Unit - 12

Origin and evolution of insects

Structure of the Unit

12.1 Objective

The objective of this unit is to know

- About the starting of insects life
- How the insects had evolved from various groups?
- Why the insects are most successful of all the organisms?
- Fossil insect discoveries gave the answers of many questions about insects.
- Insects are majority in number as far as taxa are concerned.

12.2 Introduction

The entire unit includes system of insect classification based on their evolutionary history. Insects impact the entire food chain, food web, have economic importance and the fossil record of insects tells us much about other life on Earth as well. Insects are continuosly evolving even today . This unit relates the origin and evolution of insects and how insects are changing today. The diversity of form and habitat results in presence of insects everywhere in air, water and land. The insects coming under phylum Arthropoda share some common character with other arthropodan classes. Insect fossils were abundant in the Silurian and Devonian period. The major advancement in insects were the origin of wings that facilitate dispersal, helped them to occupy new niche, being first flight organism it reduced their enemies in air and increased their chances of survival. In the Carboniferous and Permian periods evolution of winged form insects occured with hemimetabolous and holometabolous type of metamorphosis. The pupal stage development gave advantage as larva and adult forms differ in their habitat so competition among the same resources declined. The development of wing and pupal stage cause a profound effect on the success of insect world, diversity and survival.

12.3 Origin and evolution of insect orders

Before going through the origin and evolution of various insect orders we must understand the evolution of arthropods and insects. The evolution deals with three terms viz. **microevolution** when changes occurs in a population or species due to the selection pressure, **macroevolution** when changes occurs in class, order or family i.e larger than the microevolution and **megaevolution** when changes occur in phylum or more large phylogenic patterns.

12.3.1 Theories of phylogeny

The pattern of evolution shows similarities between Annelides, Arthropods and Onychophorans as they have common ancestry. **Snodgrass** (FIG 12.1) kept these three groups in superphylum Annulata. **Cuvie**r divided them into two subphylum Articulata having Annelida and Onychophorans while other being Arthropoda. Snodgrass later supported **Sharov** who said that all the segmented worm like animals diverge into two groups as one gave Polychaete annelids and other gave lobe like paired legs. Lobopods which again divided into two branches Arthropods and Onychophorans.

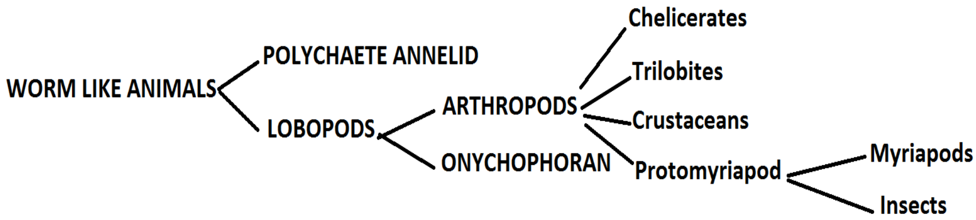


FIG 12.1: Monophyletic origin (Snodgrass and Sharov)

The origin of Arthropods seem to be monophyletic or share a common ancestry i.e. polyphyletic. On the basis of limbs, mandible and movement ,Manton grouped into two branches of polyphyletic origin :uniramous terrestrial line and biramous aquatic line. Uniramous includes Onychophora, Myriapoda and Insecta and biramous includes Crustacea, Trilobita and Chelicerata. Monophyletic all develops from worm like lobopods (FIG 12.2). Polyphyletic origin supported by hemolymoph, paired jointed appendages, trachea, malphigain tubes, compound eyes and cuticle. Monophyletic origin is supported by head ,embryology, eye structure, visceral anatomy and sensilla.

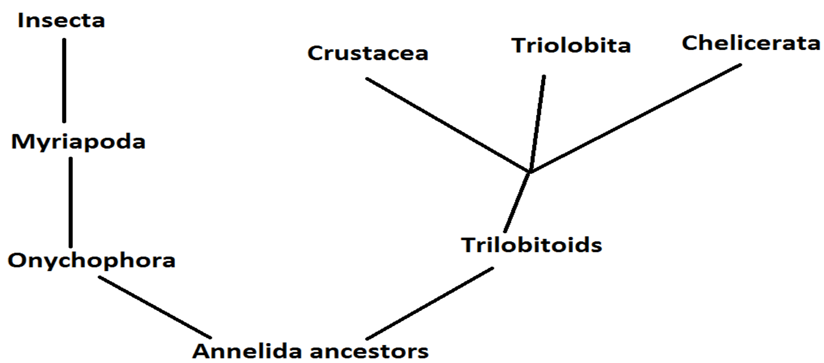


FIG 12.2: Polyphyletic origin (Given by Tiegs and Manton)

12.3.2 Major steps in evolution of insects

The class Insectais supposed to be developed from myriapods or protomyriapods during the Devonian period. Major steps involved in the origin and evolution of insects are (FIG 12.3);

- Appearance of primitive wingless insects in Devonian period
- Development of wings in late Devonian or lower Carboniferous period
- Wing folding on abdomen in lower Carboniferous period
- Complete metamorphosis in Upper Carboniferous period

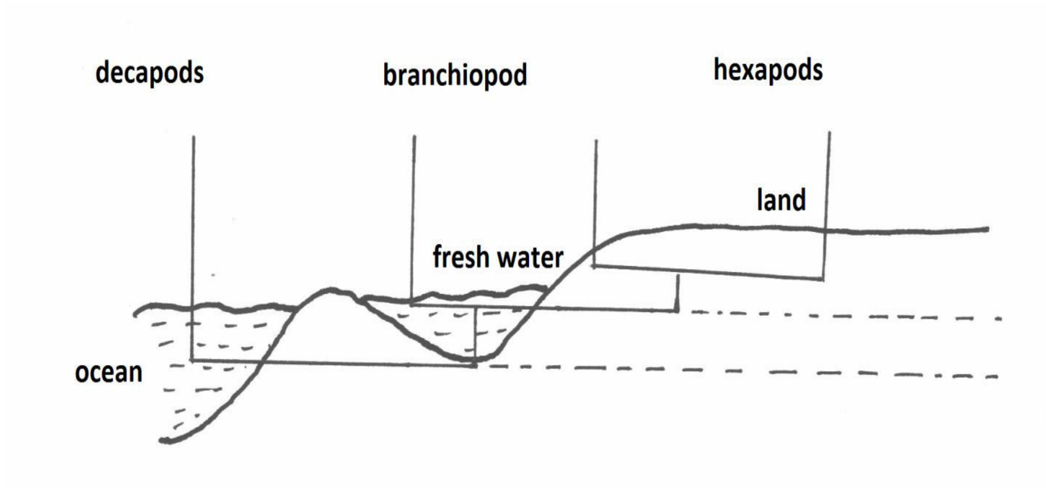


FIG 12.3: Showing the origin of hexapods

Step I- Appearance of primitive wingless insects

Carpenter gave all the major steps in the origin of primitive wingless insects. The first step in their evolution is the segmented, legless, worm like annelid stage, in which each segment is known as somite/metamere, the first segment is prostomium or acron and the last segment is periproct or telson. In the next stage the animal consists of paired lobe like appendages with simple eyes and antenna on first and second segment. The third stage protomyriapod or protoinsect as the name refers consist of insectan character like segmented appendages, somites 4,5 and 6 reduced, primitive head performing the function of food mastication and last appendage performing sensory function. Further stage refers to myriapod stage with 7,8,9 somites becoming primitive mandibulate type of mouth parts. In the next stage pauropod, chilopod or insectan level body divided into head, thorax and abdomen,abdominal segment 8 and 9 modiflied into external genitalia, `cerci on 11 abdominal segment and telson is lost. These insect resembles those of Archeognatha and Thysanura which are wingless or apterygotes, soft bodied and most of them are fossils today.

The theory of the fusion of segments is supported by the fact that the thorax has six legs derived from three segments, and the head has five fused **ganglia** and the thorax has three. Ganglia are nerve bundles, of which there is one in each segment of the annelid worms. The ganglia serve the purpose of brains in worms and play a lesser role, subordinate to the brain. One of the earliest steps in insect evolution was the development of the compound eye. Every terrestrial animal and many insects have **simple eye** only sensitive to the intensity of light and allow it to discern objects more**.** But some orders (e.g. bees) are known to need them for navigation. So the compound eyes develop for vision (FIG 12.4).

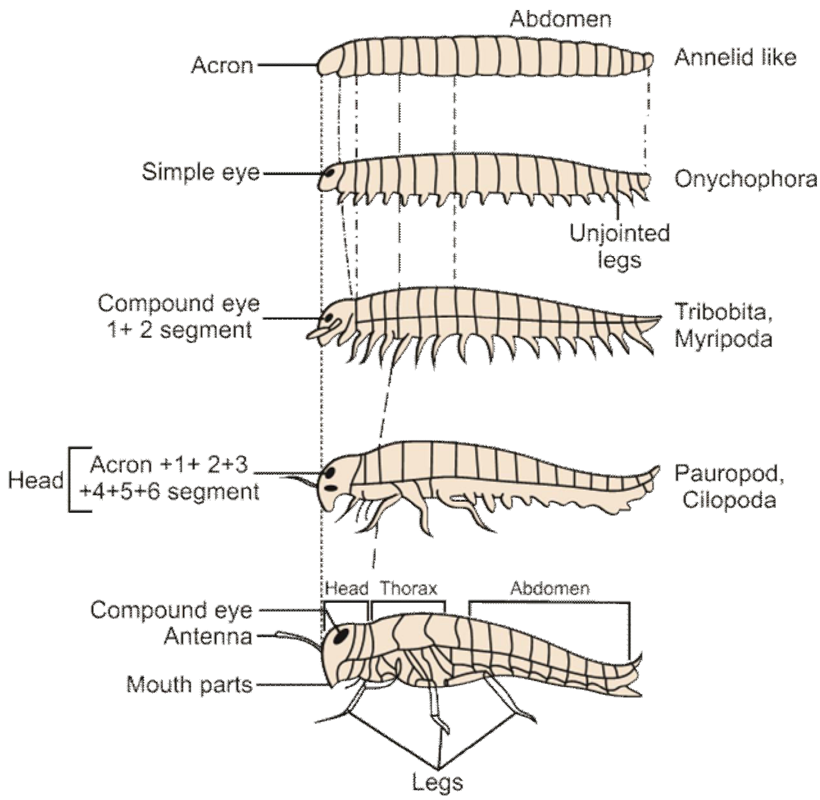


FIG 12.4: Trends of evolution in insects.

Step II- Development of wings

The development of wing was the major step in insect evolution as they were the organisms having power of flight for the first time even before birds. Flight mechanism gave success to the insect as they can escape easily when in danger and no competition is found in air. But the wings were not capable to flex on the abdomen while it remains expanded on rest. They comprised of Paleopterous primitive insects including Odonata and Ephemeroptera which were dominant in Carboniferous and Permain period. Wings were found in the thorax region not due to loss of walking appendages as that in case of vertebrates but they were added to thorax. Widely accepted theory of wing origin , the paranotal theory states that wings are the bilateral extensions of the thoracic nota. Then the wings developed articulation and neuromuscular arrangement for the gliding movement of wings. At the same time tracheal gills also developed in larval aquatic stages.

Step III- Wing folding on abdomen

Next step was the development of wing flexion mechanism which helped the insect to fold their wings on the abdomen**.** This is the character of neopteran insect group term refers to new winged form. This advantage added a significant change in survival of insect because it allowed more efficient escape and hide in the cracks and crevices and thus they become the dominant group of present day insects. As 90% of the all the orders and 97% of all the insect species belong to the Neopteran type e.g. Hemiptera, Dipteral, Hymenoptera, Siphonaptera, Anoplura, Neuropteran,Lepidoptera, Strepsiptera etc.

Step IV- Complete metamorphosis

Due to the evolution of complete metamorphosis, the different stages as larva and adult do not share common habitat and different habitat (aquatic larva and terrestrial-aerial adults) allowed them more efficient life, benefits in their predators danger, more dispersal potential, high fecundity, readily available nutrients.

With all these changes some more changes like tracheal system evolution (allows terrestrial gas exchange), impermeable cuticle (that do not allow water to escape and interrupt invasion of parasites) and fat body (help them to survive in drought and unfavorable condition) also developed.

All these changes divided insects into major groups as follows(FIG 12.6):

1. **Apterygote**s- primitive wingless insect
2. **Pterygotes-**winged insects
    i) **Peleopterous exopterygotes**- wing flexion mechanism absent, simple metamorphosis.
    ii) **Neopterous exopterygotes**- wing flexion mechanism present, simple metamorphosis.
    iii) **Neopterous endopterygotes**- wing flexion mechanism present, complete metamorphosis.

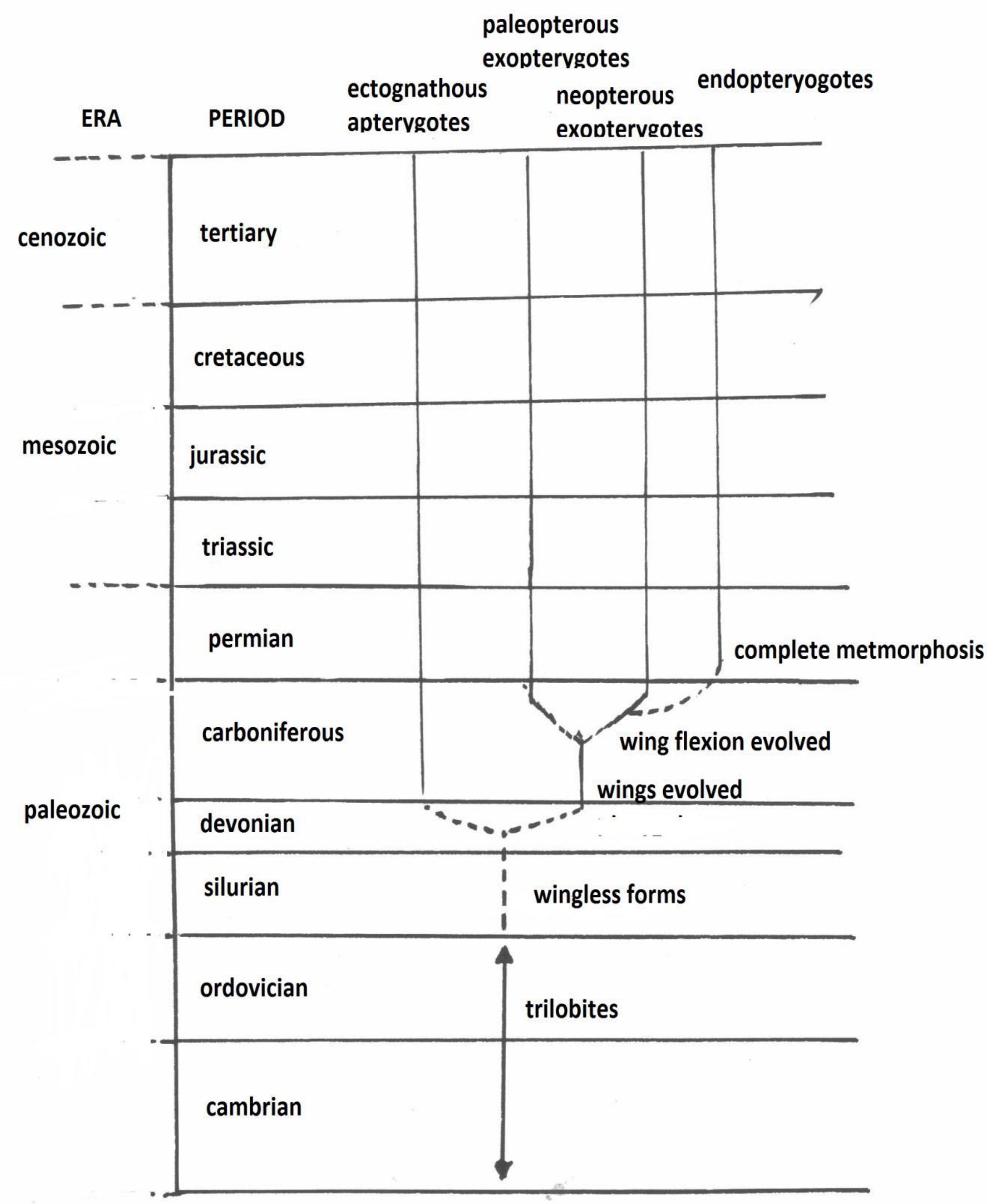


FIG 12.5: Major steps in insect evolution on a Geological time scale

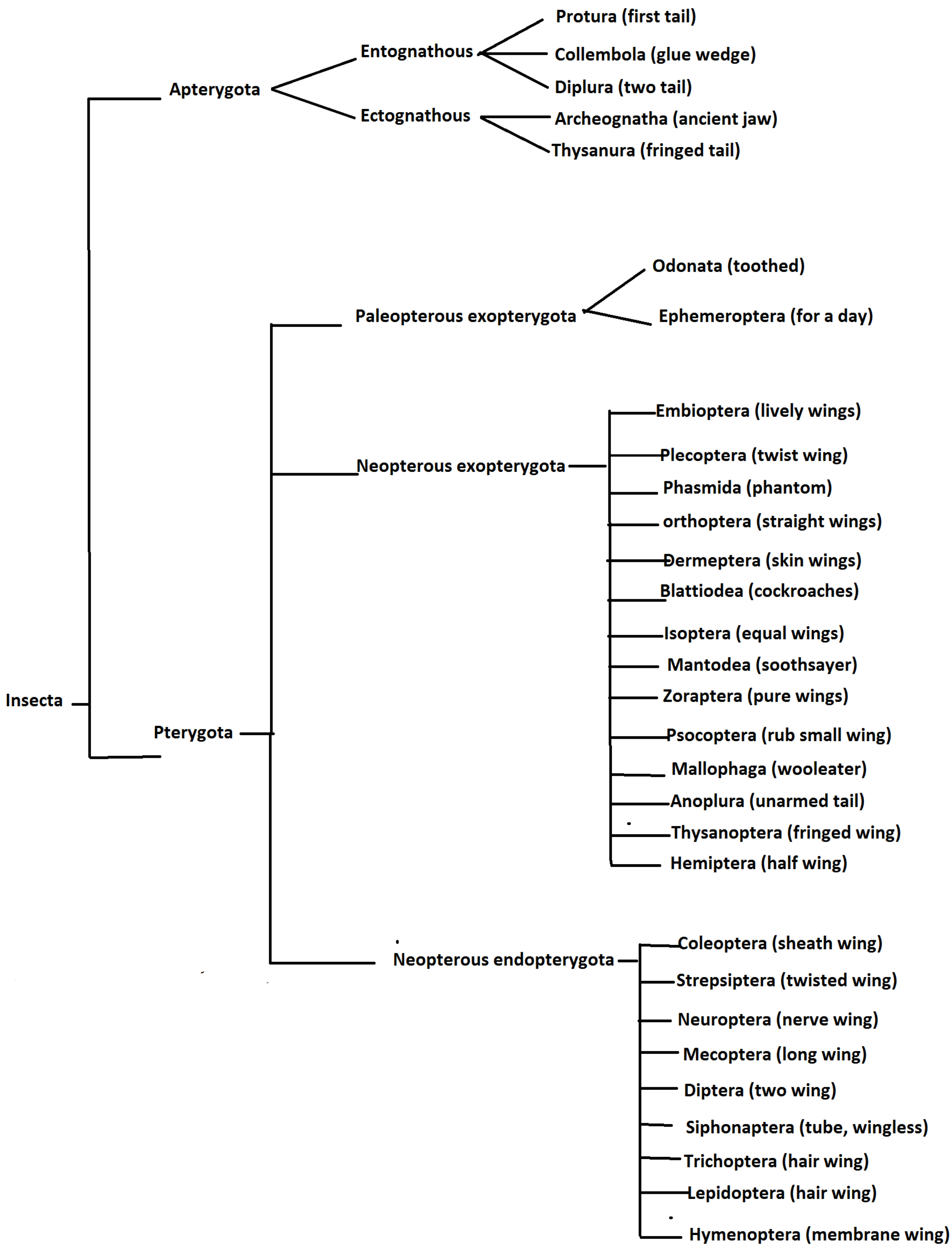


FIG 12.6: The classification of class Insecta showing all order name with their meanings

The orders of insects: Endopterygota (internal wing development) are separated from the Exopterygota (external wing development). Examples of endopterygota are the Coleoptera, Lepidoptera etc . and exopterygota are the Hemiptera, Homoptera, Orthoptera and Isoptera. The insects of Endopterygota underwent major radiation in the Permian. Most modern insect families appeared in the Jurassic, and further diversity probably in genera occurred in the Cretaceous.

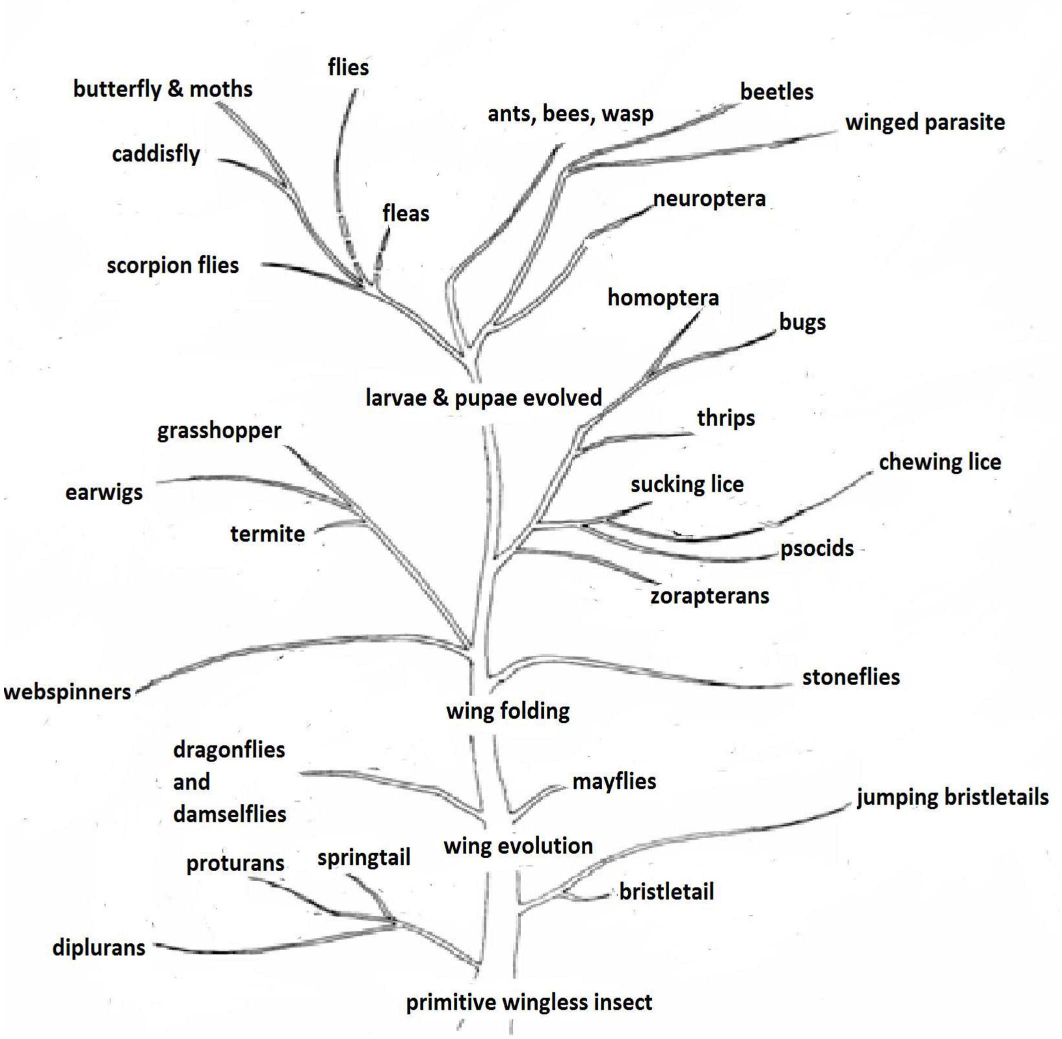


FIG 12.7: A hypothesized tree showing insect evolution

Insect evolution is characterized by rapid adaptation with selective pressures exerted by environment high fecundity, appearance of new species, diverse environmental niches and parallel evolution of flowering plants . (FIG 12.7).

So far there is nothing that suggests that the insects were a particularly successful group of animals before they got their wings. The members of the entognathous (mouthparts pulled into the head) apterygote orders include Protura, Collembola and Diplura and ectognathous (mouthparts not pulled into the head) apterygotes Archeognatha and Thysanura. The evolution of the orders of Pterygotes is described as Exopterygotes, Paleopterous endopterygotes and Neopterous endopterygotes.

Class Insecta	**Subclass: Apterygota**	Order: Thysanura (Bristletails) Order: Diplura (Two-pronged Bristletails) Order: Protura Order: Collembola – Springtails Order: Archeognatha
	Subclass Pterygota	Order: Ephemeroptera – Mayflies Order: Odonata - Dragonflies and Damselflies Order: Plecoptera – Stoneflies Order: Grylloblattodea Order: Orthoptera (Crickets, Short-horned Grasshoppers and Locusts) Order: Phasmida - Stick Insects and Leaf Insects Order: Dermaptera – Earwigs Order: Embioptera - Web-spinners Order: Dictyoptera - Cockroaches and Mantids Order: Isoptera - Termites or White Ants Order: Zoraptera Order: Psocoptera - Psocids or Booklice Order: Mallophaga - Biting Lice Order: Siphunculata (= Anoplura) - Sucking Lice Order: Hemiptera - True Bugs Order: Thysanoptera – Thrips

	Subclass: Pterygota	Order: Neuroptera - Lacewings, Alder Flies and Snake Flies Order: Coleoptera – Beetles Order: Strepsiptera - Stylopids (or Stylops) Order: Mecoptera - Scorpion Flies Order: Siphonaptera – Fleas Order: Diptera - True Flies Order: Lepidoptera - Butterflies and Moths Order: Trichoptera - Caddis Flies Order: Hymenoptera - Sawflies, Wasps, Ants & Bees

Table.1 : Classification of Insecta

12.4 Fossil insects

Insects of the primitive times are known as **Prehistoric insects** which are recorded in many groups in a past history. Some of them are extinct now; some are living fossils while others are in a group of recent evolution. The study of fossil insect is known as **Paleoentomology.** Insect shows their presence since the world of dinosaurs existed. The oldest known fossil insect was *Rhyniognatha hirsti* from the period of Devonian in the Paeleozoic Era about 400 million years ago. It is found that the modern insects have already evolved before the dinosaurs came in existing. Like today insects were the important part of the food chain and food web in the past.

The paleoentomological study shows that there are some differences between the modern insects and prehistoric insects. The primitive or prehistoric insects were larger as compared to modern insects due to the absence of the predators like bird, higher temperature that enhanced metabolism and higher atmospheric oxygen. The insect's exoskeleton is made up of chitin which in comparison to other vertebrate body is different in their burial processes. Insect remains were preserved in sap of trees like amber, in sedimentary rocks, between hard surfaces and ice.

Insects were the most successful group from the ancient times as they were the first organism capable of flight. Their number in the present status is much more than all the other living animals combined together. The fossil records are limited and only 7,000 species are known from the ancient world. Insect fossils study made some views that insects were probably fragile, lacking hard parts and lived on land in the case of wingless forms.

The primitive wingless insects like silverfish and springtail lived in the middle Devonian period about 395 million years ago. These fossil were found in the rocks of Scotland, New York and Quebec. Due to these fragments of fossil insects it was estimated that they started evolving prior to the Devonian period may be at the end of Silurian period (FIG 12.5).

Fossil wing and many specialized structures about 300 million years old were found in **Pennsylvanian rocks** . They were found in a large gap between Devonian fossil insects and Pennsylvanian fossil insects as there is no fossil record between the two in the Mississippian rocks. Therefore the origin of insect and evolution of Pterygote forms is a mystery.

Insects coming under Phylum Arthropods (jointed appendages) are relatively simple organism with a pair of antenna, chitinous body, jointed appendages, thorax with legs and wings, abdomen 10-11 segmented. As the wing contains many veins and a blood vessel therefore they can resist deterioration better than rest of the body and are commonly fossilized. They are delicate in appearance than also they can hold better compression as strengthened by network of veins. The other reason of known fossil insect by their wing alone is that the predator prefers the body of the insect to eat rather than wings.

The famous **Kansas rocks near the town of Elmo** is considered as the world's richest source of Permian fossil insects that lived between 300-250 million years ago. This area yielded thousands of the specimens. In the time of Permian period the Elmo sites were swampy, forest in the lower land and a freshwater lake nearby. This allows most efficient preservation of Elmo fossils as they got buried quickly in the fine grained sediments before they were consumed by the predators or scavengers. The insects like giant dragonfly *Meganeuropsis permiana* which is 29 inches with its wing span and it is the largest known insect ever known to us. It was predatory and got extinct in the world's largest mass extinction, a catastrophe that killed over 90% of the living creatures.

Another famous fossil site is the **limestones beds of Hamilton quarry** in the Greenwood country which includes fossils of dragonflies, crickets, cockroaches etc. A specific character of fossil insect was that they consisted of dicondylic mandibles i.e. mandibles were attached to the head by two condyles or articulation. Dicondylic mandibles are found in Thysanura (silverfish) while Archeognatha (bristletail) are monocondylic.

The winged form Pterygotes appeared in the Carboniferous period and Thysanura are more closely related to the Pterygote insects than the Acheognatha orders. The reason for their close resemblance is both of them kept a primitive anatomy as in case of Ephemeropterans representatives which are morphologically and physiologically similar to that of wingless insects, e.g mayflies larva resemble that of Thysanurans. Archeognatha and Thysanura still consist of rudimentary abdominal appendages called styli and extinct insect known as Monura had much more developed abdominal appendages. Archeognatha group generally found near the coastal region which suggests that the insects developed from marine environment and later become terrestrial and aerial.

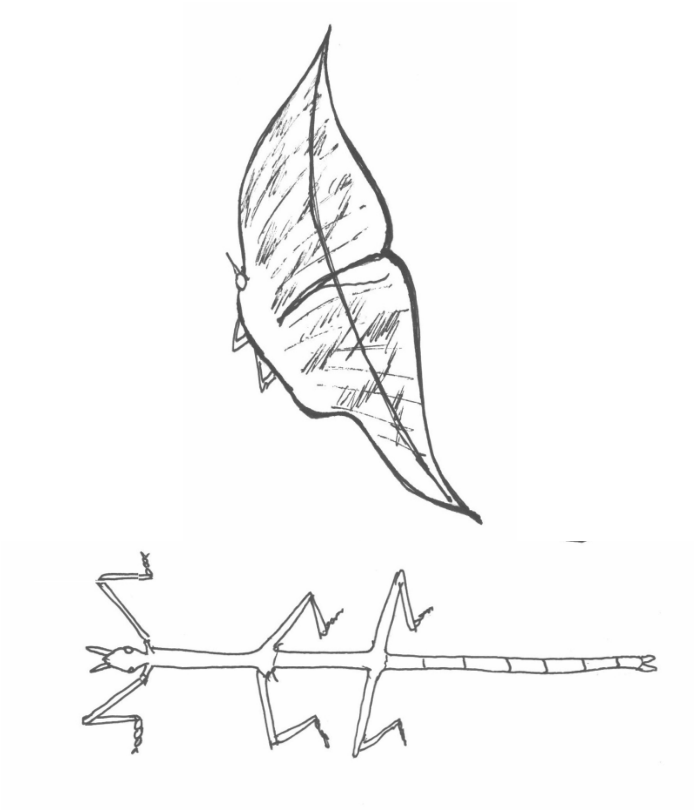
Apterygote fossil found mostly in range between Upper Carboniferous period and Lower Permian, it includes various species of *Dasyleptus* belonging to the extinct order of Monura. They lack anal cerci when compared to modern Archeognatha. Fossil Peleopterous Exopterygota orders were Paleodictyoptera, Megasecoptera, Disphanoptera which were terrestrial as their larva lacks gills, herbivorous, piercing sucking mouthparts, long cerci, external ovipositor and Protodonata similar to Odonata order. Neopterous exopterygote extinct orders includes Protothoptera (largest order, most diverse extinct group), Caloneurodea (FW and HW similarin size or shape), Miomoptera (mandibulate mouthparts, short cerci) and Protelytroptera (hard elytra, wing venation similar to Dermeptera). Neopterous endopterygote extinct orders includes only one order Glosselytrodea having hairs on wings, head and thorax similar to Neuroptera but venation is more specialized.

12.5 Causes of success of insects

There are certain factors due to which insects are the most abundant and most diverse group of organisms on earth. They have maintained their position in ecological system for about 400 million years. They were present at the time when rise and fall of dinosaurs happened. They have survived at least four major cataclysms that resulted in planet-wide extinctions; and they continue to thrive despite mankind's best efforts at eradication. There is no single factor behind the success of insects but mixer of various factor that evolve with time as mentioned above in the topic origin and evolution of insects. In short, the factors include an exoskeleton, small sized body, capability of flying, a high rate of reproductive, metamorphosis, and adaptations in an ever-changing environment.

12.5.1Exoskeleton

Like vertebrates, insect's do have supporting skeleton covering the body entirely. Exoskeleton gives shape and support to the body's soft tissues and also provides protection from attack or injury. It minimizes the loss of body fluids in both arid and freshwater environments. It gives mechanical advantage for the attachment of muscle to provide strength and movement. Exoskeleton can resist both physical and chemical attack as it is covered by impermeable layer of wax that prevents desiccation. Much of the exoskeleton is made up of chitin which is a polymer of N-acetyl-D-glucosamine, a polysaccharide similar to glucose that binds with various protein molecules to form a body wall. It may be flexible and elastic or hard and rigid due to the type of protein present in it, sclerotin protein gives hardness and resilin protein gives flexibility. The cuticular outgrowth like campaniform sensilla, trichoid sensilla and chordonotal organs acts as sensors to environmental changes. Some insects deposits excretory products below cuticle so acts as an accessory excretory organ. The scales, hairs and color are some of the external features which help in behavior modulation during mating. The color of the integument is useful in mimicry as in case of dead leaf butterfly, stick insects (FIG 12.8), that resembles those of surrounding and help them to hide from their predators, this increases the chances of survival and warning predators. Usually the chromophore is conjugated with the chromo proteins. The change in color called iridescence is common in Coleoptera and Lepidoptera. Muscles attached gives maximum strength for example in ant they can lift up to 50 times its own body weight.



A B

FIG 12.8: A) dead leaf butterfly B) stick insect

12.5.2 Small sized body

In general, the insects are very minute organisms and most of them ranges between 2 to 20 mm (0.1 - 1.0 inch) in length. Great variation like giant moths *Attacus atlas* which is more or less equal to nearly equal to computer screen and as small as tiny parasitic wasps (FIG 12.9), *Dichomorpha echmepterygis* which is like that of the all pin head also exist in them. Discovered in 1997, this Costa Rican wasp of the family Mymaridae is a parasite on other insect eggs. Adult males may be only 0.139 mm (0.00055 inch) in length nearly one third to some single celled protozoan.

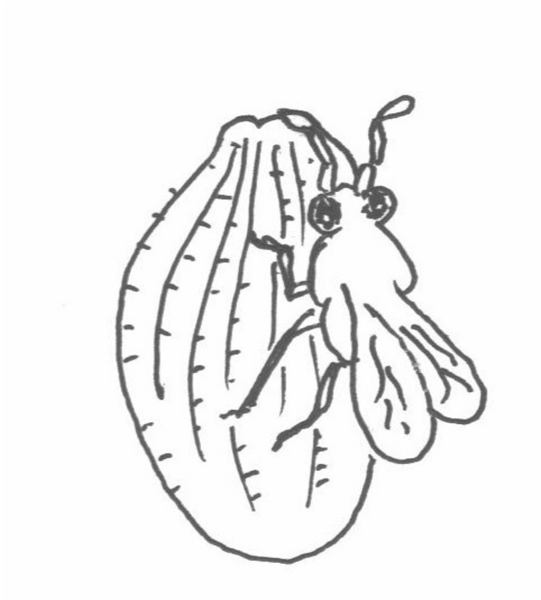


FIG 12.9: Parasitic wasp ready to lay egg on butterfly egg

Exoskeleton of small size is a distinct advantage, because if the insect is large sized then exoskeleton should be proportionately thicker to support the additional mass of body tissue. Thicker exoskeleton causes body to be heavier, which would require a larger muscle volume and consume more energy. So, two-fold increase in body length typically results in a four-fold increase in surface area and an eight-fold increase in volume and mass. If the insect becomes larger, heavier and muscular it will limit the power of flight. There is an upper limit to how large insects can become somewhere around 125-150 grams in case of heaviest insect *Golianth* (FIG 12.10) beetle which is not an efficient flier.

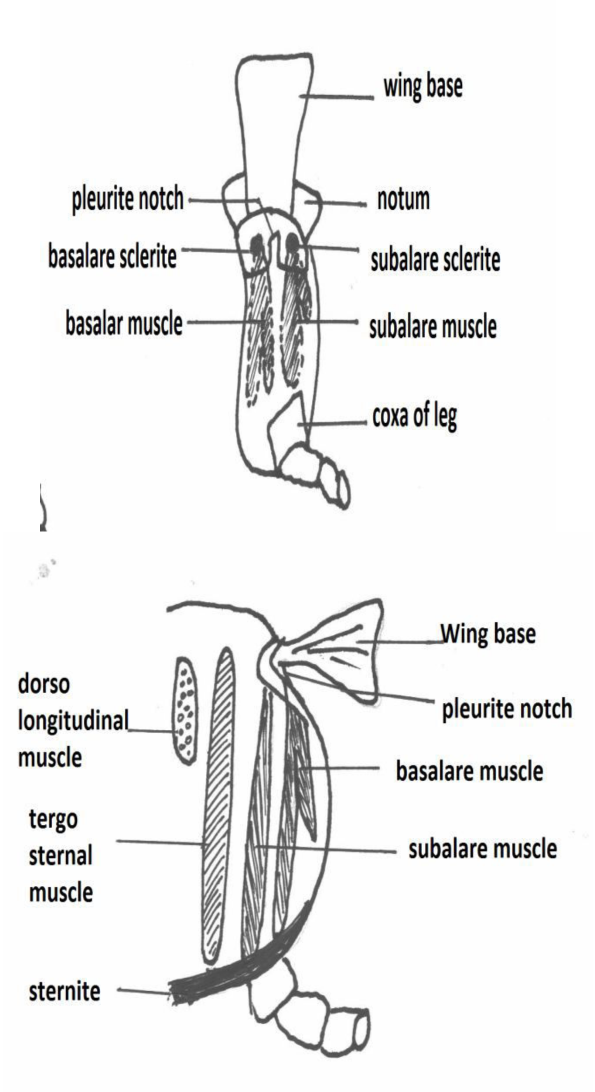
FIG 12.10: Golianth beetle

Another advantage of small size is that they can easily hide in cracks, crevices, below the stones, beneath the stone, below bark of the tree and this helps them from predators, parasites and other natural enemies. Some insects are so small that they cannot be seen with naked eyes. Small size means minimal resources for survival and reproduction. The insect may live on a single plant or animal or host for its entire life and never exhaust its food supply. For example, a leaf miner spends its entire larval stage in tunnels of parenchyma between the upper and lower epidermis of a single leaf. In some ant species, thousands of members of the entire colony may live inside a single plant gall/ hive or termatorium. Parasitic wasps (seven families of Hymenoptera) are a good example where they complete their entire development within the eggs of other insects.

Hard exoskeleton help them against injury during burrowing in between grains of sand, burrows, and other host body. Combination of small size with adaptations in body shape and coloration, gives many species the ability to mimic so well with their environment that they become virtually undetectable.

12.5.3-Capability of flying

Insects are the only exception in invertebrates that can fly. Starting from the fossil record, they acquired this flight ability about 300 million years ago and nearly 100 million years before the origin of the first flying reptiles. Flight gave one of the most important reasons in success of insects which provides a highly effective mode of escape from predators that roamed the prehistoric landscape. It also plays an important role in origin and evolution of insects. The class Insecta Is divided into subclasses and infraclasses on the basis of wings so it is a major character for classifying the insects.



A B

FIG 12.11: Insect flight muscle- A) left side of winged thoracic segment B) front view of winged thoracic segment

It is an efficient means of transportation, allowing populations to disperse more quickly into new niche and exploit new resources. The energy of flight in terms of calories per unit of lift is similar to that of birds and bats, an insect's flight musculature produces at least 2X more power per unit of muscle mass. The characteristics property of insect is largely due to elasticity of the thorax as 90-95% of the potential energy absorbed by flexion of the exoskeleton is released as kinetic energy during the wing's downstroke (FIG 12.11). Prolin is the amino acid used in flight in insects to travel great distances or remain airborne for long periods of time. Above 200 species, including moths, dragonflies, locusts, flies, butterflies are known to migrate over long distances by air. The migratory locust, *Schistocerca gregaria*, can fly for up to 9 hours without stopping and thus causing damage to large fields away from their infestation. Monarch butterflies, *Danaus plexippus* makes annual migration from North America from summer feeding grounds to overwintering sites in California and Mexico. Some primitive insects notably the dragonflies are remarkably agile fliers as they can catch its food like mosquito, horse flies while they are flying therefore it is known as **mosquito hawks**. Large hawker dragonflies (family Ashnidae) have been clocked at a top speed of 58 km/hr in comparison with the fastest human sprinters run only about 36 km/hr. The wings of a large insect can carry load on them as in case of green darner dragonflies (*Anax junius*) which are able to fly carrying a load up to 15 times their body weight. Insects having smaller wings have to work much harder than with large wings to remain airborne as tiny biting midges (like *Forcipomyia* spp.) beat their wings over 1000 times per second. A special type of muscle tissue is needed to sustain this rapid rate of contraction.

12.5.4 High rate of reproduction

Insects are having high rate of reproduction i.e reproductive potential is high. Reproductive potential is defined as the rate at which the insects add offspring to the population. This high rate causes insects to be more successful in the changing environment. Female insects have high fecundity (produce large numbers of eggs) and high fertility (most of the eggs hatch) in a short life cycle. Together, these three characteristics enable insects to produce remarkably large numbers of offspring. A typical female lays on an average about 100-500 eggs in her lifetime (FIG 12.12), but numbers in the thousands or crorers are not uncommon. The queen of an African termite colony produces more than ten million workers during her 20-25 year lifespan with only one time mating with its partner.

Antony van Leeuwenhoek, the Dutch scientist who first discovered single-celled organisms, was probably the first person to comprehend the reproductive potential of insects. In 1687, he reared blow flies (probably *Calliphora erythrocephala*) on owl meat and found 144 progeny half of which are male, half female with no mortality. So, a single female could give rise to 10,368 offspring in the third generation, 746,496 in the fourth generation, 53,747,712 in the fifth generation, and 3,869,835,264 in the sixth generation. But as the theory of natural selection given by Darwin follows the growth of larva is limited by all the limiting factors like food supply, predation, climate, and disease that keep natural populations below a certain level. This explains a quick insect population growth can cause a sudden outbreak of a pest. Since most insects die before they reach to reproduce many adaptations help maximize this potential. Most females, can store sperm for months or years within the spermatheca, a special accessory organ meant for receiving sperms of the reproductive system. A single mating can supply a female with enough sperm to fertilize all the eggs she will produce in her lifetime. There are a number of insects where males are rare, uncommon or absent e.g. aphids, scale insects, thrips, and midges contribute offspring through a process of asexual mode of reproduction like parthenogenesis, paedogenesis, polyembryony etc.

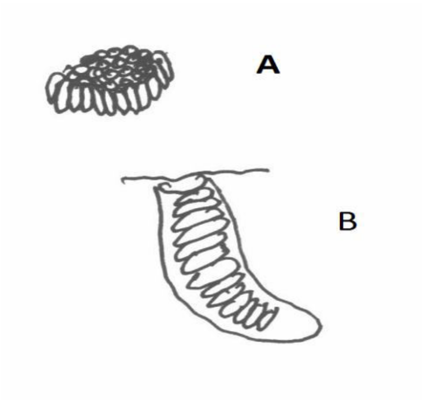


FIG 12.12: Number of eggs lay per individual in case of mosquito (A) and Grasshopper (B)

12.5.5 Metamorphosis

Metamorphosis is a process of change in shape and forms during the life cycle. Insects undergo significant developmental changes as they hatch fro egg and grow from immature to adults. These developmental changes may involve physical, biochemical, behavioral that promote survival, dispersal, and reproduction of the species. In the more primitive insects nymphs are similar to the adults except, their organs of reproduction is poor or underdeveloped and absence of wings as it develop slowly during the immature stages and become functional only in adults. Since this slow transformation does not include all body tissues and shows incomplete metamorphosis, the immature and adult share similar habitats and type of food.

More advanced insects undergo complete metamorphosis in which transformation in form and function between the immature and adult stages of development are different. In these insects, function of larva is primarily adapted for feeding and growth. It stores energy reserves which sustain the insect for the rest of its life. When fully grown larva moults into a transitional quiescent stage, called the pupa, and begins a period of massive internal and external reorganization. An adult insect called imago eventually emerges from pupal exoskeleton bearing no resemblance to its larval form. Its primary function is dispersal and reproduction. In the class Insecta, only 9 out of 29 orders undergo complete metamorphosis, these 9 orders contribute about 86% of all insect species alive today. The obvious advantage to this type of development is the differences in their food, form, shape, habitat, behavior and function of each stage larval form, pupal form and adult form are different. Each stage of the life cycle has different way to adapt to its own ecology.

12.5.6 Adaptability

Many factors discussed above like large and diverse populations, high reproductive potential, and relatively short life cycles, has lead to the most insects with the genetic resources to adapt quickly in the changing environment. Their record details give information that they were first aerial animals to adapt in the air. They were the first animals to use wings as flight organ and as an escape from predators. Even they were the first organisms to live in a complex social group with division of labor and gives parental care to the eggs or young ones. Over the ages there have been many drastic changes that have occurred including the evaporation of inland seas, formation of mountain ranges, shifts in continental plates, onset of ice ages, and the fallout from cosmic impacts but these adaptation keep the insect populations more or less constant. Perhaps the most remarkable example of insect adaptation in this century is the development of resistance to a broad range of chemical and biological insecticides used in the past years. After World War II, United States eradicated the house fly (*Musca domestica*) with DDT but with several years fly populations decreased and a few resistant flies managed to survive because they were carrying an enzyme that could detoxify DDT. These survivors reproduced and passed this resistant trait to their offspring. In time, DDT-resistant flies reestablished their environment. Significant levels of pesticide resistance have now been reported in over 500 insect species, and many of these animals are resistant to compounds from more than one chemical group.

12.6 Summary

The insects are diverse group of organism whose evolution and interrelationship with other arthropodan classes are evident from the study some fossil insects and the similar characters they share. The recent functional morphology and comparative morphology widely accepts polyphyletic theory which includes three distinct phyla Chelicerata, Crustacean and Uniramia. This theory has high degree of convergence. Hexapods or insect evolved from many legged segmented soft bodied Onychophora like organisms through a process of continuous cephalization. Insecta evolved into five groups Collembola, Protura, Diplura, Thyasanura and Pterygota. First three groups are different from each other and last two groups had a common ancestor. Thysanura like organism underwent a wide adaptive radiation into many orders to become most successful living group. The origin and evolution of insects are due to the reduction in appendages, wing development and holometamorphosis type of development. The success of insect world and diversity is due to their small size, adaptability, capablity of flight, high reproductive potential, metamorphosis and exoskeleton.

12.7 Glossary

- **Microevolution:** When changes occurs in a population or species due to the selection pressure.
- M**acroevolution:** When changes occurs in class, order or family *i.e* larger than the microevolution.
- M**egaevolution:** When changes occur in phylum or more large phylogenic patterns.
- **Apterygote**s- Primitive wingless insect.
- **Pterygote**s- All winged insect.
- **Prehistoric insects:** Insects of the primitive times are known as Prehistoric insects
- **Paleoentomology :** The study of fossil insect is known as Paleoentomology.
- **Monocondylic:** Mandibles are attached to head through one articulation or condyle.

- **Dicondylic:** Mandibles are attached to head through two articulation or condyle.

12.8 Self Learning Exercise

Section -A (Very Short Answer Type)

1. Name the smallest insect?
2. Can you give a name of heaviest beetle?
3. What was the first fossil insect identified?
4. Which place is called the world's richest source of Permian fossil insects?
5. Name the largest known insect ever known from the history to till date?
6. Which insects show mimicry?
7. *Musca domestica* is resistant to which insecticide?
8. Name the author who wrote Slient Spring?
9. Which category comprises 90% of the all the orders and 97% of all the insect species?
10. Give one example of order having dicondylic mandible?

Section -B (Short Answer Type)

1. Define Paleoentomology and prehistoric insects?
2. Give the differences between monophyletic and polyphyletic theory?
3. How will you differentiate between monocondylic and dicondylic mandibles? Give example?
4. What is the difference between the Exopterygotes and Endopterygotes? Give example of each group?

Section -C (Long Answer Type)

1. What are causes of insect's success?
2. Name all the orders of Insecta class with their meaning?
3. Give the theories related to the evolution of insects?
4. Define fossil insects? Write a brief note on insect fossils?
5. Describe the origin and evolution of various insect groups?

Answer Key of Section-A

1. *Dichomorpha echmepterygis*
2. *Golianth* beetle
3. *Rhyniognatha hirsti*

4. Kansas rocks near the town of Elmo
5. *Meganeuropsis permiana*
6. Stick insect, dead leaf butterfly
7. DDT
8. Rachel Carlson
9. Neopteran
10. Thysanura, silverfish

12.9 References

- Cedric Gillot : Entomolgy
- Kachhwaha N.: Principles of Entomology-Basic and Applied