Ministry of Higher Education and Scientific Research
University of Baghdad
College of Science
Department of Biology

Entomology
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علم الحشرات

المرحلة الثانية / الدراستين الصباحي والمسائي
الفصل الدراسي الاول

تدريسي المادة :
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Entomology Lecture 1

- ❖ the scientific study of insects
- ❖ Insects are an incredibly successful group; about 90% of all species are insects. About 1 million species of insects are described, but the total number of species is estimated to be between 2.5 and 10 million.

Why are insects so successful on earth?

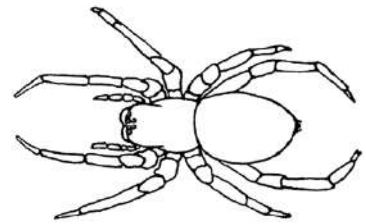
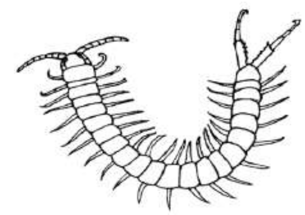
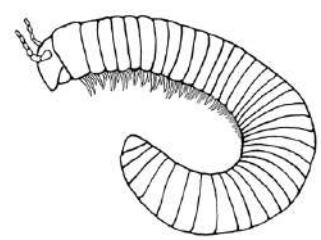
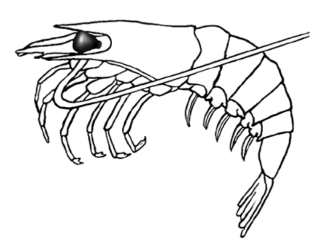
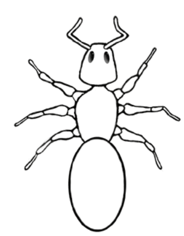
- 1- Small size.
- 2- Ability to adapt.
- 3- Ability to reproduction.
- 4- Different feeding.
- 5- Different living
- 6- Short life cycle
- 7- Covering with exoskeleton
- 8- Ability to fly

Insect Morphology

All arthropods characterize by:

- **Exoskeleton** - a hard protective covering around the outside of the body (divided by sutures into plates called **sclerites**)
- Segmented body
- Jointed limbs and jointed mouthparts - that allow extensive specialization
- Bilateral symmetry - whereby a central line can divide the body into two identical halves, left and right
- Ventral nerve cord - as opposed to a vertebrate nerve cord which is dorsal
- Dorsal blood pump

Five important extant classes of Arthropods are arachnids, chilopods, diplopods, crustaceans and hexapods.

Class Arachnida (arachnids): spiders, scorpions, ticks, mites, etc. Arachnids possess: • 2 body segments - cephalothorax and abdomen • 8 legs • 1 pair of chelicerae • no antennae	
Class Chilopoda Chilipods possess: • many body segments • 1 pair of legs per body segment • 1 pair of antennae • 1st pair of legs modified into venomous **Centipedes**	
Class Diplopoda Diplopods possess: • Many body segments • 2 pair of legs per body segment • 1 pair of antennae • **Millipedes**	
Class Crustacea (crustaceans): crabs, shrimp, etc. Crustaceans possess: • Several body segments - head, thorax and abdomen or cephalothorax and abdomen • Segments may be fused • Varied number of legs • 2 pairs of antennae	
Class Insecta (Insects); beetles, bugs, wasps, moths, flies, etc.: • 3 body segments • 6 legs • 1 pair of antennae • Diverse modifications to appendages	

The Importance of Insects to Humans, Environment & Agriculture:

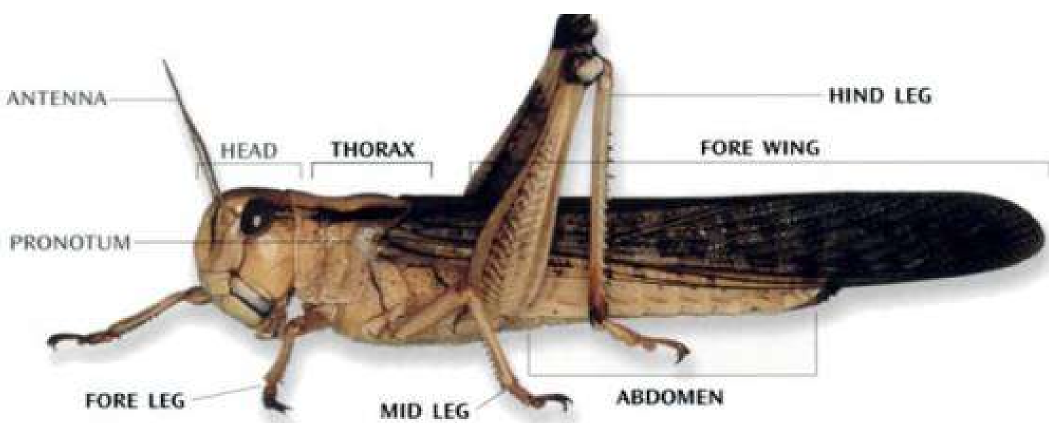
Beneficial Insects	Insect Pests
• Pollination of many flowering plants • Decomposition of organic materials • Recycling of carbon, nitrogen, and other essential nutrients • Control of populations of harmful invertebrates including other insects • Direct production of foods as honey • Manufacture of products as silk	• Damage Crops • Household Pests • Parasites • Biting and Stinging Insects • Prey on domestic animals • Eat human food, clothing & possessions • Destroy trees, wood, paper

Basic Insect Morphology: Head, thorax, abdomen

A look at the outside of an insect:

The **exoskeleton** is comprised of **sclerites**: (hardened plates)

The insect outer skeleton, the **cuticle**, is made up of two layers; the **epicuticle**, which is a thin, waxy, water-resistant outer layer and contains no chitin, and the layer under it called the **procuticle**. This is chitinous and much thicker than the epicuticle and has two layers, the outer is the **exocuticle** while the inner is the **endocuticle**.



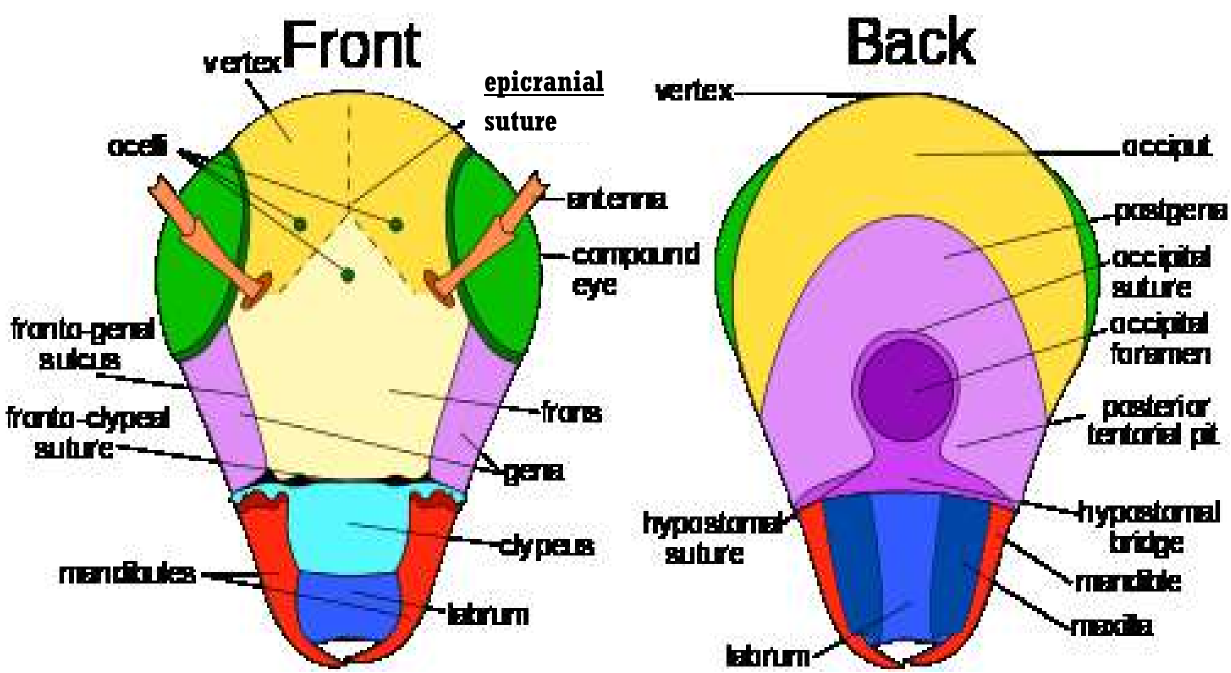
Lecture 2

THE HEAD:

The **head** in most insects is enclosed in a hard, heavily sclerotized, exoskeletal head capsule, or **epicranium**.

In most insects, the head capsule is a sturdy compartment that houses the **brain**, a mouth opening, **mouthparts** used for ingestion of food, and major sense organs (including **antennae**, **compound eyes**, and **ocelli**). Embryological evidence suggests that the first six body segments of a primitive worm-like ancestor may have fused to form the head capsule of most present-day insects.

The surface of the head is divided into regions (**sclerites**) by a pattern of shallow grooves (**sutures**). The uppermost sclerite (dorsal surface) of the head capsule is known as the **vertex**. A **coronal suture** usually runs along the midline of the vertex and splits into two **frontal sutures** as it extends downward across the front of the head capsule these sutures involve **epicranial suture**. The triangular sclerite that lies between these frontal sutures is called the **frons**. The **epistomal suture** is a deep groove that separates the base of the frons from the **clypeus**, a rectangular sclerite on the lower front margin of the head capsule.



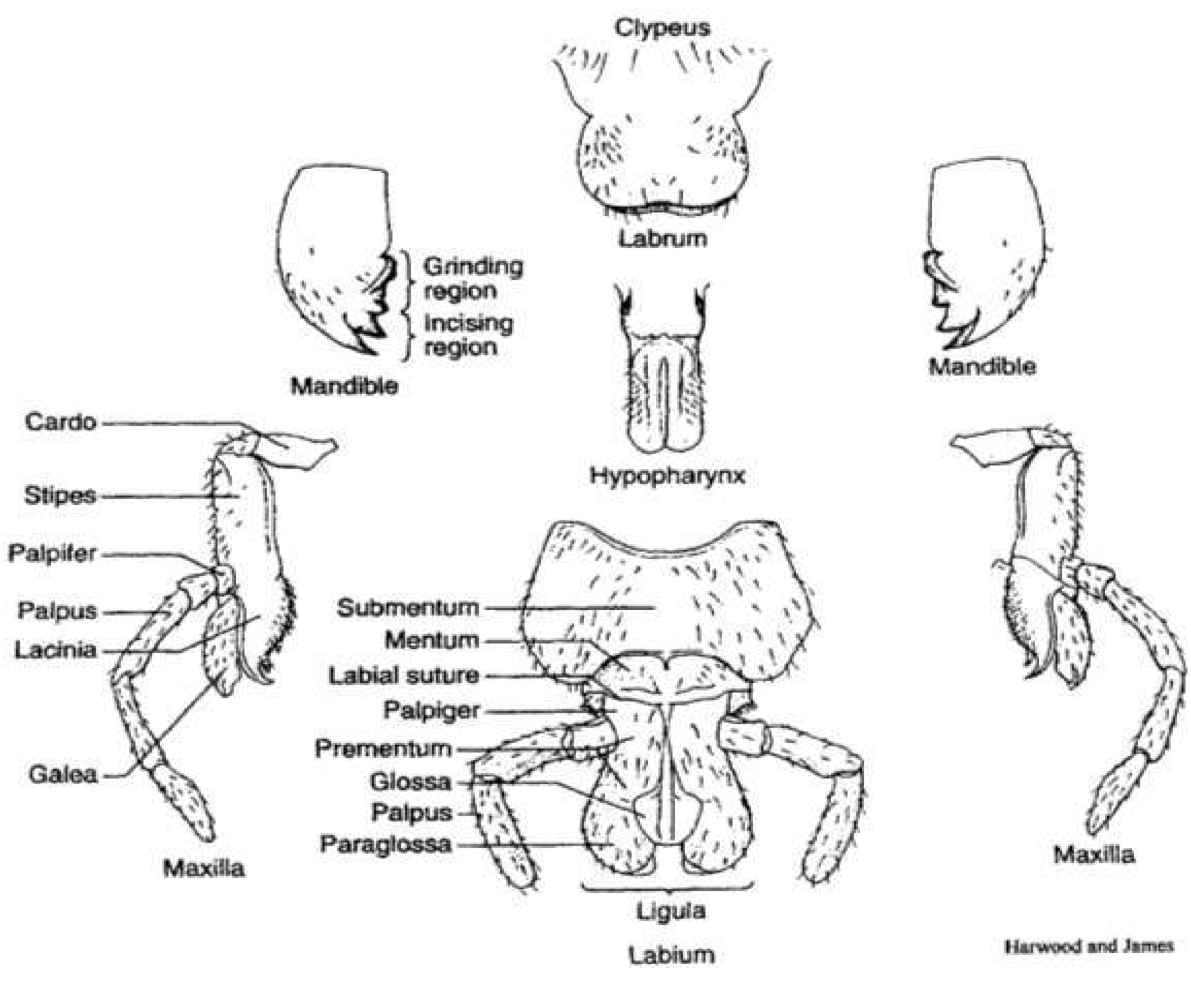
Compound eyes and ocelli:

In most insects there is one pair of large, prominent compound eyes composed of units called **ommatidia**. There may be up to 30,000 **ommatidia** in a compound eye. This type of eye gives less resolution than the vertebrate eye, but it gives acute perception of movement. When present, ocelli (either 2 or 3), detect low light or small changes in light intensity.

Mouthparts:

The 5 main mouthparts are the (**labrum, mandibles, maxillae (plural maxilla), labium and hypopharynx).** The labrum is a simple fused sclerite, often called the upper lip, and moves longitudinally. It is hinged to the clypeus. The mandibles, or jaws, are highly sclerotized paired structures that move at right angles to the body. They are used for biting, chewing and severing food. The maxillae are paired structures that can move at right angles to the body and possess segmented palps. The **labium** (often called the lower lip), is a fused structure that moves longitudinally and possesses a pair of segmented palps.

Mouthparts very greatly among insects of different orders but there are two main functional groups: **mandibulate** and **haustellate**.



1- **Mandibulate** (chewing) mouthparts and (Chewing- Lapping mouthparts)
2- **Haustellate** mouthparts can be further classified as piercing-sucking, sponging, and siphoning.

Mandibulate (chewing) mouthparts are used for biting and grinding solid foods. Two types: (Chewing mouthparts)

Examples: Dragonflies and damselflies (order **Odonata**), termites (order **Isoptera**), adult lacewings (order **Neuroptera**), beetles (order **Coleoptera**), ants (order **Hymenoptera**), cockroaches (order **Blattaria**), grasshoppers, crickets and katydids (order **Orthoptera**)

And (Chewing- Lapping mouthparts)

Examples: The mouthparts of honeybees (Family **Apidae**)

Haustellate mouthparts are primarily used for sucking liquids and can be broken down into two subgroups: those that possess stylets and those that do not.

1- Stylets are needle-like projections used to penetrate plant and animal tissue. The modified mandibles, maxilla, and hypopharynx form the stylets and the feeding tube. After piercing solid tissue, insects use the modified mouthparts to suck liquids.

Some haustellate mouthparts lack stylets. Unable to pierce tissues, these insects must rely on easily accessible food sources such as nectar at the base of a flower. One example of nonstylate mouthparts is the long siphoning proboscis of butterflies and moths (Lepidoptera). Although the method of liquid transport differs from that of the a Lepidopteran proboscis, the rasping-sucking rostrum of some flies are also considered to be haustellate without stylets.

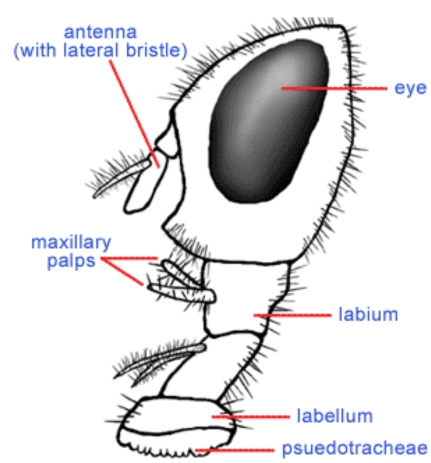
Piercing-sucking mouthparts are used to penetrate solid tissue and then suck up liquid food.

Examples: Cicadas, aphids, and other bugs (order Hemiptera), sucking lice (order Phthiraptera), stable flies and mosquitoes (order Diptera).

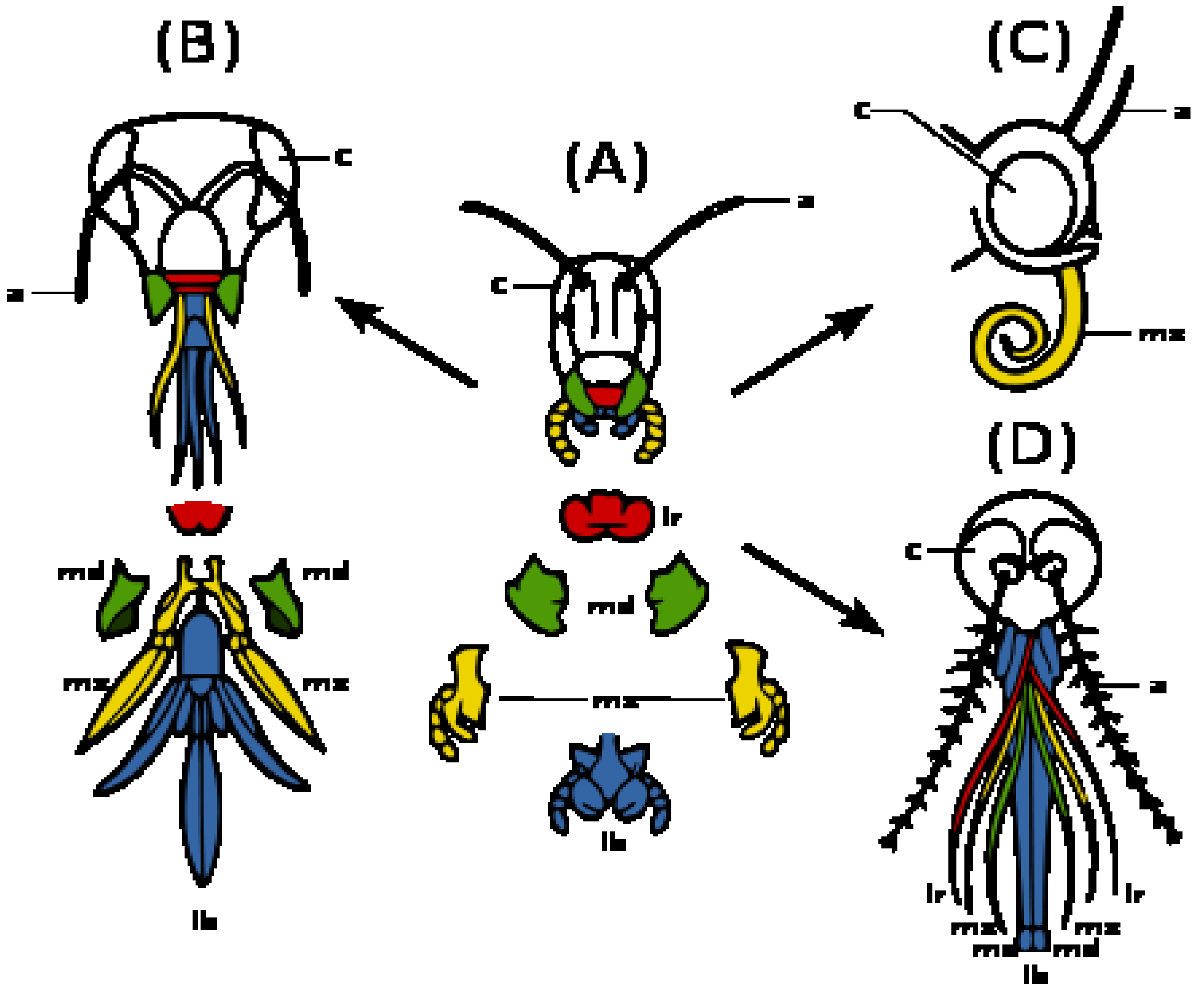
2- None Stylets

Siphoning mouthparts lack stylets and are used to suck liquids.

Examples: Butterflies, moths and skippers (order **Lepidoptera**)

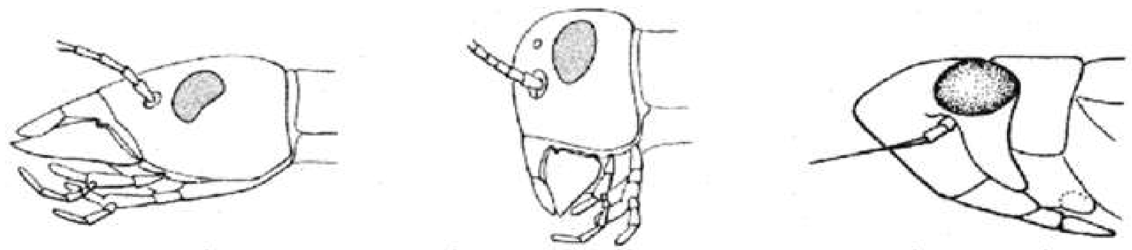


Sponging mouthparts are used to sponge and suck liquid.
Examples: House flies and blow flies (order **Diptera**).



The development of insect mouthparts from the primitive chewing mouthparts of a grasshopper in the center (A), to the chewing-lapping type (B) of a bee, the siphoning type (C) of a butterfly and the piercing-sucking type (D) of a female mosquito.
a – antennae **c -** compound eye **lb** – labium **lr** – labrum **md** – mandibles **mx -** maxillae

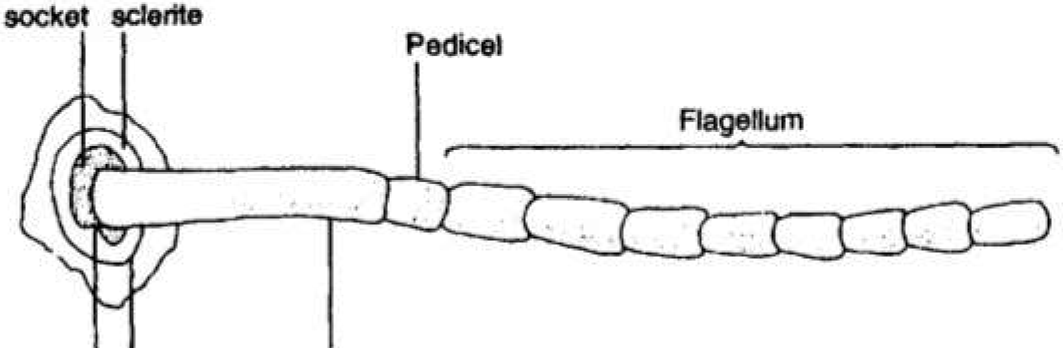
The orientation of the mouthparts on the head may differ, and they may be described as:
Prognathous: projecting forward (horizontal)
Hypognathous: projecting downward
Opisthognathous: projecting obliquely or posteriorly



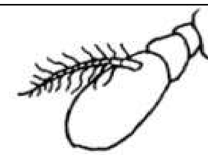
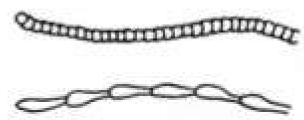
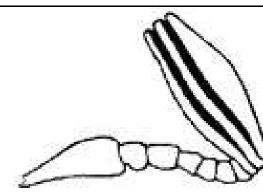
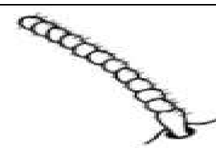
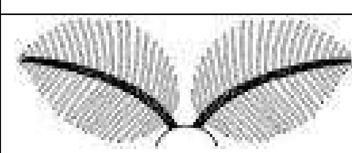
Antennae **Lecture 3**

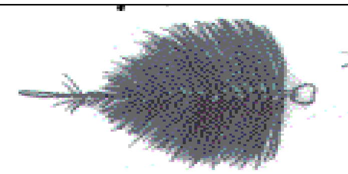
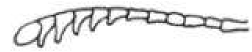
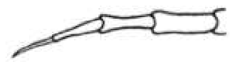
The **antennae** are a pair of sense organs located near the front of an insect's head capsule. The antennae are much more than just tactile receptors. They are usually covered with olfactory receptors that can detect odor molecules in the air (the sense of smell). Many insects also use their antennae as humidity sensors, to detect changes in the concentration of water vapor. Mosquitoes detect sounds with their antennae, and many flies use theirs to measure air speed while they are in flight. Although antennae vary widely in shape and function, all of them can be divided into three basic parts

1. **scape** -- the basal segment that articulates with the head capsule
2. **pedicel** -- the second antennal segment
3. **flagellum** -- all the remaining "segments" (individually called **flagellomeres**)



Types of Antennae:

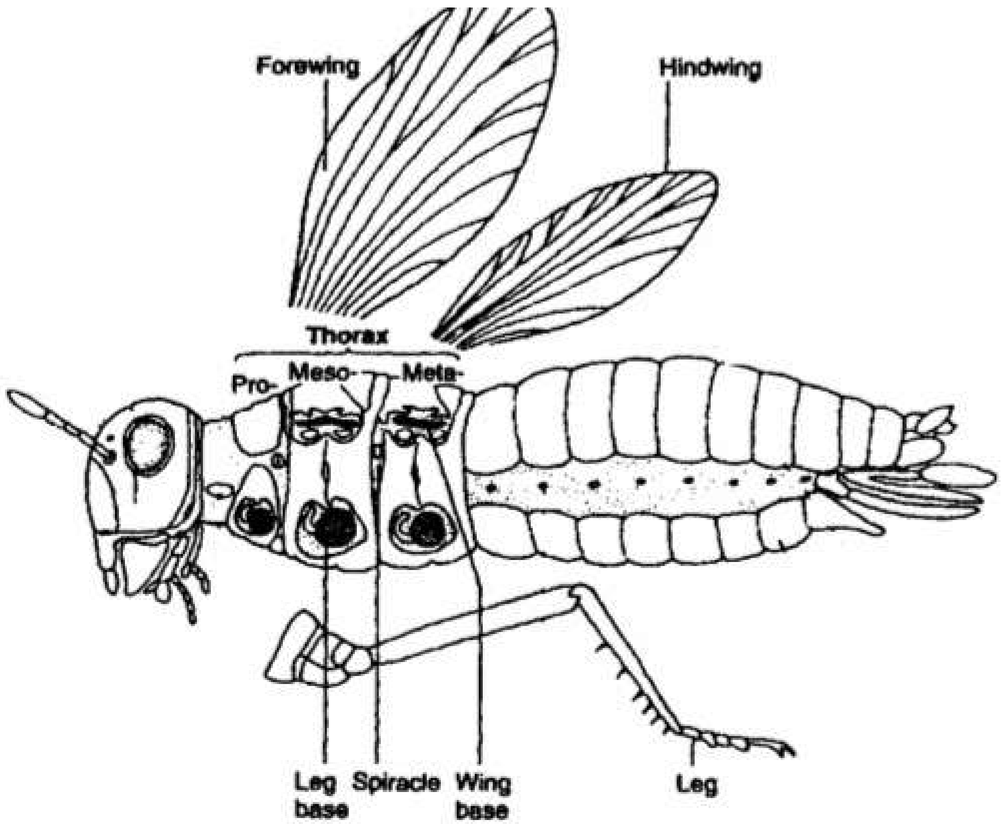
Aristate antennae are pouch-like with a lateral bristle. Examples: House and shore flies (order Diptera).	
Capitate antennae are abruptly clubbed at the end. Examples: Carrion beetles (order Coleoptera). Adult carrion beetles.	
Clavate antennae are gradually clubbed at the end. Examples: Butterflies (order Lepidoptera).	
Filiform antennae have a thread-like shape. Examples: Ground and long-horned beetles (order Coleoptera).	
Geniculate antennae are hinged or bent like an elbow. Examples: Bees and ants (order Hymenoptera).	
Lamellate or clubbed antennae end in nested plates. Examples: Scarab beetles (order Coleoptera).	
Moniliform have a beadlike shape. Examples: Termites (order Isoptera).	
Pectinate antennae have a comb-like shape. Examples: fireflies beetles (order Coleoptera).	
Bipectinated : having two margins toothed like a comb —used especially of the antennae of certain moth (Family Lymantriidae)	

Plumose antennae have a feather-like shape. Examples: mosquitoes (order Diptera).	
Serrate antennae have a saw-toothed shape. Examples: Click beetles(order Coleoptera).	
Setaceous antennae have a bristle-like shape. Examples: Dragonflies and damselflies (order Odonata).	

THORAX

The insect thorax is divided into three parts: the prothorax (pro=first), mesothorax (meso=middle), and metathorax (meta=last). Each segment consists of hardened plates, or sclerites. Dorsal sclerites are called nota (singular notum), lateral sclerites are called pleura (singular pleuron), and ventral sclerites are called sterna (singular sternum). The first segement of the prothorax is the pronotum. the notum (pronotum, mesonotum, and metanotum) which may be further subdivided into an anterior alinotum (which divided to prescutum, scutum and scutellum) and a posterior postnotum. The ventral sclerite of each segment is the sternum (prosternum, mesosternum, and metasternum).The side of each segment is called the pleuron -- it is usually divided by a pleural suture into at least two **sclerites**:; an anterior **episternum** and a posterior **epimeron**.

Each of the three thoracic segments contains one pair of **legs**. **Wings** are found only on the meso- and metathoracic segments.



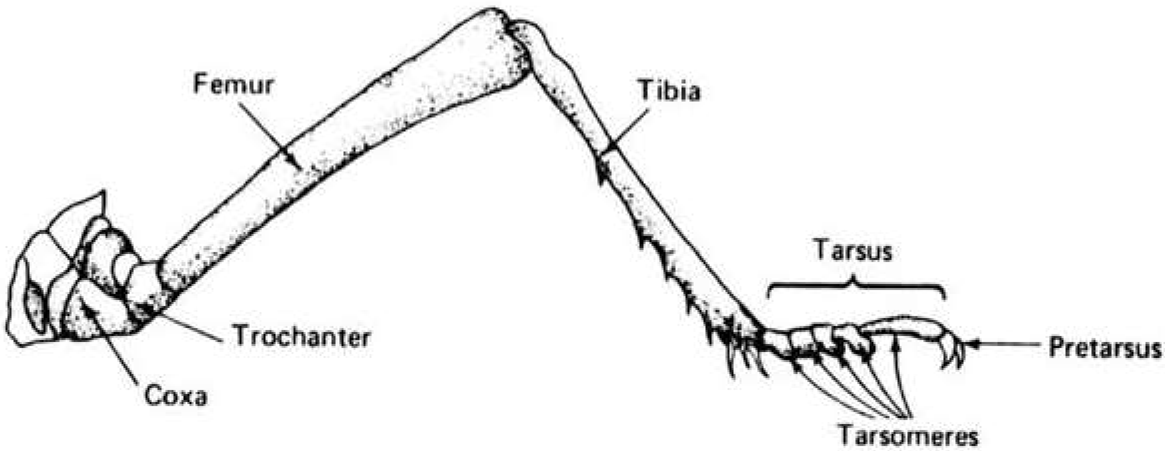
Legs **Lecture 4**

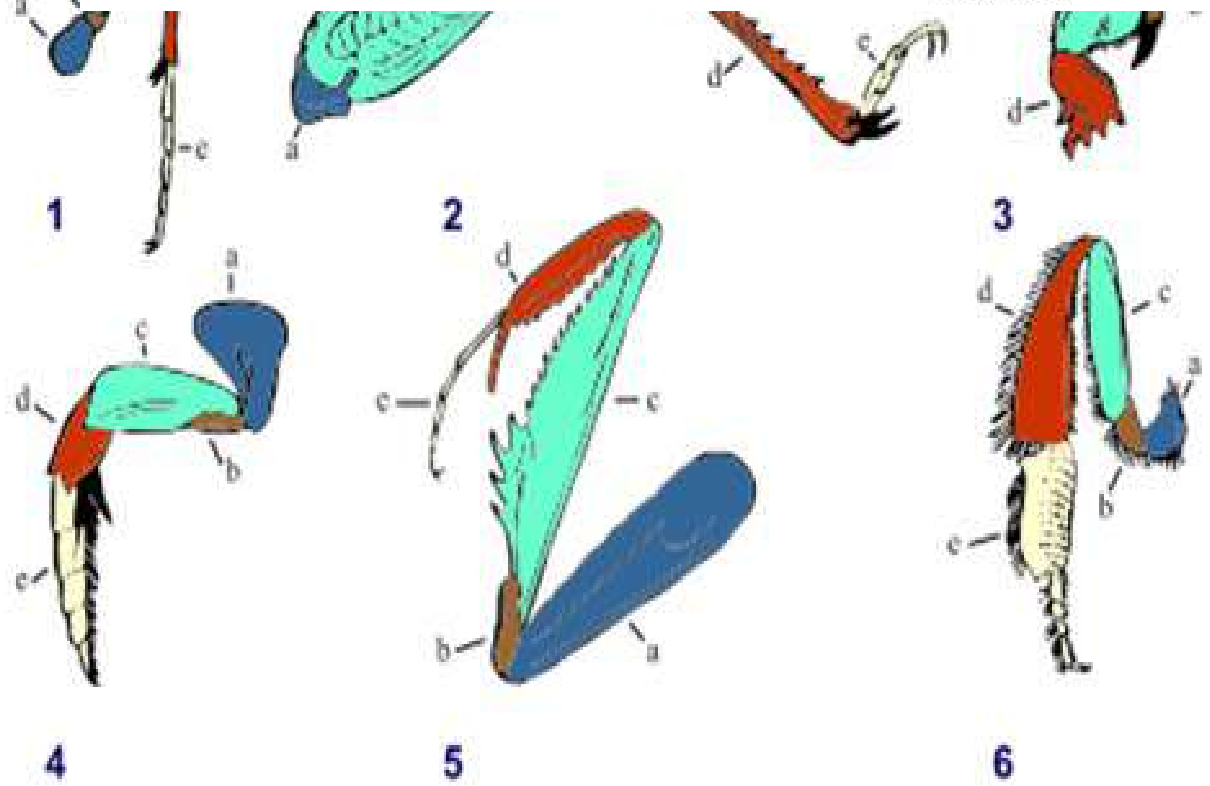
Most insects have three pairs of walking legs -- one pair on each thoracic segment. Each leg contains five structural components (segments) that articulate with one another by means of hinge joints:

1.Coxa 2.Trochanter 3.Femur 4.Tibia 5.Tarsus

The term **pretarsus** refers to the terminal segment of the tarsus and any other structures attached to it, including:

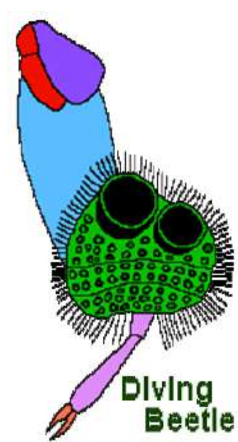
ungues -- a pair of claws
arolium -- a lobe or adhesive pad between the claws
empodium -- a large bristle (or lobe) between the claws
pulvilli -- a pair of adhesive pads





part of leg: a. coxa, b. trochanter, c. femur, d. tibia, e. tarsus

1. **Running** (or walking)(**Cursorial):** legs are modified for running(ground beetle)
2. **Jumping** (**Saltatorial**) : hind legs adapted for jumping (locust)
3. **Digging** (**Fossorial**): fore legs are modified for digging (mole cricket)
4. **Swimming** (**Natorial**): legs are modified for swimming (diving beetle) (Family Dytiscidae)



5. **Grasping** (**Raptorial**): fore legs modified for grasping. Catching prey (Mantidae))
6. **Collecting**: Leg (hind legs of worker honeybee).
7. **Cleaning:** first leg of worker honeybee).
8. **Clinging** (**Scansorial**) legs are claw-like and modified for climbing (**Lice**)
9. **Mating** legs Fore leg of the male great diving beetle (Family **Dytiscidae**)

Wings

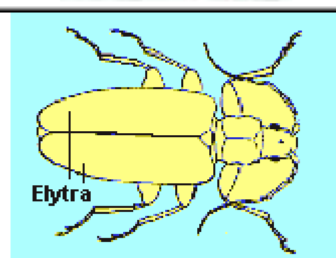
Insects are the only invertebrates that can fly. Their wings develop as evaginations of the exoskeleton during morphogenesis but they become fully functional only during the adult stage of an insect's life cycle. The wings may be membranous, leathery, heavily sclerotized, fringed with long hairs, or covered with scales. Most insects have two pairs of wings -- one pair on the mesothorax and one pair on the metathorax (never on the prothorax). Wings serve not only as

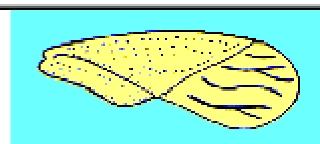
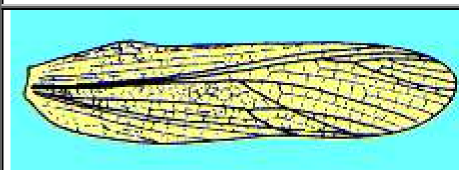
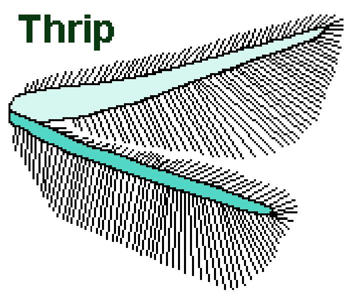
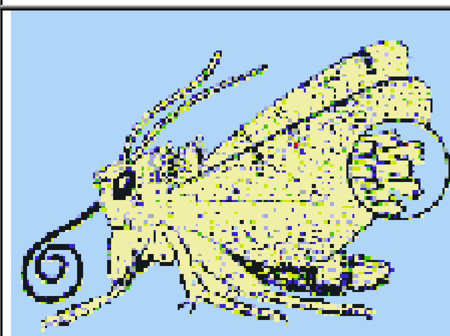
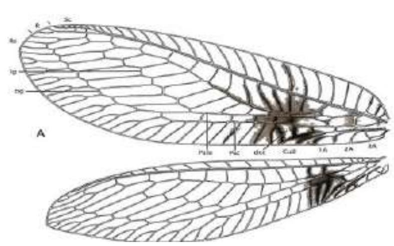
1- organs of flight, but also may be adapted variously as:

2- protective covers (Coleoptera and Dermaptera),
3- thermal collectors (Lepidoptera),
4- gyroscopic stabilizers (Diptera),
5- sound producers (Orthoptera),

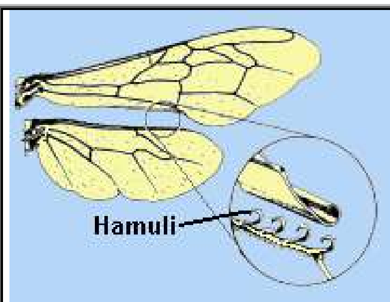
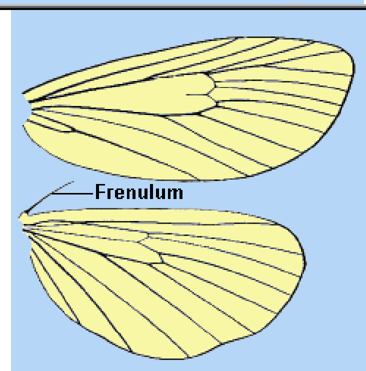
In most cases, a characteristic network of veins runs throughout the wing tissue. These veins are extensions of the body's circulatory system. They are filled with hemolymph and contain a tracheal tube and a nerve. In membranous wings, the veins provide strength and support during flight. Wing shape, texture, and venation are quite distinctive among the insect taxa and therefore highly useful as aides for identification.

Wing adaptations and modifications:

Characteristic	Appearance	Order(s)
membranous: are characterized by having thin, unscleritized (meaning not leathery or hard) membranes between the veins of the wings		**House flies; Mosquitoes (Order: Diptera**
Elytra -- hard, sclerotized front wings that serve as protective covers for membranous hind wings		**Coleoptera**

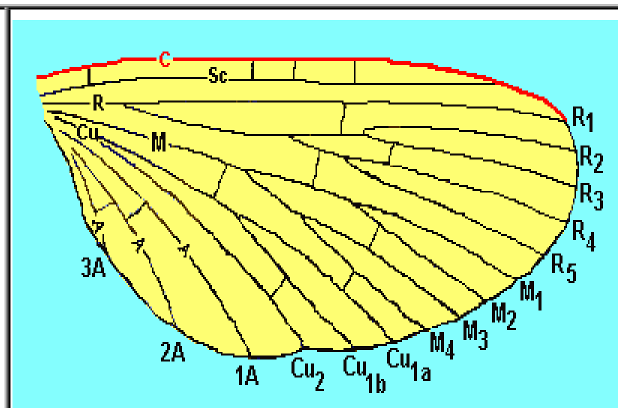
Hemelytra -- front wings that are leathery or parchment-like at the base and membranous near the tip		**Hemiptera**
Tegmina -- front wings that are completely leathery in texture		**Orthoptera, Blattodea,** and **Mantodea**
Halteres -- small, club-like hind wings that serve as gyroscopic stabilizers during flight		**Diptera**
Hairy wings -- slender front and hind wings with long fringes of hair		**Thysanoptera**
Scaly wings -- front and hind wings covered with flattened setae (scales)		**Lepidoptera**
Lance-wings: characterized by a wide coastal field in their wing venation, which includes the cross-veins.		**Neuroptera F. Chrysopidae**

Coupling mechanism in insects wings

Hamuli -- tiny hooks on hind wing that hold front and hind wings together		**Hymenoptera**
Frenulum -- Bristle near base of hind wing that holds front and hind wings together		**Lepidoptera**

Wing Venation:

The **archedictyon** is the name given to a hypothetical scheme of wing venation proposed for the very first winged insect. These veins (and their branches) are named according to a system devised by John Comstock and George Needham -- the Comstock-Needham System:

Costa (C) -- the leading edge of the wing Subcosta (Sc) -- second longitudinal vein (behind the costa), typically unbranched Radius (R) -- third longitudinal vein, one to five branches reach the wing margin Media (M) -- fourth longitudinal vein, one to four branches reach the wing margin Cubitus (Cu) -- fifth longitudinal vein, one to three branches reach the wing margin Anal veins (A1, A2, A3) -- unbranched veins behind the cubitus	

Names of cross veins are based on their position relative to longitudinal veins:
c-sc cross veins run between the costa and subcosta
r cross veins run between adjacent branches of the radius
r-m cross veins run between the radius and media
m-cu cross veins run between the media and cubitus

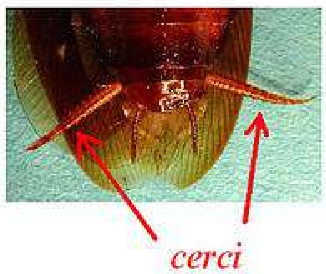
Insect Abdomen:

Insect abdomen is the third functional region of insect body. It is located behind the thorax and contains 6-10 segments. There are various types of appendages arise from the abdomen. The abdomen subdivided into:

- **pregenital segments**: which include the first seven segments in female or first eight segments in male and be free from appendages in the adult phase
- **Genital segments**: Include the ninth segment in male and carrying genital appendages. In females, paired appendages of the eighth and ninth abdominal segment fit together to form an egg-laying mechanism called the ovipositor
- **Postgenital segments**: Include the tenth and eleventh segment. carrying the two appendages anal cerci.

Appendages found on the abdomen.

1- Cerci

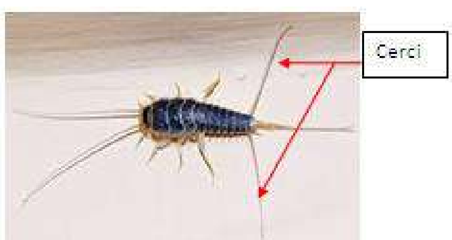


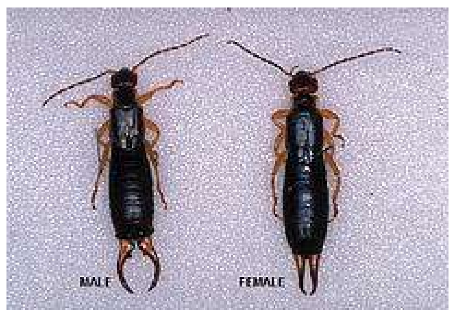
Located close to anus.

Order: Orthoptera: simple and not jointed cerci

Order: Dermaptera: Sclerotized, forceps like cerci (**Pincers).**

Order: Thysanura: Long filamentous cerci



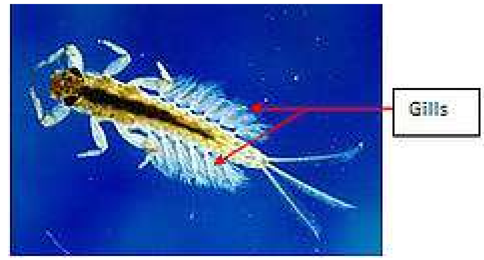


2- Styles:
Can be seen in Cockroach, It is regarded as the vestige of the walking limb.

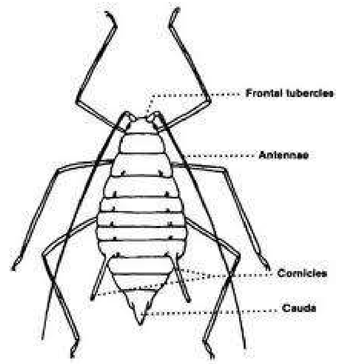
3- Median caudal filament:
This is a thread like projection arising from center of the last abdominal segment between the cerci.

4- Abdominal Prolegs:

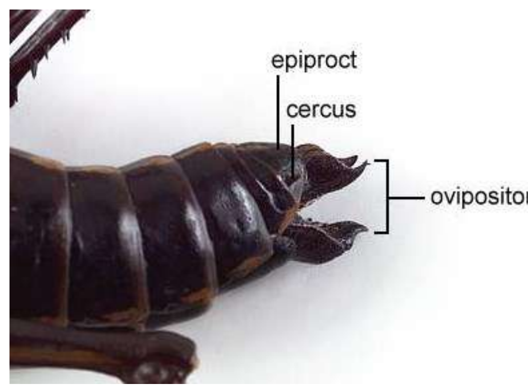
Can be seen in Lepidopera.



5- Abdominal Gills:
These are respiratory organs and found in naiad of some aquatic insects.



6- Cornicles:
These are located dorsally on the abdomen as paired secretory structures.



7- Female External Genitalia:

Ovipositors are used for oviposition and it is formed by the modification of 8-9 abdominal segments. E.x. Orders: Orthoptera, Thysanoptera and some Hymenoptera insects contain true ovipositors.

The ovipositor is modified sometime as a poison injecting sting (Wasps, bees..etc)

8- Male External genitalia:

Modification of 9th abdominal segment makes the copulatory organ of males which is consist of aedeagus and pair of lateral claspers to grasp and hold the abdomen of the female during mating.

Insect Classification: Lecture 6

The Class *Insecta* is generally studied under a classification system with approximately 30 orders. Insects can be divided into two groups historically treated as subclasses: wingless insects, known as Apterygota, and winged insects, known as Pterygota

- **Class: Insects**
  - **Subclass: Apterygota**
    - **O : Thysanura**
    - **O: Collembola**
  - **Subclass:Pterygota**
    - **Infraclass: Paleoptera**
      - **O: Ephemeroptera**
      - **O: Odonata**
    - **Infraclass: Neoptera**
      - **Division: Exopterygota**
        - **O: Orthoptera**
        - **O: Dictyoptera**
        - **O: Dermaptera**
        - **O: Embioptera**
        - **O: Isoptera**
        - **O: Homoptera**
        - **O: Hemiptera**
        - **O: Mallophagaga**
        - **O: Anoplura**
        - **O: Thysanoptera**
      - **Division: Endopterygota**
        - **O: Neuroptera**
        - **O: Lepidoptera**
        - **O: Coleoptera**
        - **O: Siphonaptera**
        - **O:Diptera**
        - **O: Hymenoptera**

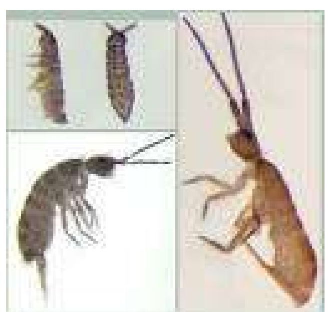
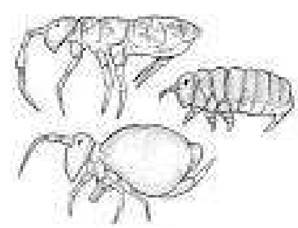
Subclass Apterygota:

Traditionally, the groups included in the term "apterygota," namely, the Collembola, Protura, Diplura, and Thysanura, were considered orders of primitively wingless insects and placed in the subclass Apterygota (Ametabolic insect). They show the following common features:

1- Wingless (apterous)
2-no metamorphosis
3- Immature individuals are called youngs
4- Adults with one or more pregenital appendages
5- Mandibles usually articulate with head capsule at a single point.
Orders: Collembola, Thysanura, Diplura, Protura.

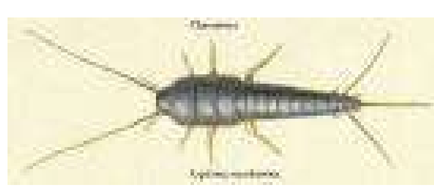
Order Collembola:

1. Mouth parts for biting and chewing.
2. delicate insects with six or fewer abdominal segments. Under side of abdomen has a sucker, and a pair or more or less fused appendages, for jumping (furculum).

Order Thysanura:

1. Very delicate insects
2. chewing mouthparts
3. Long jointed thread-like tails called (caudal filaments).
4. Has 11 abdominal segments
5. (Silverfish, bristle tails).




Subclass: Pterygota: Characterized as following:

1. Winged insects or some have lost the wings as a secondary modification.
2. Metamorphosis of various types and rarely absent.
3. Adults without pregenital abdominal appendages
4. Mandibles if not highly modified , articulate with the head capsule at two points.

Subclass Pterygota can be divided into two groups Infraclass Paleoptera and Infraclass Neoptera

pterygota (winged insects) have been divided on the basis of the ability to flex the wings horizontally over the body when at rest. In to the **Paleoptera** which are the orders Ephemeroptera and Odonata whose members do not possess a wing-folding mechanism.
The second group is **Neoptera** whose members are able to fold their wings over the body

Infraclass: Paleoptera

the **Paleoptera**: “old-winged” insects. These were unable to fold their wings back against their abdomens because they lacked certain specializations of the wing-thorax articulation area. Only two orders of Paleoptera persist today.
Order **Ephemeroptera** includes the mayflies, characterized by aquatic nymphal (immature) stages and very short-lived adults; including possession of a median caudal filament.
Order **Odonata** includes damselflies and dragonflies, which are highly efficient predatory insects with aquatic nymphal stages like the mayflies.

Order Ephemeroptera: (Mayflies)

1. Small to medium sized.
2. Elongate, very soft bodied insects with two or three long thread tails.
3. They are common about pounds or streams.
4. The front wings are large and triangular, and the hind wings are small and rounded, in some species the hind wings are vestigial or absent.

Order Odonata: (Dragonflies & Damselflies)

1. Antennae short and inconspicuous.
2. Long slender insects with long and narrow wings. Compound eyes are large and many-faced, the thorax is relatively small and compact.
3. The immature stages are aquatic, and adults are usually found near water.

Dragonflies

Damselflies

Infraclass: Neoptera:

I) Division: Exopterygota

This division characterized as following:

- Wings develop externally.
- Metamorphosis simple or slight. (Heterometabola)
- Immature stages generally nymphs which resemble adults in structures and habits.

The Exopterygota could be arranged into two groups:

Orthopteroid Orders:

Order: Plecoptera
Order: Grylloblattodea
Order: Orthoptera
Order: Phasmatodea
Order: Dermaptera
Order: Embioptera.
Order: Dictyoptera
Order: Isoptera
Order: Zoraptera

Hemipteroid Orders:

Order: Psocoptera
Order: Mallophaga
Order: Anopleura
Order: Hemiptera
Order: Homoptera
Order:Thysanoptera

Hemipteroid Orders characterized as following:	**Orthopteroid Orders characterized as following:**
▶ usually suctorial, mouthparts ▶ wing venation reduced. ▶ small anal lobe in hind wing ▶ Anal cerci Absent. ▶ few Malpighian tubules. ▶ generalized nervous system with few discrete abdominal ganglia.	▶ generalized biting mouthparts ▶ wing venation usually well developed with numerous cross veins. ▶ Large anal lobe in hind wing ▶ Anal cerci present. ▶ many Malpighian tubules. ▶ generalized nervous system with several discrete abdominal ganglia.

Orthopteroid Orders : **Lecture 7**

Order: Orthoptera: (grasshoppers, crickets and Mole crickets)

1. The body is elongate.
2. Two pairs of wings unlike in structure, the first pair long and leathery while the second pair is membranous.
3. Hind legs modified for jumping
4. Biting or chewing mouth parts.

Family: Gryllidae (Field crickets)

Family : Gryllotalpidae (mole crickets)

Family: Acrididae (Locustidae) (Locusts grasshopper)

Order: Dictyoptera: (cockroaches and mantids)

Suborder: Blattodea

- The body is flattened oval.
- The head is under the pronotum.
- All legs for walking or running

Suborder: Mantodea

- ✓ Body elongate, prothorax long and slim
- ✓ Head free,
- ✓ Front legs fitted for catching insects prey (Grasping legs)

Order Phasmida: (Walking sticks) elongate bodies. wingless however, some tropical forms are winged and are called leaf insects. They have extremely elongate and stick-like bodies with long legs and long antennae. These insects have chewing mouthparts.

Order Isoptera: (Termites)

- Many of them wingless, In the insects with wings the two pairs of wings are equal in size and with indistinct veins
- prothorax smaller than head.

Order Dermaptera : (Earwig)

- With two pairs of wings, the first pair is leathery and short while the second is membranous folded under the forewing.
- With prominent pair of pincer-like of cerci at tip of abdomen.

Order: Embioptera

- The legs are short and stout, and the hind femora are thickened, the tarsi are 3-segmented, with basal segment of frontal tarsi enlarged and containing silk gland and hollow spinning hairs.
- The male of most species are winged with two pairs of wing similar in size and venation, while the female wingless


Hemipteroid Orders

Order Hemiptera: (True Bugs**) (Cicadas, Hoppers, Aphids, Whiteflies, and Scales insects)**

- Wingless or with one or two pairs of wings.
- The wings at rest are usually held roof-like over the body, with the inner margins overlapping slightly at the apex. Mouth parts for sucking and opithisognathous in position.


Family: Pentatomidae (Stink bugs)

Family: Cimicidae (Bed bugs)

Family: Belostomatidae (Gaint water bugs)

Family: Corixidae (Water boatman)


Order: Homoptera (Cicadas, Hoppers, Aphids, Whiteflies, and Scales insects**)**

- Wingless or with one or two pairs of wings.

- The wings at rest are usually held roof-like over the body, with the inner margins overlapping slightly at the apex.
- Mouth parts for sucking and opithisognathous in position.

1) **Family: Cicadidae (**The Cicadas**)**

2) **Family: Aphididae (**Plants lice**)**

Order Mallophaga (chewing lice**)**

- Wingless, small, flat bodies insects with head as wide as body or nearly so. Chewing mouth parts.
- Antennae short, found mostly on birds, a few on mammals

Order Anoplura (sucking lice**)**

- Wingless, small, broad and flat insect fleshy leg, each with single claw for grasping hairs.
- Sucking mouth parts, founds on mammals

II) Division: Endopterygota

This division characterized as following:

- Wings develop internally.
- Metamorphosis complete. (Holometabola)
- Immature stages are larvae which are completely different from adults in both structures and habits.
- Life cycle associated with a pupal instar.

Order: Neuroptera (Lacewings)

- The fore and hind wings are similar in shape and venation and are hold roof-like over the abdomen when at rest.
- The mouthparts are chewing type.
- Antennae are generally long and segmented.
- The tarsi are 5-segmented.
- Anal cerci are absent

Order Lepidoptera (Butterflies, Moths & Skippers)

- Insects with two pairs of scaly wings.
- Siphoning mouth parts.

Butterfly

Moth

Order: Coleoptera (Beetles & Weevils **)**

- usually have two pairs of wings. The front pair of wings, called elytra, are thick and form a hard shell over the abdomen of the most beetles. Elytra meet in a straight line down the middle of the back
- Mouthparts are formed for chewing in adult beetles and immature.

Family: Carabidae (Ground beetles**)**
Family: Dytiscidae (Diving beetles**)**
Family: Scarabaeidae (Dung beetles**)**
Family: Curculiondae (Weevils**)**




Order: Siphonaptera (Fleas)

- Insects without wings, small narrow flattened on the sides.
- Sucking mouth parts.
- Hind legs for jumping.

Order Diptera (Flies)

- Insects with one pair of membranous wings, while the second pair was modified to halters.
- Mouth parts for sucking, or sponging, or lapping and well developed.

Family: Muscidae (house flies)
Family: Tipulidae (Crane flies).
Family: Tabanidae (Horse flies)
Family: Calliphoridae (Metallic fly or Blow fly)

Order: Hymenoptera (Bees, Ants, & Wasps)

- Front wings larger than hind wings with hamulate type.
- Narrow wasted ant-like insects, Chewing or lapping mouth parts

Family: Apidae (Honey bees)
Family: Formicidae (Ants)
Family: **Vespidae** (pollen wasps, paper wasps, ….etc.)

Integument (the body wall)

Lecture 8

It's the surface layer of ectoderm that surrounded the body. It's containing many kinds of external hairs and many types of internal process that attachment with muscles.

Structure of integument

The integument of insects and other arthropods are consist of

1- Cuticle.

Its non- cellular layers, covering the outside of epidermis and secreted by its. The cuticle is made up of very thin outside layer called, **epicuticle,** and thick inner layer called **procuticle.**

The epicuticle is usually only 1-4 µ thick but seems to be the layer which gives the entire cuticle, its property of impermeability. The epicuticle may be composed of several layers, the inner layer is composed chiefly of **cuticulin,** and the outer layers usually contain **waxes** which are responsible for reducing water-loss through the cuticle, as well as **cement layer.**

The procuticle is consisting of outer layer, **exocuticle** and inner layer **endocuticle**.

The **exocuticle** is a much thicker layer consisting mainly of **chitin** and **protein**, the latter being tanned by phenolic substance to produce a hard, brown material called **sclerotin** which gives the cuticle its rigidity. The exocuticle is absent or reduced in the more flexible regions of the integument and may be entirely absent from insects with a soft, thin cuticle.

The **endocuticle** also contain chitin and protein but the latter are not tanned and this part of the cuticle is therefore soft and flexible.

Both endocuticle and exocuticle consist of a fairly elastic, traversed by extremely fine opening or **pore canal**, the pore canals run from the epidermal cells into epicuticle but not completely through it. Their function is dubious, in very thick, hard cuticle as on the elytra of beetles. The cuticle may be laid down as successive series of minute parallel rodes, which give the structure additional strength.

2- Epidermis.

The most of epidermal cells are simple in type, with large nuclei, rounded with the basement membrane, epidermal cells may form specialized glands that produce components of the cuticle or may develop into particular parts of sense organs.

The function of epidermal cells is:

1- Secretion of fluid to formation of definite structure such as hairs.
2- Some of cells develop to large cells which produce various secretions, these cells are connected to the exterior by a duct running through the cuticle, Secretion of deferent types are produced by a variety of these dermal glands, including wax, many type of ill-smelling scent compounds known as pheromones.
3- Some of dermal glands (formerly though to produce molting fluid) are believed to secrete the outer waxy covering of the epicuticle.

3- Basement membrane

The epidermal cells stand on a basement membrane which is forms a continuous sheet and pointed with muscles.

Integument processes

The surface of the cuticle bears two types of outgrowths.

1- Rigid non articulated processes : these include the

a- Microtrichia , are minute, non- cellular, hair –like structures, formed entirely of cuticle and often accruing in very large numbers on the wings of certain insects.

b- Spines, are large, hollow, sclerotized, thorn- like processes of multicellular origin, they are well seen on the legs of some insects.

2- Movable articulated processes attached to the cuticle by a ring of articular membrane which may be sunk into a cuticular soket or alveolus or elevated on a tubercle; they include;

a- Macrotrichia, and setae , they are hollow extentions of the exocuticle and epicuticle . Each is secreted by the cytoplasmic outgrowth of a single modified epidermal cell. The trichogen cell, while the socket from which the seta protrudes is produced by another specializaed epidermal cell, the tromogen cell. The following specially modified setae are known;

1- **Clothing hairs,** which cover the general surface of the body and appendages, they may be branched or plumose, as in bees , or when specially stiff , they form the bristle as in Tachinid fly.

2- **Scales,** such as occur in Lepidoptera and some collembolan, diptera and coleopteran, essentially these are flattened setae, with a striate surface and sometimes containing pigment.

3**- Glandular setae**, which is serve as outlets for the secretion of epidermal glands, they include the silk- spinning hairs of embioptera and urticating hairs of some caterpillars, eg . Those of the gold – tail moth.

4- **Sensory setae,** which are more or less specialized in structure and have one or more nerve cells at their base.

4- **Spur,** differ from setae in being a thick- walled multicellular structure, they often large and occur more especially on tibia of the legs.

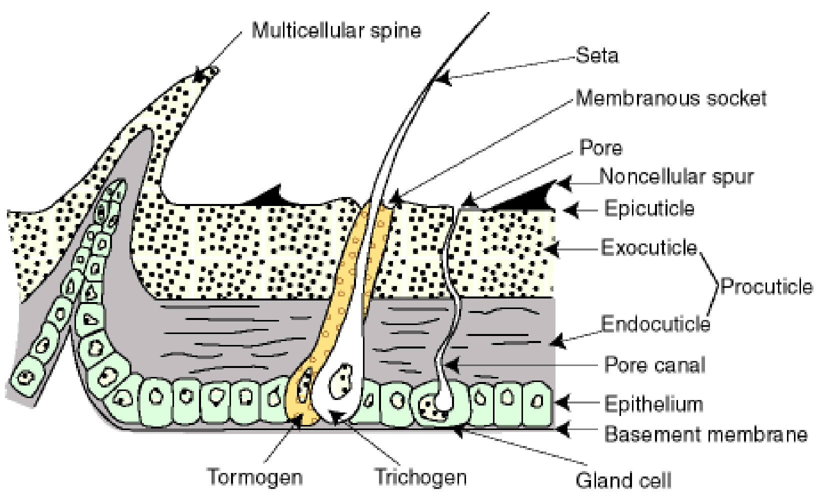


Fig.2 The insect integument

Apodemes

Ridge-like ingrowth of the exoskeleton of an insects that supports internal organs and provides attachment points for muscles. The endoskeleton of the head is known **tentorium** , its consist of paired anterior and posterior arms , the inner ends of the arms unit to form body of the tentorium.

The tentorium gives rigidity to the head capsule , proveds attachment for muscles and supports the brain esophagus. The endoskeleton of thorax usually consist of dorsal phragmata, plural apodemes and ventral apophysis . the apdomenal segments and external genitalia may also bear apodemes.

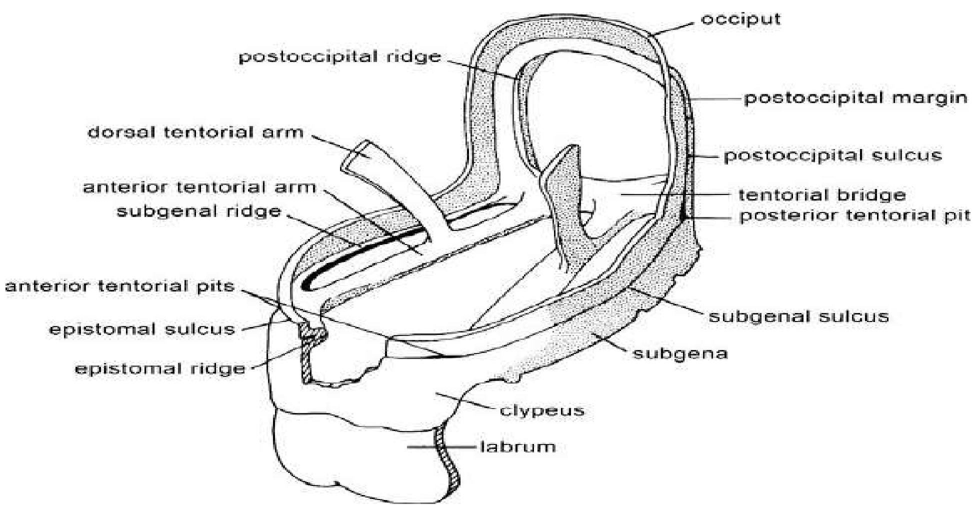


Fig.1 The tentorial in head of insects

The body wall has many functions;

1- It proved physical protection for internal organs.
2- It also reduces water loss to very low level in most insects.
3- Of its rigidity, it serves as a skeleton to which muscles can be attaced.
4- In addition to these primary function, the cuticular component of the integument performs a number of secondary duties. It acts as a metabolic reserve, to be used cyclically to construct the next stage,
5- Its prevents entry of foreign material, both living and non-living into an insect.
6- In many insects the waxy outer layer serves as respository for contact sex pheromones
7- The color of insects is also a function of the integument, especially the cuticular component.

Internal anatomy Lecture 9

The internal anatomy of insects enclosed the organs and systems connected with (digestive, circulatory, reproductive, respiratory nervous) system. These organs are protected by the body wall.

Digestive system:

The insect digestive system is a closed system, with one long enclosed tube (alimentary canal) running lengthwise through the body. The alimentary canal is a one way street-food enters the mouth and gets processed as it travels toward the anus.

An insect uses its digestive system to extract nutrients and other substances from the food it consumes. Most of this food is ingested in the form of macromolecules and other complex substances like proteins, polysaccharides, fats and nucleic acids. These macromolecules must be broken down by catabolic reactions into smaller molecules like amino acids and simple sugars before being used by cells of the body for energy, growth, or reproduction. This break-down process is known as **digestion**.

Alimentary canal

Is a long enclosed tube, which runs lengthwise through the central part of the body. The alimentary canal direct food unidirectionally from the mouth to the anus. It has three sections.

1-foregut: Stomatodeum

The first section of the alimentary canal is the foregut or stomatodeum. In the foregut, initial breakdown of large food particles occurs, mostly by saliva.

The function of this region is: stores, grinds and transports food to the next region. foregut Included : the buccal cavity, the pharynx, the oesophagus, the crop (stores food), and proventriculus or gizzard (grinds food).

2-midgut (Mesenteron)

The midgut is where digestion really happens, through enzymatic action. Microscopic projections from the midgut wall, called microvilli, increase surface area and allow for maximum absorption of nutrients.

Mesenteron (midgut): Digestive enzymes in this region are produced and secreted into the lumen and here nutrients are absorbed into the insect's body. Food is enveloped by this part of the gut as it arrives from the foregut by the peritrophic membrane which is a mucopolysaccharide layer secreted from the midgut's epithelial cells. It is thought that this membrane prevents food pathogens from contacting the epithelium and attacking the insect's body. It also acts as a filter allowing small molecules through, but preventing large molecules and particles of food from reaching the midgut cells. After the large substances are broken down into smaller once, digestion and consequent nutrient absorption takes place at the surface the epithelium. Microscopic projections from the mid-gut wall, called microvilli, increase surface area and allow for maximum absorption of nutrients.

3-Hindgut: Proctodeum

This is divided into three sections: the anterior is the ileum, the middle portion, the colon, and the wider, posterior section is the rectum. This extends from the pyloric valve which is located between the mid and the hindgut to the anus.

The stomatedeum and proctodeum are invaginations of the epidermis and are lined with cuticle (intima). The mesenteron is not lined with cuticle but with rapidly dividing and therefore constantly replaced, epithelial cells. The cuticle sheds with every moult along with the exoskeleton. Food is moved down the gut by muscular contractions called peristalsis.

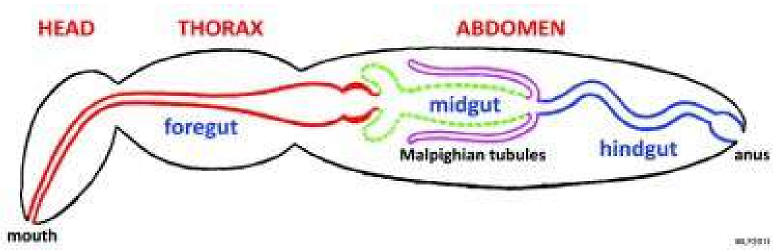


FIGURE 1. Alimentary canal and associated structures of a locust. [After C. Hodge, 1939, The anatomy and histology of the alimentary tract of *Locusta migratoria* L.

Histology of foregut:

The foregut is ectodermal in origin. It is lined with:

1- A layer of cuticle, known as, **intima,** which is shed at each moult like the cuticle of the body wall.

2-**basement membrane**: is a thin noncellular membrane, supporting the epithelial layer (bounding the outer surface of epitheliam).

3-**epithelial layer**; consists of flattened cells, outside the epithelium is a layer longitudinal muscle and layer of circular muscle, the latter often being relatively well developed.

4-**peritoneal membrane;** is consist of connective tissue, it is difficult to detect.

Preoral cavity:

Is the space between the mouth parts and the labrum, in insects with mandibulate mouthparts this space is divided by the hypopharynx into an anterior or dorsal cibarium and a posterior or ventral salivarium. The cibarium, whose wall are connected to the post-clypeus by the cibarial dilator muscles, may form only a small pouch for the temporary storage of food or be modified into a sucking-pump as in the thysanoptera, hemiptera and others.

The salivarium receives the common duct of the labial glands. These normally secrete saliva, and in the hemiptera the salivarium is modified into a salivary syringe and the silk-regulator in lepedopterous larvae.

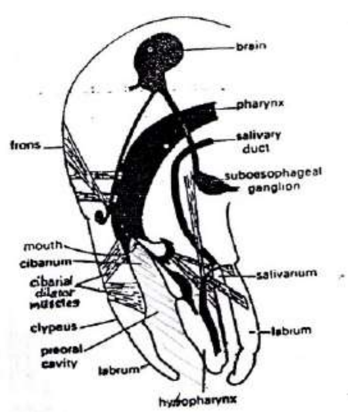


FIGURE 2 sectional diagrams of the chewing insects head showing generalized area and preoral cavity.

Foregut is consists of the following region:

1-Pharynx:

Is the first part of foregut following on from the buccal cavity. The pharynx has a series of dilator muscles into it. These muscles play a part in passing food back from the mouth to the esophagus.

2-Esophagus:

The esophagus is undifferentiated part of the foregut serving to pass food back from the pharynx to the crop. Provided with dilator muscles which are best developed than in the pharynx. It's very variable in length and the inner walls are longitudinally folded.

3-Crop:

It's an enlargement of the foregut in which food is stored. Usually it represented the posterior part of esophagus, but in some fluid feeders it is lateral diverticulum. Sometimes when empty the crop is folded longitudinally and transversely, but in *periplaneta* (Dictyoptera) when it does not contain food it is filled with air.

In general, secretion and absorption do not occur in the crop, because it's limited by the impermeable intima. Digestion can occur as a result of salivary enzymes passing back to the crop with the food and midgut enzyme, although the proventriculus acts as valve limiting the backward movement of food, it does not prevent the regurgitation of fluids.

4-Gizzard or Proventriculus:

The gizzard is variously modified in different insects. In fluid feeders it's absent except for a simple valve at the origin of the midgut. A valve is also present in many other insects and often the circular muscles from sphincter at the entrance to the midgut.

In the cockroach and cricket the intima in the gizzard is developed in to six strong plates or teeth. Which serve to break up the food. The gizzard her serves the additional function of crushing the larger food particles by its powerful radial teeth and circular muscles.

At the point of junction of the foregut and midgut, in many insects present a **stomodeal or esophageal valve**. This structure is formed by the wall of the foregut being prolonged into the cavity of the stomach as an inner tube, which becomes reflected upon itself and passes forwards to unite with the stomach wall. It exhibit varying degree of complexity among different insects and probably prevents or reduces regurgitation of food from the midgut.

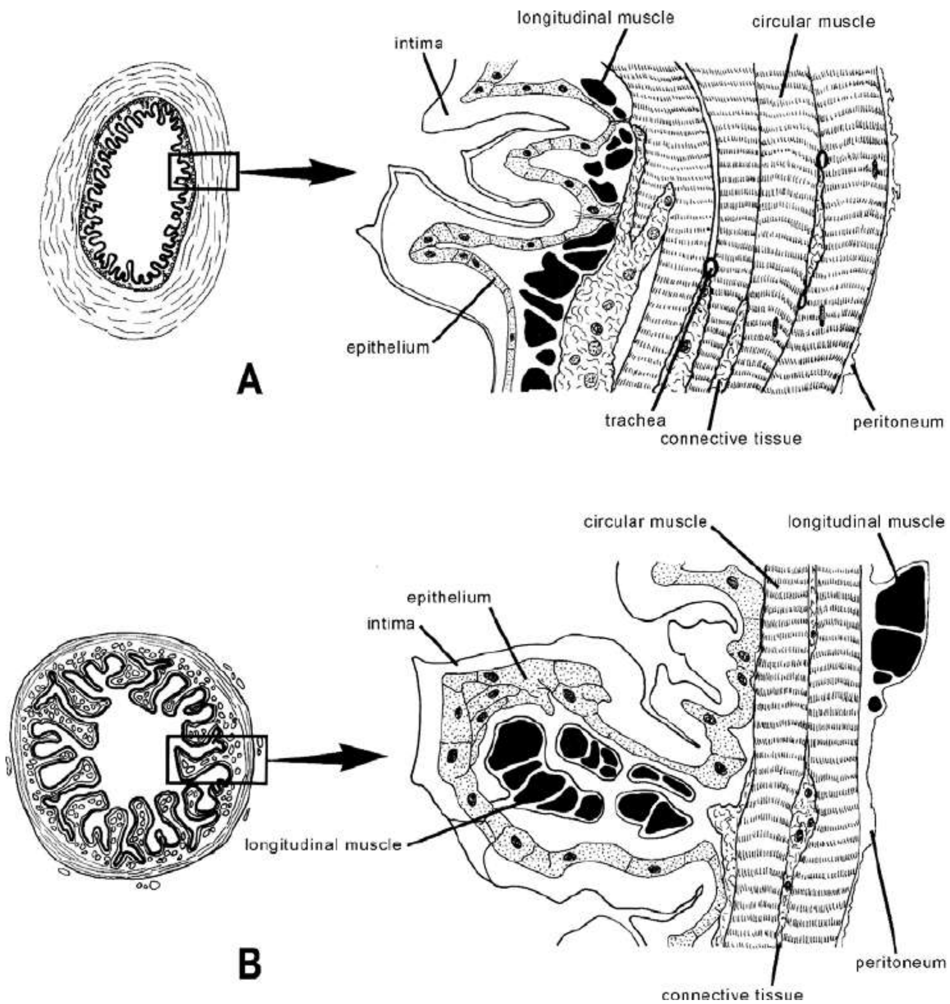


FIGURE 3 Transverse sections through (A) crop and (B) proventriculus(Gizzard) of a locust. [After C. Hodge, 1939,

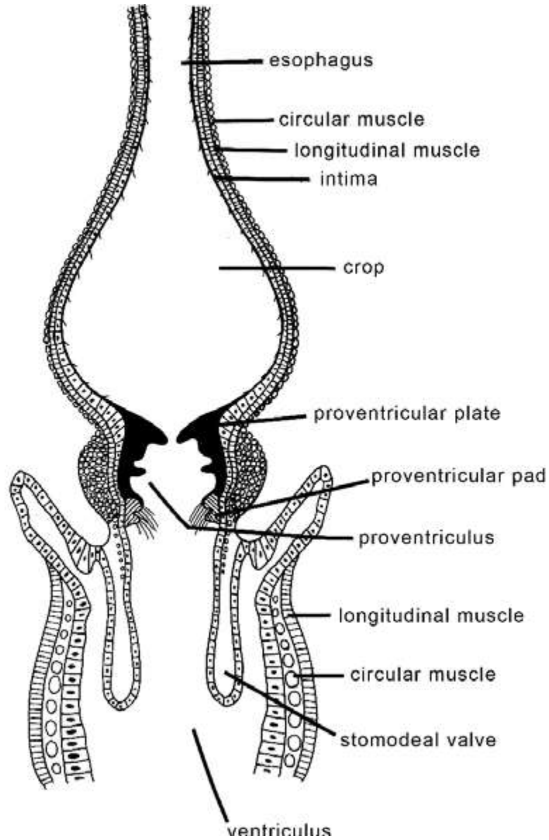


FIGURE 4 Longitudinal section through crop, proventriculus, and anterior midgut of a cockroach.

Midgut:

The midgut dose not have cuticular lining but, in the majority of a insects, it is lined by delicate peritrophic membrane. The most characteristic cells of the midgut are:

1-epithelium are tall columnar with microvilli forming a striated border bounding the lumen. typically, the basal membrane is very deeply infolded and large numbers of mitochondria are associated with the folds.

The structure of the enteric epithelium requires more detailed mention. Three main types of cells may be distinguished:

A-columnar (cylinder) cells.

B-regenerative cells.

C-calyciform (goblet) cells.

The first (**columnar cells**) are those which are with times actively involved in the secretion of enzymes and the absorption of the products of digestion. Their boundaries are generally well defined. They almost invariably possess a striated border.

The **regenerative cells**, which are absent in a few groups of adult insects, may be scattered singly beneath the cylinder cells, or grouped in to clusters (nidi) there or variously arranged in crypt-like out pocketing of the midgut, their function is to renew the other epithelial cells when these are destroyed through secretion or in the larg-scale processes of degeneration which accompany molting or pupation in certain species.

The **goblet cells**, of uncertain function, are not found in all insects, being best developed in the larval lepidoptera and trichoptera.

2-Basement membrane.

3-Muscle layers:

A-circular muscle, an inner layer.

B-longitudinal muscles, an outer layer.

Both muscle layers are composed of striated fiber and their position are the reverse to what obtain in the foregut.

4-Peritrophic Membrane:

The Peritrophic membrane is forms a delicate lining layer to the midgut, although it is absent in many fluid-feeding insects. in *Anthrenus* larvae and in carabid beetles, it contain chitin and sometimes also some protein.

Two types of Peritrophic membrane are recognized according to their modes of formation. In dipteral the membrane is usually a single layer made up, of disorientated fibers in an amorphous matrix. It is secreted as a viscous fluid at the anterior end of the midgut. This fluid is forced through a mould or press formed by the wall of the midgut so that it forms a tube which becomes the wall of the midgut so that it forms a tube which becomes the membrane.

The second type of membrane is formed by delamination form the wall surface of the midgut. This type occurs in orthoptera, odonata coleopteran and hymenoptera.

Individual cells may be in different phases at given time. Secretion and absorption are therefore though to take place by the same or similar cells. The method of secretion may be.

1-Merocrine: in which the cells drain their product through striated border (mycrovilli) without subjecting to any strong change.

2-Holocrine: it is less common and is characterized by the degradation of the cells during the process. It is occur in orthoptera.

The surface area of midgut in many insects are increased not only by microvilli but also through development of outgrowths- the enteric or **gastric caeca**. This organ usually situated at the esophageal, end of the midgut and are variable in size and number.

A third method of achieving the same result is by the folding of the epithelial layer to form crypts, all methods occur in the same species.

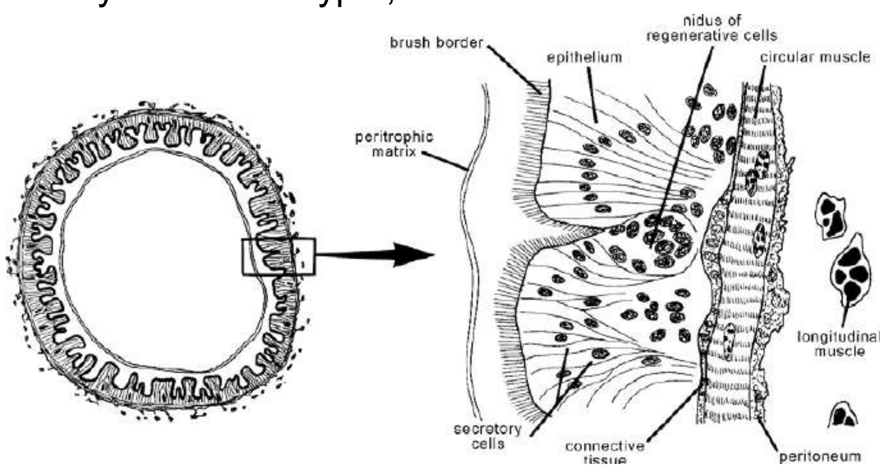


FIGURE.5. Transverse section through midgut of a locust. [After C. Hodge, 1939, The anatomy and histology.

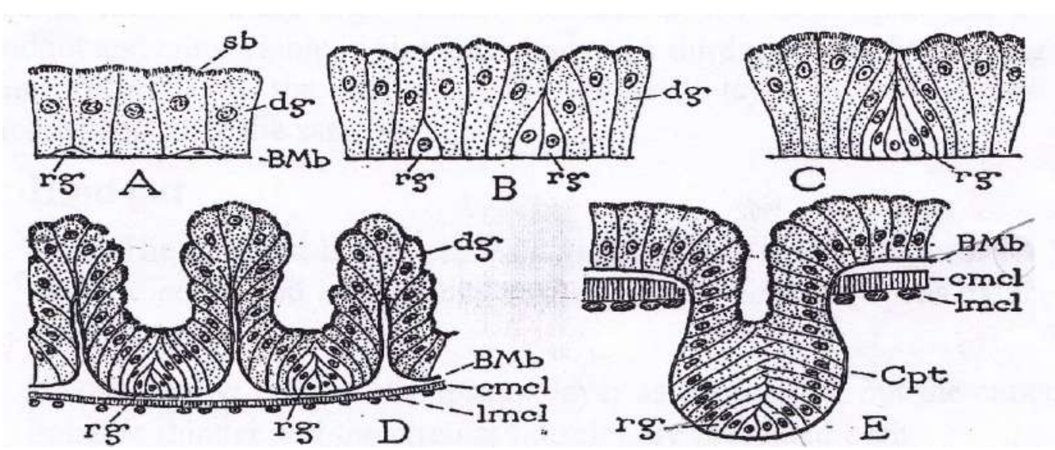


FIGURE .6 diagrams showing various position of the regenerative cells.

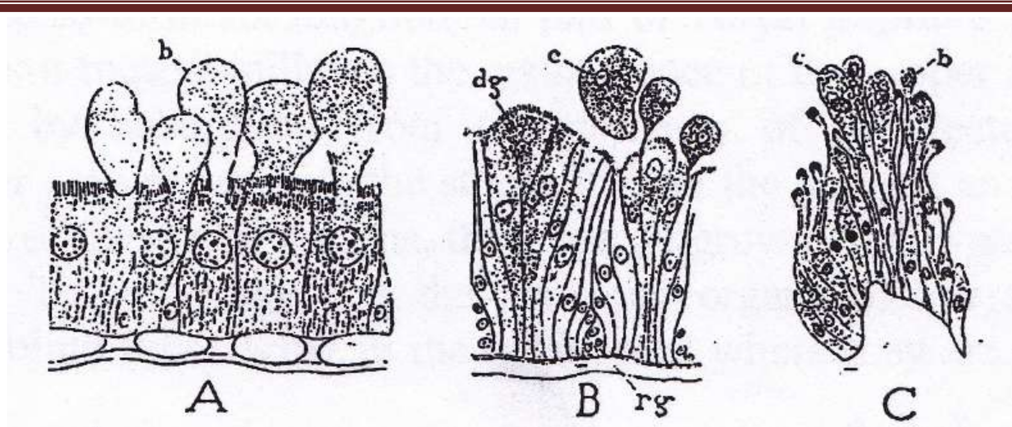


FIGURE.7 diagram showing the process of merocrine and holocrine .

Hindgut:

This is divided into three sections: the anterior is the ileum, the middle portion, the colon, and the wider, posterior section is the rectum which open exteriorly at the anus.

Histologically the hindgut lined by a layer of cuticle which is thinner and more permeable than that of foregut and the circular muscles are presented both external and internal to the longitudinal layer.

1-pylorus:

The pylorus is the first part of hindgut and from it the malpighian tubules often arise. In some insects it forms a valve between the midgut and hindgut.

2-ilum:

In most insect the ileum is an undifferentiated tube running back to the rectum, but in some termites if forms a pouch in which the flagellate concerned with cellulose digestion live.

3-Rectum:

The rectum is often enlarged sac and is thin walled except for certain region, the rectal pads, which have columnar epithelium. There are usually six rectal pads and may extend longitudinally along the rectum (cockroach) or may papilliform as in diptera. The rectum, and in particular the rectal pads, are important in the reabsorption of water, salts and amino acids from the urine.

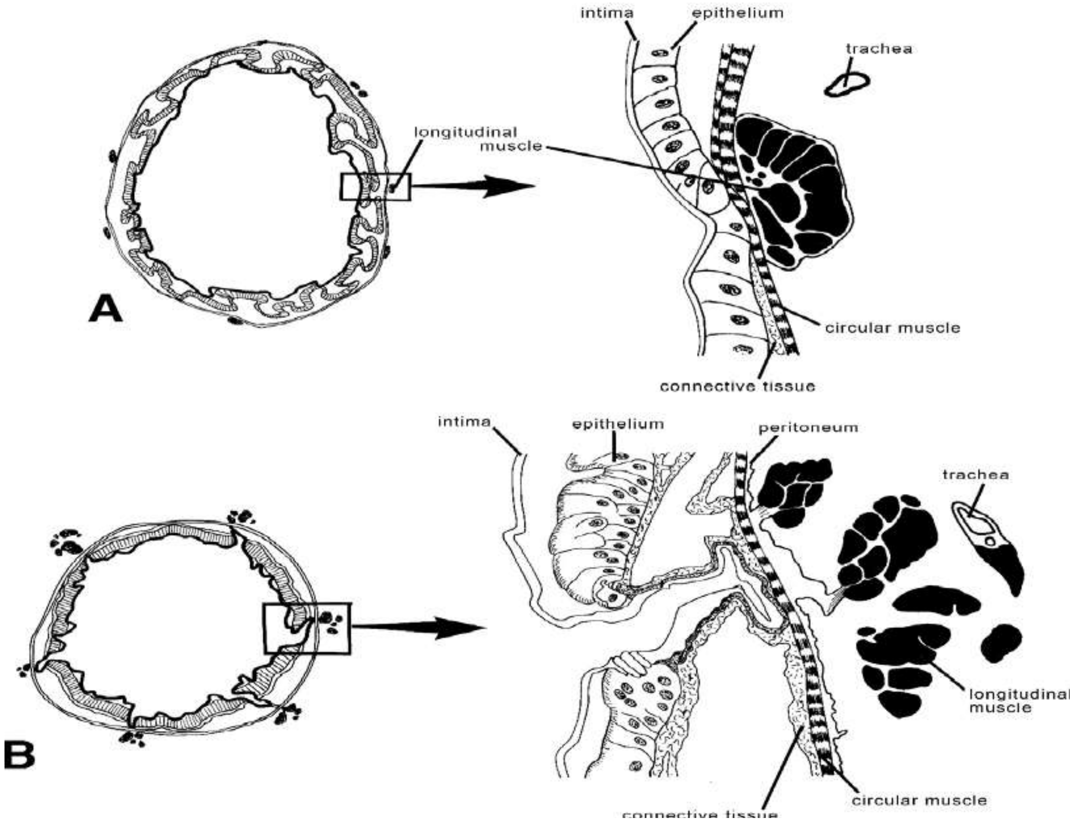


FIGURE 8 Transverse sections through (A) ileum and (B) rectum of a locust. [After C. Hodge, 1939, The

Malpighian tubules:

It's long, thin, blindly ending tubes arising from the gut near the junction of midgut and hindgut. And lying freely in the body cavity. They vary greatly in number, ranging, from example from (30-120) in orthoptera and from (4-6) among many endopterygota, in aphididae and collembola these organs are wanting.

The head glands associated with the mouthparts are the mandibular, maxillary, pharyngeal and labial glands although they are not usually all present together.

Salivary gland:

The labial glands are found in the majority of insects, although they are absent from some coleopteran. they are large and extend back into the thorax. In most insects the labial glands are describe as being acinar (resembling a cluster of grapes) each acinus bear a tiny duct communicates with other similar duct, eventually forming a lateral salivary duct. The lateral salivary duct run anteriorly and ultimately join in a common salivary duct, the last opening into salivarium.

In fluid-feeding insects the salivarium is modified to form a pump that injects salevia into whatever is being pierced. The lateral salivary ducts commonly communicate with comparatively large salivary reservoir as in the cockroaches. in other insects there are no salivary glands.

Function of the salivary glands:

1-The saliva serves to lubricate the mouthparts and moisten it.

2-They act as food solvent.

3-It also contains enzymes which start digestion of the food.

4-They form silk in larval Lepidoptera (caterpillar) and hymenoptera (bees, wasps and relative).

5-They are used to (glue) puparial cases to the substrate in certain flies.

The most common enzymes found in insect salvia are amylase, invertase are commonly present. Sometimes proteases and lipase are also present.

The saliva of some blood-sucking insects also contain an anticoagulant and if the salivary glands of *Glossina* are removed the blood eventually clots in the mouthparts.

The salivary enzymes are commonly injected into the tissues of host plant or animals or are applied to the surface of food materials, a certain amount of digestion in many insects is accomplished external to the alimentary canal (extra-intestinally). Some insects (larval dytiscid beetles) actually regurgitate digestive juices from the gut and inject them into the prey through their mandibles . In this situation a large portion of the digestion is extra-intestinal, the tissues of the prey becoming a soupy material that is drawn into the predatory larval through the mandibles.

Digestion:

In general digestion occurs largely in the medgut where most of the enzymes are produced. These enzymes break down the complex substances in the food into more simple substances which can be absorbed and later assimilated.

Three main groups of enzymes have been found in insects:

1-carbohydrases:

These catalyse more complex carbohydrates to simple sugar. The amylases acting upon starch, (widely distributed in insects). and the glycosidases control the breakdown of the complex sugars like maltose, sucrose and lactose.

2-lipases:

These catalyse the hydrolysis of fats:

3-proteases:

These are responsible for the degradation of proteins the first type are the endopeptidases which breakdown proteins or peptones to polypeptides and the exopeptidases complete protein digestion by hydrolyses of peptides to amino-acids.

The proteases are abundant in some blood-sucking insects like *Glossina*.

In butterflies and moths -which feed mainly on nectar- almost the only enzymes present are invertases which hydrolyses cane sugar. The enzymes present in the midgut are adapted to the diet. if an insect like larval blowfly, feeds on a primarily protein diet proteases are important, whereas in an adult, nectar-feeding lepidopteran they are absent, in aphids feeding on phloem containing no polysaccharides or protein the presence of amylase and proteinase has not been confirmed , but invertases do occur.

Micro-organisims may produce enzymes which are utilized , directly or indirectly, by the insect. This is the case in cellulose and wax digestion and even in *Apis* the only enzymes produced by bacteriologically sterile bees are invertase, protease and lipase: the other carbohydrases normally present are produced by bacteria.

Certain insects are able to digest substances that are ordinary highly stable. for example, chewing lice and few other insects are able to breakdown a very stable protein, keratin which occurs in wool, hair and feather.

Nutrition:

The basic nutritional requirements for growth and development are known for only a few species such as *Blattella*, *Drosophila*, *Aedes* and some insects pests of stored products. The necessary substances to synthetic experimental diets shown as follows:

1-Water:

The water is necessary for all insects. it be form by drinking, an absorption through the cuticle, or from metabolic source. Insects vary in their need for water, for example the mealworm *Teneberio moliter* can survive and reproduce on essentially dry food, others, honeybees and muscid flies requires large amount of water for survival. the excrement of meal worm is hard and dry (all the water have been reclaimed) while the excrement of bees and muscid flies contain large amount of water.

2-Mineral salt:

The insects need various mineral salts in very small amount include potassium, phosphorus, magnesium, sodium, calcium, manganese, copper and zinc. Various mineral have necessary for normal growth and development in certain insects (e.g. the aquatic larvae of mosquitoes which posess very thin-walled papillae are able to absorb mineral ions from the water through the cuticle of these structures).

3-Carbohydrates:

Carbohydrates serve as a source of energy and may be converted to fats for storage, they can be replaced by protein or fats. some such conversion probably occurs in most insects and may serve for whole of energy production. Thus in *Musca* (Diptera) development can proceed in the complete absence of carbohydrate and in the diet of *Galleria* carbohydrate can be entirely replaced by wax.

4-Amino Acids:

Amino acids are required for the production of tissues and enzymes usually present as protein, they form major part of the diet, 30-40%. there are ten essential amino acids. the absence of any one of which usually prevents growth. These are arginine, lysine, leucine, isoleucine, tryptophan, histidine, phenylalanine, methionine, valine, and threonine. but there is some variation in the requirements of different insects.

5-Vitamins:

Vitamins are required in very small amount for normal functioning of any animal. Most insects do not need to vitamin D and C (ascorbic acid) In their nutrition but vitamin C is widely distributed in insect tissues indicating that it is synthesised. And vitamin A is not necessary for many insects, the vitamin B-complex (thiamine, riboflavin, nicotinic acid, pyrodoxine and pantothenic acid) are essential to most insects. It should be noted that many insects depend on micro-organisims for their supply of essential nutrients. In some cases the bacteria, fungi are found in the material on which the insects feeds. In others the micro-organism living in the gut, e.g. the yeast like *Norcardia rhodnii* of *Rodinus*, or they are lodged in special organs (mycetomes) and this micro-organisms are often transmitted from one generation to the next. The insects may die rapidly when deprived of their micro-organisms, but their true physiological role has been established in a few cases.

6-Purine and pyrimidine:

The nucleic acid DNA,RNA are composed of purine and pyrimidine, RNA are necessary on the growth of certain fly larvae.

Coloration;

Insect coloures fall into three groups

1. **Chemical coloures (pigmental).**
2. **Physical coloures (structural).**
3. **Chemico-physical coloures.(combination)**

1- Chemical coloures (**Pigmental**) may be present in the **cuticular coloures** , the **hypodermal coloures** and **subhypodermal coloures** , and these owe their presence to substances of definite chemical composition which have the property of absorbing some light waves and of reflecting others.the .

Cuticular coloures are mostly contained in the exocuticle , they consist of black or brown and yellows , which are permanent.

hypodermal coloures are present in the form of granules or drops of fat in the cells of the hypoderms. They may be red, yellow or green.

Subhypodermal coloures, are contained in the fat body and blood.

2- Physical coloures . structural coloures differ from the others in that they are changed or destroyed by physical change in the cuticle such as shrinkage, swelling, distortion.

Fuor types of structural colors may be distinguished:

- **a- Structural white** is caused by the scattering, reflection and refraction of light by microscopic particles. Probably most insect whites have a structural basis.
- **b- Tyndall blue,** its uncommon, its due to the scattering of the shorter wavelength by particles with dimensions of about the some size as the wavelengths of light. occurs in Odonata
- **c- Interference coloures,** are produced by optical interference between reflections from a series of superimposed laminae or ribs. This one is commonest type of physical coloration ex; wing scales of butterflies.
- **d- Diffraction coloures,** resulting from the presence of closely spaced cuticular striae, Occure in some beetles.

3- Chemico-physical coloures, these are produced by combination structural modification with a layer of pigment. A structural blue may be combined with a yellow pigment to produce a brilliant green, as in som butterflies, or pigmentary red in the walls of the wing scales of another butterfly.

Lecture 10

Respiratory system:

In insects the tracheal system, a series of gas-filled tubes derived from the integument, in insects with an open respiratory system these tubes communicate with the atmosphere through one or more pairs of spiracles. Terminally the tubes are much branched, forming tracheoles that provide an enormous surface area over which diffusion can occur. In the immature stages of many aquatic insects, special respiratory organs known as gills. And these n spiracles, may or may not co-exist with ope Histologically, both types of organ consist of thin layer of cuticle an epidermal layer and usually a basement membrane, all of which are continuous with similar layers of the general integument.

The spiracles:

The spiracles are paired opening usually situated on the pleura of the meso-and metathorax and long the sides of the abdomen. In generalized insects such as Orthoptera and in some larvae there are ten pairs of spiracles, two pairs being thoracic and eight pairs abdominal in position. Reduction in this number, however, are very frequent. in these cases where prothoracic spiracles occur their presence on this segment is apparently due to migration from behind in the course of evolution. although spiracles are wanting in most Collembola, a single pair is present on the neck in some Sminthuridae. In the Diplura some Japygidae carry four pairs of thoracic spiracles, two on the mesothorax and two on the metathorax.

According to the number number and distribution of functional spiracle it is possible classify respiratory systems as follow:

1-Polypneustic respiratory system: at least eight functional spiracles on each side.

a-Holopneustic: it is present in advanced insect larvae. 10 pairs of functional spiracles being present, 8 of it on abdominal segment, two of functional spiracle in the metathoracic and mesothoracic. as in the bibioned larvae.

b-Peripneustic: nine spiracles, one on mesothoracic, eight abdominal, as in the cecidominal larvae.

c-Hemipneustic: eight spiracles, one on mesothoracic. Seven on abdominal segment as in the mycetophilidae larvae.

2-oligopneustic respiratory system: one or two of thoracic spiracles on each sides.

a-Amphipneustic: two spiracles, one on mesothoracic, one post abdominal, as in psychodid larvae.

b-Metapneustic: one spiracle, one post abdominal, as in the culicid larvae.

c-propeneustic: one spiracle, on mesothoracic, as in the dipterous pupae.

3-Apneustic respiratory system: no functional spiracle, as in the chironomid larvae.

Apneustic does not imply that the insect has no tracheal system, but that the tracheae do not open to the outside.

Structure of spiracles:

In its simplest form, found in some apterygota, the spiracle is a direct opening from the outside into a trachea, but generally the visible opening leads into a cavity, (atrium) from which the tracheae arise. In this case the opening and the atrium are known collectively as the spiracle. Often the walls of the atrium are lined with hairs which filter out dust.

The atrium consists of one or more muscle with the associated cuticular parts and by closing the spiracle aperture, prevent excessive loss of water-vapor. The atrium as in specialized region leading from the spiracular opening, it lacks taenidia and its wall are variously sculptured or are provided with hairs, trabeculae and similar cuticular outgrowths, these help to reduce water loss and prevent the entry of dust.Closely connectedwith the spiracles are frequently **perstigmatic glands** which secrete hydrophobic material preventing the wetting of those organs.

The structure of the spiracles present an enormous range of variety among different groups of insects it is also usually different in the thoracic and abdominal spiracles of the same insect and may be greatly modified in different instars it will therefore be readily appreciated that.Their classification is a matter of much difficulty.

1-simple spiracles:

They are just opening into the tracheal system. Surrounding by a simple rime, but not provided with mechanisms for regulating the size of a perture. This type is found in some apterygota.

2-Fringed spiracles:

These spiracles often have the atrial wall produced into interlacing branched hair like processes or trabeculae forming filtering apparatus. this device allows the free passage of air, while the entry into the atrium of foreign particles or water is prevented . this type is common in lepidopterous larvae.

3-Lipped spiracle:

It has a slit like opening guarded by two external valve or lips as in the thoracic spiracle of acrididae.

4-Sieve-plate spiracles:

The spiracles are circular, each consist of a crescent sieve plate and projecting tegumentry fold or bulla which is almost completely surrounded by it. the true opening is a curved slit situated near the margin of the bulla and running concentrically with it. the sieve plate consist of an outer pore membrane supported beneath by layer of trabeculae. this type of spiracles found in the larvae of melolonthaand other scarabaeidae.

5-Sinous spiracles:

In the third stage larvae of higher cyclorrhapha such as Musca domesttica the posterior spiracles consists of a pair of cuticular plates. each plate is surrounded by aperitreme and bears as a rule three opening in the form of presenting the appearance of a grating, and all three opening communicate with a common atrium.

6-Digitate spiracles:

The anterior spiracles consist of a variable number of digitate processes with apices perforated by opening. each opening communicates with a small and the ateria of each spiracle all join with the main tracheal trunk of their side. this found in the third stage larvae of higher cyclorrhapha such as Musca, Hylemia.

The tracheae and tracheoles:

The tracheae is elastic tube and when filled with air present a silvery appearance. they are lined by cuticle continuous with that of the body wall. this lining has a characteristic striated appearance due to thread-like ridges which run helically around the inner circumference and form the spiral thread or **taenidium**. Continuity of the spiral is often interrupted and a new spiral then begins. The function of this spiral thickening to keep the tracheae distended and thereby allow the free passage of air. Externally there is a layer of polygonal cells that secrete cuticular lining. when trachea is followed in its branching it finally enters a stellate end cell and there divides in to tracheal capillaries or tracheoles. The tracheoles end in the tissues in various ways, in the gut and salivary glands they branch and pass between the cells without penetrating them. In the fat-body and rectal palpillae, however, they may enter the cells, while in the flight muscles there is a network of intracellular teacheoles.

In campodea and some other Apterygotes the tracheae arising from each spiracle remain unconnected with those from the others. Elsewhere a more efficient system of longitudinal and transverse (segmental) connecting tracheae has been evolved.

In typical segment three principal tracheae arise from the main longitudinal trunk, near the point where the spiracular trachea joins it these tracheae are;

1-A dorsal tracheae. Supplying the dorsal muscles and heart.

2-Visceral tracheae. passing to the gut, fat-body and gonads.

3-venteral tracheae. Which supplies the ventral musculature, nerve cord and in the thorax.

The head and mouth parts are supplied by branches derived from anterior spiracle and dorsal longitudinal trunk.

Air-sac:

in places the tracheae are explanded to form thin-walled air-sac in which the taenidia are absent or poorly developed and often irregularly arranged. consequently, the air-sag will collapse under pressure and they play a very important part in ventilation of the tracheal system as well as having other function. air-sac have widely distributed along the main tracheal trunks of many insects. The principle function of the air-sac is a respiratory one as they serve to increase the volume of (tidal air) which is changed when respiratory movement are made... but other functions are also known. an insect with air-sacs has lower specific gravity than a similarly sized one without them and they may there for make easier the flight of large species. in some higher Cyclorrhapha the sacs occupy a space in the abdomen of the newly emerged fly which is a available for the later expansion of the ovaries while their occurrence beneath tympanal organs permits the membrane to vibrate more freely than would otherwise be possible.

The air-sac of the larvae of Caoborus and Mochlonyyx act as hydrostatic organs. enabling the insect to float at any level in the water it inhabits while it has been suggested that the pair in the abdomen of the littoral Carabids Aepus and Aepopsis acts as an air storage organ when its possessor is submerged.

Respiration:

In smoll terrestrial insects the oxygen passes along the tracheal system, from the spiracles to the finer tracheoles, by the process of the gaseous diffusion. This is possible because of the difference in partial pressure of oxygen between the atmosphere and the tracheolar ending, where the gas is constantly being removed the respiring tissues.

Surprising though it seems, a difference in partial pressure of only 2-3mm. of mercury is adequate to supply by diffusion all the oxygen that some insects require. A similar process, in the reverse direction, however, diffusion through insect tissues much more readily than does oxygen, so it is likely that much of it-perhaps 25%-is eliminated through the tracheal walls and the cuticle of the body surface rather than through the spiracles. the wall of the tracheoles are more permeable to oxygen than are the other parts of the tracheal system and it is therefore through these fine branches that the tissues receive of their oxygen supply. there is usually some liquid en the ending of the tracheoles, but in active muscular tissue the rise in osmotic pressure which accompanies contraction results in the absorption of this liquid. air can then penetrate further along the tracheoles and so increase the rate at which oxygen will diffuse into those tissues which are in great need of it.

The physical law governing the diffusion of oxygen along the tracheal system is such that large or very active insects would not receive enough by this means alone. diffusion is therefore supplemented in these insects by ventilation of the tracheal system. through respiratory movements.

Expiration is effected by various muscles of the abdomen, whose contraction the body in Orthoptera and Coleoptera, while among hymenoptera and dipteral telescopic movements of the abdominal segments result.

Inspiration is usually effected by the elasticity of the body segments as they regain their original shape. Most of the tracheas are circular in cross section and therefore compressible with difficulty, but they are readily extensible in the direction of their long axis. The main tracheal trunks are often oval in cross section and are readily compressed while the air sac even more prone to collapse. By alternately compressed and dilating the main tracheae and air sacs, respiratory movement therefore bring about mechanical ventilation of the larger tubes, in some insects it is known that there is directed air flow been shown that the first four pairs of spiracles can remain open while the remaining six pairs are closed and vice versa, with the result that the former serve for inspiration and the latter for expiration.

In the larvae of the beetle Dytiscus it has been estimated that the tracheal system is emptied during strong expiration of nearly two-thirds ($64mm^3$) of its total capacity ($107mm^3$), the remainder being changed by diffusion.

Respiratory activity is regulated by the opening or closing of the spiracles (diffusion control) and in those insects with ventilation, by variations in the intensity or frequency of respiratory movements (ventilation control). In each segment of the body, the muscular contraction responsible for these changes are governed by a primary respiratory center situated in the corresponding ganglion of the ventral nerve cord. Further co-ordination and control is exercised by the so called secondary respiratory center of the brain (diffusion control) or thorax (ventilation control). lake of oxygen or accumulation of carbon dioxide stimulate these centers and results in the opening of the spiracles or the initiation of ventilator movement.

The blood of insects play only small part in respiration, the only known exceptions to this are aquatic larvae of some Chironomid midges, known as a blood-worms, whose plasma contains hemoglobin in solution. the hemoglobin however, is such that it only transfers oxygen to the tissues when the partial pressure of oxygen is very low. it therefore appears to be an adaptation enabling the larvae to survive in the poorly oxygenated conditions which they sometimes have to endure.

Gas Exchange in Aquatic Insects:

There are many kinds of aquatic insects spend its whole life cycle in the water, have an open tracheal system and obtain oxygen from atmosphere through one or two pairs spiracles, in others the tracheal system is closed and oxygen diffusion into the water through the following.

1-Cutaneous respiration:

This type of insects obtain dissolved oxygen from the water, there are two types of Cutaneous respiration. the first type include the small aquatic insects or those with a low metabolic rate, there is no tracheal system present. diffusion of gases across the body wall provides an adequate means of obtaining oxygen and excreting carbon dioxide. In the second type in larger or more active forms, such as late stage midget larvae, the tracheal system is developed, but instead of spiracles there are clusters of fine tracheae in the epidermis. her the gas exchange through the epidermis and then take place into the fine peripheral tracheae. The diffusion pattern her is as in spiracle system.

2-Air tube:

Although many aquatic insects live underwater, they get air straight from the surface through hollow breathing tubes (sometimes called siphons) that work on the same principle as a diver's snorkel. In mosquito larvae for example, the siphon tube is an extension of the posterior spiracles. An opening at the end of the siphon is guarded by a ring of closely spaced hairs with waterproof coating. At the air-water interface, these hairs break the surface tension of the water and maintain an open airway. When the insect dives, water pressure pushes the hair close together so they seal off the opening and keep water out. Water scorpions (Hemiptera: Nepidae) and rat-tailed maggots (larvae of a Syrphid fly) are two more examples of aquatic insects that have snorkel-like breathing tubes. It does not swim to the surface but has respiratory tube which can be extend 3-4 inches to the surface.

3-diving air stores:

Some aquatic insects (diving beetle, for example) carry a bubble of air with them whenever they dive beneath the water surface. This bubble may be held under the elytra (wing) or it may be trapped against the body by specialized hairs. The bubble usually covers one or more spiracles so the insect can "breathe" air from the bubble while submerged. An air bubble provides an insect with only a short-term supply of oxygen, but thanks to its unique physical properties, a bubble will also "collect" some of the oxygen molecules dissolved in the surrounding water. In effect, the bubble acts as a "physical gill" replenishing its supply of oxygen through the physics of passive diffusion The larger the surface area of the bubble, the more efficiently this system works. An insect can remain under water as long as the volume of oxygen diffusing into the bubble is greater than or equal to the volume of oxygen consumed by the insect. Unfortunately, the size of the bubble shrinks over time as nitrogen slowly diffuses out into the water. When the bubble's surface area decreases, its rate of gas exchange also decreases. Eventually, the bubble becomes too small to keep up with metabolic demands and the insect must renew the entire bubble by returning to the water's surface.

4-Tracheal gills:

A biological gill is an organ that allows dissolved oxygen from the water to pass (by diffusion) into an organism's body.

In insects, gills are usually outgrowths of the tracheal system. They are covered by a thin layer of cuticle that is permeable to both oxygen and carbon dioxide.

In mayflies and damselflies, the gills are leaf-like in shape and located on the sides or rear of the abdomen. Fanning movements of the gills keep them in contact with a constant supply of fresh water. Stoneflies Caddisflies have filamentous gills on the thorax or abdomen. Dragonflies differ from other aquatic insects by having internal gills associated with the rectum. Water is circulated in and out of the anus by muscular contractions of the abdomen. This rectal gill mechanism doubles as a jet propulsion system. A sudden, powerful contraction of the abdomen will expel a jet of water and thrust the insect forward-a quick way to escape from predators!

5-Blood gills:

Bloodworms (Order: Diptera, Family: Chironomidae). these insects contain a sort of hemoglobin to help them breathe. Bloodworms are red because their hemoglobin makes them red. They use their hemoglobin to absorb more oxygen into their bodies than they could without it. This is important because a lot of bloodworms live in very low oxygen environments such as the bottom of deep lakes, in polluted waters (where they are sometimes one of the only insects that can survive!), and lakes with a lot of bacteria. These are habitats in which these insects would not be able to live without their hemoglobin helping them bring oxygen into their bodies.

Gas Exchange in Endoparasitic Insects:

It is probably not surprising that endoparasitic insects, as they too are surrounded by fluid, show many parallels with aquatic insects in the way that they obtain oxygen. Most endoparasitic satisfy a proportion of their requirements by cutaneous diffusion. In some first-instar larvae of Hymenoptera and Diptera the tracheal system may be liquid-filled, but generally it is gas-filled with closed spiracles and includes a rich network of branches immediately beneath integument. Many endoparasitic forms, especially larval Braconidae, Chalcididae, and Ichneumonidae (Hymenoptera), and some Diptera, possess "tails" filled with hemolymph or can evaginate the wall of the hindgut through the anus. It has been suggested that these structures may facilitate gas exchange, though the evidence on which this suggestion is based is generally not strong.

Endoparasites with greater oxygen requirements usually are in direct contact with atmospheric air either via the integument of the host or via the host's tracheal system. In larvae of many Chalcidoidea, for example, only the posterior spiracles are functional, and these open into an air cavity formed at the base of the egg pedicel that penetrates the host's integument (Figure 15.9A).

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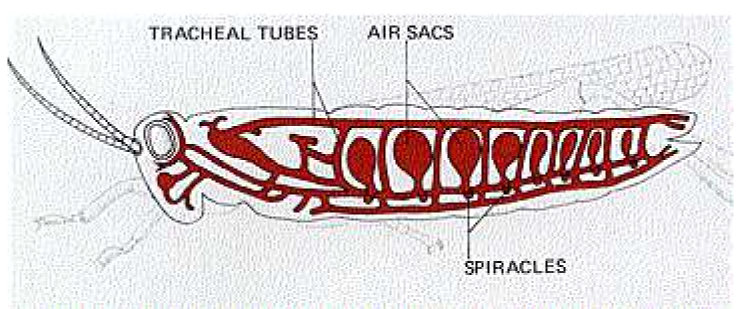

Fig (10) air sac in insects.

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The physical law governing the diffusion of oxygen along the tracheal system is in large or very active insects would not receive enough by this means alone. diffusion is therefore supplemented in these insects by ventilation of the tracheal system. Through respiratory movements.

Expiration is effected by various muscles of the abdomen, whose contraction the body in Orthoptera and Coleoptera, while among hymenoptera and dipteral telescopic movements of the abdominal segments result.

Inspiration is usually effected by the elasticity of the body segments as they regain their original shape. Most of the tracheas are circular in cross section and therefore compressible with difficulty, but they are readily extensible in the direction of their long axis.

The main tracheal trunks are often oval in cross section and are readily compressed while the air sac even more prone to collapse. By alternately compressed and dilating the main tracheae and air sacs, respiratory movement therefore bring about mechanical ventilation of the larger tubes, in some insects it is known that there is directed air flow been shown that the first four pairs of spiracles can remain open while the remaining six pairs are closed and vice versa, with the result that the former serve for inspiration and the latter for expiration.

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In the larvae of the beetle Dytiscus it has been estimated that the tracheal system is emptied during strong expiration of nearly two-thirds (64mm^3) of its total capacity (107mm^3), the remainder being changed by diffusion.

Respiratory activity is regulated by the opening or closing of the spiracles (**diffusion control**) and in those insects with ventilation, by variations in the intensity or frequency of respiratory movements **(ventilation control**). In each segment of the body, the muscular contraction responsible for these changes are governed by a primary respiratory center situated in the corresponding ganglion of the ventral nerve cord. Further co-ordination and control is exercised by the so called secondary respiratory center of the brain (diffusion control) or thorax (ventilation control). lake of oxygen or accumulation of carbon dioxide stimulate these centers and results in the opening of the spiracles or the initiation of ventilator movement.

Lecture 11

Circulatory system

Insects, like all other arthropods, have an **open circulatory system** which differs in both structure and function from the **closed circulatory system** found in humans and other vertebrates. In a closed system, blood is always contained within vessels (arteries, veins, capillaries, or the heart). In an open system, blood (usually called **hemolymph**) spends much of its time flowing freely within body cavities where it makes direct contact with all internal tissues and organs.

The insect's circulatory system is a single closed dorsal vessel. **A dorsal vessel** is the major structure of an insect's circulatory system. This tube runs longitudinally through the thorax and abdomen, along the inside of the dorsal body wall. In most insects, it is a fragile.

In the abdomen, the dorsal vessel is called the **heart**. It is divided segmentally into chambers that are separated by valves (ostia) to ensure one- way flow of hemolymph. A pair of **alary muscles** are attached laterally to the walls of each chamber contraction of the muscles force the hemolymph forward from chamber to chamber. During each rest the ostia open to allow inflow of hemolymph from the body cavity. The heart's contraction rate varies considerably from species to species, typically in the range of 30 to 200 beats per minute. The rate tends to the insect's level of activity. Fig (2)

In front of the heart, it is a simple tube called the aorta. Which continues forward to the head and empties near the brain. Hemolymph bathes the organs and muscles of the head as it emerges from the aorta.

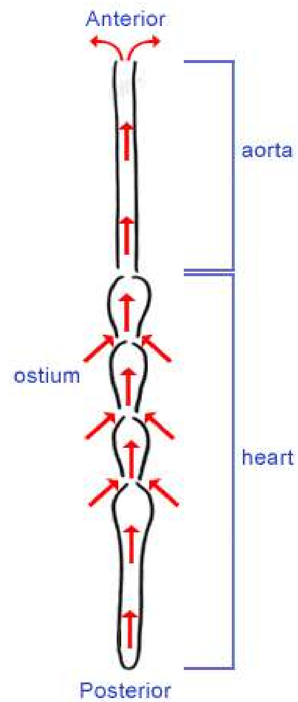


Fig. 2 transverse section (heart) of insects.

The organs and tissue belongs to circulatory system:

1-Hemolymph:

About 90% of insect hemolymph is plasma, usually clear, but sometimes greenish or yellowish in color. Exception to this are found some chironomid larvae, its reddish in color. Compared to vertebrate blood, it contains relatively high concentrations of amino acids, proteins, sugars, and inorganic ions. Over wintering insects often sequester enough ribulose, trehalose, or glycerol in the plasma to prevent it from freezing during the coldest winters.

The hemolymph make up approximately 5-40% of the total body weight of an insect, depending on the species. The PH of the blood is usually slightly acid in the range between 6-7 PH, and in few insects the PH may be slightly alkaline, PH 7-7.5.

In many insects the hemolymph osmotic pressure is held reasonably constant over arrange of environmental condition. In other species, the osmotic pressure changes in parallel with the environmental conditions, yet the body cells are able to tolerate these changes.

Insect hemolymph is slightly denser than water, having a specific gravity somewhere between 1.015 and is 1.060 and is subject to increase during period of molting.

Hemolymph in insects includes a cellular fraction, the **hemocytes**, and a liquid component, the **plasma.**

a-Plasma:

Plasma contains a large variety of components both organic and inorganic whose relative proportions may differ greatly both among species and within an individual under different physiological conditions.

It contains about 85% water; it's slightly acid and include inorganic ions, amino acid, protein, fat sugars organic acid and other substance in different amount. In variable amount Potassium, sodium and chloride ions are the major inorganic constituents. in addition, copper, iron, aluminum, zinc, manganese and other metallic element have been found in very small amount. Much of the carbohydrate found in insect blood is in combination with protein, forming glycogen. Several pigments have been identified in insect blood

b-Hemocytes:

Though several types of hemocytes have been recognized, which differ in size, function, cytology (including fine structure) there are two main categories of hemocytes. Fig (3)

First- Phagocytic cells:

The main function of the hemocytes is phagocytosis. The ingestion of small solid particles, bacteria, parasite, egg and larvae of parasitoid, and they greatly increase in numbers during ecdysis and metamorphosis. These cells are including:

1-Proleucocytes:

Initial blood cells are Small, rounded cells whose nucleus occupies most of their volume. And its shape is none fixed and are regarded as young forms of hemocytes.

2-Granular leucocytes:

These cells are grainy contain large central nucleus. These cells have different shapes (amoeboid, fusiform, or vermiform).

Second- Non Phagocytic cells:

According to its name indicates, Do not attack foreign organisms that enter the insect body and it's also called a Oenocytiod, are a large cells with rounded or spherical forms.

In addition to these, other tissues are associated with the circulatory system, but are not regarded the hemocytes because the embryonic origin of these cells are different. These cells are including:

1-Oenocytoids:

Its composed small proportion of the total, are ovoidal, with a diameter of 8-12μ. Have a large nucleus and cytoplasm. They occur in the Coleoptera, Lepidoptera, Hemiptera, and Diptera but not in the Orthoptera. The function of the oenocytes has not been completely explained although there is evidence that they secrete the lipoprotein, which form the cuticulin layer of the epicuticle and possiply the free wax on the surface of the integument of cockroach.

2-Nephrocyttes:

Nephrocyttes or pericardial cells, are occurring singly or in groups in various parts of the body they may be very large, or small and numerous and usually they contain more than one nucleus and usually present on the surface of the heart or lie on the pericardial septum or the alary muscles. Fig (4)

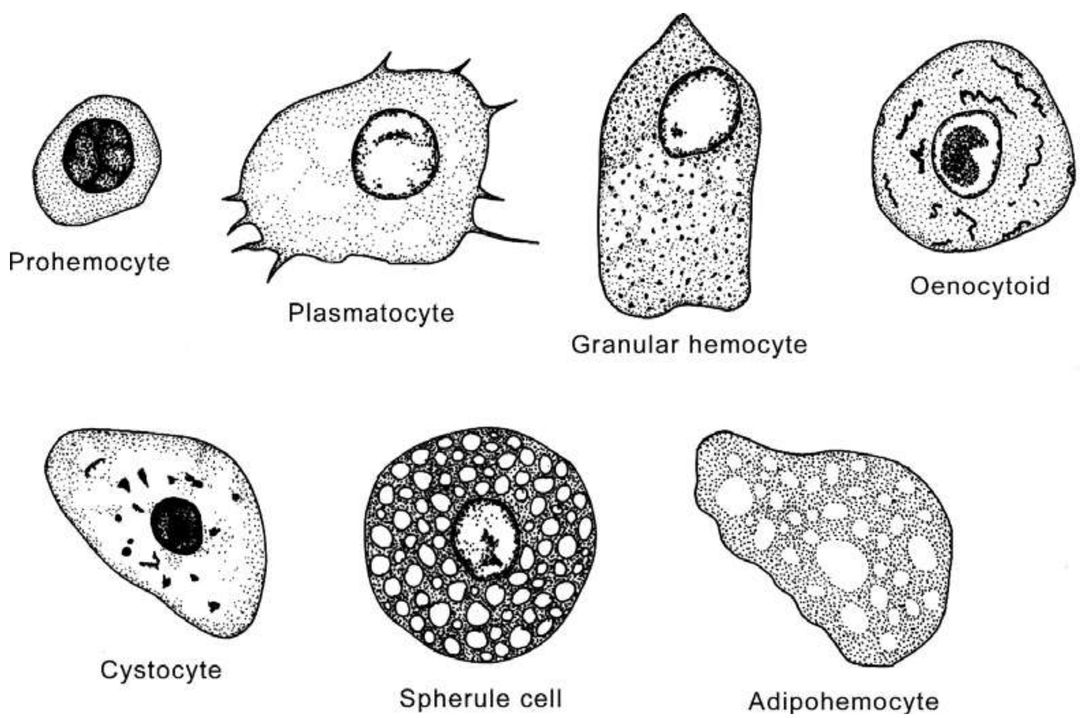


Fig. 3 - Different types of hemocytes. [After R. F. Chapman, 1971, *The Insects: Structure and Function.*

Function of the plasma:

The blood of insects has four functions:

1-Transportation:

Plasma is important in the transport of various materials, nutritive materials are carried from the alimentary canal and storage tissues to the sites at which they are to be metabolized. Excretory products from their places of origin to the malpighian tubules. And hormones from the endocrine organs to their sites of action. The blood is unimportant in the transport of oxygen to the tissues.

2-Respiration:

An insect breathing depends mainly on the tracheoles system which transports oxygen to the body tissues, but in almost insects the tracheoles didn't reach to all tissues. In this case the blood transports the oxygen to those tissues. While the carbon dioxide which results from the breathing process, its diffusion in the body tissues and then finally to the outside of the insect body.

3-Protection:

The hemocytes dispose of certain bacteria and parasite, throw healing of wounds is affected by the blood or its hemocytes.

4-Hydrolytic function:

The entire volume of blood enclosed within the body wall forms a closed hydrolytic system capable of transmitting pressure from one part of the body to another. In this purely mechanical sense it is put to many uses by the body.

a-The pressure of the blood is regulated by contraction of the thorax or abdomen or both, brought about by respiratory movement, causes the emptying and filling of the tracheal air sacs and pouches.

b-Localized blood pressure is responsible for stretching of the exoskeleton after molting.

c-Blood pressure is responsible for the inflation of the wing and frequently operation of the egg-breaking device at time of hatching.

5-Storage:

Blood act as store of water and serves as an important pool for the raw material for construction of new cells.

The organs and tissues belonging to the circulatory system are separately dealt with below.

1-The dorsal vessel:

The dorsal vessel runs along the dorsal midline, below the terga, for the whole length of the body. Anteriorly it leaves the dorsal wall and is more closely associated with the alimentary canal, it's divided into to region.

A- Heart:

The heart is the principal pulsatory organ and undergoes rhythmical contraction which is brought about by the muscles fibrillae of its walls. Whether the rhythm is purely miogenic. As the rule, the heart is a narrow continuous vessel whose sides are perforate with vertical slit-like opening or ostia. The margins of Ostia form valves, which prevent the return of the blood from the heart into pericardial sinus, are called auricular valves. In the other case the heart shows a series of dilations or chambers usually corresponding in number to the pairs of Ostia. While there may be a chamber of the heart to each segment of the abdomen and to the second and third segment of the thorax, as in the cockroach. In many insects pair of auricular valves also functions as a ventricular valve, which prevents the backward flow of the blood in the heart itself.

b- Aorta:

The aorta is the anterior prolongation to the dorsal of vessel ad it functions as the principal artery of the body its junction with the heart is frequently marked by the presence of aortie valve. The aorta extends forwards through the thorax to terminate in the head near the brain. In some insects its anterior extremity is an open funnel-like mouth but, more usually, it divides into two or more cephalic arteries, each of which may subdivided into smaller vessels. Histologically the heart is composed of a single layer of cells which large nuclei, and striated muscles fibrillae are differentiated within the cytoplasm. The cellular layer is bounded both extremely and internally by delicate membranous tunica

2-Diaphragms and sinuses:

When the diaphragms are completely developed the general body cavity or haemocoele is divided into three sinuses by means of two fibro-muscular septa. The dorsal diaphragm is the principle septum and the one most generally prevalent, its extend across the abdominal cavity above the alimentary canal and the blood-space thus enclosed is known as the dorsal or pericardial sinus. the latter is situated beneath the abdominal terga and within it is located the heart. The ventral diaphragm when present, stretches across the abdominal cavity just above the ganglia of the ventral nerve-cord, and the space limited by it is the ventral or perineural sinus. Between the dorsal and ventral sinuses is the large central cavity containing the principle internal organs. Fig (4).

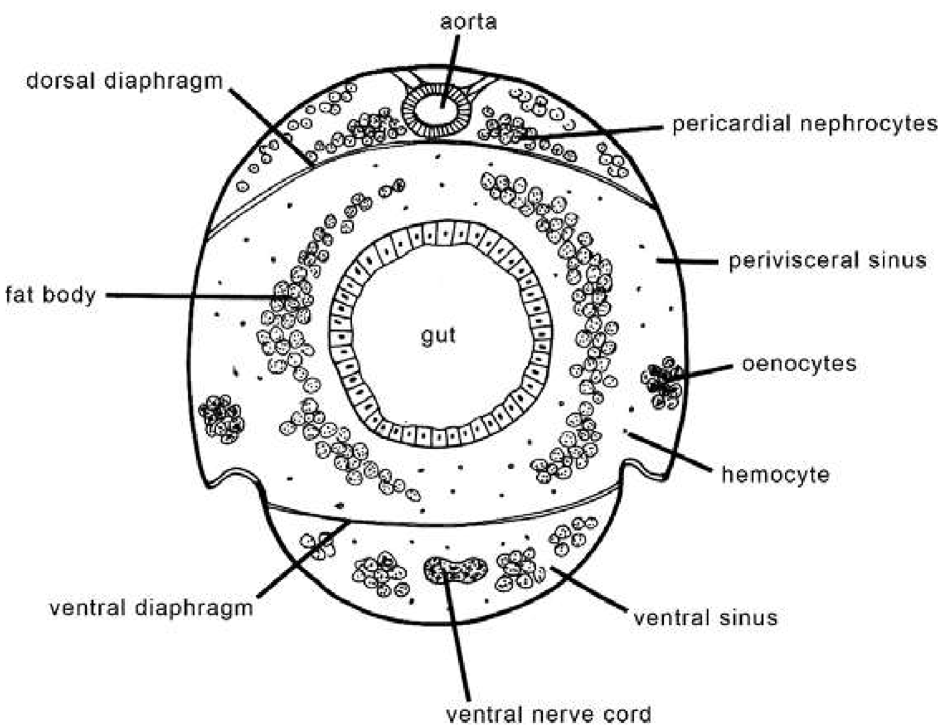


Fig. 4 Diagrammatic transverse section through abdomen to show arrangement of septa. [From R. E. Snodgrass, *Principles of Insect Morphology.*

Accessory pulsatile organs:

In addition to the dorsal vessels there are other pulsating structure connected with the haemocoel which are connected with the maintaining a circulation through the appendages. They are sac-like structures situated, insuring an adequate circulation of blood through the appendages.

Thoracic pulsatile organs:

The Thoracic plusatile organs present beneath the meso and metathoracic terga. In the mesothoracic and sometime metathoracic there is pulsatile organ concerned with the circulation through the wings. The veins of the posterior part of the wing connect with the blood space beneath the tergum via the axillary cord. Among hemiptera special plusatile organs are present in legs, at the base of each antenna, in other insect the veins at the base of the wings in cranefly larvae the aorta also plusatile. Fig. (5)A

Circulation:

To facilitate circulation of hemolymph, the body cavity is divided into three compartments (called blood sinuses) (Fig. 4) by two thin sheets of muscle or membrane known as the dorsal and ventral diaphragms. The dorsal diaphragm is formed by alary muscles of the heart and related structures; it separates the pericardial sinus. The ventral diaphragm usually covers the nerve cord; it separates the perivisceral sinus from the perineural sinus.

The heart is principle pulsatory organsand undergoes rhythmical contractions which are brought about by the muscle fibrillae of its wall. Contraction of the heart takes the form of a wave of peristalsis which runs forward from the posterior end. In some species this wave travels so quickly that the heart seems to contact at once, in other cases it is so slow that two or three waves can be seen travelling forwards at the same time. **diastole** results from the relaxation of the heart muscle aided, in some insects, by a contraction of alary muscles or elastic tension of their fibers. During diastole the blood enters the heart by the Ostia, which may exclude some or all of the hemocytes. On contraction the expanded lips of these Ostia act as valves so that the blood is prevented from returning through them (auricular valve) to the pericardial sinus and is propelled forward the blood enters the cephalic hemococele, from which apart is pumped into the antennae by accessory pulsatile organs. the circulation of blood through the wing of many insects occur indefinite channels between the inner walls of the veins and the enclosed trachea and takes the form of distally directed flow in the front of the wing and a return flow the posterior margin, it is brought about by the thoracic pulsatile organs which aspirate blood from the posterior part of the wing base. Circulation through the legs may also be achieved through accessory heart at their bases, helped by movements of the legs and presence of diaphragms within them. from the head and thorax the blood flows backward in the hemocoele and is probably assisted in this direction by undulation movement of the ventral diaphragm, and directs a blood flow backward in the perinural sinus. Leaving the latter, through spaces along its sides and posterior end, the blood ascends among the viscera. It then becomes drawn into the pericardial sinus by contraction of aliform muscles. This alters the contour of the dorsal the diaphragm and passage of the blood into the sinus occurs through perforation in this membrane. The pulsation rate is influenced by many external, endocrine and pharmacological factors. Thus, it's increased as the temperature is raised.

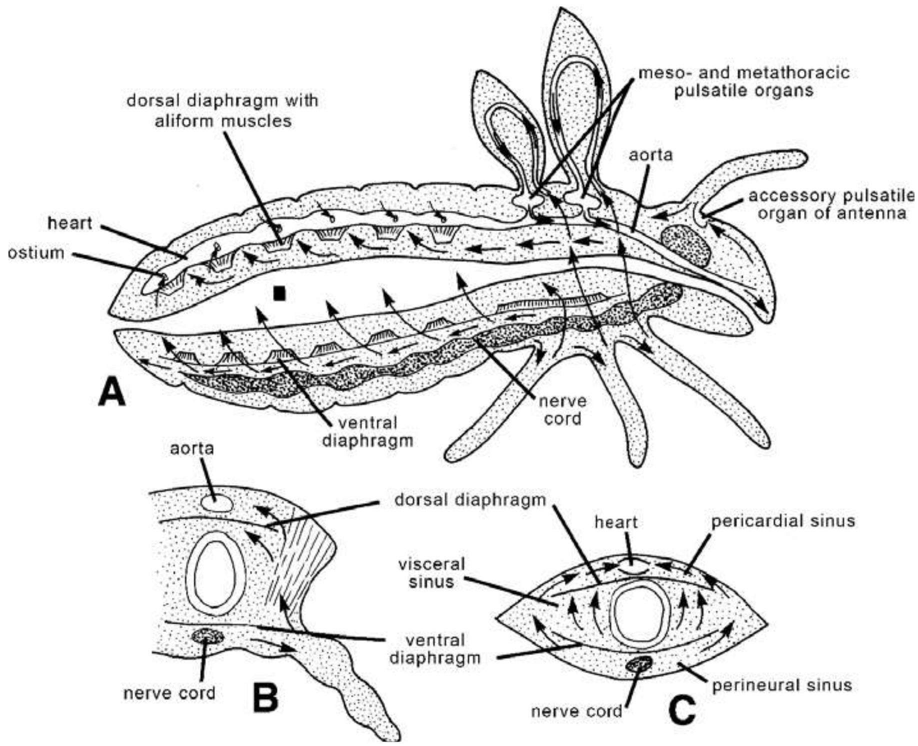


Fig. 5 Diagrams showingdirection of hemolymphflow. (A) Longitudinal section; (B) transverse section through thorax; and (C) transverse section through abdomen. Arrows indicate direction of flow. [After V. B. Wigglesworth, 1965, *The Principles of Insect Physiology*,

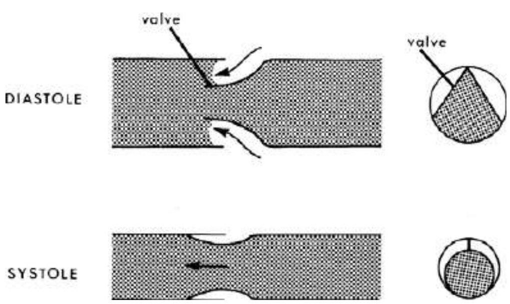


Fig. 6 diastole and systole.

Lecture 12

Excretory Systems

The function of excretory system is the maintenance of a relatively constant internal environment for the tissues of the body, among the regulatory processes involved are the elimination of the nitrogenous waste-products of protein breakdown and the control of the ionic composition of the haemolymph.

The principal excretory organs of insects are the Malpighian tubules, and an accessory excretory function is performed by the fat-body, the integument, alimentary canal, while the nephrocytes , , gut and in some Apterygota, certain cephalic glands have also been regarded as excretory to some extent.

The integument as excretory organs:

The body wall consists of chitin, while is a nitrogenous substance salts, pigments and a lot of body wastes will deposition in it. and the insect loses a large amount of nitrogen and calcium or other substances may be contain in the exuviae such as a pigment.

Respiratory in insect, always takes place through some part of the ectoderm, and this way, the ectoderm serves as an excretory tissue for the elimination of the carbon dioxide and water. Insects such as most of the Collembola, lacking tracheae or certain larvae closed or rudimentary tracheal system respire directly through the integument.

Excretortion through the walls of the alimentary canal:

Many of researchers proved that accumulation of crystalline bodies in the wall of the mesentron of the various insects. Most of these bodies are salt of calcium the bodies are probably excretory products or excess substances that cannot be utilized. the insect use little of calcium in its body structures, it must be eliminate most of the calcium absorbed from its food, and analysis of the faeces always show a percentage of calcium in the latter.

The nephrocytes:

Nephrocytes are part of the insect excretory system, drived from the embryonic mesoderm and many persist through metamorphosis into adult life. The cells are giant cells and supposed to have a similar on the substances naturally present in the blood, such as waste products of metabolism and for this reason they have been termed (storage kidneys) where they form long strands of the cells o each side of the heart, known as **pericardial cells.** These cells are agent for breaking down complex colloids. which are transformed by ferments produced in the cells into crystalloids, the latter are then given off into the blood, from which they are removed by the malpighian tubules.

Fat body:

The fat body is derived during embryogenesis from the mesodermal walls of the coelomic cavities. Its segmental disposition occurs as lose strands, sheet and lobes of tissue.

Generally there is:

1-Visceral layer around the gut.

2-Parietal or peripheral layer beneath the integument.

The fat body does have a definite arrangement in the hemoceole characteristic of the species. Typically, there are subepidermal and perivisceral layers of fat body, plus sheets or cords of cells occur in other specific locations. Tghus, the fat body presents a large surface area to the hemolymph, allowing the rapid exchange of metabolites, The fat body is therefore well adapted for main functions, the synthesis and storage of reserves materials. These include fat, protein and glycogen.

The fat body is composed mainly of cells called trophocytes, though in some species urate cells (urocytes) also can be seen scattered throughout the tissue. In embryos, early postembryonic stages, and starved insects the individual trophocytes are easily distinguishable, their nucleus is rounded, and their cytoplasm contains few inclusions or vacuoles. As such, they closely resemble hemocytes, In later larval stages and adults the trophocytes enlarge and become vacuolated. The vacuoles contain reserves of fat, protein, and glycogen. The trophocyte nuclei are proportionately large and frequently become elongate and much branched. During metamorphosis in endopterygotes, the reserves are liberated into the hemolymph. In some Diptera and Hymenoptera the majority of trophocytes also disintegrate at this time, and the fat body appears to be completely re-formed in the adult from the few cells that remain. In adult insects the fat body is more developed in female where its provides nutriment for egg development.

The fat body also perform an excretory function, in Collembolla, hymenoptera larvae, Orthoptera etc. special excretory cell containing deposits of urates are present among the ordinary cells of the tissues. The excretory cells serve in the main as storage cells until their products are eliminate at the time of population. in Collembolla, which lack malpighian tubes, urate concretions are deposited and increase in size throughout life, much the same is stated to occur in Lepisma, the Dermaptera and Othoptera, where the malpighian tubes apparently eliminate little uric acid.

Malpighian Tubules

These vessels are the principle organs of excretion and are slender blind tubes lying in the haemocoele where they are freely bathed in blood. They are vary greatly in number, ranging. for example from 30-120 in Orthoptera and from 4 to 6 among many Endopterygota. in the Aphididae and the large epithelial cells resting on an external basement membrane, outside the latter there are commonly muscle fibers. The inner margin of the cells show a striated border resembling that of the mid gut and there is no cuticular lining.

Histology of the malpighian tubules:

The transverse section of malpighian tubes is compossed about three or eight large and variably shaped epithelial cells with prominent nuclei. The latter increase in size during development and may became palmate or giant endopolypliod nuclei. each cell borders of tubules posses a brush or (honeycomb border) the appearance of which may vary over different parts of tubule. The epithelial cells also show an outer striated zone in many insects and rest externally on basement membrane which is covered by a peritoneal coat often containing muscle fibers. The muscles may run in brand or as a reticulum over the whole tube or be restricted to the proximal region, they appear not to be innervated but are responsible for peristaltic movement of the tubule. in the thysanura, Dermaptera, and thysanoptera there are no muscle and peristalsis does not accur.

In some species with cryptonephridial arrangement, the distal part hemocoele and giving a strong reaction for chlorides.

Function of Malpighian Tubules:

These remove excretory materials from the blood in the form of urine, which is secreted into the lumen of the tubule and ultimately discharged into the hind gut. Where its composition may be modified by resorption before it passes out with the faeces. The urine may be a clear aqueous liquid or a thick suspension and its composition differs in different insects. The principal nitrogenous material is uric acid-or perhaps its ammonium. sodium or potassium salts- usually appearing in the form of crytalline spheres. some species secrete substantial quantities of allantion, allantoic acid urea or ammonia. Inorganic salts in solution or as granules or spheroidal concretion also occur.

Various fanctional modifications of the malpighian tubules occur in different insects, many of these permit the elimination of nitrogenous material while conserving the limited supply of water available in terrestrial organisms.

In Rhodenius the distal part of each tubule secretes a solution of sodium or potassium acid urate while the proximal part reabsorbs much of the water and bases, the letter in the form of bicarbonate. Uric acid is thus precipitated as crystalline spheres in this part of the tubule while the water and bases are reciculated continually. Farther absorption of water and sodium ions occur in the rectum.

In lepisma, Ortoptera, Neuroptera, and many coleopteran the malpighian tubules contain fluid while precipitation of white crystalline mass of uric acid take place in the rectum through whose walls water absorption is carried out.

In mosquitoes and muscid flies, the malpighian tubules contain solid of uric acid throughout their length and a method of precipitation occurs different from that found in Rhodenius.

In many coleopteran and the larvae of Lepidoptera the distal parts of the malpighian tubules are closely water conservation by using the combined absorptive capacity of the rectum and malpighian tubules.

In the mealworm (tenebrio), where such an arrangement occurs, the malpighian tubules only contain clear fluid and the rectum is mainly occupied by a dry mass of uric acid apparently precipitated by the almost complete absorption of the available water.

Other excretory product include calcium salts that are sometime taken into the body in quantities greatly above requirement, they are present in the malpighian tubules either as amorphous granules or less frequently as soled spheres or crystals. the most general compound is calcium carbonate, which is usually stored during larval life and often used in various ways during metamorphosis, disappearing by the time the imago is reached.

Many dipterous larvae contain calcium carbonate either in the malpighian tubules or in special cells of the fat body, in phytophagous larvae of the family Agromizidae the calcium occurs as laminated body or (calcosphaerites) that are seen clearly in those of the celery fly and other species. At metamorphosis the calcium carbonate dissolve in the blood and becomes deposited on the inner wall of the puparium.

The malpighian tubules of some insects also have accessory secretory function . those of Cercopid nymphs, for example produce a foamstabilizing substance, and in several neuroptera and Coleoptera larvae they secrete the silk from which pupal cocoon is constructed.

Reproductive systems Lecture 13

The reproductive organs, which differ appreciably in the two sexes, consist of:

1-a pair of gonads, which are derived from mesoderm.

2-The system of efferent ducts, which is usually partly mesodermal and partly ectodermal.

3-The various annexes such as necessary glands and structures for the temporary retention of the spermatozoa. Closely associated with the external opening of the reproductive are the external genitalia.

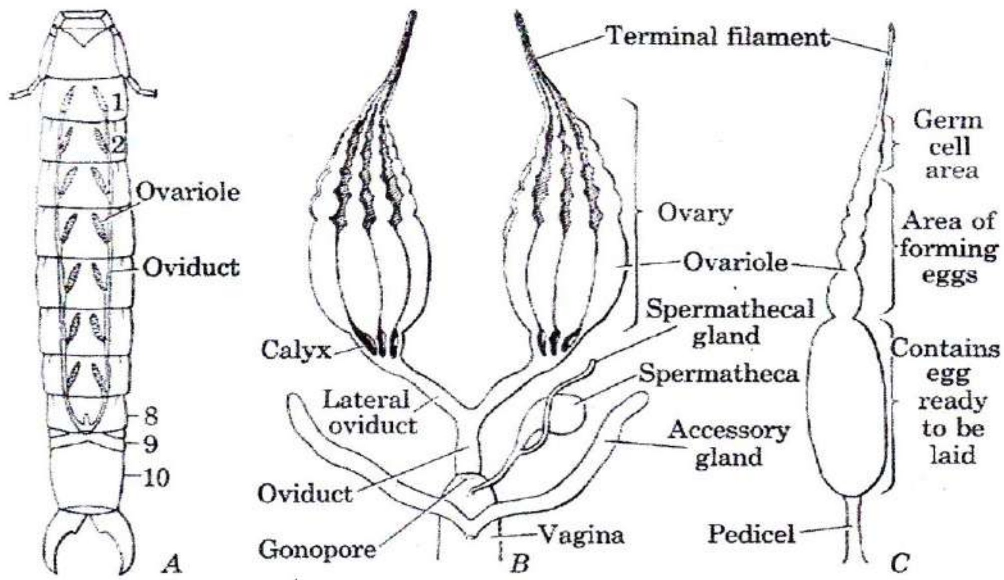
The female reproductive system

The female **ovaries** discharge the eggs into a pair of tubular **lateral oviducts**, almost always formed from mesoderm. In the mayflies, each oviduct opens by separate **gonopore** behind the seventh abdominal sternum and a condition recalling this primitive state of affairs is passed through in the immature stages of most insects. In the adults, however, the lateral oviducts generally run into an unpaired **common oviduct** which is then continued into a wider passage or **vagina**, whose orifice lies behind the eighth or ninth abdominal sternum. These unpaired parts of the reproductive system develop from one or two ectodermic invaginations. Further ectodermic ingrowths give rise to the **spermatheca** or **receptaculum seminis** and to a pair of accessory glands. In the adult these organs usually open by short ducts into the common oviduct or vagina.

The ovaries:

The ovaries are typically lying in the body cavity of the abdomen on either side of the alimentary canal. Each organ usually consist of several egg tubes or **ovarioles**. Which are only occasionally bound together by an outer membrane into a more or less compact organ. The ovarioles may open into the lateral oviduct one behind the other or they are arranged in radiating manner and all enter it at about the same place.

There are commonly 4-8 ovarioles in each ovary, but some Hymenoptera may have more than 200 and even this number is exceeded to 2,400 among species of some termites *Eutermes*. Each ovary of some viviparous Diptera, on the other hand, consists of single ovariole.



Female reproductive system. *A*, primitive type of *Heterojapyx gallardi*; *B*, diagram of common type found in many insects; *C*, diagram of a single ovariole. (Redrawn from Snodgrass)

The ovarioles:

A typical ovariole is an elongate tube in which the developing eggs are disposed one behind the other in a single chain, the oldest oocytes being situated nearest the union with the oviduct. The wall of an ovariole is a delicate transparent membrane its inner coat is a layer of epithelium whose cells rest upon a basement membrane. Outside the latter is a peritoneal coat of connective tissue which, in many insects, contains muscle fibers and is covered by a reticulate layer of tracheal end cells. Three zones or regions are recognizable in an ovariole:

1- Terminal filament.
2- a germarium.
3- a vitellarium.

1-The terminal filament.

Is the slender thread- like apical prolongation of the peritoneal layer. The filament of the ovarioles of one ovary combines to form a common thread which unites with that the ovary of the opposite side to form a median ligament. The latter aids in maintaining the ovaries in position and is attached either to the body-wall, the fat body or to the pericardial diaphragm. In some insects the ovarian ligament is wanting and the filament end free in the body cavity. The terminal filament of all the ovarioles of one side are usually united to form a suspensory ligament.

2-The germarium.

This forms the apex of an ovariole, below the terminal filament, and consists of a mass of cells from which are differentiated the primordial germ cells or oogonia. These later become differentiated into oocytes and also, when they are present, into **nurse cells** or **trophocytes.**

3-The vitellarium:

The vitellarium constitutes the major portion of an ovariole consists of a longitudinal series of developing eggs, the smallest and youngest being those nearest to the germarium. As they grow by the deposition of yolk, the eggs distant the ovariole into a series of a follicles or egg chamber. Each egg is enclosed in a layer of follicular epithelium which eventually secrets the chorion or egg-shell. In the ovarioles of some insects only the lowermost (i.e. oldest) eggs are completely developed and ready to be discharged. In others most of the eggs have completed their development by the time oviposition beings.

There are three types of ovarioles:

1-The panoistic type:

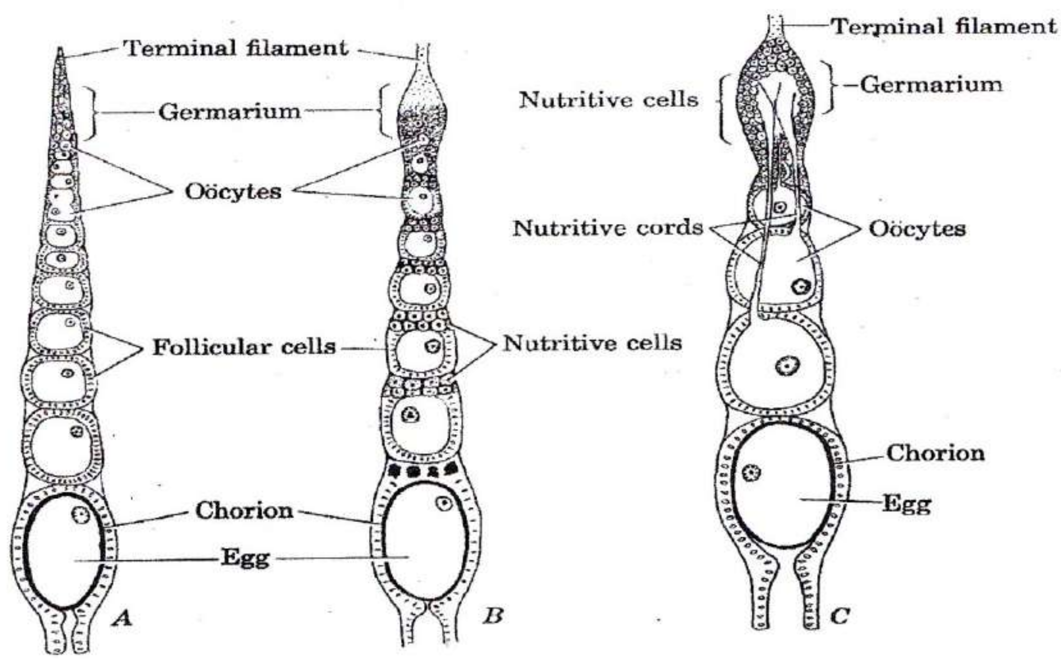
has no nurse cells, the developing egg cell may itself synthesize some components of the yolk and receives others from the undifferentiated follicular epithelium, which transfers materials obtained from the blood. This primitive type of ovarioles occur in Apterygota, Odonata, Orthoptera and other orders.

2-Polytrophic type:

each developing egg is associated with an adjacent group of nurse cells which are responsible for producing some fractions of the yolk. This type is found in most Endopterygota.

3-Acrotrophic type:

the nurse cells are confined to the germarium and are connected with the developing occyte by progressively lengthening cytoplasmic strands, along which some of the nutritive materials pass. This kind of ovariole occurs in the Hemiptera and some Coleoptera.



Longitudinal section of ovarioles. *A*, simple or panoistic type having only oöcytes; *B*, polytrophic type having oöcytes and nurse or nutritive cells alternating; *C*, teleotrophic type having nurse cells connected to oöcytes by nutritive cords. (Redrawn from Weber)

Genital ducts and associated structures:

The lateral oviducts are paired canals leading from the ovaries and are usually formed from mesoderm at the hinder extremities of the embryonic gonads. The two lateral oviducts join the common oviduct, which is initially developed from an invagination of the body wall behind the 7^{th} abdominal sternum but which generally becomes extended through the 8^{th} segment to join the vagina, which arises from an infolding behind segment 8.

In many adult insects there is no obvious distinction between these parts of the median reproductive duct but in certain viviparous insects (*Glossina*) The vagina is greatly enlarged to form a chamber or uterus for reception of the developing larva or, in the more generalized insects, it forms little more than a shallow genital chamber into which the common oviduct opens. If present, the bursa copulatrix is a pouch-like development of the vaginal region and when, as often happens, the latter becomes extended into the 9^{th} segment to open there by the definitive genital aperture, the bursa loses direct connection with the exterior.

The **spermatheca** is usually a sac like organ which opens into the common oviduct or vagina by a more or less elongate **spermathecal duct.** In some cases glandular cells are present in the wall of the spermatheca and in others a special **spermathecal gland** opens into the duct of the spermatheca, or near the aperture of the latter into the vagina. The spermatozoa received in mating are stored here and pass down the duct to fertilize the eggs as the latter move along the common oviduct before being laid.

The female accessory glands (**colleterial glands**) usually open into the vagina and often secrete an adhesive substance for cementing the eggs to each other or to the substrate on which they are laid. In the cockroaches and praying mantids their secretions produce the sclerotized ootheca or egg capsule in which the eggs of these insects are enclosed.

In the higher Lepidoptera there are two reproductive opening. The anterior one, on the eight sternums, it leads into a large **bursa copulatrix**, which is connected by a narrow **sperm duct** which the common oviduct.

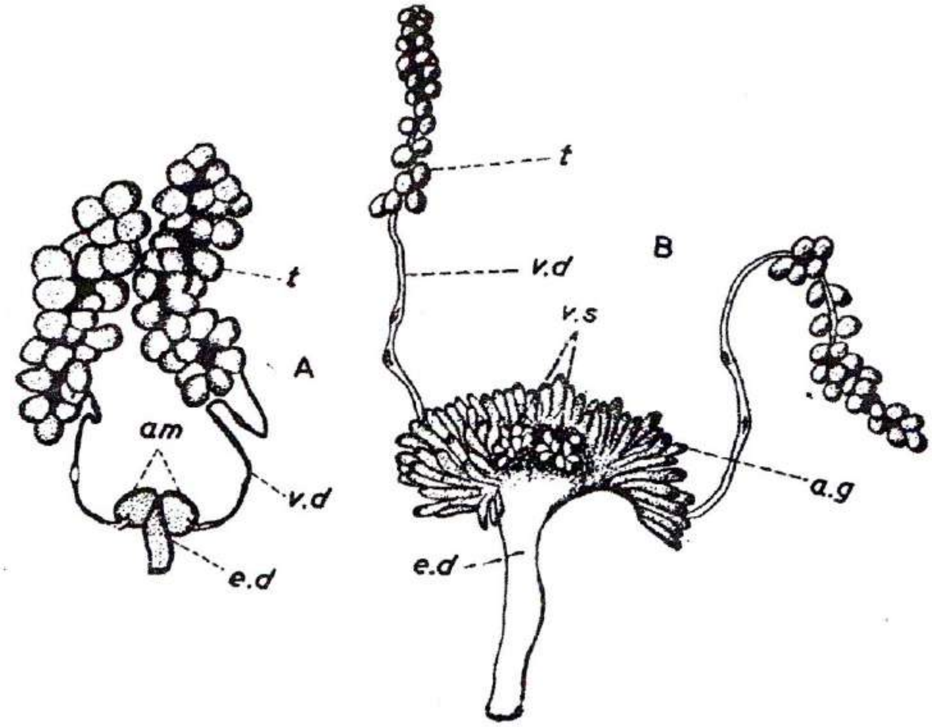
The latter is continued into the vagina along which egg pass to be discharged through the egg pore on the 9th sternum. The spermatheca joins the common oviduct by a duct in whose wall is a fine **fertilization canal.** Spermatozoa, enclosed in a protein- aceous sac or **spermatophore,** are deposited in the bursa copulatrix, from which they eventually make their way to the spermatheca.

The male productive system

The mesodermal parts of the male reproductive system are a pair of gonads or **testes** and two lateral ducts or **vasa deferentia**. The latter join a median ectodermal passage, the **ductus ejaculatorius**, which usually opens to the exterior on the **aedeagus** or **penis**. In addition to these essential parts there is frequently a pair of **vesicular seminales** or sperm reservoirs, formed by the enlargement of a part of each vas deferens. Accessory glands of ectodermal origins are also commonly present.

The testes

Each testis is composed of tubules or follicles, variable in number, which opens by narrow passage or **vasa efferentia** into the **vas deference** of their side. The testis is covered outwardly by an epithelial sheath often, though inaccurately, known as the peritoneal layer. Each follicle is lined by epithelium resting on a basement membrane, and it is from the cells of this lining that primordial germ cells are derived. A succession of zones, in which the germ cells are in different stages of development, are to be distinguished. At the apex of a follicle is the **germarium** which comprises spermatogonia among numerous somatic cells. Lower down each spermatogonium becomes surrounded by somatic cell to form a cyst. By the repeated division of a **spermatogonium** from 64 to 256 **spermatocytes** are produced. In the next zones, or **zone of maturation**, the spermatocytes undergo reduction division so that their chromosome number is halved. Each spermatocyte ultimately produces four **spermatids**. There follows **a zone of transformation** in which the spermatids, still enclosed in the cyst wall, are converted into **spermatozoa**. The latter break out of the cyst by lashing movements of their flagella. At first the spermatozoa adhere by their heads in bundles, but they ultimately become free.



Blatta orientalis, Male reproductive system
A, Reproductive system of 6th instar nymph. B, The same in adult male (both equally magnified). *am*, ampullae; *a.g*, accessory gland; *e.d*, ductus ejaculatorius; *t*, testis; *v.d*, vas deferens; *v.s*, vesicula seminalis. (*Adapted from* Qadri, 1938)

Genital ducts and accessory structures

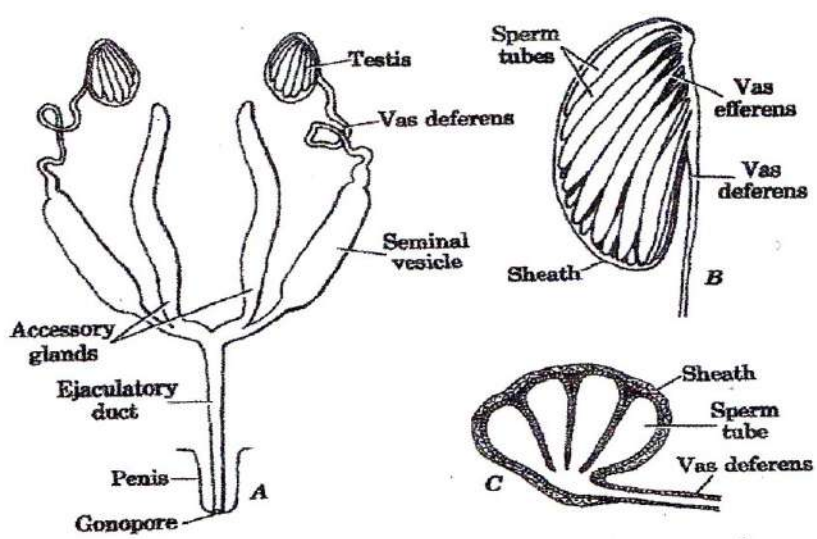
In mayflies the **vasa deferentia** remain separate and each enters the penis of its side. From this generalized condition is derived the typical system in which a median ectodermic ingrowths gives rise to the **ductus ejuculatorius**.

Where the vasa deferentia join the anterior extremity of this canal their ends become enlarged ampullae which unite to form a mesodermal vesicle.

The **accessory glands** are of two kinds. In *Blatta* and most orthoptera numerous glands arise from the vesicle just mentioned and, since they are of mesodermal origin, they are classed as **mesadenia**. In other insects from one to three pairs of accessory glands may occur, and those arising from the ectoderm of the ductus ejuculatorius are termed

ectadenia. In many cases the accessory glands produce substance which go to form a kind of capsule or spermatophore that encloses the spermatozoa. It is deposited in bursa copulatrix or vagina of the female during mating, the spermatozoa ultimately becoming free.

Spermatophores vary in form and structure and several may be produced during a single mating. They occur Orthoptera, Dictyoptera, Lepidoptera and other orders. In a few insects peptide secretions of the male accessory glands affect the female, reducing her readiness to mate again or stimulating her to lay eggs. **Vesiculae seminales** are found in many insects and are developments of the vasa deferentia. In *Blatta* they take the form of numerous outgrowths of the mesodermal vesicle, and as the testes degenerate in adult cockroaches spermatozoa are then only found in the seminal vesicles.



Typical male reproductive system of an insect. *A*, entire system; *B*, structure of a testis; *C*, section of a testis and duct. (Redrawn from Snodgrass)

Reproduction

In most insects reproduction depends on copulation between adult of opposite sex and the female then lays eggs, from each of which a single immature insect hatches after a more or less prolonged incubation period.

Exceptions to these various generalizations, however are not uncommon and are dealt with below.

Sperm Transfer

This normally occurs during copulation by methods indicated above, but a few insects show anomalous forms of sperm transfer. In many

Apterygotes the males deposit semen externally in small droplets, which are then taken up into the genital tract of the female when she moves over them. The dragonflies are unique in that before mating the male transfers' spermatozoa to a secondary copulatory organ near the front of the abdomen, from which the female receives them when the pair flies in tandem. In bed-bugs (*Cimex*) and a few related Heteroptera, the spermatozoa are transferred by the aedeagus, but pass through the abdominal body wall of the female into the haemocoele, thence migrating to the ovaries, where fertilization takes place.

Parthenogenesis

In this type of reproduction the eggs undergo full development without having been fertilized. It occurs in representatives of most orders and may be **obligate**- when males are very rare and non functional or **facultative**, when it co-exists with normal bisexual reproduction. Four important types of parthenogenesis are known:

1-in the honey bee and some other insects the females lay two kinds of eggs. Those which are unfertilized have only the reduced (haploid) number of chromosomes and give rise exclusively to males, whereas the fertilized eggs, with the full diploid number of chromosomes, produce only females (including the sterile females or workers of the honey bee).

2-In some sawflies, some stick- insects and one species of scale-insect, the female again lays two kinds of eggs. Those of which have been fertilized produce about equal numbers of males and females but in the unfertilized eggs there is a fusion of the egg nucleus with the second polar body. This restores the diploid chromosome number but such eggs develop only into females.

3-A striking type of obligate parthenogenesis occurs in some aphids, stick-insects' weevils and moths. The eggs are formed without meiosis and only female progeny result. Male do not occur in these species, which are able to reproduce rapidly but lack the genetic variability found in bisexual forms.

Viviparity

In some insects, embryonic development is completed within the body of the female parent, which therefore produces living young instead of laying eggs. Such viviparity may mean little more than the retention within the vagina of otherwise normal and fully yolked eggs until the young insects hatch out are expelled. In testse flies (*Glossina*) and pupiparan Diptera such as the sheep ked *Melophagus*, however the larvae remain after hatching in the enlarged vagina of the female, where they feed and grow and are deposited as mature larvae ready to pupate. In other cases (e.g. aphid and the ectoparasitic earwig) the eggs have no chorion and are practically devoid of yolk. A special placenta-like structure is therefore developed to nourish each embryo.

Paedogenesis

This term denotes reproduction by a juvenile stage. It occurs in only a few species, one of the best-known examples being the gall midge *Heteropeza* (Cecidomyidae). Here, as in the other known examples, reproduction involves both parthenogenesis and viviparity. Within the body of the parent larvae unfertilized eggs give rise to daughter larvae. These then eat their way out of the body of the parent larvae which during process. The daughter larvae may repeat this cycle or give rise to normal male and female insects. Paedogenesis also occurs in the complex life cycle of the beetle *Micromalthus* from N.America and South Africa.

Polyembryony

Polyembryony is the production of two or more often-very many-embryos from a single egg (which may be fertilized or developed parthenogentically). It occurs in a Strepsipteran (*Halictoxenos*) and has been evolved in several more or less widely separated genera of parasitic hymenoptera.