PRACTICAL MANNUAL

Fundamentals of Entomology

Course Code: ENT-121; Credit Hrs.: 4(3+1), and
PPH-212; Credit Hrs.: 3(2+1)

For B.Sc. (Hons.) Agriculture & B.Sc. (Hons.) Horticulture Students

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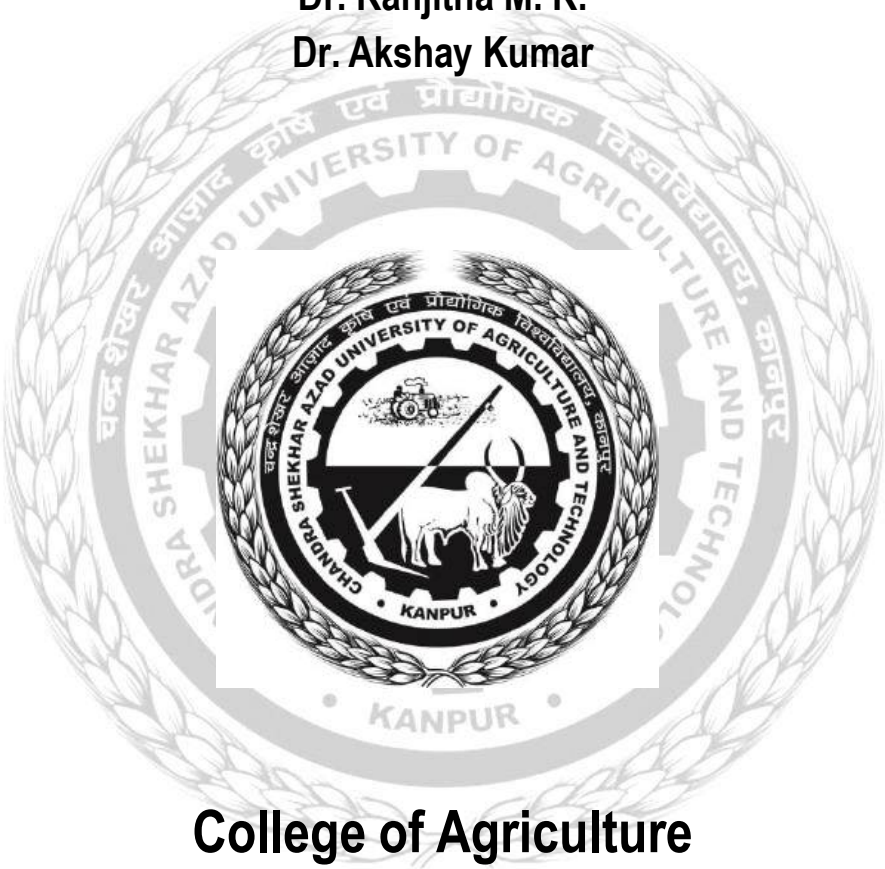

College of Agriculture
C. S. Azad University of Agriculture & Technology
Kanpur-208002

2024

Published: 2024

No. of copies: 310

Price: Rs. 105/-

Syllabus:

ENT-121: Methods of collection and preservation of insects including immature stages; External features of Grasshopper/Blister beetle; Types of insect antennae, mouthparts and legs; Wing venation, types of wings and wing coupling apparatus. Types of insect larvae and pupae; Dissection of digestive system in insects (Grasshopper); Dissection of male and female reproductive systems in insects (Grasshopper); Study of characters of orders Orthoptera, Dictyoptera, Odonata, Isoptera, Thysanoptera, Hemiptera, Lepidoptera, Neuroptera, Coleoptera, Hymenoptera, Diptera and their families of agricultural importance. Insecticides and their formulations. Pesticide appliances and their maintenance. Sampling techniques for estimation of insect population and damage.

PPH-212: 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.

Name of Student .....

Roll No. .....

Batch .....

Session .....

Semester .....

Course Name : .....

Course No. : .....

Credit .....

CERTIFICATE

This is to certify that Shri./Km. .....ID No.....has completed the practical of course.....course No. ..... as per the syllabus of B.Sc. (Hons.) Agriculture/ Horticulture/ Forestry ..... semester in the year.....in the respective lab/field of College.

Date: Course Teacher

CONTENT

Exercise No. 1

Objective: To learn about insect collection equipment

Collecting and identifying insects requires a basic understanding of insect anatomy (morphology), development, and physiology (digestion, reproduction, nervous system, circulation, and respiration), as well as behavior. This exercise deals with the methods of collection of insects, their setting and storage in the insect collection boxes for proper taxonomic studies.

Materials Required:

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Insect collection net:

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Draw diagram

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Uses: ……..

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Insect collection box:

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Draw diagram

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Uses: ……

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Aspirator:

Draw diagram

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Uses: ……

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Light trap:

Draw diagram

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Uses:……

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Draw diagram

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Killing bottle: ……

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Uses: ……

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Setting boards: ……

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Uses: ……

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Draw diagram

Cabinets: ……

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Uses:

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Draw diagram

Draw diagram

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Entomological pins: ……

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Uses: ……..

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Pinning block: ……

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Draw diagram

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Uses: ……

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Double mounting (Write the process): ……..……

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Uses: ……..……

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Pinning of insect in collection box (Write the process): ……

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Uses: ……

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Relaxing jar: ……

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Uses: ……

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Labels: A specimen in a collection box is accompanied by label bearing essential information. The following information must be written on a label in black India ink.
Host of the Insect:
Locality of collection:
Date of collection:
Name of the insect (with order and family):
Name of the collector:

Exercise No. 2

Objective: To study external features of Grasshopper

Requirement: Preserved specimen (Dry) of grasshopper, needle, hand lens and pencil.

Observation: Observe the specimen under the microscope and describe the external features of grasshopper with well-labeled diagram.

Draw diagram

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Exercise No. 3

Objective: To study insect antennae and their types

Problem: Put the already prepared slides of antennae under the microscope or (binocular) of from the field and draw the well-labelled diagram of antennae and its modifications.

Write the procedure of removal of insect antennae……

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Write the role of Insect Antennae: ……

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Exercise No. 4

Objective: To study insect Mouth parts and their types

Method:

- Cut the head from the thorax of a freshly killed grasshopper
- Hold the head gently between the thumb and index finger facing the mouth parts front side.
- Remove the labrum from the clypeus with the help of a forceps.
- Remove the paired maxillae lying behind the mandibles with the help of a needle and forceps carefully because the maxillary palps (5 segmented) may not damaged.
- Remove the labium (lower lip) gently with the help of a needle and forceps.
- Mount the mouthparts in glycerine on a slide.
- Remove the attached tissues and muscles with the help of needle.
- Examine the various parts type of mouth parts under stereo zoom microscope

'OR'

- Already prepared slides of mouthparts of insects, dissecting binocular/microscope, pencil, rubber and practical record book.

Observation: Observe the specimens under the microscope, draw the well labeled diagram of insect mouth parts and describe in detail

Write about the different parts of insect mouth parts and function

Biting and chewing type

Labrum:……
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Mandible:……...……...……
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Maxillae:……

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.Labium:……

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Hypopharynx: ……

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Draw the diagram of different type of mouth parts of insects and also write their features

Piercing and sucking type

(a) Bug type:

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Piercing and sucking type	
Bug type	**Mosquito type**

Example:

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(b) Mosquito type: ……

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Example:……

2. **Sponging type:**

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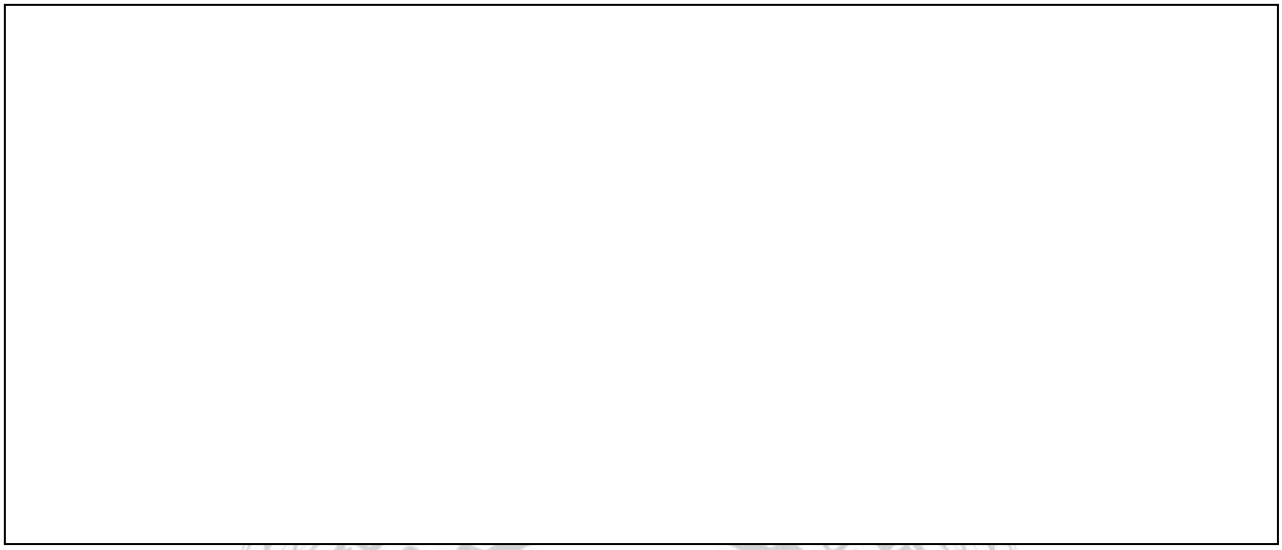

Example:……

Siphoning type :

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Example:……

Chewing and lapping type:

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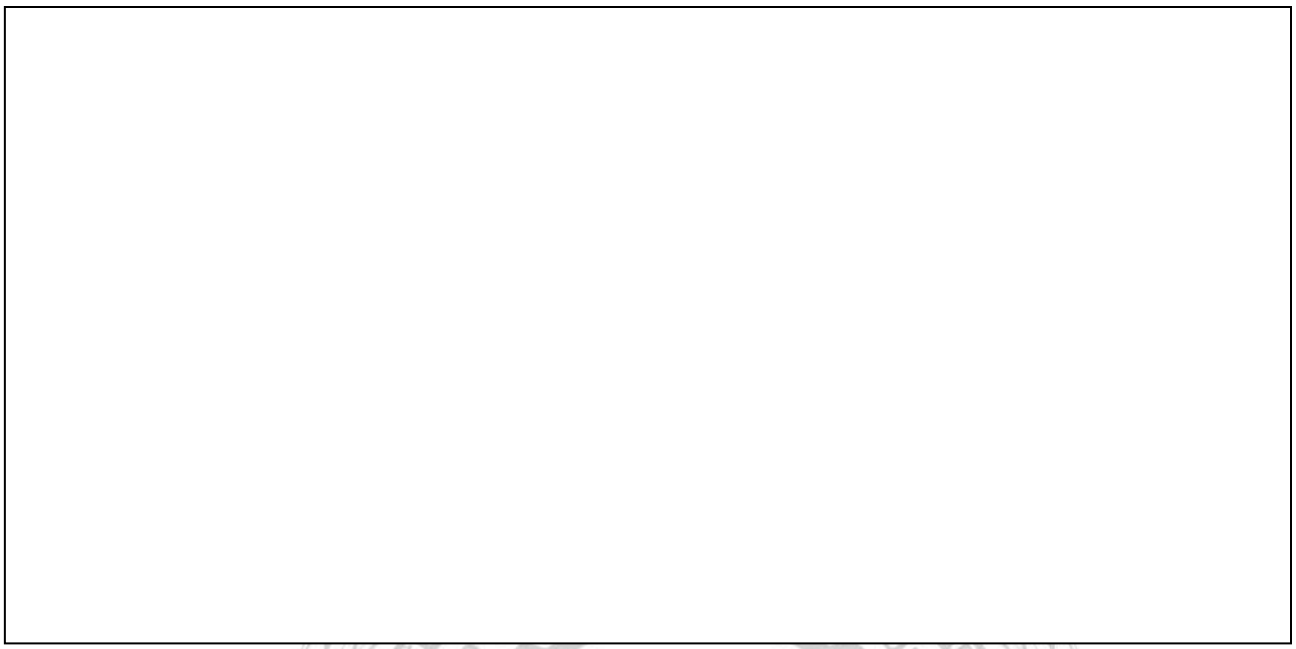

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Example:……

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Exercise No. 5

Objective: To study insect's legs and their types

Materials required: Already prepared slides, dissecting binocular/microscope, pencil, rubber and practical record book.

Method: Put the slides under the microscope/binocular and adjust the slide and eye piece in such a way to get the clear view of the parts of leg on the slide.

Observations: Observe the specimen under the microscope. Draw well labeled diagram of insect leg and its modifications.

Q. 1 Describe the different parts of insect legs

Coxa (first segment): ……

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Trochanter (second segment):……

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Femur (third segment): ……

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Tibia (fourth segment): ……

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Tarsus (fifth segment): ……

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Pretarsus (last segment having claw like structure): ……

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Describe different type of legs present in insects and also write their functions and features

Ambulatorial:……

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Cursorial: ……

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Scansorial: ……

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Saltatorial: ……

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Stridulatory: ……

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Fossorial ……

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Natatorial: ……

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Foragial: ……

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Raptorial: ……

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Climbing: ……

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Clasping ……

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Suctorial:……

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Exercise No. 6

Objective: To study insect's wings and wing venation

Requirement: Permanent mounted slides of wings, binocular hand lens etc.

Problem: Observe Insect wings under the microscope. Draw the well-labeled diagram of insect's wing with wing venation and its modifications.

Describe longitudinal veins present in insect wing: ……

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Describe the about the Cross veins present in insect wing: ……..

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Write about the features of different modification present in insect wings.

Tegmina: ……

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Example: ……

Elytra:……

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Example:……

Hemelytra: ……

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Example:……

Halters: ……

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Example:……

Fringed Wings: ……

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Example:……

Scaly Wings: ……

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Example:……

Membranous Wings: ……

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Example:……

Describe wing: ……

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Write the role of wings in insects: ……

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Exercise No. 7

Objective: Wing coupling apparatus found in insects

Requirement: Permanent mounted slides of wings, binocular hand lens etc.

Problem: Observe insect wings under the microscope. Draw the well labeled diagram of insect's wing coupling apparatus

Jugate type or jugum type: ……

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Example:……

Draw diagram

Frenulum and retinaculum type: ……

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Example:……

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Draw diagram

Amplexiform:

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Example:……

Hamuli: ……

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Example:……

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Draw diagram

Exercise No. 8

Objective: To study different types of insect larvae

Problem: Draw the diagram of different type of insect larvae and also write their features

1. Protopod larva:

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Example:……..……..

2. Oligopod larva:

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Example:……..……..

3. Polypod larva (Eruciform larva):

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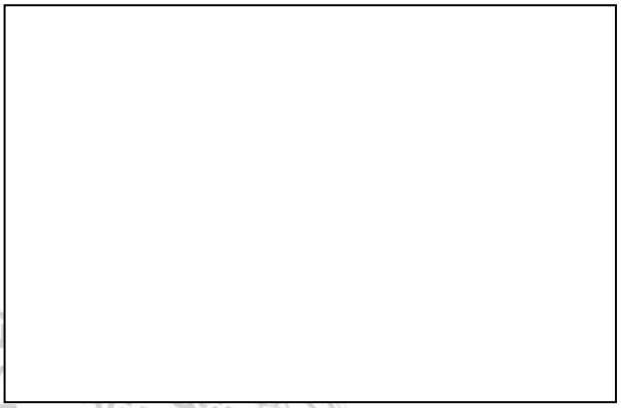
Example:……..

3. Polypod larva (Eruciform larva):



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Example:……..

Difference between:

Campodeiform	Scarabaeiform

In a phytophagous larva, how many abdominal legs are present

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Write the features and one example

Hairy caterpillar: ……..……

Eg: ……..……

Sphingid caterpillar / larva: ……..……

Eg: ……..……

Looper: ……..……

Eg: ……

Semilooper: ……

Eg: ……

Apodous larva: ……

Eg: ……

Describe in short:

Eucephalous: ……

Eg: ……

Hemicephalous. ……

Eg: ……

Acephalous ……

Eg:

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Exercise No. 9

Objective: To study different types of insect pupae

Problem: Draw the diagram of different type of insect pupae and also write their features

Write about the general feature of insect pupa

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Write about the division of insect pupae on the basis of presence and absence of powerful mandibles

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Write about the division of insect pupae on the basis of attachment on the appendages (or) shape of the pupae

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Write one example of each

1. **Exarate pupa:** ……

2. Obtect pupa: ……

3. **Coarctate**: ……

4. **Chrysalis**: ……

Collect the different type of pupae from the nearby field and identify them

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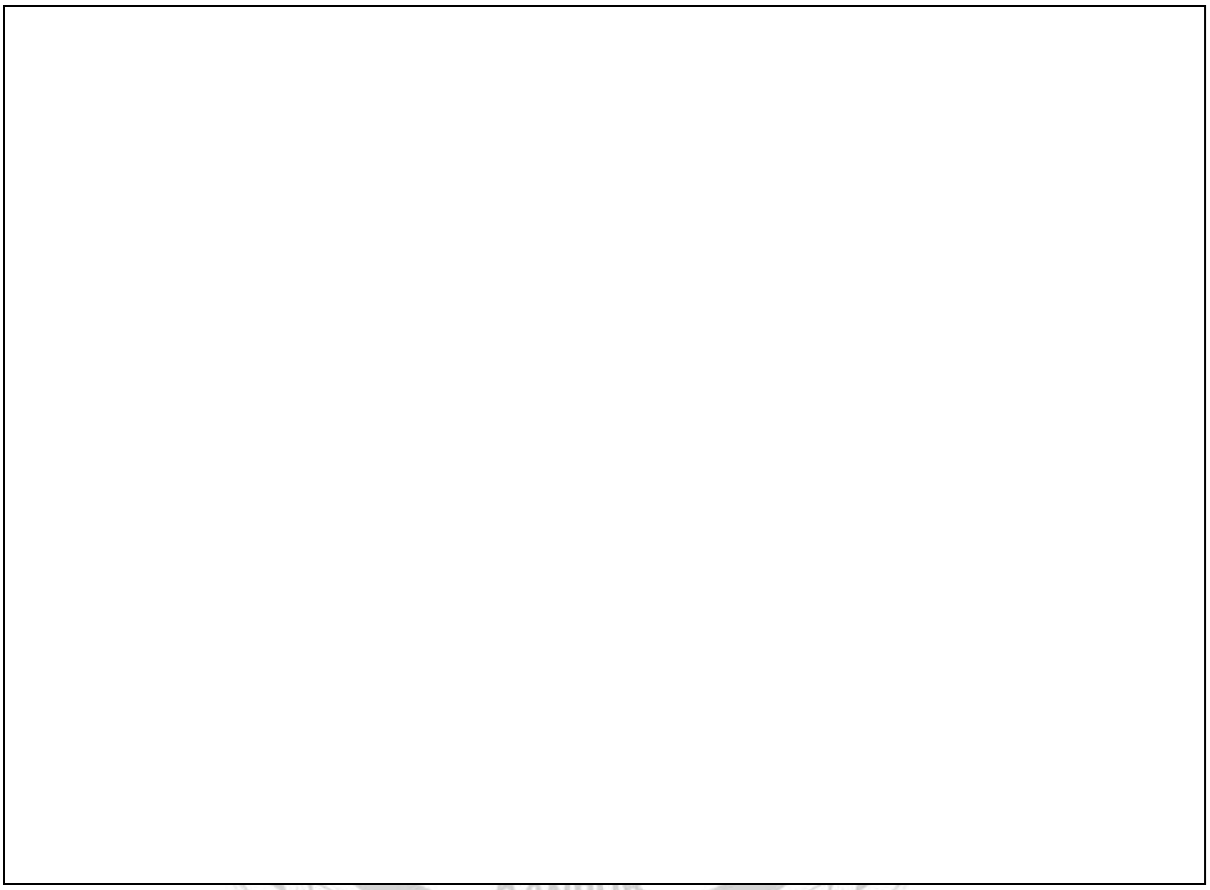
Exercise No. 10

Objective: To study digestive system in insects (Grasshopper)

Requirement: Preserved specimen of grasshopper, microscope, needle, Brush, Forceps, Scissor, Blade, hand lens and pencil.

Problem: Observe the insect specimen under the microscope and draw the well labeled diagram of digestive system of Grasshopper and describe their parts in detail



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Write the process of digestion:

Draw and describe filter chamber

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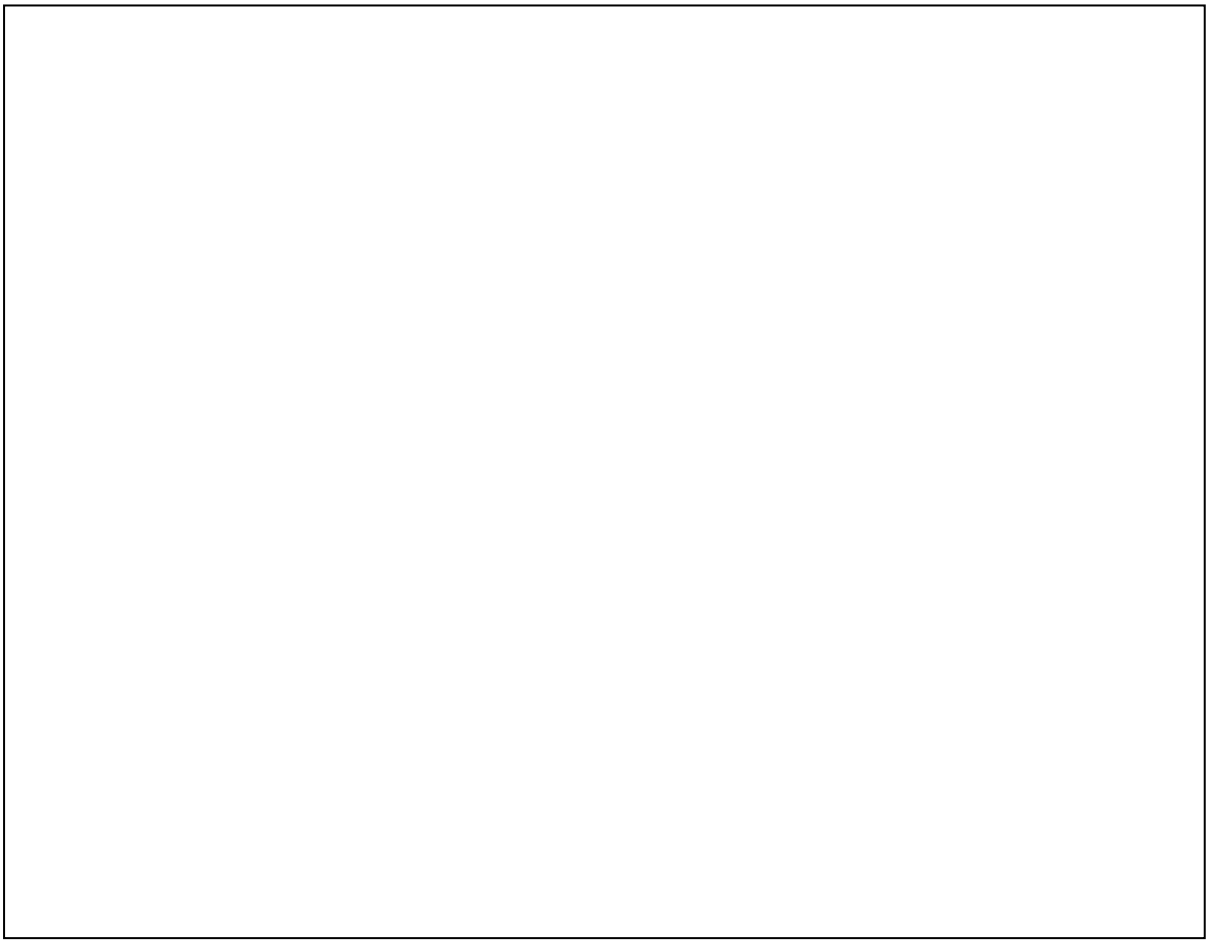
Exercise No. 11

Objective: To study male and female reproductive systems in Grasshopper

Describe the Male reproductive systems of Grasshopper with well-labeled diagram



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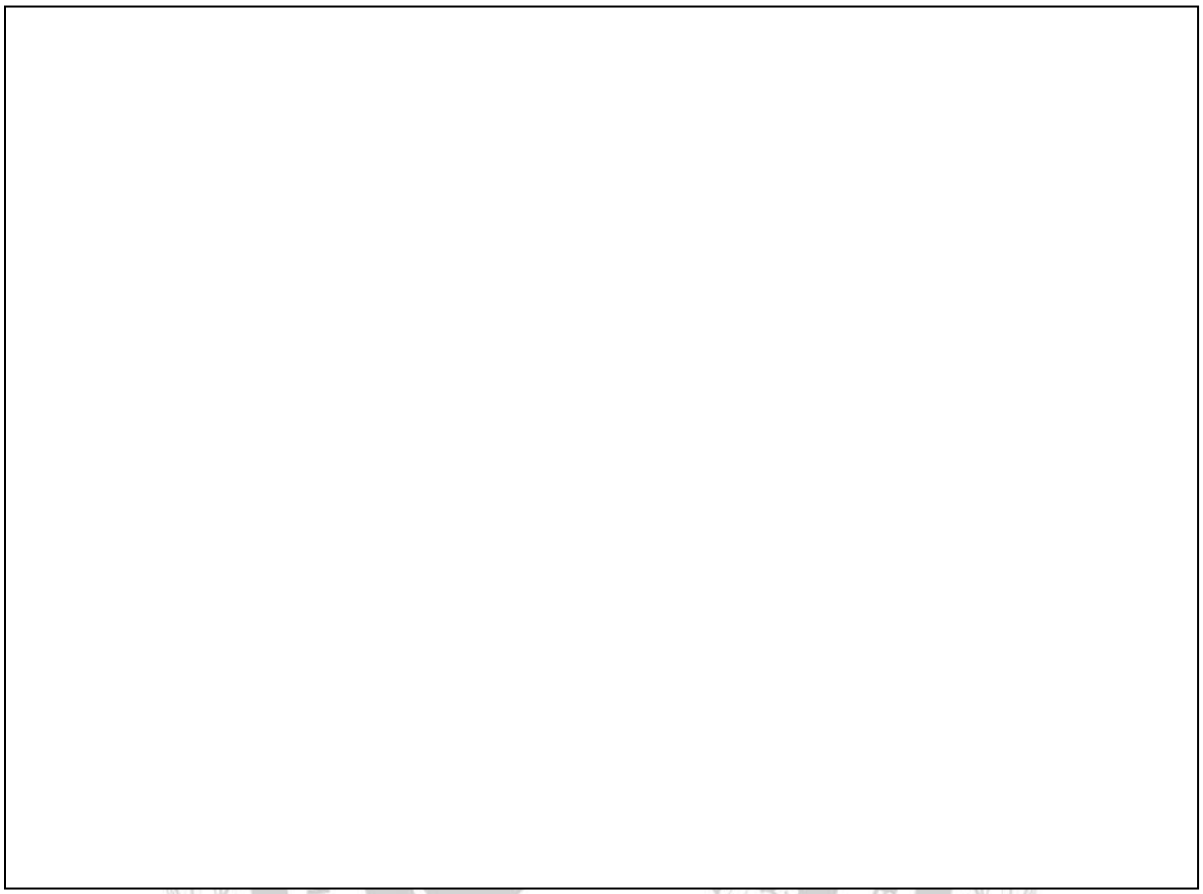
Describe the Female reproductive systems of Grasshopper with well labeled diagram



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Exercise No. 12

Objective: To study characters of orders Orthoptera, Dictyoptera and their families of agricultural importance

Write the Characters of Order Orthoptera:

- ……
- ……
- ……
- ……
- ……
- ……
- ……
- ……

Draw diagram

Family (with one Example):

- ……
- ……
- ……
- ……

Write the Characters of Order Dictyoptera:

- ……
- ……
- ……
- ……
- ……
- ……
- ……
- ……

Draw diagram

Family (with one Example):

- ……
- ……
- ……

Exercise No. 13

Objective: To study characters of orders Odonata, Isoptera and their families of agricultural importance.

Write the Characters of Order Odonata:

- ……
- ……
- ……
- ……
- ……
- ……
- ……
- ……

Draw diagram

Family (with one Example):

- ……
- ……
- ……
- ……

Write the Characters of Order Isoptera:

- ……
- ……
- ……
- ……
- ……
- ……
- ……
- ……

Draw diagram

Family (with one Example):

- ……
- ……
- ……

Exercise No. 14

Objective: To study characters of orders Thysanoptera, Hemiptera and their families of agricultural importance.

Write the Characters of Order Thysanoptera:

- ……
- ……
- ……
- ……
- ……
- ……
- ……
- ……

Draw diagram

Family (with one Example):

- ……
- ……
- ……
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Write the Characters of Order Hemiptera: (Sub order 1-Heteroptera):

- ……
- ……
- ……
- ……
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Draw diagram

Family (with one Example):

- ……
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Write the Characters of Order Hemiptera: (Sub order 1-Homoptera):

- ……
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Draw diagram

Family (with one Example):

- ……
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Exercise No. 15

Objective: To study characters of orders Lepidoptera, Neuroptera and their families of agricultural importance.

Write the Characters of Order Lepidoptera:

- ……
- ……
- ……
- ……
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- ……
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- ……

Draw diagram

Family (with one Example):

- ……
- ……
- ……
- ……

Write the Characters of Order Neuroptera:

- ……
- ……
- ……
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Draw diagram

Family (with one Example):

- ……
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Exercise No. 16

Objective: To study the characters of orders Coleoptera, Hymenoptera, Diptera and their families of agricultural importance.

Write the Characters of Order Coleoptera:

- ……
- ……
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- ……
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Family (with one Example):

- ……
- ……
- ……
- ……

Draw diagram

Write the Characters of Order Hymenoptera:

- ……
- ……
- ……
- ……
- ……
- ……
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- ……

Family (with one Example):

- ……
- ……
- ……

Draw diagram

Write the Characters of Order Diptera:

- ……
- ……
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- ……
- ……
- ……
- ……

Draw diagram

Family (with one Example):

- ……
- ……
- ……
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Exercise No. 17

Objective: Insecticides and their different formulations.

Write the properties of a good Insecticide

1. ……
2. ……
3. ……
4. ……
5. ……
6. ……
7. ……
8. ……
9. ……
10. ……

Write the properties of formulations of Insecticides with at least 2 examples:

1. Dusts (D): ……

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2. Granules or Pelleted insecticides (G): ……

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3. Wettable Powders (WP): ……

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4. Emulsifiable Concentrates (EC): ……

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5. Soluble Powder or Water Soluble Powder (SP or WSP):

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6. Suspension Concentrate (SC):

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7. Flowables (F):

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8. Water Dispersible Granules (WDG):

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9. Solutions:

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10. Concentrated insecticide liquids:

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11. Insecticide aerosols:

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12. Fumigants: ……

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13. Micro-encapsulation: ……

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14. Insecticide Mixtures: ……

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15. Baits: ……

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Exercise No. 18

Objective: To study properties of pesticide appliances and their uses

Write the Properties and uses of Pesticide appliances and also draw their diagram

HAND SPRAYER:

Draw Diagram

Properties: ……

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Uses: ……..…

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ROCKER SPRAYER:

Draw Diagram

Properties: ……

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Uses: ……..…

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FOOT SPRAYER:

Draw Diagram

Properties: ……

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Uses: ……

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KNAPSACK SPRAYER:

Draw Diagram

Properties: ……

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Uses: ……..…

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FOGGING MACHINE:

Properties: ……..……

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Uses: ……..

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Draw Diagram

HAND ROTARY DUSTER:

Properties: ……..……

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Draw Diagram

Uses: ……..……

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HAND COMPRESSION SPRAYER:

Properties: ……..……

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Uses:

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Draw Diagram

CYNOGAS PUMP:

Properties: ……..……

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Uses:

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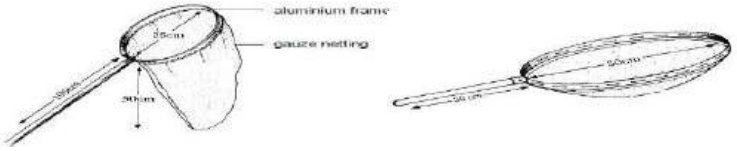
Draw Diagram

Methods of insect collection

1. **Sweep Net or Insect net**
   - ❖ It is made up of three parts: hoop (30-40 cm diameter), handle (100 cm) and porous cloth bag made up of mosquito netting material. The diameter of hoop and depth of bag should be in the proportion of 1:2.
   - ❖ The length of bag should be about twice the diameter of the ring.
   - ❖ The net may be used for aerial collection of insects like butterflies, dragonflies, wasps etc.



Care and use of nets:

- ❖ Flowers and plants should be swept with a sidewise motion.
- ❖ Sidewise movement of net collects more insects than upward and downward sweep.
- ❖ After every stroke always give a quick flick to the frame of net so that the bag of the net fallsover the frame.
- ❖ Falling of bag of net over the frame because closing of mouth of net and there by prevents insects from escaping.

2. **Hand Picking**
   - ❖ Insects were hand-picked and placed in containers.
   - ❖ This method is suitable for large insects like: beetles, bug and grasshoppers.

3. **Aspirator**
   - ❖ It consist of a bottle fitted with rubber cork having two holes for instalment of two tubes one is bent at one end and other straight glass tube attached to a rubber tube (suction tube).
   - ❖ A muslin cloth piece is placed between glass and rubber tube to avoid the entry of insect into mouth.
   - ❖ By sucking at the rubber tube, small insects can be drawn into the bottle through pipe without damaging the specimens.

4. **Berlese funnel**
   - ❖ This device is useful for collecting soil dwelling insects.
   - ❖ Soil arthropods can be sorted out by this methods. Debris including soil arthropods can be collected by using the light as the source of heat in berlese funnel method

5. **Beating**
   - ❖ This method is useful for crawling insects from plant parts. It can be done by placing beating tray or inverted umbrella and beat the plant part and collect the insects.

6. Traps- Trapping is a method of collecting insects in the absence of collector. This is the most common methods or techniques used by growers in integrated pest management programme to catch the insects. There are many different types of traps used for collection of insects. They are pheromone traps or sleeve traps, fruit fly trap, sticky traps, delta traps, water or Wota traps, pit fall trap, wind pan trap, malaise trap and light traps.

a. Pheromone traps: Synthetic sex pheromones are placed in the traps to attract male moths. The rubberized septa containing the pheromone lure are kept in the traps designed especially for this purpose and used in monitoring, mass trapping and mating disruption programmes. Sticky tarps, Water pan traps and funnel type models are available for use in pheromone based insect-pest control programmes. Yellow sticky traps: Aphids, whiteflies, thrips prefer yellow colour. Yellow colour is painted on tin boxes and sticky material like castor oil/Vaseline is smeared on the sticky material.

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

c. Pitfall traps: Containers such as small plastic buckets, plant pots, glass jars or jam tins are sunk into the ground to trap flightless, ground-living insects and arachnids, especially beetles (ground beetles), cockroaches, crickets, spiders, harvestmen and mites. 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. Radiating vanes,

such as wooden planks, placed in the substrate will increase the effective area of the trap. A bait can be added to the trap to increase its effectiveness. The type of bait will depend on the specimens one wishes to catch.

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

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

B. Killing insects

Killing should be immediately after capture. Potassium cyanide (KCN), ethyl acetate, carbon tetrachloride and chloroform are commonly used for killing insects. KCN kills the insects quickly but deadly poisonous and must be handled with extreme care. Ethyl acetate kills the insects slowly and does not last long.

a. **Pinching-** In this method, thorax is pressed between thumb and index finger swiftly and with jerk. It needs constant practice. e.g. butterfly, grasshopper.
b. **Injecting-** Hypodermic injection of fluids.
c. **Drowning-** Larvae and insects without scales, hairs or powdery covering can be killed by submerging them in water.

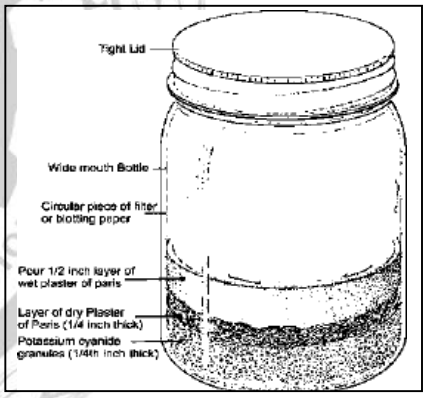
Preparation of Killing Bottle/ Cyanide Bottle

Collected insects should be killed as quickly as possible in a killing bottle to avoid damaging of specimens. A collector needs several bottles of different sizes for different types of insects.

Preparation of killing bottles:

Any wide mouthed glass bottle can be used for preparing killing bottles.

- Killing bottled\s are made with potassium cyanide, sodium cyanide or calcium cyanide.
- These compound give a concentration of deadly fumes of HCN (Hydrogen Cyanide) sufficient to kill the insects within the short time.
- The bottle is charged by filling in small amount of potassium cyanide in between the dry plaster of Paris of about 2 cm. thickness.
- A thick mixture of plaster of Paris is prepared and poured over the covered cyanide to form a smooth layer, which sets hard and keeps it in place.
- Cover the surface of the wet plaster with thick white blotting paper and it should be removed when it becomes wet or dirty.

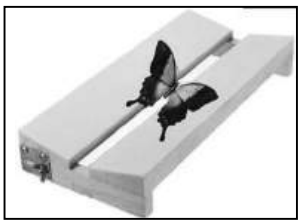


Care and use of Poison bottle

- Bottles containing cyanide must be labeled "**POISION**".
- When the bottle is broken or useless, it should be carefully disposed off by burying deep in the soil.
- The bottle should be kept closed and not opened except to put in or to take out specimens.
- Insects in cyanide bottles should be removed; as they are dead otherwise they become off-coloured and brittle.

C. Mounting

Setting board (spreading board): It's a wooden frame with centrally grooved. The either side of grooveprovided with foam sheet to enable pinning.



- Moths and butterflies are mounted with their wings spread on the setting boards.
- It is made of parallel strips of wood covered with papered cork sheet and with a space between to receive the bodies of insects.

- Properly pinned insect body is put in the groove so that the wing bases are in level with the near edge of the top pieces.
- Hold the wings at the top level by two narrow strips of paper and pull them forward until the hind margin of the front wing is at right angle to the body axis and the front margin of hind wing is just under the front wing.
- Lay long strips of card sheet over the spreaded wings and pin them down with large pins inserted close to the wings but not through them.
- Put the specimen in a dry, pest proof container for 2 or 3 weeks.
- After this process the specimen be removed from the board.
- Save the specimens form ants.

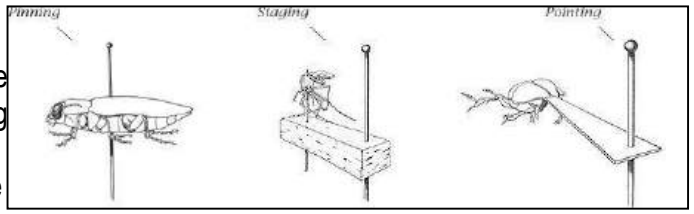
Relaxing container: The collected dead specimen becomes stiff and brittle. Stiffness can be removed by keeping the specimen in relaxation chamber. A wide mouthed air tight container filled with moist sand (for high humidity) covered with blotting paper along with the few drops of carbolic acid (prevent mould development). This chamber permits water to be reintroduced into the specimenmake them flexible.

D. Preservation

i. Paper fold (paper envelope): The triangular envelope made from absorbent paper sheet and cut into rectangle with the side proportion of 3:5. Bring the opposite corners together diagonally to leave two projecting flap. Data regarding collection should be write on outer side of projecting flap and put the insect between two overlapping triangles then fold the flaps as triangular envelope. It is suitable for temporary preservation and storage for large winged insects.

ii. Pinning of Insects:

- Generally pure nickel pins, sizes 16 and 20, which are 35 mm and 15 mm long are used forlarge and small insects.
- These two sizes of pins can be obtained from any entomological supply house.
- Insects are pinned vertically through the body.
- The place where the pin is inserted depends upon the type of insects. The following rules arefollowed in pinning the different group of insects.
- **Orthoptera** (Grasshopper, crickets & locusts, etc.)- Pin through the back of the pronotum,slightly to the right of the middle line.
- **Hemiptera**- (Bugs etc.)- Pin through the scutellum, slightly to right of the middle line.
- **Coleoptera** (Beetles)-Pin through the right elytra (wing cover) about mid-way of the body.
- **Lepidoptera** (Butterflies and moths)- Pin between the base of the fore wings.
- **Diptera** (Flies) and Hymenoptera (Bees, wasps etc.) Pin through the thorax, slightly to theright side of middle line.
- **Odonata** (Dragonflies)- Pin through the middle of the thorax.
- Very small insets be mounted on card points or on minute pins. Card points are small triangle of cardboard or on minute pins. A spot of good glue is put on the angle tip and right side of the insect is pressed against the glued surface.



iii. Double Mounting:

This method is used for smaller insects because pinning is troublesome. Methods for double mounting are:

Staging or micro pinning: The small insect can be pinned in narrow rectangular piece of pith orcork stage using micro pin and then stage is pined in store box with a bigger pin later.

Carding: The small specimen is stick directly instead of pining in 5 X 8 mm or 5 X 12 mmrectangular and then this card placed in store box with the help of glue.

Pointing or triangular carding: The specimen is glued at down ward bend tip of triangular card(10 mm x 5 mm) and then placed the card into store box using bigger pin.

Liquid preservation: The immature stages or soft bodied insects can be preserved by placing them into a screw cap vial filled with 70 % alcohol and 4 % formalin. The stopper should be seal with the paraffin wax and replace the liquid after one year because preservative are highly volatile.

iv. Setting: It is done by using setting board for the study of wing characters. Wings should be set on either side in moth, butterflies, dragonfly and damselfly while one side wing in case of grasshopper before the specimen become stiff.

v. Blowing soft bodied larva: Removed the internal content of soft bodied insect and inflating it like a balloon to its natural size and then drying in blowing apparatus.

vi. Labelling: It is the information regarding insect, common name, scientific name, place and date of collection and name of collector.

- ❖ A label should always give the date and locality of the Insects capture.
- ❖ Label should also contain additional information like-name of the collector and host orhabitat of insect.
- ❖ Label should be of uniform size about ¾ inch long and ½ inch wide and made from stiffpaper.
- ❖ The label should be as small as possible and should be run about half way up the pins, butnot too near the specimen.
- ❖ Label should be projected from the pin in the same direction as the specimens.

vii. Display:

Insect store box: The most convenient insectbox is made of good deal with top and bottom of ply wood, external dimension 17 ½ "long by 12"broad by 4" deep lined on both sides with cork covered with white paper and provided with a naphthalene.

Cork sheet are glued inside at the bottom of box that facilitate pinning while top portion fittedwith transparent glass for display preserved specimen.

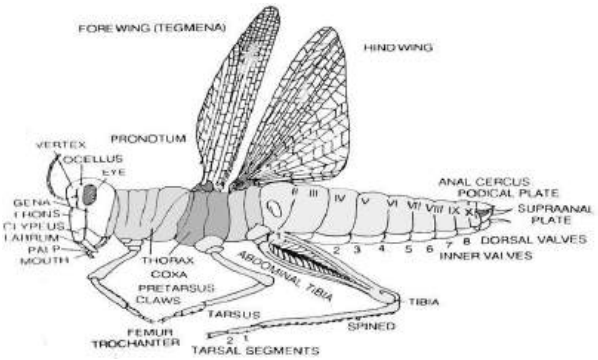
Repellents and preservatives: Preserved specimens are attacked by various microbes and other store pests. Naphthalene ball placed inside the boxes by pin. Heating the head of pin in flame and pressed against the ball and hold few second for drying.

Riker mount: American botanist discovered it hence the name. It's a flat container with a glass or transparent cover and cotton wool at bottom.

The External Features of Grasshopper

The body of grasshopper is divided into three parts *viz*, Head, Thorax and Abdomen.

Lateral view of grasshopper showing three body regions and the parts of body



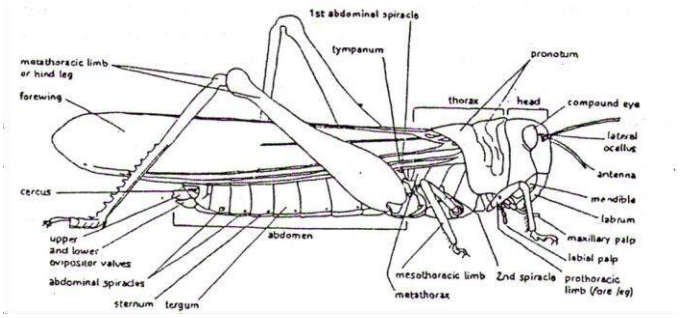


Diagram showing body parts of grasshopper (*Locusta*)

{i} Head: Hypognathous type, one pair of compound eye, three ocelli, two antennae, frontal and lateral view of head showing vertex, frons, genae, clypeus, Labrum, maxillary palp, labium.

(ii) Thorax: It is divided into three parts.

{a} **Prothorax**: Dorsally covered with triangular pronotum and ventrally one pair of first leg.

{b} **Mesothorax**: This is the middle portion of thorax. Dorsally one pair of forewing known as tegmina, which is thickened and leathery. Ventrally middle pair of leg is present. One pair of spiracles on the pleuron.

{c} **Metathorax:** It is the last thoracic segment. Dorsally there is one pair of hind wing which is hyaline and white in colour. Ventrally there is last pair of leg known as hind leg. This is bigger in size known as saltatorial leg.

{iii} Abdomen: Its posterior tagmata which soft and longer than rest body. It consist of eleven telescopic segments jointed by inter-segmental membrane called **conjunctiva** facilitates flexibility during copulation and oviposition. It has only dorsal (tergum) and ventral (sternum) region but lateral (pleuron) is absent. The first to eighth abdominal segments are provided with eight pairs of spiracles (opening of respiration system). **Tympanum** (auditory membrane) is found on first abdominal segment. The male genitalia is found in 9th sternite consisting aedeagus and lateral clasping apparatus called **parameres** while female genitalia present in 8th and 9th abdominal segments consists of **ovipositor** made up of two pairs of basal sclerite (**valvifers**) and three pairs of elongated dorsal, inner and median (**valvulae**). A pair of unsegmented sensory **cerci** is present between **epiproct** (triangular dorsal plate of eleventh segment) and **paraproct** (paired lateral plates). The anal opening is situated just below the epiproct.

The types of mouthparts and their modifications

Mouthparts of insects vary among insects of different groups depending upon their feeding habits. They are mainly of two types *viz*., Mandibulate (feeding mainly on solid food) and haustellate (feeding mainly on liquid food). Insect mouthparts have become modified in various groups to perform the ingestion of different types of food and by different methods. Indeed the modifications in the mouthparts to ingest almost all kinds of the food material, are one of thefactors for the success of the group.

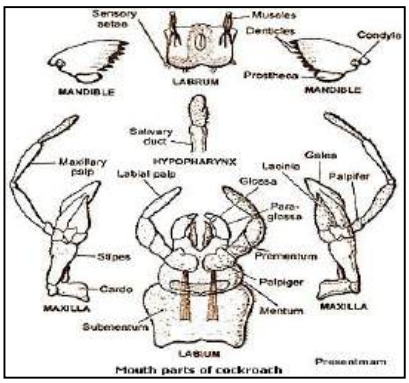
Typical mouth parts of insect consist of following parts:

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

The important modifications of Insect mouthparts are given below:

1. Biting and chewing type
2. Piercing and sucking type
3. Sponging type
4. Siphoning type
5. Chewing and lapping type
6. Rasping and sucking type
7. Degenerated type.

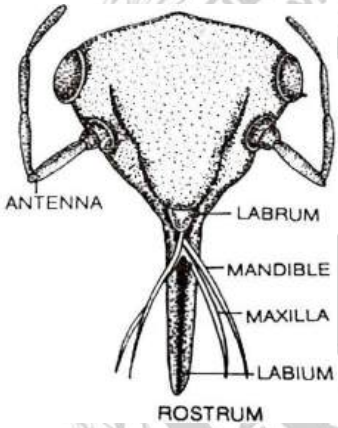
1. Biting and chewing type Example- Grasshopper/ Cockroach

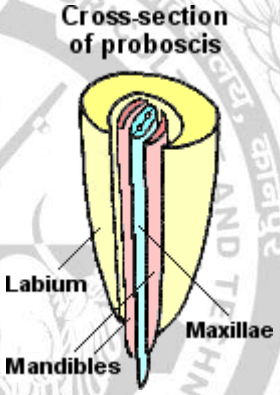


Labium-1 (Upper lip)
Mandibles-2
Maxillae-2
Labrum-1 (lower lip) and
Hypopharynx-1

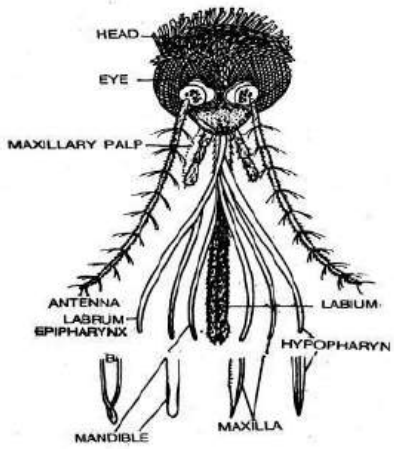
2. Piercing and sucking type

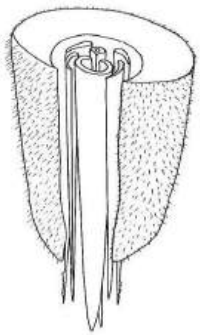
[a] Bug Type: Labrum-1 (triangular lobe), Mandible-2; (Stylate), Maxillae-2 (Stylate), Labium-4 segmented beak like; Hypopharynx- small and sclerotized lying near the base of stylets.





[b] Mosquito Type (Fig-) Following parts are present: Labrum+epipharynx-1(Stylate), Mandible-2 (Stylate), Maxillae-2 (Stylate), Labium-1 (beak like), Hypopharynx-1 (Stylate), in all there are 6 stylets.



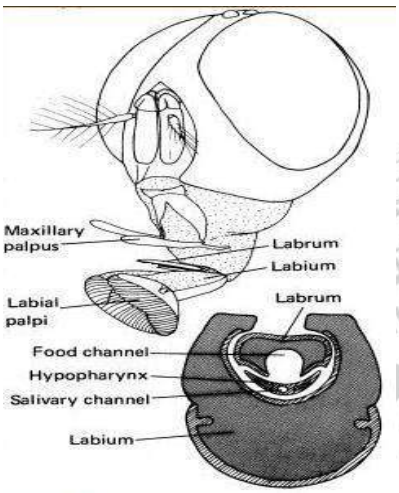


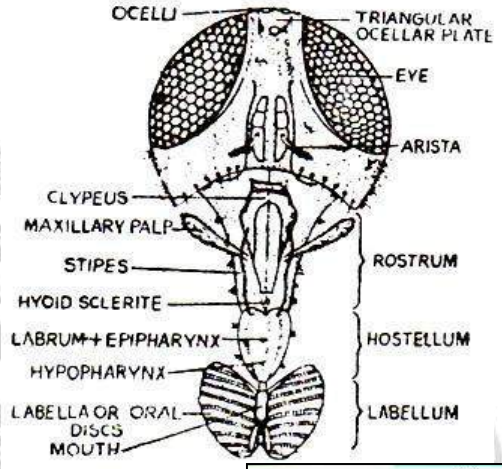
Cross-Section of proboscis

3. Sponging type (e.g.) House fly

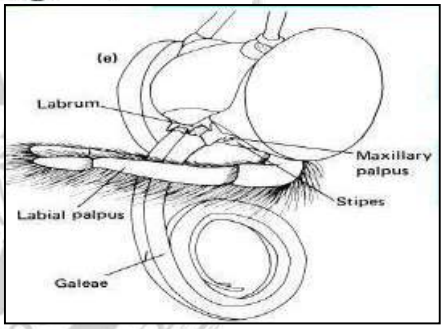
The following parts are present: Labrum epipharynx- long tapering. Mandible-absent, Maxillae- Represented by a pair of single segmented maxillary palp labium- Modified into long proboscis and it consists of following parts:

[1] Rostrum
[2] Haustellum
[3] Labellum]
[4] Hypopharynx- small



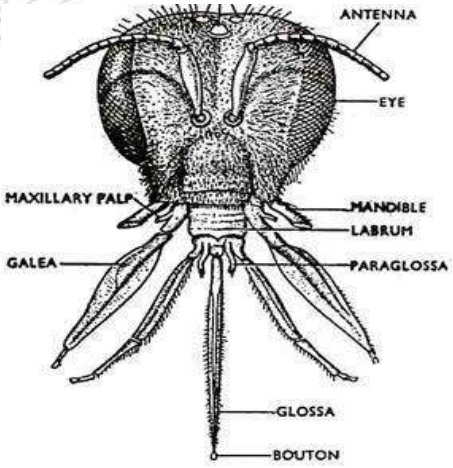


4. Siphoning type (eg,) Butterflies and Moths



(1) This type of mouthparts is found in butterflies and moths.
(2) Labrum is represented by narrow transverse band.
(3) Mandibles are absent and sometimes rudimentary.
(4) Maxillae is in the form of palpi and galeae.
(5) Galeae are greatly enlarged to take the shape of a coiled proboscis lacinia is rudimentary orwanting.
(6) Labium is undeveloped and modified in to large, hairy or scaly, three segment labial palp.

5. Chewing and lapping type (eg,) Honeybee and Wasps



1. This type of mouthparts is found in honeybee and wasps.
2. These are meant for collecting pollen, molding the wax or nest material and lapping of nectar from the flowers.
3. Labrum is small with semicircular lobe found just below the clypeus.
4. Mandibles are flattened or spoon shaped lying on the lateral side of labrum.
5. Maxillae consist of rudimentary lacinea or wanting

and galea is large, flat, blade like in structure and larger than the stipes.

6. Galea joins the subgalea at the base.

7. "V" shaped Sclerite named as lorum is found in between each cardo.

8. Labium is differentiated in to mentum, prementum, glossa, paraglossa and labial palpi

The parts of typical antenna and their modifications

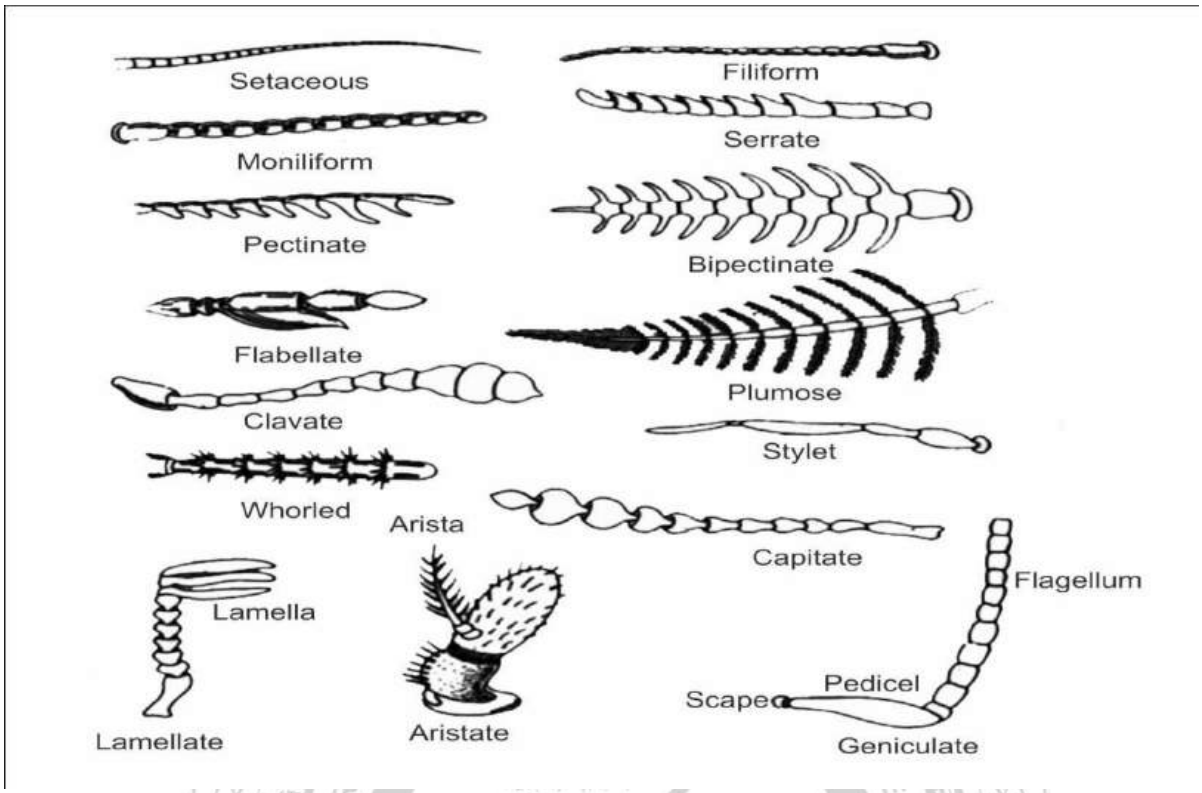
A typical antenna consists of 3 parts *viz*. Scape, pedicel and flagellum.

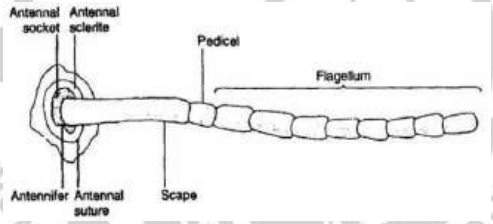
Following types of Antennal modification and their examples may be recorded in the practical note book.

Types of antennae

(1) Setaceous (bristle like)	Order: Coleoptera, Lepidoptera and Orthoptera viz. Cockroach and Cricket.
(2) Filliform (thread like)	All the segments are nearly uniform in thickness. Order: Orthoptera, Coleoptera, Lepidoptera namely grasshopper andground beetle.
(3) Moniliform (beaded)	Globular segments of uniform thickness looking like a string of beads. Order Isoptera and Coleoptera namely Termites.
(4) Serrate (saw-like)	Segments more or less triangular, projected in one direction like the teeth of saw. Example order Coleoptera; pulse beetle.
(5) Pectinate (comb like)	Antennae possess long projections like comb. Example- order Lepidoptera moths (sugarcane root borer).
(6) Bipectinate (Comb on both the sides)	It is similar to pectinate type but the comb like projections are on both the sides. eg. Order Lepidoptera (Silk moth)
(7) Flabellate (Fan like)	This is a comb like structure, which takes the form of feather(folding fan) known as flabella. Eg- Order Strepsiptera and Coleoptera viz-Cedar beetle.
(8) Plumose (feather like)	The whorls of the hair arises from the joints of each segment and look like plume eg. Order Diptera viz. male mosquitoes.
(9) Whorled	Whorls of bristle at every joint. eg- Order Hemiptera viz. male of mango mealy bug.
(10) Clavate (Clubbed)	Club shaped antennae in which the segments become broadertowards the tip and the last segment finally culminate into a round club. *eg*- order Coleoptera and Lepidoptera *viz* butterflies.
(11) Capitate (knob like)	The terminal segment form a large knob or cap. *eg*- Order. Coleoptera and Lepidoptera *viz Necrobia*
(12) Lamellate (leaf like)	This is like capitates antennae in which the terminal segments form the knobs and are extended on the side to form broad leaf like plate. *eg*.- Order Coleoptera, *viz*. Scarabeid beetles (white grub beetle)
(13) Geniculate (elbowed)	The first segment (scape) is long while second segment (pedicel) is short. The flagellum is made of small segment taking the shapeof bent elbow. *eg*- Order Hymenoptera *viz*; honey bee, wasp.

(14) Aristate	3 segmented, first segment (scape) is smaller and broader and second segment (pedicel) is longer than the first. The flagellum is longer than both the segment and possesses a heavy bristle known as arista. *eg*. Order Diptera *viz* house fly.
(15) Stylate	The last segment of flagellum is modified into a long bristle known as style *eg*. Diptera *viz*. Snipe fly
(16) Fusiform	Basal and distal segments of this antennae are small and thin while middle segments are larger just like reddish. The last segments is modified into a hook like structure. *eg*. Order Lepidoptera *viz*. Sphingid moth.
(17) Pilose	It is similar to plumose, but it is less bushy *eg*- female mosquito.

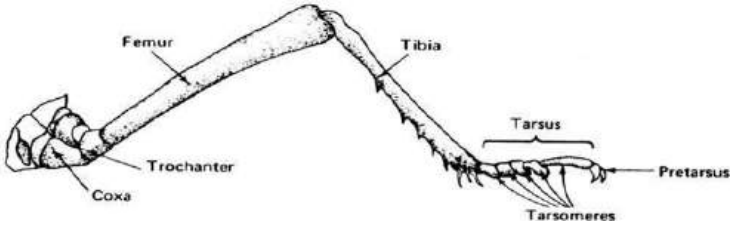




The parts typical leg of insect and its modifications

A typical insect leg consists of following parts: Coxa (first segment), Trochanter (second segment), Femur (third segment), Tibia (fourth segment), Tarsus (fifth segment), Pretarsus (last segment having claw like structure).

Structure of a Typical leg



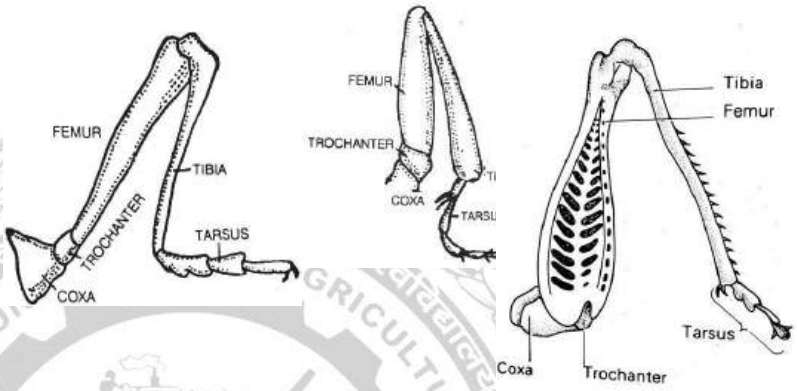
The following modifications are found in the legs-

[i] Ambulatorial (walking type)- Adapted for walking as in case of cockroach and bug.

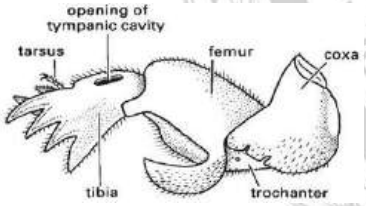
[ii] Cursorial (running type)- 1. This is adopted for running so that insect may not slip away while running on the ground. 2. E.g. Earwig.

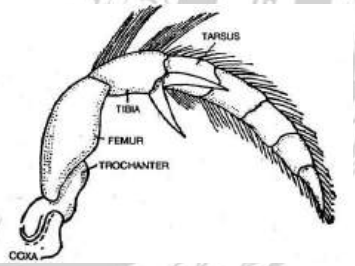
[iii] Scansorial (clinging type)- 1. These legs are smaller and flat.
2. The coxa is widely separated and one or two segmented.
3. Tarsi bear a single claw.
4. This claw to the help of tarsus helps the insect to remain attached with the host.
5. Example is head louse.

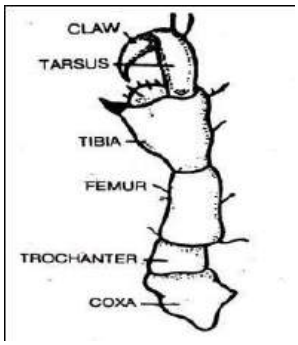
[iv] Saltatorial (jumping type)-	Femur of the hind leg gets enlarged and accommodates the powerful tibial levator muscles. It helps in jumping of the insect. This is type of leg is found in grasshopper, crickets andflea beetles.
[v]Stridulatory (soundproducingtype)	1. This leg is meant for sound production in insect. 2. The femur of hind leg is provided with row of pegs (file) on its inner side. 3. These femoral pegs work against the outer surface ofeach tergum or costal margin of the forewing therebyproducing a sound. 4. The example is male grasshopper and crickets.
[vi] Fossorial (digging type)	5. In this type of leg coxa, trochanter and femur are strong and broad. 6. The tibia is provided with four strong scrapper like prolongations at its terminal end. 7. These are used for digging the ground and cutting the roots of the plants. 8. The example is mole cricket, nymphs of Gryllotalpa and cicada.
[vii] Natatorial (swimming type)	9. This type of leg is found in insects living in water, which help them in swimming. 10. In this leg, the femur, tibia and tarsus are flattened and possess the long rows of hairs. 11. The coxa and trochanter are simple and smaller whereas the tarsus is five segmented, the last terminal segment is triangular and pointed. 12. Such type of leg is found in Dytiscus and giant water 13. bug.

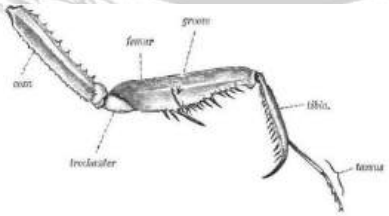
[viii] Foragial (pollen collecting type)	14. This type of modification is met in the leg of worker honey bees which is adapted for carrying the pollen from the flowers. 15. The tibia of hind leg is dilated and covered with long dense hairs forming a pollen basket, which serves as storage structure for the pollen grains. 16. The first tarsal segment is flattened and its inner surface is densely clothed with several rows of short stiff spines forming a brush. 17. It helps the bee in collecting the pollen adhering to the  18. hairs of its body.

Cursorial **Ambulatorial** **Stridulatory**









Fossorial leg **Natatorial leg** **Suctorial**
Scansorial leg **Raptorial leg**

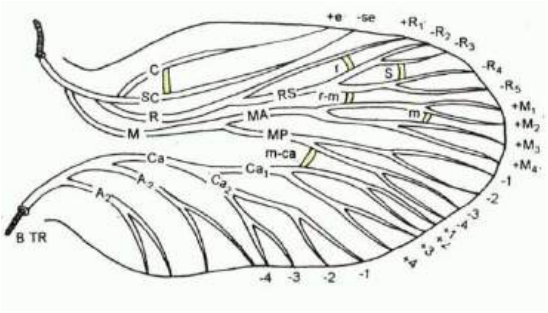
[ix] Raptorial (graspingtype)	1. Such legs are adapted for catching the prey and are found in praying mantis 2. The femur is modified in to thickly spined structure and grooved along the lower side. 3. The tibia is also spinous and fits to the groove along the femur. 4. The prey is thus secured between the grooves and is killedby the spinous femur and tibia. 5. The tarsus is long and five segmented.
[x] Climbing (sticking type)	1. Pretarsus is highly modified and represented by a pair of claws and a pair of pad like structure known as pulvilli, which are found at the base of claws. 2. These are densely clothed with numerous hollow and tubular hairs, which secrete a sticky substance on it. 3. Besides, a bristle like structure known as empodium is also present in between the pulvilli. 4. Example is housefly.
[xi] (Gripping type)	5. The tibia is slender and directed towards femur from its inner side. 6. The tarsus is one segmented and arched 7. During copulation, this adaptation helps the male to hold the female easily. 8. The example is Chleradryinus vitellics a parasite of 9. sugarcane pyrilla
[xii] Suctorial (Sucking type)	1. In this type of leg the first tarsal segment contains two vacuum cups. 2. This helps in the male in holding the female during copulation. 3. This is found in male *Dysticus* beetle.

Wing venation, types of wings and wing coupling apparatus

The wings develop as flattened, sac like expansions of meso and metanotum. The upper and lower parts of each sac they partly fuse, leaving only blood filled channels into which tracheae and nerves grow, in the mature wing these channels become rigid, sclerotized hollow struts for support of the membranous parts. They are known as veins where the upper and lower wing membranes have fused, are known as cells. The typical wing having the hypothetical wing venation based on Comstock and Needham has the following veins

Longitudinal veins

C- costa
Sc- sub costaR-radius
M-media Cu- cubitusA-anal
J-jugum
Rs-radial sector MA-media anterior MP-media posterior
CuA- cubitus anteriorCuP-cubitus posterior



Longitudinal vein

Hypothetical venation*

Folds (a) Anal fold- Between Cup & 1A or 1A & 2A

(b) Jugal fold- Posterior wing base.

Areas (a) Remigium-Anterior to anal fold

(b) Anal-Between anal and Jugal fold

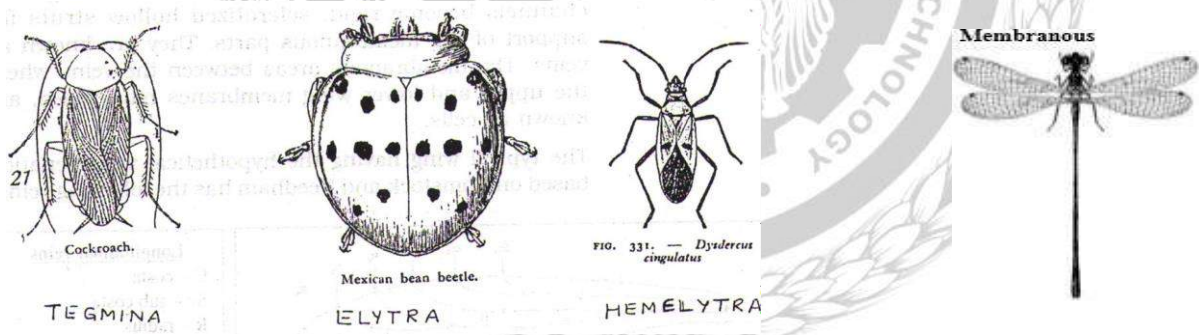
(c) Jugum-Small lobe between jugal fold and thorax.

Cross veins

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

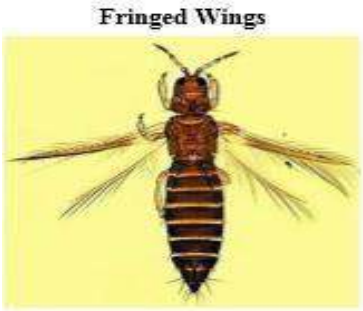
1. Humeral cross vein (h) - It extends from costa to sub-costa near the humeral angle and vein.
2. Radio-medial cross vein (r-m) - It joins the sub radius and the medius veins.
3. Medial cross vein (m) -The vein joining the m2 and m3 branches of medius is termed as medial cross vein.
4. Medio-cubital cross vein (m-cu) - It joins the medius and the cubitus longitudinal veins. (v) Radial cross vein (r) -It extends from R1 to R2

Types of Wings



1. **Tegmina:** This condition is found in the forewings of order Orthoptera, Dictyoptera and Phasmida Tegmina is hardened and leathery in consistency.
2. **Elytra:** These are found in Order Coleoptera and Dermaptera in the forewings. They are more hardened and sclerotised to form horny sheath which protects the membranous hind wing.
3. **Hemelytra:** This condition can be seen in Order Hemiptera in which the forewing are thickened at their bases like elytra while the remaining part of the wing is soft and membranous. This is the reason that they are called hemelytra. (half thick and half membranous).
4. **Halters:** Insects belonging to Order Diptera and male coccids have modified hind wing, which is in the form of knob or thread. This is used as a balancing organ known as halters or balancers**.**

5. **Scaly wings:** Scaly wings-thin and membranous front and hind wings covered over surface with flattened unicellular setae (scales). The scales make the wings colorful and used for taxonomic studies. They are useful for flight. Examples: Butterflies, moths and skippers (order Lepidoptera), caddisflies (order: Trichoptera).
6. **Fringed Wings:** Fringed wings-slender front and hind wings with long fringes of marginal hairs, giving a

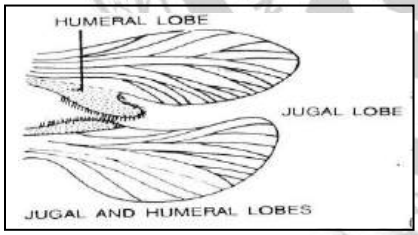


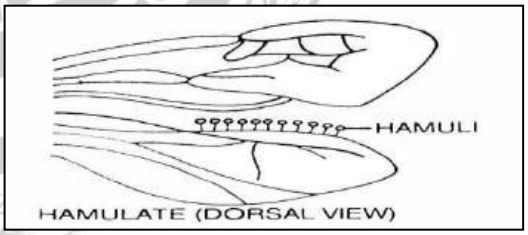
feather like appearance. The wings are highly reduced with reduced venation. They are useful for flight. Example: Thrips (Thysanoptera).
7. **Clefted Wings (Fissured Wings):** Front wing is longitudinally divided forming a fork-like structure. The hind wing is divided twice, forming two forks with three arms. All forks possess small marginal hairs. They are useful for flight. Example: Both wings of Plume Moth.

Wing coupling apparatus

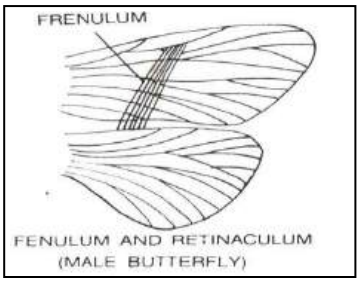
In certain insects special structures have been developed to fasten together the two wings of each side so that it may bring more synchronous action of the fore and hind wings, thereby enabling the insects to fly more swiftly. This action in many insects is ensured simply by fore wing overlapping the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

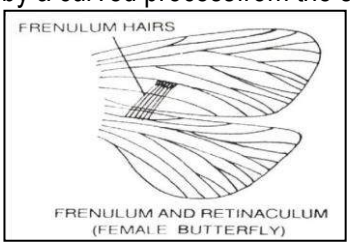
a. **Jugal and humeral lobe-** This coupling device is commonly found in Lepidoptera, Trichoptera and Mecoptera wherein the wing bases are highly modified. The posterior end of the fore wing is modified into slender finger like organ which is stiffened by a branch of IIIrd anal vein is
Known as the jugal lobe; whereas the anterior margin of the hind wings is modified in to a small humeral lobe. The lobes of fore and the hind wings are coupled with each other during flight.





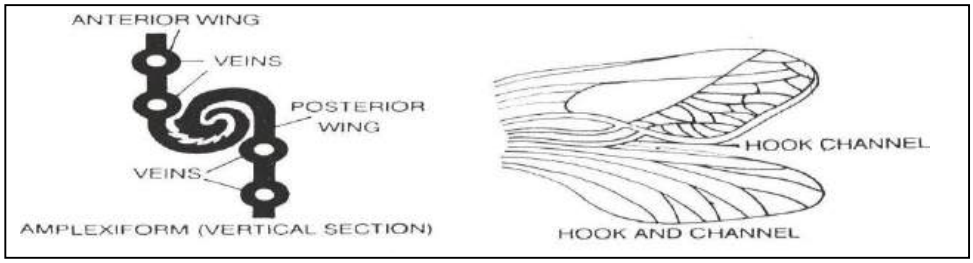
b. **Frenulum and Retinaculum -** This type of coupling apparatus is well illustrated in higher Lepidoptera wherein the jugum is lost and the frenulum assumes more importance. In female butterflies a number of stout bristle arise beneath the extended fore wing known as frenulum which engages in retinaculum from a patch of hair near the cubitus of a hind wing. However, in males the frenulum bristles are fused into a single stout structure and is held by a curved processfrom the sub-costal vein of the fore-wing.





c. **Hamuli -** In this modification the costal margin of the hind wings bears a row of small hooks known as hamuli. These hooks get attached into a fold on the inner margin of the fore-wings. Such coupling apparatus is generally met in Hymenoptera.

d. **Amplexiform -** This example is commonly met in the insects belonging to family Papilionidae and Bombycidae of order Lepidoptera. In this case the wings are coupled simply by overlappingbasally to each other.



The types of larvae and pupae in insects

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

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

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

Hemimetabolous: (Incomplete metamorphosis) e.g. Dragonfly, damselfly and may fly.

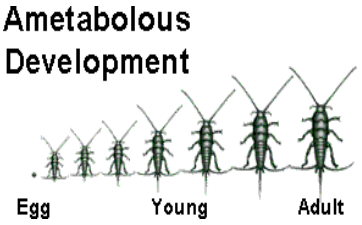
These insects also have 3 stages in their life namely egg, young ones and adults. The young ones are aquatic and are called **naiads**. They are different from adults in habits and habitat. They breathe by means of tracheal gills. In dragonfly naiad, the lower lip (labium) is called **mask** which is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

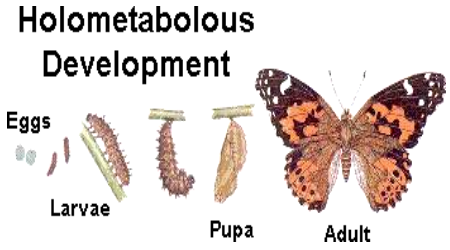
Paurometabola: (Gradual metamorphosis) e.g. Cockroach, grasshopper, bugs.

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

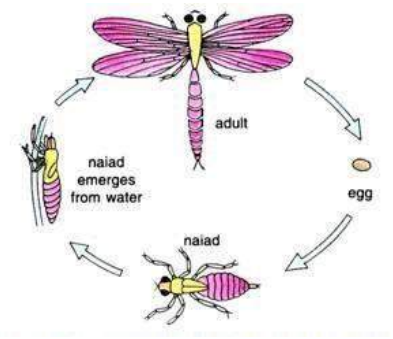
Holometabola: (Complete metamorphosis) e.g. Butterflies, moths, fly and bees.

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

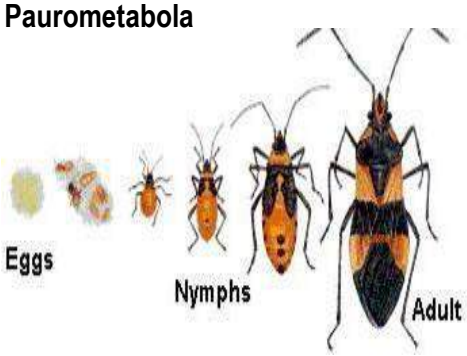




Hemimetabolou



Paurometabola



Immature stages in insects

Larva: Larval stage is the active growing and immature stage between the egg and pupal stage of aninsect having complete metamorphosis. This stage differs radically from the adults.

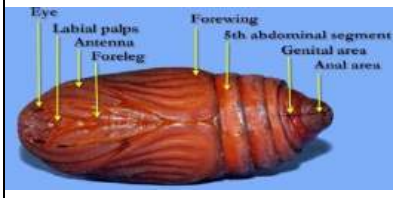
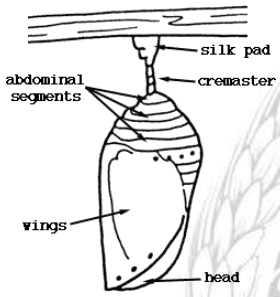
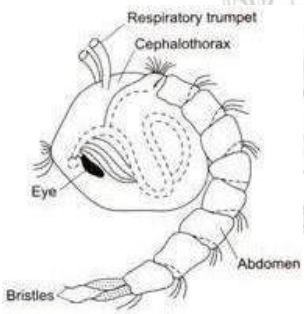
Types of larvae:

Type of larva	Photo	Modification
I. Oligopod: Thoracic legs are well developed. Abdominal legs are absent.		
i. Campodeiform  		They are similar with diplurans genus Campodea. Body is elongate, depressed dorsoventrally and well sclerotized. Head is prognathous. Thoracic legs are long. A pair of abdominal or caudal processes is usually present. Larvae are generally predators and are very active. E.g. grub of ant lion or grub of lady bird beetle.
ii. Scarabaeiform 		Body is "C" shaped, stout and sub-cylindrical. Head is well developed. Thoracic legs are short. Caudal processes are absent. Larva is sluggish, burrowing into wood or soil. e.g. grub of rhinoceros beetle. Body is "C" shaped, stout
		and sub-cylindrical. Head is well developed. Thoracic legs are short. Caudal processes are absent. Larva is sluggish, burrowing into wood or soil. e.g. grub of rhinoceros beetle.
Polypod or Eruciform: The body consists of an elongate trunk with large sclerotized head capsule. Head bears powerful mandibles which tear up vegetation. Two groups of single lensed eyes Stemmata found on either side of the head constitute the visual organs. The antenna is short. 3 pairs of thoracic legs and up to 5 pairs of unsegmented abdominal legs or prolegs or pseudo legs are present. E.g. caterpillar		

i. Hairy caterpillar 	The body hairs may be dense, sparse or arranged in tufts. Hairs may cause irritation, when touched. e.g. red hairy caterpillar.
ii. Slug caterpillar 	Larva is thick, short, stout and fleshy. Larval head is small and retractile.
iii. Semilooper 	either 3 or 4 pairs of prolegs are present. e.g castor semilooper.
iv. Looper 	They are also called measuring worm or inch worm. In this type, only 2pairs of prolegs are presentin 6th and 10th abdominalsegments. e.g. Dhaincha looper.
III. Apodous: They are larvae without appendages for locomotion. Based on the degree of development and sclerotization of head capsule.	
i. Eucephalous 	Larva with well-developed head capsule with functional mandibles, maxillae, stemmata and antennae.Mandibles act transversely. e.g. Wriggler (larva of mosquito) and grub of red palm weevil.
ii. Hemicephalous 	Head capsule is reduced and can be withdrawn into thorax. Mandibles actvertically. e.g larva of house fly and robber fly.
iii. Acephalous 	Head capsule is absent. Mouth parts consists of a pair of protrusible curvedmouth hooks and associated internal sclerites. They are also called vermiform larvae.e.g. Maggot (larva of house fly)

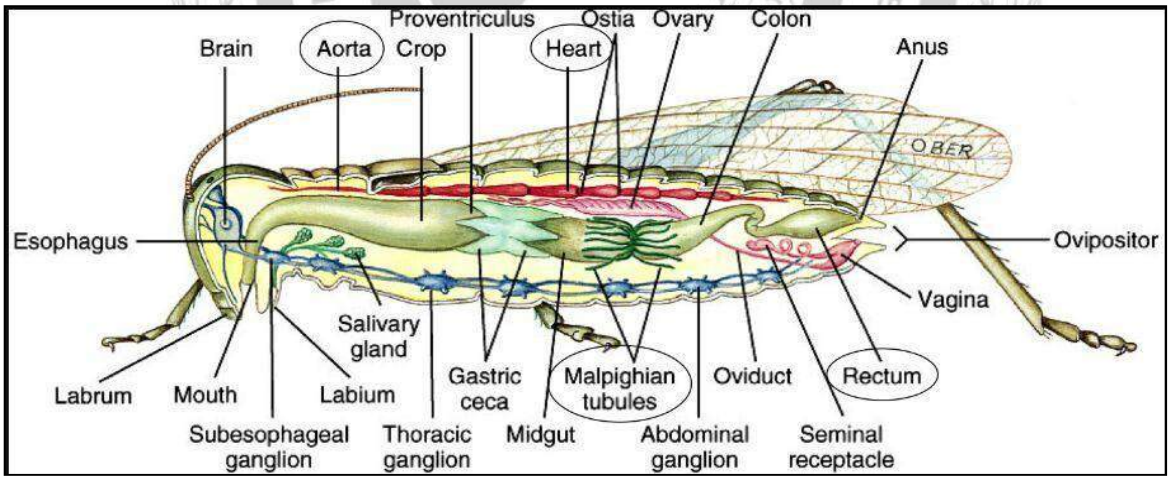
Types of pupae

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

Type of pupae	Photo	Modification
Obtect 		Various appendages of pupa *viz*. Antennae, legs andwing pads are glued to the body by a secretion produced during the last larval moult.Exposed surfaces of the appendages are more heavily sclerotized than the inner surface. e.g. mothpupa.
Chrysalis 		It is naked obtect type of butterfly. It is angular and attractive coloured. The pupa is attached to the substratum by **hooks** present at the terminal end of the abdomen called **Cremaste**r. The body of chrysalis is attached to the substratum by 2 strong silken threads called **gridle**.
Tumbler 		Pupa of mosquito is calledtumbler. It is an obtect type pupa. It is comma shaped withrudimentaryappendages. Breathing trumpets are present in the cephalic end and analpaddles 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**
Exarate 		Various appendages viz. antennae, legs and wing padsare not glued to the body. They are free. All oligopod larvae will turn into exarate pupae. The pupa is soft and pale. e.g. pupa of rhinoceros beetle.
Coarctate 		the last larval skin is changed into a pupal case and the pupa is actually an exarate pupa. The pupal case is dark brown, barrel shaped, smooth with no apparent appendages and called as**puparium**. e.g. fly pupa

The structure and position of alimentary canal/digestive systemwithin the insect body

[i] Fore gut or stomodaeum consists of following parts:	
{a} Pre-oral food cavity-	It is enclosed by mouth parts
{b} Pharynx-	It is situated in between the pre-oral cavity and Oesophagous.
{c} Oesophagous-	It is a simple straight tube and joins the crop.
{d} Crop-	It is a simple bag like structure which stores food materials.
[ii] Mid gut or Mesenteron:	It is an elongated tube with uniform diameter, which extends from hepatic caecae or cardiac valve to malphighian tubules or pyloric valve.
[iii] Hind gut or Proctodaeum-	It extends from the posterior end of midgut to the anus. The hindgut is externally marked by the insertion of malphighian tubules and internally by the pyloric valve. Hind gut may be divided into three distinct parts.
{a} Ileum or small intestine-	It is small tube which has many folds in the inner wall
{b} Colon or large intestine-	It is situated at 5th and 6th segment of the abdomen and is a slender tube in the form of "S".
{c} Rectum-	Both the ends of rectum are slender and the middle portion is thick and large. The rectum opens in to the anus, which is found on the caudal end of abdomen.

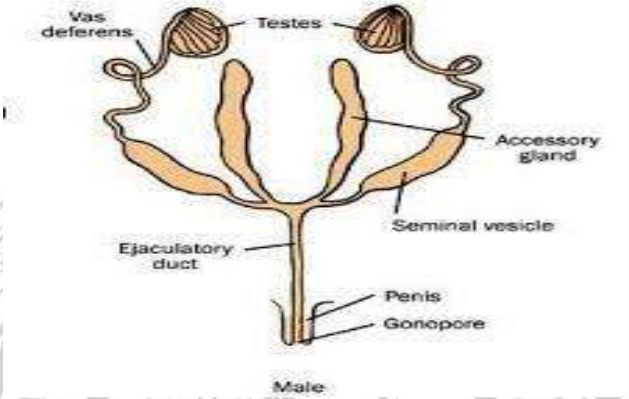


The parts of male and female reproductive system of Grasshopper

Male Reproductive Organs: It consists of the following parts:-

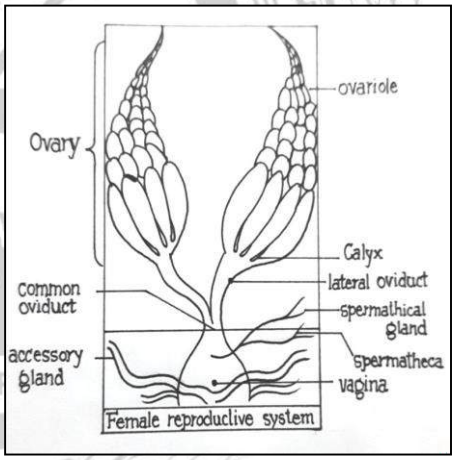
1. **A pair of testis:** These are located above the midgut and held in position by the bounding fat bodies and trachea. Each testes is a more or less ovoid body, completely divided into a variable number of follicles or lobes, which are cylindrical in shape. Each follicle is connected with vas deference with a well-developed cylindrical tube, vas-deference.
2. **A pair of vasa-vesicle:** These are the paired canals, leading from the testes.

3. **Seminal vesicle:** The vas-deference vary greatly in length and each vas difference becomes enlarged along its course to form a sac known as seminal vesicle in which spermatic fluid is collected.
4. **Ejaculatory duct:** The vasa-deferentia unite to form a short common canal which is continuous in median ectodermal tube known as ejaculatory duct.
5. **Aedeagus or Penis:** This is the terminal end of ejaculatory duct enclosed in a finger like evagination of the ventral body wall, which or the male intermittent organ known as aedeagus. It is situated in the 9th abdominal sternum of the grasshopper.
6. **Accessory gland:** 1-3 pairs of thread like accessory glands are present which open in to the seminal vesicle. Male reproductive organs of grasshopper



Female Reproductive Organs: It consists of the following parts:

1. **Ovary:** These are paired compact bodies lying in body cavity of abdomen on either side of the alimentary canal. Each ovary is 2 cm long composed of variable number of ovarioles.
2. **Oviduct**: The lateral oviduct are paired canals leading to the ovaries. These lateral oviduct form common oviduct, which opens into vagina. Each oviduct is an elongated pouch, which stores eggs. The vagina is greatly enlarged to form a chamber known as uterus for the reception of developing eggs.



3. **Spermathecae**: This is a pouch or sac for the reception and storage of spermatozoa (seminal fluid). It is also known as recepticulum seminis. It generally open by a duct into the dorsal wall of the vagina, which is known as sperm duct.
4. **Accessory glands**: These are paired structures opening into the distal portion of vagina. These glands provide material for the formation of egg pod or ootheca.
5. **Genital chamber**: The vagina opens into genital chamber on 9th Sternum and thus this chamber is called bursa copularis, which helps in the copulation.

The characters of orders: Orthoptera, Dictyoptera, Odonata, Neuroptera, Isoptera and Thysanoptera and their families of agricultural importance

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

Phylum-ArthropodaClass- Insecta
Order- Orthoptera
Sub order- CaeliferaFamily-
Acrididae Genus-*Schistocerca*
Species- *Gregaria*

Characters:

- Winged or brachypterous or apterous.
- Mouth parts are biting and chewing type (mandibulate type)
- Hind legs are enlarged and modified for jumping.
- Two pairs wings, sometimes absent or vestigial, fore wing straight, thickened called tegmina,hind pair of wing membranous.
- Gradual metamorphosis, the nymphs resemble the adults in all essential feature and habits.
- A pair of unsegmented short cerci are present.
- Antennae are shorter than their body length with less than thirty segments.
- The Tympanal organs are located at the sides of 1st abdominal segment.

Long horned Grasshopper:

Phylum-Arthropoda
Class- Insecta Order-
Orthoptera Sub order-
Ensifera
Family- Tettigoniidae
Genus- *Attractomorpha*
Species- *Crenulata*

Characters:

- Antenna longer that's why known as long horned grasshopper.
- Left Tegmen of wing overlap the right one.
- In males the cubito anal regions of the tegmina modified asymmetrically for stridulation.
- Fore tibia with tympanal organs.
- Wing less forms live near the ground.
- The eggs are not enclosed in pods.

Termite:

Phylum-ArthropodaClass- Insecta Order- Isoptera Family- Termitidae
Genus-*Odentotermis*Species- *Obesus*

Characters:

- Metamorphosis simple.

Order Isoptera (Iso=equal, pteron=wing)Termites or white ants.

- Mouthparts of the typical biting and chewing type.
- The wing are equal in size, long, narrow, membranous, some what opaque.
- Workers and soldiers of both the sexed are wingless and sterile forms.
- Members are mostly subterranean and form a termitarium.
- Wings only slightly recticulate, wings membrane and margin more or less hairy.
- Pronotum of workers and soldiers narrow.
- The queen attains enormous proportions, the increase affecting only in the abdomen and notthe head and thorax, this obesity in known as physogastory. rder-Dictyoptera (Dictyon = network; ptera=wings)

Synonyms	: Oothecaria, Blattiformia
Common names **Characters**	: Cockroaches and preying mantids
Wings	: Forewings thickened, leathery with a marginal costal vein called tegmina, Hindwings membranous and folded fanlike
Tarsi	: 5 segmented
Cerci	: Short and many segmented
Eggs	: Contained in Ootheca
Metamorphosis	: Gradual/paurometabola
Sub-orders	: Blattaria (Cockroach) and Mantodea (Preying mantids)

Important Families of Dictyoptera

Characters	**Blattidae**	**Mantidae**
Head	Not mobile in all directions	Mobile in all directions
Pronotum	Shield like and cover the head	Elongated, do not cover head
Ocelli	Degenerated- 2 called as fenestra	Three
Body	Flattened, dark colored	Elongated sometimes cylindrical
Legs	Cursorial running type	Forelegs are raptorial, middle and hind legs are Ambulatorial
Gizzard	Powerfully armed with chitinous teeth	No Chitinous teeth
Mating behaviour	Do not devour male during mating	Often (but not always)
Ootheca	Chitinous	Not chitinous
Nymphal character	Not cannibalistic	Cannibalistic
Mimicry	Absent	Mimic leaves and flowers
Habitat	Omnivorous	Mostly outdoors
Economic importance	Household pest	Predators on crop pest
Examples	American Cockroach	Preying mantids

Order- Odonata
(Odon = tooth; strong mandibles)

Common names : Dragonflies and damselflies

Characters

Antenna	Very short, bristle like, setaceous
Body	Long, cylindrical, medium to large sized, attractively coloured
Head	Globular and constricted behind into a petiolate neck
Eyes	Compound eyes are large. Ocelli- Three
Mouthparts	Adapted for biting, Mandibles are strongly toothed Lacinia and galea arefused to form mala which is also toothed
Wings	Membranous, venation is network with many cross veins. Wings have a dark pterostigma towards the costal apex. Sub costa ends in nodus. Wing flexing mechanism is absent.
Legs	Basket type arrangement, 3 segmented tarsi, They are suited for grasping, holding and conveying the prey to the mouth.

Abdomen	Abdomen is long and slender, In male gonopore is present on 9thabdominal segment. But the functional copulatory organ is present on the 2nd abdominal sternite. Before mating sperms are transferred to the functional penis. Female have gonopore on 8th segment.
Metamorphosis	Incomplete with three life stages. The Nymphs (called naiad) is aquatic. Labium is greatly elongated, jointed and bears two hooks at apex. It is called mask. It is useful to capture the prey.
Sub-orders	Anisoptera (Dragonfly) and Zygoptera (damselfly)
Importance	Adults are aerial predators. They are able to catch, hold and devour the prey in flight. Naiads are aquatic predators. Dragonflies and damselflies can be collected with an aerial net near streams and ponds especially on a sunny day. Naiads can be collected from shallow fresh water ponds and rice fields.

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

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

Body	Soft bodied insects
Antenna	Filiform, with or without a terminal club
Mouthparts	Chewing type in adults
Wings	Wings are equal, membranous with many cross veins, held in a roof like manner over the abdomen, weak fliers
Larva	Campodeiform with mandibulo-suctorial mouthparts
Pupa	Exarate, Pupation takes place in a silken cocoon, Six out of eightMalpighian tubules are modified as silk glands. They spin the cocoons through anal spinnerets.
Suborders	Megaloptera and Planipennia Planipennia : Families 1. Chrysopidae: Body pale green in colour, eyes are golden yellow in colour, Pedicellate/stalked eggs to avoid cannibalism and predation, larvae prey on soft bodied insects especially on aphids, exhibits camouflage with debris, biocontrol agents, mass multiplied easily for pest control in field. (e.g. Green lacewings, Goldeneyes, Stinkflies, Aphid lions)
	2. Mantispidae: Resemble preying mantids, larvae predaceous (e.g. Mantispidflies). 3. Myrmeleontidae: Resemble damselfly (Ant lions) 4. Ascalaphidae: resemble dragonfly (Owlflies)

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

Synonyms : Physopoda
Common names : Thrips
Characters

Body	Minute, slender, soft bodied insects

Mouthparts	Rasping and sucking type, Mouth cone is formed by the labrum and labium together with basal segments of maxilla. There are three stylets derived from 2 maxillae and left mandibles. Right mandible is absent. Hence mouth parts are asymmetrical.
Antenna	Moniliform
Eyes	Compound eyes well developed, ocelli present in alate form
Wings	Either present or absent, when present very narrow and fringed with hairswhich increase the surface area, weak fliers and passive flight in wind is common
Legs	Ambulatorial, Tarsus is with one or two segments, At the apex of each tarsus a protrusible vesicle is present.
Abdomen	11 segmented, pointed. An appendicular ovipositor may be present or absent
Cerci	absent
Metamorphosis	Paurometabola/gradual, Nymphal stage is followed by prepupal and pupal stages which are analogous to the pupae of endopterygote insects.
Sub-orders	Terebrantia (Important family is Thripidae) and tubulifera (ovipositor absent, tubular abdomen, Wing venation is absent)

The characters of order: Hemiptera their families of agricultural importance

Red cotton bug:

Phylum-Arthropoda

Class-Insecta

Order- Hemiptera

Sub order-Heteroptera

Family-Pyrrhocoridae

Genus-*Dysdercus*

Species-*cingulatus*

Order Hemiptera (Hemi=half, Petron=wing)This order is divided in to two suborders.

Suborders 1-Heteroptera (Heter=different, Petron=wing)

Characters:

- gradual.

The fore wing thickened

- Metamorphosis
- and leathery basally and membranous apically known as hemelytra.
- Metamorphosis incomplete.
- Body usually broad and flattened dorsoventrally.
- Antennae are small and four segmented.
- Insect are generally polyphagous and gregarious in habit.
- Ocelli is absent.
- A plate usually triangular in out lobe called Scutellum, located between the base of thewings.
- The abdomen has no cerci.

Rice Gundhi bug:

Phylum-Arthropoda

Class-Insecta

Order-Hemiptera

Sub order- Heteroptera

Family- Coreidae
Genus-*Leptocorisa*
Species- *varicorni*

Characters:

- Insect is medium sized and feeds on Rice.
- Mouthparts piercing and sucking type.
- Both antennae and rostrum are four segmented.
- Ocelli are present.
- The membrane of the hemelytra has many veins which arise from a transverse basal vein.
- The scutellum is small.
- Tarsi is three segmented having pulvilli.

Painted bug:

Phylum- Arthropoda
Class- Insecta
Order- Hemiptera
Sub order- Heteroptera
Family- Pentatomidae
Genus- *Bagrada*
Species- *cruciferarum.*

Characters:

- Moderate sized insect, often brightly coloured.
- Pest of cruciferous plants.
- Scutellum is very large, triangular and reach about one-half or more distance from posteriormargin of pronotum to the end of folded wings.
- The antennae are usually five segmented.
- The base of antennae is concealed by the lateral margins of the head.
- The rostrum is four segmented.
- The tarsi are two or three segmented and with pulvilli.
- The ocelli are present.

Sub order 2- Homoptera (Homo=similar, pteron=wing)

Paddy leaf hopper:

Phylum- Arthropoda
Class- Insecta
Order- Hemiptera
Sub order- Heteroptera
Family- Cicadellidae (Jassidae)Genus- *Nephotettix.*
Species- *apicales*

Characters:

- Two pair of wings usually similar in texture ad each wing is practically same thicknessthroughout.
- Excretion of honeydew is common.
- Metamorphosis usually gradual.
- These are small and elongate.
- Antennae are eight segmented and posses sensorial.
- Ocelli are present.
- Mouthparts piercing and sucking type.
- Tarsi are three segmented.
- Insects are slender usually tapering posteriorly.

Sugarcane pyrilla:

Phylum- Arthropoda
Class- Insecta
Order- Hemiptera
Sub order- Homoptera
Family- Lophopidae (Fulgoridae)Genus- *Pyrilla*
Species- *perpusilla*

Characters:

- Anal area of hind wings is reticulated.

- Ocelli are present.
- Antenna is three segmented and inserted beneath the eyes.
- Tarsi are three segmented.
- The rostrum is elongated.

Sugarcane whitefly:

Phylum- Arthropoda
Class- Insecta
Order- Hemiptera
Sub order- Homoptera
Family- Aleurodidae
Genus- *Aleurolobus*
Species- *barodensis*

Characters:

- These are small white insects.
- Two pair of wings are present with a powdery, waxy white material.
- A characteristic organ of this family is the vasiform orifice, which opens on the dorsal surface of the last abdominal segment. The opening is covered with an operculum under which there is a tongue like organ known as lingua.
- At the base of the lingua opens the anus.
- The venation is much reduced.
- Insects excrete honeydew on which a sooty mould develops and gives a black appearance to the leaves.
- The metamorphosis is complete which an exceptional feature

Mustard aphid:

Phylum- Arthropoda

Class- Insecta
Order- Hemiptera
Sub order- Homoptera
Family- Aphididae
Genus- *Hydaphis (Lipaphis)*
Species- *erysimi*

Characters:

- Both winged and wingless forms occur.
- Ocelli are present.
- Antennae are three to six segmented.
- Tarsi are two segmented along with a pair of claws.
- Sexual females reproduce by laying eggs and parthenogenetic females are viviparous.

Mango mealy bug:

Phylum- Arthropoda
Class- Insecta
Order- Hemiptera
Sub order- Homoptera
Family- Coccidae
Genus- *Drosochia*
Species- *stebbingi*

Characters:

- Insects are very small, inconspicuous soft and covered with wax.
- Legs may be present or wanting.
- Antennae may be wanting or much reduced, if present.
- Rostrum is small and double segmented.

- Males may be alate or apterous.
- Males are harmless and without mouth parts.
- Females are wingless and elongate-oval with smooth integument.

The characters of order: Lepidoptera their families of agricultural importance

Order: Lepidoptera (Lepido=scales, pteron=wing)

Moths, butterflies and skippers

This order is divided into two suborders

Suborder1 Heterocera-

Moths Characters: (i) Mostly nocturnal in habit.

(ii) Antennae are of varied from, filiform, pectinate Bipectinate etc.

(iii) The wings usually lie horizontally or roof like at the sides of abdomen.

(iv) pupae very often protected by cocoon.

Grain and flour moth, Potato tuber moth, Pink boll worm:

Phylum- Arthropoda
Class- Insecta
Order- Hemiptera
Sub order- Heterocera
Family- Gelechidae
Genus- *Sitotroga*
Species- *Cerealella*

Characters:

- It includes small moths which are mostly coloured.
- Fore wings are trapezoidal and narrower than hind wings.
- The hind tibia posses hard hairs.
- Maxillary palp are either absent or very small.

Pyralid moth- Cotton leaf roller, Jowar stem borer, Sugarcane top borer, Rice stem borer:

Phylum- Arthropoda

Class- Insect a
Order- Lepid optera
Sub order- Heterocera
Family- Pyralidiadae (Pyraustidae)Genus- *Sylepta*
Species- *derogata*

Characters:

- These are insects varying greatly in size and shape.
- Maxillary palpi are always present.
- Legs are long and slender.
- Most of the species possess abdominal tympanal organ.
- Forewings are narrow and the hind wings are broad.
- The caterpillars bore into various parts of the plant.

Hairy caterpillars- Bihar hairy caterpillar, Red hairy caterpillar, Castor hairy caterpillar, Sunhemp hairy caterpillar:

Phylu m- Arthro poda
Class- Insect a
Order- Lepid optera
Sub order- Heteroc era
Family- Arctiidae
Genus- *Spilosoma* (*Diacrisia*)
Species- *obliqua*

Characters:

- Mostly typical insects with stout body and broad brightly coloured wings with spots or bandson them.
- The larvae are densely clothed with long hairs and feed on herbaceous plants.
- Insects are generally nocturnal.
- Polyphagous in nature. Pest of many agricultural crops.

Spotted boll worm:

Phylum- Arthropoda
Class- Insecta
Order- Lepidoptera
Sub order- Heterocera
Family- Cymbidae (Arctiidae)Genus- *Earias*
Species- *vitella, insulana, crumataria*

Characters:

- The larvae are densely clothed with long hairs and feed on herbaceous plants.
- Insects are generally nocturnal.

Noctuid moths-Gram cutworm, Gram pod borer, Tobacco caterpillar, Cabbage semilooper, Army worm, Fruit sucking moth:

Phylum- Arthropoda
Class- Insecta
Order- Lepidoptera
Sub order- Heterocera
Family- Noctuidae
Genus- *Agrotis*
Species- *ipsilon*

Characters:

- The body is large in relation to the size of wings.
- Maxillary palpi are minute.
- Forewings are narrow and elongated.
- The tympanal organ is present in the metathorax.

- The caterpillars are usually leaf feeders or stem borer and provided with prologs.
- These are polyphagous, mainly feed on gram.

Silkmoth-Mulberry silk worm:

Phylum- Arthropoda
Class- Insecta
Order- Lepidoptera
Sub order- Heterocera
Family- Bombycidae
Genus- *Bombyx*
Species- *mori*

Characters:

- Antennae are pectinate in both sexes.
- Maxillary palpi and tympanal organs are absent.
- Frenulum is vestigial or atrophied.
- Proboscies is rarely developed.
- Larvae are glabrous, elongated and form dense silken cocoons before pupation.
- Mainly cultured for silk production.

***Attacus* species:**

Phylum- Arthropoda
Class- Insecta
Order- Lepidoptera
Sub order- Heterocera
Family- Saturniidae
Genus-

Attacus
Species-
ricini

Characters:

- Antennae are prominently bi-pectinate in both sexes.
- Labial palpi minute and no frenulum present.
- Very large tropical moth.
- A transparent eye spot near center of each wing.
- Larva specialized in having stout and smooth body possessing scoli.
- *Antherea assamensis* is a multivoltine semi domesticated species. It yields Munga silk.

Hawk moth:

Phylum-
Arthropoda
Class-
Insecta
Order-
Lepidoptera
Sub order-
Heterocera
Family-
Sphingidae
Genus-
Acherontia
Species-
styx

Characters:

- The adults having elongate fore wing with very oblique outer margin. The antennae arethickened in the middle and pointed at the apex and hooked.
- Proboscis is very long.
- Frenulum and retinaculum are present.
- The apex of abdomens is provided with an expansible, truncated tuft of hairs.
- The adults enter bee hives and rob honey.

Suborder- 2: Rhopalocera-butterflies and skippers

Characters:

- Diurnal in habit.
- Antennae club shaped or Clavate.
- Wings remain vertical above the body.
- Pupae are called chrysalis.

Lemon butterfly:

Phylum-
Arthro

poda
Class-
Insect
a
Order-
Lepid
optera
Sub order-
Rhopaloc
eraFamily-
Papilionid
ae Genus-
Papelio
Species- *demoleus*

Characters:

- Large and conspicuously coloured insects.
- The wings are generally iridescent black with shades of green, red, blue or yellow.
- On the prothorax of larvae an organ known as osmeteria is found.
- Setae are usually absent on the body.
- The pupa possess two lateral cephalic projections.
- Pest of citrus plants.

Cabbage butterfly:

Phylu
m-
Arthro
poda
Class-
Insect
a
Order-
Lepid
optera
Sub order-
Rhopaloc
eraFamily-
Pieridae
Genus- *Pieris*
Species- *brassicae*

Characters:

- Medium, sized white butterflies.
- Claws of pretarsus are bifid or toothed.
- Larvae are elongate with the segments divided into annulets.
- The crochets are bi or tri-ordinal arranged.
- Pupae are suspended in an upright position attached by a central band of silk at the caudalend.
- Pest of cruciferous.

Rice skippers:

Phylu
m-
Arthro

poda
Class-
Insect
a
Order-
Lepid
optera
Sub order-
Rhopaloc
eraFamily-
Hesperiid
ae Genus-
Parnara
Species-
mathias

Characters:

- The antennal apices are prolonged beyond clubs to form a recurred point.
- Larvae are moderately stout and taper towards both extremities.
- The name skippers is derived from their erratic darting flight.
- They are pest of paddy.

The characters of order: Coleoptera and their families of agricultural importance

Order-Coleoptera (Coleos=Sheath, pteron=wing) beetles and Weevils

This order is divided in to following two suborders

Suborder 1-
Adephaga

Characters:-

1. Beetles mostly predatory in habit, they feed on other insects.
2. Antennae generally Filiform.
3. Notopleural suture is present.
4. The 1st visible abdominal sternum is divided by the hind coxae and the posterior margin ofthis sternum does not extend completely across the abdomen.

Following are the important families.

Family:

1. **Cicindellidae**:-Example- Tiger beetle, *Cicindella sexepunctata*.
2. **Carabidae**:- Example-Carabid beetle, *Anthia sexguttata; Chlaenius bioculatus; Calosomaindica*.

Suborder 2-
Polyphaga

Character:

1. The 1st visible abdominal sternum is not divided by the hind coxae and the posterior marginof this sternum extends completely across the abdomen.
2. Hind trochanter are small.
3. Notopleural suture is absent.

Khapra beetle:

Phylu
m-
Arthro
poda

Class- Insecta
Order- Coleoptera
Sub order- Polyphaga
Family- Dermestidae
Genus- *Trogoderma*
Species- *granarium*

Character:

- It includes small to moderate size oval or hemispherical beetles.
- Insects are often clothed with fine scales or hairs.
- The wing completely covers the abdomen.
- Antennae are small, 11 segmented and clavate type.
- Compound eyes are well developed.
- Tarsi are five segmented.
- The larvae are hairy grubs.

Weevils or snout beetles-Rice weevil:

Phylum- Arthropoda
Class- Insecta
Order- Coleoptera
Sub order- Polyphaga
Family- Curculionidae
Genus- *Sitophilus*
Species- *oryzae*

Character:

- The adult insects are minute or large and dull brown, gray, black, sometimes green in

color.

- The head is more or less prolonged into a snout.
- The snout varies considerably in size, shape and length and bears the mouth parts at the tip.
- The mouth parts are chewing type.
- The antennae are clavate type and arise about the mid length of the snout.
- The body of few insects are clothed with scales.
- The body, elytra and legs are very hard.
- The larvae are apodous with dark head white bodies and generally stored grain feeders.

Pulse beetle:

Phylum- Arthropoda
Class- Insecta
Order- Coleoptera
Sub order- Polyphaga
Family- Bruchidae
Genus- *Callosobruchus*
Species- *chinensis*

Character:

- The insects are small, short and stout bodied, covered by setae or scale.
- Insects are usually dull grayish or brownish in colour.
- The head is prolonged into a short quadrate beak.
- The antennae are of clavate, serrate or pectinate type.
- Tarsi are five segmented ending in claws.
- The femora is often swollen and dentate.
- The wing covers are short, leaving the tip of the abdomen exposed.
- The larvae exclusively feed on seeds of legume and undergo hypermetamorphosis.

Red pumpkin beetle:

Phylum- Arthropoda
Class- Insecta
Order- Coleoptera

Sub order- Polyphaga Family- Chrysomelidae Genus- *Raphidopalpa* Species- *foveicollis*

Character:

- The insect are small, oval, convex and brightly coloured.
- The antennae are eleven segmented filiform and widely separated at the base.
- Eyes are prominent and the head is usually prognathous.
- The prothorax is laterally margined.
- Tarsi are four segmented.
- Pest of cucurbitaceous plants.

Lady bird beetle

Phylum- Arthropoda Class- Insecta Order- Coleoptera Sub order- Polyphaga Family- Chrysomelidae Sub family- coccinellinaeGenus- *Coccinella* Species- *Septempunctata*

Epilachna beetle

Phylum- Arthropoda Class- Insecta

Order-
Coleo
ptera
Sub order-
Polyphaga
Family-
Chrysomelid
ae Sub
family-
Epilachnina
eGenus-
Epilachna
Species- *vigintioctopunctata*

Character:

- The adult insects are small or medium size, oval or round convex, often brightly colouredand variously spotted.
- The head is partly concealed by pronotum.
- Antennae are small, eleven segmented and clavate type.
- Tarsi are four segmented.
- Few insects are predacious on aphids and other are phytophagous.
- Ladybird beetle is predaceous on aphids.
- Epilachna beetle is polyphagous in nature.

White grub beetle

Phylu
m-
Arthro
poda
Class-
Insect
a
Order-
Coleo
ptera
Sub order- Polyphaga
Family- Melolonthidae
(Scarabaeidae)Genus-
Holotrichia
Species- *consanguinea*

Character:

- Adult insects are medium sized, oval or round convex, brown coloured, feed on tree leaves.
- Grubs feed on plant root.
- Antennae lamellate.
- Pest of groundnut, maize, Jowar, Sorghum.

The characters of order: Hymenoptera their families ofagricultural importance

Order Hymenoptera (Hymen= membranous, pteron= wing)Bees, wasps, Sawflies and parasitic wasps

This order is divided into two suborder

Sub order 1. Symphyta:
SawfliesCharacter:

- These insects are characterized by the abdomen being broadly joined to the thorax with nomarked construction between the 1st and 2nd abdominal segments.
- Ovipositor adopted for sawing or boring but never a sting.
- Larvae (grub) are caterpillar like which possess well- developed thoracic and abdominal legs.
- Prologs without crochets.

Mustard Sawfly:

Phylum- Arthropoda
Class- Insecta
Order- Hymenoptera Sub order- Symphyta
Family- Tenthredunidae
Genus- *Athalia*
Species- *proxima*

Character:

- Medium sized brightly coloured insect.
- The ovipositor toothed in various ways and saw like.
- Abdominal feet are without crochets.
- Tarsi are five segmented.
- Pest of cruciferous.

Suborder- Apocrita (Bees, wasp, parasitic wasp etc.)

1. These insects are characterized by a deep constriction between the propodeum (1st abdominalsegment) and 2nd abdominal segment called petiole or waist.
2. The larvae are apodous (legless) or grub like with head and mouthparts reduced.
3. They possess a well-developed ovipositor with sting.

Honey bee:

Phylum- Arthropoda
Class- Insecta
Order- Hymenoptera
Sub

order-
Apocrit
a
Family-
Apidae
Genus-
Apis
Species- *florae, dorsata, indica, mellifera*

Character:

- These are social insects.
- There are three sun- marginal cells in the forewing.
- The scopa is found on the hind legs and rarely on the gastral sternites also.
- Each corner of the pronotum is round lobe like.
- The hairs of the body are branched.
- The hind basitarsus are widened and provided with fairly long hairs.
- Three castes are found in a colony of bees viz. queen, workers and drone.
- Reared for bee culture or Apiculture.

Formicidae (Ants)

Phylu
m-
Arthro
poda
Class-
Insect
a
Order-
Hymen
optera
Sub
order-
Apocrit
a
Family-
Formici
dae
Genus-
*Monom
orium*
Species
-
indicum

Characters

- They are common widespread insects. Antennae are geniculate. Mandibles are well developed.
- Wings are present only in sexually mature forms. Petiole may have 1 or 2 spines.
- They are social insects with 3 castes viz. Queen, males and workers. Workers are the sterilefemales and they form the bulk of the colony.
- Exchange of food materials between adults and immature insects is common. After a matingflight queen alone finds a suitable nesting site.
- Many species have associated symbiotic relationship with homopteran insects.

Braconidae (Braconid wasp)

Phylum- Arthropoda
Class- Insecta
Order- Hymenoptera
Sub order- Apocrita
Family- Braconidae
Genus- *Bracon*
Species- *hebetor*

Characters

- They are small, stout bodied insects. Fore wing has one recurrent vein.
- Petiole is neither curved nor expanded at the apex. Gaster is sessile or subsessile.
- Abdomen is as long as head and thorax together. They parasitize lepidopteran larvae commonly.
- They are gregarious parasites. In many species, Polyembryony is observed.
- *Bracon brevicornis* is mass multiplied and released for the control of black headed coconut caterpillar

The characters of order: Diptera their families of agricultural importance

Order: Diptera (Di=two, pteron=wing)True flies, house flies, mosquitoes *etc*.

This order has been divided into three suborders:

Suborder 1 Nematocera: Mosquitoes and Gall midge

Characters:

1. Antennae of imago (adult) usually longer than the head and thorax, many segmented,majority alike, not forming an arista or style.
2. Larvae (maggots) are eucephalous type, which have well developed head and horizontallybiting mandibles.
3. Discal cell generally absent.
4. Maxillary palpi 4-5 segmented.

Family 1 Culicidae: mosquitoes Example: *Anopheles* spp. , *Culex fattigans* **Family 2 Cecidomyiidae: Gall midge** Example: *Rice gall*

*midge (Orseolia oryzae)***Mango gall midge** *Dasyneura mangiferae*, linseed gall midge, *Dasyneura lini.*

Suborder 2. Brachycera- Horseflies, Robber flies *etc*.

Characters:

1. Antennae of imago are shorter than head and thorax, generally three segmented with the lastelongate, arista present terminal.
2. Larvae are hemi cephalous type which possess an incomplete usually retractile head and ventrally biting mandibles.
3. Discal cell almost always present.
4. Maxillary palpi one or two segmented.
5. Pupa is free.

Family 1. Tabanidae: Horseflies, *Tabanus maculicornis.*
Family 2. Asilidae: Robber flies, *Philonicus albiceps*
Family 3. Bombyliidae: Bee flies, *Bombylius major*

Suborder 3. Cyclorrhapha: Fruit flies, Syrphid flies, Vinegar flies

Characters:

1. Antennae three segmented with a dorsal bristle like arista.
2. Maxillary palpi one segmented.
3. The larvae are acephalous type, which head is reduced and the mandibles are replaced intomouth hooks, which are working in a vertical plane.
4. Pupa are enclosed in a puparium

Fruit fly:

Phylum-Arthropoda
Class- Insecta Order- Diptera
Sub order- Cyclorrhapha
Family- Tephritidae (Trypetidae)
Genus- *Bactrocera (Dacus)*
Species- *cucurbitae*

Characters:

- Small size insects usually with spots or bands on wings.
- In the wing venation the sub costa bends apically forward at almost a right angle and thenfades out.
- The females have a projecting ovipositor.
- The eggs are long white and laid under the skin of the fruit.
- The maggots are polyphagous and blunt behind bearing conspicuous spiracles and taperingto the head end.
- Pest of cucurbitaceous fruits.

Syrphid fly:

Phylum-Arthropoda
Class- Insecta Order- Diptera
Sub order- Cyclorrhapha
Family- Syrphidae
Genus- *Syrphus*
Species- *baltitus*

Characters:

- Moderate size flies resembling bees or wasps.
- A spurious vein between the radius and the media of the wing in most cases is acharacteristics feature.
- The head is big and antennae are three segmented.
- Predaceous on aphids, jassid and scale insects.

Pea leaf miner:

Phylum-Arthropoda Class-Insecta Order-Diptera Sub order-Cyclorrhapha Family-Agromyzidae Genus-*Phytomyza* Species-*atricornis*

Arhar pod fly:

Phylum-Arthropoda Class- Insecta Order-Diptera Sub order- Cyclorrhapha Family- Agromyzidae Genus- *Melanagromyza* Species- *obtusa*

Characters:

- Small sized flies.
- The maggot mines into the leaf or bore in the pod.
- The leaf miner maggot makes tunnels and pupates inside it.
- These are minor or major pests of legumes.

Insecticides and their formulations

Insecticide formulations

After an insecticide is manufactured in a relatively pure form (technical grade), it must be formulated before it can be applied. Formulation is the processing of the technical grade by various methods which is done to make the product safer, more effective and more convenient to use. Formulation is the final physical condition in which the insecticide is sold commercially. In a formulation, there are one or more chemicals (formulants) which are the active ingredients (a.i.) and other ingredients which have no pesticide action (inert ingredients). There are mainly three types of pesticide formulations (liquid, solid and gas).

A single pesticide may be sold in more than one formulation. Formulation type depends on several factors:

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

Characteristics of an Appropriate Insecticides Formulation

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

TYPE OF FORMULATIONS

Emulsifiable Concentrates (EC)

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

Dusts (D)

Simplest of all formulations and the easiest to apply.

- The technical material (active ingredient) is mixed with an inert diluents carrier such as clay, organic flour, pulverized minerals.
- In a formulated dust, the following two types of mixtures are usually found : **Undiluted toxic agent**, e.g., sulfur dust used for control of mites and powdery mildew and **Toxic** a.i. plus an inert diluent. This is the most common dust formulation sold as 2%,5%, or 10% a.i dust.
- Concentration of dust formulation ranged between 0.1% to 25%
- Particle size of dust particles 1-40 µ pass through 325 mesh sieve.
- Least effective and cause wind drift leading to poor deposit on surface. It has been calculatedthat not more than 10-15% of the applied material is retained on the surface.
- Highly toxic to beneficial insects.
- Example: Carbaryl 5 D, Malathion 5D

Granules (G)

- The chemical is in the form of small granules of inert material, either as a coating on the surface of the inert granules, or as an impregnated toxicant in the granules.
- Consist of small pellets of the active ingredients sprayed on to clay and allowing solvents to evaporate
- Size: 0.25 – 0.38 mm (20-80 mesh or 30-60 mesh i.e (i.e., the number of grits (granules) per inch of the sieve through which they have to pass). The amount of active ingredient varies from 2-10 per cent.
- Used mainly as systemic insecticides and can be applied on to the soil, or may be

placed in the whorl of leaves depending on the nature of pest control required.

- Granular insecticides may be more economic since precise applications are possible with them.
- Much safer to apply than dusts and are generally less harmful to beneficial insects such as bees.
- Example: Carbofuran 3G, Phorate 10G, Cartap 4G.

Wettable Powders (WP)

- Concentrated dusts containing a inert diluents (50-75% talc or clay) and a wetting agent tofacilitate mixing the powder with water before spraying.
- Much more concentrated than dusts, containing 15 to 95 per cent active ingredient.
- Do not dissolve washers and rubber hoses; do not damage materials sensitive to organicsolvents
- Leave effective residues in cracks and crevices and are not phytotoxic.
- Require frequent agitation and cause corrosion of valves, nozzles and pumps and sprayers should never be used without dilution
- These are easy to carry, store, measure, and mix. However, care must be taken to protectagainst inhalation during handling.
- Example: Carbaryl 50WP, Sulfur 80WP, Bacillus thuringiensis var. kurstaki 5WP.

Soluble Powders (SP or WSP)

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

Water Dispersible Granules (WDG)

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

Suspension Concentrates (SC)

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

- Farmers generally prefer suspension concentrates to wettable powders because they are non-dusty and easy to measure and pour into the spray tank.
- Example: Fipronil 5 SC, Sulphur 52 SC.

Microencapsulation/Capsule Suspensions (CS)

The polymer membrane, or microencapsulation technique, has become popular in recent years.

- These are particles of pesticide, either solid or liquid encapsulated by polymeric coatings. Microcapsule solids are suspended in water as a concentrate and diluted product (1:100 to 1:1000) is applied in spray solution to soil or foliar canopy.
- The rate of release of the active ingredient can be controlled by adjusting the microcapsule/droplet size, the thickness of the polymer membrane and the degree of cross- linking or porosity of the polymer.
- Example: Lambda Cyhalothrin 10 CS, Lambda Cyhalothrin 25 CS etc

O/W Emulsions (EW)

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

Flowable Suspension (FS)

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

Micro emulsions (ME)

- Micro emulsions are thermodynamically stable transparent dispersions of two immiscible liquids and are stable over a wide temperature range.
- Involves the incorporation of the insecticide in a permeable covering, microcapsules or smallspheres with diameter ranging from 1-50 µ.
- The total concentration of surfactants for a micro emulsion can be as high as 10–30% or more, compared with about 5% for a typical o/w emulsion.
- The insecticides escape through the small sphere wall at a slow rate over an extended period of time.
- Micro emulsions have relatively low active ingredient concentrations, but the high surfactantcontent and solubilisation of the active ingredient may give rise to enhanced biological activity.
- Example: Neemazal 30 MEC, Pyrithiobac Na 5.4 + Quizalofop-P-Ethyl 10.6 ME.

Oil Dispersion Formulations

- One of the latest formulation types is oil dispersions (ODs). This technology allows veryefficient and environmentally friendly agrochemical formulations.
- In ODs the solid active ingredient is dispersed in the oil phase, making it especially

suitablefor water-sensitive or non-soluble active ingredients.

- The oil-phase can comprise different oils such as mineral oils, vegetable oils or esters of vegetable oils.
- Special attention is needed with the auxiliaries in ODs: suitable oil-compatible dispersing agents and emulsifiers adjusted to the type of oil which forms a stable emulsion after dilutionwith water.

ZW Formulation of CS & EW

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

Flowable Powder (FP)

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

Oil solutions

- Formulated by dissolving the insecticides in an organic solvents for direct use in insect control
- Rarely used on crops as they cause severe burning of foliage.
- Effective on livestock, as weeds sprays along roadsides, in standing pools for mosquito'slarvae control, and in fogging machines for adult mosquito control.

Aerosols

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

Ultra low volume concentrates (ULV)

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

Fumigants

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

Fogging concentrates

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

Smoke generators

They are used in the form of coil like strips containing pyrethrum, oxidant and wood dust for thecontrol of mosquitoes. When ignited, these coils release vapors.

Impregnating materials

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

Poison bait

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

LABEL INFORMATION

- Every pesticide container has a label affixed on it with a leaflet. The label gives information ofthe pesticide in the container. The leaflet contains information on directions to use warnings, disposal and storage. Both the label and leaflet are statutorily required under the Insecticide Act, 1968. The following information must be furnished on the label.
- Name of the pesticide (Brand name, Trade name, Common name), Name of the manufacturer and address, Registration number, Kind and name of active ingredient and their percentage, Types of formulation, Net content by weight, Batch number(assigned by manufacturer), Date of manufacture, Expiry date, Antidote statement
- Warming symbols and signal (warming symbol is of diamond shaped consisting of two triangles with a colour in the lower triangle and a signal in the upper triangle)

Pesticide appliances and their maintenance

Plant Protection Equipments

SPRAYERS

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

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

A variety of high volume sprayers are available in the market. Almost all types of high-volume sprayers have some kind of pump to supply pressurized spray liquid to the hydraulic nozzle which breaks theliquid into spray droplets and throws the spray away from it. The high volume sprayers are both manually operated or power operated type.

Principle: The function of sprayer is to atomize the spary fluid in to small droplets and eject it withsome force.

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

Nozzle body: It is the main component on which other component of a nozzle fit. Swirl plate: It isthe part of a cone nozzle which imparts rotation to the liquid passing through it.

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

Spray boom: It is a spray lance with spray nozzles fitted to a head, mounted at right angles to the lance.

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

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

Pressure regulator: It is an automatic device to control the pressure of fluid or gas within a rangeof settings

Cut-off valve: It is a mechanism between the pump and the nozzle to control the flow of liquid fromthe sprayer. This is operated by hand.

Nozzle disc: It is component containing the final orifice of a nozzle usually Acone nozzle.

Nozzle boss: It is a lug on spray boom or spray lance to which a nozzle body or cap is screwed.

Nozzle tip: It is component containing the final orifice of a nozzle usually a fan nozzle. Spray lance:A hand-held pipe through which the liquid reaches the nozzle mounted at the free end.

TYPES OF NOZZLE: The three common types of nozzle

- **Hollow cone nozzle:** This liquid is fed into a whirl chamber through a tangential entry or through a fixed spiral passage to give a rotating motion. The liquid comes out in the form of a harrow conical sheet which then breaks up into small drops. This is used for insecticide and fungicide spraying.
- **Solid cone nozzle:** This nozzle covers the entire area at small range. The construction is similar to hollow cone nozzle with the addition of an internal jet which strikes the rotating liquid justwithin the orifice of discharge. The breaking of drop is mainly due to impact. This is used for herbicide spraying.
- **Fan nozzle:** It is a nozzle which forms narrow elliptical spray pattern. In this type the liquid is forced to come out as a flat fan shaped sheet which is then broken into droplets. This nozzleis mostly used for low pressure spraying.

TYPES OF SPRAYERS:

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

a. Hand syringe

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

b. Hand Sprayers

This is a simple sprayer. It creates hydraulic pressure by forcing spray solution to 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. The capacity of this sprayer is about 0.5 acre per day. It is useful for small scale spraying in nursery or kitchen gardens and pot plants.

c. Bucket or Stirrup Pump Sprayer:

It consist either of a double acting pump with two cylinders or a single acting pump with one cylinder. The other parts of the sprayer are the plunger assembly, foot value assembly, hose,

lance and nozzle, a stirrup and an adjustable foot rest. 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, trigger cut-off device and lance nozzle sprays pesticide. This sprayer is used both for public health spraying and agricultural spraying purposes. This type of sprayer is useful for spraying small trees. Area covered per day is 0.5 to 0.8 ha.

d. Knapsack Sprayer

The sprayer is mounded on the back of operator with help of a pair of mounting straps. The pump of the sprayer is actuated by working a hand lever 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. A bean shaped plastic tank of 14-16 liters capacity is commonly used. It is necessary to operate the hand lever continuously at the rate of 15-20strokes per minute. The normal working pressure is 40 psi. It is user for spraying field crops vegetables and nurseries. The area covered per day is 0.8 to 1 ha.

e. Rocker Sprayer

It is very much similar to the foot 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 onground and the spray solution is kept in a separate tank or container. It can develop high-pressure 10 kg/cm2. For spraying tall trees, an extension bamboo lance can be fitted. The adjustable type hydraulic nozzle (Triple Action Nozzle) is normally used. It can be used for spraying trees and tall field crops. It covers about 1.5 to 2 hectares of area in a day.

f. Foot Sprayer or Pedal Pump:

The pump of the sprayer is worked by operating a pedal lever by the foot of the operator. 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/cm2 can be achieved which is necessary to project the jet of spray to tall trees simultaneously from two spray nozzles. The foot operated sprayer is basically for orchard and tree spraying. The design is strong and sturdy. An adjustable type hydraulic nozzle
(Triple 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 pesticide solution tank is also kept on ground separately and so movement of the long delivery hose becomes very difficult. About 1 to 1.5 ha area can be sprayed in a day.

B. Manually Operated air compression Sprayers

These are also known as pneumatic sprayers because air pressure is employed for forcing the liquid though the nozzle for atomization. The containers of these sprayers should not be filled completely with the spray fluid. A part of the container is kept empty so that adequate air pressure can be developed over the spray fluid in the tank. They do not have agitators and hence are not useful spraying materials which settle down quickly.

a. Pneumatic Hand Sprayer

The container for the spray fluid also acts as the pressure chamber. An air pump attached to the chamber inside. The inner end of the discharge pipe runs down to the bottom of the container and its outlet terminates in a nozzle is filled about 3/4th of it and the pump is worked

force air into the space to build sufficient pressure upon the spray fluid. These sprayers are used extensively in kitchen gardens, in glasshouses and in doors against household insects. The capacity of tank is up to one liter, if used in field it can cover an area of 0.1 ha in a day.

b. Pneumatic Knapsack Sprayer

This is similar to compression hand sprayer but are used for spraying large quantities of liquids (9- 10 Litres). It comprises a tank for holding the spray as well as compressed air, a vertical air pump with a handle, filling hole with a strainer, spray lance with nozzle and release and shut-off devices.

The tank is provided a convenient rest with the back of the operator and has shoulder straps that allow it to be carried by him. These sprayers are used against agricultural pests and mosquito controloperations. This pump covers an area of about 0.8 to 1.2 ha in a day.

C. Power Sprayer (Mist blowers cum Duster)

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

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

The pesticides are applied as such or with less than 5 litres spray fluid produces fine droplets (80µm).These are light weight sprayers(<3kg) have a rotary atomizer(spinning disc) powered by an enclosed DC motor with a plastic spray head, a liquid reservoir, a handle and a power supply unit. Liquid is gravity fed from polyethene container screwed in to the spray head molding and the liquid is flung off by centrifugal force.

B. Electrodyn Sprayers (EDS)

It is new system of spraying for the controlled droplet application of chemicals (CDA).EDS puts more of active chemical on the target than any other spraying system since the charged particles are attracted to target crop which ensure coverage on the underside of leaves where many pests feed andalso there is minimal drift to non target areas. The EDS consists of a spray stick and an unique combination of bottle plus nozzle the bozzle. The spray stick consists of the batteries and a solid state high voltage generator. The bozzle contains ready formulated chemical for immediate application to crops. The pesticide in ULV formulation is used undiluted at a quantity less than 6

liters/ha and usually at 0.5 to2.0 liters/ha for field crops. The droplet size varies from 20-150 micron with ground spraying equipment for ULV spray an area of 5 ha can be covered in a day.

DUSTERS

The dusting powders are low concentration ready to use type, dry formulations containing 2 to 10% pesticide. The inert material or dry diluents is talc, soapstone, attapulgite, etc., and it is non toxic. The Sulphur dust is not diluted with inert material. 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. All dusters consist essentially of a hopper which usually contains an agitator, an adjustable orifice and delivery tubes. A rotary fan or a bellows provides the conveying air.

A. Manually operated dusters

a. Plunger duster

They are very simple, low cost machines and useful in a limited way. It consists of a dust chamber, acylinder with a piston or plunger, a rod and a handle. 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 pumpoperated by hand. The dust cloud is issued from the discharge outlet. It is useful for small scale usein kitchen garden and in household.

b. Bellows duster

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

c. Rotary duster:

This type of duster makes use of a fan or blower to flow large volume of air at high speed. 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 m3/min at 35 RPM. Such machine can treat 1to 1.5 ha /day.

d. 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 m3 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 is10- 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.

e. KNAPSACK DUSTER

The motorized 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 (2-5kg capacity) 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 motorized knapsack sprayer cum-duster unit is therefore useful for both low volume spraying and dusting operation.

Soil Injector

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

Granule Applicators:

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

i. There is a plastic hopper 1 liter capacity from which the granules flow by gravity to a nozzle.

ii. It is a knapsack type with hopper of 10 liters capacity.

Bird Scarer

It produce loud noise at regular interval and used to scare away the birds. It has three essential chambers, a chamber to hold calcium carbide, a smaller chamber placed inside the former to hold water and combustion chamber attached to the main chamber. Water acts with calcium carbide and generates acetylene which explodes producing the noise. The frequency of flow of water intocalcium carbide chamber. One kg of calcium carbide is sufficient for working a machine for 24 hours. One bird scarer is sufficient to cover 1 to 2 ha.

Rat Traps:

Several types of mechanical devices for trapping rats and mice are used in India. In these traps baits like dry fish are used for attracting these rats. The cage type wooden box with a door closing device and spring board types are the more common ones used in the houses.

Sampling techniques for estimation of insect population and damage

Sampling population estimates of insect pests are the fundamental activity in ecological entomology.Pest monitoring is the pre-requisite for any successful pest management program wherein, no control measure should be undertaken for a pest unless it is known that- the pest is actively present and it is present in sufficient numbers to cause an economic loss.

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

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

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

Sampling Size: In preliminary studies: sample size will be small and 10% of the mean error shall beacceptable. Number of samples depends on degree of precision required and chosen to minimize the variance and cost.

Types of Sampling

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

Stratified random sampling: It involves the division of population in to different strata based on distribution of population.

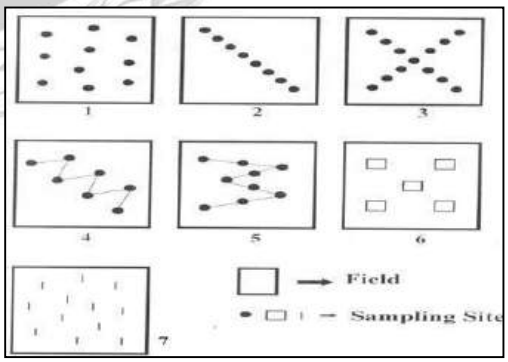
Sequential sampling: It requires continuous sampling until a pre-established upper or lower infestation level is found.

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

Systematic sampling: It involves sampling of population at fixed intervals.

Selection of Sampling Site

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



Important Sampling Methods

Absolute methods: This method is used to estimate density of insects per unit area.Different types of absolute sampling are denoted by n.

Unit of habitat method

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

Helicoverpa spp.brushing, washing etc.

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

Absolute sampling method are desirable because they are accurate, however, these methods are time consuming, often difficult to conduct and are usually expensive compared to relative methods. Relative methods are more economical in terms of time, labor and equipments. Relative methods: This method provides an identification of insect pests abundance or damage relative to other times or location. Different types of relative methods are as follows visual searches, use of various traps, plant damage etc.

Remote sensing: Acquiring information through the satellite about pest damage without coming into physical contact. It can be useful in monitoring of certain pests. A radar can monitor height, speed and direction of insects like locusts, aphids etc.

Components of Remote Sensing

1. Platform

- The vehicle/device on which sensors are mounted
- Carriers or vehicles for the sensors

2. Sensor System

- The device which senses the energy reflected/emitted by the target object

3. Data Products

- Information received from the sensor Packaged as per user requirement
-

OTHER METHODS

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

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

DIRECTIONS FOR WORKING IN LABORATORY

- Practical Manual; **HB** & **B** pencils, pencil eraser and sharpener or blade daily.
- Keep your instruments and practical notebook clean well arranged.
- Instruments should be sharp and according to the requirements.
- Before starting work listen or read carefully the instructions given by your teacher.
- Develop habit of removing your difficulties from your teacher directly. Never ask your neighbours for anything after you have once entered the laboratory.
- Maintain silence in laboratory.
- Clean your seat and wash instruments before you leave the laboratory.
- While doing dissection put every waste in the sink. Don't drop anything on table's top or on floor.

- While studying microscope preparations, never disturb the slide once fixed under microscope by your teacher.
- While studying museum specimens take following cares:
  - First study the characters or peculiarities of that particular animal you wish to draw.
  - See and find out in the specimen before you, all those characters and peculiarities, which you have studied.
  - Draw the view in which maximum structures are visible.
  - Shading should be avoided in your drawing.
  - Compare your drawing from the drawing of this manual for necessary details, corrections and labelling.
  - While drawing, special attention should be concentrated on the length and width proportions of the animal.
  - Label your drawing with the help of book and put classification of the animal.
- Put date on the left-hand corner of the page of notebook and details of the work in the top centre.
- While looking to a slide, never move the *coarse adjustment* too much for just clearing the image. Instead, use fine focus adjustment.
- Use both eyes ultimately with a microscope.
- Never tilt a microscope.S