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Regards : Zarva Chaudhary

"Chaudhary Moazzam"

Relationship of insects with other animals

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Groups of animals

- Among the larger groups of animals now recognize~ by science, the one known as the Chordata is naturally the most familiar
- Including the mammals, birds, reptiles and fishes, besides numerous forms less well known
- Another group, also familiar, called the Mollusca, includes the snails, clams, etc

Groups of animals

- The starfish and sea urchin, often seen at the seashore, belong with other similar animals to a third group called the Echinodermata
- A multitude of tiny beings, almost all too small to be seen without the aid of a microscope, are included 'in the group Protozoa
- A fifth large group is composed mainly of soft, jelly-like animals, the more common larger members being called jellyfish, and to this group the name Coelenterata is applied.
- Several other groups including various kinds of worms and less familiar forms are also known

Arthropoda

- The largest group of all, however, is the Arthropoda
- Its members found in the seas, in fresh water, on land or even flying freely
- A group with remarkable differences of structure, and so abundant that all the other animals taken together are less than one-sixth as many as the arthropods

Arthropoda

- Well-known members of this group are
  - The lobsters, cray fish and crabs
  - Scorpions, spiders, mites, ticks
  - The centipedes and millipedes
  - Last, and most abundant of all, the insects

Characteristics of Arthropod

Characteristics of Arthropod

- No one feature will serve to separate the arthropods from' all other animals
- But the possession by an animal of several of those here described will enable the observer to determine in each case whether he is examining one of this group.

Characteristics of Arthropod

- In arthropods the body is composed of a series of more or less similar pieces or segments
- Placed one behind another, the line of attachment of these to each other being usually somewhat evident on parts of the body at least

Characteristics of Arthropod

- This character is also shown, and indeed more clearly, in some worms, such as the common earthworm
- Another character of the arthropods is the presence of jointed legs (or appendages of some kind), as is indicated by the name of the group, and these are not possessed by worms

Characteristics of Arthropod

- The surface of the body is covered by a secretion which hardens on exposure to the air, forming an outside shell or external skeleton called exoskeleton

- There being practically no internal structures supporting the soft organs within this shell except as ingrowths from the outside

Characteristics of Arthropod

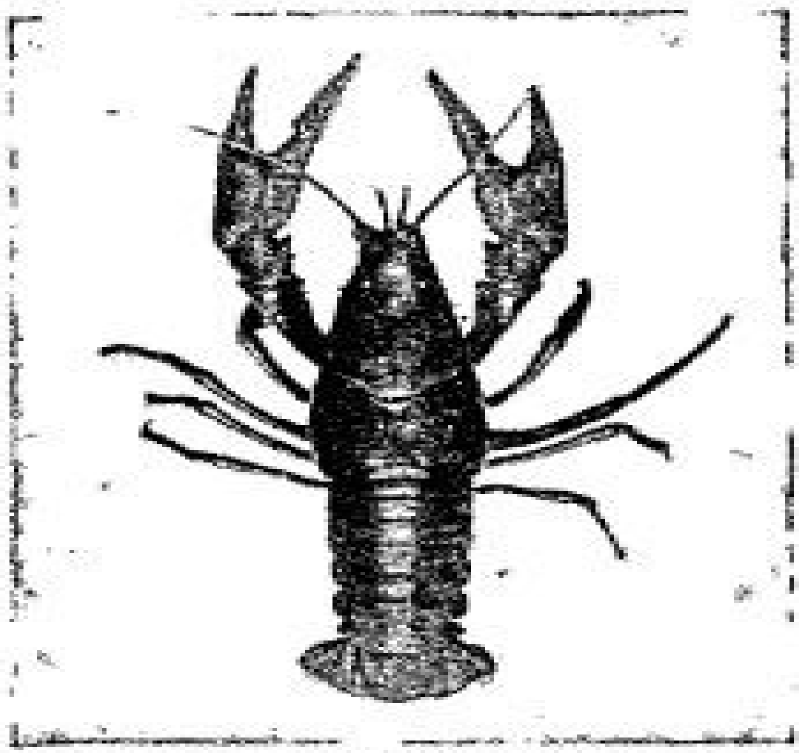

FIG. 1.—Crayfish (*Crustacea*); about one-half natural size.

Distinctive Characters of Arthropods Groups

DISTINCTIVE CHARACTERS OF THE MAIN ARTHROPOD GROUPS

	Where found	Body divisions	Antennae	Legs	Breathe by	Reproductive organs open
Crustacea	Mainly in water	Head and body: often a cephalothorax	Two pairs generally	Numerous: may be built for swimming	Gills or through body surface (rarely by air tubes)	Well forward
Diplopoda	On land	Head and body	One pair	Many: two pairs on most body segments	Air tubes	Near head
Chilopoda	On land	Head and body	One pair	Numerous: one pair on each body segment	Air tubes	Next to last body segment
Arachnida	Mainly on land	Cephalothorax and abdomen (no divisions in a few cases)	None	Eight: joined to cephalothorax	Air tubes, book lungs or body surface	Front part of abdomen (a few exceptions)
Hexapoda	Mainly on land	Head, thorax, abdomen	One pair	Six: joined to thorax	Air tubes	Near hind end of abdomen

Characteristics of Arthropod II

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Characteristics of Arthropod

- In the possession of this external skeleton these animals have a seeming resemblance to the shells (Mollusca)
- But the materials of which the skeleton is composed are quite different Being largely calcium carbonate in the Mollusca
- And chitin which somewhat resembles horn in its nature, sometimes with calcareous salts ·deposited in it, in the Arthropoda

Characteristics of Arthropod

- The simple members of arthropod have bilaterally symmetrical body, though this condition is concealed somewhat by secondary changes in many of the group

- The possession of a bilaterally symmetrical body consisting of a series of segments, an exoskeleton of chitin and the presence of jointed legs are, then, distinctive features of the arthropods

Characteristics of Arthropod

- To separate the various groups of arthropods, other characters must be Used
- Aside from several small sections not often seen, there are five large and important divisions which call for recognition

Groups of Arthropods

- 1-The **Crustacea**, including the lobster, crab, beach flea, sowbug and many Others
- 2-The **Diplopoda** or millipedes
- 3-The **Chilopoda** or centipedes
- 4-The **Hexapoda** or insects
- 5-The **Arachnida**, including the scorpions, pseudo-scorpions, spiders, mites, ticks, etc.

Crustacea

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Crustacea

- The Crustacea are mainly water-inhabiting animals which breathe either by gills or, in the smaller forms, through the surface of the body

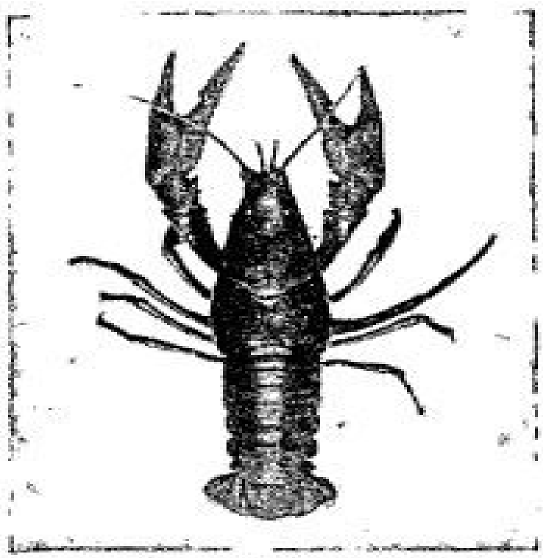

FIG. 1.—Crayfish (*Crustacea*); about one-half natural size.

Crustacea

- In those cases where its members live on land the gills are still present, though in a somewhat modified condition.

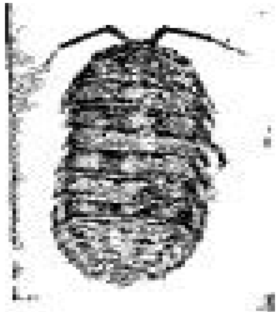

FIG. 2.—Sow-bug; slightly enlarged. A crustacean living on land.

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Crustacea

- They have numerous pairs of legs and generally two pairs of antennae (jointed "feelers")
- Often some of the bug; body segments are fused with the head to form a crustacean cephalothorax

Diplopoda

Diplopoda

- The Diplopoda are land animals breathing by air tubes opening on the sides of the body, these tubes carrying the air into all the internal parts of the animal

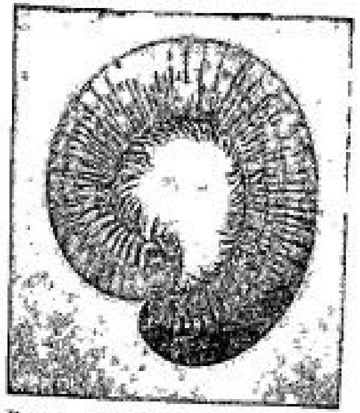

FIG. 3.—Millipede (*Diplopoda*); natural size. (*From Folsom.*)

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Diplopoda

- The head bears a pair of antennae and is followed by a series of segments all practically alike and each, except the first three, with two pairs of legs
- The reproductive organs open far forward on the body

Diplopoda

- In most of the more common members of this group the body is quite cylindrical, and when disturbed the animal usually curls up in a sort of close spiral
- Small diplopods about the diameter *of the lead of a pencil and gray in color are often found boring* into potatoes and roots in the ground In the fall and are sometimes wrongly called wireworms

Diplopoda

- The Common name, millipede, refers to the large number of legs possessed by these animals

Chilopoda

Chilopoda

- The Chilopoda are also land animals
- Like the diplopods they have antennae and breathe by air tubes, and the body segments are practically all alike

Chilopoda

FIG. 4.—Centipede (*Chilopoda*); about three-quarters natural size.

Chilopoda

- The general form, however, is rather flattened
- Each segment bears only one pair of legs
- The reproductive organs open at the posterior end of the body

Chilopoda

- The front leg on each side is modified to serve as a poison claw
- The numerous legs present in these animals have resulted in their receiving the common name, centipede

Arachnida

Arachnida

- The Arachnida generally have the segments of the body grouped into two sections called
  - **1-The cephalothorax**
  - **2-The abdomen.**

Arachnida

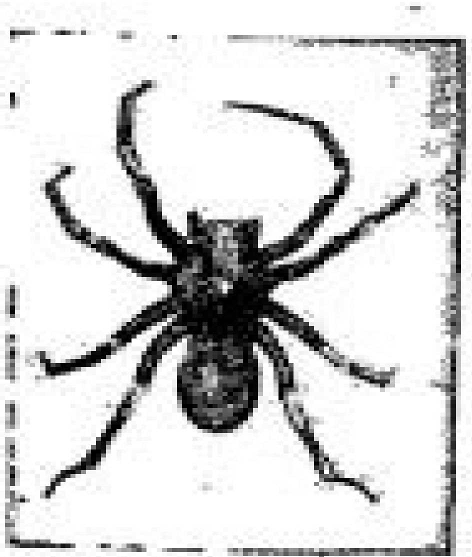


FIG. 5.—Hairy spider (*Arachnida*); about natural size.

Arachnida

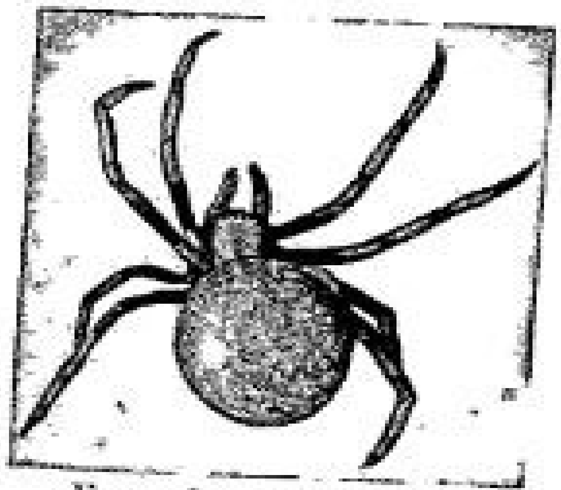


FIG. 6.—Large-bodied spider (*Arachnida*); about natural size.

Arachnida

FIG. 7.— Adult female castor-bean tick (*Arachnida*); natural size. (*From U.S. Dept. Agr. Farmers' Bull.* 1057.)

Arachnida

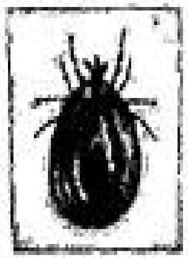


Fig. 8.—Adult female European dog tick (*Arachnida*); natural size. (*From U.S. Dept. Agr. Farmers' Bull.* 1057.)

Arachnida

- No antennae are present and the eight legs are all attached to the cephelothorax
- They breathe by air tubes somewhat similar to those of the other groups

Arachnida

- By sacs containing many thin plates resembling leaves of a book, whence these structures take the name of book lungs
- In the smallest forms, they directly breath through the body surface
- In the mites there is no evident division of the body into sections
- Though most of the group are land forms, a few are aquatic

Hexapoda

Hexapoda

- In the Hexapoda or insects the segments of the body are grouped in three distinct sections:

- 1-Head
- 2-Thorax
- 3-Abdomen

Hexapoda

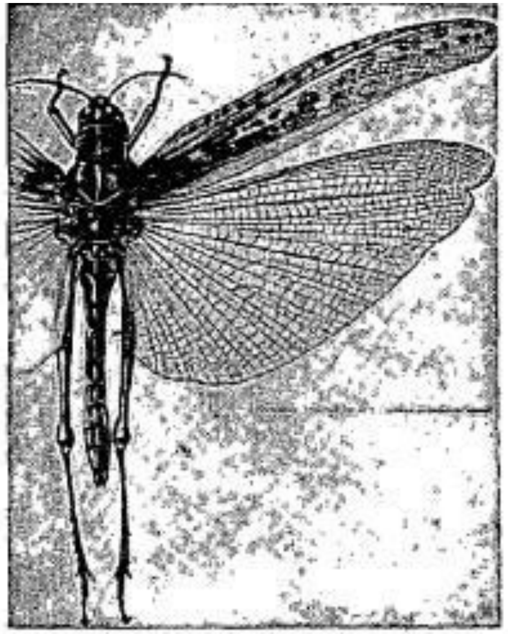


FIG. 9.—Grasshopper (*Hexapoda*); with wings spread. (*From Folsom.*)

Hexapoda

- A pair of antennae is present on the head
- The six legs are attached to the thorax
- The four wings usually present
- The animals breathe by air tubes

Hexapoda

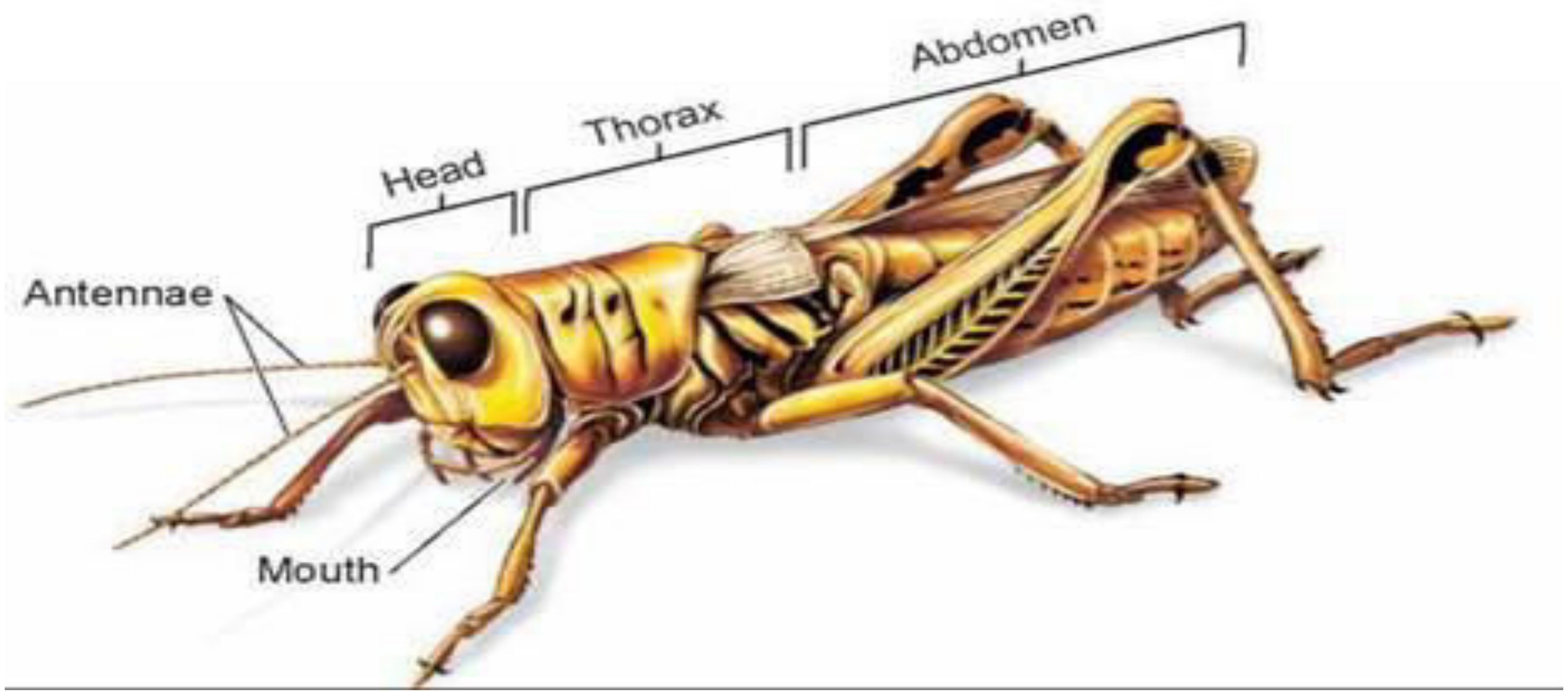
- Insects living under a great diversity of conditions, the group as a whole is emphatically a terrestrial one
- though in many cases their early life is spent in water

THE INSECT: ITS EXTERNAL STRUCTURE

General features of Insects

- Bringing together the facts already stated about insects we find that an adult insect is:
- (1) a bilaterally symmetrical animal
- (2) consisting of a series of segments one behind another;

General features of Insects



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General features of Insects

- (3) that these segments are grouped into three regions,
    - The head in front
    - Followed in order by the thorax
    - The abdomen as shown in Fig

General features of Insects

General features of Insects

- (4) that the animal is covered by a skeleton, shell-like in that it is on the outside of the body, but horny in its nature

General features of Insects

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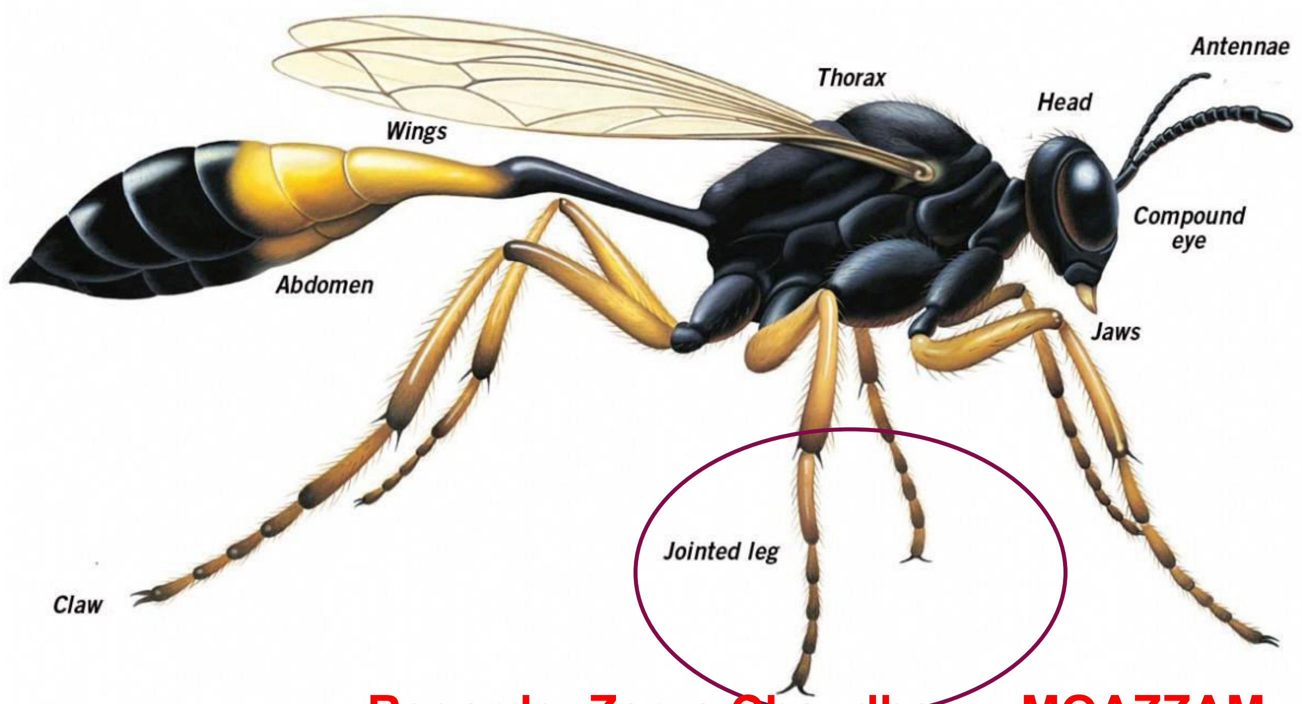
General features of Insects

- (5) three pairs of jointed legs attached to the thorax

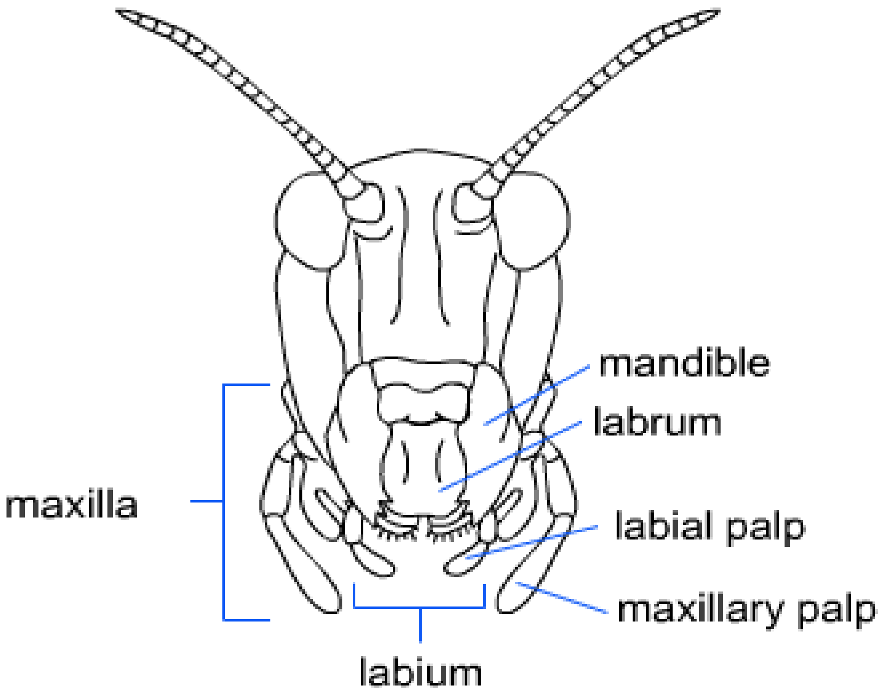


General features of Insects

- (6) that a pair of antennae

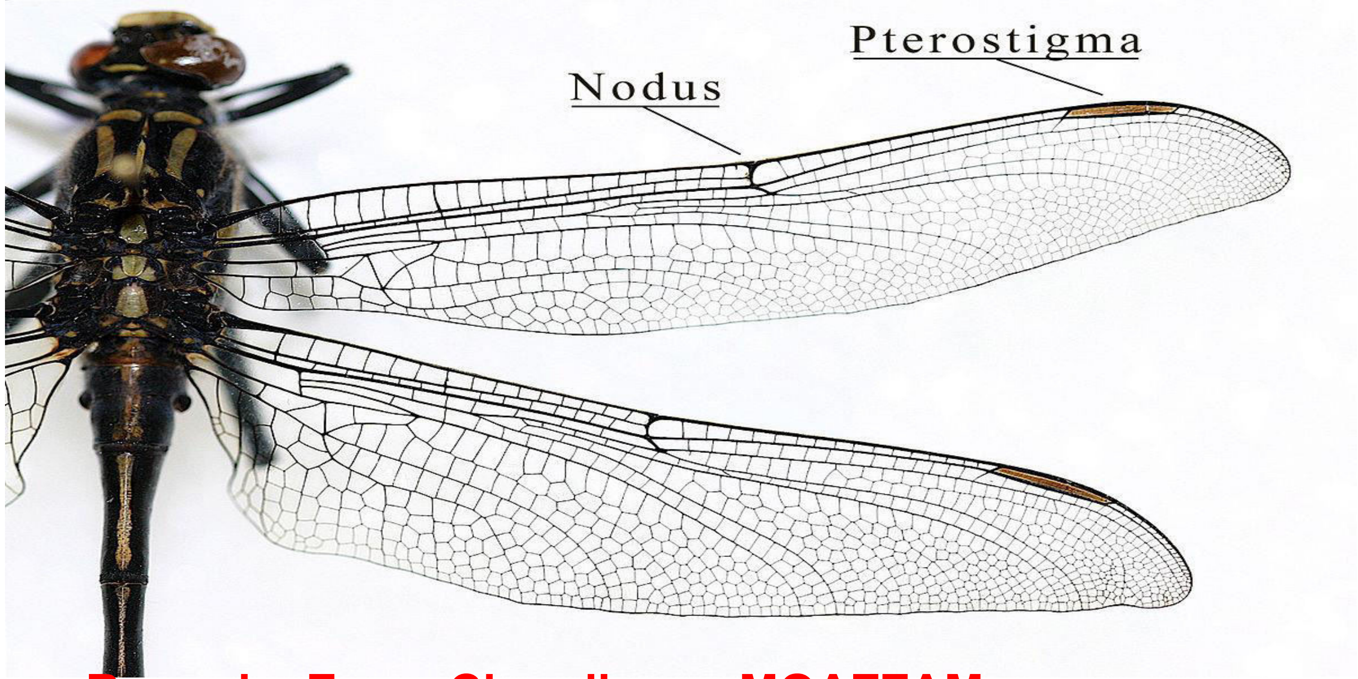
General features of Insects

- (7) mouth parts



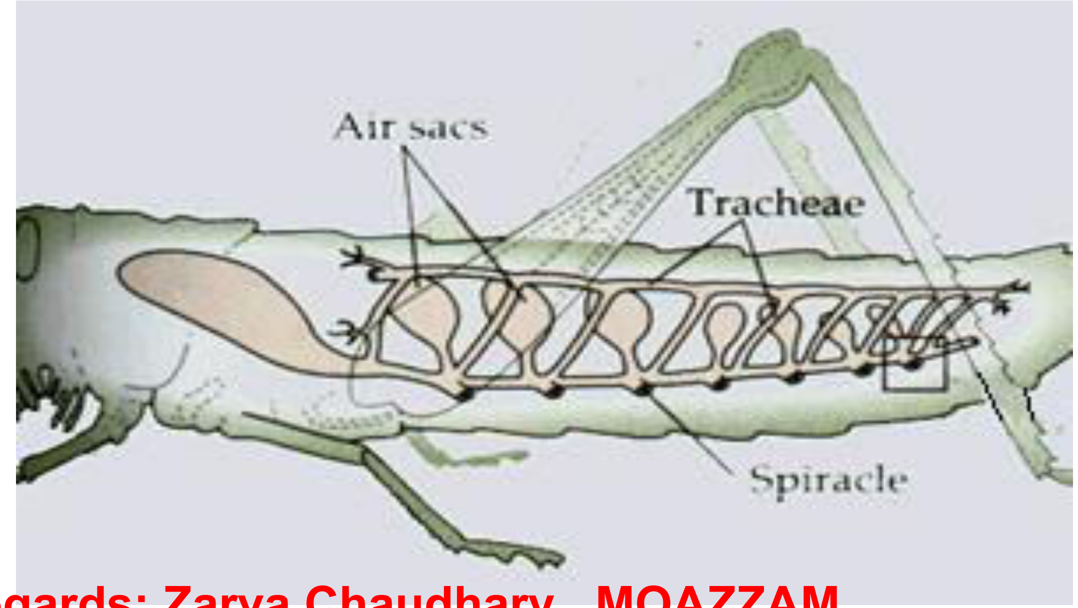
General features of Insects

- (8) and usually two pairs of wings are present



General features of Insects

- (9) that it breathes through air tubes



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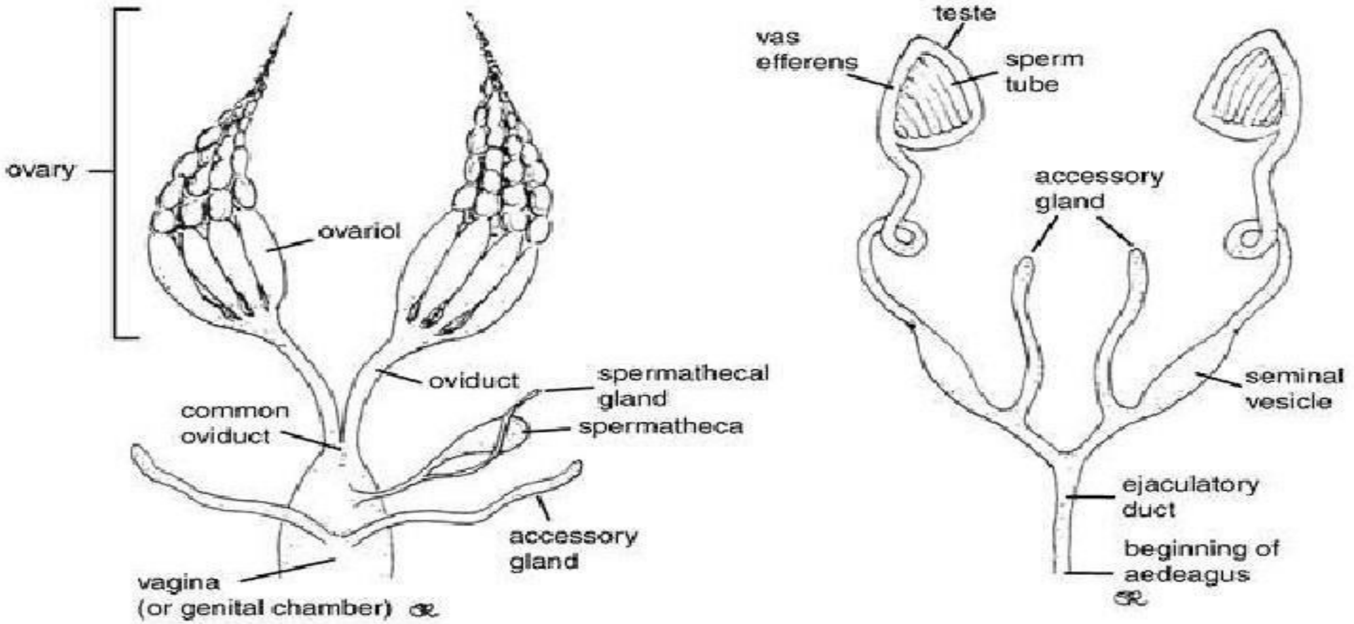
General features of Insects

- (10) that the reproductive organs open near the hinder end of the body.

Reproductive tract



General Segmentation in Insects

General Segmentation in Insects

- In the body of the adult insect there are apparently from **7 to 15** segments
- **1** in the head, **3** in the thorax and from ,**3 to 11** in the abdomen

General Segmentation in Insects

- In the egg, however, the embryo shows the presence of 6 segments in the head, 3 in the thorax and 11 or 12 in the abdomen
- Indicating that the original total number was 21

General Segmentation in Insects

- This change to the adult has been brought about in the head by an extreme amount of fusion and condensation and in the abdomen partly by fusion
- Partly by a sort of telescoping or gradual shifting of one segment within another until it has been partly or entirely concealed

Cuticle or External Skeleton

Cuticle or External Skeleton

- The skeleton of the body, or cuticula as it is called, supports and protects the soft, living tissues within it
- It rests on the outer surface of a layer of living cells, the hypodermis

Cuticle or External Skeleton

- It seems to be formed in part from a fluid poured out from the hypodermis and in part by a transformation of a portion of the hypodermis cells themselves
- The cuticula hardens quickly after its production and consists quite largely, at least, of a nitrogenous substance called chitin

Cuticle or External Skeleton

- It varies in thickness and is flexible where movement is needed, but thicker, more rigid and usually darker colored elsewhere

- The hypodermis along certain lines forms folds which project inward, carrying its cuticular secretion along with it

Cuticle or External Skeleton

- Where these infoldings occur at places that need to be movable the cuticula remains flexible
- Thus forming the movable joints; along the other infoldings it hardens (becomes sclerotized) and becomes rigid and such places show on the surface only as slight grooves or scratches called sutures

Cuticle or External Skeleton

Cuticle or External Skeleton

- These sutures and the joint lines divide the cuticula into areas called plates or sclerites
- The sutures and joint lines are sufficiently regular in position in most insects to make them convenient landmarks in descriptions

Cuticle or External Skeleton

- The sclerites on the back of each segment are usually together termed the notum or tergum; those on each side, the pleuron; and those below, the sternum

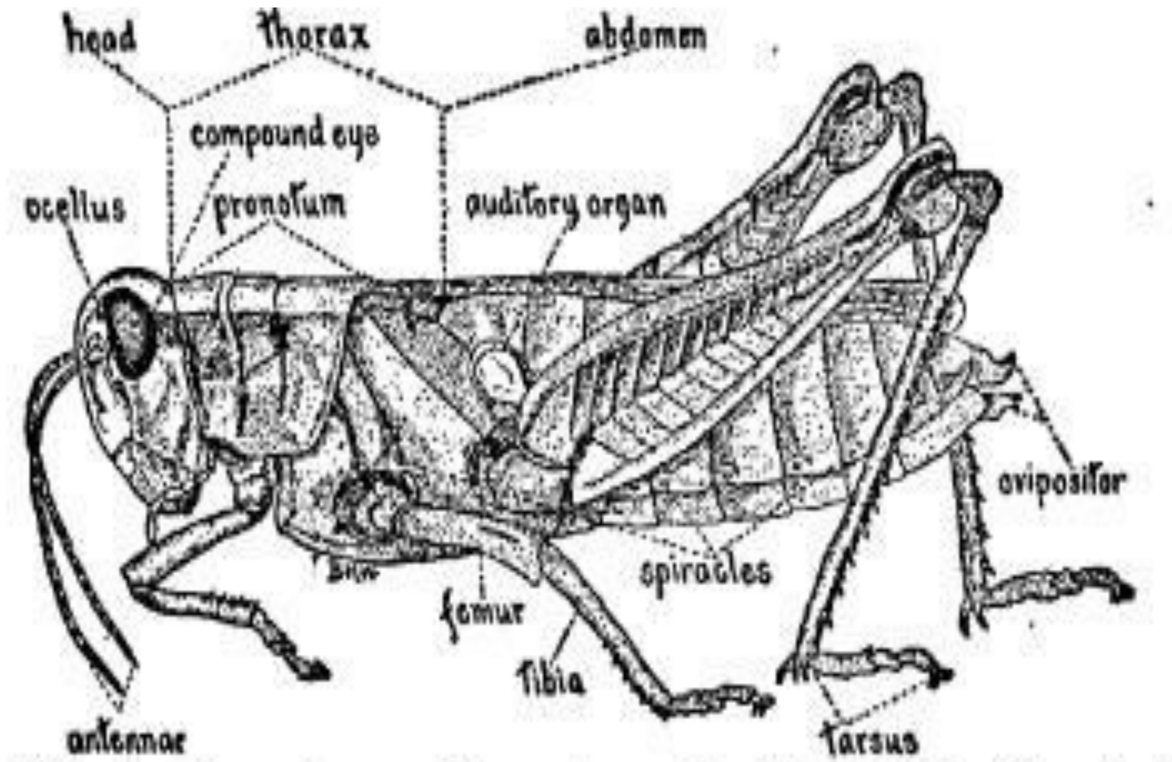
Cuticle or External Skeleton

- In the head the sutures are few in number, so only a few plates or sclerites are gener ally in evidence

- In the thorax they are more numerous, and in the abdomen often only a dorsal and aventral sclerite for each segment are found

- Occasionally weakly sclerotized areas are quite large (queen white ant) *and elastic.*

Cuticle or External Skeleton



10.—Side view of grasshopper with parts named. (*From Walden, Conn. Geol. & Nat. Hist. Surv., Bull. 16.*)

Cuticle or External Skeleton

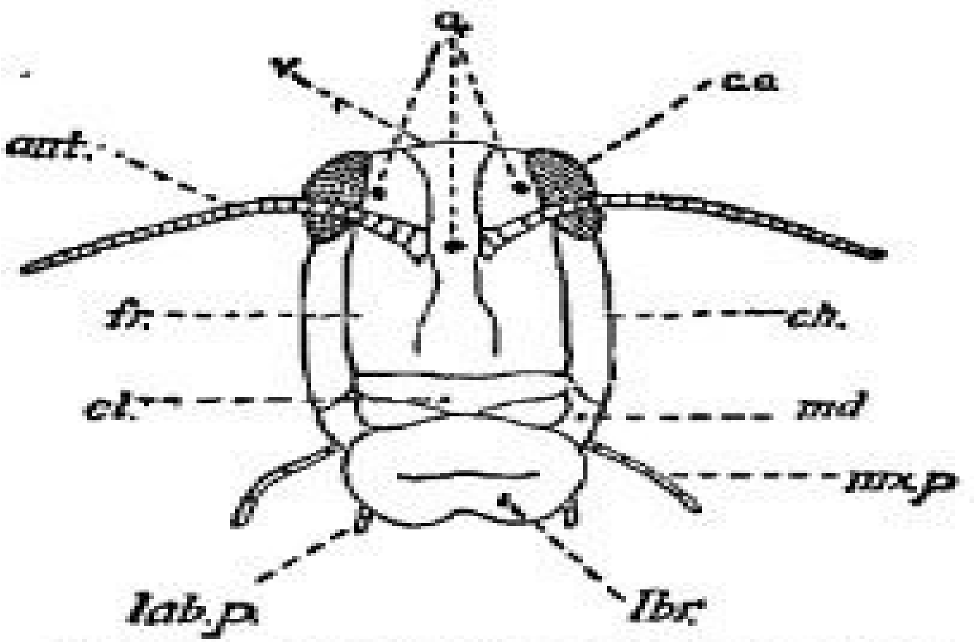


FIG. 11.—Front view of head of a grass-hopper showing a hypognathous head: *ant.*, antenna; *c. e.*, compound eye; *ch.*, cheek; *cl.*, clypeus; *fr.*, frons; *lab. p.*, labial palpus; *lbr.*, labrum; *md.*, mandible; *mx. p.*, maxillary palpus; *o.*, ocelli; *v.*, vertex.

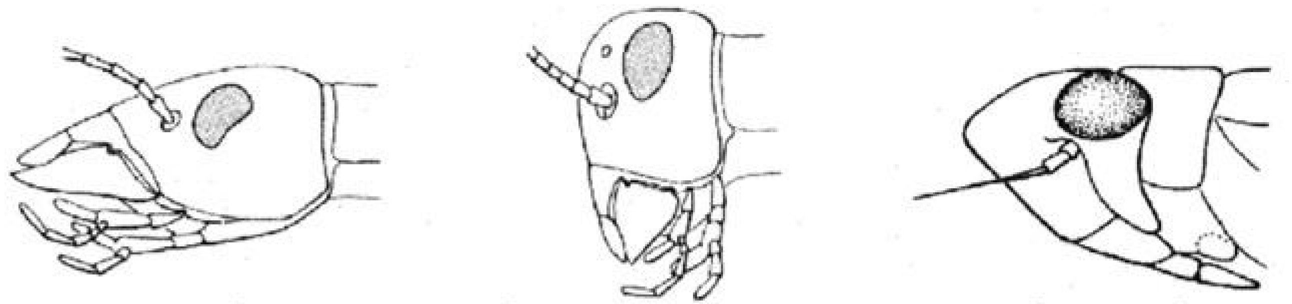
Cuticle or External Skeleton

- Usually the elasticity of these places, as, for example, the portions connecting the segments, is rather slight
- Spines, hairs, scales or other structures are often present on the cuticula, sometimes entirely concealing its surface and its sutures

Structure of Head

Structure of Head

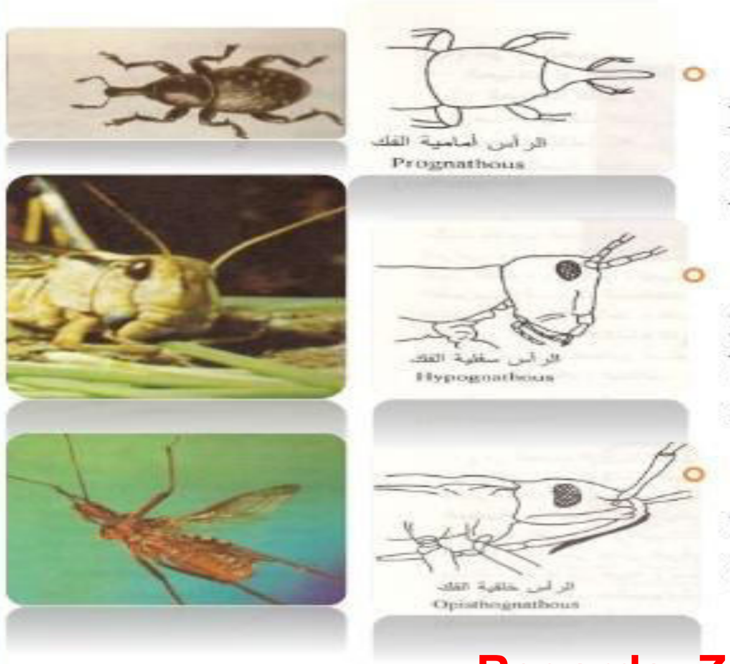
- The heads of different insects vary much in form and in the location of the mouth
- In some cases this is on the underside; in others it is practically on the front.



prognathous hypognathous opisthognathous

Structure of Head

POSITIONS OF THE HEAD



- **Pro-gnathous:** head extended longitudinally with body axis (m.p are pointed forward, Weevils)
- **Hypo-gnathous:** head perpendicular to longitudinal body axis (m.p pointed downwards, Locust)
- **Opitho-gnathous:** head bent underneath thorax during rest (m.p pointed backwards, Aphids)

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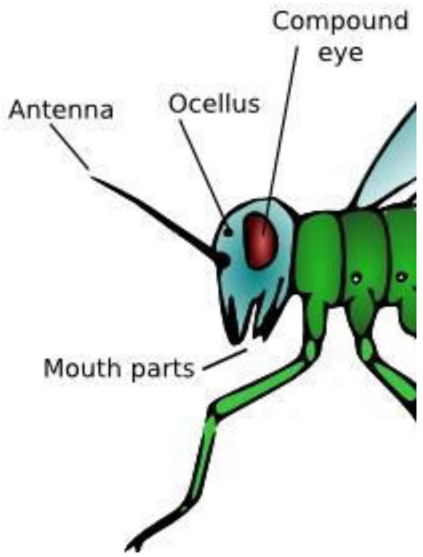
Structure of Head

- Heads with the mouth beneath are called **hypognathous**
- those with it in front are **prognathous**.

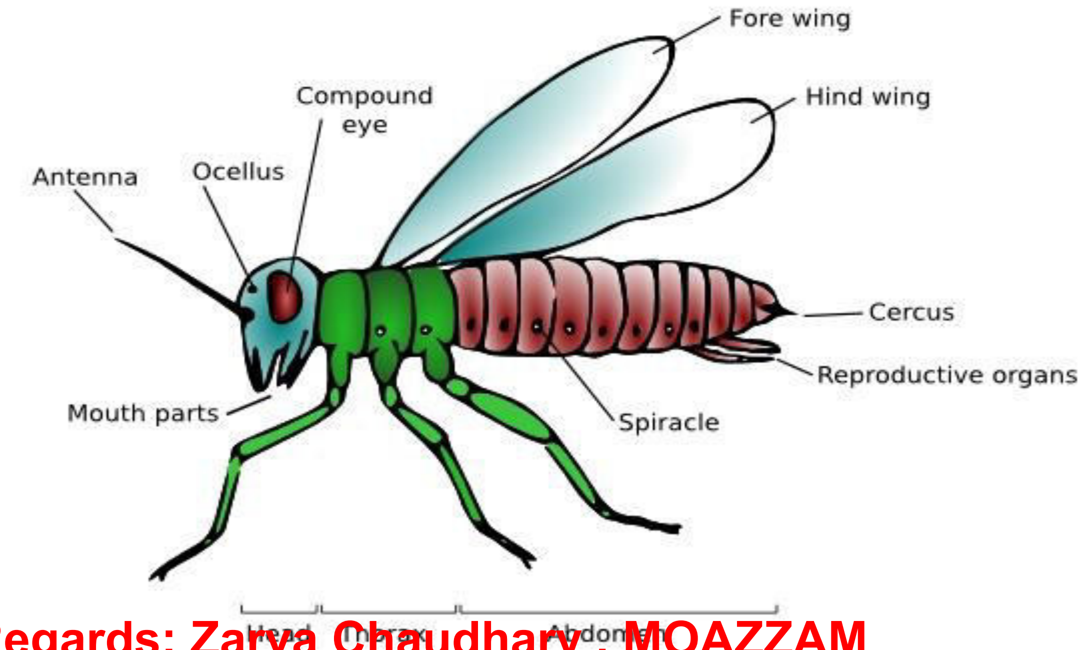
Structure of Head

- Structures found on the head are
  - A pair of antennae
  - Two compound eyes (ocelli)
  - The mouth parts



Structure of Head

- On the thorax are the wings and legs; on the abdomen are various organs such as the ovipositor, sting, cerci and styli, present in some cases, absent in others.



Antennae

Antennae

- Antennae are nearly always present
- They are usually slender, jointed
- Therefore more or less flexible organs, varying greatly in the number of segments composing them

Antennae

- They are sometimes very short; sometimes long; often thread-like; sometimes enlarged near the tip; in many cases with fine branches either on one or both sides, so that they resemble feathers or plumes; rarely they fork; in fact they arc of many forms

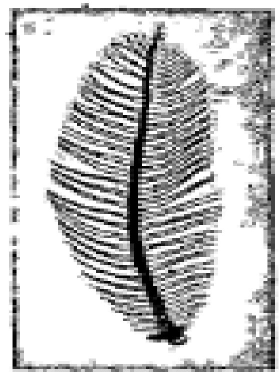


FIG. 14.—Antenna of cecropia moth. (*Samia cecropia* L.) About twice natural size.

Antennae

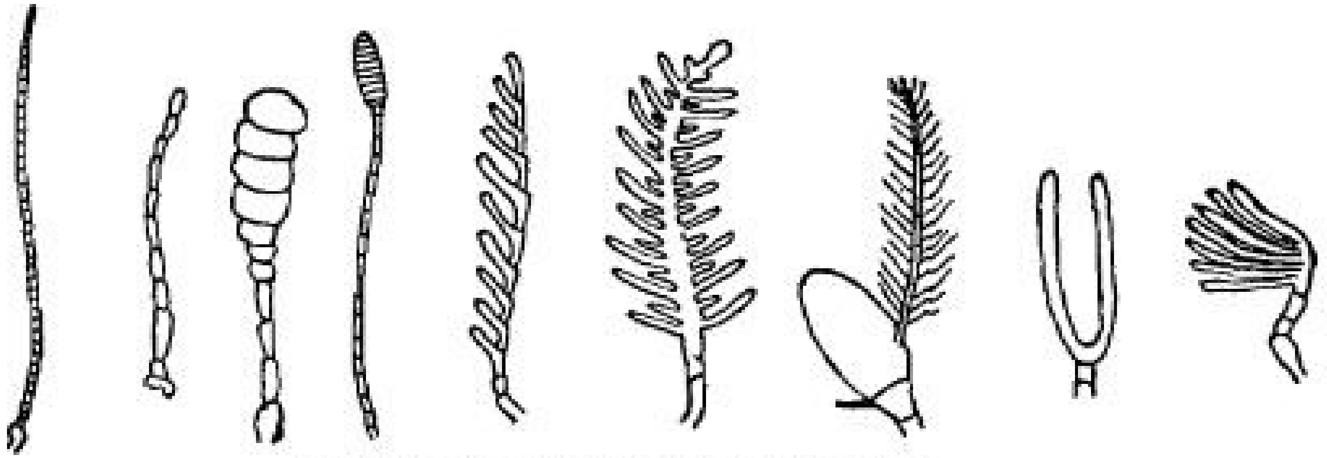


Fig. 13.—Different forms of insect antennae.

Antennae

- Sense organs are present on them for the sense of touch, and probably also for smell and hearing, at least in Some cases

Eyes

Eyes

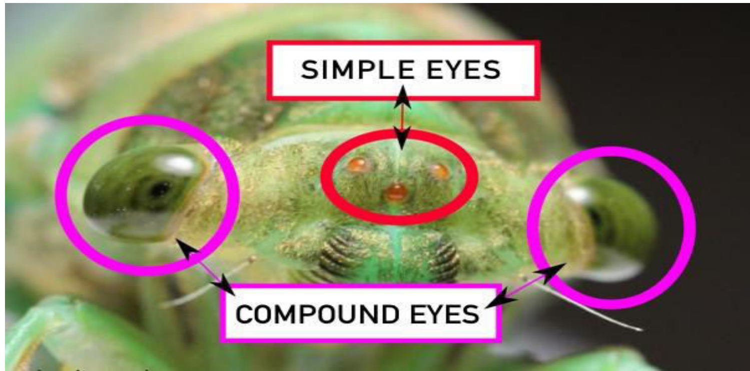
- The eyes are of two kinds
- There is a pair of compound eyes, each of which is a group of similar structures which usually are like tall, slender pyramids in form

Eyes

- Only the bases of these pyramids Show on the surface, the remainder being within the head
- The bases, closely pressed together, are usually more or less hexagonal, and their outlines can often be easily seen with a magnifying glass

Eyes

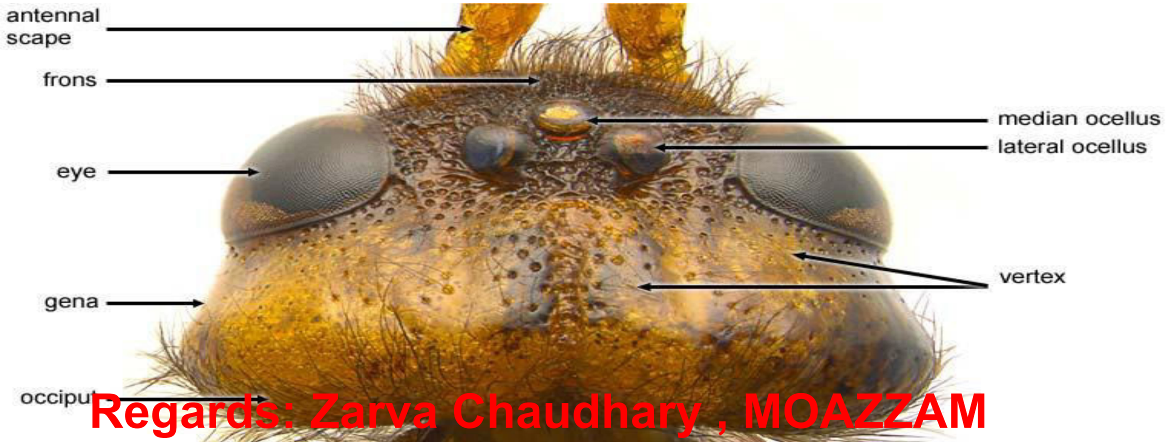
- They are called facets, and the eyes themselves are sometimes termed the faceted eyes
- The other kind of eyes, called Ocelli, may be absent or, if present, may vary in number in different insects, three being perhaps the most usual.



Eyes

- Each, as seen from "the surface, is a nearly circular, convex spot about the size of one of the facets of a compound eye

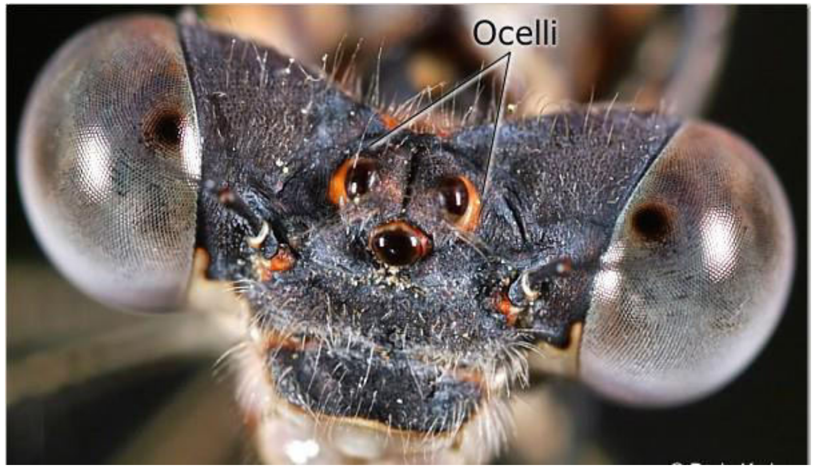
- It may be larger than this but is never equal to an entire compound eye in size



A3.6: *U. sah*

Eyes

- The cuticula of the surface of the body is transparent where it covers the surface of an eye, permitting access of light to the sensory structures within; elsewhere it is usually pigmented and rather opaque



Mouth parts of insects

mouth parts of insects

- The mouth parts of insects vary extremely in their structure
- Apparently the original mouth parts were for biting and chewing, and this type is very common

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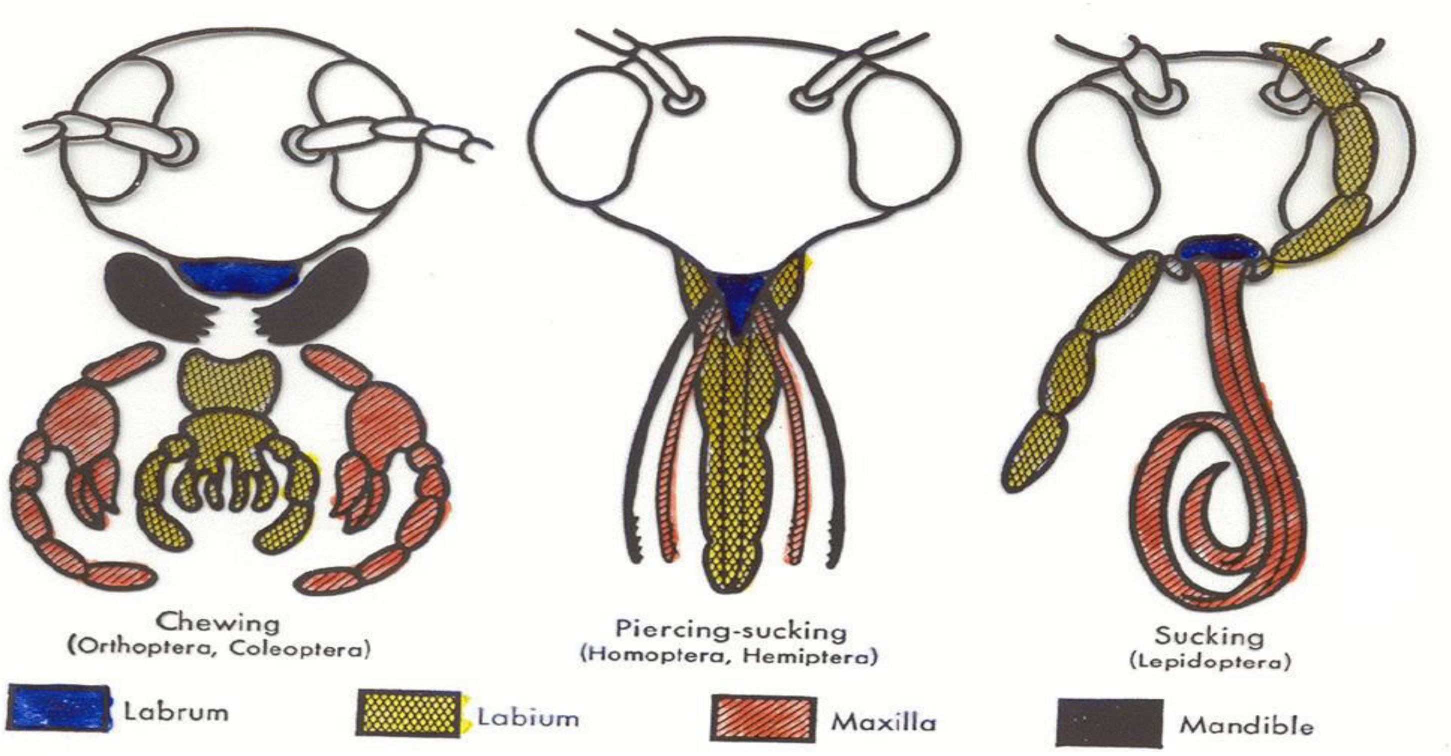
mouth parts of insects

- In some groups, however, they have been transformed into a sucking apparatus
- Biting mouth parts, being the more primitive and simple, are described here
- While sucking mouth parts having been differently transformed in different groups will be taken up in connection with those groups

mouth parts of insects



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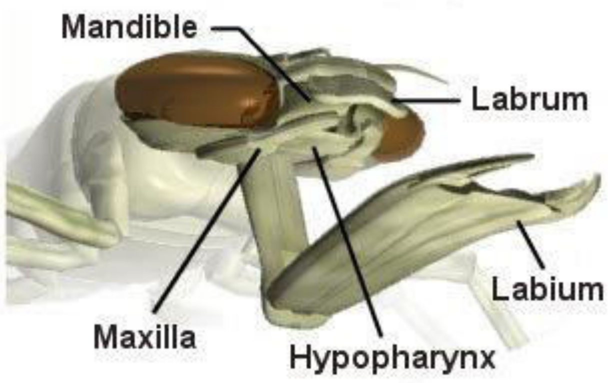
mouth parts of insects

- In front of (in hypognathous heads) or above the mouth opening (prognathous heads) is the front lip or labrum
- It is a thin flap, hinged to the skeleton of the head, and moves forward and backward



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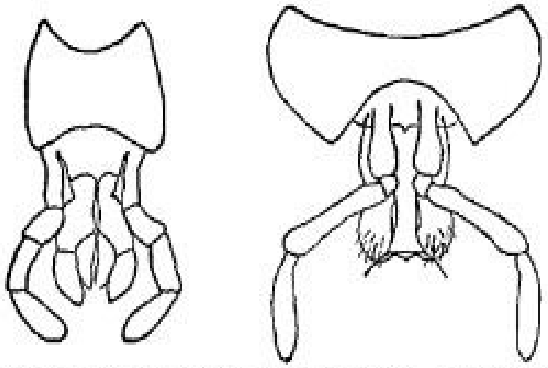
mouth parts of insects

- Attached on the outer side of each maxilla, not far from where the latter articulates with the head, is a sort of tiny antenna like structure consisting of from one to six (usually five) segments, which is called the maxillary palpus
- Behind the maxillae and closing the mouth opening behind, is the hinder lip or labium



—Two types of insect labium much enlarged. Somewhat diagrammatic.

Mouth parts of insects

mouth parts of insects

- This was evidently once a pair of jaws somewhat similar to the maxillae, but with no mouth cavity between to separate them
- their inner edges have grown together to varying degrees in different insects

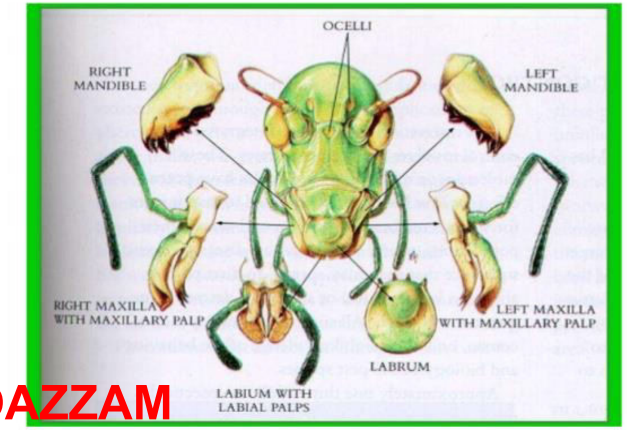
mouth parts of insects

- In some, only one or two of the pieces nearest the head have fused
- In others, fusion all the way to the tip has been accomplished; and all intermediate stages also occur
- Thus producing a structure which now moves forward and backward like the front lip, but which may be complete, or partly or almost entirely cleft in the middle line

mouth parts of insects

- The function of the maxillae appears to be to hold and retain the food in the mouth while it is being worked upon by the mandibles, and also to aid these in breaking it up

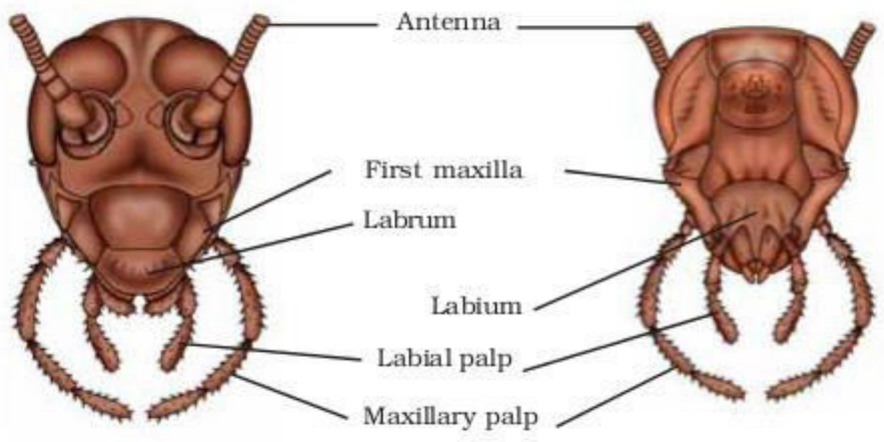
Biting and chewing mouth parts



mouth parts of insects

- The presence of sense organs on the maxillary palpi suggests that these are possibly concerned with the sense of smell

- Both mandibles and maxillae move sideways



mouth parts of insects

- Like the maxilla the labium has li, pal pus on each side arising from near its base, and composed of three (rarely four) segments

- The function of these labial palpi appears to be similar to that of the maxillary palpi

mouth parts of insects

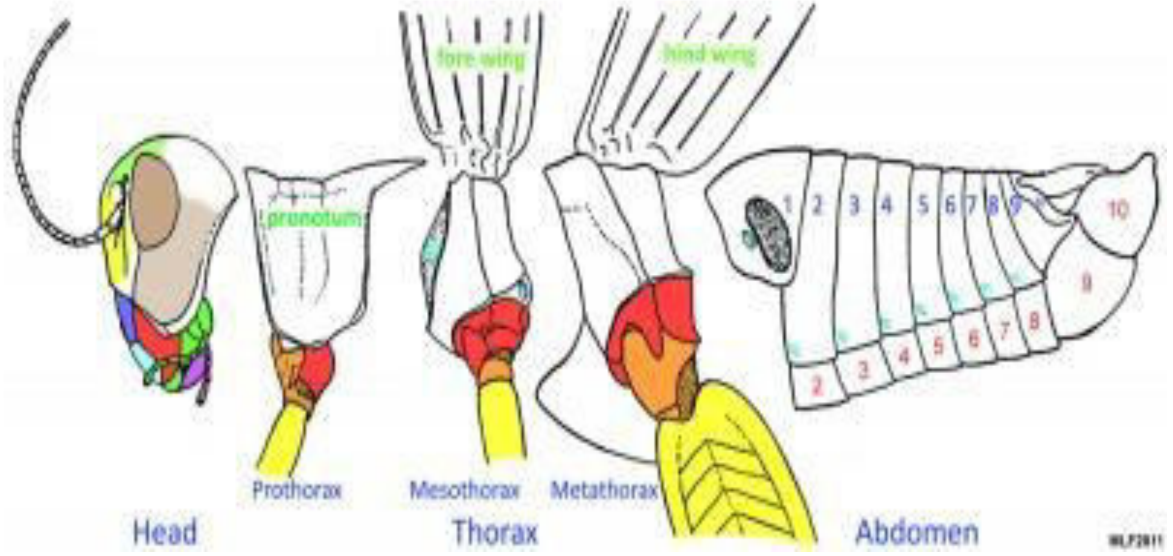
- Near the base of the labium on its inner or mouth side there is frequently a fleshy swelling more or less covered by bristles or hairs, which is called the hypopharynx, lingua or tongue

- It varies greatly in size and form

Structure of Thorax

Structure of Thorax

- The thorax has its three segments usually quite clearly marked
  - 1-Prothorax
  - 2-Mesothorax
  - 3-Metathorax



Structure of Thorax

- Each segment bears a pair of legs, but the **prothorax**, or first of the three behind the head, bears no wings
- On the second, or **mesothorax**, and on the third, or **metathorax**, both wings and legs occur in the majority of insects

Structure of Thorax

- There is a tendency in some groups, carried farthest in the higher Hymenoptera, for the first segment of the abdomen to consolidate more closely with the metathorax

- Than with the second abdominal segment, which in such cases is often slender and gives thereby a semidetached appearance to the rest of the abdomen

Structure of Thorax

- As though the line of division between thorax and abdomen were at that place instead of farther forward

- The first abdominal segment, when seemingly more apart of the thorax than of the abdomen, is called the median segment or ropodeum

Structure of Legs

Structure of Legs

- The three pairs of legs may be quite similar or differ widely, according to the uses to which they are put
- In running and walking insects they are usually most similar

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Structure of Legs

- But when, for example, the forelegs are used for capturing other insects, their form will depart greatly from that of the others
- The jumping power of the grasshopper is due to the great development of its hind legs as compared with its others

Structure of Legs

- Different types of legs are shown in Figure

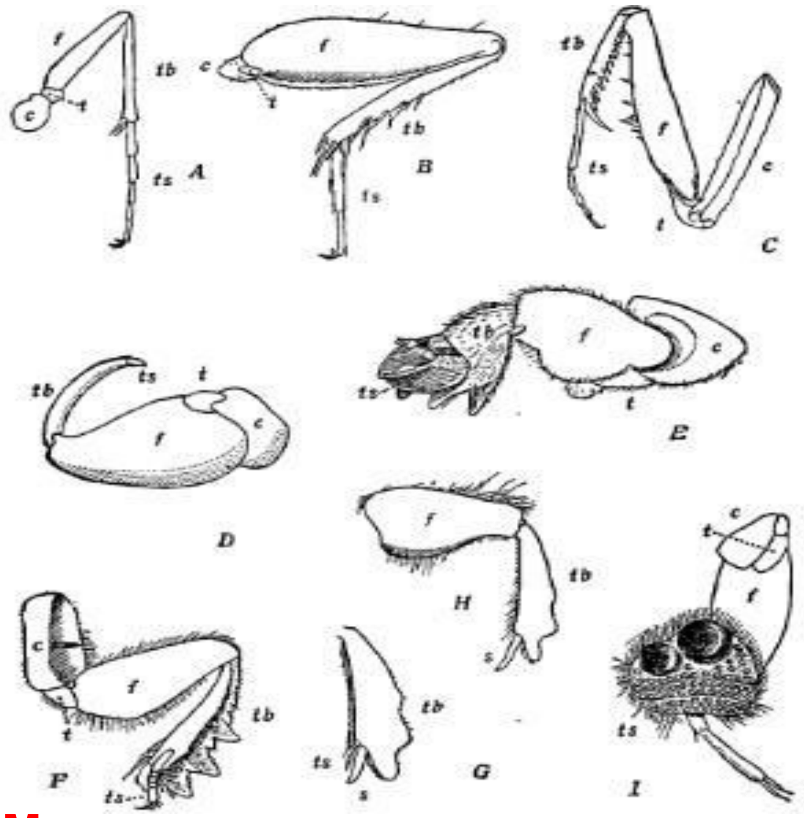

Fig. 18.—Different forms of insect legs: *A*, *Cicindela sexguttata* Fab. (beetle); *B*, *Nemobius fasciatus* De G. (cricket) hind leg; *C*, *Stagmomantis carolina* L. (mantis) foreleg; *D*, *Pelocoris femoratus* P. B. (carnivorous bug) foreleg; *E*, *Gryllotalpa hexadactyla* Perty (mole cricket) foreleg; *F*, *Canthon lævis* Dru. (a digging beetle) foreleg; *G*, *Phanæus carnifex* L. (a digging beetle) fore tibia and tarsus of female; *H*, same, fore tibia of male; *I*, *Dytiscus fasciventris* Say, male (water beetle) foreleg. *c*, coxa; *f*, femur; *s*, spine; *t*, trochanter; *tb*, tibia; *ts*, tarsus. (*From Folsom.*)

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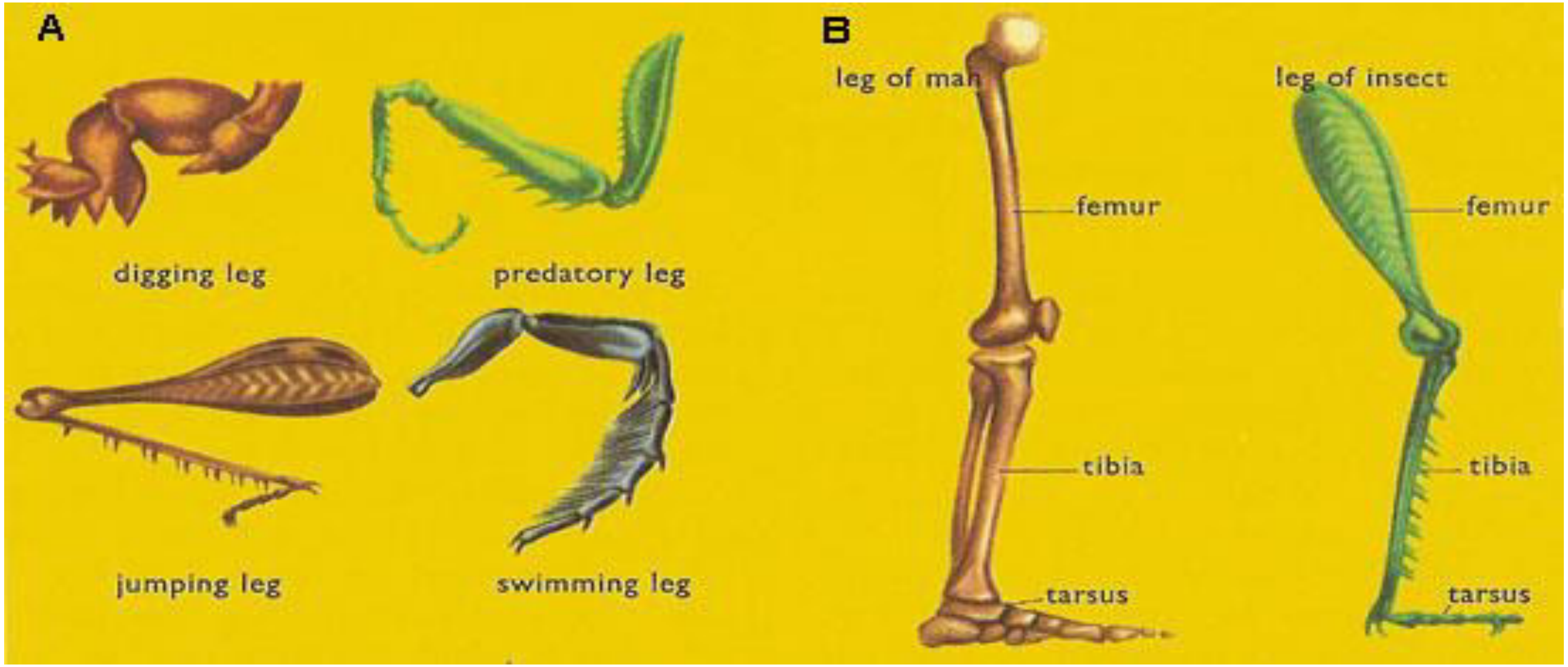
Structure of Legs



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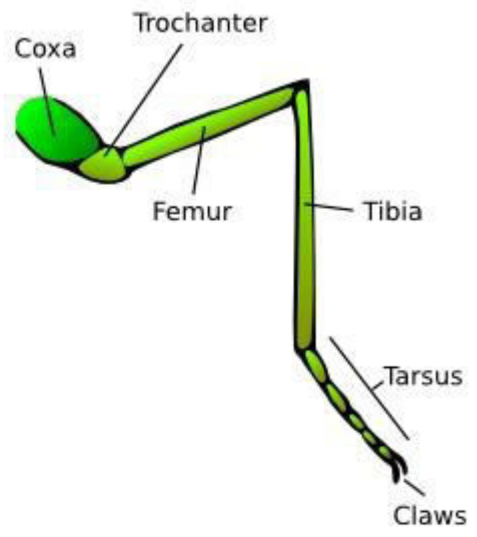
Structure of Legs

- Whatever may be the variations in form and details of the legs
- All are composed of a definite number of pieces or segments, connected by hinge joints so arranged that, by combining the motions of these
- a leg can be placed in nearly in any position desired

Structure of Legs

Structure of Legs

- The leg is composed of
- **coxa**
- **trochanter** (two in a few cases),
- **femur**,
- **tibia**
- **tarsus**
- The last is really not a single segment but a row of from one to five, small, and on the whole rather resembling each other.



Structure of Legs

- The **coxa** is the segment that articulates with the body, frequently partly lying in a more or less cup-shaped hollow of the latter
- It may be short or long and is generally freely movable on the body and powerful

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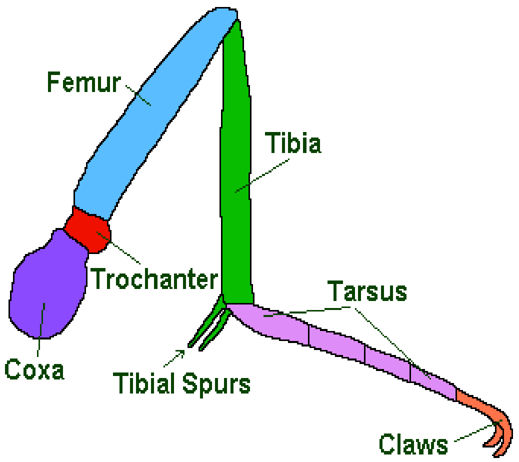
Structure of Legs

- The trochanter is usually small and may not be visible on all sides of the leg
- It is followed by the femur, generally the largest and stoutest, but not often the longest leg segment

Structure of Legs

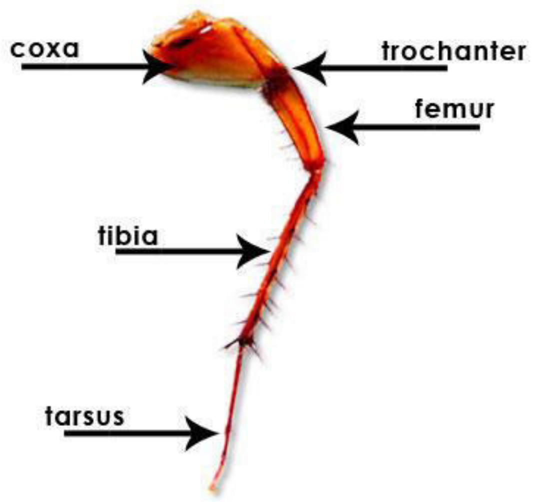
- The tibia is in most cases quite long, more slender than the femur and often provided with downwardly projecting spines or other structures which are of assistance to the insect in climbing plant stems and other objects, to help prevent slipping

- The tarsal segments are generally rather small, short, tend to be broadest at their outer ends and vary greatly in details of structure



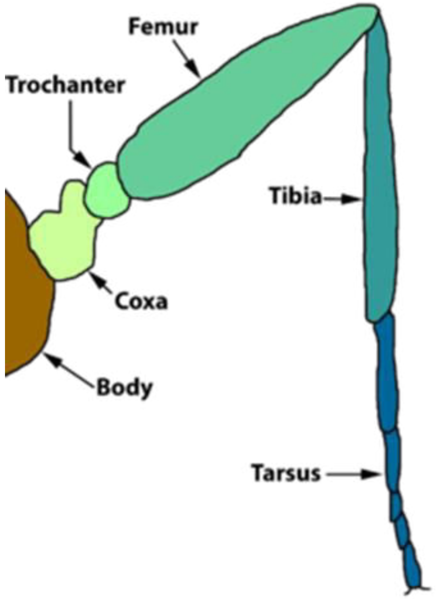
Structure of Legs

- At the end of the last a pair of claws is generally found, and between them a sort of pad or cushion, the pulvillus
- Sometimes there are three of these, in which case the outer ones are called the pulvilli and the middle one the empodium



Structure of Legs

- Where the tarsi are reduced to a small number of segments, only one claw may be present.



Structure of Wings

Structure of Wings

- The wings are chitinous outgrowths from the body which vary much in size and form in different insects

- Each consists of two delicate membranes in contact with each other except along certain lines

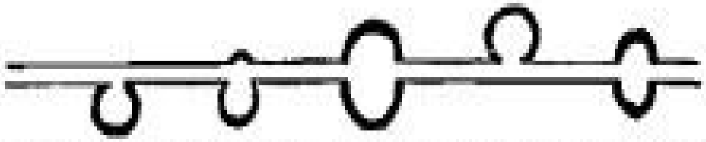


FIG. 20.—Diagram of cross section of an insect wing showing the two membranes somewhat separated and the ways in which the veins are formed. (*Modified from Woodworth.*)

Structure of Wings

- Along these lines each membrane thickens and also rises above the general surface
- So that if the two membranes could be separated and examined from the inner surface, they would appear uniform except for grooves with thickened sides and bottoms, running here and there

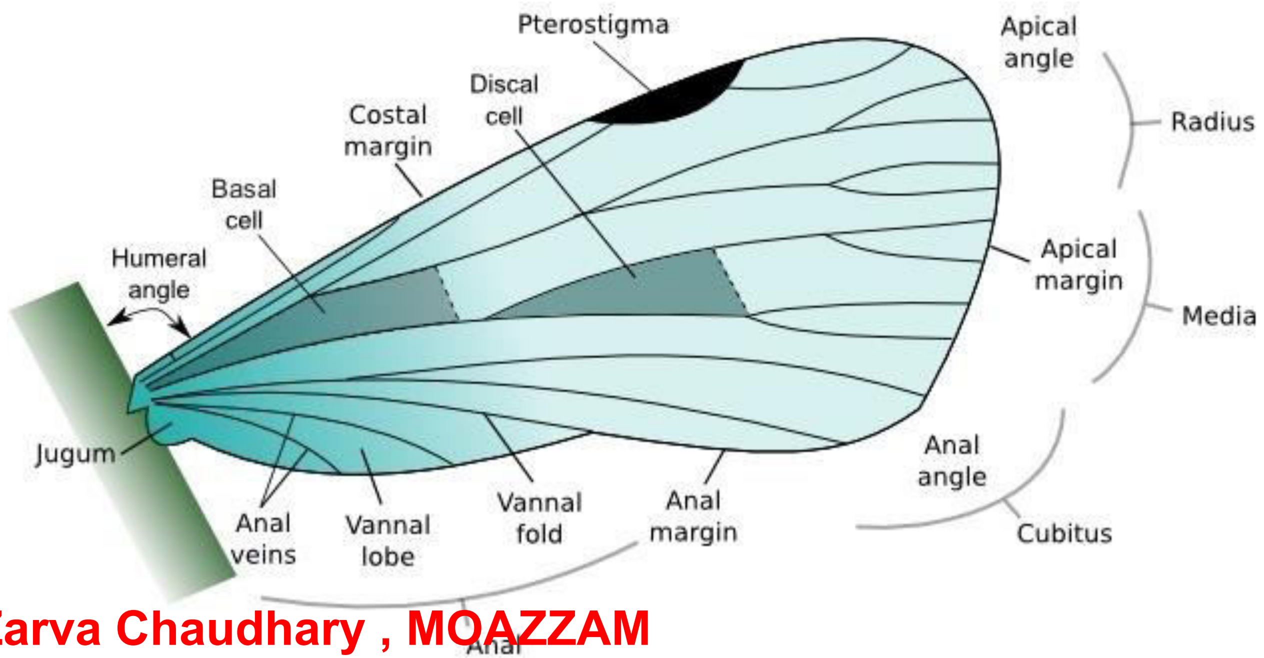
Structure of Wings

- When the membranes are brought together again, these grooves combining form hollow rods which, being stronger than the rest of the membrane, serve as its support and hold it stiff

- These hollow rods are usually called veins or nerves, though they are nothing of the sort.

Structure of Wings

- The main and largest veins arise at the base of the wing and extend outward, branching as they go, and some branch several times before they reach the wing margin



Structure of Wings

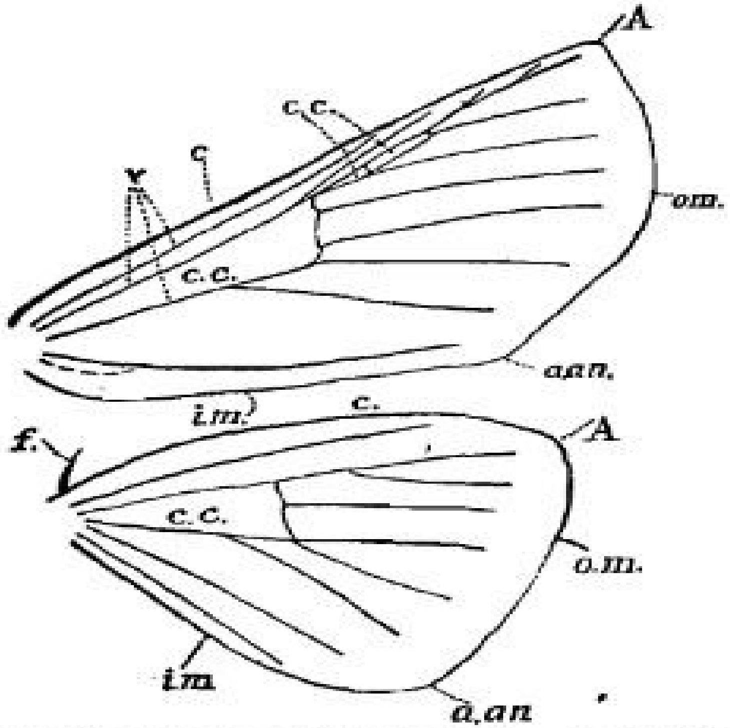


FIG. 21.—Diagram of the margins and veins in the wings of moths: A, apex; a. an., anal angle; c., costa; c.c., closed cell; f., frenulum; i.m., inner margin; o.m., outer margin; v., veins.

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Structure of Wings

Structure of Wings

- Cross veins also occur, connecting' the radiating main veins or their branches

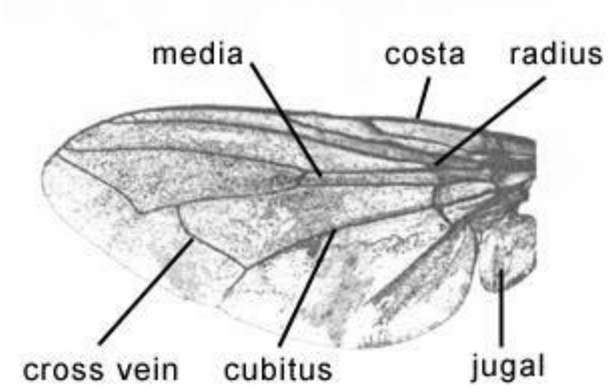
- Areas of membrane between veins are termed as cells and where entirely surrounded by veins are called closed cells

Structure of Wings

- These may be relatively few or many, according to the number of veins and their branches present
- The arrangement and number of the chief veins and their branches are of importance in identifying insects

Structure of Wings

- There is usually a point or tip called the apex, somewhere along the margin of the wing, though frequently the outline is so rounded that the exact apex is uncertain
- The front margin of the wing from where it joins the body to where the edge begins to turn backward (in an extended wing) is called the costa



Structure of Wings

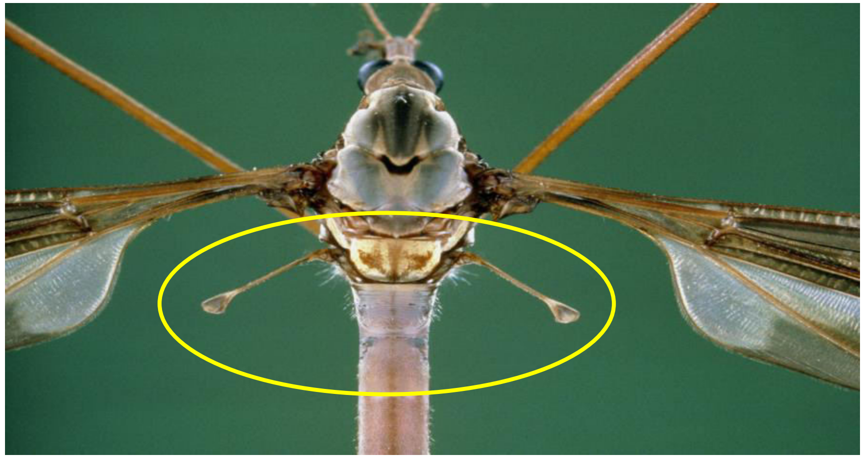
- Wings are entirely absent in some groups of insects
- It is probable that some of these are direct descendants of the earliest forms before wings were developed

Structure of Wings

- In other cases where wings are absent this condition is associated with a parasitic life
- Where they might be a distinct disadvantage, or with peculiar habits which would render them useless or even inconvenient; in such cases they appear gradually to have become lost

Structure of Wings

- In the flies the hinder pair is modified, forming small structures called **halteres**



Structure of Abdomen

Structure of Abdomen

- The abdomen does not usually show great differences in its segments except in those near the hinder end
- Which may be modified for various purposes

Structure of Abdomen

- Generally a dorsal plate (**notum or tergum**) and a ventral plate (**sternum**) are the only two skeletal plates evident in a segment

- Small openings, usually a pair in each, or at least in some of the segments, are the openings of the breathing organs

Structure of Abdomen

- And these also occur on some of the thoracic segments where they are ordinarily less notice able than on the abdomen
- Legs are very rarely present on the abdomen in adult insects but are often found in the earlier stages

Structure of Abdomen

Larva of cecropia moth showing abdominal legs

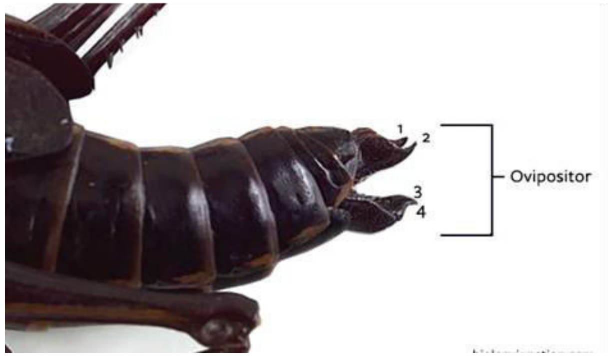
Structure of Abdomen

Structure of Abdomen

- At the end of the abdomen in the females of those insects which lay their eggs within objects is a combination of pieces known as an ovipositor

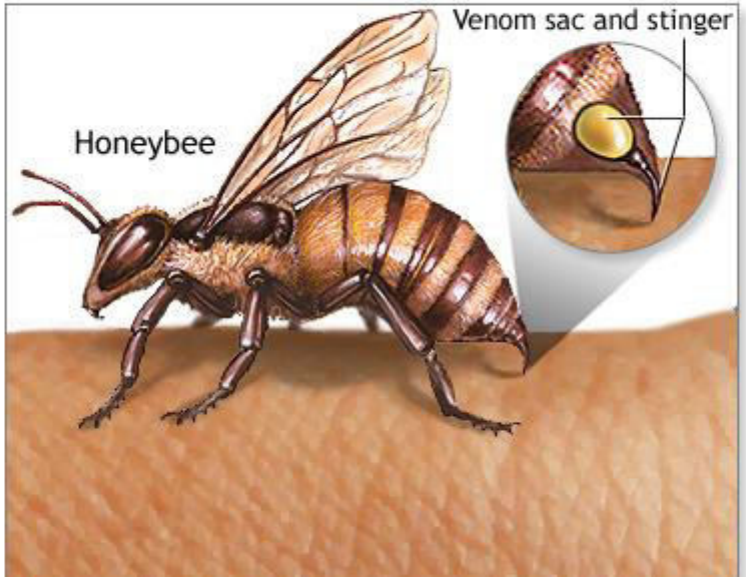
Structure of Abdomen

- Ovipositor usually consists of about three pairs of parts, long or short, slender or stout, as the case may be, for the purpose of making a hale or sawing a slit in the object in which the eggs are placed and in guiding the eggs into the hole thus made



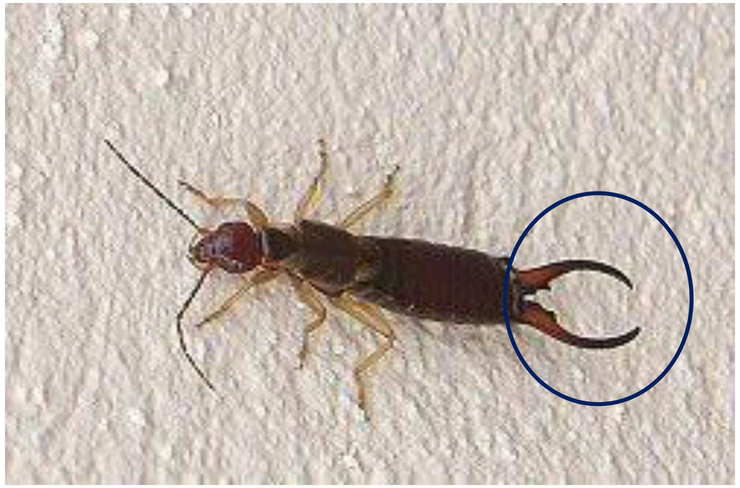
Structure of Abdomen

- In one group which has apparently changed its habits and no longer needs to make holes for egg laying, the ovipositor being unnecessary for this purpose has been transformed into a sting



Structure of Abdomen

- A pair of many-segmented, antenna-like structures, sometimes short, sometimes long, may occur at the end of the abdomen
- And these are called **cerci**
- They probably serve as organs of touch and possibly organ of smell in some cases



THE INSECT: ITS INTERNAL STRUCTURE

THE INSECT: ITS INTERNAL STRUCTURE

- Few of the internal structures of insects are of any great importance from the standpoint of control methods
- but some knowledge of them and their arrangement is desirable

THE INSECT: ITS INTERNAL STRUCTURE

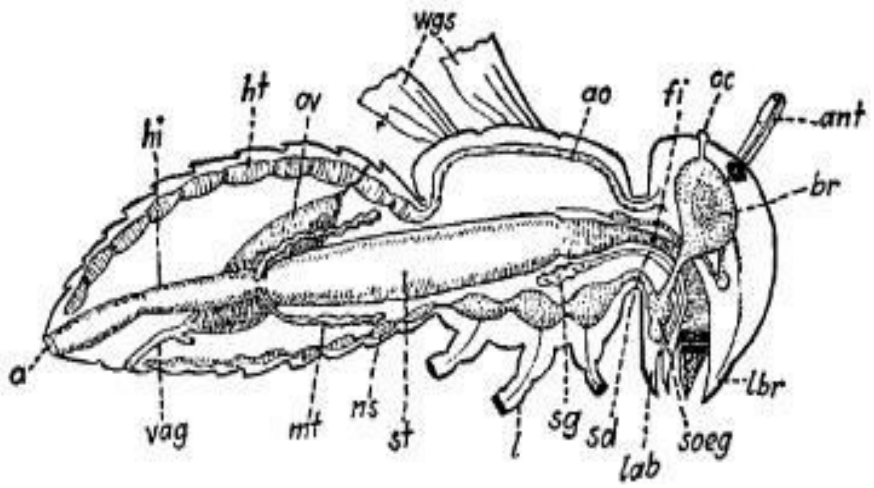
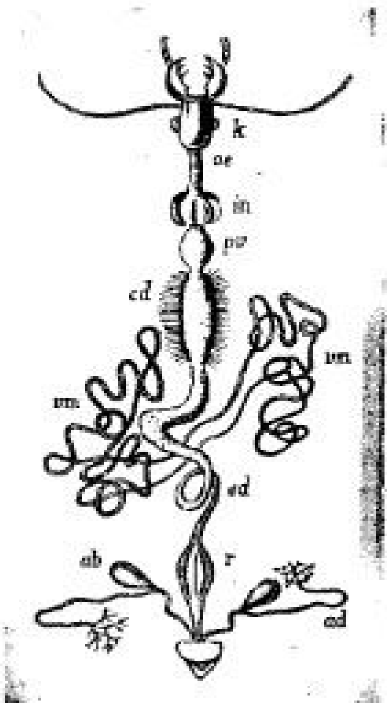


FIG. 23.—Diagrammatic longitudinal section of an insect to show the arrangement of the internal organs: *a*, anus; *ant*, antenna; *ao*, aorta; *br*, brain; *fi*, fore intestine; *hi*, hind intestine; *ht*, heart; *l*, leg; *lab*, labium; *lbr*, labrum; *mt*, Malpighian tube; *ns*, nervous system; *oc*, ocellus; *ov*, ovary; *sd*, salivary duct; *sg*, salivary gland; *soeg*, subesophageal ganglion; *st*, stomach (mid intestine); *vag*, vagina; *wgs*, wings. (*After Berlese.*)

Digestive organs

- The alimentary canal extends from the mouth through about the center of the body to the anus at the hinder end
- In those insects whose food is most concentrated
- It is in its simplest form

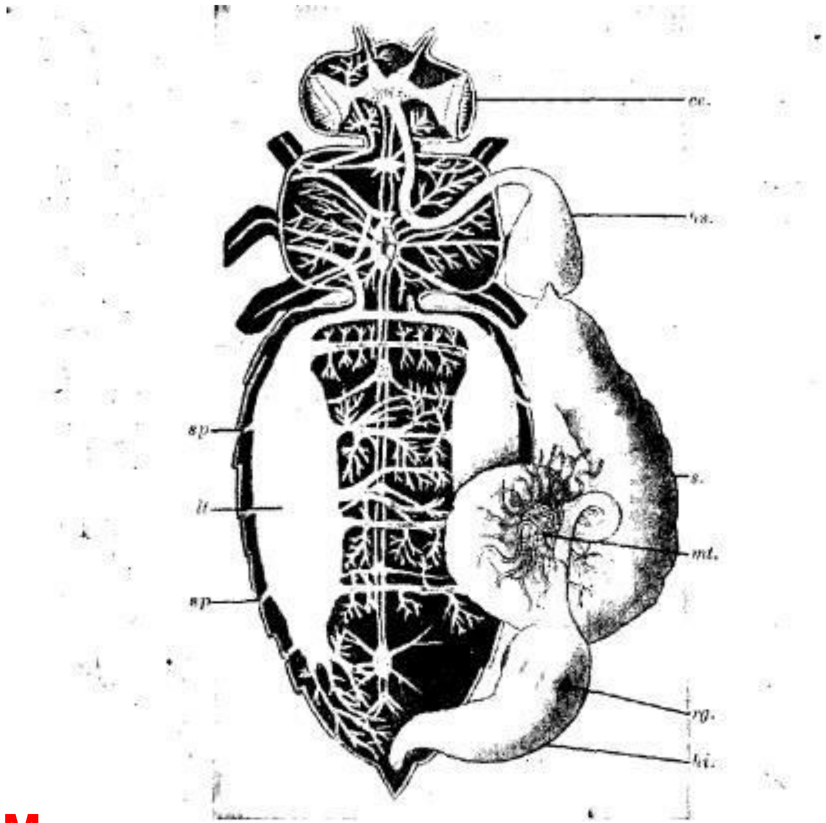
Fig. 24.—Alimentary canal of a carnivorous beetle: *ad*, anal glands; *cd*, stomach; *ed*, hind intestine; *in*, crop; *k*, head and mouth-parts; *oe*, esophagus; *pv*, proventriculus; *r*, rectum; *vm*, Malpighian tubes. (*Modified from Lang's Lehrbuch.*)



Digestive organs

- In those which feed on less concentrated food

Fig. 25.—Internal anatomy of the honeybee showing alimentary canal, tracheal and nervous systems: ce., compound eye; hi., hind intestine; hs., honey stomach; lt, lateral trachea (enlarged); mt., Malpighian tubes; rg., rectal glands; s, stomach; sp, spiracles. (*Modified from Leuckart's Wandtafeln.*)



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Digestive organs

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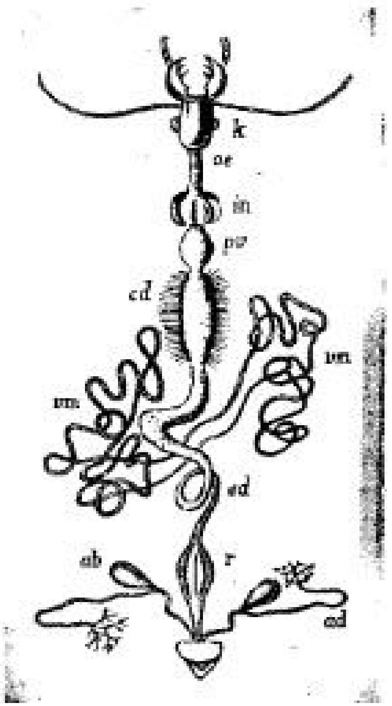

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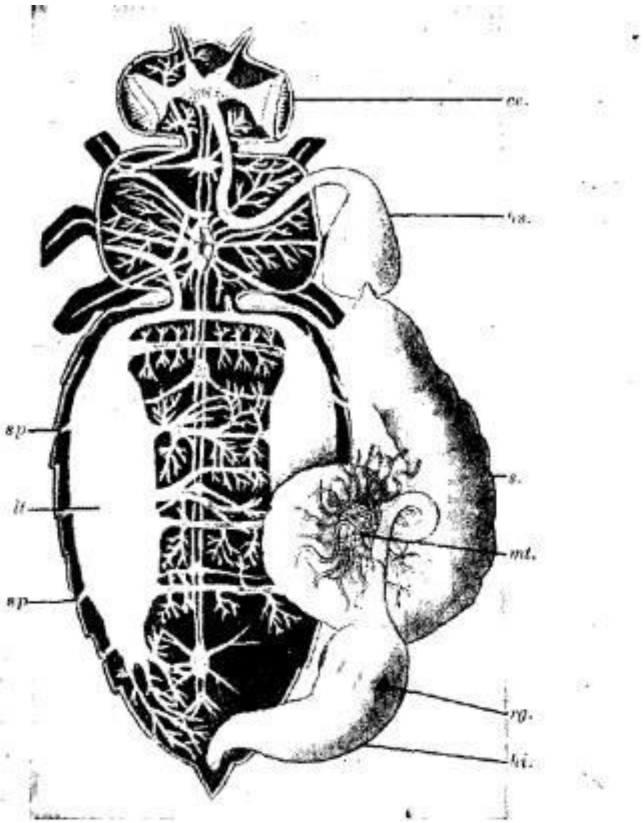

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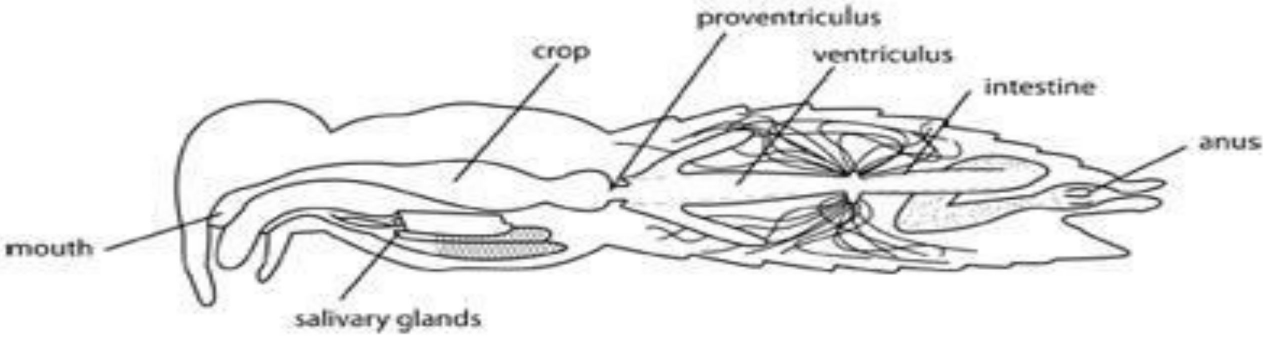
Digestive organs

- The necessity for a greater digestive and absorptive surface has resulted in an increase of its length
- And the accommodation of this within the body by the production of loops and coils



Digestive organs

- In the embryo the alimentary canal forms as three separate sections which connect later
  - 1-One of these is an ingrowth from the surface where the mouth is to be
  - 2-Another and similar ingrowth occurs where the anus forms
  - 3-And a third, forming earlier than the other two, arises as two masses of cells

Digestive organs

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Digestive organs

- One near each end of the embryo, which move inward and toward each other, unite, and surround the yolk
- Later, when this has been absorbed, a space is left with which the two ingrowths already mentioned connect
- The hollow centers of all three joining to form the tube through which the food travels

Digestive organs

- The ingrowth from the mouth is usually called the fore intestine
- The central portion the mid intestine and the ingrowth from the anus the hind intestine

Digestive organs

- The first and last of these begin to grow inward from the surface of the body after that surface has begun the formation of its chitinous exoskeleton
- And accordingly they also have this power, and line the inside of the parts of the canal which they form, with chitin

Digestive organs

- In that portion of the canal termed as the mid intestine
- However, this power does not appear to be present, and the mid intestine is without this lining

Digestive organs

- The **mid intestine** forms the stomach of the adult insect
- The **fore intestine** forms those parts of the alimentary canal from the mouth of the stomach
- The **hind intestine** those from the stomach to the anus

Digestive organs

- Each of these sections may sometimes have portions differing in structure, producing a greater or lesser number of subdivisions

Digestive organs

- Thus the fore intestine, by differences of structure, may sometimes consist of
  - Mouth cavity
  - Esophagus
  - Crop
  - Proventriculus

Digestive organs

Digestive organs

- The stomach may develop side pouches or gastric caeca
- And the hind intestine is often separable by differences of structure into an
  - Ileum,
  - Colon
  - Rectum.

Digestive organs

- Lined as these parts are by chitin which often bears rough, tooth-like projections and spine
- Some persons have suggested that in insects where these structures are present in the fore intestine
- The food is masticated more thoroughly and mixed with digestive juicer before it reaches the stomach

Digestive organs

- In the stomach, digestion is probably completed and absorption at least begun
- But the length of the hind intestine in many insects suggests the idea that absorption in those cases has not been completed when the food leaves the stomach but continues in the hind intestine

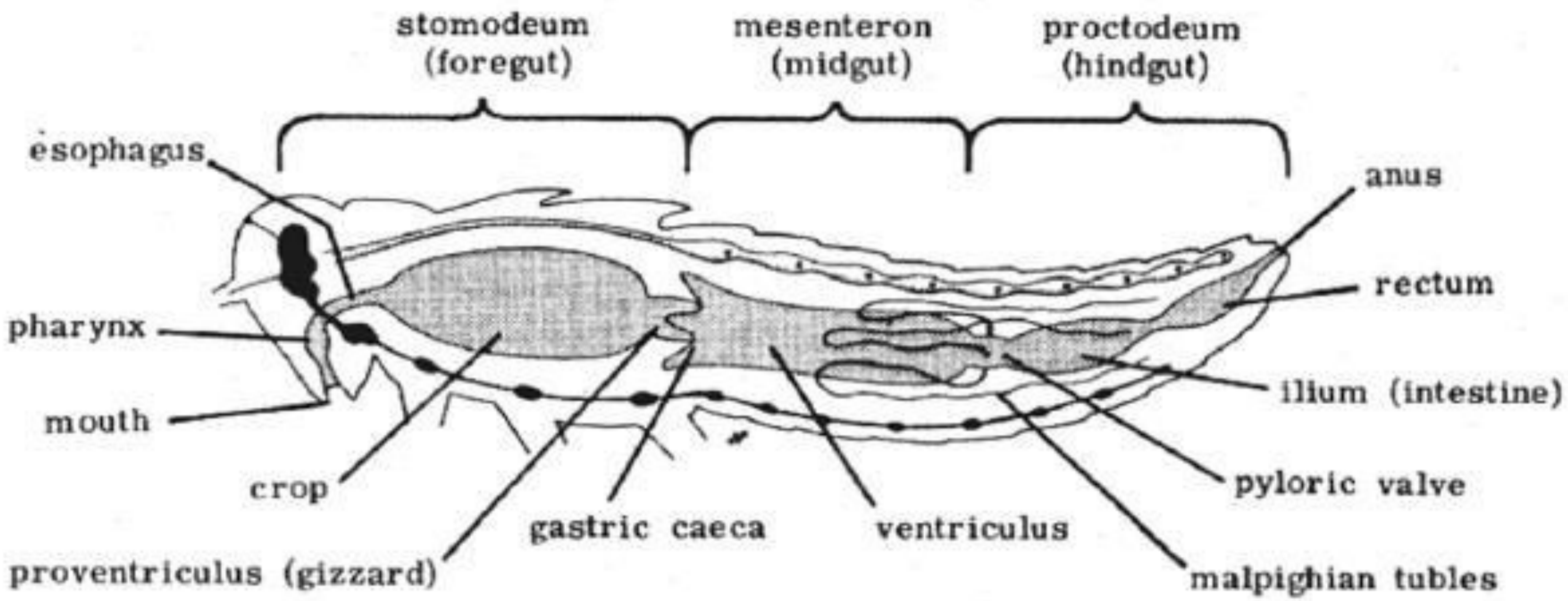
Digestive organs

- Opening into the mouth is a tube leading to the salivary glands
- Which generally lie in the front of the thorax and appear to have a similar function to those in man
- In some cases other glands for different purposes '"'are also present in the head or front of the thorax and open into the mouth

Digestive organs

- Some of the poisons used in control measures are swallowed by the insert, passing to the stomach and there are dissolved by the digestive juices
- Thus dissolved, they set up inflammation of the stomach walls and finally cause death
- Poisons acting in this way arc called stomach poisons

Digestive organs



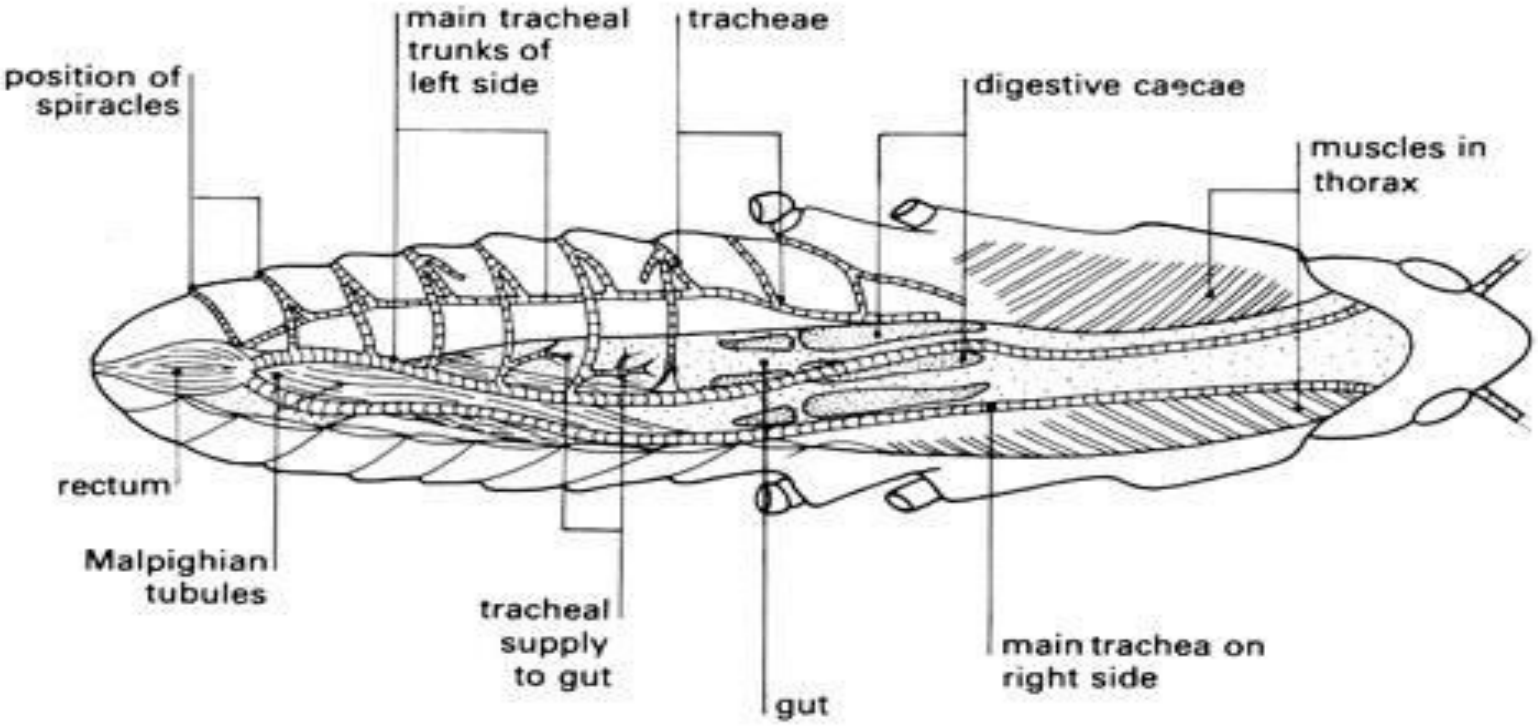
The "generalized" digestive system of insects.

Breathing organs

Breathing organs

- Respiration in insects is accomplished by a method which is nearly unique
- The oxygen needed, instead of being ,drawn into lungs and there being taken up by the blood and carried to 'the parts of the body
- Where it is needed, as in man, is carried directly to those parts by a system of air tubes which open along the sides of the body

Breathing organs



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Breathing organs

- Here the air enters the tubes and proceeds through them to where it is utilized

- The openings by which the air enters are called **spiracles**, and these occur in pairs on some of the thoracic and most of the abdominal segments,

Breathing organs

- Varying somewhat in number and in position "u the segment in different insects
- The spiracles often have valves which they can be more or less completely closed at will

Breathing organs

- Each spiracle opens into a short tube or trachea which, with the others of that side, soon joins a similar tube running along the side of the body and quite close to its surface

- From these longitudinal tracheae, branches pass off in various directions and in turn branch again and again until every part of the body is reached by its air supply

Breathing organs

Breathing organs

- The tracheae frequently enlarge here and there, forming so-called air sacs
- The tracheae are lined by chitin connected with that of the surface of the body
- In these tubes, however, it is formed with spiral thickenings which act like a spring, keeping the tracheae open when not under pressure

Breathing organs

- There is probably considerable pressure on them in different places by the movements of various parts of the body in walking and other activities
- As well as by regular respiratory movements, and the resulting temporary variations in diameter aid in the circulation of air in these tubes

Breathing organs

- Not only are the tracheae of use in: carrying oxygen to all parts of the body
- But they also receive much of the carbon dioxide gas produced by the activities of the cells and permit it to escape through the spiracles from the body

Breathing organs

- Thus per forming both of the functions which the blood, so far as gases are concerned, accomplishes in man
- Blood then, in this gas enters the spiracles and follows along the tracheae to the living tissues, which take it in place of the oxygen usually received in this way, and the insects are killed

Breathing organs

- It was formerly supposed that certain materials called contact insecticides, which kill insects by contact with their bodies
- Caused death by entering the spiracles and closing them up, thus producing suffocation.
- This has now been proved to be incorrect in most cases

Breathing organs

- Insects which in their early stage of live in water cannot, of course, breathe air into their bodies through spiracles during that period of their live
- There are enclosed in such cases and the animal obtains and usually through special structures called tracheal gills

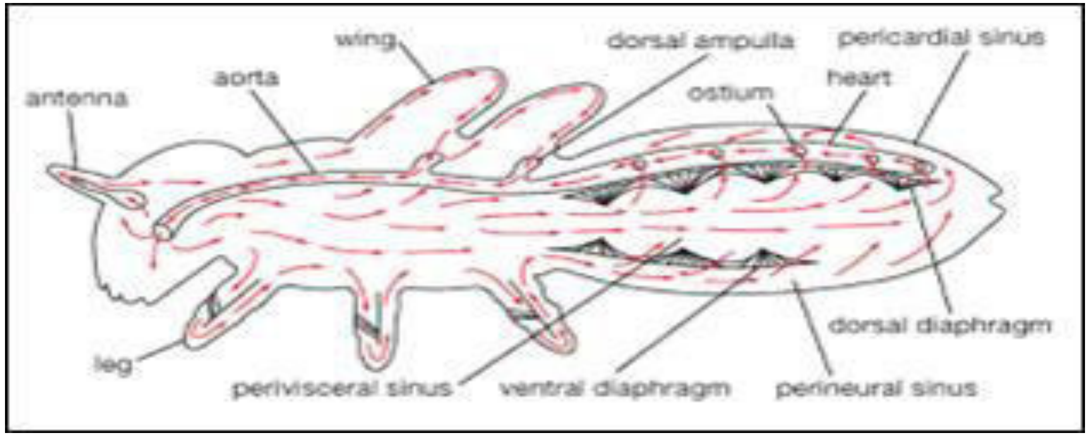
Breathing organs

- These will be described in connection with the insects that possess them
- In a few small water inhabiting forms, the chitin covering the surface of the body is so thin that oxygen present in the water can pass directly through it into the body
- and to the parts there that need it, and carbon dioxide passes in the reverse direction,

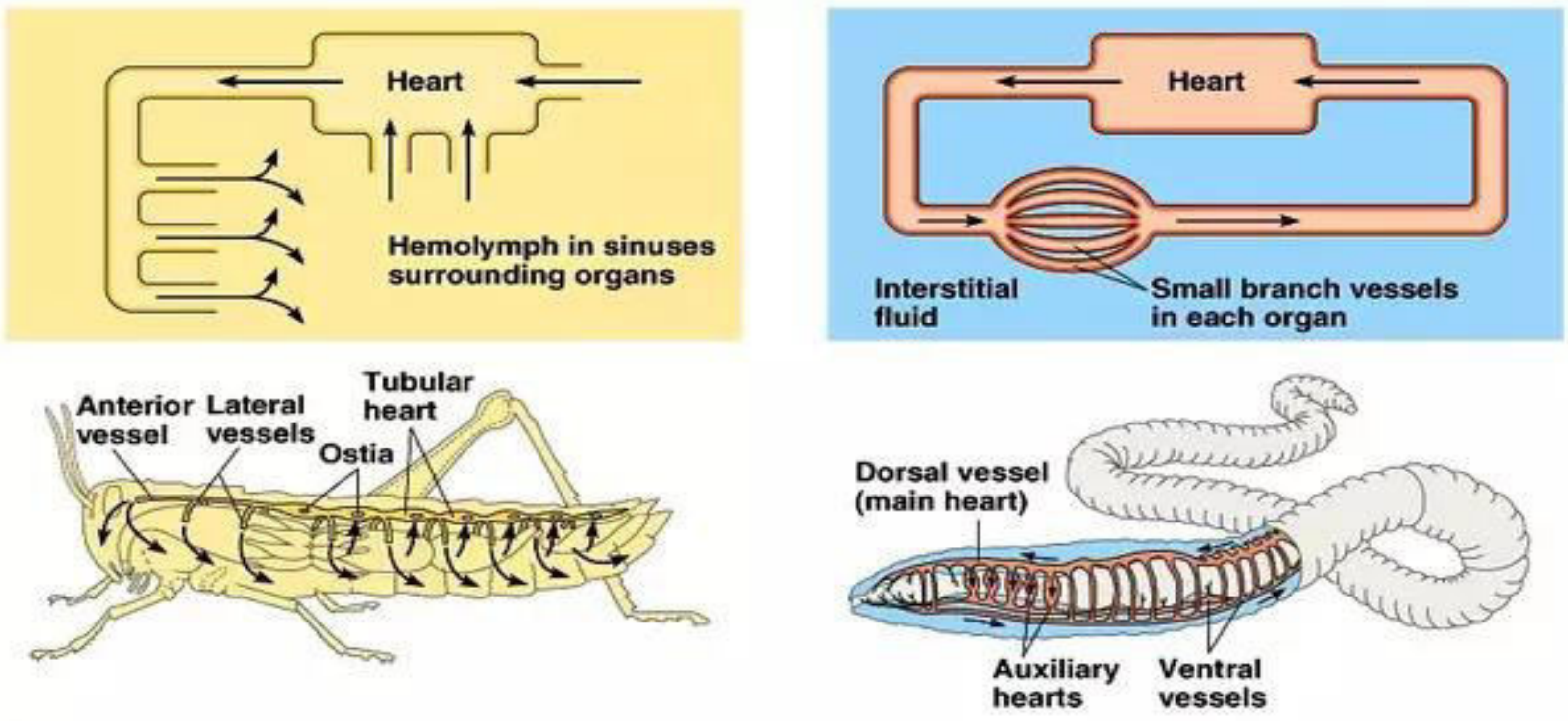
Circulatory organ

Circulatory organ

- Insects have only an incomplete system of blood vessels
- A tube lies in the middle of the body close beneath the back, beginning near the hinder end of the animal and extending forward into the head



Circulatory organ



(a) Open circulatory system
(b) Closed circulatory system

Circulatory organ

- In the abdomen this tube is constricted, forming chambers, and the chambered portion is called the heart
- There is a pair of openings on the' sides of each chamber through which blood can enter, and valves there which prevent its going out again

Circulatory organ

- The walls of the heart contain muscles which contract one after another
- Forming a sort of wave of contraction which begins at the hinder end and travels forward

Circulatory organ

Circulatory organ

- Blood in the heart, being unable because of the valves to pass out at the sides, is pressed forward by this contraction wave
- And at the front end of the heart finds itself in a tube without chambers or valves, called the aorta

Circulatory organ

- Through which it is led to the head where the aorta may divide into a few short branches or may be unbranched
- In either case, at this point the blood pours out of it into the body, the system of blood vessels coming to an end

Circulatory organ

- There is now no definite and particular path for the blood to follow
- But it would, in theory at least, remain near where it escaped from the aorta or gradually pass into any spaces it might find unoccupied between the different structures in the head
- With each heartbeat, however, more blood is poured out of the aorta, increasing the pressure upon that already in the head

Circulatory organ

- It therefore is gradually forced backward and to other parts of the body
- Each particle probably taking the path where there is least resistance to its passage
- In this way a general backward direction is given to the flow

Circulatory organ

Circulatory organ

- As it approaches the heart, another influence appears
- During each contraction, the heart occupies less space, which leads to less than normal pressure near it
- And blood close by naturally flows closer to it

Circulatory organ

- Upon its expansion again and the opening of its valves, the direction of-least resistance is now through the valves and into the heart
- As the blood passes back through the body, a given particle may at one circuit go over certain organs, and at the next over entirely different ones

Circulatory organ

- All the internal organs, however, have their surfaces bathed by blood
- And this as it passes over the stomach or other parts of the alimentary canal will pick up any food
- Which having been digested has passed through the canal walls

Circulatory organ

- Likewise in passing over any organ needing this food, it is given up to those organs
- The blood therefore serves as a distributor of food from the place where it is digested to all the parts that need it

Circulatory organ

- We have already seen that the living parts of the body-the cells-need oxygen and as the result of their activities give off carbon dioxide gas
- But that this exchange is accomplished by the aid of the tracheae

Circulatory organ

- In a somewhat parallel way, the cells that need food obtain it from the blood
- The cells by their activities produce not only carbon dioxide gas but also waste material nitrogenous in nature which must be removed like all wastes from the body

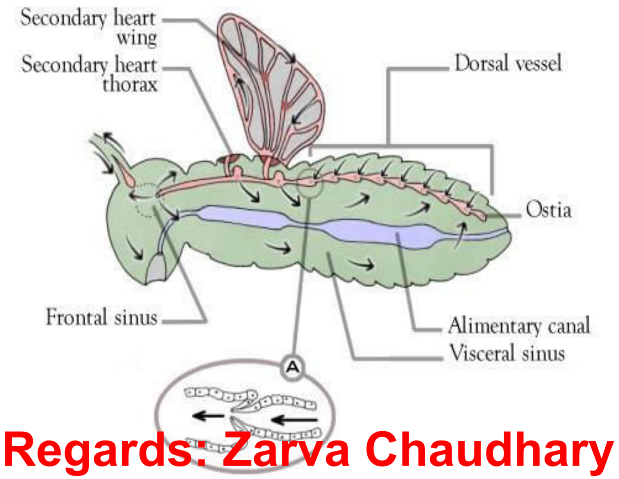
Excretory organ

Excretory organ

- This nitrogenous waste is picked up at the cells by the blood and carried along, perhaps for some time, before a place to dispose of it can be found
- Sooner or later, however, a particle of blood containing this waste material will wash over certain structures called **Malpighian tubes**, to be described in the next section

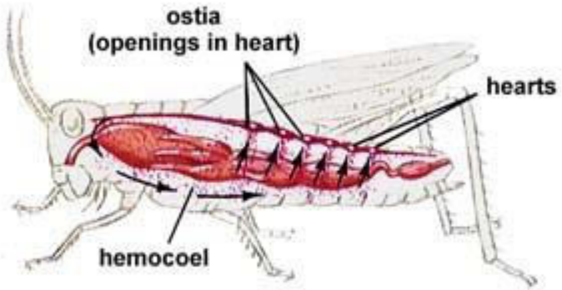
Excretory organ

- And the cells which form these tubes have the power to collect this waste material from the blood as I it flows over them, thus purifying it
- The blood itself is usually a colorless, yellowish, reddish or greenish fluid, in which are corpuscles resembling the white corpuscles of human blood



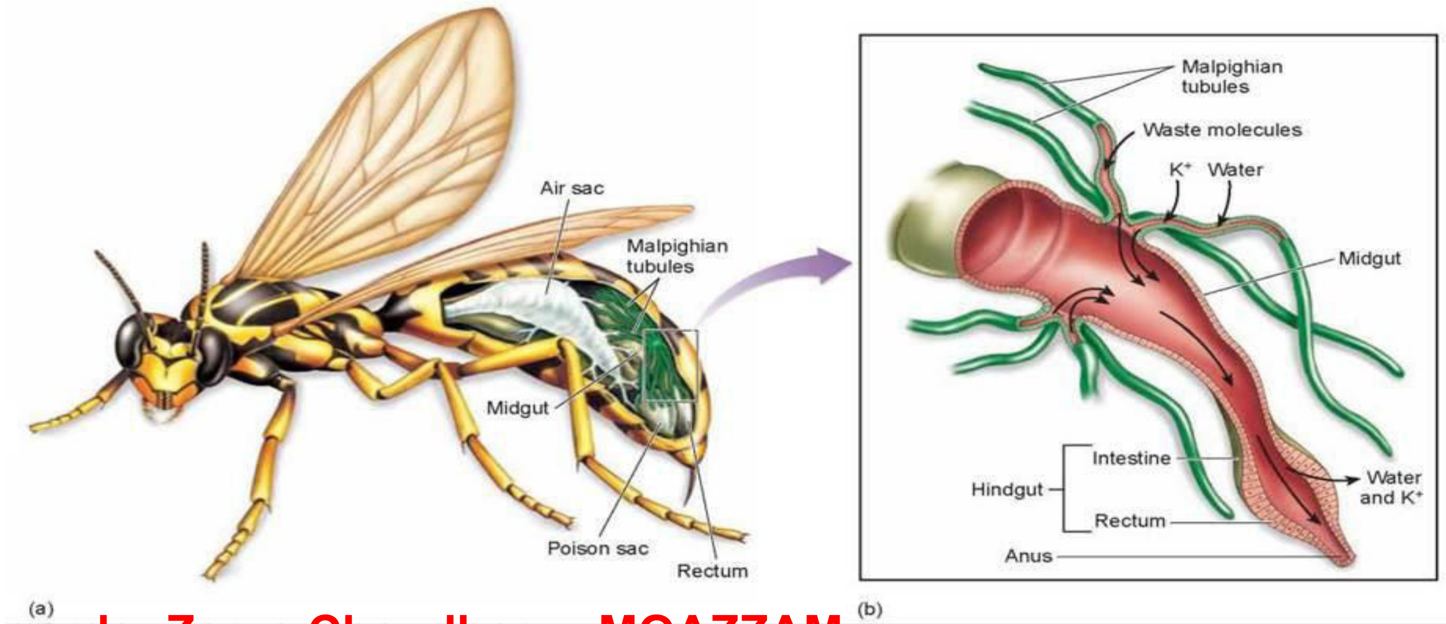
Excretory organ

- It appears to serve to carry food to the tissues and waste matter from them, and therefore has no need of structures in it like the red blood corpuscles of man
- The work of which in insects is done mainly by the tracheae



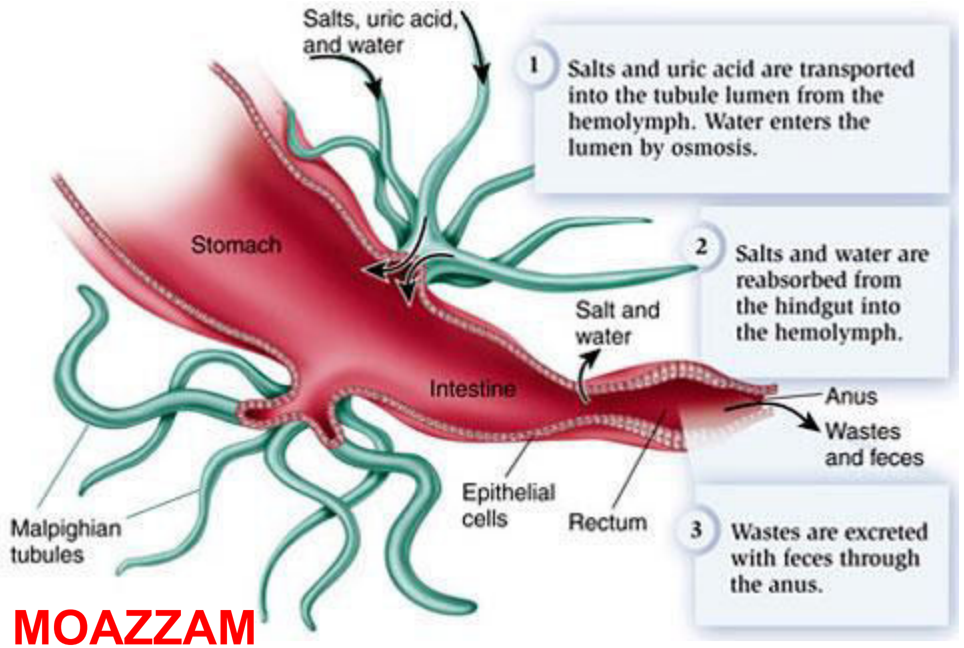
Excretory organ

- The organs that eliminate the nitrogenous wastes from the body and correspond in function to the human kidneys are known as **Malpighian tubes**



Excretory organ

- These are blind-ended tubes, the walls of which consist of a single layer of cells surrounding a central channel which at one end open into the hind intestine,
- Usually near its front, just behind the stomach



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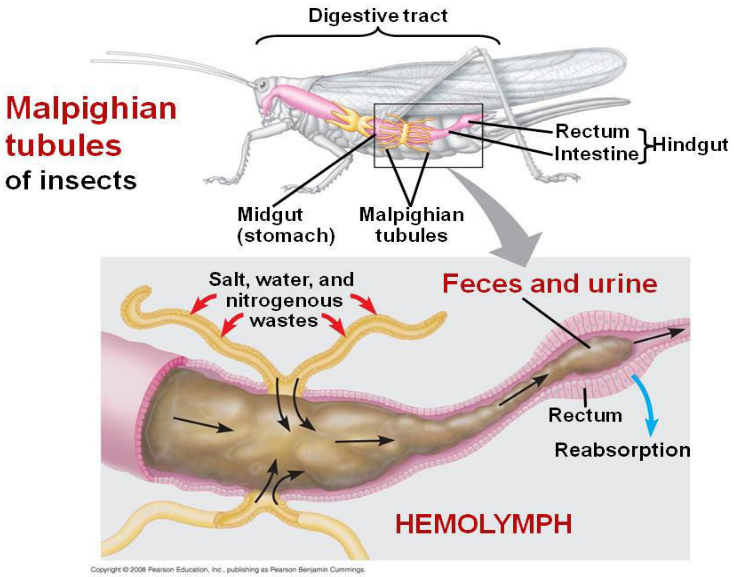
Excretory organ

Excretory organ

- When blood containing nitrogenous waste matter washes over the outer surface of a Malpighian tube
- The cells of which it is composed have the power of taking this matter out of the blood into their own substance and passing it through them

Excretory organ

- Solves into the channel between them, dowln which it moves until it enter the hind intestine, from which it is finally expelled at the anus
- The Malpighian tubes may be few or many, long or short



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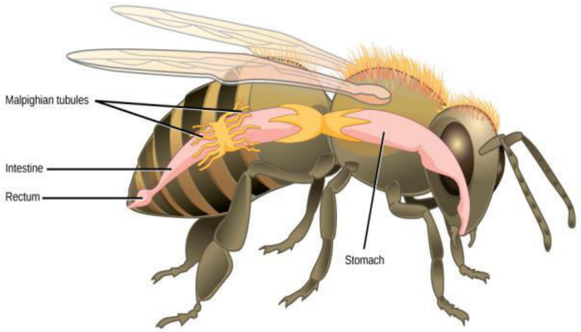
Excretory organ

- They show a tendency to collect in groups and to unite near the hind intestine
- So that their outlets into this are much fewer than the number of tubes.



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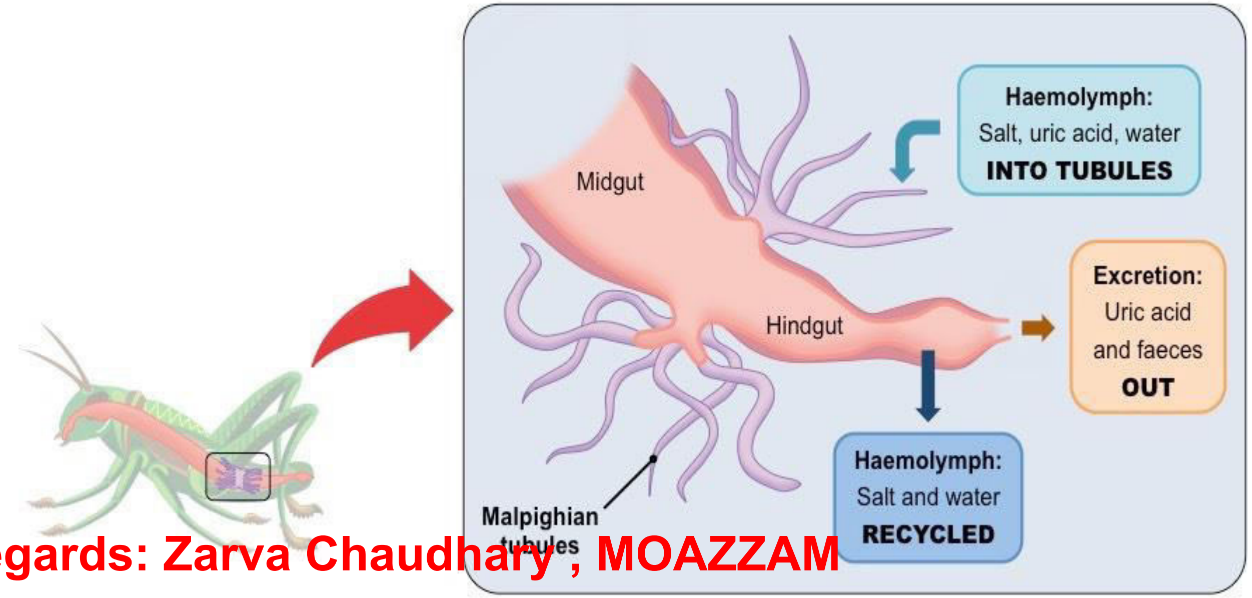
Excretory organ

- It seems possible that a certain amount of poison entering the body by way of the stomach can be eliminated by the Malpighian tubes
- Which may explain the varying degree of resistance to such poisons by different insects



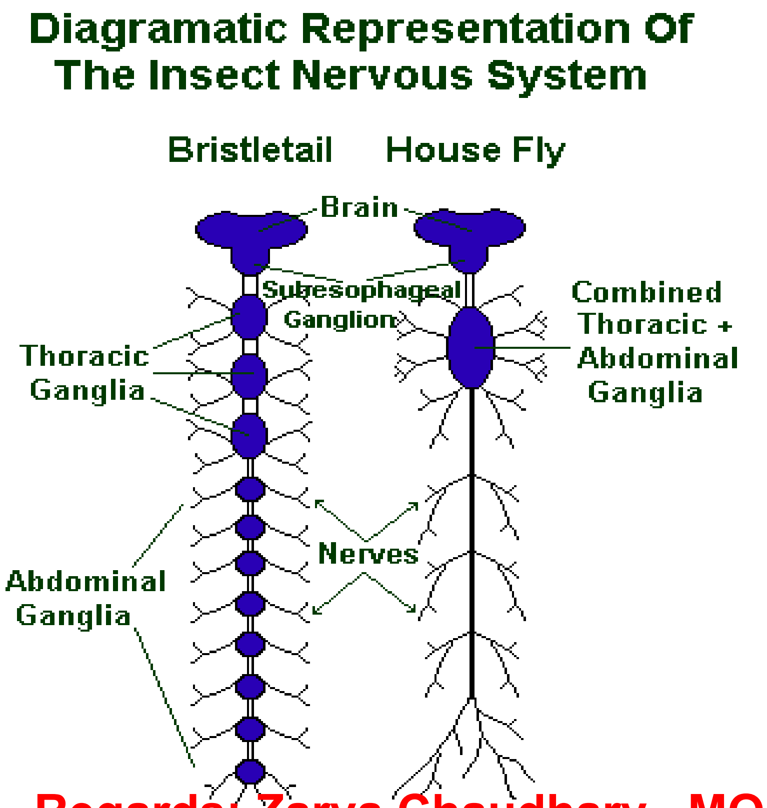
Nervous system

Nervous system

- The nervous system of insects is located along the middle line of the body quite near its under surface

- As in animals generally, it is composed of cells and fibers

Nervous system



Nervous system

- The former are for the most part gathered together in clusters which are called ganglia
- And from each of the cells in a ganglion one or more nerve fibers pass out, to connect either with some other nerve cell or with some structure of the body

Nervous system

- The larger nerves are really bundles of the fibers running side by side like the wires of a telephone cable
- Apparently each segment of the insect body once had but with the fusion of the segments tube of a fly

Nervous system

- Greatly many of these have also fused, reducing the separate ganglia in adult insects to a smaller number, which varies central in different kinds
- This fusion has been produced by the hinder ganglia moving forward until in some cases none is found in the abdomen
- Different degrees of this are shown in Figure

Nervous system

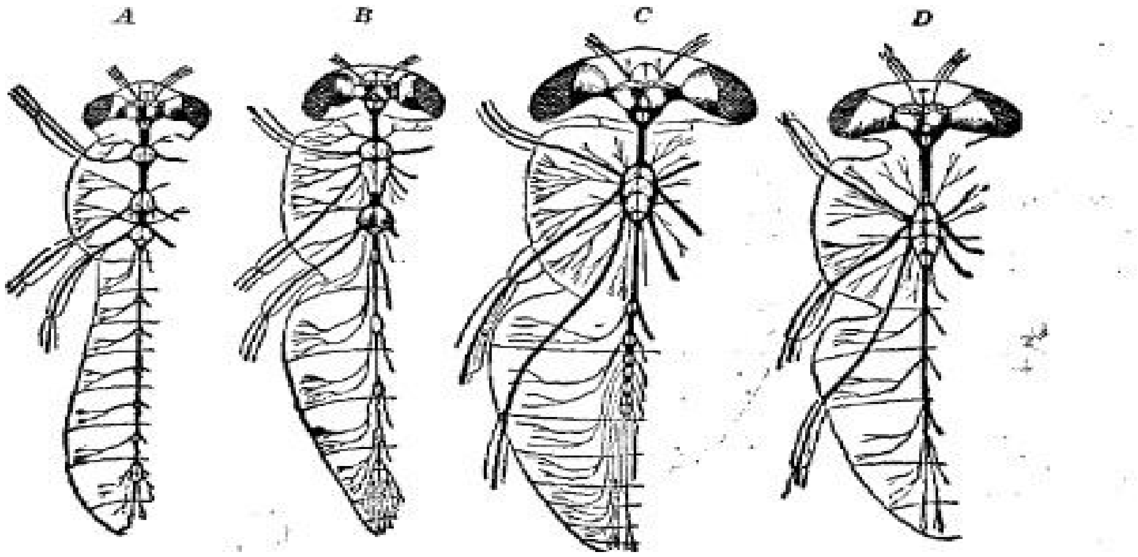


FIG. 29.—Diagram showing various degrees of concentration forward of the nervous system of four species of flies: *A*, *Chironomus plumosus*, little concentrated; *B*, *Empis stercorea*; *C*, *Tabanus bovinus*; *D*, *Sarcophaga carnaria*, most concentrated. (*After Brandt, from Lang's Lehrbuch.*)

Nervous system

- Each ganglion is connected to the one in front and the one behind by one or two bundles of nerve fibers which are called commissures

- Each consists of numerous fibers which taken together form the means of communication between the different parts of the system

Nervous system

Nervous system

- In the head, in front of or above the esophagus, is the largest ganglion of the body, called the brain, produced by the fusion of several ganglia
- In addition to its two commissures, which connect it with the ganglion next behind, it has nerves which lead to the eyes, to the antennae and to other parts of the front of the head

Nervous system

- Below or behind the esophagus is a second ganglion, also in the head, called from its position the sub esophageal ganglion
- As the esophagus lies directly between this and the brain, the commissures connecting the two do not lie close together but separate far enough to permit the esophagus to pass between them

Nervous system

- The sub-esophageal ganglion, besides being connected with the brain in front
- And the first thoracic ganglion behind it, by commissures, sends nerves to the mouth parts and other near-by regions of the head.

Nervous system

- The thoracic ganglia may be more or less separate or fused and may have fewer or more of the abdominal ganglia added commissures
- However, connect all separate ganglia, and these also send out nerves to all the parts of the segments to which they belong, no matter what their final location may be

Nervous system

- In this way, the wings, legs, muscles and other parts receive their nerve supply
- A small "sympathetic nerve system" also present, appears to concerned chiefly with the nerve supply of the alimentary canal tracheae

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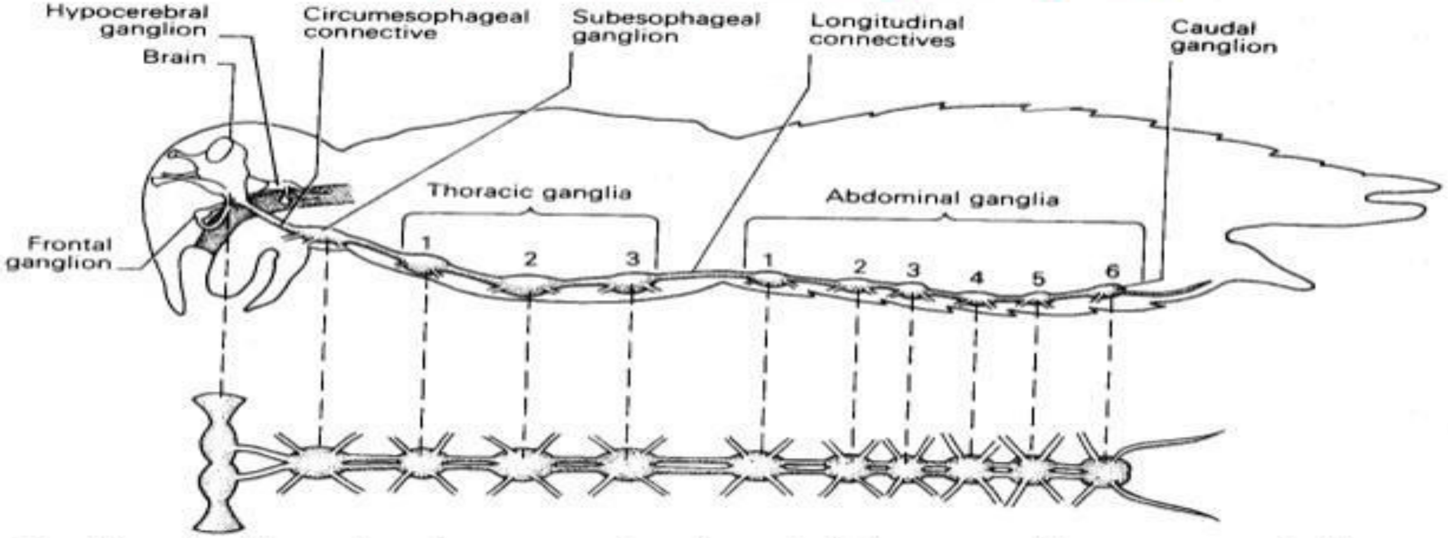
Nervous system

INSECT NERVOUS SYSTEM

i) Central nervous system (CNS)



Contains double series of nerve centers (ganglia). These ganglia are connected by longitudinal tracts of nerve fibers called **connectives.** Transverse tracts of nerve fibers called **commissures**

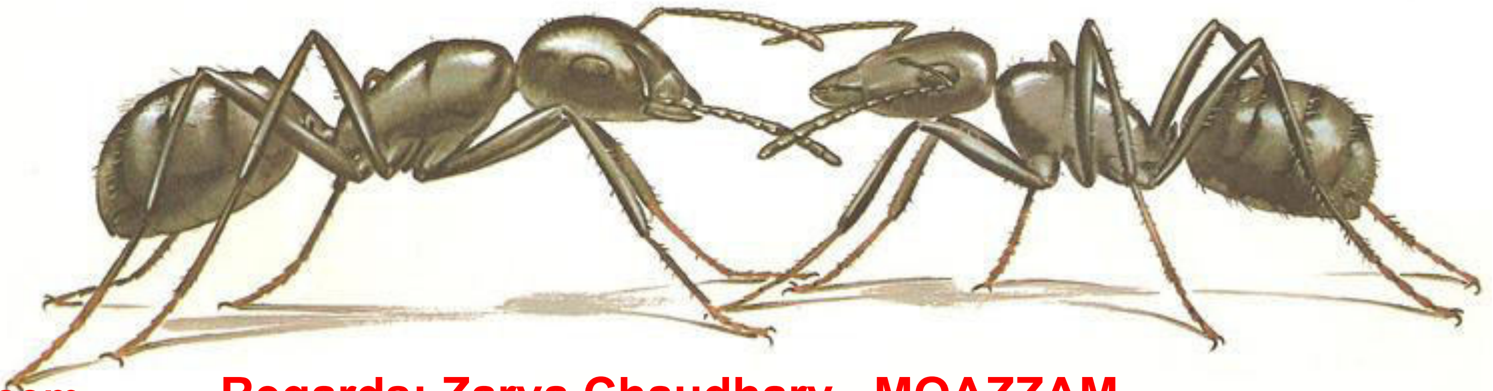
Sense organs

Sense organs

- All the more evident senses possesed by men appear to be present in *insects*
- *Except possibly taste, but not in all cases in the same individual*

Sense organs

- Thus some cave-inhabiting insects have no eyes
- It is almost certain also that insects have other senses not possessed by man



Reproductive organs

- Insects are of distinct sexes, male and female
- In many cases, however, individuals occur incapable of reproduction, their sexual organs not having become fully developed
- Such inserts may be termed **neuters**

Reproductive organs

- Most of these appear to be really undeveloped females, though undeveloped males are also known
- They are found in colonial insects where division of labor occurs

Reproductive organs

- As in the **honeybee, ants and termites**, and are known according to their duties, as workers or soldiers or by other names
- Conventional signs for the various forms of insects, as a convenience, are if male ♂ female ♀ or worker

Reproductive organs

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Female Reproductive Tract

Female Reproductive Tract

- In the female the eggs are produced in a pair of ovaries located in the upper front part of the abdomen

- Each is a cluster of ovarian tubes whose walls are cells

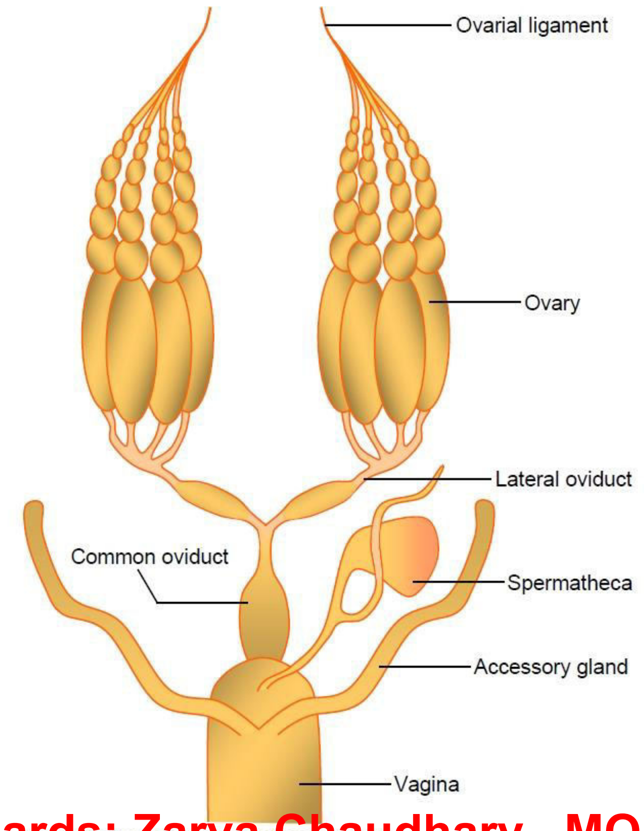
Female Reproductive Tract

- Some of these cells grow and separate from the others to lie in the central cavity of the tube and then pass downward
- Growing till they reach its hinder end
- Which connects with the similar ends of all the ovarian tubes of that side to form a single tube called the oviduct

Female Reproductive Tract

- This extends downward and back ward around the side of the alimentary canal
- Below which it joins with a similar oviduct from the other side of the body to form a single duct

Female Reproductive Tract



Female insect reproductive system

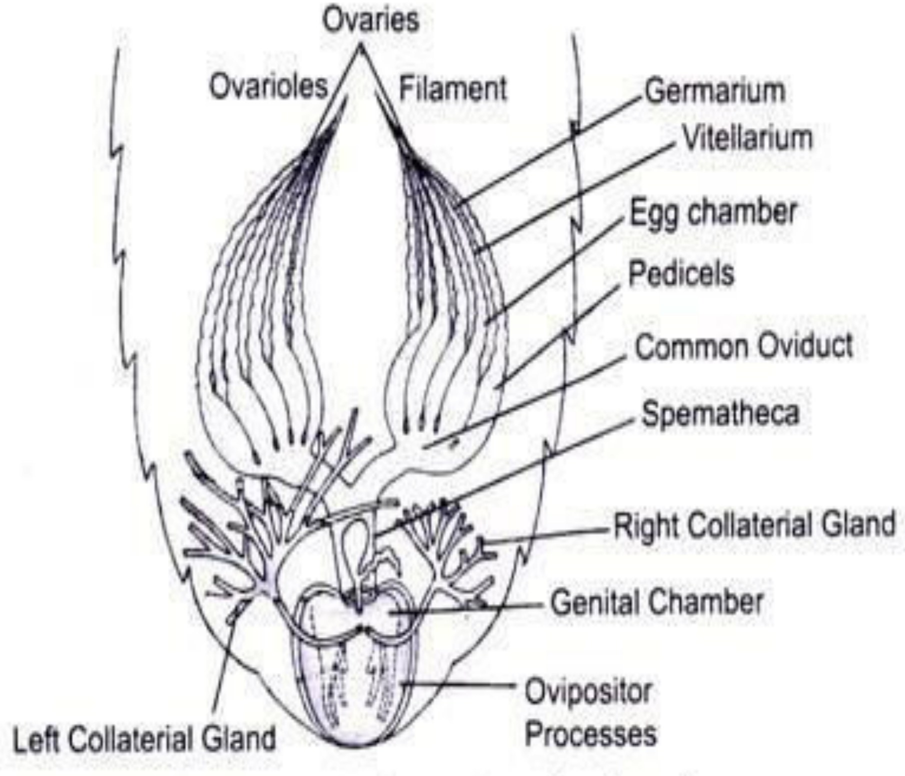
Female Reproductive Tract

Female Reproductive Tract

- The vagina, which lies between the alimentary canal and extends backward to its outer opening which is located

- In most cases, in front of the next to the last abdominal segment.

Female Reproductive Tract



Female Reproductive Tract

- Surrounding this opening may be external structures known as **ovipositor**
- For the purpose of together making holes in some object (the ground, wood, etc.) in which to deposit the eggs

Female Reproductive Tract

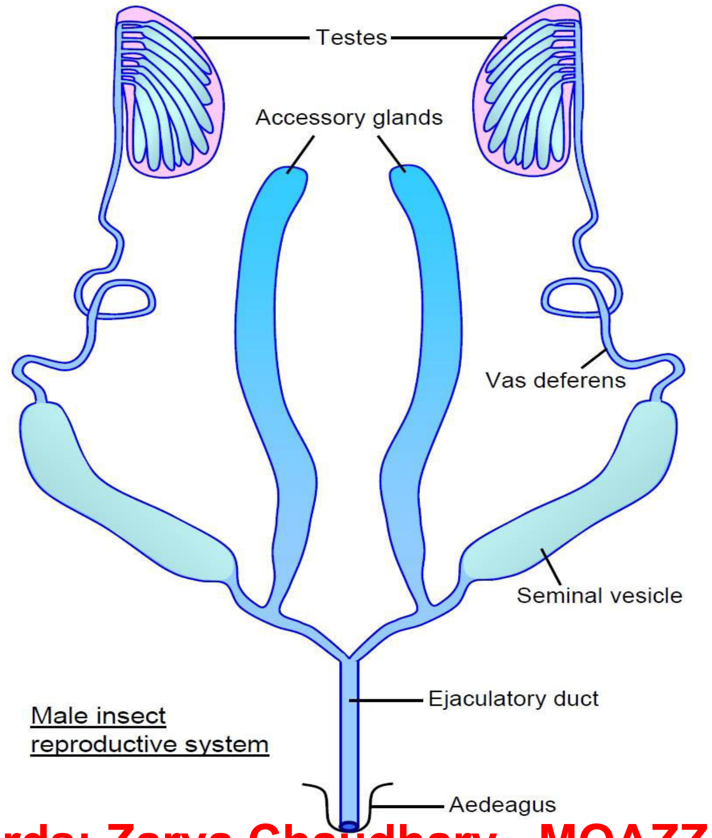
- A side pouch called **seminal receptacle** is connected with the vagina is for the storage of the sperms which fertilize the eggs
- A gland-producing material, which forms the egg shell and is known as the **shell gland**, also opens into this portion
- And other glands similarly connected with the vagina may also be present.

Male Reproductive Tract

Male Reproductive Tract

- In the male the arrangement of the organs closely corresponds to that in the female
- A pair of spermaries or testes is present in the upper front part of the abdomen
- Each consisting of a rather closely coiled mass of tubes in which the sperms are produced.

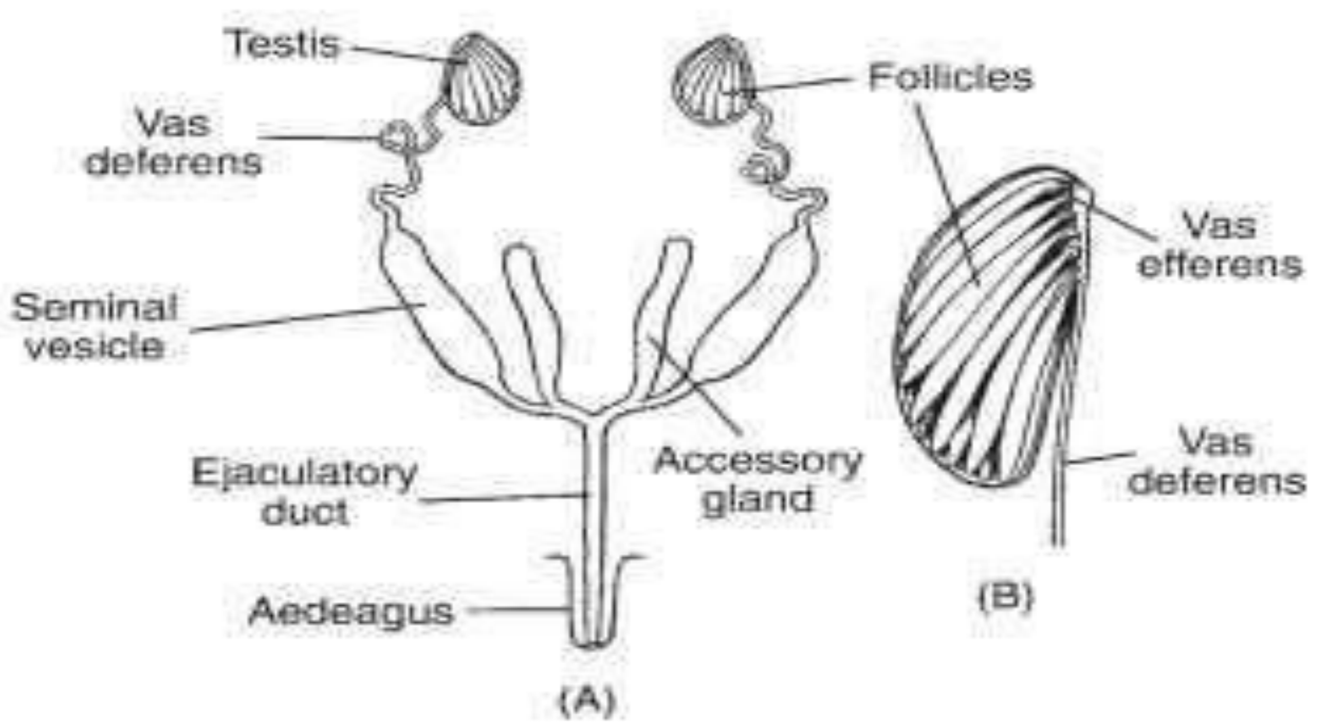
Male Reproductive Tract



Male Reproductive Tract

- The tubes on each side unite to form a single tube, the **vas deferens** (plural, vasa deferentia)
- These differ from the oviducts usually, in being much longer and coiled or twisted

Male Reproductive Tract



Male Reproductive Tract

- They pass downward and backward, however, and unite on the middle line of the body below the alimentary canal
- Forming a single tube, the ejaculatory duct, corresponding to the vagina in position
- Which leads backward to an opening in front of the last segment

Male Reproductive Tract

- An enlarged portion of the **vas deferens** is often present, for the temporary storage of the sperms, and is termed the **seminal vesicle**
- **Accessory pouches** opening into the ejaculatory duct appear to be, in part at least
- For the production of mucus and secretions to mix with the seminal fluid

THE DEVELOPMENT OF INSECTS (Egg Types)

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- Most insects lay eggs from which the young hatch after a longer or shorter time

- Though in some cases the egg appears to be retained within the body of the parent until after it has hatched

- The young then being produced in an active stage
- Those which lay eggs hatching later are termed **oviparous**

- Those having eggs that remain in the body of the parent for a time after hatching are termed **ovoviviparous**

- A few insects that supply nourishment to the young before its birth are termed **viviparous**

- Insect eggs are usually very small, vary greatly in form and may be laid singly or in clusters (Fig. 32).

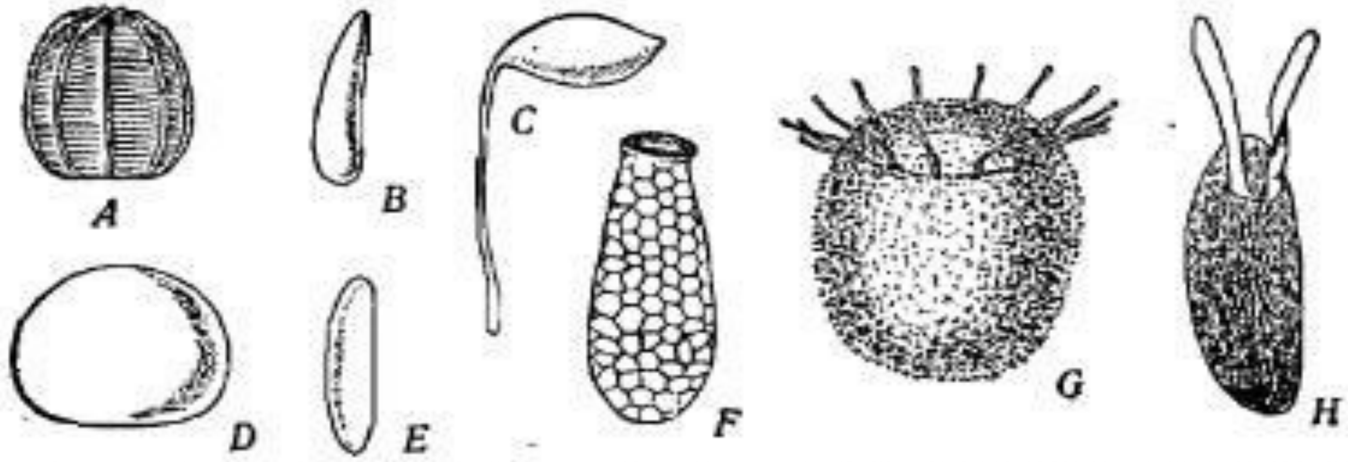
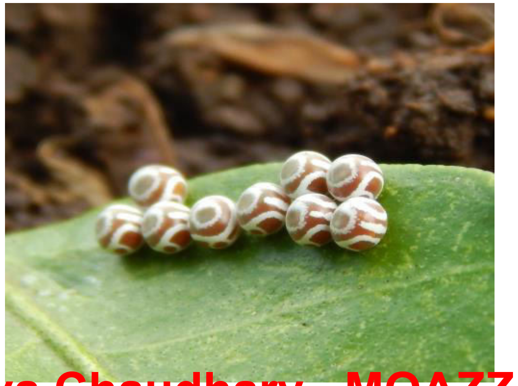


FIG. 32.—Eggs of various insects: *A*, butterfly; *B*, housefly; *C*, chalcid (*Bruchophagus*); *D*, butterfly; *E*, midge; *F*, bug (*Triphleps*); *G*, bug (*Podisus*); *H*, pomace fly. All much enlarged. (*From F*

Structure of eggs

Structure of eggs

- They are covered by a chitinous shell, the chorion, which often bears markings in the form of ridges, reticulations
- And frequently are also colored


Structure of eggs

- At one place on the surface is a minute opening or group of openings through the shell, called the **micropyle**
- Believed to be for the entrance of the fertilizing sperm

Structure of eggs

- The length of time spent in the egg differs in different insects from a few hours to many months, and in some cases the eggs
- Do not hatch until the second season after they are laid

Structure of eggs

- In hatching, the shell breaks and out of it crawls the young insect
- In the majority of cases quite unlike the adult it is to become

Structure of eggs

- In order to reach maturity it must now grow and undergo changes in structure and appearance

- These together are expressed by saying that most insects in order to become adult undergo a metamorphosis

Metamorphosis

Metamorphosis

- In some of the simpler inflects, a few changes and growth only are needed to make them mature
- And these are therefore usually grouped together as the **Ametabala**, or insects having practically no metamorphosis

Metamorphosis

- The remaining insects, from this standpoint, form two groups:
- **Hemimetabola, or Paurometabola:** Those which on hatching generally show some resemblance to the adults and reach maturity by a series of gradual changes
- **Holometabola:** And those which on hatching are totally unlike the adults and become adults by a somewhat different process

Metamorphosis

- These names suggesting the amount of metamorphosis required for members of each group to become adult
- A member of the group Ametabola upon hatching, will begin to feed and grow

Metamorphosis

- Growth, however, is restricted because the insect is enclosed by a cuticula which, while elastic, to some extent, at least at its thiner places, has its limitations in this regard
- Thus the insect is unable to reach its adult size within its cuticula, and a process called molting takes place

Metamorphosis

- This is begun by a pouring out of fluid by the outside layer of living cells, the hypodermis, between it and the cuticula, separating the two
- Next a spilt appears somewhere in the cuticula usually along the back and the insect crawls out of its skin, i.e., molts.

Types of Metamorphosis

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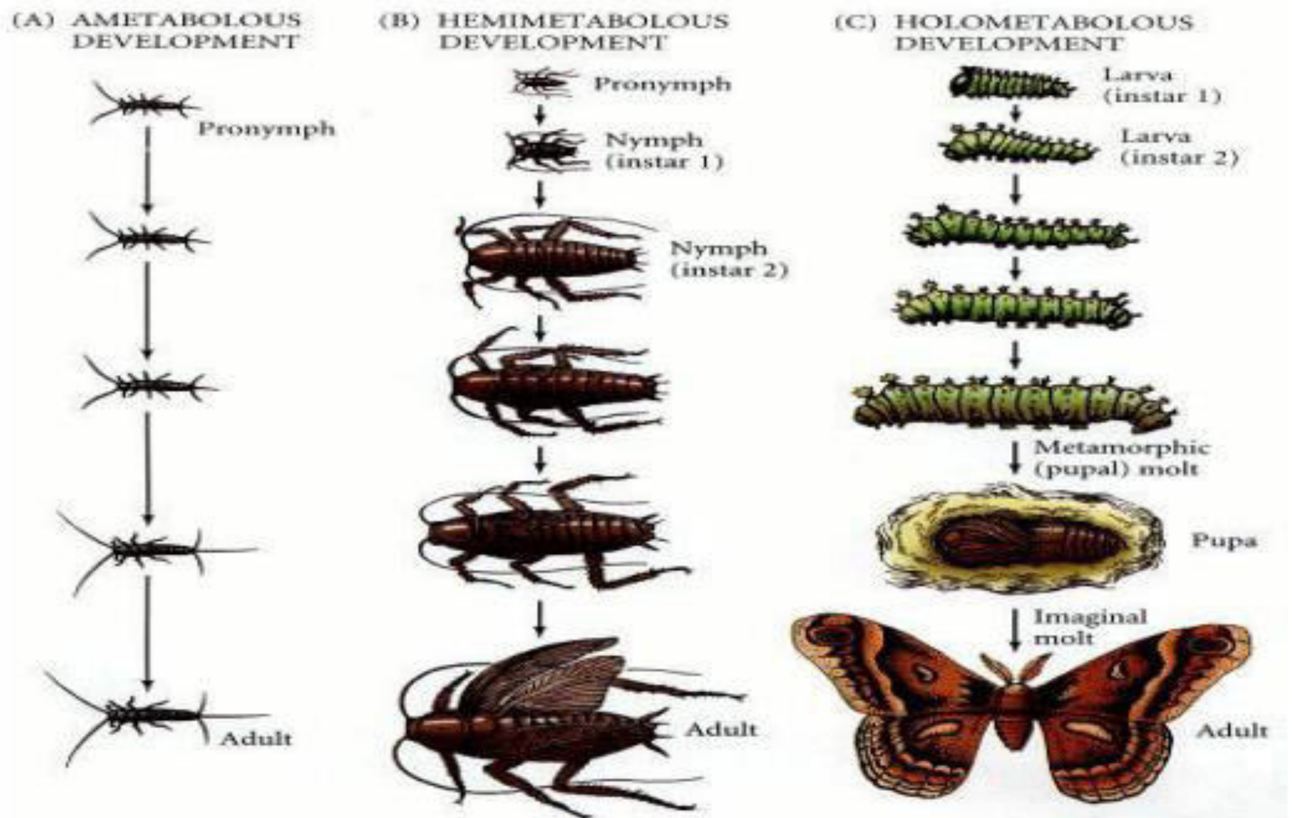
Types of Metamorphosis

- Until the fluid poured out has had time to harden, the insect is able to grow
- But in a short time it hardens to become a new cuticula and there after only such growth occurs as the elasticity of the new shell will permit
- In theory there should be some Ametabola that do not molt, the cuticula being so elastic it will stretch enough to permit growth to the adult

Types of Metamorphosis



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Types of Metamorphosis

- In fact, however, they · all appear to molt at least two or three times in a few cases it seems to occur at intervals throughout life

- In any case the reproductive organs appear not to be mature at the time of hatching and only gradually become so during the period following

Types of Metamorphosis

- In the **Hemimetabola (or Paurometabola**) the young insect on escaping from the egg, though resembling its parent to some extent
- Undergo many change in structure and a considerable increase in size as well before reaching maturity

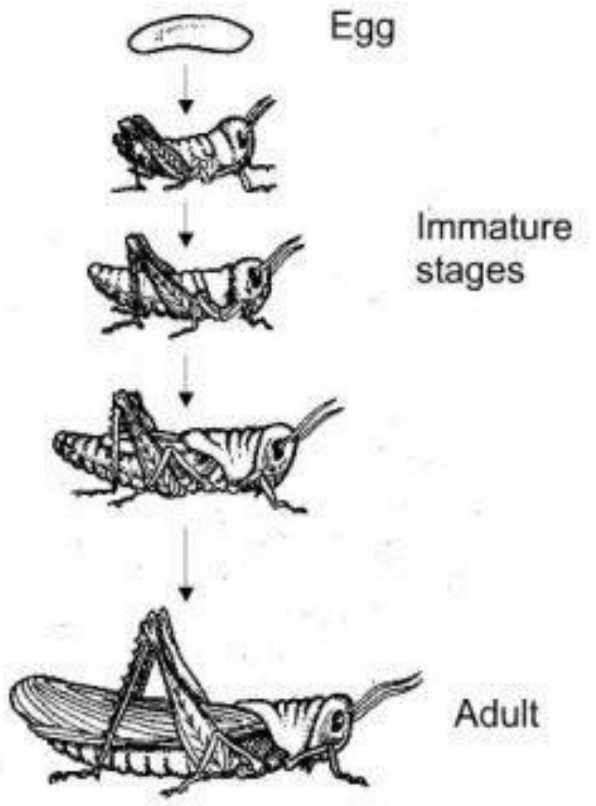
Types of Metamorphosis

- Thus a young short-horned grasshopper, on hatching, will need to grow to be about ten times as long before becoming adult

- It is without wings, which will need to be developed; its reproductive organs are not mature and must become so; and other differences occur

Metamorphosis

Metamorphosis



Metamorphosis

- All of these must be transformed into their condition in the adult; and to accomplish this, energy is necessary
- In the egg the energy for development has been provided by the yolk; after hatching the young insect must provide it by gathering food

Metamorphosis

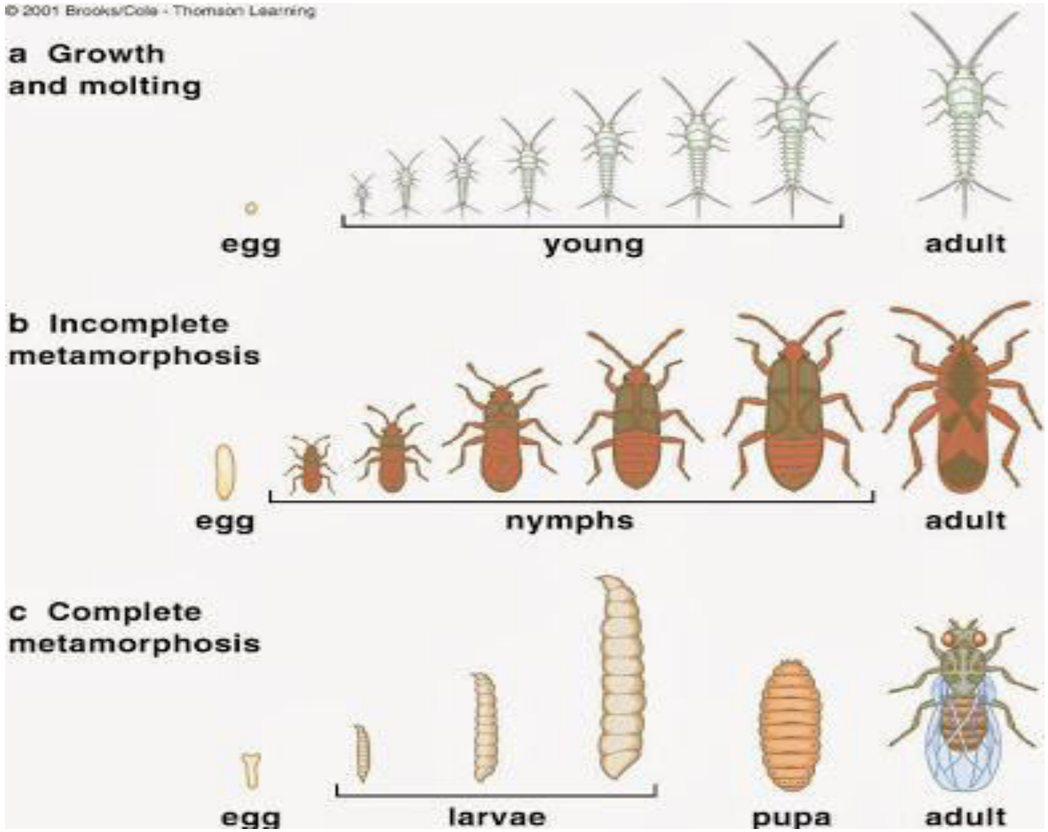
- The young insect, therefore, soon after hatching seeks for food and haring found it begins feeding
- The nourishment thus obtained results , in growth so far as this is possible within a shell which is tightly fitting and only to some degree elastic

Metamorphosis

- When no further growth in this way can occur and the body has stored within it all the materials needed for a greater increase in size

- It proceeds to molt in the manner already described for the **Ametabola**

Metamorphosis



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Metamorphosis

Metamorphosis

- On escaping from its old skin or shell, how ever, besides a rapid increase in size, changes of structure also occur
- So that a difference in appearance now becomes evident
- These changes must be produced quickly, as the hypodermal cells of these parts, as well as of all the surface, are producing a new chitinous skin

Metamorphosis

- When this has once hardened, no further changes and little further growth are possible
- Molting, then, marks the beginning of a brief period-a day, more or less-of increase in size and of changes in appearance

Metamorphosis

- These last all being in the direction of making the young insect more nearly like the adult it is to become

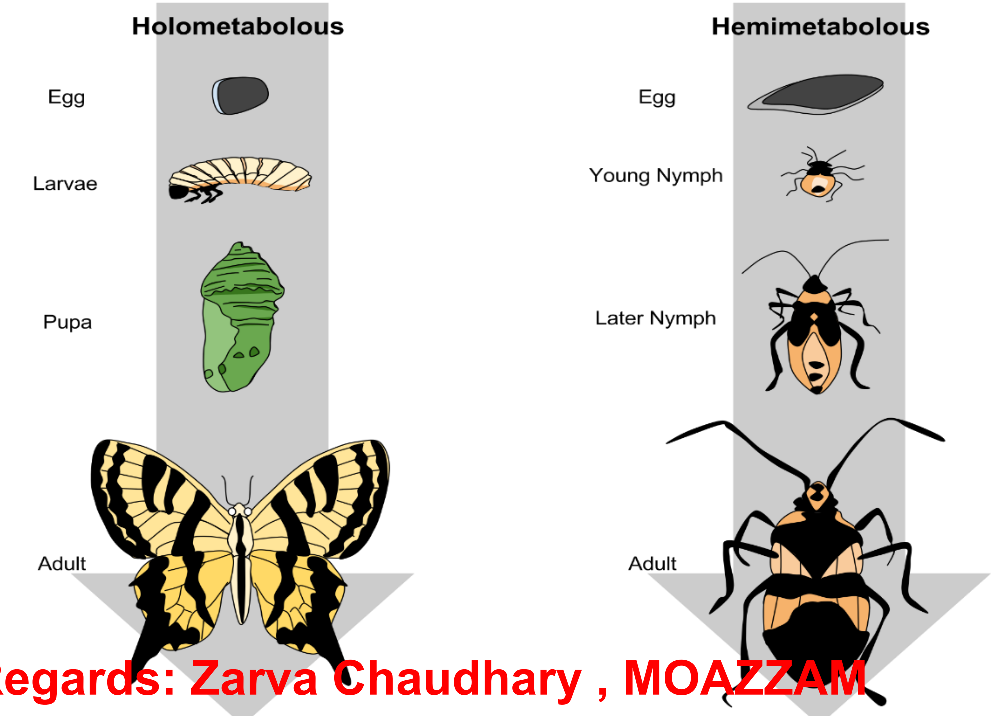
- When the new shell has become hardened, the insect resumes its feeding

Metamorphosis

- After another feeding period the young insect is again confronted with the same difficulties as before, and it meets them in the same way, by molting, and immediately thereafter
- Before its new shell has hardened, it seizes the opportunity to grow and change its appearance further

Metamorphosis

- Finally, after some molt, full adult size for the insert is attained and all its organs have also fully developed and matured, producing the adult insect itself



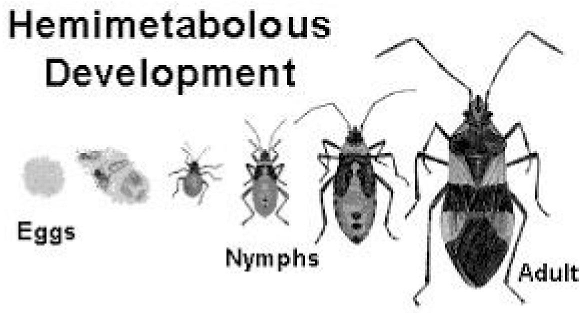
Hemimetabola

Hemimetabola

- The number of molts, and consequent opportunities for change that occur, vary in different **Hemimetabola**
- There may be only two or three in some kinds; five is perhaps the average number though more are not uncommon; forty-five are known to occur in one species

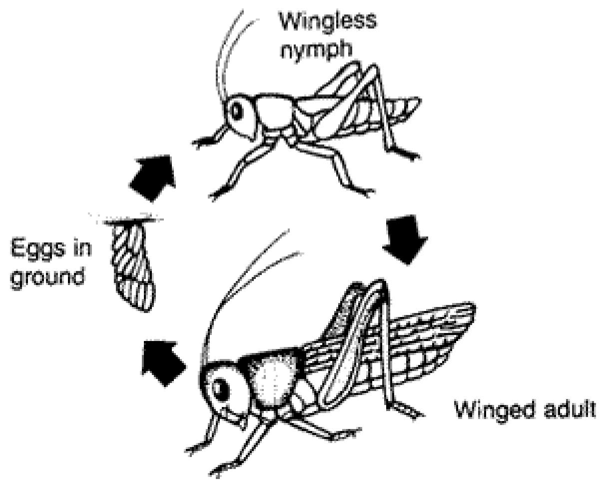
Hemimetabola

- Certain names for these different conditions are convenient for use
- The feeding periods between the **molts (or ecdyses)** are called instal's



Hemimetabola

- So that the progress of an insect from hatching to adult is by an alternation of instal'S and molts
- The insect itself, from hatching until maturity, is generally called a **nymph**
- The changes in appearance of a grasshopper after each molt



Grasshopper Lifecycle

Hemimetabola

- The term **Hemimetabola** was used for many years to include all those orders in which the insects underwent incomplete metamorphosis in the course of their development
- Found in In three of the orders
  - 1-Ephemerida
  - 2-Odonata
  - 3-Plecoptera

Hemimetabola

- In three of the orders, the young live and develop in water and differ greatly from their adults in appearance
- In recent years this has led some entomologists to divide the Hemimetabola into two groups

Hemimetabola

Hemimetabola

- The three just named were left under the Hemimetabola and the others were given the group name **Paurometabola** which means a gradual metamorphosis

- The young in the Hemimetabola thus limited are called naiads; those in the Paurometabola, nymphs

Hemimetabola

- This is by no means a classification of the insects themselves, but only of the different types of develop meant that occur

- This classification has not been adopted in this book.

Holometabola

- With the remaining group of insects, the **Holometabola**, although there is a little similarity in the metamorphosis to that in the Hemimetabola
- But there are also many differences.

Holometabola

- When a young holometabolous insect hatches, it in no way resembles its adult

- A caterpillar is totally different in appearance from the butterfly it finally becomes the white grub in the earth

- It is called June bug (May beetle) into which it transforms

Holometabola

- Nevertheless, this young insect-called a larva has to meet the same problems of growth and transformation to the adult condition as do the **Hemimetabola**
- And uses the same means for accomplishing the needed results, · viz., the utilization of the energy derived from its food

Holometabola

Holometabola

- Upon hatching, in the **Holometabola**, a feeding period or instar comes first, followed by a molt and growth
- At this point the story *of the metamorphosis differs from that of the hemimetabola, for* after the molt no change in appearance to make the young insect more nearly like the adult takes place

Holometabola

- It may be different in some regards, besides size, from what it was before the molt, but these differences do not increase its resemblance to what it finally becomes

- This holds through out the feeding period of its existence, so that after three, four or more molts a caterpillar is still caterpillar, a grub is still a grub, and this is

Holometabola

- Equally true for all **holometabolous** insects

- With in the insect during this period, however, changes not perceptible on the surface are taking place, by the construction of portions of the adult

Holometabola

- which are forming as buds or ingrowths from various parts of the body and are termed **imaginal buds** (from "imago," the adult)
- They are closely compacted and many at least are enfolded somewhat like buds, becoming finally ready to open when the proper time comes

Holometabola

- And during its feeding instars, the larva is storing energy from its food not only for its growth at each molt but also to carry it on through a period yet to be described
- During which it must transform into the adult condition while unable to feed and obtain the energy needed for this purpose

Development in insects

Development in insects

- After a varying number of feeding instars and molts, the young insect or larva has grown sufficiently and has stored within it energy

- Enough to carry it through the remainder of its changes, and internally the essential parts for the adult condition have been formed as far as it possible under existing conditions

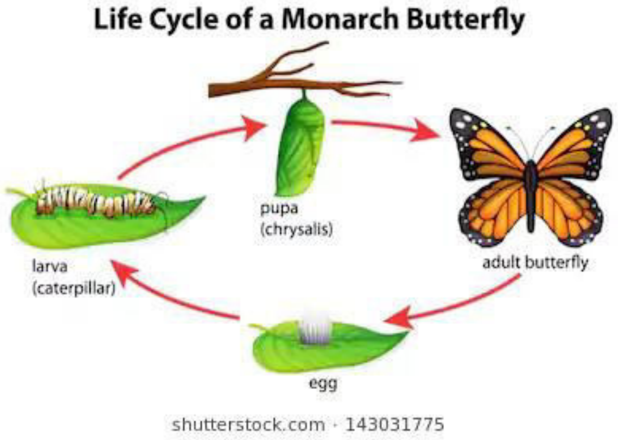
Development in insects

- As the next change will produce an animal practically helpless in most cases and unable to protect itself from its enemies, its next step is to find as much protection as possible

- Accordingly, the full-grown larva usually, though not always, leaves the place where it has been feeding and elsewhere prepares for its next change

Development in insects

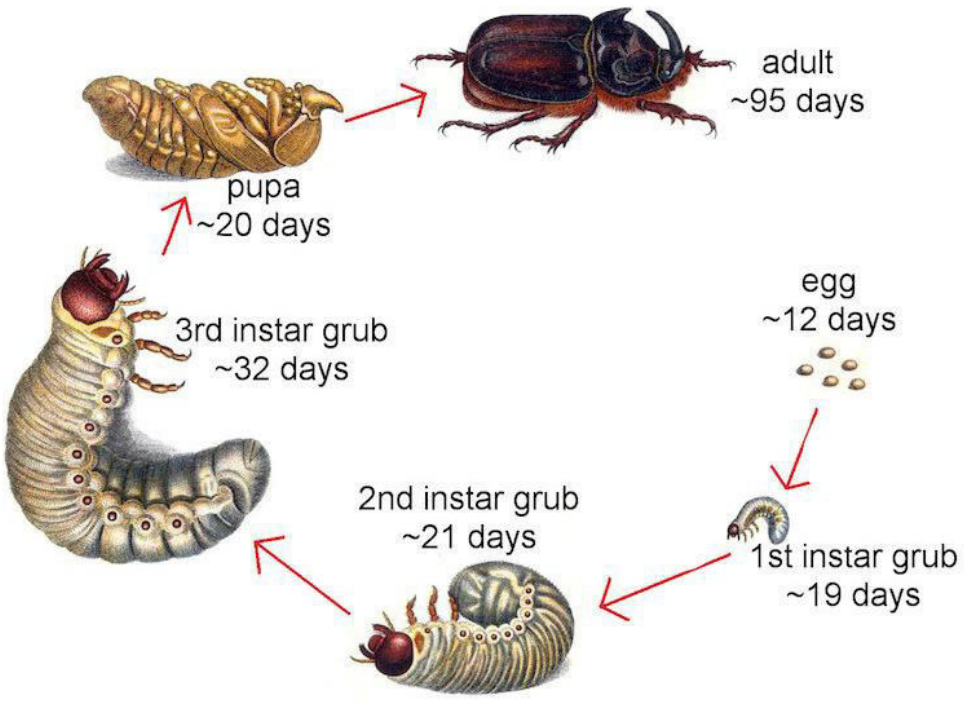
- Many larvae begin this by spinning around themselves a thread of silk, produced by glands within the body and opening to the surface on the lower lip
- This thread is spun backward and forward and around the body until it sometimes forms a complete outer covering, entirely concealing the larva within from view. This case or cocoon appears to be protective in its function



Development in insects

- Some larvae go underground for this change
- Here a cocoon, as such, seems unnecessary

Development in insects



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Development in insects

Development in insects

- But after digging into the earth a few inches, the insect forms a little earthen chamber or cell in which to lie and generally lines this more or less densely with silk, probably to keep the earthen walls from falling in and crushing it

Development in insects

- A larva transforming in tunnels in wood where it has fed may make a partial cocoon with more or less of the chewed wood fragments mixed in

- One staying above ground but not in tunnels or otherwise protected will spin more or less of a cocoon as already described

Development in insects

- The completeness of the cocoon, however, varies greatly with different insects
- Instead of being a thick, dense wrapping which entirely conceals the insect, it may be so scanty that the animal within can be seen to some extent

Development in insects

- In other cases it is merely a sort of network, in no degree giving concealment and in still others, a few scattered threads to hold the insect in place are all that represent it
- Sometimes hairs from the body of the larva, held together by silk, form most of the cocoon

Development in insects

- In the case of butterflies only threads enough to attach the hinder end of the body at the place where it is to transform and usually to form a supporting loop around its middle
- The ends of the loop also being fastened to what it rests on, are produced

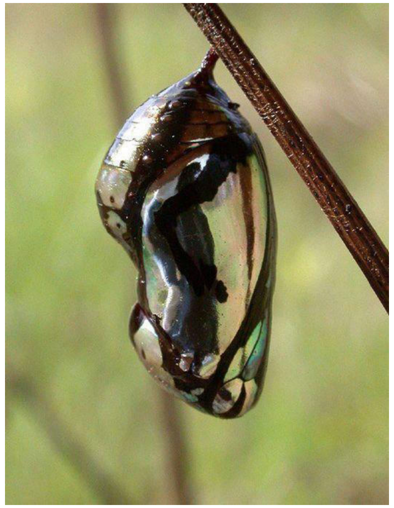
Development in insects

Development in insects

- In some flies the larva shrinks within its larval skin and transforms, this skin, now called a **puparium**, functioning like a cocoon
- The reason for such variations in a structure, presumably formed for the purpose of protection, can only be guessed at

Development in insects

- Possibly in the course of generations some insects found less need of this than others and gradually reduced it
- Thereby saving the vital energy so much needed for transformation, which would otherwise be expended in cocoon making



Development in insects

- Whether the larva forms a dense or scanty cocoon, or none whatever, the next step in the process is a molt

- When the insect escapes from this skin, however, a great change in it appearance is evident, and it is now called a pupa

Development in insects

- In a general way it may be said that it has at this one molt changed more than halfway to its adult condition
- This is due in part at least to the unfolding of the **imaginal buds** already referred to

Development in insects

- Which contribute largely to form the new surface of the body in which
  - Head
  - Thorax
  - Abdomen are evident
  - Antennae,
  - Legs, stubs of wings

Development in insects

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Development in insects

- Many of the internal organs of the larva, though, were necessary for use till the last moment before it became a pupa

- Then, too, the arrangement of the muscles in the larva would not be that needed by the adult

Development in insects

- Accordingly, most of the internal organs now gradually break down, losing all their earlier form and structure and new ones to meet the needs of the adult are constructed to take their place
- During this breaking down and the reconstruction period, the pupa is practically helpless in most cases; hence generally the need for the protecting cocoon or earthen cell it constructs

Development in insects

- When the structure of the adult insect has been completed, another molt takes place, the pupa skin splitting and setting free the insect
- If it was enclosed in a cocoon, it now produces a fluid which sufficiently softens the silken threads so that it can push its way out and it escapes or "emerges."

Development in insects

- It is now soft its wings are only partly expended as in most cases there would be no room for full-sized wings in a pupa, and because of its reconstruction there is considerable waste matter in its body

Development in insects

- The insect crawls upon whatever it may find to hold on to, expels the waste matter, and its wings begin to grow rapidly
- Drying out also takes place and in a short time (a few hours) the adult thus produced is in every way fully matured
- In some cases maturity of the reproductive organs is not complete until a little later

Development in insects

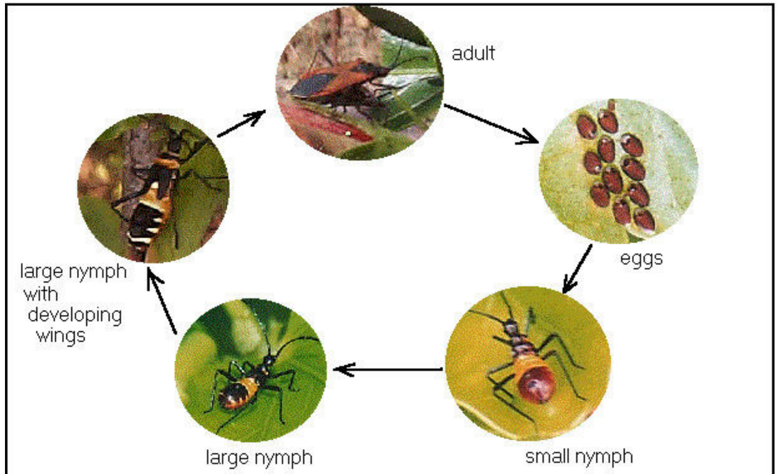
Development in insects

- To summarize the differences in metamorphosis of the three groups it may be said that in the **Ametabola**

- The insect hatches from the egg practically in an adult condition; *i.e.*, there is little or no metamorphosis

Development in insects

- In the **Hemimetabola** the insect hatches from the egg in a form somewhat resembling the adult (except in the **Ephemerida**, **Odonata** and **Plecoptera**) but much smaller



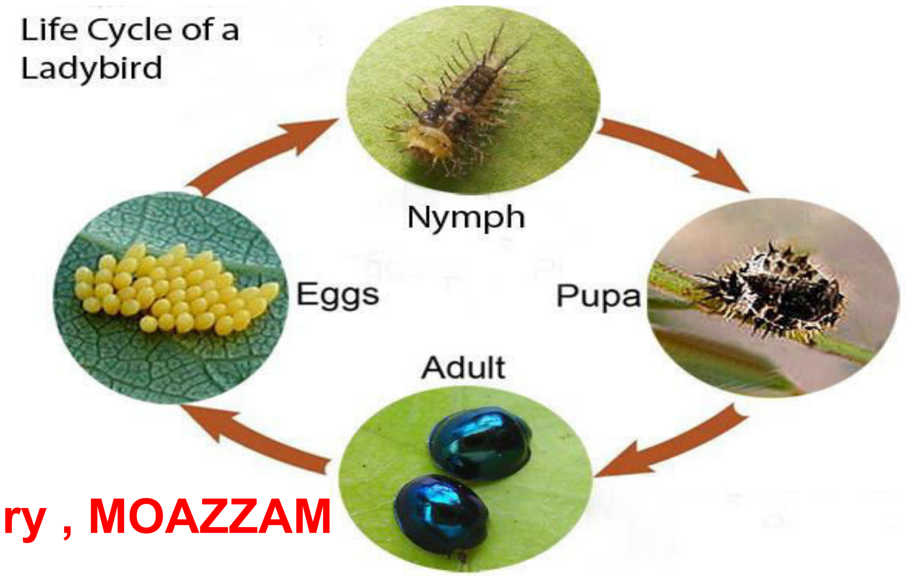
Summary of a bug's life - in-complete metamorphosis

Development in insects

- It becomes adult by alternating periods of feeding with molts, at which times growth and changes bringing it nearer
- To the adult occur, the last molt completing the growth and adult structure

Development in insects

- In this life history we have a change; but as there was a resemblance to the adult from the start, the change to it (**metamorphosis**) is only an incomplete or partial one



Development in insects

- In the **Holometabola** the insect hatches from the egg in a form totally unlike the adult

- Where as feeding periods followed by molts and growth give increase in size, no external evidence of any changes making the insect more like the adult can be found.

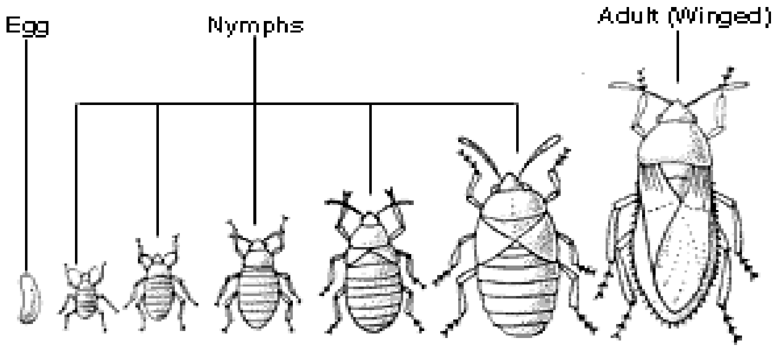
THE DEVELOPMENT OF INSECTS

THE DEVELOPMENT OF INSECTS

- These changes are largely made after the end of the feeding and growing periods during a pupa (generally quiet) stage
- In which the breaking down of the larval, and construction of the adult, structures is completed.

THE DEVELOPMENT OF INSECTS

- The difference between the larva on hatching and the adult is so great that an entire change (complete metamorphosis) takes place
- It should be evident from the foregoing that, when the adult condition is once reached
- If any growth is possible and that the belief so common that "big flies grow from little flies" is without any basis of fact



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THE DEVELOPMENT OF INSECTS

- The nymphs of the **Hemimetabola** appear not to have attracted sufficient attention to receive any special common names

- In the **Holometabola** the larvae of various groups differ greatly in appearance many are large and noticeable and some of them have, as a result, received special names.

THE DEVELOPMENT OF INSECTS

- Types of larvae:

- Larvae of butterflies and moths are commonly called **caterpillars**
- Those of beetles are usually called **grubs**
- Those of flies are called **maggots**.
- Larvae found boring in wood, however, whether they will become moths, beetles or other insects, are uniformly called **borers**.

THE DEVELOPMENT OF INSECTS

- In the **Hemimetabola**, then the stages of life are
  - Egg
  - Nymph
  - Adult
- In the **Holometabola** they are egg, larva, pupa, adult
- Whether or not the pupa is enclosed by a cocoon depends upon circumstances

ECONOMIC IMPORTANCE OF INSECTS (INSECT DAMAGES)

Introduction

- Of the many thousands of insect species known to man some affect him and his property only slightly; some are beneficial; others are injurious in various degrees

- Only rough estimates can be made of the monetary losses and gains by insect activities and even these are made with difficulty

- Although it is the general practice to express losses in terms of dollar valuation

- It probably would be safer to give them in bushels, tons, etc., because the relative values of different crops and products change from year to year

- No crop of either vegetable or animal origin appears to be entirely free from insect injury
- Field, truck and fruit of crops, both growing and in storage, household goods and food products, forests and the wood products derived from them, domestic animals and animal products, all are more or less liable to insect attack




- Because there never has been a season free from the ravages of insects which might serve as a standard for comparison, much of this loss is not appreciated
- If there could once be such a year entirely insect free, the difference would be apparent at once