(FOREST PROTECTION –B)

ZOOLOGY

AND

ENTOMOLOGY

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1. **Biological control of insect pests**
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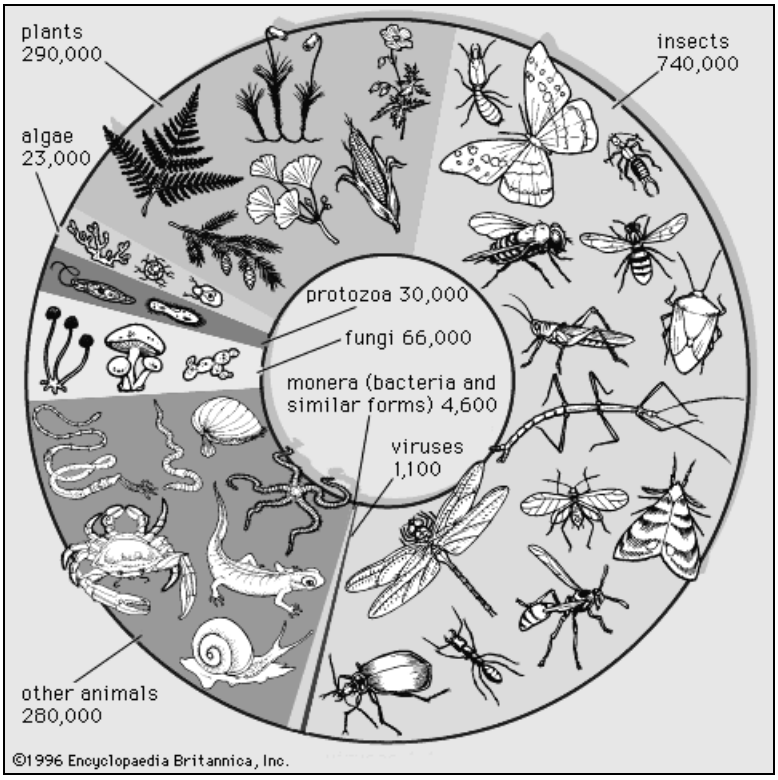
(FOREST PROTECTION –B) ZOOLOGY AND ENTOMOLOGY:

Solved Question papers

Entomology(from Greek ἔντομος, *entomos*, "that which is cut in pieces or engraved/segmented", hence "insect"; and -λογία, *-logia*) is the scientific study of insects, a branch of arthropodology, branch of **zoology.** Although insects were studied as early as the 4th century bc, particularly by Aristotle, the modern science did not begin to develop until the 17th century ad. The science of entomology received great impetus in the 19th century, largely as a result of the publication of *On the Origin of Species* (1859) Charles Darwin, which showed how the study of insects illuminates certain aspects of evolution. In the 20th century, entomological research was further stimulated by successes in the search for solutions to medical and economic problems involving insects. Today, there is more research done and literature published annually in this field than in any other branch of zoology

At some **1.3 million** described species, insects account for more than two-thirds of all known organisms, date back some **400 million years**, and have many kinds of interactions with humans and other forms of life on earth.



Q1: Give importance and nature of damage in Grybllidae, Acrididae, and Mantodea. Also give different key characters.

Gryllidae (Crickets):

Common name for insects of a family characterized by the chirping courtship call of the male and by the needlelike or cylindrical ovipositor (organ at the end of the abdomen where eggs are deposited) of the female. The male produces his courtship song by rubbing a grooved ridge on the underside of one of his front wings against the sharp edge of the other front wing. True crickets include the familiar black field cricket and the house cricket.

Cricket

The cricket's body has adapted to meet many specific survival needs. Its hind legs are elongated, allowing the insect to jump to avoid predators. The cricket obtains oxygen through spiracles, which are holes in its lower abdomen. Male crickets attract mates by rubbing their front wings together.

Importance and Key characteristics of Crickets:

- Crickets have long antennae and hind legs adapted for jumping; organs for hearing are located on their front legs.
- Solitary by day, crickets remain in crevices, under rocks, or in shallow burrows dug in the soil, emerging at night to feed on plants.
- During breeding season, the male cricket attracts a female with his call, sometimes driving off other males that intrude on his territory. The call is distinctive in each species
- In most crickets, after mating the female uses her long, spear like ovipositor to insert eggs into the soil or plant stems.
- The young, called nymphs resemble the adults. They reach full size after 6 to 12 molts during which they shed their outer covering; as adults, they usually live six to eight weeks.
- **Scientific classification:** True crickets make up the family Gryllidae in the order Orthoptera, which also includes grasshoppers and katydids

Nature of Damage:

- Make holes in logs for purpose of habitat.
- Make burrow on stem of trees
- Some time cause great damage to the leaves of trees.
- Some spp are made association with ants to show the nature of omnivorous

Acrididae (Swarming Grasshopper)

- **Swarming (climb using arms and legs; group of insects in flight) grasshopper:** a migratory grasshopper that often swarms and devours crops and vegetation. Native to: southern Europe, Asia, Africa, North America.
- Family: *Acrididae*

True Locust

The true locust is one of over 5000 species of grasshopper in the family Acrididae. Locusts travel in huge numbers capable of feeding on and destroying entire fields of cultivated plants and any nearby vegetation. Approaching swarms create an ominous hum and sometimes are large enough to block out sunlight.

Importance and key characteristics of Acrididae (Grass hopper)

- These cause great damage to crops wherever they swarm.
- **Scientific classification:** Locusts belong to the order Orthoptera. True locusts belong to the family Acrididae. Grouse, or pygmy, locusts belong to the family Tetrigidae
- Found predominatly in the hotter regions
- Stridulating (to make a chirping or grating sound by rubbing parts of the body together, as male crickets and grasshoppers do) take place in several ways
- Tegmen (the forewing of a primitive insect) is different from *Gryllidae* on the aspect of physiology and morphology
- Tegmen produce a low buzzing sound and vibration
- Some spp are able to stridulate (to make a chirping or grating sound by rubbing parts of the body together, as male crickets and grasshoppers do) during flight
- The auditory organs are located on each side of abdomen
- Four to eight ecdysis (**shedding of an outer layer:** the regular molting of an outer layer by arthropods such as insects and crustaceans, and by reptiles)

Nature of Damage:

- The female creates a hole in the decaying wood
- Some spp are primarily grass feeders by nature and damage wide ranges of area.
- Some eat broad leave trees causing damage to the physiology of plant.
- Control measures include the spreading of poison bait and the plowing under of locust eggs

Mantodea (Mantis):

- Mantis, also known as praying mantis, common name for long, slender, winged insect common in warm temperate and tropical regions throughout the world.

Praying Mantis
The praying mantis is so named for the prayerlike posture it assumes while waiting for its prey. Although the praying mantis generally eats insects and small tree frogs, the female will devour part of her own mate. Commonly found in tropical and warm temperate climates, the mantis was introduced into the United States to help control certain insect populations.

Importance and key characteristics:

- Mantis, also known as praying mantis, common name for long, slender, winged insect common in warm temperate and tropical regions throughout the world.
- Mantises are known for sitting back on their rear appendages and holding their stout front pair of appendages together in an attitude reminiscent of prayer.
- Mantises are the only insects that can turn their heads from side to side.
- Their front legs are equipped with sharp spines that enable the insects to grasp and hold their prey.
- The erroneous belief that the characteristic position of mantises waiting for prey has a religious significance has been the basis of many superstitious tales about them
- The common European mantis reaches a maximum length of about 6.3 cm (about 2.5 in).
- **Scientific classification:** Mantises make up the order Mantodea.

Q2: Give the number of Phyla of animal kingdom.

Phylum Arthropoda;
Phylum Protozoa
Phylum Chordata

Animal, multicellular organism that obtains energy by eating food. With over **2 million** known species, and many more awaiting identification, animals are the most diverse forms of life on earth. They range in size from 30-m (100-ft) long whales to microscopic organisms only 0.05 mm (0.002 in) long. They live in a vast range of habitats, from deserts and Arctic tundra to the deep-sea floor. Animals are the only living things that have evolved nervous systems and sense organs that monitor their surroundings. They are also the only forms of life that show flexible patterns of behavior that can be shaped by past experience. The study of animals is known as zoology.

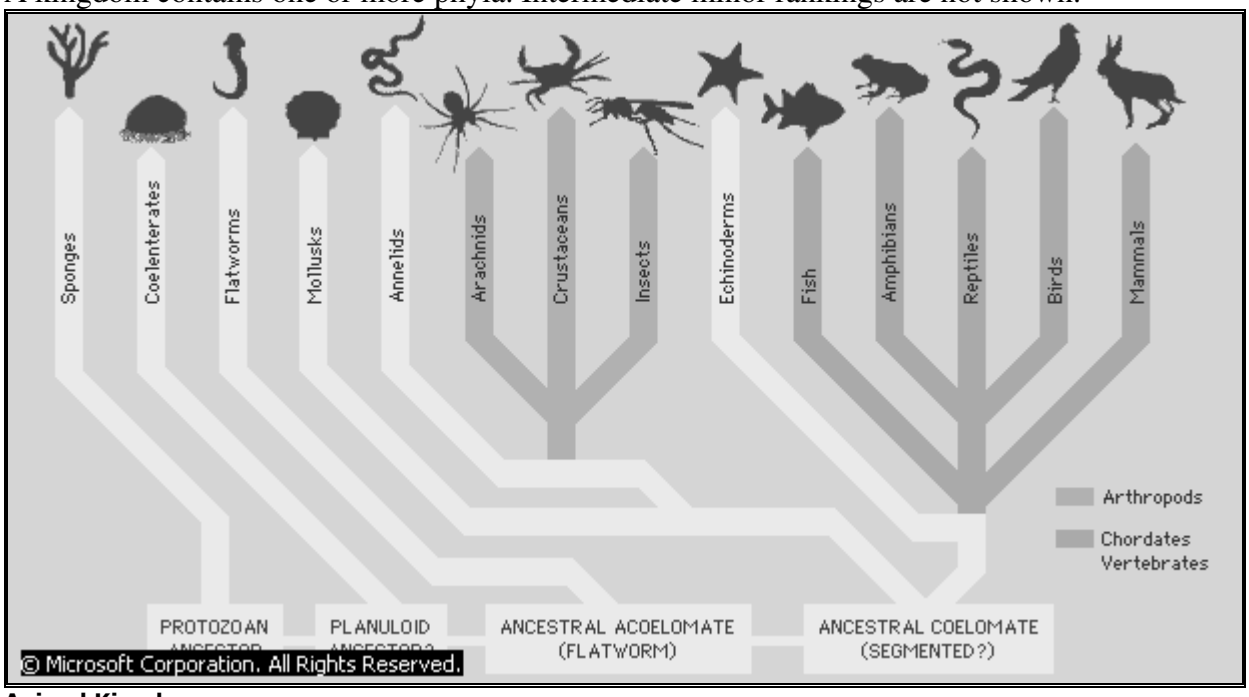
Types of Animals:

Animals are generally divided into two major groups: **i)** Vertebrates **ii)** Invertebrates

Vertebrates are the animals with backbone or an animal with a segmented spinal column and a well-developed brain, e.g. a mammal, bird, reptile, amphibian, or fish and **Invertebrates** are the animals that do not have backbone, e.g. insects or worms. Vertebrates total about **40,000 species.** Yet vertebrates account for only about **2 percent** of animal species. The remaining **98 percent**, collectively called invertebrates, are far more numerous and diverse and include an immense variety of animals from sponges, worms, and jellyfish to mollusks and insects.

ANIMAL KINGDOM:

A kingdom contains one or more phyla. Intermediate minor rankings are not shown.



Animal Kingdom

Kingdom Animalia includes more than one million living species, grouped into more than 35 phyla. Vertebrates, members of the phylum Chordata, comprise only one percent of these organisms. Phylum Arthropoda is more successful in sheer numbers, total mass, and distribution than all other groups of animals combined. The remaining animal phyla are composed of mostly marine-dwelling organisms. Illustrated here is the evolutionary relationship between all of these groups.

PHYLUM:

In biology, a phylum (plural: phyla) is a taxonomic rank below Kingdom and above Class. "Phylum" is equivalent to the botanical term division.

Informally, phyla can be thought of as grouping animals based on general body plan, as well as developmental or internal organizations. For example, though seemingly divergent, spiders and crabs both belong to Arthropoda, whereas earthworms and tapeworms, similar in shape, are from Annelida and Platyhelminthes, respectively. Although the International Code of Botanical Nomenclature allows the use of the term "phylum" in reference to plants, the term "Division" is almost always used by botanists

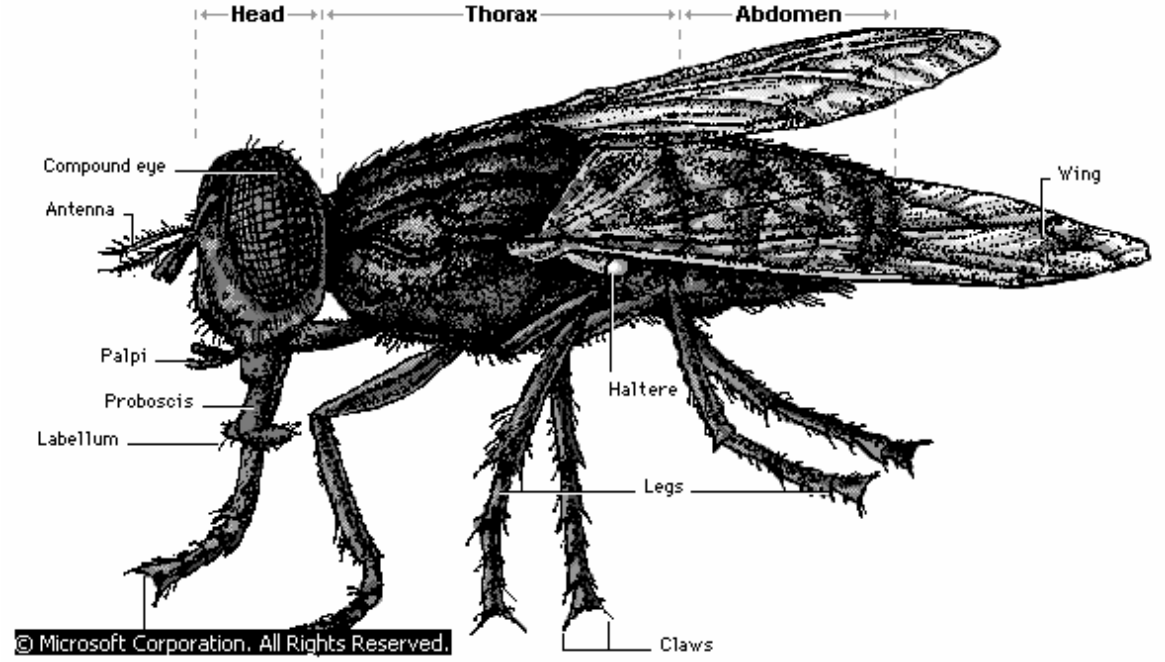
The best known animal phyla are the Mollusca, Porifera, Cnidaria, Platyhelminthes, Nematoda, Annelida, Arthropoda, Echinodermata, and Chordata, the phylum to which humans belong. Although there are approximately 35 phyla, these nine include over 96% of animal species. Many phyla are exclusively marine, and only one phylum, the Onychophora (velvet worms) is entirely absent from the world's oceans–although ancestral oncyophorans were marine.

Phylum	Meaning	Common Name	Distinguishing characteristics	Species described
Acanthocephala	Thorny headed worms	Thorny-headed worms	Reversible spiny proboscis	about 750
Acoelomorpha	Without gut	Acoels	No mouth or alimentary canal	
Annelida	Little ring	Segmented worms	Multiple circular segments	about 15,300 modern
Arthropoda	Jointed foot	Arthropods	Chitin exoskeleton	1,134,000+
Brachiopoda	Arm foot	Lamp shells	Lophophore and pedicle	between 300 and 500 extant
Bryozoa	Moss animals	Moss animals, sea mats	Lophophore, no pedicle, ciliated tentacles	about 5,000 living species
Chaetognatha	Longhair jaw	Arrow worms	Chitinous spines either side of head, fins	about 100 modern species
Chordata	Cord	Chordates	Hollow dorsal nervous chord, notochord, pharyngeal slits, endostyle, post-anal tail	about 100,000+
Cnidaria	Stinging nettle	Coelenterates	Nematocysts (stinging cells)	about 11,000
Ctenophora	Comb bearer	Comb jellies	Eight "comb rows" of fused cilia	about 100 modern species
Cycliophora	Wheel carrying	*Symbion*	Circular mouth surrounded by small cilia	at least 3
Echinodermata	Spiny skin	Echinoderms	Five-fold radial symmetry in living forms, mesodermal calcified spines	about 7,000 extant and 13,000 extinct species
Echiura	Spine tail	Spoon worms	Set of hooks at posterior end	about 140
Entoprocta	Inside anus	Goblet worm	Anus inside ring of cilia	about 150
Gastrotricha	Hair stomach	Meiofauna	Two terminal adhesive tubes	about 690
Gnathostomulida	Jaw orifice	Jaw worms		about 100
Hemichordata	Half cord	Acorn worms, pterobranchs	Stomochord in collar, pharyngeal slits	about 100 living species
Kinorhyncha	Motion snout	Mud dragons	Eleven segments, each with a dorsal plate	about 150
Loricifera	Corset bearer	Brush heads	Umbrella-like scales at each end	about 122
Micrognathozoa	Tiny jaw animals	—	Accordion like extensible thorax	1
Mollusca	Thin shell	Mollusks / molluscs	Muscular foot and mantle round shell	112,000[9]
Nematoda	Thread like	Round worms	Round cross section, keratin cuticle	80 000 – 1 million
Nematomorpha	Thread form	Horsehair worms		about 320
Nemertea	A sea nymph	Ribbon worms		about 1200
Onychophora	Claw bearer	Velvet worms	Legs tipped by chitinous claws	about 200 modern
Orthonectida	Straight swim		Single layer of ciliated cells surrounding a mass of sex cells	about 20

Phoronida	Zeus's mistress	Horseshoe worms	U-shaped gut	20
Placozoa	Plate animals			1
Platyhelminthes	Flat worms	Flat worms		about 25,000[10]
Porifera	Pore bearer	Sponges	Perforated interior wall	over 5,000 modern
Priapulida	Penis	Priapulid worms	Retractable proboscis surrounded by papillae	17
Rhombozoa	Lozenge animal	—	Single axial cell surrounded by ciliated cells	75
Rotifera	Wheel bearer	Rotifers	Anterior crown of cilia	about 2000
Sipuncula	Small tube	Peanut worms	Mouth surrounded by invertible tentacles	144–320
Tardigrada	Slow step	Water bears	Four segmented body and head	1,000+
Xenoturbellida	Strange flatworm	—	Ciliated deuterostome	2
TOTAL: 36				**2,000,000-**

Phylum Arthropods

- **Arthropoda** (from Greek ἄρθρον *arthron*, "joint", and ποδός *podos* "foot", which together mean "jointed feet")
- An invertebrate animal that has jointed limbs, a segmented body, and an exoskeleton made of chitin, e.g. an insect, arachnid, centipede, or crustacean.

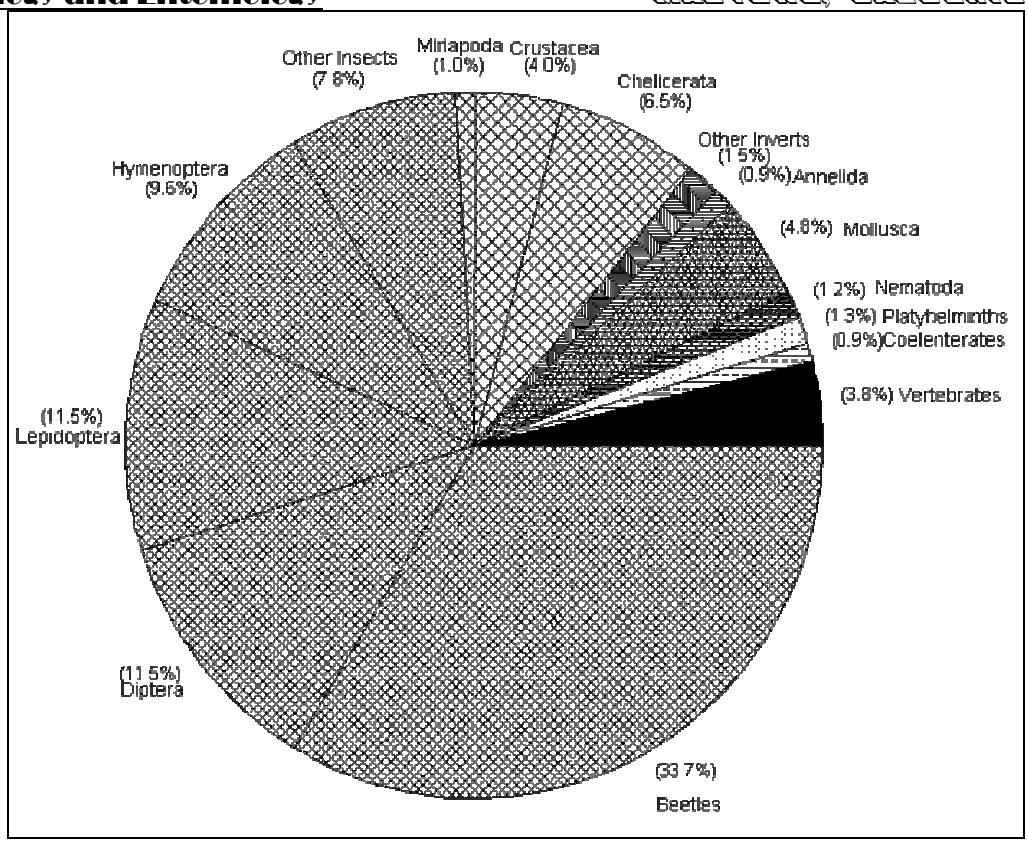


External Anatomy of a Fly

Like other insects, the fly has three distinct body regions: the head, the thorax, and the abdomen. The head bears the eyes, a pair of antennae, and the mouthparts. Legs and wings attach to the thorax. The segmented abdomen contains the tiny openings through which the fly breathes. The last few segments of the abdomen are modified for mating and egg laying.

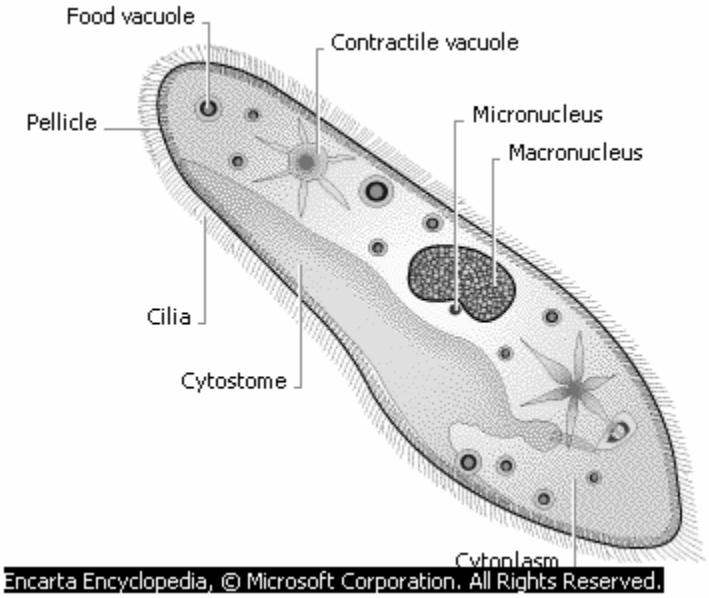
Main Characteristics of Arthropods:

- An arthropod is an invertebrate that has an exoskeleton (external skeleton), a segmented body, and jointed attachments called appendages.
- In terms of sheer numbers and the variety of niches they fill, arthropods are the most successful animals on Earth
- More than **one million** arthropod species have been identified—more than 20 times the number of known fish, amphibian, reptile, bird, and mammal species combined. This figure is considered a low estimate of the phylum's actual size because many arthropod species have yet to be discovered and documented.
- Arthropods have adapted to life on land, at sea, and in the air. They occupy an array of habitats, from scorching deserts and scalding hot springs to snow-capped mountains and frigid fjord
- They show bilateral symmetry
- Body is usu divided into three parts: head, thorax and abdomen
- Lacking internal skeletons, arthropods wear their 'bones' on the outside in the form of an armored **exoskeleton**. This durable shell is made of **chitin**, a hard material containing cellulose and further strengthened by protein
- The rigid cuticle inhibits growth, so arthropods replace it periodically by **molting**.
- Arthropods' main internal cavity is a **hemocoel**, which accommodates their internal organs and through which their blood circulates – they have open circulatory systems
- Their nervous system is "ladder-like", with paired ventral nerve cords running through all segments and forming paired ganglia in each segment.
- Their vision relies on various combinations of compound eyes and pigment-pit ocelli
- Almost all arthropods lay eggs, except for scorpions, which give birth to live young after the eggs have hatched inside the mother.
- Although arthropods contribute to human food supply both directly as food and more importantly as pollinators of crops, they also spread some of the most severe diseases and do considerable damage to livestock and crops
- The Phylum **Arthropoda** is the largest and most diverse of all animal phyla
- More than three quarters of the animals on earth are arthropods, and most of these are insects. More than 900,000 species have been described, and if biologists have the opportunity to explore the rain forests before they are completely burned to the ground, a like number will probably be discovered See this figure



Phylum Protozoa

- [Mid-19th century. < modern Latin *Protozoa* "first animals" < Greek *zōia*, plural of *zōion* "animal"]
- **single-celled organism:** a single-celled organism that can move and feeds on organic compounds of nitrogen and carbon, e.g. an amoeba. Kingdom: *Protoctista*



Paramecium Anatomy

A paramecium is a microscopic, slipper-shaped organism that lives in fresh waters throughout the world. It has a tough outer covering known as a pellicle. About 2,500 tiny, hairlike projections, called cilia,

extend from the pellicle; the cilia move back and forth like oars to help the paramecium move about. The paramecium eats tiny organisms, such as bacteria, that are swept by the cilia into an indentation in the cytostome called the oral groove. The organisms are eventually passed into a food vacuole, a small, round structure where food is digested, and are then passed into the cytoplasm. The contractile vacuole regulates osmotic pressure within the organism. The macronucleus is involved in protein synthesis and other cellular activities, while the micronucleus functions in sexual reproduction.

Main Characteristics of Protozoa:

- Protozoa have little or no differentiation into tissue systems.
- More than 20,000 species are known, including such familiar forms as paramecium and amoeba.
- Most species are found in such aquatic habitats as oceans, lakes, rivers, and ponds.
- They vary in length from 2 to 70 micrometers
- Protozoa obtain their food by ingesting bacteria, waste products of other organisms, algae, or other protozoa.
- Most species are motile, either by whiplike structures called flagella, hairlike structures called cilia, or amoeboid motion, a streaming type of movement involving the formation of pseudopods (footlike extensions).

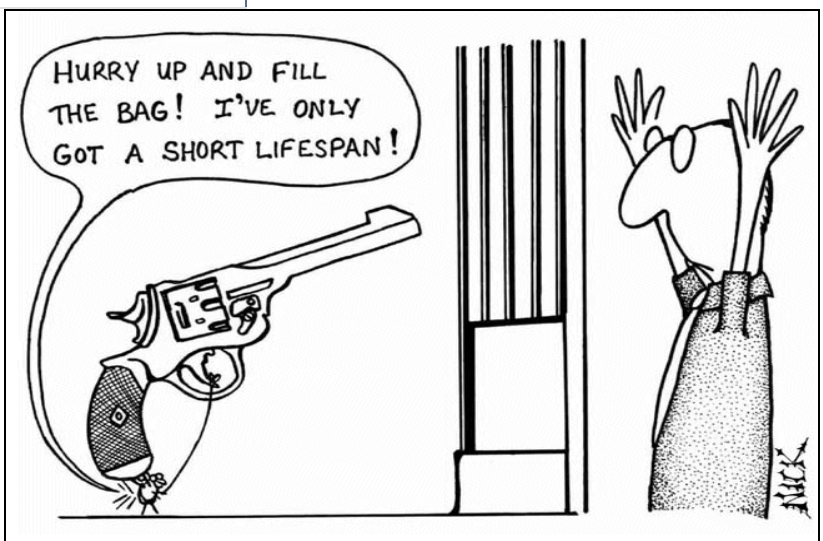
Phylum Chordata

- [Late 19th century. < modern Latin *chordata* < Latin *chorda* "cord"]
- **Animal of class including vertebrates:** an animal that at some stage in its development has a main dorsal nerve cord, a skeletal rod notochord, and gill slits, including all vertebrates and some primitive invertebrate ocean animals.
- Chordates (phylum Chordata) are a group of animals that includes the vertebrates, together with several closely related invertebrates.
- One phylum of animals, the chordates, has been more intensively studied than has any other, because it comprises nearly all the world's largest and most familiar animals as well as humans.
- This phylum includes mammals, birds, reptiles, amphibians, and fish together with a collection of lesser-known organisms, such as sea squirts and their relatives
- The feature uniting these animals is that at some stage in their lives, all have a flexible supporting rod, called a notochord, running the length of their bodies.
- The great majority of chordates, the notochord are replaced by a series of interlocking bones called vertebrae during early development.
- About **43,700 living species** are known, making the chordates the third largest animal phylum.
- Three subphyla exist: Cephalochordata, the fishlike lancelets, with 25 species; Tunicata, the highly modified tunicates, with about 2000 species; and Vertebrata, animals with backbones made up of vertebrae (including fishes, amphibians, reptiles, birds, and mammals), with about 41,700 species.

Maximum Life Span of Some Plants and Animals:

While humans can live longer than 100 years, most medium or large mammals do not see 30 years. The longest lived mammal may be the bowhead whale, which some evidence suggests can live to over 200. Birds and small rodents generally survive longer in captivity than in the wild. The longest living fish is the sturgeon; and the giant tortoise lives longest among both reptiles and amphibians. The longest lived animal of all may be the quahog clam, which can live for over 400 years. These achievements are dwarfed by those of some plants and fungi, which are capable of lasting for more than 10,000 years.

TYPE	MAXIMUM LIFE SPAN
Adult mayfly	1-3 days
Marigold	1 year
Mouse	3 years
Guppy	5 years
Large beetles	5-10 years
Swallow	9 years
Coyote	15 years
Giant spider	20 years
Toad	36 years
Lobster	50 years
Crocodile	60 years
Sea anemone	70 years
Elephant	77 years
Blue whale	80 years
Golden eagle	80 years
Sturgeon	100 years
Tortoise	100-150 years
Human	122 years
Bowhead whale	200 years?
Quahog clam	400 years
Giant sequoia	4,000 years
Creosote bush	11,700 years



Why few arthropods are criminals.

Q3: Mention usefulness of insects. Give a detail aspect of honey bee.

(For first part see Question # 19)

Honey Bee, common name for any of several species of highly social bees known for their honey-hoarding behavior and their use as a domesticated species

Honey bees can be easily reared, are adaptable to many climates and to laboratory conditions, and have a complex social life. They are among the most studied and best known insects.

Diversity:

In addition to the familiar European honey bee, there are six other recognized species of honey bees, including the Indian honey bee, Koschevnikov's honey bee, the dwarf honey bee, the andreniform dwarf honey bee, the giant honey bee, and the mountain giant honey bee.

The European, the Indian, and to some extent the dwarf honey bees are the species that have been domesticated, although the European honey bee is by far the most widespread domesticated bee and the only species kept in North America.

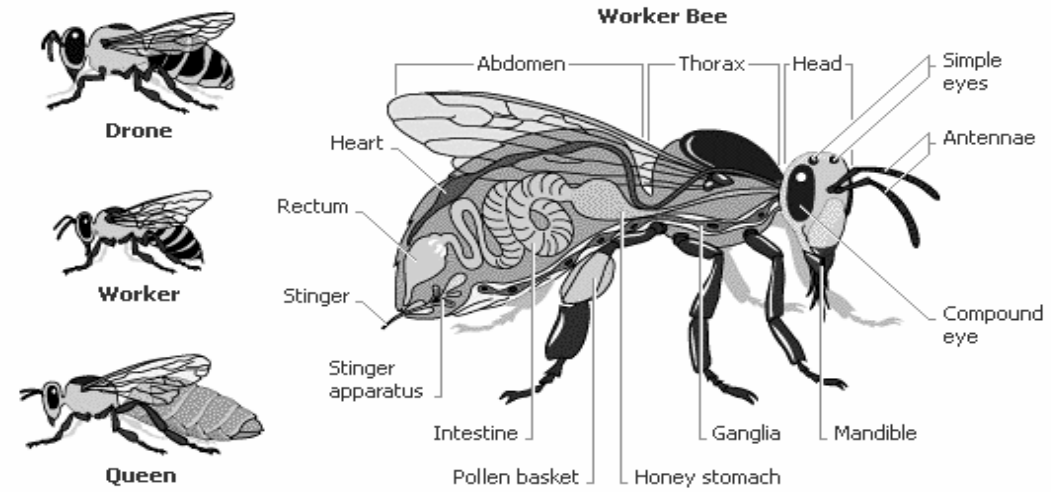
Most honey bees used in hives today are mixtures of these and sometimes other races.

Social Organization:

The honey bee is a social insect that can survive only as a member of a community, or colony. The colony inhabits an enclosed cavity, its nest. Domesticated colonies are kept in artificial containers, usually wooden boxes, known as hives.

- **Castes:**

  The honey bee community consists of three structurally different forms—the queen (reproductive female), the drone (male), and the worker (nonreproductive female). These castes are associated with different functions in the colony; each caste possesses its own special instincts geared to the needs of the colony.



Members of a Bee Colony

In each honey bee hive, there are thousands of female worker bees, hundreds of male drones, but only a single female queen, who is mother to them all. The queen is larger than the drones and workers, especially her abdomen, in which her ovaries are filled with eggs. A queen may lay as many as 1000 eggs a day. The workers provide nursing support for the larvae as well as hive maintenance. The ovaries of worker bees are shrunken and usually cannot produce eggs. Drones exist solely to mate with the queen to produce new individuals for the colony. After mating drones die.

- **The Queen:**

The queen is the only sexually productive female in the colony and thus is the mother of all drones, workers, and future queens. Her capacity for laying eggs is outstanding; her daily output often exceeds **1500 eggs**, the weight of which is equivalent to that of her own body.

Anatomically, the queen is strikingly different from the drones and workers. Her body is long, with a much larger abdomen than a worker bee. Her mandibles, or jaws, contain sharp cutting teeth, whereas her offspring have toothless jaws. The queen has a curved, smooth stinger that she can use repeatedly without endangering her own life. In contrast, the worker honey bees are armed with straight, barbed stingers, so that when a worker stings, the barbed, needlesharp organ remains firmly anchored in the flesh of its victim. In trying to withdraw the stinger, the bee tears its internal organs and dies shortly thereafter. The queen bee lacks the working tools possessed by worker bees, such as pollen baskets, beeswax-secreting glands, and a well-developed honey sac. Her larval food consists almost entirely of a secretion called royal jelly that is produced by worker bees. The average lifespan of the queen is one to three years.

- **The Worker Bee:**

Worker bees are the most numerous members of the colony. A healthy colony may contain **80,000** worker bees or more at its peak growth in early summer. Workers build and maintain the nest and care for the brood. They build the nest from wax secreted from glands in their abdomen. The hexagonal cells, or compartments, constructed by the workers are arranged in a latticework known as the *comb.*

Workers leave the hive to gather nectar, pollen, water, and propolis, a gummy substance used to seal and caulk the exterior of the nest. They convert the nectar to honey, clean the comb, and feed the larvae, drones, and the queen. They also ventilate the nest and when necessary, defend the colony with their stings.

Workers do not mate and therefore can not produce fertile eggs. They occasionally lay infertile eggs, which give rise to drones

- **The Drone Bee:**

Drones are male honey bees. They are stingless, defenseless, and unable to feed themselves—they are fed by worker bees. Drones have no pollen baskets or wax glands and cannot secrete royal jelly. Their one function is to mate with new queens. After mating, which always takes place on the wing in the open air, a drone dies immediately. Early investigators of the mating habits of the honey bee concluded that a queen mates only once in her life. Recent scientific studies, however, have established that she usually mates with six or more drones in the course of a few days

- **Reproduction and Development:**

The queen controls the sex of her offspring. When an egg passes from her ovary to her oviduct, the queen determines whether the egg is fertilized with sperm from the spermatheca. A fertilized egg develops into a female honey bee, either worker or queen, and an unfertilized egg becomes a male honey bee, or drone.

*On average, the development of the queen from egg to adult requires **16 days**; that of the worker, **21 days**; and that of the drone, **24 days***

- **Activities:**

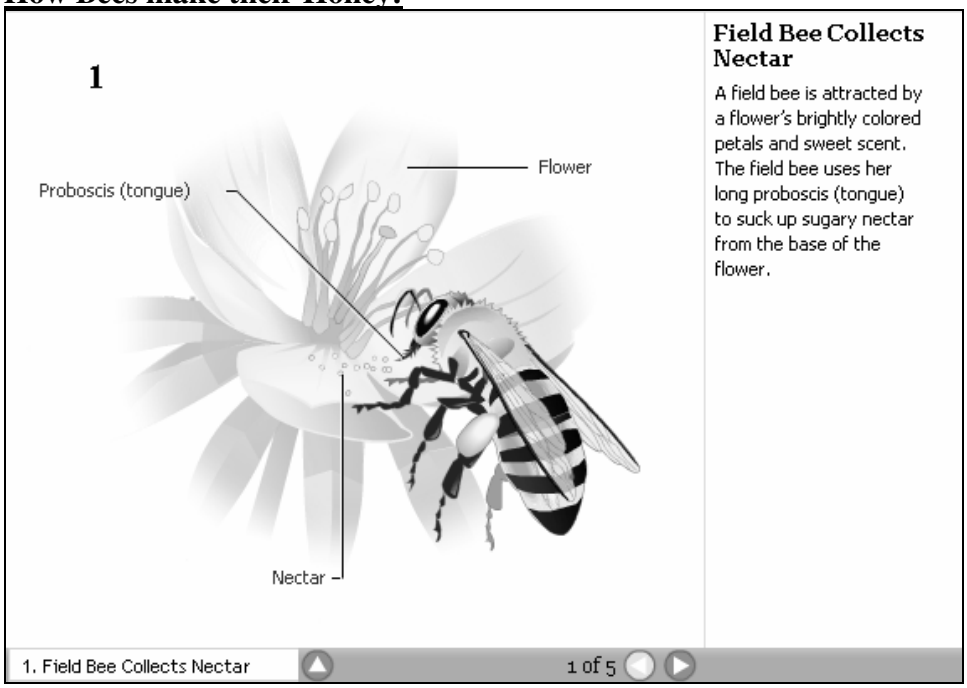
Field honey bees collect flower nectar. On entering the hive with a full honey sac, which is an enlargement of the esophagus, the field bee regurgitates the contents into the mouth of a young worker, called the house, or nurse, bee. The house bee deposits the nectar in a cell and carries out the tasks necessary to convert the nectar to honey. When the honey is

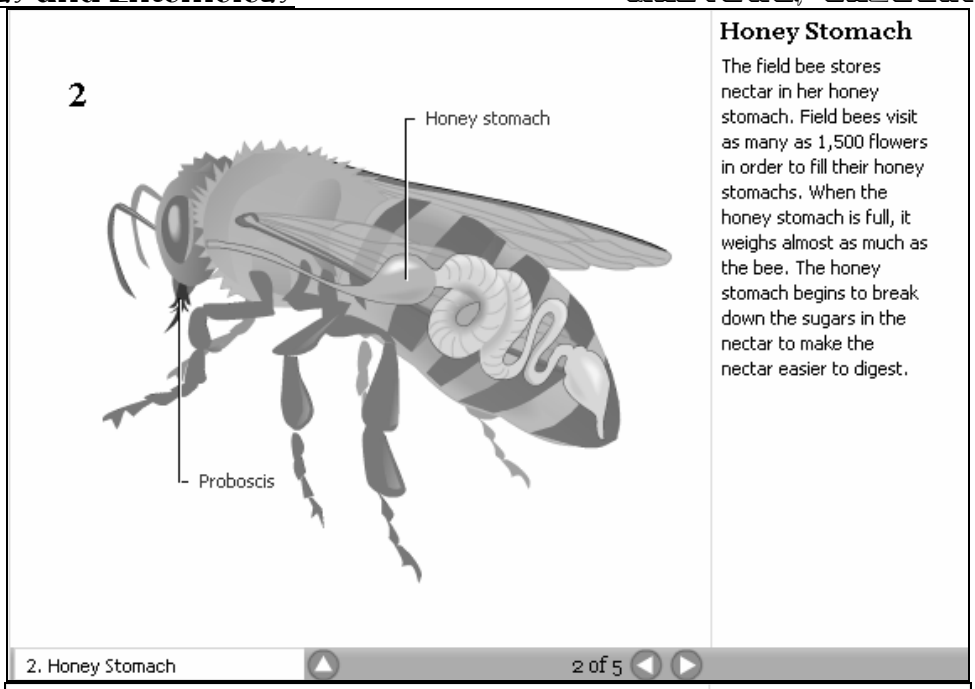
fully ripened, the cell is sealed with an airtight wax capping. Both old and young workers are required to store the winter supplies of honey.

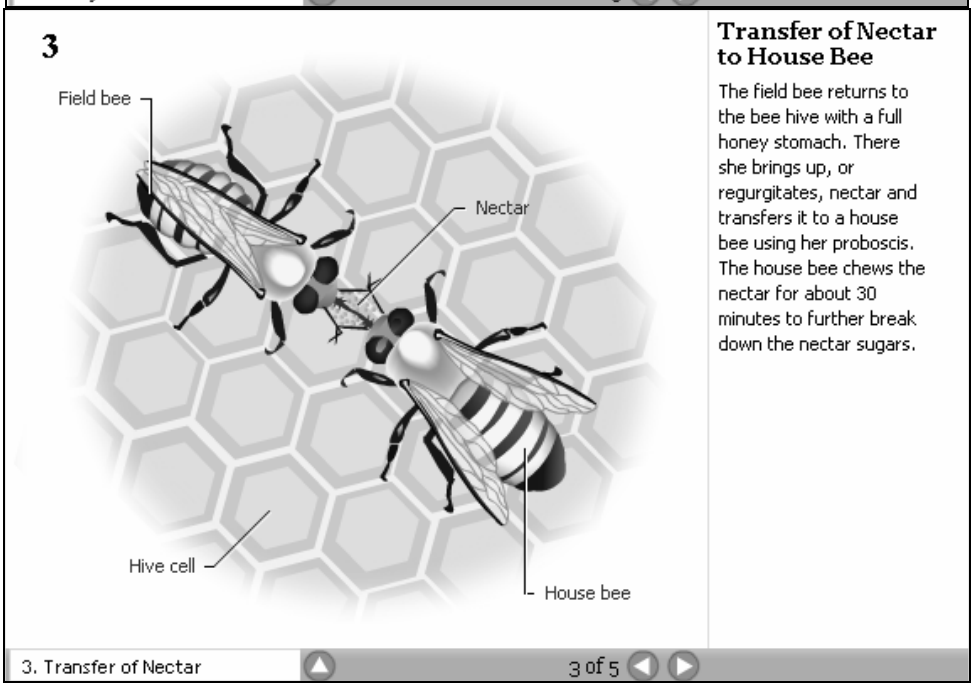
Honey Bees Making Honey

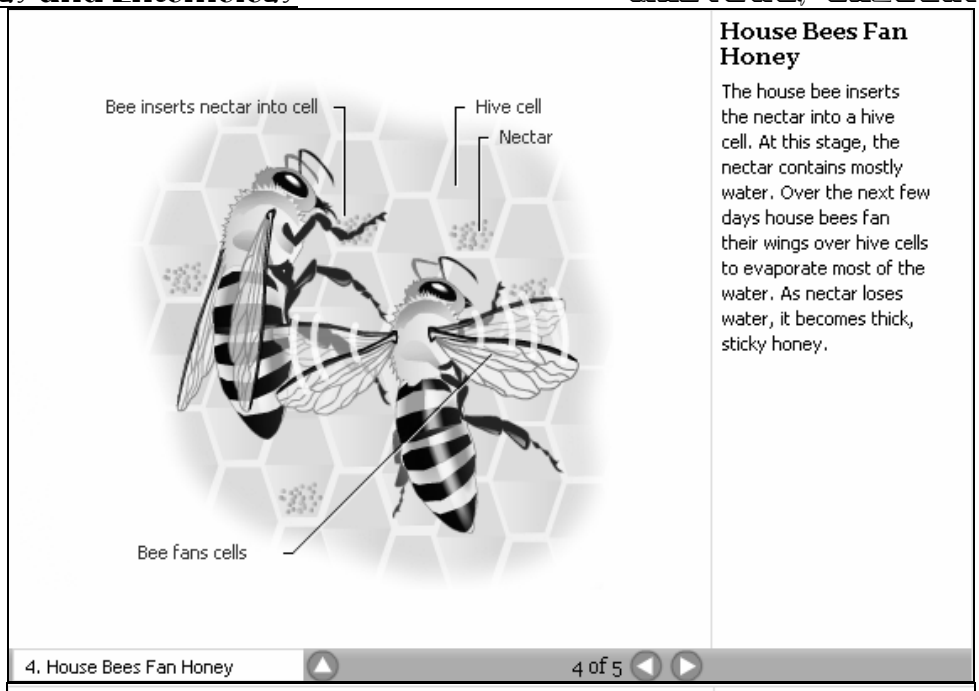
Honey bees create honey in a beehive. Honey bees gather nectar from flowers and bring it back to the hive, where they convert it to honey. The honey is stored in the cells of the honeycomb and used as food.

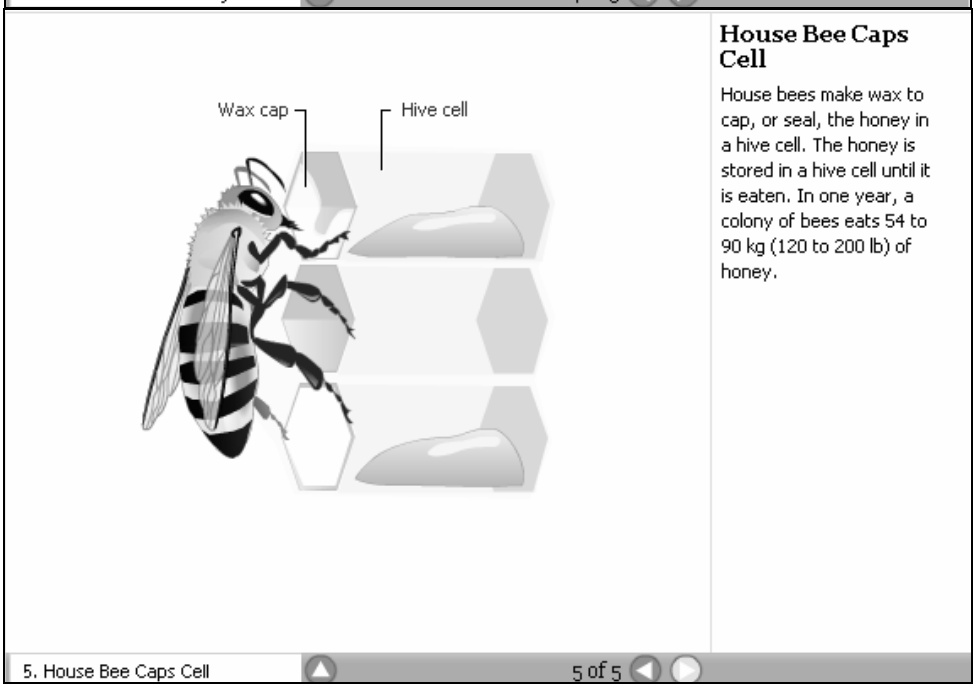
- **How Bees make their Honey:**




2
Honey stomach
Proboscis
Honey Stomach
The field bee stores nectar in her honey stomach. Field bees visit as many as 1,500 flowers in order to fill their honey stomachs. When the honey stomach is full, it weighs almost as much as the bee. The honey stomach begins to break down the sugars in the nectar to make the nectar easier to digest.
2. Honey Stomach
2 of 5


3
Field bee
Nectar
Hive cell
House bee
Transfer of Nectar to House Bee
The field bee returns to the bee hive with a full honey stomach. There she brings up, or regurgitates, nectar and transfers it to a house bee using her proboscis. The house bee chews the nectar for about 30 minutes to further break down the nectar sugars.
3. Transfer of Nectar
3 of 5





- **Importance:**
  - Honey bees have become the primary source of pollination for approximately one-fourth of all crops produced in the United States and some other countries. Examples of fruit crops that rely on honey bees are almonds, apples, apricots, avocados, blackberries, blueberries, cantaloupes, cherries, cranberries, cucumbers, pears, raspberries, strawberries, and watermelons.
  - The seeds of many vegetables are also produced with honey bee pollination.
  - Many species of wild pollinators have disappeared from the land as their habitats have been destroyed or altered by humans. The honey bee has

taken over as pollinator of many of the wild plants that remain; its ecological value in this regard is tremendous.

- Honey bees are the sole source of honey and beeswax, a fine wax with unusual qualities.
- Honey bees also produce *propolis,* a gummy substance made from tree sap that has antibacterial properties, and royal jelly and pollen for human consumption.
- Honey bee venom is extracted for the production of antivenom therapy and is being investigated as a treatment for several serious diseases of the muscles, connective tissue, and immune system, including multiple sclerosis and arthritis.

- **Scientific classification:** Honey bees comprise the genus *Apis* in the family Apidae, order Hymenoptera. The European honey bee is classified as *Apis mellifera,* the Indian honey bee is *Apis cerana,* Koschevnikov's honey bee is *Apis koschevnikovi,* the dwarf honey bee is *Apis florea,* the andreniform dwarf honey bee is *Apis andreniformis,* the giant honey bee is *Apis dorsata,* and the mountain giant honey bee is *Apis laboriosa.* The Italian race of the European honey bee is *Apis mellifera ligustica,* the Carniolan race is *Apis mellifera carnica,* and the Caucasian race is *Apis mellifera caucasia.*

Honey Bee (Quick Facts)	
Class	Insecta
Order	Hymenoptera
Family	Apidae
Names	**Reproductive female:** queen **non-reproductive female:** worker **male:** drone
Range	All continents except Antarctica.
Habitat	Open woodland, grasslands, and forests.
Size	**Queen:** 16 to 20 mm (0.63 to 0.79 in). **Worker:** 10 to 15 mm (0.39 to 0.59 in). **Drone:** 14 to 18 mm (0.55 to 0.71 in).
Feeding Habits	Honey bees are herbivores; they eat nectar and honey. Larvae eat pollen and royal jelly, which is secreted by worker bees.
Offspring	The queen bee lays all of the eggs for her hive—sometimes more than 1500 a day. The eggs, laid in the cells of the honeycomb, hatch in three days.
Life Span	Queen bees live for one to three years, while workers and drones live for about five weeks.
Did You	A healthy bee colony can have as many as 100,000 bees.

Know

Worker bees communicate with a dance, indicating the distance to and direction of a nectar source.

The drone's only function is to mate with the queen.

Worker bees maintain the temperature of the hive by beating their wings.

Only worker bees can produce the wax used to build the hive.

(Sir Walli-Ur-Rehman _ Director Sericulture)

(From left: Naimat, Imran, Sarwar, Kamran, Sulaiman, Noman, Sarmad, Ihtizaz, Liaquat and Kashif-sitting)
The PFI Volley Ball Team _ Winner of The 'Bepin Tournment'

Q4: Define and give various types of Metamorphosis along with suitable examples.

METAMORPHOSIS:

From [Greek *metamorphōsis* < *metamorphoun* "transform" and *morphē* "form">]

Definition: "*A complete or marked change in the form of an animal as it develops into an adult is termed as metamorphosis, e.g. the change from tadpole to frog or from caterpillar to butterfly*"

According to the degree of change in form the insects are divided into the following groups:

1) **Ametabola or no metamorphosis:**

In this group of insects, the development occurs without metamorphosis. The young one pass through no any changes to become adults. As these insects are considered to be preliminary wingless. They are called **Apterygota.** The young one is called **nymph** which is in similar appearance to te adult, but smaller in size. These insects have three life stages: *egg*, *nymph*, and *adult*.

The examples are silverfish telsontails, springtails, etc.

Silverfish

2) **Metabola:**

In this group of insects development occurs through metamorphosis. The newly hatched immature stages are different from adults in their external characteristics and smaller in size. This group is further divided into two sub groups.

a. **Hemimetabloa or Incomplete metamorphosis:**

Most insects hatch from eggs, but some are ovoviviparous or viviparous and all undergo a series of moults as they develop and grow in size. This manner of growth is necessitated by the inelastic exoskeleton. (Moulting is a process by which the individual escapes the confines of the exoskeleton in order to increase in size, and then grows a new and larger outer covering).

In some insects, the young are called **nymphs** are similar in form to the adult except that the wings are not developed until the adult stage. This is called **incomplete metamorphosis** and insects showing this are termed **hemimetabolous**. They have three life stages: egg, nymph and adult.

Termites undergo incomplete metamorphosis, with their freshly hatched young taking the form of tiny termites that grow without significant morphological changes (other than wings and soldier specializations). Other examples include: dragonflies, grasshoppers, crickets, etc.

Emperor Dragonfly
An emperor dragonfly emerges from its larval skin. Unlike butterflies, dragonflies do not create a chrysalis and undergo complete metamorphosis. Instead, they undergo a series of small transformations until they finally develop into the imago—the adult, winged form.

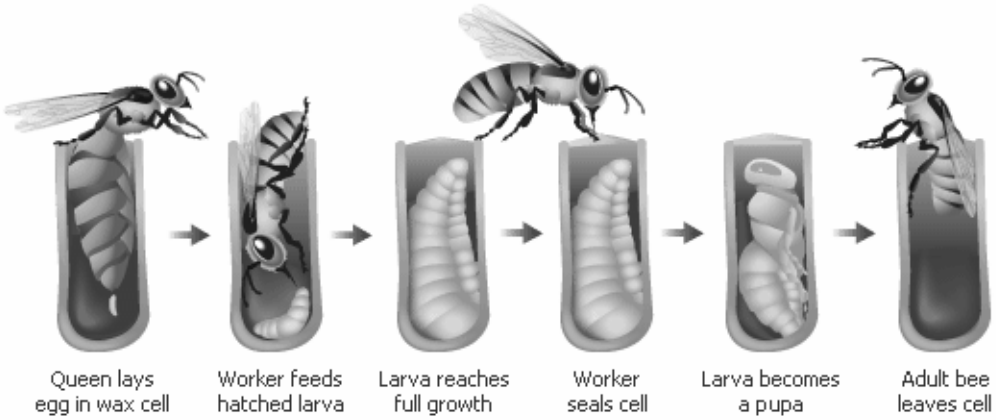
b. <u>Holometabola or Complete metamorphosis:</u>

Holometabolous insects show **complete metamorphosis**, include many of the most successful insect groups. It is divided into four stages. In these species, an **egg** hatches to produce a **larva**, which is generally worm-like in form, and can be divided into five different forms; eruciform (caterpillar-like), scarabaeiform (grublike), campodeiform (elongated, flattened, and active), elateriform (wireworm-like) and vermiform (maggot-like). The larva grows and eventually becomes a **pupa**, a stage marked by reduced movement and often sealed within a cocoon which ultimately grows into an **adult**.

These insects are either winged or secondary wingless. The winged insects deelop their wing internally within the body or larva and are thus known as **Endopterygota.** The larva has chewing mouth parts.

After moulting several times the larvae reach full size and stop to geed and then change into pupae. During pupal stage the wings develop internally after the last moult.

Butterflies are an example of an insect that undergoes complete metamorphosis. Other examples include; true flies, beetles, ants, bees, wasps, etc.



Development of the Honey Bee

The queen honey bee may lay 1,500 eggs in a single day. After it hatches, worker bees feed the wormlike larva constantly—as many as 1,300 times a day—sealing the cell when the larva has grown to fill it. The larva pupates in about 12 days, and the adult bee chews through the wax cap of its cell approximately three weeks after the eggs were first laid. Newly emerged adults perform various maintenance tasks in the hive until they are ready to begin foraging outside the hive.

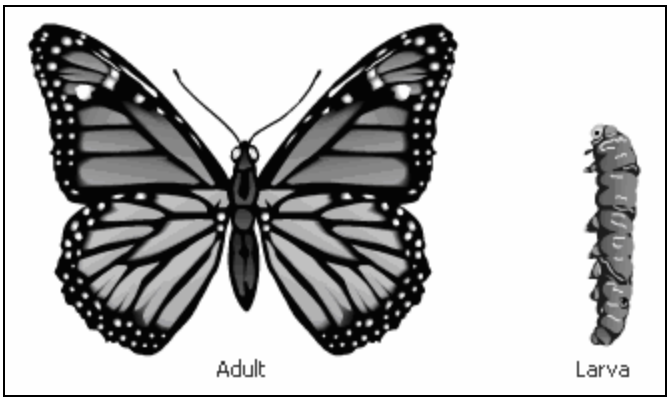
(**From left: Asad , Ashfaq Bhai, Naeem Javid, Ibrar A. Khan, and Liaquat Bhai**)
Plane Tabling Survey at Mansehra

Q5: Give various types of larva in insects. Also give its difference along with their examples.

Larva:

- A Larva, scientific term for the young of any insects that undergo a **complete metamorphosis** in the course of development into adults.

- Larvae bear little resemblance to the adult insects; they have no wings or compound eyes and are usually wormlike in form.
- They vary in structure among different insects.
- The larvae of beetles are called **grubs**; those of butterflies and moths are known as **caterpillars**; and the larval forms of certain flies are called **maggots**.
- Before becoming adults, the larvae undergo **pupal** or chrysalis stages. Among some insects the larval period is far longer than the adult period.



Types of Larvae:

Some important types of larvae are as under:

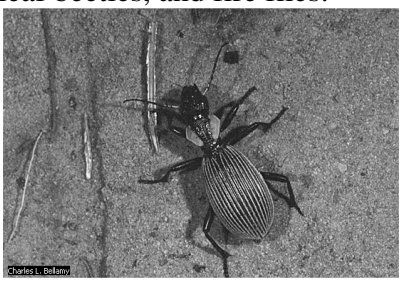
1. **Campodeiform:**

It is elongated and flattened having long thoracic legs (involving or located in the chest) and usu cerci on the end of abdomen. Eg diving beetles, rove beetles, caddis flies and nerve-winged insects.

Diving Beetle

2. **Carabiform:**

This is a modified of the campodeiform .larva. it has flattened body sorter lgs and no cerci. Eg ground beetles, leaf beetles, and fire flies.



Ground Beetle

3. **Eruciform:**

The body is cylindrical with both thoracic and abdominal legs eg butterflies, moths, and scorpion flies.

Scorpion Fly

4. **Scarabaeiform:**

The body is cylindrical and c-shaped with usu thoracic but no abdominal legs. Scarab beetles (mangourh), and pulse beetles.

Scarab Beetle Rolling a Ball of Dung

5. **Elateriform:**

The body is thin, elongated and cylindrical with short thoracic legs eg click beetles and darkling beetles.

Eyed Click Beetle

6. **Platyform:**

The body is broad with short or no legs eg some sypphid flies.

7. **Vermiform:**

The body is cylindrical elongated narrowing anteriorly and without legs eg flies, fleas, and parasitic wasps (kasabee a moungee).

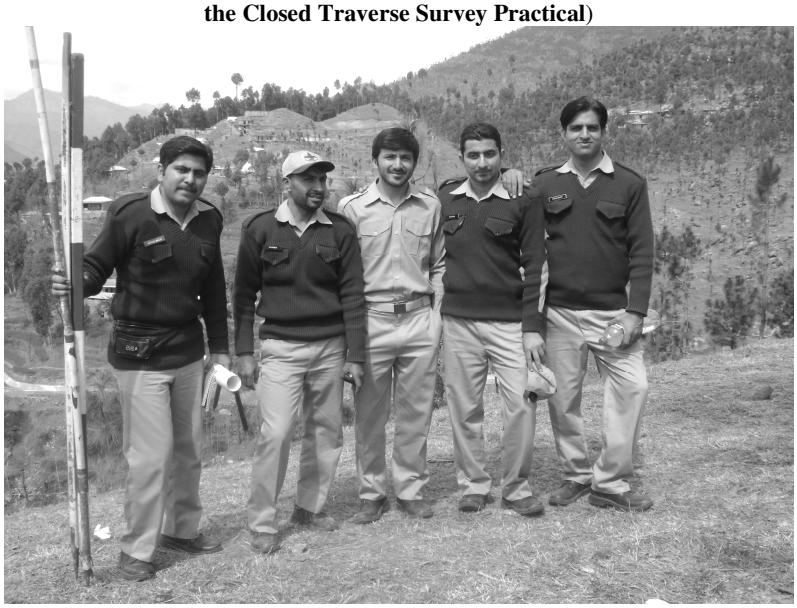
Thread-Waisted Wasp

Animal	Name of larva
Hydrozoa	planula
Many crustaceans	nauplius
Decapoda	zoea
Mayflies, Grasshoppers, True Bugs, etc.	nymph
Dragonflies, Damselflies	naiad, nymph
Butterflies and moths	caterpillar
Beetles, Bees, Wasps	grub
Flies	maggot
Mosquitos	wriggler
Certain molluscs, annelids	trochophore
Certain molluscs	veliger
Freshwater mussels	glochidium
Lamprey	ammocoete
Fish (generally)	larva
Eels	leptocephalus
Amphibians	tadpole, polliwog
Echinoderms	Bipinnaria

(Lal Tahir with his group at Shinkiari)

(From left: Sher Jan, Khalil Bhai, Sharaf Sb, Saleem Jan, Nazir Jan, Niaz Bhai, and Tariq Shah _ Plane tabling at Shinkiari during Survey Tour)

(From right: Shakeel bhai, Aqeel bhais, Imarn Shafee, Kamran Zarif, Yaseen @ Officer Club PFI performing the Closed Traverse Survey Practical)

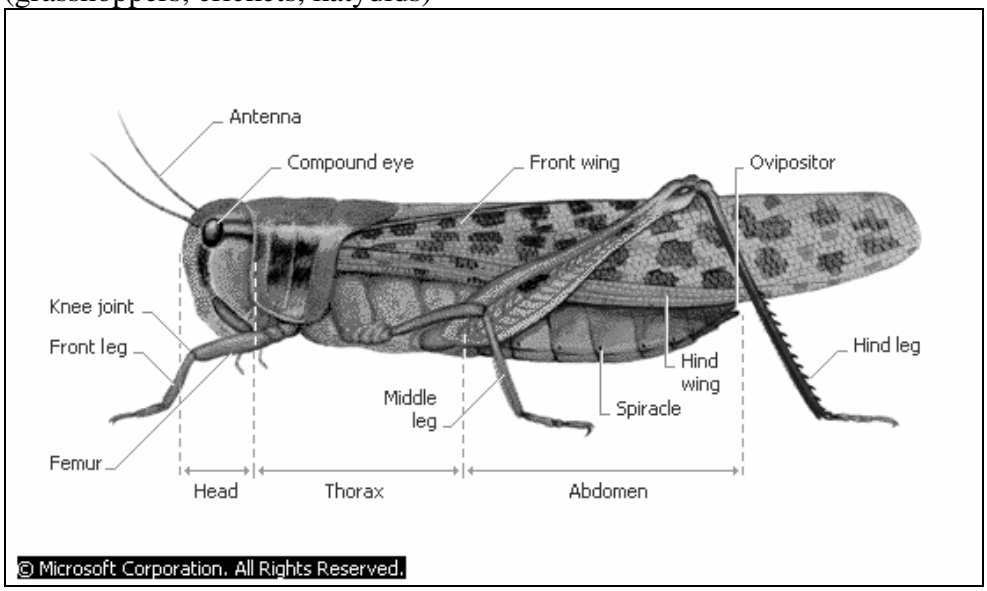


(From right: Imran Sb, Manan Bhai, Saleem Bhai, Sarwar Jan at Shinkiari)

Q6: Give external morphology of grasshopper's thoracic segments.

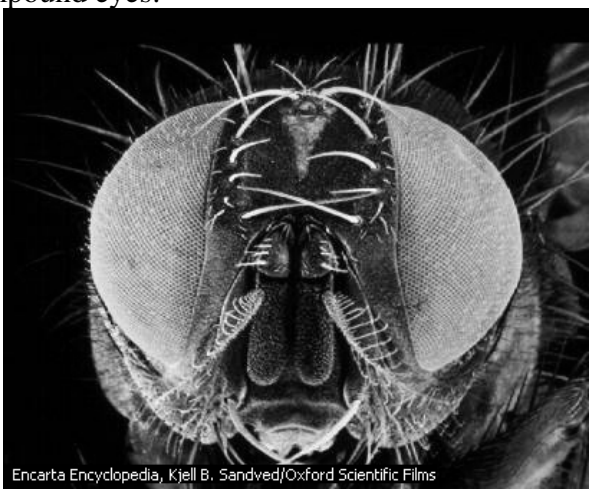
Grasshopper, common name for any of the winged orthopteran insects with hind legs adapted for jumping. They include the longhorned grasshoppers, pygmy grasshoppers, and shorthorned grasshoppers, or locusts. They subsist on vegetation and are distributed worldwide wherever vegetation grows. There are about 20,000 grasshoppers spp.

External Morphology and important characteristics:

- Grasshoppers are 3 to 13 cm (1 to 5 in) long when fully grown.
- They develop by gradual metamorphosis: The nymph is initially wingless and gradually comes to resemble the adult as it grows through progressive molts. Only the adults can fly.
- The body is divided into three parts: head, thorax and abdomen with pair of antennae and wings.
- On grasshoppers, there is a large round disc on the first segment next to the thorax. It is called a tympanum and is the grasshopper's ear. And on each abdominal segment, there is a small breathing hole called the thoracic spiracle.
- Some species undergo seasonal color changes, being green at some times and red or brown at others.
- The lifespan of the grasshopper varies widely by species and can be greatly affected by environmental conditions. Many kinds of grasshoppers live for approximately three to five months during a typical summer season.
- Grasshoppers are closely related to crickets, and male grasshoppers make chirping or stridulating noises similar to those produced by crickets.
- Pygmy grasshoppers are the smallest grasshoppers and are characterized by a greatly elongated dorsal shield, a backward extension of the thorax.
- Females usually lay their eggs in low bushes or in crevices in the bark of trees or in holes in the ground.
- The eggs hatch in the spring, and the young reach maturity in July or August
- Stridulating (to make a chirping or grating sound by rubbing parts of the body together, as male crickets and grasshoppers do) take place in several ways
- **Scientific classification:** Grasshoppers belong to the order **Orthoptera** (grasshoppers, crickets, katydids)
- 

Anatomy of a Grasshopper: This illustration of a grasshopper depicts the tiny circular openings called spiracles through which most insects obtain oxygen. From the spiracles, tubes called tracheae reach deep within the body to supply oxygen to every cell.

- A view of compound eyes:



Q7: Classify different methods of insect control. Give their principles and applications.

In the broadest sense, the insect control includes everything that makes life hard for insects and tends to kill them and to prevent their increase in a particular area. Despite all the control efforts used, pests annually destroy about 35 percent of all crops worldwide. Even after food is harvested, insects, microorganisms, rodents, and birds inflict a further 10 to 20 percent loss, bringing the total destruction to about 40 or 50 percent.

Insects are kept under control in two ways:

- **Natural Control:**

All of the measures that destroy or check insects without the influences of the man are called Natural Control. This includes climatic, topographic, and biotic factors.

  - **Climatic Factors:**

    These include rainfall, sunshine, cold, heat, and wind. These climatic factors affect the insect population to a great extent. For instance, rainfall and hail storm kill insect in larval stage. Sunshine restrict the spread of many spp while extreme hot and cold temperature affect a number of insects spp. Wind movement is also of great importance like many spp of the smaller insects which normally fly for considerable distance are unable to leave the ground during strong wind or if fly are beaten by the wind or litter.

  - **Topographic Factors:**

    These include rivers, lakes, mountains, types of soil and other barriers. Large bodies of water such as oceans prove effective barrier to the natural spread of nearly all spp of insects. While rivers and lakes affect those insects which do not possess the power of flight. Mountain ranges also are effective barriers to the spread of insects and offer varying conditions of climatic through which many insects cannot pass. The character of soil of any region affects a marked influence on the insects. Fro example, certain spp of wireworms live only in the poor drain soil and certain spp of tiger beetle larvae live in sandy soil and are unable to exist in the clayey soil.

  - **Biotic Factors:**

    These factors include predatory insects, birds, reptiles, mammals, parasitic insects, fungi, bacteria, and other microorganisms. A large no of insects

parasite on other insects while some other are predators of insects. Almost all birds feed on adult insects as well as other worms. Insects are also attacked by fungi bacterial and viral diseases.

- **Applied Control:**

To destroy insects by the uses of man made methods is know as applied control. This includes Silvicultural, biological, mechanical, physical, chemical control methods. Another method is the **integrated pest management** is a new concept of insect control.

Biological control is safe for humans, but compared to insecticides, its effectiveness can be hard to predict. For this reason, many harmful insects are now dealt with by a mix of chemical and biological means. Known as integrated pest management (IPM), this system minimizes harm to the environment while keeping problem insects in check

Insect Trap in a Cotton Field

Insect larvae, especially the pink bollworm, are especially damaging to cotton crops because they eat cotton seeds. This insect trap uses pheromones, chemical signals that affect animal behavior, to lure male insects inside the container. Without males to fertilize the females' eggs, the life cycle of the insect is disrupted. Insect traps are a form of biological pest control, a method that does not use environmentally harmful chemicals.

- **Silvicultural Method:**

Regular Silvicultural practices are adopted so as to destroy insect or prevent their injuries.

- **Raising Healthy Nurseries:**

Diseased free seeds should be collected from the healthy trees and raised in the nurseries. Excellent preparation of seeds beds and proper irrigation and fertilizing in the nurseries should be ensured from healthy nurseries.

- **Virgin Forest:**

Virgin forests have a good complex of natural enemies which keep the insect pests under their control .If these forests are not disturbed, pest problems will not arise in the forests. In advanced countries a number of forest pests existed for long time because of plenty use of pesticides against the pests. Now they have stopped the use of pesticides and restored the natural balance with other methods. In Pakistan natural forests almost remained free from the insect damages because pesticides have never been used in these forests.

- **Mixed Forests:**

Mixed forests prevent the spread of host specific pests. For example kail defoliator can be controlled by planting it in mixed crops. Similarly, the shisham defoliator can be controlled by planting it with mulberry.

- **Removing over aged trees from the fotrst:**

Over aged trees usu provide breeding place for bark and stem borers. A number of defoliators usu the attack the bark of old and weakened trees. Eg poplar borer breed well in the aged trees. Removal of the old aged and weakened trees and their stumps minimize the outbreak of these borers.

- **Debarking of felled trees:**

Logs of pines trees should be debarked just after felling to avoid the attack of bark beetles.

- **Phase wise felling:**

A large clear felled area is more attractive to forest pests than the small area. Therefore phase wise felling should be under taken in small patches. Artificial or natural regeneration should be ensured in the felled area. This will also control many forest pests.

- **Control burning:**

Large scale burning in the natural forest particularly young plantation should be avoided. Burning encourages the bark beetle and also removes natural enemies of the pests. Therefore control burning should b practiced carefully, particularly in the young plantations.

(Special Thx to: Sarmad Shafa from Gilgit)

Q8: What are basic characters for separating insects from other animals and splitting them into groups and orders? Salient characteristic of Lepidoptera

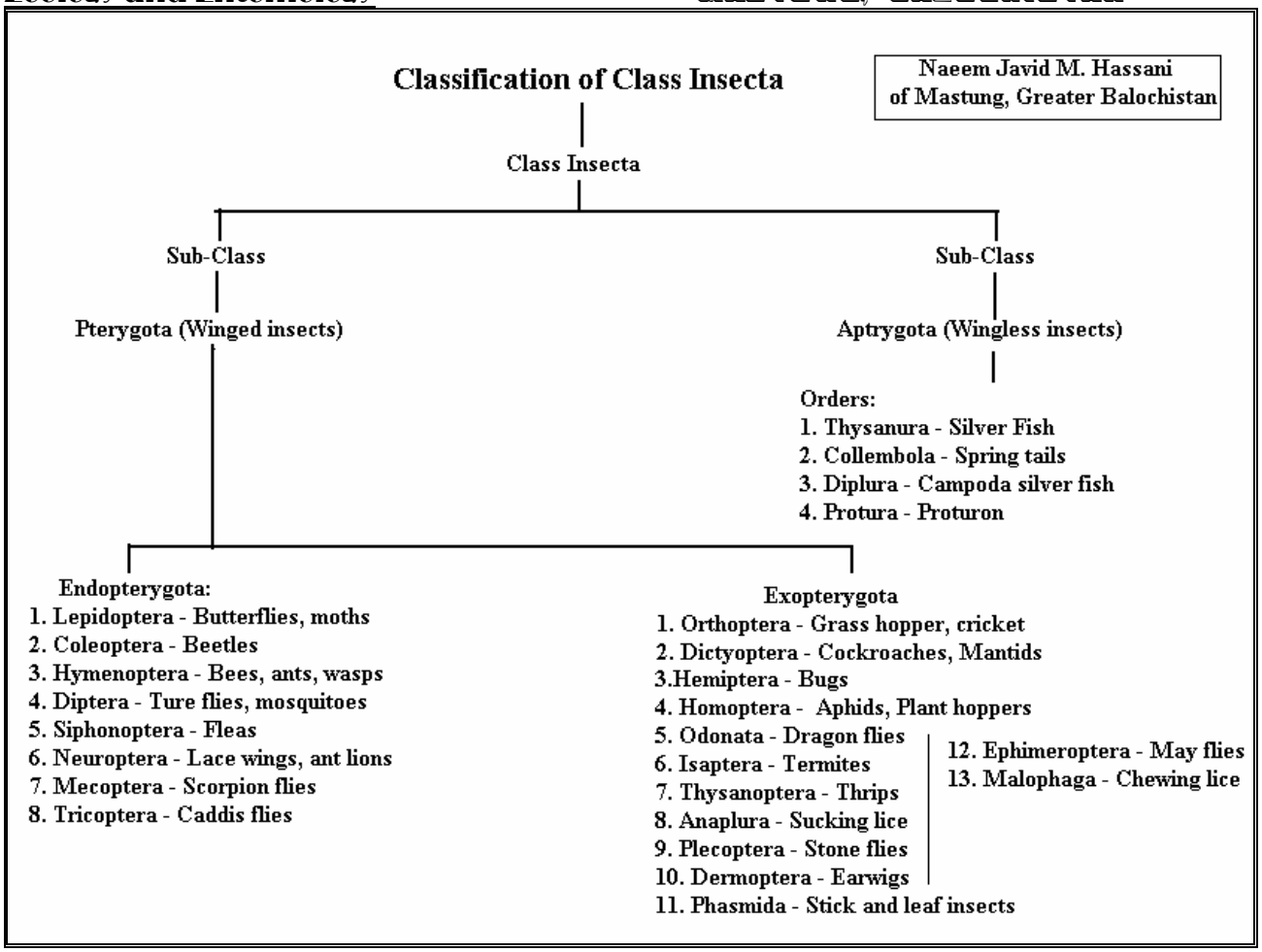
Insect: The word insect comes from [Early 17th century. < Latin *insectum* < *insecare* "cut up" < *secare* "to cut"]. An air-breathing invertebrate animal arthropod with a body that has well-defined segments, including a head, thorax, abdomen, two antennae, three pairs of legs, and usually two sets of wings. There are more than a million species of insects including flies, crickets, bees, beetles, and gnats.

Insects are the diverse organism found in nature. They are either harmful or beneficial to man and crops. The distinct characteristics of which separate them from other animals are as follows:

1. They show bilateral symmetry
2. They possess several pairs of appendages
3. They have a segmented body however in many cases their segments are modified specialiazed and fused.
4. body is usu divided into three parts i) head ii) thorax iii) abdomen
5. All the arthropoes have a covering of a chitinous cuticale on their bodies
6. Coelom is reduced and is called hamocoel because blood flows through it.
7. The nervous system is more highly developed and centralized.
8. Sensory receptors especially the eyes are very advance.
9. Breathing is through the general surface but most of them have specialized breathing organs such as gills and trachea
10. Development is usu by metamorphosis which may involve larval and pupal stage.
11. They have open circulatory system
12. There are four distinct types of arthropods.

Insects are divided into the following Groups and Orders/ classification of insects:

Scientific classification: Insects make up the class Insecta, which is part of the subphylum Unirama and the phylum Arthropoda. There are approximately 29 orders of insects.



Insect Orders:

Insect order	Examples	No of spp	Characteristics
Diplura	Japygids	600	Minute insects that are mainly active at night. Found worldwide, usually in soil, they typically have white bodies, long antennae, and no eyes or wings.
Protura	Telson tails	200	Tiny, flightless insects that feed on decayed organic matter. They have cone-shaped heads that lack antennae.
Collembola	Snow-fleas	2000	Oldest known group of insects. They have drab colors, are able to leap, and usually live in soil, where they feed on decomposing plant matter.
Thysanura	Silverfish	550	Characterized by long antennae and tapering bodies covered in tiny scales.
Ephemeroptera	Mayflies	2000	Fragile insects with two pairs of wings: a triangular front pair and a rounded rear pair. In many species, adults die within hours or days after reaching maturity.
Odonata	Dragonflies, damselflies	5000	Characterized by short antennae, keen vision, and four large wings, which are often brightly colored.
Plecoptera	Stoneflies	3000	Ancient group of insects whose early stages occur in water. Adults commonly have delicate, transparent wings and long antennae.
Grylloblattodea	Cricket-cockroaches	16	Rare, ancient insects with characteristics that are intermediate between crickets and cockroaches.
Orthoptera	Grasshoppers, crickets	17,000	High-jumping insects, most of which can use their forewings to produce sounds.

Phasmida	Walkingsticks	2500	Includes both stick-insects, which resemble sticks, and leaf-insects, which look like leaves. Living in dense shrubbery in tropical regions, these insects are primarily vegetarian.
Dermaptera	Earwigs	1200	Characterized by large, delicate wings and pincers at the ends of their abdomens. The common earwig is often found in gardens, where it feeds on wastes.
Embioptera	Web-spinners	300	Small insects that live communally and are most common in the tropics. Construct silk-lined tunnels and webs beneath stones and in the soil.
Dictyoptera	Cockroaches, mantids	6000	Hardy insects with triangular heads, long antennae, and fan-like wings. Cockroaches are mainly waste-feeders, and they are active at night. Mantids capture prey in the daytime; they are often camouflaged to resemble leaves or flowers.
Isoptera	Termites	1900	Social, nest-building insects with soft, whitish or colorless bodies and strong biting mouthparts. Nest populations range from a few dozen members to hundreds of thousands.
Zoraptera	Angel wings	22	Extremely small insects found in warm, humid climates, often in decaying wood. Both winged and wingless forms may occur in the same species.
Psocoptera	Book-lice	2000	Very small, scavenging insects, often with round abdomens. Commonly found indoors, often beneath peeling wallpaper, in upholstery, or in the bindings of old books. Both adults and larvae can spin silk.
Mallophaga	Biting lice	2800	Minute, wingless insects with mouthparts adapted for chewing rather than piercing. Typically found in the skin of birds and sometimes mammals, where they feed on skin fragments, skin secretions, feathers, and hair.
Anoplura	Sucking lice	300	Tiny insects similar to biting lice, except that mouthparts are adapted for sucking. Found in the skin of birds and mammals, they contribute to the spread of some diseases, including typhus fever.
Hemiptera	Bedbugs, aphids, cicadas	5600	Characterized by sucking mouthparts used for feeding on either plant or animal tissues.
Thysanoptera	Thrips	5000	Minute insects with a fringe of fine hairs bordering each edge of their wings. Sometimes called thunder-flies because they are particularly active in summer thunderstorms.
Neuroptera	Lacewings, antlions	4000	Characterized by long antennae, chewing mouthparts, and two pairs of large, intricately veined wings.
Coleoptera	Beetles, weevils, fireflies	330,000	Largest order of insects, characterized by hard bodies and chewing mouthparts. Adults are plant feeders and typically have two pairs of wings.
Strepsiptera	Stylopids	370	Minute, beetle-like insects that parasitize other, larger insects. Females live sedentary lives and are visited by males, which fly rapidly with wings that produce a tiny humming noise.
Mecoptera	Scorpionflies	400	Oldest group of fully metamorphosing insects. They have slender bodies and heads with beaklike extensions.
Siphonaptera	Fleas	1400	Wingless parasites that suck the blood of mammals or birds. Powerful hind legs enable them to jump from one host to another. Members of this group were responsible for spread of plague in medieval Europe.
Diptera	Mosquitoes, fruit flies, black flies	85,000	Known as the true flies, considered the most accomplished fliers of all insects, with an ability to fly backward, forward, and sideways. With few exceptions, they all have a single pair of wings, as well as structures called halteres that help them achieve balance in flight.
Lepidoptera	Butterflies, moths	160,000	Two pairs of wings, covered with thousands of overlapping scales of varying colors. They have large compound eyes and mouthparts modified for sucking plant nectar. Caterpillars, the larval form, mostly feed on plant leaves.
Trichoptera	Caddisflies	5000	Adults resemble dull moths, but their wings are covered with fine hairs rather than scales. They have soft bodies and poorly

			developed mouthparts, and they usually live near water.
Hymenoptera	Bees, wasps, ants	145,000	Some are known for their highly evolved social organization, but most species are nonsocial. All have mouthparts designed for chewing and undergo complete metamorphosis.

Q9: Name the forest Nursery Pest Insects and give life history and control of any one.

A number of Insects damage forest crops, especially at nursery level. Following are the important nursery pest insects:

Forest Nursery Pests:

1. Cutworms
2. Grasshoppers and crickets
3. Army worms
4. Cockchafers
5. Termites
6. Semul shoot borer
7. Aphids
8. Leaf miners
9. Poplar defoliators
10. Poplar pith borers
11. Mites.

1. Poplar Defoliator (*Ichthyuva anastomosis*):

- **Distribution:**

It is found throughout Pakistan with heavy infestation in Mianwalli and Jehlum.

- **Importance:**

It is a serious pest of poplars in Pakistan. The population of the pest multiplies enormously quite often and causes complete defoliation of tree which affects tree growth adversely.

- **Identification:**

Moths are grey brown in color having dense hairy thorax by the female and antennae pectinate in both sexes. Caterpillars being hairy

- **Life History:**
  - **Emergence of adults**

    The moths from the cover wintering pupae emerge in March. Mating usu takes place at night.
  - **Oviposition**

    On the average a single female lays 462 eggs with a range of 231 to 1531 eggs. Eggs are laid on the lower surface of the leaves in dusters. Eggs are semi-globular, and light green in color.
  - **Incubations**

    Incubation period varies from 3 to 10 days. Average being 6 days
  - **Larval Period**

    The newly hatched larvae feed in groups by scraping epidermis thereby skeleonizing the leaves. Later instars larvae feed gregariously and eat away the entire leaves leaving only the larger veins intact. Larval period in an average in 19 days; range being 13-28 days. One generation on an average

completes its life cycle in 40 days range being 35-59 days. There are 8 to 9 generations in a year.

- **Pupal period**

Pupation takes place b/w the leaves by spinning loose silken cocoons and sometimes on the ground pupal period for 7-14 days. The last generation passes winter in pupal stage b/w the stitched leaves.

- **Control**
  - **Mechanical**

In winter the fallen leaves should be collected and burnt so that the pupae are destroyed.

- **Biological Control**

Insect parasites of order hymenoptera (an insect that has two pairs of membranous wings and a very thin waist and that lives in socially complex colonies, e.g. the wasp, ant, and sawfly. Order: *Hymenoptera*) should be augmented by avoiding insecticidal sprays.

- **Chemical Control**

Antimoultant chemicals such as *Dimilin* and *Alsystin* should be sprayed against the pest as these chemicals are safe to wildlife and the environment.

Q10: Define Diapauses and differentiate it from hibernation and Aestivation. How can these be broke?

Diapause:

Slow-down of animal's metabolism: a period during which the metabolism of some animals or insects slows down, temporarily suspending their bodily development and growth. Such periods are linked to seasonal or environmental changes.

During embryonic development and in post embryonic stages growth can be halted resulting in a dormancy or diapause. This phenomenon permits an insect ot survive under seasonal situations when normal metabolism would produce death through lack of food, exhaustion of stored fat or freezing. Most temperate spp and some tropical one enter into diapause during some stages in life cycle.

In many instances this dormancy is genetically programmed normally includes diapause in temperate regions

Types of Diapause:

There are basically two types of diapause:

i) Obligatory
ii) Facultative

Hibernation:

Hibernation, state of reduced activity that occurs in some animals during the winter. In cold weather most animals must eat large quantities of food to obtain the energy needed to carry on normal body activities. In winter, however, food often becomes scarce; so many animals cannot survive unless they hibernate. A hibernating animal greatly reduces normal body activities that expend energy. It survives on energy reserves, such as fat, stored in the body.

During hibernation, an animal lowers its metabolic rate—the rate at which an animal uses energy and stops generating the heat necessary to keep its body temperature above that of the environment. As body activities slow, the animal becomes less and less capable of coordinated movement, gradually slipping into a state of dormancy, or torpor. If, however, the animal's body temperature slips below a certain range, the animal will

generate heat to boost body temperature to a safe range. Animals may hibernate for several months, but they do not remain completely inactive during this time. Hibernation typically occurs in bouts, or episodes, lasting from a few days to a few weeks depending upon the animal, body size, outside temperature, and time of year. These bouts of inactivity are interspersed with brief periods of activity, when the animals increase their body temperature to a normal level.

Although hibernation helps animals survive adverse environmental conditions, hibernating animals can still freeze to death, and their lack of mobility and coordination makes them vulnerable to predators. To help protect them, many animals hibernate in protected areas, such as caves or underground burrows. These sites often remain several degrees above freezing even when the outside temperature is far colder. Animals usually choose sites that are inaccessible to predators.

Difference b/w Hibernation and Aestivation:

Hibernation:

Dormancy resulting from reduced temperatures.

Aestivation:

Dormancy resulting from increased temperatures.

(From left: Sohail, Shabeer, Shahzad, Ibrar, Kashif, Naveed, Mubbashir, Ashfaq, and Ayaz Shah)

Q11: What do you know about microbial method of control of insect pests?

Throughout the age wherever harmful insect have been observed, the attention of entomologists has been attracted by activities of parasites predators and pathogens. The possibility that these organisms might be used for control purposes was recognized early.

There are two distinct approaches to use of biological factors for control.

i) Introduction of these organisms into areas where they do not occur and ii) the encouragement of those organisms already present

When we talk about microbial method of controlling of insect pest, we talk about Bacteria, Fungi, and Virus.

Bacteria:

Reference to bacterial disease of insects is very common in entomological literature.

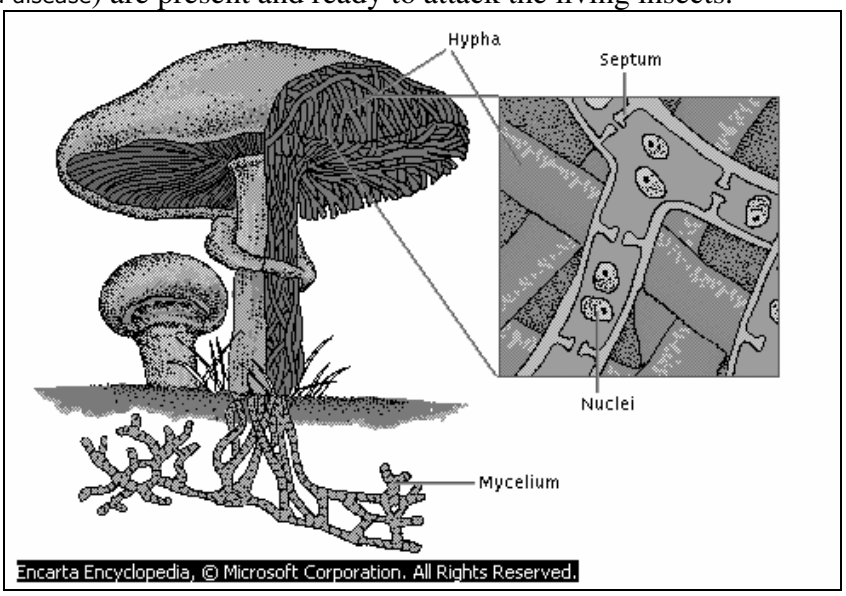
Uncertainty of action under forest conditions seems to be characteristic of many bacteria especially those that infect defoliators and other insects that live on the exposed surface of plant in certain seasons they may destroy almost every individual of a host spp in such a way that none of the host will be killed.

Fungi:

Fungi have been used successfully to control insects, fungus pathogens, roundworms, and other organisms that cause damage and disease to agricultural crops.

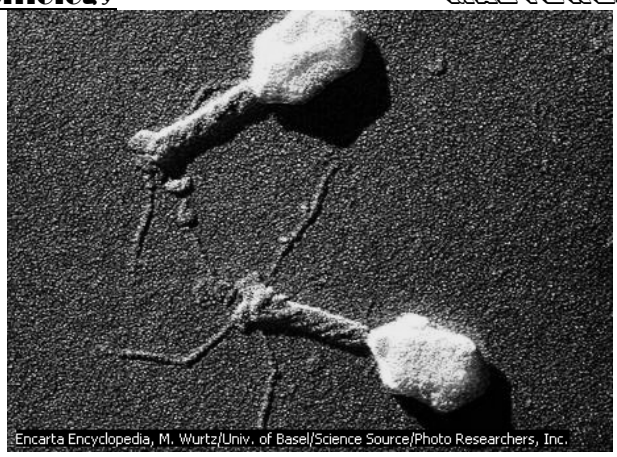
Parasitic fungi are able to check insects outbark lonely under relatively warm moist conditions. Insect outbreaks occur mostly frequently during periods of dry weather. Consequently at the time when need them the most, there is little or nothing that can be done to encourage fungal infections of insect pests. So we must recognize that during moist period.

Many fungi that attack insect may live as saprophytes for long time (periods); thus when conditions are favorable the inoculums (material injected into a person or animal to create resistance to a disease) are present and ready to attack the living insects.



Viruses:

The use of virus for control of insects in unites states was experimental until 1976, when EPA registered a nucleopolyherous virus (NPV) of the genus Baculovirus against larvae of Douglas- fir tussock moth.



Q12: What are termites? How can you control them in various situations?

Termite:

Common name for numerous species of social insects that can damage wooden structures such as furniture or houses. Termites mostly feed on dead plant material, generally in the form of wood, leaf litter, soil, or animal dung, and about **10%** of the estimated **4,000** species (about **2,600** taxonomically known) are economically significant as pests that can cause serious structural damage to buildings, crops or plantation forests., most are distributed in tropical countries and some inhabit the temperate regions. Termites are widely distributed throughout Pakistan. In Pakistan, **89** spp are native.

Importance:

Termites are known also as white ants, a misnomer based on superficial similarities in the appearance and habits of these two insect groups. True ants belong to a more advanced insect order that includes also the bees and the wasps. Termites are relatively primitive; they have thick waists and soft bodies and undergo incomplete metamorphosis. Nevertheless, they have developed remarkable patterns of social behavior that are almost as elaborate as those of the ants, social bees, and wasps.

Termite Colony Showing Different Caste Members: Termite colonies, or termitaries, range in size from several hundred to several million individuals. Common in tropical rain forests, there may be from several dozen to several thousand termitaries per acre of forest. Many species of termites have a caste system, consisting of reproductive individuals, workers, and soldiers. The workers build the nest and provide food and grooming for the greatly enlarged egg-laying female and all other colony members. The soldiers provide protection for the colony, while the reproductive pair ensures a constant supply of eggs. In many species, egg production may approach 30,000 eggs per day.

Termites severely damage wood and wood products. It also damages forest trees which are under stress particularly in drought and dry conditions. Damage seedling in forest nurseries and young transplants in the field is common. The losses caused by termites run into millions of rupees every year.

Scientific classification:

Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Subclass:	Pterygota
Infraclass:	Neoptera
Superorder:	Dictyoptera
Order:	Isoptera

Species of Termites:

Out of 89 spp, following are the most economically important spp.

1. **Heterotermes indicole:**
   It is one of the notorious subterranean wood eating termites in Pakistan.
2. **Coptotermes hemei:**
   It is one of the common termite spp living on trees and wood in Pakistan.
3. **Odontermes obesus:**
   A mound building termite
4. **Microtermes obesi:**
   It commonly feeds on stumps, logs, and twigs of shisham, mulberry, and acacia,
5. **Anacanthotermes vagans:**
   It is found throughout the Balochistan, usu destroying ceiling and other structures.

Damages of Termites:

- Damage to living plant and trees.
- Debarking and hollowing of under ground roots of trees.
- Feeding on dead bark of trees above ground under shelter of mud galleries.
- Artificial regeneration is affected
- By penetration into roots or holes of a tree through wounds.
- Damaging young transplants in the field.
- It also destroys the felled wood stumps, poles, fencing bridges, and railway sleepers.
- It damages wooden door frames, window frames, furniture, boxes, books, papers, clothes, baruk's na pats.
- It also damages wood and wood articles in store.

Control of Termites:

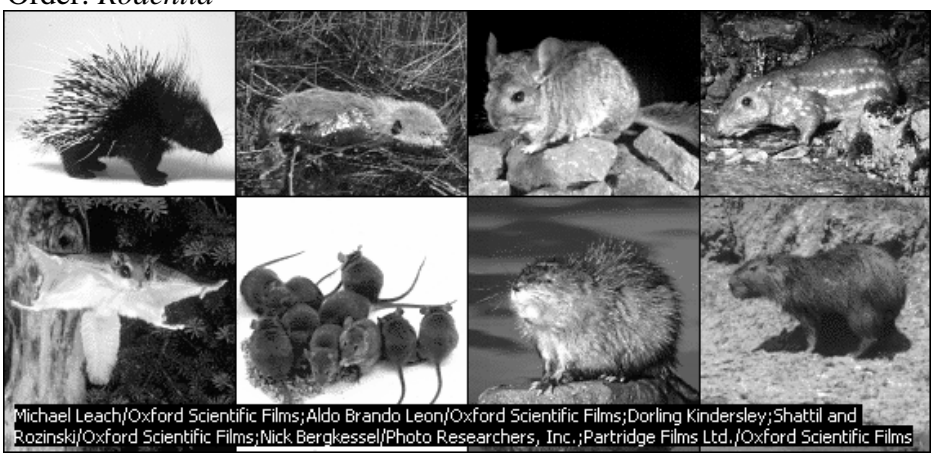
- **Nurseries:**
  - Sanitation: Dry straw wood and plant debris should be removed.

- Irrigation: Proper irrigation should be given to Nurseries to avoid termite attack.

- **Uses of Fertilizers:**
  - To keep plant healthy as termite usu attack under stressed plants.
- **Treatment of Soil:**
  - Tenekil plus 100% EC should be sprayed 5 ml / liter of water on the bed and soil.
- **Treatment of Transplant:**
  - Pits should be treated before transplanting of plants or after transplanting.
- **Treatment of Trees:**
  - Poison bands should be applied around the tree.
  - Spray of Tenekil plus should be done at the base of the trees 10ml / liter of water.
- **Treatment of Timber:**
  - Brushing of timber with the solution of Tenekil plus.
  - Spraying of Tenekil plus at 10 ml / liter of water.
  - Dipping the logs in Tenekil plus solution.
- **Building:**
  - Tenekil plus 100% EC should be sparayed before claying foundation and then at the pith level to make building termite proof.
  - In case of termite attack in the building, the base of the wooden structures should be sprayed with tenekil plus 100% EC.
  - To prevent damage by termites, building foundations should be built of materials other than wood. Because cracks may develop in such foundations and provide passageways to the wooden parts of the structure, the soil should be treated first with an insecticide to discourage termitic incursions.
  - Control is obtained also by using wood treated with creosote or some other poisonous chemical. Because most worker termites cannot live without moisture, the termitaries should be exposed to dry air.

Q13: Discuss the role of rodents in forests of Pakistan. Giving examples

Rodent: A small animal of an order with large gnawing incisor teeth that continue growing throughout the animal's life, e.g. a mouse, rat, squirrel, or marmot. Rodents make up more than a third of all living mammal species and are adapted to all terrestrial habitats. Order: *Rodentia*



Rodents:

Rodents represent nearly 40 percent of all mammal species. Over 1700 species of rodents, including (top from left) porcupines, beavers, chinchillas, pacas, (bottom from left) flying squirrels, mice, muskrats, and capybaras, can be found in nearly every terrestrial and arboreal habitat. The success of this group is due in part to its adaptability to new food sources and habitats and its relatively brief reproductive cycle.

There are more species of rodents than of any other mammalian order; more than 400 genera and about 2,000 species are widely distributed throughout the world. The order *Rodentia* contains several families of makkals which are of great importance in the forestry as well as in other disciplines like agriculture.

Many rodents are economically injurious, destroying crops and stored foods. Rodents such as the house mouse and the Norway and black rats sometimes carry disease. Some species, such as the muskrat and beaver, are valued for their fur; dams built by beavers help to prevent erosion. Albino strains of the mouse and rat are important in biological experimentation. The white mouse, the gerbil, and the guinea pig are popular house pets.

Among the large rodents **beavers** are fur-bearer and have great economic importance.

The rodents inhabiting the forest life are as follows:

- Porcupines
- Squirrels
- Rats and mice

- **Pecopines**

- A large rodent whose body is covered with long protective quills that it can erect in defense against predators. Families: *Hystricidae, Erethizontidae*
- These are the most unique and interesting mammals living in the forest areas.
- They damage the forest area on large scale when they are abundantly present.
- They prefer food plants such as Hemlock, red spruce, sugar maple, fir and shisham.
- They are slow moving animals.
- Excellent climbers (see above pic), spending much of their time on trees, where they get a large part of their food.
- They are active in all seasons.
- On ground they live in dunes, hollow trees, and similar shelter.
- They are more active at night.
- They attack the fresh, green vegetables frequently. Such as herbaceous plants, young, tree leaves, seedling, nurseries, etc.

- **Squirrels:**

- The tree and ground squirrels include about 230 species and the so-called flying squirrels include about 43 species.
- The animals are in all parts of the world except Australia.
- Ground squirrels occupy a wide rang of habitat from deserts to high mountains.
- They dig the burrows from one foot to 100 feet. Long.
- The depth of average burrow is 6 feet.
- They consume different type of vegetation.
- They also feed on nuts, fruits, and seeds of a large variety of plants.
- Insects, earthworm, mice, small birds, their eggs and young are also eaten
- Not all the squirrels are harmful, some spp living in remote areas serve as food for predatory birds and mammals.
- Some spp of squirrels of grasslands take half of their food from insects such as grasshoppers, crickets, beetles, ants and insect eggs, thus, helping in control of these insects.

- **Rats and Mice:**

- Rats have extremely powerful teeth, with which they often gnaw through wooden planks to get at stores of food, and they have even been known to bite holes in lead pipes
- A mouse is a small rodent that has a brown or grayish brown coat and a long, mostly hairless tail. Family: *Muridae, Cricetidae* while rats belong to Genus: *Rattus*
- They are usually nocturnal and live in human habitations, in forests, in deserts, and on seagoing ships.
- They are extremely prolific, breeding 1 to 13 times a year and producing 1 to 22 young in a litter.
- Most species of rats are herbivorous, but some are omnivorous. Rats have an average lifespan of eight months to one year in the wild and two to three years in captivity.

- Rats and mice (plural of mice) do a lot of damage in nurseries, young plantation and forest.
- The roots, barks, fruits and seeds are damaged.
- The great variety of herbs, shrubs, plantations, and trees provide a variety of food for rats and mice.
- Many fallen trees seeds are taken by them
- On large trees a steady attach on root system and bark, reduces tree health and reproductive capacity.
- In nurseries and plantation, water courses and ditches are damaged by burrows which result in wastage of water during irrigation.
- One of their severe damage is piping in the ground.
- They are regarded as the greatest enemies of artificial regeneration.
- Some rats and mice also provide food for predatory birds and mammals and serve as conservation for wild life.

Q14: Name insect pests of Poplars and give life history and control of any one.

Following are the important insect pests (with diseases) of Poplar in Pakistan:

Aeolesthes sarta (Poplar sapwood borer or Quetta borer)
Apricona cinerea (Poplar pith borer)
Ichthyura anastomosis (Poplar defoliator)

***Aeolesthes sarta* (Poplar sapwood borer or Quetta borer):**

Distribution:

A. sarta commonly known a Quetta borer, is widely distributed in dry, cold and hilly areas of Pakistan. It is found in Peshawar, Quetta, Chiltral, Gilgit, Dir, Swat, and Rawalpindi.

Economic Importance:

It is a serious pest of *Poplus nigra*, *P. euramericana, P. alba* damaging almost 70 t0 100% and killing 20 t0 40% trees in these areas.

Identification:

Beetles are 32 to 44mm large, elonagatte, steel grey in clor. The antennae are more than twice the length of the body in male and less than the length of the body in female.

Life History:

1. **Emergence**: These beetles emege in March and April. Making round exit holes in the poplar stems. Mating takes place on the main trunk of poplar trees. After mating female lays eggs in April on main trunk of trees.
2. **Oviposition**: Eggs are laid in groups on main trunk in wound scars made by the female. Eggs are white and elliptical in shape. A female lays from 22 – 238 eggs, average being 64 per female.
3. **Longevity of adults**: Male after mating can live for 19 – 25 days while female for 7 – 5 days.
4. **Incubation Period**: Incubation period ranges from 12 to 20 days with an average of 15 days. Incubation takes place from April to May.
5. **Larval Periods:**
   Just after hatching grubs feed on soft bark and later on penetrate into the bark by making thin galleries. As grubs grow in size they bore irregular wider galleries form ark to sapwood. These galleries are packed with wood dust in case of severe infestation sapwood in the main trunk is tunneled and bark girdled resulting in mortality of the trees. The grown up grubs pupate in the

sapwood making a pupal chamber. Larval period is 17 months. From April/ May to October/November of the following year.

6. **Pupal Period:**
   Pupal period varies from 3 – 4 months. Punation takes place in October/November and remains in the chamber till March next year. Life cycle is completed within 2 years.

Control:

1. **Silvicultural:** As healthy trees are not attacked therefore poplars should be kept healthy by proper irrigation and fertilizers. Female lays eggs in wounds therefore pruning or other mechanical injury should be avoided during March/ April.
2. **Biological:** Common crow, wood packers, feed on early instant grubs. A fungus, *Beaveris bassiana* infect the grubs of the pest.
3. **Chemical:** Two sprays of BHC insecticide during March/ April on poplar stems can kill the emerging beetles before mating and egg laying thus avoiding fresh infestation.

Q15: What is meant by integrated pest mgt? Give briefly various components.

Integrated pest management (IPM):

It is a recently developed technology for pest control that is aimed at achieving the desired control while reducing the use of pesticides. To accomplish this, various combinations of chemical, biological, and physical controls are employed. In the past, pesticides were all too often applied routinely whether needed or not. With IPM, pest populations as well as beneficial parasite and predator populations are monitored to determine whether the pests actually present a serious problem that needs to be treated. If properly and extensively employed, IPM might reduce pesticide use by as much as **50 percent,** while at the same time improving pest control. If this goal were achieved, the environmental problems would be minimized, and significant benefits would result for farmers and society as a whole.

Components of IPM:

The key components of integrated pest management

Successful integrated pest management usually has several key components.

1. **Knowledge**. Understanding the biology and ecology of the pest, and the crop (or livestock) is essential. Information about interactions within agricultural ecosystems is also important. IPM draws on the fundamental knowledge of plant and insect biology accumulated by biologists.
2. **Monitoring**. Farmers can use relatively simple techniques to keep track of what pests are where. This information, combined with knowledge of pest life cycles, can enable farmers to implement control measures at the most effective times.
   For example, the pyrgo beetle is a major defoliating insect pest of tea tree in Australia. In the past, growers have used large quantities of chloropyrifos spray to control the beetle, but this chemical has been showing up as an undesirable residue in tea-tree oil products. Clearly, better ways are needed. Field trials have demonstrated that the placement of yellow sticky traps within tea-tree plantations gives growers an accurate picture of beetle distribution at an early stage of their life cycle, enabling better targeted control programs. These would reduce both the need for and the cost of applying chemical sprays.
   Monitoring on a broader scale can also be used to predict pest outbreaks and forewarn farmers to take action. For example, scientists at the Cooperative

Research Centre for Tropical Pest Management have developed a computer model that can predict the migration of the heliothis moth using information on wind patterns and satellite data about the status of host plants and breeding sites.

3. **Economic threshold**. This takes into account the revenue losses resulting from pest damage and the costs of treatment to prevent the damage. Below the economic threshold, the presence of the pest is tolerated. Only when pest numbers increase above the threshold does the farmer take action.
4. **Adaptability**. Farmers must keep informed about what is happening in their paddocks so that they can adapt their strategies to changing circumstances. Research scientists, too, must aim to keep at least one step ahead of the pest, which is also undoubtedly changing and adapting over time.

Q16: Write an essay on the present status and future scope of Sericulture in Pakistan.

Sericulture or **Silk farming**:

It is the rearing of silkworms for the production of raw silk. Although there are several commercial species of silkworms, *Bombyx mori* is the most widely used and intensively studied.

History:

According to Confucian texts, the discovery of silk production from *B. mori* about 2700 BC, although archaeological records point to silk cultivation as early as the Yangshao period (5000 - 10,000 BC). Later it was introduced in Europe, the Mediterranean and other Asiatic countries. Sericulture has become one of the most important cottage industries in a number of countries like China, Republic of Korea, Japan, India, Brazil, Russia, Italy and France. Today, China and Japan are the two main producers, together manufacturing more than 50% of the world production each year.

Production

Silkworm larvae are fed cut-up mulberry leaves, and, after the fourth molt, climb a twig placed near them and spin their silken cocoons. The silk is a continuous-filament fiber consisting of fibroin protein, secreted from two salivary glands in the head of each larva, and a gum called sericin, which cements the two filaments together. The sericin is removed by placing the cocoons in hot water, which frees silk filaments and readies them for reeling. The immersion in hot water also kills the silkworm larvae.

Single filaments are combined to form yarn. This yarn is drawn under tension through several guides and wound onto reels. Finally, the yarn is dried, and the now raw silk is packed according to quality.

Stages of production

The stages of production are as follows:

- The silk moth lays eggs.
- When the eggs hatch, the caterpillars are fed mulberry leaves.
- When the silkworms are about 25 days old, they are 10,000 times heavier than when they hatched. They are now ready to spin a silk cocoon.
- The silk is produced in two glands in the silkworm's head and then forced out in liquid form through openings called spinnerets.
- The silk solidifies when it comes in contact with the air.
- The silkworm spins approximately 1 mile of filament and completely encloses itself in a cocoon in about two or three days but due to quality

restrictions; the amount of usable silk in each cocoon is small. As a result, 5500 silkworms are required to produce 1 kg of silk.

- The silkworm then metamorphoses and changes into a moth; however, the silkworm is usually killed with heat before it reaches this stage. The silkworms are killed, because once they reach the moth stage, the moth secretes a fluid to dissolve the silk so it can emerge from the cocoon. This damages the cocoon and the silk then becomes a lower quality. Some silkworms are allowed to live to be used for breeding.
- The silk is obtained from the undamaged cocoons by brushing the cocoon to find the outside ends of the filament.
- The silk filaments are then wound on a reel. One cocoon contains approximately 1,000 yards of silk filament. The silk at this stage is known as raw silk. Just one thread consists of 48 individual silk filaments. This could lead to at least 4000 yards in a whole cocoon.
- A yarn can now be formed by combining several threads of silk.

***Bombyx* mori:**

Silkworm Larva and Cocoon

The silkworm larva pupates within a cocoon made of one continuously wound silken thread. When straightened, each thread can reach lengths of 900 m (3,000 ft). Silkworms have been cultivated for their silk in Asian countries for centuries.

Scientific classification	
Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Order:	Lepidoptera
Family:	Bombycidae
Genus:	*Bombyx*
Species:	***B. mori***

The **silkworm** is the larva or caterpillar of ***Bombyx mori*** (Latin: "silkworm of the mulberry tree"), the **domesticated silkmoth**. It is entirely dependent on humans for its reproduction and no longer occurs naturally in the wild. A silkworm's preferred food is white mulberry leaves, but it may also eat the leaves of the Osage Orange or the Tree of Heaven. It is native to northern China.

Development

Eggs take about ten days to hatch. Silkworms have a strong appetite. They eat day and night for six weeks, the worms eat almost continuously. At the end of this period, they

are ready to spin their cocoons, and branches of trees or shrubs are placed in their rearing houses. The worms climb these branches and make their cocoons in one continuous thread, taking about eight days for the process. The amount of usable silk in each cocoon is small, and about 5500 silkworms are required to produce 1 kg (2.2 lb) of raw silk.
The cocoon is made of a thread of raw silk from **300** to about **900 meters** (1,000 to 3,000 feet) long. The fibers are very fine and lustrous, about **10 micrometers** (1/2,500th of an inch) in diameter. About 2,000 to 3,000 cocoons are required to make a pound of silk. *Based on 1 kilometer (about 1,100 yards) per cocoon, ten unraveled cocoons could theoretically extend vertically to the height of Mount Everest.* At least 70 million pounds of raw silk are produced each year, requiring nearly 10 billion pounds of mulberry leaves. According to E. L. Palmer one pound of silk represents about 1,000 miles of filament. *The annual world production represents 70 billion miles of silk filament, a distance well over 300 round trips to the sun.*
If the animal is allowed to survive after spinning its cocoon, it will release proteolytic enzymes to make a hole in the cocoon so that it can emerge as a moth. This would cut short the threads and ruin the silk. Instead, silkworm cocoons are boiled. The heat kills the silkworms and the water makes the cocoons easier to unravel. Often, the silkworm itself is eaten.

Silkworm legends

In China, there is a legend that the discovery of the silkworm's silk was by an ancient empress called Xi Ling-Shi. She was drinking tea under a tree when a ball of silk fell into her tea. She picked it out and started to wrap it around her finger, she slowly felt a warm sensation. When the silk ran out, she saw a small cocoon. In an instant, she realized that this cocoon was the source of the silk. She taught this to the people and it became widespread. There are many more legends about the silkworm.
The Chinese guarded their knowledge of silk. It is said that a Chinese monk smuggled silkworms, in a hollow stick, out of China and sold the secret to Europe.

PRESENT STATUS AND FUTURE SCOPE OF SILKWORM IN PAKISTAN:

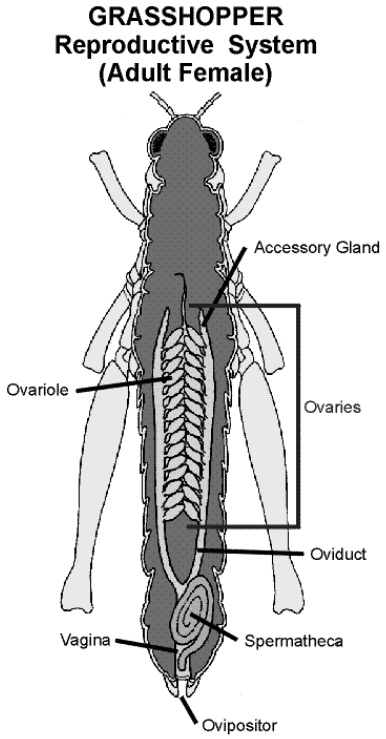
Sericulture is an important cottage industry in Pakistan and Azad Kashmir. During the past twenty years tremendous losses have been caused to the industry from disease infestations of the silk-worm B.Mori, all over the country. The present work concerned the survey and control of diseases of silkworms in Punjab, N.W.F.P and Azad Kashmir. Data were collected from the various rearing areas, i.e., Multan, Pirawala Chichawatni, Changamanga, Gujranwala, Sialkot, Gujrat, Daffar, Head Faqirian, Kahuta, Naushera, Texilla, Hazro, Sargodha, Cambelpur, Hasanabdal and Rawalpindi area in the Punjab; Peshawar, Mardan, Haripur, Bannu, Kohat, Parachinar, Miranshah, Swat, Dir. Lower Chitral and upper Chitral in the N.W.F.P, and Mirpur Afzalpur, Bhimber, Muzaffarabad. Hajera, Bagh, Kotli, Khoeratta, Panjan, Tattapani, Panjera, Sehansa, Palendri, Tararkhel, Rawalakot, Leepa valley etc, in Azad Kashmir.
The rearing periods of **B. Mori** were determined for each province, and the fluctuations arising due to variations in temperature and humidity were noted.
Details of morphology, biology, and anatomy of B. Mori were studied in the laboratory. The biology of B. Mori was studied in the rearing areas.
Diseased eggs, larvae, cocoons and moths were collected from all over the rearing areas, and the time-table of the appearance of diseases in different rearing areas was also investigated.
Pathogenic and non-pathogenic bacteria were isolated from diseased larvae, pupae, cocoons, moths and surfaces of eggs of B. Mori and from the air and dust in rearing

rooms and storage rooms. The pathogenicity of bacteria was tested and techniques were developed for quick pathological analyses and histopathology. The nature and extent of disease was also studied in various areas.
Further, the symptoms of the diseases were studied in larvae, pupae, and moths and the site of development of pathogen in the larvae was studied. The life cycle and site of infection of Nosema bombycis was studied in detail.
A thorough search was launched for tracing out the various races of B. Mori reared all over the country. The survey and laboratory studies showed that Chinese, Korean, Italian races and their hybrids have become susceptible to diseases in due course of time.
Details of methods of determining diseases of B. Mori were studied in Sericulture Grainage centers located at Murree, Khanaspur, Rawalakot, and Tararkhel. It was noted that primitive storage conditions favored the enhancement of diseases. The study found that while some 30-35 sears of green cocoons may be obtained from one ounce of healthy B. Mori eggs, diseased B. Mori eggs, costing several millions of rupees, have to be destroyed each year in the Punjab, N.W.F.P and Azad Kashmir. Further, millions of larvae may die as a result of various epidemic diseases. Larvae surviving such diseases may spin cocoons of very poor quality.
The department of Sericulture is also present in District Mastung on Shef ana Road, of Greater Balochistan. The annual production of is ☺ and it helps to increase in the GDP of the country by ☹ %.
Considering the great economic importance of sericulture, particularly to poor villagers who depend upon this industry, there is an urgent need for controlling the disease of B. Mori.

Q17: Describe the reproductive system of grasshopper illustrating with diagram.

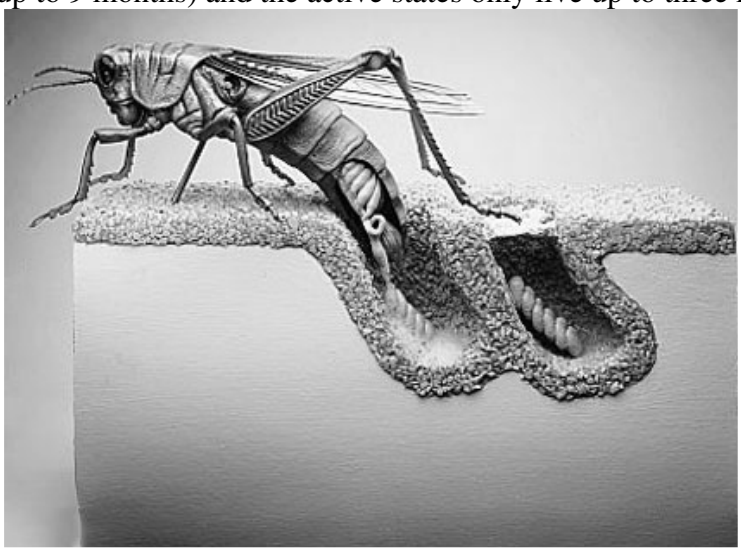
A small number of insects give birth to live young, but for most insects, life starts inside an egg. Insect eggs are protected by hard shells, and although they are tiny and inconspicuous, they are often laid in vast numbers. A female house fly, for example, may lay more than 1,000 eggs in a two-week period. As with all insects, only a small proportion of her young are likely to survive, but when conditions are unusually favorable, the proportion of survivors shoots up, and insect numbers can explode. In the 1870s, one of these population explosions produced the biggest mass of insects ever recorded: a swarm of locusts in Nebraska estimated to be over 10 trillion strong.
In all but the most primitive insects, such as bristletails, the animal that emerges from the egg looks different from its parents. It lacks wings and functioning reproductive organs, and in some cases, it may not even have legs. As they mature, young insects undergo a change of shape—a process known as metamorphosis.

Most insects undergo one of two varieties of metamorphosis: incomplete or complete. Dragonflies, grasshoppers, and crickets are among the insects that experience incomplete metamorphosis. In these insects, the differences between the adults and the young are the least marked. The young, which are known as nymphs (or naiads in the case of dragonflies), gradually develop the adult body shape by changing each time they molt, or shed their exoskeleton. A nymph's wings form in buds outside its body, and they become fully functional once the final molt is complete.



Grasshopper reproduction

• Gonads and the ducts which carry sexual products to the exterior and accessory glands
• In males, the testes with follicles, spermatocytes , spermatozoa
• During reproduction, the male grasshopper introduces sperm into the ovipositor through its reproductive organ and inserts its spermatophore, a package containing the sperm, into the female's ovipositor
• The female then lays the fertilized **egg pod**, using her ovipositor and abdomen to insert the eggs about one to two inches underground
• The egg pod contains several dozens of tightly-packed eggs that look like thin rice grains
• In temperate zones, many grasshoppers spend most of their life as eggs through the cooler months (up to 9 months) and the active states only live up to three months.



Q18: Explain in detail the role of harmful and beneficial insects.

The majority of insects are either directly or indirectly beneficial or neutral in relation ship to human beings. Although pest insects attract the most attention, many insects are beneficial to the environment and to humans. Some insects are harmful for human being as well.

USEFUL ROLE OF INSECTS:

Insects are Pollinators:

For humans, pollination is by far the most useful activity that insects carry out. The most important crop pollinators are bees although visitors to flowers also include small beetles and a variety of flies.

Although pest insects attract the most attention, many insects are beneficial to the environment and to humans. Some pollinate flowering plants (for example wasps, bees, butterflies, ants). Pollination is a trade between plants that need to reproduce, and pollinators that receive rewards of nectar and pollen. A serious environmental problem today is the decline of populations of pollinator insects, and a number of species of insects are now cultured primarily for pollination management in order to have sufficient pollinators in the field, orchard or greenhouse at bloom time.

Insects as Recyclers of Nutrients:

Other beneficial insects live on organic remains, helping to recycle nutrients that plants can then use. These recyclers include minute insects, such as springtails, and a variety of heavily built beetles. Some of these beetles bury the carcasses of small birds and mammals, slowly scraping away the ground until the corpse sinks below the surface. Others scavenge for animal droppings, or dung, rolling it into balls and then burying it as a food store for their young.

Scarab Beetle Rolling a Ball of Dung: A dung beetle—a type of scarab beetle—uses its forelegs to roll a ball of dung. Dung beetles use the dung of plant-eating animals both as food and as a nursery for their

young. To prevent competitors from stealing the valuable dung, the beetles press bits of dung into a ball and roll it to a hiding place, where they bury it under the ground.

Insects in Biological Control:

In recent decades, insects have also been turned on each other known as biological control; this method often involves using predatory or parasitic insects to kill insect pests like praying mantis. In another form of biological control, sterilized males are raised in captivity and then released. The sterile males mate with wild females, and although the females lay eggs, the unfertilized eggs fail to develop.

Praying Mantis
The praying mantis is a carnivore that feeds on smaller insects, such as flies, crickets, and grasshoppers. Its name reflects the prayer like posture it assumes while waiting for its victims to venture within reach of its long, barbed forelegs.

Insects as Food:

It has long been known that insects are an important component in the diet of birds. 50 to 60 percent of the food of birds comes from insects.

Besides, in some parts of the world, insects are used for human food, while being a taboo in other places. There are proponents of developing this use to provide a major source of protein in human nutrition. Since it is impossible to entirely eliminate pest insects from the human food chain, insects already are present in many foods, especially grains. Most people do not realize that food safety laws in many countries do not prohibit insect parts in food, but rather limit the quantity. According to cultural materialist anthropologist Marvin Harris, the eating of insects is taboo in cultures that have protein sources that require less work, like farm birds or cattle.

Insects as Scavengers:

Many insects, especially beetles, are scavengers, feeding on dead animals and fallen trees, recycling the biological materials into forms found useful by other organisms, and insects are responsible for much of the process by which topsoil is created.

Thx to Insectivores:

The most useful of all insects are insectivores, those that feed on other insects. Many insects can potentially reproduce so quickly that if all of their offspring were to survive, they could literally bury the earth in a single season. However, for any given insect one can name, whether it is considered a pest or not, there will be one to hundreds

of species of insects that are either parasitoids or predators upon it, and play a significant role in controlling it. This role in ecology is usually assumed to be primarily one of birds, but insects, though less glamorous, are much more significant.

Assassin Bug
The predatory habits of the assassin bug help to control agricultural pests. The bug paralyzes its prey with venom, and then sucks out the contents of the insect's body.

Production of Useful Substances:

Insects also produce useful substances such as honey, wax, lacquer and silk. Honey bees have been cultured by humans for thousands of years for honey, although contracting for crop pollination is becoming more significant for beekeepers. The silkworm has greatly affected human history, as silk-driven trade established relationships between China and the rest of the world. Fly larvae (maggots) were formerly used to treat wounds to prevent or stop gangrene, as they would only consume dead flesh. This treatment is finding modern usage in some hospitals. Adult insects such as crickets and insect larvae of various kinds are also commonly used as fishing bait.

Silkworm Larva and Cocoon
The silkworm larva pupates within a cocoon made of one continuously wound silken thread. When straightened, each thread can reach lengths of 900 m (3,000 ft). Silkworms have been cultivated for their silk in Asian countries for centuries.

Insects as Destroyers of Weeds:

Close to 50% of all insect spp are herbivores. Insect herbivores feed on unwanted plants or weeds are considered beneficial to human beings whereas those damage crops and forests are considered insect pests.

Aesthetic Values of Insects:

The aesthetic values of insects are unlimited and priceless because of the number, king, variations, and behavioral patterns. For example, butterfly and certain beetles

Fritillary
Fritillaries are among the most vividly colored butterflies. They are found primarily in temperate regions of North America, Europe, and Asia. The great spangled fritillary is shown here.

Scientific Value on Insects:

Beetles, houseflies, cockroaches, honeybees, wax moths, etc have been used for many years in numerous basic studies on genetics, development biology and population dynamics. Insects are chosen over other animals because they are easily collected and reared.

HARMFUL ROLE OF INSECTS:

Harmful insects fall into two categories: those that **eat crops** and those that **spread disease.** Together, they make up a huge collection of species, and the cost of controlling those runs into billions of dollars each year.

Insects damaging crops:

Insects can damage crops in a variety of different ways. Subterranean larvae chew their way into roots, while above the surface; insects feed on leaves, flowers, or seeds. Plant-eating insects are a natural part of all ecosystems, but in farms, insects can be problematic. Insects are especially able to flourish in monocultures—large areas that have been planted with a single crop, rather than with a mixture of crops—because this farming method provides a small number of insect species with nearly unlimited access to their favorite food.

One of the most infamous plant-eating pests is the Colorado beetle, a native species of North America. This beetle, which originally fed on wild relatives of potatoes, greatly expanded its range after large-scale potato cultivation began in the 16th century. The Colorado beetle is now found in many parts of the world.

Weevils
These colorful weevils are members of an order of insects called Coleoptera, which also includes beetles. Weevils, which lay their eggs in plant stalks, are extremely destructive agricultural pests.

Sap-sucking insects, particularly aphids, are also a major problem for farmers. They weaken plants by stealing the energy-rich sugars in sap, and they also spread viruses that cause disease. Because aphids can breed without mating, a few founder females can quickly cause widespread damage.

Disease causing insects:

A small number of insects attack humans, spreading diseases as they feed. Most important among these are fleas and biting flies. Fleas spread bubonic plague, one of the most feared diseases. Flies, mosquitoes, and their relatives are the most dangerous insects of all. Mosquitoes are responsible for spreading three diseases that are most common in the tropics: yellow fever, a parasitic infection called filariasis, and malaria. ***Malaria alone is estimated to kill between 1.5 million and 2.7 million people each year.***

Insects as Pest:

Many insects are considered pests by humans. Insects commonly regarded as pests include those that are parasitic (mosquitoes, lice, bed bugs), transmit diseases (mosquitoes, flies), damage structures (termites), or destroy agricultural goods (locusts, weevils). Many entomologists are involved in various forms of pest control, often using insecticides, but more and more relying on methods of biocontrol.

Effect on Human being and it domesticated animals:

Insects that injure human beings and their domesticated animals can be divided into three general groups. i) House hole pests ii) Insects of Medical importance iii) Pests of livestock, poultry and domestic pest

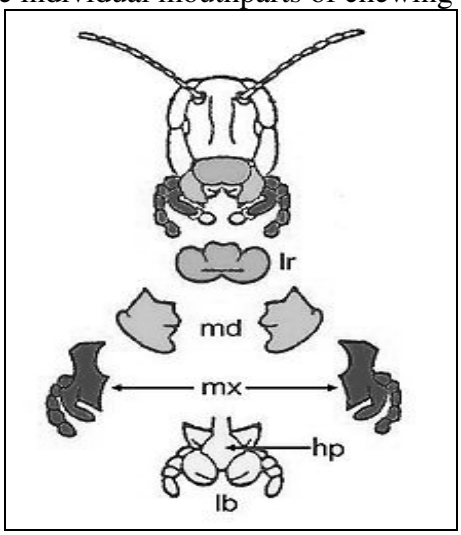
Household insect pests such as cockroaches, ants, flour beetles, and carpenter ants can cause in an individual home. Many insect pests attack livestock, poultry, and domestic pests. A number of insects damage our stored foods. Insects even damage carpets, clothes, and other fibers. Termites, powderpost beetles and carpenter ants are examples of insects that cause damage to wood products.

Q19: Describe briefly the various types of insect mouth parts.

Mouthparts:

The mouthparts of arthropods have evolved into a number of forms, each adapted to a different style or mode of feeding. Most mouthparts represent modified, paired appendages, which in ancestral forms would have appeared more like legs than mouthparts. In general, arthropods have mouthparts for **cutting** and **chewing**, **piercing** and **sucking**, **siphoning** (a tubular organ, especially of arthropods and mollusks, by which water is taken in or expelled), and **filtering**.

Insect mouthparts exhibit a range of forms. The earliest insects had *chewing* mouthparts. Specialization includes mouthparts modified for *siphoning*, *piercing*, *sucking* and *sponging*. These modifications have evolved a number of times. For example, mosquitoes (which are flies) and aphids (which are bugs) both pierce and suck, however female mosquitoes feed on animal blood whereas aphids feed on plant fluids. This section provides an overview of the individual mouthparts of chewing insects.



Chewing mouthparts of a grasshopper. Legend: lr, labrum; md, mandibles; mx, maxillae; hp hypopharynx; lb, labium.

Labrum:

The labrum is a flat extension of the head (below the clypeus), covering the mandibles. Unlike other mouthparts, the labrum is a single, fused plate (though it originally was — and embryonically is — two structures). It is the upper-most of the mouthparts and located on the midline. It serves to hold food in place during chewing by the mandibles and thus can simply be described as an upper lip.

Mandible:

Chewing insects have two mandibles, one on each side of the head. They are typically the largest mouthpart of chewing insects, being used to masticate (cut, tear, crush, chew) food items. They open outwards (to the sides of the head) and come together medially.

Maxilla:

Paired maxillae cut food and manipulate it during mastication. Maxillae can have hairs and "teeth" along their inner margins. At the outer margin, the galea is a cupped or scoop-like structure, which sits over the outer edge of the labium. They also have palps, which are used to sense the characteristics of potential foods.

Labium:

The labium is a single structure, although it is formed from two fused secondary maxillae. It can be described as the floor of the mouth. With the maxillae, it assists manipulation of food during mastication.

Hypopharynx:

The hypopharynx is a somewhat globular structure, arising from the base of the labium. It assists swallowing.

Myriapods:

Ventral view of forcipules of a centipede, arising from the first body segment

Myriapods comprise four classes of arthropod, each with a similar morphology: Class Chilopoda (centipedes); Class Diplopoda (millipedes); Class Pauropoda; and Class Symphyla. Myriapod mouthparts are similar to those of chewing insects, although there is some variation between the myriapod classes. A labrum is present but sometimes is not obvious and forms an upper lip, often in association with an epistome. The labium is formed by first or second maxillae. The preoral cavity so-formed contains paired mandibles and a hypopharynx.

Forcipules:

Centipedes, in addition to their mouthparts, possess a pair of "poison claws" or forcipules. These, like the maxillipeds of crustaceans, are modified legs and not true mouthparts. The forcipules arise from the first body segment, curving forward and to the midline. The tip is a pointed fang, which has an opening from a venom gland. The forcipules are used to capture and poison prey.

Crustaceans:

Crustaceans comprise a number of classes, with various feeding modes supported by a range of adaptions to the mouthparts. In general, however, crustaceans possess paired mandibles with opposing biting and grinding surfaces. The mandibles are followed by paired first and second maxillae. Both the mandibles and the maxillae have been variously modified in different crustacean groups for filter feeding with the use of setae.

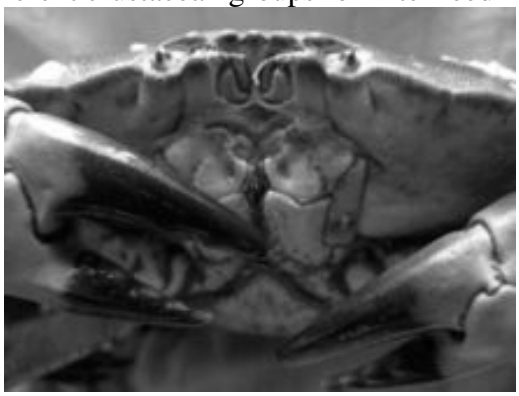


Figure 3: The mouthparts of an edible crab: the third maxillipeds conceal the remaining mouthparts; the claws are not considered mouthparts.

Maxillipeds:

Up to the first three pairs of legs are modified to maxillipeds, which assist manipulation of food items, by passing food forward to the mandibles for chewing or to the maxillae for cutting into smaller pieces.

Setae:

Filter feeding crustaceans have setae on modified appendages that act as filters. Filter feeding may have developed in association with swimming, with early morphological adaptions occurring on the appendages of the body trunk. Subsequent adaptions appear to have favoured forward filtering appendages. Filtering appendages generate water currents that bring food items into reach for collection by setae. Other setae may be used to brush the filtering setae clean, and yet other setae may transport food items to the mouth.

Cirri:

Barnacles have thoracic appendages modified for feeding, the cirri, which filter suspended food particles from water currents and pass the food to the mouth.

Chelicerates:

Chelicerates comprise four classes of arthropod, with similar gross morphology but defining differences: Class Xiphosura (horseshoe crabs); Class Eurypterida (the extinct eurypterids); Class Arachnida (spiders, scorpions, ticks and mite)s; and Class Pycnogonida (sea spiders). Chelicerates are in part defined by possessing chelicerate appendages, although crustaceans also possess chelate appendages. Chelicerates are more easily distinguished from other arthropods in lacking antennae.

Chelicerae:

Chelicerae are chelate appendages that are used to grasp food. For example, in horseshoe crabs they are like pincers, where-as in spiders they are hollow and contain (or are connected to) venom glands, and are used to inject venom to disable prey prior to feeding. In some spiders, the chelicerae have teeth, which are used to macerate prey items to assist digestion by secreted enzymes. Those spiders without toothed chelicerae inject digestive enzymes directly into their prey. Mites and ticks have a range of chelicerae. Carnivores have chelicerae that tear and crush prey, where-as herbivores can have chelicerae that are modified for piercing and sucking (as do parasitic species). In sea spiders, the chelicerae (also known as chelifores) are short and chelate, and are positioned either side of the base of the proboscis or sometimes vestigial or absent.

Pedipalps:

In addition to chelicerae, arachnids also possess a pair of pedipalps. In scorpions, the pedipalps are large and chelate. They are used to capture and hold prey items for stinging before the chelicerae tear the prey into items for digestion. In spiders, the pedipalps of males are modified and function as secondary sex organs (transmission of sperm to the female). The pedipalps of mites and ticks vary depending on the species' feeding mode. They are segmented and may be leg-like or chelate, like a second pair of chelicerae.

Proboscis:

Sea spiders possess a tubular proboscis forward from the body trunk, at the end of which is the opening to the mouth. In those species that lack chelifores and palps, the proboscis is well developed and more mobile and flexible. In such cases it can be equipped with sensory bristles and strong rasping ridges around the mouth.

Q20: Differentiate b/w flat headed and round headed borer. Give biology and control of one of them

FLATHEADED BORER

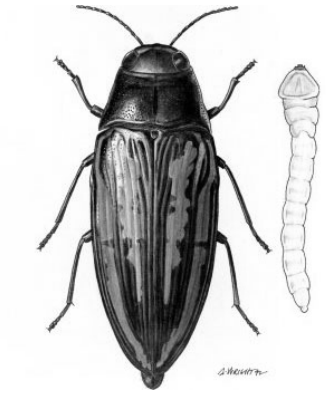
Size

Variable

Color

Metallic-colored

Description



Beetles in the family Buprestidae, or flatheaded borers, are beautifully marked, metallic-colored beetles, varying greatly in size but usually somewhat flattened and boat-shaped. The wood- boring larvae are characterized by a hammer-headed shape produced by a flattened enlargement of the body region behind the head. Flatheaded borers, adults and larvae.

The characteristics of flatheaded borer damage are: medium sized (1/4 - 1/2 inch), oval holes in the wood; flattened tunnels in the sapwood of softwoods and hardwoods; powdery, pale-colored sawdust in tunnels.

Habitat

Buprestis lineata is a common flatheaded borer in the eastern and southeastern United States. It has been found associated with loblolly pine, scrub, longleaf pine, pitch pine, and white pine. It has been found causing damage to log houses in many parts of the southeast and middle Atlantic states. The larvae feed during the summer and early fall,

Life Cycle

Adult females lay eggs singly or in groups on the bark or in crevices in the bark or wood. The young borers (larvae) mine the inner bark or wood. The galleries of the larvae are flattened, usually oval in cross section, and winding, gradually enlarging as the larva increases in size. These larval mines are always tightly packed with fine sawdust arranged in arc-like layers. The adult beetles on emerging through the bark or the wood leave a characteristic oval or elliptical exit hole.

The life cycle may be completed in part of one season or extend to two years. Some forms complete their development in the summer, transform to adults, and do not emerge until the following spring.

Type of Damage

The flatheaded borers are of considerable importance in the forest. The greatest damage results from the larvae boring into the sapwood of recently felled logs. The larvae will attack and feed on a variety of softwoods and hardwoods.

Control

Flatheaded borers are rarely a problem in Virginia, and infestations tend to be small and localized. If control is desired, the best method is to spot treat the local infestations. This can be done by applying insecticides to the surface of the wood to prevent reinfestation, and perhaps kill larvae that feed close to the surface and contact the chemical just below the surface.

ROUNDHEADED BORER

Size

Larvae up to 3 ¼ inches (80mm) or more

Color

Brown, reddish brown or black

Description

Roundheaded borers are elongate, cylindrical, and have large gnawing mandibles. The name roundheaded borer refers to the enlarged thorax directly behind the head. They are sometimes mottled or banded with white or gray. Adult roundheaded borers are often referred to as longhorned beetles because of their long and distinctive 11-segmented antennae, often longer than the beetle's body. The thorax and wing covers on some species bear small, stout spines.

Habitat

Most of the hundreds of species of roundheaded borers are found in weakened, dying, and dead trees. In addition, they feed on felled trees, stumps, and cut firewood. Roundheaded borers feed under the bark and in the sapwood of trees. Adults often emerge from firewood that is brought into the house and may cause concern. They will not infest structural wood and are a nuisance only.

Life Cycle

Adults lay their eggs on weakened and damaged parts of the tree. The larvae bore into the tree, feed under the bark at first, and later bore deep into wood. They may take one to several years to mature before they pupate inside the tree just under the bark.

Type of Damage

They bore long holes as they feed and weaken and destroy the wood. Infested trees are often rendered unusable for commercial purposes. Adult roundheaded borers (longhorned beetles) do very little damage to trees and spend most of their time feeding at flowers on pollen. A few species commonly referred to as twig pruners will kill small branches and twigs.

Control

Insecticide control is not recommended for firewood, simply burn the infested wood first.

Q21: Name and classify any four insect pests of seeds. Mention the biology and control of one of them.

The most important orders and genera of seed insects are:

- Coleoptera
  - *Curculio,* nut weevils
- Diptera
  - *Husk flies*
- Hemiptera
  - *Leptroglossus,* Seed bugs
  - *Tetrya,* Seed bugs
- Hymenoptera
  - *Megastigmus,* Seed chalicds
- Lepidoptera
  - *Cydia,* seed worms

These are the main genera most frequently encountered, but they are by no means the only destroyers of tree seeds.

Nut Weevils (Coleoptera: Curculionidae)

- The nut weevil occurs throughout the North America. The genus *Curculio* contains 27 spp, about evenly divided b/w the eastern and western US.
- The adults are active throughout the growing seasons.

- When nuts begin to ripen, the female bores a hole in the shell and oviposits several eggs.
- After the infested nut falls to the ground, the fully grown larvae usu burrow into the soil.
- Each larva spins a pupal cell, yet may remain in diapause for 1 to 3 years before pupating.
- The most common nut weevils are *Conotrachelus retentus.*
- The *Conotrachelus retentus* also inhabit the nuts as well as fresh wound on the boles of numerous hardwood species.
- **Prevention:** the prevention of nut loss due to insects begins with the location and selection of trees.
- The problem of adjacent spp is severs.
- Tree should be thinned, planted at regular intervals usu at 30 ft interval, to provide full crown exposure.
- These wide spacing permits the removal of competing vegetation, fertilizing, irrigation and application of insecticides.
- The ground should be kept free of all material that falls.
- Insecticides can be used to control the problem.
- Foresters should continue their strong support to the genetics and breeding of superior trees, the use of certified seed and the planting of sound nursery stock.
- Research to control and prevent the mortality factors affecting seed production should receive increased consideration.

Q22: Elaborate in detail the importance of Entomology. How it is useful for Forest Protection.

Entomology(from Greek ἔντομος, *entomos*, "that which is cut in pieces or engraved/segmented", hence "insect"; and -λογία, -*logia*) is the scientific study of insects, a branch of arthropodology, branch of **zoology.**

- The study of entomology is concerned with the study of insects which play a very important role in the ecosystem of every forest.
- They attack the plants during every growth stage, from seed to the finishing product.
- Insects attack plants through many ways.
    - Boring through the wood.
    - Feeding on its roots.
    - Chewing the leaves for getting food.
    - Sucking plants sap.
- Root feeders destroy our nurseries.
- Due to these insects attack the trees which result in either killing of the tree or weakening its strength and hence become susceptible to other insects and pests.
- Wood borers either kill the trees or degrade the timber, leaves ie fodder, and sap suckers decrease the growth rate due to defoliation.
- Every forester should have enough knowledge about Entomology, about insect pest and their control. He should know how and where to obtain information about insect and should be able to apply necessary remedies intelligently.
- A person totally ignorant of insects and their ways, cannot hope to get the best results.

Scope of Forest Entomology:

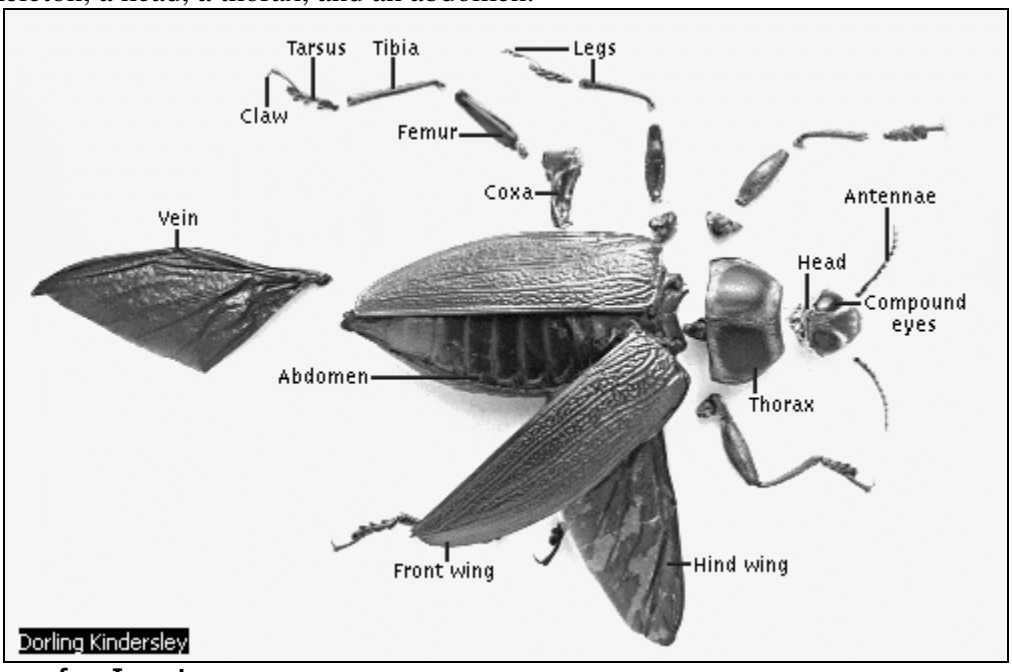
There is wide scope of forest entomology.

- The subject leads to the better understanding of forest life. It includes either curative or protective/ preservative methods to make the forest and forest products save from insects.
- The knowledge helps in control of insects by understanding their environmental conditions.
- The first need of forest entomology is knowledge of Silviculture. Which help in Silvicultural control of insects and diseases or damages caused by them
- Chemical entomology includes spraying, dusting, and fumigation, for the control of insect pests for better control of insect.
- For better control entomologist should know forest ecology and insect ecology ie effect of environment on insects.

Q23: Mention the insect body region. Report main function of each

The body of an insect has **three main parts**—the head, the thorax, and the abdomen. A hard outer covering protects the internal organs, the exoskeleton.

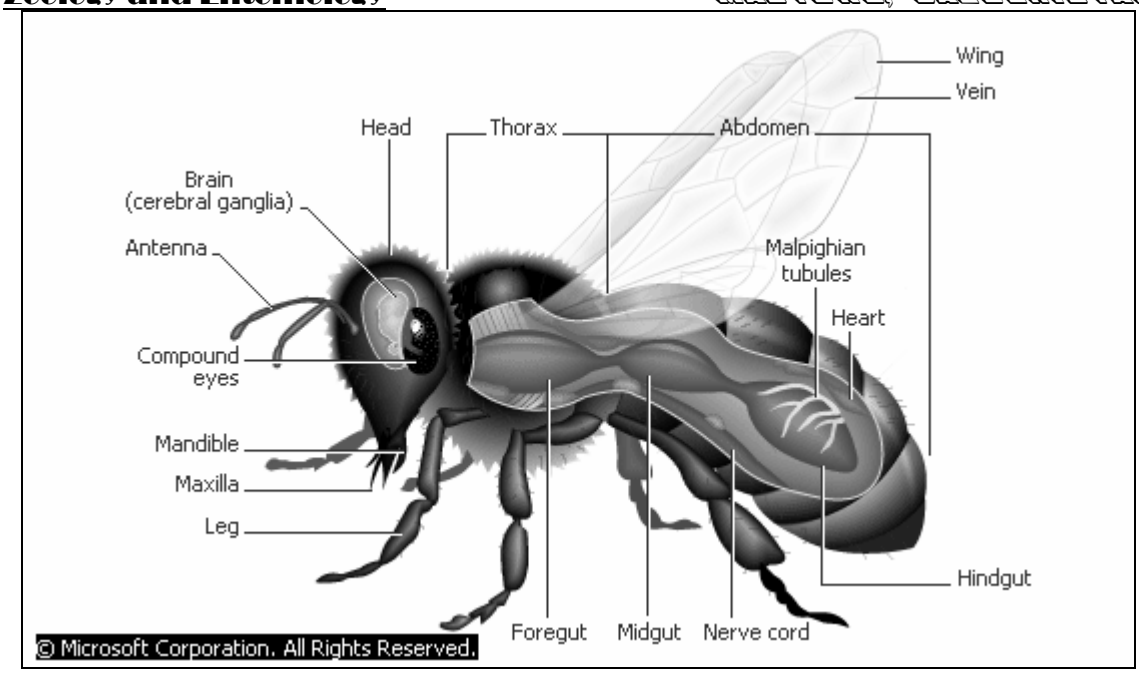
Regardless of their size, all adult insects have a similar body plan, which includes an exoskeleton, a head, a thorax, and an abdomen.



Anatomy of an Insect

This jewel beetle has been dissected to show the various components of its anatomy. The head, or front segment, contains the mouth, eyes, and antennae. The first segment of the thorax, located just behind the head, bears the first pair of legs. The large posterior section of the body, including the second and third segments of the thorax and the abdomen, contains the remainder of the walking legs and all the vital body organs. The wings lack muscles and are manipulated by muscles located inside the abdomen. The outer surface of the body, called the exoskeleton, is protected by a hard chitinous material.

Functions of Insect Body Parts:



Generalized Anatomy of an Insect

All adult insects have three main body parts—the head, which holds an insect's primary sense organs; the thorax, which is the attachment site for the legs and wings; and the abdomen, which contains the organs for digestion and reproduction. All of the insect's soft inner body parts are protected by an external skeleton, or exoskeleton, made of semirigid plates and tubes.

1. **Functions of Exoskeleton:**
   1. The exoskeleton protects the insect, gives the body its form, and anchors its muscles
   2. Like other arthropods, an insect's external skeleton, or exoskeleton, is made of semirigid plates and tubes
   3. In insects, these plates are made of a plasticlike material called chitin along with a tough protein
   4. A waterproof wax covers the plates and prevents the insect's internal tissues from drying out.
   5. Insect exoskeletons are highly effective as a body framework, but they have two drawbacks: they cannot grow once they have formed, and like a suit of armor, they become too heavy to move when they reach a certain size
   6. Insects overcome the first problem by periodically molting their exoskeleton and growing a larger one in its place
   7. Insects have not evolved ways to solve the problem of increasing weight, and this is one of the reasons why insects are relatively small
2. **Functions of Head:**
   - **a.** The head holds most of an insect's sensory organs, as well as its brain and mouth.
   - **b.** An insect obtains crucial information about its surroundings by means of its antennae, which extend from the front of the head, usually between and slightly above the insect's eyes.
   - **c.** Although antennae are sometimes called feelers, their primary role is to provide insects with a sensitive sense of smell.

d. Antennae are lined with numerous olfactory nerves, which insects rely on to smell food and detect the pheromones, or odor-carrying molecules, released by potential mates. For example, some insects, such as ants and honey bees, touch antennae to differentiate nest mates from intruders and to share information about food sources and danger.
e. The antennae of mosquitoes can detect sounds as well as odors.
f. An insect's head is typically dominated by two bulging eyes, which are called compound eyes because they are divided into many six-sided compartments called ommatidia.
g. Insect eyes provide a less detailed view of the world than human eyes, but they are far more sensitive to movement.
h. Insects with poor vision, such as some worker ants, often have just a few dozen ommatidia in each eye, but dragonflies, with more than 20,000 ommatidia, have very keen vision—an essential adaptation for insects that catch their prey in midair.
i. Most flying insects also have three much simpler eyes, called ocelli, arranged in a triangle on top of the head. The ocelli can perceive light, but they cannot form images. Clues provided by the ocelli about the intensity of light influence an insect's level of activity. For example, a house fly whose ocelli have been blackened will remain motionless, even in daylight.
j. The head also carries the mouthparts, which have evolved into a variety of shapes that correspond to an insect's diet.

3. **Functions of Thorax:**
   1. It is the attachment site for the legs and wings
   2. Adult insects can have one or two pairs of wings—or none at all—but they almost always have six legs
   3. It is the insect's center of locomotion
   4. In some insects, such as beetles, the legs are practically identical, but in other insects each pair is a slightly different shape. Still other insects have specialized leg structures.
   5. Unlike the legs, an insect's wings do not contain muscles. Instead, the thorax acts as their power plant, and muscles inside it lever the wings up and down.
   6. In addition to the legs and wings, the thorax contains part of an insect's digestive tract, which runs along the full length of an insect's body. The first section of the digestive tract is called the foregut. In many insects, the foregut contains structures called the crop and the gizzard. The crop stores food that has been partially broken down in the mouth, and the gizzard grinds tough food into fine particles.
4. **Functions of Abdomen:**
   1. Behind the thorax is the abdomen, a part of the body concerned chiefly with digestion and reproduction
   2. The abdomen contains two sections of the digestive tract: the midgut, which includes the stomach, and the hindgut, or intestine
   3. In all insects, a bundle of tubelike structures called the Malpighian tubules lies between the midgut and the hindgut. These tubules remove wastes from the blood and pass them into the intestine.

4. The abdomen holds the reproductive organs of both male and female insects. In males, these typically include a pair of organs called testes, which produce sperm, and an organ called the aedeagus, which deposits packets of sperm, called spermatophores, inside the female.
5. Many male insects have appendages called claspers, which help them stay in position during mating.
6. Female insects typically have an opening in the abdomen called an ovipore, through which they receive spermatophores.
7. Females also have a pair of ovaries, which produce eggs, and many female insects have an ovipositor, which can have a variety of forms and is used to lay fertilized eggs. Among some females, such as infertile bees, the ovipositor functions as a stinger instead of as a reproductive organ.
8. The abdomen is divided into 10 or 11 similar segments, connected by flexible joints. These joints make the abdomen much more mobile than the head or thorax; it can stretch out like a concertina to lay eggs, or bend double to jab home its sting.
9. In many insects, the last segment of the abdomen bears a single pair of appendages called cerci. Cerci are thought to be sensory receptors, much like antennae, although in some insects they may play a role in defense.

Q 24: Write a detailed note on Apiculture.

APICULTURE/ BEEKEEPING:

Beekeeping (or apiculture, from Latin *apis*, bee) is the maintenance of honey bee colonies, commonly in hives, by humans. A beekeeper (or apiarist) keeps bees in order to collect honey and beeswax, for the purpose of pollinating crops, or to produce bees for sale to other beekeepers. A location where bees are kept is called an apiary.

Study of honey bees / Background and History:

For several thousand years of human beekeeping, human understanding of the biology and ecology of bees was very limited and riddled with superstition and folklore. Ancient observers thought that the queen bee was in fact a male, called "the king bee," and they had no understanding of how bees actually reproduced. It was not until the 18th century that European natural philosophers undertook the scientific study of bee colonies and began to understand the complex and hidden world of bee biology. Swammerdam and Réaumur were among the first to use a microscope and dissection to understand the internal biology of honey bees. Réaumur was among the first to construct a glass walled observation hive to better observe activities within hives. He observed queens laying eggs

in open cells, but still had no idea of how a queen was fertilized; nobody had ever witnessed the mating of a queen and drone and many theories held that queens were "self-fertile," while others believed that a vapor or "miasma" emanating from the drones fertilized queens without direct physical contact. Huber was the first to prove by observation and experiment that queens are physically inseminated by drones outside the confines of hives, usually a great distance away.
Following Réaumur's design, Huber built improved glass-walled observation hives and sectional hives which could be opened, like the leaves of a book, to inspect individual wax combs; this greatly improved the direct observation of activity within a hive. Although he became blind before he was twenty, Huber employed a secretary, Francois Burnens, to make daily observations, conduct careful experiments, and to keep accurate notes over a period of more than twenty years. Huber confirmed that a hive consists of one queen who is the mother of all the female workers and male drones in the colony. He was also the first to confirm that mating with drones takes place outside of hives and that queens are inseminated by a number of successive matings with male drones, high in the air at a great distance from their hive. Together, he and Burnens dissected bees under the microscope and were among the first to describe the ovaries and spermatheca, or sperm store, of queens as well as the penis of male drones. Huber is universally regarded as *"the father of modern bee-science"*..

Protective clothing

Beekeepers often wear protective clothing to protect themselves from stings.
While knowledge of the bees is the first line of defense, most beekeepers also wear some protective clothing. Novice beekeepers usually wear gloves and a hooded suit or hat and veil. Experienced beekeepers sometimes elect not to use gloves because they inhibit delicate manipulations. The face and neck are the most important areas to protect, so most beekeepers will at least wear a veil.
Defensive bees are attracted to the breath, and a sting on the face can lead to much more pain and swelling than a sting elsewhere, while a sting on a bare hand can usually be quickly removed by fingernail scrape to reduce the amount of venom injected.
The protective clothing is generally light coloured (but not colourful) and of a smooth material. This provides the maximum differentiation from the colony's natural predators (bears, skunks, etc.) which tend to be dark-colored and furry.
Smoker

Bee smoker with heat shield and hook

Bee smoker:

Smoke is the beekeeper's third line of defense. Most beekeepers use a "smoker" — a device designed to generate smoke from the incomplete combustion of various fuels. Smoke calms bees; it initiates a feeding response in anticipation of possible hive abandonment due to fire. Smoke also masks alarm pheromones released by guard bees or when bees are squashed in an inspection. The ensuing confusion creates an opportunity for the beekeeper to open the hive and work without triggering a defensive reaction. In addition, when a bee consumes honey the bee's abdomen distends, supposedly making it difficult to make the necessary flexes to sting, though this has not been tested scientifically.

Bee colonies:

Castes:

A colony of bees consists of three castes of bee:

- a Queen bee, which is normally the only breeding female in the colony;
- a large number of female worker bees, typically 30,000–50,000 in number;
- a number of male drones, ranging from thousands in a strong hive in spring to very few during dearth or cold season.

THE QUEEN is the only sexually mature female in the hive and all of the female worker bees and male drones are her offspring. The queen may live for up to three years or more and may be capable of laying half a million eggs or more in her lifetime. At the peak of the breeding season, late spring to summer, a good queen may be capable of laying 3,000 eggs in one day, more than her own body weight. This would be exceptional however; a prolific queen might peak at 2,000 eggs a day, but a more average queen might lay just 1500 eggs per day. The queen is raised from a normal worker egg, but is fed a larger amount of royal jelly than a normal worker bee, resulting in a radically different growth and metamorphosis. The queen influences the colony by the production and dissemination of a variety of pheromones or 'queen substances'. One of these chemicals suppresses the development of ovaries in all the female worker bees in the hive and prevents them laying eggs.

Mating of queens

The queen emerges from her cell after 15 days of development and she remains in the hive for 3-7 days before venturing out on a mating flight.Mating flight is otherwise known as 'nuptial flight'. Her first orientation flight may only last a few seconds, just enough to mark the position of the hive. Subsequent mating flights may last from 5 minutes to 30 minutes, and she may mate with a number of male drones on each flight. Over several matings, possibly a dozen or more, the queen will receive and store enough sperm from a succession of drones to fertilize hundreds of thousands of eggs. If she does not manage to leave the hive to mate — possibly due to bad weather or being trapped

within part of the hive — she will remain infertile and become a 'drone layer', incapable of producing female worker bees, and the hive is doomed.
Mating takes place at some distance from the hive and often several hundred feet up in the air; it is thought that this separates the strongest drones from the weaker ones - ensuring that only the fastest and strongest drones get to pass on their genes.

Female worker bees

Almost all the bees in a hive are female worker bees. At the height of summer when activity in the hive is frantic and work goes on non-stop, the life of a worker bee may be as short as 6 weeks; in late autumn, when no brood is being raised and no nectar is being harvested, a young bee may live for 16 weeks, right through the winter. During its life a worker bee performs different work functions in the hive which are largely dictated by the age of the bee.

Period	Work activity
Days 1-3	Cleaning cells and incubation
Day 3-6	Feeding older larvae
Day 6-10	Feeding younger larvae
Day 8-16	Receiving honey and pollen from field bees
Day 12-18	Wax making and cell building
Day 14 onwards	Entrance guards; nectar and pollen foraging

Male bees (drones)

Drones are the largest bees in the hive at almost three times the size of a worker bee. They do no work, do not forage for pollen or nectar and are only produced in order to mate with new queens and fertilize them on their mating flights. A bee colony will generally start to raise drones a few weeks before building queen cells in order to supersede a failing queen or in preparation for swarming. When queen raising for the season is over, the bees in colder climates will drive the drones out of the hive to die, biting and tearing at their legs and wings; the drones have become a useless burden on the colony which can no longer be tolerated.

Differing stages of development

Stage of development	Queen	Worker	Drone
Egg	3 days	3 days	3 days
Larva	8 days	10 days	13 days
Pupa	4 days	8 days	8 days
Total	15 days	21 days	24 days

Structure of a bee colony

A domesticated bee colony is normally housed in a rectangular hive body, within which eight to ten parallel frames house the vertical plates of honeycomb which contain the eggs, larvae, pupae and food for the colony. If one were to cut a vertical cross-section through the hive from side to side, the brood nest would appear as a roughly ovoid ball spanning 5-8 frames of comb. The two outside combs at each side of the hive tend to be exclusively used for long-term storage of honey and pollen.
Within the central brood nest, a single frame of comb will typically have a central disk of eggs, larvae and sealed brood cells which may extend almost to the edges of the frame. Immediately above the brood patch an arch of pollen-filled cells extends from side to side, and above that again a broader arch of honey-filled cells extends to the frame tops.

The pollen is protein-rich food for developing larvae, while honey is also food but largely energy rich rather than protein rich. The nurse bees which care for the developing brood secrete a special food called 'royal jelly' after feeding themselves on honey and pollen. The amount of royal jelly which is fed to a larva determines whether it will develop into a worker bee or a queen.

Apart from the honey stored within the central brood frames, the bees store surplus honey in combs above the brood nest. In modern hives the beekeeper places separate boxes, called 'supers', above the brood box, in which a series of shallower combs is provided for storage of honey. This enables the beekeeper to remove some of the supers in the late summer, and to extract the surplus honey harvest, without damaging the colony of bees and its brood nest below. If all the honey is 'stolen', including the amount of honey needed to survive winter, the beekeeper must replace these stores by feeding the bees sugar or corn syrup in autumn.

Images of harvesting honey


A beekeeper removing frames from the hive


A frame


Smoking the hive


Using a blower to remove bees from honey super prior to removal to honey house


Opening the cells: Uncapping


An uncapping fork


Uncapping the cells by hand using an uncapping knife


Extracting the honey


Filtering the honey

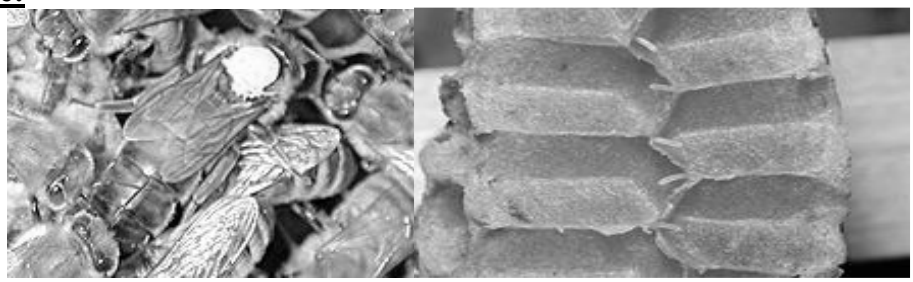

Pouring in pots (after maturation)

Honey bee

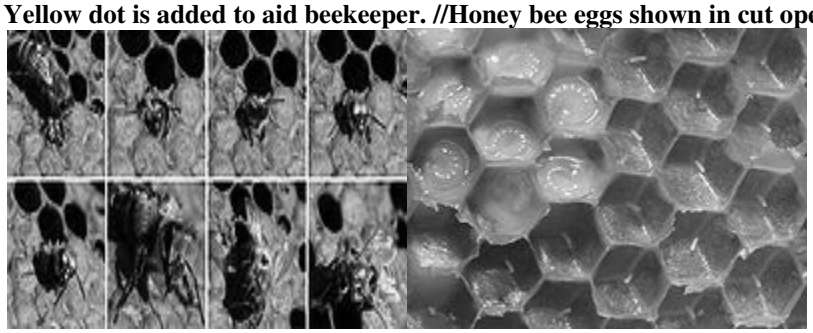
Scientific classification	
Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Subclass:	Pterygota
Infraclass:	Neoptera
Superorder:	Endopterygota
Order:	Hymenoptera
Suborder:	Apocrita
Family:	Apidae
Subfamily:	Apinae
Tribe:	Apini
Genus:	Apis Linnaeus, 1758

Honey bees are a subset of bees, primarily distinguished by the production and storage of honey and the construction of perennial, colonial nests out of wax. Honey bees are the only extant members of the tribe Apini, all in the genus *Apis*. Currently, there are only seven recognized species of honey bee with a total of 44 subspecies though historically, anywhere from six to eleven species have been recognized. Honey bees represent only a small fraction of the approximately 20,000 known species of bees. Some other types of related bees produce and store honey, but only members of the genus *Apis* are true honey bees.

Life cycle:



Queen bee. Yellow dot is added to aid beekeeper. //Honey bee eggs shown in cut open wax cells



Emergence of a black bee (*Apis mellifera mellifera*).// Eggs and larvae

(A memorable picture of M. Sc 2008-2010 @ Ayubia National Park)
(Picture Dedicated to "Esar-ul-Haq" _ From left – sitting – first with a cap)

SHORT NOTES:

28. Biological control of insect pests: (See Q # 7)

29. Caterpillar and looper

Caterpillar: [15th century. Alteration of assumed Old French *catepelose* < assumed late Latin *catta pilosa* "hairy cat"] The larva of a butterfly or moth, with a long soft body, many short legs, and often brightly colored or spiny skin

Looper (Syn Inchworm): geometrid moth larva: the larva of a geometrid moth that has legs only at each end of its body and moves by bringing its rear forward, forming a hump, then moving its front

30. Chalgoza cone-borer and its method of control

***Dioryctria abietella* (Chalghoza cone borer- A SEED PEST):**

Distribution:

Found in Chalghoza forest in Zhob Districts of Quetta and in fir forest in Gallies.

Economic Importance:

The pest causes 30 to 50 % losses in te production of Chalghoza seeds and minor infestation to fir seeds.

Identification:

The moths have the fore-wings grey mottled with black; wings expend 25 – 35 mm.

Life History:

1. **Emergence**: emergence of moth of 1st generation takes place in April and May while that of 2nd generation in July. Moths are nocturnal ie become active in night. Average longitivity of males and females ranges from 2 – 19 days.
2. **Oviposition**: female lays 10 to 200 eggs average being 120 eggs per female of both generations. Eggs are firmly glued to the surface of the cone. Eggs are creamy white and oval in shape.
3. **Incubation Period**: Incubation of both generations ranges from 5 – 16 days average being 10 days.
4. **Larval Periods:**
   Larvae after hatching search for suitable places and then chew their way in the scale. Minute holes are formed through which brownish matter, mixed with their excreta and resin is thrown out. For sometimes they feed on the pulp of the scales. Then they make their way directly toward the seeds, cut their soft shells and start feeding on the edible portion. When a seed is eaten up the larva moves on to the adjacent seed for getting its food. After devouring both the seeds of a scale, it bores towards one of the adjacent scales and start feeding its seeds. This way of feeding is continue until it if full grown. Larval period on an average is 30 days.
5. **Pupal Period:**
   Mature larvae construct cocoon for pupation. Usu a full grown larva remains inside the empty seed shell and spin a silken cocoon there. Sometimes it leaves the shell and spin cocoon at the base of the scale on in a grove on the top of the two seeds or even in the depression on the bark of the scales. Pupal period ranges from 20 to 40 days average being 25 days. There are tow generations in a year. Second generation over winter as larvae/pupae.

Control:

1. **Mechanical:** collection of the infester cones and their destruction by burning to kill the hibernating larva or pupae.
2. **Biological**
   i. Collection of the infested cones and caging them in the cages in the forest to release parasites and predators and hold back the emerging moths. The parasites and predators will attack the remaining population and reduce it to a great extent.
   ii. Encouraging predatory bird to feed on the moths and exposed pupae of the pest.
   iii. Record of pathogen of the pest and their spread in the areas to check the pest.

31. Quetta borer (Q # 15)
32. Walnut weevil (See Q # 22)
33. Coleoptera (See Q # 8 _ table of insects orders)
34. Demestid:
Beetle that eats organic materials**:** a beetle with clubbed antennae that eats organic materials, e.g. cabinet and carpet beetles. Family: *Dermestidae*
35. Differentiate b/w spraying and dusting

Spray: [Early 17th century. < Middle Dutch *sprayen* "sprinkle"] discharge liquid from pressurized container**:** to disperse a liquid in the form of fine particles, or apply a liquid in this form to the surface of something

Dust: to sprinkle a powdery substance over something

36. Economic Threshold

Economic threshold. This takes into account the revenue losses resulting from pest damage and the costs of treatment to prevent the damage. Below the economic threshold, the presence of the pest is tolerated. Only when pest numbers increase above the threshold does the farmer take action.

37. Haemolymph

Hemolymph: [Late 19th century. < hemo- + Latin *lympha* "clear liquid"] invertebrate circulatory fluid**:** a fluid in some invertebrates that functions like the blood in vertebrates

38. Hermaphrodite: organism that has both sexes**:** a plant or animal that has both male and female reproductive organs and secondary sexual characteristics

39. *Agrotis ypsilon* (Cutworm nursery pest)

Distribution:

Throughout Pakistan in forests and agricultural crops. More over found throughout the world.

Economic Importance:

It is serious pest of Pakistan nurseries, agricultural nurseries and crops. They cut young plats close to soil surface resulting death of the plants.

Identification:

The moths have the long, narrow forewings irregularly marked with shades of brown and three lack dashes and the hind wings pale or white.

Life History:

1. **Emergence of adults**: moth emeragence stats at the end of February and early March. Males live for 7-9 days and female for 9-12 days. Mating takes place at night.
2. **Oviposition**: female lays 1200 to 1800 eggs average being 1500 eggs per female. Eggs are laid singly either on leaves of the host plants or on weeds in the crops and nurseries.
3. **Incubation Period**: Incubation period is 4-6 days average being 5 days.
4. **Larval Periods:**
   The early hatched larva feed on the inner surface of the leaves and later shifts to the base of the nursery plants. At day time they hide in the soil and at night come out and cut many plants at the surface of the soil. One or two bites are taken from a plant and then attack another one. In this way it causes a lot of damage to the nursery plants in a single night. In case of heavy population all nursery plants are destroyed in a few days. Larval period of a generation ranges from 23-25 days with an average of 24 days.
5. **Pupal Period:**
   Pupation takes place in the soil in a pupal chamber. Pupal period on an average is 11 days range being 10-12 days. There are 5 generations in a year.

Control:

1. **Silvicultural:**

a. Hoeing of nurseries in March / April to expose larve as well as pupae to sunlight and the preatory birds.
b. Flood irrigation to kill the larvae hiding in the soil

2. **Mechanical:**
   a. Hand collection of larvae / pupae also helps in reduction of the pest population.
   b. Trapping of moths in light traps also reduces the populations.
3. **Chemical:**
   a. BHC or Sevin dust on the seedling at the evening.
   b. Spray of BHC or Sevin on the seedlings at the evening.
   c. Spray of Granulosis virus on seedlings.

40. *Biston regalis (*Kail defoliator*)*

Distribution:

Murree, Forest Division and kail forest at Chikar and Dunna in Azad Kashmir.

Economic Importance:

The pest caused serious defoliation of kail forest in Murree and Azad Kashmir during 1981. the pest defoliated about 2000 acres of forest at Murree and about 5000 acres of forest at Chikar and Dunna in Azad Kashmir.

Identification:

Brownish grey moths with white stripped wings. Male with brushy antennae and female moth with filiform (plane antennae)

Life History:

6. **Emergence of adults**: emergence of moths takes place from the hibernating pupae in the month of May/ June. Male and female mates at night usu on the main truck of the trees. Male live for 3-6 days, average being 4.3 days, while females live for 5-11 days, average being 7.5 days.
7. **Oviposition**: eggs are laid in crackes and crevices of the bark at a rate of 571 to 2735 eggs per female average being 1531 eggs. Eggs are creamy white and spherical in shape.
8. **Incubation Period**: Incubation period is 12-14 days average being 12.5 days.
9. **Larval Periods:**
   Blackish tiny caterpillars hatch from the eggs and ascened to the needles where tey start feeding on the needles. The body of the caterpillar is nacked and has tow distinct horn on the head. The larvae feed for 5-6 month, from May/June to Spetember/October and completely denude the trees of the needles causeing stunted growth and mortality of trees with three repeated defoliations.
10. **Pupal Period:**
    The full grown caterpillars descend to the ground through silken thread for pupation in October/November. The caterpillars make pupal chamber 3-3 inches deep in the soil and pupate there. Pupal period ranges from 7.5 months to 10.5 months. Winter is passed in pupal stage.

Control:

4. **Silvicultural:**
   As this pest exclusively feed on needles of kail trees therefore mixed forest can reduce the extent of damage.
5. **Biological:**

Birds like black bird, yellow billed, blue magpie, clack grango and scarlet miniwet are predators on moths. Earwings lizards, cats, dogs and porcupines were found feeding on the pupae. An insect parasite, Megaselia spp parasitized 35% larvae on 90% pupae on the pest.

6. **Mechanical:**
   As the pest remains in the soil fro 11 to 10 months in pupal stage therefore collection of pupae and their destruction is recommended for safe control of the pest by this method the pest was wiped out from the entire area during 1981-82.
7. **Chemical:**
   Spray of two antimoultant chemical, Dimilin and Alsystin killed 100% larvae with in 9 days in a dose of 0.04%.

41. I.P.M (Integrated Pest Management): (See Q # 16)

42. Isoptera (Q # 8)

43. Monoculture

Monoculture: practice of growing just one crop: the practice of growing a single crop in a field or larger area

44. Polyphagia:

Polyphagia: Diet of many foods: the habit on the part of some animals of feeding on many different types of food

45. Ovipositor:

Ovipositor: tubular egg-laying organ: a tubular organ at the end of the abdomen of some female fish or other organisms, especially insects, that is used to deposit eggs

46. Parthenogenesis

Parthenogenesis: [Mid-19th century. < Greek *parthenos* "virgin"] reproduction without fertilization**:** a form of reproduction, especially in plants, insects, and arthropods, in which a female gamete develops into a new individual without fertilization by a male gamete

47. Predators

Predator: [Early 20th century. < Latin *praedator* < *praedari* "seize as plunder"] carnivorous animal or destructive organism: a carnivorous animal that hunts, kills, and eats other animals in order to survive, or any other organism that behaves in a similar manner

48. Proctodeum

Proctodeum: [Late 19th century. < modern Latin < Greek *prōktos* "anus" + *hodaios* "on the way" < *hodos* "way"] part of embryo**:** the exterior section of an embryo that develops into part of the anal canal

49. Silk worm

Silkworm: moth larva that spins silk**:** a yellowish caterpillar, the larva of an Asian moth, that feeds on mulberry leaves and is a commercial source of silk. Latin name: *Bombyx mori*

50. Silvicultural control (See Q # 7)

51. Sub-esophageal Ganglia

The subesophageal ganglion of insects is composed of three pairs of fused ganglia. It controls the mouthparts, the salivary glands and certain muscles.

The subesophageal ganglion sits beneath the esophagus. It is connected to the supraesophageal ganglion, which sits above the esophagus.

52. Termites (See Q # 12)

53. Viviparous and Oviparous

Viviparous: [Mid-17th century. < Latin *viviparus* "bringing forth alive"] zoology bearing live young**:** bearing live young, not eggs ; botany producing plantlets**:** describes a plant that produces plantlets or bulbils from the flower stem, e.g. the spider plant; botany producing seedlings on plant**:** describes a plant with seeds that germinate and develop into seedlings before being shed from the parent plant, e.g. a mangrove

Oviparous: producing eggs that hatch outside body**:** describes birds, fish, reptiles, and insects that reproduce by means of eggs that develop and hatch outside the mother's body.; relating to egg production outside body**:** relating to the production of eggs that develop and hatch outside the mother's

54. Digestion and excretion in Grasshopper:

The digestive system of insects includes a foregut (stomodaeum - the mouth region), a hindgut (proctodaeum - the anal region), and a midgut (mesenteron). The mouth leads to the muscular pharynx, and through the esophagus to the crop. This leads to the malpighian tubules. These are the chief excretion organs. The hindgut includes intestine parts (including the ileum and rectum), and exits through the anus. Most food is handled in the midgut, but some food residue as well as waste products from the malpighian tubules are managed in the hindgut. These waste products consist mainly of uric acid, urea and a bit of amino acids, and are normally converted into dry pellets before being disposed of.

The salivary glands and midgut secrete digestive enzymes. The midgut secretes protease, lipase, amylase, and invertase, among other enzymes. The particular ones secreted vary within the different diets of grasshoppers.

55. Nervous system of Grasshopper:

The grasshopper's nervous system is controlled by ganglia, loose groups of nerve cells which are found in most species more advanced than cnidarians. The chemical reactions throughout their nervous system slowly destroys itself when in contact with Columbian bananas[*citation needed*]. In grasshoppers, there are ganglia in each segment as well as a larger set in the head, which are considered the brain. There is also a neuropile in the centre, through which all ganglia channel signals. The sense organs (sensory neurons) are found near the exterior of the body and consist of tiny hairs (sensilla), which consist of one sense cell and one nerve fibre, which are each specially calibrated to respond to a certain stimulus. While the sensilla are found all over the body, they are most dense on the antennae, palps (part of the mouth), and cerci (near the posterior). Grasshoppers also have tympanal organs for sound reception. Both these and the sensilla are linked to the brain via the neuropile.

56. Circulation and respiration in Grasshopper:

Grasshoppers have open circulatory systems, with most of the body fluid (haemolymph) filling body cavities and appendages. The one closed organ, the dorsal vessel, extends from the head through the thorax to the hind end. It is a continuous tube with two regions - the heart, which is restricted to the abdomen, and the aorta, which extends from the heart to the head through the thorax. Haemolymph is pumped forward from the hind end and the sides of the body through a series of valved chambers, each of which contains a pair of lateral openings (ostia). The haemolymph continues to the aorta and is discharged through the front of the head. Accessory pumps carry haemolymph through the wing veins and along the legs and antennae before it flows back to the abdomen. This haemolymph circulates nutrients through

the body and carries metabolic wastes to the malphighian tubes to be excreted. Because it does not carry oxygen, grasshopper "blood" is green.

Respiration is performed using tracheae, air-filled tubes, which open at the surfaces of the thorax and abdomen through pairs of spiracles. The spiracle valves only open to allow oxygen and carbon dioxide exchange. The tracheoles, found at the end of the tracheal tubes, are insinuated between cells and carry oxygen throughout the body

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