CHAPTER ONE - INTRODUCTION

1.1. Definition

The word ‘entomology’ comes from the Greek word ‘entomos’- meaning insects and logy meaning study. Therefore, the word entomology means the study of insects. Another word for six-legged arthropods is ‘hexapoda’ which comes from the Latin word meaning six legged. Those persons which study about insects are known as Entomologists.

Today more than one million different insect species have been described by entomologists that are nearly 75% of the all known animal species. At present we have the greatest ever number of insect species in the world and still new species will be found especially in those areas research work has been neglected. Today insects colonized nearly all areas of life in the world. Some of them are especially adapted to water for their whole life (like water beetles and water bugs) or only for certain period of development (egg, larvae, pupae) like damselflies and mosquitoes. Other are terrestrial and still some others are also adapted to extreme conditions of the earth like caves and deserts with special adaptation against sun heat and dryness, etc.

As measured by both abundance and distribution insects are the most successful organisms on the earth. Even the number of insect species out weighs that of the number of plant species.

The greatest number of insect species has lead to a lot of different relations among insects, man and his environment. Some insects are useful to humans, some are harmful and still some others are more or less indifferent to human beings and the surrounding. The useful as well as harmful insects are the subject of applied entomology.

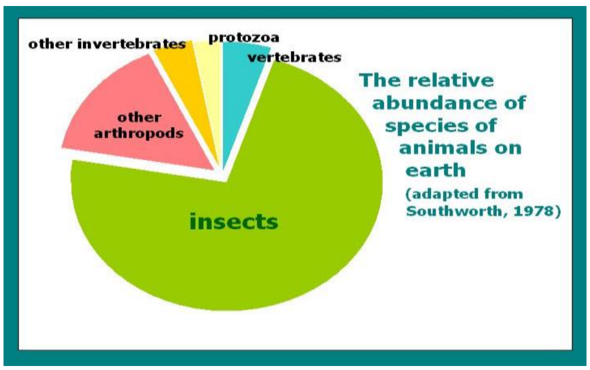

Fig. 1. Aboundance of insects relative to other animals

1.2. Fields of Entomology

From the economic point of view, the following are the important branches of entomology:-

i. **Agricultural entomology-** this mainly concerns with the study of insects, which are directly related with the crops and the stored commodities.

ii. Medical entomology- this branch deals with the insects, which are responsible for transmitting human diseases.

iii. Veterinary entomology- it includes the study of those insects, which may be beneficial or harmful to the animals.

iv. Industrial entomology- this is concerned with the insects, which are directly or indirectly related with wood, wool, cloth and the other industrial materials. It also includes the study of beneficial insects like honey bee, lac insect and silkworm.

v. Forest entomology- it includes the study of insects concerning with forest plantation.

VI. **Forensic Entomology** Study and use of insects in crime investigations.

1.3. Distinguishing characteristics of insects

Arthropods (Greek-arthros means jointed, and podos means legs). This is the largest phylum of the animal kingdom. They include animals differing widely in structures but common on certain fundamental characteristics. All of which are characterized by:

i. Bilaterally symmetrical animals

ii. Metameric segementation i.e., body of the animal is divided into a succession of homologous parts of metamers.

iii. Segments fused to form head, thorax, and abdomen

iv. Majority of the segments posses pair of jointed appendages

v. Exoskeleton contains chitin secreted by epidermis

vi. Specialized alimentary canal with chitinous teeth

vii. Metamorphosis takes place in the development

No animals, other than arthropods exhibit the above combinations of characters.

Relationships with other arthropods

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Apart from class insecta, the various major divisions of the phylum arthropods are as follows:

Classes of arthropoda

Class Crustacean

The crustaceans are a very diverse group with most members found in marine or freshwater habitats and their characteristic include: The head and thorax are merged (cephalothorax) but they have distinct abdomen, i.e. they have two body regions: cephalothorax and abdomen. They have a lot of appendages, mainly modified as walking legs, for swimming or as gills. They Respiration system is by means of gills. They have two pairs of antenna. They inhibit mostly aquatic habitats and common in marine environment. E.g. Cray fish, crabs

Class Myriopoda (literally means innumerable feet)

These are wormlike and elongated animals. Their characteristics include: They have no separation between thorax and abdomen, but they have clearly identified head. They have many pairs of legs and one pair of antenna. They are terrestrial and respiration by means of tracheal system. e.g. centipedes (Chilpoda), millipedes (Diplopoda)

Class Arachnids

The Arachnids is the largest, commonest, and most diverse class in the subphylum Chelicerata. Their characteristics include: They have two body regions:: cephalothorax (head and thorax are merged) and abdomen. They have four pairs of legs and they don't have antenna. Mostly, they are terrestrial arthropods but some live in fresh water; and they respire by tracheal means. E.g. spider, scorpions, mites, tick

Class Insecta

Insects are the most ubiquitous animals in this world. An insect may be defined as arthropods having the following features: The body is divided in head, thorax and abdomen; they have three pairs of legs and single pair of antenna (some don't have); usually one or two pairs of wings (some don't have wing). They are mostly terrestrial, but some grow in fresh water. They live in all ecosystems (ubiquitous or cosmopolitan organisms) and breath by means of tracheal system. Example- Insects (like house flies, grasshoppers, etc.)

1.4.Insects and their relation to humans

The greatest number of insect species has lead to a lot of different relations among insects, man and his environment. Some insects are useful to humans, some are harmful and still some others are more or less indifferent to human beings and the surrounding. The useful as well as harmful insects are the subject of applied entomology.

1.4.1. Benefit of insects to humans

i. Insects producing commercial products

The larvae of *Bombyx mori* (silk worm) produce commercial silk fibers. The silk from the cocoons of silk worm moth has been used for fabric for centuries. The honey bees produce honey as well as bee wax. The bee wax is used in the manufacture of medicine, cosmetics, ink, carbon paper, electrical insulators, sewing threads, and polishes for floor, furniture, shoe and leather. Cosmetics which are produced from bees wax include creams, lotions, lipsticks, etc. Bee venom is used in the production of medicines against diseases such as paralysis

ii. Insects which help in pollinating blossoms

There are a lot of useful insect species besides bees like butterflies, beetles, flies, etc. Without the presence of pollinating insects some plant species may not survive or exist.

iii. Some insects serve as food for many animals like- humans, birds, chickens, etc.

iv. Some insects serve as predators of animals including insects which are harmful to man and also as parasites of various weeds.

v. Insects are subjects of research, art, and ornament

For instance, for toxicological studies, genetics, physiology and so on. Biologists choose insects to work with insects for many reasons;

- the ease of maintaining laboratory cultures
- short shelf life cycle and availability of many individuals
- the few ethical problems concerning the experimental use of insects as compared to vertebrates, is another important considerations.

vi. Some insects increase soil fertility by decomposing dead pants and animals

For example, dung beetle, termites, etc.

It is a popular perception that entomologists kill or at least control insects but entomology includes the study of many positive aspects of insects. Entomologists also known that less than 1% of all insects are harmful to humans while others are useful or neutral groups.

1.4.2. Harmful effects of insects

i. Insects damaging growing plants by using them as food i.e. by chewing leaves stems roots, fruits seeds, etc, or by sucking plant sap such as aphids, thrips, plants bugs, stalk borers, etc.

ii. Insects which damage growing plants by using them for breeding or for the construction of nests or shelters. E.g. thrips, crickets, ants, etc.

iii. Insects as external or internal parasites of animals. E.g. blood sucking fleas, bed bugs, lice, etc.

iv. Insects as carriers of animal diseases. E.g. mosquitoes carry the cause of yellow fever, malaria, filariasis or elephantiasis. Tsetse fly (*Glossina spp*) carry the cause of African sleeping sickness in human and Trypanosomiasis in cattles. The human louse-carry the cause of the typhus fever.

v. Annoying (aggravating, irritating) insects like house flies, sting bugs, cockroaches, etc.

vi. Few venous insects. For example- caterpillar with poisonous hairs causing dangerous inflammation of the skin

vii. Insects spoil stored products and other materials

1.5. Adaptive features for the success of insects

As measured by both abundance and distribution, insects are generally considered the most successful group of living organisms on earth. This dominance is achieved by the great biological success they attain. As already stated insects comprise more than 75% of the greater a million known species of animals.

- **i. Small size**

Their small size means insects need small food or energy to complete development and sustain life and can readily find shelter in hooks and crannies and o avoid enemies and extreme of weather. Muscular action is much more efficient and gravity has less of an effect. They can utilize solar heat to heat their body because of high surface area to volume ratio.

ii. Rapid reproduction and high fecundity

Insects are prolific (productive) breeders, they produce 100-150 even more than eggs per female. The Production of many young and short life cycle enable insects dominates the ecosystem. The rapid lifecycle where in mutations can readily select for and incorporated into the population gene pool.

iii. Exoskeleton

Insects posses an exoskeleton made of chitin. It not only provides protection but also check evaporation.

iv. Wide adaptability

Insects are found in all conceivable environments that occur on land. Some insects occur on mountains peaks as high as 6000 meter and there are insects that live in arctic temperature that reaches below -20^{o}c. Insects can tolerate temperatures as high as 48 to 52^{o}c. They are also well adapted to dry and hot (xerophytic) conditions of deserts.

Perhaps the most remarkable example of insect adaptation in this century has been the speed with which pest populations have developed resistance to a broad range of chemical and biological insecticides. After World War II, public health officials in the United States made a concerted effort to eradicate the house fly (*Musca domestica*) with DDT. For several years the campaign seemed promising: fly populations decreased and optimism ran high. But a few resistant flies managed to survive because they were endowed with an enzyme that could detoxify DDT. These survivors reproduced and passed this resistant trait to their offspring. In time, DDT-resistant flies repopulated their environment and the species now appears to be living happily ever after!

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 family. In New York, for example, potato growers on Long Island must cope with a population of the Colorado potato beetle (*Leptinotarsa decemlineata*) that is resistant not only to organophosphates, carbamates, and synthetic pyrethroids, but also to some of the insect growth regulators and microbial insecticides.

v. Modifications and exploitation of appendages into the many types of function of different activities.

vi. Feeding habit

Extensive development of complete metamorphosis in which the immature and adults have evolved to feed on different food source and hence are not in competition.

viii. Evolutionary interactions with plants and other organisms

ix. Dormancy

Some insects' species have arrested development when environmental conditions are unsuitable, such as seasonal extremes of high or low temperatures or drought.

x. Flight

Insects are the only invertebrates that can fly. Judging from the fossil record, they acquired this ability about 300 million years ago nearly 100 million years before the advent of the first flying reptiles. Flight gave these insects a highly effective mode of escape from predators that roamed the prehistoric landscape. It was also an efficient means of transportation, allowing populations to expand more quickly into new habitats and exploit new resources.

Chapter two

2. External structure and functions of insects

Before considering the external anatomy of insects it should be necessary to define some directional terms.

An insect being set its feet downward; ***ventral*** refers to its lower surface, and ***dorsal*** refers to its upper surface, ***lateral*** refers to the sides and ***medial*** or ***median*** refers to the central, usually to the longitudinal midline of the insect. ***Anterior*** indicates towards the head, and ***posterior*** towards the abdomen. On appendages like leg, ***distal*** or ***apical*** indicates toward the tip and ***proximal*** or ***basal*** the reverse, towards the body.

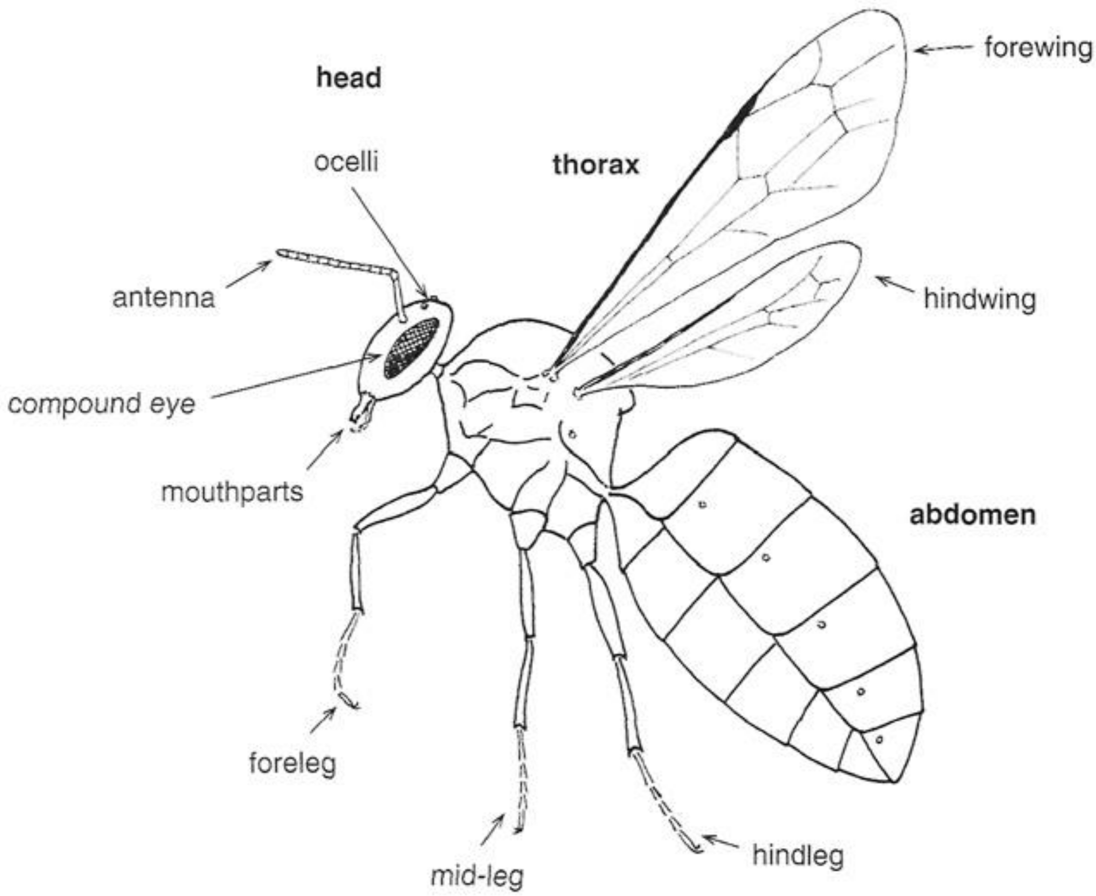


Fig. 2. General structure of an insect

Insect exoskeleton

One of the major requirements of animals is to slow down water uptake or loss from the body; this often accomplished by the production of a slime or mucoprotein that covers the body surface in arthropods in general and in insect in particular. The covering has the body surface into a solid structure, the many layered exoskeleton or integument (the outer covering of the living tissues of an insect). Exoskeleton is ectodermal layer covering externally and giving an anatomical shape (integrity). In humans the shape is governed by endoskeleton.

Basically the integument consists of a basement membrane, a layer of epidermal cells, and an externally secreted layer- the cuticle which contains up to one-half of the dry weight of the insect. One of the major compounds within the arthropod cuticle is chitin a polymer of N-acetyl

D-glucosamine and closely related to cellulose. This nitrogenous polysaccharide has a tannish color and is flexible.

Cross section through the cuticle reveal a laminate condition. The outermost multilayered *epicuticle*, consisting of lipids and polyphenols, provide waterproffing. Inside the thin epicuticle is the *procuticle*, which consists of an outer hardened *exocuticle*, the layer in which sclerotization occurs, and an inner flexible *endocuticle*. Areas that have a thick exocuticle are termed *sclerites*. Flexible regions between sclerites, which permit movement, consist primarily of endocuticle and are referred to as membrane.

Major body divisions and their functions

As an embryo develops, the segments of the body group into clusters called tagmata or body regions. From front to rear, an insect's body is divided into three regions: the head, thorax and abdomen, each made up of a ring like segments.

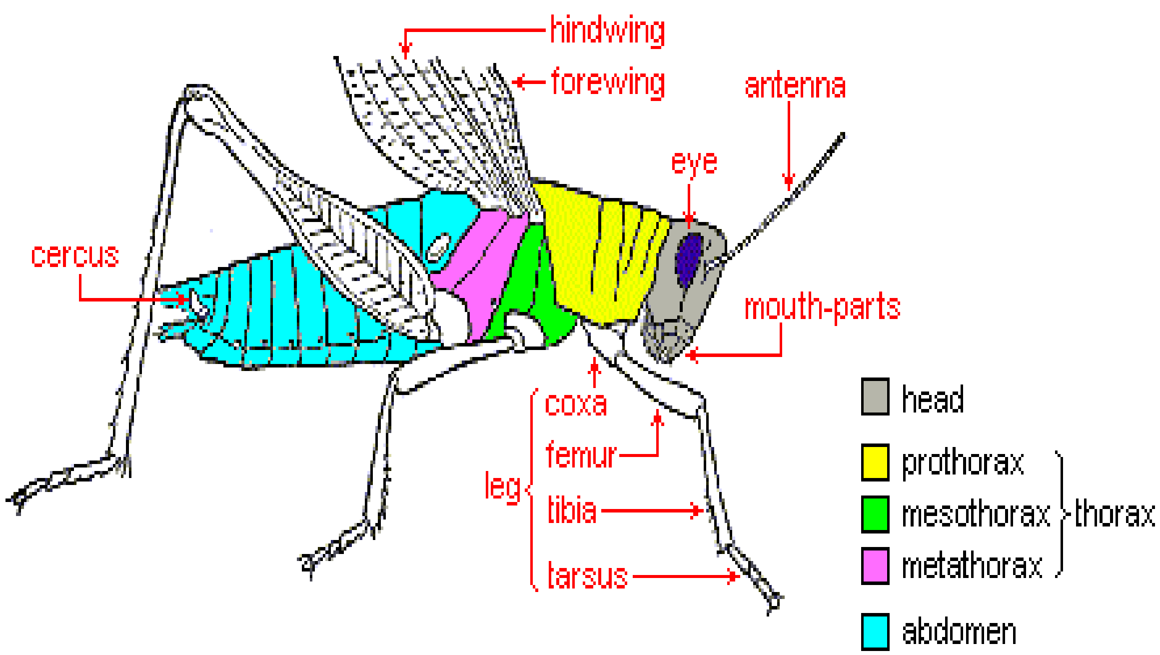


Fig. 1. Body regions of insects

2.1. Head of insects

The anterior region of the insect body, the head composed of six embryonic segments which form the head capsule. The insect head is used to carry out:

- ingestion of food
- major sensory perception
- coordination of body activities and,
- protection of the coordinating centers.

The sensory structures are located near the mouth parts and coordinating center for more effective food ingestion and to enable more rapid response to incoming stimuli. The head is therefore, defined as functional unit responsible for carrying out the above four procsesses.

In insects individual segments of the head have fused so completely that external evidence of their presence or origin is lost. How can we determine the head's segmentation? As with most animals, primary evidence of origin comes from study of embryology and the nervous system. The sclerotized upper portion of the head bears a pair of compound eyes, three simple eyes (ocelli) and a pair of antenna and mouth surrounded by three pairs of mouth parts.

The head of insects is broadly divided into three parts depending on the inclination of the long axis of the body and the positions of the mouth parts.

i.Hypognathous- the long axis of the body is vertical and the mouth parts are ventral. i.e. the mouth parts are at right angle to the body axis. In other words, it is in a continuous series with the legs and is early form or probably the primitive. It occurs mostly in vegetarian species living in open habitat. E.g. Grass hopper

ii. Prognathous- the long axis of the body is horizontal or slightly inclines ventrally while the mouth parts are anterior in position. i.e. the mouth parts joints forwards and found in carnivorous species and /or forms that burrow in wool or soil. In other forms, the head is tilted up at the neck so that the mouth part projects forwards. E.g. beetles

iii. Opisthognathous- in this type, the head is directed backwards and mouth parts are posterioventral. E.g. bugs

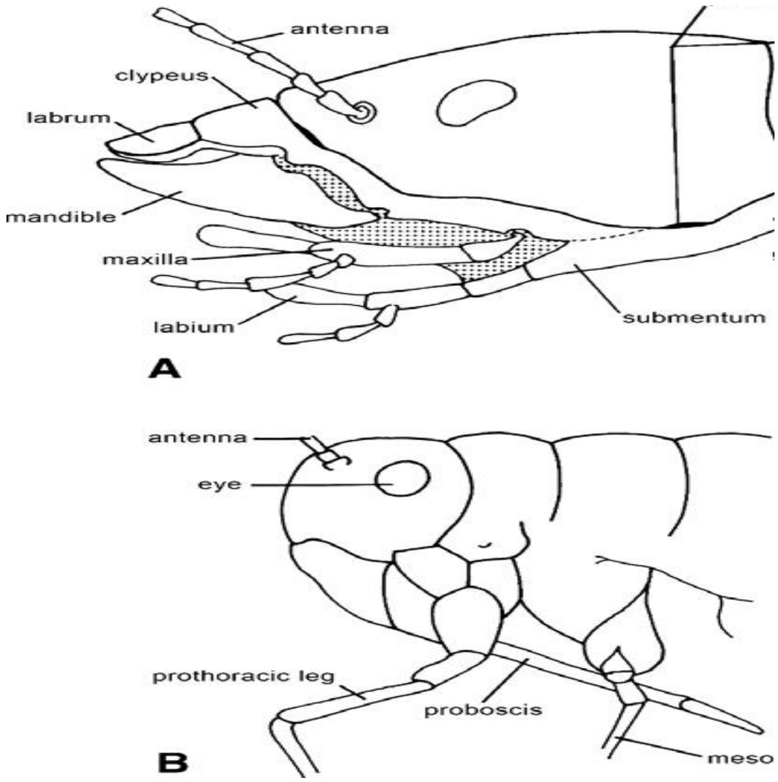


Fig. 5. (A) Prognathous; and (B) opisthognathous types of head structure. [

2.1.1 Antennae

They are paired freely mobile segmented appendages articulated with the head in front of or between the eyes. Antennae are also known as feelers. The antennae of an insect is divisible into scapes, pedicel, and flagellum

i. **Scape-** it is the basal segment of antennae, by which it is attached with head

ii. **Pedicel-** it is the second segment of antennae. It is shorter than the scape. It bears sensory apparatus known as organ of johnstons.

iii. **Flagellum-** the remaining antennal segments jointly are called the flagellum which varies greatly in its form and structure according to the surrounding and habits of insects

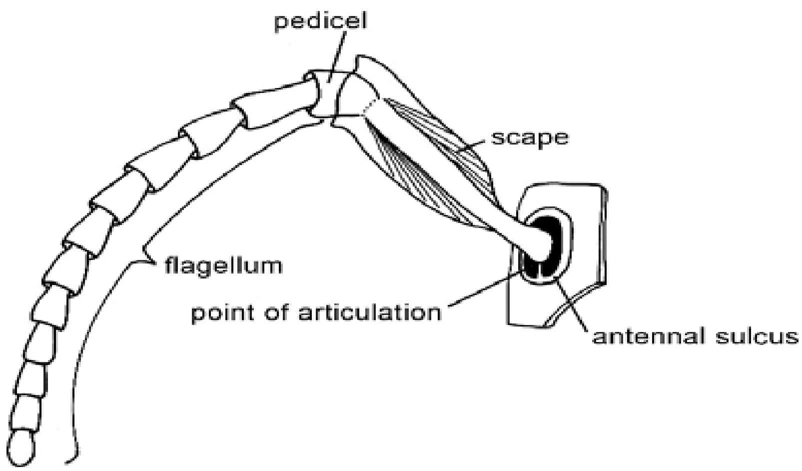


Fig. 6. Structure of an antenna.

Functions of antennae

The main functions of antenna is sensory, which is modified according to use and need of insect as given below:

i. Organs of smell- in some insects the smell organs (sensoria) are situated in the antennae by which they recognize their food etc. E.g. Ants, honey bee, moths

ii. Organs of taste- some insects bear taste hair on their antennae by which they know the taste of food. E.g. Cockoraoch

iii. Stridulatorial organs- sound producing organs are located in the antennae of some insects belonging to the order coleopteran and orthoptera. E.g. Crickets

iv. Chordotonal- the hearing organ often known as johnston's organs; situated in the second segment (pedicel) of antenna. E.g. Male mosquito

v. Sexual characters- in some of the insects belonging to the order Diptera and Hemiptera, the antennae are found of different type in male and female. E.g. Mosquito

Modifications of antennae

On the basis of shape and structure, the antenna may be of the following types:

i. Setaceous- there are bristle like antennae in which the size of each segment becomes smaller and smaller towards the flagellum and tapering into a point. E.g. Cockroach and cricket

ii. Filiform- it is thread like antennae in which all the segments are of nearly uniform in thickness and have no prominent constructions at the joints. E.g. Grasshopper

iii. Moniliform- all the segments of this antennae are globular in shape and of uniform thickness. E.g. Termite

iv. Pectinate- this is a comb like in structure in which each segment of the antennae posses lone projections. E.g. Moths

v. Flabellate- this is a comb like antennae in which the projections of some upper segments become long and form a feather (folding fan) like structures known as flabella. E.g. Beetle

vi. Plumose- in such type of antenna, the whorls of hairs arise from the joint of each segment and look like plumose. E.g. Male mosquito

vii. Clavate-these are club shaped antennae in which the segments become gradually braoder towards the tip and the last segment finally ending into a round core. E.g. Butterfly

viii. Geniculate- in this type of antenna, the first segment (scape) is long, second segment (pedicel) is short and flagellum is made of small segments which are bent on the scape just like a bent knee. E.g. Honey bees

xi. Aristate- this type of antennae is three segmented in which first segment (scape) is smaller and broader and the second (pedicel) is longer than the first. The flagellum is longer than both the segments and bears a heavy bristle known as arista. E.g. House fly

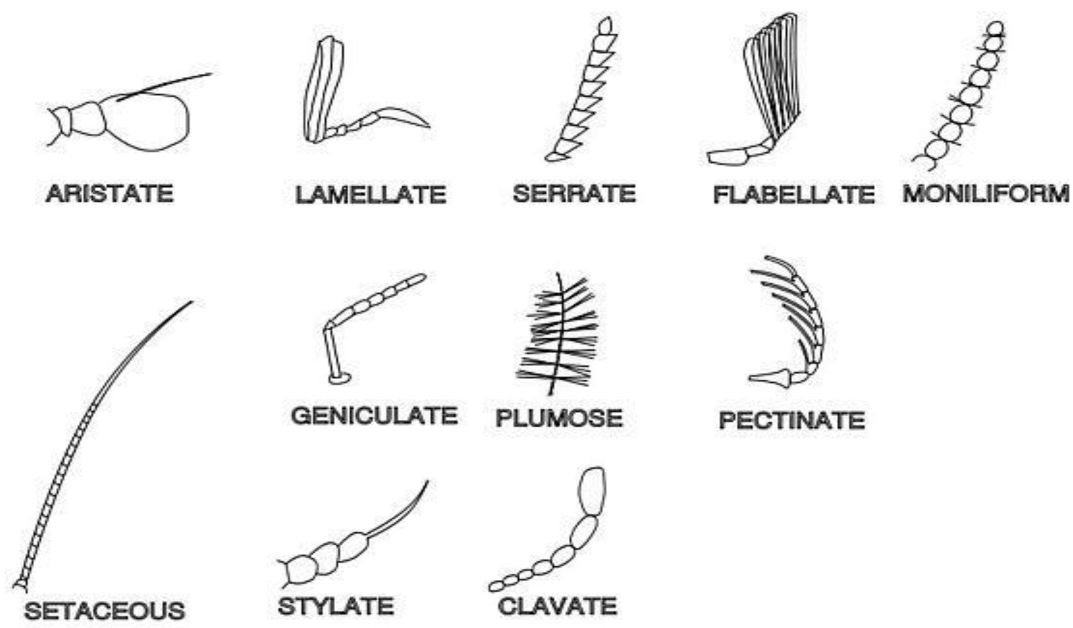


Fig. 6. Insect antennal types

2.1.2. Mouth parts

There are the organs primarily concerned with the uptake of food and sensory appreciations. The mouth parts comprise three pairs of appendicular jaws the anterior ***mandibles*** followed in turn by the ***maxillae*** and a second pair of maxilla like structures that fuse medially during embryonic development to form the ***labium*** or lower lip. Closely associated with them are two unpaired non-appendicular structures, the ***labrum*** and the median tongue like ***hypopharynx***. The mouth parts are variable being correlated with method of feeding and other uses to which they may be subjected.

Parts of insect mouth parts

The labrum

It is a simple plate hinged to the clypeus and capable of a limited amount of vertical movement. It overlies the bases of the mandibles, and forms part of the roof of the preoral cavity.

The mandibles

Are heavily sclerotized structures. They are the true jaws adapted for cutting or crushing of the food. The inner edge of each mandibles bears tooth like denticles which interlock while capturing the prey. Each jaw (the two mandibles) is moved by powerful muscles thus allowing the cutting and crushing of food.

The labrum (upper lip)

It is a simple plate hinged to the clypeus and capable of a limited amount of vertical movement.
It overlies the bases of the mandibles and forms part of the roof of the preoral cavity.

The maxillae

These are a pair of segmented structures that lie beneath the mandibles. Maxillae have got sensory in function. The two maxillae work side ways to masticate the food and to convey food into the oral cavity.

The labium

It is modified into beak like structure named as rostrum which is three or four segmented, long, slender and rigid organ. Forms protective sheath to the stylet.

The hypopharynx

Behind the mouth lies the median hypopharynx. This is usually tongue like structure and as its base on the lower side there open the salivary duct.

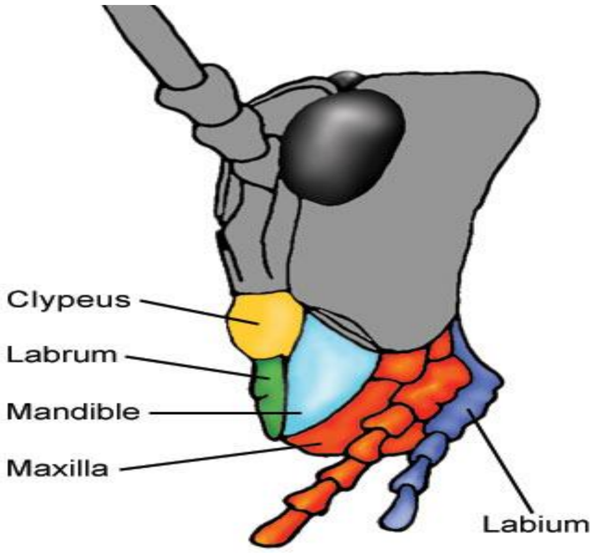


Fig. 3. Mouth parts of insect

The primary parts are the mandibles or paired appendages of the fourth segment. Supporting their action are the maxillae or paired appendages from the fifth segments and the labium or fused appendages of the sixth segments. Other parts may be involved and include the labrum and hypopharynx.

In chewing insects the anterior labrum, the mandibles and maxillae at the sides, and the posterior labium form the pre-oral cavity between the mouth parts in which chewing occurs. Food is pulled into this cavity by the maxillae and cutting action of the mandibles. Saliva is secreted between the labium and hypopharynx and is mixed with the food during chewing to assist in swallowing. The food bolus is then forced by the maxillae and hypopharynx up into mouth for swallowing

Due to the evolutionary change insects have got numerous modifications of the mouth parts that permit them to feed upon nearly all organic matter.

Insect mouth parts can be grouped under two basic types namely:

i. Those with more or less elongate or haustellate mouth parts adapted for taking up liquid without piercing. E.g. Lepidoptera, some Diptera and Hymenoptera

ii. Those with mandibulate or biting mouth parts such as Orthopteroid order and the Coleoptera.

An examination of the mouth structures of mouth parts will therefore give a clue to the feeding mechanism and frequently to the nature of the food of an insect. Broadly speaking the mouth parts and feeding habits of insects are the following kinds:

i. Biting-chewing type

Is more primitive and least specialized. The mandibles cut off solid food with its heavily sclerotized portion of the grinding surface. The food bolus is then forced by the maxillae and hypopharynx up into the mouth for swallowing. E.g. Grasshopper

ii. Piercing-sucking type

Here the labium, mandibles and maxillae are slender and fit together to form delicate hollow needles for piercing. Make small holes either blood or plant sap is taken by them. E.g. Aphids

iii. Rasping-sucking

Mandibles and maxilla function as stylet in scratching or rasping the epidermis of plants. It is primitive form of piercing and sucking mouth parts. E.g. Thrips

iv. Chewing-lapping type

In this type, the labrum and mandibles are of the same structure as in the biting-chewing type and is used for manipulation of nests (for molding wax) and holding preys. The maxillae and labrum forming channeled proboscis through which saliva is produced and take up nectar. E.g. Bees, wasps

v. spongy

Mandibles and maxillae are non-functional. Other parts, primarily labium form proboscis with fan shaped at the tip. It is used for sucking of liquid food. E.g. House fly.

vi. Siphoning

Modified to take nectar. It is a highly specialized form. Doesn’t make any hole or scratch. There is long proboscis (long tongue) modified from maxillae. It will be coiled and stay under their neck at rest condition. Normally found in adult Lepidoptera.

As already mentioned there are many differences in mouth parts of insects, though a few generalizations may be made. Predaceous insects usually have mandibles that are long. Pointed and very-sharp. These are used similarly to canine teeth in mammals, in killing prey. Since little grinding is required, the molar area is noticeably reduced to absent. Just as mammal herbivores have different tooth modifications for eating different food of various consistencies so also do insectan herbivores; those that feed on grasses or seeds have greater grinding surfaces on the mandibles than do that chew soft succulent leaves. In all instances, feeding is actually the culmination of a series of behavioral responses of stimuli. Using a polyphagous insect as an example, we see that the sequence typically follows the pattern of first being attracted to the food by odor, sensing the plant through contact receptors on the tarsi, taking a test where by the taste receptors, especially those on the palpi, can discriminate, and then feeding.

2.1.3. Eyes

As with most animals, photoreceptors are usually located near the mouth at the anterior region of the body. The most conspicuous of these photoreceptors are the compound eyes of adults and of many immature nymphs

Each receptor consists of a number of separate receptors or ommatida. The number varies from a single ommatidium in some ants to over 30,000 in some dragon flies. In most day flying insects, each appostion type of ommatidium has a light gathering apparatus. Direct bright light is focused by each lens system on its won rhabdom, which contains visual pigments, and initiates a discharge of nerve. Interpretation of this message by association centers in the brain is made, and the insect accomplishes vision.

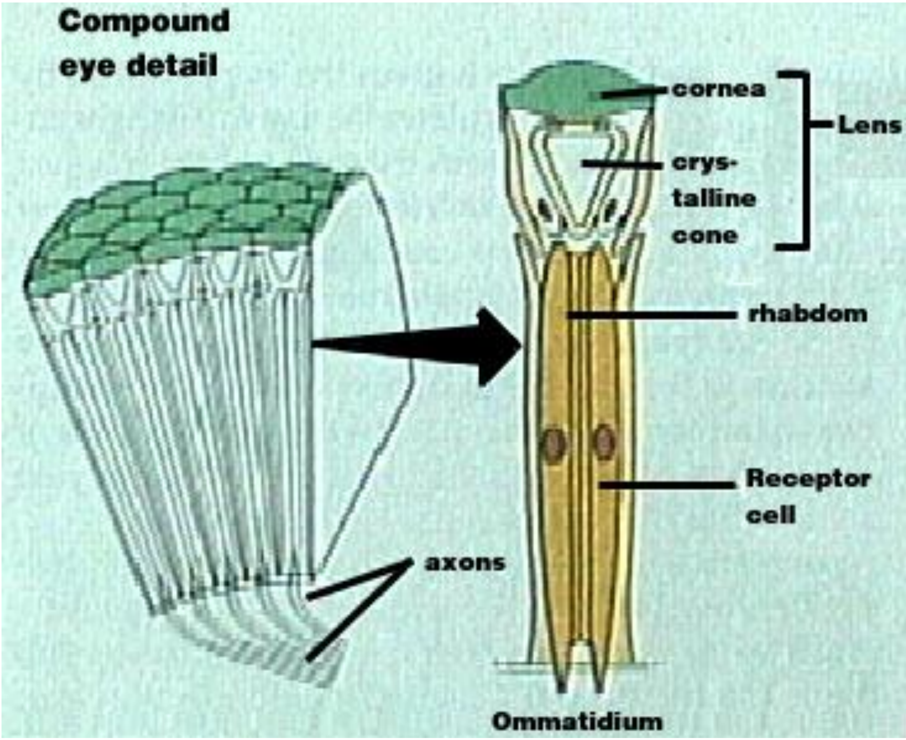


Fig.4. Insect compound eye

In general, predators and fast flying insects that seek flower or mate during flight have the greatest number of ommatida, and soil inhabitants and occasional fliers tend to have the least. One reason for large number of ommatia in predators and fast flying species seem to be the advantage of increased depth of perception. If an insect faces an object, the intervening distance is calculated by the angle between the eyes. As the two comes closer, the ommatida nearer and nearer the meson are used, there by providing a measure of distance. The greater the number of ommatida, the more precise will be this measure. Objects laterally positioned can not be seen by both eyes, and hence distance can not be adequately measured. Complexity and variation of the compound eye can not be over state. Variations from the above explanation include:

1. Insects active at night have a superposition type of compound eyes that differs from the type of eyes of insects that fly during the day. Superposition eyes have a clear zone between the light gathering and light sensing apparatus, permitting light from many lenses to be focused on a single sensing area, hereby brightening the image.
2. Lens size of eyes of fast flying insects differ from the lens size of eyes of slow flying insects.

3. Eyes of different insects vary in their capability to perceive different wave lengths; although most insect eyes are able to see ultraviolet and a few can distinguish red, blue, or green wave lengths of light. Ultraviolet receptors are most frequent in the dorsal part of an eye.

2.2. Thorax of insects

It is a body region between the head and abdomen. It is connected with the head by a membranous region which forms a neck. It consists of three body segments. These are prothorax, mesothorax, and metathorax and the body segments of 7^{th}, 8^{th}, and 9^{th} respectively. Each segment bears a pair of legs, and in most adults the meso and metathorax each carry a pair of wings and a pair of legs. In insects which do not develop wings the three segments are nearly alike in general structure.

The basic plan of each of the thoracic segments consists of a dorsal tergum (especially notum when referred to thorax), a ventral sternum, and two lateral pleura (pleuron- singular). A pair of spiracles, openings into the respiratory system is found between the prothorax and mesothorax and between the mesothorax and metathorax.

2.2.1. Wings of insects

Wings arose not as a modified appendages, as in other animals capable of flying but aa out growths of the body wall, along the lateral margins of the dorsal plate, the notum. They contain no muscles or tendons, and flight usually comes from movement of the notum, which in turn causes the wings to move. In basic design, insect wings are very simple consisting of an upper and lower membrane or layers between which are many thickened lines that strengthen the thin wing membrane. These are frame work of hollow sclerotized tubes known as veins. Between the upper and lower layer of insect wings, there may be seen trachea, nerves, and an extension of body cavity.

Veins are valuable in demonstrating relationships and are named to permit detailed studies on classification, i.e. wings exhibit innumerable differences in venation which are of great importance in classification. All types of vennation seem to have developed from the same basic pattern. The basic pattern applies only to the main trunks of veins, i.e. to veins that run from the base of the wings to ward the apex. Those veins or lines that run more or less cross-wise of the wing and connect the main trunk veins are known as cross veins. The pattern of veins and cross veins is termed vennation. When as adult insect emerges the veins contain blood, which has been observed to circulate through them, and even in the fully formed wings, the circulation is often still maintained.

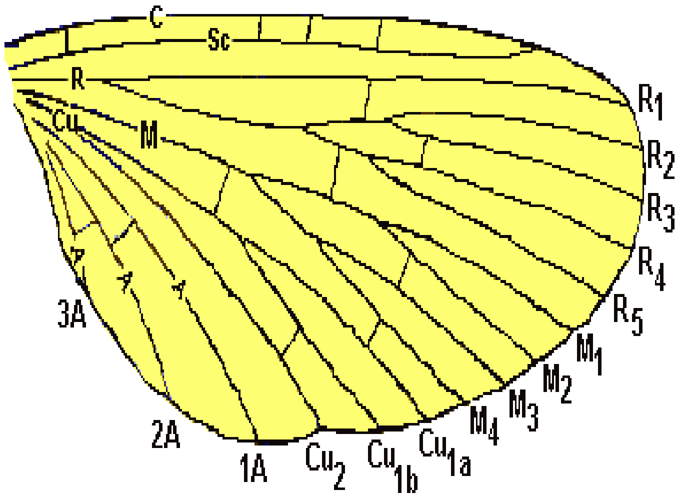


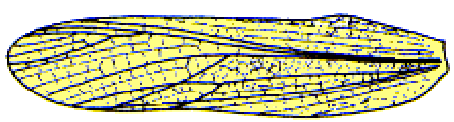
Fig. 6. Longitudinal veins and cross veins

From the leading edge of the wing towards the rear, the six major longitudinal veins are named *costa (C), subcosta (Sc), radius (R), media (M), cubitus (Cu)*, and *anal veins (A)*. Apart from the costal, subocostal and the anal veins, each vein can be branched, in which case the branches are numbered from anterior to posterior. For example, the five branches of the radius will be called R_1, R_2, R_3, R_4, and R_5. As there are several anal veins, they are called 1A, 2A, etc. They are usually unforked.

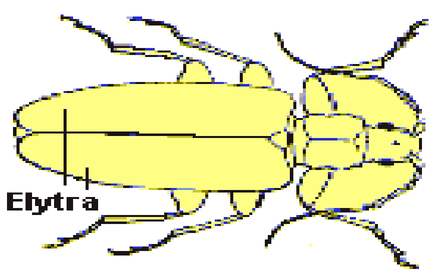
Modifications of wings

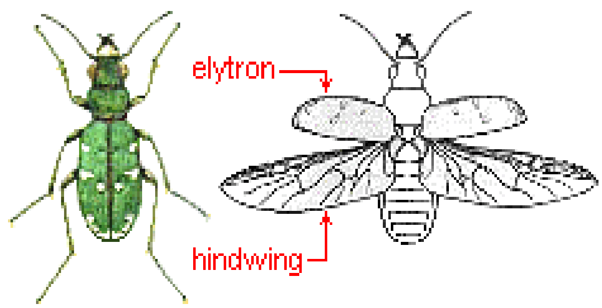
The insect wings are highly modified into various forms according to their habit and use the distinct names have been applied to those forms:

I. Tagmina- the fore wing is hard and leathery in structure. This condition is found in order Orthoptera. E.g. Grasshopper

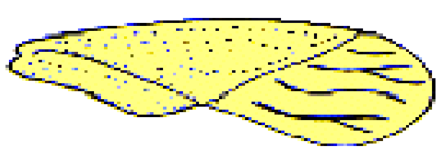


II. Elytra- the fore wings yet much hardened to form horny sheath which protects the membranous hind wings.

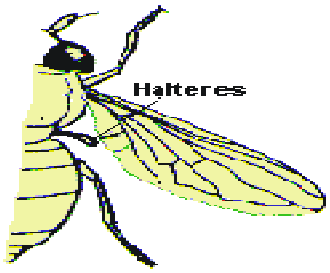




III. Hemelytra- the fore wings are thickened and their bases like elytra and remaining as soft or membraneous, that is why they are frequently termed as hemelytra. E.g. Hemipterous insects



IV. Halters- the hind wings of Diptera are modified into knobbed, thread like balancing organs known as halters or balancers. E.g. House fly



2.2.2. Legs of insects

The legs are primary organs for running or walking. But later a large number of modifications are evolved in adaptation for other uses. The leg consists of six segments the coxa, trochanter, femur, tibia, tarsus and pre-tarsus. The femur and tibia are longer than the other segments and has conspicuous ‘knee” between them that permits the insect to be slung low to the ground for stability. Although the tarsus appears to have segments, these segments are actually pseudo-segments since each lacks independent musculature. The pre-tarsus consists of only the claws. Claws enable insects to move on rough surfaces.

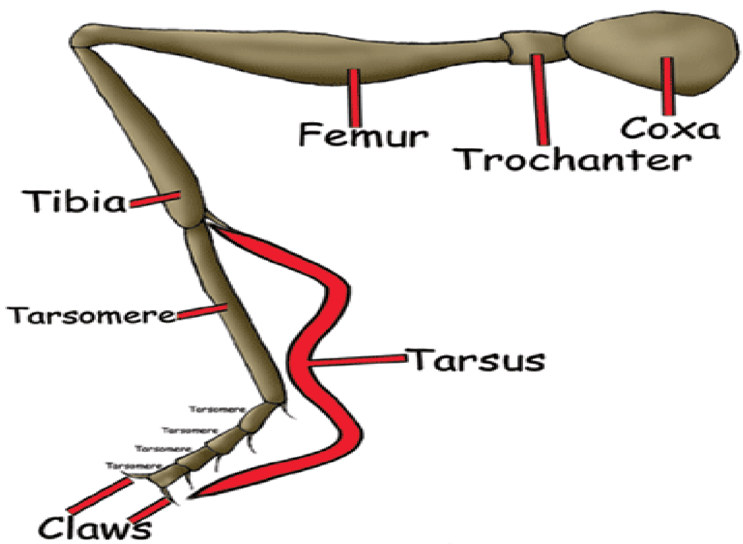


Fig. 7. A typical insect leg parts

The entire leg is moved by muscles originating on the tergum or sternum and inserted on the coxa. In addition, movement of individual segments is accomplished by muscles with in the segments. These muscles either extend or flex, there by pushing or pulling as the entire appendages is moved basally. In some insects these muscles also suspend the body above the substrate where as other insects permit their bodies to contact the surface when they are not active.

There are different modifications of insect legs according to use and habit of the insect:

i. Ambulatorial or walking type- the front and hind legs on one side and the middle leg of the opposite side are raised and moved forward together. Once these legs have completed their movement, the opposite three legs are moved. As a result the insect is always well balanced and is supported by tripod legs. Exceptions to the previous include insects that have highly modified front legs, such as the mantids during slow walking and insects that have lost legs. E.g. Ants

ii. Cursorial or running type- most running animals have legs that are elongate and slim. Increased length permits greater distances to be covered with the same muscular effort, and the slimness reduces environmental friction. E.g. Cockroaches

iii. Saltatorial or jumping type- to saltate means ‘to jump or vault” legs modified for theis function commonly have greatly enlarged femur to accommodate the enlarged extensor muscles that straighten out the tibia. Since the legs are less anchored by large tarsal pads, claws, and often spines; a rapid contraction results in the entire body being propelled. Most legs of these types are located on the metathorax, as seen in the grasshopper, so that the direction of jumping is forward, where the major sensory structures can perceive the upcoming environment.

iv. Raptroial or grasping type-the front pair of legs often modified to grasp and hold prey for feeding. The large muscles here are flexers, and the tibia is pulled back against the femur when the muscles contract. Spines may also be present on the femur and tibia, as in the mantid, to impale the prey and decrease the likelihood of escape by the victim.

v. Natatorial or swimming type- most of us is familiar with swimmers arm movements. These principles in their use are similar to the activities and modifications seen in the swimming legs of insects. Divining beetle, for example, has the middle and hind legs flattened and the segments often approximately the same size. When these legs are straightened and are rapidly moved posteriorly, the maximal surface area is exposed to the water. The net effects are to propel the organism forward.

vi. Fossorial or digging type- the fore legs of the mole cricket and cicada nymph are shortened and heavily sclerotized. Large toothed projections from the femur or tibia are used to ‘rake’ through the soil particles.

vii. Stridulatorial or sound producing type- these legs are typically adapted for producing sound where in the femur of hind leg of male grasshopper or cricket is provided with the row of pegs on the inner side. These femoral pegs work against the outer surface of each tergum or costal margin.

Viii. Climbing or sticking type- these are also termed as adhesive type of legs which are generally found in hose fly. In such type of legs the pretarsus is highly modified and represented by a pair of claws and a pair of pad like structures known as pulvilli which are found at the base of claws. They are densely closed with numerous hollow and tubular hairs.

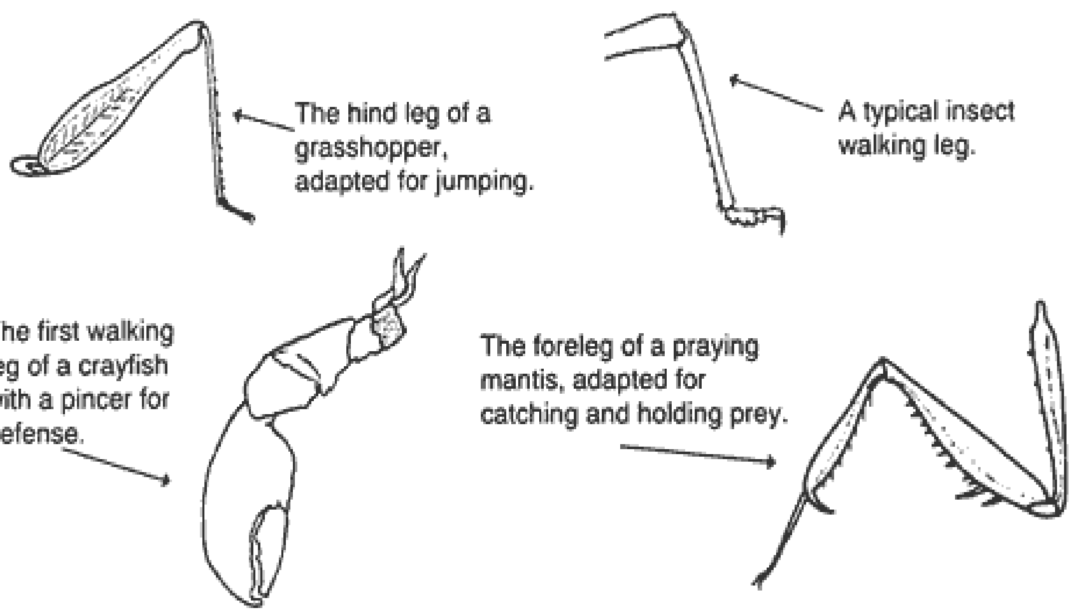


Fig. 8. The different modifications of insect legs

2.3. Abdomen of insects

The posterior regions in insects are called the abdomen. It is composed of a series of segments which are more equally developed than in other regions of the body. The number of abdominal segments varies from 9-11.

Reduction or special modifications of certain segments is evident at the anterior and posterior ends of the abdomen, more especially in latter region. The first segment may fuse with the thorax and appear to be part of the thorax. E.g. ants. The remaining segment, however, are very similar and consists of a dorsal tergum and a ventral sternum. The remaining segment, however, are very similar and consists of a dorsal tergum and a ventral sternum. The anterior eight segments usually have a pair of spiracles. Spiracles are usually absent in the terminal segments, and these segments are often fused together or are reduced in size. The functions of the abdominal region are vital to the organisms since it is in this region that the major viscera, heart and reproductive organs are located.

In many endopterygota insects, more especially those whose eggs are deposited with in plant tissues or in other concealed situations, the distal abdominal segments become attenuated and often telescoped to form a retractile tube oviscapt which is used as an ovipositor.

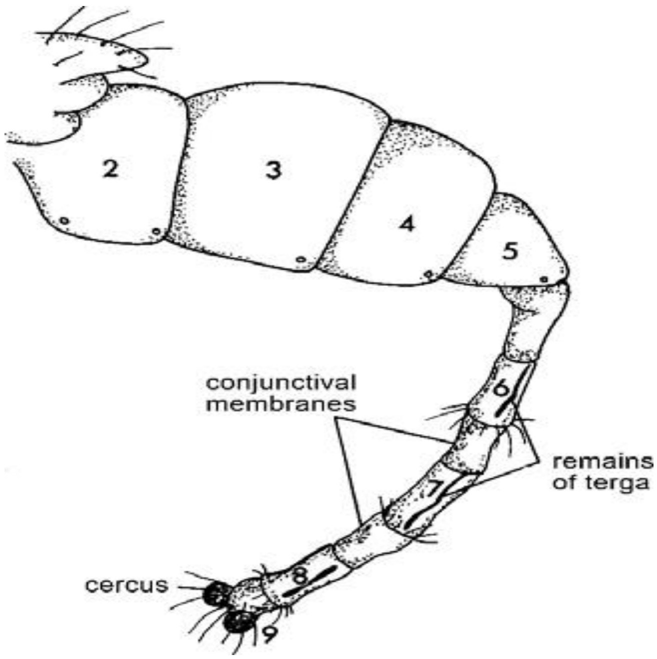


Fig. 10. Abdomen of the house fly extended. The segments are numbered.

2.3.1. Appendages of the abdomen

A variable number of these appendages may become transformed into organs that are functional during the post-embryonic life while the remainders disappear. The most conspicuous of the persistent appendages are the cerci of the 11^{th} segment, which exhibit wide diversity of form and may even be transformed into forceps as in earwigs. The cerci are usually tactile organs (sense of touch or sensory) and in some group have become part of the male genitalia.

External genitalia

These include the characteristic ovipositor of many female insects and the diverse male copulatory organs. Appendages of the reproductive types are generally located on the 8th and 9th abdominal segments in the female but only in the 9th in the male.

Female genitalia

It consists of three types of valves or blades that collectively from the ovipositor or egg laying organ. They are called 1st, 2nd, and 3rd, valvulae respectively arising from the valvifiers. Their degree of development and co-adaptation varies according to the uses to which the organ is subjected.

In most insects with well developed ovipositor as in most hymenoptera the ovipositor is greatly attenuated and modified for piercing and stinging. The first and second vulvulae form a cutting or piercing organ with an inner channel down which the egg passes. The third vulvulae forms a sheath into which the ovipositor folds when retracted. Either all three pairs of vulvulae fit together to form the functional ovipositor or the second pair forms a short egg guide.

Male genitalia

This is variable and particularly valuable for separating the genera and species of many groups of insects. The external genitalia of male insects include an organ for transforming the spermatozoa (either packed in a spermatophore or free in fluid) to the female and often involves structures that grasp and hold the partner during mating.

The appendages of the 9th segment is usually combined with parts of the tenth to form a copulatory organ. When fully developed they consists of essentially a pair of claspers which help to grip the female during copulation and between which lies the aedeagus. In insects the aedeagus is often sclerotized in varying degrees and modified sufficiently to prevent interspecies mating. A pair of claspers may be present to maintain the correct positioning of the female during copulation.

Much variation in male external genitalia correlates with mating position, which is very variable between and sometimes with in orders, mating positions include end-to-end, side-by-side, male below with his dorsum up, male on top with female dorsum up and even venter-to-venter.