PROFESSOR JAYASHANKAR TELANGANA STATE AGRICULTURAL UNIVERSITY

FACULTY OF AGRICULTURE

DIPLOMA IN AGRICULTURE

STUDY MATERIAL

COURSE NO: DA – 131

PRINCIPLES OF ENTOMOLOGY & PRODUCTIVE ENTOMOLOGY

CREDITS: 4 (3+1)

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AGRICULTURAL POLYTECHNIC

Detailed Lecture Outline

DA-131 (Principles of Entomology and Productive Entomology)

Theory:

1. Introduction of Entomology
2. Characters of class Insecta – Division of class Insecta into subclasses – pterygota, Apterygota, their characters, classifications and examples
3. Characters of Orthoptera
4. Orthoptera – Head, antenna, mouth parts, thorax, characters of wings, abdomen. Examples of agricultural importance.
5. Characters of Thysanoptera
6. Thysanoptera – Segmented antenna, compound eyes, asymmetrical mouth parts, wing characters, parthenogenetic type or reproduction.
7. Thysanoptera – example of agricultural importance.
8. Order Hemiptera Sub order Heteroptera characters
9. Heteroptera – 4 to 5 segmented antenna, well developed compound eyes, sucking type of mouth parts, large pronotum, wing characters.
10. Sub Order Homoptera Characters
11. Homoptera – Head, compound eyes well developed, 3 to 10 segmented antenna. Piercing and sucking type of mouth parts. Thoracic characters, wing characters.
12. Homoptera – insects sexual and parthenogenetic reproduction
13. Homoptera – Examples of agricultural importance.
14. Order Lepidoptera Characters
15. Lepidoptera – Mouth parts, head, compound eyes, characters of wings.
16. Lepidoptera – Differences between moths and butterflies
17. Lepidoptera – examples of agricultural importance.
18. Order Coleptera characters
19. Coleptera – antenna, bitting type of mouth parts, thoracic characters, wing characters
20. Coleptera - larval and pupa exarate
21. Coleptera - examples of agricultural importance
22. Order Hymenoptera characters
23. Hymenoptera – Head, well developed compound eyes, antenna, mouth parts, wing characters, trochanter 1 or 2 segmented, abdominal characters
24. Hymenoptera – larval and pupal characters
25. Hymenoptera - examples of agricultural importance
26. Order Diptera characters
27. Diptera – Head, eyes, antenna, mouth parts, thoracic characters, wings, halters tarsus 5 segmented
28. Diptera – larval and pupal characters
29. Diptera - examples of agricultural importance

30. External characters of cockroach
31. Cockroach – segmentation, body regions, head, throax, abdomen, head, mouth parts
32. Cockroach- thorax – prothorax, mesothorax and metathorax,
33. Cockroach- legs and wings. Abdomen-anal ceric and styles.
34. Kinds of insects mouth parts
35. Biting and chewing type, sucking type, Rasping and sucking type
36. sponging and sucking type.
37. Different Types of injuries caused by insects
38. Different types of injuries and damage symptoms caused by insects
39. Introduction to Integrated Pest Management
40. Importance, concepts and principles of IPM
41. Bio agents – parasitoids and predators
42. Chemical control – Importance of pesticides
43. Classification of insecticides
44. Different formulations of insecticides
45. Study of important group of insecticides and their examples
46. Botanical insecticides – cyclodienes, organo phosphates, carbamates, synthetic pyrethroids, novel insecticides nematicides, rodenticides, acaricides, antifeedants, attractants, sex pheromones
47. & 48. Compatibility of insecticides – insecticides mixtures, phytotoxicity

Introduction of Arthropoda

Arthropoda is a largest phylum in animal kingdom. The word Arthropoda was derived from Greek (Arthros = joint, Poda = foot/feet. In addition, the arthropods have developed a hard, protective exoskeleton (outer shell). Chitin is the main component in arthropod exoskeletons.

Many familiar species belong to the phylum Arthropoda insects, spiders, scorpions, centipedes, and millipedes on land; crabs, crayfish, shrimp, lobsters, and barnacles in water. Arthropods are considered the most successful animals on Earth. The phylum includes more species and more individuals than all other groups of animals combined. Over 85 percent of all known animal species are arthropods. They live in the widest range of habitats and eat the greatest varieties of food. The rigid cuticle inhibits growth, so arthropods replace it periodically by moulting.

General Characters of Arthropoda:

- The body of arthropods is bilaterally symmetrical.
- These animals are triploblastic, and the body is segmented into head, thorax, and abdomen.
- They have jointed appendages that help in movements.
- The body cavity is filled with white coloured blood that is known as haemocoel.
- The exoskeleton structure is hard and made of complex sugar, namely chitin.
- Arthropoda species can be both terrestrial and aquatic.
- These animals have compound eyes on their head, capable of mosaic vision.
- Their nervous system is well-developed.
- Their heads bear the brain and all the sensory organs such as antennae, hair, statocysts, and auditory organs.
- One of the most important features of arthropods is their open circulatory system with arteries and dorsal heart.

- In an Arthropoda diagram, the digestive tract is found with the mouth at one end and the anus at the opposite part of the body.
- The aquatic arthropods excrete waste through coaxal glands, and the terrestrials use malpighian tubule to excrete.
- Phylum Arthropoda shows sexual dimorphism that is either internal or external.
- These animals are unisexual.
- With the help of trachea or book lungs, the terrestrial forms perform respiration. Their aquatic type uses gills or the body surface to respire.
- Muscles are composed of striated fibres, ciliated epithelium absent
- Development may be direct or indirect.

Clasification of Arthopoda

It is the largest phylum in the animal kingdom. Besides insects, many creatures like crayfish, crabs, lobsters, centipedes, millipedes, spiders, mites, ticks, scorpions etccome under this category.

Phylum arthropoda is classified into 7 classes viz

1 .Onychophora (claw bearing): Ex: peripatus

2. Crustacea (crusta-shell): Ex: prawns, crabs, wood louse

3.Arachnida (Arachine-spider): Ex: scorpion, spider, ticks, mites

4.Chilopoda (chilo-lip,poda-legs): Ex: centipedes

5.Diplopoda (diplo-two,poda-legs): Ex: millipedes

6.Trilobita (an extinct group)

7.Hexopoda (hexa-Six; poda-legs) Ex: insects

Characters of class: Insecta (in-internal; sect-cut)

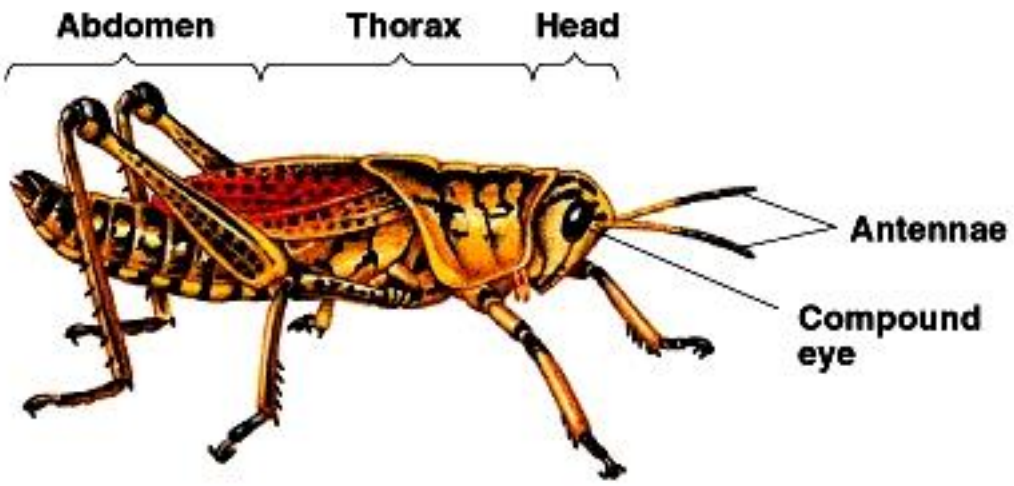
Insects have segmented bodies, jointed legs, and external skeletons (exoskeletons). Insects are distinguished from other arthropods by their body, which is divided into three major regions:

1. The head, which bears the mouthparts, eyes, and a pair of antennae,

2. The three-segmented thorax, which usually has three pairs of legs (hence “Hexapoda”) in

adults and usually one or two pairs of wings.

3. The many-segmented abdomen, which contains the digestive, excretory, and reproductive organs.



Body segmentation of Insect

In general, insect body is divided in to a series of segments, which in primitive arthropods are known as “somites” or “metameres”. During the process of evolution, these somites gets fused with each other in different ways forming the body parts of the existing arthropods.

The type of arrangement of these body segments in embryonic stage is known as primary segmentation while in adult insects is known as the secondary segmentation which differ from primary in having a sclerotized membranous intersegmental region.

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 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 7-11 segments with genital appendages on 8th and 9th segments.

Insect Head

Insect head is a hard and highly sclerotized compact structure. 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).

Six segments of head are represented as.

S.No	Segment	Appendages
1	Pre antennary segment	No appendages
2	Antennary segment	Antennae
3	Intercalary segment	No appendages
4	Mandibular segment	Mandibles
5	First maxillary segment	Maxillae
6	Secondmaxillary/labial segment	Labium

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.

These sutures provide mechanical support to the cranial wall. A general insect posses the following sclerites.

1. Labrum : It is small sclerite that forms the upper lip of the mouth cavity. It is freely attached or suspended from the lower margin of the clypeus

2.Clypeus: It is situated above the labrum and is divided in to anterior ante-clypeus and posterior post-clypeus.

3. Frons : It is the facial part of the insect consisting of median ocellus.

4. Vertex : It is the top portion of the head behind the frons or the area between the two compound eyes.

5. Epicraniun : It is the upper part of the head extending from vertex to occipital suture.

6. Occiput : It is an inverted "U" shaped structure representing the area between the epicranium and post occiput.

7. Post occiput : It is the extreme posterior part of the insect head that remains before the neck region.

8. Gena : It is the area extending from below the compound eyes to just above the mandibles

9. Occular sclerites : These are cuticular ring like structures present around each compound eye

10. Antennal sclerites : These form the basis for the antennae and present around the scape which are well developed in Plecoptera (stone flies)

All the above sclerites gets attached through cuticular ridges or sutures to provide the attachment for the muscles inside.

The common sutures present in head are

1) Clypeolabral suture : It is the suture present between clypeus and labrum. It remains in the lower margin of the clypeus from which the labrum hangs down.

2) Clypeofrontal suture or epistomal suture: The suture present between clypeus 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.

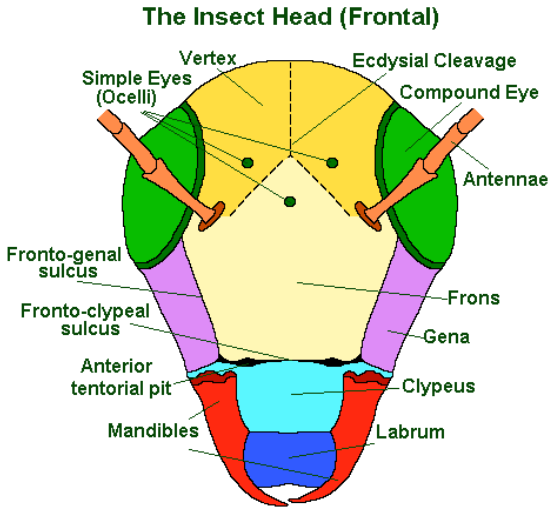
4) Occipital suture: It is 'U' shaped or horseshoe shaped suture between epicranium and occiput.

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.



Thorax

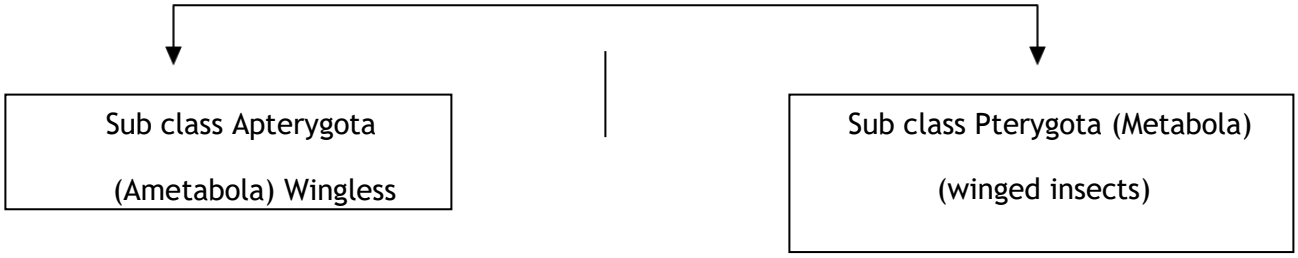
It is the middle part of the body consisting of three segments each possessing a pair of legs and a pair of wings on meso and meta thoracic segment. Meso and meta thoracic segments together known as pterothorax. Sclerite of dorsal region of thorax is tergum or notum in case of winged insect, ventral region is called sternum and lateral region is called pleuron.

Abdomen

Abdomen forms the posterior part of the insect body . Pre genital appendages are absent in pterygotes and present in Apterygotes. The abdomen in the embryo usually consists 12 segments, later the last segments degenerate and appear as 7- 11 segments. Last segment is known as telson or tail as in case of Protura. Abdominal Segments from 1 to 7 are pregenital segments, eighth and ninth are known as genital segments as they form genital appendages i.e. ovipositor in females and aedeagus or penis in males.Tenth and eleventh segments are known as postgenital segments. The 10th segment in general forms the supra anal plate and 11th segment is represented by a pair of anal cerci (usually known as post- genital abdominal appendages).

Pre-genital segments are represented by collophore, furcula and tenaculum in Collembola, styli in Thysanura and cornicles (on dorsal side of 5th and 6th abdominal segments.) in aphids. The abdominal segments consist of tracheal gills In immature forms of trichopterans, mayflies, mosquitoes etc. The last abdominal segments telescope in to each other to form a pseudo ovipositor in diptera. The 1st abdominal segment get fused to metathorax forming propodeum whereas 2nd abdominal segment forms a narrow pedicel or petiole followed by enlarged gaster (rest of the abdominal segments) in hymenoptera.

Class Insecta



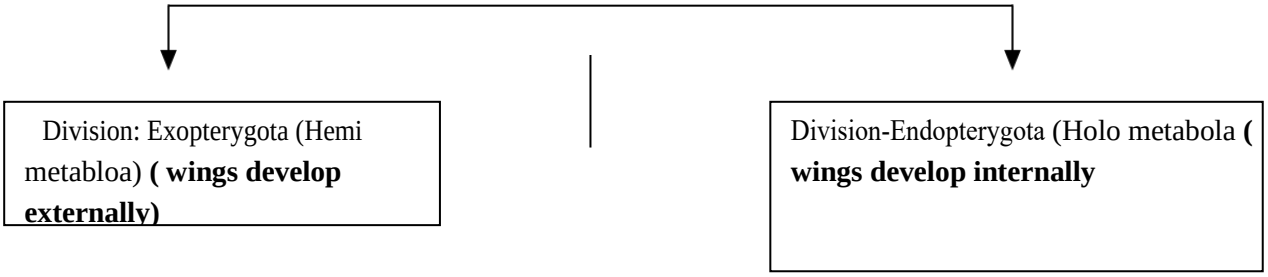
(Imm's classification)

1. Protura – Telson tails

2. Diplura –Diplurans

3. Collembola – Spring tails, snow fleas etc

4. Thysanura –Bristle tails,Silver fish etc



5. Ephemeroptera - May flies

6. Odonata - Dragon flies and Damsel flies

21. Neuroptera - Ant lions and lace wings

7. Plecoptera - Stone flies

8. Dictyoptera - Cockroaches and mantids

9. Grylloblattodea - Grylloblattids

10. Orthoptera - Grasshoppers, locusts, Crickets, mole crickets etc.

11. Phasmida - Stick insects

12. Dermaptera - Earwigs

13. Embioptera - Web spinners

14. Isoptera - Termites

15. Zoraptera - Zorapterans

16. Psocoptera - Book lice

17. Mallophaga - Bird lice

18. Siphunculata (Anoplura) - Sucking lice

19. Hemiptera - Plant bugs

20. Thysanoptera - Thrips

22. Mecoptera - Scorpion flies

23. Trichoptera - Caddis flies

24. Lepidoptera - Moths and butteflies

25. Diptera - Flies, mosquitoes

26. Siphanoptera - Fleas

27. Hymenoptera – Ants, bees, wasps

28. Coleoptera- Beetles, weevils

29. Strepsiptera-Stylopids

The class insecta has two subclasses viz., Apterygota and Pterygota.

Apterygota(Ametabola)	**Pterygota(Metabola)**
Small and primitive insects & Primarily wingless	Developed insects & Winged and secondarily wingless
Adults have pregenital abdominal appendages	Adults without pregenital abdominal appendages
Metamorphosis is simple or absent	Metamorphosis is present and variable
Mandibles articulate with head at single point -Monocondyle	Mandibles articulate with head at two points -Dicondyle

Exopterygota (Hemimetabola)	**Endopterygota (Holometabola)**
Metamorphosis simple and incomplete	Complete and complex
Wings develop externally	internally
Immature stages (nymphs) resemble adults in structure and habits	Immature stages (lava) differ adults in structure and habits
No pupal instar	Pupal instar present

CHARACTERS OF IMPORTANT ORDERS

ORDER: ORTHOPTERA (Ortho: straight, Ptera: Wings, Straight winged Insects)

Head is Hypognathous or Proganthous

Large well developed compound eyes as well as three ocelli.

Filiform Antennae

Mouthparts Mandibulate (Chewing and biting type)

Large pronotum

Fore wings are long, narrow, leathery called tegmina.

Hind wings are broad, membraneous and folded fan like beneath the forewings at rest.

Hind legs have enlarged femur used for jumping -saltatorial in grasshoppers.

Fore legs modified for digging (fossorial) in mole crickets.

Tarsi 3-4 segmented

Stridulation (sound producing) is by rubbing forewings against each other (alary type) or both hind femora over tegmina(femoro-alary type)

Tympanal organs or Auditory organs are located on either side of the first abdominal segment or at the base of fore tibia

Male genetalia concealed by the boat shaped 9th abdominal sternum.

Females usually have well developed ovipositor

Anal cerci are short and unsegmented.

Hemimetabolous (having nymphs that look like small adults and no pupa), having three stages of development; egg, nymph and adult.

Examples :Grasshoppers, Crickets, Locusts

Rice Grasshoppers-*Oxya nitidula, Heiroglyphus banian*

ORDER : THYSANOPTERA (Thysano: fringed, Ptera: Wings, Fringed-winged Insects)

Antennae 6-10 segmented

Conspicuous Compound eyes

Asymmetrical mouth parts. Right mandible is absent. Lacerating or Rasping and sucking type

Fringed wings

Tarsus is two segmented with arolium at the pretarsus.

Anal cerci are absent

Metamorphosis is Intermediate between simple and complex, in which 1st and 2nd instar larvae are active, resembling adults (called nymphs) where as 3rd and 4th instar are inactive pre-pupal and pupa like stages.

Parthenogenesis reproduction is very common, and in many species males are rare.

Eg:Thrips

Chilli thrip-*Scirtothrips dorsais*

Tobacco thrip-*Thrips tabaci*

ORDER : HEMIPTERA (Hemi: half thickened, Ptera: Wings)

I.Sub-Order- Heteroptera

Head Prognathous.

Antennae fairly long with 4-5 segments

Compound eyes well developed, 2 ocelli may be present/absent

piercing and sucking type of mouth parts

Pronotum Large, while meso- and meta-notum are relatively small

Forewings are called as Hemielytra The hindwings are membranous and folded beneath the hemielytra at rest. wings are usually held flat over the body

Scent glands are present

Ovipositor with 3 pairs of valves

Eg:True bugs

Stink Bug-*Nezara viridula*

Red Cotton bug-*Dysdercus cingulatus*

II.Sub-Order- Homoptera

Head Hypognathous / opisthognathous

Antennae 3-10 segmented

Compound eyes well developed, 2 ocelli may be present/absent

piercing and sucking type of mouth parts

forewings are uniform texture entirely sclerotized with no membranous tip.

Wings are held over the body like a tent

Wax glands are present

Abdomen 11 segments; first 2 segments are modified for sound production

Eg:Leaf Hoppers, Plant hoppers , Aphids, Mealy bugs, Scale insects , Whiteflies

Rice green leaf hopper-*Nephotettix virescens*

Castor whitefly-*Trialeurodes ricini*

ORDER : LEPIDOPTERA (Lepido: Scales, Ptera: Wings, Scaly winged Insects)

Head relatively small

Large compound eyes, ocelli two in numbers

Siphoning type of Mouth parts in Adults(long coiled proboscis formed by the galea of maxilla, mandibles are absent). Chewing and biting type in larva.

Two pairs of membranous wings covered with scales giving beautiful color patterns. A large cell called distal cell is formed in the forewing due to the absence of stems of R4, R5 and the main stem of the median vein.

scales known as androconia occur on upper surface of the wings in males and serve as the outlets of odoriferous glands.

Larvae are called caterpillars (true legs in thorax and non-segmented legs in 3,4,5,6 and 10th Abdominal segments)

Pupae are usually adecticus, obtect

Adults Harmless, except citrus fruit sucking moths, and castor semilooper

Complete metamorphosis

Character	**Butterflies**	**Moths**
Size	Bigger	smaller
Antenna	Clubbed/clavate antenna	Bipectinate antenna
Wing	brightly colored wings.	dull colored wings.
Pupa	No cocoon-Chrysalis	Cocoon
Activity	Diurnal	Nocturnal or crepuscular

Ex: American bollworm/Gram caterpillar- *Helicoverpa armigera*

Tobacco caterpillar-*Spodoptera litura*

ORDER : COLEOPTERA (Coleo: Sheath, Ptera : Wings, Sheathed winged Insects)

Head is highly sclerotized, normal in beetles or prolongated into snout in weevils

Antennae usually 11 segmented

Mouth parts are Chewing and biting type

Prothorax large and freely movable. Mesothorax much reduced and fused with metathorax

Forewings are horny, leathery and not used for flight known as elytra, Hind wings are membranous

Tarsal segments are variable.

Larvae are known as grubs-oligopod or apodous

Pupa Exarate,

Metamorphosis Complete and complex

Eg:Mango stemborer-*Batocera rufomaculata*

Coccinellid beetle-*Coccinella septumpunctata*

ORDER: HYMENOPTERA ((Hymen: membrane, ptera: wings, membranous winged Insects)

Compound eyes are large- acuteness of vision is a characteristic feature of the order

Mouthparts either chewing type or chewing and lapping type.

Two pairs of membranous wings. Hind wings interlocked with fore wings by means of row of tiny hooks (hamuli) along the costal margin.

Trochanter 1 or 2 segmented.

First abdominal segment which is attached to thorax is called propodaeum. The 2nd abdominal segment is constricted called petiole or pedicel, while all the other abdominal segments are collectively called gaster.

Ovipositor is well developed and modified for sawing, boring and piercing.

Larvae of majority of advanced hymenoptera closely resemble maggots while primitive hymenoptera(eg :sawflies) resemble caterpillars

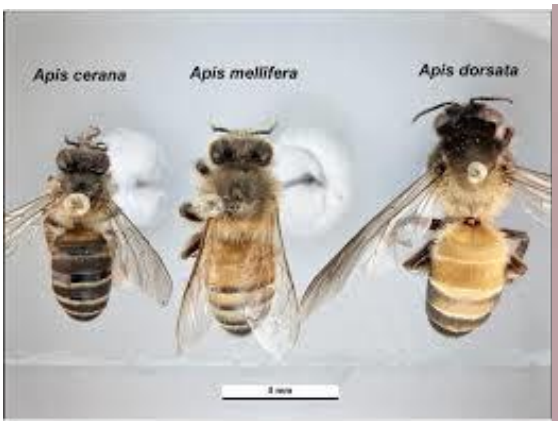
Exarate pupa and a cocoon is generally present.

Complete Metamorphosis

Eg:WASPS, ANTS, BEES, SAWFLIES

Indian honey bee-*Apis cerana indica*

Red ant-*Oecophylla smaragdina*



ORDER: DIPTERA (Di: two; ptera: wings; two winged insects*)*

Head Prominent and small neck

Compound Eyes Large, Ptilinum or frontal sac is present

Mostly 3 segmented Antenna ,aristate in flies, plumose & pilose in mosquitoes

Sucking type of Mouth parts. In mosquitoes-piercing and sucking type, House flies-sponging & lapping type

Mesothorax Large. Prothoracic and Meta thoracic segments are small

Only front pair of wings present. Hind pair modified into halteres which act as balancers

Tarsus usually 5 segmented, pulvilli and an empodium usually present

Metamorphosis Complete

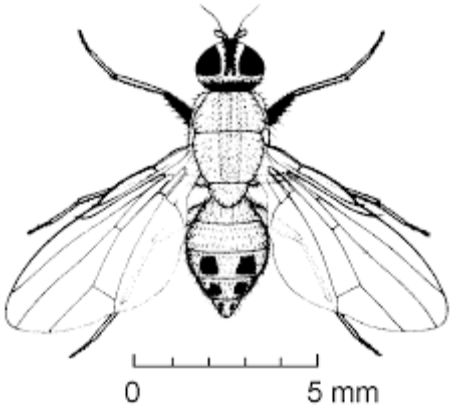
Larva Eruciform, apodous, known as maggots,

coarctate Pupa enclosed in puparium

Eg: TRUE FLIES, MOSQUITOES, MIDGES

Rice gall midge-*Orseolia oryzae*

Jowar shootfly-*Atherigona soccata*



Cockroach (*Periplaneta americana*) - External Characters

Periplaneta americana: linneaus (1758) named as blatta Americana. Barmyster (1838) proposed the genus periplaneta. It is present in all over world. They are omnivorous and scavenger insects

Classification:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Blattodea

Family: Blattidae

Genus: *Periplaneta*

Species: ***P. americana***

The cockroach is divided into three sections; the body is flattened and broadly oval, with a shield-like pronotum covering its head. A pronotum is a plate-like structure that covers all or part of the dorsal surface of the thorax of certain insects. They also have chewing mouth parts, long, segmented antennae, and leathery fore wings with delicate hind wings. The third section of the cockroach is the abdomen.

1. Segmentation:

The body shows three regions or tagmata that includes the head**,** thorax and abdomen. Embryologically, the body is formed of 20 segments. First 6 segments formed the head, next 3 segments formed the thorax and remaining 11 segments formed the abdomen. Only 10 segments are retained in the abdomen of the adult, in which only the first 7 are distinct in females, and the first 9 are distinct in males. The anus is located at the end of the abdomen and it is a 10^{th} modified segment.

2. Head:

a. Head Capsule:

Cockroach head is triangular and is formed by a fusion of 6 chitinous or sclerite plates.The head is bent downwards in a **hypognathous position**, i.e., at an angle of 90^0 from the long axis of the body. All sclerites of the head fuse to form a head capsule. The cockroach posses the following sclerites.

1. Labrum : It is small sclerite that forms the upper lip of the mouth cavity. It is freely attached or suspended from the lower margin of the clypeus

2.Clypeus: It is situated above the labrum and is divided in to anterior ante-clypeus and posterior post-clypeus.

3. Frons : It is the facial part of the insect consisting of median ocellus.

4. Vertex : It is the top portion of the head behind the frons or the area between the two compound eyes.

5. Epicraniun : It is the upper part of the head extending from vertex to occipital suture.

6. Occiput : It is an inverted "U" shaped structure representing the area between the epicranium and post occiput.

7. Post occiput : It is the extreme posterior part of the insect head that remains before the neck region.
8. Gena : It is the area extending from below the compound eyes to just above the mandibles
9. Occular sclerites : These are cuticular ring like structures present around each compound eye
10. Antennal sclerites : These form the basis for the antennae and present around the scape which are well developed in Plecoptera (stone flies)

All the above sclerites gets attached through cuticular ridges or sutures to provide the attachment for the muscles inside.

b. Appendages of Head:

The cockroarch head consist the following appendages

S.No	Segment	Appendages
1	Pre antennary segment	No appendages
2	Antennary segment	Antennae
3	Intercalary segment	No appendages
4	Mandibular segment	Mandibles
5	First maxillary segment	Maxillae
6	Secondmaxillary/labial segment	Labium

A pair of antennae arises from the membranous sockets, i.e. antennal sockets that present in front of the eyes can move in all directions, and they are very sensitive. Each antenna is formed of 3 segments *i.e.* scape (largest), pedicel (narrow and elongated) and flagellum (the long and slender part which has many jointed parts, bearing tactile sensory setae). These antennae act as sense organs of touch and smell.

c. Mouthparts:

cockroach is having the 'biting and chewing' type of mouthparts. These mouth parts consists of labrum, a pair of mandibles, a pair of first maxillae, labium or pair of second maxillae and hypopharynx.

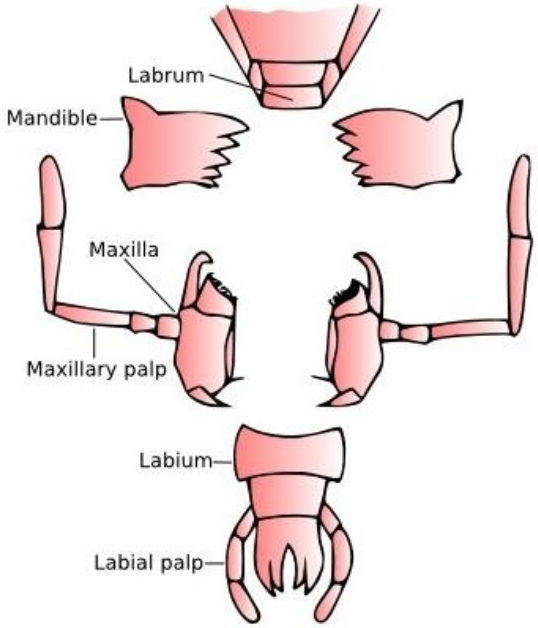
a. Labrum: It is a small sclerite that forms the upper lip of the mouth cavity. It protects the mandibles and helps in closing of the mouth cavity and guide the food in to mouth. On its inner surface, labrum consists of lobe like structure called labrum – epipharynx which is well developed. Labrum hangs down from the clypeus through a clypeo-labral suture.
b. Mandibles: These are the paired, unsegmented, strongest and sclerotized structures called 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.

c. Maxillae: These are paired 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.

d. 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 Near the base of pre mentum, on either side lobe like ‘palpiger’ is present which bears labial palps. Prementum has four terminal lobes. The median pair is ‘glossae’ and outer ‘paraglossae’ together called ligula that function mainly as gustatory sense organs.

e. Hypopharynx : It is a tongue like structure situated between labrum and labium and ducts of salivary glands open on or near its base.



3. Neck:

The Neck grease is a short slender feature that attacks to the head. The base is supported by a pair of posterior and two greiva plaques in the abdomen the muscles of the neck help the head. To rotate all the sides

4. **Thorax :** It is the middle part of the body consisting of three segments each possessing a pair of legs and a pair of wings on meso and meta thoracic segment. Meso and meta thoracic segments together known as **pterothorax**. Sclerite of dorsal region of thorax is **tergum or notum** in case of winged insect, ventral region is called **sternum** and lateral region is called **pleuron**.

a. Cockroach Leg : All the three thoracic segments of an insect possess a pair of legs as locomotory organs giving the name hexapods and the class insecta as **hexapoda**. Insect leg mainly consists of 5 parts viz. Coxa , Trochanter, Femur , Tibia and. Tarsus.

1.**Coxa**: It is the functional basal segment and it is rigidly fixed to thorax or weakly articulated.

2. **Trochanter** : It is very small and the **second** segment. It is articulated with coxa and more or less fixed to femur.

3. **Femur** : It is the largest, strongest segment and is articulated with the tibia..

4. **Tibia** : It is equal or more than the length of the femur, articulated with tarsus.

5.**Tarsus** : it is the largest segment of the leg and usually devided into sub segments tarsomeres. The number of tarsomeres vary from 1-5 and are movable one on the other. Among the 5 segments, 1st segment is large, big or broad in size known as basitarsus. The tarsus at it's 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 "**aroleum**" and if it is bristle like structure, it is called "**empodium**".

b) Wing:

These are two pairs; the first pair is mesothoracic – attached with the tergum of the mesothorax and the second pair is metathoracic – connected with the tergum of the metathorax. Mesothoracic Wings are also called wing-covers or tegmina or elytra. These are thick, large, leathery, dark coloured opaque in structure which are narrow at the distal end. They are not used for flight but cover and protect metathoracic wings. Metathoracic wings are very delicate, transparent, thin and membranous with a broad terminal end. These wings are used for flight, but in the resting position, they lie folded below the tegmina.

5.Abdomen:

There are 10 tergites in both males and females. Ventrally, the abdomen has only 9 sternites in males and seven in females. In females, the last, i.e., 7th sternite, is larger and boat-

shaped. Together with the indistinct 8th and sternites, it forms a chamber-like structure called gynatrium. The posterior part of gynatrium is called the oothecal chamber because ootheca is formed in it. Behind this chamber, the 7^{th} sternite bifurcates into two prominent oval plates called gynovalvularplates or apical lobes. These Abdominal segments lack locomotory appendages. At the posterior end, however, there are certain small structures associated with the gonopore. These are different in both sexes. It includes anal cerci, anal styles and gonapophyses. Anal Cerci are paired and jointed outgrowths that arise from the 10^{th} tergum. These are sensitive to sound and other vibrations. Anal Styles are also paired but thin and small unjointed outgrowths that projects backwardly from the sides of the 9^{th} sternum of male cockroach only and these are also sensitive to touch. Gonapophyses are present in both males and females; the genital aperture is surrounded by some sclerites called gonapophyses. In males, they arise from the 9^{th} segment and form the external genitalia or external genital organs to help the insect in the copulation process. In female cockroaches, gonapophysis belongs to the 8^{th} and 9^{th} abdominal segments to form an ovipositor. The latter is used to guide the fertilized eggs towards the oothecal chamber for ootheca formation.

Mouth parts of insects

These are the organs primarily concerned with the uptake of food. Typical mouthpart of an insect consists of the following parts. (i) Labrum (upper lip) (ii) A pair of mandibles (iii) A pair of maxillae (iv) Labium (lower lip) (v) Hypopharynx (tongue)

The mouth parts of insects can be basically grouped in to following types based on the type of food and method of feeding.

S.No	Type of Mouth parts	Examples
I	Biting and chewing type	Grasshoppers, cockroaches
II	Sucking type / Haustellate type	
	1. Piercing and sucking type	Plant Bugs and Mosquitoes
	2. Rasping and sucking type	Thrips
	3. Sponging type	Adult Houseflies
	4. Chewing and lapping type	Honey bees
	5. Siphoning type	Butterflies and moths
III	Other types	
	1. Mask type	Naids of Dragonflies
	2. Degenerate type	Maggots of Diptera

I. Biting and chewing type of Mouth Parts:

This type is considered as primitive and found in Orthoptera, Isoptera and Coleoptera, larvae of Lepidoptera and Neuroptera etc.

The mouth parts include following parts

a. **Labrum :** It is a small sclerite that forms the upper lip of the mouth cavity. It protects the mandibles and helps in closing of the mouth cavity and guide the food in to mouth. On its inner surface, labrum consists of lobe like structure called labrum – epipharynx which is well developed in Hymenoptera. Labrum hangs down from the **clypeus through a clypeo-labral suture.**

b. **Mandibles:** These are the paired, unsegmented, strongest and sclerotized structures called 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.

c. **Maxillae:** These are paired 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.

d. **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 Near the base of pre mentum, on either side lobe like 'palpiger' is present which bears labial palps. Prementum has four terminal lobes. The median pair is 'glossae' and outer 'paraglossae' together called ligula that function mainly as gustatory sense organs.

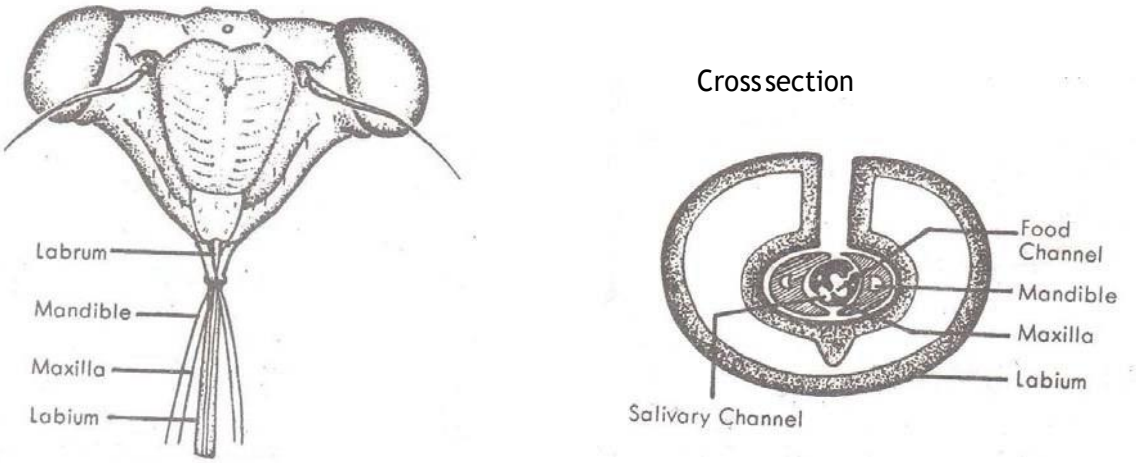
e. **Hypopharynx:** It is a tongue like structure situated between labrum and labium and ducts of salivary glands open on or near its base.

II. Sucking type of Mouth Parts:

This is considered as advanced type where the oral appendages get modified differently.

1. Piercing and sucking type e.g.: plant bugs, mosquitoes

They are mainly adopted for piercing the tissues and sucking either plant sap or the nectar or blood from the host. Mouth parts are represented by rostrum/beak which is a modification of Labium . It acts as a pouch for protecting the mandibular and maxillary stylets. Mandibles and maxillae are modified in to sharp needle like stylets. The mandibular stylets form the outer pair and possess serrated margins at their tip. The maxillary stylets forms the inner pair having smooth curved tips and combine 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. The hypopharynx is modified in to a pharyngeal pump and is situated at the tip of the food channel. Llabrum is modified into a small flap like structure at the base of rostrum. Insects with these type of mouthparts pierce the tissues with the mandibular stylets and suck the contents (sap/ blood / nectar) through cibarium with the action of pharyngeal and cibarial muscles.



Piercing and sucking type

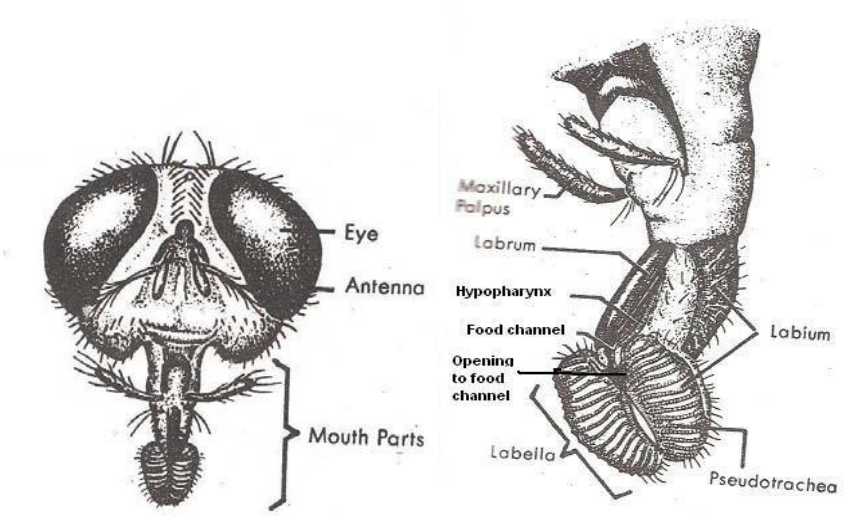
2. Rasping and sucking type of Mouth Parts : e.g. thrips

These are called asymmetrical type , since right mandible is rudimentary . They are in between the biting – chewing type; and piercing - sucking type. Mouth parts are represented by mouth cone which is formed by the labrum and clypeus above and labium below. Within the

beak/mouth cone hypopharynx and left mandible is present. Right mandible is absent where as the left mandible is modified in to a mandibular stylet. Maxillae are modified in to maxillary stylets which are mainly useful for sucking the sap that is released outside due to the rasping of tissues by the left mandible.

3. Sponging type of Mouth Parts: eg: housefly

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. Mandibles are absent (reduced) maxillary palpi are 1-3 segmented. During feeding, the proboscis is pressed over the food material. The pseudo trachea gets filled with the food material by the capillary action and is sucked up from the central point in to the oesophagus.

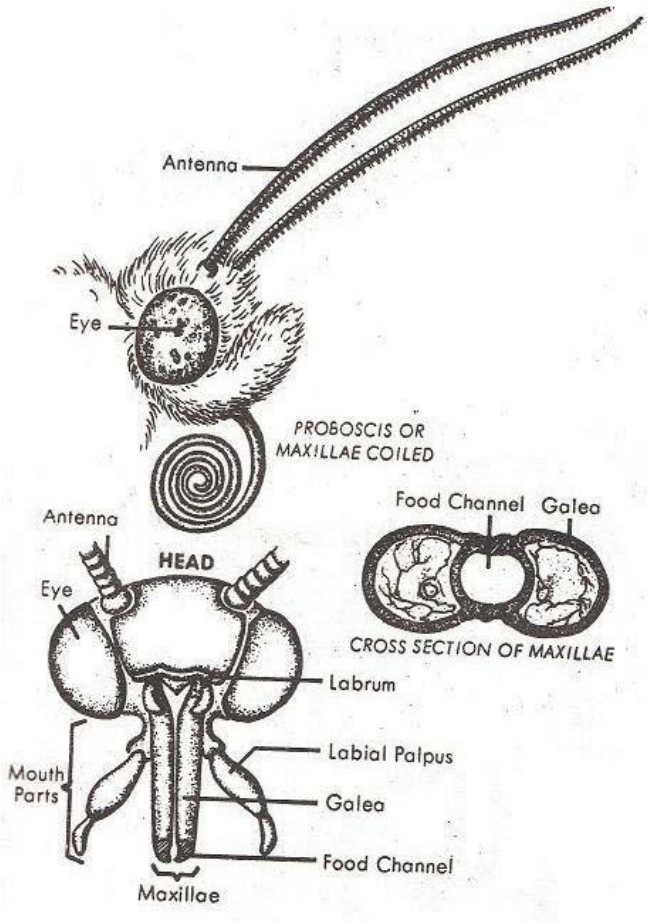


Sponging type of Mouth Parts

5. Siphoning type of Mouth parts : eg: butterflies

These are specially modified for taking nectar from the flowers. The galea of maxilla form into a slender, hollow, tubular structure which remains as an elongated coiled proboscis underneath the head during non feeding. Mandibles are totally absent. The labrum and maxilla palpi are reduced. Labium is modified in to a small basal plate possessing a three segmented

labial palpi. The food channel is formed by the fusion of both the galea. The nectar will be sucked from the flowers through muscular action.



Siphoning type of mouthparts

Damage symptoms of different Pests and their different kinds of losses

1. Root Grub/ feeders: Larvae feed on roots/root nodules resulting in stunted growth/poor tillering /drying of plants in isolated patches.

   Eg: Rice root weevil, White Grub and Banana Rhizome weevil

2. Stem borers: Larvae enter in to the stem and feed on internal contents. As a result, damaged part is cut off from the main plant and affected part wilts, dries up and exhibits symptoms like dead heart during vegetative stage and white ear during reproductive stage in case of paddy due to larval feeding inside the stem and they can be easily pulled out and bunchy top in case of sugarcane (destruction of growing point results in the activation of side buds, just below the growing point and produces a bunch of side shoots called bunchy top).

   Eg: Stem borers of paddy, millets, sugarcane and brinjal

3. Shoot borers: Larvae attack tender shoots and bore inside during vegetative stage of crop growth and cause wilting, drooping of terminal plant parts which later dry up.

   Eg: Shoot borers of brinjal, bhendi, cotton and castor

4. Defoliators/Skeletonizers: Larvae feed on the leaves completely leaving only midrib/veins or scrape the chlorophyll content of leaves or cause numerous holes.

   Eg: Castor semilooper, ash weevils, tobacco caterpillar, epilachna beetle on brinjal.

5. Leaf miners: Larvae mine leaves/leaflets between the epidermal layers and feed on greenish matter, resulting in the appearance of translucent mines/white patches/zig-zag galleries

   Eg: leaf miners of citrus, Cashew and Rice hispa.

6. Leaf Webbers: Larvae webs leaves/leaflets by means of silken threads and feed on the chlorophyll content by remaining within the web. Often faecal pellets/frass are found within the web.

Eg: Leaf Webbers on gingelly, groundnut, sapota, mango and cashew shoot and blossom webber.

7. Leaf folders: Larvae fold leaves from tip to base /longitudinally /margin to margin there by giving appearance of a fold/roll and scrape the chlorophyll content remaining within the fold.

   Eg: rice leaf folder, Cotton leaf roller (Bell shaped rolling of leaf).

8. Galls: Larvae feeding inside the stem/tiller/leaf/flower bud stimulates excessive growth of cells at the affected portion and distorts normal growth. It results in malformation of plant parts, exhibiting gall formation and gives shelter for the pest.

   Eg: Rice gall midge

9. Fruit borers: Larvae enter into the tender fruits and feed on fresh matter/pulp and plug the larval burrow with excreta.

   Eg: Fruit borer of brinjal/bhendi/tomato, mango stone weevil, Cashew apple and nut borer.

10. Bark borers: Larvae remain in a small tunnel at the axils of branches, under the bark constructing galleries of frassy web on the stem and near bark/angles of branches and move about, conceal inside the silken gallery and feed on the bark by scraping.

    Eg: Bark eating caterpillars of citrus, mango, guava, casuarina, jack etc.

11. Tree borers: Larvae bore deep into the tree trunk, make the tunnels in zig-zag manner and feed on inner tissues, arresting translocation of sap to top portions of tree, there by the tree exhibits symptoms like yellowing, withering of leaves, drying of twigs or complete drying of tree. Sometimes, gummy material oozes from the affected portion on the tree trunk. Eg: Tree borers of mango, cashew, coconut red palm weevil etc

12. Seed feeders (Stored grain pests): Grubs/larvae and adults feed on stored seeds either internally /externally by webbing the food particles.

    Eg: Rice weevil, red flour beetle, rice moth etc.,

13. Boll worms: During the reproductive stage of the crop larvae enter in to the pods, capsules and feed on the seeds/lint exhibiting symptoms like webbed condition of pods /bolls or web few pods/capsules with frass and excreta or holes of different sizes and shapes/damaged tissues (chilli/lint on Cotton).

    Eg: Bollworms in cotton.

14. Sucking Pests: Some pest in different stages attacks different parts of plants and sucks the sap and cause the damage to the plants

    Types of sucking pest:

A. SEEDS: Nymphs and adults attacks the developing seeds and sucks the sap from seeds and seeds will loss their vigour.

    Eg: paddy and jowar sucking pest**.**

B. Tender parts of plants/leaves: Both nymphs and adults suck sap from base of the plant /leaves /tender terminal plant parts and thereby affect the vigour and growth of plants. In case of severe infestation, sooty mould develops on plant parts covered with honey dew excreted by insects while feeding. Different insects exhibit different symptoms.

Damage Symptoms with Examples:

a) Sooty mould – Rice Brown plant hopper

b) Curling of leaf margins/with necrotic patches Starting from leaf margin –Cotton leaf hopper

c) Upward Curling- Chilli thrips

d) Downward Curling: Chilli Mite.

e) Uniform yellowing of leaves from mid half-Paddy leaf hopper

f) Reduced vigour/sooty mold, square/boll drop -White flies on cotton

g) Yellowing /reduced/stunted growth/sooty mould -Aphids

h) Shriveled/chaffy and discolored grains/sooty mould on grain-Sorghum ear head bug/rice gundhy bug

i).Mottled appearance with yellow patches on infested leaves/sooty mould/undeveloped grains on infested ear heads -Sorghum aphids

j) Holes on fruits / covered by excreta - fruit Flys

k) Decomposing of Fruits / Brown marks on fruits- Fruits sucking pest.

INTEGRATED PEST MANAGEMENT (IPM)

Modern concept of pest management is based on ecological principles and integration of different control tactics into a pest management system

Integrated control was defined by Stern et al., (1959) as applied pest control which combines and integrates the biological and chemical control. Later the concept of pest management has gained importance.

In 1972 the term IPM was accepted by CEQ (Council of Environmental Quality) where IPM includes

I - Integration that is harmonious use of multiple methods to control the impact of single pest as well as multiple pests.

P - Pest- any organism that is detrimental to humans including vertebrates and invertebrate or weed or pathogens.

M - Management refers to a set of decisions or rules based on ecological principles, economic and social consideration.

According to FAO (1967), IPM was defined as "a pest management system in the context of associated environment and population dynamics in pest species. It utilizes all suitable techniques and methods in as compatible manner as possible and maintains the pest population at levels below those cause economic injury.

OR

Protective management of the noxious pest in which all available techniques should be evaluated and consolidated to manage pest population so that economic damage is avoided and adverse side effects on the environment are minimized (Gieir and Clark, 1961).

IPM CONTROL METHODS:

In **IPM** There are two types of control methods

1. NATURAL CONTROL:

(a). Climatic conditions :

Climatic conditions are very important for natural control of pests. Are effectively.Rains,the resulting soft soil are required for some types of caterpillar for the transition to the pupal stage and for their adults to come out of soil. however, heavy rains can reduce the intensity of sucking pest like thrips&aphid. Similarly, if the temperature &humidity is not favourable in the air pest infestation will reduce.

(b). Natural enemies :

Each insect has many natural enemies in nature. They can feed on insects and control them. They are called as predators , parasites. Some types of viruses, bacteria and fungi, can infect insects and cause infections. Therefore , the insect progeny is avoided in a natural way.

(c). Natural barriers :

Geological conditions like hills and oceans arrest the spread of insects. Soil type can also prevent the development of insects. example, rootgrubs are more common in light soils and red soils, but can not develop in black clay soils.

2. Artificial control :

Any factor that is capable of making life hard for the insect that will repel or interfere with its feeding, mating, reproduction or dispersal can be taken as a method of insect control in its broadest application.

They can be divided into two major categories

1. Natural control
2. Applied control

Under natural control the population is kept under check by the environmental resistance without the interference of man. The control measures adopted by human agency are called applied or artificial control measures.

Artificial control methods are divided into 6 types given below

1. Cultural methods
2. Mechanical methods
3. Physical methods
4. Biological methods
5. Legislative methods
6. Chemical methods

Cultural Methods of Pest Control:

The manipulation of cultural practices at an appropriate time for reducing or avoiding pest damage to crops is known as cultural control.

The cultural practices make the environment less favorable for the pests and or more favorable for its natural enemies. It is the cheapest of all methods.

1. **Proper preparatory cultivation:** Several insects which live or hide in the soil get exposed to sun as well as predators like birds etc due to Proper preparatory cultivation. Eg.Pupae of moths, roots grubs etc.
2. **Clean cultivation:** Removal of weeds which act as alternate hosts.

Eg. Paddy gall fly Orseolia oryzae breeds on grasses such as Panicum sp. Cynodon dactylon etc.

Fruit sucking moth larvae Eudocima ancilla on weeds of Menispermaceae

3. **Systematic cutting and removal of infested parts:** Keeps down subsequent infestation.

Eg. i. Removal of sugarcane shoots affected by borers

ii. Cutting and removal of infested parts of brinjal attacked by *Leucinodes orbonalis*

iii. Pruning of dried branches of citrus eliminates scales and stem borer.

iv. Clipping of tips of rice seedlings before transplanting eliminate the egg masses of stem borer.

v. Clipping of leaf lets in coconut reduces the black headed caterpillar

4. **Changes in the system of cultivation:** Change of banana from perennial to annual crop reduced the infestation of banana rhizome weevil Cosmopolitus sordidus in addition to giving increased yields.

Eg: Avoiding ratoon redgram crop during offseason helps in reducing the carry over of pod fly *Melangromyza obtusa* and eriophyid mite *Aceria cajani*

4. **Crop rotation:** Crop rotation is most effective practice against pests that have a narrow host range and dispersal capacity. Lady's finger followed by cotton will suffer from increased infestation of pests. Hence if a non-host crop is grown after a host crop, it reduces the pest population.

Eg. i. Cereals followed by pulses.

ii. Cotton should be rotated with non hosts like ragi, maize, rice to minimize the incidence insect pests.

iii. Groundnut with non leguminous crops is recommended for minimizing the leaf miner incidence.

5. **Mixed cropping:** Intended for getting some return when one crop is attacked, the other escapes. Eg. Garden peas and sunhemp
6. **Growing resistant varieties:** certain varieties resists pest attack .

Eg: GEB-24 and MTU–5249 resistance to paddy BPH, Surekha variety to gall

midge, TKM -6 and Ratna for stem borer.

7. **Adjusting planting or sowing or harvesting times to avoid certain pests :** The manipulation of planting time helps to minimize pest damage by producing asynchrony between host plants and the pest or synchronizing insect pests with their natural enemies.

Eg. i. Early planting of paddy in *kharif* and late planting in *rabi* minimize the infestation of rice stem borer.

ii. Delaying the sowing of sun hemp till the onset of South West monsoon avoids sun hemp hairy caterpillar (*Utethesia lotrix*) attack.

iii. Early sown sorghum in *kharif* reduces the infestation of shoot fly

iv. Timely and synchronous planting has been found to reduce bollworm damage in cotton and stem borer damage in sugarcane.

8. **Trap cropping:** Growing of susceptible or preferred plants by important pests near a major crop to act as a trap and later it is destroyed or treated with insecticides. Trap crop may also attract natural enemies thus enhancing natural control.

Eg: Trap crop	Main crop	Insect pest
Castor	Chillies	Tobacco caterpillar *Spodoptera litura*
Tomato	Citrus	Fruit sucking moths *Otheris spp*
Marigold	Cotton	American bollworm (*Helicoverpa armigera)*

9. **Trimming field buds:** Grasshopper eggs, which are laid in field bunds, are destroyed by trimming field bunds.
10. **Alley ways:** Formation of alley ways for every 2 m in rice field reduces the BPH

Mechanical Methods of Pest Control

Reduction or suppression of insect pest population by means of manual devices or labour.

1. **Hand picking and collection with hand nets and killing insects:** Handpicking is most ancient method which can prove fairly effective under certain conditions. Egg masses, larvae or nymphs and sluggish adults can be handpicked and destroyed.

   Eg: 1. Egg masses of paddy stem borer and groundnut hairy caterpillar.

   2. Early stages of *Spodoptera litura*

2. **Provision of preventive barriers:** Digging of 30 -60 cm wide and 60 cm deep trenches or erecting 30 cm height tin sheets barriers around the fields is useful against pests like hairy caterpillars.

3. **Bagging / wrapping** of pomegranate and mango fruits in paper bags avoids the infestation of pomegranate butterfly and mango fruit fly
4. Tin bands are fixed over coconut palms to prevent damage by rats.
5. Extraction of adult Rhinoceros beetle (Oryctes rhinoceros) from the crown of coconut trees using an arrow headed rod/hook.
6. Use of an alkathene band around the tree trunks of mango to check the migration of first instar nymphs of mealybugs and red ants.
7. Systematic shaking of root grub adults harbored trees during evening hours to dislodge and destroy by dumping in fire.
8. Shaking of redgram plants to collect and destroy later instars of *Helicoverpa armigera*
9. **Light traps** are arranged for attracting the insects, which are trapped by keeping water or oil in a container or a killing bottle below the light trap. Light traps are useful for monitoring the population of important insect pests in an area. Eg: Most of the moths and beetles.
10. **Flame thrower** is a compressed air sprayer with kerosene oil for producing flames. There is a lance, which is fitted with a burner. When the burner is heated, the kerosene oil is released and it turns into flames. Used for burning locust populations, congregation of caterpillars, patches of weeds etc.

Physical Methods of Pest Control

Use of certain physical forces to minimize the pests

1. **A material called drie-die,** consist of highly porous, finely divided silica gel which when applied

abrades the insect cuticle thus encouraging loss of moisture resulting in death. It is mainly used against stored product pests.

2. **Kaolinic clay** after successive activation with acid and heat can be mixed with stored grain. The

clay minerals absorb the lipoid layer of the insect cuticle by which the insects lose their body moisture and die due to desiccation.

3. Artificial heating and cooling of stored products will prevent insect damage. Usually high temperatures are more effective than low temperatures.

4. Stored products can be exposed to 55°C for 3 hours to avoid stored product pests

5. **Vapour Heat Treatment (VHT):** Heated air is saturated with water (>RH 90%) for specified period of 6 to 8 hours for raising pulp temperature to 43-44.5°C in case of mango against fruit flies.

Legislative / Legal / Regulatory Methods of Pest Control :

`In early days there were no restrictions on the transport of plants and animals from one country to another since the danger involved in it is not realized, which resulted in introduction of pests form one country to another. In many countries many of the dangerous pests have frequently been found to be foreign pests and they inflict greater damage than the indigenous ones.

Plant quarantine is defined as the legal enforcement of the measures aimed to prevent pests from spreading or to prevent them to multiply further in case they have already gained entry and have established in new restricted areas.

The importance of imposing restrictions on the movement of pest-infested plants or plant materials from one country to another was realized when the grapevine phylloxera got introduced into France from America by about 1860 and the San jose scale spread into the USA in the later part of the 18th century and caused severe damage.

The first Quarantine Act in USA came into operation in 1905. While Govt. of India passed an Act in 1914 entitled “Destructive Insect and Pests Act of 1914” to prevent the introduction of any insect, fungus or other pests into our country. This was later supplemented by a more comprehensive act in 1917.

The legislative measures in force now in different countries can be grouped into five classes. They are,

1. Legislation to prevent the introduction of new pests and weeds etc from foreign countries (International quarantine)
2. Legislation to prevent the spread of already established pests, diseases and weeds from one part of the country to another (Domestic quarantine)
3. Legislation to enforce upon the farmers regarding the application of effective control measures to prevent damage by already established pests.
4. Legislation to prevent the adulteration and misbranding of insecticides
5. Legislation to regulate the activities of men engaged in pest control operations and application of hazardous insecticides

1) Legislation to prevent the introduction of foreign pests:

To prevent the entry of foreign pests all countries have restrictions. They enforce quarantine laws. The imported plant material has to be thoroughly examined at the ports of entry. The Directorate of Plant Protection Quarantine and Storage (DPPQS) was established in Faridababd in 1946. Prior to which customs authorities did the enforcement of quarantine laws. From 1949, DPPQS deals with the commercial import of consignments of grains, plants and plant products for consumption through its network of 35 Plant Quarantine Stations spread across the country including seaports, airports and land frontiers. These operate under the provisions made under the "Destructive Insect and Pests Act of 1914". The importation of plant material from foreign countries has to be done only through any of these ports. The consignment should also be accompanied with the certificate issued by the Officers of agriculture department of the exporting country so as confirm that the consignments are pest free. This certificate is called as 'Phytosanitory certificate'.

2) Legislation to prevent the spread of already established pests:

The Destructive Insect and Pests Act, 1914, have empowered the states to enact such laws as are necessary to prevent the spread of dangerous insects within their jurisdiction. The Madras Government enacted the Madras Agricultural Pests and Diseases act in 1919 and was the first state to enact such laws in our country. This act was passed to prevent the spread of pests or diseases or weeds form one part of the state to another.

3) Legislation to enforce the application of effective control measures to prevent the damage by established pests.

Under the state pests act, the farmers were asked to remove and destroy coconut leaf lets infested with black headed caterpillar around Mangalore in 1923 and in 1927 in Krishna and Guntur districts.

4) Legislation to prevent the adulteration and misbranding of the insecticides

To avoid malpractices and supply of substandard chemicals and pesticide products the Insecticide Act, 1968 has been enforced on 2nd September, 1968 by the Government of India to

regulate the import, manufacture, sale, transport and distribution and use of insecticides. The insecticide rules of 1971 framed under the Insecticides Act 1968 had come in to force in 1971.

5) Legislation to regulate the activities of men engaged in pest control operations: They have to take certain precautionary measures to avoid pesticide poisoning and undergo regular medical checkup.

BIOLOGICAL CONTROL

The successful management of a pest by means of another living organism (parasitoids, predators and pathogens) that is encouraged and disseminated by man is called biological control.

Parasite:A parasite is an organism which is usually much smaller than its host and a single individual usually doesn't kill the host. Parasite may complete their entire life cycle (eg. Lice) or may involve several host species. (or)

Parasite is one, which attaches itself to the body of the other living organism either externally or internally and gets nourishment and shelter at least for a shorter period if not for the entire life cycle. The organism, which is attacked by the parasites, is called hosts.

Control of cottony cushion scale, *Icerya purchasi* on fruit trees by its predatory vedalia beetle, *Rodolia cardinalis* in Nilgiris. The predator was imported from California in 1929 and from Egypt in 1930 and multiplied in the laboratory and released. Within one year the pest was effectively checked.

Apple woolly aphis, *Eriosoma lanigerum* in Coonor area by *Aphelinus mali* (parasitoid).

Control of shoot borers of sugarcane, cotton bollworms, stem borers of paddy and sorghum with the egg parasitoid, *Trichogramma australicum* @ 50,000/ha/week for 4-5 weeks from one month after planting

Predators: A predator is one which catches and devours smaller or more helpless creatures by killing them in getting a single meal. It is a free living organism throughout its life, normally larger than prey and requires more than one prey to develop.

MICROBIAL CONTROL

Microbial control refers to the exploitation of disease causing organism to reduce the population of insect pest below the damaging levels.

1. **Bacteria :** More than 100 pathogenic bacteria were recorded of which i. *Bacillus thuringiensis* (*B.t.*) is important. *B.t.* known as a bacterial insecticide is now being using by farmers mostly on lepidopterous larvae. It can infect more than 150 species of insects. The entry of the bacteria is by ingestion of the bacteria, which infect the mid gut epithelia cells and enter the haemolymph to sporulate and cause septicemia.
2. **Viruses**: NPV : About 300 isolates of Nuclear polyhedral virus have been isolated from the order Lepidoptera. Among these viruses Baculoviruses (Baculoviridae) are successful in IPM. The NPV is observed to affect 200 species of insects by ingestion. The virus infected dead larvae hanging upside down from plant parts (Tree top disease). The cuticle becomes fragile, rupturing easily when touched, discharges liquefied body fluids. NPV multiplies in insect body wall, trachea, fat bodies and blood cells. The polyhedra are seen in nuclei. The polyhedral bodies enlarge in size destroying the host nuclei to get released into the insect body cavity.

3. Fungi: The fungal disease occurrence in insects is commonly called as mycosis. Most of the entomopathogenic fungi infect the host through the cuticle. Most of the entomopathogenic fungi infect their hosts by penetration of the cuticle by producing cuticle digesting enzymes (Proteases , lipases chitinases).The typical symptoms of fungal infection are, mummified body of insects and it does not disintegrate in water and body covered with filamentous mycelium.

Important species are *Metarhizium, Beauveria*, *Nomuraea* and *Verticillium.*

CHEMICAL CONTROL

Control of insects with chemicals is known is chemical control. The term pesticide is used to those chemicals which kill pests and these pests may include insects, animals, mites, diseases or even weeds. Chemicals which kill insects are called as insecticides.

Insecticide may be defined as a substance or mixture of substances intended to kill, repel or otherwise prevent the insects. Similarly pesticides include nematicides – which kill nematodes, miticides or Acaricides which kill mites, Rodenticides – which kill rats, weedicides- that kill weeds,Fungicides- that kill fungus etc.

Importance of chemical control:

Insecticides are the most powerful tools available for use in pest management. They are highly effective, rapid in curative action, adoptable to most situations, flexible in meeting changing agronomic and ecological conditions and economical.

Insecticides are the only tool for pest management that is reliable for emergency action when insect pest populations approach or exceed the economic threshold. A major technique such as the use of pesticides can be the very heart and core of integrated systems. Chemical pesticides will continue to be essential in the pest management programmes.

There are many pest problems for which the use of chemicals provides the only acceptable solution. Contrary to the thinking of some people, the use of pesticides for pest control is not an ecological sin. When their use made on sound ecological principles, chemical pesticides provide dependable and valuable tools for the biologist. Their use is indispensable to modern society.

Storing and usage of insecticides

1. The labeled insecticide bottles should be stored in a cool, dry room under lock and key so that it is not accessible to children.
2. Before preparation of spray fluid read the information on the label and mix the recommended dosage of insecticides with water.
3. Under no circumstances should the insecticide spray fluid be mixed with hands.
4. Care should be taken to avoid spilling of spray fluid during its preparation or while pouring it into sprayer.

5. proper clothes and gloves should be worn while spraying the insecticides. Make sure that no part of the body is exposed to insecticide.
6. Insecticides should not be sprayed or dusted against the wind.
7. Eating, smoking beedi, cigarettes and chewing tobacco should be avoided while spraying insecticides
8. Regular inspection of spraying equipment and repairs if any should be carried out. Sprayer nozzles should not blown with mouth.
9. Neither cleaning the sprayer nor throwing the left over sprayfluid should be done in ponds or canals or it will contaminate the water.
10. Destroy the empty insecticide bottles immediately or bury in the ground.
11. Take a clean bath immediately after spraying to avoid pesticide residues.
12. Inform the farmers near the sprayed field to prevent their cattle entering the field.

Techniques in the effective use of pesticides:

1. Hand sprayer should be used in the early stage of the crop to avoid wastage of sprayfluid whereas power sprayer should be used during the later stages when the crop canopy is more.
2. Sucking insects like thrips and mites suck sap from lower leaf surface in crops like chilli, cotton, vegetables, etc., and to control them contact insecticides should be sprayed by directing the nozzle such that the undersurface of the leaves is fully covered with sprayfluid.
3. Care should be taken such that the sprayfluid drops cover both the surfaces of leaves and on insects attacking flowers and fruits in bushy plants. selection of appropriate nozzle is very important.
4. Uniform coverage of the crop and wide area coverage with the spray fluid depends on the selection of the nozzle.
5. In crops with narrow leaves sandovit or Teepol should be mixed in the sprayfluid so that it adheres to the leaves.
6. To control pupal stages of insects in the soil, dusts like carbaryl should be mixed in the soil.
7. two types of insecticides should not be mixed and sprayed. chemical reactions may occur in the mixture and it becomes ineffective. In this regard, follow the advice of the experts in the field of agriculture.
8. In order to increase the utilization efficacy of the insecticide it should be sprayed as far as possible in the evening when the stomata will be open.
9. Spraying in the evening will be more effective on nocturnal insects while those sprayed in the afternoon lose efficacy in the form of vapors.
10. Avoid contact of sprayfluid with body by wearing full clothing, mask, gloves and eyeglasses.
11. Water added to insecticide should be clean, free of mud, rotten leaves and salt.

12. Farmers should always buy the insecticides from licensed stores only.

Different Classifications of Insecticides

Insecticides are classified in several ways taking into consideration their origin, mode of entry, mode of action and the chemical nature of the toxicant.

1. BASED ON TOXICITY
2. BASED ON MODE OF ENTRY
3. BASED ON MODE OF ACTION
4. BASED ON CHEMICAL NATURE

1.BASED ON TOXICITY :

The chemical which can make changes in pest life cycle that chemical called poison. it is measured as L.D.$_{50}$. The Value of L.D.50 for a substance is the dose required to kill half members of a tested population after a specified test**.** These are two types

I.

(a) L.D. 50 ORAL : by mouth

(b) L.D. 50 Dermal : by contact

II. when quantity along with the dose is also preferred as **<u>two types</u>**

(a) ACUTE TOXICITY: Acute toxicity describes the adverse effects of a substance that result either from a single exposure or from multiple exposures in a short period of time. To be described as acute toxicity.

(b) CHRONIC TOXICITY: Chronic toxicity is the development of adverse effects as the result of long term exposure to a toxicant or other stressor.

Classification	Symbol	Oral LD_{50}	Dermal LD_{50}
Extremely toxic	Skull & Poison  Red	1-50	1-200
Highly toxic	Poison  Yellow	51-500	201-2000
Moderately toxic	Danger  Blue	501-5000	2001-20,000
Less toxic	Caution  Green	more than 5000	more than 20,000

II.Based on the mode of entry

A. **Contact poisons**: These insecticides are capable of gaining entry into the insect body either through spiracles and trachea or through the cuticle itself. Hence, these poisons can kill the insects by mere coming in contact with the body of the insects. Eg. DDT and HCH.

B. **Stomach poisons:** The insecticides applied on the leaves and other parts of plants when ingested act on the digestive system of the insect and bring aboutthe kill of the insect. Eg: Calcium arsenate, lead arsenate.

C. **Fumigants:** A fumigant is a chemical substance which is volatile at ordinary temperatures and sufficiently toxic to the insects. Fumigation is the process of subjecting the infested material to the toxic fumes or vapours of chemicals or gases which have insecticidal properties. Chemical used in the fumigant and a reasonably airtight container or room is known as fumigation chamber or “Fumigatorium”.

Fumigants mostly gain entry into the body of the insect through spiracles in the trachea. Ex. Aluminium phosphide, Carbon disulphide, EDCT (Ethylene Dichloride Carbon Tetrachloride), EDB(Ethylene dibromide) and $S_{O2.}$

III.Based on mode of action:

A. Physical poisons: Bring about the kill of insects by exerting a physical effect. Eg: Heavy oils, tar oils etc. which cause death by asphyxiation. Inert dusts effect loss of body moisture by their abrasiveness as in aluminium oxide or absorb moisture from the body as in charcoal.

b. Protoplasmic poisons: A toxicant responsible for precipitation of protein especially destruction of cellular protoplasm of midgut epithelium.

Eg. Arsenical compounds.

c.Respiratory poisons: Chemicals which block cellular respiration as in hydrogen cyanide (HCN), carbon monoxide etc.

d. Nerve poisons: Chemicals which block Acetyl cholinesterase(AChE) and effect the nervous system. Eg. Organophosphorous, carbamates.

IV.Based on the Chemical nature

a.Inorganic insecticides: comprise compounds of mineral origin and elemental sulphur. This group includes arsenate and fluorine compounds as insecticides. Sulphur as acaricides and zinc phosphide asrodenticides.

b.Organic Insecticides:

1. Insecticides of animal origin: Nereistoxin isolated from marine annelids, fish oil rosin soap from fishes etc.
2. Plant Origin insecticides or Botanical insecticides:Nicotinoids, pyrethroids, Rotenoids etc.
3. Synthetic organic insecticides: Organochlorines , Organophosphorous, Carbamate insecticides etc.,
4. Hydrocarbon oils etc.

Insecticides of plant origin

The insecticides of plant origin extracted from seeds, flowers, leaves, stem and roots, are termed as botanical insecticides. Insecticides of plant origin unlike synthetic organic insecticides are safer to use but since they are expensive and lack residual toxicity, their use has been limited in the country.

1. **Neem** (*Azadirachta indica)*

It posses medicinal, insecticidal, insect repellent, antifeedant, growth regulatory, nematicidal and antifungal properties. Neem seed extract and oil contains a number of components such as Azadirachtin, salannin, nimbin, epinimbin nimbidin that gives insecticidal, insect repellent, ovicidal, Antifeedant and growth regulator characters. Azadiractitin disrupts moulting by antagonizing the insect hormone ecdysone.

Dried powder of neem leaves are used against stored grain insect pests. Leaf extracts showed insecticidal property against, *Plutella xylostella, Aproaerema modicella; Spodoptera litura etc.*

2. Nicotine:

Nicotine is found in the leaves of *Nicotiana tabacum* and *N.rustica*from 2% to 14%. Nicotine worked as a contact insecticide with marked fumigant action in the control of sucking insect's *viz*., aphids, thrips, psyllids, leafminers and jassids. It affects the ganglian blocking conduction at higher levels.

3. **Pyrethrum:** It is extracted from dried flower heads of *Chrysanthemum cinerariaefolium* (Asteraceae). The actual chemical ingredients having insecticidal action are identified as five esters. They are: Pyrethrin I, Pyrethrin II, cinerins-I and cinerin-II and Jasmoline, which are predominately found in achenes of flowers from 0.7 to 3 %. It act as a contact insecticide.The esters are derived from the,**Two acids** – Chrysanthemic acid and Pyrethric acid **Three alcohols** – Pyretholone, Cinerolone and Jasmolone

Active principles/Esters

Pyrethrin I	= Pyrethrolone + Chrysanthemc acid
Pyrethrin II	= Pyrethrolone + Pyrethric acid
Cinerin I	= Cynerolone + Chrysanthemc acid

Cinerin II = Cynerolone + Pyrethric acid

Jasmolin II = Jasmolone + Pyrethric acid

4. **Rotenone:**

It is extracted from the roots of Derris and *Lonchocarupus* plants. Insects poisoned with rotenone show a steady decline in oxygen consumption followed by paralysis and deaths.

5. Sabadilla :

Sabadilla is derived from the seeds of *Schoenocaulon officinale*. Sabadilla is having the cevadine and veratridine alkaloids and they gives the chemical properties.

6. Tehprosine :

Tehprosia vogelli (leafs and seeds)

Tehprosia toxicaria (roots)

Tehprosia macropoda (stem)

7. Ryania:

Ryania is extracted from the stem of *Ryania speciosa*, The most active compound in ryania is the alkaloid ryanodine, which constitutes approximately 0.2% of the dry weight of stem wood.

1. Organochlorines or Chlorinated Hydrocarbons Ex: DDT, BHC

The plant protection in India owes its growth to the chemicals under this group which have revolutionized the control of pests. The organochlorines are stomach and contact insecticide and high insecticidal efficacy, long residual action, wide range of insect susceptibility, cheapness per unit area and available in different formulations. Highly purified product containing 99% of gamma isomer of HCH is known as lindane. It has been extensively used as soil insecticide. Now a day's DDT is not used for control of pests.

2. CYCLODINES :

Due to the outstanding characteristic of the cyclodienes is their longer stability in the body, the insecticides were not used but only endosulfan is used for the control of pest. Endosulfan is poisonous to honeybees and natural enemies but not to fishes at recommended dose.

Ex: Chlordine , Heptachlor , Aldrine , Diacridine , Endosulfan

3. Organophosphates:

Organophosphate came to limelight during Second World War. Organophosphate insecticides have two most important properties such as higher potency and low residual life. The organoposphates are stomach, contact and systemic insecticides. Organophosphates (OPs) inhibit the cholinesterase (Ch E) enzyme leading to blockage of synaptic transmission of nerve impulses and finally death.

Ex: Phosphamidan ,Chloripyriphos, Dimethoate.

4. CARBAMATES :

All carbamates are derivatives of carbamic acid and Dithio carbamic acid. Carbamtes also act as a stomach, contact and systemic insecticides. Carbamates are divided into three groups.

(a).Heterocyclic carbamates : Ex: isolan , pyrolan

(b).Phenyl carbamates : Ex: carbaryl , propoxur , carbofuran

(c). oxime carbamates : Ex : aldicarb , methomyl , thiodicarb

5. Synthetic pyrethroids:

Synthetic pyrethroids have got the properties of plant derivative pyrethrum as insecticides but are considerably more stable in light and air. Allethrin was first synthetic analogue of pyrethroids was discovered by Green and Laforz in the year 1949. Later, different pyrithroids are evolved to control of insects. They act on tiny channel through which sodium is

pumped to cause excitation of neurons and prevent the sodium channels from closing, resulting in continual nerve trans mission , tremors and eventually death.

Ex: Permethrin, Allethrin, Cismethrin, Resmethrin, Deltamethrin, Cypermethrin and Fenvalerate

NOVEL INSECTICIDES

6. Neonicotinoids

They represent a novel and distinct chemical class of insecticides with remarkable chemical and biological properties. Similar to nicotines in activity partially to structure. Neonicotinoids interact with acetyl choline binding site of nicotinic Ach receptor which cause excitation and eventually paralysis leading to death of insects. These are selective and safe to non target organisms.

Ex : Imidacloprid - Mango hoppers
Acetamiprid - White fly
Thiacloprid - Sucking pest like white fly and aphids

7. Juvenile Hormone (JH)Mimics

They do not allow Metamorphosis to take place there by forcing larva to continue as a larva. In case of mosquitoes metamorphosis is not take place there by forcing larva to continue as a larva. Ex: Juvabione, Methoprene, Hydroprene and Kinoprene

8. Anti JH orJH Agonists or Precocenes:

Anti-juvenile hormones found in plants that induce reversible precocious metamorphosis and sterilization in insects by suppressing the function of the corpora allata gland. Ex: Fenoxycarb and Pyriproxyfen

9. Phenyl pyrazoles: Ex: Fipronil

GABA receptors is the target site for fipronil. Blockage of GABA gated chloride channel reduces neuronal inhibition which leads to hyper exitation of the central nervous system, convulsions and death of an target pest.Used as a foliar application against stem borer, leaf miner, hoppers, root worm and mites

Formulations: 0.3 G, 5 SC

10. Spinosyns Ex: Spinosad

The extract of the fermentation broth that contains spinosad is produced by the microorganism, *Saccharopolyspora spinosa.* The primary components are spinosyn A and spinosyn D.

Spinosad kills insects by causing rapid excitation by activation of nicotinic acetylcholine receptors of the insect nervous system, leading to involuntary muscle contractions, prostration with tremors, and paralysis. It also effects GABA receptor functioning. Spinosad is a contact and stomach poison with some translaminar movement in leaf tissue.

Formulations: 45 SC, 2.5 WSC

11. Avermectins:

These are produced by the soil microorganism *Streptomyces avermitilis*. Avermectins activate the GABA gated chloride channel, causing an inhibitory effect, which, when excessive, results in the insect's death. This channel normally blocks reactions in some nerves, preventing excess stimulation of CNS.

Ex: Emamectin benzoate and abamectin are the two major compounds in this group.These are effective against tobacco hornworm, diamondback moth, tobacco budworm, serpentine leaf miner and less potent against certain Homoptera (aphids) and Lepidoptera.

12. Oxadiazines : Ex: Indoxacarb

The active ingredient indoxacarb works by inhibiting sodium ion entry into nerve cells, resulting in paralysis and death of targeted pests.

Formulations: SC 14.5, WDG 30

13.Thio-Urea Derivatives: Ex: Diafenthiuron

Diafenthiuron is new types of thiourea derivative which acts specially on sucking pests such as mites, whiteflies and aphids. Diafenthiuron is photochemically converted within a few hours in sunlight to its carbodimiide derivative which is much more powerful acaricide/insecticide than diafenthiuron. It is a inhibitor of oxidative phosphorylation, via distruption of ATP formation (inhibitor of ATP synthase).

It acts as Acaricide cum-insecticide as a foliar sprays against mites, sucking pests, lepidopteran insect pests.

14. Pyridine Azomethines: Ex: Pymetrozine

Pymetrozine is a new insecticide highly active and specific against sucking insect pests. Pymetrozine is the only representative of the pyridine azomethine. When the insertion of the stylets of sucking insects into the pymetrozine treated plant tissues, stylets are almost immediately blocked. The sucking insects die by starvation a few days later (feeding depressant)

15. Di – Acyl Hydrazones : Ex: Tebufenazyde

They inhibit the moulting process in insects and finally lead to death of the insect.

16. Ketoenols: Ex: Spiromesifen

Ketoenols act as insecticide and acaricide. Their mode of action is to inhibit lipogenesis in treated insects, resulting in decreased lipid contents, growth inhibition of younger insects, and reduced ability of adult insects to reproduce. it also strongly affects fecundity of mite (and whitefly adults by transovariole effects).

NEMATICIDES:

A nematicide is a type of chemical pesticide used to kill plant-parasitic nematodes. Nematicides have tended to be broad-spectrum toxicants possessing high volatility or other properties promoting migration through the soil.

Ex: **1.Aldicarb:**

Aldicarb is a carbamate insecticide which is the active substance in the pesticide Temik. It is effective against thrips, aphids, spider mites, lygus, fleahoppers, and leafminers, but is primarily used as a nematicide. Aldicarb is a cholinesterase inhibitor which prevents the breakdown of acetylcholine in the synapse.

2. Carbofuran :

Carbofuran is one of the most toxic carbamate pesticides. It is marketed under the trade names Furadan, it woks on sucking pest, Nemoticides and Midge.

Rodenticides :

Rodenticides are pesticides that kill rodents. Rodents include not only rats and mice, but also squirrels, woodchucks, chipmunks, porcupines, nutria, and beavers. Although rodents play important roles in nature, they may sometimes require control. these are three (3) types

1. Acute poison Ex: zinc phosphide ,aluminumphosphide
2. Anti coagulants Ex: bromadialone
3. Fumigants Ex: methyl bromide

1. Zinc phosphide:

This chemical is in the form of black powder and has a kind of smell . pre-baiting must be done . first u have to Taunt Rats (7-8) days after that hominy (96 cups) take 2 cups of chemical and mix it then use it as poison bait .

2. Aluminumphosphade :

It should be closed in a burros with Rats and then the phasphin gas release from it . this gas kills the Rats . it is available in the name of celphos

3. **Bromadiolone :**

This can be used as a poison bait . it can kills upto 90% of Rats it is available in the market like Roboncake . it should be 100 grm weight and 6 pieces . after using this with in 4-7 days the Rats will die .

Acaricides :

The chemicals can kills the mites are known as Acaricides .

Ex: Sulphur - Saltaf , Thiovit

Dicofol - kelthane – this chemical formula looks like D.D.T. D.D.T. contains 'H' part and 'OH' that's why Dicofol kills the mite. This is not Harmful to honey bees.

Insect Antifeedants

Antifeedant is a chemical that inhibits feeding but does not kill the insect directly; the insect often may remain on the treated plant material and possibly may die of starvation. These are also caused as "Feeding deterrents"

Ex: Triazines - 4 acetanilyde - red headed catter pillar
Organotin (Brestan)- Triphenyltins - potato rhizome weevil
Carbamate (Aprocarb) - cotton weevil

Advantages of Antifeedants:

1. Antifeedants affect only the phytophagous insects and so do not harm the beneficial parasitoids, predators and pollinators.
2. As the pest is not immediately killed by antifeedent, its parasites and predators continue to feed on it, thrive, and keep it under control.
3. Antifeedants produce no phytotoxicity (or) pollution.

Disadvantages of Antifeedants:

1. Only the chewing type of insects is affected by antifeedants, the sucking pests remain unaffected.
2. New growths of plant are not protected.

Insect Attractants

Chemicals that cause insects to make oriented movements towards their source are called insect attractants. They influence both gustatory (taste) and olfactory (smell) receptors (or) sensilla.

Ex: Geraniol and Eugenol (1:1) is used to attract Japanese beetle

Methyl Eugenol will attract the male fruit fly and it is used as poison bait

Sex pheromones

A Sex pheromone released by one sex only triggers off a series of behaviour patterns in the other sex of the same species and thus facilitates mating. The male insects respond to the odorous chemical released by the female. In certain species of insects the males are known to produce the sex pheromone which attracts the females. Ex: In the cotton boll weevil *Anthonomus grandis*

The following sex pheromones have been full filled.

1. Silkworms trans - 10 - cis – 12 – decadaienol
2. Gypsymoth 10 acetoxy - cis - 7 - hexadecinol

Sex pheromones in insect pest management

1) Monitoring of insect pests: Traps baited with synthetic sex pheromones is useful in estimating population and detecting early stages of pests. Four pheromone traps per acre is recommended.

2) Mass-trapping: (Male annihilation technique): Large number of pheromones baited traps can be used in the fields to capture male moths of newly emerged and reduce the number of males for mating.

3) Control of pest by mating disruption: By permeating the atmosphere with higher concentration of the pheromone the opposite sex is rendered confused and unable to locate their mates.

Formulations of Insecticides

It is essential that the toxicant must be amenable to application in an effective manner so as to come into direct contact with the pest or leaf and uniform and persistent deposit upon the plant surface. Since very small quality of toxicant is required to be distributed over a large area, insecticides are formulated in a form suitable for use as a spray, dust or fumigant. Formulation is the processing of a compound by such methods that will improve its properties of storage, handling, application, effectiveness and safety to the applicator and environment and profitability. It is the final physical condition in which insecticide is sold.

A single insecticide is often sold in several different formulations. Following are the different formulations of insecticides.

1.Dusts (D): These are ready to use insecticides in powder form. In a dust formulation the toxicant is diluted either by mixing with or by impregnation on a suitable finely divided carrier which may be an organic flour or pulverized mineral like lime, gypsum, talc etc., or clay like attapulgite bentonite etc.The toxicant in a dust formulation ranges from 0.15 to 25% and the particle size in dust formulations is less than 100 microns and with the decrease in particle size the toxicity of the formulation increases. Dusts are easy to apply, less labour is required and water is not necessary. However if wind is there, loss of chemical occurs due to drift hence dusting should be done in calm weather and also in the early morning hours when the plant is wet with dew.

Eg. HCH 10% dust; Endosulfan 4% D.

2. Granules or Pelleted insecticides(G): These are also ready to use granular or pelleted forms of insecticides. In this formulation the particle is composed of a base such as an inert material impregnated or fused with the toxicant which released from the formulation in its intact form or as it disintegrates giving controlled release. The particle size ranges from 0.25 to 2.38 mm, or 250 to 1250 microns and contains 1 to 10% concentration of the toxicant. The granules are applied in water or whorls of plants or in soil. Action may be by vapour or systemic. In application of granules there is very little drift and no undue lose of chemical. Undesirable contamination is prevented. Residue problem is less since granules do not adhere to plant surface. Release of toxicant is achieved over a long period. Easy for application as water is not required for application. Less harmful for natural enemies.

Eg: Carbofuran 3G, Phorate10 G, Cartap hydrochloride 4G

3. Wettable Powders (WP): It is a powder formulation which is to be diluted with water and applied. It yields a stable suspension with water. The active ingredient (toxicant) ranges from 15 to 95%. It is formulated by blending the toxicant with a diluent such as attapulgite, a surface active agent and an auxiliary material. Sometimes stickers are added to improve retention on plant surface. Loss of chemical due to run off may be there and water is required for application.
Eg: Carbaryl 50%WP, Thiodicarb 75% WP

4. Suspension Concentrate (SC): Active ingredient is absorbed on to a filler which is then suspended in a liquid matrix (water).It is not dusty and easier to disperse in water. Eg: Imidacloprid 50 SC

5. Emulsifiable Concentrates (EC): Here the formulation contains the toxicant, a solvent for the toxicant and an emulsifying agent. It is a clear solution and it yields an emulsion of oil-in water type, when diluted with water. The active ingredient (toxicant) ranges from 2.5 to 100 %.When sprayed the solvent evaporates quickly leaving a deposit of toxicant from which water also evaporates. The emulsifying agents are alkaline soaps, organic amines alginates, Carbohydrates, gums, lipids, proteins etc. Eg: Endosulfan 35EC, Profenophos 50EC

6. Concentrated insecticide liquids: The technical grade of the toxicant at highly concentrated level is dissolved in non-volatile solvents. Emulsifier is not added. Generally applied from high altitudes in extremely fine droplets without being diluted with water at ultra volume rates. There is greater residual toxicity and less loss through evaporation. Active ingredient ranges from 80-100%
Eg: Malathion, Bifenthrin,Fenitrothion.

7. Insecticide aerosels: The toxicant is suspended as minute particles 0.1 to 30 microns in air as fog or mist. The toxicant is dissolved in a liquified gas and if released through a small hole causes the toxicant particles to float in air with rapid evaporation of the released gas. Eg: Allethrin

8. Fumigants: A chemical compound which is volatile at ordinary temperature and sufficiently toxic is known as fumigant. Most fumigants are liquids held in cans or tanks and quite often they are mixtures of two or more gases. Advantage of using fumigant is that the places not easily accessible to other chemicals can be easily reached due to penetration and dispersal effect of the gas.
Eg; Aluminium phosphide

COMBINATION OF INSECTICIDES

When two chemicals are brought together in a single spray mixture, due to reaction, a compound differing from either parent may be formed. Knowledge of the effects of such compounds on the plants when applied is essential to avoid improper use.

The different types of incompatibility are:

i) Chemical incompatibility: Different compounds are formed due to reaction of various chemicals as in synthetic organic compounds with an alkaline material which causes injury to plants.

ii) Phytotoxic incompatibility: The component parts though themselves are not injurious to the plants and do not show any chemical reaction when mixed, the mixture causes injury to plants.

iii) Physical incompatibility: The chemicals change their physical form to one that is unstable and hazardous for application.

Insecticide Combinations:

Some of the important insecticide combinations are:

	Name of pesticides	Trade name	Recommended for pest
1	Chloripyriphos 50% cypermethrin 5%	Noorel –D 505	Leaf miner , fruit borer (2m*l/l)*
2	Profenophos 40 % + cypermethrin 5%	Palithrin	Fruit borer, sucking pest (300-400m*l/l)*
3	Triazophos 35% + Deltamethrin 1%+	spark	White fly and leaf miner (300-400m*l/l)*