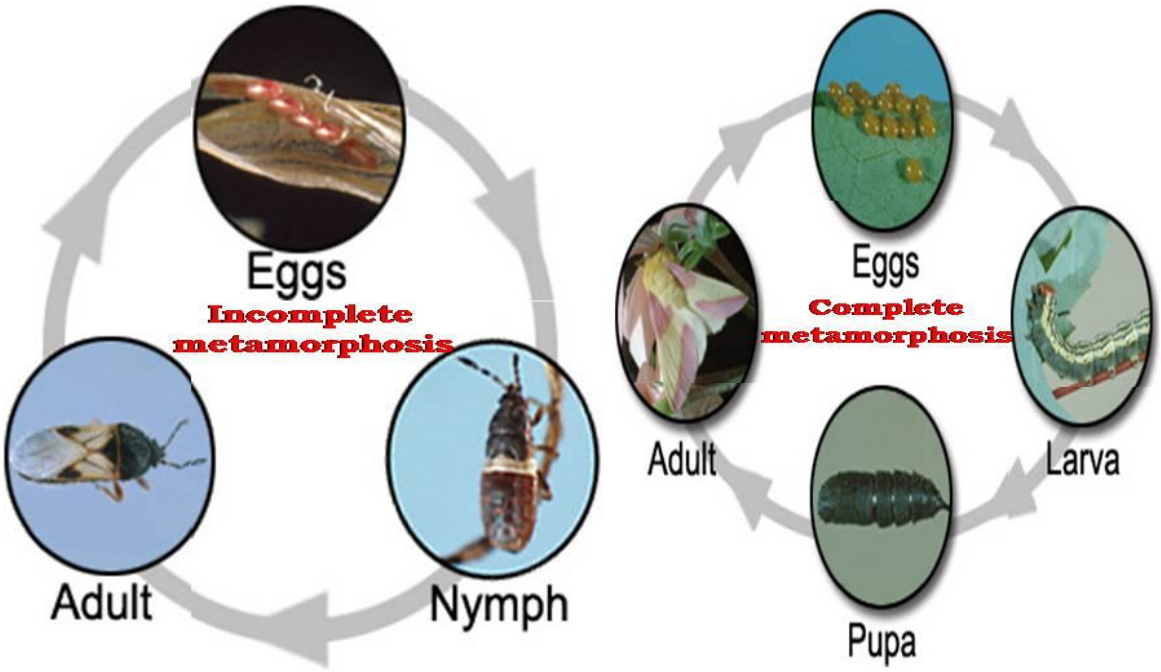
JUNAGADH AGRICULTURAL UNIVERSITY

PRACTICAL MANUAL
OF
Ag. Ento. 3.1: FUNDAMENTALS OF ENTOMOLOGY
Credits: 2+1

FOR
THIRD SEMESTER (HONS.) AGRICULTURE

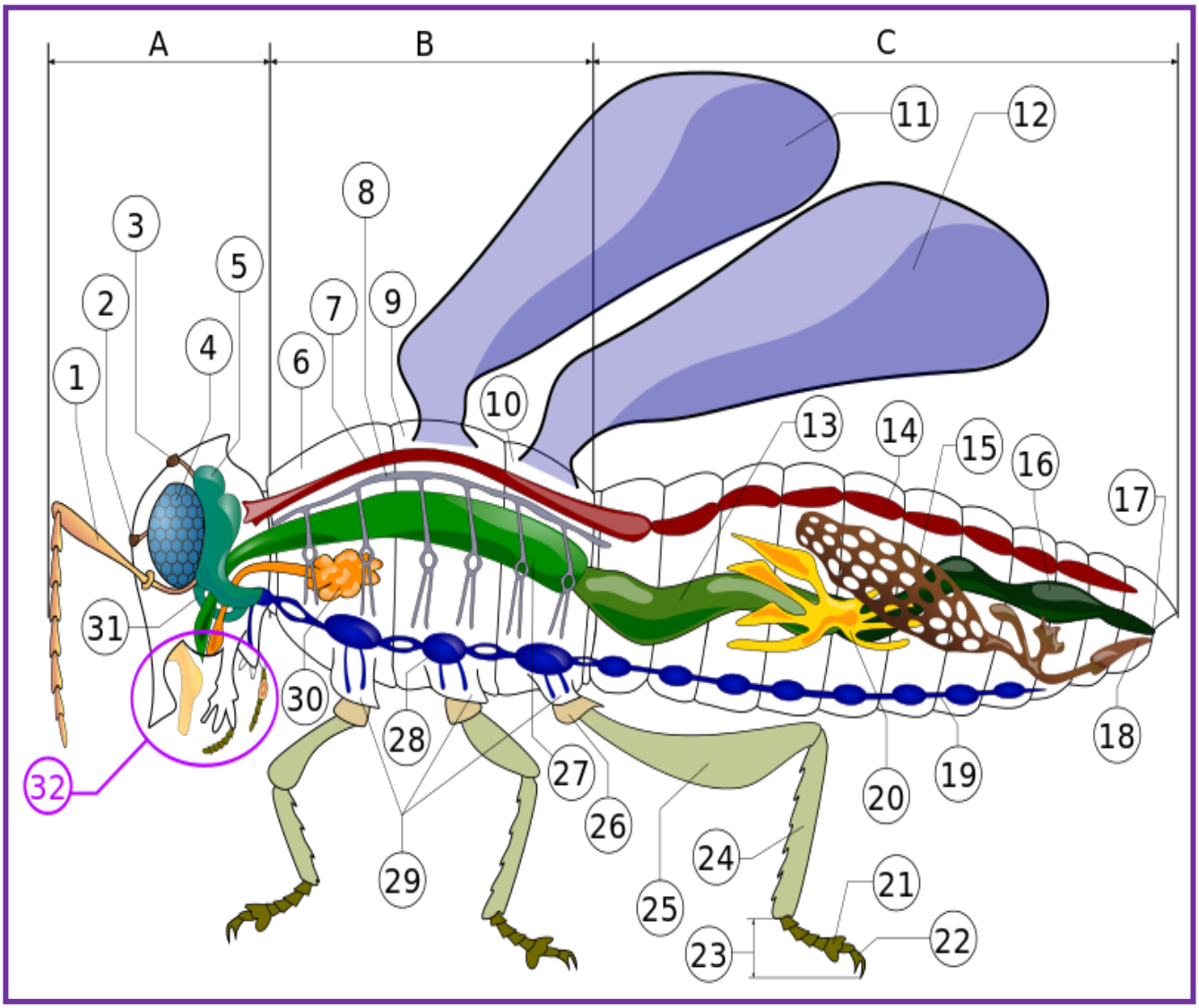
Compiled by

Dr. V. C. Gadhiya, Assistant Professor
Prof. M. K. Kanani, Assistant Professor



COLLEGE OF AGRICULTURE
JUNAGADH AGRICULTURAL UNIVERSITY
MOTA BHANDARIYA, AMRELI – 365 610
JULY, 2018

General Body Organization of Insect



A - Head
1. Antenna
2. Ocelli (Lower)
3. Ocelli (Upper)
4. Compound eye
5. Brain (Cerebral ganglia)

6. Prothorax
7. Dorsal artery
8. Tracheal tubes (Trunk with spiracle)
9. Mesothorax

10. Metathorax
11. First wing (Fore wing)

B - Thorax
12. Second wing (Hind wing)
13. Mid-gut (Stomach)
14. Heart
15. Ovary
16. Hind-gut (Intestine, Rectum & Anus)
17. Anus
18. Vagina
19. Nerve cord (Abdominal ganglia)
20. Malpighian tubes

21. Pillow
22. Claws

C - Abdomen
23. Tarsus
24. Tibia
25. Femur
26. Trochanter
27. Fore-gut (Crop, Gizzard)
28. Thoracic ganglion
29. Coxa
30. Salivary gland

31. Subesophageal ganglion
32. Mouthparts

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JULY, 2018

Name of Student:……

Registration No.:…… Roll No.:……

CERTIFICATE

Uni. No.: _____ Registration No. _____

This is to certify that Shri/Kumari _____ _____ has satisfactorily carried out the practical exercises of Course No.: Ag. Ento. 3.1, Course title: **Fundamentals of Entomology (2+1)** during the academic year _____.

The exercise No.: ____ have/has been found incomplete.

Date: / / 201 **Course Teacher**

External Examiner

I N D E X

EXERCISE – 1
METHODS OF COLLECTION AND PRESERVATION OF INSECTS INCLUDING IMMATURE STAGES

Date:_____

1.1 Objectives

(1) To acquaint the students with the different techniques of insect collection, killing and preservation including immature stages so they do not get spoiled and can be stored for a longer period to form a reference collection for future use.
(2) To learn to locate and capture specific insects in their habitats.
(3) To learn the correct methods of preserving insects for study reference.

1.2 Materials

Insect Collecting net, Forceps, Camel hair brush, Collection bag, Aspirator, Insect collecting vials, Plastic jars, Insect killing jar, Entomological pins, Pinning block, Spreading board, Labels, Card papers, Insect storage box, Preservatives etc.

1.3 INSECT COLLECTION

1.3.1 Materials required for insect collection

(1) Insect collection net
(2) Forceps
(3) Camel hair brush
(4) Collection bag
(5) Aspirator
(6) Collecting vials
(7) Plastic jar
(8) Soil digging tool/Trowel

1.3.2 When and where to collect the insects

Insects are present in virtually every habitat. The more places a person looks for insects the greater will be the variety collected. Insects may be found flying in the air or live in the soil. They may be found in the water, on vegetation or under plant debris, tree bark, logs and stones as well as on the coldest day of the year. Insects are most abundant throughout the year.

Certain insects such as moths, mosquitoes, bed bugs etc. are active at night time and may best be collected at night while butterflies, dragonflies and most hymenopterans are active during day time and therefore they can be easily collected during day.

1.3.3 Hand picking

This method is suitable for large insects like Grasshoppers, Beetles and large size larvae etc. It is a tedious method. It is unsuitable for insects inflicting painful bites and stings. Hand picking should be done by wearing hand gloves.

1.3.4 Insect collecting net

It is use to catch actively flying insects particularly adult stage of various insects viz., Butterfly, moth, dragonfly, damselfly etc. There are two types of insect nets.

(1) **Aerial net:** It is light in weight. It is useful for catching active fliers like moths, butterflies, dragonflies, flies, wasps, etc. The net consists of three parts viz., hoop, handle and porous cloth bag made out of mosquito netting material. It has a small hoop (30-40 cm dia.) and a long handle (100 cm). The diameter of the hoop and the depth of the bag should be in the proportion of 1:2. This net can be home made by using an old badminton racquet.

(2) **Sweep net:** This is heavier than the aerial net. It consists of a short handle, a large hoop and a muslin cloth bag. This is suitable for collecting leafhoppers, grasshoppers and other small insects. The net is swept over vegetation. The handle is turned by quick turn of the wrist to fold the cloth bag over the hoop in order to prevent the escape of trapped insects.

1.3.4.1 Methodology for the preparation of insect collection net

(1) To prepare the arial net make a hard wire hoop of 30-40 cm diameter and a long PVC or wooden handle of 100 cm length.

(2) The diameter of the hoop and the depth of the bag should be in the proportion of 1:2.

(3) Take porous cloth bag made out of mosquito netting material.

(4) It should be light in weight.

1.3.5 Aspirator

This is very useful device for capturing small insects like aphids and jassids particularly if you want to keep them alive. Usually sucking through the mouthpiece draws small insects into the vial and a cloth over the inner end of the mouthpiece tube prevents the insects from being sucked into the mouth.

1.3.6 Insect traps

Traps are an easy and often very effective method of collecting many types of insects. A trap is any device, often containing something to which the insects are attracted, that is so arranged that once the insects get into it, they cannot get out. The attractant used and the general form of the trap are determined by the type of insects you want to collect.

Sex lure trap	:	Moths
Food lure trap	:	Flies
Sticky trap	:	Aphids, Whiteflies, Thrips
Light trap	:	Phototropic insects
Suction trap	:	Whiteflies

1.3.7 Containers

The collector should be equipped with a variety of containers in which to hold collected specimens. Many good specimens are damaged or ruined because of inadequate containers for holding and transporting. Containers should be large enough to accommodate specimens without cramping or bending them. This requires large containers for dragonflies, butterflies, and other large, delicate insects. Required containers should be provided to prevent overcrowding as well as some of the rare or delicate specimens should be kept individually. Generally collectors are use cigarette boxes, match boxes, soap boxes, plastic jars, test tubes, vials, medicine bottles, Plastic bags etc.

1.4 INSECT KILLING

Effective collection of insects requires that the specimens are being killed so that they may be properly mounted and studied. The most widely employed method for the killing collected specimen is the killing jar. Any wide-mouthed glass jar or bottle with a tight-fitting stopper or metal screw top may be used.

The liquid or solid killing agent may be used. Liquid killing agents generally considered being slower acting but safer to use than solids such as cyanide but some of them are known to accumulate in human tissue after repeated or prolonged exposure.

1.4.1 Solid killing agents

Mostly used solid killing agents in killing jars are the cyanides, potassium cyanide (KCN), sodium cyanide (NaCN) or calcium cyanide [$Ca(CN)_2$].

1.4.2 Materials used to prepare a KCN insect killing jar:

(1) Glass jar with tight lid (500 g)
(2) Mask
(3) Hand gloves
(4) Tea spoon
(5) Potassium cyanide (KCN)
(6) Saw dust
(7) Wooden butt
(8) Blotting paper
(9) Plaster of Paris
(10) Label

1.4.2.1 Methodology for the preparation of insect killing jar

(1) First take a clean 500 g glass jar with tight fitted lid.
(2) Add one tea spoonful of KCN powder and spread it properly on bottom of the jar.
(3) Fill saw dust in the jar and press it with wooden butt to make a 5 cm thick layer over KCN.
(4) Cut a circular disc of blotting paper equal to the inner diameter of the bottom of jar.
(5) Prepare a thin paste of Plaster of Paris in a beaker and pour it on the edge of the blotting paper in the jar by rotating it in slanting position.
(6) Cover the lid tightly and keep bottle undisturbed for drying the paste.
(7) Label the killing jar **"POSION" DON'T TOUCH"** written in red colour and bold letters in English and in vernacular along with the skull and cross bone symbol.

1.4.2.2 Precautions to be taken while handling a KCN insect killing jar

(1) Proper labeling - "POSION" DON'T TOUCH" in clear, bold and bright red coloured letters.
(2) Do not test killing jar by sniffing the open jar.
(3) Avoid overloading the bottle with insects.
(4) Use a separate large killing bottle for moths and butterflies and another for beetles and grasshoppers.
(5) Never mix delicate/scaly and small insects with large insects like beetles and grasshoppers.
(6) Take out dead insects within 30-40 minutes; otherwise they become brittle and discolored which is difficult to spread/handle.
(7) Do not allow the bottle to sweat.
(8) Keep bottle away from children in lock and key. Never give to an unauthorized person.
(9) Never keep the jar open, when not in use.
(10) A cyanide jar that has become dry may be reactivating by adding a few drops of water.

1.4.3 Liquid killing agents

The liquid killing agents are ethyl acetate, ether, diethyl ether, chloroform etc. among them ethyl acetate is most widely used. All of these chemicals are extremely volatile and flammable. Ethyl acetate is the most used liquid killing agent. Its fumes are less toxic to

humans than those of the other substances although it kills them slowly. Unlike KCN the specimens does not become hard in exposing with an ethyl acetate for longer period of time.

Ethyl Alcohol (ethanol or ETOH) is widely used to kill small coleopteran adults, small hymenoptera and many immature insects and soft-bodied insects. It is most commonly used at 70-80% concentration and many workers add 5% glacial acetic acid ("acetic alcohol") which helps penetration of the alcohol into specimen and leaves specimens more relaxed.

1.5 INSECT PRESERVATION

After collecting and killing the insect specimens it should be properly preserve by dry and liquid preservation methods according to type and stage of the insect.

1.5.1 Dry preservation of insect specimens

(1) Paper folds

They are useful for temporary preservation and storage of large winged insects such as dragon files, butterflies or moths. These triangular envelopes can be made from a sheet of note book or by using absorbent type of paper used in duplicating machines.

(2) Spreading board

It is a centrally grooved wooden board. Flat cork strips are glued on either side of the groove and in the bottom of the groove to enable pinning. A sheet of cork, balsa wood and other soft material like thermocole with a centrally cut groove can also be used as a material for the preparation of spreading board. Insect spreading boards are used to facilitate proper spreading of wings and setting legs, antennae and abdomen in natural position so as to reveal maximum structures like forewings should be stretched and fixed in such a way that hind wings can be seen properly. There are two types of insect setting boards. **Sliding type:** One side top is fixed on bottom board while the other top is sliding for adjusting the width of pinning slit. **Fixed type:** Both side tops are fixed on bottom board.

Some care should be taken while spreading the insects on spreading board *viz.*, Insert the pin in middle of the slit. Stretch the front wings as it makes a right angle between anal margin and body line. Set the antenna in natural position. Arrange legs in pinning slit in natural position. Expose hind wings to the maximum extent and provide a card bridge below abdomen when it is stout one. Fix the wings in position using card paper strips and pins.

(3) Relaxing jar for brittle insects

Mount all insects as soon as possible after they have been collected. If they are allowed to dry they become brittle and are easily broken in the process of being mounted. Specimens stored in killing jar or envelopes for a long time must be relaxed before they are mounted. Relaxing may be accomplished with a relaxing chamber or a special relaxing fluid or sometimes hard bodied insects such as beetles can be relaxed enough to pin by dropping them in hot water for a few minutes.

A relaxing chamber can be made of any wide-mouthed jar that can be made airtight. The bottom of the jar is covered with wet sand (preferably with a little phenol added to prevent mold). The insects are put in the jar in open, shallow container and the jar should tightly close. Special jars for this purpose can also be obtained from supply houses. The collector must learn by experience how long it takes to relax an insect, but after a day or two in such a chamber specimens are usually sufficiently relaxed to mount.

(4) Pinning of insect

Pinning is the best way to preserve hard-bodied insects. Pinned specimens keep well, retain their normal appearance and are easily handled and studied. Common pins are undesirable for pinning insects. They are too thick, too short and they rust. Insects should be pinned with a special type of steel pin known as an insect pin. These pins are longer than common pins, they can be obtained in various sizes (thicknesses), and they never rust. Insect pin sizes range from 00 to 7. Number 2 or 3 pins are best for general use. Size 7 pins are longer than the other sizes. These pins are used in pinning very large insects, such as some tropical beetles.

Insects are pinned vertically through the body. Depending upon the size of the insect the pin has to be selected. The easiest way to pin an insect is to hold it between the thumb and forefinger of one hand and insert the pin with the other. Mount all specimens at a uniform height on the pin, about 1/3rd length of the pin should be above the insect to permit a comfortable finger hold. Exact place of insertion of the pin varies among different groups of insects are given below.

Sr. No.	Name of the insects	Site of pinning
1	Moths and Butterflies, Bees, Wasps and Flies	Through the thorax between the bases of the front wings.
2	Bugs	Through the scutellum, a little right of the midline if the scutellum is large.
3	Grasshoppers, Cockroaches, Crickets and Mantids	Through the posterior part of the pronotum, just to the right of the midline.
4	Beetles, Weevils, Earwigs and Large hoppers	Through the right forewing (elytra), about halfway between the two ends of the body.
5	Dragonfly and Damselfly	Through the thorax, with the left side uppermost.

(5) Micro pinning and staging

In this method, smaller insects like bugs, flies, hymenopterans parasites etc. are pinned with minute pins which are short and very thin. These pins are soft and difficult to insert in hard cork sheet and therefore staged on rectangular piece of soft material like thermocole. The piece of thermocole is pinned along with label kept in insect storing box.

(6) Carding

Small insects like termite soldiers, ants, hymenopterans parasites, thrips, aphids, jassids, whiteflies etc. are difficult to pin directly. Therefore, these are pasted on rectangular card (25x10 mm) or triangular card (20x10 mm) with the help of acacia gum. The card with insect is pinned and kept in insect storage box.

(7) Insect pinning block

These can be rectangular pieces of wood containing holes drilled to different depths or blocks shaped like stair steps with holes drilled to the bottom. The block usually has the holes drilled to depths of 25, 16, and 9.5 mm. After placing a specimen or label on the pin, insert the pin into the appropriate hole until it touches bottom into the deepest hole for the

specimen, the middle hole for the label bearing the locality and date, and the last hole for any additional label.

(8) Insect drying cabinet

The insects after killing, pinning and setting are dried before storing in insect boxes. The setting boards with insects are kept in insect drying cabinet.

It is a wooden air tight cabinet with double door system. Calcium chloride or other highly hygroscopic material is kept in an open jar inside the cabinet on the bottom. The chemical absorbs moisture from insect body without causing discoloration. Drying of insects through direct exposure to radiation heat may result in fading of colour of insects.

(9) Storing the dried insects

The dried insects are stored in an insect storing box in a systematic manner. They may be stored according to orders and family or according to the category of host plants if these are pests. Each insect should carry a small card paper label below it containing name of collector, place, host plant and date of collection. Two slits are provided on the short side of bottom part of storage box for filling crystals of naphthalene. Naphthalene balls should be kept inside insect box containing dead insects to keep away scavenging insects like ants and book louse.

1.5.2 Liquid preservation of insect specimens (for immature insect's stages)

Any type of insect can be preserved in fluid. Insects can be preserved in fluid temporarily until one has an opportunity to pin them, and many collectors prefer to store their collections in fluid rather than dried in envelopes.

Preservation in fluids is the standard means of preservation for the following: (1) soft-bodied insects (for example, mayflies, caddisflies, stoneflies, midges, and others), which would shrivel and become distorted if pinned and allowed to air-dry (2) many very small insects, which are best studied in detail when mounted on a microscope slide (for example, lice, fleas, thrips, collembolan (3) insect larvae and most insect nymphs and (4) arthropods other than insects.

The fluid generally used for preserving insects and other arthropods is ethyl alcohol (70-80%). The preservation or fixation of tissues is better for many forms if certain other substances are added to the alcohol. Ethyl alcohol can also be used as a killing agent for many insects and other arthropods, but it is unsatisfactory as a killing agent for insect larvae. The killing agent commonly used for larvae is KAAD mixture.

Name of solution	Name and quantity of chemicals used
KAAD mixture	95% ethyl alcohol (70-100 ml), Kerosene (10 ml), Glacial acetic acid (20 ml) and Dioxane (10 ml)

Larvae killed in this mixture are ready for transfer to alcohol for storage after 1/2 to 4 hours. In the transfer to alcohol, change the alcohol after the first few days, because it becomes diluted by the body fluids of the animal put in it. Any of these killing agents are likely to remove the bright colors of larvae, especially greens, yellows, and reds. All known killing and preserving fluids are likely to destroy some colors.

All these preservatives are highly volatile. Screw cap vials are satisfactory if the caps are tight fitting. Sealing the stopper with paraffin wax reduced the evaporation of preservative. Label is written with pencil and placed inside the vial along with the specimen.

Careful examination of liquids preserved specimens once in a year is essential to replace the evaporated fluid.

1.6 Exercise

(1) Identify the various equipments required for collection, killing and preservation of the insects in the laboratory and write its use.
(2) Which precautions should be taken while preparing and using the insect killing jar?
(3) Observe and draw proper pinning site of different insects shown in the laboratory.
(4) Write a procedure to set a butterfly on spreading board.
(5) How will you reactivate killing jar?
(6) What is the utility of insect pinning block?
(7) What is the utility of relaxing jar?
(8) Explain the procedure to prepare insect relaxing jar.
(9) What is KAAD mixture? Give its use.
(10) Collect, pin and preserve insect specimens throughout the semester and store/display in the insect storage box.
(11) Collect and preserve immature insect specimens throughout the semester and submit to the course teacher.

EXERCISE – 2
EXTERNAL FEATURES OF THE INSECTS

DATE:_____

2.1 Objective

(1) To learn the external morphology of insects this helps to distinguish one kind of insect from another.

(2) To introduce the students with the external structure and functions of insects (grasshopper or cockroach or blister beetle) and classify them on the basis of their morphological characters.

2.2 Materials

(1) Freshly killed Grasshopper or Cockroach or Blister beetle
(2) Dissecting microscope
(3) Dissecting wax tray
(4) Scissors
(5) Forceps
(6) Needles
(7) Pins

2.3 Methodology

(1) Take a grasshopper or cockroach or blister beetle and identify its three body regions - head, thorax and abdomen.

(2) Study and identify various appendages on head, thorax and abdominal regions.

(3) Separate various parts such as antennae, legs, wings with the help of sharp scissors and identify their different parts.

2.4 General body organization of a grasshopper

Insect body is differentiated into three distinct regions called head, thorax and abdomen. Grouping of body segments into distinct regions is known as **tagmosis** and the body regions are called as **tagmata**. Body of a grasshopper is divided into Head, Thorax and Abdomen. The head is a compact front division. It is followed by the middle strong division- the thorax. The last and posterior division is long, tubular and known as abdomen.

2.5 THE HEAD

The head is the first anterior tagma formed by the fusion of six segments namely preantennal, antennal, premandibular, mandibular, maxillary and labial. Head is articulated to the thorax through neck or cervix. Head capsule is sclerotized and the head capsule excluding appendages formed by the fusion of several sclerites is known as **cranium**. Insect head bears various appendages like antennae, eyes, mouthparts etc. They may be paired or single and located on different regions of the head.

2.5.1 Functions of Head

(1) To ingest the food materials.
(2) Sensory in perception.
(3) To coordinate with various body activities.
(4) Protection of the coordinating centers.

2.5.2 The head inclination

It is defined as the position of insect head and its mouth parts in relation to the rest of the body. There are three type of head inclination found in different insects *viz.,* Prognathous, Hypognathous and Opisthognathous. Grasshopper and cockroach have the hypognathous type of head inclination.

(1) **Prognathous (*Pro*-in front; *gnathus*-jaw):** The long axis of the head is horizontal and in line with the long axis of the insects body. The mouthparts are directed forwards e.g. Stick insect, soldier caste of termites, ground beetle etc.

(2) **Hypognathous (*Hypo*-below; *gnathus*-jaw):** The long axis of the head is vertical i.e. at right angle to the long axis of the body. The mouthparts are projecting downwards e.g. grasshopper, cockroach etc.

(3) **Opisthognathous (*Opistho*-hehind; *gnathus*-jaw):** The head is reflexed ventrally so that the mouth parts are projecting backwards between the coxae of the front legs e.g. Red cotton bug, stink bug etc.

2.6 THE THORAX

The thorax is second and middle region or tagma of the grasshopper body which is three segmented *viz.,* prothorax, mesothorax and metathorax. It bears the organs of locomotion like legs and wings. Each segment bears a pair of legs articulated ventrolaterally while in most adults both meso and metathorax bears the wings articulated dorsolaterally which are collectively known as Pterothorax. Thoracic segments are made up of three sclerites *viz.,* dorsal body plate tergum or notum, ventral body plate sternum and lateral plate pleuron. Two pairs of spiracles are also present on the meso and metapleuron.

2.7 THE ABDOMEN

This is the third and posterior tagma of insect body. It is the large region of body. This tagma is made up of 9-11 highly flexible segments (uromeres). Abdominal segments are telescopic in nature and are interconnected by a membrane called conjunctiva. Abdominal appendages in adult insects are external genital organs and cerci at the distal end. The abdomen function concerned with reproduction and metabolism. It contains majority of internal vital systems like, digestive system, circulatory system, reproductive system, respiratory system and nervous system.

Each abdominal segment is made up of only two sclerites namely dorsal body plate (tergum) and ventral body plate (sternum). In grasshopper eight pairs of spiracles are present on the first eight segments, in addition to a pair of tympanum (auditory organ) is present on either side of first segment. Eight and ninth abdominal segments bears the female genital organ and ninth segment bears male genital organ.

2.8 Exercise

(1) Observe the specimen of grass hopper/cockroach and draw the label colour diagram.
(2) Examine different divisions of grass hopper body and write the number of segments present in each of them.
(3) Draw the labeled colour diagram of front and lateral view of grasshopper head.
(4) Which are the appendages of head? Give it’s functions.
(5) State the type of head inclination found in grasshopper, giant water bug, mango stem borer, mole cricket, katydid and honey bee.

(6) Observe and draw the diagram of different types of head inclination showed in laboratory.
(7) Observe the antennae of grass hopper/cockroach and draw the label colour diagram.
(8) Give the functions of antennae and mouthparts.
(9) Write the name of pronotum found in grasshopper and cockroach.
(10) Draw the labeled diagram of cross section of a grasshopper thoracic segment with its sclerites.
(11) Where the wings and legs are articulated in grasshopper?
(12) What is pterothorax?
(13) Give type of leg and wing found in grasshopper/cockroach.
(14) What is the functions thorax?
(15) Draw the label colour diagram of grasshopper's abdomen.
(16) How many segments do you find in the abdomen? Which term is used for abdominal segments?
(17) What do you find between two adjacent segments of abdomen? What is the significance of such arrangement on insect body?
(18) The Spiracles are found on which segments of grasshopper body?
(19) What is tympanum?
(20) Which segments bears the male and female external genital organs?
(21) Draw the label diagram of male and female reproductive organs of grasshopper/cockroach.
(22) How the sex of grasshopper/cockroach can be judged?

EXERCISE – 3
INSECT ANTENNAE AND THEIR MODIFICATIONS

DATE:_____

3.1 Objectives

(1) To study the insect antennae and their modifications.
(2) To study the various types of antennae based on the distinguishing features of different insects.
(3) To familiarize the students with the different types of insect antennae which can be use in distinguishing their characteristics and helps in their classification.

3.2 Materials

(1) Insects specimens with different types of antennae
(2) Dissecting microscope
(3) Glass slides
(4) Scissors
(5) Forceps
(6) Needle

3.3 Methodology

(1) Take an insect, remove its antennae from the base with the help of sharp scissor with extreme care and observe the various parts under the microscope.
(2) Separate antennae from other insects and compare them with characteristics and permanent slides.

3.4 Structure of an insect antenna

Antennae are paired, highly mobile and segmented. They are also called feelers. Antennae are located on either end of upper frons and are in line and between the compound eyes. All insects except protura have a pair of antennae. Antennae are well developed in adults and poorly developed in immature stages. The antenna is set in a socket of the cranium called antennal socket (antennifer). The base of the antenna is connected to the edge of the socket by an articulatory membrane. This permits free movement of antennae. Each antenna consists of a basal segment called the scape followed by the pedicel. A mass of sense cells called Johnston's organ is present in the pedicel, which is used as a chordotonal organ in some of the insects like mosquitoes. The remaining segments are collectively known as flagellum. The scape is inserted into a membranous region (antennifer) of the head capsule.

3.4.1 Functions of insect antennae

(1) Antenna is useful to detect chemicals including food, mating partners and pheromones.
(2) It has different receptors to perceive smell, humidity changes, temperature variations, vibration, wind velocity and direction.
(3) It is a tool for communication with other members of same colony in social insects like honey bee, ants, termites etc.
(4) Antenna is useful to perceive the forward environment and detect danger.
(5) It is useful for hearing in mosquitoes and communication in ants.
(6) It is also useful to clasp the mate partner during copulation and grasp the prey.
(7) Due to different structures, it is useful in classification of insects and identifying sexual dimorphism.

3.5 Modifications of insect antenna:

The antennae of various insects differ in their shape, size and structure of various segments. Due to this, more than a dozen modifications of antennae are found.

Sr. No.	Name of antennal modification	Antennal characteristics
1	Filiform (Thread like)	Segments are usually cylindrical. Thickness of segments remains same throughout. e.g. Grasshopper
2	Moniliform (Beaded)	Segments are either globular or spherical with prominent constriction in between e.g. Termite
3	Setaceous (Bristle like)	Size of the segments decreases from base to apex. e.g. Cockroach
4	Serrate (Saw like)	Segments have short triangular projections on one side. e.g. Mango stem borer
5	Pectinate (Comb like)	Segments with long slender processes on one side e.g. Click beetle
6	Bipectinate (Double comb like)	Segments with long slender lateral processes on both the sides e.g. Silkworm moth
7	Clavate (Clubbed)	Antenna enlarges gradually towards the tip. e.g. Blister beetle and Carrion beetle
8	Capitate (Knobbed)	Terminal segments become enlarged suddenly e.g. butterfly
9	Lamellate (Plate like)	Antennal tip is expanded laterally on one side to form flat plates e.g. Dung roller
10	Aristate	The terminal segment is enlarged. It bears a conspicuous dorsal bristle called arista e.g. House fly
11	Stylate	Terminal segment bear a style like process e.g. Horse fly, Robber fly.
12	Plumose (Feathery)	Segments with long whorls of hairs e.g. Male mosquito
13	Pilose/Whorled (Hairy)	Antenna is less feathery with few hairs at the junction of flagellomeres. It look like plumose antennae. e.g. Female mosquito.
14	Geniculate (Elbowed)	Scape is long remaining segments are small and are arranged at an angle to the first resembling an elbow joint. e.g. Ant, weevil and honey bee.
15	Flabellate (with flabella)	It bears special organ flabella. The upper annulus is modified into fan like processes. e.g. Male of stepsiptera, tenthredinidae (Hymenoptera)
16	Ensiform (Sword like)	The segments of flagellum are thin and gradually taper towards the apex and form a leaf blade like structure. e.g. Green grasshopper.

3.6 Exercise

(1) Where the antennae are articulated on the insect head?
(2) Which are the different parts of the insect antennae?
(3) What is antennifer?
(4) Draw the labeled colour diagram of typical insect antennae.
(5) How antennae are useful to insects?
(6) Differentiate the following types of antennae. (a) filiform and moniliform (b) clavate and capitates (c) aristate and stylet (d) plumose and pilose (e) setaceous and serrate.
(7) Draw the neat and clean colour diagrams of various insect antennae shown in the classroom.
(8) Prepare an album on "Types of insect antennae".

EXERCISE – 4
INSECT MOUTHPARTS AND THEIR MODIFICATIONS

DATE:_____

4.1 Objectives

1) To study the insect mouth parts and their modifications.
2) To identify and categorize the various types of insect mouth parts based on their feeding habit and nature of damage to crop plants.

4.2 Materials

1) Insects specimens with different types of mouth parts
2) Dissecting microscope
3) Glass slides
4) Cover slips
5) Camel hair brush
6) Scissor
7) Forceps
8) Needle
9) Glycerin
10) Water

4.3 Methodology

4.3.1 Biting and chewing type

(1) Take a live cockroach; kill it with the help of detergent water than remove its antennae from the base with the help of sharp scissor.
(2) Hold the cockroach head in between thumb and fore finger to facilitate the dissection of mouth parts.
(3) Take a pointed forceps and first remove the flap like labrum by holding tightly from the base which is upper lip of the cockroach mouth parts. Due to this a pair of mandibles will be clearly seen.
(4) Than hold the mandibles from the base and remove from the head one by one. They are first pair of jaws. Due to this a pair of maxillae will be clearly seen.
(5) Than hold the maxillae from the base and remove from the head one by one. They are second pair of jaws.
(6) The tongue like structure will be seen after removal of the maxillae. Gently remove that part with the help of forcep.
(7) At last remove the labium from the base without damage to the labial palps.
(8) Arrange all dissected parts on the glass slide and observe under the microscope.

4.3.2 Piercing and sucking type

(1) Take a living or liquid preserved red cotton bug.
(2) Put it on the glass slide and separate the head from the thorax.
(3) Dissection should be done under the microscope with glycerin to facilitate the separation of the stylets.
(4) Gently press the labium with help of the needle it will leads to separation of the four stylets from the labial groove.

(5) Extreme care should be taken while pressing the labium to prevent the breaking of labium.
(6) Observe and identify the various mouth parts under the microscope.
(7) For comparison, take a mosquito and complete the process same as above, observe mosquito mouth parts and compare them with that of red cotton bug.

4.3.3 Chewing and lapping type

(1) Take a honeybee, cut the head from the thorax, and gently press it between two slides.
(2) Observe the various parts under the microscope and identify them.

4.3.4 Siphoning type

(1) Take a butterfly or moth, separate head from thorax, press between two slides.
(2) Observe the various parts under the microscope and identify them.

4.3.5 Sponging type

(1) Take a housefly, separate head from thorax.
(2) Observe the various parts under the microscope and identify them.

4.3.6 Rasping and sucking type

(1) Take a thrips, arrange on glass slide.
(2) Observe under microscope.

4.3.7 Mandibulosuctorial type

(1) Take a grub/larvae of ant lion, separate head from thorax.
(2) Observe under microscope.

4.4 Types of insect mouthparts

The insects are causing most of the damage by feeding on various parts of host plants through mouthparts. The type of food differs in different insects. Similarly, method of taking food also differs in various insects and so different types of mouthparts are found in different insects.

The mouthparts are developed as the appendages of various segments of the head as under:

Third segment……Labrum (Upper lip)
Fourth segment…….Mandible (First pair of jaws)
Fifth segment…….Maxillae (Second pair of jaws)
Sixth segment……Labium (Lower lip)

The mouth parts of insects can be classified into two major groups.

4.5 Major types of mouth parts of insects

(1) The biting and chewing type (Mandibulate)

e. g. Cockroach, Beetles, Grass hopper, Lepidopteron larvae etc.

4.5.1 Structure and function of mouthparts of cockroach

a. Labrum: It is a thin plate on the front of mouth. It's one side is articulated with the head capsule. It works as a cover for the underlying mouthparts. It forms a roof of the preoral cavity and mouth.
b. Epiharynx: it is swollen area of the ventral surface of the labrum which is an organ of taste.

c. **Mandibles:** It is the hardest part of all the mouthparts. It is articulated on either side, below gena. The inner margins are dark and chitinous, while the rest of the part is brown coloured. The function of mandibles is to cut and chew food material. To carry the thing. In honey bees and wasps, they are used to mould wax or mud. It may be used for defense.
d. **Maxillae:** It is the second pair of jaws. It lies behind the mandible in side view. Each maxilla consists of a cardo, stipes, inner lacinea and outer galea. A maxillary palp arises from the base of the stipes. The function of maxillae is to hold the food while mastication and it also helps in selection of food through tactile sensory hairs.
e. **Labium:** It is the lower most part made-up of several structures viz., glossae, paraglossae and labial palps. It closes the buccal cavity from lower side and helps in selecting the food by testing through sensory hairs present on it.
f. **Hypopharynx:** The flap like part which is seen in the mouth after removing the mandibles is known as hypopharynx. It is articulated with inner wall of labium. Salivary duct opens at its base. It is known as tounge of an insect.

(2) The piercing sucking type (Haustellate)

e. g. Bugs, louse, mosquito, whitefly, aphids, jassids etc.

Labium projects downwards from the anterior part of the head like a beak. Beak is four segmented and grooved throughout its entire length. At the base of the labium there is a triangular flap like structure called labrum. Labium is neither involved in piercing nor sucking. It functions as a protective covering for the four stylets (fascicle) found within the groove. Both mandibles and maxillae are modified into long slender sclerotized hair like structure called stylets. They are lying close together and suited for piercing and sucking. The tips of the stylets may have minute teeth for piercing the plant tissue. The inner maxillary stylets are doubly grooved on their inner faces. When these are closely opposed they form two canals viz., food canal and salivary canal through sap and saliva are conducted respectively. Saliva contains enzymes or toxins that can distort plant cell wall to permit the stylets to penetrate down and reach phloem for sucking the sap. Both palps are absent.

(3) Piercing and sucking / mosquito type: e.g. Female mosquito

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

(4) Chewing and lapping type: e.g. Honey bee

Labrum and mandibles are as in biting and chewing type of mouth parts. But mandibles are blunt and not toothed. They are useful to crush and shape wax for comb building; ingest pollen grains and other manipulative functions. Maxillolabial structures are modified to form the lapping tongue. The tongue unit consists of two galea of maxillae, two labial palpi and elongated flexible hairy glossa of labium. The glossa terminates into a small circular spoon shaped lobe called spoon or bouton or flabellum which is useful to lick the nectar.

(5) Rasping and sucking: e.g. Thrips

Mouth cone consists of labrum, labium and maxillae. There are three stylets derived from two maxillae and left mandible. Right mandible is absent. Stylets are useful to lacerate the plant tissue and the oozing sap is sucked up by the mouth cone. Both maxillary palpi and labial palpi are present.

(6) Mandibulosuctorial type: e.g. Grub of antlion

Mandibles are elongate sickle shaped and grooved on the inner surface. Each maxilla is elongated and fits against the mandibular groove to from a closed food canal. The body of the insect victim is pierced by the opposing mandibles and fluids are extracted.

(7) Sponging type: e.g. House fly

The proboscis is fleshy, elbowed, retractile and projected downwards from head. The proboscis can be differentiated into basal rostrum and distal haustellum. The proboscis consists of labium which is grooved on its anterior surface. Within this groove lie the labrum-epiphraynx (enclosing the food canal) and slender hypopharynx (containing the salivary canal). Mandibles are absent. Maxillae are represented by single segmented maxillary palpi. The end of the proboscis is enlarged, sponge like and two lobed which acts as suction pads. They are called oral discs or labella. The surfaces of labella are transvered by capillary canals called pseudotracheae which collect the liquid food and convey it to the canal. Labella function as sponging organs and are capable of taking exposed fluids. These insects often spit enzyme containing saliva onto solid foods to liquify them.

(8) Siphoning type: e.g. Moths and butterflies

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

4.6 Exercise

(1) Collect the cockroaches, red cotton bugs, mosquitoes, honey bees, thrips, ant lions, house flies, moths and butterfly and dissect the mouthparts in the laboratory.
(2) List out the names of the insects having biting and chewing type of mouth parts that you had seen in the insect museum of department of entomology and in field/home.
(3) Name the insects of agricultural importance possessing siphoning type of mouth parts.
(4) Write the function of labrum, mandible, maxillae, labium and hypopharynx.
(5) Enlist the names of the insects having piercing and sucking type of mouth parts that you had seen in the insect museum of department of entomology and field.
(6) How the red cotton bug suck the cell sap from the plant parts?
(7) How the study of mouth parts of insects useful in plant protection.

EXERCISE – 5
INSECT LEGS AND THEIR MODIFICATIONS

DATE:_____

5.1 Objectives

(1) To study the insect legs and their modifications.
(2) To identify various types of insect legs based on the distinguishing features of different insects and characterized them.

5.2 Materials

(1) Insects specimens with different types of legs
(2) Dissecting microscope
(3) Glass slides
(4) Camel hair brush
(5) Scissor
(6) Forceps
(7) Needle

5.3 Methodology

(1) Take an insect, carefully remove its legs from pleural area of the thorax with the help of sharp scissor and observe the various parts under the microscope.
(2) Separate antennae from other insects and compare them with characteristics and permanent slides.

5.4 Structure of an insect leg

Every insect have three pairs of legs. Each leg is made up of five parts *viz.*, coxa, trochanter, femur, tibia and tarsus. The tarsus having various structures at the pretarsus. The legs are articulated on ventrolateral region of thorax, one pair on each thoracic segment. It is the main organ for locomotion in terrestrial and aquatic habitat. The hexapod condition facilitates the insects in maintaining balance during locomotion.

5.5 Function of insect leg

(1) Its main function is locomotion in terrestrial and aquatic habitat.
(2) The leg is modified to perform the functions like; walking (ambulatorial), running (cursorial), jumping (saltatorial), digging (fossorial), swimming (natatorial), grasping (raptorial), clinging (scansorial), sound producing (stridulatorial), and pollen collection.
(3) To hold the female during mating.

5.6 Parts of the insect leg

(1) Coxa

- It is the first or proximal leg segment.
- It articulates with the cup like depression on the thoracic pleuron.
- It is generally freely movable.

(2) Trochanter

- It is the second leg segment.
- It is usually small and single segmented.

- Trochanter seems to be two segmented in dragonfly, dameselfy and ichneumonid wasp.
- The apparent second trochanter is in fact a part of femur, which is called trochantellus.

(3) Femur

- It is the largest and stoutest part of the leg and is closely attached to the trochanter.

(4) Tibia

- It is usually long and provided with downward projecting spines which aid in climbing and footing.
- Tibia of many insects is armed with large movable spur near the apex.

(5) Tarsus

- It is further sub-divided. The sub segment of the tarsus is called tarsomere.
- The number of tarsomeres varies from one to five.
- The basal tarsal segment is often larger than others and is named as basitarsus.
- Beyond the tarsus there are several structure collectively known as pretarsus.
- Tarsus terminates in a pair of strongly curved claws with one or two pads of cushions at their base between them.
- A median pad between the claws is usually known as arolium and a pair of pads, at their base is called pulvilli (Pulvillus-singular).
- Leg pads are useful while walking on smooth surface and claws give needed grip while walking on rough surface.
- When one structure is used, the other is bent upwards.

5.7 Modifications of insect legs

The main function of insect leg is walking. However, legs of various insects are modified for special purposes e.g. running, jumping, swimming, digging, grasping, preying, sound producing, holding hair, collecting pollen etc.

Sr. No.	Name of leg modification	Legs characteristics
1	Ambulatorial	It is suited for the walking purpose. Femur and tibia are long. e.g. Fore leg and middle leg of grasshopper.
2	Cursorial	Legs are suited for running. Femur is not swollen. Tarsal segments touches to ground while running. e.g. All the three pairs of legs of cockroach, ant, tiger beetle etc.
3	Saltatorial	Legs are suited for the jumping. Femur is strong. e.g. Hind leg of grasshopper.
4	Natatorial	Legs adapted for swimming. e. g. Hind legs of water beetle.
5	Fossorial	Legs are suited for digging purpose. Fore tibia are broad and highly sclerotized while tarsi reduced. e.g. Fore legs of mole cricket.
6	Scantorial	Legs are suited for climbing or clinging purpose. Single segmented tarsus bears a hook like curved claws with ventral

		pads. e.g. All the three pairs of head louse legs.
7	Raptorial	Legs are developed for grasping the prey. Coxa long, tibia can be inserted into the apical hook of the femur e.g. Forelegs of praying mantis.
8	Polleniferous	Legs adapted for collection of pollen. In honey bee fore tibia bears a terminal spur known as fibula, which can be accommodated into proximal cavity of the tarsi. Fore legs are antennae cleaner. Middle legs modified for pollen collecting. In hind legs tibia are modified to form cavities (pollen basket), fringed with spines at the proximal end of metatarsus. e.g. Legs of honey bee.
9	Stridulatorial	Legs are suited to make sound. A row of pegs situated on the inner side of each hind femur which would work against the outer surface of each tagmen. e.g. Cricket
10	Sticking leg (Pulvillus type)	Legs are suited for walking on smooth surface. Pulvilli and empodium having glandular hairs and moistened by glandular secretion so adhesion occurs and it can walk on smooth surface. e.g. All the three pairs of house fly legs.
11	Basket leg	Legs are used to hold the prey. The long legs having rows of stiff bristles along the inner margins. e.g. Legs of dragonfly and damselfly.
12	Proleg	There are two to five pairs of abdominal legs termed prolegs in caterpillar. Prolegs are thick, fleshy and not segmented. e.g. Abdominal legs of caterpillar.
13	Bladder footed	The distal tarsomeres bears a vesicle to provide a firm hold on the surface on which insects feed. e.g. Onion thrips

5.8 Exercise

(1) Where the insect legs are articulated on thorax?
(2) What is the significance of three pairs of insect legs?
(3) Which are the different parts of the insect leg?
(4) Draw the labeled colour diagram of typical insect leg.
(5) How legs are useful to insects other than walking?
(6) Differentiate the following types of leg. (a) Amulatorial and Cursorial (b) Natatorial and fossorial (c) Ambulatorial and Saltatorial.
(7) How house fly can walk on smooth surface?
(8) What is proleg?
(9) Draw the neat and clean coloured diagrams of various insect legs showed in the classroom.
(10) Prepare an album on “Types of insect leg”.

EXERCISE – 6
INSECT WINGS AND THEIR MODIFICATIONS

DATE:_____

6.1 Objectives

(1) To study the insect wings and their modifications.
(2) To acquaint students with the insect wing structure and venation as well as various modifications.

6.2 Materials

(1) Insects specimens with different types of wings
(2) Dissecting microscope
(3) Glass slides
(4) Camel hair brush
(5) Scissors
(6) Forceps
(7) Needle

6.3 Methodology

(1) Take an insect, carefully remove its fore and hind pair of wings from dorsolateral area of meso and meta thorax with the help of sharp scissor/forcep and observe the various structures and venation under the microscope.
(2) Separate fore and hind pair of wings from other insects and compare them with characteristics and permanent slides.

6.4 Structure of an insect wing

Among invertebrates, insects are the only winged organisms. Insect wings are somewhat triangular in shape, derived from the integument of thorax. Generally, insects possess two pairs of wings in their adult stage. They are located on dorsolateral region of meso and metathorax. It bears many longitudinal veins and cross veins. It exhibits various shape and colour patterns due to presence of scales. The insect wing is triangular. The anterior margin is known as costal margin while the lateral and hind margins are called apical and anal margin, respectively. The angles formed between costal and apical margins, apical and anal margins and costal and anal margins are known as apex, anal and humeral angle, respectively. The anterior area of the wing supported by veins is usually called remigium. The flexible posterior area is termed vannus. The two regions are separated by vannal fold. The proximal part of vannus is called jugum, when well developed is separated by a jugal fold. The area containing wing articulation sclerites, pteralia is called axilla.

The wings are useful to insects to search habitat, food, mate and escape from attack of natural enemies as well as adverse climatic conditions.

6.5 Functions of insect wings

(1) The main function is locomotion in terrestrial habitat.
(2) To search habitat, food, mate and escape from attack of natural enemies as well as adverse climatic conditions.
(3) It having great taxonomic importance and use in insect classification.
(4) To protect hind wings while resting in coleoptera.

(5) Sound producer in orthoptera while stabilizers in diptera and thermo regulator in honey bee.

6.6 Modifications of insect wing

Wings are modified in different insects. Some insects are primitively wingless e.g. Silverfish, while others are secondarily wingless e.g. bed bug, head louse etc. In some insects, only males are winged. e.g. mealy bugs. In social insects, only reproductive forms are winged for a short period of time. The wings may be hard shield like elytra, partially hard hemelytra, leather like tegmina, fringed- feather like or reduced to a slender knob like structure halter. These may be thin, equal and membranous with dense network of wing venation.

Sr. No.	Name of wing modification	Wing characteristics
1	Elytra	The wing is heavily sclerotised. There is no wing venation. Wing is tough and it is protective in function. It protects hind wings and abdomen. It is not used during flight. But during flight they are kept at an angle allowing free movement of hind wings. e.g. Fore wings of beetles and weevils.
2	Hemelytra	The basal half of the wing is thick and leathery and distal half is membranous. They are not involved in flight and are protective in function. e.g. Fore wing of heteropteran bugs.
3	Tegmina	Wings are leathery. They are protective in function. They are not used for flight. e.g. Forewings of cockroach and grasshopper.
4	Halteres	In true flies the hind wings are modified into small knobbed vibrating organs called halter. They act as balancing organs and provide the needed stability during flight. e.g. House fly
5	Fringed wings	Wings are usually reduced in size. Wing margins are fringed with long setae. These insects swim through the air. e.g. Thrips
6	Scaly wings	Wings of butterfly and moths are covered with small coloured scales. Scales are unicellular flattened outgrowth of body wall. Scales are inclined to the wing surface and overlap each other to form a complete covering. Scales are responsible for colour. They are important in smoothing the air flow over wings and body. e.g. Moth and butterfly
7	Membranous wings	They are thin, transparent wings and supported by many tubular veins. In many insects either forewings or hind wings or both fore wings and hind wings are membranous. They are useful in flight. e.g. Fore wing of house fly, hind wing of beetles and Both wings of dragonfly and damselfly

6.7 Wing venation:

The arrangement of longitudinal and cross veins in wing is called wing venation. Wing venation differs in different insects. It is of great taxonomic importance.

6.7.1 Types of veins

Sr. No.	Name of vein	Characteristics
1	Costa (C)	First anterior marginal vein. Strong and extends to the apex of the wing. It is unbranched and convex. Sometimes it bear stigma on fore and hind wings of Odonata and only on forewings of Hymenoptera, Psocoptera and Mecoptera.
2	Subcosta (Sc)	Second longitudinal vein. It is divided distally into two branches, the outer and inner designated as Sc_1 and Sc_2, respectively. Sc is reduced or fused with R in most Hemiptera. It is concave.
3	Radius (R)	The third vein. The strongest vein on the wing, with branches usually covers the largest area of wing apex. The first branch, outer branch (R_1) runs directly towards outer margin. The second branch is often referred to as radial sector (Rs) which is concave and gives branches as R_2, R_3, R_4 and R_5.
4	Media (M)	The fourth longitudinal vein. It divided into two branches viz., anterior media (MA) which is convex and divided into $MA_1$and MA_2 and posterior media (MP) usually with 4 branches MP_1, MP_2, MP_3 and MP_4 and are concave.
5	Cubitus (Cu)	The fifth longitudinal vein. It is divided into convex anterior CuA and concave posterior CuP branches. CuA is branched into two branches and CuP is unbranched.
6	Anal (A)	These are veins behind the cubitus, AA and AP are usually separated by the anal fold.
7	Jugal (J)	Small veins in the jugal area, found only in Neoptera.
There are four cross veins found in the insect wing based on their position relative to longitudinal veins.		
1	c-sc	Cross veins run between the costa and subcosta.
2	r	Cross veins run between adjacent branches of the radius.
3	r-m	Cross veins run between the radius and media.
4	m-cu	Cross veins run between the media and cubitus.

6.8 Wing coupling mechanisms:

The two wings of a side usually move together during flight. The two wings are kept together by means of a structure known as wing coupling. Its structure differs in different species and sometimes among two sexes of same species.

Sr. No.	Name of Wing coupling mechanisms	Characteristics
1	Hamuli	A row of small hooks is present on the coastal margin of the hind wing which is known as hamuli. These engage the folded posterior edge of fore wing. e.g. 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. e. g. Butterflies.
3	Frenate	There are two sub types. e. g. Fruit sucking moth. (1) **Male frenate:** Hind wing bears near the base of the coastal margin a stout bristle called frenulum which is normally held by a curved process, retinaculum arising from the subcostal vein found on the surface of the forewing. (2) **Female frenate:** Hind wing bears near the base of the costal margin a group of stout bristle (frenulum) which lies beneath extended fore wing and engages there in a retinaculum formed by a patch of hairs near cubitus.
4	Jugate	Jugam of the forewings are lobe like and it is locked to the coastal margin of the hind wings. e. g. Hepialid moths.
5	Fold or Hook	It is found in aphids.

6.9 Exercise

(1) Draw the labeled diagram of typical insect wing.
(2) What is the significance of insect wings?
(3) Where are the wings articulated on insect body?
(4) Which are the different margins and angles of the insect wing?
(5) Differentiate the Elytra and hemelytra, tagmina and scaly type of wing.
(6) What is halter? What is the utility of halters to a housefly?
(7) Enlist the different longitudinal and cross veins of the insect wing.
(8) What is hamuli?
(9) Draw the neat and clean color diagrams of various types of insect wings showed in the classroom.
(10) Prepare an album on “Types of insect wing”.

EXERCISE – 7
METAMORPHOSIS AND DIAPAUSE IN INSECTS

DATE:_____

7.1 Objective

(1) To study the life stages of an insect.
(2) To familiarize the students with the different developmental stages of an insect.

7.2 Materials

Preserved specimens including various stages of Silverfish, Grasshopper, dragonfly, Butterfly, Red cotton bug etc.

7.3 Methodology

(1) Observe the different growth stages of different insects in the laboratory and insect museum as well as in the field.
(2) Note the external characteristics of adults and immatures (young, nymph, naiads, larvae and pupae)

7.4 What is metamorphosis?

Metamorphosis is the change in growth and development an insect undergoes during its life cycle from birth to maturity. There are four basic types of metamorphosis found in insects as given below.

Sr. No.	Type of Metamorphosis	Description of Metamorphosis
1	**Ametabola** (No metamorphosis)	These insects have only three stages in their life namely egg, young ones and adult. It is most primitive type of metamorphosis. The hatching insect resembles the adult in all respects except for the size and called as juveniles. Moulting continues throughout the life. e.g. Silverfish
2	**Hemimetabola** (Incomplete metamorphosis)	These insects also have three stages in their life namely egg, young one and adult. The young ones are aquatic and are called as **naiads**. They are different from adults in habit and habitat. They breathe by means of tracheal gills. In dragonfly naiad the lower lip (labium) is called mask which is hinged and provided with hooks for capturing prey. After final moult, the insects have fully developed wings suited for aerial life. e.g. Dragonfly, damselfly and mayfly
3	**Paurometabola** (Gradual metamorphosis)	The young ones are called **nymphs**. They are terrestrial and resemble the adults in general body form except the wings and external genitalia. Their compound eyes and mouth parts are similar to that of adults. Both nymphs and adults share the same habitat. Wing buds externally appear in later instars. The genitalia development is gradual. Later instar nymphs closely resemble the adult with successive moults. e.g. Cockroach, grasshopper, bugs
4	**Holometabola**	These insects have four life stages namely egg, larva, pupa

	(Complete metamorphosis)	and adult. Majority of insects undergo complete metamorphosis. Larvae of butterflies are called caterpillar. Larva differs greatly in form from adult. Compound eyes are absent in larva. Lateral ocelli or stemmata are the visual organs. Their mouth parts and food habit differ from adults. Wing development is internal. When the larval growth is completed, it transforms into pupa. During the non-feeding pupal stage, the larval tissues disintegrate and adult organs are built up. e.g. Butterfly, moth, fly and bees

7.5 Diapause in insects

Diapause is a period of suspended or arrested development during an insect's life cycle. Insect diapause is usually triggered by environmental cues, like changes in daylight, temperature, or food availability. Diapause may occur in any life cycle stage – embryonic, larval, pupal, or adult – depending on the insect species.

Diapause is a predetermined period of dormancy, meaning it's genetically programmed and involves adaptive physiological changes. Environmental cues aren't the cause of diapause, but they may control when diapause begins and ends. Quiescence, in contrast, is a period of slowed development that is triggered directly by environmental conditions, and that ends when favorable conditions return.

7.5.1 Types of Diapause

Diapause can be either obligatory or facultative:

(1) **Obligatory diapause:** Insects undergo this period of arrested development at the predetermined point in their life cycle, regardless of the environmental conditions. Diapause occurs in every generation. Obligatory diapause is most often associated with univoltine insects means insects that have one generation per year.

(2) **Facultative diapause:** Insects undergo a period of suspended development only when conditions require it for survival. Facultative diapause is found in most insects and is associated with bivoltine (two generations per year) or multivoltine insects (more than two generations per year).

7.6 Exercise

(1) What is metamorphosis in insect?
(2) Name the various stages of development in a moth and write their characteristics.
(3) Differentiate the following. Complete and incomplete metamorphosis, nymph and larvae, larvae and pupae.
(4) What is diapause?
(5) Difference between obligatory or facultative diapause.
(6) Prepare a different life cycle and submit to the course teacher.

EXERCISE – 8
INSECT LARVAE AND PUPAE

DATE:_____

8.1 Objectives

(1) To learn the type of immature stages like larvae and pupae of an insect.
(2) To understand the insect development.

8.2 Materials

Preserved specimens of different larvae and pupa.

8.3 Methodology

(1) Observe the different larvae and pupa of different insects in the laboratory and insect museum.
(2) Note the external characteristics of larvae and pupa.

8.4 Insect larvae

Larval stage is the active growing stage. It is the immature stage between the egg and pupal stage of an insect having complete metamorphosis. This stage differs from the adult.

8.4.1 Types of larvae

Sr. No.	Type of larvae	Characteristics
1	Protopod	There is no segmentation in abdomen Cephalic and thoracic appendages are rudimentary. Young larvae hatch at a immature stage of development. e.g. Parasitic hymenoptera
2	Apodous	larvae without appendages **a) Eucepalous:** Larva with well developed head capsule with functional mandibles, maxillae, stemmata and antennae. Mandibles act transversely. e.g. Wriggler and grub of red palm weevil. **b) Hemicephalous:** Head capsule is reduced and can be withdrawn into thorax. Mandibles act vertically. e.g. Larva of robber fly. **c) Acephalous:** Head capsule is absent. Mouthparts consist of a pair of protrusible curved mouth hooks and associated internal sclerites. They are also called vermiform larvae. e.g. Maggot (larva of house fly).
3	Oligopod	Thoracic legs are well developed and abdominal legs are absent. **a) Campodeiform:** Body is elongate, depressed dorsoventrally 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. e.g. Grub of crysopa and lady bird beetle. **b) Scarabaeiform:** Body is `C' shaped, stout and subcylindrical. Head is well developed. Thoracic legs are short. Caudal processes are absent. Larva is sluggish, burrowing into wood or soil. e.g. Grub of rhinoceros beetle and white grub.

		c) Carabeiform: Body is dorsoventrally flat and bears three pairs of thorac legs which are short. e.g. Ground beetle and carabeidae family of coleoptera order.
4	Polypod or Eruciform	**a) Caterpillar:** It has three pair of thoracic legs and five pairs of prolegs and are situated on 3, 4, 5. 6 & 10^{th} abdominal segments. e.g. Lepidopteron larvae **b) Platyform larva:** Larva is thick, short, stout and fleshy. Laval 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. e.g. Slug caterpillar **c) Semilooper:** Either three or four pairs of prolegs are present. Prolegs are either wanting or rudimentary in either third or third and fourth abdominal segments. e.g. Castor semilooper. **d) Looper:** They are also called measuring worm or earth measurer or inch worm. In this type, only two pairs of prolegs are present in sixth and tenth abdominal segments. e.g. Daincha looper, Cabbage looper

8.5 Insect 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 the transitional stage, the larval characters are destroyed and new adult characters are created. There are three main types of pupae.

8.5.1 Types of pupae

Sr. No.	Type of pupae	Characteristics
1	Obtect	Appendages are glued to the body **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 obtect 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 very active.
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 e.g. Pupa of rhinoceros beetle.

3	Coarctate	The pupal case is barrel shaped, smooth with no apparent appendages. The last larval skin is changed into case containing the exarate pupa. The hardened dark brown pupal case is called puparium. e.g. Fly pupa.

8.5.2 Protection to the pupae

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.

Types of cocoon	Materials used	Example
Silken cocoon	Silk	Silk worm
Earthen cocoon	Soil + saliva	Gram pod borer
Frassy cocoon	Frass + saliva	Coconut black headed caterpillar
Fibrous cocoon	Fibres	Red palm weevil

8.6 Exercise

(1) Draw the labeled colour diagram of various types of larvae and pupa showed in the classroom and insect museum.
(2) What is chrysalis?
(3) What is puparium?
(4) Difference the following.
   a) Campodeiform and scarabaeiform larvae
   b) Caterpillar and semilooper
   c) Grub and maggot
   d) Oligopod and polypod larvae
   e) Obtect and exarate pupae

EXERCISE – 9
DISSECTION OF DIGESTIVE SYSTEM OF INSECTS
(GRASSHOPPER/COCKROACH)

DATE:_____

9.1 Objective

To acquaint the students with the internal structures particularly the digestive system of cockroach or grasshopper to help them to know the internal anatomy of insects.

9.2 Materials

(1) Freshly killed grasshopper or cockroach
(2) Dissecting microscope
(3) Dissecting wax tray
(4) Wash bottle with water
(5) Scissors
(6) Camel hair brush
(7) Forceps
(8) Needle
(9) Pins

9.3 Methodology

(1) Take a freshly killed cockroach.
(2) Carefully remove its antennae, legs and wings from the base to facilitate dissection.
(3) Make a lateral cut on both sides of the abdomen starting from posterior end with the help of a sharp scissor/blade.
(4) Place the cockroach in a wax tray in dorsal-ventral position (exposing dorsal side towards you).
(5) Insert a pin through the head and fix at 45 degree angle on wax tray.
(6) Pour the fresh water in wax tray to facilitate dissection process.
(7) Remove the tergum from posterior end to anterior end up to thorax with extreme care with the help of a forceps and needle. Care should be taken while removing the pronotum.
(8) Pin the lateral margins placing them at an angle of 45 degree without damaging alimentary canal
(9) Remove all fatty tissues, air sacs, tracheae and muscles surrounded from mouth to anus with the help of camel hair brush.
(10) Finally discard the dirty water and pour fresh water again to display the system.
(11) Observe and identify the various parts of alimentary canal.

9.4 Digestive system of cockroach

The organs primarily concerned with the intake of food are mouth parts which are variously modified to suit the type of food required to be taken by insects. The food that has been taken pass through the digestive tract which extends from mouth to anus is known as alimentary canal.

The digestive system of cockroach is divided into foregut, midgut and hindgut. It begins near the buccal cavity in the head and ends into anus. A pair of salivary glands lies on the side of oesophagus and produces saliva. The foregut consists of tubular oesophagus, sac

like crop and conical gizzard. At the junction of foregut and midgut one finds finger like structures known as gastric caeca or enteric caeca which developed from midgut which increase surface area for the absorption of food material. The mid intestine secretes digestive enzymes which digest the ingested food material and absorb digested food. Very fine thin hair like yellow colored numerous tubules are present at the junction of midgut and hindgut which are known as Malpighian tubules. They are associated with excretion. The hindgut is made up of ileum, colon and rectum and help in conserving salt and moisture through rectal papillae. The digestive tract ends with anus.

9.5 Exercise

(1) Draw the labeled colour diagram of digestive system of cockroach.
(2) Describe the structure and function of Oesophagous, crop, gizzard, gastric caeca, midgut, malpighian tubules, ileum, colon and rectum of digestive system of cockroach.
(3) Write the difference between foregut and midgut?
(4) Enlist the parts of alimentary canal in a sequence starting from mouth to anus.
(5) Collect the adult cockroach/grasshopper and dissect the digestive system in the laboratory.

EXERCISE – 10
DISSECTION OF MALE AND FEMALE REPRODUCTIVE SYSTEMS OF INSECTS

DATE:_____

10.1 Objective

To acquaint the students with the reproductive structures particularly male and female reproductive systems of cockroach or grasshopper to help them to understand functions and mechanism of reproduction in insects.

10.2 Materials

(1) Freshly killed grasshopper or cockroach
(2) Dissecting microscope
(3) Dissecting wax tray
(4) Wash bottle with water
(5) Scissors
(6) Camel hair brush
(7) Forceps
(8) Needle
(9) Pins

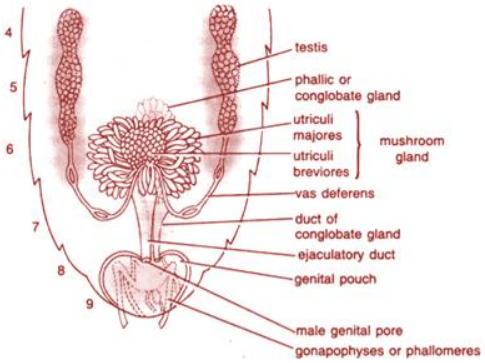
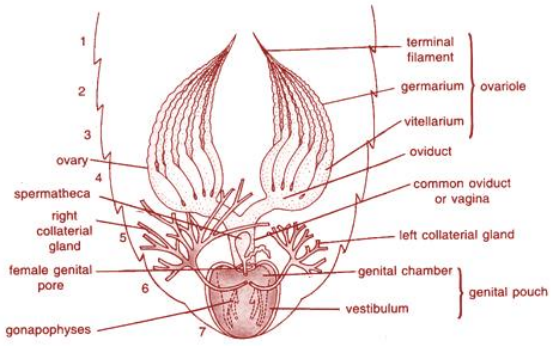
10.3 Methodology

(1) Take a freshly killed cockroach.
(2) Carefully remove its antennae, legs and wings from the base with the help of sharp scissor to facilitate dissection.
(3) Make a lateral cut on both sides of the abdomen starting from posterior end with the help of a sharp scissor/blade.
(4) Place the cockroach in a wax tray in dorsal-ventral position (exposing dorsal side towards you).
(5) Carefully insert a pin through the thorax and at the end of anus fix at 45 degree angle on wax tray.
(6) Pour the fresh water in wax tray to facilitate dissection process.
(7) Remove the tergum from posterior end to anterior end up to metathorax with extreme care with the help of a forceps and needle.
(8) Remove all fatty tissues, air sacs, tracheae and muscles surrounded to reproductive system with the help of camel hair brush.
(9) Finally discard the dirty water and pour fresh water again to display the system.
(10) Observe and identify the various parts of male and female reproductive parts, remove alimentary canal separating it from rectum, pin the rectum stretching posteriorly. Separate ovaries, testes and observe their various parts.

10.4 Reproductive systems

Cockroach is a unisexual organism. Either male or female reproductive system is present in a cockroach. The male is externally distinguished from female mainly by the presence of anal styles in addition to anal cerci.

10.5 Difference between male and female reproductive systems.

Sr. No.	Male reproductive system	Female reproductive system
		
1	Male having paired testes composed of follicles and developed from mesoderm. They produce spermatozoa (sperms).	Female having paired ovaries composed of ovarioles and develop from Mesoderm. They produce ova (eggs).
2	Male having paired vasa differentia develop from mesoderm.	Female having paired oviducts develop from mesoderm.
3	Male having seminal vesicles.	Female having egg calyces.
4	Male having median ejaculatory duct	Female having common oviduct and vagina.
5	In male accessory glands are Mesadenia and Ectadenia.	In female accessory gland is Collateral glands.
6	Male external genitalia called as aedaegus.	Female external genitalia called as Ovipositor.

10.6 Exercise

(1) Draw the labeled colour diagram of male and female reproductive system of cockroach.

(2) Write the functions of male and female reproductive parts of cockroach.

(3) How will you distinguish a male and female cockroach on the basis of external characters?

EXERCISE – 11
STUDY THE CHARACTERS OF ORDERS ORTHOPTERA, DICTYOPTERA, ODONATA, ISOPTERA, THYSANOPTERA, HEMIPTERA AND THEIR FAMILIES OF AGRICULTURAL IMPORTANCE

DATE:_____

11.1Objective

1) To learn the distinguishing features of insect orders and their families of agricultural importance.
2) To collect the insects of commonly found families of various orders.
3) To familiarize the students with different orders of insects and their characters to identify them up to family level.

11.2 Materials

Preserved specimens of different orders *viz.*, orthoptera, dictyoptera, odonata, isoptera, thysanoptera and hemiptera in the laboratory as well as insect museum.

11.3 Methodology

Carefully observed the different specimens of various insects under different order as shown in the laboratory as well as insect museum and note the different distinguishing characters.

11.4 Order: ORTHOPTERA (Orthos = Straight; Ptera = Wing) e.g. Grass hopper, cricket and locust

This is a large order with more than 18000 described species. The insects of this order are found more in the tropics but some species do occur in the coldest zone.

Generally, they are terrestrial and usually capable of jumping. Some members of this order are strong fliers, all belonging to the family Acrididae. Some of the grass hoppers are important pests of field crops, e.g. paddy grass hopper, surface grass hopper, crickets etc. The locusts which fly gregarious in large numbers invade distant areas causing depletion of green biomass resulting in famine and starvation.

11.4.1 General characters of Orthoptera

- Medium to large sized insects with well developed exoskeleton.
- Head is hypognathous.
- They are winged.
- Fore wings modified into tegmina.
- Hind legs often enlarged for jumping purpose (saltatorial leg).
- Special sound producing and auditory organs often present (Stridulatorial legs in cricket).
- Cerci short and one segmented.
- They have chewing and biting type of mouthparts.
- Female has well developed ovipositor; male genitalia symmetrical.
- They have incomplete metamorphosis.

11.4.2 Sub order: Ensifera e.g. Crickets and long horned grasshoppers

- Antenna longer than their body.

- Tympanum organs present on their fore tibia, tarsi 3 to 4 segmented.
- Ovipositor less elongated.

Sr. No.	Name of Family	Characters
1	Tettigonidae	• e.g. Katydid (Long horn grasshopper) *tetigonia* sp. • Antennae are very long. • Tegmina modified asymmetrically for stridulation. • Predominantly green colour. • They have long ovipositor.
2	Gryllidae	• e.g. House cricket *Gryllus domesticus* • Head large and antennae very long. • Eye large. • Hind legs modified for jumping type. • Cerci long and unjointed. • Ovipositor long, slender and needle like. • Stridulate by friction of modified tegmina.
3	Gryllotalpidae	• e.g. Mole cricket, *Gryllotalpa africana* • Antennae short. • Tarsi 2 to 3 segmented. • Forelegs modified for digging type (Fossorial). • Typanum on fore tibia. • Eyes reduced. • Ovipositor small.

11.4.3 Sub order: Caelifera e.g. Short horned grasshoppers and locusts

- Antennae shorter than body.
- Hind legs adapted for leaping.
- Tarsi not more than three segmented.
- Ovipositor short and stout.
- Tympanum organ present at the base of abdomen.

Sr. No.	Name of Family	Characters
1	Acrididae	• e.g. Ak grasshopper (*Poecilocerus pictus*), Surface grasshopper (*Chrotogonous* sp.), Rice grasshopper (*Hieroglyphus banian*) and Locusts (*Scitocera gragaria*) • Forewings invariably leathery called tegmina. • Pronotum is collar shaped. • Ovipositor well developed, short and curved. • Hind legs modified as jumping. • Many small peg like projections near the base of tegmen and hind femur bears a simple longitudinal ridge which are rubbed against tegmina for producing the buzzing sound Mouth parts chewing type, eyes and

		antennae well developed. • Auditory organs located on each side of the basal segment of abdomen.

11.5 Order: DICTYOPTERA (Dictyon = Net; Ptera = Wing) e.g. Cockroach and Mantids

They are medium or large sized insects. They are terrestrial and occurring in tropical and subtropical region. They are not good flier. The order includes two distinct sub orders.

11.5.1 General characters of Dictyoptera

- Long filiform antennae, pronotum large as in praying mantis and shield shaped as in cockroaches.
- Ovipositor reduced.
- Tarsi 5 segmented.
- Stridulatory and auditory organs absent.

11.5.2 Sub order: Blattoidea e.g. Cockroaches

- Head nearly or completely cover.
- Pronotum shield shaped.
- Cerci prominent.
- Swift runners with ambulatorial and curssorial type of legs.
- Antennae long filiform.
- Mouthparts are typically mendibulate.
- Compound eyes present.
- They are nocturnal but also seen venturing during day time.
- They are omnivorous.
- They are household pests and spoil kitchen articles and food.

11.5.3 Sub order: Mantoidea e.g. Mantid

- Pronotum large elongated.
- Forelegs raptorial, helps in seizing the prey.
- Antennae long filiform.
- Head triangular with vertical face and movable on slender neck hence can see at 360^{O}.
- Eggs are deposited in ootheca or capsule formed of frothy quick drying material.
- They are largely arboreal and occur in all warmer parts of the world.
- They are carnivorous and live predaceous life both as young and adult.
- They feed on grasshoppers, flies, caterpillars etc.
- The female usually devours the male after mating.

11.6 Order: ODONATA (Odoun = Tooth) e.g. Dragonfly and damselfly

These conspicuous insects comprise a largely tropical order containing about 5500 described species. These are predatory insects. They catch and devour small flying insects. These are found in large numbers flying nearby stream, river etc. It can fly at a speed of 100 km/hr. They are fastest flying insects. The nymphs are aquatic in habit. Wide range of coloration is found in the adult.

11.6.1 Sub order: Anisoptera e.g. Dragonfly

- Predacious insect with biting mouthparts.
- Large insects with two pairs of unequal membranous wings, each with a large number of veins and cross veins and a prominent stigma known as Pterostigma**.**
- Unequal wings. Hind pair broadened basally.
- Wings held horizontally at rest.
- Antennae setaceous very small and the eyes are very long.
- Abdomen extremely long and slender.
- Metamorphosis hemimetabolous.
- Nymph is aquatic; respiration by means of caudal or rectal gills.
- They are diurnal in habit found in proximity of water.

11.6.2 Sub order: Zygoptera e.g. Damselflies

- Fore and hind wings similar and petiolated basally.
- Wings held vertically above the abdomen.
- Eyes projected laterally and separated by a space more than their dorsal diameter.
- Nymphs are slender, elongated abdomen and three caudal gills.
- They are diurnal in habit, found in proximity of water and predaceous in nature.

11.7 Order: ISOPTERA (Iso = Equal; Pteron = Wings) e.g. Termites

The isoptera is a small order of some 2600 described species of hemimetabolous neopterans. Termites are found throughout the tropics. Termites live in a nest called **termitaria** which are subterranean and which sometimes rise above the soil surface as large mounds. A termite colony has usually royal pair - the king and the queen which are primary reproductive castes; sterile castes consist of soldiers and workers, both are apterous. They feed on wood and are able to digest cellulose with the help of protozoa in their gut. They exhibit symbiosis with intestinal protozoans.

11.7.1 Different castes in a termite colony

1) **Queen**: It is reproductive caste that is responsible for maintaining the population of workers and soldiers in the termitaria.
2) **King**: It has a function of copulation with queen and accompany the queen for rest life
3) **Soldier**: They perform the function of patrolling the termitaria and defend the colony from the enemies.
4) **Workers**: They are actual workers, who find and collect foods and nourish young one, queen, king and maintain cleanliness of termitaria.

11.7.2 General characters of Isoptera

- Termites are soft bodied social and polymorphic (Queen, king, soldiers and workers) insects.
- Two pairs of similar wings present in sexually mature males and females.
- The wings are deciduous.
- The wings are membranous with restricted venation.
- Mouthparts biting and chewing type.
- Termites feed predominantly on cellulose rich material; wood, rotting timber, paper, books, furniture, many harvest grasses, many crops etc.

- Antennae short moniliform.
- External genitalia are absent.

Sr. No.	Name of Family	Characters
1	Termitidae	• e.g. *Odontoterms obesus* and *Microterms obesi.* • Ground dwelling with wide range of food habits and colony structure. • Worker castes well developed. • Pest of sandy soils and wood. • Wings very slightly reticulate. • Pronotum of workers and soldiers narrow with raised anterior lobe.

11.8 Order: THYSANOPTERA (Thysanos = Fringed; Aura = Tail) e.g. Thrips

This is a worldwide order of minute to small insects commonly known as thrips, comprising about 5000 species. They are mostly yellow, yellowish brown or black and may found among all kinds of vegetation, both on reproductive and vegetative parts. When disturbed, some species crawl in a leisurely fashion, other run quickly or leap and large number is flying but do not readily do so. Member of this order cause damage to cotton, onion, castor, groundnut, pulses, rose, tomato, chilly, tobacco etc.

11.8.1 General characters of Thysanoptera

- Their development is intermediate between hemi- and holometabolous; metamorphosis accompanied by two or three inactive pupa-like instars.
- The body is slender and elongate.
- Head hypognathus.
- Short antennae with 6 to 10 segment.
- Mouthparts are asymmetrical stylet like for rasping and sucking type.
- Right mandible is reduced in size.
- Fore and hind wings are similar and narrow with a long fringe.
- In female the cerci are absent.
- Many species curving the abdominal tip upward and movement.

Sr. No.	Name of Family	Characters
1	Thripidae	• e.g. *Thrips tabaci* • Mouthparts not bilaterally symmetrical. • Tarsus has claw like appendages. • Antennae 4-9 segmented with slender, simple or forked sense cones. • At rest the wings are parallel. • In female the cerci are absent.

11.9 Order: HEMIPTERA (Hemi = Half; Ptera = Wing) e.g. Aphids, Jassids, Whiteflies, Mealy bugs, Scale insects, Red cotton bug

The hemiptera distributed worldwide and is most diverse of the non endopterygote orders, with more than 90000 described species. The hemiptera or “true bugs” are easily

recognized by the form of their mouthparts. Some of them are blood suckers and transmits diseases in vertebrate animals. Several bugs are natural enemies that help to destroy insect pest.

11.9.1 General characters of Hemiptera

- Usually small to large insects.
- Bugs have somewhat flattened body.
- Forewings are hemelytra (i.e. leathery at the base and membranous at the tip) in Heteroptera and uniform wings in Homoptera.
- Mouthparts piercing and sucking type, mandibles and maxillae are modified into needle like stylets.
- Metamorphosis usually gradual (incomplete), rarely complete.

19.9.2 Economic importance of Hemiptera

- Aphid, jassid and whitefly act as vectors of plant viruses.
- They transmit many diseases in plant.
- They suck the cell sap from the plant parts and cause economic damage.
- They attack a wide variety of crops, vegetables crops, fruit crops, garden crops etc and cause heavy loss farmers.

11.9.3 Sub-order: Homoptera

- Forewing either leathery or membranous folded roof like.
- Abundant discharge of a sugary waste product of honey dew especially in aphids.
- Pronotum small.
- Eggs lay singly mostly in plant tissues.
- Hemimetabolous.
- No scutellum.
- Body shape is either wedged or oval, slender and elongated.

Sr. No.	Name of Family	Characters
1	Delphacidae	• e.g. Sugarcane leafhopper • Mediun ocellus absent. • Hind tibia large. • Large aedeagus. • Movable spur.
2	Fulgoridae	• e.g. Sugarcane Pyrilla (*Pyrilla perpusilla*) • Ocelli 2 or 3 or absent. • Antennae 3 segmented. • Rostrum elongated. • Tarsi 3 segmented. • Aedeagus with a clear thecae surrounding penis. • Incomplete ovipositor.
3	Cicadidae	• e.g. Cicadas (*Magicicada septemdecim*) • Sound producing insects.

		• Tympanal and auditory organs present. • Empodia absent. • Femur and tibia of fore legs greatly enlarged and modified.
4	Memracidae	• e.g. Tree hoppers • Vertical crown on head. • Pronotum large having spine like structure on both sides.
5	Cicadellidae	• e.g. Leaf hopper (*Amrasca bigutella bigutella*), Green leaf hopper (*Nephotettix virescens*), Brown plant hopper (*Nilaparvata lugens*) and Mango planthopper (*Ideocerus atkinsoni*) • Wedge shaped or slender in form. • Ocelli absent. • Antenna 8 segmented when disturbed they often leap several feet and always ready for flight. • An adult walks diagonally.
6	Aleyrodidae	• e.g. Cotton whitefly (*Bemisia tabaci*), Citrus whitefly (*Dialeurodes citri*) and Sugarcane whitefly (A*leurolobus barodensis*) • Wings powdery with white waxy material. • Wing venation reduced. • Excrete honeydews. • Incomplete metamorphosis.
7	Aphididae	• e.g. Mustard aphid (*Lipaphis erysimi*), Cotton aphid (*Aphis gossypii*), Peach aphid (*Myzus persicae*) and Black bean aphid (*Aphis craccivora*) • Winged or wingless adults. • Ocelli absent and cornicles present on abdomen. • Antennae 2-3 segmented. • Tarsi 2 segmented having pair of claws. • Parthenogenetic reproduction.
8	Lacciferidae	• e.g. Lack insects (*Laccifer lacca*) • Female apterous and male winged. • Antennal vestigial. • Body globose type enclosed in dense resinous cells. • Legs reduced of absent. • Body covered with lac glands and open in epidermis.
9	Coccidae	• e.g. Sugarcane scale insects (*Melanspis glomerata*), Cottony scale insect (*Icerya puchasi*) and Mango mealy bug (*Drosicha mangiferae*) • Males harmless without mouthparts. • Females smooth with smooth integument. • Body small inconspicuous, soft covered with wax, scale like or gall like structures or powdery exudates. • Antennae much reduced or absent. • They secrete honeydew.

		• Rostrum small and double segmented.

11.9.4 Sub-order: Heteroptera

- Two pairs of wing present which are different to each other folded flat over the abdomen.
- Mouthparts typically piercing and sucking type.
- Flat body.
- Antennae 4-5 segmented.
- Large pronotum.
- Formation of shield like scutellum.
- Forewings basally sclerotized and apically membranous called hemelytra and hind wings are transparent and membranous.

Sr. No.	Name of Family	Characters
1	Tingidae	• e.g. Brinjal Lace wing bug (*Urntius hystricellus*) • Ocelli absent. • Scutellum concealed by the pronotum. • Body and hemelytra densely reticulated.
2	Reduviidae	• e.g. Assasin bug (*Reduvius personatus*) • It includes predatory bugs, pests of crops, vector of human diseases. • Head prolonged and narrowed behind the eyes. • Rostrum pointed. • Labium stout and robust with 3 segments. • Generally wings don't cover the lateral part of abdomen fore legs with fossula spongiosa for adhesion. • Antennae long with intercalary segments.
3	Cimicidae	• e.g. Bed bug (*Cimex lectularius*) • Ectoparasites of man and other animals • Ocelli absent
4	Anthocoridae	• e.g. *Anthocoris* sp. • Predaceous on small insects. • Body small, elongated and flat. • Ocelli absent. • Scent glands present on metathorax. • Legs with empodium.
5	Miridae	• e.g. Tea bug (*Helopeltis* sp.), Lygus plant bug (*Lygus pabulinus*) • Delicate small to medium insects. • Ocelli absent. • Empodium instinct.
6	Lygaeidae	• e.g. Dusky cotton bug (*Oxycarenus hyalinipennis*) • Ocelli present. • Small, dark or brightly coloured insects. • Antennae inserted below the head.

		• Veins in the hemelytra never more than five.
7	Pyrrhocoridae	• e.g. Red cotton bug (*Dysdercus koenigii*). • Insect contrasting red and black colouration. • Polyphagous insects and gregarious in habit. • Both antennae and rostrum 4 segmented. • Ocelli absent.
8	Coridae	• e.g. Rice gundhi bug (*Leptocorisa acuta*). • Medium to large sized, elongated or oval polyphagous insects. • Both antennae and rostrum 4 segmented. • Ocelli present. • Scutellum small. • Legs strong with pulvelli. • Scent glands opening conspicuous that produce disagreeable odour.
9	Pentatomidae	• e.g. Painted bug (*Bagrada hilaris*), Stink bugs. • Moderate to large insects often brightly coloured. • Scutellum large that cover half abdomen. • Rostrum 4 segmented. Tarsi 2-3 segmented. • Ocelli always present. • Well developed hemelytra. • Triangular bugs with five segmented antennae.

11.11 Exercise:

(1) Draw the color diagram of the Grasshopper, cricket, cockroach, praying mantis, dragonfly, damselfly, termite (all casts), thrips, aphid and red cotton bug as shown in the classroom as well as insect museum.

(2) Write two important characters of Orthoptera, Dictyoptera, Odonata, Isoptera, Thysanoptera and Hemiptera orders and their families of agricultural important.

(3) Differentiate the following. (a) Caelifera and Ensifera (b) Dragonflies and Damselflies (c) Antlion and Dragonfly (d) Anisoptera and Zygoptera (e) Homoptera and Heteroptera.

(4) Visit to the nearby field and collect as well as preserve the different insects and arrange according to order in the insect storage box.

EXERCISE – 12
STUDY THE CHARACTERS OF ORDERS LEPIDOPTERA, COLEOPTERA, NEUROPTERA, HYMENOPTERA, DIPTERA AND THEIR FAMILIES OF AGRICULTURAL IMPORTANCE

DATE:_____

12.1 Objective:

(1) To learn the distinguishing features of insect orders and their families of agricultural importance.
(2) To collect the insects of commonly found families of various orders.
(3) To familiarize the students with different orders of insects and their characters to identify them up to family level.

12.2 Materials:

Preserved specimens of different orders *viz.*, Lepidoptera, Coleoptera, Neuroptera, Hymenoptera and Diptera in the laboratory as well as insect museum.

12.3 Methodology:

Carefully observed the different specimens of various insects under different order as shown in the laboratory as well as insect museum and note the different characters.

12.4 Order: LEPIDOPTERA (*Lepidos* = Scale; *Pteron* = Wings) e.g. Butterfly and moth

The Lepidoptera is one of the major insect orders, both in terms of size with some 160000 described species and popularity. Both moth and butterfly live on nectar of flowers; over ripen fruits, honey dew and other substances.

12.4.1 General characters of lepidoptera

- Small to large insects with two pairs of membranous wings covered with overlapping flat scales.
- Forewings are always larger than hind wings.
- Antennae pectinate, bipectinate or club shaped.
- Mouthparts siphoning type spirally coiled suctorial proboscis.
- Larvae phytophagous, polypod and having biting type of mouthparts.
- Pupae adecticous and obtect type usually form the cocoon or earthen cell.
- Head hypognathus.
- Butterflies are diurnal and moths are nocturnal.
- Holometabolus insects.

12.4.2 Economic importance of lepidoptera

- The larvae cause damage to the commodities of human interest.
- Some of the Lepidopteran acts as parasites of crop insect pest e.g. *Epericanea melanoleuca* on sugarcane pyrilla.
- Many of them play important role in pollination of flowers.
- Silkworm moth yields silk which is of high commercial value.
- It increases the aesthetic values of nature.

Sr. No.	Name of Family	Characters
A. Families of moth		
1	Gelechiidae	• e.g. Pink bollworm (*Pectinophora gossypiella*), Angoumois grain moth (*Sitotroga cereallela*) and Potato tuber moth (*Gnorimoschema operculella*). • Usually small and delicate moth. • The hind tibia possesses hard hairs. • Maxilary palp either absent or very small. • Fore wings trapezoidal and stalk at the base narrower than hind wings.
2	Pyralididae	• e.g. Sugarcane shoot borer (*Chilo infuscetellus*), Sugarcane top borer (*Scirpophaga* sp.), Rice moth (*Corcyra cephalonica*), Almond moth (*Ephestia cautella*), Brinjal fruit and shoot borer (*Leucinodes orbonalis*), Cotton leaf roller (*Sylepta derogeta*), Sorghum stem borer (*Chilo partellus*). • Large family varying greatly in shape and size. • Maxillary palp always present. • Legs long and slender. • Forewings usually narrow and hind wings broad. • Moths have abdominal tympanal organs.
3	Noctuidae	• e.g. Gram cutworm (*Agrotis ypsilon*), Gram pod borer (*Helicoverpa armigera*), Tobacco leaf eating caterpillar (*Spodoptera litura*), Spoted boll worm, (*Earias vittella*) and Green semilooper (*Plusia ni*, *Chrysodexis* spp.). • Eminently nocturnal moths attracted to light. • Frenulum present as wing coupling apparatus. • Maxillary palp vestigial. • Proboscis stout or flexible. • Forewings coloured and cryptic or dull. • Larvae have setae and prolegs.
4	Arctiidae	• e.g. Bihar hairy caterpillar (*Spilosoma obliqua*), Gujarat hairy caterpillar (*Amsacta moorei*) and Sunhemp caterpillar (*Utethesa pulchella*). • Moths with stout body. • Broad brightly coloured wings with spots or bands on them. • Generally nocturnal. • Larvae densely clothed with long hairs and fed on herbaceous plants.
5	Sphingidae	• e.g. Spinx moth (*Acherontia styx*) and hawk moth (*Agrius convolvuli*). • Moderate to large sized moth. • Antennae gradually thickened and in male they are ciliated with partial whorls. • Apex of antennae are pointed or hooked. • Tympanal organs absent.

		• Moths have exceptionally powerful flight, crepuscular or nocturnal of diurnal in habit.
6	Pterophoridae	• e.g. Tur plume moth (*Exelastis atomosa*). • Both pairs of wing split into feather like structure (plumes). • Haustellum naked. • Legs usually long and slender. • Small sized moth.
7	Bombycidae	• e.g. Silk worm (*Bombyx mori*). • Generally white moth with several faint brownish lines across the front wings. • Antennae pectinate in both sexes. • Maxillary palpi and tympanal organs absent. • Proboscis rarely developed. • Adults don't feed and they rarely fly. • Larvae glabrous elongated and form dense silken cocoons before pupation.
8	Saturniidae	• e.g. Atlas moth (*Attacus atlas*). • Large moths (Biggest moth in insect world in terms of total wing surface area). • Antennae bipectinate in both sexes. • Frenulum absent. • Labial palpi very small. • Wings broad with transparent eye spot near center.
B. Families of butterfly		
1	Lycaenidae	• e.g. Blue butterfly and Anar butterfly. • Moderate sized butterfly. • Upper surface of wings metallic blue or coppery, dark or orange. • Underside of the wing is more dull with dark centered eye spots. • Hind wings with delicate tail like prolongations. • Tarsi more or less abbreviated with claw. • Antenna ringed white. • Rim of white around each eye.
2	Pieridae	• e.g. Cabbage butterfly (*Pieris brassicae*). • Medium sized butterflies usually white, yellow or orange marked with black colour. • Legs well developed and claw toothed. • Larvae green and covered with fine short hairs. • Pupae with single median projection or spine.
3	Papilionidae	• e.g. Lemon butterfly (*Papilio demoleus*). • Large and conspicuously coloured butterflies with tail like prolongations on hind wings.

		• Wings generally glossy black with shades of green, red, blue, orange or yellow. • Setae usually absent on the body. • Pupa with two lateral projections.
4	Hesperidae	• e.g. Rice skipper (*Parnara mithias, P. Colaca*). • Antennae gradually clavate or club shaped which often last in hook. • Forewings without cubitous 2 (Cu_2). • Hind wings without frenulum. • Erratic darting flight.
5	Nymphalidae	• e.g. Rice horn caterpillar (*Melanitis* spp.). • Anterior legs of adults unfit for walking. • Tibia short and clothed with long hairs. • Antennae club shaped and without scales. • Tuft of hairs produces peculiar odours.

12.5 Order: COLEOPTERA (*Coleos* = Sheath; *Ptera* = Wing) e.g. Beetles and Weevils

The coleoptera is the **largest order** in the animal kingdom, with about **350000** described species of holometabolous.

12.5.1 General characters of Coleoptera

- Minute to large insects with hard exoskeleton.
- Forewings are modified into horny shell like elytra (vein less sheath).
- Elytra covering the folded hind wing at rest.
- Mouthparts biting and chewing type.
- Prothorax large.
- Antenna lamellate, serrate or clubbed type.
- In weevil, antennae carried forward; the frons and vertex prolonged anteriorly to form rostrum or snout.
- Ocelli are usually absent.
- Metamorphosis complete.
- Larvae types are apodous, campodeiform, euriciform or scarabaeiform.
- Pupation in a specially constructed cell or chamber.
- Most of the beetles are ground-dwellers, some are aquatic.

12.5.2 Sub-order: Adephaga

- Grub has a single tarsus and one or two claws.
- No molar area in mandibles. Four malpighian tubules.

Sr. No.	Name of Family	Characters
1	Carabidae	• e.g. Ground beetle and Tiger beetle • Grubs and beetles are predatory in nature. • They are occurring in soils. • Legs slender adapted for running or digging. • Body brightly coloured.

		• Prominent eyes and large mandibles.
2	Dyticidae	• e.g. Water beetle • Grubs and adults are aquatic but adults can live on land also. • Carnivorous in habit. • Natatorial types of legs and fringed with long hairs. • Capable of prolonged flight. • Antennae filiform. • The fore tarsi dilated to form adhesive pad or cup like structure. • Elytra elevated to enter the air.

12.5.3 Sub-order: Polyphaga

- Elytra shorter than abdomen hence not fully covered with elytra.
- Fore tibia toothed or with spines.
- Antennae filiform or club shaped or serrate type.

Sr. No.	Name of Family	Characters
1	Scarabaeidae	• e.g. White grub (*Holotrichia consanguinea*) and chaffer beetle (*Melolontha* sp.) • Forelegs with spines or toothed. • Hind tibias with a single terminal spur. • Antennae 10 segmented. • The larvae live in decomposing organic matter, the larvae attacks roots of plants. • Hypognathous mouthparts. • Grubs scarabaeiform living in soil. • Pupation in earthen cocoons.
2	Buprestidae	• e.g. Jewel beetle (*Sphenoptera indica*) • Serrated antennae 11 segmented. • Thorax and abdomen firmly united. • Adults love bright sunshine, inhabit wooded areas. • Grub with free labrum and bore into the stem. • Eyes absent. • Elytra strongly sclerotized and hard and most brilliantly coloured.
3	Elateridae	• e.g. Firefly • Elongated insects dull or metallic coloured. • Emit bright light from round yellow area on either sides of the thorax. • Flat head with a transverse ridge above the antennal sockets • Largest prothorax. • Body reddish brown. • Antennae short.
4	Lampyridae	• e.g. Glowworms (*Lamprophorous tardus*) • Antennal socket facing dorsally.

		• Luminous organs present on hind segments of the abdomen which emit bright light. • Nocturnal in nature.
5	Dermestidae	• e.g. Khapra beetle (*Trogoderma granarium*) • Small and hemispherical oval beetle. • Body cover with fine scales or hairs. • Antennae small clavate type 11 segmented. • Tarsi 5 segmented. • Well developed compound eyes.
6	Anobiidae	• e.g. Drug beetle (*Stegobium paniceum*) and Cigarette beetle (*Lasioderma serricorne*) • Antennae very short. • No anal processes or cerci. • The terminal abdominal segments are large. • Pests of spices, cigarette, drugs, bakery and furniture.
7	Bostrychidae	• e.g. Lesser grain borer (*Rhizopertha dominica*) • Pronotum hood like. • Antennae with less than 11 segments and last three segments form club. • Only thorax and abdomen visible dorsally because head deflected downwards.
8	Coccinellidae	• e.g. Ladybird beetle (*Coccinella septumpunctata*): beneficial and Hadda beetles (*Epilachna vigintioctopunctata*): harmful • Small or medium sized oval or round convex brightly coloured and black spotted adults. • Predaceous or phytophagous insects. • Head almost concealed under the pronotum. • Antennae small, clavae type with 11 segmented. • Tarsi 4 segmented.
9	Tenebrionidae	• e.g. Red rust flour beetle (*Tribolium castaneum*) • Small, narrow elongated body. • Head, thorax and abdomen distinctly visible. • Antenna capitates type.
10	Meloidae	• e.g. Blister beetle (*Mylabris pustulata*) • Hypognathous head. • Prothorax narrow and elongated. • Grubs predator and adults pests of crops; generally feeds on flower. • Faeces frequently coming out and most of time attached with anus. • The adult produce pharmaceutical product cantharidin.
11	Cerambycidae	• e.g. Mango stem borer (*Batocera rufomaculata*) and Long horned beetles (*Saperia populanea*) • Big beetles, very long antennae like dried twigs usually 2/3rd as long as

		body and fixed backwardly. • Cryptic colouration of the body. • Tibia has two spurs. • Six malpighian tubules.
12	Bruchidae	• e.g. Pulse beetle (*Callosobruchus chinensis*) • Small, short, stout, dull grayish to brownish body covered setae or scales. • Antennae clavate, serrate or pectinate type. • Head prolonged, prognathous type. • Femora swollen and tarsi 5 segmented ending into claws. • Wings short keeping the abdominal tip exposed.
13	Chrysomelidae	• e.g. Red pumpkin beetle (*Rhapidopalpa foveicollis*) and Rice hispa (*Dicladispa armigera*) • Orange or bright or elongated metallic colour or leathery or shield like or flattened tortoise adults. • Elongated body. • Sunken needle spots on elytra. • Hispa usually covered with long stout upright spines.
14	Curculionidae	• e.g. Rice weevil (*Sitophilus oryzae*), Coconut palm weevil (*Rhynchophorus ferrugineus*) • Head produced into pronounced rostrum or snout or beak like • Geniculate or clubbed antennae. • Trochantur elongated. • Reduced rigid palps.
15	Staphylinidae	• e.g. Rove beetle • Beetles, primarily distinguished by their short elytra that leave more than half of their abdomens exposed. • Second largest family of beetles after the Curculionidae (the true weevils).

12.6 Order: NEUROPTERA (Neuron = Nerve; Ptera = Wing) e.g. Green lacewing (*Chrysoperla carnea*) and Antlions (*Myrmeleon*)

Approximately 5000-6000 species are described.

12.6.1 General characters of Neuroptera

- Two pairs of wing are similar membranous and folded roof like over the body at rest.
- Mandibulosuctorial type mouthparts.
- Prothorax often larger than meso- and metathorax.
- Cerci absent.
- Antennae long well developed and filiform.
- Larvae campodeiform with prognathous head and predaceous in nature.
- Pupae exarate decticous.
- Both larvae and the adults are predaceous on other insects.

- Ant lions are often attracted to light at night. During the day it hides amidst the vegetation.

12.6.2 Economic importance of Neuroptera

- Chrysopa feeds on aphids thus act as biological control agent of aphids.
- The larvae of ant lions feed on ants. The ant lion prepare a tunnel like pits in the soil when the runway ants slips into the pit, the larvae capture the victim and sucks out the body fluids.

Sr. No.	Name of Family	Characters
1	Chrysopidae	• e.g. Green lacewing (*Chrysopa* sp.) • Antennae longer than forewings. • Mandibles long and strong. • Wings and body green with golden eyes. • Eggs stalked. • Larvae with hooked hair on the body for supporting the dead host. • Chrysopa feeds on aphids.
2	Myrmeleontidae	• e.g. Antlion • Antennae longer than forewings. • The adult has two pairs of long, narrow, multi-veined wings in which the apical veins enclose regular oblong spaces. • It has long, slender abdomen. • It has prominent, apical clubbed antennae. • They are highly active in desert regions and are a nuisance. • They will deliver a small, mildly painful bite if given the chance to land on someone.

12.7 Order: HYMENOPTERA (Hymen = Membrane; Ptera = Wing) e.g. Wasps, Ants, Sawflies and Honey bees

The hymenoptera is an order of about 100000 described species of holometabolous neopterans. Most of the species of the sub order symphyta are phytophagous, while most of the insects of the sub order apocrita are useful in one of the other way in agriculture.

12.7.1 General characters of hymenoptera

- Small to medium sized insects.
- Head extremely mobile hypognathous or prognathous.
- Mouthparts biting, lapping or sucking type.
- Antennae geniculate or variable.
- Compound eyes are usually large.
- Wings membranous, hind wings are smaller than the fore wings, hind and fore wings interlocked with hooklets, the 'hamuli'.
- Abdomen basally constricted.
- Ovipositor modified for sawing or piercing or stinging.
- Larvae generally apodous or may be polypod, rarely eruciform with locomotory appendages.
- Tracheal system holopneustic or peripneustic.
- Pupae adecticous and exarate (rarely obtect) generally in cocoon.
- Metamorphosis usually complete.
- They are diurnal who love sunshine and warmth.
- They are free living or phytophagous or entomophagous parasitic or social insects

12.7.2 Economic importance of hymenoptera

- They are act as biological control agents of many crop pests.
- Many are crop pests.
- They are helpful in pollination of various crop plants.
- Honey bees are very beneficial as it provide honey and bees wax.

12.7.3 Sub-order: Symphyta

- Slender waist or petiole absent.
- Abdomen broadly attached with thorax.
- No constriction between 1st and 2nd abdominal segment.
- Legs with 2 segmented trochanter.
- Ovipositor used for sawing and boring.
- Prolegs without crochets.

Sr. No.	Name of Family	Characters
1	Tenthridinidae	• e.g. Mustard sawfly (*Athalia proxima lugens*). • Medium sized brightly coloured insects. • Antennae serrate and clubbed type. • Scutellum with defined post scutellum. • Ovipositor is modified into saw like structure. • Prolegs without crochets. • Tarsi 5 segmented.
2	Cephidae	• e.g. Stem sawfly (*Cephus cinctus*). • Slender narrow bodied insects with thin integument. • Mostly black or dark coloured insects with or without yellow band. • Prothorax large with hind margin straight.

12.7.4 Sub-order: Apocrita

- Abdomen deeply constricted or petiolated between 1st and 2nd segments.
- No constriction between 1st and 2nd abdominal segment.
- Trochanter with 1 or 2 segments.
- Ovipositor well developed.
- Prolegs without crochets.

Sr. No.	Name of Family	Characters
1	Ichneuminidae	• e.g. Ichneumon wasp. • Forewings with cross veins (2m-Cu) present. • Propodium elongated. • Parasites of many Lepidoptera and Coleoptera etc.
2	Braconidae	• e.g. Parasitic wasps *Bracon chinensis*, *Apanteles* spp., *Chelonus* spp., *Microplitis* spp. • Body small and stout.

		• Abdomen sessile and petiolated. • Thick hind femur. • Forewings with cross veins (2m-Cu) absent.
3	Chalcididae	• e.g. Chalcid fly • Parasites of Lepidoptera and Coleopteran etc. • Hind femur with short teeth. • Wings not folded while resting, wing venation reduced. • Ovipositor short and straight.
4	Eulophidae	• e.g. *Tetrastichus pyrillae.* • Very small insects. • Parasites of aphids, coccids and pyrilla. • Forewings not broad. • Pubescence not in rows. • Tarsi 4-5 segmented.
5	Trichogrammatidae	• e.g. *Trichogramma chilonis.* • Very small insects. • Egg parasites of lepidopterous insects. • Forewings broad. • Pubescence in line. • Tarsi 3 segmented. • Marginal and stigma veins in curve.
6	Formicidae	• e.g. Ants (*Formica indica*). • Polymorphic ants. • Demarcation between head, thorax and abdomen very well differentiated. • Scape in antennae very large. • Pedicel (Propodium) well develop. • Wings long in sexually matured insects. • Social insects includes three castes – King, Queen and Workers.
7	Vespidae	• e.g. Yellow wasp (*Vespa orientalis*). • Solitary and social wasps. • Wasp often yellow or red with black markings. • Legs moderate size. • Hind wings lack anal lobes. • Abdomen with well developed stings. Sting very painful for animals and human beings.
8	Apidae	• e.g. Honey bees (*Apis dorsata, A. Indica, A. Florea and A. mellifera*). • Social insect living in colony – Queen, king (Drone), Soldiers and workers. • Mouthparts chewing and lapping type.

		• Solitary, parasitic honey bees. • Antennae geniculate. • Hind legs pollen collecting. • Ovipositor modified for stinging.

12.8 Order: DIPTERA (Di = Two; Ptera= Wings) e.g. House fly, Mosquitoes, Fruit fly, Tachinid fly, Tsetse fly, Syrphid fly, Robber fly, Tur pod fly etc.

The diptera is one of the large insect orders, includes over 125000 described species. The adults of most species are diurnal in habit but many mosquito species are nocturnal. Majority are either flower lovers which feed upon nectar or frequently decaying organic matter of various kinds. Some are predacious and live on various insects. Some suck blood of vertebrate animals including men. A few are phytophagous. The pathogens of most virulent diseases such as malaria, sleeping sickness, elephantiasis and yellow fever are transmitted to man through blood sucking diptera.

12.8.1 General characters of Diptera

- Small to medium sized insects.
- Forewings are membranous and hind wings modified into halters or balancers.
- Antennae aristate or plumose.
- Mouthparts sponging type forming proboscis or sucking and piercing type.
- Larvae apodous (maggot).
- Pupae adecticous, obtect or exarate type.
- Prothorax and metathorax are reduced and fused with the well developed mesothorax.
- Holometabolus insects. Metamophosis complete.

12.8.2 Economic importance of Diptera

- Blood sucking insects are capable of transmitting disease causing microorganisms from one host to other.
- They cause great annoyance.

12.8.3 Sub-order: Nematocera

- Antenna many segmented, elongated and generally plumose type.
- Larvae have well developed head.

Sr. No.	Name of Family	Characters
1	Culicidae	• e.g. Mosquitoes • They are slender, long-legged insects. • Larvae are distinguished from other aquatic insects by the absence of legs, the presence of a distinct head bearing mouth brushes and antennae.
2	Cecidomyidae	• e.g. Gall midges, Sorghum midge (*Contarinia sorghicola*) • Minute and delicate fly • Antennae moniliform with whorl of hairs • Wings with few longitudinal veins

		• Larvae peripneustic with reduced head responsible for producing galls on leaves, stem and other plants.

12.8.4 Sub-order: Brachycera

- Tracheal system amphineustic.
- Prothoracic respiratory organs sessile.
- Abdominal segments with girdles of spines.
- Terminal segment armed with pointed process.
- Larva with incomplete head with vertically biting mandibles.
- Simple obtect pupa.

Sr. No.	Name of Family	Characters
1	Asilidae	• e.g. Robber flies (*Laphria* spp.) • Proboscis adapted for piercing • Pulvilli large and empodium bristle like • Long and powerful legs • Body elongated with numerous bristle.
2	Bombylidae	• e.g. Bee flies (*Bombylius major*) • Proboscis very long • Empodium rudimentary • Body stout and densely covered with hairs

12.8.5 Sub-order: Cyclorrhapha

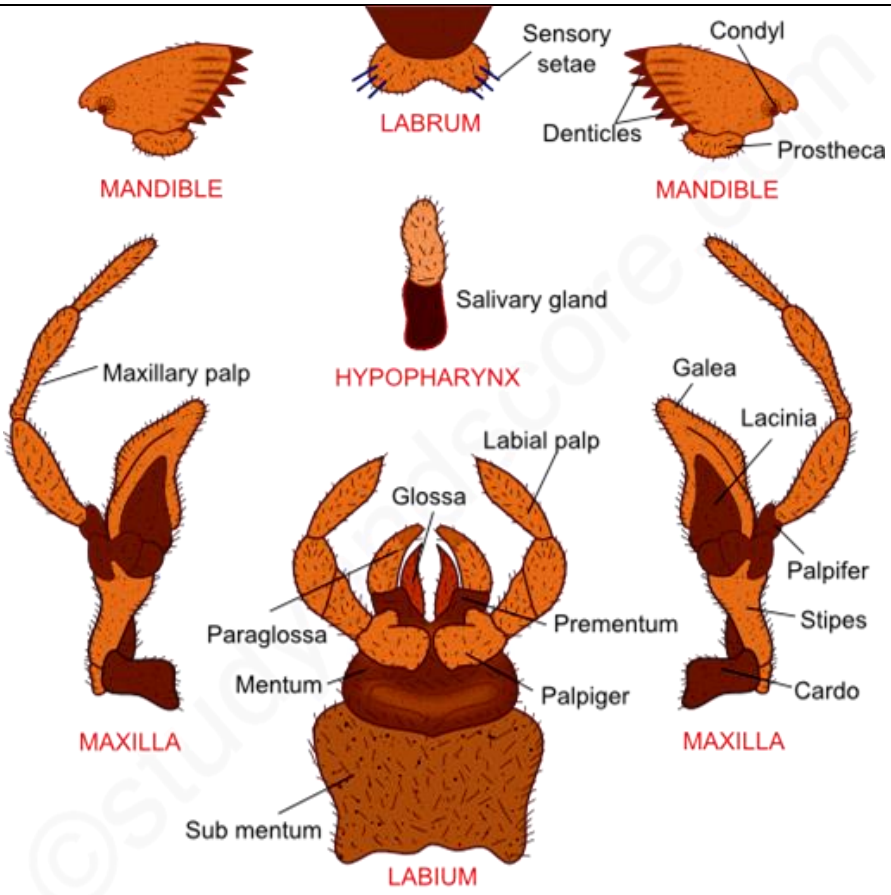
- Antenna three segmented, flagellum bears spiny projection (arista).
- Larva has vestigial head.
- A pupa enclosed in a hardened puparium.
- Circular-seamed flies.

Sr. No.	Name of Family	Characters
1	Phoridae	• e.g. Phorid fly (*Aneurina* sp.), Mashroom fly • Antenna long apical or sub dorsal arista. • Wings vestigial or absent.
2	Syrphidae	• e.g. Syrphid fly • Moderate to large bristle. • Brightly coloured markings. • Arista dorsal.
3	Drosophilidae	• e.g. Drosophilla (Drosophilla melanogastor)
4	Psilidae	• e.g. Carrot fly (*Psila rosae*) • Cubitus well developed.
5	Anthomyiidae	• e.g. Leaf miner (*Pegomyia* spp.) • Vein Cu1+ 1A reach the vein margin but faint distal.
6	Tachinidae	• e.g. Tachinid fly (*Sturmiopsis inferens*)

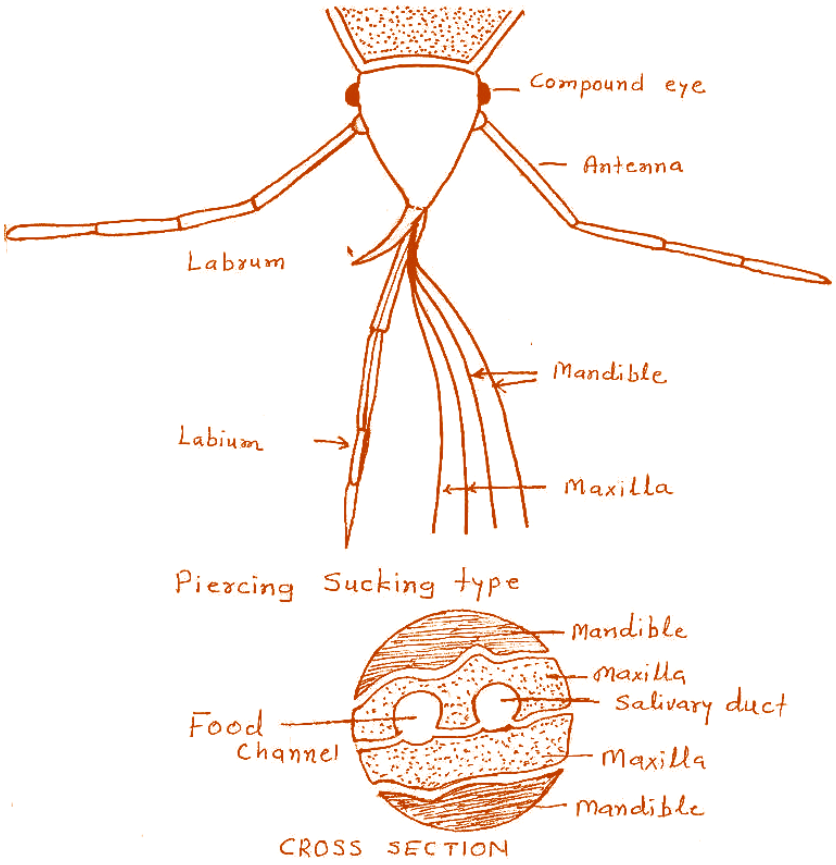
		• Parasites of the lepidopterous larvae. • Arista bare. • Abdomen elongated with numerous bristles. • Postscutellum little developed.
7	Agromyzidae	• e.g. Tur pod fly (*Melanagromyza obtusa*), Pea leaf miner (*Phytomyza horticola*) and *Liriomyza* spp. • Small sized black with bluish, shiny coloured insects. • Larvae mine in leaves, stem or developing pods.
8	Tephritidae	• e.g. Cucurbits fruit fly (*Bactrocera cucurbitae*), Ber fruit fly (*Carpomyia vesuviana, Dacus dorsalis*) • Fore wings either with brownish spots or strips. • Abdomen oval in shape. • Inner orbit sclerotized. • Male with long, flexible, coiled aedeagus.

12.9 Exercise:

1) Draw the color diagram of moth, butterfly, beetle, weevil, Green lace wing (Crysopa), honey bee, wasp and house fly as shown in the classroom as well as insect museum.
2) Write two important characters of Lepidoptera, Coleoptera, Neuroptera, Hymenoptera and Diptera orders and their families of agricultural important.
3) Difference between the following (a) Butterfly and Moth (b) Beetle and Weevil Nematocera and Brachycera (c) Symphyta and Apocrita.
4) Visit to the nearby field and collect as well as preserve the different insects and arrange according to order in the insect collection box.



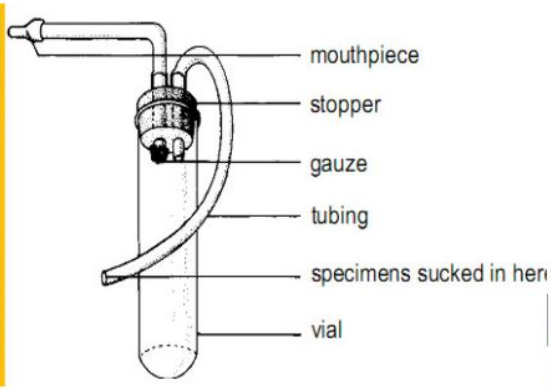
Mouth parts of cockroach (Biting and chewing type)



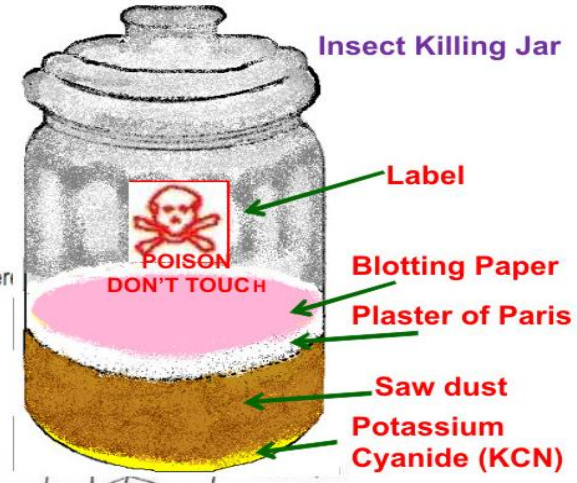
Mouth parts of Red cotton bug (Piercing and sucking type)

Insect Collecting Equipment

Insect Collecting Net

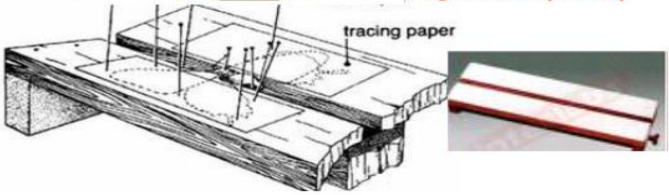


Aspirator



Insect Storing Box

Insect Pinning block



Insect Spreading board

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