Hexapoda

- External Structure and Locomotion
- Nutrition and the Digestive System
- Gas Exchange
- Circulation and Temperature Regulation
- Nervous and Sensory Functions
- Excretion
- Chemical Regulation
- Reproduction and Development

GENERAL CHARACTERISTICS:

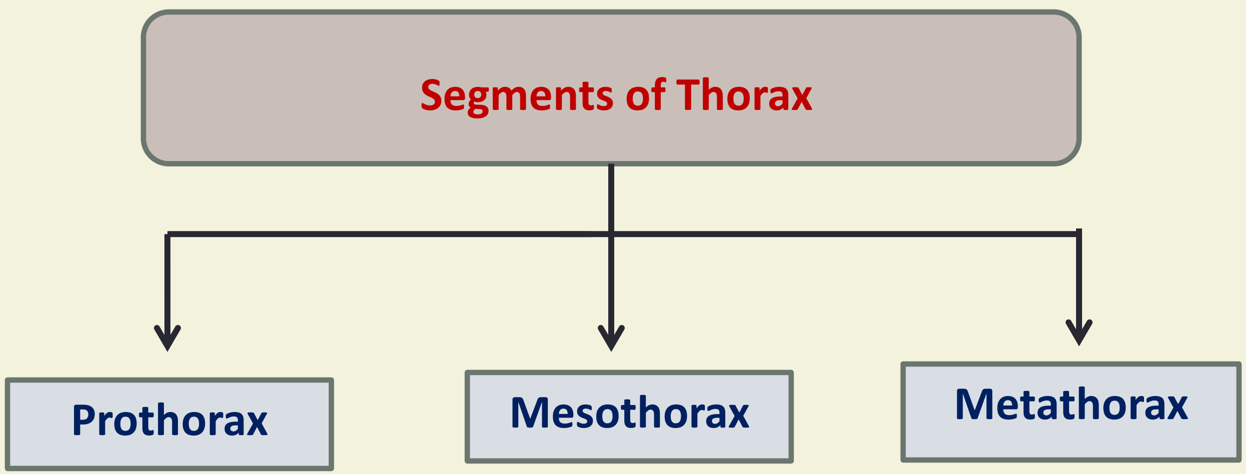
- In terms of numbers of species and individuals, the most successful land animals.
- Many insects have wings and one pair of antennae, three pairs of legs.

EXTERNAL STRUCTURE AND LOCOMOTION

- The body of an insect is divided into three tagmata: **head, thorax, and abdomen**.

i) **HEAD :** bears a single pair of antennae.

ii) **THORAX:** Contains two pairs of spiracles



iii) ABDOMEN:

- Most insects have 10 or 11 abdominal segments.
- Each abdominal segment has a pair of spiracles.
- Also present are genital structures used during copulation and egg deposition, and sensory structures called cerci.
- Gills are present on abdominal segments of certain immature aquatic insects.

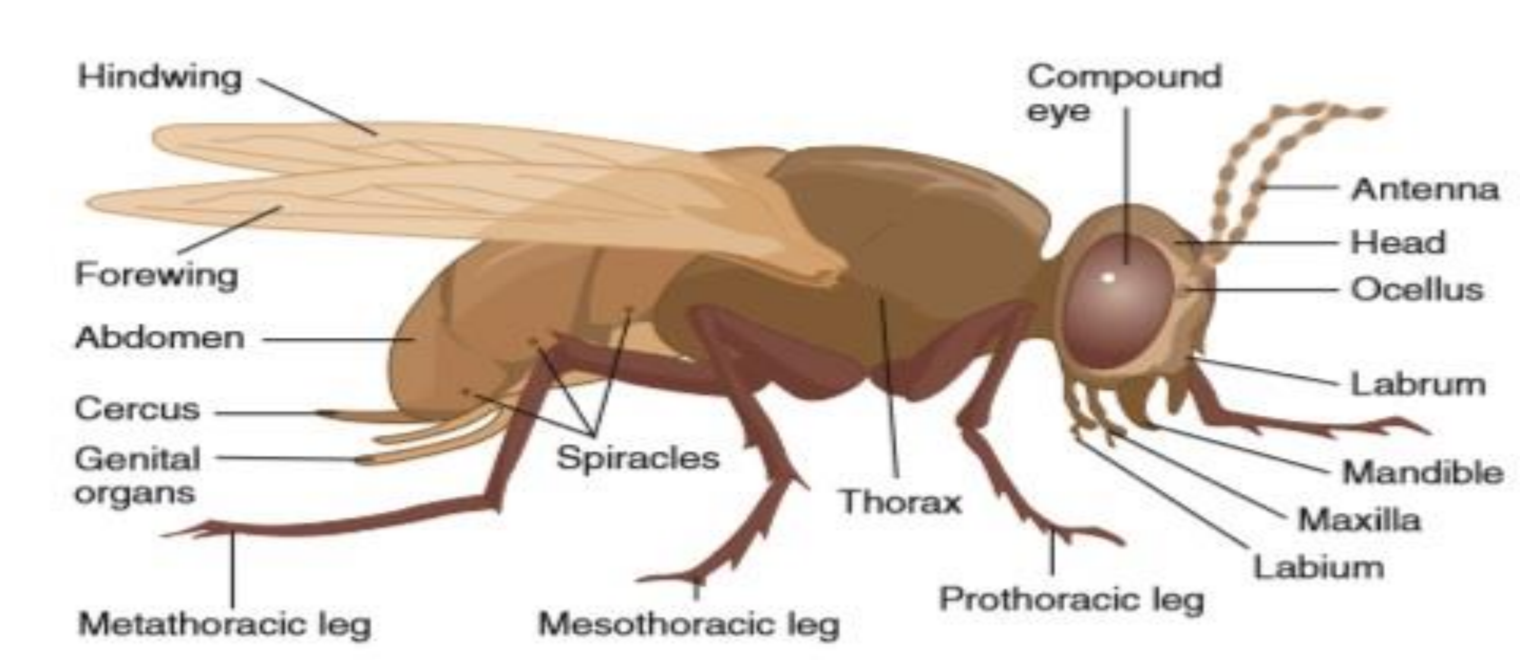


Fig: External Structure of a Generalized Insect. Insects are characterized by a body divided into head, thorax, and abdomen; three pairs of legs; and two pairs of wings

Insect Flight

- wings may have evolved from rigid, lateral outgrowths of the thorax that probably protected the legs or spiracles.
- Later, these fixed lobes could have been used in gliding from the top of tall plants to the forest floor.
- The ability of the wing to flap, tilt, and fold back over the body probably came later.
- Another requirement for flight was the evolution of limited thermoregulatory abilities.
- Thermoregulation is the ability to maintain body temperatures at a level different from environmental temperatures.
- Relatively high body temperatures, perhaps 25° C or greater, are needed for flight muscles to contract rapidly enough for flight.

Synchronous flight mechanism

- ✓ Muscles acting on the bases of the wings contract to produce a downward thrust.
- ✓ muscles attaching dorsally and ventrally on the exoskeleton contract to produce an upward thrust.
- ✓ The synchrony of direct flight mechanisms depends on the nerve impulse to the flight muscles that must precede each wingbeat.
- ✓ Butterflies, dragonflies, and grasshoppers are examples of insects with a synchronous flight mechanism.

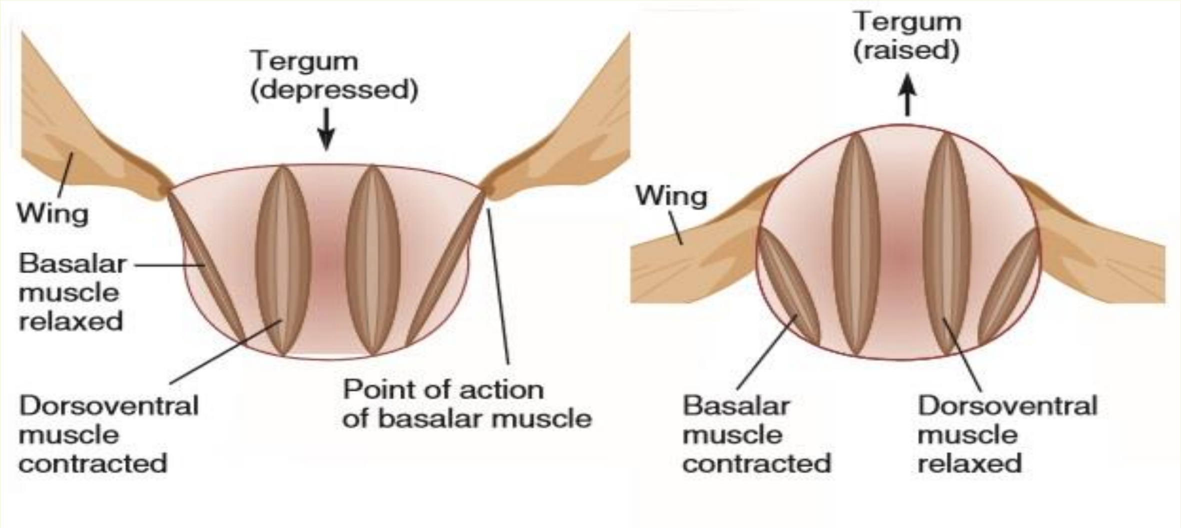


Fig: Insect Flight. Muscle arrangements for the direct or synchronous flight mechanism. Note that muscles responsible for the downstroke attach at the base of the wings.

Asynchronous flight mechanism

- Muscles act to change the shape of the exoskeleton for both upward and downward wing strokes.
- Dorsoventral muscles pulling the dorsal exoskeleton (tergum) downward produce the upward wing thrust.
- The downward thrust occurs when longitudinal muscles contract and cause the exoskeleton to arch upward.
- Indirect flight muscles are frequently called fibrillar flight muscles.
- Flies and wasps are examples of insects with an asynchronous flight mechanism.

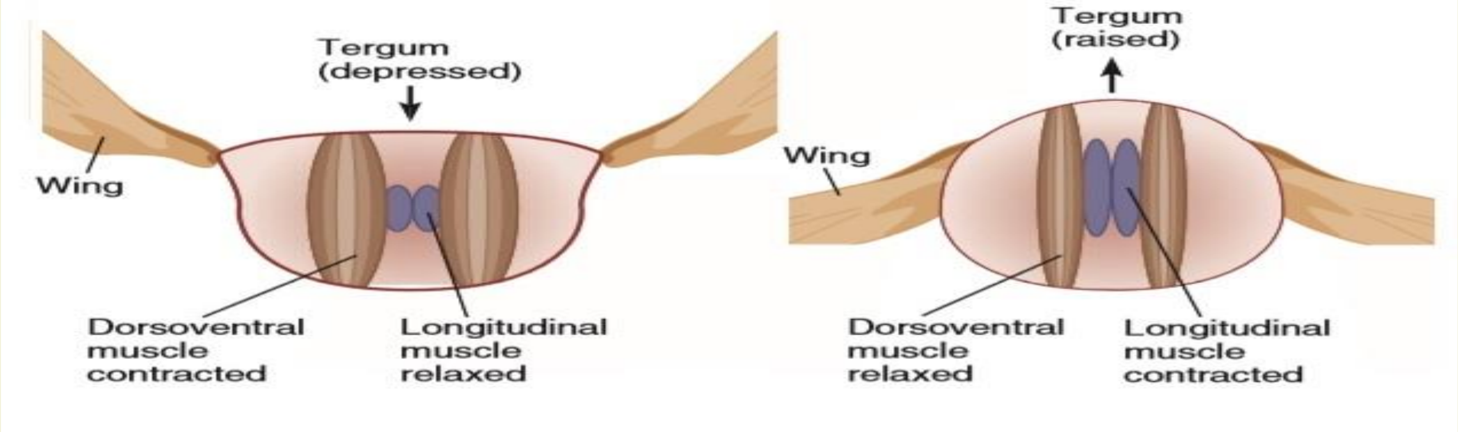


Fig: Insect Flight. Muscle arrangements for the indirect or asynchronous flight mechanism. Muscles changing the shape of the thorax cause wings to move up and down

Other Forms of Locomotion

- Insects walk, run, jump, or swim across the ground or other substrates.
- **When they walk**, insects have three or more legs on the ground at all times.
- **When they run**, fewer than three legs may be in contact with the ground.
- **Jumping** insects usually have long, metathoracic legs in which leg musculature is enlarged to generate large, propulsive forces.
- Energy for a flea's (order Siphonaptera) jump is stored as elastic energy of the exoskeleton.
- A **catch mechanism** holds the legs in this "cocked'' position until special muscles release the catches and allow the stored energy to quickly extend the legs.

NUTRITION AND THE DIGESTIVE SYSTEM

- The diversity of insect feeding habits parallels the diversity of insects themselves.
- An upper, liplike structure is called the **labrum.**
- **Mandibles** are sclerotized, chewing mouthparts.
- The **maxillae** often have cutting surfaces and bear a sensory palp.
- The **labium** is a sensory lower lip. All of these aid in food handling.
- The digestive tract, as in all arthropods, consists of a **foregut**, **a midgut**, and **a hindgut**.
- Enlargements for storage and diverticula that secrete digestive enzymes are common.

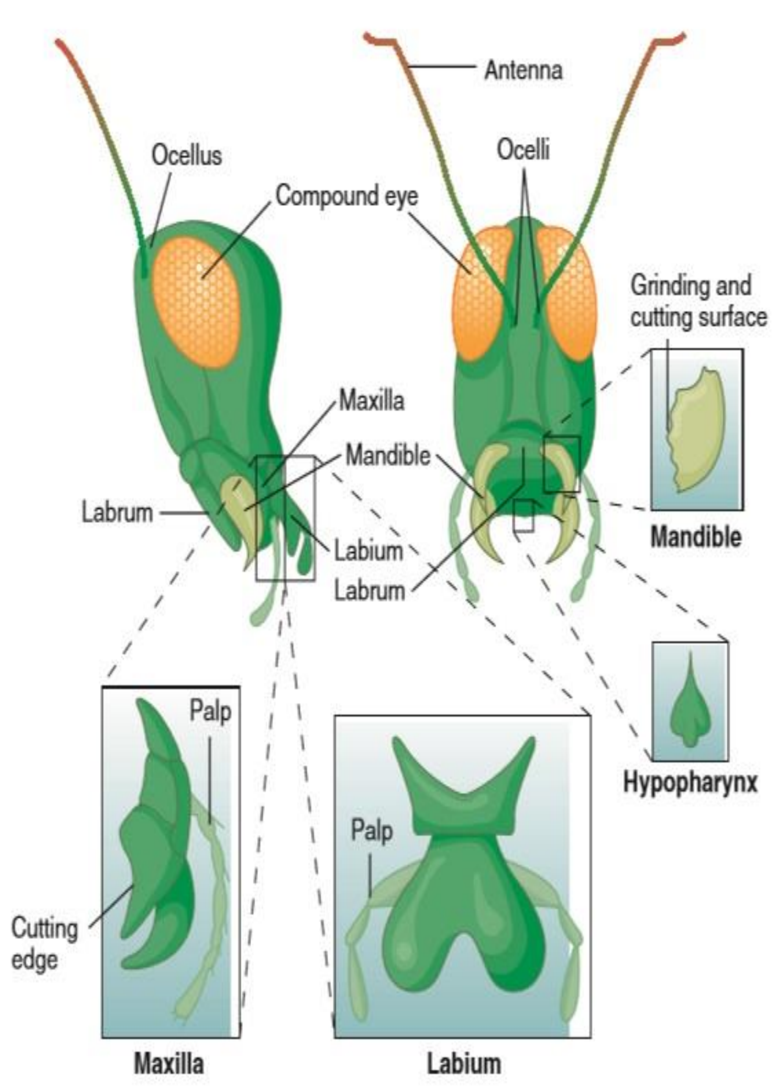


Fig: Head and Mouthparts of a Grasshopper

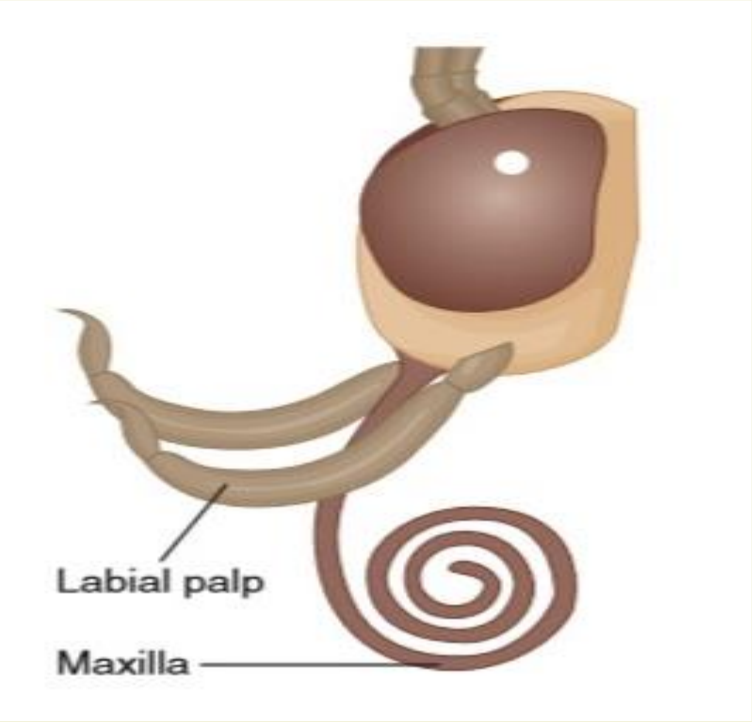


Fig: Specialization of Insect Mouthparts. The mouthparts of insects are often highly specialized for specific feeding habits. For example, the sucking mouthparts of a butterfly consist of modified maxillae that coil when not in use. Mandibles, labia, and the labrum are reduced in size. A portion of the anterior digestive tract is modified as a muscular pump for drawing liquids through the mouthparts

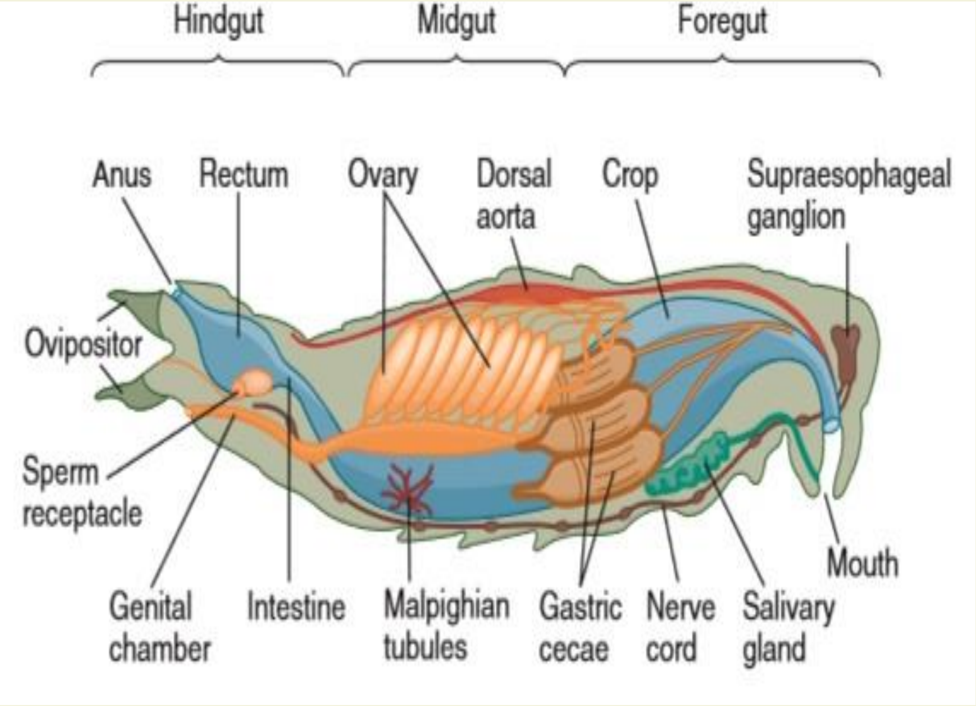


Fig: Internal Structure of a Generalized Insect. Salivary glands produce enzymes but may be modified for the secretion of silk, anticoagulants, or pheromones. The crop is an enlargement of the foregut and stores food. The proventriculus is a grinding and/or straining structure at the junction of the midgut and hindgut. Gastric cecae secrete digestive enzymes. The intestine and the rectum are modifications of the hindgut that absorb water and the products of digestion.

GAS EXCHANGE

- Gas exchange with air requires a large surface area for the diffusion of gases.

Tracheal System

- Respiratory water loss is reduced through the invagination of respiratory surfaces to form highly branched systems of chitin-lined tubes, called tracheae.
- Tracheae open to the outside of the body through spiracles, which usually have some kind of closure device to prevent excessive water loss.
- Spiracles lead to tracheal trunks that branch, eventually giving rise to smaller branches, the tracheoles.

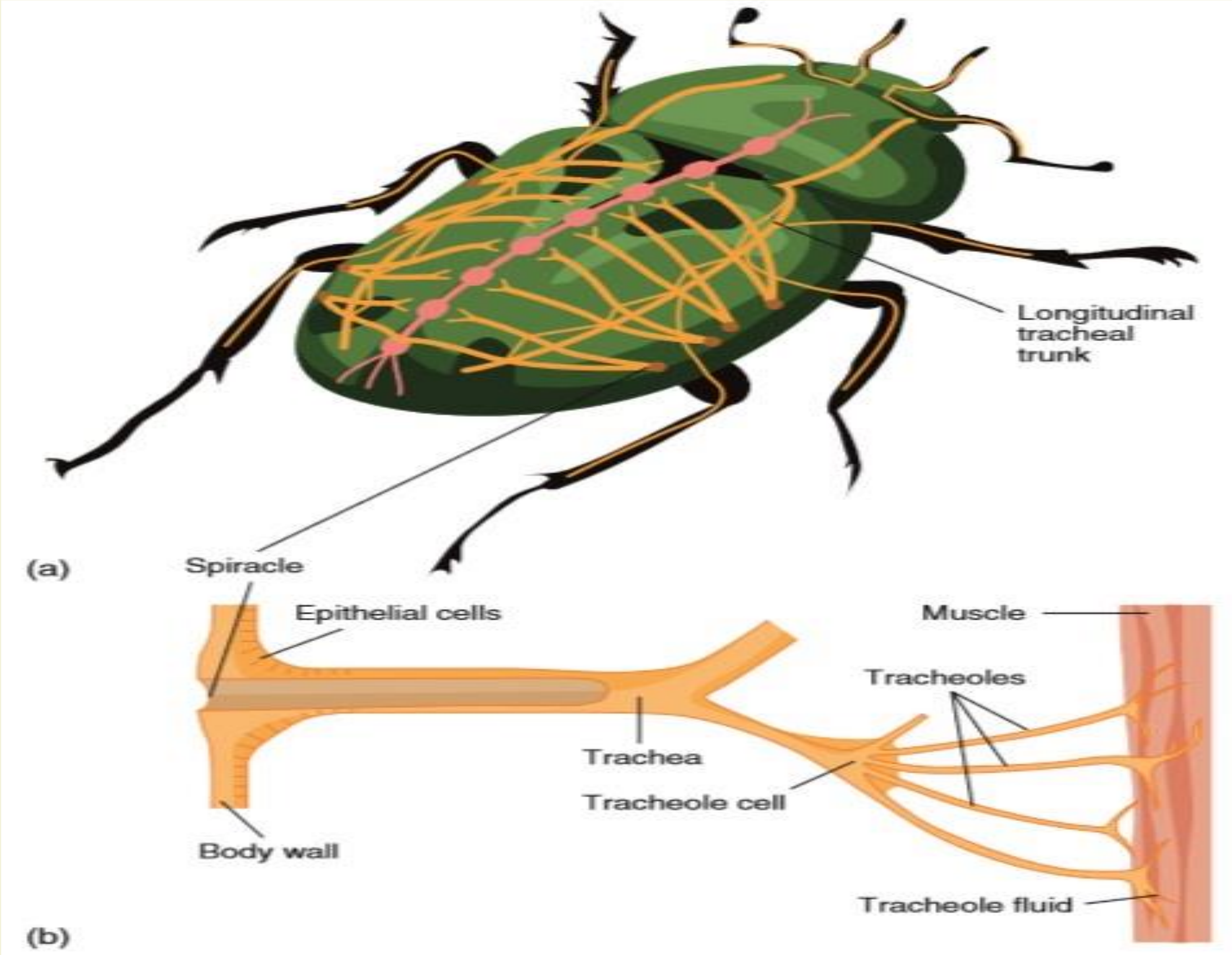


Fig: Tracheal System of an Insect. (a) Major tracheal trunks. (b) Tracheoles end in cells, and the terminal portions of tracheoles are fluid filled.

Ventilating mechanisms

Ventilating mechanisms that move air into and out of the tracheal system:

i. **contracting flight muscles** alternatively compress and expand the larger tracheal trunks and thereby ventilate the tracheae.

ii. In some insects, **carbon dioxide** that metabolically active cells produce is sequestered in the hemocoel as bicarbonate ions ($HCO3^-$).

Passive suction : As oxygen diffuses from the tracheae to the body tissues, and is not replaced by carbon dioxide, a vacuum is created that draws more air into the spiracles. This process is called passive suction.

CIRCULATION AND TEMPERATURE REGULATION

- the blood vessels are less well developed.
- Blood distributes nutrients, hormones, and wastes, and amoeboid blood cells participate in body defense and repair mechanisms.

Basking:

- all insects warm themselves by basking in the sun or resting on warm surfaces.
- insects are generally considered **ectotherms.**

Shivering thermogenesis:

- Other insects (e.g., some **moths, alpine bumblebees, and beetles**) can generate heat by rapid contraction of flight muscles, a process called shivering thermogenesis.

- Because some insects rely to a limited extent on metabolic heat sources, they have a variable body temperature and are sometimes called **heterotherms.**
- Insects are also able to cool themselves by seeking cool, moist habitats. Example **Honeybees**

NERVOUS AND SENSORY FUNCTIONS

- The nervous system of insects is similar to the pattern described for annelids and other arthropods.
- The supraesophageal ganglion is associated with sensory structures of the head.
- Connectives join the supraesophageal ganglion to the subesophageal ganglion, and has a general excitatory influence on other body parts.
- Insects also possess a well-developed visceral nervous system that innervates the gut, reproductive organs, and heart.
- Research has demonstrated that insects are capable of some learning and have a memory. For example, bees

NERVOUS AND SENSORY FUNCTIONS

- Sense organs of insects are similar to those found in other arthropods

Setae

- Setae are distributed over the mouthparts, antennae, and legs.
- Touch, air movements, and vibrations of the substrate can displace setae
- Stretch receptors at the joints, on other parts of the cuticle, and on muscles monitor posture and position.

Johnston's organs

- Johnston's organs are in the base of the antennae of most insects, including mosquitoes and midges (order Diptera).
- Vibrating setae move the antenna in its socket, stimulating sensory cells.
- Sound waves in the frequency range of 500 to 550 cycles per second (cps) attract and elicit mating behavior in male mosquitoes (*Aedes aegypti*).

Tympanal (tympanic) organs

- Tympanal organs consist of a thin, cuticular membrane covering a large air sac.
- The air sac acts as a resonating chamber.
- Just under the membrane are sensory cells that detect pressure waves.
- Bilateral placement of tympanal organs allows insects to discriminate the direction and origin of a sound.

Chemoreception

- Insects use chemoreception in feeding, selection of egglaying sites, mate location, and sometimes, social organization.
- Chemoreceptors are usually abundant on the mouthparts, antennae, legs, and ovipositors, and take the form of hairs, pegs, pits, and plates that have one or more pores leading to internal nerve endings.
- Chemicals diffuse through these pores and bind to and excite nerve endings.

Compound eyes

- Consist of a few to 28,000 receptors, called ommatidia, that fuse into a multifaceted eye.
- The outer surface of each ommatidium is a lens and is one facet of the eye.
- Below the lens is a crystalline cone.
- The lens and the crystalline cone are light-gathering structures.
- Certain cells of an ommatidium, called retinula cells, have a special light-collecting area, called the rhabdom.
- The rhabdom converts light energy into nerve impulses.
- Pigment cells surround the crystalline cone, and sometimes the rhabdom, and prevent the light that strikes one rhabdom from reflecting into an adjacent ommatidium .

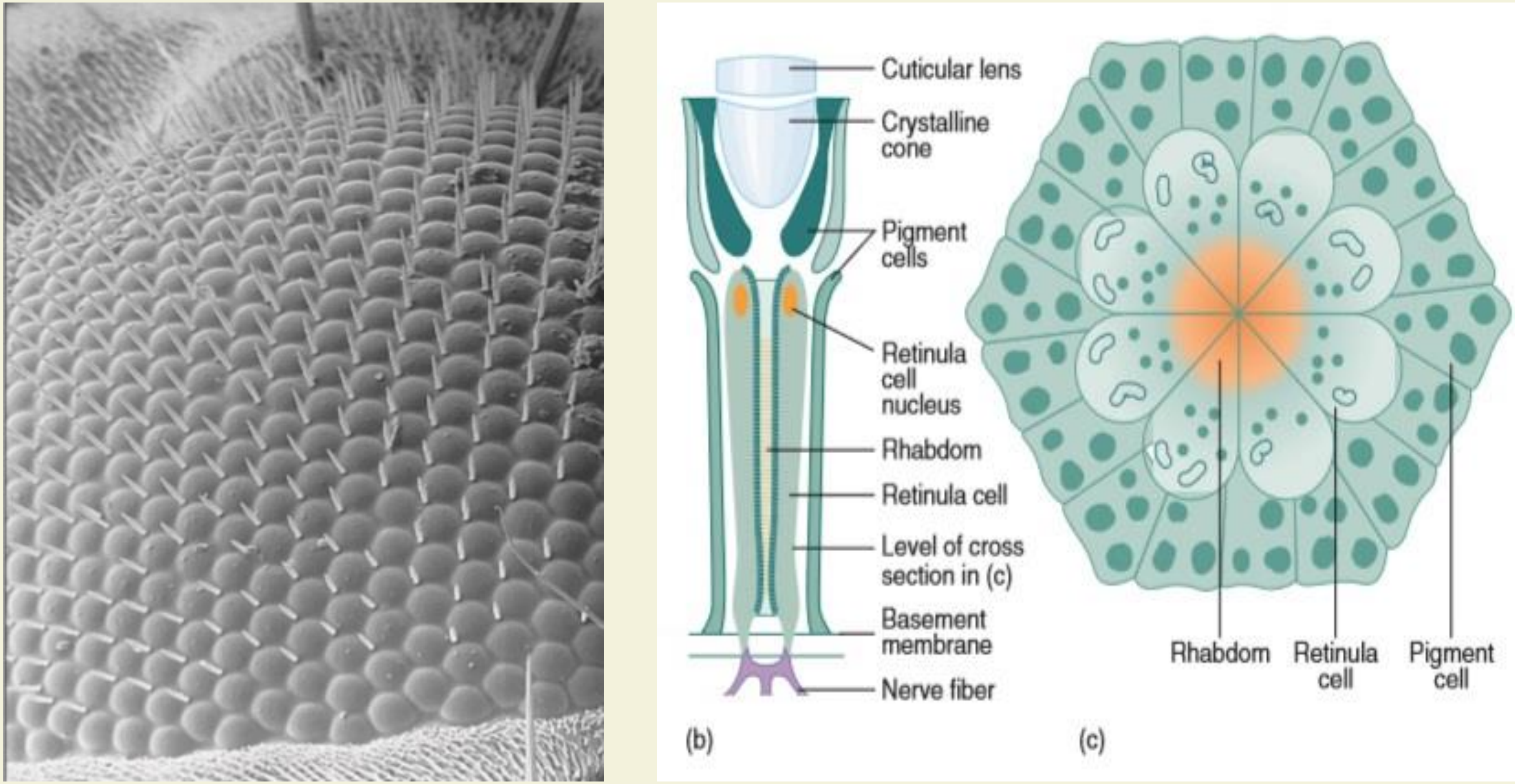


Fig: Compound Eye of an Insect. (a) Compound eye of Drosophila. Each facet of the eye is the lens of a single sensory unit called an ommatidium. (b) Structure of an ommatidium. The lens and the crystalline cone are light-gathering structures. Retinula cells have light-gathering areas, called rhabdoms. Pigment cells prevent light in one ommatidium from reflecting into adjacent ommatidia. In insects that are active at night, the pigment cells are often migratory, and pigment can be concentrated around the crystalline cone. In these insects, low levels of light from widely scattered points can excite an ommatidium. (c) Cross section through the rhabdom region of an ommatidium.

EXCRETION

The primary insect excretory structures are the

i) Malpighian tubules ii) rectum.

i) Malpighian tubules

- Malpighian tubules end blindly in the hemocoel and open to the gut tract at the junction of the midgut and the hindgut.
- Microvilli cover the inner surface of their cells. Various ions are actively transported into the tubules, and water passively follows.
- Uric acid is secreted into the tubules and then into the gut, as are amino acids and ions.

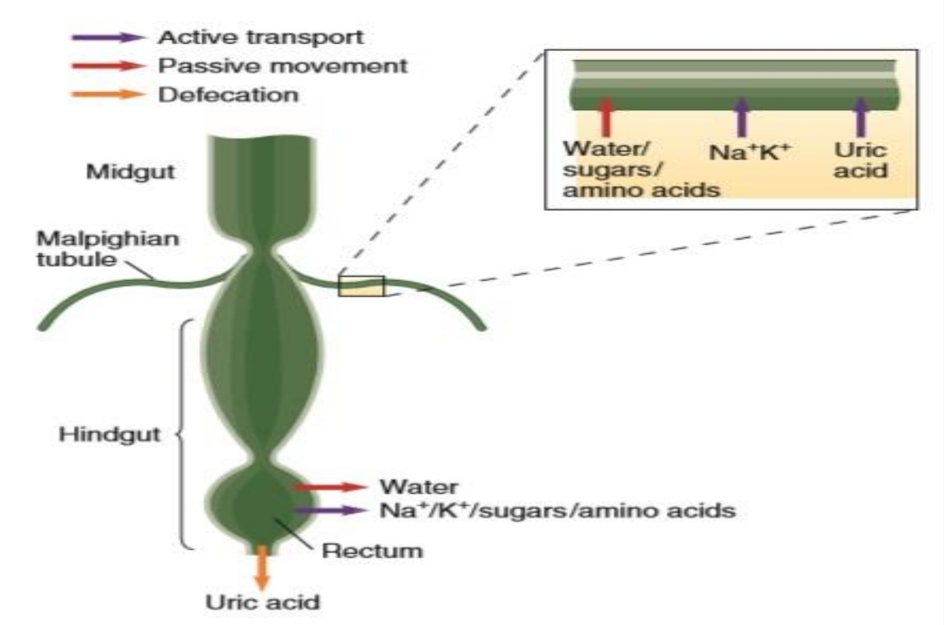


Fig: Insect Excretion. Malpighian tubules remove nitrogenous wastes from the hemocoel. Various ions are actively transported across the outer membranes of the tubules. Water follows these ions into the tubules and carries amino acids, sugars, and some nitrogenous wastes along passively. Some water, ions, and organic compounds are reabsorbed in the basal portion of the Malpighian tubules and the hindgut; the rest are reabsorbed in the rectum. Uric acid moves into the hindgut and is excreted.

Casteregulating Pheromone

- ✓ A pheromone that the queen releases controls the honeybee caste system.
- ✓ Workers lick and groom the queen and other workers.
- ✓ In so doing, they pick up and pass to other workers a casteregulating pheromone.
- ✓ This pheromone inhibits the workers from rearing new queens.
- ✓ As the queen ages, or if she dies, the amount of caste-regulating pheromone in the hive decreases.
- ✓ As the pheromone decreases, workers begin to feed the food for queens **("royal jelly")** to several female larvae developing in the hive.
- ✓ This food contains chemicals that promote the development of queen characteristics.
- ✓ The larvae that receive royal jelly develop into queens, and as they emerge, the new queens begin to eliminate each other until only one remains.
- ✓ The queen that remains goes on a mating flight and returns to the colony, where she lives for several years.