Insect Morphology

Lecture 1

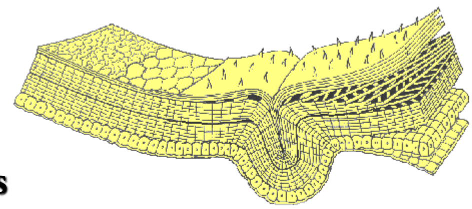
Why Study Morphology ?

- **An understanding of the external structure of the insect is necessary…**

  - to allow the identification of insects and other arthropods

  - to understand their biology and control

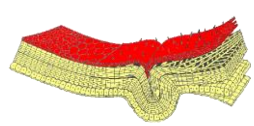
Exoskeleton



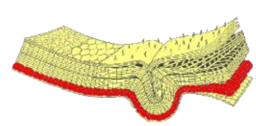
- Outer layer or "skin"
- Functions:
  - Protection of soft parts
  - Muscle attachment
  - Support
  - Site for sensory organs
  - Helps prevent desiccation
  - Reduces pathogen entry

Components of the Exoskeleton

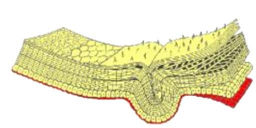
- Cuticle
  - non-living



- Epidermis
  - living
  - secretes the cuticle



- Basement membrane
  - non-living
  - function not known



Cuticle

- **Key contributor to the success of insects**
  - **barrier between living tissue/environment**
  - **restriction of water loss**
  - **abrasion protection**

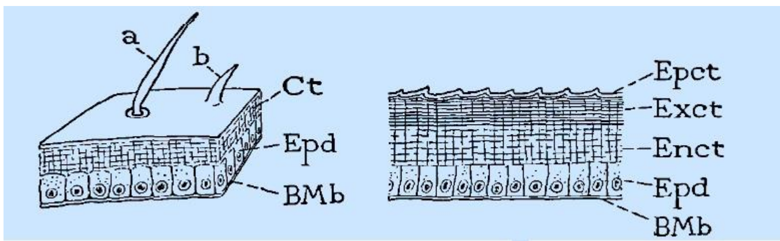


Fig: Structure of body wall. A, piece of body wall bearing a movable seta (a) and immovable process (b).Ct: cuticula; Epd: epidermis; Bmb: basement membrane. B, vertical section of body wall, Epct: epicuticula; Exct: exocuticula; Enct: endocuticula.

Sclerotization

- **The most important feature of insects' body wall is its ability to produce definitely limited sclerotic areas in the cuticula.**
- **It mainly served for protection.**
- **the presence of integumental plates having the muscles attached on the body wall gave the possibility of a new mechanism of movement and locomotion.**

Sclerotization

Sutures:

- **The terms suture comes from the latin word *suere*, is to sew.**
- **It is a narrow space separating sclerotic areas of the cuticula**.

Four distinct varieties of sutures:

1. **External grooves of linear inflections of the cuticula that form internal plates to strengthen the skeletal walls to increase surfaces for muscle attachments.**
2. Lines where the Sclerotization of cuticula has become secondarily discontinuous in order to give flexibility.
3. Lines where Sclerotization has never taken place.
4. True sutures or lines of union between originally distinct sclerites.

The majority of insects sutures belong to the first category.

Sclerotization

Apodemes:

- **Any internal cuticular process of the body wall is apodeme.**

Types of apodemes:

1. **An inflection of cuticula (A, B& C).**
2. **solid cuticular ingrowth (D & E).**

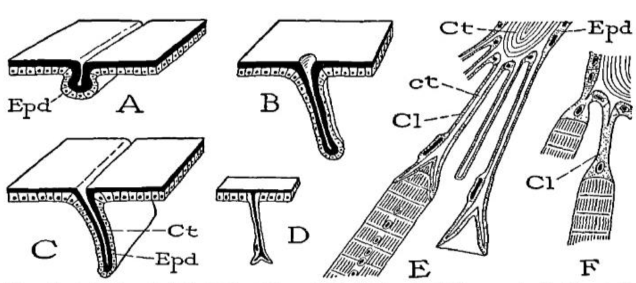


FIG. 26.—Apodemes, or internal processes of the body wall. A, B, C, various forms of multicellular apodemes, diagrammatic. D, a unicellular apodeme. E, unicellular muscle "tendons" at the end of a multicellular apodeme. F, formative stage of the same. (E, F *from Janet*, 1907.)

Articulations

- **Where there is a line of movement in the body wall.**
- **The flexible area or joints is the nonsclerotized cuticula between two adjacent regions of Sclerotization. (fig, A)**
- **The movements possible at the joints will depend on the extent of the articular membrane.**
- **if the articular membrane is wide and completely separates the sclerotic parts, as between the segments of the abdomen, (fig, B) the movement is unrestricted.**

Articulations

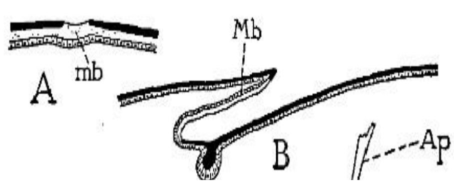
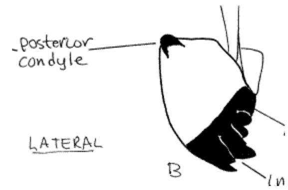


FIG. 27.—Sutures, joints, and articulations, diagrammatic. A, section through a simple membranous "suture." B, a conjunctival membrane (*Mb*) between two body

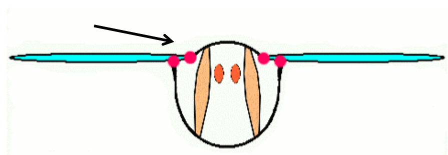
Articulations

According to whether an articulated joint has one pair or two pairs of articulating surfaces it is said to be:

- **Monocondylic (joint have a partial rotary movement) – antennae and mandibles**



- **Dicondylic (joint is restricted to hinge movement).Wings**



Articulations

Articulations are of two types of structure:

- **Intrinsic articulation:**

Points making contact are sclerotic prolongations within the articular membrane (The articulations of the legs with the body or between leg segments “the pleuro- coxal articulations”. (Fig , C, e& f).

- **extrinsic articulation:**

The articulating surfaces are areas of contact on the outside of skeletal parts

(are usually of the ball and socket type and found in the articulation of mouth appendages with the wall of the cranium. (Fig 3, D, a & c),

Articulations

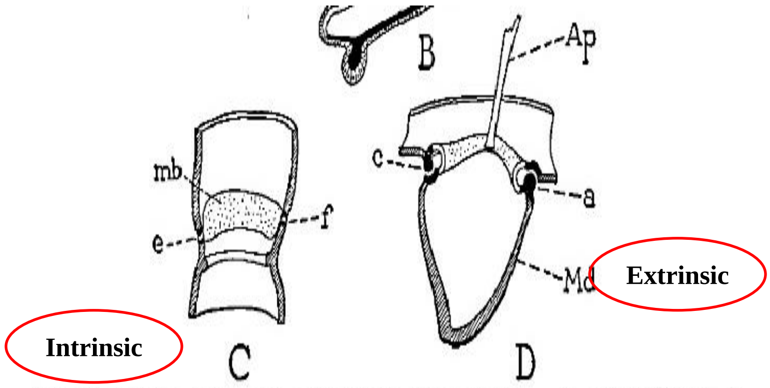
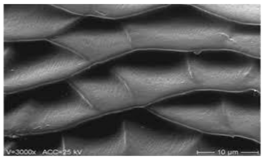


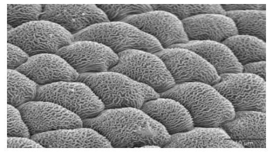
FIG. 27.—Sutures, joints, and articulations, diagrammatic. A, section through a simple membranous "suture." B, a conjunctival membrane (*Mb*) between two body segments. C, a dicondylic leg joint with intrinsic articulations (*e*, *f*). D, the typical extrinsic dicondylic articulation of the mandible with the cranium.

External processes of the body wall

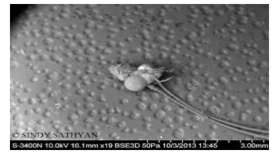
- The outer surface of the cuticula is rare smooth or bare.
- It presents a great variety of microscopic roughening in the form of points, pits, ridges, and sculptured designs, and it is covered with larger outgrowths that take the shape of spicules, spines, hairs, and scales.



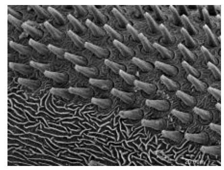
pits



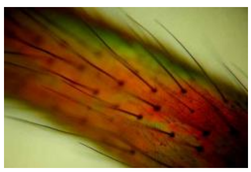
ridges



points

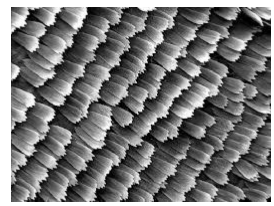


spicules



hairs

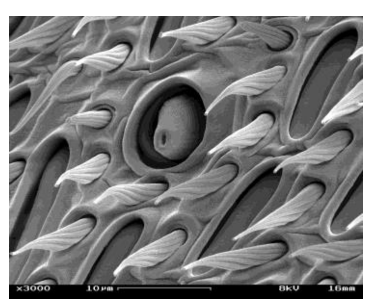
spines



scales

External processes of the body wall

two groups

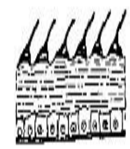


External processes of the body wall

Noncellular process:

- They have the form of minute points or nodules (spicules, small spines, hairs).
- cytoplasmic processes of the epidermis when the outer layers of the cuticula are being generated and become solid. (Fig A & B).

A



B

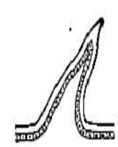
External processes of the body wall

Cellular process:

- **Multicellular process:**

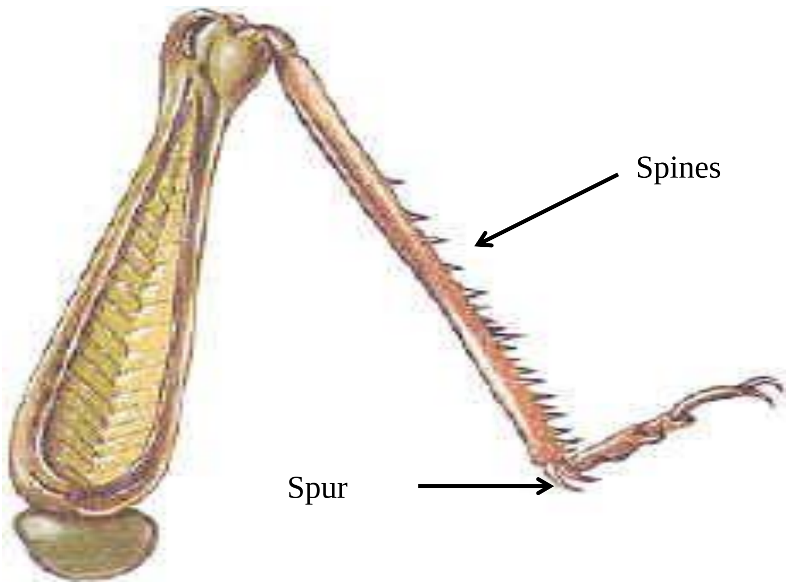
1. hollow outgrowths of the entire body wall and are lined by a layer of epidermal cells.(C)
2. large and spine-like, and they are strongly fixed to the surrounding cuticula, but some are set in membranous ring and are movable (D).

Movable structure (spurs) , Immovable (spines)



C

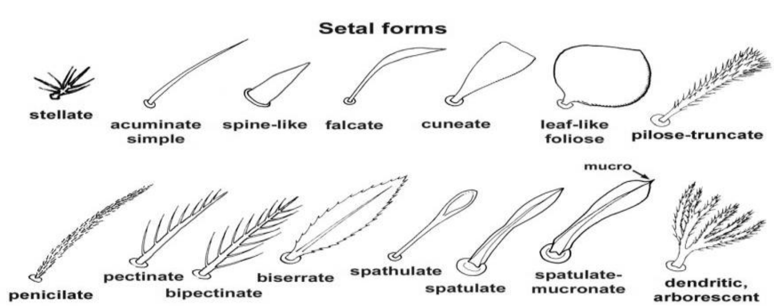
D



External processes of the body wall

Unicellular process:

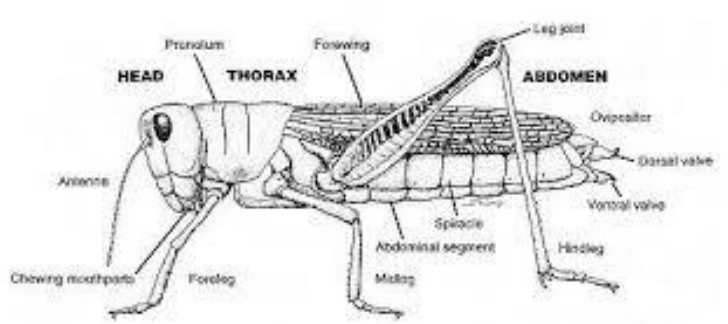
The typical outgrowths of the body wall in this class are the hairlike processes, termed **setae**, which constitute the principal body covering of most insects.



Insect Morphology

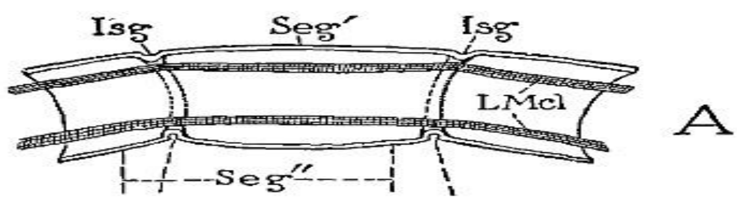
lecture 2

Body regions, Sclerites and segmentation



Segmentation

- In soft bodied segmented animals the segmental regions of the body are separated by circular constrictions of integument.
- Intersegmental grooves form folds internally.
- On these folds are attached the fibers of the principal longitudinal bands of somatic muscles.



Body regions

- Insect bodies consists of cylindrical trunk containing visceral organs and series of ventrolateral limbs .
- The body divided into three main parts

1- Head

2- Thorax

3- Abdomen

The Head

- The head is enclosed in a hard, heavily sclerotized, exoskeletal head capsule, or **epicranium**.
- The **epicranium** bears most of the main sensory organs. **(antennae, ocelli, compound eyes and mouth parts).**
- Head capsule is apparently unsegmented.
- But embryological studies show it to consist of six segments.

The Head

Head capsule is consists of :

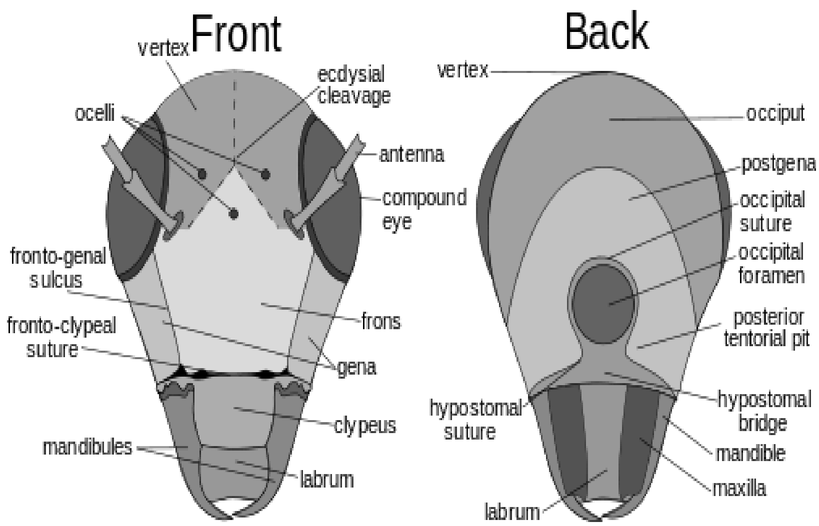
1- vertex:

Or the apex (dorsal region) is situated between the compound eyes.

2- Frons:

- lies ventrad or anteriad of the vertex.
- Is bordered at its anterior by the **frontoclypeal** or **epistomal sulcus** above the clypeus.

The Head



The Head

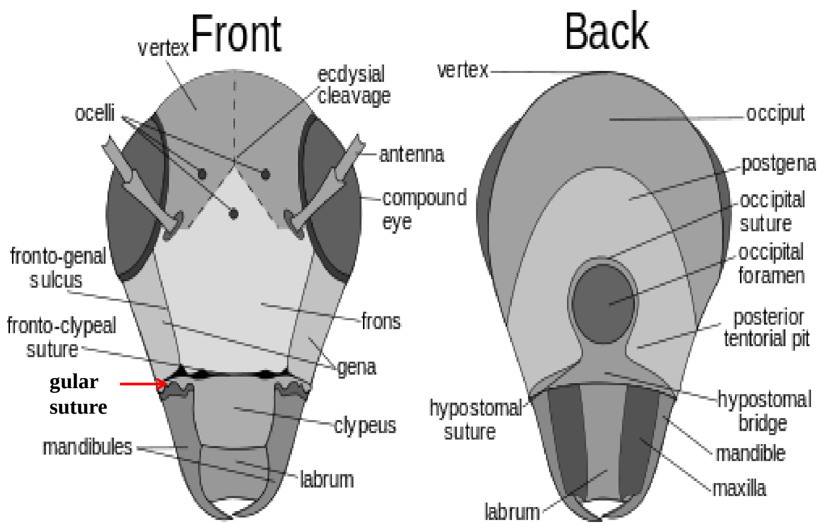
3- clypeus :

Sclerite between the face and labrum, which is dorsally separated from the frons by the frontoclypeal suture

4- gena : **The cheek**

- forms the sclerotized area on each side of the head below the compound eyes extending to the gular suture.

The Head



The head appendages

The usual appendages of the insect head include:

- **The Antennae**
- **Mouth parts**
- **Eyes**

The head appendages

The Antennae:

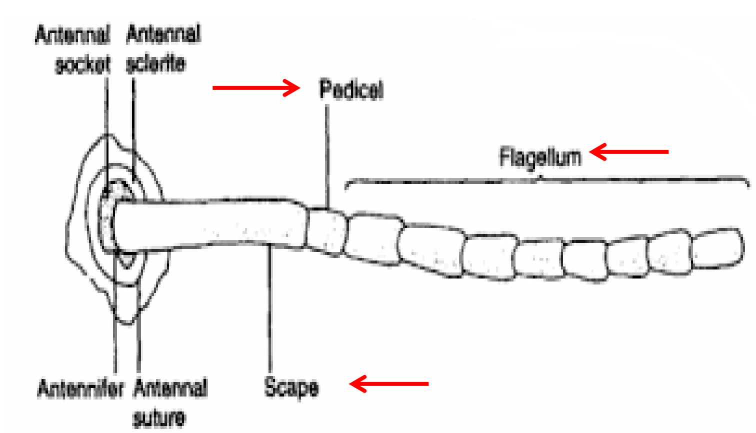
- The antennae are the first of the appendicular organs of the head present in the adult insect.
- Insect antenna is many jointed filament, but generally composed of three main parts:

1-Scape

2- Pedical

3- Flagellum

The head appendages



The head appendages

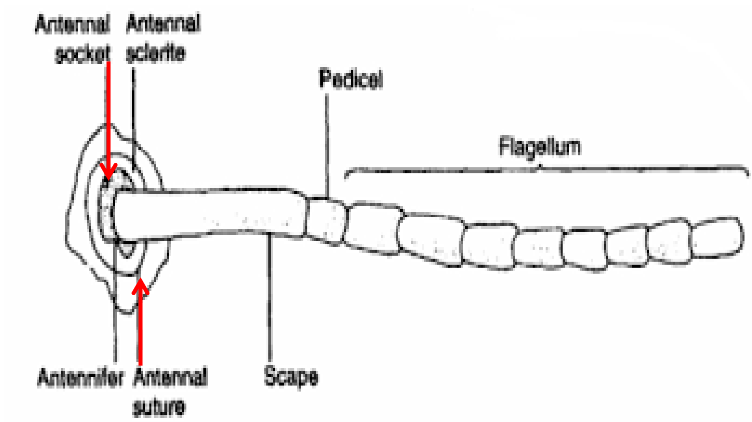
Scape: by which the antenna is attached to the head and is usually larger than other segments.
Pedical: is short and nearly all insects contains a special sensory apparatus known as the **organ of Johnston.**
Flagellum: or **clavola**, is the part beyond the pedical. and is usually long and made up of many small subsegments, but it may be reduced to a single piece.

The head appendages

How is attached to the head??????

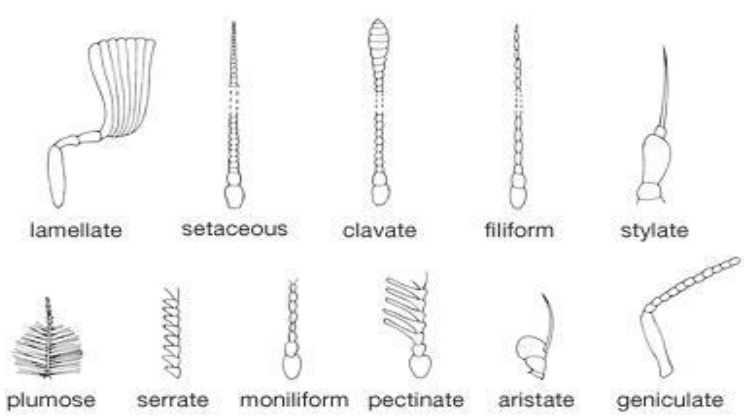
- The base of the antenna is set into a small membranous area of the head called the **antennal socket**. The edge of the socket is strengthened by internal submarginal ridge formed by an external inflection called the **antennal suture**.
- Each antenna is moved as a whole by muscles inserted on the base of the scape.

The head appendages



The head appendages

Types of antennae:



The head appendages

Mouth parts

The five primary parts of the insect "mouth" are:

1) The clypeus

2) The "upper lip", or labrum

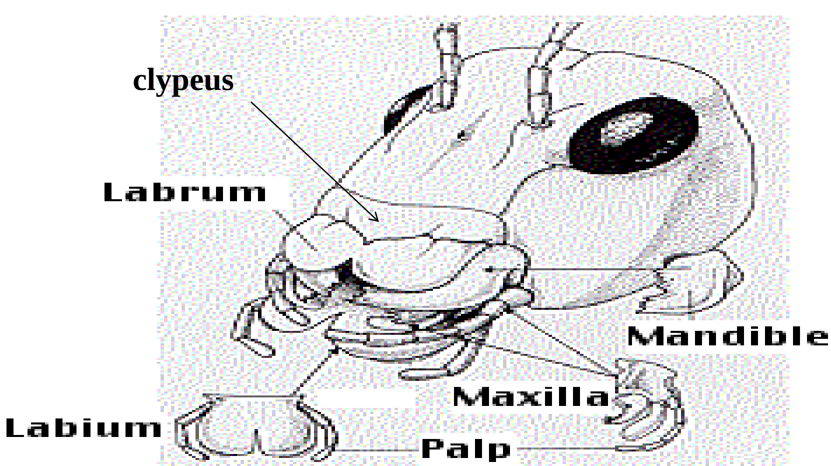
3) Two "jaw-like structures", or mandibles

4) The maxillae (sing. maxilla)

5) The "lower lip", or labium

The head appendages

Mouth parts



The head appendages

Mouth parts

1) The clypeus:

- **Make up insects face**
- **it delimits the lower margin of the face with the labrum articulated along the ventral margin of the clypeus.**

The head appendages

Mouth parts

2) The "upper lip", or labrum: flap-like structure that lies immediately in front of the mouth, and it acts as the upper lip in the chewing mouth parts.

The head appendages

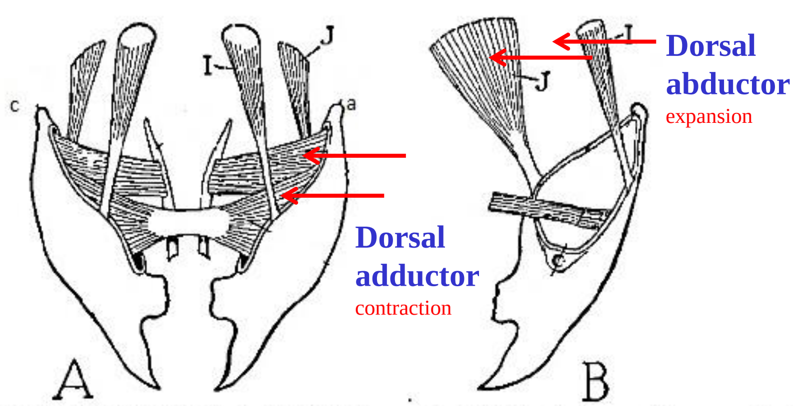
Mouth parts

3) Two "jaw-like structures", or mandibles:

- the first gnathal segment.
- strong biting jaw
- hinged to the head by anterior and posterior articulations.
- with one points of articulation with the head capsule (monocondylous).
- transverse movement produced by abductor and adductor muscles arising on the dorsal wall of the cranium.

The head appendages

Mouth parts



—Diagrams of types of insect mandibles. A, apterygote type with one articulation (a′). B, pterygote type with two articulations (a′, c).

The head appendages

Mouth parts

4) The maxillae (sing. maxilla)

- Situated beneath the mandibles
- Its dorsal side bears a **single condlys** by which it articulates with the lower lateral margin of the tergal region of the cranium .

The head appendages

Mouth parts

4) The maxillae (sing. maxilla) divided into

1. **Cardo**

Usually the cardo is flexed on the upper end of the stipes.

1. **Stipes :**bears two endite lobes

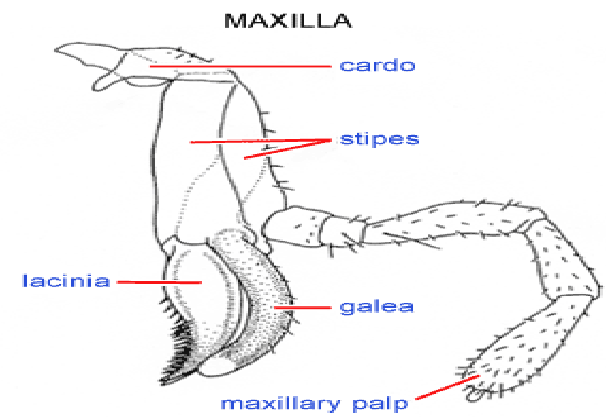
A- **Lacinia**

B- **Galea**

Latered to the galea arises the palpus

The head appendages

Mouth parts



The head appendages

Mouth parts

5) The "lower lip", or labium

- It is the major component of the floor of the mouth.
- quadrilateral structure
- formed by paired, fused secondary maxillae.
- assists manipulation of food during mastication.

The head appendages

Mouth parts

5) Labium divided into three regions:

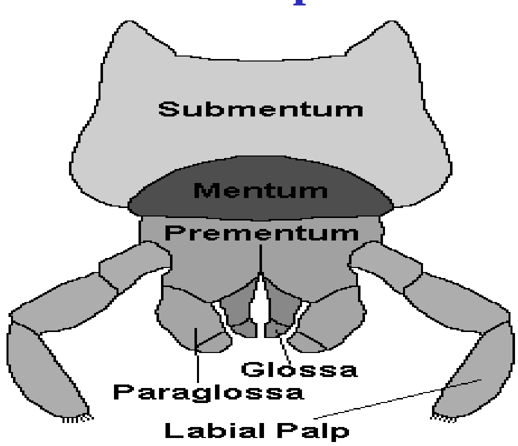
- **Submentum**
- **mentum**
- **Prementum**

bears (ligula) a- glossa b- paraglossa

c- labial palp

The head appendages

Mouth parts



The head appendages

Mouth parts

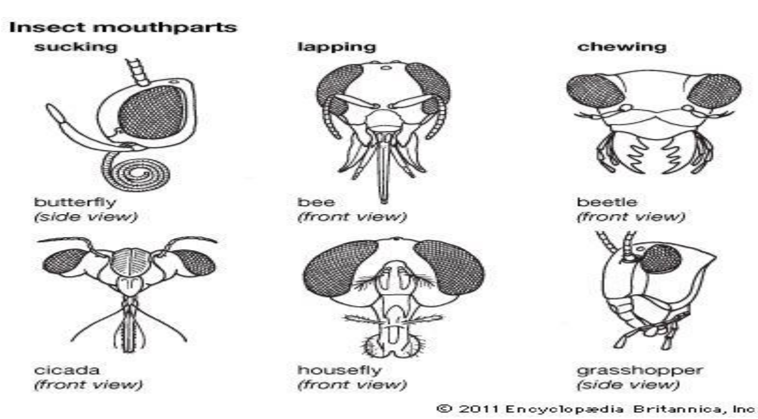
Glands of the head appendages:

1. **Antennal glands**
2. **Mandibular glands**
3. **Maxillary glands**
4. **Labial glands**

The head appendages

Mouth parts

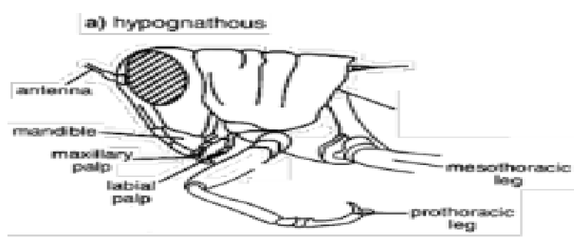
Types of mouth parts



Orientation of the mouthparts:

1- Hypognathous:

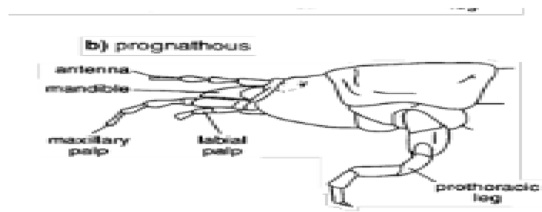
- Mouthparts are directed ventrally downward.
- Common in phytophagous groups inhabiting open habitats (Thysanura, cockroaches, mantids, phytophagous beetles).



Orientation of the mouthparts:

2-Prognathous:

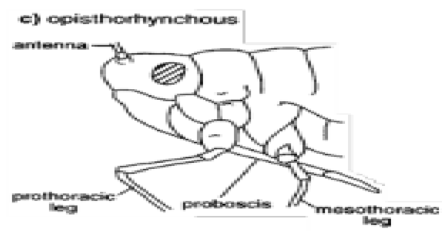
- Mouthparts directed forward.
- Common in carnivorous groups that actively pursue prey (earwigs, larval neuropterans, coleopterans, termite soldiers and ants).



Orientation of the mouthparts:

3- Opisthognathous:

- Mouthparts directed backward.
- Common in hemipteroid orders with sucking mouthparts.



Modifications in mouth parts

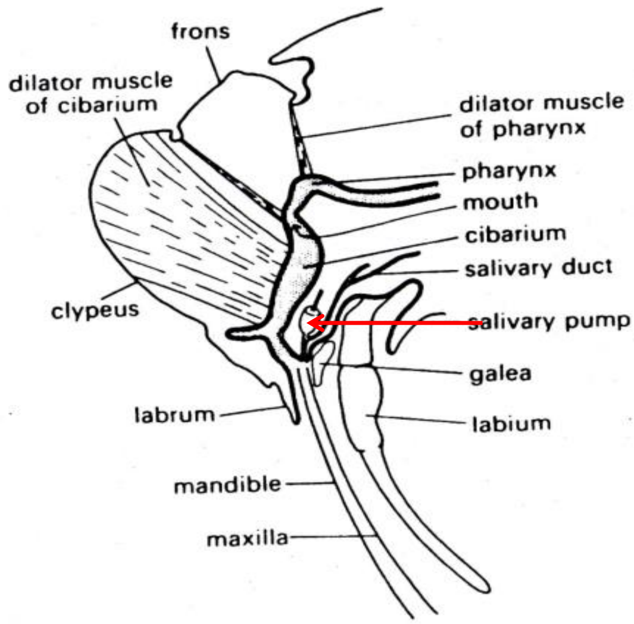
1- sucking mouthparts:

a-Presence of a sucking tube:

- **The sucking tube is the means by which liquid food is drawn into the mouth**.
- Mouthparts used to form this structure vary among groups.

b-Presence of a sucking pump:

- **The sucking pump creates the negative pressure necessary to draw the food into the mouth.**
- Many insects with sucking mouthparts also have a salivary pump for injecting saliva into the preoral cavity.



Modifications in mouth parts

2- Paraneoptera Mouthparts (piercing and sucking):

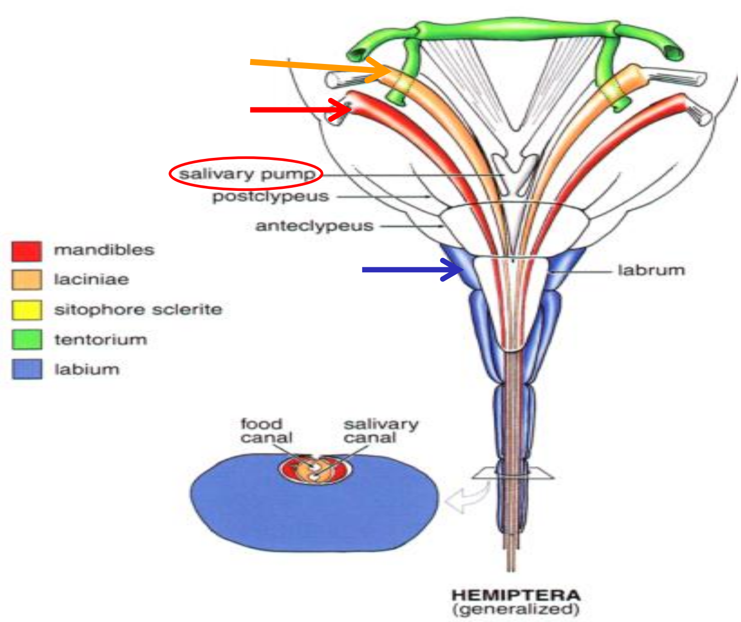
- **The sucking tube** (beak) in the Hemiptera is formed from the **mandibles, maxillae and the labium**.
- The **labium** forms the protective sheath that folds back during feeding.
- The **mandibles** form the outer stylets that surround the inner stylets.

Modifications in mouth parts

2- Paraneoptera Mouthparts (piercing and sucking):

- The **laciniae** of the maxillae form the inner stylets with the food and salivary channels.
- **The sucking pump** is formed in the pharynx.

❖ Negative pressure is generated by the enlargement of the cibarial dilator muscle attached to the clypeus.



Modifications in mouth parts

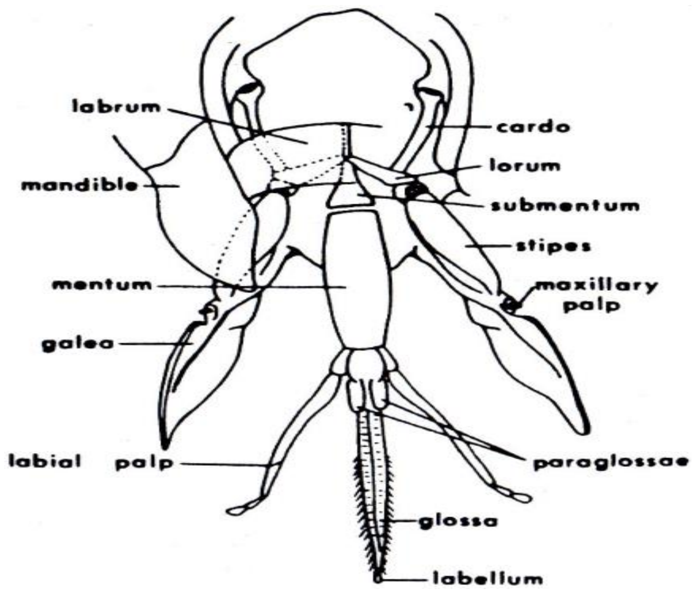
3- Lapping mouth parts: honey bee.

- Maxillae and labium are fused into a single structure.
- **The sucking tube** (tongue) is formed by the fusion of the **glossa** of the **labium**, sometimes together with the **paraglossa**.
- Maxillae and galea are enlarged and modified to form a cutting appendage used by short tongue bees to cut holes in flowers.
- Laciniae are lost and the maxillary palps reduced.

Modifications in mouth parts

3- Lapping mouth parts: honey bee.

- Mandibles are flattened and used for grasping and manipulating objects, rather than for biting and cutting.
- **The sucking pump** is formed by, the pharynx and the buccal cavity.
- Muscles associated with the sucking pump are attached to the **frons and the clypeus**.



Modifications in mouth parts

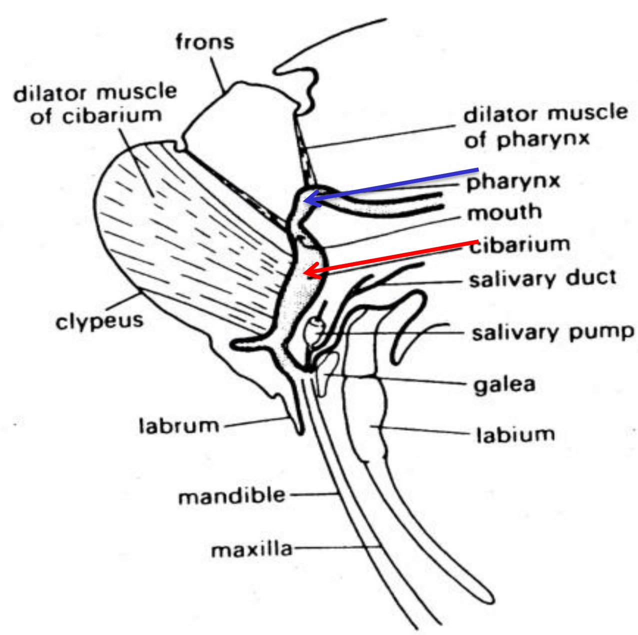
3- Lepidoptera mouth parts:

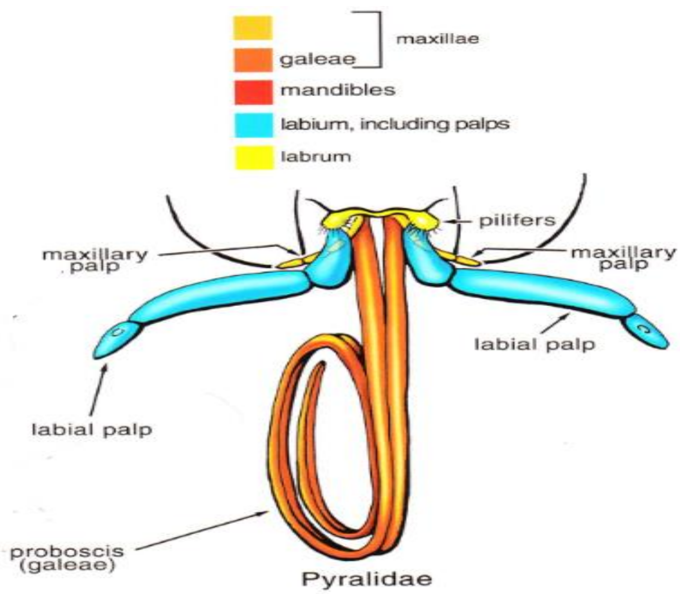
- **The sucking tube** (proboscis) is formed from the maxillae galea with the food channel running down the center.
- Outer walls of the galea scleritized
- This arrangement facilitates coiling (think of a vacuum hose).
- Extension of the proboscis is accomplished by blood pressure.
- Coiling is automatic.

Modifications in mouth parts

3- Lepidoptera mouth parts:

- **Mandibles are completely lost**
- labrum is reduced to a small transverse sclerite
- labium is reduced to a small flap.
- Labial palps are large.
- **Sucking pump** is formed by the cibarium and the pharynx.
- Muscle attachments are similar to those in the Hymenoptera(to frons and clypeus).
- **The sucking pump** is absent in Lepidoptera that do not feed as adults.





Modifications in mouth parts

4- Diptera adult mouth parts:

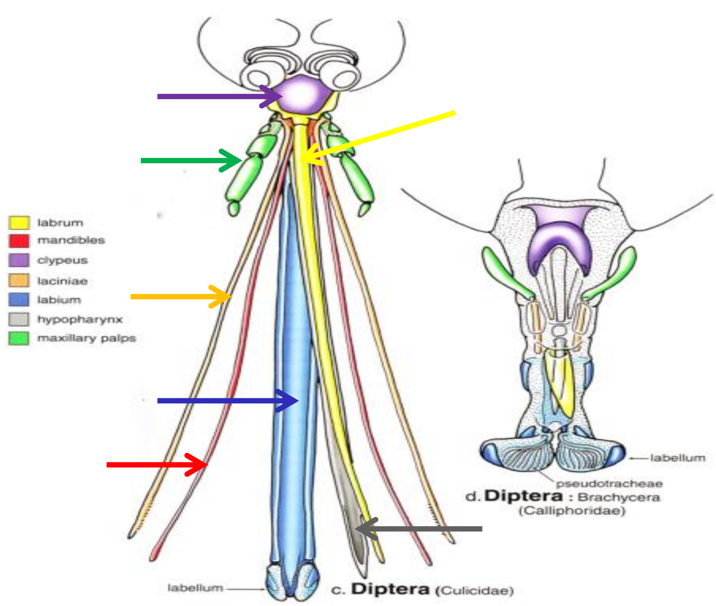
a- Biting flies (mosquitos, black flies, deer flies, horse flies)

- Mandibles are present and used for piercing the host's skin.
- They are long and **sharply pointed**.
- **The sucking tube** is formed by the labrum anteriorly and the mandibles posteriorly.
- Food is drawn up the food channel which is a groove on the posterior side of the labrum.
- The maxillae retain most of the components of the typical biting form.
- the galeae are long and bladelike and the palps are enlarged.

Modifications in mouth parts

4- Diptera adult mouth parts:

- The **hypopharynx** is stylet-like and contains the salivary duct.
- The **labium** is a large, thick appendage with a deep anterior groove into which the other mouthparts normally fit.
- Distally the labium bears two large labellar lobes with pseudotracheae, which directs the blood towards the food canal.
- In mosquitos the food canal is formed between the **hypopharynx** and the **labium**.
- **The sucking pump** is formed in the **cibarium**.

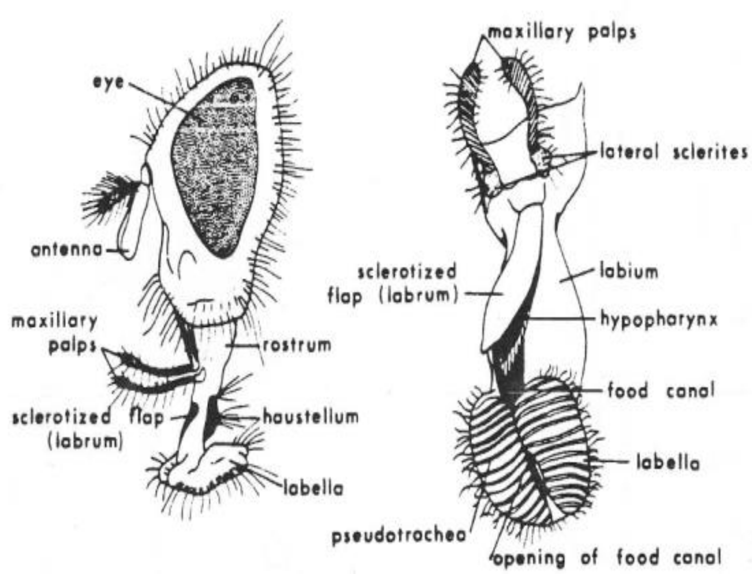


Modifications in mouth parts

4- Diptera adult mouth parts(sponging)

b- lapping muscids (houseflies, blowflies):

- **Sucking tube** (proboscis) is a composite structure that includes the **labrum, hypopharynx and labium**.
- The tube is divisible into a basal rostrum bearing the maxillary palps, a median flexible haustellum and two apical labellae.
- The labellae are broad sponging pads, equipped with pseudotracheae along which food passes to the oral aperture.
- Mandibles are completely lost.
- **The sucking pump** is formed from the cibarium and its dilator muscles.

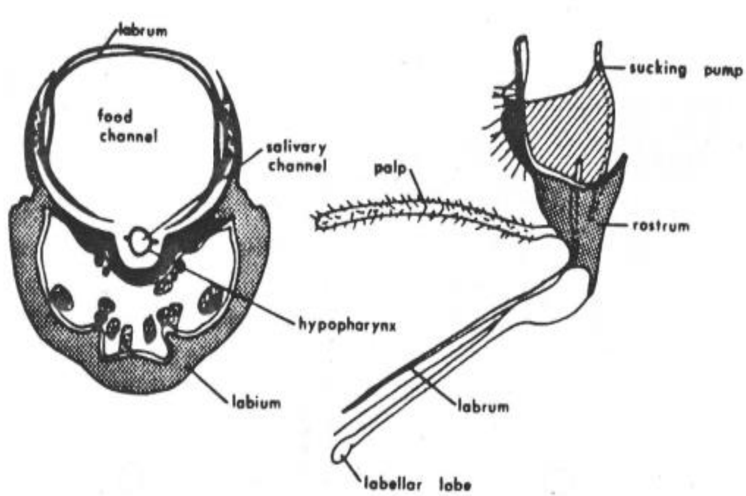


Modifications in mouth parts

Another example:

Biting Muscids (tsetse flies, stable flies):

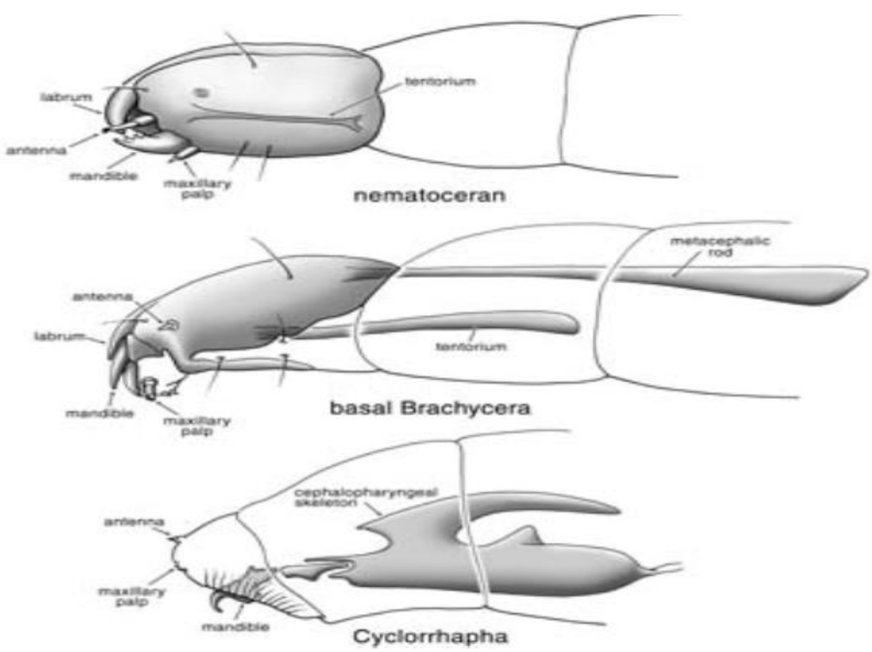
- **sucking tube** is a composite structure as in the lapping Muscids labrum, hypopharynx and labium
- However, the haustellum is **elongate and rigid**, and the distal labellar lobes are small and bear rows of prestomal teeth on their inner walls.
- The labrum and labium fiused to form the food canal within which lies the hypopharynx enclosing the salivary duct.



Modifications in mouth parts

6- Diptera larval mouth parts:

- **Nematoceran** larvae have typical **chewing mouthparts** as do the larvae of most holometabolous insects.
- **Basal Brachycera** larvae show modifications away from the typical chewing mouthparts.
- **Derived Brachycera** larvae in the Cyclorrhapha have highly modified mouthparts in which the typical mouthparts are lost or fused. Mandibles are modified into vertically directed mouth hooks.



The head appendages

Eyes: compound and simple (ocelli)

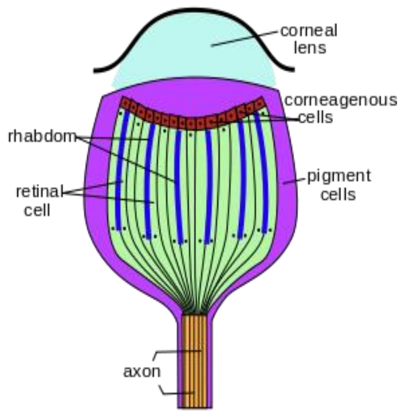
- Most insects have one pair of large, prominent compound eyes.
- composed of units called **ommatidia** (ommatidium, singular) **possibly up to 30,000 in a single compound eye.**
- gives less resolution than eyes found in vertebrates.
- but it gives acute perception of movement.
- There can also be an additional **two or three ocelli**, which help detect low light or small changes in light intensity.

The head appendages

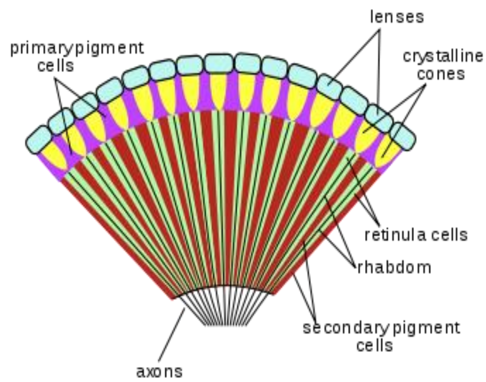
Eyes: compound and simple (ocelli)

- The image perceived is a combination of inputs from the numerous ommatidia.
- Ommatidia located on a convex surface.
- pointing in slightly different directions.
- **Compound eyes possess very large view angles, and can detect fast movement.**

The head appendages

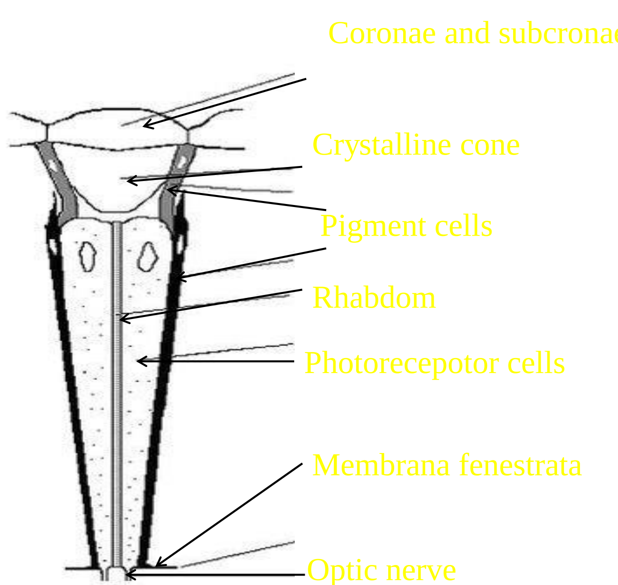


Ocellus cross-section



Compound eye cross-section

Ommatidium structure:

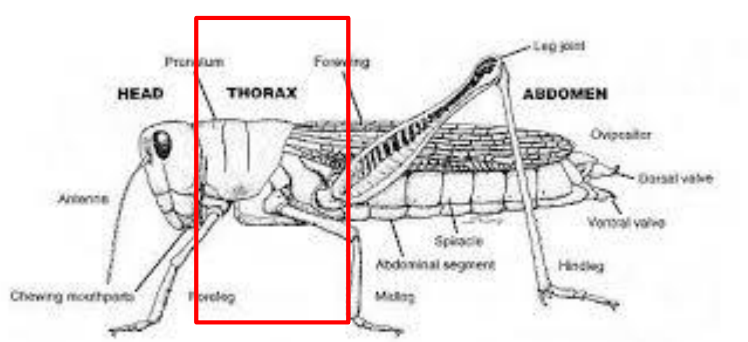


QUESTIONS

Insect Morphology

lecture 3

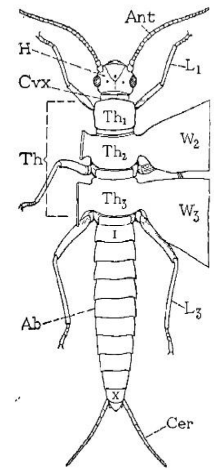
The thorax



The thorax

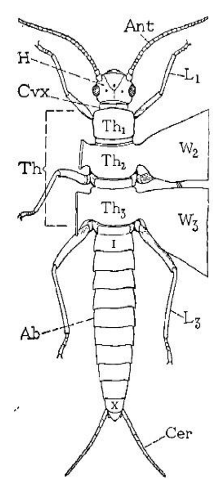
The thorax is consists of three segments :

- ❑ Prothorax
- ❑ Mesothorax
- ❑ Metathorax



The thorax

- Each segment bears a pair of legs (hexapoda)
- Second and third segments carry wings in Pterygota



The thorax

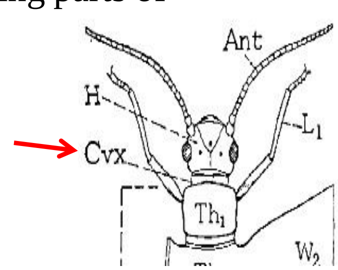
The thorax contains:

- Muscles of legs
- Muscles of wings
- Thoracic ganglia are the chief centers of control for both sets of appendages.

The thorax

The neck: cervix

- Is a narrow membranous part between head and thorax.
- formed from the labial and the prothracic segments
- concealed within overlapping parts of prothorax.



The thorax

The thoracic terga:

- These segments are simple back plates.
- Each plate comprises the primary segmental sclerotization of the dorsum
- and the preceding intersegmental sclerotization.

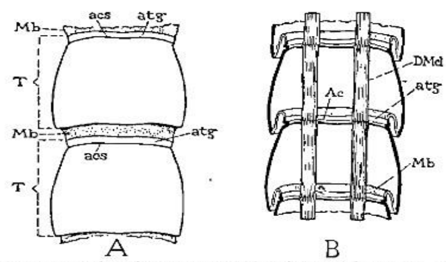
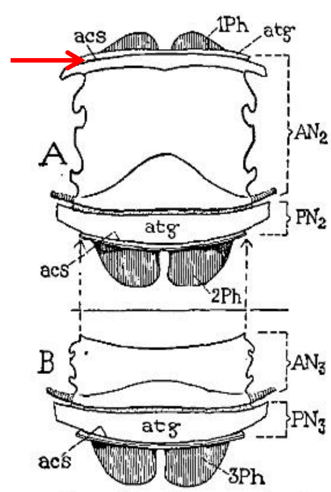


FIG. 86.—Diagrams illustrating intersegmental relations between the tergal plates of generalized segments.

The thorax

The tergum, is crossed anteriorly by the line of the primary intersegmental groove.

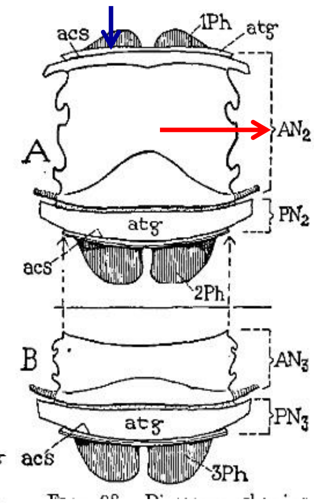
- Externally formed (acs) antecostal suture
- Internally formed (AN) submarginal antecosta.

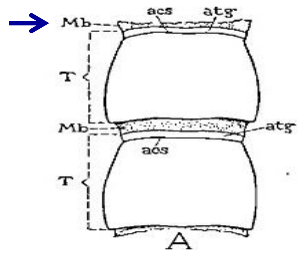


The thorax

Submarginal antecosta (**AN**)
Divided into:

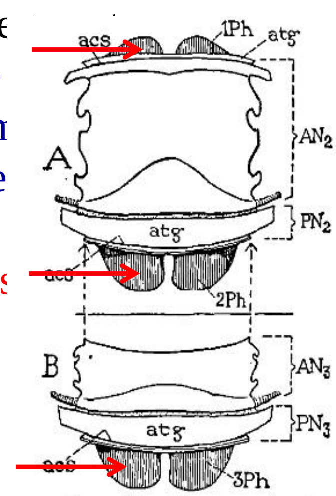
1. Precostal acrotergite (**atg**)
2. long postcostal area ending at the secondary intersegmental membrane (**Mb**)





The thorax

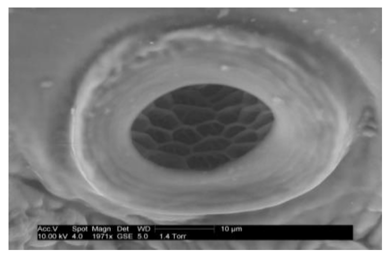
- In most winged insects, muscles are greatly enlarged in the wing bearing se
- There are developed plate-like form antecostae of mesotergun and 1st abdominal tergum calle apodemes (**phragmata**).
- They are paired or sometimes s
- There are three.

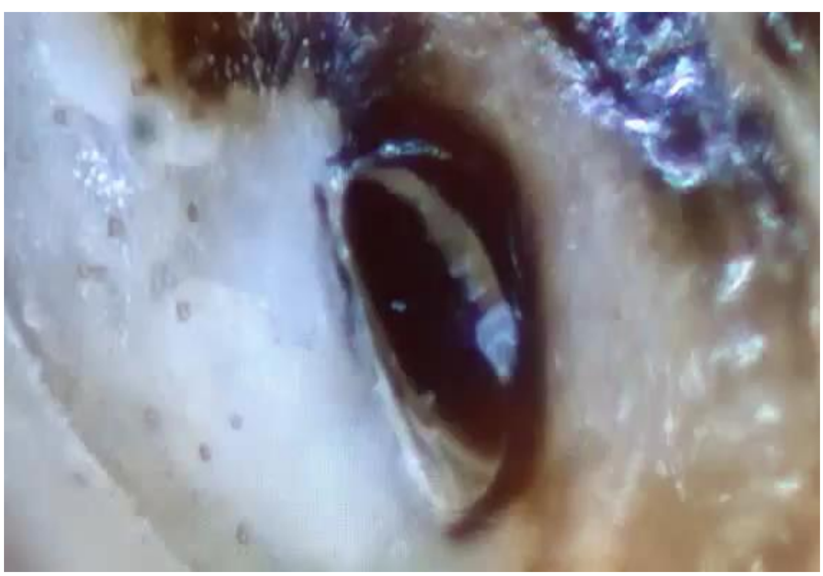


The thorax

The thoracic spiracles :

- generally situated on the sides of the segments between **the1st and 2nd** , **2nd and 3rd** , **3rd** thoracic segments, **and 1st** abdominal segment.
- The area occupied by them supposed to belong to the **dorsum**.
- they are **beneath** the wing bases in winged (**alate**) segments.



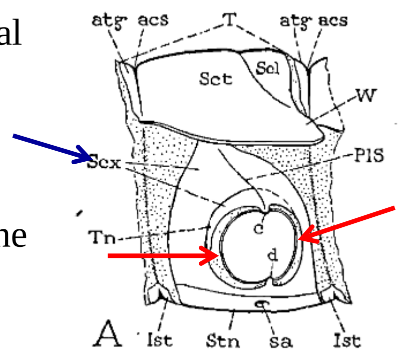


The thoracic spiracles

The thorax

The Thoracic Pleura:

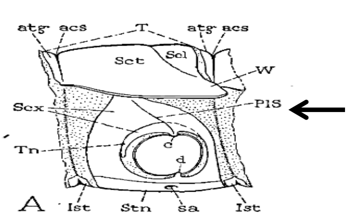
- associated with the functional leg bases.
- formed by the union of the **two supracoxal arches** of the **subcoxa**

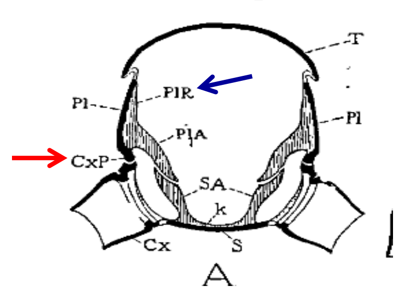


The thorax

The Thoracic Pleura:

- Above the coxa the pleuron is reinforced by a strong **internal pleural ridge**, (**PlR**).
- extending upward from the **coxal articulation** (**CxP**).
- a linear inflection of the outer wall, known as the **pleural suture** (**PlS**).





The thorax

The sternal plates:

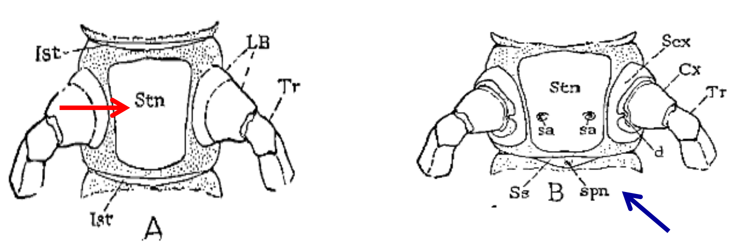
Differ generally in three respects from those of the abdomen:

1. In the independence of the primary segmental and intersegmental sclerotizations.
2. In the reversed overlapping of the plates at the secondary intersegmental lines.
3. In a transposition of the attachments of most of the ventral muscles from the intersegmental to the segmental sclerites.

The thorax

Basic Structure of the Thoracic Sterna:

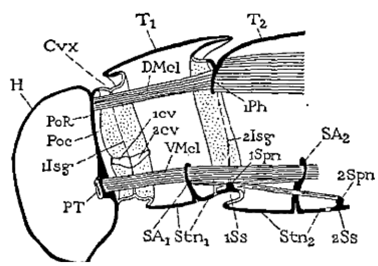
- The segmental plate of the venter of a thoracic segment may be designated the **eusternum** (Stn).
- The intersternites of the thorax called **spinasterna**



The thorax

❑ The prothorax:

- Its tergum and sternum always lack the **antecostal** and **precostal** elements of typical segmental plates.
- these parts apparently have been lost by membranization in the neck.
- The prothoracic tergum is a plate of the primary segmental region only (**T1**)
- **It never bears a phragma**.



The thorax

❑ The pterothorax:

- **The wing-bearing segments** differ structurally from the prothorax only in details that are clearly adaptations to the function of movement in the wings.
- The modifications affect chiefly the **terga**, in a lesser degree the pleura, and least the sterna.

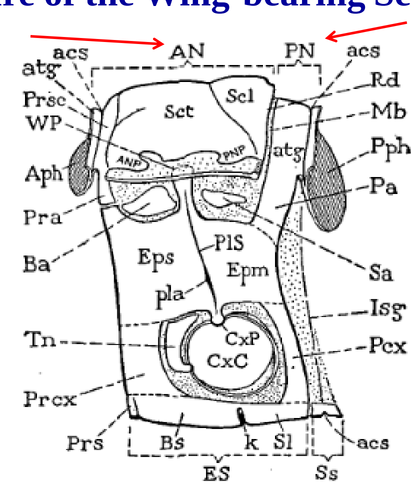
The thorax

General Structure of the Wing-bearing Segment:

- The dorsum of the segment may be occupied entirely by a single tergal plate, **alinotum** **(AN)**, which bear wings.
- usually the segment in which the wings are better developed contains also a second posterior plate, **postnotum** **(PN),** which carries a phragma (**Pph**).

The thorax

General Structure of the Wing-bearing Segment:



The thorax

General Structure of the Wing-bearing Segment:

- The **alinotum** is often supported on the pleura by **prealar arms (Pra)** extending laterally or downward from its anterior angles to the **episterna**.
- the **postnotum** is generally firmly braced upon the pleura by lateral postalar extensions (**Pa**) united with the **epimera**.

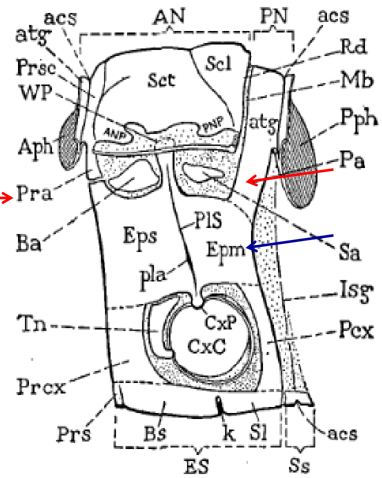


FIG. 96.—Diagram of the typical sclerites of a wing-bearing thoracic segment, and

The thorax

General Structure of the Wing-bearing Segment:

- The phragmata are inflection of the intgument on the primary intersegmental groove(**acs**).
- The phragma-bearing **postnatal plates** of the dorsum are in comparable with the spinasterna of the venter (**Ss**).
- The true intersegmental lines of the thorax (**Isg**) run dorsally through the bases of the phragmata, and ventrally through the bases of the intersegmental groove.

The thorax

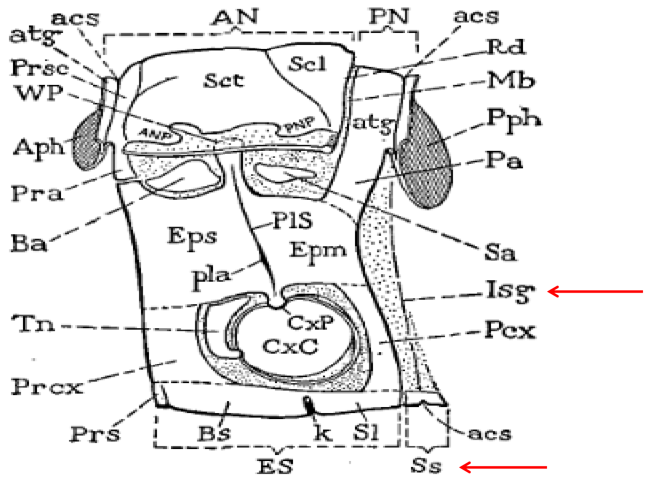


Fig. 96.—Diagram of the typical sclerites of a wing-bearing thoracic segment, and

The thorax

General Structure of the Wing-bearing Segment:

- The phragma-bearing plates of the dorsum differ from the spina-bearing plates of the venter in that they may be more closely united with the segmental plate either before or behind them.
- Thus the segment carrying the principal pair of wings may have a phragma at each end of its tergal region.
- The anterior phragma in this case may be distinguished as a **prephragma** (**Aph**), and the posterior one as a **postphragma** (**Pph**).

The thorax

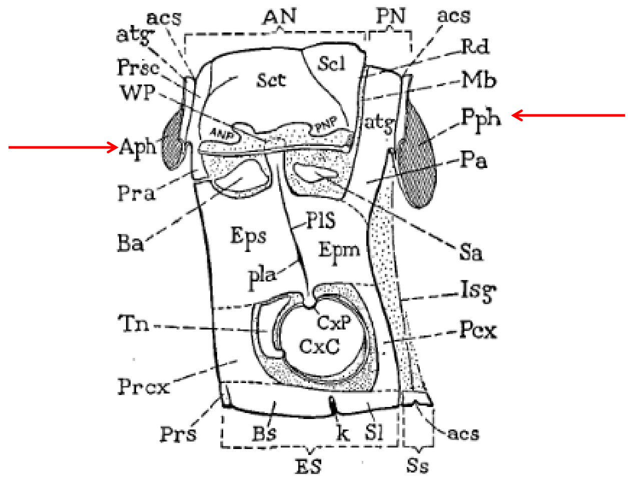


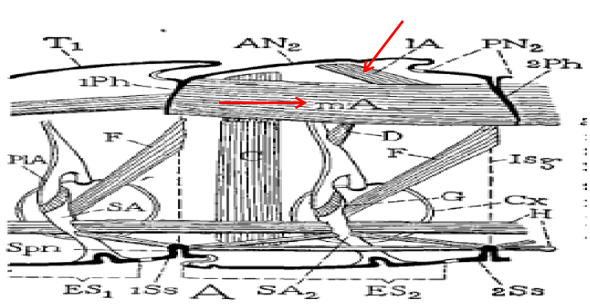
FIG. 96.—Diagram of the typical sclerites of a wing-bearing thoracic segment, and

The thorax

The thoracic muscles:

1. Dorsal muscles:

The muscles of this group comprise longitudinal median muscles and oblique lateral muscles **(mA, lA).**



The thorax

The thoracic muscles:

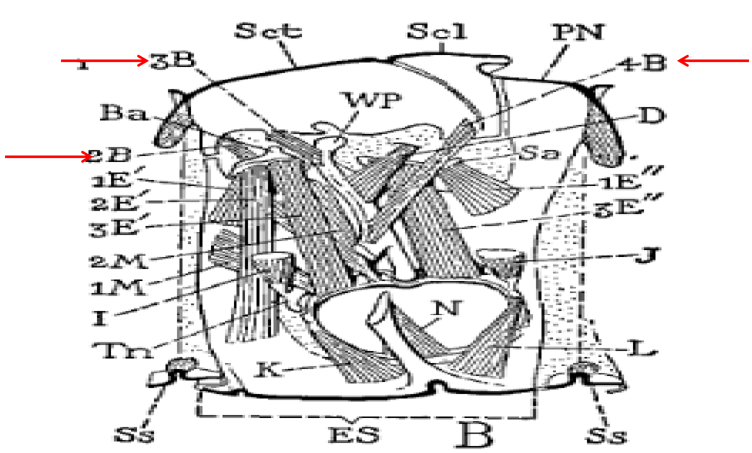
2. Tergopleural muscles:

Four muscles of this group have been recorded in the mesothorax of different insects.

1. One goes from the prealar arm of the tergum to the episternum (not shown in the figure)
2. From the lateral tergal margin to the basalare, (**2B**).
3. from the tergum to the wing process (**3B**)
4. The fourth muscle (**4B**) extends from the posterior part of the scutum to the base of the pleural arm or the lower part of the pleural ridge.

The last is an important muscle in Ephemerida, Plecoptera, Sialidae, Mecoptera, Trichoptera, Aphididae and is often two branched.

The thorax



The thorax

The thoracic muscles:

3. Tergosternal muscles: or venteral musles

- Generally large muscles of the pterothorax in flying insects.
- Attached above on the scutum, below on the basisternum anterior to the coxae, **(C).**
- Absent in weak-flying insects, and not represented in the prothorax.
- These muscles are the principal levators of the wings.
- Being functionally opposite to the dorsal muscles in their action on the tergum.

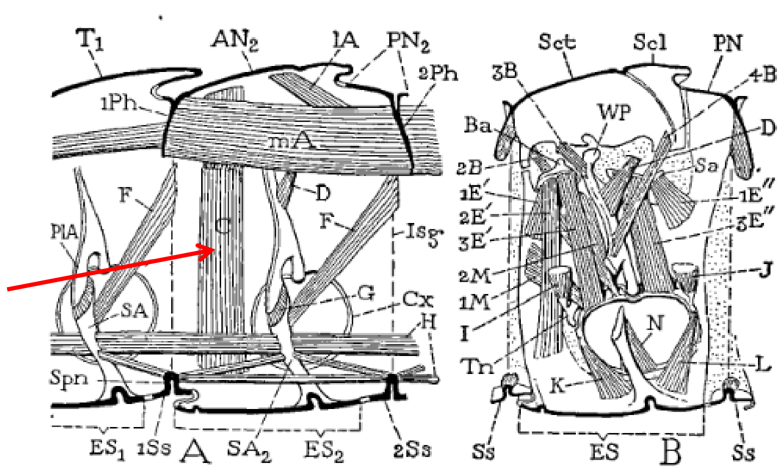


Fig. 103.—The thoracic musculature, diagrammatic, showing most of the muscles known to occur in a wing-bearing segment. A, dorsal, ventral, tergosternal, and oblique muscles of right side, inner view. B, lateral and leg muscles of right side. *A*, dorsal muscles (*lA*, oblique lateral dorsals; *mA*, longitudinal median dorsals); *B*, tergopleural muscles; *C*, tergosternal muscle; *D*, the wing flexor; *E′*, basalar muscles (*1E′*, pleurobasalar; *2E′*, sternobasalar; *3E′*, coxobasalar); *E″*, subalar muscles (*1E″*, pleurosubalar; *3E″*, coxosubalar); *F*, oblique intersegmental muscle; *G*, pleurosternal muscle; *H*, ventral muscles; *I*, *J*, tergal promotor and remotor of coxa (upper parts cut off); *K*, *L*, sternal promotor and remotor of coxa; *M*, abductors of coxa; *N*, adductor of coxa.

The thorax

The thoracic muscles:

4. Tergocoxal muscles:

The muscles of the axillary sclerites of the wing base arise on the pleuron. Two muscles occur in this group:

1. Known only in Diptera, is inserted on the first axillary.
2. Present in all winged insects (**D**), is inserted on the third axillary and is the usual **flexor** of the wing.

It is a simple or branched muscle arising on the upper part of the pleuron.

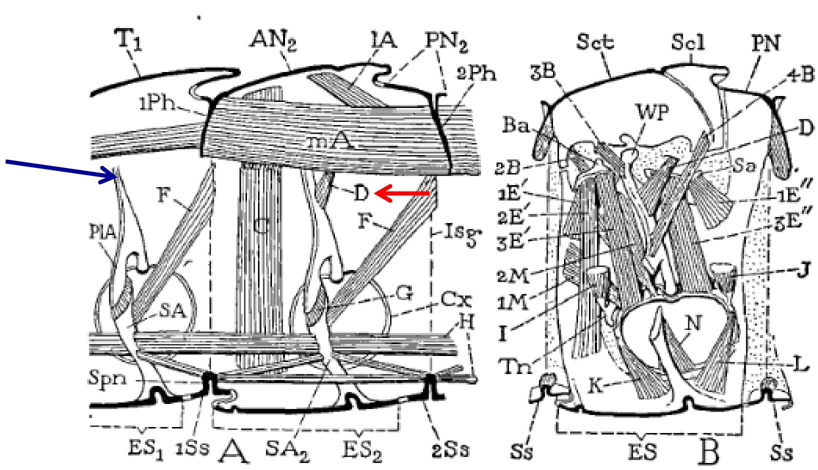


Fig. 103.—The thoracic musculature, diagrammatic, showing most of the muscles known to occur in a wing-bearing segment. A, dorsal, ventral, tergosternal, and oblique muscles of right side, inner view. B, lateral and leg muscles of right side. *A*, dorsal muscles (*lA*, oblique lateral dorsals; *mA*, longitudinal median dorsals); *B*, tergopleural muscles; *C*, tergosternal muscle; *D*, the wing flexor; *E′*, basalar muscles (*1E′*, pleurobasalar; *2E′*, sternobasalar; *3E′*, coxobasalar); *E″*, subalar muscles (*1E″*, pleurosubalar; *3E″*, coxosubalar); *F*, oblique intersegmental muscle; *G*, pleurosternal muscle; *H*, ventral muscles; *I*, *J*, tergal promotor and remotor of coxa (upper parts cut off); *K*, *L*, sternal promotor and remotor of coxa; *M*, abductors of coxa; *N*, adductor of coxa.

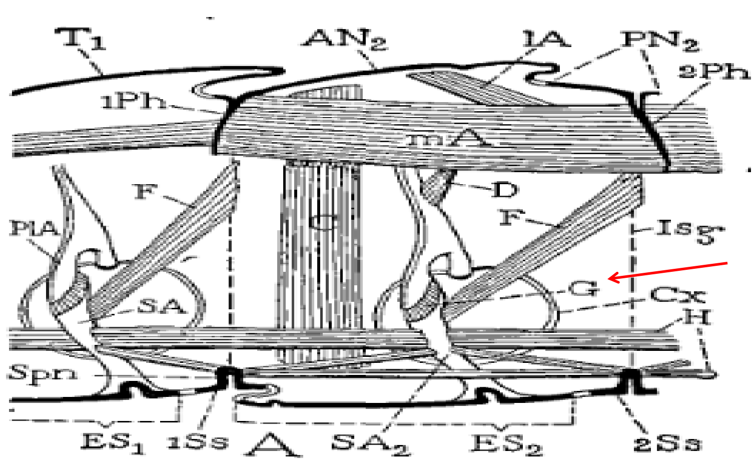
The thorax

The thoracic muscles:

5. Pleurosternal muscles:

The muscle most commonly present in this group consists of short fibers connecting the opposed ends of the pleural and sternal apophyses on each side of the segment (**G**).

The thorax



'IG. 103.—The thoracic musculature, diagra

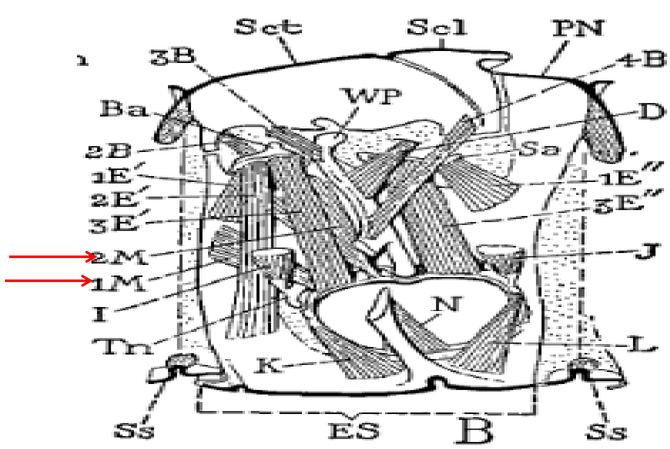
The thorax

The thoracic muscles:

6. Pleurocoxal muscles:

- Usually two muscles, arising on the episternum, inserted on the coxal base anterior to the pleural articulation **(1M, 2M**).
- These muscles appear to be abductors of the coxa.

The thorax



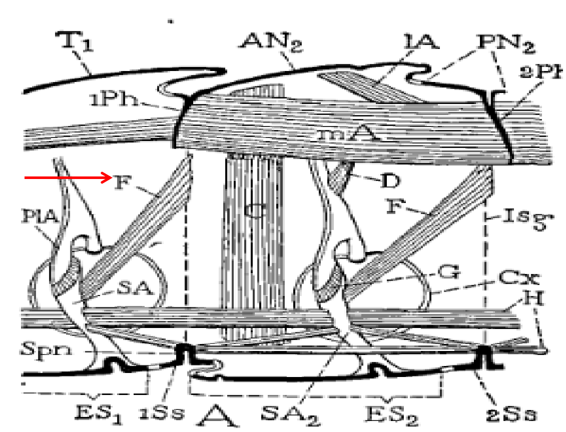
The thorax

The thoracic muscles:

7. Lateral intersegmental muscles:

- An oblique muscle attached below on the sternal apophysis, dorsally on the anterior margin of the following pleuron or tergum (**F**).
- This muscle is more commonly present in generalized insects and in larval forms.
- in adults it usually occurs only between the prothorax and the mesothorax,
- but a corresponding muscle is sometimes present between the mesothorax and the metathorax.

The thorax



The thorax

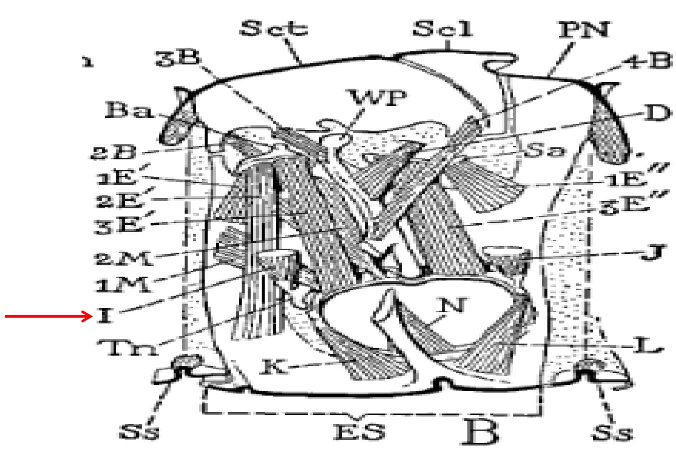
The thoracic muscles:

Promotors of legs:

1: Tergal Promotor of the Leg:

- Usually a single large muscle, sometimes double, arising dorsally on the tergum,
- inserted below on the ventral end of the trochantin (tn) (**I**).

The thorax



The thorax

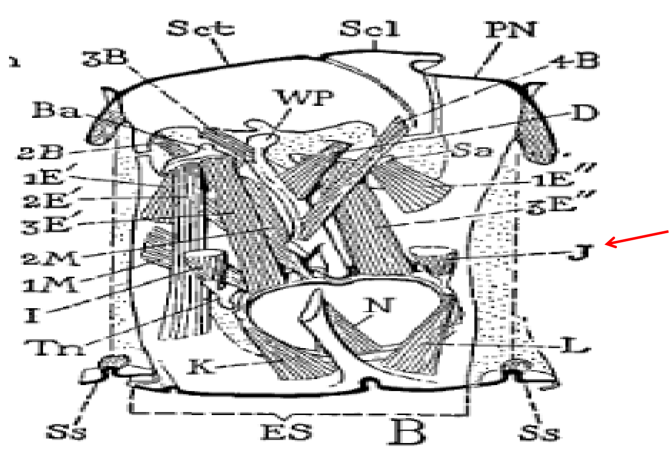
The thoracic muscles:

Promotors of legs:

2. Tergal Remotor of the Leg:

- A single muscle, or a group of muscles, arising dorsally on the posterior part of the tergum,
- inserted ventrally on the posterior rim of the coxa (**J**).

The thorax



The thorax

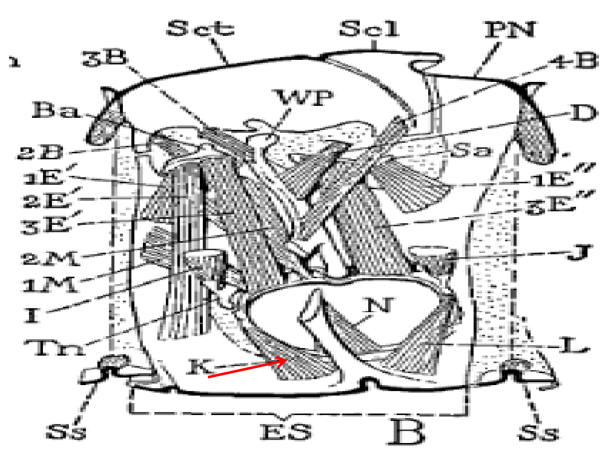
The thoracic muscles:

Promotors of legs:

3. Sternal Promotor of the Leg:

- Origin on the sternum;
- inserted on the anterior part of the coxal base **(K)**.

The thorax



The thorax

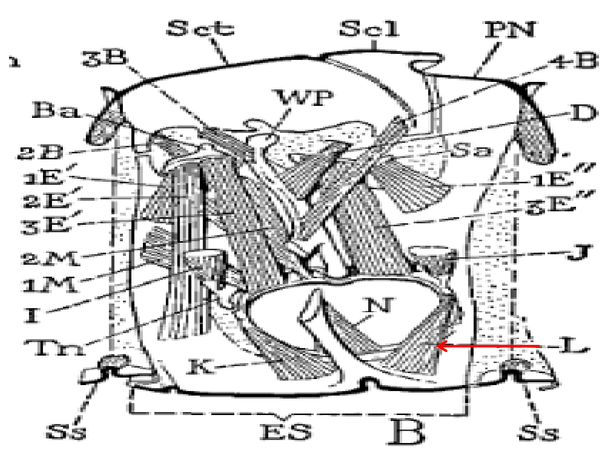
The thoracic muscles:

Promotors of legs:

4. Sternal Remotor of the Leg:

- Origin on the sternum, the sternal apophysis, or the spina.
- inserted on the posterior part of the coxal base (**L**).
- This muscle, is a rotator of the coxa if the latter has a free movement on the pleuron only.

The thorax



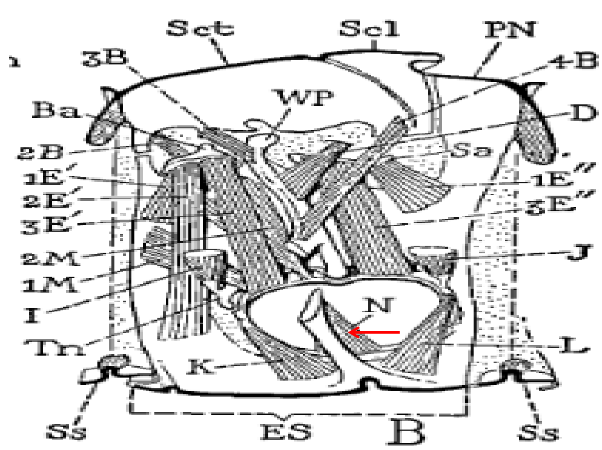
The thorax

The thoracic muscles:
Promotors of legs:

5. Adductor Muscle of the Coxa:

- A muscle present in insects lacking a sternal articulation of the coxa,
- arising on the sternal apophysis, inserted on the mesal margin of the coxa (**N**).

The thorax



The thorax

The thoracic legs:

The typical and usual segments of the insect leg are the **coxa** (**Cx**), one **trochanter** (**Tr**), the **femur** (**Fm**) , the **tibia** (**Tb**), the **tarsus** (**Tar**), and the **pretarsus** (**Ptar**).

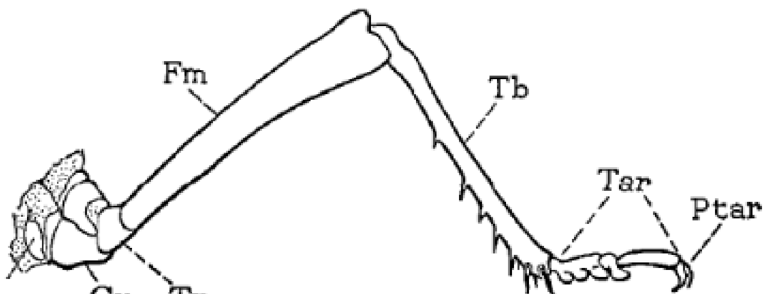


FIG. 104.—Middle leg of a grasshopper, anterior view.

The thorax

The Leg Joints:

- The joints of the legs are membranous rings of the leg wall between the cylindrical sclerotized areas that constitute the segments.
- The membrane of the joint is the articular corium (leathery).
- Sometimes there are no adjecent points of articulation between adjoining segments.
- but usually one or two pairs of opposed articular surfaces limit the movement of the joint to that of a hinge.
- Hinged joints are therefore either monocondylic **(A)** or dicondylic **(B,C).**

The thorax

The Leg Joints:

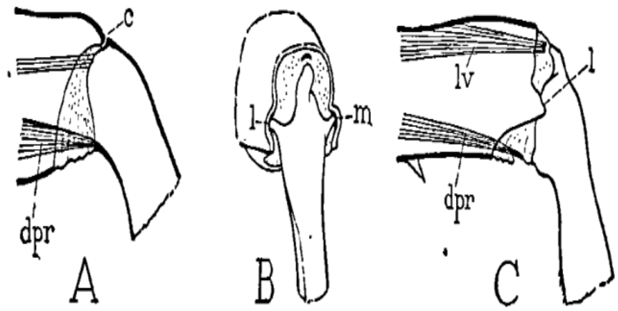


FIG. 105.—Diagrams of articular mechanisms at the femoro-tibial joint of a leg. A, monocondylic joint. B, C, dicondylic joint, end view and side view with levator and depressor muscles.

The thorax

Muscles of the legs:

The muscles of the legs, as of any segmented appendage, are comprised in two sets:

1. Muscles of the limb basis, or those that move the appendage as a whole.
2. Muscles of that move individual parts of the limb.

Muscles of the second class are usually named according to the limb segment on which they have their insertions.

The thorax

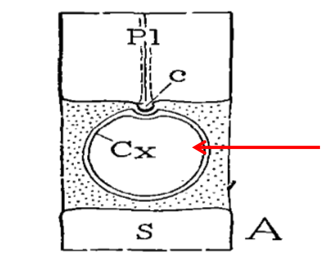
Mechanism of the leg base:

The possible movements of the coxa depend upon the nature of the coxal articulation with the body.

three types of structure:

1. If the coxa is articulated to the pleuron only

(it is **free to make any movements** that its musculature will impart to it).

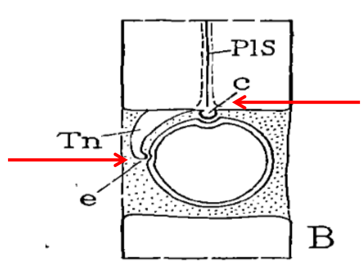


The thorax

Mechanism of the leg base:

2- If the coxa is hinged between pleural and trochantinal articulations.

its movements may be **more limited.**

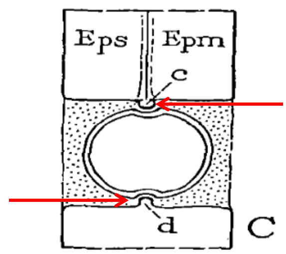


The thorax

Mechanism of the leg base:

3- If the coxa is articulated to the pleuron dorsally and to the sternum ventrally

its movements are **strictly limited.**



The thorax

Mechanism of the leg base:

- Insects are able to walk through the contraction and relaxation of thoracic muscles attached to the leg base and to the cuticle.

- These muscles act firstly on the base of the leg, and the contraction is then transmitted through internal leg muscles through the leg, causing the leg to extend or flex.

The thorax

Mechanism of the leg base:

Insects use mostly two gait types for walking:

1. Tripod gait:

- Three legs are in contact with the ground at all times.
- fore and hind legs of one side
- the mid leg of the other side
- The rest of the legs swing forward
- the stable legs push the body forward and provide support.

This gait is very stable, and used for fast motion

The thorax

Mechanism of the leg base:

Insects use mostly two gait types for walking:

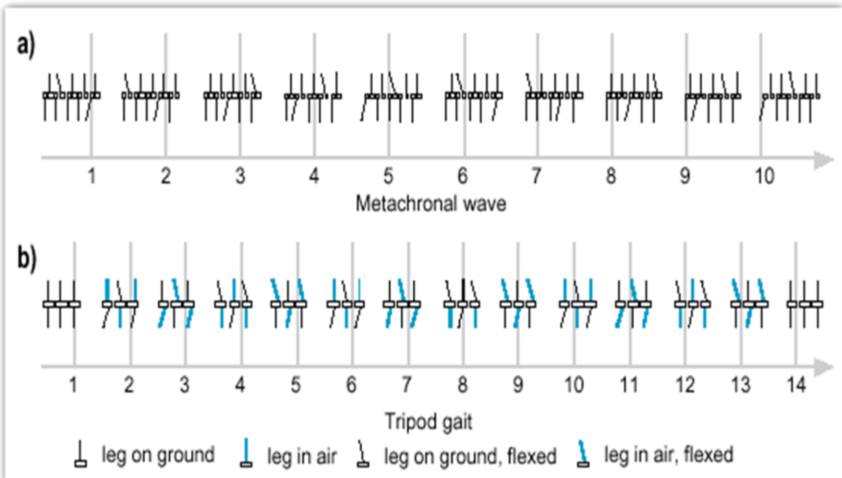
2. Metachronal or wave gait:

- Involves moving only one leg at a time.
- starting at a hind leg on one side of the insect
- then the mid leg on the same side
- then the foreleg
- then the same on the other side

This gait is slower than the tripod gait, but more stable, as there are more legs in contact with the ground during each leg movement.

The thorax

Mechanism of the leg base:



The thorax

Mechanism of the leg base:

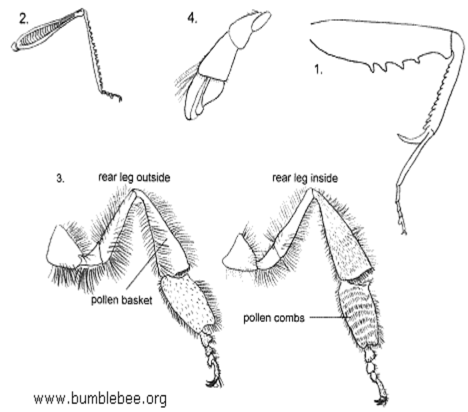
Insects have a number of options they can use to enable them to move at higher speeds. They can:

1. Increase the frequency of leg movements.
2. Increase their stride length.
3. Raise two or four of their legs above the substrate and switch to quadrapedy or hind leg bipedality.

The thorax

Types of legs:

1. **Walking leg**
2. **Running leg**
3. **Jumping leg**
4. **Clining leg**
5. **Digging leg**
6. **Grasping leg**
7. **Swimming leg**
8. **Sticking leg**
9. **Basket-like leg**



Insect Morphology

lecture 4

Wings

Origin and evolution of the wings:

- The oldest insects known from the fossil records lived in Carboniferous times, their remains being found in the lower beds of the Upper Carboniferous or Pennsylvanian period.
- These ancient insects had two pairs of fully developed wings
- Many of the Carboniferous insects, had in addition to the wings a pair of small, **flat lobes** (**pnl**) projecting laterally from the tergum of the prothorax.
- these lobes suggest that at an earlier period the wings were developed from similar tergal lobes of the mesothorax and the metathorax.

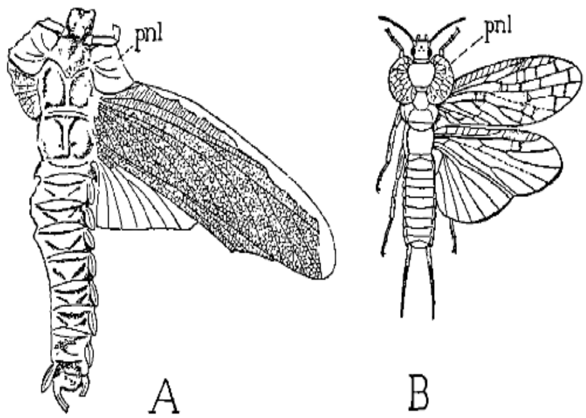


FIG. 119.—Examples of fossil insects with paranotal lobes on the prothorax. A, *Stenodictya lobata.* (*From Brongniart*, 1890.) B, *Lemmatophora typica.* (*From Tillyard*, 1928.)

Wings

The structure and development of the wings of modern insects:

- Wings are not a modified forelimbs like other animals
- Each wing is essentially a hollow extension of the body wall.
- Wings are expansion of the epicuticle of the 2nd and 3rd thoracic segments.

Wings

The structure and development of the wings of modern insects:

- The dorsal lamina with the tergal plate supporting it.
- the ventral lamina is reflected into the lateral wall of the segment
- The pleural plates of the thoracic segments supporting the bases of the paranotal lobes from below.

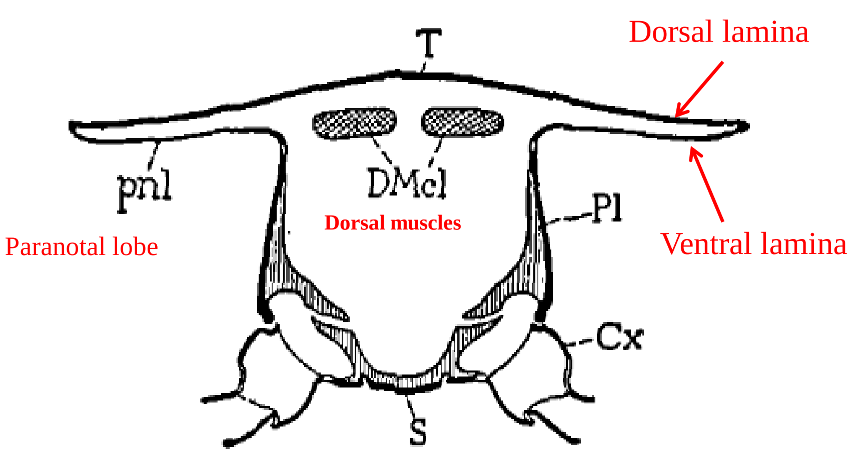


Fig. 120.—Diagrammatic cross section of a thoracic segment with paranotal extensions of the tergum.

Wings

Wing venation:

•The theoretically complete archetype venation includes the following veins:

1- Small **precosta** (Pc) 1

2- **Costa** (C), which is usually marginal in modern insects. 1

3- two-branched **sub costa** (Sc) 2

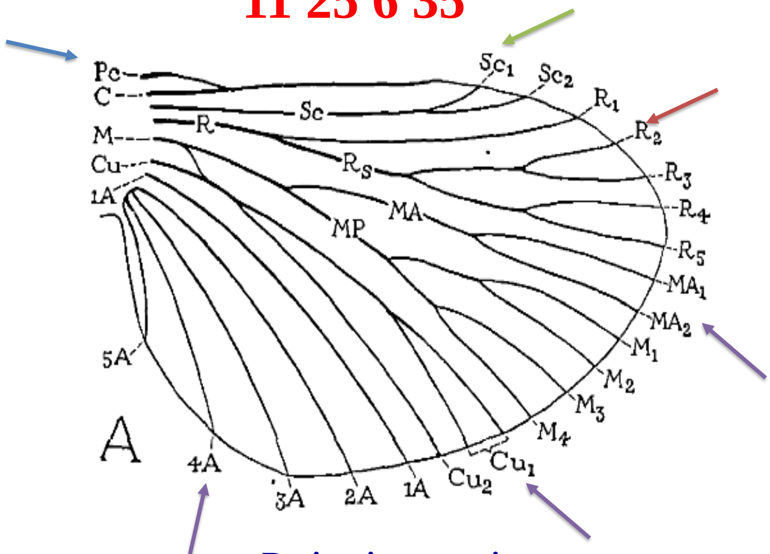
4- five-branched **radius** (R) 5

5- six-branched **media** (M) 6

6- three-branched **cubitus** (Cu) 3

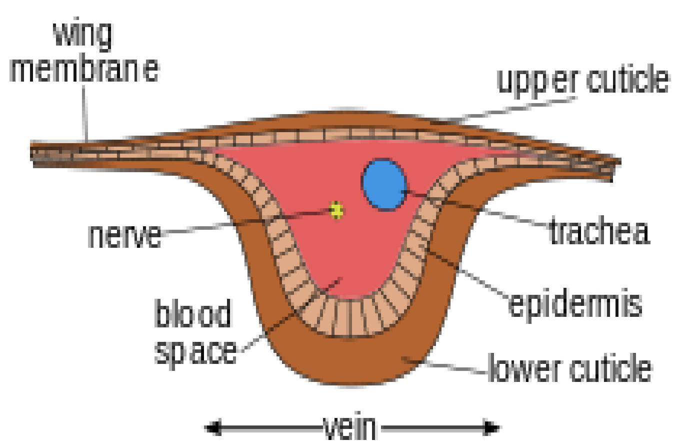
7- Varying number of **anal** veins (A). 5

11 25 6 35



Basic wing venation

Wing vein structure

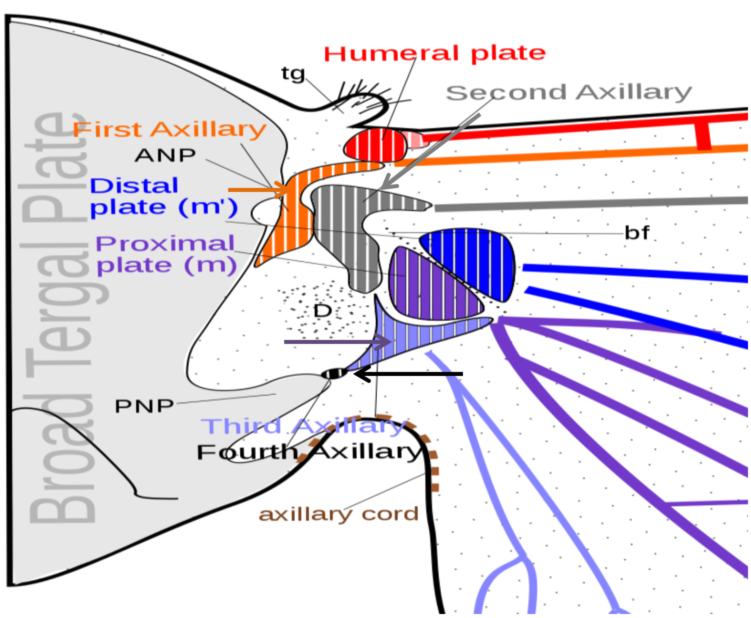


Wings

The Wing Region:

1. The Axillary Region:

- containing the axillary sclerites has in general the form of a triangle. (**Ax)**
- the base of the triangle (**a-b**) is the hinge of the wing with the body.
- the apex (**c**) is the distal end of the third axillary sclerite.
- the longer side (**a-c**) is anterior to the apex.
- The point (**d**) on the anterior side of the triangle **marks the articulation of the radial vein with the second axillary sclerite**.
- **d-c** is the plica basalis "*The basal fold of the wing*" (**bf**).



Wings

The Wing Region:

2- The Remigium:

- The wing region anterior to the vannal fold (**Rm**)
- the part of the wing chiefly productive of the movements of flight
- it is directly affected by the motor muscles of the wing.
- The remigium contains the **costal, subcostal, radial, medial, cubital, and postcubital veins**.

Wings

The Wing Region:

3- The Vannus:

- occurs between the post cubitus and the first annal vein. (**Vn**)
- triangular in shape
- its veins typically spread out from the third axillary like the ribs of a fan.
- usually best developed in the hind wing, in which it may be enlarged to form a sustaining surface, as in Plecoptera and Orthoptera.

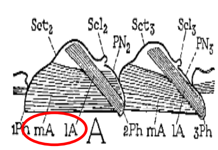
Wings

The Wing Region:

4- The Jugal Region, or Neala:

- usually a small membranous area proximal to the base of the vannus strengthened by a few small, irregular veinlike thickenings. (**Ju**).
- When the jugal area of the fore Wing is developed as a free lobe, it projects beneath the humeral angle of the hind wing and thus serves to yoke the two wings together.

Wings



The wing muscles

five pairs sets of muscles in each alate segment.

1-The dorsal muscle:

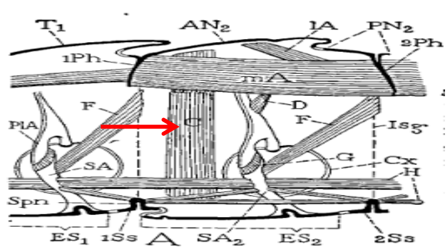
- the ordinary longitudinal muscles of the back
- extend from the antecosta of one tergum to the next tergum.
- differentiated into **median longitudinal muscles** (**mA**) and **lateral oblique muscles** (**lA**).

Wings

The wing muscles

2-The Tergosternal Muscle

- lie to the sides of the median dorsal muscles in the anterior part of the segment.
- They are attached dorsally on the anterior lateral areas of the tergum, and ventrally on the basisternum before the coxae.
- There may be one or several pairs of them in each segment. (**C**)



Wings

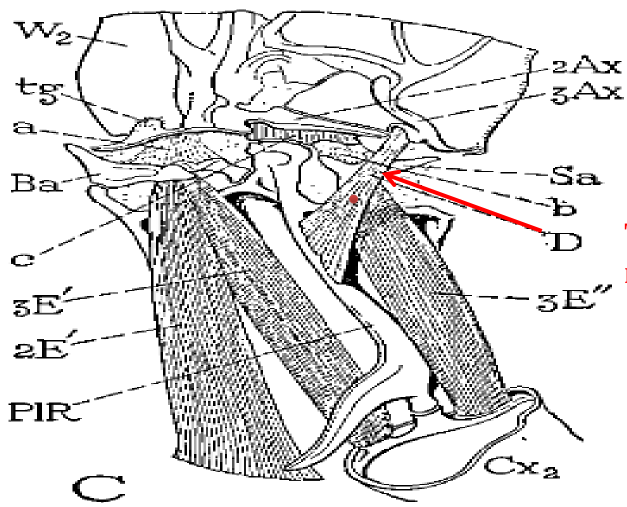
The wing muscles

3-The Axillary Muscle:

The only muscles attached directly on the wing bases, and consists of two groups:

1-A muscle of the first axillary is known to occur only in diptera. this muscle consists of two parts, one arising on the episternum, the other behind the pleural ridge, both inserted on the inner margin of the first axillary.

2- The muscle of the third axillary is present in all the wing-flexing insects, since it is the effector of the flexion movements of the wing



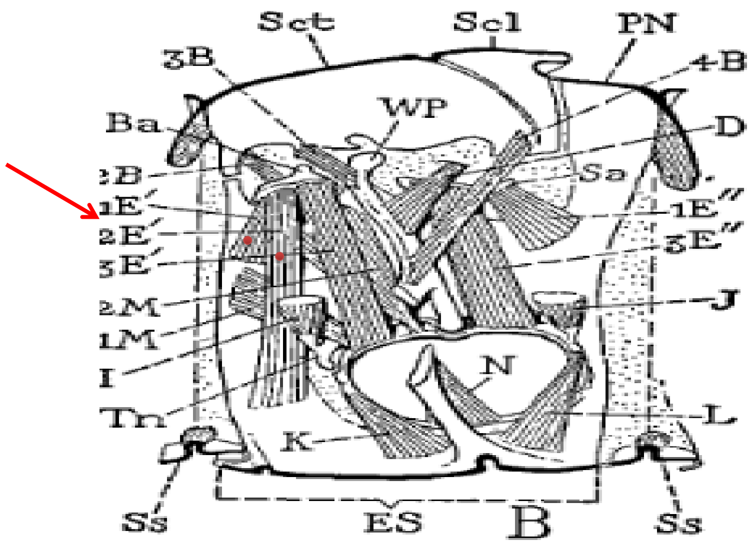
Tergocoxal muscles

Wings

The wing muscles

4-The Basalar Muscle

- The muscles of the basalar sclerites, or of the basalar lobe of the episternum
- include three muscles on each side
- muscles of this group arises on the episternum. (**1E,2E**)
- **function as depressors of the costal margin of the wing during flight**
- **and as extensors of the flexed wing, for which reasons they may be termed the pronator-extensor muscles of the wing.**

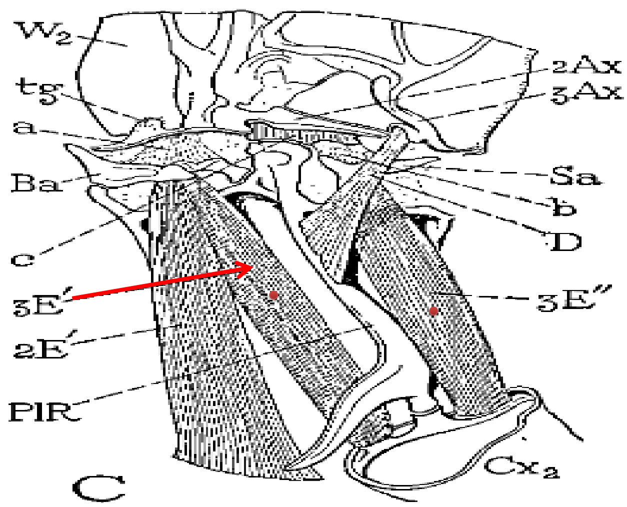


Wings

The wing muscles

5-The Subalar Muscle:

- In most insects there is a single subalar muscle
- usually of large size
- lying against the epimeral wall of the pleuron on each side of each wing-bearing segment, which is attached ventrally on the meron of the coxa. (**3E”**).
- The subalar muscles serve to extend and to depress the wing because of the close connection of the subalar sclerite with the second axillary sclerite of the wing base .
- They may be called, the **depressor-extensor muscles** of the wing.



Wings

The wing movements

- The insect wing is movable on the body by the flexibility of its basal connections with the **tergal plate** and with the **pleural wall** of the segment
- it is hinged to the tergum by the **first and third axillary sclerites**.
- is capable of responding only to the up-and-down movements of flight on its extreme base line.

Wings

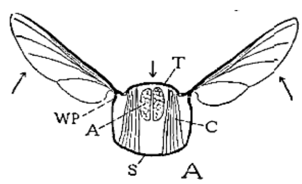
Motion of the wings:

The wing movement is indirect musculature movement in most of winged insects

The motion of the wings fall into two catergories:

1-The Upstroke of the Wings

- The elevation of the wings in flight is produced by the simple device of depressing the tergum of the segment bearing the wings
- The action being the result of a contraction of the **vertical tergosternal muscles**

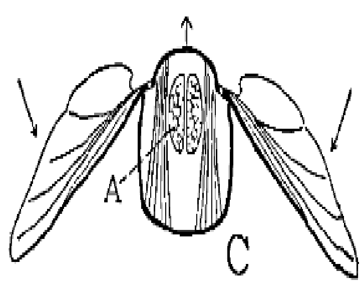


Wings

Motion of the wings:

2-The Downstroke of the Wings:

It results of the contraction of the **longitudinal dorsal muscle**



In Odonata the wing movement is direct musculature movement

Wings

Motion of the wings:

- The motion of each wing in flight is the resultant of its several elemental movements.
- During the upstroke, the wing goes upward and relatively backward, and its posterior surface is deflected.
- During the downstroke, the wing goes from above downward and forward, its anterior margin is deflected and its posterior area turns upward

Wings

Motion of the wings:

- the wings of an insect in motion describe a series of open loops.
- The distance between the loops depending on the speed at which the insect flies.

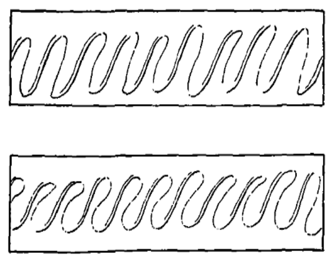
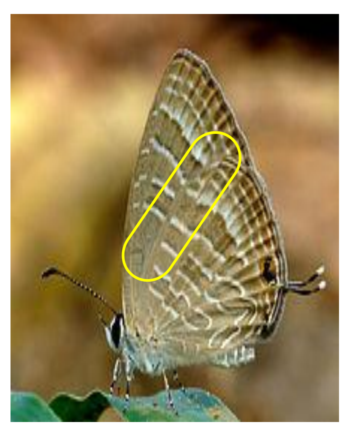


FIG. 132.—Curves described on a moving recorder by the wing tip of a stationary blow fly making the wing movements of flight. (*From Ritter*, 1911.)

Wing coupling

1. Amplexiform :

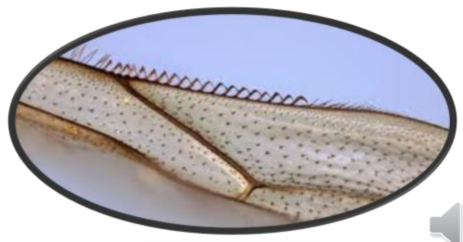
- It is the simplest form of wing coupling.
- **A linking structure is absent.**
- Coupling is achieved by broad overlapping of adjacent margins.
- e.g. butterflies.

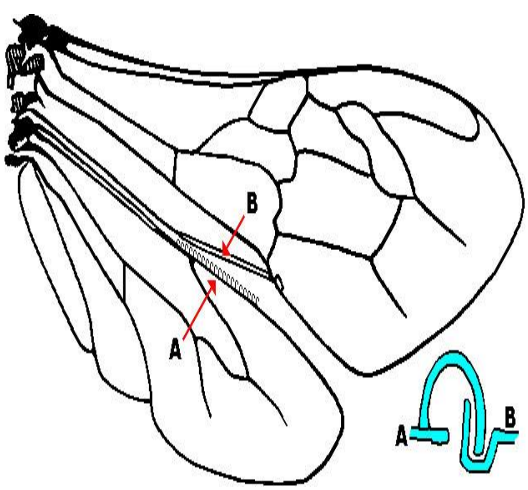


Wing coupling

2. Hamulate :

- A row of small hooks is present on the coastal margin of the hind wing which is known as hamuli.
- These engage the folded posterior edge of fore wing.
- e.g. bees.



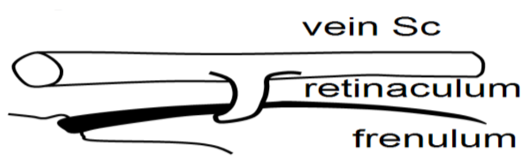


Hamulate

Wing coupling

3. Frenate

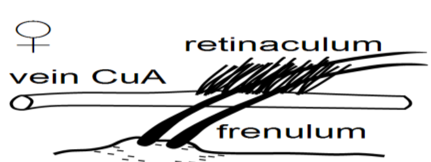
- **There are two sub types.** e.g. Fruit sucking moth.
- **A. Male frenate** : Hindwing bears near the base of the coastal margin a stout bristle called frenulum which is normally held by a curved process.
- retinaculum arising from the subcostal vein found on the surface of the forewing.

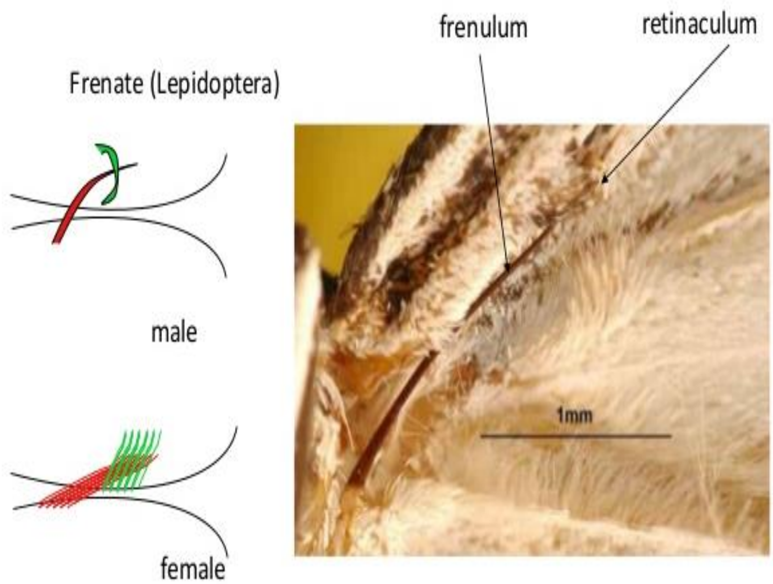


Wing coupling

3. Frenate

- **B. Female frenate :** Hindwing bears near the base of the costal margin a **group of stout bristle** (frenulum) which lies beneath extended forewing and engages there in a retinaculum formed by a patch of hairs near cubitus.

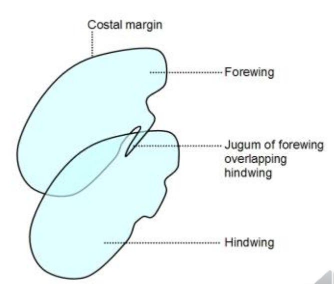




Wing coupling

4. Jugate :

- Jugam of the forewings are lobe like and it is locked to the coastal margin of the hindwings.
- e.g. Hepialid moths.



Jugal coupling

Insect Morphology

lecture 5

Abdomen

- The third division of the insect trunk.
- Differs from the head and the thorax by its simplicity of structure and general lack of segmented appendages.
- the primitive number was no greater than 12 in adult Protura.
- The usual number of segments in the abdomen of adult insects is 10 or 11.

Abdomen

- The abdomen serves as a container of the principal viscer
- Is the chief part of the body that produces movements of **respiration**.
- the ventral surface of its posterior part are situated the apertures of the genital ducts (**organs of copulation and oviposition).**
- the alimentary canal opens at the end of its terminal segment

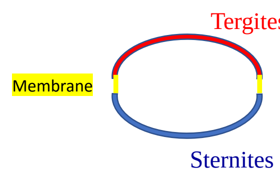
Abdomen

- The median female genital aperture varies in position.
- in a few insects it is located just behind the **seventh** abdominal sternum
- in others it is on or behind the **eighth** sternum
- in others it is on or behind the venter of the **ninth** segment.
- The **male** aperture appears to be always on the posterior part of the ninth segment, except in Collembola, in which the gonopore in each sex is between the **fifth and sixth segments.**

Abdomen

General structure of the abdominal segments:

- Is built up of a series of concave upper integumental plates known as 'tergites' 'sternites'
- the whole being held together by a tough stretchable membrane (**no pleura**).

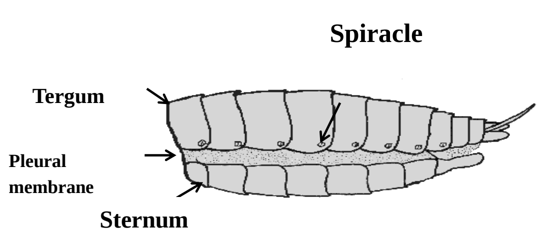


- convex lower integumental plates known as

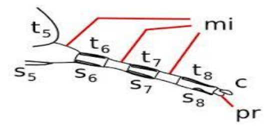
Abdomen

The abdominal sclerotization:

The sclerotized parts of the abdominal integument usually take the form of dorsal and ventral segmental plates, separated by membranous areas on the sides.



Abdomen

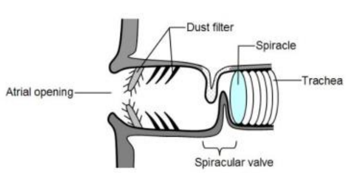


The abdominal sclerotization:

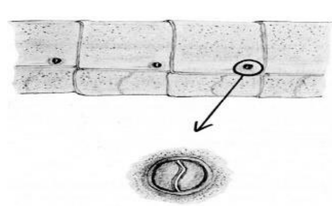
- The front margins of each segment often "telecope" inside the sclerites of the preceding segment.
- Abdomen is expand and contract in response to the actions of skeletal muscles.

Abdomen

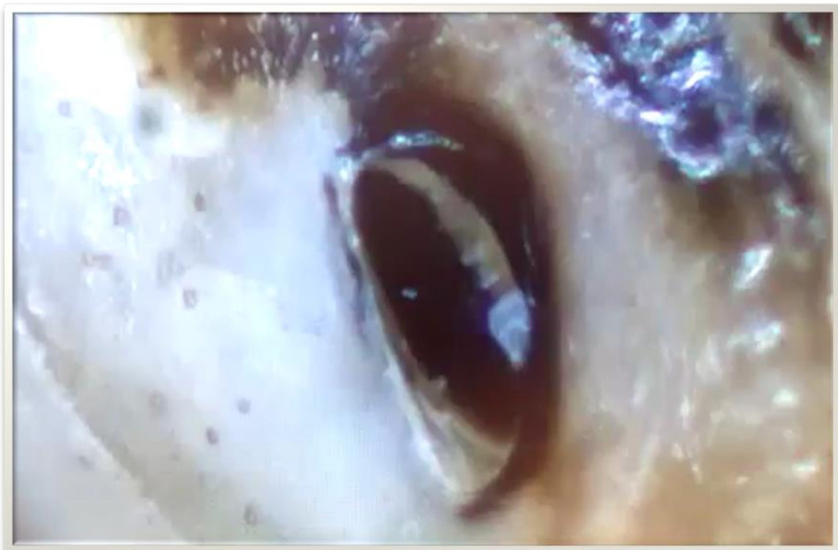
- A spiracle (opening to the respiratory system) near the pleural membrane on each side of the first eight abdominal segments.
- Some spiracles may be permanently closed, but still represented by a dimple in the sclerite.



A spiracle equipped with valve, atrium and dust filter



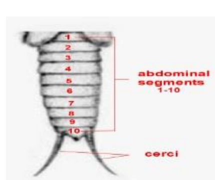
Spiracle

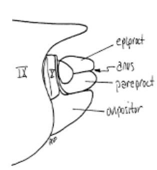


Abdomen

The abdominal sclerotization:

- the anus (rear opening of the digestive system) is nestled between three protective sclerites, a dorsal **epiproct** and a pair of lateral **paraprocts**.
- A pair of sensory organs, the **cerci**, may be located near the anterior margin of the paraprocts.
- These structures are tactile (touch) receptors.





Abdomen

Other abdominal structures may also be present in some insects:

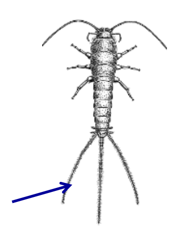
- **Pincers**: In Dermaptera (earwigs), the cerci are heavily sclerotized and forceps-like.
- They are used mostly for defense, but also during courtship, and sometimes to help in folding the wings.

Abdomen

Other abdominal structures may also be present in some insects.

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

-This structure is found only in "primitive" orders (e.g. Diplura, Thysanura, Ephemeroptera).

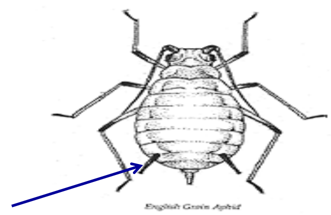


Abdomen

Other abdominal structures may also be present in some insects.

Cornicles : paired secretory structures located dorsally on the abdomen of aphids.

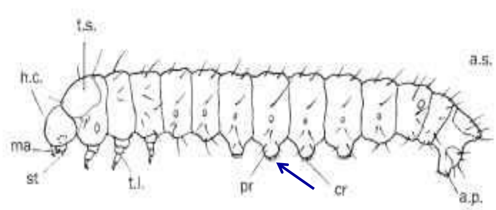
-The cornicles produce substances that repel predators or elicit care-giving behavior by symbiotic ants.



Abdomen

Other abdominal structures may also be present in some insects.

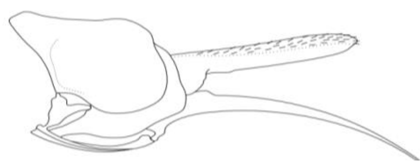
Abdominal prolegs: fleshy, locomotory appendages found only in the larvae of certain orders (Lepidoptera, Mecoptera and some Hymenoptera)



Abdomen

Other abdominal structures may also be present in some insects:

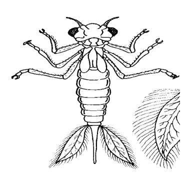
Sting: a modified ovipositor, found only in the females of Hymenoptera (ants, bees, and predatory wasps).



Abdomen

Other abdominal structures may also be present in some insects:

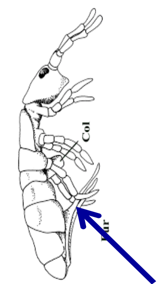
Abdominal gills : respiratory organs found in the nymphs of certain aquatic insects.
In Ephemeroptera, paired gills are located along the sides of each abdominal segment.
In Odonata (damselflies), the gills are attached to the end of the abdomen.



Abdomen

Other abdominal structures may also be present in some insects:

Furcula: the "springtail" jumping organ found in Collembola on the ventral side of the fifth abdominal segment. A clasp (the tenaculum) on the third abdominal segment holds the springtail in its position.

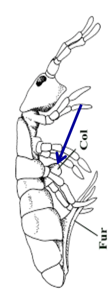


Abdomen

Other abdominal structures may also be present in some insects.

Collophore: a fleshy, peg-like structure found in Collembola on the ventral side of the first abdominal segment.

-It appears to maintain homeostasis by regulating absorption of water from the environment and secret mucus substance.



Abdomen

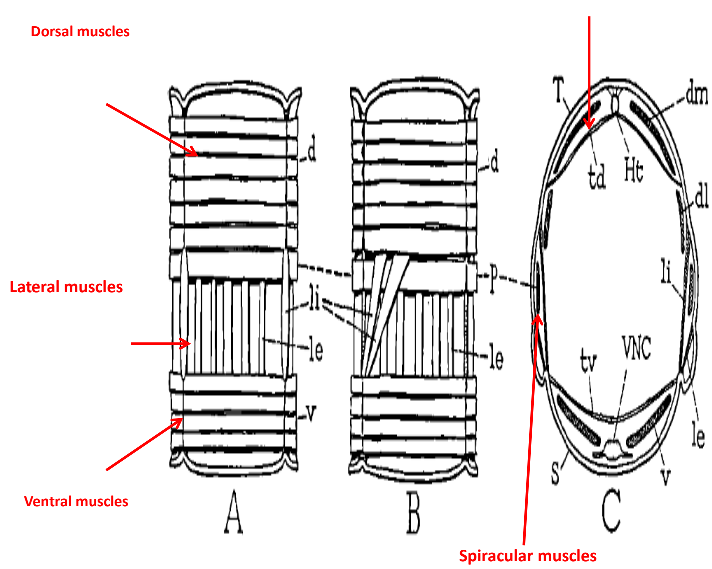
The abdominal musculature:

- **Dorsal muscles**

The fibers of which are typically longitudinal and attached on the intersegmental folds or on the antecostae of successive terga. (**Fig, A: d)**

- **Ventral muscles**

Resembling the dorsal muscles in that their fibers are typically longitudinal and attached on the intersegmental folds or on the antecostae of successive sterna. (**Fig, A: v)**



Abdomen

The abdominal musculature:

- **Lateral muscles**

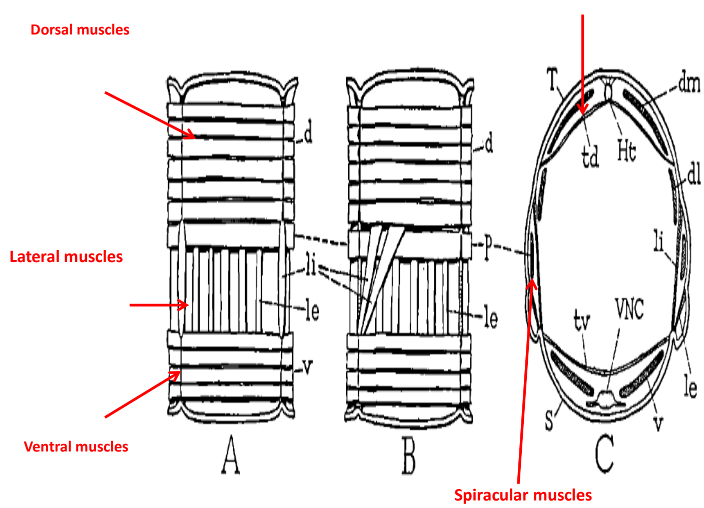
Typically dorsoventral, and both intrasegmental (**le**) and intersegmental (**li**) in position. (**Fig, A: L)**

- **Transverse muscles**

Lying internal to the longitudinals, including dorsal transverse muscles (**td**) and ventral transverse muscles (**tv**). (**Fig, C: t)**

- **Spiracular muscles**

generally not more than two connected with each spiracle, one an occlusor, the other a dilator.



Insect Anatomy

lecture 6

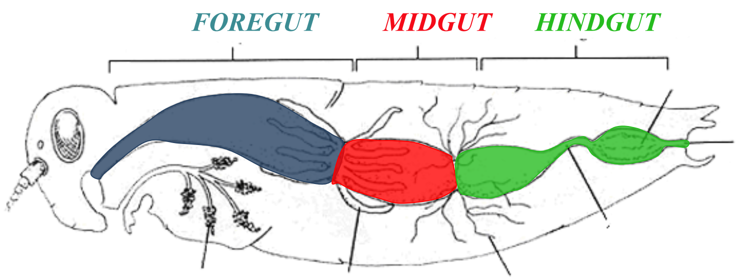
DIGESTIVE SYSTEM

The digestive tract not only aids in obtaining, processing and digesting food molecules - **It is the largest endocrine tissue in both humans and insects.**

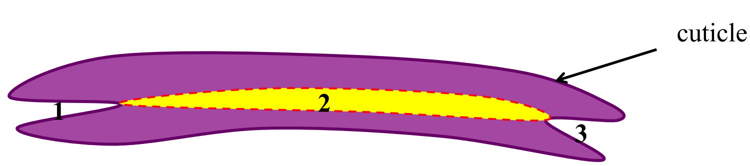
The digestive system is involved in:

1. **Obtaining** food
2. **Mechanically** breaking it down into smaller particles that facilitate digestive enzymes acting on them
3. **Enzymatic** breakdown of larger food molecules into molecules that can pass through the digestive tract (midgut) and enter the hemolymph
4. **Produces molecules** or MESSENGERS (eg. Endocrines), that coordinate feeding and other activities of the digestive tract.

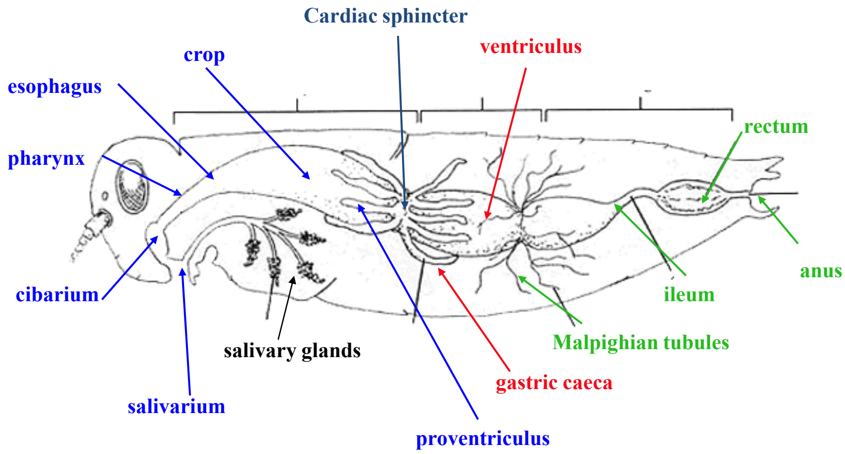
1. **Foregut (stomatodeum) or stomodeum**
2. **Midgut (mesenteron)**
3. **Hindgut (proctodeum)**



Development of digestive system



1. Foregut (stomatodeum) – ectodermal
2. Midgut (mesenteron) - endodermal
3. Hindgut (proctodeum) - ectodermal

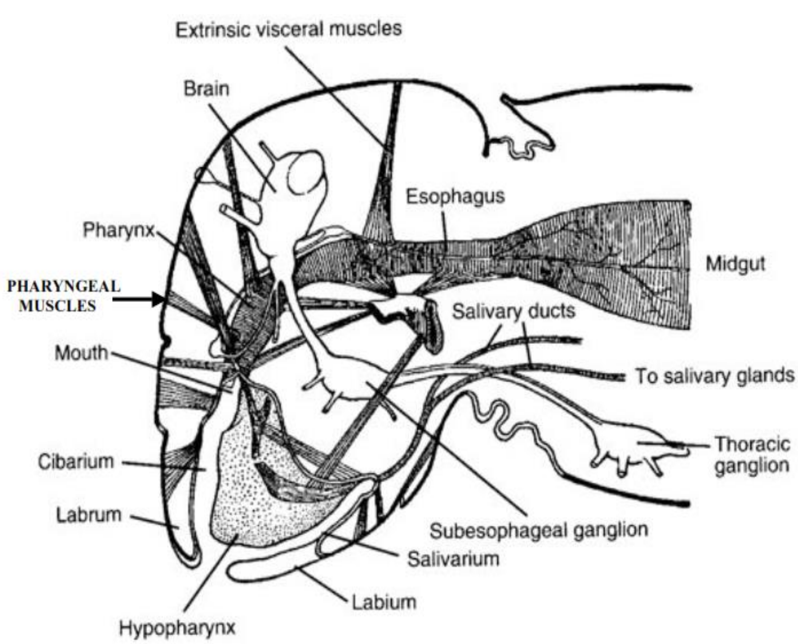


FOREGUT

1. Foregut starts at mouth and ends just after proventriculus but before the cardiac sphincter
2. Little or no digestion occurs in the foregut
3. Foregut is mainly involved in ingestion of food and the mechanical softening of it with salivary secretions and breakdown with special 'teeth' as in the cockroach or muscle-sets in other insects
4. In some insects it has a dilated structure called the crop while in other insects this crop may be diverticulated and connected by a crop duct
5. The salivary glands empty into the foregut or mouth area depending on the insect

The preoral cavity: mouth cavity

- It is not a cavity at all but an external space bounded **anteriorly** by the epipharyngeal wall of the labrum and clypeus.
- **posteriorly** by the labium, and **laterally** by the mandibles and maxillae.
- Within the preoral cavity lies the tongue-like **hypopharynx**.
- At the posterior end of the hypopharynx, between the latter and the base of the prementum, is the opening of the salivary duct.
- The food passage is closed laterally by the mandibles, and its upper or inner part.

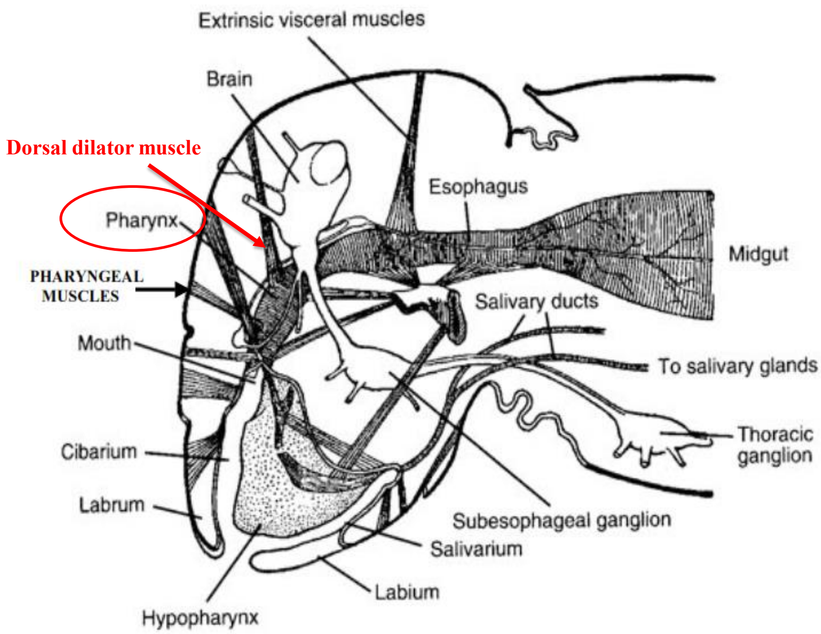


Buccal Cavity:

- The true buccal cavity of the insect is the oral part of the stomatodeum (foregut).
- Is not structurally differentiated from the pharynx
- it may be defined as the initial part of the stomodaeum on which are inserted the second group of dilator muscles taking their origins on the clypeus, or the clypeal area of the head, and having their insertions anterior to the frontal ganglion and its connectives

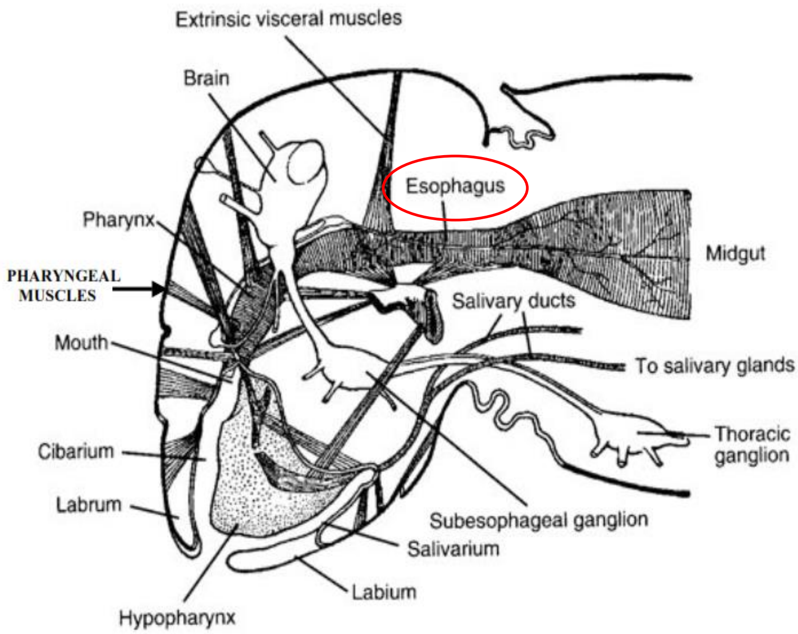
The Pharynx:

- The pharyngeal part of the stomodaeum follows the buccal cavity
- it is identified as that part of the stomatodeum whose dorsal dilator muscles take their origin on the frontal and dorsal areas of the head wall and are inserted posterior to the frontal ganglion and its connectives.
- The pharynx typically lies before the nerve connectives between the brain and the suboesophageal ganglion.



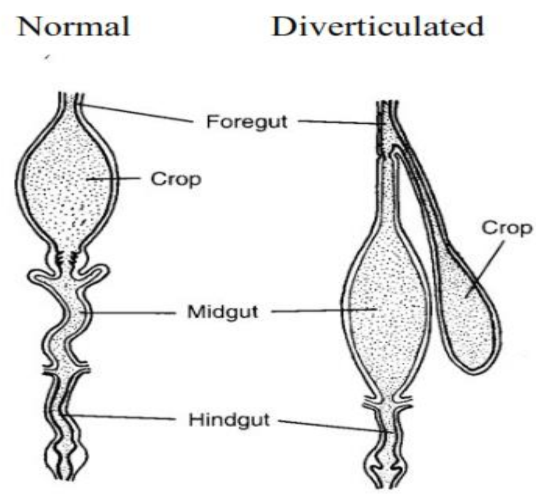
The Oesophagus:

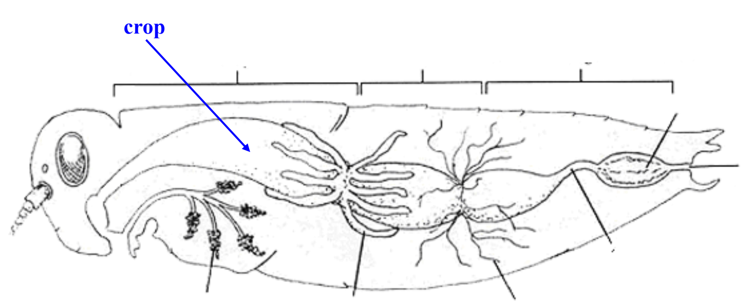
- Has no definite morphological status.
- it is merely the narrow part of the stomatodeum following the pharynx.
- Oesophagus is a slender tube and may extend, direct to the stomach.
- it is limited posteriorly by a proventricular or the crop section of the stomatodeum.



The Crop:

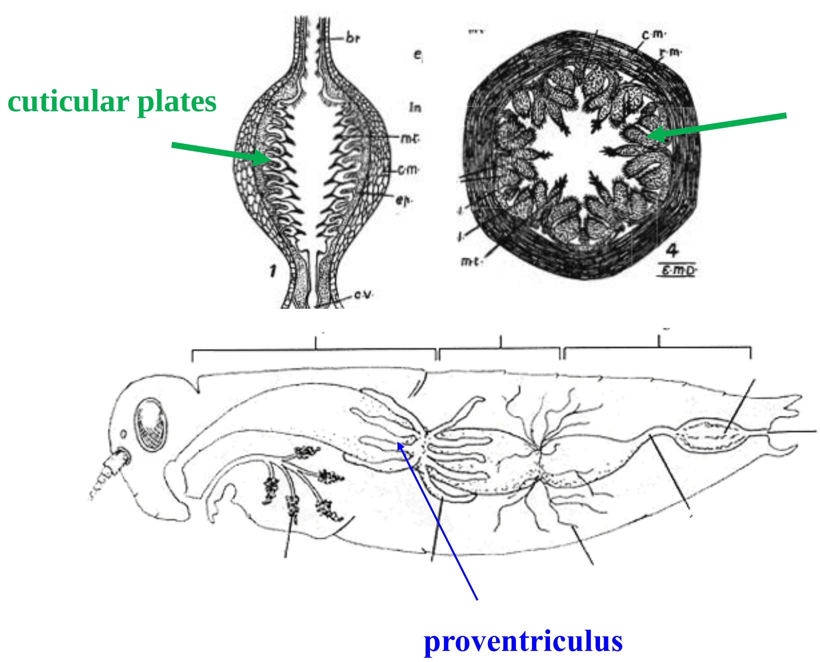
- An enlargement of the posterior part of the oesophagus.
- primary function of the crop is **storage of food.**
- It receives digestive liquids both from the salivary glands and from the ventriculus.

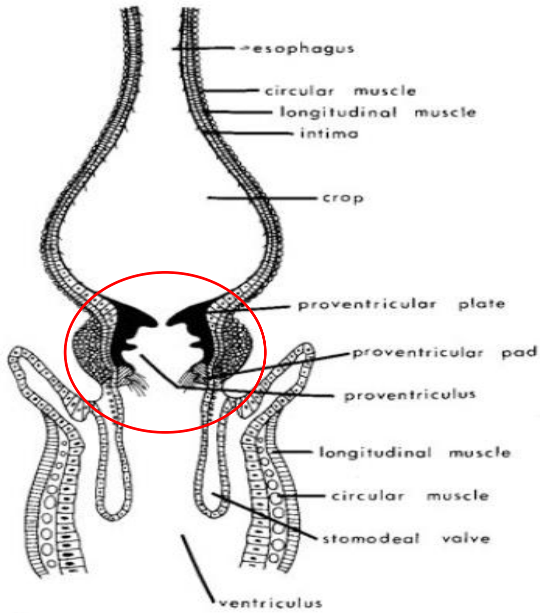

Normal
Diverticulated
Foregut
Crop
Crop
Midgut
Hindgut


crop

The Proventriculus: (Gizzard)

- the terminal region of the stomatodeum.
- The most highly specialized part of the alimentary canal.
- It is the narrowed posterior end of the stomatodeum which is more or less invaginated into the anterior end of the mesenteron to form the cardiac valve.
- In adult insects that feed on solid food it differentiated as a definite part of the alimentary tract between the crop and the ventriculus.
- Its inner walls armed with **strong cuticular plates or teeth .**





The Proventriculus: (Gizzard)

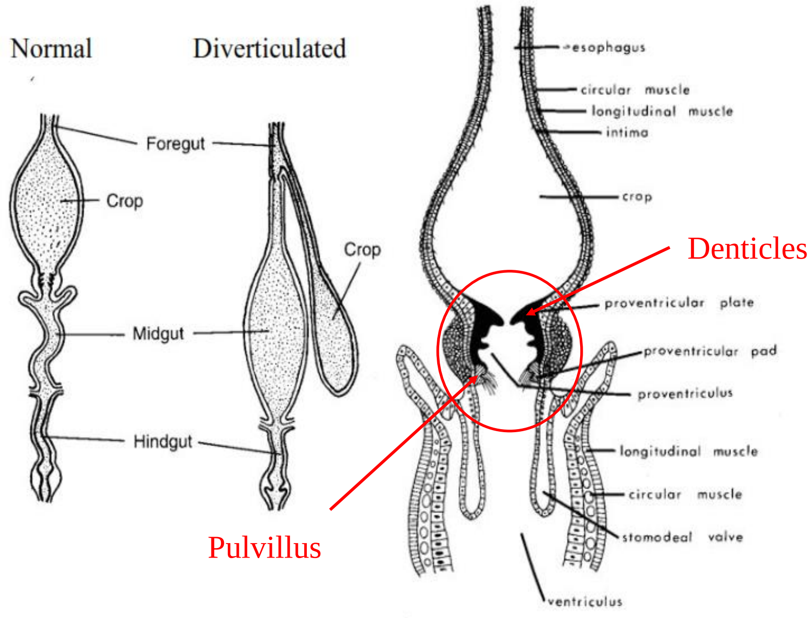
- In the inside the walls of the gizzard there are two major thickening :

A- The Denticles or proventricular plates:

It is a highly sclerotized plates located in the anterior part of the gizzard, used for crushing food particles.

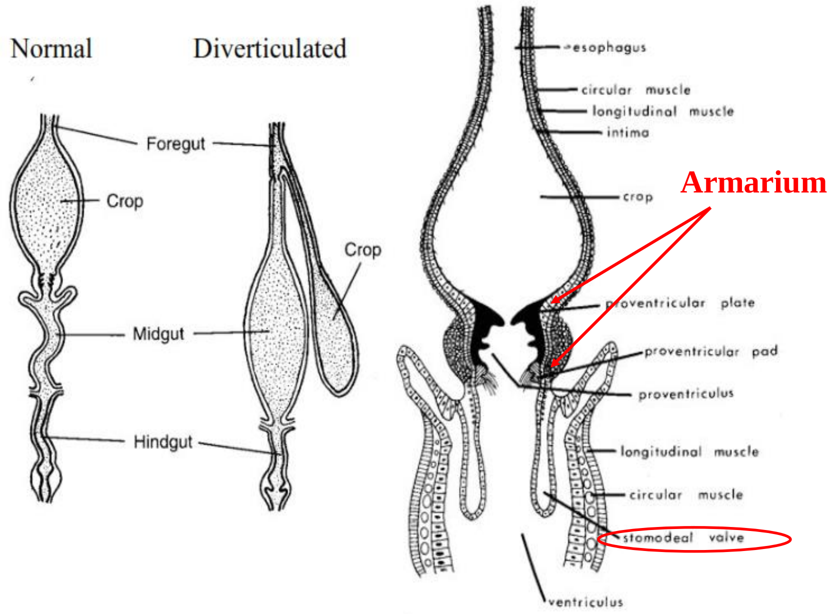
B- The pulvillus:

10 plates located in the posterior part of the gizzard act as sieve allow only the fine particles to go through

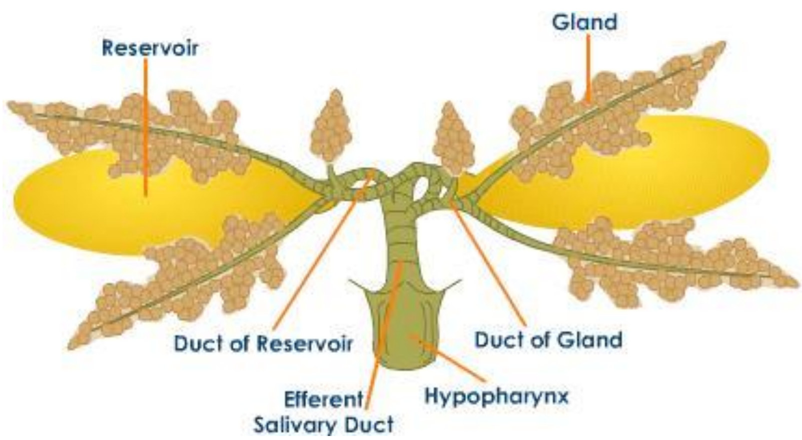


The Cardiac Valve: (stomodael valve)

- a circular fold of the stomodael wall projecting into the ventriculus from the posterior end of the stomatodeum.
- is composed of two cellular lamellae and is covered on each side by the stomodael intima.
- The basal ring of the outer lamella marks the morphological end of the stomatodeum.
- It is cylindrical of funnel shaped.
- The two lamellae are free from each other and may include between them an extension of stomodael muscles.
- The function of the cardiac valve is preventing a return movement of the food from the stomach .



Salivary Glands



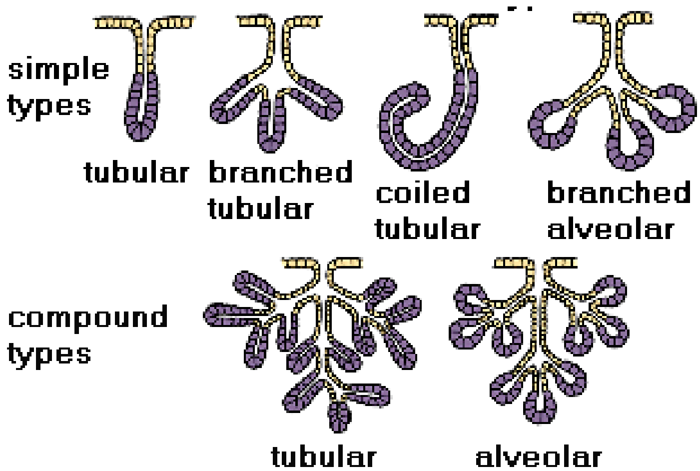
FUNCTIONS OF SALIVARY GLANDS

1. Moisten food
2. Lubricate the mouthparts
3. Contains digestive enzymes
   a. May contain enzyme amylase, which breaks down complex sugars into simpler sugars
   b. Digestive enzymes that are used by both predatory insects that inject the saliva or preoral digestion that occurs in some insects

Major types of salivary glands

1. Acinous - acinous gland (ˈas·əˈnəs ˈgland) (*anatomy*) A multicellular gland with sac-shaped secreting units. Also known as alveolar gland. **They are usually innervated** by neurons from suboesophageal ganglion and stomatogastric system. Cockroach and locust.
   a. One neuron produces dopamine which stimulates fluid secretion
   b. Another neuron produces serotonin which causes cells to produce the enzymes.

2. Tubular glands – **Not directly innervated**
   a. *Aedes* and *Calliphora* serotonin is released into hemolymph and regulates the production and release of saliva.



SALIVARY TOXINS

Below you can see that a giant water bug has paralyzed or killed a water snake. Strong salivary toxin.

The asilids have large salivary glands that produce a toxin that can kill an 85 gm. mouse. Above you can see the fly has taken down a bigger and better flyer, a dragonfly adult.

Involvement of salivary glands in pathogen or parasite transmission

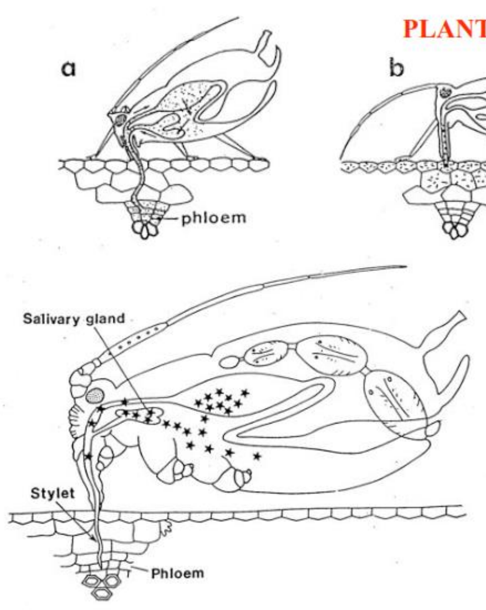
Plant feeders

a. Aphids and viruses

Blood feeders

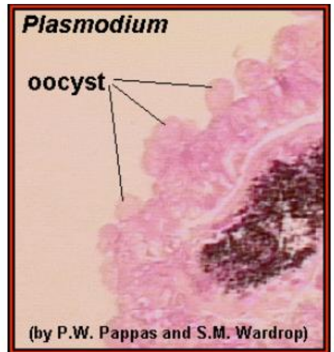
a. Mosquito and plasmodium

PLANT FEEDERS



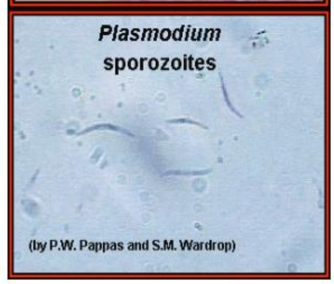
Virus transmission in aphids involves the passage through the midgut, then into the hemolymph and finally into the salivary glands where they are then passed onto another host while feeding.

To the right are the oocysts that form on the mosquito's midgut epithelia cells. Note the digested blood in the gut lumen. Inside these oocysts the parasite matures and changes to a sporozoite.



(by P.W. Pappas and S.M. Wardrop)

The sporozoites break out of the oocysts and swim through the mosquito's hemolymph and find their way to the salivary glands. They penetrate and invade a specific region of the female's salivary gland. When the now infected mosquito feeds on another host, it transfers the sporozoites with its saliva into the capillaries of the host.



(by P.W. Pappas and S.M. Wardrop)

Insect Anatomy

lecture 8

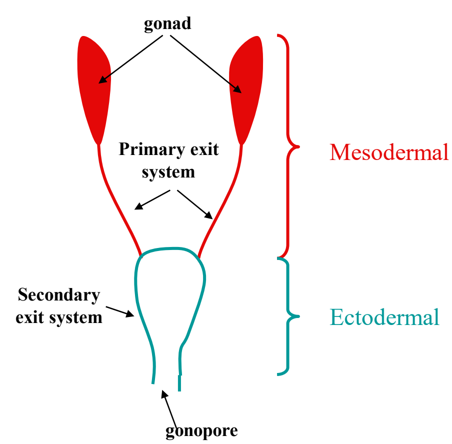
INSECT REPRODUCTIVE SYSTEM

Reproductive system

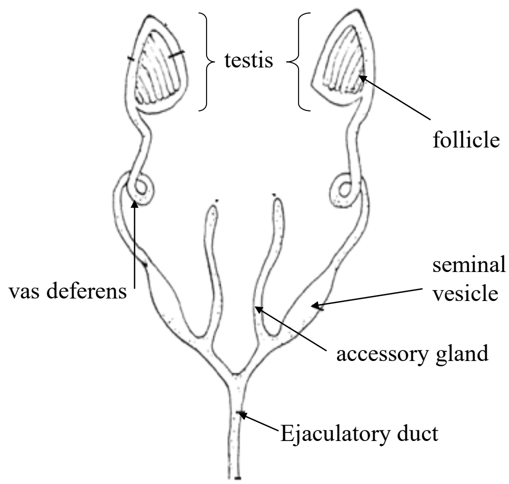
- Mixed embryonic origin **ecto- & mesoderm**
- only functional in adult
- not required for survival of individual

Male Reproductive System

- pair of testes connecting with paired seminal vesicles
- and a median ejaculatory duct
- In most insects there are also a number of accessory glands which open into the vasa deferentia or the ejaculatory duct.



Male Reproductive System



Male Reproductive System

- The testes may lie above or below the gut in the abdomen and are often close to the midline.
- each testis consists of a series of testis tubes or follicles ranging in number from **1** in Coleoptera Adephaga to over **100** in grasshoppers (Acrididae).
- the testes of Diptera consist of simple, undivided sacs, which may be regarded as single follicles.

Male Reproductive System

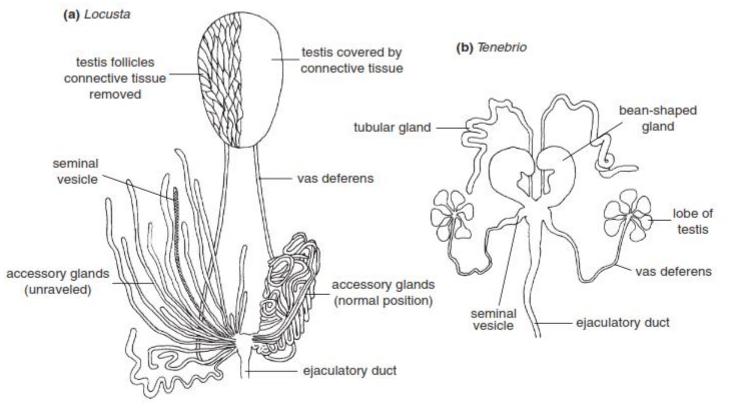
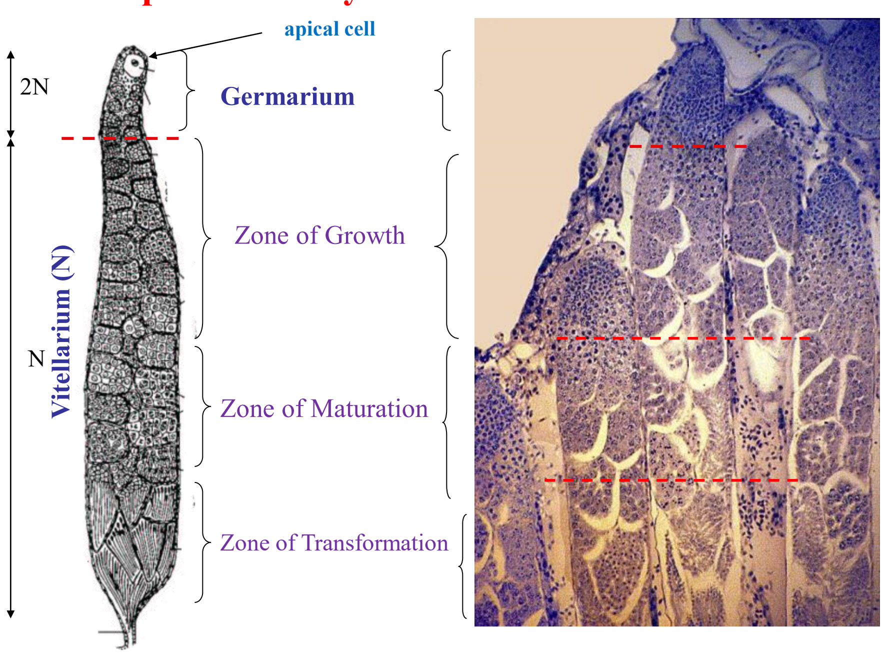
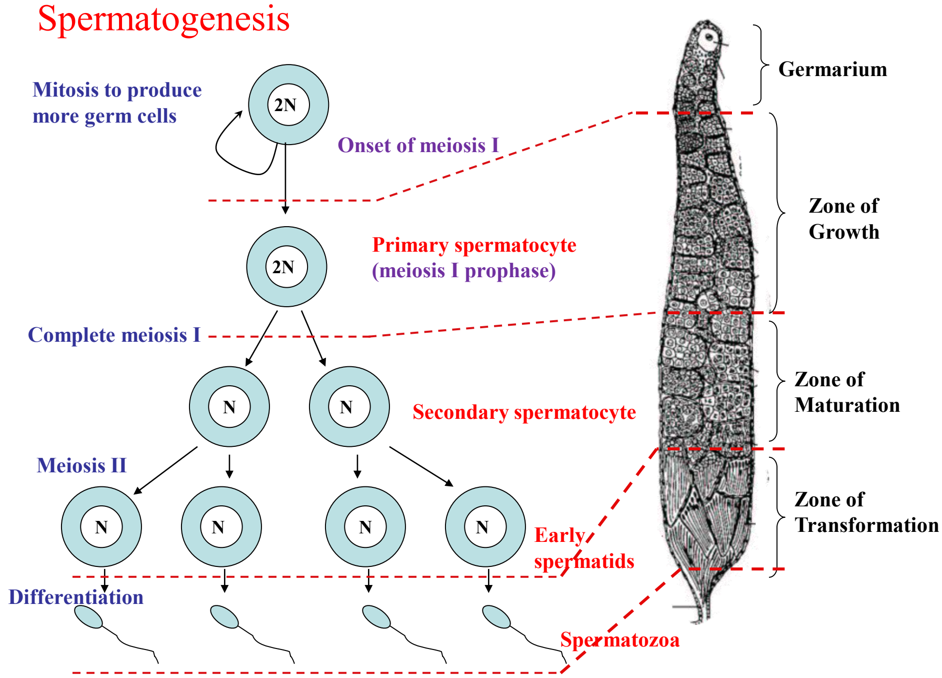


Figure 12.1 Basic structure of the internal reproductive organs of the male. (a) An insect with a large number of testis follicles and accessory glands. The testes lie close together in the midline, but are distinct. The glands are of different types (but this is not shown in the diagram) (*Locusta* [Orthoptera]) (from Uvarov, 1966). (b) An insect with several distinct testis lobes and only two pairs of accessory glands (*Tenebrio*, Coleoptera) (from Imms, 1957).

Male Reproductive System

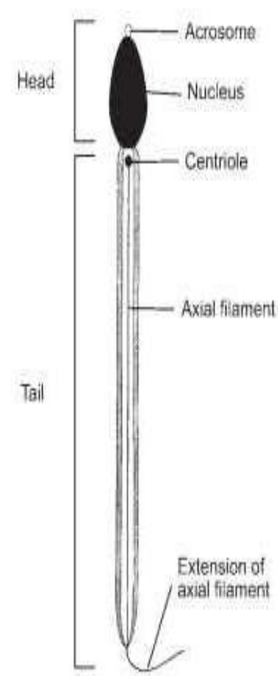


Spermatogenesis



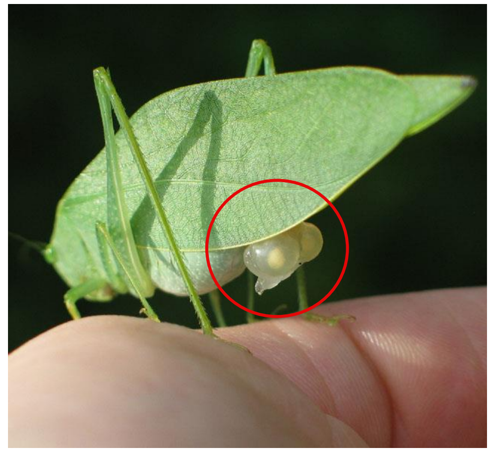
Structure of Sperm

- The mature sperm of most insects are flagellate
- 300 micron long and less than a 1 micron in diameter
- with head and tail regions of approximately the same diameter

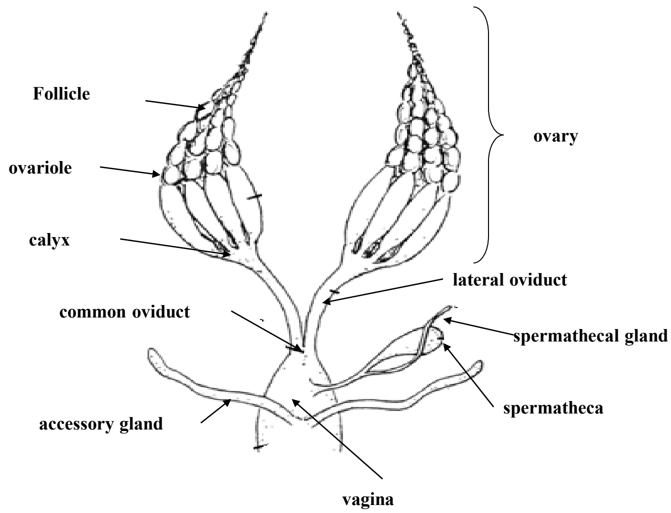


Accessory gland products - Spermatophore

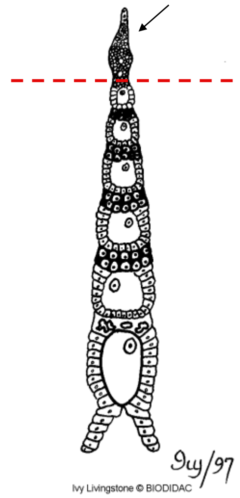
a protein capsule containing a mass of spermatozoa, transferred during mating



Female Reproductive System



Ovarioles



Germarium (2N)

Vitellarium (N)

Types of Ovarioles

1. **Panoistic:** no nurse cells
2. **Meroistic:** nurse cells are presents
   a. **Polytrophic**
   b. **Telotrophic**

Types of Ovarioles

2. Panoistic

Ovarioles that have **no specialized nurse cells** and are of a primitive type.

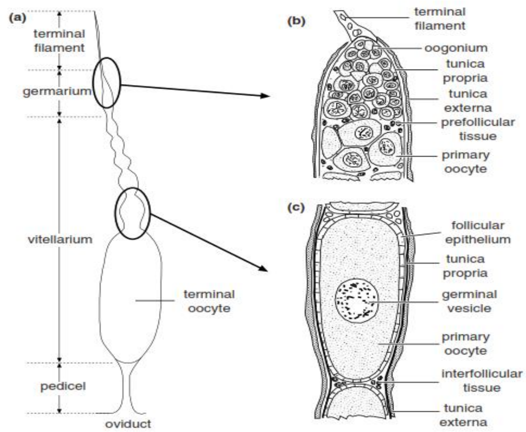


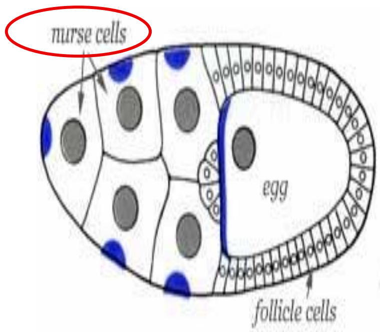
Figure 13.4 Parts of a panoistic ovariole. (a) Diagram of a whole ovariole; (b) the distal region (germarium); (c) a proximal region (part of the vitellarium).

Nurse cells:

- Cells of developing oocytes that provide material for further growth.
- In some species, the nurse cells synthesize nucleic acids and possibly protein and supply them to the oocyte via intercytoplasmic connections.

Trophocytes:

are sister cells of the oocytes so they have the same genome, retain their connections with the oocytes and supplement the oocyte.



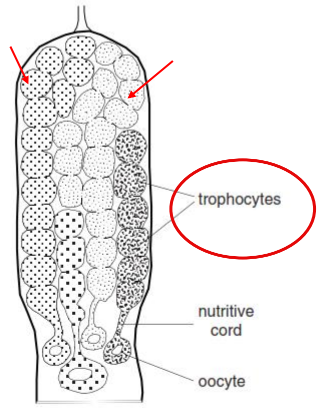


Figure 13.6 Telotrophic ovariole of a beetle. Each oocyte is shown with its associated cluster of trophocytes (Coleoptera, Polyphaga) (after Büning, 1993).

Types of Ovarioles

2. Meroistic

An ovariole in which **nurse cells, or trophocytes are present.**

a. Polytrophic:

- Divisions of the cells derived from stem cells in polytrophic ovarioles are incomplete.
- Cluster cells are formed
- the trophocytes move down the ovariole with their associated oocyte and become enclosed in the follicle

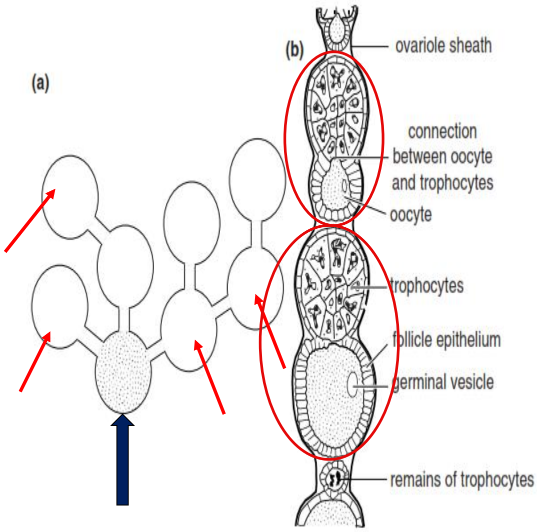


Figure 13.7 Polytrophic ovariole. (a) Diagram showing the interconnections that remain between the oocyte (stippled) and its associated trophocytes as a result of incomplete cell divisions. The oocyte always occupies the most posterior (proximal) position as it moves down the ovariole (after King, 1964). (b) Diagram of part of an ovariole in which the trophocytes are in separate follicles from the oocytes (*Bombus* [Hymenoptera]) (after Hopkins and King, 1966).

Types of Ovarioles

2. Meroistic

b. Telotrophic:

- are characterized by the presence of trophic tissue in the terminal regions.
- This arrangement is found in Hemiptera and Coleoptera Polyphaga
- Trophocyte cells are divided more than oocytes so they are large in numbers
- The cells remains connected to a central region called the trophic core
- the oocytes become clothed by follicle cells as they leave the germarium.
- but each oocyte remains connected to the germarium by a cytoplasmic nutritive cord that extends to the trophic tissue elongating as the oocyte passes down the ovariole

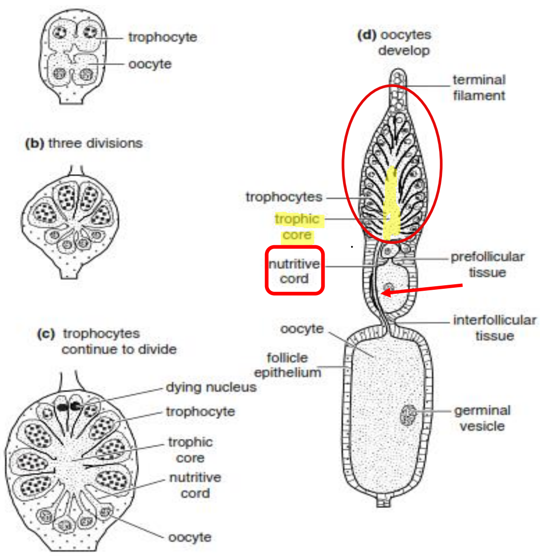
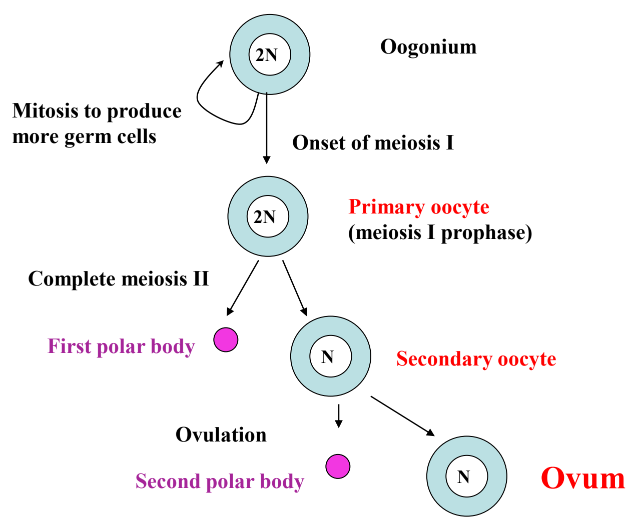


Figure 13.5 Telotrophic ovariole of a hemipteran. (a)–(c) Successive stages in the formation of a cluster of oocytes and trophocytes (after Büning, 1993). (d) Diagram of a later stage in the development of the oocytes which remain connected to the trophic core by the nutritive cords (after Huebner and Diehl-Jones, 1993).

Oogenesis



Insect Anatomy

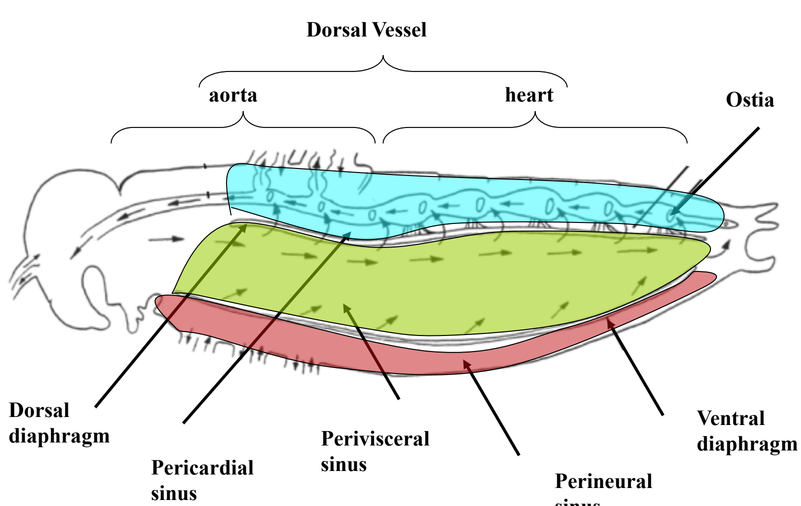
lecture 9

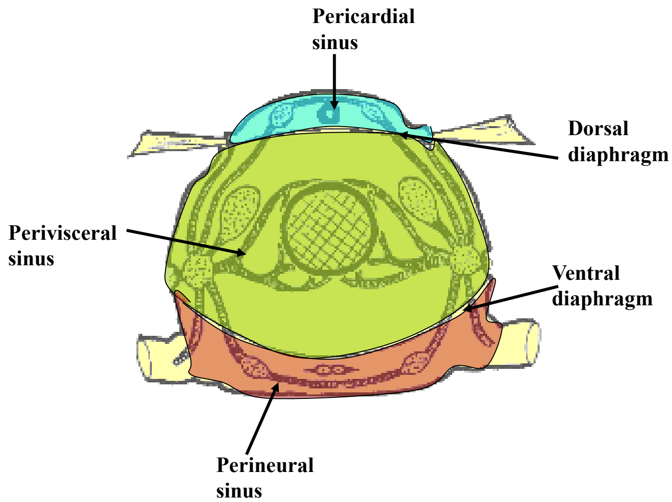
INSECT CIRCULATORY SYSTEM

Comparison of Mammal and Insect Circulatory Systems

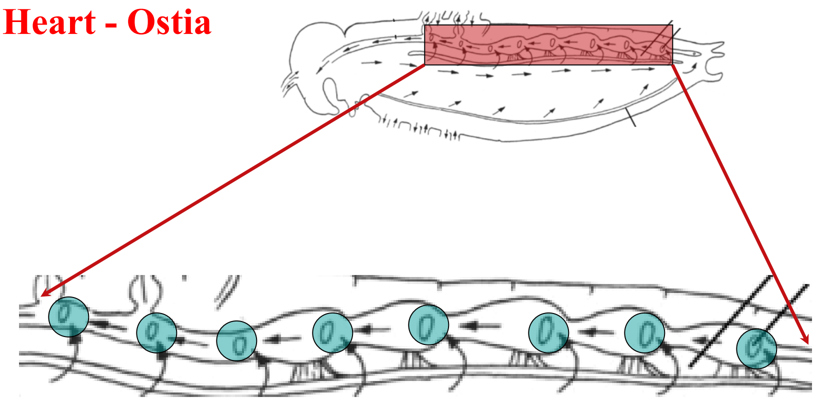
Mammal	Insect
1. Closed system with blood vessels and heart	1. Open system-hemocoel
2. Heart - ventral	2. Heart/aorta - dorsal
3. Red blood cells carry O_2 and CO_2. Use hemoglobin carrier molecule	3. No red blood cells. O_2 delivered by trachea
4. Have an immune system with long-term recognition system	4. No long-term immune response, recognition system
Acquired immunity	No acquired immunity

Generalized Insect Circulatory system



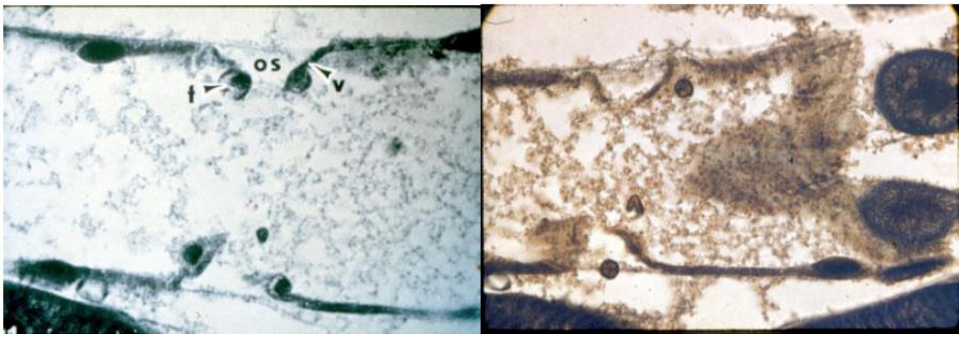


Heart - Ostia

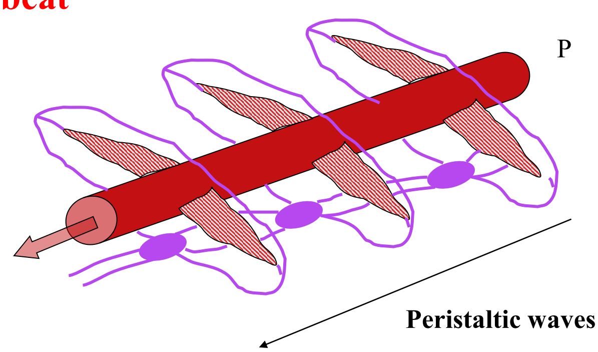


One-way valves

Heart - Ostia



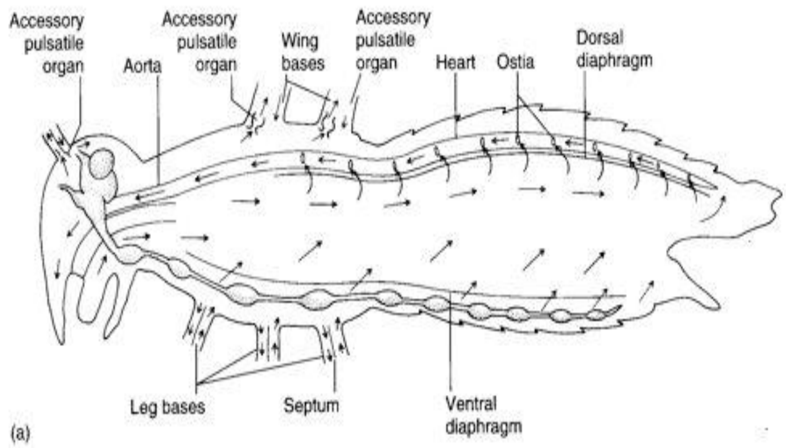
Heartbeat



Peristalsis:

involuntary movements of the longitudinal and circular muscles, primarily in the digestive tract but occasionally in other hollow tubes of the body, that occur in progressive **wavelike contractions**.

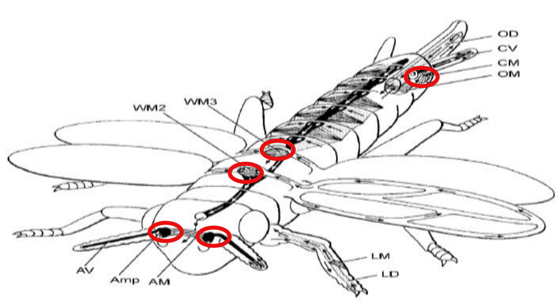
Circulation of hemolymph



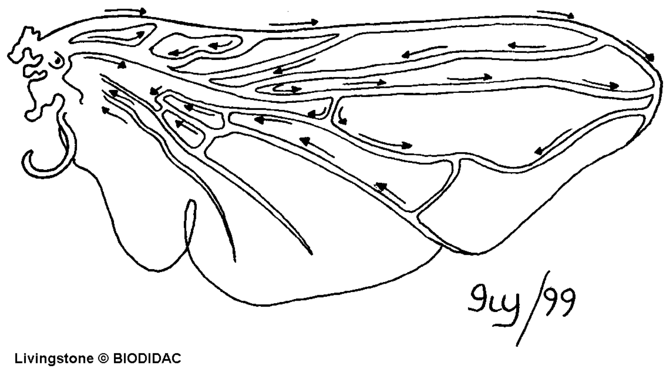
Anti clockwise circulation

Accessory Pulsatile Organs

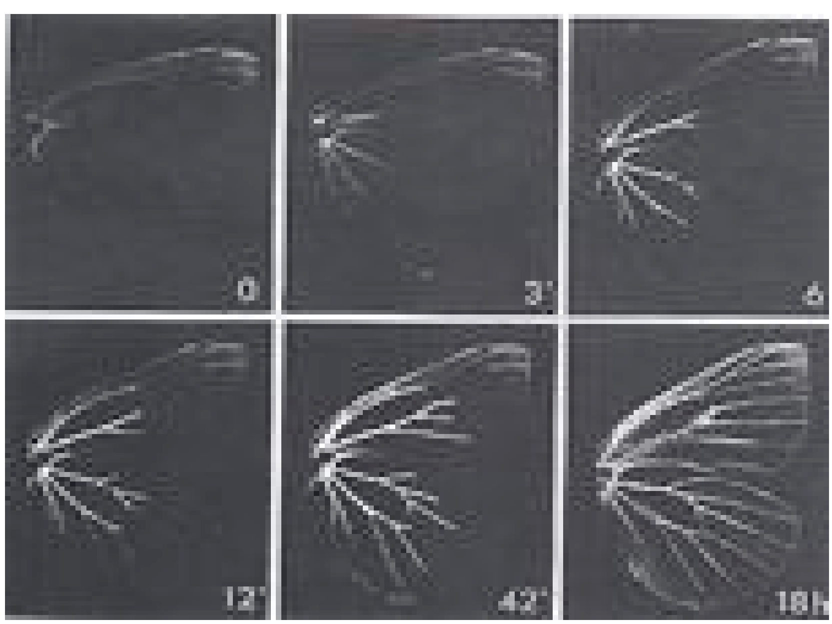
- In addition to the dorsal vessel ("heart"), insects have **accessory pulsatile organs** ("auxiliary hearts")
- that supply body appendages with hemolymph.
- They are necessary in the open circulatory system for hemolymph exchange in antennae, mouthparts, legs, wings, and abdominal appendages.



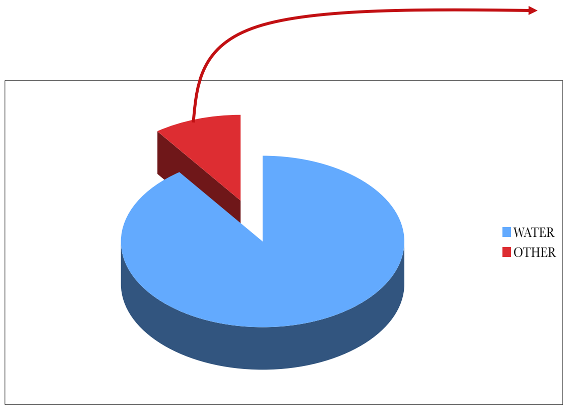
Circulation in the Wings



IN: costa, subcostal, radial, median, cubitus
OUT: anal



Hemolymph - Composition

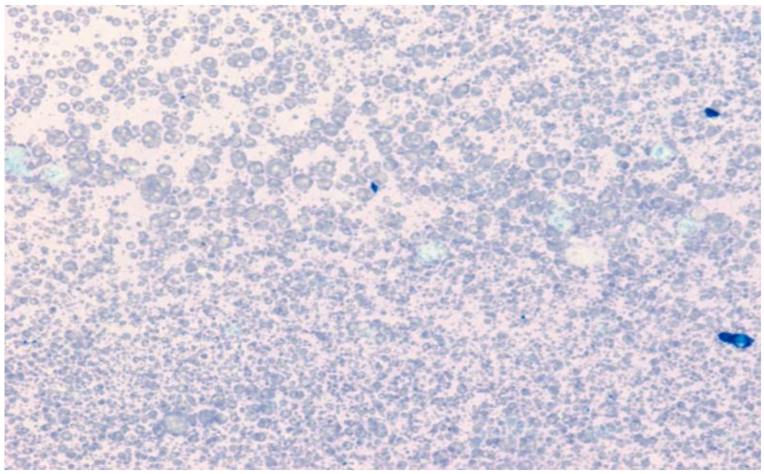


5%
Inorganics (Na, Ca, K)
Nitrogenous waste
Lipids
Amino acids
Proteins
Pigments
Hormones

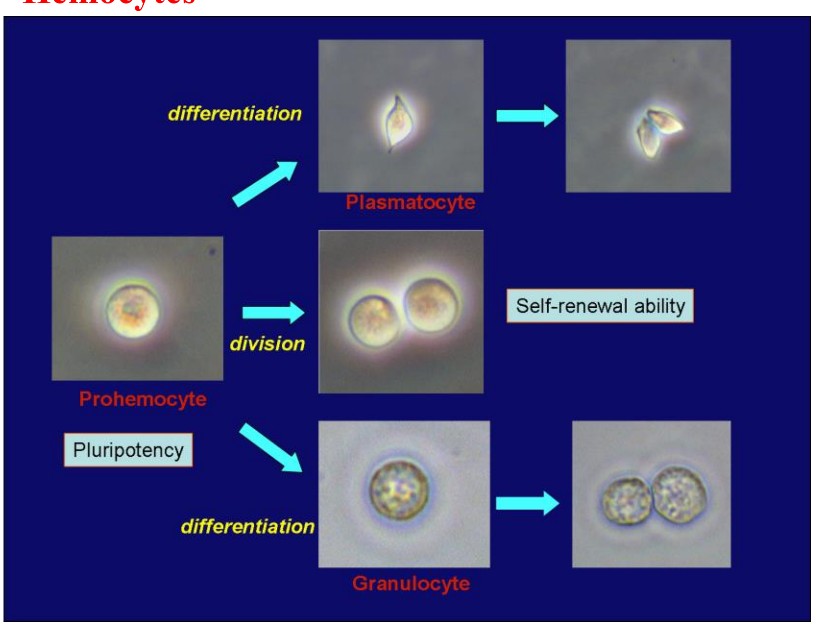
Hemolymph - Functions

1. Lubricant for tissues
2. Hydraulic fluid
3. Transport water
4. Storage - amino acids and glycerol
5. Protection - reflex bleeding
6. Non-cellular immune responses

Hemolymph - Insect Blood



Hemocytes



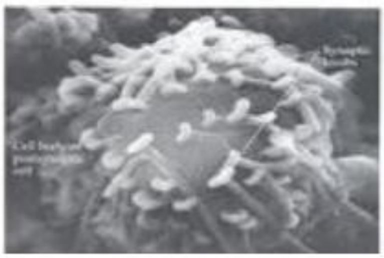
Insect Anatomy

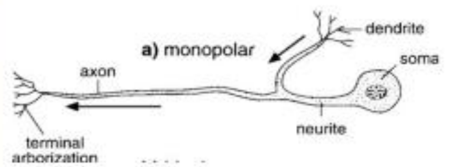
lecture 10

INSECT
Insect nervous Systems

Differences between the human and insect nervous systems

HUMAN	INSECT
1. Dorsal nervous system	1. Ventral nervous system
2. Soma or perikarya can have synaptic input on them	2. Soma or perikarya do not have have synaptic input on them
3. No monopolar neurons	3. Most common neuron is monopolar
4. Cell bodies not on periphery of ganglia	4. Cell bodies on periphery of ganglia
5. Have myelinated neurons	5. Lack classical myelin sheaths
6. CNS has about 10^{10} neurons	6. CNS has about 10^5-10^6 neurons





FUNCTIONS OF THE NERVOUS SYSTEM

is an information processing and conducting system

1. **To provide for coordination of events involving most of the other systems that are under nervous control**
2. **To provide for feedback from various parts of the insect that then can impact the central nervous system.**
3. **To act as the 'windows' of the insect by providing sensory input from the various sense organs, sensilla, receptors or better known as the affectors.**
4. **Provides rapid response and feedback from its peripheral receptors**
5. **Rapid transfer of information concerning short-term events and also the coordination of these short-term events**
6. **Transfer of messages to the effectors (i.e., muscles and glands)**

INSECT NERVOUS SYTEM

A. Central nervous system (CNS)

1. Brain-supraesophageal ganglion. Is the result of the fusion of first ganglion in early ancestors

a. Protocerebrum

b. Deutocerebrum

c. Tritocerebrum

2. Ventral nerve cord and segmental ganglia

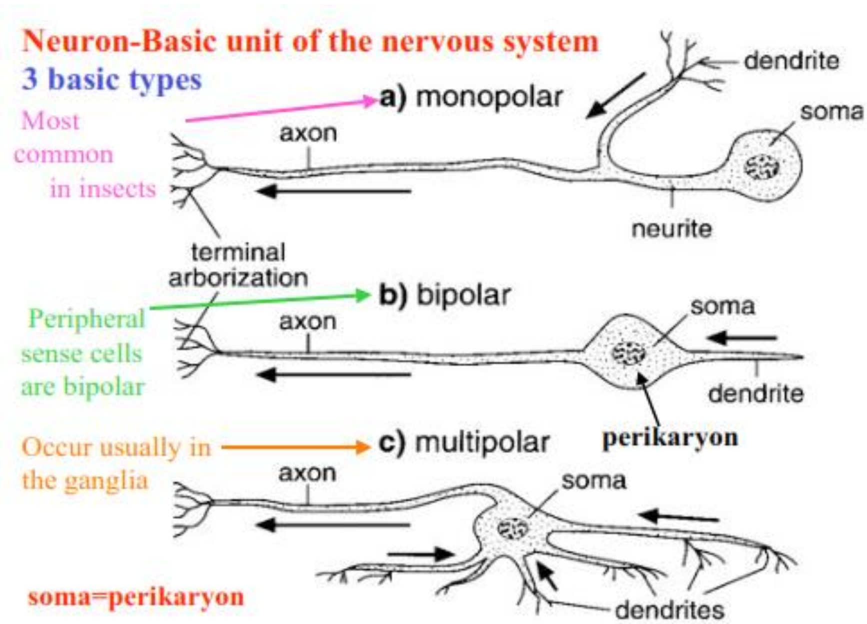
a. Subesophageal ganglion. Is the result of the fusion of ganglia 2,3 and 4 in early ancestors

B. Stomatogastric, stomodael or visceral nervous system (VNS)

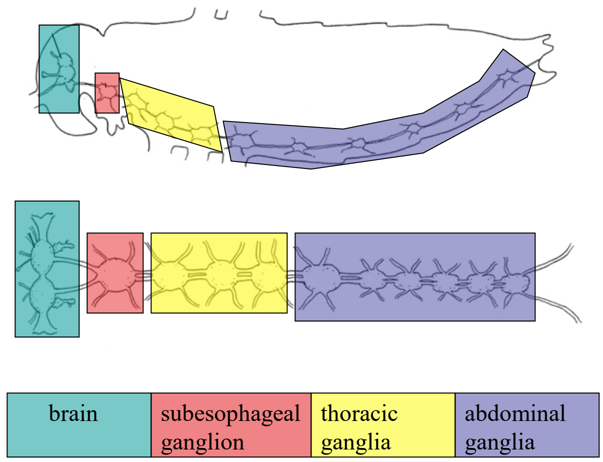
1. Frontal ganglion
2. Recurrent nerve
3. Hypocerebral ganglion complex

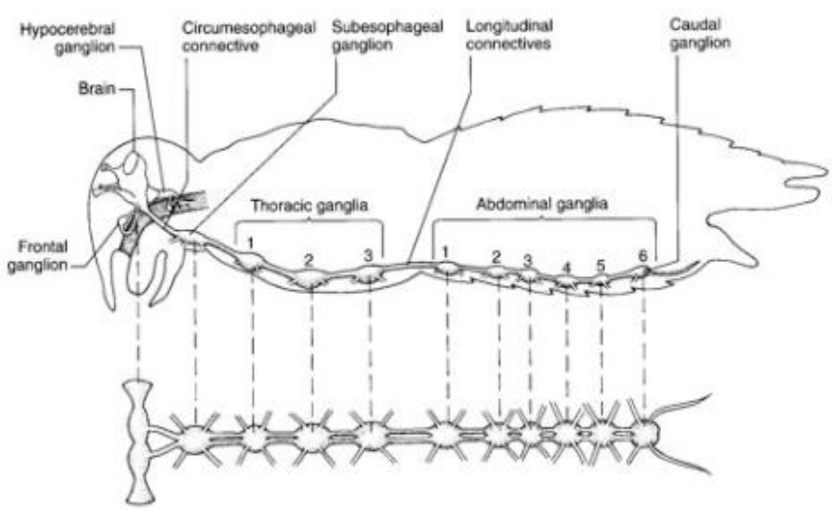
C. Peripheral nervous system (PNS)

1. **Receptor-cell** or part of a cell that converts stimuli into nerve impulses
   example=chemoreceptor, mechanoreceptor
2. **Sensillum** a simple sense organ composed of a few neurons
   example=chemosensillum
3. **Sense organs**-grouping of several kinds of cells or tissues built around a group of receptor cells of a specialized type. Example=eye, antenna



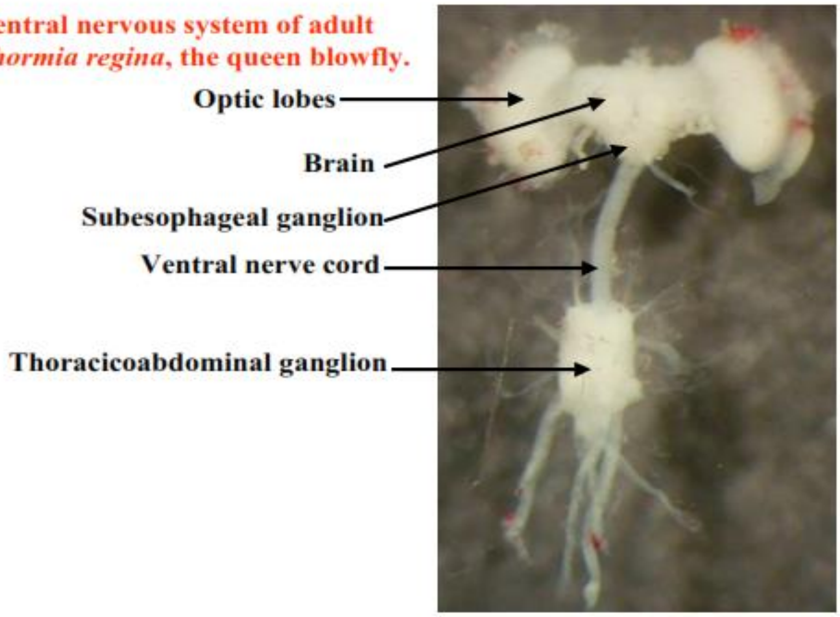
Insect Central Nervous System

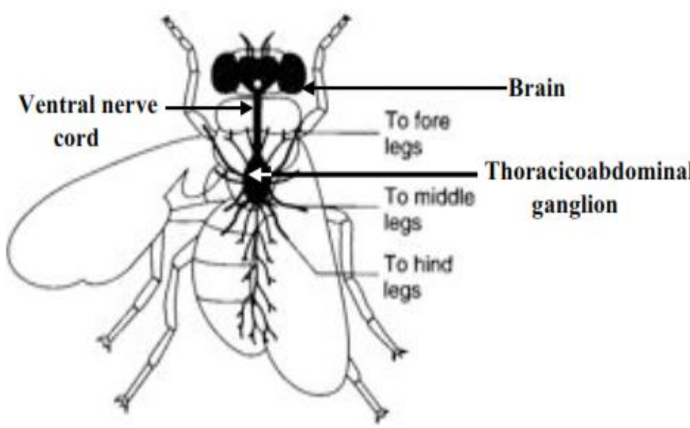




Ganglion=a collection of neurons. Note the CNS is composed of a double chain of ganglia joined by lateral and longitudinal connectives. In many insects the ganglia have fused (e.g., the Diptera).

Central nervous system of adult *Phormia regina*, the queen blowfly.





1. Brain or supraesophageal ganglion

A. Protocerebrum

Innervates compound eyes and ocelli and is the area where complex behaviors are summated and integrated.

In insects that have a well developed directional sense to return to a nest the corpus pedunculatum is large compared to other insects.

B. Deutocerebrum

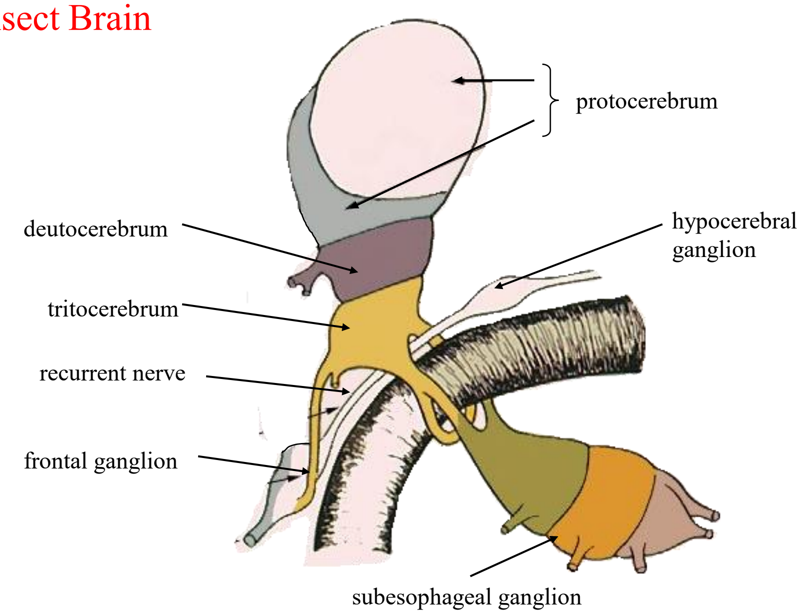
Innervates and coordinates information from the antennae.

C. Tritocerebrum

Connects brain to visceral nervous system via the recurrent nerve and to the ventral nerve cord via the circumesophageal connectives.

Connect to the frontal ganglion and innervates the labrum.

Insect Brain



2. Ventral nerve cord

Conducts impulses to and from the brain and ganglion from the peripheral nervous system.

3.Ventral ganglia

Thoracic: control flight, locomotion and breathing

Abdominal: control breathing, reproductive tract, copulation and ovipositioning.

Centers: for various preprogrammed motor outputs.

4.**Suboesophageal ganglion**

Resulted from the fusion of the 2,3 and 4 ganglia of early ancestors. It innervates the muscles and sense organs associated with the mouthparts (excluding the labrum), plus the salivary glands.

In some insects it has an excitatory and inhibitory influence on motor activity in the whole insect

LIST OF RECEPTOR TYPES

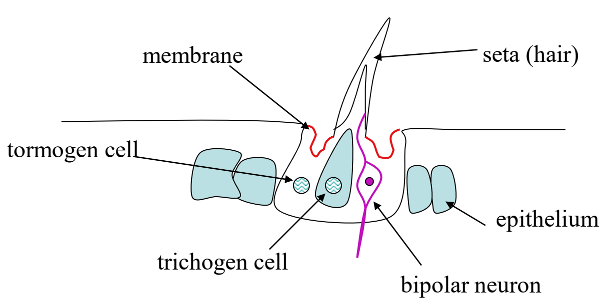
1. Mechanoreceptors
2. Chemoreceptors
3. Proprioceptors
4. Thermoreceptors
5. Osmoreceptors
6. Photoreceptors
7. Hygroreceptors

Mechanoreceptors

- Mechanoreception is the perception of distortion of the body caused by mechanical energy, which may originate either internally or externally.
- Produces the senses of

a. gravity
b. pressure
c. touch
d. position
e. current flow (air or water)
f. vibration
g. hearing

Sensory Organs - Mechanoreceptors

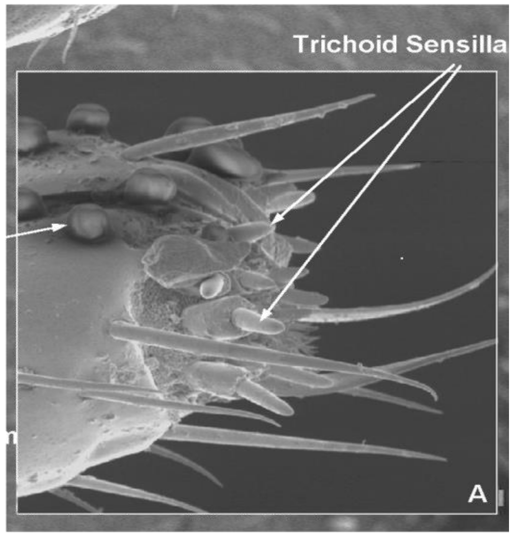


Hair sensillum (trichoid sensillum)

tormogen cell. : a specialized epidermal **cell** in insects that forms a socket at the base of some hairs.

trichogen cell. (hair cell**)**. It is An epidermal cell that is part of a cell cluster organ of the insect integument and that secretes a cuticular specialization, often in the form of a hair, bristle, peg or scale.

Hair sensillum (trichoid sensillum)



Hair sensilla serve various functions in the insect:

1. Sense of touch

a. All over the body
b. Ovipositor
c. Cerci
d. Antennae
e. Mouthparts including palps

2. Air movement

a. Antenna
b. Cerci
c. Front and top of head for monitoring air flow when in flight. Responsible for maintaining wing beat; aerodynamic sense organs. Are directionally sensitive
d. Caterpillar hairs respond to wing beat frequency of wasp

Hair sensilla serve various functions in the insect:

3. Orientation with respect to gravity

Usually involved proprioreceptors

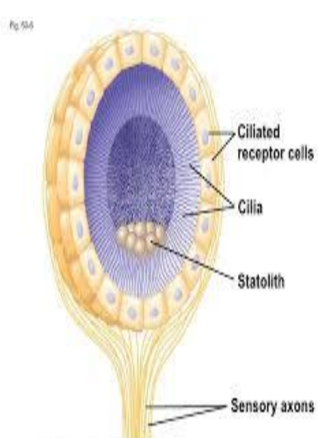
a. In desert locust they have specialized hairs with swollen bulbs at the tip that are located on the cerci. Center of gravity is presumed to be inside the bulb.

b. Some have statolith-like structure but they have not been clearly demonstrated to be gravity receptors

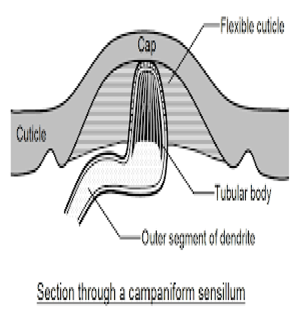
4. Pressure receptors-Found in some aquatic insects to monitor depth they are at head and body orientation

5. Proprioceptors-Mechanoreceptors that usually signal movements or position of parts of the body. Respond to deformations (changes in length) and stresses (tension and compressions) of the body.

note: The insect maintains position by assessing much information from a multitude of receptors."



statolith-like structure



Pressure receptors

Chemoreceptors

Olfaction:

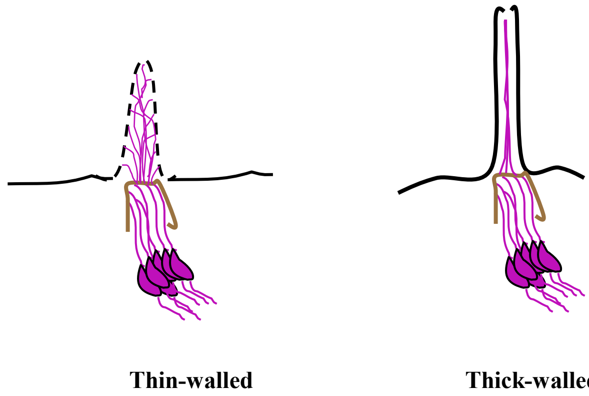
1. The sense of smell or response to volatile or gaseous chemicals
2. Axons from the olfactory receptors terminates in **antennal lobes**
3. Sensilla are multiporous
4. Usually no socket region to hair
5. Number of neurons in each olfactory sensillum varies from 2 to 20
6. Pheromone-binding protein is produced by the trichogen and tormogen cells
7. Located on:
   a. antenna b. palps c. genitalia

Chemoreceptors

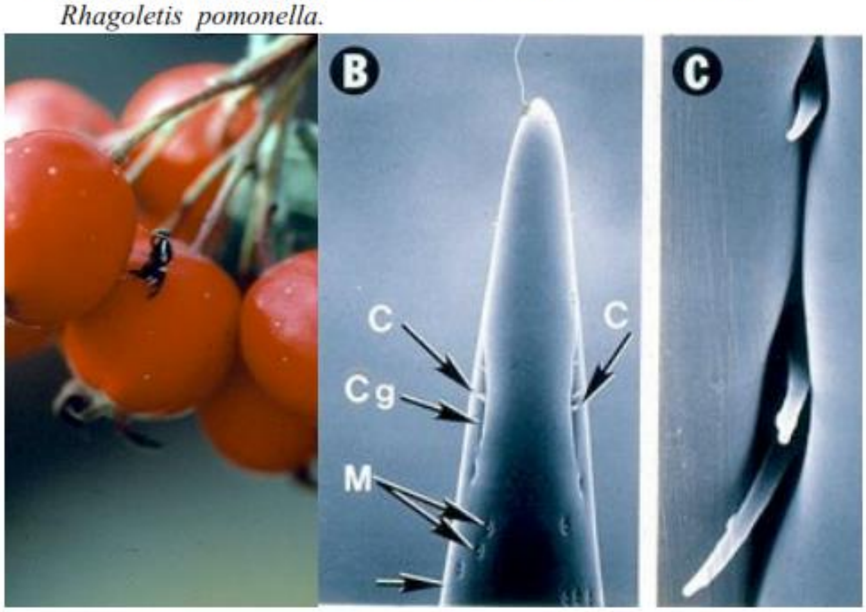
Gustation or Contact chemoreception:

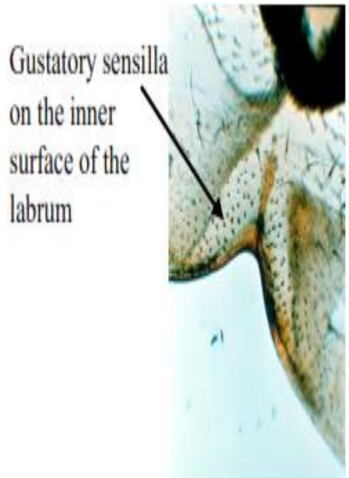
1. Detection of chemicals by contact
2. Axons from the contact chemoreceptors terminate in the ganglion in which the receptors are located
3. Sensilla are uniporous with pore at tip
4. Usually has a socket region to hair giving it some mobility
5. Usually have 4 chemosensitive neurons
6. They can be located any where on the body but are found on:
   a. labrum
   b. maxillae
   c. labium
   d. antenna
   e. tarsi
   f. ovipositor

Chemoreceptors



Contact chemosensilla (C) on the ovipositor of the apple maggot, *Rhagoletis pomonella.*





PROPRIOCEPTORS

Hair plates or position receptors-Hair sensilla that are located in patches. Located in neck region, joints of legs and palps. The hairs are stimulated by folds of the intersegmental membrane or contact with adjoining surfaces as the joints move.

Inner coxal hair plate of *Periplaneta*

Thermoreceptors

Heat reception is used by:

1. Hematophagous insects to induce biting

   a. Two hairs on tarsi of the forelegs of *Glossina morsitans*

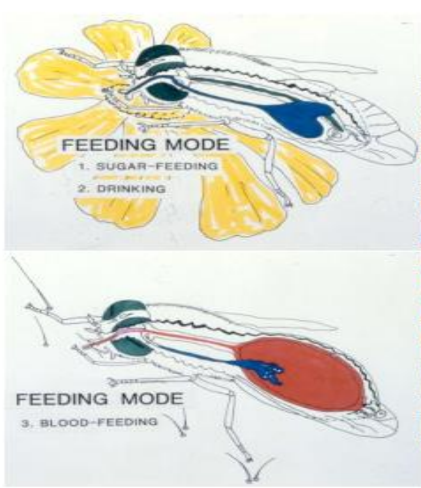
2. Heat seeking (smoke and fire) beetles

3. Find the favored environment for survival

   a. On tarsi of *Periplaneta americana*

Osmoreceptors

The ability to respond to changes in the osmotic pressure of a fluid



In tabanids, a sugar meal is directed to the crop while a blood meal is sent to the midgut. What are the controlling mechanisms that regulate where the meal is shunted? **In order to look at this, studies were done by changing the osmolarity of both sugar and ATP (which is a phagostimulant) for hematophagous insects.** In the next slide(s) we will present some of this data and also the flow diagrams or models that were generated from these studies.

PHOTORECEPTORS

Photoreception is perception to electromagnetic stimuli in the organism's receptor ability to perceive that stimuli or wavelength.

1. Compound eyes
2. Ocelli or simple eyes

HYGRORECEPTORS-
Sensilla that response to changes in the humidity and are extremely important to insects that need to conserve water loss.

Sense cells responsive to temp. and humidity are usually present in the same sensillum.
Have a short peg and no pore.

All insects studied have these on the antenna.