EXERCISE NO. 1

Date: ----------

Methods of Collection and Preservation of Insects Including immature stages

Objectives: -

1) To know the pest occurrence of the locality.
2) To study the taxonomic character of insects.
3) To send the specimens to different places for identification.
4) To keep the different insects in museum.
5) To study the bionomics of pests.

I) Equipment required for insect collection: -

1) Insect Collecting Net
2) Insect Storage Box
3) Insect Killing Bottle
4) Aspirator
5) Insect Setting/Spreading/Stretching Board
6) Entomological Pins of different sizes
7) Small Hair Brush
8) Insect Rearing Cages
9) Insect Killing/Preserving Media
10) Hand Lens
11) Forceps/Needles
12) Specimen tubes and Glass Vials

1) **Insect Collecting Net: -** The net with handle nearly 2 ft. in length having circular iron of ring of 1 ft. diameter attached to it. A collecting bag made up of ordinary mosquito netting cloth is attached to the iron ring. It is used to catch the flying insects. Collecting nets come in three basic forms: Aerial nets- It is designed especially for collecting butterflies and other flying insects. Both the bag and handle are relatively light weight. Aquatic nets - are used for gathering insects from water. Sweeping Nets: it is moved quickly through foliage, shrubbery and other vegetation to dislodge insects feeding or resting on foliage.
2) **Aspirator: -** A glass tube is used for collecting the small size insects which is fitted with rubber cock. A rubber cock is having two holes in which small tubes are fitted. Out of the small two tubes one is longer and another is shorter, which is used for sucking collected insects to escape. The other tube is further fitted with rubber tube which is used for collecting smaller size insects. After collection of insects 70 % alcohol may be added into the specimen tube and preserved collected insects.
3) **Insect Storage Box:** - The insect stored boxes are made up of seasoned wood in such way that their joints are intact and dust proof. The bottom as well as top portion is covered with cork sheet. The pinned insects can be easily mounted is these boxes. After drying, the insect specimens are transferred to insect stored box hence insect box is used to store the insect specimens.
4) **Insect Setting/Stretching/Mounting Board: -** This board has a groove down the middle that holds the insect's body and two flat pieces that the wings will rest on. Take your specimen (let's say a butterfly) and using a pinning block (above) pin it through the thorax. Now put it on the mounting board so that the legs and body are in the groove down the middle and the dorsal surface is up. Carefully pull the wings into the desired position and hold them down with a strip of paper that lies across them and is held down with pins. You should do this with each wing.
5) **Killing Bottle: -** It is used for terrestrial insects. Consist of a glass bottle with metal lid with a thin layer of plaster-of- Paris in the bottom. The plaster layer is saturated with ethyl acetate and the insects placed in the jar are killed by asphyxiation. The most important chemicals used to kill insects Sodium or potassium, chloroform and ethyl acetate.
6) **Specimen tubes and Glass Vials:** - It is used for aquatic and soft bodied insects. Insect specimen may be preserved in 70% Ethyl alcohol.

II) Preservation of hard bodies insects: -Materials required for preservation is Killing bottle, Entomological pins, Setting board, insect store box, drying chamber etc.

a) Preparation of killing bottle- Take an ordinary wide mouth bottle, having 500 gm. capacity with tight metal screw cap /lid. Wash and dry the jar. Put 1 to 2 spoonful of potassium cyanide or sodium cyanide at the bottom of bottle and cover this poison by putting a layer of Plaster of Paris up to the height of 2-3 cm. Add two drops of water over it. Allow the plaster of Paris to harden the layer. A circular blotting paper over it and bottle is ready for use after a couple of days.

Precaution:

i) Killing bottle should never be kept open as it gives out hydrocyanic acid gas which is poisonous.

ii) The bottle must be labelled as "POISON"

iii) Broken pieces of the bottle should be disposed-off by burying.

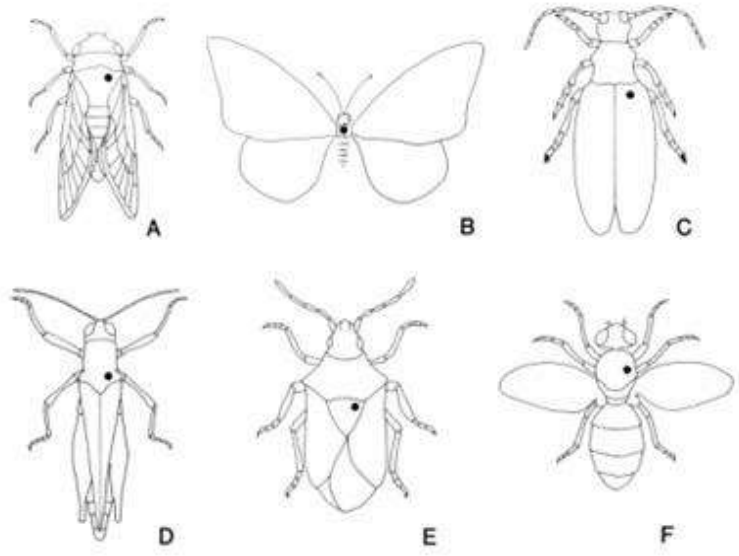
iv) Do not keep the lepidopterans insects simultaneously with other insects.

b) Mounting the insect specimen: The collected specimens if not mounted immediately, they become very hard and brittle. Such insects are relaxed before mounting. Relaxation is done in wide mouth air tight jar which is filled with moist sand and covered with a blotting paper. In this jar a few drops of carbolic acids are added to prevent mould formation. The insects are placed in this container for a day or two.

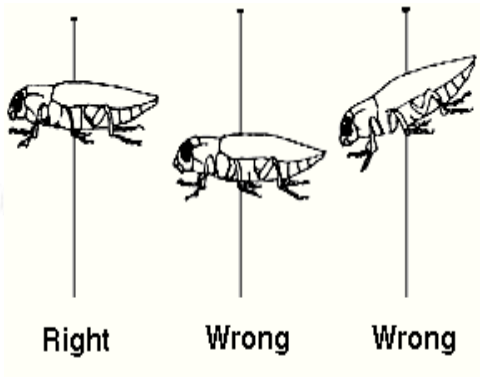
c) Pinning: It is best method for preserving the hard bodies insects. Pinning facilities convenient handling of the specimen for study purpose and also for safe storing. Special rust proof entomological pins are used for this purpose. Pinning should be done vertically though the thorax. As per the rule $1/3^{rd}$ portion must be above the insect body and $2/3^{rd}$ portion must be below. Pinned insects are carefully set on setting board and then are kept for drying in the drying chamber. The wings of lepidopterans insects are required to be spread before keeping them in drying chamber. The hind margin of the first pair of the wings must be at right angle to the body. The specimens are to be labelled indicating scientific classification, locality, host plant, date of collection, name of collector etc. Entomological pins are made up of mixture of brass and nickel.

Insect should be pinned as shown below:

Sr. No.	Name of insect order	How to pinned the insects
1	Orthoptera (Grasshopper)	Pin through the back of pronotum, slightly to right of middle line.
2	Hemiptera (Plant bugs & Hoppers)	Pin through the scutellum, slightly to right of middle line.
3	Hymenoptera (Bees, Ants & Wasps)	Pin through the center of the thorax.
4	Coleoptera (Beetle & Weevils)	Pin through the right elytron about midway of the body.
5	Odonata (Dragonfly & Damselfly)	Pin through the center of the thorax.
6	Diptera (Flies)	Pin through the thorax slightly to right side to middle line, near base of wings.
7	Dictyoptera (Cockroach & Mantid)	Pin through the center of the thorax.
8	Phasmida (Stick insects)	Pin through the posterior part of metanotum in the midline.
9	Dermaptera (Earwig)	Pin through the anterior part of right elytron.
10	Neuroptera (Ant lion)	Pin vertically through the mid line of thorax.
11	Lepidoptera (butterfly & Moths)	Pin through the center of the thorax.



Pinning locations for different kinds of insects



Placement of pinning

d) Drying: Insect specimens after pinning should be kept in drying chamber to avoid rotting. After drying, the specimens are transferred to insect stored box.

e) Storing: Pinned insects are to be stored in the insect stored boxes for preserving them in safety for longer period. Dried specimens become very brittle and extreme care is to be taken while handling the specimens. The specimens without legs or antennae are considered are useless. Only best specimens are to be preserved. The proper time of insect collection is early morning or at night with the help of light traps. Mercury light is always attractive to the insects than any other light.

f) Protecting insect collection from petst: One of the worst enemies is development of mould. It is often difficult to avoid mould developing on newly caught and imperfectly dried specimens, especially in damp climate. Before keeping specimens, it is desirable to treat the boxes with saturated solution of naphthalene in benzene. Few drops of carbolic acids on cotton balls are also kept in these boxes at regular intervals to avoid fungus attack on specimens. If collected insects in store boxes are attacked by dermestid larvae, ants and other pests and repellent action of naphthalene is in sufficient, it is necessary to fumigate the boxes by fumigants viz; ED, CT, CS_2 etc.

III) Preservation of soft bodies insects: Soft bodies insects like Aphids, Jassids, Thrips, Midges, Scales, bugs and immature life stages of the insect pests are preserved in 70-75% ethyl alcohol with little quantity of glycerine in small specimen tubes or glass vials. The tubes are properly labelled. These insects are also preserved in 5% formalin solution.

IV) Permanent Mounting: - The very small insects are also preserved by mounting on permanent slides. Their various structures and stages are also studied by preserving them by this method. The insects to be preserved are boiled in 10% KOH solution for few minutes then they are to be passed through 20-100% alcohol for dehydration and then mounted on cavity slides in Canada balsam.

Lab work: Collect and preserved at least 100 insects belonging to different orders

EXERCISE NO. 2

Date: ----------

Study of External Features of Typical Insect (E.g. Cockroach) (Structure of Head, Thorax and Abdomen/General Body Organization)

Cockroach, *Periplanata americana* is a typical insect as it possesses all important characters of class insecta. In general, insect body is divided in to a series of rings or segments are known as "somites" or "metameres". Insect body is divided in to three regions or tagmata namely head, thorax and abdomen. This grouping of body segments in to regions is known as tagmosis. Head consists of 6 segments possesses mouthparts, compound eyes, simple eyes (ocelli) and a pair of antennae. Thorax consists of 3 segments i.e. prothorax, mesothorax and metathorax. Meso and metathorax are together known as pterothorax. All the three thoracic segments possess a pair of legs and meso and meta thorax possess one pair of wings. Abdomen has 11 segments with genital appendages on 8th and 9th segments. The insect body generally consists of 20 segments.

Structure of Insect Head: -

It is the foremost part in insect body consisting of 6 segments that are fused to form a head capsule. The head segments can be divided in to two regions i.e. Procephalon and Gnathocephalon (mouth). Head is attached or 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. Inside the head, an endoskeleton structure called the tentorium which give supports to the brain, and provides a rigid origin for muscles of the mandibles and other mouthparts. Head is concerned with feeding and sensory perception.

Six segments of insect head-			
	Segment		**Appendages**
1	Pre antennary segment	Procephalon	Pair of compound eyes & three ocelli (Simple eyes)
2	Antennary segment		Pair of Antennae
3	Intercalary segment		Single Labrum (Upper Lip)
4	Mandibular segment	Gnathocephalon	Pair of Mandibles (Upper Jaw)
5	Maxillary segment		Pair of Maxillae (Lower Jaw)
6	Labial segment		Single Labium (Lower Lip)

Types of insect head position:

The orientation of head with respect to the rest of the body varies. According to the position or projection of mouth parts the head of the insect can be classified as;

1) **Hypognathous (**Hypo – Below: Gnathous – Jaw): The head remain vertical and is at right angle to the long axis of the body and mouth parts are ventrally placed and projected downwards. This is also kwown as Orthopteroid type. E.g.: Grass hopper, Cockroach.

2) **Prognathous:** (Pro – in front: Gnathous – Jaw): The head remains in the same axis to body and mouth parts are projected forward. This is also known as Coleopteroid type. E.g.: beetles.

3) **Opisthognathous:** (Opistho – behind: Gnathous Jaw): It is same as prognathous but mouthparts are directed backward and held in between the fore legs. .This is also known as Hemipteroid or Opisthorhynchous type. E.g.: bugs

Sclerites and Sutures of Head:-

The head capsule is formed by the union of number of sclerites or cuticular plates or areas which are joined together by means of cuticular lines or ridges known as sutures or any of the large or small sclerotized/harden areas of the body wall. These sutures provide mechanical support to the cranial wall. Suture: The sclerites separated from each other by means of thin impressed line called suture. (Sometimes referred as a sulcus)

The common sclerites present in insect head are:

1) **Labrum:** It is small sclerite that forms the upper lip of the mouth cavity. It isfreely attached clypeus by means of clypolabral suture.
2) **Clypeus:**It is situated above the labrum, separated by fronto-clypeal suture & also separated from gena by clypogenal suture.
3) **Frons:** It is unpaired, facial part of the head capsule lying between the arms of epicranial suture.
4) **Gena:** It is the area extending from below the compound eyes to just above the mandibles. It is separated from frons by frontoganal suture and from clypeus clypogenal suture.
5) **Epicraniun:** It forms the upper part of the head extending from frons to the neck.
6) **Vertex:** It is the top portion of epicranium which lies behind the frons or the area between the two compound eyes.
7) **Epicranial Suture:** Starting from the dorsal portion of the epicranium is an inverted Y shape suture known as epicranial suture or ecdysial line. The head capsule breaks open along this line at the time of moulting.
8) **Occiput:** It is an inverted "U" shaped structure representing the area between the epicranium and post occiput.
9) **Post occiput:** It is the extreme posterior part of the insect head that remains before the neck region.
10) **Occular sclerites:** These are cuticular ring like structures present around each compound eye.
11) **Antennal sclerites:** These form the basis for the antennae and present around the scape.

The common sutures present in head are:

1) **Clypeolabral suture:** It is the suture present between clypeus and labrum.
2) **Clypeofrontal suture or epistomal suture:** The suture present betweenclypeus and frons.
3) **Epicranial suture:** It is an inverted 'Y' shaped suture distributed above the facial region extending up to the epicranial part of the head. It consists of two arms called frontal suture occupying the frons and stem called as coronal suture. This epicranial suture is also known as line of weakness or ecdysial suture because the exuvial membrane splits along this suture during the process of ecdysis.
4) **Occipital suture:** It is 'U' shaped or horseshoe shaped suture between epicranium and occiput.
5) **Post occipital suture:** It is the only real suture in insect head. Posterior end of the head is marked by the post occipital suture to which the sclerites are attached. As this suture separates the head from the neck, hence named as real suture.
6) **Genal suture:** It is the sutures present on the lateral side of the head i.e. gena.
7) **Occular suture:** It is circular suture present around each compound eye.
8) **Antennal suture:** It is a marginal depressed ring around the antennal socket.

Insect Insect Thorax: -

It is the middle part of the insect body consisting of 3 segments such as prothorax, mesothorax and metathorax, each possessing a pair of legs and a pair of wings on meso and meta thoracic segment. Meso and meta thoracic segments bear a pair of wings each together known as Pterothorax (Ptera = wings). Thorax generally concerned with locomotion.

The body wall of a typical insect is divided into four regions; the dorsal (Upper) region is called dorsum or tergum/notum. The ventral (Lower) region is called as venter or sternum. The two lateral regions are known as pleurae/pleuron.

The cuticle hardens at localized areas form sclerites. The sclerites are separated from each other by means of thin impressed lines called as sutures. Sclerites forming these regions are called as tergites, sternites and pleurites, respectively.

Sclerites of thoracic segments: -

- **Sclerites of tergum (tergites) -** The dorsal sclerites consists of three segmental plates (nota) called pro-notum, meso-notum and meta-notum. Each notum is again divided into three parts i.e pre-scutum, scutum and scutellum.
- **Sclerites of pleuron (pleurites) –**it is fully developed in winged insects. It is divided into two parts, anterior episternum and posterior epimeron. It is absent in prothorax.
- **Sclerites of sternum (sternites)**–It is divided into eusternum and spinasternum.

Structure of Insect Abdomen:-

The abdomen in the embryo usually consists 11 segments. The abdominal segments are sometimes designated as uromeres. The terminal region of abdomen is called telson which bears anus. The 1st abdominal segment gets fused to metathorax forming propodeum. (In ants, bees and wasps).The first eight abdominal segments carry a pair of spiracles each. Thorax generally concerned with reproduction and metabolic activity.

Appendages of abdomen–

Non reproductive appendages –

- ✓ **Cerci –**They are present on 11^{th} segment in most of the insects. It is present inmale cockroach, silverfish, grasshopperCerciusuallyact as tactile organ or sound receptors in grasshopper. They become a part of male genitalia in caddis fly. In earwigs, cerci are modified into defensive organ.
- ✓ **Prolegs in insect larvae-** The larvae of Lepidoptera bear five pairs of abdominal legs called **Prolegs** on 3^{rd} 4^{th} 5^{th} 6^{th} and 10^{th} segments. These Prolegs bear spines like structures called **crochets**, on terminal ends to grip the plant surfaces. In case of larvae of sawfly there are eight pairs of Prolegs but are without crochets.
- ✓ **Abdominal gills-** It is present in aquatic insects for respiration. e.g. nymph of odonata
- ✓ **Cornicles:** Aphids have a pair of short tubes known as cornicles or siphonculi projecting from dorsum of fifth or sixth abdominal segment. They permit the escape of waxy fluid which perhaps serves for protection against predators.

Reproductive appendages

- ✓ It includes abdominal Segments from 1 to 7 are pregenital segments, 8^{th} and 9^{th} are known as genital segments as they form genital appendages i.e. ovipositor in females and aedeagus or penis in males. 10^{th}and11^{th}segments are known as postgenital segments. These organs are specially concern with mating in male and deposition of eggs in females. They are collectively called as external genitalia or gonapophysis. Male external genitalia-The 9^{th} sternum bears two styli and pair of claspers which help to hold female during copulation. The aedeagus lies between claspers. Female external genitalia- It has a special egg laying organs called ovipositor for egg lying on 8^{th} and 9^{th} segments.The ovipositor of house fly& fruit fly is called pseudo-ovipositor

Lab work: - i) Examine the Cockroach/Grasshopper and observe different body parts.
ii) Draw a neat and labelled diagram of structure of head, thorax and abdomen.

EXERCISE NO. 3

Date: ----------

Structure of Insect Antennae and Its Modifications Along With Examples

Antennae are a pair of sensory pre-oral appendages arising from the 2nd or antennal segment of the head possessing nerves coming from deutocerebrum of the brain. Antennae are also called feelers. They are well developed in adults and poorly developed in immature stages. Antennae are absent in order protura and class Arachnida whereas 2 pairs of antenna (antennules) are present in class Crustacea. Antennal socket (Antennifer) is provided with an antennal suture. The base of socket is connected to the edge of the socket by an articulatory membrane. This permits free movement of antennae.

Antenna consists of 3 parts:-

1) Scape: It is the first segment of antenna. It articulates with the head capsule through antennifer which provides movement for the scape.

2) Pedicel: It is the 2nd or middle segment of antenna that forms a joint between scape and flagellum. It consists of the special auditory organ known as "Jhonston's organ".

3) Flagellum: It is the last antennal segment which consists of many segments that varies in shape and size.

Types of Insect antennae

Sr. No.	Type of antennae	Example
1	Filiform (Thread like)	Grasshopper
2	Setaceous(Whip/ bristle like)	Cockroach
3	Moniliform (Like string of beads)	Termites & Thrips
4	Pectinate (Comb like)	Female mulberry silk moth
5	Bipectinate (Double comb)	Male mulberry silk moth
6	Serrate (Saw like)	Pulse beetle, Mango stem borer
7	Clavate (Clubbed)	Butterflies, Moths
8	Clavate with hook	Skipper butterflies
9	Capitate (Clubbed with knob)	Red flour beetle
10	Geniculate (Elbowed)	Ants, honey bees, Wasps
11	Lamellate (plate like)	Rhinoceros beetles, dung rollers, chaffer beetles
12	Plumose(Feather like)	Male Culex mosquito, stylopids
13	Pilose (brush like hairs)	Female Culex mosquito
14	Aristate (antennae with arista)	House fly
15	Stylate (antennae with style)	Jassids, Robber fly

Functions of Antennae

- ✓ To feel and locates its way.
- ✓ To detect danger and locate their foods.
- ✓ To find the opposite sex for copulation.
- ✓ To communicate with each other e.g. (Ants).
- ✓ To smell – bears olfactory organ e.g. (House fly).
- ✓ To perceive the sound Chorodontonal organ e.g. (Male mosquito).
- ✓ To serve secondary sexual characters.
- ✓ It possesses hydro fuse hairs to form air funnel e.g. (Water beetle).
- ✓ It possesses taste hairs occur on antennae e.g. (Cockroach).
- ✓ It helps in mating by holding opposite sex e.g. (Flea, spring tails).
- ✓ It is useful for clasping the female during copulation.

Lab Work: - Draw the structure of typical insect antennae and their types.

EXERCISE NO. 4

Date: ----------

Study and Dissection of Chewing and Biting Type of Mouthparts of Insects

Mandibulate Type of Mouth Parts - Present in are those insects which feeding on solid food material such as leaves, fruits and tree bark etc. such as;

Chewing And Biting Type of Mouth Parts - Found in Grass hopper, Cockroach, Beetles, and Lepidopterans larvae.

Typical mouthpart of an insect consists of the following parts: - Labrum (upper lip) A pair of mandibles (upper Jaw) A pair of maxillae (lower Jaw) Labium (lower lip) Hypo -pharynx (tongue).

- ✓ **Labrum:** It is a single unpaired that forms the upper lip of the mouth cavity. It protects the mandibles and helps in closing of the mouth cavity and guides the food in to mouth or hold the food material while feeding. Labrum hangs down from the clypeus through a clypeo-labral suture. The inner surface of labrum is lined by small lobe like epipharynx, which is the taste organ.
- ✓ **Mandibles:** These are the paired, unsegmented, and strongest and sclerotized structures called first pair of jaws. They are attached to the head capsule by means of two joints known as ginglymus and condyle. They possess teeth like molars and incisors that help in the process of cutting the food material. Each mandible is moved by powerful Abductor and adductor muscles.
- ✓ **Maxillae:** These are paired and also known as second pair of jaws. These are homologous structures with basal triangular 'cardo', middle rectangular 'stipes' and the lateral 'palpifer' bearing maxillary palpi and lobe like inner 'lacinia' and outer 'galea'. Maxillary palps possess olfactory and gustatory sense receptors and function as sensory organs. These Galea and lacinia helps in holding the food material along with the mandibles.
- ✓ **Labium:** It is known as lower lip and is also called as second maxillae. It closes the mouth cavity from below. It is divided in to proximal prementum. Central mentum and distal submentum Prementum has three terminal lobes. Near the base of pre mentum, on either side lobe like 'palpiger' is present which bears labial palps. The median pair is 'glossae' and outer 'paraglossae' together called ligula that function mainly as gustatory sense organs.
- ✓ **Hypo-pharynx:** It is a tongue like structure situated between labrum and labium and ducts of salivary glands open on or near its base. The function of hypo-pharynx is to mix saliva with the food material.

- ➢ **Instruction for Dissection of Moth Parts of Cockroach: -** Hold the head capsule between the thumb and the index-finger and gently press it. All the components of mouthparts will be seen distinctly. Remove labrum right and left mandibles, right and left maxillae, hypopharynx and labium and mount them in a drop of glycerin on a slide. place a cover slip over it and examine under a microscope.

Lab Work: - Dissect the mouth parts of a cockroach. Draw a neat and labelled diagram.

EXERCISE NO. 5

Date: ----------

Study and Dissection of Chewing and Lapping Type of Mouthparts of Insects

Haustellate Type of Mouth Parts- Present in are those insects which feed on liquid food material (Sap feeder) such as plant sap, fruit juice, blood etc., such as;

Chewing and Lapping Type of Mouth Parts: e.g.: honey bees

It consists of the following parts: -

- ✓ **Labrum:** It is narrow plate attached to clypeus.
- ✓ **Mandibles:** The mandibles are dumbbell shaped, used for molding wax and squeezing the nectar.
- ✓ **Maxillae:** Both maxillae are modified and suspended from head. They are articulated through like cardo to which is attached stipes. The maxillary palpi are very small or reduced and it is peg like structure articulating with stipes. The cardo of maxillae unite with submentum of labium forming an inverted "V" shaped lorum. Galea and lacinia attached at the lorum.
- ✓ **Labium:** It is also called as proboscis and consist of following parts; Submentum (lorum), mentum, prementum, labial palp and glossa. Glossae are provided with long hairs and a small spoon shaped lobe, called flabellum or bouton at its apex. Two paraglossa are cup like structure situated at the base of glossa. The labrum and mandibles are biting type whereas maxillae, labium and hypopharynx combine together to form a sucking proboscis.
- ✓ **Hypopharynx:** It is vestigial or reduces.

- **Feeding Mechanism:** When at rest the mouthparts are folded down beneath the head. During feeding they become straight and shot out glossae and lick the nectar with the help of flabellum. The glossal toung thus smeared with nectar is rapidly retracted between labial palp and galeae. As a result the nectar is squeezed off and deposited in a small cavity formed by paraglossae and sucked in by the capillary action of pharyngeal pump.

- ➢ **Instruction for Dissection of Moth Parts of Honey bee: -** Cut the head from the thorax. Hold the head between the thumb and the index-finger with the mouthparts facing you. Remove each mandible by exerting outward pressure at the base with needle. Remove the labrum by exerting upward pressure at its base with needle. Change the position of head, So that its posterior side faces you in an inverted position. Make it flaccid by applying some pressure and remove the maxilla-labial complex by exerting upward pressure at its base with a needle. Mount the mouthparts in a glycerin on a slide and remove the extraneous tissues from them. Place a cover slip over them and examine under a microscope.

Lab Work: - Dissect the mouth parts of a honey bee. Draw a neat and labelled diagram.

EXERCISE NO. 6

Date: ----------

Study and Dissection of Piercing and Sucking Type of Mouthparts of Insects

These mouthparts are generally found in plant bugs, Aphids, Jassids, Whitefly, and mosquitoes etc. They are mainly adopted for piercing the tissues and sucking either plant sap or the nectar or blood from the host.

It consists of the following parts: -

- ✓ **Labrum:** Labrum is modified into a small flap like structure at the base of rostrum.
- ✓ **Mandibles & maxillae:** Mandibles and maxillae are modified in to sharp needle like stylets. (Four in numbers) The mandibular stylets form the outer pair and possess serrated margins at their tip. The maxillary stylets forms the inner pair having smoothed curved tips and combining together enclosing a food channel. The food channel is divided in to an upper cibarium and lower salivarium with the help of the grooves present inside the maxillary stylets. Salivarium is used for releasing the saliva and cibarium is used for sucking the sap.
- ✓ **Labium:** Mouth parts are represented by rostrum/beak/Proboscis which is a modification of Labium. It acts as a pouch for protecting the mandibular and maxillary stylets. Rostrum has sensory hairs at its tip for sampling the food and locating spot for piercing.
- ✓ **Hypopharynx:** The hypopharynx is modified in to a pharyngeal pump and is situated at the tip of the food channel.

- **Feeding Mechanism:** At rest proboscis is always held parallel to ventral side of insect body. During feeding the rostrum shot out, stylets released and rostrum looped behind to allow the stylets to penetrate plant tissues. Mandibular stylets by their sliding movement puncture a hole in plant tissues. Then maxillary stylets are pushed inside. Saliva is injected through salivary channel to dilute the cell sap, dissolve the cell wall. Then suck the contents (sap/ blood / nectar) through cibarium with the action of pharyngeal and cibarial muscles.

- ➢ **Instruction for Dissection of Moth Parts of Red cotton bug: -** Cut the head from the thorax. Hold the head between the thumb and the index-finger and make it flaccid by applying some pressure. Place it on microscope slide and moisten the proboscis with drop of water. Press the proboscis gently at various places with the help of needle till the stylets come out of the labial sheath and get disengaged. Mount the mouthparts in glycerin on a slide and arrange them as shown in the diagram. Place a cover slip over them and examine under a microscope.

Lab Work: - Dissect the mouth parts of a Red cotton bug. Draw a neat and labelled diagram.

EXERCISE NO. 7

Date: ----------

Study and Dissection of Sponging Type of Mouthparts of Insects

This type of mouthparts is possessed by the common house fly. The house flies feed on exposed liquid food material such as milk or by dissolving solid food materials like crystals of sugar in their saliva and hence the mouthparts are modified accordingly. The prominent fleshy and retractile proboscis mainly of labium which is attached in elbow-like form to the elongated head.

It consists of the following parts: -

- ✓ **Labrum:** It is represented by labrum epipharynx. It forms stylet. It is born on anterior face of haustellum.
- ✓ **Mandibles:** They are entirely absent.
- ✓ **Maxillae:** They are represented by a pair of maxillary palps. Maxillary palpi are 1-3 segmented
- ✓ **Labium:** These mouthparts are represented by proboscis formed from the labium. The proboscis is divided into a basal rostrum, middle haustellum and a distal labellum. The labellum is a sponge like structure. It is traversed by a number of narrow transverse channels called pseudotrachea which converge at one point in the centre of the labellum. From this point, the food enters in to food channel which is formed by the labrum-epipharynx and hypopharynx.
- ✓ **Hypopharynx:** It is also modified into stylet like structure and is present on haustellum.

- **Feeding Mechanism:** During feeding, the proboscis is pressed over the food material. The pseudo trachea gets filled with the food material by the capillary action which converges at one point in the centre of the labellum. From this point, the food enters in to food channel which is formed by the labrum- epipharynx and hypopharynx and is sucked up from the central point in to the oesophagus.

- ➢ **Instruction for Dissection of Moth Parts of Housefly: -** Cut the head from the thorax. Hold the head between the thumb and the index-finger with the posterior side of the proboscis facing you in an inverted position. Remove the proboscis by exerting upward pressure at its base with a needle. Place the proboscis in glycerin on a microscope slide and remove the extraneous tissues from it. Place a cover slip over them and examine under a microscope.

Lab Work: - Dissect the mouth parts of a house fly. Draw a neat and labelled diagram.

EXERCISE NO. 8

Date: ----------

Study of Structure of Typical Leg and Modifications of Legs of Insects

Insect legs are paired; hollow more or less cylindrical and jointed outgrowth of thoracic segments. All true insects have three pairs of leg born on each of the thoracic segments. They are the important locomotor organ but in addition to this they have to perform several other functions to which they are subjected to and modified accordingly. The fore legs are organ of traction (Pulling), the middle legs are organ of support and the hind legs are the organ of propulsion (Pushing). The legs move in two alternate groups. The fore and hind legs of one side and the middle legs of opposite side move forward simultaneously while the remaining three legs remain stationary in the form of a tripod and support the body. Thus they move in a tripod and a stable equilibrium is maintained.

Insect leg mainly consists of 5 parts viz.

- ✓ **Coxa:** It is the functional basal segment and it is rigidly fixed to thorax.
- ✓ **Trochanter:** It is very small and the second segment. It is articulated with coxa and fixed to femur.
- ✓ **Femur:** It is the largest, strongest segment and is articulated with the tibia.
- ✓ **Tibia:** It is equal or more than the length of the femur, articulated with tarsus
- ✓ **Tarsus:** it is the largest segment of the leg and usually devided into sub segments tarsomeres. The number of tarsomeres vary from 1-5.
- ✓ **Pretarsus:** The tarsus at its end consists of pretarsus which is in the form of a pair of claws and cushion like pulvilli. In between the claws, if there is lobe like structure, it is known as "arolium" as in Orthoptera (grass hopper) and if it is bristle like structure, it is called "embodium" as in Diptera.
- ✓ **Unguitractor:** It is the plate on ventral surface of pretarsus to which the flex or muscles are attached for movement of claws. Legs pads (covered with tenant hairs) help the insects to climb smooth and steep surface. While claws give grip while walking on rough surface.

Modifications of legs in Different Insects

Type of Leg	Modification of leg	Examples	Purpose
Cursorial	All legs	Blister beetle, wasp	Walking
Ambulatorial	All legs	Cockroach	Running
Saltatorial	Hind legs	Grasshopper, gryllids	Leaping and jumping
Fossorial	Front legs	Mole crickets, dung rollers	Digging
Raptorial	Front legs	Preying mantid	Preying (grasping)
Natatorial	Hind legs	Water beetle, water bugs	Swimming
Scansorial	All legs	Head louse	clinging
Prehensile	All legs	Dragon flies	Catching prey, basket Forming type
Antennal cleaning legs	Front legs	Honey bee	For cleaning antennae
Pollen basket and brush type	Hind legs	Honey bee	For collecting pollen & cleaning the body

Lab Work: - Draw the figures of typical leg and modifications of legs and label the parts.

EXERCISE NO. 9

Date: ----------

Study of Insect Wings: Structure, Wing Venation, Types of Wings and Wing Coupling Apparatus Along With Examples

Among the vertebrates, only insect possess wing. Normally two pairs of wings are present Based on the presence or absence of wings, class insecta is divided into two subclasses; Apterygota & Pterygota. The primitive apterygotes are wingless. E.g.: Silver fish and spring tails. Secondarily wingless insects: Among pterygotes, some insects in their advanced stage of growth (Adult) shed the wings e.g. Bed bugs, head louse and flea have become secondarily wingless. There is only one pair of wings in houseflies and mosquitoes. In some insects both pairs of wings have been reduced, hence based on the degree of development of wings the insects may be classified into three forms; 1) Macropterous, 2) Brachypterous & 3) Apterous.

Wing areas: -

- ✓ The insect wings may sometimes possess some pigmented spot near coastal margin known as pterostigma or stigma as in Odonata (dragon flies and damsel flies).
- ✓ A typical insect wing is triangular with three margins and three angles.
- ✓ The anterior margin strengthened by the costa is called coastal margin and the lateral margin is called apical margin and the posterior margin is called anal margin and Three angles are, Humeral angle: between body wall and costal margin, Apical or outer angle: between costal and apical margin, Anal angle or tornus: between apical and anal margin.
- ✓ Wings areas are; the surface area of typical insect wing is divided in to two portions i.e. Remegium and Vannal Area.
- ✓ The anterior (upper) part of the wing towards coastal margin where more no of longitudinal veins are present is called remigium.
- ✓ The posterior part of the wing where veins are sparsely distributed is known as Vannal Area, which is called as clavus in forewings and vanus in hindwings.
- ✓ Jugum is the inner most portion of the wing that is cutoff from the main wing by jugal fold.

Wing venation-Wings are very thin broad leaf like structures strengthened by a number of hollow narrow tubular structures called veins. Arrangement of veins on wing surface is known as Wing venation, which consists of two types of veins; longitudinal veins: Extend from base of the wing to the margin. They may be convex (∩) or concave (U) and Cross veins: That interlinks the longitudinal veins.

Longitudinal veins: Costa (C): It forms the thickened anterior margin of the wing (costal) and is un-branched and is convex. **Sub costa (Sc):** It runs immediately below the costa always in the bottom of a trough between C and R. The two branches of SC are Sc1 and Sc2 and is concave. **Radial vein (R):** It is the next main vein, it divided in to two branches R1 and Rs (Radial sector). R1 goes directly towards apical margin and is convex; Rs is concave and divided in to 4branches, R2, R3, R4, and R5. **Media (M)** It is divided in two branches 1. Media anterior (MA) which is convex and 2. Media posterior (MP) and is concave. Media anterior is again divided into MA1 and MA2. Median posterior is again divided in to MP1, MP2, MP3, and MP4. **Cubitus (Cu):** Cubitus is divided into convex CU1 and concave CU2. CU1 is again divided into CU1a and CU1b. **Anal veins (A):** These veins are convex. They are individual un-branched, 1-3 in number.1 or 2 jugal veins (unbranched) are present in the jugal lobe of the forewing.

Cross veins: - Small veins often found inter connecting the longitudinal veins are called cross veins. **Humeral cross vein (h):** between costa and subcosta. **Radial cross vein (r):** between radius and radial sector. **Sectorial cross veins (s):** between sub branches of radial sector. **Radio**

medial cross vein (r-m): between radius and media. **Medical cross veins:** between branches of media. **Medio-cubital veins:** between media and cubitus.

Different Types of Wings: -

1) **Tegmina:** Forewings are leathery and tough. They are protective in function. They protect the membranous hindwings. They are not used for flight. e.g.: forewings wings of cockroach, grasshopper.
2) **Elytra:** The wing is heavily sclerotized without clear venation. Wing is tough and it is protective in function. They protect the membranous hind wings and abdomen. e.g.: Forewings beetles and weevils.
3) **Hemelytra:** The base of the wing is thick like elytra and the remaining half is membranous. They are not involved in flight and are protective in function. e.g.: Forewings of bugs.
4) **Membranous:** Naked thin with clear venation. e.g.: Both the wings of Dragonflies, bees and wasps, Hind wings of grasshopper, beetles, cockroach, both fore wings and hind wings of (wasp, bees, dragonfly and damselfly).
5) **Scaly wings:** Wings thin, membranous but covered with unicellular scales all over the surface. Scales are responsible for colour. e.g.: Both the wings of moths and butterflies.
6) **Fringed wings:** Wings are highly reduced with reduced venation. The wings are fringed with long marginal hairs giving a feather like appearance e.g. both the wings of thrips.
7) **Fissured wings:** Forewings are longitudinally divided twice forming a fork like structure whereas hindwings are divided twice in to three arms. All the forks possess small marginal hairs. E.g. both the wings of plume moth.
8) **Halters**: In houseflies the hind wings are modified into small microscopic structures/ knobbed vibrating organs called haltere**.** They are divided in to three regions namely scabellum, pedicel and capitellum. They act as balancers. E.g. Hind wings housefly and front wings, male stylopids, mosquito and male scale insect.
9) **Pseudohalteres:** They are short and modified in to pseudohalteres which are dumbbell shaped. E.g.: Front wings of Strepsiptera.

Wing Coupling Apparatus/Organs/Mechanisms: -

Among the insects with two pairs of wings, the wings may work separately as in the dragonflies and damselflies. For taking flight, insect need to keep both the fore and hind wings together as a single unit. The structures in the form of lobes, bristles, hairs or spines that help the wings to be together are known as wing coupling organs. Following wing organs found in different insects;

1) **Jugate type or jugum type:** The costal margin of the front wing possess a small lobe at the base called fibula which rest on the surface of the hind wing or sometimes engages with spines present on the upper surface of hind wings . e.g.: primitive lepidopterans of the family Hepialidae.
2) **Frenulum/Franate/retinaculum type:** The hind wings possess bristle or spine like structure or group of hairs known as frenulum**.** The forewings possess hook like **retinaculum** on anal side. During flight the frenulum passes beneath the retinaculum and thus the both the wings are kept together. e.g.: Fruit sucking moth.
3) **Amplexiform:** Costal margin of hind wing and anal margin of forewing overlap one above the other e.g.: butterfly.
4) **Hamuli / Hamulate:** The Small curved hook like structures present on the costal margin of the hind wing known as Hamuli that fit into the upward fold of the anal margin of the forewings. E.g. hymenopterans (wasps and bees).

Lab Work: - Sketch out hypotheticla wing venation, wing margins and angles and wing coupling apparatus.

EXERCISE NO. 10

Date: ----------

Metamorphosis in Insect Along With Its Significance and Types of Insect Eggs, Larvae and Pupae

Metamorphosis is derived from Greek word 'Meta' = Change, 'morph' = form or structure. Series of changes that takes place during the development of an insect from egg to adult are collectively known as metamorphosis. It include three developmental processes namely, growth, differentiation and reproduction which takes place in larval, pupal and adult stages respectively.

Types of metamorphosis:

1) Ametamorphosis (Ametabolous)
2) Incomplete metamorphosis (Hemimetabolous)
3) Gradual metamorphosis (Paurometabola)
4) Complete metamorphosis/Holometabolous
5) Hyper metamorphosis

1) Ametamorphosis: - E.g.: Apterygote insects viz; silver fish, springtails. Insects do not undergo any metamorphosis. These insects have only three stages in their life namely egg, young ones and adult. The hatching insect resembles the adult in all respects except for the size and called as juveniles. Moulting continues throughout the life.

2) Hemimetabola: - (Incomplete metamorphosis) - E.g. Dragonfly, damselfly and may fly. These insects also have three stages in their life namely egg, naiads and adult. Pupal stage is absent. 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.

3) Paurometabola: - (Gradual metamorphosis) - E. g. grasshoppers, cockroaches, termites, true bugs, cicadas, and hoppers. It is also called as simple metamorphosis. The life cycle includes egg, nymph and adult stages. The nymph resembles the adult in all the characters except wings. Nymphs possess wing buds which transform in to fully developed wings in adult stage. Both nymphs and adults share the same habitat. In these insects, wings develop externally and hence are also called as Exopterygote. Pupal stage is absent hence, development is said to be direct and simple.

4) Complete or Holometamorphosis or indirect development: - E.g. Butterfly, moth, Beetles, weevils, fly and bees. The life cycle includes four stages; egg, larva, pupa and adult. Larvae of butterflies are called caterpillar. Larva differs from the adult both in body structure and habits. Larva has both thoracic and abdominal legs, sometimes legs may be absent in larva, whereas adult has only thoracic legs. Compound eyes are absent in larva. Larva undergoes moulting to enter in to pupal stage from which the adult insect emerges. Wings develop internally during the pupal stage and hence, they are called Endopterygote.

5) Hyper metamorphosis: - This is a peculiar type of development which consists of two or more types or forms of larvae in the life cycle of insects. In majority of the cases the first larval, instar is campodeiform and the subsequent larval forms depends on type and mode of life of the larva. E.g.: In blister beetle (Meloidae; Coleoptera), the first larval instar is Campodeiform followed by Scarabaeiform larval type.

Significance of Metamorphosis-

- ✓ It helps the insect to tide over unfavorable climate conditions by entering into Diapause condition such as hibernation and aestivation.
- ✓ Diapause: - It is the period of arrested growth or development in the life cycle of the insects during which the physiological processes like differentiation and reproduction are suspended. The occurrence of diapause during summer due to high temperatures is known as "aestivation" Whereas the period of inactivity during winter due to low temperatures known as "hibernation".
- ✓ It helps the insect to accommodate growth by periodical shedding of their old cuticle and by formation of new cuticle.
- ✓ It helps the insect to reduce or avoid competition for food amongst themselves by either entering into inactive stage or by acquiring different feeding habits and habitats.
- ✓ It helps the insect as a protective adaptation by a way of mimicry. i.e. resembles to the nature.
- ✓ It also serves as an important aspect in classification of insects

IMMATURE STAGES OF INSECTS

Insect Egg: -

Egg-stage is the first life stage of an insect. Oviposition (Egg deposition) takes place in diverse ways. Eggs may be laid singly or in groups, enclosed in gelatinous masses/scales or may be laid in protective case (egg-pod/ootheca). Mostly, the egg are laid in a situation where they are afforded some protection or where the young ones on hatching, will have suitable conditions for their development. The number of eggs laid by a female varies (50 to few hundreds) with the insect species.

Different forms of eggs: - Eggs of different insects vary greatly in appearance. Most eggs are spherical, oval or elongated, but some are barrel shaped, some are disk-shaped. The eggs is covered with, a shell that varies in thickness, sculpting and colour. Many eggs are provided with characteristics ridges, spines or other processes and some are brightly coloured.

Structure of typical insect eggs: -

i) **Chorion/Egg shell:** It is secreted by the cell of follicular epithelium of the ovary and is composed of lipo-proteins (arranged in a number of layers) and is devoid of chitin. It is formed by two layers viz; Exochorion (outer) and Endochorion (inner). In some of the insects, there is a wax layer coated on the Exochorion as outer most layers.

ii) **Micropyle:** One (or more) small opening, through the chorion, usually at one end of the egg. Spermatozoa enter through the micropyle to fertilize the ovum. Besides, these openings serve as respiratory channel.

iii) **Vitelline membrane** (cell wall): It is delicate membrane, completely lining the egg shell from inner side which encloses the cytoplasm, yolk and nucleus. Periplasm is another more delicate lining prevails from inner side of the vitelline membrane.

iv) **Cytoplasm: -** It is living substance of an egg.

v) **Yolk/Deutoplasm: -** It is non-living substance of an egg which consists of carbohydrates, proteins and lipids scattered as globules throughout the reticulum of the cytoplasm.

vi) **Nucleus: -** It is highly organized dynamic part of the egg containing chromatin which forms the chromosomes. These are composed of large number of giant molecules of DNA, which are the genes the bearer of heredity character.

Immature stages of exopterygote insects are known as Nymphs and endopterygote insects are known as Larvae.

Differences between Larva and Nymph

Sr. No.	Larva	Nymph
1	Immature stage of Endopterygote.	Immature stage of Exopterygote
2	It undergoes Holometamorphosis	It undergoes Hemimetamorphosis
3	Body is vermiform which differs from the adult both in structure and feeding habits	Body resembles the adult in all the characters except wings
4	Consists of ocelli and reduced Antennae	Have compound eyes and antennae
5	Possess both thoracic and abdominal legs	Possess only thoracic legs.
6	The larva is different from adult in feeding habits and behaviour	Nymph resembles the adult in feeding habits and behaviour
7	The larva enters pupal stage	No pupal stage
8	It includes insect orders like Lepidoptera, Coleoptera so on	Hemiptera, Orthoptera, Thysanoptera

Insect Larva: - The larva is a general term to denote young one or immature stage of insect between egg and pupa having complete and hyper metamorphosis. The larvae are classified into four groups on the basis of development appendages;

1) **Protopod larva:** E.g.: Larvae of Endoparasitic Hymenoptera- The larvae are partially developed. They possess well developed head and thoracic segments but lack segmentation in the abdomen. They possess rudimentary cephalic and thoracic appendages but no abdominal appendages. They have partially developed digestive system and underdeveloped respiratory and nervous systems.

2) **Oligopod larva:** These larvae have well segmented body and they bear well developed cephalic (Head) appendages. Thoracic legs are well developed. Abdominal legs are absent. On the basis of structure these larvae are further classified in to two types' viz., Campodeiform and Scarabaeiform.

Differences between Campodeiform and Scarabaeiform

Sr. No.	Campodeiform Larva	Scarabaeiform Larva
1	The body is Elongated, flattened and fusiform in shape with prominent antennae called Crawler	Body is Body robust and 'C' shaped
2	Body is dorso-ventrally compressed with sclerotized cuticle	Body is cylindrical or sub cylindrical, stout and fleshy in nature
3	Prognathous type of head	Hypognathous type of head
4	Long thoracic legs adapted for running	Short thoracic legs
5	A pair of terminal abdominal processes (anal cerci) are present	Absent
6	These are active	Inactive
7	Predatory in nature	Phytophagous
8	e.g. grub of antlion /grub of lady bird beetle and Green Lace wing	e.g.: grub of rhinoceros beetle/white grub/June beetle/dung beetle

3) **Polypod larva (Eruciform larva):** The larva possess well defined segmentation of the body with three pairs of thoracic legs and 2-5 pairs of abdominal legs (3^{rd}, 4^{th}, 5^{th}, 6^{th} and 10^{th} abdominal segment. Body cylindrical with short thoracic legs and fleshy abdominal prolegs. They are phytophagous and destructive. The respiratory system is peripneustic type i.e. only prothoracic and abdominal spiracles only are open. E.g. larvae of butterfly and moth. On the basis of number and location of prolegs, these larvae are further classified as;

i) **Caterpillar:** It is type of polypod larva which bears 3 pairs of thoracic legs and 5 pairs of prolegs. The prolegs are present on 3rd, 4th, 5th, 6th and 10th abdominal segments. E.g. larvae of lemon butterfly and gram pod borer etc. Further classified as a **Hairy caterpillar**-The larval body is fully covered with hairs E.g.: Red hairy caterpillar, Castor hairy caterpillar and **Sphingid caterpillar** / larva the larva consists of a horn (or) hook on the dorsal surface of 8th abdominal segment. E.g.: Sesamum and Sweet potato leaf eating caterpillar.

ii) **Looper:** It is type of polypod larva which bears 3 pairs of thoracic legs and only two pairs of prolegs or abdominal legs present on 6th and 10th abdominal segment during walking the insect body forms a complete loop like structure hence, the name looper. E.g. Cabbage Looper and Mango Looper etc.

iii) **Semilooper:** It is type of polypod larva which bears 3 pairs of thoracic legs and only three pairs of prolegs or abdominal legs. First two pairs of abdominal legs (on 3rd and 4th segments) are reduced; hence a part of the insect body forms a small loop during its movement. E.g. Castor Semilooper, Cotton Semilooper etc.

4) **Apodous larva:** Body fleshy, worm-like called maggot. These are characterized by the absence of thoracic as well as abdominal legs. They possess 3 pairs of sensory papillae in the place of thoracic legs. E.g. House fly, Fruit fly, Honey bee etc. Based on the degree of development of the head capsule and its appendages, these larvae are divided in to three types,
   - **a) Eucephalous:** The larva consists of a well sclerotized head capsule. e.g.: Larva of Mosquito, mango stem borer etc.
   - **b) Hemicephalous.** Larva possess partially developed head capsule. e.g.: Larva of robber flies, horse flies, honey bee etc.
   - **c) Acephalous** The larva is characterized by the absence of head capsule and mouth parts are represented by mouth hooks. e.g.: Larva of housefly.

Insect Pupae: -

It is resting or inactive stage of the holometabolous insects and transitional phase between larva and adult. The pupa is incapable of feeding, locomotion except in some cases where they crawl (Aphid lion), Later it emerges as adult, pupation may be takes place either in soil, or on the plant surface or within the webs. Pupae are divided on the following bases;

- **Based on the presence or absence of powerful mandibles:-**

1. **Decticous pupae** - They possess relatively powerful mandibles which are used for escaping of the adult from the cocoon i.e. to break the cocoon. This type of pupa is always Exarate (free) type e.g.: Lace wing, scorpion flies etc.
2. **Adecticous pupae** - They do not possess the mandibles but with the help of other appendages, adults escape from the cocoon e.g.: Lepidoptera, Diptera. Based on the attachment on the appendages (or) shape of the pupae adecticous pupae further classified as:-
   1. **Exarate pupa:** All developing appendages which are free without any secondary attachment to the body and visible externally. e.g.: Honey, wasp, white grub etc.
   2. **Obtect pupa:** All the eveloping appendages (antennae, wings, legs, etc.) held tightly against the body by a shell-like casing. Often found enclosed within a silken cocoon. The pupa is highly chitinized. eg: Butterfly and Moths.
   3. **Coarctate:** The pupa remains enclosed in a puparium formed by the last larval skin and the pupa looks like a capsule or barrel. e.g.: housefly, fruit fly etc.
   4. **Chrysalis:** It is an obtect type of pupa which has golden colouration and a stalk. e.g.: Lemon butterflies.

Lab Work: - Draw neat and labelled diagram of insect larvae and pupae.

EXERCISE NO. 11

Date: ----------

Study and Dissection of Digestive System of Cockroach

- Digestive system of insect consists of Alimentary canal and Salivary glands.
- **Alimentary canal:** It is a long, muscular and tubular structure. The alimentary canal in insects extends from mouth to anus which is divided in to three parts, foregut, midgut and hindgut.
    - **a) Foregut (stomodaeum):** Ectodermal in origin. Ectodermic Cells secretes cuticular layer called Intima. It is the anterior part of the alimentary canal which starts with the mouth cavity and ends with the gizzard (or) proventriculus. It is divided in to Mouth, Pharynx, esophagus, crop and gizzard.
        - ✓ **Mouth:** Terminal mouthparts lead into a preoralcavity. Preoralcavity between epipharynx and hypopharynx is called as Cibarium. Preoralcavity between hypopharynx and salivary duct is Salivarium.
        - ✓ **Pharynx:** Behind the mouth a well musculated organ called Pharynx is present which pushes the food into esophagus. Pharynx also acts as a sucking pump in sap feeders. It is the region between the mouth and oesophagus. It concerned with ingestion and back word flow of food.
        - ✓ **Esophagus:** It is a narrow Simple tube of the foregut through which the foods get transported from pharynx into the crop.
        - ✓ **Crop:** It is a sac like structure which is a dilated form and mainly serves the purpose of storage of food material. In honey bees crop is called as honey stomach where nectar conversion occurs.
        - ✓ **Gizzard (Proventriculus):** It forms the last portion of foregut. This consists of the cuticular intima layer modified in to teeth like denticles that help for grinding the food material. It is found in solid feeders and absent in fluid feeders or sap feeders.
- **Stomodeal valve or cardiac valve:** After gizzard the foregut forms into a stomodeal valve or cardiac valve which is surrounded by gastric (or) hepatic caecae. This prevents backward movement of food. Foregut opens in to midgut through stomodael / cardiac valve.
    - **b) Midgut (Ventriculus or Mesenteron or Stomach):** Endodermal in origin. It concern with; Secretion of Enzymes, Digestion of food, and Absorption of food. An endodermic cell does not secrete intima but instead of that secretes delicate membrane called Peritrophic membrane.
        - ✓ Midgut consists of an inner delicate layer called Peritrophic membrane secreted by the epithelial cells. The Peritrophic membrane protects the tender epithelial cells of the midgut from abrasion by hard food particles. Present in solid feeders and absent in sap feeders.
        - ✓ The midgut is a long tube it carries eight small blunt tubes known as gastric or hepatic or enteric caeca. It increase the surface area of Malpighian tubules and they are secretary and absorptive in function.
- **Filter chamber:** This is a characteristic arrangement of the midgut in hemipteran insects (fluid feeders). This is closely bound to either posterior part of midgut or the anterior hindgut and Malpighian tubules. Filter chamber enables the excess fluids including sugar in the food to pass directly from the anterior part of the midgut to the hindgut without passing through the middle portion of midgut thus preventing excessive dilution of haemolymph, enzymes and facilitate better enzyme activity.

- **Pyloric valve or proctodeal valve:** Present between midgut and hindgut, which regulate food flow.

c) Hindgut (Proctodaeum): Ectodermal in origin. Intima layer is present.

- ✓ Anterior end of the hindgut can be marked by the presence of a set of Malpighian tubules which are excretory in function.
- ✓ Hindgut is divided into 3 regions namely ileum, colon and rectum.
- ✓ **Ileum**- It is a small/mid intestine (or) tube like structure.
- ✓ **Colon**- It is a large/hind intestine. In termites, digestion takes place in colon of hindgut which secretes the enzyme Cellulase for digest the wood material rich in cellulose.
- ✓ **Rectum**- The rectum may sometimes get differentiated into rectal papillae (or) pads which vary in number from 3-6. These are involved in reabsorption of water, salts from the fecal (waste) matter.

❖ **Salivary glands: -** These are a pair of glands involved in the secretion of salivary juices. These glands present either sides of esophagus which open at the base of the hypopharynx through small salivary ducts. In case of silkworm (or) lepidopteran larvae, the salivary glands produce silk and anti-coagulants in blood suckers like mosquitoes.

- **Instruction for Dissection of Digestive System of Cockroach: -**

1) **Alimentary canal:** Kill the cockroach with the help of chloroform. Cut the wings and legs from their bases. Give the lateral cuts in the region of abdomen in order to separate the terga from the sterna with the help of scissor. Keep the cockroach in wax dish in its natural position. Fix the cockroach by inserting one pin through the head (Labrum) and second through the last abdominal segment. Pour sufficient water (submerge the specimen) in wax dish. Remove abdominal terga from behind forward with the help of forceps. Also remove the meso and metanotum carefully Use fresh water for cleaning and separating the fat bodies, tracheae and muscles carefully with the help of forceps and observed the coiled part of alimentary canal outside carefully and pin down on the left side of the wax-dish.
2) **Salivary glands:** Lift up the crop and observed the salivary glands in its both sides, above the alimentary canal, in the thoracic region. Cut open the neck and head in the median line, above the alimentary canal and up to the pin in the head. Lift up the crop, separate the glands from the crop and observe the ducts running from the cut off the ventral nerve cord which crosses the ducts of the glands and glands along with ducts. Mount it in glycerin and observe under dissecting microscope.

Lab Work: - Dissect the digestive system of cockroach and explore alimentary canal along with salivary glands. Draw a neat labelled diagram.

EXERCISE NO. 12

Date: ----------

Study and Dissection of Central Nervous System of Cockroach

The nervous system functions as a link between the sense organs which respond to various external and internal stimuli and the effectors organs such as muscles, glands**.** The sense organs include the structures with various sensilla that respond to sounds, weather factors, smell etc. Nervous system consists of elongated cells which form the physiologically functional elements that are known as neurons (nerve cell). These neurons carry the information in the form of electrical impulses. It is a unit of nervous system.

- **Structure of Neuron**: **-** The nerve cells are called neurons which are derived from ectoderm. Each neuron consists of a prominent nucleated cell body known as perikaryon (or) soma and an elongated cytoplasmic thin fiber called the 'axon' extends to make contact with other neurons or with effector organs, the muscles and group of small branches called the 'dendrites'. The axon gives lateral branches called collaterals. Both the axon and collaterals end in fine fibrils known as terminal arborizations.
- **Synapse: -** The neurons get connected with each other by having a link between the terminal arborizations of the axon of one neuron and dendrites of the soma of other neuron through a 'synapse' or the point at which neurons receive information from or convey to another neuron is known as synapse. Synaptic gap is approximately $100A^0$ (20-25nm).
- **Classification of neurons:**
  - **Based on their structure -**
    1) **Unipolar / monopolar:** Have a single axon without collaterals and dendrites.
    2) **Bipolar:** Have either collaterals or dendrites in addition to axon.
    3) **Multipolar:** Neurons have an axon with several collaterals and dendrites**.**
  - **Based on function-**
    1) **Sensory / afferent:** Present just beneath the integument and associated with sensory organs. Carry impulses from sense organs to the central nervous system.
    2) **Motor / efferent neurons:** Always unipolar / monopolar. Carry impulses from central nervous system to the organs.
    3) **Association neurons:** Associated in between sensory and motor neurons.

Nervous system can be grouped in to three; Central nervous system (CNS), Visceral or sympathetic nervous system and Peripheral nervous system.

Central Nervous System of Cockroach (CNS): -

Insect has a centralized nervous system. The group of nerve cells or neurons is called ganglion. CNS consists of double series of ganglia joined together by longitudinal and transverse fibres. Generally each body segment possesses a pair of ganglia, so closely united as they appear to be one. The ganglia of adjoining segments are joined together by longitudinal fibers called as connectives. The ganglia of same segment unite by transverse fibres called as commissures.

- CNS consists of brain (supraoesophageal/cerebral ganglion), sub-oesophageal ganglion and ventral nerve cord.
- **Brain (Supra-oesophageal ganglion):** It is present in the head above the oesophagus in the head. It is formed by the union of the ganglia of first 3 segments of the head. Brain is divided into protocerebrum, deutocerebrum and tritocerebrum.

- ✓ **Protocerebrum:** It is also known as fore-brain. It is formed by the union of the ganglia of pre-antennary segment and forms the greater part of the brain. It gives nerve connection to the compound eyes and ocelli. It is bilobed and continuous laterally with the optic lobes.
- ✓ **Deutocerebrum:** It is also known as mid-brain. It is formed from the ganglia of antennary segment and it gives nerve connection to the antenna.
- ✓ **Tritocerebrum:** It is also known as hind brain. It is formed by the union of ganglia of intercalary segment and is relatively small. It gives nerves connection to the labrum.

❖ **Sub-oesophageal ganglion:** It is present in the head below the oesophagus in the head. It is formed by the union of ganglia of the gnathocephalic segments. It gives nerves to mandibular, maxillary, labial segment, salivary ducts, and part of cervical muscles in the neck region and corpora allata.

❖ **Ventral Nerve Cord (VNC):** Ventral nerve card consists of a chain of segmented ganglia connected by means of longitudinal connectives and transverse commissures. In thorax, there are 3 ganglia. It controls the locomotory organs and gives nerve connection to the legs and wings called thoracic ganglia. In abdomen, there are about 8 ganglia. Each ganglion gives off nerves to respective segments.

❖ **Mechanism of impulse conduction: -** Conduction of nerve impulse is mainly of two types-

a) **Axonic conduction-** Electrical conduction through Na and K ionic movement. In this conduction ionic composition varies between inside and outside of axon resulting in excitable conditions, which leads to impulse conduction as electrical response

b) S**ynaptic conduction** (Bio-Chemical transmission with Acetylcholine production) in this conduction neurochemical transmitters are involved in the impulse conduction through the synaptic gap.

➢ **Instruction for Dissection of Central Nervous System of Cockroach: -** Cut open the cockroach as instructed earlier in digestive system. Remove the alimentary canal and remaining fat bodies and observe the ventral nerve cord. Trace the three pairs of thoracic ganglia by pulling apart a legs and removing the muscles. Remove the viscera, fat bodies and trachea and observe the abdominal ganglia. Locate brain which is situated in the head, in between two eyes and below the epicranium. Hold the head in hand and take cuts on lateral sides outside the antenna. Insert the angular scissor and cut the epicranium transversely. Lift up the front part of the head capsule and remove it by scrapping with arrow headed needle and observe the bi lobed brain. Cut open the neck and part of head capsule up to the brain and separate them from the brain with the help of forceps find out the hard part of occipital ring, break it and trace the sub-oesophageal ganglion. Mount the system on black-ground and observe the brain, sub-oesophageal ganglion, thoracic ganglia and abdominal ganglia.

Lab Work: - Dissect the central nervous system of cockroach and Draw neat labelled diagram.

EXERCISE NO. 13

Date: ----------

Study and Dissection of Female Reproductive System of Cockroach

The reproductive system is divided in to two parts namely, internal genitalia and external genitalia. The internal genitalia serve to the development of germ cells. The external genitalia accomplish the union of two sexes and enable the female to deposit eggs.

Female reproductive system: - The main functions of the female reproductive system are egg production and storage of male's spermatozoa until the eggs are ready to be fertilized.

- ✓ It consists of; A pair of ovaries which possess number of ovarioles, A pair of oviducts, A common oviduct / Median oviduct, Spermatheca, A pair of accessory glands and Bursa copulatrix/copulatory pouch/genital chamber/vagina.
  1) **Ovaries: -** These are the prominent visceral organs present on the either side of alimentary canal. These are paired in structured mainly covered with fat body and trachea. Each ovary consists of eight ovarioles or egg tubes. It consists of 3 parts namely; Terminal filament, Egg tube, Pedicel. The functions of ovary are production of eggs or ova and storage of male's spermatozoa.
  2) **Lateral oviducts:** Proximal end of the ovarioles of each ovary join to form a lateral oviduct on each side. Function is to transfer the eggs form ovary to the median oviduct.
  3) **Median Oviduct:** Two lateral oviducts combine to form a median oviduct.
  4) **Vagina: (genital chamber)** Median duct opens in to a tubular genital chamber or vagina formed by invagination of body wall from VIII segment.
  5) **Bursa Copulatrix:** In some insects the genital chamber or vagina develops a separate pouch called Bursa Copulatrix in to which insects have two reproductive openings, one is vulva for receiving the sperms open on VIII sternum and another one is ovipore or gonopore on IX segment for discharging eggs. E.g.: Lepidoptera and water beetles.
  6) **Spermatheca:** It is a sac like structure consisting of a spermathecal gland and opens in to vagina through spermathecal duct. This is mainly used for temporary storage of sperms. It also produces some fluids responsible for longevity of cells for several hours.
  7) **Accessory glands: (collateral glands)**: - These are a pair structured which open in to the distal portion of vagina. They secrete the sticky substance responsible for the formation of ootheca of cockroach, preying mantid and poisonous secretions in case of Hymenoptera. These sticky substances are useful for attachment of egg to the substrate on which they are laid.

- ➢ **Instruction for Dissection of Female Reproductive System of Cockroach: -** Cut open the cockroach as instructed earlier in digestive system. Do not press the abdomen. Separate and remove the alimentary canal from the body. Carefully shake the fat bodies on the lateral sides and locate the tip of ovarioles tubules of the ovaries laying embedded in the fat bodies. Remove the fat bodies and exposed the ovaries on each side. Lift up the ovary on each side and remove the fat bodies laying in between the ovaries and sterna. Cut the part of the sterna on the lateral sides and separate the ovaries on the sides and pin them. Carefully remove the median fat bodies and find out the spermatheca. Observe the milky white branches of collateral glands. Remove the remaining fat bodies, trace lateral oviduct and common oviduct. Observe the ovaries, short oviducts, common oviduct, spermatheca and collateral glands.
- ➢ **Lab Work: -** Dissect the female reproductive system of cockroach and draw a neat labelled diagram.

EXERCISE NO. 14

Date: ----------

Study and Dissection of Male Reproductive System of Cockroach

The main functions of the male reproductive system are the production and storage of spermatozoa and their transport in a viable state to the reproductive tract of the female.

- A male reproductive organ consists of; a pair of testes composed of follicles or sperm tubes, a pair of vasa deferens, seminal vesicle, ejaculatory duct, accessory glands and Genitalia.
    1) **Testes:** These are paired in structured & lie in visceral cavity above the alimentary canal. Each testes are well supplied with trachea and fat body tissues. Each testis consists of number of oval shaped structures known as follicles or sperm tubes. Each follicle has a layer of epithelial cells. The entire follicle is covered by a peritoneal membrane whereas the testes are completely enveloped within a coat known as scrotum. The functions of testes are production and storage of spermatozoa.
    2) **Vasa differentia:** These are the long tubes formed by the union of vasa efferent which receives the sperms from testis and allow their transport to the ejaculatory duct.
    3) **Seminal vesicles:** Each vasa deferens becomes enlarged posteriorly to form a sac like structure called seminal vesicle for storage of spermatozoa for some time.
    4) **Ejaculatory duct:** Both the vasa deferens of the two testes unites posteriorly to form a common median ejaculatory duct.
    5) **Aedeagus or Penis**: - The terminal section of ejaculatory duct is enclosed in a finger like invagination of body wall called male copulatory organ or aedeagus or penis. The function of aedeagus is that ejaculate the spermatozoa into the female genital tract.
    6) **Accessory glands:** These are 1-3 pairs of glands which open in to the ejaculatory duct. In most cases their secretion mix with spermatozoa. These glands are called mushroom glands in cockroaches and mantid because of their appearance as mushrooms. This secretion facilitates sperm transmission from male to female.

- **Instruction for Dissection of Female Reproductive System of Cockroach: -** Cut open the cockroach as instructed earlier in digestive system. Separate the fat bodies at the anterior region of abdomen and locate the bunch of testes which can be distinguished by its different shape. Separate the alimentary canal slowly and remove it by cutting at the crop at one end and at the rectum at another. Detach lobes of testes from the sterna along with fat bodies with the help of needle and forceps. Pin down the whole mass of testes on both sides. Gently shake the fat bodies near the base of the mass and observe the vasa difference running as thin straight whitish line. Separate the fat bodies with the help of forceps and trace the vasa difference and lobes of the testes. Remove the remaining fat bodies in the abdomen and expose milky white, much branched mushroom gland. Remove the ventral nerve cord and observe the club shaped conglobate gland. Trace the ejaculatory duct which is milky white in colour. Observe a pair of tastes, a pair of vasa difference, mushroom gland, ejaculatory duct and conglobate gland.

Lab Work: - Dissect the Male reproductive system of cockroach and draw a neat labelled diagram.

EXERCISE NO. 15

Date: ----------

Study of Distinguishing Taxonomic Characters of Orders and Families of Agricultural Importance: Odonata, Orthoptera and Dictyoptera.

ORDER: ODONATA :- (Odous - Tooth; anus – having) - E.g. Dragonflies and damselflies.

Economic Importance: Adults are aerial predators. They are able to catch, hold and devour the prey in flight. Naiads are aquatic predators. Adult predacious on mosquitoes, Houseflies etc. and nymph feed on mosquito larvae.

Characters:

1) Medium to large sized insects.
2) They are attractively coloured.
3) Head is Mobile and attached to slender neck.
4) Compound eyes are large. Three ocelli are present.
5) Antennae are filiform.
6) Chewing and biting type of mouth parts.
7) Wings are membranous.
8) Wings have a dark pterostigma towards the costal apex.
9) Prothorax is reduced; meso and meta thorax is fused.
10) Basket like legs presents to catch prey in flight.
11) Abdomen is long and slender.
12) Metamorphosis is incomplete with three life stages.
13) The naiad is aquatic.
14) Labium is greatly elongated, jointed and bears two hooks at apex. It is called mask. It is useful to capture the prey.
15) Respiration by means of rectal or caudal gills.
16) Immature stage of Odonata is called "Naiads".
17) There are three sub-orders. **Anisoptera, Zygoptera and Anisozygoptera**

Sr. No.	**ANISOPTERA** (Anisos = Unequal & Ptera = Wing)	**ZYGOPTERA** (Zygon = Equal & Ptera = Wing)
	Adult Characters	
1	Strong fliers	Weak fliers
2	Compound eyes large meet each other (Holoptic)	Compound eyes button like, wide apart (Dichoptic)
3	Hind wings basally broader than forewings	Both Pair equal with identical venation
4	Wings spread laterally at rest	Wings held at an angle above abdomen
	Nymph (Naids) Characters	
5	Stout and robust	Weak and fragile
6	Rectal gills present	Caudal gills present
7	Jet propulsion Mechanism present	Absent
8	E. g. Dragonfly	E. g. Damselfly

ORDER: ORTHOPTERA: - (Orthos - Straight; Ptera-Wings) - E.g. Grasshoppers, Locust, Katydids, Mole cricket, house and field cricket.

Economic Importance: Majority of insects are phytophagous like grasshopper, locust some create noisy loud sound**.**

Characters:

1) Antenna is filiform.
2) Mouthparts are mandibulate.
3) Head position is hypognathous.
4) Prothorax is large and distinct.
5) Legs are saltatorial type. Legs normally developed, or forelegs modified for digging (fossorial) as in mole crickets or hind legs modified for jumping (saltatorial) as in grasshopper.
6) Forewings are leathery, thickened and known as Tegmina and Hind wings are membranous.
7) Specialized stridulatory (sound-producing) organs are present. Usually males alone can produce sound. Auditory or tympanal (hearing) organs are also well developed and are located on either side of the first abdominal segment or at the base of fore tibia.
8) Cerci are short and unsegmented.
9) Metamorphosis is gradual. (simple or incomplete) (Egg – Nymph - Adult).
10) Ovipositor is well developed in female on 7 & 8^{th} abdominal sternum.
11) Male genitalia on 9^{th} abdominal sternum.
12) This order is sub divided into two suborders, viz., **Caelifera** and **Ensifera**.

Sr. No.	CAELIFERA	ENSIFERA
1	Antennae are shorter than body less than 30 segments	Antennae are longer than body more than 30 segments
2	Tympanum is found on the lateral side of the first abdominal segment.	Tympanum is found on the fore tibia.
3	Diurnal(Active at day)	Nocturnal(Active at night)
4	Feed on monocot plants	Feed on dicot plants
5	Eggs laid in soil.	Eggs laid in plant tissue
6	Ovipositor is short	Ovipositor is more or less elongate.
7	Stridulatory organ (Femoro-alary type)	Stridulatory organ (Tegminal)
8	**Family: Acrididae:** E.g. Short horned grasshoppers, Surface grasshoppers and locusts.	**Families:** **1. Tettigonidae:** E.g. Long horned grasshoppers, Katydids and bush crickets. **2. Gryllidae:** E.g. House and field Crickets. **3. Gryllotalpidae:** E.g. Mole crickets.

ORDER: DICTYOPTERA :- (Dictyon - Network; Ptera – Wings) - E.G. Cockroaches and Preying Mantid.

Economic Importance: Cockroaches are household pests and Mantid predatory in habit

Characters:

1) Head is usually hypognathous.
2) Antenna is filiform/ cetaceous.
3) Mouthparts are mandibulate type.
4) Forewings are tegmina and Hind wings are large membranous.
5) Prothorax with pronotum covering.
6) Cerci are short and many segmented.
7) Fore legs is walking/raptorial type. Eggs are contained in an ootheca.
8) Metamorphosis is gradual. (Simple or incomplete)
9) Female with reduce ovipositor on 7^{th}abdominal sternum.
10) Male genitalia on 9^{th} abdominal sternum.
11) Dictyoptera is divided into two suborders viz., **Blattaria** (cock-roaches) and **Mantodea** (preying mantid). The important families are **Blattidae** and **Mantidae.**

Sr. No.	Blattaria	Mantodea
1	Head is completely covered with pronotum.	Head is not covered with pronotum.
2	Two ocelli are present.	Three ocelli are present.
3	Legs cursorial (All pairs)	Fore legs is raptorial type.
4	Proventriculus with powerful teeth.	Proventriculus not powerful teeth.
5	Eggs laid in oothecal.	Eggs laid in spaumaline
6	Omnivorous	Carnivorous
7	No mimicry found	Mimicry found
8	Nymph not cannibalistic	Nymph cannibalistic
	Family: Blattidae- e.g. Cockroaches	Family: Mantidae- e. g. preying mantid

EXERCISE NO. 16

Date: ----------

Study of Distinguishing Taxonomic Characters of Orders and Families of Agricultural Importance: Isoptera, Thysanoptera and Hemiptera.

ORDERS: ISOPTERA: - (Iso - Equal; Ptera - Wing) - E.g. Termites (White Ants)

Economic Importance: Termites are nature's scavengers. They convert logs, stumps, branches etc., to humus. Many are injurious to crops, furniture and wood works of buildings

Characters:

1) They are ancient polymorphic, social insects living in colonies White, soft bodied insects.
2) Antennae are short and moniliform.
3) Compound eyes present in winged forms.
4) Mouthparts are adapted for biting and chewing.
5) Wings are membranous. Wings are present only in sexually mature forms during swarming season.(Deciduous type)
6) Tarsi are always 4 segmented
7) Circi are short
8) External genital organs are lacking in both the sexes.
9) Metamorphosis simple or incomplete.
10) Caste system: Following are the difference castes that are usually seen in a termite colony
    A) Reproductive Cast: - King & Queen
    B) Sterile Cast: - Workers & Soldiers. (Workers is the damaging caste)
11) Important families:-Termitidae- e.g. *Termes* spp, *Odontotermes* spp. and Kalotermitidae- e.g. Dry wood termites.

ORDER: THYSANOPTERA : - (Thysano: Fringed and Pteron: Wing), E.g. Thrips

Economic Importance: Most of the thrips species belong to the family Thripidae and are phytophagous. They suck the plant sap. Some are vectors of plant diseases. Few are predators.

Characters:

1) They are minute, slender, soft bodied insects.
2) Mouthparts are rasping and sucking. Right mandible is absent Hence mouthparts are asymmetrical.
3) Antennae short moniliform.
4) Fringed wings are present
5) Prothorax is free and well develops.
6) Abdomen is elongate with 10-11 segments, usually tapering posteriorly.
7) Cerci absent.
8) Metamorphosis is incomplete with inactive pupa like instars (Aberrant Hemimetabola).
9) Parthenogenetic type of reproduction is very common and in many species males are rarely seen.
10) This order is subdivided into two suborders- Terebrantia: Important family is Thripidae, e.g. Onion Thrips and Tubulifera: Important family is Phaleothripidae e.g. Olive Thrips

ORDER: HEMIPTERA : - (Hemi - Half; Ptera – Wing) - E.g. Bugs, Aphids, Whiteflies, Mealy Bugs, Scales etc.

Characters:

1) Head is Opisthognathous.
2) Mouthparts are piercing and sucking type.
3) Forewings (Hemelytra) are either uniformly thickened throughout distally membranous.
4) Cerci are always absent.
5) Metamorphosis usually incomplete.
6) Alimentary canal is suitably modified (filter chamber) to handle liquid food.
7) There are two suborders *viz*., Heteroptera and Homoptera.

Sr. No.	**Heteroptera** (Hetero-different; Ptera-wing)	**Homoptera** (Homo-uniform; Ptera-wing)
1	Head is porrect or horizontal	Head is deflexed
2	Pronotum usually large	Pronotum small and collar like
3	Forewings hemelytra	Forewings uniform in consistency
4	Wings fold flat over the body at rest	Wings held roof like over the body
5	Tarsi – 3 segmented antennae 4-5segmented	Tarsi 1-3 segmented antenna 3-10segmented
6	odoriferous glands are present	wax glands are present
7	Herbivorous, predaceous or blood sucking.	Herbivorous
8	Both terrestrial and aquatic	Terrestrial
9	Honey dew secretion uncommon	Honey dew secretion common
10	**Important families of heteroptera;** **Cimicidae:** E.g. Bed bugs) **Tingidae:** E.g. Lacewing bugs or Tingid bug **Miridae:** E.g. Plant bugs or Leaf bugs **Lygaeidae:** E.g. Dusky cotton bug **Pyrrhocoridae:** E.g. Red cotton bug **Coreidae:** E.g. Rice earhead bug, Tur pod bug, **Pentatomidae:** E.g. Stink bugs, Painted bug **Belostomatidae:** E.g. electric light bugs	**Important families of homoptera;** **Cicadellidae:** E.g. Leaf hoppers or Jassids **Delphacidae :** E.g. Delphacids **Aleyrodidae:** E.g. Whiteflies **Aphididae:** E.g. Aphids **Coccidae:** E.g. Scale insects **Kerridae:** E.g. Lac insect **Pseudococcidae:** E.g. Mealy bugs

EXERCISE NO. 17

Date: ----------

Study of Distinguishing Taxonomic Characters of Orders and Families of Agricultural Importance: Neuroptera, Lepidoptera and Hymenoptera.

ORDER: NEUROPTERA: - (Neuron-Nerve; Ptera - Wings) - E.g. Green Lace Wings, Ant Lions, Alder Fly, Snake Fly

Economic Importance: Insects are predacious (on aphids, White flies, thrips) – beneficial, Dobson flies called hellgrammites use for fish baiting.

Characters:

1) They are soft bodied insects
2) Antenna is filiform
3) Mouthparts are chewing type in adults.
4) Two pairs of similar membranous wings in rest form roof on abdomen
5) Larva is carnivorous, Campodeiform
6) Pupa is Exarate, Decticous. Pupation takes place in a silken cocoon.
7) Malpighian tubules are modified as silk glands.
8) Abdomen without cerci.
9) Metamorphosis complete type (Egg – Larva – Pupa - Adult)
10) Classification: This order is subdivided into two suborders viz., Megaloptera and Planipennia.
    Sub order: Planipennia:
    Chrysopidae: E.g. Green lacewings, Goldeneyes, Stink flies, Aphid lions)
    Mantispidae: E.g. Mantispid flies
    Myrmeleontidae: E.g. Ant lions
    Ascalaphidae: E.g. Owlflies

ORDER: LEPIDOPTERA :- (Lepidos - Scales; Ptera – Wings) - E.g. Moths, Butterflies, Skippers

Characters:

1) Head relatively small free with small neck.
2) Compound eyes are relatively large; two ocelli present one on each side close to the margins of compound eyes.
3) Mouthparts in adults are of siphoning type. Mandibles are absent.
4) Antennae are clubbed in butterflies and filamentous in moths.
5) Wings are membranous and scaly. Wings are coupled by either frenate or amplexiform type of wing coupling.
6) Larvae are called caterpillars usually polypod - eruciform type.
7) Two to five pairs of fleshy unsegmented prolegs are found in the abdomen. At the bottom of the proleg, crochets are present.
8) Pupa is generally Adecticous and obtect.
9) Adults are harmless except fruit sucking moths.
10) Undergo complete metamorphosis.
11) There are three sub-orders. Zeugloptera, Ditrysia, Monotrysia.

Sr. No.	Zeugloptera	Monotrysia	Ditrysia
1	Adults with functional mandibles	Adults without functional sometimes with vestigial mandibles	Adults without functional mandibles
2	Female bursa copulatrix opening into common oviduct	Female with 1 or 2 genital opening behind sternite	Female with opening bursa copulatrix on sternite
3		Female insects have one pore.	Female insects have two pores.

Important family of suborder Ditrysia:-

Family: Noctuidae - This is the largest family in this order. E. g. Army worms, cutworms, Spodoptera, Helicoverpa, Fruit sucking moth, Castor Semilooper.

Family: Gelechidae – E. g. Potato tuber moth, Pink bollworm, Groundnut leaf miner, Angoumois grain moth.

Family: Pyralidae – E. g. Cotton leaf roller, Jowar stem borer, Wax moth

Family: Pterophoridae – E. g. Tur plume moth

Family: Arctiidae – E. g. Hairy caterpillar

Family: Hesperiidae – E. g. Rice skipper

Family: Shingidae – E. g. Sesamum and Sweet potato leaf eating caterpillar

Family: Papilionidae – E. g. Lemon butterfly

Family: Lycanidae – E. g. Anar caterpillar

Family: Pieridae – E. g. Cabbage butterfly

Family: Bombycidae – E. g. Mulberry silk worm

Family: Saturnidae – E. g. Tasar and Eri silk worm

Differences between moths and butterflies:

Sr. No.	Moths	Butterflies
1	Nocturnal in habit	Diurnal in habit
2	Antennae either Pectinate or bi Pectinate plumose type	Antennae Clavate type
3	Ocelli Present	Ocelli Absent
4	Mandibles Present	Mandibles Absent
5	Wing coupling Frenate type	Wing coupling Amplexiform type
6	Abdomen Large and stout	Abdomen Comparatively small and slender
7	Obtect pupa within a cocoon	Obtect pupa without cocoon.
8	At rest, wings held roof like on body	At rest, wings held erect straight upward.

ORDER: HYMENOPTERA: - (Hymen - membrane; Ptera - wings.) - E. g. Wasps, bees, ants, sawflies, Parasitoids etc.

Economic Importance: Red ant, mustard saw fly are crop pest. Many insects are beneficial parasitoids or pollinators

Characters:

1) This is the most beneficial order in the class insecta comprising of parasites, predators and bees involved in pollination and honey production.
2) Most of them are social living
3) Mouth parts are biting type modified for lapping or sucking
4) Wings are membranous. Wing venation is hamuli type.
5) Abdomen is basally constricted. The first abdominal segment is called propodeum.
6) It is fused with metathorax.
7) The second segment is known as pedicel which connects the thorax and abdomen.
8) Abdomen beyond the pedicel is called gaster or metasoma
9) Larvae are known as grubs with well-developed head and usually apodous and Eucephalous
10) Pupa is Exarate and a cocoon is generally present
11) Metamorphosis complete and complex also.
12) Fertilized eggs develop into females and males are produced from unfertilized eggs.
13) Males are haploid and females diploid.
14) This order is subdivided into two suborders; **Symphyta and Apocrita**

Differences between Symphyta and Apocrita:

Sr. No.	Symphyta	Apocrita
1	Abdomen is broadly joined to the thorax	Abdomen is petiolated
2	Larva is a caterpillar and it belongs eruciform type	Larva is a grub and it belongs apodous eucephalous type
3	Stemmata are present	Stemmata are absent.
4	Both thoracic and abdominal legs are present	Legs are absent
5	Ovipositor is saw like and suited for piercing the plant tissues	Ovipositor is not saw like and is suited for piercing in parasitic groups or for stinging in other groups.
6	Behavioural sophistication is less.	Behavioural sophistication is more
7	They are phytophagous	They are generally parasitic
8	**Important families:** Tenthredinidae : E.g. Sawflies	**Important families:** Apidae : E.g. Honey bees Vespidae: E.g. Wasps Megachilidae: E.g. Leaf cutter bees Formicidae: E.g. Ants Braconidae : E.g. Braconid wasps Trichogrammatidae: E.g. Egg parasitoids

EXERCISE NO. 18

Date: ----------

Study of Distinguishing Taxonomic Characters of Orders and Families of Agricultural Importance: Diptera and Coleoptera.

ORDER: DIPTERA: - (Di-Two; Ptera-Wing) - E.g. Housefly, Fruit Fly, Horse Fly, Pod Fly, Stem Fly, Mosquito, Midge Fly, Shoot Fly, Gall Fly.

Economic Importance: Considerable number of flies is predacious. some are act as a vectors for transmission of disease, fruit flies, leaf miners, stem fly and root maggots are crop pest

Characters:

1) They are small to medium sized, soft bodied insects.
2) Mouth parts sucking type usually forming a proboscis. In many they are piercing and sucking and in others they are sponging type.
3) Antennae mostly 3 segmented and Aristate type.
4) Forewings are larger, membranous and used for flight. Hind wings are highly reduced, knobbed at the end and are called halters.
5) Prothorax and metathorax are small and fused with large mesothorax.
6) Metamorphosis is complete.
7) Larvae of more common forms are known as maggots. They are apodous and acephalous (eruciform). Maggots mostly amphipneustic.
8) Pupa is generally with free appendages, often enclosed in the hardened last larval skin called puparium. Pupa belongs to the coarctate type.
9) Legs well developed, tarsus usually 5 segmented pulvilli and an empodium usually present.
10) This order is sub divided in to three suborders; Nematocera, Brachycera and Cyclorrhapha.

Comparative characters of these sub-orders

Sr. No.	Nematocera	Brachycera	Cyclorrhapha
1	Antenna is long and many segmented in adult.	Antenna is short and few segmented in adult.	Antenna is aristate in adult
2	Larval head is well developed.	Larval head is retractile into the thorax.	Larval head is vestigial with mouth hooks.
3	Larval mandibles act horizontally.	Larval mandibles act vertically	Larval mouth hooks act vertically.
4	Pupa is weakly obtect.	Pupa is exarate.	Pupa is coarctate.
5	Pseudotrachae absent	Pseudotrachae present	Pseudotrachae present
6	**Important families:** **Culicidae**: E.g. Mosquitoes **Cecidomyiidae** : E.g. Paddy gall fly	**Important families:** **Asilidae**: E.g. Robber flies **Tabanidae**: E.g. Horse flies **Trypetidae**: E.g. Fruit flies **Agromyzidae**: E.g. Tur pod fly, Leaf miner	**Important families:** **Syrphidae**: E.g. Syrphid fly **Tachinidae**: E.g. Tachinid flies **Muscidae**: E.g. House fly

ORDER: COLEOPTERA: - (Coleos - Sheath; Ptera-Wing), E.g. Beetles, Weevils

Economic Importance: It is the largest order. It includes predators, scavengers and many crop pests. They also damage stored products.

Characters:

1) They are minute to large sized insects.
2) This is the largest order in class insecta comprising about 1/3rd or 40% of the known insect species.
3) Mouthparts are chewing & biting type.
4) Head position is prognathous type
5) Antenna is usualy 11 segmented.
6) Prothorax is large, distinct and mobile. Mesothorax and metathorax are fused with the first abdominal segment.
7) Forewings are horny or leathery known as Elytrate is not used for flight. Hind wings are membranous with few veins and are useful in flight.
8) Legs well developed for walking, running.
9) Cerci and a distinct ovipositor are absent.
10) Metamorphosis is complete.
11) Larvae are often called grubs it is campodeiform or eruciform.
12) Pupae adecticous and Exarate.
13) This order is divided into four suborders, viz., Adephaga (devourers) and Polyphaga (eaters of many things), Archostemata (wood feeders) and Myxophaga (Found in wet places

Important Families:

Sr. No.	Adephaga	Polyphaga
1	**Cicindelidae:** E.g. Tiger beetles)	**Meloidae:** E.g. Blister beetles, Oil beetles
2	**Dytiscidae:** E.g. True water beetles	**Coccinellidae:** E.g. Lady bird beetles, Epilachna beetle
3	**Carabidae:** E.g. Ground beetles	**Scarabaeidae:** E.g. White grub, Dung beetles
4		**Cerambycidae:** E.g. Mango stem borer, Grape stem girdler
5		**Bruchidae:** E.g. Pulse beetles, Seed beetles
6		**Tenebrionidae:** E.g. Rust red flour beetle
7		**Bostrychidae:** E.g. Lesser Grain borers
8		**Melolonthidae:** E.g. Chafer beetles, June beetles
9		**Dynastidae:** E.g. Rhinoceros beetles
10		**Curculionidae:** E.g. Weevils, snout beetles
11		**Chrysomelidae:** E. g. Red pumpkin beetle

Differences between Beetle and Weevil

Sr. No.	Beetle	Weevil
1	Mouthparts typically chewing type	Mouthparts chewing type but modified into snout like structure.
2	Both pairs of wings present.	Hind wing absent.
3	Antennae capitates/ serrate/ Lamellate	Antennae clavate
4	Tarsi 3 to 5 segmented	Tarsi 4 segmented
5	Larvae Oligopod	Larvae apodous