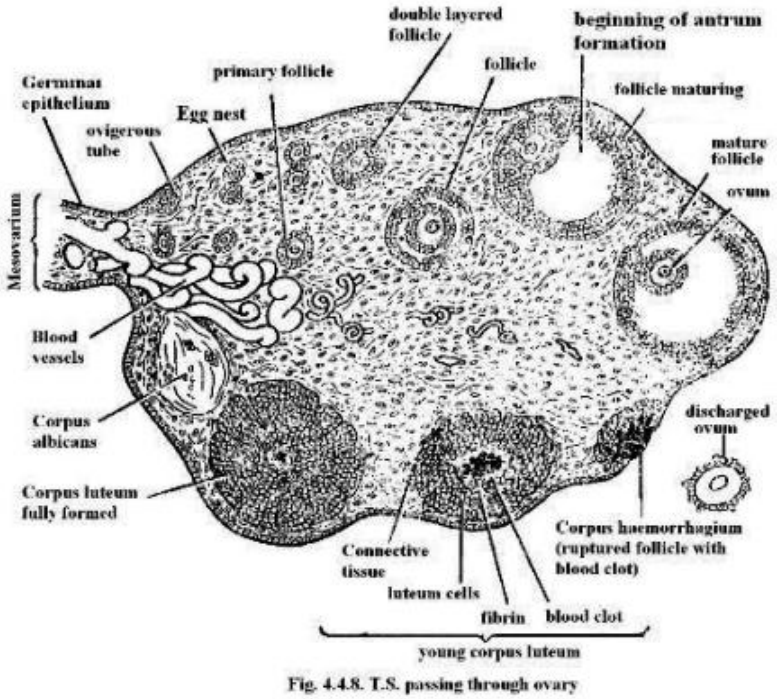


Fig. 4.4.8. T.S. passing through ovary

Fig – 4.12

7. The follicle and ovum slowly move deeper into the stroma and become larger.

8. Later ovum and cells around it become separated by fluid filled space from the rest of the follicle cells except at one point forming the antrum.
9. Further the enlargement of the ovum and follicle results in the production of a mature follicle or Graafian follicle.
10. A mature follicle (Graafian follicle) is made up of three layers, an outer theca externa, middle layer theca interna and the inner layer membrane granulose.
11. A mature Graafian follicle then migrates to the surface of the ovary and ruptures releasing the ovum into the Fallopian tube.
12. After discharging of ovum, the follicle cells undergo proliferation and change in structure to form corpus luteum which secretes hormone, progestrone.

4.4.9 V.S. passing through thyroid gland

Comments:

Vertical section of thyroid gland of a mammal shows the following histological details:

1. The thyroid gland of a mammal lies on the ventro-lateral surface of the larynx and the posterior portion of trachea.
2. It consists usually of two lobes connected by an istbumus.
3. Histologically it consists of an outer fibrous capsule and a number of rounds, oval or oblong thyroid follicles separated by interior-follicular tissue.
4. The fibrous capsule is composed of fibrous connective tissue containing large blood vessels and surrounds the thyroid gland.
5. Each thyroid follicle is lined with simple cuboidal epithelium.
6. The cells of cuboidal epithelium contain large nuclei and pour their secretion into the cavity of follicle.
7. The cavity of lumen of each follicle is filled with colloid.
8. The inter-follicular tissue is composed of reticular connective having numerous food vessels and capillaries.
9. Thyroid gland secretes thyroxine hormone.
10. Thyroxine controls the entire metabolism of animals.
11. Thyroid is an endocrine gland.

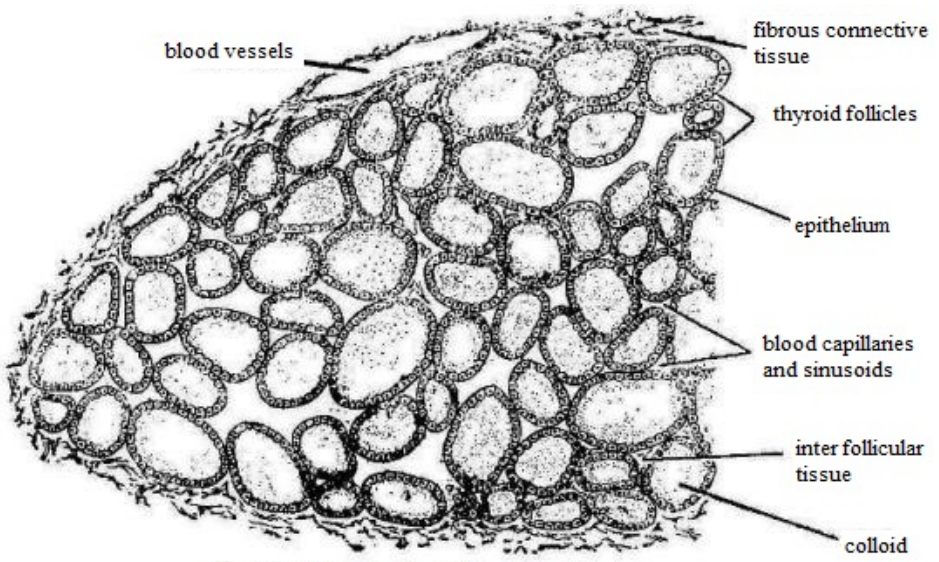


Fig. 4.4.9. V.S. passing through thyroid gland

Fig – 4.13

4.4.10. T.S. passing through adrenal gland

Comments:

Transverse section of adrenal gland of a mammal shows the following histological structures:

1. The adrenal gland is composed of two distinct parts, i.e., outer cortex and inner medulla surrounded by the capsule.
2. The capsule is composed of fibrous connective tissue containing blood vessels and nerves.
3. The cortex lies next to the capsule and is differentiated into three zones namely zona glomerulosa. Zona fasciculate and zona reticularis.

   (i) Zona glomrulosa is made up of columnar cells containing large nuclei. The cells are arranged in oval groups which resemble either closed or open vesicles.

   (ii) Zona fasciculate consists of columns of large rounded cells containing nuclei. The cells are arranged radially in double rows.

   (iii)Zona reticularis consists of networks of columnar cells containing pigment granules. Numerous blood sinusoids are found in the networks.

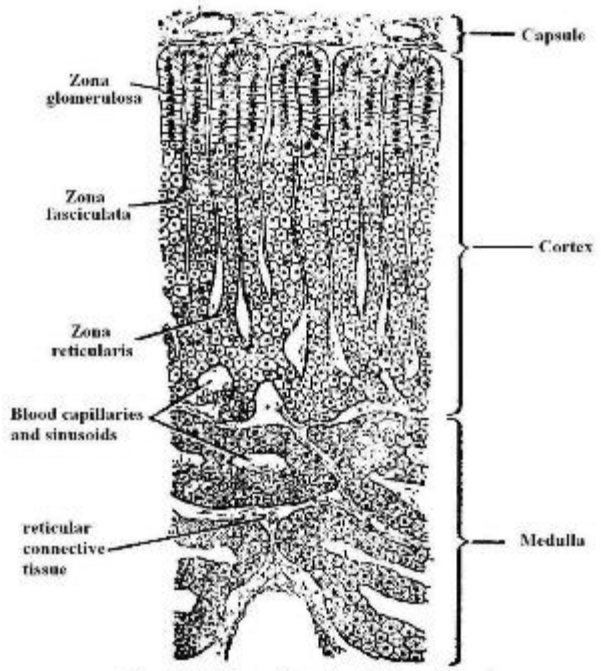


Fig. 4.4.10. T.S. passing through adrenal gland

Fig – 4.14

4. The cortex produces a hormone known as cortin. It regulates the general metabolism, controls the sodium chloride content of the blood and also promotes the breaking down of the tissue proteins top amino acids.
5. Medulla is the central portion, consists of networks or cords of polygonal cells and clusters of chromaffin cells, networks of cells contain numerous blood capillaries, sinusoids and in the centre of a central vein.
6. Medulla secretes a hormone known as adrenalin. It is responsible for maintaining the blood pressure, dilation of vessels and muscles, increasing the general metabolism rate and also for hastening the coagulation of blood.
7. The adrenal glands are endocrine glands and lie just above the kidney attached to it by a fold of mesentery.

4.4.11. V.L.S passing through anterior lobe of pituitary gland

Comments:

Vertical longitudinal section of anterior lobe of pituitary gland of a mammal shows the following histological structures:

1. The pituitary gland is more or less glandular in shape and occurs at the base of brain in the region of diencephalon.
2. It is composed of three lobes namely, anterior lobe, intermediate lobe and posterior lobe,.
3. The anterior lobe forms the largest part of pituitary gland.
4. It is formed of three distinct kinds of cells differing in their staining reactions.
5. Usually on the outerside are basophil cells which are stained by basic stains.
6. In the centre are found acidophil or oxyphil cells which take stain with acid stains.
7. The third type of cells is chromophobe cells which are indifferent to either basic or acid stains. They are found scattered throughout the anterior lobe.

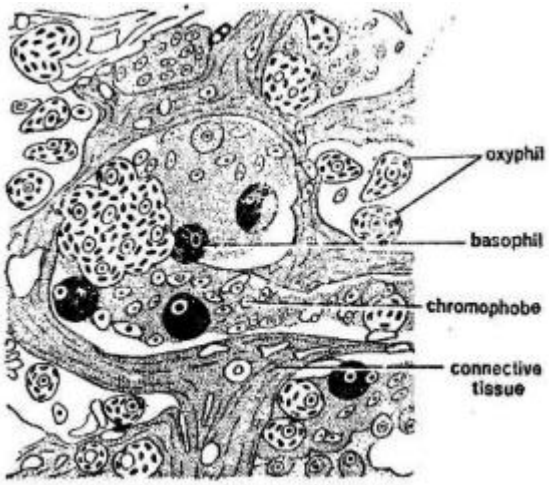


Fig. 4.4.11. L.S. passing through pituitary gland

Fig – 4.15

8. The anterior lobe produces many hormones namely somatotrophic hormone, adrenocorticotrophic hormone, gonadotrophic hormone and thus controls growth, development of sex glands as well as the activities of thyroid, adrenal and parathyroid glands.
9. The intermediate lobe is composed of cell cords with colloid filled follicles. It produces an intermedin hormone.
10. The posterior lobe is composed of neurological cells, connective tissue fibres and blood vessels. It produces pituitrin, vasopressin and oxytocin hormones.

11. The pituitary gland is an endocrine gland of utmost importance to organisms.

4.4.12. T. S. passing through lung

Comments:

Transverse section of lungs of a mammal shows the following structures:

1. Histologically it consists of numerous alveoli.
2. The alveoli communicate with one another by a pertures in their walls.
3. Around each alveolus is a network of capillary blood vessels in connection with pulmonary artery or vein of the lung.
4. Numerous alveoli from clusters which open in a alveolar duct.
5. Each bronchus s it enters the lungs, divides and sub-divides into the finer and finer branches, the bronchioles.

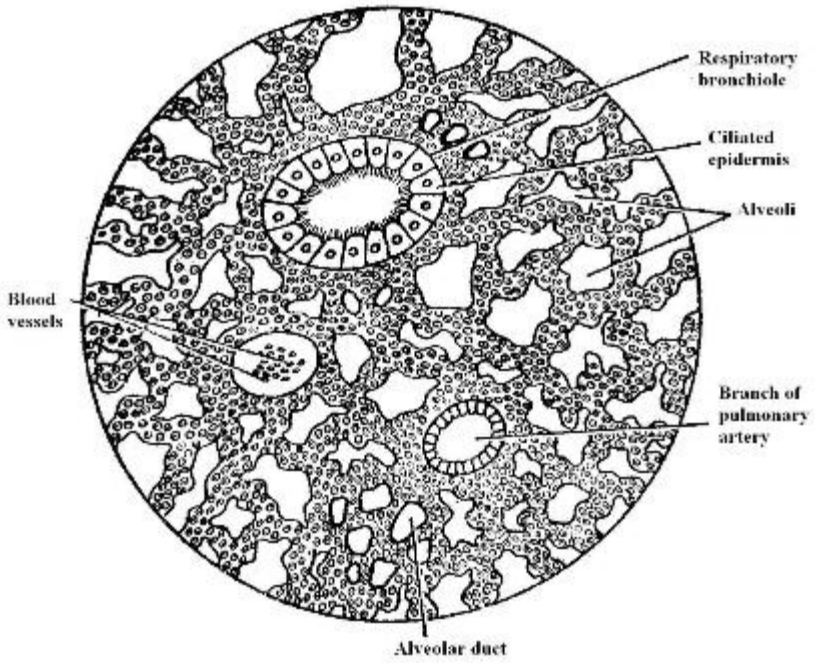


Fig. 4.4.12. T.S. passing through lung

Fig – 4.16

6. The bronchioles are subdivided into respiratory bronchioles.
7. The respiratory bronchiole gives rise to several alveolar ducts which open into alveoli or air-sac.
8. The alveoli which are richly supplied with blood vessels form the seat of respiration

9. The air is taken into the alveoli by the respiratory bronchioles through alveolar ducts which get it from bronchioles which in their turn get it from the bronchus.

   Air⟶ trachea⟶ bronchus⟶ bronchioles⟶ respiratory bronchioles⟶ alveolar ducts⟶ alveoli⟶ gaseous exchange takes place and CO_2 is taken out.

4.4.13. T.S. passing through bone

Comments:

1. **Haversian system**

   (i) Each consisting of a central Haversian canal surrounded by rings of osteocyytes lying each in a lacuna.

   (ii) The lacunae are connected together by five canaliculi.

   (iii) Among the rings of lacunae lie very thin concentric layers of bone lamellae which compose the matrix of tissue.
2. Some bone lamellae, bone lacunae and canaliculi are present among the Haversian system but are not arranged around Haversian canals. These are called interstitial lamellae or non Haversian system.
3. Haversian canals are about 22-110 microns in diameter.

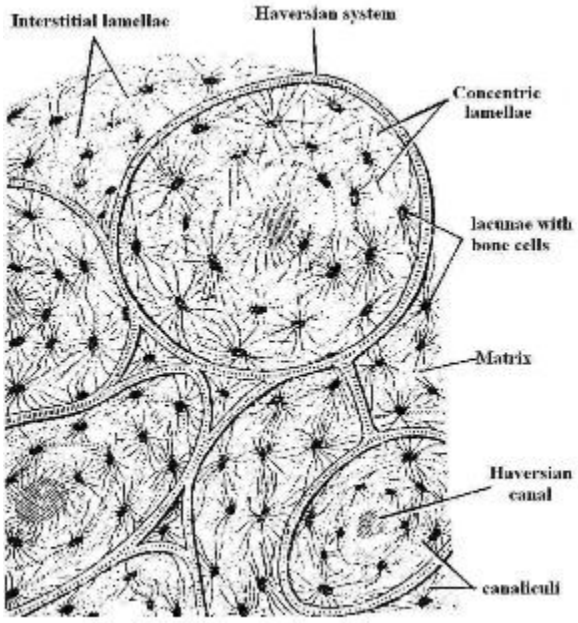


Fig. 4.4.13. T.S. passing through Bone

Fig – 4.17

4.4.14. T.S. passing through spinal cord

Comments:

Transverse section passing through spinal cord shows the following structures:

1. The thin layer of piameter surrounds the spinal cord.
2. In the mid-dorsal surface is a dorsal fissure or septum and in the mid-ventral surface is a ventral fissure which is slightly wider.
3. In the centre there is a small cavity known as central canal. It is lined by simple epithelial cells.
4. The substance of the cord is differentiated into two zones i.e., the central zone called grey matter and a peripheral zone called the white matter.
5. The grey matter is H-shaped projecting dorsally into two dorsal horns and ventrally into two ventral horns.
6. The grey matter shows the presence of bodies of neurons with tree-like branching of their dendrons and neuroglial cells.
7. The white matter is composed of obliquely running medullated nerve fibres supported by prolongations of the neuroglia.
8. The bands of fibres which extend transversely, one dorsal and other ventral to the central canal, are known as dorsal and ventral commissars respectively.

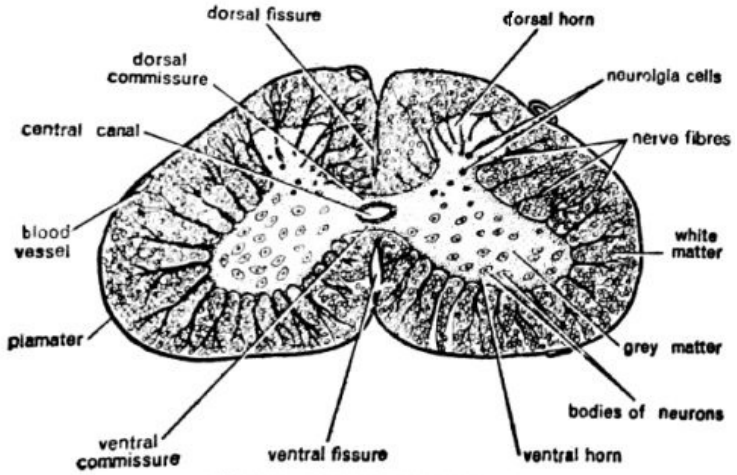


Fig. 4.4.14. T.S. passing through spinal cord

Fig – 4.18

4.4.15. Blood smear

Comments:

The thin film of mammalian blood on slide shows the following structures:

1. It shows numerous blood corpuscles of different shapes and size suspended in the plasma.
2. The erythrocytes (R.B.C.) are round, non-nucleated and biconvex blood cells plays role in oxygen transportation.
3. The leucocytes (W.B.C.) are colourless, nucleated and shows amoeboid movement. Three types of leucocytes are seen in blood smear:
   (i) Polymorphonuclear leucocyte: The nucleus of this type of leucocytes is divided into a number of segments (3-5) connected with one another by fine thread. The cytoplasm of this type of cells is granular.
   (ii) Macrocytes are largest leucocytes and posses a horse shoe-shaped nucleus. The cytoplasm of these cells is without granules.
   (iii) Lymphocytes are small with large nucleus and little cytoplasm.
4. The number of erythrocytes in normal adult man and woman is about 4.5 million or 5.0 million/mm^3 of blood.

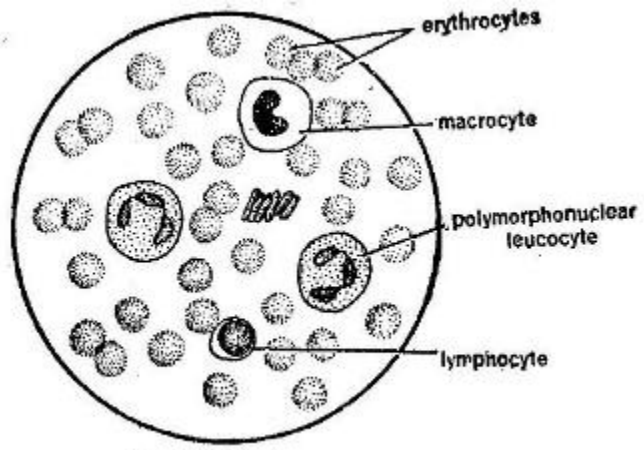


Fig. 4.4.15. Blood smear

Fig – 4.19

4.4.16. Simple Cuboidal epithelium

Comments:

1. All body surfaces except the teeth and the gliding surfaces of joints are normally covered with epithelium.

2. It is tightly-joined cells over a layer of collagen i.e. basement membrane which join it with connective tissue.
3. It is single layered and most elementary epithelium.
4. It is found in small surfaces of glands. Also found in endocrine glands (ductless gland) having epithelium as secretary in function.

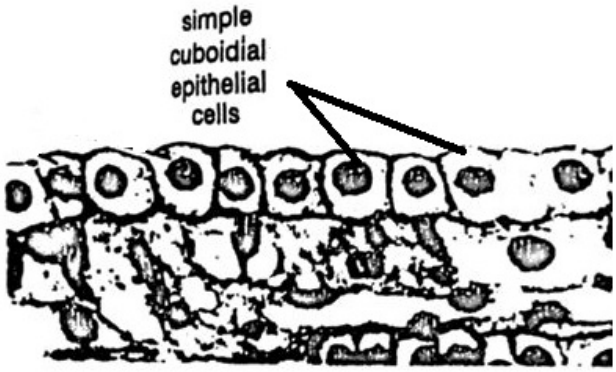


Fig. 4.4.16. Simple Cuboidal epithelium

Fig – 4.20

4.4.17. Simple Columnar epithelium

Comments:

1. Simple columnar epithelial cells are column shaped.
2. Their nucleui are found at the base of the cell.
3. The cells are connected by tight junctions.
4. The cells receive nutrients through the basement membrane, which separates the cells from the capillary basal layer.
5. Simple columnar epithelium lines most organs of the digestive tract including the stomach, small intestine and large intestine which mostly protective in function.

Fig. 4.4.17. Simple Columnar epithelium

Fig – 4.21

4.4.18. Simple squamous epithelium

Comments:

1. It consists of a single layer of flattened plate- like cells.
2. The cells are closely fit together by their edges and form a sort of mosaic.
3. The cells frequently have a roughly hexagonal, irregular and wavy outline.
4. Each cell contains a nucleus.

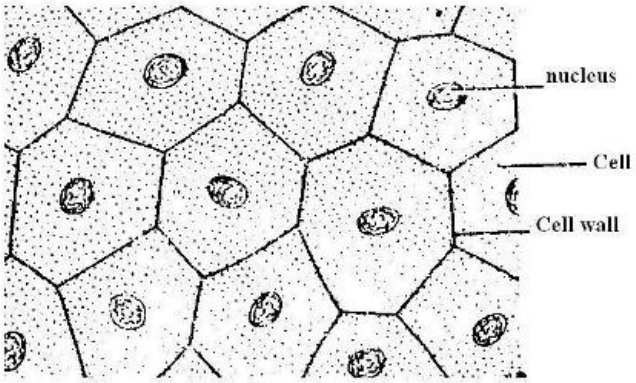


Fig. 4.4.18. Simple suamous epithelium

Fig – 4.22

4.4.19. Adipose tissue

Comments:

1. Adipose tissue is located beneath the skin, around internal organs, in bone marrow (yellow bone marrow) and in the breast tissue.

2. Adipose tissue is found in specific locations which are known as adipose depots.
3. Cells of adipose tissue are known as adipocytes.
4. Their main function as reserviour of lipids.
5. These lipids can be burned to meet the energy needs of the body and to protect it from excess glucose by storing triglycerides produced by the liver from sugars.

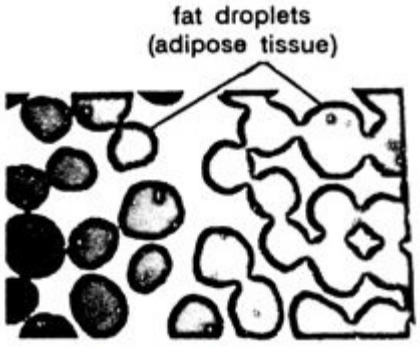


Fig. 4.4.19. Adipose tissue

Fig – 4.23

4.4.20. Reticular tissues

Comments:

1. Reticular tissue consists of network of reticular fibers.
2. Reticular fibers are synthesized by special fibroblasts known as reticular cells.
3. These cells contain stiff interconnected cytoplasmic fibrils.
4. In space between reticular cells, other kind of cells like blood cells, nerves are present.
5. These tissues form a soft skeleton to support the lymphoid organs (lymph node, spleen and red bone marrow.

Fig. 4.4.20. Reticular tissues

Fig – 4.24

4.5 Self-Learning Exercise

1. What is the identification feature of Skin of Lizard and Bird?
2. What is difference between contour and down feather?
3. Name the layers of mammalian stomach.
4. Describe T.S. of mammalian liver.
5. Which hormones are released by pancreas?
6. Name the blood structure seen in a thin film of mammalian blood.
7. Differentiate between simple, cuboidal and columnar epithelium.
8. What are the functions of adipose tissue?
9. Where does adipose tissue located?
10. What is reticular tissue?
11. Comments upon the following:
    - i) T.S. passing through skin of mammal.
    - ii) T.S. passing through kidney of mammal.
    - **iii)** T.S. passing through testis of mammal.

4.6. References

- ***A manual of practical Zoology: Chordates:*** Verma, P. S. ; S. Chand and Company Ltd.
- ***Practical zoology Vertebrate:*** Lal, S. S. ; Rastogi publications.
- ***Vertebrate Practical Zoology:*** Agarwal, S. C. and Mishra, S. P. ; Pragati Prakashan, Meerut.
- ***Advanced Practical Zoology***: Verma, P.S. and Srivastava, P.C., S. Chand and Company Ltd.

Unit-5

Comparative Osteology

Structure of the Unit

5.0. Objectives

After going through this unit you will be able to understand the osteology of various representatives of vertebrate animals. In this section you will learn the endoskeleton of Frog, *Varanus*, Fowl and Rabbit. After going through this section will be able to distinguish the bones of different animal and you can compare the bone of each animal with another one.

5.1. Introduction

The skeleton refers to the bones inside the body, which is describing as an endoskeleton means internal framework of bones. The endoskeleton is an important system inside the body. On the basis of endoskeleton, two distinct divisions in the Fauna have been made- one Chordata and other Non-chordata, with and without internal framework. Broadly endoskeletal system is differentiated into three parts as follows:

I. **Axial skeleton**: It includes Skull, and bones of face.
II. **Vertebral column**: It includes vertebrae, ribs and sternum.
III. **Appendicular skeleton**: It includes Girdles and limb bones.

The skeletal system may be studied in comparative manner. To study vertebrate osteology four typical animals, namely Frog (Amphibia), *Varanus* (Reptile), Fowl (Aves) and Rabbit (Mammal) have been used.

5.2. Skeleton of Frog

5.2.1. AXIAL SKELETON

1. Skull of frog

1. Skull is triangular, dorso-ventrally flattened and broad.
2. Skull is dicondylic, i.e., two occipital condyles, one on each exoccipital. It articulates with the atlas vertebra by two occipital condyles.
3. Occipital region is greatly reduced.
4. The cranium is small and narrow.
5. Platybasic. i.e., an inter-orbital septum is absent and the cranium extends beyond orbits.
6. The fronto-parietal is present on the roof of the cranium.

7. The nasals are large triangular bones covering the olfactory capsules.
8. The shbenethmoid extends forward into the region of olfactory capsule and is partly covered by the fronto-parietal and nasals above and parasphenoid below.
9. Parasphenoid is dagger-shaped bone forming the floor of the cranium.
10. Vomers lie beneath the nasals and bear vomerine teeth.
11. Upper jaw consists of premaxillae, maxillae and quadratojugals.
12. Lower jaw consists of dentaries and angulosplenials.
13. The supensorium is autostylic, i.e., the lower jaw is attached to the skull through rod-like quadrate cartilage.
14. Basisphenoids, alisphenoids, presphenoids and supra-and basioccipitals are absent.
15. Prootic bones are present on the sides of the exoccipitals.
16. Squamosals are T-shaped present on the dorsal side.
17. Pterygoids lie opposite to the squamosals on the ventral side.
18. Palatines are rod-shaped present on the ventral side with one end touching the maxilla and the other sphenethmoid.

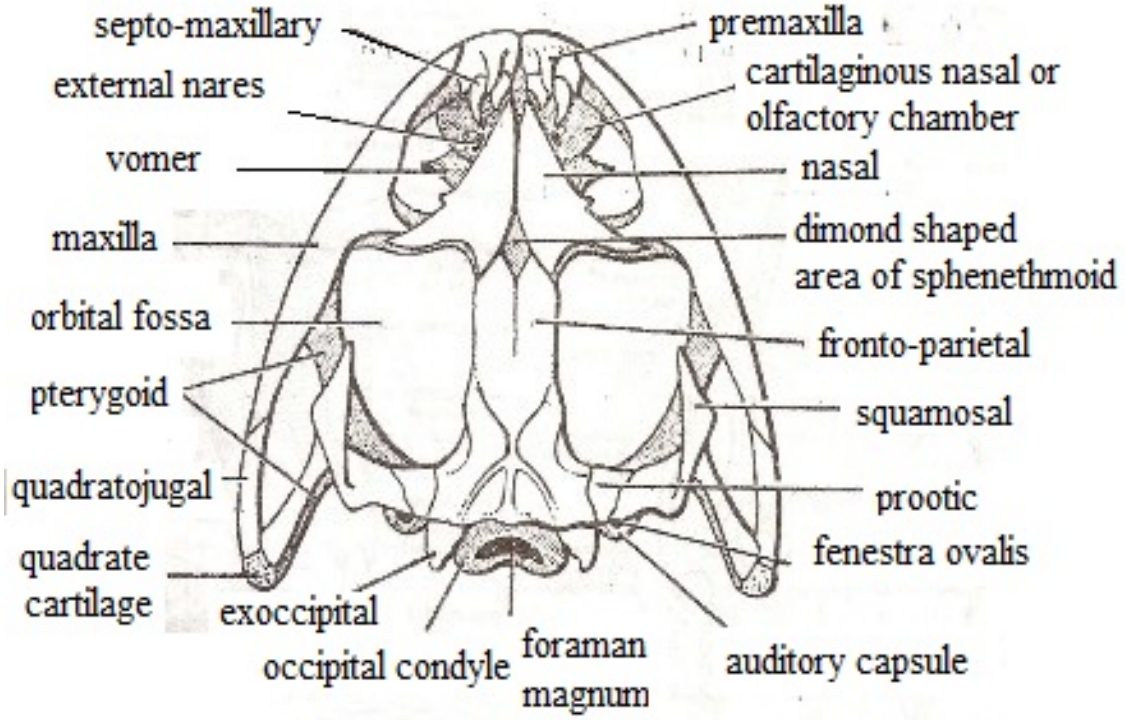


Fig. Skull of frog (dorsal view)

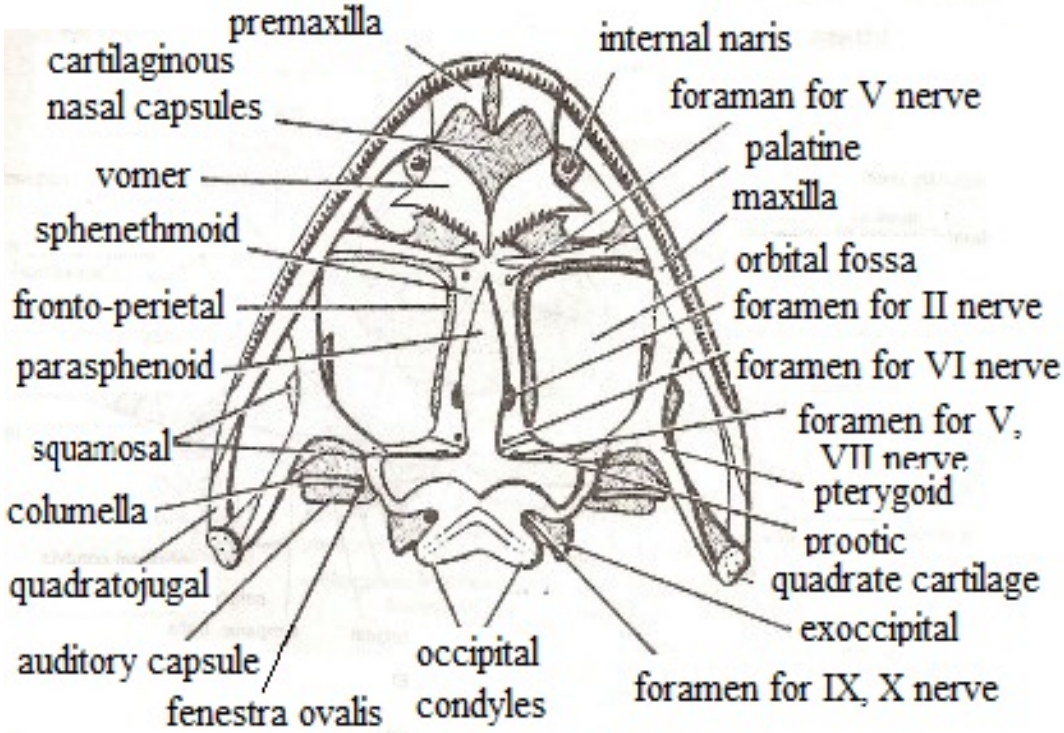


Fig. Skull of frog (ventral view)

Bones seen on the dorsal surface:

Premaxillae, maxiallae, quadrotojugals, squamosals, septomaxillaries, nasals, fronto-parietals, prootics, excocipitals and occipital condyles.

Bones seen on the ventral surface:

Premaxillae, maxiallae, quadrotojugals, vomers, palantines, sphenethmoids, parasphenoid, pterygoids and exoccipitals.

2. Occipital segment

1. Occipital segment forms the posteriormost part of the skull.
2. There is present a large hole, the foramen magnum through which the spinal cord enters the cranium.
3. The exoccipitals are present on either side of the foramen magnum.
4. Each exoccipitals bears an occipital condyle on its posterior surface.
5. Occipital condyles articulate with atlas vertebra.
6. On the outer side of each occipital is fused an auditory capsule are formed by the prootic bone.
7. The fronto-parietal forms the roof of the foramen magnum, while its floor formed by parasphenoid.
8. Supraoccipital and basioccipitals are absent.

3. Fronto-Parietals

1. These are compound and membranous bones of the fronto-parietal region of the skull.
2. These are formed by the fusion of two frontals and two parietals.
3. The frontals and parietals of both the sides unite along the middorsal line to form the fronto-parietals.
4. Fronto-parietals extend in front overlapping the sphenethmoid and behind upto the excoccipitals.
5. These articulate with the prootic bones on its posteriror sides.

4. Parasphenoid

1. Parasphenoid is dagger or inverted ‟ ” shaped bone of the skull.

2. It covers the floor of the cranium in the mid-ventral line.
3. The blade is directed anteriorly and covers the sphenethmoid.
4. The handle with the croos-piece overlaps the occipital region

5. Sphenethmoid

1. Sphenethmoid is the hollow tubular bone extending forward into the region of olfactory capsules.
2. It is partly covered by the fronto parietals and nasals above and paraphenoid below.
3. It is divisible into an anterior ethmoidal portion and a posterior sphenoidal portion.
4. The ethmoidal portion is divided by a longitudinal septum into right and left portion enclosing the olfactory sacs.
5. The sphenoidal portion encloses the fore brain.

6. Premaxilla

1. Premaxilla is the anteriormost bone of the upper jaw.
2. It is a smaller irregular bone in the anterior portion of the snout and meeting with its counterpart in the middle line.
3. It bears two rows of 5 and 4 concial teeth on tis ventral surface along the anterior end.
4. Dorasally it gives off a posterirorly directed end.
5. Thje dorsal process forms the part of the inner boundary of external nostril.
6. On its posterior side, the premaxilla meets the maxilla of its side.

7. Maxilla

1. It is a long, thin and slightly curved bone.
2. Maxilla constitutes the greater portion of the outer margin of the upper jaw.
3. It bears numerous minute, sharp, pointed and backwardly directed homodont leeth along its whole length.
4. It articulates in front with premaxilla and behind with quadrojugal.

5. On its inner side it articulates with the palatine and the anterior limb of pterygoid.

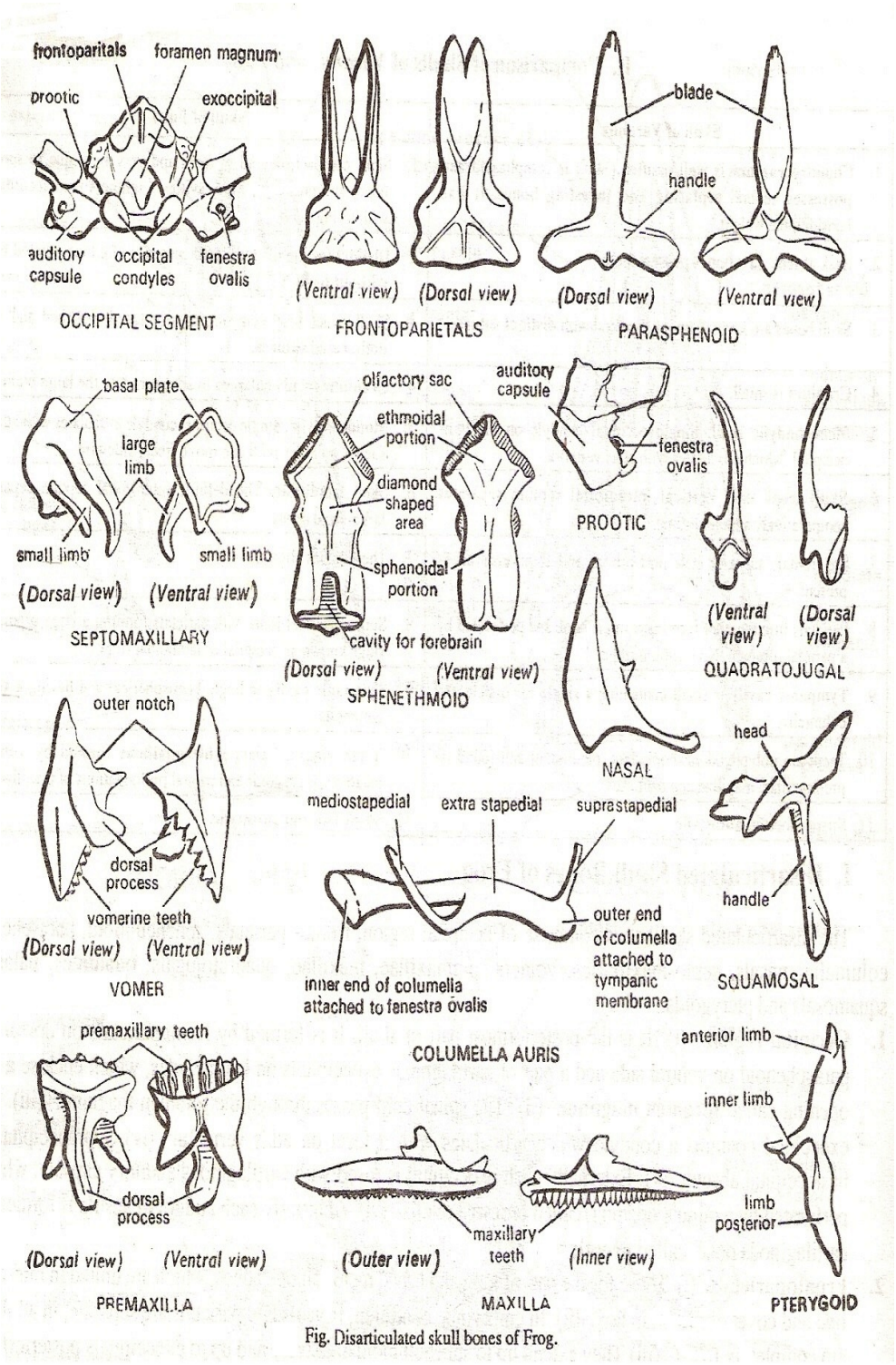


Fig. Disarticulated skull bones of Frog.

8. Quadrato-jugal

1. Quadrate- jugal is small, slender and croma-shaped bone.
2. It forms the posterior portion of the outer margin of the upper jaw.
3. It articulates anteriorly with the maxilla and posteriorly with the quadrate cartilage and squamosal.

9. Nasal

1. Nasal is large, flat, triangular and membranous bone covering the olfactory capsule.
2. It lies nearly on the mid-dorsal side of the skull and unites with its counterpart in the median line.
3. Its anterior end reaches upto the dorsal process of premaxilla.
4. Its outer process unites with the maxilla, while its posterior process overlaps the ethmoidal portion of sphenethmoid.

10. Septomoxillary

1. Septomxillary is a small irregular bone.
2. It consists of a basal plate and a pair of backwardly directed processes.
3. The backwardly directed processes are distinguished as large and small limb.
4. It lies near the anterior of each nasala.

11. Vomer

1. Vomer is somewhat triangular bone lying below the nasal.
2. The posterior margin bears about 7 vomerine teeth.
3. It forms ventrally the floor of olfactory capsule and inner margin of the posterior nares.

12. Palatine

1. Palatine is a slender, rod-like bone lying just in front of the orbit on the ventral surface of the skull.
2. Its outer end touching with the maxilla and inner end touching the sphenethmoid.

13. Squamosal

1. Squamosal is "**T**" or hammer shaped bone lying on the dorso-lateral side of the posterior end of cranium above the pterygoid.
2. It consists of a backwardly directed handle and a forwardly directed head.
3. The handle articulates to the quadrate cartilage and the posterior limb of the head articulates to the outer side of the auditory capsule.

14. Pterygoid

1. Pterygoid is a triangular bone lying almost opposite to the squmosal on the ventral side towards the posterior end of the cranium.
2. Its anterior limb articulates with the maxilla.
3. Its inner limb joins with the parasphenoid and auditory capsule.
4. The posterior limb meets the quadratojugal and quadrate cartilage.
5. Pterygoid also forms the posterior ventral boundary of the orbit.

15. Lower jaw

1. The lower jaw of frog is composed of two halves or rami.
2. The two rami united anteriorly by a ligament.
3. Each half of ramus consists of three portions, *viz.,*mentro-meckelian, dentary and angulosplenial.
4. Mentomeckelian is a small cartilaginous bone, present at the anterior symphysis of two rami.

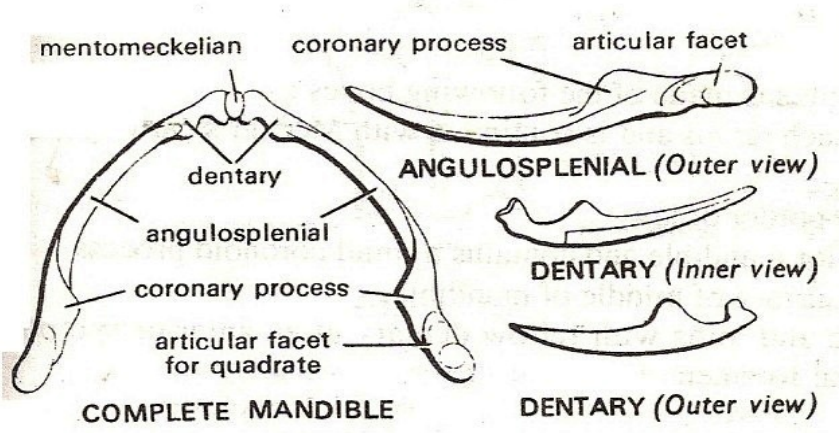


Fig. Mandible of Frog.

16. Dentary

1. It is a small, flat and dagger-shaped bone of the lower jaw.
2. Anteriorly it unites with the menfomeckelian, while its posterior part runs along the outer side of the angulosplenial.
3. There are no teeth on it.

17. Angulosplenial

1. It is a long and curved bone, constituting the most of the inner and posterior portion of each ramus of the lower jaw.
2. Its anterior end is tapering, while its posterior end bears articular surface for the articulation with the quadrate cartilage.
3. Just in front of the articular surface is present a protuberance the coronary process.
4. Teeth are absent.

18. Hyoid apparatus

1. The hyoid apparatus is a cartilaginous plate supporting the base of tongue.
2. It lies below the tongue in the floor of buccal cavity.
3. It composed of three parts, viz., body of hyoid, anterior cornua and posterior cornua.
4. Body of hyoid is a thin, membranous and squarish plate bearing short process at each angle of the plate.

5. From the antero-lateral ends of the body of hyoid arise a pair of long, slender and curved cartilaginous process, the anterior cornua.
6. From the middle of the posterior side of the body of hyoid arise a pair of short and stout processes the posterior cornua.
7. Posterior cornua support the laryngo-tracheal chamber.

5.2.2. VERTEBRAL COLUMN

1. Atlas vertebra

1. First vertebra is called the atlas.
2. It is small and ring-like in form.
3. Centrum and neural spine are reduced.
4. Transverse processes and prezgapophysis are present.
5. The neural arch is large.
6. The anterior face of centrum possesses a pair of concave facets for the articulation with th occipital condyles of the skull.
7. The posterior margin of the neural arch bears a pair of postzgapophyses.

2. Typical vertebra

1. In frog 2-7 vertebrae are typical in structure.
2. The centrum is procoelous(concave on the anterior face and convex on the posterior face).
3. It is ring-like having a large hole called the neural canal.
4. The solid arch on the dorsal side of the ring is called the neural arch.
5. The neural arch bears a small, blunt and mid-dorsal neural spine which is directed backwards.
6. Transverse processes are long,tapering and outwardly directed.
7. A pair of small upwardly and inwardly directed articular facets called the prezygaphophyses is present on the anterior margin of neural arch.

8. A pair of small downwardly and outwardly directed postzygapohpyses is present on the posterior margin of the neural arch.

3. Second vertebra

Second vertebra resembles the typical vertebra in structure except slight variations.

1. Its neural spine is comparatively short and concical.
2. Its transverse processes are small, flat and distantly broad.

4. Fourth vertebra

Fourth vertebra also resembles the typical vertebra in structure except slight difference.

Its transverse processes are broad distally.

5. Eight vertebra

1. The centrum is amphicoelous (biconcave on both the sides).
2. The anterior concavity receives the posterior concavity of seventh vertebra.
3. The posterior concavity receives the anterior convexity of ninth vertebra.
4. Transverse processes are long, slender and outwardly directed.
5. Prezgapophyses and postzygaprophyses are present on the anterior and posterior margins respectively.

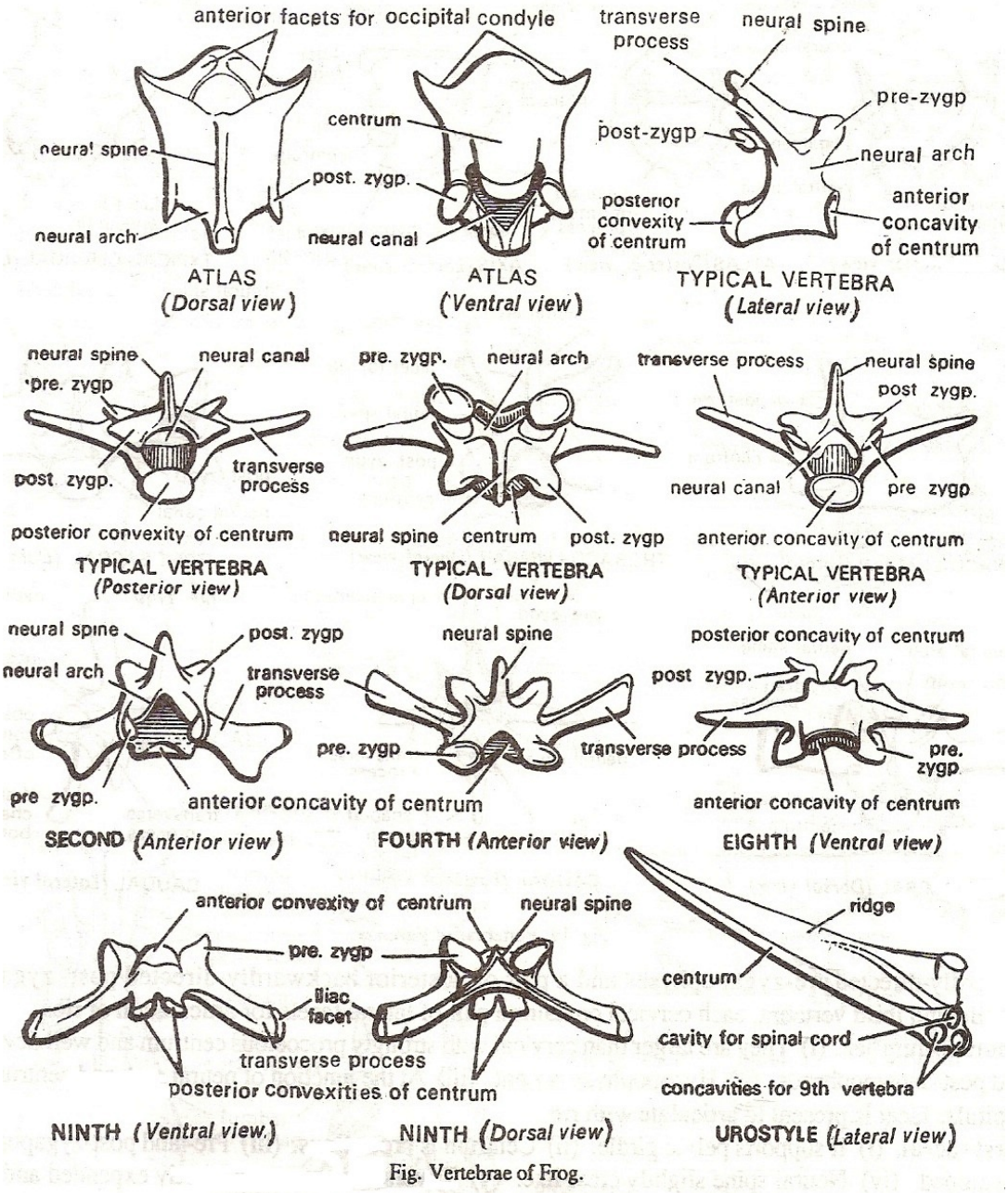


Fig. Vertebrae of Frog.

6. Ninth vertebra

1. Ninth vertebra is also known as sacral vertebra.
2. The centrum is biconvex, i.e., convex on both the sides (bearing one convexity anteriorly and two convexities posterior).
3. The anterior convexity fits into the posterior concavity of eighth vertebra.
4. The posterior convexities fit into the anterior concavities of urostyle.
5. Transverse processes are cylindrical, stout and backwardly directed.
6. Iliac facet is present at the tip of each transverse process for the articulation of ilium of pelvic girdle.
7. Neural spine is inconspicuous i.e., greatly reduced.
8. Prezygapophyses are well developed along the anterior end of neural arch, while the postzygapophyses are entirely absent.

7. Urostyle

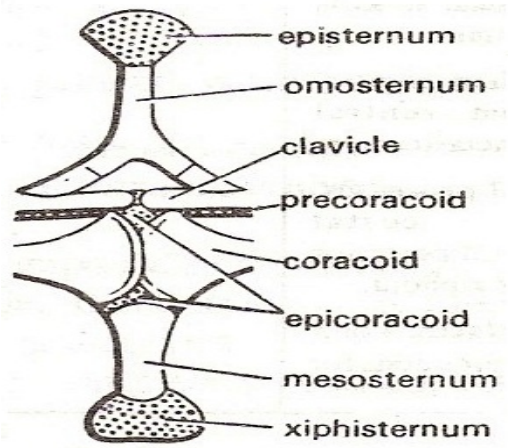
1. Urostyle is the xth vertebra representing the caudal region in the frog.
2. It is long and triangular with pointed apex directed backwards.
3. Centrum is long, rod-like broad anterior end bearing two concavities to receive the convexities of IXth vertebra.
4. Dorsally it is raised into a vertical ridge gradually tapering posteriorly.
5. Anteriorly the vertical ridge contains a short, narrow canal for spinal cord.
6. Transverse processes, pre- and postzygapophyses are entirely absent.

5.2.3 APPENDICULAR SKELETON

1. Pectoral girdle and sternum

1. Pectoral girdle is present in the thoracic region (shoulder region) and provides attachment to the fore-limbs and their muscles.
2. It protects the interior softer parts of the thorax.
3. It consists of two similar halves united mid-ventrally and separated dorsally.

4. Each half is divided into a dorsal scapular portion and a ventral coracoids portion.
5. The scapular portion comprises the supra-scapula and scapula.
6. Supra-scapula is a thin cartilaginous plate on the dorsal side.
7. Scapulas is a bony plate having a glenoid cavity into which articulates the head of humerus.
8. The coracoids portion comprises the clavicle, coracoids, precoracoid and epicoracoid.
9. Clavicle and coracoids meet mid-ventrally with the sternum and their counterparts of other side by a strip of cartilage-the epicoracoid.
10. The sternum lies in the mid-ventral line, it consists of episternum, omosternum and xiphisternum.
11. The episternum is flat, almost circular plate of cartilage.
12. The omosternum is a bony rod connected to the episternum on the anterior side and clavicle on the posterior side.
13. The mesosternum is cartilaginous rod lying opposite the omosternum.
14. The xiphisternum is the terminal broad cartilaginous plate lying at the tip of the mesoternum.



STERNUM OF FROG
(Ventral view)

2. Pelvic girdle

1. Pelvic girdle lies in the posterior region of the trunk.
2. It gives support to the hin-limbs.

3. It is V-shaped and composed of two similar halves each of which is known as os-innominatum.
4. Each os-innominatum is composed of three bones-ilium, pubis ans ischium.
5. Ilium is greatly elongated and forms the major part of each osinnominatum. It runs forwards to meet the transverse process of the ninth vertebra.
6. It bears a prominent vertical ridge the iliac crest on its dorsal surface.
7. Pubis is much reduced. It is a triangular piece of caclcified cartilage.
8. Ischium is larger and slightly oval bone.
9. The disc formed by the union of three bones contains a cup-shaped cavity acetabulum.
10. In acetabulum the head of the femur articulates.

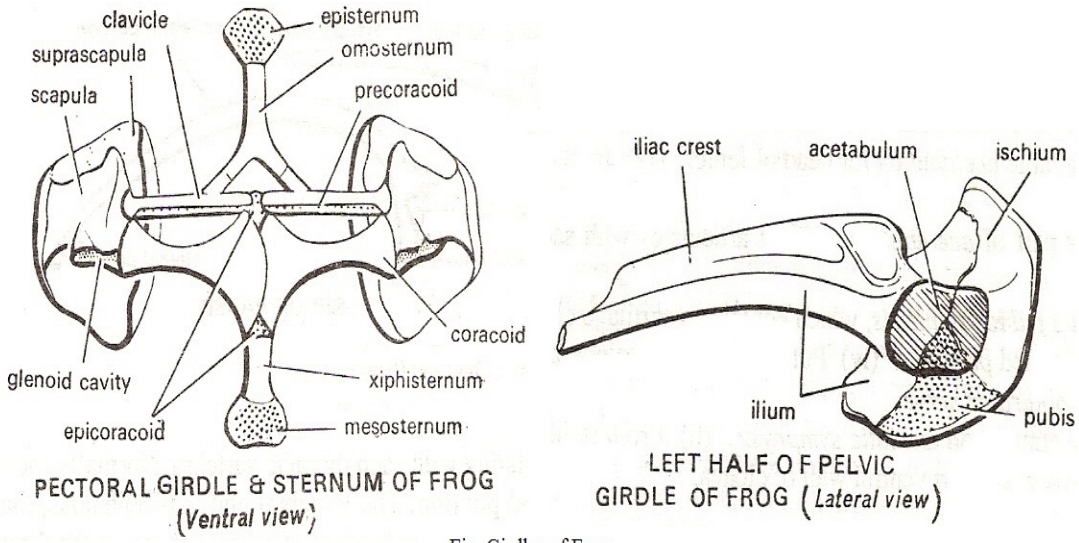


Fig. Girdles of Frog

3. Humerus

1. It is the bone of fore-limb and is the component of upper arm.
2. It is a short, stout and cylindrical bone with a slightly curved shaft.
3. Its proximal end is known as the head which fits into the glenoid cavity of pectoral girdle.
4. The head is covered with calcified cartilage.
5. The ridge below the head is known as deltoid ridge.

6. The distal end forms a rounded trochlea with a condylar ridge on the either side.
7. The trochlea articulates with the groove of radio-ulna.

4. Radio-ulna

1. It is a compound bone of fore-limb and is the component of the fore-arm.
2. It is formed by the fusion of radius and ulna bones.
3. Its proximal end has a concavity to receive the trochlea of humerus.
4. The ulna projects into an olecranon process.
5. The distal portion of radio-ulna is somewhat flat having a groove.
6. Distal portion has an articular surface for the metacarpals.

5. Bones of hand

1. The bones of the wrist are called carpals.
2. The carpal bones are six in number and arranged in two rows of three each.
3. The bones of the proximal rows are called ulnare, intermedium and radiale. These bones articulate with the radio-ulna.
4. The bones of distal row are called capithomatum, Trapezoid and trapezium. These bones articulate with the metacarpals.
5. The hand is provided with five slender metacarpals. The first metacarpal is rudimentary.
6. The digit corresponding to thumb is absent.
7. The remaining four metacarpals are supported by phalanges.
8. The second digit bears 2 phalanges.
9. The third and fourth digits bear 3 phalanges.

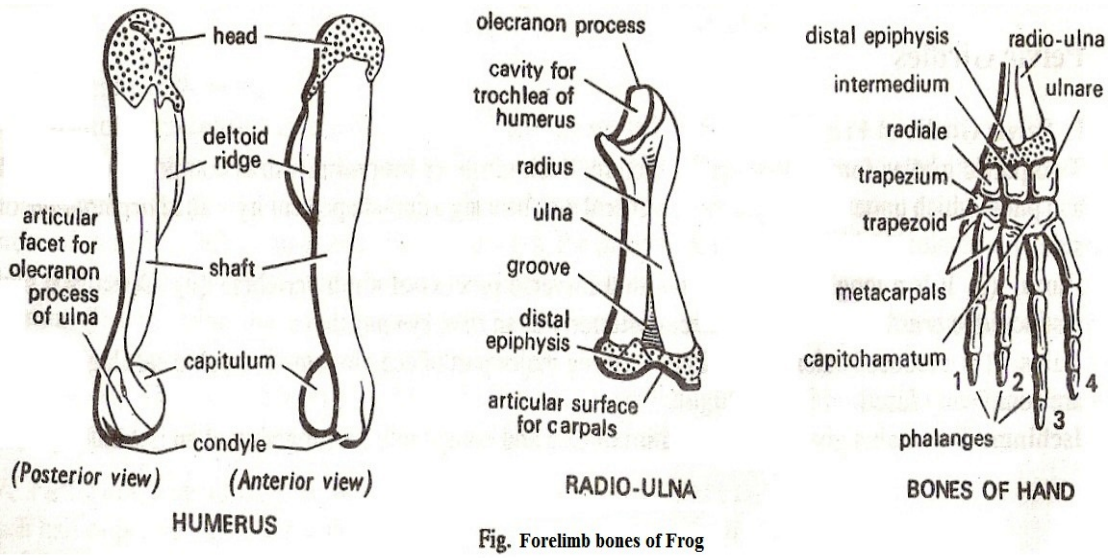


Fig. Forelimb bones of Frog

6. Femur

1. Femur is the bone of thigh region of hind-limb.
2. It is long and slender having a slightly curved shaft.
3. The proximal swollen end is called the head.
4. Head fits into the acetabulum of pelvic girdle.
5. The distal end forms a condyle which articulates with the tibio-fibula.
6. The head and condyle are covered by calcified cartilage.

7. Tibio-fibula

1. Tibio-fibula is a compound bone of the shank region of hind limb.
2. It is formed by the fusion of tibia and fibula bones forming a single bone cslled the tibio-fibula.
3. The proximal and distal ends are covered by cartilage.
4. Near the proximal end tibia bears a cnemial or tibial crest.
5. The proximal end articulates with astragalous calcaneum.

8. Astragalus-calcaneum

1. Astragalus-calcaneum is a compound bone of ankle of hind-limb.

2. The ankle consists of two rows of four bones. The first or two long proximal row consists of two long bones fused together at their proximal and distal ends with a wide gap in the middle.
3. The inner bone is thicker and straight curved called the astragalus or tibiale.
4. The outer bone is thicker and straight called the calcaneum or fibulare.
5. The proximal and distal ends are covered by epiphyses of calcified cartilage.

9. Bones of foots

1. The foot of frog is supported by five metatarsals bearing five true toes.
2. The metatarsals are long and slender bones.
3. The first, second, third and fourth metatarsals bear 3 phalanges each.
4. A small preaxial sixth toe composed of 2 or 3 bones is present on the inner side of the first toe or hallux.
5. Preaxial sixth toe is called the prehallux.

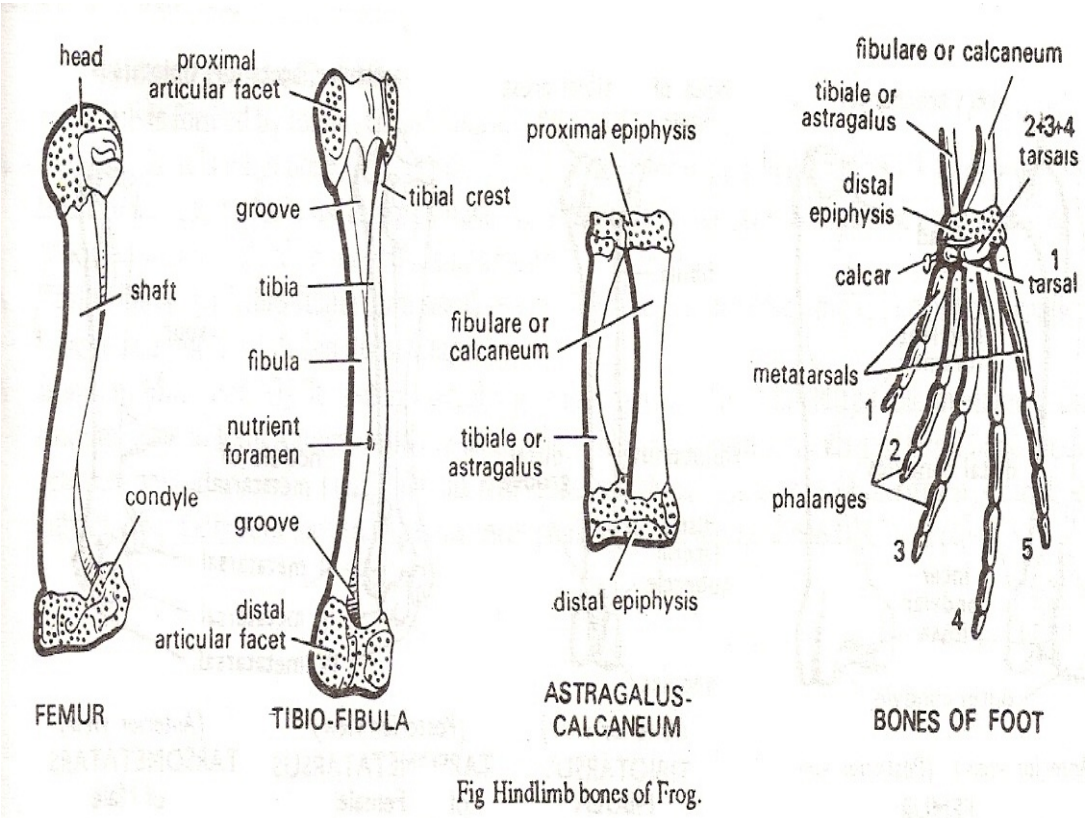


Fig Hindlimb bones of Frog.

5.3. Skeleton of Varanus

5.3.1. AXIAL SKELETON

1. The Skull

1. The skull is monocondylic, compact, elongated and conical.
2. The bones are solid and sutures and distinct.
3. Orbits are comparatively small but skull is tropibasic and has an interorbital septum.
4. The temporal region has two fossae, the lower-intrafossa is incomplete.
5. Suspensorium is autostylic and skull is microsomatic.
6. Jaws have homodont and pleurodont teeth.
7. The premaxillae, nasals, frontals and parietals are not fused.
8. Lower jaw is basically complete and has 6 bones.
9. Occipital region has 3 bones.
10. The alisphenoids are orbitosphenoids are absent.
11. Auditory regions is made up of epiotic, opisthotic and pro-otic bones in embroyo but only protic in adults. It is secondarily united with occipital segment.

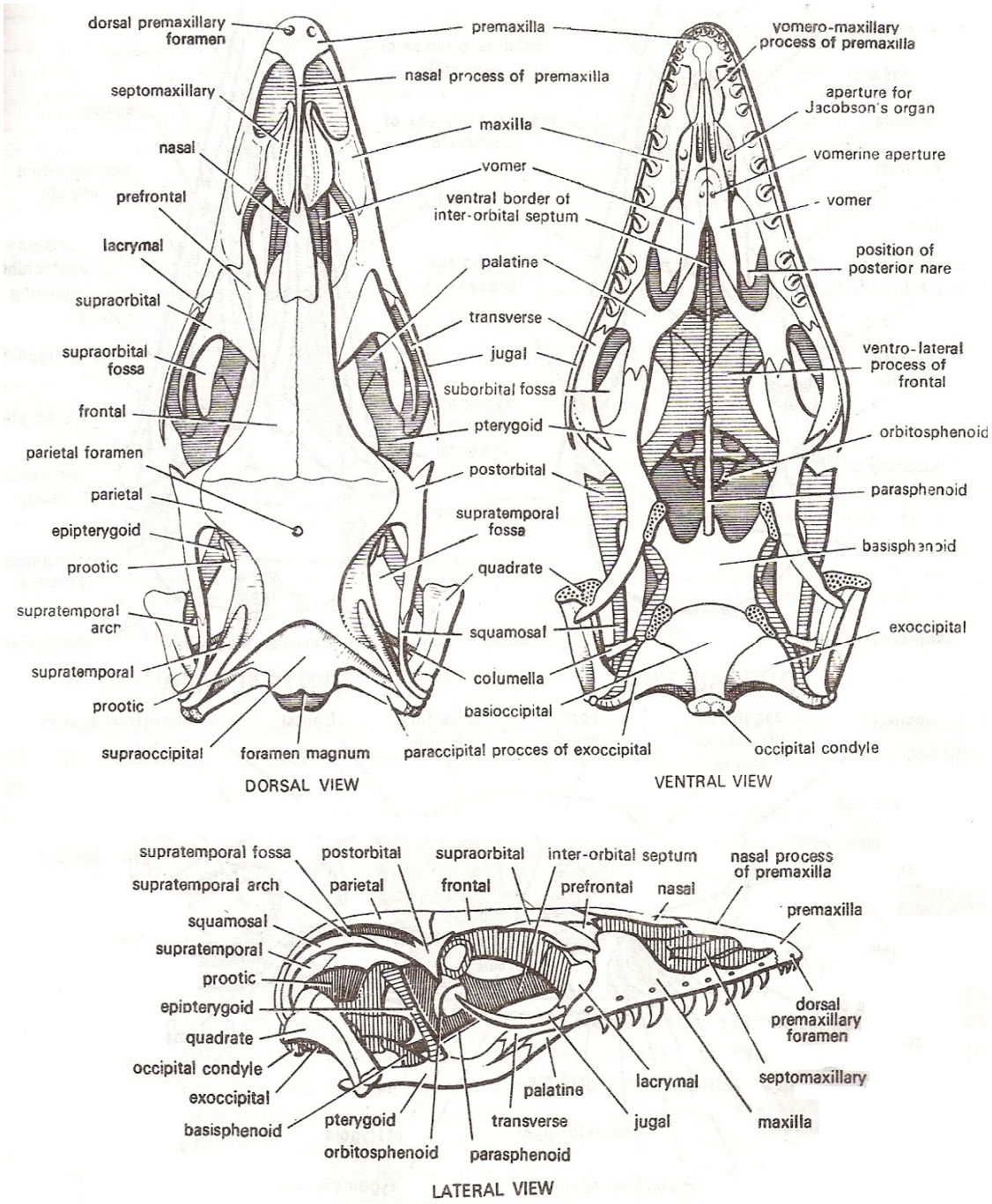


Fig. Skull of *Varanus*.

2. Occipital Segment

1. It is the hind most region of cranium of varanus and has large foramen magnum surrounded by supra, basi and exoccipitals.
2. The rectangular supraoccipitals lies on the roof of caranium, articulates with parietals and prootics and contributes to the post-temproral fossa.

3. The basioocipital lies on the floor of caranium. It bears single round occipital condyle and articulates with basisphenoid, exoccipitals and protics.
4. The ex-occipitals contribute to the foramen magnum and post temporal fossa and form the walls of caranium. Each bone is produced behind into a paroccipital process articulating with supra-temporal, parietal and quadrate. Each bone is perforated by a foramen for X-XIIth cranial nerves.
5. On either side of occipital segment and auditory capsule is attached which, although represented by epiotic, opisthotic and prootic in embroyo, is formed by only prootics in adult.
6. The occipital segment articulates behind with atlas vertebra through occipital condyle.

3. Parietals

1. It is compound bone of parietal region of varanus.
2. It is formed by complete fusion of the two parietals and forms the roof of caranium.
3. They are produced behind into supra-temporal processes for articulation with quadrates, squamosal, supra-temporals and execipitals.
4. These processes form the outer margins of post temporal fossa.
5. The bone has a parietal foramen in the centre and articulates with post-orbitals, supraoccipitals, prootic and epipterygoid.
6. It articulates infront with frontals and behind with the occipital segment.

4. Frontal

1. It is a compound bone of frontal region of varanus.
2. It is formed by the fusion of two frontal bones. Each of the frontals abruptly widens behind.
3. The anterior end of frontal is slightly forked.
4. They articulate with nasals, prefrontals, palatines, postorbitals, parietals and parasphenoid.
5. It lies along the roof of cranium.

5. Basisphenoid

1. It is the bone of parietal region of varanus.
2. It is broad and lies on the floor of cranium in front of basioccipital.

3. A pair of basipterygoid processes come out from its anterolateral ends and bears a small notch at their base.

6. Nasals

1. It is compound bone of alfactory capsules of varanus.
2. It is formed by the fusion of two nasal bones medially through an incomplete suture.
3. It lies on the roof of alfactory capsule and participates in the formation of nare.
4. Each nasal is a flat, triangular and small bone articulating with premaxillae in front and frontals behind.

7. Vomer

1. It is the boe of alfactory capsule of varanus.
2. The bone is rod like and meets its fellow in the median line in its anterior half.
3. It contributes to the formation of posterior nare and is perforated with a vomerine aperture.
4. It is edentulous and articulates with premaxilla and palatine.

8. Quadrate

1. It is the bone of plato-pterygo-quadrate bar and constitutes the autostylic suspensorium.
2. It is small, rod-like and is situated on the outer side of postorbital and squamosal bones.
3. It bears a condyle for suspending the lower jaw and articulates with supratemporal, squamosal, parietal, exoccipital and pterygoid.
4. It is present on the posterolateral corner of skull.

9. Pterygoid

1. It is the bone of palate-pterygo-quadrate bar of varanus.
2. It forms the part of upper jaw.
3. It lies on the floor of orbit.
4. It is irregular and roughly **"Y" shaped** bone with inner limb articulating with palatine, the outer limb with transverse and hind median limb with process of basisphenoid and quadrate.

10. Palatine

1. It is the bone of palate-pterygo-quadrate bar of varanus.
2. It contributes to the formation of incomplete palate and jaw.
3. It is an irregular bone which lies in between vomer, pterygoidand maxilla.
4. It forms the posterior boundary of posterior nare.

11. Prefrontal

1. It is the bone of orbital capsule of varanus.
2. It forms the anterior boundary of orbit.
3. It is a triangular bone bearing a cup-like concavity infront.
4. It lies in between frontal and maxilla and articulates with supraorbital.

12. Supraorbital

1. It is the bone of the orbital capsule of varanus and overhangs the orbit.
2. It is roughly a tri-radiate bone with its broad base fused with prefrontal. Its pointed end slightly curves outwards and downwards and remains free.
3. It also abuts against the anterior end of frontal.

13. Post-orbital or Post-frontal

1. It is the bone of orbital capsule of varanus and contributes to the formation of its posterior boundary.
2. It is a tetraradiate bone.
3. Its two inner processes articulate with parietals and frontals. The posterior process articulates partly with squamosal while the anterolateral remains free.

14. Lacrymal

1. It is a bone of orbital capsule of varanus.
2. It is a small and flat piece of bone attached to maxilla, prefrontal and jugal.
3. It lies along the anterior boundary of orbit and is perorated with a small foramen.

15. Maxilla

1. It is the bone of palate-pterygo-quadrate bar of varanus.
2. It contributes to the formation of most of the upper jaw.
3. It is long, rough and triangular bone and lies on sides behind premaxillae.
4. It bears a number of foramins and about 8-10 conical and pleurodont teeth along its inner lower margin.

5. It articulates with premaxillae, palatine, prefrontal, lachrymal, jugal, and transverse bones.

16. Premaxillae

1. It is a compound bone of papato-pterygo-quadrate bar of varanus.
2. The two premaxillae are united and form the anterior limit of upper jaw and join the two maxillae.
3. Each premaxilla is produced behind into a long nasal process which is lodged between two nasals.
4. Above, is present a pair of foramins and below in front a row of 6-8 pleurodont and homodont teeth and behind a pair of maxilla-vomerine processes for vomers.

17. Jugal

1. It is the bone of palate-pterygo-quadrate bar of varanus.
2. It is a slender and thin rod, which lies all along the outer boundary of orbit close to the transverse bone.
3. It articulates with maxilla and lacrymail in front and remains free behind.

18. Squamosal

1. It is a slender, thi nand curved bone forming the supra-temporal arcade of varanus's skull.
2. The curved lower half resembles the handle of a walking stick.
3. It articulates with post-temporal and quadrate in front.

19. Transverse

1. It is a stout bone and forms the outer boundary of orbit of varanus. It runs all along the jugal.
2. It is slightly curved and its two ends are notched.
3. It articulates with maxilla in front and with outer limb of pterygoid behind.

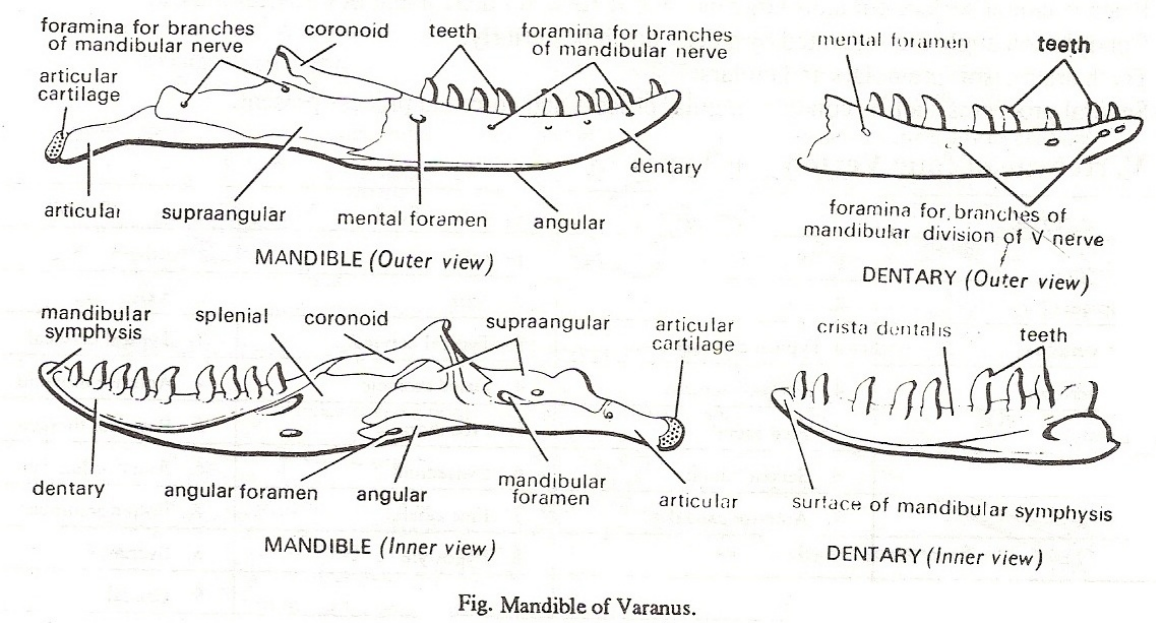


Fig. Mandible of Varanus.

20. Lower jaw ramus

1. It is the ramus (half) of lower jawof varanus.
2. It is the bone of Meekel's cartilage which is a component of mandibular arch.
3. It is ossified with all the basic six bones i.e., the angular, articular, supra-angular, splenial. Coronary and dentary.
4. Of these, the articular is hind-most and dentary is anterior-most.
5. The dentary bears about 8 to 10 pleurodont teeth along its dorssl inner surface and a few foramina for nerves and arteries.
6. The articular bears a cartilaginous patch at its posterior tip for suspension from cranium.
7. The splenial and angular are present along the inner surface. The supra angular and coronary are present along outer surface in between articular and dentary.

21. Dentary

1. It is the bone of Meekel's cartilage of varanus which is a component of mandibular arch.
2. It is the anterior-most bone of lower jaw ramus and is somewhat conical in shape.
3. It bears a row of 8pleurodont and homodont teeth along its innerdorsal surface.
4. A deep groove for the splenial is present along its posterior end.

5. It also articulates behind with coronary and supra-angular and infront it articulates with dentary of the opposite ramus.
6. It is perforated with numerous apertures for arteries, veins and nerves.

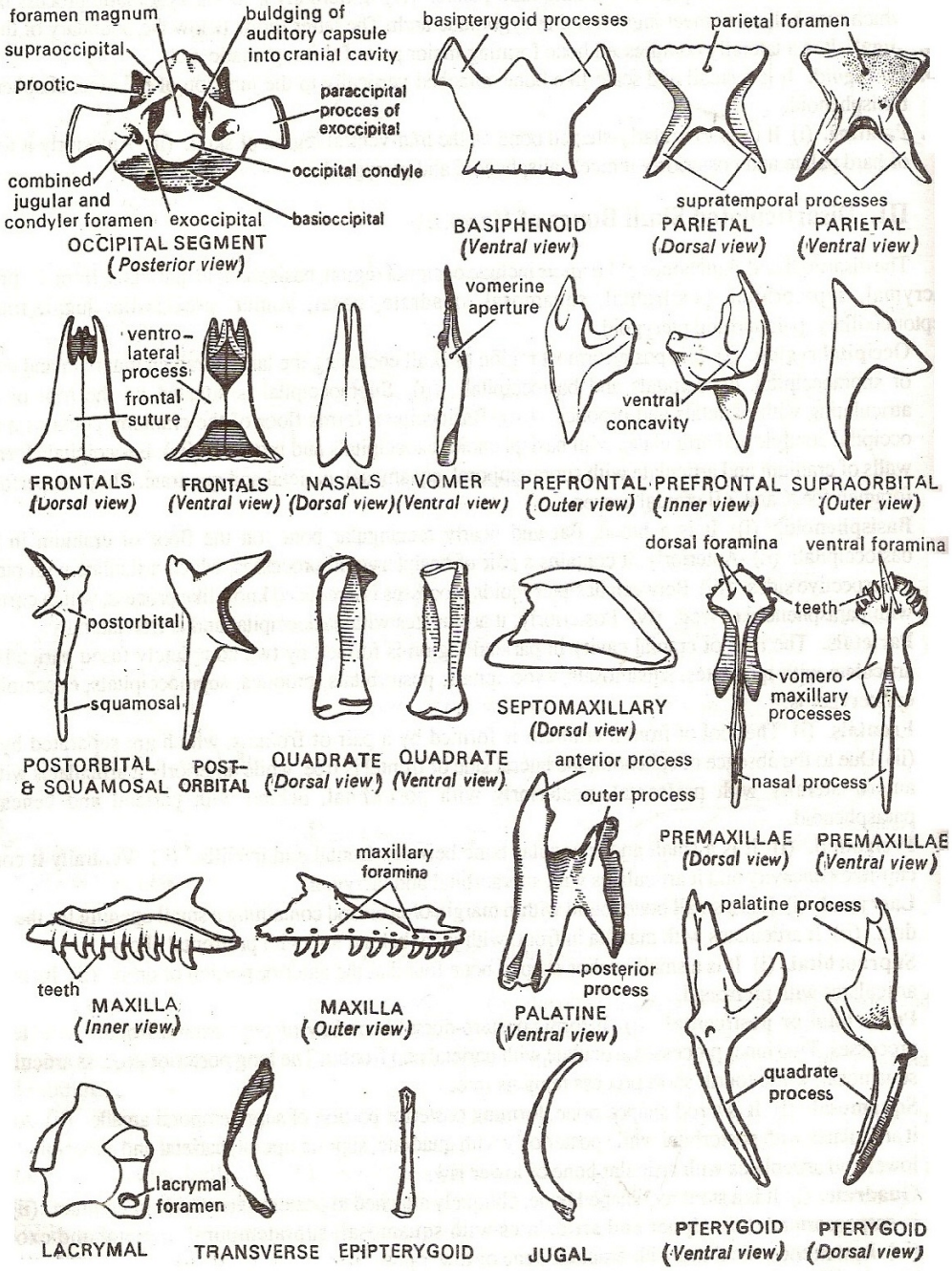


Fig. Disarticulated skull bones of *Varanus*.

5.3.2. VERTEBRAL COLUMN

1. Atlas vertebra

1. It is the first cervical vertebra of varanus and is ring-like.
2. It is devoid of centrum.
3. It is made up of 3 pieces, of which 2 are dorso-lateral and one is ventral.
4. The neural canal is divided by a transverse ligament into an upper and a lower space.
5. Through the upper space passes the spinal cord and through the lower space the arteries and viens.
6. Transverse processes are absent but rudimentary neural spine is present.
7. Prezygagophyses are absent but post-zygapophyses are present.
8. Along anterior and posterior faces of the ventral piece are present facets for occipital condyle and odontoid process of axis vertebra respectively.
9. It helps in articulation of the skull with the vertebral column through axis vertebra.

2. Axis

1. It is the second cervical vertebra.
2. Transverse processes are absent.
3. Pre-zygapophyses reduced, while post-zygapophyses well developed.
4. Neural spine large and crest-like.
5. Centrum contains a spine-like process below odontoid process and a hypapophysis.

3. Typical cervical

1. Centrum elongated and strongly procoelous.
2. It contains a ventral backwardly-directed hypapophysis.
3. Neural spine is crest-like.
4. Neural arch contains a pair of anterior upwardly directed pre-zygapophyses and a pair of posterior backwardly-directed post-zygapophyses.
5. Behind third vertebra, each cervical contains a pair of lateral facets for articulauion of ribs.

4. Thoraco-lumber

1. They are larger than cervical with strongly procoelous centrum and well developed pre- and post- zygapophyses.
2. Hypapophysis absent.
3. At the junction of neural arch and centrum a distinct capitular face is present to articulate with ribs.

5. First sacral

1. It supports pelvic girdle.
2. Centrum is procoelous.
3. Pre- and post-zygapophyses well developed.
4. Neural spine slightly crest-like,
5. Transverse processes greatly expanded and notched to articulate with ilia.

6. Second sacral

1. It resembles first sacral in having procoelous centrum, low crest-like neural spine and well- developed pre- and post-zygapophyses.
2. It differs from first sacral in the absence of a notch in transverse processes.

7. Anterior caudal

1. It is like sacral superficially, but it contains a long centrum, slender neural spine and transverse processes and fairly developed zygapophyses.
2. Specific feature of the vertebra is the presence of a Y-shaped chevron bone beneath centrum.

8. Thoracic Rib

1. All the thoracic vertebrae bear one pair of thoracic ribs.
2. They are slender, curved rods of bone and cartilage.
3. Each rib is dimerentiated into a dorsal bony vertebral portion and cartilaginous sternal portion.
4. Ribs are unicephalous or single-headed, that is, the vertebral end bears a single facet, or capitulum, which articulates with the centrum of the vertebra.
5. The sternal parts of the anterior free thoracic ribs reach ventrally which join the stemal plate.

9. Sternum

1. It is in the form of a rhomboidal plate of calcified cartilage lying embedded in the ventral thoracic wall.
2. Its antero-lateral borders articulate with the coracoids and epicoracoids of the pectoral girdle.
3. Along its each postero-lateral border it bear two small facets for the articulation with the sterna ribs.
4. At posterior end it also bears two sternal ribs.

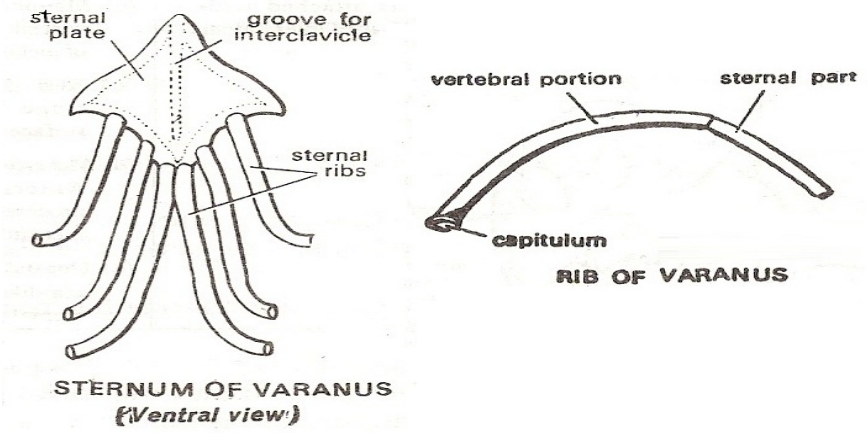


Fig. Thoracic rib and sternum of *Varanus*,

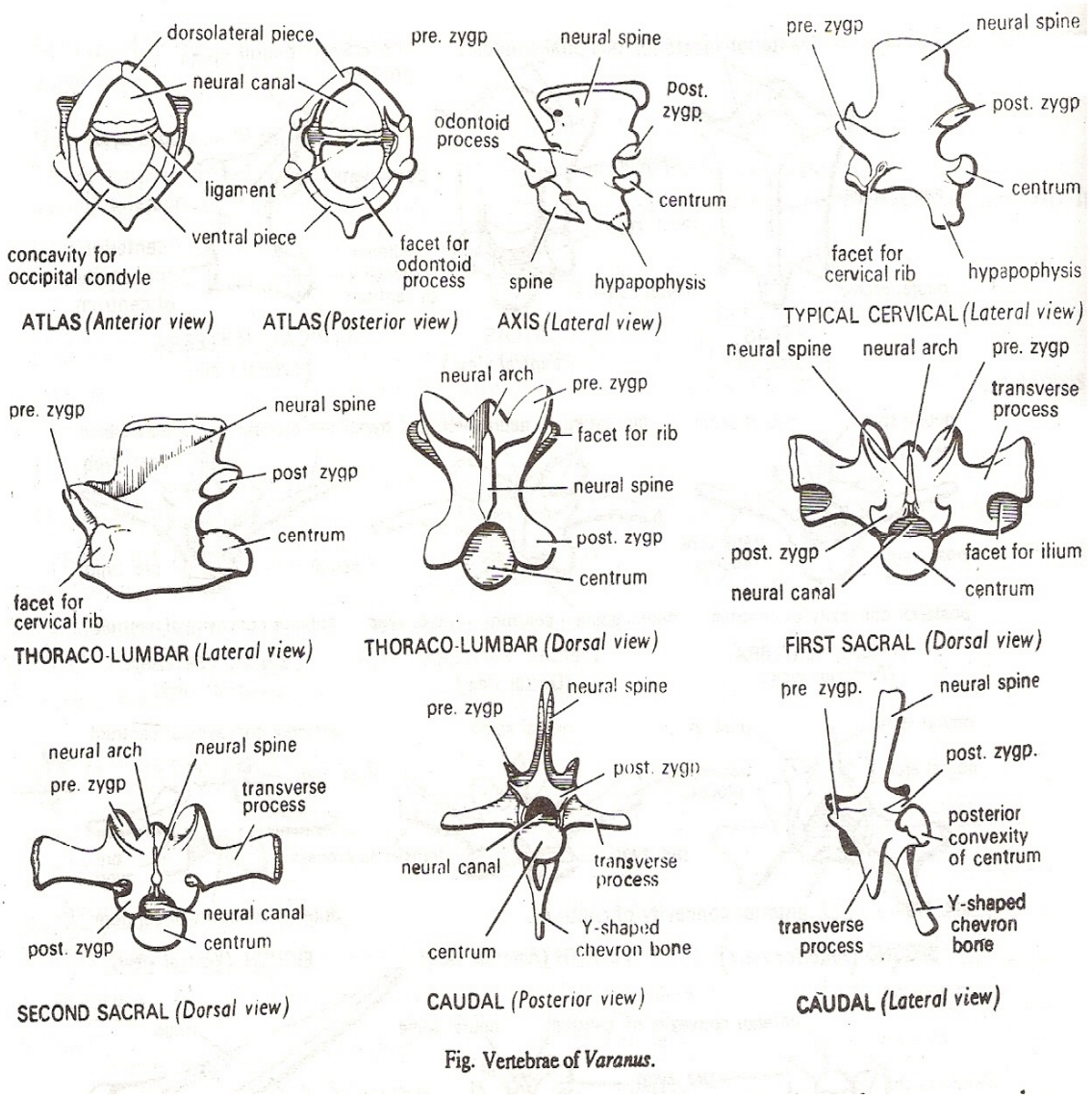


Fig. Vertebrae of *Varanus*.

5.3.3. APPENDICULAR SKELETON

1. Pectoral Girdle

1. Pectoral girdle of Varanusis also made up of two identical halves, firmly attached with a T-shaped interclavicle or episternum.
2. Each half is composed of supra-scapula, scapula, coracoid, interclavicle and clavicle,
3. **Supra-scapula**: It is flattened, calcified and cartilaginous plate, articulating ventrally with scapula. Its dorsal margin is free and curved.
4. **Scapula:** It is completely ossified, flattened and unfenestrated plate, articulating with supra-scapula and coracoid.

5. **Coracoid.** It is a flat bone partly ossified and partly cartilaginous. It contains two large fenestrae, which divide ossified region into three parts, namely anterior pro-coracoid, middle mesocoracoid and posterior broad coracoid proper. Inner end of coracoid lying over fenestrae is cartilaginous and termed epicoracoid. At the posterior junction of scapula and coracoid is a cup-shaped **glenoid cavity** for the head of humerus.
6. **Interclavicle or episternum**: T-shaped investing bone between two halves,
7. **Clavicle:** Short, curved dermal bone, articulating with supra-scapula and interclavicle.

2. Pelvic Girdle

1. (i) It is composed of usual three bones, namely ilium, pubis and ischium. (ii) Three bones are very hard and solid. (iii) Extremely, at the junction of three bones is a large *acetabulum* for head of femur, (iv) Joints are distinct.
2. **Ilium**: It is a rod-shaped bone constituting major part of acetabulum. (i) It articulates with sacral vertebrae. (iii) It has a pre-acetabular process.
3. **Pubis**: (i) It is a curved bone. (ii) Two pubes meet at a *pubic symphysis*, which contains a cartilage called **epipubis**. (iii) Pubis gives out a small rod-like process called *prepubis*. (iv) Pubis contributes to one-third of acetabulum and is perforated by a small foramen for obturator nerve.
4. **Ischium:** (i) Two ischia are flat and curved bones meeting at an *ischiaric symphysis*. (ii) From ischiatic symphysis, a rod-shaped hypoischium extends backwards to support ventral wall of cloaca.

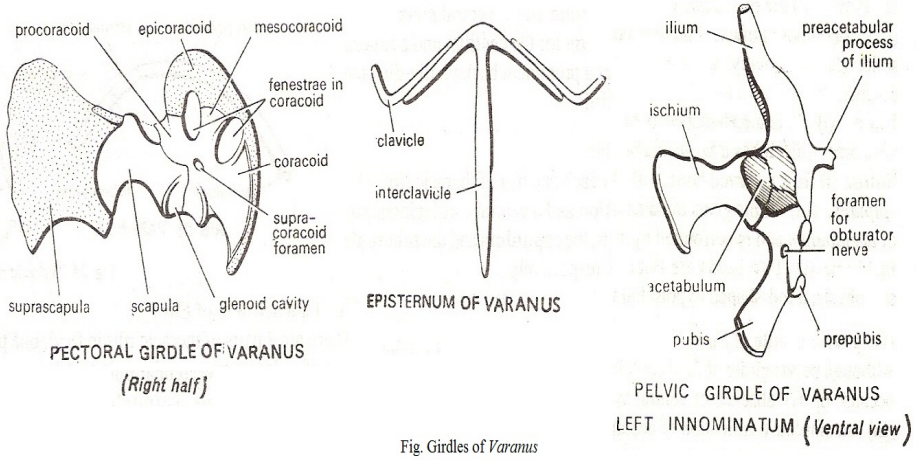


Fig. Girdles of *Varanus*

Forelimb Bones

Forelimb is constituted by humerus, radius and ulna and bones of forefoot or hand.

1. Humerus

1. It is upper arm, single bone, with both ends expanded.
2. Proximal end contains head which fits into glenoid cavity.
3. The head and a medial process enclose a *bicipital fossa*.
4. Deltoid ridge present.
5. Distal end pulley-like and trochlea contains two articular facets for radius and ulna.

2. Radius and ulna

1. Unlike frog, radius and ulna are not fused.
2. Radius is slender and made up of a shaft and two epiphyses.
3. Distal end contains a concave articular facet and a pre-axial styloid process.
4. Ulna is stouter. Proximal end contains olecranon process and distal end has a convex articular surface for carpus.

3. Bones of forefoot or hand

1. Wrist is made up of 10 small polyhedral rounded bony carpals arranged in two rows.
2. Proximal row contains three carpals, namely radiale, ulnare and intermedium.
3. Distal row has 5 carpals.
4. A centrale is found between two rows and a pisciform is attached to the distal epiphyses of ulna.
5. Manus contains five elongated metacarpals and bears 5 digits made up of 2, 3, 4, 5 and 3 phalanges, respectively.
6. Each terminal phalanx contains a horny claw.

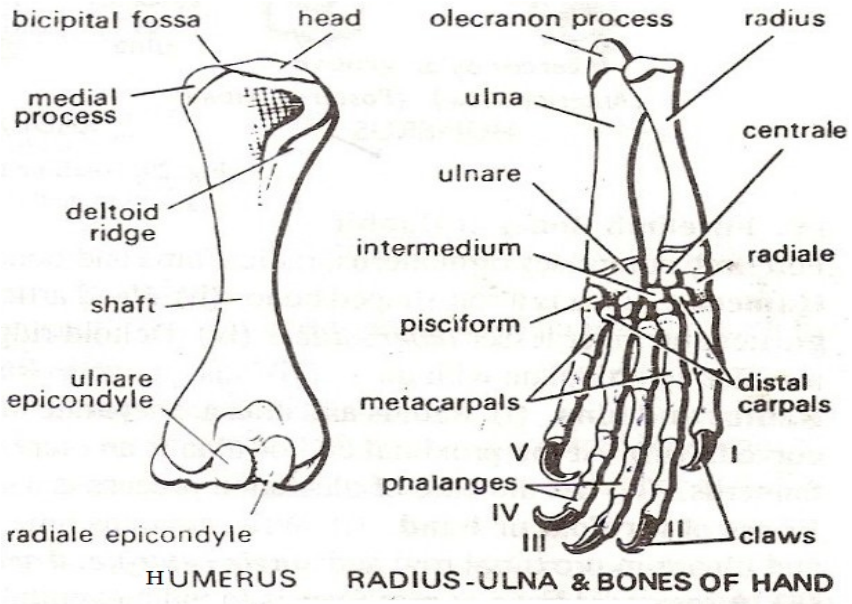


Fig. Forelimb bones of *Varanus*

Hindlimb Bones

Hindlimb consists of femur, tibia, fibula and bones of hind foot.

1. Femur

1. It is thigh bone having two epiphyses.
2. Proximal end contains head, which fits into acetabulum, while distal end is pulley-shaped, having two tuberosities or condyles for articulation with tibia and fibula.
3. Femur has lesser trochanter and greater trochanter on preaxial and post-axial sides, respectively.

2. Tibia and fibula

1. These are shank bones.
2. Tibia is stout, curved and on pre-axial side, while fibula is slender and on post-axial side.

3. Bones of hind-foot

1. It is made up of 5 tarsal bones.
2. First, second, third, fourth and fifth toes contain 2, 3, 4, 5 and 3 phalanges, respectively.
3. Each toe bears a terminal horny claw.

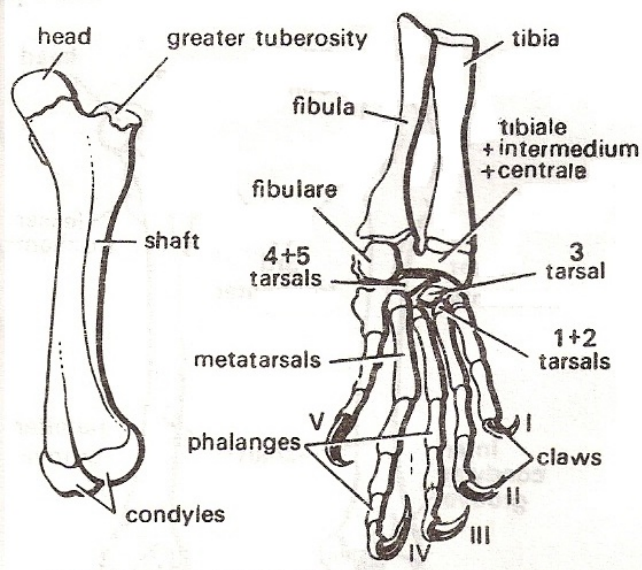


Fig. Hindlimb bones of *Varanus*.

5.4. Skeleton of Fowl

5.4.1. AXIAL SKELETON

1. Skull of Fowl

1. The skull of fowl is monocondylic and almost weightless due to pneumatic bones.
2. The skull is compact and almost devoid of sutures.
3. The occipital region is directed slightly downwards and thus foramen magnum shifts to ventral side.
4. Jaw bones are modified into beak. Jaws are slightly movable and edentulous. The suspensorium is autostylic.
5. Each ramus of lower jaw comprises of five fused bones.
6. Large orbits are on sides and are separated by thin interobital septum.
7. It is tropibasic and micrognathus.
8. Palate is schizognathus and quadrate is movable.

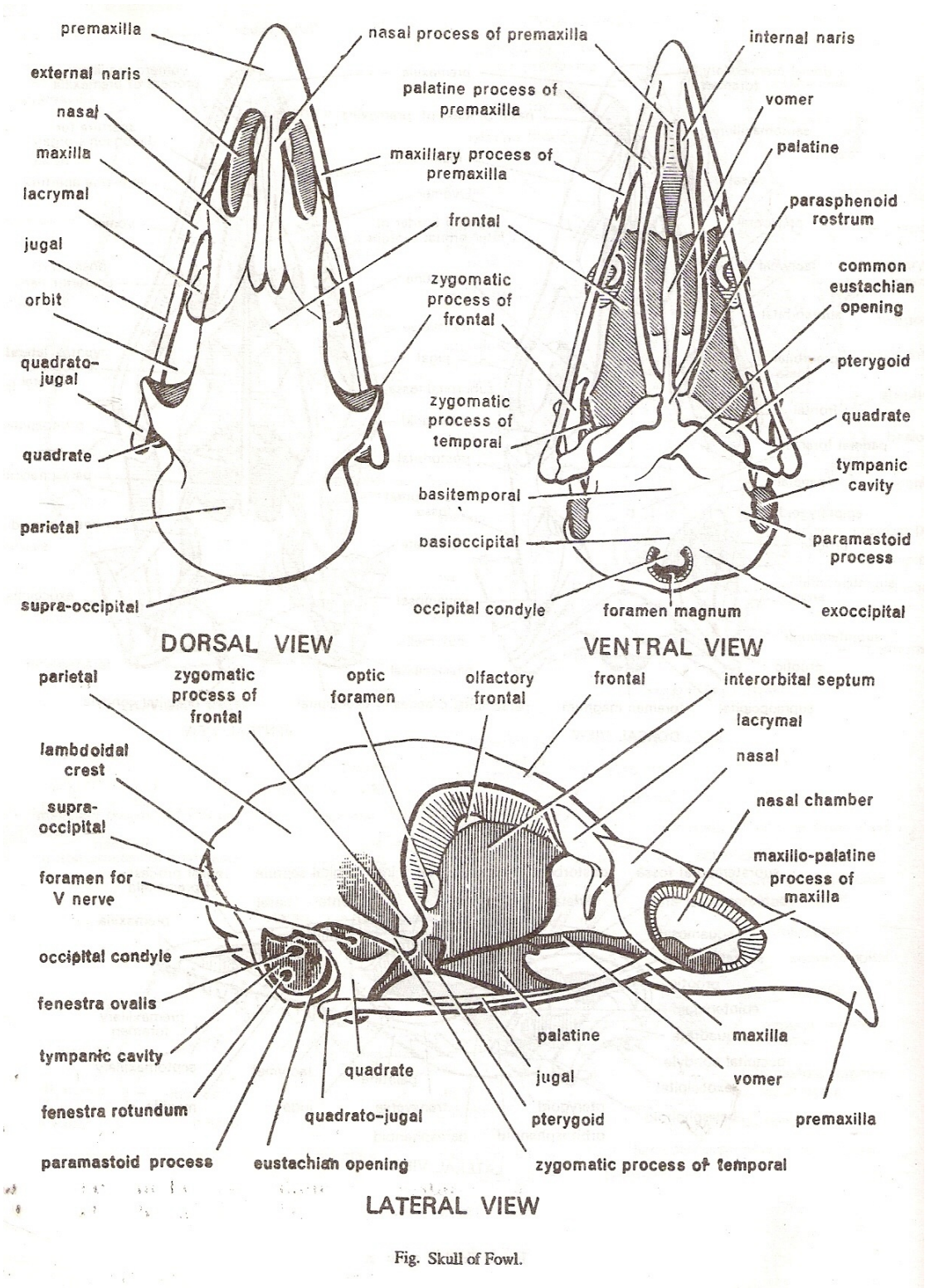


Fig. Skull of Fowl.

1. Occipital segment

1. It is the posteriormost region of skull, containing a large foramen magnum and is composed of basioccipital, exoccipitals and supraoccipital.

2. Beneath foramen magnum is a single occipital condyle,

2. Premaxillae

1. Two premaxillaries are completely fused together forming anteriormost region of upper jaw and entire upper beak.

2. Each premaxilla contains three processes; nasal process ascends to join with frontal forming boundary of external nare, maxillary process extends backwards and outwards to join with maxilla and palatine process, joins with palatine to form palate.

3. Maxilla

1. It is a rod-shaped bone of anterior upper jaw.

2. Anteriorly it articulates with premaxilla and nasal and is expanded into laminated spongy maxillopalatine processes which articulate with palatine.

3. Posteriorly the zygomatic process of maxilla constitutes anterior part of suborbital bar.

4. Jugal

It is a rod-shaped bone forming middle region of suborbital bar and is found dorsal to maxilla and quadrato-jugal.

5. Quadratojugal

It forms posteriormost part of suborbital bar and is thickened posteriorly to articulare with quadrate.

6. Quadrate

1. It is a tough triadiate bone, situated in front of tympanic cavity.

2. It takes part in suspensorium.

3. It has three arms anterior arm extends above pterygoid and terminates freely, dorsal arm is movable and articulated with squamosal, ventral arm gives rise to condyle which articulates with mandible.

7. Nasal

1. The nasals form sides and roof of olfactory chambers and are separated by nasal processes of premaxilla.

2. Each nasal is a thin triangular plate-like bone having processes, two anterior processes form boundary of external nare and join premaxillary processes, posterior process articulates with frontal and lachrymal.

8. Lacrymal

1. A pair of lacrymals forms anterior boundary of orbits.
2. It contains a curved process and a characteristic foramen.

9. Pterygoid

1. A pair of pterygoids forms posterior boundary of mouth cavity.
2. Each pterygoid articulates with inner surface of ventral arm of quadrate and in front with palatine and parasphenoid rostrum of its side.

10. Palatine

1. It is a slender and rod shaped bone forming inner arcade of upper jaw.
2. Anteriorly palatine joins with maxillary and premaxillary processes and it movably articulates with pterygoid.
3. Posterior end is broadened to articulate with parasphenoid rostrum.

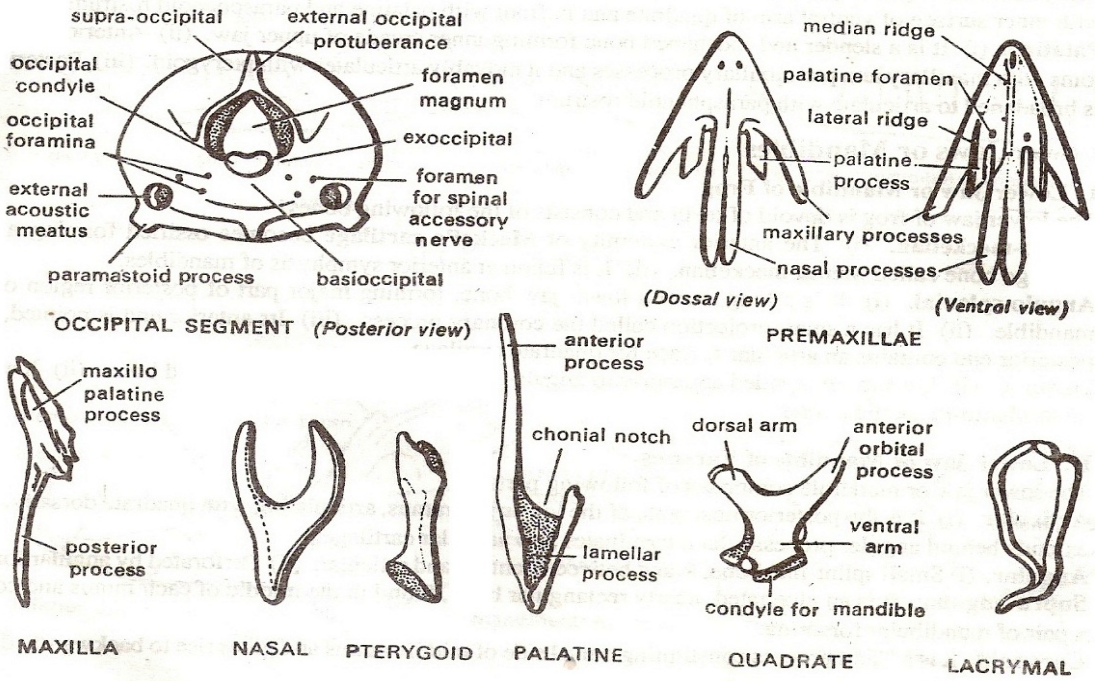


Fig. Disarticulated skull bones of Fowl

11. Lower Jaw or Mandible

The lower jaw of fowl is devoid of teeth. Each ramus is made of the following bones:

1. Articular. (i) It expands from posterior and of each ramus and is continued with Meckel's cartilage. (ii) It contains mandibular condyle dorsally.

2. Angular. It lies below articular and forms lower border of jaw.

3. Supra-angular. It forms upper margin of posterior mandible and contains a small coronoid process.

4. Splenial. It is a thin bone found along the inner surface of middle of mandible.

5. Dentary. (i) It forms anterior half of mandible and joins with fellow dentary at an anterior symphysis. (ii) It is devoid of teeth and contains a mandibular foramen

5.4.2. VERTEBRAL COLUMN

1. Atlas vertebra:

1. It is the first vertebra of cervical region of fowl which connects the skull with vertebral column.
2. It is ring shaped and made up of only one piece.
3. The centrum and transverse processes are absent.
4. The prezygapophyses are absent but downwardly and outwardly directed post zygapophyses are present.
5. The ventral half of the ring bears a concavity in front and a concavity behind in the centre for occipital condyle and odontoid process respectively.
6. The neural spine is absent.
7. It articulates with skull in front and with axis vertebra behind.

2. Axis vertebra:

1. It is the second vertebra of cervical region of fowl.
2. It is somewhat ring like.
3. The centrum is heterocoelous and rod-like.

4. At the anterior end above the centrum is present an odontoid process (actually it is the centrum of atlas, which is secondarily fused with its centrum).
5. The neural spine is small but crest-shaped.
6. Upwardly and inwardly directed prezygapophyses and downwardly and outwardly directed postzygapophyses are present.
7. Transverse processes are absent.
8. A small and feeble hypapophysis is present below the posterior face of centrum.
9. It articulates with atlas in front and first typical cervical vertebra behind.

3. Anterior Cervical Vertebra:

1. it is one of the typical cervical vertebra of fowl.
2. The vertebra is elongated and ring like.
3. Its centrum is heterocoelous.
4. The transverse processes are rudimentary.
5. Neural spine is feebly developed.
6. Odontoid process and hypapohyses are absent.
7. Long, splint-like and undetachable cervical ribs are present just below the transverse processes.
8. The bases of transverse processes are perforated with vertebrarterial foramen.
9. Upwardly and inwardly directed prezgapophyses and downwardly and outwardly directed potzygapophyses are present.
10. It articulates with axis in front and 2nd cervical vertebra behind.

4. Posterior cervical vertebra

1. It is the last cervical vertebra of fowl.
2. It is small and ring-like.
3. The centrum is heterocoelous but not so elongated as in anterior cervical.
4. Small nodule- like cervical ribs are present.
5. The cervical ribs are fused and outer side of transverse processes.
6. The neural spine is rudimentary.
7. Transverse processes are very small.
8. Vertebrarterial foramen is present in between transverse processes and cervical ribs.

9. Pre-and post zygapophyses are present.
10. A forwardly and downwardly directed hypapohysis is also present below centrum.

5. Fused Thoracic Mass

1. It is compound structure formed by the fusion of last cervical and three auterior thoracic vertebrae of fowl.
2. The neural spines are well developed, crest-shaped and fused with each other.
3. The transverse processes are well developed and fused with each other.
4. The centrum is heterocoelous.
5. Pre- and postzygapophyses are present.
6. In the three thoracic vertebrae, below tansverse processes and on side of centrum, are present facets for tubercular and capitular processes of thoracic ribs.
7. All vertebrae are provided with downwardly directed hypapophyses which are fused with each other.

6. Free Thoracic Vertebrae

1. It is fourth free thoracic vertebra of fowl.
2. The neural spine is well developed and crest-shaped and the centrum is heterocoelous.
3. Its transverse processes are well developed and outwardly directed.
4. Pre- and postzygapophyses are present.
5. Hypapophysis is present below the centrum.
6. Facets for tubercular and capitular heads.
7. It articulates with fused thoracic mass in front and synsacrum behind.

7. The Synsacrum

1. It is synsacrum of fowl, which is made by the fusion of last thoracic+ 6 lumbars + 2 sacrals + 6 to 8caudal vertebrae.
2. This compound bone supports the ilia of fused pelvic girdles during flight and perching.
3. All the vertebrae in this compound bone are fused and inseparable.
4. The neural spines of all the vertebrae are flat and fused with each other to form a flat plate.

5. The transverse process of all vertebrae is well developed and in case of first seven vertebrae they also bear facets for ilia at thwir tips, whereas in the last ten vertebrae they are divided into a dorsal pat and a ventral part.
6. All the dorsal components of transverse processes of last ten vertebrae are united with each other into a plate-like structure.
7. The heterocoelous centra of all vertebrae are also fused intimately with each other.
8. This bone articulates in front with free thoracic vertebra and behind with free caudal vertebra.

8. Free caudal vertebra

1. It is a small ting-like vertebra of tail region of fowl.
2. Its neural spine is bifurcated. The centrum is hetrocoelous.
3. The transverse processes are well developed and directed downwards and outwards.
4. The pre-and post zygapophyses are absent.
5. All the six free caudal vertebrae are movable articulated with each other.

9. Pygostyle

1. It is last compound, somewhat triangular and laterally compressed vertebra of tail region of fowl.
2. It is commonly known as plough share.
3. It is formed by the fusion of 4 caudal vertebrae.
4. The neural arch, centrum and transverse processes are absent.
5. The bone supports the tail feathers, the rectrices.

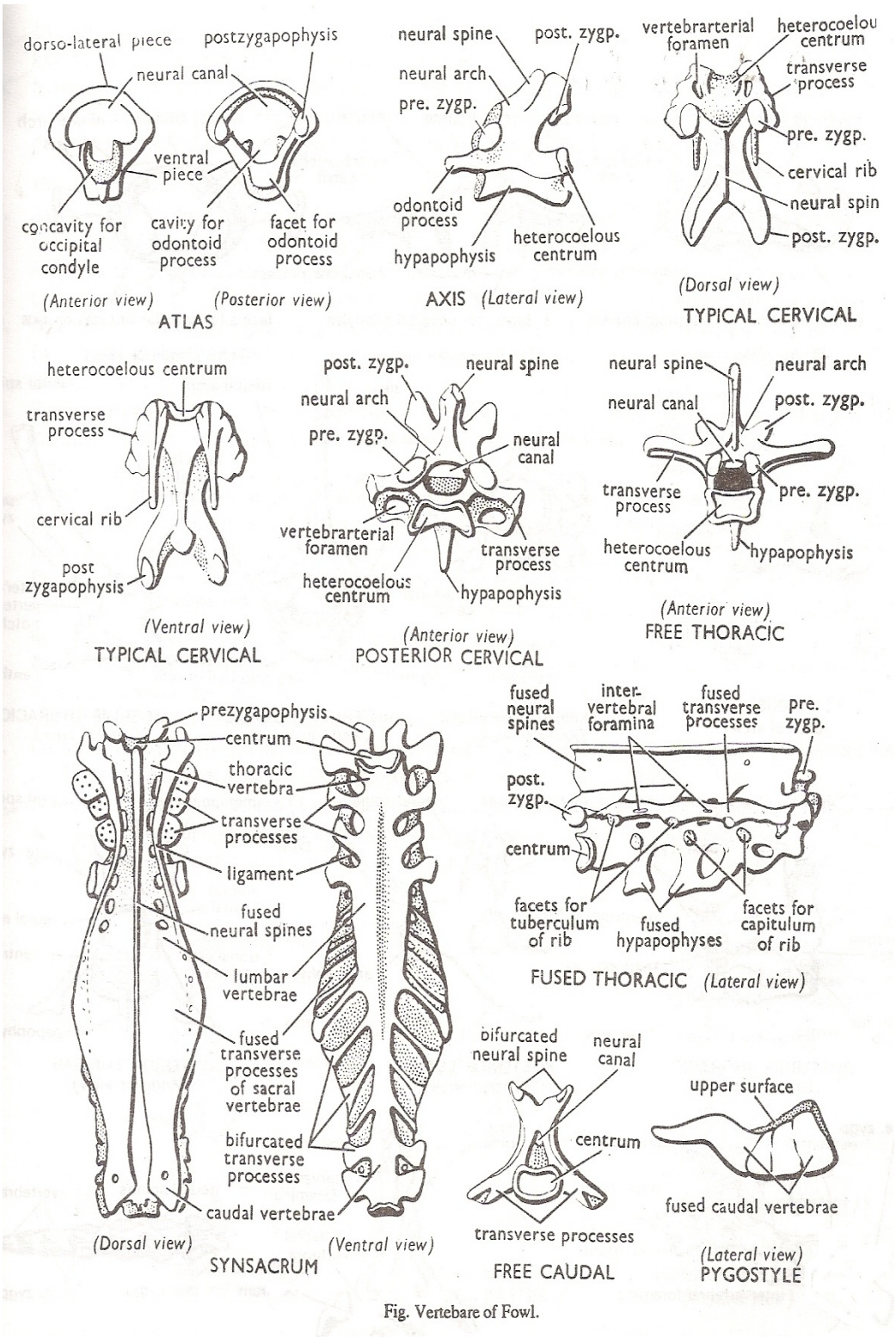


Fig. Vertebare of Fowl.

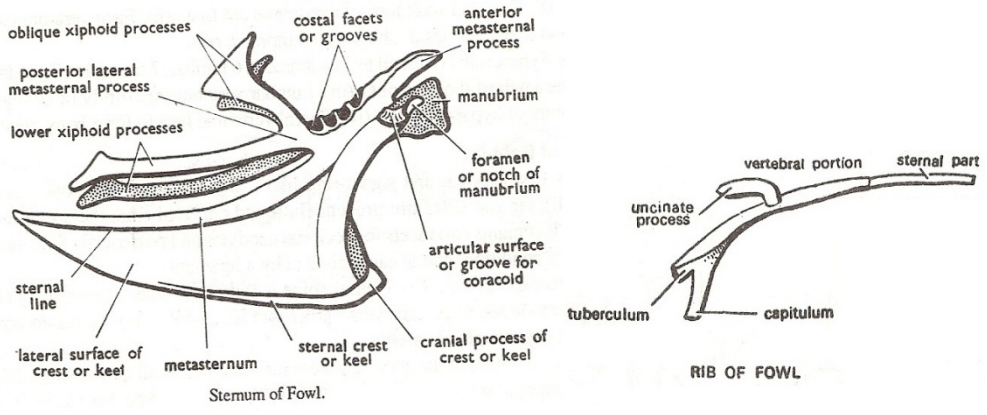
10. Sternum

1. It is breast bone of fowl and it lies in median line in the region of breast.

2. This is boat-shaped and is made up of a laterally compressed keel and is produced into a small median process infront, the manubrium.
3. Near the union of keel and manubrium arises a backwardly directed posterior processes and a forwardly directed metasternal process.
4. The posterior process bifurcates into oblique lateral xiphiod process and a posterior lateral xiphoid process.
5. Between the metasternal and posterior processes the whole dorsal surface of keel is provided with shallow coastal facets for articulation with sterna part of thoracis ribs.
6. The median posterior part of the keel, the metasternum, is broad, flat and plate-like and is concave dorsally and concave ventrally.
7. The keel provides attachment to pectoral flight muscles.
8. The menubrium provides attachment to coracoids and interclavicles of pectorial girdle.

11. Thoracic Rib

1. Thoracic ribs are five flattened bony rods attached to the thoracic vertebrae.
2. Each thoracic rib consists of vertebral and sterna portions meeting at an angle.
3. By the sternal portion the ribs are united to the sternum.
4. The vertebral portion of the ribs bear backwardly directed uncinate processes.



Sternum of Fowl.

Fig. Sternum and Rib of Fowl

5.4.3. APPENDICULAR SKELETON

1. Pectoral girdle

1. It is one half of the shoulder girdle of fowl.
2. It provides support to the wings which are modified fore-limbs.
3. Each half is formed of a coracoids and a scapula bone. The two bones are attached to each other at right angles.
4. The clavicles and interclavicles is a separate npmr and is called furcula and is attached to pectoral girdle through ligaments.
5. At the joint of scapula and caracoid is present a glenoid cavity.
6. The scapula is long, narrow, slightly curved and saber-shaped bone, which lies parallel to vertebral column.
7. Beyond the glenoid cavity, the inner surface of scapula is produced into acromian process. It also bears a tubercle in the middle.
8. The caracoid is stout, straight rod-like and broader at two ends.
9. Beyond the glenoid cavity the dorsal end of coracoids is produced into acromian process.
10. The free end of coracoids articulates with manubrium of sternum.
11. The acromian and acrocoracoid processes along with the free end of clavicle enclose a foramen triossium through which pass the tendons of pectoral muscles.
12. The supra-scapula is absent.

2. Furcula

1. It is roughly a “Y” –shaped or fork-shaped bone of fowl formed of two clavicles and interclavicles.
2. It is commonly known as merry thought or wish bone.
3. Originally, these bones are part of pectoral girdle which have secondarily become free.
4. The clavicles articulate at their free ends with acromian processes of scapula and acrocoracoid processes of coracoid and surround the foramen triosseum.
5. The free end of interclavicles articulates with manubrium of sternum through ligament.

3. Pelvic girdle

1. It is hip girdle of fowl and it provides articulation to the hind limbs.
2. Each girdle is made of two identical halves-the os-innominata, each of which is made up of ilium, ischium and pubis.
3. At the junction of the three bones is present a cup-like acetabulum.
4. The ilium is broad and flat and is divided into a post acetabular ilium and preacetabular ilium.
5. At the posterior border of acetabulum the ilium is produced into a small process, the antitrochanter.
6. The pubis is distinct, slender and splint-like bone and is produced into prepubis or preactabular process beyond the acetabulum.
7. The ischium and pubis enclose an obturator foramen in between.
8. The ischium is broad and flat plate between acetabulum, postacetabular ilium and pubis.
9. Between postacetaular ilium and ischium is present a large ilio-ichiatic fenestra.
10. The inner border of ilium fuses with synsacrum.
11. The two ossinnominata do not form symphysis.

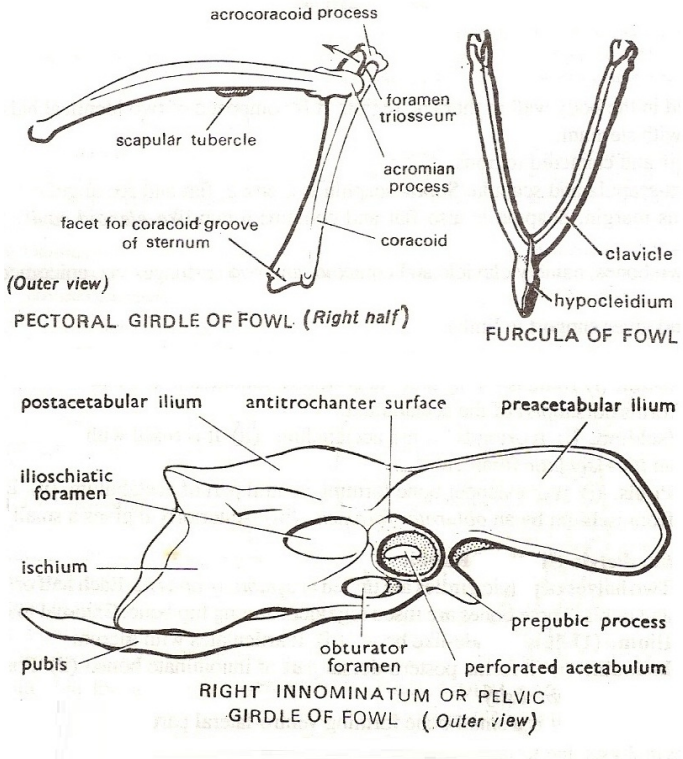


Fig. Girdles and furcula bone of Fowl

4. Humerus

1. It is the bone of upper arm region of forelimbs (wing) of fowl.
2. The bone is light in weight due to pneumaticity.
3. It is alongated, stout and slightly curved and its both ends are comparatively broad and flat.
4. Along the tip of its proximal and is present a convex surface, the head, which glides in the glenoids cavity of pectoral girdle.
5. Two tuberosities are present on either side of head. The smaller tuberosity bears a prominent vertical ridge, the deltoid ridge for attachment of muscles.
6. Near the deltoid ridge is present a pneumatic foramen.
7. The distal end bears a pulley-like trochlea with two epicondyles for radius and ulna.

5. Radiua and Ulna

1. These are the bones of fore arms and forelimbs (wing) of fowl.
2. The two separate bones are attached to each other only at their ends.
3. The radius is slender, straight and slightly smaller bones.
4. The ulna is strout, curved comparatively longer bones.
5. The meeting of two bones at the anterior end results in the formation of shallow sigmoid notch.
6. The ulna is produces beyond sigmoid notch into an olecranon process.
7. The distal end is attached to proximal carpals.

6. Carpometacarpus

1. It is the compound bone of manus (palm) region of forelimbs (wing) of fowl.
2. It is form by the fusion of three distal metacarpals and proximal row of three carpals.
3. The three carpals form the proximal head.
4. The main body is form by second and third metacarpals which are long and stout and widely separated.
5. The first metacarpal is fused to second metacarpal near the proximal end.
6. The third metacarpal is curved while the second metacarpal is straight.
7. The second metacarpal is provided with spine.

8. The distal end is formed by the union of second and third metacarpal.
9. It provides attachment to remiges feathers.

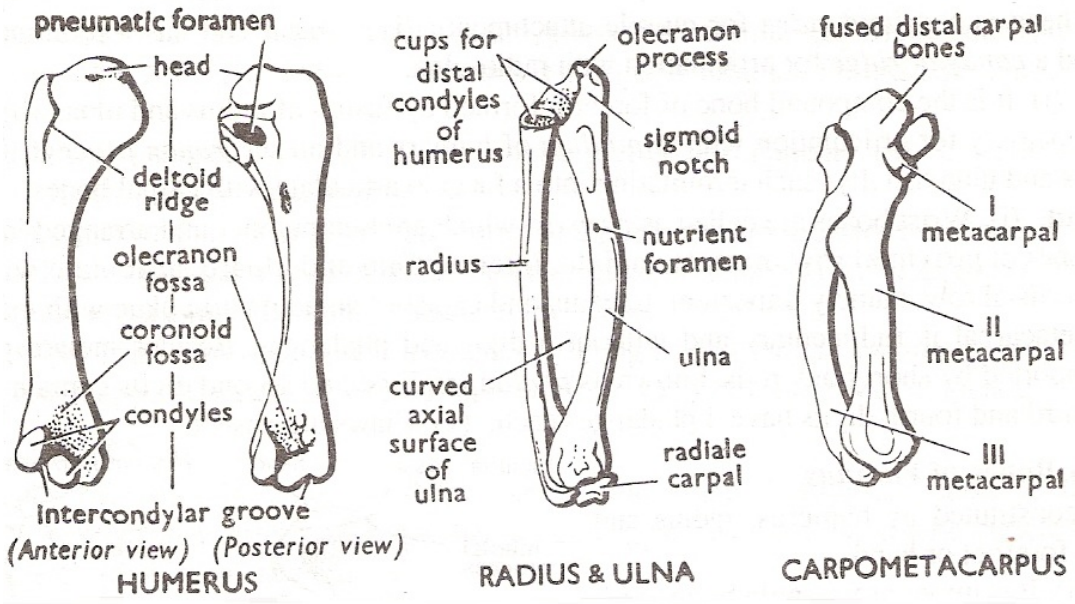


Fig. Forelimb bones of Fowl

7. Femur

1. It is the bone of thigh region of hind limbs of fowl.
2. The bone is sout and slightly curved with flat ends.
3. The proximal ends of the bones bears a well defined, round and ball like head on inner side and a great trochanter on the outer side.
4. The distal end is pulley-like end has a depression-the intercondylar fossa which is laterally bound by two distinct condyles. The outer condyles bears a deep groove for articulation with fibula.
5. The head glides in the acetabulum and the distal and articulates with tibio-tarsus fibula. The greater trochanter articulates with antitorchanter of ilium.

8. Tibio-tarsus Fibula

1. It is the compound bone of shank region of hind limb of fowl.
2. It is formed by the inner long and strout bone, the tibio-tarasus and an outer slender and splint like bone, the fibula.
3. The tibio-tarasus is made by tibia and proximal row of tarsals fused with it.

4. Proximaly tibio-tarsus bears two facets for articulation with femur and along the side it bears a cnemial crest for muscle attachment.
5. Distally, it bears a pulley like structure for articulation with tardo-metatarasus.
6. Proximal end or head of fibula articulates with outer condyle of femur and distal tapers to a point.

9. Tarso-metatarsus of male

1. It is the compound bone of the ankle region of the hind limb. Of male fowl.
2. It is formed by the fusion of the proximal row of tarsals with second, third & fourth metatarsals distally. The first metatarsal is attached by ligament to the inner surface of other metatarsals.
3. Proximally it bears two facets and one ridge for condyles of tibio-tarsus.
4. Distally the three metatarsals (second-fourth) are clearly demarcated and form a pulley like articular surface for attachment of phalanges.
5. Near the distal end is present a prominent and strong spur, which is used for the purpose of offence and defence.

10. Tarso-metatarsus of Female

1. It is the compound bone of ankle region of hind limb of female fowl.
2. It is formed by the fusion of the proximal row of tarsals with second, third and fourth metatarsals. The first metatarsal is attached by ligament to the inner surface near the distal end.
3. Proximally it bears two facets and one ridge for condyles of tibio tarsus.
4. Distally the three metatarsals (second-fourth) are clearly demarcated and form a pulley like structure for attachment of toes.
5. The spur is absent. Allantois and amniotic cavity have also developed.

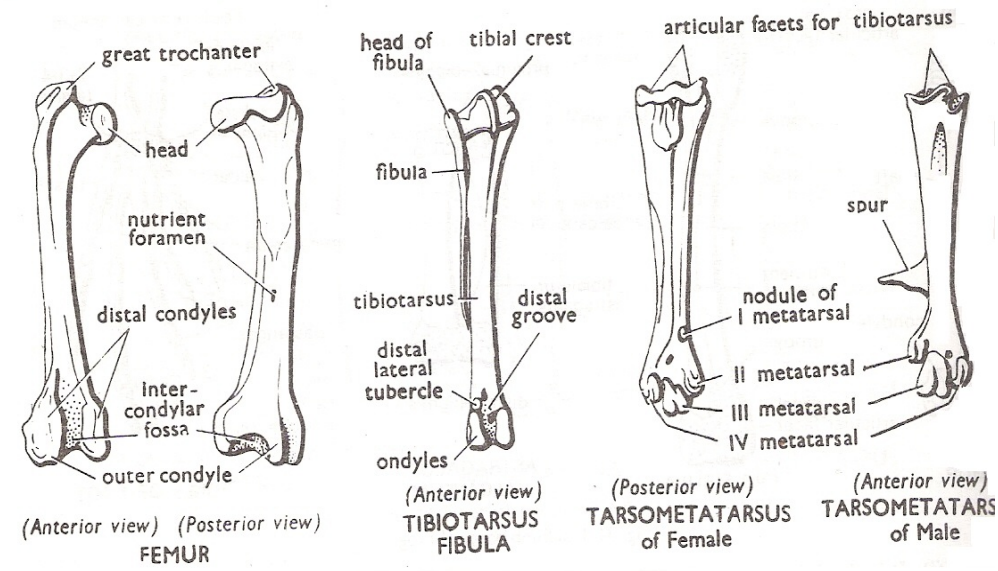


Fig. Hindlimb bones of Fowl

5.5. Skeleton of Rabbit

5.5.1. AXIAL SKELETON

1. Skull

1. Skull is dicondylic, i.e. two occipital condyles.
2. It is completely ossified with more or less sutures.
3. Tropibasic, i.e. inter-orbital septum is present.
4. Cranial portion is small while the facial portion is elongated and somewhat deflected.
5. Occipital region comprises of four bones, i. e., two exoccipitals, one basioccipital and one supraoccipital.
6. Auditory region is composed of periotic bone and tympanie bulla.
7. Cribriform plate is present between the cranium and olfactory chamber.
8. Turbinals or scroll bones occupy the greater portion of the nasal cavities.
9. Jugal forms the outer boundary of the orbit.
10. Zygomatic arch and inter-parietal bone is present.
11. Suspensorium is craniostylic, i.e., the lower jaw articulates with the skull by squamosal.

12. Teeth are *heterodont*, i. e., differentiated into incisors, premolars and molars: *diphyodont*, i .e., both milk and permanent teeth are present and *thecodont* embedded in the sockets.
13. Between incisors and premolars is present a gap called *diastema*.
14. Each half of the lower jaw consists of a single bone, the dentary.
15. Prefrontal, postfrontal, parasphenoid and quadratojugal are absent.
16. Dental formula is *I* 2/1, *c* %, *pm* 3/2, *m* 3/3 = 28.

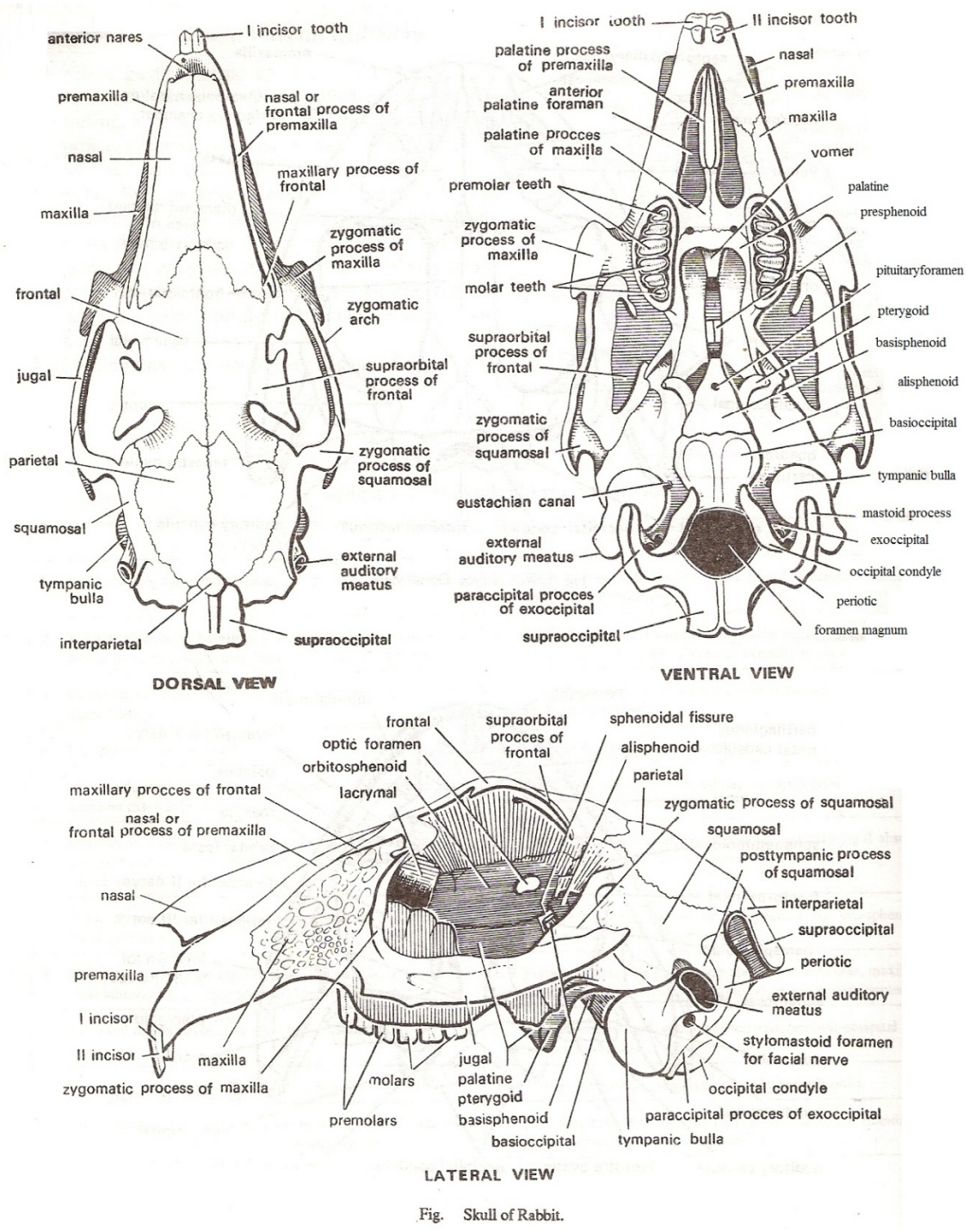


Fig. Skull of Rabbit.

2. Occipital segment

1. Occipital segment is the posteriormost part of the skull.
2. It is composed of two exoccipitals, one basioccipital and one supraoccipital.
3. Exoccipitals bound the foramen magnum on its lateral sides and contribute in the formation of condyles.

4. Each exoccipital is produced on its outer side into a paroccipital process.
5. Basioccipital is a flat median bone forming the ventral boundary of foramen magnum and the floor of the posteriormost part of the cranial cavity.
6. Basioccipital also bears two occipital condyles.
7. Supraoccipital is a large median bone forming the dorsal boundary of foramen magnum.
8. It articulates in front with inter-parietal and parietals and laterally with squamosals and periotics.

3. Basisphenoid and alisphenoid

1. It is a compound bone of the parietal region of skull.
2. Basisphenoid is a median bone lying just in front of the basioccipital and united with it by a thin plate of cartilage.
3. It is triangular having a broad base posteriorly and narrow anteriorly.
4. Near the anterior end it bears a small pituitary foramen.
5. On the dorsal surface a depression sella tursica is present for lodging the pituitary body.
6. It articulates in front with presphenoid and laterally with alisphenoids.
7. Alisphenoids are paired wing-like bone attached obliquely to the sides of the basisphenoid.
8. From the ventral surface of each alisphenoid projects an external pterygoid process connected along the inner edge with the palatine.
9. At the anterior end between the alisphenoid and basisphenoid is slit-like notch the sphenoidal fissure for the passage of 3rd, 4th and 6th nerve.

4. Parietal

1. It is the bone of the parietal region of the skull.
2. It is small flattened membrane bone lying along the roof the cranial cavity.
3. The parietal bones of both sides join with each other in the mid-dorsal line by a prominent suture.
4. Posteriorly it gives rise to a thin plate-like ventral process.
5. It articulates anteriorly with frontal, laterally with squamosal and posteriorly with the inter-parietal and supraoccipital.

5. Parasphenoid and orbitosphenoid

1. It is a compound bone of the frontal region of the skull.

2. Pre sphenoid is a median, narrow and laterally compressed bone lying in front of basisphenoid.
3. It forms the inner margin of optic foramen and articulates anteriorly and posteriorly with palatines.
4. Orbitosphenoids are paired wing-like thin bones intimately associated with the presphenoid.
5. Each orbitosphenoid forms the outer margin of optic foramen.
6. Orbitosphenoids articulate anteriorly with palatine, posteriorly with squamosals and alisphenoids and above with frontals.

6. Frontal

1. Frontals are paired membranous bones forming the roof and sides of anterior part of the cranial cavity.
2. The frontals of both the sides are united mid-dorsally forming a suture.
3. The outer portion of each frontal gives rise to a triangular posterior supra-orbital process.
4. It forms the dorsal and inner boundary of the orbit.
5. Anteriorly it gives off a slender process between the maxilla and premaxilla of that side.
6. It articulates anteriorly with the nasal, posteriorly with the parietal and ventrally with orbitosphenoid.

7. Nasal

1. Nasals are paired membranous bones of the olfactory capsule of skull.
2. It is a large, thin and elongated bone.
3. It articulates anteriorly and laterally with the premaxilla and posteriorly with the frontal.
4. Anteriorly it forms the border of anterior nares along with premaxilla.

8. Periotic and tympanic bulla

1. It is a compound bone of the auditory capsule of skull.
2. Periotic is irregular, perforated and divided into a dense petrous portion and porous mastoid portion.
3. Petrous portion encloses the mastoid portion occupies the outer and posterior region.
4. The mastoid portion is produced ventrally into a mastoid process.

5. Tympanic bulla is more or less flask shaped applied to the outside of periotic between the basisphenoid and squamosal.
6. The body of flask encloses the tympanic cavity containing the tympanic membrane and a chain of three auditory oscicles- *malleus, incus* and *stapes*.
7. The narrow neck-like portion of the flask is called as *external auditory meatus*.

9. Squamosal

1. It is a rectangular plate like bone.
2. It gives rise to posterior tympanic process and zygomatic process.
3. It articulates anteriorly with frontal and jugal, laterally with parietal and posteriorly with supraoccipal.
4. It also bears a facet for the articulation of mandibular condyle.

10. Premaxilla

1. Premaxilla is the bone of upper jaw and occupies the anteriormost boundary.
2. It is thick and more or less triangular in outline.
3. It bears two sockets along its lower surface for the incisor teeth,
4. It is produced behind into elongated thin nasal process and palatine process.
5. It articulates anteriorly with its counterpart and posteriorly with the maxilla.

11. Maxilla

1. Maxilla is an irregular bone forming the major part of the upper jaw.
2. Along the lower surface it bears many sockets for premolar and molar teeth.
3. In the middle it gives off palatine process inwards which meets with its counterpart and forms the hard palate.
4. From its outer surface arises a thick zygomatic process which continues backward to meet the jugal forming the anterior boundary of the orbit.
5. Anteriorly it gives off a facial plate forming the side wall of the olfactory chamber.
6. It articulates anteriorly with premaxilla on the inner lateral side and posteriorly with palatine and dorsally with nasal and frontal.

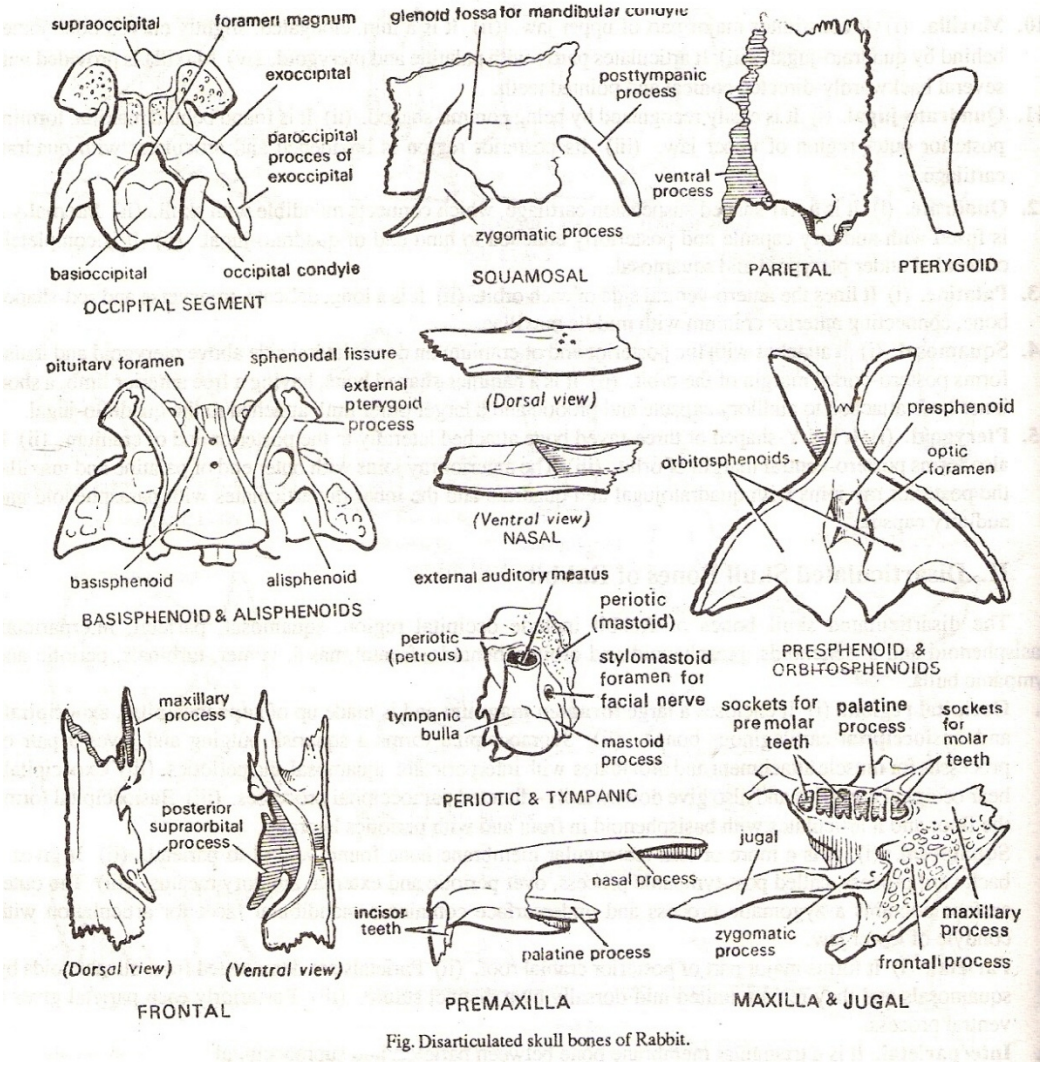


Fig. Disarticulated skull bones of Rabbit.

12. Lower jaw

1. Lower jaw comprises two rami, the dentaries meeting in front by a suture.
2. Each dentary is more or less triangular and flattened plate-like.
3. The anterior part of each dentary is stout and bears along its upper surface sockets for incisors and grinding teeth (premolars and molars).
4. Posteriorly each dentary bears a condyle upwards, a coronoid process anterior to condyle and an angular process below.

5.5.2. VERTEBRAL COLUMN

1. Atlas

1. It is first cervical and signet-ring like.
2. Centrum, zygapophyses absent and neural spine rudimentary.

3. On the sides are present flattened cervical ribs, the transverse process.
4. Anteriorly, it contains two facets for occipiul condyles and posteriorly, three facets odontoid process
5. During living condition, neural canal divided by a ligament. ridge-like.

2. Axis

1. It is second cervical.
2. Neural spine is flattened, antero-posteriorly elongated and ridge-like.
3. Cervical ribs or so called transverse processes are small.
4. Centrum contains peg like odontoid process,
5. Pre-zygapophyses absent.

3. Typical cervical

1. Rest of the cervicals are typical having small neural spine, large neural arch, flattened centrum, pre-zygapophyses and post-zygapophyses.
2. Transverse process bifurcated and perforated by a vertebraterial canal.

4. Anterior thoracic

1. It contains a backwardly-oriented neural spine.
2. Neural arch has upwardly-directed pre zygagophyses and downwardly-directed post- zygagophyses.
3. Transcerse processes short and contain facets for tuberculum ribs.
4. Centrum short.

5. Posterior thoracic

1. Last 4 or 5 thoracic vertebrae anterior ones in having a long centrum, short neural spine, distinct zygagophyses and reduced transverse processes.
2. It contains capitular facets,neural spine, distinct zygapophyses and reduced transverse processes. melapophyses and anapophyses.

6. Anterior lumbar

1. Out of 7, first two called as anterior lumbar vertebrae.

2. Neural arch on either side cotains an anteriorly directed process called metapophysis which bears pre- zygapophysis,and a posteriorly and backwardly directed anapophyses which bears post zygagophysis.

7. Posterior lumbar

1. 3rd to 7th vertebrae are called as posterior lumbar.
2. The resemble anterior lumbar in all respects except that a ridge-like hypapophysis is prevent below centrum.

8. Sacrum

1. Sacral vertebrae (4 in number) are fused to form a compact bone supporting pelvis.
2. The neural spines, zygapophyses and intervertebral formina are peculiar.
3. Metapophyses are reduced and anapophyses are absent.

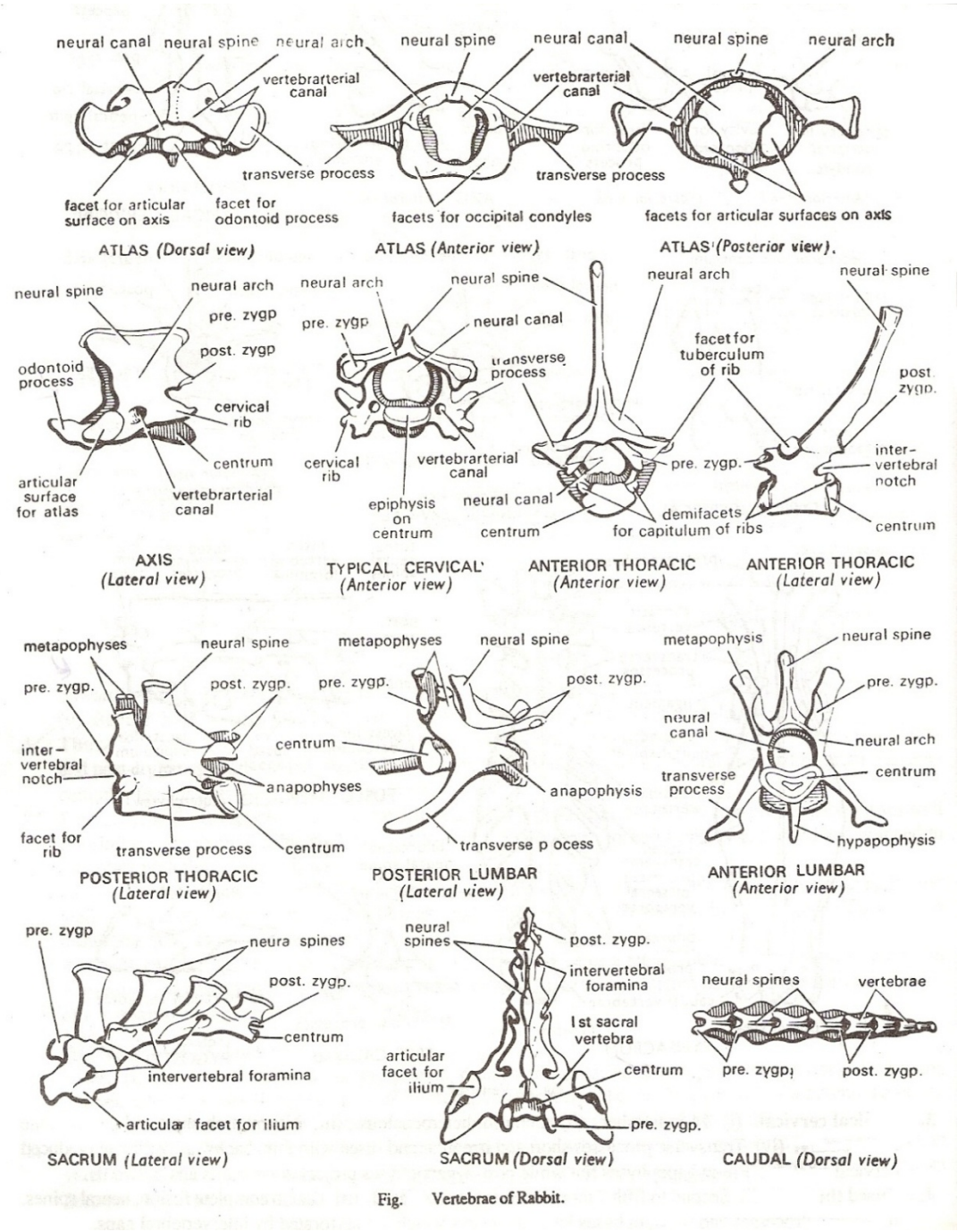


Fig. Vertebrae of Rabbit.

9. Thoracic Rib

The thoracic vertebrae carry each one pair of thoracic ribs. Ribs are slender, curved and each differentiated into dorsal bony vertebral portion and a ventral cartilaginous sternal portion. The vertebral end is bicephalous or two-headed, bearing two facets, the capitulum and the tuberculum,

articulating with the centrum and transverse process of the thoracic vertebra, respectively.

10. Sternum

1. Sternum is composed of six rod like pieces, the sternabrae arranged in a straight line.
2. The first piece is called the *manubrium*.
3. The last piece is long and slender called the *xiphisternum* which terminates in an expanded plate of cartilage the *xiphisternal cartilages* or xiphoid cartilage.

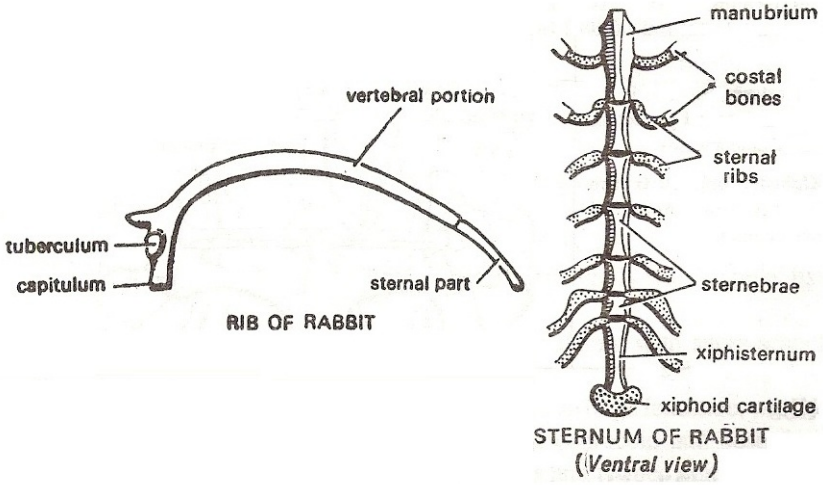


Fig. Thoracic ribs of and sternum of Rabbit

5.5.3. APPENDICULAR SKELETON

1. Pectoral Girdle

Each half of pectoral girdle is made up of clavicle and scapula-coracoid.

Clavicle

(i) Slender rod shaped, curved and membrane bone. It articulates with manubrium of sternum and acromian process of scapula.

Scapula-coracoid

(i) It is a triangular replacing bone. (ii) The apex contains a concavity called *glenoid cavity* for humerus head. (iii) Over glenoid cavity hangs a coracoid process. (iv) A distinct vertical spine divides outer surface of scapula and it terminates below into an *acromian process*, which further gives posteriorly a *metacromian process*.

2. Pelvic Girdle

1. Two halves of pelvic girdles are united at a *pubic symphysis*. Each half or innominatum contains ilium, ischium and pubis. Three bones are fused together forming hip bone. External to hip bone is a cup-shaped *acetabulum*.
2. **Ilium**- It is a blade-like bone which articulates with sacrum.
3. **Ischium**. It forms postero-dorsal part of innominate bone. Posteriormost part is thickened forming an *ischial tuberosity*.
4. **Pubis-** (i) It is a small bone forming ventro-lateral part of girdle. (ii) A small *cotyloid bone* prevents pubis from reaching up to acetabulum. (iii) Pubis is separated from ischium by a large *obturator foramen*.

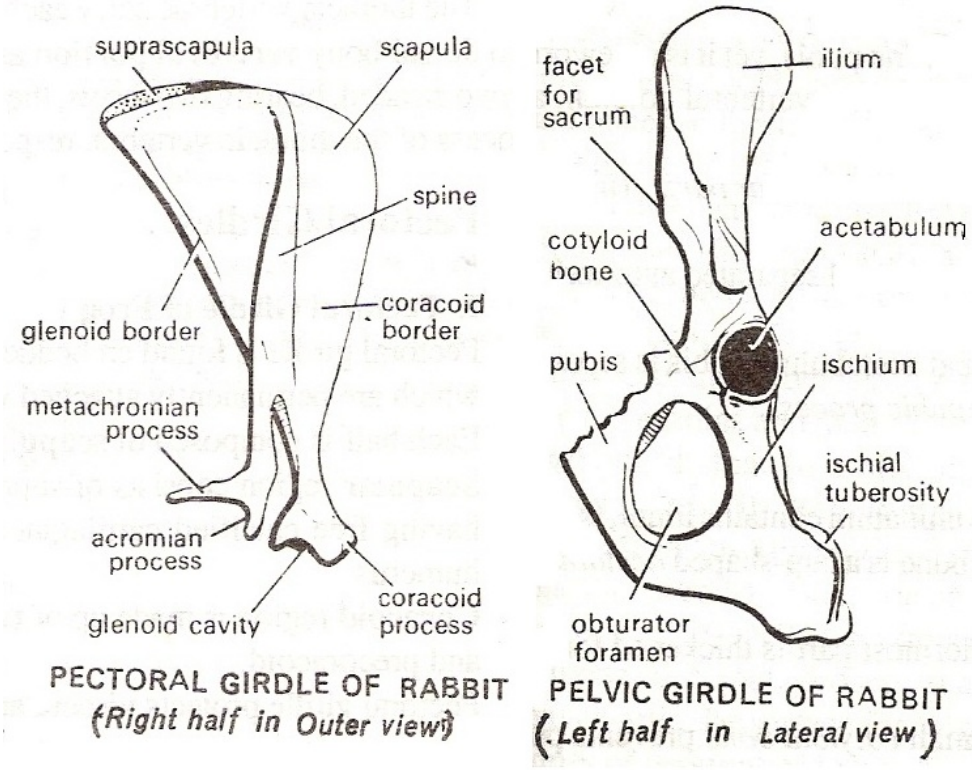


Fig. Girdles of Rabbit

Forelimb Bones

Forelimb comprises of humerus, radius, ulna and bones of forefoot or hand.

3. Humerus

1. It is a rod shaped bone.
2. Head articulate with glenoid cavity.

3. Close to head are outer greater and inner lesser tuberosities.
4. Deltoid ridge present.
5. Distally humerus contains a pulley-like trochlea to articulate with ulna.
6. Just above trochlea are coronoid and *olecranon fossae*.

4. Radius and ulna

1. Radius and ulna are separate but united firmly at both ends.
2. Radius is smaller and curved.
3. At the proximal end of ulna is an olecranon process which articulates with olecranon fossa of humerus.
4. At the base of olecranon process is a sigmoid notch which fits into trochlea of humerus.

5. Bones of forefoot or hand

1. Wrist contains nine small bones in two rows, namely *radiale, intermedium* and *ulnare* in proximal row and single *centrale, trapezium, trapeziod, magnum*, and *unciform* in distal row.

2. A sesamoid bone or *pisciform* is found on ventral side of carpus.
3. Manus has five digits with 2, 3, 3, 3 and 3 phalanges, respectively.
4. Terminal phalanx bears a horny claw.

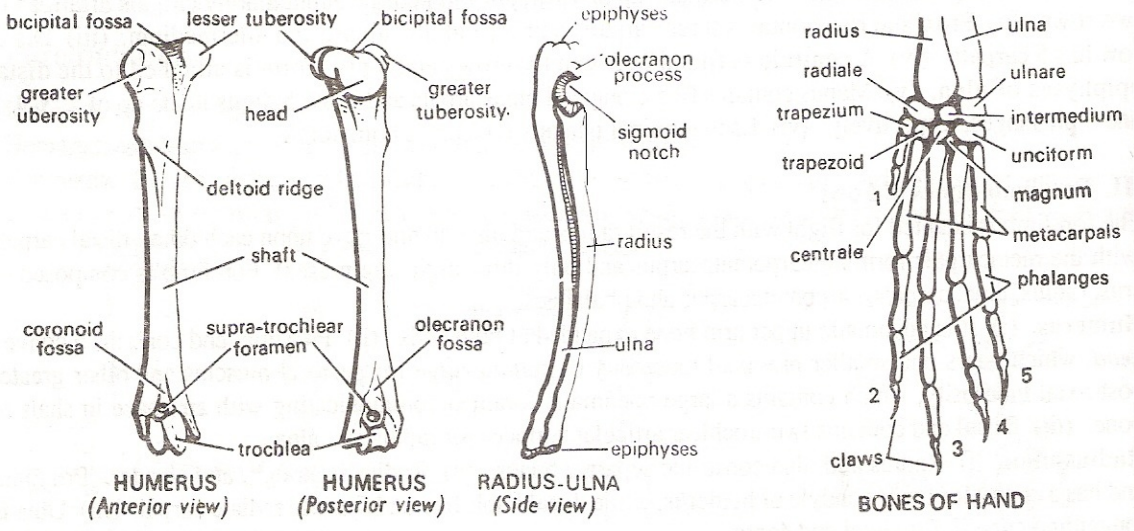


Fig. Forelimb bones of Rabbit

Hindlimb Bones

Hindlimb is formed by femur, tibio-fibula and bones of hindfoot.

6. Femur

1. It is thigh bone.
2. Proximal head articulates with acetabulum.
3. Lesser, greater and third trochanters present for muscle attachment.
4. Distally it has pulley-shaped structure, having two lateral condyles which enclose an intercondylar groove.

7. Tibio-fibula

1. Tibio-fibula form shank bones.
2. They are free proximally and united distally.
3. Tibia is large and fibula small and distally tapering.

8. Bones of hind foot

1. It contains tarsal bones in two rows.
2. Tibiale and intermedium of the proximal row are fused to form astragalus on pre-axial side, while calcaneum is the largest tarsal bone produced into a *spur* on post-axial side.
3. Distal row contains three bones-mesocuneiform, ectocuneiform and cuboid.
4. Only four toes each having three phalanges, the terminal one bearing a claw.

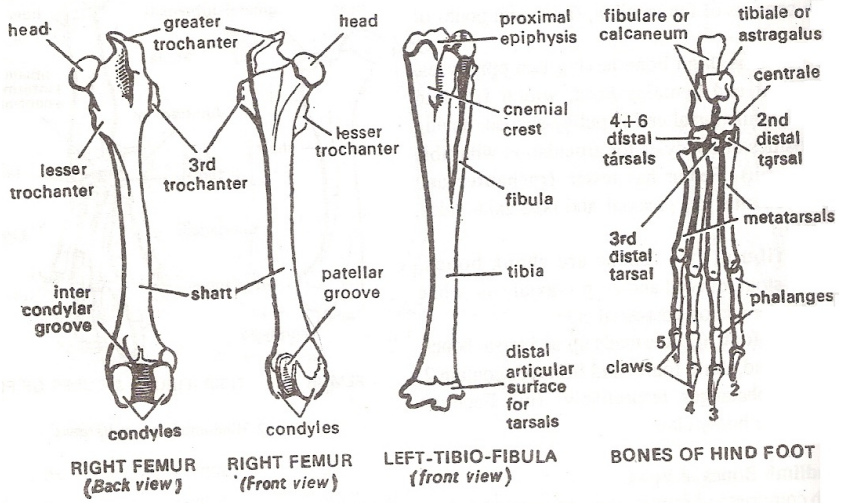


Fig. Hindlimb bones of Rabbit

5.6. Self learning exercises

1. Give a comparative account of skull of Frog, *Varanus*, Fowl and Rabbit.
2. Draw a labeled diagram and comments upon the following:

   (i) Pectoral girdle of Fowl

   (ii) Synchacrum bone

   (iii) Furcula bone

   (iv) Astragallus-calcanium bone
3. Make a comparative account of limb bones of Frog, *Varanus*, Fowl and Rabbit and study the peculiarities of each bone.

5.7. References

- ***Practical zoology- Vertebrate*****:** S.S. Lal; Rastogi publishers.
- ***Advanced Practical Zoology*****:** Verma, P.S. and Srivastava, P.C.: S.Chand and Company Ltd.
- ***A manual of Practical Zoology-CHORDATE:*** P.S. Verma; S.Chand and Company Ltd.
- ***https://en.wikipedia.org***.

Unit- 6

Genetic-I

Structure of the Unit

6.0. Objectives

After going through this exercise the students will learn about the genetics and inheritance in *Drosophila*. They will distinguish between male and female *Drosophila* by observing the structural changes as there are a lot of difference between male and female *Drosophila*. In nature genetically there occur many mutant variety of *Drosophila* which structurally differ with Wild one, here given in detail the difference between wild and mutant variety. At the end student can identify the sex, wild and mutant forms of *Drosophila*.

6.1. Introduction

Drosophila is commonly known as fruit fly as it is commonly found on fruits. It specially used in the study of animal genetics. Due to its small size, short life cycle, abundance of genetic variability, and relative inexpensiveness, Drosophila used as the model organism in research. The wild-type phenotypes were winged flies and red eyes, while the mutant phenotypes were apterous (wingless) and sepia (brown) eyes.

6.2. Identification of male and female *Drosophila*

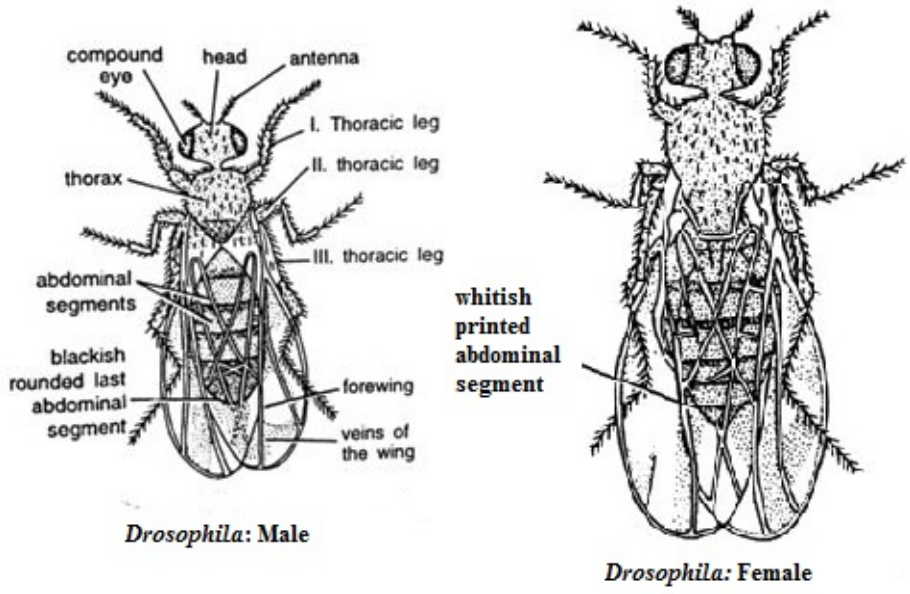
There are several morphological differences between male and female Drosophila as following:

6.2.1. *Drosophila*: Male

Comments

1. Males are smaller than females (Fig. 1).
2. Body is divided into head, thorax and abdomen. Head is joined to thorax by a narrow neck
3. Head contains large compound eyes and a pair of antennae. Antennae bear setae or brisks.
4. Thorax contains 3 paired thoracis legs; each leg bears setae or bristles.
5. Thorax contains wings extended beyond abdomen.
6. The abdomen of the male has only five segments, two dark stripes, and a more rounded, heavily pigmented tip.
7. The mature male show dark genitalia (Fig. 2).

8. Male flies have a secondary sex characteristic called a sex comb (Fig.3), which is a small tuft of about 10 black bristles at the front of the last large segment.



Drosophila: Male

Drosophila: Female

Fig. 1 showing *Drosophila* male and female

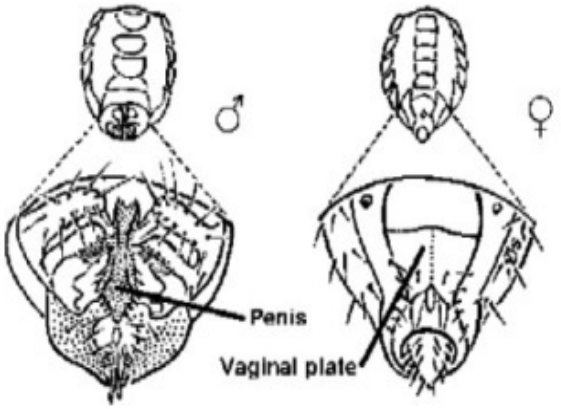


Fig. 2. Ventral view of genitalia of male (left) and female (right) *Drosophila*

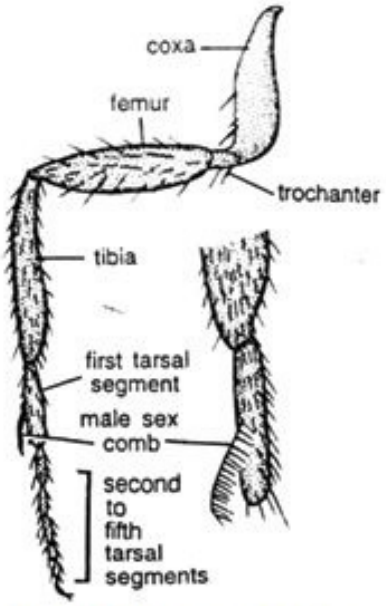


Fig. 3 Male sex comb

6.2.2. *Drosophila*: Female

Comments:

1. Females are larger than males (Fig. 1).
2. Body divisible into head thorax and abdomen.
3. Head contains paired large black compound eyes and paired antennae. Antennae contain bristles.
4. Thorax contains 3 pairs of legs and 2 pairs of wings. Thorax and legs contain large number of bristles.
5. The female abdomen pale in colour and relatively smooth.
6. The abdomen of the female has seven segments, several dark transverse stripes and is pointed at the tip
7. Last abdominal segment contains anal plates which are pointed and last abdominal segment looks like pointed.
8. Hind wings in fold condition extend males beyond last abdominal segment.

6.3. Identification of wild and mutant forms of *Drosophila*

6.3.1 Wild type

Comment:

1. Body divisible into head, thorax and abdomen (Fig.4).
2. Head contains antennae and large compound eyes.
3. Wild type was grey or brown colour.
4. Eyes are brick red colour.
5. Thorax contains wings, halters and secretellum.

6.3.2. Mutant types

Certain mutant types of *Drosophila* are found to taking place of mutation which is as follows:

6.3.2.1. *Drosophila*: Yellow body.

Comments:

1. Body divisible into head thorax and abdomen (Fig.4).
2. Head contains antennae and compound eyes.

3. Thorax contains 3 pairs of legs and 2 pairs of wings
4. Characterized by yellow colour of the body.

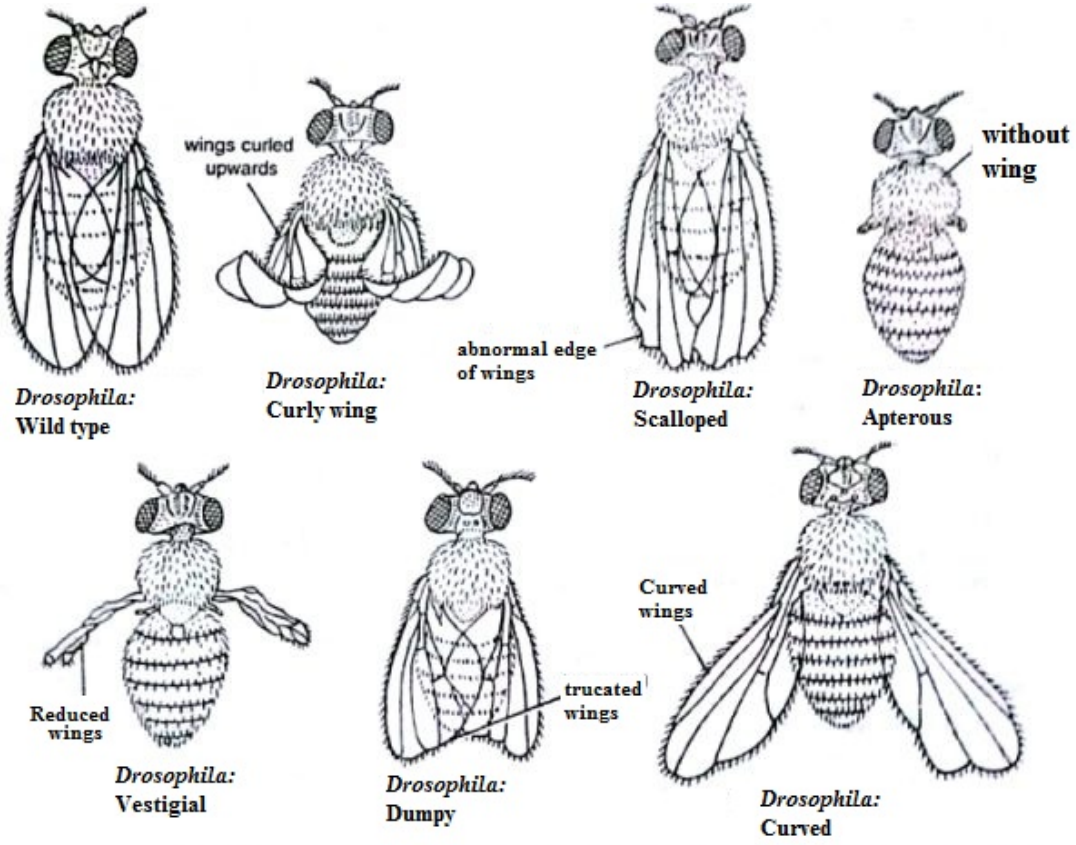


Fig. 4 shows structural variation in wild and mutant types of *Drosophila*

6.3.2.2. *Drosophila*: Curly wings

Comments:

1. Body divisible into head, thorax and abdomen (Fig.4).
2. Head contains antennae and compound eyes.
3. Thorax contains 3 pairs of legs and 2 pairs of wings.
4. Hind wings are curly, they curled upwards.

6.3.2.3. *Drosophila*: Scalloped

Comments:

1. Body divisible into head thorax and abdomen (Fig.4).
2. Head contains antennae and compound eyes.

3. Thorax contains 3 pairs of legs and paired forewings and hindwings.
4. Wings have abnormal edges.

6.3.2.4. *Drosophila*: Apterous (wingless)

Comments:

1. Body divisible into head, thorax and abdomen (Fig.4)
2. Head contains compound eyes and compound eyes.
3. Wings absent known as apterous.
4. Bristles present all over body.

6.3.2.5. *Drosophila*: vestigial

Comments:

1. Body divisible into head, thorax and abdomen (Fig.4).
2. Head contains small antennae and compound.
3. Thorax has 3 pairs of legs.
4. Wings reduced vestigial types.

6.3.2.6. *Drosophila*: Dumpy

Comments:

1. Body divisible into head, thorax and abdomen (Fig.4).
2. Head contains antennae and compound eyes.
3. Wings truncated.
4. Bristles present all over body.

6.3.2.7. *Drosophila*: Curved.

Comments:

1. Body divisible into head, thorax and abdomen (Fig.4).
2. Head contains compound eyes and antennae.
3. Bristles present all over the body.

4. Wings curved.

6.4. Monohybrid and Dihybrid inheritance in *Drosophila*

6.4.1. Monohybrid inheritance

The simplest form of a cross is a **monohybrid cross**, which shows the inheritance of a single trait and its associated variations. Through analysis of a cross below shows the progression of a pair of alternative alleles for inheritance of a single gene through two generations. A cross between homozygous ebony body (ee) and wild type body (e+e+) carried to study inheritance of a single gene.

CROSS DIAGRAM

Parent 1 (P1) **ee** (ebony body) x **e+e+** (wild-type body) [homozygous parents]

Gametes **e** **e+**

F1 **e+e** (all wild-type body) [heterozygous offspring]

gametes of F1 **e+** & **e**

Cross between F1 offsprings:

F / M	e+	e
e+	e+ e+	e+ e
e	e+ e	e e

F2 Phenotype ratio 3 wild-type: 1 ebony body

Genotype ratio 1 **e+e+** : 2 **e+e** : 1 **ee**

During gamete formation, the members of a pair of alleles are duplicated and then segregated from one cell into four separate gametes so that each contains only one member of the pair (**Law of Segregation**).

A **Punnet Square** diagram can be used to calculate the various combinations. The gametes

from one parent are written across the top, and those from the other go down the side. Each one of these gametes has an equal chance of combining with either of the gametes from the other parent (known as **Random Union of Gametes**).

In cases as in the above example, the F2 phenotype ratio of 3:1 indicates a case of **complete dominance.** That is, one allele completely masks the expression of the other (**recessive**) allele.

In cases of **incomplete dominance**, on the other hand, neither allele masks the other, and heterozygous individuals express new phenotypes that are intermediate between the homozygous parents. This may arise for example if the dominant homozygous phenotype results from the expression of a double-dose of gene product, and the heterozygous phenotype from a single dose. The F2 phenotype ratio of 1:2:1 is characteristic. A non-*Drosophila* example of this is seen in red- and white flowered snap dragons:

P1 **RR** (red) x **rr** (white)

F1 **Rr** (pink)

F2 1 **RR** (red) : 2 **Rr** (pink) : 1 **rr** (white)

When both alleles are expressed the effect is known as **codominance**. Heterozygous individuals express gene products from both alleles: unlike incomplete dominance, the phenotype need not be intermediate. This sort of interaction is seen in the **ABO** blood group system of humans. One allele controls the production of **A** antigen while the other controls the **B** antigen (a third allele **O** produces no antigen). Heterozygotes carrying the allele for antigen **A** and the allele

for antigen **B** have blood type **AB** in which both proteins are present in equal quantities. The F2 shows a ratio of 1:2:1, as in the case of incomplete dominance.

6.4.2. Dihybrid inheritance

Dihybrid inheritance involves manipulation and analysis of two traits or characters controlled by pairs of alleles at different loci. Dihybrid inheritance can be shown by the cross between ebony body, wild type wing and wild type body, vestigial wings where the loci for ebony body colour and vestigial wing are on separate autosomes. Therefore the genotypes and gametes are the same for male and female.

e is ebony body colour

e+ is wild-type body colour

vg is vestigial wing shape

vg+ is wild-type wing shape:

CROSS DIAGRAM

P1 ebony body, wild type wings x Wild type body, vestigial wing

ee vg+vg+ **e+e+ vgvg**

gametes **e vg+** **e+vg**

F1 **e+e vg+ vg** (all wild-type)

Gametes for F2 **e+vg+, e+ vg, evg+, e vg** F2 genotype combinations:

M \ F	e^+vg^+	e^+vg	$e\ vg^+$	$e\ vg$
e^+vg^+	$e^+e^+vg^+vg^+$	$e^+e^+vg^+vg$	$e^+e\ vg^+vg^+$	$e^+e\ vg^+vg$
e^+vg	$e^+e^+vg^+vg$	e^+e^+vgvg	$e^+e\ vg^+vg$	$e^+e\ vgvg$
evg^+	$e^+e\ vg^+\ vg^+$	$e^+e\ vg^+\ vg$	$ee\ vg^+\ vg^+$	$ee\ vg^+\ vg$
evg	$e^+e\ vg^+\ vg$	$e^+e\ vg\ vg$	$ee\ vg^+\ vg$	$ee\ vg\ vg$

F2 Phenotype ratio: 9 wild-type: 3 ebony: 3 vestigial: 1 ebony vestigial

In a dihybrid cross, each of the F1 parents can produce four different gamete types, so there are 16 (= 4 x 4) possible offspring combinations. Because the two traits show complete dominance and separate independently of each other (**Law of Independent Assortment**), the expected genotypic and phenotypic ratios from an analysis of these 16 possibilities can be calculated.

Phenotype	Genotype
9:3:3:1	1:2:1:2:4:2:1:2:1

These ratios can be derived from the results of a monohybrid ratio. A basic principle of probability theory is that the probability of two independent events occurring together is equal to the *product* of the two independent probabilities.

For example, the expected proportions of flies with wild-type and ebony body colours in a

monohybrid cross are 3/4 and 1/4, respectively. Likewise, in a monohybrid cross involving vestigial wings, the proportions are 3/4 wild-type and 1/4 vestigial-winged. In a dihybrid cross, the proportions of flies with various combinations of *both* characters can be calculated as:

wild-type & wild-type = 3/4 x 3/4 = 9/16.

Ebony = 1/4 x 3/4 = 3/16

wild & vestigial = 3/4 x 1/4 = 3/16

ebony & vestigial = 1/4 x 1/4 = 1/16

This produces the familiar 9:3:3:1 ratio. In a similar manner, the expected genotype proportions can be predicted because each monohybrid cross produces a 1:2:1 genotype ratio. The product [1:2:1] x [1:2:1] = [1:2:1:**2:4:2**:1:2:1] then gives the results of the dihybrid cross.

6.5. Self learning Exercise

1. What do you mean by monohybrid and dihybrid inheritance?
2. What is genotypic ratio?
3. What is phenotypic ratio?
4. What is significance of Punnet Square?
5. What is the phenotypic and genotypic ratio of monohybrid?
6. What is the phenotypic and genotypic ratio of dihybrid?
7. Describe the monohybrid inheritance in *Drosophila*.

6.6. References

- ***Genetics, Evolution and Ecology:*** Gupta, P.K. : Rastogi Publications.
- ***Wikipedia encyclopedia*.**
- ***Advanced Practical Zoology:*** Verma, P.S. and Srivastava, P.C. : S.Chand and Company Ltd.

Unit- 7

Genetic-II

Structure of the Unit

7.0. Objectives

After going through this unit you will be able to understand the laws of genetics i.e. mendelian genetics through exercises based on law of dominance, law of segregation, law of independent assortment and related exception of these laws. In this unit you will learned about types of blood groups and their identification in laboratory. You come to know about sex chromatin which is responsible for differentiation of sex i.e. male and female.

7.1. Introduction

The Genetics deals with the mechanism of heredity and causes of variations in living beings. Several interesting experiments based on the principles and laws of heredity can be conducted in laboratories. But due to many limitations our laboratories are not fully equipped for conducting such genetic experimentation. Therefore, we are left with the option of discussing the principles and laws of heredity theoretically. Here some exercises in form of question are solved for understanding mendelian laws of genetics.

7.2. Simple problems based on Mendelian genetics

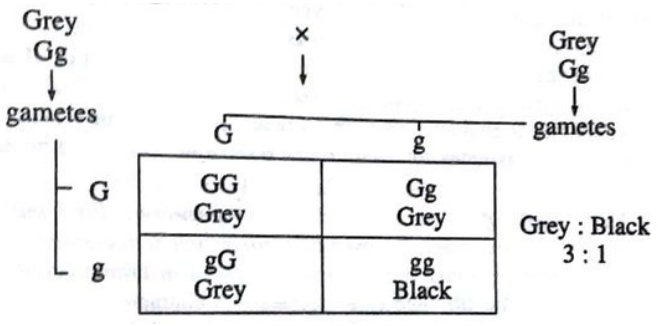
7.2.1. Based on Dominance and recessive (Exercise no.: 1-3)

EXERCISE No. 1

Object: Two grey *Drosophila* flies on breeding produce 152 grey and 49 black offsprings. Give the genotype of the parents and justify your answer giving reasons. (Given grey is dominant over black).

Observation: The ratio of the dominant and recessive offsprings in the given problem 152:49 comes to be approximately 3:1. Hence, the parents of these offsprings will be heterozygous for grey and black traits having genotypes **Gg** and **Gg.**

Explanation: In case of a monohybrid cross when heterozygous individuals are crossed among themselves, they produce offsprings with dominant and recessive characters in a ratio of 3:1(see the cross given below),



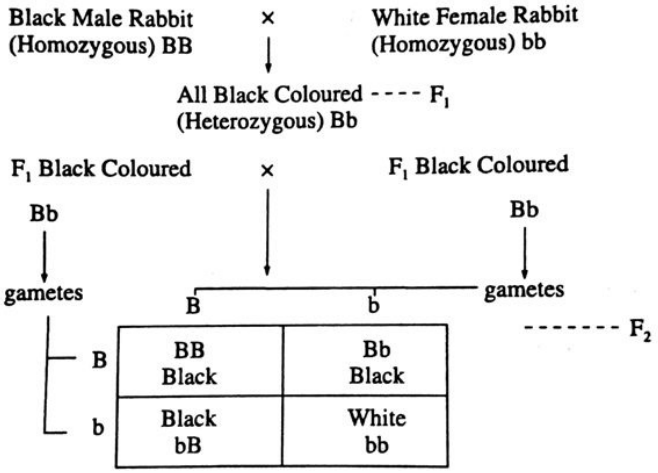
Conclusions: The genotypes of the parents will be Gg and Gg. It is a case of simple Mendelian inheritance showing the phenomenon of dominance and recessive.

EXERCISE No. 2

Object: Work out the phenotypic and genotypic ratio of F_1, and F_2, generations from a cross of a homozygous black-coloured male rabbit with homazygous white-coloured female rabbit considering black is dominant over white. Mention the genetical principles involved.

Observation: The given problem is a case of monohybrid inheritance. It is related to the phenomena of dominance, recessive and segregation. Hence, it is a case which will be governed laws of inheritance.

Explanation: When homozygous black coloured male rabbit (BB) is crossed with a homozygous white-coloured female rabbit (bb), the F_1 offsprings would be all black coloured but heterozygous with genotype, Bb. When the individuals of F_1 are crossed among themselves then the F_2 offsprings would be phenotypically of two types in the ratio of 3:1 (3 dominant and 1 recessive) and their genotypic ratio would be 1:2:l (See the cross worked out below).



Conclusions: F_1 phenotype is black and genotype is Bb (all individuals). F_2 phenotypic ratio is 3:1 (3 dominant and 1 recessive) and genotypic ratio is 1:2:1 (1 homozygous black, 2 heterozygous black and 1 homozygous white). In addition to these results something more can be concluded:

That, individuals with dominant character may be both homozygous and heterozygous. That, individuals with recessive character will only be homozygous. That, individuals with different genotypes may have similar phenotypes. That, the genetical principle involved is the law of dominance and recessive which states that one factor(gene) in a pair may mask or prevent the expression of the other as is apparent from black heterozygous

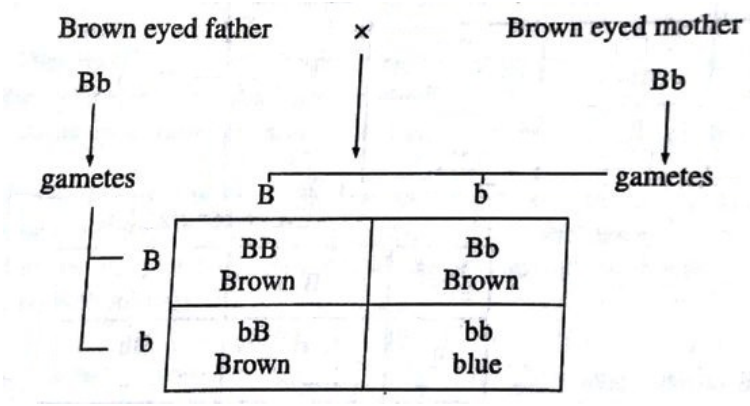
individuals in which B masks the expression of b That, the other genetical principle involved is the law of segregation or of purity of gametes which states that during gamete formation, the two factors(genes) of each character segregate leaving one factor(gene) of a character in each gamete. It is apparent when F_1 black-coloured heterozygous individuals form gametes, the factor B and b separate. Hence, gametes are always pure.

EXERCISE No. 3

Object: Both the parents of a blue-eyed child are brown-eyed. Find out the genotypes of the parents if brown eyes (B) are dominant over blue (b) which is recessive.

Observation: Since recessive character is only expressed in homozygous condition, hence, the genotype of the child will be *bb*. The child receives its characters from both the parents in equal amount. Therefore, its one *b* has come from one parent and the other *b* from other parent causing his eyes blue. But in the given problem both the parents are brown-eyed. Therefore, they must have been heterozygous with genotypes *Bb* and *Bb*.

Explanation: When heterozygous brown eyed parent cross, they produce brown-eyed and blue-eyed offspring in the ratio 3:1. The brown-eyed offsprings having genotypes *BB* and *Bb*, while blue eyed with *bb*. (See the cross worked out below).



Conclusion: The genotypes of the parents of a blue-eyed child will be *Bb*. It is a case of simple Mendelian monohybrid inheritance showing the phenomena of dominance, recessive and segregation.

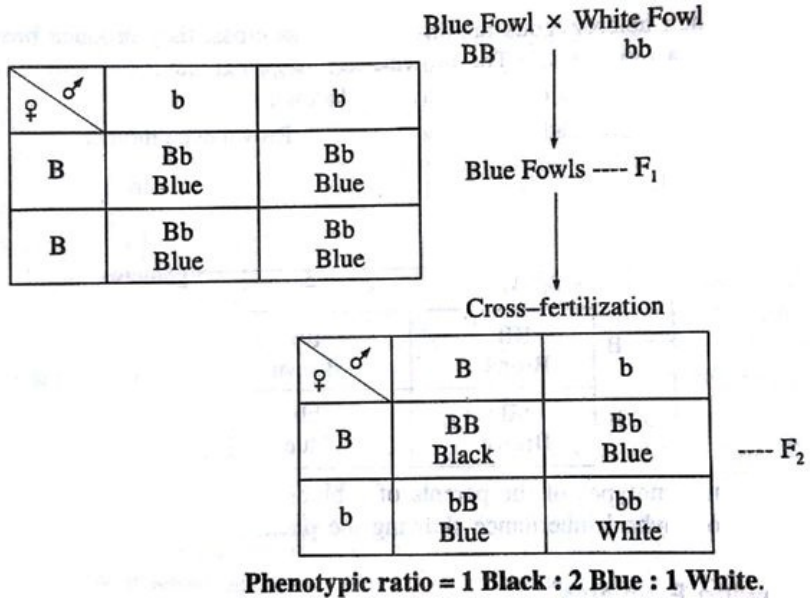
7.2.2. Based on Incomplete dominance (Exercise no.: 4)

EXERCISE NO. 4

Object: Explain giving reason for the occurrence of modified 3:1 phenotypic ratio to 1:2:1 for in a monohybrid cross.

Observation: According to the phenomenon of dominance, a monohybrid cross should always result into F_2 offsprings in a phenotypic ratio of 3:1 and their genotypic ratio being 1:2:1. But sometimes, due to incomplete dominance, 3:1 phenotypic ratio comes to be 1:2:1. It means that the phenomenon of dominance shows exceptions.

Explanation: Let us consider an example to illustrate the modified 1:2:1 phenotypic ratio. In Andalusian fowl a cross between its homozygous black and white varieties results in blue hybrids. These blue hybrids when crossed among themselves, the F_2 generation offsprings are 1 black: 2 blue: 1 white (see the cross given below). The colour of F_1 hybrid blue is a blended character, i.e., a colour midway between the two parents. It means that none of the colour of the parents are either fully dominant or recessive. Therefore, both the factor express themselves partially resulting into a blending of parental characters. Such factors are usually referred to as intermediate factors or genes.



Conclusions: The modified phenotypic 1:2:1 ratio is due to the phenomenon of incomplete dominance. As referred to, it is due to intermediate genes, hence, called intermediate inheritance.

7.2.3. Based on Lethal genes (Exercise no.: 5-6)

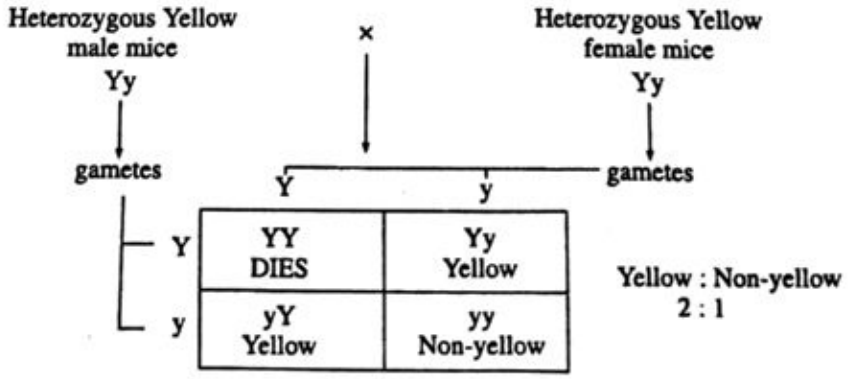
EXERCISE No. 5

Object: In a monohybrid cross a modification of usual 3.1 phenotypic ratio comes to be 2:1. Explain giving full explanation of such a result.

Observation: According to the laws of inheritance, a monohybrid cross should always yield a phenotypic ratio of 3:1 but in the given problem the phenotypic ratio 2:1 which appears to be due to some lethal factor causing death of one of the offsprings before birth.

Explanation: Let us consider an example to illustrate the modified 2:1 phenotypic ratio. In case of yellow race of house mouse (*Mus musculus*) though yellow colour is dominant over non-yellow yet it comes into expression only in the heterozygous individuals (see the cross given below). When two heterozygous yellow mice are mated with each other, the offsprings show a ratio of 2 yellow to 1 non-yellow instead of a usual ratio of 3 yellow homozygous and 2 heterozygous) to 1 non-yellow expected for a monohybrid cross of heterozygous parents.

In such a cross postmortem examination (autopsis) of female mice shows that the homozygous yellow coat coloured offspring dies in the embryonic condition before birth. Thus, only the heterozygous offsprings and pure recessive offspring survive. Therefore, the normal 3:1 ratio is modified to 2:1



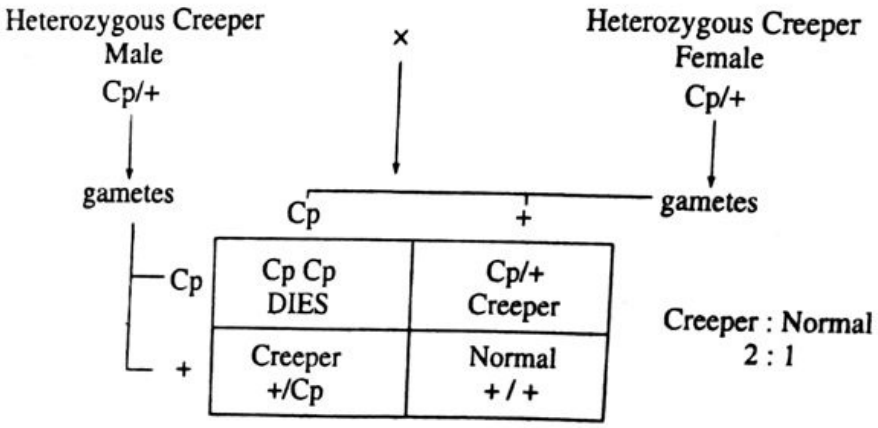
Conclusions: This modification is due to some lethal genes which cause lethality showing abnormal ratio in the offsprings. In fact, various plants and animals are known to possess some genes, which when come in homozygous condition cause an early death of the offspring in embryonic condition.

EXERCISE No. 6

Object: A poultry farmer crossed two creeper birds and got 4 eggs. When he incubated the eggs, 2 creepers and 1 normal birds were obtained. One bird died during incubation. Explain the cross and point out genetic principles involved.

Observation: It appears from the problem/object that it is a case of monohybrid inheritance yielding a phenotypic ratio of 2:1 Thus; it is a case of lethal gene action.

Explanation: From the object it is apparent that the two creeper birds considered in the cross would have been heterozygous for creeper genes. The creeper genes are lethal in birds. Hence, when they came in homozygous condition in one case, caused death of the bird in embryonic condition during incubation Therefore, only 3 offsprings survived (2 heterozygous creepers and 1 normal). See the cross given below:



Conclusion: It is a case of absolute lethal gene action. Hence, one homozygous creeper (Cp Cp) died during incubation. The offsprings which survived are 2 heterozygous creepers and normal.

7.2.4. Based on Law of independent assortment (Exercise no.: 7-8)

EXERCISE No. 7

Object: In garden pea, tall (*T*) is dominant over dwarf (*t*) and red flower colour (*R*) to white (*r*). If pure red tall is crossed with a dwarf white, what will be (i) P_1 genotypes, (ii) the gametes of P_1, (ii) the F_1 phenotype and genotype, (iv) the gametes of F_1, and(v) F_2 phenotypic ratio. Point out the genetic principles involved.

Observation: It appears from the object that it is a case of dihybrid cross and based on the principles of Mendelian inheritance.

Explanation: To find out the solutions of the questions asked in the object, work out the cross as suggested below:

Pure red tall means homozygous tall plants with red flowers; genotype will be *TTRR*. Dwarf white means homozygous dwarf plants with white flowers; genotype will be *ttrr*. It will be homozygous because recessive characters are expressed only when they are in homozygous condition.

(P_1)	**Phenotype**	Tall red	×	Dwarf white
	Genotype	TT RR		tt rr
	Gametes	TR, TR		tr, tr
(F_1)	**Genotype**	TR tr ;		TR tr
	Phenotype	Tall red		Tall red
	Gametes	TR, Tr, tR, tr;		TR, Tr, tR, tr

×

(F_2) Genotypes and Poenotypes

♀ \ ♂	TR	Tr	tR	tr
TR	TR TR Tall red	TR Tr Tall red	TR tR Tall red	TR tr Tall red
Tr	Tr TR Tall red	Tr Tr Tall white	Tr tR Tall red	Tr tr Tall white
tR	tR TR Tall red	tR Tr Tall red	tR tR Dwarf red	tR tr Dwarf red
tr	tr TR Tall red	tr Tr Tall white	tr tR Dwarf red	tr tr Dwarf white

Phenotypic ratio 9 Tall red 3 Tall white: 3 Dwarf red 1 Dwarf white.

Conclusions: (i) P_1 genotypes are *TTRR* and *ttrr*, (ii) the gametes of P_1 are *TR* and *tr* types, (iii) F_1 phenotype is Tall red and genotype is *TRtr* for all possible offsprings, (iv) the gametes of F_1 are *TR, Tr, tR* and *tr*, and (v) the F_1 phenotypic ratio is 9:3:3:1.

The genetic principles involved are the phenomena of dominance and recessive, law of segregation and the law of independent assortment.

EXERCISE No. 8

Object: A plant breeder crossed a pure variety of tall tomato plant having hairy stem with a dwarf tomato plant without hairy stem (hairless) and in F_2, generation he got 4 varieties of plants numbering 619, 185, 188 and 61, Find out F_1 phenotype and genotype, F_2 phenotypic ratio and genotypic ratios if tall (T) and hairy (H) characters of tomato plant are dominant over their alleles dwarf and hairless. Point out the genetic principles involved.

Observation: It is apparent from the object that it is a case of Mendelian dihybrid inheritance,

Explanation: A cross between pure tall hairy tomato plant with that of dwarf hairless plant yields 4 varieties of plants in F_2 generation in a ratio of 619:185 188:61. The numbers of 4 varieties of plants suggest an approximate ratio of 9:3:3:1. To find out the solutions, work out the cross given below:

(P_1)	**Phenotype**	Tall hairy	×	Dwarf hairless
	Genotype	TT HH		tt hh
	Gametes	TH, TH		th, th
(F_1)	**Genotype**	THth		THth
	Phenotype	Tall hairy		Tall hairy
	Gametes	TH, Th, tH, th;		TH, Th, tH, th

×

(F_2) Genotypes and Poenotypes

♀ \ ♂	TH	Th	tH	th
TH	TH TH Tall hairy	Th TH Tall hairy	tH TH Tall hairy	th TH Tall hairy
Th	TH Th Tall hairy	Th Th Tall hairless	tH Th Tall hairy	th Th Tall hairless
tH	TH tH Tall hairy	Th tH Tall hairy	tH tH Dwarf hairy	th tH Dwarf hairy
th	TH th Tall hairy	Th th Tall hairless	tH th Dwarf hairy	th th Dwarf hairless

Phenotypic ratio = Tall hairy 9, Tall hairless 3, Dwarf hairy 3, and Dwarf hairless 1.

No. of plants	*Genotype*	*Phenotype*
1	TTHH	Homozygous tall hairy
2	TTHh, TTHh	Homozygous tall hairy
2	TtHH, TtHH	
4	TtHh, TtHh, TtHh, TtHh	
9	**1 : 2 : 2 : 4**	**Tall hairy**
1	TThh	Homozygous tall hairless
2	Tt hh, Tt hh	Homozygous tall hairless
3	**1 : 2**	**Tall hairless**
1	tt HH	Homozygous dwarf hairy
2	ttHh, ttHh	Heterozygous dwarf hairy
3	**1 : 2**	**Dwarf hairy**
1	tthh	Homozygous **dwarf hairless**
Total F_2 offsprings **16**		**Phenotypic ratio 9 : 3 : 3 : 1**

Conclusions: F_1 phenotype is tall hairy and genotype is *Tt Hh*, F_2 phenotypic ratio is 9:3:3:1 and F_2 genotypic ratio is 1:2:2:4 (9 Tall hairy), 1:2 (3 Tall hairless), 1:2 (3 Dwarf hairy) and 1 dwarf hairless.

The genetic principles involved are the phenomena of dominance and recessive, law of segregation and the law of independent assortment.

7.2.5. Based on Interaction of genes

EXERCISE No. 9

Object: A farmer crossed a homozygous dominant white Leghorn fowl with a poultry homozygous recessive white Plymouth Rock fowl and then inbred the individuals of F_1 and got white feathered and coloured feathered fowls in the ratio of 13:3. Explain the principles involved.

Observation: It appears to modified ratio of 9:3:3:1. The modified ratio 13:3 has of the interaction of be a genes. It is because of epistatic or inhibiting genes. When a pair of genes at one locus prevent the expression of a pair of genes at another locus, then such genes are called inhibiting genes. The phenomenon of the prevention of the expression of one pair of genes by another pair of genes is called **epistasis**. Epistasis is, in fact, inter-allelic suppression. Such genes are called **epistatic genes** and those which are prevented from expression are called **hypostatic genes**.

Explanation: In poultry a basic gene *C* produces colour in feathers, while the inhibiting gene *I* prevents the development of colour, Thus, gene I interacts with the gene *C* to suppress its expression. Because of this

interaction, the Leghorn fowl is white having genotype *CCII* but the Plymouth Rock fowl is white because it has recessive genes *ccii.* However, work out the cross given in the object and notice that in F_2 offsprings, the individuals having *I* gene along with colour producing gene *C* in their genotypes produce white feathered fowls, while those without gene *I* produce coloured feathered fowls. (See the cross given below).

	Phenotype	Homozygous dominant White Leghorn fowl	×	Homozygous recessive White Plymouth Rock fowl
(P_1)	**Genotype**	CCII		ccii
	Gametes	CI, CI		ci, ci
	Genotype	CIci		CIci
(F_1)	**Phenotype**	Heterozygous white	×	Heterozygous white
	Gametes	CI, Ci, cI, ci		CI, Ci, cI, ci

(F_2) **Offsprings**

♀ \ ♂	CI	Ci	cI	ci
CI	CICI White	CiCI White	cICI White	ciCI White
Ci	CICi White	CiCi **Coloured**	cICi White	ciCi **Coloured**
cI	CIcI White	CicI White	cIcI White	cicI White
ci	CIci White	Cici **Coloured**	cIci White	cici White

Phenotypic ratio = White : Coloured
13 : 3

Conclusions: It is a case showing dominant epistasis. Due to interaction of epistatic genes and the dihybrid ratio 9:3:3:1 is modified into 13:3.

7.2.6. Based on Multiple alleles

EXERCISE No. 10

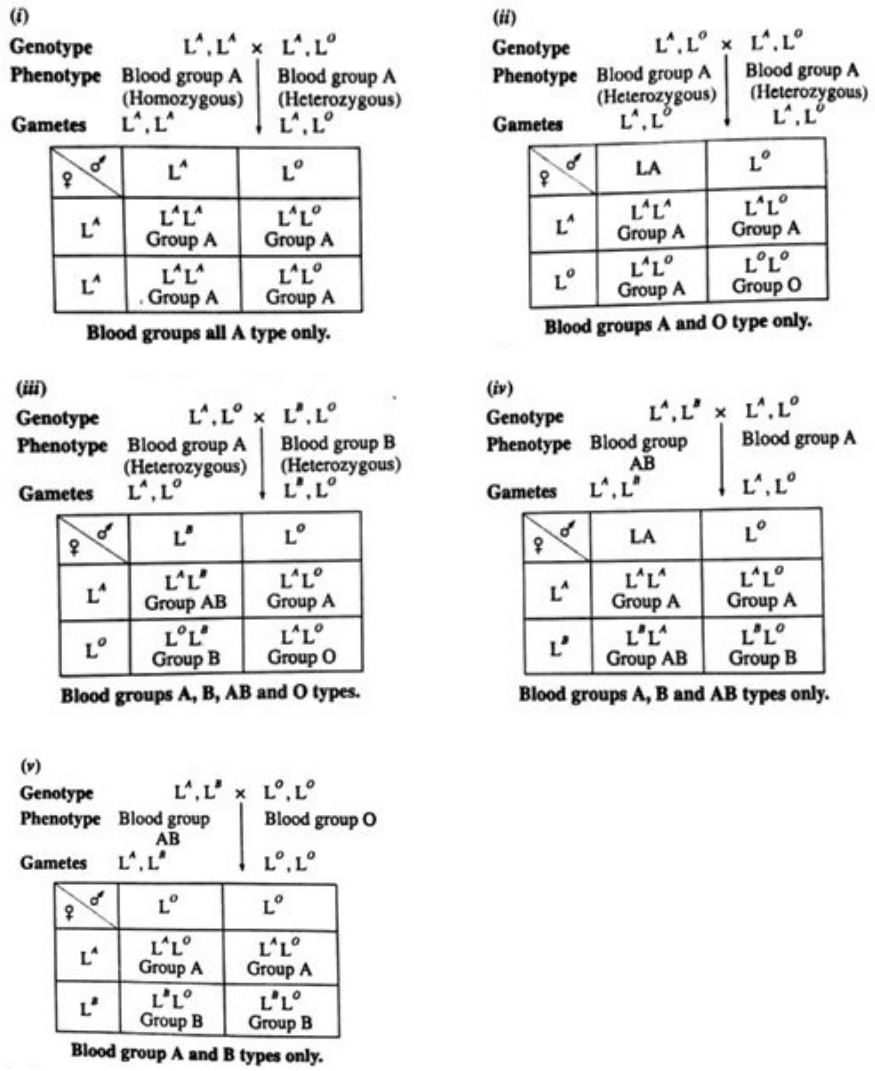
Object. What would be the phenotypes of the progeny if the parents of following genotypes for their blood groups are mated?

(i) $L^AL^A \times L^AL^O$ (ii) $L^AL^O \times L^AL^O$ (iii) $L^AL^O \times L^BL^O$ (iv) $L^AL^B \times L^AL^O$ (v) $L^AL^B \times L^OL^O$.

Observation: There are 4 blood groups in human population. These are A, B, AB and O. In fact, these letters denote a protein substance called **antigen**. The persons with blood group A produce A antigen, those with blood group B produce B antigen, those with blood group AB produce both antigens A and B, and those with blood group O do not produce any of these antigens. The 4 phenotypes of blood group A, B, AB and O are produced by

three alleles **A, B** and **O**. The gene O is recessive to the other two but the genes A and B are **co-dominant** and do not interfere with the expression of each other.

Explanation: Work out the crosses as given below:



Conclusions: The blood groups of the progeny in the crosses asked would be: (i) All with blood groups A. (ii) Blood group A and O only in 3:1 ratio, (iii) All four types of blood group A, B, AB, and O in ratio 1:1:1:1, (iv) Blood groups A, Band AB types only in ratio 2:1:1, and (v) Blood groups A and B types only in 2:2 ratio.

7.2.7. Based on Sex-linked inheritance. (Exercise No. 11-12)

EXERCISE No. 11

Object: In man colourblindness is caused by a recessive gene *c* carried by the X chromosome. If a colourblind man marries a normal (homozygous) woman, what proportion of the sons and daughters will be colourblind in F_1 and F_2 generations?

Observation: Colourblindness is, in fact, the inability of certain human beings to distinguish red and green colour. It is a sex-linked character and is produced by a recessive gene *c*. Normal eyesight is dominant to colourblindness. Since male possesses one X and one Y sex-chromosome and the gene for colourblindness lies on x chromosome, hence, if his X chromosome carries *c* then he will be colourblind because there is no homologous gene on Y chromosome to check its expression. Female possesses two X chromosomes. So, for female to be colourblind, her both X chromosomes must carry a gene for colourblindness. If her one X chromosome carries a gene for colourblindness, its expression is checked by its dominant homologous gene present on the other X chromosome. It is, therefore, colourblindness is more commonly confined in males only.

Explanation: Work out the cross as given below:

	Phenotype	Man colourblind	×	Woman normal homozygous		
(P_1)	**Genotype**	X^c Y	↓	X X		
	Gametes	X^c, Y		X, X		
(F_1)	**Phenotype**	Carrier females	×	Normal males		
	Genotype	X^c X, X^c X		XY, XY		
	Gametes	X^c, X		X, Y		
(F_2)	**Phenotype**	Carrier female (Normal)	Colourblind male	↓	Normal female	Normal male
	Genotype	X^c X,	X^c Y		XX,	XY

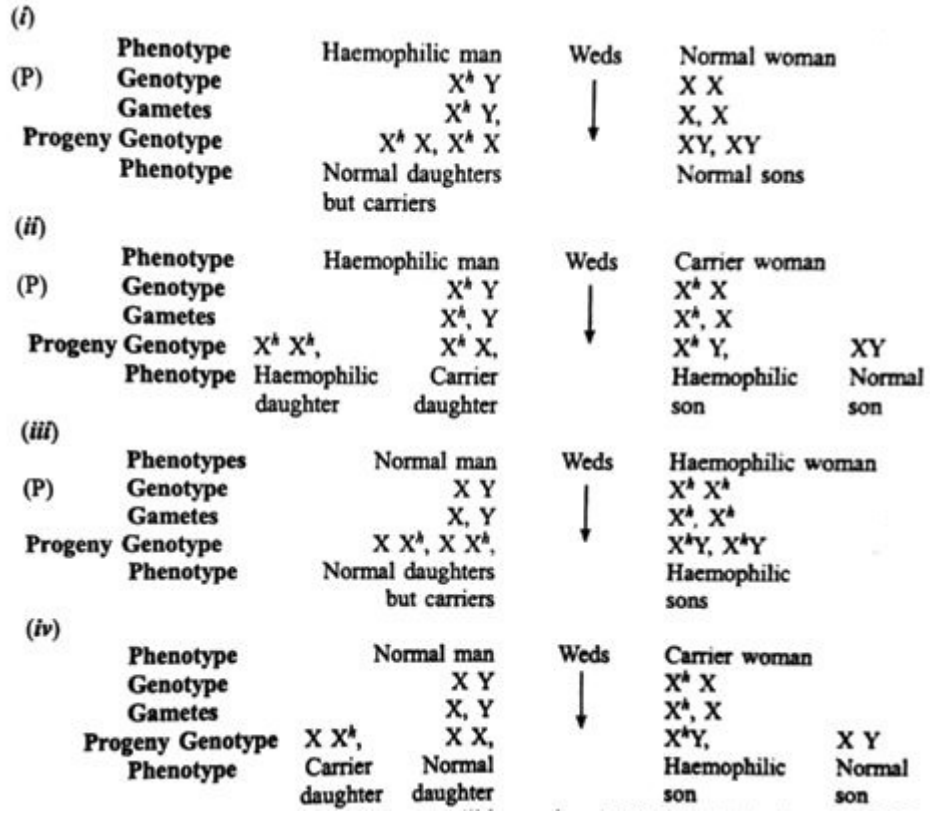
Conclusions: All F_1 females (daughters) are carrier but normal in regard to colourblindness and all males (sons) are normal. All females of F_2 are normal (though 50% carrier) but males are colourblind as well as normal in a ratio of 1:1.

EXERCISE No. 12

Object: In man haemophilia is caused by a recessive gene (*h*) located on the X chromosome. What would be the chances of haemophilic condition in children if (i) a haemophilic man weds a normal woman, (ii) a haemophilic man weds a carrier woman, (iii) a normal man weds a haemophilic woman, and (iv) a normal man weds a carrier woman.

Observation: Like colourblindness, haemophilia is also a character which is sex-linked. Haemophilia (bleeder's disease) is a disease of blood which prevents its clotting. It is caused by a recessive gene *h* located on X chromosome. Normal blood is dominant to defective blood.

Explanation: Work out the crosses given below.



Conclusions: (i) No haemophilic progeny will be produced (ii) 50% of daughters and 50% of sons will be haemophilic (iii) All daughters will be normal but 100% sons will be haemophilic, and (iv) All daughters will be normal but 50% sons will be haemophilic.

7.3. Identification of blood groups in man

Object: Identification of blood group of given blood sample.

Principle: It is by means of the agglutination reaction of red cells that the blood group of an individual is determined. It can be effected either by testing the individuals red cells with std. Anti- A and Anti-B sera or by testing his serum with standard red cells of group A and B. The most reliable grouping is achieved if both these N methods are used.

Requirements: Sterilized needle. A Cotton, Sprit, readymade anti-A, and-B, and anti-D, and microscope.

Procedure: The blood groups of human beings is determined by the Anti-A, Anti-B and Anti-D, which is present as a readymade serum A in the market.

1. Take 2 dry and clean slides. A and B
2. Take 1 drop of Anti-A on slide-A and Anti-B on slide-B.
3. Put one drop of blood sample on each slide A and B.
4. Mix blood sample and Anti serum on both slides with the help of separate glass rods.
5. Observe the reaction after 5 minutes by macro or microscopically-

a) If the blood sample is agglutinated by Anti-A, but not by Anti-B, the blood sample is said to belong to Blood group-A
b) If the blood sample is agglutinated by Anti-B but not by Anti A, the blood sample belongs to Blood group-B.
c) If the blood sample is agglutinated by both Anti A and Anti-B then, the blood sample belongs to Blood group AB.
d) If the blood sample is not agglutinated by both Anti-A and Anti-B; the blood sample belongs to the Blood group O

Rh Grouping

Put a drop of Anti-D on a dry clean slide and then add a drop of blood sample, and mix gently with the help of a glass rod and examined after 5 minutes by macro or microscopically.

a) If blood sample is agglutinated with Anti-D; the blood sample is Rh positive.

b) If blood sample is not agglutinated with chan strip Anti-D; the blood sample is Rh negative.

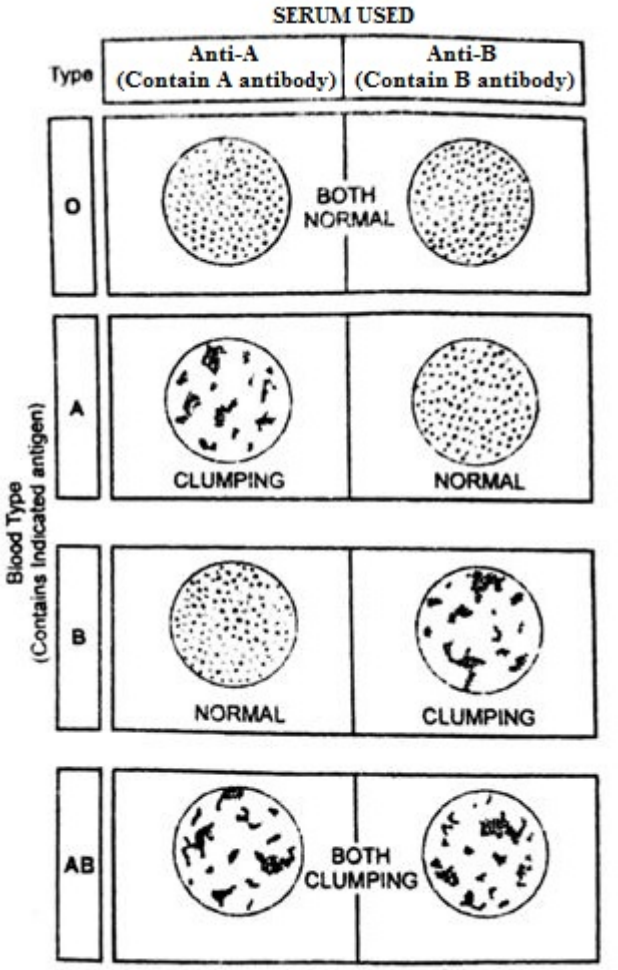


Diagram showing the determination of A, B, O blood groups

7.4. Demonstration of sex chromatin (Barr body)

Barr body

Barr and Bertram (1949) made outstanding discovery that in the interphase nucleus of females, there is small chromatin body called as **sex chromatin** or Barr body. This **sex-chromatin** body is absent in males. Now this chromatin body is called as **X-chromatin**.

The X-chromatin in interphase stage become heterochromated and condensed and are best seen. Frequency of detection of X-chromatin or Barr body varies with tissues to tissue-60% In nervous tissue, 96% in amniotin epithelium and in oral smears and leukocytes 20-50% and in human polymorphic (polymorphonuclear leucocytes). Barr body is clearly observed as drum stick in a nuclear appendage.

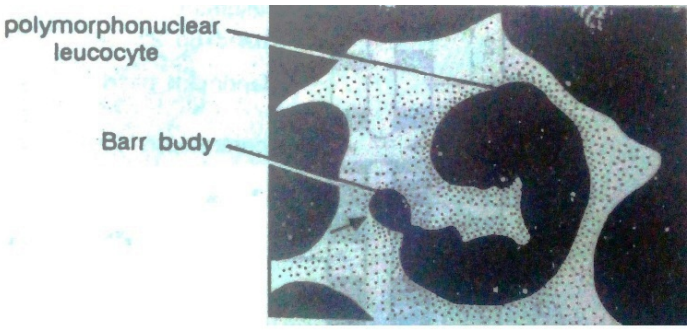


Fig. Female Bar body (Sex Chromatin)

Medical significance

Study of above has great medical applications and it has potential to relate certain congenital diseases and chromosomal abnormalities. In Olympic games certain males disguise themselves as females to compete in the events of female games. Barr body helps in identification of such suspected males because it is absent in males.

Procedure

From the finger tips of females, blood is collected by puncturing the tip of finger by sterilized needle. Make a thick blood film of the blood on slide. Let the film dry for 30 minutes. Treat the slide with a mixture of glacial acetic acid and tartaric for hydrolysis of haemoglobin. Stain the slide with **Leishman stain** and wash the slide with tap water. Dry the slide and study under **oil immersion**.

Result

Barr body is seen like drumstick in one of the nuclear appendage of a chromosome.

7.5. Self learning exercise

1. A cross between two varieties of 4 'O' clock plant (*Mirabilis jalapa*), pure for red (RR) and white (rr) flower results into 12 flowers of three colours, i.e., 3 red, 6 pink and 3 white in F_2 generation. Explain the cause of such a result.

2. On crossing pink flowered pea plant, we obtained 14 red, 25 pink and 13 white flowered plants. Discuss the result and find out the genotype of the parent and progeny.
3. How would you produce 4 O' clock seeds all of which should yield pink-coloured plants when sown?
4. What would be the phenotypes in respect to the coat colour of the progeny if two rabbits of the following genotypes are mated?

   (i) CC × Cc^{ch} (ii) $C^{ch}C^{ch}$ × cc (iii) C^{ch} c^{h} × c^{h} c^{h} (iv) C c^{ch} × cc

7.6. References

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Unit-8

Ethology-I

Structure of the Unit

8.0 Objectives

After going through this you will be able to understand the various learning methods in animal by set up different experiments like trial and error in maze, using aquarium etc.

8.1 Introduction

Learning represents change in behaviour, it is different than instinct because it is not genetically controlled and is flexible. Learning is a relatively permanent modification of behaviour due to motivation. It is associated with reward and punishment. However, in the absence of reward or punishment it can go extinct.

When animals are motivated by thirst, hunger, sex or fear they show restlessness and exploratory behaviour during the course of which it performs spontaneous/ a variety of motor patterns viz. sniffing, walking and looking around. If one of these patterns is followed by reinforcement e.g. a hungry animal while exploring the surroundings receives food and if this association is repeated the animal learns to perform a pattern regularly to that particular situation. Animals learn to eliminate behaviour, which lead to no reward and increase the frequency of behaviour that is rewarding by trial and error.

8.2 Learning by trial and error in animals using maze

Introduction

Network of few lines and paths is called a Simple maze. A system of complex passages where only one leads to the goal while others come to a dead end is called a complex maze. Maze experiments have played an important role in studying the learning behaviour. The rats were placed at the entrance and they reached the food in 30 minutes. On subsequent trials, the time became still shorter and the error was decreased. It was noted that when rats were not hungry, they would play in the blind alley but quickly dash to the goal box when hungry.

Observations:

Table: Time taken and no. of errors made to reach B chamber

No.of Trial	Rat 1		Rat 2		Rat 3		Rat 4	
	Time	Error	Time	Error	Time	Error	Time	Error
1.	12	15	20	23	9	12	13	15
2.	14	17	12	12	9	10	14	17
3.	11	13	14	10	9	12	11	12
4.	9	14	12	8	8	13	9	11
5.	9	14	11	9	6	9	8	9
6.	10	12	14	6	7	8	7	8
7.	10	18	10	3	5	10	9	17
8.	9	10	9	5	4	4	6	14
9.	7	11	8	8	3	4	9	12
10.	8	10	5	9	3	3	5	10
11.	3	7	7	10	3	4	4	9
12.	2	9	6	7	2	3	3	8

13.	2	8	5	6	2	3	4	7
14.	2	7	6	7	1	3	5	6
15.	2	7	6	6	1	3	5	7
Mean	7.3	11.5	9.7	8.6	4.8	6.7	7.5	10.8

Brightest Rat = 3, Dullest Rat = 1

Material

One cage, 4 white male rats, maze, stop watch, water and food for rats. Before any experiment is carried on animals, it is necessary for the students to get familiar with the animal. This can be done by observation and handling of the animals.

Methods:

1. Check all the light points.
2. Mark 4 male rats differently using a permanent marker.
3. Starve the animals 24 hours prior to reading, but give them water.
4. Keep a starved rat in chamber A the bulb lights.
5. Keep nice odourous food in chamber B.
6. Start the stop watch when the rat comes out of the chamber A, close the door of chamber A.
7. Whenever rat enters a blind alley note it as an error.
8. Note the time when rat reaches chamber B, the bulb lights.
9. By this time, we will have total number of errors and total time taken.
10. Repeat the same with remaining rats.
11. After training put the rats back to the cage. Give them food.
12. Keep the cages clean and repeat the procedure after every second day after starving them.

Result

With subsequent trials, the time taken to reach chamber 'B' and number of errors is reduced indicating that rats learnt the maze by trial and error. Also from the experiment, it has been concluded that 3rd rat is the brightest while the first rat is the dullest.

8.3 Study of movement of fish in Aquarium

Material

Chana punctatus (Ophiocephalus), a cat fish or any other medium sized fish, aquarium (3 ft x 1.5 ft), permanent marker, stop watch, a toxicant.

Method

1. Draw vertical and horizontal lines on the outer sides of aquarium with a thick water proof marker pen, at least 3 inches apart, on all five sides of the aquarium (four sides and bottom).
2. The toxicant is either injected or given orally by force feeding or mixed in water.
3. Two fishes are taken, one as control and other experiment.
4. Start the preliminary experiment, watch their movement practice and count how many squares a fish enters in two minutes. Decrease the interval if the fish is active, if it is slow increase the time interval.
5. Take actual observations, first on untreated fish then of treated fish.
6. Analyze the data using 't'-test.

Observation and calculations:

Table: Number of squares entered in two minutes

S.No.	Control		Experimental	
	X_1	X_1^2	X_2	X_2^2
1.	4	16	10	100
2.	4	16	11	121
3.	5	25	12	144

4.	7	49	15	225
5.	6	36	10	100
6.	5	25	9	81
7.	7	49	8	64
8.	7	49	7	49
9.	6	36	10	100
10.	6	36	5	25
11.	5	25	5	25
12.	5	25	15	225
13.	7	49	24	576
14.	7	49	20	400
15.	8	64	9	81
16.	6	36	7	49
17.	7	49	17	289
18.	7	49	12	144
19.	5	25	18	324
20.	8	64	17	289
21.	9	81	15	225
22.	7	49	17	289
23.	7	49	12	144
24.	6	36	10	100
25.	5	25	11	121

26.	7	49	20	400
27.	7	49	18	324
28.	8	64	17	289
29.	9	81	15	225
30.	5	25	13	169
	$\sum X_1 = 192$	$\sum X_1^2 = 1280$	$\sum X_2 = 383$	$\sum X_2^2 = 5529$

Calculation

Table value of 't' on df58 ($\therefore$ n1+n2 – 2 = 30 + 30 – 2 = 58) at 0.05 level of significance is 1.96

Result

Since the calculated value of 't' 7.1 is very high than the tabulated 't' value 1.96, the toxicant has significant effect on the movement of fish.

8.4 Study of courtship in birds

Introduction

Courting birds and fish have always fascinated people with their apparent graceful movements and the beauty of their body parts and eye catching colourful display. Scientists define the term "display" as “behaviour patterns which exposes special structures and “colours”. The general understanding is that Courtship refers to all expressive movements involved in pair-formation and copulation. Everyone has been fascinated by this behaviour through direct observation of animals, or through books or films. Very common examples around us are the courtship in pea fowls, pigeons and ring doves.

Material: A good site where you can observe Doves. Paper, pencil and Camera

Method

Sexual dimorphism is distinct in pea fowl, but it is not clear in doves. Locate a pair of any of doves birds. Watch them carefully. Start taking notes in sequence as soon as they approach each other you will see that Male bird bloats the throat , bows and coos and go around and round the female. He climbs on female and mates.

Start taking notes in sequence as soon as you identify male and female , record all their activities till they mate .

Result

Write the courtship sequence:

a. Male female find each other.

b. Male spreads its caudal feathers, bows and coos and goes round and round female.

c. Male climbs on female and mates.

d. Both male and female preen.

e. Both male and female search for a nesting site, collect twigs, make a nest, female lays eggs.

8.5 Self learning exercise

1. Set up an experiment to study of movement of fish in Aquarium.
2. Perform an experiment to study the courtship in birds.

Unit-9

Ethology-II

Structure of the Unit

9.0 Objectives

After going through this unit you will be able to understand the food preferences of *Tribolium*, role of pheromones in Earthworm.

9.1 Introduction

Tribolium is commonly found in all the stored grains and pulses having variety of food preference. Through an experiment it can be understand the preference of its food. Visual and auditory stimuli cannot carry message for earthworm since they do not have visual or auditory organs. Through an experiment here we try to learn the effect of chemical stimuli on Earthworm. To know about faunal diversity, Zoological park are the best place. Visit a zoo and submit report on faunal diversity.

9.2 Food preference in *Tribolium*

Introduction

Tribolium is commonly found in all the stored grains and pulses. An experiment can be set to know their food preference.

Material

A container with 100 *Tribolium*, one medium sized plastic "ilayachi – supari" box, a point brush, thick paper (card board) cut to the size of box with one window, thin cloth to cover the box, rubber band, grains (wheat, rice, maize, jwar, bajra), pulses (moong, masoor, wead, rajma, soya) flours (aata, besan, suji, maida).

Procedure

1. The different food types are filled up to the brim in different chambers of the box.
2. The Tribolium are placed in the centre.
3. The container is covered with thin cloth tied around by rubber band and kept in a dark place at 35-37 degree temperature (may be in an oven).
4. After a week, take the box out, remove the cloth, cover the box with cardboard, take out the food one by one and count the number of tribolium in each food type with the help of brush. Count the dead tribolium also.

Observations:

Table: Food Preference in *Tribolium*

Day	No. of					
	Besan	**Maida**	**Suji**	**Aata**	**Mortality**	**Total**
3rd day	19	24	38	12	07	100
4th day	13	20	42	15	10	100

Result

This experiment indicates that *Tribolium* preferred 'Suji' over other food type.

9.3 Pheromones in Earthworm

Introduction

Visual and auditory stimuli cannot carry message for earthworm since they do not have visual or auditory organs. Mechanical stimuli can be used for communication but this would be limited to a time when worms are in proximity. However, earthworm rely most on chemical communication.

Material

Blunt forceps, paper-towels, scissors, waxed paper or polished tiles, two sized D batteries connected in series with a wire. A strong solution of table salt and water, live Earthworms.

Method

1. At first cut strips of paper towels 2 cm wide, soak them in the salt solution and arrange them in a square on a piece of waxed paper.
2. Put two earthworms in the centre of square and then observe their response of each other to the waxed paper and to salt solution.
3. Put another earthworm on the waxed paper or a tile, give mild shock to earthworm by touching it briefly with the wires coming out from the two size D batteries. The shock will cause the earthworm to extrude yellowish coelomic fluid from the grooves between the segments.
4. Remove this and put another worm and observe its reaction towards the yellow fluid which had oozed out of the first worm.

Observation

If the response is negative, the worm will jerk its head up and move back, away from the yellow exude, thus showing that the coelomic fluid given out by the worm due to electric shock was a repelling pheromone. If the experiment is done 100 times then 95% of times earthworms will show negative response.

Result

The earthworms communicate by pheromones which are the chemicals expelled from an organism and elicits a response in a conspecific organism.

9.4 Visit to nearby zoo and submission of report

Introduction

It has been commonly observed that students studying zoology in the class are not fully aware of fauna found around them. Sometimes students do not know the names of all the creatures found in and around their own houses specially invertebrate. Prepare a list of vertebrates and invertebrates found around the house or in a Zoo or Sanctuary or a national Park. Try to find out their scientific name too. It is just a simple way of getting familiar with animals.

Method

Refer books (Birds of India by Salim Ali and Animals of India by Prater both are published by Bombay Natural History Society, Mumbai) for identification. Carry paper and pencil, a camera if possible, a cap to cover head, water bottle, wear sun-glasses and dull coloured clothes. Collect brochures and other literature about the zoo or a park you are visiting and prepare a check sheet.

Observations

Make a list of animals, birds you see. Write classification, characters, habitat of Tiger, lion, Leopard , Four horned Antelope , Blackbuck , Gharial , four horned antelope , Lion tailed Macaque Peacock , Chinkara Indian peafowl, Great Indian Bustard, Sambar, Nilgai and Chital.

9.5 Self learning exercise

1. Find out the food preference of *Tribolium* by setup a experiment using few food material.
2. What is the role of pheromones in Earthworm?
3. Visit a nearby Zoo and submit a report to examiner mentioning the faunal diversity.

Unit- 10

Ecology-I

Structure of the Unit

10.0. Objectives

After going through this unit you will learn the term 'Limnology', and it role in ecosystem. Limnology deals with the study of physicochemical factor of water bodies and their interaction with aquatic biota. Main objectives of this unit include the study of limnological factors and submission of a written report to the teacher, identification of various zooplanktons. Handling and performing the laboratory exercise to analysis the physicochemical parameter viz. pH, Free CO_2 and alkalinity.

10.1. Introduction

Limnology is the study of the physical, chemical, and biological interactions within inland waters. Limnological studies include the movements and biogeochemical changes that occur in water. The physicochemical parameters like Dissolved oxygen, pH, alkalinity, nitrate, phosphate etc. of water body affect the aquatic flora and fauna which limit the growth and development of these biotic components. Zooplankton are primary consumer of aquatic ecosystem, they are highly influenced by variation in these limnological parameters.

10.2. Limnological study of local water body

10.2.1. What is limnological study

Study of any locally found water body that is study of the physical, chemical, and biological interactions of water body it said Limnological study. The study of the relationships between living things and their environment is known as ecology.

The ecological relationships that exist within a pond community considered in smaller division of ecology called limnology, the science that deals with the interrelationships of plant and animals in aquatic environments.

A water body is shallow enough for sunlight to reach the bottom, permitting the growth of rooted plants at its deepest point, reach more that 3.6-4.5 meters (12 to 15 feet) in depth.

Water bodies are considered to be part of the freshwater habitat-which are divided into flowing water and standing water. The flowing water habitat is divided into rapid and slow streams. The standing water habitats are divided into lakes, ponds, and swamps. Ponds can be even further divided into those with bare bottoms and those whose bottom contain vegetation.

Water bodies are noted for their abundant and rich varieties of plant and animal life, which all are maintained in a delicate ecological balance.

The Scientific Method of study

Basically purpose of such project for student is to explore them about scientific research and to know how scientists work.

Limnological study comprises in the following points:

The Hydrologic Cycle

The hydrologic cycle, commonly referred to as the water cycle, is closely related to the interrelationship of the biotic and physical environment. The water cycle is continuous movement of water from the atmosphere to the earth and from the earth back to the atmosphere.

Habitats for aquatic community

The place where an organism lives is considered its habitat. Four distinctive habitats can be found within the pond community. These four habitats are the surface habitat, open water habitat, bottom habitat and the shore habitat.

Food Webs and Chains

Living things interact with each other by feeding on one another. Therefore, energy, compounds, and chemical elements are transferred from creature to creature along the food chains.

The Ecological Makeup of a water body

The components of pond ecosystems are very diverse, but it can be divided into several basic units: (1) abiotic substances; (2) producer organisms; (3) consumer organisms; and (4) saprotrophic organisms.

Listing physical and chemical factors that exist in the aquatic habitat

In order for an organism to live in any given habitat, it must have the necessary materials that it needs for growth and reproduction. Anything that is essential for an organism's survival, and for which there is competition, is called a limiting factor. A deficiency or an over-abundance of any kind can limit the survival of an organism in a particular habitat.

List out all the physicochemical parameters viz and analyze them in laboratory for the qualitative and quantitative estimation. Example: Temperature, Light, Carbon Dioxide, Oxygen, Turbidity, Transparency, BOD, COD, Chloride, Fluoride, Nitrate, Phosphate, Nutritional Relationships, Pollution etc.

10.2.2. Preparation of report on study of local water body and submission of written report

The format, in which the report is written, depends highly on the type of work carried out. The student should keep in mind the following guidelines:

The report should contain:

- ✓ All the information related to study/project
- ✓ All used methods and techniques
- ✓ Discussion of all discovered results

Outline of Report submission

- ✓ Abstract/Summery
- ✓ Introduction
- ✓ Materials and Methods
- ✓ Results
- ✓ Discussion
- ✓ Bibliography/References

The report is approximately 20-30 pages excluding Bibliography. The report is written in English.

The following information should be stated on the front page of your report:

- ✓ Title of study
- ✓ Student's name and student's Scholar ID
- ✓ Class
- ✓ Name of supervisor
- ✓ Name of college/study centre
- ✓ Date

10.3. Water analysis

10.3.1. Estimation of pH (Electrometric method)

Objective: To estimate pH of given water sample.

Principle:

The pH is determined by measurement of the electromotive force (emf) of a cell comprising of an indicator electrode (an electrode responsive to hydrogen ions such as glass electrode) immersed in the test solution and a reference electrode (usually a calomel electrode). Contact is achieved by means of a liquid junction, which forms a part of the reference electrode. The emf of this cell is measured

with pH meter.

Since the pH is defined operationally on a potentiometric scale, the measuring instrument is also calibrated potentiometrically with an indicating (glass) electrode and a reference electrode using standard buffers having assigned pH value so that

$pH_B = -\log_{10} [H^+]$

where pH_B = assigned pH of standard buffer.

The operational pH scale is used to measure sample pH and is defined as:

$pHs = pH_B + F (E_s – E_B) / 2.303 RT$

where,

pHs = potentiometrically measured sample Ph

F = Faraday 9.649×10^4 coutomb/mole

E_s = Sample emf V

E_B = Buffer emf V

R = Gas constant 1.987 cal deg-1 mole-1

T = absolute temperature, °K

Apparatus and equipment

a. pH meter
b. Reference electrode
c. Sensor (glass) electrode
d. Beakers
e. Stirrer

Reagents

a. pH 4 buffer solution: Dissolve 10.12g potassium hydrogen phthalate, $KHC_8H_4O_9$ in distilled water. Dilute to 1L.
b. pH 7 buffer solution: Dissolve 1.361g anhydrous potassium dihydrogen phosphate, KH_2PO_4, and 1.42g anhydrous disodium hydrogen phosphate, Na_2HPO_4, which have been dried at 110°C. Use distilled water which has been boiled and cooled. Dilute to 1L.
c. pH 9.2 buffer solution: Dissolve 3.81gm borax, $Na_2B_4O_7.10H_2O$ in

distilled water, which has been previously boiled and cooled. Dilute to 1L.

Calibration

Before use, remove the electrodes from the water and rinse with distilled or demineralised water. Dry the electrodes by gentle wiping with a soft tissue. Calibrate the electrode system against standard buffer solution of known pH. Because buffer solution may deteriorate as a result of mould growth or contamination, prepare fresh as needed for work or use readily available pH buffers.

Procedure

a. Before use, remove electrodes from storage solutions (recommended by manufacturer) and rinse with distilled water.

b. Dry electrodes by gently blotting with a soft tissue paper, standardise instrument with electrodes immersed in a buffer solution within 2 pH units of sample pH.

c. Remove electrodes from buffer, rinse thoroughly with distilled water and blot dry.

d. Immerse in a second buffer below pH 10, approximately 3 pH units different from the first, the reading should be within 0.1 unit for the pH of second buffer. (If the meter response shows a difference greater than 0.1 pH unit from expected value, look for trouble with the electrodes or pH meter)

e. For samples analysis, establish equilibrium between electrodes and sample by stirring sample to ensure homogeneity and measure pH.

f. For buffered samples (or those with high ionic strength), condition the electrodes after cleaning by dipping them into the same sample, and read pH.

g. With poorly buffered solutions (dilute), equilibrate electrodes by immersing in three or four successive portions of samples. Take a fresh sample and record the pH.

Calculation

The pH value is obtained directly from the display of instrument.

Result

The pH of given water sample is _____.

10.3.2. Estimation of Dissolved Oxygen

Objective: To estimate DO in given water sample.

Principle

Oxygen present in sample rapidly oxidises the dispersed divalent manganous hydroxide to its higher valency, which is precipitated as a brown hydrated oxide after the addition of NaOH/KOH and Kl. Upon acidification, manganese reverts to divalent state and liberates iodine from Kl equivalent to the original DO content. The liberated iodine is titrated against Na $_2S_2O_3$ (N/40) using starch as an indicator. The chemical reactions involved in the method are given below:

1. $MnSO_4 + 2KOH \rightarrow Mn(OH)_2 + K_2SO_4$ (white ppt)
2. $2\ Mn(OH)_2 + O_2 \rightarrow 2\ MnO\ (OH)_2$ (Brown ppt)
3. $MnO(OH)_2 + 2H_2SO_4)_2 + 3H_2O$
4. $Mn(SO_4)_2 + 2\ Kl \rightarrow MnSO_4 + K_2SO_4 + l2$
5. $2Na_2S_2O_3.5H_2O + l_2 \rightarrow Na_2S_4O_6 + 2NaCl + 10H_2O$
6. $2NaN_3 + H_2SO_4 \rightarrow 2HN_3 + Na_2SO_4$
7. $HNO_2 + HN_3 \rightarrow N_2 + N_2O + H_2O$

Apparatus and equipment

a. BOD bottles, capacity 300mL

b. Sampling device for collection of samples

Reagents

1. Manganese sulphate: Dissolve 480g $MnSO_4.4H_2O$ or 400g $MnSO_4.2H_2O$ in distilled to 1000mL. Filter if necessary. This solution should not give colour with starch when added to an acidified solution of Kl.
2. Alkali iodide-azide reagent.
3. Sulphuric acid: H_2SO_4, conc., 1mL is equivalent to about 3mL alkali-iodide-azide reagent.
4. Starch indicator: Prepare paste or solution of 2.0g of soluble starch powder and 0.2g salicylic acid as preservative in distilled water. Pour this solution

in 100mL boiling distilled water. Continue boiling for a few minutes, cool and then use.

5. Stock sodium thiosulphate, 0.1N: Dissolve 24.82g $Na_2S_2O_3.5H_2O$ in distilled water. Preserve by adding 0.4g solid NaOH or 1.5mL of 6N NaOH and dilute to 1000mL.
6. Standard sodium thiosulphate, 0.025N: Dilute 250mL stock $Na_2S_2O_3$ solution to 1000mL with freshly boiled and cooled distilled water. Add preservative before making up the volume.

Sample collection, preservation and storage

Sampling for dissolved oxygen depends upon the source and method of analysis. While sampling, sample should not remain in contact with air or should not be agitated. These conditions can cause severe change in gaseous content. Sampling from any depth in streams, lakes or reservoir needs special precautions to eliminate changes in pressure and temperature. There are specific procedures and equipment developed for sampling water under pressure and unconfined water.

Sample should be collected in narrow mouth glass BOD bottles of 300mL capacity. Let the bottle overflow for some time and then stopper the bottle so that no air bubbles could form.

The DO determination should be carried out immediately after sampling.

Procedure

1. Collect sample in a BOD bottle using DO sampler.
2. Add 1mL $MnSO_4$ followed by 1mL of alkali-iodide-azide reagent to a sample collected in 250 to 300mL bottle up to the brim. The tip of the pipette should be below the liquid level while adding these reagents. Stopper immediately. Rinse the pipettes before putting them to reagent bottles.
3. Mix well by inverting the bottle 2-3 times and allow the precipitate to settle leaving 150mL clear supernatant. The precipitate is white if the sample is devoid of oxygen, and becomes increasingly brown with rising oxygen content.
4. At this stage, add 1mL conc. H_2SO_4. Replace the stopper and mix well till precipitate goes into solution.

5. Take 201mL of this solution in a conical flask and titrate against standard $Na_2S_2O_3$ solution using starch (2mL) as an indicator. When 1mL $MnSO_4$ followed by 1mL alkali-iodide-azide reagent is added to the samples as in (2) above, 2mL of original sample is lost. Therefore 201mL is taken for titration which will correspond to 200mL of original sample.

   200 x 300/ (300-1) = 201mL

Calculation

1mL of 0.025N $Na_2S_2O_3$ = 0.2mg of O_2

$$\text{DO in mg/l} = \frac{(0.2 \times 1000) \times (0.025N) \text{ ml of thiosulphate}}{200}$$

Result

The DO in given water sample is _____ mg/l.

10.3.3. Estimation of Free CO_2

Objective: To estimate the Free CO_2 in given water sample.

Principle

Free carbon dioxide in the waters accumulates due to microbial activity and respiration of organisms. This imparts are acidity to the waters because of the formation of carbonic acid. Generally it is produced during the respiration and consumed during the photosynthesis. CO_2 is less during the day time and more at night. The optimum level of CO_2 is 5 ppm. At high CO_2 levels. pH decreases, CO_2 accumulated in the blood of the fish and water becomes more acidic. The fish becomes sluggish, loss of resistance occur. Free CO_2 is determined by titrating the sample using a strong alkali of pH 8.3.

Reagents

A. Sodium hydroxide, 0.05 N: Dissolve 40 g of NaOH in boiled CO_2 free distilled water and make up the volume to 1 litre. Filter the solution through a sintered glass filter to remove any Na_2CO_3. This is 1.0 NaOH solution. Store it in a ploythene air tight bottle. Dilute this solution to 20 times to prepare 0.05 N solution only at a time of titration. Standardize the diluted solution with H_2SO_4, HCl or oxalic acid.

B. Phenolphtalein indicator: Dissolve 0.5 g of phenolphtanlein in 50 ml of 95% ethanol and add 50 ml of distilled water. Add 0.05 N CO_2 free NaOH solution dropwise, until the solution just turns faintly pink.

Procedure

1. 100ml of the sample in a conical flask and add a few drops of phenolphtalein indicator.
2. The colour change to pink indicates the absence of free CO_2.
3. In case the sample remains colourless, titrate it with 0.05 N NaOH.
4. At the end point a pink colour will appear note down the reading and calculate as given below.

Calculation:

$$\text{Free } CO_2, \text{ mg/L} = \frac{(\text{ml} \times \text{N}) \text{ of NaOH} \times 100 \times 44)}{\text{ml sample}}$$

Sl. No	Volume of the sample	Burette reading		Average
		Initial	Final	
1				
2				
3				

Table: showing reading for calculation

Result

In given water sample the amount of Free CO_2 is _____ mg/l.

10.3.4. Estimation of Alkalinity/Salinity

Objective: Estimation of Alkalinity of given water sample.

Principle

Alkalinity of sample can be estimated by titrating with standard sulphuric acid (0.02N) at room temperature using phenolphthalein and methyl orange indicator. Titration to decolourisation of phenolphthalein indicator will indicate complete neutralization of OH^- and ½ of CO_3^{--}, while sharp change from yellow to orange of methyl orange indicator will indicate total alkalinity (complete neutralisation of OH^-, CO_3^{--}, HCO_3^-).

Apparatus

1. Beakers
2. Pipettes (volumetric)
3. Flasks (volumetric): 1000mL, 200mL, 100mL

Reagents and standards

1. Standard H_2SO_4, 0.02 N: Prepare 0.1N H_2SO_4 by diluting 3mL conc. H_2SO_4 to 1000mL. Standardise it against standard 0.1N Na_2CO_3 solution. Dilute appropriate volume of H2SO4 to 1000mL to obtain standard 0.02 H_2SO_4.
2. Phenolphthalein indicator: Dissolved 0.5g in 500mL 95% ethyl alcohol. Add 500mL distilled water. Add dropwise 0.02N NaOH till faint pink colour appears (pH 8.3).
3. Methyl orange indicator: Dissolve 0.5g and dilute to 1000mL with CO_2 free distilled water (pH 4.3-4.5).

Procedure

a. Take 25 or 50mL sample in a conical flask and add 2-3 drops of phenolphthalein indicator.

b. If pink colour develops titrate with 0.02N H_2SO_4 till disappears or pH is 8.3. Note the volume of H_2SO_4 required.

c. Add 2-3 drops of methyl orange to the same flask, and continue titration till yellow colour changes to orange. Note the volumes of H_2SO_4 required.

d. In case pink colour does not appear after addition of phenolphthalein continue as above.

e. Alternatively, perform potentiometric titration to preselected pH using

appropriate volume of sample and titration assembly. Titrate to the end point pH without recording intermediate pH.

As the end point is approached make smaller additions of acid and be sure that pH equilibrium is reached before adding more titrant. The following pH values are suggested as equivalence points for corresponding alkalinity as mg $CaCO_3$/L (Table).

Table : End point pH values

Alkalinity range and Nature of sample	End point pH	
	Total Alkalinity	Phenolphthalein Alkalinity
Alkalinity, mg $CaCO_3$/L:		
30	4.9	8.3
150	4.6	8.3
500	4.3	8.3
Silicates, phosphates known or suspended	4.5	8.3
Industrial waste or complex system	4.5	8.3
Routine or automated analyses	4.5	8.3

Calculations

Calculate total (T), phenolphthalein (P) alkalinity as follows:

$$\text{Phenolphthalein alkalinity as mg } CaCO_3/L = \frac{A \times 1000}{\text{ml sample}}$$

$$\text{Total alkalinity as mg } CaCO_3/L = \frac{B \times 1000}{\text{ml sample}}$$

Where,

A = ml of H_2SO_4 required to bring the pH to 8.3

B = ml of H_2SO_4 required to bring the pH to 4.5

N = normality of H_2SO_4

Result

The given water sample have total alkalinity_____ and Phenolphthalein alkalinity_____mg $CaCO_3$/l.

10.4. Zooplankton Study

10.4.1. Study and identification of Zooplankton

The freshwater zooplanktons are comprised of three major groups of invertebrate animals: the rotifers, copepods, and cladocerans. The rotifers constitute a phylum found almost exclusively in freshwater. The copepods and cladocerans are both groups of the large subphylum Crustacea. Copepods constitute a class which is widespread in both freshwater and marine environments. Cladocerans constitute a group of four orders living primarily in freshwater environments. All three of these major groups have species adapted to pelagic (open water), or littoral (vegetated), and benthic (bottom) environments. The detailed descriptions and identification can taken from the zooplankton identification manual present in laboratory like Dodson and Frey (1991) and Williamson (1991). These sources also provide information on sampling, culturing, identification techniques, and include a good review of literature on these groups.

To identify zooplankton requires use of a compound microscope. A dissecting microscope is also handy for sorting and counting. Specimens are mounted on glass slides and examined at 25-100X magnification. Comparison of your animal with an image, whether a photo or line drawings (in taxonomic keys), is only a first step to identification. In order to identify your animal to species requires, learn some anatomical terminology, and follow the keys. In particular, consider the following characters, what is the general body shape? (Try drawing the outline of the body.) What is the colour? Opaque or translucent. Examine the relative length of appendages (e.g. antennae, legs) and setae (hair-like processes). Use available literature in institution library for more detailed study.

10.4.2. Preparation of Slide of various zooplanktons

1. Collection of zooplankton:

The zooplankton collection involves primarily the filtration of water by net, collecting the water in bottles/ water samplers or by pumps.

2. Fixation

After the sampling, the fixation of samples should be carried out, as early as possible, at least within 5 minutes after the collection to avoid damage to animal tissue by bacterial action and autolysis. The most common fixing and preserving reagent is (4-5%) formaldehyde (formalin). It is the cheapest fixative and the zooplankton samples can be stored for number of years. The other fixatives occasionally used are ethanol, picric acid, acetic acid etc.

3. Preservation

Allow 10 days as the minimum fixation periods. After fixation, the zooplankton are transferred and stored in airtight containers with sufficient quantity of preservative. While transferring, due care should be taken so that no part of the zooplankton sample is lost. Various types of preservatives are available. The buffered formalin (4 to 5%) is mostly used both as fixative and as the preservative. The other preservative used is 70% ethanol or 40% isopropanol.

4. Dehydration

In this process before proceeding for mounting animal on slide, most of the water in an animal must be removed. This process is commonly carried out by immersing specimens in a series of ethanol (alcohol) solutions of increasing concentration

until pure, water-free alcohol is reached. The need of passing tissue in different grade of alcohol is to avoid the shrinkage and distortion of tissues by abrupt use of strong alcohol. Along with concentration, duration to remain animal in each stage of series also fixed and may be varying according to type of animal. Alcohol series for dehydration: 30 %, 50 %, 70%, 90% and 100% alcohol (ethanol). Generally animal keep into each grade of alcohol for 10-15 minutes time duration.

5. Staining

By staining the parts or components of cell or of organism can be clearly differentiated. In staining the tissue or organisms are coloured by particular dyes. The commonly used dyes in laboratory are, borax carmine, methylene blue, haematoxylin, eosin, sudan black etc. for staining zooplankton we generally used eosin dye.

6. Clearing

Although the animal is now essentially water-free, we therefore have to use an intermediate solvent that is fully miscible with ethanol. This solvent will displace the ethanol in the specimens. This stage in the process is called “clearing” and the reagent used is called a “clearing agent”. A popular clearing agent is xylene and after passing through Alcohol series and staining the specimens put into xylene for 5 to 10 minute which proceeds into mounting.

7. Mounting

It is last step in the permanent mounting and essential for the study and preservation of the material for longer time. The commonly used mounting medium is Canada balsam or D.P.X.

8. Procedure for preparation of permanent slide

Wash the slide and coverslip with 95% ethanol. Place a drop of mounting medium on the slide using a slender glass rod. Transfer the stained specimen to the drop. Place the coverslip at one edge of the drop and lower gently to avoid trapping air bubble in the mountant. Keep the slide horizontal and do not use until dry. Drying time may be reduced by heating in an oven at about 35°C. The excess mountant (D.P.X.) can be removed by using Xylene as it dissolve the D.P.X.

10.5. Self learning exercise

1. Visit a local water body to study flora and fauna around it and submit written report.
2. Estimate the Dissolved oxygen of water sample from local water body.
3. Estimate the following limnological parameter of any fresh water pond.

   (i) pH (ii) Free CO_2 (iii) Alkalinity
4. Collect the zooplankton from fresh water body and identify them by preparing permanent slide under microscope.

10.6. References

- ***APHA*** (1992) Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association (APHA), American Water Works Association (AWWA), Water Pollution Control Federation (WPCF), Washington, DC.
- ***WHO (1993) Guidelines for Drinking-water Quality:*** Volume 1 Recommendations Second edition, World Health Organization, Geneva.
- ***Standard Analytical Procedures for Water Analysis*** (1999): Hydrology project, Govt. of India and Netherland.
- ***Advanced practical Zoology***: P.S. Verma and P.C.Srivastava, S. Chand and Company Ltd.

Unit-11

Ecology-II

Structure of the Unit

11.0. Objectives

After going through this unit you will learn to study some limnological experiment like estimation of productivity of pond, estimation of productivity of aquatic ecosystem through light and dark bottle method and more you will understand the aquatic population study which includes count, identification of zooplanktons. These exercises are necessary required for the study of aquatic ecology and limnology.

11.1. Introduction

Measurement of conductivity of water body is necessary to find the variations in the dissolved mineral contents of a water body. In ecosystem by measuring the rates of oxygen production and of oxygen consumption in a known volume of water, estimates of the rate of gross photosynthetic productivity, net productivity,

and respiration rate can be calculated. Estimation of productivity is necessarily required for the aquatic biota diversity and their survival.

11.2. Estimation of Conductivity

Objective: To estimate conductivity of given water sample.

Principle

This method is used to measure the conductance generated by various ions in the solution/water. Rough estimation of dissolved ionic contents of water sample can be made by multiplying specific conductance (in mS/cm) by an empirical factor which may vary from 0.55 to 0.90 depending on the soluble components of water and on the temperature of measurement.

Conductivity measurement gives rapid and practical estimate of the variations in the dissolved mineral contents of a water body.

Apparatus and equipment

a. Self-contained conductance instruments: (Conductivity meter).
b. Thermometer, capable of being read to the nearest 0.1°C and covering the range 10-50°C.
c. Conductivity Cells

Reagents and standards

Conductivity Water: The conductivity of the water should be less than 1 $_{m}$mho/cm; Standard potassium chloride: 0.01M; dissolve 745.6mg anhydrous KCl in conductivity water and make up to 1,000mL at 25°C. This is the standard reference solution, which at 25°C has a specific conductance of 1,413 $_{m}$mhos/cm. It is satisfactory for most waters when using a cell with a constant between 1 and 2. Store the solutions in glass stoppered Pyrex bottles.

Procedure

a. Rinse conductivity cell with at least three portions of 0.01M KCl solution. Measure resistance of a fourth portion and note temperature.
b. In case the instrument indicates conductivity directly, and has internal temperature compensation, after rinsing as above, adjust temperature compensation dial to 0.0191/ °C and with the probe in standard KCl solution, adjust meter to read 141.2 mS/m (or 1412 µ mho/cm) continue at step d.

c. Compute the cell constant, K_C according to the formula:

$$K_C = \frac{1412}{C_{KCl}} \times [0.0191(t - 25) + 1]$$

where:

Kc = the cell constant, 1/cm

C_{KCl} = measured conductance, µmho

t = observed temperature of standard KCl solution, °C

d. Rinse cell with one or more portions of sample. The level of sample aliquot must be above the vent holes in the cell and no air bubbles must be allowed inside the cell. Adjust the temperature of sample to about 25°C (outside a temperature range of 20 - 30°C, error increases as the sample temperature increasingly deviates from the reporting temperature of 25°C). Read sample conductivity and note temperature to nearest 0.1°C.

e. Thoroughly rinse the cell in distilled water after measurement, keep it in distilled water when not in use.

Calculation

a. When sample conductivity is measured with instruments having temperature compensation, the readout automatically is corrected to 25°C. If the instrument does not have internal temperature compensation, conductivity at 25°C is:

$$\text{ElectricalConductivity(mS/cm)} = \frac{C_M \times K_C}{0.0191(t - 25) + 1}$$

where:

Kc = the cell constant, 1/cm

C_M = measured conductance of the sample, mS

t = observed temperature of sample, ^{0}C

b. Record the meter reading, the unit of measurement and the temperature of the sample at the time of reading. Report the electrical conductivity at 25°C. Report conductivity preferably in $_{m}$mho/cm.

Result

The conductivity of given water sample is _____ $_{m}$mho/cm.

11.3. Estimation of productivity of water body (light and dark bottle method)

Objective: Estimation of productivity of a water body through light and dark bottle method.

Principle

In aquatic ecosystems, producers and primary consumers are largely microscopic plankton suspended in the water. By measuring the rates of oxygen production and of oxygen consumption in a known volume of water, estimates of the rate of gross photosynthetic productivity, net productivity, and respiration rate can be calculated.

Using the light and dark bottle method, samples of water are placed in two glass bottles of the same volume. One bottle is left clear, and the other bottle is covered or paint black to prevent entry of light. The initial O_2 concentrations are measured as per the methods given to estimate dissolved oxygen, and then the two bottles are returned to the light conditions in same pond from which they were taken for 24 hours. After 24 hours, the bottles are retrieved, and the final O_2 concentrations are measured.

Apparatus

- Two clear glass bottles of identical volume with lids or stoppers; one left clear and the other covered to prevent light (Paint, tape, aluminum foil, or black plastic may be used) named dark bottle.
- Water sampler to take sample from different depth of pond.
- A float and line or pole apparatus to hold the bottles in place at the depth the samples were taken.

Reagent

Same chemicals and reagent, required for Dissolved oxygen.

PROCEDURE:

Prepare your sample bottles. Each pair of bottles should consist of one clear, and one covered to keep light out. The bottles need to be of identical volume, and should be labelled for the intended depth.

1. Take water samples just below the surface by directly holding the sample bottle in the water. Use a third bottle to collect some water as before to top-off the sample bottles, if necessary, after O_2 readings are taken.
2. Measure the O_2 concentration of each bottle according to method used for estimation of dissolved oxygen. If water is lost in the measurement, replace from the third bottle of sample that is identical to the sample pair. Secure the caps and suspend both the sample bottles in the pond with the help of line, thread or apparatus you constructed. Record the date and time, and the initial O_2 concentration as mg / L in the data table.
3. Allow respiration and photosynthesis to proceed for 24 hours.
4. Retrieve the sample bottles and measure the O_2 concentrations of each bottle. Record the concentrations, along with the date and time, in the appropriate place on the data table.
5. Calculate the respiration rate (R) in terms of oxygen consumption as follows:

   Daily Community Respiration Rate = (DO initial – DO dark)/# hours or days

   Respiration rate at surface = _____ mg O2/L/day

   Respiration rate at depth 1 = _____ mg O2/L/day
6. Calculate the net photosynthetic productivity of oxygen (PN) in mg O_2/liter/day, as follows:

   Where

   CL is the final concentration of oxygen in the light bottle.

   Net Photosynthetic Activity = (DO light – DO initial)/# hours or days

Net photosynthetic productivity at surface = _____ mg O_2/l/day

Net photosynthetic productivity at depth 1 = _____ mg O_2/l/day

7. The gross productivity of oxygen (PG), expressed in mg O_2/liter/day, is calculated as:

   Gross Photosynthetic Activity = community respiration + net photosynthetic activity

   Gross productivity surface= _____ mg O_2/l/day

   Gross productivity depth 1= _____ mg O_2/l/day

8. The release of 1 mg O_2 during photosynthesis is equivalent to ~ 0.375 mg fixed C

   Net primary production surface = net photosynthetic activity surface * 0.375 = _____ mg C/L/d

   Net primary production depth 1 = net photosynthetic activity depth 1* 0.375 = _____ mg C/L/d

   Gross primary production surface = gross photosynthetic activity surface * 0.375 = _____ mg C/L/d

   Gross primary production depth 1 = gross photosynthetic activity depth 1 * 0.375 = _____ mg C/L/d

11.4. Aquatic Biota study

11.4.1. Quantitative estimation of aquatic biota: Zooplankton count and population density.

Object

Quantitative study of planktons (Zooplankton, phytoplankton) in the sample of water.

Requirements

Microscope with mechanical stage, plankton counting slide (Sedgwick Rafter's counting slide), plankton collecting net, plankton collecting jar, plankton sample, plastic bucket, petridish, dropper, 10% formalin, plankton centrifuge, etc.

Description of plankton net

Plankton net (Figure) is made of a circular iron rim attached to a handle. The rim is tied with bolting silk cloth of specified number like 12, 16, 20, etc. In one square inch of bolting silk, there is fixed number of meshes in different types of bolting silk cloth e.g., No. 12 possesses 800 meshes/sq.inch, No 16 bears 10,000 meshes/sq.inch and so on. Muslin cloth may also be used in place of bolting silk. At the other end of bolting silk cloth a plankton collecting jar desired capacity is tied (here it is of 250 ml capacity). A thick band-shaped cloth or rubber is used to tie the plankton collecting jar with the bolting silk tightly at their junction.

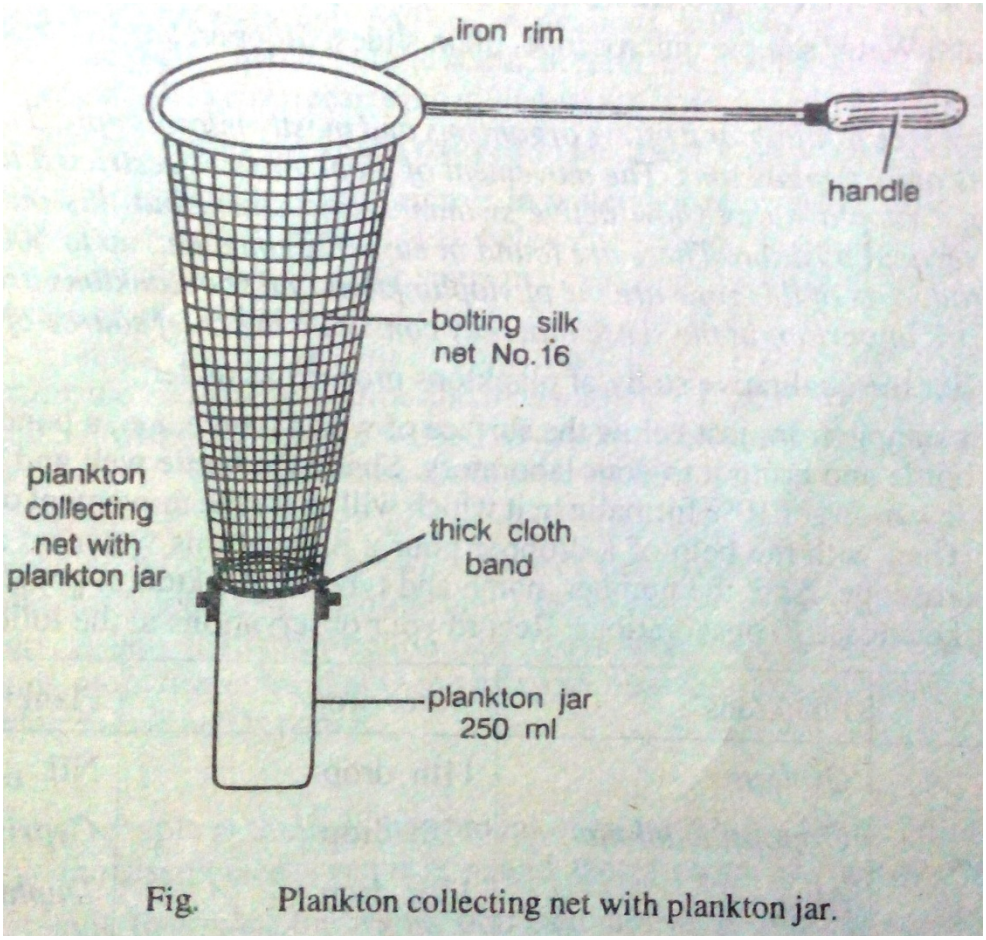


Fig. Plankton collecting net with plankton jar.

Description of Sedgwick Rafter's counting slide

Sedgwick Rafter's counting slide (Fig. A and B) is a special type of grooved slide meant for counting planktons, therefore, commonly referred to as plankton counting cell or slide. This slide has a groove of 50 mm length, 20 mm width and 1 mm depth. The groove is graduated having 50 squares along its length and 20 squares along its width total squares being 50 x 20 = 1,000 and total area being 1000 mm^2 or 1 ml, one counting chamber (unit) is 1 mm^3.

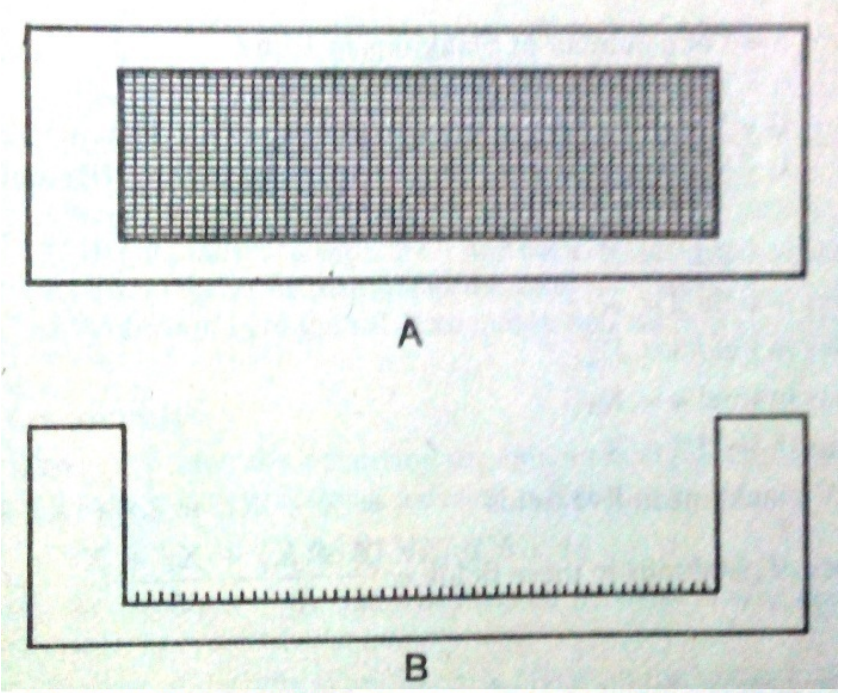


Fig. A- Sedgwick Raftler's counting slide (surface view); B- Sedgwick Raftler's counting slide in T.S.

Procedure:

For quantitative study of planktons in the water sample proceed as under:

Filter about 50 litres of water from a pond through plankton net having bolting silk No.16 and collect planktons in plankton collecting jar of 250 ml capacity.

Preserve the filtrate in 10% formalin and then sample is centrifuged in a plankton centrifuge. Take formalin treated centrifuged sample in the groove of plankton counting slide (described above) and cover it with the help of a long rectangular coverglass; when there is no air bubble, the groove contains 1 ml of sample. Now, bring the slide under mechanical stage of microscope and examine for the count of planktons. Choose 2, 3, 4 or more random areas (hereafter called fields) containing 100 squares on the slide and proceed as under:

A. Total count

Total count of plankton means an enumeration of all planktons recognizable under the condition of examination without an attempt to distinguish between the different kinds. Each complete plankton or a part of plankton in one square (counting unit) is counted as one plankton.

As referred to, count the total number of planktons in randomly chosen area, say field 1(see Fig.), Repeat it by choosing not less than 5 fields on the slide. Add all

the number of planktons counted to get total number of planktons in the examined fields. Divide this number by the number of fields examined to get an average number.

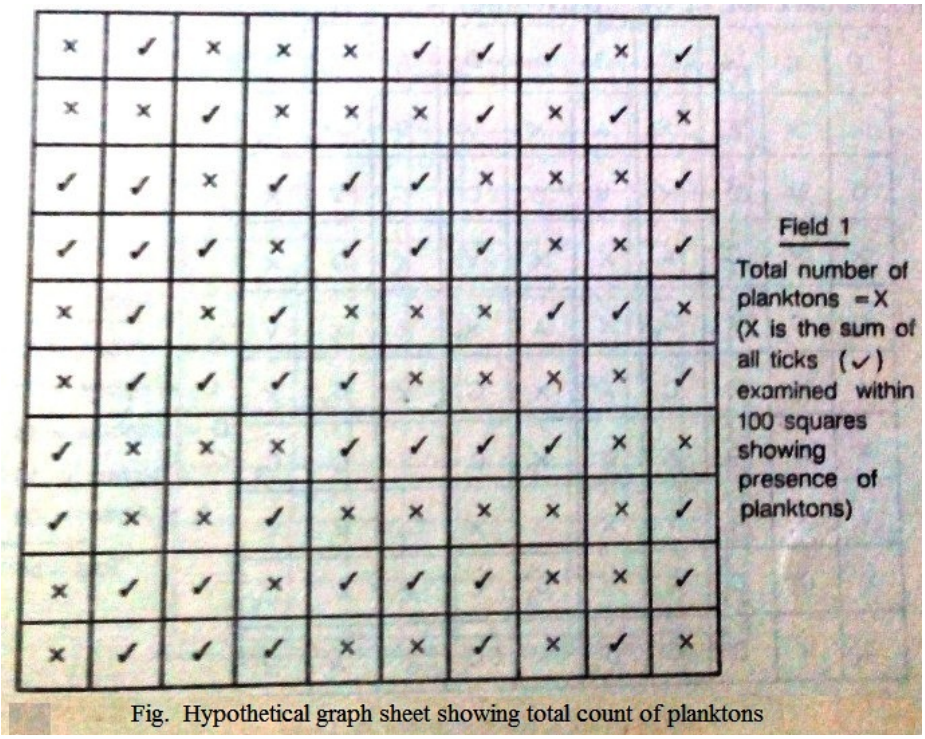


Fig. Hypothetical graph sheet showing total count of planktons

Calculation

Total number of planktons present in 1 litre of water can be calculated by the following formula:

$$n = \frac{a \times 1000 \times C}{L}$$

Where,

n= Total number of planktons in 1 litre

a= Total number of planktons in 1 ml.

C= Volume of concentrate expressed in ml (Here it is 250 ml)

L= Volume of water filtered expressed in litres (Here it is 50 litres)

Suppose

No. of planktons in field 1 = X

No. of planktons in field 2 = X_1

No. of planktons in field 3= X_2

No. of planktons in field 4= X_3

No. of planktons in field 5= X_4

Total number of planktons in five fields= $X + X_1 + X_2 + X_3 + X_4$

Average number of planktons in these fields= $\frac{X + X_1 + X_2 + X_3 + X_4}{5}$

Let it be Y

Thus, Y planktons are present in 100 squares on average.

Therefore, 1000 squares (1 ml sample) contain Y × 10 = 10 Y plankton

Now, a= 10Y plankton in 1ml

C= 250ml and L= 50 litres

Putting the values in the above formula:

$$n = \frac{10\ Y \times 1000 \times 250}{50}$$

Its value will give the **total numbers of planktons** in 1litres of water.

B.Differential count or qualitative study of planktons in the water sample

This refers to the enumeration of all of the different kinds of planktons by distinguishing them qualitatively. For this, proceed as under:

First of all choose and identify all kinds of planktons to be counted. For this also prepare the sample and slide for study in the same way as described above. As mentioned earlier different random fields are chosen on the slide. Then prepare your own graph sheet having 100 squares. Make a coding for different planktons, viz., C for *Cyclops*, Cy for *Cypris*. D for *Daphnia*, V for *Volvox*, A for *alga* etc. Then examine the slide for these planktons and record them in the square graph sheet prepared as shown in Fig. Court their number separately, Repeat it for the different fields chosen, find out the total number of different planktons separately and their average value also, that too separately, to get the value of a for its use in the same formula as mentioned in the case of total count. The values of C and L to be used in the formula are the same as mentioned earlier. Calculation is to be done in the same way.

Density of a particular species is the number of its individuals occurring per unit area. It can be calculated for particular species by using formula:

$$\text{Density} = \frac{\text{Total number of individuals of species}}{\text{Total number of quadrats (squares) studied}}$$

D	×	×	C	D	×	C_y	A	×	V
×	×	A	×	A	×	V	D	×	C_y
C	×	D	×	V	D	C	C_y	V	×
×	×	C	A	×	×	V	×	D	×
D	C	×	C_y	×	A	×	×	×	V
A	×	V	D	×	×	C	×	C_y	×
×	×	A	×	D	×	D	×	C	C_y
V	×	C	V	×	A	×	C_y	×	C
×	D	C_y	×	V	C_y	C	×	V	C_y
C_y	×	D	C	D	×	C	×	A	×

Field 1

C = *Cyclops* = 12

C_y = *Cypris* = 11

D = *Daphnia* = 14

V = *Volvox* = 10

A = *Algae* = 09

Total = 56

Fig. Hypothetical graph sheet showing differential count of planktons.

11.4.2. Identification of Zooplankton and their Significance in primary productivity

Basics of zooplankton identification

Essential anatomical terminology must be learned in order to positively identify an organism. General elements that need to be assessed for all zooplankton groups are: body shape and size, relative length of various appendages, including antennae, legs, and setae, presence and relative sizes of spines although several anatomical features used to differentiate species.

The attempt was to keep the list of features to a minimum while ensuring accurate species assignments. Although some dissection may be required, this Guide generally only depicts anatomical details that can be viewed under a dissection microscope. For more detailed information on identification of zooplankton, laboratory manual and cited literature available in institution library can be used From there you must refer to the main identification characteristics for each group of studying species.

Significance in primary productivity: These are free floating or drifting organisms categorized as **planktons** mostly microscopic. The movement of

plankton are restricted to some extent by water current. Some zooplankton show active swimming movement but this only helps them in maintain their vertical position. These are found in euphotic zone (upto 600 feet depth from surface). The producers of this zone are the phytoplankton and zooplanktons are consumers. In aquatic ecosystem zooplankton are significantly important because they constitute the chief source of food for fishes and mostly aquatic fauna.

11.5. Self learning exercise

1. Estimate the conductivity of any fresh water sample and show result to your teacher.
2. Estimate the productivity of fresh water body through light and dark bottle method.
3. What is the significance of zooplankton in primary productivity of aquatic ecosystem?
4. Quantitatively estimate the total count and population density of the zooplankton of any locally found water body.

11.6. References

- ***APHA*** (1992) Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association (APHA), American Water Works Association (AWWA), Water Pollution Control Federation (WPCF), Washington, DC.
- ***WHO 1993 Guidelines for Drinking-water Quality:*** Volume 1 Recommendations Second edition, World Health Organization, Geneva.
- ***Standard Analytical Procedures for Water Analysis*** (1999): Hydrology project, Govt. of India and Netherland.
- ***Advanced practical Zoology***: P.S. Verma and P.C.Srivastava, S. Chand and Company Ltd.

Unit-12

Microbiology

Structure of the Unit

12.0 Objectives

After going through this unit you will able to understand the role of various forms of Bacteria and how to culture them in laboratory condition. You will learn to stain the bacteria, culture bacteria from food, environment etc.

12.1 Introduction

The most common and widespread danger associated with drinking water is contamination, either Several enteric bacteria, coliforms and several other pathogenic bacteria directly or indirectly, by sewage, other wastes or human and animal excreta which contain several enteric bacteria, coliforms and several other pathogenic bacteria. Water purification is, therefore, the most important measure available for ensuring public health. Potable water can be defined as any water that is clear, free from undesirable flavours, odors, of reasonable temperature, neither corrosive nor scale forming, free from minerals that could produce undesirable physiological effect and does not contain pathogenic microorganisms capable of causing human diseases. The survival and growth of microorganisms depend on

available and a favorable growth environment. Culture media are the nutrient solutions used in laboratories to grow microorganisms.

12.2 Bacteriological analysis of potable water

Aim: To study the bacteriological analysis of potable water.

Principle

The most common and widespread danger associated with drinking water is contamination, either directly or indirectly, by sewage, other wastes or human and animal excrement. As a result, water has become a formidable factor in disease transmission. It may act as a potential common source of pathogenic and non-pathogenic microorganisms. Water purification is, therefore, the most important measure available for ensuring public health.

Several enteric bacteria, coliforms and several other pathogenic bacteria, (*Pseudomonas, Serratia, Aeromonas, Enterobacter, Escherichia coli, Streptomyces, Vibrio cholerae, Cryptosporidium, Yersinia enterocolitica, Campylobacter sp., streptococci* etc.)

Water in relation to human consumption is classified as (i) the potable water (drinking water) and (ii) the unpotable water or waste water (sewage). Potability refers to the pollution level or drinking quality of water. It is therefore, highly desirable that the water, before its wide circulation for consumption purposes, should be undergone for proper bacteriological testing.

Potable water can be defined as any water that is clear, free from undesirable flavours, odors, of reasonable temperature, neither corrosive nor scale forming, free from minerals that could produce undesirable physiological effect and does not contain pathogenic microorganisms capable of causing human diseases.

Apparatus, Glasswares and Chemicals

Potable water sample, sterile water sample, Lactose broth, Test tubes, Inoculating loop, Durham tubes, `Culture media,

Procedure

The standard plate count method for total bacterial counts (ACC):

- This test provides an estimate of the total number of bacteria in a water sample which will grow and develop in a particular culture medium.

- For this the water sample is first diluted with sterile water
- After dilution the sample is plated on nutrient agar medium plates.
- The plates are incubated at 37^0C under laboratory conditions.
- The bacterial colonies developed on plates are counted to give the total bacterial counts.
- Total cfu counts/ml is calculated.
- Water of good quality has low bacterial counts of less than 100/ml

Presumptive test for Detection of Coliforms by Most Probable Number (MPN) Technique:

- Inoculate each of 3 test tubes containing 10.0 ml of double strength lactose broth of a set aseptically with 10.0 ml of water sample.
- Similarly inoculate 1.0 ml and 0.1 ml of water samples into each of three small tubes of 2nd and 3rd sets respectively containing single-strength lactose broth.
- Incubate all tubes at 37^0C for 2 days.
- Observe for gas production after 24 and 48 hours.
- The presence of gas in any tube after 24 hr is a positive presumptive test.

Observation and Calculation

Total cfu counts/ml is calculated using the following formula:

$$\text{cfu counts/ml} = \text{Dilution factor of original sample} \times \text{No. of colonies}$$

Precautions

- Use freshly prepared chemicals.
- Always use clean glassware in the experiment

12.3 Identification of gram+ve and gram-ve bacteria

Aim: To study the identification of gram+ve and gram-ve bacteria.

PRINCIPLE

When the bacteria is stained with primary stain Crystal Violet and fixed by the mordant, some of the bacteria are able to retain the primary stain and some are

decolorized by alcohol. The cell walls of gram positive bacteria have a thick layer of protein-sugar complexes called peptidoglycan and lipid content is low. Decolorizing the cell causes this thick cell wall to dehydrate and shrink, which closes the pores in the cell wall and prevents the stain from exiting the cell. So the ethanol cannot remove the Crystal Violet-Iodine complex that is bound to the thick layer of peptidoglycan of gram positive bacteria and appears blue or purple in colour.

In case of gram negative bacteria, cell wall also takes up the CV-Iodine complex but due to the thin layer of peptidoglycan and thick outer layer which is formed of lipids, CV-Iodine complex gets washed off. When they are exposed to alcohol, decolourizer dissolves the lipids in the cell walls, which allows the crystal violet-iodine complex to leach out of the cells. Then when again stained with safranin, they take the stain and appears red in colour.

Apparatus, Glasswares and Chemicals

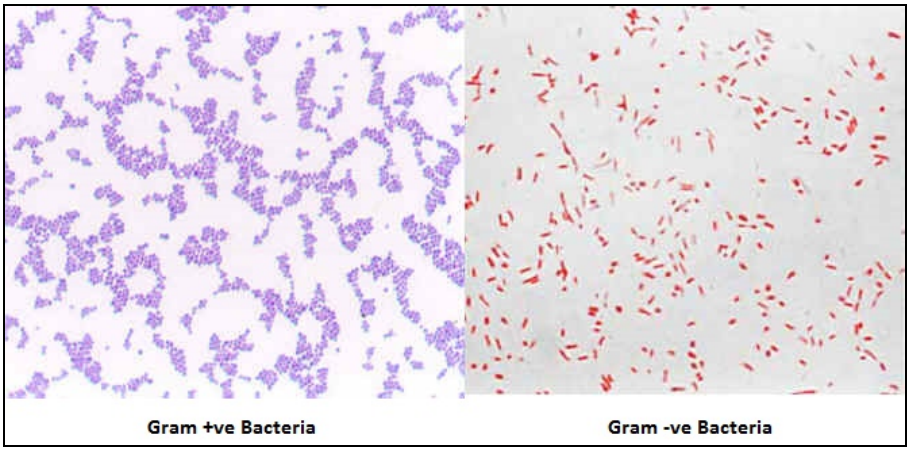
24 hour old bacterial culture, Crystal Violet, Iodine, acetone and alcohol (95%), Safranin, Inoculation loop, Slide, and Sterile water.

Procedure

- Take a clean, grease free slide.
- Prepare the smear of suspension on the clean slide with a loopful of sample.
- Air dry and heat fix
- Crystal Violet was poured and kept for about 30 seconds to 1 minutes and rinse with water.
- Flood the gram's iodine for 1 minute and wash with water.
- Then, wash with 95% alcohol or acetone for about 10-20 seconds and rinse with water.
- Add safranin for about 1 minute and wash with water.
- Air dry, Blot dry and Observe under Microscope.

Observation and Calculation

1. Gram positive bacteria *(thick layer of peptidoglycan-90% of cell wall*)- **stains purple**
2. Gram negative bacteria *(thin layer of peptidoglycan-10% of cell wall and high lipid content)* –**stains red/pink**



Precautions

- Use freshly prepared chemicals.
- Always use clean glassware in the experiment

12.4 Study the microbes in food material (Fish)

Aim: To study the microbes in food material (Fish)

Principle

The Aerobic Colony Count (ACC) estimates the number of bacteria per g or mL of product. A portion of the product is mixed with a specified agar medium and incubated under specific conditions of time and temperature. It is assumed that each bacterium will multiply under these conditions and give rise to a visible colony which can be counted.

Apparatus, Glasswares and Chemicals

Plate count agar, Sample, Peptone water diluent (0.1%), 2% sodium citrate, pH meter, Incubator, Colony counting device

Procedure

The test shall be carried out in accordance with the following instructions:

Handling of Samples: During storage and transport, the following shall apply: the sample units refrigerated (0-5 ^{o}C). Thaw frozen samples in a refrigerator or under time and temperature conditions which prevent microbial growth or death.

Preparation of Media

- Prepare plate count agar and dispense in appropriate quantities.
- Temper prepared melted agar in a water bath to 45^{o}C ensuring that the water level is 1 cm above the level of the medium in the bottles.
- Clean surface of working area with a suitable disinfectant and clearly mark the duplicate Petri plates.

Preparation of Dilutions: Prepare sterile 0.1% peptone water diluent. To ensure a truly representative analytical unit, agitate liquid or free flowing materials until the contents are homogeneous. If the sample unit is a solid, obtain the analytical unit by taking a portion from several locations within the sample unit. Prepare a 1:10 dilution of the food by aseptically blending 25 g or mL (the analytical unit) into 225 mL of the required diluents. If a sample size other than 25 g or mL is used, maintain the 1:10 sample to dilution ratio, such as 11 (10) g or mL into 99 (90) mL.

Plating: Agitate each dilution bottle to resuspend material that may have settled out during preparation. Pipette 1 mL or 0.1 mL of the required dilutions to appropriately marked duplicate Petri plates. Pour 12-15 mL of tempered agar into each plate, and mix by rotating and tilting. Allow to solidify.

Incubation: Incubate plates in the inverted position for 35±2^{o}C for 48 hours. Incubation temperature is dependent on the growth temperature requirements of the target organisms.

Counting Colonies: Count colonies promptly after the incubation period. If possible, select plates with 20-200 colonies.

Observation and Calculation

Calculate the average count (arithmetic mean) of the plates.

Precautions

- Use freshly prepared chemicals.
- Always use clean glassware in the experiment

12.5 Brief idea of composition of readymade culture media

Aim: Brief idea of composition of readymade culture media

Principle

The survival and growth of microorganisms depend on available and a favorable growth environment. Culture media are the nutrient solutions used in laboratories to grow microorganisms. For the successful culture of a given microorganism it is necessary to understand its nutritional requirements and then supply it with its essential nutrients in the proper form and proportions in a culture medium.

The general composition of a medium is as follows:

1.	H-donors and acceptors (approximately 1-15 g/L)
2.	C-source (approximately 1-20 g/L)
3.	N-source (approximately 0,2-2 g/L)
4.	Inorganic nutrients e.g. S, P, (50mg/L)
5.	Trace elements (0,1-1 µg/L)
6.	Growth factors (aminoacids, purines, pyrimidines, occasionally 50 mg/L, vitamins occasionally 0,1-1 mg/L)
7.	Solidifying agent (e.g agar 10-20 g/L)
8.	Solvent (usually distilled water)
9.	Buffers

According to the consistency three types of media are used: liquid, or broth, media; semisolid media; and solid media. The major difference among them is that solid and semisolid media contain a solidifying or gelling agent, whereas a liquid medium does not.

- Liquid media, such as nutrient broth, tryptic soy broth or glucose broth can be used in studies of growth and metabolism in which it is necessary to have homogenous media conditions, to follow optical density, and to allow early sampling for analysis of substrates and metabolic products. Tubes and flasks with liquid cultures can be incubated with either static or shaken incubation.
- Semisolid media can also be used in fermentation studies, in determining bacterial motility, and in promoting anaerobic growth.
- Solid media, such as nutrient agar, are used 1) for the surface growth of microorganisms in order to observe colony morphology, 2) for pure culture isolation, 3) often in the enumeration and isolation of bacteria from a mixed population by diluting the original bacteria suspension and spreading a small inoculum over the surface of the solidified medium

Media are categorized by their function:

- An all-purpose medium, such as Tryptic Soy Agar, supports the growth of most bacteria cultured in the laboratory. They do not contain any special additives.
- Selective media enhance the growth of certain organisms while inhibiting the growth of others due to the inclusion of particular substrate.
- Differential media allow identification of microorganisms usually through the (visible) physiological reactions unique to those bacteria. The most practical media are those that both select for and differentiate common pathogens.
- Enrichment media allow metabolically fastidious microorganisms to grow because of the addition of specific growth factors. Enrichment culture is one obtained with the use of selected media and incubation conditions to isolate the desired microorganisms from natural samples.

Storage of Prepared Media

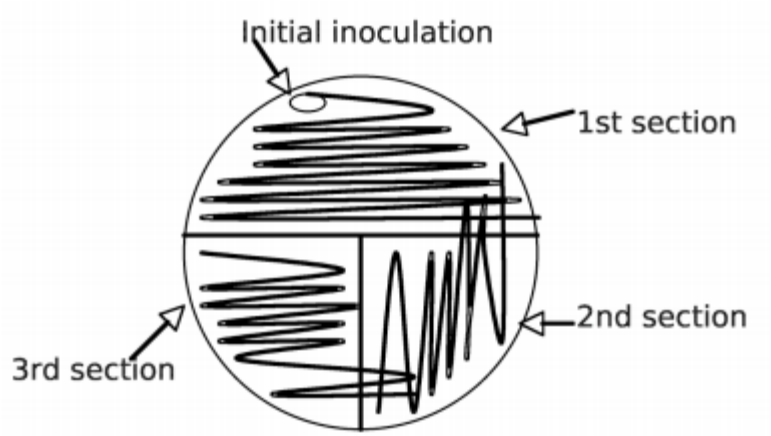
- The recommended expiration date of prepared culture media varies greatly. Screw-capped tubes can be stored for 6 months or longer at low to ambient temperatures. Plated media may be stored inverted in a plastic bag or other container in a refrigerator for 1–2 weeks or longer.
- Store all media away from light.
- Prepared media shall not be stored in areas of the laboratory where Biohazardus materials are kept. 4. Older stock of media and reagents should be used first.
- It is good laboratory practice to establish expiration dates for all prepared media.

12.6 Study the culture of bacterial broth, slants, plating and streaking

Aim: To study the culture of bacterial broth, slants, plating and streaking.

Principle

The purpose of this experiment is to separate a mixed culture of bacteria and obtain single, isolated colonies of each bacterial species. When working with microorganisms, it is desirable to start with single, isolated colonies to ensure you are working with a pure culture. Cultures that are visible on the surface of solid media are called colonies. A colony forms on a plate when a single microbe is inoculated onto the surface of the plate and reproduces until there are enough cells to form a visible colony. Since a colony theoretically forms from a single cell, a colony should then represent a pure culture. One way to obtain single, isolated colonies is using the quadrant streak method. The quadrant streak plate method allows sequential dilution of the original microbial material over the entire surface of a fresh plate. As the original sample is diluted by streaking it over successive quadrants, the number of organisms decreases. Usually by the third or fourth quadrant only a few organisms are transferred, and these produce single, discrete colonies



Apparatus, Glasswares and Chemicals

Nutrient agar medium, Inoculation loop, Bacterial culture, Incubator

Procedure

Inoculation of culture into Sterile Broth

- Obtain a broth culture of bacteria.
- Using a wax pencil, label the sterile broth tube with the initials of the organism and the initials of someone in the group.
- Mix the tube of bacterial culture by rolling it between your hands.
- Sterilize the inoculating loop by holding it at a downward angle in the center of the flame of the Bunsen burner.
- Flame the whole wire until it turns red by moving it through the flame from the loop to the top.
- Hold the inoculating loop and let the loop cool for 20 seconds. Do not lay the loop down or wave it in the air.
- Open the tube of broth culture and holding it at an angle, pass the mouth of the tube through the flame a couple of times.
- Insert the inoculating loop into the broth culture without touching the sides of the tube.
- Remove the loop and hold it.
- Pass the mouth of the culture tube through the flame a couple of times.

- Recap the tube and place it in the test tube rack.
- Obtain the labeled sterile broth tube, remove the cap and holding it at an angle, pass the mouth through the flame a couple of times.
- Insert the inoculating loop into the tube without touching the sides of the tube and immerse the inoculating loop into the sterile broth.
- Shake the loop a couple of times and touch the loop to the side of the tube to remove the excess broth.
- Flame the mouth of the tube a couple of times, recap, and place it in the test tube rack.
- Flame the loop to sterilize it.

Inoculation of an agar slant:

- Rest the inoculators gently at the lower end of the slant.
- Withdraw it slowly upwards moving it from side to side (the surface of the agar should not be broken).
- This should leave a streak on the surface of the slant (In some specific experiments you may be require to stab the slant just under the agar surface, if that is the case it will be clearly specified in the instructions).

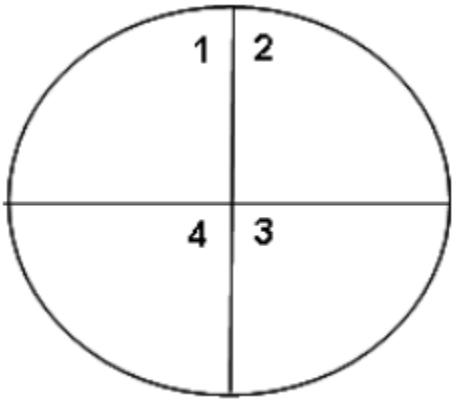
Inoculation of an agar plate:

- Working with agar plates is bit different than working with media in tubes in that you have a wide lid instead of narrow cap.
- This means there is a greater surface area of sterile media that can be exposed to contaminations in the atmosphere.
- The key is to keep as much of the lid over (covering) the open agar plate as possible.
- Never set the lid down on the lab bench when in an open contaminating environment.
- Divide the agar plate into 4 quadrants.
- Place a loopful of culture onto the plate in Quadrant 1 with a sterile loop and streak the loop very gently using a back and forth motion.

- Sterilize loop. Go back to the edge of Quadrant 1 and extend the streaks into Quadrant 2, going back into Quadrant 1 twice.
- Sterilize loop. Go back to the edge of Quadrant 2 and extend the streaks into Quadrant 3, going back into Quadrant 2 twice.
- Sterilize loop. Go back to the edge of Quadrant 3 and extend the streaks into Quadrant 4, going back into Quadrant 3 twice. Be careful NOT to go back into Quadrant 1!
- Tape plate closed on both sides.
- Make sure the plate is labeled with your name, date, and the organism(s), and incubate upside down (to prevent condensation from getting on to agar) at 30°C.

Observation and Calculation

Examine your isolation streak plate. Did you obtain single, isolated colonies.



Precautions

- Use freshly prepared media.
- Always use clean glassware in the experiment

12.7 Study the microbes in food material (Fish)

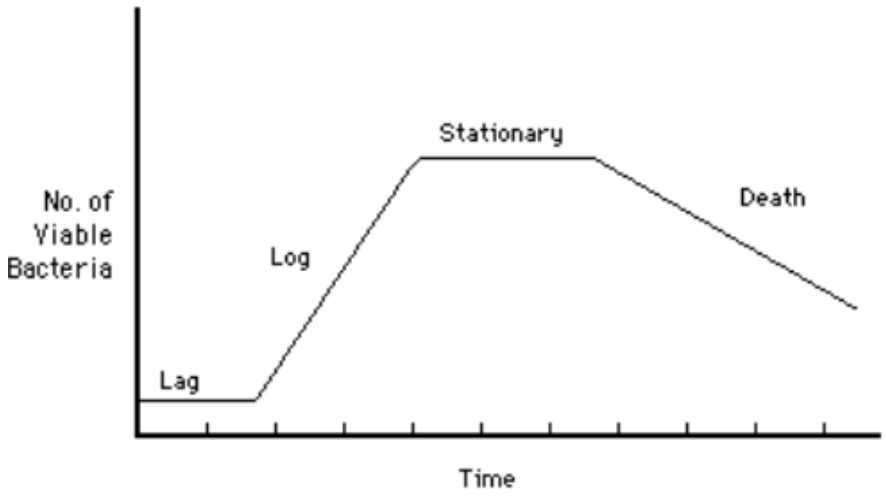
Aim: To study the microbes in food material (Fish)

Principle

Escherichia coli (E. coli) is a rod-shaped (*bacillus*), enteric (gut) bacterium of the

family Enterobacteriaceae. *E. coli* can be grown in solid or liquid culture media that contains nutrients such as carbohydrates, proteins, nucleic acids, salts and vitamins such as LB broth. LB media was designed by Salvador Luria and Guiseppi Bertrani in 1952.

When a small amount of bacteria is inoculated into a large amount of media (50:1) the bacteria enter into a lag phase. During this time, there is little to no growth because cells are adjusting to their new environment. During the logarithmic (log) phase, cells grow exponentially and the cell number doubles every 20-30 minutes. During the stationary phase, cell division matches cell death and the total cell number remains constant. After an extended period of time (>24 hours) cells enter the death phase and the culture slowly dies due to depletion of nutrients and build-up of wastes. *E. coli* are used extensively in molecular biology labs as a means of manipulating DNA and cloning genes. It is often useful to know the concentration of cells in a bacterial culture and also to know the growth rate of that culture. There are several methods by which the number of bacterial cells in a culture can be determined. One method is to make serial dilutions of the culture, spread a known volume of the dilutions on LB agar plates and then incubate the plates at 37^{o}C overnight. A single cell will divide many times; giving rise to a colony that is visible to the unaided eye. The number of colonies are counted and then multiplied times the dilution factor to determine the number of cells/ ml in the original culture. This method is very accurate, but time consuming. Spectrophotometry offers an alternative method to estimate the concentration of cells in a bacterial culture. Bacterial cells are small particles capable of absorbing and scattering light. When placed in a spectrophotometer the scattering of light by bacteria can be measured as apparent absorbance at a wavelength of 650 nm. Absorbance values gained in this way are also known as Optical Density or OD_{650}. The greater the density of the bacterial culture, the greater the OD_{650} for the culture. Using OD_{650} values and a standard curve (generated by our colony count experiment) we will estimate the number of cells/ml for a given culture of bacteria. We will also determine the growth rate of *E. coli* bacteria by measuring the OD_{650} of actively dividing cells at regular time intervals.



Apparatus, Glasswares and Chemicals

Culture of an *E.coli,* Spectrophotometer, LB broth, Cuvettes, Water bath

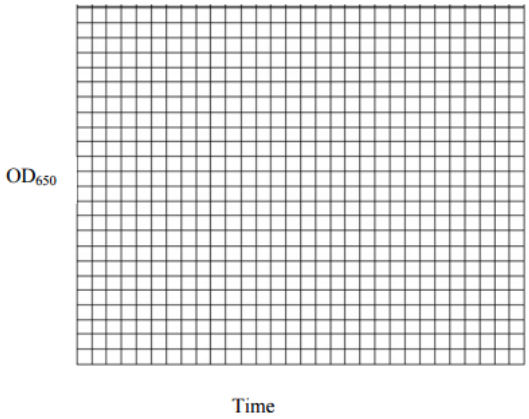
Procedure

- Calibrate the spectrophotometer.
- Take a flask which contain 30 ml of LB broth and label it with your initials.
- Using sterile technique, add 0.6 ml of stock *E. coli* to the flask and mix.
- Pipet 3 ml of the mixture into a glass culture tube, measure the OD_{650} in the spectrophotometer and enter that data in Table beside time zero.
- Place the flask back in the shaking 37^{o}C water bath. Note the time. Time Zero _____
- Determine the OD_{650} for the culture every 30 minutes (by repeating step 4) and enter the values in Table.

Observation and Calculation

Plot the data in Table on the graph in Figure and draw a best fit

Time (min)	OD_{650}
0	
30	
60	
90	
120	
150	
180	
210	
240	



line.

Precautions

- Use freshly prepared chemicals.
- Always use clean glassware in the experiment

12.8 Self learning exercise

1. Study the bacteriological analysis of potable water and write the procedure and result in your own words.
2. Study the microbes in food material (Fish) and write the procedure and results in your own words.

Unit-13

Developmental Biology

Structure of the Unit

13.0. Objectives

After going through this unit you will able to understand the development of Chick embryo at different hours incubation period. Incubation of egg shows significance development in which many structural modification, appearance or disappearance of any organ viz, somites, neural tube, brain, optic vesicle etc.

13.1. Introduction

Development of an organism involves all the changes it undergoes from its beginning until death. Most of the vertebrate animals include two distinct phases in their life history viz. 1) Embryonic or pre natal period, and 2) Post embryonic or post natal period. Chick embryology bears many resemblances with reptiles and mammals therefore it is important in phylogenetic significance. The Chick embryology is usually studied according to the hours incubation of eggs. The age of chick embryos is designated in terms of hours of incubation and in terms of numbers of somites.

13.2. Embryological slides of Chick

13.2.1. Chick embryo- 18 hours (whole mount)

Comments:

1. Notochord has become markedly elongated to form a conspicuous structure.
2. Notochord extending towards the cephalic region in the middle from Hensen's node.
3. Embryo of 18 hours of incubation is often spoken of being in the "head process stage".
4. Neural plate develops around the notochord.
5. The dark peripheral area opaca, inner translucent area pellucid and central embryonal area is seen.
6. In the anterior region is present a small and more translucent portion of area pellucid which is known as proamnion.
7. Proamnion is characterized by the absence of mesoderm.
8. Primitive streak lies in the middle of the pellucid in the posterior half.
9. Neural plate and primitive streak are separated by Hensen's node.

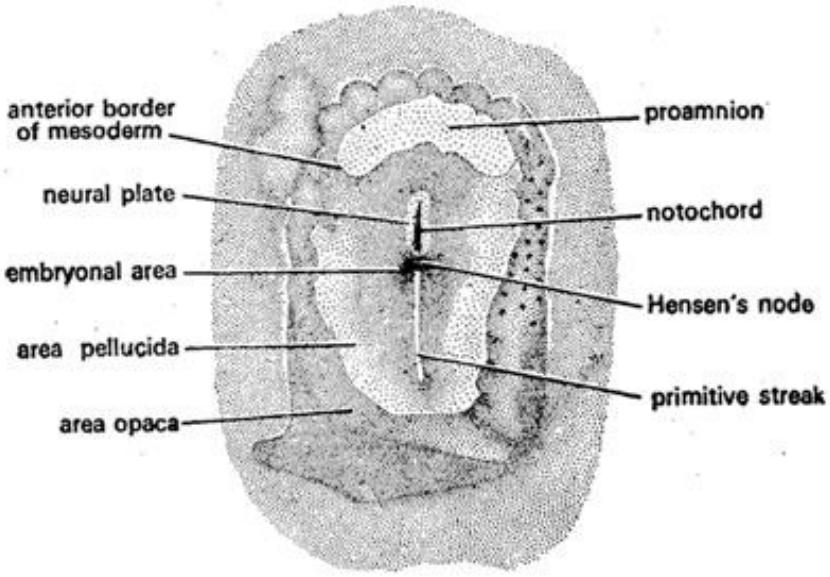


Fig.13.2.1. Chick embryo- 18 hours (whole mount)

13.2.2. Chick embryo- 24 hours (Whole mount)

Comments:

1. In 24 hours chick embryo cephalic region undergoes rapid growth. It extends anteriorly overhanging the proamnion region.
2. The cephalic region which projects free from the blastoderm may now properly be termed as the head of embryo.
3. The space formed between the head and the blastoderm is called the subcephalic pocket.
4. In the mid-line the notochord is seen. It is larger caudally near its point of origin than it is cephalically.
5. The neural plate is much more clearly marked.
6. The neural folds appear as a pair of dark bands.
7. At its cephalic end, the neural groove is deeper and the neural folds are correspondingly more prominent than they are caudally.
8. Four pairs of somites are seen in the mid-line.
9. Primitive streak gradually decreases in size.
10. Foregut is also formed. The part of the gut caudal to the foregut is termed the midgut and opening from the midgut into the foregut is called the anterior intestinal portal.
11. Besides the above structures, area opaca vitellina, area pellucid, proamnion, Hensen's node, area vasculosa, blood islands and unsegmented mesoderm are also seen.

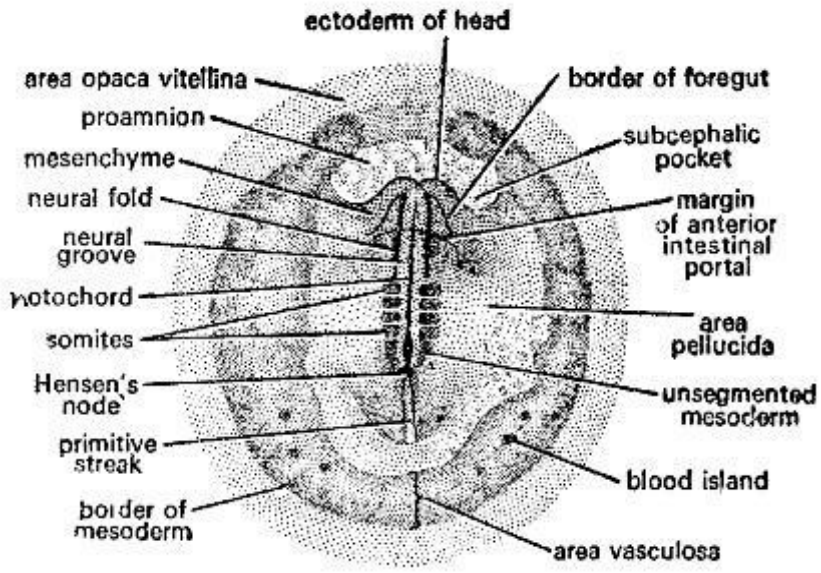


Fig. 13.2.2. Chick embryo- 24 hours (Whole mount)

13.2.3. Chick embryo-33 hours (Whole mount)

Comments:

1. The embryo of 33 hours of incubation shows some of the fundamental steps in the formation of central nervous system and circulatory system.
2. Brain is differentiated into prosencephalon (fore-brain), mesencepahlon (mid-brain) and rhombencephalon (hind-brain).
3. The optic vesicles are established as paired lateral out growths of the prosencephalon.
4. The optic vesicles soon extended to occupy the full width of the head.
5. Infundibulum is formed in the floor of prosencephalon.
6. Mid-region of the heart is considerably dilated and bent to the right.
7. Twelve pairs of somites are formed.
8. Anterior omphalomesenteric veins have developed.
9. Primitive streak becomes shorter because of the lengthening of the neural tube.
10. Proamnion, neural tube, notochord, sinus rhomboidalis and sinus terminalis arre also present.

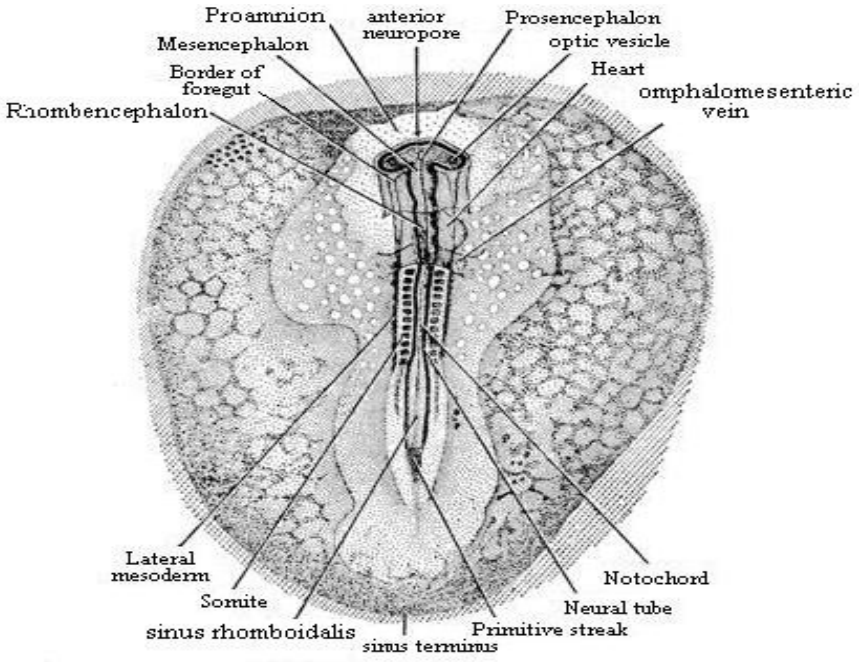


Fig. 13.2.3. Chick embryo- 33 hours (Whole mount)

13.2.4. Chick embryo- 48 hours (Whole mount)

Comments:

1. The position of the embryo with respect to the yolk changes strongly about 48 hours after fertilization.
2. In addition to the head fold of the amnion, also the lateral and caudal amniotic folds begin to form.
3. The outgrowth of the cranial flexure is so strong that the forebrain and hindbrain vesicles become almost located to each other.
4. The cephalic region of the embryo is twisted in such a manner that the left side comes to lie next to the yolk.
5. A second flexure appears at the transition of the head and the body just behind the heart region.
6. The embryo takes now the shape of a 'C'.
7. The head becomes covered by a double fold. These folds definitely establish the first extra embryonic membrane (outside of the embryo): the amnion membrane.
8. The vitelline (yolk rich) arteries and veins become connected with the extra embryonic circulatory vessels. The brain divides in to 5 vesicles: telencephalon and diencephalon (both formed by the division of the

forebrain vesicle), mesencephalon, metencephalon and myencephalon (both formed by the division of the hindbrain vesicle).

9. The lens placode (placode-plate) will form the lens vesicle, the optic vesicle will become the optic cup and the auditory placode the auditory pit.
10. The heart differentiates in to 4 compartments: the sinus venosus, connected with the veins, the atrium, the U-shaped ventricle and the bulbus cordis.
11. The atrium and ventricle are well distinguishable in the figure.

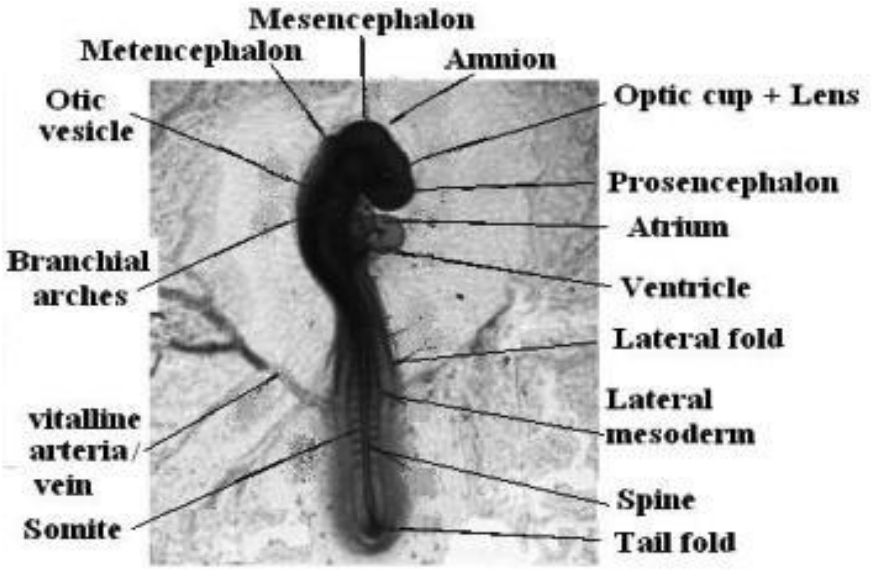


Fig 13.2.4. Chick embryo- 48 hours (Whole mount)

13.2.5. Chick embroyo-72 hours (Whole mount)

Comments:

1. The chick embryo of 72 hours of incubation has been affected by torsion throughout its entire length.
2. The torsion is complete well posterior to the level of heart but the caudal portion of the embryo is not turned on its side.
3. Due to the cranial and cervical flexures, the long axis of the embryo shows nearly right angled bends in the mid-brain and in the neck region.
4. The mid-body region is slightly concave dorsally because of the fact that the embryo is still attached to yolk in this region.
5. The visceral arches are thicker and more conspicuous than in the anterior embryo.

6. Both the anterior and posterior appendage buds have appeared in the embryo.
7. Telencephalon is also formed.
8. In the eye, lens, sensory and pigment layers are developed.
9. The number of somites increases to 36 pairs.
10. Vitelline arteries and vitelline veins are also well developed.
11. Nasal pits appear as shallow depressions in the ectoderm of the rostral part of the head which overhangs the mouth region.

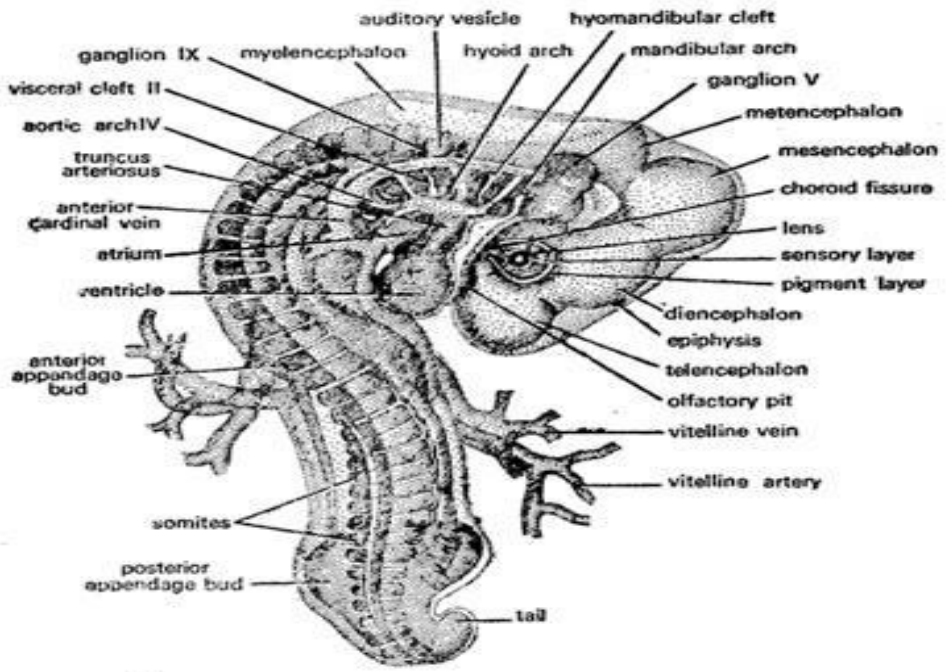


Fig.13.2.5. Chick embryo- 72 hours (Whole mount)

13.3. Self-Learning Exercise

1. What do you mean by primitive streak?
2. At which hour incubation stage primitive streak become visible?
3. Describe the features of 48 hours incubation stage of chick egg.
4. Tell the name of embryonic membrane of chick egg.
5. Describe the structures seen in 72 hours incubation.
6. What do you mean by neural tube?

13.4. References

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- ***Vertebrate Practical Zoology;*** Agarwal, S. C. and Mishra, S. P. ; Pragati Prakashan, Meerut.
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Unit-14

Dissections

Structure of the Unit

14.0 Objectives

The present unit is design to learn the practical aspect of animal dissection to separate the several parts from one another, so as to define their boundaries and display clearly their mutual relations. In this unit you will go through dissection of cranial nerves of *Wallago attu* or any other locally available fish, accessory respiratory organs of *Anabas* and *Heteropneustes.*

14.1 Introduction

The meaning of **"dissection"** is to cut open the animal in order to ascertain the structure of its parts. Dissection consists mainly in removing the connective tissue which binds the several parts together. Dissection must be carried out in water and water must completely immerse the dissection. Display your dissection by placing black paper below the target organ or organ system exposed. **Invertebrate** are always dissected from the **dorsal side** and **Vertebrate** are always dissected from **ventral side**.

14.2 Cranial nerves of *Wallago attu* or any other locally abundant fish

Cranial Nerves of *Wallago attu*

Procedure for dissection:

Take either a freshly- killed or preserved fish or wash it thoroughly if the fish is preserved. If the fish is preserved make a longitudinal incision in the integument at mid-dorsal region of the head from pectoral fin to snout. Likewise, make a transverse incision in the integument at the level of pectoral fin to the mid-ventral make a transverse the half line of the lower jaw. Remove the integument so that dorsal, lateral and ventral exposed. Now, break off the cranium carefully to expose the brain. Then trace the cranial nerves from their origin to their innervations. When your dissection is complete, display the nerves by placing black paper below them. Draw a neat and well labelled diagram of the same in your practical record with the help of given diagram.

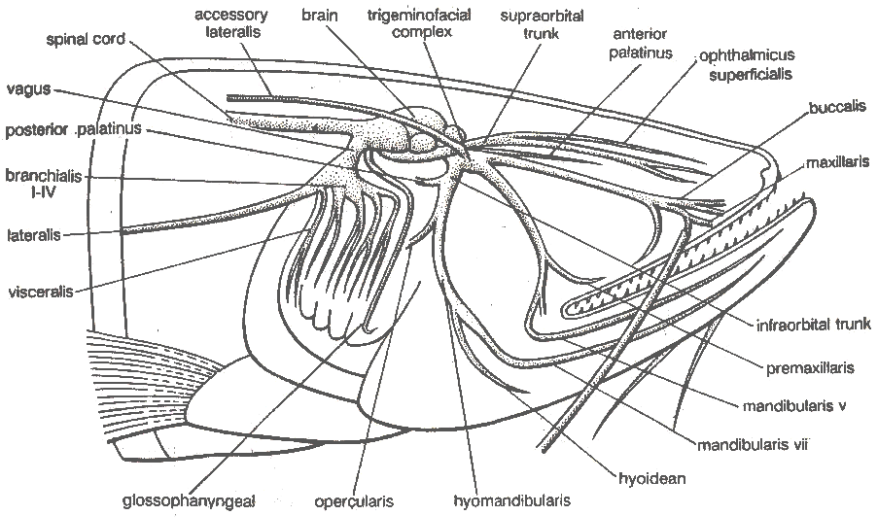

Fig. *Wallago attu*. Cranial nerves.

There are 10 cranial nerves on one side, thus, there would be 10 pairs of cranial nerves, which arise from the brain and symmetrically disposed on the two sides of the head. The students are usually asked to expose V, VII, IX and X cranial nerves.

The various cranial nerves are as follows:

I. Olfactory: Arises from olfactory lobe and innervates the olfactory folds.

II. Optic: Arises from the optic thalamus of diencephalon, enters the eye ball and supplies to retina.

III. Oculomotor: Arises from the ventral aspect of midbrain and supplies to eye muscles.

IV. Trochlear: Arises from the dorso-lateral aspect of the optic lobe and cerebellum, and innervates the eye muscle.

VI. Abducent: Arises from the ventral side of medulla and innervates to eye muscle.

V. Trigeminal and VII. Facial: Arise from the side of medulla, join immediately to form a trigeminofacial complex. The complex separates intracranially into three branches. These are:

1. Supraorbital trunk: which runs forward and forms inner ophthalmicus superficialis and outer ophthalmicus superficialis. These supply to the skin of snout.

2. Infra orbital trunk: Which runs forward and outward, and divides into maxillaris, buccalis and mandibularis. Maxillaris supplies to maxillary barbel, buccalis supplies to the skin of snout and also to maxillary barbel, while mandibularis bifurcates to give rise mandibularis externus supplying to overlying skin of the anterior end of mandible, and mandibularis internus supplying to the mandibular barbel and anterior end of head.

The infraorbital trunk, before dividing into above 3 branches, also gives off following two branches:

(a) **Premaxillaris** supplying to the upper jaw.

(b**) Palatinus anterior** which runs on the roof of buccal cavity.

3. Hyomandibular trunk: Which immediately gives out a stout opercularis nerve supplying to operculum and then divides into hyoidean and mandibularis branches. The hyoidean branch supplies to the branchiostegal membrane on under-side of the head. The mandibularis supplies to the lower lip and mandibular teeth. Hyomandibular trunk immediately after its origin from the complex also gives off a slender palatinus posterior nerve which also supplies to the roof of the buccal cavity.

From trigeminofacial complex also arises a lateralis accessory nerve which receives dorsal rami of spinal nerves.

VIII. Auditory: Aarises from the lateral side of medulla and divides into vestibular branch supplying to the utriculus, and saccular branch supplying the sacculus , lagena and sinus endolymphaticus.

IX. Glossopharyngeal: Arises from the ventro-lateral side of medulla behind the origin of auditory nerve. It has only post-trematic branch, enters the first gill and gives a branch to the roof of pharynx.

X. Vagus: Arises from the ventro-lateral aspect of medulla immediately behind glossopharyngeal. It divides to form two branches:

(i) Branchialis, these are 4 in number. Each with pre- and post-trematic branches supplying to the gills.

(ii) Visceralis, arises from behind the fourth branchialis, which gives a branch supplying to the pericardium and heart, and other branch to the viscera.

The **lateralis nerve** originates from close to the origin of yagus nerve from the medulla and runs back to the posterior end of tail beneath the lateral line system to which it innervates.

14.3 Neural complex of *Herdmania*

Procedure

Take a complete *Herdmania* and fix it by pins passing through the siphons and stretch the inter siphonal region as far as possible, because neural complex is embedded in body wall in the t middle of inter siphonal region. Expose the neural gland from above and proceed along the sides till the whole of the nerve ganglion is exposed and trace the nerves at the two ends. Srip off the mantle present on either side of these organs with the help of a pair of forceps till the wall of branchial sac is reached. Carefully remove the wall of peripharyngeal zone and expose the dorsal tubercle. Now these three organs, neural gland, nerve ganglion and dorsal tubercle are dissected out keeping the neural duct intact. Wash the neural complex in water and dehydrate upto 70% alcohol then lightly stain with borax carmine and again dehydrate up to absolute alcohol. Dealcoholize or clear the material in xylol or clove oil and finally mount on a cavity slide in D.P.X. or canada balsam. For glycerine preparation wash the neural complex in water thoroughly and stain with aqueous eosin and mount on a cavity slide in glycerine.

Characters

1. Neural complex is composed of neural gland which opens into dorsal tubercle and nerve ganglion. Nerve ganglion gives nerve fibres to dorsal tubercle.
2. Neural gland is oral-shaped structure. Anteriorly, it gives a duct of neural gland which opens by a ciliated funnel near the base of dorsal tubercle. Neural gland is supposed to be excretory in function. It secretes excretory material appearing as pigmented granules in the substance of the gland.
3. Dorsal ganglion or nerve ganglion is solid, elongated structure, found dorsally between branchial and atrial openings. It constitutes central nervous system.
4. Dorsal tubercle has a broad base from which 2 spirally coiled cones originate. Each cone has 3 coils of spirally ciliated channel. It is supposed to be chemosensory.

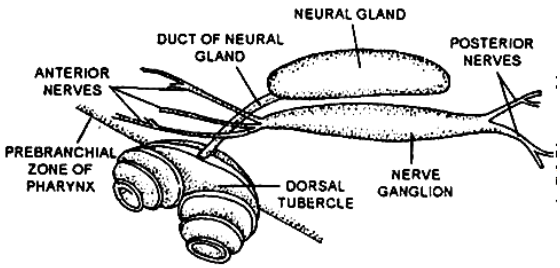

Figure. Neural complex of *Herdmania*

14.4 Accessory respiratory organs of *Heteropnuestes*

Heteropnuestes has a pair of tubular **extrabranchial diverticulum** as outgrowths of the gill-chamber extending as far as the middle of the tail region. At the hind end of the extrabranchial diverticulum, there are folds forming a sort of air chamber. The air chamber communicates with the buccal cavity by a slit through which the air passes in and out.

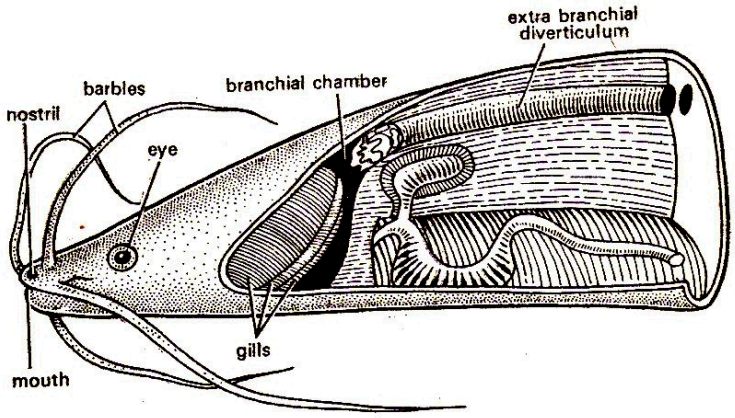

Fig. Dissection of accessory respiratory organs of *Heteropneustes*

14.5 Labyrinthine organs (Accessory respiratory organs) of *Anabas*

There are two air chambers, one on each side of the head. These are the extensions of the branchial cavities. They contain concentrically arranged wavy plates **(labyrinthiform organs)** which are the outgrowths of the upper part of the first branchial arch. The plates are covered with vascular membrane. Each chamber communicates with the pharynx by the first gill-slit and with the gill cavity by an opening situated between the hyoid and the first branchial arch. Air is drawn in by mouth in to the air chamber by the first gill-slit and it passes out by the branchial aperture.

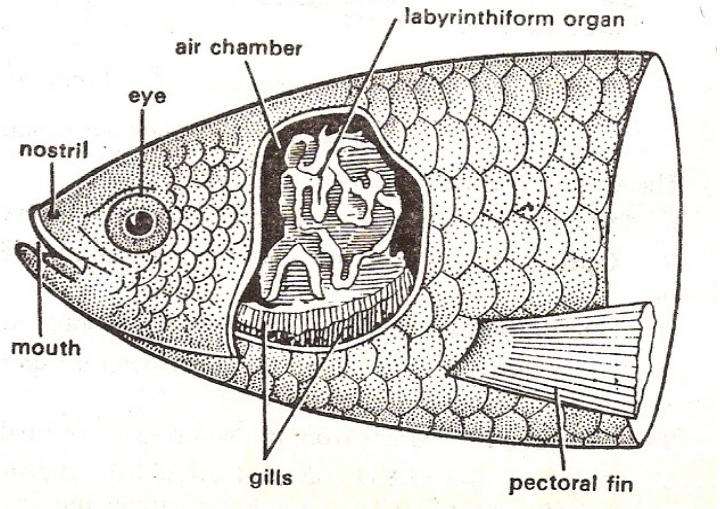

Fig. Dissection of accessory respiratory organs of *Anabas*.

14.6 Self learning exercise

1. Dissect out the *Wallago attu* so as to expose the V, VII, IX and X nos. cranial nerves and insert black paper.
2. Dissect out the *Anabas* to expose the accessory respiratory organ.
3. Dissect out the *Heteropneustes* to expose the accessory respiratory organ.
4. Dissect out the *Herdmania* to expose the neural complex.

14.7 References

- ***A manual of practical Zoology: Chordates***: Verma, P. S. ; S. Chand and Company Ltd.
- ***Practical zoology Vertebrate*****:** Lal, S. S. ; Rastogi publications.
- ***Vertebrate Practical Zoology*****:** Agarwal, S. C. and Mishra, S. P. ; Pragati Prakashan, Meerut.
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Unit-15

Field Entomology

Structure of the Unit

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15.0 Objectives

After going through this unit entomology students will be able to understand the use of different equipment for insect collection like Aspirators, Hand Collecting, different types of collection nets - Aerial Nets, Sweep Nets, Aquatic Nets ; Beating sheets, Knock Down Sprays, Extractors, Sieves, Baits and Refuges, different types of insect capturing traps, methods of insect Rearing and related Equipments, Killing Methods, how to recordfield data, various methods of insect Preservation,

Different methods for collection of different orders insects, Different methods for preservation of different orders insects, how to mount insects of different types, different types of entomological Pins, Pinning rules and different pinning positions of Insects, Spreading (Setting) methods, Labelling, Types of entomological collections, how to cure a entomological collection.

15.1 Inroduction

Insect collection refers to the collection of insects for scientific study, as a hobby. Most insects are small and the majority of them cannot be identified without the examination of minute morphological characters, entomologists often make and maintain insect collections. Very large collections are conserved in natural history museums or universities where they are maintained and studied by specialists. Many college courses require students to form small collections. There are also amateur entomologists and collectors who keep collections.

Historically insect collecting has been widespread and was in the Victorian age a very popular educational hobby. Insect collecting has left traces in European cultural history, literature. The practice is still widespread in many countries but nowadays due to continuous loss in biodiversity and entofauna some countries had made strict laws to ban this activity and to conserve and protect there is an increasing trend to discourage collection and preservation of insects. Although insects can be studied and enjoyed without killing them by observing them lively and photographic methods, there are number of reasons for insect collection and preserving them as museum specimens:

- Identification of insects is a specialty within the study of insects (entomology) based on studies by taxonomists that describe species or groups of species (e.g., families, orders, genera, etc.). Through collection and preservation efforts, new species are found and described. Many undescribed insects remain in the world, even in India.
- Properly preserved and stored insect specimens can be studied for hundreds of years while most insects live only for a period of days to months before they die and decompose. Specimens in museums, along with the data provided on the specimen labels constitute an historic record of biological diversity and can be used to document changes in distribution and

abundance of species over time. Some museums contain specimens of now-extinct insect species.

- Names and identities of insects (and other organisms) change over time when new studies reveal the need for a name change. If specimens were used as the basis for a scientific study on, voucher specimens are submitted and stored in a recognized, reputable insect collection. Only then can researchers in the future double check to make sure the species cited in these studies were accurately identified. In some cases, specimens that looked identical to early researchers are later found to actually represent two or more species through further study or use of new techniques.
- Insects are the most common form of wildlife encountered by people and are excellent models of living systems useful in learning about several fields of science. Most species are common and abundant and are not threatened by casual collection activities. Close observation of preserved specimens can result in an understanding of form and function of bodies (morphology and behavior), relationships between organisms or groups of organisms (systematics and evolution), methods of identifying organisms (taxonomy), and life cycles (developmental biology).
- During the exercise of collecting insects, collectors learn about relationships between insects and their environment, the importance of habitat, keys to species survival, and the relationships between species groups such as hosts, predators and parasites, i.e., trophic levels. Closer inspection of predaceous insects, for instance, reveal adaptive features enabling those species or groups or species to capture prey or what features allow a walking stick to mimic a twig.
- The study of insects in collections provides knowledge that can lead to a better understanding and higher tolerance of this group of animals in our environment.
- Insects and their relatives are fascinating creatures so unlike ourselves. Yet they share many features with humans and other animals. People of all ages can participate in the study of insects and making an insect collection is an activity to be shared with others, providing enjoyment and exercise while being educational.

- Assuming laws and regulations pertaining to the collection and transport of biological specimens are honored, specimens collected on vacation trips can make useful reminders of these trips to far-away places. Properly maintained, the specimens can last more than a person's lifetime.

15.2 Knowledge and Use of Different Equipment for Collection

A large variety of methods have been devised for collecting insects. Some methods are suitable for collecting a wide range of arthropod groups that occur in many different habitats, whereas others are designed for catching specific types of insects and arachnids in particular habitats. The collecting method chosen will depend on the particular species or groups that are being sought, and whether live or dead specimens are required.

15.2.1 Aspirators (Pooter)

An aspirator is a simple suction apparatus that is used for picking up numbers of insects or for selecting individual specimens out of a large number or off a plant. It ismainly used for catching small specimens by sucking them into a container that need to be kept alive. An aspirator consists of a glass or Perspex vial, with a stopper pierced by two flexible tubes. The end of one of the tubes is covered by a small piece of gauze to prevent specimens from being drawn into the operator's mouth. Specimens are collected by sucking on the end of the gauze-covered pipe while holding the end of the other tube close to them. A piece of absorbent paper should be placed in the vial to absorb moisture. Specimens that have been caught in the aspirator can be killed by introducing a small piece of cotton wool dipped in ethyl acetate into the vial. This ball of wool can be blown down the open-ended tube into the vial, to avoid having to remove the stopper and risk specimens escaping. Aspirators are commercially available but can easily be home-made. An aspirator is convenient for collecting small specimens caught in the net.

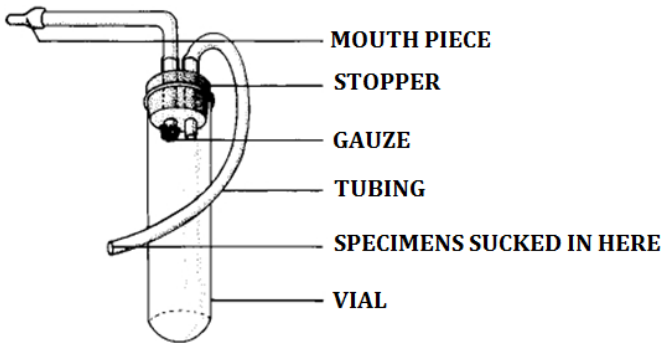

Figure - Aspirator

15.2.2 Hand collecting

Sedentary or slow-moving insects can be collected simply by hand picking method. As many insects are poisonous and can be bite or sting,therefore forceps should be used to pick them up, unless one is certain that they are harmless. A wide variety of specimens can be found by searching on plants, which are a food source, refuge or place to lay eggs for many species. Specimens occur on or in various parts of the plant, such as leaves, roots, stems, seeds, fruit and flowers. These places are habitats for different adult and immature insects like moths, flies, butterflies and wasps as well as mites, harvestmen, scale insects, planthoppers, stick insects and mantids. Crevices in the rough bark of trees are also home to various insects. Brushing the bark with a soft brush will dislodge them and some insects such as parasitic wasps and flies, can be detected by the damage they cause to plants. Galls, bud-scales, shoot- and twig-clustering, twig-rosettes and brooming should be collected and examined under a stereo-microscope for specimens. Numerous earwigs, beetles, fishmoths etc. can be found by looking under stones and logs and in leaf litter. Stored grain may be infested with a variety of beetles, moths. Bedbugs and house-dust mites may be found in bedding and crevices in neglected rooms. The timber of buildings may be inhabited by termites and wood-boring beetles.

15.2.3 Collecting nets

Usually three basic types of nets are used for insect collection:

1. **Aerial nets**

   Aerial nets are light weighted and made of a fine, soft, durable material used to collect flying insects like butterflies, antlions, flies, dragonflies, grasshoppers, wasps and bees. Usually white coloured fabric is used but in case of Lepidoptera collection black coloured nets are preferred as white

frights butterflies. Aerial nets have a circular frame made from an aluminium strip to which the net is attached. Holes are made at regular intervals in the metal frame for tying on the net. A frame can also be made of thick wire. A band of cloth, with a deep hem to allow the frame of the net to pass through, is sewn around the top of the net. This band should be strong enough to withstand knocks of the frame against stones, trees and other hard objects. The handle of the net can be of wood or aluminium, and should have a comfortable grip. A detachable extension to the handle is useful for collecting insects flying or sitting out of normal reach. Once the insect has been caught, the end of the net must be flipped over to prevent it escaping. Specimens can be removed from the net with the fingers if harmless, or directed into a killing bottle or vial of preservative.

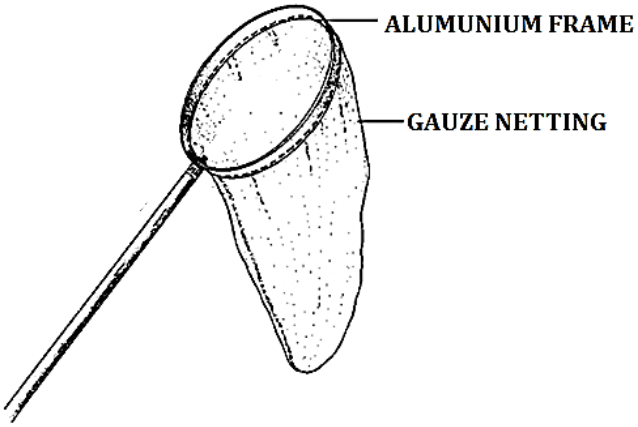

Figure – Aerial Net

2. **Sweep nets**

Sweep nets are heavy nets that can moved quicklythrough foliage, shrubbery and other vegetation to dislodge insects feeding or resting on foliage.This is the most effective way of collecting large numbers of specimens, especially the many small bugs, beetles, parasitic wasps and many other insects which are found in grass and plant foliage, is by means of a sweep net. These types of nets are swung through the vegetation to dislodge the specimens, which are knockedoff plants into the bag of the net. Sweep nets are stronger than aerial nets, with a wider diameter. They usually have a hexagonal shape which

allows better contact with the foliage being swept. During sweeping care should be taken to prevent too much plant debris accumulating in the bag, since this will damage the vegetation and insect specimens and make it difficult to extract them.

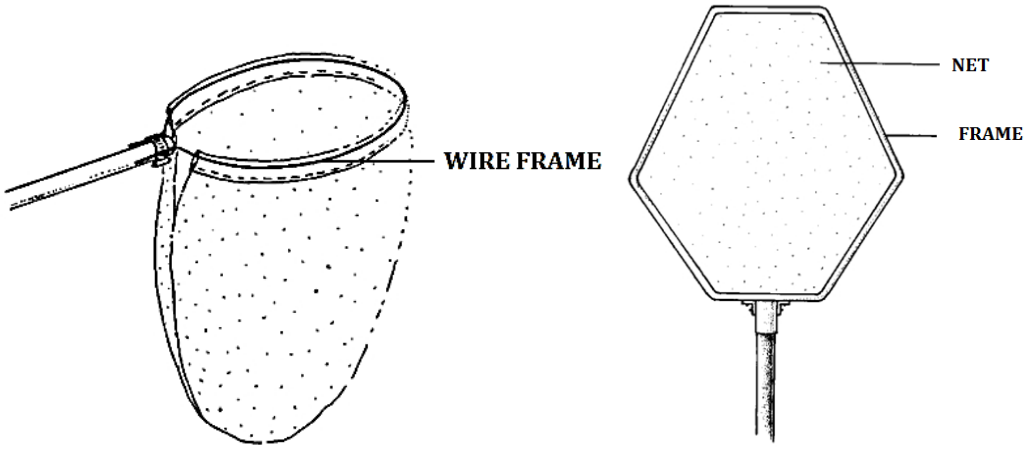

Figure –Sweep Net

3. **Aquatic nets (Dip Nets)**

   An aquatic net can be used in aquatic medium to collect aquatic insects. This net can be dipped in water and offer minimum resistance when dragged through water, but have a fine enough mesh to capture small specimens. The bag of the net need not be deep, and should be made of a synthetic mesh such as nylon. Transparent material is preferable, to make viewing of the catch possible. The band at the top of the net, as in other nets, must be of strong material.

Figure – Aquatic Nets

15.2.4 Beating sheets

By these nets hidden insects species on plants are collected with a beating sheet. This method is useful for collecting sessile or wingless groups such as some beetles and bugs, stick insects, caterpillars, etc. These are knocked from the vegetation, by beating it with a stick, onto a sheet placed beneath the plants. A hand-held beating sheet is especially convenient for sampling vegetation. This consists of a shallow canvas bag, preferably white, stretched over a folding frame.

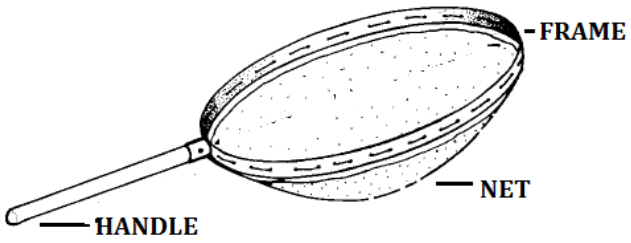

Figure- Beating Sheet

15.2.5 Knock-down sprays

Knock-down sprays enable the collector to sample areas of a plant that are inaccessible to a net or beating sheet. White sheets are placed beneath a tree or shrub, which is then sprayed with a fast-acting pesticide, such as a synthetic pyrethroid. The dead specimens fall from the tree onto the sheets. This technique does not work well for fast-flying insects that are easily disturbed, such as wasps, flies and grasshoppers.

Figure – Knock down spray

15.2.6 Extractors

1. Leaf-litter and humus extraction devices

Many tiny insects live in leaf-litter, humus, decomposing wood, detritus and the

nest litter of small mammals and birds. Examples include fishmoths, bristletails, booklice, wingless parasitic wasps and cockroaches. These species are generally photophobic, usually preferring moist conditions. A Berlese (Tullgren) funnel is a very effective way of sampling them. Leaf- and stem-mining species, such as the potato tuber moth, can also be extracted from plants with this device. A sample of humus or leaf-litter is placed on a gauze tray in a funnel. A light bulb is positioned above the sample, and a bottle of alcohol below the funnel. The bright light and the drying effect of the hot bulb on the sample drive the specimens down into the funnel until they fall into the alcohol. Care must be taken not to dry the sample out too rapidly as this will kill the slow-moving specimens before they reach the bottom of the funnel. The Moczarsky-Winkler selector is another type of extractor that works on the same principle as the Berlese funnel, but is made of canvas and allows the sample to dry out under natural conditions. It is designed for use in the field where there is no electricity.

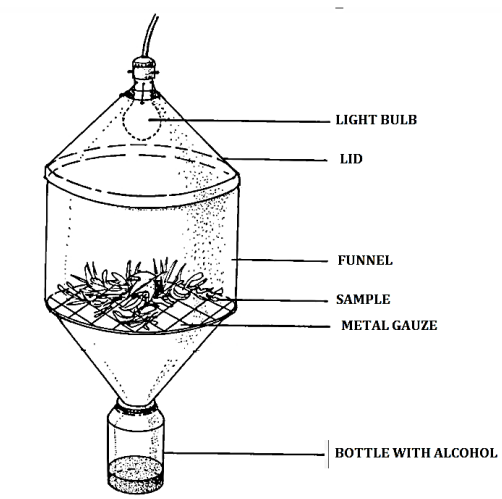

Figure - Berlese (Tullgren) funnel

15.2.7 Sieves

Sieves are used for collecting insects living in soil (e.g. ant lion larvae, grubs, ear wigs, etc.), on plant foliage or aquatic species in mud and streams. Insects that live in leaf-litter or decomposing wood can also be collected by sieving. Any frame with a wire mesh, such as a kitchen sieve, tea strainers can be used. The size of the mesh will depend on the size of the specimens being sought.

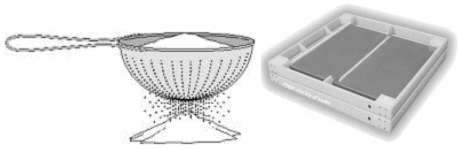

Figure - Sieve

15.2.8 Baits and refuges

Many materials like fermenting fruit, dung, detritus substances or carrion cause attraction to many insects. These can be used as baits or attractants to lure specimens into a trap, or to an area where they can be collected. Carrion flies, Bow flies and beetles can be collected at a carcass. Many wasps and bees nest in small holes and can be attracted to holes made in blocks of wood, known as trap-nests. When the insects have made their nests, these are collected and placed in an emergence box until the progeny emerge.

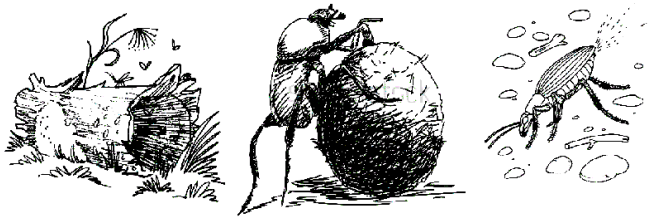

Figure – Detritus Insects

15.2.9 Traps

1. **Yellow-pan traps**

   Many day-active insects are attracted to the colour yellow. This trapping method uses small yellow dishes filled with water mixed with a little detergent.The dish liquid (or detergent) is used to break the surface tension of the water, so the insects will fall through. Pan traps need to be checked at least daily. They can be made from trays measuring about 40 cm in diameter and painted yellow. The dishes are placed on the ground in open areas in the morning. When flying insects land on the surface of the water they rapidly sink and drown. At the end of the day, the water is strained through a fine sieve and the specimens are retrieved. Blue dishes can also be effective and often attract different insects. Yellow-pan traps are used mainly to collect aphids.

2. **Sticky traps**

Small flying insects such as aphids, wasps, psyllids, thrips and flies can be collected using sticky traps. These are small yellow plates of about 15 cm square, or a yellow cylinder with a diameter of about 15 cm and 20 cm long. The plate or cylinder is covered with a sticky substance, such as 'Flytac', and attached to a pole. The cylinder has the advantage of attracting specimens from all directions and is suitable for areas where the wind direction varies. The sticky substance is dissolved with a suitable solvent, like xylene or ethyl acetate, to release the trapped specimens. As sticky traps tend to damage specimens, they are mostly used for monitoring populations. A glass Petri-dish or tile covered with firm grease and suspended in grass can also be used. The trap should be left for 2-3 days. The grease can be dissolved in a mixture of benzene and isopropyl alcohol to free the specimens.

3. **Paper-band traps**

Paper band traps are specifically used to collect insects that live in crevices in the bark of trees or tree trunks after overwintering in the ground.Brown ridged paper strips of about 15 cm wide are wrapped twice around the trunk of a tree and fastened with string. The corrugations should be approximately 3 mm in diameter. The traps should be positioned at different heights on the tree, and left for several days or even up to a month. The tunnels of the paper provide a refuge for various insects. After specific time each paper strip is carefully removed and placed in a plastic bag with any anaesthetic chemical. The paper strip is then examined and refugee insects are collected.

4. **Pitfall traps**

A pitfall trap is a trapping pit for capturing insects, etc. Pitfall traps are mainly used for ecology studies and ecologic pest control.Insects that enter a pitfall trap are unable to escape. Containers such as small plastic buckets, plant pots, glass jars or jam tins are sunk into the ground to trap flightless, ground-living insects, especially beetles, cockroaches, crickets, etc.The container should be placed in a hole with the upper rim flush with the ground surface. A killing agent and preservative, such as

ethylene glycol, should be placed in traps that are not emptied daily. A bait can be added to the trap to increase its effectiveness. The type of bait will depend on the specific insect to capture. Decomposing meat or fish is ideal for attracting carrion beetles, whereas fermenting fruit is used to lure fruit beetles. The bait should be placed in a separate container, covered with gauze, inside the trap. This prevents the specimens from becoming embedded in the bait. A funnel must be placed over the opening of the trap when collecting active insects, as they are very agile and can easily escape. Pieces of vegetation added to the trap will provide some protection from predators. This is a form of passive collection, as opposed to active collection where the collector catches each animal. Active collection may be difficult or time consuming, especially in habitats where it is hard to see the animals such as thick grass.

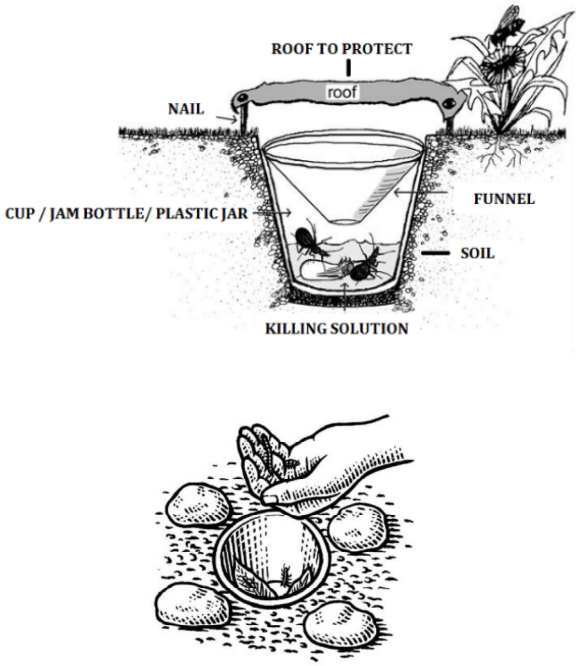

Figure – Pit Fall Trap

5. **Butterfly traps**

Butterfly traps are specifically used to capture fast-flying butterflies, such as nymphalids and*Charaxes* thatlive in tree shelters and cannot otherwise be reached. These butterflies are attracted to a bait in the trap. It is made from a vertical gauze cylinder, closed at the top, with a

landing platform at the bottom. A gap is left between the bottom edge of the cylinder and the platform. The bait of over-ripe banana mixed with a little rum or rotten meat or fish and animal dung is placed in a small bowl positioned in the centre of the platform. The trap is hoisted over a high tree branch with a rope, and lowered to remove the catch. The butterflies alight on the platform, walk under the edge of the cylinder to feed on the bait, and then fly upwards to settle inside the trap. Butterfly traps should be monitored regularly, as they can fill quite quickly and specimens will be damaged if they flutter against each other.

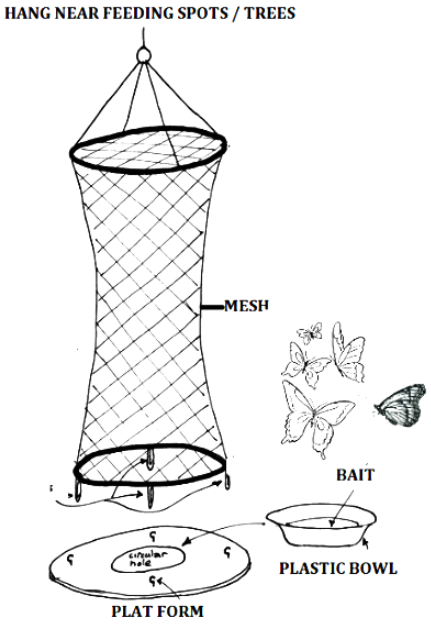

Figure – Butterfly trap

6. **Pheromone traps**

Pheromones are chemical substances emitted by insects for communication. Sexual pheromones can be used in traps to attract specimens of the opposite sex. Live females of some species, like emperor moths, that are confined in a trap will attract males over a long distance. A trap placed in a field will give an indication of the presence and numbers of a pest. These traps can also be used to remove large numbers of specimens from a population, thus reducing reproductive capacity. Many of these traps are commercially available and are specifically designed to target particular pest species.

Figure – Pheromone Trap

7. Suction traps

Suction traps capture insect specimens into a net by creating a down-draught. They are used to collect small flying insects such as flies, aphids and wasps. This trap is generally used in ecological studies, museum specimens can also be collected this way. A portable vacuum cleaner can be modified to form a suction trap by simply placing a small gauze bag into the pipe to catch specimens.

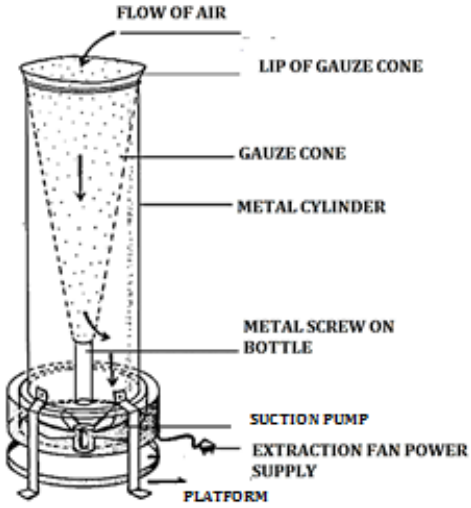

Figure – Suction Trap

8.Light traps

Light traps are used for collecting nocturnal insects that are active only during night time. Large numbers of insects and a wide variety of species can be caught at night using light traps. The simplest light trap consists of a suspended white sheet with a light hung in front of it. The trap shows a refinement of the light sheet trap, consisting of a white gauze cylinder. Light tubes are attached to the central pole inside the

gauze cylinder. Normal bulb, CFL Bulb or other light sources can be used as per our requirement. The ultraviolet lights are most effective, but specimens will be attracted to any white light. Where electricity is not available, a generator or battery can be used, otherwise gas and paraffin lamps will meet our requirements. The best time to trap is on a warm, still, humid, dark nights. Weather conditions such as wind speed and humidity can affect the numbers of specimens coming to a trap.

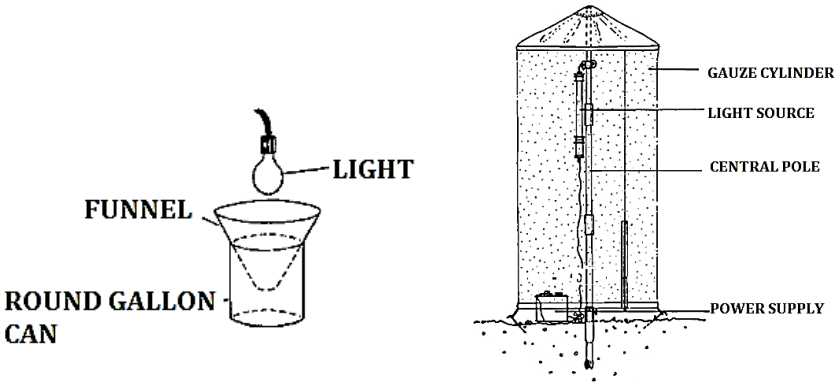

Figure – Light Traps

9. **Flight-interception traps**

1. **Windowpane trap**

Windowpane trap is made up of a vertical pane of glass, plastic or gauze placed atcrosswaysor in the mid of the flight path of insects, above a trough of soapy water or ethylene glycol Insects flying into the pane drop into the trough below. This method is particularly suitable for heavy bodied insects such as beetles.

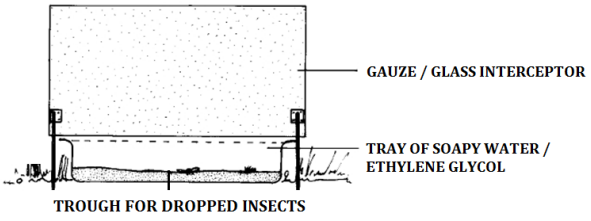

Figure - Flight-interception Trap

2. Malaise trap

This trap was invented by René Malaise in 1934. It is a large, tent-like

trap used for trapping flying insects, particularly Hymenoptera and Diptera. The trap is made of a material such as terylene netting and can be various colours. Insects fly into the tent wall and are funnelled into a collecting vessel attached to highest point. Large numbers of specimens will be taken with very little effort by using this method. Malaise traps are mainly used to catch bees, wasps and flies. This type of trap resembles a tent with two open sides. A vertical gauze wall in the middle intercepts flying insects, which are directed upwards into a killing bottle fixed to the highest point of the trap. The insects that enter the trap move slowly upwards into the bottle, which usually contains alcohol to kill and preserve the insects.

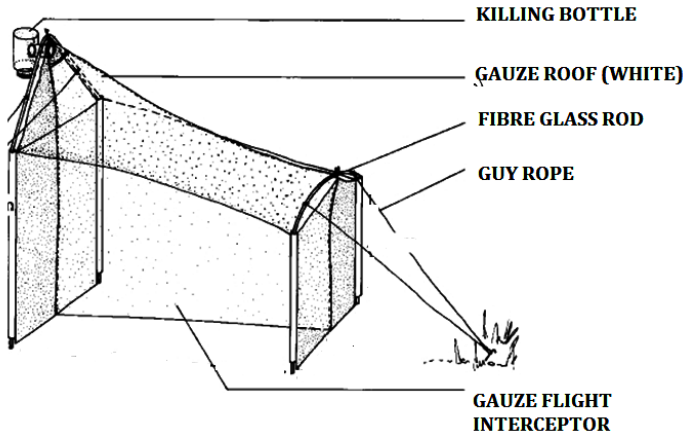

Figure – Malaise Trap

15.3 Insect Rearing

Rearing specimens provideoriginal specimens as well as access to life stages often not collected, associates larvae with adults, and reveals parasitoid relationships. The most important considerations are containment, proper food, and proper environmental conditions.

1. **Acquiring specimens for rearing**: Eggs can sometimes be obtained from gravid females. Some female moths will oviposit on the walls of a collecting vial or container. Sometimes it is necessary to have the proper host plant material available to stimulate oviposition. If larvae are collected from host material, be sure to collect extra material.

2. **Rearing containers**: Small plants can be grown in screen cages or enclosed in clear plastic bags. However, it could be difficult to collect reared specimens from these containers. Dark cages with collection jars make it easier to collect reared specimens. Mason jars with screen or gauze lids work for smaller situations. Be sure to include adequate space for emerging specimens to expand their wings. Also be sure that specimens are not able to chew their way out of the container (See Rearing equipments later on in this section).
3. **Food**: If possible, host plant material should be exchanged regularly with fresh material. For internal feeders, such as leaf miners or seed borers this is not an option. In these cases, great care should be taken to avoid desiccation or molding of the host material. If the collected specimen was not associated with a host plant a "salad" of plant materials from the surrounding environment should be provided then inspected to see which plant is the preferred host. Carnivorous species can often be maintained on easily massed-reared insects such as waxworms, mealworms, maggots, mosquito larvae, or fruit flies. We can even take raw meat dangled from a thread.
4. **Artificial medium**: Artificial rearing media have been formulated for many agricultural and other economic pests and work for many related groups. Most consist of an agar base with nutrients and feeding stimuli added and can be obtained from biological supply houses.
5. **Environmental conditions**: Temperature, humidity, and day-length should simulate natural conditions as much as possible. Environmentally controlled rearing facilities are preferred, a damp cotton ball, sponge, or paper towel can maintain elevated humidity, but particular humidity requirements can be maintained with saturated salt solutions. Pupae may be placed on damp sawdust or moss for eclosion. For larger cages with plants, occasional misting with a spray bottle may be appropriate. Excess moisture can lead to mold or fungus growth or can trap insects in the surface tension. Direct sunlight may cause over-heating and moisture build up in containers, indirect sunlight is preferred. Some species may require a "cold shock" that causes the insect that winter has passed and to break dormancy. This can be simulated with refrigeration
6. **Pupation**: Few insect species require particular microhabitats for pupation. Layered paper towels or corrugated cardboard can be substituted for loose soil

and leaf litter as pupation sites. Moisture is crucial at eclosion – use moist saw dust, moss, sponge, cotton, or paper towel to maintain elevated humidity, but take care that pupae are not in direct contact with water.

7. **Sanitation**: Waste products, such as frass and the remains of eaten host material, should be removed regularly to avoid build-up of unsanitary conditions. Occasionally wiping down the rearing container with a dilute bleach solution or ethanol will help prevent the growth of mold and bacteria. Good ventilation or proper air circulation within the rearing setup will also prevent moldy conditions.
8. **Mating studies**: Place males and females in a vial for a day or two. Host (oviposition) material may help stimulate mating and oviposition.
9. **Culturing**: In order to maintain insectscultures of particular species above mentioned conditions will be applied in most cases.

15.3.1 Rearing Equipments

Artificial favourable conditions are provided to insect for their rearing. For this various types of equipment are used. With help of these we can get information on life stages and hosts. Most insects can only be identified in the adult stage, as immatures are poorly known. Thus, if only live immature specimens are available, they can be reared to the adult stage for identification.

15.3.2 Rearing in cages

During insect collection many larvae of ground-dwelling insects, beetles etc that lives in soil habitat are captured. For identification they are reared to the adult stage. Empty aquariums are easy to do insect culture. Insects like moths, butterflies, beetles and bugs can be reared on their host plants in a gauze cage. They can also be confined in a gauze sleeve placed over the branch or stem of the plant on which they are feeding. Insect enemies must be removed from the rearing cage. Overpopulation must be avoided, this can cause cannibalism. Cages should be cleaned regularly, and dead and unhealthy specimens removed to prevent disease.

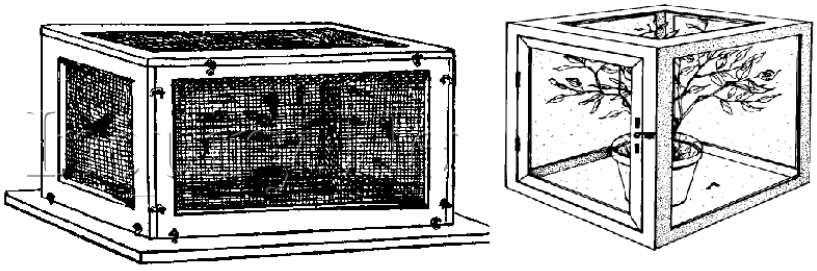

Figure – Different types of rearing cages

15.3.3 Rearing in aquaria

Aquatic insects can be reared in an aquarium. The water should be aerated when rearing insects like mayflies, which live in running water. Stagnant water is suitable for various other insects, like mosquitoes. Suitable food should also be provided. The aquarium should be closed at the top with gauze to prevent emerging adults from escaping. A perch above the water should also be provided for the adults.

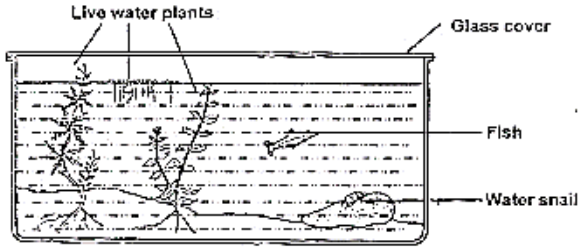

Figure - Insect rearing aquaria

15.3.4 Rearing in emergence boxes

Emergence boxes are used to rear different types of insects like parasitic wasps, gall-forming flies, moths and seed beetles can be reared in an emergence box. These insects emerge from galls, pods, insect eggs, oothecae, larvae, puparia, spiders' egg-sacs or scale insects and mealybugs.

The plant material is placed in the emergence box, and the vial directed towards a light source, such as a window. Most insects are attracted to light and will crawl through the funnel into the vial where they can be collected. The vial should be emptied daily to prevent specimens from being eaten by spiders or other predators that may be on the plant sample. Large insects such as wood-boring longicorn

beetles can be reared by placing infested logs in an emergence box. This container should be of metal, as wood-borers will chew through a cardboard box and escape. A square 25 litre paraffin drum, with a large bottle attached to a hole in one side, is ideal.

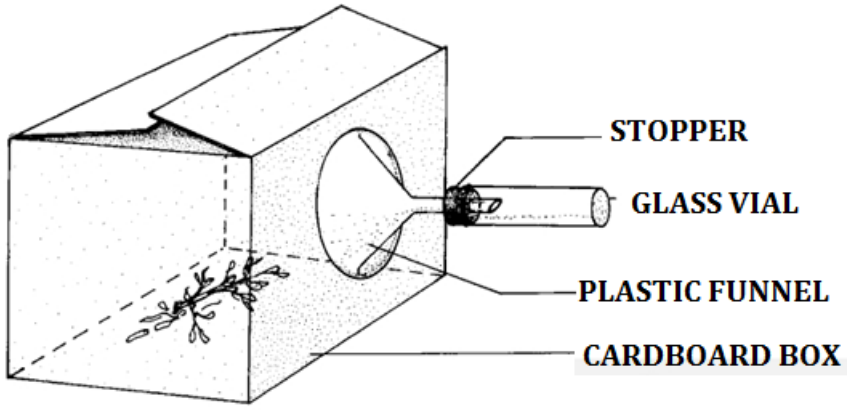

Figure- Emergence box

15.4 Killing Methods

15.4.1 Use of liquid

Killing methods depends upon the insects body, liquid method is generally used for soft-bodied insects like aphids and termites etc. and their eggs and larvae. These should not be allowed to dry out once they are dead. They should either be placed directly into a liquid preservative like 70-95 % ethyl alcohol or, into a fixative such as Pampel's fluid. **Formalin (formaldehyde) should not be used for storing insects as it makes specimens hard and difficult to examine.** Robust, non-hairy insects like beetles can be killed by immersing them in boiling water. Small delicate specimens should be placed in a glass tube before immersion in hot water. Larvae of Lepidoptera and Coleoptera should be placed live into near-boiling water to denature their body proteins and prevent decay. They should then be placed in a fixative like Pampel's fluid before being transferred to a preservative. Each sample should be collected into a separate vial

The following insects should NEVER be placed in liquid: those with scales on their wings (e.g. Lepidoptera), hairy insects (e.g. some Diptera and Hymenoptera), and insects covered with a waxy bloom (some Coleoptera).

Composition of Pampel's fluid:

1. 95 % ethanol (750 ml)

2. distilled water (1375 ml)
3. 40 % formalin (250 ml)
4. glacial acetic acid (125 ml)

15.4.2 Freezing

Insects and arachnids can be killed by placing them in a freezer. This method is particularly suitable for reared moths and butterflies. Care should be taken to ensure the specimens are dead before removing them from the freezer, which may take up to 48 hours

15.4.3 Pinching

Larger butterflies can be stunned or killed by pinching the thorax between the thumb and fore-finger

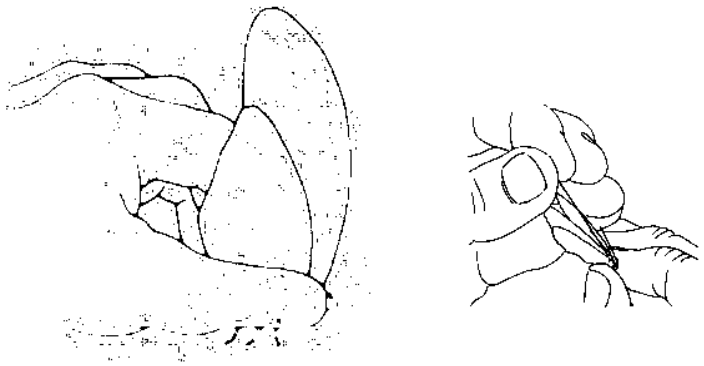

Figure - Pinching of abdomen of butterfly with hand

15.4.4 Killing bottles

Killing bottles are used to kill trapped live insects. The bottle should be wide-mouthed and made of glass, polypropylene or polyethylene (ethyl acetate dissolves many other plastics). Absorbent paper should be placed inside the bottle to soak up condensation, regurgitated or defaecated liquid and to prevent insects from damaging each other. Many species of large beetles takes long time to die in the killing bottle therefore they should not be removed too soon and the delicate specimens should be removed from killing bottle very soon just after capturing because there is a risk of damage. Delicate specimens, and all butterflies and moths, should be killed in separatebottles from other insects, otherwise they may be damaged by more robust specimens such as large beetles. The poisons used in killing bottles are hazardous and should be handled with great care. Bottles should

be held away from the face when opening them, and care must be taken to avoid inhaling their fumes. They should be kept away from foodstuffs and preferably cleaned outdoors. All killing bottles should be labelled **POISON** and kept out of reach of children.

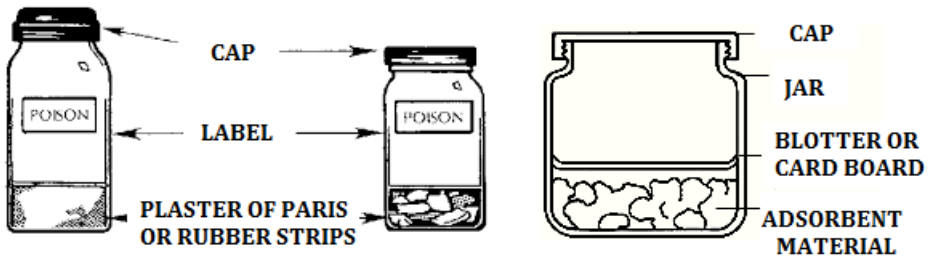

Figure –Killing Bottle

15.4.5 Ethyl acetate bottles making procedure:

- First place a thick layer of plaster of Paris at the bottom of a wide mouthed bottle.
- A pad of cotton wool can also be used in place of plaster of Paris, but it should be covered with a tight-fitting piece of cardboard to prevent insects from becoming entangled in the cotton fibres.
- Now wait till the plaster of Paris layer dries.
- Now saturate the plaster of Paris with ethyl acetate.
- Place crumpled absorbent paper on top of the plaster of Paris.
- Let the bottle dry out before recharging it with ethyl acetate. Ethyl acetate bottles are easy to prepare and are less toxic to humans than potassium cyanide bottles. Green insects should be removed from the bottle as soon as they are dead, as ethyl acetate discolours them.
- Ammonia, benzene, chloroform, carbon tetrachloride and trichloroethylene can also be used, but most of these are hazardous to health.

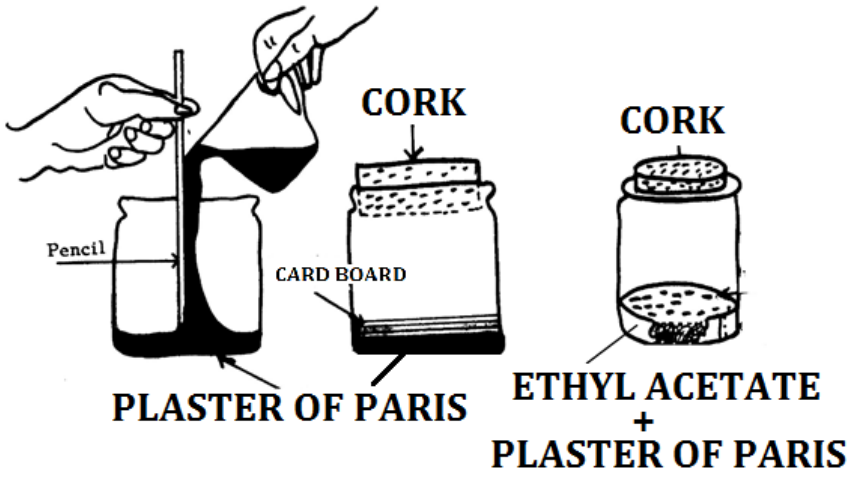

Figure - Ethyl acetate killing bottle

15.5 Temporary Storage

15.5.1 Dry specimens

During field collection butterflies and other large-winged insects can be stored in folded protectivepaper envelopes (preferably waxpaper / Butter paper). Most insect specimens can be conveniently stored between layers of absorbent paper. Any sturdy container can be used to store insects. Small cardboard or wooden boxes are especially useful, as they permit the specimens to dry out. It is very important to realise that freshly-killed specimens will develop mould if sealed in non-porous containers, such as plastic or glass vials with tight stoppers. Allow the material to dry out thoroughly first, beforeclosing the container. A fungicide such as dichlorobenzene, phenol, camphor balls, chlorocresol, ethyl acetateor 'Dettol', should be added to the container if the material is not yet completely dry. The fungicides should be added in such a way that it does not damage any specimen; ethyl acetate can damage hairy insects and those with a waxy bloom.

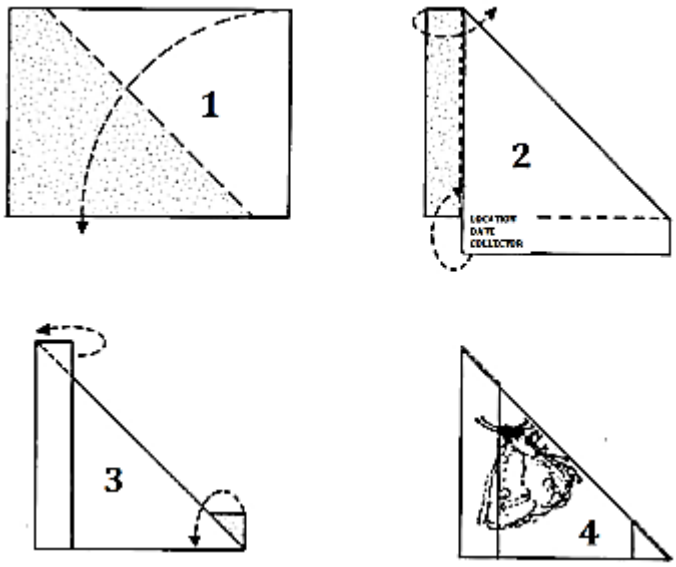

Figure – Preparation of protective paper envelopes for storage of insects

15.5.2 Specimens in liquid

In liquid preservative insects are usually killed by placing them directly into a vial of preservative or fixative. Material that has first been placed in a fixative medium should be transferred to a preservative fluid for temporary storage.

15.6 Recording Field Data

With collection an entomologist have to record and maintain all relevant data at the time of collection like location, date, collector's name, time, latitude and altitude and many other information, such as host plant. This is best done by writing the information on a small piece of paper, using a pencil or pen with indelible drawing ink, and placing the label inside the container with the insect sample. A numbering can also be done to record collecting data, where the samples are numbered with small labels, and the associated collecting information recorded against the numbers in a field book.

15.7 Insect Preservation

After insect collection the main issue arise to how to preserve insects for a long time. Now the next step is preservation. There are many methods and materials used depending on the type of insect and the purpose and size of the collection. The

key to long-term success in making a collection is attention to detail and organization while selecting the proper methods of preservation. Insects of all kinds may be killed and preserved in liquid agents or a dry gaseous agent. Some of the insect preservatives are as follows:-

1. **Formalin (formaldehyde)** solutions are not suitable for insect preservation because the tissuesbecome excessively hardened and the specimens then become difficult to handle.
2. **Ethanol (grain or ethyl alcohol)** mixed with water (70 to 80 % alcohol) isusually the best general killing and preserving agent. For some kinds of insects and mites, other preservatives or higher or lower concentrations of alcohol may be better. Because pure ethanol is often difficult to obtain, some collectors use isopropanol (isopropyl alcohol). Isopropanol does not seem to harden specimens as much as ethanol. Concentration to use depends on the kind of insect or mite to be preserved. Some examples:
    a) Parasitic Hymenoptera (tiny wasps) are best killed and preserved in 95% alcohol. This high concentration prevents the membranous wings from becoming twisted and folded, hairs from matting, and soft body parts from shriveling.
    b) Soft- bodied insects (aphids, thrips, small flies) become stiff and distorted if preserved in 95% alcohol and should be preserved in alcohol of a lower concentration.
    c) Adult bees should not be collected in alcohol because their usually abundant body hairs become badly matted.
    d) Adult moths, butterflies, mosquitoes, moth flies, and other groups with scales and long, fine hairs on the wings or body may be worthless if collected in alcohol regardless of the concentration.
3. **Special care for caterpillars/larvae and others**

    In order to prevent blackish coloring of larvae of most insects just after collection, they should be kept in boiled in water to "fix" their proteins, and placed in alcohol. Larvae should be left in hot water for 1-5 minutes, depending on the size of the specimens, and then transferred to 70-80% alcohol. Thrips are best collected in an alcohol- glycerin-acetic acid (AGA).

15.7.1 Time duration for preservation

In some cases we have to preserve insects or their developmental stages for a short time or temporarily. Larvae and most soft-bodied adult insects can be kept almostindefinitely in liquid preservatives; however, fora permanent collection, mites, aphids, thrips,whiteflies, fleas, and lice usually are mounted onmicroscope slides. Larvae are usually keptpermanentlyin alcohol, butsome may bemounted bythe freeze-dryingtechnique or byinflation. Manyinsects collected in alcohol are later pinned for placement in a permanent collection. Hardbodied insects such as beetles can be pinned directly after removal from alcohol, but for them and all softer insects such as flies and wasps special procedures must be followed

15.7.2 Temporary Storage of Specimens

After specimens have been collected, there are several ways to keep them in good condition until they can be prepared properly. The method used depends largely on the length of time that the specimens may have to be stored temporarily.

15.7.3 Refrigeration and Freezing.

This methodis for cryopreservationof insects.In this method mediumto large specimens may be left intightly closed bottles for several days in a refrigerator and still remain in good condition for pinning as will smaller specimens if left overnight. Some moisture must be present in the containers so that the specimens do not become "freeze-dried," but if there is too much moisture, it will condense on the inside of the bottle as soon as it becomes chilled. Absorbent paper placed between the jar and the insects will keep them dry. When specimens are removed for further treatment, place them immediately on absorbent paper to prevent moisture from condensing on them.

15.7.4 Alcohol

Insects may be placed in alcohol and can be preserved safely for several years before they are pinned or otherwise treated. However, it has been shown that many insects, especially small ones, can deteriorate in alcohol stored at room temperature. Long term storage of specimens that suffer from this kind of deterioration can be lessened by storing the containers in a freezer. Even though the alcohol will not freeze at the temperatures obtained by most ordinary freezers, the lower temperature seems to slow or stop deterioration of the specimens.

15.7.5 Dry Preservation

It is the most common and a standard practice to place different insects in small boxes, paper tubes, triangles, or envelopes for an indefinite period, allowing them to become dry but this method is not suitable for soft-bodied insects. Almost any kind of container may be used for dry storage; however, tightly closed, impervious containers of metal, glass, or plastic should be avoided because mold may develop on specimens if even a small amount of moisture is entrapped. Nothing can be done to restore a mouldy specimen.

Alwayslabel specimens with complete collection data in or on each container. Organization is the key! Label should contained the following information:

1. Locality,
2. Date,
3. Collector,
4. Other data.

15.7.6 Papering or Storage Method

Although pinning specimens when they are fresh is preferable, the storage method known as paperinghas long been used successfully for larger specimens of Lepidoptera, Trichoptera, Neuroptera, Odonata, and some other groups. Papering consists of placing specimens with the wings folded together dorsally (upper sides together) in folded triangles or in small rectangular envelopes of glassine paper, which are the translucent envelopes. It is a traditional way of storing unmounted butterflies, moths, In case of less space odonata members can be kept permanently in clear plastic envelopes instead of pinning them.

15.7.7 Preservation for Molecular Studies

Nowadays taxonomists are increasingly using molecular methods to study insects like DNA bar coding etc. Some of these techniques, such as the study of cuticular hydrocarbons, can be used on dried insects, even those stored in museum collections. the specimens should be kept in such a way that their DNA or other molecules are preserved. In general, specimens for molecular work should be collected in 95% or absolute (100%) ethanol (ethyl alcohol). It is best if specimens are thoroughly dehydrated by changing the alcohol at least a couple of time before the specimens are stored for any length of time. It is also advisable to keep

specimens cold or frozen if possible.

15.8 Different Methods for Collection of Different Orders Insects

Some preferred methods for collection of following insects with their common names are:

- **Alderflies**: larvae: aquatic net, adults: aerial net
- **Antlions and Lacewings**: larvae: sieving, adults: aerial net, light trap, rearing
- **Ants**: hand collecting
- **Aphids**: yellow-pan trap, hand collecting, suction trap
- **Aquatic bugs**: aquatic net
- **Bedbugs:** hand collecting
- **Beetles (aquatic)**: aquatic net
- **Bees**: malaise trap, aerial net
- **Beetles**: most methods, especially pitfall trap, light trap, beating sheet
- **Booklice**: hand collecting, rearing
- **Bristletails**: Berlese (Tullgren) funnel
- **Bugs**: sweep net, beating sheet
- **Butterflies**: larvae: hand collecting, beating sheet, adults: aerial net, rearing
- **Caddisflies**: larvae: aquatic net, hand collecting, adults: aerial net
- **Cockroaches**: pitfall trap, light trap
- **Crickets**: light trap, sweep net
- **Dragonflies and Damselflies**: nymphs: aquatic net, adults: aerial net, rearing
- **Earwigs**: baits and refuges, hand collecting
- **Fishmoths**: hand collecting, Berlese (Tullgren) funnel
- **Fleas**: baits and refuges, hand collecting
- **Flies**: most methods, especially aerial net, sweep net, rearing, malaise trap

- **Grasshoppers and Locusts**: light trap, sweeping
- **Lice**: baits and refuges, hand collecting
- **Mayflies**: nymphs: aquatic net, adults: light trap, aerial net
- **Mealybugs**: hand collecting
- **Moths**: larvae: hand collecting, beating sheet, adults: light trap, rearing
- **Parasitic wasps**: sweep net, suction trap, rearing
- **Praying mantids**: light trap, hand collecting, aerial net
- **Scale insects**: hand collecting
- **Scorpionflies**: aerial net
- **Stick insects**: sweep net, beating sheet
- **Stoneflies**: nymphs: aquatic net, adults: sweep net, hand collecting, beating sheet, light trap
- **Termites**: hand collecting
- **Thrips**: beating sheet, sweep net, Berlese (Tullgren) funnel, sticky trap
- **Wasps**: aerial net, malaise trap

15.9 Different Methods for Preservation of Different Orders Insects

- **Collembola (springtails):** to be preserved into 95% ethyl alcohol or isopropyl alcohol. Specimens can also be mounted on microslides with with water-miscible mountants such as Hoyer's or with Heinz (PVA) mounting medium if permanent storage is not required.
- **Diplura:** to be preserved into 75% ethyl alcohol or isopropyl alcohol or mounted on microslides with Hoyer's or other water-miscible mountants or with Heinz (PVA) if permanent storage is not essential.
- **Protura:** to be preserved into 80% ethyl alcohol or isopropyl alcohol or mounted on microslides with Hoyer's or other water-miscible mountant.
- **Archaeognatha (bristletails):** to be preserved into 80% ethyl alcohol or isopropyl alcohol.

- **Thysanura (silverfish):** to be preserved into 80% ethyl alcohol or isopropyl alcohol.
- **Ephemeroptera (mayflies):** preserve nymphs in 80% ethyl alcohol or isopropyl alcohol with about 5% glycerol. Adults can be preserved pinned through the centre of the thorax with the wings spread.
- **Odonata (dragonflies, damselflies):** preserve nymphs in 80% ethyl alcohol or isopropyl alcohol. Adults can be preserved pinned through the centre of the thorax with the wings spread and front of forewings set at right angles to the body.
- **Plecoptera (stoneflies):** preserve nymphs in 80% ethyl alcohol or isopropyl alcohol. Adults can be preserved pinned through the centre of the thorax with the wings spread.
- **Blattodea (cockroaches):** preserve pinned through the centre of the thorax. The wings on the left side may be spread if desired. Large specimens may need to be gutted.
- **Isoptera (termites):**preserve nymphs in 80% ethyl alcohol or isopropyl alcohol. Make sure to collect a series of castes especially soldiers and winged adults as identification is determined by these individuals.
- **Mantodea (praying mantids):** preserve adults pinned between base of wings, open the fore tibia and femur to about right angles and spread the left hand wings. Nymphs preferably reared through to maturity.
- **Dermaptera (earwigs):** to be preserved in 75% ethyl alcohol or isopropyl alcohol.
- **Orthoptera (grasshoppers, crickets, katydids):** preserve adults pinned through the right side of the thorax with the left hand wings spread. Large specimens may need to be gutted. Nymphs and very soft bodied individuals should be preserved in 75% ethyl alcohol or isopropyl alcohol.
- **Phasmatodea (stick insects):** gut larger specimens and preserve pinned through the base of the mesothorax and bases of the mesothoracic legs.

Spread left wings and fold the antennae back along the body. Ideally nymphs should be reared through to maturity.

- **Embioptera (web-spinners):** to be preserved in 75% ethyl alcohol or isopropyl alcohol or mounted on slides with resin based mountants such as Euparal. Winged adults can be pinned through the centre of the thorax with the wings spread.
- **Psocoptera (booklice):** to be preserved in 80% ethyl alcohol or isopropyl alcohol. May be mounted on slides with a resin based mountant as required.
- **Phthiraptera (lice):** to be preserved in 80% ethyl alcohol or isopropyl alcohol or mounted onto slides with a resin based mountant.
- **Hemiptera (bugs, aphids, scale):** due to the variety of Hemipteran types the preservation techniques vary between groups. Most can be preserved into 75-80% ethyl alcohol or isopropyl alcohol. Larger adults can be pinned just right of the centre of the thorax, while smaller species can be placed on points. Spread wings of some pinned species such as cicadas and hoppers. Other soft bodied species including scale, mealybugs or aphids can be mounted onto slides with resin based mountants.
- **Thysanoptera (thrips):** to be preserved mounted onto slides with a resin based mountant, spreading the legs, wings and straightening the antennae.
- **Megaloptera (alderflies, dobsonflies):** to be preserved in 80% ethyl alcohol or isopropyl alcohol. Some species may be preserved dry and pinned through the centre of the thorax with the wings spread.
- **Neuroptera (antlions, lacewings):** smaller species to be preserved in 80% ethyl alcohol or isopropyl alcohol. Others pinned through the right side of the thorax with the wings spread making sure the body is well supported.
- **Coleoptera (beetles, weevils):** larvae to be fixed in KAA or hot water and then preserved in 80% ethyl alcohol or isopropyl alcohol. Adults should be pinned through the right side of the elytra towards the front, small species on points. Large numbers of adults can be stored dry with tissues in tubes.

- **Strepsiptera (stylopids):** to be preserved in 80% ethyl alcohol or isopropyl alcohol or mounted on slides with a resin based mountant. Winged males can be pinned or placed on points.
- **Mecoptera (scorpion-flies):** adults should be pinned through the right of the thorax with wings spread. Care should be taken to fold legs so they do not break off. Larvae and pupae can be fixed in KAA and preserved in 80% ethyl alcohol or isopropyl alcohol.
- **Siphonaptera (fleas):** to be preserved in 80% ethyl alcohol or isopropyl alcohol or mounted on slides using a resin based mountant.
- **Diptera (flies, mosquitoes):** larger adults can be pinned through the right side of the thorax while smaller specimens pinned onto stages or cube mounts. Larvae and small specimens preserved in 70% ethyl alcohol or isopropyl alcohol while some species can be mounted on slides.
- **Trichoptera (caddisflies):** to be preserved in 80% ethyl alcohol or isopropyl alcohol or pinned through the right side of the thorax with the wings spread.
- **Lepidoptera (moths, butterflies):** fix large larvae in KAA and then preserve in 95% ethyl alcohol or isopropyl alcohol. Smaller larvae can be fixed in hot water then into 95% ethyl alcohol or isopropyl alcohol. Adults should be preserved pinned through the thorax with the wings spread, never store adults in alcohol.
- **Hymenoptera (ants, bees, wasps):** preserve adults in 80% ethyl alcohol or isopropyl alcohol or pin through the right side of the thorax with smaller specimens on points. Some species may need to be pinned obliquely to miss the forelegs. Ants are always mounted on points, never pinned. Preserve larvae and pupae in 80% ethyl alcohol or isopropyl alcohol.

15.9.1 Mounting

1. Mounting large insects

Insects having length more than 8 mm are usually mounted on pins pushed through the thorax. Entomological pins are longer than ordinary pins, and are made of stainless steel or nickel coated which prevent them from rust. Entomological pins of

No. 2 or No. 3 is commonly used for most insects but for delicate insects entomological pins of No. 0 or No. 1 are used. After pinning insects should be left to dry in a ventilated drying cabinet or cupboard for about a week. Insects left to dry in the open may eaten by ants or cockroaches, so take care to protect them by keeping various insect repellents near pinned insects.

2. Entomological Pins

Entomological pins or Continental pinsare used internationally by museums and collectors. They are made of stainless steel for preference, especially for very long-term storage of specimens, but blackened steel also is used. The pins have round plastic or solid metal heads. Continental pins are of a standard length (40mm), but they are available in thicknesses numbered 000 (the thinnest), 00, 0, 1, 2, 3, 4, 5, and 6 (the thickest). This standard pin length is sufficient to accommodate an adequate number of data labels and to permit convenient handling with suitably curved forceps.As an exception to this standard, there also are pins of size 7, extra-long and very strong pins for very large beetles; they are 52mm long and thicker than size 6 pins.

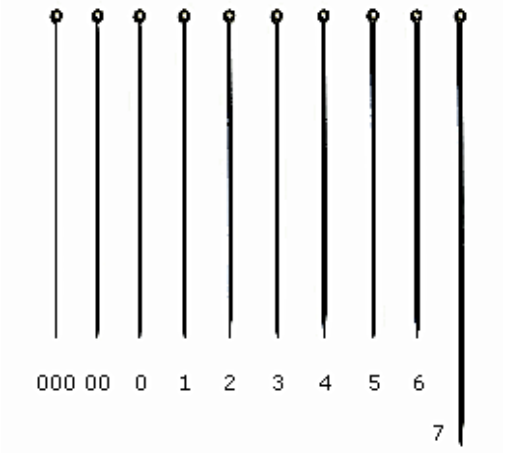

Figure – Entomological pins of different numbers

3. Pinning and different pinning positions of Insects

- Prepare a mounting board made of polystyrene covered with paper or expanded polyethylene, at least 30 mm thick.
- Push the pin vertically through the thorax, avoiding the legs as the point of

the pin emerges on the underside of the body.

- The pinning position is specific in eight different orders as shown in figure.
- Wooden pinning block is used to pin the insect for proper adjusting the specimen on the pin at a height which leaves the top 8-10 mm of the pin projecting above the insect, to facilitate handling.
- Push the pin with the insect into the mounting board until the underside of the body rests on the board. Spread properly the legs and antennae close to the body and secure them in their positions with bracing pins. Most insects are pinned with their wings folded (e.g. bugs, cockroaches, bees, wasps and beetles).
- Fix a label with proper information with the insect.
- Remove the supportive all pins or bracing pins when the specimen is completely dried.

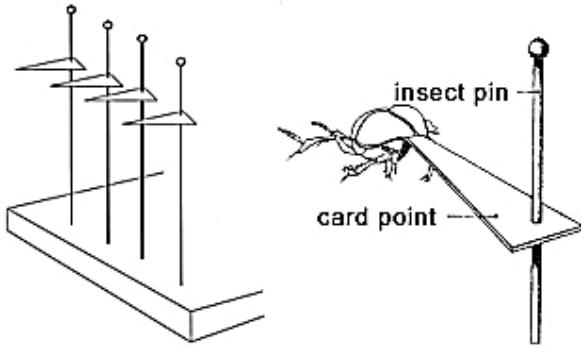

Figure -Entomological Pins with Insects

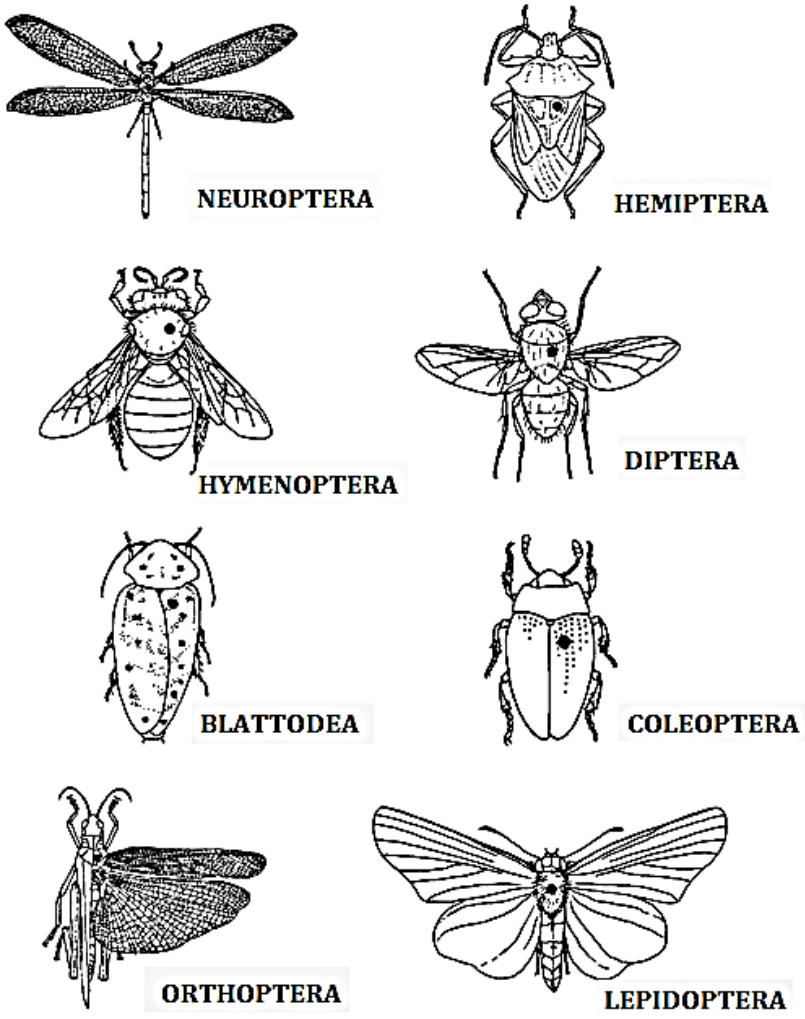

Figure- Pinning positions of insects belonging to different orders

15.9.2 Spreading (Setting)

- For taxonomic significance wings of the insects play a very important role. The wings of particular insects must be spread properly, because the wing venation or wing pattern is important for identification. These insects require special setting boards. Moths, butterflies, lacewings, antlions and dragonflies are conventionally set with both pairs of wings spread, whereas grasshoppers, cockroaches, mantids, stick insects and occasionally bees, are set with only one pair of wings extended.
- Make a simple setting board by glueing a sheet of thick polystyrene to the smooth side of a masonite board. Cut a groove down the middle, as wide and deep as the body of the insect to be set . Cover the upper surface of the

polystyrene with ruled paper to facilitate alignment of the wings. The wings of moths and butterflies tend to sag, even after the insect has dried completely, so angled setting boards are used for Lepidoptera. Setting boards can also be purchased from commercial entomological dealers.

- Pin the insect through the thorax, and insert the pin into the middle of the groove in the setting board so that the wings are level with the board. Brace the body if necessary by placing a pin on either side of the base of the abdomen. Lepidoptera are mounted with their legs folded under the body, whereas in other groups (e.g. lacewings, antlions, dragonflies and damselflies) the legs are displayed next to the wings.
- Carefully arrange the wings by moving them with a fine pair of forceps or insect pins hooked behind the veins. Hold the wings in position with strips of plastic, paper or cellophane and secure these with pins inserted alongside the outer wing margins. The wings of moths and butterflies are set with the rear margin of the forewing at right angles to the body. In grasshoppers, dragonflies, lacewings and most other insects, the front margins of the hind wings should be at right angles to the body, with the forewings set forward and clear of the hind wings.
- Support the insect's abdomen with a wad of cotton wool or pairs of crossed pins to prevent it from sagging.
- Keep aninformative data label next to the specimen.
- Remove the bracing pins when the specimen is dry

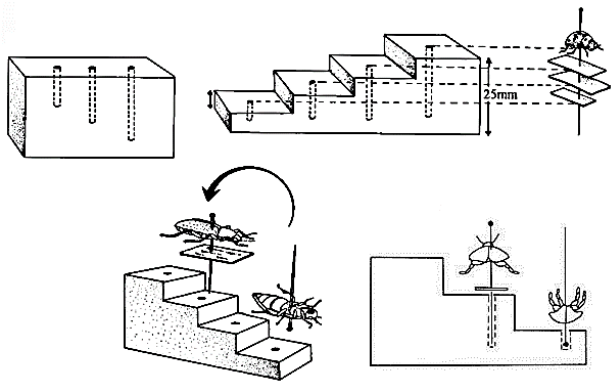

Figure – Pinning Blocks

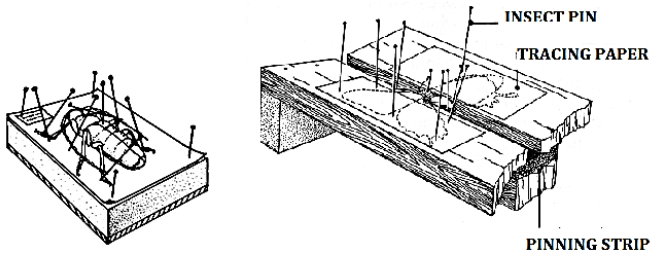

Figure - Insect spreaded with brace pins on mounting board

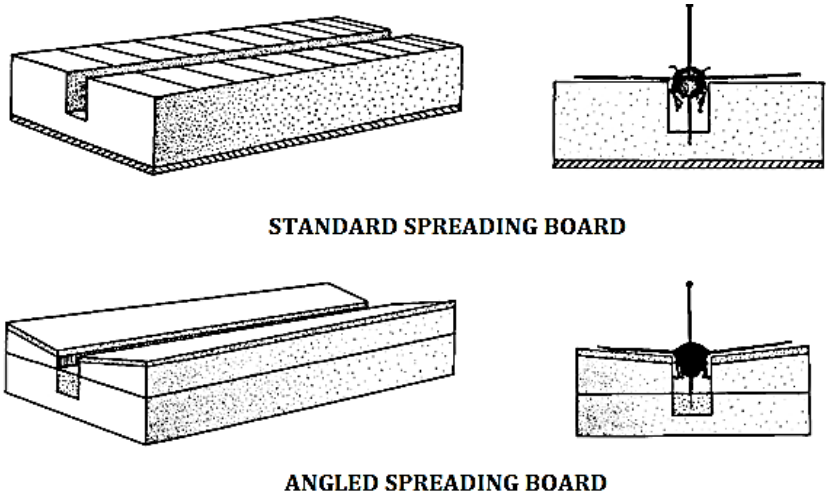

Figure – Different types of Spreading Boards

Some examples of spreading:

1. Mounting of Butterfly

Although there are many techniques to mount butterflies and moths, there is a description of the one most preferred method.

- **Collecting, Killing and Storing Specimens**

  After netting a butterfly in an aerial net, the best way to kill it is by pinching its thorax (middle body segment) between our thumb and forefinger. This technique takes some practice to learn the proper pressure, but it will stun the specimen immediately and prevent it from damaging itself. The stunned specimen can then be slid into an envelope or a paper triangle, with its wings over its back. Butterfly specimens can be kept in this condition indefinitely in a box with moth balls or other insecticide to protect specimens from damaging dermestid beetle larvae and book lice, until they are "relaxed" for mounting. In other method

freshly papered specimens can be kept in a plastic bag in a freezer until they are mounted.

- **Relaxing Dried Specimens**

  After insects are dead, they become extremely brittle. However, dried specimens can always be relaxed and mounted in any desired position. The only potential drawback is mold. Relaxing jars can be made from jars, plastic boxes, or any other airtight containers. These containers are partially filled with sand or paper towels and then water is added to make conditions in the box very humid. The only other concern before adding dried specimens is adding a substance to prohibit the growth of mold on the specimen. The ideal fungicide is chlorocresol can be added The time required to relax a specimen will vary and depend upon the specimen's size, the level of humidity in the relaxing jar, and the storage temperature. Don't be impatient. However, if any mold begins to form, remove the infested specimen immediately.

- **Pinning the Specimen**

  After relaxing the specimen, remove it from its envelope carefully using forceps . Holding the specimen by the thorax, force an insect pin through the middle of the body between the wings. The wings may be forced backwards in order to insert the pin far enough through the body. After the pin is through the body, it is often helpful to force the wings down briefly with forceps. This step makes the specimen easier to manipulate once it is on the mounting board. Next pin the specimen onto the mounting board being certain to keep the side of the butterfly, where the wings are hinged to the body, just above the surface of the mounting board.

- **Mounting the Wings, Body and Antennae**

  When the specimen has been properly placed on the mounting board, wings can be folded down using strips of paper and pins. Avoid touching the wing surfaces with your fingers which would rub off scales. Once both pairs of wings are pinned down, move the front wings forward individually or both at the same time to avoid twisting the body around the pin. Be certain to only insert pins into the wings behind larger veins to prevent ripping the wings. Move the front wings forward

far enough so that their hind margins form a nearly straight line. Move the hind wings forward underneath the front wings enough to match patterns, but not so far as to obscure color patterns. Next, pay attention to antennae and the abdomen, pinning them in their proper positions. Check the overall position of the specimen and make any adjustments necessary before placing wider strips of paper over the wings to keep them from curling up during the drying period. Drying time will depend upon specimen size, temperature and humidity. Drying can be sped up by placing the specimen underneath a lamp. After the specimen is dry, carefully remove the pins and discard the paper strips. Reusing these strips may result in the loss of scales from the wing surfaces.

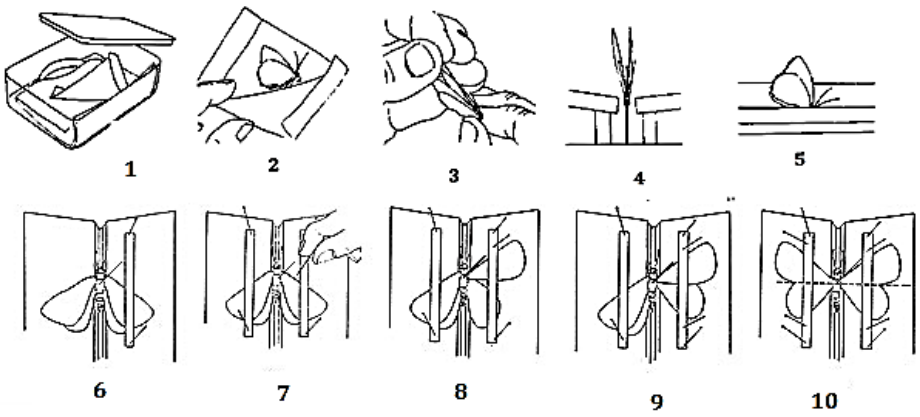

Figure – Butterfly Mounting and Spreading technique

- **Mounting small insects**

  It is a very tough job to mount small insects. Insects that are too small for mounting are mount directly on standard pins are double-mounted on card points, card platforms, minute pins or in gelatine capsules. They can also be glued to a pin. Each card point is set at a consistent height on a pin, using a pinning block.

2. Mounting of Leaf hopper

1. Under a dissection microscope, position the insect, ventral side up, on the edge of a small block.
2. Carefully spread the legs, using forceps or fine needles, so that the

mouthparts and genitalia are not obscured.

3. Place a small drop of glue on the tip of a card point mounted on an insect pin. Use only enough glue to attach the insect to the point. Clear-drying, non water-soluble project or wood glue is most suitable. For slightly larger insects, bend the point of the card downwards before applying the glue, to make a bigger adhesive area.
4. Press the drop of glue on the card point tip against the right side of theinsect's thorax

3. Mounting of beetles

- After relaxing an insect, loosen its legs, antennae, and other moveable parts by gently wiggling them and then stretching them out. Use a toothpick, wooden probe, or teasing needle.
- Insert an insect pin through the middle of the thorax, slightly of-center to the right.
- Push the pin all the way through the insect's body, then about ½" into the spreading board or another piece of Styrofoam board.
- The insect should typically be about half way up the pin or far enough above the spreading board so we can freely position the legs.
- Carefully move the legs and antennae into the positions desired using a probe or forceps. This takes some patience. It may take several attempts before we are able to get a leg or antennae into the position we want.
- For support and shaping cross two pins over each other to hold each section of the limb in place to dry. It is easiest to first position a foot where you want it and pin it in place. Then we can move up the leg to position and pin each additional leg section using two more crossed pins.
- Now allow the insects to dry for 1-2 days, or until the legs stay in position when the pins are removed.
- Now finally we have to remove all pins except for the one through the insect's thorax very carefully. This requires great care as the insect is now very brittle and fragile again. Removing a pin by pulling the wrong direction can break a leg or antennae.

- Transfer the insect to the display case. Use the pin through the thorax to pin the insect into the display case. On larger, heavier insects you may want to use additional pins to keep the insect's body from pivoting.

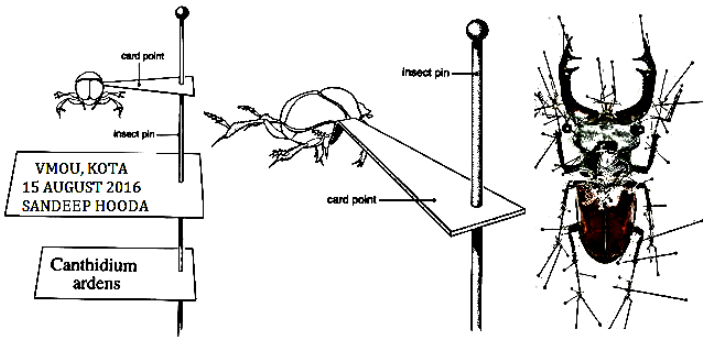

Figure – Mounting and Pinning of Beetles

4. Card platforms

Small insects, particularly certain beetles and parasitic wasps (but not bugs ormoths) are suitable for mounting on card platforms measuring 5- 10 mm. These may be purchased from a supplier or cut to size from good quality drawing card or Bristol board. A standard insect pin is pushed through one end of the platform. This mounting method is explained below, using a beetle as an example.

- Under a dissecting microscope, pin the card platform to the surface of a block of polystyrene or 'EPX'.
- Place the insect upside down in front of the card and spread the legs and antennae.
- Turn the specimen over with forceps or a fine, damp paintbrush, and place it on a small drop of water-soluble glue on the card platform, with its head facing away from the pin.
- When the glue starts to dry, arrange the legs and antennae neatly around the body.
- Position the platform with the mounted specimen on the pin using a pinning block.
- Small beetles which are difficult to mount, or are likely to be damaged easily, can be glued on their right sides to card platforms. Minute wasps

are glued on their right sides with the lower set of wings spread out on the card platform

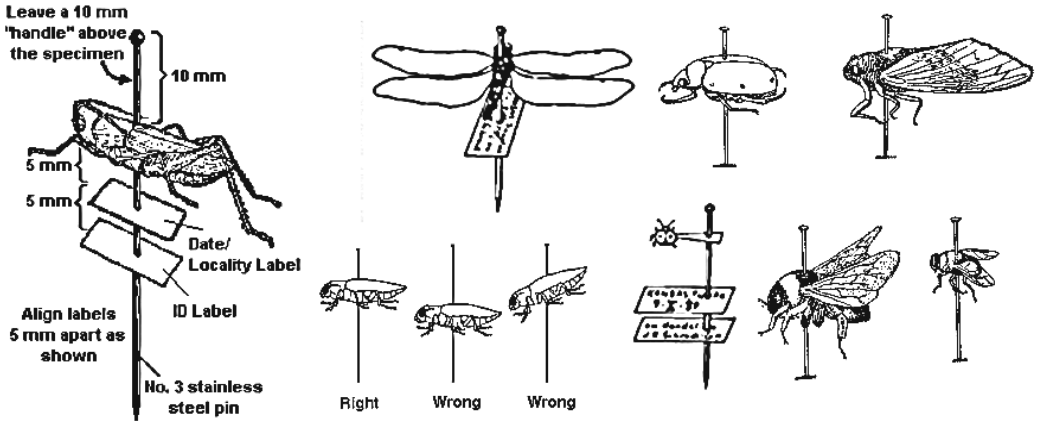

Figure – Pinning of Insects

5. Minuten pins

- These are used for very small moths and other small insects, such as flies and bugs (e.g. jumping plant lice (Psyllidae)). Stainless steel minuten pins are small, 10-15 mm long, without heads.
- Under a dissecting microscope, pin the specimen through the thorax, onto a mounting board or block of 'EPX'.
- Arrange the legs and antennae with fine forceps and brace them with minuten pins. Secure the body of small moths by bracing the abdomen on either side with minuten pins .
- Position and brace the wings and antennae with minuten pins.
- Remove the bracing pins when the specimen is dry.
- Push a large insect pin (size No. 3) through the end of a strip of cork or *Polyporus,* measuring 10-15 mm. Moulded sheets of commercially available silicone rubber, cut into small blocks (3 mm), can also be used for very small insects.
- Using fine forceps, remove the minuten pin with the specimen from the mounting board and push it into the other end of the strip

- Very delicate specimens can be mounted on minuten pins set horizontally into a short strip of *Polyporus,* inside a gelatine capsule.

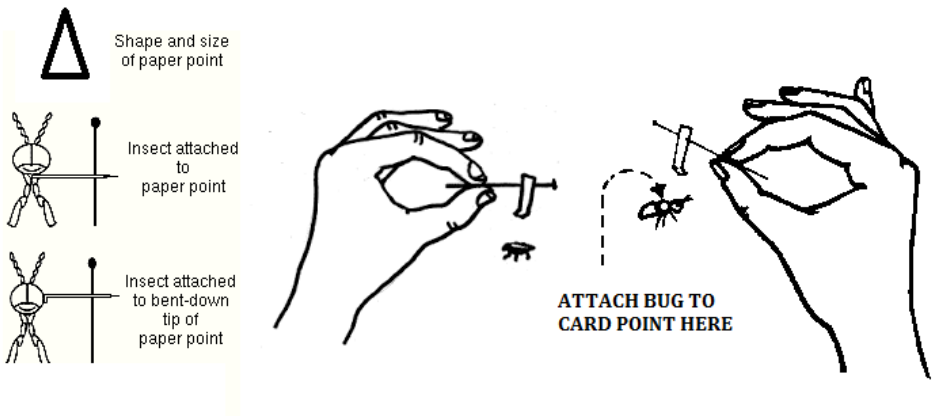

Figure – Pinning of small Insects

15.10 Labelling

Insects that are collected for scientific or research studies must always be labelled. The correct labelling of specimens cannot be overemphasised. Specimens without labels are of no scientific value, while incorrect information on labels can lead to misinterpretation of results, often with serious consequences. Therefore great care should be taken to ensure that all specimens are labelled correctly. All available information pertaining to a specimen should be recorded on a label attached to the specimen. Specimens that are being processed should also be labelled, so that collecting data do not get lost.

15.10.1 LabellingFormat

As per scientific rules an unlabelled specimen is unacceptable, therefore specimen should be well labelled as per norms. The labels should not be larger than 6x16 mm. Labels should be written in pencil, or printed. The standard format for label for every specimen is with the following information:

1st line – Specimen number and order

2nd line - Place of collection (country, state and county)

3rd line - Place of collection (nearest post office)

4th line - Date collected

5th line - Name of collector

Use second level of the pinning block to set this label.

Other additional information can be given if it is required:

1 The name of the host plant or animal.

2 The type of habitat in which the specimen was collected if host information is not available.

3 Any information noted on the habits of the insect, such as flying at dusk, or feeding at host flower.

An identification (ID) register indicating family or order names should be produced separately and printed/handed in as a collection notebook. The identification register should list the specimen number followed by the order, family and the ecological category any representative belongs into. All supplemental materials also need to be included.

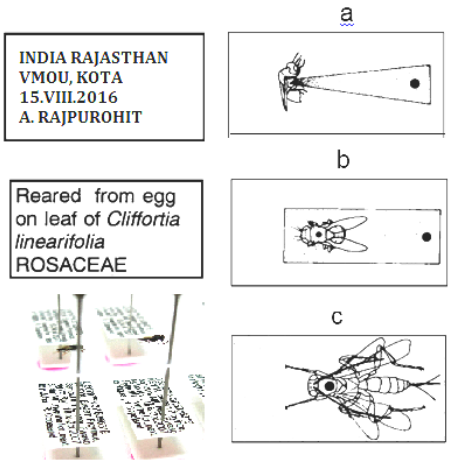

Figure - Position of pin through label, (a & b) double-mounted specimens; (c) single-mounted specimen

15.11 Permanent Storage And Curation

Entomological collections are of huge value as records of biodiversity, and as a scientific resources for taxonomic and applied research. Now the next step is to keep them preserve for a long time safely.

15.12 Types of Collections

15.12.1 Dry collections

Collected pinned specimens are usually stored in wooden glass-topped drawers slotting into special wooden or steel cabinets. The drawers have tight-fitting lids to keep out museum pests, dust and moisture. The drawer bottoms are lined with a soft substrate into which the pins are inserted. This substrate is traditionally cork, but modern plastic products such as expanded polyethylene ('EPX', 'DEP') are generally more suitable. The drawer may be lined with a single sheet of substrate. However, a system of interchangeable unit trays made of cardboard or plastic, and lined with pinning substrate will facilitate rearrangement of the collection.

In colleges or schools wooden boxes are a simpler way of storing pinned insects.The inside of both sides is lined with a layer of 'EPX' or similar pinning substrate, and the specimens are pinned onto both surfaces. The box must be deep enough to accommodate standard insect pins on both sides without them touching, and must close tightly to prevent insect pests from entering. Such boxes are stored in an upright position on shelves

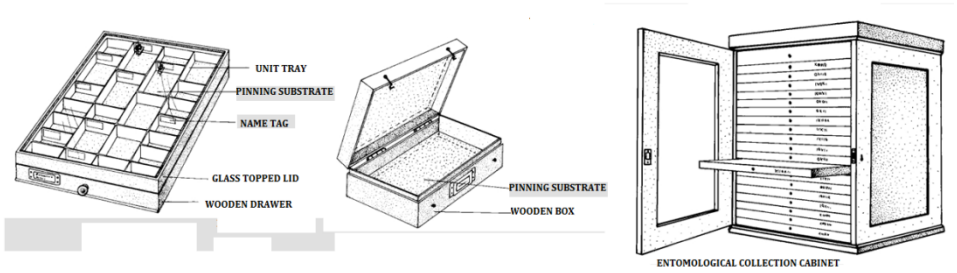

Figure – Entomological storage equipments

15.12.2 Wet collections

These are mostly collections of specimens stored in ethanol, or other preserving fluid, in glass vials with tight-fitting stoppers. Ideally, the vials should be of uniform size, and are best stored upright in single rows in specially made racks. These racks are stored on shelves in cabinets. Honey jars are also convenient containers for preserving specimens in liquid

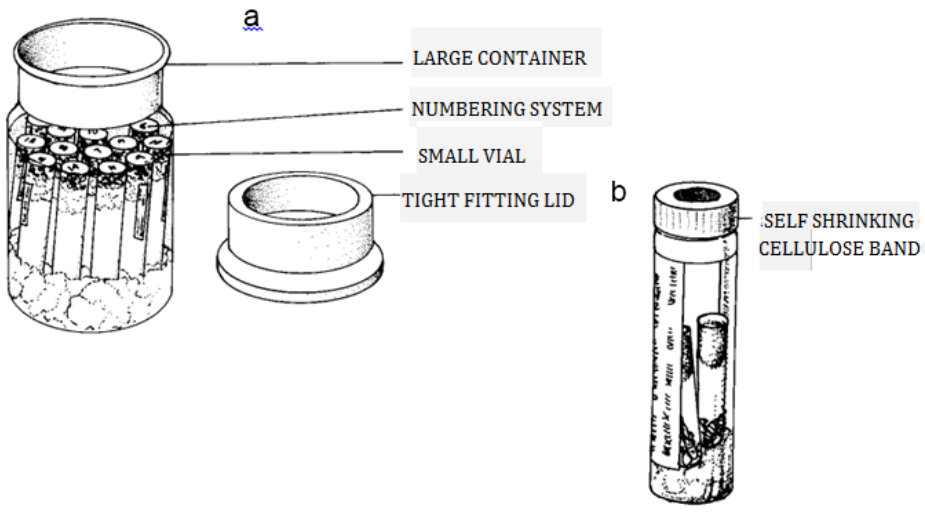

Figure - (a) insects stored in liquid in glass vials (b) containersealed with celluloseband

15.12.3 Slide mount collections

Permanent slide mounts of insects usually are stored in slide boxes. These have grooves to hold the slides.They are stored on shelves in an upright position, so that the slides inside lie horizontally, with the side containing the specimen facing upwards. Alternatively, cabinets made specifically for this purpose can be used. These cabinets, which occupy relatively little space, consist of trays that hold the slides horizontally. Small collections can be stored in flat cardboard trays, with flap-over lids

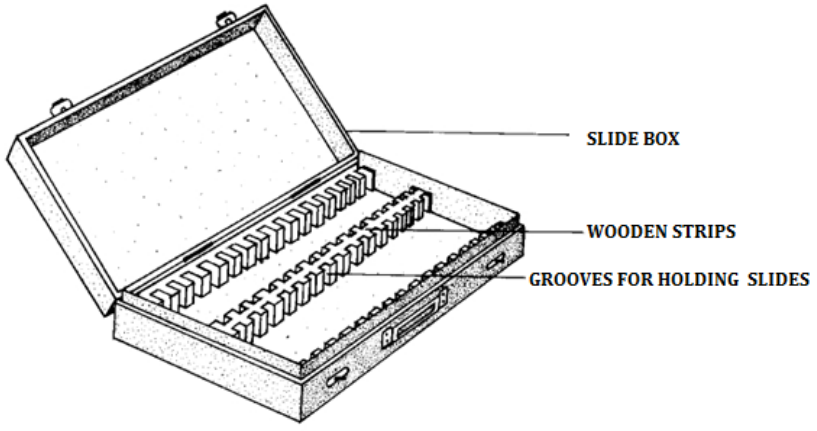

Figure- Slide box for entomological mounts slides

15.13 Curating a Collection

After Insect collections it is very important to store them in a safe place protected against fire, pests, fungus, moisture etc other hazards, and should be inspected on a regular basis for any sign of damage.

15.13.1 Arrangement of a collection

Identified specimens of the same species are usually placed together in the same drawer, row or unit tray. A larger label with the name of the species is placed inside the drawer or unit tray, or ahead of the row containing all the specimens of the particular species. This allows easy reference to the species. Alcohol collections are usually arranged within genera or even families and then numbered, allowing easy retrieval when linked to an accession system. Specimens may also be arranged according to localities or host plants, making such information easy to access. A correct species identification is the key to any information pertaining to an organism and is essential for a meaningful comparison of research results. One can go a long way in identifying specimens oneself to family, and even genus level in some groups, by consulting available publications and books. As insecta is such a large groups, more often than not one will need to consult a specialist in order to obtain an accurate genus and species identification. In some of the lesser-known groups, even an identification to family level may require the input of a specialist. Zoological Survey of India, other national and international museums and other institutions can be referred for identifications.

15.13.2 Preventing insect damage

After hard efforts of insect collection and spreading the next challenge for an entomologist is to prevent this valuable museum insect specimens from various insects, fungus, moisture etc. many factors for a long time. A number of insectslike booklice,museum beetles and certain moths, feed on dried insects. For this insect boxes and drawers should be covered with tight-fitting lids and sealed. Insect repellents like dichlorobenzene, naphthalene, or insecticides such as dichlorphos,these chemicals must be replaced in the boxes or drawers periodically.Fumigation can be done to prevent infestation from time to time. Proper observation of all insect boxes should be done at least twice or thrice in a year for any sign of damage, indicated by a little heap of dust-frass at the base of

the pin, or exuviae of museum beetles. Infested drawers should be fumigated immediately.

15.13.3 Preventing mould

Other problem for insect specimens is fungus infestation. In moist climate or conditions or in the rainy season, in coastal areas with high levels of humidity usually fungus damages the insect collection.Mould causes insect specimens to disintegrate totally, and it is usually impossible to save specimens attacked by mould. Insect drawers may be treated with a fungicide such as phenol, thymol,chlorocresol or ethyl acetate to prevent the development of mould, but these substances are again hazardous to humans and also quite corrosive, attacking the metal of insect pins. Placing a sachet of silica gel crystals in each drawer is a better and safer method. Silica gel is a desiccator that absorbs moisture from the air and discolours when saturated. The crystals can be dried out and used again.

15.13.4 Protection from light

High intense light can causes decolouration of insects and fade their original colours. Therefore valuable specimens should be stored in darkness. Keep insect boxes in closed cabinets, or in tight-fitting drawers.

15.14 Self Learning Exercises

1. What are the different methods for entomological collection?
2. Describe various preservation methods of insects.
3. Explain different types of entomological equipment.
4. How will you spread butterfly on spreading board?
5. Collect any 50 insects from your surroundings or college or university campus or home and identify them with the help of your teacher and preserve and properly arrange them in Insect collection box.
6. How will you collect nocturnal insects?
7. What information you will write on insect pinning label?
8. Write the various precautions during curation of your entomological collection?
9. How can you prepare killing bottles?
10. What is the best time for insect collection?

11. Describe the different types of insect traps.

15.15 References

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Unit-16

Use of Key to Identify Insects

Structure of the Unit

16.0 Objectives

After going through this unit entomology students will be able to understand what is key, its importance in taxonomy, what is the concept of dichotomous keys, Method to use key, How to identify insects with the help of generalized key to common insect orders, Brief description of some common insect orders – Collembola, Thysanura, Ephemeroptera, Odonata, Orthoptera, Phasmatodea, Mantodea, Blattaria, Isoptera, Dermaptera, Plecoptera, Psocoptera, Phthiraptera, Hemiptera, Homoptera, Thysanoptera, Neuroptera, Coleoptera, Mecoptera, Diptera, Siphonaptera, Trichoptera, Lepidoptera, Hymenoptera

16.1 Inroduction

16.1.1 Taxonomic keys

In biological sciences a taxonomic key is a simple, written tool used to determine the taxonomic identification of plants, animals, soils, a specific object etc. A taxonomic key is one of the most useful tools available to academicians, scientists, students, researchers, etc. trying to identify an unknown organism. The main purpose of a key is to facilitate identification or to distinguish one type of organism from another. A key may or may not reflect ideas of evolutionary or phylogenetic relationship. Taxonomists rely on keys to help identify known organisms and determine whether they have discovered a new organism entirely. However, all taxonomic keys are not created equally. They are often created on a regional level or for a particular group of organisms. So it is important to use a key that represents the diversity of the region or group of organisms we are interested in examining.

Recently, there has been considerable research in developing computerized keys that have multiple entries derived from a detailed data base of the taxa. The interactive nature of computerized keys makes them highly desirable and allows users to identify a insect when some characters are missing on a specimen.

16.1.2 Dichotomous keys

Dichotomous keys allow the user to determine the identity of items using a sequence of alternative choices. Dichotomous comes from the Greek root *dich*-, meaning "two" and *temnein*, meaning "to cut". Dichotomous keys always give two, mutually exclusive choices in parallel statements. The pair of statements is referred to as a couplet and each 1/2 of a couplet is a lead. At each couplet of a dichotomous key the user is presented with two choices about a specific character present in the group of organisms, a specific character state is described for each lead. Sometimes the characters are quantitative (measurements) and sometimes the characters are qualitative (texture). A dichotomous or branching key is one in which there are two choices, or leads, at each branching point. The two choices constitute a couplet, which is denoted usually by a number followed by a and b, such as 1a and 1b or 9a and 9b. There may be many couplets in a key, depending on the number of species or taxa included. Each couplet provides characteristics that become progressively more specific until the final step is reached and identification is made. Followed correctly, keys will lead us to the correct name of an unknown organism or object. Dichotomous keys can be developed to identify anything in any sort of classification.

16.1.3 Insects Taxonomic Keys

Insects are small creatures, differentiating among species, families and even orders is usually very difficult. However, examination beneath a hand lens or microscope will allow us to see many of the characters mentioned in the key. Sometimes, we can identify an insect quickly by comparing it to pictures in field guides or on the internet. Pictures are a great tool, but the use of a key is essential to guarantee that our identification is accurate. Because some insects, even ones from separate orders, can look almost exactly alike. For example, many flies (order Diptera) look almost exactly like wasps (order Hymenoptera). Using key, we can find that a fly has 1 pair of wings, whereas wasps have 2 pairs of wings.

During identification the immature insects and adult insects are often very different. This is especially true for holometabolous (complete metamorphosis) insects where the immature stages are larvae and pupae. The key included in this chapter is only useful for keying adult insects to order. There are over 30 insect

orders, some of which we will never encounter. The following key includes only 24 of the more common orders.

16.1.4 Method to use a key-

A key begins at number “1" with a set of paired, numbered statements called a couplet. Each of the two statements in a couplet is lettered with an "a" or a "b". The statements are in contrast with each other. The insect we are looking at should agree with either "a" or "b," but not with both. When we choose the statement that agrees with what our insect looks like, we will be given a different number. This number tells us what couplet we should read next. We then make another choice, and proceed in this way until the name of an insect order appears at the end of the statement we choose. We can then read the section with details on that insect order to check our accuracy in using the key.

For example, to key out a butterfly:

- Start at couplet “1.” Since the butterfly has wings, pick statement “b” and go to couplet number 17.
- From couplet 17; a butterfly has 2 pairs of wings, therefore choose “b” and go to couplet 18.
- From couplet 18; the front and back wings are the same texture, therefore choose “b”, and go to couplet 24.
- From couplet 24; butterflies have scaly wings and coiled tongues, so pick “a”, which tells us the order name, Lepidoptera.

16.1.5 Generalized Key to Common Insect Orders

1 a. Without wings; all of the abdominal segments visible in a top view of the insect……..…2

b. With wings; wings may be difficult to see because they are hidden by hard wing covers (as with beetles). In these cases, the wing covers lie over the back and hide all or parts of the abdomen…….17

2 a. Without legs, eyes, or antennae; living under a waxy or cottony covering and occurring in colonies firmly attached to tree twigs, fruit, or leaves (e.g. scale insects)..... HOMOPTERA

b. Legs, antennae, and (usually) eyes present……..….3

3 a. Abdomen ending in three long, thread-like tails; antennae long ……..THYSANURA

b. Abdomen without long tails; antennae may be long or short.....4

4 a. Antennae are shorter than the head, and not easily seen; body flattened from side-to-side or from top-to-bottom; parasites on animals…….…5

b. Antennae longer than the head, easily seen; not usually parasites…….7

5 a. Body flattened from side-to-side; legs long and able to jump; with siphoning mouthparts…….SIPHONAPTERA

b. Body flattened from top-to-bottom; legs short and not able to jump….6

6 a. Abdomen sac-like and without distinct segments; eyes clearly visible; tarsi 5-segmented; about 1 cm long; sheep parasites.....…DIPTERA

b. Abdominal segments distinct; eyes small or absent; tarsi 1- to 2-segmented; less than 3 millimeters long.....PHTHIRAPTERA

7 a. Body strongly constricted between the thorax and abdomen.....HYMENOPTERA

b. Thorax and abdomen broadly joined…….8

8 a. Body scaly; a coiled tongue sometimes visible; usually found on tree trunk…….LEPIDOPTERA

b. Body not scaly……..9

9 a. With a sucking beak; the beak of some may seem to come from between the front legs…….10

b. Beak absent, chewing mouthparts……..……11

10 a. With 2 tube-like projections near the end of the abdomen; soft-bodied and living in colonies on plants; antennae long; beak arises near the front legs….....HOMOPTERA

b. Without tube-like projections on abdomen; beak arises from front of head.....HEMIPTERA

11 a. Tarsi either 5-segmented or the hind legs adapted for jumping…….12

b. Tarsi with less than 5 segments and the hind legs not adapted for jumping……14

12 a. Hind legs adapted for jumping.....ORTHOPTERA

b. Hind legs not adapted for jumping.....13

13 a. Body flattened from top-to-bottom, head hidden from above by thorax……...BLATTARIA

b. Body stick-like, not flattened; head not hidden by thorax.....PHASMATODEA (PHASMIDA)

14 a. Ant-like appearance, except with soft, white bodies; 4-segmented tarsi; eyeless; antennae resemble a string of round beads; thorax and abdomen are broadly joined.....ISOPTERA

b. Not fitting the description of 14a; eyes usually well-developed.....15

15 a. With a forked tail near the end of the body used for jumping; this tail may be folded under the body.....COLLEMBOLA

b. Without a forked tail……..16

16 a. Oval-shaped and louse-like in appearance; antennae long, thread-like.....PSOCOPTERA

b. Body narrow; found on leaves and flowers.....THYSANOPTERA

17 a. With only one pair of wings, the hind pair reduced to small structures that resemble golf tees (halteres).....….....DIPTERA

b. With two pairs of wings, although the first pair may be hardened and do not function in flight (as with beetles)…….18

18 a. Front wings thicker in texture than hind wings for all or part of area……...19

b. Front and hind wings both of the same texture throughout.....24

19 a. Front wings hard or leathery in texture throughout and almost always meeting in a straight line down the center of the back……..……20

b. Front wings parchment-like or leathery throughout or on the basal half only - they do not meet in a straight line down the center of the back. In the lace bugs (HEMIPTERA), the entire top of the insect resembles lace……21

20 a. Front wings short, leaving much of the abdomen exposed; a pair of pincher-like appendages extend from the end of the abdomen…….DERMAPTERA

b. Front wings usually cover all of the abdomen; never with abdominal appendages.....COLEOPTERA

21 a. With a jointed beak; basal part of the wing thickened and the tip membranous. Antennae with 5 or less segments.....HEMIPTERA

b. With chewing mouthparts; front wings parchment-like throughout; antennae with many segments……..22

22 a. Hind legs adapted for jumping.....ORTHOPTERA

b. Hind legs not adapted for jumping……..……..…23

23 a. Front legs adapted for capturing prey (praying mantises)..MANTODEA

b. Front legs not adapted for prey; body flattened from top-to-bottom; head hidden from above by thorax.....BLATTARIA

24 a. Wings with scales on all or part of their area; siphoning mouthparts in the form of a coiled "tongue"……..LEPIDOPTERA

b. Wings without scales, although they may have hairs……25

25 a. Wings long, narrow, veinless, and all 4 are of equal size and have fringes with long hairs; small insects about 2 mm long; tarsi 1- or 2 segmented……..….....THYSANOPTERA

b. Not fitting the description in 25a……26

26 a. Mouthparts composed of a beak arising far back on the underside of the head near the front legs; wings held roof-like over the body, the hind pair smaller than the front pair.....HOMOPTERA

b. Mouthparts not in the form of a piercing beak, although the front of the head may be prolonged into a long snout; wings not held roof-like over the body; usually the hind pair of wings are about the same size as the front pair OR the abdomen has 2 or 3 long, thread-like tails……..27

27 a. With many cross-veins (more than 15) in each wing…….28

b. With few cross-veins, or the veins are indistinct……32

28 a. Antennae about as long as the head and thorax together, or longer…….30

b. Antennae short and bristle-like, same length as head alone or shorter. Hind wings much smaller than front wings; occasionally, hind wings absent; abdomen ending in 2 or 3 long, thread-like tails.....…….....EPHEMEROPTERA

b. Front and hind wings nearly equal in size; no abdominal tails……...ODONATA

30 a. Abdomen ending with 2 short tails.....PLECOPTERA

b. Abdomen without tails……..31

31 a. Head prolonged into a snout; the tip of the abdomen sometimes resembles a scorpion tail.....MECOPTERA

b. Head not prolonged into a snout.....NEUROPTERA

32 a. All four wings long, narrow, equal-sized, without distinct veins; wings about twice the body length.....ISOPTERA

b. Not fitting the description in 32a……33

33 a. Wings hairy; antennae thread-like and usually as long as or longer than the body; mouthparts indistinct; front and hind wings nearly equal in size.....…….....TRICHOPTERA

b. Wings not hairy; chewing mouthparts present; hind wings noticeably smaller than the front wings……34

34 a. Tarsi 2- or 3-segmented; small insects less than 3mm long. Never constricted between the thorax and the abdomen.....PSOCOPTERA

b. Tarsi 4 or 5 segmented; size variable; most are constricted between the thorax and the abdomen.....HYMENOPTERA

16.2 Brief Description of Common Insect Orders

16.2.1 Collembola: Springtails (*colla* = glue + *embolon* = wedge or peg)

Collembola are tiny, wingless insects with chewing mouthparts and incomplete metamorphosis (hemimetabolous). The antennae are usually conspicuous. The scientific name comes from the fact that on the first abdominal segment there is a short tube (called a "collophore") with which springtails can stick to smooth surfaces. The common name, springtail, refers to the springing structure (furcula) near the tip of the abdomen. Some Collembola can spring several inches, and because of their tiny size seem to disappear when they jump. One species is dark colored, and on warm winter days large numbers of them will come out of hibernation to bask in the sun on the surface of the snow. These are often called "snowfleas". The Collembola are of no economic importance, but they are plentiful and can be found in many kinds of habitats under loose bark, logs, stones, and in damp leaf litter where they feed on decaying organic material.

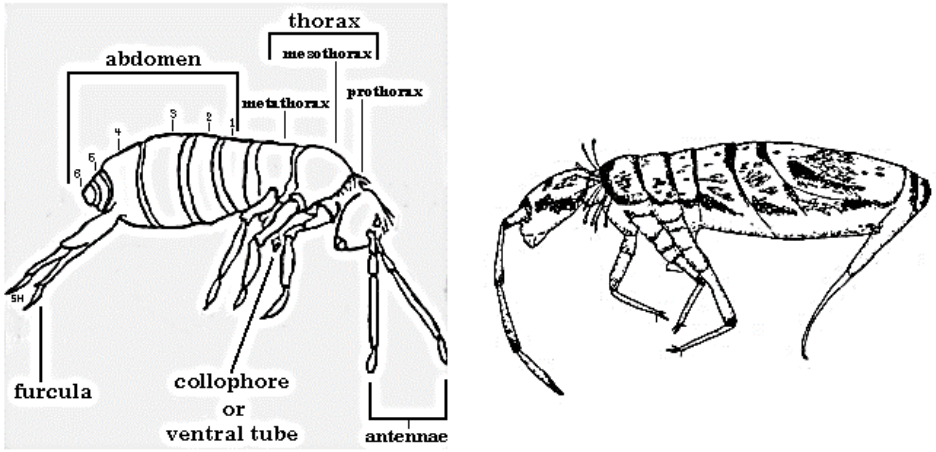


Figure – Collembola members

16.2.2 Thysanura: Silverfish, Firebrats, Bristletails (*thysanos* = tassel + *oura* = tail)

Thysanura are wingless insects with chewing mouthparts, long, thread-like antennae, incomplete metamorphosis, and three thread-like tails at the end of the abdomen. There are also tiny appendages on the underside of the abdomen. In some species the body is covered with scales. Two species, the silverfish and the firebrat, are considered pests. The firebrat prefers warm places, such as in kitchens near ovens. The silverfish is often found in homes. Both species eat starchy materials, such as flour and paste. In bad infestations, silverfish may roughen book

covers and papers on which they chew. Jumping bristletails are found out of doors under rock piles or in forest litter.

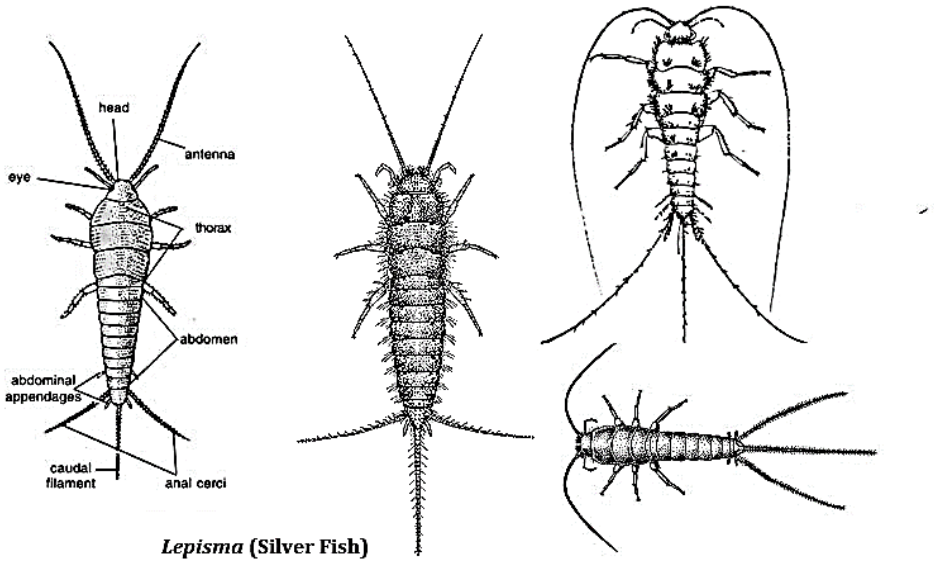


Figure – Thysonura Members

16.2.3 Ephemeroptera: Mayflies (*ephemeros* = living but a day)

Mayflies are small- to medium-sized, soft-bodied insects with incomplete metamorphosis. Mayflies have undeveloped chewing mouthparts, 2 or 3 thread-like abdominal tails, and short, bristle-like antennae. The wings are membranous, with many cross-veins, and the hind pair is much smaller than the front pair. (Note: some small species have only one pair of wings, but most species have two pairs of wings.) Immature mayflies, called “naiads,” are aquatic. Mayflies have an unusual life-cycle: they molt after they grow wings. Most insects stop moulting after they become winged-adults, but mayflies undergo one additional molt. The winged mayfly that emerges from the naiad has hairy wings and is called a "dun," or a “subimago.” After a brief period, the subimago molts to produce the “imago,” which has clear wings. The subimago is not a true adult - only the imago is able to mate. Mayfly adults live only a short time, usually less than one week. The development of the naiad is much longer, taking 1 to 3 years. These insects often emerge in great hordes and can be a nuisance. They cover the sides of buildings,

sidewalks, and streets to the extent that walking and driving are difficult. Despite the nuisance they sometimes cause, mayflies are valuable as food for many fishes.

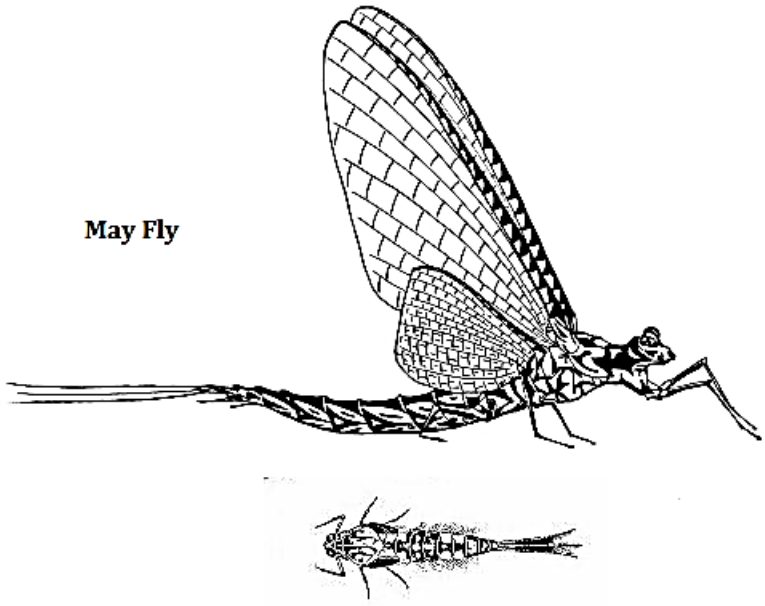


Figure - Ephemeroptera Members

16.2.4 Odonata: Dragonflies and Damselflies (*odontos* = tooth)

Odonata are medium to large-sized insects with bristle-like antennae, chewing mouthparts, and 2 pairs of membranous wings. The front and hind wings are of equal length with many cross-veins. The abdomen is long and narrow. In some dragonflies, the abdomen tapers to a point like a long fang, or tooth (hence the name Odonata). Immature Odonata are underwater predators. They are fully aquatic, complete with gills. There are two main groups of Odonata: the damselflies and the dragonflies. Damselflies are weak fliers and are found along the banks of streams and ponds. Their wings are narrow at the bases. Dragonflies are strong fliers, and often range long distances from water. They can hover and quickly change direction when in full flight. Because Odonata are predaceous on other insects, they are considered beneficial.

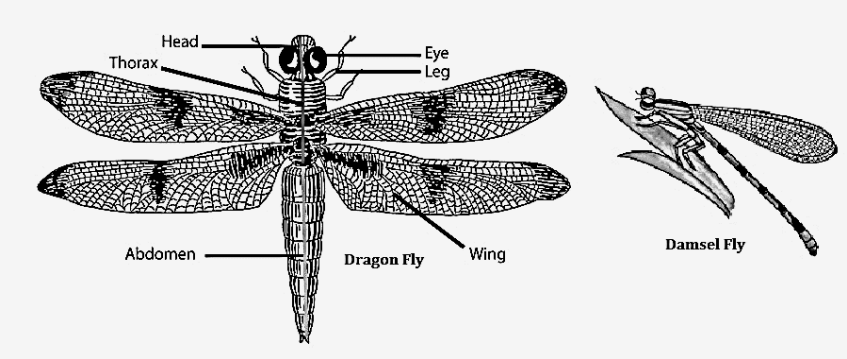


Figure - Odonata Members

16.2.5 Orthoptera: Grasshoppers, Crickets, Katydids (*orthos* = straight+*ptera* =wings)

Orthoptera include crickets, grasshoppers, katydids, and other medium- to large-sized insects with incomplete metamorphosis and jumping legs. Some Orthoptera are wingless, but most have 2 pairs of wings. When there are 2 pairs of wings, the front wings are usually leathery or parchment-like in texture. The hind wings are membranous and folded (like a fan) underneath the front wings. The front wings (called "tegmina") are straight and narrow, which is the basis for the scientific name of this order. The antennae of Orthoptera are long; in many cases, longer than the rest of the body.

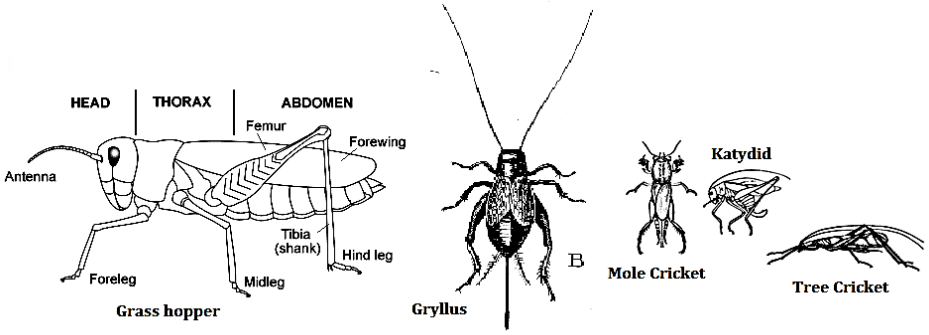


Figure – Orthoptera members

16.2.6 Phasmatodea (Phasmida): Walking Sticks (*phasm* = phantom)

Walking sticks are long, stick-like, wingless insects with chewing mouthparts and incomplete metamorphosis. Walking sticks are herbivores, and are closely related

to mantids, crickets, and grasshoppers, and are included in the order Orthoptera in some insect guides.

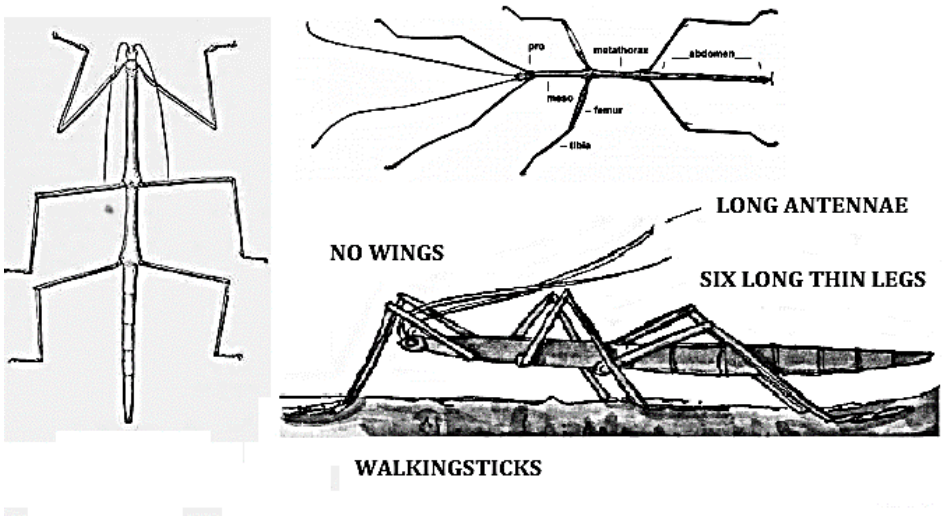


Figure – Phasmida members

16.2.7 Mantodea: Praying mantids (*mantis* = soothsayer)

This order consists of praying mantids are the "mantidflies." Mantidflies are in the Large, "raptorial" front legs make these insects easy to recognize. Praying mantids have 2 pairs of wings, and the front pair is thickened, much like the front pair of grasshopper wings. Mantids have chewing mouthparts, large eyes, and incomplete metamorphosis. The only insects sometimes mistaken order Neuroptera, and resemble small praying mantids. Like all insects in Neuroptera, though, the front wings on a mantidfly are not thickened as with true mantids. Mantids are often found in vegetation, gardens, and similar habitats. They are predators and feed on almost any creature that they can capture. Praying mantids are closely related to walking sticks, crickets, and grasshoppers, and included in the order Orthoptera in some insect guides.

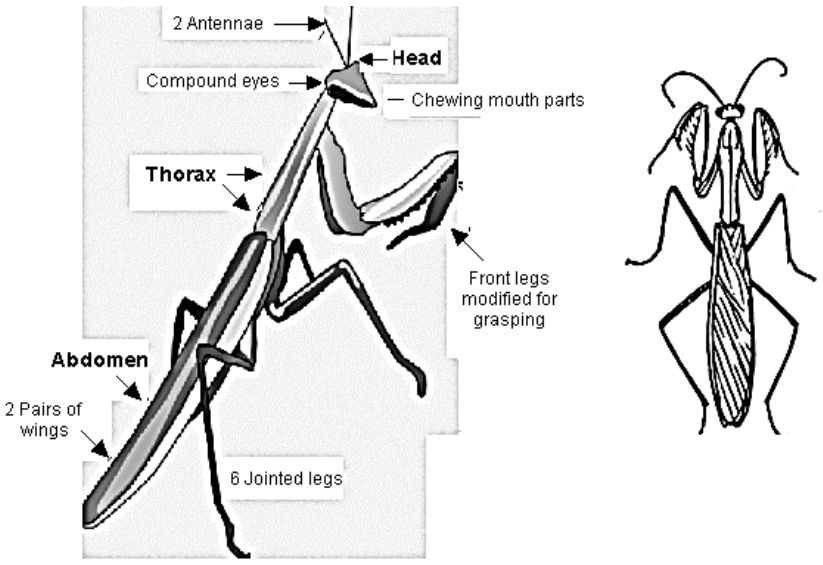


Figure – Mantodea Members

16.2.8 Blattaria: Cockroaches (*blatta* = cockroach)

Cockroaches are flattened insects with 2 pairs of wings, chewing mouthparts, and incomplete metamorphosis. Cockroaches, like crickets and grasshoppers, have thickened front wings called "tegmina." Cockroaches are fast runners, and their flat shape allows them to fit under rocks, logs, and other tight places. They are omnivores, feeding on virtually anything organic. Several species are pests, including German and American cockroaches, which commonly infest buildings. Other species, such as the wood roach, rarely enter homes and are important scavengers.

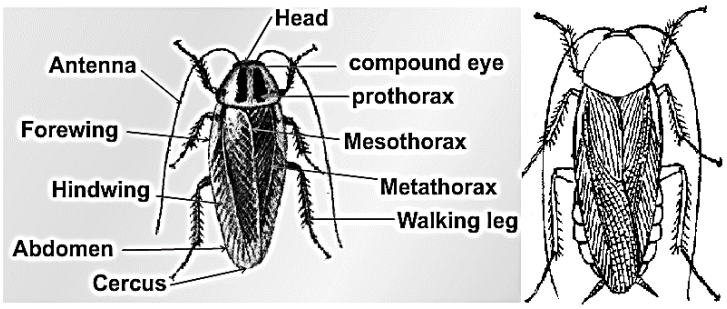


Figure – Blattaria Members

16.2.9 Isoptera: Termites (*isos* = equal + *ptera* = wings)

Termites are small soft-bodied, social insects with incomplete metamorphosis, chewing mouthparts and "beaded" antennae composed of a series of round

segments. They nest in colonies and stay underground at all times, except for the kings and queens, which are active during the swarming season. The colony is made up of castes, including many workers, some soldiers, and a queen. Termites either feed on wood that is beneath the soil or they build hollow, mud-like, shelter tubes from the ground to reach wood not in contact with the soil. The shelter tubes protect the termites from being exposed to light, dry air, and predators. In nature, termites are an essential part of the ecosystem, but when termites attack homes and other structures, they are serious pests. Ants that nest or swarm around homes are often confused with termites.

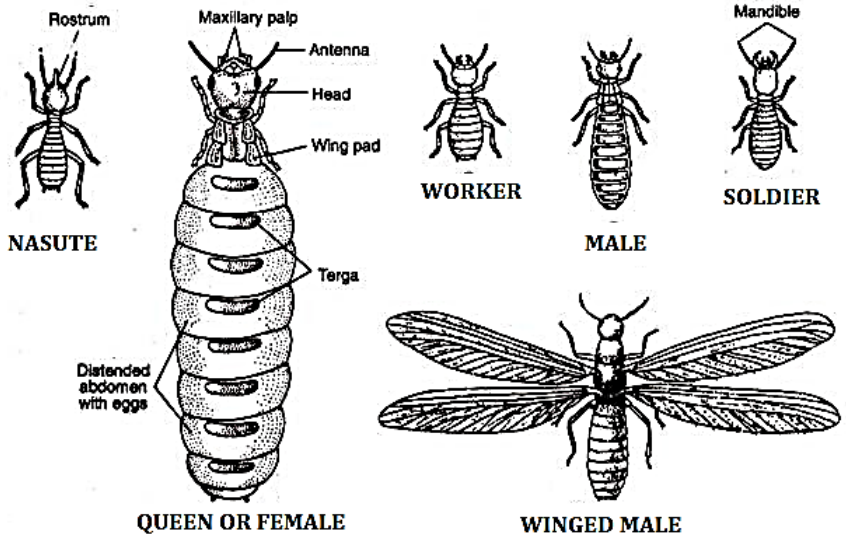


Figure – Isoptera Members

16.2.10 Dermaptera: Earwigs (*derma* = skin + *ptera* = wings)

It appears to be a common myth that the Earwig creeps into the ears of persons sleeping in the open air, passes thence into the brain, and causes death but it is false. Earwigs have incomplete metamorphosis, chewing mouthparts, and either 2 pairs of the wings or no wings. The front wings, when present, are short and hardened, and act as coverings for the membranous back wings. Earwigs are easy to recognize by the large pincers on the end of the abdomen. Female earwigs lay eggs under rocks or logs and guard both the eggs and, for a short time, the nymphs. Earwigs are nocturnal and are not often seen, although they are fairly common. They sometimes fly to lights at night, and are occasionally pests on fruit..

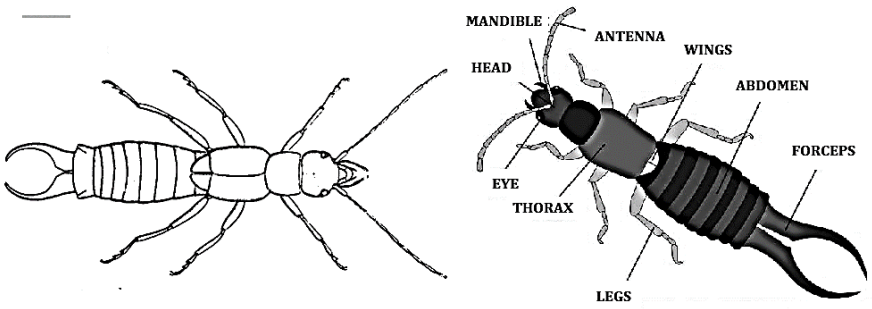


Figure – Dermaptera Members

16.2.11 Plecoptera: Stoneflies (*plekos* = plaited + *ptera* = wings)

Plecoptera members are commonly termed as stone flies. Stoneflies are small- to medium-sized insects with 2 pairs of membranous wings held flat over the back when not in use. The front wings are long and narrow, and the hind wings are enlarged and folded fanwise like grasshopper wings. Both wing pairs have many cross- veins. They have chewing mouthparts and long antennae. The abdomen ends in 2 short, thread-like tails. Metamorphosis is incomplete, and the aquatic nymphs (naiads) live under rocks in fast-flowing streams. The adults usually do not range far from water. Plecoptera are not of great economic importance except as a source of food for fishes. The naiads are sometimes collected and sold as fish bait, but they are hard to keep alive in captivity. Some species, called winter stoneflies, are among the first winged insects to appear in the year. They can be found clinging to bridges in late winter or very early spring. They are black or brown.

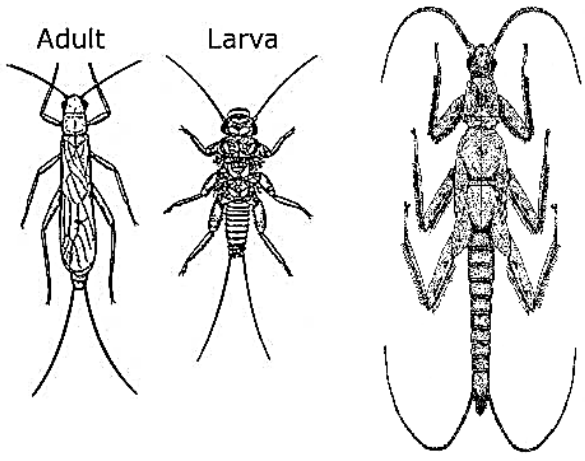


Figure – Plecoptera members

16.2.12 Psocoptera: Psocids, Barklice, Booklice

(*psocho* = to rub or grind into small pieces + *ptera* = wings)

Psocoptera members primarily feed on tiny fungi that grows on moldy or decaying wood. They are small, delicate insects, with long thread-like antennae, and chewing mouthparts. They are wingless or have 2 pairs of wings. Metamorphosis is incomplete. Booklice are wingless and are common in homes, often occurring in large numbers around musty books or in humid flour or meal. Bark lice are usually winged and can be found scurrying on tree bark.

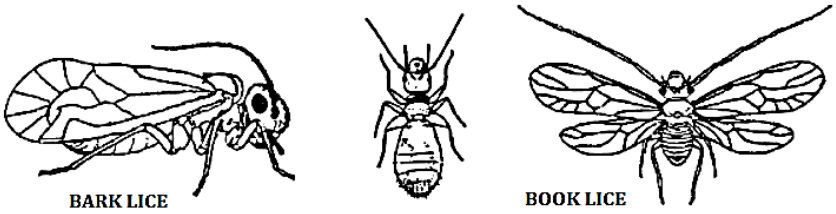


Figure – Psocoptera Members

16.2.13 Phthiraptera: Lice (*phthir* = lice + *aptera* = wingless)

Phthiraptera is famous for its lice members. Lice are tiny, flattened, wingless insects with soft bodies and incomplete metamorphosis. All lice are external parasites of birds and mammals. Lice antennae are short, and the eyes are absent or poorly developed. Most lice are host specific; that is, each louse species will live on only one kind of host, and the entire life cycle is spent on the host animal. The eggs (called "nits") are glued to the host's hair or feathers. There are two main groups of lice: chewing lice and sucking lice. Chewing lice have chewing mouthparts and feed on the hair or feathers and skin of their host. Although chewing lice can cause much irritation, they do not spread disease organisms as do the sucking lice. Sucking lice feed on blood, and often transmit diseases between organisms. No species of chewing lice are parasitic on humans, but there are several types of sucking lice (body, head, and crab lice) that attack humans.

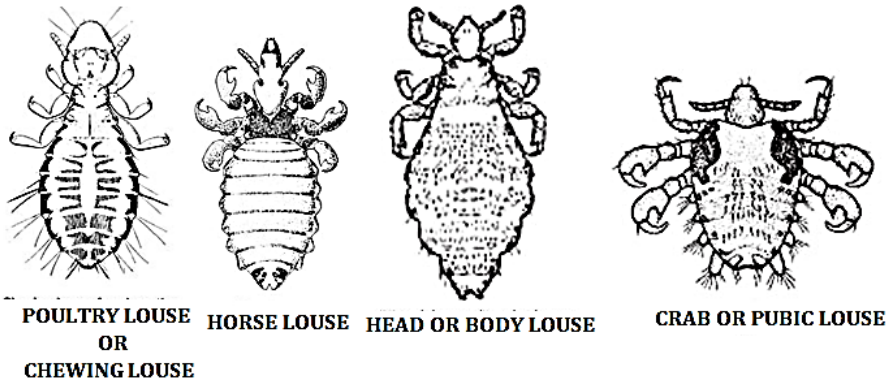


Figure – Phthiraptera Members

16.2.14 Hemiptera: True Bugs (*hemi* = half + *ptera* = wings)

Hemiptera order consists of true bugs although bug term is used for many other types of arthropods. For all insects in this order, "bug" is written as a separate word (e.g. plant bug, bed bug, squash bug). Whenever an insect or related arthropod in another order is called a bug, the names are written as one word (e.g. sowbug, mealybug). All Hemiptera have sucking mouthparts and incomplete metamorphosis. They typically have 2 pairs of wings. The front pair is leathery at the base and membranous at the tip. When at rest, the wings lie flat on the back. Some true bugs are wingless or are short-winged or have atypical front wings. The front wings of lace bugs are lace-like and do not conform to the general description of true bug wings.

The true bugs are very closely related to the Homoptera, and can be difficult to distinguish. Hemipterans have jointed beaks that arise from the front of the head. The homopteran beak arises farther back on the head and sometimes seems to come from between the front legs. Also, the wings of true bugs are held flat over the back. Those of homopterans are most often held roof-like over the back. Many true bugs are important plant pests, and a few are blood-sucking pests of animals, including humans. Some bugs are beneficial predators of other insects.

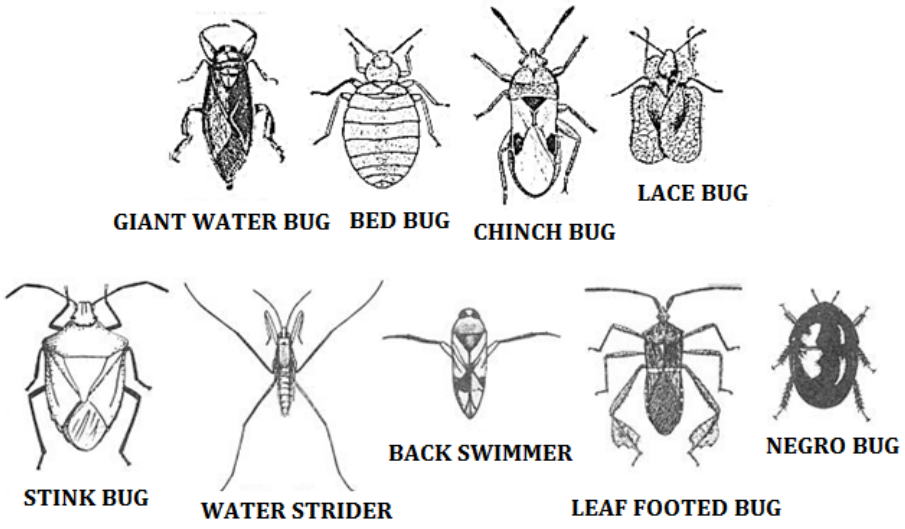


Figure – Hemiptera Bugs

16.2.15 Homoptera: Aphids, Cicadas, Scales, Leafhoppers, etc. (*homos*

= same + *ptera* = wings)

The Homoptera is closely related to Hemipterans, and the two orders can be difficult to distinguish. Like Hemiptera, Homoptera have piercing mouthparts, 2 pairs of wings, and incomplete metamorphosis. Unlike the Hemiptera, the mouthparts of Homoptera arise further back on the head, near the front legs. The wings, when present, are not like Hemiptera wings: they do not have a thickened basal section and a clear tip, and they are usually held "roof like" over the back instead of flat. All Homoptera are plant feeders. The largest members are the cicadas, which produce the familiar buzzing sound during summer months. Adult cicadas damage twigs and the subterranean nymphs feed on tree roots. Some cicada species have a long life-cycle, with the nymphs taking 17 years to grow. Aphids, often called "plant lice," are very common Homoptera. They are soft-bodied and have 2 short tubes projecting from the ends of the abdomens. Aphids are usually wingless and live in colonies on plants. Aphids are often pests, spreading diseases to crop and garden plants.

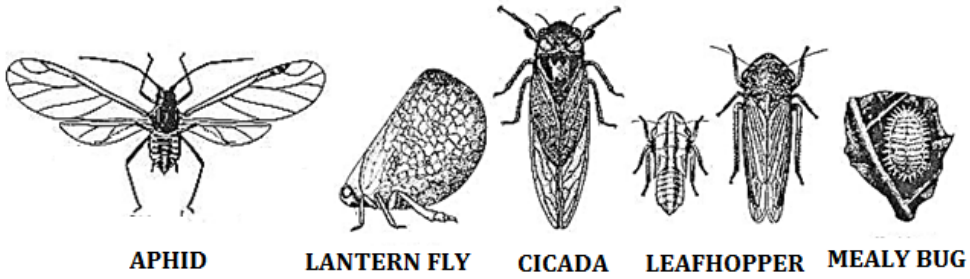


Figure – Homoptera Bugs

16.2.16 Thysanoptera: Thrips (*thysanos* = fringe + *ptera* = wing)

Thysanoptera order is known for thrips. Generally all the members of this order are tiny, narrow insects with short antennae. They are either wingless or have 2 pairs of long narrow wings fringed with long hairs. When at rest, the wings are held flat over the back. Thrips are poor fliers and their flights resemble flea hops. Their mouthparts are not fully developed, and they feed by scraping leaf surfaces and sucking the sap that flows from the wounds. Some thrips are important pests, causing leaf wilt or causing flower buds to drop or to open unevenly. Flower petals may be streaked or browned by thrips damage. Some also spread plant diseases. A few thrips species are beneficial also, they feeds on fungi and other insects.

Figure – Thysanoptera Members (Flower Thrips)

16.2.17 Neuroptera: Lacewings, Dobsonflies, Antlions, others (*neura* = nerves + *ptera* = wings)

This order members are commonly termed as lacewings and antlions. Neuroptera have chewing mouthparts, long antennae, and 2 pairs of membranous wings with many cross veins. Metamorphosis is complete. Most members of this order are small- to medium-sized. The dobsonfly is larger, ranging from 1 1/2 to 3 1/2 inches long. Members of this order are parasitic or predaceous on other invertebrates. Antlions are well- known members of this group. The larvae, called "doodlebugs," catch insects at the bottom of pits that they construct in sandy soil. Adult antlions resemble damselflies, but have longer antennae. Other common Neuroptera include: owlflies, mantidflies, dobsonflies, and lacewings. The mantidflies resemble miniature praying mantids. The green lacewing is a common representative of this order and is a beneficial insect because it destroys aphids. The larva of the green lacewing is commonly called the "aphid lion." Note: some keys place dobsonflies, alderflies, and fishflies into a separate order, the Megaloptera.

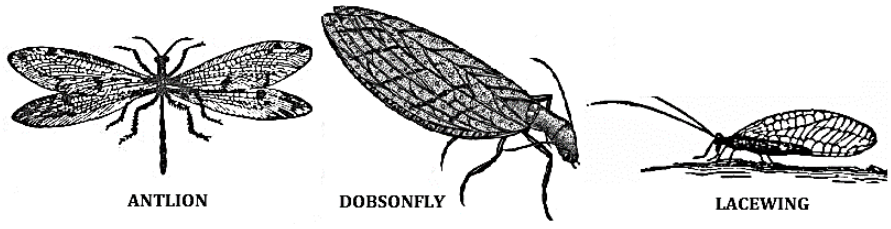


Figure – Neuroptera Members

16.2.18 Coleoptera: Beetles (*coleos* = sheath + *ptera* = wings)

The coleopteran members are commonly called as Beetles. All beetles have distinctive front wings (called "elytra)" which form a covering or sheath over the

hind wings. Usually the elytra are hard and meet in a straight line down the center of the back and extend to the tip of the abdomen. An important exception: the elytra of rove beetles are short, leaving most of the abdomen exposed. Some beetles, such as lightning beetles, soldier beetles and blister beetles, have elytra that are not as hard as those of most other beetles. Most beetles can fly, but the flying wings are hidden under the elytra when the beetles are at rest. All beetles have chewing mouthparts, but the jaws of weevils are at the end of a snout. The snout is sometimes long and thin and resembles a sucking beak. The antennae of beetles may be long or short and of many different shapes. Beetles undergo complete metamorphosis, and the larvae of some have special common names, such as white grubs and wireworms. Coleoptera contains the most members of any insect order, with over 300,000 known species worldwide.

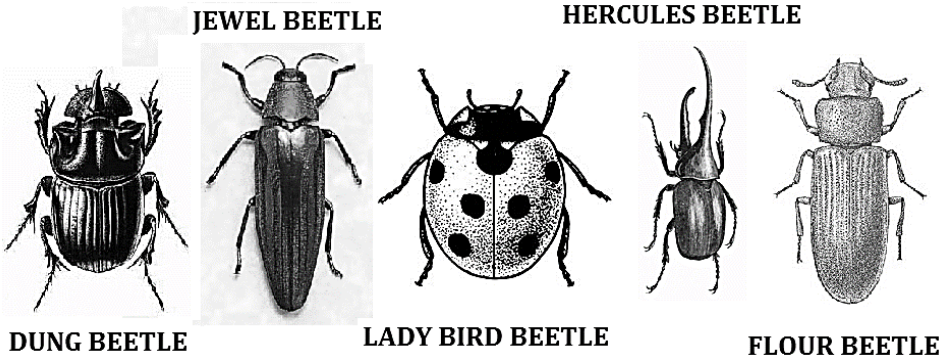


Figure – Coleoptera Members

16.2.19 Mecoptera: Scorpionflies and Hanging Scorpionflies (*mecos* = long + *ptera* = wings)

The order mecoptera members are commonly called as scorpionflies. Scorpionflies are medium-sized, soft-bodied insects with complete metamorphosis, 2 pairs of wings, long antennae, and chewing mouthparts. Scorpionflies are easy to identify because of their long "noses." Scorpionflies get their names because on some species, the male abdomen ends in a tail resembling that of a scorpion. Most common scorpionflies in are orange in color. Larval scorpionflies live in leaf litter and feed on a variety of organic material. Most adults are predators

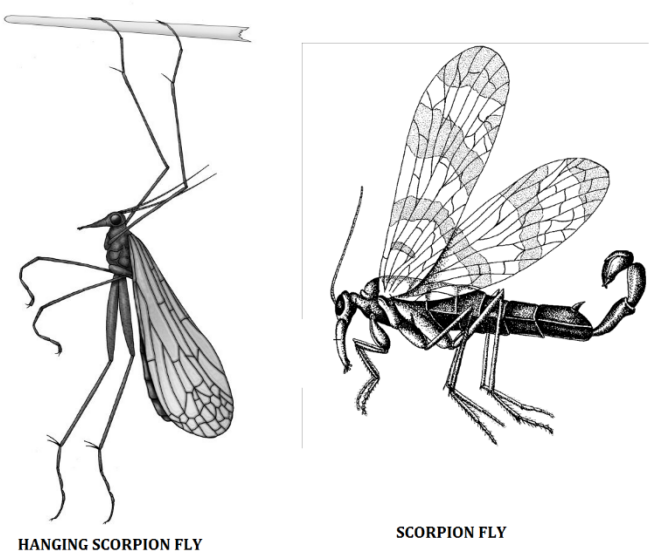


Figure – Mecoptera Members

16.2.20 Diptera: Flies, Gnats, Midges, Mosquitoes (*di* = two + *ptera* = wings)

Although a lot of flying insects are referred to as "flies" like butterflies, dragonflies, mayflies, and so on but the true flies belong to the Diptera. The name means "two wings," and true flies bear only one pair of functional wings. All Diptera have modified sucking mouthparts, and they are the only group of commonly encountered insects which have only 1 pair of wings. Where the second pair of wings would be located, there is a small structure called a “haltere” which looks like a tiny golf tee and which helps in balance. A few rarely encountered insects in other orders have only 1 pair of wings, such as the Strepsiptera and a few cricket species, but these insects usually have chewing mouthparts. Some rarely encountered flies, such as the sheep ked, are wingless. Fly antennae may be short or long and of various shapes. The eyes are typically very large. In many species, the mouthparts are adapted for piercing plants or animals and sucking sap or blood. In some cases, as with house flies, the mouthparts may be capable of only “sponging” liquid food. House flies are able to feed on solid food only by first dissolving it with excreted saliva. Flies have complete metamorphosis, and the larvae are usually called maggots. Many kinds of flies are serious economic pests of plants and animals**.** Flies are the most important insects in regards to the health of man and animals because of the diseases they spread. Many kinds of flies are beneficial as parasites and predators of pest insects, or as plant pollinators. When

writing the common names of true fly species, "fly" is always written as a separate word, such as “house fly,” “deer fly,” or “stable fly.” When "fly" is part of the name of an insect in another order, it is written as a compound word, such as “dragonfly,” “butterfly,” or “caddisfly.”

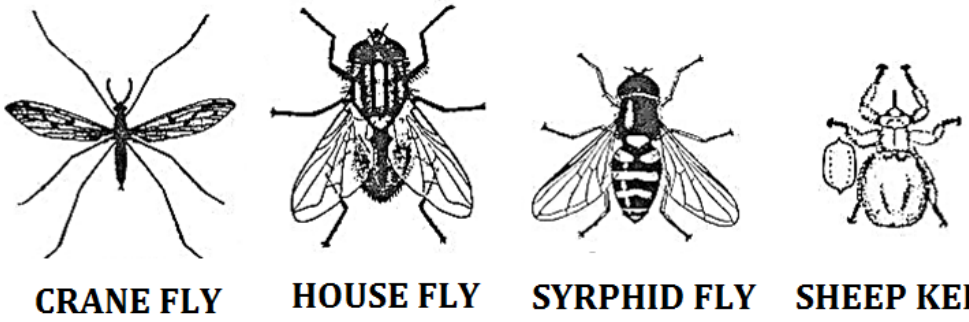
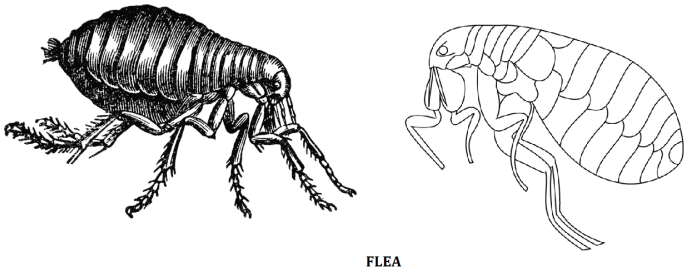


Figure – Diptera Members

16.2.21 Siphonaptera: Flea**s** (*siphon* = tube + *aptera* = without wings)

Order Siphonaptera are one of the major groups of blood-sucking insects. They belong to holometabolic insects. Holometabolism is a feature characteristic also of Diptera, Lepidoptera, etc. Fleas form a separate well differentiated order, although phylogenetically they are regarded to be closer to Diptera and Mecoptera. At present approximately 2000 species and subspecies of fleas are known. Siphonaptera are always wingless and have sucking mouth parts. They are flattened from side to side, have long legs and are good jumpers. Their antennae are short and eyes are usually present. All fleas are parasites on the bodies of mammals or birds. Fleas lay eggs while they are on the host, and the eggs fall to the ground. When the larvae hatch they feed on bits of skin and hair in the host animal's lair or den. After several molts, the larva pupates. When the adult emerges from the pupa, it can go for months without food. Most flea species prefer one or two types of host, but they often will take experimental tastes of other animals. Dog and cat fleas will bite humans but will not live on them. One of the most dread diseases of the past was bubonic plague, which was spread by fleas from rat to man and man to man. Bubonic plague, or the "Black Death," killed 70,000 people in London, England between 1664 and 1666. In the 1500's the Black Death claimed 25 million lives in Europe.

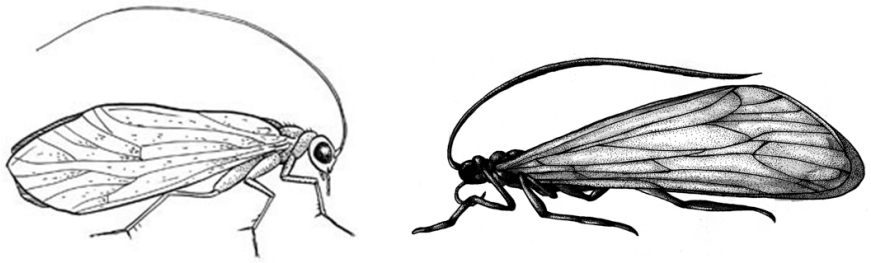


FLEA

Figure –Siphonoptera Members

16.2.22 Trichoptera: Caddisflies, Caseflies (*trichos* = hair + *ptera* = wings)

Trichoptera comprise the most diverse insect order whose members are exclusively aquatic. Only aquatic Diptera outnumber them in species and ecological diversity. The larval stages are found in lakes, rivers, and streams around the world, and are important components of food webs in these freshwater ecosystems. Trichoptera are closely related to Lepidoptera, but have chewing mouthparts and wings that are hairy instead of scaly. In side view they often have a triangular outline, and the antennae are long and thread-like. The larvae also differ: caddisfly larvae, unlike butterfly and moth caterpillars, never have abdominal legs with crochets (groups of hooked spines at the end of abdominal legs). Trichoptera have complete metamorphosis, and all caddisfly larvae are fully aquatic. The larvae of many species construct cases around themselves with saliva and bits of twigs, reeds, or sand. This gives them their other common name; "caseflies." Some construct webbed nets, but no case. Trichoptera are the largest single group of aquatic insects and are an important source of food for fish. The adults, most of which are 1/2- 1 1/2 inches, tend to fly at night and are attracted to lights.



CADDIS FLY

Figure – Trichoptera Members

16.2.23 Lepidoptera: Moths, Butterflies, and Skippers (*lepidos* = scale + *ptera* = wings)

Lepidopteran any of more than 155,000 species of butterflies, moths, and skippers. This order of insects is second in size only to Coleoptera, the beetles. Because of their day-flying habits and bright colours, the butterflies are more familiar than the chiefly night-flying and dull-coloured moths, but the latter are far more varied and abundant. The skippers are a worldwide group intermediate between butterflies and moths. Lepidoptera are easy to recognize. They have coiled sucking mouthparts, scales on their wings, and complete metamorphosis. The main difference between moths, butterflies, and skippers is in the antennae. Butterflies have thread-like antennae that are thickened or knobbed at the end. Skippers have thread-like, knobbed antennae as well, but the knobs are tipped with distinct hooks. Moth antennae may be thread-like, feathery or spindle shaped, but never have knobs. Most moths fly at night, while butterflies and skippers tend to be day fliers. Most moth caterpillars spin a cocoon in which to pupate, but butterflies never spin a cocoon. A few moths are wingless. Caterpillars of many moths are important pests of plants. Most caterpillars eat plant leaves, but the caterpillars of some moths eat woolen materials and stored food. Some bore into plants. A few kinds of caterpillars are adapted for living in water. Some caterpillars have poisonous spines on their body, and if they are handled carelessly can produce a sting as bad as a wasp sting.

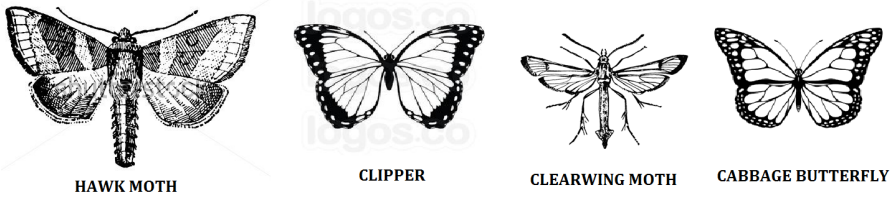


Figure – Lepidoptera Members

16.2.24 Hymenoptera: Wasps, Bees, Ants, Sawflies, Horntails (*hymen* = membrane + *ptera* = wings)

Order Hymenoptera is the third largest order and perhaps the most beneficial to humans among all insect orders. More than 115,000 species have been described. Hymenoptera have chewing mouthparts and either two pairs of membranous wings or no wings. When winged, the front pair is longer than the hind pair. The antennae are well developed and often are quite long. In bees, wasps and ants, the body is constricted between the thorax and abdomen, but in sawflies and horntails the abdomen and thorax are broadly joined. All Hymenoptera have complete

metamorphosis. Some Hymenoptera are solitary, others are organized into highly socialized colonies. The greatest degree of social organization occurs among the honey bees, but ants are also highly socialized. The social organization of wasps is not as complex. None of the sawflies or horntails lives in colonies. Many of the Hymenoptera, in the process of feeding on pollen, also pollinate flowers and are useful insects for this reason. Honey bees also produce honey, wax, and propolis. Other Hymenoptera are beneficial predators or parasites of pest insects. Many species of sawflies and horntails are pests which feed on leaves or bore in wood. Some bees, wasps and ants are pests. Those that can sting cause the most concern.

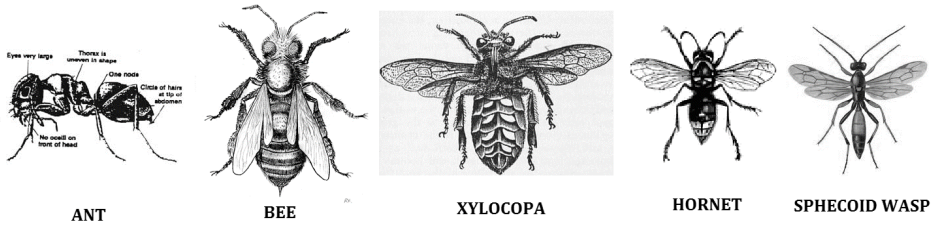


Figure – Hymenoptera Members

16.3 Self-Learning Exercises

1. Collect any 50 insects from your locality and try to identify them with the help of your entomology teacher with the help of taxonomic key.
2. Explain the importance of taxonomic keys?
3. Describe the pattern of dichotomous keys.
4. Explain different characters of coleoptera.
5. What is the difference between ants and termites?
6. Differentiate between dragon fly and damsel fly?
7. Differentiate between moth and butterfly?
8. Write the various characteristic features of order lepidoptera?
9. Describe the method of identification of insects with the help of key?
10. What are the features of order hymenoptera?
11. Describe the different types of orders of class insecta in brief.

16.4 References

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Unit - 17

Insect Morphology

Structure of the Unit

17.0 Objectives

In this unit you will be able to understand the body segmentation in Insects, various appendages and their permanent mounting to study their taxonomic importance. You will also understand the different sense organs found in invertebrate organisms.

17.1 Introduction

Segmentation of the insect body may be primary or secondary. Primary segmentation is a type of segmentation where entire cuticle is thin and flexible and

integument invaginates to form inter-segmental folds. Secondary segmentation is another type of segmentation where due to heavily sclerotization the sclerites are divided into dorsal terga, ventral sterna and lateral pleura. The division of body into functional regions is known as tagmosis. Insect's body is divided into segments differentiated into three body regions named head, thorax, and abdomen. Different types of external genitalia are specific to insects, which play role in reproduction.

17.2 Body tagmata of insect

Comments

1. The division of body into functional regions is known as t**agmosis**.
2. Tagmata is a plural word, singular is tagma.
3. Insect's body is divided into segments differentiated into three body regions named head, thorax, and abdomen.
4. Head is important as it bears eyes, antenna, mouthparts, brain and sensory centers.
5. Thorax is important as it function commonly in flying and locomotion.
6. Finally the role of abdomen is to bear genital openings and external genital apparatus that it is function in reproduction. So each tagmata has a specific function.
7. Annelida it is divided into segmented body called metameric segmentation where each segment perform all functions and are copy of each other while in insects tagmata are group of segments that are specialized to perform a function.

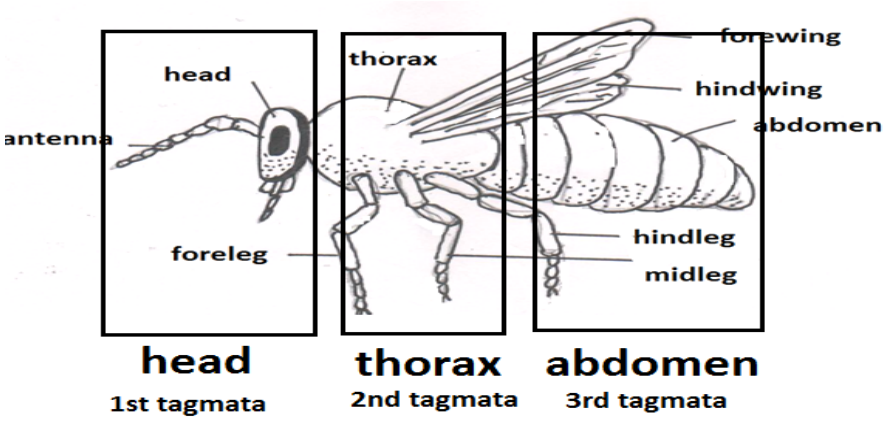


Fig 1 Diagram showing three tagmata in insects

17.3 Sclerites

Comments

1. A scerite is a Greek word "*scleros means hard".*
2. In Arthropods the hardening of sclerites is obtained by the process of sclerotization.
3. Body of insect is covered with hard and tanned exocuticle but in areas of joints exocuticle is wanting and a membrane is found which is flexible and folded.
4. There are three plates one at dorsal side called tergum, at ventral surface called sternum and at lateral side called pleuron.
5. The subdivisions of terga, sterna and pleura are tergites, sternites and pleurites.
6. The terga of thoracic region are differentiated in prothorax as pronotum, mesothorax as mesonotum and metathorax as metanotum.
7. The abdominal segments are connected through a less sclerotized and soft membrane called intersegmental membrane to provide a little flexibility needed for the movement.
8. There are some lines with sclerites called sulcus/suture. Suture is a line between two sclerites and sulcus is a ridge between the two sclerites.

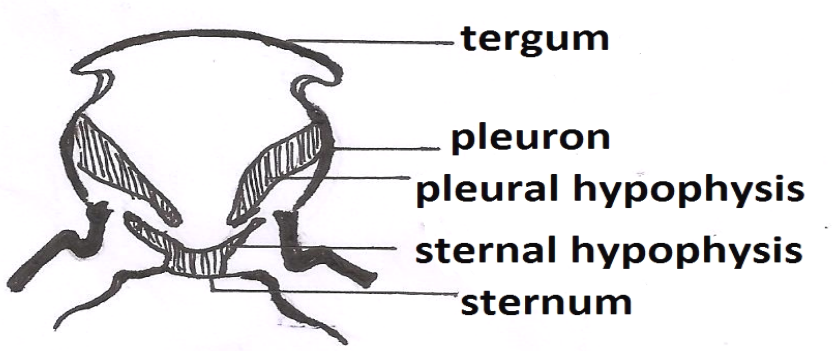


Fig 2 Endoskeleton and sclerites

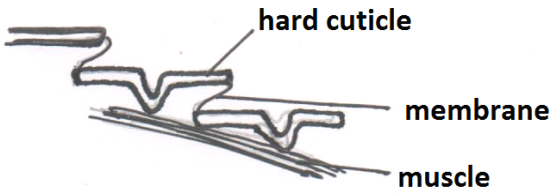


Fig 3 Diagram showing membrane between segments

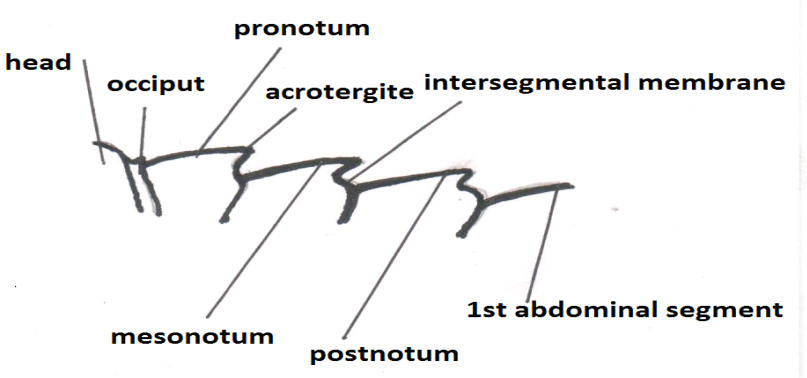


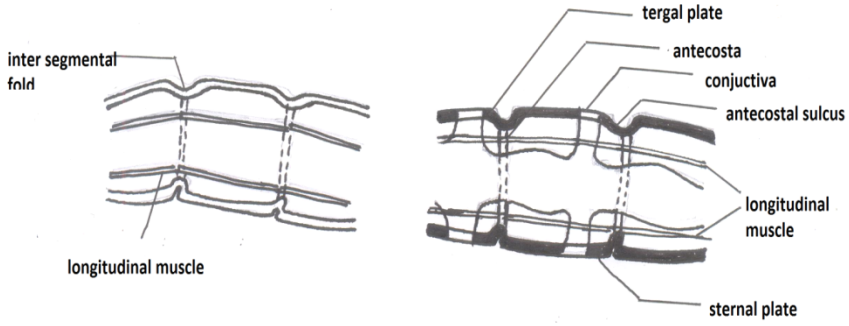
Fig 4 Insect thorax with pro, meso and metathorax

17.4 Primary and secondary segmentation

Comments

1. Segmentation of the insect body may be primary or secondary.
2. **Primary segmentation** is a type of segmentation where entire cuticle is thin and flexible and integument invaginates to form inter-segmental folds.
3. The inter-segmental fold in between segments provides attachment to longitudinal muscles.
4. Primary segmentation is found in larval stage which provides them to move freely.
5. **Secondary segmentation** is another type of segmentation where due to heavily sclerotization the sclerites are divided into dorsal terga, ventral sterna and lateral pleura.
6. The primitive inter-segmental fold becomes internal ridge of cuticle called antecosta seen externally as antecostal sulcus.

7. Secondary segmentation if found in adults.



A) B)

Fig 5 Types of body segmentation A) primary B) secondary

17.5 External genitalia: male grasshopper

Comments

1. Male grasshopper is smaller than females.
2. In males 9th abdominal segment are modified to form reproductive appendages.
3. Male genitalia are symmetrical and concealed at rest by 9th abdominal sternum.
4. Male grasshoppers are distinguishable by the cerci, furcula, subgenital and supra anal plates.
5. In most insects the male transfers sperm directly into the female's reproductive system. This is accompanied by some sort of intromittent organ, often called a penis or aedeagus.
6. Cerci are usually very short and unsegmented.
7. The male genital pore called gonopore is located on segment 9th.
8. Aedeagus is derived from a pair of appendages of the 9th segment and sometimes parts of the 10th segment.
9. It is also accompanied by appendages of segment 9 (external genitalia) called claspers, which serve to hold the female in position during sperm transfer.
10. The male external genitalia are derived from the ninth abdominal coxites.

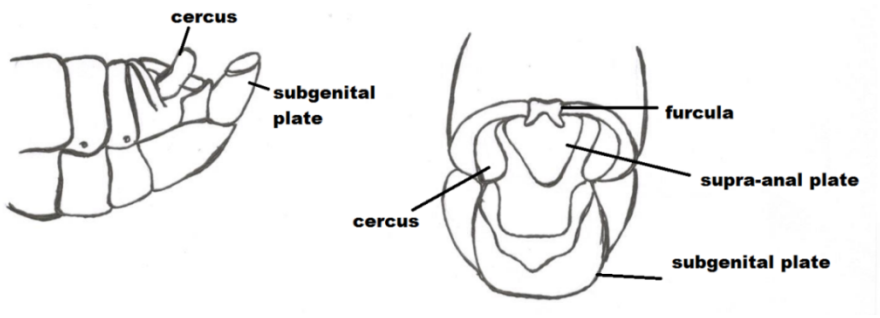


Fig 6 External male genitalia of grasshopper

17.6 External genitalia: female grasshopper

Comments

1. Female grasshopper is larger than females.
2. The ovipositor is the egg laying apparatus in female insects developed from 8^{th} and 9^{th} abdominal segments.
3. Ovipositor is conspicuous blunt blade-like functions to dig or bore eggs in soil or wood.
4. First pair of valvulae borne from first valvifer on 8^{th} segment.
5. Second and third pair of valvulae born from common basal sclerite, second valvifer on 9^{th} segment.
6. The female grasshoppers have ovipositor dorsal and ventral valves which can be used to separate some species.
7. The genital ducts open outside through genital openings, on the underside of segment 8 or 9.
8. In the female two sets of valves (appendages from segments 8 and 9) form the shaft of the ovipositor.
9. These valves connect to basal sclerites called valvifers which articulate with the abdominal terga.
10. These valves interlock and can slide over one-another, moving the egg along inside the shaft, assisted by spines or ridges on the inside surface of the shaft which grip the egg. The shaft of the ovipositor consists of two pairs of elongate, closely appressed sclerites called the first and second valvulae.
11. Insects have three plates on 11th segment. The paraproct two in number on both side of the anus and one epiproct dorsal side or above the anus.

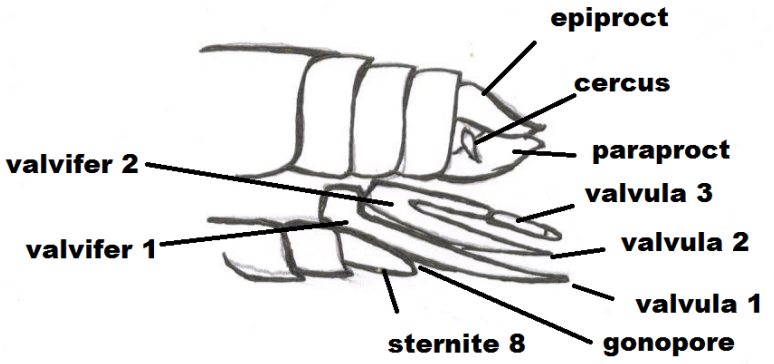


Fig 7 Female genitalia of grasshopper

17.7 External genitalia: female cockroach

Comments

1. Abdomen of female is short, broad and boat shaped.
2. Only seven segments are visible as 7th segment of abdomen covers both 8th and 9th segments.
3. Tenth abdominal segment carries one pairs of appendages segmented anal cerci.
4. Anal styles are absent.
5. Sternum of seventh segment is divided.
6. A genital pouch is present.
7. Third basal segment of antenna is larger than second basal segment.

17.8 External genitalia: male cockroach

Comments

1. Abdomen of male is long and narrow.
2. All nine abdominal segments are visible.
3. Tenth abdominal segment carries two pairs of appendages segmented anal cerci and unsegmented anal style or caudal style.
4. Genital pouch is absent.
5. Sternum of seventh segment is not divided.
6. Eighth sclerite is overlapped with 7th segment.
7. Second and third basal segment of antenna are equal.

8. In order Dictyoptera phallomere do not form aedeagus and both pairs are asymmetrical.
9. Left parameres having titilator, pseudopenis and accutolobus.
10. The right paramere is having paired plates.

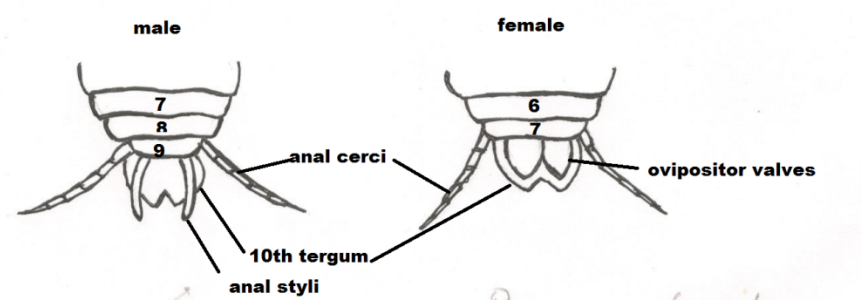


Fig 8 Male and female external genitalia of cockroach

17.9 External genitalia: male dragonfly

Comments

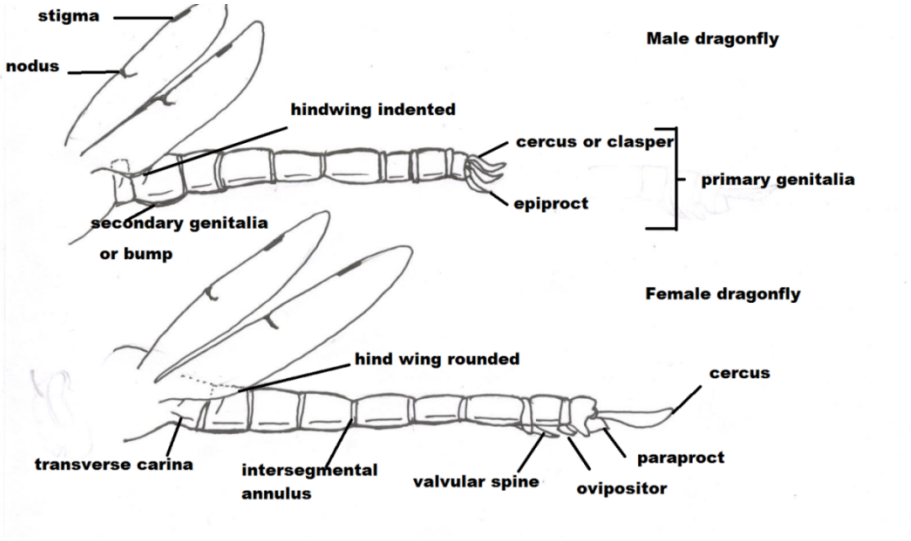
1. The external genitalia is present at the end of 10 segmented abdomen.
2. There is a bump underside of the abdomen at the joint with the thorax.
3. Male dragonfly has primary and secondary genitalia.
4. Primary genitalia are present at the end of the abdomen and secondary genitalia are located at the base of the abdomen.
5. Sperms are produced in primary genitalia in 9^{th} segment and before mating it transfer sperms to the sex organ or secondary genitalia for storage.
6. Secondary genitalia consist of hamules which are located at 2nd and 3rd abdominal segments.
7. These segments called terminal appendages collectively claspers.
8. The claspers used to grab the female head while mating.
9. It has 3 anal appendages including a pair of cerci also called superior appendages and unpaired epiproct also called inferior appendage.
10. Spermaries open on the 9th segment.
11. Another external feature to identify male is its hind wing are indented near the body.

17.10 External genitalia: Female dragonfly

Comments

1. It is fairly simple and easy to identify male and female dragonflies.

2. There is smooth surface underside of the abdomen at the joint with the thorax i.e. no bump.
3. The female genitalia is found on segment 8th.
4. Genital opening on the 8th segment is covered by a simple flap or ovipositor depending upon the type of species and method of egg laying.
5. Dragonflies forms mating wheel in order to connect their genitalia during copulation.
6. Females have 2 anal appendages as anal cerci.
7. Another external feature to identify female is its hind wings are rounded in shape near body.



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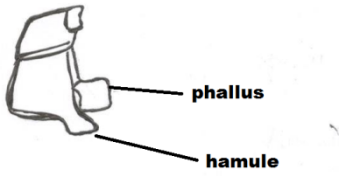

B

Fig 9 A) Male and female dragonfly differnces B) Secondary genitalia

17.11 Johnston's organ

Comments

1. Johnston’s organ is discovered by Christopher Johston who first described this organ in mosquito.

2. It is the chordonotal organ present in most of the insects.
3. It is found at the base of pedicel the second part of antenna.
4. It is highly developed in dipterans.
5. It is mechanosensory in function such as touch, gravity, wind and sound. It is an important organ for deciding position of head, direction and orientation of body.
6. In male mosquito and chironomids these locate female while flying for the purpose of mating. For this reason male bears bushier antenna with long hair which vibrate and give information to the organ.
7. The Johnston's organ consists of two rings of scolopidia.
8. The inner ring is parallel to the flagellum and the outer ring is perpendicular to flagellum. Inner scolopidia are more sensitive.

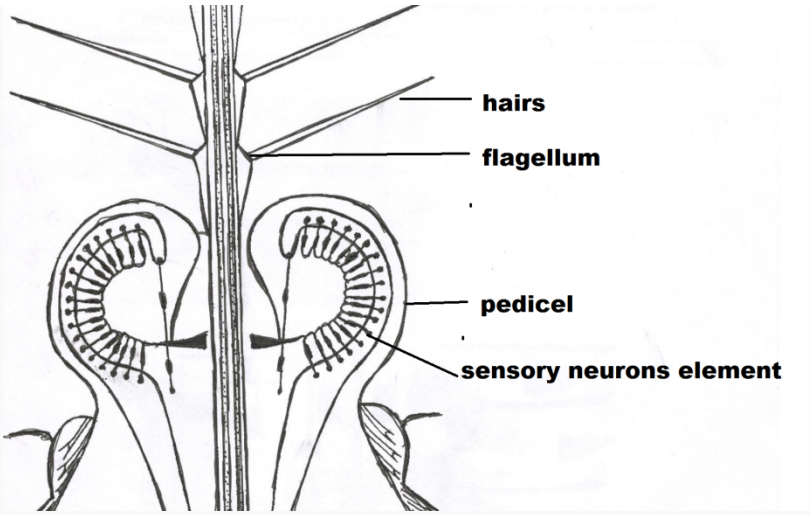

Fig 10 Johnston organ of mosquito antenna.

17.12 Tympanal organ

Comments

1. They are located on foretibia of Tettigonidae, Gryllidae (Orthoptera), abdomen in cicada (Hemiptera) and metathorax in Noctuidae (Lepidoptera).
2. Due to their different location in different insect group tympanal organ is used to determine the taxonomy of the species.
3. In grasshopper tympanum is located below the hind wing on each side of thorax.
4. They are the hearing organs in insects and consist of tympanic membrane, tracheal air sac and a group of chordonotal sensilla.

5. The tympanum is associated with sensory neurons.
6. Sound waves are received by tympanic membrane causes it to vibrate which stimulates the chordonotal sensilla.
7. From these sensilla message is conveyed to auditory nerves and impulse is produced.
8. The air sacs behave as air cushions and improve the auditory sensitivity.

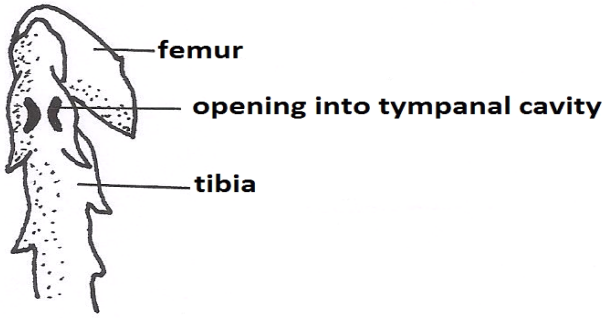

Fig 11 **Tibial Tympanal organ of *Decticus***

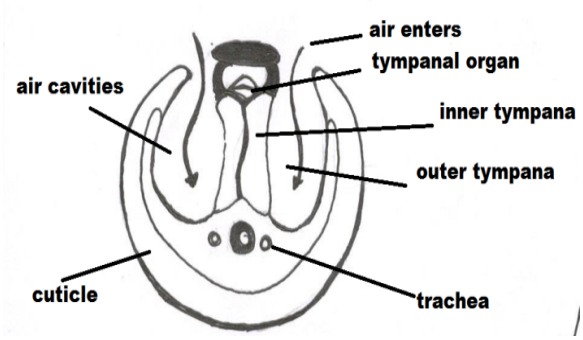

Fig 12 Tympanal organ and air sacs

17.13 Compound eyes

Comments

1. A pair of compound eyes is present on the dorsal side of the head and is well developed in most of the insects.
2. There are number of small units called ommatidia each forms a part of image and join to each other to form a single image therefore called compound eyes.

3. Each ommatidium consists of cornea, cornegean cells, cone cells, crystalline cone, retinal cells, rhabdom, primary and secondary iris pigment.
4. The ommatidium consists of light gathering component made of corneal lens and crystalline cone.
5. The retinular cells are the primary sense cells which collect and transduce light energy.
6. Crystalline cone is secretes by four cone cells/ Semper's cell.
7. Although there are eight retinal cells but one degenerate and rest seven eccentrically arranged with centrally placed receptive area called rhabdom.
8. Rhabdom contains visual pigment which are conjugated proteins called rhodopsin resembling the pigment of vertebrate eye. The photosensitive chromophores consist of aldehyde of vitamin A *i.e* retinaldehyde.
9. Secondary pigment cells consisting of ommochromes which contain granules of brown, red and yellow pigments.
10. Two types of images are formed apposition and superposition.
11. The sharpness of image depends upon the number of ommatidia per unit surface area of the eye. Since the surface of the eye is curved, insect can detect the distance to their prey or predator from them.

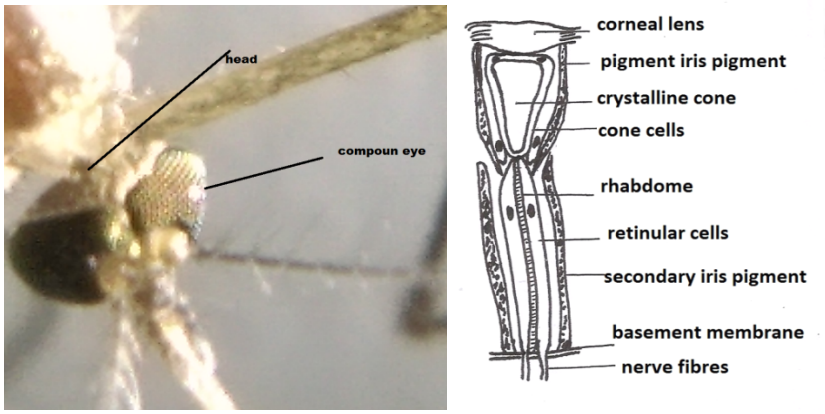

Fig 13 A) Compound eye of mosquito B) A single ommatidium

17.14 Ocelli

Comments

1. They are the type of simple eye located dorso-frontal region of head.

2. They contain 500-1000 photosensitive cells below the common lens.
3. At the distal part each of them forms rhabdom.
4. They are more sensitive and respond more rapidly than compound eyes.
5. They are not able to form image below rhabdom that is why no physiological significance.
6. They can measure light intensity and are essential to maintain diurnal rhythms.
7. Ocelli are found in many adult insects and young ones of many exopterygotes.

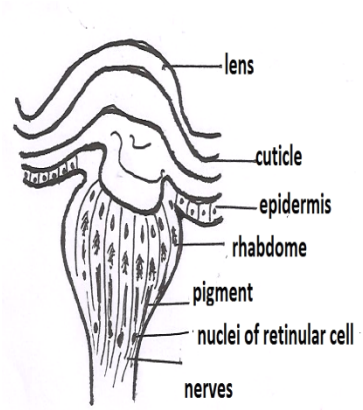

Fig 14 Structure of ocelli

17.15 Stemmata/ lateral ocelli

Comments

1. They are another type of simple eye found in larva of many endopterygotes behaving as photosensitive structure in body.
2. They lie laterally in position therefore called lateral ocelli.
3. In saw fly and beetle larva one pair of stemmata on either side is present consist of single lens with many photosensitive cells lying beneath ending in a single rhabdom.
4. Several stemmata are present in larvae of Neuroptera, Trichoptera and Lepidoptera but with above components they also bear corneal and retinal cells.
5. Sometimes, from outside there is no sign of stemmata but pocket of photosensitive cells are present below cuticle in larvae of Diptera (cyclorrhapha).

6. They are responsible for color discrimination.

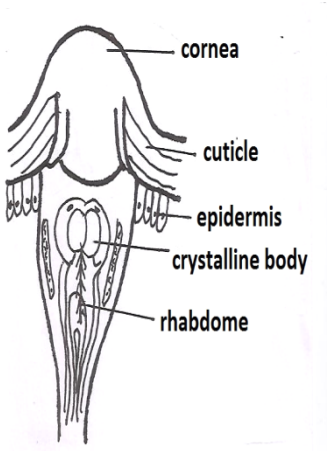

Fig 15 Stemmata (Lepidoptera)

17.16 Spiracle of cockroach

Comments

1. In cockroach there are 2 thoracic (1 mesothoracic and 1 metathoracic) and 8 abdominal spiracles (from first to eighth abdominal segment).
2. To make a permanent mount stretch the abdomen on the ventral side, locate the spiracle and cut it out.
3. Spiracles are located at the pleura of their respective segment.
4. The spiracle of cockroach is polyneustic and holopneustic type (means it carry 10, 9 or 8 functional spiracles).
5. All spiracles are valvular and lined by a chitinous ring called peritreme.
6. Each spiracle bears hair like structure called trichomes to filter dust particles.
7. Spiracle opens into a small chamber atrium.
8. Through atrium it leads to tracheal orifice which further opens into trachea.

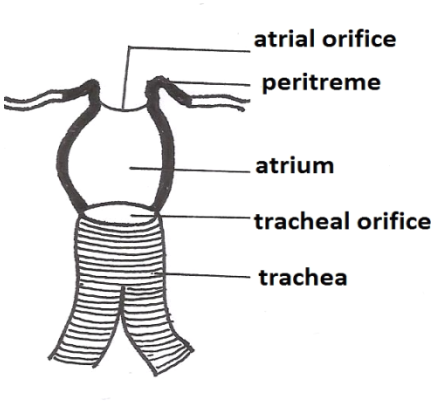

Fig 16 Structure of spiracle of cockroach

17.17 Trachea of cockroach

Comments

1. To make a permanent mount dissect the cockroach and remove abdominal segments. Trachea will be seen as silvery white tubes. Take a few pieces and stain with picro-indigo carmine and dehydrate.
2. From the atrium of abdominal spiracle three tracheal tubes arises dorsal, ventral and lateral tracheal tube.
3. All these tracheal tubes open into three longitudinal tracheal trunks dorsal, ventral and lateral longitudinal tracheal trunks.
4. The wall of trachea consists of three layers outer basement membrane, middle epithelium and innermost layer of cuticle.
5. The inner cuticle layer is also termed as intima.
6. The intima is thickened at regular interval to form taenidia.
7. The function of taenidia is to keep the trachea open and prevent it from collapsing.

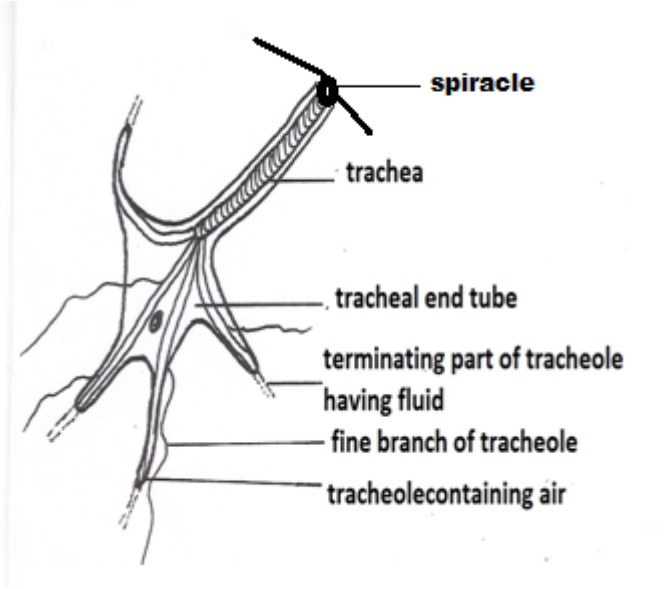

Fig 17 Structure of trachea of cockroach

17.18 Self learning exercise

1. Prepare a permanent slide of external genitalia of cockroach and draw its diagram.
2. Prepare a permanent slide of external genitalia of grasshopper and draw its diagram.
3. Comment upon the following and draw neat and clean diagram:
   i. Ocelli
   ii. Spiracle of cockroach
   iii. Johnston organ of mosquito antenna
   iv. Stemmata

17.19 References

- Experimental Entomology by G.T. Tonapi.
- The preparation and curation of insects by Annette K. Walker and Trevor K. R. Crosby.
- Modern Entomology by D. B. Tembhare
- Practical Zoology by S.S. Lal

Unit-18

Dissection of Insect

Structure of the Unit

18.0 Objectives

The present unit is design to learn the practical aspect of animal dissection to separate the several parts from one another, so as to define their boundaries and display clearly their mutual relations. After going through this unit you will be able to learn dissection of various insect to study different anatomical organs. In this

section you will learn about anatomy of cockroach, grasshopper, honey bee and house fly.

18.1 Introduction

The meaning of **"dissection"** is to cut, open the animal in order to ascertain the structure of its parts. Dissection consists mainly in removing the connective tissue which binds the several parts together. Dissection must be carried out in water and water must completely immerse the dissection. Display your dissection by placing black paper below the target organ or organ system exposed. **Invertebrate** are always dissected from the **dorsal side** and **Vertebrate** are always dissected from **ventral side**.

18.2 Dissection of cockroach

18.2.1 Alimentary canal of cockroach

1. Nutrition in cockroach is holozoic and it is an omnivore, feeding on different kinds of organic matter. It takes in pieces of food and has to grind them before digesting them. Thus its mouth parts are modified accordingly for chewing the food. American cockroach (*Periplaneta americana*), for feeds on a great variety of foodstuffs including bread, fruit, leather, starch in book bindings, paper, glue, skin flakes, hair, dead insects and soiled clothing.
2. The alimentary canal is divided into three regions, viz. foregut, midgut and hindgut. The mouth opens into a short tubular pharynx.
3. The pharynx opens into a narrow tubular oesophagus. The oesophagus opens into a sac-like structure called cropin which food is stored. The crop is followed by gizzard and proventriculus.
4. The gizzard has an outer layer of thick circular muscles and thick inner cuticle; forming six highly chitinous plate called teeth. Food particles are ground in the gizzard. The entire foregut is lined by cuticle.
5. At the junction of foregut and midgut, a ring of 6 – 8 blind tubules are present. These are called gastric or hepatic cecae and secrete digestive juice. The hindgut is broader than the midgut.

6. The hindgut is differentiated into ileum, colon and rectum. The rectum opens through anus.
7. Many species of cockroach harbor symbiotic protozoans and bacteria in their gut which are able to digest cellulose. However some species secrete cellulase in their saliva, and the wood-eating cockroach, *Panesthia cribrata*, is able to survive indefinitely on a diet of crystallized cellulose while being free of micro-organisms.
8. All species studied so far carry the obligate mutualistic endosymbiont bacterium, *Blatta bacteriu* with the exception of *Nocticola australiensise*, an Australian cave-dwelling species without eyes, pigment or wings, which recent genetic studies indicate is a very primitive cockroach

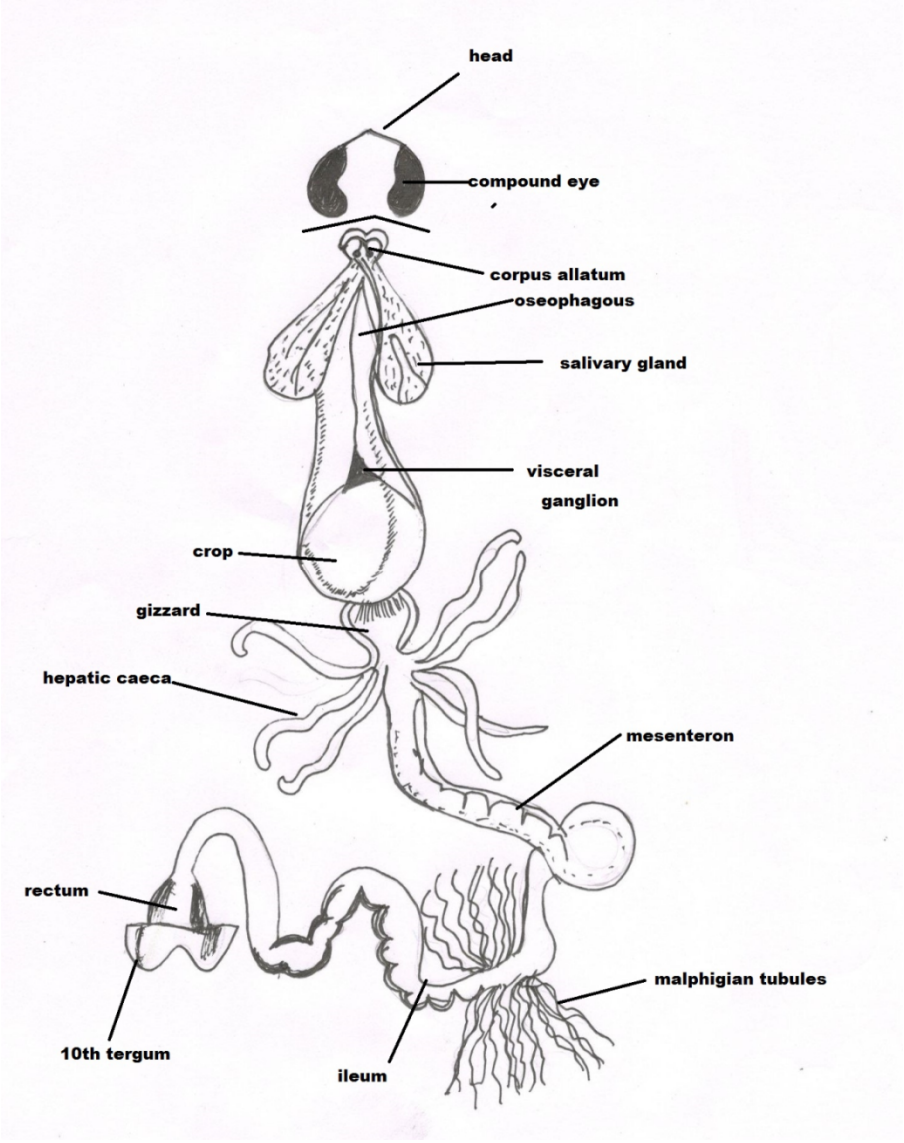

Fig 1: Alimentary canal of cockroach

18.2.2 Nervous system of cockroach

1. The nervous system of cockroach is a very important part of boy systems consists of a group of different ganglions and differentiated into Central Nervous System (CNS), Peripheral Nervous System (PNS) and Stomogastric Nervous System (SNS).
2. CNS consist of brain or supra- oesophageal ganglion. Brain gives off a pair of short, stout cords passes backwards into the thorax, a double ventral nerve-cord.
3. The nervous system of cockroach consists of a series of fused, segmentally arranged ganglia. The ganglia are joined by paired longitudinal connectives on the ventral side.
4. Three ganglia lie in the thorax and six in the abdomen. The nervous system in cockroach is spread throughout the body. In the head region, the brain is represented by supra-oesophageal ganglion. It supplies nerves to antennae and compound eyes.
5. The ganglia are joined by paired longitudinal connectives on the ventral side.
6. Peripheral Nervous System consists of nerves, which are given off from the ganglia so as to innervate all the parts of the body
7. Sympathetic or Stomatogastric Visceral Nervous System consists of a frontal ganglion, which is situated on the dorsal side of the oesophagus in the head. From this ganglion, a median unpaired recurrent nerve reaches the visceral ganglion situated on the crop.
8. Various nerve branches are given off from the visceral ganglion. The frontal ganglion is jointed with the central nervous system by nerves, which connect the circumoesophageal commissure**.**

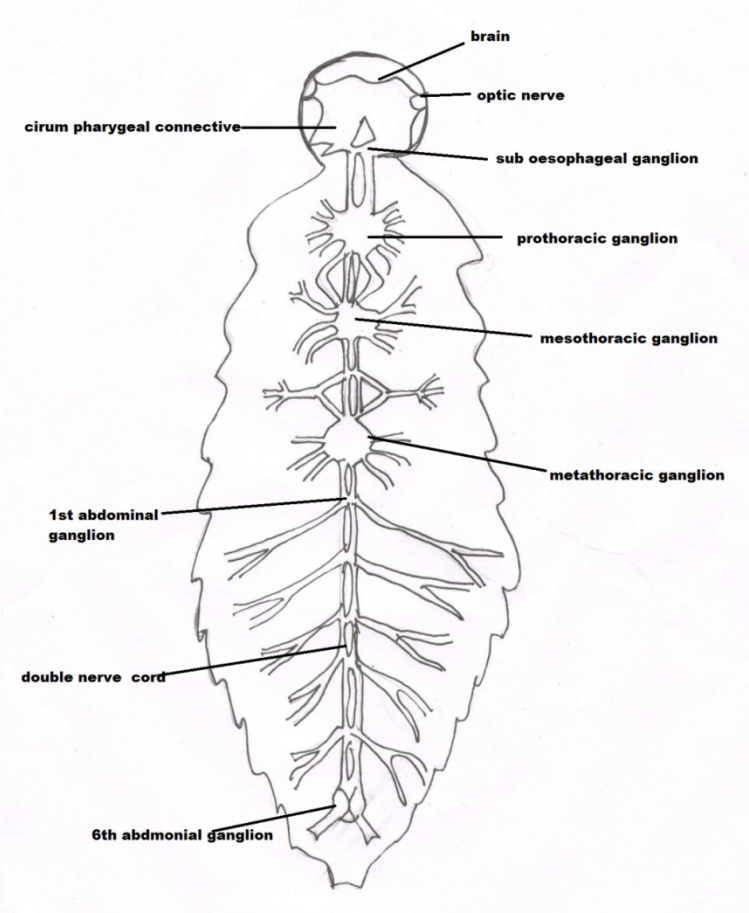

Fig 2: Nervous system of cockroach

18.2.3 Reproductive system of cockroach

1. Male reproductive system of cockroach

1. In cockroach, sexes are separate, so dioecious.
2. The **male reproductive system** of cockroach consists of a pair of testes. The testes lie on each lateral side in the 4th – 6th abdominal segments.
3. A thin vas deferens arises from each testis. It opens into ejaculatory duct through seminal vesicle. The ejaculatory duct opens into male gonopore which is situated ventral to anus. A typical mushroom-shaped gland is present in the 6th-7th abdominal segments. It is an accessory reproductive gland. Mushroom gland or utricular gland consists of two types of tubules, (a) the long slender tubules the utriculi majores of peripheral tubules and (b) short tubules, th**e** utriculi breviore**s,** making up of the major part of the gland.
4. Small seminal vesicles are also found associated with mushroom gland.

5. Male gonapophysis or phallomeres represent the external genitalia. These are made up of chitin. They are asymmetrical structures and surround the male gonopore. It has chitinous plates as right phellomere, left phallomere (largest) and ventral phellomere (smallest).
6. The sperms are stored in the seminal vesicles. The sperms are glued together in the form of bundles called spermatophores. Spermatophores are discharged during copulation.
7. Spermatophore has three layered wall inner layer secreted by utriculi majores; middle layer secreted by ejaculatory duct and outer layer secreted by phallic gland or conglobate gland.

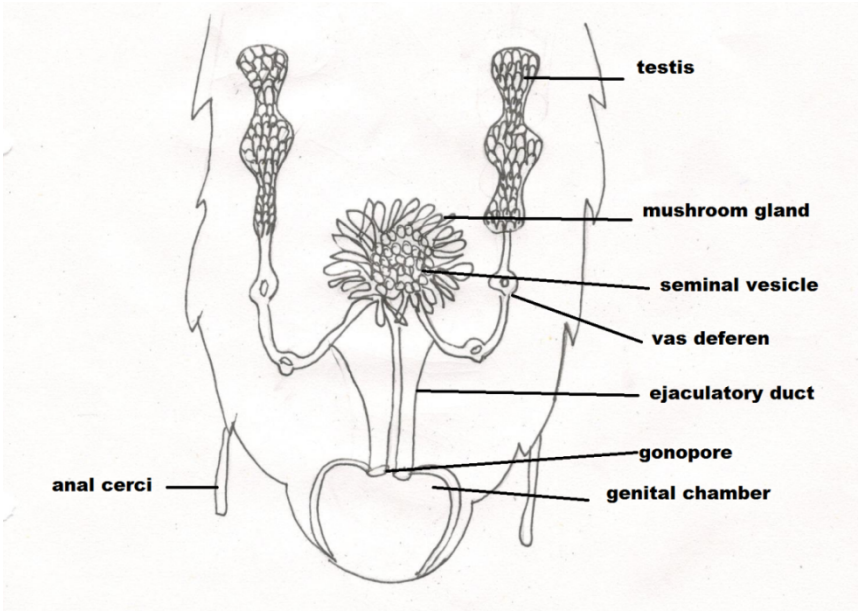

Fig 3: Male reproductive system of cockroach

2. Female reproductive system of female

1. The female reproductive system of cockroach consists of two large ovaries. The ovaries lie laterally in the 2nd – 6th abdominal segments. Each ovary is formed of a group of eight ovarian tubules or ovarioles.
2. They contain a chain of developing ova. Oviducts from each ovary unite into a single median oviduct. This is also called vagina and it opens into the genital chamber. A pair of spermatheca is present in the 6th segment which opens into the genital chamber.

3. Female organ consist of ovaries, oviduct, vagina, genital chamber, sperm thecae, colleterial glands and female ganopophysis (ovipositor processes). Ovaries of cockroach are located in the abdominal segments 2 to 6. Each ovary consists of eight ovarioles.
4. Two oviducts from each side open into a common oviduct or vagina which opens into genital chamber.
5. Pair of collaterial glands also opens in genital chamber.
6. Genital pouch or gynatrium is divisible into a genital chamber in front and oothecal chamber behind.
7. Female genitalia consist of 3 pairs of chitinous processes hanging from the roof of oothecal chamber into its cavity.
8. Ootheca of cockroach contains sixteen fertilized eggs. Ootheca of cockroach is formed of a protein secreted by collaterial glands.

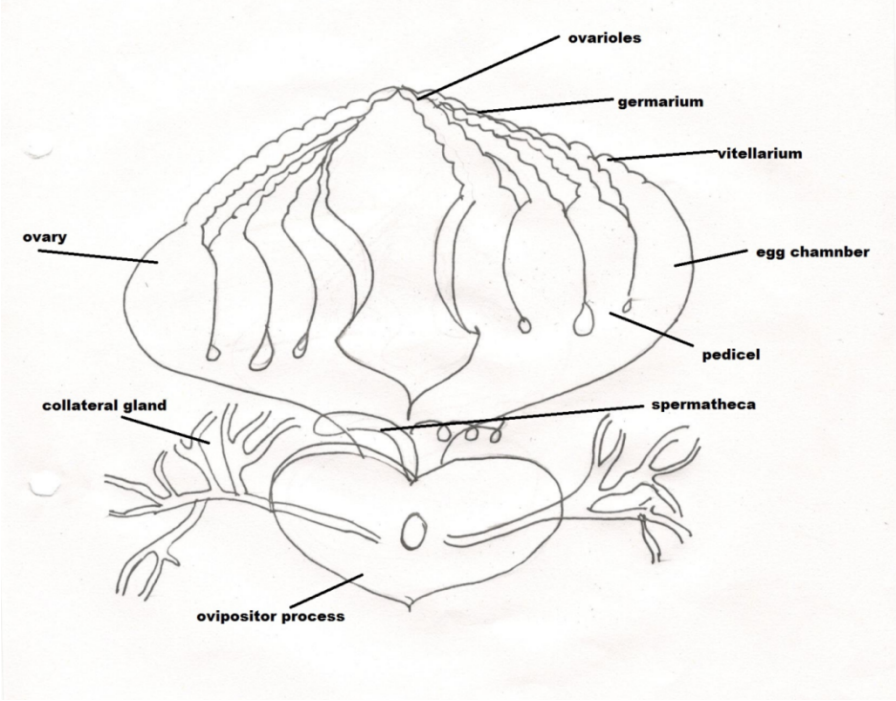

Fig 4: Female reproductive system of cockroach

18.3 Dissection of grasshopper

18.3.1 Alimentary canal of grasshopper

1. Grasshoppers have the typical insect body plan of head, thorax and abdomen. The head is held vertically, at an angle to the body with the mouth at the bottom.
2. The downward-directed mouthparts are modified for chewing and there are two sensory palps in front of the jaws.
3. The alimentary canal is divided into three main portions foregut, midgut and hindgut.
4. It consists of the mouth surrounded by the mouthparts. The mouth cavity is called the pharynx. It continues as the oesophagus that is short, narrow and thin-walled.
5. The canal then enlarges into crop which is also thin-walled. The crop opens into short, muscular organ, the gizzard or the proventriculus.
6. A pair of salivary gland lies outside and below the crop. Each salivary gland is branched, the secretions of all the branches pouring into a common duct. The two ducts, one of each side, open into the mouth cavity at the labium.
7. The entire foregut is lined with chitin. In the gizzard, the chitin (a polysaccharide forming the major constituent in the exoskeleton of arthropods and in the cell walls of fungi) forms teeth and plate to facilitate grinding of the food.
8. Midgut consists entirely of stomach or ventriculus. At the junction of the gizzard and stomach are six pairs of gastric caecae ('gastric' means pertaining to stomach). These are pouch-like structures arranged in a ring-like manner around the anterior end of the stomach. The anterior lobe of each pair of the caecae extends over the proventriculus and the posterior lobe extends over the ventriculus.
9. Hindgut is a coiled structure consisting of anterior ileum, middle colon and posterior rectum. The rectum opens to the exterior

through the anus. The hindgut is lined with cuticle. At the junction of the stomach and ileum are attached numerous long tubules called the Malpighian tubules.

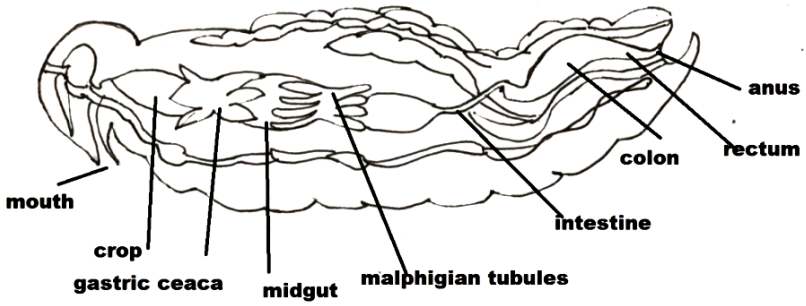

Fig 5:Alimentary canal of grasshopper

18.3.2 Nervous system of grasshopper

1. The nervous system of a grasshopper, like that of a human, can be divided into the peripheral nervous system and the central nervous system.
2. The peripheral nervous system consists of the *sensory* system, which tells the animal what's going on in its environment (internal as well as external), and the motor system, which carries the commands which control the muscles.
3. The central nervous system, which in humans consists of the brain and spinal cord, insect consists of the ventral nerve cord.
4. The ventral nerve cord, as its name suggests, is a cord of nervous tissue that runs the length of the animal in the lower part of its body.
5. Grasshoppers are segmented animals, and each segment is controlled by its own ganglion. A ganglion is a package of neurons, containing anything from a few dozen to hundreds of thousands of neurons.
6. The ganglia of each segment are joined to their adjacent ganglion by the interganglionic connectives (although some ganglia are fused directly together). Thus the ventral nerve cord consists of this chain of linked ganglia.
7. One of the advantages of studying the nervous systems of invertebrates is that they have far fewer neurons than vertebrates. Not only that, but in invertebrates such as grasshoppers, individual neurons can often be

recognized from animal to animal. This means that one can study the properties of single identified neurons, confident in the knowledge that you can visit the same homologous neuron time and again, in different individual animals.

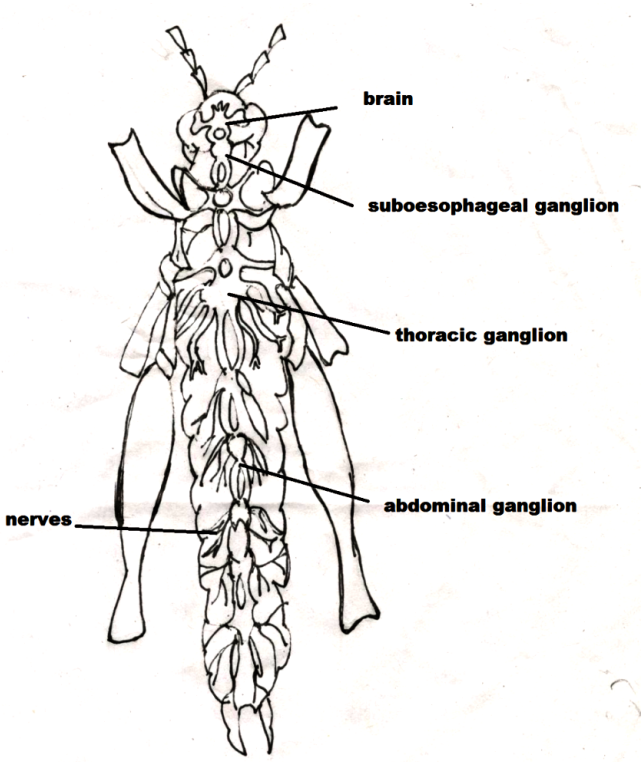

Fig 6: Nervous system of grasshopper

18.3.3 Reproductive system of grasshopper

1. The grasshopper's reproductive system consists of the gonads, the ducts which carry sexual products to the exterior and accessory glands.
2. In males, the testes consist of a number of follicles, which hold the spermatocytes as they mature and form packets of elongated spermatozoa.
3. After they are liberated in bundles, these spermatozoa accumulate in the vesicula seminalis (vas deferens).
4. During reproduction, the male grasshopper introduces sperm into the vagina through its aedeagus (reproductive organ), and inserts its spermatophore, a package containing the sperm, into the female's ovipositor

5. In females, each ovary consists of ovarioles. These converge upon the two oviducts, which unite to create a common oviduct which carries ripe eggs.
6. Each of the ovarioles consists of a germarium (a mass of cells that form oocytes, nurse cells, and follicular cells) and a series of follicles.
7. The nurse cells nourish the oocytes during early growth stages, and the follicular cells provide materials for the yolk and make the egg shell (chorion).
8. The female then lays the fertilized egg pod, using her ovipositor and abdomen to insert the eggs about one to two inches underground, although they can also be laid in plant roots or even manure. The egg pod contains several dozens of tightly-packed eggs that look like thin rice grains. The eggs stay there through the winter, and hatch when the weather has warmed sufficiently.
9. In temperate zones, many grasshoppers spend most of their life as eggs through the "cooler" months (up to nine months) and the active states (young and adult grasshoppers) live only up to three months.
10. The orthopteran courtship and mating behaviors are among some of the "most complex and fascinating spectacles in the insect world," involving sound production and visual, tactile, and olfactory signals.

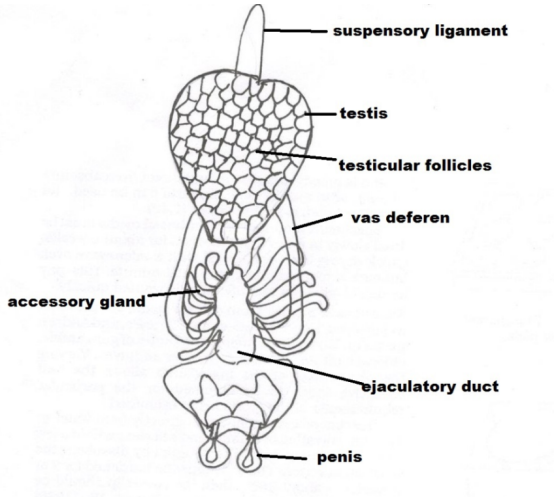

Fig 7: Male reproductive system of grasshopper

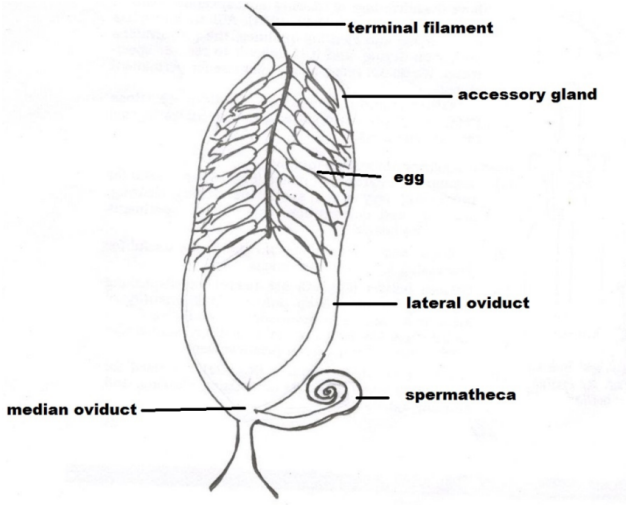

Fig 8: Female reproductive system of grasshopper

18.4 Dissection of Honey bee

18.4.1 Alimentary canal of honey bee

1. The honey bee digests its food and the nutrients extracted from that food is circulated by the bee's blood and used for energy and to build, maintain and repair the body.
2. The waste products as with all living things then need to be excreted from the bee's body. The alimentary system or canal and its associated glands are where the process of digestion and excretion take place.
3. The bee's alimentary canal starts with the bee's mouth which is situated between the base of the mandibles. Inside the mouth the canal expands into a cavity which is attached by muscles to the front of the bee's head.
4. The honey stomach has a valve at the end of it called the proventriculus which prevents the nectar from passing further, unless the bee needs some of it for its own use
5. the bee is a forager it will carry the nectar back to the hive in its honey stomach where it will regurgitate it back into its mouth and then pass it to other house bees for food or to store and turn into honey.
6. The proventriculus also acts as a sieve for the nectar in the honey stomach, sieving out solids, such as pollen grains and plant spores and even bacteria
7. The bee digests two types of food, protein mainly from the pollen and sugars from the nectar.

8. The residue of the digestive process is passed into the rectum where it is held as faeces until the bee can leave the hive and void itself. Bees never pass waste inside their hive except if they are seriously ill. The presence of waste matter inside the hive is usually an indication that the colony is not healthy.

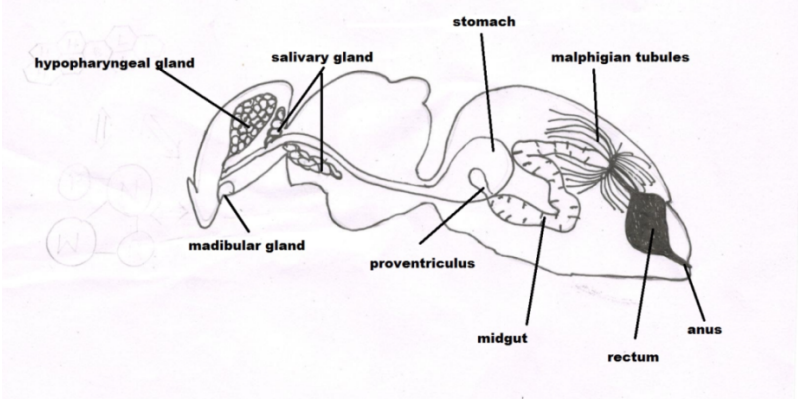

Fig 9: Alimentary canal of honey bee

18.4.2 Nervous system of honey bee

1. Honey bees like most insects not only have a brain in their head but several sub brains or *ganglia* (7 of these) spread throughout their bodies.
2. There are 2 ganglia in the thorax and 5 in the abdomen. Ganglia function independently but can be controlled or over written by instructions from the main brain. They also send feedback to the main brain about the state of the environment in their particular area.
3. Most locomotion is controlled by the ganglia, not the brain and in fact bee can move it's legs and wings vigorously
4. A bee will be able to walk and sting for a while when decapitated, but not fly as its balance will be out without a head.
5. An adult honey bee is one of the most advanced insects and is capable of a huge range of different complex behavior. Honey bees are capable of learning and have short-term memory.
6. In the worker bee the brain consists mainly of the optic lobes, with the central part acting as a coordinating centre and this central part is larger

than in most other insects. Nerve fibers connect the brain to the 2 ganglia in the thorax and the 5 in the abdomen.

7. Each ganglion has nerve fibres which connect it to sensory receptors on the outside of the body, to bring information back from the outside environment. The antennae are of course the main sites for sensory reception in the bee.
8. The ganglia also each have fibres which bring information about the condition of the internal organs of the bee and those which send back regulatory information. Fibres also carry information to the muscles to control their actions.

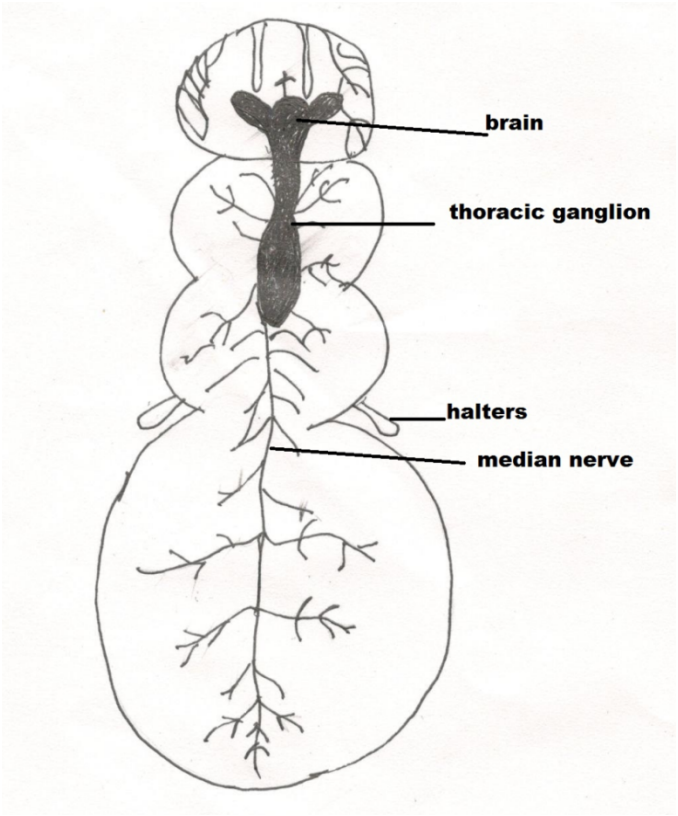

Fig 10: Nervous system of honey bee

18.4.3 Reproductive system of honey bee

1. Important structures in the honey bee reproductive system include the ovary and spermatheca. In the ovary of a laying queen, there are indivial ovarioles, with mature eggs appearing yellowish.
2. Egg cells move down the tube of ovarioles as they become larger and more mature, eventually reaching the oviduct and being laid out by the queen.

3. The spermatheca contains the sperm from the queen's single mating flight during a one week window around the age of 6-16 days. She will use this sperm to fertilize all the eggs produced in her lifetime.
4. The sperm inside can live up to 4 years. The spermatheca is covered with a rich network of trachea. Once removed, the spermatheca is a shiny, perfectly spherical organ. In un-mated queens, the spermatheca will be clear.
5. Queen breeders learning to use artificial insemination will sometimes check the spermetheca color in a sample of inseminated queens to see if their technique is working.
6. In order for one colony to survive, the queen must lay fertilized eggs to create worker bees, which forage for food and take care of the colony.
7. A honey bee queen has one mating flight and stores enough sperm during the mating flight to lay eggs throughout her life. When a queen can no longer lay eggs, new queens become responsible for mating and laying honey bee eggs.
8. Honey bee eggs measure 1 to 1.5 mm long, about half the size of a single grain of rice. When the queen lays her eggs, she moves through the comb, closely examining each cell before laying her eggs.
9. The process of laying one egg takes only a few seconds, and a queen is capable of laying up to 2,000 honey bee eggs within a single day.
10. A young queen lays her eggs using an organized pattern, placing each egg next to others within a cell. Queens begin laying their eggs in the center of the cell frame, so workers can place honey, royal jelly and other foods for larvae on the outer edges. However, as the queen ages, she lays fewer eggs in a less organized pattern.
11. When the queen lays a honey bee egg, it becomes attached to the cell by a mucous strand. During the first stage of development, the digestive system, nervous system and outer covering are formed. After three days, the eggs will hatch into larvae, which will be fed by worker honey bees with honey, royal jelly and other liquids from plants.
12. These honey bee larvae have no legs, eyes, antennae or wings; they resemble a grain of rice with a small mouth. They will eat and grow into adult workers, queens or drones.

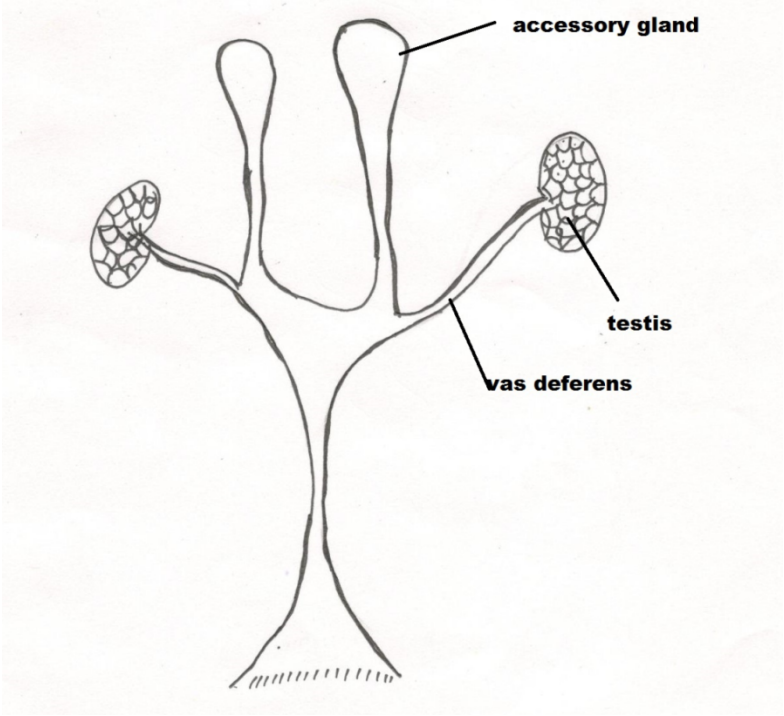

Fig 11: Reproductive system of male honey bee

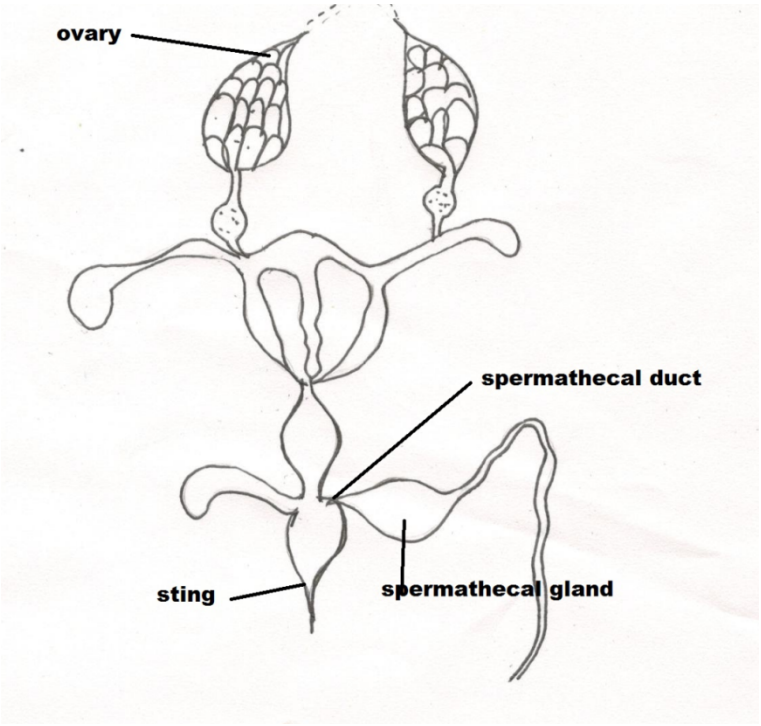

Fig 12: Reproductive system of female honey bee

18.5 Dissection of House fly

18.5.1 Alimentary canal of house fly

1. An insect uses its digestive system to extract nutrients and other substances from the food it consumes. Most of this food is ingested in the form of macromolecules and other complex substances (such as proteins, polysaccharides, fats, and nucleic acids) which must be broken down by catabolic reactions into smaller molecules (i.e. amino acids, simple sugars, etc.) before being used by cells of the body for energy, growth, or reproduction. This break-down process is known as digestion.
2. The insect's digestive system is a closed system, with one long enclosed coiled tube called the alimentary canal which runs lengthwise through the body.
3. The alimentary canal only allows food to enter the mouth, and then gets processed as it travels toward the anus. The insect alimentary canal has specific sections for grinding and food storage, enzyme production and nutrient absorption. Sphincters control the food and fluid movement between three regions.
4. The three regions include the foregut, stomatodeum the midget mesenteron, and the hindgut proctodeum.
5. In addition to the alimentary canal, insects also have paired salivary glands and salivary reservoirs. These structures usually reside in the thorax (adjacent to the fore-gut).
6. The salivary glands produce saliva, the salivary ducts lead from the glands to the reservoirs and then forward through the head to an opening called the salivarium behind the hypopharynx; which movements of the mouthparts help mix saliva with food in the buccal cavity. Saliva mixes with food which travels through salivary tubes into the mouth, beginning the process of breaking it down.
7. The stomatedeum and proctodeum are invaginations of the epidermis and are lined with cuticle (intima). The mesenteron is not lined with cuticle but with rapidly dividing and therefore constantly replaced, epithelial cells.
8. The cuticle sheds with every moult along with the exoskeleton. Food is moved down the gut by muscular contractions called peristalsis.
9. **Parts of digestive system**. **Stomatodeum** (foregut): This region stores, grinds and transports food to the next region. Included in this are the buccal

cavity, the pharynx, the oesophagus, the crop (stores food), and proventriculus or gizzard (grinds food). Salivary secretions from the labial glands dilute the ingested food.

10. **Mesenteron** (midgut): Digestive enzymes in this region are produced and secreted into the lumen and here nutrients are absorbed into the insect's body. Food is enveloped by this part of the gut as it arrives from the foregut by the peritrophic membrane which is amucopolysaccharide layer secreted from the midgut's epithelial cells. It is thought that this membrane prevents food pathogens from contacting the epithelium and attacking the insects' body. It also acts as a filter allowing small molecules through, but preventing large molecules and particles of food from reaching the midgut cells. After the large substances are broken down into smaller ones, digestion and consequent nutrient absorption takes place at the surface of the epithelium. Microscopic projections from the mid-gut wall, called microvilli, increase surface area and allow for maximum absorption of nutrients.
11. **Proctodeum** (hindgut): This is divided into three sections; the anterior is the ileum, the middle portion, the colon, and the wider, posterior section is the rectum. This extends from the pyloric valve which is located between the mid and the hindgut to the anus. Here absorption of water, salts and other beneficial substances take place before excretion. Like other animals, the removal of toxic metabolic waste requires water. However, for very small animals like insects, water conservation is a priority. Because of this, blind-ended ducts called Malpighian tubules come into play. These ducts emerge as evaginations at the anterior end of the hindgut and are the main organs of osmoregulation and excretion. These extract the waste products from the haemolymph, in which all the internal organs are bathed).
12. These tubules continually produce the insect's uric acid, which is transported to the hindgut, where important salts and water are re-absorbed by both the hindgut and rectum. Excrement is then voided as insoluble and non-toxic uric acid granules. Excretion and osmoregulation in insects are not orchestrated by the Malpighian tubules alone, but require a joint function of the ileum and/or rectum.

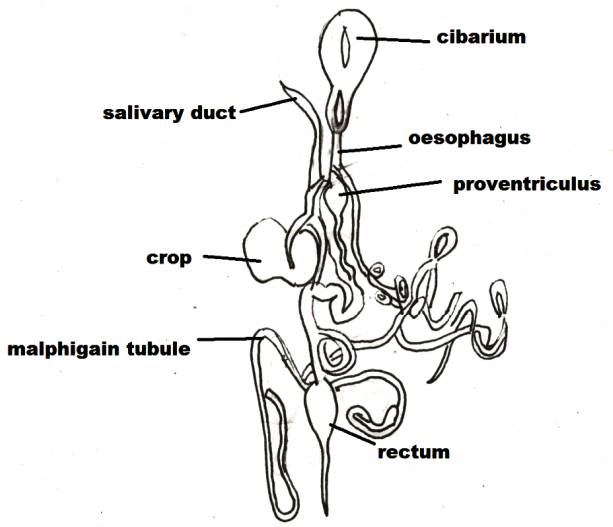

Fig 13: Alimentary canal of house fly

18.5.2 Nervous system of house fly

1. This species is always found in association with humans or the activities of humans.
2. Excessive fly populations are not only an irritant to farm workers but, when there are nearby human habitations, a public health problem could occur.
3. Insects have a complex nervous system which incorporates a variety of internal physiological information as well as external sensory information.
4. As for vertebrates, chemicals such as acetylcholine and dopamine) are released at synapses. An insect's sensory, motor and physiological processes are controlled by the central nervous system along with the endocrine system. Being the principal division of the nervous system, it consists of a brain, a ventral nerve cord and a sub-esophageal ganglion. This is connected to the brain by two nerves, extending around each side of the oesophagus.
5. The brain has three lobes **Protocerebrum**, innervating the compound eyes and the ocelli, **Deutocerebrum**, innervating the antennae and **Tritocerebrum**, innervating the foregut and the labrum.

6. The head capsule (made up of six fused segments) has six pairs of ganglia. The first three pairs are fused into the brain, while the three following pairs are fused into the sub-esophageal ganglion.
7. The thoracic segments have one ganglion on each side, which are connected into a pair, one pair per segment. This arrangement is also seen in the abdomen but only in the first eight segments.
8. Many species of insects have reduced numbers of ganglia due to fusion or reduction. Some cockroaches have just six ganglia in the abdomen, whereas the wasp *Vespa crabro* has only two in the thorax and three in the abdomen. And some, like the house fly *Musca domestica*, have all the body ganglia fused into a single large thoracic ganglion.
9. The ganglia o The ventral nerve cord extends from the suboesophageal ganglion posteriorly. A layer of connective tissue called the neurolemma covers the brain, ganglia, major peripheral nerves and ventral nerve cords. The central nervous system act as the coordinating centers with their own specific autonomy where each may coordinate impulses in specified regions of the insect's body.
10. Peripheral nervous system consists of motor neuron axons that branch out to the muscles from the ganglia of the central nervous system, parts of the sympathetic nervous system and the sensory neurons of the cuticular sense organs that receive chemical, thermal, mechanical or visual stimuli from the insects environment The sympathetic nervous system includes nerves and the ganglia that innervate the gut both posteriorly and anteriorly, some endocrine organs, the spiracles of the tracheal system and the reproductive organs.

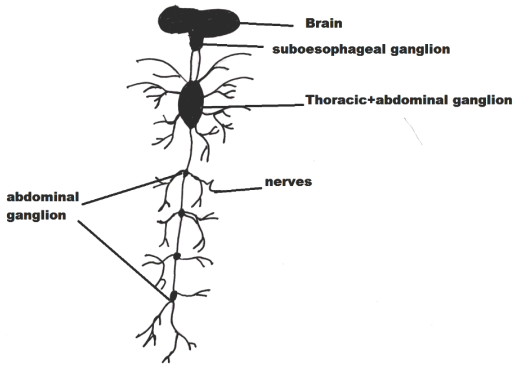

Fig 14: Nervous system of house fly

18.5.3 Reproductive systems of house fly

1. Most insects have a high reproductive rate. With a short generation time, they evolve faster and can adjust to environmental changes more rapidly than other slower breeding animals.
2. Although there are many forms of reproductive organs in insects, there remains a basic design and function for each reproductive part.
3. These individual parts may vary in shape (gonads), position (accessory gland attachment), and number (testicular and ovarian glands), with different insect groups.
4. The reproductive system of house fly is separate male and female system.

1. Male housefly reproductive system.

1. The male reproductive system of house fly reproductive system consists of testis, vas deferen and ejaculatory duct.
2. A pair of testis is present in the abdomen of male housefly.
3. They are present on each side of the ventral nerve cord and function to produce sperms.
4. Vas deferen are the two tubes or ducts that collect sperms from testis.
5. The two vas deferen are joined to form a single ejaculatory duct. It sends the sperms outside the body during sexual act.

2. Female housefly reproductive system

1. The female housefly reproductive system consists of (i) Ovaries (ii) Oviducts (iii) Female genital aperture.
2. There are a pair of ovaries present in the abdomen that produces ova.
3. Oviducts are a pair of tubes which collect ova from the ovaries and form median oviduct which opens outside in female genital aperture.
4. The oviducts open to the outside of the body through the female genital aperture.
5. Sac like structures called spermatheca collect sperms from the male housefly during sexual act.
6. A special organ called ovipositor helps in laying fertilized eggs.

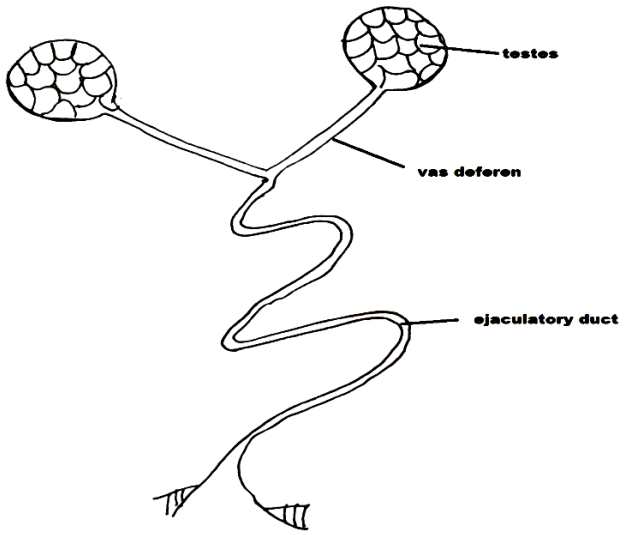

Fig 15: Male reproductive system of house fly

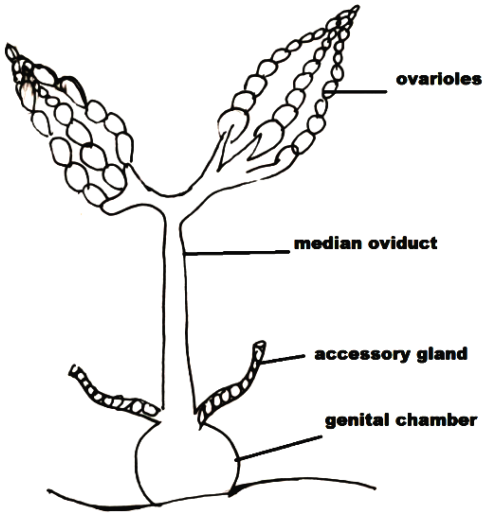

Fig 16: Female reproductive system of house fly

18.6 Self learning exercises

1. Dissect out Cockroach and expose its nervous system.
2. Dissect out grasshopper to expose its reproductive organs.
3. Dissect out honey bee to expose reproductive organs.

Unit-19

Insecticides

Structure of the Unit

19.0 Objectives

19.1 Introduction

- Insecticide
- Action and mechanism of Insecticide

19.2 Insecticide formulations

- Liquid formulations
  - Ready to use Low concentrate Solutions (RTU)
  - Ultra low Volume (ULV)
  - Emulsifiable Concentrates (EC or E)
  - Solutions (S)
  - Invert Emulsions -Flowables (F)/Liquids (L)
  - Aerosols (A)
  - Ready-to-use Aerosols
  - Formulations for Smoke or Fog Generators
  - Liquid Baits
- Solid Formulations
  - Dusts (D)
  - Tracking Powders
  - Baits (B)
  - Pastes, Gels, and Other Injectable Baits
  - Granules (G)
  - Pellets (P or PS)
  - Wettable Powders (WP or W)
  - Soluble Powders (SP or WSP)
  - Water-dispersible Granules (WDG) or Dry Flowables (DF)
- Other Formulations

- Common Abbreviations Used To Describe Insecticides Formulations
- Making up of formulation
- Training and equipment
- Formulation methods

19.3 Insecticide Label

19.4 Dilution of Insecticides

19.5 Precautions before Leaving Field and During Operation

19.6 Disposing of Leftover Insecticides

19.7 Insecticide Persistence

19.8 Appliances Used For the Application of Insecticide

- Insecticide Application Techniques
- Classification of Plant Protection Equipments
- Selection of Equipment
  - Sprayers
  - Dusters
  - Nozzles

19.9 Self learning exercises

19.10 References

19.0 Objectives

After going through this unit you will be able to understand the different methods of insecticide formulation and handling information, active ingredients, strengths and weaknesses of common types of insecticide formulations, know how to interpret common abbreviations used to describe formulations, insecticides are manufactured in different formulations, describes the benefits and disadvantages of different formulations, how can applicators work safely with each type of formulation, different types of sprayers and dusters.

19.1 Inroduction

Insecticide

Insecticides are formulated to be toxic to their specific targeted pests, whether they are insects, causing plant disease, or are weeds or other unwanted home and garden invaders. When they are used with precautions and properly way, the insecticides can protect ourselves, our plants, home from different types of damages. If the insecticide label instructions are not followed correctly, health hazards, plant injuries, ecological imbalances may occur, and pests may not be controlled and insecticides may contribute to soil, air, or water pollution. Therefore before purchasing and using any type of insecticide, we should learn each and everything about the material, formulation, dilution, method of its use and lastly the method to dispose off the empty containers properly.

Aninsecticide is any material used to control, prevent, kill, suppress, or repel pests. The legal definition of aninsecticide covers a broad range of substances like it includes insecticides (insect killers), herbicides (weed or plant killers), fungicides (fungus killers), herbicides, rodenticides (rodent killers), bactericides, baits, growth regulators, and other materials like miticides, which are used for mite control, or products that kill snails and slugs (molluscicides) andrepellents.etc.

Some external parasite treatments are also considered to be insecticides. Aninsecticide is any substance or mixture of substances used to destroy, suppress or alter the life cycle of any pest. Aninsecticide can be a naturally derived or synthetically or organically produced substance. Aninsecticide can also be an organism, for example, the bacterium *Bacillus thuringiensis* which is used to control a number of insect pests, or even a genetically modified crop. They are used in commercial, domestic, urban and rural environments. There are currently thousands of insecticide products registered for use in various regions of India.

Action & Mechanism of Insecticide

Insecticides control pest organisms by physically, chemically or biologically interfering with their metabolism or normal behaviour. Most insecticides are lethal to target pests when applied at the rate specified on the insecticide label. Some insecticides are non-lethal to the target pest. These include repellents or attractants (personal insect repellents), sterilizing agents (which interfere with the reproductive ability of a pest), some defoliants (that cause leaf drop without killing

the plant) and some insecticide products that boost the action of another insecticide without being particularly toxic themselves (such as piperonylbutoxide which may form part of pyrethrum-based insecticides).

The route that brings aninsecticide in contact with the target pest depends on the nature of the insecticide, how it is applied and the type of environment in which the insecticide is placed. Common application methods include spraying, fumigating and baiting. Many insecticides are 'contact' insecticides. This means to be effective they must be absorbed through the external body surface or the exposed plant tissue; for example, tetramethrin used in household fly sprays, and bipyridillium herbicides such as paraquat.

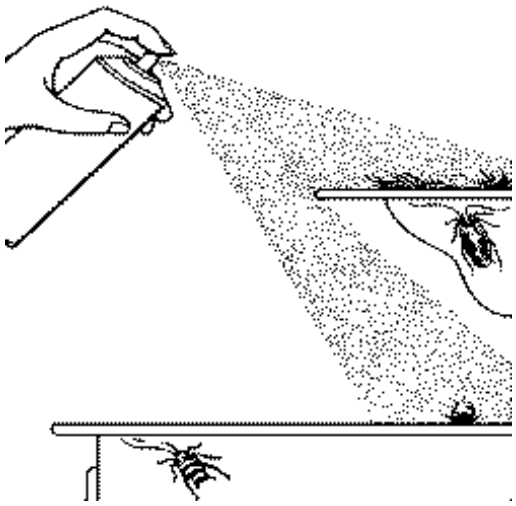

Figure -Contact insecticides have to reach their target directly to be effective.

Systemic insecticides can be translocated from the site of application to another site within the plant or animal where they become effective; for example, insecticides that are absorbed by foliage and translocated throughout the plant where they kill chewing or sucking insects.Similarly, blood anticoagulant rodenticides in baits take effect once they have been transferred from the digestive system to the bloodstream of rats or mice.

19.2 Insecticide Formulations

Aninsecticide formulation is a mixture of chemicals which effectively controls a pest. Formulating aninsecticide involves processing it to improve its storage, handling, safety, application, or effectiveness. Insecticide active ingredients in their

"raw" or unformulated state are not usually suitable for pest control. Manufacturers of insecticides mix in other ingredients to "formulate" the insecticide into a usable final product. Insecticide active ingredients by themselves may not mix well with water, may be chemically unstable, may be difficult to handle or store, and may be difficult to apply for good pest control. To make an active ingredient useful, manufacturers add other ingredients (sometimes called inert ingredients) to "formulate" the insecticide into the final product offered for sale.

INSECTICIDE FORMULATION = ACTIVE INGREDIENT + INERT INGRADIENT

An insecticide formulation may consist of:

- The insecticideactive ingredient (A.I.) that controls the target pest
- The carrier, such as an organic solvent or mineral clay
- Surface-active ingredients, such as stickers and spreaders
- Other ingredients, such as stabilizers, dyes, and chemicals that improve or enhance pesticidal activity.

The biological activity of aninsecticide, be it chemical or biological in nature, is determined by its active ingredient (AI) also termed as the active substance. Insecticide products very rarely consist of pure technical material. The AI is usually formulated with other materials and this is the product as sold, but it may be further diluted in use. Formulation improves the properties of a chemical for handling, storage, application and may substantially influence effectiveness and safety. Formulation terminology is represented by a 2-letter abbreviation: (for example - GR – granules,WP for wettable powders, List is given later on in this unit).

A single active ingredient may be sold in several formulations, how the insecticide is used (Example: TC for termiticide concentrate); or the characteristics of the formulation (Example: LO for a low-odor formulation). The amount of active ingredient and the kind of formulation are listed on the product label. For example, an 80 percent soluble powder (SP) contains 80 percent by weight of active ingredient. If it is packaged in a 10-pound bag, it contains 8 pounds of A.I. and 2 pounds of inert ingredient. Liquid formulations indicate the amount of A.I. in

pounds per gallon. In case if more than one formulations are available for our pest-control situation, in that case the best one formulation is used for particular task.

The ingredients in insecticide products come from many sources. Some, such as nicotine, pyrethrum, and rotenone, are extracted from plants. Others have a mineral origin like copper, sulfur), while a few are derived from microbes (Example: *Bacillus thuringiensis*). However, the vast majority of active ingredients are made in the laboratory. These synthetic active ingredients may have been designed by a chemist or discovered through a screening process examining chemicals generated by various industries. Regardless of their source, insecticide active ingredients have a range of solubility. Some dissolve readily in water while some only in oilsthis all depends upon the composition of particular insecticide. Some active ingredients may be relatively insoluble in either water or oil. Solubility characteristics and the intended use of the insecticide generally define which formulations best deliver the active ingredient.

As per the chemical terminology the different types of formulations are as follows.

1. **Solution**

   A solution results when a substance is dissolved in a liquid. The components of a true solution cannot be mechanically separated. Once mixed, a true solution does not require agitation to keep its various parts from settling. Solutions are frequently transparent.

2. **Suspension**

   A suspension is a mixture of finely divided, solid particles dispersed in a liquid. The solid particles do not dissolve in the liquid, and the mixture must be agitated to keep the particles evenly distributed. Most suspensions will have a cloudy, murky appearance. The label directs the user to shake well before using. Such products also form suspensions when mixed with water for application as a spray. Explicit label information describes the need for sufficient agitation to keep the solid particles of the product dispersed in the spray tank.

3. **Emulsion**

   An emulsion occurs when one liquid is dispersed (as droplets) in another liquid. Each liquid retains its original identity. Some degree of agitation

generally is required to keep the emulsion from separating. Emulsions usually have a milky appearance. The active ingredient is dissolved in an oil-based solvent. When the product is mixed with water, an emulsion (oil in water) is formed. An emulsifying agent (often called an emulsifier) formulated into the product helps prevent the emulsion from separating.

Figure - Various parts shown on the Insecticidebottle.

Today numerous types of formulations are in common use, these terms and processes leads to a greater understanding and appreciation of the advantages and disadvantages of many commonly used insecticide formulations.

Liquid formulations

Liquid formulations are generally mixed with water, but in some instances labels may permit the use of crop oil, diesel fuel, kerosene, or some other light oil as a carrier.

Readyto use Low concentrate Solutions (RTU)

Low-concentrate formulations are ready to use and in this type of formulation no dilution is required before application. They consist of a small amount of active ingredient (often 1 percent or less per unit volume) dissolved in an organic solvent. They are especially useful for structural and institutional pests and for household use. Major disadvantages of low-concentrate formulations include limited

availability and high cost per unit of active ingredient. Many organic solvents are harmful to foliage, so they often cannot be used as plant sprays.

Ultralow Volume (ULV)

These concentrates may approach 100 percent active ingredient. They are designed to be used as is or to be diluted with only small quantities of a specified carrier and are used at rates of no more than a half-gallon per acre. These special-purpose formulations are used mostly in outdoor applications, such as in agricultural, forestry, ornamental, and mosquito-control programs.

Advantages:

- Relatively easy to handle, transport, and store.
- Remain in solution; little agitation required.
- Not abrasive to equipment.
- Will not plug screens and nozzles.
- Leave little visible residue on treated surfaces.

Disadvantages:

- Difficult to keep insecticide on target—high drift hazard.
- Specialized equipment required.
- Easily absorbed through skin of humans or animals.
- Solvents may cause rubber or plastic hoses, gaskets, and pump parts and surfaces to deteriorate.
- Calibration and application must be done very carefully because of the high concentration of active ingredient.

Emulsifiable Concentrates (EC or E)

Usually an EC formulation contains a liquid active ingredient, one or more petroleum-based solvents (which give EC formulations their strong odor), and an agent that allows the formulation to be mixed with water to form an emulsion. ECs are among the most versatile formulations. They are used against agricultural, ornamental and turf, forestry, structural, food processing, livestock, and public health pests. They are adaptable to many types of application equipment, from

small, portable sprayers to hydraulic sprayers, low-volume ground sprayers, mist blowers, and low-volume aircraft sprayers.

Advantages:

- It is easy to handle, transport, and store.
- There is a need of little agitation because it will not settle out or separate when equipment is running.
- This is not abrasive.
- Another property of this type of formulation is that this will not plug screens or nozzles.
- Little visible residue on treated surfaces.

Disadvantages:

- High A.I. concentration makes it easy to overdose or underdose through mixing or calibration errors.
- May cause damage to desirable plants (phytotoxicity).
- Easily absorbed through skin of humans or animals.
- Solvents may cause rubber or plastic hoses, gaskets, and pump parts and surfaces to deteriorate.
- EC may cause pitting or discoloration of painted finishes.
- Flammable—should be used and stored away from heat or open flame.
- This may be corrosive.

Solutions (S)

Some insecticide active ingredients dissolve readily in a liquid carrier such as water or a petroleum-based solvent. When mixed with the carrier, they form a solution that does not settle out or separate. Formulations of these insecticides usually contain the active ingredient, the carrier, and one or more other ingredients. Solutions may be used in any type of sprayer, indoors or outdoors.

Invert Emulsions

Flowables (F)/Liquids (L)

A flowable or liquid formulation combines many of the characteristics of emulsifiable concentrates and wettable powders. Manufacturers use these formulations when the active ingredient is a solid that does not dissolve in either water or oil. The active ingredient, impregnated on a substance such as clay, is ground to a very fine powder. The powder is then suspended in a small amount of liquid. The resulting liquid product is quite thick. Flowables and liquids share many of the features of emulsifiable concentrates, and they have similar disadvantages. They require moderate agitation to keep them in suspension and leave visible residues, similar to those of wettable powders. Flowables/liquids are easy to handle and apply. Because they are liquids, they are subject to spilling and splashing. They contain solid particles, so they contribute to abrasive wear of nozzles and pumps. Flowable and liquid suspensions settle out in their containers. Always shake them thoroughly before pouring and mixing. Because flowable and liquid formulations tend to settle, manufacturers package them in containers of five gallons or less to make remixing easier.

Aerosols (A)

These formulations contain one or more active ingredients and a solvent. Most aerosols contain a low percentage of active ingredients. There are two types of aerosol formulations—the ready-to-use type commonly available in pressurized sealed containers and those products used inelectrical or gasoline-powered aerosol generators that release the formulation as a “smoke” or “fog.”

Ready-to-use Aerosols

These formulations are usually small, self-contained units that release the insecticide when the nozzle valve is triggered. The insecticide is driven through a fine opening by an inert gas under pressure, creating fine droplets. These products are used in greenhouses, in small areas inside buildings, or in localized outdoor areas. Commercial models, which hold five to 5 pounds of insecticide, are usually refillable.

Advantages:

- Ready to use.
- Portable.
- Easily stored.

- Convenient way to buy a small amount of ainsecticide.
- Retain potency over fairly long time.

Disadvantages:

- Practical for only very limited uses.
- Risk of inhalation injury.
- Hazardous if punctured, overheated, or used near an open flame.
- Difficult to confine to target site or pest.

Formulations for Smoke or Fog Generators

These aerosol formulations are not under pressure. They are used in machines that break the liquid formulation into a fine mist or fog (aerosol) using a rapidly whirling disk or heated surface. These formulations are used mainly for insect control in structures such as greenhouses and warehouses and for mosquito and biting fly control outdoors.

Advantages:

- Easy way to fill entire enclosed space with insecticide.

Disadvantages:

- Highly specialized use and equipment.
- Difficult to confine to target site or pest.
- May require respiratory protection to prevent risk of inhalation injury.

Liquid Baits - effective in controlling rodents, especially rats, in areas where they cannot find water. They are also effective in areas of poor sanitation where ready availability of food renders traditional baits ineffective. Liquid baits also must be frequently replaced. Dry or Solid Formulations

Dry formulations can be divided into two types: ready-to-use and concentrates that must be mixed with water to be applied as a spray.

Solid formulations

Dusts (D)

Most dust formulations are ready to use and contain a low percentage of active ingredients (usually 10 percent or less by weight), plus a very fine, dry inert carrier made from talc, chalk, clay, nut hulls, or volcanic ash. The size of individual dust particles varies. A few dust formulations are concentrates and contain a high percentage of active ingredients. Mix these with dry inert carriers before applying. Dusts are always used dry and can easily drift to non-target sites. They are used as seed treatments and sometimes for agricultural or home gardening applications. In structures, dust formulations are used in cracks and crevices and for spot treatments to control insects such as cockroaches. Insects ingest poisonous dusts during grooming or absorb the dusts through their outer body covering. Dusts also are used to control lice, fleas, and other parasites on pets and livestock.

Advantages:

- Most are ready to use, with no mixing.
- Effective where moisture from a spray might cause damage.
- Require simple equipment.
- Effective in hard-to-reach indoor areas

Disadvantages:

- Easily drift off-target during application.
- Residue easily moved off-target by air movement or water.
- May irritate eyes, nose, throat, and skin.
- Will not stick to surfaces as well as liquids.
- Dampness can cause clogging and lumping.
- Difficult to get an even distribution of particles on surfaces.

Tracking Powders

Special dusts known as tracking powders are used for rodent and insect monitoring and control. For rodent control, the tracking powder consists of finely ground dust combined with a stomach poison. Rodents walk through the dust, pick it up on their feet and fur, and ingest it when they clean themselves. Tracking powders are useful when bait acceptance is poor because of an abundant, readily available food supply. Non-toxic powders, such as talc or flour, often are used to monitor and track the activity of rodents in buildings.

Baits (B)

A bait formulation is an active ingredient mixed with food or another attractive substance. The bait either attracts the pests or is placed where the pests will find it. Pests are killed by eating the bait that contains the insecticide. The amount of active ingredient in most bait formulations is quite low, usually less than 5 percent. Baits are used inside buildings to control ants, roaches, flies, other insects, and rodents. Outdoors, they sometimes are used to control snails, slugs, and insects such as ants and termites. Their main use is for control of vertebrate pests such as rodents, other mammals, and birds.

Advantages:

- Ready to use.
- Entire area need not be covered, because pest goes to bait.
- Controls pests that move in and out of an area.

Disadvantages:

- Can be attractive to children and pets.
- May kill domestic animals and non-target wildlife outdoors.
- Pest may prefer the crop or other food to the bait.
- Dead vertebrate pests may cause odor problems.
- Other animals may be poisoned as a result of feeding on the poisoned pests.

If baits are not removed when the insecticide becomes ineffective, they may serve as a food supply for the target pest or other pests.

Pastes, Gels, and Other Injectable Baits

Pastes and gels are mainly used in the pest-control industry for ants and cockroaches. Insecticides formulated as pastes and gels are now the primary formulations used in cockroach control. They are designed to be injected or placed as either a bead or dot inside small cracks and crevices of building elements where insects tend to hide or travel. Two basic types of tools are used to apply pastes and gelssyringes and bait guns. The applicator forces the bait out of the tip of the device by applying pressure to a plunger or trigger.

Advantages:

- They are odorless, produce no vapors, have low human toxicity, and last for long periods.
- Applicator exposure is minimal.
- Hidden placements minimize human and pet exposure.
- Very accurate in their placement and dosage.
- Easily placed in insect harborage for maximum effectiveness.

Disadvantages:

- Can become contaminated from exposure to other insecticides and cleaning products.
- When exposed to high temperatures, gels can run and drip.
- May stain porous surfaces.
- Repeated applications can cause an unsightly buildup of bait.

Granules (G)

Granular formulations are similar to dust formulations, except granular particles are larger and heavier. The coarse particles are made from materials such as clay, corncobs, or walnut shells. The active ingredient either coats the outside of the granules or is absorbed into them. The amount of active ingredient is relatively low, usually ranging from 1 to 15 percent by weight. Granular insecticides are most often used to apply chemicals to the soil to control weeds, nematodes, and insects living in the soil, or for absorption into plants through the roots. Granular formulations are sometimes applied by airplane or helicopter to minimize drift or to penetrate dense vegetation. Once applied, granules release the active ingredient slowly. Some granules require soil moisture to release the active ingredient. Granular formulations also are used to control larval mosquitoes and other aquatic pests. Granules are used in agricultural,structural, ornamental, turf, aquatic, right-of-way, and public health (biting insect) pest-control operations.

Advantages:

- Ready to use—no mixing.
- Drift hazard is low, and particles settle quickly.

- Little hazard to applicator—no spray, little dust.
- Weight carries the formulation through foliage to soil or water target.
- Simple application equipment needed, such as seeders or fertilizer spreaders.

May break down more slowly than WPs or ECs because of a slow-release coating.

Disadvantages:

- Often difficult to calibrate equipment and apply uniformly.
- Will not stick to foliage or other uneven surfaces.
- May need to be incorporated into soil or planting medium.
- May need moisture to activate insecticide.
- May be hazardous to non-target species, especially waterfowl and other birds that mistakenly feed on the seed-like granules.
- May not be effective under drought conditions; the active ingredient is not released in sufficient quantity to control the pest.

Pellets (P or PS)

Most pellet formulations are very similar to granular formulations; the terms are used interchangeably. In a pellet formulation, however, all the particles are the same weight and shape. The uniformity of the particles allows use with precision application equipment. A few fumigants are formulated as pellets. However, these are clearly labeled as fumigants. Do not confuse them with non-fumigant pellets.

Wettable Powders (WP or W)

Wettable powders are dry, finely ground formulations that look like dusts. They usually must be mixed with water for application as a spray. A few products, however, may be applied either as a dust or as a wettable powder—the choice is left to the applicator. Wettable powders contain 5 to 95 percent active ingredient by weight; usually 50 percent or more. The particles do not dissolve in water. They settle out quickly unless constantly agitated to keep them suspended. They can be used for most pest problems and in most types of spray equipment where agitation is possible. Wettable powders have excellent residual activity. Because of their

physical properties, most of the insecticide remains on the surface of treated porous materials such as concrete, plaster, and untreated wood. In such cases, only the water penetrates the material.

Advantages:

- Easy to store, transport, and handle.
- Less likely than ECs and other petroleum-based insecticides to cause unwanted harm to treated plants, animals, and surfaces.
- Easily measured and mixed.
- Less skin and eye absorption than ECs and other liquid formulations.

Disadvantages:

- Inhalation hazard to applicator while measuring and mixing the concentrated powder.
- Requires good and constant agitation (usually mechanical) in the spray tank and quickly settles out if the agitator is turned off.
- Abrasive to many types of pumps and nozzles, causing them to wear out quickly.
- Difficult to mix in very hard, alkaline water.
- Often clog nozzles and screens.
- Residues may be visible on treated surfaces.

Soluble Powders (SP or WSP)

Soluble powder formulations look like wettable powders. However, when mixed with water, soluble powders dissolve readily and form a true solution. After they are mixed thoroughly, no additional agitation is necessary. The amount of active ingredient in soluble powders ranges from 15 to 95 percent by weight; it usually is more than 50 percent. Soluble powders have all the advantages of wettable powders and none of the disadvantages, except the inhalation hazard during mixing. Few insecticides are available in this formulation because few active ingredients are readily soluble in water.

Water-dispersible Granules (WDG) or Dry Flowables (DF)

Water-dispersible granules, also known as dry flowables, are like wettable powders, except instead of being dust-like, they are formulated as small, easily measured granules. Water- dispersible granules must be mixed with water to be applied. Once in water, the granules break apart into fine particles similar to wettable powders. The formulation requires constant agitation to keep it suspended in water. The percentage of active ingredient is high, often as much as 90 percent by weight. Water- dispersible granules share many of the same advantages and disadvantages of wettable powders, except they are more easily measured and mixed. Because of low dust, they cause less inhalation hazard to the applicator during handling.

Other Formulations

Other formulations include chemicals that cannot be clearly classified as liquid or as dry/solid insecticide formulations.

Microencapsulated Materials

Manufacturers cover liquid or dry insecticide particles in a plastic coating to produce a microencapsulated formulation. Microencapsulated insecticides are mixed with water and sprayed in the same manner as other sprayable formulations. After spraying, the plastic coating breaks down and slowly releases the active ingredient. Microencapsulated materials have several advantages:

- Highly toxic materials are safer for applicators to mix and apply.
- Delayed or slow release of the active ingredient prolongs its effectiveness, allowing for fewer and less precisely timed applications.
- The insecticide volatilizes slowly; less is lost from the application site, allowing for greater effectiveness.
- These formulations often reduce injury to plants.

Microencapsulated materials, however, pose a special hazard to bees. Foraging bees may carry microencapsulated materials back to their hives because they are about the same size as pollen grains. As the capsules break down, they release the insecticide, poisoning the adults and brood. Breakdown of the microencapsulated materials to release the insecticide sometimes depends on weather conditions. Under certain conditions, the microencapsulated materials may break down more

slowly than expected. This could leave higher residues of insecticide active ingredient in treated areas beyond normal restricted-entry or harvest intervals with the potential to injure fieldworkers. For this reason, regulations require long restricted-entry intervals for some microencapsulated formulations.

Water-soluble Packets

Water-soluble packets reduce the mixing and handling hazards of some highly toxic insecticides. Manufacturers package precise amounts of wettable powder or soluble powder formulations in a special type of plastic bag. When you drop these bags into a filled spray tank, they dissolve and release their contents to mix with the water. There are no risks of inhaling or contacting the undiluted insecticide as long as you do not open the packets. Once mixed with water, insecticides packaged in water-soluble packets are no safer than other tank mixtures.

Attractants

Attractants include pheromones, a chemical that is secreted by an animal, especially an insect, which influences the behavior or development of others of the same species. Other attractants are sugar and protein hydrolysate syrups, yeasts, and rotting meat. Pest managers use these attractants in sticky traps and capture bags. Attractants also can be combined with insecticides and sprayed onto foliage or other items in the treatment area.

Impregnates

Formulators may impregnate (saturate) fertilizers and other materials with ainsecticide. Such materials must be handled as insecticides and their use must follow all insecticide laws, regulationsand safety and environmental requirements. Some materials are impregnated in ways that allow the insecticides to evaporate over time so the vapors provide control of nearby pests. These types of insecticide impregnated products include pet collars, livestock ear tags, adhesive tapes, and plastic pest strips. Some paints and wood finishes have insecticides incorporated into them to kill insects or retard fungal growth.

Repellents

Various types of insect repellents are available in aerosol and lotion formulations. People apply these to their skin or clothing or to plant foliage to repel biting and nuisance insects. You can mix other types of repellents with water and spray them

onto ornamental plants and agricultural crops to prevent damage from deer, dogs, and other animals.

Animal Systemics

Systemic insecticides protect animals against fleas and other external blood-feeding insects as well as against worms and other internal parasites. A systemic animal insecticide is one that is absorbed and moves within the animal. These insecticides enter the animal's tissues after being applied orally or externally. Oral applications include food additives and premeasured capsules and liquids. External applications involve pour- on liquids, liquid sprays, and dusts. Most animal systemics are used under the supervision of veterinarians.

Fumigants

Fumigants are insecticides that form a gas when applied. Some active ingredients are liquids when packaged under high pressure and change to gases when they are released. Other active ingredients are volatile liquids when enclosed in an ordinary container and therefore are not formulated under pressure. Others are solids that release gases when applied under conditions of high humidity or in the presence of water vapor. Fumigants are used for structural pest control, in food and grain storage facilities, and in regulatory pest control at ports of entry and at state and national borders. In agricultural pest control, fumigants are used in soil, greenhouses, granaries, and grain bins.

Advantages:

- Toxic to a wide range of pests.
- Can penetrate cracks, crevices, wood, and tightly packed areas such as soil or stored grains.
- Single treatment usually kills most pests in treated area.

Disadvantages:

- The target site must be enclosed or covered to prevent the gas from escaping.
- Non-specific—highly toxic to humans and all other organisms.
- Require the use of specialized protective equipment, including respirators specifically approved for use with fumigants.

COMMON ABBREVIATIONS USED TO DESCRIBE INSECTICIDES FORMULATIONS

- A – Aerosol
- AF – Aqueous flowable
- AS – Aqueous solution or aqueous suspension B – Bait
- C – Concentrate
- CM – Concentrate mixture
- CG – Concentrate granules
- D – Dust
- DF – Dry flowables
- DS – Soluble dust
- E – Emulsifiable concentrate
- EC – Emulsifiable concentrate
- F – Flowable (liquid)
- G – Granules
- GL – Gel
- L – Liquid (flowable)
- LC – Liquid concentrate or low concentrate
- LV – Low volatile
- M – Microencapsulated MTF – Multiple temperature formulation
- P – Pellets
- PS – Pellets
- RTU – Ready-to-use S – Solution
- SD – Soluble dust SG – Soluble granule SP – Soluble powder or soluble packet ULV – Ultra low volume
- ULW – Ultra low weight or ultra lowwettable
- W – Wettable powder WDG – Water-dispersible granules WP – Wettable powder

- WS – Water soluble WSG – Water-soluble granules
- WSL – Water-soluble liquid
- WSP – Water-soluble powder or water-soluble packet

Making up of formulation

The insecticide formulation is a mixture of active and other ingredients (previously called inert ingredients). An active ingredient is a substance that prevents, kills, or repels a pest or acts as a plant regulator, desiccant, defoliant, synergist, or nitrogen stabilizer. Insecticides come in many different formulations due to variations in the active ingredient's solubility, ability to control the pest, and ease of handling and transport.

Synergists are a type of active ingredient that are sometimes added to formulations. They enhance another active ingredient's ability to kill the pest while using the minimum amount of active ingredient, but do not themselves possess pesticidal properties. For example, insecticides containing the active ingredient pyrethrins often contain piperonylbutoxide or n-octylbicycloheptanedicarboximide as a synergist.

Other (or inert) ingredients may aid in the application of the active ingredient. Other ingredients can be solvents, carriers, adjuvants, or any other compound, besides the active ingredient, which is intentionally added. There are many types of other ingredients: solvents are liquids that dissolve the active ingredient, carriers are liquids or solid chemicals that are added to a insecticide product to aid in the delivery of the active ingredient, and adjuvants often help make the insecticide stick to or spread out on the application surface (i.e., leaves). Other adjuvants aid in the mixing of some formulations when they are diluted for application.

Training and equipment

Many insecticide products that the public purchases and uses are ready-to-use (RTU) formulations which require no dilution and can be applied quickly and conveniently. Examples of ready-to-use formulations used by homeowners are granules for insect and weed control and baits for rodent control.

Many of the formulations used by farmers and commercial applicators (like pest control companies) need to be applied with certain equipment. These formulations may also require certification or training for individuals performing the

application. For example, termiticide applicators may be required by the Department of Agriculture in each state to complete specific training in the use of termiticides. Some liquid insecticide formulations commonly used by farmers and commercial applicators are applied with a compressed air sprayer, fogger, or soil injector. Other liquid insecticide formulations used by farmers may require the use of aircraft, low pressure boom sprayer, high-pressure sprayer, or ultra-low-volume sprayer.

Formulation methods

The insecticide formulation is a mixture of active and other ingredients (inert ingredients). An active ingredient is a substance that prevents, kills, or repels a pest or acts as a plant regulator, desiccant, defoliant, synergist, or nitrogen stabilizer. Insecticides come in many different formulations due to variations in the active ingredient's solubility, ability to control the pest, and ease of handling and transport.

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19.3 Insecticide Label

The label on the insecticide container is an essential and important source of information about the insecticide. We must read the label, before using a insecticide so that can be alert during its use. Precautionary measures should be

written on label during use of the insecticide. The product does not mentioning complete information on the label should not be purchased. Before purchasing any type of insecticide, the label should be checked:

- Be aware about the chemical composition or particular type of plant or site we plan to treat should listed.
- Clear description should be given in Label that whether it is for use on edible plants or ornamental plants.
- Insecticides should be labelled whether they are used in outdoor or indoor?
- Sometimes insecticides can seriously damage some plants therefore read the label properly to prevent any plant injury.

Figure - Reading the labeling is a necessity for any formulation.

Important information regarding the insecticide can be found on the product's label. The label is a legal document required for every insecticide registered in the India. Always keep the product in the original package. Some of the information that is contained on the label includes:

- Trade name or brand name
- Active ingredients and their percentage by weight
- Types of plants or sites where insecticide may be used
- Pests targeted
- How much to use
- How and when to apply

- Required protective clothing and equipment
- Signal word defining short-term toxicity to people (DANGER, WARNING, or CAUTION)
- Precautionary statements defining hazards to people, domestic animals, or the environment
- Emergency and first aid measures to take if someone has been exposed
- How to properly store and dispose of the insecticide and empty containers

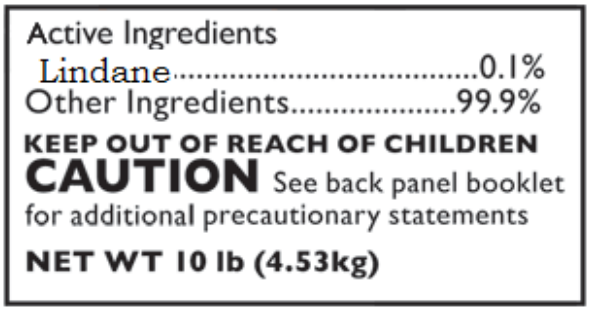


Figure -Always read the insecticide label

19.4 Dilution of Insecticides

Insecticides purchased for spraying programs will come in the form of insecticide concentrate. This concentrate is very strong and must be diluted before use by mixing a small volume (amount) of the insecticide with a larger volume of water. It is necessary to work out how much of the concentrate will be needed for the spraying job and how much water it must be mixed with. Only enough insecticide solution to fill the sprayer should be mixed at any one time.

This dilution exercise should be carried out carefully because the insecticide chemical is dangerous. Properly measuring concentrated formulations of insecticides is essential for their effective and safe use. The application rate for most insecticides and fungicides is given on the label in ounces per gallon of water used in the spray applicator. It is essential that we follow these procedures properly and dilute and apply materials as required. For herbicides and some uses of insecticides and fungicides, the label will indicate the amount of insecticide to use for a given area. In these cases, we'll need to measure the area we are treating to calculate how much to mix up.

If the label specifies a dilution rate, we need to follow the label directions precisely. Before mixing up our insecticide, test out our sprayer with water to assure us will cover the recommended area with the recommended amount of diluted spray. If not, we will need to adjust our application rate accordingly by walking or spraying slower or faster.

Insecticide directions for fruit or ornamental trees often don't specify areas in square feet to be treated. If wet plants to dripping point, thoroughly cover both sides of leaves. For these applications or for spot treatments, it is also a good idea to test out our sprayer with water to see how much spray we need to cover a fruit or oa5rnamental tree or other area. That way we'll know how much product to mix up. Never use more than what the directions recommend. The pest will not be controlled any faster and we will be wasting the insecticide, our time, and money while potentially causing plant injury and contaminating the environment with excess chemicals. Mix up only as much as we need immediately; don't store leftover insecticide solutions. They may be susceptible to quality changes at high or very low temperatures or by settling out.

These are the rules which should always be followed when diluting insecticide concentrates:

- Always work in the open and avoid breathing the fumes.
- Read the label and put on the appropriate protective equipment as indicated.
- Depending upon the type of insecticide it may be appropriate to wear a respirator. Mix water and concentrate in a large clean container, such as a 10 L bucket. This container and any measuring cups must be used only for this purpose. They should be clearly labelled ‘DANGER - POISON: DO NOT TOUCH’. When they are not being used they should be stored safely in the equipment shed.
- Put a small amount of water into the bucket first. Place the required amount of insecticide into the water.
- Rinse the measuring cup with clean water and add this solution to the bucket. Stir it so that it is thoroughly mixed into the water. Pour this solution into the sprayer tank and then add the rest of the water to the tank. Make sure this water is well mixed into the insecticide solution.

- Stir the solution carefully with a flat paddle (stirrer) and avoid splashing. The safest paddles are made of plastic, aluminum or steel because these materials are impervious. This means the insecticide cannot soak into them. They can be washed and used again. Wooden paddles soak up the insecticide and must be disposed of immediately after use. This must be done with extreme care. It is best to bury them along with the empty insecticide containers.

19.5 Precautions before Leaving Field and During Operation

- Individuals who apply, handle, transport, or dispose of insecticides should know the proper manner in which to deal with them. Safety gear is important to minimize potential exposure to insecticides during an application. An applicator's proper personal protective equipment (PPE) may include a long sleeve shirt, pants, closed-toe shoes, chemically resistant rubber gloves, a respirator, and/or eye protection. The equipment required for an application will be listed on the label.
- In addition to the safety of those working with insecticides, the safety of people, pets, and the environment near the site of application need to be taken into account.[7]To facilitate this, the label often has precautionary statements to protect wildlife and other non-target species.
- Applicator will use such methods for minimizing environmental contamination. Use spot treatments where the pest is most prevalent; avoid widespread applications of the insecticide throughout garden or home. For spot treatments, mix the insecticide according to label instructions, and apply the mixture only to the affected area. Bait stations for ants, wick or shielded applicators for some herbicides, and tree trunk treatments for certain insects are other ways of limiting environmental exposure.
- Also avoid applying insecticides to hard surfaces such as sidewalks, driveways, and foundations, because they can easily be washed off and go into storm drains. Follow the guidelines below for protecting environmental quality and keeping insecticides out of our waterways.
- It is very important to keep check that insecticides applied should not move off target by drifting in the air or washing off into storm drains or creeks.

- Be aware of weather patterns and do not apply insecticides just prior to rainfall or during windy conditions.
- Avoid applying insecticides to hard surfaces such as sidewalks or driveways, where they can easily be washed off.
- Check insecticide labels for warnings regarding use near bodies of water such as streams, rivers, and lakes.
- Never dispose of insecticides in storm drains, sinks, or toilets.
- Under no circumstances should pest control equipment be cleaned in a location where rinse water could flow into gutters, storm drains, or open waterways.
- Never apply more than the rate listed on ainsecticide label.
- Be aware that some insecticides are more easily carried in surface runoff than others and therefore have a greater potential to move off site during irrigation or storms. The leaching and runoff risks of specific

19.6 Disposing of Leftover Insecticides

Try to purchase only as much insecticide as we will use in the immediate future. This will eliminate the need to store the unused products. If we can't use up our insecticides in a timely manner, share them with a friend or neighbour who can use them, but always keep these materials in their original containers. Do not use an old soda bottle or anything that could be mistaken for a drink container. People have been poisoned and killed by inadvertently drinking from these containers. Don't dilute more insecticide than you can use right away. Diluted insecticide needs to be applied according to label directions to plants or sites listed on the label and at label rates until the spray tank is empty. Excess diluted insecticide should be disposed of at a household hazardous waste facility.

Do not dump excess, unwanted, or old material down the drain, onto the soil, or into open waterways, gutters, storm drains or sewers, or in the trash. The only legal way to dispose of insecticides is to take them to our local household hazardous waste disposal facility. Empty containers of concentrated home-use insecticides in the possession of a homeowner on his/her property may be disposed of in the trash without rinsing. Empty containers of ready-to-use products may also be disposed of in the trash. Add water to the empty insecticide container, put the cap on, swirl

the water around the container, and transfer the liquid to the spray tank. Repeat two times. If necessary, add more water to the spray tank to reach the correct concentration. This way, we will have rinsed the bottle three times and used the rinse water to make the insecticide application.

Use only insecticides specifically labelled for indoor use inside the house. Many outdoor insecticides are designed to break down into less toxic substances with ventilation and in the daylight and the rain. Without these conditions the insecticides may linger and cause toxic conditions for humans or pets.

19.7 Insecticide Persistence

Many people applies different insecticides products unnecessarily but sometimes other causes of damage can also be because of incorrect irrigation, poor drainage, herbicide toxicity, or physical damage. Many insecticides are residual in action and continue to be effective for days, weeks or months after their application. Examples are the triazine herbicides that persist in the soil and kill emerging weeds over the lifetime of a crop and some insecticides that remain active in the soil for several years when used as a chemical barrier to termites entering buildings. Nowadays many modern insecticides do not persist for long in the environment to keep less pollution in environment. They act quickly and are then degraded to non-toxic substances by environmental or microbial processes. This helps prevent their build-up in crops or non-target organisms. How quickly ainsecticide breaks down depends on its chemical properties, how much is applied and how it is distributed, as well as environmental factors such as temperature, moisture, soil pH and the availability of micro-organisms.

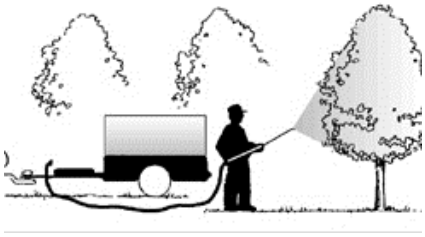


Figure – Outdoor Insecticide Spraying

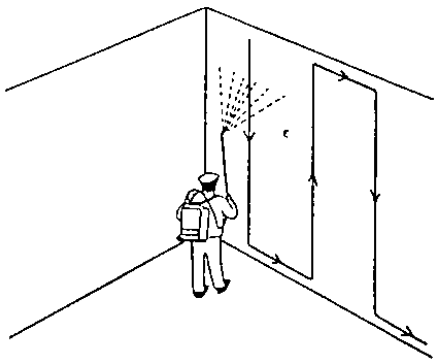


Figure – Indoor Insecticide spraying

19.8 Appliances Used For the Application of Insecticide

First and the most important step for the applicator should be to read the insecticide label carefully and must be sure about safety equipment for applying. Before moving towards field the applicant will need protective clothing to protect himself from exposure even when applying the safest insecticides. Minimum requirements are rubber gloves, eye protection, a long-sleeved shirt, long pants, and closed shoes. Do not use cottongloves or lightweight dust masks because they may absorb the spray and result in prolonged contact with our skin. Read the insecticide label carefully for additional protective requirements.

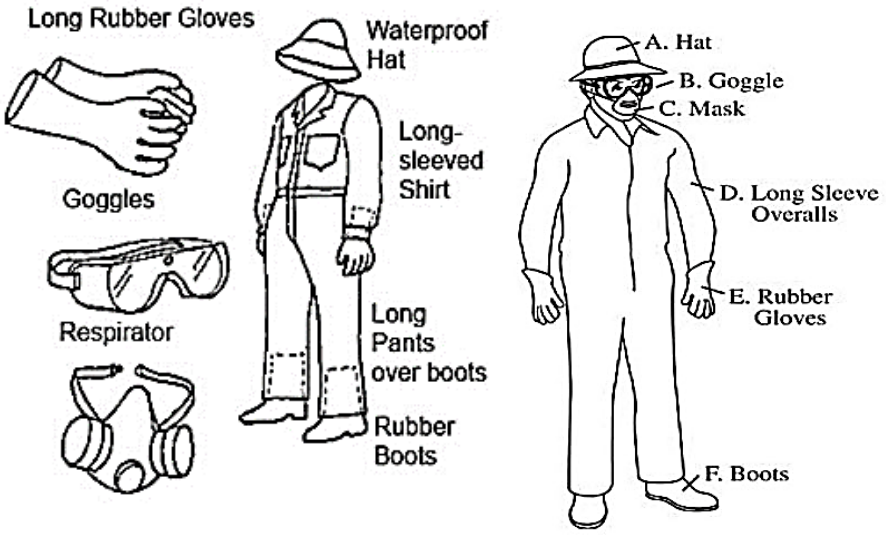


Figure – Protective clothing and equipment for insecticide applicator

Required equipment varies according to our application site, our choice of insecticide, and our willingness to work with more complicated application devices. For many home and garden insecticide applications, the best choice is to

purchase a ready-to-use product in a trigger pump type of sprayer. Ready-to-use products eliminate the need to dilute and mix insecticides or purchase special equipment and are excellent for spot treatments on small plants and shrubs. At the other end of the spectrum are compressed air sprayers, which require careful maintenance and operation as well as precise mixing of chemicals.

If we mix our own insecticides, keep a set of measuring spoons or cups for use only with insecticides. It is a good idea to write "INSECTICIDE ONLY" on them to distinguish them from our other utensils, and keep them well away from food preparation areas. A locked storage cabinet in a garden shed, garage, or well-ventilated utility area is the best place to store insecticides and equipment we use to mix or apply insecticides. If we are spraying for weed control, keep a sprayer specifically for that purpose and label it "WEEDS ONLY." Otherwise, herbicide residue in the sprayer may injure plants if the same sprayer is used for applying another type of insecticide or fertilizer.Last but most important is to take a shower as soonas possible after insecticide application. Wash clothing separately from other laundry. Never smoke, drink, eat, or use the bathroom after insecticide application without washing first.

Inscecticide Application Techniques

Insecticide application plays an important role in pest management. Proper technique of application of insecticide and the equipment used for applying insecticide are vital to the success of pest control operations. The application of insecticide is not merely the operation of sprayer or duster. It has to be coupled with a thorough knowledge of the pest problem. The use of insecticides involves knowledge not only of application equipment, but of pest management as well.

The main purpose of insecticide application technique is to cover the target with maximum efficiency and minimum efforts to keep the pest under control as well as minimum contamination of non-targets. All insecticides are poisonous substances and they can cause harm to all living things. Therefore their use must be very careful. The application techniques ideally should be target oriented so that safety to the non-targets and the environment is ensured. Proper selection of application equipment, knowledge of pest behaviour and skilful dispersal methods are very important. There should be complete knowledge about pest problem like location of the pest (on foliage, under the leaves, at root zone etc). The most susceptible stage of the pest for control measures will help to decide the time of application.

The requirement of coverage and spray droplet size depends upon the mobility and size of the pest. The mode of action of insecticide, its relative toxicity and other physicochemical properties, help to decide the handling precautions, agitation requirement etc. Further the complete knowledge of the equipment is necessary to develop desired skill of operation, to select and to estimate the number and type of equipment needed to treat the crop in minimum time and to optimize use of the equipment.

Insecticides are dispersed by different methods like spraying, dusting etc. For spraying of insecticides different types of nozzles such as hydraulic, air blast, centrifugal and heat energy type are used. Water is a common carrier of insecticides but air or oils are also used as carriers. Selection of proper droplet is an important consideration. The shape, size and surface of the target vary greatly. For spraying against flying insects, the hydraulic nozzles will not be effective. Here we need fine size spray particles to remain airborne for longer time. However, for weed control operation usually the requirement is drift free application or coarse spray droplets. Adequate number of spray droplets should be deposited necessarily. For fungicide application the number of droplets deposited per unit area should be more and may be for translocated herbicide application it can be less in number. It may need fewer numbers of droplets to be deposited in case of highly mobile (crawling) insect pest. The insecticides are formulated in liquid form, dust powder or granule forms such that it makes possible to apply small quantities ofinsecticides over large area. Some of the insecticides are applied as low as few gram a.i.per hectare. Therefore adoption of proper Application Technique is vital for uniform depositing of insecticide. The method of setting the insecticide application equipment to ensure evendistribution of certain quantity of insecticide over the desired area is called Calibration

Classification of plant protection equipments selection of equipment

- Insecticides are available in various forms therefore application Equipment are designed according to the types of formulations to be sprayed.
- Application Equipment are available in a variety of sizes ranging from small to big keeping in view the application capacity and the source of energy.
- These application equipment may be either manually or power operated.

- They can be further classified into moveable and portable appliances.
- By ‘Moveable’ is meant that which can be moved around on wheels or lifted by two or more persons.
- ‘Portable’ means equipment which can be carried by one person.
- Purchase of insecticide appliance is a long term investment. One needs to keep in mind the type of job one wants to handle and check the appliance for the following
    1. Suitability for the job
    2. Ease of operation and maintenance
    3. Good performance
    4. Good serviceability
    5. Easy availability of spare parts
    6. Reasonable cost

SPRAYERS (Hydraulic energy)

Manually operated

- Syringes, slide pump
- Stirrup pumps
- Knap sack or shoulder-slung
    - Lever operated K.S. sprayer
    - Piston pump type
    - Diaphragm pump type
- Compression sprayer
    - Hand compression sprayer
    - Conventional type
    - Pressure retaining type
- Stationary type
    - Foot operated sprayer
    - Rocker sprayer

Powered operated

- High pressure sprayer (hand carried type)
- High pressure trolley/ Barrow mounted
- Tractor mounted/ trailed sprayer
- High pressure knap sack sprayer
- Air craft, aerial spraying (Fixed wing, helicopter)

SPRAYERS (Gaseous energy)

- Manually operated
    - Hand held type
- Powered operated
    - Knap sack, motorized type
    - Hand/ Stretcher carried type
    - Tractor mounted
- SPRAYERS (Centrifugal energy)
    - Hand held battery operated ULV sprayer.
    - Knapsack motorized type
    - Tractor/ vehicle mounted ULV sprayer
    - Aircraft ULV sprayer
- OTHER SPRAYERS
    - Aerosol sprayers
    - Liquefied-gas type dispensers
    - Fogging machines
    - Exhaust Nozzle Sprayer
- OTHER SPRAYERS
    - Aerosol sprayers
    - Liquefied-gas type dispensers
    - Fogging machines
    - Exhaust Nozzle Sprayer

DUSTERS

- Manually operated
    - Plunger duster

    - Bellow duster
    - Rotary duster
        - Belly mounted model
        - Shoulder-slung model
- Powered operated
    - Knapsack motorized duster
    - High pressure trolley/ Barrow mounted
    - Tractor mounted/trailed duster
    - Aircraft

GRANULE APPLICATOR

- Manually operated
    - Broad-casting tins
    - Knapsack Rotary granule
- Powered operated
    - Knapsack motorized type
    - Tractor mounted/ trailed duster
    - Aircraft

SPRAYERS

- Commonly most of the insecticides are applied in sprays form.Liquid formulations of insecticide either used in diluted form with water, oil or directly are applied in small drops to the crop by different types of sprayers. Usually the EC formulations, wettable powder formulations are diluted suitably with water which is a common carrier of insecticides. In some cases however, oil is used as diluent or carrier of insecticides.Sprayer should be well maintained during the spraying season. Checking and preparation should commence well before the beginning of the season. It is of paramount importance to clean both inside and outside of sprayer after each day's work, even if the same chemical is being used the next day. Sprayer should be lubricated thoroughly and regularly, especially all moving parts, before starting the work. All parts should be inspected. Worn out, broken and damaged parts should be replaced immediately. These costs are nominal, compared with the value of the chemicals to be used. The

nozzle is the most neglected, precision component of sprayer. If nozzle is worn out and delivers a 10 % overdose, chemical wastage in a couple of hours would cover the cost of a new one.

- Sprayer should be cleaned thoroughly, since residual chemical if left over for several months will corrode parts of sprayer. Filters and Nozzles should also be cleaned thoroughly. Corroded parts should be painted. The pump should be greased and operating / moving parts should be well oiled. The volume of spray liquid required for certain area depends upon the spray type and coverage, total target area, size of spray droplet and number of spray droplets. It is obvious that if the spray droplets are coarse-size then the spray volume required will be larger than the small size spray droplets. Also if the thorough coverage (eg. both the sides of leaves) is necessary then the spray volume requirement has to be more.
- There is distinct advantage in the case of lower volume of application over the high volume application. The higher the volume to be applied the more the time, the more the labour and the more the cost of application due to labour cost. However the lower volume applications are concentrated spraying of insecticide which should also be considered properly.

Working principle of spray equipment

- Conversion of spray liquid into droplets is achieved using some form of energies.
- Various forms of kinetic energies such as hydraulic, gaseous and centrifugal are utilized in this process.
- The type of sprayer and nozzles or atomizers can be classified according to the energy used.

Hydraulic Energy

- A reciprocating pump operated mechanically by a lever. Pressurised by compression.
- This pressure forces the liquid out of nozzle in the form of spray particles.

Gaseous energy

- A blower generates high wind velocity air. A liquid or dust is fed into air stream to be carried to the target.

Centrifugal energy

- A high speed spinning disc (flat, concave or cage or perforated cylinder atomizes the spray liquid to fine droplets.

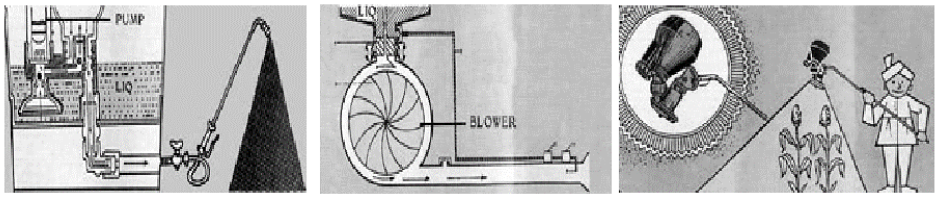


Figure - Different principles of sprayers

On the basis of volume of spray-mix the technique of spraying and its range of volume is classified as**:**

1. **High Volume Spraying 300 - 500 L/ha (Spraying Technique –I)**

   This is very common and popular method of insecticide spraying. The spray solution is prepared by mixing water with insecticide formulation in appropriate quantities. This diluted mixture is sprayed through hydraulic nozzles. The spraying is usually to the point of drip from foliage. In this method large volume of spray liquid is applied. Usually the spraying volume is 300-500 L/ha. The spray volume is not always rigid. The spray volume requirement depends on many factors eg. Sprayer capability, nozzle characteristics, stage of growth of crop, type of crop etc. A variety of high volume sprayers are available in the market. Almost all types of high volume sprayers have some kind of pump to supply pressurized spray liquid to the hydraulic nozzle which breaks the liquid into spray droplets and throws the spray away from it. The high volume sprayers are both manually operated or power operated type.

2. **Low Volume Spraying 50 - 150 L/ha (Spraying Technique –II)**

   The high volume spraying is labour intensive and time consuming. In water scarcity area it is diffcult to practice high volume spraying. Also in situation where large area treatment in very short time is important, the high volume spraying has limitations. The low volume spraying methods essentially reduce quantity of spray solution. Spraying as against 300 to 500 L/ha in H.V. spraying technique is reduced to 50 to 150 L/ha in L.V. spraying technique.

3. Ultra Low Volume Spraying < 5 L/ha (Spraying Technique –III)

The range of volume of spray mix in each of the above case is arbitrary. There is distinct advantage in the case oflower volume of application over the high volume application. The higher the volume to be applied the more the time, the more the labour and the more the cost of application due to labour cost. However the lower volume applications are concentrated spraying of insecticide which should also be considered properly.The ULV spraying is the method of insecticide application at minimum volume to achieve economic pest control. In this technique of insecticide application the volume applied per hectare is less than 5 liters which is extremely low as compared to the conventional High Volume and Low Volume spraying methods.

The spray droplets in ULV spraying methods are very fine in size. Therefore, the nozzles used in these methods are different. Various designs of rotoryatomiser are used to generate droplets of 70 to 100 μ VMD. The vortex nozzles produce droplets in aerosol range i.e. 20 μ VMD. For large area ULV spraying as in the case of locust control exhaust nozzle sprayer which is mounted on a vehicle is used where thermal energy of the engine exhaust gases is used to atomise the insecticide liquid in droplets of 20–50 μ. The thermal foggers using pulse jet engines are used for indoor ULV application. The fogging machines are also used by public health personnels for mosquito control.

SOME IMPORTANT COMMONLY USED SPRAYERS

A) SPRAYING TECHNIQUE – I (HIGH VOLUME SPRAYING)

1. SLIDE PUMP OR HAND SPRAYERS

This is a simple sprayer. It creates hydraulic pressure by forcing spray solution to a nozzle 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 hand actuation of the plunger. Held by both the hands the piston pump is worked by sliding action. For want of a pressure chamber it is not possible to retain pressure and therefore the operator has to pump continuously without break. Due to constant engagement of both the hands it is difficult for the operator to ensure thorough coverage. Further due to pressure fluctuation the nozzle

performance is not stable. The discharge rate varies, spray angle changes and spray droplets size fluctuates. This sprayer is suitable for small scale application in nursery or kitchen gardens etc. It is not a good sprayer for large area treatment. The capacity of this sprayer is about 0.5 acre per day.

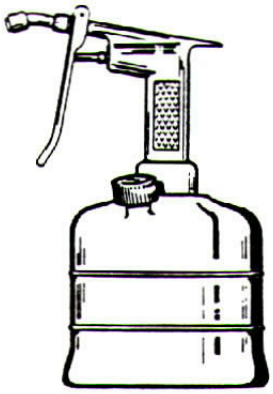


Figure – Small Hydraulic Hand Sprayer

2. STIRRUP PUMP SPRAYER

This is a simple hydraulic sprayer. It consists of hand operated hydraulic pump. The suction part of the pump is immersed in the spray solution kept on floor in a bucket. The pump is operated by hand by one person while the other person holding the delivery line, tigger cut-off device and lance nozzle sprays insecticide. In few models an air chamber is also provided in the pump system which helps continuous spraying. Also in some models provision of hydraulic agitation is made. This sprayer is used both for public health spraying and agricultural spraying purposes.

3. COMPRESSION SPRAYER

It comprises of a cylindrical metal tank for holding the spray liquid, a hand operated piston type air pump, a filler hole in the tank out let with delivery pipe, cut-off, lance and hydraulic nozzle. There is metal or plastic skirit as the base of the tank. A pair of adjustable shoulder straps is provided for mounting the sprayer on the back of the operator.The sprayers with tanks of different capacities are manufactured, but 18 litre capacity sprayers are commonly used for field spraying. The filtered spray solution is filled to 2/3 of the tank capacity. Then the air pump is

operated by hand and air pressure (50-60 psi) is built up. The compressed air exerts pressure to move spray liquid to the nozzle via delivery pipe, cut-off device & lance system.

The spray design is strong and strudy. It is also easy to operate. The operater need not pump continuously so that he can divert his attention to better coverage. However, as the pressure cannot remain constant due to gradual decrease of pressure, the nozzle discharge rate changes so also angle of spray and droplet size. This sprayer is not recommended for herbicide spraying due to high initial pressure. The field capacity is 0.75 - 1.0 acre/day

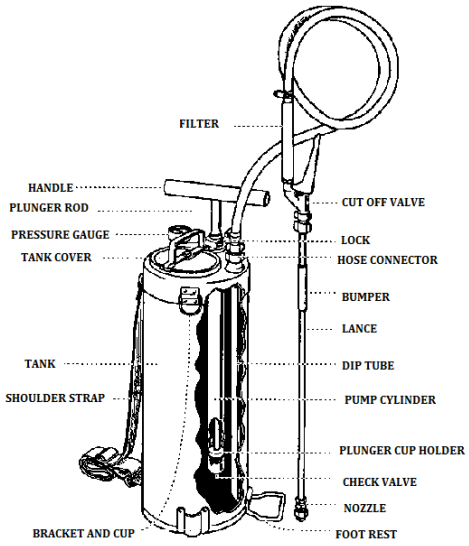


Figure – Compressor sprayer

4. FOOT OPERATED SPRAYER

The pump of the sprayer is worked by operating a pedal lever by the foot of the operator. It requires two persons to work. The spray liquid is kept in bucket or container and it is sucked by a suction hose through a filter (strainer) due to piston movement. A suitable ball valve is provided in the piston assembly to serve as suction valve. The liquid from the pump cylinder is then delivered into a pressure chamber where from the pressurized liquid reaches hydraulic nozzle. Minimum two person team is required to work on this machine. Hydraulic pressure of 10 kg/cm^2 can be achieved which is necessary to project the jet of spray to tall trees simultaneously from two spray nozzles.The pump in the foot sprayer consists of a pump barrel and a pressure chamber. The plunger with a suction cup or piston drives into the pump barrel, thus sucking the liquid into the pressure chamber and

expelling it through the discharge line. The return stroke of the plunger pulls the liquid in through the suction hose for the next discharge. The sprayer develops a pressure of 60 – 80 psi and has a provision for attaching two discharge lines.

The foot operated sprayer is basically for orchard and tree spraying. The design is strong and strudy. Hydraulic pressure of 10 kg/cm^2 can be achieved which is necessary to project the jet of spray to tall trees simultaneously from two spray nozzles. An adjustable type hydraulic nozzle (Tripple Action Nozzle) is generally used which can generate different types 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 for tree spraying. The spray jet can reach height of 15 - 20 feet. For spraying taller trees an extra extension like bamboo lance may be used to gain additional height by 8 - 10 feet.It is difficult to treat field crops by foot sprayers because the sprayer is kept on ground and insecticide solution tank is also kept on ground separately and so movement of the long delivery hose becomes very difficult.

Figure – Foot Sprayer

5. ROCKER SPRAYER

It is very much similar to the foot sprayer, operates on the same principle as the foot operated sprayer. The main difference is the operation of pump. The pump actuation is done by hand of the operator. The sprayer pump mounted on wooden platform is kept on ground and the spray solution is kept in a separate tank or container. It can develop high pressure 10 kg/cm^2. For spraying tall trees, an extension bamboo lance can be fitted. The adjustable type hydraulic nozzle (Triple Action Nozzle) is normally used, the pressure vessel is detachable. The options of two lines are available. The Rocker Sprayer develops 60 – 80 psi pressure.

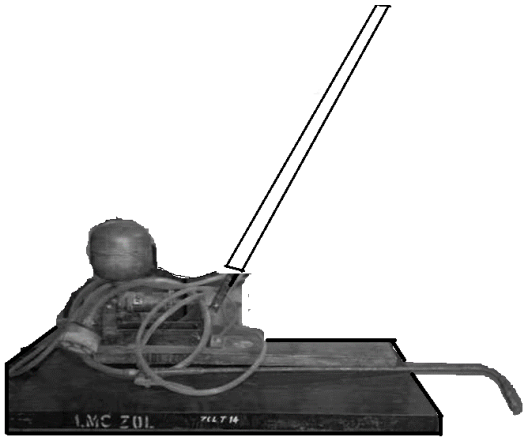


Figure – Rocking Sprayer

6. LEVER OPERATED KNAPSACK SPRAYER

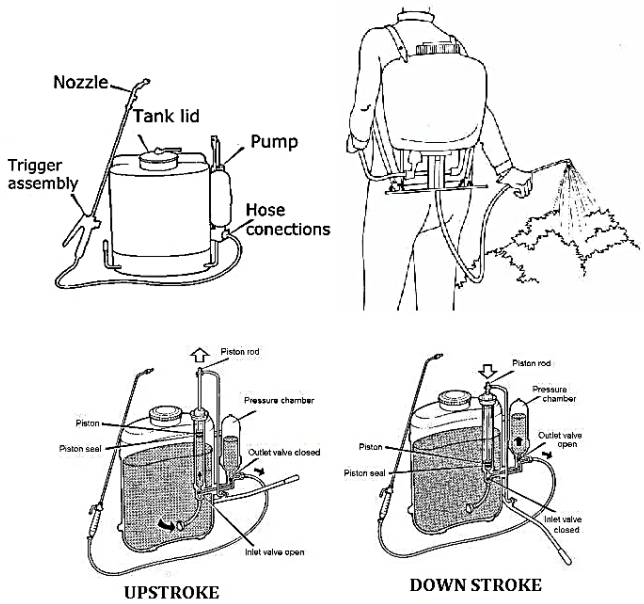


Figure – Knapsack Sprayer

It is commonly known as knapsack sprayer. The sprayer is mounded on the back of operator with help of a pair of mounting straps. The pump of the sprayer is actuated by working a handlever up and down by one hand of the operator and the other hand holds the cut off device for spraying purpose. This sprayer consists of liquid tank, hydraulic pump, operating lever, pressure chamber, agitator, delivery hose, spray lance and nozzle.The pump may be fitted into or outside the tank, and sucks the liquid from the tank and expels it through the discharge line. A spray boom or rig may be attached when wider areas have to be covered. A bean shaped plastic or brass, or galvanized steel tank of 14-16 liters capacity is commonly used. It is necessary to operate the hand lever continuously at the rate of 15-20 strokes per minute. The normal working pressure is 40 psi.

KNAPSACK SPRAYERS

7. HIGH PRESSURE POWER SPRAYER

These are high capacity power operated hydraulic sprayers. They are the high volume spraying machines good for large scale application in orchards and tree crops. The source of power is engine or electrical motor. A pressure regulator is used to control the pressure in the discharge lines and bye-pass from the pressure regulator is used for hydraulic agitation in spray tank. High pressure like 400 psi can be built up and large spray discharge rate like 30 L/min. can be obtained. The engine or electrical motors 3 - 5 H.P capacity power the sprayer.

8. BUCKET SPRAYERS

In the single barrel type the plunger is hollow and acts as a pressure chamber. In the double barrel variety, one barrel is of smaller diameter than the other and acts as a pump, while the bigger barrel serves as a pressure chamber, to produce more continuous spraying. A pressure of 30 – 40 psi is generated.

BUCKET SPRAYERS

B.SPRAYING TECHNIQUE – II (LOW VOLUME SPRAYING)

1. MOTORISED KNAPSACK SPRAYER

Motorised knapsack sprayer, also called Mist blower is a L.V. sprayer in which gaseous energy nozzle is used for fine breakup of spray liquid. This type of nozzle is also called Air blast nozzle. The force of escaping air at high velocity is utilised to shear down the spray liquid into fine spray droplets. The size of spray droplets depends upon:

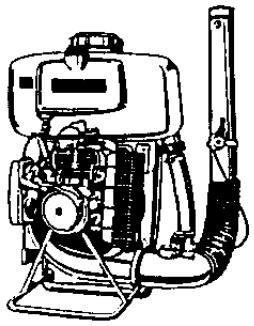
1. Air velocity and volume
2. Liquid flow rate
3. Properties of spray liquid

The spray droplets are then blown away from the nozzle outlet. The blast of air disperses the droplets over wide area and helps penetration of spray into the crop canopy. The gyrating movement of droplets in the canopy improves the underleaf depositing of the spray particles.A two-stroke petrol engine (35 cc capacity) is used as prime mover to run a fan blower. The engine runs usually at 5000 - 6000 RPM and the blower emits at nozzle outlet about 5 m^3 air per minute and at about 170 km/hr velocity.

The spray droplets are about 150 - 220 micron VMD size. The nozzle flow rate can be adjusted by a regulator provided in the liquid line. The regulator can be a variable restrictor type or different size fixed aperture type. The later type is better because in the variable restrictor type regulator, it is difficult to achieve exact repeat application rates. The flow rate up to 2 L/min can be obtained.

If required the motorized knapsack sprayer can be converted into power duster also. Then it is called motorised knapsack sprayer-cum-duster. In most of the machines the spray tank itself is used as dust hopper. In such a tank (dust hopper) suitable dust agitator attachment is fixed inside the hopper and dust-ejector tubes

are fitted in the outlet of the discharge pipe. It is necessary to avoid compaction of insecticide dust while filling it in the hopper. The rate of flow of the dust from hopper to the discharge tube is controlled by variable restrictor aperture. In some models this is achieved by placing a butterfly type restrictor.



MOTORIZED KNAPSACK SPRAYER

2. AIR RAFTS

For low volume spraying the aircrafts are also used to spray insecticides at 20 - 25 L/ha. An aircraft has been built or converted for agricultural use - usually aerial application of pesticides spraying or crop dusting or fertilizer (aerial topdressing); in these roles they are referred to as "crop dusters" or "top dressers".

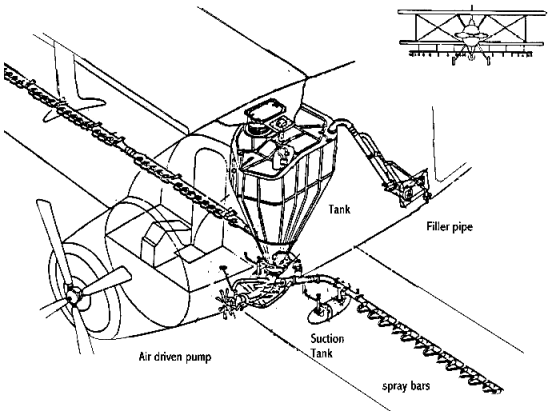


Figure – Air raft sprayer

Note –At present the use ofair raft sprayer foraerial spraying has been banned in several countries, due to environmental concerns about pesticide drift. It is now often subject to restrictions, for example spraying pesticide is banned in Sweden,

although exceptions can be made such as for an area plagued by mosquitoes during summer. Even the spread of fertilizer has raised concerns, for example in New Zealand fertilizer entering streams has been found to disproportionately promote growth of species that are more able to exploit the nutrients, which has led to restrictions on topdressing near waterways.

C. SPRAYING TECHNIQUE - III (ULTRA LOW VOLUME SPRAYING TECHIQUE)

1. Electrostatic spraying

This sprayer consists of a battery operated motor with a spinning disc, a liquid tank, a handle and a set of batteries.This is a fairly new technique, which has greatly enhanced uniformity of spraying throughout the plant canopy.In this process, a free charge flows to the plant in response to the presence of an electrical field, which is created by a charged cloud. The surface charge is of the opposite polarity to the charged cloud, and has a magnitude and distribution that maintains the plant at ground potential (Zero Volts) in the presence of the charged cloud. The most commonly used version of this new system is the hand-held Electrodyn Sprayer, which atomises and propels charged droplets, by means of electrical forces set up between a high voltage, positively charged nozzle, the droplets and the earthed crop. The formulation is fed by gravity to the ‘bozzle’ (bottle plus nozzle) where it picks up a high voltage charge.

The formulation then forms a number of uniform ligaments, which in turn are broken up into electrically charged droplets. These droplets are of uniform size and mutually repellent and form a tenacious, even coating all over the crop, including stems and undersides of leaves. No mechanical energy is required at the nozzle to induce droplet formation; neither are compressors or centrifugal energy employed, so the whole system works without moving parts.

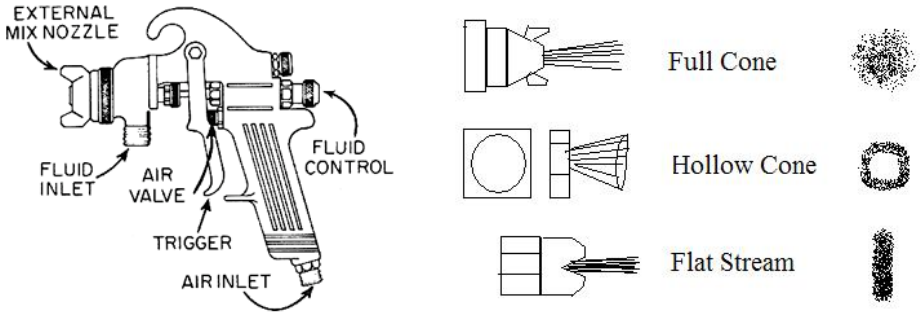


Figure – Electrostatic Sprayer

Power Operated Sprayers

Hydraulic Sprayers

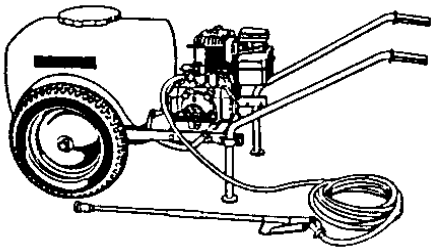
Hydraulic sprayers may be engine or electric motor driven, and are available with single, double, and the triple piston pumps. The single piston pump develops a maximum pressure of 150 psi, whereas the double and triple piston type develops 300 – 400 psi. Only two discharge lines can be used with the single piston pump, whereas the double and triple piston pumps can accommodate 4 – 6 discharge lines. Operation is by means of 1 – 2 HP electric motor, or 2 – 3 HP petrol, petrol-kerosene or diesel engine. These sprayers can also be driven by a power tiller or tractor.

HYDRAULIC SPRAYERS

Motorised Knapsack Mistblower cum duster

This sprayer cum duster is fitted with a two-stroke air cooled engine of 35 or 70 cc capacity, connected to a centrifugal fan by a direct drive. The spray liquid is first pressurized by air generated by the blower. This air current achieves a velocity of over 275 kmph at the nozzle, and sprays the chemical in fine particles than can be measured in microns. The nozzle design enables even spraying at maximum efficiency.When dusting, the air blast enters the tank from an air inlet, which is

connected, to a tube with several holes on its surface. This agitates the powder which is then thrust out by the velocity of the air coming out of the blower, through the pleated hose and out through the nozzle.



MOTORIZED MOBILE SPRAYER

Tractor mount sprayers

As the name indicates, this sprayer is attached to a tractor for use. The pump is driven by the PTO shaft of the tractor, and the sprayer unit sucks the chemical and discharges it through the spray boom, or through the discharge line consisting of a delivery hose and spray guns.The boom has a swivel arm to direct the spray correctly. The main frame allows the spray boom to be adjusted according to the height of the crops being sprayed. Tractor mounted air carrier sprayers are also used for low volume spraying in orchard and tree spraying.

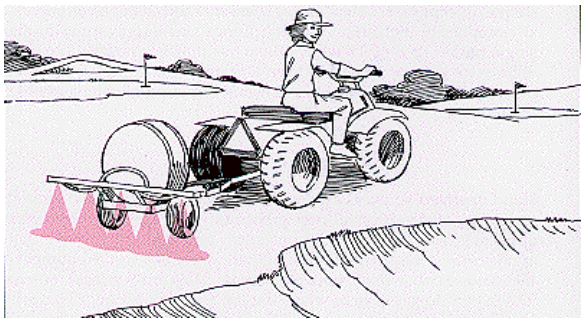


Figure – Tractor mount sprayer

Spinning disc sprayers

Liquid is fed from the tank on to the spinning disc by the force of gravity. The spinning disc, which has 180 channels on the wall and 180 teeth on its periphery, operates at 4000 – 5000 rpm to stir the liquid and create very fine, even particles for low volume spraying. A smooth flow of liquid with highly controlled droplet (100 – 165 microns) application is thus achieved. The stainless steel disc is interchangeable.

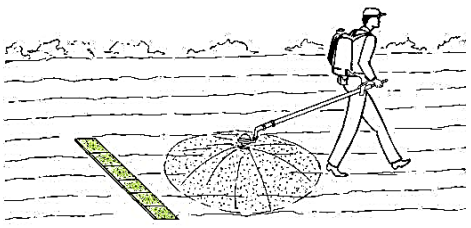


Figure- Spinning Disc Sprayer

DUSTERS

Solid formulations insecticides are the dry dusting powders with low concentration and ready to use containing 2 to 10% pesticide. The inert material is talc, soapstone, attapulgite, etc., and it is non toxic. The sulphur dust is not diluted with inert material.

The advantages of pesticide dusting application are:

1. We can use directy they are ready to use product no need for concentrate handling and diluting
2. It can easily be used in dryland agriculture because no water is required.

The major problem during dust spraying is the pesticide drift which means the fine dust particle cause serious drift problems and the operator and field laborer are exposed to dermal and inhalation hazards, besides pesticide causes pollution to the neighbouring area. This is the main reason why the herbicides are not formulated as Dusting Powders..

The dusts are applied at 20 - 50 kg/ha. It should be noted that the application is done in highly concentrated form, as compared to high volume or low volume spraying technique. Therefore, adequate precautions must be taken in handling the dust and during the application in field. The dusters are available both manually operated and power operated models.

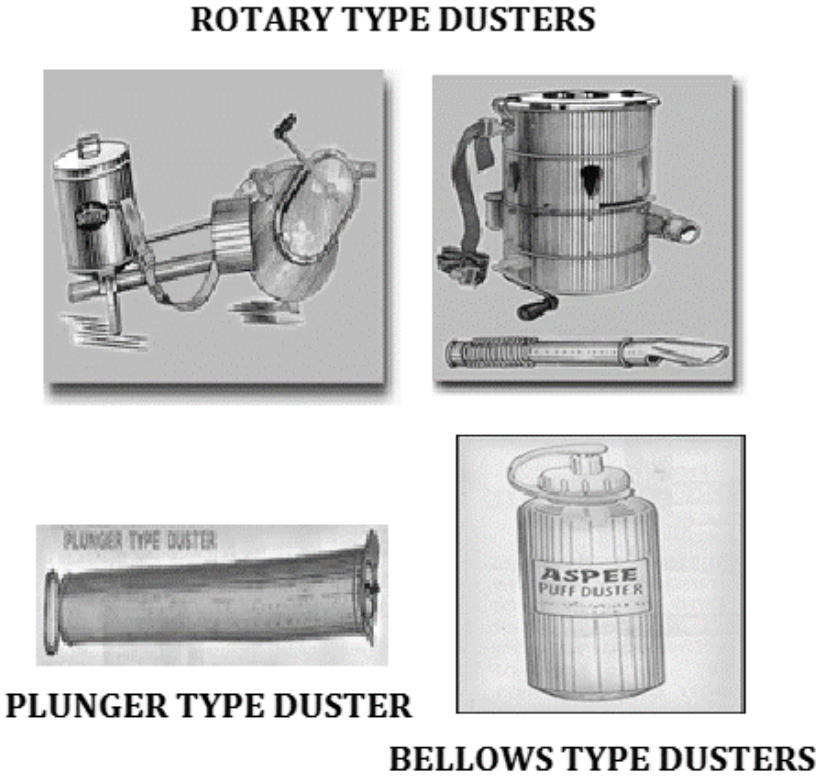


Figure – Different types of dusters

MANUALLY OPERATED DUSTERS

PLUNGER DUSTER:

Plunger Duster operates on the piston principle, by generating an air blast, which passes through the dust chamber and expels the dust through the discharge outlet.They are very simple, low cost machines and useful in a limited way. The field application capacity is low. They hold 200 to 400 g of dust in a chamber into which air is pushed by an adjoining piston type air pump operated by hand. The dust cloud is issued from the discharge outlet.

BELLOWS TYPE DUSTER:

Bellow type duster is a simple design low cost dusting machine. This variety of duster is not popular in India.This type of duster also creates a blast of air through the dust chamber to discharge the powder, the significant difference being that the force is generated by means of bellow operation. A collapsible bellows pushes air into a dust hopper of 1-2 kg capacity and dust is discharged from the nozzle outlet.

HAND SHAKE DUSTER:

This is a simple device to apply pesticide dusts. This is useful in pesticide dust application in low height crops. The brown plant hopper is a serious pest in many parts of the paddy growing areas. This equipment is well suited for pesticide application for control of brown plant hopper in paddy crop.

It consists of a metal container cylindrical in shape with 5½" diameter and 7" long. At its bottom, one convergent and divergent cones are fitted. The duster is provided with suitable handle on top with galvanized iron wire. The total length of the duster is 30". Sufficient number of perforations are made all-round the container at its lower end and on the bottom case. The divergent cone which is inside the container helps to push quickly the dust through perforations. The bottom cone helps in keeping the duster away from the soil and water in the paddy fields. The dust hopper can contain about 2 kg dust. The dust is emitted by shaking the duster by hand, in trilling or up down jerk motion.

Brown plant hoppers generally harbor at the lower portion of the paddy crop and hand rotary duster usually fails to apply the dust at the bottom of the crop. Hence, this device is very useful for the farmers. This is cheap and can be fabricated by local tinsmith. It costs about Rs. 100/- or so. A farmer can cover one acre of paddy in a day with the help of this duster. This could be utilized for other crops as well.

HAND ROTARY DUSTER:

Hand rotary duster makes use of a fan or blower to flow large volume of air at high speed. Rotary dusters are provided with an agitator, which stirs the powder and releases it evenly through the discharge vent. The blower sucks the dust or powder from the hopper through the connecting pipe, and pushes it out forcefully to achieve efficient dispersal. The operator carries the duster by means of one or two shoulder straps, and holds the lance in his left hand cranking the handle with his right. The dust powder is fed into the stream of air and blown from the outlet tube. The fan or blower rotates at high speed by hand cranking handle, which is geared to it. The higher gear-ratio and better blower design provide easy cranking and good volume of air is emitted. The dust hoppers are generally cylindrical and are provided with agitator, feeders and dust metering mechanism.

Such rotary dusters are either shoulder slung type or belley mounted type. The shoulder-slung models are better balanced when the dust hoppers are filled. But it becomes inconvenient to operate in crops like sugarcane and cotton. The belley

mounted type can be used in such situations. A hand rotary duster can discharge dust powder from 0 – 150 g/min and displace air about one m^3/min at 35 RPM. Such machine can treat 1 to 1.5 ha /day.

POWER DUSTER

These are bigger machines run with the help of engine or electrical motor. Some power dusters are tractor mounted type and are driven by tractor P.T.O. The equipment is mounted on iron frame (stretcher) and can be carried by 2-3 men. The engine/motor drives a centrifugal fan usually via V-belt drive. The engine is petrol/ diesel run and 3 - 5 H.P. The fan displaces 20 m^3 air/min or more at 100-250 km/hr air velocity. These dusters are good for large 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 the delivery channel by air blast. The dust hopper capacity is 10-20 kg and dust can be discharged at a rate of 1 to 8 kg/min. A power duster can cover about 10 ha/day.

KNAPSACK DUSTER

The motorised knapsack sprayer can be converted to a duster by replacing some plastic fittings inside the hopper. Almost all mist blowers have provision of converting them from spraying unit to dusting unit. The two stroke petrol engine runs a blower fan and delivers the air through a hose pipe system. The dust is agitated and lifted by the blast of air in the hopper and it is fed into the main air hose or a long dusting hose (40-50 ft long polythene perforated hose) can also be attached to knapsack duster. Such an attachment is very good for large area treatment in less time. The dust output can be adjusted from 0 to 1.5 kg/min. The motorised knapsack sprayer-cum-duster unit is therefore useful for both low volume spraying and dusting operation.

PRECAUTIONS:

The dusting powers are very finely divided particles which can remain air-borne for long time and can drift far distances. The fine particles can very easily enter into body system by inhalation. Therefore, the operator should wear protective clothing. He must cover his nose and mouth in order to avoid inhalation of pesticide drift. The operator should never operate against the wind direction. Also if the wind velocity is more or wind turbulance exists, the dusting application should not be done. It is better to apply the dust power in early morning hours and

in late evening hours, avoiding the mid-day and afternoons.

WET DUSTING EQUIPMENT FOR DRY LAND CROPS*:*

This equipment is a low cost devise for wet dusting on crops. It is specially suitable for dryland crops. The losses in dust application due to drift is minimised. Wet dusting is more effective and economical to farmer than mere dusting on crops. A small hand operated sprayer of two litres capacity is amounted on the lid of the shoulder mounted rotary duster. On the top of the duster's outlet, one spray nozzle was provided to issue water spray. The nozzle was connected with a long hose pipe from the outlet of sprayer which is kept on the duster. In this process the dust particles becomes wet when released from the duster and also the leaves and other plant parts become wet and the dust depositing is improved. The operator of the duster carries the duster and sprayer combined. He operates the crank of the duster. The sprayer's trigger is made on with the help of latch and the spraying of water takes place continuously. Four kgs of dust needs two litres of water for the wet dusting operations effectively.This equipment is more useful for dryland farmer when there is water scarcity always. This equipment can be used for simultaneous spraying and dusting of two pesticides if they are compatible.

Power operated dusters

Rotary type

In this type of power operated duster the air is sucked in by a motorized blower and discharged through the blower outlet.

Air Jet Type

This is for aerial dusting with the help of a jet. In this air craft the air comes from the blower and enters into the hopper, which agitates the dust and blows it out simultaneously with a jet of air.

Type of appliances

- Insecticides are available in various forms.
- Application Equipment are designed according to the types of formulations to be sprayed.
- Application Equipment are available in a variety of sizes ranging from small to big keeping in view the application capacity and the source of energy.

- These application equipment may be either manually or power operated.
- They can be further classified into moveable and protable appliances.
- By ‘Moveable’ is meant that which can be moved around on wheels or lifted by two or more persons.
- ‘Portable’ means equipment which can be carried by one person.

Nozzle

- The nozzle performs four basic functions
- Atomizes liquid into droplets.
- Disperses the droplets in a specific pattern.
- Meters liquid at a certain flow rate.
- Provides hydraulic momentum.

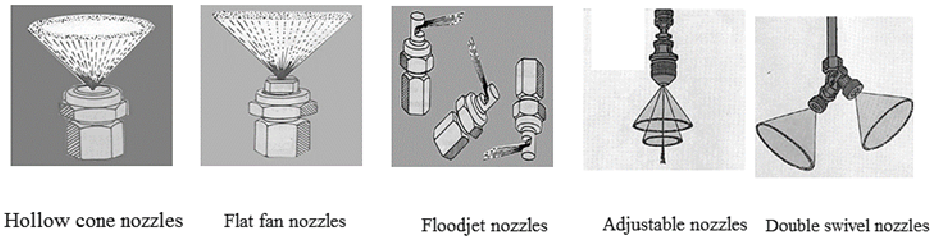


Figure – Different types of nozzles

The Nozzle Tip is one of the most important and least expensive part of a spraying system.

Adjustable nozzle

- Most suitable for spraying targets which are not within the reach of a man.
- Gives a wide angle hollow cone to a straight solid stream that is, it gives a jet to a cone type of spray pattern.
- Difficult to calibrate as the flow and droplet sizes vary widely with the nozzle angle.

Double swirl spray nozzle

- Used for spraying in two different directions simultaneously.
- Nozzles can be fitted with different types of tips like hollow cone, solid cone or flat fan.

- Suitable for high volume applications
- The shape and size of Nozzle Tip orifice controls the spray angel, discharge rate and spray pattern. Spray angle influences the swath of a spray.
- And also:-Droplet size increases as orifice size increases (for any given pressure). Droplet size decreases with an increase in fan angle (for any given nozzle size and pressure). When it is desired to spray with more than one nozzle with the help of a spray rig or a spray boom, care should be taken in mounting to avoid overlapping or gapping. Overlap causes double dose,higher dose is harmful to crop Gap leaves untreated area Poor biological efficacy.

19.9 Self Learning Exercises

1. What are insecticides? Explain their action and mechanism briefly.
2. Define insecticide formulations.
3. Explain different types of insecticide formulations.
4. Give only names of different types of insecticide formulations.
5. What do you mean by dilutions of insecticides?
6. What information you can get from an insecticide label?
7. Write the various precautions during insecticide spraying by an applicator?
8. How can we dispose the leftover insecticides bottles and packets?
9. Explain the various appliances used for application of insecticides.
10. Give the classification of various types of plant Protection Equipments.
11. Describe the different types of insecticide sprayers.
12. What are dusters? Explain its different types which are commonly used.
13. What do you mean by insecticide persistence?
14. Name some common abbreviations used for insecticide formulations
15. Describe different types of nozzles used for insecticide appliances.

19.10 References

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Unit-20

Knowledge of Rearing Insects and Maintain Insectary

Structure of the Unit

20.0 Objectives

In this unit you will be able to understand the rearing of insects in variety of habitat, their economic importance in relation to food, health etc. you will practice the rearing of insect in laboratory conditions.

20.1 Introduction

It is well known that whenever harvested products are stored in godowns, warehouses or granaries they are attacked by a number of stored grain insects that grow and develop suitably there. Other than this fungus, rodents, birds also cause considerable damage to the stored grains. Whenever open stagnant water is found nearby us it is infested by the eggs of mosquito which when becomes adult

function as vector to carry pathogens of the diseases malaria, yellow fever, dengue, filariasis etc.

Rearing of insects

Insects are the one having a variety of habit and habitats in air, water and land. Therefore, the rearing of insects requires specific techniques for different insect type. The stored grain insect pest are easily breed in captivity as its requirements like food, space, humidity and temperature can be maintained in the laboratory. We can get successive generation in the wide glass jars with food material like wheat, rice, suji, wheat. Stored grain insects can be reared and maintained in large number with minimum of efforts and are ideal experimental animals.

This chapter leads to rearing of many stored grain insect pest and mosquito rearing in the laboratory**.** There are mainly four aspects which are to be kept in mind for the rearing.

Food: First to identify the type of food preferred by the insect. Example, phytophagous insect as *Papilio demoleus* feed upon fresh citrus leaves, blood feeder mosquito needs warm blooded host rat, rabbit or human. Fresh food should be kept in rearing cages and changed everyday.

Temperature: Almost all the insects can be reared and breed at the temperature ranging from 25±35ºC temperature below which they undergo diapause. Small insects can be reared in the laboratory in BOD incubator.

Humidity: Majority of insects shows their development with high humidity 70-80%RH. For maintaining the humidity the cotton soaked in water or wet sand is kept at the bottom of the rearing cages especially in summer. In case of stored grain pest the beakers filled with water is kept in BODs.

Space: Different space is required for different types of insects as stored grains pest requires small spaces and moths and butterflies needs wide space like garden cages for their nuptial flight. Specially designed cages are prepared of variable sizes depending upon the insect.

20.2 Experiment 1

Aim: Rearing of the *Corcyra cephalonica* in the laboratory.

Requirements: Italian millet, 3% dextrose, yeast, ware house, aspirator tube, mosquito net, vitamin E, refrigerator, cotton wool, thread, honey.

Common name: The rice moth

Order: Lepidoptera

Family: Pyralidae

Host: Stored rice, millets and other cereals, prefers broken grains and flour.

Damage: Caterpillars damage the grains by webbing and forming lumps, feed inside. This reduces the quality of the rice in market.

Pest status: Secondary pest or scavenger

Life cycle: Adults are greyish brown in color, 12 mm long, 15mm wing span, no marking on wings, veins slightly dark, head with projected tuft of scales. Adults are having pale buff hind wing and forewing with midline brown or grey. At rest tip of the forewing appears more tapered than other pyralid moths. Males are smaller than females. The labial palps of female are long, curved downward while in male it is short and hidden by scales. Moths are short lived and lay 150-200 eggs per female within a few days after emergence. Eggs are laid anywhere on the grains, on container, any surface near the grains either singly or in clusters. Eggs are white, oval, 0.5mm long, has nipple like process at one end and hatch after 4-5 days. Freshly hatched larvae are creamy white with a prominent brown head moves actively and feed on broken grain and soon start webbing to join grains. A full grown larva is pale white in color, 15mm long, scattered hairs, prolegs on abdominal segment 3-6 and 10 and no marking on the body. It takes 25-35 days in summer and longer than this in winter. Larvae are mobile, external feeder and produce large quantities of silk. Pupation takes place inside an extremely tough, opaque white cocoon surrounded by webbed grains. Pupa takes 10 days to emerge to an adult. Adult commence mating and egg laying immediately after emergence. They are short lived and do not feed the food commodities.

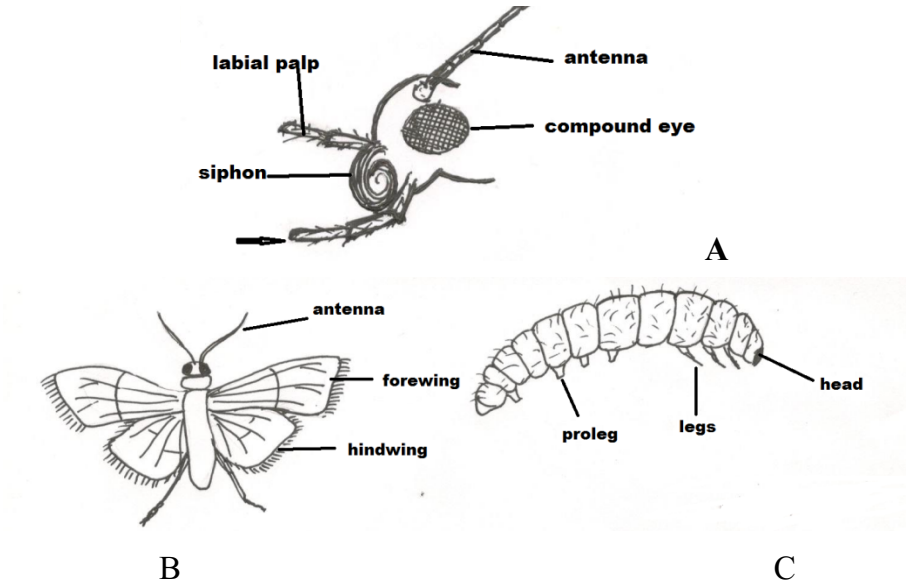


Fig 1 A) Head of the female showing labial palp long and farward B) Adult of *Corcyra* C) larva

Procedure: The food to rear the rice moth is maize, wheat, Italian millet or rice. The most suitable food for rearing is wheat alone or Italian millet with 3% dextrose and yeast combination. Adults are collected from the ware houses where food materials are stored. The eggs laid overnight are collected from the trays and added to the rearing jars. The adults are handled by aspirator tube in the tent of mosquito net. The food of the adult is made up of 50ml honey, 50ml water and 5 capsules of vitamin E. the feed is stored in refrigerator and used whenever needed. The pieces of cotton wool tied with a thread is soaked in the solution and inserted in a drum containing the adults.

Precaution: Workers handling the adult must use mask to avoid inhalation of scales.

20.3 Experiment 2

Aim: Rearing of the *Callosobruchus chinensis* (Linnaeus) *or Bruchus chinensis or Pachymerus chinensis* in the laboratory.

Requirements: Wide mouth glass jars, BOD incubator, muslin cloth, rubber bands, beakers, food source.

Common name: The pulse beetle or cowpea bruchid.

Order: Coleoptera

Family: Bruchidae

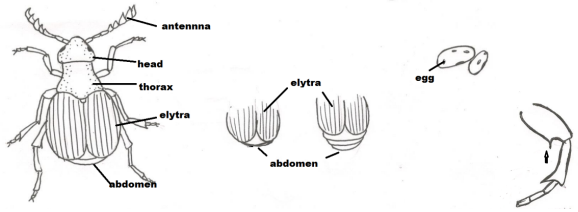
Subfamily: Bruchinae

Host: pulses, cowpea, soyabean, gram, lablab, pigeon pea.

Damage: It infests whole grain and called primary pest. Larvae and adult both causes damage to the grain. Larvae bite the hole in grain to feed the kernel and adult can infest the grain in stored granaries or in the field as they are active fliers and deposit their eggs on the pods.

Pest status: Primary pest

Life cycle: Adult beetle is 3-4 mm long and having globular tear shape body. They can climb on vertical surface of the jar as they are strong fliers. It is brown in color with dark patches on elytra and thorax. Male is smaller than female, deeply emarginated eyes, serrate type antenna, abdomen is covered by elytra and female don't have these marks and tip of abdomen is exposed not covered by elytra posteriorly. The abdomen is covered with fine hairs. The inner and outer ridge of ventral margin of hind femur carries a spine. They are active fliers and female lays egg 100 eggs which are white, elongated and stuck on the grains, on pods or surface of container. After 3-6 days eggs hatch and scarabeiform or eruciform larvae yellowish color, short legs and a pair of thoracic plates to facilitate boring into the seeds. They feed into the grain and takes 12-20 days to form pupa. Before pupation larvae eat a round hole to the surface of seed but leave the seed coat intact which is visible on the surface and called window. Pupa is dark brown in color and adult emerges by biting and pushing its way from window leaving a perfectly round hole in the seed. Adult life is short only 10-12 days.



A **B** **C** **D**

Fig 2 A) Adult of *Callosobruchus* B) adult male and adult female C) eggs on mung bean D) hind leg femur showing spine on ventral side

Procedure: Collect adults from the stored grain houses and keep them in the wide mouth jars containing three quarter full of disinfected cowpea grains. These jars

are covered by muslin cloth tied by rubber band and place them in the BOD maintaining the temperature 27±1ºCand 60-90% RH allowed to mate for seven days. Remove the adults after egg laying and generation can be maintained in the laboratory. Larvae can be collected by using camel hair brush. Put the rearing glass jars in the incubator and further care is not required until the food get exhausted or overpopulation in the jar.

20.4 Experiment 3

Aim: Rearing of the *Tribolium castaneum* (Herbst) in the laboratory.

Requirements: Wide mouth glass jars, BOD incubator, muslin cloth, rubber bands, beakers, food source, stereoscopic microscope, powdered milk and dried yeast.

Common name: Red flour beetle or rust red flour beetle.

Order: Coleoptera

Family: Tenebrinoidae

Host: Common pest of stored grains, flour, cereals, dried fruits.

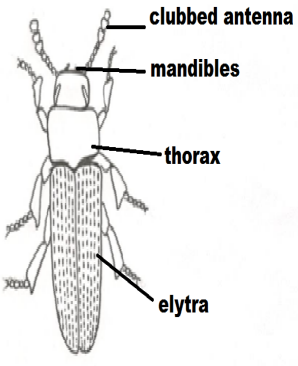
Damage: Larvae and adult both causes damage by feeding on grains. They lead to persistent disagreeable odors in the food due to the secretion of benzoquinones from abdominal glands.

Pest status: Secondary pest.

Life cycle: Female lays 300-500 eggs in her life cycle and 2-3 eggs per day which are microscopic, white, oblong and typically coated with flour. Eggs takes 5-7 days to hatch, newly emerged elateriform larva are active and move through the food. They moults 6-11 times to become fully mature larva in 20 days. Pupa is naked found amongst the food and does not move until it is disturbed. It takes 4 days to become adult at 30-34ºC. Males live 4-6 months and female 3-4 months. Sexual dimorphism is possible in the adult and pupal stages. Pupal stage is more easily identified as compared to the adult because adult moves readily under the stereoscopic microscope. In the female pupa there are two finger like projection called **genital papillae** above the two pointed **urogomphi** which are longer than males. Adults are sexed by putting them on the ice block placed in the petridish

under the stereoscopic microscope. There is a pair of small patch of short bristles on the first leg of the male 1/3 from the base of the leg called **sex patches**. If they carry flour in it they appears as domes of flour or if they are not tangled by flour they appear as dark textured spot on the leg. Adults are 2-4 mm in length and reddish brown in color. There is a small puncture in the centre of the pronotum and the last three segments are clubbed in antenna. Cannibalism is common both in adult as well as in larvae.

Procedure: Pairs of sexually mature adults placed in wide mouth jars which is half filled containing any wheat flour or maida and food can also be supplemented by powdered milk and dried yeast, the mouth is covered with muslin cloth tied with rubber band. Place these jars in BOD incubator maintaining suitable temperature and humidity. The beakers filled with water are kept to maintain 80-90% RH and temperature is set 25±35ºC in the BOD incubator. The insects allowed copulating and laying eggs for 7-10 days.the experiment is set in four or five replicates. Eggs oviposit in the flour and newly hatched larvae feed on it. We can get many generations in laboratory. To separate the stages we can use different sieves as 25”brass sieve is used to filter adults, pupa and full grown larvae, 30”mesh sieve for newly hatched larvae and 50”mesh sieve for eggs. The number of eggs, larvae and pupae count at every five day interval until all adults emerge from the second generation. Place the adults in new jars containing same type of food to avoid overlapping of the generation.



A

B

C

Fig 3 A) Adult of *Tribolium* B) larva C) pupa

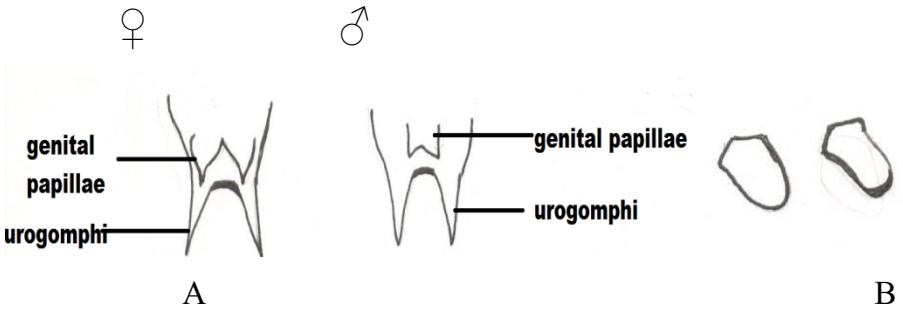


Fig 4 A) Female pupa and male pupa B) Eggs

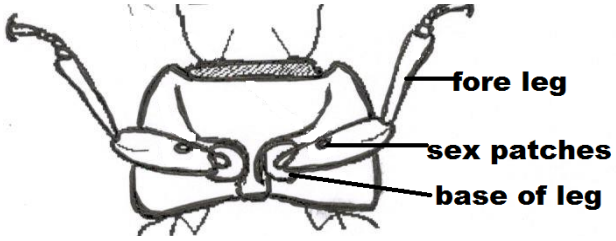


Fig 5 Male *Tribolium castaneum* showing sex patches

20.5 Experiment 4

Aim: Rearing of the *Rhizopertha dominica* (Fabricus) in the laboratory.

Requirements: Wide mouth jars, BOD incubator, Steroscopic microscope, wheat flour, food grain, muslin cloth, rubber bands, camel hair brush.

Common name: lesser grain borer, American wheat weevil, Australian wheat weevil or stored grain borer

Order: Coleoptera

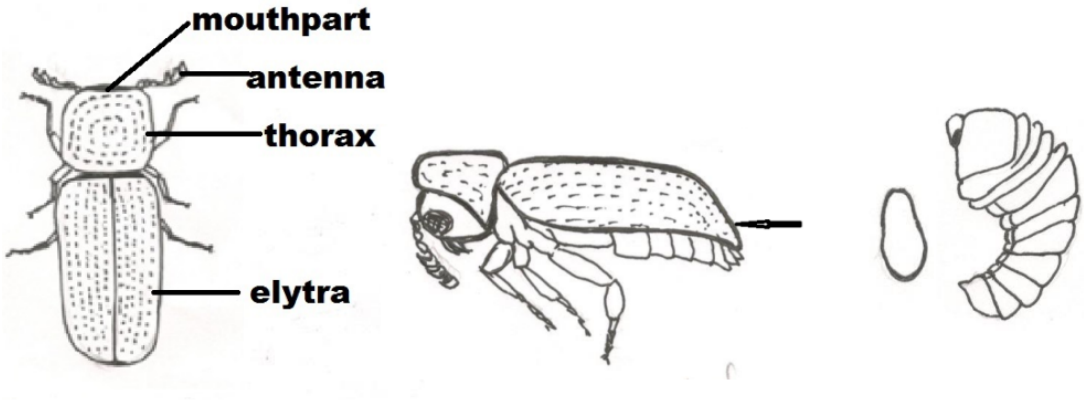
Family: Bostrichidae

Host: It is cosmopolitan in distribution and a serious pest of stored wheat and other cereal products wheat, oat, barley, rice, maize, millet, sorghum. It is found in tropic, subtropic and some temperate region.

Damage: Larvae and adult both feed primarily the stored cereal seed grain. It is the primary pest as it damages whole grains.

Pest status: Primary pest.

Life cycle: Adult is 2-3 mm in length. It is reddish-brown and cylindrical in shape. The forewing elytra are placed parallel sided and the end of the elytra curves gradually when viewed from the side. Eytra is having distinct rows of pits running their length. The antenna is 10 segmented with last three segments are enlarged. Pronotum has rasp like teeth at the front and head is not visible from above. Male adult are good fliers and they secrete aggregate pheromone that aggregates both male and female. Tip of the abdomen is tapered when viewed from above or below. Adult lays 200-500 eggs in their life time. The eggs are laid singly or in batches loosely in the grain. Eggs are white, oval, 0.6 mm and 0.2 mm in diameter when freshly laid turning rose to brown before hatching. Eggs hatch in 2 days and newly hatched larvae feed amongst the matrix of damaged grain and flour produced by the adults. There are 4 larval instars which are scarabeiform. The first two instars are not recurved while 3rd and 4th larval stages are recurved as their head and thorax recurved towards the abdomen becomes immobile when fully matures. First larval instar is 0.7 mm in length and fully grown is 3.07mm long. Larva takes 17 days to become a pupa which is 3.91 mm and can be sexed in this stage. End of the abdomen of male pupa have a pair of 2 segmented papillae fused to the abdomen for their entire length whereas female pupae is 3 segmented papillae and projected from the abdomen. Pupa takes 3 days to emerge an adult. Adult lives about four to eight months. It has ability of high fecundity and a faster rate of development



A **B** **C** **D**

Fig 6 A) Adult of *Rhizopertha* B) Lateral view to show gradual slop of tip of elytra C)egg D) larva

Procedure: Twenty to thirty pupa are collected from the store houses and sexed under the stereoscopic microscope as male and female pupa. Then placed these sexed pupae in 100 grams of wheat grains or flour or rice kept in wide mouth jars. The jars are covered with muslin cloth tied with rubber band. Now place the jars in BOD incubator maintaining the temperature 27±2ºC and 70±5% RH. Egg will be seen after 15 days and further larval stages can be seen in the culture. The lowest temperature at which they can develop is 20 ºC and takes 90 days for completing their life cycle. As the temperature raises their rate of development also gets faster up to 34 ºC and complete their development in 4-5 weeks. Above this temperature the development rate starts declining and stops above 40 ºC.

20.6 Experiment 5

Aim: Rearing of the *Lesioderma* (Fabricius) in the laboratory.

Requirements: Electric heater, fan, glass jars, cotton plug, food such as tobacco, microscopic.

Common name: Cigarette beetle or tobacco beetle.

Order: Coleoptera

Family: Anobiidae

Subfamily: Anobiinae

Host: Tobacco products, stored food products, dried fruits, dates, resin, cereal, cocoa, coffee beans, herbs, spices, nuts.

Damage: Most anobiinae are called wood borers and are serious pest of timber. Larva causes direct damage as it feed on dried tobacco in the form of leaves, cigars or cigarette and other stored products. Adults are short lived (live only 25 days) and do not feed on commodities. Adults, pupa, eggs with their excreta causes foul smell and change texture of food.

Pest status: primary or secondary pest

Life cycle: Adults are small 2-3 mm in size with rounded or oval body shape. They are reddish brown in color and with serrate antenna. The antennas are waved rapidly when walking. The head is concealed by thorax and elytra smooth covered with fine hairs. Adults don't feed they drink liquids. Adult female lays 10-100 eggs

in the food singly in crevices or folds of the substrate in her life span. Egg hatches in 6-10 days which is white in color larva, scarab like or scarabeiform and hairs are longer than found in adults. The larval head is rounded evenly with dark markings and claws with arolium. They burrow in to the food stuff becomes more crecent shape and immobile as they becomes mature. After feeding up to 5-10 weeks and it moult 5 times to become fully grown larva. Mature larvae pupate in a flimsy cocoon and takes 1-3 weeks to become adult.

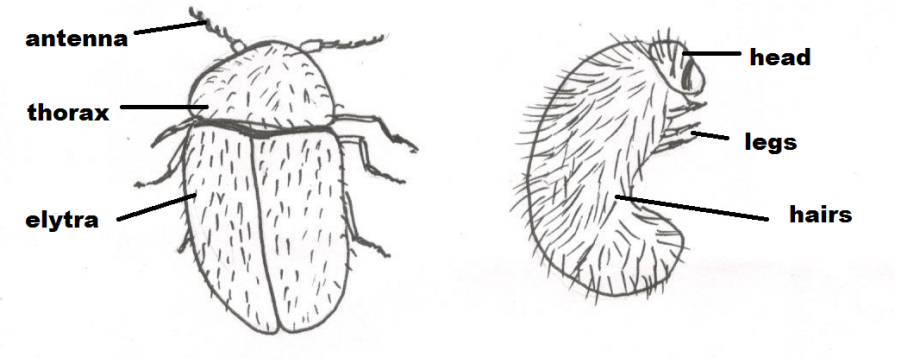


Fig 7 A) Adult of *Lesioderma* B) larva

Procedure: A separate room of 8 by 10 feet is required with walls of sugarcane fibres and shelves built to accommodate rearing. The temperature is maintained at 80ºF and supplementary source of heat electric heater to maintain the constant temperature and a fan to circulate the air in room. Glass jars of handy size covered with cotton plug provided with the food cereal products as well as in tobacco are required for rearing. Eggs of cigarette beetle glued to the surface and are microscopic.

Check the stock if not producing progeny:

1. Check the proportion of the male to female adults.
2. The color of the larvae, pupae changes if they became dead.
3. Check mite infestation in the stock culture.
4. Check overcrowding of the insect.
5. Highly infested grains also do not support the culture.
6. Adults may be transferred time to time to a new food because old culture jars contains dead egg, larva, pupa or adult, their shed cuticle, excreta.

20.7 Experiment 6

Aim: Rearing of the *Heliothis sps*. in the laboratory.

Requirements: Light trap, plastic oviposition cage, polythene sheet, filter paper, nylon mesh, 5-10% solution of pollen and honey, container.

Common name: Gram pod borer

Order: Lepidoptera

Family: Noctuidae

Host: It is polyphagous pest feed on pulses, soya bean, black gram, pea, cotton, maize, tomato, sunflower, cotton bolls and variety of vegetables.

Damage: caterpillar causes damage to different crops, feed on leaves, tender shoots, fruits and pods.

Life cycle: Adult moths are medium size, wing span 3-4cm, variable color from buff to light brown marked with grey lines. Eggs are spherical, dome shaped with flat base, 0.5mm diameter laid singly on leaves. Eggs hatches in 2-4 days and full grown larva is green or pale brown in color with dark strip on lateral side of the body, scattered hairs. There are six larval instars and takes 20-25 days to become pupa. Pupation takes place in soil and pupal period is 10-15 days and moth takes its way out of the soil when emerges.

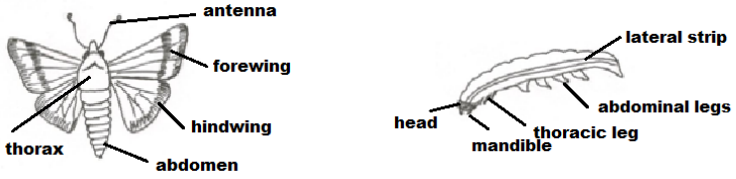


Fig 8 A) Adult of *Heliothis* B) caterpillar

Procedure: To start the colony light trap the adults moths from the field and place them in the clear plastic oviposition cage 19X21cm diameter lined with scored polythene sheet held by a paper clip. The bottom of the cage completely covered 24cm diameter filter paper with 3cm cuts from the edge towards the centre and so fitted that moth could not be trapped between polythene linings of the container. The top the cage is covered with nylon mesh on which moist filter paper are kept. The filter papers are considered as the site for egg laying as it absorbs excess moisture. The adults fed with 5-10% solution of pollen and honey with the help of cotton wick. The temperature of the laboratory maintained at 20ºC and high

moisture content by placing water filled containers in the cage. Eggs can be collected from the cage and surface sterilized with 10% formalin for 20 minutes and then rinsed with distill water 20-30 minutes and dried with filter paper and kept in plastic container at 25ºC until they hatch in 2-3 days. To rear larva transfer the newly hatched larva in the container with food diet and a layer of vermiculite for last instar development and pupation. Pupae were sexed and kept in cage for emergence.

20.8 Experiment 7

Aim: Rearing of the *Culex, Anopheles, Aedes* sps. in the laboratory.

Requirements: Rearing trays, rearing cages, temperature and humidity measuring instruments, food source.

Common name: mosquito

Order: Diptera

Family: Culicidae

Host: Human and animals

Damage: They are the vectors as they carry pathogens *Plasmodium* in female adult *Anopheles* mosquito for the transmission of malaria, Filarial worm in female adult *Culex* mosquito for the transmission of Filariasis or elephantitis, Den virus in female adult *Aedes* mosquito for the transmission of Dengue. In spite of these major diseases chikunguniya and yellow fever is also transmitted by mosquito. Every year they are responsible for the major part in global disease burden. Many deaths are reported every year due to mosquito borne diseases.

Life cycle: Mosquito has four different stages in its life cycle as adult, egg, larva and pupa. Out of these eggs, larvae and pupae are the aquatic stages while the adult mosquito is aerial in habitat. Adult is a blood sucker having piercing and sucking type of mouthparts, long and slender legs, three pairs of legs and body is differentiated into head, thorax and abdomen. There is only one pair of functional forewings while the hind wings are reduced called halters to balance the body in dipterans. The male and female mosquito can be differentiated by their antenna a female antenna is less hairy called pilose type while the male antenna is more bushy called plumose type. The adult lays eggs in bunches or singly depending

upon the species in the stagnant water sources. Eggs freely floats on water white in color when freshly laid then turns brown and black before hatching. The egg hatches in 2-3 days and first larval instar called wrigglers stays in water for 7-14 days. It is having biting and chewing type of mouthpart feeds on micro-organism and decaying organic matter found in water and moults three times to become fully mature fourth instar larva. They carry respiratory siphon at the end of abdomen to inhale air and comes at surface to breathe. From fully mature larva pupa or tumblers develop which is highly mobile and comma shape which moves up and down but do not feed. Their head and thorax fuses to form cephalothorax which consists of two breathing tubes called trumpets. From pupa adult emerges in the air in 2-3 days. Whole life cycle is completed in 21 to 24 days but the time differs according to the species and also with the season, temperature and humidity.

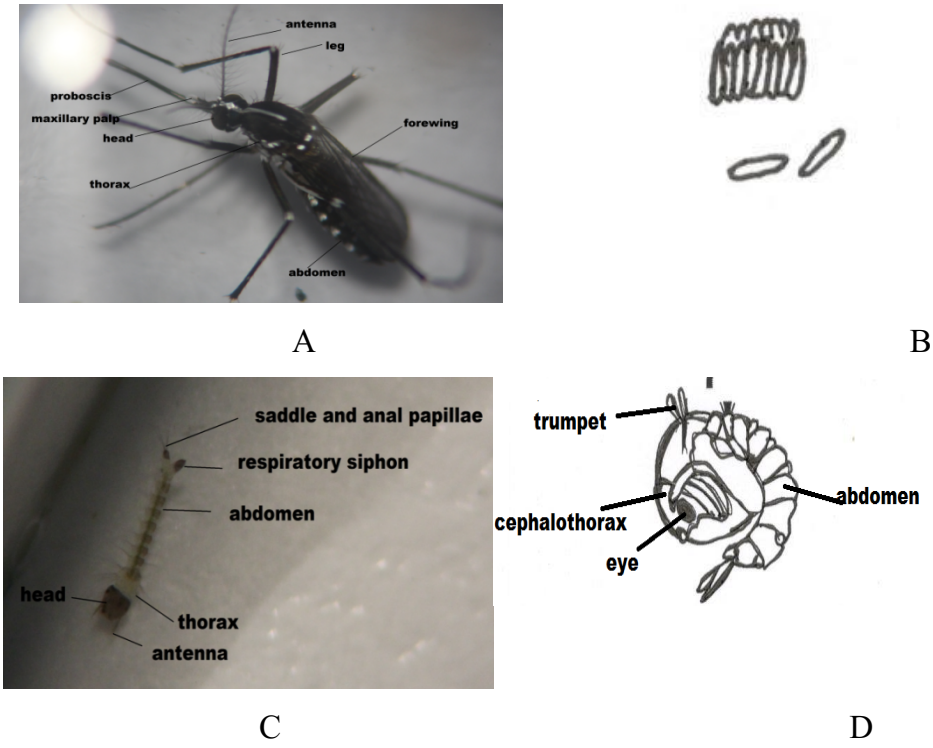
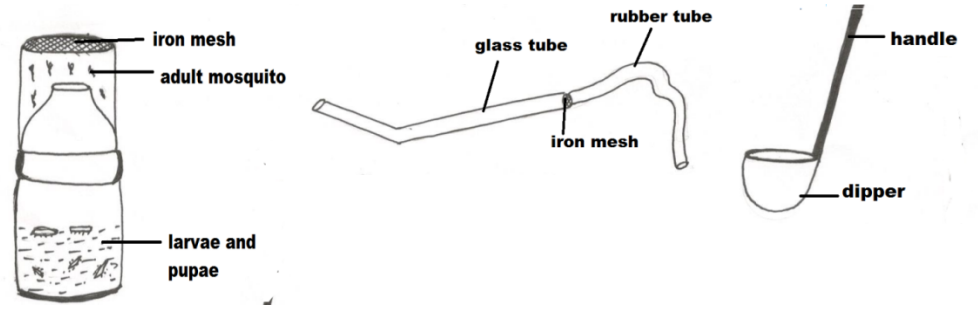


Fig 9 A) Adult mosquito B) Egg C) Larva D) Pupa

Procedure: Mosquito larvae can be collected from the breeding sites to start the culture in the laboratory. Breeding sites are different for different kinds of

mosquito species as *Anopheles* species are found in clean potable stagnant freshwater sources like banks of streams, fountains, rice fields, ponds, lakes, pots, parindas, matkas, khelies and many more, *Aedes* mosquito shares common breeding sites with *Anopheles* but they can even lay eggs in small water sources like disposable cups, flower pots, coconut shells, construction sites and as far as *Culex* mosquito is concerned they breeds in polluted and semi-polluted water sources as nala, nali, sewerages, open spaces. Mosquito larvae called wrigglers live in water and feed on micro-organisms but they respire through the tracheal gills so they have to come to the surface for breathing. Larvae are kept in rearing trays with the food like bits of bread crump or wheat bran is added to water so that fermentation takes place to produce the growth of micro-organism or we can also put brewer's yeast or dog biscuit as an alternative food. When the larvae moults to pupa or tumblers they are kept in different rearing tray in the rearing cage as they do not feed and easily capture in different cage. Pupa becomes adult in 24-48 hours. Female adults feed on blood and male adult feed on nectar. For this requirement female can be feed on warm blooded host for which rat, rabbit, pigeon are commonly used which are shaved or defeathered on some parts of the body for the ease of feeding of mosquito can be kept for 2-3 hours in rearing cage or we can also put our hand into the cage. A separate cage is used for feeding and care should be taken to tie the legs and wings of the animal so that they may not run or destroy the cage. Well males are equally important to maintain the colony and feed on 10% glucose solution soaked in cotton or 30% honey and water solution placed in the cage. For all these a separate room is required which can be maintain at a temperature of 27±2ºC and 80±10% RH.



A B C

Fig 10 A) Rearing jars B) aspirator tube to collect adult while sitting C) ladle for larvae collection from the field

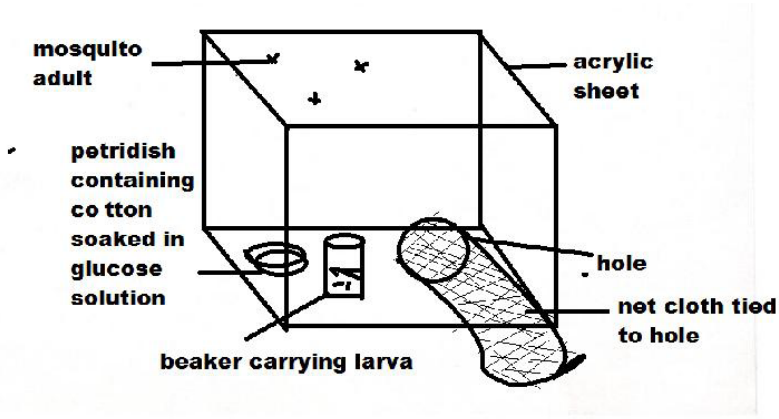


Fig 11 Rearing cage of acrylic sheet for catching adult and maintaining pure culture

Fig 12 Different breeding sites in the field like fountain water, pots for animals, overhead tanks, other articles, dustbins, parindas, coolers where larvae collection can be made for rearing.

20.9 Self learning exercise

1. Set up an experiment to rear the *Corcyra cephalonica* in slandered condition of laboratory.
2. Set up an experiment to rear the *Tribolium castaneum* in slandered condition of laboratory.
3. Set up an experiment to rear the species of *Culex, Anopheles* in slandered condition of laboratory.

20.10 References

- Modern Entomology by D. B. Tembhare
- Stored grain pest by
- Practical Zoology by S.S. Lal

Unit-21

Study of Prepared Slides

Structure of the Unit

21.0 Objectives

After going through this section you will be able to understand the slide preparation of whole mount of the minute insect less than 1mm in length or its parts like leg, antenna, wing or mouth parts.

21.1 Introduction

The insects can be collected by netting, picking, light trapping etc and then be preserved by direct pinning or mounting or liquid preservation. Small insects and their parts that have to be seen under the microscope are mounted on microscopic

slides. Then the coverslips are placed to protect the specimen. Coverslips and slides vary according to the size of the specimen.

Requirements: Different types of forceps for handling different specimens (storkbill forcep, pinning forcep, watchmaker's forcep, feather light forcep), different types of slides on the basis of specimen thickness, coverslips, 10% KOH solution, ethanol, acid fuschin, Harris haematoxylin, distill water, eugenol, clove oil, Canada balsam or DPX, PVA lactophenol.

Type of forceps

1. **Lightweight forcep:** it is fine tipped storkbill forcep (Fig 1 A) for handling unmounted and dry specimens. It has blunt nosed and feather light (Fig 1 B) for handling larva of insects.

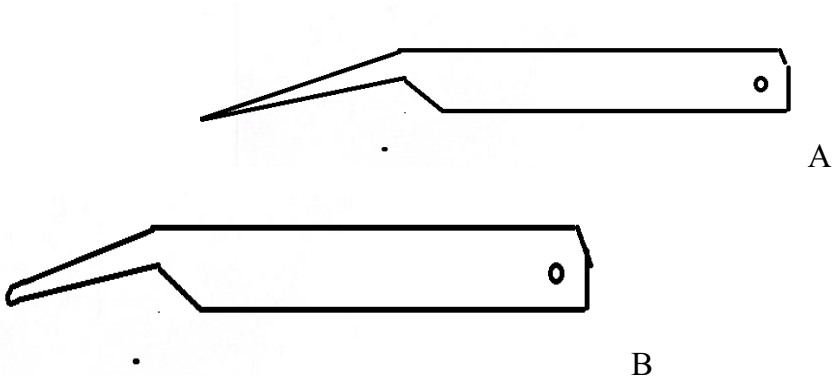


Fig 1 A) Storkbill forcep B) feather light blunt forcep

2. **Pinning forcep:** It is used for pinning the insects so it has grip to hold the shaft of the pin well not the head of the pin (Fig 2).

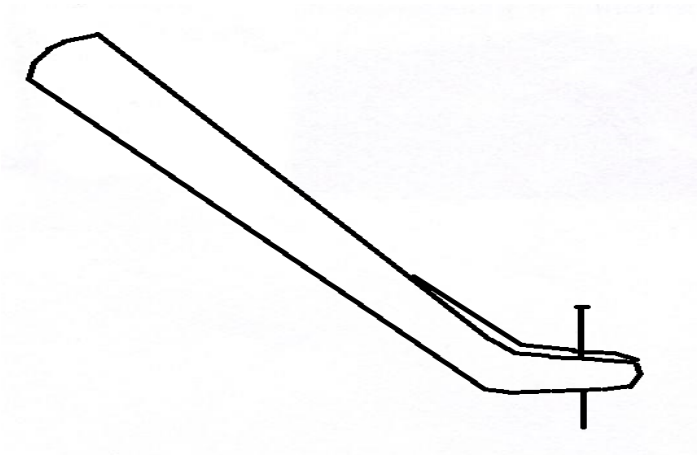


Fig 2 Pinning forcep

3. **Watchmaker's forcep:** These forceps have fine hard tips and are useful in doing dissections (Fig 3). The pressure applied to the specimen can be cushioned on will by placing the edge of the forefinger between the jaws.

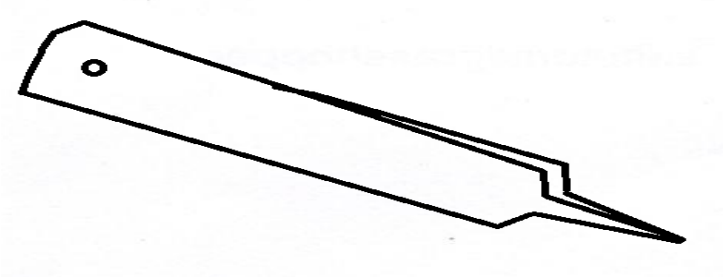


Fig 3 Watchmaker's forcep

Type of slides

1. **Glass slide**: It measures 76x25 mm and 0.8-1 mm in thickness having ground edges.
2. **Cobb aluminium double coverslip:** It is significant to view the specimen from both the sides. The frame has a hole cut in the bottom over which 25 mm square coverslip is positioned (Fig 4). The specimen is mounted and covered with coverslip 0in a routine way. Thick card is then positioned each side of the square ocoverslip and the slide frame margins crimped down to hold the card. They are costlier and preparation takes longer time.

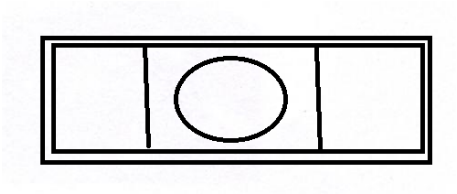


Fig 4 Cobb aluminium double coverslip

3. **Cavity slide**: They measures about 76x25mm size with a shallow depression in the middle which are significant to mount the large specimen which cannot be mounted on the normal slide (Fig 5).

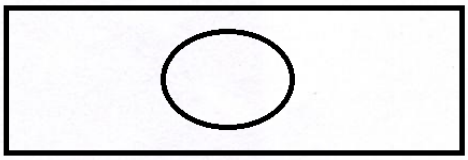


Fig 5 Cavity slide

Transparent pyrex spot plate: It is used to process small specimen for clearing, staining and dehydration if the specimen need to be heated (Fig 6).

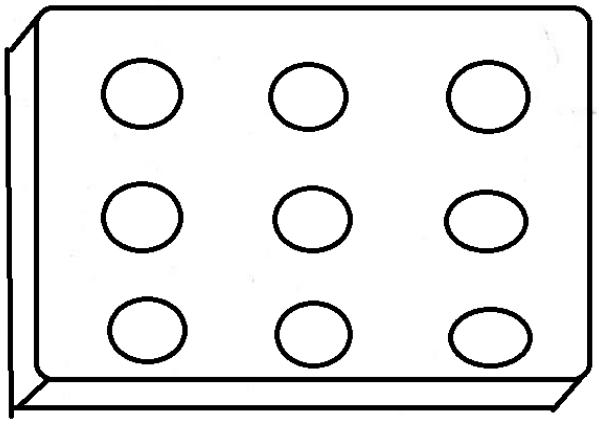


Fig 6 Transparent pyrex spot plate

Staining well or cavity dishes: They are useful for the individual specimen (Fig 7).

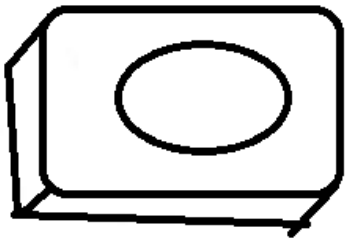
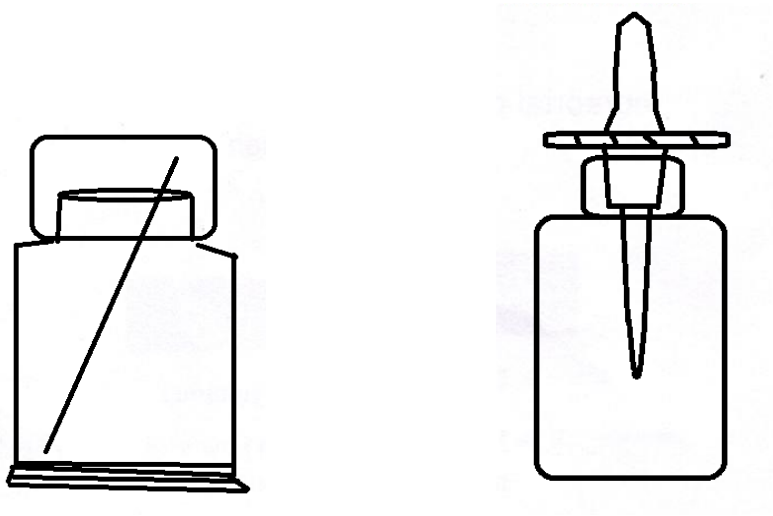


Fig 7 Staining well or cavity dish

Balsam bottles: To carry DPX or any other mounting media with a dropping glass rod to put it on the slide (Fig 8 A).



A B

Fig 8 A) Balsam bottle B) Droppping bottle

Dropping or pipette bottles: They are used for dispensing small amount of ethanol, xylol or stains (Fig 8 B).

Procedure

a) **Balsam mounts**

By this method only slightly sclerotized material can be mounted without preliminary bleaching and maceration of internal organs and if the material is heavily sclerotized it is follows both the process.

1. **Bleaching:** it is essential for the specimen or body part to be cleared to pass light through them. Clearing dissolves the soft body parts allows the structure of the cuticle to be seen. If the material is dry then first dip the material in 95%ethanol and then into 10% KOH solution. Now place the test tube rack in water bath for about 20 minutes and puncture the abdomen with needle so that it becomes translucent which is called as maceration. If the bleaching is not done properly return to the KOH (Fig 9). If the mounting material is heavily pigmented then bleach it with full strength clorox for few minutes followed by KOH and distill water. Another method named as cold KOH treatment can also be used by leaving the specimen overnight in 10% KOH at room temperature and next day returned into neutral alcohol before dehydration.

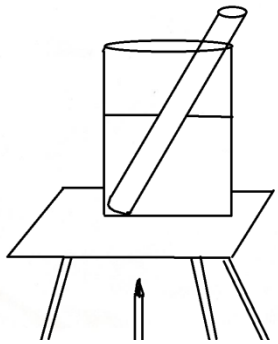


Fig 9 Method of heating a specimen in 10% KOH solution in a water bath

2. **Staining:** Two types of cuticle stain can be used acid fuschin and Harris haematoxylin. After distill water transfer it to aqueous acid fuschin for 10-20 minutes in a test tube. It is then again passing to distill water to remove excess stain.

3. **Dehydration:** It can be done by passing the specimen through a series of increasing grades of ethanol. The protocol used to dehydrate depends upon mounting media.
    i. Euparal –Specimen passes from 70% ethanol to 95% before mouting.
    ii. Permount- It passes in stages from 70%, 80%, 90%, 95% to 100% ethanol for 15-20 minutes each.
4. **Clearing:** For clearing the mounting material put it into eugenol or clove oil for indefinite time until it becomes transparent and sinks.
5. **Mounting of the material:** Put the Canada balsam or DPX on the slide and place the material from clove oil to the slide in the centre. If the material is thick small squares of the celluloid are embedded in the DPX to support the coverslip. Now place the coverslip either by dipping it in xylol or put a drop of DPX on coverslip to prevent the movement of the material. Make the preparation clean and clear.
6. **Drying and labeling:** Place the slide in horizontal position at about 50ºC for 2-3 weeks and label the slide. Slide labels should be of high quality paper with long lasting adhesive. It is generally 23 mm square size paper fix at one side of the slide.

b) **PVA lactophenol mounts:** This mounting procedure is used when the material is soft like larvae of mosquito, protura, collembolan, diplura, mites. In this process maceration is not needed. Put the PVA lactophenol on the slide, place the material alive or from the preserved fliud and cover it with coverslip. In the same way dry the slide for 2-3 weeks and label it.

21.2 Whole Mount Of Insect

1. Aphids

Classification

Order: Hemiptera

Suborder: Sternorryncha

Superfamily: Aphidoidea

Family: Aphididae

Comments

1. They are also called plant lice, green flies, blackflies or whiteflies.
2. They are small sap sucking insects destructive to plants in temperate region.
3. They are considered as highly successful group of organism due to their asexual reproductive capacity. They also show sexual phases, both winged and wingless forms are found.
4. They are easily identified by their round body form and dull green, yellow or black on color.
5. They are having six segmented antenna and sucking type of mouthparts with stylets enclosed in a sheath of rostrum (modified from mandible and maxilla).
6. Three pairs of thin two jointed leg bearing two clawed tarsi.
7. It has a pair of cornicles or siphunculi at abdomen secretes wax.
8. It also has a tail like protrusion called cauda.
9. They show mutualistic relation with ants as they secrete honey dew (therefore they are also called as ant cows) and ants protect them.

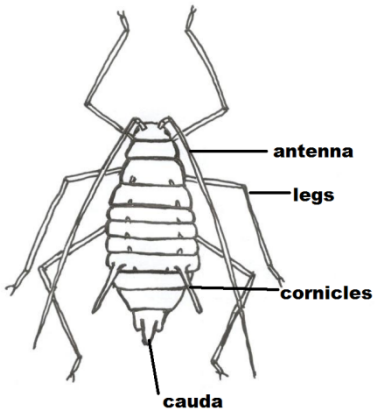


Fig 10 Aphid adult

2. *Pediculus humanus*

Classification

Order: Phthiraptera or Anoplura

Family: Pediculidae

Comments

1. It is commonly known as head louse.
2. They are wingless insect spending their whole life on the human scalp and feed on human blood.
3. They have short stumpy clinging type of leg not able to jump can walk efficiently on the scalp.
4. It bears 5 segmented antenna and piercing and sucking type of mouthparts can be retracted into head.
5. Mandibles are rudimentary while maxillae and labium forms dorsal and ventral stylets.
6. Abdomen is 9 segmented out of which first 6 segments of abdomen have a pair of spiracles to breath and last segment bears anus and genitalia.
7. Males are smaller in size (2-3mm) than females (3-4mm) and males have forelegs larger than females to grasp it during mating.
8. In males the posterior end turns upward.
9. It is responsible for the transmission of relapsing fever, typhus and trench fever.

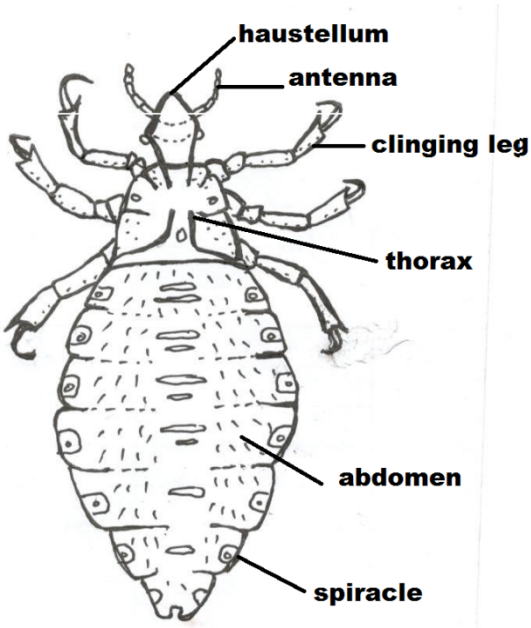


Fig 11 Pediculus humanus

3.*Tribolium castaneum*

Classification

Order: Coleoptera

Family: Tenebrinoidae

Comments

1. It is commonly known as red flour beetle and measures about 3-4mm in length.
2. It is a worldwide pest of stored grains such as flours, cereals, biscuits, beans, rice, suji, dried fruits, spices etc.
3. The adults are long lived may live up to three years in favorable conditions.
4. The adults are reddish brown in color, chewing type of mouth parts and bears clubbed antenna.
5. They have tarsal formula 5, 5, 4 and notched eyes.
6. The head is not visible from above and does not have a beak.
7. The thorax region has slightly curved sides.
8. Fore wing are hard elytra and hind wing are membranous folded beneath the forewing.

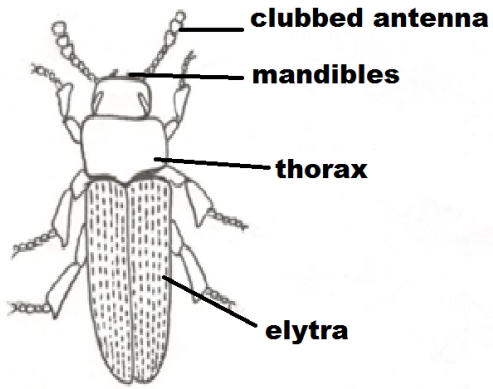


Fig 12 Tribolium castaneum

4. Pulex irritans

Classification

Order: Siphonaptera

Family: Pulicidae

Subfamily: Pulicinae

Comments

1. They are commonly called as human flea.
2. It is an ecto-parasite of many species of mammals and birds including dogs, monkeys, rats, chickens, pigs, bats etc.
3. The adult is 1.5-4mm in length and are having laterally flattened body making them easy to move within hairs of the host.
4. They are dark brown in color, rounded head and wingless.
5. They bear piercing and sucking type of mouth parts with no mandibles adapted to feed on blood.
6. Their legs are long with hind legs are adapted for jumping and can jump vertically up to 18 cm and horizontally up to 13 cm.
7. The legs end with a strong claw to grasp the host.

8. The body is covered with hard plates sclerites which further covered with hairs and short spines which are backwardly directed.
9. In unfavorable conditions they can remain dormant up to one year in pupal case.
10. It is an intermediate host of cestode *Dipylidium caninum.*
11. It is a carrier of bacterium *Yersinia pestis* causing plague a disease that affects human and other mammals.

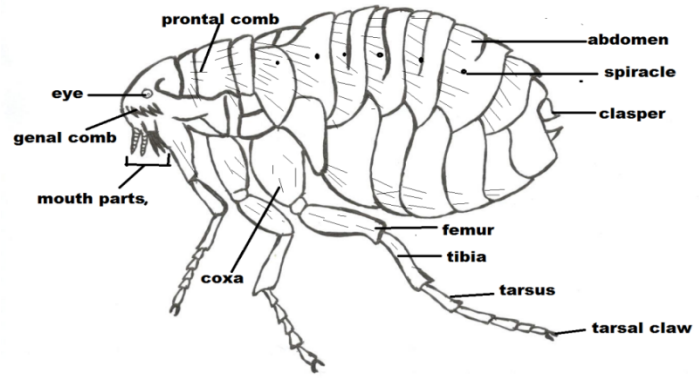


Fig 13 Pulex irritans

5. Mosquito

Classification

Order: Diptera

Superfamily: Culicoidea

Family: Culicidae

Comments

1. They are well known vector causing disease malaria, dengue, chikunguinya, yellow fever, filariasis.
2. They have slender body with long and thin legs.
3. Head is having antenna in male plumose type and female pilose type.
4. They have piercing and sucking type of mouth parts having forwardly projected proboscis used to feed on blood of the host.
5. Two maxillary palps are responsible for identifying host as they carry receptors of carbon dioxide.

6. Males feed on nectar as female only feed on blood essential for the development of their eggs.

6. *Aedes* male

Comments

1. Aedes mosquito sits parallel to the surface.
2. It is banded in appearance; body is black with white strips on the legs, abdomen and mouthparts.
3. White bands on the tarsal segment and pointed abdomen.
4. Abdomen is pointed at the end and with white scales on the lateral side and belly.
5. The claws on foreleg is toothed and paratergite with scales.
6. White knee spots found in all femora- fore, mid and hindleg.
7. Maxillary palp is as long as proboscis and 3 segmented.

7. *Aedes* female

Comments

1. Aedes mosquito sits parallel to the surface.
2. It is banded in appearance; body is black with white strips on the legs, abdomen and mouthparts.
3. White bands on the tarsal segment and pointed abdomen.
4. Abdomen is pointed at the end and with white scales on the lateral side and belly.
5. The claws on foreleg is toothed and paratergite with scales.
6. White knee spots found in all femora- fore, mid and hindleg.
7. Maxillary palps of female are 3 palpomere.
8. Maxillary palp is shorter than proboscis.

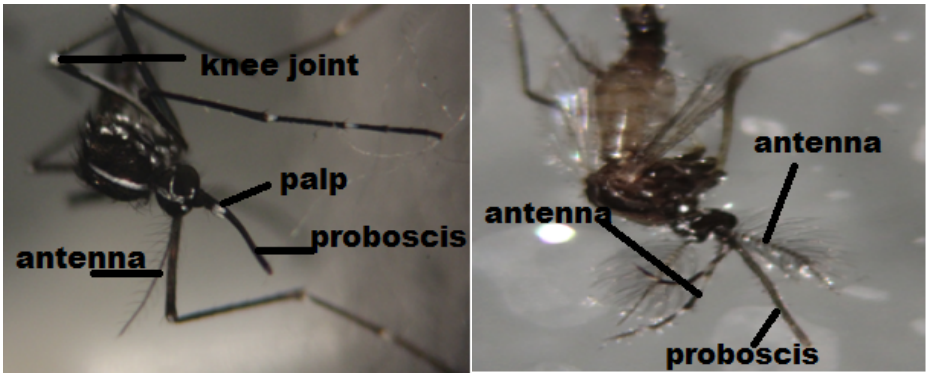


Fig 14 Female *Aedes* and male mosquito

8. *Anopheles* male

Comments

1. Maxillary palps are 5 segmented (5 paplomere) and clubbed at the apex.
2. The length of the maxillary palps are equal to the proboscis.
3. Anopheles sits at an angle to the surface.
4. Antennas are of plumose type.
5. Fore wings are with dark and pale spots more than 2 on Costa, Radius and Radius 1 veins.
6. It feed on plant juices.
7. Head consists of large compound eyes.

9. *Anopheles* female

Comments

1. Antennae are of pilose type.
2. Maxillary palps are 5 segmented (5 paplomere) which are simple and length of the maxillary palps are equal to the proboscis.
3. Anopheles sits at an angle to the surface.
4. Fore wings are with dark and pale spots more than 2 on Costa, Radius and Radius 1 veins.
5. It act as vector and responsible for the transmission of malaria Pf, Pv, Po and Pm.

6. It feeds on mammal's blood.

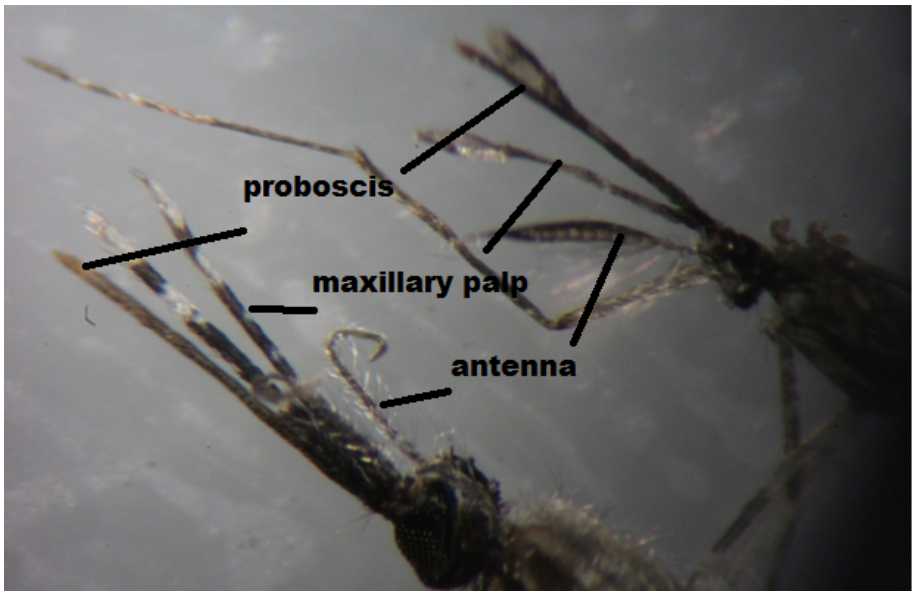


Fig 15 Female and male *Anopheles* mosquito

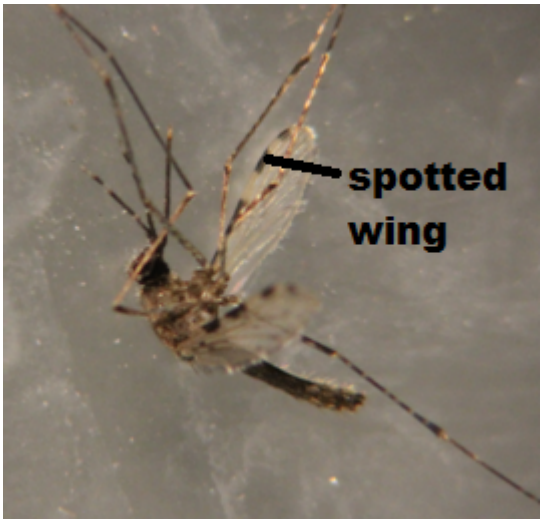


Fig 16 Whole mount of *Anopheles* mosquito

10. *Culex* male

Comments

1. Whole body is brown and a plexus of long hair grown on the pronotum .
2. In male *Culex* maxillary palps are 3 segmented and longer than labium.
3. proboscis without pale band on tip.
4. Antenna possess long, delicate and bushy hairs in bunches at joint (plumose type).
5. Maxillary palps and labium contains tactile hairs forming proboscis sheath.
6. Mandibles are needle like and all the mouth parts maxillae, hypopharynx, labium, maxillary palp consists of tactile hairs.
7. Adult *Culex* mosquito sits parallel to the surface.
8. The legs are with pulvillus and hind tarsomere 1 is as long as hind tibia.
9. The abdomen is blunt at the end.

11. *Culex* female

Comments

1. Whole body is brown and a plexus of long hair grown on the pronotum.
2. Maxillary palps are exceedingly short and three segmented.
3. proboscis with pale band on the tip.
4. Antenna consists of few hairs at joint (pilose type).
5. Maxillary palps and labium contains tactile hairs forming proboscis sheath.
6. Adult *Culex* mosquito sits parallel to the surface.
7. The legs are with pulvillus and hind tarsomere 1 is as long as hind tibia.
8. The abdomen is blunt at the end.
9. Basal bands of abdominal terga slightly paler or white than the sternal scaling.
10. It is a vector of elephantitis or filariasis.

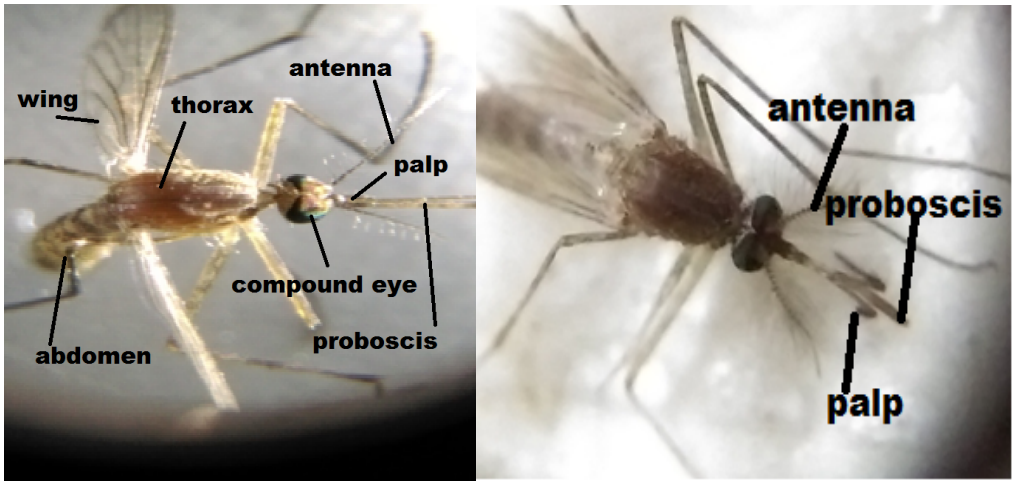


***Fig 17 Culex* female and male mosquito**

12. Mymar flies

Classification

Order: Hymenoptera

Superfamily: Chalcidoidea

Family: Mymaridae

Comments

1. It is commonly known as fairy flies or fairy wasp found in tropical and temperate regions.
2. They are world's smallest insect ranging from 0.5 to 1mm in size.
3. They are non metallic brown, black or yellow colored.
4. Female antenna is clubbed and male antenna is filiform or thread like.
5. The wings are slender with long bristles or may be greatly reduced stubby wing or absent altogether. Females with extraordinary dense hairs and domed forewing.
6. They are distinguished from other wasp as they are having H shaped pattern of suture called trabeculae or carinae.
7. The antennas are long and the sockets of the antenna called toruli are set high on the head distinctly.
8. They are known as biological control agent as they are parasitoids of the eggs of other insects.

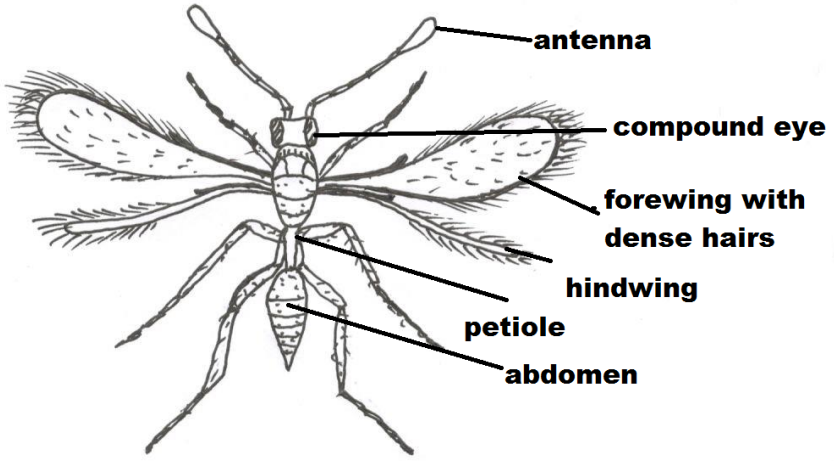


Fig 18 Mymar flies

13. *Rhizopertha dominica*

Classification

Order: Coleoptera

Superfamily: Bostrychoidea

Family: Bostrychidae

Comments

1. It is commonly called as lesser grain borer.
2. It is a pest of stored wheat and other cereal products wheat, oat, barley, rice, maize, millet, sorghum.
3. Larvae and adult both damage the grain.
4. Adult 2-3mm long in length and reddish-brown in color.
5. Body is cylindrical and elytron is parallel sided, they have regular rows of coarse punctures covered with curved setae or hairs.
6. The head not visible from above, pronotum has rasp like teeth at the front.
7. Antenna is 3 segmented club shaped at the end.
8. Adult lays 200-500 eggs in their life time.

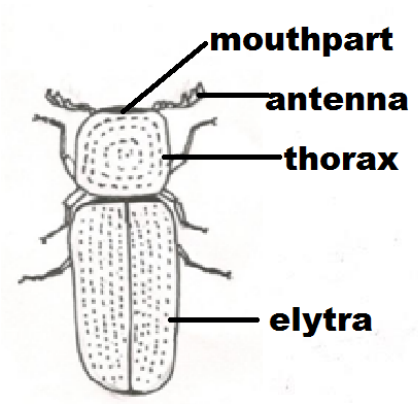


Fig 19 ***Rhizopertha dominica***

14. Drosophila melonogaster

Classification

Order: Diptera

Family: Drosophilidae

Subfamily: Drosophilinae

Comments

1. Commonly it is known as fruit fly or vinegar fly.
2. It is widely used in biological research in studies of genetics, physiology, microbial pathogenesis and life history evolution.
3. It is yellow brown in color with beautifully colored brick red eyes.
4. They are having black rings across their abdomen.
5. Adults are 2-4mm long and males are slightly smaller than females with dark patch on the back.
6. The end of the abdomen of male is blunt while in female it is pointed.
7. Males also differentiate as it bears a sex comb on the tarsus of the fore leg and also has spicky hairs or claspers at the end of abdomen to hold the female while mating.
8. Sx comb contains ten dark black colored bristles which are easily distinguished.

9. It consist of only two wings and the hind wing is reduced as halters for balancing the body.

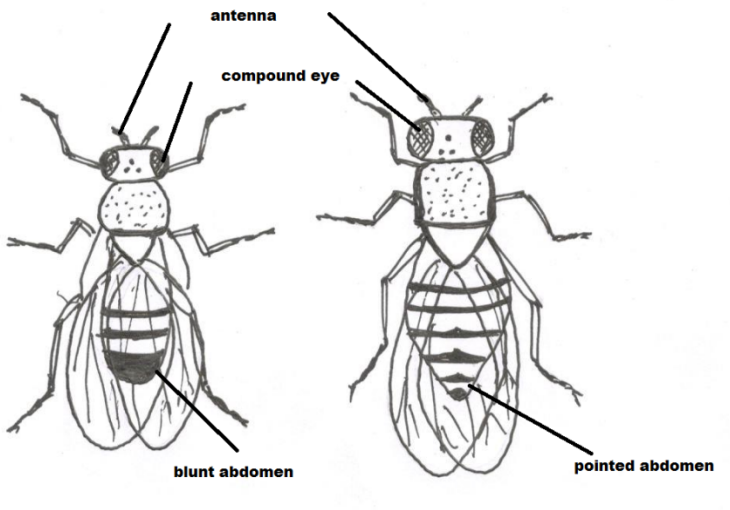


Fig 20 *Drosophila* melonogaster male and female

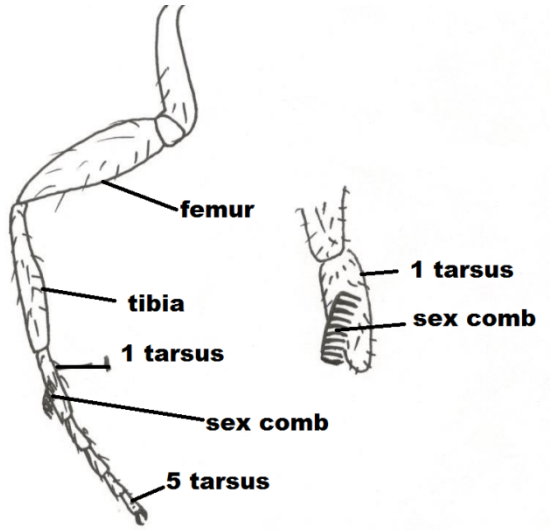


Fig 21 *Drosophila melonogaster* male fore leg and 1st tarsus enlarged to show the sex comb

15. *Cimex lectularis*

Classification

Order: Hemiptera

Suborder: Heteroptera

Superfamily: Cimicoidea

Family: Cimicidae

Comments

1. Commonly called as bed bug.
2. They are cosmopolitan nocturnal ectoparasite inhabits beds, blankets and carriages.
3. Body measures about 5mm in length and it is oval and dorsoventrally flattened in shape.
4. Mouthparts are piercing and sucking type.
5. Forewing is vestigial called wing stubbs or hemielytra and hindwing is completely absent.
6. Female contains specific region called Organ of Berlese in which male inserts its penis to transfer sperms.
7. Due to its sucking it causes irritation, erythma, sleeplessness and inflammation.
8. It also acts as carrier and transmit diseases such as relapsing fever, plague or typhoid.

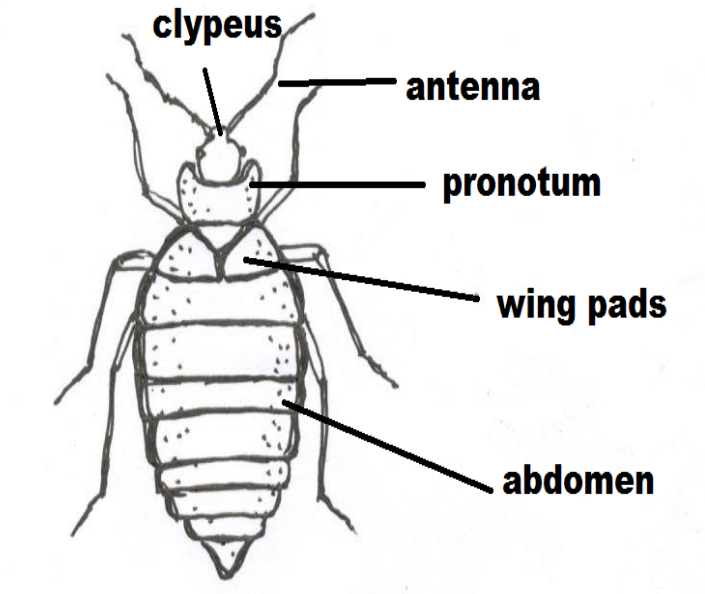


Fig 22 *Cimex lectularis*

16. Ants

Classification

Order: Hymenoptera

Suborder: Apocrita

Superfamily: Vespoidea

Family: Formicidae

Comments

1. They are eusocial insects along with wasp and bees.
2. Ants form colonies that vary from few dozen to highly organized colonies occupies a large territories.
3. Colony consist of sterile wingless females, forms workers ans soldiers, fertile drones, one fertile queen.
4. Their size ranges from 0.75 to 52 mm.
5. Ants has various body segments head, mesosoma, metasoma and gaster.
6. Mesosoma is thorax and first abdominal segment.
7. Gaster is the abdomen less the abdominal segments in the petiole.
8. There are two stong mandibles used to carry food, manipulate objects, construction of nest and defence of the colony.
9. Only reproductive ants queen and males have wings and legs terminate in hooked claw.
10. Antenna are of elbowed type, and consist of a strong constriction on second abdominal segment into a node like petiole.

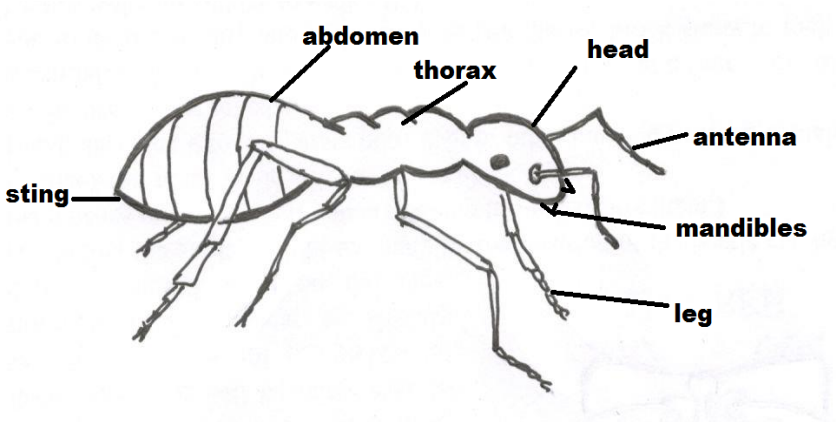


Fig 23 Termite worker

17. Termites

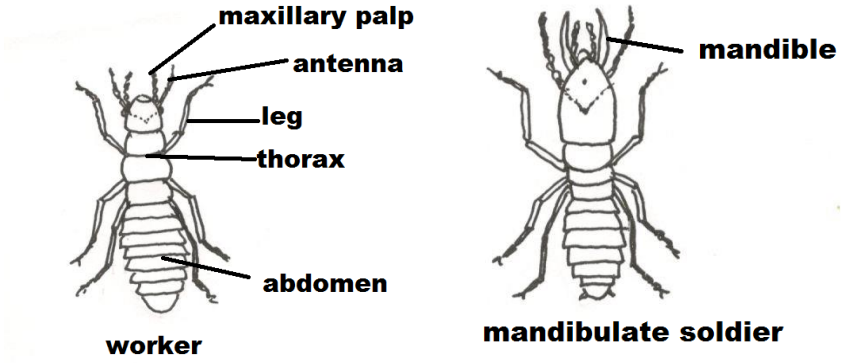
Classification

Order: Isoptera

Family: Termitidae

Comments

1. Termites are social insects live in colonies with different caste system.
2. The caste includes king queen, worker, soldiers ans nasute.
3. Workers are havind underdeveloped wingless forms. They contains antenna, maxillary palp, compound eyes and three pairs of legs. They are meant for construction of nests and collection of food.
4. Soldiers are having large head as compared to workers and easily distinguished. They have long and strong mandibles and they protect the colony.
5. Nasute caste is specific as it has rostrum well developed and it secretes sticky to defend its colony from enemies.
6. Queen is the reproductive caste which has much elongated abdomen and only lays egg.It has a pair of wing stubbs which shed after nuptial flight.



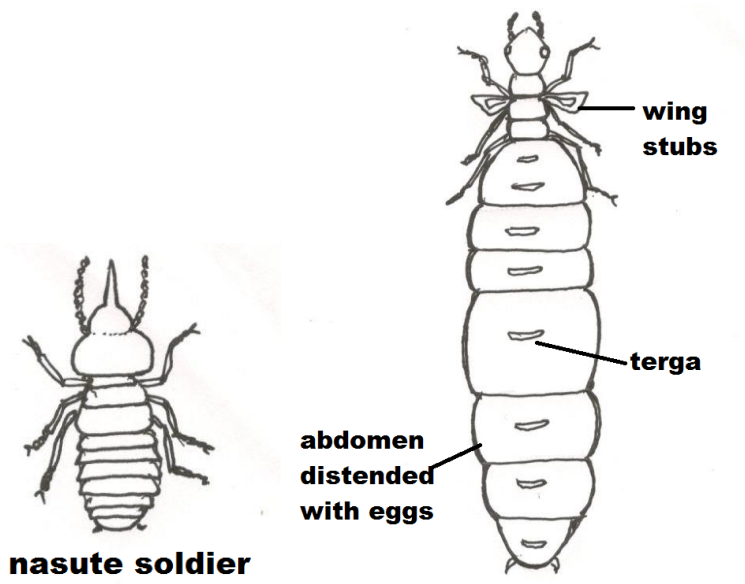


Fig 24 Different caste of termite

21.3 Histological Slides

1. T.S of Integument

Comments

1. Cuticle is the outermost layer of insect integument which is differentiated into outer epicuticle and inner procuticle.
2. Epicuticle is 0.03-4 µm thick and made up of cement layer, wax (lipid), polyphenol, sulphur and cuticulin (lipoprotein).
3. Cuticulin is a thin layer rich in polyphenol resistant to acids and organic solvents. It is due to this cuticulin that allows expansion of cuticle during moulting.
4. Procuticle is 200µm thick further distinguished into outer exocuticle and inner endocuticle. It is made of chitin and a mixture of protein.

5. Exocuticle is a highly stabilized layer which is pigmented and consists of sclerotin protein.
6. Epidermis/ hypodermis is a layer of living cells resting on basement membrane. It consists of cells like tormogen cells, trichogen cells, nerve cells, sensory cells, oenocytes and dermal glands.
7. Epidermis is meant for the secretion of cuticle and moulting fluid that dissolves older cuticle layer and forms new cuticle. The process of shedding of cuticle is known as ecdysis/ moulting.
8. Basement membrane: It is the lowest membrane of integument 0.5µm thick and contains neutral mucopolysaccarides. It is secreted by haemocytes.

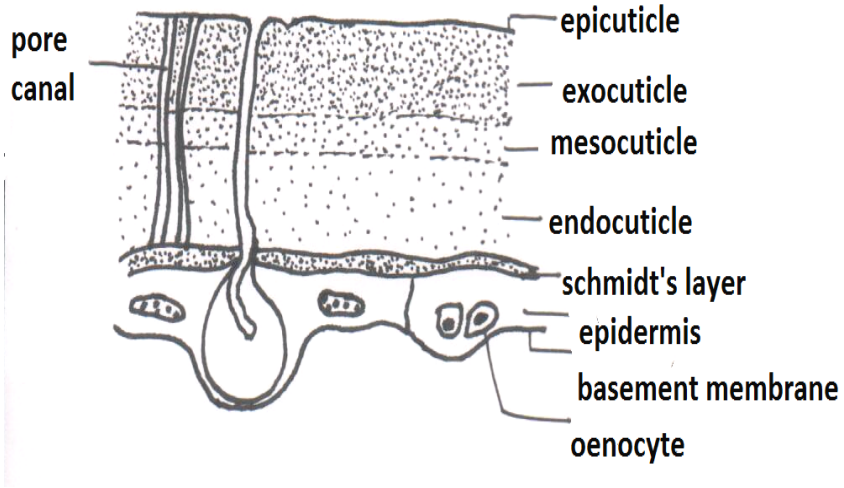


Fig 25 T.S of Integument

2. Outgrowths of integument

Comments

1. Internal processes are restricted to apodemes but external processes may be cellular or non-cellular.
2. Unicellular outgrowths are like hairs, bristles, setae and scales. In all of these membraneous articulation is absent.
3. Hairs/ sensilla trichoidea occurs on all parts of body but more confined to antenna, legs and mouthparts.

4. Setae proper are the outgrowth of entire integument lined by layer of epidermal cells.
5. They may be of different shapes and consist of membraneous articulation.
6. Setae is fixed in a socket and develop from trichogen cell and supported by tormogen cell. Setae function to cover the body like hair.
7. Sensory setae found on appendages are associated with nervous system and sensory in function.
8. Multicellular outgrowths include spurs and spines.
9. Spurs are present on the legs of many insects. Among non-cellular outgrowths microtricha are present in Mecoptera and Diptera. Papilla is a conical protrusion secreted around microvilli.

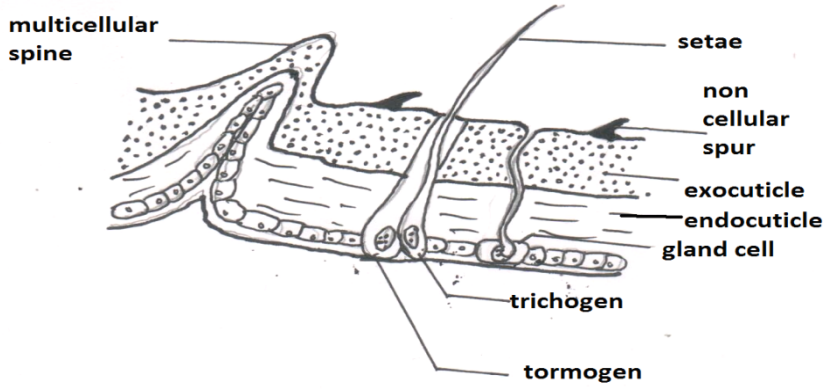


Fig 26 Integument with tormogen, trichogen spur,setae, spine

3. Salivary gland of mosquito

Comments:

1. The paired salivary gland is situated in the thorax flanking the oesophagus.
2. Each gland has three lobes two lateral and one median.
3. Lateral lobes are formed by proximal, intermediate and distal regions.
4. The extreme anterior part of each gland is innervated and ingluvial ganglia are situated at the junction of fore gut and midgut supply neuroseceretory axons to the gland.

5. The ducts from each lobe fuse to form lateral salivary ducts which run forward to form one median duct that opens at the base of hypopharynx.
6. Salivary gland of mosquito is the place where sporozoites of plasmodium lives and transfer the host when it sucks blood through the proboscis**.**

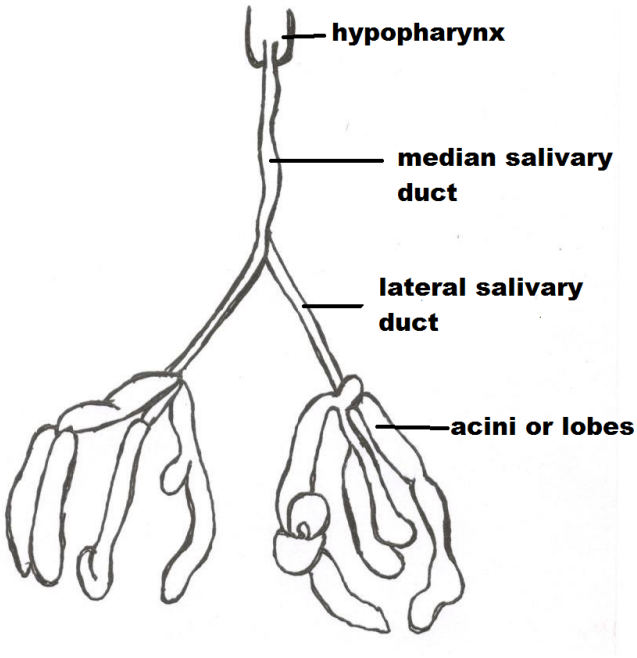


Fig 27 Salivary gland of mosquito

4. Sting apparatus of honey bee

Comments

1. In Hymenoptera ovipositor is modified into sting and accessory /collateral gland into poison gland.
2. It consists of sting, bulb, levering plates and glands.
3. Sting is made of two pairs of gonapophysis 8th segment forms stylet and 9th segment forms stylet sheath which enclose poison canal.
4. Stylet contains pointed spines or barbs.
5. Stylet sheath is expanded at the end forming bulb.
6. There is three pair of plate's anterior fulcra plate, posterior-dorsal quadrate plate and inner oblong plate.

7. The two glands are associated poison gland which opens into poison sac and alkaline gland opening into bulb.
8. Biting of the sting causes sensation, pain and swelling.
9. It shows altruistic behavior (sacrifice for the colony to defend) as the barbs are backwardly directed so when it stings and after ejection of poison raises its abdomen the barbs do not come out and the apparatus completely come out of the abdomen and the bee dies.

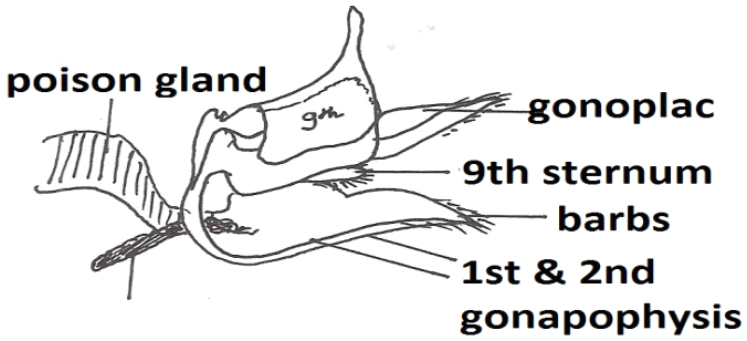


Fig 28 sting from external view

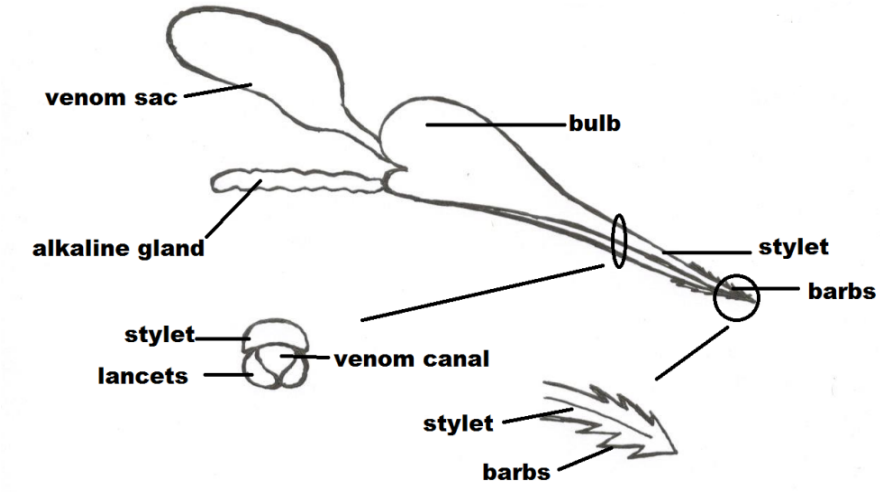


Fig 29 Sting from internal view

5. Salivary gland chromosome

Comments

1. Dissect out the salivary gland of third instar larvae of *Drosophila* in ringer's solution. Place the salivary gland in 2-3 drops of acetomethanol and stain with acetocarmine. Mount on the slide and see under the microscope
2. Polytene or salivary gland chromosome of Drosophila is the oversized chromosomes. Chromosomes are visible in the form of bunch about 200 µm in length.
3. Cells undergo repeated DNA replication without cell division.
4. It contains four chromosomes.
5. Light and dark banding pattern are seen in each chromosome.
6. Dark bands represent inactive chromatin and light bands indicate higher transcriptional activity.
7. At some places the chromosomes are swollen called as chromosome puffs which are the uncoiled regions where RNA transcription takes place.

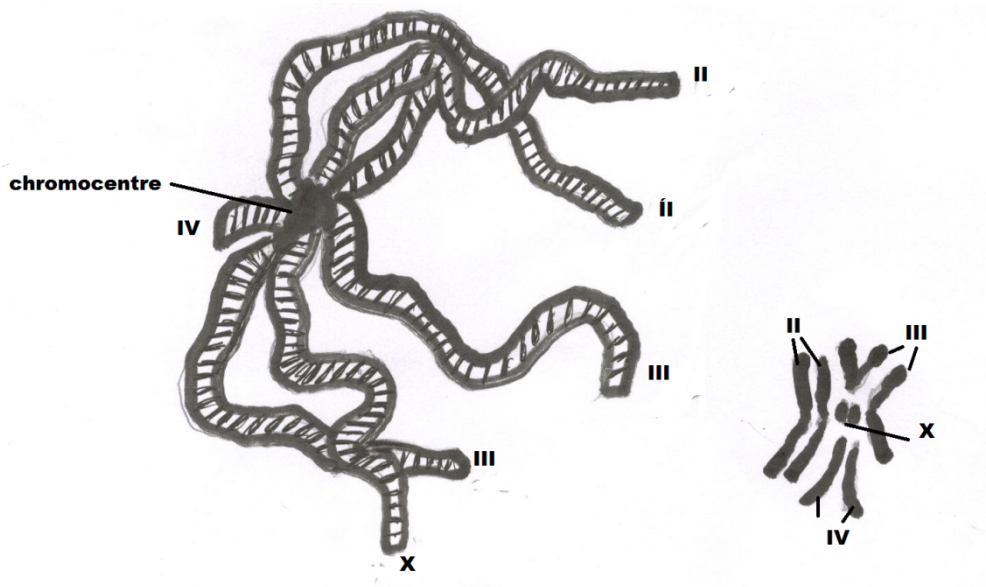


Fig 30: Salivary gland chromosome

6. T.S of midgut

Comments

1. The outermost layer is the basement membrane.
2. There is a layer of circular muscle and longitudinal musles below the basement membrane.
3. At the base of circular muscle a layer of epithelium is present consisting of two cells.
4. One is the tall columnar secretory cells with microvilli forming a striated border.
5. Second type is nidi cells or regenerative cells.
6. The number and frequency of the nidi cells vary with the insects and it may be absent as in the case of thrips.
7. Secretory cells secretes enzymes and also function in absorbtion while the regeneration cells replaces the dead secretory cells.
8. Lastly a soft peritropic membrane is present lining the lumen which protects the mid gut epithelium.

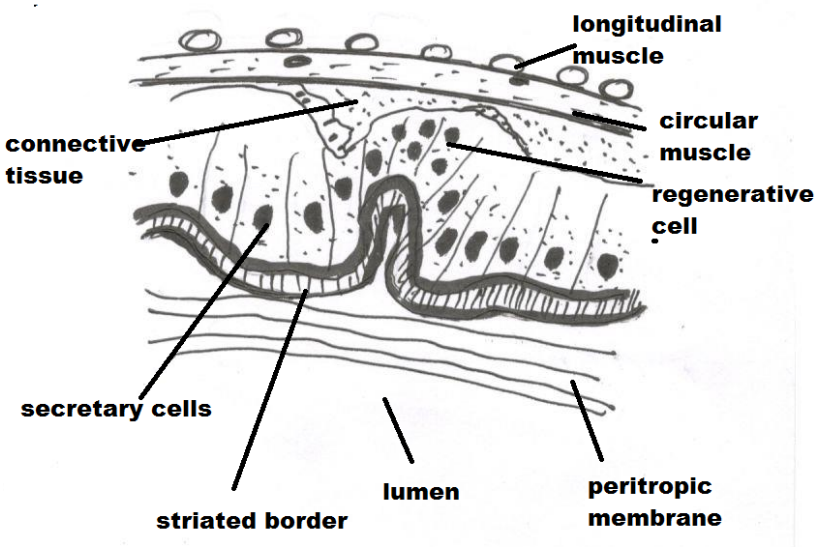


Fig 31: T.S of midgut

7. T.S of brain

Comments

1. Brain consists of three parts protocerebrum, deuterocerebrum and tritocerebrum.
2. Protocerebrum are the fusion of ganglions of the optic segments and innervates the compound eye and ocelli.
3. Protocerebrum consist of bilobed protocerebral ganglion and optic lobes.
4. Deuterocerebrum is formed by the fusion of antennary segment ganglion.
5. It is made up of partly fused lobes from which antennary lobes arises.
6. Tritocerebrum formed by the fused ganglion of intercalary segment of the head.
7. Neurosecretory cells NSC are present in brain and axons of NSC innervate the corpus cardiacum.

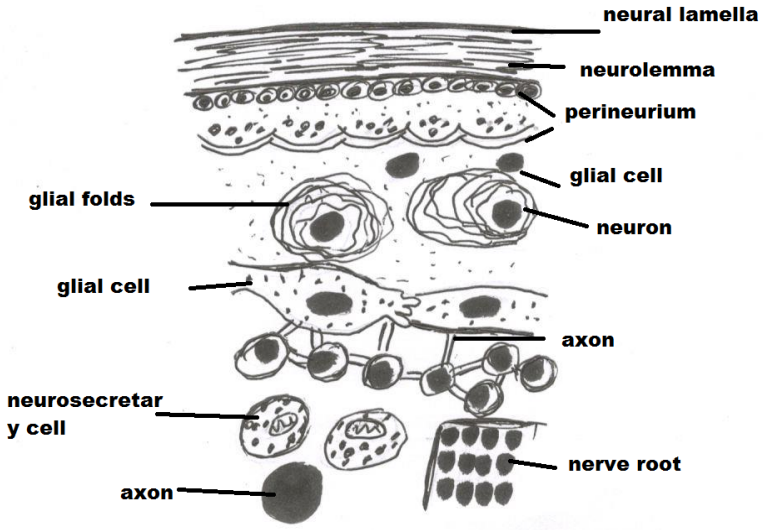


Fig 32: T.S of brain

21.4 Types Of Antenna

Antennae are the highly mobile and sensory organs present between the compound eyes which perform a variety of functions to detect motion and orientation, odor, sound, humidity, and a variety of chemical**.** Antennae consist of basal first segments called **scape**, second segment is **pedicel** and last remaining antennal segments or flagellomeres are jointly called the **flagellum** which may be further divided into third segment **meriston,** ring segments, funicle and club region.

No antenna-Protura

Many segmented- Orthoptera, Dictyoptera, plecoptera, Ephemeroptera, Psocoptera

More than 40 segments- Orthoptera, Neuroptera, Trichoptera

Reduced- Hemiptera, Hymenoptera, some Coleoptera, Diptera

Modified antenna- Lepidoptera, Coleoptera, some Hymenoptera

Function: It is used as sensory structure as it has chemoreceptors and sensitivity ranges from few meters to upto 7 kilometers. Many insects use their antenna as humidity sensors to detect changes in the concentration of water vapours. It is also used to detect sound waves and to gauge air speed while flying. It can be used as legs in stick insects, accessory respiratory organ in Hydrophilidae (Coleoptera), as auditory organ in Dipterans.

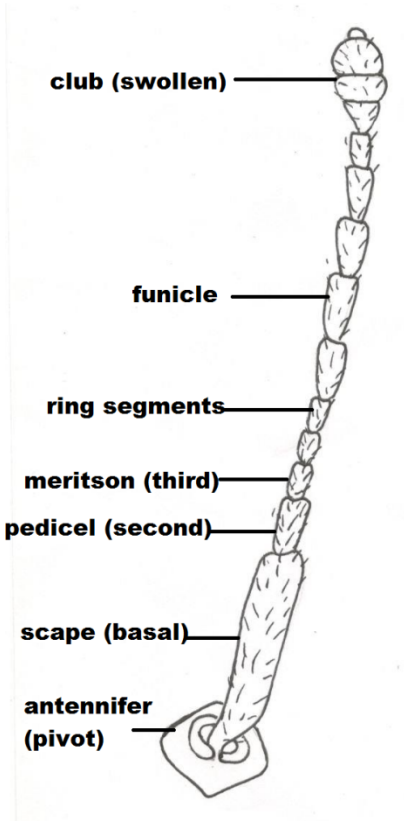


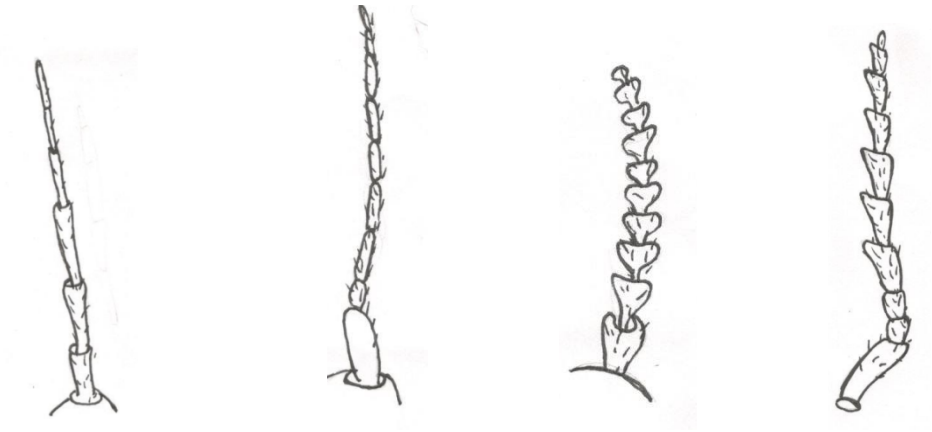
Fig 33 Structure of antenna

Comments

1. **Aristate** antennae are pouch-like with a lateral bristle and last segment is aristate type, housefly and shore flies (order Diptera).
2. **Capitate** antennae are having sudden enlarged segments forming head like structure or clubbed at last segments, Butterflies (order Lepidoptera).
3. **Clavate** antennae are gradually broadened or clubbed at the end, Carrion beetles (order Coleoptera), butterflies, Mallophaga, Siphonoptera.
4. **Filiform** antennae have a thread-like shape, segments are of same thickness. Grasshoppers, ground beetles and longhorned beetles (order Coleoptera), cockroaches (order Blattaria).
5. **Geniculate** antennae having three parts club, funicle, ring segments. The scape is long forming a sharp bend like a flexed arm. Formicidae, Cucurlionidae, Lucanidae, honey bee.
6. **Lamellate** antennae having terminal segments of the flagellum extended inot leaf like plates at the end or nested plates on one side, Scarab beetles (order Coleoptera).
7. **Monoliform** have a bead like or globose shaped segments, Termites (order Isoptera).
8. **Pectinate** antennae have a comb-like in appearance. The segments of flagellum have long thick projections which may be on one side monopectinate or both side bipectinate, Fire-colored beetles, cardinal beetles and fireflies (order Coleoptera), unipectinate - moths, bipectinate-silk moth, Saturniidae family.
9. **Plumose** antennae have thick whorls of bristles or hairs at each segment, male mosquito. Pilose (thin whorls of hairs), female mosquitoes.
10. **Serrate** antennae have a saw-toothed shape structures, the segments are angles at one side giving it a saw like appearance. Pulse beetle (*Callosobruchus*), Click beetles, elatridae family (order Coleoptera).

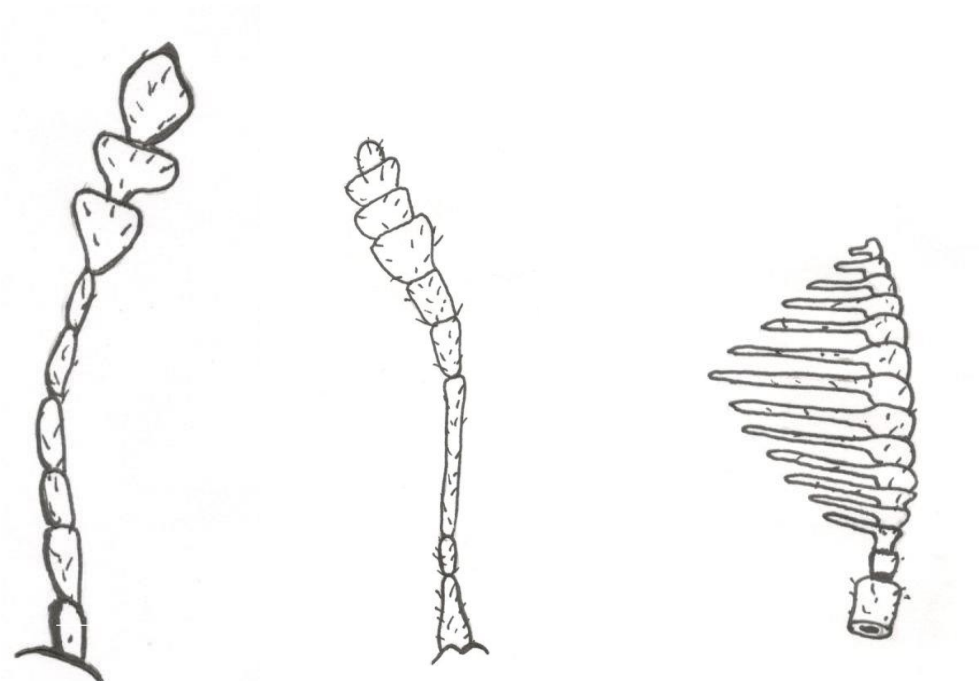
11. **Setaceous** antennae have a bristle-like shape, segments broader at base gradually tapers at the tip. Dragonflies and damselflies (order Odonata), bristle tails, caddisfly, stone flies.

12. **Flabellate** antenna, the segments of the flagellum produced into long and thick tongue like projections Strepsiptera -male stylopids.
13. **Stylate (Stetiform)** antenna the flagellum forms a long and unsegmented with terminal hair, robber flies.
14. **Ensiform antenna –** The segments of the flagellum are thin and gradually tepers towards the apex and look like leaf blade or sword in appearance, green grasshoppers.



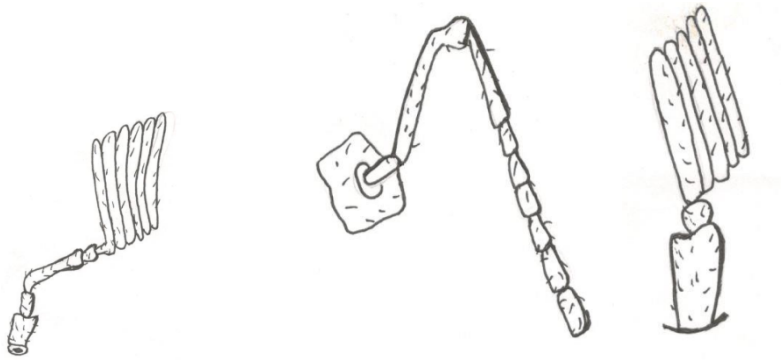
A B C D

Fig 34 A) Filiform-thread like B) setaceous-tapered C) monoliform-beaded D) serrate-saw like



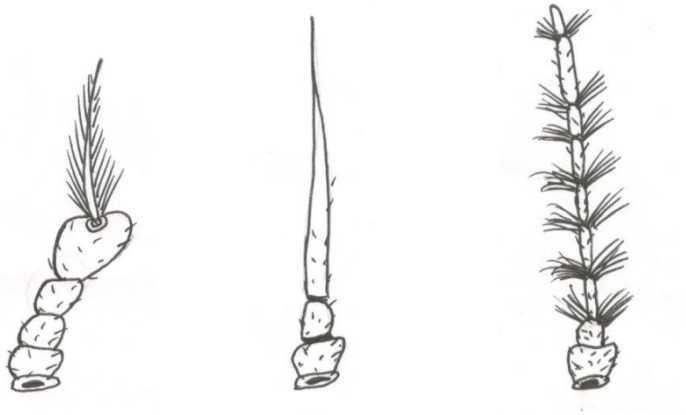
A **B** **C**

Fig 35 A) capitates B) clavate or clubbed C) Pectinate-comb like



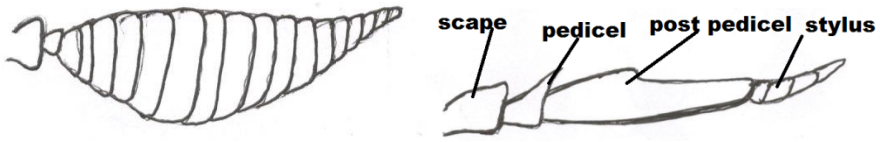
A **B** **C**

Fig 36 A) lamellate -leaf like B) geniculate –elbowed C) flabellate- fan like fold



A B C

Fig 37 A) aristate -bears bristles B) stylate - pointed needle C) plumose - hairy



A B

Fig 38 A) Stylate or Stetiform B) Ensiform

21.5 Types Of Mouthparts

Several types of mouthparts occur in insects groups with modifications that are evolved from the basic chewing type. For this to study cut the head with the blade or with the help of forcep and mount as given above.

1. Piercing and sucking mouthparts:

Comments

1. They are modified mouth parts used to pierce food items to enable sucking of the internal fluids.

2. Proboscis are modified structure of mandible and maxillae sheathed within the modified labium.
3. Labium encloses all other mouth parts like a cover or sheath.
4. The mandibles and maxillae are needle like in structure together forms stylet to pierce through the skin. During piercing labium remains outside.
5. In maxilla maxillary palp are absent.
6. For example, Hemiptera, Diptera- mosquito, aphids, bedbugs, leaf hoppers.

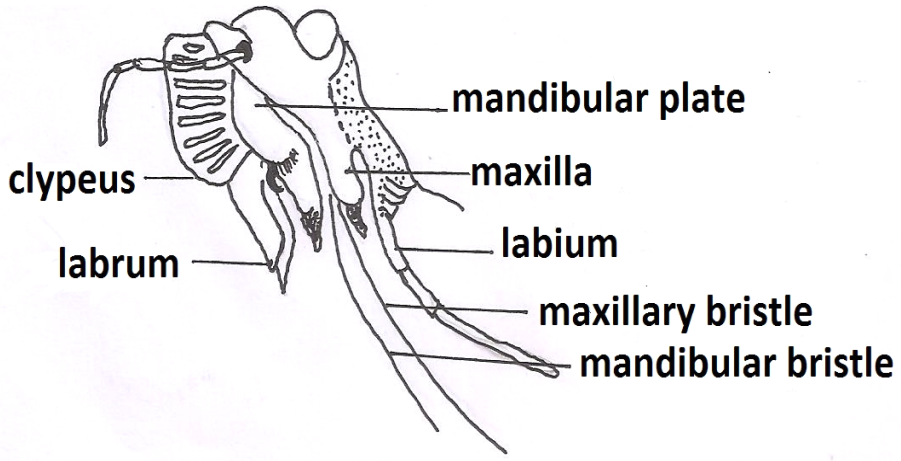


FIG 39 Mouthparts of Hemiptera piercing and sucking type

2. Biting and chewing type:

1. These insects have two mandibles on each side which are strong.
2. They are the largest part of biting chewing mouthpart used for cutting, tearing, crushing and chewing food.
3. Mandibles open outward and meet medially.

4. In carnivorous insect mandibles are knife like, herbivorous insects (caterpillars) have broad and flat mandibles, in male stag beetle used to defend mating sites and in ants (soldier caste) used as hunting appendages.
5. Maxilla is situated beneath the mandibles used to manipulate the food.
6. Maxilla has hairs and teeth along their inner margins.
7. Maxillary palps of maxilla are sensory structure used to find food potentials.
8. Labium is composed of submentum, postmentum and prementum.
9. Labium is secondary maxilla fused together and assists in manipulating food during mastication.
10. Labial palps are also sensory like maxillary palps.
11. It is the most generalized type of mouthpart.
12. For example Orthoptera, dragon flies, Coleoptera, grasshoppers, lice beetles and some of the larvae.

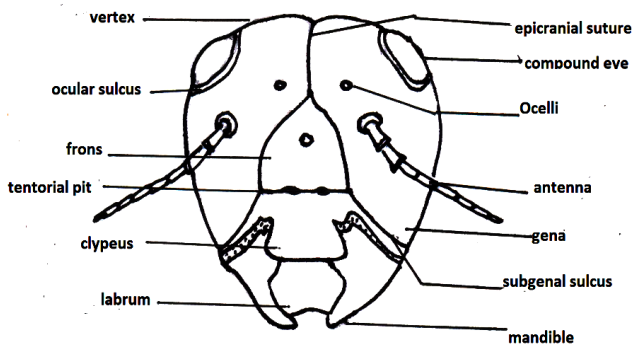


Fig 40 Generalized mouth part in frontal view

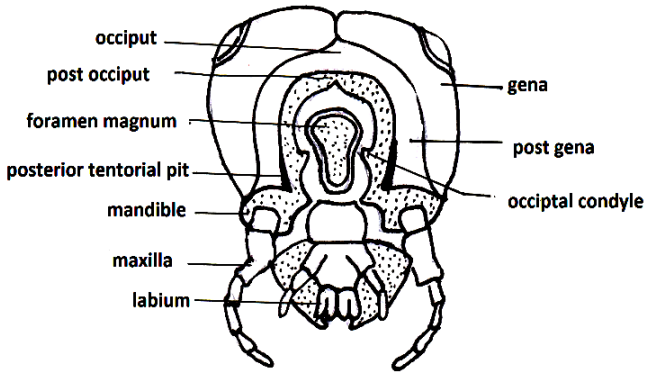


Fig 41 Generalized mouth part in ventral view

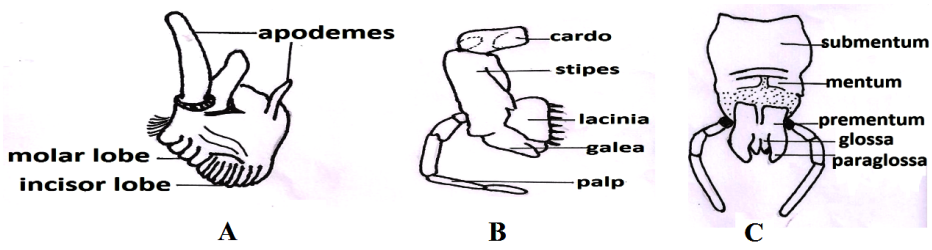


Fig 42 Mouthparts biting and chewing A) mandible B) Maxilla C) labium

3. Rasping and sucking type:

1. Forwardly projected beak formed of labrum and maxilla.
2. Left mandible is present but right one is reduced.
3. For example, thrips.

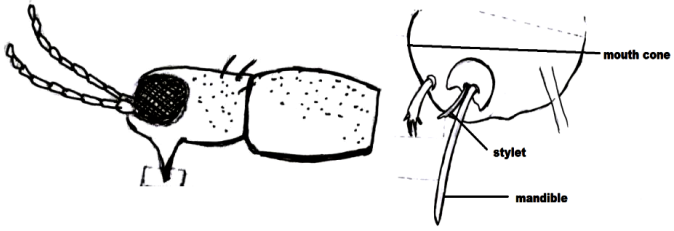


Fig 43 Mouthparts of thrip

4. Siphoning type:

1. Moths and butterflies are characterized by coiled proboscis held under the head when not in use. When it feeds it is extended to reach the nectar of the flower.
2. Mouth parts consist of clypeus, triangular labium and coiled proboscis.
3. Maxilla is hollow tube like in which galea are fuse to forms proboscis forming food canal to reach the nectar.
4. Proboscis is coiled structure and straightens when feed on nectar due to rise in blood pressure.
5. Maxillary palp and labrum are reduced.

6. Mandibles are absent but in some mandibulated moth mandibles are fully developed..
7. For example, moths and butterflies.

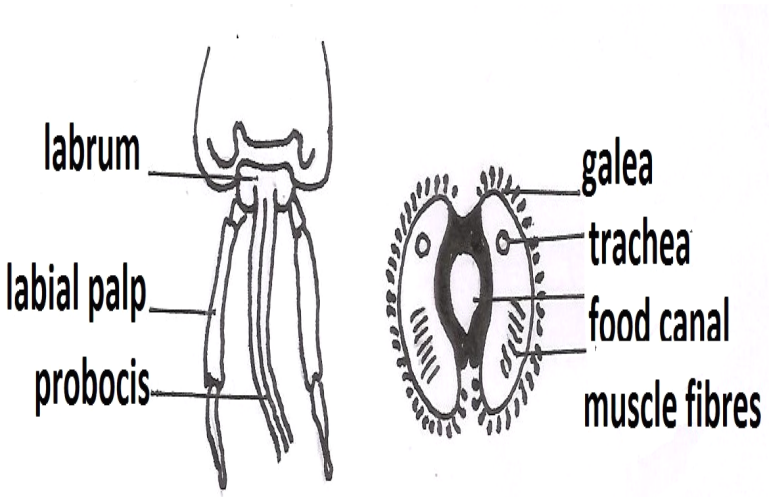


Fig 44 Siphoning mouthpart butterfly

5. Sponging type:

1. The insect lacks cutting apparatus.
2. Mouthparts consist of proboscis, short maxillary palp, labrum epipharynx, and hypopharynx.
3. Fleshy and retractile proboscis is the modified structure formed from labrum, labium, hypopharynx.
4. It consists of labium which is divided into 3 parts rostrum, haustellum, and labellum.
5. The surface of the labellum is also covered with minute food channels formed by interlocking hypopharynx and epipharynx forming a tube leads to oesophagous.
6. Hypopharynx is narrow and contains salivary duct.
7. Labellum contains pseudotracheal canals bounded by pseudotracheal membrane
8. Paired mandibles and maxilla are present but reduced or non functional.

9. Unjointed maxillary palps present before the rostrum.
10. For example Diptera- housefly, fleshfly. Housefly is able to feed solid food as saliva dissolves food and then drawn up into the mouth as a liquid by capillary action.

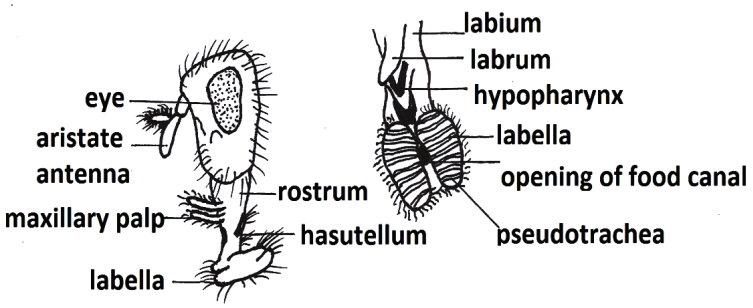


Fig 45 Mouth parts of house fly Sponging type and its proboscis enlarged

6. Chewing and rasping type:

1. Mouthparts consist of spoon shaped mandibles, labrum and maxillae devoid of lacinia.
2. Mandibles are smooth and spatulate type found on either side of labrum.
3. Labellum is spoon shaped grooved internally forming tongue.
4. Epipharynx is soft and triangle shaped below the labrum, cardo and stipes are well developed.
5. Labrum and mandibles are of chewing type.
6. Maxillary palps and labial palps are small or reduced.
7. When food is take it converts into honey in honey sac with the help of enzymes secreted by salivary gland.
8. For example Hymenoptera- honeybees, wasp

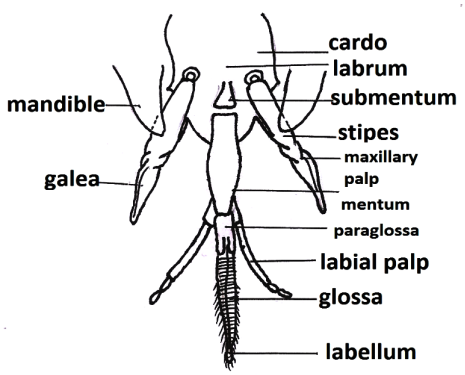


Fig 46 Honeybee mouth part

21.6 Types of Leg

Legs are also differentiated on the basis of which part of thorax it is present. Prothoracic legs attached on prothorax, mesothoracic legs attached on mesothorax and metathoracic legs attached on metathorax.

Insect legs are segmented appendages consisting of five segments. From the part nearest to body towards farthest, these segments are the coxa the base of the leg, trochanter smallest part, femur largest and strongest part, tibia the longest part, and tarsus which is subdivided into tarsomeres. It consists of segments varying in number from 1to 5 segments. In Collembola order tarsus fuses with tibia to form **tibiotarsus** as it is a primitive order**.** Last tarsal segment is called pretarsus consist of a pair of claws with a pad called the **arolium/pulvillus/empodium** meant for adhesion.

Depending upon the environment in which insect adapt and acclimatize legs are modified to capture prey, offense, defense, mimicry, behavior etc. In legs femur and tibia are the usual segments showing modification. The tarsus may sometimes divided into subsegments /pseudosegments called **tarsomeres**.

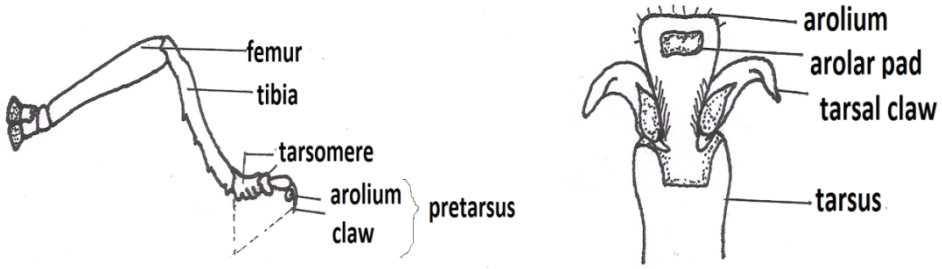


Fig 47 Generalized leg with all its parts and its tarsus enlarged

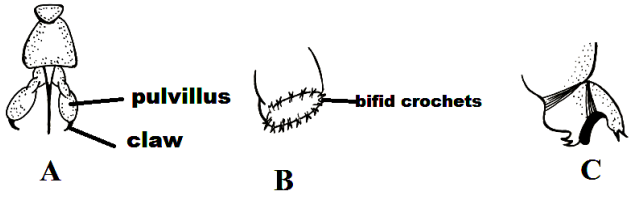


Fig 48 A) Empodium B) larval proleg C) larval body-planta

Comments

1. **Cursorial legs**

1. They are simple structures meant for running.
2. It consists of long and narrow leg segments so that insect can move quickly and hard to catch when they are running.
3. Examples: Cockroaches (order Blattaria), ground beetles and tiger beetles (order Coleoptera).

Fig 49 Cockroach leg

2. Fossorial forelegs

1. They are modified legs for digging in those insects which lives underground.
2. Generally spade like forelegs are modified fossorial legs.
3. Legs are broad, much flat and dense.
4. They often have big, strong claws.
5. Tibia consists of triangular tarsomeres.
6. Examples: mole crickets (order Orthoptera) and cicada nymphs (order Hemiptera).

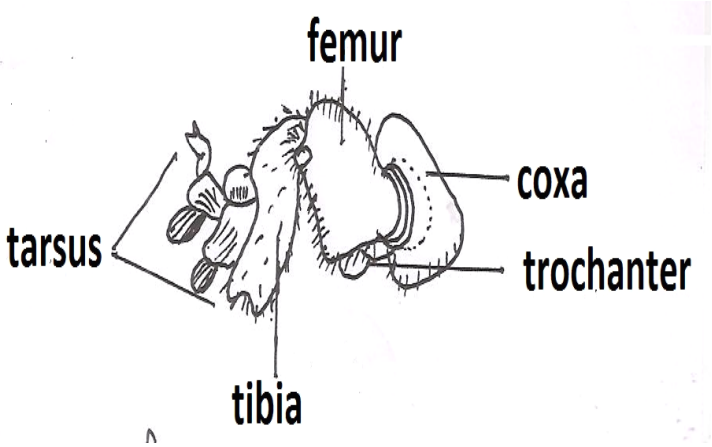


Fig 50 Foreleg of mole cricket (digging)

3. Natatorial legs

1. They are modified for swimming in aquatic insects.
2. Here tibia and tarsi have bears swimming hairs or setae to move swiftly through water.
3. These legs are flattened, broad and fringed with dense hairs.
4. These modification increases the surface area of the legs.
5. Modifications are seen in the middle and hind pair of legs.
6. Examples: water beetles (order Coleoptera) and water bugs (order Hemiptera) hindleg of *Gyrinus*.

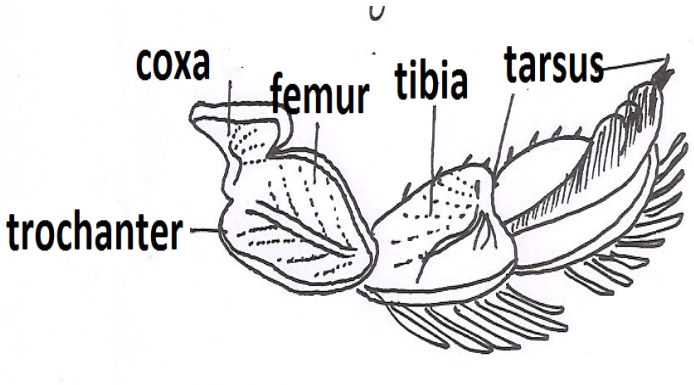


Fig 51 Hind leg of *Gyrinus* (swimming type)

4. Raptorial legs

1. They are modified forelegs for grasping (catching prey).
2. They are the hunting legs in predatory insects.
3. Here coxa is movable with tibia spinose and femur is swollen and spiny.
4. These legs are enlarged full of strong and powerful muscles to hold and grab the prey while feeding.
5. Examples: Mantids (order Mantoidea), water scorpions (order Hemiptera), giant water bugs.

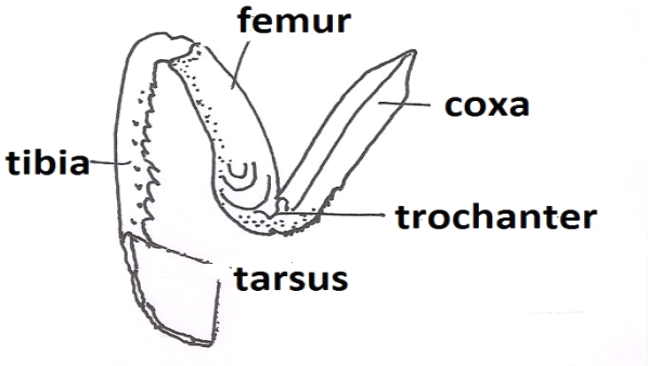


Fig 52 Foreleg of *Mantis* (raptorial type)

5. Saltatorial legs

1. They are the legs modified for jumping or hopping.

2. These have an elongated and enlarged femur and tibia filled with bulky and strong muscles.
3. All these muscles allow the leg to jump and propel them forward to a long distance very quickly.
4. Generally the hindlegs are the modified saltatorial legs.
5. Examples: Grasshoppers, crickets, katydids (order Orthoptera), fleas.

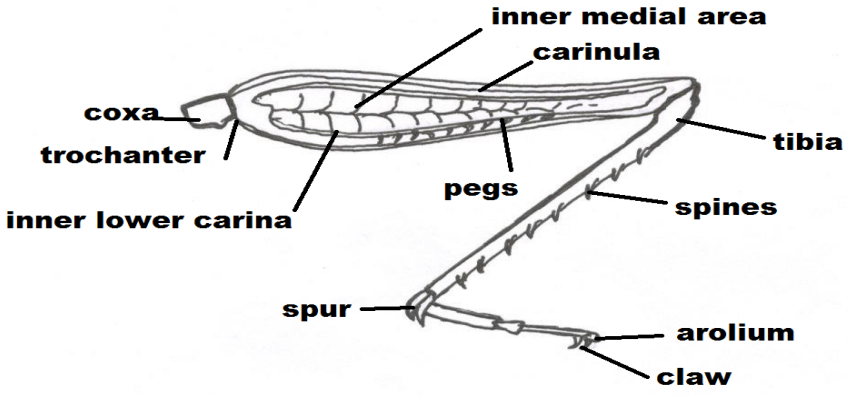


Fig 53 Hind leg of grasshopper

6. Stridulatory legs-

1. They are part sound producing organs to communicate during intraspecific interaction.
2. It has enlarged femur.
3. For example grasshoppers.

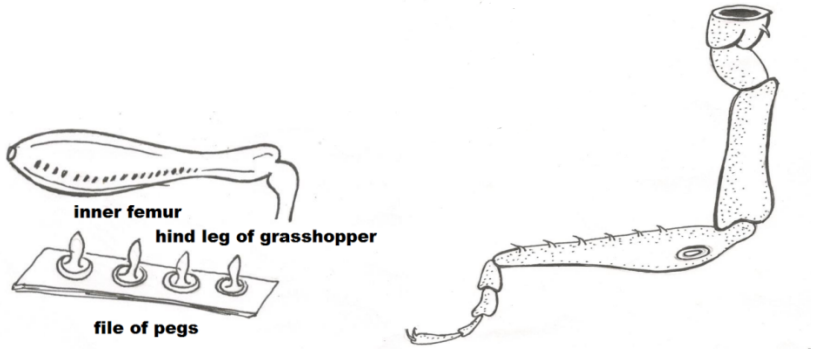


Fig 54 Leg with file of pegs and tympanum

7. Scansorial legs

1. They are clinging legs.
2. The tarsi are one segmented with a sharp, curved and pointed claw meant for holding the hair of the host.
3. For example head louse, biting louse (order Mallophaga).

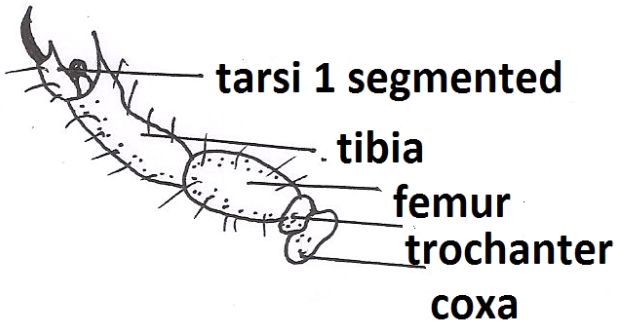


Fig 55 Foreleg of louse (clinging)

8. Ambulatory legs

1. These are the legs which are meant for walking.
2. They are elongate and slender.
3. Legs are clawed at the end.
4. It bears many soft and custioned pads that enable the insect to stick on smooth surface.
5. Example housefly, bugs and leaf beetles.

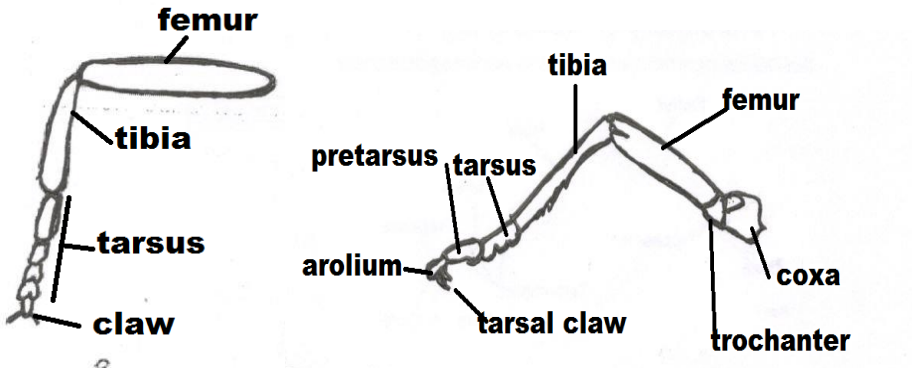


Fig 56 Leg of house fly

9. Corbiculate leg

1. The hind legs are the modified structure.
2. There are three interesting structures pollen basket, pollen comb and pincers.
3. Proximal tarsus has stiff hairs which help in removing the pollen from the body.
4. The tibial podomere is concave and fringed with brush like structure due to many hairs present on them called pollen basket or corbicula to put nectar in it.
5. Distal end of the tibia has stiff bristles called pecten below which a plate like auricle is present.
6. Pecten and auricle forms wax spincer for removing wax from abdomen.
7. Outer surface of tarsus has pollen brush while inner surface has pollen comb or scope.
8. Terminal segment of tarsus contain a claw and pulvillus.
9. Example honey bees (order Hymenoptera).

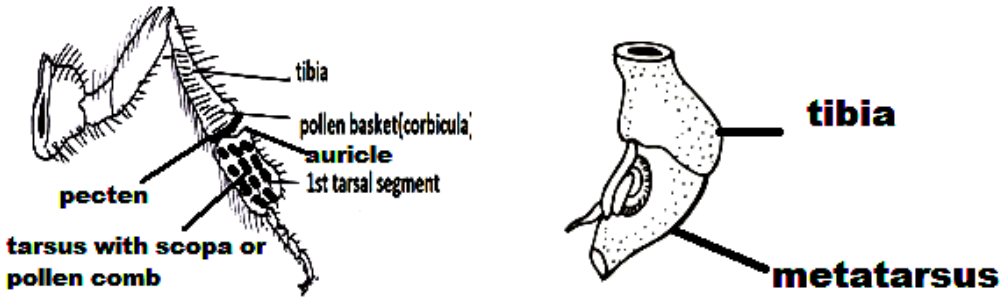


Fig 57 A) Corbiculate leg-hindleg of honey bee showing pollen basket B) toilet organ

10. Skating legs

1. They are having long and thin legs.

2. They bear hydrophobic tarsal hairs which help them to skate on the surface of water.
3. It also bears an apical claw.
4. Example water striders (family Gerridae).

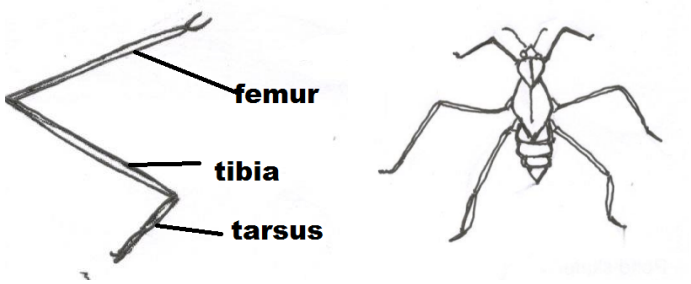


Fig 58 Leg of pond skater and adult

Function of legs

1. It plays a defensive role and used for locomotion.
2. It is used in different forms for running, walking, jumping, burrowing and swimming.
3. They are also sensory in some insects.
4. They are used to hold prey, objects and partners.
5. They are also used in mimicry, camouflage and courtship.

21.7 Types of Wing

Veins in wing shows nomenclature known as wing venation given by Comstock and Needham. It is used as identification of insect of particular order or family. It consists of longitudinal veins precosta (PC), costa (C) a convex vein, subcosta (SC) a concave vein divided into SC1 and SC2, radial (R) divided into five branches R1 (convex), R2,R3,R4 and R5 (rest all concave), medial branched into anterior MA1,MA2 (convex) and posterior MP1, MP2, MP3, MP4 (concave), cubitus Cu1 (Cu1a, Cu1b) and Cu2 all convex, anal A1,A2, A3 all convex and sometimes jugal J1, J2 may be present.

Along with these straight veins some cross veins are also found humeral (h) connect costa and subcosta, sectional (s) between R2+R3 and R4+R5, radiomedial

(rm) between radius and medial, median between M2 and M3 and mediocubitus between medial and cubitus. The transverse section shows that the vein consists of trachea, nerve, blood space.

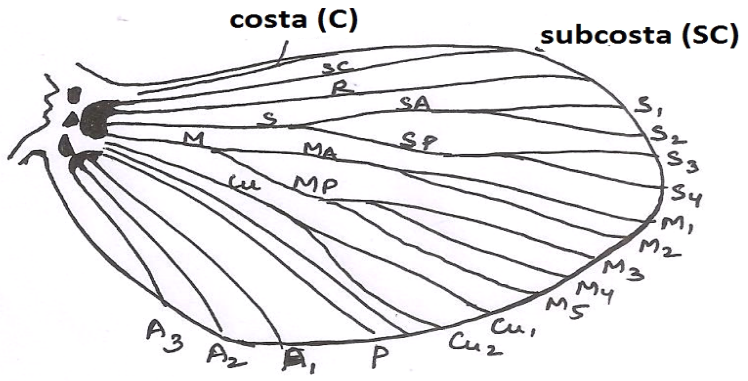


Fig 59 Hypothetical structure of wing showing venation

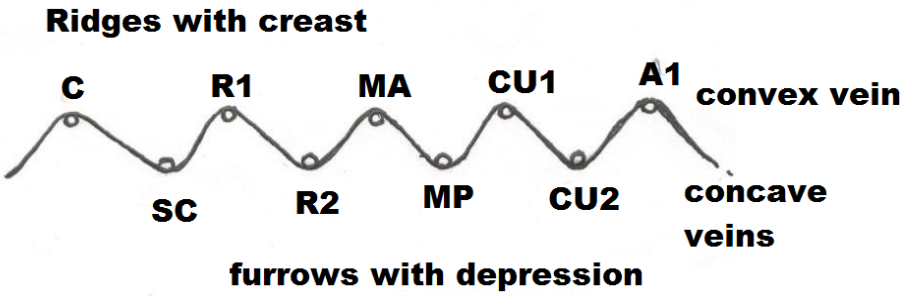


Fig 60 Wing showing concave and convex veins

Wing margins and angles

There are three margins and three angles found in generalized wing. On outer side apical margin, anterior costal margin and inner anal margin is present. Humeral angle at the base of costal margin, apical angle between costal and apical margin and anal angle between apical and anal margin.

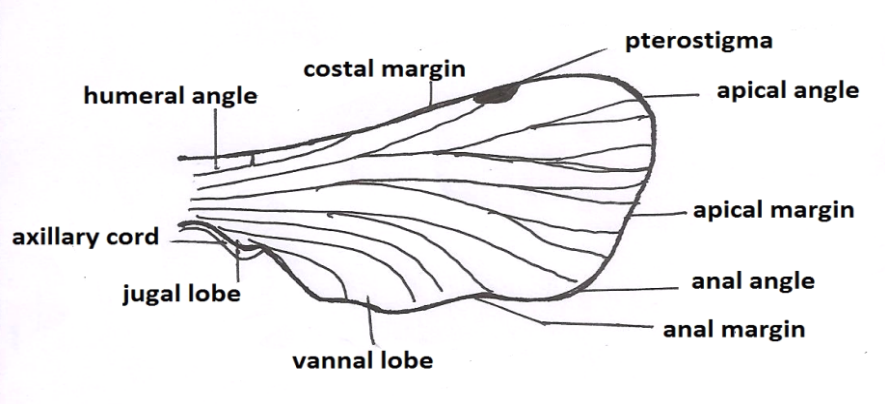


Fig 61 Diagram showing wing margins and wing angles

Comments

1. Halters wings

1. They are the reduced hind wings in some insects.
2. They are small knobbed vibrating organ.
3. They are used for balancing and directs the insect during flight.
4. Halteres are found among the order Diptera (true flies)- mosquitoes, houseflies.

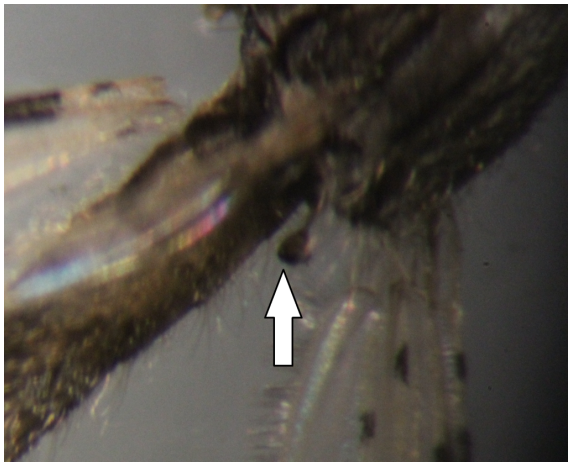


Fig 62 Halter of mosquito pointed by an arrow

2. Elytra (singular elytron)

1. These are the hard, thick, tough and heavily sclerotized forewings.
2. Wing venation is lost in elytra.

3. During flight they are kept at an angle to allow free movement of the hind wing.
4. They don't fly but function to protect the hind wings and abdomen when at rest.
5. They are found in beetles, weevils (order Coleoptera).

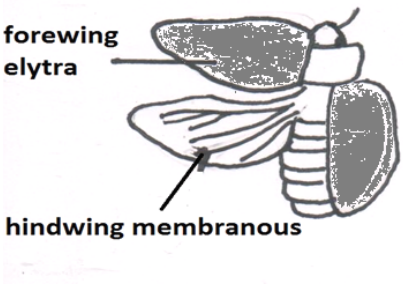


Fig 63 Coleopteran showing elytra

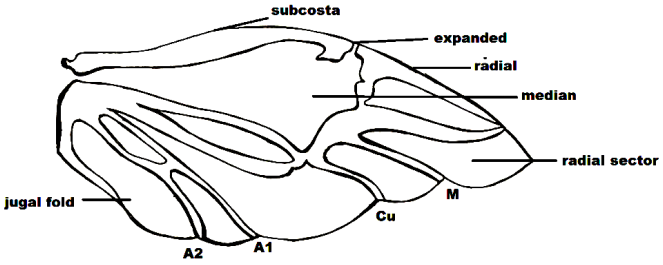


Fig 64 Coleoptera hind wing

3. Hemielytra

1. They are modified forewings less sclerotized from elytra.
2. They are hardened or sclerotized only at the proximal two-thirds, while the distal portion is membranous.
3. They function as flight wings.
4. In hemielytra cells are specifically named as embolium, corium, cuneus, membrane and clavus.
5. Examples: Bugs (order Hemiptera FIG 2.19, 20).

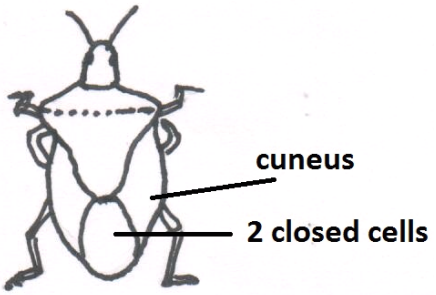


Fig 65 Hetropteran showing their hemielytra folded at rest

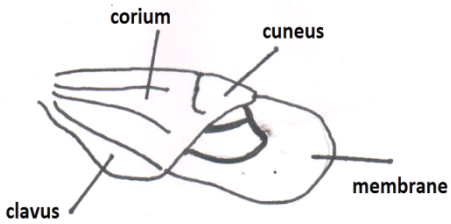


Fig 66 A single hemielytra showing its various parts

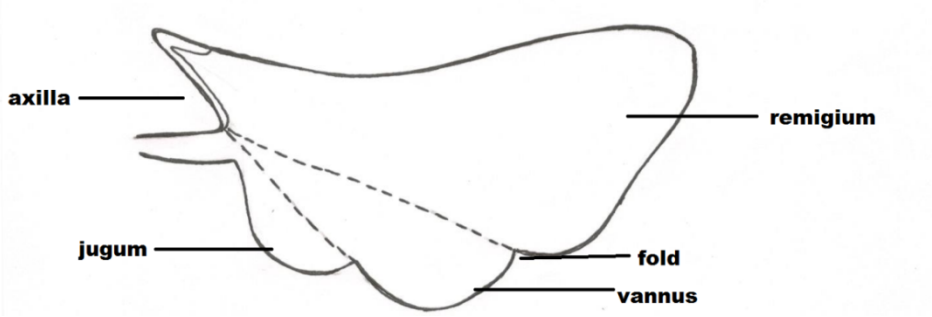


Fig 67 Different regions of heteropteran wing

4. Tegmina (singular tegmen)

1. They are the leathery parchment like and thickened forewings of some insects.
2. The tegmina are used to protect the more vulnerable and longer hind wings.
3. The tegmina offer little or no power during flight.
4. Examples: orders Orthoptera, Blattaria, and Mantodea.

5. Pterostigma

1. They are the wings bearing an opaque spot on wings.
2. They are found only in forewing of Plecoptera.
3. They are found in both wings in Odonata.

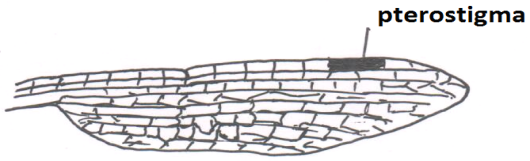


Fig 68 A dragonfly wing showing pterostigmata

6. Fringed wings

1. Wings margins are covered with many long hairs or bristles or setae.
2. Wing lamina is usually reduced in size.
3. These insects fly swiftly in air.
4. Example Thrips.

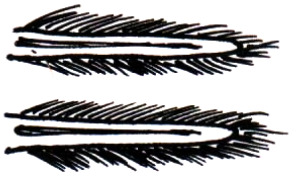


Fig 69 Thrips wing

7. Membranous wings

1. They are thin and transparent wings.
2. They are supported by the system of tubular veins.
3. They are useful in flight.
4. Example honeybee, termite, dragon fly.

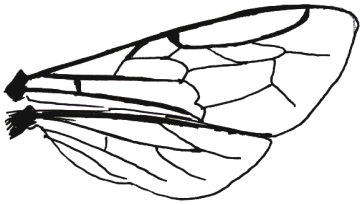


Fig 70 Wing of honeybee

8. Scaly wings

1. Wings are covered with scales.
2. Scales are unicellular, flattened outgrowths of the body wall.
3. Scales are responsible for the color of the wing.
4. These scales are important in smoothening the airflow over wings and body.
5. They also insulate insect against cold.
6. Example butterflies and moths.

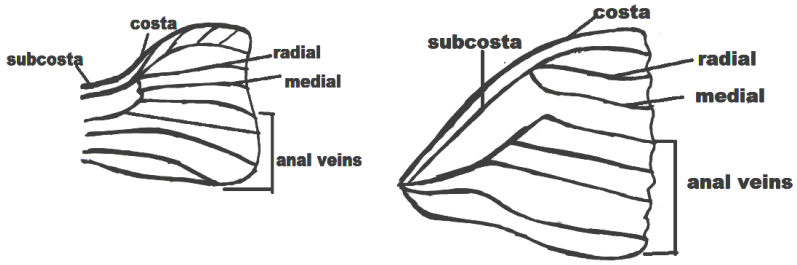


Fig 71 Forewing of silk moth and forewing of blue morpho butterfly

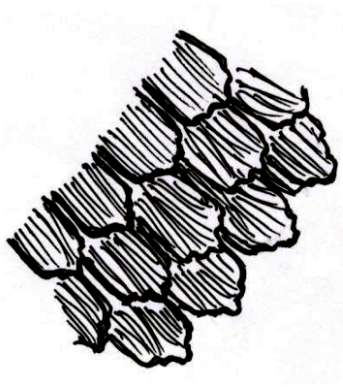


Fig 72 Scales on the wing

Precautions for slide mounting:

1. It is necessary to note that all the coverslips and slides are neat and clean by ethanol with the help of tissue or filter paper.
2. Only one specimen or part of specimen is place over slide.
3. Place the specimen in the centre of the slide.

4. Gently lower the coverslip upon the moun ting media to avoid bubbles.
5. Use the standard label format as described earlier.
6. Always place the specimen in reverse paoition of the label i.e head of the specimen must be placed at the lower side of the label so that when viewed under the microscope its image is the right way.

21.8 Method Of Preparing Reagents Or Fixatives

Ethanol general preservation	60%	70%	75%	80%	90%
Ethanol commercial grade 95%	6 parts	7 parts	7.5 parts	8 parts	9 parts
Distill water	3.5parts	2.5 parts	2 parts	1.5 parts	0.5 parts

FAA fixative

Formalin commercial grade 40% formaldehyde	10 parts
Ethanol 95%	50 parts
Glacial acetic acid	1 part
Water	40 parts

KAA solution for killing soft bodied insects

Kerosene	10 parts
Ethanol 95%	10 parts
Glacial acetic acid	2 parts

KOH 10% solution

Potassium hydroxide (KOH) pellets	25 gms
Distill water	250 ml

21.9 Self Learning Exercise

1. Prepare a permanent slide of whole mount of following:
   i) *Pediculus humanus*
   ii) *Tribolium castaneum*
   iii) *Anopheles* female,
   iv) *Culex* male
2. Prepare histological slides of following:
   i) T.S of Integument
   ii) Sting apparatus of honey bee
   iii) Salivary gland chromosome
3. Draw neat and clean diagram and comment upon the following:
   i) Biting and chewing type of mouth parts
   ii) Fossorial forelegs
   iii) Raptorial legs
   iv) Wing margins and angles
   v) Elytra
   vi) Hemielytra

21.10 References

- Handbook of insect collection by Courtenay Smithers.
- Experimental Entomology by G.T. Tonapi.
- The preparation and curation of insects by Annette K. Walker and Trevor K. R. Crosby.