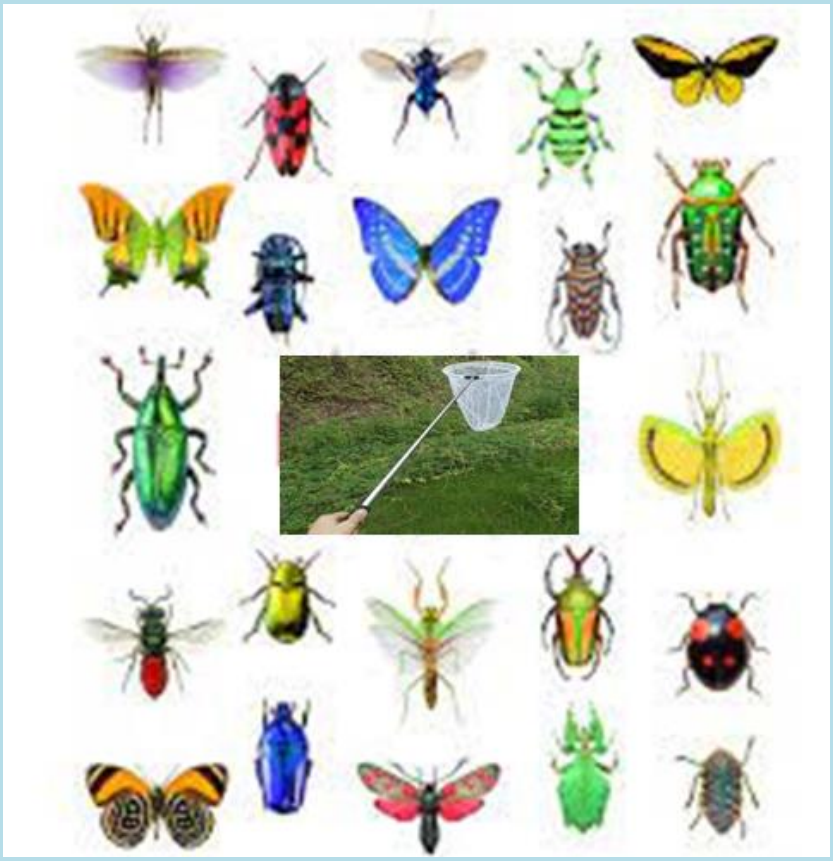
DKSGACA Manual No. 08/2021

Fundamentals of Entomology

A Laboratory Manual



Compiled by
Dr. Yogeeta Thakur

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Eternal University, Baru Sahib,
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2021

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Approved vide item no. 74/19/2021 in the Academic Council Meeting held on 15/06/2021

Dr. Khem Singh Gill Akal College of Agriculture
Eternal University, Baru Sahib,
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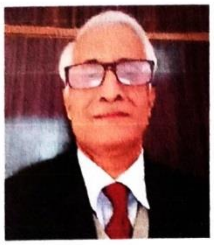
FOREWORD



Dr. S K Sharma

Dean,
Dr. KS Gill Akal College of Agriculture
Eternal University Baru Sahib, Rajgarh, Sirmour (HP)

Entomology is an ancient science, dating back to the establishment of biology as a formal field of study. The insects have different roles in varied ago-ecosystem. The thorough knowledge of insects' habits and habitat are the fundamentals of insect study. To identify the insects and their management depends upon the basic information about them and applied tactics to be used. This manual offers insight into the fundamental knowledge of entomology in the laboratory and as well as in the in the field conditions. This is the guide that gives an overview of the subject from basic information to practically applied field. The pictures illustrate a complete reference on identifying types of insects found in various cropping systems.

Sincere efforts have been made by resource personnel to incorporate detailed account of fundamental as well as applied entomology for guidance of the students, extension officers to educate, motivate and guide the farmers to use the knowledge of fundamentals of entomology to plan pest management strategies. This manual would have useful to students' preparation for various competitive examinations conducted by Indian Council of Agricultural Research State, Agricultural Universities, Union Public Service Commission, other similar competitive examinations. This will also be suitable for those students who take Entomology as a special paper during their Master and Ph.D. Degree Programme. I hope that the information given in this manual will be useful to the students of SAUs and ICAR institutions as well as extension specialists and Scientists for fundamental information.

I appreciate and congratulate Dr. Yogeeta Thakur, Associate Professor, Entomology for her painstaking efforts to compile this manual.

(S K Sharma)
Dean

PREFACE

Entomology is the study of insects and their relationship to humans as well as environment. Entomologists make great contributions to such diverse fields as agriculture, biology, human/ animal health etc. Agricultural entomology is a branch of entomology that deals with arthropods which affect the welfare of men, his crops and domesticated animals, either through their direct attacks, through their ability to transmit causal agents of diseases, or as a result of harmful effects from direct contacts. This manual on the fundamentals of entomology has been written to provide practical knowledge necessary for a beginner and for those who plan to major in entomology; this manual will provide sufficient background in important phases of entomology adequate to cope with the future and more specialized subjects. The objectives of this manual are to introduce the basic techniques of insect collection and preservation, modifications of their appendages, identification features and spraying techniques and formulations of pesticides.

This manual furnishes a detailed account of fundamental as well as applied entomology. The exceptionally clear writing style, minimal scientific jargon, and vivid photos, this manual provides a comprehensive view of the fundamentals of entomology. It cover the collection and preservation of insects, external features of insects, modification of appendages, types of larvae and pupae, anatomy, characters of different orders, insecticides' formulations, pesticide appliances and their maintenance as well as Sampling techniques. This would have useful to Amateur entomologists, interested in insects because of the beauty and diversity of these creatures students and professional entomologists to study the insects serves as the basis for development, their identification, relation to the crops, biological and chemical pest control, food/ fiber production and storage, epidemiology, biological diversity, and other fields of science. Their contribution helps in betterment of humankind by detecting the role of insects in the spread of disease and discovering ways of protecting food and fiber crops from being damaged and the way beneficial insects contribute to the well being of humans, animals, andplants.

Since this manual is an outcome of information compiled from various sources, therefore, I must express my most humble and profound gratitude to all of them. I am grateful to the Department of Entomology, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib for providing the opportunity support.

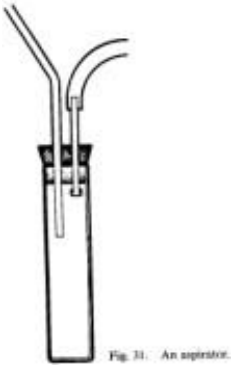
Eternal University
26/05/2021

Yogeeta Thakur

EXPERIMENT-1

AIM: Methods of collection and preservation of insects including immature stages.

1. Collection equipment andmethods:



A. ASPIRATOR

Simple suction apparatus that is used for picking up numbers of insects or for selecting individual specimens out of a large number or off a plant.

B. NETS:

Aerial nets: light nets for capture of insects in flight

Sweep nets: heavy, canvas bag with heavy mounting ring for net. In use, it is moved quickly through foliage, shrubbery and other vegetation to dislodge insects feeding or resting on foliage.

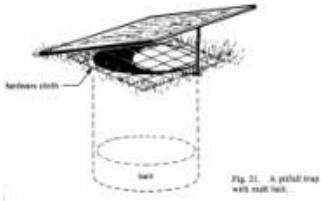
Dip nets: heavy, canvas bag with mesh at tip, for sampling aquatic insects.

C. BEATING

Beating sheets or trays: placed beneath foliage, branch is struck with a stick in a downward motion to dislodge insects in the foliage. Insects can be collected from the sheet with an aspirator.

D. LIGHTS AND LIGHTTRAPS

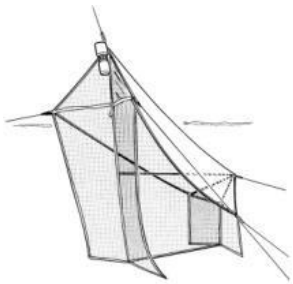
Ultraviolet light traps: light source placed behind a suspended, white sheet and specimens are collected off the sheet. Used to collect nocturnal insects. Night-flying insects can also be collected from incandescent light sources.



E. TRAPS

Pitfall traps: usually consists of a glass jar partially filled with a killing agent (ie. EtOH). Trap is submerged in the ground so that the lip of the jar is flush with the ground. It is useful for collecting ground-dwelling insects.

Pan traps: generally yellow, liquid-filled traps, placed flush to or above the ground surface. Passive trap for ground-active insects, yellow color attracts microhymenoptera.



Malaise traps: flight interception trap for active flying insects. Specimens collected into liquid and must be mounted from 70% EtOH. It is productive trapping method for Diptera andHymenoptera.

Window traps: passive, flight-interception traps. Window can have pan filled with killing agent below or be coated with a sticky substance to capture insects. This is productive trapping method for Coleoptera.

Emergence traps: cages which are placed in habitats to collect insects emerging from the substrate.

F. SEARCHING

Searching within specific habitats: e.g. rotting logs, in lichens, beneath moss, under bark, logs, rocks and on foliage. Use your natural history observations to find microhabitats.

G. REARING

Different techniques used for different species. Many techniques have been developed and are reported in the primary literature. Good for larval-adult associations. The abiotic factors plays important role therefore, should be kept in consideration.

H. EXTRACTION FROMSUBSTRATE

Berlese funnel: uses heat and light to extract small arthropods from litter or organic soils.

Vacuum sampling

Seives: mesh screens or bags

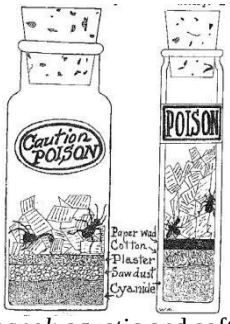
Flotation

I. AQUATICCOLLECTING

Dip nets

Dredging or coring

Surface emergence traps



Ethanol: aquatic and soft bodied insects may be preserved in 70% EtOH.

J. KILLINGAGENTS

Killing jars: used for terrestrial insects. Consist of a glass jar with a thin layer of plaster-of-Paris in the bottom. The plaster layer is saturated with ethyl acetate and the insects placed in the jar are killed by asphyxiation.

2. Equipment and methods for preserving and mountinginsects

A. PINNING

Direct pinning: pin is inserted directly through the body of the specimen. Pins are available in sizes from 000 to 7 but generally the insect is pinned with the thickest one it will take without damage. The specimen should be pinned through the thorax or elytra (see figures) and arranged so the appendages are well displayed for study. Use the first level of the *pinning block* to obtain the correct level of the insect on the pin. Sufficient pin must be left exposed above the specimen to allow safe handling, so large, robust insects may have to be mounted by eye, rather than on the pinningblock.

Pointing: Insects that are too small to be pinned directly may be mounted on a *point*. A point is a triangular piece of stout white paper that you can make with a point punch. A pin is inserted through the broad end of the point and the small end is bent with forceps at a right angle. A very

small amount of glue is placed on this turned-over tip and this is then applied to the right side of the thorax of the insect. A correctly pointed specimen has its body horizontal when the pin is upright, with the long axis of the body at right angles to thepoint.

Gluing: Small Diptera (true flies) are mounted by applying a small amount of glue (clear finger nail polish) about below the top of the pin and then touching it to the right side of the thorax of the insect.

Fig. 94. Specimens on points showing positioning of points and labels and angle of specimen.

B. PRESERVATION INLIQUID

Most larvae and nymphs (immature insects) and some adult insects that are soft-bodied, must be preserved in liquid rather than pinned. It is best to kill the specimen in boiling water prior to preservation as this leaves them plump and limp and deactivates autolytic enzymes. A number of preservatives can be used but a solution of 70% alcohol, which preserves specimens in a supple condition, is one of the best. The specimens are stored in a stoppered vial with the data labels enclosed.

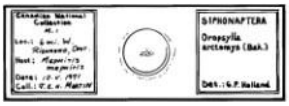


Fig. 100.
A slide mount showing position of specimen and labels.

C. SLIDES

Many techniques have been developed for slide-mounting insects that are too small for pinning. Arrange object on slide so position suitable for study and customary for objects of its nature, that appendages or other structures are spread out and displayed.

Various *mounting media*, some require dehydration and clearing of the specimen before mounting.

D. SPREADING

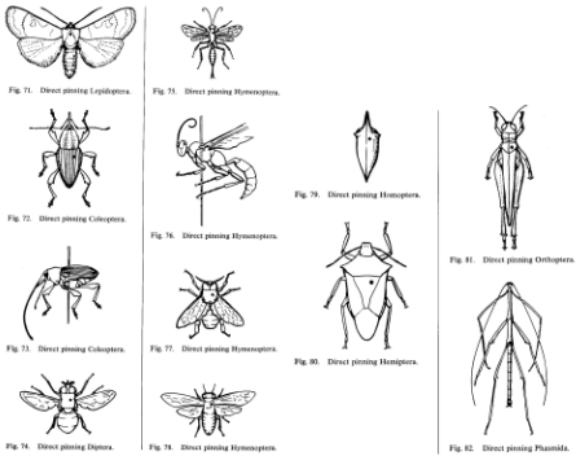
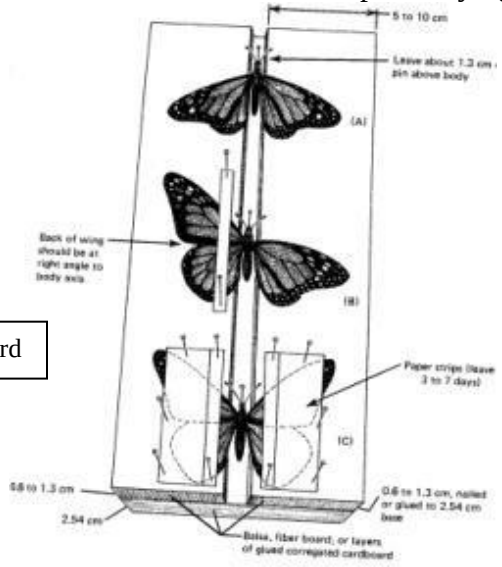


Fig. 71. Direct pinning Lepidoptera.
Fig. 73. Direct pinning Hymenoptera.
Fig. 72. Direct pinning Coleoptera.
Fig. 76. Direct pinning Hymenoptera.
Fig. 79. Direct pinning Homoptera.
Fig. 81. Direct pinning Orthoptera.
Fig. 73. Direct pinning Coleoptera.
Fig. 77. Direct pinning Hymenoptera.
Fig. 80. Direct pinning Hemiptera.
Fig. 74. Direct pinning Diptera.
Fig. 78. Direct pinning Hymenoptera.
Fig. 82. Direct pinning Phasmida.

The wings of many insects show important taxonomic characters and should be mounted in a manner that will allow their examination. If the wings do not spread naturally when pinned, they must be spread manually. Spreading is done using a special board, called a *spreading board*. The spreading board has a central groove for the insect's body and a surface on either side of the groove on which the wings are pinned. Fresh, pliable specimens must be used (older specimens can be *relaxed* and then pinned). The wings are manipulated by inserting the point of a very fine pin behind a main longitudinal vein. In most insects the fore wings are pushed forward until their posteriormarginsareinlinewitheachotherandatrightanglestothebody.Next,thehindwings

are brought forward in the same manner until the anterior margin of each is just underneath the posterior margin of the fore wing. The wings are held in place by pins, or by strips of paper held down by pins. The abdomen and antennae may need to be supported by pins to prevent drooping. Larger specimens should remain on the board for 3 weeks to ensure complete drying.

Spreading board



3. Labelling collected insectspecimens

An unlabeled specimen is incomplete and unacceptable. Labels should not be larger than 6x16 mm. Labels should be written in pencil, or computer-generated. Every specimen must have the following information on the label:

1st line – Specimen number and order

2nd line - Place of collection (country, state and county)

3rd line - Place of collection (nearest post office)

4th line - Date collected

5th line - Name of collector

Use second level of the pinning block to set this label.

Supplementary information to be given on additional labels where applicable and wheneverpossible:

1stThe name of the host plant or animal.

2nd The type of habitat in which the specimen was collected if host information is not available.

3rd Any information noted on the habits of the insect, such as flying at dusk, or feeding at host flower.

An identification (ID) register indicating family or order names should be produced separately and printed/ handed in as a collection notebook (no hand written copies will be accepted). The identification register should list the specimen number followed by the order, family and the ecological category any representative belongs into. All supplemental materials also need to be included.

EXPERIMENT-2

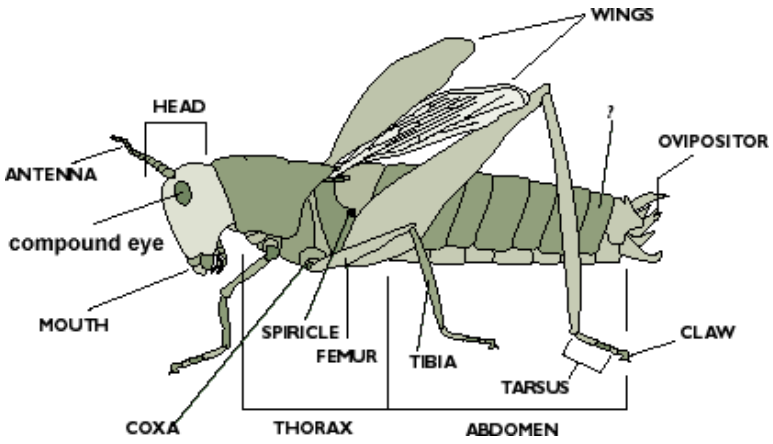
AIM: External features of Grasshopper.

Requirements: Grass hopper, wax slab, pins

Observation:

Grasshopper Anatomy Like all insects, the grasshoppers have three main body parts – the head, the thorax and the abdomen. They have six jointed legs, two pairs of wings and two antennae. Their body is covered with a hard exoskeleton. Most grasshoppers are green, brown, or olive-green.

The biggest Grasshoppers are about 4.5 inches (11.5 centimetres) long. Their legs are long hind legs that are used for hopping and jumping. The short front legs are used to hold prey and to walk.



Hold your mouse cursor over the image to reveal answers.

Abdomen – the segmented tail area of a grasshopper, which contains the heart, reproductive organs, and most of the digestive system.

- Antennae – like all insects, grasshoppers have 2 segmented antennae that sense touch andodours.
- Compound eye – grasshoppers have 2 faceted eyes made up of many hexagonallenses.
- Head – the head is at the front end of the grasshoppers body and is the location of the brain, the two compound eyes, the mouth parts, and the points of attachment of its twoantennae.
- Jumping legs -the long, hindmost pair of the grasshoppers sixlegs.
- Mandibles – the jaws, located near the tip of the head, by the palps; the jaws crush thefood.
- Palps – long, segmented mouth parts (under the jaws) that grasp thefood.
- Spiracles – a series of holes located along both sides of the abdomen; they are used forbreathing.
- Thorax – the middle area of the grasshoppers body – where the legs and wings areattached.
- Walking legs – the four, short front legs that are used for walking and holding prey while theyeat.
- Wings – grasshoppers have two long wings which they use forflying.
- Short-horned grasshoppers have ears in the sides of theabdomen.
- Long-horned grasshoppers and crickets have ears in the knee-joints of their frontlegs.

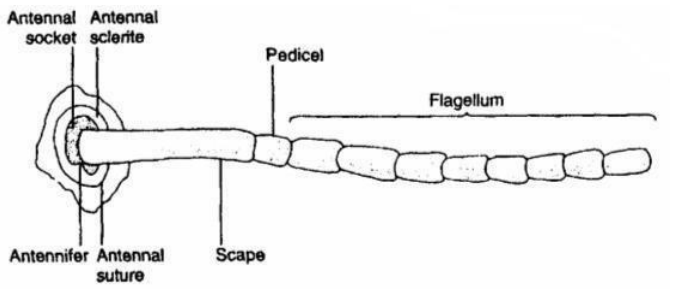
EXPERIMENT-3

AIM: Types of insect antennae, mouthparts and legs.

Requirements: Insects of different orders, slides, glycerine, cover glass, microscope.

Observation:

STRUCTURE OF INSECT ANTENNAE



Antennae function almost exclusively in sensory perception. Some of the information that can be detected by insect antennae includes: **motion and orientation, odour, sound, humidity, and a variety of chemical cues.** Antennae vary greatly among insects, but all follow a basic plan: segments 1 and 2 are termed the scape and pedicel, respectively. The remaining antennal segments (flagellomeres) are jointly called the flagellum.

MODIFICATIONS OF INSECT ANTENNAE

1. ARISTATE

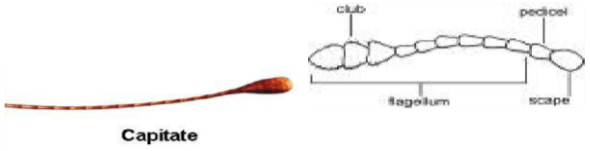
Aristate antennae are pouch-like with a lateral bristle.

Examples: House and shore flies (order Diptera).

The antennae are important sensory structures used to detect air movement and odors.

Among the olfactory receptors are sensilla located in several pits which lie ventrally on the basal one-third of the third segment of the antenna. The antenna is three-segmented with abranched arista projecting dorsally from the third segment. A U-shaped groove around the lateral and dorsal part of the depression housing the pair of antennae is the frontal lunule (the suture through which the ptilinum was everted as the fly emerged from thepuparium).

2. CAPITATE



Capitate antennae are abruptly clubbed attheend.

Examples: Butterflies (orderLepidoptera).

3. CLAVATE

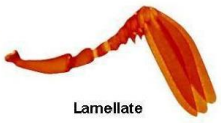
Clavate antennae are gradually clubbed at the end. Examples: Carrion beetles (order Coleoptera). Adult carrion beetles feed on decaying animal matter or maggots.

4. FILIFORM

Filiform antennae have a thread-like shape. Examples: Ground and longhorned beetles (order Coleoptera), cockroaches (order Blattaria).

5. GENICULATE

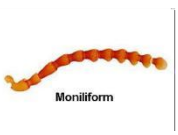
Geniculate antennae are hinged or bent like an elbow. Examples: Bees and ants (order Hymenoptera).



6. LAMELLATE

Lamellate or clubbed antennae end in nested plates.

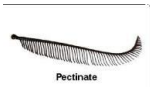
Examples: Scarab beetles (order Coleoptera).



7. MONILIFORM

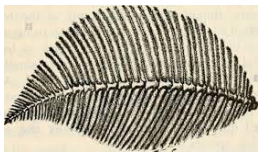
Moniliform have a bead like shape. Examples: Termites (order Isoptera).

8. PECTINATE



Pectinateantennae have a comb-like shape. Examples: Fire-colored beetles and fireflies (order Coleoptera).

9. BIPECTINATE



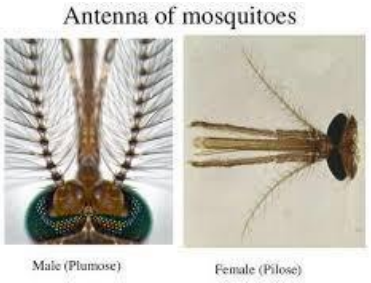
Bipectinateantennae have a double comb-like shape.

Examples: Silkworm (order Lepidoptera).

10. SERRATE

Serrate antennae have a saw-toothed shape. Examples: Click beetles (order Coleoptera).

11. PLUMOSE



Plumose antennae have a feather-like shape. Examples: Moths (order Lepidoptera) and mosquitoes (order Diptera).

12. PILOSE

Piloseantennae are less feather, have hair like structures at the junction of flagellum. Examples: female mosquitoes (order Diptera).

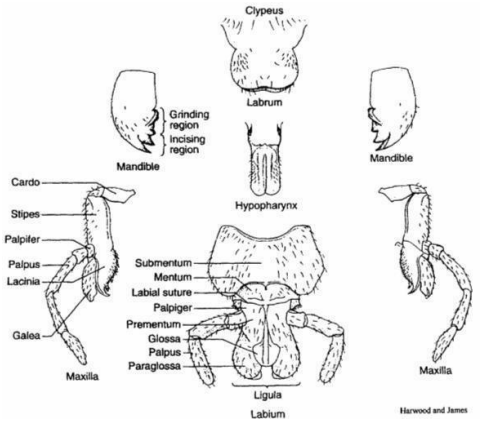
13. SETACEOUS

Setaceous antennae have a bristle-like shape. Examples: Dragonflies and damselflies (orderOdonata).

FLABELLATE

Flabellate antennae have bifurcate appearance of terminal segment and the succeeding segments are seen to be enclosed it. Example: Stylopids.

MOUTH PARTS AND THEIR MODIFICATIONA



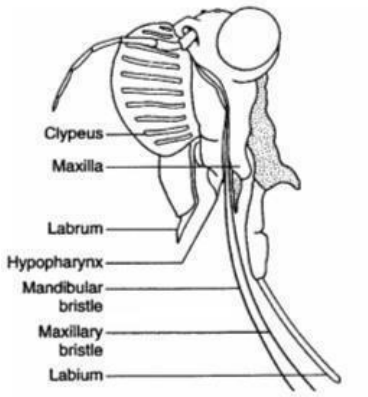
The 4 main mouthparts are the **labrum, mandibles, maxillae (plural maxilla) and labium.** The labrum is a simple fused sclerite, often called the upper lip, and moves longitudinally. It is hinged to the clypeus. The mandibles, or jaws, are highly sclerotized paired structures that move at right angles to the body. They are used for biting, chewing andsevering food. The maxillae are paired structures that can move at right angles to the body and possess segmented palps. The labium (often called the lower lip), is a fused structure that moves longitudinally and possesses a pair of segmented palps.

MANDIBULATE MOUTH PART

Mandibulate (chewing) mouthparts are used for biting and grinding solid foods. Examples: Dragonflies and damselflies (order Odonata), termites (order Isoptera), adult lacewings (order Neuroptera), beetles (order Coleoptera), ants (order Hymenoptera), cockroaches (order Blattaria), grasshoppers, crickets and katydids (order Orthoptera), caterpillars (order Lepidoptera). Adult Lepidoptera have siphoningmouthparts.

HAUSTELLATE MOUTH PARTS

Haustellatemouthparts are primarily used for sucking liquids and can be broken down into two subgroups: those that possess stylets and those that do not. **Stylets**are needle-like projections used to penetrate plant and animal tissue. The modified mandibles, maxilla, and hypopharynx form the stylets and the feeding tube. After piercing solid tissue, insects use the modified mouthparts to suck liquids from the host. Some haustellate mouthparts lack stylets. Unable to pierce tissues, these insects must rely on easily accessible food sources such as nectar at the base of a flower. One example of nonstylate mouthparts are the long siphoning proboscis of butterflies and moths (Lepidoptera). Although the method of liquid transport differs from that of Lepidopteran proboscis, the rasping-sucking rostrum of some flies is also considered to be haustellate without stylets.

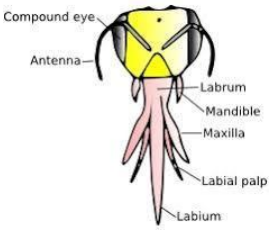


Order Hemiptera

1. **Piercing-suckingmouthparts**

Piercing-sucking mouthparts are used to penetrate solid tissue and then suck up liquid food.

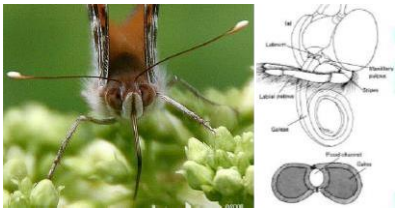
Examples: Cicadas, aphids, and other bugs (order Hemiptera), sucking lice (order Phthiraptera), stable flies and mosquitoes (order Diptera).



2. Lapping mouthparts

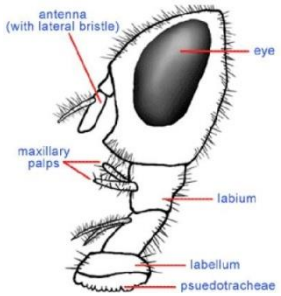
Lapping mouth parts are modified for collecting the nectar and pollen from flowers and also for moulding the wax.

Examples: honeybees, wasps, etc.



3. Siphoningmouthparts

Siphoning mouthparts lack stylets and are used to suck liquids. Examples: Butterflies, moths and skippers (order Lepidoptera), bees (order Hymenoptera). Larval Lepidoptera have chewing mouthparts.



4. Spongingmouthparts

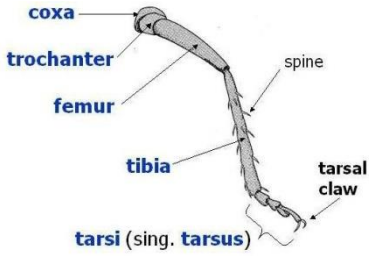
Sponging mouthparts are used to sponge and suck liquids.

Examples: House flies and blow flies (order Diptera).

LEGS AND THEIR MODIFICATION

Legs

The fore-legs are located on the prothorax, the mid-legs on the mesothorax, and the hind legs on the metathorax. Each leg has six major components, listed here from proximal to distal: coxa (plural coxae), trochanter, femur (plural femora), tibia (plural tibiae), tarsus (plural tarsi), pretarsus. The femur and tibia may be modified with spines. The tarsus appears to be divided into one to five "pseudosegments" called tarsomeres. The term pretarsus refers to the terminal segment of the tarsus and any other structures attached to it, including:



- ungues -- a pair ofclaws
- arolium -- a lobe or adhesive pad between theclaws
- empodium -- a large bristle (or lobe) between theclaws
- pulvilli -- a pair of adhesivepads

Like the mouthparts and antennae, insect legs are highly modified for different functions, depending on the environment and lifestyle of an insect.

Leg Modifications

1. Ambulatorylegs

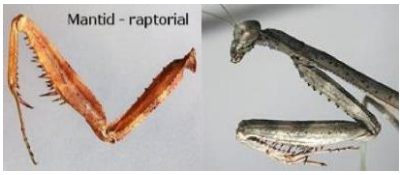
Ambulatory legs are used for walking. The structure is similar to cursorial (running) legs.

Examples: Bugs (order Hemiptera), leaf beetles beetles (Corderoleoptera).

2. Saltatoriallegs

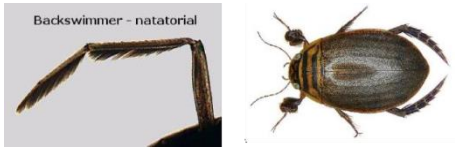
Saltatorial hind legs adapted for jumping. These legs are characterized by an elongated femur and tibia.

Examples: Grasshoppers, crickets and katydids (order Orthoptera).



3. Raptoriallegs

Raptorial fore legs modified for grasping (catching prey). Examples: Mantids (order Mantodea), ambush bugs, giant water bugs and water scorpions (order Hemiptera).



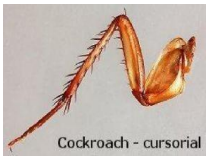
4. Fossoriallegs

Fossorial fore legs are modified for digging. Examples: Ground dwelling insects; mole crickets (order Orthoptera) and cicada nymphs (order Hemiptera).

5. Natatoriallegs

Natorial legs are modified for swimming. These legs have long setae on the tarsi.

Examples: Aquatic beetes (order Coleoptera) and bugs (order Hemiptera).



6. Cursoriallegs

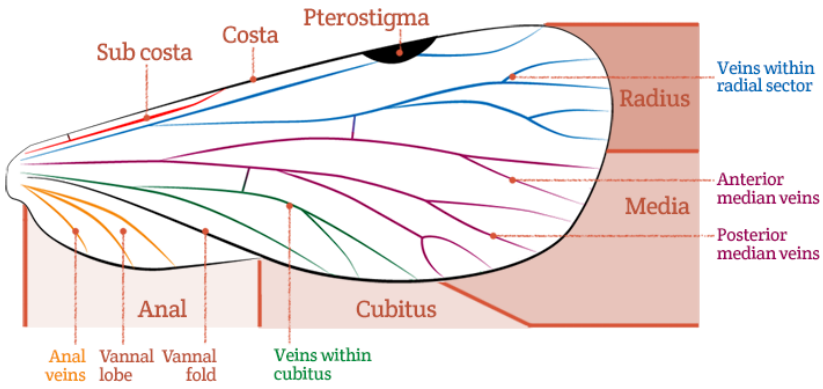
Cursoriallegs are modified for running. Note the long, thin legsegments.

Examples: Cockroaches (order Blattaria), ground and tiger beetles (order Coleoptera).

EXPERIMENT-4

AIM: Wing venation, types of wings and wing coupling apparatus.

Requirements: Insects of different orders, slides, microscope.



Wings venation

Among the invertebrate animals, only insects possess wings. Wings are present only in adult stage. Number of wings varies from two pairs to none. Certain primitive insects like silver fish and spring tail have no wings (apterous). Ecto parasites like head louse, poultry louse and flea are secondarily wingless. Wings are deciduous in ants and termites. There is only one pair of wings in the true flies. Normally two pairs of wings are present in insects and they are borne on pterothoracic segments viz., mesothorax and metathorax. Wings are moved by thoracic flight muscles attached to theirbases.

Wing is flattened double layered expansion of body wall with a dorsal and ventral lamina having the same structure as the integument. Both dorsal and ventral laminae grow, meet and fuse except along certain lines. Thus a series of tracheae, nerves and blood. Wing is nourished by blood circulating through veins. Later the walls of these channels become thickened to form veins or nervures. The arrangement of veins on the wings is called venation which is extensively used in insect classification. The principal longitudinal veins arranged in order form the anterior margin are costa (C) , sub costa (Sc), radius ®, median (M), cubitus (Cu) and anal veins (A). Small veins often found inter connecting the longitudinal veins are called cross veins. Due to the presence of longitudinal veins and cross veins, the wing surface gets divided into a number of enclosed spaces termed cells. In insects like dragon fly and damselfly, there is an opaque spot near the coastal margin of the wing calledpterostigma.

Margins and Angles

The wing is triangular in shape and has therefore three sides and three angles. The anterior margin strengthened by the costa is called costal margin and the lateral margin is called apical margin and the posterior margin is called anal margin. The angle by which the wing is attached to the thorax is called humeral angle. The angle between the costal and apical margins is called apical angle. The angle between apical and anal margins is called anal angle.

WING REGIONS

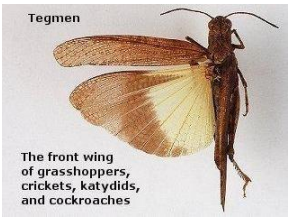
The anterior area of the wing supported by veins is usually called remigium. The flexible posterior area is termed vannus. The two regions are separated by vannal fold. The proximal part of vannus is called jugum, when well developed is separated by a jugal fold. The area containing wing articulation sclerities, pteralia is called axilla.

Insects have evolved many variations of the wings, and an individual insect may posess more than one type of wing. Wing venation is a commonly used taxonomic character, especially at the family and species level.

In most living insects (the Neoptera), there are three axillary sclerites that articulate with various parts of the wing. In the Neoptera, a muscle on the third axillary causes it to pivot about the posterior notal wing process and thereby to fold the wing over the back of the insect. (In some groups of Neoptera, such as butterflies, the ability to fold the wings over the back has been lost.) Two orders of winged insects, the Ephemeroptera and Odonata, have not evolved this wing-flexing mechanism, and their axillary sclerites are arranged in a pattern different from that of the Neoptera; these two orders (together with a number of extinct orders) form the Paleoptera

MODIFICATION OF WINGS

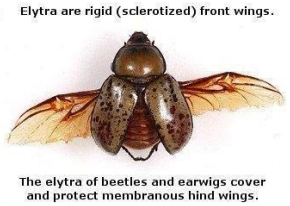
1. TEGMINA



Tegmina (singular tegmen) are the leathery forewings of insects in the orders Orthoptera, Blattaria, and Mantodea. Like the elytra on beetles and the hemelytra on bugs, the tegmina help protect the delicate hind wings.

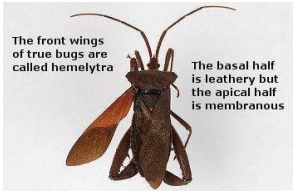
Examples: Grasshoppers, crickets and katydids (order Orthoptera), Cockroaches (order Blattaria), Mantids (order Mantodea).

2. ELYTRA



Elytra (singular elytron) are the hardened, heavily sclerotized forewings of beetles and are modified to protect the hind wings when at rest. Examples: All beetles (orderColeoptera).

3. HEMELYTRA

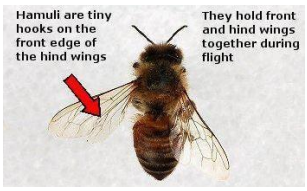


A variation of the elytra is the **hemelytra**. The forewings of Hemipterans are said to be hemelytrous because they are hardened throughout the proximaltwo-thirds,whilethedistalportionismembranous.Unlikeelytra, hemelytra function primarily as flight wings. Examples: Bugs (order Hemiptera).

4. HALTERES

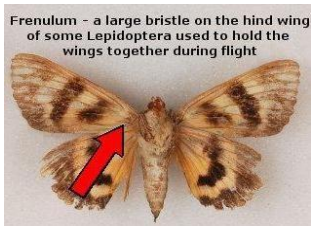
Halteres are an extreme modification among the order Diptera (true flies), in which the hind wings are reduced to mere nubs used for balance and direction during flight. Examples: All flies (order Diptera).

5. HAMULI



Hamuli are hook-like setae on the anterior margin of the hind wing which interlock with the recurved posterior edge of the fore wing in the Hymenoptera during flight, making them functionally two winged. The possession of hamuli is an autapomorphy for the Hymenoptera.

6. FRENULUM



The **frenulum** is a row of bristles along the leading (front) edge of the hind wing of butterflies and moths and also in some Hymenoptera such as bees and wasps. The **frenulum** connects the hind wing and fore wing and makes the two wings act a single surface during flight.

7. MEMBRANOUSWINGS

Membranous wings are thin and more or less transparent, but some are darkened. Examples: Dragonfiles and damselflies (order Odonata), lacewings (order Neuroptera), flies (order Diptera), bees and wasps (order Hymenoptera), termites (order Isoptera). Note the paleopterous wing conditions of the damselflies and dragonfly to the right and below and the neopterous wing conditions of the other insects.

8. SCALES

Some insect wings are covered with **scales**. The scales make the wings colorful.

Examples: Butterflies, moths and skippers (order Lepidoptera), caddisflies (order Trichoptera).

WING COUPLING

Higher pterygotes have attained virtual dipterism by co ordinate wing movements. Such insects have devices for hooking fore and hind wings together so both the pairs move synchronously. By coupling the wings the insects become functionally two winged.

TYPES OF WING COUPLING

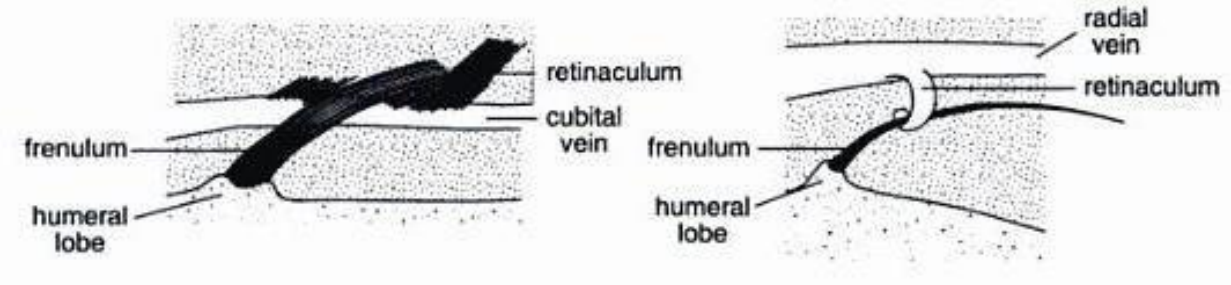
1. Hamulate: A row of small hooks is present on the costal margin of the hindwing which is known as hamuli. These engage the folded posterior edge of fore wing. Eg:Bees.

2. Amplexiform: It is the simplest form of wing coupling. A linking structure is absent. Coupling is achieved by broad overlapping of adjacent margins. Eg:Butterflies.

3. Frenate: There are two sub types. Eg: Fruit suckingmoth.

(1) Male frenate: Hindwing bears near the base of the costal margin a stout bristle called frenulum which is normally held by a curved process, retinaculum arising from the subcostal vein found on the under surface of theforewing.

(2) Female frenate: Hindwing bears near the base of the costal margin a group of stout bristle (frenulum) which lies beneath extended forewing and engages there in a retinaculum formed by a patch of hairs nearcubitus.



Frenate coupling-female **Frenate coupling -mal**

EXPERIMENT-5

AIM: To study different types of insect larvae and pupae**.**

Requirements: Collection jars, collection vials and ethanol

LARVAE: There are three main types of insects larvae namely oligopod, polypod and apodous.

1) OLIGOPOD: Thoracic legs are well developed. Abdominal legs are absent. There are subtypes:

a) Campodeiform: They are so called from their resemblance to the dipluran genus campodea. Body is elongate, depressed dorso ventrally and well sclerotised. Head is prognathous. Thoracic legs are long. A pair of abdominal cerci or caudal processes is usually present. Larvae are generally predators and are very active. Eg: grub of ant lion or grub of lady birdbeetle.

b) Scarabaeiform: Body is 'C' shaped, stout and subcylindrical. Head is well developed. Thoracic legsa re short. Caudal processes are absent. Larva is sluggish, burrowing into wood or soil. Eg: grub of rhinocerousbeetle.

1) POLYPOD OR ERUCIFORM: The body consists of an elongate trunk with large sclerotised head capsule. Head bears a pair of powerful mandibles which tear up vegetation. Two groups of single lensed eyes found on either side of the head constitute the visual organs. The antenna is short. Three pairs of thoracic legs and upto five pairs of unjointed abdominal legs or prologs are present. Thoracic legs are segmented and they end in claws which are used for holding typically bears rows or circlet of short hooked spines or crochets which are useful in clinging to the exposed surface of vegetation and walking. Abdominal segments three to six and ten typically bear prologs. Eg: caterpillar (larvae of moths andbutterflies).

a) **Hairy caterpillar:** The body hairs may be dense, sparse or arranged in tufts. Hairs may cause irritation, when touched. Eg: Red hairy caterpillar.

b) **Slug caterpillar:** larva is thick, short, stout and fleshy. Larval head is small and retractile. Thoracic legs are minute. Abdominal legs are absent. Abdominal segmentation is indistinct. Larva has poisonous spines called scoli distributed all over the body. Such larva is also called platyform larva.

c) **Semilooper:** either three or four pairs of prologs are present. Prologs are either wanting or rudimentaly in either third or third and fourth abdominal segments. Eg: Castorsemilooper.

d) **Looper:** They are also called measuring worm or earth measurer or inch worm. In this type only two pairs of prologs are present in sixth and tenth abdominal segments. Eg: Dainchalooper.

3) APODOUS

They are larvae without appendages for locomotion. Based on the degree of development and sclerotization of head capsule, there are three subtypes.

a) **Eucephalous:** larva with well developed head capsule with functional mandibles, maxillae stemmata and antennae. Mandibles act transversely. Eg: Wriggler (larva ofmosquito).

b) **Hemicephalous:** Head capsule is reduced and can be with drawn into thorax. Mandibles act vertically. Eg: Larva of horse fly and robberfly.

c) **Acephalous:** Head capsule is absent. Mouth parts consists of a pair of protrusible curved mouth hooks and associated internal sclerites. They are also called vermiformlarvae.
Eg: maggot (larva of housefly).

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

1) **OBTECT:** Various appendages of the pupa viz., antennae, legs and wings pads are glued to the body by a secretion produced during the last larval moult. Exposed surface of the appendages are more heavily sclerotised than those adjacent to body. Eg: mothpupa.

a) Chrysalis: It is the naked obtect pupa of butterfly. It is angular and attractively coloured. The pupa is attached to the substratum by hooks present at the terminal end of the abdomen called cremaster. The middle part of the chrysalis is attached to the substratum by two strong silken threads called gridle.

b) Tumbler: Pupa of mosquito is called tumbler. It is an object type of pupa. It is comma shaped with rudimentary appendages. Breathing trumpets are present in the cephalic end and anal paddles are present at the end of the abdomen. Abdomen is capable of jerky movements which are produced by the anal paddles. The pupa is veryactive.

2. **EXARATE:** Various appendages viz., antennae, legs and wing pads are not glued to the body. They are free. All oligopod larvae will turn into exarate pupae. The pupa is soft and pale. Eg: pupa of rhinocerousbeetle.

3. **COARCTATE:** The pupal case is barrel shaped, smooth with no apparent appendages. The last larval skin is changed into a case containing the exarate pupa. The hardened dark brown pupal case is called puparium. Eg: Flypupa.

PUPAL PROTECTION

In general pupal stage lacks mobility. Hence, it is the most vulnerable stage. To get protection against adverse conditions and natural enemies, the pupa is enclosed in a protective cover called cocoon. Based on the nature and materials used for preparation of cocoons, there are several types:

S. No.	Types of cocoon	Materials used	Example
1.	Silken cocoon	silk	silkworm
2.	Earthern cocoon	Soil + saliva	Gram pod borer
3.	Hairy cocoon	Body hairs	Wolly bear
4.	Frassy cocoon	Frass + saliva	Coconut black headed caterpillar
5.	Fibrous cocoon	Fibres	Red palm weevil
6.	Puparium	Hardened last larval skin	House fly

EXPERIMENT-6

AIM: Dissection of digestive system in insects.

Requirements: Dissecting pan with wax pad, dissecting pins, forceps, hand lenses and scissors

Procedure:

1. Place the specimen in the dissecting pan ventral side up. Use scissors to cut through the exoskeleton's ventral side from the head to the posterior end of theabdomen.
2. Pull the cut sides apart and observe the internal organs. Pin sides of the insect to the dissectingpan.

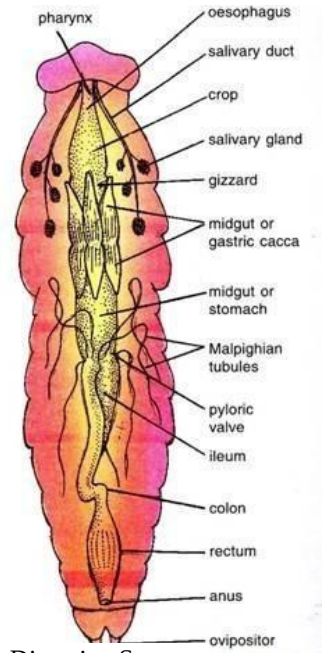
The Observation of digestive system is asfollows:

Digestion takes place in specialised cavities joined together to form a continuous canal. It is called the alimentary canal.

The alimentary canal is divided into three main portions: Foregut, Midgut and Hindgut

Foregut: It consists of the mouth surrounded by the mouthparts. The mouth cavity is called the pharynx. It continues as the oesophagus that is short, narrow and thin-walled. The canal then enlarges into crop which is also thin-walled. The crop opens into short, muscular organ, the gizzard or the proventriculus. A pair of salivary glands lie outside and below the crop.

Each salivary gland is branched, the secretions of all the branches pouring into a common duct. The two ducts, one of each side, open into the mouth cavity at the labium. The entire foregut is lined with chitin. In the gizzard, the chitin forms teeth and plate to facilitate grinding of the food.



Digestive System

Midgut: Midgut consists entirely of stomach or ventriculus. At the junction of the gizzard and stomach are six pairs of gastric caecae. These are pouch-like structures arranged in a ring-like manner around the anterior end of the stomach. The anterior lobe of each pair of the caecae extends over the proventriculus and the posterior lobe extends over the ventriculus**.**

The caecae secrete digestive juices and pour them into the stomach. The midgut is not lined by chitin or cuticle but by a peritrophic membrane. This membrane protects the stomach wall from abrasions and is fully permeable to enzymes and digested food.

Hindgut

Hindgut is a coiled structure consisting of anterior ileum, middle colon and posterior rectum. The rectum opens to the exterior through the anus. The hindgut is lined with cuticle. At the junction of the stomach and ileum are attached numerous long tubules called the Malpighian tubules.

EXPERIMENT-7

AIM: Dissection of male and female reproductive systems in insects.

Requirements: Dissecting pan with wax pad, dissecting pins, forceps, hand lenses and scissors

Procedure:

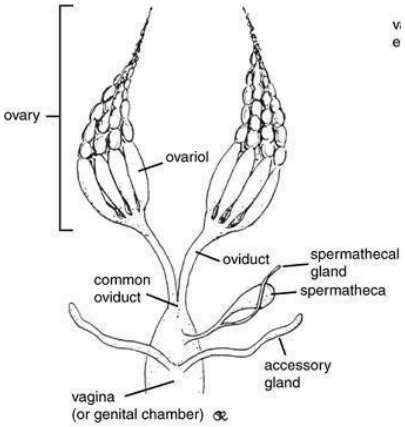
1. Place the specimen in the dissecting pan ventral side up. Use scissors to cut through the exoskeleton's ventral side from the head to the posterior end of theabdomen.
2. Pull the cut sides apart and observe the internal organs. Pin sides of the insect to the dissectingpan.

The Observation of reproductive systems of male and female are asfollows:

FEMALE REPRODUCTIVE SYSTEM

The main functions of the female reproductive system are egg production and storage of male's spermatozoa until the eggs are ready to be fertilized. The basic components of the female system are paired ovaries, which empty their mature oocytes (eggs) via the calyces (Calyx) into the lateraloviductwhichunitetoformthecommon(median)oviduct.

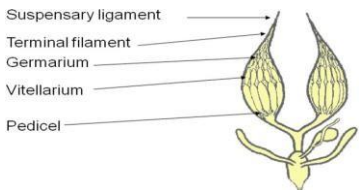
The gonopore (opening) of the common oviduct is usually concealed in an inflection of the body wall that typically forms a cavity, the genital chamber. This chamber serves as a capulatory pouch during mating and thus is often known as the bursa copulatrix. Its external opening is the vulva. In many insects the vulva is narrow and the genital chamber becomes an enclosed pouch or tube referred to as the Vagina.



Two types of ectodermal glands open into the genital chamber. The first is the spermatheca which stores spermatoza until they are needed for egg fertilization. The epermatheca is single and sac-like with a slender duct, and often has a diverticulum that forms a tubular spermathecal gland. The gland or glandular cells within the storage part of the spermatheca provide nourishment to the contained spermatozoa.

The second type of ectodermal gland, known collectively as accessory glands, opens more posteriorly in the genital chamber.

Each ovary is composed of a cluster of egg or ovarian tubes, the ovarioles, each consisting of a terminal filament, a germarium (in which mitosis gives riseto primary oocytes), a vitellarium (in which oocytes grow by deposition of yolk in a process known as vitellogenesis) and a pedicel. An ovariole contains a series of developing oocytes each surrounded bya



layer of follicle cells forming an epithelium (the oocyte with its epithelium is termed a follicle), the youngest oocytes occur near the apical germarium and the most mature near the pedicel.

The different types of ovariole are based on the manner in which the oocytes are nourished.

(i) Paniosticovariole: Lacks of specialized nutritive cells so that it contains only a string of follicles, with the oocytes obtaining nutrients from the haemolymph via the follicular epithelium. E.g. Cockroach.

Ovarioles of the other two contains trophocytes (nurse cells) that contribute to the nutrition of the developing oocytes.

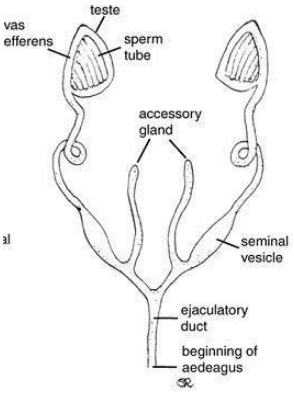
(ii)Telotrophicovariole(**Acrotrophic**): The trophocytes are confined to the germarium and remain connected to the oocytes by cytoplasmic strands as the oocytes move down the ovariole, e.g.bugs.

(iii) Polytrophic ovariole: A number of trophocytes are connected to each oocyte and move down the ovariole with it, providing nutrients until depleted, thus individual oocytes alternate with groups of smaller trophocytes. E.g. moths andflies.

Accessory glands of the female reproductive tract are often called as colleterial or cement glands, because their secretions surround and protect the eggs or cement them to thesubstrate. e.g. egg case production in mantis, ootheca formation in cockroach, Venom production in bees.

Structure of egg: Chorion, Vitelline membrane, Micropyle and Periplasm with yolk

MALE REPRODUCTIVE SYSTEM



The main functions of the male reproductive system are the production and storage of spermatozoa and their transport in a viable state to the reproductive tract of the female. Morphologically, the male tract consists of paired testes, each containing a series of testicular tubes or follicles (in which spermatozoa are produced) which open separately into the mesodermally derived sperm duct or Vas deferens which expands posteriorly to form a sperm storage organor seminal vesicle. Tubular paired accessory glands are formed as diverticula of the vasa deferentia. Sometimes the vasa deferentia themselves are glandular and fulfil the functions of accessory glands. The paired vasa deferentia unite where they lead into the ectodermally derived ejaculatory duct (the tube that transports the semen or the sperm to thegonopore).

Accessory glands are 1-3 pair, either mesodermal of ectodermal in origin and associated with vasa deferentia or ejaculatory duct. Its function is to produce seminal fluid and spermatophores (sperm containingcapsule).

EXPERIMENT-8

AIM: Study of characters of orders - Orthoptera, Dictyoptera, Isoptera, Thysanoptera, Hemiptera, Lepidoptera, Coleoptera, Hymenoptera, Diptera and their families of agricultural importance.

Requirements: Agriculturally important insects of each order

ORTHOPTERA:

Examples: Grasshopper, cricket, etc.

Metamorphosis: Paurometabolous

Mouthparts: Chewing

Significance: Variable or Pest

Characteristics:

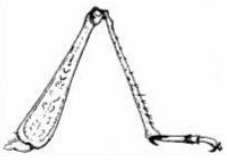
- They are medium to large sizedinsects.
- Antenna isfiliform.
- Mouthparts aremandibulate.
- Prothorax is large. Pronotum is curved, ventrally covering the pleuralregion.
- Hindlegs aresaltatorial
- Forewings are leathery, thickened and known astegmina.
- They are capable of bending withoutbreaking.
- Hindwings are membranous with large anal area. They are folded by longitudinal pleats between veins and kept beneath thetegmina.
- Cerci are short andunsegmented.
- Ovipositor is well developed infemale.
- Metamorphosis is gradual. In many Orthopterans the newly hatched frist instar nymphs are covered by loose cuticle and are called pronymphs. Wing pads of nymphs undergo reversal during development.
- Specialized stridulatory (sound-producing) and auditory (hearing) organs arepresent.

This order is sub divided into two suborders, viz., **Caelifera**and**Ensifera**.

I. Families ofCaelifera

1. Acrididae: (Locusts,Grasshoppers)

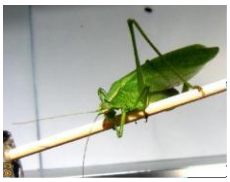
➢ Antenna isshort



- Tarsus is threesegmented
- Ovipositor is short and horny
- Tympanum is located one on either side of the first abdominalsegment.
- Sound is produced by **femoro-alary** mechanism. A row of **peg** like projections found on the innerside of each hindfemur is rubbed against the hard **radial vein** of the closedtegmen.
- Locusts are a serious threat to tropical agriculture. They swarm under favourable conditions and mainly feed on grasses, cerealsetc.

II. Families of Ensifera

1. Tettigonidae : (Katydids, Long hornedgrasshoppers)




- Antenna is long, slender as long as or longer than thebody.
- Tarsus is foursegmented.
- Ovipositor is swordlike.
- Auditory organs are found in foretibiae. In each foretibia a pair of tympanum is present. The outer tympanum is larger than theinner.

Sound production is **alary type**. A thick region on the hind margin of the forewing (**scraper**) is rubbed against a row of teeth on the stridulatory vein (**file**) present on the ventral side of another forewing which throws the resonant area on the wing (**mirrors**) into vibrations to producesound.

2. Gryllidae (Cricket)


- Antenna islong.
- Tarsus is foursegmented.
- Ovipositor is slender and needlelike.
- Forewings are abruptly bent down to cover the sides of thebody
- Hindwings are acuminate. They are produced into a pair of long processes which project beyond theabdomen.
- Cerci are long andunsegmented
- Auditory organs and stridulatory organs are similar to long horned grasshopper. Males stridulate during night. They produce a shrill chirpingnoise.
- *Gryllus sp*. It is householdpest.


3. Gryllotalpidae : (Molecrickets)

- They are brown coloured insects found inside the burrows. Eyes arereduced.
- Pronotum is elongate, ovate and roundedposteriorly.
- Forelegs are fossorial. Tibiae are expanded anddigitate.

- Hindwings are extended beyond the tegima as a pair ofprocesses
- Special stridilatory structures are absent. A humming sound is produced by rubbing theforewings.
- A pair of tympanum is found on the order surface of thetibiae.
- Ovipositor isvestigeal.
- Mole crickets burrow into the soil and feed on tender roots of growing plants. *Gryllotalpaafricana* is a pest on stored potatoes.

DICTYOPTERA:

Examples: Cockroach, praying mantis, etc.

Metamorphosis: Holometabolous

Mouthparts: Chewing

Characteristics:

- Head ishypognathous.
- Antenna isfiliform.
- Mouthparts are chewingtype.
- Tarsus is fivesegmented.
- Forewings are more on less thickened, leathery with a marginal costal vein. They are called tegmina.
- Hindwings are large, membranous and folded fanlike and kept beneath theforewings.
- Cerci are short and manysegmented.
- Eggs are contained in anootheca.

There are two important families viz., **Blattidae**and **Mantidae**

S. No.	**Blattidae**	**Mantidae**
1.	Head is not mobile in all directions	Head is mobile in all directions
2.	Head is hidden by the pronotum	Pronotum does not cover the head
3.	Two fenestrae (dagenerated ocelli sensitive to light) occur in the place of ocelli	Three ocelli are present
4.	Pronotum is shield like	Pronotum is elongate
5.	Legs are cursorial and are adaptedfor running	Forelegs are raptorial middle and hindlegs suited for walking
6.	Gizzard is powerfully armed with chitinous teeth to grind food	Chitinous teeth are absent in gizzard
7.	Female does not devour the male during mating	Often (but not always) devours the male during mating
8.	Eggs are laid inside a chitinousootheca	Eggs are enclosed in filled solidfied foam Ootheca is not chitinous.

9.	Nymphs are not cannibalistic	Nymphs are cannibalistic
10	No mimicry is found	Mimic leaves and flowers
11.	Omnivorous	Carnivorous
12.	Found in household, dead wood, litter etc.	Found mostly outdoors
13.	Economic importance: They feed on food stuff, clothes and paper. They impart a foul smell to the food by contaminating with excreta. Hence they are harmful.	Economic importance: They are predators on moths, flies, grasshoppers, cater- pillars, etc. Hence they are beneficial.
14.	Important species: American cockroach *Periplanataamericana*	Important species: *Mantis religiosa*

ODONATA:

Examples: Dragonflies, damselflies etc.

Metamorphosis: Hemimetabolous

Mouthparts: Chewing

Significance: Beneficial

Characteristics:

- Mediumtolargesizedinsects
- They areattractivelycoloured
- Headisglobularandconstrictedbehindintoapetiolateneck.
- Compound eyes arelarge.
- Three ocelli arepresent
- Mouthparts are adapted for biting. Mandibles are strongly toothed Lacinia and galea are fused to form mala which is alsotoothed.
- Wings are either equal or sub equal, membraneous; venation is net work like with many cross veins. Wings have a dark pterostigmatowards the costal apex. Sub costa ends in nodus. Wing flexing mechanism isabsent.
- Legs are anteroventrally placed. They are suited for grasping, holding and conveying the prey to the mouth. Spinose femora and tibiae are useful for holding the prey. Forward shift of leg attachments allow easy transfer of prey items to mouth in flight. Legs are held in such a way thata

basket is formed into which the food is scooped.

- Abdomenislongandslender.Inmalegonoporeispresentonninthabdominalsegment.
- But the functional copulatory organ is present on the second abdominal sternite. Before mating sperms are transferred to the functional penis. Cercus is onesegmented.
- Metamorphosis is incomplete with three life stages. The naiad is aquatic. Labium is greatly elongated,jointedandbearstwohooksatapex.Itiscalledmask.Itisusefultocapturetheprey.

There are two sub-orders. Dragonflies are classified under **Anisoptera**and damselflies are grouped under **Zygoptera.**

	Anisoptera (Dragonflies)	**Zygoptera (Damselflies)**
	Adults	
1.	Strong fliers	Weak Fliers
2.	Wings are unequal, Hindwings are basally broader than forewings	Equal
3.	Wings are broadly attached to the abdomen	Wings are petiolated and narrowly attached
4.	Venation is not similar in both forewings and hind wings.	Venation is identical in both the wings.
5.	Wings are spread laterally at rest	Wings are held at an angle above the abdomen
6.	Compound eyes are large and meet mid dorsally (holoptic)	Compound eyes are button like, wide apart (dichoptic)
7.	Male has three abdominal appendages. Two superior and appendages (cerci) and one inferioranal appendagen(epi-proct) are present.	Four terminal abdominal appendages are present. A pair of superior anal appendages (cerci) and a pair of inferioranal appendages. (paraprocts) are present.
8.	Oviposition is exophytic	Oviposition is endophytic
		
	Naiad	
1.	Stout and robust	Slender and fragile
2.	Gills are internal and found associated with rectum	Three caudal gills are present which are visible axternally.
3.	Able to propel themselves by forciblyejectin water through anus from rectum	Lack jet propulsion mechanism

Families of Anisoptera (Dragonflies)

Aeshnidae(Darners): These insects are notable for their large size and brilliant blue or green coloration. Includes the common green darner (*Anaxjunius*).

Libellulidae(Common Skimmers): This is the largest family in the order. It contains many species with dark spots on thewings.

Gomphidae(Clubtails): These dragonflies have the terminal abdominal segments swollen, hence the common name.

Families of Zygoptera(Damselflies)

Calopterygidae(Broadwinged Damselflies): The wings of these insects are shaped like the seeds of a maple tree.

Coenagrionidae(Narrowwinged Damselflies): Small, delicate insects. The body is usually black with blue markings. At rest, the wings are held together over the back.

Lestidae(Spreadwinged Damselflies): These damselflies rest with the body nearly vertical and the wings partlyoutspread.

ISOPTERA:

Examples: Termite

Metamorphosis: Hemimetabolous

Mouthparts: Chewing

Significance: Pest

Characteristics:

- Pale, elongate bodies, and are sometimes called "whiteants."
- Reproductive individuals have two pairs of membranous wings, all of equallength.
- Termites shed their wings aftermating.
- Have chewingmouthparts.
- Antennae are roughly the length of theirheads

Major Families

Rhinotermitidae(Subterranean termites): These insects build nests in the soil and generally infest wood that is in contact with the ground.

Hodotermitidae(Rottenwood termites): Generally found inhabiting moist wood. Contact with the soil is not a requirement.

Kalotermitidae(Drywood and dampwood termites): These insects nest in the wood itself and do not require contact with the soil.

Termitidae: This is the largest family of termites worldwide.

THYSANOPTERA:

Examples: Thrips

Metamorphosis: Hemimetabola

Mouthparts: Rasping - sucking

Significance: Variable

Characteristics:

- They are minute, slender, soft bodiedinsects.
- Mouthparts are rasping and sucking. Mouth cone is formed by the labrum and labium together with basal segments of maxillae. There are three styletsderived from two maxillae and left mandibles. Right mandible is absent. Hence mouthpartsareasymmetrical.
- Wings are either absent or long, narrow and fringed with hairs which increase the surface area. Theyareweakfliersandpassiveflightinwindiscommon.
- Tarsus is with one or two segments. At the apex of each tarsus a protrusiblevesicle ispresent.
- Abdomen is often pointed. An appendicular ovipositor may be presentorabsent.
- Nymphal stage is followed by prepupal and pupal stages which are analogous to the pupae of endopterygoteinsects.

Major Families of Thysanoptera

Aeolothripidae(Predatory Thrips): mostly beneficial species.

Thripidae(Common Thrips): herbivores, including many pests such as the flower thrips (*Frankliniellatritici*), and the soybean thrips (*Sericothripsvariabilis*).

Phlaeothripidae(Tube-tailed thrips): largest faimly in the order; contains numerous pests as well as a few beneficial species (e.g., the black hunter, *Leptothripsmali*).

HEMIPTERA:

Examples: True bugs, whiteflies, plant hoppers etc.

Metamorphosis: Hemimetabolous

Mouthparts: Piercing-sucking

Significance: Pest

Characteristics:

- Head isopisthognathous.
- Mouthparts are piercing and sucking type. Two pairs of bristle like styletswhich are the modified mandibles and maxillae are present. Styletsrest in the grooved labium or rostrum. Both labial palps and maxillary palpsareatrophied.
- Mesothorax is represented dorsally byscutellum.
- Forewings are either uniformly thickened throughout or basally coriaceous and distally membranous,
- Cerci are alwaysabsent.
- Metamorphosis usually gradual; rarelycomplete.
- Alimentarycanalissuitablymodifiedtohandleliquidfood.(filterchamber)
- Salivary glands are universallypresent,
- Extra-oral digestion is apparentlywidespread.
- Abdominal ganglia fused with thoracicganglia.

There are two suboders viz., Heteroptera andHomoptera.

S. No.	**Heteroptera (Hetero-different; ptera-wing)**	**Homoptera (Homo-uniform; ptera-wing)**
1.	Head is porrect or horizontal	Head is deflexed
2.	Bases of the forelegs do not touch the head	Bases of the forelegs touch the head
3.	Beak arises from the anterior part of the head	Beak arises from the posterior part of the head
4.	Gular region of the head(midventral sclerotised part between labium and foramen magnum) welldefined.	Gular region not clearly defined
5.	Pronotum usually greatly enlarged.	Pronotum is almost alway small and collar-like.
6.	Scutellum (triangular plate found between the wing bases) well developed	Scutellum not well developed.
7.	Forewings heavily sclerotized at the base and the apical half is membranous (Hemelytra)	Forewings are of uniform texture. They are frequently harder than hind pair.
8.	Wings are held flat over the the back at rest and the left and right side overlap on the abdomen.	Wings are held roof-like over the back and wings do not over lap.
9.	Honey dew secretion uncommon	Honey dew secretion common
10.	Repungnatorial or odori-ferous or scent glands present.	Wax glands usually present.
11.	Both terrestrial and aquatic	Terrestrial.
12.	Herbivorous, predaceous or blood sucking.	Herbivorous.

Important families of Heteroptera

1. Cimicidae(Bedbugs)

- Bodyisdorsoventrallyflattenedsothattheycanhideincracksandcrevices. Body is oval inoutline.
- It is dull reddish brownincolour.
- Thoraxisdeeplynotchedinfronttoreceivetheshortheadup tobulgingeyes.
- Hemelytra short and reduced to scale likepads.
- Hindwings are completelyatrophied.
- Stinkglandsarelocatedinthedorsalsurfaceoffirstthreeabdominalsegments.
- Male bed bugs pierce the integument of the female and inject the sperm into the haemocoelduring copulation (Haemocoelicor traumaticinsemination).
- Beg bugs hide in crevices of beds, furniture, etc., during the day and emerge at night to seek a blood meal. They are blood sucking ectoparasiteson birds and mammals. They are known for their irritating bite. *Cimexlectularisand Cimexhemipterus*are two important species affecting man in temperate and tropicalconditionsrespectively.

2. Lygaeidae(Seed bugs or Chinchbugs)

- Cuneusis absent inhemelytra.
- Membranehasafewirregular veins(4-5veins)arisingfroma transverse basalvein.
- e.g. Dusky cotton bug *Oxycarenushyalinipennis*nymphs and adults suck the sap from seedsof injured or already opened bolls and reduce the seedquality.

3. Pyrrhocoridae(Red bugs orStainers)

- They are elongate ovalbugs.
- Theyshowwarningcolouration.Theyarebrightlymarkedwithredandblack.
- Membrane is with more branched veins and cells. e.g. Cotton stainer*Dysdercuscingulatus.*
- Feeding injury caused by these bugs leads to the contamination by thefungus
- *Nematospora*resulting in yellowish brown discolouration of thelint.

4. Coreidae(Squash bugs or leaf footedbugs)

- Membranewithmanybranchingveinsarisingfromatransversebasalvein.
- Stink glands are found inside the metathoraxand glands openings arefound on the sides of the thorax between middle and hind coxae. They emit a bad odour.
- Hindtibiaandtarsiareexpandedandleaflike.

- The edge of the abdomen is raised and wings lie in a distinct depression.e.g. Podbug,
- *Riptortuspedestris*nymphs and adults suck the sap from pods ofpulses.

5. Pentatomidae (Stink bugs or Shieldbugs)

- Antenna is fivesegmented.
- Scutellum is prominent and shieldlike.
- Adults and nymphs produce a disagreeable odour from stink glands located in metathorax and abdomenrespectively.
- Somearephytophagousandsomearepredaceous.e.g. Greenstinkbug*Nezaraviridula*isapest onmillets.

Important families of Homoptera

1. Cicadidae(Cicadas)

- Males have sound producing organs at the base of the abdomen. Sound producing organs consist of a pair of large plates, the opercula covering the cavity containing structures producing sound. In the anterior part of the cavity benath each operculum is a yellowish membrane. Ashinning mirror is located in the posterior part of the cavity. In the lateral wall of the cavity is an oval shaped ribbed structure, the tymbal. These are vibrated by strong muscles to produce sound. Eachspecieshasacharacteristicsong.Tympanumispresentinboth insexes.
- Wings aretransparent.
- Eggs are inserted into the tree twigs bythefemale.
- Nymphsdroptotheground,enterthesoilandfeedonrootsap.
- Anterior femora of the nymph isthickened with spines beneath and are suited for digging the soil.
- Life cycle of periodical cicada lasts for 13-17years.

2. Cicadellidae(Leaf hoppers orJassids)

- Elongate insects with a wedge shapedbody.
- Attractivelycoloured.
- Hind tibiae have a double rowofspines.
- Ovipositoriswellsuitedforlaceratingtheplanttissue.
- Nymphs and adults have the habit ofrunningsidewise.
- They suck the plant sap and transmit diseases. eg. Green leaf hopper *Nephotettixvirescens* transmitstungro disease in rice.

3. Delphacide(Planthoppers)

- Largemobileflattenedspurispresentattheapexofhindtibia
- eg. Brown plant hopper *Nilaparvatalugens*causes hopper burn, transmits viral diseaes inrice.

4. Lophopidae

- Head is produced into asnout.
- Hind trochanter is directedbackward
- Hind basitarsus is moderately long. e.g. Sugarcane leaf hopper *Pyrillaperpusilla* nymphs and adults suck the sap and reduce the quality and quantity of cane juice.

5. Aleurodidae(Whiteflies)

- Minute insects which superficially resembletinymoths.
- Wings are opaque and dustedwith mealy white powdery wax. Wing venation is muchreduced.
- Vasiformorifice is present in the last abdominal tergite. It is a conspicuous opening providedwith an operculum. Beneath the operculum there is a tongue-like organ termed lingula. The anus opens at the base of the lingula through which honey dew is excreated in largeamount.
- Immature instars are sessile, scale like, withwaxycovering.
- Metamorphosis approaches the homometabolustype due to the presence of a quiescent stage prior to the emergence ofadults.
- e.g. Cotton whitefly *Bemisiatabaci*transmits vein clearing disease inbhendi.

6. Aphididae (Aphids or Plant lice or Greenflies)

- Body is pearshaped
- Both apterous and alateforms arefound.
- A pair of cornicles or siphonculior wax tubes is present in the dorsum of fifth or sixth abdominal segments which secretes wax likesubstance.
- They excrete copious amount of honey dew on which ants feed and sooty mould fungusgrows.
- Aphids are known for their extraordinary fecundity,short life cycle and parthenogenitic reproduction. Life cycleishighlycomplexanditinvolvealternationofgeneration.
- Theyfeedonplantsapanddisseminateplantdiseases.
- e.g. Cotton aphid *Aphisgossypii*.

7. Coccidae (Scale insects or Softscales)

- Sexual dimorphism ispresent.
- **Male**: They are gnat like, with long antennae, lateral eye andvestigeal

mouth parts.

- Mesothorax is enlarged bearing one pair of wings with on or two veins. Hind wings are reduced tohalteres. Aquiescentstageispresentinthelifehistory.
- **Female**: Body segmentation is indistinct. Body wall naked and covered with a waxy coating. They are wingless, legless and suck theplantsap.
- The first instar nymph is active and is known as crawler which moults and becomes legless. e.g. Coffee green scale*Coccusviridis*.

8. Pseudococcidae(Mealybugs)

- Body is elongate oval inshape.
- Body segmentation isdistinct.
- Bodyiscoveredbylongradiatingthreadofmealysecretion.
- Functional legs are present in allinstars.
- Wings areabsent.
- e.g. Coconut mealy bug,*Pseudococcuslongispinus*.
- Nymphsand adultssuckthesapandaffectthegrowthofspindleleaf.

LEPIDOPTERA:

Examples: Butterfly and moth

Metamorphosis: Holometabolous

Mouthparts: Siphoning, chewing

Significance: Pest, beneficial, or variable

Characteristics:

- Body, wings, appendages, are densely clothed with overlapping scales, which give colour, rigidity andstrength.Theyinsulatethebodyandsmoothenairflowoverthebody.
- Mouthparts in adults are of siphoning type. Mandibles are absent. The galeaeof maxillae are greatlyelongated and are held together by interlocking hooks and spines. The suctorialproboscis is coileduplikeawatchspringandkeptbeneaththeheadwhennotin use.
- Wings are membranous and are covered with overlapping pigmented scales. Forewings are larger than hind wings. Cross veins are few. Wings are coupled by either frenate or amplexiformtype of wingcoupling.
- Larvae are polypod-eruciformtype. Mouthparts are adapted for chewing with strong mandibles. A group of lateral ocelli is found on either side of the head. The antenna is short andthree

segmented. There are three pairs of five segmented thoracic legs ending in claws. Two to five pairs of fleshy unsegmentedprolegsare found in the abdomen. At the bottom of the proleg, crochetsarepresent.

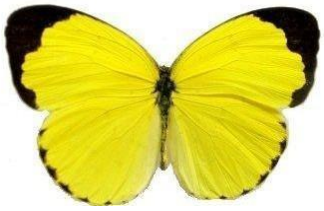
- Pupa is generally obtect. It is either naked or enclosed in a cocoon made out of soil, frass, silk or larvalhairs.

Butterfly families

1. Papilionidae (Swallowtails)

- They are often large andbrightlycoloured**.**
- Prothoracic legs have tibialepiphysis.
- In ma nyspecies hindwingshas tail likeprolongation**.**
- Amplexiform type of wing coupling ispresent.
- Larval body is either smooth or withtubercles.
- Retractile osmeteriaare present on the prothoracic tergumofthecaterpillar
- e.g. Citrus butterfly , *Papiliodemoleus*.

2. Pieridae(whites orSulphurs)



- Theyarewhiteor yellowororangecolouredwithblackmarkings.
- Larva is green, elongate and covered withfindhairs.
- Larval body segments haveannulets.
- e.g. Daincha caterpillar, *Euremahecabe*.

Moth families

1. Arctiidae(Tigermoths)

- Wings are conspicuously spotted orbanded.
- They are nocturnal and attracted tolight**.**
- Larvaiseithersparselyhairyordenselyhairy(woolybear).
- e.g. Black hairy caterpillar, *Estigmenelactinea*.

2. Bombycidae(Silk wormmoths)

- Antenna isbipectinate.
- Larvae is either with tuft of hairs or glabrous with medio dorsal horn on the eighth abdominal segment**.**
- Pupation occurs in dense silkencocoon.
- e.g. Mulberry silk worm, *Bombyxmori an* important source of naturalsilk.

3. **Gelechiidae**

- Forewings trapezoidal and narrower thanhindwings.
- Caterpillars bore into the seeds, tubers, andleaves.
- e.g. Cotton pink boll worm, *Pectinophoragossypiella*.

4. **Noctuidae (Noctuamoths)**

- They are medium sized, stoutly builtmoths.
- They are nocturnal and attracted tolight.
- Labial palp is welldeveloped.
- Crochetsonthelarvalprolegsareallofonesizeandarrangedinsemi-circle.
- Somelarvaearesemiloopers.Theyhaveeitherthreeorfourpairsofprolegs.
- Larvae attack the plants during night. Larvae of some species remain concealed beneath the surface of the ground or litter on the surface during day and feed on plants during night. They often cut small seedlings close to the ground and hence they are called cutworms.
- e.g. Tobocco cut worm, *Spodopteralitura*.

5. **Saturniidae(Moon months, giant silk wormmoths)**

- They are large sizedmoths.
- Antenna isbipectinate.
- Transparent eye spots are present near the centre of each wing. The spots are either circular or crescentshaped.
- Larva is stout and smooth withscoli.
- Cocoon is dense andfirm.
- e.g. Tussor silk worm, *Anthereapaphia*yieldssilk

6. **Pyralidae**(**pyralidmoths**,**snout moths** or **grassmoths)**

- These are generally small moths and are sometimes known asgrass moths.
- They have long legs and a beak like proboscis, which is covered in scales.
- Their forewings are triangular in shape with broader hind wings, and have a tendency to sit with their wings open and forming a distincttriangle
- The wing spans for small and medium-sized species are usually between 9 and 37 mm with variable morphological features.

7. Sphingidae(Hawk moths, Sphinx moths, Hornworms)

- They are large sized stoutly builtmoths.
- Antenna is thick towards middle and hooked atthetip.
- Proboscis is verylong.
- Forewings are elongated and pointed with very obliqueoutermargin.
- Hindwings are reduced in width fitting into the indendtedmargin of forewings. They are powerfulfliers.
- Larvaissmoothwithamiddorsalhorn(analhorn)ontheeighthabdominalsegment.
- Pupation takes place in earthern cells. In many species the proboscis is enclosed in a separate sheath.
- e.g. Death's head moth, *Acherontiastyx*is a defoliator on gingelly. Markings present on the thorax of the adult moth resemble humanskull.
- Wings are comparatively small. They are often held partly open at rest. Flight is erratic and darting.
- Larval head is large. There is a constriction beyond the head. Larva tapers towards both extremities. Larvae are often concealed in thehostfoliage.
- e.g. rice skipper, *Pelopidasmathias.*

COLEOPTERA:

Examples: Beetles

Metamorphosis: Holometabolous

Mouthparts: Chewing

Significance: Pest, beneficial, and variable

Characteristics

- They are minute to large sizedinsects.
- Antenna is usualy 11segmented.
- Mouthparts are chewing type. Mandibles are short with blunt teeth at the mesalface in phytophagous group. In predators the mandibles are long, sharply pointed with blade like innerridge. In pollen feeders teeth are absent and the mandibles are covered with stiffhairs.
- Prothoraxis large, distinct andmobile.
- Mesothoraxandmetathoraxarefusedwiththefirstabdominalsegment.
- Forewings are heavily sclerotised, veinlessand hardened. They are calledelytra.

- Forewings do not overlap and meet mid-dorsally to form a mid-dorsal line. It is not used for flight. They serve as a pair of convex shields to cover the hindwings and delicate tergites of abdomen.
- Hindwings are membranous with few veins and are useful in flight. At rest they are folded transversely and kept beneath the elytra. In some weevils and ground beetles the forewings are fused and hindwingsareatrophied.
- A small part of the mesothorax known as scutellum remains exposed as a little triangle between the bases ofelytra.
- Cerci and a distinct ovipositor areabsent.
- Metamorphosis is complete. Larvae are often calledgrubs.
- Pupae are usually exarate and rarely foundincocoons.

Families of Coleoptera

Families of Predators

1. Coccinellidae(Lady birdbeetles)

- Theyarehemispherical.Thebodyisconvexaboveandflatbelow.
- Their body appearance resembles a splitpea.
- Headissmall,turneddownwardandreceivedintoaprominentnotchofprothorax.
- Elytra is strongly convex, brightly coloured andvariouslyspotted.
- Grubs are compodeiformandspiny.
- Thelastlarvalskin,eithercoverthepupaorgetsattachedtotheanalendofthepupa.
- Exceptthegenus*Epilachna*,othersarepredatorsonaphids,scales,mitesandwhiteflies.

Family of Scavengers

1. Scarabaeidae (Scarabs, Dungbeetles)

- Head is broad andflat.
- Mandibles are membranous and incapable ofchewing.
- Many have spines and horns on headandprothorax.
- Forelegs arefossorial.
- Middle legs are widelyseparated
- Adults and larvae are scavengers. They feed upon the droppings of animals and human excreta. They role on the dung into balls and bury them in underground chambers. They use their head and forelegs for handling dung and digging pits in the soil. Head is used as an excavator and fore-tibia as shovel. They show remarkableparentalcare.

- Common Indian dung beetle :*Heliocoprisbucephalus*

Family of Stored Product Pests

1. Bruchidae(Pulse beetles, Seedbeetles)

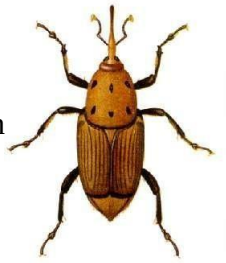
- They are small, shortbeetles.
- Head is small and the snout isblunt.
- Antenna isserrate.
- Hind femur isthick.
- Elytra are short and do not cover the abdomenfully.
- Eggs are whitish, scale like and glued to the pods or seeds by a glutinous secretion. Grubs feed exclusively on seed legumes. Pupation occurs within the seed. Adult emerges by cutting a circularexithole.Developmentissimilartohypermetamorphosis.
- Pulse beetle: *Callosobruchuschinensis*. It is a serious pest on storedpulses.

FAMILIES OF CROP PESTS

4. Cerambycidae(Longicorn beetles)

- Body iscylindrical.
- Compound eyes arenotched.
- Antenna is as long or longer than the beetle itself. Antenna can be flexed backwards. It is surrounded at the base bycompoundeye.
- Pronotumis with one to three laterallylocatedspines.
- Grubs are called round headed borers. They are apodousbut have psuedopodsboth on dorsal and ventral side. They are wood borers. They develop beneath the bark and tunnel into the branchesormainstem.Mangostemborer:*Batocerarufomaculata*

5. Curculionidae(Weevils, snoutbeetles)



- Minute to large sizedinsects.
- Frons and vertex of the head are produced into snout. It is cylindrical and in some species larger than the beetleitself.
- Mouthparts (Mandibles and maxillae) are present at the tip of the snout. It is usefulto feedoninternaltissuesoftheplantandprovideaplaceforegglaying.
- Antennaisgeniculateandfoundusuallyinthemiddleofthesnout.
- Grubs are apodousandeucephalous.
- Weevilsareimportantcroppestsoccurbothinfieldandstorage.
- Coconut red palm weevil: *Rhynchophorusferrugineus.*

6. Chrysomelidae (LeafBeetle)

- Most species in this family, adults and larvae, feed onleaves.
- Leaf beetle adults range from 5 to 15 mm in length and are brightly coloured.
- They have different body shapes, from elongate, flattened toglobular.
- Their antenna usually less than half the length of theirbodies.
- One of their characteristics is that they can hide their legs and antennae under their wing covers while sitting on aleaf.

HYMENOPTERA:

Examples: Ant, bee, wasp

Metamorphosis: Holometabolous

Mouthparts: Chewing, chewing-lapping

Key Membranous wings, front pair larger than rear

Significance: Pest, beneficial, or variable

Characteristics

- Mouthparts are primarily adapted for chewing. Mandibles are very well developed. In bees both labiumandmaxillaeareintegratedtoformthelappingtongue.
- Thorax is modified for efficient flight. Pronotumis collar like. Mesothoraxis enlarged. Metathorax is small. Both prothorax and metathorax are fused withmesothorax.
- Wings are stiff and membranous. Forewings are larger than hind wings. Wing venation is reduced.Both forwingsand hind wings are coupled by a row of hooklets(hamuli) present on the leading edge of the hindwing.
- Abdomen is basally constricted. The first abdominal segment is called propodeum. It is fused with metathorax. The first pair of abdominal spiracles is located in the propodeum. The second segment is known as pedicel which connects the thorax and abdomen. Abdomen beyond the pedicel is called gasterormetasoma.
- Ovipositor is always present in females. It is variously modified for oviposition or stinging or sawing or piercing planttissue.
- Metamorphosis is complete. Often the grub is apodousand eucephalous. Larva is rarely eruciform. Pupa is exarate and frequently enclosed in a silken cocoon secreted from labialglands.

- Sexisdeterminedbythefertilizationoftheeggs.Fertilizedeggsdevelopintofemalesandmalesare producedfromunfertilizedeggs.Malesarehaploidandfemalesdiploid.

This order is subdivided into two suborders: Symphyta and Apocrita

S. No.	**Symphyta (Chalastogastra)**	**Apocrita (Clistogastra)**
1.	Abdomen is broadly joined to the thorax.	Abdomen is petiolated.
2.	Larva is a caterpillar and belongs to eruciform type	Larva is a grub and it belongs to apodous eucephalous type
3.	Stemmata are present	Stemmata are absent.
4.	Both thoracic and abdominal legs are present	Legs are absent
5.	Ovipositor is saw like and suited for piercing the plant tissue	Ovipositor is not saw like and is suitedfor piercing in parasitic groups or for stinging in other groups
6.	Behavioural sophistication is less	Behavioural sophistication is more.
7.	They are phytophagous	They are generally parasitic

I. Family ofSymphyta

1. Tenthredinidae(Sawflies)

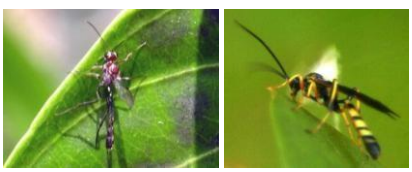
- They are wasp likeinsects.
- Abdomen is broadly joined to thethorax.
- Theovipositorissawtoothedandsuitedforslicingtheplanttissue.
- Larvae iseruciform. It resembles a lepidopterancaterpiller. It has one pair of ocelli, papillae (reduced antenna) three pair of thoracic legs and 6-8 pairs of abdominallegs.

Prolegs lack crochets. They are external feeders on foliage. Larvae while feeding usually have posterior part of the body coiled over the edge of the leaf.

Mustard sawfly: *Athalialugensproxima*is a defoliator of mustard and cruciferous vegetables.

II.Family ofApocrita

2. Ichneumonidae(Ichneumonflies)



- Adults are diurnal and visitflowers.
- Trochanter is two segmented. Hind femur is withtrochantellus

- Forewing has two recurrentveins.
- Petiole is curved and expanded at theapex.
- Sternitesof the gaster aremembranous
- Ovipositor is arising anterior to the tip of abdomen. It is often longer than the body and exerted outpermanently.
- Larvae are mostly parasites and less frequently hyperparasites. They are solitary parasites. They spin cocoons in or outside the host. *Eriborustrochanteratus*is an exotic larval parasite of coconut black headedcaterpillar.

3. Braconidae(Braconidwasps)

- They are small, stout bodiedinsects
- Forewing has one recurrentvein.
- Petiole is neither curved nor expanded at theapex.
- Gasteris sessile orsubsessile.
- Sternitesof the gaster are partlymembranous.
- Abdomen is as long as the head andthoraxtogether
- They parasitize lepidopteranlarvaecommonly.
- They are gregariousparasites.
- In many species polyembryonyisobserved.
- Pupation occurs in silken cocoons either externally on the host or away from the host in groups. *Braconbrevicornis*is mass multiplied and released for the control of coconut black headed caterpillar.

4. Chalcididae

- They are small to medium sizedinsects.
- Hindcoxaearefivetosixtimeslargerthanforecoxae.
- Hind tibial spurs are larger than midtibialspurs.
- Hind femora are larger with a row ofshort-teethbeneath.
- Wing venation is reduced to a single anteriorvein.
- Ovipositor is short andstraight.
- *Brachymeriasp*is a pupalparasite on coconut blackheadedcaterpillar.

5. Trichogrammatidae

- They are very tiny insects (0.3 to 1.0mmlong)
- Tarsus is threesegmented.

- Forewing is broad with pubascence(Microscopic hairs) inrows.
- Hindwingis reducedand fringedwithhairsalongthemargins.
- They are mainly egg parasites onLepidopteraninsects.
- *Trichogrammasp*.isextensivelyusedinthebiologicalcontrolofsugarcanemothborers.

6. Apidae (Honeybees)

- Body is covered with branching orplumosehairs.
- Mouthparts are chewing and lapping type. Mandibles are suited for crushing and shaping wax for buildingcombs.
- Legsarespecializedforpollencollection.Scopa(pollenbasket)is presentonhindtibia.
- They are social insects with three castes viz., queen, drone and workers. Temporal separation of duties is noticed amongworkers.

Indian honey bee *Apisindica*is a productive insect.

Apisindica ***Apisdorsata*** ***Apisflorae***

7. Chalcididae

- They are often black with yellow, red, or white markings,rarely brilliantly metallic, with a robust mesosoma and very strong sculpturing.
- Hind leg with femur characteristically swollen with one or moreteeth on its inner margin and with tibia markedlycurved
- Antennae are bent and verysmall
- Body is laterally compressed, robust, about 2.5-9.0mm inlength
- Ovipositor isshort
- Eggs are produced parthenogenetically at the rate of300-400.

DIPTERA:

Examples: Fly, midge, mosquito, etc.

Metamorphosis: Holometabolous

Mouthparts: Piercing-sucking, cutting-sponging, sponging, chewing, cutting-lapping

Significance: Pest, beneficial, or variable

Characteristics

- Theyaresmalltomediumsized,softbodiedinsects.
- The body regions aredistinct.
- Headisoftenhemisphericalandattachedtothethoraxbyaslenderneck.
- Mouthparts are of sucking type, but may bemodified.
- All thoracic segments are fused together. The thoracic mass is largely made up of mesothorax. A small lobe of the mesonotum(scutellum) overhangs the base of theabdomen.
- They have a single pair ofwings.
- Forewings are larger, membranous and used forflight.
- Hindwings are highly reduced, knobbed at the end and are called halteres. They are rapidly vibrated during flight. They function as organs of equilibrium. Flies are the swiftest among allinsects.
- Metamorphosis is complete. Larvae of more common forms are known as maggots. They are apodous and acephalous. Mouthparts are represented as mouth hooks which are attached to internal sclerites. Pupa is generally with free appendages, often enclosed in the hardened last larval skin calledpuparium.Pupabelongstothecoarctatetype.

Families of Diptera

1. **Culicidae(Mosquitoes)**

- They are delicate, fragile, slenderinsects
- Femaleshavepiercingandsuckingtypeof mouthpartswithsixstylets.
- Antennaisplumose(bushy)inmaleandpilose(lesshairy)infemale.
- Legs are slender, delicate andlong.
- Wingsarefringedwithhairsandscalesonhindmarginandonsomeveins.
- Malesareshortlivedandfeedonnectarordecayingfruits.
- Females live long and are bloodfeeders.
- Larvae are called wrigglers. Larval head is large with chewing mouthparts and mouth brush aiding infilterfeeding.Thoraxislargewithoutlegs.Respiratorysiphonislocatedinthepenultimate

abdominal segment. Anal gills are present at the terminal end of the abdomen.

- Pupa is known as tumbler. It is very active. It has a pair of prothoracic horns which houses the anteriorpairofspiracles. Apairofanalpaddlesispresentattheterminalend aidsinswimming.

Malarial mosquite

Filarial mosquito

*Anopheles sp*transmitsmalaria
Mosquito larvaewriggler

*Culexsp*transmitsfilariasis
Mosquito pupatumbler

2. Cecidomyiidae(Gallmidges)

- They are minute delicate, mosquito likeflies.
- Antennae and legs arelong
- Wing venation is reduced. Wings are covered withlonghairs.
- A dark sclerotised area is present midventrallyon the prothoraxin the larva called `chestbone'.

Rice gall midge: *Orseoliaoryzae - maggot* feeding produces galls.

3. Tephritidae (Fruitflies)

- Sub costa bends apically and fadesout.
- Wings are spotted orbanded.
- Female has a sharp andprojectingovipositor.
- Maggots can hop. They are highly destructive to fruitsandvegetables.
- Curcurbitfruit fly : *Dacuscucurbitae*

4. Tachinidae(Tachinidflies)

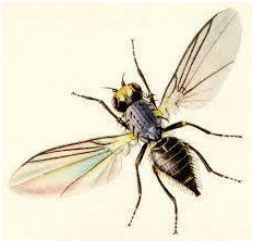
- Arista is completelybare.
- Abdomen is stout with several noticeablebristles.
- They are non specificendoparasiteson the larvae and pupae of Orthoptera, Hemiptera, Lepidoptera andColeoptera.

5. Muscidae(Housefly)

- Antennal arista isplumose.
- Mouthparts are sponging type. Labium is distally modifed into a pair of oval shaped fleshy lobes calledlabella.
- Pretarsusconsits of two claws and twoadhesivepads.
- First abdominal segment is yellow in colour. Terminal abdominal segments are telescopic formingapseudoovipositor.Abdomenisnotbristlyonbasalpart.

- Maggots are scavengers. Adults carry certain disease causing microbes on its legs, body hairs and mouthparts, e.g. Common house fly: *Muscadomestica*

6. Agromyzidae(leaf-minerflies)



- The Agromyzidae are a family commonly referred to as the leaf-miner flies, for the feeding habits of their larvae, most of which are leaf miners on variousplants.
- These are small, sometimes minute, flies, at most 0.9 to 6.0 mm in length.
- They are often yellow and/or black, brown or grey, a few have some metallic greenish, bluish or copperycoloration

- The body is usually short, and the thorax has a rectangular profile.
- The abdomen is broad and the legs areshort.
- The wings are equal in length to the body or slightlylonger.
- The abdomen is moderately long and consists of sixsegments and with a coating of short pubescence well-developed at some places.
- The female has an elongated telescopic ovipositor, which in the resting position is retracted into the elongated tergite 7, often called theovipositor.

EXPERIMENT-9

AIM: To study about Insecticides and their formulations

Requirements: Insecticides of different types

Insecticide chemicals in their "raw" or unformulated state are not usually suitable for pest control. These concentrated chemicals and active ingredients may not mix well with water, may be chemically unstable, and may be difficult to handle and transport. For these reasons, manufacturers add inert substances, such as clays and solvents, to improve application effectiveness, safety, handling, and storage. Inert ingredients do not possess Insecticidal activity and are added to serve as a carrier for the active ingredient. Manufacturers will list the percentage of inert ingredients in the formulation or designate them as "other ingredients" on their labels. There are several inert substances, such as petroleum distillates and xylene, which will have a specific statement identifying their presence in the formulation. The mixture of active and inert ingredients is called a pesticide formulation. This formulation may consist of:

- The pesticide active ingredient that controls the targetpest
- The carrier, such as an organic solvent or mineralclay
- Adjuvants, such as stickers andspreaders
- Other ingredients, such as stabilizers, safeners, dyes, and chemicals that improve orenhance pesticidalactivity

Types of Formulations

- Emulsifiableconcentrates
- Wettablepowders
- Dusts
- Aerosols
- Granularformulations
- Baits
- Microencapsulatedproducts

Emulsifiable Concentrates (EC or E)

An emulsifiable concentrate formulation usually contains a liquid active ingredient, one or more petroleum-based solvents (which give EC formulations their strong odor), and an agent—known as an emulsifier—that allows the formulation to be mixed with water to form an emulsion. Upon mixing with water, they take on a "milky"appearance.

Most ECs contain between 2.5% and 75% active ingredient. ECs are among the most versatile formulations. They are used against agricultural, ornamental and turf, forestry, structural, food processing, livestock, and public health pests. They are adaptable to many types of application equipment including portable sprayers, hydraulic sprayers, low-volume ground sprayers, mist blowers, and low-volume aircraftsprayers.

Wettable Powders

Wettable powders are dry, finely ground formulations that look like dusts. They usually must be mixed with water for application as a spray. Wettable powders contain 5%–95% active ingredient by weight. The particles do not dissolve in water. They settle out quickly unless constantly agitated to keep them suspended. Wettable powders are one of the most widely used pesticide formulations. They can be used for most pest problems and in most types of spray equipment where agitation ispossible.

Dust

Most dust formulations are ready to use and contain a low percentage of active ingredients (usually 10% or less by weight), plus a very fine, dry inert carrier made from talc, chalk, clay, nut hulls, or volcanic ash. The size of individual dust particles varies.

A few dust formulations are concentrates and contain a high percentage of active ingredients. These concentrates are mixed with dry inert carriers before applying.

Dusts are always used dry and can easily drift to nontarget sites. They are widely used as seed treatments and sometimes for agricultural applications. In structures, dust formulations are used in cracks and crevices and for spot treatments to control insects such as cockroaches. Insects ingest poisonous dusts during grooming or absorb the dusts through their outer body covering. Dusts also are used to control lice, fleas, and other parasites on pets andlivestock.

Aerosols

These formulations contain one or more active ingredients and a solvent. Most aerosols contain a low percentage of active ingredients. There are two types of aerosol formulations: the ready-to-use type commonly available in pressurized, sealed containers and those products used in electric- or gasoline-powered aerosol generators that release the formulation as a "smoke" or "fog."

Ready-to-use aerosols are usually small, self-contained units that release the pesticide when the nozzle valve is triggered. The pesticide is driven through a fine opening by an inert gas under pressure, creating fine droplets. These products are used in greenhouses, in small areas inside buildings, or in localized outdoor areas. Commercial models, which hold 5–10 pounds of pesticide, are usually refillable.

Granular formulations

Granular formulations are similar to dust formulations except granular particles are larger and heavier. The coarse particles are made from materials such as clay, corncobs, or walnut shells. The active ingredient either coats the outside of the granules or is absorbed into them. The amount of active ingredient is relatively low, usually ranging from 1 to 15 percent by weight.

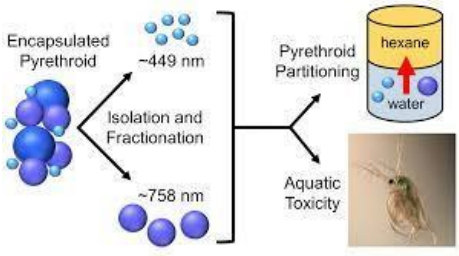
Granular pesticides are most often used to apply chemicals to the soil to control weeds, fire ants, nematodes, and insects living in the soil or for absorption into plants through the roots. Once applied, granules release the active ingredient slowly. Some granules require soil moisture to release the active ingredient. Granules are used in agricultural, structural, ornamental, turf, aquatic, and public health (biting insect) pest control operations.

Baits

A bait formulation is an active ingredient mixed with food or another attractive substance. The bait either attracts the pests or is placed where the pests will find it. Federal regulations require that certain rodenticide baits must be contained in tamper-resistant bait stations. Pests are killed by eating the bait that contains the pesticide.The amount of active ingredient in most bait formulations is quite low, usually less than 5%.

Baits are used inside buildings to control ants, roaches, flies, other insects, and rodents. Outdoors they sometimes are used to control snails, slugs, and insects such as ants and termites. Their main use is for control of vertebrate pests such as rodents, other mammals, andbirds.

Microencapsulated products



Manufacturers cover liquid or dry pesticide particles in a plastic coating to produce a microencapsulated formulation. Microencapsulated pesticides are mixed with water and sprayed in the same manner as other sprayable formulations.

After spraying, the plastic coating breaks down and slowly releases the active ingredient.

EXPERIMENT-10

AIM: To study about the pesticide appliances and theirmaintenance

Requirements: Different types of pesticide appliances

PESTICIDEAPPLIANCES

The application appliances or device must be able to apply the pesticide to the intended target at the proper rate. The label specifies the legal application rate and may suggest the appropriate equipment for use with the product.

Granular Applicators

Granular applicators are available for either band or broadcast applications. They may be operated as separate units but often are attached to other equipment, such as planters or cultivating equipment, to combine two or more operations. Granular applicators usually operate by gravity feed and have an adjustable opening to regulate the flow.

Band applicators use hoses or tubes with deflectors on the bottom to drop the pesticide along a row. Broadcast applicators use a system of tubes and deflectors or a spinner to spread the granules. The application rate is affected by ground speed; granule size, shape, and density; field terrain; and even relative humidity and air temperature. Calibrate each unit of a multiple band applicator with the specific material to be applied to ensure accurate application.

Rotary and drop spreaders are two common types of granular applicators. Rotary spreaders distribute granules to the front and sides of the spreader, usually by means of a spinning disk or fan. In a drop spreader, an adjustable sliding gate opens holes in the bottom of the hopper. Granules flow out of the hopper by gravity feed. Drop spreaders are superior to rotary spreaders when more precise placement of the pesticide is desired**.**

Sprayers

Sprayers range from large powered units with multiple-nozzle booms to small manual backpack or hand-held compressed-air sprayers. In all cases, pressure from either a pump or compressed gas or air is used to atomize the spray mix at the nozzle.

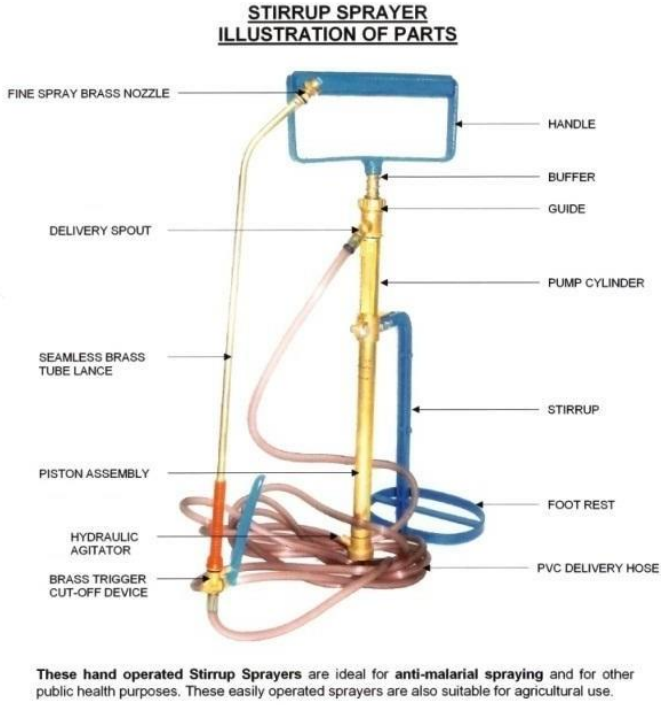
Manual sprayers are designed for spot treatments and for areas unsuitable for larger units. They are relatively inexpensive, simple to operate and maneuver, and easy to clean and store. Adjustable spray guns are often used with these units but some models have the option for a spray boom. The air-blast (or mist) sprayer uses both water and air as carriers. Spray droplets are formed by the nozzles and delivered to the target by an airstream. Air-blast sprayers are typically used for disease and insect control on fruit trees, vineyards, vegetables, etc

PESTICIDE APPLIANCES

HAND SPRAYERS

- This is a simplesprayer.
- The spray solution is filled in a plastic can (1-10 L) which is usually carried in hand or shoulder slung. A dip-tube draws liquid from the tank due to hand actuation of theplunger
- Hydraulic pressure is created by direct action of hand pumping, which force spray solution to anozzle.
- It is not possible to retainpressure.
- Due to pressure fluctuation the nozzle performance is notstable.
- The discharge rate varies, spray angle changes and spray droplets size fluctuates. It is difficult to ensure thorough coverage.
- This sprayer is suitable for small scale application in nursery or kitchen gardens etc. It is not a good sprayer for large areatreatment.
- The capacity of this sprayer is about 0.5 acre perday.

STIRRUP PUMP SPRAYER



- This sprayer is used both for public health spraying and agricultural sprayingpurposes.

COMPRESSION SPRAYER

- It comprises of a cylindrical metal tank for holding the spray liquid, a hand operated piston type air pump, a filler hole in the tank out let with delivery pipe, cut-off, lance and hydraulicnozzle.
- 18 litre capacity sprayers are commonly used for fieldspraying.
- The filtered spray solution is filled to 2/3 of the tank capacity. Then the air pump is operated by hand and air pressure (50-60 psi) is built up. The compressed air exerts pressure to move spray liquid to the nozzle via delivery pipe, cut-off device & lancesystem.

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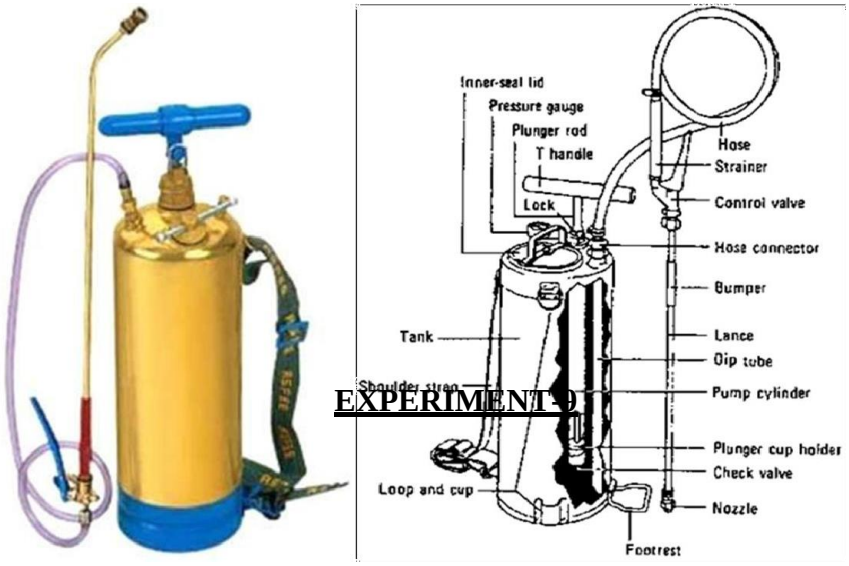
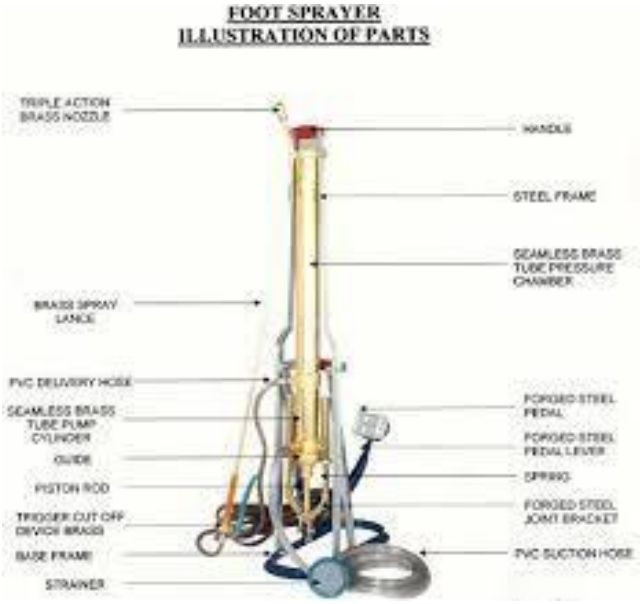


EXPERIMENT-9

FOOT OPERATED SPRAYER

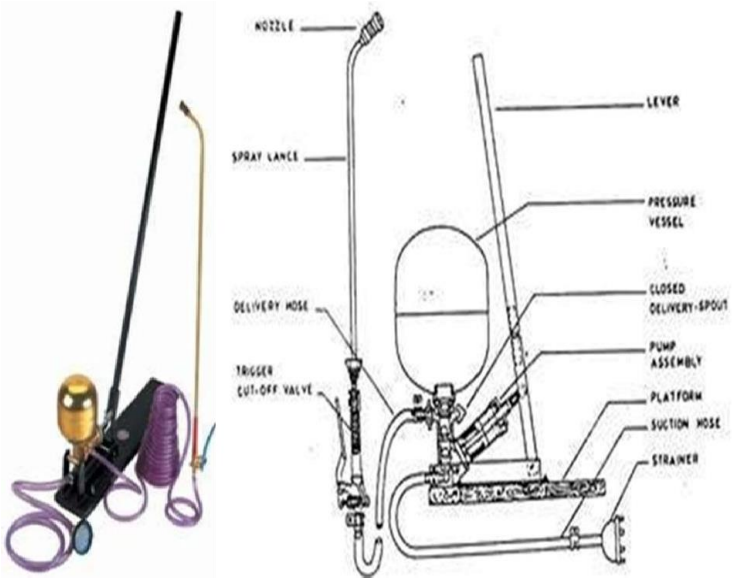
- The pump of the sprayer is worked by operating a pedal lever by the foot of the operator. The spray liquid is kept in bucket or container and it is sucked by a suction hose through a filter (strainer) due to piston movement. The liquid from the pump cylinder is then delivered into a pressure chamber where from the pressurized liquid reaches hydraulicnozzle.
- The foot operated sprayer is basically for orchard and treespraying.

- Hydraulic pressure of 10 kg/cm^2 can be achieved which is necessary to project the jet of spray to tall trees simultaneously from two spraynozzles.
- 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 heightorchards.
- Jet spray is necessary for treespraying.
- The spray jet can reach height of 15 - 20 feet. Forspraying taller trees an extra extension like bamboo lance may be used to gain additional height by 8 - 10feet.



ROCKER SPRAYER

- It is very much similar to the foot sprayer. The main difference is the operation ofpump.
- The pump actuation is done by hand of the operator. The sprayer pump mounted on wooden platform is kept on ground and the spray solution is kept in a separate tank orcontainer.
- It can develop high pressure 10kg/cm^2.



- For spraying tall trees, an extension bamboo lance can be fitted. The adjustable type hydraulic nozzle (Triple Action Nozzle) is normallyused.

KNAPSACK SPRAYER

- It is commonly known as knapsacksprayer.
- The sprayer is mounded on the back of operator with help of a pair of mounting straps. The pump of the sprayer is actuated byworking

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 andnozzle.
- A bean shaped plastic tank of 14-16 litres capacity is commonlyused.
- It is necessary to operate the hand lever continuously at the rate of 15-20 strokes perminute.
- The normal working pressure is 40psi.

POWER SPRAYER.

- Thesearehigh capacity power operated hydraulic sprayers.
- They are the high volume spraying machines good for large scale application in orchards and tree crops.
- The source of power is engine or electricalmotor.
- A pressure regulator is used to control the pressure in the discharge lines and bye-pass from the pressure regulator is used for hydraulic agitation in spraytank.
- High pressure like 400 psi can be built up and large spray discharge rate like 30 L/min. can be obtained.
- The engine or electrical motors 3 - 5 HP capacity power thesprayer.

Sprayer Components

Tank

A tank is necessary to contain the spray mix. Choose one made of, or coated with, a material that does not corrode and that can be cleaned easily. Cleaning prevents accumulations of corrosion and dirt that clog screens and nozzles, increasing wear on the equipment. Large tanks require an opening in the bottom to aid in cleaning and draining. A large top opening is useful for filling, cleaning, and inspecting the tank. The opening must have a watertight cover to prevent spills. A tank agitation system/ device is useful for most sprayable formulations, especially for wettable powders or dry flowables. Constant mixing of a pesticide and liquid carrier produces a uniform spray mixture (suspension) and results in an even application of thechemical.

Exposure to sunlight and corrosive chemicals can shorten the life of polyethylenetanks.

Three common signs of wear and potential tank failureare:

- **Scratches**are on the surface and can be seen andfelt

- **Crazing**is a network of fine lines or cracks that may look like a patchwork, but often cannot beseen with a visual inspection. Crazing can be seen when using one of the testing methods explained below. Crazing occurs within the tank wall and can be a sign of deterioration of the plastic, which may lead to cracks**.** Tanks that show signs of crazing will still hold liquids, but the integrity of the tank is questionable. For this reason, caution should be used when putting any hazardous substance in tanks that showcrazing.
- **Cracks**extend through the plastic wall and can be visually seen and felt. Cracks may run parallel or at right angles to eachother.

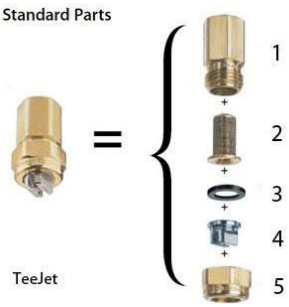
Pump

A pump agitates the spray mixture and produces a steady flow to the nozzles. Pump parts must resist corrosion and abrasion, especially when wettable powders or similar formulations are used. Never operate a sprayer pump at speeds or pressures above those recommended by the manufacturer. You may damage the pump if it is operated dry or with a restricted flow at the inlet or outlet. Pumps depend on the spray liquid for lubrication and to prevent overheating.

Nozzles

The proper selection of a nozzle type and size is essential for proper pesticide application. The nozzle is a major factor in determining the amount of spray applied to an area, the uniformity of application, the coverage obtained on the target surface, and the amount of potential drift.

Nozzles break the liquid into droplets, form the spray pattern, and propel the droplets in the proper direction. Nozzles determine the amount of spray volume at a given operating pressure, travel speed, and spacing. Drift can be minimized by selecting nozzles that produce the largest droplet size while providing adequate coverage at the intended application rate and pressure.



Nozzle parts:

1) The nozzle body holds the strainer andtip;
2) A strainer screen prevents a clogged nozzle. It is the best defense against nozzle plugging and pump wear. The screen can remove dirt and rust flakes from the spray liquid before it reaches thenozzle.
3) Tipgasket
4) The spray tip determines the flow rate and dropletpattern;
5) The cap holds the nozzle body and tip inplace.

The Spray Tip

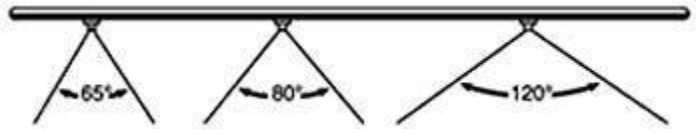
The spray tip determines the flow rate and droplet pattern.

110 is the spray angle in degrees, 04 is the output - 0.4 gallons per minute at 40 psi

Equip nozzle tips with check valves to help prevent dripping when the pump is off. Be sure the spring-loaded ball valves are working properly.

Nozzle Spray Angle, Spacing, and Boom Height

Nozzle spray angle is formed by the edges of the spray pattern. Common angles are 65°, 80°, and 120°. A wide-angle nozzle (110°) produces a thinner sheet of water with smaller droplets than a narrow angle nozzle (65°) with the same delivery rate.



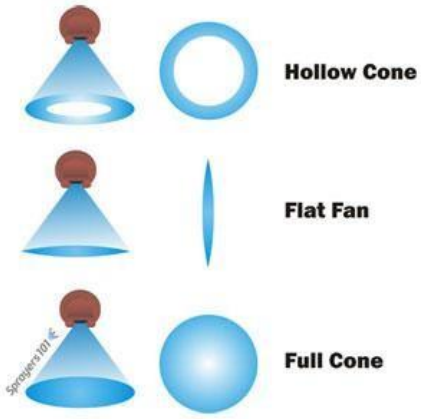
Flow meters and other devices measure the uniformity of nozzle flow rate from nozzles along a boom. They are very useful when calibrating sprayers with multiplenozzles.

Common Nozzle Spray Patterns

Hollow cone nozzles produce a fine spray pattern to completely cover leaf surfaces.

Flat fan nozzles form narrow, oval patterns with tapered ends. They are spaced along a boom and overlap by 30% to 50 % for even broadcast spray distribution to the soil surface or plant canopy.

Full cone nozzles produce large, evenly distributed droplets at high flow rates. These two cone nozzles are best suited to apply fungicides and insecticides.



Three common nozzle spray patterns: hollow cone, flat fan and full cone

Nozzle Maintenance

- Nozzles are available in various materials: brass, aluminum, plastic, stainless steel, hardened stainless steel, and ceramic. Select the material best suited for the pesticide formulation being used.
- Never use brass or aluminum tips to apply abrasive materials (such as wettable powders and dry flowables) because they wear too fast. This wear increases the opening size of the nozzle, which increases itsoutput.
- Reduce wear by using nozzle tips made of a hard, wear-resistant material: plastic, hardened stainless steel, orceramics.

- Be sure you have the correct screen size for eachnozzle.
- Clean nozzle tips with a soft brush, not wire or a knifetip.

Sprayer Cleanup

- Clean your equipment thoroughly after each use or when changing chemicals. Pesticide residues can corrode metal, plug hoses, or damage pumps and valves unless removed immediately after use. Sometimes residues react with pesticides used later, reducing the effectiveness of the pesticides or causing crop damage. Some pesticide labels provide specific information on cleaning spray equipment; consult the label forguidelines.
- Do not clean spray equipment in areas where rinse water will contaminate water supplies, streams, or injure susceptibleplants.
- Mixing, loading, and application equipment should be cleaned and rinsed as soon as pesticide application isfinished

Pay special attention to areas that can be missed or are difficult to clean:

- Spray surfaces or components where buildup of dried pesticides mightoccur
- Inside the top of the spray tank and aroundbaffles
- Irregular surfaces inside tanks caused bybaffles
- Plumbing fixtures, agitation units,etc.
- Collection points where the hoses connect to the nozzle fittings in dry boomsprayers.

Special tank-cleaning nozzles are available to clean the interior walls of spray tanks. For all application scenarios, make sure the entire spray system is cleaned, not just the tank. This is especially true for commercial row-crop boom sprayers. Besides the spray tank, problem spots for pesticide contamination include the inductor; plumbing, which includes valves and hoses; filters and screens; boom segments; nozzle bodies; and nozzles and screens.

When possible, thoroughly rinse equipment with a strong water-detergent solution. Allow the water-detergent solution to circulate through the system for several minutes. Remove the nozzles and screens, then flush the sprayer system twice with clean water. Some pesticide labels may require triple rinsing to rid the spray system of any possible pesticide contamination. Regardless of how the spray system is cleaned, make sure all visible deposits areremoved.

Sloppy cleanup practices are one of the main causes of equipment failure or malfunction. Pesticides allowed to dry in the application equipment tend to clump and stick and cannot be easily removed. These deposits may eventually dissolve into the spray solution. Thus, improper cleanout may lead to contamination of tank mixes and damage to susceptible crops. Several commercial compounds will

aid in tank cleaning. These can neutralize and remove pesticide residues, remove mineral deposits and rust, and leave a protective film on tank walls to help preventcorrosion.

Protection of Sprayer

When preparing to store the sprayer, add lightweight oil (depending on the size of the tank) before the final flushing. As water is pumped from the sprayer, the oil leaves a protective coating on the inside of the tank, pump, andplumbing.

To prevent corrosion, remove nozzle tips and screens and store them in a can of light oil, such as diesel fuel or kerosene. In addition, add a small amount of oil and rotate the pump four or five revolutions by hand to coat interior surfaces completely.

It may be necessary to winterize the spray system to prevent damage from freezing temperatures. After thoroughly cleaning and draining the equipment, store it in a dry, clean building.

Replace worn-out, deteriorated, or broken parts.

Remove the hoses, wipe them clean of oil, and store them inside where they will not become damaged.

As with any pesticide-related procedure, remove contaminated clothes and take a shower immediately after cleaning equipment. Waiting until the end of the day to clean up may allow additional absorption of the pesticide through theskin.

EXPERIMENT-11

AIM: To study about the sampling techniques for estimation of insect population and damage

Requirements: Clipboard, Pencils, Hand lens, Pocket knife, insect catching nets, attractants, spread sheet Collection bags and vials, Camera etc.

Sampling techniques are used to draw valid inferences about the population parameters using the sample statistics

Components of an insect sampling program

Knowledgeofpestandbeneficialinsects

Identification

Life cycle andbiology

Injurycaused

Sample: Sample is a subgroup of the population. It is defined as a collection of individual observations from the population about which inferences are to be made, and is obtained by a specific method.

Sampling: It refers to the process of selecting a portion of the population to represent the entire population.

Sampling gives valuable information:

- Detect pestpresence
- Detect damagingstage
- Presence of naturalenemies
- Populationsincreasingordecreasingindensity(fromrepeatedsamples)
- Effectivenessofcontrolmeasures

Nature of sample

This depends on the insect, its distribution and the stage of the pest to be sampled. The methods are:

1. Netsweepings	9. Sightcounting
2. Suddentrappings	10. Fixed volume or area ofearth
3. Narcotizedcollections	11. Crop samples
4. Light trapcatch	12. Emergencecages
5. Water trap	13. Amount ofdamage
6. Suction trap	14. Marking andrecapture

7. Adhesive or inspection or stickytraps	15. Colonies of socialinsects
8. Bait trapcatch	16. Transect and pointsampling

- **NetSweepings**

- The points to be considered in this methods assessment are time of sampling, density and height of the crop, the number of sweeps required and the type of insect pest involved in thestudy.
- A sweep consists of a half circle 0r 180º swing with a hoop of 43 cm insect held in a verticalplane.
- The length of the handle should be onemeter.
- Usually ten sweeps may be sufficient to assess the general population of any species and the population is terms of number per 100sweeps.
- This method is useful in insects like adult beetles, nymph and adults of bugs andgrasshoppers.

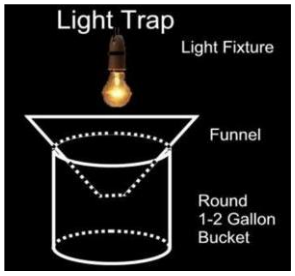
Sudden trappings

- Insect in a unit area are suddenly trapped with suitable traps without causing disturbance and trapped insects are latercounted.
- This is useful in the case of collembola, certain grasshoppers, sorghum earhead bugetc.

Narcotized collections

- This method is useful for counting quick movinginsects
- The insects are killed by spraying non persistent chemicals such as dichlorvos, pyrethrum etc. or anesthetized
- Falling insects are collected on a sheet below the plant andcounted
  e.g. mirid bugs on fruit trees

Light trap catch



- This method is useful in the quantitative estimation of seasonal abundance of several species of moths and other insects which are attracted tolight.
- Most effective bulbs to use for survey trapping would be 60W ‘black lightbulb’.
- The brood emergence of the rice stem borer *Scirpophagaincertulas*and defoliating beetles are fixed by light trapcatches.

Water trap

- A floatation pan trap is used for insects associated with watersurface

Suction trap

- In this method the flying insects are trapped by sucking air into some form of trap with a sucking apparatus operated either by hand or by means of amotor.

Adhesive or inspection or Sticky traps

- A suitable persistent and adhesive material like gum, grease, tar etc. which do not dry out, is spread on strips of paper and supported on acylinder.
- Such sticky traps set in the fields and flying insects are trapped inthem.
- The factors like wind velocity, temperature, colour of the trap etc. Have a bearing number of the insects caught in suchtraps.
- It is also necessary to clean the traps often; otherwise the efficiency of the trap may godown
- Used for aphid migrationstudies
- Yellow sticky traps have been used to trap adults of the aleyrodids (*Bemisiatabaci*and *Trialeurodesvaporariorum*) for monitoring.

Bait trap catch

- Many materials varying from raw plant materials and crushed insects to refined chemical attractants which stimulate sexual odours or food odours are known to attractinsects.
- These materials are used as baits in special type of traps made for the purpose depending on the insect species to betrapped.
- This type sampling is more complex and is utilized in the case of fruitflies.

Sight counting

- The population of the insects in measured area iscounted

Fixed volume or area of earth

- For soil insects like grubs this method is suggested wherein the soil samples of known volume are taken from fixed area to fixeddepths.
- Insects extracted from these samples which can be done by Berless funnel method, floatation method, hand picking method etc. thencounted.

Emergence cages

- Emergence cages of known sampling area are used so that emerging adults are trapped and counted.

Crop samples

- The population of the insect in the crop samples drawn is counted andrecorded.
- This method is very widely followed in economic entomology with reference to insect pests like rice stem borer, sorghum stem borer, gall midges, aphids, thrips, ballworms
- However the technique are to be perfected depending on the pest species andcrops

e.g. in cotton for estimating the population of aphids, leaf hoppers and thrips – leaves from terminal, central and basal portions of the plants are examined.

Amount of damage

- The degree of damage is taken as the index in estimating the population fluctuation ofpest.
- In cotton four grade of damage due to leaf hopper attack have beenrecognized.

Marking and recapture

- A large number of individuals are marked with paint or tagged, released in the field to mix with general population and later collected at different distances from the releasingpoint.
- This would be helpful in assessing population, growth and activity of the pestspecies.
- Tagging insects with radio-active tracers is anothermethod.
- This type of study is mainly intended for study of rate of dispersal, flight range and migration of insects.

$$\text{Population density} = \frac{N1 \times N2}{N3}$$

$_1$ = no: of individuals marked and released

$_2$ = total no: of individual captured second time (with and without a mark)

$_3$ = total no: of individual recaptured (with a mark)

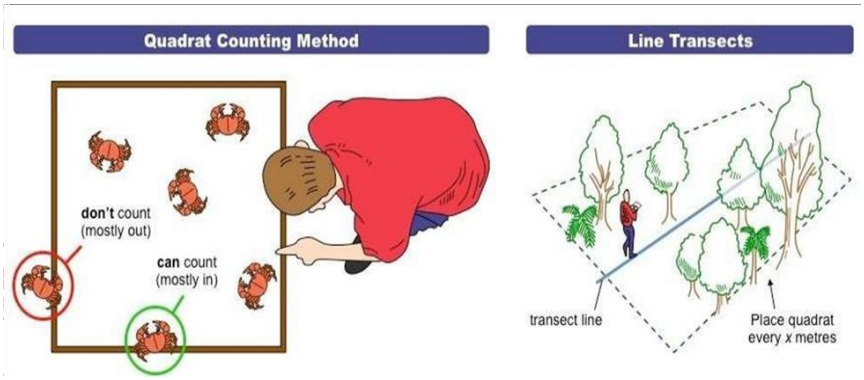
Colonies of social insects

- Though a very difficult process especially in ants and termites, the counting of individuals is done generally during cold weather when they will beinactive.
- In honey bee it is further complicated as the population to be assessed insections.
- In the case assessing field bee population, the difference between the maximum (morning) and minimum (afternoon) weights of the hive gives the weight of filed bees from which the actual population iscomputed.
- Similarly the area of the brood cell given an idea of the population of thebrood.

Transect sampling

- In transect samples, the person taking the samples follows a predetermined sampling path and records the presence of all organisms that are to be counted within a fixed distance (i.e. 1m, 5m) on either side of a specified length of travel along thetransect.
- Data reported as the no: of organisms per unit of ground surface, calculated as length traveled along the transect times, lateral distanceexamined.

i.e., if someone traveled 100m along the transect and counted all ladybugs within 1m on either side of the transect they would report data as the number per 200 m².



Point sample technique

- Fixed sample sites are established and the person making the counts moves from sites to site recording the no: of organisms observed during a predetermined period of time (i.e., 5 min, 10 min) at each samplesite.
- Sites should be chosen so that all habitat types within the study area areincluded.
- These data reported as the no: of organisms per unit observation time (i.e., number of butterflies per 15minutes).