Advanced Insect physiology / M.Sc. Lecture 1

Introduction to insect physiology

Insects External Anatomy

Insect Morphology

MORPHOLOGY: IS THE STUDY OF FORM AND FUNCTION.

Insects are arthropods: Arthropoda: "jointed feet"

General characteristics of arthropods:

Exoskeleton

Bilateral Symmetry

Segmented bodies

Paired segmented appendages

Ventral nerve cord

Dorsal heart and open circulatory system

General characteristics of insects:

The body is comprised of 3 distinct body regions -- head, thorax, and abdomen

The thorax of adults bears 3 pairs of legs and 2 pairs of wings if present.

The "breathing" system is comprised of air tubes

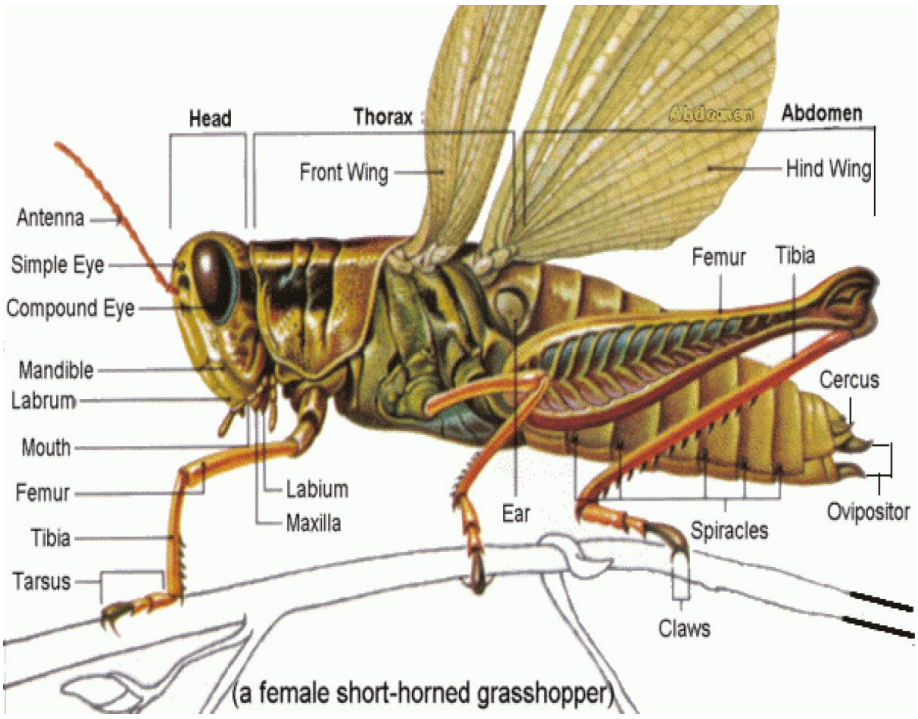
The exoskeleton is comprised of(3) types of sclerites(hardened plates)

Tergites: Dorsal plates

Sternites: Ventral plates

Pleuron: Lateral area, often membranous

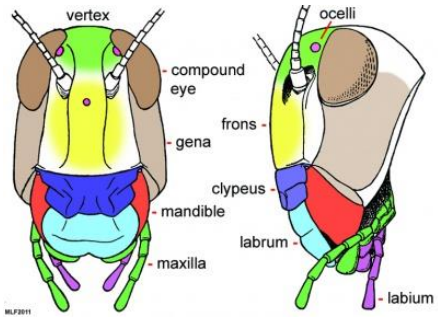
The insect head bears: mouthparts, eyes, and antennae.



Head

Generally, a head has four functions:

1. For food ingestion
2. For sensory perception
3. To coordinate body activities
4. To protect coordination centers



Mouthparts

Labrum (1) (Upper lip) The **labrum** partially or completely obscures the **mandibles** and helps hold food in a position when the insect feeds.

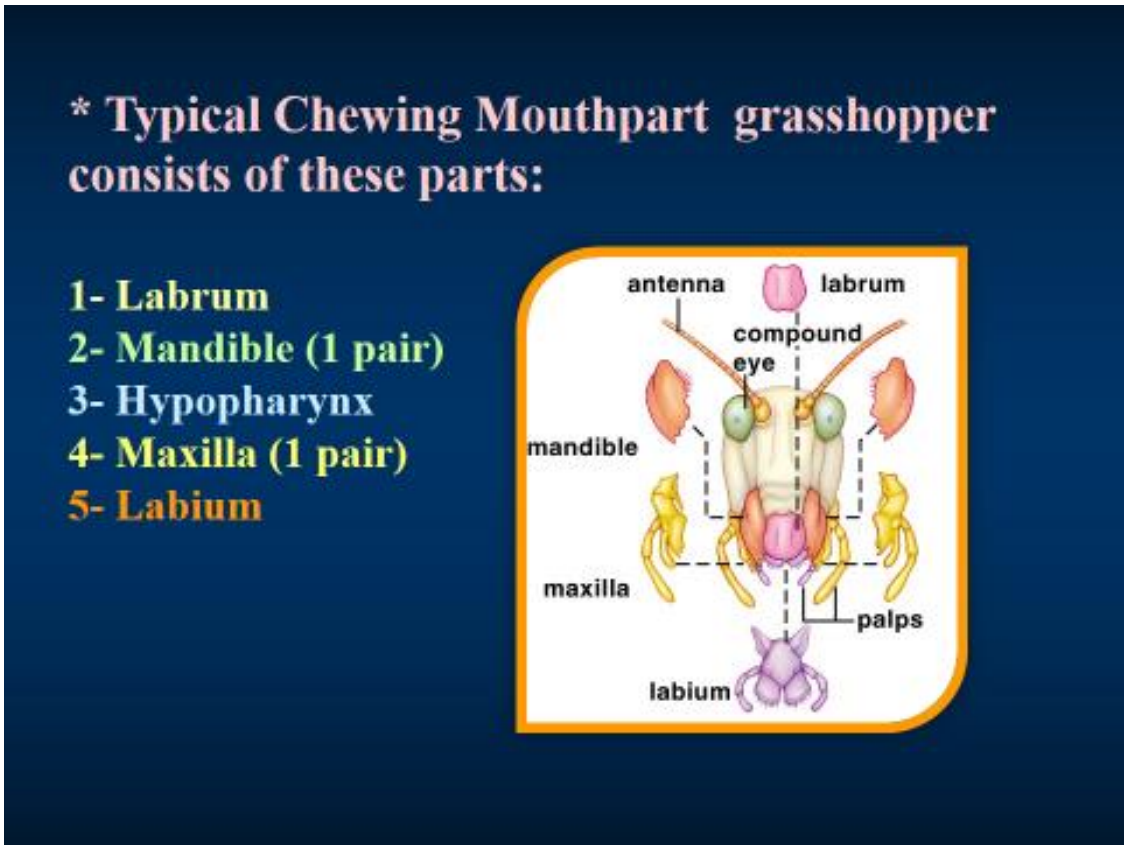
Mandibles (2) (upper jaws) A pair of jaws for crushing or grinding the food.

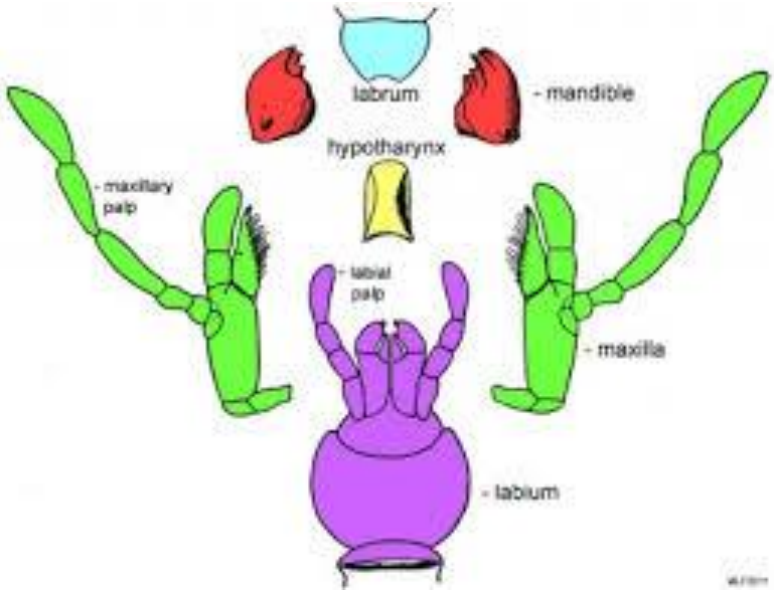
Maxillae (2) (More jaws) Sensory in function, taste.

Labium (1) (Lower lip) Typically, together with the maxillae, the labium assists manipulation of food during mastication.

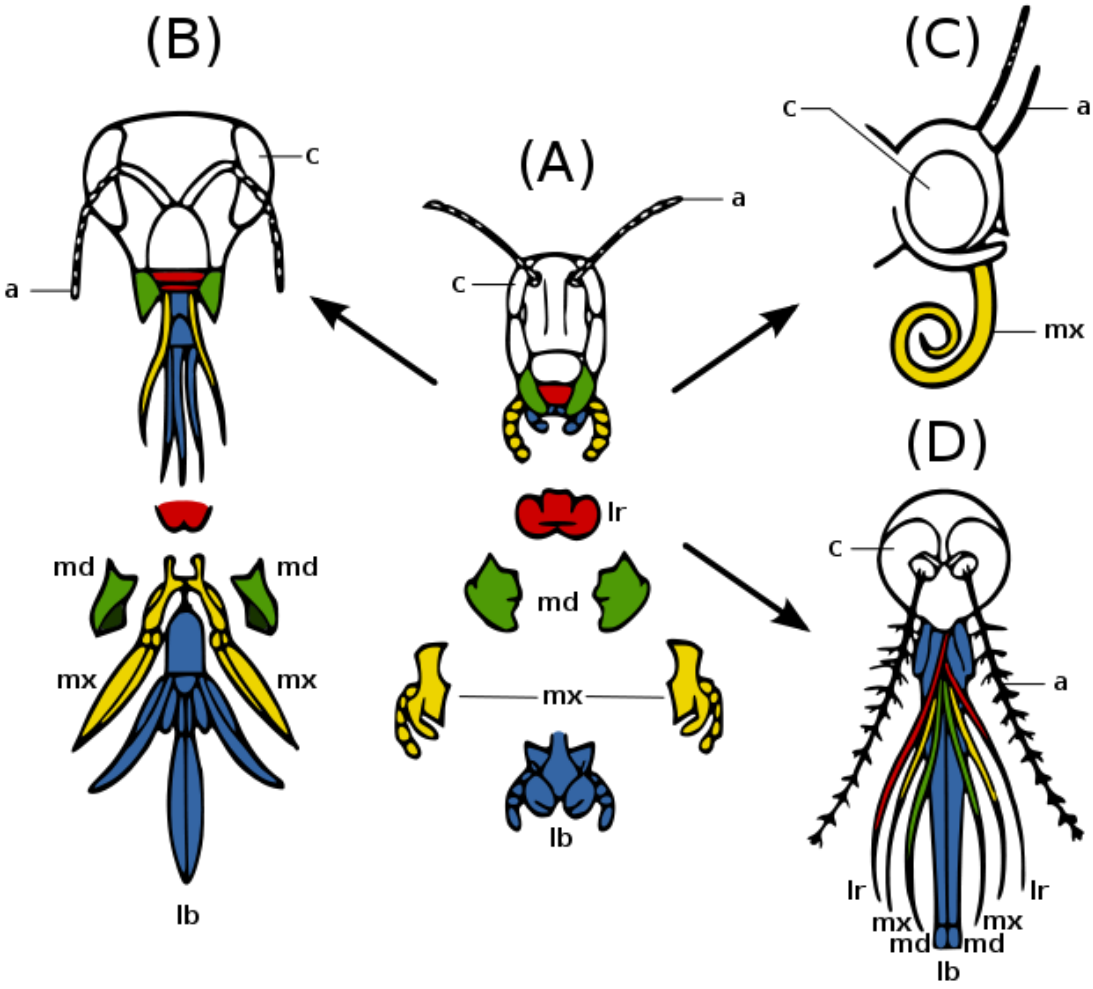
Hypopharynx (1) (A tongue-like process that helps mix food and saliva)

Labrum-epipharynx (1) (Fleshy inner surface of labrum - sensory)



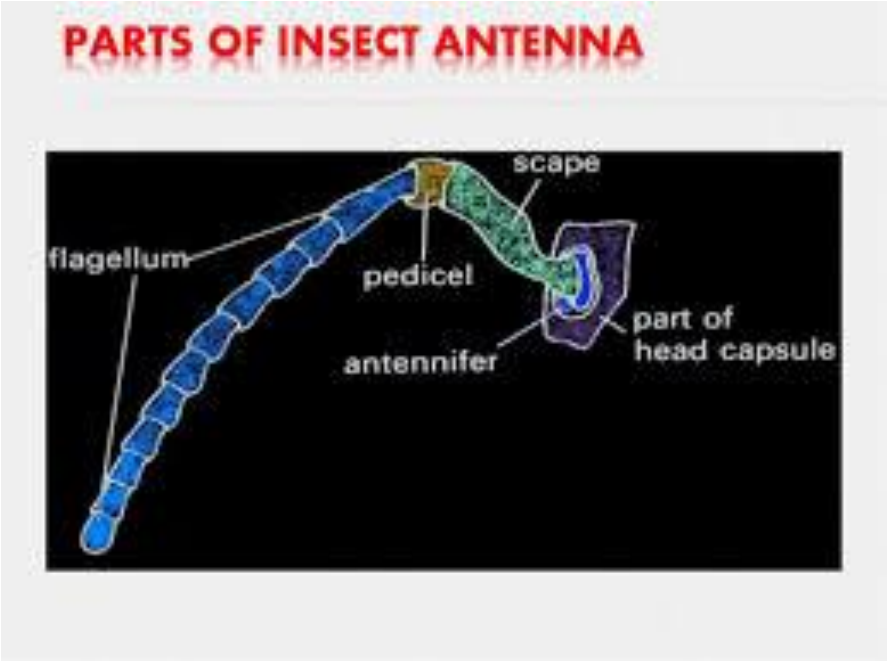


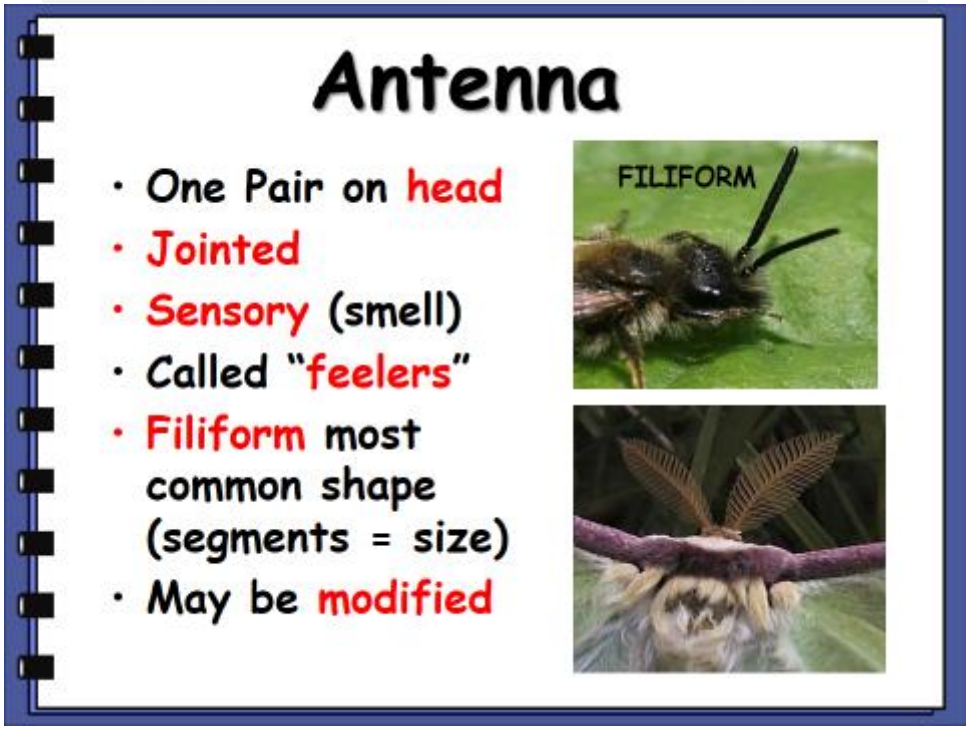
The mouthparts of Cockroaches

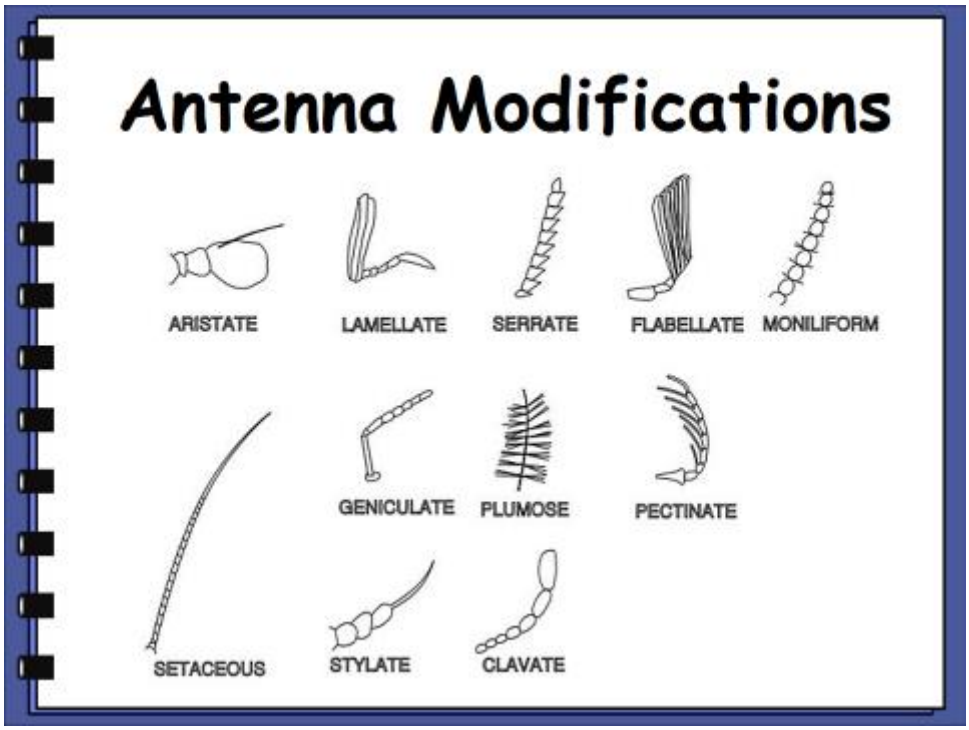


Modifications of mouthparts

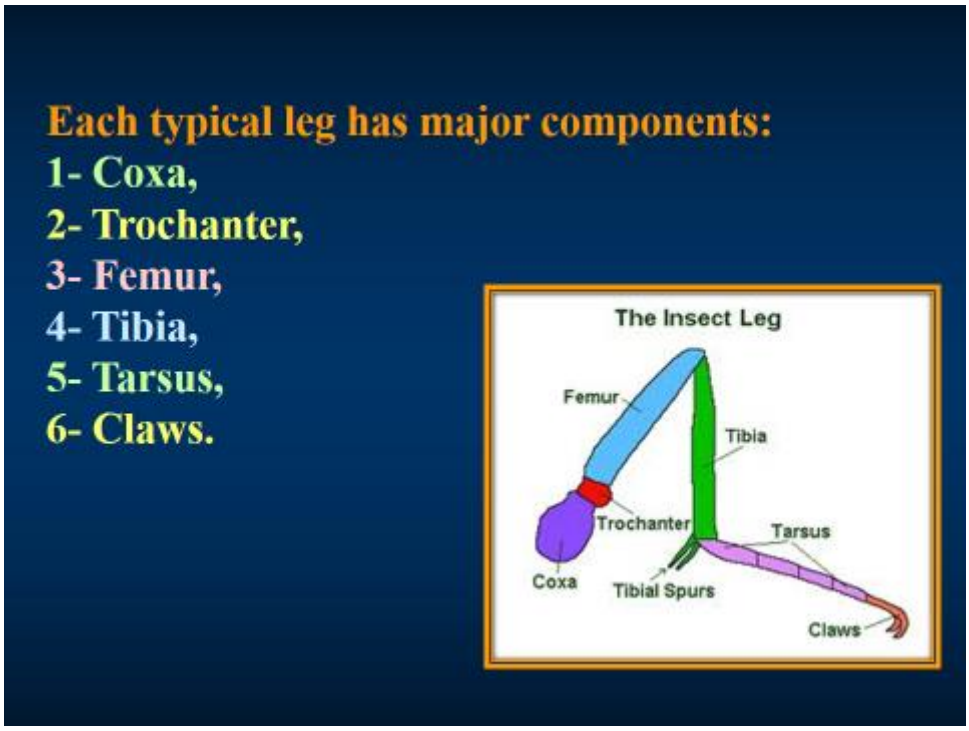
The antennae

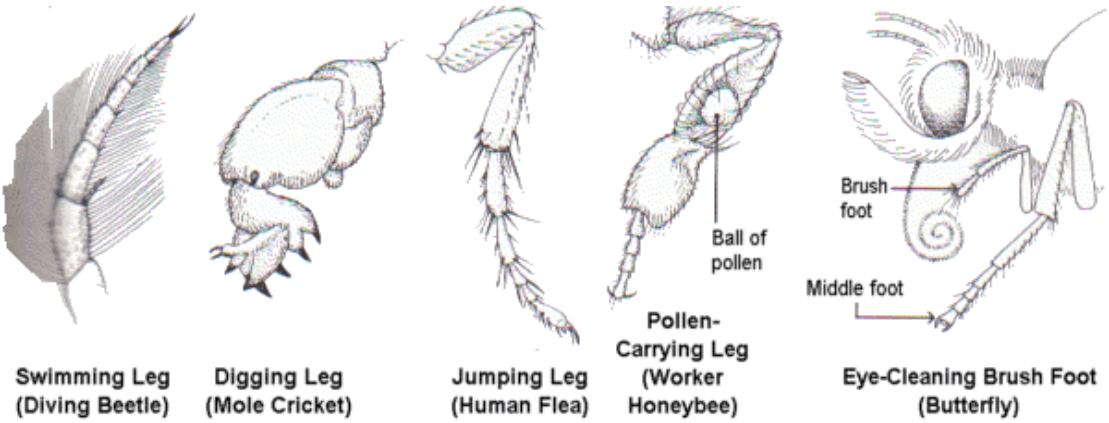





Antenna Modifications
ARISTATE
LAMELLATE
SERRATE
FLABELLATE
MONILIFORM
GENICULATE
PLUMOSE
PECTINATE
SETACEOUS
STYLATE
CLAVATE

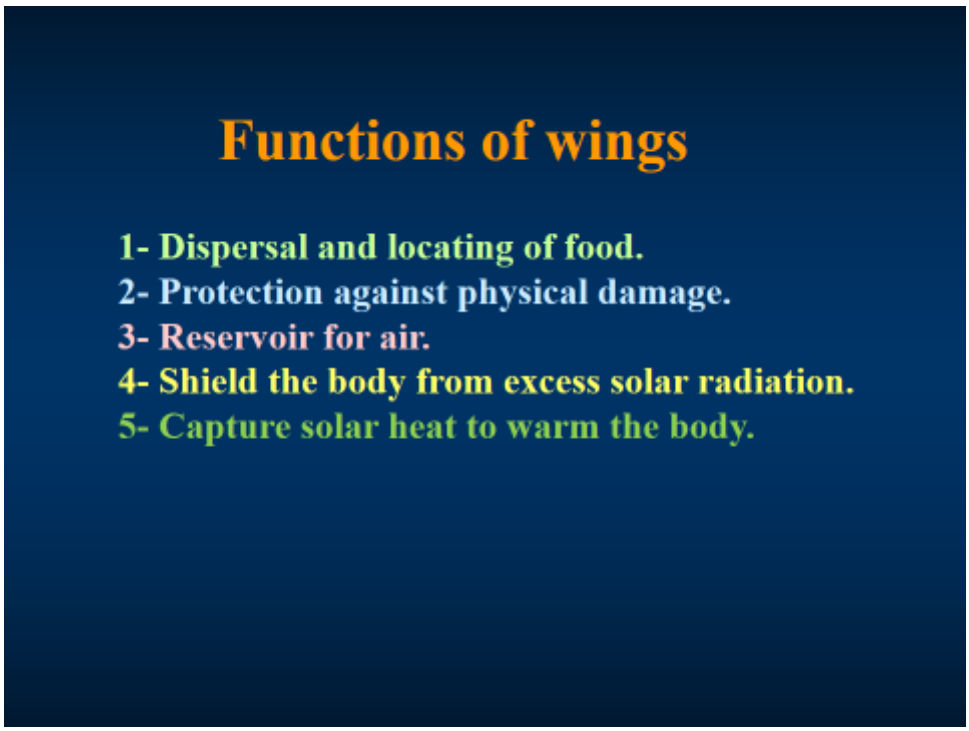
The legs

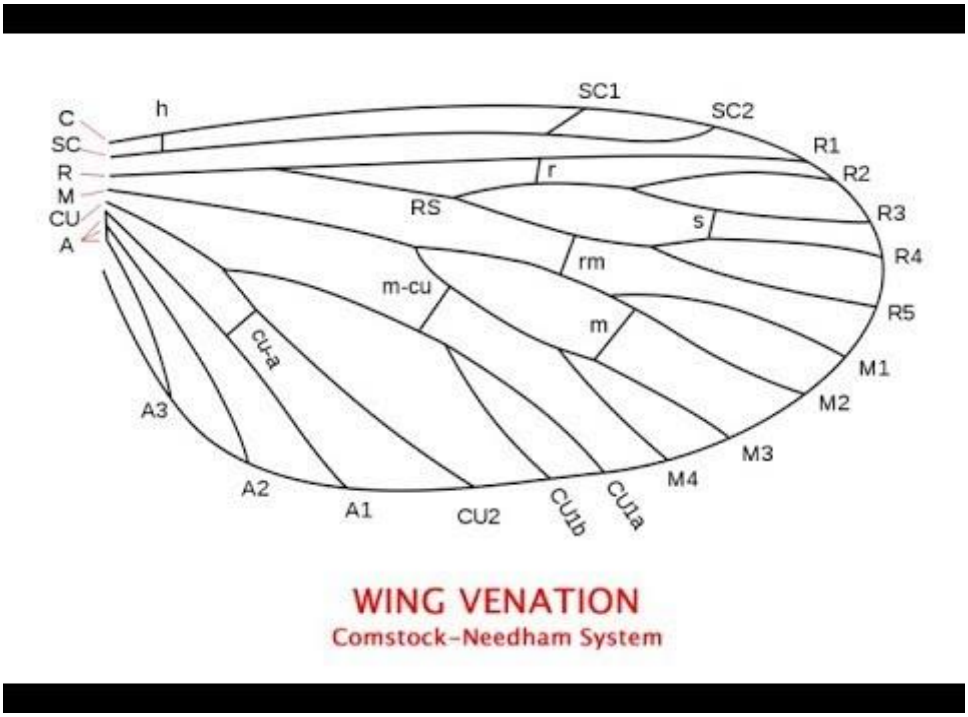

Each typical leg has major components:
1- Coxa,
2- Trochanter,
3- Femur,
4- Tibia,
5- Tarsus,
6- Claws.
The Insect Leg
Femur
Tibia
Trochanter
Tarsus
Coxa
Tibial Spurs
Claws



The modifications of insect legs

The wings

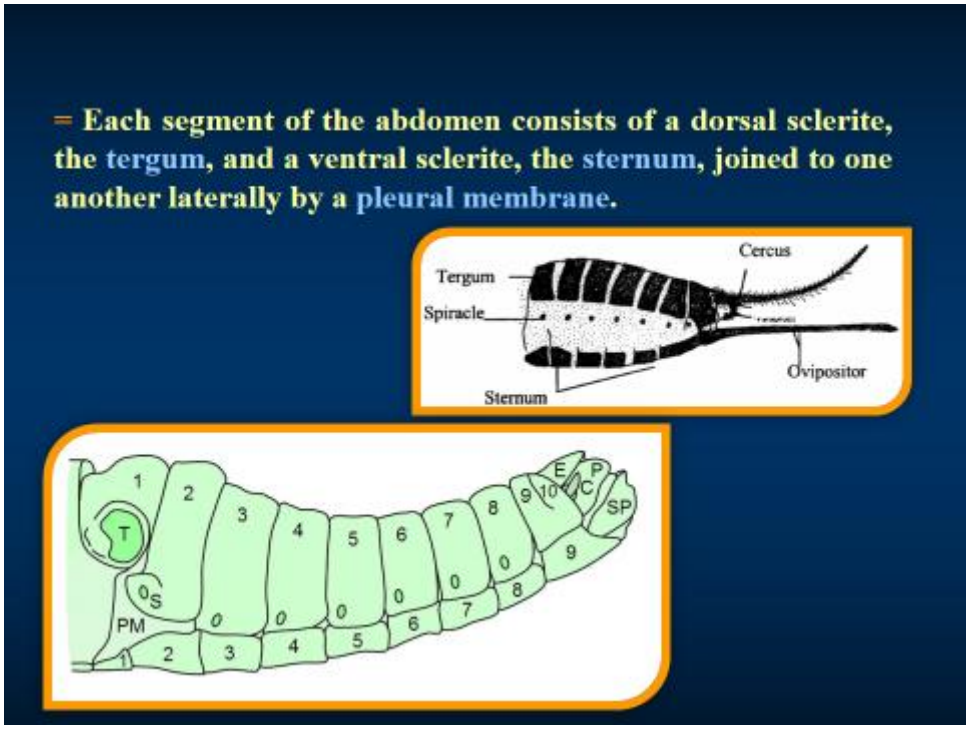




Abdomen

Abdominal Segments:

- In the embryo usually consists 12 segments, later the last segments degenerate and appear as (7-11th) segments.
- Last segment is known as telson or tail as in case of Protura.
- From (1-7th) are (pre-genital segments).
- From (8-9th) are known as (genital segments)
- From (10-11th) are known as (post- genital segments).



What is physiology?

Physiology is the study of how the body functions. It is a branch of biology that deals with the structure and function of the body's organs and tissues. Physiology is divided into five main branches: Anatomy, histology, cellular physiology, organ physiology, and systemic physiology.

Insects are the most diverse of all organisms on earth. Their general body plan allows for this great diversification in form. Insects are arthropods meaning they have an external skeleton that covers the internal tissues.

The exoskeleton protects the internal tissue but also allows for sensory systems to function.

Insect physiology is the specialized study of how insects live and reproduce. The aim of studying insect physiology is to understand the functions of the insects' internal organs and their different structures and organs and function of each organ.

The Body wall of an insect

Integument and Exoskeleton

The **integument** is the outer protective covering of insects and other arthropoda, forming the **exoskeleton** or **body wall**. Unlike vertebrates that have an internal skeleton(endoskeleton), insects possess a capsule-like exoskeleton. The exoskeleton is produced by the underlying epidermal cells and is separated from the hemolymph by a basement membrane.

STRUCTURE, PARTS OF THE INTEGUMENT

a. Cuticle (epicuticle & procuticle)

b. Epidermis (hypodermis)

c. Basement membrane

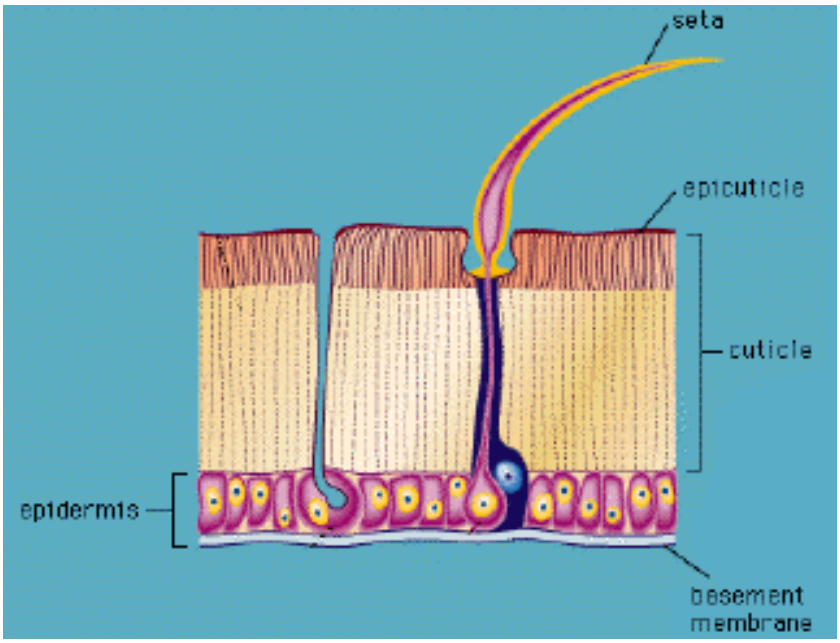


Fig. 2 General structure of the insect integument

The outer most layer, the Epicuticle, is the thinnest layer with its primary function of water protection. Lipids are found on the surface of the epicuticle to provide protection against water loss in terrestrial insects and water gain in aquatic insects.

The exocuticle and endocuticle make up the majority of the thickness of the exoskeleton.

These layers are primarily made up of a protein and chitin complex that is held tightly together with small molecular weight.

Epicuticle

The thin, top layer of the cuticle, consisting of the inner and outer epicuticles, the wax layer, and the cement layer.

Exocuticle

The outer layer of the procuticle that is sclerotized and incapable of resorption.

Endocuticle

The innermost layer of the cuticle secreted by epidermal cells. It is unsclerotized and capable of being resorbed during the molting process.

Procuticle

The undifferentiated chitinous cuticle that develops into the endocuticle and exocuticle.

Epidermis

The single layer of cells that secrete the cuticle.

Basement membrane

The innermost layer of the integument that is secreted by hemocytes, forming a continuous layer of connective tissue that separates the body cavity from the integument.

Dermal gland

A modified epidermal cell that produces the cement layer, as well as defensive secretions and pheromones.

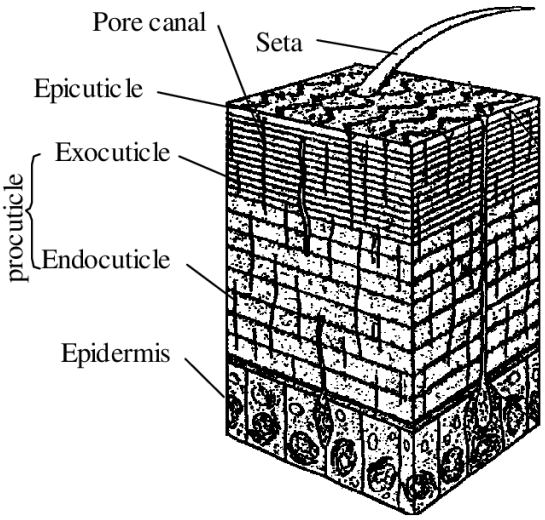


Fig. 3 General structure of the insect integument showing the different types of cuticles

Roles And Functions of integument

1- Determine the habit of the insect body (form, surface markings).

2- Protects against harmful external effects (mechanical, physical, chemical, and biological).

3- Keeps water, ion, and thermal balance.

4-External skeleton (*exoskeleton*) providing places for muscle attachments within the body.

5. Forming Walls of fore gut, hind gut, and external genitalia.

6. Forming Trachea system and sensory organs

7. Protection against germs and other parasites.

Moulting (Ecdysis)

The molting process is triggered by hormones released when an insect's growth reaches the physical limits of its exoskeleton. Each molt represents the end of one growth stage (**instar**) and the beginning of another (Figure 1). In some insect species the number of instars is constant (typically from 3 to 15), but in others it may vary in response to temperature, food availability, or other environmental factors. An insect is known as an **imago** (adult) when it becomes sexually mature. At this point, molting stops and energy for growth is channeled into production of eggs or sperm.

An insect cannot survive without the support and protection of its exoskeleton, so a new larger replacement must be constructed **inside** the old one. much like putting an overcoat under a sweater! The molting process begins when epidermal cells respond to hormonal changes by increasing their rate of protein synthesis. This quickly leads to **apolysis** -- physical separation of the epidermis from the old endocuticle. Epidermal cells fill the resulting gap with an inactive molting fluid and then secrete a special lipoprotein (the **cuticulin layer**) that insulates and protects them from the molting fluid's digestive action. This cuticulin layer becomes part of the new exoskeleton's epicuticle

After formation of the cuticulin layer, molting fluid becomes activated and chemically "digests" the endocuticle of the old exoskeleton. Break-down products (amino acids and chitin microfibrils) pass through the cuticulin layer where they are

recycled by the epidermal cells and secreted under the cuticulin layer as new procuticle (soft and wrinkled). **Pore canals** within the procuticle allow movement of lipids and proteins toward the new epicuticle where wax and cement layers form.

When the new exoskeleton is ready, muscular contractions and intake of air cause the insect's body to swell until the old exoskeleton splits open along lines of weakness (ecdysial sutures). The insect sheds its old exoskeleton (**ecdysis**) and continues to fully expand the new one. Over the next few hours, sclerites will harden and darken as quinone cross-linkages form within the exocuticle. This process (called **sclerotization** or tanning) gives the exoskeleton its final texture and appearance.

An insect that is actively constructing new exoskeleton is said to be in a **pharate** condition. During the days or weeks of this process there may be very little evidence of change. Ecdysis, however, occurs quickly (in minutes to hours). A newly molted insect is soft and largely unpigmented (white or ivory). It is said to be in a **teneral** condition until the process of tanning is completed (usually a day or two).

The stages of molting

Step 1: Apolysis-separation of old exoskeleton from epidermis.

Step 2: Secretion of inactive molting fluid by epidermis.

Step 3: Production of cuticulin layer for new exoskeleton .

Step 4: Activation of molting fluid.

Step 5: Digestion and absorption of old endocuticle .

Step 6: Epidermis secretes new procuticle.

Step 7: Ecdysis -- shedding the old exo- and epicuticle.

Step 8: Expansion of new integument.

Step 9: Tanning - sclerotization of new exocuticle.

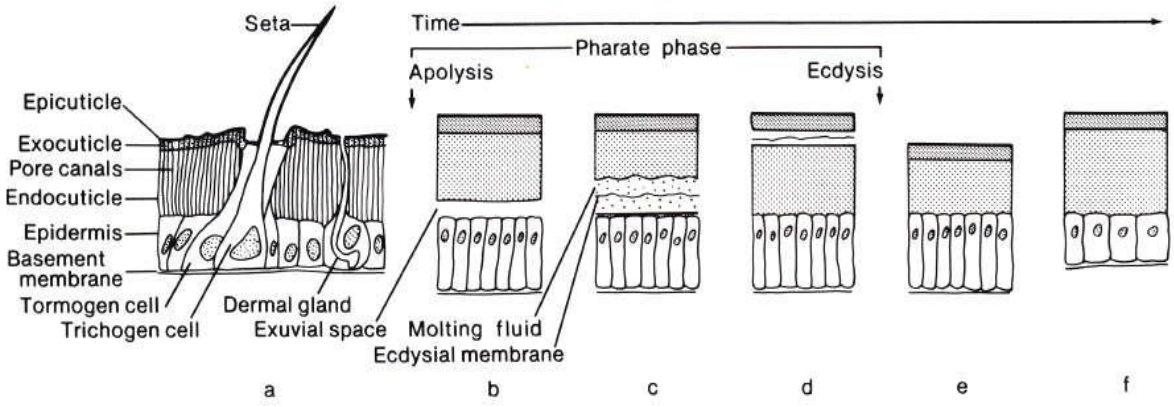


Fig (4) The stages of molting.