TEXT BOOK OF ENTOMOLOGY

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They have sufficient teaching and research experience with expertise in Entomology and its significance. They have written this book for the benefits of undergraduate and postgraduate students.

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PREFACE

The first edition of “Textbook of Entomology” this book was written to help students to learn about Entomology is the study of insects. More than one million different species of insect have been described to date. They are the most abundant group of animals in the world and live in almost every habitat. Entomologists are people who study insects, as a career, as amateurs or both.

Professional entomologists contribute to the betterment of humankind by detecting the role of insects in the spread of disease and discovering ways of protecting food and fiber crops, and livestock from being damaged. They study the way beneficial insects contribute to the wellbeing of humans, animals, and plants.

We welcome comments by readers of “Textbook of Entomology” for ways to improve the book and to increase its value. Such suggestions will be seriously considered in the preparation of subsequent editions.

CHAPTER-I

CLASSIFICATION

Classification of insects up to order with examples.

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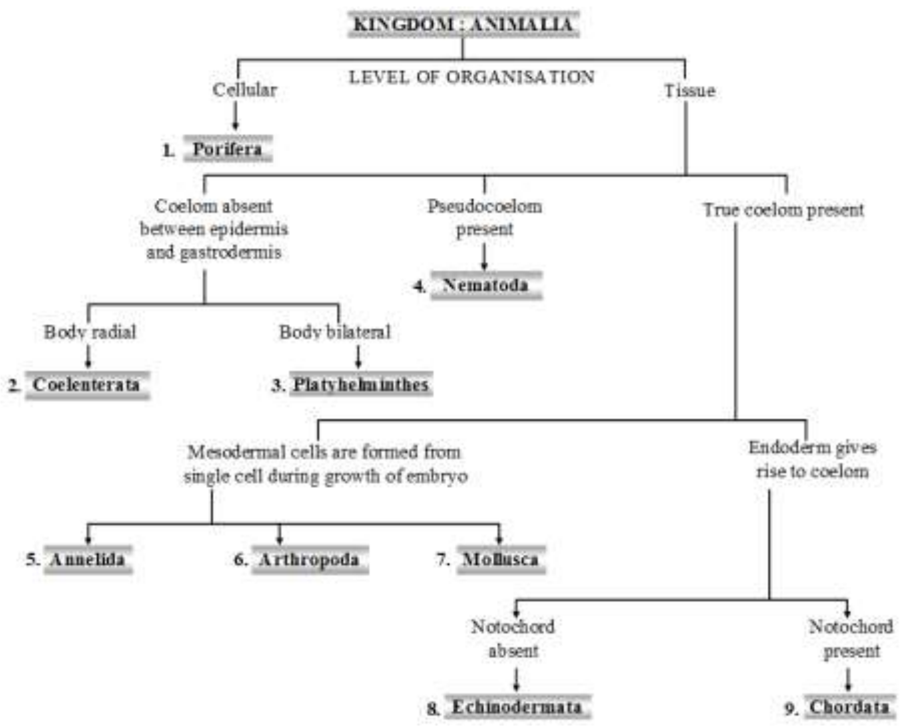
Phylum Arthropoda

Arthropods are joint-legged animals and you must have come across a few of these animals. Some prominent ones include insects, spiders, ants, bees, crabs, shrimps, millipedes, centipedes etc. Scientifically speaking, they all come under the Animal Kingdom under phylum Arthropoda.

The success of the arthropods can mainly be attributed to the presence of exoskeleton, which makes them versatile, is protective in nature and also allows flexibility and mobility. You can see arthropods living on land and in water.

KINGDOM: ANIMALIA OR ANIMAL KINGDOM



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Characteristics

Phylum Arthropoda

The word **arthropod** derived from the Greek root words *arthro-* meaning *joint* and *-pod* meaning *foot* refers to a unique feature of the group—jointed legs, called appendages, which vary widely in number and function. Appendages are used for eating, feeling, sensing, mating, respiring, walking, or defence.

The phylum **Arthropoda** contains a wide diversity of animals with hard exoskeletons and jointed appendages. Many familiar species belong to the phylum Arthropoda—insects, spiders, scorpions, centipedes, and millipedes on land; crabs, crayfish, shrimp, lobsters

All animals are multicellular, eukaryotic heterotrophs

- They have multiple cells with mitochondria and they rely on other organisms for their nourishment.
- Adult animals develop from embryos: small masses of unspecialized cells
- Simple animals can regenerate or grow back missing parts
- Most animals ingest their food and then digest it in some kind of internal cavity.

- Somewhere around 9 or 10 million species of animals inhabit the earth.
- About 800,000 species have been identified.
- Animal Phyla- Biologists recognize about 36 separate phyla within the Kingdom Animalia.

Characteristics of Class Insect

- These are tracheated arthropods.
- It possesses 3 pairs of jointed legs.
- Body is segmented.
- Insect body is divided into 3 regions viz., head, thorax and abdomen.
- It possesses a pair of compound eyes & antennae.
- Two pairs of wings are present in adult stage.

The earth is literally crawling and buzzing with insects, otherwise known as members of the class **insecta**. It would be hard to get through the day without a close encounter with a six-legged species. Insects are so prolific that added together they outnumber all other life forms combined. They are found on land, in the air, and in the sea. And the diversity is astounding. From the minuscule pesky flea to the majestic monarch butterfly, there are around a million different species. In spite of their vast differences, all insects

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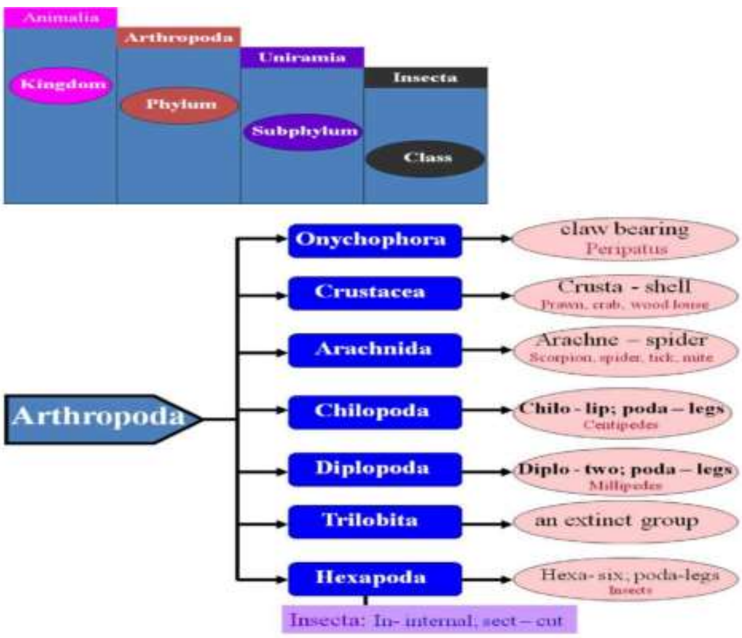
The Insects (Class Insecta) are divided into a number of Orders. These are grouped together into two sub-classes called the Apterygota (wingless insects) and the Pterygota (winged insects)

POSITION OF INSECTS IN ANIMAL KINGDOM



Subclass 1. Apterygota (Ametabola) (Gr., a=without ptera=wings)

- Primitive insects without wings.
- Abdomen with cerci and style-like appendages.
- Metamorphosis is little or absent.
- It includes the orders **Thysanura** and **Diplura** (bristletails), **Collembol a** (springtails) and **Protura**.

Subclass 2 – Pterygota

Winged or secondarily wingless; metamorphosis; adults without pregenital abdominal appendages; adult mandibles (unless greatly modified) articulating with head capsule at 2 points. Infraclass Paleoptera Mostly extinct; wings held aloft over back or extended permanently on each side of the body, unable to fold back

Ametabolous

The most primitive insects, such as springtails, silverfish, and firebrats, undergo little or no true metamorphosis over the course of their life cycles. Entomologists refer to these insects as "ametabolous," from the Greek for "having no metamorphosis." When they emerge from the egg, immature ametabolous insects look like tiny versions of their adult counterparts. They continue molting and growing until they reach sexual maturity.

Hemimetabolous

Growth for hemimetabolous insects occurs during the nymph stage. Nymphs resemble the adults in most ways, particularly in appearance, exhibit similar behaviors, and typically share the same habitat and food as the adults. In winged insects, nymphs develop external wings as they molt and grow. Functional, fully-formed wings mark their emergence into the adult stage of the life cycle. Some hemimetabolous insects include grasshoppers, mantids, cockroaches, termites, dragonflies, and all true bugs.

Holometabolous

Most insects undergo complete metamorphosis over the course of a lifetime. Each stage of the life cycle—egg, larva, pupa, and adult—is marked by a distinctly different appearance. Entomologists call insects that undergo complete metamorphosis "holometabolous," from "holo," meaning "total." The larvae of holometabolous insects bear no resemblance to their adult counterparts. Their habitats and food sources may be entirely different from the adults as well. Larvae grow and molt, usually multiple times. Some insect orders have unique names for their larval forms: butterfly and moth larvae are caterpillars; fly larvae are maggots, and beetle larvae are grubs. When the larva molts for the final time, it transforms into a pupa.

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The pupal stage is usually considered a resting phase, although many active changes are occurring internally, hidden from view. The larval tissues and organs break down entirely, then reorganize into the adult form. After the reorganization is complete, the pupa molts to reveal a mature adult with functional wings. Most of the world's insect species—including butterflies, moths, true flies, ants, bees, and beetles—are holometabolous.

Outline classification of insects

S. No.	**Subclass**	**Orders**	**Examples**
1	Apterygota/ Ametabola	Thysanura	Silverfishes
2		Diplura	Compodea
3		Protura	Proturans
4		Collembola	Springtails
5	Metabola	Ephemeroptera	Mayflies
6		Odonata	Dragonflies and *Damselflies*
7		Plecoptera	Stoneflies
8		Grylloblattodea	Grylloblatta
9		Orthroptera	Grasshoppers, Crickets, Locusts
10		Phasmida	Stick insects and Leaf insects
11		Dermaptera	Earwigs

12	Hemimetabola	Embioptera	Embid
13		Dictyoptera	Cockroaches, Mantis
14		Isoptera	Termites
15		Zoraptera	Zorapteran
16		Psocoptera	Psocids, Booklice
17		Mallophaga	Biting lice, bird lice
18		Siphunculata	Sucking Lice
19		Hemiptera	Cicadas, Leaf hopper, aphids
20		Thysanaptera	Thrips
21	Metabola Holometabola	Neuroptera	Lacewings, ant lions
22		Coleoptera	Bettles
23		Strepsiptera	Stylopids
24		Mecoptera	Scorpion flies
25		Siphonoptera	Fleas
26		Diptera	Flies
27		Lepidoptera	Butterflies, moths
28		Trichoptera	Caddis flies
29		Hymenoptera	Sawflies, ants, Beetles, wasps

1. Order Thysanura

Characteristics Features

- Body is elongate and flattened. Body is glistening and clothed with scales.

- Compound eyes are present or absent. Antennae is long, filiform and multisegmented.
- Mouthparts are ecotognathous, biting type. They are primarily wingless insects. Abdomen is 11 segmented.
- Varying number of bilateral styli are present on abdominal sternites. Styli are believed to be reduced abdominal legs.

- Female has elongated jointed ovipositor. Abdomen at its tip carries a pair of elongate many segmented cerci and a median caudal filament. Insemination is indirect.
- Metamorphosis is absent. Moulting continues even after attaining sexual maturity.
- It is often a pest in home and libraries.
- Ctenolepisma sp. is the common household silverfish. It feeds and destroys paper, book bindings and starched clothing.
- It can be collected from amongst old books, behind calendar, photo frames, etc.

  Eg: Silverfish

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Silverfish

2. Order: Diplura (Diplurans)

Characteristics Features

The diplurans appear somewhat similar to the silverfish and bristletails, but they lack a median caudal filament and thus have only two caudal filaments or appendages. The body is usually not covered with scales; compound eyes and ocelli are absent; the tarsi are one segmented; and the mouthparts are mandibulate and withdrawn into the head. The antennae are long and multisegmented; styli are present on abdominal segments 1-7 or 2-7. These hexapods are small and usually pale in color. They are found in damp places in the soil, under bark, under stones or logs, in rotting wood, in caves, and in similar moist situations. Small to large, narrow bodied entognathous insects Antennae moniliform, with intrinsic musculature Compound eyes and ocelli absent

Abdomen with 10 segments, ending in a pair of cerci Larval development epimorphic E.g. Campodea

Campodea

2. Order: Protura (Proturans)

Characteristics Features

The proturans are minute whitish hexapods, 0.6 to 1.5 mm in length. The head is somewhat conical, and there are no eyes or antennae. The mouth parts do not bite, but are apparently used to scrape off food particles that are then mixed with saliva and sucked into the mouth. The first pair of legs is principally sensory in function and is carried in an elevated position like antennae. The tarsi are one-segmented.

Styli are present on the first three abdominal segments. On hatching from the egg, the proturan abdomen consists of 9 segments. At each of the next three molts, segments are added anterior to the apical portion (the telson), so that the adult abdomen appears to have 12 segments (11 metameric segments and the apical telson).

These hexapods live in the moist soil or humus, in leaf mold, under bark, and in decomposing logs. They feed on decomposing organic matter and fungal spores. They are found worldwide and approximately 200 species are known at present.

- Minute insects, with entognathous piercing mouth parts
- Antennae and eyes are absent
- Abdomen 11 segmented with a terminal telson, first 3 segments with a pair of small appendages called styli
- Forelegs sensory and held above the head, like antennae
- Metamorphosis slight, chiefly evident as an increase in number of abdominal segments following each moult (anamorphosis)

E.g. Proturans

Proturans

4.Order: Collembola

Characteristics Features

They are minute insects. Body is globose or tubular. Compound eyes are absent. One to several pairs of lateral ocelli form an eye patch. Antenna is four segmented. Mouthparts are entognathous biting type and found within a pouch. Tibia is fused with tarsus to form tibio-tarsus. They are primarily wingless. Abdomen is six segmented with their medially situated pregenital appendages. * Ventral tube or Collophore or Glue peg: It is a bilobed adhesive organ found on the first abdominal sternite. It is believed to be associated with respiration, adhesion and water absorption.

E.g. Springtails

Springtails Snow flea

Hamula or Tenaculum or Retinaculum: It is present on the third abdominal sternite. It consists of a fused basal piece, corpus and free distal part called rami. It holds the furcula. * Furcula or Springing organ: It consists of a basal manubrium, paried dens and distal claws called mucro. It is held under tension beneath the abdomen by retinaculum when at rest. Malpighian tubules, tracheal system and metamorphosis usually absent. Importance: Sminthurus viridis is a pest on alfalfa. It can be collected from moist places in soil. They are also found in mushroom houses as a pest.

Metabola/Hemimetabola

5. Order: Ephemeroptera

Characteristics Features

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Small to medium sized soft bodied insects. Compound eyes are large. There are three ocelli. Antenna is short and setaceous. Mouthparts in adults are atrophied. Forewings are large and triangular. Hind wings are small and absent in some species. Numerous cross and intercalary veins are present. Wings are held vertically over the abdomen. Wing flexing mechanism is absent. Abdomen is slender with a pair of long cerci. Median caudal filament may be present or absent. Metamorphosis is incomplete with three stages viz., egg, naiad and adult. Naiad is aquatic with biting mouthparts.

It breaths through bilateral abdominal gills. At tip of the abdomen a pair of long cerci and a median caudal filament are usually present. Immediately after the adult emergence body of the insect is covered with closely set fine hairs called pellicle and this stage is called as subimago. It is dull in colour with opaque wings and legs and cerci are not well developed. In imago wings are transparent. Legs and cerci are well developed. Body is shiny and not covered with pellicle. Adults are found near lakes and ponds and are also attracted by light.

Eg., Mayflies, Shadflies, Dayflies

Mayflies

Importance: Naiads are important fish food. Adults are short lived and hence the name dayfly. When they emerge in large numbers the pose nuisance problem.

6. Order: Odonata

Characteristics Features

Medium to large sized insects. They are attractively coloured. Head is globular and constricted behind into a petiolate neck. Compound eyes are large. Three ocelli are present. Mouthparts are adapted for biting. Mandibles are strongly toothed Lacinia and galea are fused to form mala which is also toothed. Wings are either equal or sub equal, membraneous; venation is network like with many cross veins. Wings have a dark pterostigma towards the costal apex. Sub costa ends in nodus. Wing flexing mechanism is absent.

Legs are anteroventrally placed. They are suited for grasping, holding and conveying the prey to the mouth. Spinous femora and tibiae are useful for holding the prey. Forward shift of leg attachments allow easy transfer of prey items to mouth in flight. Legs are held in such a way that a basket is formed into which the food is scooped. Abdomen is long and slender. In male gonopore is present on ninth abdominal segment. But the functional copulatory organ is present on the second abdominal sternite. Before mating sperms are transferred to the functional penis. Cercus is one segmented.

Eg: Dragonflies and damselflies

Importance: Adults are aerial predators. They are able to catch, hold and devour the prey in flight. Naiads are aquatic predators. Dragonflies and damselflies can be collected with an aerial net near streams and ponds especially on a sunny day. Naiads can be collected from shallow fresh water ponds and rice fields.

Dragonflies

Damselflies

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7. Order: Plecoptera

Characteristics Features

Stoneflies are mostly medium-sized or small, somewhat flattened, soft-bodied, rather drab-colored insects found near streams or rocky lake shore. They are generally poor fliers and are seldom found far from water. Most species have four membranous wings. The front wings are elongate and rather narrow and usually have a series of crossveins between hind wings are slightly shorter than the front wings and usually have a well-developed anal lobe that is folded fanwise when the wings are at rest.

A few species of stoneflies have reduced wings or lack wings, usually in the male. Stoneflies at rest hold the wings flat over the abdomen. The antennae are long, slender, and many-segmented. The tarsi are three-segmented. Cerci are present and may be long or short. The mouthparts are of the chewing type, although in many adults (which do not feed) they are somewhat reduced. The stoneflies undergo simple metamorphosis, and the nymphal stages of development are aquatic.

- Soft bodied insects with long setaceous antennae

- Mouth parts weak, biting type, mandibles normal or vestigial, ligula 4 lobed.
- Wings membranous, held flat over the body at rest; hind pair usually larger, with well developed anal lobes
- Tarsi 3 segmented; cerci long.

Eg: Stoneflies

Stoneflies

8. Order: Grylloblattodea (Rock crawlers)

The first member of this group was not discovered until 1914, when Walker described *Grylloblatta campodeiformis* from Banff, Alberta. Rock crawlers are slender, elongate, wingless insects, usually about 15-30 mm in length. The body is pale in color and finely pubescent. The eyes are small or absent, and finely are no ocelli. The antennae are long and filiform, consisting of 23 to 45 segments; the cerci are long, with either 5 or 8 segments; and the sword-shaped ovipoisitor of the female is nearly as long as the cerci. There are only 25 species and four genera of living rock crawlers in the world. Rock crawlers live in cold places such as the talus slopes at the edges of glaciers and in ice caves, often at high elevations. They are mainly nocturanal, and their principal food appears to be dead insects and other organic matter found on the snow and ice fields. They are soft-bodied, and probably best preserved in alcohol.

Characteristics Features

- Slender, elongated wingless insects (15-30mm)
- Body is pale and finely pubescent
- Eyes are small or absent and no ocelli
- Antennae long filiform
- Cerci are long and the sword-shaped ovipositor Eg. *Grylloblatta*

Grylloblatta

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9. Order: Orthoptera

Characteristics Features

They are medium to large sized insects. Antenna is filiform. Mouthparts are mandibulate. Prothorax is large. Pronotum is curved, ventrally covering the pleural region. Hind legs are saltatorial. Forewings are leathery, thickened and known as tegmina. They are capable of bending without breaking. Hindwings are membranous with large anal area. They are folded by longitudinal pleats between veins and kept beneath the tegmina.

Cerci are short and unsegmented. Ovipositor is well developed in female. Metamorphosis is gradual. In many Orthopterans the newly hatched frist instar nymphs are covered by loose cuticle and are called pronymphs. Wing pads of nymphs undergo reversal during development. Specialized stridulatory (sound-producing) and auditory

Eg.: Grasshoppers, Locust, Katydid, Cricket, Mole cricket

Grasshoppers **Mole cricket**

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10. Order: Phasmida

Characteristics Features

Body is stick - like or leaf – like. Head is prognathous. Mouthparts are chewing type. Prothorax is short. Meso and metathorax are long. Metathorax is closely associated with the first abdominal segment. Legs are widely separted. They are long and slender resembling twigs in stick insect. Tibia and femur shows lamellate expansion in leaf insects. A line of weakness is found between the tro-chanter andrest of the leg. The legs get broken easily at this region and such legs get regenerated subsequetly. Tarsus is five segmented. Wings may be present or absent. Forewings when present are small and modified into tegmina. In leaf insects the wing venation mimics leaf venation. Cerci are short and unsegmented. They show protective resemblance. They are herbivorous

Eg.: Stick insects, Leaf insects

 

Stick insects **Leaf insects**

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11. Order: Dermaptera

Characteristics Features

They are generally elongate insects. Head is with a distinct `Y' shaped epicranial suture. They have chewing mouthparts. Prothorax is large, well developed and mobile. Meso and Metathorax are fused with the first abdominal segment. Forewings are short, leathery and veinless. Both the wings meet along a mid dorsal line. They are called tegmina or elytra. They are protective in function and are not used for flight. Hindwings are large, membranous, semicircular and ear like. The anal area of the wings is large with a number of branches of anal veins which are radially arranged. They are folded fan like, longitudinally and twice transversely and kept beneath the forewings at rest. Wings do not cover the abdomen fully. Cerci are found at the end of the abdomen. They are unsegmented enlarged, highly sclerotised and forceps like. They are large and bowed in male and nearly straight in female. They are useful in defence, folding and unfolding of wings, prey capture and copulation. Parental care is shown by female earwigs. It literally, roost on the eggs until hatching occurs and also cares for the nymphs.

Eg.: Earwigs insects

Earwigs insects

Importance: *Euborellia annulipes* bores into groundnut pods and feeds on the kernel.

12.Order: Embioptera

Characteristics Features

They are small elongate soft bodied insects. Antenna is filiform. Mouthparts are chewing type. Basitarsus of the foreleg is greatly enlarged. Silk glands and spinnerets are found in the basitarsus. Hind femur is enlarged and helps in backward running. Male has well developed wings; while female is apterous. Wings are elongate, nearly equal, smoky brown with reduced wing venation. Radial vein is thick. Cerci are asymmetrical; left cercus is one segmented and it serves as clasper. Cerci are equal and two segmented in female. Embiids are gregarious and live inside tubular silken tunnels beneath stones, logs and bark of trees. Silken tunnels give protection against predators, prevent excessive water loss from the body and provide a humid atmosphere. Females show strong parental care and they nurse the eggs and nymphs. They feed on decaying plant matter.

E.g.: Webspinners

Webspinners

13. Dictyoptera-

Characteristics Features

Large or medium sized insects. They can be separated into two suborders, Blattodea (cockroaches) and Mantodea (mantids). Some books include the Isoptera (termites) in this order. They have two pairs of wings, but the front pair is leathery and held flat over the body when at rest. The antennae are long, and may be longer than the entire body length. Cerci (two small appendages sticking out of the rear of the insect) are visible, and the hairs on the cercus are very sensitive to air movement in cockroaches, which explains why it is almost impossible to catch them. Cockroaches can run pretty fast, speeds of 1.5 metres per second have been recorded.

Biting mouthparts. Females lay their eggs in batches in hard-walled capsules or oothecae.

Eg : Cockroach

Cockroaches: about 4500 species worldwide, 150 in Europe, 9 in British Isles, but only 3 are native, and these 3 are small and harmless. Cockroaches are mainly nocturnal and omnivorous. Mantids: about 2000 species worldwideMantid size ranges from 1 - 15 cm long.

Cockroach

14. Order: Isoptera

Characteristics Features

They are small greyish white, soft bodied insects. The body is pale yellow in colour because of weak sclerotization. Compound eyes are present in alate forms and usually absent in apterous forms. Antennae are short and moniliform. Mouthparts are adapted for biting and chewing. Two pairs of wings are present which are identical in size form and venation. Wings are membranous and semitransparent. Venation is not

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distinct. Veins near the costal and anal margin alone are distinct. Anterior veins are more sclerotised. Wings are flexed over the abdomen at rest. They are extended beyond the abdomen. Wings are present only in sexually mature forms during swarming season. Wing shedding takes place along the basal or humeral suture, after swarming. The remanant or the stump remaining behind is called `scale'. Abdomen is broadly jointed to the thorax without constriction. External genital organs are lacking in both the sexes. Cerci are short.

Eg., : Termites, White ants

 

Termites White ants

Specialities: They are ancient polymorphic, social insects living in colonies. Salivary glands are well developed. Rectum is distended forming rectal pouch to accommodate large number of intestinal symbionts. Fat body development is extensive in male and female reproductives. Soil inhabiting termites construct earthern mounds called termitaria. They have evolved complex relationships with other organisms like bacteria, protozoa and fungi which help them in the digestion of wood. Incessant food sharing (trophallaxis) occurs between the members of the commounity by mouth-to-mouth and anus-to-mouth food transfer.

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

15. Order: Zoraptera

Characteristics Features

The zorapterans are minute insects, 3 mm or less in length, and may be winged or wingless. The winged forms are generally dark, and the wingless forms are usually pale. The zorapterans are a little like termites in general appearance and are gregarious. The order was not discovered until 1913.

Winged and wingless forms occur in both sexes. The four wings are membranous, with much reduced venation and with the hind wings smaller than the front wings. The wings of the adult are eventually shed, as in ants and termites, leaving stubs attached to the thorax. The antennae are moniliform and nine-segmented as adults. The wingless forms lack both compound eyes and three ocelli. The tarsi are two-segmented, and each tarsus bears two claws. The cerci are short and unsegmented and terminate in a long bristle. The abdomen is short, oval and

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terminates in a long bristle. The abdomen is short, oval and 10 segmented. The mouthparts are simple. Apparently, there are four juvenile instarts in the common species in North America. Eg. Angelinsects

Angelinsects

16. Order: Psocoptera

Characteristics Features

They are minute and soft bodied insects. Head has a distinct `Y' shaped epicranial suture. Clypeus is swollen. Mouthparts are biting and chewing type. Mandibles are with well developed molar and incisor areas. Lacinia is rodlike (`pick') which is partially sunken into the head capsule. Legs are slender. Wings may be present or absent. Forewings are larger than hind wings. Wings are held roof like over the abdomen. Cerci are absent. Psocids are frequently gregarious. Some psocids have the ability to spin silk. Dorsal pair of labial glands are modified into silk glands.

Eg: Book lice, Bark lice, Dust lice.


Book lice **Bark lice**

Importance: The common book louse is *Liposcelis* sp. They feed on paper paste of book binding, fragments of animal and vegetable matter and stored products. They are also damage dry preserve insects and herbarium specimens.

17. Order: Mallophaga

Characteristics Features

The chewing lice are wingless, flat-bodied insects, parasitic on birds and, to some extent, mammals (warm-blooded animals that have hair). They have chewing mouthparts and feed on bits of hair, feathers, scales and dried blood. They develop with gradual metamorphosis, the life stages being the egg, nymph, and adult. All adults are wingless. Chewing lice attack all kinds of wild and domesticated birds as

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well as many of the common mammals. The eggs are glued to the feathers or hair of the host.

E.g. Biting lice and birds lice

Birds lice

18. Order : Siphunculata

Characteristics Features

Small, wingless parasites in both adult and nymphal stages of mammals. Head narrow and eyes reduced or absent. Antennae short. Piercing/sucking mouthparts, retracted into head when not feeding. Feeds solely on blood injecting an anticoagulant to allow free flow for feeding. Each leg ends in a strong claw well-developed for clinging to the host .Eggs are usually stuck on to the host's hair and hatch when the temperature is sufficiently high 500 species world wide, fewer than 50 in Europe, and 35 British species. Nearly all species of mammals are infected including seals and whales The

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Anoplura are sometimes combined with the Mallophaga into one order called the Phthiraptera.

Eg: Sucking lice

Sucking lice

19.Order: Hemiptera

Characteristics Features

Head is opisthognathous. Mouthparts are piercing and sucking type. Two pairs of bristle like stylets which are the modified mandibles and maxillae are present. Stylets rest in the grooved labium or rostrum. Both labial palps and maxillary palps are atrophied. Mesothorax is represented dorsally by scutellum. Forewings are either uniformly thickened throughout or basally coriaceous and distally membranous. Cerci are always absent. Metamorphosis usually gradual; rarely complete. Alimentary canal is suitably modified (filter chamber) to handle liquid food. Salivary glands are universally present. Extra-oral digestion is apparently widespread. Abdominal ganglia fused with thoracic ganglia.

Eg: True bugs

True bugs

There are two suboders *viz*., Heteroptera and Homoptera. Head is project or horizontal Head is deflexed. Bases of the forelegs do not Bases of the forelegs touch touch the head the head. Beak arises from the anterior Beak arises from the posterior part of the head part of the head. Gular region of the head Gular region not clearly (midventral sclerotised defined part between labium and foramen magnum) well defined. Pronotum usually greatly Pronotum is almost alway small enlarged and collar-like. Scutellum (triangular plate Scutellum not well developed, found between the wing bases) well developed. Forewings heavily sclerotized Forewings are of uniform at the base and the apical texture. They are frequently half is membranous (Hemelytra)harder than hind pair. Wings are held flat over the Wings are held roof-like over the back at rest and the left theback and wings do not over and right side overlap on lap the abdomen. Honey dew secretion uncommon

Honey dew secretion common. Repungnatorial or odori- Wax glands usually present ferous or scent glands present.

Eg: Cicadas, leafhoppers, scales insects, aphids, plant bugs

Leafhoppers Aphid

20. Thysanoptera

Characteristics Features

They are minute, slender, soft bodied insects. Mouthparts are rasping and sucking. Mouth cone is formed by the labrum and labium together with basal segments of maxillae. There are three stylets derived from two maxillae and left mandibles. Right mandible is absent. Hence mouthparts are asymmetrical. Wings are either absent or long, narrow and fringed with hairs which increase the surface area. They are weak fliers and passive flight in wind is common. Tarsus is with one or two segments. At the apex of each tarsus a protrusible vesicle is present. Abdomen is often pointed. An appendicular ovipositor may be present or absent. Nymphal stage is followed by prepupal and pupal stages which are analogous to the pupae of endopterygote insects.

This order is subdivided into two suborders.

Terebrantia: Female with an appendicular ovipositor. Abdomen end is not tube like. Wing venation is present. Important family is Thripidae

Tubulifera: Ovipositor is absent. The abdomen end is tubular. Wing venation is absent.

Eg: Thrips.

Importance: Most of the thrips species belong to the family Thripidae and are phytophagous. They suck the plant sap. Some are vectors of plant diseases. Few are predators. e.g. Rice thrips: *Stenchaetothrips biformis* is a pest in rice nursery.

Thrips

21. Order: Neuroptera

Characteristics Features

They are soft bodied insects. Antenna is filiform, with or without a terminal club. Mouthparts are chewing type in adults. Wings are equal, membranous with many cross veins. They are held in a roof-like manner over the abdomen. They are weak fliers Larva is campodeiform with mandibulosuctorial mouthparts. Pupa is exarate. Pupation takes place in a silken cocoon. Six out of eight Malpighian tubules are modified as silk glands. They spin the cocoons through anal spinnerets.

Eg.: Lace wings, Ant lions, Mantispidflies, Owlflies.

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Lace wings **Owlflies**

Classification: This order is subdivided into two suborders viz., Megaloptera and Planipennia.

22. Order: Coleoptera

Characteristics Features

They are minute to large sized insects. Antenna is usualy 11 segmented. Mouthparts are chewing type. Mandibles are short with blunt teeth at the mesal face in phytophagous group. In predators the mandibles are long, sharply pointed with blade like inner ridge. In pollen feeders' teeth are absent and the mandibles are covered with stiff hairs. Prothorax is large, distinct and mobile. Mesothorax and metathorax are fused with the first abdominal segment. Forewings are heavily sclerotised, veinless and hardened. They are called elytra. Forewings do not overlap and meet mid-dorsally to form a mid-dorsal line. It is not used for flight. They serve as a pair of convex shields to cover the hind wings and delicate tergites of abdomen. Hind wings are membranous with few veins and are useful in flight. At rest they are folded transversely and kept beneath the elytra. In some weevils and ground beetles the forewings are fused and hind wings are atrophied. A small part of the mesothorax known as scutellum remains exposed as a little triangle between the bases of elytra. Cerci and a distinct ovipositor are absent. Metamorphosis is complete. Larvae are often called grubs. Pupae are usually exarate and rarely found in cocoons.

Eg: Beetles, Weevils

Beetles **Weevils**

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

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23. Order: Strepsiptera

The strepsiptera are minute inects, all of which are parasitic on other insects. The two sexes are quite different; the males are free-living and winged, whereas the females are wingless and often legless, and in most species do not leave the host. Minute insects and are parasitic on other insects. Males-free living & winged, whereas the females are wingless and often legless. Front wings are reduced and hind wings are large and membranous, fanlike. Have chewing mouth parts and compound eyes.

Eg. Stylopids

Stylopids

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24. Order: Mecoptera

Characteristics Features

Scorpionflies and hangingfies are medium-sized (about 9-25 mm long), slender- bodied insects with the head prolonged below the eyes as a beak, or rostrum. The rostrum is formed primarily by elongation of the clypeus. Its posterior surface consists partly of the lengthened maxillae and labium, but the mandibles are not unusually elongate and are at the lower end of the rostrum. Most Mecoptera have four long, narrow membranous wings. The front and hind wings are similar in size and shape and have similar venation. Slender, moderate sized, carnivorous insects, usually with two pairs of subequal wings. Head produced into a vertically deflected rostrum with biting mouthparts. Abdominal tergum 1 fused with the thorax. Male genitalia held like a scorpion sting at the end of the abdomen. Larvae eruciform with compound eyes.

E.g. Scorpionflies

Scorpionflies

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25. Order: Siphonoptera

Fleas are small, wingless, holometabolous insects. With rare exception, the adults depend for nourishment on the blood of warm-blooded vertebrates. However, the larvae are relatively free-living and feed on organic material in the larval habitat. The bodies of adult fleas tend to be laterally compressed and usually have caudally directed setae and spines that expedite forward progress through the vestiture of the host while resisting the backward movements frequently associated with the grooming activities of the host. Adults have shiny, hairy bodies and range from light, yellowish brown to almost black.Small, wingless, laterally flattened insects with backwardly directed spine like setae. Mouth parts adopted for piercing and sucking, laciniae of maxillae forming the suctorial apparatus. Legs long with coxae greatly enlarged, have tremendous capacity to jump. Antennae short, lie in grooves in the head. Both sexes suck blood from mammals and birds, some are vectors of deadly pathogens.

E.g. : Human flea and Rat flea

Human flea

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26. Order : Diptera

Characteristics Features

Member of an order of insects containing the two-winged or so-called true flies. Although many winged insects are commonly called flies, the name is strictly applicable only to members of Diptera. One of the largest insect orders, it numbers more than 125,000 species that are relatively small, with soft bodies. Flies range in size from midges of little more than 1 mm to robber flies more than 7 cm long. In general, the more-primitive flies (e.g., mosquitoes, midges, fungus gnats) are fragile insects with delicate wings. The more-advanced flies (e.g., blow flies, houseflies) are generally squat, sturdy, and bristly. They are stronger fliers than midges and gnats.

Eg: Flies

Flies

Importance

The abundance, worldwide distribution, and habits of flies combine to make them a nuisance to humans. Swarms of midges are a common annoyance. Sweat flies and face flies gather around the eyes, nose, and mouth and also suck blood and pus from wounds and sores. Such flies move constantly from one person to the next and in so doing may at times transfer disease-causing organisms.

27. Order: Lepidoptera

Characteristics Features

Lepidoptera is an order of insects that includes butterflies and moths. About 180,000 species of the Lepidoptera are described, in 126 families and 46 superfamilies, 10 percent of the total described species of living organisms. It is one of the most widespread and widely recognizable insect orders in the world.

Eg: Butterflies and moth

Butterfly Moth

The name of this order Lepidoptera is due to the presence of the scales. The head, thorax, abdomen, wings, and legs are covered with minute scales, are lamellar or blade-like, and are attached with a pedicel, while other forms may be hair-like or specialized as the secondary sexual characteristics. They are 'typical' insects, in that they have 4 wings, 6 legs, 2 antennae and a body divided into sections - a head, thorax and abdomen. The leg and wings are attached to the thorax. In a few species of moths, the females have evolved to become wingless.

28. Order: Trichoptera

Characteristics Features

The order Trichoptera is another likely descendant of the Mecopteran lineage. Adults are mostly nocturnal, weak-flying insects that are often attracted to lights. During the day, they hide in cool, moist environments such as the vegetation along river banks. The body and wings are clothed with long silky hairs (setae) -- a distinctive characteristic of the order. In flight, the hind wings are coupled to the front wings by specially curved hairs. At rest the wings are held tent-like over the abdomen. Many caddisflies have reduced or vestigal mouthparts. Few species have actually been observed feeding, and most adults are relatively short-lived. Many species of

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Trichoptera are very similar in appearance, both as larvae and as adults. It is often easier to identify a species by the structure of its case than by the features of its body.

While still in their pupal case, caddisfly adults have sharp mandibles used for cutting through the pupal case. Once they emerge, their mandibles degenerate and become nonfunctional. From this time on they do not feed (or ingest food only in liquid form).

E.g. : Caddisflies

Caddisflies

29. Order: Hymenoptera

Characteristics Features

Mouthparts are primarily adapted for chewing. Mandibles are very well developed. In bees both labium and maxillae are integrated to form the lapping tongue. Thorax is modified for

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efficient flight. Pronotum is collar like. Mesothorax is enlarged. Metathorax is small. Both prothorax and metathorax are fused with mesothorax. Wings are stiff and membranous. Forewings are larger than hindwings. Wing venation is reduced. Both forwings and hindwings are coupled by a row of hooklets (hamuli) present on the leading edge of the hindwing.

Eg: Ants, Bees, Wasps, Parasitoids.



Ants **Bees** **Wasps**

Abdomen is basally constricted. The first abdominal segment is called propodeum. It is fused with metathorax. The first pair of abdominal spiracles is located in the propodeum. The second segment is known as pedicel which connects the thorax and abdomen. Abdomen beyond the pedicel is called gaster or metasoma. Ovipositor is always present in females. It is variously modified for oviposition or stinging or sawing or piercing plant tissue. Metamorphosis is complete. Often the grub is apodous and eucephalous. Larva is rarely eruciform. Pupa is excrete and frequently enclosed in a silken cocoon secreted from labial glands. Sex is determined by the fertilization of the eggs. Fertilized eggs develop into females and males are produced from unfertilized eggs. Males are haploid and female's diploid.

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CHAPTER – II

BENEFICIAL INSECTS

Biology of honey bees, lac insects and their management.

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BIOLOGY OF HONEY BEE

INTRODUCTION:

The process of managing and breeding honey bees for acquiring honey and beeswax is known as **apiculture or beekeeping**.

In India, three species of *Apis* are commonly found. They are ***Apis dorsata, Apis florea* and *Apis indica*.**

- ***Apis dorsata*** (Rock bee) is the largest Indian honey bee (20 mm) and prepares large open combs (1 metre x 1.5 metre) singly on trees or caves, walls and other parts of the buildings.
- ***Apis indica*** (Indian bee) is the common honey bee found in plains and forests throughout India. It builds several parallel combs about one foot across in protected places like hollow of trees, thick bushes, within caves of rocks, wells, on walls and other places of safety in buildings.
- ***Apis florea*** is the little bee of India. Their workers are very small in size but this species is non-gregarious and builds a single comb, which is about 15 cm across, suspended on the branches or under caves of buildings. This does not yield much honey, but hardly a few mililitres per comb.

CLASSIFICATION:

Kingdom : Animalia

Phylum : Arthropoda

Class : Insecta

Order : Hymenoptera

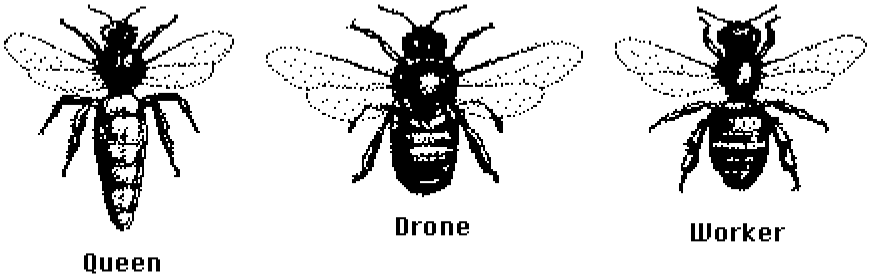
Family : Apiidae

Genus :Apis

CASTES OF HONEY BEE:

The colonies of honeybee are perennial. Honey bees are one of the few insects that have a social structure that has 40 to 50 thousand individuals consisting mainly of three castes: a **single reproductive queen** (only egg layer in the colony), **numerous drones** (males) depending on time of year, and a small number to about 60,000 **worker bees or non-reproductive female bees**.

The number of workers in one colony exceeds 90 per cent of the total population. Both queen and workers are female and diploid. Drones are males and haploid. A strong or healthy colony possesses maximum number of workers in the colony.



MORPHOLOGY:

(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 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.

(b) The antennae - These are a pair of sensitive receptors whose base is situated in a 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) Probocsis - 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 muscled 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- Wings 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 armour-plated and contains vital parts like the heart, honey sac, stomach, intestines and the sting. An adult insect bee abdomen has nine segments, 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 - This is located in the head of the worker bee in front of the brain. It starts to mature three days after the emergence of the bee, and develops only when the insect secretes royal jelly to feed the young larvae and the queen.

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 stop comb building.

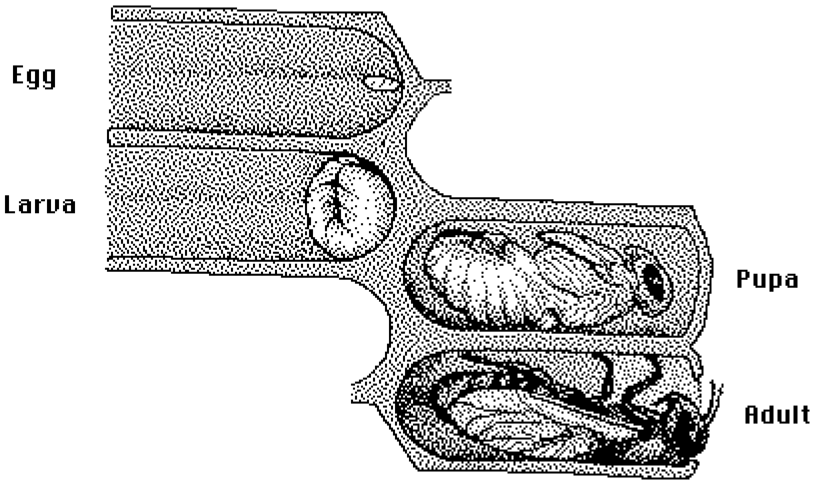
c) Scent glands - A worker bee produces three main scents.

- 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, that are 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. They help 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 and to attract drones during mating flights.

e) The sting - A worker bee's sting is designed to perforate the skin of the enemy and pump poison into the wound. It has about ten (10) barbs, so that when it is thrust into flesh, the bee cannot pull it back again. It breaks off with the poison sac always attached to it. 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. The sting of the queen is longer than that of the worker. It is used only to fight and kill rival queens in the hive. The drone has no sting and is totally defenseless.

LIFE CYCLE:



Stage 1 – The Egg Stage:

Queen bee is the only bee in the colony, capable of laying about 2,000 to 3,000 eggs in one day. The egg is positioned upright and falls on the side by the third day. The queen bee lays both fertilized egg and unfertilized egg. The fertilized egg develops into female bees or queen bees. The unfertilized egg hatches and male bees are born; also known as drone bees.

Stage 2 – The Larval Stage:

The difference between a worker and the queen bee is made, three days after the egg transforms into larvae and six days after the egg is laid in the beehive. The "royal jelly" is fed to all the larvae, i.e., the female bees, the workers and the drone bees during their initial three days as larvae. The larva sheds skin multiple times throughout this stage. Later, the royal jelly is fed only to the female larvae, which eventually becomes a queen bee. Finally, the worker bees cover the top of the cell with beeswax to protect and facilitate the transformation of the larvae into a pupa.

Stage 3 – The Pupal Stage:

Here the bee has developed parts like wings, eyes, legs and small body hair that physically appears close to an adult bee.

Stage 4 – The Adult Stage:

Once the pupa is matured, the new adult bee chews its way out of the closed-cell. The queen bee takes 16 days from the egg stage to form into an adult. The worker bee takes 18 to 22 days for complete development, and drone bees take 24 days to develop into an adult bee.

QUEEN BEE:

Generally, there is only one laying queen per hive and she can live several years under healthy conditions. The size of the queen is nearly 2.5 times longer than that of a worker bee. It is characterized by the long tapering abdomen, well-proportioned body, short and golden coloured wings and colour of the legs. They are 2.8 times heavier than the worker bees.

The queen bee basically keeps the workers uninterested in reproduction on their own by secreting a pheromone. This chemical is spread from body to body among the workers starting with those tending the queen.

The queen bees are responsible for laying eggs and have no time to eat or fly around. A group of five to ten workers feed her a small bit after she lays about 20 eggs.

The queen is capable of laying about 1000- 2000 eggs every day, depending upon seasonal variation and seasonal factors. The eggs may be either fertilized or unfertilized.

The queen deposits each egg in a cell prepared by the worker bees. After three days, the eggs hatches into small larvae. The larva is fed with a special food called '**royal jelly'** and develops into queen. The royal jelly is a high proteinous substance produced by the hypopharyngeal glands of the workers.

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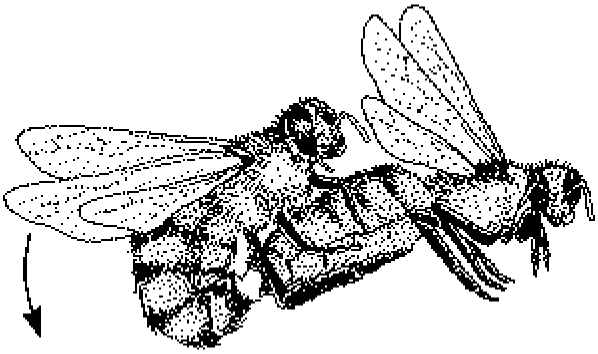
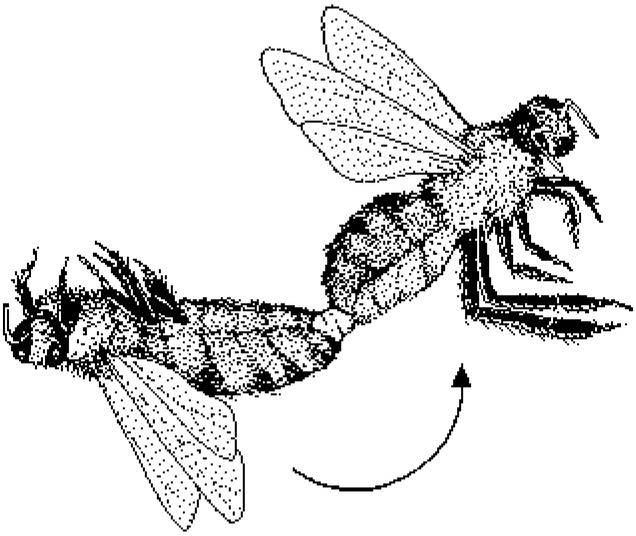
The larva selected to become queen is taken before the third day of development, in a special chamber called '**queen's chamber'**. On average, the queen lives five to eight years and her fertility decreases with increase of age. The sting of the queen serves as an ovipositor for lying of eggs and is also used for defence. The sting is used, only when she meets another rival queen.

She mates with various male drones (generally drones produced from other hives) and stores their sperm to be used throughout her life. Queens are, however, not immortal. When her health is weakening or the hive is preparing to swarm, she will secrete a chemical substance with hormonal properties from the mandibular glands, called '**pheromone or queen substance'**, which inhibits the growth of ovaries of workers and control the activities of all bees within the hive. Once the virgin queens emerge, they are are not immediately recognized as the queen bee until they are fertilized by drones and emit the proper pheromones. Virgin queens will seek each other out and attempt to kill one another until just only one remains. The last one standing, takes on the role of the egg-layer, '**Queen Bee'**, in the recently abandoned hive.

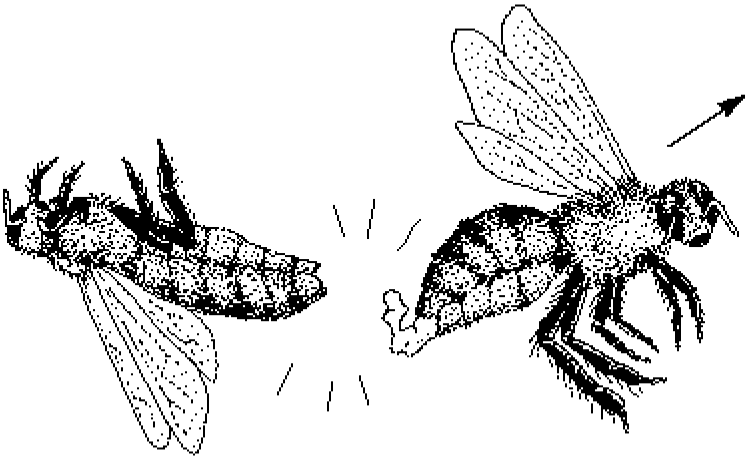
The virgin queen flies to a congregation area where hundreds or thousands of unrelated drones await. The drones pursue the queen and several mate with her in flight.



The drone mounts the queen, inserts his endophallus, and ejaculates his semen.



During ejaculation, the male falls back and his endophallus is ripped out of his body and remains attached to the queen.



Drones mounting later remove the previous drone's endophallus and lose their own through similar matings. The emasculated drones die very quickly with their abdomens burst in this fashion.

Of the 90 million sperm deposited by several males in the queen's oviducts, a mixture of about 7 million are stored in a special pouch in her body called the spermatheca.

These sperm will be used, during the queen's life to fertilize her eggs. The one (or few) mating flight(s) in her first few days of life are her last. The old queen run out of sperm; a new queen will be produced through the intervention of the workers.

THE DRONE BEE:

Drones are male bees produced from unfertilized eggs. The main responsibility of drone bee is to reproduce with queens at surrounding hives. The drones take 24 days to develop from the egg to adult. They are only produced when the hive is growing, usually during peak pollination season, and before a swarm or when the queen is running low on sperm. Drones die once they reproduce. All drones from the same hive are clones of the queen, since they are produced without genetic material from a male bee.

Drones lack the body parts to effectively harvest nectar or pollen to feed themselves. Drones also lack a stinger of any kind. They are designed for mating only. Drone's eyes and antennae are specialized for seeing, following, and mating with a queen. Most of the drones' internal organs are designed for flying fast, to catch the queen or for delivering sperm cells into her oviduct. If the drone succeeds in this, it dies. Hence, the surviving drones are virgin.

THE WORKER BEE:

Worker bees are female and hatch from fertilized eggs laid by the queen. They are reproductively underdeveloped females. The sperm from multiple drones provides genetic diversity. A colony may have 2,000 to 60,000 workers. It takes 20 days from egg to adult and life span is about 6 weeks. The mouth parts are modified for collecting nectar and moulding wax, the epidermis of abdomen for secreting wax, and their legs for collecting pollen. Worker bees have stingers and pollen sacs, but they are unable to reproduce. Instead, the female workers help to care for young, collect and process pollen, produce honey, guard the hive, and engage in hive keeping.

They secrete wax from glands on the abdomen and fashion the honeycomb and broodcomb from it. This comb contains hexagonal cells, that hold a drone, a small quantity of honey, or pollen. When the cells are filled with honey, pollen, or a pupa, a worker caps the cell, by sealing the contents inside.

Depending on the season, and after few days, the worker works at gathering operations. The bee will fly out of the hive and visit flowers in search of nectar and pollen, or will visit trees for harvesting resin to make propolis. The propolis is used as glue and caulk to seal cracks in the hive. The nectar and pollen are collected and returned to the hive for use and storage.

When a worker egg has been selected to become a queen, it is moved to a much larger queen cell and is fed large quantities of "royal jelly",that contains more mandibular gland secretions and more honey.

The workers defend the hive with their sting. The worker bee develops a barbed stinger and a muscular venom pouch, to kill an intruder.

HIVE OR COMB:

- The Indian honeybees live in hives, made of combs prepared by the workers with the help of wax secreted by wax-secreting glands of the abdomen.
- Each hive is made up of a number of combs generally remaining parallel to each other.
- Each comb has thousands of hexagonal cells arranged in two sets opposite to each other on a common base.
- They repair the cracks of the walls of hive with propolis (resinous substance collected by bees from different parts of plants for use as glue) and balm collected from the plants and is used in the construction of comb.
- The propolis is used as a glue to bind broken parts, and balm is taken for polishing inner walls.
- The cells are thin-walled and so arranged that each side-wall serves for two adjacent cells and each cell-base for two opposite cells.
- The worker cells, where workers are reared and honey is stored, are about 5 mm across, and the drone cells 6 mm across, serve to rear drones and for storage.
- Large vertical peanut-like queen cells, open below, are built along the lower comb margins for queen rearing.

- The combs keep a vertical plane, while the cells are in horizontal position.

These cells are of 5 types:

1. Queen cells:

These are a very few in number in a hive. They are larger than the other cells and vase-shaped, and are situated at the margin of the comb. These cells are used for queen rearing.

2. Drone cells:

There are about 200 drone cells in each hive and are smaller than the queen cells. The drones are reared in these cells.

3. Worker cells:

Majority number of cells is worker cells and each cell is about 5 mm across. The workers are reared in these cells.

4. Brood cells:

The larvae of the honey bee are reared in these cells.

5. Storage cells:

These cells are mainly for the storage of honey and pollen.

EFFECT OF HORMONE:

The mandibular glands of queens are situated in the head and open at the base of mandible. The queen secretes a kind of chemical substance that inhibits the development of ovaries of worker bees. A British researcher, C. G. Butler found that the nature of the inhibiting substance was **oxy-deconoic acid**, a substance with hormonal properties that controls the activities of all bees in the hive. The queen bee secretes a pheromone by mandibular gland and attracts drones.

COMMUNICATION OF HONEY BEE:

Honey bees have the ability to communicate amongst themselves. In 1946, Karl Von Frisch, a Vienna scientist discovered the language of bees and was awarded a Noble Prize in 1973.

They perform certain **rythmic movements** and **emit odours** that are easily received by other bees. When the source is nearer to hive (within 100 metres), worker bee performs a round dance. Round dance informs the distance of source of food which is less than 100 metres but cannot give the indication of direction.

If the source is further away, the reporter bee performs a tail wagging dance. These dances are closely watched by other bees in the hive and then immediately they come out in search of the source.

Bees can signal when the hive is too hot, too cold, when a potential threat is close, when more pollen needs to be collected, when nectar stores are high or low, the direction of food and water sources, etc.

Odours play a vital role in their communication. Sudden death of queen bee is relayed to 60,000 or more bees of the hive in less than an hour. Healthy queen secretes an aromatic substance called ‘queen substance’ which is licked off by her nurse bees.

ECONOMIC IMPORTANCE:

- Honey is used as the chief source of natural sweet in preparing candies, cakes, bread, etc. It is an important food for patients of diabetes or for persons undergoing very strenuous physical exertion. It is also used as a laxative and as antiseptics.
- Bee wax is used to manufacture cosmetics, face creams, paints and polishes, ointments, preparing candles, shaving creams, cold creams, castings of models, carbon paper, cryons, electrical and other products.
- Royal jelly is used in the treatment of asthma and also as a dietary supplement.
- The venom of bees is used in the treatment of nerve pain, multiple sclerosis, rheumatoid arthritis and snake bite.

- The bees are the chief pollinators. They perform cross pollination, leading to an increase in yielding of plant products due to hybridization.

MANAGEMENT:

- Hive inspection should be done at least twice a week. Details about the presence of queen, eggs and brood, honey and pollen storage and bee enemies should be noted. Hive record must also be maintained for each hive.
- The brood net should be expanded during honey flow period.
- During honey flow season, additional space with supply of new, clean, yellow combs or comb foundation sheets is needed.
- Swarming can be controlled by clipping off special queen brood cells, because colony does not send out a swarm unless a new queen is ready to replace.
- If there is shortage of nectar and pollen in nature, artificial feeding is necessary.
- Water is necessary near the apiary. Water is required to blend with the food and to reduce the temperature of the hives.

- Queen is the most important and indispensable and so it must be handled properly and carefully. The presence of an active queen is known by the presence of worker eggs.
- The bee colony should be increased every year by dividing the existing colonies into 2 or 3 sub colonies with new queens.
- During the honey flow season, provide more space for honey storage, prevent swarming and provide sugar syrup.
- During summer season, provide sufficient shade, sprinkle water often, increase ventilation etc.
- During winter season, provide new queen to the hives and maintain disease free colonies.
- During the death period, the empty combs must be removed
- During rainy season, avoid dampness in apiary site and provide proper drainage.

BIOLOGY OF LAC INSECT

INTRODUCTION:

The word "*lac*" is derived from a Sanskrit word which means "hundred thousand" that indicates the gregarious habit of this insect. It is commonly called as **shellac or seedlac or button**

lac. Lac is a natural commercial resin of animal origin. It is the secretion from a scale insect, as a hard protective covering around its body. It has a reddish or dark brown colour with a disagreeable smell. The insects are commercially exploited worldwide for the production of lac, because of its diverse industrial applications.

Laccifera lacca is the common Indian lac insect. Lac is produced mainly in India, Bangladesh, Thailand, and China. India is still the largest producer of lac in the world.

CLASSIFICATION:

Kingdom : Animalia

Phylum : Arthropoda

Class : Insecta

Order : Hemiptera

Super family : Coccoidae

Family : Lacciferidae

Genus : Laccifera

Species : *Laccifera lacca*

MORPHOLOGY:

Lac insect is a hemimetabolous i.e. it undergoes gradual metamorphosis. It has three life stages namely egg, young one and adult. The young ones are called as nymph. The nymphs are similar to adult, except their size and reproductive organs. The adult male and female are different from each other. Female is about three time larger than the male.

Male:

They are pinkish red in colour and may be winged or wing less. Winged male possesses only one pair of translucent membranous forewing. They are mostly found during dry season. They survive for 3 to 4 days and die after coupulation.

- Head is large, with prominent mouthparts but vestigial
- Ocelli are two pairs with seven segmented antennae, and possess hair on them.
- Mouth parts are absent and hence the male adult insect is unable to feed.
- Tarsi 3 segmented.
- The abdomen is large, 8 segmented, broader anteriorly and narrower posteriorly.
- It has a pair of caudal setae and sheath containing penis at the posterior end.

Female:

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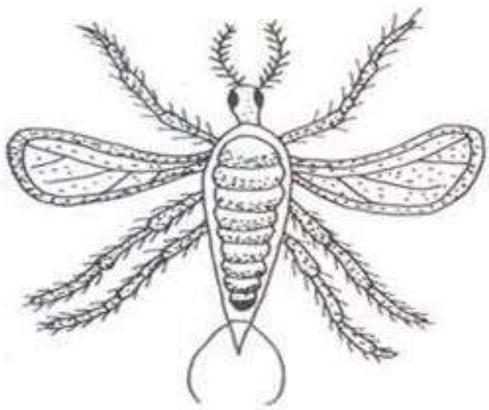
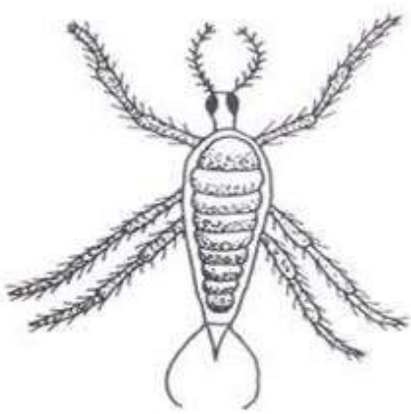
- The female is pinkish in colour. The ventral surface of body is flat and the dorsal surface is convex.
- The female have degenerated eye, legs and wings.
- Antennae are vestigial, small and 3 to 4 segmented.
- Mouthparts are piercing and sucking type, rostrum is two segmented.
- Mesothorax is provided with an appendage on which spiracles open.
- The abdomen is round and on the dorsal surface, a spine is provided.



Fig; Male with wings



Fig; Male without wings

FERTILIZATION PROCESS:

While attaining the maturity period, the male lac will emerge out from the cells and move towards the lac incrustations. The male will enter the female cell through anal tubular opening. After entering inside the female cell, it starts fertilizing the

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female. After copulation, the male will die. One male has the capability of fertilizing several females. Females develop very rapidly after fertilization. They take more sap from plants and exude more resin and wax.

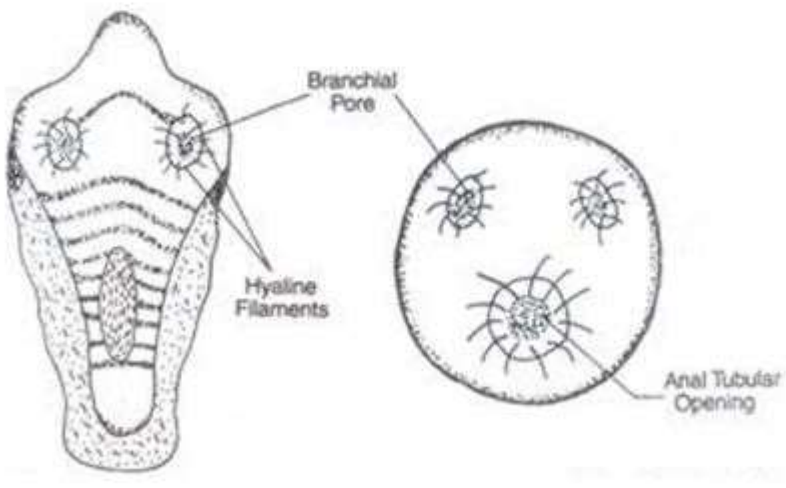
LIFE CYCLE:

After the process of fertilization, the females are capable of producing eggs. In lac insects, the post fertilization developments start when the eggs are still inside the ovary. These developing eggs are oviposited into the incubating chambers (formed inside the female cell by the body contraction of females). A female is capable of producing about one thousand eggs (average 200-500). Inside incubating chamber, the eggs hatch into larvae.

The larvae are minute, boat shaped, red coloured and half millimeter in length. Larva has head, thorax and abdomen. Head bears a pair of antennae, a pair of simple eyes and a single proboscis. All three thoracic segments are provided with a pair of walking legs. Thorax also possess two pairs of spiracles for respiration. Abdomen is provided with a pair of caudal setae. These larvae will search for a suitable centre to fix them. This movement of larvae from female cell to the new off-shoots of host plant, is known as “swarming”.

The emergence of larvae from female cell occurs through anal tubular opening of the cell and this emergence may continue for three weeks. The larvae of lac are very sluggish and feed continuously when once they get fixed with the twig. Also, they start secreting resinous substance around their body through certain glands present in the body. Then, the larvae gets fully covered by the lac encasement, also known as lac cell. Once they are fully covered, they moult and begin to feed.

The male cells are elongated and cigar shaped. There is a pair of branchial pores in the anterior side and a single large circular opening covered by the flap in the posterior side. The matured male lac insect emerges out of its cell through the posterior circular opening. The female cell is oval, with small branchial pores in anterior side and a single round anal tubular opening in posterior side. Through the anal tubular opening are protruding waxy white filaments, secreted by the glands in the insects body.



Fig; Male cell Fig; Female cell

Larvae moult in their respective cells. It is the second stage larva which undergoes pseudopupation, and changes into adult stage. Now the male emerges out from the cell, moves on lac incrustation and enters the female cell for fertilization.

LAC SECRETION:

Lac is a resinous substance secreted by certain glands present in the abdomen of lac insects. The secretion of lac begins immediately after the larval settlement on the new and tender shoots. This secretion will appear as a shining layer and later gets hard.

Further, this makes a coating around the insect and the twig. As the secretion continues, the coating around one insect will fuse completely with the coating of other insect. Thus, continuous

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or semi-continuous incrustation of lac is formed on the tender shoots.

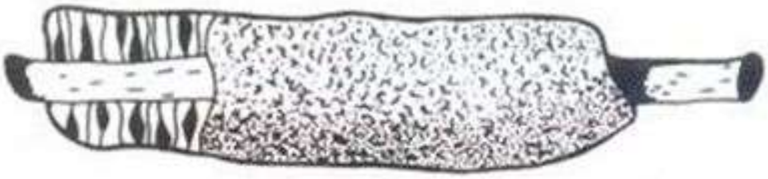

Fig. Lac incrustation on a twig

COMPOSITION OF LAC:

The main compositions of lac are:

Resin – 68 to 90%, Dye – 2 to 10%, Wax – 5 to 6%, Mineral matter – 3 to 7%, Albuminous matter – 5 to 10% and Water – 2 to 3%.

USES:

Lac is used in making toys, bracelets, sealing wax, gramophone records etc. It is also used in making grinding stones, filling ornaments, manufacturing of varnishes and paints, silvering the back of mirror, encasing cable wires etc. Waste materials produced during the process of stick lac is used for dying purpose. Nail polish is a good example of the by-product of lac. From the stick-lac (twigs encrusted with lac), shellac is obtained after purification. Shellac is used as a coating for medicines. In Ayurveda, Siddha and Unani system of medicine, lac is used for treating various diseases. In Ayurveda, lac is considered for astringent, cool and pungent. It balances pitta-kapha dosh and promotes strength. In Unani, lac is considered as a tonic for liver, stomach and intestine.

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CHAPTER-III

SERICULTURE

Prospects of sericulture, Biology of silkworm (Nutrition, Genetics, Endocrinology, Reproduction, Pest and Diseases).

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SERICULTURE

Silk is the most elegant textile in the world with unparalleled grandeur, natural sheen, and inherent affinity for dyes, high absorbance, light weight, soft touch and high durability and known as the “Queen of Textiles” the world over. On the other hand, it stands for livelihood opportunity for millions owing to high employment oriented, low capital intensive and remunerative nature of its production. The very nature of this industry with its rural based on-farm and off-farm activities and enormous employment generation potential has attracted the attention of the planners and policy makers to recognize the industry among one of the most appropriate avenues for socio-economic development of a largely agrarian economy like India.

Silk has been intermingled with the life and culture of the Indians. India has a rich and complex history in silk production and its silk trade which dates back to 15th century. Sericulture industry provides employment to approximately 8.7 million persons in rural and semi-urban areas in India. Of these, a sizeable number of workers belong to the economically weaker sections of society, including women. India's traditional and culture bound domestic market and an amazing diversity of silk garments that reflect geographic specificity has helped the country to achieve a leading position in silk industry.

Apart from silk, there are several other bye-products from sericulture. The mulberry fruits are rich in minerals and vitamins and from the roots, barks and mulberry leaves several Ayurveda and herbal medicines are prepared. Some of the woody mulberry trees provide timber which are resistant to termites and the timber is used for making sports items, toys etc. The mulberry branches after silkworm feeding are generally dried and used as fuel particularly in the villages. The foliage of mulberry is used as a fodder for cattle. The mulberry trees are also planted in the embarkment area for protection of the soil to prevent soil erosion, and mulberry trees are planted as avenue trees. The silkworm pupae are rich in oil content and pupal oil is used in cosmetic industry and the remaining pupal cake is a rich source of protein suitable for poultry and fisheries. In some tribal population, the people eat eri pupa as a source of protein and nourishment. The silkworm litter is used for bio-gas production and used as a fuel for cooking in the rural area. Thus sericulture not only provides silk for fashionable clothings, it also provides several very useful bye products to the human society. Therefore, sericulture development provides opportunities to improve the living standards of people in the rural area in developing countries.

Though accurate data are not available on the silkworm germplasm in different countries of the world, an approximate information indicate that there are 4310 silkworm germplasm accessions available in different countries. There is every likelihood that some of these silkworm accessions are duplicated; for instance the silkworm germplasm from China, Japan, France, Russia and India might be represented in the germplasm collection of other countries since these are the principal source of sericultural germplasm and also several countries might have exchanged some silkworm germplasm for silkworm breeding and hence a proper documentation on the availability of silkworm germplasm in different countries is very much required.

A very recent compilation of silkworm genetic stocks indicate that there are around 3000 genotypes of Bombyx mori at the global level, which includes mutants, parthenoclones, polyploids and geographical races. In fact much of the genetic diversity of Bombyx mori is derived from the inbred lines of land races and elite stocks evolved by the silkworm breeders and also from hybridisation of different geographical races; mainly the Japanese, Chinese, European and tropical races, which are distinct for several economic characters. The geographical races also possess several heritable characters for a variety of morphological, biochemical and quantitative characters. Among the four geographical races, the bivoltine and univoltine races of temperate origin and multivoltine races of tropical origin differ widely and exhibit contrasting characters. The bivoltine and univoltine races produce high quantity of good quality silk, whereas the multivoltine races are hardy, tolerant to pathogen load and thereby resistant to diseases compared to the bivoltines but produce low amount of poor-quality silk. Thus, these geographical races are very valuable genetic stocks for further improvement of silkworm races and evolution of superior breeds of B. mori.

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Apart from a rich biodiversity of geographical races, there are also a large number of mutants. The silkworm genetic stocks include more than 500 mutants for a variety of characters viz., serosal colours; larval and adult integument colours; skin markings and body shapes; cocoon colours and shapes; physiological traits such as diapause, number of larval moults and timing of larval maturity; food habits and biochemical features such as digestive amylase, blood and egg esterases, larval integument esterase, alkaline and acid phosphatases; haemolymph proteins; silk production and fibroin secretion; homeoproteins and body plan determination etc. and the various mutants, gene locus and phenotype were documented recently.

Apart from the geographical races and mutants there is a large genetic stock of B.mori evolved by the breeders mostly utilizing the geographical races and mutants of larval, pupal and cocoon colour variants of sex limited races, particularly in Peoples Republic of China, Japan, India and erstwhile United Soviet Socialist Russia (USSR) and some of these breeds are commercially exploited in these countries for silkworm rearing to produce raw silk and the remaining breeds are maintained in the silkworm germplasm of these countries as breeders genetic stocks and they are utilised as the genetic material in the silkworm breeding programmes for evolution of more superior and elite races.

Thus, the geographical races, mutants and the elite breeders stock constitute the major portion of the present day silkworm germplasm at the global level apart from the parthenoclones, triploid, polyploids and wild relatives of Bombyx and Bombycidae

Silk production in India

India has the unique distinction of being the only country producing all the five known commercial silks, namely, mulberry, tropical tasar, oak tasar, eri and muga, of which muga with its golden yellow glitter is unique and prerogative of India.

Mulberry sericulture is mainly practised in states such as Karnataka, Andhra Pradesh, Assam and Bodoland (Kokrajhar, Chirang, Baksa and Udalguri districts of Assam), West Bengal, Jharkhand and Tamil Nadu who are the major silk producing states in the country. North East has the unique distinction of being the only region producing four varieties of silk viz., Mulberry, Oak Tasar, Muga and Eri. Overall NE region contributes 18% of India's total silk production.

India is the second largest producer of silk in the world. Among the four varieties of silk produced in 2020-21, Mulberry accounted for 70.72% (23,860 MT), Tasar 8.02% (2,705 MT), Eri 20.55% (6,935 MT) and Muga 0.71% (239 MT) of the total raw silk production of 33,739 MT (Provisional).

The silk production has been reduced in the country during 2020-21 due to the disruptions caused by the Covid-19 pandemic. The total raw silk production in the country during 2020-21 was 33,739 MT, which was 5.8% lesser than the production achieved during the previous year 2019-20 and registered around 86.5% of achievement against the annual silk production target for the year 2020-21. The bivoltine raw silk production declined by 3.4% to 6,772 MT during 2020-21 from 7,009 MT during 2019-20. Similarly, vanya silk, which includes Tasar, Eri and Muga silks, have reduced by 13.8%, 3.7% and 0.8%, respectively during 2020-21 over 2019-20. The area under mulberry has reduced by 0.8% in 2020-21 compared to previous year. (2.38 lakh ha.) The export earnings during 2020-21 were Rs. 1418.97 crores. The estimated employment generation under sericulture in the country was 8.7 million persons during 2020-21 compared to 9.4 million persons in 2019-20, indicating a reduction of 7.4%.

The demand for superior quality bivoltine silk is increasing in India for domestic consumption as well as value added silk products for the export market. The Ministry of Textiles Government of India and Departments of Sericulture in various states provide technical and financial assistance for enhancing the bivoltine silk production.

Silkworm, voltinism and biology of silkworm. Silk has been under use by human beings for various purposes since ancient times. Pure silk is one of the finest and most beautiful natural fibres of the world and is said to be “the queen of fibres. One of the methods was the rearing of silkworms on large scale with great care in natural and controlled conditions. Different rearing techniques are applied in different parts of the world for large scale production of silk threads of fine quality. This is known as sericulture. Types of Silk: Moths belonging to families Satumidae and Bombycidae of order lepidoptera and class Insecta produce silk of commerce. There are many species of silk-moth which can produce the silk of commerce, but only few have been exploited by man for the purpose. Mainly four types of silk have been recognized which are secreted by different species of silk worms.

(i) Mulberry Silk: This silk is supposed to be superior in quality to the other types due to its shining and creamy white colour. It is secreted by the caterpillar of Bombyx mori which feeds on mulberry leaves.

(ii) Tasar Silk: It is secreted by caterpillars of Antheraea mylitta, A. paphia, A. royeli, A. pernyi, A. proyeli etc. This silk is of coppery colour. They feed on the leaves of Arjun, Asan, Sal, Oak and various other secondary food plants.

(iii) Eri Silk: It is produced by caterpillars of Attacus ricini which feed on castor leaves. Its colour is also creamy white like mulberry silk, but is less shining than the latter.

(iv) Munga Silk: It is obtained from caterpillars of Antheraea assama which feeds on Som, Champa and Moyankuri. Voltinism: Voltinism refers to the number of breeds raised per year. Voltinism is a genetically determined heritable character under hormonal control.

Based on voltinism B.moriis divided into three type of races: univoltines, bivoltines, and poly or multi-voltines.

1. Univoltine races produce only one generation per year. The eggs laid remain in a diapausing (quiet) condition till the next spring. Larvae of univoltines are very sensitive to temperature and other environmental conditions. They are unsuitable for summer and autumn rearing by artificial breaking of egg diapause. The larval period is very long. All European races are Univoltines. The cocoons produced are commercially very superior.

2. Bivoltine races have two generations per year, the first generation adults developing from eggs hatched in spring lay non dipausing eggs. The second generation adults developing from these eggs lay eggs which remain in the dormant state till next spring. The larval duration is as long as univoltines. Larvae are robust and tolerate environmental fluctuations. They can be used for 'Summer and autumn rearing and three crops can be raised per year. The cocoons are commercially superior. Japanese and Chinese races have both uni and bivoltine varieties.

3. Multi or polyvoltines have more than three generations per year. The larval duration is short, and larvae are resistant to high temperature and high humidity. Larvae and cocoons are small in size. Commercially cocoons are of poor quality. The adults lay nondiapausing eggs. Life cycle of tasar silkmoth They are bivoltine i.e.; two crops in a year, one from August-October and other from October-December. It is from August to December that the tasar insects are active and for the rest of the year they are inactive i.e.; under dipause. The active and inactive phases of life of tasar insects is controlled by environmental and hormonal factors. Biology of Tasar silk moth Systemic position Phylum : Arthropoda Class : Insecta Order : Lepidoptera Family : Saturniidae Genus : Antheraea Species : mylitta (Drury) The adult : The tasar insect is a very large moth exhibiting sexual dimorphism. The females are bigger with a wing-span of 18 cms. The wings are grey or yellow or light brown with patterns of red, with and black (brown) lines. Each wing has an eyespot or a circular ocellus in the centre. The male are smaller with brown wing and wing span of 16 cms. The

males have a narrow abdomen with broad antennae when compared with the females.

The egg : The egg is oval, dorsomventrally flat and bilaterally symmetrical aliong the anteroposterior axis. It is 3 mm long and 2.5 mm in diameter. Althouhg the egg is pale white, it appears brown due to a gummy coating. Two brown parallel lines are present along the equatorial plane.

The larva (Caterpillar) : The larva is cruciform or polypod type, with biting and chewing type mouth parts. It is dull brown-yellowish with black-head about 7 mm long weighing 8 mg. the body turns green in 2 days. It grows and undergoes four moults and the fifth inserar larva is large 13 cms long and weights 50 gms. Shining white lareral spots appear on 3rd instar larva. The thorax is three segmented and bears 3 pairs of walking legs, one pair per segment. The terminal segment bears a anal flap and a pair of claspers. The fifth instar larva spins a cocoon.

The cocoon : The cocoon is single-shelled, yellow or grey pendent, oval, closed and reelable with a hard non-flossy grainy shell. At the anterior end there is a well formed dark brown penduncle with a ring. Female spins larger cocoon than the male. The larva transforms into the pupa inside the cocoon.

The Pupa : The pupa is abtect, a dectious with well defined segmental body, the dark brown pupa measures about 4.5 X 2.3 cm and weight 10.3 gm.

Bombyx mori Phylum : Arthropoda Class : Insecta Order : Lepidoptera Family : Bombaycidae Genus : Bombyx Species : mori Life history of mulberry silk worm, Bombyx mori (L) : The adult of Bombyx mori is about 2.5 cm in length and pale creamy white in colour. The entire body is covered with scales. The males have longer antennae and narrow abdomen while the female has small antennae, large and flat abdomen and is less active than the male. Due to heavy body and feeble wings, flight is not possible by the moth. This moth is does not feed during its very short life period of 2-3 days.

Fertilization: Fertilization is internal preceded by copulation. Just after emergence male moth copulates with female for about 2-3 hours and if not separated they may die after few hours of copulating with female.

Egg laying : Just after fertilization, female starts egg laying which is completed in 1-24 hours. One moth lays

400-500 eggs depending upon the climatic conditions and the supply of food material to the caterpillar from which the female moth is obtained. The egg is laid in form of clusters and covered with gelatinous secretion of the female noth which helps them in proper attachment.

Egg : The eggs laid by the female moth are rounded and white in colour. The weight of the newly laid 2,000 eggs comes to about 1 gm. With the increase in time after laying. Eggs become darker. Two types of eggs are generally found viz., Diapause type and Non-Diapause type.

Hatching : The eggs after ten days of incubation hatch into a larva called as caterpillar. Hatching is the most important phase of silk moth life. After hatching caterpillars need continuous supply of food because they are voracious feeders. It proper supply of mulberry leaf is not possible the development of caterpillar would not be in a proper curse. Sometimes, due to lack of food material, young caterpillars die causing great loss to the sericulture industry.

Caterpillar : The newly hatched caterpillar is about 1 /8 th of an inch in length and is pale, yellowish white in colour.

The caterpillars are provided with well developed mandibulate biting and chewing type of mouth-parts adapted to feed easily on the mulberry leaves. The caterpillar is twelve segmented and the abdominal region has ten segments having five pairs of pseudo-legs. It is also provided with a small dorsal horn on very soft leaves of mulberry plants. As they are voracious feeders, they grow rapidly which is marked by four moultings. After 1st, 2nd, 3rd and 4 thmoulting caterpillars get changed into 2nd, 3rd, and 4th , 5th instars respectively. It takes about 21 to 25 days after hatching. The full grown caterpillar is 7.5 cm in length. It develops salivary glands, stops feeding and undergoes pupation. The time taken for the full growth of the caterpillar from young to the well grown stage varies with regard to the temperature, humidity, food supply and type of race. The weight of the full grown caterpillar varies from 4 to 6 gm.

Pupa : The caterpillars stop feeding and move towards corner among the leaves and secrete a sticky fluid through silk gland. The secreted fluid comes out through spinneret (a narrow pore situated on the hypopharynx) and takes the form of long fine thread of silk which hardens on exposure to the air and wrapped around the body of the caterpillar in the form of covering called as Cocoon.

Cocoon : Cocoon is the white coloured bed of the jpujpa whose outer threads are irregular while the inner threads are regular. The length of continuous thread secreted by a pupa for the formation of cocoon is about 1000-1200 metres which requires 3 days to complete. The thread is wound around the cocoon in concentric manner. The binding of threads round the cocoon is achieved by the constant round motion of the head of te pupa from one side to the other at the rate of 65 times per minute. The weight of one cocoon is about 1.8 to 2.2 gm and the weight of the cocoon shell only is 0.45 gm. The size of the thread is 2.0 to 2.8 denier. The pupal period lasts for 10 to 12 days and the pupae cut the cocoon and emerge into adult moths.

Emergence of imago: Due to active metamorphic changes during pupation period the abdominal pseudo-legs disappear and two pairs of wings develop. The silk worm within the cocoon secretes an alkaline fluid to moisten its one end. The moistened end becomes soft where the threads are cut open by the silk.

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Nutritional Requirements of Silkworm:

The nutrition of the silkworm, Bombyx mori L., has been of primary importance in sericulture, because not only larval growth and survival but also cocoon and egg production have been known to be influenced by the nutritive value of the foodstuff, mulberry leaves. The previous studies have been directed mainly at measuring the usefulness of the leaves or their specific components. This is, of course, one aspect of nutrition in animals which feed natural foodstuff, and the results so far obtained on the silkworm nutrition on this line are evaluated properly even now. However, no information has been available on the requirements for specific substances, either qualitatively or quantitatively, which enable the silkworm to grow and develop normally. In 1960 the rearing of the silkworm entirely on artificial diets has been reported for the first time.Since then, the studies in our laboratory have been concerned with the elucidation of nutritional requirements of this insect, by means of artificial diets. The present report summarizes the results on the requirements for carbohydrates, amino acids, lipids, vitamins, and minerals.

Nutritional tests were mostly carried out by rearing larvae on artificial diets, and the effects of supplementation or omission of specific substance on larval growth, development, and survival were carefully examined. Synthetic diet or amino-acid diet has successfully been formulated for the nutritional tests. When necessary, axenic rearing method was used. Furthermore, enzymatic methods were used for the study of metabolic events on nutrients.

Carbohydrates. The nutritive effects of carbohydrates were studied either by determining their effects on weight gain and survival or by assaying the rate of conversion to blood trehalose or fat body glycogen, both of them occurring as main carbohydrates in the body, when each compound was administered orally to the larvae without any other nutrient. Since some of sugars possess a strong phagostimulating action for silkworm larvae, it was afraid to get a misleading result when synthetic diets containing different sugars were compared. Similar to other species of insects, silkworm larva did not show any specific requirements for carbohydrates, although several compounds were utilized more readily than others. In general, pentoses were poorly utilized. Of hexoses tested, glucose, fructose, and mannose were utilized well. Disaccharides, especially sucrose, cellobiose, and maltose, were uniformly good. Trisaccharides, melezitose and raffinose, showed a high value. Among sugar alcohols only sorbitol was utilized. Utilization of polysaccharides was entirely dependent on silkworm strains, that is, on the presence or absence of amylases in digestive juice, Furthermore, nutritive values of various oligosaccharides were shown to be relating with the presence or absence of corresponding glycosidases. Glycolytic pathway and pentose cycle of larval tissue were also investigated. Proteins and amino acids. Nutritive values of different proteins for the silkworm varied largely. Milk protein, egg albumin, and soybean protein were utilized well, whereas gluten, edestin, and zein possessed very poor value. These differences in the food value seem to depend on qualitative and quantitative amino acid composition of proteins. The silkworm required arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine, which are the same ten acids reported to be essential for other species of insects. Without any one of these acids, no larva could survive at all. In addition to these ten acids, the silkworm required proline, but proline was considered to be semi-essential, since some growth was obtained even in the absence of proline. However, when compounding the diet containing these eleven acids, the larval growth was poor. Subsequently, either aspartic or glutamic acid was proved to be necessary. The almost normal growth was obtained on the diet containing eleven essentials plus acidic amino acid(s). Requirements for these acidic amino acids are also evident from the fact that a detrimental effect is obtained when both of them are omitted from the complete diet containing nineteen amino acids. It is of interest that so-called non-essential amino acids, alanine, cystine, glycine, serine, and tyrosine, possess some nutritive effects. Optimal growth was obtained by the addition of these non-essentials. The nutritive effect of these non-essentials was clearly observed, even when acidic amino acids were previously included in the diet. No D-amino acids were shown to possess any nutritive activity The nutritional requirement for sterols has been demonstrated in every insect studied for this purpose. Nutritional Requirements of Silkworm in the silkworm. Without dietary sterol no growth and development were obtained. R-Sitosterol, stigmasterol, campesterol, cholesterol as well as natural sterol mixtures from various sources, such as soybean, mulberry leaf, and rape-seed, were all effective. Inability of utilizing mevalonic acid or squalene in lieu of sterol suggests the lack of synthetic pathway of sterol from acetate in the larva. Lipid requirements of the silkworm are, however, not satisfied unless fatty acids or vegetable oils are supplied, Linoleic and linolenic acids were most effective, but other fatty acids including both saturated (myristic, palmitic, stearic, arachidic) and unsaturated (oleic) ones also possessed some activity. Sole addition of fatty acids or vegetable oils, without sterol, did not improve any dietary efficiency, whereas the addition in combination with sterol improved markedly. Fatty acids enhanced the rate of utilization of dietary sterol, and furthermore, sparing effects with fatty acids on sterol utilization were demonstrated. Phospholipids extracted from soybean were also proved to be effective for growth improvement. The B vitamins so far demonstrated to be essential for the silkworm are biotin, choline, inositol, nicotinic acid, pantothenic acid, pyridoxine (or pyridoxal), riboflavin, and thiamine. Results are still inconclusive as for folic acid requirements. Minimal optimal levels required varied according to different vitamins, and larger amounts of both choline and inositol were required. In general, there is a good agreement between quantitative requirements for vitamins and their contents in fresh mulberry leaves. The silkworm requires ascorbic acid. Without this vitamin no growth was obtained beyond the second instar. Nutritional studies suggested that the biosynthetic pathway of ascorbic acid from Dglucose via D-glucuronolactone and D-gulonolactone did not occur in the larval body. D-Ascorbic (araboascorbic) acid showed a very high substituting activity for L-ascorbic acid. Content of ascorbic acid in the larval body was shown to be entirely dependent on the amount of the vitamin contained in the diet.

Minerals: The silkworm is hardly able to reach the end of the first instar on the diet without any additional minerals, such as, Wesson's salt mixture, ash of mulberry leaves, or ash of soybean meal. The compounds so far demonstrated to be necessary are potassium, phosphorus, calcium, magnesium, manganese, iron, and zinc. Dose requirements for various nutrients, including amino acids, sterol, fatty acids, vitamins, and minerals, were investigated in detail, and minimal optimal levels were obtained by each nutrient. Furthermore, the proportions of nutrients were proved to be very important for good nutrition, especially for growth of silkglands and cocoon production. For example, the ratio of carbohydrate vs, protein influenced not only larval growth and development but also cocoon production. Dietary conditions influenced various enzyme activities of larval tissues; on a high-protein diet xanthine oxidase activity of larval tissues increased, and the rate of uric acid excretion increase.

Genetics of Silkworm

The silkworm is important not only for silk production but also for biological studies. After Drosophila melanogaster, the bulk of studies on insect genetics relates to the silkworm. Almost 4310 silkworm strains (including geographical strains, consanguineous lines and mutants) have been identified. Of these, about 2000 strains belong to the B. mori L silkworm. In addition, about 230 gene and locus patterns have been recognized.

Because of the deep-rooted history of silkworm nurturing for economic benefits, silkworm genetics has been an important topic among scientists. This significance has resulted in the collection of, study of and conservation of silkworm genetics for scientific and economic utilization. Additionally, the genetics of successful traits of silkworms have been well investigated in scientific sources which have put the emphasis on qualitative traits. The appearance of these traits for one or several genes can be identified easily. So, on the basis of these genetic traits, we can anticipate possible variation intervals of a specific trait while regenerating and improving another trait. The number of chromosomes in the domesticated silkworm (B. mori) is 28, while in the wild silkworm (Bombyx mandarina) it is 31. Moreover, the wild silkworm contains 27 haploid chromosomes. More than 450 morphological and biochemical characteristics have been recorded for the silkworm. Of these, 300 characteristics have been determined on 27 groups of chromosomes.

The reasons are: (1) the mature insect has a short longevity and the nymph is latent in the cocoon so the chance of exposure is too small; and (2) larvae are killed after the cocoon spinning phase in order to procure silk and only a few of them are used for producing eggs.

Several investigations have been carried out on the genetics, nutrition and biochemistry of silkworms. In 1928, Kavagushi had crossed domesticated silkworms (B. mori) with wild silkworms (B. mandarina) and observed that one of the 27 chromosomes of the wild silkworm paired with two chromosomes of the domesticated silkworm and resulted in a viable cross-breed. He concluded that one of the B. mandarina chromosomes had fractured and changed into two parts and thereupon, giving rise to the domesticated silkworm. Meiosis immediately begins after fecundation. When the embryo formation is complete, the larvae break the egg shells and emerge. The newborn larvae are black and grey and covered with hair. For this reason, it is called Hair worm or Ant worm.

Numerous traits are significant in sericulture and the importance of these traits varies in different sections of the industry. Silkworm egg producers aim to possess lines with high breeding potency, while cocoon producers endeavour to improve production, cocoon shell per cent and resistance against illness.

Variation in the breeding programmes results in the construction of a silkworm population with a firm base. Moreover, evaluation of genes helps in distinguishing lines via specific characteristics such as the length of fibre, denier, resistance against tension, resistance against illness, etc.

Endocrinology of Silkworms in Sericulture

The domesticated silkworm, Bombyx mori L., is one of the most useful insects in agdculture. Before the World War II, Japanese sericulture was the most important export industry, and produced about 400,000 ton of the silkworm cocoon. Although it was decreased extremely during the War, this industry is still important in Japanese agriculture. Bombyx mori is classified as belonging to the order Lepidoptera, the suborder Heteroneura, and the family Bombycidae. Newly hatched larvae grow very quickly, feeding solely on mulberry leaves, and they become mature larvae after 20-23 days, then spin cocoon with silk materials from fully-grown silk gland. The silk gland produces a large amounts of various silk proteins (fibroin and three kinds of sericins). The gland is a large, tubular gland, and is composed with anterior, middle, and posterior divisions. The main fibrous component of silk fibroin is produced in the posterior division of the gland, while the gelatinous component, sericin, which coats the fibroin, is secreted in the middle division.

The silk gland is also one of the most effective organ for insect hormones, especially, ecdysone and juvenile hormone (JH). Growth and differentiations of the gland cells are accelerated by ecdysone, and are controled by JH. JH administrations induced additional accumulation of silk protein in the gland. Methoprane, a kind of synthetic JH analogues, was developed as a commercial drug in 1977, and named "Manta". The Manta is starting to be used by Japanese sericultural farmers to produce more silk. In this paper, the author will describe the recent studies and the progress on hormonal control of silk production in silkworm, especially, structure and function of the silk gland, hormonal control of silk-protein synthesis, and utilization of JH for sericulture.

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Structure and function of silk gland

The nucleus contains numerous nucleoli and chromatin bodies, and they ramified extremely like a mesh-work with the lapse of time of larval development. Also, the nucleoli develop enormously during the most active period of RNA synthesis, and incorporate labelled uridine into them in same times. In the cytoplasm, granular endoplasmic reticulum, Golgi complexes and fibroin globules are also conspicuous during the duration of active fibroin synthesis. Labelled glycine which is one of the main composing amino acids of the fibroin, is incorporated into the granular endoplasmic reticulum at first, then, transferred into the Golgi complexes, fibroin globules, and finally, into the liquid fibroin in the lumen. In both Golgi vacuoles and fibroin globules, elementary fibers of fibroin which presumably represent newly synthesized fibroin molecules transported from the granular endoplasmic reticulum, were detected. Each elementary fiber in the Golgi vacuoles was seen as a helical bundle of five to seven threads. The bundles were about 130 A in diameter, and the threads were 20 to 30 A in diameter. These elementary fibers are only a fundamental structure in the liquid fibroin in the gland. The major liquid fibroin in the lumen is consisted with numerous spherical masses of the elementary fibers.

Hormonal control of silk production in silk gland

As mentioned above, the silk gland is one of the most responsive organs to insect hormones, ecdysone and JH. The former is secreted from prothoracic glands, and the latter from corpora allata. When the corpora allata were removed from early 4th instar larvae, they become precocious pupae without the 4th larval molting. During this process the silk gland shows hypertrophic development like a developmental pattern of the 5th instar. By the electron microscopic observation, enormous amounts of fibrous fibet are secreted from the posterior silk gland of the allataectomized larvae as compared with normal 4th ins tar larvae (Akai and Kiguchi, 1978).

By the administration of considerable amounts of ecdysone in middle stage of the 5th instar, the silk gland cells are rapidly changed toward the histolysis producing numerous lysosomes. At several hours after the ecdysone administration, the granular endoplasmic reticula are concentrated in everywhere, and then, they are enclosed by a separate membrane with some mitochondria and ground matrix. Finally, they become lytic vacuoles through the autophagosome. Similar ultrastructural changes in the gland cell occm· during larval and pupal molting stages. During the larval-pupal metamorphosis, however, the silk gland cells are histolysised completely. On the other hand, JH administration controls the larval period and silk production by the supplied amounts and developmental stages. In the early experiments, we found that 10 p.g JH administration prevented any pupal development including spining for co coon formation. Such larvae were called as "dauer larvae". Their silk glands contained a large amount of liquid silk in the lumen, and the gland cells were well developed and showed no signs of histolysis (Akai and Kobayashi, 1971) So Sericulture plays a very effective role in the utilization of the natural resources in a most effective manner for socio-economic upliftment with livelihood, employment and income generation (Malik et al.,2008)

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CHAPTER -IV

INSECT PESTS

Insects as crop pests: Types of injuries and loss caused to plants in general. Factors governing the outbreak of pests.

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INTRODUCTION-

The scientist has catalogued about 1.5 million of species of organisms on the planet, the insects has making up two third of this boundary. The oldest insect fossil part mandible or jaw found in Scotland about between 408 and 338 million years old. In Devonian period a oldest winged fossil found it has date back 330 million ago insects first animal to leave ocean for land. The birds eat about 400 to 500 million tons insects per year. Insects are important part in ecosystem they pollinate plants and create food for other animals. They also decompose plant and animal matter and they source of food. It has most diverse group of organisms, about nine hundred thousand different kinds of insects living known they all belongs phylum Arthopoda. Insects live in nearly every habitat, and it’s estimated that there are currently 10 quintillion insects on the globe. So far scientists who study bugs, called entomologists, have named one million insect species but studies estimate that four million are still uncategorized. The insects have tiny size it making hiding easier and reduce overall energy requirements, widely diet both natural and artificial food. The protective exoskeleton, frequent possession of wings it helps reaches safely. The beetle's order of insect Coleoptra is most bio-diverse group having 380,000 species makes 40% of all insects. The new estimates indicate that globally approximately 1.5 million beetles, 5.5 million insects and seven million terrestrial arthropods. Over one million species of insects has discovered and described but its estimated number is about 10 million species on earth. The total weights of insects that present on earth are 70 times more than all the people of earth. The honey is for one-pound collection makes ten billion nectar collecting trips on flower. The insects found in almost every habitat from mountain ranges covered to snow also in hottest deserts on the planet. There are many species of insects. Many are beneficial and pollinate flowers, or prey on pests. A few species damage plants and become pests. Insects and mites are considered pests when they reach high enough numbers to cause damage injury thresholds. When this occurs, they are usually controlled and steps are taken to prevent damage in the future. It is difficult to set injury and action thresholds that work in all situations. Thresholds for insects and mites in the landscape can be defined using f percentage of

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leaves damaged on a given plant, percentage of plants affected on a site. Number of pests counted per leaf or shoot for landscape plants, or area for turf. Number of pests counted against the number of beneficial insects present for turf pests, the number of insects that can be tolerated injury level often depends on the health of the turf grass. Healthy turf quickly fills in thin or sparse areas caused by insect feeding. Poor turf can show damage from insect numbers that would have little or no effect on healthy turf. The insects number of individuals per unit of area density is as like the one beetle larva occur in per cubic foot of soil, ten caterpillars occurs per ten feet of crop row and one hundred aphids per leaf. The insects with chewing mouthparts, for example, grasshoppers, caterpillars, and beetles, cause feeding damage such as holes or notches in foliage and other plant parts, leaf skeleton zing (removal of tissue between the leaf veins), leaf defoliation, cutting plants off at the soil surface, or consumption of roots. Some insects with chewing mouthparts bore or tunnel into plant tissue. Stem-boring insects can kill or deform individual stems or whole plants. Leaf mining insects feed between the upper and lower surfaces of leaves, creating distinctive tunnel patterns visible as translucent lines or blotches on leaves. Insects with sucking mouthparts, such as aphids, scales, leafhoppers, and true bugs, feed by sucking sap from plant tissues. This type of feeding can cause spotting or stippling of foliage, leaf curling, and stunted or misshapen fruits.

The many insects are studied by human by different ways this study is done under a zoology branch called entomology. Entomology is a biological science dealing with a specific group of organisms, the insects. Man originated about a million years ago, and insects at least 500 million years ago. Insects constitute the largest Class of the whole living organisms and about 72 per cent of all living animals are insects with 9-15 lakhs known species. Entomology (from Greek, entomon= insect and logos= study) is the scientific study of insects, a branch of zoology. It aims at understanding their body organization & functions, their habit and habitat, their classification, development, distribution, origin past history and economic importance. About one million different insect's species has been studied till today. The entomology is crucial to understanding of human diseases, agriculture, evolution, ecology and biodiversity.

The William Kirby is widely considered as the father of Entomology. In collaboration with William Spence, he published a definitive entomological encyclopedia, Introduction to Entomology, regarded as the subject's foundational text. Maria Sibylla Merian wasn't always known as the mother of entomology.

Born in the Netherlands in 1647, Merian spent her early years as a homemaker for her husband and daughters. However, a childhood love of insects blossomed into a fascination with caterpillars, especially with their metamorphosis into butterflies. Having come from a family of artists, Merian was able to use her drawing talents to capture the life stages of insects, from larva to pupa to adult, in a way that had never before been documented. The common belief held during Merian's time was one of "spontaneous generation," the idea that insects and other living creatures spontaneously emerged from dew, dung and mud, which had its origins in a theory first outlined by the Greek philosopher Aristotle. William Kirby (1759-1850) known as the father of entomology, Reverend William Kirby graduated from Caius College in Cambridge, England, in 1781 and was ordained a year later. He spent the next 68 years of his life living just 2.5 miles from his birthplace in Suffolk. This somewhat isolated life afforded the opportunity to connect with local scholars and scientists and learn about the surrounding plants, animals and insects in great detail. Over the course of his life, Kirby helped found the Entomological Society of London became President of the Ipswich Museum and is associated with founding the Linnaean Society, but his greatest contribution to the field of entomology came between 1815 and

1826. Together with friend William Spence, Kirby produced “An Introduction to Entomology, or Elements of the Natural History of Insects,” four volumes that would become the foundational text for modern entomology.

INSECTS AS CROP PEST-

Farmers in the tropics lose up to 50% of their crops to pests including insects and plant pathogens compared with just 25–30% in Europe and the United States. Part of the problem is that pests are a year-round problem in the tropics, and farmers are often poorer and rarely have access to safe and effective pesticides, robust varieties of plants and adequate irrigation. As global temperatures rise, pests that are now confined to the tropics may spread to cooler parts of the world. Farms at mid-latitudes may face a doubling of crop loss due to pests by the end of this century, with up to 40 percent of global crop production already lost to pests, according to FAO estimates, any migration into new land could see the scale of that destruction shoot higher. Insects injure plants by chewing leaves, stems and roots, sucking juices, egg laying or transmitting diseases. Less than 1 percent of insects are pests, but that small fraction can do expensive damage. Insects cause damage in a variety of ways.

How Insects Injure Plants

Insects may feed on leaves, stems, roots, and flowers of plants. The chewing insects actually consume the infested parts. Types of leaf feeding by chewing insects include pit feeding on leaves by leaf beetles, flea beetles, and young caterpillars. Irregular notches along the edges of leaves are typically caused by various weevils, larger caterpillars, grasshoppers and katydids. Perfect semicircular cut portions of leaves indicate the presence of leaf cutter bees. Feeding entirely within leaves is called mining. Leaf miners can be found among beetles, flies, sawflies, and moths. Stem chewing typically is done by borers, which feed internally as larvae. Important borers include long horned beetles (round headed borers), metallic wood boring beetles (flat headed borers), engraver beetles, clearwing moths, American plum borer (a moth), and a few less commonly encountered moths. Root chewing insects include species that subsist entirely on plant tissue for development, such as root weevils and root maggots, and those that feed on a combination of soil organic matter and roots most white grubs.

Injury by Chewing Insects- Insects take their food in a variety of ways. One method is by chewing off external plant parts. Such insects are called chewing insects. It is easy to see examples of this injury. Perhaps the best way to gain an idea of the prevalence of this type of insect damage is to try to find leaves of plants with no sign of insect chewing injury. Cabbageworms, armyworms, grasshoppers, the Colorado potato beetle and the fall webworm are common examples of insects that cause chewing injury.

Injury by Piercing-Sucking Insects- Another important method which insects use to feed on plants is piercing the epidermis (skin) and sucking sap from cells. In this case, only internal and liquid portions of the plant are swallowed, while the insect feeds externally on the plant. These insects have a slender and sharp pointed part of the mouthpart which is thrust into the plant and through which sap is sucked. This results in a very different but nonetheless severe injury. The hole made in this way is so small that it cannot be seen with the unaided eye, but the withdrawal of the sap results in either minute white, brown or red spotting on leaves, fruits and/or twigs; leaf curling; deformed fruit; or a general wilting, browning and dying of the entire plant. Aphids, scale insects, squash bugs, leafhoppers and plant bugs are examples of piercing-sucking insects.

Injury by Internal Feeders- Many insects feed within plant tissue during a part or all of their destructive stages. They gain entrance to plants either in the egg stage when the female thrust into the tissues with sharp ovipositors and deposit the eggs there, or by eating their way in after they hatch from the eggs. In either case, the hole by which they enter is almost always minute and often invisible. A large hole in a fruit, seed, nut, twig or trunk generally indicates where the insect has come out, and not the point where it entered. The chief groups of internal feeders are indicated by their common group names: borers; worms or weevils in fruits, nuts or seeds; leaf miners; and gall insects. Each group, except the third, contains some of the foremost insect pests of the world. In nearly all of them, the insect lives inside the plant during only a part of its life and emerging sooner or later as an adult. Control measures for internal feeding insects are most effective if aimed at adults or the immature stages prior to their entrance into the plant. A number of internal feeders are small enough to find comfortable quarters and an abundance of food between the upper and lower epidermis of a leaf. These are known as leaf miners. Gall insects sting plants and cause them to produce a structure of deformed tissue. The insect then finds shelter and abundant food inside this plant growth. Although the gall is entirely plant tissue, the insect controls and directs the form and shape it takes as it grows.

Injury by Subterranean Insects- Subterranean insects are those insects that attack plants below the surface of the soil. They include chewers, sap suckers, root borers and gall insects. The attacks differ from the above ground forms only in their position with reference to the soil surface. Some subterranean insects spend their entire life cycle below ground. In other subterranean insects, there is at least one life stage that occurs above the soil surface; these include wireworm, root maggot, pill bug, strawberry root weevil, and corn rootworm. The larvae are root feeders while the adults live above ground.

Injury by Laying Eggs- Probably 95% or more of insect injury to plants is caused by feeding in the various ways just described. In addition, insects may damage plants by laying eggs in critical plant tissues. As soon as the young hatch, they desert the plant causing no further injury.

Soil Insects- The soil insects include wireworms, white grubs, fire ants, cutworms, seed maggots and the sweet potato weevil. These insects can be damaging because they feed on the roots, stems and tubers of plants. Often soil insects, especially cutworms, are common in uncultivated soil sites that have had grass and weeds growing the previous season. These undisturbed areas often harbor high populations of soil insects. Once seeds or transplants are planted, soil insects are difficult to control and may begin feeding immediately on the crop. There is a real need for producers to inspect fields for soil insects prior to planting. One or two soil insects per square foot of soil can cause serious damage. Oftentimes soil insects are clumped in a field, that is, they may be in one area and not in another. Low areas or those areas with the most vegetation often hold the most insects. Controlling soil insects is much easier if done prior to planting. Most insecticides for the control of soil insects should be applied 6 weeks before planting and incorporated into the top 6 inches of the soil. Liquid or granular materials may be used.

Chewing Insects- Many chewing insects have a complete life cycle. Therefore, depending on species, there may be one or two damaging stages. Grasshoppers have a chewing-type mouthpart but have an incomplete life cycle. Chewing insects include all species of beetles, grasshoppers and moths and butterfly larvae (most often called worms). Chewing insects damage foliage, stems and fruit. They may become as numerous as to completely defoliate plants. Eggs of most insects are laid on the plant, and the larvae upon hatching begin to feed. Others may invade the crop by "marching in" or by flying into the field. Control of chewing insects is basically twofold. One, the grower must watch for eggs and small larvae that begin to feed; two, he must watch for the adults and control them when necessary. Control of these insects is important in the early infestation of the plant. Often, the insect after hatching may bore into the fruit or stem and be hidden from pesticide applications. These insects often become numerous because producers do not begin treatment early enough. It is vital that fields be watched and these insects controlled at the earliest possible moment.

Sucking Insects- Sucking insects include aphids (“plant lice”), stink bugs, squash bugs, leafhoppers and spider mites. Spider mites are not insects but are just as damaging and numerous as are some insects. Sucking insects have an incomplete life cycle. After hatching from the egg, they may begin to feed and move about on the plant. They are usually attracted to the most succulent part of the plant. Aphids usually are found in the terminal or on flowers. Stink bugs and squash bugs readily feed on the tender fruit. These insects damage the plant by reducing the vigor or by injecting a toxin or disease-causing organisms into the plant. Heavy feeding may cause flowers to abort or the leaves to turn yellow and fall off. Feeding on the fruit may cause cat facing injury, hard spots or twisted and misshapen fruit. Control is easiest to obtain soon after the insects hatch from eggs. This is when the insects are the smallest and most vulnerable to the pesticide. Look for egg clusters, so that timing of the insecticide can be more accurate.

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Most true bugs have large eggs that can be seen without the aid of a magnifying glass. They are often on the undersurface of leaves and laid in tight groups and glued together, or in the case of squash bugs, they may be laid singly but in a loose fitting group and not glued together.

TYPES OF INJURIES AND LOSS CAUSED TO PLANTS IN GENERAL-

"An insects that cause economic loss to plant and plant produces and attack livestock or man". A pest is a general term used to describe any organism (usually insect or animal) that is harmful to our health and properties including crop and livestock. The term, in its broader sense also includes micro-organisms, parasitic plants and weeds.

Insects can become pests in the garden when they cause damage to garden plants. The signs of damage vary, typically depending on the way that the insect feeds on the plant. Damage from insects with **chewing mouthparts** typically appears on leaves or stems as ragged edges, holes, or other missing tissue. Insects that often cause chewing damage include caterpillars and Eastern lubber grasshoppers. Insects with **piercing-sucking mouthparts** have strong mandibles that they move laterally to often cause yellowing or browning on plants, and possible wilting. Examples include aphids, scales, spider mites, and whiteflies. Pest insects can also be classified by the types of damage they cause. For example, **defoliators** tend to feed voraciously and strip a plant nearly bare. Many caterpillars fall into this category. Other insects include **leaf miners**, which burrow into the leaves of plants leaving tell-tale tunnels in the leaves. One well-known leaf miner is the citrus leaf miner, which is actually a larval stage of a moth. **Gall makers** insert all or part of their bodies into plant tissue typically into leaves, stems, or twigs and cause the tissue to swell. Examples include blueberry gall midge larvae that burrow into leaves to feed, and gall wasps that deposit their eggs into plant tissue. **Wood/phloem borers** include twig girdlers and powder post beetles that cause damage by feeding on living wood and wooden structures.

Scales: These remain covered inside a hard coating which looks like a waxy scale and infests lower surface of leaves and veins of branches.

Thrips: These are minute sucking insects that mainly attack tender leaves, twigs and flower buds, making the affected plants weak with burnt appearance.

Aphids: These brownish or green insects suck sap from tender shoots, leaves and flower buds. The affected plant becomes weak and retards in growth.

Mealybugs: These are small fleshy insects which remain covered in white, wooly and waxy secretions. The older plants are affected.

Whiteflies: These are tiny insects, white in color and are very active in damp and dark conditions.

Spider-Mites: This is a minute dot sized dangerous, shoot sucking pest, red in color, almost invisible to the naked eyes, resembling the spider but not an actual spider.

Caterpillars: Various caterpillars feed on foliage; they damage the leaves by feeding continuously.

Leaf Beetles and Weevils: These leaf infesting flying insects are considered as serious pests on flowering plants like Roses.

Leaf-miners: The larvae of theses insects mine into leaves between tissue layers, leaving excreta on leaf surface & creating typical white patterns on leaves.

Insects and their Injury to Plants- The majority of small invertebrate animals belong to Phylum Arthropods, which consists of organisms with external skeletons and jointed legs. Insects, Class Hexapod (meaning "six-footed"), has the largest number of species within this phylum. In addition to the characteristics already mentioned, insects also are distinguished by having one pair of antennae, and most have wings and three body regions as adults. Centipedes, millipedes, mites, sow bugs, and spiders are non-insect arthropods: all have external skeletons but adults have more than six legs. Insects are by far the most abundant animals in the world, both in numbers of species and individuals. Fossil remains show that insects inhabited the world long before other animals now living appeared. Most insects obtain their food from plants. Bees live on nectar and pollen from flowers. The larvae of many beetles, moths, butterflies, and flies live in or on plants. Many bugs suck the sap or cell contents from plants as a source of food. Many other insects, such as the parasitic wasps, feed as parasites, usually in the bodies of host insects. Others, such as the praying mantis, some trips, bugs, flies, beetles, ants, and wasps, prey on other insects. This publication focuses on the insects more commonly considered to be plant pests.

Chewing insects- One way an insect feeds is to bite off and chew the external parts of a plant. This type of injury may weaken the plant and cause it to be less productive or to die. Many pests such as grasshoppers feed on many different plants, while other insects such as cabbageworm and Colorado potato beetle feed on only a few types of plants.

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Piercing-sucking insects- Insects such as aphids and scales feed on the sap from plants by piercing the epidermal layer of the plant and sucking the plant sap from the cells. In this process, they damage the plant cells and remove valuable nutrients. Plant damage may include distorted leaves, curled leaves, chlorotic-looking (yellow) tissue, deformed fruit and even death of the entire plant. Some insects inject a salivary toxin into the plant that does additional damage. Well-known insects with piercing-sucking mouthparts include aphids, scales, leafhoppers, squash bugs and plant bugs.

Internal feeders- Many insects feed internally within the plant tissue, which makes control difficult or impossible. These insects enter the host plant either through the egg stage when the female adult lays the egg within the plant tissue, or they hatch and immediately eat their way into the plant tissue. Internal feeders include wood borers, codling moth in apples, leaf miners, seed weevils and gall insects. Perhaps the most widely noticed internal feeders are those that cause galls. These unusual growths on plants can be caused by many different insects, including wasps and flies. Most internal feeding insects emerge as adults. Control must be aimed at the immature stage before it enters the plant or at the emerging adult to reduce the population in subsequent generations by reducing the number of females that will lay eggs.

Major diseases- No major disease currently limits commercial production in Asia. Diseases are more important after harvest, although undoubtedly many of the fruit are infected before picking. There are a few organisms that infect the leaves, flowers and fruit, and a few others associated with tree decline and tree deaths. Chemicals are generally available for controlling diseases on the flowers and fruit. In contrast, more efforts need to be made to control the loss of trees.

FACTORS GOVERNING THE OUTBREAK OF PESTS-

The word pest derived from French word 'Peste' and Latin term 'Pestis' means plague or contagious disease. Pest is any animal which is noxious, destructive or troublesome to man or his interests

CATEGORIES OF PESTS –Based on occurrence and locality

A) Based on association with the crop-

- **Regular pests:** Pests that occur more frequently on a crop having close association with particular crop. Example- Rice stem borer, Mustard aphid, Chilli thrips

- **Occasional pests:** Pests that occur rather infrequently and have close association with a particular crop. Example- Rice horn caterpillar, Rice case worm Based on the seasonality
- **Seasonal pests:** Pests that occur on a crop during a particular season of the year. Example- Red hairy caterpillar in groundnut in Saurashtra and maize in Dahod in June - July.
- **Persistent pests:** Pests, which occur persistently on a crop almost throughout the year. Example- Thrips on chillies
- **Sporadic pests:** Pests, which occur in a few isolated localities during some period. Occasionally causing serious damage. Example- Rice ear head bug, Mango shoot borer

- **Based on intensity of infestations-**

- **Epidemic pests:** Pests, which occur in severe form in a region or locality at a particular season. Examples- RHC in maize in Dahod in monsoon.
- **Endemic pests:** Pests, which occur regularly and confined to a particular area of locality. Examples- Mustard aphids in North Gujarat, Rice Gall midge in Madurai district
- **Migrant pests:** These pests are highly mobile and can infest crops for short periods of time through movement.

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Examples- Locust Others a. Exotic Pests: Non-Native or Non-Indigenous Pests not known to occur in the state or country.

B) Based on damage potential-

- **General Equilibrium Position: -** The average population density of insect over a long period of time, around which the pest population tends to fluctuate due to biotic and a biotic factors and in the absence of permanent environmental changes. It is unaffected by temporary interventions of pest control.
- **Damage Boundary: -** The lowest level of damage which can be measured.
- **Economic Injury Level**: - The lowest pest population density that will cause economic damage. It is the level before which the control measures are initiated.
- **Economic Threshold Level**: **-** The population density at which control measure should be initiated against an increasing pest population to prevent economic damage. Economic threshold level is always a pest density lower than that of the Economic threshold level.
- **Key pests:** These are the most severe damaging pests. The damage is always above the DB and Economic threshold

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level. General Equilibrium Position lies always above Economic threshold level. Human intervention may bring the population temporarily below the Economic Injury Level, but it rises back rapidly and repeated sprays may be required to minimize damage. Examples- cabbage diamond back moth.

- **Major pests:** These are pests with the population crosses Economic threshold level quite frequently and require repeated control measures to avoid economic damage. (Damage >10%). General Equilibrium Position lies very close to Economic Injury Level or coincides with Economic Injury Level Examples- Cotton jassid, Rice stem borer.
- **Minor pests:** These are pests with population rarely crosses Economic Injury Level and fluctuates around Economic threshold level. But these pests are easily control by available control measures and a single application of insecticides. (5-10% damage). General Equilibrium Position is usually below the Economic Injury Level. These are occasional pests. Examples- Cotton strainers, Rice hispa

- **Negligible Pest:** Population never increases high enough to cause economic injury. That cause less than 5% loss in yield, are said to be negligible pests.
- **Potential pests:** These pests normally do not cause any economic damage. Hence, they are not pests at present but any change in the ecosystem may make them to cause economic damage (Damage > 5%). General Equilibrium Position always less than economic Injury Level.
- **Sporadic pests:** General Equilibrium Position generally below Economic Injury Level. Sometimes it crosses Economic Injury Level and cause severe loss in some places/periods Examples- Sugarcane pyrilla, White grub, Hairy caterpillar.
- **Secondary pests:** These pests are usually kept under adequate control by natural enemies, but can increase and produce economic losses if the natural enemies are disrupted by agricultural practices.
- **Severe pest:** They have Economic Injury Level below the General Equilibrium Position. Regular and constant interventions with insecticides are required to produce marketable crops. Economic Injury Level decreases as the

value of crop increases. It also depends on the stage of the crop, stage of the pest etc.

A pest insect is one that is judged by man to cause harm to himself, his crops, animals or his property. In farming an insect may be classified as a pest if the damage it causes to a crop or livestock is sufficient to reduce the yield and/or quality of the 'harvested product' by an amount that is unacceptable to the farmer. Insects may be classed as pests because they cause damage directly to harvestable products, e.g. codling moth larval damage to apples, or because they cause indirect damage or harm in other ways, e.g. by causing a nuisance to livestock or humans or as vectors of plant or livestock diseases. There are a myriad of ways in which insects can cause harm and they have done so for the thousands of years that man has occupied the earth. Likewise man's attempts to control or manage the harm caused by insects have a long and varied history. Knowledge of this history adds an important dimension to the study of pest management because it can provide insights into the driving forces that have forged current pest management practices which in turn will provide some idea of the forces likely to be acting in the future. Pest is a general term used to describe any organism that is harmful to our health and properties including crop and livestock. The term, in its broader sense also includes micro-organisms, parasitic plants and weeds. Pest outbreak factors affecting natural insect population the way that the numbers of an insect species change represents the balance of birth and deaths over a given time period Birth rate is influenced by

1. Weather and climate 2. The food quality received by the adult's 3. The degree of crowding of the individuals.

Crowding affects birth rate partly through affecting the quality of the food but also by more direct influences such as stimulating restlessness of individual's death rate is influenced by climate, natural enemies, diseases and crowding. The crowding may lead to cannibalism or starvation. Moreover, crowding may also lead to emigration which, like death, leads to a reduction in the number of individuals in an area. With natural enemies for own survival Directly Differential effect on organism and natural enemies Mortality e.g. Frost, storms Natality e.g. Fecundity, development rate Growth and condition of food plant indirectly with other species e.g. for food, ovipositor sites within the species e.g. Overcrowding, starvation

Factors Affecting Insect Population Competition Climate-

Causes of pest outbreak 1.Favourable weather 2.Intensive cultivation and monoculture 3.Destruction of natural enemies

4.Destruction of natural habitat 5.Introduction of new crops 6.Accidental introduction of foreign pests 7.Use of pesticides Favorable weather condition direct effect: under favorable weather conditions, birth rate is high and death rate low. Indirect effect: a) through the improvement in the growth and condition of food plants. b) The differential effect. If the good weather and climate favors the pest more than it favors the natural enemies, it will increase the rate of growth of the pest population Intensive cultivation and monoculture Intensive cultivation means making rigorous use of the cultivable land. Both intensive cultivation and monoculture favor insect pests. When land is intensively cultivated, pests get a continuously supply of food and natural enemies of pests are low or absent. In an uncultivated land, individual plants of any one kind are often few and scattered. Arriving insects are met by a bewildering mixture of odor cues which makes it much harder for them to locate their host plants, and it is hard for overcrowded population on one plant to spread to another; large mortalities are likely to occur in the process. In a monoculture system plants have been specially selected and managed so as to emerge, grow and mature in synchrony. Provided that the pest arrives at the right time, it will find a very large population of the plants at a high level of suitability. In a

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monoculture system Fertilizers and thinning are among the management practices which maintain a high plant quality suitable also for the rapid development of pest infestations. Infestation spreads much more evenly, and average densities can be very high before emigration or other competition effects of crowding cause significant reductions. Destruction of natural habitat Agriculture generally involves destruction of the natural areas including forests that are the natural habitat of insects and natural enemies. When the natural areas including forests are encroached upon for cultivation, habitation or industrial development, insects migrate to fields. Accidental introduction of pests when planting materials are brought into the country, new pests may be accidentally introduced. These new pests may have been under suppression in its native place but in the new place where natural enemies are absent, it can multiply and buildup population. The use of insecticides on plants but when insecticides are used excessively, not only the pests are killed but also the natural enemies of the pests are wiped out. In the absence of natural enemies, the surviving populations of insect pests multiply rapidly and reach epidemic proportions. Indiscriminate use of pesticides also leads to development of resistance in pests. This occurs as a result of killing the susceptible genotypes and selecting the more resistant genotypes at every pesticide application event. After several years of using the same pesticide, there would come a time when that particular pesticide will have no effect on the pest because they have developed resistance to the pesticide.

A pest is any organism which occurs in large numbers and conflict with man's welfare, convenience and profit - A pest is an organism which harms man or his property significantly or is likely to do so. Insects are pests when they are sufficiently numerous to cause economic damage. Pests are organisms which impose burdens on human population by causing

(i) Injury to crop plants, forests and ornamentals
(ii) Annoyance, injury and death to humans and domesticated animals
(iii) Destruction or value depreciation of stored products.

Pests include insects, nematodes, mites, snails, slugs, etc. and vertebrates like rats, birds, etc. Depending upon the importance, pests may be agricultural forest, household, medical, aesthetic and veterinary pests.

Many plants offer a suitable breeding place for many kinds of insects. Apples, cabbage, corn, elm, grape, grass, maple, oak, peach, pear, pines, poplar, potatoes, and roses have many serious pests. However, insects seldom destroy these plants. The threat of damage by insects need not prevent an attempt to grow any of these plants. Knowledge of what to expect and how to control the pests when they are destructive enables anyone to tolerate low numbers of insects.

Some insects are perennial pests. Plum curculio, flea beetles, striped cucumber beetles, Colorado potato beetle, plant bugs, white grubs and many others regularly occur in some locations whenever appropriate plant hosts are available. Other insects seem to be influenced easily by the weather. Temperature and rainfall seem to affect the numbers of aphids, mites, gall midges, and some scale insects. The third type is represented by the gypsy moth, canker worms, and tent caterpillars. The abundance of these pests changes over several years. The "boom and bust" phases are apparently caused by interactions with predators, parasites, and diseases. The key to successfully growing plants and living with insects is to understand management principles. The need to protect plants is based on whether damaging populations of certain pests are present or expected to be present. The decision to treat plants, for example by spraying with insecticides, should be determined by an economic injury level or aesthetic injury level. These levels define the break-even cost for the extent of damage caused by insects or mites compared to the cost of the control measure. For example, if it costs $15 in labor and chemical costs to control imported cabbage worm by spraying, then the effort would only be justified if the value of cabbage saved by this action exceeds $15. Preventive measures may be warranted for perennially damaging pests, especially when we lack a method to determine whether a damaging pest population is present quickly enough to react in a timely manner to prevent economic injury. The best strategy for these pests is to base the need for treatment on the past history of the site, with treatment timing dictated by crop development. For example, plum curculio is active every year for approximately one month following fruit set when nighttime minimum temperatures exceed 65 F. To protect tree fruits, the decision to spray is based on fruit development and predicted moderate night temperatures. Another example is treating lawns to control white grubs. The most effective insecticides work best when applied at the time adults are active, long before a homeowner can determine whether a damaging population will result. A third example of justifiable preventive insecticide application is when specimen trees are being dug for transplanting. These trees are especially prone to attack from opportunistic borers (beetles and lepidoptera) because the stress induced from

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root loss causes the trees to emit chemical cues that these borers can detect from a considerable distance. Therefore, these trees can be protected with residual insecticides either immediately prior to or following digging. For pests that are sporadic due to weather or biotic factors, or that take a long time to build to damaging populations, scouting and reactive treatments are most appropriate. Scouting, or monitoring for the presence of pests, is the key to integrated insect and mite management in most crops. Some pests, like spider mites, only become damaging when reaching high populations. Regular scouting can detect these populations long before damage occurs; giving plenty of time to plan needed treatment. Most shade tree pests, for example, are sporadic and, thus, can simply be managed when the numbers increase to unacceptable levels. By observing the presence and abundance of pests and their response to treatment measures, one can gain experience in fine-tuning pest management to an individual's needs.

Pest Outbreak -Birth rate, Weather and climate, Food quality received by the adults, Degree of crowding of the individuals- affect the quality of the food but also by more direct influences such as stimulating restlessness of individuals. Temperature, humidity, rainfall, host-plant species, and a variety of other

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environmental factors have a major influence on field insect population dynamics it is an increment in the population of any insect pest more than the ETL value (economic threshold level) or sudden increasing in the population of any individual sp. of an insect is called pest outbreak.

Reasons for pest outbreak: - Pest outbreak is a sudden increment in a population but it takes a long time to happen in any ecosystem. It can occur when the condition is favorable for the individual insect.

An introduction of exotic insect species: - When any new species introduced to the area where it is not found normally, it increases its population due to the absence of natural enemies and proper availability of resources for their development, due to these condition their mortality is sufficiently reduced, causing population outbreak occur.

An introduction of exotic plant species: - When any new plant species introduced to a new biological community, there are many insect pests which will feed on it and it will favor for pest outbreak occur.

High yielding varieties/cultivars: - After the development of high yielding varieties of food crop there is sufficient amount of food for insect pest which results in the quick multiplication of the insects and pest outbreak occur.

High amount of fertilizers: - Use of the high amount of fertilizers leads to vigorous growth of crop, standing crop releases some volatile compounds by which insect attracted to crop and start multiplication due to availability of food.

Destruction of natural enemies: **-** Indiscriminate use of the high amount of pesticide leads to killing the natural enemies with the pest. And in the absence of natural enemies, pest increase their population.

Temperature: - It is an environmental factor and it is the most important factor that favors the rate of growth and development of insect pest if the temperature increases the population of insect pest increases, and if the temperature decreases the population of insect pest decreases.

Mono-culture: - It is an old method of farming which is not in use nowadays but somewhere it is being used in mono-cropping, we provide food to insect pest continuously season to season, which results in pest outbreak to occur.

Weather pattern: - Sometimes weather also favor for the insect to outbreak for examples such as locusts, the wind with higher velocity is important to determine where they will fly

Grasshopper lays eggs more in the temperature in 32 C^{o} than 22 C^{o}.

Migration: - Some insects migrates from one area to another for better favorable conditions, which allows them to escape from control measures and leads to their multiplication

Insects that transmit plant diseases

Many insects pick up plant viruses and bacteria as they feed and then later transmit diseases to healthy plants. They may actually carry the disease from plant to plant on their body, or transmit the disease through plant injection as they feed. This can result in severe damage or death to the plant. Insects that transmit plant diseases include the bark beetles that move fungi that cause Dutch elm disease and the aster leafhopper that injects the bacteria that cause aster yellows. Insects can spread plant diseases in many different ways. Their feeding or boring into plants can create openings through which diseases can enter the plant.

India’s farmers are hard at work. Not only do they help to feed a nation that contains 1.3 billion people one fifth of the world’s population but they also produce around 20 percent of the world’s cotton. However their productivity is threatened by pests that can ruin their crops and their livelihoods. Here’s a glimpse of how plant science is helping reduce the threat. According to a study by the Associated Chambers of Commerce and Industry of India, annual crop losses due to pests and diseases amount to Rs.50,000 crore ($500 billion), which is significant in a country where at least 200 million Indians go to bed hungry every night. The value of plant science is therefore huge. Indians rely heavily on chick peas, pigeon peas, mung beans and lentils for their daily protein requirements and these are an essential ingredient in many native dishes, but it is estimated that without crop protection products the pulse crop yield can fall by around 30%. India is also well known for its cotton production, and is the second biggest cotton producer in the world. Plant science plays a vital role at keeping insects at bay to keep cotton production and quality high. In 2002, India’s farmers planted their first biotech crop, an insect-resistant cotton variety, which protects the plants from the specific insects which can destroy cotton crops. Today Bt cotton accounts for more than 90 % of cotton grown in Indian and the impact has been impressive. Plant science is keeping India’s insects in line. As much as 40 per cent of the world’s agricultural crops are lost to pests each year, according to a recent report. Invasive pests cost countries at least $70 billion annually and are one of the main drivers of biodiversity loss, according to estimates from the Food and Agriculture Organization of the United Nations The scientific review analyzed 15 plant pests and found that climate change will increase the risk of pests spreading in agricultural and forestry ecosystems, especially in cooler Arctic, boreal, temperate and subtropical regions.

There are around 10,000 species of insects that eat and damage crops, of these, only 10 per cent are considered to be major pests. These insect pests are responsible for destroying one fifth of the global crop output annually. In India the losses due to insect pests have come down from 23.3 per cent in the post green revolution era to 15.7 per cent now. This loss calculates to around US$ 36 billion annually. The crop losses due to insect pests were less in the pre-green revolution period as compared to those in the post-green revolution period and beyond, throughout the world in almost all the crops except cotton and rice.

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CHAPTER-V

PESTS CONTROL

Principles and methods of pest suppression: Natural, Cultural, mechanical, physical, chemical, Biological and Integrated pest management.

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PEST - Any organism that cause significant and economic damage to crops, stored produced and animals". - A pest is any organism which occurs in large numbers and conflict with man's welfare, convenience and profit - A pest is an organism which harms man or his property significantly

Pests are organisms which impose burdens on human population by causing

(i) Injury to crop plants, forests and ornamentals

(ii) Annoyance, injury and death to humans and domesticated animals

(iii) Destruction or value depreciation of stored products.

Pests include insects, nematodes, mites, snails, slugs, etc. and vertebrates like rats, birds, etc. Depending upon the importance, pests may be agricultural, forest, household, medical and veterinary pests.

Types of Pests

- Types of pests include:
- Insects, such as roaches, termites, mosquitoes, aphids, beetles, fleas, and caterpillars.
- Insect-like organisms, such as mites, ticks, and spiders,
- Microbial organisms, such as bacteria, fungi, nematodes, viruses, and mycoplasmas,

- Weeds, which are any plants growing where they arc not wanted,
- Mollusks, such as snails, slugs, and shipworms, and
- Vertebrates, such as rats, mice, other rodents, birds, fish, and snakes.

Most organisms are not pests. A species may be a pest in some situations and not in others. An organism should not be considered a pest until it is proven to be one. Categories of pests include:

- Continuous pests that arc nearly always present and require regular control.
- Pporadic, Migratory, or cyclical pests that require control occasionally or intermittently.
- Potential pests that do not require control under normal conditions, but may require control in certain circumstances.

History of pest management

Chemical pesticides date back 4,500 years, when the Sumerians used sulfur compounds as insecticides. The Rig Veda, which is about 4,000 years old, also mentions the use of

poisonous plants for pest control. It was only with the industrialization and mechanization of agriculture in the 18th and 19th century, and the introduction of the insecticides pyrethrum and derris that chemical pest control became widespread. In the 20th century, the discovery of several synthetic insecticides, such as DDT, and herbicides boosted this development.

Chemical pest control is still the predominant type of pest control today, although its longterm effects led to a renewed interest in traditional and biological pest control towards the end of the 20th century

CATEGORIES OF INSECT PESTS

Insects are harmful to man as pests of cultivated crops, animals, stored products, carries of human diseases and pests of household and industrial articles. They are also helpful as producers of honey, lac, silk, dyes, etc., pollinators of crops and as natural enemies of crop pests. They also serve as important link in the foodweb of biological cycle in ecosystem. Insects are grouped with other animals with similar characteristics in the Phyllum Arthropoda.

Insect pests A thorough knowledge of morphology, nature of damage, vulnerable stage of pest, damaging stage, pre-disposing factors, susceptible stages of host, natural enemies and predators help in preventing and controlling them effectively. All insects belong to the class Insecta. Their body is segmented and mostly comprises three main segments, i.e., head, thorax and abdomen. Insects have two pair of wings and three pairs of legs. According to structure of wing (pteron), they are classified into different orders, such as Coleoptera, Diptera, Hemiptera, Hymenoptera, Isoptera, Lepidoptera and Orthoptera, etc. All these insects belonging to different orders may have different life cycles with different damaging stages and nature of damage. With a view to accomplish a better pest management, all these factors are important, but the most important is how (nature of damage) and when (damaging stage) they attack the host

Insect pests are classified as follows based on season and locality

a. Regular pests: Regular pest: Occur most frequently (regularly) in a crop and have close association with that particular crop.

Eg: Chilli Thrips, Scirtothrips dorsalis , brinjal shoot and fruit borer, Leucinodes orbonalis, Rice stem borer.

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Leucinodes orbonalis **Rice stem borer**

b. Occasional pests: Here a close association with a particular crop is absent and they occur infrequently.

Eg: Rice case worm, *Nymphula deputalis* castor slug caterpillar, *Parasa lepida*, mango stem borer, *Batocera rufamaculata*

Rice case worm **Mango stem borer**

c. Seasonal pests: Occur mostly during a particular part of the year, and usually the incidence is governed by climatic conditions. Eg: Red hairy caterpillar on groundnut-June - July, Rice grasshoppers –June-July


Red hairy caterpillar **Rice grasshoppers**

d. Persistent pests: Occur on a crop almost throughout the year. Eg. Thrips on chillies.

Thrips on chillies

e. Sporadic pests: Pests, which occur in a few isolated localities Eg. Rice ear head bug.

Rice ear head bug

Pest Control

Any time you are considering whether pest control is necessary, remember:

- Control a pest only when it is causing or is expected to cause more harm than is reasonable to accept.
- Use a control strategy that will reduce the pest numbers to an acceptable level.
- Cause as little harm as possible to everything except the pest.
- Even though a pest is present, it may not do very much harm. It could cost more to control the pest than would be lost because of the pest's damage.

Principles of Pest Control

A pest is anything that:

- competes with humans, domestic animals, or desirable plants for food or water,
- injures humans, animals, desirable plants, structures, or possessions,
- spreads disease to humans, domestic animals, wildlife, or desirable plants,
- annoys humans or domestic animals.

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Pest Control Goals

Whenever you try to control a pest you will want to achieve one of these three goals. or some combination of them:

- prevention - keeping a pest from becoming a problem.
- suppression - reducing pest numbers or damage to an acceptable level, and .
- eradication - destroying an entire pest population.

Prevention may be a goal when the pest' s presence or abundance can be predicted in advance. Continuous pests, by definition, are usually very predictable. Sporadic and potential pests may be predictable if you know the circumstances or conditions that will favor their presence as pests. For example, some plant diseases occur only under certain environmental conditions. If such conditions are present, you can take steps to prevent the plant disease organisms from harming the desirable plants.

Suppression is a common goal in many pest situations. The intent is to reduce the number of pests to a level where the harm they are causing is acceptable. Once a pest's presence is detected and the decision is made that control is necessary, suppression and prevention often are joint goals. The right combination of control measures can often suppress the pests already present and prevent them from building up again to a level where they are causing unacceptable harm.

Eradication is a rare goal in outdoor pest situations, because it is difficult to achieve. Usually the goal is prevention and/or suppression. Eradication is occasionally attempted when a foreign pest has been accidentally introduced but is not yet established in an area. Such eradication strategies often are supported by the Government. Mediterranean fruit fly. gypsy moth, and fire ant control programs are examples.

In indoor areas, eradication is a more common goal. Enclosed environments usually are smaller, less complex, and more easily controlled than outdoor areas. In many enclosed areas, such as dwellings; schools; office buildings; and health care, food processing, and food preparation facilities, certain pests cannot or will not be tolerated.

Threshold Levels

Thresholds are the levels of pest populations at which you should take pest control action if you want to prevent the pests in an area from causing unacceptable injury or harm. Thresholds may be based on esthetic, health, or economic considerations. These levels, which are known as "action thresholds," have been determined for many pests.

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A threshold often is set at the level where the economic losses caused by pest damage, if the pest population continued to grow, would be greater than the cost of controlling the pests. These types of action thresholds sometimes are called "economic thresholds."

In some pest control situations, the threshold level is zero: even a single pest in such a situation is unreasonably harmful. For example, the presence of any rodents in food processing facilities forces action. In homes, people generally take action to control some pests, such as rodents or roaches, even if only one or a few have been seen.

To solve pest problems. you must:

- Identify the pest or pests and determine whether control is warranted for each.
- Determine your pest control goal(s).
- Know what control tactics are available.
- Evaluate the benefits and risks of each tactic or combination of tactics.
- Choose a strategy that will be most effective and will cause the least harm to people and the environment.
- Use each tactic in the strategy correctly.

- The strategy you choose will depend on the pest you have identified and the kind and amount of control you need.

Natural Controls

Some natural forces act on all organisms, causing the populations to rise and fall. These natural forces act independently of humans and may either help or hinder pest control. It may be able to alter the action of natural forces on a pest population, but you should be aware of their influence and take advantage of them whenever possible. Natural forces that affect pest populations include climate, natural enemies, natural barriers, availability of shelter, and food and water supplies.

Climate

Weather conditions, especially temperature, day length, and humidity, affect pests' activity and their rate of reproduction. Pests may be killed or suppressed by rain, freezing temperatures, drought, or other adverse weather. Climate also affects pests indirectly by influencing the growth and development of their hosts. A population of plant-eating pests is related to growth of its host plants. Unusual weather conditions can change normal patterns so that increased or decreased damage results.

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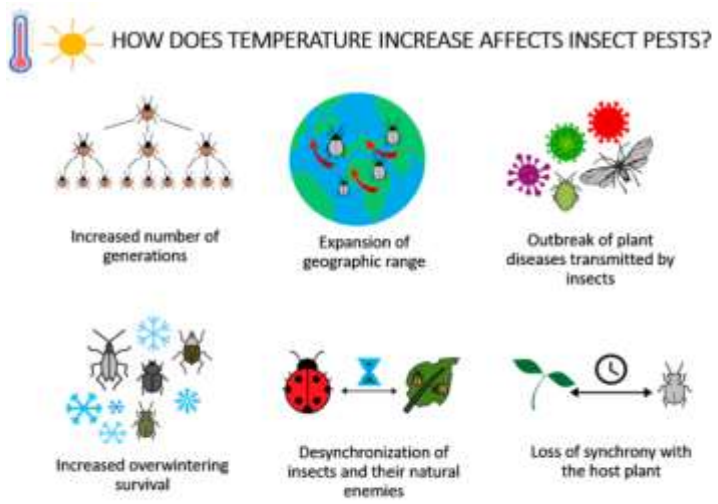

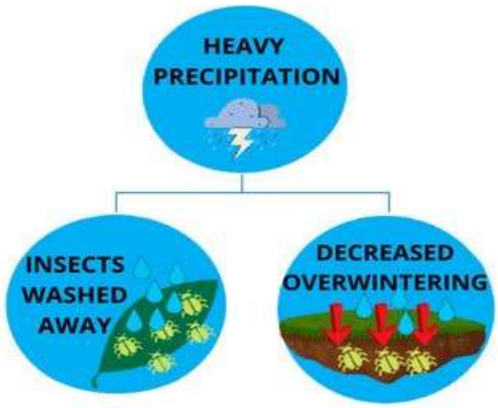

Natural enemies

Birds, reptiles, amphibians, fish, and mammals feed on some pests and help control their numbers. Many predatory and parasitic insect and insect-like species feed on other organisms, some of which are pests. Pathogens often suppress pest populations.

Geographic barriers

Features such as mountains and large bodies of water restrict the spread of many pests. Other features of the landscape can have similar effects.

Food and water supply

Pest populations can thrive only as long as their rood and water supply lasts. Once the food source - plant or animal - is exhausted, the pests die or become inactive. The life cycle of many pests depends on the availability of water.

Shelter

The availability of shelter can affect some pest populations. Overwintering sites and places to hide from predators arc important to the survival of some pests.

Applied Controls

Unfortunately, natural controls often do not control pests quickly or completely enough to prevent unacceptable injury or damage. Then other control measures must be used. Those available include:

- Cultural
- Mechanical
- Physical
- Chemical,
- Biological and
- Integrated pest management

Cultural Control

Cultural controls are the oldest methods that have been used to manage pest populations. These methods are aimed either at reducing the sources of inoculum or at reducing the exposure of plants to infection. Its primary objective is the prevention of pest damage and not the destruction of an existing and damaging pest population.

Planting Design and Management:

Crop isolation: the location of crops with respect to one another and their degree of isolation can affect their likelihood of being invaded by pests. Isolation from old crops of the same type, and from closely related indigenous host-plants that act as sources of pests, is one way of reducing the probability of attack. The chance of invasion occurring will, however, increase with time. Hence, this practice is most appropriate for annual crops, especially when climatic conditions are not ideal. Separation of sequentially planted crops in time to disrupt host-plant continuity and prevent easy pest dispersal may be useful, e.g., for carrot fly control.

Planting density and spacing: the primary objective of this cultural method is to maximize yield per unit area without reducing crop quality, so that yield advantages overide pest incidence reduction. It can also be used to reduce pest numbers and damage. Spacing may affect the relative rate of growth of the plant and its pest population per unit of time, and the behavior of the insect pest in searching for food or for an oviposition site. It is based on the following observations:

i) close spacing may add to the effectiveness of natural enemies and result in greater control of a pest population;

ii) some insect pests are attracted by low density planting because they are silhouetted against bare ground, e.g., at low density brassicas attract more aphids;

iii) some populations of pests can increase on high density crops. Because of the variety of existing responses to crop spacing, a detailed knowledge of the pest's biology is of extreme importance.

Plant spacing is also used to promote vigorous and strong plants, which in itself can be a good cultural control measure, e.g., a good protection for corn against corn stalkborer.

Plant spacing that encourages rapid crop maturation could also provide a means of encouraging early fruiting and harvesting of crops of indeterminate flowering plants. This has been used in the south against bollweevils and pink bollworms.

Mixed cropping: in this approach, more than one crop is grown on the same piece of land. This reduces phytophagous insect pests by encouraging increases in natural enemies due to:

i) greater temporal and spatial distribution of nectar and pollen sources;

ii) increased ground cover, particularly important for diurnal enemies;

iii) increased prey, offering alternative food sources when the pest species are scarce or at an appropriate time in the predator's life cycle. It also affects the pest's ability to find host plants by conferring associational resistance, by the non-host plant masking the odors of the host plant.

Timing of seeding and planting: this is used largely to:

i) avoid invasion by migrants, or the oviposition period of particular pests, and the introduction of disease in the crop by insect vectors;

ii) to synchronize the pest attack with its natural enemies, with weather conditions that are adverse for the pest or with the abundance of an alternative host;

iii) to make it possible to destroy the crop before the pest enters diapause.

Timing can be used to allow young plants to establish to a tolerant stage before attack occurs, to reduce the susceptible period of attack, to mature the crop before a pest becomes abundant, to allow it to compensate for damage and to fill gaps where plants have been damaged or killed, and to avoid the egg-laying period of a particular pest.

Crop rotation: an effective rotation is one in which a crop of one plant family is followed by one from a different family that is not a host crop of the pest to be controlled. Most common rotations include grasses, legumes and root crops. Rotations are effective against pests that have a limited host-plant range and dispersiveness and/or that cannot survive for more than one or two seasons without suitable host crops. Pests most subject to

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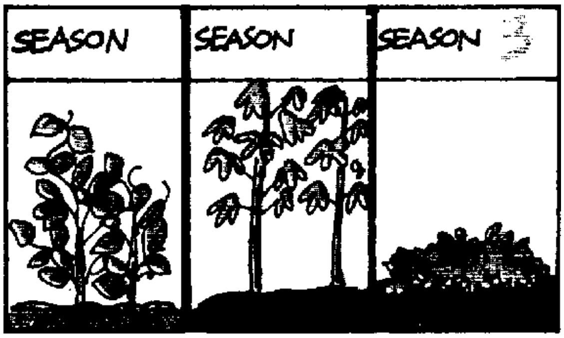
this type of control are poorly mobile, soil-inhabiting species with a restricted host range and a life cycle of 1 year or longer.



Destruction of volunteer plants: such plants are very attractive to many insects and serve as the focal point for future infestations. Unless they are destroyed they can help perpetuate a pest problem by furnishing a food source to long life-cycled pests of preceeding crops.

Management of alternate hosts: many insects reproduce on weeds or other alternate hosts and then attack the main crops. It is therefore usually desirable to destroy brambles or other weeds on uncultivated land to assist in the control of insects such as aphids, beet leafhopper and raspberry caneborer. Care must be taken, however, not to destroy nursery sites for the pest's natural enemies.

Management of trap crops: trap crops (often small plantings, often made earlier than the main plantings) are used to divert insect attack away from the crop at risk by using more attractive food sources. The trap crop must usually be destroyed before the insects reproduce.

This method involves the planting of a crop upon infested land so that the pest is stimulated to attack, but the crop is either removed before the pest can complete its life cycle or it will not provide all the requirements necessary for the completion of the pest's life cycle. Alternatively the trap crop may be preferentially attacked in the presence of the crop one needs to protect.

Management of nursery crops: like trap crops, these are plants that are more attractive to the pest than the commercial crop, but in this case the aim is to provide a site where both pests and their natural controls can build up, the latter dispersing to the crop and providing effective control.

Management of surrounding environments (field borders, hedges, adjacent woodlots and bodies of water): these habitats can be designed and managed to provide ideal conditions for the natural enemies of pests. Often this involves providing suitable flowering plants for predators and parasites of pests and making such sites unsuitable for overwintering pests, e.g., coniferous litter around an orchard makes the woodlot unattractive to overwintering plum curculio, thereby forcing them to overwinter in the orchard where they suffer higher mortality than in a suitable woodlot.

Maintenance of site:

Cultivation, tillage: this approach can help in the control of soil inhabiting forms of field crop pests by:

i) bringing larvae and pupae onto the soil surface, thereby exposing them to desiccation and predation, freezing and thawing;

ii) damaging the pest in its soil inhabiting phase, e.g., wireworms;

iii) destroying crop residues, which might harbour pests that could invade new crops;

iv) burying residues so deep that emergence from eggs or pupae is made impossible.

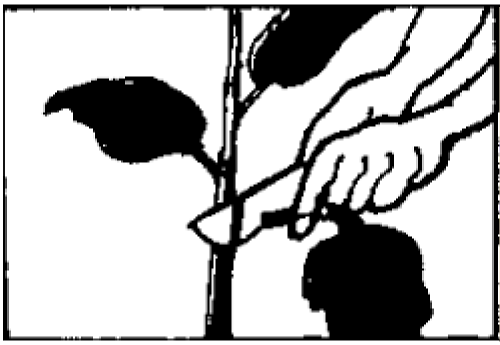
Fertilization, liming and manuring:

i) plant nutrition can influence the feeding, longevity and fecundity of phytophagous pests; the common fertilizer elements (nitrogen, phosphorous and potassium) can have direct and indirect effects on pest supression. In general, nitrogen in high concentrations has the reputation of increasing pest incidence, particularly of sucking pests such as mites and aphids. On the other hand, phosphorous and potassium additions are known to reduce the incidence of certain pests, e.g., in low phosphorous soils wireworm populations often tend to increase;

ii) fertilization promotes rapid growth and shortens the susceptible stages. It gives better tolerance to, and opportunity to compensate for, pest damage. Trace mineral and plant hormones sprays (e.g., from seaweed extracts) have been found to reduce damage by certain pests, particularly sucking pests such as some aphids and mites.

Timing of tillage and fertilization operations: this may affect pests favorably or unfavorably. Efforts should be made to avoid damage and stress to plants, and also overfertilization, thereby avoiding making the crop particularly attractive and susceptible to pests.

Pruning, defoliation and topping: during the dormant phase, removal and destruction of dead, diseased, or infested wood can greatly reduce overwintering stages of pest populations and thus their spread the next year, e.g., mite eggs, aphids, scale and fire blight infested terminals. In apples and other fruit trees, pruning water sprouts, sucker growth or foliage that is prefered by aphids, helps control these pests. Pruning that is excessive, (e.g., in relation to fertilization practices), can increase the population of certain pests such as mites, aphids, and leafhoppers.




Pruning **Defoliation**

Irrigation, drainage: moisture is an important limiting factor that affects the survival of some pests. Where sufficient water is available, flooding is sometimes used for insect and nematode control, e.g., flooding of infested soils. Certain other wireworm species are unable to withstand desiccation. Where these wireworms occur, drying out the soil is an effective control measure.

Sanitation and crop residue destruction: this method is used to reduce pest infestation through the removal of breeding and hibernating sites. Sanitation has broad applicability; to be most effective, it requires knowledge of the habits of the pest species and careful timing. It involves:

i) eradication of harmful weed hosts or alternate hosts;

ii) timely destruction of crop residues;

iii) cleaning of field borders of alternate hosts, and removal of scrub or shelter in which pests might hide; e.g., in orchards, destruction of cull or dropped fruits and pupation sites for codling moth, apple maggot , and plum curculio may be achieved by means of livestock, and suction or cultivation equipment.

Mulches: natural or synthetic soil coverings may encourage or discourage pests. Plastic mulches may exclude soil pests, and organic mulches may permit their control by providing a suitable habitat for their natural enemies. Crop residue mulches around fruit trees can help control a number of pests of fruit, but the trees will need extra protection from mice, which also tend to become more abundant.

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Harvesting Procedures:

Timing of harvesting: early harvesting can be used to disrupt survival of the pest in its habitat. Also, clipping or early harvesting can be helpful in destroying immature insects that are in the foliage.

Strip harvesting: in this system, crops are harvested in alternate strips, so that two different aged growths occur simultaniously in a field. When one series of strips is cut, the alternate strips are about half grown and the field becomes a rather stable environment. This is used in alfalfa, where Lygus bugs are a problem. They move into the younger hay strips as the older ones are harvested, instead of flying to other crops as they do if the entire field is cut at one time. Since natural enemies of the Lygus bug also move from strip to strip, there is no increase in the Lygus population. When the Lygus adults move into the uncut strip, they deposit eggs in the half-grown hay, but, since the hay is cut in about 15 days, many of the eggs and newly hatched nymphs are removed or destroyed at harvest.

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Strip harvesting

Advantages

- Cultural controls are generally the cheapest of all control measures because they usually only require modifications to normal production practices. Sometimes they do not even require extra labour, only careful planning. Often, they are the only control measures that are profitable for high acreage of low value crops.
- Cultural controls are dependable, and are usually specific. Of major importance is the fact that they do not possess some of the detrimental side effects of pesticides, namely the creation of resistance to pesticides, undesirable residues in food, feed crops and the environment, and the killing of non-target organisms.

Disadvantages

- Cultural controls require long-term planning for greatest effectiveness and they need careful timing. They are often based on the substitution of knowledge and skills for

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purchased inputs and, as such, are more demanding on the farmer's competence. They may be effective for one pest but may be ineffective against a closely related species.

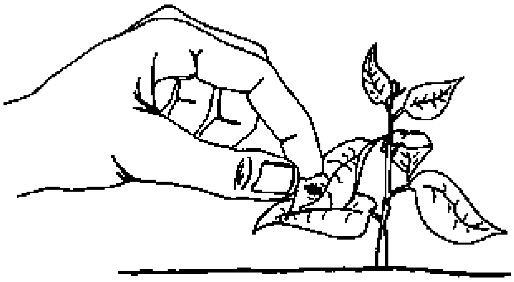
- Effectiveness of cultural controls is difficult to assess and they do not always provide complete economic control of pests.
- Some cultural controls have adverse effects on fish and wildlife and may also cause erosion problems.

Mechanical control

Devices, machines, and other methods used to control pests or alter their environment arc called mechanical pest control is the management and control of pests using physical means such as fences, barriers or electronic wires. It includes also weeding and change of temperature to control pests. Mechanical control can be accomplished as the follows

1. Handpicking

The use of human hands to remove harmful insects or other toxic material is often the most common action by this method. Insect can be hand-picked and destroyed of their easily accessible to the pickers large and conspicuous and present in large number of clusters. e.g. Egg mass of rice stem borer, early larval stage of jute hairy caterpillars, adult of sugarcane stem borer etc. can be maintained by hand and destroyed.



2. Use of hand net and bag nets

Some adult insect can be collected and destroyed with hand nets. e.g. Green leaf hopper, Grasshoppers etc. can be controlled with hand nets when they migrate in April-May from maize to sugarcane. The bag nets can be used to control the some insects. e.g. Rice hispa from the field partially.

3. Beating and hooking

Various household pest like as housefly, cockroach etc. can be killed by beating with brooms, flappers etc. Again some pests which hide in the holes or crack of host such as Rhinoceros beetle, Jackfruit beetles etc. are killed by hooking with the help of crooked hooks.

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4. Shaking and garring

Different insect such as cotton bug, mango shoot borer & defoliator etc. can be killed by shaking the small trees or shrubs. Particularly, every in the morning in cold season when insect are remain in the tree and collecting them tab containing kerosinized water or by hand crashing or leg crushing.

5. Sieving and winnowing

These method are commonly used against stored grain pest. Some insects, e.g. Red flour beetle are destroyed by collecting them through sieving and some insects. e.g. Rice weevil are destroyed by collecting them winnowing.

6. Mechanical Exclusion

Some of the insects are controlled by creating a barriers for insects in reaching the place where they causes. e.g.

Application of a band of sticky material like 'Ostico' or a band of slippery sheets like alkathene around the trunk of a mango tree to prevent the upward movement of the mango mealy bug. Using of screens over the windows, doors and ventilators of house to keep away houseflies, Mosquitoes, bugs etc. Making trench of 30 cm depth around the field and applications on jute hairy caterpillar, Jute Semilooper from infested area to new field; Using red light in the monsoon to keep away most of insects.

7. Use of mechanical traps

Various type of traps has been used for collecting and killing different type of insect

i) Light trap

Light trap can be used to attract and kill the nocturnal insects. e.g. Leaf hopper, Jute hairy caterpillar, moths, stem borer of rice etc. An electric bulb or a lamp is place in the wide flat vessel containing kerosinized in which the moth, beetles get drowned.

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ii) Air suction trap

Air suction trap used to against stored grain pest in godown.

iii) Electric trap

Like metal screens are used on which birds or insects are electrocuted.

8. Burning

Locust can be killed by the burning with the help of flame torches. Stored grain pest are also controlled by burning.

9. Crushing and grinding

This devices are used for Sugarcane. Sugarcane shoot borer are controlled by harvesting the sugarcane and then crushing for obtaining sugar.

10. Sound production

This device are mainly used in scaring these birds which attack fruits and grain crops. This is also used to control some insects like mosquitoes. Male mosquitoes can be attracted to outside of house by producing sound of female mosquito from outside.

11. Rope dragging in field

Rice case worm larva pupate in case prepared by the leaves which remains attached to the plant and can be removed by the dragging rope. Due to this case can fall in the stagnating water and removed easily.

12. Banding the trees

Mealy bugs on mango comes on soil for egg laying which can be prevented by putting sticky bands on stem.

13. Bagging the fruits

Fruit sucking moth on citrus or pomegranate suck the juice with the help of stout which can be prevented by bagging fruits.

14. Trenching the field

Pest like army worm, grasshoppers march from one field to other which can be prevented by trenching in field.

15. Tin collars on stem-rat can climb on coconut tree and damage the fruits. When we put the tin collars on stem they cannot climb.

Advantages

1. Skilled labours are not required.
2. Cost required is very less.
3. There are no any side effects.

Disadvantages

1. Time and labour requirement is high.
2. This method is applicable only on small scale.
3. This requires repeated application.

Physical Pest Controls

Methods in this category use some physical component of the environment—for example, temperature, humidity, or light—to suppress pest populations or damage. Some examples of physical and mechanical pest controls include:

- Tillage
- Flaming
- Flooding
- Soil solarization or Soil heating
- Row Covers

Tillage can help minimize damage from soil-dwelling insects by directly killing the insect, exposing insects to predation by birds or other predators, and by helping the plant grow more rapidly (this is not a guaranteed outcome). The principle behind this approach is that the sun will warm up the soil around the plants faster and allow them to outgrow the pest's feeding.

Heat or steam sterilization of soil is commonly used in greenhouses for control of soil-borne pests and diseases. In soil solarization, clear plastic mulch is applied to bare soil for an extended period of time (4–6 weeks) during the warmest, sunniest time of year to disinfest soil. The clear plastic allows the sun's energy to heat the soil below to temperatures over

100°F. This method is not selective, so heat sensitive beneficial organisms will also be destroyed.

Floating row covers over vegetable crops exclude many pests. The edges and ends of the row covers should be completely sealed to the ground to effectively prevent the entry of pest insects. When using floating row covers, timing of removal of row covers for access by pollinators and for weeding must be considered.

Chemical control

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

Insecticide may be defined as a substance or mixture of substances intended to kill, repel or otherwise prevent the insects. Similarly pesticides include nematicides – which kill nematodes, miticides or Acaricides which kill mites. Pesticides: Chemicals which are used to kill pests

Insecticides: Chemicals which are used to kill insects.

PESTICIDES

Pesticides are chemicals used to destroy pests, control their activity, or prevent them from causing damage. Some pesticides either attract or repel pests. Chemicals that regulate plant growth or remove foliage also are classified as pesticides. Pesticides are generally the fastest way to control pests. In many instances, they are the only tactic available.

INSECTICIDES

Insecticides are any chemical substances that are used for insect extermination. They successfully help to eliminate insects and any life stage, including ovicides, larvicides, eggs and larvae.

Particular types of insecticides are used for exact purposes in a field like agriculture and medicine. One of the main reasons for the increased productivity of agriculture in the last century is the development of better and more affordable insecticides.On the other hand, insecticides are able to cause damage to the ecosystem and health, that's why recent studies and efforts are made towards increased implementation of organic pest control methods.

There two major classifications of insecticides:

With residual effect

Without residual effect (contact insecticides)

Another classification of the insecticides may be made based on their repellant qualities, this categorizes them in:

Repellent

Repellent insecticides are more suitable when a pest is targeted for extermination. This way it will bring much of the insecticide to the colony and will wipe it out.

Repellents are used in agriculture when people want only to keep the pest away from plants. When extermination is not planned, repellents give great efficiency. The drawback is that repellents should be applied more often, especially if water has been applied over the plants after a rain for instance.

Repellents have much quicker effect in terms of crops preservation but don't deal with the source of the infestation, while non-repellent insecticides kill the insect but such compounds are often more toxic and contaminate both – the soil and the crops often beyond the suggested requirements.

Synthetic Insecticides

- Organophosphates and carbamates
- Neonicotinoids
- Ryanoids
- Organochlorides
- Pyrethroids

Advantages of Chemical Control

1. It is often the only means of combating pests.
2. It is curative in effect.
3. It is easy to apply/adopt.
4. Farmers can apply when and where required.
5. Large area can be covered in relatively short time.
6. Broad spectrum activity: A single or combination of two insecticides in a single application may control the pest complex.
7. Depending upon crops, pests and nature of damage, a range of insecticides is available to choose from.
8. Highly effective against pests than other methods of insect control.
9. It can be used in human health programme

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10. It can protect animals from illness that can be caused by parasites such as fleas.

11. Growers can get high returns on his investment in a short time.

12. It is compatible with many component of IPM.

Disadvantage of Chemical Control

1. It is non selective: May harm natural enemies (Parasites and predators) and pollinators.

2. Insecticides cause resurgence of insect pests

3. It leads emergence of secondary pest outbreak.

4. Resistance often develops: Insects tend to become resistant to insecticides after sometime, cannot be killed.

5. It pollutes air, water and land.

6. It may cause phytotoxicity.

7. Insecticides residues in food commodities and other components of the environment affect wide variety of organisms in the food chain.

8. It upset the balance of nature, which may result in unexpected problems

9. Noncompatible with biological control method. 10. Adverse effect on animals and man himself. 11. It is dangerous to

consumers, workers during and after use. 12. As it is recurring, a cost increases as control is not permanent.

Biological control

Biological pest control is a method of controlling pests such as insects, mites, weeds and plant diseases using other organisms. It relies on predation, parasitism, herbivory, or other natural mechanisms, but typically also involves an active human management role.

- There are three basic strategies for biological pest control: classical (importation), where a natural enemy of a pest is introduced in the hope of achieving control; inductive (augmentation), in which a large population of natural enemies are administered for quick pest control; and inoculative (conservation), in which measures are taken to maintain natural enemies through regular reestablishment.
- Natural enemies of insect pests, also known as biological control agents, include predators, parasitoids, pathogens, and competitors. Biological control agents of plant

diseases are most often referred to as antagonists. Biological control agents of weeds include seed predators, herbivores, and plant pathogens.

- Biological control can have side-effects on biodiversity through attacks on non-target species by any of the above mechanisms, especially when a species is introduced without a thorough understanding of the possible consequences.
- Biological control involves the use of natural enemies — parasites, predators, and pathogens. It is supplement tonatural control by releasing more of a pest's enemies into the target area or by introducing new enemies that wnot in the area before. Biological control usually is not eradication. The degree of control fluctuates. There is a time lag between pest population increase and the corresponding increase in natural controls. But, under proper conditions, sufficient control can be achieved to eliminate the threat to the plant or animal to be protected.

Predators

Predatory are available from biocontrol dealers. Predators are mainly free-living species that directly consume a large number of prey during their whole lifetime. Many major crop pests are insects, many of the predators used in biological control are insectivorous species.

Lady beetles, and in particular their larvae which are active between May and July in the northern hemisphere, are predators of aphids, and also consume mites, scale insects and small caterpillars.

The running crab spider *Philodromus cespitum* also prey heavily on aphids, and act as a biological control agent in European fruit orchards.

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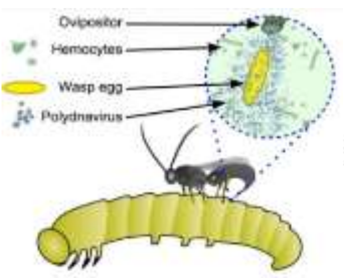
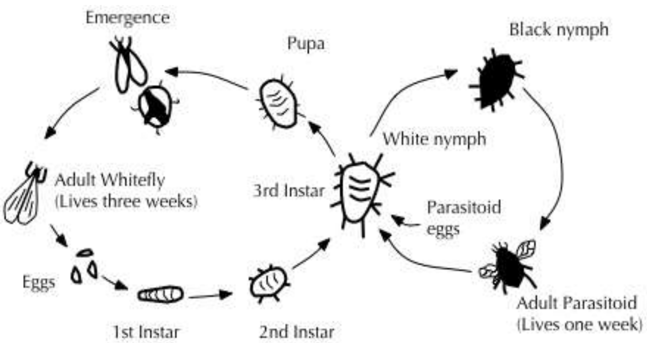
Parasitoids

Parasitoids lay their eggs on or in the body of an insect host, which is then used as a food for developing larvae. The host is ultimately killed.

Most insect parasitoids are wasps or flies, and many have a very narrow host range. The most important groups are the ichneumonid wasps, which mainly use caterpillars as hosts; braconid wasps, which attack caterpillars and a wide range of other insects including aphids; chalcidoid wasps, which parasitize eggs and larvae of many insect species; and tachinid flies, which parasitize a wide range of insects including caterpillars, beetle adults and larvae, and true bugs.

Parasitoids are most effective at reducing pest populations when their host organisms have limited refuges to hide from them.





Pathogens

Pathogenic micro-organisms include bacteria, fungi, and viruses. They kill or debilitate their host and are relatively host-specific. Various microbial insect diseases occur naturally, but may also be used as biological pesticides. When naturally occurring, these outbreaks are density-dependent in that they generally only occur as insect populations become denser.

Bacteria

Bacteria used for biological control infect insects via their digestive tracts, so they offer only limited options for controlling insects with sucking mouth parts such as aphids and scale insects.

Bacillus thuringiensis, a soil-dwelling bacterium, is the most widely applied species of bacteria used for biological control, with at least four sub-species used against Lepidopteran (moth, butterfly), Coleopteran (beetle) and Dipteran (true fly) insect pests.

Pheromones

Biological control also includes methods by which the pest is biologically altered, as in the production and release or large numbers of sterile males and the use of pheromones or juvenile hormones. Pheromones can the useful in monitoring pest populations. Placed in a trap, for example. they can attract the insects in a sample area so that pest numbers can be estimated. Pheromones also can be a control tool. Sometimes a manufactured copy of the pheromone that a female insect uses to attract males can be used to confuse males and prevent mating, resulting in lower numbers of pests. Applying juvenile hormones to an area can reduce pest numbers by keeping some immature pests from becoming normal, reproducing adults.

Pheromones Trap

Integrated Pest Management

Integrated pest management is the combining of appropriate pest control tactics into a single plan (strategy) to reduce pests and their damage to an acceptable level. Using many different tactics to control a pest problem tends to cause the least disruption to the living organisms and nonliving surroundings at the treatment site. Relying only on pesticides for pest control can cause pests to develop resistance to pesticides, can cause outbreaks of other pests, and can harm surfaces or non-target organisms. With some types of pests, use of pesticides as the only tactic will achieve very poor control.

Basic principles of Integrated Pest Management:

1.Consideration of Ecosystem

Control of insect pest population is a function of the ecosystem itself by means of natural enemies and other factors. Knowledge of the role of the principle elements of the units is essential to an understanding of population phenomenon. The study of individuals is of prime importance, their biology behaviour response to other members of the same species and to other organisms and to biotic factors in the environment. The study of individuals offers a potent method for this analysis of population change. The most effective system for controlling pests can be derived only after

understanding the principles responsible for the population fluctuation in the ecosystem.

2. Pest Surveillance

Pest Surveillance and forecasting are having a vital part in the integrated pest management. Surveillance or monitoring means constant observation of a subject i.e., a crop or pest, and recording the factors observed, compilation of information obtained and prediction of future events about pest population. Hence pest surveillance comprises of three basic components.

a. Determination of the level of incidence of the pest species.

b. Determination of what loss the incidence will cause.

c. Determination of economic benefits or other benefits the control will provide.

The above information would be immense use in determining the need for a pest control measure. Mere presence of a few numbers of pest species should not be the criterion for pesticide application and there should be sufficient justification. Surveillance can provide the necessary information to determine the feasibility of a pest control programme. It should be a tool that assists pest management specialists in determining the actual factors that are involved in a pest build up, so that the specialists can determine practices that will manage these factors and prevent the initial build up of a pest.

3. Utilization of Economic Threshold Levels (ETL)

The level of pest population is very important consideration for taking up control measures. Pest population must be maintained at levels below those causing economic injury. The economic threshold is the pest density at which control measures should be determined to prevent an increasing pest population from reaching economic injury level. The determination of these thresholds is a pre-requisite to the development of any pest management strategy.

4. Application of minimum selective hazards :

The application of chemical measures to pest population has to be in such a manner that target pest populations are just kept below economic injury thresholds. By observation of this principle the development of resistant populations of pest is avoided or delayed, the possibility of resurgence of treated population is decreased, adverse effect on non target organism and amount of environmental contamination are reduced, and the cost of control is also lowered.

When insecticide treatments are deemed necessary special consideration should be given to

(1) Effectiveness of the insecticide against most vulnerable life stage of the pest

(2) Employing an insecticide that will cause least disturbance in the ecosystem.

(3) Applying the insecticide in such a way that it will restrict its distribution to the area where it is needed.

Advantage of Integrated Pest Management

1. Fits better in National Economy.

Pest control activities at present are mainly based on the application of chemical pesticides, quite a large proportion of which has to be imported. The expenditure envisaged for plant protection runs into crores of rupees even when only one or at the most two pesticide application are envisaged per crop. High yielding varieties show that many more pesticide applications are called for many crops if pest control has to depend only on the use of pesticide. Thus a time has come where Integrated Pest Management is not only advisable but also inevitable.

2. More efficient and cheaper method.

In IPM schedule efforts are made to utilize various methods of control including use of pesticides but some times and in some cases it is feasible to nip the trouble in the bud itself even by a mechanical campaign like destruction of egg masses of some pests or collecting the caterpillar stages. In such cases it envisages a lot of saving in the use of pesticides, this means saving of money and saving of foreign exchange and also the destruction of the pest before it has been able to inflict damage.

3. Avoid upsetting the balance of nature.

Chemical control has often been reported to upset the balance of nature at times leading to upsurge of new type of pest problem which did not exist before. The seriousness of mites in many parts of the world has occurred by the use of DDT. It is confidently expected that such adverse side effects will be much less as a result of integrated pest management schedule.

4. Minimises residue hazards of pesticides :

It is obvious that in an IPM schedule the use of pesticides will be considerably reduced, hence the pesticide residue hazards will also get automatically minimised.

Disadvantages of IPM:

More involvement in the technicalities of the method

- IPM needs to be planned
- IPM demands more attention and dedication
- Requires expertise of various field
- All those involved in the IPM needs to be educated and trained which often requires much time.

Time and energy consuming

- Application of IPM takes time.

- Much time is needed in planning itself.
- As IPM strategies differs from region to region, a separate plan is required for each region.
- The expected results of intervention may take long time to be achieved.

Pest Control Failures

Sometimes you may find that even though you applied a pesticide, the pest has not been controlled. You should review the situation to try to determine what went wrong. There are several possible reasons for the failure of chemical pest control.

Pest Resistance

Pesticides fail to control some pests because the pests are resistant to the pesticides. Consider this when planning pest control programs that rely on the use of pesticides. Rarely does any pesticide kill all the target pests. Each time a pesticide is used, it selectively kills the most susceptible pests. Some pests avoid the pesticide. Others withstand its effects. Pests that are not destroyed may pass along to their offspring the trait that allowed them to survive.

When one pesticide is used repeatedly in the same place, against the same pest, the surviving pest population may be more resistant to the pesticide than the original population was.

The opportunity for resistance is greater when a pesticide is used over a wide geographic area or when a pesticide is applied repeatedly to a rather small area where pest populations are isolated. A pesticide that leaves a residue that gradually loses its effectiveness over time will help select out resistance. Rotating pesticides may help reduce the development of pest resistance

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CHAPTER-VI

INSECTS AS VECTORS

Vector borne diseases: Method of transmission of parasitic agents with special reference to mosquitoes and houseflies

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INSECTS AS VECTORS

1. INTRODUCTION

Insects constitute the largest group in the animal kingdom. They are closely associated with a man like his domestic animals and live on and around human beings. They are inseparable from human lives. Based on their importance to man, insects are classified into two groups, namely,

1. Beneficial insects
2. Harmful insects.

1.1. VECTORS

Vectors are insects that transmit disease-producing parasites from one human being to another. They are mosquitoes, house flies, lice, bugs, etc., are responsible for transmitting diseases.

1.2. VECTOR-BORNE DISEASE

The disease that results from an infection transmitted to humans and other animals by blood-sucking arthropods, such as mosquitoes, ticks, and fleas is called vector-borne disease. Examples include Dengue fever, West Elephantiasis, Lyme disease, and malaria.

1.3. GENERAL MODE OF TRANSMISSION

- Vector transmission occurs when a living organism carries an infectious agent on its body (mechanical) or as an infection host itself (biological), to a new host.
- Vehicle transmission occurs when a substance, such as soil, water, or air, carries an infectious agent to a new host**.** Humans and an agent like amoeba could be a reservoir for transmission.
- When the pathogen is transmitted by a vector, the pathogen will be benefitted from extensive reproduction and spread within the host.
- If pathogen levels are very high in the host, a vector such as a biting insect has a better chance of picking up the pathogen and transferring it to a new host. Indeed, pathogens transmitted by biting arthropods such as mosquitoes often are very virulent (eg., malaria, typhus, sleeping sickness). Such pathogens must take good care of their vectors, and the vector generally remains healthy, at least long enough for pathogen transmission.

1.4. FACTORS INFLUENCING MODE OF TRANSMISSION

- Vectors and hosts involved in the transmission of these infective pathogens are sensitive to climate change and other environmental factors include, including vector and host survival, reproduction, development, activity, distribution, and abundance, pathogen development, replication, maintenance, and transmission; a geographic range of pathogens, vectors, and hosts; human behaviour; and disease outbreak frequency, onset, and distribution.
- The mode of transmission could be a vector such as a mosquito, and a vehicle such as food. The susceptible host has multiple portals of entry such as the mouth or a syringe. The following are the insect-vectors transmitting diseases.

a. ***Anopheles* mosquito**

The female anopheles mosquito transmits *Plasmodium* causing malaria.

b. *Culex* mosquito

The culex mosquito transmits *Wuchereria bancrofti* causing elephantiasis.

c. **Tse-tse fly**

It transmits *Trypanosoma gambiense* causing sleeping sickness.

d. Housefly

The housefly *Musca domestica* transmits many diseases like typhoid, diarrhoea, cholera, leprosy, tuberculosis, etc.,

e. Termites

Termites transmit viruses that cause mosaic disease of tobacco and leaf–crinkle disease of cotton.

Tale 1.1. Some common diseases of humans by insect vectors are listed below

Name of Disease	Cause	Method of spread	Signs and Symptoms	Type of Vaccination
Yellow fever	*Arbovirus* (Arthropod-borne RNA Virus)	Vector-arthropods, e.g.ticks, mosquitoes	1. Fever, headache, backache, nausea, tenderness in pit of stomach.	Living attenuated virus (control of

			2. Affects lining of blood vessels and liver. 3. Fourth-day vomiting blood and bile (so-called 'Black vomit') 4. Eyes becomes yellow 5. Faeces colored black due to digested blood.	vectors also important).
Typhus	*Rickettsia*	Epidemic typhus: Vector-Louse. Endemic typhus: Vector-rat flea. From	1. After 12-14days, headache, pain in back and limbs. 2. Measles-like rash on armpits, hands, and forearm. 3. Delirium sets in, then coma.	Killed bacteria or living nonvirulent strain. Antibiotics e.g. tetracyclines, chloramphenico

		rat to rat by flea and louse.	4. May affect linings of blood vessels causing clots. 5. Death can result from toxemia, heart or kidney failure.	l (control of vectors also important).
Cholera	*Vibrio cholera* (comma-shaped Gram-negative bacteria)	Faecal contamination a.Food-or-water borne material contaminated with faeces from infected persons.	1. Bacteria-producing toxins causing inflammation of the gut and severe diarrhoea. 2. Fluid loss so intense that diarrhoea is termed ‘rice water’.	Killed bacteria: short-lived protection and not always effective. The genetically engineered vaccine is now available. Antibiotics, e.g.tetracycline

		b.Handling of contaminated objects. c.Vectors, e.g. flies moving from human faeces to food.	3. Resulting dehydration and loss of mineral salts can cause death.	s, chloramphenicol.
Typhoid fever	*Salmonella typhi*	As cholera	1. Mild fever, slight abdominal pains. 2. Affects alimentary canal, spreading to lymph and blood, lungs, bone marrow, and spleen.	Polysaccharide extract from the bacterial capsule. The genetically engineered vaccine is now available.

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			3. Intensity of fever and pain increase and diarrhoea follows. 4. Ulceration and rupture of the intestine may follow. 5. Infection spreads to other organs- lungs, bone marrow, and spleen. Occurs 2 or 3 weeks after infection.	
Bacterial dysentery	*Shigella dysenteriae*	As cholera	1. Bacteria produce toxins in the intestine causing abdominal pain	No vaccine. Antibiotic, e.g. tetracyclines.

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(bacillary dysentery)			with blood and mucus in diarrhoea. 2. Comes on rapidly 2 or 3 days after swallowing an infecting dose of bacteria.	
Plasmodium sp	Malaria	*Anopheles* sp. Mosquito bite	1. After 10days high fever develops. 2. Fever may be continuous, irregular, or twice daily.	Destruction of mosquito larvae with oil spray or insecticide. Drainage of breeding places of mosquitoes. Preventive drugse.g. chloroquine(prophylactics).

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				Drugs to kill parasites in humans e.g.primaquine.
Trypanosoma sp	Trypanosomiasis (sleeping sickness) is also the disease of cattle(nagana), transferable between cattle and humans.	Tsetse fly bite	1. Lymph glands enlarge, fever, enlargement of spleen and liver follow. 2. Later parasite invades the nervous system, resulting in sleepiness and muscular spasms.	Tsetse flies live in restricted areas-fly belts. Flyscreens on doors and windows, spraying of cattle, moving human settlements to areas cleared of flies. Drugs to kill parasites in humans, e.g. pentamidine.

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1.5. VECTOR-BORNE DISEASES-ARTHROPOD BORNE DISEASES

The arthropod-borne viruses (arboviruses) are transmitted by blood-sucking arthropods from one vertebrate host to another. They multiply in the tissues of the arthropod without producing diseases and the vector acquires a lifelong infection. Diseases produced by the arboviruses can be divided into three clinical syndromes. They are

a. Fevers of an undifferentiated type
b. Encephalitis
c. Haemorrhagic fever

Immunity is permanent after a single infection.

1.6. ARTHROPOD VECTORS

The vectors are transmitting the disease-producing germs from one host to another host. The following are the important arthropod vectors.

a. House-fly
b. Head-louse
c. Bed-bug
d. Mosquito
e. Fleas
f. Ticks, and

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g. Mites.

1.6.1.House-fly

(*Musca domestica*)

Phylum	:	Arthropoda
Class	:	Insecta
Order	:	Diptera
Family	:	Muscidae
Genus	:	*Musca*

The common housefly, *Musca domestica*, lives in close association with people all over the world (Fig. 1.1). The insects feed on human foodstuffs and wastes where they can pick up and transport various disease agents. In addition to the housefly, several other fly species have adapted to life in human settlements, where they present similar problems. In warmer climates, the filth fly, *M. sorbens* is of particular interest in this regard. It is closely related to the housefly and is considered important in the spread of eye infections. Blowflies (*Calliphoridae*) and other flies have been associated with the transmission of enteric infections. The general features are following,

1. It lives in human dwellings

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2. The body is divisible into a head, a thorax, and an abdomen.
3. The head bears a pair of compound eyes, a pair of antennae, and mouthparts.
4. Houseflies process visual information around seven times more quickly.
5. It has three pairs of legs and two wings
6. The life cycle includes four stages, namely the egg, the maggot, the pupa, and the adult.
7. It transmits diseases like diarrhoea, amoebiasis, cholera, typhoid, etc.
8. Each fly can lay about 9,000 eggs in its life, in several batches of about 75 to 150.
9. The eggs are laid on or near meat, often dead animals.

CONTROL

House flies can be controlled by spraying malathion. The houses should be kept clean.

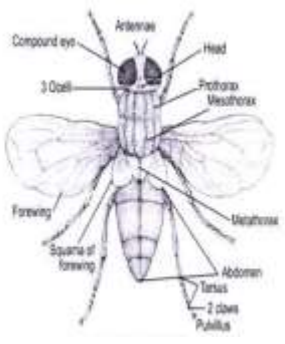

Fig1.1. Housefly

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1.5.1a. Diarrhoea

(i). Definition

Diarrhoea is the frequent passing of loose, watery, and unformed faeces. Acute diarrhoea is the sudden onset of three or more loose stools per day, lasting less than 14 days. The most common cause of acute diarrhoea is an infection of the intestines, such as gastroenteritis or food poisoning.

(ii). Causative agent

1. Bacteria from contaminated food or water.
2. Viruses such as the flu, or rotavirus.
3. Vectors, like house flies are responsible for the contamination of food or water.

(iii). Mode of Transmission

The disease-causing agents can either be transmitted by the body hairs or by the tarsi to food or surfaces when the fly lands. It takes only a matter of seconds for them to transfer these pathogens to food or touched surfaces. A single fly may carry up to 6,500,000 bacteria.

(iv). Symptom

- Abdominal cramps or pain
- Bloating
- Nausea

- Vomiting
- Fever
- Blood in the stool
- Mucus in the stool
- Urgent need to have a bowel movement

(v). Treatment

- Plenty of fluids to prevent dehydration.
- Oral rehydration solutions (ORS) or drinks to replace lost salts and minerals.
- Intravenous replacement of fluids in severe cases.
- Medications such as antibiotics and anti-nausea drugs.
- Anti-diarrhoeal medications, but only on the advice of your doctor.Antidiarrhoeal drugs such as loperamide and fluoroquinolone, such as **ciprofloxacin** (500 mg twice daily for one to three days), are usually safe and effective in adults with traveler's diarrhea may also help.

(vi). Prevention

- Access to safe drinking water,
- Use of improved sanitation,
- Handwashing with soap,
- Exclusive breastfeeding for the first six months of life,
- Good personal and food hygiene,

- Health education about how infections spread; and.
- Rotavirus vaccination.
- Infectious pests should be eliminated.

Fig 1.2. Treatment of Diarrhoea

1.5.1.b. AMOEBIASIS

(Amoebic dysentery)

(i). Definition

Amoebiasis, or amoebic dysentery, is an infection caused by any of the amoebae of the *Entamoeba* genus. It is a parasitic infection of the colon with the amoeba *Entamoeba histolytica*. Amoebiasis infection is most common in tropical areas with untreated water.

(ii). Causative agent

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The cause of amoebiasis is mainly the protozoan parasite *Entamoeba histolytica*. Some risk factors for amoebiasis include consuming contaminated food or water, association with food handlers whose hands are contaminated, contact with contaminated medical devices such as colonic irrigation devices, and being pregnant.

(iii). Mode of transmission

The parasite lives only in humans and is passed in the faeces of an infected person. A person gets amoebiasis by putting anything in their mouth that has touched infected faeces or by eating or drinking food or water contaminated with the parasite. It spreads through drinking or eating uncooked food, such as fruit, that may have been washed in contaminated local water. Vectors such as flies, cockroaches, and rodents can also transmit the infection.

(iv). Symptoms

- Abdominal cramps.
- Diarrhoea: the passage of 3 to 8 semiformed stools per day, or passage of soft stools with mucus and occasional blood.
- Fatigue.
- Excessive gas.
- Rectal pain while having a bowel movement (tenesmus)

- Unintentional weight loss.

(v). Treatment

There are many home remedies for amoebiasis available. They range from increased fluid intake, coconut water, buttermilk, black tea, and herbal tea to garlic, Indian lilac, oregano, and apple cider vinegar.

Gastrointestinal amoebiasis is treated with nitroimidazole drugs, which kill amoebas in the blood, in the wall of the intestine, and liver abscesses. These drugs include metronidazole (Flagyl) and tinidazole (Tindamax, Fasigyn).

(vi). Prevention

1. Thoroughly wash fruits and vegetables before eating.
2. Boiled or water treated with iodine is safer to drink.
3. Avoid ice cubes or fountain drinks.
4. Eradicating faecal contamination of food and water through improved sanitation, hygiene, and water treatment. In non-endemic areas, disease transmission can be reduced by early treatment of carriers.
5. Infectious pests should be eliminated.

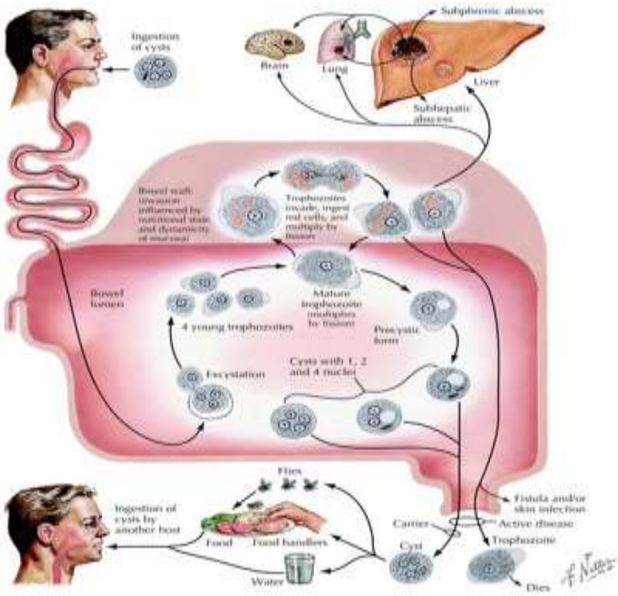

Fig 1.3.The life cycle of Amoebiasis

1.5.1.c.Cholera

(i). Definition

It is an acute diarrheal disease caused by *Vibrio cholera*. In its most severe form, cholera is a dramatic and terrifying illness in which profuse watery diarrhoea and vomiting lead to hypovolemic shock and death in less than 24hours. In treated cases, the disease may last -6days, during this period the patient may pass a total volume of liquid stool equal to twice his body weight.

(ii). Causative agent

It is caused by *Vibrio cholera* acquired by ingesting food or water contaminated by faecal material from patients or carriers like houseflies, shellfish, and copepods. They are natural reservoirs.

(iii). Mode of Transmission

The common housefly can transmit the pathogens that cause shigellosis, typhoid fever, *E. coli*, and cholera. The disease-causing agents can either be transmitted by the body hairs or by the tarsi which are transmitted to food or surfaces when the fly lands.

(iv). Symptoms

- Profuse watery diarrhoea, sometimes described as "rice-water stools
- Vomiting.
- Thirst.
- Leg cramps.
- Restlessness or irritability.
- Pain in the abdomen
- Nausea, severe diarrhoea, vomiting, or watery diarrhoea
- Whole-body suffered by dehydration, lethargy, or water-electrolyte imbalance.
- Shock and seizures may occur in severe cases.

(V). Treatment

- Oral or intravenous hydration is the primary treatment for cholera. In conjunction with hydration, treatment with antibiotics is recommended for severely ill patients. It is also recommended for patients who have severe or some dehydration and continue to pass a large volume of stool during rehydration treatment.

- Tetracycline is an effective treatment for cholera and is superior to furazolidone, chloramphenicol, and sulfaguanidine in reducing cholera morbidity.

(vi). Prevention

- These include drinking and using safe water, washing hands with soap and water, using latrines or proper sanitation methods, proper cooking of food, covering it, and eating it hot, proper cleaning up of places used for bathing and washing clothes.
- Infectious pests should be eliminated.

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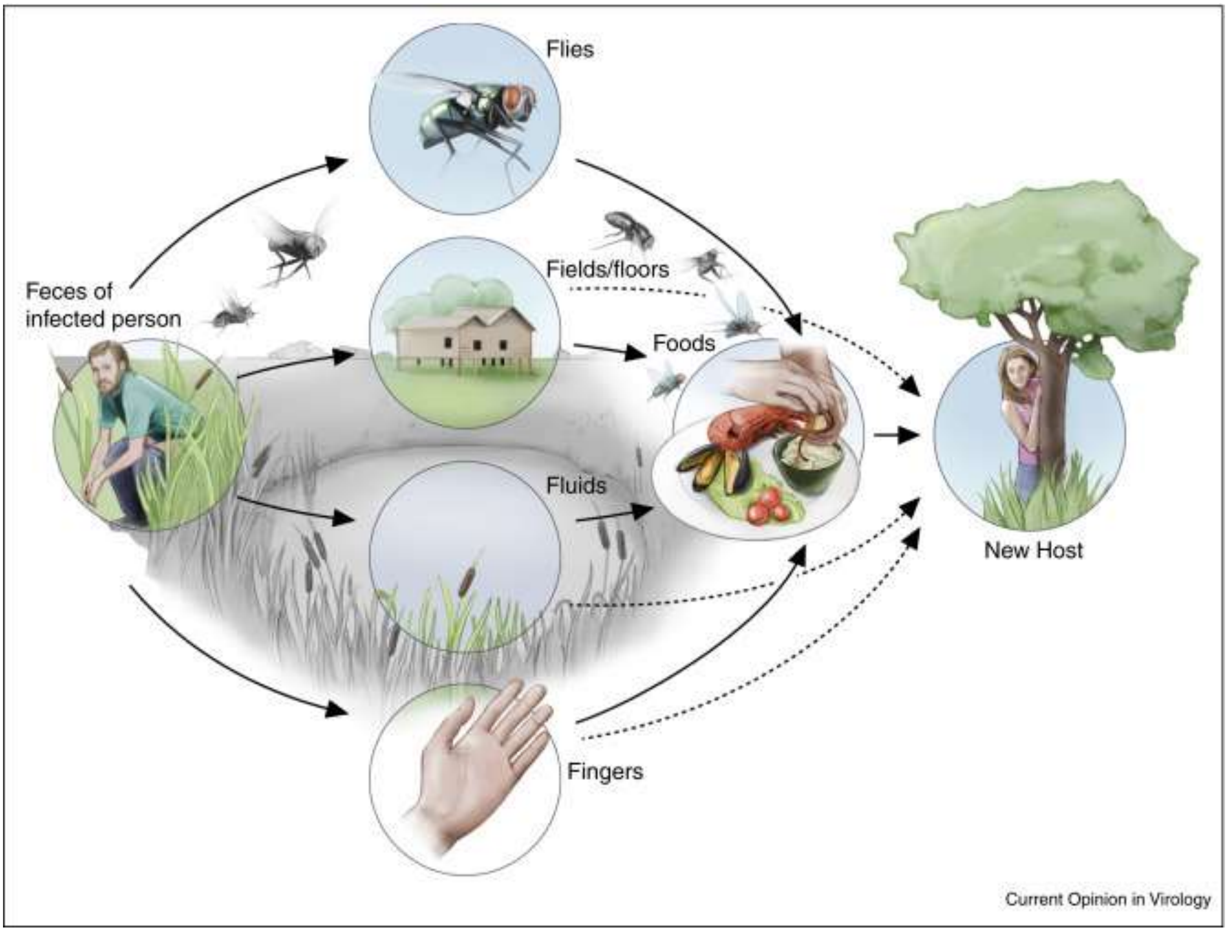

Fig.1.4.Mode of transmission

1.7.2.Mosquito

(Culicidae)

Phylum	:	Arthropoda
Class	:	Insecta
Order	:	Diptera

Mosquitoes are insects. They are vectors and they transmit many diseases. Two species of mosquitoes are harmful to human beings. They are *Anopheles* and *Culex*. *Anopheles* transmits Plasmodium causing malaria; *Culex* transmits the filarial worm causing elephantiasis. The following are the salient features of mosquitoes,

1. It is an insect and is cosmopolitan in distribution.

2. The female mosquito sucks the blood of man and transmits diseases. Hence it is a vector.

3. The *Anopheles* mosquito transmits *Plasmodium* which causes malaria.

4. The *Culex* mosquito transmits the filarial worms which cause elephantiasis.

5. The body consists of a head, a thorax, and an abdomen.

6. The head bears a pair of compound eyes, a pair of antennae, and the mouth-parts.

7. The mouth-part is of the piercing and sucking type.

8. The thorax bears a pair of wings and three pairs of legs.

9. The life cycle includes four stages, namely the egg, the larva, the pupa, and the adult.

10. Control

a. Pools and ditches are filled up.

b.Mosquito repellents and electrical devices (mosquito bats) are used to kill them.

c.DDT is sprayed.

d.Larvivorous fishes are reared.

e. By sterilizing males or females, the mosquitoes can be prevented from reproduction.

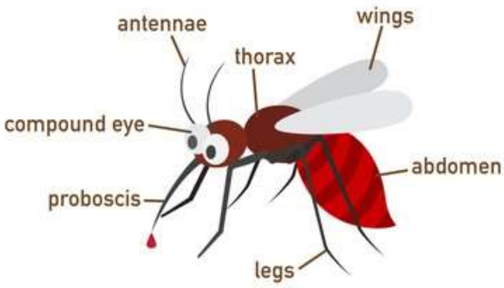

Fig.1.5.Mosquito

1.7.2.a.Malaria

(i). Definition

Malaria is a mosquito-borne infectious disease that affects humans and other animals. Malaria causes symptoms that typically include fever, tiredness, vomiting, and headaches. In severe cases, it can cause yellow skin, seizures, coma, or death.

(ii). Causative agent

Malaria is caused by single-celled microorganisms of the *Plasmodium* group. It is an endoparasite living in the blood of man. Spread exclusively through bites of infected *Anopheles* mosquitoes. Fives species of *Plasmodium* can infect and be spread by humans. Most deaths are caused by *P. falciparum* whereas *P.Vivax*, *P.ovale*, and *P.malariae* generally cause a milder form of malaria. The species *P. knowlesi* rarely causes disease in humans.

(iii). Mode of Transmission

Plasmodium completes its lifecycle in two hosts, namely man, and the female *Anopheles* mosquito. It is a digenic parasite. Man is the primary host and the mosquito is the intermediate host or secondary host or vector. The life cycle of Plasmodium in man is called the cycle of Golgi. It occurs in three stages. They are

a. Pre-erythrocytic cycle

b. Exo-erythrocytic cycle and

c. Endo-erythrocytic cycle.

The life cycle in man starts with the bite of an *Anopheles* mosquito. When this mosquito bites a man, it introduces a small amount of saliva that contains the parasite. Along with the saliva the parasite is introduced into the blood of man. For about 30 minutes it swims actively in the blood and then disappears from the blood and enters the liver in sporozoite form. In there, it crosses many stages and finally enters into the RBC in gametocytes form. For further development, the gametocytes must be taken into the body of the female *Anopheles* mosquito.

The life cycle of *Plasmodium* in mosquitoes was first studied by Sir Ronald Ross. Hence this cycle is called the cycle of Ross. When a female *Anopheles* mosquito sucks the blood of a man, the gametocytes enter the gut. Further fertilization and development occur there and finally, from the gut, they are transported to the salivary glands of mosquitoes in sporozoite form.

When this mosquito bites a man, it introduces a small amount of saliva to prevent the coagulation of blood. Along with the saliva, the sporozoites are also introduced into the blood of man, and the cycle is repeated.

(iv). Symptoms

The severity of malaria varies based on the species of *plasmodium.*

- People traveling to areas where malaria is common typically take protective drugs before, during, and after their trip. The following are the general symptoms that are occurring a few weeks after being bitten.,
    1. Loss of appetite
    2. Nausea
    3. Constipation
    4. Headache

5. Muscular pain and ache in joints
6. Shaking chillness
7. Sweating
8. Raise in body temperature
9. Anaemia

(v). Treatment

The general medicines are following in the treatment

- Atovaquone-proguanil (Malarone)
- Quinine sulfate (Qualaquin) with doxycycline (Oracea, Vibramycin, others)
- Primaquine phosphate.
- Doxycycline: This daily pill is usually the most affordable malaria drug. You start taking it 1 to 2 days before your trip and continue taking it for 4 weeks afterward.
- Others include Daraprim, Chloroquine, Paludrine Plasmoquine etc.

(vi). Prevention

Malaria can be controlled and prevented by the following methods

1. Destruction of mosquito and its larva
2. Spraying DDT in and around the house
3. Sterilization of mosquito

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4. Rearing larvivorous fishes like sticklebacks, minnows, and trouts, ducks and dragonflies, etc. This method of control is called the biological method.
5. Constructing mosquito-proof houses
6. Using mosquito nets.
7. Applying anti-mosquito creams on the surface of the body.

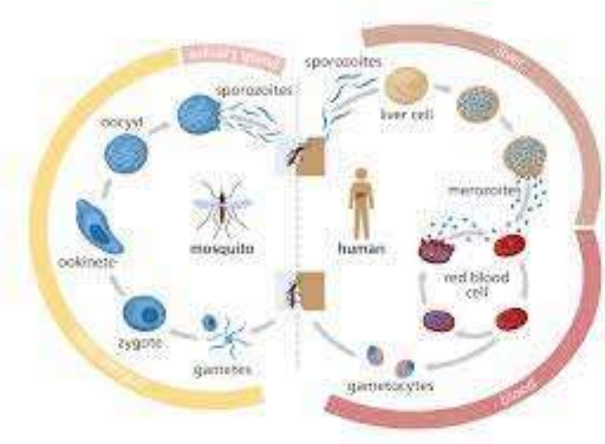

Fig.1.6.Malarial infection

1.7.2.b.ELEPHANTIASIS

(i). Definition

Enlargement and thickening of tissues specifically enormous enlargement of a limb or the scrotum caused by obstruction of lymphatic vessels by filarial worms called *Wuchereria bancrofti*.

(ii). Causative agent

The causative agent is the filarial worm Wuchereria bancrofti and this parasite enters into the blood of man by the bite of mosquitoes.

(iii). Mode of transmission

Elephantiasis occurs in the presence of microscopic, thread-like parasitic worms such as *Wuchereria bancrofti* (the most common), *Brugia malayi*, and *Brugia timori*, all of which are transmitted by bites from infected mosquitoes. It is a digenic parasite. Man is the primary host and the mosquito is the secondary host. This worm lives in the lymph nodes and lymph vessels of man. The larva is called microfilaria. This larva passes from the lymph vessels into the blood vessels.

The larva comes to the peripheral blood vessel in the night. When the mosquito bites the man, the larva enters the gut of the mosquito. Moulting occurs there and now it is called filariform larva. It penetrates the gut and migrates to the muscles of the mosquito. Then it reaches the mouthparts.

When the mosquito bites a man, the larva enters the blood of the man. From the blood, it goes to the lymph vessel and it lymph nodes. It causes obstructions of the free flow of lymph. As a result, the lymph glands and lymph vessels of the affected

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parts usually legs, arms, and scrotum are enlarged. This condition is known as elephantiasis.

(iv). Symptoms

Most cases are symptomless. Rarely, long-term damage to the lymph system causes swelling in the legs, arms, and genitalia because of the accumulation of fluid. The arms and legs are the areas most often affected. An entire arm or leg may swell to several times its normal size resembling the thick, round appearance of an elephant's leg.

It also increases the risk of frequent bacterial infections that harden and thicken the skin (elephantiasis). The most common symptom of elephantiasis is swelling of body parts. The swelling tends to happen in the following parts,

- legs
- genitals
- breasts
- arms

The legs are the most commonly affected area. The swelling and enlargement of body parts can lead to pain and mobility issues.

The skin is also affected and maybe

- dry

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- thick
- ulcerated
- darker than normal
- pitted

Some people experience additional symptoms, such as fever, chills, and mental depression. Elephantiasis affects the immune system. People with this condition are also at increased risk for a secondary infection.

(v). Treatment

Treatment for elephantiasis includes

- Antiparasitic drugs, such as diethylcarbamazine (DEC), mectizan, and albendazole (Albenza)
- Using good hygiene to clean the affected areas
- Elevating the affected areas
- Caring for wounds in the affected areas
- Exercising based on a doctor's directions
- Surgery in extreme cases, which may include reconstructive surgery for the affected areas or surgery to remove affected lymphatic tissue
- Treatment may also include emotional and psychological support.

(vi). Prevention

Prevention may be possible by:

- Avoiding mosquitoes or taking precautions to reduce the risk for mosquito bites.
- Getting rid of mosquito breeding areas
- Using mosquito nets
- Using insect repellents
- Wearing long-sleeved shirts and pants in areas with a lot of mosquitoes.
- Take diethylcarbamazine (DEC), albendazole, and ivermectin as a preventive treatment before traveling to areas prone to infection.

If traveling to tropical or subtropical regions short term, the risk of getting elephantiasis is low. Living in these areas for a long term can increase the risk.

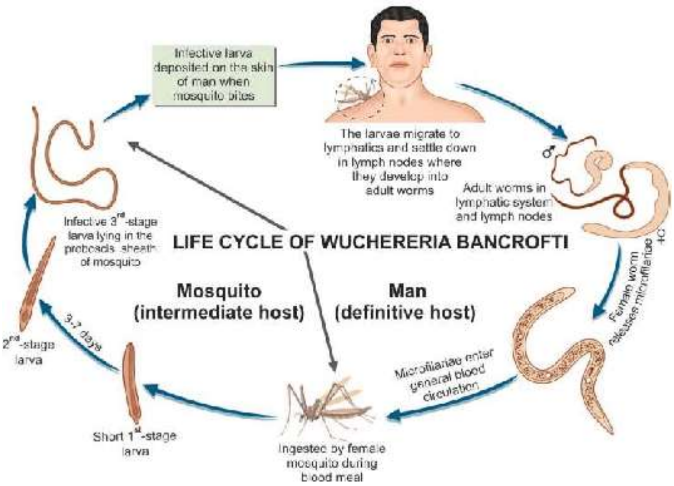

Fig.1.7. Elephantiasis

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1.7.2.c.Dengue fever

(i). Definition

It is a mosquito-borne viral disease occurring in tropical and subtropical areas. Dengue begins abruptly after a typical incubation period of 5–7 days, and the course follows 3 phases: febrile, critical, and convalescent.

Those who become infected with the virus a second time are at a significantly greater risk of developing severe disease. The severe form of dengue fever, also called dengue hemorrhagic fever, can cause serious bleeding, a sudden drop in blood pressure (shock), and death.

(ii). Causative agent

Dengue virus is the cause of dengue fever. It is a mosquito-borne, single positive-stranded RNA virus of the family Flaviviridae; genus Flavivirus. Four serotypes of the virus have been found, a reported fifth has yet to be confirmed, all of which can cause the full spectrum of disease.

The two types of mosquitoes that most often spread the dengue viruses are common both in and around human lodgings. When a mosquito bites a person infected with a dengue virus, the virus enters the mosquito. Then, when the infected mosquito bites another person, the virus enters that person's bloodstream and causes an infection.

After recovery from dengue fever, leads to long-term immunity to the type of virus that infected. But these are not the other three dengue fever virus types. This means an individual can be infected again in the future by one of the other three virus types.

(iii). Mode of transmission

Dengue fever is transmitted to humans through the bites of infective female *Aedes* species mosquitoes (*A. aegypti* or *A. albopictus*). When a patient suffering from dengue fever is bitten by a vector mosquito, the mosquito is infected and it may spread the disease by biting other people. The disease cannot be spread directly from human to human. These are the same types of mosquitoes that spread Zika and chikungunya viruses.

- These mosquitoes typically lay eggs near standing water in containers that hold water, like buckets, bowls, animal dishes, flower pots, and vases.
- These mosquitoes prefer to bite people and live both indoors and outdoors near people.
- Mosquitoes that spread dengue, chikungunya, and Zika bite during the day and night.

- Mosquitoes become infected when they bite a person infected with the virus. Infected mosquitoes can then spread the virus to other people through bites.

From mother to child

- A pregnant woman already infected with dengue can pass the virus to her foetus during pregnancy or around the time of birth.
- To date, there has been one documented report of dengue spread through breast milk. Because of the benefits of breastfeeding, mothers are encouraged to breastfeed even in areas with a risk of dengue.

Through infected blood, laboratory, or healthcare setting exposures causes dengue in pregnancy. Rarely, dengue can be spread through blood transfusion, organ transplant, or through a needle stick injury.

(iv). Symptoms

Many people experience no signs or symptoms of dengue infection.When symptoms do occur, they may be mistaken for other illnesses such as the flu and usually begin four to 10 days after the bitten by an infected mosquito. Dengue fever causes a high fever 104^{o} F (40 C) and the following are the signs and symptoms

- Headache
- Muscle, bone, or joint pain
- Nausea
- Vomiting
- Pain behind the eyes
- Swollen glands
- Rash

Most people recover within a week or so. In some cases, symptoms worsen and can become life-threatening. This is called severe dengue, dengue hemorrhagic fever, or dengue shock syndrome.

Severe dengue happens when the blood vessels become damaged and leaky. And the number of clot-forming cells (platelets) in the bloodstream drops. This can lead to shock, internal bleeding, organ failure, and even death.

Warning signs of severe dengue fever are,

warning signs usually begin the first day or two after your fever goes away, and may include:

- Severe stomach pain
- Persistent vomiting
- Bleeding from your gums or nose
- Blood in your urine, stools, or vomit

- Bleeding under the skin, which might look like bruising
- Difficult or rapid breathing
- Fatigue
- Irritability or restlessness

(v). Treatment

There is no specific treatment for dengue fever. Fever reducers and pain killers can be taken to control the symptoms of muscle aches and pains, and fever. The best options to treat these symptoms are acetaminophen or paracetamol.

(vi). Prevention

- Prevent dengue by avoiding mosquito bites.
- The mosquitoes that spread dengue are found in most tropical and subtropical regions of the world, including many parts of the United States. *A. aegypti* and *A. albopictus* bite during the day and night.
- A dengue vaccine is now recommended for U.S. territories of American Samoa, Puerto Rico, and the U.S. Virgin Islands, and freely associated states, including the Federated States of Micronesia, the Republic of Marshall Islands, and the Republic of Palau.

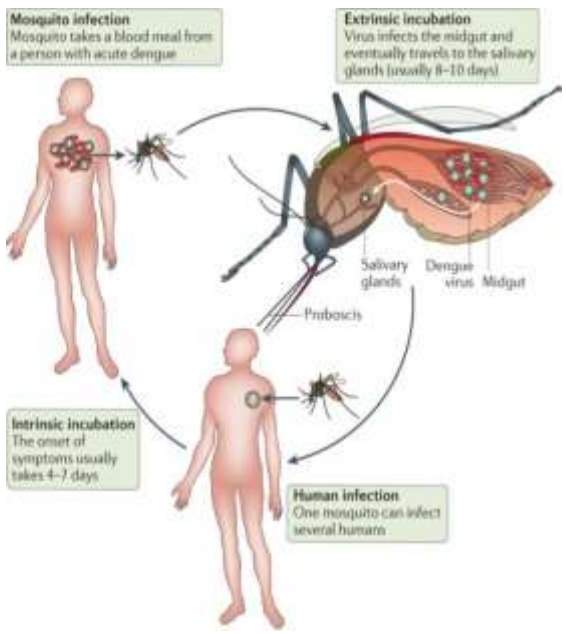

Fig1.8. Dengue fever

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