PRACTICAL MANUAL

Fundamentals of Entomology

(HPP 228) 3(2+1)

For B.Sc. (Hons.) Horticulture III Semester

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Syllabus:

Insect collection and preservation. Identification of important insects. General body organization of insects. Study on morphology of grasshopper or cockroach. Preparation of permanent mounts of mouth parts, antennae, legs and wings. Dissection of grasshopper and caterpillar for study of internal morphology. Observations on metamorphosis of larvae and pupae. Dissection of cockroaches.

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CONTENTS

EXPERIMENT NO. 1

Objective: Acquaintance with major equipments use for insect collection.

Exercise: Visit Departmental Laboratory for insect collection equipments and draw the diagram with details.

Materials Required: ……

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Observation to be recorded:

Material	Use	Diagram
Insect collecting net	…… …… …… …… ……	
Aspirator	…… …… …… …… ……	
Insect traps	…… …… …… ……	
Killing bottle	…… …… …… …… ……	
Entomological pins	…… …… …… ……	
Entomological pins Box	…… …… ……	

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Insect collecting box	……..…… ……..…… ……..…… ……..……	
Setting boards	……..…… ……..…… ……..…… ……..……	
Forceps	……..…… ……..…… ……..…… ……..……	
Hand lens	……..…… ……..…… ……..…… ……..……	
Camel hair brush	……..…… ……..…… ……..…… ……..……	
Insect labels	……..…… ……..…… ……..…… ……..……	
Naphthalene balls	……..…… ……..…… ……..…… ……..……	
Insect rearing cage	……..…… ……..…… ……..…… ……..……	

EXPERIMENT NO. 2

Objective: To study on insect preservation techniques.

Exercise: Make a preservative for insects under Laboratory with write-up and note down the type of preservatives processor.

Materials Required: ……

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Observation to be recorded:

Type of preservative:

1. **Fluid preservation:** ……

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2. **Making permanent slides:** ……

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3. **Dry preservation:** ……

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Pinning:

Insect	Pinning place on insect body
Butterflies, moths, dragonflies & damselflies	…… …… …… …… ……
Beetles and weevils	…… …… …… ……
Bugs	…… …… …… ……
Grasshoppers	……

	…… …… ……
Flies, bees, wasps	…… …… …… …… ……

Mounting:

1) **Direct Pinning:** ……

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2) **Pointing:** ……

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3) **Labeling:** ……

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4) **Protection of stored Insects:**

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Types of preserving fluids: ……

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EXPERIMENT NO. 3

Objective: To study on preparation of an insect killing bottle.

Exercise: Preparation Temporary bases and permanent insect killing bottle under Laboratory and draw the diagram with details..

Materials Required: ……

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Observation to be recorded:

1. **Temporary bases (Ethyl acetate bottles):**

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Permanent bases (Potassium cyanide bottles): ……

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EXPERIMENT NO. 4

Objective: Familiarization with different body organization of an insect.

Exercise: Observe the Grasshopper specimen in the laboratory using magnifying lens and note down the morphological characters of Grasshopper with diagram.

Materials Required: ……

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Observation to be recorded:

1. **Head:** ……

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2. **Thorax:** ……

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3. **Abdomen:**……

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Body regions of a

EXPERIMENT NO. 5

Objective: To study on insect antennae and their modification.

Exercise: Visit nearest a type of Crop cafeteria and collect the insects for observe the antennae modification in the laboratory using magnifying lens and draw the diagram with details of insect antennae.

Materials Required: ……

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Observation to be recorded:

Structure of Antenna:

1. **Scape:** ……
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2. **Pedicel:** ……
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3. **Flagellum:** ……
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Modifications in insect antennae:

Type of modification	Examples	Modification	Diagram
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EXPERIMENT NO. 6

Objective: To study on insect legs and their modification.

Exercise: Visit nearest a type of Crop cafeteria and collect the insects for observe the leg modification in the laboratory using magnifying lens and draw the diagram with details of insect leg.

Materials Required: ……

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Observation to be recorded:

Structure of leg:

1) **Coxa:** ……

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2) **Trochanter:** ……

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3) **Femur:** ……

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4) **Tibia:** ……

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5) **Tarsus:** ……

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Modifications in insect leg:

Type of modification	Examples	Modification	Diagram
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EXPERIMENT NO. 7

Objective: To study on insect wings and their modification.

Exercise: Visit nearest Crop cafeteria and collect the insects for observe the wing modification in the laboratory using magnifying lens and draw the diagram with modified characters of insect wings.

Materials Required: ……

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Observation to be recorded:

Structure of an insect wing:

1. **Wing veins:** ……

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2. **Wing margin:**

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3. **Wing angle:** ……

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4. **Wing regions:** ……

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Modifications in insect wing:

Type of modification	Examples	Modification	Diagram
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EXPERIMENT NO. 8

Objective: To study on dissection of mouth parts of grasshopper.

Exercise: Dissection of the mouth parts of Grasshopper in the laboratory. Mounting the mouth parts under the microscope and note down modified characters with draw the diagram.

Materials Required: ……

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Observation to be recorded:

Mouth parts of grasshopper:

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Labrum (Upper lip):……..……

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Mandibles: .....

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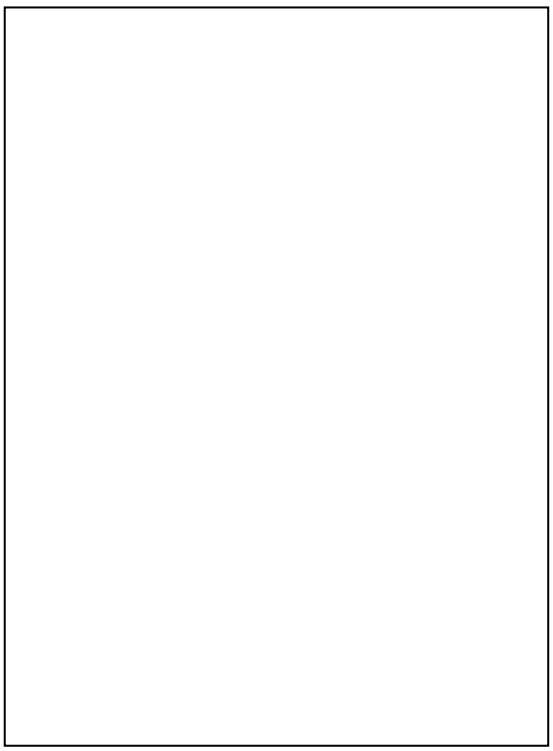

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Maxillae: .....

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Hypopharynx:

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Labium /lower lip: ……..……..……

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EXPERIMENT NO. 9

Objective: To study on modification of mouth parts of insects.

Exercise: Visit nearest crop cafeteria for collection a variety of insect and mounting mouth parts of collected in the laboratory. Mounting and note down modified characters with draw the diagram.

Materials Required: ……

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Observation to be recorded:

Mouth parts modification (example)	Modified part	Diagram
	…… …… …… …… …… …… …… ……	
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EXPERIMENT NO. 10

Objective: To study on abdominal structures in insect.

Exercise: Visit nearest crop cafeteria for collection a variety of insect. Mounting abdominal appendages under microscope and note down modified characters with draw the diagram.

Materials Required: ……

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Observation to be recorded:

Appendages	Characters	Draw diagram
Pregenital abdominal appendages in wingless insects:		
	…… …… …… ……	
	…… …… …… ……	
	…… …… …… ……	
	…… …… …… ……	
Abdominal appendages in immature insects:		
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	…… …… ……	

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Abdominal appendages in winged adults		
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EXPERIMENT NO. 11

Objective: To study on external reproductive organs of grasshopper.

Exercise: Visit nearest crop cafeteria for collection male and female Grasshopper. Mounting reproductive appendages under microscope and note down modified characters with draw the diagram.

Materials Required: ……

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Observation to be recorded:

Male genitalia of grasshopper: ……

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Male external genitalia

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Female genitalia of grasshopper:

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Male external genitalia

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EXPERIMENT NO. 12

Objective: To study on dissection of alimentary canal of grasshopper.

Exercise: Dissection and mounting of alimentary canal of given specimen under microscope and note down anatomical characters with draw the diagram.

Materials Required: ……

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Observation to be recorded:

Stomodaeum:……

i) **Pre-oral food cavity:** ……

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ii) **Pharynx:** ……

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iii) **Oesophagous:** ……

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iv) **Crop:** ……

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v) **Gizzard:** ……

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Mesentron: ……

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Proctodaeum: .....

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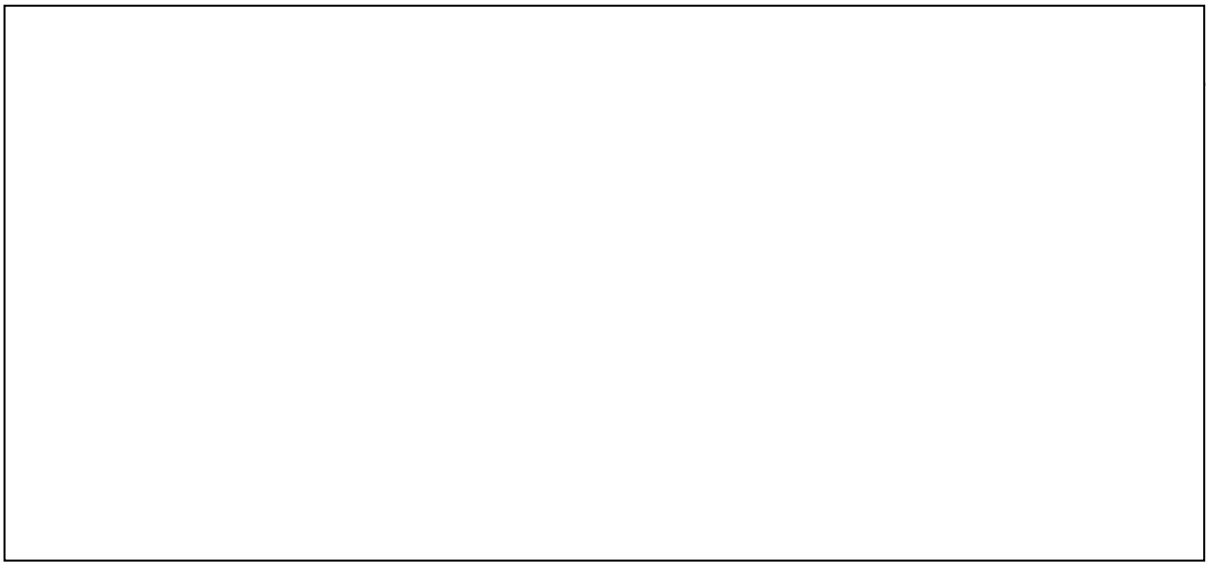

Fig. Alimentary canal of Grasshopper

EXPERIMENT NO. 13

Objective: To study on anatomy of reproductive organs of insect.

Exercise: Dissection and mounting of reproductive organs of given specimen under microscope and note down anatomical characters with draw the diagram.

Materials Required: ……

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Observation to be recorded:

Reproductive organs of a male grasshopper:

1) **A pair of testes:** ……

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2) **A pair of vasa deferentia:** ……

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3) **Seminal vesicles**: ……

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4) **Ejaculatory duct:** ……

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5) **Penis or Aedeagus:** ……

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6) **Accessory glands:** ……

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7) Male genital atrium: ……

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Reproductive organs of a female grasshopper:

1) A pair of ovaries: ……

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2) A pair of lateral oviducts: ……

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3) Spermatheca: .....

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4) Vagina and genital chamber: .....

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5) Accessory glands (Collaterial glands): .....

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Female reproductive organs **Male reproductive organs**

EXPERIMENT NO. 14

Objective: To study on metamorphosis in insects.

Exercise: Observe developmental life stages on rearing insects inside the Laboratory. Mounting and note down characters with draw the diagram.

Materials Required: ……

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Observation to be recorded:

Type of metamorphosis	Characters	Draw diagram
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EXPERIMENT NO. 15

Objective: To study on immature stages of insect life.

Exercise: Field visit and observe immature stages of insect life. Mounting and note down morphological characters with draw the diagram.

Materials Required: ……

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Observation to be recorded:

Insect eggs: .....

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Larvae: .....

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Pupae:

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EXPERIMENT NO. 16

Objective: To study of characters of orders Orthoptera, Dictyoptera, Isoptera and Thysanoptera its families.

Exercise: Observe morphological characters with magnifying lance under Laboratory. Mounting and note down morphological characters with draw the diagram.

Materials Required: ……

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Observation to be recorded:

Orthoptera: .....

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Family	Characters	Draw diagram
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	…… …… …… …… …… ……	
Dictyoptera: …… …… …… ……		
Family	**Characters**	**Draw diagram**
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	…… …… …… …… …… …… ……	
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Isoptera: .....

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Family	Characters	Draw diagram
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Thysanoptera: ....

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Family	Characters	Draw diagram
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EXPERIMENT NO. 17

Objective: To study of characters of order Hemiptera, Lepidoptera and Coleoptera.

Exercise: Observe morphological characters with magnifying lance under Laboratory. Mounting and note down morphological characters with draw the diagram.

Materials Required: ……

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Observation to be recorded:

Hemiptera: .....

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Family	Characters	Draw diagram
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Lepidoptera:		
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Family	**Characters**	**Draw diagram**
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Coleoptera: ……
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Family	Characters	Draw diagram
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	…… …… …… …… …… …… ……	
	…… …… …… …… …… …… ……	

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EXPERIMENT NO. 18

Objective: To study of characters of order Hymenoptera and Diptera.

Exercise: Observe morphological characters with magnifying lance under Laboratory. Mounting and note down morphological characters with draw the diagram.

Materials Required: …………………………………………………………………………………………

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Observation to be recorded:

Hymenoptera: ………………………………………………………………………………………………

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Family	Characters	Draw diagram
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Diptera: .....

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Family	Characters	Draw diagram
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APPENDICES

MAJOR EQUIPMENTS USE FOR INSECT COLLECTION

1. **Insect collecting net:** The frame of the net should be 12-18 inches or 30 - 40cm across and either circular or pear shaped. The handle should be 100-125cm in length for convenient handling. Mosquito netting cloth or fine muslin cloth is best suited for bag. The material with which the bag is made should be light and soft, so that the bag opens fully during sweeping of net.
2. **Aspirator:** Aspirator is useful to collect small insects from a net or directly from foliage; Aspirator bottle may be prepared with any small bottle or tube fitted with a cork containing two holes. Two bent glass tubes at right angles may be fitted in the holes of the cork. One glass tube may be open at both ends while the other tube may be closed at its inner end with a piece of muslin cloth held by a rubber band. The outer end of the second tube may be fitted with long rubber tube, which may act as suction tube.
3. **Insect traps: D**ifferent type of traps use in insect monitoring like light trap, pitfall trap, sticky traps, pheromone traps, bait traps, fishmeal trap, yellow traps etc.
4. **Killing bottle:** Simple wide mouthed bottle can be used for preparing the killing bottle. The killing bottles are of two types namely, Temporary killing bottle (liquid killing agents like chloroform, benzene, ethyl acetate, ammonia, carbon tetra chloride etc.) and Permanent killing bottle (solid killing agent like potassium cyanide and plaster of paris in 1:4 ratio by volume).
5. **Entomological pins:** Different type pins are available in the market. Continental pins are made of stainless or black steel and they are different in size and length like size 00 is fine, Size 3 medium thickness and 6 is robust and size 7 is a very strong pin and longer (52mm).
6. **Entomological pins Box:** It's made of wood with 6 holes to store different size of entomological pins and keep the same handy.
7. **Insect collecting box:** Insect store boxes may be either of wood or cardboard boxes lined with cork sheet inside for easy pinning of insects. The standard size of insect store box is 45 cm x 3 cm x 10 cm. The box must be light, air tight, strong and carefully made and last a long time.
8. **Setting boards:** Useful for spreading the wings of an insect. It is a simple board made up of plywood lined by cork sheet on the top. It is provided with central longitudinal groove to fit the abdomen of the insect. Different sizes of setting boards are available for different sizes of insects.
9. **Entomological pins:** These are special type of rust proof nickel pins available in different sizes to suit different types of insects. These pins should be used for pinning insects for taxonomic studies. The museums will accept to deposit the insects which, are pinned with these pins only.
10. **Forceps:** Small to large size forceps are use to lift carefully of small to large size insects from source to collecting materials.
11. **Hand lens:** Different type hand lens are available in the market but a magnifying glass is a convex lens that is used to produce a magnified image of an object. Their uses help to enlarge the image of small insect slightly.
12. **Camel hair brush:** A paintbrush with soft bristles made from natural hairs and its use to pick up and handle small insects when collecting or working at lab bench. Brushes have woody handles with metal ferrules and pointed shape tips.
13. **Insect labels:** We can use of different type of labels for insect notification after pinning and store in insect store box. It may by triangle, rectangle or circular shape. There are given a short detail about specimen like, common name, scientific name, family, order, date of collection, collection site and founder/collector name.
14. **Naphthalene balls:** It's also known as moth balls or camphor balls are spherical pieces of a white solid material containing at least 98% naphthalene. They are use to repel insect parasite mites that feed on dead body of stored specimens of insects. They are available in various sizes in the market.
15. **Insect rearing cage:** It is prepare by aluminum or wood with fine mesh provided on side and top. Hinged door provided with clips for tight closing. A variety of insect rearing case are available in the market. There use for insect breeding and collection of different stages of rearing insects.

PRESERVATION OF INSECTS

a) **Fluid preservation:** All the soft bodied insects (adults or immature stages) are preserved in fluids like alcohol 70% or formaldehyde 4%. Insects preserved in alcohol remain soft, while those preserved in formaldehyde become brittle.
b) **Making permanent slides:** Minute insects or any part of the insect body may be mounted on slides and can be preserved permanently.
c) **Dry preservation:** Insect collected is to be killed in killing bottle, pinned, set and dried. Well dried specimens can be preserved in insect store boxes or insect show cases. The wing spread is to be done on the same day of killing, of the specimen is dried without spreading the wings, a procedure known as relaxing may be followed to make the specimen soft and spread the wings.

Pinning: Pinning is the best way to preserve hard bodied insects. Pinned specimens keep well, retain their normal appearance, and can be easily handled and studied. Insects are usually pinned vertically through the body. About 1/3 of the

pin length should be seen above the body. The place of pinning on the insect body varies according to the group of insect as follows.

Insect	Pinning place on insect body
Butterflies, moths, dragonflies & damselflies	Through the central portion of the thorax
Beetles and weevils	On right elytra at 1/3 length of wing from its base
Bugs	Through the central point of the scutellum just right side of the middle.
Grasshoppers	Through the pronotum at about 2/3 the length from the head towards the right side.
Flies, bees, wasps	Through the center of the thorax just right side of the middle point.

MOUNTING:

- **Direct Pinning:** Large insects can be directly pinned with entomological pins and preserved in store boxes.
- **Pointing:** specimens too small to pin can be mounted either by pointing or stage mounting.
- **Labeling:** The scientific value of an insect specimen depends to a large extent on the information regarding the date and locality of its capture. Fairly stiff white paper may be used for preparing labels. The label should be pinned to the specimen. Each label should contain the information indicating 1. Host, 2. Locality,3. Date of collection and 4. Name of the collector.
- **Protection of stored Insects:** The insects stored in store boxes or insect cabinets are damaged by various other stored pests. Naphthalene balls or Para dichlor benzene. packets may be arranged in store boxes to prevent the attack and damage by psocids and other insect pests.

Types of Preserving fluids:

➢ Ethyl alcohol ……75 to 80% ➢ Formaldehyde ……4 % ➢ 95% ethyl alcohol------100 parts Distilled Water----------100 parts Formaldehyde----------13 parts Glacial acetic acid-------5 parts	➢ 95% ethyl alcohol--------- 55 parts Distilled Water----------35 parts Formaldehyde----------5 parts Glacial acetic acid----------5 parts	➢ 95% ethyl alcohol---------15 parts Distilled Water----------30 parts Formaldehyde----------2 parts Glacial acetic acid----------2 parts ➢ 95% ethyl alcohol----------2 parts Distilled Water----------1 part Acetic acid----------few drops Glycerine----------1parts

Temporary bases (Ethyl acetate bottles) processor:

- ✓ Make a paste of plaster of Paris and water, and place a thick layer on the bottom of a 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 specimens from becoming entangled in the cotton fibers.
- ✓ Allow the plaster of Paris to dry in a well-ventilated place.
- ✓ Saturate the plaster of paris with ethyl acetate. Any excess liquid should be poured off.
- ✓ Place crumpled absorbent paper on top of the plaster of Paris.
- ✓ Let the bottle dry out before recharging it with ethyl acetate.

Permanent bases (Potassium cyanide bottles) Processor:

- ✓ Place crushed potassium cyanide crystals mixed with sawdust or cotton wool to a depth of 15 mm in a suitable bottle.
- ✓ Cover the crystals with a fairly thick layer of plaster of Paris mixed into a paste. A removable porous stopper, made from foam plastic can also be used, which allows for periodic recharging with cyanide.
- ✓ Allow the plaster of Paris to dry in a well-ventilated place.
- ✓ Add crumpled absorbent paper to the bottle and close the bottle.
- ✓ Add a few drops of water to the plaster of Paris (or foam stopper) to activate the bottle an hour or so before use. The water will react with the crystals to produce hydrogen cyanide gas.

GRASSHOPPER

Head: Hypognathous head orientation and connected to the thorax by the flexible cervix (neck). Epicranial suture is bound by two antennae on frons. It is consete by different suture and plates. One pair compound eyes, three ocelli and biting and chewing type mouth part are present.

Thorax: Center region of body and further divided in to prothorax, mesothorax and metathorax. Prothorax is exceedingly large and covered by a conspicuous sclerite plate which known as 'pronotum'. Two pairs of wings on meso- and metathorax. First pair of wing is Tegmina' and second pair is membranous. Three pairs of jointed legs on each thoracic segment. First two pair's legs are walking type but hind legs are saltatorial type where enlarged femur and use jumping called. Each leg is divided in to five segments like coxa, trochanter, femur, tibia and tarsus. Two spiracles are present on lateral plate.

Abdomen: The posterior region of the body is comprised of 10 or 11 ring like segments. Abdomen uromeres composed three plats like Dorsal or Tergum (which forms the 2/3 portion of each segment), ventral plat or sternum and lateral plate or pleura. Ten pairs of spiracles 2 thoracic +8 abdominal) and an auditory organs "Tympanal" is present on each side of first abdomen segment. Anal appendages like, supra anal plate, a pair of pedicel plates and a pair of anal cerci. Reproductive appendages at last abdomen segment.

Structure of Antenna: Antennae consist of three parts:

1) **Scape:** First basal segment of antenna by which the antennae is attached to the head. It is often distinctly larger than the other succeeding joints. It articulates with the antennal ridge.
2) **Pedicel**: Second segment and joint immediately followed the scape is pedicel. It is usually smalland contains a special sensory structure known as Johnston's organ, which is absent in Dipluran and Collembolan members.
3) **Flagellum**: It is also known as clavola, and is the remaining part of theantenna. Flagellum segments (flagellomeres) increase in number in certain insects. Itis modified according to the surroundings and habits of the insects.

MODIFICATION OF ANTENNAE

S. No	Type of modification	Modification	Examples
1.	Filiform (Thread like)	Segments are more or less uniform throughout from base to apex and never end with bristle.	Grasshopper
2.	Setaceous (Bristle like)	Size of the segments decreases from base to apex.	Leafhopper, Dragonfly,
3.	Moniliform (Beaded)	Segments are either globular or spherical with prominent constriction in between.	Termite
4.	Serrate (Saw like)	Segments have short triangular projections on one side.	Longicorn bettle
5.	Pectinate (Comb like)	Segments with long slender processes on one side	Sawfly
6.	Bipectinate	Segments with long slender lateral processes on both the sides	Silkworm moth
7.	Clavate (Clubbed)	Antenna enlarges gradually towards the tip.	Blister beetle
8.	Capitate (Knobbed)	Terminal segments become enlarged suddenly	Butterfly
9.	Lamellate (Plate like)	Antennal tip is expanded laterally on one side to form flat plates	lamellicorn beetle
10.	Aristate	The terminal segment is enlarged. It bears a conspicuous dorsal bristle called arista	House fly
11.	Stylate	Terminal segment bear a style like process	Horse fly,
12.	Plumose (Feathery)	Segments with long whorls of hairs	male mosquito
13.	Pilose (Hairy)	Antenna is less feathery with few hairs at the junction of flagellomeres.	Female mosquito
14.	Geniculate (Elbowed)	Scape is long remaining segments are small and are arranged at an angle to the first resembling an elbow joint.	Ant, & honey bee

STRUCTURE OF LEG

1) Coxa: Its often divided into two parts, the posterior and the anterior (usually the larger part) being called the meron.
2) Trochanter: It is articulates with the coxa, but usually forms an immovable attachment with the femur.
3) Femur: It is longest leg segments and attached with trochanter and tibia.
4) Tibia: are typically the longest leg segments.
5) Tarsus: It is derived from a single segment, - is usually sub-divided into individual tarsomeres. The pretarsus may consist of a single claw, but it is usually composed of a pair of moveable claws and one or more pads or bristles. Legs are usually looked upon as the principal organs of terrestrial locomotion. They have undergone many modifications and have been adapted to a wide variety of functions including swimming, prey capture, pollen collection and digging.

MODIFICATION OF INSECT LEGS

1. **Ambulatorial** (Walking leg): Fore leg and middle leg of grasshopper. Femur and tibia are long. Legs are suited for walking.
2. **Cursorial (Running leg):** All the three pairs of legs of cockroach. Legs are suited for running. Femur is not swollen.
3. **Saltatorial (Jumping Leg)**: Hind leg of grasshopper.
4. **Scansorial (Climbing leg):** All the three pairs of legs of head louse.
5. **Fossorial (Digging or Burrowing leg)**: Fore legs of mole cricket.
6. **Raptorial (Grasping leg):** Forelegs of preying mantis.
7. **Natatorial (Swimming leg):** Hind legs of water bug and water beetle.
8. **Sticking leg:** All the three pairs of legs of house fly.
9. **Basket like leg:** Legs of dragonfly and damselfly.
10. **Clasping leg:** Forelegs of male water beetle.
11. **Foragial leg:** Legs of honey bee.
    a) **Forelegs:** The foreleg has three important structures (Eye brush, antenna cleaner or strigillis and pollen brush).
    b) **Middle legs**: It has two important structures like, i) **Pollen brush**: Stiff hairs on basitarsus form pollen brush which is useful to collect pollen from middle part of their body. **ii) Tibial spar:** At the distal end of the tibia, a movable spur is present which is useful to loosen the pellets of pollen from the pollen basket of hind legs and to clean wings and spiracles.

c) **Hind legs:** It has three important structures viz., pollen basket, pollen packer and pollen comb.

12. Prolegs or False legs or Pseudolegs: Abdominal legs of caterpillar. Prolegs are thick, fleshy and not segmented. One pair of prolegs on the last abdominal segment is called anal prolegs or claspers. The tip of proleg is called planta upon which are borne hooks or claws known as crochets which are useful in crawling or clinging to surface.

STRUCTURE OF AN INSECT WING

1) **Wing veins:** Principal longitudinal veins in order from the anterior margin are costa (C), sub costa (Sc), radius (R), median (M), cubitus (Cu) and anal veins (A). Small veins often found inter connecting the longitudinal veins are called cross veins. In dragonfly and damesefly, there is an opaque spot near the coastal margin of the wing called pterostigma.
2) **Wing margin:** The wing is triangular in shape and has therefore three sides and three angles. The anterior margin strengthened by the costa is called coastal margin and the lateral margin is called apical margin and the posterior margin is called anal margin.
3) **Wing angle:** The angle by which the wing is attached to the thorax is called humeral angle. The angle between the coastal and apical margins is called apical angle. The angle between apical and anal margins is anal angle.
4) **Wing regions:** The anterior area of the wing supported by veins is usually called remigium. The flexible posterior area is termed vannus. The two regions are separated by vannal fold. The proximal part of vannus is called jugum, when well developed is separated by a jugal fold. The area containing wing articulation sclerites, pteralia is called axilla.

MODIFICATION OF INSECT WINGS

1. **Tegmina:** Leathery or parchment like and protective in function where not used for flight. e.g. Forewings of cockroach and grasshopper.
2. **Elytra:** Heavily sclerotised, no venation, tough, protective in function for hind wings and abdomen and not used during flight. e.g. Fore wings of beetles and weevils.
3. **Hemelytra:** The basal half of the wing is thick and leathery and distal half is membranous. They are not involved in flight and are protective in function. e.g. Fore wing of heteropteran bugs.
4. **Halteres:** Hind wings are small knobbed vibrating organs called haltere and the terminal part is known as capitellum and base is called scabellum where sensory papillae are present. They act as balancing organs during flight e.g. true flies, mosquito, and male scale insect.
5. **Fringed wings:** Reduced in size, wing margins are fringed with long setae and it use literally swim through the air. e.g. Thrips.
6. **Scaly wings:** Wings of butterfly and moths are covered with small coloured scales.
7. **Membranous wings:** Thin, transparent wings and supported by a system of tubular veins. In many insects either forewings (true flies) or hind wings (grass hopper, cockroach, beetles and earwig) or both fore wings and hind wings (wasp, bees, dragonfly and damselfly) are membranous. They are useful in flight.

STRUCTURE OF MOUTH PARTS OF GRASSHOPPER

After dissection of mouth parts, we observe one labrum, one pair mandible, one pair maxilla, one labium and a hypopharynx in the center of mouth cavity.

1. **Labrum (Upper lip):** Flap like, bilobed and attached to the clypeus and covers the mouth cavity from above. It. It helps to pull the food into the mouth.
2. **Mandibles:** A pair of mandibles or primary jaws or true jaws and heavily sclerotised. They are toothed on their inner border.
3. **Maxillae:** A paired secondary jaws or accessory jaws. It is consisted cardo, stipes (outer lobes galea and inner lobe is lacinia), palpifer and maxillary palp. On the distal end of the stipes, there are two lobes.
4. **Hypopharynx**: A tongue like organ located centrally in the preoral cavity.
5. **Labium /lower lip:** It consists of three median sclerites viz., submentum (large basalsclerite), mentum (middle sclerite) and prementum (apical sclerite). Prementum have two smalls lateral sclerites called palpiger bearing three segmented labial palpi. Distally prementum bears two pairs of lobes. The other pair of lobes is called paraglossae and inner pair of lobes, glossae. Both pairs when fused are called ligula.

MODIFICATION OF MOUTH PARTS

Description after dissection of mouth parts of different insect according to its modification are given below:

1. **Biting and** chewing type: The mouth part of grasshopper. We discussion in Experiment no.08.
2. **Piercing and sucking/hemipterous/bug type**: The mouth part of plant bugs. Labium is a beak like four segmented and grooved throughout its entire length. Both mandibles and maxillae are modified into long slender sclerotized hair like structure called stylets. The inner maxillary stylets are doubly grooved on their inner faces. Both palps are absent. The mouth parts of a female mosquito, labium which is grooved which encloses six stylets. The stylets are composed of labrum - epipharynx (enclosing the food canal), the hyphophrynx (containing the salivary canal), two maxillae and two mandibles.

3. **Chewing and lapping type**: The mouth parts of a honey bee, labrum and mandibles are well developed but mandibles are dumbbell shaped. The tongue unit consists with two maxillae galea, two labial palpi and a hairy glossa of labium. The glossa terminates into a small circular spoon shaped lobe called spoon or bouton or flabellum which is useful to lick the nectar.
4. **Rasping and sucking**: The mouth part of thrips consists of labrum, labium and maxillae. There are three stylets derived from two maxillae and left mandible. Right mandible is absent. Both maxillary palpi and labial palpi are present.
5. **Mandibulo-suctorial type**: The mouth parts of grub of antlion, mandibles are elongate sickle shaped and grooved on the inner surface. Each maxilla is elongated and fits against the mandibular groove to from a closed food canal. The body of the insect victim is pierced by the opposing mandibles and fluids are extracted.
6. **Sponging type**: The mouth part of house fly, proboscis is projects downwards from head. The proboscis basal is rostrum and distal haustellum. Mandibles are absent. A is single segmented maxillary palpi. The end of the proboscis is enlarged, sponge like and the surfaces of labella are pseudotracheae. Labella function as sponging organs and are capable of taking exposed fluids.
7. **Siphoning type:** The mouth part of a butterfly is consists of elongate sucking tube or proboscis. Galeae are grooved on their inner surface as sucked up. The proboscis is coiled up like watch spring. Other parts are reduced or absent except the labial palpi and smaller maxillary palpi.
8. **Mask type**: Mouth parts of naids of dragon flies cover a part of the head. Labium is modified in to a mask where the prementum and post mentum forms into an elongated structure with a joint. The labial palpi are represented as teeth like structures / spines at the tip of the labium that are helpful for catching the prey. All other parts remain rudimentary (reduced).
9. **Degenerate type:** Mouth parts of maggots of Diptera. Head is absent and mouth parts are highly reduced and represented by mouth hooks/spines.

ABDOMINAL APPENDAGES

- **Pregenital abdominal appendages in wingless insects:**
  1) Styli: Tube like outgrowths are found on the ventral side of the abdomen of silverfish.
  2) Collophore or ventral tube or glue peg: Cylindrical adhesion organ located on ventral side of the 1st abdominal segment of spring tail.
  3) Retinaculum or tenaculum or catch: Ventral, 3rd abdominal segment in spring tail.
  4) Furcula or Furca: 'Y' shaped organ on the ventral side of 4th abdominal segment.
- **Abdominal appendages in immature insects:**

1) Tracheal gills: Seven pair's of lateral gills are present in the first seven abdominal segments of naiads of mayfly. Three or two leaf like caudal gills is found at the end of abdomen of naiad of damselfly. The rectal gills as a pouch like structure present at rectum of naiad of dragonfly.
2) Anal papillae: A group of four papillae surrounds the anus in mosquito larvae. These papillae are concerned with salt regulation.
3) Dolichasters: It is a segmental protuberance fringed with setae and present on the abdomen of antlion grub.
4) Proloegs: These are present in the larvae of moth, butterfly and sawfly. Two to five pairs are normally present but in grub of sawfly have seven pairs. They are unsegmented, thick and fleshy. planta at the tip with crochets. They aid in crawling and clinging to surface.

- **Abdominal appendages in winged adults:**

1) Cornicles: In aphids, a pair of short tubes on dorsum of 5th or 6th abdominal segment and secrete honey dew for protection against predators.
2) Caudal breathing tube: A hollow tube at the apex of abdomen water scorpion.
3) Median caudal filament: In mayfly and a wingless insect silverfish.
4) Pygostyles: Unsegmented cerci like structures are found in the last abdominal segment of scoliid wasp.
5) Anal styli: A pair, short, unsegmented structure found at the end of the abdomen of male cockroach.
6) Ovipositor: Short and horny in short horned grasshopper, long and sword like in Katydid and long horned grasshopper, needle like in cricket and it modified into sting in worker honey bee.
7) Pseudoovipositor: An appendicular ovipositor is lacking in fruit flies and house flies.
8) Cerci: On 11th abdominal segment and act as sensory organ. Structural difference as
   a) Long and many segmented:- Mayfly
   b) Long and unsegmented:- Cricket
   c) Short and many segmented:- Cockroach
   d) Short and unsegmented:- Grasshopper
   e) Sclerotised and forceps lik: Earwig.
   f) Asymmetrical cerci:- Male embiid.
9) Grasshopper genitalia: External sexual organs of male and female insects at last abdominal segments but in damselfly, copulatory organ is present on the venter of 2nd abdominal segment.

Male genitalia of grasshopper: Male genitalia are located only 9th abdominal segment. The 9th and 10th abdominal tergites are partly fused to supra-anal plate, besides a pair of podical plates and a pair of anal cerci. On the 9th sternum, genital apparatus differentiated into two parts as proximal and subgenital plate or gonocoxite. Abdomen posterior enclosed directly by supra-anal plate, laterally by podical plates and ventrally by the subgenital plates. These plates and the aedeagus which are the proximal and distal ends, respectively. All these structures constitute a sperm ejection pump in which opens the ejaculatory duct on the dorsal side of the phallobase, a Targe complex sclerite is found known as pseudo-sternite which forms an important organ for copulation, and while in its lateral side two projected parameres are found.

Female genitalia of grasshopper: The external genitalia of female grasshopper consists of a copulatory pouch is known as ovipositor and considered of 8th and 9th abdominal segments. There are three pairs of valves; first pair dorsal valves on 9th stertnum, second peir ventral valves on 8th sternum and third pair is inner valves between the dorsal aud ventral valves. The dorsal and ventral valves fit together to form the functional ovipositor. Besides, an egg guide is also found originating from the base of 8th sternum and extending as a slender appendage through the ventral valves to the genital chamber.

Alimentary canal of grasshopper:

A tubular structure runs from the buccal cavity to anus and divided in to three regions like stomodaeum, mesenteron and proctodaeum. Stomodaeum is again divided in five sub regions *viz*., i) Pre-oral food cavity, ii) Pharynx, iii) Oesophagous, iv) Crop- bag like structure and serves as a storage reservoir for the food and e) Gizzard-It is situated in the posterior region of the crop. Mesentron is central part of alimentary canal and divided into two region anterior and posterior regions. The anterior region have antlobe of gastric caeca and posterior lobe of gastric caeca. Proctodaeum is consisted with four sub regions *viz*., i) Ileum- many folds tube in its inner wall. ii) Colon- situated on the 5th and 6th segments of the abdomen. iii) Rectum- it is consists of six rectal papillae internally and six ridges of longitudinal muscles externally. The rectum opens to exterior through the anus which is situated at thecaudal end of the abdomen. iv) Anus last opening of alimentary canal.

METAMORPHOSIS IN INSECTS

1. **Ametamorphosis:** It is observing in silverfish there is no changing at nymphal stage after hatching except size and it is become adult after last moult, until they reach sexual maturity with well developed reproductive organs.
2. **Incomplete metamorphosis:** It is observing in cockroach, here three different stages of life cycle can be seen like egg, nymph and adult stages, so their pupal stage is absent. Nymph resembles the adult in all the characters except wings but nymphs possess wing buds which transform in to fully developed wings in adult stage.
3. **Complete (or) holometamorphosis:** It is observing in butterfly, here four different stages of life cycle can be seen like egg, larvae (caterpillar), pupa and adult. Larva undergoes moulting to enter in to pupal stage from which the adult insect emerges.
4. **Intermediate metamorphosis:** It is observing in thrips, in this case, insects may undergo either hemi or holometamorphosis. If they undergo holometamorphosis, there is a short pupal stage.
5. **Hyper metamorphosis:** It is observing in blister beetle, here is a peculiar type of development which consists of two or more types or forms of larvae in the life cycle of insects. In majority of the cases the first larval instar is campodeiform and the subsequent larval forms depends on type and mode of life of the larva.

TYPE OF INSECT LARVAE

i) Oligopod: Thoracic legs are well developed. Abdominal legs are absent.

1) **Campodeiform:** it is observing in grub of lady bird beetle where body is elongate, depressed dorsoventrally and well sclerotized. Head is prognathous. Thoracic legs are long. A pair of abdominal or caudal processes is usually present.
2) **Scarabaeiform:** it is observing in grub of white grub where body is "C" shaped, stout and sub-cylindrical. Head is well developed. Thoracic legs are short.

ii) **Polypod or Eruciform:** like caterpillars, body is elongate trunk, large sclerotized head capsule with powerful mandibles, stemmata found on either side of the head. The antenna is short. 3 pairs of thoracic legs and up to 5 pairs of unsegmented abdominal legs or prolegs or pseudolegs are present.

1) Hairy caterpillar: red hairy caterpillar, body is covered with hairs.
2) Slug caterpillar: Larva is thick, short, stout and fleshy. Larval head is small and retractile.
3) Semilooper: like caster semilooper, either 3 or 4 pairs of prolegs are present.
4) Looper: Like dhaincha looper, only 2 pairs of prolegs are present in 6th and 10th abdominal segments.

iii) **Apodus larvae:** larvae without appendages for locomotion and sclerotization of head capsule.

1) Eucephalous: Wriggler, well developed head capsule with functional mandibles, maxillae, stemmata and antennae. Mandibles act transversely.
2) Hemicephalous: Larvae of robber fly; head capsule is reduced and can be withdrawn into thorax. Mandibles act vertically.
3) Acephalous: larvae of house fly; head capsule is absent. Mouth parts consist of a pair of protrusible curved mouth hooks and associated internal sclerites.

TYPE OF PUPAE

1) Obtect: In case of moth larvae their appendages of pupa are glued to the body under last covering of body.
2) Chrysali: Pupa of butterfly is attached to the substratum by cremaster (hook) from terminal end of the abdomen and 2 gridle (silken threads) on abdomen.

3) **Tumbler:** Pupa of mosquito is comma shaped with rudimentary appendages. Breathing trumpets are present in the cephalic end and anal paddles are present at the end of the abdomen. Abdomen is capable of jerky movements which are produced by the anal paddles. The pupa is very active.
4) **Exarate: P**upa of rhinoceros beetle; body appendages are not glued to the body. They are free. The pupa is soft and pale.
5) **Coarctate:** Fly pupa covered under pupal case (puparium) which forming last larval skin it is dark brown, barrel shaped, smooth with no apparent appendages.