MSCZO-610

Entomology (Systematic and Applied Entomology)

M. Sc. IV Semester

DEPARTMENT OF ZOOLOGY
SCHOOL OF SCIENCES
UTTARAKHAND OPEN UNIVERSITY

Entomology (Systematic and Applied Entomology)
(MSCZO-610)

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Course 1: Entomology (Systematic and Applied entomology)

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UNIT 1: ORIGIN AND EVOLUTION OF INSECTS

CONTENT

1.1 OBJECTIVES

Students will be able to study about insects fossils and fossils preservationStudents will understand the essential characteristics of freshwater and marine insects fossilsStudents will be able to make study on compressions, impression and mineralization.Students will be able to understand evolutiotionary history in Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, Paleogene, Neogene in different periodStudents learn about phylogeny (evolutionary relationships), taxonomy, early evidence, origin of insect flight and different theories.

1.2 INTRODUCTION

The **evolution of insects** was based on studies of the following branches of science: molecular biology, insect morphology, paleontology, insect taxonomy, evolution, embryology, bioinformatics and scientific computing, it is a recent understanding. The estimation of the class of insect originated on Earth approximated 480 million years ago, in the Ordovician, in the same time of terrestrial plants appeared. Evidences occurred that the Insects may have evolved from a group of crustaceans. The primitive insects were land bound, but before 400 million years ago in the Devonian period one lineage of insects evolved flight, The oldest insect fossil has been proposed to be *Rhyniognatha hirsti*, estimated to be 400 million years old, but the insect identity of the fossil has been decided. Worldwide climate conditions changed several times during the past of Earth, and along with it the variation of insects. The winged insects (Pterygotes) underwent a major radiation in the Carboniferous (356 to 299 million years ago) while the insects that go through different life stages with metamorphosis (Endopterygota) underwent another major radiation in the Permian (299 to 252 million years ago). Survivors of the mass extinction at the *Permian–Triassic* boundary evolved in the Triassic to what are essentially the modern insect orders that persists to modern times. Insect families of most modern time appeared in the Jurassic, and further diversity probably in genera occurred in the Cretaceous. It is believed that by the Tertiary there existed many of what are still modern genera; hence most insects in amber are indeed member of extant genera.

1.3 ORIGIN OF INSECTS

There is a Cambrian explosion before 500 million years ago, a remarkable evolutionary event. During this period the emergence of a plethora of life forms-some gigantic, other small, some that lived on land and other in water. Giant insects – some with wingspans of 2.3 feet – inhabited the earth made their first appearance before 412 millions year ago. Biologist analyze that insect become top predators for nearly 100 million year ago.

The most devastating mass extinction period means Permian-Triassic (P-T) extinction event that the earth has ever witnessed nearly 90 percent of all life forms extinct. These extinctions continued for nearly 12 million years (Around 251 Million Year Ago), and the insects took a massive beating.

Eight orders of insects were completely extinct and 10 insect orders lost a majority of their species. Evolutioists believe that 30 percent of the insects were lost during this period and some without even leaving a trace of their existence.

The surviving orders, however, adapted for surviving and evolved to occupy every possible nook and corner of the planet. Most modern-day insects originated after Permian-Triassic (P-T) extinction period. The parallel survival of plant species further assisted their expansion. Together, insects and flowering plants populated the earth.

And now, once again the insects are being challenged by, what evolutionists call, the sixth extinction event.

1.4 ***EVOLUTION***

Insect evolution is characterized by repid adaptation with selective pressure exerted by environment, with rapid adaptation being furthered by their high fecundity. It appear that rapid radiation and the appearance of new species, a process that continues to this day, result in insects filling all available environmental niches.

1.4.1 Evolutionary history

The insect fossil record found back of 400 million years ago to the lower Devonian, the Pterygotes (winged insects) faced a major radiation In the Carboniferous period the Perygotes insects faced a major radiation and the Endopterygota faced another major radiation in the Permian period. Modern insects order re-originated and survived after Permian and Triassic extinction. More modern insect families appeared in the Jurassic, and further variation and diversification probably in genera occurred in the Cretaceous. By the Tertiary, there existed many of what are still modern genera; hence, most insects in amber are, indeed, members of extant genera. Into essential modern form most insects diversified in only about 100 million year. Insect evolution occurred due to hight fecundity and environmental pressure created. The insect regular filling the all availability in environmental niche and changes accordingly. The insects regularly changes itself according to the changes in flowering plants and other vegetation present around it. It is due to dependent of insects on their environment. The evolution of insects is closely related to the evolution of flowering plants. Insect adaptations include feeding on flowers and related structures (with some 20% of extant insects depending on flowers, nectar or pollen for their food source), This symbiotic relationship is even more paramount in evolution considering that more than 2/3 of flowering plants are insect pollinated. Which insect have to created the diseases on animals, they are responsible for the the decimation or extinction of some mammalian species.

1.4.1.1 Devonian

419 to 359 million years ago was a warm period without any glaciers is known as Devonian period. The first insects probably appeared, in the Silurian period, and probably insects got wings in Devonian according to the phylogenetic study. The fossil records are not well known about of this. The fossils that were considered as Devonian insects, such as *Rhyniognatha hirsti* or *Strudiella devonica* are studied that affinities as insects are insufficient. The entomologists found the first complete insects in the late Devonian period (425 to 385 million years ago). This observation reduces a previous gap of 45 million years in the evolutionary history of insects. In this period the insects body segments, legs and antennae are visible, however genitalia were not preserved. Both the above mentioned species represents new species. Insect without wing but it may be a juvenile.

1.4.1.2 **Carboniferous**

359 to 299 million years ago is famous period for its wet, warm climates and extensive swamps of mosses, ferns, horsetails, and calamites is known as Carboniferous. Glaciations of the Carboniferous continued into the Permian and because of the lack of clear markers and breaks,

the deposits of this glacial period are often referred to as Permo-Carboniferous in age. Due to cooling and drying of the climate Carboniferous rainforest have collapse. All remaining of insects are scattered throughout the coal deposits, particularly of wings from cockroaches deposits in particular are in France. The earliest winged insects are from this time period (Pterygota), including the aforementioned Blattodea, Caloneurodea, primitive stem-group Ephemeropterans, Orthoptera, Palaeodictyopteroidea. In 1940, the largest complete insect wing ever found as a fossil of *Meganeuropsis Americana* (Fig-01). Juvenile insects are also known from the Carboniferous Period.

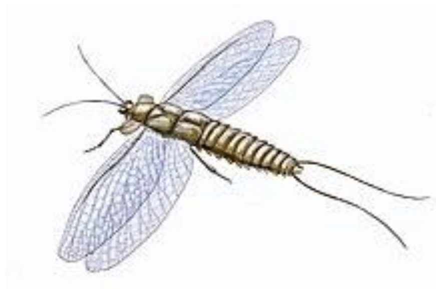

Fig-01.*Meganeuropsis Americana* (Fossil member)

Restoration of *Mazothairos*(a Carboniferous member of the now extinct order Palaeodictyoptera.) (Source-https://en.wikipedia.org/wiki/Evolution_of_insects)

The primitive Blattopterans had a large, disciform pronotum and leathery forewings with a distinct CuP vein (a unbranched wing vein, lying near the claval fold and reaching the wing posterior margin). These were false characteristics of cockroaches, as they had an ovipositor, although through the Carboniferous, the ovipositor started to diminish. The previous orders Caloneurodea and Miomoptera recently known, with Orthoptera and Blattodea to be among the earliest Neoptera which is evoluted from the upper Carboniferous to the Permian. These insects had wings with similar form and structure: small anal lobes.Species of Orthoptera, like grasshoppers and related and adaptive for jumping, hind legs is preserved.

1.4.1.3 Permian

The Permian (290 to 245 millions year ago) during which all the Earth's major land masses were collected into a single supercontinent known as Pangaea. At the end of the Permian, the biggest mass extinction in history occurred, collectively called the Permian–Triassic extinction event: 30% of all insect species became extinct; this is one of three known mass insect extinctions in Earth's history. 2007 study based on DNA of living beetles and maps of likely beetle evolution indicated that beetles may have originated during the Lower Permian, up to 299 million years ago. During this time, many of the species from the Carboniferous diversified, and many new orders developed, including: Protelytroptera, primitive relatives of Plecoptera (Paraplecoptera), Psocoptera, Mecoptera, Coleoptera, Raphidioptera, and Neuroptera, the last four being the first definitive records of the Holometabola

1.4.1.4 Triassic

A period (252 to 201 million years ago) is known as The Triassic(During the Triassic, almost all the Earth's land mass was still concentrated into Pangaea) was when arid and semiarid savannas developed and when the first mammals, dinosaurs, and pterosaurs appeared. The climate was hot and dry, forming typical red bedsandstones and evaporites during the Triassic. There is no evidence of glaciations at or near either pole; in fact, the polar regions were apparently moist and temperate, a climate suitable for reptile-like creatures.

There is only little fossil record of insects including beetles from the Lower Triassic.However, there are a few exemptions, like in Eastern Europe entire specimen of the infraorders Archostemata (i.e., Ademosynidae, Schizocoleidae), Adephaga (i.e., Triaplidae, Trachypachidae) and Polyphaga (i.e., Hydrophilidae, Byrrhidae, Elateroidea) and in nearly a perfectly preserved condition. However, species from the families Cupedidae and Schizophoroidae are not present at this site, whereas they dominate at other fossil sites from the Lower Triassic.

Around this time, during the Late Triassic, mycetophagous, or fungus feeding species of beetle (i.e., Cupedidae) appear in the fossil record. In the stages of the Upper Triassic representatives of the algophagous, or algae feeding species (i.e., Triaplidae and Hydrophilidae) begin to appear, as well as predatory water beetles. The first primitive weevils appear (i.e., Obrienidae), as well as the first representatives of the rove beetles (i.e., Staphylinidae), which show no marked difference in physique compared to recent species. This was also around the first time evidence of diverse freshwater insect fauna appeared.

During the Triassic.Hemiptera included the Cercopidae, the Cicadellidae, the Cixiidae, and the Membracidae. Coleoptera included the Carabidae, the Staphylinidae, and the Trachypachidae. Hymenoptera included the Xyelidae have appeared. Thysanoptera first appeared as well as Diptera included the Anisopodidae, the Chironomidae, and the Tipulidae are of some of the oldest living families appear. The first true species of Diptera are known from the Middle Triassic and Late Triassic.

1.4.1.5 Jurassic

There is warm and humid climate in Jurassic period. It is during 201 to 145 million years ago. During this period it was important in one of the insects' major predators and the development of birds. Approximate 150 important sites with beetle fossils are in many important sites in Eastern Europe and North Asia. In North America there are only a few sites with fossil records of insects in the Jurassic period. In Asia and Europe numerous deposits of other insects are occure.

During the Jurassic there was a dramatic increase in the known diversity of family level Coleoptera. the development and growth of carnivorous and herbivorous species includes in this. Close to the Upper Jurassic, decreased the Copepode portion, however increased the diversity of the early plant eating, or phytophagous species at the same time. Most of the recent phytophagous species of Coleoptera feed on flowering plants or angiosperms.

1.4.1.6 Cretaceous

Approximately 145 to 66 million years ago the Cretaceous had much of the same insect fauna as the Jurassic not after. one-third of Earth's present land area was submerged at the peak of the Cretaceous transgression,. It had been seen in the last epoch of the Jurassic in which the Berriasian epoch showed a cooling trend. Snowfalls were common in the higher latitudes and the tropics became wetter than during the Triassic and Jurassic, it is evidence.

From the Cretaceous there are a large number of important fossil sites worldwide containing beetles. During the Cretaceous most of them are located in Europe and Asia and belong to the temperate climate zone.

During the Cretaceous the diversity of Cupedidae and Archostemata decreased considerably. There is distribution of different pattern of Predatory ground beetles (Carabidae) and rove beetles (Staphylinidae): whereas in the warm region the Carabidae predominantly occurred, preference of many areas with temperate climate the Staphylinidae and click beetles (Elateridae) are found. Likewise, there is hunted their prey under the bark of trees together with the jewel beetles (Buprestidae) by predatory species of Cleroidea and Cucujoidea. The primary consumers of wood, the jewel beetles diversity increased rapidly during the Cretaceous, while longhorn beetles (Cerambycidae) were rather rare and their diversity increased only towards the end of the Upper Cretaceous.

1.4.1.7 Paleogene

From this era there are many fossils of beetles known, though the beetle fauna of the Paleocene (65 to 56 million years ago) is comparatively poorly investigated. Beetle fauna is very good in contrast; the knowledge on the Eocene while there are many fossils of beetles known from this era, though the beetle fauna of the Paleocene is comparatively poorly investigated. The reason is the occurrence of fossil insects in amber and clay slate sediments. Amber is fossilized tree resin, that means it is not consists of minerals, it is consists of fossilized organic compounds. Location, age and species of the resin producing plant, distinguished the different type of amber. Amber is most important for the research on the Oligocene beetle fauna, Baltic and Dominican.The first butterflies are from the Upper Paleogene, while most, like beetles, already had recent genera and species already existed during the Miocene, however, their distribution differed considerably from todays.

1.4.1.8 Neogene

The Neogene (23 to 0 million years ago) is most important sites for beetle fossils are situated in the warm temperate and to subtropical zones. During the Miocene many recent genera and species already existed, however, the distribution differed considerably from today's. The most important fossil sites for insects of the Pliocene is Willershausen near Göttingen, Germany with most preserved beetle fossils of various families (longhorn beetles, weevils, ladybugs and others) as well as representatives of other orders of class insect. Well known fauna of beetle is in the Pleistocene, since the composition of the beetle fauna has been used to reconstruct climate conditions.

1.5 *PHYLOGENY*

We believe is the world's oldest known full-body impression of a primitive flying insect, a 300 million-year-old specimen from the Carboniferous Period. Millipedes and Centipedes are closely related to crustaceans. Mellepede centepedes, Scorpion and spider are sometimes confused that they are very similar to insects with their body plans. From the 396 million year old Rhynie chert fossils is the oldest definitive insect fossil is the Devonian*Rhyniognatha hirsti*. It is superficially resembled a modern-day silverfish (Order-Thysanura) insect. This species already possessed dicondylic mandibles (two articulations in the mandible), It is a wingless insects but have a character associated with winged insects, it is a evidence that wings may already have evolved at this time. In the Silurian period, it seem that the first insects probably appeared earlier, There have been four super radiations of insects: beetles (evolved around 300 million years ago), flies (evolved around 250 million years ago), moths and wasps (evolved around 150 million years ago). These four groups account for the majority of described species. Mecopteraevolved the flies and moths along with the fleas.

The origins of insect flight remain not well known, since the earliest winged insects currently known appear to have been capable fliers. Some extinct insects had an additional pair of winglets attaching to the first segment of the thorax, for a total of three pairs. There is no evidence that suggests that the insects were a particularly successful group of animals before they evolved to have wings.

The record of insect fossil extends back some 400 million years to the lower Devonian, while the Pterygotes (winged insects) undergo a major change in the Carboniferous. The Endopterygota undergo another major change in the Permian. In the Jurassic period most modern insect families appeared, and further modification probably in genera occurred in the Cretaceous. In essential modern form the insects have diversified in only 100 million years. The insect have evolutes due to rapid adaptation by selective pressure of climatic conditions and their high fecundity. Regular adaptations result was new species formation. This process was continue till now, its result that the insects filling all available environmental niches.

Approximately 20% of extant insects were depending on flowers, nectar or pollen for their food source and the symbiotic relationship is even more paramount in evolution considering that more than 2/3 of flowering plants are pollinated by insect. The extinction of some mammalian species was done by some particularly flies and mosquitoes which was the vectors of some pathogens.

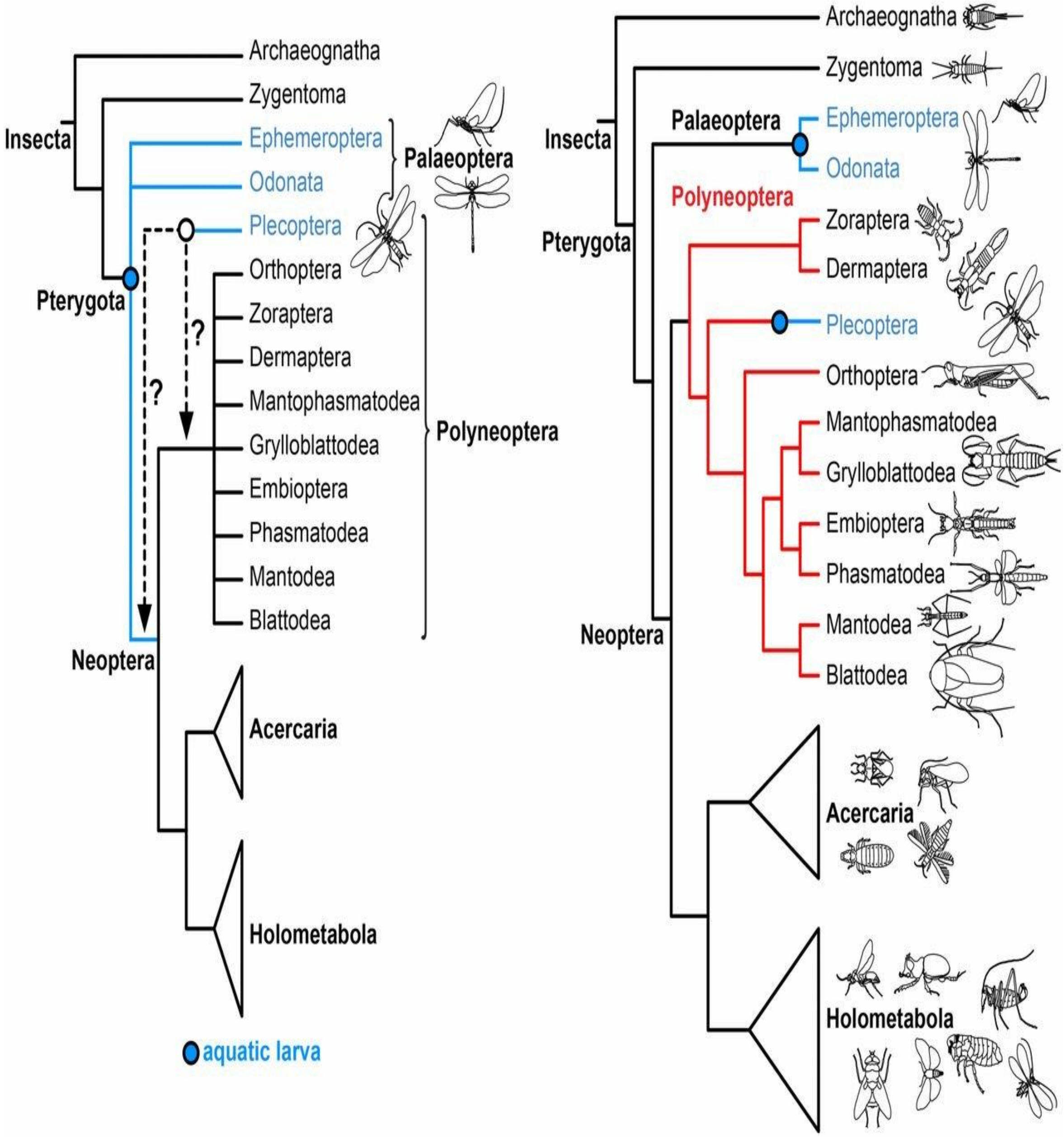

Fig-02(*Left*) Traditional phylogeny of insects reflecting the uncertain placement of key groups with aquatic larvae (blue) and inferred ancestral state in the common ancestor of Pterygota (the winged insects). Tree topology integrates over a number of historical phylogenies, based on morphological data and/or Sanger-sequenced loci. (*Right*) Phylogenomic tree of a resolved Polyneoptera (red) from the supermatrix analyses of Wipfler et al. (2019), reflecting the ancestral state reconstruction of an aquatic larval stage.

The insects phylogeny is the sequential study that underlies various macroevolutionary phenomena, such as the winged flight evolution (Fig-02), parental care, interaction study with plants, and morphological specializations for diverse modes of feeding (specialization of mouth parts). However, a stable insect phylogeny has historically remained, but now it is basis on molecular systematic nearly two decades ago.

1.6 SUMMARY

The animal groups and the evolutionary relationships of insects are not clear, although there have been many number of opinions expressed. Few evolutionists explain that the arthropods are a phylogenetic group and that of many similarity has been found as a result of convergent evolution, however few of explain that it is monophyletic, having evolved from a common ancestor.

There is five major theories of the ancestry of insects exist, with one or more leading scientists explain for each, they include the speculation that the ancestor common to all insects was an annelid or annelid-like form that looked something like a modern earthworm.

Class insecta is also explained by many scientists to have evolved from a Myriapod (Mellepede) or some type of proto-myriapod animal during the Devonian period, but even this conclusion about insect origin is controversial.

The segment worms apparently evolved from the ancient protostomes concluded by Meglitsch and other, which also gave rise to the mollusk and were the ancestors of insects. Labandeira explain on the basis of bimolecular studies that insects evolved from an unspecified lineage of Crustaceans. They admit that insect' origins remains unsettled and that morphological evaluations still favour a non-crustacean ancestor.

The most common theory is that insects evolved from some type of Myriapod. Myriapods and insects both evolved from some unknown common ancestor, it is concluded by Romoser and Stoffolanon. Some evolutionists explain that it is near to suppose that the earliest insects were similar to silverfish, it appeats in the fossils record an estimated 350 million year ago.

The rarity of transitional forms is the major reason why phylogenetic trees vary so drastically. The dominant view of insect evolution (from Myriapods) is not supported by RNA analysis. The limbs of crustaceans are Branched (biramous) it is one major difference whereas those of insects and myriapods are always unbranched, even in their embryonic stages-thus their new name Uniramia. The mouthparts of Chelicerate also have unbranched set, in particular a pair of pincer like structure called chelicerae. Finally there are fundamental difference between the group in the way the legs and jaws move, which suggest that each developed limbs independently. Of the ancestors themselves, little is known, and only the worm-like onycophorans provide any real evidence. The construction of either body wall and excretory system is distinctly annelid-like, but they have appendages also that could have been the forerunners of the insects segmented limbs, as well as insect-like antennae, and trachea for breathing.

All this suggests that the Uniramia evolved from annelid like but the ancestors from the other groups-the crustaceans and chelicerates-remain a complete mystey. The great advantage of using insect fossils to test evolution is that most insects have exoskeletons, and consequently their external morphology is usually well preserved.

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1.8 *TERMINAL QUESTIONS AND ANSWERS*

Q1. Write a brief account on Origin of insects.

Q 2. Write an account on insect Evolution.

Q 3. Write in brief about Evolutionary history of Insects.

Q4. Explain the insects' origin in Devonian period.

Q 5. Explain the Insects order which evolutes in Carboniferous period.

Q 5. Write the name of new orders developed in Permian period.

Q 6. Which order seen from the Middle Triassic and Late Triassic.

Q 7. Jurassic most of the recent ……….. species of Coleoptera feed on flowering plants or angiosperms.

Q 8. The primary consumers of wood, ………… diversity increased rapidly during the Cretaceous Cretaceous

Q 9. The first butterflies are from the Upper Paleogene. Explain it.

Q 10. Explain that the Neogene is most important sites for beetle fossils.

Q 11. Write in brief the Phylogeny of insects.

UNIT 2: INSECT CLASSIFICATION

CONTENT:

2.1 OBJECTIVES

- To study insect Classification upto families
- To study phylogeny of Arthropoda and Insecta
- To study the apterygota (Primitive insects)
- To Construct the dichotomous key for insect identification
- To study how to identify the insects with the help of Dichotomous key

2.2 INTRODUCTION

Insecta is the largest class of Phylum Arthropoda, it including nearly millions known species (about three-fourths of all animals) in which an estimated 5–10 million undescribed species. Insect body divided into three parts head, thorax (which bears three pairs of legs and usually two pairs of wings), and many-segmented abdomen. Many species undergo incomplete and complete metamorphosis or metamorphosis absent. Insecta are divided into two subclasses: Apterygota (primitive, wingless forms, including silverfish and bristletails) and Pterygota (more advanced winged or secondarily wingless forms). The approximately 29 orders of Pterygota are generally classified by wing form: e.g., Coleoptera (beetles), Diptera (dipterans), Heteroptera (bugs), Lepidoptera, Hemiptera etc. Insects are found in almost all terrestrial and freshwater and some marine habitats. On the basis of wings present or absent insect divided into two subclass, Apterygota and Pterygota. Apterygota subclass further divided into four order on the basis of tail structure and Pterygota subclass divided into two division division I is exopterygota and division II Endopterygota on the basis of wing develop externally and internally respectively. Exopterygota division further divided into 16 order and division II Endopterygota divided into 10 orders. Total orders are 30 according Imm´s classification:

ClassInsecta
(Imm'sclassification)

SubclassApterygota
(Ametabola)Wingless

1. Protura–Telsontails
2. Diplura–Diplurans
3. Collembola –Springtails,snowfleasetc
4. Thysanura –Bristletails,Silverfishetc

SubclassPterygota(Metabola)

(wingedinsects)

Division:Exopterygota(Hemimetabloa)
(wingsdevelopexternally)

5.Ephemeroptera-Mayflies

6.Odonata-DragonfliesandDamselflies

7. Plecoptera-Stoneflies

8. Dictyoptera-Cockroachesandmantids

9. Grylloblattodea-Grylloblattids

10.Orthoptera-Grasshoppers,locusts,

11.Crickets,molecricketsetc.

12.Phasmida-Stickinsects

13.Dermaptera-Earwigs

14.Embioptera-Web spinners

15.Isoptera-Termites

16. Zoraptera-Zorapterans

17.Psocoptera-Booklice

18.Mallophaga-Birdlice

19.Siphunculata(Anoplura) -Suckinglice

Division-Endopterygota(Holometabola
(wingsdevelop

21. Neuroptera-Antlionsandlacewings

22. **Mecoptera-Scorpionflies**

23. **Trichoptera-Caddisflies**

24. **Lepidoptera-Mothsandbutteflies**

25. **Diptera -Flies,mosquitoes**

26. **Siphanoptera-Fleas**

27. **Hymenoptera–Ants,bees,wasps**

28. **Coleoptera-Beetles,weevils**

29. **Strepsiptera-Stylopids**

20.Hemiptera-Plantbugs

21.Thysanoptera-Thrips

CharactersofSubClasses:

Apterygota(Ametabola)	Pterygota(Metabola)
Primitiveinsects and small insects	Advance and most Developedinsects
MostlyWingless	Wingedandsomewingless
Mouth parts are encloses or hidden inthehead	Mouthpartsareexposed or externally visible
Mandibles Monocondylic which articulatewithheadat a singlepoint	Mandibles Dicondylic which articulatewithheadat twopoints.
Excretory organs is Malphigiantubules which are areabsentor rudimentary	arepresent
Only in Adults there havepregenitalabdominalappendages	Adultswithoutpregenitalabdominalappendages
In thorax Pleuralsutureisabsent	Episternumand epimeron is the two division of Pleuralsuture of thoracic pleuron
Simple Metamorphosisisfound or absent	Metamorphosisare found andvariable
Abdominalsegmentsare11 to 12	Abdominalsegmentsare Reduced from 8to10.
Moulting found in several times in	Only immature stage moult.

adults

CharactersofdivisionsofSubclassPterygota

Exopterygota(Hemimetabola)	Endopterygota(Holometabola)
Wings are developexternally	Wings are develop internally
Metamorphosis is a simple typeandincomplete(Nymph stage is a immature stage in life cycle)	Metamorphosis is Completeandcomplex (Immature stage is the one or more type of larva)
Nymph stage are resemble with adultsinstructureand habits remaining few structure such as wings and size	Immaturestages(lava)differadultsinstructureandhabits
Nopupalinstar found	Pupalinstarfound

ECONOMIC CLASSIFICATION OF INSECTS

1. **Insects PossessingEconomicimportance(EconomicEntomology)**
2. **Insects Possessingofnoeconomicimportance(Harmlessinsects)**

Economic Importance

HarmfulInsects **BeneficialInsects**

A. Insects which harm the Agriculture crops and plants	A.Insects produces beneficial

(AgriculturalEntomologyand Foresttrees(ForestEntomology)	products for human being
Damagecausedby (i) Feeding habit –Damage leaf, stem and root (ii) Oviposition- Usingplantpartsforconstructionof nests*etc.*, (iii) Some insects pests transport other pests and diseases	1.Productsfromsecretionofinsec ts -Silk(silkworms) -Beewax(Honeybee) -Honey -Propolis - Shellac(lacinsect) - Illumination (Giant firefly) 2.Bodiesusefulasorcontainsubst ancessuchas : -Dye(cochinealinsect)
	- Cantharidin(Blisterbeetle) - Fishbait(stoneflynymph)
	3. Collect, elaborate and store Plantproduct.
	4. Products from plant gallsCausedbyinsects.
	-Tannicacid,Inks,Dyes

	5.Insectsasfoodforfishes,birds, hogs,certainanimalsandhuman beings.
B.Pestsofstoredproducts(StorageEntomology)	B.HelpfulInsects
Byfeeding,contaminatingwiththeirexcretions,seekingprotectionorbuildingnestsortunnelsandnecessitating frequent sorting, packingandpreservingofmaterial. C.Inimicaltoman(Medicalentomology)&Animals(Veterinaryentomologybycausingannoyance,applyingvenoms,disseminatingthediseases,feeding`extra.	- Aidinpollination - Parasitesandpredators ofinjuriousinsects - Destroyweeds - Improve soil fertility (AgriculturalEntomology) - Asscavengers - Insectsandtheirproductsusefulinmedicine(MedicalEntomology) - Certainspeciesareideal materialsinscientific investigations. - Have aesthetic and entertainingvalues

2.3 Historical basis of Insect classification

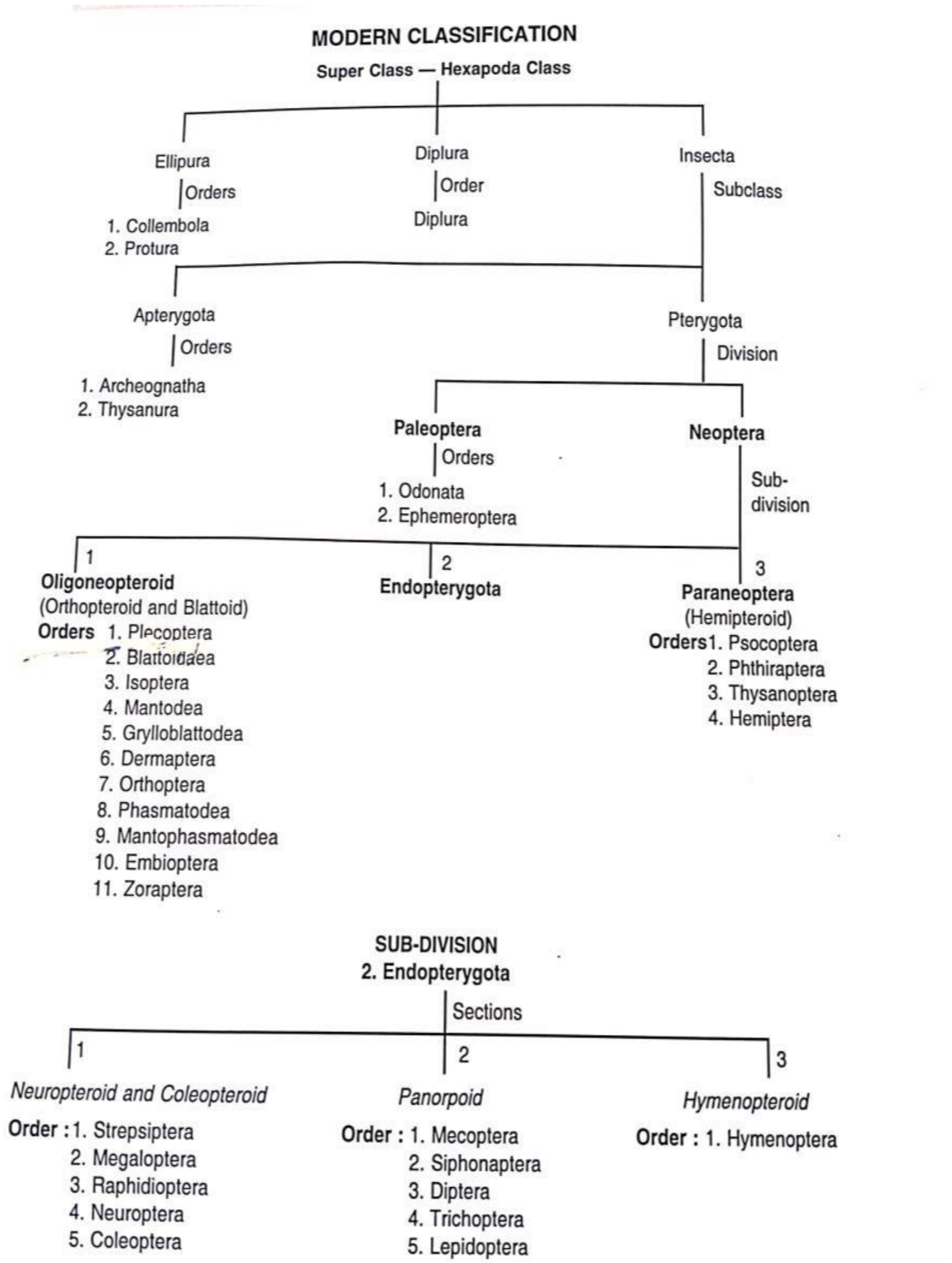
Important books on insect classification in past and their authors (based on ENGEL and KRISTENSEN, 2013)

S.No.	Author Name	Book Title
1	Aristotle (384-322 BC)	Historia Animalium

2	St. Isidore of Seville (ca. 560-636 BC)	Etymologiae
3	Ulissw Aldrovandi of Bologna (1522-1603)	De Animalibus Insectin Libri VII
4	Thomas Mouffet (1553-1604)	Insectorumsive Minimorum Animalium Theatrum
5	John Ray (1627-1705)	Historia Insectorum
6	Maria SibyllaMerian (1647-1717)	Metamorphosis Insectorum Surinamensium
7	August Johann Rösel von Rosenhof (1705-1759)	Insecten-Belustigung
8	Carl Linnaeus (1707-1778)	Systema Naturae, Fauna Svecica
9	Johan Christian Fabricius (1745-1808)	Philosophia Entomologica, Systema Entomologiae, Genera Insectorum
10	Pierre Andrè Latreille (1762-1833)	Précis des Caractères Génériques des Insectes
11	William Sharp MacLeay (1792-1865)	Horae Entomologicae (Essays on the Annulose Animals)
12	William Kirby (1759-1850) and William Spence (1783-1850)	An Introduction to Entomology
13	Karl Hermann Konrad Burmeister (1807–1892)	De Insectorum Systemate Naturali, Handbuch der Entomologie
14	John Obadiah Westwood (1805–1893)	An Introduction to the Modern Classification of Insects

15	Ernst Heinrich Philipp August Haeckel (1834–1919)	Generelle Morphologie
16	Alpheus Spring Packard (1839–1905)	Guide to the Study of InsectS
17	Frank M. Carpenter (1902–1994)	Brues & Melander's Classification of Insects (2nd ed.), Treatise on Invertebrate Paleontology
18	August D. Imms (1881–1949)	General Textbook of Entomology
19	Emil Hans Willi Hennig (1913–1976)	Grundzügeeiner Theorie der phylogenetischen Systematik, Die Stammesgeschichte der Insekten

The most primitive evidence on insect classification comes from the writings of Aristotle (384-322 BC), who, in his book which based in artificial classification and grouped all flying insects with other flying animals like bats and birds. Carl Linnaeus (1707-1778) classified insects on the basis of presence or absence and the number of wings present in adult insect. William Kirby (1759-1850) proposed two new orders i.e. order Strepsiptera and order Trichoptera and along with William Spence (1783-1850), he wrote a book "An Introduction to Entomology". William Kirby is considered as the **Father of entomology** (Clark, 2009). The classification of insects which we follow today is the Imms classification. Modern classification of insects is based on evidences derived from multiple sources. This makes this classification more reliable and accurate. With accumulation of more evidences, there is always a possibility of new additions, arrangements and subtractions of taxa from existing classification scheme.David Sharp (1840-1922) divided winged insects into Exopterygota and Endopterygota on the basis of external or internal development of wings that was adopted by August D. Imm (1881-1949) too in his influential book (Richards and Davies, 1957; “General Text Book of Entomology” Richards and Davies, 1977).


MODERN CLASSIFICATION
Super Class — Hexapoda Class
Ellipura
Orders
1. Collembola
2. Protura
Diplura
Order
Diplura
Insecta
Subclass
Apterygota
Orders
1. Archeognatha
2. Thysanura
Pterygota
Division
Paleoptera
Orders
1. Odonata
2. Ephemeroptera
Neoptera
Sub-division
1
Oligoneopteroid
(Orthopteroid and Blattoid)
Orders 1. Plecoptera
2. Blattoidaea
3. Isoptera
4. Mantodea
5. Grylloblattodea
6. Dermaptera
7. Orthoptera
8. Phasmatodea
9. Mantophasmatodea
10. Embioptera
11. Zoraptera
2
Endopterygota
3
Paraneoptera
(Hemipteroid)
Orders 1. Psocoptera
2. Phthiraptera
3. Thysanoptera
4. Hemiptera
SUB-DIVISION
2. Endopterygota
Sections
1
Neuropteroid and Coleopteroid
Order : 1. Strepsiptera
2. Megaloptera
3. Raphidioptera
4. Neuroptera
5. Coleoptera
2
Panorpoid
Order : 1. Mecoptera
2. Siphonaptera
3. Diptera
4. Trichoptera
5. Lepidoptera
3
Hymenopteroid
Order : 1. Hymenoptera

2.4 PHYLOGENY OF ARTHROPODA AND INSECTA

Phylogeny of Arthropods:

The monophyletic theory is proposed by Snodgrass (1938), Sharov (1966) and they suggest that all arthropods have evolved from a single annelid-like ancestral stock whose limbs are lobopod-like. This lobopod- annelid gave rise to Tetracephalosomita and the most primitive arthropods—Trilobitomorpha evolved from the Tetracephalosomita, and Chelicerata and Mandibulata originated from Tetracephalosomita. Onychophora evolved from lobopod annelid-like ancestor and represent an early lateral branch of the evolutionary line. The monophyletic theory is based on the segmentation between the annelids and arthropods, and the prostomium and pygidium of the annelids correspond to the acron and telson of arthropods. A number of anatomical features, such as chitinous cuticle, haemocoel, dorsal blood vessel, segmental jointed appendages and centrolecithal eggs constitute the basis for the view that the arthropods are monophyletic (Anderson, 1998). The polyphyletic theory is proposed by Tiegs and Manton (1958).

They suggested that there were two ancestors of arthropods:

(i) The lobopod-annelid is considered to be the ancestor of Onychophora which was originated in the Pre-Cambrian period about 525 million years ago. The group Uniramia which includes chilopodes, diplopodes and insects is thought that they have evolved from the base of onychophores.

(ii) The protoannelid ancestor is considered as the primitive annelids from which the most primitive extinct arthropod group- Trilobitomorpha arose, from which two extant groups—Crustacea and Chelicerata evolved by two separate evolutionary lines. Manton (1973), Ruppert and Barnes (1994), support the polyphyletic theory.

They suggest that 3 different living groups-Chelicerata (e.g., horse-shoe crabs, spiders, scorpions, etc.), Crustacea (e.g., copepods, barnacles, prawns, crabs, etc.) and Uniramia have evolved separately, possibly from the annelid ancestors. This view is based on the locomotory structures and embryonic development of the different major groups.

Insect affinities have long been controversial, there is two putative sister-groups being Myriapoda and Crustacea, but the recent morphological and molecular advances support a– Crustacea clade. The monophyletic theory of the insecta is also well supported. It is a very ancient group, as the oldest records are from the Early Devonian. Among animals, arthropods have been considered to be earliest colonizers of land based on fossil evidence. However, it is possible that other animal taxa (e.g. Nematodes, Tardigrades, and Annelids) grouping land even earlier, but these groups have relatively poor fossil records. Nevertheless, they are far from being the oldest terrestrial animals as the first traces of a possible terrestrial arthropod are from the Cambrian or Ordovician of Australia. Arachnids and Myriapods are represented to Ordovician and Silurian terrestrial arthropods. This hypothesis is not supported by the Fossil record of the early a, based on taxa described from very few Devonian outcrops. These Devonian apterous s belong to two main lineages the Entognatha (Collembola, Protura, Diplura) with mouth parts hidden in the cephalic capsule, and the Insecta, a clade that comprises the two apterous orders Archaeognatha

and Zygentoma, plus the winged forms or Pterygota (Zygentoma and Pterygota are characterized by dicondylic mandibles). All these clades are known in the Devonian or the Carboniferous and are still living, except perhaps the controversial order Monura that comprises the sole extinct family Dasyleptidae, recorded from the Late Carboniferous to the Triassic. This situation is extraordinary compared to the fact that many of the Early Palaeozoic major vertebrate clades are now extinct (Thelodonti, Osteostraci, Placodermi, Embolomeri, etc.). Even the oldest Collembola Rhiniella praecursor has a very modern habitus similar to those of the modern springtails. The situation completely changed after the Early Carboniferous with an explosion ofdiversity that affected the winged insects, but not the apterous lineages. The oldest known outcrops with Pterygota are dated from the Namurian of Germany, Czech Republic, and China. These localities provided very rich and diverse entomofaunas,with species belonging to extant taxa (cockroaches, Orthoptera or grasshoppers, Odonatoptera or dragonflies, etc.), but also other that correspond to extinct, strictly Palaeozoic groups as Paoliida a neopteran group dominating in the earliest Late Carboniferous deposits, and the most famous one being the Palaeodictyoptera. Our knowledge on these earliest winged insects has greatly increased during these last years.

2.5 Introduction to Primitive Insects

2.6 CONSTRUCTION OF DICHOTOMOUS KEY FOR IDENTIFICATION

A dichotomous key is a technique of identification whereby groups of insects are divided into two categories repeatedly

- With each continuous sequential division, more information is revealed about the specific features of a particular insects
- When the insects no longer shares its totality of selected characteristics with any insects, it has been identified

When using a dichotomous key to identify insect specimens it is preferable to use immutable features (i.e. features that do not change)

- Size, shape, colouration, colour pattern, habit , habitate and behavioural patterns may all vary amongst individuals and across lifetimes
- Physical structures (e.g number of legs, prolegs, number of wings, antennae shape and size) and biological processes (e.g. reproduction methods, type of genitalia, type of respiration, structure of spiracle) make for better characteristics

Dichotomous keys are usually represented in one of two ways:

- As a branching flowchart (diagrammatic representation)
- As a series of paired statements laid out in a numbered sequence (descriptive representation)

2.7 SUMMARY

It is unclear the relationships of insects to other animal group. There is the more traditionally grouped with millipedes and Centepedes, the closer evolutionary evidence ties with crustaceans has emerged in favour. The insects together with Remipedia and Malacostraca according Pan-Crustacean theory make up a natural Clade. Such as Centepede, Mellepede, scorpions and spiders some terrestrial arthropods body similar to some insects are confused. The first insect was origin earlier in the Silurian period. It have been four super radiations of Insects: Beetle (250 millions year ago) , Flies (500 millions year ago), Moths and Wasps (150 millions year ago)

These groups for the majority of insects species. Flies , Moth and Fleas evolved from the Mecoptera. Large number of successful insect groups has evolved in cooperation with flowering plants a powerful combination of Co-evolution. Some modern insect genera develop ed during the Coenozoic era.

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2.9 TERMINAL QUESTIONS AND ANSWERS

1. Write an account on the Phylogeny of Insects

2. Explain evolutionary relationship of Insects with other.

3. Explain monophyletic theory for insects evolution.

4. Write the name of arthropods which related to insects

5. How to Construct of Dichotomous key for identification of Insects.

6. Differentiate between damsel flies and Dragon fly.

7. Which class is instinct in Phylum Arthropoda. Explain.

8. Explain the mouthparts of insects according their origin.

9. Which mouthparts is more primitive in insects.

UNIT 3: METHODS OF COLLECTION AND PRESERVATION

CONTENTS:

3.1 OBJECTIVES

- To study the different method of insects collection
- To study the different method of killing of collected insects
- To study the pinning of the killed insects.
- To study the spreading of the pinned insects
- To study the different method of drying of the insects
- To study the preservation of the insects.

3.2 INTRODUCTION

Insect collecting refers to the collection of insects. Most insects are small and these cannot be identified without the minute morphological characters, so entomologists often make and maintain insect collections. The collections are conserved in research institution or universities or colleges where they are maintained and studied by specialists. Many college courses curriculum require students to form small collections. Historically, insect collecting has been widespread and was a very popular educational hobby. Slow active Insects are caught using funnels, pitfall traps, bottle traps, malaise traps, flight interception traps and other slow active of insect traps, some of which are baited with small bits of sweet foods (such as honey). Different designs of ultraviolet light traps such as the Robinson trap are also used by entomologists for collecting nocturnal (night active) insects (especially moths) during faunal survey studies. Pooters or Aspirators suck up insects too small or delicate to handle with fingers.

Different types of nets are commonly used actively to collect insects. Flying insects are used to collected by Aerial insect nets. The bag of a butterfly net is generally constructed from a lightweight mesh due to minimize damage to delicate butterfly wings. A sweep net is used to collect insects from grass and brush. Sweep net is similar to Butterfly net, except that the bag is generally constructed from more hard material. The sweep net is swept back and forth through vegetation quickly turning the opening from side to side and following a shallow figure eight pattern. During sweeping, the collector walks forward while, and the net is moved through plants and grasses with force. This requires a heavy net fabric such as sailcloth to prevent tearing, although light nets can be used if swept less vigorously. Continuous sweeping for some distance and then the net is flipped over, with the bag hanging over the rim, cought the insects until they can be released by a pooter. Many types of nets used for collecting insects include beating nets and aquatic nets.[2]Leaf litter sieves are used by coleopterists and to collect larvae.

Once collected, a killing jar is used to kill required insects before they damage themselves trying to escape. However, killing jars are generally only used on hard-bodied insects. Soft-bodied insects, such as those in the larval stage, are generally fixed in a vial containing an ethanol and water solution.[3] Another (now mostly historical) approach is caterpillar inflation, where the innards were removed and the skin dried

Insects and mites of all kinds may be killed and preserved in liquid agents or a dry gaseous agent. Some kinds of insects are best kept dry.

Ethanol (grain or ethyl alcohol) mixed with water (70% to 80% alcohol) is usually the best general killing and preserving agent. For some kinds of insects and mites, other preservatives or higher or lower concentrations of alcohol may be better. Because pure ethanol is often difficult to obtain, some collectors use **isopropanol, or isopropyl alcohol**. Isopropanol does not seem to harden specimens as much as ethanol. The specific concentration to use depends on the kind of insect or mite to be preserved.

3.3 COLLECTION OF INSECTS

Mass Collection Devices

Light Trapping

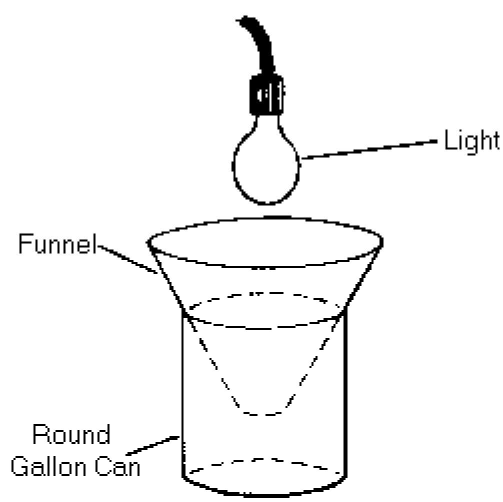


Fig-01: Light trap

(https://vikaspedia.in/agriculture/agri-inputs/bio-inputs/production-of-ipm-inputs/traps/light-traps)

We take a bucket and make 4 holes at the top rim and make one larger hole at the bottom rim. Adjust small sized light shade on the bucket in inverse direction. Fix four rods with screws/nuts with the bucket for holding up the large sized light shade. Fix the light source as shown in the figure. Hang the light trap (Fig-01) on the large sized light shade. Drainage hole on the bucket should be kept closed by the rubber plug while at the bottom of bucket we take swab with chloroform . Light attracted insects come toward light and capture in bucket bottom and killed by chloroform.. Collect/drain out trapped insects periodically, pinned, spreading drying process takes place for further study.

- The light trap installing near or within the field where the maximum diversity occur.
- Secure the poles firmly on the ground
- Approximately the electric bulb on the frame adjust above five meters from the ground
- It esure that the electric bulb and wiring are not in contact with water to avoid electrocution
- Put the light trap from early evening 6:00 PM to 10:00 PM
- Collect the trapped insects daily and separate the useful insects for study and useless insects dispose them properly.

Flight Intercept Traps

Flight Intercept Traps: FITs (also known as barrier traps) are passive traps that are used to collect insects flying through an environment. Many insects when encountering a barrier while flying will either fly up to go over the barrier, or drop down to the ground. This behavior can be exploited to collect insects. Ground level FITs consist of a vertical barrier, collection containers and a horizontal rain fly (**Flight Intercept Trap**, Fig-02). The vertical barrier is typically made of fine mesh, such as mosquito netting, although it could be made of clear plastic or glass. The rain fly is typically plastic. It obviously functions to keep rain from flooding the collection containers, but also functions as a top barrier to reduce escapes, thus enhancing trap success.

Fig-02 Flight Intercept Trap

(https://en.wikipedia.org/wiki/Flight_interception_trap#/media/File:A_modified_windowpane_trap.jpeg)

Collection containers are filled with a killing agent and/or preservative agent. Water, with soap to act as a surfactant, may be used as a killing agent, but the traps must be serviced and specimens removed daily, otherwise specimens will begin to rot. Propylene glycol[6] based antifreeze[7] (or pure propylene glycol) can be used as a killing and preserving agent. DO NOT USE ethylene glycol antifreeze[8] because of its toxicity to mammals (the sweet taste also increases the likelihood of mammals disturbing the collection containers). If propylene glycol is used, traps can be left for long periods without servicing. Ground level FITs collect an enormous number of specimens over time (100+ per day), and will collect numerous non-flying ground-dwelling insects and arthropods as well.

Sifting and Berlese Funnels

Sifting and Berlese Funnels (Fig-03 & 04) are used to extract small insects and arthropods from leaf litter and other debris (dung, mushrooms, flood debris, etc.). A sifter is a device used to concentrate individuals by removing large pieces of substrate. This is done using a container with a wire mesh bottom. The debris is placed in the container, agitated, and the smaller particles and individuals fall through (see **Sifting**, right). If you sift over a **white pan** (see below) or white sheet you can immediately begin collecting specimens with an **aspirator** or **brush.**

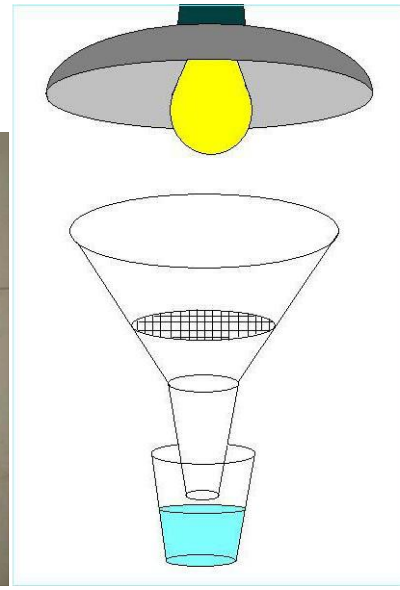


Fig- 03 Sifting for insects Fig- 04 Berlese Funnels

(https://mealwormmachine.com/commercial-mealworm-sifting-machine-tenebrio-molitor-separator/)

(https://bughunter.tamu.edu/collection/collectionequipment/berlese-funnel/)

Bait Traps

Bait Traps (Fg-05), using fruit, dung, carrion, pheromones, heat, color, etc. as attractants can be general or targeted collection devices. Many bait traps are homemade, while others are available commercially.

The general design of a bait trap includes two elements.

A place to hold the bait: Attractants such as pheromones or colors can be incorporated in the structure of the trap, while fruit, dung, carrion, etc. typically need a cup or compartment in which to be placed.

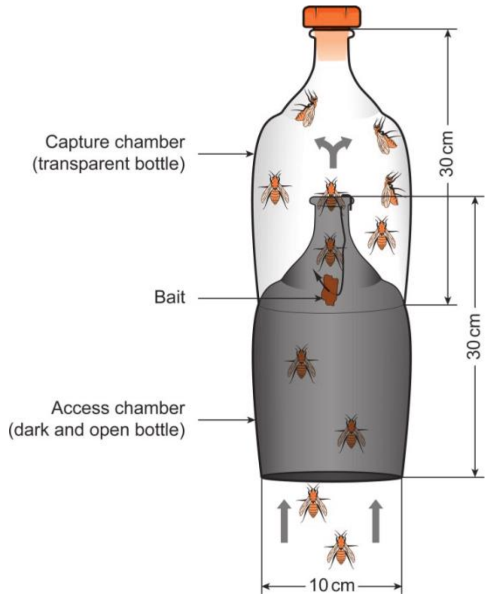


Fig-05 Bait Trap

(Source-https://www.researchgate.net/figure/Carrion-trap-used-to-collect-necrophagous-insects-in-southeastern-Brazil-adapted-from_fig2_236091501)

2) A means of killing and preserving the specimens: If the killing/preservative agent is liquid a cup or basin is needed, typically this is separate from the compartment used to hold the bait. Another common killing agent, especially for traps that use color or pheromones, is the use of a sticky substance, such as “tangle foot”. This is not a preservative, and “sticky traps” should be checked often if quality (or even identifiable) specimens are desired, and special solvents must be employed to remove the sticky material from the specimens.

Pitfall Traps

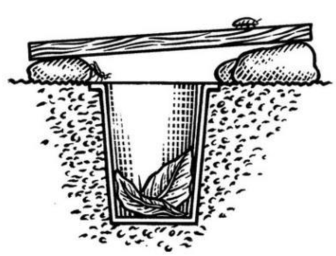


Fig-06 Pit Fall Trap(Source-https://www.discoverwildlife.com/how-to/make-things/how-to-make-a-pitfall-trap/)

A pitfall (Fig-06) trap is a simple device used to catch small insects that spend most of their time on the ground. In its most basic form, it consists of a container buried so that its top is level with the surface of the ground. Pitfall traps come in a variety of sizes and designs. They come in 2 main forms: dry and wet pitfall traps. Dry pitfall traps consist of a container (tin, jar or drum) buried in the ground with its rim at surface level used to trap mobile insects that fall into it. Wet pitfall traps are basically the same, but contain a solution designed to kill and preserve the trapped insects. The fluids that can be used in these traps include formalin (10% formaldehyde), methylated spirits, alcohol, ethylene glycol, trisodium phosphate, picric acid or even (with daily checked traps) plain water. A little detergent is usually added to break the surface tension of the liquid to promote quick drowning. The opening is usually covered by a sloped stone or lid or some other object. This is done to reduce the amount of rain and debris entering the trap, and to prevent animals in dry traps from drowning (when it rains) or overheating (during the day) as well as to keep out predators.

Collection Equipment

Nets

Nets: Nets used to collect insects and arthropods fall into three general categories; aerial nets, sweep nets, and aquatic nets. Each is specifically designed to interface with the environment in which the sampling will take place. Nets consist of three elements, the handle, the hoop, and the bag (Fig-07, 08).

Fig-07 Insect Net

(Source- https://www.eiscolabs.com/products/bi0140a)

Note on the use of nets: Many insects are vigilant. If you intend to sample with a net do so with competence, do not blunder around, cast a shadow willy-nilly, shake branches and vegetation, or stomp around in the water or on the bank before collecting. Otherwise your intended specimens will fly/swim away, drop to the ground, or otherwise disappear long before you take a single swipe.

Aquatic nets are used to sample aquatic environments ranging from lakes, ponds, rivers, streams, abandoned tires, puddles, tree holes, etc. Aquatic nets range from a standard size, with a ~1.5 m (5 ft) long handle, to diminutive sizes, such as aquarium nets with 5 cm (2 inch) wide hoops. Standard sized aquatic nets are robust and can be used somewhat forcefully, but be careful not to rip the bag on hidden underwater debris. Generally hoops of aquatic nets are flat on the distal (away from the handle) edge to facilitate collection against the benthos (bottom) of the water column. Do not use an aquatic net like a shovel; scooping too much muddy substrate, gravel, or aquatic vegetation will make separation of specimens from the sample difficult or impossible. After you have collected a sample, it can be "washed" by bobbing the sample in the water, making sure that the lip of the net doesn't go below the water and allow specimens to escape. Samples placed in a water tight container and kept cool will retain live specimens for hours. Otherwise samples should be preserved in 80% ethyl alcohol (with replacement 24 hours later if the sample was particularly watery) or can be sorted immediately. Sorting an aquatic sample in the field is best done using a **white pan** but care should be taken that small or cryptic organisms are not overlooked.

Fig-08 Aquatic Insect Net

(Source- https://www.indiamart.com/proddetail/aquatic-net-6195442197.html)

Beat Sheets

Beat Sheets: Beat Sheets are an important way to survey specific plants for insects (Beat **Sheet**, Fig-09). Foliage should be struck soundly with a stick so insects are jarred loose and fall onto the sheet. Rather than holding the beat sheet horizontal, tip the far corner up, insects will walk upslope and are less likely to immediately fly away. Specimens are easily collected with an aspirator.

Fig- 09 Beat Sheets

(https://www.wardsci.com/store/product/8867542/ward-s-beating-sheet)

Aspirator

aspirator (Fig-14), also known as a **pooter** in entomology, is a device used in the collection of small insects, usually for scientific purposes, for field and lab work. One of the most common designs consists of a small resealable jar or vial, the lid or stopper of which is penetrated by two tubes. On the inner end of one tube, fine mesh or another type of filter is attached, and this tube leads to the user's mouth (usually connected by a long, flexible piece of tubing). The end of the second tube projects into the collecting chamber, and its far end can then be placed over an insect or other small organism; the user sucks on the first tube, and the insect is drawn into the collecting chamber through the other.

3.3.1 Killing jars

Insect kill jars (Fig-10) are an essential piece of equipment for anyone making an insect collection and allow the collector to quickly and easily dispatch the insects they find in the field. While it is possible to make a very simple kill jar that contains only a paper towel soaked in a killing agent, it is nice to have a more permanent jar so you’re not getting the fluids all over your bugs.

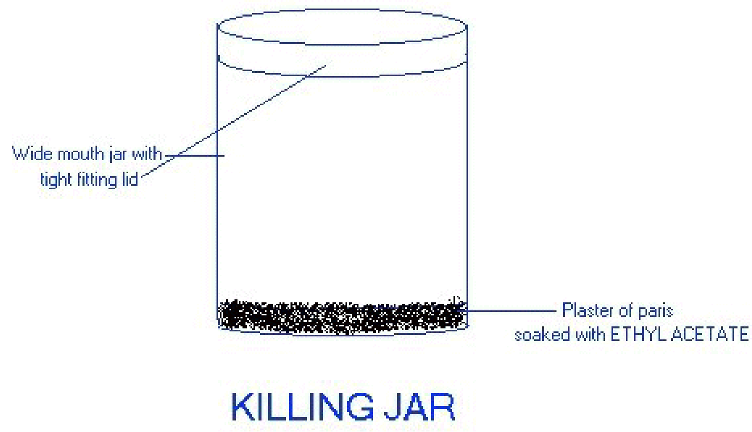


Fig-10 Killing Jar. (https://labnut.tripod.com/entomology/equipment.htm)

3.3.2 Relaxing jars

To make a relaxing chamber (Fig-11), **place 1 to 2 inches of clean sand or sawdust in the bottom of a large, airtight jar**. The jar must be large enough to allow small dishes to be placed inside, and must have a screw type or other lid to create airtight conditions inside the bottle.

Fig-11 Relaxing Jar

3.3.3 Aerial Nets

Aerial nets (Fig-12) are used to collect flying insects such as mayflies, dragonflies, butterflies, moths, true flies, bees, and wasps. Aerial nets are deliberately built light, with long thin handles, sometimes flexible hoops, and a soft bag with a large mesh size. These are ideal for collecting delicate specimens, such as mayflies or butterflies. An aerial net should never contact any solid things, but only "scoop" the insect from the air. The bag is long so it may be flipped over the hoop trapping the specimen after a catch. Generally specimens collected in aerial nets are removed from the net with the hands or transferred from the net to a **killing jar** (Fig-10). Aerial nets should never be used for beating vegetation or in the water (unless you absolutely have to. The only thing worse than ruining a fine net is not collecting a rare specimen).

Fig-12 (https://www.amazon.in/RESTCLOUD-Butterfly-Telescopic-Catching-Extends/dp/B07JZ5LL7K)

3.3.4 Sweeping or Beating Nets

Sweep nets (Fig-13), or beat nets, are used for sweeping vegetation or beating dead limbs, etc. They are very robust, with short thick handles, heavy inflexible hoops, and have hardy bags of very small mesh or light canvas cloth. The durability of the net allows the user to assault the substrate with such force that insects are jarred loose and collected in the net. Sweep net samples can be “quantified” if the area swept per sweep and number of sweeps per sample are held constant. Generally specimens are collected from a sweep net using an aspirator. If small flies, wasps, or other fast flying organisms are desired, the entire sample can be dumped into a plastic bag or other container, the specimens can be killed, cooled, frozen, etc. and dealt with later. Sweep nets can be used as aquatic nets in a pinch, although sweeping with a wet bag can be difficult.

Fig-13 (https://gemplers.com/collections/pest-insect-control-sweep-nets)

3.3.5 The Aspirator

Aspirator: An aspirator (also known as a "pooter" and more colloquially as a "sucky uppy thing") is a small device used to collect specimens (Fig-14). A collecting vial is sealed by a stopper that has two tubes. The fixed metal tube is the collection tube and the flexible yellow tube is the suction tube. Notice in the figure's insert that the opening to the suction tube is covered with very fine mesh. This is important. Small insects are sucked through the collection tube and trapped in the collection vial when suction is applied to the suction tube. The fine mesh over the suction tube keeps the specimens from being eaten by the collector. If you use a collection vial with a lid, then multiple collections can be kept separate by capping one vial and getting another.

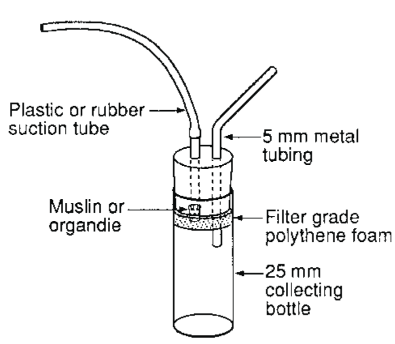


Fig-14 Aspirator

(Source-https://www.researchgate.net/figure/Standard-aspirator_fig11_236020507)

The collector does not need to fully inhale in order to create proper suction to capture a specimen, in fact inhaling through the device is not recommended. A "kissing" technique may be used where air is taken only into the mouth and not into the lungs. Use caution aspirating near fungal spoors, dust, or dead animals. Some people attach a new car gasoline in-line filter to the end of their suction tube to keep from inhaling dirt and debris.

Aspirators can be used for any and all types of collection and should be available whenever one is in the field.

3.3.6 Light traps

Light Trapping (ultraviolet lights ("black lights"), mercury vapor, and various others) is a general term describing the use of lights to collect insects. It exploits some insect's behavior of traveling to a light at night. This is a well-known phenomenon, although definitive explanations of this behavior are lacking. Insects tend to be best attracted to the shorter wavelengths given off by ultraviolet and mercury vapor lights.

Trap is a light sheet. This particular example is homemade but contains the basic design elements. The white sheet reflects light and acts as a structure for insects to land on. The sheet can be hung on a tight rope if trees/structures are available. Keep the hanging sheet tight (unlike what is illustrated in the figure) and do not bump it. A sheet on the ground is important as many insects will accumulate there. Mercury vapor (top) and ultraviolet (hanging) lights can be used together or in concert. Insects at light sheets are easily collected with **aspirators**.

Different groups of insects tend to come to light traps at different times of the night, for example bark beetles (Scolytinae) tend to arrive in the early evening, while saturniid moths (Saturniidae) may not arrive until 1 or 2 am. The best strategy is to turn the light on at dusk and keep it on until at least midnight.

3.3.7 Pitfall traps

Pitfall Traps (Fig-06) are used to collect ground dwelling insects and arthropods. The concept is simple; a container with preservative is placed in a hole in the ground and organisms fall in. The best design is a double cup design. After the hole is dug, two cups (typically robust disposable plastic drink cups, the expensive brands) are placed in the hole and soil packed around it to the level of the lip of the inner cup. The inner cup can now be removed and emptied while the outer cup keeps the hole from back filling with soil. It is important that the lip of the inner cup is level with the surrounding soil, otherwise small organisms may see it as a barrier and go around the cup or burrow beneath it.

3.3.8 Pan traps

Pan traps (Fig-15) are primarily used to capture micro Hymenoptera, but also trap many other insects. All you need for a pan trap is a small colored pan filled with soapy water. In fact, plastic bowls or plates using for picnicking are ideal. Use different colored bowls to catch different insects. Yellow, blue, white, and red are common colors used. To use the trap, just place a bowl on the ground and partially fill with water and a drop of dish liquid or other soap. The dish liquid is used to break the surface tension of the water, so the insects will fall through. Pan traps need to be checked at least daily. To collect the arthropods captured, the water is poured through a fine aquarium mesh net. It is then rinsed with water into a jar of 70% ethanol.

Fig-15 (https://u.osu.edu/biomuseum/tag/yellow-pan-trap/)

3.4 PRESERVATION

Insects specimens, if properly preserved and cared for, can last hundreds of years. Any collected specimen carries an enormous potential to inform about itself and the time and place of collection. Maintaining any specimen for many years carries a cost. Proper preservation ensures a high quality specimen, which increases the quality of information the specimen contains, and increases the value of the maintenance of the specimen. Generally two types of insects preserved on the basis of softness and hardness of the body. The soft bodied insects preserve in alcohol or other liquid preservative while the hard bodied insect preserve in dry method. Both preservation are as follows-

3.4.1 Soft bodied Insects

Soft-bodied insects should be preserved in plastic or glass vials with alcohol (70%-85% isopropyl or ethanol alcohol is ideal). These insects include larvae, scale insects, termites, aphids, thrips, silverfish, mayflies and earwigs. Other insects can be preserved in alcohol as well (with the exception of butterflies, moths, and bee flies (bombillids) because the alcohol will damage their wings). Preserve larval stages of insects and other soft-bodied specimens immediately by dropping them directly into a 70 to 90 percent ethyl or isopropyl alcohol solution. When collecting in the field, carry a few small vials of preservative fluid to store specimens.

An even better method of preserving caterpillars, grubs, and maggots, is to carry them home alive in separate plastic or glass containers, then submerge them for 1 to 2 minutes in boiling water. After this they can be immediately placed in the vials of alcohol. This process kills bacteria in the digestive tract and prevents discoloration. After a day or two, the liquid may become discolored. When this happens, transfer the specimens permanently to fresh alcohol solution. Specimens in vials must be labeled exactly as described for pinnedspecimens with two exceptions. Labels must be written with a soft-lead pencil or with India ink so that the writing does not dissolve or run. Only one label should be used, thus append any information such as host and identification to the bottom of the label. Cut labels longer to allow for this. Labels must be included with the specimen inside the vial. Do not attach them to the outside as this has proven to be an unreliable method of labeling.

3.4.2 Hard bodied Insects- The hard bodied insects preserved by dry preservative method. The steps have included in this method is Collecting, Killing, Pinning, Spreading, Drying and preservation the specimens. The details of this method is as follows-

(i) Collection-The insects have been collected by the different method and procedure which explain in above text.

Fig-16 Insect Spreading Board

The procedure is as follows-

(ii) Pinning Insects-Insect pins of various sizes are available from entomological suppliers. It recommend getting size as they're good general-purpose sizes for most insects. Use only pins designed for pinning insects as other household pins may rust and damage the specimens. Any insect large enough to be pinned without the risk of breaking or distorting it is pinned from the top (dorsal) side, straight down through its body. The correct point of insertion depends on the type of insect are pinning. The insect will be most pliable and easy to pin and preserve right after it dies. Try to pin the insect as soon as possible after it dies for the best results Generally, the area is just slightly right of the midline of the insect's thorax. To pin the insect in the recommended location which reduce the risk of damaging important identifying characteristics of the insects.

Insert an insect pin through the middle of the thorax (the middle section between the head and abdomen), slightly off-center to the right (Fig-17). Push the pin all the way through the insect's body, then about ½" into the spreading board or another piece of Styrofoam board. The insect should typically be about half way up the pin or far enough above the spreading board so that you can freely position the legs.

After a butterfly or moth is relaxed, carefully hold the specimen under its thorax between your thumb and forefinger. Gently squeeze the thorax; the wings should separate slightly. From the top, insert a pin through the center of the thorax.

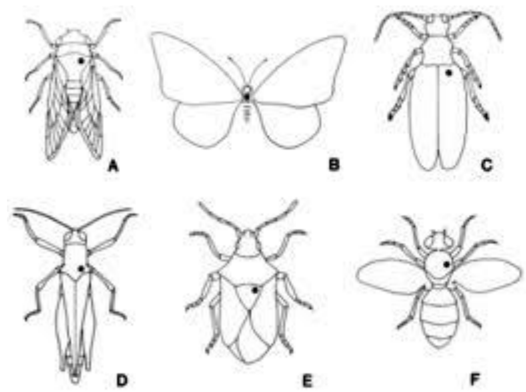


Figure- 17 Pinning Method, A-Fly, B- Butterfly, C-Beetle, D-Grasshopper, E-Bug, F-Wasp

Different insects will be pinned at different part without damaging its identifying characteristics.

1. *Bees, wasps, flies, etc.* - Pin through the thorax between bases of fore wings and slightly to right of middle line.
2. *True bugs* - Pin through the scutellum, which is the triangular area between the bases of the wings.
3. *Grasshoppers, crickets, etc.* - Pin through the prothorax or "saddle" slightly to the right of the center line.
4. *Beetles* - Pin through the forepart of the right wing cover near the centerline.
5. *Butterflies, moths, dragonflies, etc.* - Pin through center of thorax between the bases of forewings.

3.5 PINNING, MOUNTING AND DISPLAYING OF INSECTS

The preferred way to display and study adult insects is to pin them into display boxes using special insect pins. The pins are pushed through the thorax of the insects while they are still fresh and the legs and antennae are placed in a natural position. This allows the specimens to be handled and studied without damaging them. In pinning insects always use special insect mounting pins (Entomological Pin) that are specially treated to resist rusting. Insect pins vary in size from 000 to number 8. The latter is the largest in diameter. Numbers 2 and 3 usually work the best for the amateur collector. A good rule is to pin the insect slightly to the rightside of the middle and down through the area where the middle pair of legs is attached. Styrofoam is an excellent base for positioning the legs so they will dry in the correct position. There is a slight variation in the pinning of the different kinds of insects.

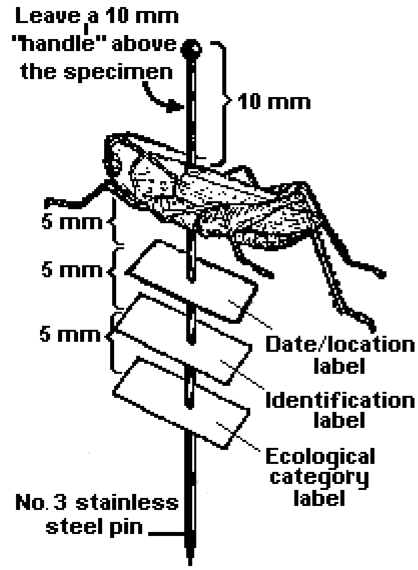
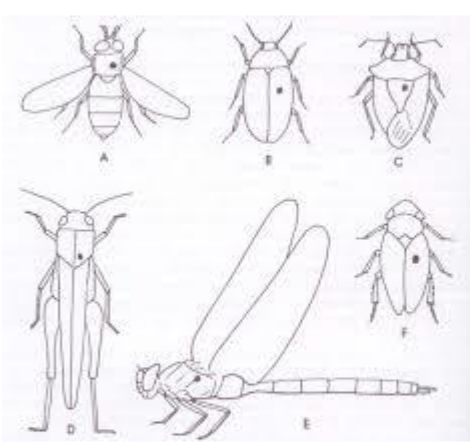


Fig-18 Pinning and Labeling of insects

Correct Pinning Important- To do a nice job of pinning insects will require some practice. All insects must be pinned so that they are straight on the pins. Do not tilt the specimens on the pin. The height of the specimen on the pin will depend somewhat on the size of the insect; however, always keep the distances from the top of the insect's body to the head of the pin the same. Usually 1/3 of the pin should be above the upper surface of the insect; this will allow enough room to permit handling specimens without actually touching them.

Specimens should be handled carefully to keep all legs and antennae (Fig-18).



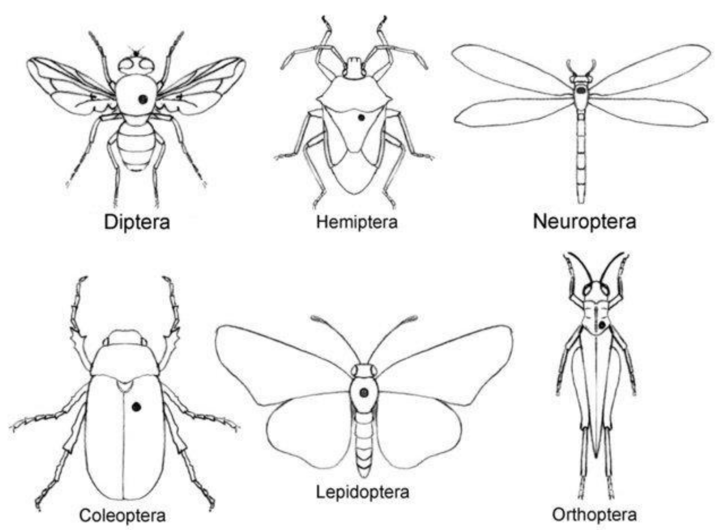


Fig-19 Different insects pinning method

A small amount of time spent positioning the legs and antennae will dress up the collection. Insect specimens can be kept for long periods of time. Many of the specimens in university collections are nearly 100 years old.

Labeling - By using pinning block, it can also properly space the labels that go on the pin (beneath the insect specimen). The label nearest the insect gives the common name. The second label gives the scientific name. All labels should be of uniform size, white in color, and the information type written or printed neatly. The appearance of a collection of insects is important if all the specimens and labels are placed at a uniform height on the pins. This is easily done by using a wooden pinning block (Fig-20).

Pinning Small Insects- Many of the smaller insects cannot be pinned directly through the body with regular insect pins. These should be mounted on card points. Card points are slender triangles of paper. These triangles are pinned through the broad end with a regular insect pin and the insect is glued to the narrow point (Fig-19 & 20).

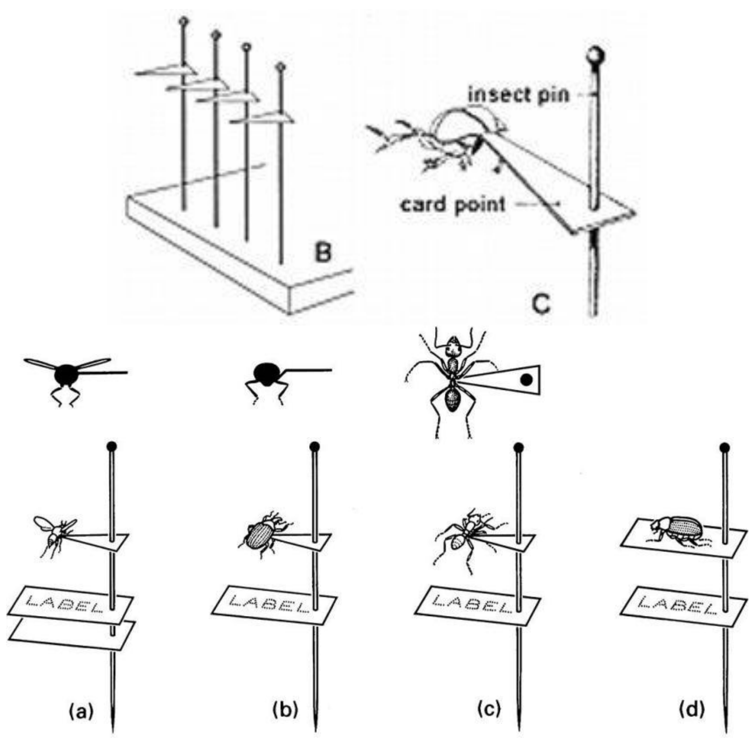


Fig-20 Labeling of insects

3.6 SUMMARY

The collection of insects is a important practices in which the insects identified easily. It is used for study the insects in relation to their beneficial and harmfulness. Insects are collected using funnels, pitfall traps, bottle traps, malaise traps, flight interception traps and other slow active of insect traps, some of which are baited with small bits of sweet foods (such as honey). Different designs of ultraviolet light traps such as the Robinson trap are also used by entomologists for collecting nocturnal (night active) insects (especially moths) during faunal survey studies. Pooters or Aspirators suck up insects too small or delicate to handle with fingers.

Different types of insects collecting nets are used for this practices. Aerial insects are used to collected by Aerial insect nets. Grass and brush insects are collected with the help of Sweep net.. Sweep net is generally constructed from more hard material. During sweeping, the collector walks forward while, and the net is moved through plants and grasses with force. Continuous sweeping for some distance and then the net is flipped over, with the bag hanging over the rim, cought the insects until they can be released by a pooter. Once collected, a killing jar is used to kill required insects before they damage themselves trying to escape. However, killing jars are generally only used on hard-bodied insects. Soft-bodied insects, such as those in the larval stage, are generally fixed in a vial containing an ethanol and water solution. 70% alcohol is usually the best general killing and preserve agent. Some collectors use **isopropanol, or isopropyl alcohol because** Isopropanol does not seem to harden specimens as much as ethanol. . Generally two types of insects preserved on the basis of softness and hardness of the body. The soft bodied insects preserve in alcohol or other liquid preservative while the hard bodied insect preserve in dry method. Soft bodied insects include larvae, scale insects, termites, aphids, thrips, silverfish, mayflies and earwigs. Specimens will be mounted only when they are fully relaxed, i.e. when their legs and wings are freely movable, rather than stiff or dry and brittle. All dry- mounting methods use entomological **macropins** — these are stainless steel pins. arding is not recommended for adult insects because structures on the underside are obscured by being glued to the card; however, carding may be suitable for mounting exuviae, pupal cases, puparia, or scale covers. **Spreading** involves holding the appendages away from the body while the specimens are drying. Legs and antennae can be held in semi-natural positions with pins and the wings can be opened and held out horizontally on a setting board using pieces of tracing paper, cellophane, greaseproof paper, etc. **Setting boards** can be constructed from pieces of polyethylene foam. Drying process completed after 24 hours from spreading. Dry specimens transfer in preserving naphthalene balls fumigated insects box.

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3.8 TERMINAL QUESTIONS AND ANSWERS

Q1. What is collection and Preservation Method of Insects.

Q2. Explain Insects collection Method.

Q3. How you preserve the soft bodied and hard bodied insects.

Q4. How you Preserve Small sized insects.

Q5. Write the significance of Wet preservation.

Q6. Write about the hard bodied insects' preservation.

Q7. Write the short notes on-

(a) Entomological pins (b) Spreading board (c) Insect drying (d) Hand pick method (e) Light Trap (e) Adhesive Trap

UNIT - 4 PARENTAL CARE IN INSECTS

CONTENTS:

Parental care may be defined as any effort of the parent that increases the overall developmental rate of their offsprings, It is a kind of parental investment to increase the propagation of its species .It affects the overall performances of the offsprings.

4.1 OBJECTIVES

- The main objective of this study is to understand the positive aspects of parental care in insects
- The learner will be able to understand how the parental care increases the survival chances of the offsprings when they are associated with their parents.
- The learner will also able to know how parental care directly increases the reproductive success of the offsprings when they are associated with their parents till adulthood
- The learner will also be able to know about the brood parasitism which is a breeding strategy in which the parasitic female lays her eggs in the host nest and relies on the host to take care of her offsprings.

4.2 INTRODUCTION

Parental care may defined as any investment made or any effort taken by parents to take care of their young ones in order to increase the chances of their survival and hence increase their reproductive capabilities. The parents provide food to the young ones, protect them from predators and help them to be successful in life.

Parental care is most highly evolved in mammals and bird but examples of parental care are also found in other animals like fishes, amphibian, insects and other invertebrates. Since insects are a highly diverse group, parental behavior has developed many times independently in response to environmental factors. Insects show the highest diversity with more than 1 million species in the world but only 1% species have developed parental behavior.

Parents of most insects provide almost no care for their offsprings beyond supplying the eggs with a little amount of yolk and placing the eggs in a location safe from environmental hazards. The rare occurrence of post oviposition parental care in some insects is thought to reflect the early evolution of a complex of traits that effectively protected the eggs and larva stages from predators, parasites and other environmental hazards .So insects provide post ovipositional parental care that enhances the survival and overall development of the offsprings, often a substantial cost to the parents future reproductive potential. Most parents provide simple form of care whereby the female attends the eggs until hatching. However, a few insects exhibit elaborate forms of parental care similar to those of birds and mammals.

Selection pressure favours lots of offsprings and parental care is limited to species which produce fewer young ones .Parental care can mediate transition from solitary to group of family living both for an individual and on an evolutionary scale. It is likely to have developed as an altruistic trait to enable the parents to better pass on their genes by improving the survival of their offsprings even at the cost of their own energy, food or even future reproductive opportunities. Parental behavior in insects ranges from

- Covering of eggs with protective coating
- Finding a good habitat for egg laying
- Forming eusocial societies with alloparental care
- Feeding and protecting the young ones
- Lifelong association of parents and offsprings

Parental behavior can be observed at the beginning of the egg stage and can last upto the larval stage.Some species however ,put more effort on parental care after the egg hatching stage as larva are more vulnerable and dispose to predators. Generally parental care is provided by only females(**maternal care**),however uniparental male care (**paternal care**) is quite rare. In some cases **biparental care** has been seen i.e.,male and female form long association to rear young ones to adulthood.

Parental behaviour is most developed in the following insects orders:

- Hemiptera (true bugs)
- Thysanoptera (thrips)
- Embioptera (Web-spinners)
- Coleoptera (beetles)
- Hymenoptera (ants,wasps, and bees)
- Isoptera (termites)

4.2.2 Brood parasitism

Parental care have evolved in some insects from time to time bur brood parasitism is also seen in some insects.It is a reproductive strategy whereby the offsprings of one species are reared in the nest of the same species (interspecific brood parasitism)or different species (intraspecific brood parasitism).Brood parasite manipulates the behavior of the host so that the host takes care of the young ones of the parasites instead of its own young ones. Thu the host is cheated .The cuckoo bees, for example ,lay her eggs in the brood chambers of other bees. The young ones of cuckoo bees eat the pollen grains stored in the hive and often eat the eggs of the host species.

4.2.3 Forms of parental care

Parental care is a significant behavioural adapation in the life history of a number of animals including insects. The forms of parental care are quite diverse ranging from uniparental care (generally female care) to elaborate and long term biparental care. Parental care is an ancient behavioral strategy that has occurred independently many times in different insect orders and several other arthropods. It enhances the fitness and survival of offsprings by providing protection from predators, parasites and various environmental hazards as well providing food to the young ones.

- **Maternal care:**

Maternal care is the most common type of parental care in insects. The female takes care of the eggs and the young one. The simple forms of maternal care provided by the mothers to their eggs is to incorporate some defensive chemical into their eggs ,laying eggs in a protected place or covering the eggs with a shell or some waxy substance before abandoning them.

Example: Female webs pinner (Embioptera),***Antipaluria urichi*** (fig:1) covers her eggs with macerated bark and other substance like silk to protect them from hymenopteran parasites. It constructs silk galleries and remains with her eggs and nymphs .females of some insect species guard their eggs and nymphs until maturity by defensive behavior.

Fig: 1 Antipaluria urichi producing a silk covering

Example: Female eggplant lace bugs *Graphia solani*, (fig.2)rushes at any approaching predator by fanning her wings. Some females facilitate nymphal feeding

Fig 2.Female eggplant lace bugs *Graphia solani* fanning her wings

Example: The female plant feeding bug, ***Umbonia crassicornis, (fig-3)***remain with the nymphs until they reach adulthood and help them in feed.It cuts slits in the bark with her ovipositor so that the nymphs can easily feed.In some insects maternal care is in the form of period of internal development.

Fig.3 Plant feeding bug, *Umbonia crassicornis*

Example: The oviparous German cockroach,***Blattella germanica*** **(fig.4)**carries her egg sac until the nymphs hatch, *Blattella vaga* produces a secretion on which the newly hatched nymphs feed for a short time.

Fig: 4 German cockroach,*Blattella germanica*

- **Paternal care**

Paternal care exclusively by male is quite rare and is limited to about 100 insect species, mostly of the order Hemiptera.

Example: The female of the ferocious water bug,***Abedus herbertii (fig.5)***glues the eggs on the hemelytra of the male.It stops feeding and spends his time with the eggs until they hatch. It aerates the eggs and also protects them from predators.Males also contributes to offspring fitness in indirect manner. They transfer proteins or protective substances in a spermatophore and these have been shown to be important for the reproductive success of the female,

Fig: 5 Giant water bug,*Abedus herberti* carrying egg on her back

Example: The male Katydids provide a spermatophore during copulation which may contain 40% of its body mass .Male arctid moth, ***Utethesia ornathrix*** (**fig:6**), transfers pyrrolizidine alkaloids to the female during copulation. This alkaloid is passed on the eggs which become unpalatable to the predators.

Fig6 Male arctid moth, *Utethesia ornathrix*

- **Biparental care**

Biparental care is the care of the eggs and young ones by both the parents .It is not very common and is restricted to the beetles, termites and cockroaches and earwigs. It may be elaborate and extensive.

Example: Male and female woodroach, *Cryptocercus punctulatus* (**fig.7**)and all termites construct an extensive nest .They guard ,protect and facilitate feeding of young ones till they reach adulthood. Woodroaches produces a secretion from their hindgut which contains symbiotic fauna which is necessary for digestion of wood on which the young ones feed .In most of the termites the workers and soldiers' do not reproduce and remain as alloparents.

Fig*7: Cryptocercus punctulatus* in nest

4.3 CARE FOR EGGS

The eggs of insects are microlecithal and centrolecithal. Most insects just drop their eggs and keep moving but in some insects parental care starts from the eggs stage. Oviparous insects have three main options to increase their reproductive success: investing into egg number, investing into egg mass and egg care. The female makes all efforts to avoid desiccation and predation of her eggs. There are various methods by which female take care of their eggs to enhance the fitness of their offspring.

i.)**Coating the eggs**:

The female of some species secrete a protective coating on the eggs.For example: The meadow spittle bug, ***Philaenus, spumarius***, (Fig.8)lays large egg masses and cover them with frothy foam. It keeps the egg and nymphs hydrated and protected from natural enemies.

Fig: 8 The Spittle bug, *Philaenus, spumarius*, lays large egg masses and cover them with frothy foam

ii)**Egg brooding**: The gravid female ferocious water bug, *Abedus herberti* approaches the male and repeatedly attempts to ovposit on his back. Prior to oviposition, the female secretes sticky mucus that covers the males back. Ovipositions continues for 12-48 hours and the whole hemelytra of the male is covered with egg. The male moves about with the eggs and takes care of them until they hatch. They protect them from the approaching predators. Furthermore, egg brooding may lower the cost of care by allowing the parents to forage while caring for the eggs.

In the golden egg *bug Phyllomorpha laciniata* (**fig.9)**the eggs might be carried by the male that fertilized the egg or by conspecifics that are not related to the eggs this example suggest that some cases of apparent egg brooding might have evolved as a form of intraspecific brood parasitism rather than a form of parental care.

Fig9 *Phyllomorpha laciniata*

iii**)Provisioning of gametes**: In most insects the amount of resources allotted to each egg is the primary and ancestral mechanism by which the parents provide care to their offspring against various environmental hazards, such as, desiccation, drowning predators and pathogens. This is beneficial to the offspring as it enhances their survival but is costly for the females left with less resources to invest on other eggs.

Examples: The female of seed-beetle, ***Stator limbatus***,(fig.10) shows plasticity in the size of its egg depending on the host plant, *Cercidium floridium* and *Accacia greggii*. Consequently the female produces larger and few eggs when she oviposits on tougher seeds of *C .floridium* and smaller and large no. of eggs when she oviposits on softer seeds *A.greggi*i.

Fig10 Stator limbatus,the seed beetle

It has been shown experimentally that variation in egg size has important effects on offspring fitness. When females entrained to lay small sized egg on softer seeds of *A.greggii* are forced to oviposits on tougher seeds of *C.floridium,* the survival of larvae is much lower as compare to larger eggs.

iv)**Supplying eggs with defensive chemicals**: Females of some insects enhance the fitness of their off springs by supplying the eggs with defensive chemicals or structures which protect them from predators, parasitoids or pathogens.

Examples: The female of seven spotted ladybird, ***Coccinella septempuncta*** (**fig 11**)supply their eggs with alkaloids that are produced de novo by the adults. The female swallow tail butterfly ***Atrphaneura alcinus*** supply their eggs with bitter aristolochic acid which they obtain through their diet. They feed on the larvae of birthworts (*Aristolochia spp).*

Fig11 Coccinella septempuncta

The female seed beetle, ***Mimosestes amicus*** (**fig12)** protect their viable eggs from parasitic wasp, ***Uscana semifumipennis*** by shielding them with additional inviable eggs. These inviable eggs are smaller in size and the wasp larvae developing inside them suffer higher mortality then those developing within viable eggs.

Fig.12 Mimosestes amicus showing egg protection

v) **Ovipositions site selection**:

The females of some insects enhance the fitness of their offsprings by selecting such a site oviposition that ensures protection from a wide range of environmental hazards and that provides an adequate amount or resources after hatching.

Example : The female parasitic wasp, ***Megarphyssa atrata***,(**fig.13**)has a long ovipositor which can bore through 14cm wood to oviposit on the larvae of its host *Tremex columba*, the wood eating sawfly.

Fig13 Megarphyssa atrata,with a long ovipositor

vi)**Eggs attendance**

Eggs attendance is one of the most common type of post oviposition care in some insects like earwigs, hemipterans and beetles, etc. it occurs when the parents remain with their egss at a fixed location after oviposition, usually at the oviposition site

Example: in the treehopper, *Pubilia concave*, hatching success as twice as high when the female parent attends the eggs after oviposition as compare to when she is removed experimentally .

vii**) Nest building and burrowing**: Nest building and burrowing may increase the fitness of the offsprings by concealing the eggs and juveniles from predators and parasitoids and other environmental hazards. They use different materials to build their nests.

Examples : the mud dauber wasp, ***Trypoxylon politum*** (fig.14)use mud to build their nest. The wasp Polistes build their nest from processed plant material such as paper .

Fig: 14 mud dauber wasp, *Trypoxylon politum* use mud to build their nest

The female European earwing ,***Forficula auricularia*** (fig15)constructs burrows for concealing their r eggs and juvenile, the female guards over a brood of nymphs .

Fig 15 *Forficula auricularia*(female earwig)with egg brood and nymph

viii.) **Viviparity and ovoviviparity**:

Viviparous females give births to young once that have hatched within the female, while ovoviviparous females oviposit eggs at an advanced stage of development that hatch during or soon after oviposition. All ovoviviparous females are lecithotrophic, i.e, they nourish the developing embryos on the yolk present in egg. The viviparous females exhibit diverse forms of embryonic nourishment. They may be lecithotrophic or metrotrophic where the embryo is nourished by sources other than yolk.

Example: ***Diploptera punctate***,(fig 20) the pacific beetle cockroach is metrotrophic . It nourishes broods of about 10 embryos with a milk like secretion produced by the uterine lining of the female.

Glossina(tsetse) females (fig.17)nourishes a single embryo within utero and gives birth to a larva that may weigh ,more than the female. The larva obtains all nutrients from the females. The other adult body size is determined by the amount of nutrients the larva has obtained from the female during the gestation period.

fig17 Glossina(tse-tse fly)

4.4 BROOD CARE

Brood care is an altruistic trait that has evolved to enhance the fitness and survival of the offsprings at the cost of the parents in terms of time and resource expenditure.

- **Uniparental Care:**

The female potter wasp builds small clay nests for their young ones, bring food for them and protect them from predators, repair damage and remove debris from the nest. Male do not play any role in taking care of larvae but do patrol the nests to find the females to make with them.

- **Biparental larval care**

The male and female burying beetle (***Nicrophorus spp***.(fig 19) dig beneath the dead body of a vertebrate (mouse) and conceal it from other animals like badges, crows, foxes, etc. and flies which very quickly lay eggs on it. While digging through the carcass the couple spreads antimicrobial chemicals over it to prevent bacterial and fungal growth. It slows down decay and reduces the small of the corpse. This takes almost two days and the corpse is buried almost 60cm underground the beetles excavate a crypt for the carcass(fig.18). The pair then mates and female lays fertilized eggs in the soil around the body after two days. The pair waits for the eggs to hatch and in the meantime continue to spread the antimicrobial covering over the corpse to keep it fresh. When the larvae emerge out they move into a trough in the body excavated by their parents. They call their parents and beg for food. They feed their young ones by regurgitating pieces of corpse in liquid form. This continues for about two weeks during which they continue for about two weeks, during which they continue to spread microbial covering, protect their offspring from predators and feeding their offspring.

The larvae dig into the side of the crypt to form small individual chambers in which they overwinter up to next spring and then pupate and finally emerge as adults. The parents unearth themselves and fly their separate ways. The parents do not form monogamous pairs but stay together until their larvae search adulthood. The burying beetles are only distributed in temperate regions. They are not found in tropical regions as these habitats are too warm. The corpse decay very rapidly in tropics and fungi and bacteria also grow very fast and the beetles are not able to find the corpse and bury it in time.

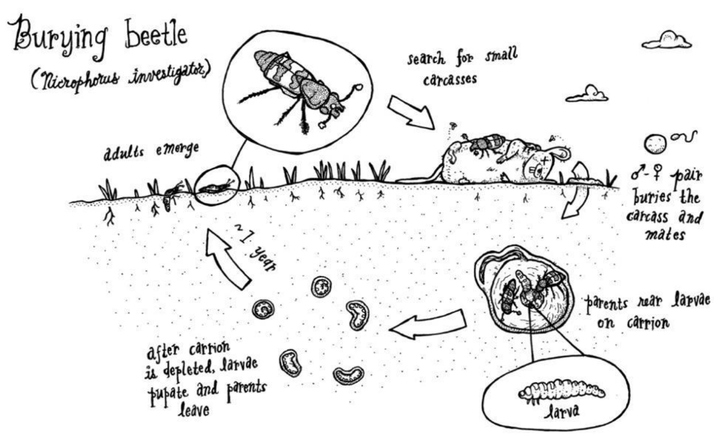

Fig 18.Life cycle of burying beetle

Fig 19.Burying beetle Nicrophorus feeding her nymph

- **Family group**

Cockroaches are occasionally cannibalistic but they exhibit one of the most comprehensive parental cares among insects. The females of some species are viviparous. They keep their offspring under their wings and feed them on a protein and carbohydrate rich milk diet until they are old enough to be born. Both cockroaches and burying beetles form family group. In cockroaches it is necessary because nymphs need gut protozoa which is essential for digesting wood cellulose as the nymphs feed on wood. They lose their gut protozoa after each molt. It means that the adults have to live with the nymphs till they reach adulthood.

Fig20 Cockroach Diploptera punctate showing viviparity

Termites are closely related to cockroaches and family groups gradually evolved to become eusocial colony organization. Living close together with, millions of siblings allow the termites to be secure and have a constant food supply. It allows development of traits like monogamy, foraging and nest building the switch from parental care to sibling care is thought to have led to social behavior in ants, wasps and bees. It is thought that brood care has driven the formation of families and social groups' invertebrates.

4.5 BROOD PARASITISM

Brood parasitism also known as social parasitism is a breeding strategy in which the female brood parasite frees herself from all parental care by laying its eggs in the nest of another individual, the host, of the same species (intraspecific or conspecific brood parasite) or of different species (intraspecific brood parasitism) .The brood parasite relies on unrelated foster parents for the care of its eggs or hatchlings. It is therefore, the exploitation by one individual, the brood parasite, of the parental care of another individual, the host. A brood parasite manipulates the behavior of the host so that the host raises the young ones of the parasite at the expense of its own young ones. There are many different types of cuckoo bees and all of them lay their eggs in the cells of other bee's hive. They are normally known as kleptoparasites and not brood parasites, because the hatchlings are not directly fed by the adult host. They simply eat the food gathered by their host. A kleptoparasites is an animal that steals food and prey from other animal. Brood parasitism is a form of kleptoparasitism .Similarly the cuckoo wasps also kleptoparasites .They lay their egg in the nests of other wasps like potter wasp and mud wasps. The Cuckoo bumble bees (**fig 23**) exhibit true brood parasitism. Their young ones are fed by adult hosts. The queen cuckoo bumblebee kills and replaces the queen of the colony of the host species. It then forces the workers of the host colony to feed their brood. The paper wasp *Polistes sulcifer* also exhibit true brood parasitism. It has lost its ability to build its own nest and relies on its host *P. dominuta* to raise its brood. The adult host wasp directly feeds the larvae of the parasite. Sometimes the host insect is tricked to bring the larvae of the parasite species into its own nest. Example, the parasitic species is a butterfly *Phengaris rebeli* and the host is ant, *Myrmic schenckii* (interspecific brood parasitism)

The butterfly larvae release a chemical that confuse the ant. They treat the larvae of butterfly as their own larvae, bring them into their nest and feed them.

Fig21 Paper wasp:*Polistes*

Fig22 Paper nest of *Polistes* wasp

Fig23 Cuckoo bumble- bee exhibit brood parasitism

4.5.1 Benefits of brood parasitism

The benefits of brood parasitism are:

(i)Brood parasitism relieves the parasitic parent from the investment of rearing of young one.

(ii.)It enables the brood parasite to spend more time on other activities like foraging and producing offspring.

(iii.)The risk of egg loss is mitigated as the eggs are laid and young ones are reared in the nest of other host.

4.6 SUMMARY

Parental care is a significant behavior adaptation in the life history of several animals including insects. It is any effort of the parent that enhances the survival and fitness of their offspring. The parents, mostly females, provide food to the young ones .Insects show highest diversity with more than 1 million species but 1% species have developed parental behavior. Selection pressure favors lots of offspring and parental care is limited to species which produce fewer offspring. Most simple form of parental care is when the female attends the eggs until hatching. Parental care can mediate transition from solitary to group two family living. It is likely to have developed as an altruistic trait to enable the parents to better pass on their genes by improving the survival of their offsprings even at the cost of their own energy, food or even future reproductive opportunities.

Parental care may be the maternal parental care, care provided by female parent only it is the most common form of parental care. Paternal care - care provided by male parent only it is very rare. Biparental care- both male and female parents form long association to rear the offspring to adulthood. It is also rare females make all efforts to prevent desiccation and predation of her eggs. Viviparous female birth of young ones, example: the cockroach, *Diploptera punctate.* Oviparous female oviposit at an advanced stage of development, for example: tsetse fly, *Glossina.* Brood care is an altruistic trait that has evolved to enhance the fitness and survival of the offsprings. The male and female burying beetle *(Nicrophorus spp*.) exhibit biparental larval care. Cockroach and burying beetles form family groups. Family group gradually evolved to become eusocial colony organization as in termites, bees, ants and wasps. Brood Care has driven the formation of families and social groups in vertebrates. Brood parasitism is a breeding strategy in which the female brood parasite relies on other individuals (the host) to raise their young ones. Thus the female brood parasite frees herself of all parental care by laying her eggs in the host nest.

4.7 TERMINAL QUESTIONS AND ANSWERS

I .Multiple choice questions

1. Parental care increases

a) Survival chances of offsprings b) Fitness of offspring

c) Quality of offsprings d) All of these

2. *Nicrophorus* spp. is commonly known as

a) burying beetle b)giant water bug

c) tse-tse fly d) potter wasp

3. Which of the following show biparental larval care

a) Potter wasp b) Cuckoo wasp

c) Burying beetle d) Web spinner

4) Which of the following is viviparous?

a) *Diploptera punctata* *b)Glossina spp.*

c) Nicrophorus spp. *d)Polistes*

5. Which of the following is a true brood parasite?

a)Cuckoo bee b)Cuckoo bumble bee

c) Cuckoo wasp d) All of these

1.(d) 2.(a) 3.(c).4.(a) 5 (b)

- **Fill in the blanks**

1 .Parental care is a kind of parental ……….

2. Brood parasitism is a …….strategy.

3. Parental care by only female is known as …….

4. Brood parasitism is a form of ………

5. The ….of *Abedus herberti* take care of eggs.

6…..wasp make nest from paper.

1**.investment**2.**breeding** 3.**materna**l 4.**kleptoparasitism** 5 **mal**e 6.**Poliste**s

- **Answer the following questions**

Q1.What is parental care?Give its different forms and benefits.

Q2.Give three examples of egg -care in insects.

Q3.What is brood care? Explain this with the example of burying beetle.

Q4.What is viviparity and ovoviviparity? Explain it with few examples.

Q5. Define brood parasitism. Give few examples of brood parasitism.

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UNIT-5 GENERALIZED STRUCTURE, HABIT AND HABITAT OF THE FOLLOWING ORDERS WITH FAMILIES

CONTENTS:

5.1 OBJECTIVES

- The learner will be able to familiarise itself with the five important orders of economic importance including their structure, habit, habitat and distribution.
- Students will also be able to make predictions and collect data for their research studies by going through the distinguishing characteristics of the different insect orders and their families.
- The learner will be able to study the specializations and adaptability of their structures such as the mouthparts, antennae, legs, wings and pronotum etc.
- This unit will help the student to understand how an insect lives, functions, and reproduce also

5.2 INTRODUCTION

Insects are present everywhere in the world where life is possible. The ecological importance of insects cannot be underestimated: They form the basal part of the food pyramid and impact our agriculture ecosystems as well as human health. Their extinction can have a cascading effect on the upper levels of the food pyramid.because they have invaded almost all the habitats. They differ widely in their forms, structure and behavior in relation to the mode of life they adapted. They are so abundant that they represent 80% of the animal kingdom. After knowing about the different insects orders of economic importance we could gain a better understanding of their role in the web of life, as indicators of environmental quality, as predators of harmful species, and their potential threats to crops, homes and health too. They also help us to learn about human health in many ways. In the present unit, we will discuss about the structure, habit and habitat of different orders along with their families of economic importance.

5.3 Order: Thysanura(Thrips) (Thysan-fringed.ura-tail;bristle tails silverfishes,or firebrats) (fig1&2)

(These are apterous (Wingless) insects. These are characterized by ectognathous biting mouthparts having 11-segmented abdomen with lateral styliform pregenital segmental appendages,a pair of cerci and a long median caudal filament).

- **Habit and Habitat**: They are mostly adapted for a concealed life in the soil, rotting wood under stones, in the leaf deposits of forest floors, nests of ant and termites, extremely active, diurnal or nocturnal. They are truly omnivores usually feed on dead vegetable matter. They usually lay eggs in crevices, the larva undergoes 6 or more instars stages before maturity. They are capable of jumping with agility**.**Their mating habits are peculiar because when the males drop a spermatophore, the female picks it from the substrate during the mating dance.
- **Distribution:** They are cosmopolitan and have about 550 species in the world, while 32 species from five families been recorded in India.
- **Structure**
  - **Head:** Prognathous, broadly sessile and very little movable. Antennae are long ,filiform and composed of more than 30 segments, compound eyes are larger or sometimes vestigial or absent
  - **Thorax:** Thoracic segment distinct with well-developed paranotal lobes supplied by tracheae.
  - **Leg:** All are of equal size with a pair of claws, coxae are large, tarsi are with 2-3segments.
  - **Abdomen:** Abdomen with 10 complete segments, , XI segment often modified with paired multi segmented cerci and a median long caudal filament. Each abdominal segment bears a pair of styliform appendages and one or two median avertible sac or vesicles.
  - **Mouth parts:** Ectognathous, biting and chewing, mandible dentate, dicondylic; maxillae well developed with distinct galea and lacinia and palpi. 4, 5, 7 segmented ,labium well developed, with separate glossa and paraglossa; mentum and submentum with broad plates; prementum often paired**.**
  - **Alimentary canal:** Alimentary canal is a straight tube with large crop proventriculus, large midgut with diverticula, hindgut coiled , salivary gland well developed.

- **Malpighian tubules: 4**-8 in number in *Lepismatids* and 12-20 in *Machilids*
- **Heart:** Heart with numerous ostia
- **External genitalia:** The 8th and 9th abdominal segments possess an ovipositor in female and and male genitalia in male, while the penis is on the 9th segment.
- **Nervous system:** It consists of brain ,sub-oesophageal .three thoracic and eight abdominal ganglia.
- **Reproductive system**: Testes with 2-6follicles,the vas deferens often long and greatlyy convulated, ductus ejaculatorious short and ends in aedeagus, ovary with 5-7 panoistic ovarioles, sometimes arranged segmentally ,the oviducts join together just before opening in eighth sternum.
- **Ecdysis/molting**: Thysanurans molts, for more than 41 times, however the sexes are distinguishable after the 8th molt.

Figure1 silver fish

Figure2 fire brat

5.3.1 Order Thysanura is divided into two sub-orders namely **Microcoryphia**and Z**ygentom**a.

Microcoryphia consists of *superfamily :**Machiloidea*** and *family:Machilidae,*While Zygentoma represents the superfamily :***Lepismatoidea***and *family:Lepismatidae.*

The *machiloids* and *lepismatoids* are generally called as the bristle tails and the silverfish respectively. The distinguishing features of both the families are mentioned below-

Character	*superfamily :Machiloidea eg.Pterobius,Machilus*	*superfamily :Lepismatoidea eg.Silverfish*
Body	Cylindrical,dorsal side greatly reduced	Dorsal side very slightly arched,wider in the thoracic region
Prothorax	Smaller than mesothorax	Prothorax not narrower but as wide as mesothorax
Maxillary palp	Composed of 7 segments	Composed of 5 segments
Eyes	Large contiguous	Small,separate or absent or often represented by few ommatidia
Ocelli	Three in number	Absent
Mandibles	Monocondylic,molar and incisor areas are distinct	Dicondylic molar and incisor areas are confluent
Abdominal segment(meso and meta coxa)	With large plate like coxites with styles	Without styles
Styliform appendage	Present on 2-9 abdominal segments	Present on fewer number on abdominal segment
Malpighian tubule	12-20 in number	4-8 in number
Spiracles number	9 pairs	10 pairs
Ovarioles	Ovary with 7 ovarioles	Ovary with 5 ovarioles
Testis	6 on each side, without receptaculum ,seminis and accessory gland	Numerous testes, segmented penis, receptaculum and accessory gland present.

Economic importance: Thysanura, despite being placed among apterygotea exhibit numerous affinities with pterygotes. The mouth parts are typically of pterygote type with dicondylic mandible. The abdominal segmentation, the compound eyes, the antennae and tracheal system are wholly different from those of the apterygota order and aretypically pterygote in character.

5.4 COLLEMBOLA (SPRINGTAILS)

(Coll-glue,embol-a wedge;springtails,(fig 3)

Collembola are aterygotes with entognathous biting mouthparts, small, wingless arthropods, usually much less than 6 mm long having six segmented abdomen and with a springing apparatus but without compound eye tracheal system malpighian tubule, external genitalia and cerci.

- **Habit and Habitat:** They are minute soft bodied apterus springtails occurring under stones, fallen leaves, on snow, sand and in termite nests. They are non-pestiferous but few may harm mushroom green houses, cereal crops sugarcane etc.
- **Distribution:** Collembolans are cosmopolitan in distribution. These is the largest order of Apterygota and are widely distributed with the highest numbers found in organic rich, humid environments, such as soil and leaf litter of forests, and the lowest densities in arid regions. There are about 7,000 described species; however as many as 100,000 species are distributed worldwide.
- **Structure:**
    - **Body:** slightly sclerotized,often covered with setae,scales or tubercles and pigmented
    - **Head:** Freely movable, ocelli occur in variable number (stemmata) but only up to 8 on each side. A pair of ring or rosette like post- antennal organ functions as the chemoreceptor**.**

- **Thorax:** Segmentation of trunk is remarkable, 3 thoracic and 6 abdominal segment present in *Poduridae*,while in *Sminthuridae* the abdominal segmentation is completely obliterated.
- **Abdomen:** Abdominal appendages comprises of the springing apparatus which includes a ventral tube, a retinaculum and furca. The furca is capable of being bent forward under the abdomen and its sudden backward release jerks the body forward when collembolan jumps**.**
- **Legs:** Similar ,but lacks tibio-tarsal joint ;pterasyrs with simple or dentate claws and movable empodium
- **Antennae:** Antenna with 3-6 segments often modified into claspers in the male and of variable length.
- **Mouth parts:** Elongated and sunk in head cavity, piercing ,sucking or biting-chewing type ,mandibles monocondylic, slender with toothed extremities, palpi vestigial .Superlinguae well developed, labrum well distinct but labium is degenerated.
- **Alimentary canal:**The digestive tract consists of three main components: **the foregut, midgut, and hindgut**. The midgut is surrounded by a network of muscles and lined with a monolayer of columnar or cuboidal cells.
- **Malpighian tubules:** wanting or absent, fat body act as an excretory organ
- **External genitalia:** absent, cerci is also absent
- **Nervous system:** with a brain, sub-oesophageal and three thoracic ganglia, corpora allata well developed.
- **Reproductive system:** Testis and ovary are paired but not sac like without ovarioles or testicular follicles without accessory glands. Male or female gonopore is present on 5^{th} abdominal segment**.**

- **Economic importance**

Springtails are the most abundant hexapods and are found as high as 200,000 individuals per square metre. Because of their abundance and ubiquity,they are the vital part of our detritus food web ,thus facilitating the breakdown of plant-material, nutrient cycling and thus enhancing the soil fertility and structure. Therefore, they have been used for environmental assessment and habitat change monitoring purposes.

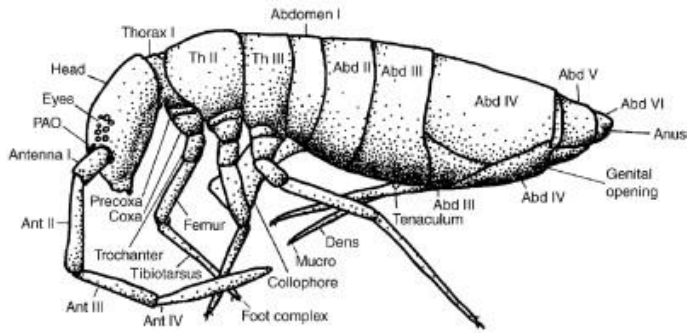

Figure3 Springtail

5.5 *ISOPTERA (ISO:EQUAL.PTERA-WING,TERMITES (FIG 4)*

(They are soft bodied, social and polymorphic species composed of sterile worker ,soldier, reproductive, queen, and larva, having two pair of similar ,elongated and membranous, incomplete metamorphosis(without external genitalia)

- **Habit and habitat**: They are widely distributed in tropics and subtropics, and the semiarid regions of the world. They live in large communities in underground nest or t**ermitorium or** in dry wood. They aerate and can make up to 95% of the soil insect biomass .In addition to wood, termite feed on a variety of cellulose-containing material, fungi and dried animal remains. The digestion of cellulose is carried by a flagellate protozoan eg *Trichonympha or bacteria* which are mutualistic inhabitant of the gut.
- **Distribution**

  Termites are found in all continents except Antarctica. The diversity of termite species is low in North America and Europe .They thrive best in warmer climates eg in South America, where over 400 species are known.
- **Structure**

- **Body:** Body small or medium sized ,pale colored, weakly sclerotized**.**
- **Head:** Movably articulated, prognathous, highly sclerotized spherical or oval ,large and elongated or pyriform in soldiers, compound eye well developed in sexual form but

reduced or absent in sterile forms, ocelli are two in number, antennae are short, moniliform with 9-30segments

- **Thorax:** Prothorax freely movable, narrower then head, rarely enlarged, meso-metathorax are more wider than long.
- **Abdomen***:*Abdomen is broadly jointed to the thorax without constriction.
- **Legs:** Similar with large and broad coxa meron, long and slender tibia armed without spines,4-segmented tarsi, peculiar sense organ is present on fore tibiae
- **Wings**: Wings are present only in sexually mature males and females, usually two pairs, much larger than the body size, similar, equal, membranous with reduced anal lobe, The nymphs, workers and soldiers lack wings. The sexual forms shed them ,leaving inly the scales.
- **Mouth parts:**The mouth parts are biting and chewing, contain **maxillae**, a labium, and a set of mandibles. The maxillae and labium have palps that help termites' sense food and handling, Salivary gland are large, recemose type with salivary reservoir. A frontal gland (in head) is highly developed in soldiers for secreting defensive pheromone.
- **Alimentary canal:** A coiled tube with well-developed gizzard, oesophageal valve, tubular coiled midgut-hindgut differentiated into ileum .,colon and rectum
- **Malpighian tubules:** 2-8 in number, 2 thoracic and 8 abdominal
- **External genitalia:** .External genital organs are lacking in both the sexes. Cerci are short.
- **Nervous system:** with brain, sub-oesophageal ganglion, 3 thoracic and 6 abdominal ganglia.
- **Reproductive system:** The male reproductive organ developed only in reproductive caste, a pair of testes, simply consisting of 8-10 digitate follicle,,a pair of vasa deferentia and an ejaculatory duct receiving a pair of seminal vesicles**.** The female reproductive system consists of a pair of panoistic ovaries, consisting of 30-3000 ovarioles**.**

➢ **Economic importance**

Among isopterans, only termites exhibit social life. They usually inhabit in the earthen mounds, as high as 3 or 4 metres depending on the species. Few termites build smaller earthen nests in trees while, others construct a complex network of subterranean tunnels connecting larger galleries. Wood dwelling species do not build nests but live within the on. Termites carry cellulose-digesting flagellates (Protozoa) called *trichonympha* inside their intestines. They make underground nests called **termatorium**, in which they maintain constant temperature and humidity. When outside ground they constructs intricate overground natural air conditioners called termite-hills. As the wind passes through the ventilation galleries of the termite hill, the temperature of the nest drops fast. Although, they have rudimentary eyes, they communicate exclusively in the chemical language. This peculiar underground habitat and shy nature has evolved in them due to a large number of predatory animals like giant anteaters, scaly anteaters, spiny anteaters etc. which exclusively live on termite diet and are always looking for them.

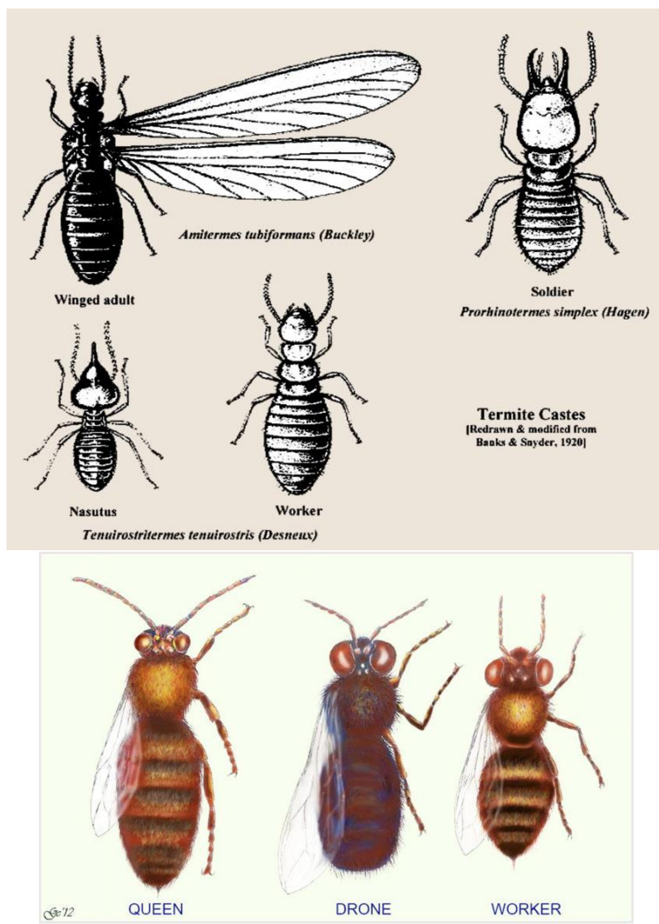

Figure4 Termite family

5.6 PTHIRAPTERA (FIG.5)

(Minute,flattened ,apterus ,blind bird lice-ectoparasites with reduced eyes,3-5 segmented antennae and 1 or 2 segmented tarsi, with terminal claws,with ventral thoracic spiracles but without cerci and ocelli.)

True lice have simple metamorphosis, the female glues eggs to the hairs or feathers ,the immature stages look similar to adults, and they undergoes three larval instars stages before entering into the adult stage

- **Habit and Habitat**

Lice are parasitic on almost all birds and mammals and are distributed worldwide where their hosts occur. Some species of lice are restricted to just one host species and will often spend their entire life on only on particular part of the body**.** They are found everywhere and in every habitat occupied by birds and mammals.

- **Structure:**

- **Head:**Small dorso-ventrally flattened parasitic insects. Eyes reduced or absent, ocelli absent, antenna three- to five-segmented, mouthparts mandibulate or piercing. Obligate permanent ectoparasites of birds and mammals. mandibulate mouthparts.
- **Leg:** Legs usually short/stout bearing single or paired pretarsal claws. . Each leg has a single tarsal segment ti with a singl curved claws.
- **Abdomen:** Abdomen has 11 segments, although one or more are always partly or wholly suppressed. Typically nine segments are visible, the first comprising segment I and II are the true segment IX, X and XI are fused segment.
- **Mouth parts:** Sucking lice have piercing mouthparts, which they use to suck the blood of the hosts - mostly human. They hang on to hair with a single large claw at the end of their strong legs. The antennae are usually 5 segmented and the thoracic segments are fused
- **Alimentary canal**:Alimentary canal is a straight tube with a large crop, large midgut, short hindgut,a pair of enteric caeca. They lack a mouth or an alimentary canal; as they feed by absorbing nutrients from the host's intestine

- **.Malpighian tubules**:4 in number
- **Heart:**The circulatory system is open and contains a dorsal **heart**,
- **External genitalia:**. Male **external genitalia** are highly variable.
- **Nervous system**: The brain of pthirapterans is U-shaped compact unit which is tilted backwards to cover the tritocerebral commissure, circum-oesophageal connectives and a large portion of sub-oesophageal ganglion.
- **Reproductive system**: The female reproductive system consists of paired ovaries, with 5 polytropic ovarioles, The male genital opening is posterior to sternum IX and consist of a paired vasa deferentia ,lateral canals, vescicula seminalis and an ejaculatory duct

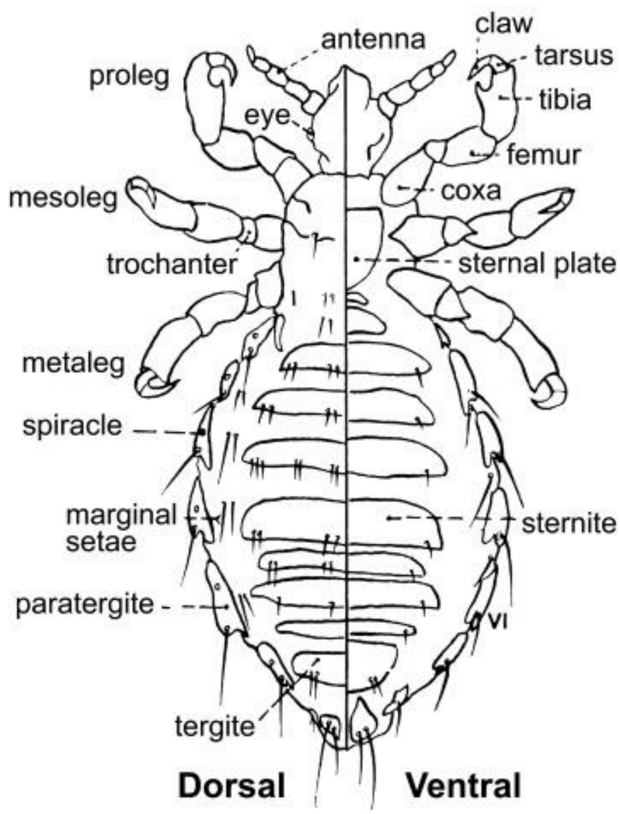

Figure5 Pthiraptera(lice)

The order Phthiraptera are divided into the chewing lice (Mallophaga) and sucking lice (Anoplura). These insects are wingless parasites

5.6.1 Suborder: Mallophaga(Mallo-wool,phaga-eat;chewing lice,bird lice

The sub-order Mallophaga also known as **chewing lice**, biting lice or bird lice, containing more than 3000 species. These lice are external parasites that feed mainly on birds, although some species also feed on (only 12%) mammals.

Suborder:Anoplura(Anopl-unarmed.ura-tail;Sucknig lice)

The sub-order Anoplura are all blood-feeding ectoparasite of mammals. They only occur on about 20% of all placentalian mammal species, and can cause skin irritations and are the vectos of several blood-borne diseases. Children are more susceptible to lice attack, due to their fine hair.

Characters of Suborder Mallophaga and Suborder Anoplura

Character	Suborder-Mallophaga	Sub-order-Anoplura
Body	Dorsoventrally flattened and Sclerotized	Dorsoventrally flattened ,tough and elastic,partly sclerotized,smooth and hairy
Head	Large, horizontal, free ,tentorium is highly reduced	Small narrow,pointed,prognathous,freely movable,tentorium lacking
Antenna	Short with 3-5 similar or dissimilar segments,clubbed,free or often concealed in a lateral ventral groove in the head,in male modified into clasping chelicerate	Short,3-5 segmented.,the antenna occur as tuft of four sensory hair with a tube penetrating into sensory ganglion.
Eyes	Reduced or absent, ocelli absent	Reduced,absent or vestigeal
Mouthparts	Biting type,labrum narrow,mandibles well developed,tridentate,sometimes asymmetrical.maxillae very reduced,galea present,,weakly sclerotized, labium without lobes,	Piercing and sucknig,concealed within a sheath ventrally inside the headcavity when not in use,but feeding, it is everted out through the mouthcone(internally lined with sharp teeth0 like tip of head.Labrum

	hypopharynx with posterior sitophore sclerites and lingual filaments,labium fused basally with 2 or more or less vestigeal endites,uni or biarticulate palpi	modified into a protrusible,ventrally cleft mouthcone,.The true mouth open from behind.
Thorax	Free,Prothorax usually narrower than head,free,rarely fused with mesothorax The meso and metathorax generally fused with the abdomen	Small,all segments are fused ,indistinct
Legs	Equal,short,stout,sometimes slender with coxae moderatly broad ,tarsi with 1-2 segmented,and bear a pair of claws or a single claw without pulvilli and empodium.	Modified for clasping the hair of host,short,thick,with single segmented tarsi bearing a hook like claw with a pad,the pretarsus unguiform and opposable with the claw and to the tip of the tibia
Abdomen	Segments are reduced to 8-10,1st sternite vestigeal.VIII sternite of female with minute gonapophyses like structure,cerci absent.	Abdomen sessile,with 9 segments,narrow and ovalor broad;tergites,pleurites and sternites well sclerotized and darkly pigmented,without cerci
Alimentary canal	Straight,with oesophagus,a large crop,large midgut,short hindgut,a pair of enteric caeca,4 malpighian tubules,6 rectal pads,a pair of salivary glands in thorax with reservoirs and one or two pairs of extra glands opening into oesophagus.	Alimentary canal with large stomach occupies a great part of thye cavity of abdomen;two enteric caeca present,the hindgut straight;malpighian tubule four,rectal papilla six in a whorl, A pair of Pawlowsky glands discharge lubricant in stylet sac to lubricate stylets.
Tracheal system	Ist prothoracic and abdominal pairs	7 pair of spiracles ,one mesothoracic

	of spiracles on 3 to 8 segments or 2 to 7 segments	and six on the 3rd to 8th abdominal segment
Nervous system	Ventral cord possessing a large sub-oesophageal ,3 post thoracic ganglia, ;none in abdomen	Highly condensed ,abdominal and thoracic ganglia fused together into a composite mass
Male reproductive organ	Testis one on each side consists of 2-3 separate,oval or pyriform follicles ,opening into vas deferens, seminal bilobed and extending to ductus ejaculatorius.	Paired, bilobed open into vasa deferentia ,later into vesiculae seminalis or ductus ejaculatorious.
Female reproductive organ	Ovary on each side consists of 3-5 short, meroistic ovarioles,vagina open behind seventh sternite sometimes with accessory glands(secrete cement substance for fixing the egg on hair) , ovipositor absent.	Paired ovaries,with 5 polytrophus ovarioles esch ,accessory gland paired;seminal receptacle absent,a pair of short gonopods serve for grasping the hair of the host while cementing the eggs.

Economic importance

The economic importance of most louse species is unknown, although they cause irritation, inflammation, and itching and serve as vectors of diseases and other parasites. However, high louse densities are found most on weak or sick hosts, especially the birds with damaged bills or those unable to perform normal grooming activities. Lice also infest a number of domestic animals including poultry, domestic dogs and cats, cattle, sheep, goats, horses, pigs. The human body louse serves as the vector of epidemic typhus and epidemic relapsing fever and as an occasional vector of murine typhus.

5.7 ORTHOPTERA (ORTHOS – STRAIGHT & PTERON =WING)

e.g. Grass hoppers, Locusts, Crickets, mole crickets

The saltatorial exopterygotes with mandibulate mouthparts having large prothorax ,hind legs modified for jumping ,forewings modified into leathery tegmina often with auditory and stridulatory organ,a pair of short unsegmented cerci and female with ovipositor.

- **Habit and habitat**: They are median or large , terrestrial salutatory jumping insects and are mostly ground living forms .Many are arboreal and some are subterrarean and caverniuculus. Few species swim and dive in water, while certain species swim and dive in water, while certain species migrate in great swarm at intervals. They constitute more than 20,000 species and are distributed worldwide and most abundant in tropics

- **Head**: Hypognathous,broadly articulated to the trunk with only slight freedom of movement.
- **Mouthparts:** Mandibulatee type with well-developed mandible ,clypeus and labrum distinct ,maxillae with powerful galea and lacinia, maxillary palps are 5-segmented,labial palp are 3-segmented.
- **Antennae**: Short with few segments or long and filiform with many segments. compound eye well developed ocelli mostly 1 to 3
- **Thorax**: Prothorax large movable ,pronotum extended backward and laterally, meso and metathorax form a strong pterothorax, pleurites and sternites well developed
- **Wings:** Fore and hindwings are unequal and dissimilar, forewings are small, sclerotized, leathery forming tegmina.in *tettigonidae* and *Gryllida*e, stridulatory apparatus occur in cubito-anal area. The hind-wings are membranous with large anal lobe which is folded fanwise.
- **Abdomen:** Abdomen has 10 evident and a vestigial eleventh segment cerci mostly present,the 7^{th} and 8^{th} sternite of the female and 9^{th} sternite of male are less developed.
- **Legs:** well -developed, their foreleg in some species modified for digging, the hind leg for jumping and have long basally stout femora ,the tarsi have 3-4segments
- **Alimentary canal:** well developed and differentiated into the pharynx, oesophagus, crop ventriculus with chitinous armature, ,midgut with two or more caeca, small intestine and a large hindgut ,salivary gland variable,
- **Malpighian tubule:**numerous ,long and grouped**.**

- **Nervous system:** 4-6 abdominal segments, sympathetic nervous system well developed consisting of frontal and hypocercal ganglia ,a pair of oesophageal nerves, corpora cardiaca ,corpora allata and a pair of ingluvial ganglia. thoracic and abdominal medial and transvers nerves and neurohemal organs are well developed.
- **Male reproductive system:** comprising a pair of multi follicular testes, fused in acridoideae, a pair of vasa deferentia, anteriorly modified into convulated epididymis, median ejaculatory duct, a pair of seminal vesicle and a median mushroom gland**.**
- **Female reproductive system:**ovaries paired with numerous panoistic ovarioles.in Acridids ,a pair of Comstock-kellogg gland and a genital chamber are present. .

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

5.7.1 Sub- order -Caelifera

1. Antenna is short with less than 30 segments. 2. Tympanum is found on the lateral side of the first abdominal segment, Vision and hearing acute. Mandibles are specialized for consuming monocot foliage Rely on jumping to escape from predators, Eggs are laid in groups in soil inside shallow burrows, Diurnal

5.7.2 Sub -order Ensifera

Antenna is long with more than 30 segments.,Tympanum is fund on the the foretibia.,Tactile responses is well developed. ,feed on dicot plants,. Nocturnal, Rely on crypsis(camouflage) ,Eggs are singly inserted into plant tissue or soil.

A)Sub order -Caelifera

1. Familty: Acrididae: (Locusts(fig.6)Grasshoppers)

They are herbivores and mainly feed on grasses, cereals etc they are the most destructive agricultural pests, the plague or migratory species are called locusts. They range in size from 5mm-11cm length, Antenna is short, Tarsus are three segmented , their ovipositor is short and horny, Tympanum is situated one on the either side of the first abdominal segment. They produces sound by femoro-alary mechanism. A row of peg like projections found on the innerside of each hindfemur is rubbed against the hard radial vein of the closed tegmen

Figure 6 -Locust

B) **Sub order: Ensifera**

a) Family: Tettigonidae : (**Katydids, Long horned grasshoppers (fig .7)**

Tettigonids are distinguished by having the hearing organ (tympanum) located on the front leg, when the male rubs his wings cover together ,he produces a song that is used to attract the females, each species has its own characteristic song, their antenna is long, slender as long as or longer than the body. Tarsus is four segmented. Ovipositor is just like sword,Auditory organs are found in foretibiae. The outer tympanum is larger than the inner. Sound production is alary type. A thick region on the hind margin of the forewing (scraper) is rubbed against a row of teeth on the stridulatory vein (file) present on the ventral side of another forewing which throws the resonant area on the wing (mirrors) into vibrations to produce sound.

Figure7Long horned grasshopper

b)Family: Gryllidae (Cricket,fig.8)

It includes common crickets,they have long and elongated, cylindrical long spear shaped ovipositor, Tarsus is four segmented,forewings are abruptly bent down to cover the sides of the body, Hindwings are acuminate. They are produced into a pair of long processes which project beyond the abdomen. Cerci are long and unsegmented . Auditory organs and stridulatory organs are similar to long horned grasshopper.outer auditory organ is larger while inner one is smaller, Males stridulate during night. They produce a shrill chirping noise.They are omnivores living in holes, burrows ,under logs or leaves.

Figure8 Cricket

c) Family: Gryllotalpidae : (Mole crickets,fig.9)) forelegs are modified for digging, the tibia are terminally flat and bear strong teeth and resemble the forepaw of a mole. Eyes are reduced, winged, brachypterus or apterous, the forewings are short and hindwings are folded over abdomen, no stridulatory organs, ovipositor vestigial .They are brown coloured insects found inside the burrows. A humming sound is produced by rubbing the forewings. A pair of tympanum is found on the order surface of the tibiae. Mole crickets burrow into the soil and feed on tender roots of growing plants. *Gryllotalpa africana* is a pest on stored potatoes.

Figure9 Mole cricket

5.8 PHASE THEORY OF LOCUSTS (FIG.10)

The term phase refers to the different forms of the insect. This term here account for the sporadic appearance and disappearance of the locust swarms. The locust are the short-horned grasshoppers belonging to the family- Acrididae (Orthoptera). **Uvarov**'(1921) proposed the phase theory of locusts. In (1929), **Uvarov and Zolotaresvsky** stated that species of locusts are phase polyphonic existing in a series of forms, sharing the same genotype but displaying different phenotypes that causes variation in their color, morphology and in there ,reproductive behaviour .

According to the phase theory, the two main forms or phases i.e the ,solitary phase, *phasis solitaria* , which led a solitary sedentary life and the other gregarious or migratory phase.,*phasis gregaria,*active phase, Earlier they were regarded as a separate species by taxonomists .Sometimes a third phase also occurs during the transition of the population from one extreme phase to other called the third phase ie**. *Phasis transiens.*** It has no definite form but represented by a continuous series of transitional or intermediate form. When phase transition occur from solitary to gregarious phase ,these forms are called ***Phasis congrigens,*** when phase transition occur from gregarious to solitarious phase then it is called ***Phasis dissocians*.** Transition always occurs from solitarious to gregarious one and vice-versa. Swarming always occur in the gregarious phase, which is the characteristic of the migratory locus while solitary phase represent merely the grasshoppers which are often isolated and confined to their breeding locality**.** The gregarious and solitary forms differ as follows**.**

Table1: Phases of the locust

Character	Solitary phase	Gregarious
Habit	Solitarious or isolated ,walk slowly with creeping, diet restricted and active at night	Gregarious or crowded,walk rapidly, diet broad and active at day
Egg	Egg develops without undergoing diapause	Diapause at low temperature
Nymphs (Body color)	Variable, like green ,grey or brown	Black and yellow, orange band irrespective to the environment
Adult A)Pronotum B)Wings c)Habit d)Body temp. e)Sexual maturity f)Corpora allata g)Behaviour	It is large with a mid-longitudinal crest or carina. Normal Dull Low Without color change Small Behave independently	It is shorter and saddle shaped Wings conspicuous and proportionally large Overactive High With color change Large They behave cohesively. They are destructive to the green foliage

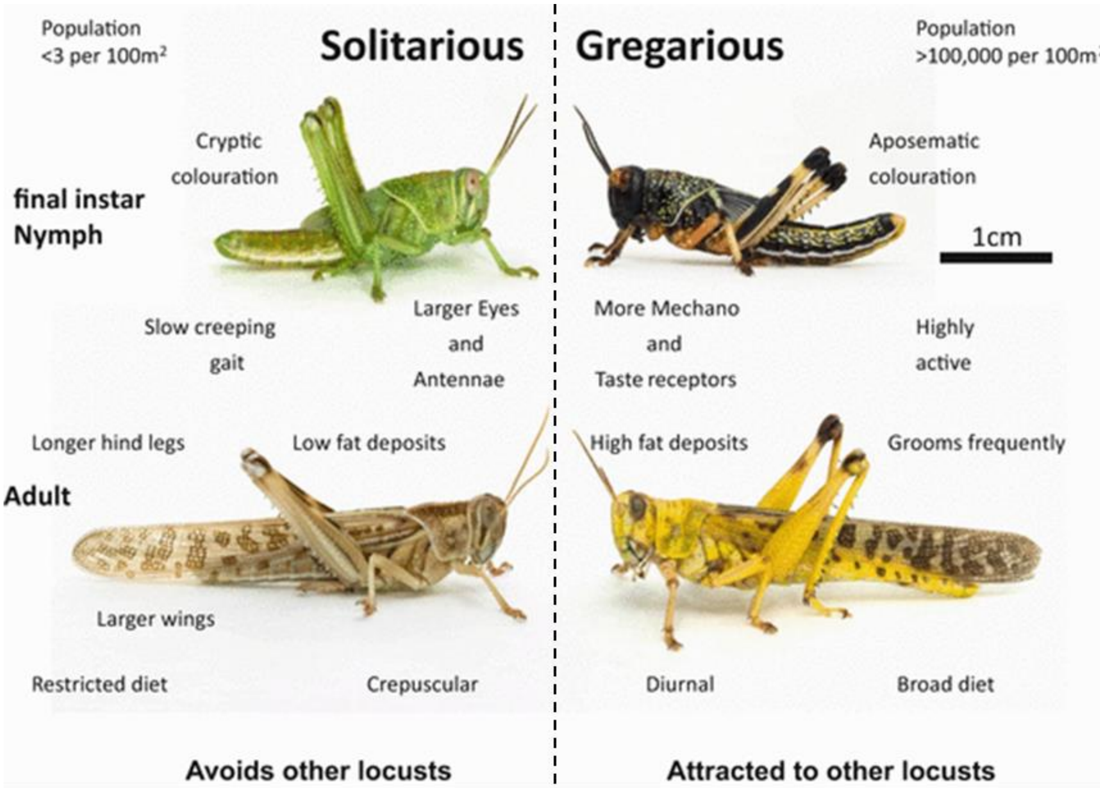

Figure 10 Phases of locust

(Only four species viz. Desert locust (Schistocerca gregaria), Migratory locust (Locusta migratoria), Bombay Locust (Nomadacris succincta) and Tree locust (Anacridium sp.) are found in India. The desert locust is most important pest species in India as well as in intercontinental context.)

➢ Locust swarm

Periodic swarms of locusts have been recorded since the ancient times. The gregarious form arises from an increase in population density which causes the locusts to aggregate, to multiply, concentrate and aggregate and form swarms .The locusts can efficiently and continuously fly for 17-18 hours a day and the swarms can travel 15-320 kms a day during a normal migration. Overall they migrate distant regions up to hundreds and thousands of kms away from the place of their origin and may return back after crossing the equal distance. The gregarious form undergoes a colour change which makes them more conspicuous, and a behavior change which makes them band together. Sudden rainfall, for example, could help feed a growing population and cause flooding that corrals locusts together and attract more locusts to join together. While, some species of locusts become migratory, flying long distances across borders in search of food. The most devastating, best-known, and most frequently studied example is the desert locusts *(Schistocerca gregaria*). They have their origin from Saudi Arabia.

Swarms typically contain between 4 billion and 8 billion locusts, and can eat in a day. A desert locust adult can consume roughly about two grams every day.According to FAO, a single square kilometre of the locust swarms can contain up to 80 million adults and can eat as much food as 35,000 people in terms of weight in a single day.Recently, locust swarm has affected five states in India namely – Maharashtra, Rajasthan, Punjab, Haryana and Madhya Pradesh. The year 2020 had also seen extensive rain in India before the expected months following which moisture and greenery have attracted locusts since egg-laying also occurs in the rainy season only. When desert locusts meet, their nervous systems release the chemical serotonin, which causes them to become mutually attracted, as a result of which their population density begins to increase The initial bands of gregarious hoppers are known as "**outbreaks"**, and when these join together into larger groups, the event is known as an "**upsurge".**

5.9 SUMMARY

Insects are classified primarily on the basis of their wing structure, mouthpart structure and type of metamorphosis after knowing their details; we could gain a better understanding of their role in the web of life, as indicators of environmental quality, as predators of harmful species, and as potential threats to crops, homes and health. It is Importance to know about external structure of an insect because it helps to distinguish one kind of insect from another. They form the basal part of the food pyramid and impact our agriculture ecosystems as well as human health. They differ widely in their forms, structure and behaviour in relation to the mode of life they adapted. Different orders with their families are discussed in the above unit that includes the following orders and families such as ,the thysanurans(thrips) which are apterous (wingless) insects. They are cosmopolitan and have about 550 species in the world, while 32 species from five families been recorded in India. Thysanura, despite being placed among apterygotea exhibit numerous affinities with pterygotes. The mouth parts are typically of pterygote type with dicondylic mandible. The Collembola(Springtails) are apterygotes with entognathous biting mouthparts, small, wingless arthropods, usually much less than 6 mm long having six segmented abdomen and with a springing apparatus but without compound eye tracheal system ,malpighian tubule, external genitalia Springtails are the most abundant hexapods and are found as high as 200,000 individuals per square metre. Because of their abundance and ubiquity, they are the vital part of our detritus food web, thus facilitating the breakdown of plant-material, nutrient cycling and thus enhancing the soil fertility and structure. The Isopteran are soft bodied, social and polymorphic species composed of sterile worker ,soldier, reproductive, queen, and larva, having two pair of similar ,elongated and membranous, incomplete metamorphosis(without external genitalia)They are widely distributed in tropics and subtropics, and the semiarid regions of the world. They live in large communities in underground nest or termitorium or in dry wood. Among isopterans only termites exhibit social life. They usually inhabit in the earthen mounds, as high as 3 or 4 metres depending on the species. Few termites build smaller earthen nests in trees while, others construct a complex network of subterranean tunnels connecting larger galleries. The Pthirapteran are minute, flattened, apterus, blind bird lice-ectoparasites with reduced eyes, Lice are parasitic on almost all birds and mammals and are distributed worldwide where their hosts occur. Some species of lice are restricted to just one host species and will often spend their entire life on only on particular part of the body**.** They are found everywhere and in every habitat occupied by birds and mammals.Orthopteran are the the saltatorial exopterygotes with mandibulate mouthparts having large prothorax ,hind legs modified for jumping ,forewings modified into leathery tegmina often with auditory and stridulatory organ.. According to the phase theory of locusts, the two main forms or phases are the, solitary phase,*phasis solitaria* , which led a solitary sedentary life and the other gregarious or migratory phase.,*phasis gregaria*,active phase, Earlier they were regarded as a separate species by taxonomists .Sometimes a third phase also occurs during the transition of the population from one extreme phase to other called the third phase ie**.** *Phasis transiens*. Recently, locust Swarm has affected five states in India namely – Maharashtra, Rajasthan, Punjab, Haryana and Madhya Pradesh. 2020 had also seen extensive rain in India before the expected months following which moisture and greenery have attracted locusts. In 2020, the locust swarm is worst in 26 years,' and the united nations (UN) has warned it to be posing a 'severe risk' to India's agriculture also.

5.10 TERMINAL QUESTION AND ANSWERS

Multiple choice questions

1. Head of Thysanura is

a)Prognathous **c)** Opisthognathuos

b)Hypognathous: d) Ectognathous

2.Collembola are commonly called

a) bristle tails b)springtails

c) silver fish d)firebrats

3) The suborder Mallophaga is characterized by

a) Piercing and sucking mouth parts b) Small thorax and fused segment

c) Sessile abdomen d) small thorax and free segment

4) Ocelli in Machiloids (bristle tails) are

a) three in number **b**)five in number

c) absent d)twelve in number

5) Pthirapterans are characterized by

a) pterus ,with well-developed eyes b)saltatory insects

c)endopterygotes with mandibulate mouth parts d) apterus, bird lice with reduced eyes

6) Which of the following is the most devastating locust-

a)*Schistocerca gregaria* *b) (Locusta migratoria*

c) Nomadacris succincta *d) Anacridium sp.*

7) Mallophaga are commonly called as

a) Sucking lice b)chewing lice

c) crab lice d) head louse

8) Head of orthopterans is of which type

a)Hypognathous b)Opisthognathous

c)Prognathous d)Endognatous

Answers 1) a, 2)b, 3) d, 4)a 5)d, 6) a), 7)b,8)a

- **Fill in the blanks**

1. Tettigonidae are commonly known as ……….

2. Anoplurans are ……

3……….. proposed phase theory of locust.

4. When the phase transition occur from solitary to the gregarious phase then it is called ….

5 .The malpighian tubules in silver fish ranges from …. in number

6. Antenna in thysanura is……..

7. Digestion of cellulose in termites carried out by protozoan called ….

8. Termites are commonly known as ….

Answers(Fill ups)

1). katydid or bush cricket 2)Ectoparasites 3)Uvarov 4)Phasis congrigens 5)4-8 in number 6)long and filiform 7) Trichonympha 8) white ants

- **Answer the following question in details**

Q1. Explain the "Phase theory of locusts" in details.

Q2.Write an account of "Termites as a social insect".

Q3.Give a detailed account of the order Thysanura and its families

Q4. Write in details about the structure, habit and habitat of the order Orthoptera.

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UNIT 6: GENERALIZED STRUCTURE HABIT AND HABITAT OF THE FOLLOWING ORDERS WITH FAMILIES

CONTENTS

6.1 OBJECTIVES

- To study the general characters, habit and habitat of the suborders Heteroptera and Homoptera which belongs to the order Hemiptera and order Coleoptera.
- Study the various habitats of some insect orders and to assess their geographical distribution.
- Identification of insects on the basis of their morphological characters, their feeding habitat, and on the basis of their mouth part orientation.
- Taxonomic aims at classifying insects into taxa on the basis of similarities in phenotypic (phenetic) characteristics.

6.2 INTRODUCTION

Hemiptera means "half wing". Hemiptera are primarily terrestrial but some species are adapted to aquatic or semi aquatic life. Majority of them are plant-sap feeders but some are predators and ectoparasites. There are several pests causing damage top various economics crops. Some act as vectors for a variety of pathogens causing diseases in plants and animals. Few species are voracious predators of fish-fry, or fingerlings in the nurseries.

Coleoptera is the largest order in not only the Arthropoda but in the entire animal kingdom, consisting about 330,000 species. They are adapted to various modes of life, viz.- terrestrial, aquatic, areal, fossorial, subterranean, carnivorous etc. and are mostly concealed in habit. The order represents a heterogenous assemblance of very minute size. Several membranes are the pests of crops, vegetables, timber, furniture, cloths, stored food grains and even the drugs and thus they attribute great economic importance. Large number of chrysomelids are entomophagous predators and are successfully used in eradication of various pests. Several members of the order are specifically capable of producing the light and sound through stridulation. e.g., Scarabaeoidea.

HEMIPTERA

Order Hemiptera is classified **into two suborders – Heteroptera and Homoptera.**

6.3 HETEROPTERA

GENERAL CHARACTERS

Head: Mostly hypognathous, porrect. Sclerites are fused, clypeus divided into anteclypeus and postclypeus; the mandibular plates and maxillary plates form a ventral gulla.

Eyes: Well-developed but absent in ectoparasites, ocelli-2 in Heteroptera,

Mouthparts: Piericing and sucking type, mandibles and maxillae are modified into bristle-like hollow, slender stylets; labium is modified into long rostrum, labrum is short and form base of rostrum; palps are atrophied.

Thorax: Prothorax – large and free and with large pronotum; meso and metathorax dissimilar. Mesonotum is subdivided into a number of sclerites mostly five. Scutellum in pentatomids extends posterior to cover wing bases and even abdominal region. Metanotum is variable, small, well-developed except in Cicadellidae.

Wings: The forewings are modified into the hemelytra with proximal area sclerotized and distal small membranous area. Hind wings are membranous, folded beneath the hemelytra at rest. Hemelytra may be further divided into two parts- *clavus* or basal narrow area near scutellum and *corium* or terminal broad area.

Legs: Well-developed, hind legs longer, Tarsi- 2-3 segmented. Claws-2. Legs are modified into saltatorial, fossorial, raptorial or natatorial legs.

Abdomen: it is 11-segmented but 10^{th} and 11^{th} segments are greatly reduced into annuli. In Heteropteran, first, second as well as 10^{th} and 11^{th} segments are fused and indistinct.

Sound Producing Organs: Among Hemiptera, Cicadidae are well-known for sound production. The sound producing organs are situated on the 1^{st} abdominal segment and are of complex type. Similar type of organs is present in the leaf-hoppers also.

Among heteropteran, the sound producing organs are of 5 main types:

1. **Postrenal Furrow:** Furrow is cross-striated and rubs with rogue's apex of rostrum. **e.g.** *Phymatidae* and *Reduviidae.*
2. **Strigose Ventral Areas:** Strigose areas are on 4th and 5th abdominal sterna. Hind tibia with wart-like tubercles bearing teeth. **e.g.** *Cicada*
3. **Pedal Organs:** Spinose area of clypeus strides with strigose area inside the fore-femur. **e.g.,** *Scutellerinae, male Corixidae.*
4. **Coxal Stridulatory Organs:** Two opposing structures rasp on coxa. e.g., *Ranatra.*
5. **Dorsal Stridulatory Organs:** Striated surface or file on the 1st abdominal segment and a comb of teeth on the undersurface of wings near the base. e.g., *Tessaratoma.*

General Characters of Family Pentatomidae

This family includes Stink Bugs.

1. They are brightly coloured, moderate sized bugs mostly greenish, shield-like in shape.
2. Antennae-4 or 5 segmented, basally concealed by lateral margin of head. Scutellum – triangular, covering half of the abdomen (mesoscutellum).
3. Tarsi – 2 or 3 segmented claws with pulvilli.
4. Hemelytra – well-developed and membrane with 5-12 veins.
5. Mostly phytophagus while those of Asopinae are predaceous on lepidopteran larvae. e.g., *Terodahisteroides, Menidahistrio.*

General Characters of Family Pyrrhocoroidea

It includes two families- Pyrrohocoridae and Largidae. The major difference is that the female with undivided 7th abdominal sternum in Pyrrhocoridae and divided one in Largidae. In India Pyrrhocoridae is represented by red cotton bug, *Dysdercus cingulatus* while Largidae by *Loita grandis* (5 cm lomg) or *Iphita limbata* pest on *Hydnocarpus* and *Plumaria* plants.

1. Red or black coloured body or with brightly coloured spots or stripes.
2. Eyes greatly developed. Ocelli absent.
3. Rostrum – slender, 4-segmented. Antennae – 4- segmented. Hemelytra with 5 unbranched veins.

4. Tarsi 3 – segmented, rotator cosae, pretarsi with pulvilli, e.g. Cotton-stainer- *Dysdercus* cingulatus: serious pest of cotton in India.

General Characters of Family Coreoidea

It includes about 5 families – Coreidae, Alydidae, Rhopalidae, Stenocephalidae, and Hyocephaiidae. Family Coreidae is large and of economic importance.

1. They are dull coloured, brownish bugs.
2. Body – oval or elongate with narrow head. Antennae – 4-segmented.
3. Clavus runs beyond scutellum. Hemelytra membrane with 5 long branched veins.
4. Legs – strong with claws and pulvilli. Legs are flattened. Leaf-like (hind tibia in male) Tarsi – 3 – segmented.
5. Rostrum 4-segmented. They produce a pungent scent, e.g. –*Leptinot*arsa *acute varicornis, Anoplocnemis*.

General Characters of Reduviidae

It consists of Assassin bugs or conenose bugs.

1. They are blood-sucking predaceous insects, with long head, large eyes and ocelli, Antennae- geniculate, long.
2. Rostrum-3-segmented pointed. Hemelytra-without cuneus. Antennal segments multiply up to 40.
3. Body colour is brownish or black.
4. Forelegs bearing adhesive pads on tibiae. Metathoracic scent glands absent.
5. Antennae rub against prosternal stridulatory groove. E.g. *Triatoma*- American , *Rhodnius prolixus*

General Characters of Nepidae

This family includes water scorpions.

1. Antennae are 3-segmented.
2. Forelegs are raptorial, prehensile, hindlegs are natatory, with hairs fringe on tibia. Tarsi-1-segmented.

3. Abdomen with apical respiratory tube consisting two elongate spinelike processes, each of which is grooved to form a half canal.
4. Ovipositor is pointed, toothed.
5. Lifehistory lasts for 70 days with diapauses. e.g., Water scorpion, *Ranatra quadridentata*.

General Characters of Belostomatidae

This family includes giant water bugs.

1. Body is brownish in color, oval, flattened, 11 cm or 190mm. long body.
2. Antennae are 4-segmented, lodged basally into grooves.
3. Forelegs are raptorial, prehensile. Middle and hindlegs are natatory, hair fringe on tibia. Air is stored beneath wings.
4. Forewings are sclerotized and membranous partly.
5. Abdomen with 2 retractile apical appendages forming a respiratory tube, associated with spiracle of 6th abdominal segment.
6. Feed on small fish, tadpoles, and insects.
7. Parental care occurs commonly, eggs are laid on elytra of male and guarded by females. E.g. *Lethocerus grandis, Zaitha flumineum.*

6.4 HOMOPTERA

GENERAL CHARACTERS

Head: Head is deflexed in homoptera. Sclerites are fused, clypeus divided into anteclypeus and postclypeus; the mandibular plates and maxillary plates form a ventral gulla.

Eyes: Well-developed but absent in ectoparasites.

Antennae: Mostly 4- or- 5 segmented, 10-segmented in Sternorrhyncha, 25 in male coccids, or vestigial in some cases.

Mouthparts: Piericing and sucking type, mandibles and maxillae are modified into bristle-like hollow, slender stylets; labium is modified into long rostrum, labrum is short and form base of rostrum; plaps are atrophied.

Thorax: Prothorax – large and free and with large pronotum; meso and metathorax dissimilar. Mesonotum is subdivided into a number of sclerites mostly five. Scutellum in pentatomids extends posterior to cover wing bases and even abdominal region. Metanotum is variable, small, well-developed except in Cicadellidae.

Wings: The forewings are uniformly but slightly hard. Hindwings are membranous; both pairs may be reduced or absent. Females are apterous in Coccoidea, Aphidoidea while males may be elate or apterous.

Legs: Well-developed, hindlegs longer, Tarsi- 1-3 segmented. Claws – 2. Legs are modified into saltatorial, fossorial, raptorial or natatorial legs.

Abdomen: it is 11-segmented but 10th and 11th segments are greatly reduced into annuli. Reduction of other segments vary in different families of Homoptera.

General Characters of Family Membracidae

This family includes Tree-hoppers.

1. Head is modified. Pronotum is enlarged with a spine and prolonged backwards into a distinct elevated hood or horn lying over the abdomen.
2. Ocelli are 2.
3. Antennae are concealed beneath eyes. Wings are concealed by pronotum. Stridulatory organs are absent.
4. Tegmina is transparent and Tegulae is absent.
5. Hindlegs are saltatorial. Tibia is with longitudinal ridge and spines on lateral margins. e.g., *Tricenturs bicolor, Tricenturs congestus*.

General Characters of Family Fulgoridae

This family includes Lantern flies.

1. Postclypeus is greatly reduced.
2. Insects are brilliantly coloured, large sized insects.
3. Only lateral ocelli situated close to eyes.

4. Wings are reticulate with large number of cross veins and supernumerary veins.

5. Antennae are 3-segmented, concealed beneath eyes.

6. Proboscis is peanut like elongated which was earlier considered as light producing organ and named, the lantern flies, e.g., *Pyrops chennelli*, *Kalidas asanguinalis*.

General Characters of Family Cicadidae

1. These are long lived insects – 13-17 years.

2. Head with 3 ocelli.

3. Tegmina is transparent, Tegulae is absent. Wings are covered with anbient veins.

4. Forelets with enlarged femora empodia wanting. Hind legs are elongate. Slender, not saltatorial. Males with distinct stridulatory or tymbal organs at the base of abdomen and are concealed by opercula developed from metathoracic epimer. e.g., *Cicada arni*, *Magicicada septendecim*.

General Characters of Family Aphididae

1. They are minute pear-shaped body with a pair of compound eyes.

2. Mouth parts are well developed in both the sexes.

3. Antennae are 1-8 segmented. Penultimate and last segment with a rhinarium.

4. They are polymorphic, elate forms with 2 pairs of transparent membranous wings.

5. Legs are long, slender, tarsi – 2 segmented with paired claws.

6. Only sexual female are oviparous, otherwise viviparous.

7. Some insects are gall-makers and some are wooly aphids. e.g. *Aphis gossypil,Eriosoma,lanigera.*

General Characters of Family Coccidae

1. This family includes scale insects.

2. Females are apterous, degenerate larviform, scale like gall like insects with functional mouth parts.

3. Males are normal with one pair of wings but with vestigial mouthparts.

4. Tarsi is 1 segmented with a single claw.

5. Body is obscurely segmented with waxy or powdery coating.

6. Antennae and legs of female are atrophied, rostrum is short.

7. Forewings with greatly reduced venation.

8. Reproduction is bisexual or parthenogenic. e.g. *Coccus viridis, Pulvinaria psidii*

6.5 COLEOPTERA

GENERAL CHARACTERS

Head: Head is strongly sclerotized, pro or hypognathous, mobile with reduced or absolute epicranial suture. In some beetles an elongated rostrum is formed due to prolongation of frons and vertex. Rostrum possesses mouthparts at the apex and antennae elsewhere in the forward position.

Antennae: Antennae are usually 11-segmented and of variable type-filiform, moniliform, clavate, serrate, lamellate etc.

Compound Eyes: Distinct, except in some subterranean and caverniculous forms, where the eyes are totally lacking. The eyes are of three types- acone, eucone and pseudocone.

Ocelli: Usually absent while only a median ocellus is present in Dermestidae.

Mouthparts: Biting-chewing type.

Labrum: Concealed beneath or fused with clypeus.

Mandibles: Variably developed. In carnivorous beetles they are acute with fine cutting edge and canaliculated for fluid feeding while in phytophagous forms they are short, broad, bluntly toothed. They have serrate edge and are longer even more than the whole body.

Maxillae: Fully developed, bilobed while only a single lobe or mala. Maxillary palps are 4-segmented, Lacinia are blade like.

Labium: Variably lobulated. Mentum fused with gulla and glossa-paraglossa are fused to form ligula; labial palps are 3-segmented.

Thorax: Prothorax – freely movable with large, free, visible, single undivided pronotum. Notopleural sutures absent in polyphaga, pleurosternal sutures are distinct. Meso-and metathorax-reduced, fused and tier terga are divided into pre-post-scutum, besides the middle scutellum.

Legs: Modified widely- walking, jumping, running, fossorial, natatorial. In aquatic forms mid- and hindlegs or only hindlegs are modified for swimming.

Wings: (a) Forewings: Two pairs, unequal forewings modified into elytra. Both remain free, often open and allow the hind wings to perform flight. The elytra may be united and immovable in Carabidae, Curculionidae where the hindwings are absent. (b) Hindwings: larger than elytra, membranous, folded.

Abdomen: Sessile, first segment membranous or atrophied. Eight tergites are commonly visible. 5-7 sternites are visible.

Development: Eggs are laid in clusters or enclosed in cocoons (Hydrophilidae) or in ootheca (Cassidinae) or in the tissues of plants (Curculionidae).

Larvae: With strongly sclerotized head, biting type of mouthparts, lacking abdominal legs. Thoracic legs-well developed. There are 2 types of larvae. *Campodeiform*-in Adephaga, *Eruciform*in polyphaga.

General Characters of Family Hydrophilidae:

This family includes Water scavenger beetles.

1. They are aquatic or terrestrial inhabiting decomposing vegetable matter.
2. Small or large, black or dull coloured oval, flattened and predaceous beetles including larvae.
3. Elongate maxillary palps performing functions of antennae. Antennae are short 6-9 segmented with hairy terminal clubs and function as respiratory organs. Tarsi of forelegs modified into clinging organs to hold female. Mid and hindlegs are fringed with setae.
4. Elytra encloses dorsal air reservoir and ventral hairy tracts which hold air film. e.g., *Hydrous indicus, Hydrous opacus.*

General Characters of Family Meloidae:

This family includes Blister oil beetles.

1. Body is medium size and elytra are brightly coloured as metallic blue, green, black, brown, transverse coloured stripes are common.
2. Head is hypognathous, strongly deflexed. Neck –narrow but distinct between head and thorax.
3. Legs are long and with secrete tarsal claws. Tarsi are 5 segmented.
4. Wings are well developed, Elytra cover the body incompletely and both are free
5. Adults on disturbance, emit a defensive oily fluid containing canthardine chemical compound, from the apices of femur.
6. Female lay eggs in a hole under the ground.
7. Larvae develop in eggs of other insects. e.g. *Mlabris, Epicauta, Lytta, Meloe*

General Characters of Family Coccinellidae:

This family includes Lady Bird beetles.

1. Adults are small, oval or spherical convex, brightly colored with red, black, yellow, brown spots.
2. Mostly carnivorous, feeding on aphids, coccids etc. some are herbivorous.
3. Head is concealed in pronotum.
4. Tarsi are 4 segmented.
5. On disturbance, adults discharge a bitter amber colored fluid having defensive function from tibio-femoral articulation containing dermal gland, e.g., *Epilachna, Menochilus sexmaculatus.*

General Characters of Family Curculionidae:

This family includes Weevils.

1. Head is modified into a long rostrum.
2. Antennae are often clubbed, geniculate or clavate.
3. Gular sulci are mostly confluent.
4. Mouthparts at the tip of rostrum.
5. Labrum is wanting, palps are reduced.
6. Body is clothed with scales.

7. Mandibles – lacking or reduced.

8. Larvae are apodous and phytophagous.

9. Rostrum is used by female as a drilling instrument to bore hole for placing the eggs. e.g., *Rhynchaenus, Pempherulus affinis.*

General Characters of Family Scarabaeidae:

This family includes Dung beetles.

1. Small or large, oval or spherical or convex body.

2. Head and prothorax with horns.

3. Antennae are 8-10 segmented.

4. Hind tibia with spur.

5. Mandibles are membranous.

6. They feed upon dung and roll the dungball to a suitable place. The egg is enclosed in a small ball of dung in underground chamber and a nest is guarded by a female. e.g., *Helicorpis, Cartharsisu, Copris.*

General Characters of Chrysomelidae:

This Family includes Potato/cucumber/flea beetles).

1. The beetles are of moderate size, oval, convex, black, blue, green, brown, yellow, metallic brightly coloured beetles with beautiful spots or stripes.

2. Antennae are widely separated.

3. Dorsal surface of body is greatly plane and shining with metallic colouration.

4. Eyes are small.

5. Prothorax is laterally margined and narrow.

6. Elytra cover entire body. Forecoxae is globose.

7. Legs are well adapted for running and jumping. e.g., *Leptinotarsa, Longitarsus.*

General Characters of Family Cerambycidae:

This family includes Long horned wood-boring beetles.

1. Some species of adults attain largest body size among insects; e.g. *Tiatnus giganteus*.
2. Body is long and cylindrical and with attractive colouration.
3. Antennae are very long at least 2/3 of body length.
4. Tibia is with 2 spurs. Tarsi is 5 segmented.
5. Stridulatory organs are on hind margin of prothorax-scutellar base or hind femora – elytral edge.
6. Grubs are apodous, elongate, cylindrical, whitish and bore into woods, stems, roots of mostly forest plants and some domestic ones; e.g. *Anoplophora versteegi, Sthenias grisator.*

6.6 SUMMARY

Hemiptera means "half-wing" is an order of insects commonly called true bugs, Majority of them are plant-sap feeders but some are predators and ectoparasites. There are several pests causing damage top various economics crops. Some act as vectors for a variety of pathogens causing diseases in plants and animals. Order Hemiptera is classified into two suborders – Heteroptera and Homoptera. In Heteroptera head mostly hypognathous mouthparts Piericing and sucking type Wings The forewings are modified into the hemelytra, Hindwings are membranous Legs Well-developed, hindlegs longer, Tarsi- 2-3 segmented. Legs are modified into saltatorial, fossorial, raptorial or natatorial legs. Abdomen it is 11-segmentedm, Sound Producing Organs among Hemiptera, Cicadidae are well-known for sound production. In Homoptera Head is deflexed in homoptera Antennae Mostly 4- or- 5 segmented Mouthparts Piericing and sucking type Wings The forewings are uniformly but slightly hard Legs Well-developed, Abdomen it is 11-segmented.

Coleoptera is the largest order in not only the Arthropoda but in the entire animal kingdom, consisting about 330,000 species. They are adapted to various modes of life, viz.- terrestrial, aquatic, areal, fossorial, subterranean, carnivorous etc. and are mostly concealed in habit. The order represents a heterogenous assemblance of very minute size. In Coleopterans head is strongly sclerotized, pro or hypognathous Antennae are usually 11-segmented Mouthparts

Biting-chewing type Mandibles Variably developed. In carnivorous beetles they are acute with fine cutting edge and canaliculated for fluid feeding while in phytophagous forms they are short, Maxillae Fully developed Wings (a) Forewings: Two pairs, unequal forewings modified into elytra. Development Eggs are laid in clusters or enclosed in cocoons (Hydrophilidae) or in oothecae (Cassidinae) or in the tissues of plants (Curculionidae). Larvae have strongly sclerotized head, biting type of mouthparts, lacking abdominal legs. Thoracic legs-well developed. There are 2 types of larvae. *Campodeiform*-in Adephaga, *Eruciform* in polyphaga.

6.7 TERMINAL QUESTIONS AND ANSWERS

Q1- What type of mouth parts are present in the case of heteropterans insects?

Q2- Comment upon the modification of wing in order heteroptera?

Q3- Write about the insect species of order hemiptera that shows parental care?

Q4- Describe the characters of family Coccidae and cicadidae?

Q5- Discuss about the family of Beetle which is known for feeding upon aphids?

UNIT 7 GENERALIZED STRUCTURE HABIT AND HABITAT OF THE FOLLOWING ORDERS WITH FAMILIES

CONTENTS

7.1 OBJECTIVES

1- To study the general characters, habit and habitat of the orders Lepidoptera, Hymenoptera and Diptera.
2- Study the various habitats of some insect orders and to assess their geographical distribution.
3- Identification of insects on the basis of their morphological characters, their feeding habitat, and on the basis of their mouth part orientation.
4- Taxonomic aims at classifying insects into taxa on the basis of similarities in phenotypic characteristics.

7.2 INTRODUCTION

These are endopterygote insects having soft body covered with pigmented scales, with two pairs of membranous wings and suctorial proboscis, with eruciform larvae bearing eight pairs of legs and with adecticous-object pupae. It is one of the largest orders consisting of more than 105,000 species. The moths are nocturnal while the butterflies are diurnal in habit. They are beautiful insects representing species-specific colour pattern of the wings. The adults feed upon nectar and juices of flowers, and fruits while larvae exclusively feed upon a variety of plants and are destroying foliage, shoots, shoots of trees, crops, vegetables, fruits, food grains, flour, clothing etc. and behave as the external feeders or internal borers. The lepidopteran larvae are, therefore, pests of various economic crops and timber. The adults are, on the contrary, harmless except some species of fruit sucking moths, such as the citrus fruit sucking moth.

The order Hymenoptera consists more than 100,000 species and large number of them are still undiscovered due to severe parasitic mode of life. They may be free-living, phytophagous, predatory, entomophagous parasitic or social insects. trophallaxis or mutual exchange of food between adults and larvae, is common among ants and wasps. They have very diversified, behavior, habits, nest building, caste system, chemical communication system etc. Honey bees are the best natural pollinators and honey and wax producers. Chalcid, braconid and icneumoni flies are well known parasites and are widely used in the pest control management throughout the world. This method of pest control is referred as to the biological control. In various families of Hymenoptera, particularly in the honey bees, some wasps and ants, the males are reproduced through parthenogenesis.

Diptera is one of the largest orders of insects consisting more than 85,000 species. They are highly evolved in their biology. They are highly evolved in their biology. They feed upon nectar, decaying organic matter, micro-organisms, on the tissues and blood of various animals, some species (one or both sexes) spread or transmit various pathogens causing diseases in man and several vertebrates (farm animals) and thus acquire medical and veterinary importance.

7.3 LEPIDOPTERA

GENERAL CHARACTERS

1. **Head:** Head is small, spherical and hypognathous, with a large fronto- clypeal region.
2. **Antennae:** Antennae are long but of variable length, often clavate, pectinate. Plumose type in the males of Saturniidae.
3. **Eyes:** Eyes are compound, large, globular: Ocelli lateral, concealed under scales, situated closely ventral to eyes.
4. **Mouthparts:** Mandibles are wanting; Maxillae- both galea become elongated greatly, inner face become concave and are held together by hooks and spines so that a coiled suctorial proboscis is formed.
5. Thorax: Thoracic segments are fused but mesothorax is large and distinct.
6. **Wings:** Wings are 2 pairs, large, covered with scales on wing membrane. Microtrichia are common. Metathorax bears tympanal organs. Vestigial wings are even absent in the females of Psychididae. Wings are folded vertically upward (butterflies) or eld roof like over dorsum (moths) at rest. Forewings are always larger than hindwings. Marginal lobes are common; coupling of both wings are common: longitudinal veins are numerous.
7. **Forelegs:** Forelegs are reduced, coxae is large, long and immovable. Tarsi- 5- segmented with a pair of claws, legs are degenerated in the females of bagworms (Psyphalidae).
8. **Abdomen:** Abdomen is slender or tubular, 10-segmented; 9^{th} and 10^{th} segments in female form telescopic ovipositor. Tympanal organs are present at the base of abdomen.

9. **Male Genitalia:** Median saccus on the 9th segment with a pair of claspers, a median process or uncus, with aedeagus below gnathos and with a juxta or penis-funnel.
10. **Female Genitalia:** 9th and 10th segments form telescopic ovipositor.

General Characters of Family Noctuidae:

This family includes Army worms and cut worms, borers.

1. Wings with areole, cryptic and dull coloured. SC free at base. Tympanum is present on metepimeron.
2. Proboscis is present, Hind tarsi is slender, tibial spurs is long, Frenulum is present.
3. Larvae are with all prologs bearing crochets except in Catocalinae, Plusiinae and Hypeninae in which first two pairs are wanting and they become semiloopers.
4. Some moths are adapted for the habit of fruit sucking.
5. e.g., *Achaea Janata, Spodoptera exigua, Mythimma separate.*

General Characters of Family Bombycidae:

This family includes Mulberry silk moths.

1. Male and female with pectinate antennae.
2. Moths are robust and large.
3. Larvae are large, wrinkled, white silk worms.
4. Body is cylindrical and feed on mulberry plants.
5. Larvae with a short anal horn, medio dorsal on the 8th abdominal segment.
6. Pupa is formed under silken cocoon.
7. Wings, are without frenulum. Proboscis is vestigial or absent. e.g., *Bombyx mori, Eupterote, Nisaga.*

General Characters of Family Sphingidae:

This family includes Hawk moths.

1. These are large, robust, flying moths.

2. Antennae are hooked apically.
3. Proboscis is extremely long.
4. Forewings are larger than hindwings.
5. Larvae have body segments, with longitudinal and oblique stripes. Larvae also have a horn on segment 8.
6. Pupation occurs inside cocoon. e.g. *Acherontia, Deilephila.*

General Characters of Family Nymphalidae:

This family includes Emperor butterflies.

1. Butterflies are brightly coloured with clubbed antennae.
2. Forelegs are reduced and vestigial, folded on the thorax. Tibia is short, covered with long hairs. Foreleg tarsi are unjointed in male but 4 to 5 segmented in female.
3. Larvae are covered with spines and a pair of anal processes directed backwardly.
4. Pupa is naked. e.g., *Vanessa cardui, Nymphalis.*

General Characters of Family Pieridae:

This family includes white, orange or yellow butterflies.

1. Forelegs are normal with bifid claws. Foretibia are without pads.
2. Antennae are clubbed. forewing Cu vein with 3 branches.
3. Larvae are segmented divided into annulets with setae.
4. Prologs with bi- or trirdinal crochets.
5. Pupa is naked, attached to host by a silken thread from the anal end with a single ventral spine. e.g., *Pieris brassicae, P. Napi.*

General Characters of Family Papilionidae:

This family includes Swallow-tail butterflies.

1. They are iridescent black blue or green, spotted, yellow, orange coloured.
2. Antennae are clubbed.

3. Large butterflies with tail-like prolongation of hindwings. Claws never bifid. Fore-tibia are with pads.
4. Larvae are without setae.
5. Pupa are with two lateral cephalic processes. Naked and suspended by a thread from anal end. e.g., *Papilio demoleus, P. Polytes.*

General Characters of Family Saturniidae:

This family includes Tsar silk moths.

1. They are very large, coloured moths, tropical.
2. Wings with transparent fenestrae or eye-spots.
3. Proboscis is aborted (vestigial or absent).
4. Antennae are pectinate in males and females, long in males.
5. Frenulum is absent.
6. Hind wings with tail like processes.
7. Larvae are large, smooth with scoli, with spiny tubercules.
8. Pupation occurs in silken cocoon

7.4 HYMENOPTERA

GENERAL CHARACTERS

Head: Head is free, mobile, hypognathous.

Antennae: Geniculate, clavate, filiform or pectinate. Segments – 4 (ants) to 70 (Ichneumonidae), - sexual dimorphism – 13 segments in males and 12 in females in Apoidea and Vespoidea.

Eyes: Well-developed except in some ants where they are atrophied.

Ocelli: 3 but sometimes absent.

Mouthparts: Biting- chewing in Symphyta, lapping-sucking in bees. Mandibles are well-developed but do not serve trophic function and are modified for moulding wax, cutting leaves or tearing plant fibers. They carry out nest building in Apocrita. They are prehensile or feeding dentate organs in sawflies. Labial palps: 4-segmented. Glossa modified into proboscis bearing a spoon like lobe, flabellum. Paraglossae- vestigial or absent. Galea in sawflies modified into large blades.

Thorax: Mesothorax – largest. First abdominal segment (tergite) is fused with meta – (post) notum forming propodeum. Mesonotum is divided by a transfer suture into anterior scutum and posterior scutellum.

Wings: Two pairs usually present, sometimes greatly reduced, vestigial or absent. Forewings large while hindwings small, during flight, forewings are interlocked with hindwings by frenal hooks, a row of hooks or hamuli along the coastal margin of the hind pair. These hooks catch on fold along posterior margin. Venation is greatly reduced in Apocrita while generalized venation in Symphyta, Total absence of venation – Platygasteridae, - apterous – workers of ants., apterous males of Aqaonidae.

Legs: Trochanter along with trochantellus present. Apocrita forelegs with spur or calcar at apex of the tibia opposite to cavity of basitarsus. Basitarsus cavity with fine comb-like teeth which remove pollen from antennae and latter are inserted and thus act as preening organ. Fossorial legs: Sphecoidea use for digging. Bees with pollen carrying hindlegs, tibia with a large pollen brush or scope and margined with long hair forming pollen basket or corbicula while basitarsus forms preening organ, Tarsi-5-segmented. Pretarsi with arolium and a pair of claws.

Abdomen: 1st abdominal segment is fused with the metathorax forming-propodeum. Rest of the abdomen forms gaster of metasoma. 1st segment or gaster is broad and unmodified in Symphyta while modified into petiole in Apocrita.

General Characters of Family Ichneumonidae

This family includes Ichneumon Flies.

1. Largest family, body is large, slender, black, yellow or brown insects.

2. Antennae are filiform, never geniculate but often long having 16 or more segments.

3. Hind femur is with a trocantellus.

4. Forewings is with a pterostigma at distal end of costa. Costal cell is usually narrow.
5. Venetation is complete. Abdomen is with pygostyles.
6. Ovipositor is long, extruded permanently.
7. Pupation is inside cocoon.
8. Parasitism is exclusive on larvae of Coleoptera, Lepidoptera, Diptera, Hymenoptera, aphids. e.g., *Amauro morpha.*

General Characters of Family Chalcididae

This family includes Chalcid wasps.

1. It is one of the largest family of the order.
2. Minute or small metallic colored, primary or secondary parasites of eggs, larvae and pupae of Lepidoptera, Hemiptera, and Diptera.
3. Labrum is concealed. Mandibles are atout with 34 teeth.
4. Antennae are geniculate, 2 to 13 segments, clavate.
5. Pronotum is not extending towards tegulae. Propodeum is wanting from mesothorax.
6. Wings are not folded longitudinally. Fore wings- hyaline or spotted, with marginal fringe, venation-greatly reduced.
7. Ovipositor is not curved over the dorsum, short and straight. e.g. *Meyeriella indica, Stematocerus.*

General Characters of Family Vespidae

This family includes Social wasps.

1. Red or yellow body with black markings.
2. Antennae is with 12 segments in females longitudinally, with a long, first discoidal cell, veins do not reach apical margin. Submarginal cells are 3.
3. Hindwings are without anal lobes.
4. Petiole is distinct long, slender. Pronotum extends back, lateral to tegula.
5. Mandibles are strongly dentate. Claws are simple.
6. Abdomen is sessile, conical, with well-developed terminal ovipositor or sting.

General Characters of Family Braconidae

This family includes Braconid-flies.

1. Small, stout insects.

2. Hindwings with a cross vein rem but differs in position from that in Ichneumonidae. Forewings- without 2m-cu cross-vein, but – with M + Rs sector cross-vein so there is only a single recurrent vein.
3. Larva is with 13 segments, with caudal appendage in endoparasites. Procctodaem in larva with swollen anal accessory respiratory organ.
4. Pupation is within cocoon inside or outside the body of host. e.g., *Apanteles*, *Microplitis, Stenobracon.*

General Characters of Family Apidae

This family includes Honey bees.

1. Small, black or brown, densely hairy, golden brown coloured.
2. Hind tibia is without spurs. Clypeus is elongate, Tongue is elongate.
3. Forewings is with 3 submarginal and 1 radial cells. Fore and mid tibia are with apical spines. Hind tibia and metatarsus are flattened and fringed.
4. With pollen collecting apparatus: best pollinators.
5. Sting is with terminal barbs. e.g. *A. dorsata, Apis indica.*

General Characters of Family Formicidae

This family includes Black ants.

1. All are social and with worker caste.
2. Male and fertile female are primary winged castes, workers-wingless; queen-secondarily wingless after mating.
3. Antennae are Geniculate, 4-13 segmented.
4. Labrum is vestigial.
5. Mandibles are excessive and variably modified.
6. Eyes and Ocelli are developed in male, vestigial in male.
7. Wings are with 1-2 cubital and one discal cell.
8. Queen once fertilized, lays eggs and they often replace queens.

7.5 DIPTERA

GENERAL CHARACTERS

Head: Prognathous, freely movable, and relatively larger than the body.

Eyes: Large, occupying most of the dorsum of head capsule, both eyes may be fused (holoptic, mostly in the males) or separated (dichoptic mostly in the females). In some species eyes are larger in the males than females.

Ocelli: Mostly 3, arranged in a triangle.

Antennae: Nematocera-filiform in females, plumose in males, Brachycera-stylet type, Cyclorrhapha-aristate type.

Mouthparts: Sponging in nonblood sucking Cyclorrhapha or piercing and sucking type in blood sucking forms. Females of Nematocera and Brachycera possess well-developed blood-sucking mouthparts while both males and females of some Cyclorrhapha are well-equipped for blood sucking. Labium universally forms the proboscis. Mandibles are absent or greatly reduced in non-sucking Cyclorrhapha. In the blood sucking Cyclorrhapha proboscis alone functions as piercing organ and the labella bear prostomial sharp teeth for cutting the tissues and skin of the host but lack pseudo trachea.

Thorax: Mesothorax is greatly developed, pro and metathorax reduced, with dense bristles showing characteristic arrangement.

Wings: Single pair of forewings only, hind wings modified into club-shaped halters. Wings are modified into club-shaped halters. Wings are membranous, hyaline or coloured, covered with setae or scales, venation reduced, 2A, 3A as vestigial and atrophy of Cu is common. Posterior margin of wings at base possesses lobes – the alula and squammae in many species.

Legs: Slender or stout; weekly developed, mostly fit for clinging, tarsi – 5 segmented, claws – paired, with empodium and pulvilli. Pulvilli are reduced or wanting in Nematocera or replaced by a single arolium.

Abdomen: Distinctly segmented but some segments or sternites are reduced.

Female Genitalia: Segments 6 or 7 – 10 often modified into telescopic ovipositor.

Male Genitalia: In male, 9 and 10 segments form a curved twisted hypopygium supplemented by a pair of claspers, aedeagus and with or without some accessory structures.

General Characters of Family Tipulidae:

This family includes Crane flies.

1. They are large-sized nematoceran flies.

2. Antennae are multi-segmented, pectinate or serrate.

3. Head is anteriorly modified into a beak or elongate proboscis.

4. Ocelli are absent.

5. Te mesothorax bears V-shaped suture on notum. Legs are very long.

6. Wings are often spotted.

7. Larvae have hemi cephalous head, body is elongate, cylindrical, with or without pseudopods and trunk 11 or 12 – segmented.

8. Pupa is elongated with slender or plate like thoracic respiratory horns; e.g. *Conosia irrorata.*

General Characters of Family Chironomidae:

This family includes Midges or Gnats.

1. Antennae are plumose in males and pilose in female.
2. Antennae are 15-segmented.
3. Wings are not covered with scales, anterior wing veins are thickened.
4. Mouthparts are poorly developed.
5. Forelegs are elongate, slender. Ocelli are absent.
6. Head is small, concealed in thorax.
7. Larvae are aquatic, red due to stored haemoglobin, with blood-gills and 2 pairs of anal gills. e.g. *Chironomus vicarius, C. cubicularum*

General Characters of Family Culicidae:

This family includes Mosquitoes.

1. Body-slender, long. Without ocelli. Palpi is stiff. With elongate piercing proboscis consisting stylets.
2. Wings are fringed, scales along veins and posterior margin.
3. Legs-long covered with scales.
4. Larvae are aquatic with respiratory siphon, metapneustic, with feeding brushes.
5. Anal segment with four tracheal gills.
6. Pupa-aquatic and active.

2. The members are vectors of diseases like malaria, yellow fever, dengue etc. e.g. *Anopheles*

General Characters of Family Muscidae:

This family includes True flies- Houseflies, Stable flies, Buffalo flies and Cattle botflies.

1. Small or medium sized flies.

3. Eyes are large, holoptic in males (rarely).
4. Mouth parts- sponging in houseflies, sucking in others.
5. Antennae are with basal arista of plumose type. e.g. *Musca domestica, M. nebula*

General Characters of Family Tabanidae:

This family includes Horseflies.

1. Body is without bristles, flattened, stout, metallic brown, tawny or grey.
2. Antennae are without style.
3. Eyes are large, holoptic in males, dichoptic in females.
4. Females are blood suckers, males are nectar feeders.
6. Larvae are 12 segmented, small, with retractile head, with antennae and mouth hooks.
7. They are active blood suckers of cattle, horses and man. e.g. *Tabanus striatus*

General Characters of Family Drosophilidae:

This family includes Pomase-flies, Vinager flies or fruit flies.

1. Small flies occurring about flowing sap, decaying fruits, wine, vat, vinegar fermentation products.
2. Eyes are red. Antennae with 2nd segment cleft, Arista dorsally, pectinate.
3. Larvae are predatory, on fruits.
4. Body of larvae are 11-segmented and each segment is surrounded by a girdle of minute hook-like spines. e.g. *Drosophila melanogaster, D. montium*

General Characters of Family Bombylildae:

This family includes Bee-flies.

1. Body is covered with pubescent hairs.
2. Proboscis is extremely long and piercing.
3. Legs are long and slender. Antennal style-minute or vestigial.
4. Males with holoptic eyes. e.g. *Bombylus major, Halictus*

7.6 SUMMARY

The order Lepidoptera is one of the largest orders consisting of more than 105,000 species. The moths are nocturnal while the butterflies are diurnal in habit. They are beautiful insects

representing species-specific colour pattern of the wings. The adults feed upon nectar and juices of flowers, and fruits while larvae exclusively feed upon a variety of plants and are destroying foliage, shoots, shoots of trees, crops, vegetables, fruits, food grains, flour, clothing etc. and behave as the external feeders or internal borers. Head is small, spherical and hypognathous, Antennae are long but of variable length, often clavate, pectinate. Plumose type in the males of Saturniidae. Eyes are compound, large, globular Thorax Thoracic segments are fused but mesothorax is large and distinct. Wings are 2 pairs, large, covered with scales on wing membrane. Wings are folded vertically upward Forelegs are reduced, coxae is large, long and immovable. Abdomen is slender or tubular, Male Genitalia Median saccus on the 9^{th} segment with a pair of claspers, a median process or uncus, with aedeagus below gnathos and with a juxta or penis-funnel. Female Genitalia 9^{th} and 10^{th} segments form telescopic ovipositor.

In Hymenoptera Head is free, mobile, hypognathous. Antennae Geniculate, clavate, filiform or pectinate.Eyes well-developed except in some ants where they are atrophied.Ocelli 3 but sometimes absent. Mouthparts Biting- chewing in Symphyta, lapping-sucking in bees. Thorax Mesothorax – largest. First abdominal segment (tergite) is fused with meta (post) notum forming propodeum. Wings Two pairs usually present, sometimes greatly reduced, vestigial or absent. Forewings large while hindwings small, during flight, forewings are interlocked with hindwings by frenal hooks, a row of hooks or hamuli along the coastal margin of the hind pair. Legs Trochanter along with trochantellus present. Bees with pollen carrying hindlegs, Abdomen 1^{st} abdominal segment is fused with the metathorax forming-propodeum.

Diptera is one of the largest orders of insects consisting more than 85,000 species. They are highly evolved in their biology. They feed upon nectar, decaying organic matter, micro-organisms, on the tissues and blood of various animals, some species (one or both sexes) spread or transmit various pathogens causing diseases in man and several vertebrates (farm animals) and thus acquire medical and veterinary importance Head Prognathous, Eyes Large, occupying most of the dorsum of head capsule, both eyes may be fused (holoptic, mostly in the males) or separated (dichoptic mostly in the females). Antennae Nematocera-filiform in females, plumose in males, Brachycera-stylet type, Cyclorrhapha-aristate type. Mouthparts Sponging in nonblood sucking Cyclorrhapha or piercing and sucking type in blood sucking forms. Thorax Mesothorax is greatly developed, pro and metathorax reduced, with dense bristles showing characteristic arrangement. Wings Single pair of forewings only, hind wings modified into club-shaped halters. Wings are membranous, hyaline or coloured, covered with setae or scales, Legs Slender or stout; Abdomen Distinctly segmented but some segments or sternites are reduced. Female Genitalia Segments 6 or 7 – 10 often modified into telescopic ovipositor. Male Genitalia In male, 9 and 10 segments form a curved twisted hypopygium supplemented by a pair of claspers, aedeagus and with or without some accessory structures.

7.7 TERMINAL QUESTIONS AND ANSWERS

Q1-Write some general characters of family Apidae?

Q2- Write some characters of these families Vespidae and Chalcididae and how they are differ from each other?

Q3- Write about the family of wasp which is known for their social behaviour.

Q4- Write some characters of family Tipulidae?

Q5- Write some morphological differences between the family Chironomidae and culicidae?

UNIT 8: INSECT PESTS (Agro Horticultural)

CONTENTS

8.1 OBJECTIVES

After studying this module, you shall be able to learn and understand:

i. Introduction to insect pest
ii. Different types of insect pests
iii. Life cycle and nature of damage of the major insect pests of agriculture and horticultural crops

8.2 INTRODUCTION

The term pest is derived from French word 'Peste' and Latin term 'Pestis' meaning plague or contagious disease. In other words, a "pest" is defined as any organism that causes annoyance or injury to human beings, human possessions, or human interests. The injury may be physical (bites and stings), medical (causing illness or disease), or economic (monetary loss to goods or property). Injury may arise directly from the pest itself, or may develop indirectly as a result of the actions or behavior of the pest. Being the most diverse and widely distributed animal groups on earth, different insect species act as the pest to human beings in most if not all the above mentioned categories. Specifically, several herbivorous insect species feed on one or many crop plant species and cause serious economic damage to important crop plant species and are considered as the major pest for agricultural and horticultural crop commodities. Insectspopulations increase above a certain level and cause economic losses to crop/fruit/product yields and stored products.

In order to identify a pest species, an insect pest's population density is crucial. To reiterate, population density is a key idea that underpins knowledge of pests and their dynamics in agriculture. Even while there may be several different insect species present in a location at once, not all of them qualify as pests. Only those whose populations exceed a particular threshold and causes economic harm are referred to as pests. Such population densities of insect pests, which can cause economic damage to the crop have been categorised into different levels.

Concept of Injury levels

1. General Equillibrium Position (GEP): It is the average population density of any insect pest throughout a given time period and is unaffected by the pest control methods used on the crop field. Population density at GEP does not significantly harm the crop economically for the majority of insect pest species. However, due to any biotic or abiotic reason, the population density at this level might vary and reach up to EIL.

2. Economic Threshold Level (ETL): It is an index of decision making regarding pest management. Stern et al. (1951) defined the ETL as "the population density at which control action should be determined (initiated) to prevent an increasing pest population (injury) from reaching the economic injury level." The ETL is essentially a time to take initial action, therefore even though it is measured in bug density, numbers are merely an index of that time. ETL is merely an action threshold since the level of harm produced by one insect, like that caused by other insects, can likewise cause significant crop damage.

3. Economic Injury Level (EIL): It is the lowest insect population in field which causes economic damage to the crop. According to Stern et al. (1951), EIL is the amount of injury which will justify the cost of artificial control measure. Preventive control methods or management strategies implemented at ETL stop the pest population before it reaches the point when crop damage is economically detrimental. Economic injury can be simply described in terms of the cost of pest treatment and the cost of yield loss due to pest infestation. Economic damage/injury results when the cost of pest treatment is less than the cost of yield reduction.

8.3 ORIGIN OF INSECT PESTS

Insects have been believed to be emerged roughly 480 million years ago, during the Ordovician period, around the same time as the earliest terrestrial plants. The coexistence of the two types also gave rise to herbivory, one of the most significant co-evolutionary phenomena. After that, the appearance and subsequent fast success of blooming angiosperm species throughout the Cretaceous period led to the creation of insect societies, ranging from ant, termite, and nectar-feeding bee communities. Insects that consumed plants acquired a variety of mouthparts during the course of the following many hundreds of years, from biting and chewing to piercing and sucking varieties.

On the other hand, human first appear on earth merely 6 million years ago during late Miocene epoch of the Cenozoic tertiary period. As humans during early phases of evolution did not grew any crops and did not knew the concept of homes and had nothing to very few possessions, we can imagine that their pest problems would have been limited to the insects, such as lice, fleas, flies, and mosquitoes, causing different fatal diseases. Several examples of such insect transmitted diseases/plague have been reported in prehistoric and historic period of most if not all the human civilisations.

It was only after the development of agriculture (approximately 10,000 years ago), the establishment of permanent settlements, and the introduction of a life-style that required the storage of greater or lesser quantities of food and other items that a concerted effort to control a large variety of organisms became necessary. Early pest control practices were often based on mysticism or superstition but some of the evidence from the Chinese ancient texts reports for different pest management techniques of historic period some of which are still in use.

The Sumerians were utilising sulphur compounds to keep insects and mites under control well before 2500 B.C. Plant-derived insecticides (similar to modern botanicals) had also been produced for seed treatment and fumigation purposes by 1200 B.C. in China, thousands of kilometres to the east. For the prevention and management of pests in buildings and on stored goods, the Chinese also utilised chalk and wood ash.

Similar methods of pest control can be found in Greek and Roman history. Homer recognised the benefits of burning for locust control about 950 B.C. In order to prevent mosquitoes, Herodotus (450 B.C.) recounts the use of mosquito nets and the custom of constructing tall sleeping towers. Aristotle documented the long-standing use of fumigants by the Greeks in 350 B.C., while the Roman Cato noted the use of oil sprays, oil and bitumen sticky bands, oil and ash, and sulphur bitumen ointments as pest control methods in 200 B.C.

Apart from all these techniques, Roman people would also recurrently turn to religion and superstition for help with their pest problems of plague, locust swarm and plant diseases. One of several such mysticism including a woman running on the garden and nailing crayfish in the different parts of the field has been reported in the book on Ancient Roman Agriculture, *De re Rustica* (50 A.D.).

The first use of the word “Pest” also been mentioned in the ancient Roman civilisations where traditional rites were performed by Roman people in the month of April to appease the goddess

Robigo. Robigo was considered synonymous with the cereal rust disease and was given the name "*Maxima segetum pestis*" meaning- the worst pest of the period.

8.4 FACTORS AFFECTING THE ABUNDANCE OF INSECT PESTS

In his novel work Charles Darwin (1859) explained the idea of environment having various components which might act individually or in combination to influence the survival and multiplication of any living species. The basic components of food and other resources formed the living or biotic factors, while climatic components made for the abiotic factors.

In a similar way, physical and abiotic elements were discovered and used to explain how insects evolve and survive both as individuals and as a group. This was strongly confirmed by the effect of abiotic variables on the growth of insects, but the effect of several integrated components could not be fully understood for several decades. Regarding the density of the insect population, Howard and Fiske (1911) provided an explanation of how these components function. They separated environmental factors into two groups based on whether their detrimental effects increased with population density **(facultative factors)** or were independent of density **(catastrophic factors)**.

Nicholson (1933) demonstrated environmental factors into two parts, reactive (controlling) and non-reactive factors. These reactive factors were similar to facultative factors of Howard and Fiske, whereas the non-reactive factors were analogous to the catastrophic factors.

Smith (1935) described facultative factors as **density dependent factors** and catastrophic factors as **density independent factors**. Generally, the density dependent factors are biotic in nature and the density independent factors are abiotic or primarily climatic in nature.

Any insect species that feeds on or harms crop plants can only be referred to as a pest if it causes significant crop damage or accumulates to a specific level of abundance in a certain location. Any insect species' distribution and abundance are influenced by interactions with biotic and abiotic elements of the environment. Temperature, moisture, and soil nutrients, along with biotic interactions within and between species, can all have significant effects on how plants and animals are distributed in space.

Apart from the general biotic and abiotic factors influencing the reproductive success and dispersion of the insect pests some major limiting factor can be categorized as the most important biotic and abiotic factors for the insect pest population. There are many factors that, alone or in combination, allow insect populations to reach densities that are of economic importance. Different such factors are following:

Destruction of forests: Large-scale deforestation for the purpose of crop production creates favourable conditions for some insect populations to exponentially grow and turn into pests by altering the habitat's topography. Additionally, the deforestation-related changes in many abiotic parameters, such as temperature, diurnal fluctuations, humidity, rainfall, etc., have a significant impact on the insect population densities.

Extensive monoculture: Any pest population of that crop plant species will have a suitable habitat if a single plant type is produced over a vast area. Since the pest has access to enough food and shelter throughout the year, intensive cultivation of such crops in more than one season in a year accelerates this population growth.

Introduction of new crops and improved strains: Some natural insect populations that were previously not thought of as pest species may benefit from the cultivation of new plant types in a region where they are not native to the crop itself.

Introduction of a new insect species in a new habitat: In order to control existing insect pest species as natural enemies, different bug species are introduced to new locations. The result is that the introduced bug species, which lacks any local natural enemies, proliferates in the area and begins to harm local economies. The best illustration of this type of outbreak was the introduction of the wolly aphid, *Eriosoma lanigerum*, to the Nilgiri region, where it quickly established itself as a significant apple pest in the absence of any local natural enemies.

Accidental invasion of a foreign pest: The pest outbreak is also made easier by the pest's entry into a non-native location where natural enemies are absent via one of the various transport routes. The most prominent instance of these invasions is the recent spread of the invasive alien fall army worm in the Indian subcontinent.

Host Location and Suitability: A series of steps is completed as an insect start to settle into a crop, and the amount of time devoted for this purpose is influenced by the characteristics of the habitat of neighboring crops and species diversity of the area. The total time allocated to these steps and the number of insect species present in the same area determines the rate of colonization. These steps are host-habitat selection, host location, host recognition, host acceptance, and host suitability.

Reproductive potential: The rate of establishment and population growth of an insect pest into a crop plant species is substantially influenced by the life history characteristics of the insect pest population. For instance, a migratory insect pest species must have a high reproductive potential if it typically cannot withstand the harsh winters of a region. This result in the colonisation of these species in high numbers for a brief period of time as their life cycles ought to be brief as well. All of these life history characteristics are shared by both the locust swarm and the fall armyworm, *Spodoptera frugiperda*.

Environmental Limitations: In addition to the general abiotic factors such as temperature, moisture, air current and other calamities, pest population can also be checked by the natural enemies, residing in a new landscape or habitat. In case of biological control experiments (inundative release) the parasites or predators, released in the locality cause sufficient mortality in the pest population and reduce the colonizing population to a level that is far below the economic levels the following season. Furthermore, extreme fluctuation in the summer and winter temperatures can inflict high mortality on overwintering pest populations, effectively reducing the number of newly established insect pest population.

Crop Production Practices: Differentcrop production practices like, crop rotation, disturbed crop sowing and harvesting time and weeding can cause the pest population density to increase or decrease in any crop field.

Pesticide Application: Since ancient times, it has been customary to use chemical insecticides to clear afflicted areas of the pest insect populations. However, the use of such insecticides or other chemical pesticides can also present a chance for non-target insect pest species that are already present at densities far lower than those required for economic activity. When a pest becomes resistant to a wide range of insecticides and pesticides eliminate its natural enemies, the most severe outbreaks are likely to happen.

Another scenario of a sudden rise in insect pest density is brought on by the disruption of food chain, resulted due to the pesticide treatment. For instance, if aphids, spider mites, and thrips—the typical prey of numerous, omnivorous predators like *Coccinella* spp. And *Chrysopa* spp. are eradicated from the cotton agroecosystem by insecticides early in the season, predators will eventually starve to death, will leave their area, or stop reproducing. Later, when migratory pests like *Spodoptera* species and *Helicoverpa* species infest the areas that have been treated, they are essentially safe from predators, resulting in enormous epidemics of these pests.

Host Plant Resistance: Cultivation of resistant plant species in new habitats or the switch from susceptible to resistant crop varieties in addition to the cultural practices have a detrimental impact on the abundance of insect pest populations. However, such cultivation also encourages the transition of a pest species that was once crop-specific to polyphagous or generalist pest species. Additionally, an existing problematic insect pest species may become even more diverse due to increased population density of a biotype in the population.

8.5 TYPES OF INSECT PESTS

Insect pests have been categorized based on different characteristics of pest and its infestation.

1. Based on occurrence

i. Regular pest: Variousinsect pests favors certain crop and thus are closely associated with it resulting in frequent infestation in similar crop and are called as regular pests. Example: Thrips on chilli and aphid infestation on mustard in North Indian conditions.

ii. Occasional pest: Such insect infestation occurs less frequently and are associated with more than a single crop. Example- Mango stem borer, rice caseworm, etc.

iii. Seasonal pest: Such pests infest the host crop in certain season and month of the year are called seasonal pests. Example- Red hairy caterpillar (*Amsacta albistriga*) in groundnut and rice grasshopper (*Hieroglyphus banian*).

iv. Persistant pest: The insects which infest a crop almost throughout the year are called persistant pests. Example- Mealy bugs on different crops, chilli thrips, etc.

v. Sporadic pest: The insects which are confined in few localities or isolated area are known as sporadic pests. Example- Rice earhead bug (*Leptocorisa acuta*).

2. Based on level of infestation

i. Epidemic pest: Epidemic pests are those insects that suddenly appear in a severe form across a certain area at a specific period. Example- Brown plant hopper (*Nilaparvata lugens*) on rice in Tanjore.

ii. Endemic pest: Pest activity that is limited to a certain area and occurs on a regular basis in a few pockets at a low level. Example- Rice gall midge in Madurai, Mango hoppers in Periyakulam.

3. Based on damage boundary

i. **Key pest:** These are the worst and most destructive insect pests that can harm any crop. They have a GEP that is constantly above the EIL, therefore even the existence of the pest might result in financial loss. The occurrence of these pests is persistent. Example: Diamond backmoth and cotton bollworm.

ii. **Major pest:** Such insect pests have a GEP that is near to the EIL, and the only way to stop the economic damage is by timely and frequent insecticide application. Example-Rice stem borer, cotton jassid.

iii. **Minor pest:** Population density of such pests rarely crosses the EIL and GEP is always below the economic damage.

iv. **Potential pest:** Different insect population present at a crop field does not persist as major pests but can become serious pests with the change in abiotic factors. Example- *Spodoptera litura*.

8.6 PESTS OF STORED GRAINS

Several insect species are known to infest and be responsible for the huge economic losses to the stored products. The important species which are considered as the major pest of stored products are described following.

1. **Rice weevil, *Sitophilus oryzae* (L.):** It belongs to the family Curculionidae. The 4mm long weevil has a dark brown colour with four light reddish or yellowish spots on elytra. The female weevil bores a hole on the paddy grains, deposits a single egg and covers it with gelatinous fluid. The grub is apodous and feed and pupate inside the grain itself, followed by emergence through an irregular hole. The insect is a major and destructive pest of rice, wheat, corn and sorghum in filed as well as in storage conditions.

2. **Khapra beetle, *Trogoderma granarium* Everts (Family: Dermestidae; Order: Coleoptera):** The beetle is reddish brown in colour and measures upto 4-6 mm long. It is a serious pest of stored wheat grains. Apart from wheat the grub also feeds on oilseed and pulse seeds.

Nature of Damage:Larvae feeds on the grains from inside resulting into a hollow grain. This causes a rapid and serious loss of the produce. Larval exuviae also contaminate the product.

Life History: Female lays 30-35 eggs in her entire life span of total 3-12 days. Larval development is completed in 18 days with male moulting 4 times in comparison to the 5 times moulting in female larvae. During adverse conditions, larvae can undergo a facultative diapause for 9 months.

3. **Lesser grain borer or Paddy borer, *Rhyzopertha dominica*(F.) (Family: Bostrychidae; Order: Coleoptera):** *R. dominica* is a serious pest of stored grains particularly the wheat. The adults are more injurious than the larvae. Whole grains may support several adult grain borers. It is thought that *R. dominica* is a secondary grain pest, however first instar larvae have been observed to enter grain through the intact kernel. The beetles have been observed to infest and attack other stored food commodities such as storage paddy, corn, millets, tobacco, nuts, beans, biscuits, cassava, cocoa beans, dried fruits, peanuts, spices and dried meats/fish. Larvae are voracious feeders.

Identification: The adults are either black or reddish brown and grow to a size of 3 mm. Their head is turned upside down into a hood, forming a triangle under the thorax. They have a distinctive shape, with a large pronotum. There is a prominent constriction between prothorax and mesothorax, giving the appearance of having only two body sections when viewed from above.

Life cycle and Nature of Damage: April is the month of egg laying. As the adults live long, up to 500 eggs may be laid in total. The eggs are laid close to the embryo end of the grain which is softer than other parts. It makes the young larvae easy to enter the grain. Eggs are laid singly and in groups. Incubation period varies with temperature and ranges 5-6 days in summer and 7-11 days in autumn. The young larvae pass through 4-5 moults before pupation which takes place inside grain. The adults emerge within a week and begin to feed on the grain. The minimum time to complete the life cycle under ideal conditions is 25 days, however generally it takes 2 months.

4. Confused Flour beetle, *Tribolium confusum* and Red flour beetle, *T. castaneum* (Family: Tenebrionidae; Order: Coleoptera):

Both flour beetles are found throughout the world attacking primarily milled grain products. The confused flour beetle predominates in temperate region whereas the red flour beetle is more common in subtropics.

Identification: Beetles are 4 mm in length and reddish brown in colour. The head and dorsal sides of the thorax are densely covered with minute punctures. The easiest distinguishing character is that the segments of antennae of the confused beetle increases in size gradually from the base to the tip, whereas in the red flour beetle the last few segments are abruptly much larger than the preceding ones.

Nature of Damage:Both larvae and adults damage the wheat grains and flour. The confused flour beetle is the most abundant and injurious pest of flour mills. The beetles attack flour and broken kernels, more severely during monsoon period. It also damages beans, peas, baking powder, ginger, dried fruits, insect collection, nuts, chocolate, etc.

Life cycle: Each female deposits 400-500 eggs in flour or other foods. The eggs are white, translucent, sticky, slender and cylindrical and hatch in a week. The larva moults 6-7 times before reaching full-grown stage within 3 weeks. Full grown larvae transform to naked pupa and a week later adult emergence takes place. The larvae to adult developmental period completes within a month. Adults can live up to 1-2 years.

5. Pulse Beetle or Chinese bruchid, *Callosobruchus chinensis* (Family: Bruchidae; Order: Coleoptera): The pulse beetle, *C. chinensis* is native of China but is distributed in India, Myanmar, Japan, Africa, USA, Philippines, Malaysia etc.

Identification: The adult beetle is small and short being 3-4 mm in length, stoutly built and dark brown in colour. Head is small with rostrum and bears a pair of serrated antennae. The elytra are short and do not reach up to the tip of abdomen.

Nature of Damage:*C. chinensis* is a major pest of pulses particularly chickpea, pea, lentil, beans etc. The grubs eat up the interior of the grain leaving the outer shell of the grain. The beetle can thrive on milled whole pulse with husk, while it does not grow on processed pulse products. The beetles also infest the grains in field. Adults are short lived and do not feed on stored products at all.

Life cycle: The female lays 40-120 eggs either singly or in cluster on the grains in stored conditions whereas, in the field, eggs are laid on the pod and sometimes dropped loosely among the seeds. The eggs hatch within a week into white and curved larvae. The larvae eating through the inner wall of the egg shell into the seed coat and then into the seed itself where it feeds on the cotyledons. The larval period varies from 2 to 3 weeks. When fully grown the larva measures 6-7 mm in length and cuts a disc in the seed coat almost through and pupates below. The pupation period ends in 2 weeks. At adult emergence, the disc readily opens for adult to come out. There may be 6 generations in a year.

8.7 PESTS OF SUGARCANE

1. Sugarcane leaf hopper, *Pyrilla perpusilla* (Family: Lophopidae; Order: Hemiptera): The sugarcane leaf hopper, *Pyrilla perpusilla* is distributed throughout in India where sugarcane is cultivated. It usually severely damages the cane in Uttar Pradesh, Bihar, Punjab, Madhya Pradesh and Maharastra.

Identification: The straw-coloured adult insect has two pairs of wings which are folded on the abdomen in shape of a roof. The length of the body is about 8-10 mm. They possess long pointed snout with prominent red eyes. The female has a pair of pads on the abdominal end of the body. The adults are very active flier.

Nature of Damage: The nymph and adults, both damage the crop by sucking the sap from the foliage depriving the plants with nutrients. As a result, the foliage of the canes become pale yellow and dry up. Like aphids, the *Pyrilla* also excretes honeydew upon which sooty mould develops turning the leaves black.

Life cycle: The female lays eggs in large clusters, containing 10-65 eggs which are covered with white waxy filaments secreted by the anal tuft of the females. Egg laying site is the underside of leaves during summer and inside leaf-sheaths during winter. The eggs hatch into nymphs after 7 days in summer and 22 days in winter. The freshly hatched nymphs are cream coloured, soon turning into pale brown, and have a pair of characteristics anal filaments. Nymphal period varies with climatic conditions. In summer it is about 6-8 weeks but in winter it is about 17-18 weeks. The winter is passed in nymphal stage.

2. Sugarcane shoot borer, *Chilo infuscatella* Snellen (Family: Crambidae; Order: Lepidoptera): *C. infuscatellu*s is a major pest of sugarcane in peninsular regions of India and more vital in early stages of crop growth causing heavy economic losses. Additionally, the larvae also feed on oat, sorghum, millets, sugarcane, barley, corn and wild grasses.

Identification: Adult moth is straw coloured with white hind wings and measures about 3-3.5 mm. The forewing is greyish brown and have dark marking on it.

Nature of Damage: The pest attacks the crop in its early stages of growth with peak activity during March–June. Shoot borer larva enters the plant laterally in its third instar by making entry holes at the base of the stalk. The larva feeds on the soft tissues and makes cavities extending to the setts, killing the growing point. This causes a severe damage to the central leaf spindle which dries up and form a **dead heart** that can be pulled out easily. The cut-off portion inside the bored plant decays, and the dead heart emits an offensive odour when pulled out. ETL for shoot borer is 15.0–22% dead hearts for late sown sugarcane varieties, whereas, for early variety ETL is 16.8% dead hearts.

Life cycle: The eggs are laid in overlapping rows, either in the basal or middle region of the lamina on underside of the leaves. After hatching in 4–6 days, the larva wanders for a few hours and reaches the base of the stem by crawling or hanging by silken thread. The larva enters the gap between the first leaf sheath and stem and feeds on the inner tissue of leaf sheath like a leaf miner for a few days. Later, the larva bores into the stalk and kills the growing point in 10–12 days. Larva passes through five instars. Grown-up larva is dirty white in colour with dark-brown head and five violet dorsal stripes.

3. Sugarcane Root borer, *Emmalocera depressella* (Swinhoe) (Family: Pyralidae; Order: Lepidoptera): The root borer of sugarcane does not feed upon the root of the plant but instead it feeds upon the oldest internodes present just above the mother or seed sett.

Identification: Moths have straw-coloured forewings and whitish hindwings with 20-25 mm in wing span. The moth has dark lengthwise strip on each wing. The head of the adult moth is pale-pink while wings are pale or dirty brown. The life span of male moth is 3-10 days and that of female is 10-15 days.

Nature of Damage: It attacks the underground stalk portion of cane, and the intensity of damage varies with the stage of the crop. In the early stages, i.e. during May–June, dead hearts are formed which cannot be easily pulled out nor do they emit offensive smell as in the case of shoot borer.

Life cycle: Flat, scale like and creamy white eggs were laid singly on the underside of the leaves along the midrib. The first instar larva crawls to the base of the stem and enters it by making a single hole at or just below the ground level. The larva feeds in an irregular semicircular pattern and may leave the bored stem and enter into another underground stem of the same clump or adjoining shoots. Larval period varies from 23 to 43 days in summer and longer during rainy season and winter.The full-grown white-coloured larva cuts an opening at the exterior end prior to pupation and constructs a silky pupal tube up to the surface of soil for easy emergence of the adult. Pupal period lasts for 7–11 days during summer and rainy seasons and 8–14 days during winter.

4. Sugarcane Top borer, *Scirpophaga excerptalis* (Walker) (Famly: Pyralidae; Order: Lepidoptera): *Scirpophaga excerptalis* is commonly known as top borer, sugar cane top borer, top shoot borer. Earlier, *Scirpophaga nivella* was considered top borer of sugarcane.

Identification: Adult moth is silvery white in colour with or without one black spot on each of the forewings. The female has a tuft of crimson red-, orange- or buff-coloured anal hairs.

Nature of Damage: Top borer occurs as a major and regular pest in the subtropical region but as a minor and occasional pest in the tropics. Capable of attacking the crop at all stages of growth, top borer characteristically produces leaf mines, shot holes on opened leaf, atrophied central shoot, stunting of cane and sprouting of axial buds leading to bunchy top formation. The unique early symptom of attack is tunnelling by the first instar larva into the midrib causing a white streak that subsequently turns reddish brown and becomes visible on the ventral surface of the midrib.

Life cycle: The white egg mass is laid on the ventral side of basal or middle portion of top second or third lamina in two to three overlapping layers, covered with the orange or dull golden-yellow-coloured hair mass from anal tuft of the adult female. Newly hatched larvae crawl actively on leaves, suspend themselves by silken threads and get dispersed to adjacent plants by wind. After 3–4 h, they bore into the midribs of leaves through the lower epidermis. The larvae prefer the most tender visible midrib mostly that of the "-1" leaf, which is rolled with only the lower epidermis exposed. The larva feeds above the growing point up to the fourth instar after which it cuts across the growing point, causes dead heart and enters the top internodes either tunnelling down in the centre or moving superficially towards the rind. Pupae are brown obtect and the pupal period varies from 6 to 8 days.

8.8 PESTS OF COTTON

1. Red Cotton Bug, *Dysdersus cingulatus* (Fabricius) &*D. koenigii* (Fabricius) (Family: Pyrrhocoridae; Order: Hemiptera): Both the species of red cotton bugs have always been a source of serious damage to the crop by feeding on developing cotton bolls. The red cotton bugs have been declared as one of the most destructive cotton pest in India and Pakistan and also in other parts of the world.

Identification: The adults are deep red in colour and measure 12-13 mm in length and have deep red legs and antennae. The membranous portion of the forewings and the eyes are black in colour. There is also a black spot in each forewing.

Nature of Damage: They may start feeding with young flower buds, flowers and then young bolls. The growing bolls with buttery content in them are fed aggressively by a number of bugs. These fruits open prematurely, and they continue feeding on the seeds and immature lint, sucking the sap in them. In ripened cotton seeds, bacterium *Namataspora gossypii* enters at the site of injury and stains the cotton fibre. Due to this staining, they are also called as cotton stainer.

Life cycle: During spring, the female lays the spherical yellow eggs in the soil and are covered with loose soil or with small dry leaves. Nymphs hatch out in about 7 days and after hatching are wingless. The nymphs feed gregariously and voraciously on the cotton bolls. Nymphs pass through five moults with wings developing from the third instar and attaining full form after the fifth. Female nymphs are larger than male ones.

2. Spiny Bollworm, *Earias insulana* (Boisduval), and Spotted Bollworms, *Earias vittella* (Fabricius) (Family: Nolidae; Order: Lepidoptera): Spiny bollworms and spotted bollworms are the early season pests of cotton in India. They are seen from 35 days of crop growth in different parts of the country.

Identification: The adults of *E. vitella* is small (10-15 mm in length and 20-25 mm) across wing-span, having pale white forewings with broad greenish bands in the middle whereas in *E. insulana* the forewings are completely greenish.

Nature of Damage: The initial infestation generally occurs on 6 weeks old crop in which the caterpillar cause drooping and drying of shoot due to its feeding by boring into it. In the later stages the larvae feed on buds, flowers and bolls. As a result, flower buds and fruits drop prematurely. Fruits remaining on the plants get deformed and often show exit holes of the larvae. One caterpillar is able to destroy several bolls until pupation. The infested bolls produce poor lint having very low commercial value.

Life cycle: The female moth lays 2-3 eggs on bracts, leaf axils and veins on the under surface of the leaves at night. A single female may lays up to 300-400 eggs. The newly hatched larvae bore into the growing shoots or bolls consuming the plant tissue. The full-grown larva is about 13-18 mm in length and is brownish white with a number of black and brown spots on the body, hence, called spotted bollworm. The last instar larvae come out the boll and pupate in tough felt-like silken cocoons which is attached to dry leaves of the food plant or in soil or among the fallen leaves and rubbish material.The pupal period is about 10-15 days in summer, 20-25 days in autumn and 40-85 days in winter. In summer, total life cycle completes within a month.

3. Pink Bollworm, *Pectinophora gossypiella* (Saunders) (Family: Gelechiidae; Order: Lepidoptera): This oligophagous pest is extensive cotton pest in all cotton-growing continents and countries. Possibly originated in the erstwhile Indian subcontinent, this gelechiid insect has caused huge crop loss in both diploid and tetraploid cotton varieties.

Identification: Adults have a 12 mm wingspan and are greyish or dark brown, with inconsistent black markings. The antennae are filiform and the hindwings are deeply fringed. The adult moths are nocturnal and fly around after dusk. Adults feed on nectaries under the cotton leaves and may live for up to two months.

Nature of Damage: The damage to fruiting bodies of cotton crop is extensive due to the feeding of pink bollworms. Cotton plants produce three to six flushes of reproductive bodies in the active phase when the lint quality is at its best. The pest feeds on the seeds affecting the growing lint. Larvae in older squares web the unopened petal rims and feed inside, causing 'rosetted' flowers.

Life cycle: Singly laid or in small groups of three to five eggs, flattened oval eggs measuring 0.5 mm long by 0.25 mm width. The eggs are laid in protected locations on the plan, such as axils of petioles, peduncles, lower side of leaves, old leaves at the junction of main vein, bracts, squares, flowers and 2-week-old bolls. One millimetre-long, black-headed neonate caterpillars with translucent body hatch out. The neonates move to the nearest food substrates such as squares, open flowers or bolls and commence feeding on tissues. Second instar caterpillars have creamy-white body, dark brown head and paler thoracic shields. Third instar larvae are 6 mm long and have creamy-white body with two transverse dorsolateral pink streaks in each body segment. Those larvae that feed on flowers or on shed rotting fruit bodies have no pink colour. Pupation is generally in soil; the mature larvae cut a round hole on boll wall and fall out into soil. Pupae emerge between 8 and 13 days during cotton season. The greyish-brown adult moths with black bands on forewings and silver-grey hindwings emerge from pupae in early mornings or in the evenings.

4. Leaf Roller, *Syllepte derogata* (Fabricius) (Family: Crambidae; Order: Lepidoptera):

Identification: Moth with yellow wings having brown wavy markings, whereas the larvae are bright greenish in colour with a dark head.

Nature of Damage: Rolled leaves fastened with silken thread to make a trumpet like shape is the most characteristic damage symptom of this pest. Large-scale damage gives a pale look of crop with rolled leaves and stunted growth. The pest frequently occurs in unclean farms with shaded areas.

Life cycle: The moths lay eggs on the leaves, which hatch greenish-white, semitranslucent caterpillars. The larvae feed on the epidermis and cortex of leaves causing them to roll. Leaf cases formed by the feeding larvae act as the pupation site for an obtect pupa. The life cycle of the moth completes in 20-25 days.

8.9 PESTS OF CEREALS

1. Corn Earworm, *Helicoverpa zea (Heliothis zea)* (Boddie) (Family: Noctuidae; Order: Lepidoptera): Corn earworm is a key pest of baby corn in USA and is also found infesting the corn crop in different parts of India.

Identification: Forewing yellowish tan with variable reddish brown, olive green, or gray markings and shading. Reniform spot usually filled with dark gray. Hindwing whitish with dark gray veins and border, with surrounds whitish patch at midpoint of outer margin. Larvae are translucent or yellowish white in colour with black head.

Nature of Damage: Corn earworm damage the whorl of sweet corn plants and the symptoms resembles that of early season European corn borer. Feeding is largely done on the developing milky grains at the top of the cob. In larger plants, caterpillar also grazes on the maize silk and eggs can also be found stuck in this silk. Corn earworm are cannibalistic in nature and thus are found singularly.

Life cycle: Subspherical eggs are laid individually to the plant substrate, white to yellowish-green when laid, developing a reddish band and finally turning dark grey before hatching in 2-3 days. Developing larvae initially feed on the corn leaves, making circular holes, reaches to the cob where it feeds over the developing milky grains. Larva passes through 5-6 larval instars and pupates in earthen cells on the ground. Depending upon the season, pupal period varies from 10-25 days.

2. Paddy earhead bug, *Leptocorisa acuta* (=*L. varicornis*)(Family: Coreidae; Order: Hemiptera): It is major pest of rice/paddy in different parts of India. The pest generally occurs during the flowering stage and feeds upto the milky stage of the crop.

Identification: The adult is green, light brown or mixed yellow in colour with a slender body and long legs. The male measures 13-14 mm and female 16-19 mm in length. Head is triangular and bears 4 segmented antennae.

Nature of Damage:Adults and nymphs both suck the sap of developing rice grains at the milky stage and cause considerable yield loss. Sucking of the grain sap by this bug causes ill-filled/partial filled and chaffy grains and also enhances subsequent fungal and bacterial infection.

Life cycle: The females lays 250-300 eggs during night in 2 or 3 straight rows of 10-20 eggs along with the midrib on the upper surface of the leaf blade. Incubation period last for 6-7 days. First instar nymph is very small, nearly 2 mm long, pale green in colour and look ant-like. It grows to deepen green through different instars. Wing pads appeared on the third instar nymphs. Well-developed wings appeared after the final moult from the fifth instar nymph into adults. Total development period varies from 15-20 days.

3. Rice grasshopper, *Hieroglyphus banian* Fabricius (Family: Acrididae; Order: Orthoptera): It is a popyphagous insect pest of several crops including pulses, millets, corn and rice.

Identification: Dull green coloured hoppers with brown-black lower surface. Adult hoppers can vary from 18-40 mm in body size. Hindlegs are modified for jumping and head is hypognathous.

Nature of Damage: It is serious pest of rice in north Indian states. It is a sporadic pest but the level and intensity of infestation is severe in most of the incidences. Nymph feed gregariously on the germinated seedlings causing it to wither away. Adults on the other hand feed on the shoot and leaves but can also cut the earhead in severe infestation.

Life cycle:Females deposit eegs inside the ootheca in to the soil from October to December. Each eggpod/ ootheca contains 30-35 eggs in the wet sandy soil at 3-5 cm depth. The eggs remain in the soil till rains begin during the following June - July. The nymphs hatch out after the onset of the rainy season. Newly hatched young hoppers are brownish-yellow and afterwards turn to dull green. After passing through 5-7 instars nymphs attain adulthood. Developmental period of females is more than males. Adults mate after 1-3 days after emergence and survived for 1-6 months. There is only one generation of the insect in a year.

4. Yellow stem borer, *Scirpophaga incertulas* Walker(*Tryporyza incertulas*) (Family: Pyralidae; Order: Lepidoptera): *S. incertulas* is distributed primarily in tropical Asia. It also occurs in temperate areas where the temperature remains above 10 °C and annual rainfall is >1000 mm. India, Nepal, Sri Lanka, Pakistan, Afghanistan, Nepal, Bangladesh, Myanmar, Vietnam, Thailand, Malaysia, Indonesia, the Philippines, China, Japan and Taiwan are the main habitat of this pest.

Identification: The abdomen of the female is wide, and the tip is covered with tufts of yellowish hairs forming a circle, while the abdomen of the male is slender, and the anal end has a thin, hairy covering dorsally. Forewings of the female are pale yellow to dark yellow towards the tip or yellow with a pale-orange tinge, and the discal spot is black and prominent.

Nature of Damage:Newly hatched larva enters into the leaf sheath, feeds voraciously for 2–3 days and then bores into the stem and, staying in the pith, feeds on the inner surface of the walls. When this occurs during the vegetative phase of the plant, the central leaf whorl does not unfold, but turns brownish and dries off, although the lower leaves remain green and healthy. This condition is known as dead heart, and the affected tillers dry out without bearing panicles.

Life cycle: Eggs are laid by female moth in batches of 50–80 covered with yellow tuft of hair at the tip of leaf blade. Larvae undergo four to seven moults and during dispersal larvae hang down by silken thread and get blown to adjoining plants or may fall on water and swim freely till they get to rice plant. After cutting an exit hole, it pupates inside a white silken cocoon from which adult emerge out during the month of April-May.

8.10 PESTS OF VEGETABLES

1. Hadda Beetle, *Henosepilachna vigintioctopunctata* (=*Epilachna*)(Fabricius) (Family: Coccinellidae; Order: Coleoptera): Originated in Russia, hadda beetle is now a cosmopolitan pest of various vegetable crops like, potato, brinjal and other Solanaceous and Cucurbit plant species.

Identification: Adult beetles are about 8 mm in length and 5–6 mm in breadth and deep red in colour. The body is hemispherical and smooth. Adults are good fliers and move from plant to plant.

Nature of Damage: Both larvae and adults are destructive. Adult and grubs both scrap the lower epidermis on the green tissues of leaves in characteristic manner leaving behind stripes of uneaten areas. In severe infestation, all leaves may be eaten off leaving only the veins intact and which ultimately dries up.

Life cycle: After mating, the female starts laying eggs in the month of March–April. Eggs are laid in the cluster of 120-180eggs, arranged side by side on the upper surface of the leaves. After 3-4 days of incubation period, newly hatched, yellowish grubs feed on epidermis. Grubs are oval in shape having spines and hairs on the body surface. After completing 4 instars, grub pupates either on leaves, stem or at the base of the plant. Pupation period is 3-4 days and the whole life cycle completes within 20 days in favourable conditions during summer season. Whereas in winters it goes upto 50 days.

2. Red pumpkin beetle, *Aulacophora foveicollis* (Lucas) (Family: Chrysomelidae; Order: Coleoptera): Red pumpkin beetle is the major insect pest of cucurbitaceous vegetables in all over Asia, Africa and Europe and Australia. Its host range varies among the vegetables crops from pumpkin, melon, cucumber to variety of gourds.

Identification: Adult beetles are yellowish brown to orange in colour with shiny elytra, while grub is white to brown in head.

Nature of Damage: Adult and grub both cause extensive damage to different parts of the plant. The grubs, upon hatching, bore inside the root and start feeding, resulting in wilting and drying of plants. The adult beetles feed extensively on leaves, flowers, and fruits. The feeding hole seen on the leaves is a characteristic symptom of damage by adult beetles.

Life cycle:Female lays eggs either singly or in a batch of 8-9 eggs in the soil which hatch in 6-8 days. The grubs during feeding into the basal portion of the plant moult 4 times and finally move downward deep into soil for pupation. Pupation, generally takes 7-17 days after which adult comes out of soil and feeds upon the foliage part of the crop. Adult passes winter by hibernation inside the soil from November onwards only to emerge out in the next March.

3. Cabbage butterfly, *Pieris brassicae* (Linnaeus) (Family: Pieridae; Order: Lepidoptera):

The cabbage butterfly is a serious pest of cabbage world over and is more prevalent in northern states of the country.

Identification: Butterfly is yellowish white in colour with black apical margin of the otherwise white wing. Forewings are having 2 black spots each. Female are longer than the males.

Nature of Damage: Only caterpillar is the destructive stage where it feeds on cabbage and cauliflower leaves, resulting into their total destruction. The pest is believed to incur more than 40% of annual yield loss in different crops.

Life cycle: The female butterflies lays eggs in bunches (50-80) on the undersides of leaves. Incubation period varies as per the climatic conditions from 3-17 days. Upon hatching, young pale yellow coloured caterpillar with hairy body starts feeding actively. Caterpillar undergoes five moults to become bluish green in colour with grey and black head. Larval period varies from 15 days in summer to 40 days in winter, which is followed by pupation in the cabbage leaves for 7-28 days.

4. Onion Thrips, *Thrips tabaci* Lindeman (Family: Thripidae; Order: Thysanoptera): Thrips are polyphagous polyphagous pests of Cucurbitaceae and Solanaceae. Among vegetables, injured are onion, bean, cabbage, chili, Chinese cabbage, cowpea, cucumber, bean, eggplant, lettuce, melon, okra, pea, pepper, potato, etc.

Identification: Adults are pale-yellow or whitish or brown in color but with numerous dark setae on the body. A black line resulting from the juncture of the wings runs along the back of the body.

Nature of Damage: Thrips cause severe injury to infested leaves which develops silvery patches all over the leaves and then crinkle and die. In severe infestation, leaves dry from tip to downward which is a characteristic damage symptom for thrips.

Life cycle: Female lays eggs in leaf tissue by making a slit cut in the leaf surface. Incubation period for these eggs is 7-16 days. Wingless, small larvae resemble the adults. Larvae feed in group along with the midrib and veins in older leaves. The larval period is followed by two inactive prepupal and pupal stages, which last upto 3-12 days.

8.11 PESTS OF FRUITS

1. Melon fruit fly, *Bactrocera* (=*Dacus*) *cucurbitae* Coquillett (Family: Tephritidae; Order: Diptera): Fruit fly is a major pest of more than 81 different crop plant species, with its host range from fruit crops to different cucurbitaceous vegetables.

Identification:The adult fruit fly is similar to housefly in their size, about 6-8mm long. These flies are orange to brown in colour with T shaped marking on the abdomen. The wings are transparent with prominent brown spot at the tip of the wings. The female is having a tapering abdomen with a pointy ovipositor which is used to puncture the fruits for egg laying.

Nature of Damage: Female prefer tender fruits for egg laying, while the hatching maggots feed inside these soft tissues. The point of puncture oozes with seepage of fruit pulp and becomes hard resinous, concave point ultimately reducing the commercial value of the infested fruit.

Life cycle: A female melon fly usually lays eggs under the skin of host fruit, flowers, stems, and exposed roots. These eggs hatch into apodous maggots, which tunnel through the flesh of the fruit, leaving the fruit as a rotten mass and making it unfit for consumption. After completing three larval instars, larvae come out of the fruit and burrows inside soil (upto 3 cm) to pupate. Life cycle completes in one or two months and several generations can be observed annually.

2. Lemon butterfly, *Papilio demoleus* (Family: Papilionidae; Order: Lepidoptera): The citrus or lemon butterfly is also known as the swallowtail butterfly Major host of the butterfly is citrus or lemon along with curry leaf.

Identification: It is a large butterfly measuring upto 28 mm long and 100 mm of wingspan. The wings contain large buff spots with black borders along with two brightly colored eyespots n the hind wings.

Nature of Damage: The caterpillars of lemon butterfly feed on tender shoots and leaves of the citrus plants leaving only midrib behind. Severe infestation and large defoliation causes no fruit bearing on the plants.

Life cycle: The female butterfly lays single eggs on the under surface of the tender citrus leaves. The incubation period is 4-6 days and newly hatched brown to black colored caterpillars start feeding onto the tender leaves. Caterpillars pass 5 larval instars and upon growing turns bright green in colour with orange prolegs and a spine on thorax and 9th abdominal segment. Larval period last for 2 weeks and pupa are attached to the stem by silken thread. Life cycle completes in 3 to 13 weeks and four overlapping generations can be observed in a year.

3. Mango Leaf Hopper, *Idiocerus atkinsoni* (Family: Jassidae; Order: Hemiptera): It is a serious pest of mango crop all over the south east Asian countries.

Identification:The adults are greyish brown in colour with wings held as a roof like structure over the body. Head is broad and prominent, whereas the hind legs are provided with thick layer of bristles.

Nature of Damage: The adult and nymph stages are destructive and cause damage by sucking cell-sap from young shoot, flowers or whole inflorescence ultimately causing them to dry and fall off. Honey dew secreted on leaves by these hoppers facilitates the fungal growth over the leaf surface resulting in unsatisfactory photosynthesis. Infested young trees are unable to grow and fruit bearing in older trees is hampered by severe infestation.

Life cycle: White to dull white colored eggs are laid singly on the mango leaves and flower buds. The incubation period lasts for 3-6 days and hatching nymphs are yellowish green in colour. These nymphs then suck the cell sap from young leaves, buds and inflorescence, secreting honey dew for the fungal growth. The developed fungal growth gives mango tree a dull black colour. The wingless nymphs can jump from one stem on to another in search of tender leaves and attain full growth after 8-14 days. After attaining maturity, the wingless nymphs moults into winged adults and life cycle completes within 15-20days. Only one generation is found in a year.

4. White grub, *Anomala dimidiata* (Family: Scarabaeidae; Order: Coleoptera): It is a major pest in Himalayan region and is prevalent in hilly states like, Kashmir, Himachal Pradesh and Uttarakhand. These beetles feed on the leaves of various fruit and vegetables crops such as, apple, pear, plum, poplar, sugarcane, cauliflower, okra, pea, capsicum, potato, garlic, rose, etc.

Identification: The adult beetles are oval to convex in shape and range from 18 to 21mm in body length and 10-12mm in width. The elytra are shiny apple green in colour with a metallic texture.

Whereas, the legs are bluish green in colour. The larva is a C-shaped grub and lives under the soil where it feeds upon the roots of various plant species.

Nature of Damage: Both adult and grub stages are destructive pests of different crop plants. The adult beetles prefer to feed upon the foliage of crop plants whereas, the grub cause damage to the growing roots. The adult beetles start feeding from the outer periphery of the leaves and shoot at night. The larvae feed upon the roots by cutting the roots and cause severe damage.

Life cycle: The adult beetles emerge during the onset of Monsoon season (May-June). The female lays single eggs under the soil surface, which has an incubation period of 8-16 days. Newly hatched grub is white in colour and ranges upto 11-13 mm. These grubs actively feed on the developing roots of various host species and cause serious damage to the crop. Grub passes three larval instars during the month of September. Third instar white grub larva goes into winter diapause during October inside the earthen cells and begins feeding again at the onset of March. Once feeding completes during the first two three weeks of March, third instar grub goes to pupa stages which last upto 2 weeks.

8.12 POLYPHAGOUS INSECT PESTS

1. Locust (Family: Acrididae; Order: Orthoptera): Locust are short horned grasshopper with polyphagous and voracious feeding habits. Different species of these grasshoppers has marked polymorphism and make swarm to migrate several hundred kilometers. Locust swarms infest large areas on route and can devastate millions of square area in short time to cause massive economic and environmental losses. Among the several species of polyphagous locust, only four species, namely desert locust (*Schistocerca gregeria*), migratory locust (*Locusta migratoria*), Bombay locust (*Nomadacris succincta*) and tree locust (*Anacridium* spp.) are found in India.

Identification:Adult locust varies in body sizes as male are 25-30mm and the females are 30-45mm long. Body colour also varies from grey, brown to green. Hind wings bear large dark spots at the tip and hind legs are distinctive red in colour.

Nature of Damage: Under normal circumstances, locusts do not cause much damage and are considered as harmless insects as they do not pose any economic threat to the crops. It is only in their migratory phase, where a drastic change occurs in their reproductive behaviour and they dramatically increase their rate of reproduction. Locusts are voracious feeders and feed almost all the different parts of a plant including, leaves, flowers, fruits, seeds, bark and growing parts of the plant. A locust swarm spread over one square mile is believed to be containing more than 300 ton of locusts, resulting into a total loss of lives in that area. Largest locust swarm till date was recorded to be spread over 300 square miles.

Life cycle:The female lays eggs inside pod under the moist sandy soils at a depth of 10cm.Each pod of eggs consists of 100-160 eggs. The incubation period varies with the variation in soil temperature. The most rapid incubation takes place at a soil temperature of 31-35°C, where it ranges from 10 to 12 days. In lesser temperature (19°C) the incubation period increases upto 70 days. After hatching nymph passes through 5 nymphal instars during the gregarious phase and 5-6 nymphal instars during solitary phase. The nymphal development also varies with the air temperature from 22 days during summers to 70 days during the winter season. The fifth instar nymph moults into adult and this process is known as fledging and the young adult is known as fledgling.

2. Termites (Family: Termitidae; Order: Blattodea; Infraorder: Isoptera): Termites have recently been classified under the order Blattodea after being placed under Isoptera for a long time. Isoptera has been newly categorized as the infra order or suborder, containing 7 termite families worldwide. Termites are one of the most destructive pest of human household and can also infest several crop plant species to cause major economic damage. These are social insects consisting colonies having presence of members belonging to different castes with a division of labor and overlapping generations. Each termite colony contains three major castes namely: workers, soldiers, and reproductives. Upto 2700 known species of termites are distributed all around the tropical parts of the world.

Ecologically, termites are beneficial as they act as decomposers to the dead wood and vegetable products, thus ultimately enriching soil with more porous and permeable to the air.

Identification: Termites are commonly called as white ants. Worker termites, which make for almost 90% of total population of the colony, are wingless and sterile with no pigment, hence look pale white in colour. Similar to workers, soldiers are also tiny white in colour with no pigments and are provided with hard and powerful mandibles. Male reproductive or the kings are very few (5-10) in number and their sole responsibility is to constantly provide sperms to the queen. There is only one or rarely more queens in a single termite colony. Queen is physogastric with a large, swollen abdomen. A termite queen can live upto 15 years and lays millions of eggs during its life cycle.

Nature of Damage: Termites form their nest (termitaria) beneath the soil surface upto 20-50 cm depth and comes to the ground level and upward through tunnels made of digested wooden and soil particles. The termites often infest buildings and damage lumber, wood panels, flooring, wallpaper, plastics, paper products and fabric made of plant fibers. The most serious damage is the loss of structural strength. Other costly losses include attacks on flooring, carpeting, art-work, books, clothing, furniture and valuable papers. Subterranean termites do not attack live trees. The termites also damage the standing crops like sugarcane, wheat, paddy, groundnut, cotton, corn, sorghum, chilli, brinjal, cauliflower, cabbage, beans, potato etc. The crops are attacked from the time of transplantation to harvest.

Life cycle: Similar to honey bees, construction or establishment of a new colony in termites takes place through swarming. During spring or fall seasons, several hundred to thousand winged primary reproductive male and female termites perform the swarming in search of suitable nest. This flight is followed by shedding of wings and settlement of such males and female in pair into the moist damp wood. The royal couple then reproduce and inside a sealed chamber and females starts laying over 30000 eggs per day. The yellowish eggs hatch within 50-60 days.

3. Cutworms, *Spodoptera litura* (Family: Noctuidae; Order: Lepidoptera): The cutworm pest group belongs to the family Noctuidae. These insects are major pest of several crops and wild plant species. Among the different cutworm species, the rice, tobacco and cotton cutworm, *Spodoptera litura* is the most destructive and polyphagous pest, as its host range vary upto 100 plant species.

Identification: Adults are nocturnal and are dull gray to brown and yellow in colour. These adults can be found at the basal area of the plant during day time and are attracted towards light source during night period. Cutworm caterpillars are plump and smooth, growing to about 40mm long, but they usually cannot be seen as they hide under the soil or litter by day. Newly emerged larvae are translucent green with a dark underside. Young larvae are smooth skinned and translucent green, and dark underneath. The third instars have red and yellow longitudinal lines. Fourth and fifth instars have yellow longitudinal 8 lines and black triangular spots on each side of the middle line on top. Often they can be located by scratching the surface near damaged plants where they can be seen curled up in a defensive position. The adult of rice-cotton and tobacco cutworm, *Spodoptera litura* resembles to the army worm, *Spodoptera furgiperda*, which is also a major alien species, capable of damaging wide array of plant types.

Nature of Damage: Cutworm larvae feed by cutting into the budding and weak plant leaves. Presence of skeletonized leaves is a characteristic damage symptom of *S. litura* larva. The young caterpillar feeds on soft and tender leaves at seedling stage. whereas the fully grown larvae also attack the whole leaf, flowers and fruits.

Life Cycle: Female moth lays eggs underside of the leaves in a batch of 200-300 eggs, covered with tuft of hairs. The eggs hatch in 4-12 days. Newly hatched larvae stay inactive during the day time and feed on soft tender leaves only during the night. Second instar and further, the larvae actively feeds upon leaves, flowers, buds and fruits to seriously damage the crop. Pupation takes place inside the soil and develops within 6-7 days.

5. Gram Pod Borer, *Helicoverpa armigera* (Family: Noctuidae; Order: Lepidoptera): *H. armigera* is one of the most destructive pest of major crops in nearly all the areas where it occurs. The host range extends more than 200 different plant species, including food, fibre, oilseed, fodder, commodity and horticultural crops. *H. armigera* has been reported causing serious losses throughout its range, in particular to cotton, tomatoes and maize. In India, *H. armigera* commonly destroys over half the yield of pulse crops, pigeon pea and chickpea, and tomato.

Identification: Adult moth ranges 12-20 mm in body length. Forewings in females are yellow to brown and greenish gray in males, with a brown spot near the anterior margin. Hindwings pale yellow with a brown band at the posterior edges and a dark round spot in the middle. The larva is 35-40 mm in length, its pale-green to dark-brown color depends on the host plant, and with a dark, dorsal stripe. The head, pronotum, the thoracic legs and the five pairs of abdominal prolegs are dark brown or black.

Nature of Damage: Reproductive parts of different crops, *viz.* flower and fruits are more prone to the *Helicoverpa* attacks but larvae also feed upon the leaves in early stages of its development in certain crops like, chickpea, groundnut and pigeon pea. Different damaging symptoms of *H. armigera* in major crops are as following:

Chickpea: Foliage is eaten by the young larvae and the 3rd instar larvae bores into the pod with posterior half of the body hanging outside. Due to such damage to the pod the pest is known as gram pod borer.

Corn (Maize): Larvae feeds on developing grains inside the ears.

Cotton: Larva bores hole at the base of flower buds and hollows the buds from inside. Grown larvae enter the young cotton bolls and feeds inside them, resulting in dropping of the infested bolls. The pest is commonly known as American boll worm in cotton agro-ecosystem.

Tomato: Fruit borers in tomato enter into the young fruits and cause dropping of such fruits. Secondary infestation by other organisms causes rotting of infested fruits.

Life Cycle: Female moths lay single eggs on different host plant near to their respective reproductive parts. Sometimes, eggs are also laid on leaf surfaces which are densely provided with pubescent surface. Emerging larvae initially feeds on the tender parts of the host plants like, leaves, buds and tender fruits and later on bores inside the developing or mature fruits. After eating inside the fruits, larvae drop down on the ground and pupates inside the soil. The pest shows facultative diapause in pupal stage and passes winters in this stage. Next generation adult emerge in next April to June depending upon the geographical location of the host plant.

6. Aphids: (Aphididae: Hemiptera): Aphids are small insects found sticking onto the stem of different host plant species and are variable in colour. Aphids are sap sucking insects and are cosmopolitan in their distribution. Several species of Aphids infest a wide range of economically important crop plant species of Agricultural, floricultural and horticultural importance. Few of the most destructive and economically significant aphid species and their host plants are listed below:

Common name	**Scientific name**	**Host plant**
Mustard aphid	*Aphis gossypii*	Rapeseed and Mustard, citrus

Bean aphid	*Aphis fabae*	Leguminous crops
Cabbage aphid	*Brevicoryne brassicae*	Cole crops
Green peach aphid	*Myzus persicae*	Pepper, tomato, carrot, corn, flowers, cucurbits
Potato aphid	*Macrospihum eurphorbiae*	Potato, lettuce and tomato

Identification: Aphids have soft pear-shaped bodies with long legs and antennae and may be green, yellow, brown, red, or black depending on the species and the plants they feed on. A few species appear waxy or woolly due to the secretion of a waxy white or gray substance over their body surface. Most species have a pair of tube like structures called cornicles projecting backward out of the hind end of their body. The presence of cornicles distinguishes aphids from all other insects.

Adults are wingless but winged forms are also common in most of the aphid species. Development of winged aphids takes place during the spring or fall seasons when the population density reaches its maximum. High population density of aphids on a single host causes host scarcity and in such cases development of winged forms helps in dispersion.

Nature of Damage: Large aphid populations on host plant causes leaves to turn yellow and the main shoot to have a stunted growth. Aphid produce large quantity of excreta or honey dew which in turn attracts the growth of sooty mold. This fungus causes host leaves to turn black in colour thus, hampering normal photosynthesis.

Different aphid species of act as vector for wide variety of plant pathogenic viruses in vegetables crops. Some of the major pathogenic viruses transmitted by aphids are given below

Crop	**Virus**
Bean	Bean Common Mosaic Virus
Brassica	Turnip Mosaic Virus
Capsicum	Cucumber Mosaic Virus and Potato Virus Y
Papaya	Papaya Ringspot Virus

Life Cycle: Aphids have a complicated and variable life cycle which includes a peculiar mode of development along with presence of polymorphism in different generations of the same species. Certain aphids are anholocyclic, where they continuously multiply parthenogenetically, and others are holocyclic in nature of their reproduction where sexual generation alternates with parthenogenesis. In Indian sub-continent, aphids survive winters on their primary host in egg stage, laid by the sexual female during autumn season. Upon commencement of next spring season, these eggs hatch to produce all apterous female progenies, which are parthenogenetic and viviparous in nature. These females are known as fundatrices. These fundatrices further produce the similar forms along with few winged females. The apterous females are called fundatrigeniae, whereas the winged forms are known as migrants or alate forms.

This parthenogenetic and viviparous reproduction continues during the summer season when host is in abundance. Once the host availability starts to shrink and the alate aphids, which becomes common after various round of parthenogenesis, starts to migrate in swarms for searching of new host plants. By the end of summer season, the alate aphids (on new hosts) along with apterous forms (still on the original host) reproduce parthenogenetically to produce the sexual males and females. These alate forms which ends the cycle of parthenogenesis by producing sexual forms are known as sexuparae.

8.13 SUMMARY

A "pest" is defined as any organism that causes annoyance or injury to human beings, human possessions, or human interests. The injury may be physical (bites and stings), medical (causing illness or disease), or economic (monetary loss to goods or property). The first use of the word "Pest" also been mentioned in the ancient Roman civilisations where traditional rites were performed by Roman people in the month of April to appease the goddess Robigo.

Any insect species, feeding or damaging a crop plant species can only be termed as pest if it achieves either the enough damage to the crop or reaches a certain levels of abundance in an area. Insect pests have been categorized based on different characteristics, such as occurrence, level of intensity and damage boundary of pest and its infestation. Distributions and abundance of any insect species is dependent on interactions with abiotic and biotic factors in the environment. Abiotic factors like temperature, moisture, and soil nutrients, along with biotic interactions within and between species, can all have strong influences on spatial distributions of plants and animals. There are many factors that, alone or in combination, allow insect populations to reach densities that are of economic importance.

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8.14 TERMINAL QUESTIONS AND ANSWERS:

Question No.1: What is a pest?

Question No.2: Describe different categories of insect pests.

Question No.3: What are factors contributing in insect pest outbreak?

Question No.4: Enlist major insect pests of rice and their characteristic damaging symptoms.

Question No.5: Which are the major insect pests of sugarcane?

Question No.6: Describe the damaging symptoms of poyphagous pest, *Helicoverpa armigera* in different host crop plant species.

UNIT 9: HOUSEHOLD PESTS

CONTENTS

9.1 OBJECTIVES

After studying this module, you shall be able to learn and understand:

iv. What are household insect pest?
v. Different types of household pests
vi. Nature of damage caused by household pests

9.2 INTRODUCTION

Insects are the most varied and common class of life on earth. This dominance and diversity of insects in nature are largely due to creative methods for occupying odd and limited functional niches in restricted spaces. Due to its smaller size, high fecundity, brief life cycle, and existence of morphologically and physiologically distinct life stages, a single insect species can live in more than one habitat and experience a rapid growth in population. Owing to these traits, insects are adapted to every land and freshwater habitat where food is available, including human household. Many species ofinsects have the ability to invadeorremainpermanently in and around human household.Aside from agricultural and animalcommodities, these insect species cause irritation inavariety of ways,including: resting on sensitive part of our body, biting and causing pain, making irritating noise, damaging the household furniture and food etc.

9.3 COCKROACHES

Cockroaches are the most common insect found in human household. Cockroaches are especially problematic in household kitchen and are found mostly in unhygienic conditions. Most people find cockroaches disgusting and unpleasant just by their mere existence. They can contaminate food, cookware, and other home items, and they leave a bad odour. Cockroaches occasionally occur as mechanical vectors of bacteria that cause food poisoning. Asthma is frequently brought on by cockroach outbreaks, extended contact to cockroaches, and their moulting exoskeletons (or "skin"), especially in urban settings.

Classification:

Kingdom: Animilia

Phylum: Arthropoda

Class: Hexapoda/ Insecta

Order: Blattodea

Family: Blattidae

Types: Cockroaches of different types and sizes can be seen and found in our households running around different commodities. Majorly four species of cockroaches are commonly found in human households.

1. **German Cockroach (*Blattella germanica*):** It is the most common household insect pest species, found all over the globe.

***Habit and habitat*:** The German cockroach favours locations near food sources and water. It is 0.625 inch in length at maturity with two dark streaks behind the head in pronotum. These cockroaches aggregate in numbers few to several around different areas in home. The most common of such places include cracks and crevices around cabinets, wall and ceiling voids, in and around refrigerators, stove and oil containers. Female of these cockroaches can be seen carrying an ootheca (egg casing) at the end of its abdomen. Female carries this ootheca until the eggs are matured and ready to emerge. Nymphs are smaller and darker tan in colour.

Damage:Large population and in scarce of food, these can be found in various parts of the house including closet, bathrooms and bedrooms.

2. **American Cockroach (*Periplaneta americana*):** At about 1 to 1/2 inches long when fully grown, this roach is the largest roach commonly found in a home. Its colour ranges from reddish-brown to brown, with a pale yellow band surrounding the thorax. Adults have well-developed wings but rarely fly. Nymphs are smaller and wingless, but similar in appearance.

Habit and habitat: German cockroaches and American cockroaches have different reproductive rates. These cockroaches prefer moist, dark environments. They usually congregate in boiler rooms, steam tunnels, laundry rooms, floor drains, drain pumps, pipe ducts, and sewage systems. They can also be found outside in gardens and among trash cans during the warmer months.

Damage: With their frequent association with sewage, decaying organic matter and dirty conditions, American cockroaches can be a health hazard as they act as vector for human disease pathogens. They transfer the germs and bacteria upon close contact with food and food surfaces.

3. **Oriental Cockroach *(Blatta orientalis)* –** The oriental cockroach is shiny black or dark brown, and the adult is about 1-inch long. The females have very short wings, and the males have wings that cover about half the abdomen.

Habit and habitat: Sewers, crawlspaces, cellars, and basements are typical habitats for this cockroach, which prefers cool, dark, wet environments. The nymphs and adults are typically found at ground level and move very slowly. They frequently reside in floor drains and sump pumps. They also reside outside beneath rocks, trash, and plant matter and enter buildings through vents, door thresholds, and other holes.

Damage:Oriental cockroaches are particularly unhygienic because they frequently eat trash, animal and human waste, and decomposing organic substances. Additionally, cockroaches can carry disease-causing bacteria and protozoa on their legs and bodies and deposit them on food, utensils, and other surfaces. These pathogens include bacteria and protozoans causing various types of gastroenteritis and diarrhoea.

4. **Brownbanded Cockroach *(Supella longipalpa)* –** Despite being much less prevalent than the German cockroach, this species occasionally poses a nuisance in houses. The German cockroach is larger than the brownbanded cockroach, however the German cockroach lacks black longitudinal bands on the area below the head. Instead, there are two transverse yellowish stripes across the wings and a black bell-shaped pattern behind the head.

Habit and habitat: Because of its propensity to spread throughout homes, including non-food-containing settings like the bedroom, under tables, and behind pictures on the walls, the brown-banded cockroach is frequently referred to as the "furniture cockroach."

Damage: The brownbanded cockroach feeds upon a range of household goods. It may devour substances like glue or paste (particularly made from animal-based materials), starch, and specific colour dyes, just like members of other cockroach species. Therefore, artefacts like stamps, envelopes, ancient book bindings, draperies, and infrequently wallpaper, may exhibit feeding symptoms. This species has also been observed chewing on non-food items like nylon stockings, likely in search of leftover skin flakes and body oils.

5. W**ood Cockroaches *(Parcoblatta species)* –** The wood cockroach is regarded as a sporadic pest that causes annoyance in households. Adult males have complete wings, whereas females have noticeable wing pads that serve no purpose. While the female's wing pads only cover one-third to two-thirds of the abdomen, the male's wings are longer than its body. The males fly quickly but lack the endurance to stay in the air for extended periods of time.

Habit and habitat: These are generally outdoor cockroaches that inhabit woodpiles, logs that have fallen, and dead trees. Although these cockroaches prefer to live outside, they can cause problems if infested firewood is brought indoors or if they enter homes from the nearby forests. Although they cannot live inside, they can be a nuisance in the spring and summer seasons when a lot of cockroaches come inside from the outdoors. In the winter, these cockroaches get transported in firewood into homes.

Damage: Decaying organic matter acts as the primary food source for wood cockroaches. These cockroaches breed outside the household and are rarely found breeding indoors. However, as the use of wooden tiles and decorative material along with use of wood as building material is ever growing, a serious outbreak of these cockroaches is looming in different parts of the world.

9.4 ANTS

Ants are some of the most ubiquitous insects found in community environments. Ants can survive in almost every conditions with access to food and water. Outdoors, ants are mostly beneficial, as they feed on a wide array of organic matter and also act as predator for small insects. Furthermore, ants also help in seed dispersal of certain plants.

A well-known feature of ants is their sociality, which is also found in many of their close relatives within the order Hymenoptera, such as bees and wasps. Ant colonies vary widely with the species, and may consist of less than 100 individuals in small concealed spaces, to millions of individuals in large mounds that cover several square feet in area. Functions within the colony are carried out by specific groups of adult individuals called ‘castes’. Most ant colonies have fertile males called “drones”, one or more fertile females called “queens” and large numbers of sterile, wingless females which function as “workers”. Many ant species exhibit polymorphism, which is the existence of individuals with different appearances (sizes) and functions within the same caste. For example, the worker caste may include “major” and “minor” workers with distinct functions, and “soldiers” that are specially equipped with larger mandibles for defense.

Classification:

Kingdom: Animilia

Phylum: Arthropoda

Class: Hexapoda/ Insecta

Order: Hymenoptera

Family: Formicidae

Types

1. One-node ants/Argentine ant (*Linepithema humile*): These ants are found in colonies with large and polygynous conditions, sometimes comprising hundreds of queens and many thousands of workers. New nests are founded by migration or budding. Adults are dull brown in color. All workers are uniform sized, queens are larger. Waist has one erect node. Thorax is uneven in shape when observed from the side.

Habit and habitat: Worldwide, in regions with Mediterranean, subtropical and mild temperate climates. Native to Northern Argentina. In the southwest, mostly found in irrigated, moist areas in urban and agricultural settings. *L. humile* appears to be more successful in subtropical and Mediterranean climates than in extremely cold, arid or tropical climates. Where it has been introduced, this species is mainly found in close association with humans, with a preference for anthropogenically disturbed areas, but it also has the capacity to invade natural ecosystems around the world.

Damage:These are also known as "sugar ants,". Although they do not generally bite or sting, these ants are considered a nuisance and a cause for concern because of their huge colonies. Prefer sweets, but will feed on many different food materials. These ants commonly infest houses and other premises, contaminating and spoiling stored food and other products. Argentine ants are extremely invasive and can displace native ant species when they are introduced to a new area.

2. Carpenter ant(*Camponotus modoc*): Carpenter ants are the largest ant species. Waist with single node found in community environments. The western carpenter ant *C. modoc* is black in color, with dark red legs. Queens can measure up to 0.75 inch, and workers from 0.25 to 0.5 inch in length. Waist has one erect node. Thorax is uniform in shape when observed from the side.Other species of carpenter ants include,*C. vicinus, C. herculeanus, C. noveboracensis and C. essigi*.

Habit and habitat: The tunnels may resemble subterranean termite tunnels, but can be distinguished by absence of soil or other termite tubes.

Damage: Damage wooden structures by nesting in them, but do not eat wood. They chew along or across the grain of the wood, creating clean and smooth tunnels. Feed on a wide range of food material, including human food. Prefer sweets and meat.

3. Odorus House Ant(*Tapinoma sessile*). They are the "sugar ants" of the kitchen because they enjoy sweets but also eat grease and decaying insects. Winged reproductive appear during May through July. Workers are quickly moving and are quite active. These ants can build their nests outdoors or indoors close to heat sources, inside insulation, or somewhere else.

Habit and habitat:Although they can nest within buildings, nests are typically found outside under rocks, boards, and the like. Colonies range in size from a few hundred to tens of thousands of individuals, with one to several queens per colony. House odorous ants build their nests indoors near sources of warmth and moisture, in crevices, although they can also do so in termite-damaged wood.

Damage: The odorus house ants may eat a wide variety of foods. Only because they contaminate various items kept in the pantry do these ants come into contact with human settlements.

9.5 WASPS

Wasps belong to the highly evolved insect order of Hymenoptera. They are the predatory insects in the suborder Apocrita along with honey bee and bumblebees. Unlike bees, wasps use their sting for the predation not just for the self-protection. They have a smooth exoskeleton with few hairs on their legs, which give them a sleeker appearance than the bees. Several species of wasps live in social colonies and depending upon the species single wasp nest can hold upto 10 thousand individuals. The Vespidae family of wasps, which includes the yellowjacket and hornet, are the most well-known wasps. They are eusocial wasps that live in a nest with an egg-laying queen and non-reproducing workers. All species of social wasps use some type of plant fibre, usually wood pulp, to build their nests. This material may be augmented with mud, plant resin, and the secretions from wasps themselves.

Wasps are considered household pest when these wasp nests are constructed near to the anthropogenic settlements. When wasps sting people while they are looking for sugar and carbohydrates, which make up a significant amount of their diet during the fall or autumn season, wasps come into close contact with humans and come into conflict with them. Wasps have a variety of ecological tasks to play. To meet their own or the needs of their nests, several species function as pollinators or predators. Wasps prey on other insects like grasshoppers, flies, and other small insects when they are predatory in nature. They are also regarded as a severe honey bee pest because they assault bee hives to steal food that is high in protein for their young. Wasp nests built within or adjacent to dwellings, such as in attics, can be dangerous because the wasps may sting if people approach them. Stings are often painful rather than harmful, but in rare instances, a person may experience a potentially fatal anaphylactic shock.

Classification

Kingdom: Animilia

Phylum: Arthropoda

Class: Hexapoda/ Insecta

Order: Hymenoptera

Family: Vesipidae,

Types

1. Yellow Paper Wasp (*Polistes versicolor*): The bright yellow bands on the thorax and abdomen of this social wasp are well known. Female faces are triangular, but male skulls are more square and light in colour. *P. versicolor* has a black body with conspicuous yellow bands on the thorax and abdomen, as well as bright yellow wings, on both the male and female. Females can only be distinguished from one another by size. Under building overhangs, a thin paper nest (comb) with a hexagonal shape and a petiole-like connection is frequently spotted.

The *P.versicolor* nest is often a single, exposed comb made of chewed vegetable fibre that is connected to the substrate by a single petiole. New colonies and nests are often established by a group of females; female associations are in charge of making new colonies and nests successful.

Habit and habitat: The yellow paper wasp regularly constructs its nests on organic materials such as leaves, branches, roots, stones, and even the remains of other social wasp species' abandoned nests. In certain cases, the wasp lays its eggs in the abandoned nests of other species rather than its own. These wasps coexist closely with human communities. These wasps can have several nests in an area with even a modest human population.

Damage: Yellow paper wasps seek a variety of advantages from nesting in human-made structures in metropolitan areas, such as a reduction in interspecific competition, protection from varied climatic conditions, and safety from vertebrate predators. Paper wasps eat nectar and pollen, but they also feed the larvae of their colonies on invertebrates like caterpillars. Wasps can be a serious issue, especially in the summer. In the spring, these sociable insects begin to build their nests and lay their eggs.

The majority of wasp nests are built nearby, so wasps can be seen flying inside homes and can sting people if they come in contact with them.

2. AsianGiant Hornet Wasp (*Vespa mandarinia*): It is the biggest hornet wasp in the world, as its name says. Its unparalleled size and distinctive markings allow it to be easily differentiated from other Asian hornet species. The head, thorax, and abdomen all have different densities of setae (hairs). These hornets feature ocelli in addition to compound eyes, just as other Hymenoptera. The presence of stingers distinguishes female reproductives (queen) and non-reproductive workers from stingless males. The stinger is smooth and over a centimetre long.

Habit and habitat: Native to Japan, the Asian gigantic hornet has since expanded to a number of other Asian countries, where it has thrived in both temperate and tropical conditions. Finding colonies of Asian giant hornets can be difficult because they frequently construct their nests underground. Typically, hornets may hunt for sites near decaying tree roots, dig nests in the ground, or live in tunnels that have previously been dug by other animals like rats.

Damage: With its sting, this wasp may kill humans and decimate numerous insect populations, most notably managed and wild honey bee populations. Persons who are allergic to the venom of stinging insects should be concerned because *V. mandarinia* has been associated to severe reactions in people who are not considered anaphylactic or allergic. This hornet's defensive behaviour puts individuals at risk for developing potentially fatal medical conditions. According to estimates, about 40 people in Japan per year pass away after being stung. Kidney failure, anaphylactic shock, heart attacks, and multiple organ failure—often as a result of numerous stings—have all been implicated in these deaths. In China, this wasp species was responsible for more than 1700 injuries and fatalities (Stankus 2020). When there are accidents that require hospitalisation.

3. European Hornet Wasp (*Vespa crabro*): Workers of European hornets can reach a length of up to an inch (25 mm), while queens can reach a length of 1.3 inches (35 mm). They are among the largest wasp species, only behind the huge Asian hornet that was previously mentioned. The two categories are interchangeable but can be distinguished by morphological characteristics. In contrast to Asian hornet wasps, which have a black thorax with yellow spots, an entirely yellow head and abdomen, and yellow, black, and brown bands, European hornets have a red and brown thorax, a red and yellow head, and an abdomen that is predominantly yellow posteriorly with brown teardrops on the anterior side.

Habit and habitat: The European hornet builds paper nests like other hornets and yellow jackets. Contrary to bald-faced hornets and yellow jackets, which commonly build paper nests in the ground and enormous, exposed nests in trees, European hornets build their nests in protected aerial spaces, such as hollows in large, standing trees and occasionally in the wall voids of houses. Similar to other social wasps, European hornets construct annual nests. According to this, only the fertilised queens are left to establish nests the following year after the nest and its workers die in the fall.

Damage: Compared to honey bee stings, European hornet stings are not as painful despite their size. In contrast to honey bees, European hornets may sting repeatedly and have smooth stingers. Unless the person is allergic to bee and wasp stings or has received multiple stings, European hornet stings should go away on their own in one to a few hours without causing any harm. Killing or catching and releasing hornets is the best immediate management for hornets that overwinter in homes during the winter and spring (for example, using a glass and some paper or cardboard).

4. Yellowjacket Wasp (*Vespula germanica*): While queens can reach lengths of up to 18 mm, all sterile female *V. germanica* workers are only about 13 mm (1/2 inch) long. The abdomen of the yellowjacket normally has a series of black spots running down both sides from the second to the fifth abdominal segments, as well as a small spade-shaped black mark on the first segment. It is black and yellow in colour.

Most of the wasp species are known to construct annual nests as large portion of the colony, the sterile workers die during the autmn season, the German yellowjacket wasps reuse the old nest.

Habit and habitat: There are numerous populations of German yellowjackets in and around anthropogenic communities. It frequently builds nests inside of structures. In addition to urban and suburban regions, it can be found in rural constructions.

Damage: Yellowjackets, on the other hand, feed on other insects as well as forage for meat, bringing them into contact and into conflict with people. In addition, although yellowjacket stings have caused numerous injuries to people, no deaths have yet been associated with them.

Each year, a number of people get stung by these wasps throughout the summer, when they become a severe nuisance.

9.6 CARPET BEETLE

Carpet beetles, as their name implies, sometimes infest carpets. The pests prey on numerous other materials made of wool, fur, felt, silk, feathers, skins, and leather, just like clothes moths do. These substances include keratin, a fibrous animal protein that the larvae can consume. Cotton and synthetic textiles, like polyester and rayon, are generally resistant to attack, unless they are extensively stained with body oils or combined with wool. Unnoticed carpet beetle infestations can spread and destroy delicate things. Homes frequently have carpet beetles, and clothes moth damage is sometimes mistaken for carpet beetle damage.

Identification: The adults are tiny (1/16 to 1/8 inch), oval-shaped beetles with a variety of "mottled" patterns in white, brown, yellow, and orange in addition to black. Adult carpet beetles don't harm wool or other materials since they eat flower pollen for food. They frequently develop on windowsills in the spring, which could indicate that there is an infestation within the house. About 50–100 eggs are laid by female beetles on or close to weak materials. Breeding habitats can range from the overt (like a wool rug kept in a closet) to the covert, such as pet hair accumulations near baseboards, air vents, and ducts.

Kingdom: Animilia

Phylum: Arthropoda

Class: Hexapoda/ Insecta

Order: Coleoptera

Family: Dermestidae

Types

1. Varied Carpet Beetle (*Antherenus verbasci*):*Anthrenus verbasci,* is a common house and museum pest. It is a little (1.5-3.5 mm) spherical beetle with scales on its elytra (wing casings) that form a pattern of white, orange, and black patches. Head is the small and mostly concealed behind the upper thorax. Large and dark eyeballs can be seen. The antennae are clubbed, with the two bottom segments bulging and the three top segments creating the club. *Anthrenus museorum*, is a similarly related museum beetle, with rust-colored legs and a black body with some orange dots.

Habit and habitat: The larvae can also be found in the nests of birds and mammals. They are typically domestic pests of woollen products or museum pests. The adults often can be seen on windowsills in homes, seeking to get outside, and they visit flowers to eat pollen and nectar.

Damage:Due to their ravenous appetites, carpet beetle larvae can seriously harm dried insect and animal collections as well as woolens. They don't exclusively consume synthetic textiles for food. The only *Anthrenus* species that can also be found in food-stored goods is the diverse carpet beetle.

2. Two-spotted Carpet beetle (*Attagenus pellio*): One of the most prevalent species of carpet beetles is the two-spot carpet beetle, also known as the fur beetle. The adult is a very dark brown to black beetle that is 4.5–6 mm long with two white spots on the wing cases.

Habit and habitat: Its larvae are often found in old houses associated with birds' nests. It is also a well-known pest of museums with natural history collections.

Damage: The keratin-containing materials that the larvae consume include wool, fur, feathers, skins, leather, silk, and dried insects. Plant products like cereals and fibres can occasionally come under attack. They have the potential to destroy huge apparel retailers by drilling holes in the fabric, beginning at the seams. The larvae of this pest are among the most feared museum pests because they can obliterate insect, bird, and mammal collections.

3. Brown Carpet beetle (*Attagenus smirnovi*): Brown carpet beetles, commonly referred to as vodka beetles, are typical museum and small-scale domestic pests. Adults have oval bodies that are 2 to 5 mm long and 2 to 2.5 mm wide. Their base colour is black, and their thick hairs produce brown to reddish-yellow elytra (wing cases). The adult beetles can fly, are mobile, and spend the majority of their time active throughout the day.

Habit and habitat: They are often found on windowsills, seeking light, and also seeking food sources for the larvae, where females will lay their eggs.

Damage: Larvae of carpet beetles consume animal products, particularly wool, felt, fur, silk, feathers, and leather. Items including sweaters, scarves, coats, blankets, rugs, down comforters, furniture, toys, home accents, and taxidermy mounts are frequently attacked. When objects are kept for extended periods of time in closets, chests, or boxes, the larvae frequently feed among the folds of the fabric (hems, collars, cuffs, etc.). Regularly worn clothing and blankets hardly ever experience attack; the same is true of regularly swept rugs. Rug and carpet edges and bottoms are more prone to be contaminated than exposed sections. Small, clean holes that are not followed by strands of silk webbing (as is typically the case with clothes moth infestations) and have droppings that resemble powdery dust can be used to identify clothing and carpets that have been impacted by the larvae of these beetles. Another obvious indicator of infestation is the cast, which are the transparent skins the larvae exoskeleton.

9.7 FURNITURE BEETLE

One of the most troublesome wood-eating pests in the world is the common furniture beetle. These wood-boring insects can significantly impair the strength of the infected woods as the actual damage is caused inside the timber, where it goes undiscovered and untreated for several years. Adult beetles emerge through "exit" or "flight" holes after spending their larval stage inside the wood, which is a common sign of damaged wood. Woodworms are the larval stage of wooboring or furniture beetles. In India, primarily five woodworm beetles species cause significant damage to the timber. Some of these are more destructive than others, and each has a different life cycle, favorite wood they infest, and levels of damage they may produce.

Classification

Kingdom: Animilia

Phylum: Arthropoda

Class: Hexapoda/ Insecta

Order: Coleoptera

Family: Ptinidae

Types

1. **Common furniture beetle*(Anobium punctatum):*** Beetles are 2.5–5 mm long and dull reddish to dark brown in colour as adults. Their antennae, which are shorter than their legs and have three flattened segments at the tip, have small grooves running lengthwise along them. The upper portion of the thorax, which is severely humped, conceals the head.

Habit and habitat: It prefers ivy and grows on dry wood of coniferous and deciduous trees, furniture and woodwork in homes, shops, and warehouses. Rather than furniture, these beetles cause more damage to structural timber and woodwork, such as in the attic.

Damage: These beetles target dried-out sapwood rather than live or new wood. *Anobium punctatum*, or woodworm, frequently destroys structural wood like floor boards and wood-framed roofs. Heartwood is typically avoided. If left unchecked, furniture bugs can seriously harm structural timbers. The larvae of furniture beetles, often known as woodworms, will devour both seasoned hardwoods and softwoods that are at least ten years old. Adult furniture beetles do not eat wood. In order to provide the emerging larvae with an immediate food source, furniture beetles prefer to lay their eggs in fissures in wood framework, flooring, and furniture.

2. **House longhorned beetle (*Hylotrupes bajulus*):** The mature beetle has a range of 8 to 25 mm in length. The beetle has two pale pubescent spots on its elytra and is black or brown in

colour. These beetles can spend up to 11 years as larvae inside wooden buildings, tunnelling there depending on the age, texture, and moisture.

Habit and habitat: These beetles are cosmopolitan in their distribution and are present in new houses infesting soft and aged timber during their larval stages.

Damage: Old and weathered lumber is infested with longhorn beetles. The larvae make a lot of cylindrical pellet-containing bore-dust, also known as frass. This can sometimes be seen in the surface wood's "blistered" appearance.

3. Death Watch beetle (*Xestobium rufovillosum*): The length of these insects varies from 5 to 9 mm. Their heads and bodies are cylindrical, which is a trait of species that bore into wood. When viewed from above the beetle, the top of the thorax typically conceals the head. The common furniture beetle (*Anobium punctatum*), which is smaller and has longitudinal rows of pits on its elytra, might be mistaken for adult death watch beetles.

Habit and habitat: The beetle is located outside in the deadwood of trees. It can be a pest of structural wood and furniture indoors. Females place their eggs in tiny divots in trees or on wood. After developing inside the wood while feeding, the larvae eventually start to pupate in a pupation chamber. Following pupation, the adult beetle tunnels out of the wood, leaving distinctive exit holes that can be used to locate them.

Damage: The existence of holes in indoor wood is the main sign of these beetles, which can cause damage. The round holes and tunnels have a 3mm diameter. Around the openings, the larvae leave behind unique little pellets of faeces (frass) that resemble buns.

4. Powder Post beetle (*Lyctus brunneus*) Family- Bostrichidae: Although adult beetles typically appear in the summer, they can be found all year long in heated buildings. The adults range in size from 3-5mm and are fairly flattened with reddish brown colouring.

Habit and habitat: The larval stage of these beetles occurs inside the various types of timber found in wood yards and new furniture, however they are primarily spotted on dead wood.

Damage: These beetles primarily attack wood yards and can easily get inside household furnishings. The larva gradually degrades the quality of wood by feeding on sap wood and producing a powdery material. The infected wood weakens over time and can be broken with light disturbance. Their infestation is frequently mistaken for a termite infestation because they produce a powdery material.

9.8 BOOKLICE

Usually measuring 1 mm, booklice are tiny, soft-bodied, light-colored, grey, or brown insects. Most species of indoor booklouse lack wings. The abdomen and head are both enormous, while the thorax, or centre, is slender. Booklice have long, segmented antennae, a big face, and paired eating mouthparts (unlike the long straw-like mouthpart of a bed bug).

A huge collection of ancient insects called Psocoptera is also known as booklice, dustlice, and deathwatches. "Booklice" are not genuine lice because they do not bite people or other animals and are not external parasites. A suitable title for this group might be "psocid," which is short for Psocidae, a family of Psocoptera. Other psocids, such as several types of barklice, can be found outside.

Indoor psocids rarely actually cause harm as a group unless they contaminate food that has been preserved, but their abundance can be exceedingly bothersome. The term "booklouse" refers to a few species that are associated with books, particularly in environments with higher natural humidity levels like houses and libraries, where mildew growth on book bindings and pages occurs more frequently. Psocids are believed to mostly consume minute moulds, but they are also capable of attacking a wide range of foods, both of plant and animal origin. Species of booklice that live indoors may eat coated papers, wall paper, starched book bindings, or moulds that are growing on starchy surfaces.

Classification

Types: The booklouse, which are very little (1 mm long), wingless, and resemble tiny moving whitish to yellowish specks, include *Liposcelis divinatoria*, *Liposcelis corrodens* (Psocoptera: Liposcelidae), and similar species like *L. bostrychophila* that are frequently found indoors. Other, less frequent species of indoor psocids, including the "small-winged southern house psocid," *Psocatropos microps* (Enderlein) (Psocoptera: Psyllipsocidae), have wings and actively leap when startled.

Habit and habitat: Booklice, also known as psocids, are common in a wide range of settings, including residences, warehouses, herbaria, bug collections, libraries, and facilities used for food storage. Especially if they are maintained in a moist environment, they are frequently spotted scuttling through books and papers.

Damage: Booklice are not actual lice and do not bite on people. Booklice typically cause very little damage. They can turn out to be really uncomfortable if they begin to crawl all over the house. Booklice typically eat tiny moulds, but on occasion they will also consume the sizing of paper that has been kept in warm, humid conditions. Any manmade material derived from plants (such as furniture, paper, books, etc.) may encourage the formation of mould or mildew and encourage booklouse infestations when kept in moist environments. A few species of booklice are also known to infest grains including rice, wheat, and maize that are kept.

9.9 SUMMARY

Many species ofinsects have the ability to invadeorremainpermanently in and around human household.Aside from agricultural and animalcommodities, these insect species cause irritation inavariety of ways,including: resting on sensitive part of our body, biting and causing pain, making irritating noise, damaging the household furniture and food etc.

Damage incurred by most of the household pests like, cockroaches, ants, waps include nuisance and painful bites. Whereas, others like, carpet beetle, booklice and furniture beetle cause damage to different human possessions inside household.

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9.10 TERMINAL QUESTIONS AND ANSWERS

Question No.1: Describe the habitat and damage incurred by economically important species of cockroaches.

Question No.2: Enlist the economically important carpet beetle species.

Question No.3: Describe different wasp species found in and around human household.

Question No.4: Describe habit and habitat along with damaging symptoms of different furniture beetle species.

UNIT 10: PEST OF FARM ANIMALS AND THEIR CONTROL

CONTENTS

10.1 OBJECTIVES

After studying this module, you shall be able to learn and understand:

vii. What are the insect pest of farm animals?

viii. Different diseases of farm animals transmitted through insect vectors

ix. Life cycle and management of different insect and arachnid pests of farm animals.

10.2 INTRODUCTION

Arthropod species are most widely distributed among the any other animal phyla on the earth. Their small, generous yet peculiar feeding habits have largely contributed in developing relationships with several plants and other animals in one way or another. This generosity in their habit and habitats make arthropods as direct competitor to others for different natural resources. Thus, arthropods also become a problem or nuisance for humans in one or the other way. Arthropods, mainly insects share a variety of natural resources with human and are considered as serious pests of these commodities. One such commodity is the livestock or farm animals. There are several insect and arachnid species that spend all or some portion of their lives affecting the well-being of livestock, poultry, or companion animals.

Arthropods associated with livestock, poultry, and companion animals cause problems in a variety of direct and indirect ways. Direct damage by parasitic arthropods ranges from bite irritation, blood loss, tissue consumption and damage, and toxic and allergic reaction to arthropod venoms and feeding antigens. Indirect damage may be caused by introduction of pathogens, nuisance leading to stress and annoyance, self-inflicted wounds from scratching and pest avoidance, and in creating susceptibility to other infestations.

The repercussions of arthropod attack and annoyance on cattle, poultry, and companion animals result in decreased productivity, animal well-being, and profitability. Animals use more energy to replenish lost blood, heal damaged tissue, and engage in avoidance behavior, which limits grazing activity, resulting in lower weight gains and feed efficiency. Arthropod-affected animals frequently exhibit indicators of decreased vigor and bodily condition, which can impair their appeal and profitable sale values.

The two classes of organisms in the phylum Arthropoda of importance to livestock, poultry, and companion animals include Arachnida (scorpions, mites, ticks, spiders) and Insecta (insects). Insects make up 70% to 75% of all known animal species. Within the class Arachnida, mites and ticks are of the most veterinary importance. Most mite species are free living, but some are parasitic on wild and domestic animals, such as mange mites on livestock and mites that attack poultry. All tick species are parasites of vertebrate animals.

Within the class Insecta, there are four orders of insects that are of primary importance as pests of domestic animals. These include Phthiraptera (Anoplura—sucking lice, and Mallophaga—chewing lice), Siphonaptera (fleas), Hemiptera (true bugs), and Diptera (true flies). All species of Phthiraptera (including Anoplura and Mallophaga) and Siponaptera are parasites of vertebrate animals. There are various types of sucking and chewing lice that are parasitic on domestic animals. Most lice species are host specific, meaning they only live on one or a few closely related host species. There are various flea species in Siphonaptera that affect household animals. Only a few species, however, are of great veterinary relevance. A few Hemiptera species (for example, bed bugs) are parasitic on vertebrate animals. As adults, several Diptera suckers blood and are significant pests of both humans and livestock (e.g., mosquitoes, black flies, horse and deer flies, stable flies, horn flies, sheep keds). Other Diptera cause injury in their larval stages by entering mammalian flesh and tissue (e.g., cattle grubs, horse bots, sheep nose bot, screwworms).

10.3 BLOOD-SUCKING FLIES:

Systematic Position:

Kingdom	**Animilia**
Phylum	**Arthropoda**
Class	**Hexapoda/ Insecta**
Order	**Diptera**
Suborder	**Nematocera and Brachycera**

The blood sucking flies belong to the order Diptera, which is one of the largest order in class insecta. The order contains the most numerous and diverse species of insects that have economic importance as veterinary pests. True fly species are the member of this order. Most true flies from Diptera are small and soft-bodied insects. Several of these fly species are considered to be significant pests of both free-ranging and confined cattle. Flies affecting domestic animals range from small biting flies to larger species, wingless ectoparasites, larvae that invade animal tissue, to nonbiting flies. Several of these insects are known to be the vectors for transmitting diseases whereas few others act as bloodsuckers to livestock.

The order Diptera has been divided into two suborders, Nematocera and Brchycera. The blood sucking flies have been categorized into different families of two suborders namely, Nematocera and Brachycera.

The suborder Nematocera, which includes tiny flies with long/narrow wings and long antennae formed of multiple segments, is thought to be the most primordial Diptera. Nematocera larvae are aquatic, free swimming, or live under rocks, and have well-developed head capsules. Among the more notable families in this suborder of veterinary importance include the Ceratopogonidae (biting midges), Culicidae (mosquitoes), Simuliidae (black flies), and Psychodidae (sand flies, moth flies).

The second suborder **Brachycera** is comparatively bigger with almost 120 families of flies.In contrast to the earlier, number of antennal segments are reduced in Brachycera. Insects belonging to this suborder has short and clubbed shaped antenna.

Brachycera of veterinary importance include three infraorders: **Tabanomorpha, Asilomorpha** and **Muscomorpha**. The Tabanomorpha include Tabanidae (horse flies, deer flies) and Stratiomyidae (soldier flies), the two families which are of significant veterinary importance. Flies in this group are usually larger, robust flies. Larvae have a head capsule that is relatively incomplete and often retracted into a fleshy body. The second infra-order Asilomorpha does not carry any veterinary significance. Whereas, the third infraorder, Muscomorpha has several families of important veterinary pests. Some of the serious veterinary pests like, house fly, stable fly, horn fly (Family: Muscidae), tsetse fly (Glossinidae), louse flies (Hypoboscidae), blow flies (Calliphoridae), flesh flies (Sarcophagidae), horse bots (Gasterophilidae), cattle grubs

(Hypodermatidae), rodent bots (Cuterebridae) and sheep nose bot (Oestridae) all have been categorized under infraorder Muscomorpha. Adults in this group have three-segmented aristate antennae. The wing venation is somewhat reduced as compared to the Nematocera and Tabanomorpha. Larvae have no definite head capsule.

10.3.1 Causes/ Mode of Parasitism:

Using their piercing-sucking mouthparts, blood sucking flies feed on blood by puncturing the skin of their hosts. These flies are among the most important arthropod taxa associated with animal health and production from a commercial standpoint. More than half of the estimated yearly losses to livestock output attributed to arthropods are attributable to blood sucking flies, which include direct losses from exsanguination and animal discomfort as well as indirect losses from pathogenic organism transfer and secondary sickness. Some of the most significant blood sucking flies, disease and their management are discussed as following:

10.3.2 Disease/Effected Host:

1. Suborder Nematocera (Infraorder Muscomorpha):

Mosquitoes (Family: Culicidae): Over 3000 species of mosquitoes occur worldwide. Two subfamilies of the mosquito family, Culicidae are of primary medical and veterinary importance: Anophelinae (e.g., Anopheles) and Culicinae (e.g., Aedes, Ochlerotatus, Psorphora, Culex, Culiseta, Coquillettidia, and others).

Disease/Host: Mosquitoes' preferences for hosts vary widely. Few species prefer avian hosts, while yet others will almost exclusively consume amphibian or reptilian blood as a food source. Some species prefer mammalian blood. Mosquitoes act as vectors for a wide range of disease pathogens and are a direct cause of discomfort and blood loss in cattle and companion animals. They may obstruct grazing and typical animal behaviour. An increase in scratching after being bitten by a mosquito can lead to secondary infections, hair loss, and skin abrasions. The majority of household animals serve as mosquito hosts. The diseases spread by mosquitoes that harm domestic animals range from nematodes to viruses, such as encephalitis, the West Nile virus, and Rift Valley sickness (e.g., dog heartworm).

Black flies (Family: Simuliidae):

Disease/Host: Black fly /buffalo gnats or turkey gnats, feed as blood suckers on poultry, cattle, swine, sheep, goats, horses, and other animals and are of significant veterinary importance. They typically feed on the legs, abdomen, head, and ears. *Simulium vittatum*, for example, is frequently seen eating in the ears of horses, cattle, swine, sheep, and other animals, producing pain, scabbing, and irritation. *S. meridionale*, often known as the turkey gnat, feeds extensively on the comb and wattles of poultry.

Black flies have also been linked to disease transmission in animals, serving as vectors for filarial nematodes (Onchocerca) that cause bovine onchoceriasis and protozoans (Leucocytozoon) that cause leucocytozoonosis in poultry.

Severe infestation with large numbers of black flies sometimes can cause animal death. Largely the death in livestock animals by black fly infestation can be attributed to acute toxemia by fly bites. The fly bites can be painful and cause considerable annoyance and decreased productivity.

2. Suborder Brachycera(Infraorder Tabanomorpha):

Horse/Deer flies (Family: Tabanidae):

Disease/Host: Horse and deer flies are widespread pests of livestock and companion animals, particularly cattle and horses kept outside. They are notorious for their terrible bites and relentless bothering of animals. Their mouthparts are strong and bladelike, capable of causing deep, painful, bleeding cuts and lapping up blood that pools on the surface. Tabanid infestations can cause calves to grow less weight, produce less milk, and cause direct skin irritation. Tabanid flies are also known to act as vector for different disease causing pathogen of veterinary importance including viruses (equine infectious anemia, bovine leukemia, hog cholera), bacteria/rickettsia (*Anaplasma marginale*, *Francisella tularenisis*, *Bacillus anthracis*), protozoa (*Trypanosoma* sp.), and nematodes (*Elaeophora* sp.).

3. Suborder Brachycera(Infraorder Muscomorpha):

Stable fly, *Stomoxyscalcitrans* (Family: Muscidae): Stable flies are extremely bothersome pests of domestic and livestock animals and cause severe bites.

Disease/Host: Stable flies generally feed on lower portions of animal bodies, like on the legs and undersides. However, flies can also be observed on head, and ears in smaller animals. The main issues are blood loss and animal disturbance. Animals that are being attacked will stomp and kick in order to avoid getting bitten. They are tenacious and powerful fliers, capable of pursuing host animals for several kilometers. Although stable flies are not a major vector of animal infections, they have been implicated as vectors of retroviruses (equine infectious anemia in horses, bovine leucosis in cattle), nematodes, and parasites (*Habaronema microstoma* that causes habronemiasis in horses, and a blood parasite *Eperythrozoon suis* in swine).

Horn fly, *Haematobia irritans* (Family: Muscidae): The horn fly is a serious pest of pasture and is regarded as such by cattle.

Disease/Host: Horn flies feed on cattle several times a day and their numbers on a single host can range from 1000 to 4000 or more. Such heavy infestation causes a significant blood loss to the host animal. Horn fly infestations cause pain and annoyance, which affects animal behavior and grazing time.

Heavy infestation might result in decreased weight increase and feed efficiency. An economic threshold level of 200 horn flies per animal has been recorded. Horn flies have been implicated in the spread of the worm *Stephanofilaria stilesi*, which causes granular dermatitis on cattle skin.

Tsetse fly, *Glossina* sp. (Glossinidae): Females and males both feed on blood. Tsetse flies are particularly important as vectors of the protozoan *Trypanosma brucci*, which causes nagana and bovine trypanosomiasis. Affected animals become anemic, feeble, and their growth is stunted. Infected animals are unfit for human consumption. Direct consequences and/or secondary infection can cause premature death. The Nagana disease remains a severe impediment to commercial cattle production in more than one-third of Africa.

10.3.3 Control Measures:

Management practices for the effective control of various blood sucking fly species in livestock animals mainly involve timely surveillance and diagnostic for the pest species and curative practices, involving use of different pesticides. Constant monitoring for the occurrence of different blood sucking flies should be done by close inspection of livestock.

The use of insecticides has become an integral part of an integrated fly pest management program. They can be used for fly control in several ways. Application methods include space (area) sprays, residual sprays, on-animal sprays, baits, larvicides, and oral treatments.

Self-application devices that include insecticide dustbags and backrubbers/ oilers can be effective for horn flies and face flies. These devices need to be in a forced-use treatment situation where the animals make contact with them daily. Placing them in a path to water or salt/mineral source and positioning them so cattle will rub them onto their heads and down their backs will provide the most effective control.

Insecticide-impregnated ear tag devices are also available and can provide effective control of horn flies and aid in the control of face flies. In these ear tags, the insecticide is in the matrix of the tag. As the insecticide leaches to the surface of the tag, it rubs onto the hair coat of the animal, providing fly control. There are numerous trade names and designs currently marketed containing pyrethroid and organophosphate insecticides. Depending on the product, one or two tags are recommended for installing per animal. Other methods available for fly control on pastured cattle are the use of insecticide pour-on treatments, oral bolus treatments, or insecticide feed additive/ mineral supplements. With insecticide pour-on treatments, the pour-on product, which is generally formulated as a ready-to-use product, is applied from the poll of the head down the backline to the tail-head using an applicator gun or device.

10.4 MYIASIS FLIES

Myiasis is the invasion of organs and/or tissues of living vertebrates by the larval stages of flies (Diptera). It includes the process of consuming the host's necrotic or dead tissues. In myiasis, various fly species are involved. Myiasis is a type of parasitism that can seriously affect animals, result in death, and in some circumstances have less severe consequences that leave little to no tissue damage.

Systematic Position of Flies involved in Myiasis:

Most of the fly species, causing myiasis in different types of livestock are categories under the unranked taxon of Cyclorrhapha in infraorder Muscomorpha of suborder **Brachycera** under the order Diptera of Class Hexapoda. Flies involved in different types of myiasis like, screwworm flies and blow flies belong to the family Calliphoridae, whereas, horsebot fly, sheep bot fly and rodent bot fly belongs to the family Oestridae. All of these fly families have been categorized under the Superfamily Oestroidea.

Furthermore, myiasis can also be classified clinically according to tissue invaded by the fly larvae or in terms of the host–parasite relationship.

Clinical Classification

1. **Cutaneous myiasis:** In this type of myiasis infestation by fly larvae in dermal or subdermal tissue of the skin is involved.
2. **Traumatic myiasis:** It is the type where open or sore wounds are infested by the flies.
3. **Gastrointestinal myiasis:** It is invasion of the alimentary tract of the host by fly larvae.
4. **Enteric myiasis:** Invasion of the intestinal tract of the host is known as enteric myiasis.
5. **Urogenital myiasis:** It involves the invasion of urethra or genitalia.
6. **Occular/Opthalmic myiasis:** It involves eye tissue infesction.
7. **Nasopharyngeal myiasis:** In this type nasal passages, sinuses and pharyngeal cavities are invaded by the fly larvae.
8. **Auricular myiasis:** It is the invasion of ear cavity.
9. **Furuncular myiasis:** In this type fly larvae forms boils or burrows in their hosts.

Classification of Myiasis on the basis of host–parasite relationship

1. **Accidental myiasis:** This type of myiasis generally occurs due to the contamination of ingested food by fly eggs or larvae. In such cases non parasitic flies pass through the alimentary tract of the host.

2. **Facultative myiasis:** This is also known as secondary myiasis. In this type, fly develops in living as well as dead host. Flies feed on either dead or living tissues nearby to a wound and open sore. Ex. Blow fly.

3. **Obligatory myiasis:** Sometimes refers to as primary myiasis occurs when the fly species directly feeds on the living tissues and depends upon the living hosts to complete its development.

10.4.1 Cause/Mode of Parasitism:

The maggots that feed on the dead tissue of living animals in open wounds, chronic nasopharyngeal or urogenital wounds attract these flies. In addition, they will invade wounds caused by husbandry procedures including dehorning, castration, branding, and shearing as well as other procedures that can put the host tissue under stress. Seepage from medical procedures can also lead to infestation. Some species live in the same wounds that the primary screwworm feeds on, as well as feeding sores brought on by ticks. Blow flies are attracted to and lay their eggs on sheepskin that has been contaminated by dung, urine, blood, or body fluids. These species are known as fleece worms and wool maggots when they infest sheep.

10.4.2 Disease/Effected host:

Several diseases and infections are caused by wide array of myiasis flies. Such diseases and their respective host are discussed under following:

Screwworm, *Cochliomyia hominivorax* (Family: Calliphoridae): Domestic animals, particularly cattle and other livestock, are severely affected by the screwworm infestation. Screwworm larvae consume their host's live tissue directly. Infestations typically begin on warm-blooded animals' exposed wounds. Deep scratches, insect bites, lacerations, and wounds from castration, dehorning, branding, and shearing are just a few examples of infected wounds. If left unnoticed, screwworm infestation can result in death through tissue and important organ deterioration as well as subsequent diseases. Usually the host is physically eaten alive by screwworm maggots. A self-perpetuating infestation results from the feeding damage, which draws more gravid female screwworm flies to lay additional eggs.

Cattle Grubs (Family: Oestridae): These flies can cause damaged hides, decreased weight growth, meat damage due to excessive loss of fat from body by trimming and carcass downgrading at slaughter. Self-injury among terrified calves who run away from adult female flies is also common. Gadding is the term for this panicky conduct. Cattle will also stand in ponds and streams and seek for dense foliage in addition to their irregular running behaviour to avoid the flies.

Horse Bot Flies (Family: Oestridae): The size and colouring of adult Gasterophilus bot flies superficially resemble honeybees. Equids frequently have infestations, at least at some points in their lives. Light infections frequently don't harm the host much. Bots, however, can hurt their host in a variety of ways and raise serious concerns. Adult female bot fly oviposition behaviour can cause obvious distress and panic in the host mammal. In their avoidance behaviour, horses frequently have aggressive reactions to ovipositing females and hurt themselves or others. First-instar bot larvae can irritate the mouth and cause loose teeth, pus pockets, and appetite loss after entering the mouth through the mouth. Inflammation, tissue sloughing, ulcerations, modular mucosal and stomach growth, abscesses, peritonitis, and problems with digestion may result from larvae passing through the esophagus and stomach and attaching to the inner surface of the gastrointestinal mucosa and stomach wall.

Flesh Fly (Family: Sarcophagidae): At fur farms, this fly is known to parasitize fox and mink. They have occasionally been discovered on humans, dogs, cats, and rabbits, among other animals. Young animals commonly die from infestations. At some ranches, mink kits have been lost at rates as high as 30%. At these ranches, May and June are the months that young animals are most in need of protection. *W. vigil* can cause their host to lose their appetite, experience a fever, and become agitated while developing boil-like sores. Even five larvae per animal might cause significant losses.

Rodent Bots, *Cuterebra* sp. (Family: Oestridae): The majority of the species in the genus *Cuterebra* are rodent and rabbit parasites, though they can infrequently infect dogs and cats as well. The infestation is not significant, yet few of such infestations have been known to kill young cats and dogs. These bot larvae produce a warble that contains a thin coating of necrotic tissue.

Blow flies (Family: Calliphoridae): Different species of flies are categorized or commonly known as blow flies.

Green bottle flies— *Lucilia* sp.

Blue bottle flies— *Calliphora* sp.

Black blow fly— *Phormia regina*

Secondary screwworm— *Cochliomyia macellaria*

Hairy maggot blow fly— *Chrysomya rufifacies*

Despite merely feeding on dead tissue, blow fly larvae and wool maggots can seriously damage animals. Larvae-induced cutaneous irritation results in skin secretions and subsequent bacterial infections. This may accelerate the infestation's spread throughout the body of the host. Additionally, it draws more female blow flies to lay their eggs on the host. In sheep, heavily contaminated areas frequently experience wool loss. Blow fly and wool maggot infestations can significantly reduce animal growth and productivity if they are left untreated. Wool loss may be substantial. Animals with severe injuries may pass away.

10.4.3 Control Measures:

Avoiding contact between possible hosts and myiasis-causing flies, treating wounds promptly to prevent myiasis, and reducing or eliminating myiasis-fly populations are the three main methods for controlling myiasis. In general, sanitation and medical or surgical intervention are heavily relied upon. The most typical strategy used in veterinary instances is the administration of the host with systemic insecticides, particularly those that target the parasite larvae.

The removal of carrion that may attract flies, prompt treatment of open wounds to minimise fly infestation and limiting injuries during the peak fly season are the key prevention strategies for the management of myiasis in cattle and domestic animals. An integrated pest management programme may also make use of biological control agents, such as parasitic pteromalid wasps that infest fly pupae and the physical removal of adult flies via trapping.

Regular examination of animals to find and treat all wounds, deep burial or cremation of carrion, restricting dehorning, castrating, and branding to off-fly seasons, removing sharp objects and other materials that can cause wounds (such as horns, barbwire, and thorny shrubs), and effective tick and fly control are among the husbandry practises that can help to lower the incidence of myiasis. Applying a salve, such as ointments or "smears," can help stop fly strikes or eliminate any existing maggots. Smears include insecticides like benzol or Lindale as well as repellents like pine-tar oil. To avoid the negative effects of crushing the larvae inside the warble, which might result in an allergic reaction, hydrogen peroxide has been directly pumped into warbles to eliminate them in an antiseptic manner.

One popular method of applying pesticides to farm animals to protect them from flies that cause myiasis is the use of ear tags impregnated with insecticidal formulations. In a similar manner, ankle bands with insecticide embedded in them that are fastened around the hind legs of animals have also been employed to control these flies.

Systemic insecticides can also be administered by injection, applied to the back as pour-ons to be absorbed by the bloodstream, as boluses placed in the animal's stomach to provide slow release of systemic compounds, or in mineral blocks (salt licks) for ad libitum consumption by livestock.

10.5 LICE

Domestic animal lice are host-specific, persistently required ectoparasites. They reside on their host for their entire life. There are three life phases for lice: the egg, the nymph, and the adult. Three nymphal phases are present. To spend their whole life cycle on their host, lice are highly adapted. Adult lice are tiny, ranging in length from 0.5 to 8 mm, dorsoventrally flattened, and wingless. They have modified tarsi and legs for slipping through fur, hair, and feathers. Individual eggs laid by adult female lice are permanently attached to their hosts' hair or feathers.

Systematic Position: Lice belong to the order **Phthiraptera**, which is further divided into two taxa namely, **Anoplura** and **Mallophaga**. The first taxonomic group, Anoplura is classified as a suborder and consists of sucking lice. Whereas, the Mallophaga contains chewing or biting lice and has been further categorised into three orders, namely Amblycera, Ischnocera and Rhynochophthirina.

10.5.1 Cause/Mode of Parasitism:

Mallophaga lice adults have mandibles that can be used for chewing. These lice feed off of their host's various skin, hair, or feather fragments. Some animals will consume blood that leaks from skin scrapes or from rasping and sucking mouthparts. Chewing lice consume both mammals and birds as food sources.

The sucking lice known as anoplura only eat mammals. The head is little, slender, and lengthy. Their mouth parts have been altered to pierce human skin. Three stylets that pierce the skin and a sucking tube for ingesting the blood meal make up the mouthpieces. The mouthpieces are retracted into the head within a modified snout-like labrum while the animal is at rest. To cling to the host during feeding, its snout has tiny hook-like teeth.

10.5.2 Disease / Effected host:

As with the hog louse, different chewing and sucking lice species exhibit a key host specialisation that can range from one host species to some lice species parasitizing two or more closely related species. The horse sucking louse parasitizes horses, donkeys, and mules, while dog lice may infest other canines like foxes, wolves, and coyotes.

Under such species, the infection and diseases spread by lice species have been covered individually.

Cattle lice

Cattle biting louse, *Bovicola bovis* (Suborder: Ischnocera; Family: Trichodectinae): The back line, shoulders, and base of the tail are common locations for these lice. Populations of louse frequently spread to different areas of the body as their numbers rise. Where intensive feeding takes place, they are frequently observed in clusters of several lice each. They mostly eat skin scales that have shed, but chewing creates sores on the skin that resemble mite-caused mange. Animals that have been infected may have skin that is highly infected, ragged, and discoloured. Animals noticeably spend a lot of time licking and rubbing their bodies.

Short-nosed Cattle louse, *Haematopinus eurysternus* (Suborder: Anoplura; Family: Haematopinidae): It is the most frequently observed infesting mature animals, and its population is at its highest during the winter. The top of the neck, dewlap, brisket, base of the horns, and base of the tail are common areas where they can be spotted feeding during the winter. Higher infestation levels may result in anaemia and condition loss.

Cattle tail louse, *Haematopinus quadripertusus* (Suborder: Anoplura; Family: Haematopinidae): Cattle tail louse populations are mainly found in the long hair surrounding the tail. Tail hairs can become matted with lice eggs during severe infestations, and hair can even fall out of the tail heads. Anemia in cattle may result from severe infestations. The condition, weight gain, vitality, and milk output of cattle are all poor.

Long-nosed Cattle louse, *Linognathus vituli* (Suborder: Anoplura; Family: Linognathidae): This louse rarely infests significant populations of mature animals and is particularly prevalent on calves and dairy cattle. The dewlap and shoulders are the preferred areas for infestation. Economic concerns might arise from this louse, especially in younger animals where it may reduce the effectiveness of weight increase.

Little blue louse, *Solenoptes capillatus* (Suborder: Anoplura; Family: Linognathidae): On the dewlap, shoulders, back, tail, and shoulders of mature animals, the small blue louse is typically seen in clusters. Aggregations of this louse frequently encircle the host's eyes in animals that are severely afflicted. The small blue louse, like other bovine lice, can make cattle noticeably agitated and uneasy, leading to skin abrasions and hair loss from scratching.

Swine Lice

Hog Louse, *Haematopinus suis* (Suborder: Anoplura; Family: Haematopinidae): Pigs of any age or condition can get hog lice, but weak, underweight animals are more prone to infection.

Swine may experience observable irritation and discomfort as a result of hog lice feeding activities. Large amounts of blood can be lost, especially in young animals. Animals that are infected scratch ferociously and brush against feeders, posts, and other items.

They have the ability to spread the swine pox virus, a dangerous and potentially fatal condition that affects swine. Additionally, hog lice have been linked to the spread of the viruses that cause African swine fever, hog cholera, and eperythrozoonosis.

Sheep Lice

Sheep Biting Louse, *Bovicola ovis* (Suborder: Ischnocera; Family: Trichodectidae): Older sheep and animals in poor condition are more likely to be infected by the sheep biting louse. They can be extremely irritating, prompting sheep to rub abrasively against surfaces and bite and tug at their wool. They feed on skin scurf. Sheep that have been severely affected develop ragged, ripped fleece that frequently has huge sections of wool missing.

Sucking Lice on Sheep, *Linognathus* sp. (Suborder: Anoplura; Family: Linognathidae): The body areas of sheep that different species of sucking lice prefer to infest vary, with *L. ovillus* favouring the face region and *L. pedalis* favouring the legs. *L. africanus*, however, can infest any area of the sheep's body. Heavy infections of any of the aforementioned lice can significantly irritate sheep and result in wool loss. On the other hand, deer have been recorded to die from severe infestations.

Goat Lice

Sucking Lice, *Linognathus stenopsis* (Suborder: Anoplura; Family: Linognathidae): In cases of more severe infestations, sucking lice can hinder weight gain and result in anaemia. Although severe infestations typically only appear in stressed or ill goats, infestations can cause stunted weaned goats and even occasionally result in infant fatalities.

Lice of Domestic Fowl

Chicken Body Louse, *Mencanthus stramineus* (Suborder: Amblycera; Family: Menoponidae): The most prevalent and economically significant louse species on poultry is the chicken body louse. Birds suffering from acute irritation from heavy infestations develop skin inflammation and scabs as a result. These lice frequently pierce skin and quills while feeding on the barbs and barbules of feathers. This louse can kill younger, weaker birds by causing feather loss, weight loss, decreased egg production, and other symptoms.

Shaft Louse, *Menopon gallinae* (Suborder: Amblycera; Family: Menopnidae):The thigh and breast regions of poultry birds are home to the shaft louse. These lice predominantly feed on the barbs of feathers. Although it rarely poses a severe threat, large infestations can result in the mortality of young birds.

Chicken Head Louse, *Cuclotogaster heterographus* (Suborder: Ishnocera; Family: Philopteridae): This louse is commonly found in the skin tissue, detritus, and feathers of their host's head and neck are where it feeds on the blood. Typically, younger birds are more impacted than older ones. Sometimes, severe infestations might be fatal.

Wing Louse, *Lipeurus caponis* (Suborder: Ischnocera; Family: Philopteridae): The adult wing louse measures about 2.2 mm length and 0.3 mm wide, and it is elongate and slender. At the base of the wings, the nymphs hatch and eat on their own.

Horse Sucking Louse,*Haematopinus asini* (Suborder: Anoplura; Family: Haematopinidae): The horse sucking louse is commonly found on the head, neck, back, and inner surface of the thighs. It is generally seen more commonly than infestations of the horse biting louse, while not being as economically important. This blood-sucking louse can seriously irritate its host during severe infestations. Animals get agitated and degrade physically. Animals appear unhygienic or untidy in appearance. Infested host animals cause damage to their hair coat by constantly rubbing and scratching against various objects. Additionally, with severe infestations, anemia might arise.

Lice in Cats and Dogs

Cat Biting Louse, *Felicola subrostrata* (Suborder: Ischnocera; Family: Trichodectidae): The only type of louse that frequently affects cats is the cat biting louse. Although it is uncommon in healthy cats, it can occasionally be observed in elderly, chronically unwell, or malnourished cats.

The louse can infest almost any part of the body. Severe itching might occur during heavy infestations. Cats with infestations frequently scratch, causing skin and fur coat damage.

Dog Biting Louse,*Trichodectes canis* (Suborder: Ischnocera; Family: Tricodectidae): While not frequently found on healthy animals, the dog biting louse can occasionally develop severe infestations in malnourished dogs. It might be dangerous, especially for puppies. The head, neck, and tail are the areas where it is most usually found. On dogs, it is quite active. The activity of lice feeding on the skin can cause severe itchiness, and vigorous scratching can result in skin damage. The damage may become more complicated by inflammation and consequent bacterial infection. Additionally, this louse may act as an intermediary host for the canine double-poured tapeworm, *Diplidium caninum*. When lice consume live *D. caninum* eggs from dried host excrement, they get infected.

Dog Sucking Louse, *Linognathus setosus* (Suborder: Anoplura; Family: Linognathidae): With the exception of severe infestations, the canine sucking louse rarely irritates dogs. Usually under dog collar, infestations are most common on the neck and shoulders. Similar to the dog-biting louse, severe infestations can be uncomfortable and cause the host to rub, scratch, and bite at the infected areas. This may cause alopecia, anxiety, insomnia, and a rough, matted coat. Very young, aged, or disabled animals as well as animals housed in filthy conditions are more likely to experience infestations.

10.5.3 Control Measures:

The key factor in effectively managing lice in animals is constant surveillance for infestations. Smaller infestations of lice are especially difficult to detect because cattle farmers don't notice a problem until their animals start losing hair noticeably and scratching excessively. By this time, lice numbers frequently exceed the economic cutoff point. Therefore, it is important to regularly check cattle and other livestock for lice infestations.

Five to six areas of the cow's body should be examined, including the head, neck, shoulders, back, hips, and tail. One can identify a lice infestation by separating the hair and looking for lice on the skin. If the average number of lice per hair part or square inch is 10, treatment is usually indicated. Also crucial is figuring out whether the lice are biting or bloodsucking. This could decide on the most suitable control strategy.

Examining carefully for an infestation while introducing new animals to the herd is the most crucial and effective way to control a lice infestation in various farm animals. There are numerous insecticides and application methods available to control lice on cattle. The numerous control methods include sprays, dust, pourons, injections, and self-application devices (e.g., dustbags, oilers, back rubbers). In addition, biting (or chewing) lice cannot usually be controlled by systemic insecticides. Treatments with surface-acting insecticides are required in cases with biting lice infestations.

10.6 FLEAS

The insect order Siphonaptera contains every species of flea that infests livestock. More than 95% of the 2500 species that make up this tiny insect order are mammalian ectoparasites. A small number of species are parasitic to avian hosts in addition to the mammalian ectoparasites.

10.6.1 Cause/Mode of Parasitism

Fleas have highly developed mouthparts for sucking and piercing in order to consume blood. Adult males and females both consume blood as food. Fleas go through two life stages: a parasitic one where the adults are found on the host, and a nonparasitic one where the larvae feed on the host. Typically, eggs are placed on the host or occasionally close to the host. They quickly detach from the host and land on the ground or in the host nest. Within a few days of oviposition, eggs hatch. In addition to hair, skin, scales, scabs, dried host blood, feathers, and even cast exoskeletons and adult flea excrement, proteinaceous organic detritus is also consumed by larvae. A mature flea larva will construct a silken cocoon that is woven using waste products from the environment where the larva was developing.

Adult fleas, both male and female, eat their hosts' blood for food. Despite the modest size of individual blood meals, frequent feeding and heavy infestations can result in considerable blood loss. Flea bites itch and can result in swelling and itching at the bite site. The host animal biting and scratching itself, frequently result in additional injury. The victim of a flea bite may experience allergic reactions. In addition, different species of fleas are known to act as intermediate hosts or vectors for a variety of pathogens, including as viruses, bacteria, rickettsiae, and helminthes.

10.6.2 Disease / Effected host:

The crucial host specificity that flea species exhibit is comparable to that of livestock lice, with one species specialising in infesting one or more closely related animal species. Along with cats, dogs, and rats, poultry birds are heavily infested with fleas. Different flea species have been examined individually under separate species with regard to the infection and damage they spread.

Cat Flea, *Ctenocephalides felis* (Order: Siphonaptera; Family: Pulicidae): The most prevalent flea on household cats and dogs is the cat flea. Humans and various other mammals are also host for these fleas. It can cause severe irritation that leads to dermatitis and skin inflammation. Heavy infestations can cause young animals to become anaemic. Strong grooming reactions might occur in the host animal as a result of flea allergy dermatitis. Animals with allergies repeatedly lick, scratch, and bite flea bites, leading to hair loss and skin ulcers. Lesions at the biting site frequently develop secondary infections. The double-pored tapeworm, *Dipylidium caninum*, uses the cat flea as an intermediary host. The flea larval, pupal, and adult stages serve as host for the tapeworm larvae develop. The tapeworm becomes a cysticercoid and encapsulates inside the adult flea. Adult tapeworms seek entry into the digestive tract of host via ingestion of infected flea by host while grooming its own self.

Dog Flea, *Ctenocephalides canis* (Order: Siphonaptera; Family: Pulicidae): The dog flea is substantially less frequent than the cat flea, while being widespread globally. Actually, the flea most frequently discovered on dogs is the cat flea. Similar harm is inflicted on the host by the dog flea, including host hypersensitivity and flea allergy dermatitis. Additionally, it acts as a host for the double-pored dog tapeworm, just like the cat flea does.

Sticktight Flea, *Echidnophaga gallinacea* (Order: Siphonaptera; Family: Pulicidae): The sticktight flea is chiefly significant as a bird parasite. It can be a major problem for chickens. Around the head, where the adult flea firmly embeds its mouthparts into the host skin, infestations of poultry might take place. These fleas frequently gather in groups around the eyes, comb, wattles, and other exposed areas. Both skin irritation and ulceration may result from them. Infestations that are more severe will reduce bird egg production and diet effectiveness. Young birds who are subjected to severe infestations risk blindness and possibly death.

Northern Rat Flea,*Nosopsyllus fasciatus* (Order: Siphonaptera; Family: Ceratophyllidae): It mostly parasitizes the Norway rat (*Rattus norvegicus*), while it also affects several other rodents and domestic mammals on occasion. It has been proven to spread a number of zoonotic infections, including the plague and murine typhus virus. It is typically thought to be of negligible veterinary significance.

European Chicken Flea, *Ceratophyllus gallinae* (Order: Siphonaptera; Family: Ceratophyllidae): This flea feeds on poultry, which can make the birds irritable, agitated, and anaemic. They can occasionally become a nuisance for those who work in poultry plants where they are present or in homes where wild birds have taken up residence. It is frequently discovered in bird nesting materials.

10.6.3 Control Measures:

Flea populations are naturally kept below economic thresholds by efficient host animal grooming techniques as well as predators that eat both the adult and larvae, such as predatory mites, pseudoscropions, beetles, and ants. *Yersinia pestis*, protozoa, nematodes, and a parasitoid wasp are among the parasites that can infect fleas. Vacuuming can get rid of practically all flea larvae and roughly 60% of flea eggs in mechanical control methods. The larvae, which resemble worms, are readily removed with the vacuum.

Different insecticidal treatments can also be used to manage the flea populations in addition to cultural activities such maintaining adequate cleanliness and timely inspection for the presence of fleas in poultry and other domestic animals. Spot applications of insecticides like fipronil and methoprene and various insect growth regulators (IGR) can effectively manage these pests.

10.7 TICKS

Ticks are destructive external blood-feeding parasites of mammals, birds, and reptiles all throughout the world, with many distinct species having regional relevance.

Systematic Position: Ticks are the close relatives to the insects of Phylum Arthropoda and belong to the class Arachnida. Unlike the three segmented body of insects, ticks have a two segmented body, having cephalothorax and abdomen. Ticks are in the class Arachnida and subclass Acari and are closely related to mites. Within the order Parasitiformes, ticks are represented by three families: Ixodidae, Argasidae, and Nuttalliellidae. Family Ixodidae, the hard ticks, contains most of the species of veterinary importance.

10.7.1 Cause/Mode of Parasitism

The tick uses its chelicerae to sever the host's skin in order to eat. The hypostome is then inserted while the palps are spreading out on the host's skin. Short-mouthed ticks adhere to their hosts through the secretions from their salivary glands. To help with successful feeding, other chemicals, including anticoagulants, are also released. The lifecycles of several tick species varies significantly. They can be divided into groups based on the number of hosts they have fed on and their off-host times during various life stages. When using ixodid ticks, lifecycles can be divided into one-host, two-host, or three-host ticks depending on how many hosts are used.

One-Host Ticks: In these types of ticks unfed larvae attach to the host and remain on the single host through three separate blood feedings of the larval, nymphal, and adult stages. During any of these stages, they may reattach on the host several times before complete engorgement.

Two-Host Ticks: In these species (e.g., Rhipicephalus evertsi), larvae and nymphs feed in the same host with engorged nymphs dropping to the ground. Emerged adults then seek another host to feed upon.

Three-Host Ticks: Few tick species have (e.g., *Dermacentor variablis, Amblyomma americanun,* others) a separate host is used for each feeding stage. Upon the completion of each blood meal, engorged larvae and nymphs drop to the ground to molt. Adult females upon repletion drop to the ground to oviposit eggs.

10.7.2 Disease / Effected host:

Different types of ticks, infesting variety of livestock animals including rodents, ground-inhabiting birds, deer, cattle, horses, sheep, dogs, and several other animal species.

Lone Star Tick, *Amblyomma americanum* (Order: Acari; Family: Ixodidae): The majority of lone star tick sightings occur in forested settings with healthy numbers of their natural hosts. Host animals have been seen to contain hundreds to thousands of lone star ticks at any given time in strongly infested locality. Lone star tick infestations in cattle will typically be detected in or near the dewlap, udder, scrotum, ancillaries, tail head, and escutcheon. Lone star ticks have mouthparts that can penetrate deeply and cause the host to experience painful reactions. Inflammation, developing sores, and pain are the effects of the host's reaction to the tick attachment. At the attachment site, secondary infection will frequently happen. Animals that have been heavily infested exhibit decreased performance, weight loss, decreased milk production, and reproductive issues.

Gulf Coast Tick, *Amblyomma maculatum* (Order: Acari; Family: Ixodidae): Within its zone of distribution, the Gulf Coast tick is a significant pest of cattle. Other domestic animals (such as horses, sheep, pigs, and dogs) as well as wild animals are also infected by it (e.g., deer, coyotes). Significant infestations can occur in range cattle. On the inner portions of the outer ears of cattle, adult ticks like to attach and eat. They frequently cause severe discomfort and host reactions because of their large mouthparts and concentration in this particular area of the host. Open, scabby lesions cause the infected ears to swell up and become painful. The gotch ear appearance due to the inward curling of tick infested, swollen ears is a characteristic symptom of gulf coast ticks. Due to the severe irritation, there is a significant loss of weight and a reduction in grazing duration and feed efficiency. Secondary infections can occur in the infested and unhygienic ears.

Cayenne Tick, *Amblyomma cajennense* (Order: Acari; Family: Ixodidae): This particular kind of tick can be a major cow pest. Although it is present year-round, cattle are most frequently infested from March through May. *A. cajennense* can cause excruciating wounds at the sites of attachment thanks to its large mouthparts, like those of other *Amblyomma* ticks. They favour the dewlap, axillaries, udder/scrotum, escutcheon, and tailhead region of cattle as attachment sites.

Cattle Tick (Cattle Fever Tick), ***Rhipicephalus (Boophilus) annulatus*** **(Order: Acari; Family: Ixodidae):** The protozoan parasite *Babesia bigemina*, which is the cause of Texas cow fever, is spread mostly by this tick. *Babesia bovis* can also be spread through this tick species. Eradication operations were started as a result, and permanent quarantine areas were set up along the Mexican border for avoidance against this tick. The discovery of *Babesia bigemina* by R. annulatus in cattle in 1893, which was significant historically, was the first account of a disease transmission by an arthropod. Additionally, the tick can spread *Anaplasma marginale*, the causalagent of anaplasmosis in cattle. *R. annulatus* plays a crucial role in the spread of disease, but it can also severely impair animal output and harm hides.

Brown Dog Tick, ***Rhipicephalus sanguineus*** **(Order: Acari; Family: Ixodidae):** This tick may be found in both tropical and temperate locations, making it the tick with the greatest geographic distribution. It mainly bothers dogs and hardly ever feeds on humans or other animals. It can be frequently discovered in and around pet bedding in kennels and inside homes. Dogs are used in all feeding stages. Adults frequently attach between the toes and behind the ears. Nymphs and larvae are frequently seen along the back. Ticks can be discovered on any area of the dog's body in severe infestations. Skin discomfort and injury are possible effects of severe infestations. *Ehrlichia canis*, which causes canine ehrlichiosis, and *Babesia canis*, which causes canine babesiosis in dogs, are both known to be transmitted by the brown dog tick.

Dog Tick, ***Dermacentor variabilis*** **(Order: Acari; Family: Ixodidae):** As a livestock pest, this tick is regarded as being of relatively low concern. However, it has been shown to be capable of spreading *Anaplasma marginale* in cattle, the pathogen that causes anaplasmosis, under controlled circumstances. It is the primary vector of *Rickettsia rickettsii*, which causes Rocky Mountain spotted fever (RMSF).

Winter Tick, ***Dermacentor albipictus*** **(Order: Acari; Family: Ixodidae):** It is a one host tick species, infesting cattle and horses. Heavy infestations of this tick on cattle and horses can cause significant loss of productivity with symptoms of lethargy, inappetence, lusterless hair coat, general debilitation, and edema, and even death from anemia. Infestations are generally found on the axillaries, dewlap, udder/scrotum, and escutcheon, but can be found anywhere on the body in heavy infestations.

10.7.3 Control Measures:

It is a species of tick with only one host and infests cattle and horses. Heavy infestations of this tick on cattle and horses can result in severe productivity loss, overall debilitation, edoema, lethargy, loss of appetite, lusterless hair coat, general weakness, ultimately anemia-related death. Heavy infestations can occur everywhere on the body, however they typically occur on the axillaries, dewlap, udder/scrotum, and escutcheon.

A variety of predators, including birds, rodents, shrews, ants, and spiders, contribute to the decline in the population of free-living ticks. Acaricides are the most widely used and efficient way to manage tick populations in the environment or against parasitic stages on hosts, in addition to cultural, mechanical, and biological control methods. Amitraz-based acaricides are the most widely used chemical treatments worldwide for the control of ticks in livestock out of all the different types of acaricides that are readily available. For the control of ectoparasitic tick species in farm animals, insecticides like Fipronil and pyrethroid insecticides like Aplha cypermethrin, Cyhalothrin, and Deltamethrin can be used.

10.8 MITES

Systematic Position

Mites are small, microscopic arthropods and have been classified under the similar class **Arachnida** and subclass of **Acari** as ticks. Mite body resembles a sac and lacks segmentation. The anterior gnathosoma, which makes up the mouthparts, and the posterior idiosoma, which makes up the rest of the body, are its two body regions. The legs-containing podosoma and the opisthosoma make up the idiosoma. Larvae have three pairs of legs, whereas adult and nymphal mites have four pairs. While each type of mite has a unique set of mouthparts, most parasitic species employ chelicerae to pierce their host's skin. According to reports, mites live in a variety of habitats, including soil, hot springs, water, plants, and animal bodies, including those of mammals.

The majority of the 30,000 or more mite species that have been described are free-living, predatory, or plant feeders. However, some 250 species of mites are known to be significant for human and/or veterinary health. Numerous mite species are important ecto- and endo-parasites in veterinary medicine. All of the mite species found on various types of animals, including horses, cattle, sheep, goats, chickens, dogs, and cats, are members of one of three mite orders: **Mesostigmata, Prostigmata,** and **Astigmata**.

10.8.1 Cause/Mode of Parasitism:

Either of the three approaches allows a particular mite species to infest its cattle host. While some mite species feed externally, some feed subcutaneously, and a third variety infests their host inside through various bodily channels. Additionally, it is known that mite infestations can cause dermatitis, allergic reactions, hypersensitivity, or the spread of several pathogens in animals.

10.8.2 Disease / Effected host:

As vector of numerous disease-causing pathogens and because the majority of species are linked to at least one type of mite-induced scab or dermatitis, mites are considered as one of the most significant livestock pests. Mites have a wide host range including most of the farm animals, such as cattle, chickens, horses, goats, and sheep, as well as domestic pets like dogs and cats.

Various mite species with veterinary significance, their nature of damage, irritation, and disease transmitted by various mite species according to the three different ways of mite infestation have been discussed separately.

a. **External Feeding Mites**

1. **Northern Fowl Mite, *Ornithonyssus sylviarum* (Order: Mesostigmata; Family: Macronyssidae):** One of the most significant external parasites of chicken, if not the most significant, is the northern fowl mite. In caged poultry enterprises, it is very costly. They live their entire lives as continuous, obligatory parasites on their host. The area around a bird's vent is where mite infestations are most frequently seen. Light infections frequently go unnoticed at first, but as mite populations rise, vent area feathers become matted and develop a grey to black discoloration due to greater mite populations, mite faeces, cast exoskeletons, and mite eggs. The skin becomes scaly, scabby, and thicker around the vent

area where mites feed. Heavy infestations may result in reduced egg production, anemia, weight loss, condition loss, and occasionally even death.

2. **Chicken Mite, *Dermanyssus gallinae* (Order: Mesostigmata; Family: Dermanyssidae):** The chicken mite, commonly referred to as the chicken red mite, is a parasite that infects both domestic and wild birds. It occasionally infects mammals that get linked with poultry operations, such as dogs, cats, horses, cattle, and rats. Due to the fact that it does not finish its lifecycle entirely on the host, this mite can be a serious issue in poultry operations, particularly for birds kept in floor operations as opposed to caged laying hens. It just stays around and eats birds at night. Additionally, it has been discovered to be a concern in brooder houses that use nest boxes. Devastating chicken mite infestations can cause severe skin irritation and sores (often observed on the breast and legs of birds), loss of vitality, slowed growth, feather loss, decreased egg production, anaemia, and occasionally death, particularly in young birds. The chicken mite has been linked to the spread of many encephalitis viruses and pathogens that cause chicken cholera and fowl spirochetosis.

3. **Chiggers, *Tombicula (Eutrombicula) alfreddugesi* (Order: Prostigmata; Family: Trombiculidae):** The family Trombiculidae has more than 1500 species of mites, of which 50 are thought to be significant for human and/or animal health. These parasitic six-legged larvae have six legs. Small arthropods and their eggs are the main food source for nymphs and adults, who are predators that live in the wild. The majority of domestic animal species are prone to chigger infestations. In regions where chiggers are active, pets kept outside such cats, dogs, horses, and animals are susceptible to infection. Chigger infestation typically results in minor pruritis. Heavy infestations, however, may cause excruciating itching and the development of scabby skin sores. Chigger infestations in mammals can affect the bottom, appendages, face, ears, neck, and feet. The skin damage incurred during rubbing, scratching or biting the mite infested areas or skin portion results into intensely discomforting lesions.

b. Subcutaneous Feeding or Scab-Forming Mites

1. Sheep Scab Mite, *Psoroptes ovis* (Order: Astigmata; Family: Psoroptidae): Sheep and cattle can suffer serious economic losses as a result of this mite. Cattle scab and sheep scab are the results of it. Psoroptic mites do not enter the epidermis; instead, they feed on the skin surface. With the aid of their sucking mouthparts, they consume lipids, skin cells, and skin secretions. Serous exudates produce a dry, yellow crust as a result of the host's reaction to this feeding activity, which is bordered by inflammatory skin coated in a moist crust. On the wet tissue near the edge of these lesions, there are mites. If left untreated, these lesions can cover a significant percentage of the body in animals. Significant hair and wool loss, decreased weight increase, and decreased feed efficiency can all be effects of this.

2. **Hog mange or Sarcoptic mite, *Sarcoptes scabiei* (Order: Astigmata; Family: Sarcoptidae):** *Sarcoptes scabiei* has a number of host-specific variants despite being categorized as a single species. This mite affects a variety of domestic and wild animals in addition to people. Adult female mites of *Sarcoptes scabiei* injure their hosts by tunnelling through the epidermis. In varied degrees, this burrowing behaviour and feeding on disintegrated skin tissues culminate in dermatitis, which causes pruritis, hair loss, and cutaneous crusty sores. Initial lesions can develop everywhere on the host body, but they tend to be more prevalent in areas with sparser hair, frequently around the head. The infestation may then quickly spread to other body parts. As it worsens, the skin in the affected places thickens, crusted scabs develop that are prone to cracking and oozing exudates, and significant hair loss may take place. The host's rubbing and scratching results in further damage, and subsequent infections might be problematic. Animals that are severely infected lose weight, have lower feed efficiency, fewer offspring, produce less milk, are lethargic, and may even die.

3. **Sheep and Cattle Itch Mites, *Psorobia ovis* (Order: Prostigmata; Family: Psorergatidae):** *P. ovis*, the sheep itch mite, is known to have greater veterinary significance. There have been reports of severe infestations harming livestock economically. Small, pale spots of the wool on the shoulders, thighs, and/or flanks are the first indications of an infection. The infestation will progressively spread to the body's remaining areas. When there is a serious infestation, the sheep may scratch and bite at the affected areas, severely damaging their skin and wool. The wool turns yellow-orange in hue and becomes dry, stringy, matted, and damaged. Scurf also thickens where the mites are feeding on the skin.

4. **Demodex Mites (Order: Prostigmata; Family: Demodicidae):** Demodex mites come in a variety of species and are generally found on agricultural and domestic animals. Numerous wild and domestic animals, as well as people, carry *Demodex* spp. Each species has distinct host requirements. These mites are mostly nonpathogenic and are frequently seen on their hosts. They are often located in dermal glands or hair follicles. In dogs, clinical demodectic mange is frequently at its worst. Mites pierce epithelial cells in hair follicles and glands with their chelicerae to feed, which results in host damage. Normal host reaction is negligible. Dermal papules and nodules can sometimes form as a result of infected hair follicles and glands swelling and blocking, and scaly dermatitis is frequently the result. Secondary bacterial infections that result in inflammation, pruritis, and pustule production can also result in hair loss. Clinical lesions frequently start out on the face and head before spreading to other body areas. Dogs (*Demodex canis*) can occasionally get severe demodectic mange, which most frequently affects younger animals that are physiologically more vulnerable to it. Initial clinical infestations in dogs are frequently seen around the mouth's corners and eyes.

5. **Ear Mite, *Otodectes cynotis* (Order: Astigmata; Family: Psoroptidae):** This is an extremely prevalent mite that affects dogs, cats, and other carnivores. *Otodectic mange* is the result of the parasite's deep external ear canal infestation of the host. It may also be found infesting other body parts, such as the head, back, tail, and feet, in cases of severe infestations. These mites feed on their hosts by penetrating the epidermis and sucking in blood, serum, and lymph as well as aural exudates in the ears.

6. **Notoedric Cat Mite, *Notoedres cati* (Order: Astigmata; Family: Sarcoptidae):** Primarily domestic and wild cats, as well as rarely rabbits and canids like dogs, are affected by this mite. Typically, the shoulders, neck, face, and ears are where lesions initially show up. Lesions may then appear on the belly, legs, and genital region as the infestation spreads. Similar to *S. scabiei*, crust and scab formation appears in contaminated areas. The dermatitis that results in severe pruritis, erythema, crusty skin scaling, and hair loss. Skin ages and thickens, developing wrinkles. Animals with an infestation will scratch constantly. Animals with infestations may grow fatally ill or become seriously disabled if left untreated.

c. Internal Feeding Mites

1. Cattle Ear Mite, *Raillietia auris* (Order: Mesostigmata; Family: Halarachnidae): This mite is regarded as mostly harmless. It mostly consumes wax and skin debris from cattle's ear canals. It could obstruct the auditory canal. In severe situations, ear canal inflammation, pus development, ulcerated lesions, and bleeding might happen. Hearing loss can occur in animals.

2. Fowl Cyst Mite, *Laminosioptes cysticola* (Order: Astigmata; Family: Laminosioptidae): This mite is a parasite that lives inside chickens and can be found in the subcutaneous tissue of the vent, flanks, breast, and neck. Small, hardened nodules develop. These nodules can number in the hundreds in areas with severe infestations. The carcass value may be affected by these calcified nodules..

3. Airsac Mite, *Cytodites nudus* (Order: Astigmata; Family: Cytoditidae): Birds infested with this mite species have infected bronchi, lungs, air sacs, and bone cavities. Small infestations typically do not affect their hosts clinically. Serious infestations may result in coughing fits and mucus buildup in the trachea and bronchi. Weakness and weight loss are symptoms that can be brought on by emaciation, peritonitis, pneumonia, and airway obstruction.

10.8.3 Control Measures:

The following guidelines should be followed to prevent mite infestation:

When buying or boarding new animals, exercise caution; stay away from animals with obvious skin sores or scratching, in feedlot operations, treat all new animals with chemicals when brought in, clean stalls between animals and put in new bedding, disinfect grooming tools and other instruments that are used on animals, keep animals healthy and well-nourished, and call a veterinarian right away if any signs of itching or lesions develop to check the herd.

The best ways to apply acaricides to beef cattle and non-lactating dairy cattle are by injecting ivermectin or dipping the animal in a solution containing an approved acaricide, such as amitraz, coumaphos, permethrin, or phosmet, or using a spray-dip machine. Pour-on treatments of moxidectin or eprinomectin or permethrin or coumaphos can be used to treat lactating dairy cattle.

10.9 SUMMARY

Different arthropod species spend all or some portion of their lives affecting the well-being of livestock, poultry, or companion animals. Arthropods from two different classes namely, Insecta and Arachnida consists the most notorious and economically significant pests of farm animals. These arthropods associated with livestock, poultry, and companion animals cause problems in a variety of direct and indirect ways. Direct damage by parasitic arthropods ranges from bite irritation, blood loss, tissue consumption and damage, and toxic and allergic reaction to arthropod venoms and feeding antigens. Indirect damage may be caused by introduction of pathogens, nuisance leading to stress and annoyance, self-inflicted wounds from scratching and pest avoidance, and in creating susceptibility to other stressors. Constant scouting and surveillance for detecting the pest infestation in its earlier phases is the most important factor for proper management of various pests in farm animals. Further, in case of severe infestation, chemical control is done with the help of different systemic insecticides and acaricides.

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10.10 TERMINAL QUESTIONS AND ANSWERS

Question No.1: Describe the mode of parasitism of blood sucking flies in livestock.

Question No.2: What is myiasis? Enlist five insects associated with myiasis in livestock.

Question No.3: Describe the different tick species associated with one, two and three hosts.

Question No.4: Write a short note on Arachnid species associated with livestock.

Question No.5: Enlist five important mite species infesting farm animals.

UNIT 11: MEDICAL ENTOMOLOGY

11.1 OBJECTIVES

By the end of this unit the learner will be able to:

1). Understand the mode and behavior of transmission of various insects.

2). Determine the importance, life cycle and preventive measures of insect pests.

3). Learn about the insect borne diseases, their cause, symptoms and treatment.

4). Understand the importance of Arthropods in Forensic Sciences

11.2 INTRODUCTION

Many dangerous diseases are transmitted through the agency of insects. Insect- borne diseases take a heavy toll of human life. About a million of people die and a few hundred million suffer from such diseases throughout the world within a year. About 400 million people live in areas where malaria is still highly endemic. It is estimated that at least 100 million cases occur annually resulting in death of one million. Filariasis is a common disease in tropical areas affecting more than 250 million people. The number of deaths due to plague during 1898-1957 has been estimated, up to 12,707,475. Similarly, in 1970-1980, sleeping sickness took toll of one million lives in West Africa.

MODE OF TRANSMISSION

The insects often transmit pathogens at the same time of blood sucking. The pathogens are mostly the bacteria, viruses, rickettsiae, spirochaetes, protozoans and helminths. The insects transmit these pathogens primarily in three ways: mechanical transmission, biological transmission, and myiasis.

1. The Mechanical Transmission:

(a) Indirect Mechanical Transmission: It is the exogenous infection carried out with the help of feet or body of an insect. It is indirect transmission, in that, the insect acts merely as a passive agent, e.g. housefly. The common housefly, *Musca domestica* visits infected human faeces or dirty places and picks up pathogenic microbes on their legs and other parts of body and subsequently contaminate human food- stuff.

(b) Direct Mechanical Transmission: It is the endogenous contamination made due to direct way in which the insect picks up the germs from an infected animal and directly inoculate them into the blood of a host animal: e.g., common eye fly, *Siphunculina funicola* is responsible for spreading conjunctivitis from man to man.

2. The Biological Transmission: The insect plays a part in the life of the pathogenic organism. It may be of three types; propagative, cyclo propagative and cyclo developmental.

(a) Propagative Transmission: The pathogen undergoes no cyclic changes but simply multiplies inside the body of insect as in an artificial culture tube. e.g., Bubonic plague.

(b) Cyclo propagative Transmission: The pathogen undergoes cyclical changes and multiplies in the body of the insect: e.g., malaria parasite, *Plasmodium*.

(c) Cyclo developmental Transmission: The pathogen undergoes cyclic developmental changes inside the insect body but does not multiply, e.g., filariasis worm, *Wuchereria.*

3. The Myiasis: Infection by lodging the living dipterous larvae in the open body cavities of man and domestic animals is called, myiasis. The species concerned are either parasitic or saprophagous. They cause primary myiasis when it is induced by true parasites or secondary myiasis which is induced by saprophagous larvae. The latter only follows on diseased conditions or wounds and usually where there is microbic infection.

11.3 PEST OF PUBLIC IMPORTANCE AND THEIR CONTROL

11.3.1 MOSQUITOES: (Diptera: Culicidae)

The much popular economic important genera are the *Anopheles, Ades and Culex* related directly to the public health. They are most abundant during spring and females are the biting gnats.

Life-Cycle

Eggs: *Anopheles* and *Aedes* females lay eggs singly, while *Culex* in a group or rafts of several hundreds. *Aedes* lays eggs out of water but mostly in floated areas while *Anopheles* and *Culex* lay eggs on the surface of water. The eggs of *Anopheles* and *Culex* generally hatch in one to three days, while that of *Aedes* may hatch variably, within a period of 2-3 days to even a year.

Larvae: The larvae are also called wriggles, phototrophic and are microscopic on hatching. They have gradual four larval instars, which are aquatic. They are free-living, air-breathers and found under the water surface with their spiracles open to the air above the water level. They feed on bacteria, protozoans, yeasts and other microorganisms. The larval period lasts for 3-4 days or commonly 8-10 days or even more than six months depending upon the climatic conditions.

Pupae: Unlike the pupae of other holometabola, they are very active insect pupae. The pupal period lasts for about a week. By the end of pupal period, the air is swallowed, the abdomen straightens, pupal skin splits and the adult extricates itself and stands on the moulted skin.

Adults: Adult life is species- specific ranging from a few weeks to even more than six months. The males fly in group but the females independently. Females join the swarms, mate and then depart. *Anopheles* adults may cover a half mile while many others, such as *Ades* may cover an area of 10 miles or more. The males fly in group (swarming) but the females independently (solitary), Females join the swarms, mate and then depart.

CONTROL

Chemical control: Floodwater mosquitoes in irrigated pastures and rice or grass fields can be controlled with parathion at 0.01 to 0.1PPM or Dipteran at 0.5 PPM. Adult mosquitoes may be controlled by indoor sprays or but residual application with DDT, chlorine and lindane, malathion etc. DDT at 100 or 200 mg per square foot, dieldrin at 50 mg per square foot. The breeding places of mosquitoes to be sprayed with petroleum oils or with a mixture of caustic soda, resin and phenol in water.

Biological control: Dragonfly nymphs are found in Florida, USA to be controlling successfully the growing population of mosquitoes. Recently *Bacillus thuringiensis* strain proved much competent in controlling *Aedes* and WHO started world-wide campaign for the use of this microbial agent in mosquito control. The carnivorous fishes like *Gambusia* are now introduced in the mosquito-breeding places at various places in India which feed voraciously on the mosquito larvae.

Preventive control: Mosquitoes repellents, such as citronella, odomos, indalone and other repellent creams are to be applied to the exposed parts of the body. Fine mesh mosquito-nets should be used in order to prevent mosquito bites during sleeping.

11.3.2 HOUSE FLIES

(Diptera: Muscidae)

Musca domestica is a very common Indian housefly. The flies are abundant and very active during summer and rainy seasons.

Life Cycle: The housefly lays 120-160 eggs at a time in decaying organic matter, wet stable manure, even in human feces or garbage. Within a breeding period of two months of active adult life, up to 600 eggs are laid by a single female.

Eggs: The eggs are whitish, cylindrical and about 1mm long with paired rib-like chitinous lines on one side. They hatch within 8-24 hours during summer.

Larvae: The larva after hatching feeds on the organic matter and grows rapidly. The development passes through three instars in 5 – 15 days before pupation. The first instar larva is 2mm long and metapneustic. It moults after 2-3 days into second instar and besides large in size. It possesses one anterior pair of spiracles in addition to the posterior abdominal paired spiracles, amphipneustic. After a day, it moults to the third instar which is 12mm long. It possesses an indistinct head and a 12-segmented trunk. The anteriorly pointed end bears an oral aperture with a pair of hooks and a lateral pair of oral lobes, each showing a minute sensory papilla. It lasts for about 3-5 days and after searching dry, dark crevices of the manure, it modifies into the pupa.

Pupa: It is covered by old-skin of the last instar larva called the pupal case or puparium. It is barrrel-shaped and brown in colour. It lasts for 4-10 days. It is an immobile stage. The newly transformed adult has a flexible membrane on the anterior part of the head, called the ptilinus from which the puparium opens and adult fly emerged out.

Adult: After emergence, the adult flies mate after 2-12 days and after about 4 days, the gravid female starts laying eggs.

CONTROL

Primary Measures: The kitchens should be well screened and food is to be properly covered. Manure or dirt/dust must be removed quickly and sanitary care to be taken at the first priority. Garbage and refuse should be treated with calcium borate etc., to avoid development of larvae.

Chemical Control: The large population of houseflies can be killed by spraying the houses, barns, and privies with DDT, BHC or Chlordane, 3% solution of formalin is also effective in mass killing of the flies.

11.3.3 BEDBUGS

Bed bugs are insects from the genus *Cimex* that feed on blood, usually at night. Their bites can result in a number of health impacts including skin rashes, psychological effects, and allergic symptoms. Bed bug bites may lead to skin changes ranging from small areas of redness to prominent blisters. Symptoms may take between minutes to days to appear and itchiness is generally present. Some individuals may feel tired or have a fever. Typically, uncovered areas of the body are affected. Their bites are not known to transmit any infectious disease. Complications may rarely include areas of dead skin or vacuities. Bed bug bites are caused primarily by two species of insects: *Cimex hemipterus*, and *Cimex lectularius.* Their size ranges between 1 and 7mm. They spread by crawling between nearby locations or by being carried within personal items. Infestation is rarely due to a lack of hygiene but is more common in high-density areas. Bed bugs spend much of their time in dark, hidden locations like mattress seams, or cracks in a wall.

Life Cycle of Bed Bugs

There are seven stages to the life cycle of a bed bug, from its birth to maturity stage which are as follows.

Egg Stage: It is the initial stage of the life cycle of a bed bug. Eggs are laid by a female bed bug who is supposed to lays around 250-300 eggs in their whole life and about 1-12 eggs per day. These eggs are in a grainy structure and a pearl white color. The length of these eggs is nearly 1 mm and can be seen with the naked eye. An enlarged bed bug has red dots as it develops eyespots. These eggs are laid in between the cracks of the floors in a cluster form. After two weeks, these eggs start to hatch at a temperature greater than 70 Fahrenheit. Although, the hatching time can be increased by decreasing the temperature to 50 Fahrenheit.

i. **1st Nymph Stage:** In the 1st Nymph Stage, the length of the nymph becomes 1.5 mm. These **nymphs** start feeding as soon as they are hatched. Although, they cannot breed as they are not grown-up bugs.
ii. **2nd Nymph Stage:** After the 1st nymph, they come to the 2nd nymph stage where the length of the nymph is around 2 mm.
iii. **3rd Nymph Stage:** As the molting process is still going on, they come to the 3rd stage of a nymph with a length of 2.5 mm.
iv. **4th Nymph Stage:** In the 4th nymph stage, the length of the nymph is 3 mm.
v. **5th Nymph Stage:** It is termed as the final stage of the nymph where they are around 4.5 mm in length.
vi. **Adult:** All this process takes a time of 5 weeks when they finally turn into an adult. As they are adults now, they can participate in the process of breeding. They are not in a compulsion to feed every night. These bug bites are not noticeable by many people as they do not react to them. These adult bed bugs can live for around 6-18 months.

CONTROL:

Controlling Bed Bugs Using Integrated Pest Management

In most cases, pesticides alone will not eliminate bed bugs. **Integrated Pest Management (IPM)**, needs to be implemented for effective bed bug control. IPM is an environmentally sensitive approach to pest management that relies on knowledge of the pest and a combination of common sense practices, such as inspection, monitoring, reducing clutter, sealing cracks, the use of barriers, non-chemical methods and the judicious and careful use of pesticides, if needed.

1. Environmental Modification

1. Vacuuming reduces bed bug populations. Clean and vacuum bed bug prone areas daily. Immediately seal and dispose of vacuum bag.
2. Install encasements on mattress and box spring.
3. Make the bed an island: Keep bed away from wall and do not let bedding touch the floor.
4. Install bed bug interceptors under bed and furniture legs.
5. Remove clutter where bed bugs can hide.
6. Keep clothing off of the floor.
7. Isolate infested items in sealed plastic bags or containers.
8. Seal cracks where bed bugs can hide.
9. If you live in an apartment or other multi-family dwelling, and you see a bed bug, contact your landlord immediately.

Non-Chemical Controls

Items that cannot be washed or dried may be steamed, heated or frozen using specialized equipment. Raising the indoor temperature with a thermostat or space heaters will not kill the bed bugs.

1. Launder bed sheets and clothing regularly. Dry for 30 minutes on highest heat setting.
2. Put small items in a freezer for 4 days.
3. Apply hot steam to infested furniture.

4. Dispose of heavily infested items.
5. Other methods available to professionals: Place items in heat chambers designed for controlling bed bugs.

3. Monitoring

1. Visually inspect bed and sofa.
2. Place interceptors under bed and sofa legs. Interceptors should be checked every 1-2 weeks.
3. If you cannot find bed bugs but are still concerned about their presence, you may set up a home-made monitor to detect low numbers of bed bugs.

Insecticide Treatments

1. **Diatomaceous Earth (DE)**: DE is a natural, white powder-like substance that kills insects. When used properly, bed bugs will have to crawl through DE around your home. Use only DE labeled for insects and follow the directions.
2. Apply DE to cracks and crevices in walls, bed frames, spaces around the bed, behind wall plates and along junction of wall and floor.
3. Wear a mask to apply DE.
4. Apply DE dust to new harborages found during follow-up inspections.
5. DE may take one to two weeks to kill bed bugs and two months to eliminate an infestation. Be patient.

11.4 INSECT BORNE DISEASES

11.4.1 TYPHUS:

Typhus is a disease caused by infection with one or more rickettsia bacteria. Fleas, mites (chiggers), lice, or ticks transmit it when they bite you. Fleas, mites, lice, and ticks are types of invertebrate animals known as arthropods. When arthropods carrying around rickettsia bacteria bite someone, they transmit the bacteria that cause typhus. Scratching the bite further opens the skin and allows the bacteria greater access to the bloodstream. Once in the bloodstream, the bacteria continue to reproduce and grow.

There are three different types of typhus:

- epidemic (louse-borne) typhus
- endemic (murine) typhus
- scrub typhus

The type of typhus with one is infected with depends on what bites. Arthropods are typically carriers of a typhus strain unique to their species.

Typhus outbreaks usually only occur in developing countries or in regions of poverty, poor sanitation, and close human contact. Typhus is generally not a problem in the United States, but one may become infected while traveling abroad.

Untreated typhus can lead to serious complications, and it’s potentially fatal. It’s important to see doctor if anyone suspect that they may have typhus.

Cause of typhus

Typhus is not transmitted from person to person like a cold or the flu. There are three different types of typhus, and each type is caused by a different type of bacterium and transmitted by a different type of arthropod.

Epidemic/louse-borne typhus

This type is caused by *Rickettsia prowazekii* and carried by the body louse, and possibly by ticks as well. It can be found around the world, including in the United States, but is typically found in areas of high population and poor sanitation, where conditions promote lice infestation.

Endemic typhus

Alternatively known as murine typhus, this type is caused by *Rickettsia typhi* and is carried by the rat flea or cat flea. Endemic typhus can be found worldwide. It may be found among people in close contact with rats. It isn’t commonly found in the United States, but cases have been reported in some areas, primarily Texas and southern California.

Symptoms and treatments

Scrub typhus

This type is caused by *Orientia tsutsugamushi* and carried by mites in their larval stage when they are chiggers. This type of typhus is more commonly found in Asia, Australia, Papua New Guinea, and the Pacific Islands. It's also called tsutsugamushi disease.

The louse, flea, tick, or mite becomes a carrier of the bacteria when they feed on the blood of an infected person (epidemic typhus) or an infected rodent (any of the three typhus forms mentioned above).

If you come in contact with these bacterium-carrying arthropods (for example, by sleeping on bed sheets infested with lice), you can become infected in a couple ways. The bacteria, in addition to being transmitted through your skin by their bites, can also be transmitted through their feces. If you scratch the skin over an area where lice or mites have been feeding, the bacteria in their feces can enter your bloodstream through the tiny wounds on your skin.

Symptoms of typhus

Symptoms vary slightly by the type of typhus, but there are symptoms that are associated with all three types of typhus, such as:

- headache
- fever
- chills
- rash

Symptoms of epidemic typhus usually appear suddenly and include:

- severe headache
- high fever (above 102.2°F)
- rash that begins on the back or chest and spreads
- confusion

- stupor and seeming out of touch with reality
- low blood pressure (hypotension)
- eye sensitivity to bright lights
- severe muscle pain

The symptoms of endemic typhus last for 10 to 12 days and are very similar to the symptoms of epidemic typhus but are usually less severe. They include:

- dry cough
- nausea and vomiting
- diarrhea

Symptoms seen in people with scrub typhus include:

- swollen lymph nodes
- tiredness
- red lesion or sore on the skin at the site of the bite
- cough
- rash

Treatment for typhus

Antibiotics most commonly used to treat typhus include:

- Doxycycline (Doryx, Vibramycin): the preferred treatment
- Chloramphenicol: an option for those not pregnant or breastfeeding
- Ciprofloxacin (Cipro): used for adults who are unable to take doxycycline.

11.4.2 YELLOW FEVER

Yellow fever is a viral infection spread by a particular type of mosquito. The infection is most common in areas of Africa and South America, affecting travelers to and residents of those areas. In mild cases, yellow fever causes a fever, headache, nausea and vomiting. But yellow fever can become more serious, causing heart, liver and kidney problems along with bleeding. Up to 50%

of people with the more-severe form of yellow fever die of the disease. There's no specific treatment for yellow fever. But getting a yellow fever vaccine before traveling to an area in which the virus is known to exist can protect you from the disease.

Symptoms

During the first three to six days after you've developed yellow fever — the incubation period — you won't experience any signs or symptoms. After this, the infection enters an acute phase and then, in some cases, a toxic phase that can be life-threatening.

Acute phase

Once the infection enters the acute phase, you may experience signs and symptoms including:

- Fever
- Headache
- Muscle aches, particularly in your back and knees
- Sensitivity to light
- Nausea, vomiting or both
- Loss of appetite
- Dizziness
- Red eyes, face or tongue

These signs and symptoms usually improve and are gone within several days.

Toxic phase

Although signs and symptoms may disappear for a day or two following the acute phase, some people with acute yellow fever then enter a toxic phase. During the toxic phase, acute signs and symptoms return and more-severe and life-threatening ones also appear. These can include:

- Yellowing of your skin and the whites of your eyes (jaundice)

- Abdominal pain and vomiting, sometimes of blood
- Decreased urination
- Bleeding from your nose, mouth and eyes
- Slow heart rate
- Liver and kidney failure
- Brain dysfunction, including delirium, seizures and coma

The toxic phase of yellow fever can be fatal.

Causes

Yellow fever is caused by a virus that is spread by the *Aedes aegypti* mosquito. These mosquitoes thrive in and near human habitations where they breed in even the cleanest water. Most cases of yellow fever occur in sub-Saharan Africa and tropical South America.

Humans and monkeys are most commonly infected with the yellow fever virus. Mosquitoes transmit the virus back and forth between monkeys, humans or both.

When a mosquito bites a human or a monkey infected with yellow fever, the virus enters the mosquito's bloodstream and circulates before settling in the salivary glands. When the infected mosquito bites another monkey or human, the virus then enters the host's bloodstream, where it may cause illness.

Prevention

Vaccine

A highly effective vaccine exists to prevent yellow fever. Yellow fever is known to be present in sub-Saharan Africa and parts of South America. If you live in one of these areas, talk to your doctor about whether you need the yellow fever vaccine. If you plan to travel in these areas, talk with your doctor at least 10 days, but preferably three to four weeks, before your trip begins. Some countries require travelers to present a valid certificate of immunization upon entry.

A single dose of the yellow fever vaccine provides protection for at least 10 years. Side effects are usually mild, lasting five to 10 days, and may include headaches, low-grade fevers, muscle pain, fatigue and soreness at the site of injection. More-significant reactions — such as developing a syndrome similar to actual yellow fever, inflammation of the brain or death — can occur, most often in infants and older adults. The vaccine is considered safest for those between the ages of 9 months and 60 years.

Talk to your doctor about whether the yellow fever vaccine is appropriate if your child is younger than 9 months, if you have a weakened immune system, are pregnant or if you're older than 60 years.

Mosquito protection

In addition to getting the vaccine, you can help protect yourself against yellow fever by protecting yourself against mosquitoes.

To reduce your exposure to mosquitoes:

- Avoid unnecessary outdoor activity when mosquitoes are most active.
- Wear long-sleeved shirts and long pants when you go into mosquito-infested areas.
- Stay in air-conditioned or well-screened housing.
- If your accommodations don't have good window screens or air-conditioning, use bed nets. Nets that have been pre-treated with insecticide offer additional protection.

11.4.3 DENGUE FEVER

Dengue fever is a disease caused by four dengue viruses spread by the *Aedes aegypti* mosquito.

Once you contract one of the dengue viruses, you develop immunity to that virus for the rest of your life. However, you can still contract the other three viruses, so it’s possible to get all four dengue viruses in your lifetime. The viruses that cause dengue fever are related to those that cause yellow fever and West Nile virus infection.

The Center for Disease Control and Prevention (CDC) estimates that at least 400 million cases Trusted Source of dengue fever occur across the globe every year. Tropical regions are heavily affected. Areas that have the greatest risk of infection include Trusted Source:

- Sub-Saharan Africa
- Central America
- Mexico
- the Caribbean
- Pacific Islands
- India
- South America
- Southeast Asia
- Southern China
- Taiwan
- northern parts of Australia

Very few cases occur in the United States. Most diagnosed cases occur in people who contracted the virus while traveling abroad. However, risk of infection is increasing for residents of Hawaii, Florida, and in Texas near the Mexican border.

Dengue fever is transmitted via the bite of a mosquito harboring the dengue virus. Person-to-person transmission doesn't occur. However, a pregnant person with dengue can Trusted Source pass the disease to their child.

Dengue fever symptoms

If you develop dengue fever, symptoms usually begin about 4 to 10 days Trusted Source after the initial infection. In many cases, symptoms will be mild. They may be mistaken for symptoms of the flu or another infection.

Young children and people who've never experienced infection may have a milder illness than older children and adults. Common symptoms generally last for 2 to 7 days and can include Trusted Source:

- sudden, high fever (up to 106°F or 41°C)
- severe headache
- swollen lymph glands
- severe joint and muscle pains
- skin rash (appearing between 2 and 5 days after the initial fever)

Symptoms of severe dengue can include:

- belly pain and tenderness
- mild to severe vomiting (three times in 24 hours)
- mild bleeding from the nose or gums
- vomiting blood or blood in stool
- fatigue, restlessness, or irritability

Diagnosing dengue fever

Doctors use blood tests to check for antibodies the dengue viruses or the presence of infection. A doctor may use a virological test or a serological test.

Virological test

This test directly tests for elements of the virus. This type of testing often requires specialized equipment and a staff that's technically trained, so this type of testing may not be available in all medical facilities.

Serological test

This test detects antibodies in the blood to confirm a current or recent infection.

If you experience dengue symptoms after traveling outside the country, you should see a healthcare professional to check whether you have the virus.

Treating dengue fever

There's no medication Trusted Source or treatment specifically made for dengue infection.

If you believe you may have dengue, you should use over-the-counter pain relievers to reduce your fever, headache, and joint pain. However, you should avoid aspirin and ibuprofen, as they can cause more bleeding.

Your doctor will perform a medical exam, and you should rest and drink plenty of fluids. If you feel worse after the first 24 hours of illness — once your fever has gone down — you should be taken to the hospital as soon as possible to check for complications.

Complications of dengue fever

A small percentage of people who have dengue fever can develop a more serious form of disease known as dengue hemorrhagic fever Trusted Source.

Dengue hemorrhagic fever

The risk factors for developing dengue hemorrhagic fever includes having antibodies Trusted Source to dengue virus from a previous infection and a weakened Trusted Source immune system.

This rare form of the disease is characterized by:

- high fever
- damage to the lymphatic system
- damage to blood vessels
- bleeding from the nose
- bleeding under the skin
- internal bleeding
- bleeding from the gums
- liver enlargement
- circulatory system failure

The symptoms of dengue hemorrhagic fever can trigger dengue shock syndrome, which is also characterized by Trusted Source

Centers for Disease Control and Prevention (CDC)

- Governmental authority

Go to source

low blood pressure, weak pulse, cold, clammy skin, and restlessness. Dengue shock syndrome is severe and can lead to excessive bleeding and even death.

How to prevent dengue fever

There's now a new dengue vaccine Trusted Source called Dengvaxia that was approved by the Food and Drug Administration (FDA) in 2019. It's available in some countries and requires three doses spread 6 months apart.

The best method of protection is to avoid mosquito bites and to reduce the mosquito population. When in a high risk area, do the following:

- Avoid heavily populated residential areas.
- Use mosquito repellent indoors and outdoors.
- Wear long-sleeved shirts and pants tucked into socks.
- Use air conditioning instead of opening windows.
- Ensure that window and door screens are secure and that any holes are repaired.
- Use mosquito nets if sleeping areas aren't screened.

Reducing the mosquito population involves getting rid of mosquito breeding areas. These areas include any place where still water can collect, such as:

- birdbaths
- pet dishes
- empty planters
- flower pots
- cans

- any empty vessel

These areas should be checked, emptied, or changed regularly.

11.4.4 SLEEPING SICKNESS

Sleeping sickness is a tropical disease that can prove fatal if not treated properly. It spreads through the bite of the Tsetse fly, a species that is native to the African continent. The people living in the rural parts of Africa are more at risk of contracting this disease.

The fly bite develops into a red sore and the person soon experiences fever, muscle and joint ache, swelling in the lymph glands, irritation and headache.

In advanced stages, the disease attacks the central nervous system and people experience changes in personality, alteration in the biological clock, difficulty in walking and talking, seizures, and difficulty in speaking. It these problems are not treated for a longer period of time, the person dies.

Sleeping Sickness Causes

The two parasites named *Trypanosoma bruceigambiense* and *Trypanosoma brucierhodesiense* cause this disease. These parasites are present in the flies like the Tsetse fly that is mainly involved in transmitting the disease. When this fly bites the humans, the infection spreads throughout the body through the blood.

These parasites can also transfer the placenta and can be transmitted through the mother to the child.

Contaminated needles are also responsible for spreading the disease.

Symptoms of Sleeping Sickness

A lot of changes occur in the body after the infection. Few symptoms of sleeping sickness are listed below:

- An unclear speech.
- Seizures.
- Irritation.
- Swelling of the brain.
- Swelling of the lymph nodes.
- Causes weakness in the body.
- Feeling of sleeplessness.
- Severe sweating.
- Formation of red sores on places of infection.
- Severe fever conditions.
- Mood changes.
- Skin Rashes.
- Severe headaches.
- Develop severe pain in the joint.
- Personality changes.
- Feel difficulty in walking and etc.
-

Sleeping Sickness Prevention

Early recognition of the disease might help to avoid the difficulty and major risks. Some of the prevention and treatment measures include:

- Early treatment of the infected persons, including the person showing no symptoms.
- Using insecticides to protect oneself against the bite of Tsetse fly.
- By maintaining clearings around the villages and also residential areas.
- Use of repellents or fly traps to stay away from the flies.

11.4.5 ENCEPHALITIS

Encephalitis (en-self-uh-LIE-tis) is inflammation of the brain. There are several causes, including viral infection, autoimmune inflammation, bacterial infection, insect bites and others. Sometimes there is no known cause.

Encephalitis may cause only mild flu-like signs and symptoms — such as a fever or headache — or no symptoms at all. Sometimes the flu-like symptoms are more severe. Encephalitis can also cause severe symptoms including confusion, seizures, or problems with movement or with senses such as sight or hearing.

In some cases, encephalitis can be life-threatening. Prompt diagnosis and treatment are important because it's difficult to predict how encephalitis will affect each individual.

Symptoms

Most people with viral encephalitis have mild flu-like symptoms, such as:

- Headache
- Stiff neck
- Fever
- Aches in muscles or joints
- Fatigue or weakness

Sometimes the signs and symptoms are more severe, and might include:

- Confusion, agitation or hallucinations
- Seizures
- Loss of sensation or being unable to move certain areas of the face or body
- Muscle weakness
- Problems with speech or hearing
- Loss of consciousness (including coma)

In infants and young children, signs and symptoms might also include:

- Bulging in the soft spots (fontanels) of an infant's skull
- Nausea and vomiting
- Body stiffness
- Poor feeding or not waking for a feeding
- Irritability

Causes

The exact cause of encephalitis is often unknown. Autoimmune inflammation, viral and bacterial infections, and noninfectious inflammatory conditions all can cause encephalitis.

There are two main types of encephalitis:

- Primary encephalitis. This condition occurs when a virus or other agent directly infects the brain. The infection may be concentrated in one area or widespread. A primary infection may be a reactivation of a virus that had been inactive after a previous illness.
- Secondary encephalitis. This condition results from a faulty immune system reaction to an infection elsewhere in the body. Instead of attacking only the cells causing the infection, the immune system mistakenly attacks healthy cells in the brain. Also known as post-infection encephalitis, secondary encephalitis often occurs 2 to 3 weeks after the initial infection.

Common viral causes

The viruses that can cause encephalitis include:

- Herpes simplex virus (HSV). Both HSV type 1 — associated with cold sores and fever blisters around your mouth — and HSV type 2 — associated with genital herpes — can cause encephalitis. Encephalitis caused by HSV type 1 is rare but can result in significant brain damage or death.

- Other herpes viruses. These include the Epstein-Barr virus, which commonly causes infectious mononucleosis, and the varicella-zoster virus, which commonly causes chickenpox and shingles.
- Enteroviruses. These viruses include the poliovirus and the coxsackievirus, which usually cause an illness with flu-like symptoms, eye inflammation and abdominal pain.
- Mosquito-borne viruses. These viruses can cause infections such as West Nile, La Crosse, St. Louis, western equine and eastern equine encephalitis. Symptoms of an infection might appear within a few days to a couple of weeks after exposure to a mosquito-borne virus.
- Tick-borne viruses. The Powassan virus is carried by ticks and causes encephalitis in the Midwestern United States. Symptoms usually appear about a week after a bite from an infected tick.
- Rabies virus. Infection with the rabies virus, which is usually transmitted by a bite from an infected animal, causes a rapid progression to encephalitis once symptoms begin. Rabies is a rare cause of encephalitis in the United States.
- Childhood infections. Common childhood infections — such as measles (rubeola), mumps and German measles (rubella) — used to be fairly common causes of secondary encephalitis. These causes are now rare in the United States due to the availability of vaccinations for these diseases.

Risk factors

Anyone can develop encephalitis. Factors that may increase the risk include:

- Age. Some types of encephalitis are more common or more severe in certain age groups. In general, young children and older adults are at greater risk of most types of viral encephalitis.
- Weakened immune system. People who have HIV/AIDS, take immune-suppressing drugs or have another condition causing a weakened immune system are at increased risk of encephalitis.
- Geographical regions. Mosquito- or tick-borne viruses are common in particular geographical regions.

- Season of the year. Mosquito- and tick-borne diseases tend to be more common in summer in many areas of the United States.

Complications

The complications of encephalitis vary, depending on factors such as:

- Your age
- The cause of your infection
- The severity of your initial illness
- The time from disease onset to treatment

People with relatively mild illness usually recover within a few weeks with no long-term complications.

Complications of severe illness

Inflammation can injure the brain, possibly resulting in a coma or death.

Other complications may last for months or be permanent. These complications can vary widely in severity and can include:

- Persistent fatigue
- Weakness or lack of muscle coordination
- Personality changes
- Memory problems
- Paralysis
- Hearing or vision defects
- Speech impairments

Prevention

The best way to prevent viral encephalitis is to take precautions to avoid exposure to viruses that can cause the disease. Try to:

- Practice good hygiene. Wash hands frequently and thoroughly with soap and water, particularly after using the toilet and before and after meals.
- Don't share utensils. Don't share tableware and beverages.
- Teach your children good habits. Make sure they practice good hygiene and avoid sharing utensils at home and school.
- Get vaccinations. Keep your own and your children's vaccinations current. Before traveling, talk to your doctor about recommended vaccinations for different destinations.

Protection against mosquitoes and ticks

To minimize your exposure to mosquitoes and ticks:

- Dress to protect yourself. Wear long-sleeved shirts and long pants if you're outside between dusk and dawn when mosquitoes are most active, and when you're in a wooded area with tall grasses and shrubs where ticks are more common.
- Apply mosquito repellent. Chemicals such as DEET can be applied to both the skin and clothes. To apply repellent to your face, spray it on your hands and then wipe it on your face. If you're using both sunscreen and a repellent, apply sunscreen first.
- Use insecticide. The Environmental Protection Agency recommends the use of products containing permethrin, which repels and kills ticks and mosquitoes. These products can be sprayed on clothing, tents and other outdoor gear. Permethrin shouldn't be applied to the skin.
- Avoid mosquitoes. Refrain from unnecessary activity in places where mosquitoes are most common. If possible, avoid being outdoors from dusk till dawn, when mosquitoes are most active. Repair broken windows and screens.

- Get rid of water sources outside your home. Eliminate standing water in your yard, where mosquitoes can lay their eggs. Common problems include flowerpots or other gardening containers, flat roofs, old tires and clogged gutters.
- Look for outdoor signs of viral disease. If you notice sick or dying birds or animals, report your observations to your local health department.

Protection for young children

Insect repellents aren't recommended for use on infants younger than 2 months of age. Instead, cover an infant carrier or stroller with mosquito netting.

For older infants and children, repellents with 10% to 30% DEET are considered safe. Products containing both DEET and sunscreen aren't recommended for children because reapplication — which might be necessary for the sunscreen component — will expose the child to too much DEET.

Tips for using mosquito repellent with children include:

- Always assist children with the use of mosquito repellent.
- Spray on clothing and exposed skin.
- Apply the repellent when outdoors to lessen the risk of inhaling the repellent.
- Spray repellent on your hands and then apply it to your child's face. Take care around the eyes and ears.
- Don't use repellent on the hands of young children who may put their hands in their mouths.
- Wash treated skin with soap and water when you come indoors.

11.4.6 LEISHMANIASIS

Leishmaniasis is caused by a protozoa parasite from over 20 Leishmania species. Over 90 sandfly species are known to transmit Leishmania parasites. There are 3 main forms of the disease:

- Visceral leishmaniasis (VL), also known as kala-azar is fatal if left untreated in over 95% of cases. It is characterized by irregular bouts of fever, weight loss, enlargement of the spleen and liver, and anemia. Most cases occur in Brazil, East Africa and in India. An estimated 50 000 to 90 000 new cases of VL occur worldwide annually, with only between 25 to 45% reported to WHO. It remains one of the top parasitic diseases with outbreak and mortality potential. In 2020, more than 90% of new cases reported to WHO occurred in 10 countries: Brazil, China, Ethiopia, Eritrea, India, Kenya, Somalia, South Sudan, Sudan and Yemen.
- Cutaneous leishmaniasis (CL) is the most common form of leishmaniasis and causes skin lesions, mainly ulcers, on exposed parts of the body, leaving life-long scars and serious disability or stigma. About 95% of CL cases occur in the Americas, the Mediterranean basin, the Middle East and Central Asia. In 2020 over 85% of new CL cases occurred in 10 countries: Afghanistan, Algeria, Brazil, Colombia, Iraq, Libya, Pakistan, Peru, the Syrian Arab Republic and Tunisia. It is estimated that between 600 000 to 1 million new cases occur worldwide annually.
- Mucocutaneous leishmaniasis leads to partial or total destruction of mucous membranes of the nose, mouth and throat. Over 90% of mucocutaneous leishmaniasis cases occur in Bolivia (the Pluractional State of), Brazil, Ethiopia and Peru.

Transmission

Leishmania parasites are transmitted through the bites of infected female phlebotomine sandflies, which feed on blood to produce eggs. The epidemiology of leishmaniasis depends on the characteristics of the parasite and sandfly species, the local ecological characteristics of the transmission sites, current and past exposure of the human population to the parasite, and human behavior. Some 70 animal species, including humans, have been found as natural reservoir hosts of Leishmania parasites

Major risk factors

Socioeconomic conditions

Poverty increases the risk for leishmaniasis. Poor housing and domestic sanitary conditions (such as a lack of waste management or open sewerage) may increase sandfly breeding and resting sites, as well as their access to humans. Sandflies are attracted to crowded housing as these provide a good source of blood-meals. Human behavior, such as sleeping outside or on the ground, may increase risk.

Malnutrition

Diets lacking protein-energy, iron, vitamin A and zinc increase the risk that an infection will progress to a full-blown disease.

Population mobility

Epidemics of both cutaneous and visceral leishmaniasis are often associated with migration and the movement of non-immune people into areas with existing transmission cycles. Occupational exposure as well as widespread deforestation remains important factors.

Environmental changes

The incidence of leishmaniasis can be affected by changes in urbanization, and the human incursion into forested areas.

Climate change

Leishmaniasis is climate-sensitive as it affects the epidemiology in several ways:

- changes in temperature, rainfall and humidity can have strong effects on vectors and reservoir hosts by altering their distribution and influencing their survival and population sizes;
- small fluctuations in temperature can have a profound effect on the developmental cycle of Leishmania promastigotes in sandflies, allowing transmission of the parasite in areas not previously endemic for the disease;
- drought, famine and flood can lead to massive displacement and migration of people to areas with transmission of Leishmania, and poor nutrition could compromise their immunity.

Diagnosis and treatment

In visceral leishmaniasis, diagnosis is made by combining clinical signs with parasitological, or serological tests (such as rapid diagnostic tests). In cutaneous and mucocutaneous leishmaniasis serological tests have limited value and clinical manifestation with parasitological tests confirms the diagnosis.

The treatment of leishmaniasis depends on several factors including type of disease, concomitant pathologies, parasite species and geographic location. Leishmaniasis is a treatable and curable disease, which requires an immune competent system because medicines will not get rid of the parasite from the body, thus the risk of relapse if immune suppression occurs. All patients diagnosed as with visceral leishmaniasis require prompt and complete treatment. Detailed information on treatment of the various forms of the disease by geographic location is available in the WHO technical report series 949, "Control of leishmaniasis".

Prevention and control

Prevention and control of leishmaniasis requires a combination of intervention strategies because transmission occurs in a complex biological system involving the human or animal reservoir host, parasite and sandfly vector. Key strategies for prevention are listed below:

- Early diagnosis and effective prompt treatment reduces the prevalence of the disease and prevents disabilities and death. It helps to reduce transmission and to monitor the spread and burden of disease. Currently there are highly effective and safe anti-leishmanial medicines particularly for visceral leishmaniasis, although they can be difficult to use. Access to medicines has significantly improved thanks to a WHO-negotiated price scheme and a medicine donation programme through WHO.
- Vector control helps to reduce or interrupt transmission of disease by decreasing the number of sandflies. Control methods include insecticide spray, use of insecticide–treated nets, environmental management and personal protection.
- Effective disease surveillance is important to promptly monitor and act during epidemics and situations with high case fatality rates under treatment.
- Control of animal reservoir hosts is complex and should be tailored to the local situation.
- Social mobilization and strengthening partnerships – mobilization and education of the community with effective behavioral change interventions must always be locally adapted.

Partnership and collaboration with various stakeholders and other vector-borne disease control programmers is critical.

11.5 VENOMS AND ALLERGENS

Insect Venom Allergy

During the spring and summer months, allergy sufferers are not the only ones wary of bees, wasps and other insects. These belong to the Hymenoptera order of insects, and their stings cause painful swelling and itching in non-allergic individuals. However, the proteins in the venom also activate the immune system in allergic individuals.

Allergic reactions are most frequently triggered by the stings of colony-building hymenopterans. They include **bees, bumblebees, wasps, hornets and ants**. In **Europe**, the **Vespula** genus is responsible for a large part of the allergic reactions. Unlike the wasps of the *Dolichovespula* genus, Vespula wasps are carnivores. As a result, they often come into contact with human populations – for example, people eating outdoors. In the **US and South and Central America, fire ants** are the cause of many of the reactions. European wood and garden ants only have a very small stinger, which is why their stings seldom lead to allergic reactions.

Prevalence

Insect stings can trigger **local allergic reactions** around the puncture site or reactions with symptoms that appear entirely elsewhere in the body, such as respiratory or circulatory problems. Doctors refer to this as a generalized or **systemic reaction**. **Researchers believe that 0.3 to 7.5% of the European population suffers from systemic allergic reactions to insect stings**, depending on the region and occupation. Since the risk increases with the frequency of the stings, beekeepers are among those most often affected. According to data from the Anaphylaxis Registry, insect stings are one of the main triggers of anaphylactic shock in adults. Experts assume a prevalence of between 0.8 and 5% in Germany for systemic reactions. There are currently no precise figures for local reactions. Research has shown that local reactions occur more frequently than generalized reactions.

Insect Venom Allergy in Childhood and Adulthood

There are no precise figures on the prevalence in childhood. However, we do know that children under twelve have a lower risk than adults of recurring generalized reactions. Adults 40 years of age and over with other conditions such as cardiovascular disease or asthma have an increased risk of experiencing severe allergic reactions to insect stings. Patients who have already had a severe reaction to insect stings should speak to their doctor about the possibility of immunotherapy.

Triggers

Allergic reactions to insect venoms are triggered by **proteins** in the venom. **Twelve bee venom allergens, six wasp venom allergens, two bumblebee venom allergens and two hornet venom allergens have been identified so far**. While bee stings occur mostly in the spring and summer, wasps are active in summer and autumn. Both species are frequently in contact with people – for example, on picnics or in flowering meadows. Hornet and bumblebee stings occur less frequently.

Risk factors for severe allergic reactions to insect venom:

- Increasing age (older than 40 years of age)
- Cardiovascular disease
- Allergic asthma
- Masto cytosis (a disease in which the body produces too many mast cells)
- A severe allergic reaction to an insect sting in the past

Symptoms

Insect stings can trigger the following reactions:

- Normal local reactions with no allergic immune response, with swelling to less than 10 cm in diameter. This swelling usually subsides within a few hours, while the itching at the puncture site can continue for several days

- Severe local allergic reactions with swelling to less than 10 cm in diameter. These reactions last longer than 24 hours, in some cases up to a week

- Severe systemic allergic reactions with nausea, vomiting, diarrhoea and, in rare cases, circulatory collapse

Non-allergic individuals can also experience severe reactions if they are stung by 50 to 100 insects at once (10 to 50 in children). With this many stings, a dangerous amount of venom enters the body, which can cause damage to the kidneys and liver. Stings in the facial area – the lips, for example – are more dangerous than stings on the legs or arms.

Diagnostic Procedure

Diagnosis begins with a **discussion** during which the doctor asks the patient about the exact circumstances of the sting, any hereditary predisposition to allergies, and details about the reaction. It is important for the next phase of therapy to determine which insect triggered the allergic reaction and how high the risk is of (additional) severe reactions. The doctor therefore performs a **skin and/or blood test** in order to confirm whether the patient has been sensitized, i.e. whether he or she has developed specific antibodies following a previous sting. The results of these tests do not provide evidence of an allergy, but they reveal important information about allergic events in the body.

In **patients with a high risk of anaphylaxis, skin tests are usually performed in hospital** in order to minimize the risk of severe reactions to the test. A **sting challenge test**– the specific provocation of an insect sting – is only conducted on patients who have already successfully completed immunotherapy (for at least three to five years). It is carried out under strictly controlled conditions and only under medical supervision.

Therapy

Specific immunotherapy (**SIT**) is available for patients with a severe insect venom allergy. Immunotherapy treats not only the symptoms but also the actual cause of the allergy. If the immune system is stimulated with the insect venom allergen for a period of at least three to five years, 95% of people with a wasp venom allergy do not experience any reaction or only a very weak reaction when stung again. For people with a bee venom allergy, 80% of those treated have full protection; the remaining 20% generally have milder reactions than before. This protection does not last a lifetime in all patients. People at very high risk should therefore consider lifelong immunotherapy.

People at high risk of anaphylaxis must always carry an **emergency kit** with them containing an adrenaline auto-injector, a corticosteroid (in liquid or tablet form) and an antihistamine (in liquid or tablet form).

11.6 BLISTER AND URTICA-INDUCING INSECTS

Many insects cause blisters, but many blisters are so tiny that you experience them as just little bumps. However, some insects and spiders produce distinct and often very large blisters. In the United States, the bites of the brown recluse spider, the yellow sac spider and fire ants cause characteristic blisters. Handling of blister beetles also causes eruption of blisters on the skin. The blister-causing bites of these insects and arachnids are not life-threatening except in cases of hypersensitive individuals, who may have a severe allergic reaction to the venom or toxin.

Brown Recluse Spider

The brown recluse spider, native to the United States, is found in Midwestern and Southern states. You can identify the spider by the dark violin marking on its back. It is less than one half inch long. The spider likes to hang out in undisturbed dark indoor and outdoor places. It is not aggressive, but will bite if disturbed. When you get bitten, you may not feel the bite, but after two to eight hours, a small blister appears, surrounded by a red swollen area. **The swollen area**

may become bluish-grey and enlarge to almost 3 inches. The bite from a brown recluse spider may take a long time to heal 1.

- The brown recluse spider, native to the United States, is found in Midwestern and Southern states.
- You can identify the spider by the dark violin marking on its back.

Yellow Sac Spider

Yellow sac spiders live outside and inside homes. They account for most spider bites, but bites are often misdiagnosed by health care providers as brown recluse spider bites, according to the Michigan State University Extension 1. They are small spiders, 1/8 to 3/8 inches long with a light yellow or beige body. The spiders usually hide by day and come out at night.

They bite when they become trapped between human skin and clothing or bed sheets. People often get bitten while gardening. The bite is usually painful; a blister will develop one to 10 hours later. The blister and redness is generally less severe than that produced by the brown recluse spider.

- Yellow sac spiders live outside and inside homes.
- The spiders usually hide by day and come out at night.

Fire Ants

Fire ants are 1/8 to 1/4-inch long and reddish-brown. They originated in South America, but now have spread and are prevalent in the southern part of the United States. Fire ants build large mounds in sunny locations in fields and gardens. When coming in contact with people or animals, they will attack, biting the skin repeatedly.

The sting of these ants is very painful and will itch before forming blisters. **Although deaths are rare from fire ant bites, some people are allergic to the fire ant's venom.**

- Fire ants are 1/8 to 1/4-inch long and reddish-brown.
- The sting of these ants is very painful and will itch before forming blisters.

Blister Beetle

Blister beetles range in length from less than half an inch to 1 inch. They have a narrow body, which can be black, grey, metallic or striped. They usually hang out in groups and feed on ornamental plants, vegetables and alfalfa. The bodies of these beetles contain a toxin, cantharidin, which causes blisters on the skin. Wear gloves when handling these beetles or crops containing live or dead beetles. **Horses become very ill and may die when they eat feed contaminated with dead blister beetles.**

- Blister beetles range in length from less than half an inch to 1 inch.
- The bodies of these beetles contain a toxin, cantharidin, which causes blisters on the skin.

11.7ARTHROPODS OF FORENSIC IMPORTANCE

Forensic entomology proceeds on the common observation that exposed remains present a temporary and progressively changing habitat and food source for a wide variety of organisms ranging from microbes like bacteria and fungi to vertebrate scavengers. Out of these, arthropod fauna comprises a major element of the biota and insects form the most constant, diverse and conspicuous group. These six-legged creatures predominate the terrestrial and fresh water carrion fauna (Payne, 1965). He reported 522 species of animals from decomposing pig carcasses out of which 84% were insects. Goff *et al.* (1986) while studying carcass decomposition reported 140 arthropod taxa out of which 83% were insects. These insects are attracted in the first instance, to the body fluids oozing from natural openings and to blood or serum escaping from the wounds.

Cadavers are often fierely contested by great number of insect species. The overwhelming majority are flies and beetles. Dipteran families *Calliphoridae*, *Sarcophagidae, Muscidae***,** Sepsidae, ***Sphaeroceridae*****,** Piophilidae and Phoridae and coleopteran families Histeridae, Staphylinidae, Silphidae, Cleridae, Dermestidae and Tenebrionidae predominate the scene.

These insects form a complex food web within carrion. This web gets more complicated because of the fact that many species have different adult food preferences from that of their larvae.

1. Flies: (Order – Diptera) are often first on the scene. They prefer a moist corpse for their offspring (maggots) to feed on. The most significant types of fly include:

(a) Blow Flies (Family Calliphoridae)- Flies in this family are often metallic in appearance and between ten to 12mm in length. In addition tp the name blow-fly, some members of this family are known as blue bottle fly, cluster fly, greenbottles, or black blowfly. A characteristic of the blow-flies its 3-segmented antennae. Hatching from an egg to the first larval stage takes from eight hours to one day. Larvae have three stages of development (called instars); each stage is separated by a molting event. The forensic importance of this fly is that it is the first insect to come in contact with carrion because they have the ability to smell death from up to ten miles (16 km) away.

(b) Flesh flies (Family Sarcophagidae)- Most flesh flies breed in carrion, dung, or decaying material, but a few species lay their eggs in the open wounds of mammals; hence their common name. Characteristics of the fleshly are its 3-segmented antennae. They are medium-sized flies with black and grey longitudinal stripes on the thorax and checkering on the abdomen. Flesh-flies, being viviparous, frequently give birth to live young on corpses of human and other animals, at any stage of decomposition, from newly dead through to bloated or decaying.

(c) Cheese flies (Family Piophilidae)- Most are scavengers in animal products and fungi. The best-known member of the family is *Piophilacasei*. It is a small fly, about four mm (1/6 inch) long, found world-wide. This fly's larva infests cured meats, smoked fish, chesses, and decaying animals and is sometimes called the cheese skipper for its leaping ability. Forensic entomology uses the presence of *Piophila casei* larvae to help estimate the date of death for human remains. They do not take up residence in a corpse until three to six months after death. The adult fly's body is black, blue-black, or bronze, with some yellow on the head, antennae, and legs. The wings are faintly iridescent and lie flat upon the fly's abdomen when at rest.

(d) Black soldier flies (Stratiomyidae) – They have potential for use in forensic entomology. The larave are common scavengers in compost heaps, are found in association with carrion, can be destructive pests in honey bee hives, and are used in manure management. The adult fly is a mimic, very close in size, color, and appearance to the organ pipe mud dauber wasp and its relatives. Larvae feed on decaying bodies; some species can burrow to a depth of 50 cm over 4 days important in buried bodies.

2. Beetles: Beetles (Order Coleoptera) are generally found on the corpse when it is more decomposed. In drier conditions, the beetles can be replaced by moth flies.

(a) Rove beetles (family Staphylinidae) the rove beetles are elongate beetles with small elytra and large jaws. Like other beetles inhabiting carrion, they have fast larval development with only three larval stages. *Creophilus* species are common predators of carrion, and since they are large, is a very visible component of the fauna of corpses. Some adult Staphylinidae are early visitors to a corpse, feeding on larvae of all species of fly, including the later predatory fly larvae. They lay their eggs in the corpse, and the emerging larvae are also predators.

(b) Hister beetles (family Histeridae) – Adult histerids are usually shiny beetles (black or metallic-green) which have an introverted head. The carrion-feeding species only become active at night when they enter the maggot-infested part of the corpse to capture and devour their maggot prey. During daylight they hide under the corpse unless it is sufficiently decayed to enable them to hide inside it. The adult laid their eggs in the corpse, inhabiting it in the later stages of decay.

(c) Carrion beetles (family Silphidae)- Adult Silphidae have an average size of about 12mm. They are also referred to as burying beetles because they dig and bury small carcasses underground. Both parents tend to their young and exhibit communial breeding. The male carrion beetle’s job in care is to provide protection for the breed and carcases from competitors.

(d) Skin/hide beetles (family Dermestidae) – Hide beetles are important in the final stages of decomposition of a carcass. The adults and larvae feed on the dried skin, tendons and bone left by fly larvae. Hide beetles are the only beetle with the enzymes necessary for breaking down keratin, a protein component of hair.

3. Mites- Many mites feed on corpses with *Macrocheles* mites common in the early stages of decomposition, while Tyroglyphidae and Oribatidae mites such as Rostrozetes feed on dry skin in the later stages of decomposition. *Nicrophorus* beetles often carry on their bodies the mite *Poecilochirus* which feed on fly eggs. If they arrive at the corpse before any fly eggs hatch into maggot development is delayed.

4. Moths (Order Lepidoptera)- Specifically clothes moths Family Tineidae are closely related to butterflies. Most species of moth are nocturnal, but there are crepuscular and diurnal species. Moths feed on mammalian hair during their larval stages and may forage on any hair that remains on a body. They are amongst the final animals contributing to the decomposition of a corpse.

11.8 INSECTS SUCESSION ON CORPSE AND ITS RELTIONSHIP IN DETERMINING TIME OF DEATH

The science of forensic entomology is based on the analysis of those insects which sequentially colonize a corpse as decomposition progresses and on the rate at which the various stages of their progeny develop. This entomological information can be useful during criminal investigations in order to following:

Time of Death: There are two basic approaches to the application of entomological data for estimating the time of death. During earlier stages of decomposition, the time elapsed since death or postmortem interval (PMI) may be determined by calculating the time required for a given species to reach the particular stage of development recovered from the corpse at the time of discovery. The insects involved in this approach are mostly dipterans, especially those belonging to the families Calliphoridae and Sarcophagidae.

There are two main ways of using insects to determine elapsed time since death:-

1. Using successional waves of insects
2. Using maggot age and development.

The first method is based on the fact that a human body, or any kind of carrion, supports a very rapidly changing ecosystem going from the fresh state to dry bones in a matter of weeks or months depending on geographic region. During this decomposition, the remains go through rapid physical, biological and chemical changes, and different stages of the decomposition are attractive to different species of insects. Certain species of insects are often the first witnesses to a crime. They usually arrive within 24 h of death if the season is suitable i.e. spring, summer or fall in Canada and can arrive within minutes in the presence of blood or other body fluids. Many species are involved at each decomposition stage and each group of insects overlaps the ones adjacent to it somewhat. Therefore, with knowledge of the regional insect fauna and times of carrion colonization, the insect assemblage associated with the remains can be analyzed to determine a window of time in which death took place. This method is used when the decedent has been dead from a few weeks up to a year.

This second method, that of using maggot age and development can give a date of death accurate to a day or less, or a range of days, and is used in the first few weeks after death. Maggots are larvae or immature stages of Diptera or two-winged flies. The insects used in this method are those that arrive first on the corpse. These flies are attracted to a corpse very soon after death. They lay their eggs on corpse, usually in a wound.

Mode of Death: A dead body having external injuries is more attractive to insects than one having none. So, depending upon the degree of degradation brought about by maggots, an entomologist may be able to suggest the possible mode of death. Another application is in the cases where death has occurred due to intake of drugs. A chemical analysis of the maggots found on the dead body can reveal the specific drugs, especially helpful when no human tissues are available for sending to the laboratory for other tests.

Place of Death: The deceased may have been killed at a place other than the body is found. With knowledge about the carrion fauna of an area and specific habits of species found on the cadaver, an entomologist can help to determine whether the person died at a place other than where the body has been found. Similarly, route of transport of a dead body may also be traced by using entomological data. There are numerous other special situations where entomologists can help to solve crimes. If a body is found buried is soil, the entomological data can be helpful in determining the period intervening death and burial.

11.9 SUMMARY

Arthropods are one of the most remarkable creatures on the earth. They have an unsurpassed diversity. Entomology, the study of insects includes many fields; one of them is Medical Entomology. It is a field which directly concerns with the impact of arthropods and related insects on the physical as well as mental health of humans. Arthropods affect human health in multiple ways. The most significant role involves as vectors and alternate hosts of many diseases, out of which some can be fatal as well. Insect vectors, venoms, blister causing, allergens, etc, are only a few category of insects, there are many more arthropods that are yet to be identified. The usual fear of insects possessed by people is perhaps the least serious. Proper knowledge is the key to identify and differentiate between the harmful, beneficial and harmless arthropods.

Here, we have studied about the mode and behavior of transmission of various insect pests, their life cycle, importance and preventive measures. On one hand, where the arthropods are so infectious and injurious to human health as well as wildlife, on the other hand, we learnt about their importance in Forensic Sciences and their relationship in determining the time of death.

11.10 TERMINAL QUESTIONS AND ANSWERS

Q1). Define Medical Entomology.

Q2). Explain the different transmission mechanisms exhibited by arthropods.

Q3). Discuss the harmful as well as beneficial impacts of arthropods with example.

Q4). Differentiate some insects on the basis of their mode of causing disease (i.e., venoms, allergens, blister causing, etc.)

Q5). Describe the role of arthropods in Forensic Sciences.

UNIT 12: INSECT PEST CONTROL: NATURAL CONTROL

CONTENTS

12.1 OBJECTIVES

By the end of this unit, the learner will be able to:

1). Understand the preventive measures of various insect pests.

2). Learn about the various practices opted to control the insects pests.

3). Understand the Intercropping system and its role in pest control.

12.2 INTRODUCTION

Pest controls the regulation or management of a species defined as a pest; any animal, plant or fungus those impacts adversely on human activities or environment. The human response depends on the importance of the damage done and will range from tolerance, through deterrence and management, to attempts to completely eradicate the pest. Pest control measures may be performed as part of an integrated pest management strategy.

In agriculture, pests are kept at bay by mechanical, cultural, chemical and biological mean. Ploughing and cultivation of the soil before sowing mitigate the pest burden, and crop rotation helps to reduce the build-up of a certain pest species. Concern about environment means limiting the use of pesticides in favor of other methods. This can be achieved by monitoring the crop, only applying pesticides when necessary, and by growing varieties and crops which are resistant to pests. Where possible, biological means are used, encouraging the natural enemies of the pests and introducing suitable predators or parasites.

In homes and urban environments, the pests are the rodents, birds, insects and other organisms that share the habitat with humans and that feed on and/or spoil possessions. Control of these pests is attempted through exclusion or quarantine, repulsion, physical removal or chemical means. Alternatively, various methods of biological control can be used including sterilization programmers.

Physical and Mechanical Control:

The protection of crops and foods from insect attack by physical and mechanical means is the simplest and most effective method. Such measures consist of destruction of insects by mechanical means, burning, trapping, protective screens or barriers, use of high or low temperature, soaking in water and drying.

1. Hand Picking:

When only a few plants are infected, certain large conspicuous species may be removed from the plants by hand and destroyed just by pressing the abdomen or dipping them in kerosenized water.

2. Mechanical Means:

A rotary blow has been found to destroy over 96% of white grubs as well as cut worms, army worms and other caterpillars. The cutting wheel is thirty two inches in diameter and fourteen inches wide and carries sixteen steel blades. It operates by power take off from a tractor at 150 rpm.

3. Trapping:

The insects may be turned into a tray by light and baits or the trap may be mobile and drawn across a field.

4. Light Traps:

The attraction of nocturnal insects to light is a common observation and the light traps have been invented and tested for killing crop pests. The attractiveness of an artificial light depends upon its candle power and color. A yellow light will attract 60% fewer insects than a white light of the same candle power and brightness. The insects attracted by light may be destroyed as they hit electric grid or they may be drowned in water and oil after they have been turned into the trap.

5. Bait Traps:

Baits are a form of control whereby insects are attracted to a selected spot on which they can be easily removed. Bait traps have been found to be very effective in controlling the nocturnal insects like cockroaches, crickets, caterpillars and nocturnal moths.

APPLIED CONTROL:

Biological Control:

The term biological control means control of insects by several biological agencies such as parasites, predators and pathogens. The introduction of sterile males in a normal population and use of sex attractants have been reported to bring about effective biological control. De Bach (1964, 1974), Reay (1969), Huffaker (1974), etc. have given exhaustive account on Biological control-

The theoretical basis of the biological control defends on the existence of a natural enemy.

The most essential characteristic is high searching ability. It should be borne in mind that a really effective enemy may be scarce in its native home because it regulates the host population at low level. There usually is one best enemy for each species in a given habitat and one frequently is sufficient for complete biological control, often, however, a second or third enemy species may add to host population regulation and may in fact be necessary to achieve satisfactory biological control.

The best enemy species may differ for different host habitats. Hence there is generally no single best natural enemy extending throughout the range of a pest species. With these qualities the introduced natural enemy by itself or in conjunction with other mortality factors is expected to prevent outbreak of the pest species or at least to drop down major population fluctuations.

The essential principle of biological control is to maintain a state of biological equilibrium of a living organism. This biological equilibrium is normally maintained by a set of forces called environmental resistance.

Often the biological equilibrium of a living organism is disturbed either due to environmental or biotic factors and consequently a particular organism multiplies and spreads in a unlimited manner so as to assume the status of a pest. The inherent ability of an organism to survive and to reproduce within a given time and under optimal environmental conditions is known as biotic potential.

Types of Biological Control:

There are 4 main types of biological control viz.:

(i) Introduction of parasites,

(ii) Predators,

(iii) Pathogenic organisms such as bacteria, viruses and fungi etc. and

(iv) Removal of fertile males and creating sterility in males by gamma radiation and introducing these sterile males in a normal population. In addition to these 4 main types, there is a fifth type of biological control where the indigenous parasite of the locality is being utilized for this purpose.

1. Parasites:

Parasitic insects develop as larvae on or in a single host individual from eggs generally laid on, in or near the host and usually consume all or most of the host body, killing the host and then pupate, either within or outside the host. The free living adult parasite emerges from the pupa and starts the next generation a new by actively searching for host in which to ovipositor.

They tend to attack only one host stage i.e. eggs, larvae, or pupae, although there is also some overlapping in certain cases, adult insects do not serve as hosts. Very often life cycles are commonly short, ranging from 10 days to 2 weeks or so in mid-summer but correspondingly longer in cold weather. In general, they all have great potential rates of increase.

Hymenoptera:

This is the dominant order among all entomophagous insects. Over two thirds of the cases of successful biological control of pest's species have been achieved by hymenopterous parasites. The most important and numerous hymenopterous parasites occur in the major groups commonly known as chalcids, braconids, ichneumonids and proctotrupeds.

(I) The Chalcids:

The chalcids attack species in nearly all orders of insects, the preferred ones being Coleoptera, Diptera, Homoptera and Lepidoptera which also happen to include the bulk of our chief crop pests. The immature stages of chalcids predominantly develop in host's eggs or larvae or pupae and some develop in adults of Homoptera. The encyrtids and aphelinids include many that specialize in attacking scale insects, mealy bugs, white flies, and related forms and have been so outstandingly successful in biological control.

(ii) The Braconids:

This is a major large family of parasitic wasps. They have been used in biological control. Only an occasional rare species is hyperparasitic hence the family is nearly entirely beneficial. Parasitism may be external or internal, solitary or gregarious. Their host preferences are mainly lepidopterous and coleopterous larvae but also commonly Diptera, including the damaging fruit flies and Homoptera, particularly aphids.

(iii) The Ichneumonids:

The Ichneumonidae comprise about 20 per cent of all parasitic insects. Most are primary parasites, hence the family is predominantly beneficial. Some of the largest and most conspicuous parasite species occur in this family, Ichneumonidae probably parasitize wood and stem boring larvae in the Lepidoptera, Coleoptera or Hymenoptera but many attack lepidopterous pupae too. Some species have a very wide host range.

Most of the Tryphoninae are solitary parasites of sawflies. The Ophioninae are predominantly internal parasites of lepidopterous larvae although a few develops in the grubs of root feeding scarabs in the soil.

(iv) The Serphoids:

This contains several families, the most important of which are the Platygasteridae and the Scelionidae. All are parasitic on immature stages of other insects and they are predominantly primary internal parasites.

Diptera:

In addition to tachinids which comprise the most important dipterous family in biological control, this order contains several parasitic families including – Cyrtidae, Nemestrinidae, Pipunculidae and Conopidae etc. However, tachinids constitute the major parasitic family both in numbers of species and in economic importance and have been the only group utilized extensively in biological control.

Predators:

Predator insects differ from parasitic ones in that the larvae or nymphs, as the case may be, require several to many prey individuals to attain maturity. The adults generally deposit their eggs near the prey population and after hatching the active mobile immature search out and consume prey individuals. This need of larvae or nymphs to search is an important distinction from parasitic forms whose larvae develop on a single host individual and thus have the advantage of not having to discover additional hosts.

Adults of many species are also predatory. There may be one or several generations to one of the prey. Larvae and nymphs as well as corresponding adults may be predaceous or only one stage may exhibit the habit.

i. Coleoptera:

The main predaceous families of the Coleoptera are:

Coccinellidae, Staphylinidae, Histeridae, Lampyridae, Cleridae, Cantharidae, Meloidae, Cicindelidae, Carabidae, Dytiscidae and Gyrinidae. The Coccinellidae and the Carabidae are of most important in biological control of agricultural pests.

ii. Neuroptera:

Most of the species of the order Neuroptera are predatory. The most important families in biological control have been the Chrysopidae and Hemerobiidae which attack many agricultural pests including scale insects, mealy bugs, aphids, white flies, mites etc.

iii. Hymenoptera:

About one quarter of the families of this order is strictly predaceous. Most of the predatory forms tend to be social and live in colonies. The colonial vespid, wasps provision their paper nests with the bodies of caterpillars and other soft bodied insects. Species of Polistes have been used in several biological control projects.

iv. Diptera:

A few families are entirely predaceous and many others contain predatory species. The more common or important economic families include the Syrphidae, Asilidae, Cecidomyiidae, Anthomyiidae, Calliphoridae and Sarcophagidae. Of the latter four, many are predaceous in the egg masses of grasshoppers.

v. Odonata:

The dragon flies and damselflies are predaceous both as nymphs and as adults. The nymphs are all aquatic and feed on a wide range of aquatic insects.

Biological control has been very successful in certain cases where injurious insects have become established in land, they did not previously inhabit and have developed into persistent pests. A classical example of such a biological control is that of the cottony cushion scale, Iceryapurchasi in California, by a predatory coccinellid beetle, Rodolia cardinalis introduced from Australia.

Introduction of this beetle in California resulted in almost complete and permanent destruction of Icerya, within less than 5 years. This species was so completely destroyed that the survival become numerically insignificant. Subsequently the predator achieved complete biological control of the cottony cushion scale in 25 additional countries and a substantial degree of control in four other countries.

Many outstanding successes in the biological control of serious coccid pests have since been recorded. Some notable cases include the complete biological control of the Citrophilus mealy bug, *Pseudococcus fragilis* in California, the coconut scale – Aspidiotus destructor in the island of Fiji, Maritius and Principe, Green’s mealy bug, *Pseudococcus citriculus* in Israel; the red wax scale, *Ceroplastes rubens* in Japan; and Coffee mealy bug, *Planococcus kenyae* in Kenya.

A mention may be made of the vertebrate predators like fishes, frogs, reptiles, insectivorous birds and mammals etc. which are the regular feeders and deserve to be provided with suitable conditions to grow and breed profusely.

3. Pathogens:

Pathogenic microorganisms attack insects and have life cycles more or less characteristic or similar microorganisms developing in other groups of animals. Insects are probably subject to as wide as variety of disease as are the vertebrates. Except for the fungi, disease organisms gain entry in the host via mouth or the digestive tract, i.e. the insect host must eat plant or other food contaminated with pathogen. In case of fungi, entrance is gained through the insect integument and free water or very high humidity is generally required.

Thus, fungi tend to be restricted to moist environments. However, fungi do have advantage of attacking sucking insects which because of the nature of their feeding on sap, tend to be fairly free of disease caused by microorganisms because they rarely ingest them. Virtually no insect disease organisms occur in mammals and none have been recorded from man. Thus they are safe to use in biological control even in large scale microbial spraying operations.

The most common disease of insects is caused by bacteria, fungi, viruses, and protozoa:

i. Bacteria:

Because it can be produced fairly easily on a large scale and has a wide spectrum of activity, *Bacillus thuringiensis* was of the first microorganisms to be incorporated into a commercial "microbial insecticide". The most sensitive insects appear to be lepidopterous caterpillars, particularly those in which alkaline conditions prevail in the midgut. This is related to the fact that the spores (it is a crystal bearing spore former and can be conveniently stored and applied in the resistant state without loss of potency) can only enter the insect on ingestion and that the proteinaceous crystals of toxin is only liberated at around pH 9-10.

Those pathogenic bacteria which do not form spores have proved to be of little practical value in the field and indeed only two other groups of spore formers have been employed with any success i.e. Bacillus popilliae and Bacillus cereus. The former species produces a condition known as milky disease in the Japanese beetle, Popillia japonica and has been used extensively in North America for control of this pest and Chaffer beetles.

Although Bacillus cereus does not produce a crystalline toxin, it also requires closely defined mid gut conditions with an optimum around pH 7. This Bacillus is active against the codling moth and certain Hymenopterous pests.

ii. Viruses:

The classic example of the employment of viruses in pest control is the highly successful use of polyhedrosis viruses against the pine sawfly, Neodiprion sertifer in Canada. A related pest Neodiprion sainei and the spruce sawfly, Diprionhercyniae are similarly controlled by a polyhedrosis virus.

Another example is the control of alfalfa caterpillar, Coliaseurytheme by introduction of polyhedrosis virus. The cabbage looper, Trichoplusiani and other brassica caterpillars have been controlled in a similar way. Only one other group of viruses, the granulosis type has been used against pests in field, in this case the Lepidopterans, Pieris brassicae and Pieris rapae. Further, for Nucleopolyhedro viruses, which are used for the control of insect pests.

Iii. Fungi and Protozoa:

Pathogenic fungi have several properties which should make them ideal organisms for use in biological control. They produce highly resistant stages and are capable of prolific spore production once they became established. However, their great dependence on microclimatic conditions, especially humidity has seriously curtailed their use and only a few have been employed successfully of these – Entomophthoraexitialis has produced promising results against the spotted alfalfa aphid, Therioaphismaculata.

Many protozoa appear to cause chronic rather than acute symptoms in their victims and the microsporidian, Thelohaniahyphantriae takes upto four weeks to exert its full effect which has been shown to cause mortality in the fall webworm, Hyphantriacunea.

4. Genetic Methods:

Genetic pest control implies the manipulation and use of genetic material in a manner injurious to pest insects. The control of insect pest populations by the release of sterile males has been demonstrated with at least five insect species. This spectacular technique has been termed autocidal control and involves using an insect species to bring about its own self-destruction.

It is accomplished by irradiating laboratory reared males of the species to an extent sufficient to disrupt the genetic function of the sperm nucleus but not appreciably interfere with the normal ability of the male to mate or of the sperm to penetrate the egg of the female. However, such fertilized eggs fail to develop so a wild female mated with a sterilized male produces no progeny.

If sterile males are released in large enough number in relation to the wild population they will fertilize more females than will the wild males. The advantage is cumulative in each generation hence eradication may be achieved within a few generations under ideal conditions. The major success thus far has been with the screw worm which was eradicated from the Island of Curacao, from Florida, and from Texas to California by massive annual release of sterile males.

A low infestation of the Oriental fruit fly was eradicated from Guam in 1963; the melon fly was eradicated from Rota Island in 1963 using a combination of a bait spray and sterile insect release, and the field cockchafer eradicated from a seventy four acre plot in Switzerland in 1962.

The boll weevil is reported to have been eradicated from a small isolated field by the release of chemically sterilized males. Chemosterilants have been under intensive investigation but are not as yet practical. They offer the advantage of treating the wild population directly and thus avoiding the mass rearing necessary with gamma radiation.

Use of Pheromones:

The ability of an insect to locate a mate and to copulate once it has been found is often directed by natural specific chemicals produced by the insect called pheromones. Natural chemical attractants and mating stimulants have been shown to occur in many pest insects. They are often effective in incredibly small concentrations; one caged virgin female of the introduced pine sawfly attracted over 11000 males.

Some have been chemically identified and even synthesized. Its high specificity for particular target insects however makes this approach highly desirable. Such phenomena gave rise to the intriguing idea of using these natural or artificial pheromones to attract and trap insects, to lure them to contact poisons, chemosterilants or pathogens and to mask the location of females by saturating the environment with synthetic sex pheromones. Such techniques could offer highly specific control methods with little or no ecological side effects.

An example of possibility is furnished by the eradication of the Oriental fruit fly on Rota I'sland where the artificial pheromone or attractant viz. methyl eugenol lured the male flies to a poisoned coated surface. A similar but more important achievement was the eradication of the mediterranean fruit fly from about one million acres in Florida in 1956-57.

It appears that adequate control from pheromones or attractants probably can only result if they are so highly effective as to be able to reduce the pest population to low level in the treated area and are used over a large area so that immigration of the pest from the outside would not negate the effort. Pheromone traps are commonly used for controlling various moths Heliothis, Spodoptera, Leucinodes etc.

Chemical Control:

Recent discoveries of new synthetic insecticides have sparked exciting advances and major breakthroughs in the control of insect enemies. Chemicals have subdued pests that once caused wide spread crop destruction, death of domestic animals and epidemics of insect borne human diseases. The modern insecticides are both effective and reliable. The whole world is resorting to them more and more for the solution of many insect problems.

The chemicals which kill the insects by their chemical action are termed as insecticides. They are used for the protection of men, domestic animals, crops, agricultural products from the attack of insects when other methods fail to control the pests. Insecticides are seldom used in full strength but are formulated in a variety of ways to make them easier for application.

Formulations of Insecticides:

Following are the common formulations of insecticides viz.:

1. Dusts,
2. Granular formulations,
3. Insecticide-fertilizer mixtures,
4. Wettable powders,
5. Solutions,
6. Emulsifiable concentrates,
7. Aerosoles,
8. Fumigants and
9. Miscellaneous formulations.

Whatever may be the formulations the poisonous chemical present in an insecticide must penetrate the vital organs and tissues of the insect and ultimately kill it.

(1) Dusts:

Insecticidal dusts are those powders which are used dry and mixed with or impregnated with certain organic materials or pulverised minerals (powders) such as talc, pyrophyllite, bentonite etc. These minerals are called carriers or vehicles since they carry the insecticide. Dusts are blown to deposit on plants by dusting machinery or blowers.

Ground to a fine size, most dust will pass through a 325 mesh screen and range in size from 1 to 40 μ. The finished dust may be 0.1 to 25% active material. In dust form, in general, the toxicity of an insecticide increases as the particle size decreases.

(2) Granular Formulations:

These are similar to dusts except for larger particle size. The range of particle size in a granular product is designated by a two figures mesh classification e.g. 30/60 means that virtually all the insecticide granules will pass through a standard 30-mesh sieve while a negligible quantity will pass through a standard 60 mesh sieve.

Some of the common granular formulations are 16/30, 20/40, 24/48 and 30/60. Granular insecticides are generally used as dressings on or in the soil and may be applied with fertilizer spreaders or special granule applicators.

(3) Insecticide Fertilizer Mixtures:

Insecticide fertilizer mixtures may be formulated by adding granular insecticides to commercial fertilizers or by spraying insecticides directly on to the fertilizer. Such mixtures are applied at the regular fertilizing time to provide both plant nutrients and control of soil insects.

(4) Wettable Powders:

These are similar to dusts but they are meant to be diluted and suspended in water and used as spray. To make an insecticidal dust act in this manner a dispersing and wetting agent is added to the formulation. They are more concentrated than dust as they may contain as high as 75% toxicant.

(5) Solutions:

Many of the modern synthetic insecticides are insoluble in water but soluble in organic solvents. These soluble insecticides in solution form are used directly for insect control. They are however seldom used on plants because of their phytotoxic reaction.

(6) Emulsifiable Concentrates:

The most common and versatile formulation is the emulsifiable concentrate. This formulation consists of an insecticide, a solvent (for the insecticide) and an emulsifying agent. Mixing the concentrate with water forms an emulsion. The solvent used may evaporate quickly after spraying leaving a deposit of toxicant after the water has evaporated.

The use of an emulsifying agent serves several purposes; it makes possible the diluting of a water insoluble chemical with water, it reduces the surface tension of the spray thus allowing it to spread and wet the treated surface more effectively, helps the spray and make a better contact with the insect cuticle.

Generally oil soluble emulsifying substance is used. Normally emulsions are unstable and break up into their component parts. This action is termed breaking. For spraying on plants a quick breaking mixture is preferred. Since this results in heavier deposits of toxicant.

(7) Insecticidal Aerosols:

Aerosols are minute particles suspended in air or fog or smoke. The diameter of these particles ranges from 0.1 to 50 µ. The dispersion of insecticide into aerosol form may be accomplished by burning, vapourising with heat, atomizing mechanically or releasing through a small hole an insecticide that has been dissolved in a liquified gas. The last method of aerosol preparation gives the popular aerosol bomb.

(8) Fumigants:

Insecticides used in the gaseous form are known as fumigants. Fumigants are most often formulated as liquids under pressure and are held in tanks. When the liquid is released in open air it changes back to a gas, quite often fumigants are a mixture of two or more gases.

(9) Miscellaneous Formulations:

There are certain insecticides which are special formulations meant for specific uses. Often insecticides are stuffed in large pills and capsules and introduced into the stomach of animal. Insecticides may be mixed in shampoos; intended for use on house pets waxes for use on floors may contain an insecticide. Poison baits consist of toxicants combined with food stuff attractive to the insect pests. All these types of insecticides are special formulations designed for special purposes.

Synergists:

Some chemicals have the property of greatly increasing toxicity of certain insecticides. When the increased toxicity is markedly greater than the sum of the two used separately, it is termed a synergistic action. Most synergists have been used with pyrethrum or allethrin etc. Synergistic action is important because it provides a means for a more effective insecticide and it reduces the cost of control.

12.4 Cultural Control: Agronomic practices

By cultural control, it is meant those methods of planting, growing and harvesting a crop which will prevent or lessen insect damage. This method consists of a slight departure from the usual time of planting, sowing or harvesting the crops or changing the plan of crop rotation, weed control, disposal of the crop remnants after harvest. Planting good seeds and resistant varieties are very important in controlling some insect pests.

Since cultural methods are usually economical, they are especially useful against pests of low unit-value crops. Practices which reduce the chances of buildup of pest populations may hold them below the level which will cause economic damage. Such methods are particularly applicable to field crops and forests. Knowledge of the life history or bionomics of a pest species is essential to the effective use of cultural control methods. The principle of the “weakest link” or most vulnerable part of the life cycle usually applies. The environment is changed by altering farming practices at the correct time so as to kill the pests or to slow down their multiplication. In this way, the method is aimed more at prevention than at cure. If the environment is unfavorable, the pest may not reach a population level which will cause serious damage.

Cultural controls are often used when chemical or biological methods have not yet been devised for an injurious species. Cleanup of the sources of infestation and changes in the planting or harvesting time are particularly important when no effective method of killing the pest is known.

1. Control by Planting Pest Resistant Varieties:

Seeds of healthy plants preferably of a resistant variety only should be sown as far as possible. Certain varieties are naturally resistant or less susceptible to insect attack e.g. certain varieties of wild apples are immune to aphid attacks while most of the cultivated varieties are very susceptible. Hence, by interbreeding wild with cultivated variety, a strain can be evolved which yield good fruits and shall also will be immune to pests.

Similarly the Indian cotton *Gossypium orboreum* is much more resistant to the attack of jassids, whiteflies and the pink bollworms than the American cotton, *G. hirsutum*. Also the indigenous cotton is resistant to leaf roller but susceptible to pink boll worm and the foreign variety behaves in an opposite manners. Hence, by crossing the Indian species with the American species a new strain, immune to aphids, jassids and pink bollworms etc. can be developed.

2. Tolerance to Insect Infestation:

A variety may be infected by insects yet survive and show less injury than others because of its ability to replace injured parts such as leaves and rootlets.

3. Ploughing in Relation to Insect Control:

The plough if used at right time is a good tool for combating many insect pests; it disturbs or kills them, eradicates weeds upon which they might feed and breed, exposes them to natural enemies or to weather control and buries them so deeply that few adults can emerge. A thorough stirring of the soil before planting is an indirect method for controlling the corn root aphids, because, it breaks up ant colonies, kills many aphids and prevents the growth of weeds on which they live until corn roots are available.

4. Clean Cultivation:

Clean cultivation means the removal of weeds, plant residues, and other materials from the fields and growing only healthy crops. The destruction of crop residues is a very good preventive measure for controlling certain species of insects e.g. caterpillars or beetles. The elimination of remaining effectively stops further insect breeding by cutting of their food supply and shelter.

Many insects infesting crops will develop on weeds which may or may not be related to these crops botanically. Hence, weed control is a good practice for reducing insect infestation. Damage due to Leptocorisa is very serious when paddy fields are surrounded by weeds which provide a good shelter to the pests till the ears have been formed in them. Similarly various species of red hairy caterpillar, Amsactamoorei, Amsactacollaris and other species of this insect are polyphagous and lay eggs on a number of weeds and on emergence the caterpillars feed on the weeds and then migrate to the nearby fields of any crop.

12.4.1 CROP ROTATION: Crop rotation is effective as preventive measures against insects that feed on relatively few plant species or where the insects are incapable of long distance migration but crop rotation is useless against a general feeder. If one and the same crop is grown every year the insect population is bound to increase due to abundance of food material. On the contrary, if crops are grown in rotation or alternate years e.g. a crop of one plant family followed by that of different family e.g. barley grown in spring may be followed by legumes or pulses and then wheat in winter and so on.

The crops of the same family e.g. cotton, and lady’s finger (okra) belonging to the same family Malvaceae must not follow same year. Mixed crops are sometimes useful as pests do not thrive in large number.

12.4.2 TILLAGE PRACTICE:

Tillage, in agriculture, the preparation of soil for planting and the cultivation of soil after planting. Tillage is the manipulation of the soil into a desired condition by mechanical means; tools are employed to achieve some desired effect (such as pulverization, cutting, or movement). Soil is tilled to change its structure, to kill weeds, and to manage crop residues. Soil structure modification is often necessary to facilitatethe intake, storage, and transmission of water and to provide a good environmentfor seeds and roots. Elimination of weeds is important, because they compete for water, nutrients, and light. Crop residues on the surface must be managed in order to provide conditions suitable for seeding and cultivatinga crop. If the size of the soil aggregates or particles is satisfactory, preparation of the seedbed will consist only of removing weeds and the management of residues. Unfortunately, the practices associated with planting, cultivating, and harvesting usually cause destruction of soil structure. This leaves preparation of the seedbed as the best opportunity to create desirable structure, in which large and stable pores extend from the soil surface to the water table or drains, ensuring rapid infiltration and drainage of excess or free water and promoting aeration of the subsoil. When these large pores are interspersed with small ones, the soil will retain and store moisture also. Seedbed preparation procedures depend on soil texture and the desired change in size of aggregates. In soils of coarse texture, tillage will increase aggregate size, provided it is done when only the small pores are just filled with water; tillage at other than this ideal moisture will make for smaller aggregates. By contrast, fine-textured soils form clods; these require breakage into smaller units by weathering or by machines. If too wet or too dry, the power requirements for shattering dry clods or cutting wet ones are prohibitive when using tillage alone. Thus, the farmer usually attempts tillage of such soils only after a slow rain has moistened the clods and made them friable. Some soils require deepening of the root zone to permit increased rate of water intake and improved storage. Unfavorable aeration in zones of poor drainage also limits root development and inhibitsuse of water in the subsoil.

Tillage, particularly conventional plowing, may create a hardpan, or plow sole—that is, a compacted layer just below the zone disturbed by tillage. Such layers are more prevalent with increasing levels of mechanization; they reduce crop yields and must be shattered, allowing water to be stored in and below the shattered zone for later crops. Tillage is also associated with the loss of fertile topsoil through erosion, a serious threat to the longevity of arable land.

Primary tillage equipment

Equipment used to break and loosen soil for a depth of 15 to 90 cm (6 to 36 inches) may be called primary tillage equipment. It includes moldboard, disk, and rotary, chisel, and subsoil plows. The moldboard plowis adapted to the breaking of many soil types. It is well suited for turning under and covering crop residues. There are hundreds of different designs, each intended to function best in performing certain tasks in specified soils. The part that breaks the soil is called the bottom or base; it is composed of the share, the landside, and the moldboard.

When a bottom turns the soil, it cuts a trench, or furrow, throwing to one side a ribbon of soil that is called the furrow slice. When plowing is started in the middle of a strip of land, a furrow is plowed across the field, and on the return trip a furrow slice is lapped over the first slice. This leaves a slightly higher ridge than the second, third, and other slices. The ridge is called a back furrow. When two strips of land are finished, the last furrows cut leave a trench about twice the width of one bottom, called a dead furrow. When land is broken by continuouslapping of furrows, it is called flat broken. If land is broken in alternate back furrows and dead furrows, it is said to be bedded or listed. Different soils require different-shaped moldboards in order to give the same degree of pulverization of the soil. Thus, moldboards are divided into several different classes, including stubble, general-purpose, general-purpose for clay and stiff-sod soil, slit, black land, and chilled general-purpose. The black land bottom is used, for example, in areas in which the soil does not scour easily—that is, where the soil does not leave the surface of the emerging plow clean and polished.

The share is the cutting edge of the moldboard plow. Its configuration is related to soil type, particularly in the down suction, or concavity, of its lower surface. Generally, three degrees of down suction are recognized: regular for light soil, deep for ordinary dry soil, and double-deep for clay and gravelly soils. In addition, the share has horizontal suction, which is the amount its point is bent out of line with the landside. Down suction causes the plow to penetrate to proper depth when pulled forward, while horizontal suction causes the plow to create the desired width of furrow.

Moldboard plow bottom sizes refer to width between the share wing and the landside. Tractor plow sizes generally range from 10 to 18 inches (25 to 45 cm), although larger, special-purpose types exist.

Secondary tillage

Secondary tillage, to improve the seedbed by increased soil pulverization, to conserve moisture through destruction of weeds, and to cut up crop residues, is accomplished by use of various types of cultivators, harrows, rollers, or pulverizers, and tools for mulching and fallowing. Used for stirring the soil at comparatively shallow depths, secondary tillage equipment is generally employed after the deeper primary tillage operations; some primary tillage tools, however, are usable for secondary tillage. There are five principal types of harrows: the disk, the spike-tooth, the spring-tooth, the rotary cross-harrow, and the soil surgeon. Rollers, or pulverizers, with V-shaped wheels make a firm and continuous seedbed while crushing clods. These tools often are combined with each other. When moisture is scarce and controls of wind and water erosion necessary, tillage is sometimes carried out in such a way that crop residues are left on the surface. This system is called trash farming, stubble mulch, or subsurface tillage. Principal equipment for subsurface tillage consists of sweeps and rod weeders. Sweeps are V-shaped knives drawn below the surface with cutting planes horizontal. A mounted set of sweeps provided with power lift and depth regulation is often called a field cultivator.

The typical rod weeder consists of a frame with several plow like beams, each having a bearing at its point. Rods are extended through the bearings, which revolve slowly under power from a drive wheel. The revolving rod runs a few inches below the surface and pulls up vegetative growth; clearance of the growth from the rod is assisted by its rotation. Rod weeders are sometimes attached to chisel plows. Some control of weeds is obtained by tillage that leaves the middles between crop rows loose and cloddy. On mechanized farms this is often accomplished with a cultivator pulled by a tractor. When a good seedbed is prepared only in the row, the seeded crop can become established ahead of the weeds. Plowingwith the moldboard plow buries the weed seeds, retards their sprouting, and tends to reduce the operations needed to control them. If weed infestations become bad, they can be reduced somewhat by undercutting.

Minimum tillage

The use of cropping systems with minimal tillage is usually desirable, because intensive tillage tends to break down soil structure. Techniques such as mulching also help prevent raindrops from injuring the surface structure. Excessive tillage leaves the soil susceptible to crusting, impedes water intake, increases runoff, and thus reduces water storage for crop use. Intensive vegetable production in warm climates where three crops per year may be grown on the same land may reduce the soil to a single-grain structure that facilitatessurface cementation and poor aeration. The loosening and granulating actions of plowing may improve soil structure if the plowing is done when the moisture content is optimal; if not so timed, however, plowing can create unfavourable structure. The lifting and inversion of the furrow slice likewise may not always be desirable, because in many cases it is better to leave a trashy surface.

The concept of minimum tillage and no-till agriculture has received much attention. One type of minimum tillage consists in seeding small grain in sod that has been relatively undisturbed. Narrow slits are cut in the sod, and seed and fertilizer are placed in the breaks thus formed. Soil normally subject to erosion can be planted to grain this way while still retaining the erosion resistance of the sod. The technique has been successful in preparing winter grazingin southeastern portions of the United States. In another type of minimum tillage, the land is broken and planted without further tillage in seedbed preparation. One approach involves breaking the land and planting seeds in the tractor tracks (wheel-track planting); the tractor weight crushes clods and leaves the seed surrounded by firm soil. Another method consists of mounting a planter behind the plow, thus planting without further traffic and leaving a loose seedbed that is satisfactory in areas where post-planting rains may be heavy. In some areas, where winter rain often comes after wheat is drilled, a rotation of wheat following peas has been successful. After the peas have been harvested, the field is rough plowed, and fall wheat is then drilled in directly. All these methods minimize expense and land preparation, tending to leave the soil rough, which reduces erosion and increases water intake. Somewhat similar systems are employed with row crops, where chemical weed control assists in reducing need for cultivation.

Mulch tillage

Mulch tillage is a system in which crop residues are left on the surface, and subsurface tillage leaves them relatively undisturbed. In dryland areas, a maximum amount of mulch is left on the surface; in more humid regions, however, some of the mulch is buried. Planting is accomplished with disk openers that go through several inches of mulch. Since mulch decomposition may deprive the crop of nitrogen, extra fertilizer is often placed below the mulch in humid areas. In rainy sections, intercropping extends the protection against erosion provided by mulches. Intercrops are typically small grains or sod crops such as alfalfa or clover grown between the rows of a field crop that reach maturity shortly after the field crop has been established and furnish mulch cover for a long time. If growth of the intercrop competes with the main crop for moisture and nutrients, that growth may be killed at seeding time or soon thereafter by undercutting with sweeps.

Tillage in dry areas must make maximum use of scanty rainfall. The lister (double-moldboard) plow, or middle breaker, is here used to make water-impounding ridges that promote infiltration.

12.4.3 Planting/Harvesting date manipulation

The availability of crop varieties with a range of maturity periods allows considerable flexibility in planting dates. The most common manipulation of planting dates is the utilization of "safe dates" which are a range of dates where a given crop can be planted such that it is in a relatively invulnerable stage when the damaging stage of the pest is present. For example, delaying the planting of winter wheat till "fly-free" dates in the fall reduces damage of Hessian fly, *Mayetiola destructor*.

Alternatively, planting can be timed so that the vulnerable stage of the plant coincides with periods when alternate hosts are abundant or weather conditions are likely to be unsuitable for pests to exploit the crop. The use of safe planting dates was an important form of pest control before the advent of chemical insecticides. In light of the technological advances that allow more accurate predictions of pest and crop phenology, the use of this safe and inexpensive alternative deserves reconsideration.

Limiting the length of time that a crop is exposed to insects can provide a useful alternative insect management strategy. Short-season cotton varieties have been adopted widely across the U.S. with the aim of avoiding insect problems by producing an early-maturing crop.

12.4.4 Sowing / Plant Density

Sowing density determines the amount of light available for plants, affects the efficiency of photosynthesis, and has an impact on the plant nutrition area. Plant spacing and shading can be an important influence on the population growth of some pests. Corn earworms prefer open plant canopies. They therefore most readily infest late-planted and wide-row soybeans. Soybean canopies will close sooner if planted in narrow rows and can help reduce an infestation. Similarly, planting young spruce trees as close together as possible can achieve early closing of the canopy and can suppress infestations of a spruce weevil, *Thylacitesincanus*, which seem to require open sunlit areas for survival. Thinner and less healthy stands of grain fields tend to be attacked by the chinch bug. Because canopy shading is apparently not preferred by the pest, chinch bug management recommendations often include practices that encourage thick, vigorous stands.

12.4.5 INTERCROPPING

Intercropping is a method of **increasing agricultural productivity** by planting **two or more crops simultaneously** on a specific plot of land in a **specific row pattern.**

The primary goal of this type of cropping is to **make use of the space between two rows of main crop** and produce more grain per unit area.

Small farmers who depend on rain for higher production are more likely to use it.

This procedure has a **specific row pattern, such as 1:1 or 1:2,** which means that the primary crop is in the first row and the other crops are in the second or third row.

These crops are blended in this technique despite having different nutrient needs. It guarantees the **best possible use of the nutrients given.**

Additionally, it **stops pests and diseases** from spreading to every plant involved in a particular crop.

Principles of Intercropping

Crops grown in tandem should have complementary rather than competitive effects. The subsidiary crop should be of shorter duration and faster-growing habits to take advantage of the main crop's early slow-growing period, and it should be harvested when the main crop begins to grow. Agronomic practices for the component crops should be similar.

Erect growing crops should be intercropped with cover crops such as pulses to reduce or control soil erosion and weed population. This also aids in reducing water evaporation from the soil's surface.

The root depths of the component crops should be different so that they do not compete for nutrients, water, and root respiration. A standard plant population of the main crop should be maintained, whereas the plant population of subsidiary crops can be increased or decreased depending on the situation. Component crops infested with similar pest and disease pathogens and parasites should not be chosen. The planting method and management should be simple, less time-consuming, less cumbersome, economical, and profitable in order to be widely adopted.

Types of Intercropping

- **Strip Intercropping**- The term "strip cropping" refers to the practice of cropping different cultures in strips. To prevent soil erosion, it is a common practice on sloped terrain. Strip cropping in agriculture also applies to even terrains. The strips are sufficiently narrow to generate agronomic interactions between neighboring crops. Strip width is therefore essential to the design and operation of this cropping pattern. The strips are frequently changed from year to year. Basically, strip cropping agriculture is utilized to either enhance the growth of primary species or improve soil health.
- **Parallel Cropping -** Parallel cropping is the practice of growing crops that have different natural behaviors but no competition. An example of parallel cropping is wheat and mustard. After planting wheat, farmers typically broadcast mustard in the same field. It makes greater use of resources like light, nutrients, and moisture. The productivity of the

system is hampered by inefficient moisture usage and competition between the various root systems of the crops cultivated together.

- **Synergistic Cropping -** Synergistic cropping is when two crops are grown on a unit area at the same time and produce more as a whole than they would if they were grown separately on a unit area basis. The concept of synergistic cropping first emerged in the 1980s.This technique is based on agronomic approaches primarily targeted at improving soil fertility. As a result, the overall health of the soil-microorganism-plant system is focused, rather than on production alone.
- **Multi-storey Cropping-** Multi Storey Cropping is the process of cultivation of more than two crops at once on the same plot of land with varying heights. Examples: coconut, pepper, cocoa, and pineapple. The crops are cultivated together on the land, utilizing land, water, and space in the most effective and inexpensive ways possible. Plantings having an over story of trees or shrubs and an understory of specialized or agronomic crops or pastures are referred to as multi-story crops. There is enough space between trees to allow forage or crops in the understory to receive enough sunlight. Multi Storey cropping is sometimes known as "Forest Farming."Native forest tree canopies would be controlled to permit the cultivation of such crops or forage.
- **Relay Intercropping-** Relay cropping is a type of cropping arrangement in which one crop is seeded into a standing second crop well before the second crop is harvested. Growing Rice-Cauliflower-Onion-Summer gourds is an example for relay intercropping. Relay cropping has the potential to resolve a number of conflicts, including inefficient use of available resources, disagreements over sowing time, fertilizer application, and soil degradation. Relay cropping is a complex set of resource-efficient technologies capable of improving soil quality, increasing net return, increasing land equivalent ratio, and controlling weed and pest infestation. Relay planting has less risk because it does not require relying just on one crop. Relay cropping is also known as overlapping cropping.
- **Alley Cropping-** Alley cropping is one of several practices that deal with trees and crops growing on the same plot of land. Alley cropping is a method of growing trees or shrubs and agricultural crops in alternate rows. Trees are frequently pruned to reduce the shading of agricultural crops. Alley cropping can help with nutrient cycling and erosion control as well. Alley cropping can thus be regarded as re-creating a savanna's structure in an agro

forestry system with many canopy layers, including an over story of nut trees, a mid-layer of fruiting small trees and shrubs, and a groundcover of annual crops or perennial grass groundcover.

- **Row Intercropping -** Plants are arranged in rows in this case, as the name suggests. Cereals and legumes such as corn and beans are a common and beneficial combination. Row ratios can range from single to multiple rows. Row cropping provides additional nitrogen fixation by legumes in symbiosis with bacteria of the Rhizobium genus.
- **Temporal Intercropping-** The combined plants in this intercropping method require different maturing times. When the fast-growing plant is harvested, the slow-growing plant is given more room to grow.
- **Mixed Intercropping-** The practice of intercropping entails sowing different species (two or more) in the same terrain with no distinct arrangement in rows or in the same rows. In this case, the sowing and harvesting seasons coincide. Mixed cropping protects the primary culture from winds, frosts, droughts, and other extreme weather conditions.

12.4.6 TRAP CROPPING AND IRRIGATION

The intercropping technique, as the name implies, aids in pest trapping to protect the main culture. Among the most common trapping plants are mustard and marigold. The basic concept is to attract insects or fungi to the sacrificial secondary crops, protecting the cash crop. Blue Hubbard squash is said to be effective against squash bugs, squash vine borers, and spotted and striped cucumber beetles. Trap intercropping allows for pesticide savings by requiring no or only partial chemical application to trapping areas.

Guard Cropping

Guard crops are thorny or tough plants that grow around cash crops or along field edges. Crop guards are used as barriers to keep the main species safe from winds and invasions. As a result, sorghum is grown next to cotton and safflower next to chickpea.

Repellant Intercropping

Farmers use pest-repellant plants as a sustainable pest-management technique when using this intercropping method. It is based on the repellant effect of specific species, which protects the cash crop. The repellant keeps insects away from their host plant, as in the case of planting leeks to keep bean flies away from beans.

Push-Pull Cropping

For the sake of the cash crop, the intercropping practice combines both trap and repellent plants. While trap species attract (or pull) pests, repellant species repel them. Growing Napier grass (to pull) and Desmodium legume (to push) to protect corn from stem boring corn larvae is an example of this technique.

12.5 SUMMARY

Pest control, a process that maintain nuisance organisms below economic thresholds. Agricultural infestation results in widespread deterioration of biodiversity, with important implications for pest control.

Pest control is a program to eliminate pests from fields to practice good hygienic practices. It could include many of the measures to prevent entry, harborage and infestation of pests. Moreover, it should be effective enough to provide a means to monitor, detect, and eradicate pests. Different techniques work for different pests. Most of the pests can be controlled by intercropping the fields without using any chemicals, like insecticides, pesticides, etc. Many genetically modified organisms, some agricultural methods and organic oils can prove really beneficial in biological or natural pest control.

12.6 TERMINAL QUESTIONS AND ANSWERS

Q1) What are Insect Pest?

Q2) Describe biological control practices that can be used to control insect pests.

Q3) What is Tillage? How it can be incorporated into fields?

Q4) Discuss various pest control techniques other than natural control.

Q5) Explain Intercropping.

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UNIT 13: CHEMICAL CONTROL

CONTENTS

13.1 OBJECTIVES

After studying this module, you shall be able to learn and understand:

- Formulations and Insecticide Toxicity
- Botanical Pesticides and their mode of action
- Synthetic Organic Insecticides and their Mode of Action
- Insect Growth regulators

13.2 INTRODUCTION

Botanical versus synthetic pesticides

Natural compounds called botanical pesticides are taken from plants with known insecticidal characteristics. Botanical pesticides are being used as vital alternatives to synthetic pesticide chemicals because the bulk of them pose environmental risks. Botanical insecticides were regarded as vital crop protection techniques before the development of the synthetic pesticide DDT. Initially, the usage of botanical insecticides was obsolete due to the emergence of low-cost, extremely efficient synthetic insecticides. However, a number of issues with synthetic pesticides, including environmental contamination, residues in food and feed, and insect resistance, have brought them to the forefront once more.

Several commercial solutions manufactured from plants like neem (*Azadirachta indica*),which has demonstrated good effectiveness as a botanical pesticide, are already available on the market. As insects and other organisms developed resistance to synthetic pesticides throughout time, bota-nical pesticides have grown in popularity relative to chemical pesticides. Chemicals like nicotine and oils like citrus oils are among the insecticides found in plants. These natural pesticides are us ed to create insecticides that are quick to kill insects and have little to no negative impact on the environment.

Why should biopesticides be used instead of synthetic pesticides?

- Biodegradable
- Less toxic to humans

Act quickly

Non-pollutant

Easily available in environment

Advantages of botanical pesticides over synthetic pesticides are listed below:

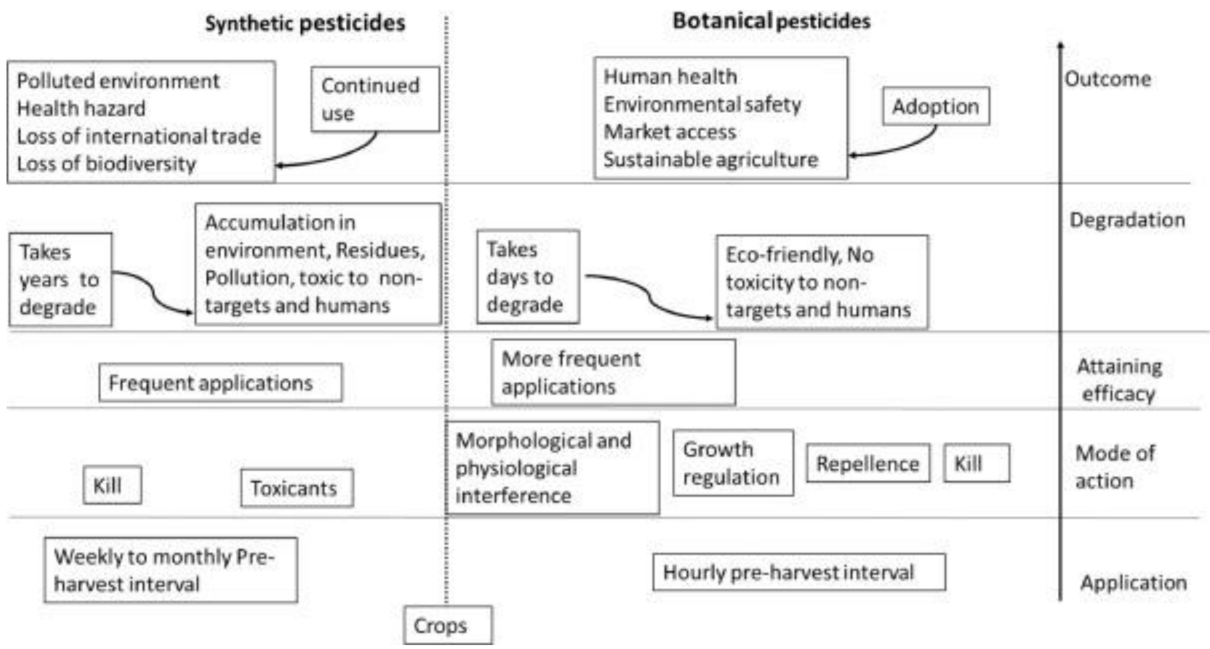


Table 1: Comparison of botanical versus synthetic pesticides (Lengai et al 2020).

Due to their numerous benefits and drawbacks, botanical pesticides should only be used as alternatives in IPM programmes and in conjunction with other available control techniques.

13.3 FORMULATIONS AND INSECTICIDE TOXICITY

Toxicity is ability to pesticide to cause illness in pests. For testing toxicity animal is exposed to different degrees of pesticides (formulated product). The types of toxicity include:

Acute: In this exposure is for shorter duration; It is chemical ability to cause illness to a person on single exposure. Main route of inhalation includes dermal (skin), inhalation (lungs), oral (mouth), and eyes.

Chronic: It occurs after long-term exposure to harmful pesticide. In this small term exposure is repeated several times. Effect of chronic exposure includes birth defects, nerve disorder, tumor production etc.

Pesticide toxicity is either measured as LD50 (Lethal dose) or LC50 (Lethal concentration). LD50 is amount of chemical that causes death in 50% animals on exposure to oral or any other exposure. LC50 is the concentration of a chemical in inhalable form that is lethal to 50% of test organisms. Its units are milligrams of substance per kilogram of test animal body weight (mg/kg).

Effect of LD50 and LC50 includes:

Even a low value of toxicant can cause high toxicity.

They are based on single dose or short term acute exposure. LD50 does not include combine effect leading to carcinogenic effects.

Toxicity Rating, Category	High Category I	Moderate Category II	Low Category III	Very Low Category IV
Signal Word	DANGER-POISON, DANGER	WARNING	CAUTION	CAUTION, No Signal Words
LD_{50} toxicity ratings for oral exposure *	0-50	>50-500	>500-5,000	>5,000
LD_{50} toxicity ratings for dermal exposure *	0-200	>200-2,000	>2,000-5,000	>5,000
LC_{50} toxicity ratings for inhalation exposure **	0-0.05	>0.05-0.5	>0.5-2.0	>2.0

*milligrams of chemical per kilogram of body weight of test animal (mg/kg)
**milligrams of chemical per volume of air or water in liters (mg/L)

Ref: Understanding Pesticide Risks: Toxicity and Formulation (2016)

Formulation of insecticides

Formulation makes the toxicant easier to use, and more effective through the addition of emulsifiers, wetting agents, stickers, spreaders, etc.

Importance of pesticide formulation:

Pesticide formulation lowers the risk of people and other non-target organisms

Pesticide application should be specific as given on pesticide labels.

Applying pesticides in greater amount is illegal and not cost effective.

It may leads to risk on non-target species.

Methods of Pesticide formulation includes:

BAITS: They are target specific and useful for social insects like ants and termites. They contain food products to attract a specific group of pests.

DUSTS: Dust is dry and fine powders, applied in case sprays are harmful for plants in indoor space. Pest get harmed either through absorption or ingestion during grooming. Protective masses should be wearied against them.

GRANULES: These particles are larger in size than dusts. They are applied to soil to control weeds, nematodes, and soil dwelling insects. In this active ingredient is released slowly and may require moisture or soil incorporation.

SPRAYS: They come as wettable powder, flowable, emulsifable concentrate, sprayable oils, and oil-base sprays. They are easily absorbed through skin, flammable and corrosive.

AEROSOLS: They arepurchased in pressurized containers in a ready-to-use form.

13.4. BOTANICAL PESTICIDES

Botanical insecticides are substances that contain dried, pulverized plant material, unprocessed plant extracts, or compounds that have been extracted from plants and are used to kill or repel insects. They are made of organic and natural components and are natural pesticides. These work well against various organisms such as viruses, nematodes, bacteria, fungus and insect pests.

Classification of Pesticides

Based upon target pests, the mode of action, and the chemical makeup of pesticides can be categorized as:

(A) **Synthetic pesticides**: There are four subgroups of synthetic pesticides.

(B) **Bio-pesticides**: These are broken down into four subgroups: pheromones, plant-incorporated protectants, microbial bio-pesticides, and botanical pesticides. The botanical pesticides are the main topic of this chapter.

Table 1: Different types of pesticides

Pesticides	
Synthetic pesticides	**(B) Bio-pesticides**
Organochlorines	Microbial Bio-Pesticides
Organophosphates	Plant incorporated Protestants
Carbamates	Botanical Pesticides
Phrethrins	Pheromones

Classification of botanical pesticides

The bio-pesticides are divided into different categories based on kind, active ingredient, crop type, and area. It is separated into insecticides, fungicides, and herbicides based on kind. Nicotine, pyrethrin, rotenone, matrine, and azadirachtin are some of them.

Table 2: Botanical pesticides on the basis type, active substance and crop type can be divided as:

Type	**By active substance**	**Crop type**
Insecticides	Nicotine	Oil seeds and Pulses
Herbicides	Pyrethrin	Vegetables and Fruits
Fungicides	Rotenone	Turfs and Ornamentals
	Matrine	
	Azadirachtin	

Advantages of Botanical pesticides

The active ingredients quick decomposition is advantageous.

Products can be utilized right before harvesting.

A lot of these products work fairly rapidly to stop insects from feeding, even though they don’t kill insects over time.

Since most of these products have a stomach action and are quick decomposition, the majority of these compounds may be more selective to insect pests and less aggressive with natural enemies.

Not phytotoxic.

Resistance to these substances does not spread as quickly.

Less damaging to the environment and less environment load (eco-friendly).

Affect only one pest (target specific)

Biopesticides work against pests in little dosages.

Biodegradable and non persistent.

Disadvantages of Botanical pesticides

They are not truly insecticides since many are merely insect deterrents.

Slow effect

Not all natural insecticides are safer for other animals to consume

They might not be accessible all year round.

Lack specified tolerances for residues.

There are no legal registrations establishing their use.

Not every advice given to growers has been backed up by research.

It causes neurological, psychological, behavioural dysfunction and diseases including cancer, blood disorder in humans.

They harm the environment by destroying marine life, reducing biodiversity, and other things.

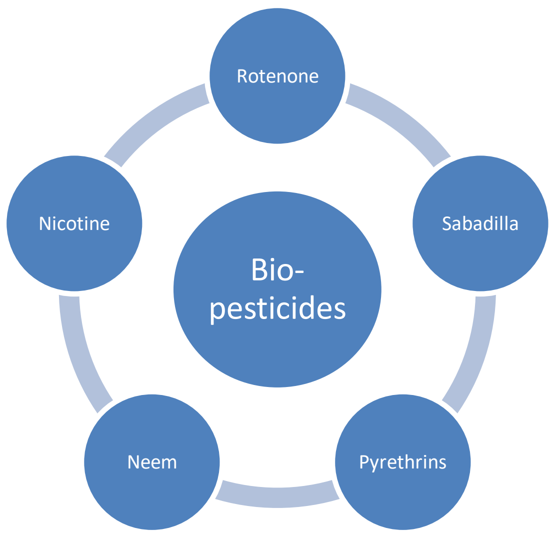
Insects may quickly adapt a resistance to them.

Repression of predators and parasitoids.

Negative impacts on organisms that are not the target and loss of soil fertility.

Mode of Action

The exact biochemical interaction that a pesticide uses to achieve its impact is referred to as its mode of action. The mode of action typically includes the particular enzyme, protein, or biological process impacted. Mode of action particularly relates to which biological process the pesticide inhibits, unlike the majority of other classifications, which focus on the pests controlled, physical qualities, or chemical makeup.

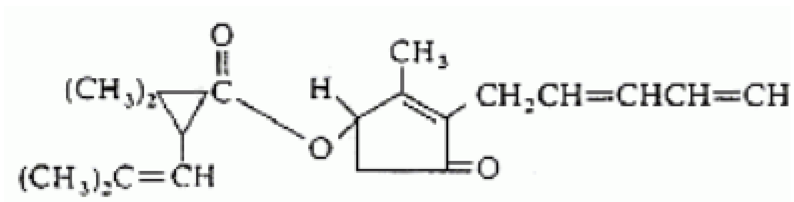


13.4.1 PYRETHRINS

Structure

Cinerin I	$C_{20}H_{28}0_3$
Cinerin II	$C_{21}H_{28}0_5$
Cinerin III	$C_{21}H_{30}0_3$
Jamolin I	$C_{21}H_{30}0_3$
Jamolin II	$C_{22}H_{30}0_5$
Pyerethrin I	$C_{21}H_{28}0_5$
Pyrethrin II	$C_{22}H_{28}0_5$

Source: It is one of the most significant botanical pesticides used in India.It is made from flower of*Chrysanthemum cinerariaefolium*. Pyrthrum is concentrated heavily in a flowers blooms.Six esters are produced when the acids chrysanthemic and pyrethric and the alcohols piretrolone, cinerolone, and jasmolone are combined.These chemicals are derived from this plant and have been shown to have known insecticidal activity. Six active ingredients—pyrethrin I, pyrethrin II, cinerin I, cinerin II, jasmolin I, and jasmolin II—combine to form pyrethrum. The esters of chrysanthemic acid are pyrethrin I, cinerin I, and jasmolin I, while the esters of pyrethric acid are pyrethrin II, cinerin II, and jasmolin II. The ratio of pyrethrins, cinerins, and jasmolins in a typical pyrethrum extract is 10: 3:1. In terms of concentrations, pyrethrins are the most prevalent form of active components when compared to cinerins and jasmolins.



Pyrethrin structure

Major target pests of Pyrethrins are: Mosquitoes, sawfly larvae, caterpillars, leafhoppers, aphids, and beetles; *Culicoides variipennis* (Coquillett); House flies and Flour beetle.

Mode of Action: It affects both central nervous system and peripheral nervous of insects. It prevents the process of sodium-potassium ion exchange in the nervous system of insects. The insect get paralyzed as a result. Pyrethrum pesticides target the insect’s nerve cells, causing paralysis and ultimately death.

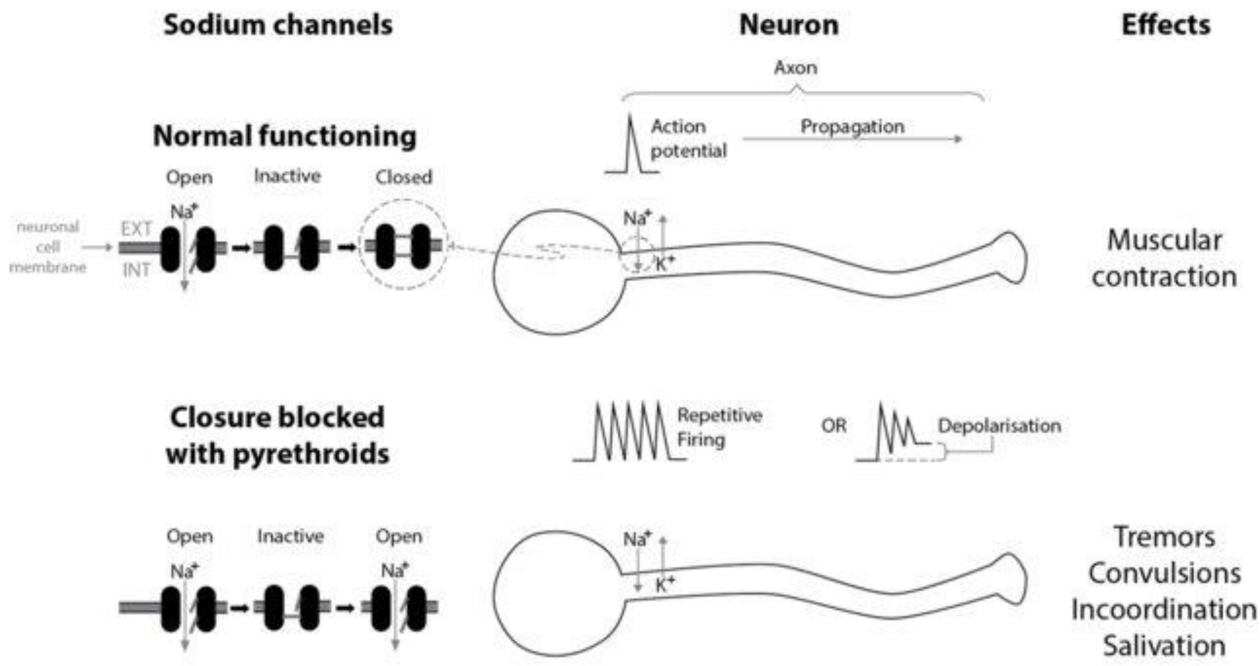
Mechanism of Action

Impact CNS

Prolonged deactivation of sodium channels that are voltage gated.

Prolonged fibers excitation

Greater selectivity with additional neurotoxins.



Source: Louise Hénault-Ethier, 2016. Pyrethroids' mode of action on neurons

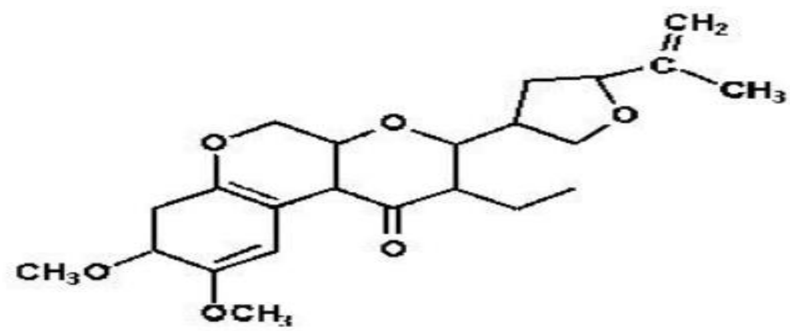
Disadvantages: Many insects can metabolize pyrethrins, thus after a brief time of paralysis, they recover instead of dying. Therefore, piperonyl butoxide (PBO) is combined with pyrethrins to impede metabolization and recovery from poisoning induced by pyrethrins alone, which results in insect death. Pyrethrins are less effective without PBO.

Toxic effects on Mammals: Although pyrethrins are not poisonous to humans, they do have an impact on cats. When consumed, they are not easily absorbed by the digestive system and are instead quickly hydrolyzed in the liver's alkaline environment and the gut's acidic environment.

Pyrethrins become harmful when inhaled rather than when they were consumed directly. High dose inhalation may result in headaches, nausea, vomiting, diarrhoea, and other nervous system abnormalities. Pyrethrum dust exposure can induce allergic responses or skin rashes. On Genetic changes or birth problems are not brought on by prolonged exposure to pyrethrins. There are no current treatments for its toxicity.

13.4.2 ROTENONE

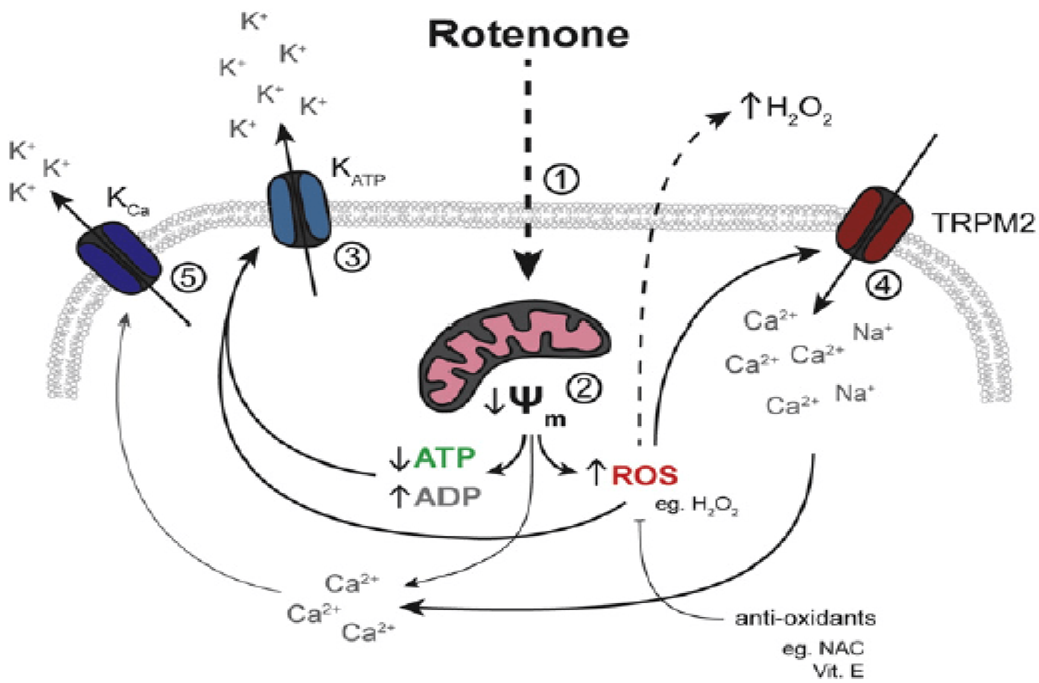
Structure: $C_{23}H_{28}O_6$; It is iso-flavonid chemically.



Rotenone Molecular structure

It is made from the tropical plants *Tephrosia virginiana, Lonchocarpus utilis, Lonchocarpus urucu,* and the bean Derris (*Derris elliptica, Derris involuta*). Both Derris and *Lonchocarpus* provide 13% of the rotenone. While *Lonchocarpus* spp. is indigenous to the western hemisphere, namely South America, Derris spp. is indigenous to the eastern tropics, such as Asia. Roots and stems of plants are used to make rotenone extract. It is a plant insecticide with a broad spectrum. It can be sprayed on plants or used as root powder. It is derived from cube root in acetone or ether. Following extraction, 2-4 percent of rotenone resins-which contain a number of similar but less insecticidal chemicals known as rotenoids-are formed. Cube root can also be dried, ground into a powder, and combined with an inert binder to create an insecticidal dust.

Mode of action: The active ingredient is Rotenone, which serve as a contact and food poison, cellular respiratory enzyme inhibitor, stomach poison. Rotenone a potent inhibitor of cellular respiration, causes nutritional compounds to be converted into energy at the cellular level. Rotenone is a substance that can be ingested and used as a repellant. Inhibiting electron transport at the mitochondrial level blocks the phosphorylation of ADP to ATP, which in turn prevents the metabolism of insects. Rotenone poisoning in insects causes symptoms such as a decrease in oxygen consumption, respiratory depression, ataxia, convulsions, and ultimately paralysis and respiratory arrest. Rotenone poisons the nerve and muscle cells in insects, forcing a swift end to feeding. Insect death happens several hours after chronic exposure.



It is extremely poisonous to fish and is employed in water management programmes as fish poison (piscicide). It is created by PBO (piperonyl butoxide).

Other effects of rotenone include:

Elevated level of nitric oxide and malondialdehyde

Global cellular impairment

Accumulation of alpha-synuclein and polyubiquitin

Activation of astrocytes and microglial cells

Neuroinflammatory responses

Glutamate excitotoxicity

Oxidative stress

Abnormalities in microtubule assembly and spindle formation during mitosis

Toxic effects on Mammals: Its direct contact leads to skin irritation and irritation of mucosa membrane. Its chronic exposure leads to liver and kidney damage. It may leads to tumor formation but until now it is been considered as non-carcinogenic. Commercial rotenone has not shown hazards to human beings. It is a strong cell poison that mammals detoxify with the help of their liver enzymes. Rotenone is also more poisonous when inhaled than pyrethrins are.

Rapid breathing, muscle tremor, nausea, and vomiting are symptoms of excessive rotenone exposure. The strong dose results in convulsions followed by death from circulatory collapse and respiratory paralysis.

13.4.3 SABADILLA

Structure

Cevadine $\mathbf{C_{32}H_{49}0_9}$

Veratridine $\mathbf{C_{36}H_{51}0_{11}}$

Source: It is made from ripe *Schoenocaulon officinale* seeds (Liliaceae). Central and South America are the two continents where this tropical lily plant is found. This plant's seeds have been found to contain significant amounts of the alkaloids that give it its toxic effects. It comes from Venezuela and contains schistocyanatelene.

Several alkaloids are produced when its seeds are roasted and aged. Alkaloids are substances that have physiological effects and are found in many plants. They belong to the heterogeneous class of cyclic compounds, and their rings contain nitrogen. Caffeine, nicotine, cocaine, quinine, and strychnine are some of its alkaloids. Veratrine alkaloids are the name given to its alkaloids. They make up 3-6% of ripe, old seeds.

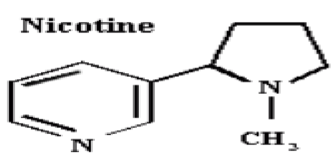
Mode of Action: It damages the neuron's cell membrane, which results in decreased nerve activity, paralysis, and eventual death. Toxic alkaloids in insects alter the function of the nerve cell membrane, leading to a loss of nerve function, paralysis, and insect death.

Toxicity to mammals: Contrary to the ground seeds, which are one of the plant insecticides with the lowest animal toxicity, the isolated alkaloids of these plants are among the most toxic and skin irritants. It lasts for a long period, has lingering effects in sunshine, and dissolves quickly. It also has a smooth toxic effect. By interfering with the functioning of the sensory, motor, and respiratory nerves, the insect is paralyzed and dies. Caterpillars, leafhoppers, thrips, stink bugs, and squash bugs are all susceptible.

It appears like dust and is made from ground seeds. Pure alkaloids from it are exceedingly harmful. It has a strong sneezing-inducing action and is exceedingly irritating to the skin and mucous membrane when inhaled. It can affect circulation and cause headaches, nausea, vomiting, and diarrhoea even at tiny doses. An excessive amount may cause convulsions, heart paralysis, and breathing failure. Their alkaloids can penetrate the mucosa membrane and be absorbed.

13.4.4 NICOTINE

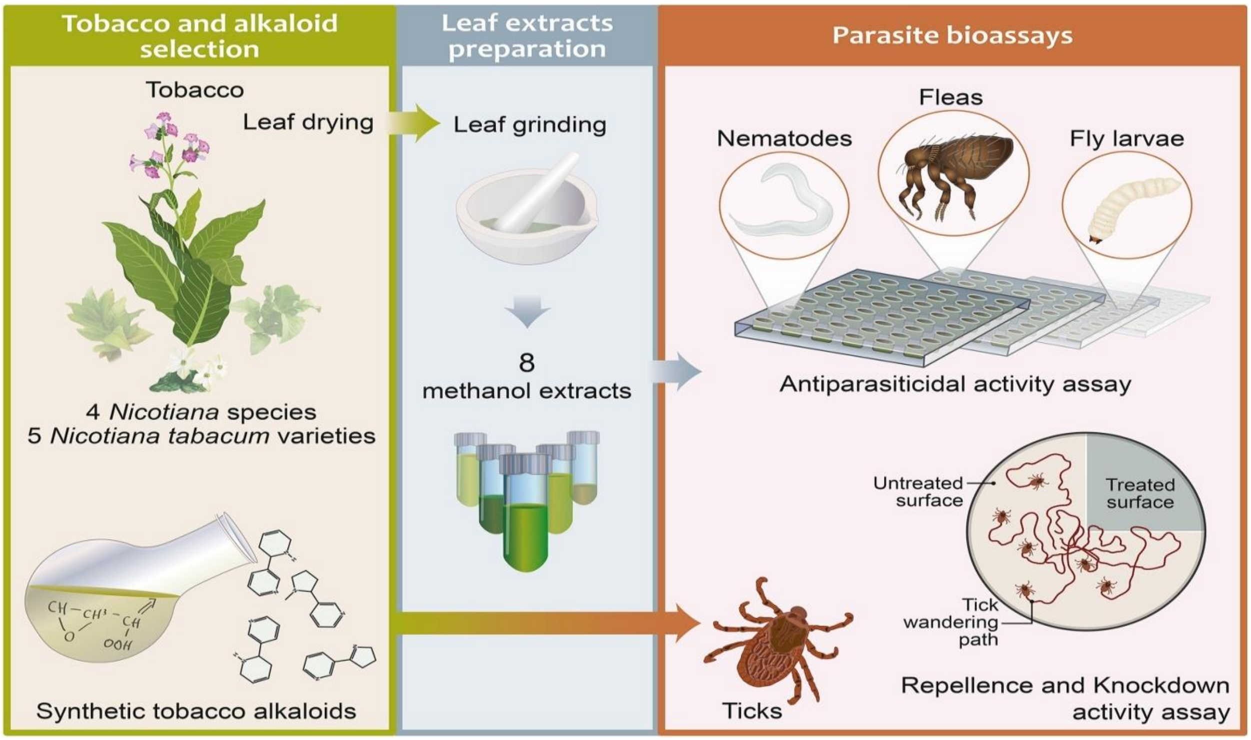
Structure: $C_{10}H_{16}N_2O_4S$



Source:

It is a fundamental alkaloid generated from tobacco, Nicotiana tabacum, which is found in a few Solanaceae plants. It has 2-8 % dried tobacco leaf content. It has 40% nicotine sulphate in it.

Mode of action: In both mammals and insects, it is a rapidly acting nerve poison. It competes with the acetylcholine receptor by binding with it and causing controlled nerve firing. The postsynaptic membrane's principal neurotransmitter, the cholinergic receptor, interacts with acetylcholine and changes the membrane permeability. The physiological systems that depend on nerve input for optimal operation are quickly rendered incapable of operating as a result of this interruption of regular nerve impulse activity. New nerve impulses are produced as a result of nicotine action, and these impulses result in convulsions and death.Neo-nicotinoids, an important new class of insecticides, are synthetic analogues or derivatives of the nicotine structure. These include, among others, imidacloprid, thiamethoxam, nitempiram, and acetamiprid.

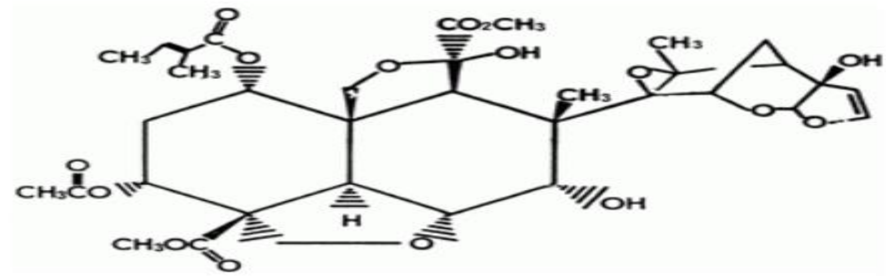


Mammalian toxicity: It is a class I (most lethal) poison in its pure form and highly poisonous to mammals. It can be fatal if inhaled or come into contact with the skin, eyes, or mucous membrane. Due to the liver's efficient detoxification, eating is less dangerous.

Symptoms of nicotine poisoning include: Nausea, vomiting, excess salt, trembling, and ultimately death from circulatory and respiratory collapse, rapid poisoning is frequently lethal. The only necessary treatment for nicotine toxicity is symptomatic and includes extended artificial breathing.

13.4.5 NEEM

Structure Azadiractin



This substance is a tetraterpenoid found in the Meliaceae family, namely in the Neem tree (*A. indica*), a native of India.

Source: It comes from the *Azadirachta indica* neem tree. On various continents, this tree can be found in arid tropical and subtropical climates. Bitter azadirachtin, its main ingredient, is both a feeding inhibitor and a growth regulator. The substance is present in the tree's bark, leaves, and fruits, although the concentration is highest in the seeds. Although this molecule hasn't been artificially created in the lab yet, pure samples of it have shown better outcomes in tests than extracts have. Salanine, meliantrol, and azadiractin are the three most notable chemicals in the extract, with the latter having the highest concentration. There are 18 different components in the extract. Numerous additional elements of neem, including as meliantriol and salannin, are also active in different ways. Numerous additional elements of neem, including as meliantriol and salannin, are also active in different ways. Its products include teas, dusts, and extracts from whole fruits, seeds, and seed kernels manufactured from leaves and bark. Its seeds can also be used to extract oil. Its oil suffocates insects and is more akin to vegetable or horticulture oil. Commercial neem preparations are available under a variety of brand names, including Neem Gold, Neemazal, Eco-neem, Neemark, Neemcure, and Azatin.

Mode of Action: It is a complex mixture of substances with biological activity. Neem is primarily effectiv e in controlling eating behaviour in insects, while it can also be a repellant, growth regulator, ovi position suppressor, sterilant, or poison.

It serves as an insect repellant and stops insects from starting to feed. Insects stop feeding while using this detergent as a feeding agent. Neem is a growth regulator that is suspected to interfere with chitin formation, disrupting normal development.

13.5 SYNTHETIC ORGANIC INSECTICIDES AND THEIR MODE OF ACTION

The synthetic insecticides have become primary agents for insect control. In general they penetrate insects readily and are poisonous to variety of species. Synthetic pesticides have negative impact on environment, health of animals and humans. Farmers heavily rely on synthetic
pesticides to control insects in their crops, and their use grew ubiquitous after World War II.
DDT was first synthetic organic insecticide in 1874.

Environmental contamination and resistance

The synthetic insecticides remain essential in modern agriculture despite their environmental drawbacks. By preventing crop losses, raising the quality of produce, and lowering the cost of farming, modern insecticides increased crop yields by as much as 50 percent in some regions of the world in the period 1945–65. They have also been important in improving the health of both humans and domestic animals; malaria, yellow fever, and typhus, among other infectious diseases, have been greatly reduced in many areas of the world through their use.

But the use of insecticides has also resulted in several serious problems:

Environmental contamination
Development of resistance in pest species.
After adversely non-target organism because of their poisonous properties. Some pesticides are persistent and when used in large quantities they permeate the environment, whereas others are short-lived or are digested by the animals they are consumed by.
When an insecticide is used, much of it enters the soil, and runoff from treated areas or direct application can contaminate groundwater. Chlorinated hydrocarbons including DDT, aldrin, dieldrin, heptachlor, and BHC are the primary pollutants in soil. They become associated with food chains. Predator birds like eagles, hawks, and falcons are

typically the most seriously impacted, and DDT's impacts have been linked to significant population decreases in these species.

Another issue with insecticides is that some target insect populations have a tendency to become resistant when susceptible members are eliminated and the resistant strains that remain proliferate, maybe eventually making up the majority of the population. Numerous synthetic organic insecticides no longer work on hundreds of kinds of dangerous insects.

Because of the problems associated with the heavy use of some chemical insecticides, current insect-control practice combines their use with biological methods in an approach called **integrated control**. In this approach, a minimal use of insecticide may be combined with the use of pest-resistant crop varieties; the use of crop-raising methods that inhibit pest proliferation; the release of organisms that are predators or parasites of the pest species; the disruption of the pest’s reproduction by the release of sterilized pests.

There are many classes of synthetic pesticides. The main groups of Synthetic Organic Insecticides consist of:

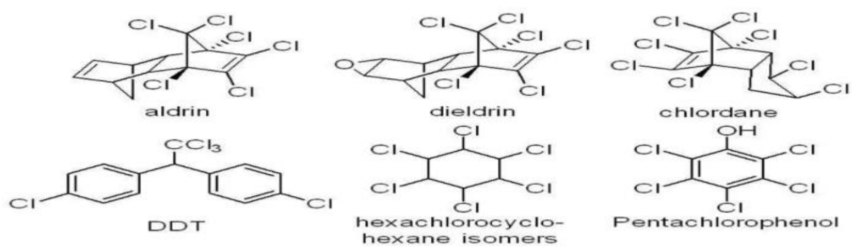
Class	**Examples**	**Area of Effect**
Organochlorines(OC)	DDT, toxaphene, dieldrin, aldrin	Reproductive, nervous, endocrine and immune system
Organophosphates (OP)	Diazinon, glyphosate, malathion	Central nervous system
Carbamates(C)	Carbofuran, aldicarb, carbaryl	Central nervous system
Pyrethroids/ Synthetic Pyrethroids (SP)	Fenpropanthrin, deltamethrin, cypermethrin	Poorly understood

Others like Neonicotinoides, Insect Growth Regulators (IGRs), Pheromones etc.

13.5.1 ORGANOCHLORINES

Structure

STRUCTURE



Organochlorines are organic molecules that contain chlorine. They were the first to be discovered as organic insecticides. DDT and its related compounds (Methoxychlor and Kelthane), BHC, Lindane, Toxaphene, and cyclodiene insecticides are included (eg. Aldrin, dieldrin, endrin, Mirex, chlordane, heptachlor, Endosulfan).

Commonly Used

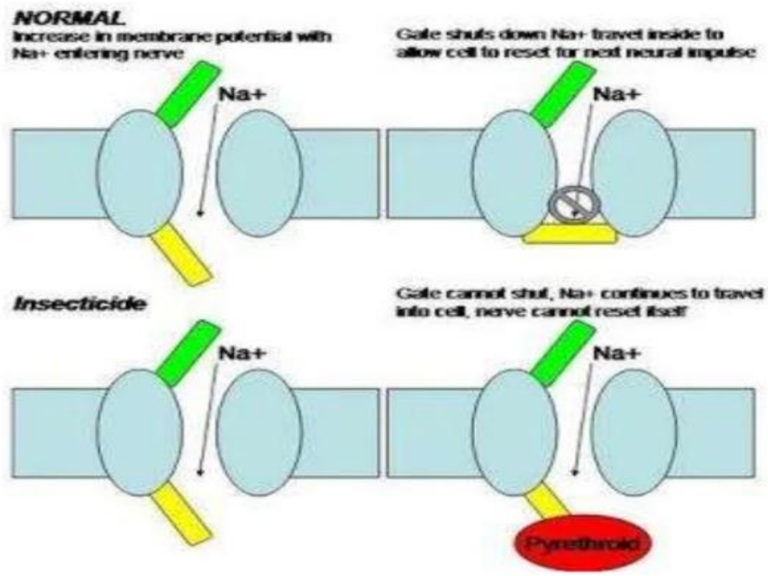
Lindane
Aldrin
Dieldrin
Chlordane
Benzene hexachloride
Endrin,
Heptachlor
Endosulfan

Banned Pesticides

DDT
Dieldrin
Chlordane
Aldrin

Mode of Action: OCs were useful in agriculture during the "Green Revolution," and they were even effective against malaria. However, their toxicity has been confirmed in birds and fish. Because of bioaccumulation, their degradation products were discovered in many ecosystems.

They have also been found in underground waters. As a result, OCs can spread far beyond the areas where they can be used. They work on insects by opening sodium ion channels in their neurons or nerve cells, causing them to fire at the same time. The insect dies as a result of a spasm.



Effect of organochlorines: They have the ability to easily bioaccumulate in biota. They increase their concentrations (biomagnifications) as they move up the food chain. Food contaminated with organochlorines enters the human body, and the effects of long-term exposure can be seen. Mutagenicity, endocrine disruption, carcinogenesis, and central nervous or peripheral disorder are the most serious health effects of OCs. Because these compounds are more soluble in fats, they accumulate in fatty tissues and concentrate in organisms at the top of the food chain in a community (bioaccumulation). Lindane is still used to control human lice, as are endosulfan and kelthane.

Harmful effects of OCs

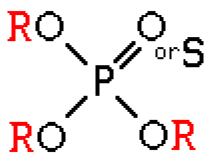
They have long half-lives ranging from months to years, and in some cases decades;

They are toxic to humans and other animals, as well as most aquatic life. Even at low concentrations, they can have serious short- and long-term consequences. Furthermore, non-lethal effects of some of these pesticides, such as immune system and reproductive damage, may be significant

They accumulate in human, plant, and animal fatty tissues. The majorities of them are drawn to fatty tissues and organs and accumulate significantly in animals like fish. This means that higher-up the food chain animals such as birds of prey and human, can accumulate higher levels of pesticides than lower-level animals.

ORGANOPHOSPHATES

Structure:



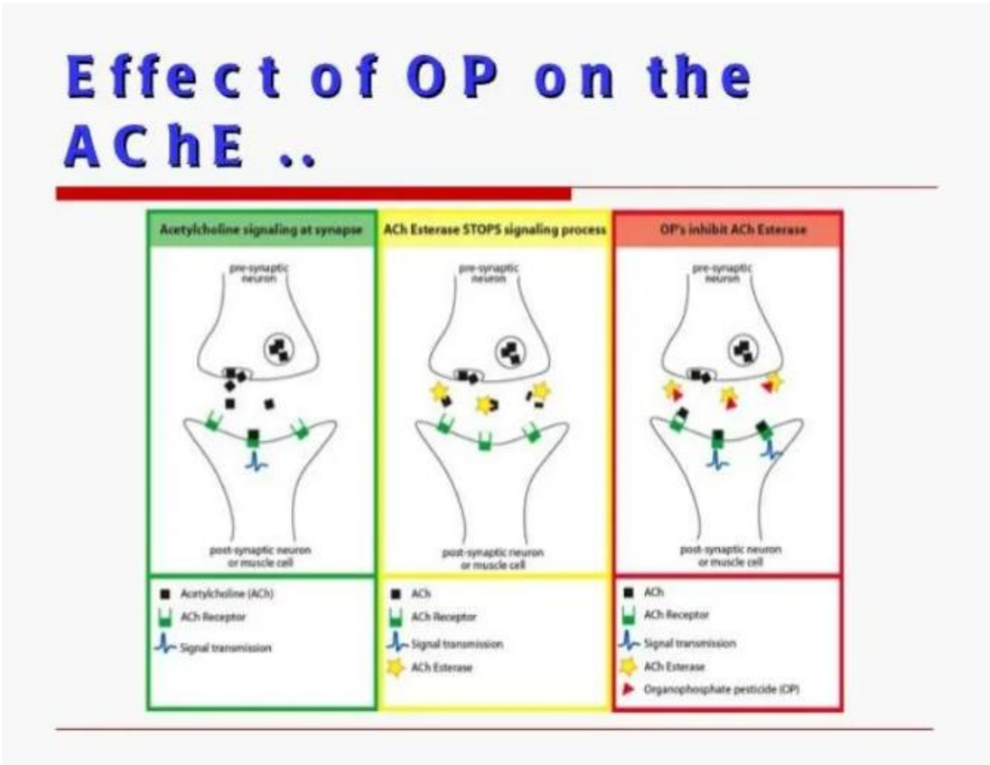
Organophosphates are the most common and versatile class of insecticides. They have a shorter half-life than OC and do not accumulate in fatty tissues. They have wide range of mammalian toxicity (e.g., Malathion, Parathion, Diazinon, Chlorphrifos, Acephate), fumigants (e.g., DDVP), and systemic insecticides are among them (dimethoate, disulfoton, ronnel).They are organic derivates of phosphorous and are nerve agents and are highly toxic.

Two widely used compounds in this class are:

Parathion
Malathion
other examples are: Diazinon, Naled, methyl parathion, and dichlorvos.
Mode of Action: They are especially effective against sucking insects that feed on plant juices, such as aphids and mites. The chemicals are absorbed into the plant by spraying the leaves or applying solutions impregnated with the chemicals to the soil, allowing intake through the roots.

Organophosphates kill insects by inhibiting the enzyme **cholinesterase**, which is required for nervous system function. These are phosphorus-containing insecticides derived from one of the phosphorous acids. Organophosphates are effective at controlling insect populations because they inhibit the nervous system's function. They have a low level of residual activity.

All these are nerve poisons. They block the site of an enzyme (**acetylcholinesterase; ACh**) that breaks down and removes acetylcholine from the nerve synapse. Normally, nerve cells in humans or insects brains or muscles send tiny electrical pulses down tendrils to the cell's end, where the pulse must jump across a gap-known as a synapse-to other nerve cells. ACh moves from one cell to the next and binds with new cells, sending the electrical pulse down the new cell. These insecticides, as well as nerve gas agents, keep the Ach from escaping from the new cell, preventing it from receiving any more impulses.



Commonly used organophosphates

Monocrotophos
Parathion
Malathion
Cholopyriphos
Phosmet
Diazinon
Methyl Parathion

Fenitrothion

Bannedorganophosphates

Chlorpyrifos : Banned in most countries but still used in India.

Diazinon: Banned in Agriculture but used in House holds

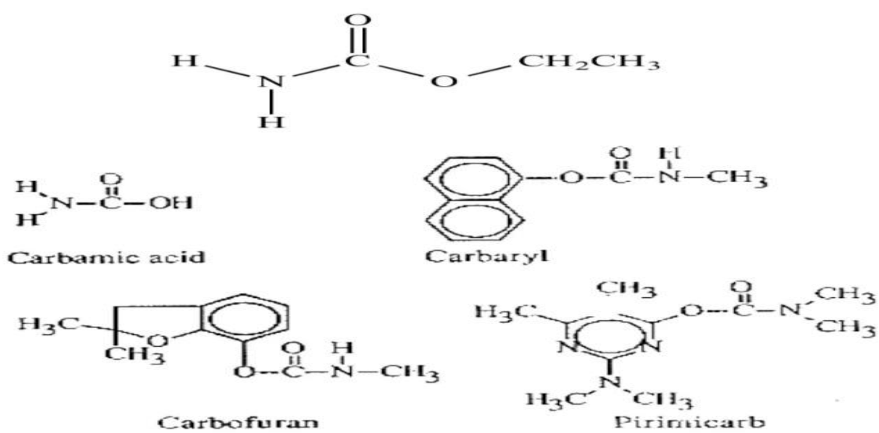
Fenitrothion: Banned in Agriculture except locust control

Parathion: Banned for used in fruit and vegetables

Monocrotophos : Banned on vegetables

CARBONATES

Structure:



The carbamates are a class of insecticides that includes carbamyl, methomyl, and carbofuran. Carbamates are insecticides made from carbamic acid. They are comparable to OPs in terms of mode of action, biodegradability, low solubility in fat, and mammalian toxicity.

Carbaryl (Sevin) is the most well-known carbamate; it is extremely toxic to humans. Carbofuran, propoxur, methomyl, oxamyl, aldicarb, methomyl, bendiocarb, and formetanate are some other carbamates. Carbonates have an advantage over organophosphates in that their inhibitory reaction with acetylcholinesterase is reversible. Chronic carbonate exposure causes less illness than chronic organophosphate exposure.

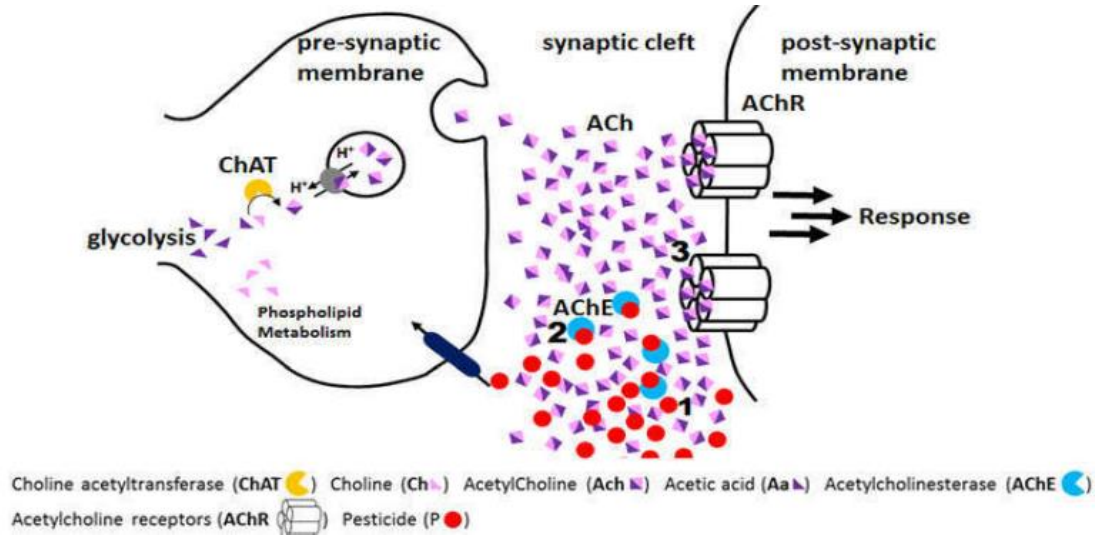
They are rapidly detoxified and eliminated from animal tissues. It is thought that their toxicity is caused by a mechanism similar to that of organophosphates. They repel insects well, but they can also be rapidly detoxified from mammalian tissues, making them less toxic to both animals and humans.

Mode of Action: Carbamates have properties similar to organophosphates, but they last in the environment for a shorter period of time. They are believed to be less toxic. Carbamates inhibit AChE by carbamoylating the serine moiety at the active site rather than phosphorylating it. Because this is a reversible type of binding, their toxicity is milder and lasts less time. Carbamates have low CNS toxicity because they do not penetrate the CNS to a great extent.

Because it is easily hydrolyzed, carbaryl is not considered a persistent compound. It is widely used in agriculture, including home gardens, where it is typically applied as a dust or solution, such as aldicarb (Temik), aminocarb (Matacil), approcarb (Baygon), carbaryl (Sevin), carbofuran, and carbofuran-based products (Furaxdan).

Neurotoxic Mode of Action of Carbamate Insecticides

The carbamates, like the OP insecticides, inhibit acetyl cholinesterase by carbamylation of the serine moiety at the active site rather than phosphorylation, with the important difference being that this is a reversible type of binding. Because the carbamylated enzyme reactivates quickly in the presence of water, the symptoms are less severe and last less time. Furthermore, because carbamates do not effectively penetrate the CNS, toxic CNS features are not prominent in the event of poisoning.



Commonly used carbamates:

Carbaryl

Methiocarb

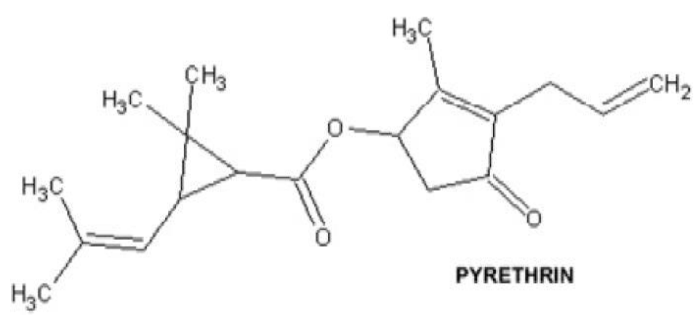
Thiodicarb

Carbofuran

Banned carbamates:

Aldicarb

PYRETHROIDS



Pyrethroid insecticides are a chemical class of active ingredients found in wide range of modern insecticides. Pyrethroids are insecticides are used to kill mosquitos and other insects. Pyrethroids have been demonstrated to be extremely safe for human health and the environment. It comes from the dried and crushed flower heads of two aster species: *Chrysanthemum cinerariifolium* and *Chrysanthemum coccineum.*

Natural pyrethrum degrades rapidly in sunlight. Pyrethrins are widely used to control pests such as mosquitoes, fleas, flies, moths, ants, and other pests. Pyrethroids are present in many commercial insecticides, including household insecticides, pet sprays, and shampoos. They typically last for one or two days in the environment. Pyrethroids are difficult for plant roots to absorb because they bind to the soil. Pyrethroids rarely enter groundwater and do not contaminate drinking water supplies.

Characteristics of pyrethroids

- Low toxicity to mammals and birds
- High toxicity for fish
- Require very low doses to kill insects
- Fast-acting
- Effective against chewing insects
- Bind tightly to soil and organic matter
- Dissolve very poorly in water.

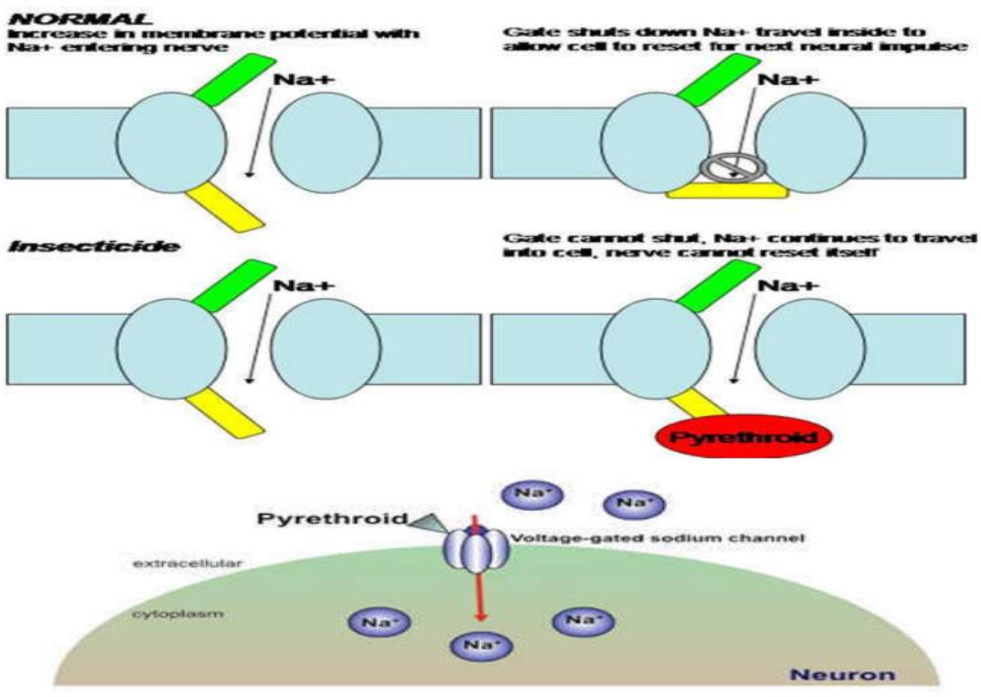
Commonly used pyrethroid:

- Allethrin
- Resmethrin
- Permethrin
- Cyfluthrin
- Esfenvalerate.

Mode of Action: Pyrethrins stimulates the nervous system of insects that touch or eat it. This quickly leads to paralysis and eventually their death. Pyrethrins are frequently mixed with other chemicals to increase their effectiveness. Pyrethrins are generally non-toxic to humans and other mammals. However, if it gets on your skin, it can be irritating. When inhaled, it has been reported to cause respiratory irritation, runny nose, coughing, difficulty breathing, vomiting, and diarrhoea. People who have been exposed to pyrethrins have reported some of the same symptoms as those associated with asthma.

Pyrethroids disrupt the voltage-gated sodium channels that keep the nerve cell membrane electrically charged in mammals. Pyrethroids bind to the sodium channel's subunit and slow the rate of activation (opening) as well as the rate of inactivation (closing), resulting in a stable hyperexcitable state. Sodium channels then open at more hyperpolarized potentials and stay open longer, allowing more sodium ions to cross the neuronal membrane and depolarize it. Based on its sign and mechanism of action Pyrethroid has been divided into two types:

Type I (T) and Type II (CS) Syndrome : Type I compounds only keep the channel open long enough to cause action potentials to fire repeatedly. Type II compounds keep the channels open for so long that the membrane potential ultimately becomes depolarized to the point at which generation of action potential is not possible. GABA gated chloride channels are also bound and inhibited by type II pyrethroids. These differences in the time of opening of sodium channels are believed to be at the basis of the differences observed between the T and CS syndromes.



Neonicotinoids

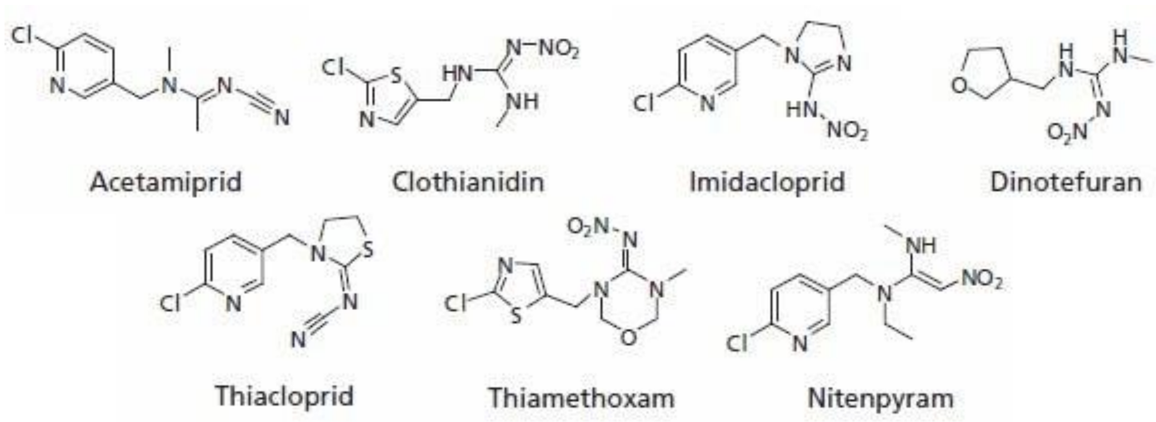


Figure 1.*Neonicotinoids*

The most important new class of synthetic insecticides is neonicotinoids. Imidacloprid, thiamethoxam, clothianidin, thiacloprid, dinotefuran, acetamiprid, nitenpyram, and sulfoxaflor are main Neonicotinoids. They are an insecticide class that is chemically related to nicotine. The neonicotinoids, like nicotine, act on specific receptors in the nerve synapse. They are much more toxic to invertebrates, like insects, than they are to mammals, birds and other higher organisms. Neonicotinoid insecticides are water soluble; they can be applied to soil and absorbed by plants.

Neonicotinoids are a type of insecticide that works by affecting the central nervous system of insects, causing paralysis and death. According to research, neonicotinoid residues accumulate in the pollen and nectar of treated plants, posing a risk to pollinators. As a result of this, and their widespread use, there is major concern that neonics play a significant role in pollinator declines. Neonicotinoids are also persistent in the environment, and when used as seed treatments, they translocate to residues in treated plants' pollen and nectar. A songbird can be killed by as few as one seed. These pesticides pollute waterways and are extremely toxic to aquatic organisms. Imidacloprid was the first neonicotinoid. It has systemic as well as contact activity against a wide range of sucking insects such as aphids, leafhoppers, and whiteflies. This product can be sprayed on plants, but it is usually more effective when applied to the soil. Dinotefuran is another highly water-soluble neonicotinoid that is particularly effective against sap-feeding insects.

List of neonicotinoid:

- Acetamiprid
- Clothianidin
- Dinotefuran

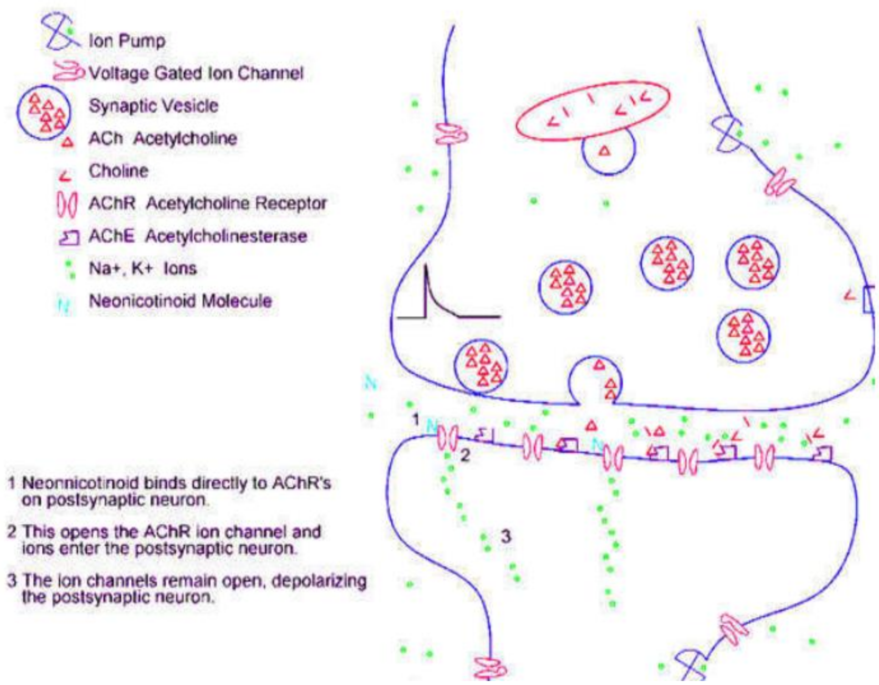
- Imidacloprid
- Nitenpyram
- Thiocloprid
- Thiamethoxam

Mode of Action: Neonicotinoids act as selective aganist at nicotinic acetylcholine receptors (nAChRs). Neurotoxicity was described for both target and non-target species (insect pollinators).Sublethal concentrations of neonicotinoids alter social bee behavior, reduce colony survival, and impair the honeybee's olfactory memory and learning capacity as well as orientation and foraging activity.

They bind to and interact with the insect nicotinic acetylcholine receptor site in insects. When neonicotinoids bind to an insect binding site, their electronegative tip, which contains a nitro or cyano group, interacts with a specific cationic subsite of the insect's receptor. Protonated nicotinoids requires a cationic interaction to bind to a mammalian receptor. These insecticides are selectively more toxic to insects than mammals.

Neurotoxic Mode of Action of Neonicotinoid Insecticides

Neonicotinoids, like nicotine, bind to or fill the nicotinic-acetylcholine receptors, preventing neural transmission. Nicotinic acetylcholine receptors are found in cells of both the central and peripheral nervous systems of mammals. Acetylcholine, a neurotransmitter, activates nicotinic acetylcholine receptors. While low to moderate activation of these receptors causes nervous stimulation, excessive activation causes paralysis and death by blocking the AchR receptors. Acetyl cholinesterase degrades acetylcholine in order to stop signals from these receptors. However, neonicotinoids cannot be broken down by acetyl cholinesterase, and their binding is irreversible.



13.6 Insect Growth Regulator (IGR)

Insect Growth Regulators (IGRs) are compounds that inhibit insect growth, development and metamorphosis. They prevent insects from reproducing. They are used as insecticide to control the population of harmful pests like cockroaches and fleas. IGRs include synthetic analogues of insect hormones like

- Ecdysoids
- Juvenoids
- Non-hormonal compounds such as precocenes (Anti JH)
- Chitin synthesis inhibitors.

Advantages:

- Effective in small quantities
- Economical
- Target specific and so safe to natural enemies: They target juvenile harmful insect populations while causing less harm to beneficial insects. IGRs do not

affect an insect's nervous system making them more friendly to "worker insects" in closed environments

- Bio-degradable, non-persistent and non-polluting
- Non-toxic to humans, animals and plants
- IGRs are also more compatible with biological pest management systems
- Insects can develop resistant to insecticides; they are less likely to develop resistance to IGRs.

Disadvantages

- Kills only certain stages of pest
- Slow mode of action
- Because they are chemicals resistance may develop
- Uncertainty in the environment

Mechanism of Action

In order to produce a new exoskeleton underneath its existing one and then shed the old one so that the new one can solidify and swell, an insect moults as it grows. IGRs stop insects from maturing by interfering with the moulting process. As a result, infestations are reduced since young insects cannot reproduce. These IGRs kill insects more slowly than conventional pesticides because they prevent an insect from moulting properly. Depending on the IGR product, the insect's life stage at the time the product is administered, and how quickly the insect develops, death normally happens within 3 to 10 days. Before some IGRs kill insects, they stop feeding.

IGRs stop insects from maturing by interfering with the moulting process. Immature insects are unable to reproduce, which lessens infestations. Because they impede the process of moulting, these IGRs kill insects more gradually than conventional insecticides. Depending on the IGR product, the insect's life stage at the time the product is administered, and the rate at which the insect develops, death occurs in 3 to 10 days. Some IGRs make insects stop feeding for a long time before they eventually perish.

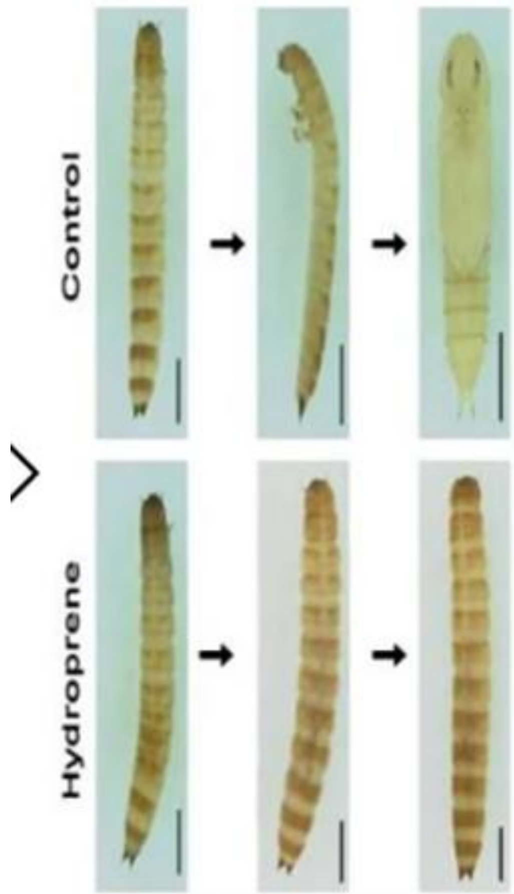
13.6.1 Juvenoids

Juvenile Hormone is also called as neotinin. It is secreted by paired glands present behind insect brain corpora allata. They keep the larva in juvenile condition. JH I, JH II, JH III and JH IV have been identified in different groups of insects. Juvenile hormone concentration decrease as larvae reaches the pupal stage. Juvenile hormone I, II and IV are found in larva and Juvenile hormone III is found in adult of insects. This hormone also helps in development of ovary in adults.

Synthetic analogues of Juvenile Hormone are called **Juvenoids**. They are hormonal insecticides. They sterilization, change the behavior of insect and disrupt diapauses and trigger dormancy.

Mode of Action:

On insect larvae, juvenoids have an anti-metamorphic impact. Insects maintain their current state (the larva remains the larva), and additional (supernumerary) moultings occur, resulting in super larva, larval-pupal, and pupal-adult intermediates, all of which result in the death of insects. Juvenoids interrupt diapause, impair insect development, and have larvicidal and ovicidal effects. As a JH mimic, methoprene is effective against hornfly larva, pests from stored tobacco, homopterans in greenhouses, red ants, and leaf-mining flies of vegetables and flowers. A high concentration of juvenilizing chemical results in the production of an intermediate larval stage or pupa.



- Some of the juvenile hormone analogs:
- Fenoxycarb (Varikill, Insegar, Logic)
- Hydroprene (Gentrol)
- Methoprene (Precor)
- Pyriproxyfen (Nyguard, Nylar, Sumilarv)

13.6.2 Ecdysoids

Ecdysoids are also called as moulting hormone. Its synthetic analogues are called Ecdysoids. Ecdysone is secreted by Prothoracic Glands. They are steroids. Moulting in insects possible because of the secretion of ecdysone. In adults its level decreased and it's almost absent. When Ecdysoids the synthetic analogue is applied in insects, is forms defective cuticle ultimately insect is killed.

13.6.3 Anti hormones

Anti JH or Precocenes obstruct JH synthesis and damage corpora allata. By preventing the generation of juvenile hormone, they counteract its effects. When applied to an insect in its juvenile stage, it skips one or two larval instars and develops into a tiny, immature adult. Early instars given an anti-juvenile hormone treatment moult into non-functional adults before they should. They are unable to reproduce and will soon pass away. Example: EMD, FMev, and PB (Piperonyl Butoxide). The fact that these chemicals are selective may make it difficult for manufacturers to create them economically.

13.6.4 Chitin inhibitors

Chitin synthesis inhibitors prevent the production of chitin, a carbohydrate necessary for the formation exoskeleton of the insect. With these inhibitors, an insect grows normally until it molts. The inhibitors prevent the new exoskeleton from properly developing, which kills the insect. Depending on the insect, death may occur quickly, or take up to several days. Inhibitors of chitin production can potentially destroy eggs by interfering with proper embryonic development. Chitin synthesis inhibitors affect insects for longer periods of time than hormonal IGRs.

Benzoylurea insecticides are among the substances.It has been discovered that benzoyl phenyl ureas can prevent chitin synthesis from occurring in living organisms by suppressing the action of the chitin synthetase enzyme. Diflubenzuron (Dimilin) and Penfluron are two significant substances in this group. Among the effects they have on insects are Moulting disruption Labrum and mandible displacement Inability to break free of the pupal skin results in death for the adult. Chitin synthesis inhibitors have been successfully used against pests of soybean, cotton, apple, fruits, vegetables, forest trees, mosquitoes, and stored grain in numerous countries where they have been approved for use.

Chitin synthesis inhibitors

Diflubenzuron (Vigilante), a benzoylurea

Triflumuron (Starycide), another benzoylurea

13.7 SUMMARY

Pest management is important component in management of the pest. Conventional chemical pesticides are harmful as they cause various environmental issues like change in soil fertility, change in aquatic food chain, health issues such as severe cancer, neurological disorders, hormonal disturbances, and reproductive issues etc. Furthermore, most synthetic pesticide are ineffective as insect develop resistance against them. Botanical pesticides are alternative of conventional pesticides. Example includes: Pyrethrins, Rotenone, Sabadilla, Nicotine and Neem. Out of this neem based pesticides are highly used in India of pest management followed by Pyrethrins.

13.8 TERMINAL QUESTIONS AND ANSWERS

Question 1: What are different botanical pesticides? Write in brief their mode of action

Question 2: How botanical pesticides differ from chemical pesticides?

Question 3: What are synthetic insecticides? Brief about their mode of action

Question 4: Write short note on formulation and insecticide toxicity.

Question 5: What are IGRs? Briefly describe some of its types.

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UNIT 14: BIOLOGICAL CONROL

CONTENTS

14.1 OBJECTIVES

After studying this module, you shall be able to learn and understand:

i. Biological control through parasites, parasitoids and predators
ii. Methods for using biocontrol agents
   - ✓ Classical biological control
   - ✓ Augmentation and inoculation techniques
   - ✓ Conservation biological control
   - ✓ Microbial control (virus, bacteria and fungi)
iii. Behavioural control through pheromones and uses of pheromones in pest management
iv. Genetic and biotechnological control
v. Insect attractants, repellents and anti-feedants

14.2 INTRODUCTION

The use of natural enemies for the control of harmful insects, other living creatures like animals and plants is known as **Biological Control**. Basically, living organisms are used to suppress pest population so that they are less damaging. Term Biological control was first used by **Smith** in 1919. It is also called as **Bio-control.** In insects it relies on predation and parasitism or other natural mechanism. It is important for Integrated Pest Management (IPM). Biological Control agents includes: Predators, parasitoids, pathogens and competitors.

There are three basic strategies for biological pest controls are:

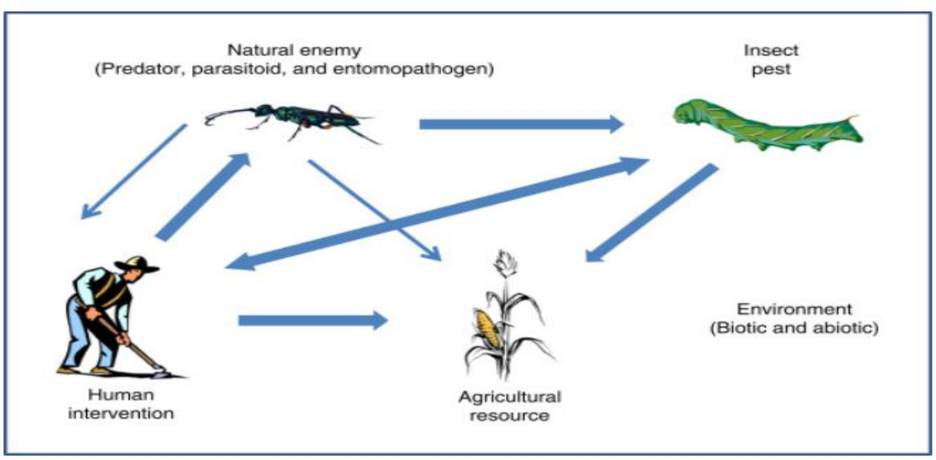
1. **Classical (Importation):** In this a natural enemy of a pest is introduced in the hope of achieving control.
2. **Inductive (Augmentation):** In which a large population of natural enemies are administered for quick pest control.
3. **Inoculative (Conservation):** In which measures are taken to maintain natural enemies through regular reestablishment.

Disadvantages of Biological control are:

- It can have side effects on biodiversity through attack on non-target species when species is introduced without thorough understanding of its consequences on biodiversity. It can also disturb natural food chain.
- It is slow process
- It is costly to start with. Lots of planning and money is required to start it.

Advantages of Biological control are:

- Due to negative use of chemical pesticide on the environment and human health there is growing need of utilizing bio-pesticides.
- No damage to the mammals and environment
- Quick action and breakdown
- Low phyto-toxicity
- Only targeted pests will be eliminated
- No problem of resistance



14.3 PARASITES

The organisms that lives and feeds on host are called parasites. Parasite obtains food and shelter from host's expense. Most of the species used in biological control kills the host and are called as

"Parasitoids". Many insects and microbial parasites are important biological control agents. Most of parasitic insects are either flies (Order Diptera) or wasps (Order Hymenoptera). Examples:

- Adult females of parasites like wasps that attack scales and whiteflies feeds and kill their host. Thus they are important biological control and causes host mortality due to parasitism.
- Water born mold-*Lagenidium giganteum* parasitizes the larval stage of mosquitoes. They infect mosquito larvae as motile spores in water. This mold is resistant to desiccation and can remain dormant for many years.
- The fungus-*Ampelomyces quisqualis* parasitizes powdery mildew fungi on several fruit crops. Likewise *Beauveria bassiana* (fungus) parasitizes many insects; *Trichoderma harzianum* (fungus) parasitize Pythium, *Rhizoctonia* and other pathogens.
- *Trichoderma* species, parasitize soil borne pathogens such as *Rhizoctonia* and *Pythium*.
- Even more interesting are soil-inhabiting fungi that trap and devour nematodes with specialized structures that resemble lollipops and lassos.
- Some bacteria's are also parasitize nematodes. For example, the bacterium *Pasteuria penetrans* attacks the root knot nematode.
- Aphelinid wasps-Aphidiinae (Subfamily-Braconidae) attack aphids.
- Trichogrammatidae parasitize insect eggs.
- Aphelinidae, Encyrtidae, Eulophidae, and Ichneumonidae parasitize insect pests.

Some more examples of parasites and their hosts are:

- ***Tachinid* flies:** Caterpillars, beetles
- ***Trichogramma* wasps:** Moth eggs
- ***Bacillus thuringiensis* (bacterium):** Butterfly/moth larvae
- ***Pseudomonas fluorescens* (bacterium):** Fungi
- **Polyhedrosis virus:** Butterfly/moth larvae
- ***Arthrobytris* (nematode-trapping fungus):** Nematodes

- ***Steinernema* (nematode):** Insect larvae

14.4 PARASITIODS

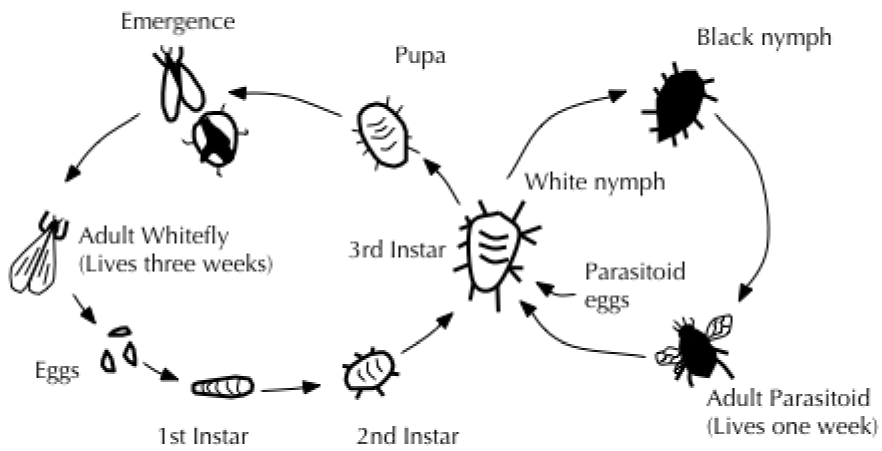
Parasitoids lay their eggs inside body of insect host. They are insects with an immature stage (mostly larvae) that develops on or in a single insect host, and ultimately kills the host. They used host cells resources for food of developing larvae. Firstly, larvae grow on fatty tissues that allows host to grow normally, as it's develops further it utilizes host cells vital organs and kill it. They are mostly patristic in immature stage but free living in adult stage. Parasitoids are mostly small flies or wasps. Few parasitoids attack one or two species and called **specialists** while other attack large number of species therefore are **generalists.** On the basis of mode of development ofparasitoids can be categorized as Endoparasitoid (internal) or Ectoparasitoid (external).

The adults are typically free-living, and may be predators. They may also feed on other resources, such as honeydew, plant nectar or pollen. Because parasitoids must be adapted to the life cycle, physiology and defenses of their hosts, they are limited in their host range, and many are highly specialized. Thus, accurate identification of the host and parasitoid species is critically important in using parasitoids for biological control. They includes mostly wasps or flies, they have narrow host range. Commercially, there are two types of rearing systems for Parasitoids:

- Short-term daily output with high production of parasitoids per day : These facilities are used seasonally
- Long-term, low daily output systems: These are used on yearlong basis

Examples:

Parasitoids	**Host**
The ichneumonid wasps	Caterpillars
The braconid wasps	Caterpillars, aphids
The chalcidoid wasps	Parasitize eggs and larvae of many insect species
Tachinid flies	Caterpillars, beetle adults and larvae, and true bugs
Encarsia formosa-Wasp (Green house horticulture)	Whiteflies; Sap-feeding Insects; First biological control agents developed
Gonatocerus ashmeadi	Glassy-winged sharpshooter
Eastern spruce budworm	Insect in fir and spruce forests



Life-cycles of greenhouse whitefly and parasitoid wasp-*Encarsia formosa*

Encarsia formosa cause wilting and black sooty moulds in glasshouse vegetable and ornamental crops.

14.5 PREDATORS

Predator is an organism that lives by feeding on another species. Insect and other arthropod predators are more often used in biological control because they feed on a smaller range of prey species, and because arthropod predators, with their shorter life cycles, may fluctuate in population density in response to changes in the density of their prey. Important insect predators include lady beetles, ground beetles, rove beetles, flower bugs and other predatory true bugs, lacewings, and hover flies. Spiders and some families of mites are also predators of insects, pest species of mites, and other arthropods. Most of the pests of crops are insects; mostly insectivorous species are used for biological control. Most of the predators attack wide range of pest species and control their population densities. Examples:

1. Lady beetles: They are predators of Aphids, they also consume mites, scales insects pear psyllamealy bugs and small caterpillars. Spotted lady beetle (*Coleomegilla maculata*) feeds on the eggs and larvae of the Colorado potato beetle (*Leptinotarsa decemlineata*).
2. Running crab spider-*Philodromus cespitum*- They are also predators of aphids, leafhoppers and pear psylla.
3. *Polistes* wasp feeds on bollworms and caterpillars of cotton plants.

4. Entomopathogenic nematodes are predators of insects and invertebrates. They generally spread in the soil and infect the insects host by entering in their hemolymph and releases their bacterial symbionts. These symbionts reproduce and release toxins and kill the host insect. Entomopathogenic nematodes have limited resistance to high temperature and dry conditions. Their effectiveness also depends upon kind of soil.
5. A microscopic nematode-*Phasmarhabditis hermaphrodita* kills slugs. Nematodes get associated with pathogenic bacteria like *Moraxella osloensis*. Nematode enters the slug through their posterior mantle but slug is killed by bacteria associated with nematode.
6. The predatory mites-*Phytoseiulus persimilis*,*Neoseilus californicus*,and *Amblyseius cucumeris*, the predatory midge *Feltiella acarisuga*,and a ladybird *Stethorus punctillum*used for control of spider mites.
7. The bug *Orius insidiosus* is used against the two-spotted spider mite and the western flower thrips (*Frankliniella occidentalis*).
8. *Aedes aegypti* –the dengue causing mosquito was controlled by community action of copepods, baby turtles and juvenile tilapia in growing water tanks.

Some more examples of predators of crops are:

Predators	Pests
Big eyed bugs	Lygus bugs, aphids, leafhoppers, spider mites
Amoebae	Soil borne fungi, bacteria
Predatory mites	Plant-feeding mites
Anthocorid bugs	Spider mites, thrips, aphids, pear psylla, young scale, various insect eggs
Mirid bugs	Spider mites, aphids, leafhoppers, pear psylla, scale insects

Some of the examples of biological control agents of insect's pests on crops

Vegetables	Insect pest	Biological control agents		
		Predators	**Parasitoids**	**Microbial agents**
Bhendi	Shoot and fruit borer	*Chrysoperla carnea, Geocoris spp. Eocanthecona furcellata. Coccinellid beetles*	*Trichogramma chilonis (egg), Tetrastichus spp. (egg), Telenomus spp. (egg), Chelonus blackburni (egg-larval) Campoletis chlorideae (larval), Goniophthalmus halli (larval), Bracon spp. (larval)*	*Ovomermis albicans, a nematode*
	White fly	*Mirid bug (Dicyphus hesperus), (Geocoris sp) etc*	*Encarsia sp, Eretmocerus sp, Chrysocharis pentheus*	
Onion	Thrips	*Aelothrips spp. Coccinellids Galendromus occidentalis, lacewings (Chrysopa spp., Chrysoperla spp.) Amblyseius cucumeris and Amblyseius barkeri. A. cucumeris (mites)*	*Ceranisus menes, Orius spp. and Anthocoris spp*	*Beauveria bassiana Metarhizium anisopliae (Fungus) Heterorhabditis indica Steinernema carpocapsae; Heterorhabditis bacteriophora*
	Maggot	*Braconid wasp Aphaereta pallipes, Staphylinid and Aleochara bilineata*		
Potato	Tuber moth	*Lacewing, red ant, ladybird beetle, spider, robber fly, dragonfly etc.*	*Chelonus blackburni, Copidosoma koehleri, Trichogramma spp., Apanteles sp., Pristomerus vulnerator*	
	Aphids	*Ladybird beetle, lacewing, spider, hover fly et*	*Lysiphlebus sp, Diaeretiella sp., Aphelinus sp., Aphidius colemani etc*	
Cabbage	Head borer	*Chrysoperla carnea, coccinellids, (Geocoris sp), pentatomid bug (Eocanthecona furcellata*	*Trichogramma spp. (egg), Bracon gelechiae (larval), B. Hebetor (larval) etc.*	*Paecylomyces spp., Zoophthora radican etc*

14.6 METHODS FOR USING BIO-CONTROL AGENTS

14.6.1 Classical biological control (Importation)

Classical biological control or Importation involves introduction of new pests natural enemies in new are to establish new permanent population. Many organisms that are not pests in their native habitat become unusually abundant after colonising new areas where their natural controls are absent. For introduction of new species to new area lots of prior research information is required about pest species such as:

- Their physiological adaptation, negative effect on native species, effect on biodiversity etc.
- Natural enemies should be quarantined to prevent their escape until research confirms that they will have little negative impact in the new country of release.
- Biological control agent should have colonizing ability to new area to keep pace with changes in habitat with and space
- Control is greatest if the agent has temporal persistence so that it can maintain its population even in the temporary absence of the target species, and if it is an opportunistic forager, enabling it to rapidly exploit a pest population.

Negative impact: If species are introduced before prior research species become serious pests themselves.

After selection of suitable pest species they are kept under quarantine condition to eliminate from any kind of pathogens or natural enemy population. Natural pest are released in field after carefully examining pest as well as natural enemies life cycle for maximum efficiency. Natural enemies are released at proper timing when the target pests are in abundant and disturbance of the newly released enemies is minimized. This is long and tedious process but results are permanent and effective. It provides long term benefits over a large area. Examples:

1. The alfalfa weevil-*Hypera postica*: It is native of Europe and became serious pest in US by 1970s. It is controlled by introduction of natural enemies. Several parasitoids introduced against the pest out of which two were more effective one species of parasitoid attack the larvae of weevil and other adult. By introduction weevil population was decreased upto 75% in small time span.

2. *Rodolia cardinalis*- the vedalia beetle for control of *Icerya purchasi* (cottony cushion scale). The vedalia beetle-a predator insect was imported from Australia to California for control of cottony cushion scale.
3. Control of*Antonina graminis* in Texas by *Neodusmetia sangwani* the beetle and a parasitoidal fly, *Cryptochaetum iceryae*
4. *Levuana iridescens*, the Levuana moths population was controlled by biological control program.
5. *Trichogramma ostriniae*-Parasitoidal wasps used as biological control agent against European corn borer (*Ostrinia nubilalis*)
6. *Alternanthera philoxeroides* (Alligator weed) was biologically controlled introducing alligator weed flea beetle in USA.
7. The giant salvinia (*Salvinia molesta*) was controlled by salvinia stem-borer moth (*Samea multiplicalis*)

14.6.2 Augmentation and inoculation techniques

Augmentation involves the supplemental release of natural enemies that occur in a specific area boosts the naturally occurring populations there. Sometimes resident natural enemies are present is lesser number in their original population, so population is augmented (supplemented) by purchasing and releasing commercially available beneficial species for biological pest control. Augmentation is used when enemy populations are lacking or unable to react to the pest population. As a result, unlike importation or conservation methods, augmentation usually does not provide permanent pest suppression. It is direct manipulation of natural enemies to increase their effectiveness.

Augmentation requires lots of research work on natural enemies, advance planning, expert biological advice, regular monitoring, optima; release time etc so that certain levels of pests and damage can be tolerated.

In inoculation small numbers of natural enemies are released but at an intervals to allow them to reproduce for long-term control to keep the pest population to low level. In contrast, in inundative release, large numbers of natural enemies are released to reduce damaging pest population. Inundative releases involve the release of a large number of a natural enemy to the point where their population completely outnumbers that of the pest.

Augmentation can be achieved by any of the two methods:

1. **Mass production and periodic colonization**: It is most commonly used approach in which natural enemies are controlled either inoculatively or inundatively. If in certain locations pest cannot overwinter, natural enemies are released in each spring to population to establish. This approach is more commercially used than others.

2. **Genetic enhancement of natural enemies**: Other ways to release genetically modified natural enemies. With the help of conventional selection techniques, it has been possible to genetically improve a number of predators and parasitoids.

Limitations:

- ✓ It is effective method but its guarantee to work is sometimes low, it depends upon interaction between pest and control agent.
- ✓ In some cases it does not provide adequate pest control. Many natural enemies feed on both pests and beneficial species and reduce the effectiveness of biological control.

Examples

1. The parasitoid wasp, *Encarsia formosa* used to suppress populations of the greenhouse whitefly, *Trialeurodes vaporariorum*: Release of low densities (inoculation) of *E. formosa* immediately after the first whiteflies are detected on a greenhouse crop can effectively prevent populations from developing to damaging levels.

2. The predatory mite *Phytoseiulus persimilis* is used for control of the two-spotted spider mite.

3. The egg parasite- *Trichogramma* released inundatively to control harmful moths. In response to the presence of pest eggs, these tiny endoparasitoids of insect eggs are rele ased in vast numbers in crops or forests.

4. *Bacillus thuringiensis* and other microbial insecticides are also used.
5. The European native, *Trichogramma brassicae* is used to suppress the European corn borer, *Ostrina nubilalis* in corn fields.
6. *Trichogramma* spp. that are inundatively released to suppress sugarcane borer.
7. Nematodes that kill insects are released to soil-dwelling insect pests.
8. *Hippodamia convergens* -the convergent lady beetle, is used for biological control of aphids.
9. Beneficial nematodes are inundatively released. They infect insect host by traveling through the soil. Inside insect they release symbiotic bacteria which kill the insect.
10. Laboratory-selected, the predatory mite, *Metaseiulus occidentalis* were commonly used in an integrated mite management.
11. *Pediobius foveolatus*, isinoculative release in the field against Mexican bean beetles; The parasitic wasp, *Edovum puttleri*, isinoculative release against the Colorado potato beetle.

14.6.3 Conservation-biological control

This is the third method of biological control. Conservation of natural enemies that are already adapted to target pest is simpler and cost effective method. In order to boost the effectiveness of the beneficial species, it is necessary to discover the factor(s) that may be limiting a specific natural enemy's effectiveness and adjust them. In this approach natural enemies are preserved by cultural, mechanical or selective chemical controls in a way that they do not harm the beneficial species. Most of the pests are attacked by multiple species so conservation can be main way of biological control for them. Conservation of natural enemies involves either, providing resources that natural enemies require in their surrounding or eliminating factors that interfere with them. Main conservation strategies include:

Pesticide Management: Use of broad spectrum pesticides sometimes leads to outbreak of secondary pests therefore it is necessary to reduce the use of broad spectrum pesticides. Most of hazardous broad spectrum pesticides include Carbamates, organophosphates, and pyrethroids that kill the natural enemies. Even low level of pesticides residues interferes with reproduction and their ability to locate and kill pests. Neonicotinoids translocate into natural enemies and honey bees that feed on nectar and pollen. Example: Spider mite population is affected by application of carbamate and organophosphate.

To prevent the long term control of the pest non-persistent pesticides provides less harm to natural enemies. These include azadirachtin, insecticidal soap, narrow-range oil (horticultural oil), neem oil, and pyrethrins.

- **Ant Control and Honeydew Producers:** This is typically done by(i)soilcultivation around ant nests (ii) encircling trunks with ant barriers of sticky material (iii) Use of insecticide baits near plants. If the population of ants is controlled natural enemies will increase in population and ultimately pest population can be reduced
- Example: Many species of ants are considered as pest because they consume the honeydew produced by insects, aphids, mealybugs, soft scales, psyllids, and whiteflies. Producers of honeydew are shielded by ants from parasites and predators that could otherwise control them.
- **Habitat Manipulation:** Various ways of habitat manipulation includes**:**

(i) Many natural enemies perform poorly if nectars producing plants are not present to supplement their diet. Planting different species of flower at different times can give regular supply of nectar, pollen, and shelter to natural enemies.

(ii) Growing diverse species of plants well adapted to local species can retain predators and parasites relationship. These plants can tolerate low populations of plant-feeding insects and mites.

(iii) Reduce dust: Dust can interfere with natural enemies and may cause outbreaks of pests such as spider mites.

(iv) Avoid excess fertilization and irrigation: It can cause phloem-feeding pests, such as aphids, to reproduce more rapidly than natural enemies can provide control.

Factors interfere with the effectiveness of a natural enemy are:

- The use of pesticides may result in the direct death of natural enemies or indirect impacts due to a decrease in the quantity or accessibility of hosts.

- A number of cultural techniques, like tillage or burning crop detritus, can destroy natural enemies or render the ecosystem unsuitable for crops. Repeated tillage in orchards can result in dust deposits on the leaves, which can kill small predators and parasites and increase the population of some insect and mite pests. Examples:

1. In Rice fields Nectar-producing crop plants are grown. These plants nectar for parasitoids and predators of plant-hopper pests and found to decrease the pest densities by 10 to 100folds.
2. Aphid’s predators are found in tussock grasses by field boundary hedges but their growth is slow. Strip of tussock grasses is planted in the centers of field enabling aphid predators to overwinter there.
3. Prune trees are planted in grape vineyards to provide an improved overwintering habitat or refuge for a key grape pest parasitoid.
4. Artificial shelters in form of caskets, boxes or flowerpots in gardens to attract natural enemies. Example: Earwigs are controlled by hanging flower pots filled with straw or wood wool; Birdhouses are attractive for nesting of insectivorous insects.
5. Periodic washing of citrus tree foliage resulted in increased biological control of California red scale, *Aonidiella aurantii*

Limitations:

- Some host-plant effects are harmful to natural enemies but to which the pest are adapted reduce the effectiveness of biological control.
- Some pests have the ability to sequester poisonous elements from their host plant and use them to defend themselves against other pests.
- The natural enemy's capacity to locate and attack hosts may be hampered by physical traits of the host plant, such as leaf hairiness.

14.6.4 Microbial control (virus, bacteria and fungi)

Insects are bio-controlled via various predators; pathogenic micro-organisms such as bacteria, fungi, and viruses. They are mostly host specific in killing natural enemies. Many insects are infected by bacteria, fungi, protozoans and viruses that cause disease. Due to these diseases growth of insect pests and reproduction slows down. Some bacteria’s have symbiotic association with nematodes that kill insects by infecting them.

Bacteria

Bacteria’s have limited use in biological control of insects they can be mainly used for control of other bacteria, fungi, aphids, viruses and scale insects. Bacteria’s infect insect’s digestive tracts. Bacteria’s are used to control growth of microorganisms in food, water and soil.

Example:

1. Bacteria’s from genera *Bacillus* is entomopathogenic and mostly used in bio-control of insects. *Bacillus thuringiensis*, a soil-dwelling bacterium is used to control Lepidopteran (moth, butterfly), Coleopteran (beetle) and Dipteran (true fly) insect pests. These bacteria’s kill the target insects by use of enterotoxins. These bacteria’s are available to organic farmers in sachets of dried spores. After mixing with water they are sprayed on plants like brassicas and fruit trees. Transgenic plants are also prepared using *B. thuringiensis*. *B. thuringiensis var israelensis* used for control of mosquito larvae and the blackfly *Simulium damnosum*. VectoBac, Bti is effective against *C. pipence* than *M. domestica*.
2. *Paenibacillus popilliae*-bacterium has been used to of Japanese beetle.
3. The bacterial pathogen- *Paenibacillus glabratella* causes high mortality insnails.
4. Bacterium-*Streptomyces avermitilies* produces toxins called “avermectins” effective against insect, Arachnida and nematode.

Fungi

Fungi are mainly used as biological control agents as they cause diseases in insects mainly they attack aphids. Fungi can be broadly classified into two categories based on their mode of action: Entomopathogenic fungi and nematopathogenic fungi.

Examples:

1. The fungus *Entomophaga maimaiga*, a pathogen of the gypsy moth. Spores of fungus germinate when gypsy moth larvae are present. Infected caterpillars carry spores for the next winter.
2. *Beauveria bassiana* is used to control insect pests such as whiteflies, thrips, aphids

and weevils.

3. *Lecanicillium* can be deployed against white flies, thrips and aphids.
4. *Metarhizium* are used against pests including beetles, locusts and other grasshoppers, Hemiptera, and spider mites.
5. *Paecilomyces fumosoroseus* is effective against white flies, thrips and aphids.
6. *Purpureocillium lilacinus* is used against root-knot nematodes
7. *Trichoderma* species against certain plant pathogens.
8. *Trichoderma viride* has been used against Dutch elm disease
9. *Synchytrium solstitiale* is being considered as a control agent of the yellow star thistle (*Centaurea solstitialis*).
10. *Metarhizium* and *Beauveria* are commonly used entomopathogenic fungi used against arthropods.

Entomopathogenic fungi: These kill arthropods like insects, ticks or mites. These fungi produce spores as the insect comes in contact with them. These spores germinate in the presence of humidity and penetrate the cuticle of insect leads to death of insect after 4 to 10 days. Some fungi produce myotoxins that kill insects. Ascomyctes with mitosporic fungi used for bio-control of insects. They provide long term control against larvae and puparia as they recycle them in the soil. Examples: *Metarhizium* and *Beauveria* are used to control mosquitoes. Fungal spores are used as odour traps on indoor house surfaces to control mosquitoes.

- *Fusarium* is able to increase dead spikes of obligate holoparasitic weed, broomrape.
- *Lagenidium giganteum* is pathogenic to larvae of certain mosquitoes.

Nematopathogenic Fungi

Those fungi that kill nematodes are called Nematopathogenic Fungi.These includes:

(i) Nematode trapping fungi: Most of fungi belong to this group. They grow hyphal elements with the host that kills the host. Example: *Arthrobotrys candida(*they have ability to reduce helminths eggs) *Drechmeria coniospora* (It is effective in destroying larval stages in Parasitic nematodes).

(ii) Endoparasitic Fungi: they infect nematode by spores. Example: *Harposporium anguillulae*

(iii) Fungal Parasite: They invade the eggs of females by vegetative hypae. Example, *Verticillium chlamydosporum*

Viruses

Viruses are useful in biological pest control. They are used to control the growth of other viruses and microorganism in food, water and soil. Examples:

- The *Lymantria dispar* multicapsid nuclear polyhedrosis virus used against spongy moth. Its larvae are killed by the viruses these disintegrating cadavers infect other larvae.
- RNA mycoviruses are used to control fungal pathogens.
- Baculovirus are widely used bio-control agents. More than 16 bio-pesticides are prepared from this group or are under development.CpGV(Cydia pomonella Granulovirus) is biopesticide against Codling moth which is pest of apples.
- Leafhopper infecting virus, HoCV-1(Homalodisca coagulate Virus-1) kills leafhopper mortality.

14.7 BEHAVIOURAL CONTROL

Most of the insects are considered as pests to crops they can be controlled by toxic pesticides or by manipulating behaviour of the pests. Behavioural control refers to pest management techniques that can manipulate and regulate pest insect populations by taking use of their natural instincts. In behavioral control large amount of sex pheromones are dispense within the crop. In this normal behavior of male is disturbed so that they cannot find the female ultimately mating in different species of insects is interfered.

14.7.1 **Types of pheromones**

Pheromones are substances secreted by insects and other animals for communication purpose. They affect the behaviour of the insects. They can be spread through air, soil, vegetables or various items. It causes specific types of specific reaction in receiving insects. These reactions include alarm signals, mating signals, mates, aggregation near food resources; warm other predators, food finding, oviposition site protection, sexual determination etc. Pheromones are target specific and required in low quantity. They also travel slowly but effective over longer distance. Examples:

- Pheromones have important role in insects mating; some moth travel upto 30 miles to female following pheromone trail.
- Beet army-worms are a serious pest in cotton. Flooding with sex-attractant pheromones in cotton field males was unable to find females for more than 100 days.
- Queen of honey bee secrete a glandular substance (a pheromone) passed to all the workers of the colony for co-ordination of all the activities of worker bees.

Benefits

- Well-suited for integrated pest management (IPM) and insecticide resistance management programs
- Ideal for use in organic fruit production
- Species specific action works on the pests you need to control
- No significant acute toxicity to mammals
- Safe to use around beneficial insects and non-target species
- Developing resistance is unlikely as it is natural to the insect's mating process

Pheromones can be sub-divided into following categories:

1.Sex-pheromones: These are types of pheromones produced for mate location and courtship. These are produced by females to attract male for mating purpose. It triggers number of behaviour pattern in other sex for mating. However, in some species they are produced by males to attract females. They are very common in insect particularly in Lepidoptera's (butterflies and moths) these pheromones are widely studied till date. In Lepidoptera sex pheromones are secreted by eversible glands on the terminal end of the female insect and released by sensory receptors of the male antennae Eg. moths. In

Coeloptera (beetles) they vary in chemical structure. In Diptera (flies and mosquitoes) these are produced by glands opening on the terminal segment of the female abdomen. They are further in males by specialized chemosensory sensilla of the niale antenna. Eg. *Bombex mori*.

2.Aggregation pheromones: These are kind of hormones produced by both the sexes. It brings both the sexes to come together for feeding and reproduction. If these are released in high concentration they may act as repellent, spacing phenomena. They can overcome host resistance by mass attack. Other function includes defence against predators. This is beneficial for mating, predation and utilization of resources in both the sexes. They are mainly produced by members of Coleopterous, collembolan, diptera, Hemisphere species. They are used against pests such as the boll weevil (*Anthonomus grandis*), the pea and bean weevil (*Sitona lineatus*).

3.Alarm pheromones: These are pheromones produced to repel and disperse other insects in their area. This cause alarm behaviour by which insects are dispersed when some predator arrives. They are mainly found in social or gregarious insects. They are more common in Aphididae and Thripidae. Honey Bees, Honey wasps, ants, termites, *Vespula squamosa* produce it when attacked by predators. To prevent incoming predator's *polistes exclamans* release alarm pheromones. They are pheromones are elaborated by the mandibular glands, anal glands, or the sting apparatus. They typically lead to flight or aggression in insects. 2-methylheptanone is alarm pheromone secreted by Dolichoderine ants with fruity odour.

4. Epideictic pheromones: These are used to mark territories in insects.In these insects lays eggs so that other insect would not enter their area. Females of some insects release the Epideictic pheromones near their eggs in fruits to signal other females in vicinity to lay eggs at other places.

5.Allochemical : These are substances secreted by insects for reasons other than food.

6.Host marking pheromones: Theses pheromones reduce the competition among insects of same species.

7.Trail pheromones: Social insects release these hormones for food trails and nests. They have low persistence and are secreted in foraging ants and termites. Ant Formica species uses formic acid as two trail marker. Trial marking pheromones isoptera (termites) consists of various substances examples hexanoic acid in Zootermopsis sp.eg Leaf cutting ants (*Atta taxana*).Some ants make their path with hydrocarbons as signal to return home. These trails serve as a guide for other ants.

8.Apneumone: It is a pheromone released by a non-living substance that causes a behavioural or physiological response that is adaptively beneficial to the receiving organism.

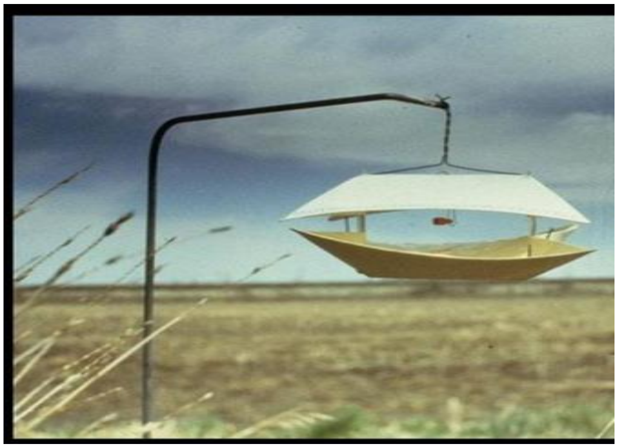
9.Synomone: A material created or acquired by an organism that, when it comes into touch with a member of another species in the wild, causes the recipient to respond behaviorally or physiologically in a way that is advantageous to both the emitter and the receiver in terms of adaptation.

14.7.2 Uses of pheromones in pest management (monitoring, mass trapping and mating disruption)

In crop management trap cropping (the process by which pests are attacked to protect valuable resources) is been used from long time. Some of the methods of pest management are enlisted below:

Monitoring Traps

Sex pheromones are widely used to monitor insect pest specificity, selectivity and abundance. Sex pheromones traps are designed to attract individuals, usually males with a sex pheromone. Traps based on pheromones are also used for monitoring. Trapping provides information that is essential in the timing of other control methods. In the case of traps, several attractants can be used like pheromones, food and attractive colours. Pheromone bait traps help detect density of both density and presence of insect pests. Food attractants are used to monitor pests such as fruit flies in horticulture. Food baits are used for attraction of insects and pests. These baits consist of brown sugar, sucrose, hydrolysed corn protein and wine vinegar. Monitoring by visual stimuli by colored trap is also possible. In this method insect are exposed to colored surface impregnated with glue. Example: Indian Meal Moths (Pantry Moths), gypsy moths, Japanese beetles are attracted to a pheromone in a small box lined with a sticky substance and are thus captured for disposal.



Pheromones bait traps

For monitoring sticky traps are placed in a field or orchard to catch them. Later on their number is monitored. Numbers of males are counted every week to monitor development of population. **Examples:** Cockroaches and Stored grain pests. Monitoring allows spatial and temporal distribution of the insect. In pest monitoring several devices such as traps can be used aiming to quantify specific insects.

Advantages

- It is efficient and economical method of pest management.
- It reduces cost and sampling time.

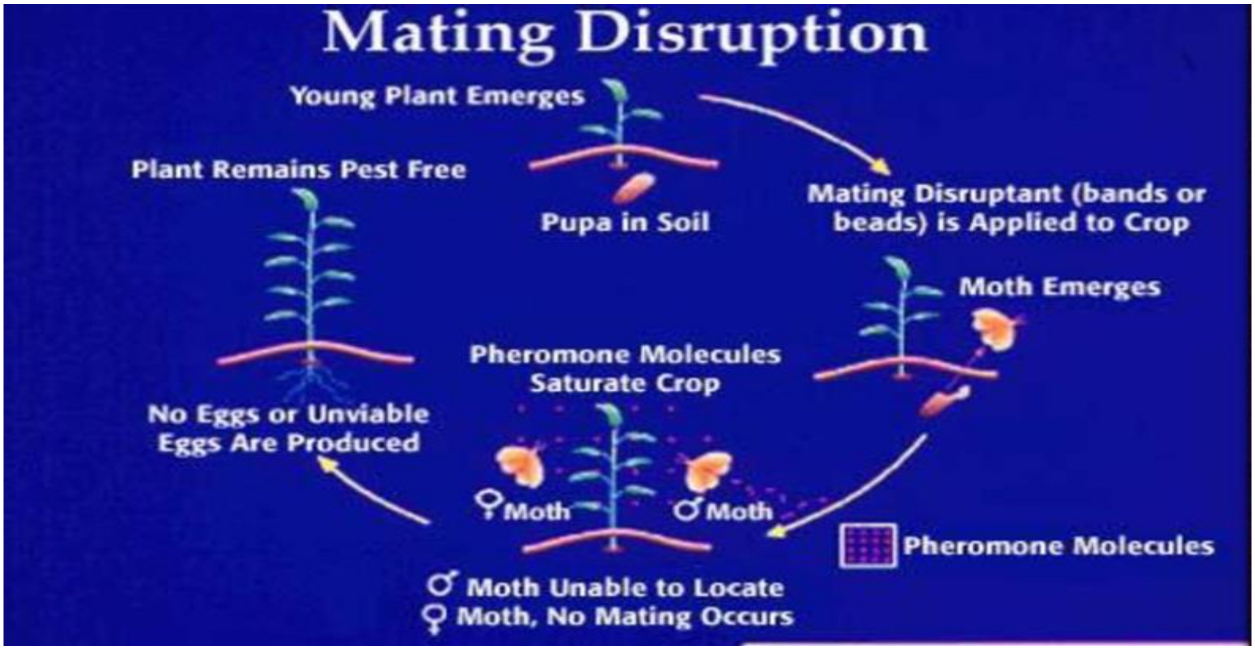
Precautions:

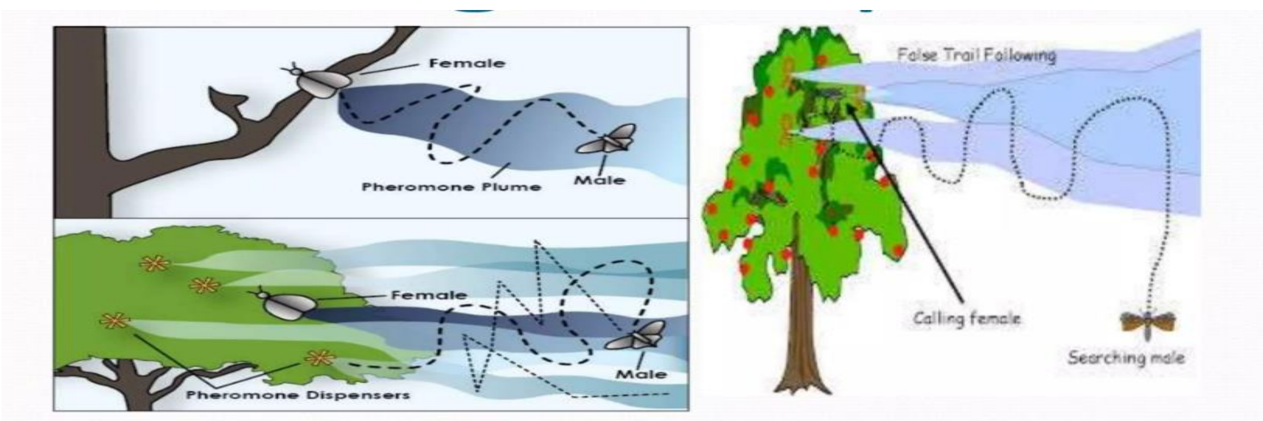
- Trap baits must be selective and selective in insect capturing.
- Trap location and its height in the field should be determined properly.
- Monitoring tools must be efficient enough to capture the target pest at low densities
- It must be low cost and easy to carry

Mating Disruption

In this males of insects are confused by filling with similar pheromones in the air, so it hinders their mating process. In presence of excessive amount of pheromones in air males are unable to locate females. In this method large amount of synthetic sex hormones are distributed in field to disturb mating.

Males are unable to find natural pheromones by females thus unable to inseminate the females. This method is also called "**Male inhibition technique**". Example: Control of Pink bollworm





Examples:

- Normally males of moth locate female by sex pheromones secreted by females. But when the location is saturated with appropriate pheromone male moth gets confused leads to mating disruption.
- Pink boll worm *Pccrinophoru gossypiellu* controlled using gossyplure

- This method is useful against orchard pests as Oriental fruit moths in peaches, codling moths, peach tree borers, lesser peachtree borers, and dogwood borers.

Advantages

- It is effective method of reducing the population of harmful insects,
- It also limit the use of insecticides
- In some cases insects are eradicated from their areas.

Limitation: Although it eradicate the primary pest but sometimes lead to outbreak of secondary pests

Mass trapping (Attract and Kill)

This method is extension of mating disruption in which insecticide is used along with pheromones. This is a technique by which large numbers of target insects are removed from the population for IPM (Integrated Pest Management). It is used to control back beetles with aggregation pheromones. **Example**: Effective against alfalfa loopers.

Mass trapping is the method to reduce the number of individuals of the next generating by using males of both the sexes of the area. It is done in combination of other method for control of pests. Example: white flies can be trapped with this method.

Advantages:

It is newly appreciated, highly effective, environmentally friendly and reasonably priced method of reducing populations of insect species that are susceptible to this approach due to pheromone communication systems and bionomical characteristics make them. In this experimental traps are placed in large number to collect large number of insects. Example: American palm weevil (*Rhynchophorus palmarum*) was collected using pheromone traps. These species damage coconut palms.

14.8 GENETIC AND BIOTECHNOLOGY CONTROL

Biotechnology and genetics are tools that is recently been used for manipulating gene of bio-control, and efforts are been made to enhance their expression in bio-control agents. Biotechnology uses biological agents or living system for manipulation of living organisms (plants and pests). For these purpose bacteria, fungi, nematodes and insects are manipulated. For example: Insects are genetically modified for advanced production of toxins (scorpion toxins, mite toxins etc.), production of metabolic enzymes to enhance production of killing substrates, virulence and host specificity. They are called as GMOs (Genetically modified organisms). They are largely being used in insect pest control in agriculture, safe for human and mostly environment friendly. Example: *Bacillus thuringiensis* which codes for insecticidal protein. In pest management biotechnology approach is broadly categories in two categories:

i. **Conventional Biotechnology**: It involves whole range of bio-agents, tissue culture techniques and bio-fertilizers. Bio agents consist of microorganisms, natural enemies, parasites and botanicals. Bioagents mostly composed of bio-agents and their secondary metabolites. To maximize their benefits these agents are used in combination. Plant tissue culture technology has also emphasised in insect pest management. It involves multiplication of disease free plants under aseptic conditions. By this technology secondary metabolites are produced and it is also helpful in disease resistant plants.

ii. **Modern biotechnology**: These involve non-transgenic or organisms that do not involve gene transfer.

With the help biotechnology bio pesticides are also being prepared, viruses are studied that act specifically on host arthropod species like agriculture pests.Encapsulted biofertlizers or nano fertilizers are also prepared by used to genetic manipulation. In recent years encapsulated bio-fertilizers or Nano-fertilizers are also found to be effective. Other important biotechnology agents are bionano agents, parasites, biopesticides etc. Baculovirus recombinants produce Bt toxins. These biopesticide have efficiency than wild type Baculovirus. Nanotechnology another field related to biotechnology is largely being used for insect pest control, plant pathogen and insects. It is highly effective and green technology. Nanoparticals are for formulation of pesticides, insecticides and insect repellents. Molecular breeding is another way in which DNA markers are employed in plant genome to analyse characteristics like genetic variability, fingerprinting, population genetics, plant breeding etc. These markers include RFLP, RAPD, SSR and SNPs. These markers are applied at seedlings stage to manipulate the traits.

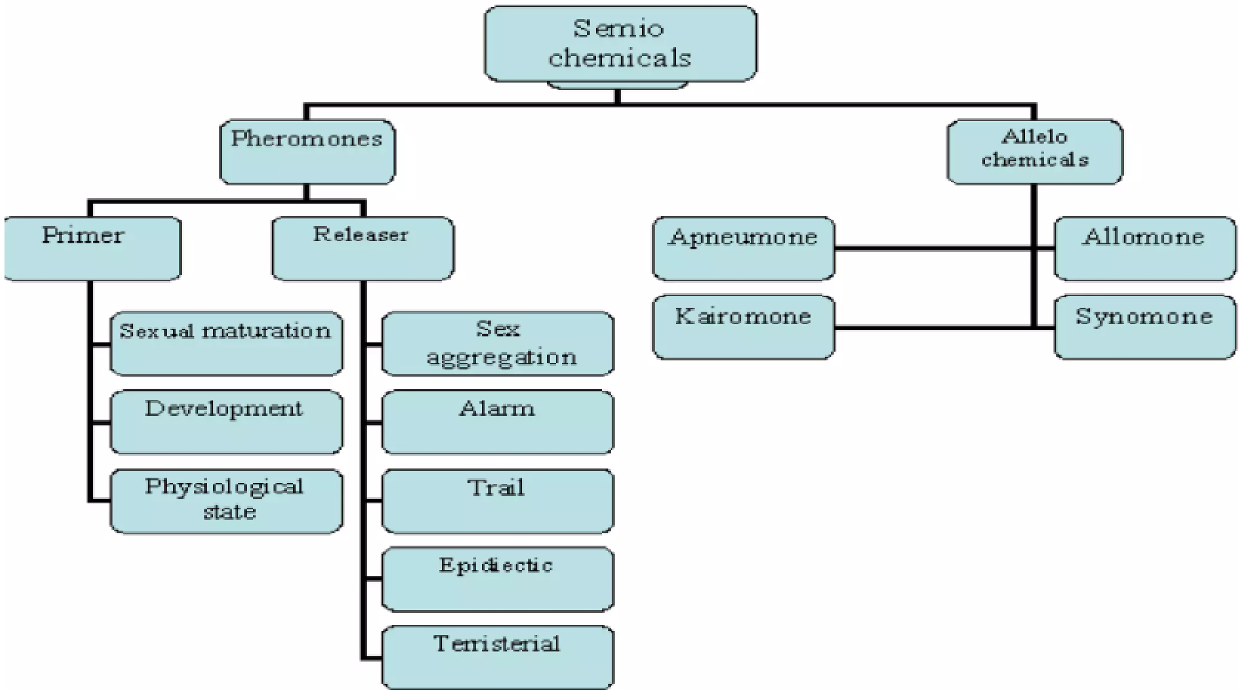
14.9 INSECT ATTRACTANTS, REPELLENTS AND ANTI FEEDANTS

Attractants

Attracts are substances used to attract in insect pest management. Attractants are active in minute quantity and changes the behaviour of the insects and help in pollution and density regulation of insects. Mostly behaviour like search for food, shelter, mating activity, aggregation, oviposition etch are manipulated.

Semiochemicals

Semiochemicals are chemicals that stimulate and use for interactions amongst organisms. These chemicals manipulate the behavirol in insects. They include intraspecific (pheromones) and interspecific (allelochemicals). They can be further divided as allomones, kairomones and pheromones. **Allomones** are inter-specific semiochemicals provide advantage to producer species. **Kairomones** provides adaptive advantage to the receiver species. They are products of secondary metabolites. They are natural chemical substances present in plants that direct the insect pest towards suitable sites of feeding. They function as olfactory stimulants, produce orientation behaviour similar to sex pheromones. The third categories include pheromones and are intra-specific semiochemicals. Please see section 14.7.1 for details about pheromones



Repellents

Repellents are chemical substances that make insects move away from food resources. They prevent insect damage to plant by portrait them unattractive and offensive. They include wide range of chemicals. Naturally occurring feeding repellents exist for many insects and are helpful in host selection and specificity.

Examples:

- Dimethyl phthalate and 2-ethyl-] -3-hexanediol; it is used as repellent against biting flies and mosquitoes
- Bordeaux mixture and tetramethylthiuram disulfide feeding detergent to foliage feeders. Bordeaux mixture consists of copper sulphate, hydrated lime, and water and used as repellent to flea beetles, leafhoppers, and potato psyllid.
- Tetra-methylthiuram disulfide repels Japanese beetle, *Popilliu japonica*
- 4- (di-methyltriazeno)-acetanilide, which is a feeding repellent used against of foliage feeding insects like the cabbage looper, the cotton leaf worm, cotton boll weevil, spotted cucumber beetle etc

- Natural repellent: 6-methoxybenzoxazolinone (6-MBOA): It provides protection to European corn borer
- Creosole or 4,6-dinitro-o-cresol: They are soil barrier against bug migration from small grain to corn
- Wood feeding insects: Some species of wood are resistant from termite attack. Example: pinasylvin monomethyl ether in pine, taxifolin in Douglas fir and P-methylanthraquinone from the Indian teak. Treating with Chlorpyrifos EC also prevent termite attack.
- Fabric eating insects: Colourless dye stuffs Eulans and Mitin FF can be firmly affixed to wool during the dyeing operation and provide protection over lifetime. Sodium aluniinunl fluosilicate is effective repellent for fabric pests

Antifeedants

Antifeedants are substances that inhibit the feeding of the insects kill them by making them starve. It inhibits feeding of insect on plant rather than keeping them away unlike repellents. They work by acting on taste receptor of the insects and inhibit their perception of the stimuli. Some of the examples of antifeedants are:

- Traiazenes (herbicides)
- Organotins (fungicides)
- Carbamates (insecticides)
- Natural antifeedant(Neem; Indian lilac, *Azudiruchtu indicu*)

14.10 SUMMARY

Many technologies and strategies are being used for control of natural enemies including large use of chemicals. But chemical method result in rising resistance and have environmental risks. Biological control is suitable alternative to chemical control it includes use of predators, parasites and pathogens. Biological control is especially effective in agriculture sector to control parasites. However, sometime bio-control agents have negative impact on biodiversity. With recent advance in genetics and biotechnology bio-control can be used in more effective ways. In this method new biological control agents are identified and older ones are genetically engineered to make them more effective against natural enemies. Thus in future this strategy will become more effective than chemical control method.

14.11 TERMINAL QUESTION AND ANSWERS

Question 1: What are pheromones? What are its different types?

Question 2: Discuss how parasites and predators are being used as biological control agents?

Question 3: What are different methods of biological control?

Question 4: Write short note about insect attractants, repellents and antifeedants?

Question 5: How pheromones are used in pest management

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UNIT 15: MULBERRY AND NON-MULBERRY SERICULTURE

CONTENTS

15.1 OBJECTIVES

After studying this module, you shall be able to learn and understand:

(i) Sericulture

(ii) Distinguish between mulberry and non-mulberry sericulture

(iii) Cultivation of Food Plants

(iv) Methods of rearing of Silkworms

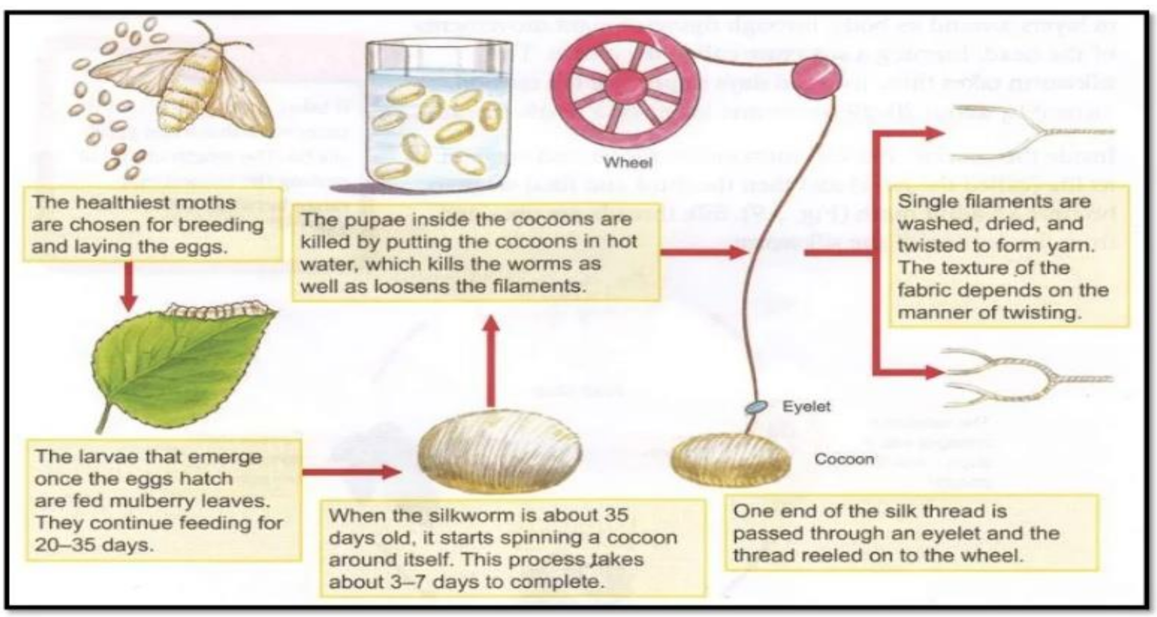
(v) Cocoon Harvesting

(vi) Diseases of Silkworm

(vii) Economic importance of sericulture

15.2 INTRODUCTION

Sericulture is the process of breeding and managing silkworms for commercial silk production. Silkworms are raised on various mulberry plant species. The silkworm is the caterpillar or larva of the domesticated silk moth, *Bombyx mori*. Silkworm rearing entails a series of events such as the collection and processing of silkworm cocoons in order to extract raw silk fibres. Raw silk is yarn made from cocoons spun by certain insect species. The main activity of sericulture is the collection of silk filaments, which provides millions of people with high-paying jobs with little capital investment.



Mulberry and Non-mulberry sericulture

There are five major commercially important types of silk. **Mulberry types** are those that are grown on Mulberries while **Non-Mulberry types** are those that are not grown on Mulberries. Non-Mulberry varieties are obtained from various species of silkworms, which feed on a variety of food plants. Other than mulberry silks, other types of silks are known as non-mulberry silks.

Types of Silkworms

- **Mulberry Type**
- **Non-Mulberry Types**
  - Tasar
  - Oak Tasar
  - Eri
  - Muga

Mulberry type

Silkworm: *Bombyx mori*

Mulberry silk is produced from the silkworm-*Bombex mori* which only consumes the leaves of the mulberry plant. The majority of silk that is sold commercially is obtained from mulberry silk. Silkworms for mulberry silk are completely domesticated and reared indoors.

Major Mulberry silk producing states in India: Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu and Jammu and Kashmir.

Non-Mulberry Silk Types

(a) Tasar silk

Silkworm:*Antheraea mylitta*

Antheraea mylitta, which feeds on the food plants Asan and Arjun, is the primary source. It is raised in the open trees under natural conditions. Its culture is primarily carried out by tribal communities in India. This copper-colored silk is used for furnishings and interiors. It lacks the lustre of mulberry silk but has its own distinct feel and appeal.

Major Mulberry silk producing states in India: Jharkhand, Chattisgarh, Orissa, Maharashtra, West Bengal and Andhra Pradesh.

(b) Oak Tasar Silk:

Silkworm: *Antheraea proyeli*

It is fine silk obtained from *Antheraea proyeli* which feeds on oak plants found in abundance in India's sub-Himalayan belt.

Major Mulberry silk producing states in India: Manipur, Himachal Pradesh, Uttar Pradesh, Assam, Meghalaya and Jammu & Kashmir. China is the major producer of oak tasar in the world.

(c) Eri/Endi or Errandi Silk

Silkworm:*Philosamia ricini*

It is made of multi-voltine silk spun from open-ended cocoons. Its silk worm is easily domesticable. *Philosamia ricini* is a parasite that feeds on castor leaves. It is also grown by tribal communities because the pupae are high in protein. Silk is used by tribals to make chaddars (wraps).

Major Mulberry silk producing states in India: The North-eastern states, Assam, Bihar, West Bengal and Orissa.

(d) Muga Silk

Silkworm: *Antheraea assamensis*

It is golden yellow silk produced by *Antheraea assamensis*, a multivoltine silkworm that feeds on the aromatic leaves of Som and Soalu plants. It is semi-domesticated varieties. Muga silk is used to make sarees, mekhalas, chaddars, and other items.

Major Mulberry silk producing states in India: Assam

15.3 CULTIVATION OF FOOD PLANTS

15.3.1 Mulberry Plant

15.3.2 Mulberry species and varieties

15.3.3 Soil and climatic conditions

15.3.4 Establishment of Mulberry Garden in First Year

15.3.5 Maintenance of Mulberry Garden

15.3.5.1 Prunning

15.3.5.2 Bio-fertilizers and micronutrients

15.3.5.3 Inter-cropping

15.3.5.4 Weed management

15.3.5.5 Harvesting

15.3.5.6 Leaf yield

Basic steps of cultivation of Mulberry plants are:

- Initially, land is selected and prepared after ploughing, levelling, manuring and so on.
- After sufficient rainfall, saplings are planted. The distance between two samplings should be 20 and 25 feet. Watering, manuring, and ploughing of the soil around the samplings are done at predetermined intervals.
- Bushes are pruned every 3-5 weeks before the start of rearing season.
- Because the plant will not have enough foliage to rear worms every year, the land has been divided into two plots.
- It is necessary to provide proper care and attention to host plants at regular intervals in order for offshoots to grow quickly and healthily. This includes ploughing, manuring, watering, and prunning.

A. Mulberry Plant

Host plant of Mulberry silkworm

Silkworm feed on mulberry treeleaves, which are highly digestible ob them. The leaves and young stems are high in protein and minerals. The leaves and young stems are high in protein and minerals. There are no anti-nutritional or toxic compounds in it. Variety, location, average temperature, solar radiation, rainfall, plant density, fertiliser application, and harvesting techniques all influence plant yield. Mulberry silkworm is a monophagous insect that only feeds on mulberry leaves; **Morin** found in the leaves attracts the silkworm.

B. Mulberry species and varieties

Classification of mulberry

- Division (Phylum): Phanerodgams (Flowering plants)

- Sub-Division (Sub-phylum): Anglosperms
- Class: Dicots
- Order: Urticales
- Family: Moracease
- Genus: Morus
- Species: *Morus alba*

Species and improved cultivars of mulberry

Important Species: *Morus alba*; *M. lavogata*; *M. bombycis*; *M. indica, Morus nigra, M. serrata, M. laevigata*

Mulberry varieties

Irrigated	:	Kanva 2, MR 2, S 30, S 36, S 54, DD (Viswa), V1
Semi irrigated	:	Kanva 2, MR 2
Rainfed	:	S 13, S 34, RFS 135, RFS 175, S 1635

Distribution:*Morus alba, M. indica. M. serrata* and *M. laevigata* grow wild in the Himalayas. For the purpose of rising silkworm, *M. indica* and *M. alba* are grown in the hilly and plain regions of India (Himalayan region). Maharastra and Meghalaya are where you can find *M. indica*. North-east and central India are home to *M. laevigata*. The Red mulberry (*Morus rubra*) is a native of North America, and the Black mulberry (*Morus nigra)* naturally grows in Western Asia and the Middle East.

Tasar silkworm

Host plants: Arjun *(Termanalia arjuna*), Asan *(Termanalia tomentosa*), Sal *(Shorea robusta*),Phutuka *(Melastoma melabathricum*), Bogori *(Zizyphus jujuba*) *Antheraea proylei* (temperate species).

Muga Silkworm

Host plants *Antheraea assama, A. knyvetty, A. compta and A. helferi, Machilus bombycina and Soalu (Litsea monopetela),* Digloti *(Litsaea salicifolia),* Mejankari *(Litsaea cubeba),* Bogori or ber *(Zizyphus jujuba),* Champa *(Michelia champaca),* Bhomloti *(Symplocous* *grandifolia),* Patihonda *(Actinodaphnae obovata),* Gamari *(Gamelina arborea)* Panchapa *(Magnolia sphenocarpa),* Katholua *(Cyclicodaphne nitida),* Gansarai *(Cinnamomum glanduliferum),* Bojramoni *(Xanthoxylum rhesta).*

Eri Silkworm

Host Plants; Eri (*Samia ricini* and *Samia Cynthia); Attacus atlas; Cricula species; Castor (Ricinus communis*) is primary food plants of Eri silkworm. Several alternative food plants areBorkesseru *(Ailanthus excels),* Barpat *(Ailanthus grandis),* Topioca *(Manihot esculanta),* Gulancha *(Plumeria acutifolia),* Gamari *(Gmelina arborea),* Payam *(Evodia flaxinifolia).*

C. Soil and climatic conditions

Mulberries can be grown upto 800 meters.

Optimum temperature range for Growth of Mulberry: 13 °C to 37.7 °C is the temperature for mulberry growth. The ideal temperature is from 24 and 28 °C with a relative humidity of 65 to 80%.

Sunshine: of 5-12h/day.

Rainfall: 600mm to 2500mm per year

Soil conditions: Plants grow in loamy to clayed loam soils. It can withstand acidic soil conditions. In the case of alkaline soils, pH below 5 can be maintained by applying Dolomite or Lime. Gypsum is sometimes added as well. Mulberry grows best in soil with a water retention capacity of 40-45%. Mulberry plants grow best in slightly acidic soils (6.2 to 6.8 pH) that are free of harmful salts. Soils that are saline or alkaline are not recommended.

D. Establishment of Mulberry Garden in First Year

(a) Nursery land preparation: InGeneral, 800 sqm area of red loamy soil is selected in the main field, to which manure is added and proper drainage is provided.

(b) Nursery Bed Preparation: It is mostly done before the arrival of the monsoon because there are a lot of seedlings available before the monsoon. Nursery can also be prepared from mature seed after the monsoon. Seeds can be directly used to raise plantations and transplant them in the field to shorten the establishment period.

(c) Bed Layout / Bed size: Choosewell-drained high land in a shady location. The soil is dug or ploughed twice or three times up to a depth of 30 cm, then properly levelled. Seed beds of a suitable size have been prepared.

(d) Pre-treatment of cuttings: In 40L of water, 1 kg of *Azospirillum* culture is added for cutting treatment.Before planting, soak the bottom end of the cutting for 30 minutes. *Azospirillum* is used to promote early rooting.

(e) **Planting and management of Nurseries:** The nursery must be irrigated every three days. By adding one kg of malathion-5 D and quinalphos-1.5 D, termite infection can be avoided.The soil is treated with carbendazim-50 WP or Trichoderma viride to prevent root rot and collar rot. Urea is added after weeding.

(f) Sapling Age: After 90-120 days of planting, the saplings are ready for transplanting in the main field.

Methods of Irrigation

It is artificial application of water to soil in order to access the crop production. It supplements the water available from rainfall and ground water.

Ridges and furrows method	Flat bed method	Drip Irrigation

• Irrigation requires less water. • During heavy rains, furrows act as drainage channels. • Water infiltrated the soil and spread throughout the root zone. It lowers evaporation losses. • A low-cost method • In clay or deep clay soils, a shadow furrow is formed along with a guiding ridge to prevent soil cracking. This type of furrow is known as a corrugated furrow.	▪ Rectangular beds and channels form ▪ Water runoff is relatively low ▪ More land is wasted ▪ More labour is required for field preparation.	▪ Reduced water loss ▪ Improved crop growth ▪ Suitable for undulating terrains ▪ Ability to apply fertilizers in addition to irrigation water ▪ Clogging of emitters by physical, chemical and biological pollutants ▪ High initial cost

Propagation of Mulberry:

Mulberry can be propagated in two ways:

(i) Sexual **(ii) Asexual**

Sexual Propagation: It is done through seedlings for this seed population is selected and hybridization is done. Seed selected for propagation should have following qualities:

(i) High quality seed
(ii) High germination rate
(iii) Seed must be collected from fully ripened fruits
(iv) Seed must not be damaged.

Merits:

- Sexual propagation introduces variability in the progeny and gives scope for selection of new varieties.

Demerits

- Comparatively long gestation period to provide leaves for silkworm rearing.
- The desirable traits of improved cultivars cannot be perpetuated.

Raising seedlings: Seedlings can be raised by sowing seed in soil directly or in polytubes.

Pre treatment of seeds and Seed dressing: Before sowing seeds are soaked in water for 20-24h and treated with Bavistin or Carbendazim.

Seed sowing: Seeds are sown in lines in the prepared beds at a spacing of 15 cm in the row and 15 cm between rows at a depth of about 2-4 cm.

Seed germination: After 30-45 days of seedling, seed germination begins. However, polyembryonate seedlings are also known to exist. Normally, one seed only produces one seedling. Twins and triplets have been seen in seedlings from polyembryonate embroys.

Transplantation of seedlings to poly tubes

1. Polythene tubes can also be used to grow the seedlings. For nursery preparation, seedling of six months old and 10 to20 cm tall is gathered. After being collected, the seeds are placed on a moist bed shaded by a tree, covered with moist gunny bags, and sprinkled with water to keep them moist. Four weeks later, the germination process begins. Daily sorting and individual sowing of the germination seeds takes place in 9 x 6 inch, 150-220 gauge polythene tubes that are filled with rooting material and maintained shaded by trees.
2. The rooting media for growing seedlings in polythene tubes is a mixture of soil, sand, and farm yard manure (FYM), in the proportions of 1:1:1.

Asexual Propagation: Vegetative plant parts are used in this type of propagation. The parent stock's inherited features can be preserved through asexual reproduction. The desired characteristics can be carried to next generation.

Three basic types of propagation are used in mulberry:

1. Cutting.
2. Grafting.
3. Budding.

The most common method of Mulberry propagation is "**cutting**." Plants can either be planted directly in the ground or they can be started in a nursery and then transplanted into the main field as sprouted and rooted saplings.

Precautions while selecting proper plant for cutting: The cutting material should have a diameter of 10-12mm and be free from insect and diseases. The mulberry plants are grown from cuttings of semi-hardwood. Cuttings are selected from well established, 8-12 months old gardens. Cutting material should have three to four active buds, be between 15 and 20cm thick and have a 45 degree slanting cut at the bottom.

Methods of Plantation:

Row System By creating ridges and furrow, the land is prepared using this technique. Between two ridges, there is a 45-60cm space. Water used for irrigation runs though the ruts between the rows, and in most cases, bush mulberries are produced and collected via bottom pruning.

Pit System: uses a greater spacing, is used for crops that are fed by rain. Instead of ploughing the entire field, standard sized pits (40×40×40 cm) are dug with 90×90 cm between plants and row for a bush type of agriculture. After mixing equal amounts of organic manure, red soil, and sand in each pit, a cutting or a sapling is planted. It is initially watered every day until it roots. The trenches are larger (45×45×45 cm) if tree-type plants are to be grown on hedges, the side of the road, etc.

E. Maintenance of Mulberry Garden

(a) **Pruning:** Afterone year of planting, mulberry tree are pruned. There are three ways to do it:

(i) **Ground/ Bottom pruning**: The plants are clipped at the ground, leaving a stump that is 10 to15 cm above the ground level. Once in a year, this kind of pruning is carried out. This kind of pruning involves cutting of branches at the stems at ground level base.

(ii) **Middle pruning**: At 40-60 cm above the ground, the branches are cut. Following bottom pruning, subsequent cuts are made at a height of 45-50 cm. Cutting bush mulberry at a height of 45-60 cm above the ground is known as middle Pruning. This approach is used in regions with lower rainfall, flood-prone fields and larger mulberry farms.

(iii) **Kolar or Strip system**: This method of trimming is done in densely planted areas. Every time, the branches are cut at ground level. As a result, it undergoes five prunings per year. It's necessary to fertilise heavily and irrigate after this kind of harsh pruning. At each harvest, the entire stalk is removed and cut to the ground. This is only appropriate in regions where mulberries sprout all year round without a latent season for bud sprouting.

(iv) **Top clipping**: This technique entails only cutting off the branch's top. It is typically practised in the winter. It offers greater benefits for growing and harvesting high-quality mulberry leaves. Since it is merely a certain branch of training, it has no impact.

Advantages:

(i) Leaf yield can be improved through pruning, and leaf production can be coordinated with silkworm rearing schedules at all times of the year.

(ii) Pruning schedules regulate mulberry branches irregular growth, preventing wasted food and energy.

(iii) Pruning should be done closer together and at a height of 3 to 8 cm above the ground in under row systems.

Various pruning techniques include: -

(a) **Fist form:** Refers to the mulberry plant being cut annually at the same location on the main stem. After a few years, the portion thickens and takes on the shape of a fist; therefore, the name. With this approach, mulberry diseases and pests are simple to control.

(b) **Non-fist form:** Pruning is carried out in such a way that 2-3 branches are permitted to sprout from the main stem (basal sections), and secondary branches also developed as a result. Resistance to disease and pest control is considerably lower using this approach.

Fertilizers and Mineral Nutrients

(a) Bio-fertilizers

- *Azospirillum*
- Phosphobacterium

(b) **Micro nutrients v**arious micro-nutrients are used depending on the symptoms of deficiency. Zinc sulphate, Ferrous sulphate, Borax, Copper sulphate, Manganese, or Sodium molybdate are a few examples.

Inter cropping

Mulberry may successfully intercrop with a variety of vegetables. The farmers benefit financially from it. The farmers may receive additional income as a result.

Advantages: Short duration pulse intercropping improves the soil, generate extra income, and inhibit weed growth.

Weed Management

Cultural method	**Mechanical method**	**Chemical method**
By using this procedure, weeds' stump roots are eliminated.	Hand hoes are used to eradicate weeds.	In this Paraquat (Grammoxone) @ 2-3 lit/ha is used. Ammonium sulphate/ litre is also used

Some of the major weed flora's are:

Botanical Name	**English name**
1. MONOCOTYLEDONOUS WEEDS (Grassy weeds)	
Cyperus rotundus	Nut grass
Cynodon dactylon	Bermuda grass
2. DICOTYLEDONOUS WEEDS (Broad leaves)	
Abutilon indicum	Velvet leaf
Amaranthus viridis	Pig weed
Acalypha indica	Copper leaf
Boerhaevia diffusa	Hog weed
Croton sparsiflorus	Croton
Parthenium hysterophorus	Carrot grass
Trianthema portulacastrum	Carpet grass
Tridax procumbens	Tridax

Mulching

The following benefits come from mulching with clipped mulberry twigs as well as other materials like straw and dry leaves.

- Controls the development of weeds
- Preserve soil moisture by decreasing run-off
- Increases water infiltration
- Lower soil temperature

Harvesting

The technique used to collect leaves is determined by the type of rearing used. The best time to collect the leaves is early in the day. Mulberry leaves can be collected using one of three techniques.

(a) **Leaf picking:** Individual leaves, with or without petiole are harvested. Leaf picking begins 10 weeks following bottom pruning, with subsequent pickings spaced 7 to 8 weeks apart.

Branch cutting: The entire branches are cut and fed to the worms. To ensure that the lower leaves mature uniformly, topping is done first.

(b) **Whole shoot harvest**: Using bottom pruning, the branches are chopped at the ground level. Shoots are harvested every 10-12 weeks, resulting in 5 to 6 harvests each year.

Time of harvest: It is preferable to harvest the leaves in the morning.

Preservation of leaves: To keep the leaves cold and fresh, cover the bamboo basket with moist gunny sacks or store them in leaf preservation chamber.

Yield of mulberry leaves: Under a row system of production, an average of 25 to 30 MT of leaves (without twigs) can be gathered annually per hectare.

15.4 REARING OF SILKWORM

Basics of Silk worm culturing:

The caterpillars are maintained in bamboo trays that also contain freshly chopped mulberry leaves.The caterpillars stop eating the leaves after about 30-40 days and then moves inside the small chambers in the bamboo trays to spin cocoons. These are produced when their salivary glands secretes the liquid protein. Small racks are given in the trays so that the cocoons can cling to them. The cocoons are where silk moth develops.

A silkworm goes through a complete metamorphosis (Holometabola). In 45-55 days, mulberry silkworm'slife cycle of completes. The stages include egg, larva, pupa and moth. The egg stage lasts for 9-10 days; the larval stage lasts for 24-28 days, the pupal stage for 8-10 days and the moth stages 3-4 days.

Life stages of Silkworm-*Bombyx mori*

1. **Egg**: A silkworm eggs weights about 2000 eggs, or one gram. The season affects the egg's size and weight. A multivoltine breed from India produces 400 eggs every laying. The outer covering of egg is called chorion. Egg oozing is referred to as microphyle.

2. **Larval Stage**: Newly hatched larvae are 3 mm long and are referred to as ANT or KEGO. The body is coated in bristles, and the head is huge. It has four pairs of tubercles i.e., sub dorsal, supra spiracular, intra spiracular and basal tubercle. It takes 20 to 24 days for it to moult. There are five phases of larval life. The fifth instar larva is produced after moulting. The mulberry leaf is the primary food source for phytophagous (plant-eating) larvae. The head, thorax, and abdomen are the three sections of the body. The thin elastic chitinous cuticle permits rapid growth of the larvae during any instar.

Distinct features based on voltinism

(a) Univoltine: The larvae have large bodies and a prolonged growing period, making them suitable for cooler climates. The quality of silk and cocoon is excellent. High temperature and high humidity are inappropriate for growth.

(b) Bivoltine: It is suitable for warmer environments. Shorter larval duration than univoltines. The quality of silk, cocoon and larva are all excellent. Moderately suited to temperature over 100 degree and extreme humidity.

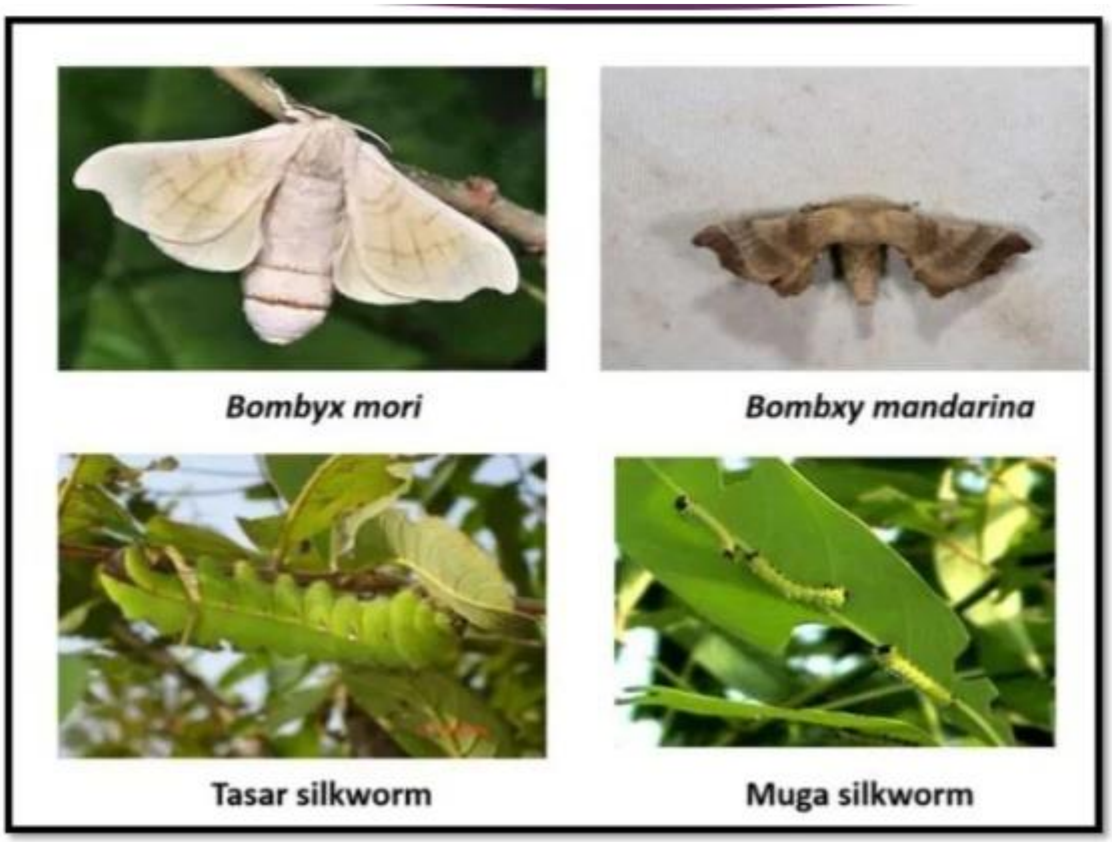
(c) **Polyvoltine:** Adaptable to warmer climates, shorter larval period, stronger larva, tiny cocoon, low silk quality. Solely produces non-hibernating eggs.

3. **Pupa:** It is encased in a cocoon. The cocoon is made up of silk fibre secreted larvae in their fifth instar. Pupa resides within the cocoon. Pupa does not move or eat. Pupa is made up the head, thorax and abdomen. The pupal stage lasts approximately 10-12 days.

4. **Adult:** The adult emerges from pupa. Adult life lasts approximately 3-5 days. The adults do not consume food. They exist solely to reproduce. They die after copulation.

Varieties of silk worms

1. Mulberry silk worm-*Bombyx mori*
2. Tasar silk worm-*Antheraea mylitta*
3. Muga silk worm-*Antheraea assama*
4. Eri silk worm *Philosamia ricini*



Life cycle of different varieties of silkworms

Life cycle: 6-8 weeks

	Egg	Larvae	Pupae	Adult
Mulberry Silkworm	Round and White Weight: 2,000 eggs is about 1.0g. Measures: 1-1.3mm in length and 0.9- 1.2mm	Pale yellowish white. Incubation period: 10 days Size: 0.3cm in length	Inactive and resting stage	Size: 2.5cm in length Pale creamy
Tasar Silkworm	Oval and dorso-ventrally flattened 150-200 eggs per laying	Incubation period: Larvae hatch in 10 days	Construction of a scaffold of silk threads between leaves of food plant and the production of stalk or penduncle which attaches the cocoon to the leaf petiole.	
Muga Silkworm	Golden brown (amber) colour of the cocoon; It is a polyphagous insect; Multi-voltine	It passes through four moults and five instar stages		Both male and female have brown, black or green coloured wings with white crescent markings and woolly white abdomen. The male is smaller than female and bear bushy antennae and narrow abdomen
Eri Silkworm	Multi-voltine			

Rearing of mulberry silkworm

Silkworm rearing is the process of raising silkworms in an ideal environment to produce silk cocoons. Rearing is done 5-6 times a year in India. The following requirements must be met for successful silkworm rearing:

• An adequate supply of mulberry leaves;

• A large number of labourers.

Rearing house: The rearing house must be a concrete structure with a wood ceiling. The house should be well-lit. Rearing devices are required. Mulberry silk worm races are classified as Uni-, Bi-, or Multivoltine based on the number of generations produced in a year under natural conditions; or as Tri-, Tetra-, and Penta moulters based on the number of moults that occur during larval growth; or as pure strain and hybrid variety based on genetic recombination. The house must be 18 feet x 12 feet x 10 feet in size, with a 3 foot balcony around the rearing house. The house should be properly ventilated to allow free air circulation inside the rearing house. To prevent house flies from entering, windows and ventilators are covered with nylon net.

Disinfection with 5% Bleaching powder

Approximately 50 g of bleaching powder is dissolved in 1 litre of water and sprayed with 2% formalin solution in the rearing house and rearing appliances three days before rearing. Close windows, doors, and ventilators to make the room airtight. Schedule of disinfection events

Order of work	**Detail of work**
After completion of previous rearing	• Disinfection of rearing house and appliances through fumigation • Disinfection of diseased larvae and melted coccon
5 days before brushing	• Appliance cleaning and washing • Appliance sun drying
3 days before brushing	Second disinfection of the rearing house and its equipments
2 days before brushing	Disinfectant dusting in front of the rearing house
1 day before brushing	Brushing preparation

Rearing appliances

- Power sprayer
- Rearing stands
- Rearing trays
- Foam pads
- Wax coated paraffin papers
- Nylon nets

- Basket for keeping leaves
- Gunny bags
- Rotary or bamboo mountages
- Chopping board
- Chopping knife
- Chop sticks
- Mats, Feather
- Feeding stand
- Mountages and drier.

Rearing Stand

- The rearing stand is used to keep the rearing trays in place.
- It is made of wood or bamboo and measures approximately 2.5m in height, 1.5m in length, and 0.65m in width.
- It has 10 to 12 shelves on which to store rearing trays.
- The four sand legs are placed on ant wells. It is full of water. It is effective in preventing ant entry.

Rearing Trays

- Silkworms are raised in rearing trays.
- The trays are constructed of bamboo or wood.
- Cowdung paste mixed with formalin is applied to the trays.
- Many silkworms can be reared in a single tray.
- On the rearing stand, the trays are stacked.
- Paraffin paper is used to cover the tray's bottom. It keeps water from evaporating. It aids in humidity regulation.
- Polythene sheets, dried banana leaves, and dried banana barks are also used in the village instead of paraffin paper.
- To maintain high humidity, foam rubber strips are also used in the trays.

- The strips are 2.5 x 2.5cm in size.
- They have been soaked in water. They are then placed around the silkworm bed.

Chop Sticks

- The two bamboo sticks are chop sticks (17.5cm).
- They have one pointed end.
- The other ends are tied together with a small thread.
- They function similarly to forceps.
- They are used to collect larvae.

Feather

Brushing newly hatched larvae from the egg card to the rearing trays is done with bird feathers. I t is also used to disperse larvae.

Leaf Basket

A bamboo basket is used to transport mulberry leaves from the field to the rearing house.

Leaf Chamber

- Leaf chamber is constructed of wooden reepers.
- The mulberry leaves are stored in this chamber, which is closed on the sides and bottom.
- To keep the mulberry leaves fresh, wet gunny bags are placed on the leaf chamber.

Chopping Board

A chopping board is a rectangular mulberry board used for cutting leaves made of wood.

Chopping Knife

A chopping knife is a sickle-shaped knife with a sharp blade that is used to cut leaves.

Mats

- Mats are used to collect cut leaves and are placed beneath the chopping board.
- Newspapers can be used as well.

Feeding Stand: A feeding stand is a stand on which trays are placed after being removed from the stand in order to feed and perform other tasks.

Cleaning Net: The bed is cleaned with a nylon net. The net is draped across the tray. The net is covered with fresh chopped leaves. Worms from the tray crawl through the net meshes and feed on the fresh leaves. The net is removed, and the worms are moved to a new tray. The old tray has been removed.

House: Any well-ventilated building or thatch can be used to rear the worms, but mud-walled thatched houses are the best because they are cool in the summer and warm in the winter. During the summer, water can be sprinkled inside the thatch to keep it cool. For proper silkworm growth and development, the temperature inside the house should be kept between 70° and 75° F, with a similar percentage of humidity.

Mountage

- Mountage is a device that assists silkworms in spinning the cocoon.
- It is also known as cocoon age.
- Mountages of various types are used in India.
- It is the most important tool in silkworm rearing.
- It influences the quantity and quality of good cocoons.
- The mountages are constructed from wood, bamboo, plastic, grass, dry leaves, and twigs.

Incubation and brushing

Eggs are laid in a single layer on paraffin paper on a bamboo tray for rearing. The room temperature is kept between 25 and 26 degrees Celsius, and the relative humidity is kept at 80%. Wrap the eggs in tissue paper and place them in a black painted box or cover with black cloths or papers for 1-2 days after the blue pinhead appears. The next day, place the eggs in diffused sunlight or shade.

Brushing of newly hatched worms

Transfer the newly hatched worm to a paraffin coated paper kept on a rearing tray using a soft br ush or feather. Tender leaves can be fed to the worms.

Chawki Rearing

Silk worms go through five instars from hatching to full-grown, and the worms up to stage two are known as young age worms or chawki. Chawki rearing involves carefully transferring newly hatched larvae onto chopped succulent mulberry leaves. During the first instar stage, feed 3-4 times with tender leaves of cut piece of size 0.5-2cm. During the second stage, cut the leaf into 2-4 cm pieces and feed 3-4 times. To achieve the best possible results in rearing, the size of the leaves and the spacing of the rearing bed are strictly maintained. Care is provided until the third instar. Maintain a temperature of 27-28 degrees Celsius and a relative humidity of 80-90%. Prior to moulting, reduce the thickness of the bed. Stop feeding and apply slaked lime to the worms when 97% of them have settled for moulting. Remove the paraffin paper and foam pad during moult.

Methods of late age rearing

Various methods are used to rear mature silkworms. Rearing of late age worms begins from third instar. These worms are voracious eaters. Maintain the rearing / feeding room temperature at 25-26 °C and relative humidity at 65-70%. Only use mulberry leaf from plants that are at least 60 days old. Feed the silk worm four times. Transfer the worm to a larger number of trays, keeping the density of the worm at 60-70 larvae per square foot. Clean the bed three times during the third instar and daily during the fourth and fifth instars using a bed cleaning net. Replace the paraffin papers with clean newsprint. Allows for cross ventilation.

The silkworm rearing can be of 3 types:

(1) **Tray rearing,**

(2) Floor rearing

(3) Shoot rearing.

The last three stages of silkworm rearing will be carried out using mulberry shoots rather than individual leaves in this method. This is the most cost-effective method of rearing because it saves approximately 40% of rearing labour. Other benefits include:

- Less handling of silkworms reduces contamination and disease spread.
- Because worms and leaves are separated from faeces, secondary contamination is reduced.
- Keeping the environment clean.

- Improved leaf quality preservation during storage and on the bed.
- Improved aeration in the bed.
- Improved cocoon quality and larvae survival.
- Lower non-recurring expenses.

Mounting and Harvesting

Select fully mature worms for moulting. Mount 40-45 worms per sqft. Rotary mounting is ideal for easy self-installation and improved cocoon quality. Remove any diseased or dead worms. Maintain a temperature of 27-28 °C and a relative humidity of 60-70%. Aeration should be used to remove excess moisture. Avoid direct sunlight. On the fifth day of mounting, harvest the cocoons.

Tasar Silkworm rearing:

Silkworm Tasar *Antheraea mylitta* D is a polyphagous insect that is raised outside.

Eri Silkworm rearing: Eri silkworm are naturally multivoltine. It can reproduce 4-5 times per year.

Feeding: Four-five feedings per day at regular intervals are recommended.

Muga Silkworm rearing: It is rear in outdoor on tree. One tree can be used for two rearings in a year, alternately during spring and autumn, yielding 1000 cocoons in a year and 5 trees are required to produce 5000 cocoons yielding one kg of muga silk. Muga silkworm is a semi-domesticated, multi-voltine species with 5 to 6 generations per year.

15.5 Harvesting and Processing of Cocoons

When placed in the mountage, the mature larva will spin a cocoon by ejecting a silk filament from its silk gland through an opening (spinneret). In nature, silk filament is a protein that hardens when exposed to air. It takes 3-4 days for a mature silkworm larva to spin a cocoon. Metamorphosis occurs after complete silk ejection and cocoon formation, and the larva transforms into a pupa. There is a pre-pupal stage in between. This transition period is extremely delicate. Within ten days, the pupa metamorphoses again and emerges as a moth by piercing the cocoon.

Time of Harvest:

The gathering and collection of produced cocoons from a spinning tray or mountage. It takes about 5-6 days to complete spinning and metamorphosis. While harvesting, keep in mind that the process is faster in the summer and slower in the cooler months. The cocoons can be harvested after pupation when the pupa's integument turns brown and hard on the fifth day. Premature cocoon collection or harvesting may result in the loss of silk content due to incomplete spinning or the death of the delicate pre-pupa or pupa within the cocoons. To avoid this, harvest cocoons on the sixth day after completing the full five days of mounting, beginning with the last day of mounting. The pupa will be hard and the cocoon shell dry. This condition will allow for the safe handling and transportation of the cocoon. Even after spinning is completed, cocoons release moisture. Cocoons will lose weight if harvesting is delayed. As a result, you should stick to harvest season.

Method of Harvest

The harvesting of silk cocoons differs depending on the mountage (spinning tray) used. Remove litters and leftovers of leaves, dead or un-spun larva, naked pupa (without cocoon), flimsy and melted cocoons from the mountage first. Flimsy and melted cocoons may stain the good cocoons. Spiral bamboo mountage (Chandrika) is most commonly used in India. Chandrika cocoons are harvested by hand. Harvesting in plastic collapsible mountages is done by hand picking. Harvesting by hand is difficult and time consuming in the rotary card board mountages. A wooden harvester can be used for quick harvesting.

Mounting and Spinning

Process of ripening of worms:

- Toward the end of the fifth stage, the silkworm stops eating and transforms into a mature larva, at which point it begins spinning the cocoon. When properly reared worms reach maturity, they will attempt to spin good cocoons even in unfavourable conditions.
- The rearer can only receive this reward for his efforts if he works with the worm to create conditions in which it can most efficiently protect itself by spinning a commercially good

cocoon. This collaboration entails providing the ripe silkworm with suitable mountages to aid in the spinning of good cocoons.

- The eating period during the fifth stage may last five to seven days for multivoltine and bivoltine races in tropical areas and seven to nine days for bivoltine and univoltine races in subtropical areas. The translucent colour of the mature worm easily distinguishes it. The body also shrinks in length, with a visible constriction at the fourth and fifth segments. The worm loses its appetite and begins to look around for a suitable location to attach itself.
- In general, ripening worms move to the periphery of the rearing trays in search of anchorage to begin cocoon spinning. This is the season for picking ripe worms and mounting them. This is referred to as 'mounting.'
- If the worms are mounted before they are fully mature, they will move around and occasionally fall off, and they will also defecate in the cocoon age, soiling and lowering the value of the cocoons that other worms are spinning. Worm cocoons that are mounted too soon will be smaller and inferior. It is therefore critical that the rearer has the required number of mountages on hand and that the worms are mounted when they are fully mature.

Process of Spinning: As the mature worms are mounted on the mountages, they expel the last semi-solid excreta. Excess body moisture is eliminated as liquid urine at the time of mounting during rains when the humidity is high.

- Following defecation, the worm begins spinning the cocoon. It first anchors itself to the mountage by oozing a tiny droplet of the silk fluid, which immediately hardens and sticks to the mountage.
- The silkworm then draws silk fluid from the two silk glands on either side of its body by swinging the anterior part of its body continuously. Silk fluid is excreted in minute amounts, hardening to form the long continuous silk filament.
- At first, the worm spins a loose hammock, which provides it with the necessary foothold to begin spinning the cocoon itself. The filament is spun into the shape of or, with the former being more common in the outer layers of cocoon shells and the latter being more common in the middle and inner layers. Layers upon layers of filament are laid in this manner to form the Cocoon's compact shell.

- Once the cocoon's compact shell has formed, the shrinking larva wraps itself in a gossamer layer and detaches itself from the shell to transform into a pupa or chrysalis. This last layer is only a worm's body sheath and does not form part of the main shell, so it, like the floss layer, is not reelable. The process of spinning the cocoon by the worms takes 1 to 2 days for multivoltines and 2 to 3 days for uni/bivoltine worms.

Mounting of worms:

- The most common type of mountage is "chandrike." It is also possible to eliminate diseased larvae using this method, resulting in a reasonable degree of cocoon uniformity.
- The "branch method" involves placing branches with green leaves over the rearing bed and shaking them off over a mat to dislodge the worms, which are then collected and placed on the mountages.
- In the "net method," a net is spread on the bed after feeding, and mature worms that no longer feed will come up and crawl on to the net, which is then removed and shaken off the net over a mat, as in the case of branching.
- In the shoot rearing method, larvae that mature early, accounting for 10 to 20% of the total larvae, can be picked by hand as they ripen.

Methods of free mounting: There is no hand picking of ripe worms in this process. The mountages, which are made of straw in this case, are placed directly over the trays containing the ripening worms. The mature worms crawl onto the mountages and begin to spin cocoons.

Care during Moulting

- Maintain good ventilation and a dry environment in the rearing house during the moulting period.
- Gently spread the bed soon after the worms settle for moult and apply slaked lime powder evenly over the bed to ensure drying.
- Avoid extreme temperature and humidity fluctuations, as well as strong winds and bright light.
- Restart feeding when 95% of the worms have arrived.

Care during spinning:

- Worms require attention during cocoon spinning because the quality of cocoons is greatly influenced by the environmental conditions that exist when the worms are on the mountages.
- In general, worms require a slightly higher temperature during spinning than during rearing; however, too high a temperature is to be avoided as it will force the worms to spin in haste, wasting a lot of silk.
- Ventilation is an important consideration because there is a lot of moisture to get rid of, as well as a lot of excreta-solid, liquid, and gaseous. Inadequate ventilation will harm the health of the worms and the quality of the cocoons, as well as produce the worst damp effects.

Harvesting and deflossing the cocoons are as follows:

(a) **Cocoon Harvester**: This device is made of iron or wood. It is made up of two parts and is used to collect cocoons from rotary mountages. Cardboard mountages are inserted into the wooden frame, and cocoons are pushed out with a pusher the same size as the mountage's holes.

(b) **Cocoon Deflosser**: For quick deflossing of cocoons, hand-operated and motorised cocoon deflossing machines of varying capacities are available. Cocoons are spread in trays with a maximum of two layers of cocoons after harvesting. Heaping cocoons may cause moisture and heat to accumulate, resulting in cocoon melting.

Deflossing

Floss is a soft and loose layer of silk filaments that covers the cocoons after harvesting. Deflossing is the removal of the flossy layer from the cocoon. Deflossing is required before silk extraction (Reeling). Brushing is used to remove floss during the reeling process. Some reelable silk is also wasted during this process. Deflossed cocoons reduce losses during reeling. Cocoons used for egg production are also deflossed to assess quality and facilitate moth emergence. Manual deflossing is also possible, but it is time consuming and labour intensive.

Cocoons sorting:

After deflossing, the majority of the cocoons have a specific shape and size because shape and size are inherited racial or genetic characteristics, and there are some odd shaped and defective cocoons. Sorting of cocoons refers to the removal of odd-shaped and defective cocoons from lots. Defective cocoons have an impact on reeling performance and silk quality. To achieve the best results during reeling, unsuitable cocoons must be separated from the good cocoons. The cocoons are classified as follows:

a) Good

b) Double

c) Uzi pierced

d) Flimsy or thin shelled

e) Melted or stained

f) Thin-end cocoons.

Sorting will improve the image and marketability of the product. Reelers always prefer a lot of uniform shape. A consistent shape improves reeling performance and silk quality. Among the sorted out cocoons, you will find the following defective cocoons:

1.Melted and Stained Cocoons: Melting or inner soiling occurs when spinning larvae or pupae die inside the cocoon during spinning or transportation. Sometimes the inner melted material oozes out, staining the cocoon. Urination may also cause cocoon staining.

2. **Flimsy or Thin Shelled Cocoons**: Silkworms that were weak or malnourished spun looser, less compact cocoons. These develop flimsy or thin shells. These cocoons have a low reelability.

3. **Deformed Cocoons**: Deformed cocoons are caused by weak larvae or improper mounting. These cocoons have an impact on the reelability and quality of raw silk.

4. **Thin-end Cocoons**: Thin end cocoons may be caused by the genetic characteristics of the silkworm races or by improper rearing and spinning conditions. These cocoons have an impact on reeling performance.

5. **Pierced Cocoons**: Cocoons may be pierced by the emergence of parasitic Uzi fly maggots or the emergence of the silkworm moth. These are not appropriate for reeling.

6. Double Cocoons: Double cocoons are unusually large, usually oval in shape, and contain two or more pupae. This could be due to genetics or overcrowding in the mountage. Improper mounting also results in double cocoons. In these cocoons, two or more filaments are entangled. Although these cocoons cannot be reeled normally, they can be reeled into a special type of silk known as 'dupion.'

Cocoons Assessment

Following points/ characters are generally considered to assess the cocoons in fixing the price.

1. **Cocoon Weight**: The weight of the cocoons gradually decreases as a result of moisture loss and fat consumption until the pupa transforms into a moth and emerges. Defloss, sort, and weigh the good cocoons immediately after harvest.
2. **Assessment of Cocoons for Defective Cocoon Percentage**: Sort out defective cocoons such as double, flimsy, melted, pierced, and so on. Separately count and weigh good and defective cocoons. The following formula can be used to calculate the percentage of defective cocoons: 100 wt. cocoon taken 1 kg/wt. defective in 1 kg
3. **Rendita**: It denotes the number of green (fresh) cocoons required to produce one kilogramme of raw silk. If a lot requires 10 kg of green (fresh) cocoon to produce 1 kg raw silk, the lot's Rendita is 10. It is an indicator of the cocoon's price fixation when purchased for reeling.
4. **Shell ratio** (%):It denotes the amount of silk shell expressed as a percentage of cocoon weight. This value indicates the amount of raw silk that can be reeled from a large number of fresh cocoons. It is used to estimate Rendita and, as a result, aids in price fixing.
5. **Stifling** Stifling is the process of killing pupa inside a cocoon. For further processing, good-sized cocoons 8-10 days old are chosen. Stifling is accomplished by exposing the cocoon to hot water, steam, dry heat, sun exposure, or fumigation.
6. **Reeling:** Reeling is the process of removing the threads from a dead cocoon. The cocoons are first cooked in hot water at 95-97 °C for 10-15 minutes to soften the adhesion of silk threads among themselves, loosen the threads so they can separate freely, and facilitate silk thread unbinding. This is known as cooking. Cooking softens the sericin protein, allowing for easy unwinding without breaks. The cocoons are then reeled in hot water using a suitable machine. Four or five free ends of cocoon thread are threaded through eyelets and guides, twisted into one thread, and wound around a large wheel. The twisting is accomplished through the use of croissure. The silk fibre separates when the cocoons are exposed to sunlight, steam, or are boiled. Reeling of the silk is the process of extracting silk threads from cocoons for use as silk fabric. Special machines are used to reel in the silk. These machines separate the silk fibres or threads from the cocoon.

Finally, the silk is transferred to spools, and the silk obtained on the spool is known as Raw Silk or Reeled Silk. The raw silk is then boiled, stretched, and purified by acid or fermentation before being washed several times to bring out the lustre. Raw Silk or Reeled Silk is finished into skeins and trading books. The outer waste layer or damaged cocoons and threads are separated, teased, and spun into filaments. This is known as Spun Silk.

15.6 GENETIC IMPROVEMENT OF SILKWORMS

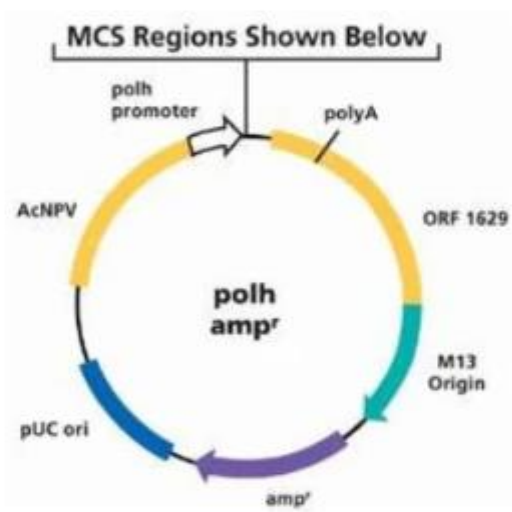
The techniques which revolutionized genetics research are:

1. Recombinant DNA techniques
2. Genetic engineering through manipulation of desirable traits

Micro-engineering process combines the power of microfluidic manufacturing with the value of natural silk.

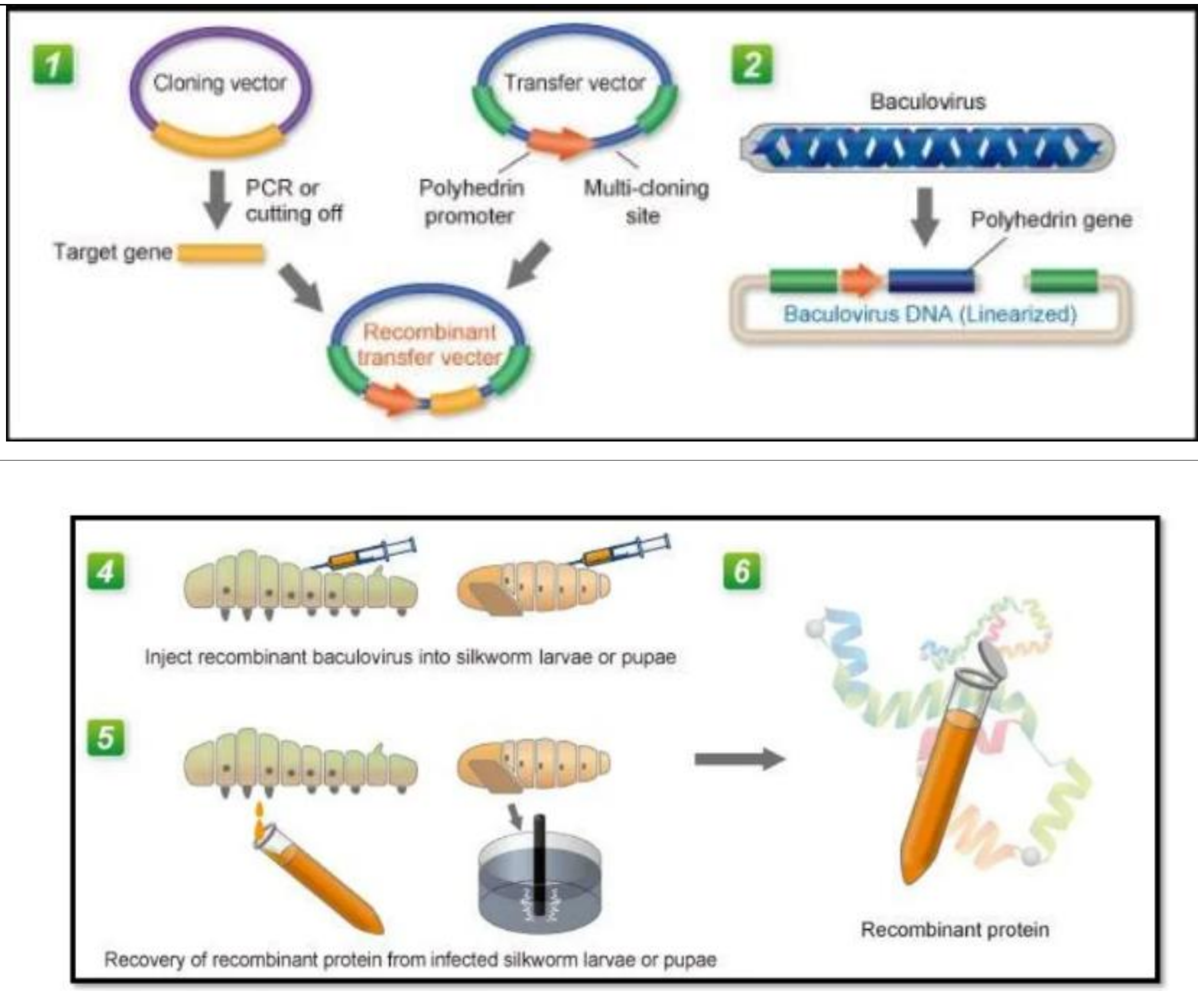
Baculovirus have widely been used as a vector to express heterogonous genes in cultured insect cells and insect larvae. Its genome contains:

- Gene encoding polyhedron
- It has strong promoter
- Non-essential genes are replaced by heterologous genes



Production of proteins for Silkworm manipulation

- Baculovirus infection is used to infect the silkworm body, resulting in the rapid production of structurally complex and biologically active protein.



Production of recombinant Silkworm

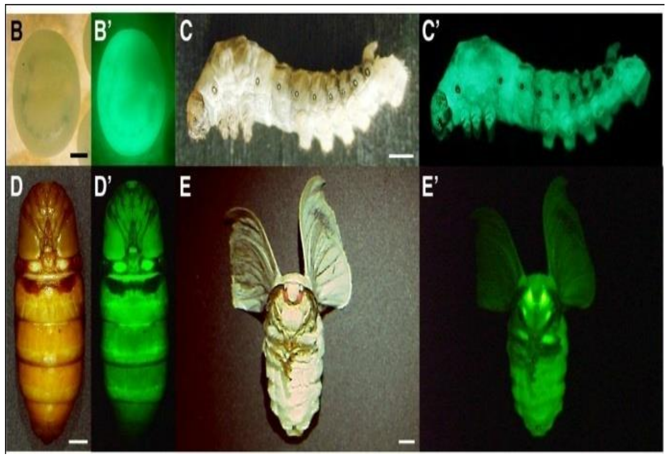
1. Transferring "sturdiness" genes: Indian native races that are tolerant to high temperatures as well as temperature fluctuations also tolerate poor feed quality: these genes are transferred to high yielding strains.

2. Fibroin gene transfer: A high-quality strain's fibroin gene is transferred to strong native races.

Gene transfer methods

1. **Microinjections:** Cloned genes (fibroin) are introduced directly into eggs or early embryos. If the embryo accepts and integrates the microinjected DNA into their genome, transgenic organisms develop.

2. **Electroporation:** Foreign DNA was mass-mobilized into silkworm eggs. The successful transfer of foreign DNA by electroporation is confirmed by a Southern blot.
3. **Virus mediated gene transfer:** The Bm-NPV vector is used to successfully express marker proteins (luciferase and green fluorescent protein).



INDIA's PROGRESS IN SERIBIOTECHNOLOGY

- Attempts have been made to develop molecular markers for high cocoon, shell weight, and virus resistance, with the characters being established using divergent parents such as Sarupat and CSR2.
- CSR&TI, Mysore, has identified eight molecular RFLP markers linked to cocoon shell character in silkworm for the first time in order to generate improved races with high silk yield.
- The Central Sericultural Germplasm Resources Centre (CSGRC, Hosur) maintains 1053 mulberry and 438 silkworm genetic resources collected from various locations in India and abroad in order to identify duplicates and identify recognized molecular markers for important economic traits.

List of some of the important breeds or hybrids:

Breed	EGG	LARVA	COCOON	MOTH
CSR2	Yellow, Egg no-450-500	Deep brown Mature larva: Bluish White Larval Duration 23-24days	White , Oval, Survival: 85-90% Cocoon weight 1.80-1.95g, Raw silk % 20-22%,	Emergence period: 13days No of eggs /grem: 1880
CSR4	Bright yellow	Blakish	White, elongated	Emergence period:

	Egg no-600-650	Mature larva: Reddish tinge Larval duration : 24-25days	dumbbell with round end, fine to medium grains with scanty floss cocoon weight 1.90-2.15g Survival 90-95%, Raw silk % 16-17%,	14days No of eggs /grem: 1810
CSR5	Bright yellow Egg no-475-525	Blakish in colour, Mature larva: Bluish with Reddish tinge Larval duration : 24-25days	White, elongated dumbbell Survival 85-90%, cocoon weight 1.80-1.05g Raw silk % 20-21%,	Emergence period: 14days No of eggs /grem: 1780

15.7 DISEASES OF SILKWORM

More than 500 fungal and bacterial diseases that attack mulberry are known, but only about 30 of them are severe, and only 7-8 of them cause significant damage. Pests and diseases are less likely in India due to the climate and soil.

1. **Viral Disease**
2. **Bacterial Diseases**
3. **Fungal Diseases**
4. **Protozoan disease : Pebrine**

A.Viral Disease

Symptom:

- The larvae is sluggish with swollen intersegmental region
- The integument of diseases larvae is fragile and easily breaks
- On infury milky fluid containing many polyhedral inclusion bodies oozes out from the larval body
- The diseases larvae do not settle for moult and show shining integument
- The larvae appear to be restless
- The larvae is sluggish with swollen intersegmantal region

Grasserie

Flacherie

Infectious flacherie: Infectious Flacherie Virus (IFV), an RNA virus, can also cause flacherie in the host silkworm, forming irregular inclusions primarily in the midgut goblet cells.

Modes of transmission: The causative virus enters the host midgut via the oral route via contaminated leaves consumed.

Symptoms: Body shrinkage with a transparant appearance; vomiting of digestive juice.

(C) Gattine: Because of the transparent appearance of affected worms, this disease is also known as clear head disease.

Causative agents:*Streptococcus bombycis*

a. Bacterial Diseases

Bacteria and viruses, either alone or in combination, cause the disease. Temperature and humidity fluctuations, as well as poor mulberry quality, all contribute to disease development.

- The diseased larvae will grow slowly, be lethargic, and appear flaccid.
- The cephalad region may be translucent.
- The larvae vomit gut juice, develop dysentery, and excrete chain type fecus.
- When the larvae die, they putrefy, change, and emit a foul odour.

b. Fungal Diseases: Muscardine is a fungus that causes the bodies of silkworm larvae to mummify due to calcium oxalate deposition; thus, the disease is also known as 'calcino'.

Symptoms

- The diseases larvae are lethargic prior to death and flaccid after death
- Oil specks may be seen on the surface of the larvae
- They gradually become hard, dry, and mummify into a white or green coloured structure
- The diseases pupae are hard, lighter, and mummify

Muscardine

Causative organisms:

(i) White muscardine- *Beauveria bassiana*

(ii) Black muscardine-*Marrhizium arisopliae*.

(iii) Yellow muscardine- *Poecilomyces farinosus*

(iv) Brown muscardine- *Aspergillus flavus* and *A. oryzel*

(v) Red muscardine- *Sorosporella uvella* and *Spicaria fumosorosea*

Modes of transmission:

Contact: All muscardine infections are spread through the skin. However, oral transmission via ingestion of contaminated leaves and transmission via spiracles have been observed. When fungal spores land on the silkworm's body surface, they germinate and gradually penetrate the cuticle via mechanical and enzymatic forces. The growing hyphae then consume the host's tissue and eventually kill it.

The fungi then consume saprophytic nutrition from the dead larvae tissue and form mycelia in the form of white flakes on top of the dead tissue. Reproductive conidiophores with distinct colours emerge from the mycelia. The dead tissue of host larvae becomes hard and mummified as a result of the continuous growth of the fungi-colony and their release of calcium oxalate as a metabolite.

c. Protozoan disease: Pebrine

- Diseases larvae exhibit slow growth, an undersized body, and a poor appetite.
- Diseases larvae exhibit a pale, flaccid body. On the larval integument, tiny black spots appear.
- Dead larvae remain rubbery and do not decompose quickly after death.

Pebrine

Pebrine: Pebrine, so named because infected worms have pepper-like black spots, is the most virulent protozoan disease of silkworm.

Causative organisms: *Nosema bombycis*

Modes of transmission:

(a) Oral: Spores liberated through the faeces of infected worms or through dead larvae, contaminate the mulberry leaves given in rearing bed. When other larvae consume such leaves, they become infected. Again, eggs may be contaminated by such faecal matter or dead tissues containing the spores during or after oviposition. The newly hatched larvae that consume the chorion of such contaminated eggs may become infected.

(b) Contact: Larvae can become infected through their skin if their rearing bed is contaminated with *Nosema* spores containing faeces or dead tissues.

(c) Transovarial: If the infection occurs in the fifth instar, the adult moth will normally emerge through the pupal stage. However, ingested *Nosema* spores sporulate within the oocyte and pass on to the eggs. As a result, the egg becomes infected from the layers (mother) and hatches into primary infected larvae. However, only a small percentage of infected eggs hatch, and the larvae that do hatch usually die before reaching the third instar. Through their faeces or dead tissues, these larvae serve as a source of secondary infection for other larvae.

Symptoms:

Egg: Infected eggs do not adhere firmly to the egg card due to improper glue deposition. These eggs are a pale yellow colour and may not hatch.

Larvae: Typically, primary infected larvae die before exhibiting any typical symptoms. Larvae with secondary or tertiary infections may exhibit symptoms such as loss of appetite, 'unequals' appearance caused by slow and irregular growth, clean worm symptom caused by irregular and incomplete moulting, black pepper-like spots on the body, irregular brown patches caused by dead hypodermal cells, spitting and wasting silk instead of spinning the cocoon, and so on. Infected larvae also produce soft faeces and frequently die after spinning but before pupating.

Pupa: A live infected pupa inside the cocoon may have a black, swollen body with black spots on the sides of the abdomen.

Adult moth: Adult moths with pebrine infection have a black spot on their abdomen, deformed antennae, unstretched wings, and discoloured wings. Females typically deposit their eggs in irregular, loose heaps. Scales easily fall off the bodies of pebrine-infected moths.

(B) Septicemia:

Causative organism: Septicemia mainly caused by *Bacillus*, *Streptococcus*

Modes of transmission:

1. Contact through wounds on skin
2. Oral route or consumption of contaminated food can also spread the infection.

Symptoms:

(i) Body softening

(ii) Body colour changes to brown

(iv) Liquid excreta,

(v) Loss of proleg clasping power

(vi) Death of larvae.

(C) Sotto disease:

Causative organism:*Bacillus thuringiensis,*

Mode of transmission: Toxin-crystal-contaminated mulberry leaves can be toxic to larvae if consumed orally. The same bacterial toxins, however, have no effect on silk worm larvae when infected by injection.

Symptoms:

(i) Lack of appetite,

(ii) Sluggish movement,

(iii) Skin shrinkage of skin,

(iv) Diarrhoea,

(v) Loss of prolegs clasping power

(vi) Death.

(D) Court disease:

Causative organism:*Serratia marcescans*

Mode of transmission:

(i) Through skin wounds and

(ii) oral route.

Symptoms:

(i) Affected larvae are flaccid

(ii) Death and following death, the body colour of larvae changes to crimson

Mulberry weed

Mulberry weed (Fatoua villosa) causes a lot of problems for growers and Extension Agents. It invades landscapes, field nurseries, and containerized ornamentals and is also known as crabweed or hairy crabweed.

15.8 ECONOMIC IMPORTANCE AND SUSTAINABLE LIVELIHOOD THROUGH SERICULTURE

Economic Importance

- **Bridal and formal wear**: Because of its beautiful drape, silk is a staple of many gowns and dresses, and the long floats of yarn on one side create a dressy and lustrous appearance.
- **Ties and scarves**: Because of the material's strength and colour nuances, it's ideal for accessories. Many high-end ties are made of heavy silk, which allows for tightly woven patterns, vibrant colours, and long-lasting fabric. Silk is also an excellent material for scarves, both for decoration and warmth.
- **Bedding**: Silk sheets are the epitome of luxury, and the material's softness and absorbency shine through in the bedroom.
- **Parachutes**: Silk was originally used for parachutes due to its strength and elasticity, but nylon is now more commonly used.
- **Upholstery**: Because of its strength and durability, silk is used to cover furniture and pillows. It provides long-lasting protection.
- **Wall hangings**: Silk is a popular material for decorative wall hangings because it is beautiful and reacts dynamically with colours and dyes.
- **Bicycle tires**: Due to its lightness, durability, and flexibility, the material is sometimes used in the tyre casing. Because silk can be costly, the casings can also be made of nylon or cotton.
- **Surgical sutures**: Because silk is a natural material, it has numerous applications in medicine. The substance does not elicit an autoimmune response and cannot be absorbed by the human body.
- **Medicinal uses**: The various parts of the mulberry plant are used in ayurvedic preparations. The leaves are both diaphoretic and emollient. The leaves are used to make a decoction that can be gargled to relieve throat inflammation. The fruits are used to treat sore throats, depression, high fevers, and as a laxative and coolant. The extract of the roots has hypoglycemic properties. The root bark has antihelmintic, purgative, and vermifuge properties. Patients with high blood pressure are given mulberry root juice. Young leaf tips are used by the Chinese.

Economic importance of silk beyond silk production: Following the production of silk threads or silk waste, several stages are required before silk can be used, which has a significant impact on the gross national product and job creation. Spinning, colouring, blending, weaving silk into fabric or sarees, and apparel production are all downstream activities. The majority of weaving is done on handlooms or power looms in rural areas. Though some components of such weaving can be made from bamboo, no further research for such uses is deemed necessary because wood, plastics, and metals have gradually replaced bamboo.

Sustainable livelihood through Sericulture

High employment potential

- 60 lakh people are employed in various sericulture activities in India.

- Sericulture can generate employment at a rate of 11 man days per kg of raw silk producti on
throughout the year. Because no other business generates this type of employment, partic ular-lly in rural areas, sericulture is used as a tool for rural reconstruction.

Eco-friendly Activity

- Mulberry contributes to conservation and provides green cover as a perennial crop with good foliage and root spread.
- Silkworm rearing waste will be recycled as garden fertiliser.
- Because this is primarily an agricultural activity, the use of smoke-emitting machinery is minimal.

- Developmental programmes for mulberry plantation have been initiated primarily in upland areas where unproductive cultivable land has been made productive.
- Intercropping is also possible with a variety of plantations.
- Because it is a deep-rooted perennial plant, it can be grown in vacant lands, hill slopes, and watershed areas.

- Currently, only about 0.1% of the country's cultivable land is under mulberry cultivation.

Low Gestation, High Returns

- An estimated investment of Rs.12, 000 to 15,000 (excluding land and rearing space costs) is
  sufficient for mulberry cultivation and silkworm rearing on one acre of irrigated land.
- It only takes six months for mulberry to mature before silkworm rearing can begin.
- Once planted, it will continue to support silkworm rearing for another 15-20 years, depending on inputs and management.
- Under tropical conditions, five crops can be harvested in one year.
- By implementing the prescribed set of practises, a farmer can achieve net income levels o f up to Rs.30000 per acre per year.

15.9 SUMMARY

Sericulture is the cultivation of silkworms for the production of silk. *Bombyx mori* is the most important silkworm species for commercial purposes. *Bombex mori* feeds on mulberry leaves and, after the fourth moult, climbs a nearby twig to spin their silken coccon. The silk is made up of fibroin protein, which is secreted by the salivary gland in the worm's head, and a gum called sericin. The sericin is removed from the cocoons by immersing them in hot water, which loosens the silk filaments and prepares them for reeling.

Female silkmoth lays 300 to 500 eggs during the first stage of silk production. Silkworms are larvae or caterpillars that hatch from silkmoth eggs. Mulberry leaves are consumed by the larvae. After several moults, the silkworm extrudes a silk fibre and forms a net to protect itself. When the silk comes into contact with air, it solidifies. In two or three days, the silkworm spins approximately one mile of filament and completely encases itself in a cocoon. Each cocoon contains a small amount of usable quality silk. As a result, it takes approximately 2,500 silkworms to produce one pound of raw silk. The silkworm pupa is killed by boiling the intact cocoons. Silk is obtained by brushing the undamaged cocoon to locate the silk.The silk is obtained by brushing the undamaged cocoon to find the filament's outside end. After that, the silk filaments are wound onto a reel. A cocoon contains about 1,000 yards (910 metres) of silk filament. At this point, the silk is referred to as raw silk. A single thread can contain up to 48 individual silk filaments.

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15.10 Terminal Questions and Answers

Question 1: Describe Mulberry and Non-Mulberry Silkworm types and rearing in detail.

Question 2: Describe the silkworm rearing process in detail.

Question 3: What exactly is chawki rearing?

Question 4: How important is sericulture economically?

Question 5: How is silk extracted from cocoons?

UNIT 16: APICULTURE

CONTENT:

16.1 OBJECTIVES

The aim to provide an advanced understanding of beekeeping. It starts with the knowledge about the Bee colony. Hence, the main objectives are:

- To communicate the basic knowledge on apiculture.
- To become familiar with different species of honey bees.
- To understand about the commercial methods of rearing honey bees and their enemies.
- To learn handling of bee colonies and precautions required.
- To familiar with the Extraction methods of Honey and Wax and other Bee Products.
- To know about the importance of different flora used by honey bees in Crop Pollination.

16.2 INTRODUCTION

The term 'apiculture' derives from the Latin word 'Apis,' which means "Bee."It is the practice of honeybee management in hives for pollination and the production of honey and other products, such as wax, royal jelly, propolis and pollen. For commercial purposes, bees are bred in apiaries, which are large areas where many beehives can be housed. For example, in areas with flowering plants, apiaries are typically established in regions with adequate bee pastures.In addition, the production of live material, such as bees and queens, may represent other outputs of beekeeping. Beekeeping is a significant sustainable and environmental sound activity involving integration of forestry and agriculture. The most interesting behaviour of the bees is communication where the workers communicate each other through their dances. They give information about the distance and direction of the food source.

16.3 CONSERVATION OF IMPORTANT BEE FLORA FOR FORAGE

Production of honey and other products of honey bees depend on availability of floral resources (bee forage) and is a very important field for honey beekeepers. Nectar as sources of honey provides heat and energy for honey bees and pollen provides protein, vitamins, fatty substances, and other nutrients. Adequate nectar and pollen resources are critical in maintaining honey bee health. A deficiency in quantity and quality of pollen and nectar can lead to demographic decrease of bee colonies leading to low colony populations, which collect pollen and nectar. Depending on the period of availability in relation to bee colony development, bee pasture can be classified as build up, honey flow, and dearth period flora. It is characteristic of an area's agroclimatic conditions that its flora varies from place to place. Additionally, this flora provides food for a large number of pollinators. Nearly 3,08,000 species of flowering plants in the world are pollinated by animals (including insects, birds, bats, etc.). Most of them are pollinated by bees.

Practical information on equipment required, handling of honey bee colonies, seasonal managements and economics has been provided in concise form. Since this course has no theory (only practical), the basic information for each practical has been briefly described in the beginning of each practical to unable the students to understand the subject before starting the practical.

The basic concepts of beekeeping are required to be understood by the undergraduate students and beginners more clearly so that the knowledge gained by them can be utilized in the field or even to start their own enterprise after completing the studies. This course has been designed to meet these objectives. Additional reading material will provide the student additional information on different aspects of beekeeping.

Key to success of beekeeping lies in understanding the needs of the bee colonies during different seasons and providing them space, food and protection from enemies. This course provides tips for handling of bee colonies, feeding methods, extraction of honey etc. Students will learn important terms related to Apiculture.

16.4 TYPES OF HONEYBEES

All honey bees are classified into the genus Apis and the family Apidae. There are four accepted groupings of honeybee species each morphologically distinct. Each of the Asian species groups is subdivided into two or more further species. It is characteristic of all species of honey bees to control their brood nest temperature, to separate their brood from their food by storing their food above their brood and to live exclusively on pollen and honey. Two of the groups are characterized by cavity nesting while the other two groups make a single comb in the open. The greatest diversity of honey bee species is in India and adjacent regions, with all the species of honeybee except Apismellifera present as native species. The Asian hive bee, *Apiscerana*, which is extremely closely related to the Western Honey bee, is only found in Asia where it is widely kept for its honey. The so-called giant honey bee, *Apisdorsata* and the closely related Himalayan honey bee, Apislaboriosa are large bees that build a single comb in the open. These species are frequently exploited by honey hunters. The little honey bee, *Apisflorea* is probably the closest, living descendant of the earliest honey bees and has spread from Asia into the Middle East. The following species are now recognised as distinct species of honey bee (Michener 2000): • Small bees nesting with with single exposed combs: *A. florea*Fabricius A. andreniformis Smith • Large species nesting with single exposed combs *A. dorsata*Fabricius, A. laboriosa Smith (*A.beviligula*Maa, *A. binghami*Cockerell) • Middle sized species nesting with multiple combs in cavities: *A. mellifera* Linnaeus, A. ceranaFabricius , A. koshevnicoviButtelReepen, A.nigrocincta Smith, A.nuluensisTinget, Koeniger and Koeniger Bees belong to super-family Apoidea of the order Hymenoptera. Their bodies are covered with small, branched hairs. Nests are made from wax secreted by their bodies. In addition to resin, leaves, sand, secretions from the sting gland, and silk produced by the adult bees, they make nests from resin, leaves, sand, and secretions from the sting gland. There are about nine bee families in the superfamily Apoidea, which live either a solitary or a social life. Honey is produced by bees who lead an advanced social life. They are divided into three groups - Apidae, Bombidae and Meliponidae. Honeybees are of two types: 1. True honeybees of genus Apis 2. In India, four types of honey bees belong to the genus *Apis*, including stingless bees of the genus Trigona. They are *Apisflorea*, *A. ceranaindica*, *A. dorsata*and*A.laboriosa*.The bee species people most use for their own benefit is the common honey bee Apismellifera. This honey bee is native to the continents of Europe and Africa but, since the 1600s CE, has been widely and successfully spread throughout the Americas and Australasia as part of these countries' colonial or trading history. Latterly Apismellifera has spread throughout Asia. Dwarf honey bees (*Apisflorea*) are the smallest honeybees and are often mistaken as stingless bees as they do not sting readily. Their preferred climate is hot and dry, so they are found in plains and subtropical areas. There is a distinct honey portion at the top of their comb. Nests are usually built in trees with dense leaves or in plant stalks such as jowar or rice. A Rock Bee (*Apisdorsata*) builds its nest out in the open and uses a tree branch, cliff, or rock to support it. It is for this reason that they are called rock bees. Their hives can measure up to 200 cm X 150 cm in size. Hanging from above, they are semicircular. Even at night, they forage for food. Rock bees are commonly used to hunt forest honey. They are, as their name suggests, Indian hive bees and are considered to be a subspecies of Asian bees *Apiscerana*. In this case, there are two varieties: 1. The Gandhianas are large and dark. 2. Indica- They are yellow colored and smaller. The Gandhiana variety is considered plain. Combs are made in cavities such as tree crevices, rock cavities, etc. Even though they are domesticated, they exhibit an absconding tendency. European Bee (*Apismellifera*) They are believed to have originated in Italy and introduced into different countries worldwide. Punjab was the original source of the stock when it was introduced in India in 1965. ICAR Central Bee Research and Training Institute, Khadi and Village Industries Commission, and All India Co-Ordinated Project on Honey Bee Research Training successfully multiplied and distributed progenies to other states. Compared to Apisindica, it yields 4-5 times more honey. This is one of the most preferred bees for honey bee farms worldwide because: 1. It has a gentle temper. 2. It is less swarming. 3. There is a prolific queen 4. It is a good honey gatherer. 5. It can protect itself and the hive against its enemies except wasps. 6. It adapts very easily to frame hives.

16.5 ORGANIZATION OF BEE COLONY

As one of the few insects that have social structures, honey bees have a caste, made up of a single female queen (the colony's only egg layer), several drones (males) depending on the season, and up to 60,000 worker bees (non-reproductive females). An egg, larva, pupa, and adult honey bee undergo a complete metamorphosis (holometabolism). Nest building, food collection, and brood rearing are all coordinated by several thousand worker bees. Throughout the worker caste, honey bees perform tasks related to their age, beginning inside the hive (house bee) and eventually foraging outside. A worker bee caste feeds and cares for the immature forms of the bee, called brood. Beekeepers need to be aware of the following biological features: basic bee nest ecology, bee caste system, bee anatomy, bee brood development, worker bee sequence of duties, caste brood rearing/adult population seasonality, communication as a "key" to maintaining social cohesion in a colony, queen reproduction and colony replacement, and how to read/understand bee behavior.

16.6 LIFE HISTORY AND BEHAVIOR OF BEES

GENERAL MORPHOLOGY

Like all insects, the honeybee has three main parts: the head, the thorax and the abdomen. (1) THE HEAD This is triangular in shape and bears eyes (a pair of compound eyes and 3 small simple eyes (ocelli)), a pair of antennae, jaws, antennae, and mouth. (a) The eyes A bee has a pair of compound eyes and three small simple eyes called ocelli. The compound eyes are composed of several thousands of simple light-sensitive cells called ommatidia that enable the bee to distinguish between light and colour and to detect directional information from the sun's ultraviolet rays. The eyes of the drone are larger by far than those of the worker or queen-bee occupying a larger proportion of the total volume of the head. These assist the drone to locate the queen as he pursues her during the mating flight. (b) The antennae These are a pair of sensitive receptors whose base is situated in a small socket-like membranous area of the head wall. These serve to guide the bee outside and inside the hive as they are sensitive to touch and smell. They also assist the bee to differentiate floral and pheromone odours and to locate hive intruders. (c) Mandibles These are a pair of jaws suspended from the head and parts of the mouth. They are used to chew wood when re-designing the hive entrance, chew pollen and work wax for comb building. (d) Proboscis Unlike the proboscis of other sucking insects, that of the honeybee is not a permanent functional organ. It is temporarily improvised by assembling parts of the maxillae and the labium to produce a unique tube for drawing up liquids such as sweet juices, nectar, water and honey. The bee releases it when needed for use, then withdraws and folds it back beneath the head when it is not needed. (2) THORAX This is an armour-plated mid -section of the insect. It supports two pairs of wings and three pairs of legs. It has muscles that control movement of the head, abdomen and wings. (a) Legs- Each pair of legs differs from the other two pairs and is jointed into six segments with claws at the tip that help the bee to cling to surfaces. Legs help the bee to walk and run but various parts also serve special purposes other than locomotion e.g. sweeping pollen and other particles from the head, eyes and mouth. i) Antennae cleaner This is located on the inner margin of the tibia of the forelegs. It consists of a deeply cut semi-circular notch, equipped with a comb-like row of small spines. This cleaning device is on all the workers, queen and drones. ii) Pollen baskets The pollen baskets (corbiculae) are located on the tibia of the hind legs of the worker bee to enable it to carry pollen. Pollen baskets are concave in shape and are surrounded by several long hair which bind the pollen into a solid mass which is easy to carry back to the hive. (b) Wings- Like in other insects' wings, these are thin, flat and two layered. The front pair is much longer than the rear pair. Workers wings are for flight and ventilating the hive while those for the drone and queen are for flight only. (3) ABDOMEN This is also armour-plated and contains vital parts like the heart, honey sac, stomach, intestines and the sting. An adult insect bee abdomen has nine segment while the larva has 10 (ten).

INTERNAL ORGANS: The internal organs include hypopharyngeal gland, wax gland, scent or pheromone glands, the queen's pheromone glands and the sting. a) **Hypopharyngeal gland:**It islocated in front of the brain in the head of a worker bee. Developing only after the insect secretes royal jelly to feed the young larvae and queen, it begins to mature three days after the insect emerges. b) **Wax gland:** This is located in the lower part of the young worker's abdomen. It releases wax between a series of overlapping plates called sterna below the abdomen. The worker begins to secrete was 12 days after emerging. Six days later, the gland degenerates and the worker stops comb building. c) **Scent glands:** A worker bee produces three main scents. The gland beneath the sting produces a special pheromone consisting mainly of Isopental acetate which it sprays around the spot of the sting. The odour stimulates other workers to pursue and sting the victim. - Another alarm pheromone is released by glands at the base of the mandibles. It has the same function as the first one. - The third gland is located near the rear of the abdomen. This produces a pheromone which when released by scout bees, attracts swarms of other bees to move towards them. d) **Queen's pheromone glands:** These are located in the queen's mandibles, and release pheromones called the queen substances. These enable her: - To identify members of the colony; - To inhibit ovary development in worker bees; - To prevent workers from building queen cells; - Help a swarm (colony) to move as a cohesive unit; - To attract drones during mating flights.

NOTE: Absence of the queen substance (e.g. when the queen dies) produces opposite responses it enables worker bees to begin developing ovaries and to build queen cells, and a swarm searching for a accommodation will not cluster but will divide into smaller groups which cannot support the normal life of a bee colony. e) The sting A worker bee's sting is designed to perforate the skin of the enemy and pump poison into the wound. A bee cannot pull it back when it is thrust into flesh because it has about ten (10) barbs. The poison sac is always attached to it when it breaks off. This enables more poison to penetrate for as long as it remains in the flesh. The sting is lodged in a special sheath and is only released when the need arises. In the hive, it is only used to fight and kill rival queens. Drones lack stingers and are totally defenseless.

SOCIAL ORGANIZATION OF BEE COLONY (QUEEN, DRONE, WORKER)

In an average bee colony there are: a) One fertile queen whose main activity is laying eggs. b) From 20,000 to 80,000 sterile female worker bees who do everything that needs to be done in the colony. c) From 300 to 800 fertile males called drones. In addition to these, there are about 5,000 eggs and 25,000 – 30,000 immature bees, called the brood, that are in various stages of development. Of these, some 10,000 newly hatched ones are the larvae which have to be fed by the workers. The remainder, after the larval stage, are pupae sealed into their cells by the workers to mature- These are called the seal brood. The honeybee nest The beehive or colony nest consists of a number of vertical combs that hang parallel to each other at a distance of about 10 mm. The combs, which are about 25 mm wide, are composed of hexagonal cells. - In the worker cells in the lower part of the comb, the bees rear the worker brood. - Pollen and honey are stored in the upper part of the comb. - Drones are reared in the drone cells. - Occasionally, a third type of cell known as the queen cells are built for the rearing of queens.

BEE COLONY AND CASTE DISTINCTION

Being social insect honeybees have divided their society into different castes viz. drone bees, queen bees and worker bees.

Drone Bees: They are the male bees developed from the unfertilized eggs. Larvae developing from unfertilized eggs are fed on the royal jelly by the worker bees thus giving rise to drones. Drones are stout and larger than the workers, they do not have suitable proboscis for gathering nectar, no sting to defend self or the colony, no baskets for collecting pollen grains, no glands for secreting wax for comb construction and does not work in the hive but is fed and eats large quantities of food and moves about in sunshine. Their main purpose is to mate the queen bees and fertilize the eggs. The spermatozoa are produced in the drones' testes during the pupal stage. After the drone emerges from the comb cell, the spermatozoa pass into seminal vesicles where they remain until mating. During mating spermatozoa pass into the copulatory apparatus. Mating occurs in the open air in the drones' congregation areas. During mating, the drone inserts his copulatory organ (apparatus) injecting the semen into the queen's oviducts and leaving part of the apparatus in the tipoff in the queen's abdomen. That part visible in the queen remaining from the mating flight is called the mating sign. The drone dies during mating. The male bees are taken care of by the worker bees till the queen in the colony is ready to mate. After mating the drone dies. Similarly, once the mated queen returns to hive, the drones are neglected by the worker bees. When fresh nectar becomes scarce, the workers prevent drones from feeding. They first push the drones from the broad combs to the side combs and eventually drag them half starved from the hive. During unfavourable conditions (periods), drones are tolerated only in queen-less colonies or those containing unmated queens. Therefore, the presence of drones in a colony during such periods indicates that something is wrong with the queen, so the beekeeper should act. Queen Bees Queens are the fertile females in the beehive. In every hive, there is one queen who stays for about 10 days until she reaches maturity. When they reach maturity, they go on mating flights. Upon mating, they return to the hive to lay eggs in the role of queen mothers. Normally, they lay up to 15,000 eggs a day. The availability of royal jelly, however, controls egg laying. A queen's effective fertilized egg laying period lasts up to two years, but she can live up to three years. Worker brood cells receive fertilized eggs, while drone brood cells receive unfertilized ones, which develop into worker larvae and drone larvae, respectively. A hive always has one queen; - She is larger than the workers and longer than the drone; - Its wings are much shorter than its body, and can't cover the whole abdomen; - Its long, tapering abdomen makes her look like a wasp; - Her sting body is covered with sparkling gold hairs; - She has a sting but unlike the aggressive workers, she does not use it to fight hive intruders but only rival queens. - She does not go out to collect pollen, nectar, water or propolis and therefore, unlike the worker bee, she does not have collecting apparatus like pollen baskets, long proboscis for drawing nectar or wax glands to secrete wax to build comb cells. She does not feed herself. When the queen emerges, she immediately tours the hive to see if there are any rival queens. Two queens will fight until one is killed if there are any. The newly emerged queen looks for potential queens hiding in comb cells if the colony is not preparing to swarm. Pops a special noise, and the hidden capped queen responds. After locating the cell, the emerged queen rips it apart and kills the unemerged queen. In some cases, the workers watching as spectators will assist the queen in evacuating the contents of every queen cell.

- Five days after the queen emerges from her cell, she starts to fly out of the hive, making orientation flights of about five minutes.
- Next, she makes mating flights which last about 30 minutes.
- She flies to an area 6 – 10m above the ground where drones have congregated because she is not attractive to drones in other places.
- About eight drones mate with her during a successful mating flight.
- She makes another flight the next day if the first doesn't work out.
- During mating, the drones semen is injected into her oviducts and from there, the spermatozoa enter into a special reservoir called spermatheca.
- A well inseminated queen carries about 5,000,000 spermatozoa stored in her spermatheca.
- Each queen produces a queen substance called a pheromone which controls many and most of the activities of the bee colony.
- Worker cells containing young larvae are transformed into queen cells in the absence of a queen or pheromone.
- Unless there are larvae younger than three days in the colony, the bees cannot rear new queens. Some workers begin to lay eggs when their ovaries develop.
- However, as worker bees, they cannot be inseminated and so they lay only unfertilized eggs. Such workers are called laying workers.

Worker Bees: Workers are the smallest and most numerous of the colony’s population, constituting over 98%. One colony may have as many as 80,000 workers. Although they never mate, workers possess organs necessary for carrying out many essential duties in the well being of the colony. They have a longer proboscis than the queen and drones and so are well suited for sucking nectar from flowers. Workers have large honey stomachs to carry nectar from the field to the hive.They have pollen baskets on their third pair of legs to transport the pollen to the hive. They have glands in their head which produce royal jelly as food for the larvae , glands in their thorax which secrete enzymes necessary for the ripening of honey and four sets of wax glands inside the last four ventral segments of the abdomen which produce wax for comb construction. They have a well-developed sting which permits them to defend the colony very efficiently. Infertile female workers are developed from fertilized eggs. The number of workers determines the strength of the hive and the success of the honey bee farm. They are smaller than drones and queens and are strongly influenced by the pheromones produced by queens. It has a maximum lifespan of six weeks. As house bees, they spend the first two weeks following birth doing indoor duties like cleaning the hive, nursing the young, repairing damaged parts of the hive, secreting royal jelly, attending to the queen, etc. Field bees spend the next 3 weeks gathering nectar, pollen, water, ripening honey, etc, and are referred to as field workers. It has no individual identity but spends its life doing well for the colony.

16.7 DISEASES OF HONEYBEES

I. BACTERIAL BEE DISEASES

1. American foulbrood (AFB)

It is a bacterial disease of pupal stage caused by Gram positive sporulating*Paenibacillus*larvae (White) Heyndricx*et al.* This disease results in occasionally the death of pupae inthe sealed cells. Cell cappings are sunken, watery, discoloured and sometimes punctured withirregular holes. Dead pupae are dull-white and watery changing to brown ropy stage. At thisstage, if a match is thrust into dead pupa and then removed, a semi fluid ropy thread is drawn.Affected colony gives a distinct fish or glue-pot like odour.

2. European foulbrood (EFB)

It is caused by the bacterium *Melissococcusplutonius*(White) Truper&De'Clari. This disease is occasionally found in both *A. mellifera* and *A. cerana*colonies in India. Larvae get displaced in their cells and die in the unsealed cells when they are only 4-5 days old. Dead larvae become soft, watery and dull yellow. Their breathing tubes are prominent at this watery stage. The affected larvae are discoloured, first creamy yellow, then turn to light brown and then dark brown and occasionally black. The infected larvae lie upright attached with side walls of the cells and sometimes appear just melted down at the base of the cells. Dead larvae finally dry to brown removable rubbery scales at the bottom of the cell.

II. PROTOZOAN DISEASES

1. Nosema disease

This disease is caused by *Nosemaapis*Zander. It is disease of adult bees and the protozoan parasitizes all the castes. The infectious spores germinate in the ventriculus of the host. Its spores are shed in the lumen of digestive tract of the affected bee and are then excreted out. Infection spreads through ingestion of faecal matter with contaminated food. This disease is dent on *A. mellifera*colonies in the eastern part of the country.

2. Amoeba disease

It is caused by *Malpighamoebamellifecae*Prell. This infection is caused by ingesting the cysts along with contaminated food. Cysts germinate, amoeba migrate to malpighian tubes and feed on cell contents. Cysts accumulate in the mid-gut / rectum. Cysts are shed in the intestine and are excreted out with faecal matter. Spring dwindling of colony strength can be experienced in such case.

C. FUNGAL DISEASES

Two fungal diseases are important *viz.* Chalk brood and Stone brood.

1. Chalk brood

This disease is caused by *Ascosphaeraapis*(Maassen ex Claussen) Olive &Spiltoir. It is of very rare occurrence and is found in weaker colonies in high humid areas.

2. Stone brood

This disease is caused *by Aspergillus flavus* Link. Its spores are ingested with food. These spores germinate in the alimentary canal. The mycelia attack the soft tissues. The spores also germinate on the cuticle and mycelia penetrate inside.

D. VIRAL DISEASES

1. Sacbrood disease

This disease is caused by Sacbrood Virus (SBV). The virus is ingested with food. Two days old larvae are more susceptible for catching the infection. Virus multiplies in body tissues. Disease in the colony is spread nurse bees and among the colonies through swarming, drifting and robbing.

2. Chronic bee paralysis

This disease is also called hairless black bee syndrome / little black robbers. Infected bees die within a week. The causal viral particles are irregular in shape. Enzyme ribonuclease found in nectar destroys viral RNA. Bees become hairless, shiny and small.

3. Iridescent virus

This disease is caused by iridovirus. Its infection is serious during hot / dearth seasons. It is transmitted by nurse bees through glandular secretion (food).

16.8 BEEKEEPING METHODS

16.8.1 Equipment and tools

A movable frame hive is composed of the following parts/appliances

1. Bee hive:

• It is movable wooden hive for bees with an entrance and parallel movable frames on which bees raise their combs.

2. Nucleus hive:

• Small bee hive for keeping 4-6 frames. These are used for mating of queens and division of colonies.

3. Observation hive:

• Small hive with glass sides to observe movements and behaviour of bees.

4. Synthetic combs:

• High density polythene (plastic) is used to make it. Both supers and brood chambers can use it.

5. Hive stand:

• This is used to keep the bee hive above the ground so as to protect the colony from termites, ants and other crawling insects and also prevent soil moisture getting into the hive or facilitate ventilation from below the hive.

6. Bottom board:

• One or two pieces of wood are joined together to form the floor of the hive.

7. Brood chamber:

• It is a four sided rectangular wooden box without a top and bottom.

8. Super chamber:

• The brood chamber is over it, and its construction is similar to that of the brood chamber.

9. Hive cover/Top cover:

• It insulates the interior of the hive.

10. Inner cover:

• A central ventilation hole covered with wire gauze is provided in the inner cover for air circulation.

11. Hive frames:

• A series of frames may be placed vertically in the brood chamber or super chamber so that bees have space between them.

12. Dummy or Division board/ Movable wall:

• There is a wooden board that is slightly larger than the brood frame.

13. Bee feeder:

• Used for providing sugar syrup as feed to the bees during dearth period.

14. Queen excluder:

• It is made up of perforated zinc sheet.

15. Queen gate:

• It is a piece of queen excluder sheet and fitted on the slot of entrance gate.

16. Queen cage:

• This is used for transport of queen either with a few attendant worker bees, in packages.

17. Queen cell protector:

• Wire wound spirally forms a cone-shaped structure. Fits around a queen cell.

18. Swarm trap:

• It is a rectangular box used to trap and carry the swarm.

19. Drone excluder or drone trap:

• It is a rectangular box with one side open. The other side is fitted with queen excluder sheet.

20. Pollen trap:

• Pollen trapping screen inside this trap scrapes pellets from the legs of the returning foragers.

21. Hive tool:

• It is a piece of flattened iron with flattened down edge at one end.

22. Protective dress:

(a) Bee veil:

• It is worn over the face for protection against stings.

(b) Gloves:

• These are used while inspecting and handling colonies to protect hands and arms. Soft leather gloves with canvas gauntlets to the elbow are the best for use.

(c) Boots:

• A pair of gum boots will protect the ankles and prevent bees from climbing up under trousers.

(d) Overalls:

• White overalls are occasionally worn. Light colored cotton materials are preferable since they are cooler and create less risk for antagonizing bees.

23. Bee brush:

• A soft-camel-hair brush is used to brush the bees off the honeycomb before it is taken for extraction.

24. Smoker:

• The smoker is used to calm bees and drive away bees from super.

25. Decapping knife/ uncapping knife:

• Single or double edged steel knife is used for removing wax capping from the honey comb before putting it in the honey extractor.

26. Honey extractor:

• It is invented by Frang von Hruschkain 1885.

27. Travelling screen/net:

• It is a wooden frame with wire screen. It is highly useful for migration of honey bee colonies during hot summer season.

28. Comb foundation mill:

• This is a machine to prepare comb foundation sheet used in beekeeping to make-bees build regular combs in frames that are convenient to handle.

29. Comb foundation sheet:

• It is a thin sheet of bee wax embossed with a pattern of hexagons of size equal to the base of the natural brood cells on both sides.

30. Embedder:

• It is a small tool with a spur or round wheel on the top. It is used to fix the comb foundation sheet on the wires of the frame.

31. Miscellaneous:

• Apart from these equipments, there are several miscellaneous equipment which are required from time to time *viz*., propolis screen, venom extractor, drip tray, swarm basket, wax melter, queen bee rearing equipment, comb foundation making equipment, honey straining, storage and processing equipment, etc.

16.8.2 APIARY MANAGEMENT

SEASONAL MANAGEMENT OF HONEY BEE BOXES:

Seasonal management is most important and essential part ofapiculture for the better production of honey, pollen (Mishra, 1995).he abundance of bee flora and their continuous availability is one of the majorpre-requisites for successful beekeeping. This enables the beekeepers to exploit these sourcesto the maximum utilization by the bees. Every region has its floral dearth periods of short orlong duration and it is essential to manage the honey bees and bee hives in the dearth period.As during this period, there is lack of availability of nectar and pollen in flora required forquantitative and qualitative production of honey (Akratanakul, 1987). To overcome this problem. It is importantto find out the suitable bee flora available in the locality to propagate and manage the plantspecies with a option of abundant nectar and or pollen to overcome the problem during thedearth period for commercial apiculture.Pollens and nectar are available only during certain period. When surplus food source isavailable is known as “honey flow season”. In contrast during dearth periodthere will bescarcity of food. Suitable season for starting beekeeping coincides with mild climatic conditionsand availability of bee flora in plenty. Normally, spring (February-April) and post-monsoon (Sep.- Nov.) seasons are the best periods to start beekeeping. Indian seasons are Spring season (*Vasantritu*: mid February – mid April), Summer season (*Grishmaritu*: mid April to mid June), Monsoon season (*Varsharitu*: mid June to mid August), Autumn season (*Sharadritu*: mid August- mid October), Pre-winter season (*Hemantritu*: mid October- mid December) and Winter season (*Shishirritu*: mid December- mid

February). Various operations required to be undertaken for augmenting colonies productivity are given below:

I. SPRING MANAGEMENT

Management operations to be undertaken during spring are given below:

1. Examination of colonies

On some warm and sunny day, examine the colonies quickly and carefully with least exposure to the chilling weather and robber bees.

2. Equalizing the colonies

The colonies can be equalized by:

a) Substituting the combs with food reserves/supplementary feeding.

b) Providing the emerging bee combs.

c) Uniting the bee combs/colonies.

d) Giving young bees to the weaker colonies.

3. Provision of space

During spring, the colonies enhance the brood rearing. Hence, there should be no dearth of space to cope up with increased egg laying by the queen bee.

4. Swarm prevention and control

a) Examine the colonies and remove congestion. Provide more drawn combs/comb foundations, supers, etc.

5. Control of mites and brood diseases

Examine the symptoms of various mites and brood diseases. On spotting any, take appropriate management measures to contain the menace.

6. Colony multiplication and commercial queen rearing

March-April is the best season for colony multiplication and commercial queen rearing. Improve the existing stock by selective breeding of best performing colonies. Mass reared queen bee can also be used for multiplication of existing stock and also for replacement of older queen bees (re-queening).

7. Extraction of spring season honey

Multiple extractions of honey during this period are possible. Only ripe honey from broodless combs from super chamber should be extracted.

II. SUMMER MANAGEMENT

Mid April to June months are extremely hot. However, this is the major honey flow period too. The following operations need to be considered during the season.

1. Shifting the colonies to thick shade

Colonies should be moved to shady places every day by less than three feet.

2. Regulating the microclimate of the colonies

By using wet gunny bags over the colonies and sprinkling water around the colonies in the apiary during noon hours, temperature in the apiary can be reduced and humidity increased in hot and dry months of May and June.

3. Provision of ventilation

Improve the ventilation of the colonies to cope up with the respiration of the bees and hastening the honey ripening.

4. Provision of fresh water

5. Honey extraction

Summer season honey can be extracted.

III. MONSOON MANAGEMENT

Manage the colonies during this season as below:

a) Ensure colonies placement on upland area and away from village water ponds.

b) Clean and bury deep the debris lying on the bottom board.

c) Keep the surrounding of the colonies clean by cutting the unwanted vegetation which may hamper circulation of air.

d) Provide **sugar feeding (sugar : water=l:l),** if required.

e) Check robbing within the apiary.

f) Unite weak/laying worker colonies. Control wax moth, ants, wasps and bee eating birds.

IV. AUTUMN MANAGEMENT

Important operations to be undertaken during this season, are:

a) Provision of space.

b) Strengthening the colonies to stimulate drone brood rearing, if queen bee rearing is to be undertaken.

c) Control of ectoparasitic mites, brood diseases, wax moths and wasps.

d) Autumn honey extraction before the winter sets in.

V. WINTER MANAGEMENT

Normally winter extends from December to mid February but this period may vary from region to region. During winter, very low temperature, westerly chilly winds, foggy/cloudy days and winter hamper the bee activity. *Brassica* comes in bloom during January. To perpetuate the colonies through winter, following operations are generally required:

1. Colony examination

Examine the colonies on a warm, sunny day for the presence of queen, brood and food reserves. Open the colony for minimum time to avoid chilling of brood. Weak colonies should be united with stronger ones so that the strong unit over-winters well.

2. Feeding

If there is food scarcity or expected in the ensuing winter, feed concentrated **(sugar: water = 1:1) sugar syrup** (supplementary feeding) by filling in the drawn combs at the onset of severe winter.

3. Shifting colonies to sunny places

The colonies should be shifted to sunny places with hive entrances facing south-eastwards.

4. Protection from the chilly winds

Plug cracks and crevices and narrow down the hive entrance.

5. Unite weak colonies with stronger ones

Follow newspaper method for uniting the colonies.

6. Removal of extra drawn combs and winter packing

Remove the extra empty combs and store them properly to save them from mice/rats. Depending upon the strength of the colonies and severity of winter, provide one or two-sided inner winter packing combined with need based outer packing.

16.8.3 Controlling Swarming

a) Examine the colonies and remove congestion. Provide more drawn combs/comb foundations, supers, etc.

b) Improve ventilation and provide required shade.

c) Clip the wings of the laying queen.

d) Use wire entrance guard/queen excluder at the bottom board.

e) Reversing brood and honey chambers for mitigating congestion in brood chamber.

f) Destruction of the queen cells raised due to swarming instinct,

g) Dividing over-crowded colonies.

16.8.4 Handling of Bees

DIVISION AND UNITING OF HONEY BEE BOXES:

I. Division of honey bee boxes:

Colony division is a method of multiplying bee colonies, *i.e.* producing two or more colonies from a mother colony. Colony division is used to control swarming as well as in commercial beekeeping to increase the number of colonies.

Methods for colony division:

(i) Natural division using queen cells developed during swarming

The presence of multiple queen cells in a colony during the swarming season indicates a need for division. Dividing such colonies and using the queen cells in new daughter colonies can help control swarming. However, although it solves the immediate problem of swarming it does not help improve the genetic traits.

(ii) Colony division from queen production

Select the best colony based on the selection criteria given above. Produce queens from this colony before the onset of honey flow. These queens can be used to replace the old queen andto start new daughter colonies. The mother colony can be multiplied into several nucleus coloniesbut each should have at least 2 brood combs and 3–4 combs with food (nectar and pollen). Theprepared colonies can then be sold or migrated according to need.

(B) Uniting of honey bee boxes:

Uniting two colonies into one is done when one of them is weak or queen less or for other reason like bad traits etc. Each colony has its own colony specific odours and it is very difficult tocombine the two colonies unless their odour is mixed well. Any attempt to unite these colonies without mixing their odour result in infighting and deaths will occur on large scale. Therefore, first step will involve bringing the two colonies into contact with each other. If uniting is done abruptly, the field workers of the colony shifted will not recognize the new place and returning to their original place will persist. This problem can be overcome by moving a hive gradually at the rate of two or three feet per day, so that the field bees get habituated to the changing position of their hive and will not drift back to the old site. When colonies are sufficiently close, one or two feet apart, they are ready for uniting. They can be united by three methods either (1) Direct uniting (2) Newspaper method (3) Smoking method.

(i) Direct uniting:

The two hives to be united are brought near gradually and kept side by side. A queen with undesirable traits is removed from one of the hives. In the morning, when the bees are busy, the frames from two hives are gently inserted into one hive. Using this method successfully depends on how well it is executed.

(ii) Newspaper method:

Top cover is removed and the frames are covered with a piece of newspaper having a few holes made with a small nail the bottom, board of the upper colony is then removed and the brood chamber, is placed above the other colony, the newspaper forming a partition between the two. After a day or two, the odours of the colonies will mix and the bees will cut through the paper and will unite together, forming a single colony. After a few days all the frames can be placed in one hive and the upper chamber can be removed.

(iii) Smoking method:

Colonies can be united using smoke method. When the colonies to be united have been brought close to each other, both should be smoked heavily and thin sugary syrup scented with oil of peppermint or wheat flour sprinkled over them. The combs with the bees of the colony to be united should be altered with the combs of the other colony. More smoke and syrup or flour should be applied and the colony closed. The work of the queen may be checked up after three or four days. It is better to unite a laying worker colony to several strong colonies by giving from one to two frames to each of them. If all its frames are united to one colony there is danger of latter's queen being killed by the laying workers.

16.8.5 Extraction of Honey and Wax and Other Bee Products

In addition to honey, beeswax, royal jelly, bee venom, propolis, and pollen are other important honeybee products. Honey is harvested after a flowering season. Beekeepers select combs with ripe honey covered with a fine layer of beeswax, usually those closest to the outside of the nest, in traditional or top-bar hives. Honey extractors are used only to extract honey from super combs. Before placing combs in the extractor, the sealing of cells on the combs is removed with a sharp knife. Extractor should be worked slowly at the beginning and at bout 150 rpm at the end for about 1 to 2 minutes. After that, the frames are reversed and the extractor is used again. A muslin cloth is used to filter the honey after it has been extracted. On the day prior to honey extraction, bees escape between the brood and super. Remove the escape as soon as possible after honey extraction. It is recommended to remove the super chambers during the lean season (May-September), arrange the healthy brood combs in the brood chamber, and use division boards to restrict the space. Feed artificially once a week with 1:1 sugar syrup in water. According to the size of the colony and the availability of stored food, each colony may require 500-750 grams of sugar per week. In the absence of natural pollen sources, pollen substitutes may be provided to the colony.

1. **Honey**

It is a solution of sugars and other minor constituents that bees collect from flowers and concentrate into honey. Honeybees produce this sweet, viscous fluid. Nectar is collected from nectarines at the base of flowers. Also collected from extra floral nectaries, which secrete nectar other than flowers. It is collected also from fruit juice, cane juice etc.

Collection and ripening of honey

Depending on the nectar source, honey contains a wide range of sugars, as well as minerals, vitamins, proteins and amino acids. Nests near honey storage areas usually have a temperature of 35 °C. A field bee draws nectar with its lapping tongue, known as a proboscis. The nectar collected by hive bees is regurgitated by field bees. There is 20 to 40 percent sucrose in nectar. Sucrose is converted into glucose and fructose by the enzyme invertase. Honeybees produce invertase in their saliva and in nectar. Finally, honey is ripened by enzyme action and evaporation of water due to temperature and ventilation produced by bees' fanning their wings. When the water content in the cell reaches about 20 percent, the bees cap it with wax. Honey is now considered "ripe" and will not ferment. Bees prepare for themselves a concentrated food source in this way. Since the honey does not ferment, bacteria cannot grow in it, and it will not deteriorate over time. When there are no flowers, this food sustains the bees.

2. **Beeswax**

Beeswax is the material that bees use to build their nests. It is produced by young honeybees that secrete it as a liquid from special wax glands. Worker bees secrete wax when they are 14 to 18 days old. On contact with air, the wax hardens and forms scales, which appear as small flakes of wax on the underside of the bee. About one million wax scales make 1 kg of wax. Bees use the wax to build the well-known hexagonal cells that make up their comb, a very strong and efficient structure. Bees use the comb cells to store honey and pollen; the queen lays her eggs in them, and young bees develop in them. Beeswax is produced by all species of honeybees, although the waxes produced by different species have slightly different chemical and physical properties.

Processing

Beewax is obtained from the cappings collected during honey extraction. Wax is obtained from old combs that are unfit for use and from combs damaged during honey extraction. Best grade wax is obtained from cappings where the recovery per cent is higher. In India, major proportion of wax is from combs of *Apis dorsata.*

3. Bee venom

Sting of worker bee is attached to a poison sac where venom is stored. Newly emerged bee is unable to sting because she cannot insert the sting which is not fully chitinized. Also little amount of venom is stored in the venom sac. A bee, when two weeks old has maximum venom in her poison sac.

Production

Bee venom is commercially obtained by the use of electric shock. An electric current is passed through copper wires at 12 volts. The bees get shock, irritated and release venom by inserting the sting into a thin nylon cloth below the copper wires. Venom is deposited on a glass plate placed below the nylon sheet. The venom on drying is scrapped from the glass plate. One *Mellifera* colony yields about 50mg of venom.

4. Propolis

Propolis gathered by bees from resinous exudes of tree. In the bee colony propolis is used for sticking frames, sealing cracks and crevices but it is a contaminant of comb wax. Propolis is obtained by scrapping it from the frames.

5. Royal jelly

Royal jelly is secreted by gland of nurse bees of the age of 6 to 12 days when the glands are fully active. It is very nutritious food and is fed to the young worker larvae and the queen larva and adult. Royal jelly is milky or light pale in colour.

Production

The queen cell is trimmed to the level of the royal jelly. After 2 or 3 days of grafting, larvae are gently removed with forceps and the royal jelly is removed with royal jelly spoon. This is stored in refrigerated conditions. In case of *Apismellifera* 200mg of royal jelly is obtained from a queen cell.

6. **Pollen**

It is collected by pollen trap from ingoing pollen foragers. Pollen is a rich protein source for human diet.

16.9 ROLE OF HONEY BEE IN CROP POLLINATION

Qualities of honeybees which make them good pollinators

1. Body covered with hairs and have structural adaptation for carrying nectar and pollen.
2. Bees - Not injurious to plants
3. Adult and larva feed on nectar and pollen - Available in plenty
4. Superior pollinators - Since store pollen and nectar for future use
5. No diapause - Need pollen throughout year
6. Body size and probascis length - Suitable for many crops
7. Pollinate wide variety of crops
8. Forage in extreme conditions also (weather)

Effect of bee pollination on crop

- It increases yield (seed yield, fruit yield) in many crops
- It improves quality of fruits and seeds
- Bee pollination increases oil content of seeds in sunflower
- Bee pollination is a must in some self incompatible crops for seed set

Scope of beekeeping for pollination in India

- Total area under bee dependant crops - 50 million ha
- At the rate of 3 colonies/ha - 150 million colonies needed
- In India only 1.2 million colonies exist - There is scope

Management of bees for pollination

- Place hives very near the field (source) - to save bee’s energy
- Migrate colonies near field at 10% flowering

- Place colonies at 3/ha - Italian bee; 5/ha - Indian honey bee
- The colonies should have 5-6 frame strength of bees, possess sealed brood, have young mated queen
- Allow sufficient space for pollen and honey storage

16.10 SUMMARY

The science of beekeeping is known as apiculture. Apiculture makes use of low-cost, locally available resources that yield quick results. Honey bees are important for cross pollination and crop yield improvement, which is a profitable venture with environmental, socioeconomic and cultural implications. However, due to some constraints such as improper harvesting, bee diseases, pests and predators, poisoning from agro-chemicals and deforestation, beekeeping expansion has been slow.

16.11 TERMINAL QUESTIONS AND ANSWERS

1. How long does a honeybee live? How long does a queen live?

A worker bee typically lives six weeks during the summer, and during that time it has a variety of different jobs — nurse, undertaker, architect, cleaner, attendant, guard, forager. However, worker bees that live in the wintertime have a longer lifespan and can live up to six months. If they couldn't survive longer, they would all die, because the queen doesn't lay eggs in the winter. In the spring, when the queen begins to lay eggs, the overwintering workers transform back into "job mode" and start their typical six-week lifespan.

A queen bee lives anywhere from one-five years, and a drone lives about six months. However, a drone dies after he mates with another queen, so his lifespan could be much shorter.

2. How can you tell the difference between a worker bee, drone and queen bee?

A worker bee is the typical bee that you would see, and the queen looks similar except her abdomen is about twice the length of a worker. This allows her to drop her abdomen into a honeycomb cell to lay an egg at the bottom. A drone bee is larger than a worker and is fuzzier.

3. How do bees carry pollen?

A honeybee carries pollen in specialized sacs on its hindlegs. You might have seen one with bright yellow packets of pollen on its legs as it returns to a hive from foraging. Many native, solitary bees are covered in stiff hairs to which pollen sticks. These bees can carry pollen all over their bodies, depositing it and helping with pollination as they move from flower to flower.

4. What are flowers that bees like? How can I help bees?

It boils down to the fact that bees and other pollinators like native flowers — because that is what they are adapted to — that are bright, fragrant and have easily accessible and ample nectar. You can plant a pollinator garden in your yard or help support large pollinator plantings in the community. It is best to plant a variety of flowers, because different species are attracted to different species of flowers, and to plant flowers that bloom from early April through October. This allows for habitat and food throughout the growing season.

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UNIT 17: LAC CULTURE

CONTENTS

17.1 OBJECTIVES

The aim is to study in detail the lac insects, host plant management and lac cultivation methods for the improvement of livelihood and socio-economic condition of poor tribal and backward families.

17.2 INTRODUCTION

Systematic Position:

Phylum: Arthropoda

Class: Insecta

Order: Hemiptera

Superfamily: Coccidae

Family: Lacciferidae

Genus: *Laccifer*

Species: *lacca*

- Lac is an animal-derived natural resin. Lac insect secretes it.
- This technique is called lac-culture and it involves cultivating insects in order to obtain lac.
- This involves the proper care of host plants, the regular pruning of host plants, the propagation of host plants, the collection of lac, and the processing of lac.
- To protect themselves, some Hemipterans secrete lac over their bodies, such as Lacciferidae and Tachardinidae.
- The Lac insect belongs to the superfamily Coccoidea of the order Hemiptera and is classified as a Laccifer.

- A total of 22 species have been recorded in the Indian subcontinent under the genus Laccifer.
- India is still considered to be the world's top lac producer. In the sixteenth century, Burma began trading lac.
- A lac culture dates back at least 4000 years in China, and lac is used to dye silk and leather goods. Approximately 65% of the world's production is produced in India.
- India's total lake production is accounted for by Bihar and Jharkhand.

17.3 LAC INSECT AND ITS LIFE HISTORY

Hosts

Plants such as:

Kusum (*Schleicheratrijuga*)

Palas (*Buteafrondosa*)

Ber (*Zizyphus jujube)*

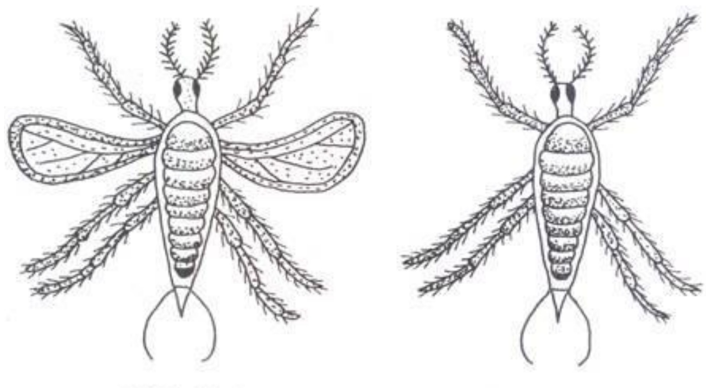
Babul (*Acacia arabica*)

Khair (*Acacia catcchu*)

Arhar (*Cajanusindicus*)

- *Laccifer (= Tachardia) lacca* is commonly found on *Zizyphusmauritiana, Buteamonosperma, Acacia arabica, A. catechu, Cajanuscajan, Ficusbenghalensis, F. cunia*, and *F. religiosa*.

Biology Of Lac Insect



Adult lac insect

The lac insect,*Lacciferlacca (Tachardialacca),* is commercially cultivated. Indian and Bangladeshi host plants include ber *(Zizyphusmauritiana),* palas *(Buteamonosperma),* and kusum*(Schleicheraoliva).*

Structure of Male Lac-insect:

- It is larger and red in color.
- Typically, the body is divided into three parts: the head, thorax, and abdomen.
- Antennae and eyes are present on the head.
- Male adult insects lack mouth parts, so they cannot feed.
- There are three pairs of legs on the thorax. There may or may not be wings.
- Located at the posterior end of the body, the abdomen bears a pair of caudal setae and a sheath containing a penis.

Structure of Female lac-insect:

- The size of the device is smaller.
- A pair of antennae and a single proboscis are located on the head.

- There are no eyes. There are no wings or legs on the thorax.
- Female larvae lose their eyes, wings, and legs because they never move again after settling down, making these parts useless and eventually atrophying.
- There are two caudal setae on the abdomen.
- The bulk of lac is secreted by female lac insects.

Life Cycle

- A female insect produces approximately 1000 nymphs with black eyes and a deep red colour.
- Larvae settle on a suitable plant host gregariously.
- Larvae begin secreting lac a day or two after settlement, except on the rostrum, spiracles, and abdomen tip.
- Thus, the insect is enclosed in a cell of lac that gradually increases in size as it grows.
- Before reaching maturity, the insect moults twice.
- Male larvae produce elongated lac cells, while females produce oval cells.
- Larvae lose their legs, antennae, and eyes after their first moult.
- A pseudo-pupal stage is reached after the third moult. The males emerge, copulate with the females, and then die.
- The female larvae never regain their appendages and remain under the lac cell until they become adults and reproduce.
- On the tree branch, lac secretion from adjacent cells coalesces to form a continuous encrustation as the lac insects remain close together.

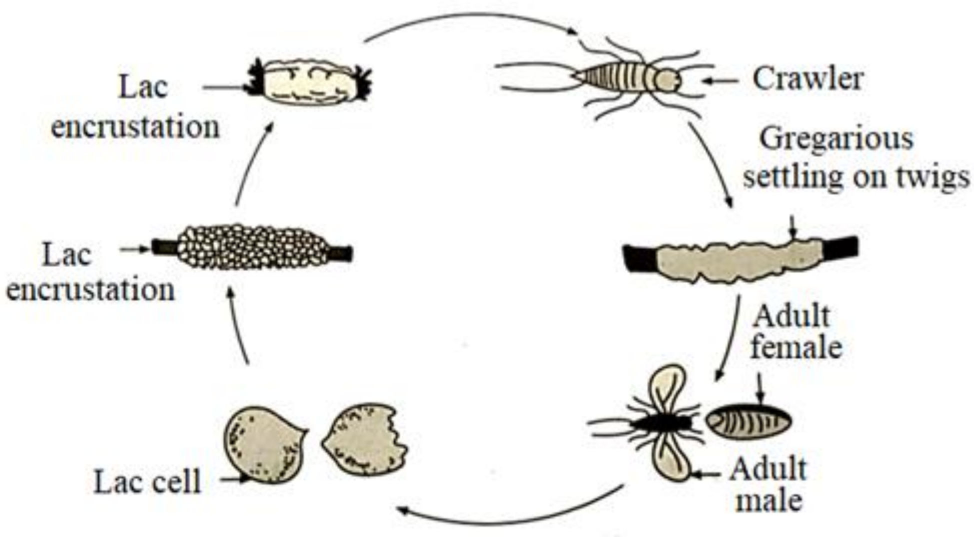
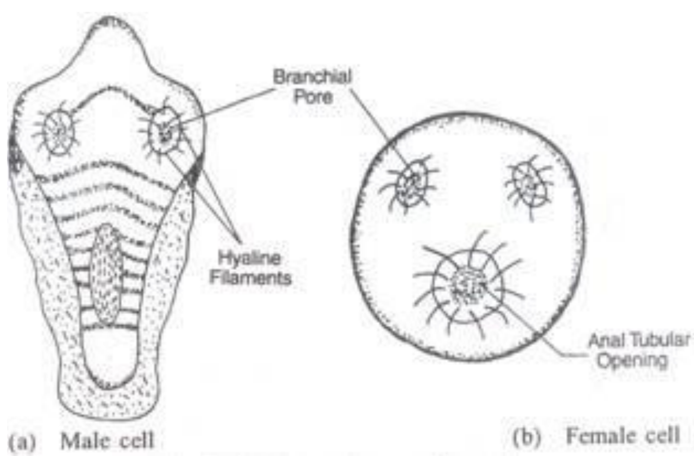


Fig: Life Cycle of Lac Insect



Different forms of lac cell

17.4 HOST PLANT MANAGEMENT

Production of lac crop is very much dependent on the species of host and obviously on the health status of the lac host. The health of lac host again depends on the fertility status of soil. Besides, there are a number of abiotic factors influencing lac production critically. Few of these factors are beneficial for lac production, few are beneficial for growth of the host tree and rest is beneficial for both. Each of these factors are effective at a critical level for optimum production of lac. Thus, challenges of lac cultivation are different from that of general agriculture due to influence of so many factors. Management of soil and crop in a sustainable manner can only increase profitability in a lac production system. There could be a long list of such factors. These are crop rotation, irrigation and drainage, plant breeding, plant physiology, soil classification, soil fertility, weed control, insect and pest control. Therefore, maximization of production is possible when all these factors are manipulated in a compatible way to harness the positive interaction of factors on lac yield.

Canopy management

In the natural stand of ber, plants with spreading, semi-erect, erect and umbrella (bushy type) shaped are observed. Spreading type trees are usually vigorous in nature and good producers of lac, provided the insect settlement is not affected due to poor light interception. Erect type trees are most consistent yielders due to good distribution of sunlight and ventilation throughout the canopy. Umbrella shaped or bushy trees are poor lac yielders due to poor distribution of light and improper ventilation inside the canopy. The causes of yield variation are mainly due to branching behaviour, dimension of shoots, internodes length etc. Whatever may be the canopy structure, small shoots (< 1.0 cm basal diameter at maturity i.e. 0.7 cm during inoculation) are not good for lac production due to high lac mortality on such shoots. By and large such shoots (60-75%) are unproductive for brood lac. Interception of light can be facilitated if these unproductive shoots are removed. So, by removing such shoots in one hand we can create good environment for lac growth on bigger shoots and on the other hand, wastage of broodlac can be minimized. Similarly, in case of semialata, shoots having basal diameter of approximately 6 mm may be removed for facilitating better ventilation.

Shoot characteristics

Lac production capacity is dependent on the physiological characteristics of host species and on nutrient supply to the host. Texture and size increases with the age of the shoots. Under normal soil fertility condition, when lac cultivation is practiced regularly on shoots with basal diameter ranging from 1.0 cm to 2.5 cm are considered to be the best for different lac hosts. In general, lac survival per cent (living lac encrustation to length of settlement) increases with increase in diameter but length of lac insect settlement decreases as the diameter of the branch increases and tend to settle on secondary branches. Usually, an increase in the diameter of the branch between broodlac inoculation in July to harvesting in February is about 35 per cent in case of ber. Therefore, at the time of inoculation branches with diameter varying from 0.75 cm to 1.85 cm are considered to be optimum. Normally best age of shoots for kusum, ber and palas are 18, 6 and 7 months. Best shoots are neither very tender nor very old. At proper age certain portion of it assumes a characteristic grayish colour. Lac insect encrustation grown on it remains attached very firmly and doesnot detach from stem. Good quality broodlac with smooth encrustation are produced from such shoots.

17.5 STRAINS OF LAC INSECTS:

RANGEENI AND KUSUMI are two strains of lac insects recognized in India. Both strains complete their life cycle twice a year, but their maturity season differs greatly. In a year, there are four lac crops named after Hindi months.

The crops are shown in the table given below:

Strains of Lac	Crop	Weather	Lac Host Plant	Seed Inoculation (dhVlapkj.k)	Crop Harvesting	Time (In month)
Rangeeni	Katki	Rainy Season	Palas	June-July	October-November	4
	Baisakhi	Summer	Palas	October - Nov	June-July	8
		Summer	Ber	October - Nov	May-June	6
	Aghani	Winter	Ber	June-July	Januray-	6

Kusumi					February	
	Jethwi	Summer	Kusum	January-February	June-July	6

S. No	Lac Host Plant	Lac Crops	Crop Season
1	Palas	Rangeeni	Summer & Rainy Season
2	Kusum	Kusumi	Summer & Rainy Season
3	Ber	Rangeeni	Summer
4	Ber	Rangeeni	Winter Season

17.6 PROPAGATION OF LAC INSECTS

Lac insects live in cavities or cells made in resin or lac secreted by their host plants. The average female lays 200-500 ready-to-hatch eggs per cycle,a mature embryo is inside the eggs when they are laid, i.e. it is fully developed. Lac insets reproduce ovoviviparously. Insects lay three types of eggs: i) from which males emerge in greater numbers than females; ii) from which females emerge in greater numbers than males; and iii) from which both males and females emerge in equal numbers. The tiny crimson-red first instar nymphs emerge from the lac encrustation within a few hours of laying the eggs. The nymphs have six anal setae, two compound eyes, and two pairs of antennae. Nymphs in their first instar are known as crawlers. During swarming, nymphs emerge for five or more weeks at a time. Upon reaching soft, succulent twigs, the nymphs settle down, thrust their needle-like proboscis into the bark, and begin sucking the sap. The nymphs settle on twigs that are neither too soft nor too hard, and they settle at a rate of 200-300 insects per inch, depending on the number of broods they have. In a few days, after settling, the nymph begins secreting resin from glands under the cuticle, except near the mouthparts, breathing pores and anus. A semisolid resin is secreted, and when exposed to air, hardens into a protective coating called lac. Before reaching maturity, nymphs moult three times inside their cells. The duration of each instar depends on several factors, including temperature, humidity, and host plant. A nymph loses its legs, antennae, and eyes after its first moult, but the number of its anal setae increases from six to ten. At this stage, the male and female cells can be distinguished, the male being slipper-like with an operculum at the rear and the female being nearly globular. Male nymphs regenerate their appendages during their second moult, while females feed, grow, and secrete resin during their pupal stage. A male emerges as an adult with wings and without wings after his third and final moult. In the second generation, only wingless forms are born, and the males mature half as quickly as the females. As soon as they emerge, they start mating with as many females as possible and die due to atrophy of their mouth parts. Females remain inside their lac cells and start growing rapidly. Female cells increase in size so that they contribute the bulk of the lac. Lac cells become globular as they grow, filling the entire space. In preparation for laying eggs, they shrink in size to make room for the eggs. In the rear end of the cell, two yellow spots appear. As the spot grew, it became orange in color. Under the tail ends of the females, a large number of eggs are oviposited in the space called the ovisac. Eggs in the ovisac appear orange, which indicates that they will hatch within a week. For inoculation of new trees, the twigs (brood lac) are cut from the tree.

17.7 LAC CROP MANAGEMENT

It is a complex process to cultivate lac. In order to cultivate lac, it is necessary to take good care of the host plants, propagate them, and collect the milk. Lac cultivation involves the following steps:

1. Selection of site and the host plants
2. Pruning
3. Inoculation
4. Swarming
5. Harvesting of lac

Site selection and the host plants: A good host plant selection is crucial to lac cultivation, since the quality and yield of the lac are directly proportional to the number of host plants. Babul, Pipal, Palas, Kusum, Khair, etc., are some of the host plants. Thus, the cultivation site should have more and more host plants.

Plants that host lac insects must be fast growing, have low sap density, and able to withstand heavy infestation. The lac from Kusum (Schleicheratrijuga) attracts the highest market price of all the plants listed above. Then there are the host plants such as Palas (Buteafrondosa), Ber (Zizyphusjujuba), and Sirrus (Albizzialebbak).

Pruning

Lac production is also influenced by the time of pruning. Pruning must be done properly so that the host plant does not lose health and nutrition, and also produces better quality and quantity of lac.

Lac insect inoculation is usually performed 6-12 months prior to pruning. If inoculation is to be done in June-July, pruning should be done in January-February. If inoculation is to be done in October-November, pruning should be done in April-May. Pruning should take care of the following points:

- Pruning should not be excessive. As a result, the tree's general health and strength are maintained.
- Only cut the old branches of the host plant. It is prohibited to cut branches larger than two inches in diameter.
- Make sure the tree is shaped well so that new shoots can grow freely.
- Thin branches should be cut close to the trunk from which they arise.
- Branches that are dead or diseased should be removed
- Split or broken branches should be cut below the split or break
- Lac bearing branches should not be cut indiscriminately.

Inoculation:

Innoculation is the first step in cultivating the lac insect. It is the process by which the young ones become properly associated with the host plants. There are two methods of vaccination: natural inoculation and artificial inoculation.

Natural inoculation occurs in normal routine and is a very simple process where swarmed larvae infect and suck out sap from the same host plant. Artificial inoculation involves cutting twigs with insect larvae that are about to swarm. In order for the larvae to swarm to the new host plant, the cut pieces are tied to fresh trees. As a general rule, artificial inoculation is considered to eliminate all possible drawbacks of natural inoculation.

Swarming

Lac insects swarm during their swarming phase. Yellow spots appear on the upper surface of the anal region during swarming. Muscles contract at this stage, and the insect is detached from its attachment point. A hollow cavity is left behind, which is later filled with resin. Experience can be used to determine the exact time of swarming.

Harvesting of lac

Harvesting is the process of collecting ready lac from a host tree. There are two types of harvesting:

Immature harvesting: Lac harvesting before swarming is called immature harvesting. Ari lac is the lac thus obtained. Insects may be destroyed during harvesting, which leaves cultivators at a great loss. Only Palas host plants should be harvested for Ari lac.

Mature harvesting: Mature harvesting occurs after swarming. Mature lac is thus collected.

Lac is most abundant when twigs are harvested while the females are still alive. It is possible to harvest twice a year. Lac and eggs are carried by a twig called a brood lac stick, and the lac itself is called brood lack or stick lac.

Lac cultivation is a complex process. Lac cultivation involves taking care of the host plants, propagating the seeds, and collecting the lac. Lac cultivation involves the following steps:

1. Site selection and host plant selection
2. Pruning
3. Inoculation
4. Swarming
5. Harvesting of lac

Selection of site and the host plants

Lac cultivation relies heavily on the selection of suitable host plants since quality and yield are directly proportional to the number of host plants. Babul, Pipal, Palas, Kusum, Khair, etc., are some of the host plants. As a result, the cultivation site should have a greater number of host plants.

It is necessary that the host plants grow quickly, have a low sap density, and be able to withstand heavy infestations of lac insects. In the market, the lac from the host plant Kusum

(Schleicheratrijuga) commands the highest price. There are also host plants like Palas (Buteafrondosa), Ber (Zizyphusjujuba), and Sirrus (Albizzialebbak).

Pruning

Lac production is also influenced by the time of pruning. Pruning must be done with proper care so that the host plant does not lose health, nutrition, and also produces better lac quality and quantity.

Lac insect inoculation is usually performed 6-12 months prior to pruning. If inoculation is to be done in June-July, pruning should be done in January-February. If inoculation is to be done in October-November, pruning should be done in April-May. Pruning should take care of the following points:

- Pruning should not be excessive. As a result, the tree's general health and strength are maintained.
- Only cut the old branches of the host plant. It is prohibited to cut branches larger than two inches in diameter.
- Make sure the tree is shaped well so that new shoots can grow freely.
- Trim thin branches close to the trunk.
- Branches that are dead or diseased should be removed
- Split or broken branches should be cut below the split or break
- Lac bearing branches should not be cut indiscriminately.

Inoculation

Innoculation is the first step in cultivating the lac insect. It is the process by which the young ones become properly associated with the host plants. There are two methods of vaccination: natural inoculation and artificial inoculation.

During the natural inoculation process, swarmed larvae infect and suck out sap from the same host plant again. Artificial inoculation, on the other hand, involves cutting the twigs containing the insect larvae that are about to swarm. The larvae are tied to fresh trees so that they swarm to the new host plant. In general, artificial inoculation is considered to eliminate all possible drawbacks associated with natural inoculation.

Swarming

Lac insects swarm during their swarming phase. Yellow spots appear on the upper surface of the anal region during swarming. Muscles contract at this stage, and the insect is detached from its attachment point. A hollow cavity is left behind, which is later filled with resin. Experience can be used to determine the exact time of swarming.

Harvesting of lac

Harvesting is the process of collecting ready lac from a host tree. There are two types of harvesting:

Immature harvesting: Lac harvesting before swarming is called immature harvesting. Ari lac is the lac thus obtained. In this process, the insects may be destroyed during harvesting, causing the cultivators great loss. Only Palas host plants should be harvested for Ari lac.

Mature harvesting: Lac is harvested after swarming is called mature harvesting. Mature lac is thus collected.

The highest yield of lac is obtained by harvesting twigs while the females are still alive. It is possible to harvest twice a year. Lac-bearing twigs along with eggs are called brood lac sticks, and lac itself is called brood lac or stick lac.

17.8 NATURAL ENEMIES OF LAC INSECTS AND THEIR MANAGEMENT

Lac enemies pose a challenge to lac culturists, as they not only reduce lac insect population, but also retard lac production and quality. There are two types of damage caused to lac insects (a) damage caused by insects (b) damage caused by animals other than insects. Lac crop enemies include predators and parasites. Chalicides are the most common parasites of lac insects. They are small, winged insects that lay their eggs inside the lac insect's coat either on the body of the insect or inside it. Upon hatching, larvae feed on lac insects, causing their deaths. About 5-10% of the lac crop is destroyed by this parasite.

Predators cause more damage (35% of the total destruction). The lac insect is primarily preyed upon by Eublemmaamabilis and Holococerapulverea. Termites not only eat lac insects, but also destroy the lac they produce. Aside from insects, squirrels, monkeys, rats, bats, birds (woodpeckers), man, etc., are the enemies that destroy the lac crop. In addition to climatic factors like excess heat, cold, heavy rain, and storms, faulty cultivation methods also cause damage.

Control: Damage caused by the above mentioned animals can be reduced to certain extent by the use of the following methods.

1. Cultural Method:

• The amount of damage by infection can be reduced to a greater extent by taking care during the culture of lac insects, especially at the time of inoculation. The brood lac showing the minimum enemy attack should be selected for inoculation and should be cut from the host plant very near to the time of emergence of larvae (about one week before the emergence). This will reduce the chances of parasite attack on the emerging larvae at new place (host).

• The brood lac used for inoculation should be removed from the new host's branches as soon as the emergence of larvae stops (approx. 3 weeks after inoculation). It reduces the chance of transference of enemies to the new host plant from the brood lac. The infected brood lac not fit for inoculation or the used up brood lac should not be retained for long. The lac should be scrapped at once and the rest may be crushed or dropped into fire in order to destroy the predators and parasites.

• The delay m processing also gives chances to the enemy insects to escape into field. So the manufacturers should try to convert stick lac into seed lac as soon as possible. By these cultural methods the future production can be saved from infection to some extent.

2. Artificial Method:

During the crop reaping, it is not always possible for the manufacturers to convert the huge amount of stick lac to seed lac at a time. To avoid the spreading of enemies at this time from stocked stick lac simple artificial method can be used. Bundles of stick lac should be tied with stones and immersed in fenced water (river or ponds) for about a week. This kills all the parasitic and predator insects as they cannot survive in water.

3. Biological Method:

It is an indirect method for killing the parasitic and predator insects. For this purpose hyperparasitic insects are used which attacks the parasitic insects of lac and kill them. These hyperparasitic insects are however, not harmful for lac crop.

17.9 LAC EXTRACTION

Lac is processed after it is harvested from the host plants. The first step in processing stick lac is scraping it off the twig. This scraped lac must now be cleaned of impurities such as dead lac insects, eggs, and coloring matter. Finally, hand-operated mortars are used to crush the lac after it has been cleaned. Crushed lac is air dried, resulting in pale yellow granules. Seed lac is what it is called.

Lac incrustation

After soaking, seed lac is washed, dried in the sun, bleached, and heated to melt on charcoal in cloth bags. As the bag is heated, the lac is squeezed out, leaving the impurities in the bag. Kirri lac is the name given to this lac.

To form button lac or pure lac, kirri lac is allowed to cool and solidify around button-shaped forms. Sheet lac is made from pure lac stretched into thin sheets. When dissolved in water, sheet lac produces shell lac, which is white or orange in color.

Lac quality is determined by the host plant. A kusumi lac is said to be the best and most expensive lac, while a dhak lac is said to be the worst and cheapest. Lac quality and color vary depending on the presence of gum and resin in the host plant.

Types of lac

- The immature lac harvested from the host plant is known as Ari lac
- A stick of mature lac is harvested from a host plant in the form of a stick (lac)
- The seed lac is obtained by removing the lac from the stick and washing it
- After grinding seed lac, dust lac is obtained
- Shellac is prepared by heating seed lac and dust lac together

17.10 SUMMARY

Lac culture is a lesser-known, but economically sustainable, part of animal husbandry. During its life cycle, the lac insect, a small insect of the order Hemiptera, secretes resinous material. Lac is produced by larvae and pupae. The only commercial resin derived from animals is lac.

A lac culture is the scientific management of lac insects and their hosts as well as pest management, cultivation, and harvesting of lac. Economically, lack of culture is a stronger option for self-employment, and many villagers, including tribals, are in this business. Lac production in India is the highest in the world.

17.11 TERMINAL QUESTIONS AND ANSWERS

1. Write down the scientific classification of Lac insect.
2. Write the importance of lac and position of India in its production.
3. Discuss the history and other names gives to Lac insect.
4. Explain the importance of lac with reference to India.
5. Write the economics of lac production in India.
6. How can the lac production be increased in India.

7. Discuss the life cycle of Lac insect.
8. Draw a neat labelled diagram of the life cycle of lac insect.

QUESTIONS WITH ANSWERS:

Q.1: What are the uses of lac culture?

Ans: Lac is used in a variety of applications, including filling ornaments, making bangles, sealing wax, making toys, gramophone records, grinding stones, silvering mirror backs, and encasing cable wires. Lac is also used to make by-products such as nail polish, varnish, and dyes.

Q.2: Lac culture has what major function?

Ans: Lac culture serves the following functions:

a. Growing host plants for lac insects

b. Managing host plant pests

c. Lac insect breeding

d. Management of lac insect pests

e. Harvesting of the lac

f. The production of lac that is commercially usable

Q.3: What is Lac?

Ans: Lac is a resinous substance secreted by the lac insect. As far as we know, it is the only commercial resin of animal origin.

Q.4: What is the binomial name of lac insect?

Ans: The binomial name of lac insect is *Lacciferlacca*.

Q.5: What is the definition of lac culture?

Ans: For the production of high-quality lac, lac insects are managed and reared in a scientific manner.