Zoology Department

Zoology II

(Physiology and Invertebrates Taxonomy)

By/

Dr. Heba M. Fangary

Dr. Mariam A. Fawy

Teaching by

Dr. Azza M. Gaber

Dr. Mariam A. Fawy

Science faculty- Zoology department

Second Semester 2022-2023

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Introduction

The number of animals inhabiting the earth today is more than one million. Since it is impossible for man to keep in mind separately all the million of animals which exist. He must of necessity arrange them into groups. This arrangement is created the origin of **classification** or **taxonomy** or **systematic**. In such a system animals with several similar characters are placed together in the same group. So, the branch of zoology for grouping or classification of animals on scientific bases is called taxonomy systematic zoology.

Taxonomy is the science of defining and naming groups of biological organisms on the basis of shared characteristics.

History of scientific taxonomy:

One of the first persons collected and organized animals classification system was the Greek philosopher Aristotle (384-322 BC). He classified beings by their parts, such as having four legs, laying eggs, having cold blood, or being warm-bodied, carnivorus or herbivorus. He classified about 500 types of animals in 11 categories according to their structure from and their degree of development at birth.

In the 17th century John Ray (England, 1627–1705) wrote many important taxonomic works and he defined the species.

A species is often defined as the largest group of organisms in which any two individuals of the appropriate sexes or mating types can produce fertile offspring, typically by sexual reproduction.

The Swedish botanist Carl Linnaeus (1707–1778) formalised the modern system of naming organisms called binomial nomenclature. **Binomial nomenclature** ("two-term naming system") is a formal system of naming species of living things by giving each a name composed of two parts, both of which use Latin grammatical forms. The first part of the name – the *generic name* – identifies the genus to which the species belongs, while the second part – the **specific name** identifies the species within the genus.

Kingdoms of the living world

Robert Harding Whittaker (1920 – 1980) was an American plant ecologist, He was the first to propose the five-kingdom taxonomic classification of the world's biota into the Animalia, Plantae, Fungi, Protista, and Monera in 1969

Kingdom: **Monera**

- 1 cell, no true nucleus - prokaryote (genetic material scattered and not enclosed by a membrane) examples - bacteria, blue-green bacteria.

Kingdom: **Protista**

- 1 cell, have a true nucleus – eukaryote
- examples - *Amoeba*, Diatom, *Euglena*, *Paramecium*, some algae (unicellular), etc….

Kingdom: **Fungi**

Kingdom: **Plantae**

Kingdom: **Animalia** (animals)

- multicellular
- have nuclei
- do move
- examples - sponge, jellyfish, insect, fish, frog, bird, man

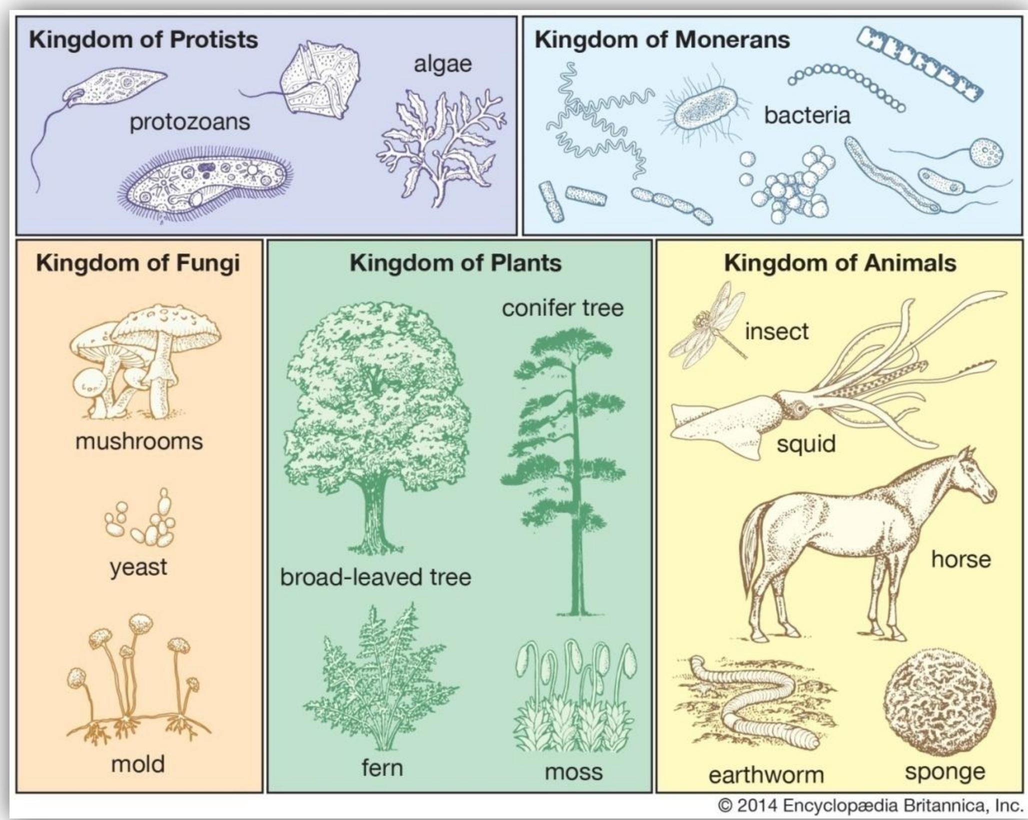


Figure 1: Animal kingdoms

Kingdom: **Protista** (protists)

Subkingdom: **Protozoa**

Phylum: Protozoa

General characters:

1- Very small in size, can only be seen by the light microscope and live in all environments.

2- Many species live as solitary individuals, while a few live in colonies.

3- In majority of cases there is only one nucleus in the cytoplasm with distinct (endosome). Cytoplasm is usually differentiated in to outer clear ectoplasm and inner granular endoplasm.

4- The cell is covered by a plasma membrane or by a pellicle.

5- They move either by pseudopodia, flagella, cilia and some have no locomotory organelles.

6- Nutrition: some are heterotrophic: feeds on other organisms (bacteria, algae, smaller protozoa, …) and some are autotrophic).

7- Osmoregulatory organelles, in the form of contractile vacuoles present in freshwater forms.

8- Respiration by simple diffusion through the body surface.

9- Excretion takes place by simple diffusion through the body surface.

10- All protozoans can reproduce asexually, either by binary fission or by multiple fission. But some protozoans can reproduce sexually by forming male and female gametes.

11- Encystement is common in protozoa under unfavorable conditions.

Taxonomy of Protozoa

- **Class: Sarcodina**

  Includes protozoans which move by pseudopodia

  ex.: *Amoeba*.

- **Class: Mastigophora**

  Includes protozoans which move by one or more flagella,

  ex.: *Trypanosoma* and *Euglena*

- **Class: Ciliophora**

  Includes protozoa which move by cilia,

  ex.: *Paramecium*

- **Class: Sporozoa**

  Includes protozoa which have no distinct locomotory organelles,

  ex.: *Plasmodium*

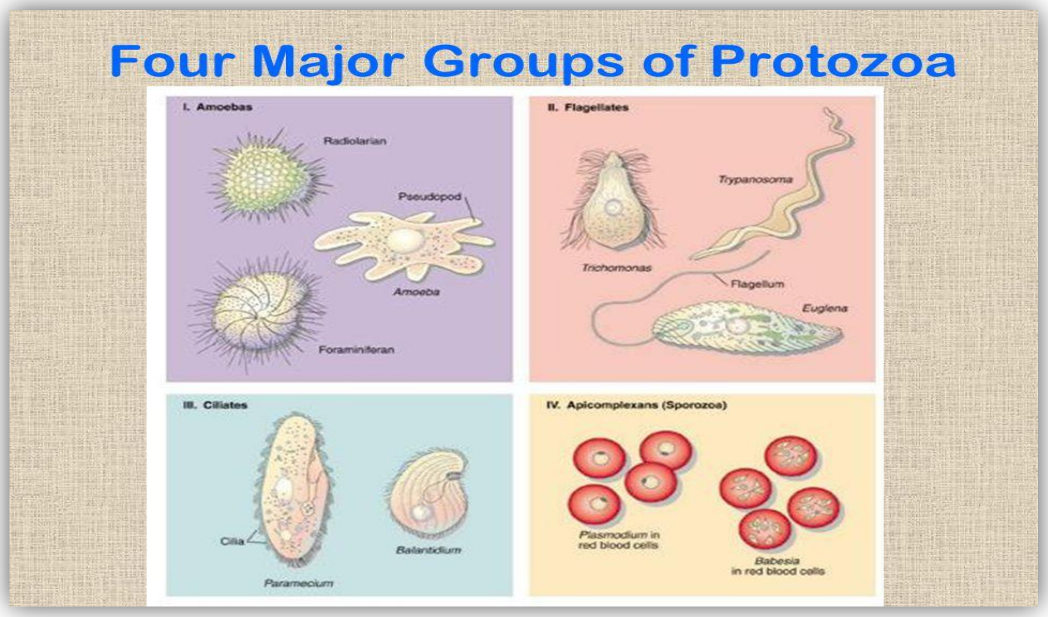


Figure 2: Groups of Protozoans

Amoeba

- **Shape***:* *Amoeba* has the ability to alter its shape, primarily by extending and retracting pseudopods.
- ***Amoeba*** moves and feeds by using pseudopods, which are bulges of cytoplasm. The appearance and internal structure of pseudopods are used to distinguish groups of *Amoeba* from one another. The food sources of amoebae vary. Some amoebae are predatory and live by consuming bacteria and other protists. Some are detritivores and eat dead organic material.
- ***Amoeba*** contains an endoplasm that is granular in nature. This granular endoplasm contains the nucleus and various food vacuoles.

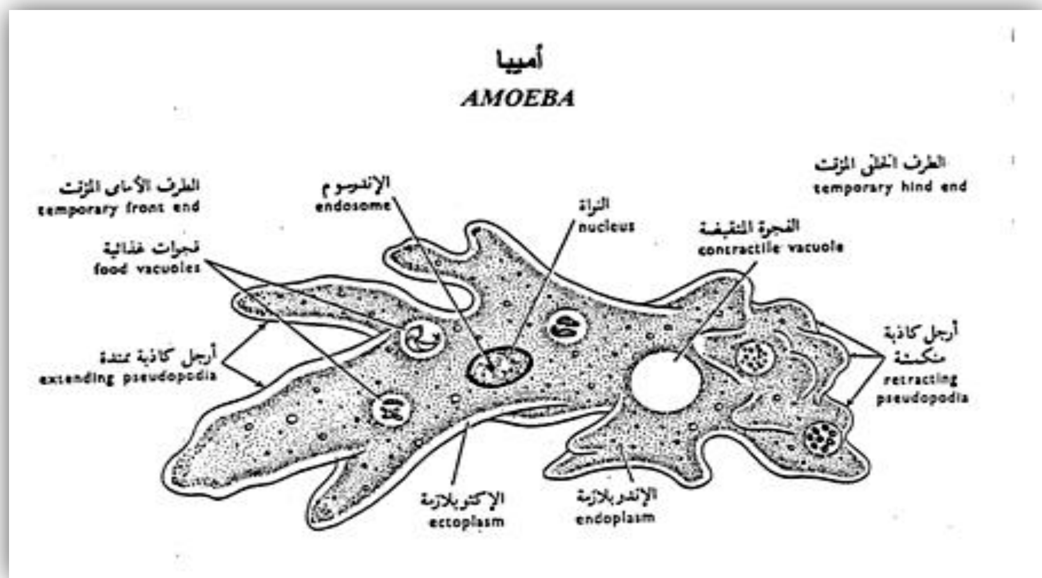


Figure 3: Amoeba

- To regulate osmotic pressure, most freshwater *Amoeba* have a contractile vacuole which expels excess water from the cell. This organelle is necessary because freshwater has a lower concentration of solutes (such as salt) than the amoebas own internal fluids. Marine amoebae do not usually possess a contractile vacuole, because the concentration of solutes within the cell is in balance with the tonicity of the surrounding water.

- Reproduction by binary fission, and multiple fission during encystment under unfavorable conditions.

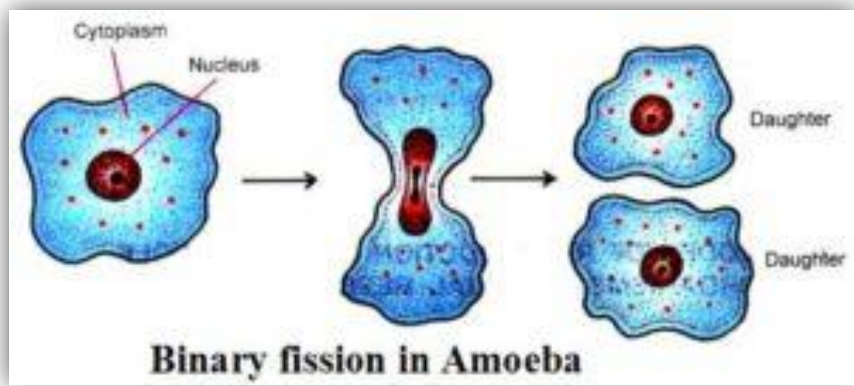


Figure 4: Binary fission in Amoeba

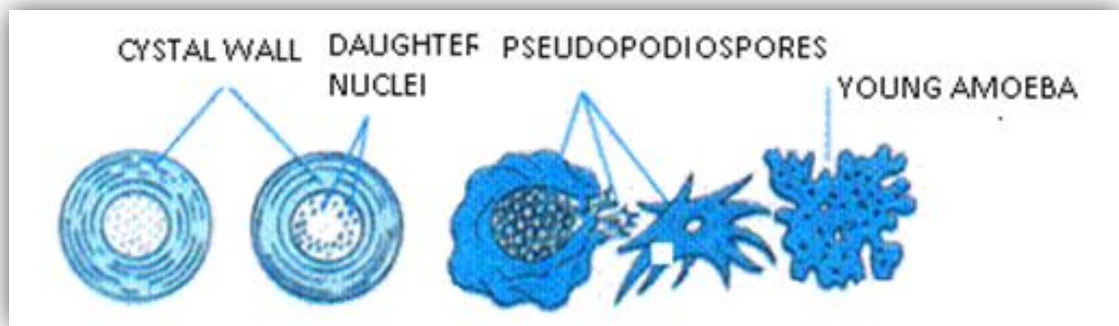


Figure 5: Encystement in Amoeba

Class: Mastigophora
e.g.: *Trypanosoma*

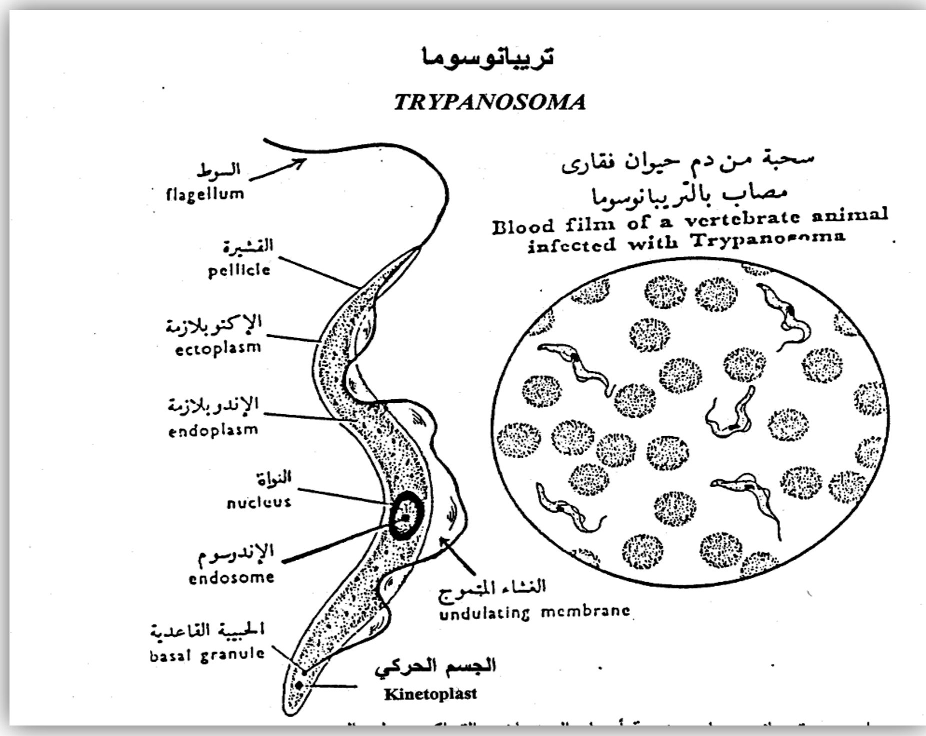


Figure 6: ***Trypanosoma***

- *Trypanosoma* is a flagellate parasite, live in two hosts: invertebrate and vertebrate hosts. In the former they usually infest the alimentary canal while in the latter they live in the blood.

- Trypanosomes infect a variety of hosts and cause various diseases, including the fatal human diseases sleeping sickness.

- It has a long slender undulating body with a flagellum at the anterior end. The flagellum connected to the body by a thin membrane called: the undulating membrane. The flagellum arises from the basal granule situated near the posterior end of the body.

- Reproduction asexually by longitudinal binary fission.

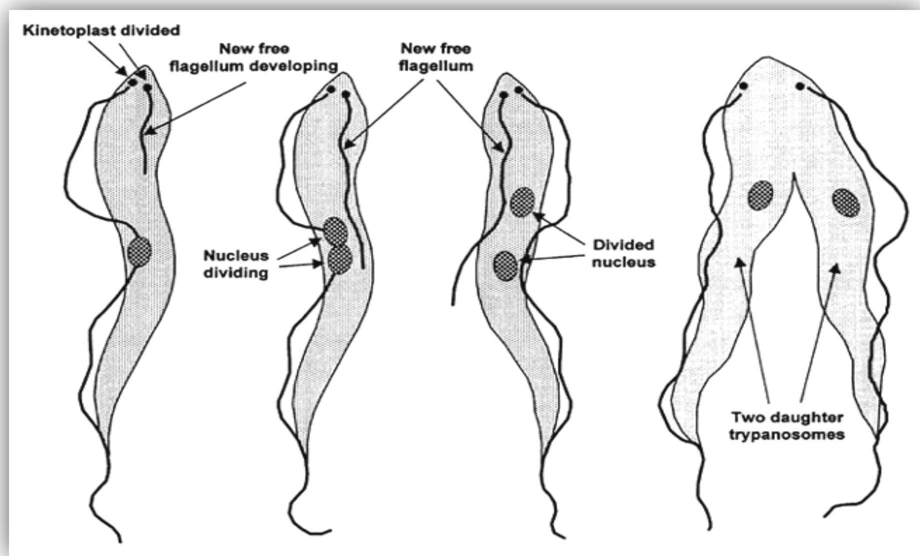


Figure 7: Binary fission in *Trypanosoma*

Kingdom: **Animalia** (animals)
Subkingdom: **Parazoa**

Phylum: Porifera

General characters:

- Sponges are sessile and mostly marine animals which show little or no detectable movement.
- They are primitive multicellular animals.
- They are thin flattened or have irregular shapes.

- The body has numerous pores or canals.
- Inside the body there is a single cavity lined by flagellated cells.
- The body cells are less specialized , they do not form proper tissues or organs.
- They have a skeleton of calcareous spicules or organic spongin fibres.
- They are holozoic, digestion is entirely intracellular. They generally feed on bacteria and other food particles that are present in the water
- They respire and excrete by simple diffusion.
- They have no sensory or nerve cells.
- They reproduce asexually by budding, gemmule formation or by regeneration, they also reproduce sexually by gametes (most sponges are hermaphrodite).
- There are three types: (ascon, sycon and leucon).

The Ascon type (*Leucosolenia)*

- This is the simplest type of sponges.
- The body is tube in shape, live in colonies. It has triradiate spicules.

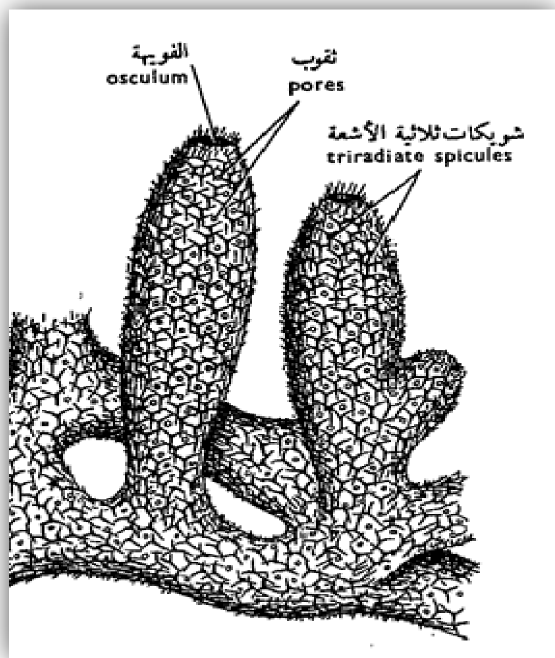


Figure 8: ***Leucosolenia***

- The body wall surrounds a central cavity known as paragastric cavity lined with flagellated cells.
- The wall is thin, contains many openings (ostia) which lead directly to the paragastric cavity which open outside through osculum.

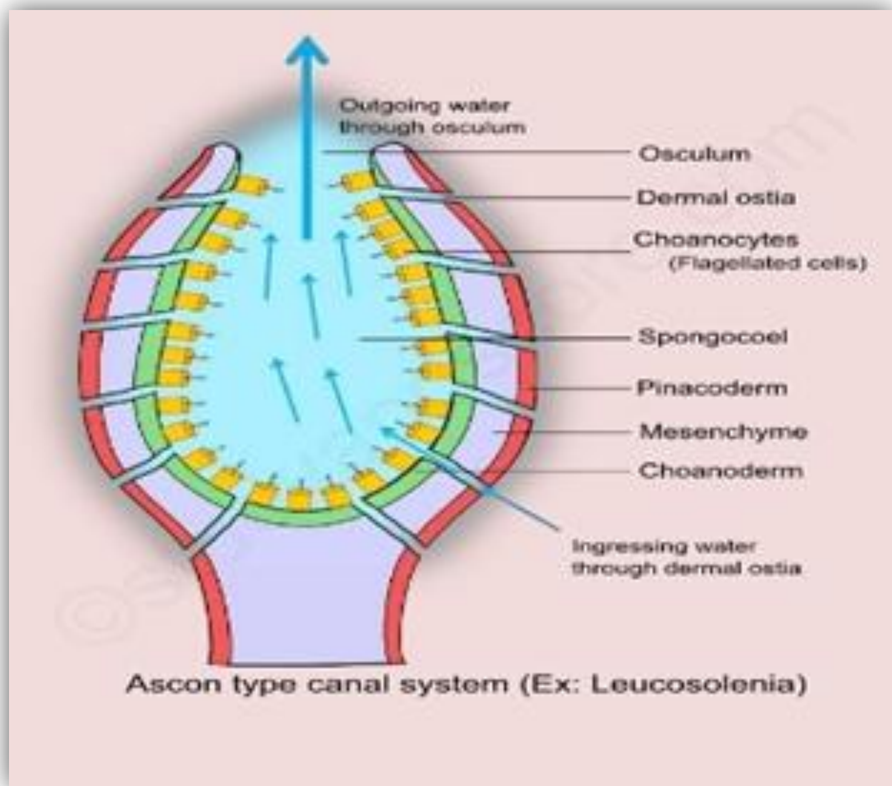


Figure 9: Internal structure of *Leucosolenia*

The body wall of *Leucosolenia* consists of two cellular layers:

1- The dermal layer: the outer layer formed of thin flattened cells: **pinacocytes.**

2- The gastral layer: contains choanocytes with flagellates extend to the paragastric cavity.

The gastral layer: contains choanocytes with flagellates extend to the paragastric cavity, and between the two layers there is a jelly substance contains three types of cells (**scleroblasts**, **amoebocytes** and **porocytes**). **Scleroblasts** secrete calcareous spicules**, amoebocytes** can develop into any other cell in the body and **porocytes** acts as a pore**.**

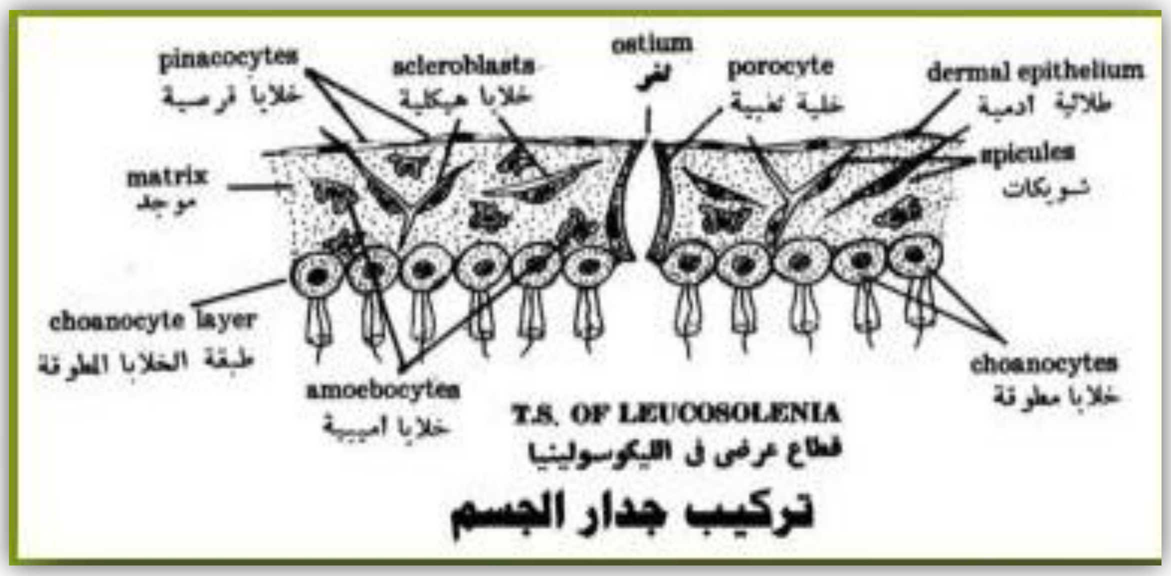


Figure 10: Body wall of *Leucosolenia*

The Sycon type: *Sycon*

This is a solitary marine sponge, live attached to rocks in shallow waters, it has a vase shaped body with a single large osculum at the free end.

The body wall is relatively thick, folded forming many horizontal flagellated chambers

The flagellated chambers are lined with choanocytes

Water is drawn through the ostia into the inhalant canals, then pass to the flagellated chambers then to the paragastric cavity, and finally to the outside through the osculum.

figure 11: The sycon type

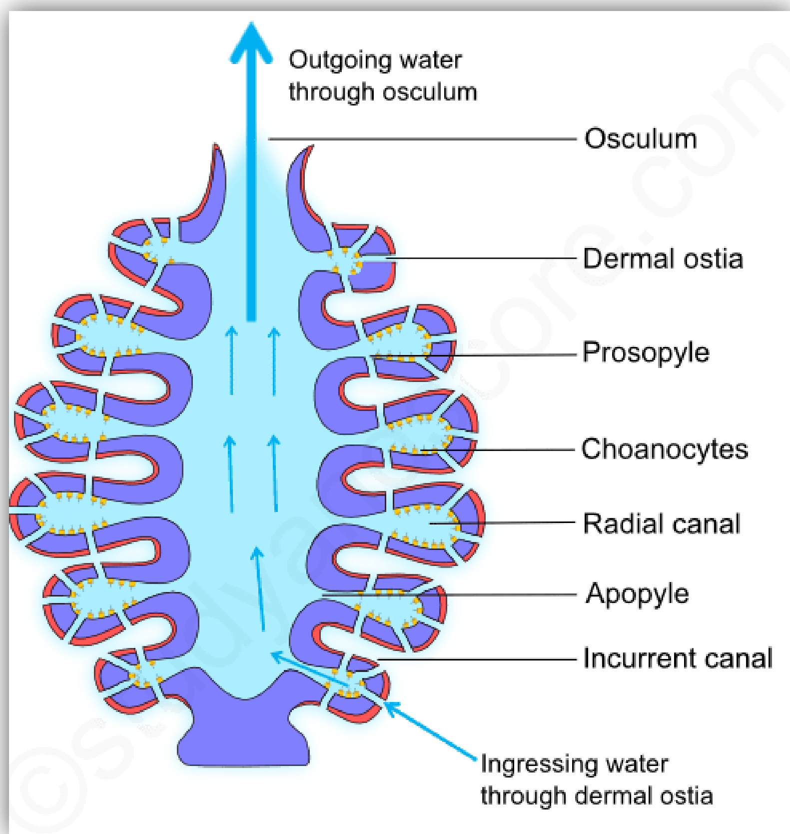


Figure 12: Sycon type canal system

The Leucon type: *Euspongia*

- Spherical, irregular or cup shape.
- They live on the sea bottom attached to rocks.
- The body surface contains minute ostia, in between there are several larger oscula with more complex structure.
- It contains a complex network of branching spongin fibres extends within the jelly and gives the animal the characteristic spongy texture.
- The layer of choanocytes is highly folded and the paragastric cavity is reduced.
- The ostia found on the outer surface lead into large subdermal cavities, from which some inhalant canals extend to the flagellated chambers.

Figure 13: ***Euspongia***

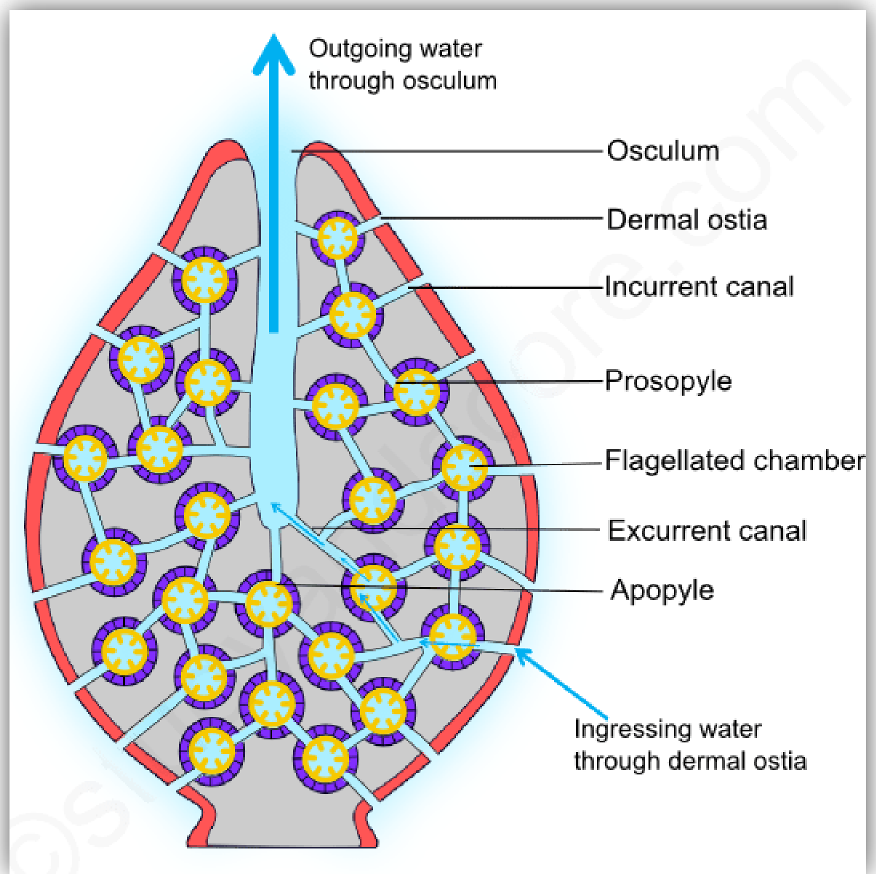


Figure 14: Leucon type canal system

Subkingdom: Eumetazoa

- ……………Diploblastica

Phylum: Coelenterata

1- Simple aquatic metazoa, mostly marine and sessile.

2- They are radially symmetrical (the body is divided into two symmetrical halves if cut in any direction pass in through the axis).

3- There are two layers in the body (ectoderm, endoderm) separated by a jelly – like mesogloea.

4- They have nematocysts (stinging structures), not found in any other phylum.

5. There is a single cavity (the gastrovascular cavity or coelenteron cavity).
6. Respiration and excretion by simple diffusion.
7. They have a simple diffuse nervous tissue in the form of a nerve net.
8. They reproduce asexually by budding, and sexually by gametes.
9. Most have two forms during the life cycle (hydroid form or polyp), and free swimming jelly-fish like form (medusa).
10. Some forms with external calcareous skeleton.

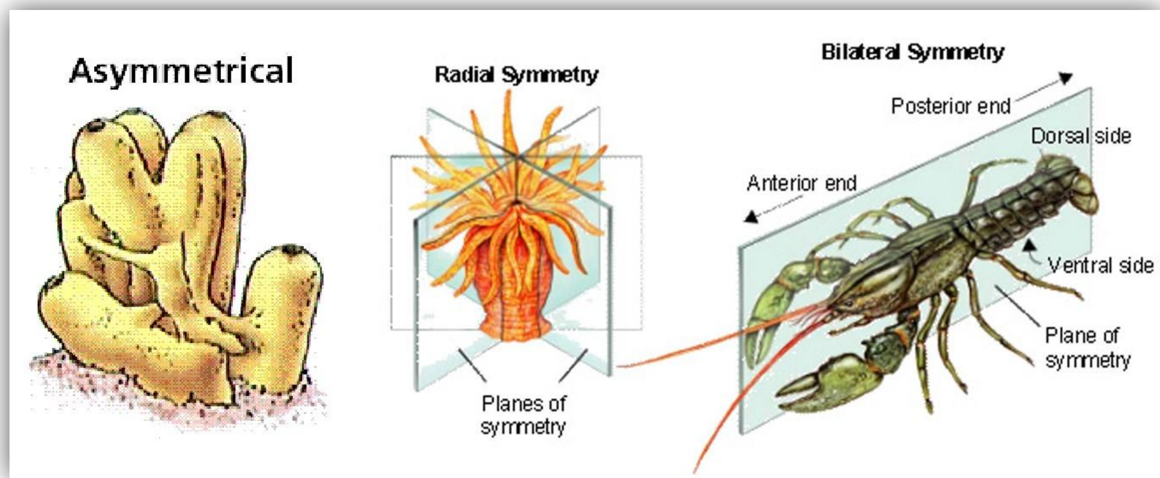


Figure 15: Types of Symmetry

Radial symmetry generates identical body halves around the central axis whereas bilateral symmetry generates only two sides as left and right.

Classification of Coelenterata

- **Class: Hydrozoa**
- Most have the polyp and medusa forms during the life cycle.
- **Order: Hydroidea**
- Have the polyp form only: ex.:*Hydra*
- **Order: Calyptoblastea**
- Have the two forms (polyp and medusa) ex.: *Obelia*
- **Class: Scyphozoa**
- Contains the jelly-fishes, have only the medusa form.
- **Class: Actinozoa**
- Contains the sea anemones (the sea flowers) and the stony corals, have only the polyp form.

Hydra

- ***Hydra*** is a genus of small, fresh-water organisms. It measures from 2 to 20 mm in length.
- ***Hydra*** has a tubular, radially symmetric body, secured by a simple adhesive foot called the basal disc.
- At the free end of the body (the oral cone), there is a mouth opening surrounded by 6 to 8 thin, mobile tentacles.

Each tentacle is clothed with highly specialised stinging structures called nematocysts.

- If *Hydra* attacked, the tentacles can be retracted to small buds, and the body column itself can be retracted to a small gelatinous sphere.

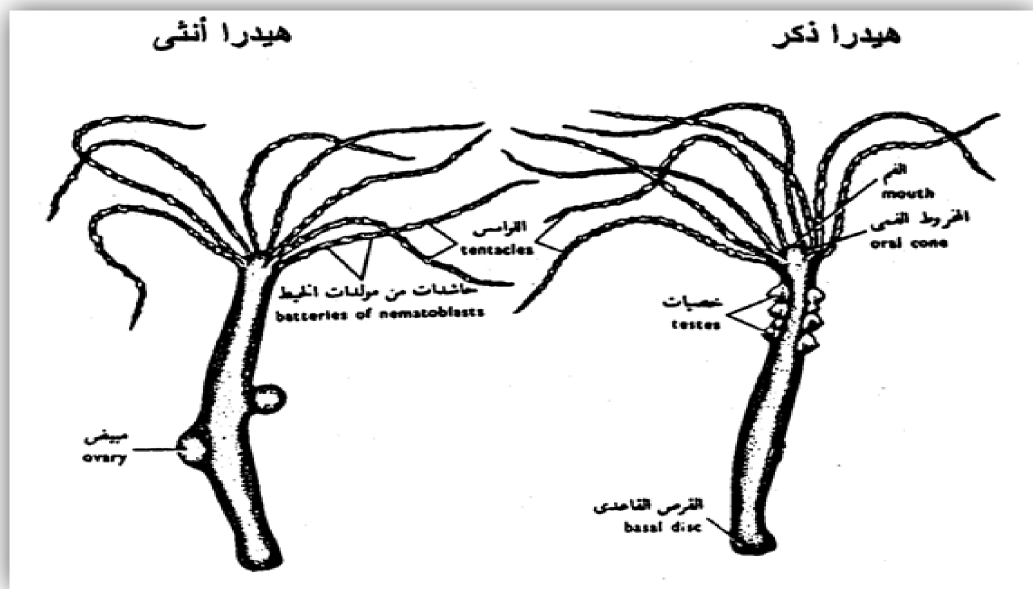


Figure 16: ***Hydra***

- *Hydra* is generally sedentary or sessile, but do move, especially when hunting. They have different distinct methods for moving: 'looping‘, 'somersaulting‘, floating, swimming,…….

- *Hydra* mainly feeds on aquatic invertebrates such as *Daphnia* and *Cyclops*.

- <u>Locomotion in *Hydra*</u>

- **1- Looping = walking:** the body at first extends and then bends and fixes the tentacles to the substratum. It then releases the attachment of the basal disc, reattaches the basal disc near the tentacles and again take an upright position by releasing its tentacles.

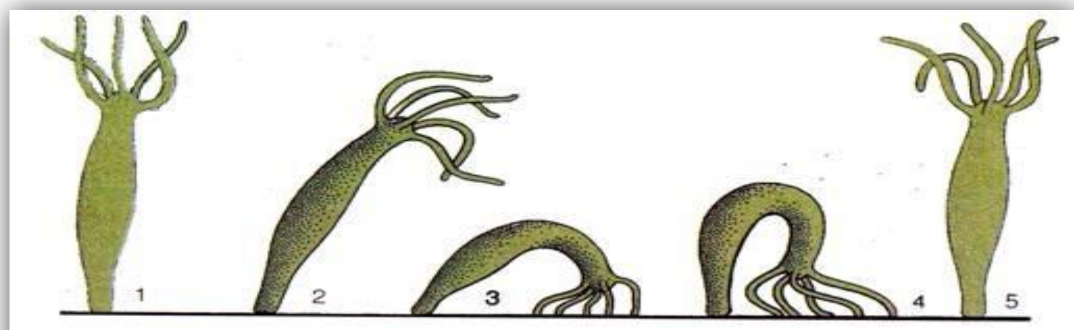
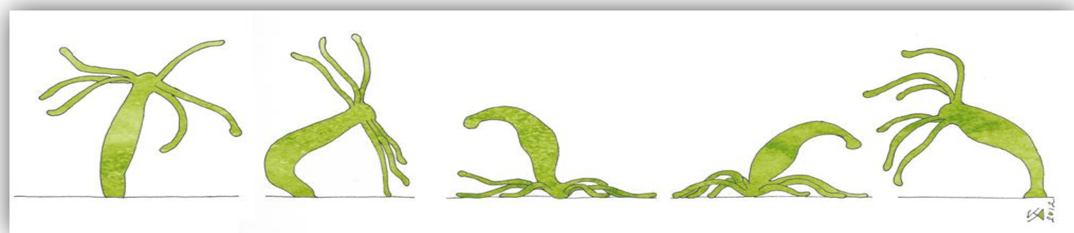


Fig. 31.15. *Hydra* showing looping movements.

- **2- Somersaulting:** *Hydra* extends its body and is bent to one side to place the tentacles on the substratum. The basal disc is freed from its attachment, and the animal stands on its tentacles.
- The body is then extended and bent to place the basal disc on the substratum, the tentacles loosen their hold and the animal regains an upright position



- **3- Gliding:** *Hydra* can glide slowly along its attachment by pseudopodia from the basal disc.
- **4- Cuttlefish-like movement:** The tentacles are fixed to the substratum and with the pedal disc up, *Hydra* moves over the substratum by pulling its tentacles along.

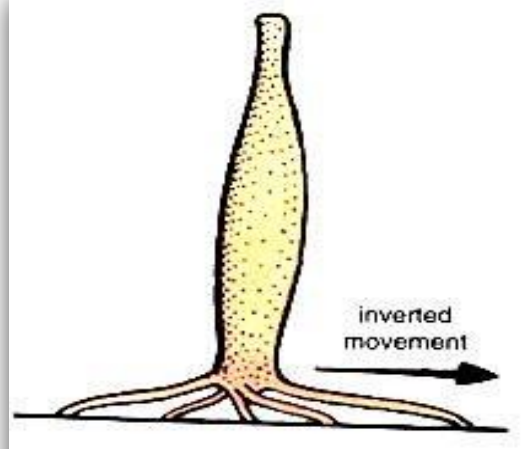


Fig. 31.17. *Hydra* showing cuttle-fish-like movements.

- **5- Floating:** *Hydra* can produce a bubble of gas secreted by some ectodermal cells of the basal disc which helps the animal to float on the surface of the water and is passively carried from one place to another by water current.
- **6- Swimming:** By freeing itself from the substratum and with the help of wave-like
- movements of the tentacles,

Hydra swims in water

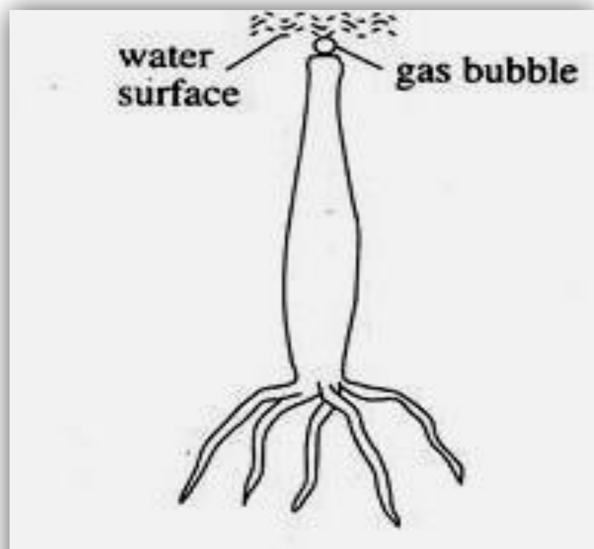


Fig. 2.21 : Floating in *Hydra*.

- **7- Climbing**
- *Hydra* can climb by attaching its tentacles to some distant objects and then releasing the basal disc and by contracting the tentacles the body is drawn up to a new position.

<u>Watch</u> video

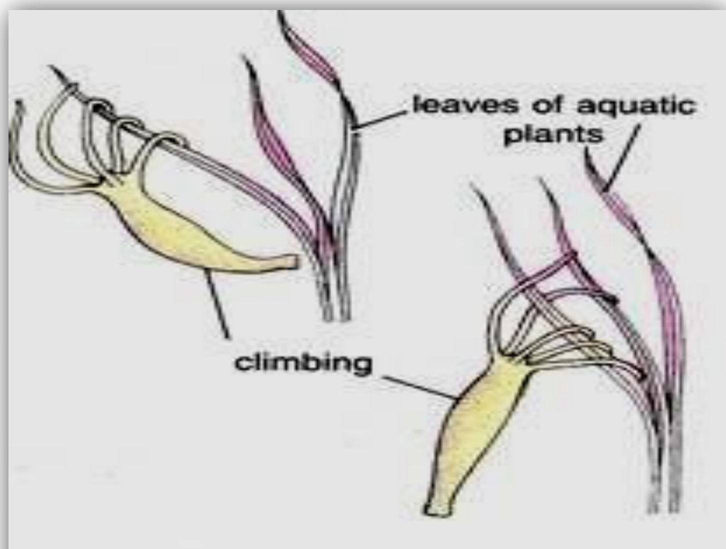


Fig. 31.19. *Hydra* showing climbing.

Reproduction

- When food is plentiful, many *Hydra* reproduce asexually by producing buds in the body wall, which grow to be miniature adults and break away when they are mature.

- When *Hydra* is well fed, a new bud can form every two days. When conditions are harsh, often before winter or in poor feeding conditions, sexual reproduction occurs in some *Hydra*. Swellings in the body wall develop into either ovaries or testes. The testes release free-swimming gametes into the water, and these can fertilize the egg in the ovary of another individual. The fertilized eggs secrete a tough outer coating, and, as the adult dies (due to starvation and/or cold), these resting eggs fall to the bottom of the lake or pond to await better conditions. Some *Hydra* species are hermaphrodite.

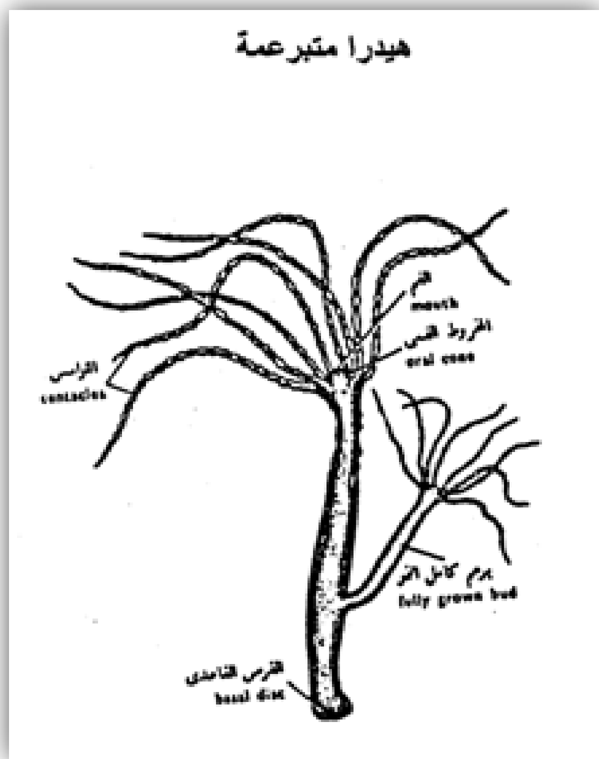


Figure 17: Budding in Hydra

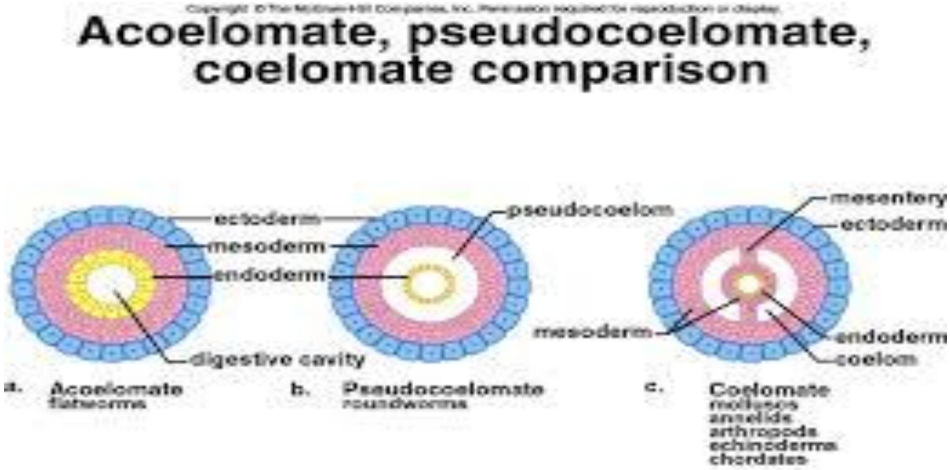
Subkingdom: Eumetazoa

- **…………..Triploblastica**

Triploblastic animals have three germ layers: ectoderm, mesoderm and endoderm. Mesoderm allows development of muscle layers in body wall, allows more elaborate organs, more specialization and greater division of labor.

- They are classified into three groups according to the presence of the true coelom, Acoelomata, Pseudocoelomata and coelomata.

- The true <u>coelom</u> is a fluid-filled body cavity, which is completely lined by the tissues derived from the <u>mesoderm</u>.



Acoelomata: **(Animals without body cavity)**

Phylum: Platyhelminthes

<u>General characters:</u>

- They are the first animals which illustrate the development of organ system.
- May be free living or parasites.
- They are soft bodied, unsegmented worms.
- They are bilateral symmetry and dorsoventrally flat worms.
- They show three germinal layers i.e. ectoderm, mesoderm and endoderm.
- A true body cavity or coelom is absent, and the space between the body organs is filled with loose parenchyma.

- Muscular system is well developed.
- The alimentary canal is either absent or highly branched. Anus is absent.
- Excretory system consists of flame bulbs or flame cells or protonephridia connected to the excretory ducts.
- Circulatory and respiratory systems are absent.
- Nervous system and sense organs are poorly developed, consists of a pair of ganglia connected to 3 pairs of nerve cords.
- Usually hermaphrodite animals.
- Fertilization is internal and development may be direct or indirect
- Direct development: It is a type of development in which an embryo develops into a mature individual without involving a larval stage.
- Indirect development: It is a type of development that involves a sexually-immature larval stage, having different food requirement than adults.

Classification of Platyhelminthes

Class 1 Turbellaria

- Mostly Free-living fresh water organism
- Body: dorso-ventrally flattened
- Hooks and sucker usually absent
- Examples: *Planaria*

Class 2 Trematoda

- Mostly parasitic
- Body: dorso-ventrally flattened leaf like
- Hooks and sucker are present
- Examples; *Fasciola hepatica* (Liver fluke) *Schistosoma* (blood fluke)

Class 3 Cestoda

- Exclusive parasitic
- Body: dorso-ventrally flattened tape like
- Hooks and sucker are present
- Digestive system-absent
- Excretion: Protonephridia with flame cell
- Examples: *Taenia* (tapeworm)

Schistosoma haematobium

- ***Schistosoma*** is a genus belongs to Class: Trematoda, Order: Digenea, commonly known as **blood flukes**. They are parasitic flatworms responsible for a highly significant group of infections in humans termed *schistosomiasis.*

- Two species infect man in Egypt. *S. haematobium* which lives in venous vesical plexus and drops the eggs in the venules of the urinary bladder to pass out with the urine. The other species is *S. mansoni* which lives in the mesentric veins and drops the eggs in the venules of the rectum to pass out with the faeces.

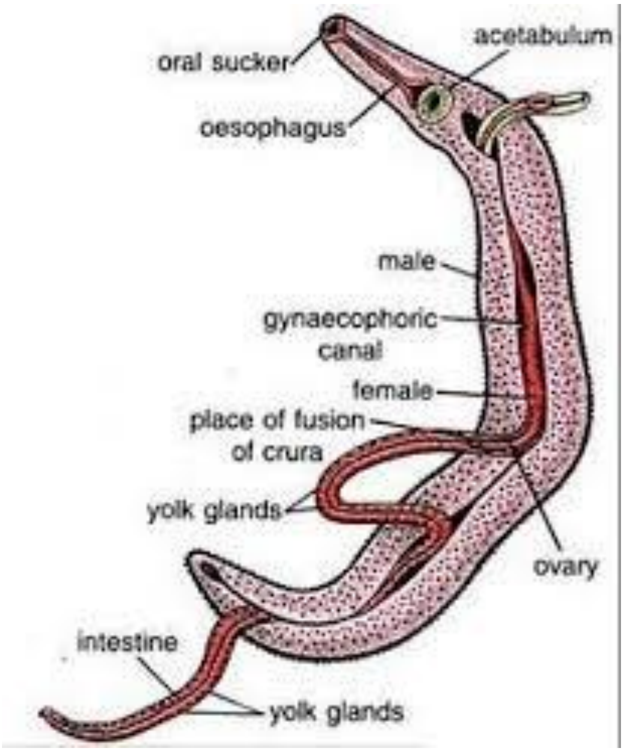


Figure 18: Male embracing female

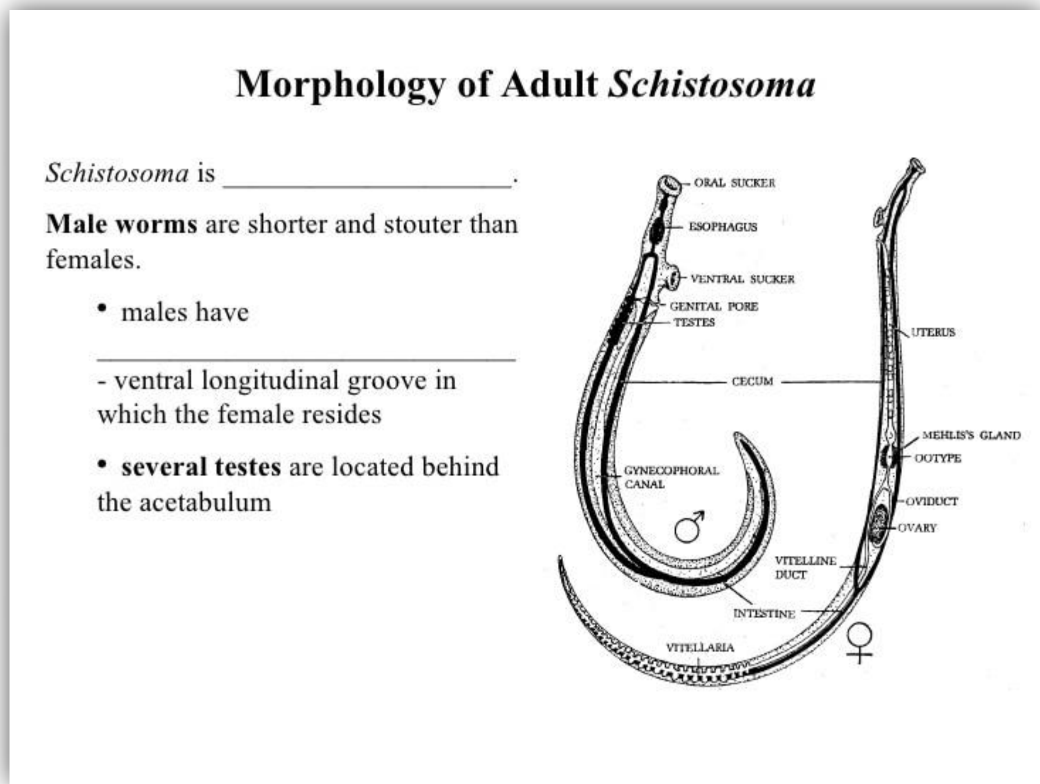


Figure 19: Morphology of *Schistosoma*

- ***S. haematobium***: the sexes are separate but usually found in pairing condition. The male (10-15 mm long) broader and shorter than female (16-20 mm) and has a cylindrical appearance but is actually flat with the sides rolled ventrally to form the gynaecophoric groove in which the narrower female is partly lodged. The body of male covered with tubercles for clinging to the walls of the venules while moving against the blood stream. The female body is cylindrical and smooth to pass easily through the small blood vessels for laying the eggs.

Life cycle

- Eggs are eliminated with faeces or urine to the water. Under optimal conditions the egg hatch and release miracidium , which swim and penetrate specific snail intermediate host (*Bulinus truncatus* snail for *S. haematobium* and *Biomphalaria alexandrina* snail for *S. mansoni*). The stages in the snail include 2 generations to produce the infective stage (cercariae). Upon release from the snail, the (cercariae) swim, penetrate the skin of the human host, and migrate through several tissues to their residence in the veins.

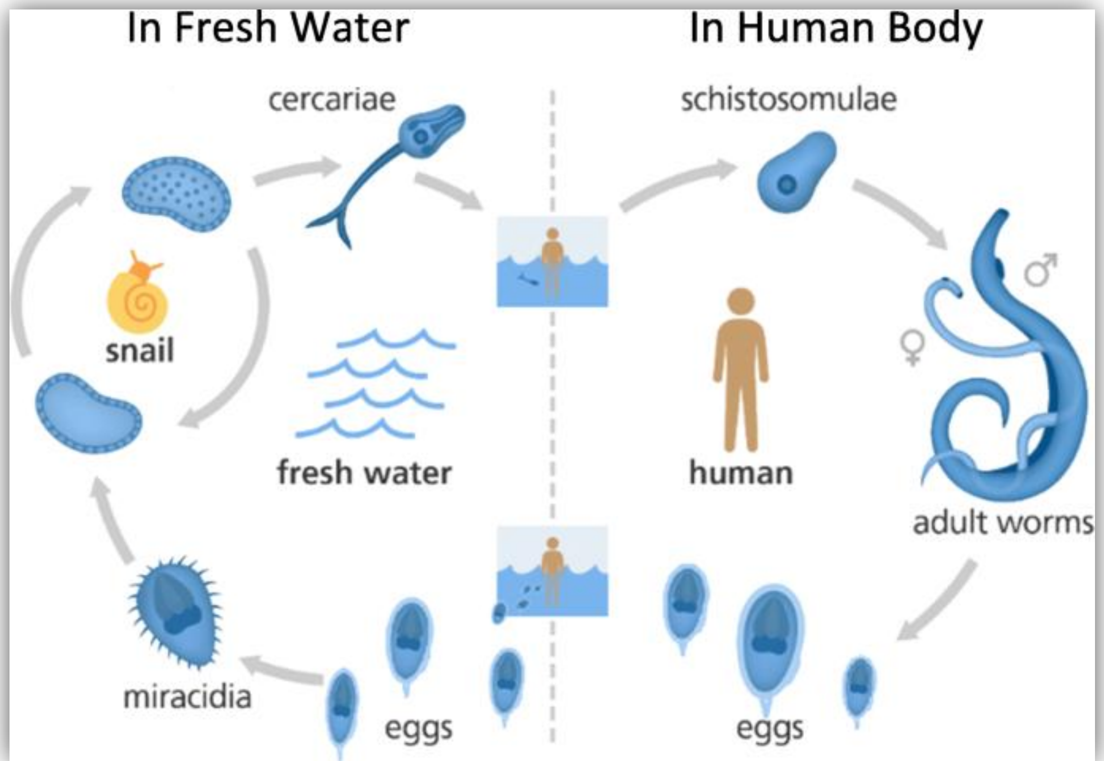


Figure 20: Life cycle of *Schistosoma*

Figure 21: ***Biomphalaria alexandrina***

Figure 22: ***Bulinus truncatus***

Taenia saginata

T. saginata is the largest of species in the genus *Taenia*. An adult worm is normally 4 to 10 m in length, but can become very large; specimens over 22 m long are reported. Typical of cestodes, its body is flattened dorsoventrally and heavily segmented. It is entirely covered by a tegument. The body is white in colour and consists of three portions: scolex, neck, and strobila. The scolex has four suckers, but they have no hooks. Lack of hooks and a rostellum is an identifying feature from other *Taenia* species. The rest of the body proper, the strobila, is basically a chain of numerous body segments called proglottids. The neck is the shortest part of the body, and consists of immature proglottids. The midstrobila is made of mature proglottids that eventually lead to the gravid proglottids, which are at the posterior end. An individual can have as many as 1000 to 2000 proglottids.

T. saginata does not have a digestive system, mouth, anus, or digestive tract. It derives nutrients from the host through its tegument, as the tegument is completely covered with absorptive hair-like microtriches. It is also an acoelomate, having no body cavity. The inside of each mature proglottid is filled with muscular layers and complete male and female reproductive systems, including the tubular unbranched uterus, ovary, genital pore, testes, and vitelline gland. In the gravid proglottid, the uterus contains up to 15 side branches filled with eggs

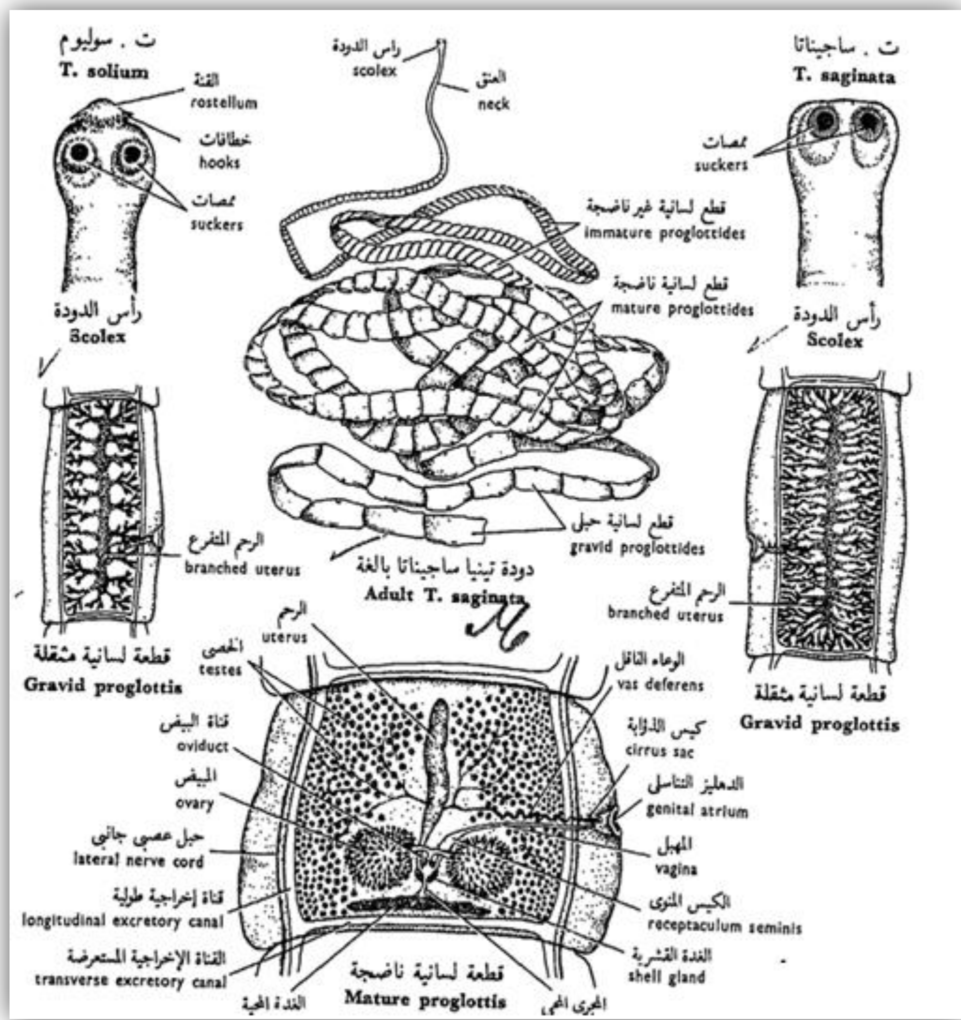


Figure 23: ***Taenia***

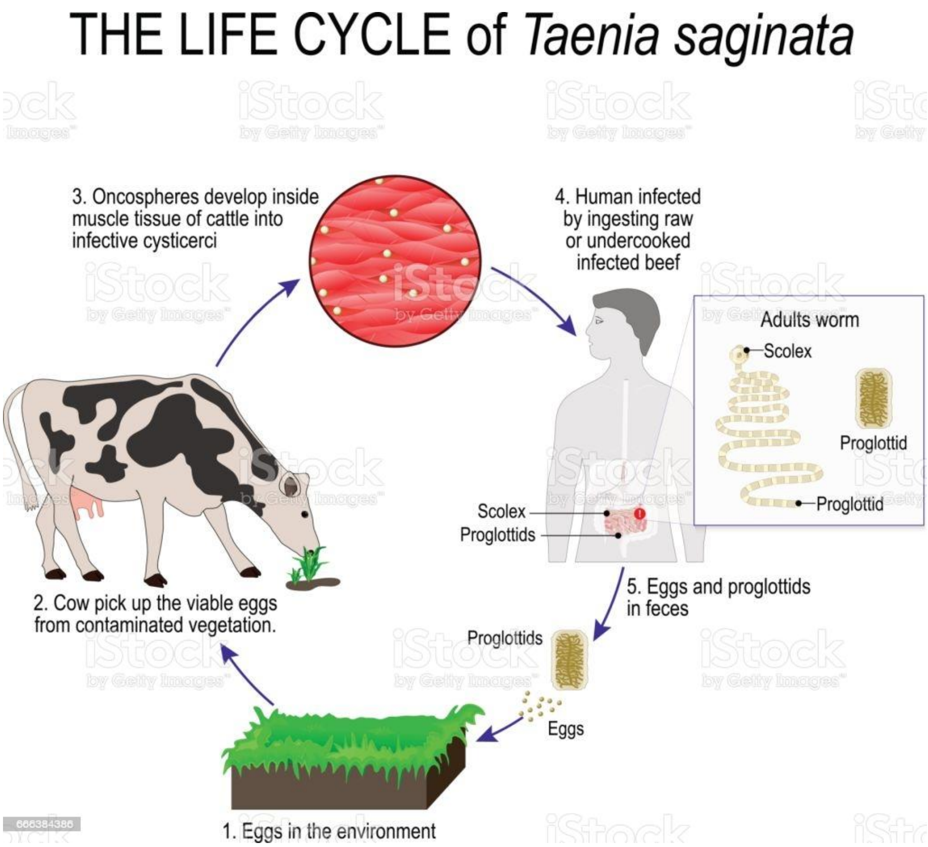


Figure24 : Life cycle of *Taenia*

The eggs are released when a proglottid detaches from the tapeworm in the intestinal lumen or when a segment disintegrates outside the host. The eggs are small diameter 30–40 µm) and round. *The eggs are highly resistant and can remain infective in a moist environment for weeks or months.

Carried by feces of humans infected with Taenia, they contaminate pastures or feed either directly or via sewage. When the cattle ingest the eggs, the oncospheres hatch in the small intestine, migrate into the intestinal wall, and are transported with the bloodstream into the striated musculature of the cattle.

Pseudocoelomata

A pseudocoelomate is an organism with body cavity that is not derived from the mesoderm, as in a true *coelom*, or body cavity

Phylum: Aschelminthes (Nematods)

(the round worms)

- They may be free living (aquatic and terrestrial) or parasitic on plants and animals.
- They are bilaterally symmetrical, triploblastic and pseudocoelomate animals.
- The body is cylindrical. unsegmented with smooth cuticle and well developed muscle fibers.
- The alimentary canal is complete with a mouth, a well-developed muscular pharynx and anus.
- Two lateral excretory tubes removes body wastes from the body cavity through one excretory pore.
- No respiratory or circulatory systems.
- Nervous system with circumenteric ring, 6 anterior and 6 posterior nerves.
- Sexes are separated. Often females are longer than males.

Order: Ascaridata
Genus: *Ascaris*

- Some species of this genus are the largest round worms. There are 3 species: *A. lumbricoides* which lives in the small intestine of man, *A. megalocephala* lives in the small intestine of the horse and *A. vitulorum* in that of the cow. They resemble each others closely and differ in few details.

- The body form is cylindrical, Long and the length in male about 15-26 cm and in female about 22-30 cm. The two ends are tapring. The female is the larger and has a straight posterior end, while the male is slender and has a sharply curved posterior end.

- There are 4 longitudinal streaks run the entire length of the body, 2 thin dorsal and ventral lines (contain two nerve cords) and 2 broader lateral lines (contain two execretory canals).

- The mouth lies at the anterior end of the body and the execretory pore lies on the ventral side, 2 mm behind the mouth. The female genital opening lies on the ventral side near the anterior end. The cloaca (the genital duct joins the hind gut) in male opens near the posterior end and two copulatory spicules project from the cloaca.

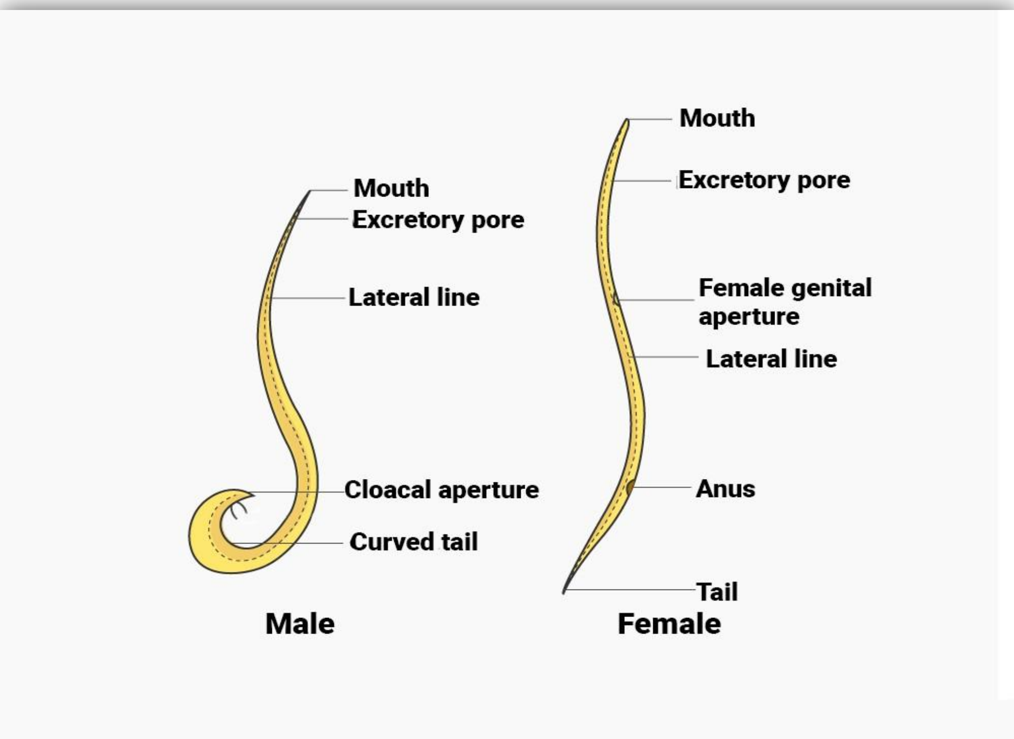


Figure 25: ***Ascaris***

- The female lays about 200,000 eggs daily which pass out with the faeces.
- The infective stage is the egg which contains an embryo, that molts inside the egg ready to infect a new host.
- *Ascaris lumbricoides*, infects humans via the fecal-oral route. Eggs released by adult females are shed in feces. Unfertilized eggs are often observed in fecal samples but never become infective. Fertilized eggs embryonate and become infective after 18 days to several weeks in soil, depending on the environmental conditions (optimum: moist, warm, shaded soil). When an embryonated egg is ingested, a Rhabditiform larva hatches then penetrates the

wall of the gastrointestinal tract and enters the blood stream. From there, it is carried to the liver and heart, and enters pulmonary circulation to break free in the alveoli, A microworm moves through the small intestine and matures into an adult worm until it emerges through the abdominal cavity. Fertilization can now occur and the female produces as many as 200,000 eggs per day for 12–18 months. These fertilized eggs become infectious after two weeks in soil; they can persist in soil for 10 years or more.

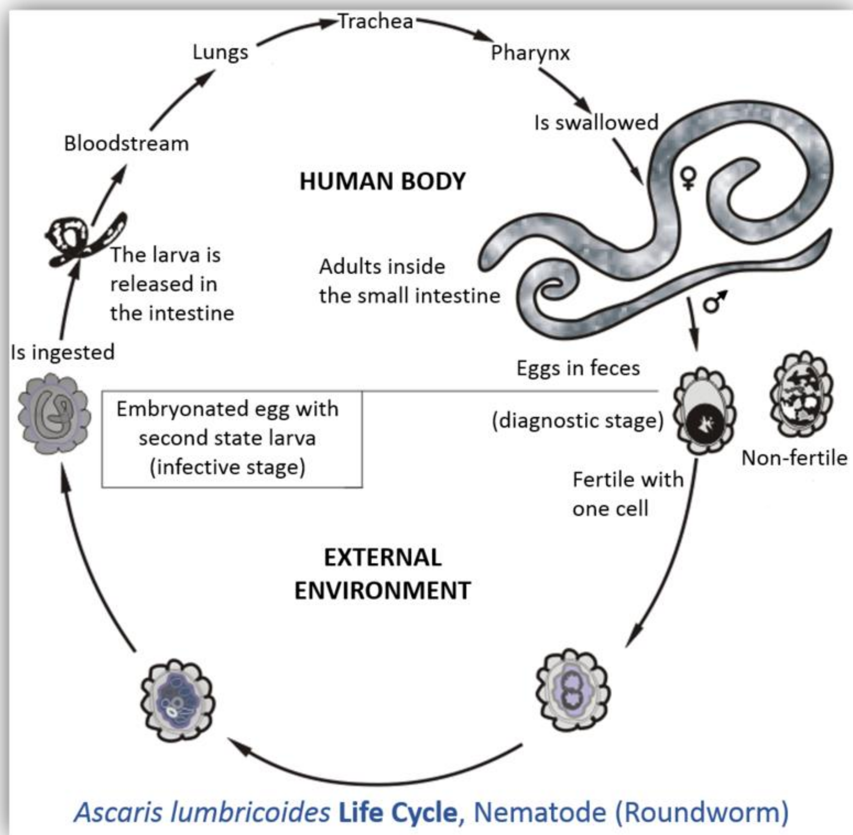


figure 26: Life cycle of *Ascaris lumbricoides*

Coelomata

Phylum: Annelida

General characters:

- These animals are found on land, in moist soil, freshwater or in the sea and they are free living or ectoparasites.
- They are triploblastic, coelomate and bilaterally symmetrical animals.
- They have an elongated and metamerically segmented body.
- The body covered with a thin non- chitinous cuticle and the body wall is muscular with circular and longitudinal muscles.
- They possess chaetae on the segments, some forms with parapodia.
- The alimentary canal is elongated and a tube like. It extends from the mouth to the anus.
- The respiration takes place through the external surface of the body.
- They have closed type of circulatory system, i.e., the blood flows in the blood vessels.
- The excretion by tube- like organs, called nephredia. In each segment a pair or more nephredia are present.
- The nervous system consists of a brain and double nerve cord, with many ganglia in each segment.

- Sexes are separated or occur in the same body. Development may be direct or through a trochophore larva. Regeneration is also common.

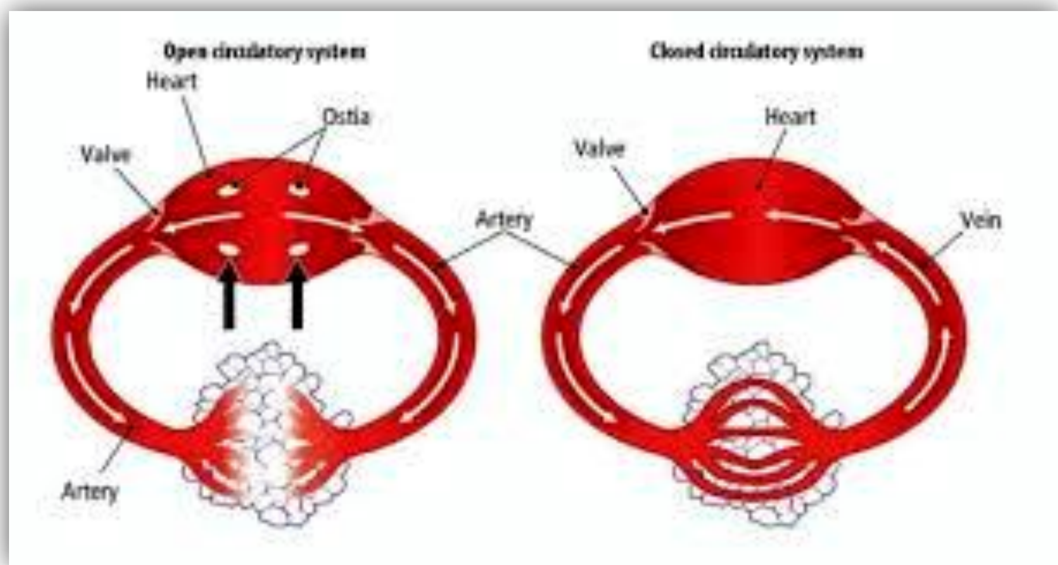


Figure 27: Opened and closed circulatory system

Classification of Annelida

Class: Oligochaeta

Includes the earthworms, live in moist soil or in freshwater. They are hermaphrodite and without parapodia. Ex. *Allolobophora*

Class: Polychaeta

Includes marine forms swim freely in water or live burrowing in the sand and mud near the shore. The sexes are separated and have parapodia. Ex. *Neries*

Class: Hirudinea

Includes the leeches which feed on the blood of vertebrates (parasites). They are hermaphrodite and without parapodia and chaetae. Ex.: *Hirudo*

Allolobophora caliginosa

- Earthworms live in moist soil, build burrows and feed on organic matter.
- The body is cylindrical and divided into great number of segments separated by intersegmental grooves, pointed at the anterior end and flattened at the posterior end.
- The mouth and anus open at the anterior and posterior ends respectively.
- The clitellum (secretes the cocoon) is the thickened skin of segments 26-34 and lies on the dorsal and lateral sides but these segments are distinct on the ventral side. The edges of the clitellum are thickened on segments 31-33 forming the puberty crests.
- Every body segment, except the first and the last, bears 4 pairs of chaetae, two ventral pairs and one pair on each lateral side.

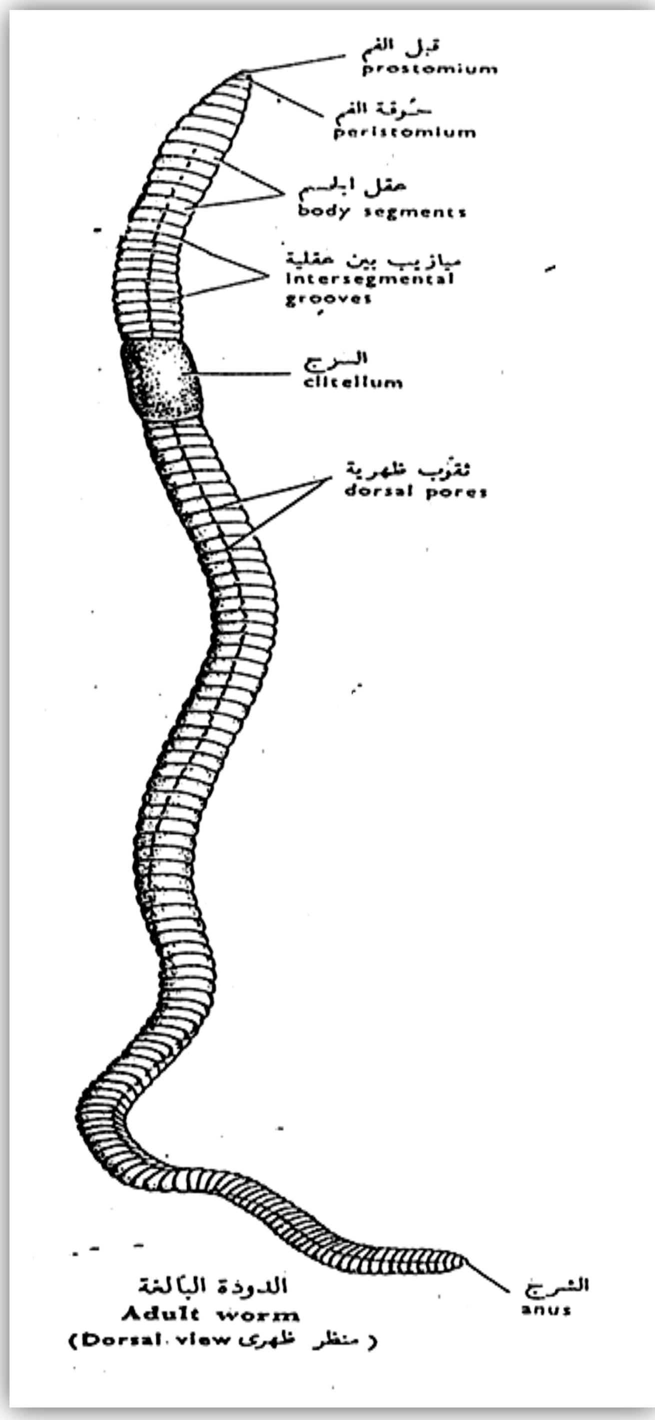


Figure 28: ***Allolobophora caliginosa***

- **The external body openings:**
- The mouth on the first segment.
- The anus on the last segment.
- The female genital openings (2) on the ventro-lateral sides of segment 14.
- The male genital openings (2) on the ventro-lateral sides of segment 15.
- The spermathecal pores are 2 pairs lies in the intersegmental grooves between segments 9-10 and 10-11 and they are surrounded by three pairs of copulatory papillae on segments 9, 10 , 11
- The dorsal (coelomatic) pores lies mid- dorsally on the grooves from 8-9 to the posterior end, connect the internal coelom with the external environment.
- The excretory pores or nephridiopores lies on the ventral side, a pair on each segment except the first three segments and the last segment.

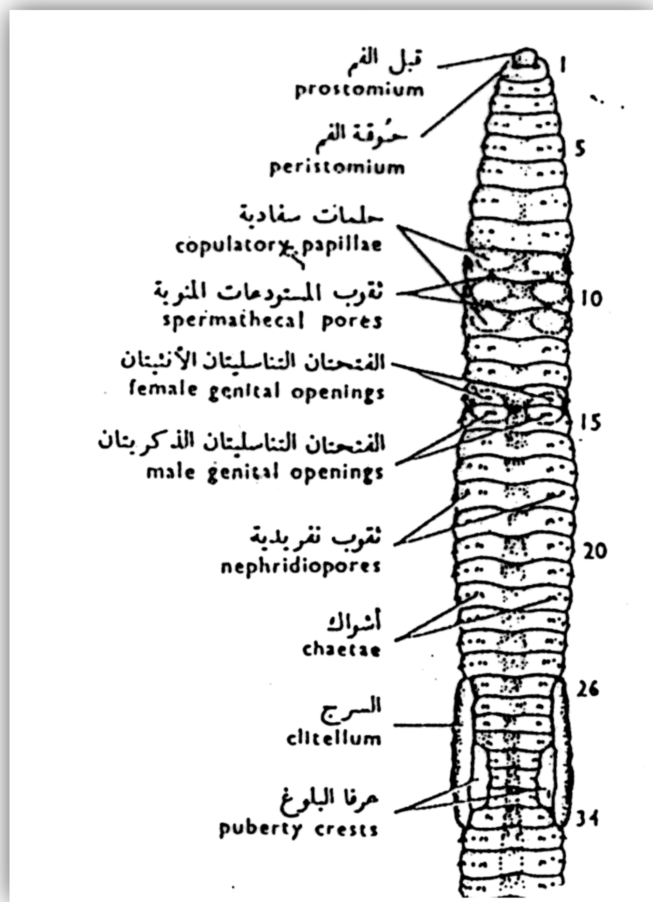


Figure 29: Ventral view of *Allolobophora*

Phylum: Arthropoda

- The largest phylum in the Animal kingdom.

General characters

- Cosmopolitan in distribution, found as aquatic, terrestrial and aerial forms. Some are ectoparasites and vectors of disease.
- Body is triploblastic and bilaterally symmetrical.
- Body is segmented. Number of segments is less than this in Annelida and forms certain regions. It is divisible into head, thorax and abdomen.
  NOTE: In some forms, body is divisible into cephalothorax (head and thorax are fused) and abdomen, or head and trunk
- Body has jointed appendages or legs (which modified to different structures to perform different functions like jaws, walking legs, paddles).
- Body is covered with chitinous exoskeleton formed by epidermis. The exoskeleton forms internal projections useful for muscle attachment. The exoskeleton is casts off periodically and a new one is secreted. That is called molting or ecdysis.
- True coelom is greatly reduced. It is represented only by the cavities of the reproductive and excretory organs. The general body cavity (haemocoel) is filled with blood.
- Digestive system is complete, straight and well developed. The mouth bears mouth parts for ingestion of food.
- Respiration takes place by general body surface or gills, trachea, booklungs or bookgills.

- Circulatory system is of opened type i.e. do not have blood vessels and the blood enters directly into the body chambers or (haemocoel), and returns back to the heart through ostia.
- Excretion takes place through Malphigian tubules (in terrestrial form) or green glands (in aquatic forms).
- Nervous system is of annelidian type, which consists of a brain and a ventral nerve cord.
- Sensory organs include antennae, sensory hairs for touch and chemoreceptor, simple and compound eyes, auditory organs (in insects) and statocysts (in crustacean).
- Striated muscles are presented segmentary.
- Unisexual i.e. sexes are separated. Fertilization is internal or external. They are either oviparous or ovoviviparous. Development may be direct or indirect.
- Oviparous: lying leggs hatch out of the female body.
- Ovoviviparous: form eggs but still inside the female till hatching.
- Direct development: It is a type of development in which an embryo develops into a mature individual without involving a larval stage.
- Indirect development: It is a type of development that involves a sexually-immature larval stage, having different food requirement than adults.

Classification of phylum Arthropoda

Subphylum: Mandibulata

Class: Crustacea

General characters:

- Mainly aquatic, few live in moist places. Few are parasitic forms.
- The body is divided into 3 regions: head, thorax (usually fused in one part : cephalothorax) and abodomen.
- The head contains 6 segments :
- The first segment disappears in adult.
- The second bears the first anntennae or (antennules)
- The third bears the secont antennae or (Antennae)
- The fourth bears the Mandibles
- The fifth bears the first maxillae or (Maxillules)
- The sixth bears the second maxillae or (Maxillae)
- The thoracic and abdominal segments differ from one crustacean animal to another, but generally each segment with a pair of appendages and sometimes disappear from abdomen.
- The digestive tract is almost straight. It consists of an anterior foregut and a posterior hind gut, both lined by chitin and separated by the unchitinised midgut which often give rise to digestive glands.
- The opened circulatory system includes a contractile heart enclosed in pericardial cavity.
- Respiration takes place by general body surface or gills.
- Excretion takes place through coxal or anntennal glands (green glands).

- The sexes are usually separated. Development usually indirect forming (Nauplius larva).

The Prawn

- Class: Crustacea
- Subcalss: Malacostraca
- Order: Eucarida
- Suborder: Decapoda
- Family: Macrura
- e. g.: *Penaeus japonicus*
- It is a prominent member of our marine fauna.
- The body is divided into an anterior cephalothorax and a posterior abdomen.
- The cephalothorax (6 cephalic (5 in adult)+ 8 thoracic segments) is covered on all sides except ventrally by carapace which extended anteriorly into a long serrated pointed rostrum.
- No external signs of segmentation on head and thorax.
- On each side of the carapace, a V-shaped cervical groove that demark between head and thorax. Also note 3 dorsal grooves two of these are branchiocardiac grooves and the third is the rostral groove.
- The dorsal part of carapace is called cardiostegite and the sides are called branchiostegite.

- On both sides of rostrum two compound eyes are present carried on long stalks. Each eye made up of a large number of structural & functional units called ommatidia
- The abdomen with (6) segments ended with a small telson and the anus opens on its ventral surface.
- The segments of abdomen can be moved upon one another according to the presence of the peg and socket hinges on each side.
- A pair of appendages arises on each segment of the body. So 19 pair of appendages are present in adult animal.

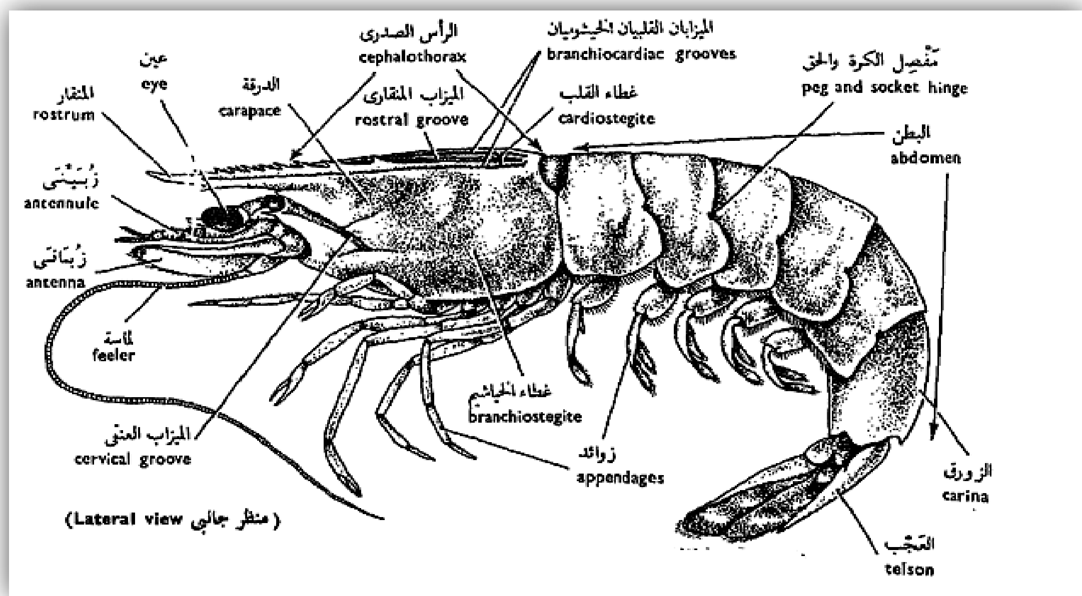


Figure 30: ***Penaeus japonicus***

<u>Watch</u> video

Class: Myriapoda

General features:

1- All are terrestrial.

2- The body is elongated with a consicous head and a trunk consisting of many segments between 11- 177 segment, each one bears one or two pairs of appendages.

3- Each appendage with 7 segments and a claw.

4- The head bears two antennae, two or three pairs of jaws and simple eyes.

5- Respiration through spiracles which connected internally with the tracheal system.

6- Excretion through Malpighian tubules which open in the hind-gut.

7- Sexes are separated. Development usually direct.

Subclass: Chilopoda
e.g.: *Scolopendra morsitans*

- Hides by the day below stones or plant leaves and runs faster at night to prey insects and earthworms.
- The body is elongated, dorsoventrally flattened and divided into head and trunk.

Watch video

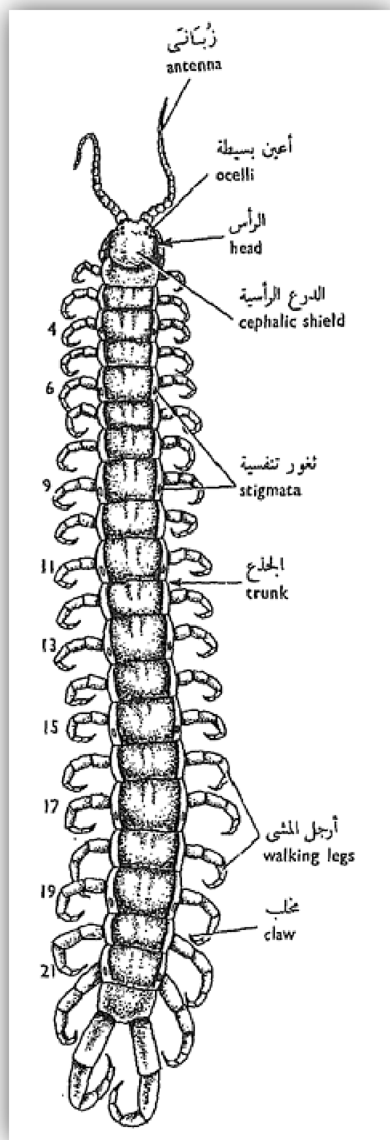


Figure 31: ***Scolopendra morsitans***

- The head consists of 6 segments covered by a cephalic shield. There are two lateral groups of simple eyes (ocelli), each group of 4 ocelli. The head bears two segmented antennae (the main sensory organs).

- The trunk with 22 segments, each segment covered by a dorsal tergum, ventral sternum and 2 lateral pleura. The first segment has no separate tergum (maybe fused with the cephalic shield), this segment bears ventrally the maxillipeds or two poison claws, each ends in a sharp claw on which opens the poison gland.

Figure 32: The poison claws

- Each segment from 2-22 carries one pair of walking legs (which together with the 2 antennae make the 44 appendages). Each leg is built up of 7 segments named from the base: coxa, trochanter, femur, tibia and 3 tarsi ending in a claw.

- Paired respiratory openings or stigmata lie on the pleural shields of the segments 4, 6, 9, 11, 13, 15, 17, 19 and 21. Note that these segments longer than the other segments. The anus opens ventrally on the last segments.

Class: Arachnida

1- Most are terristrial and some are aquatic.

2- The body is divided into two regions: the prosoma and the opisthosoma.

** the prosoma includes head and thorax and in adult consists of 6 segments: the first bears a pair of chelicera, the second bears a pair of pedipalps and the 4 other segments with 4 pairs of walking legs.

** the opisthosoma consists of 13 segments and divided to mesosoma and metasoma (or not divided) and without any appendages.

3- The exoskeleton is strongly chitinized.

4- The eyes are sessile and mostly simple.

5- Respiration by lung-books, tracheae or by gill-books in aquatic forms.

6- Excretion by coxal glands or Malpighian tubules.

7- Sexes are separate and development is usually direct.

Watch video

Order: Scorpionidea
e.g.: *Buthus (Leiurus) quinquestriatus*

It is a dangerous animal, spread in tropical and temperate regions. It is nocturnal (active at night), feeds on juice of insects and spiders.

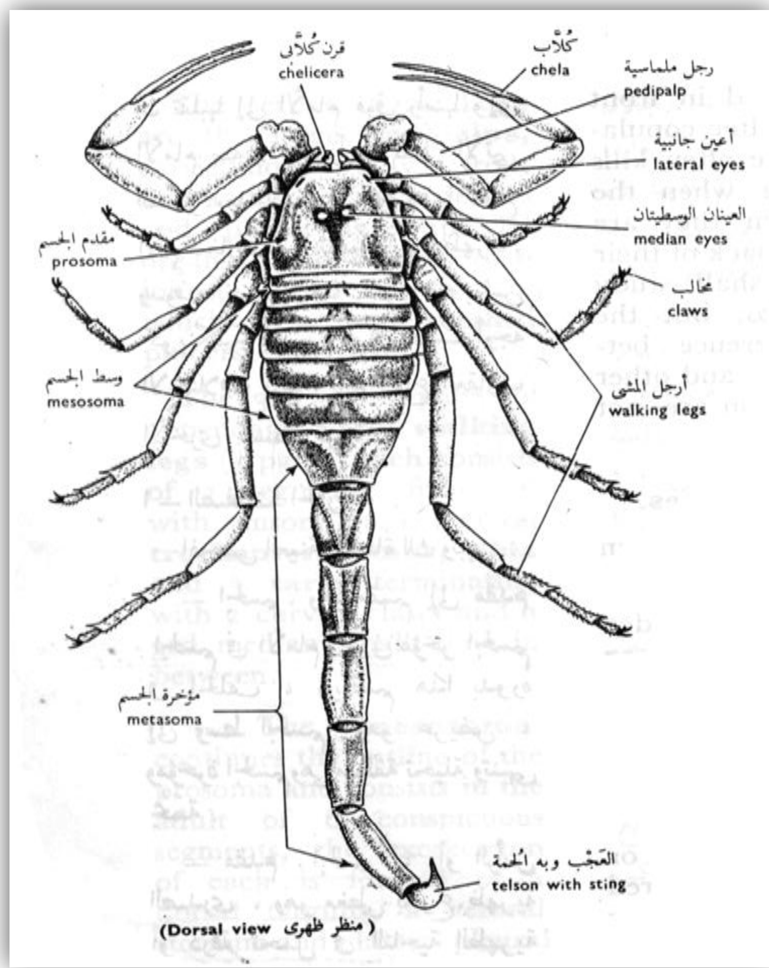


Figure 33: ***Buthus quinquestriatus***

—

— The body is divided into prosoma and opisthosoma which is subdivided to a broad mesosoma and a slender matasoma ends in a sting.

— The prosoma is covered by a dorsal shield (carapace) which carries dorsally a pair of median eyes and two groups each of 5 smaller lateral eyes (all are simple).

- The prosoma carries 6 pairs of appendages: the chelicerae (with a chela), the pedipalps (as feelers and with toothed pincers for offensive action) and 4 pairs of walking legs.
- The mesosoma in adult consists of 6 segments, the first segment carries on its ventral side a divided genital operculum covers the gental opening. The second segment carries a pair of comb-like structures (the pectens) act as tactile organs (longer in the male). The 4 other segments with 4 pairs of stigmata on their ventral side, lead internally into the lung-books.
- The metasoma consists of of 6 narrow cylindrical segments jointed to one another. The last segment terminates with the telson which forms the sting. Two poison glands are found within the sting and open near the spine.

Phylum: Mollusca

General characters:

- Lives in water (freshwater or marine) and some forms are terrestrial. Molluscs come in the second rank after arthropods according to the number of species.
- They are triploblastic, mostly bilaterally symmetrical except **class: Gastropoda**.
- The body is soft, unsegmented without any appendages and divided into: head, a ventral foot and a dorsal visceral hump (no head in **class: Bivalvia).**

- The visceral hump is covered by a thin, fleshy fold called mantle. Mantle secretes a calcareous shell, which may be external or internal or not present at all.
- Mantle also encloses an opened mantle cavity, within lie a pair of gills, the anus and renal openings.
- Coelom is reduced represented by the pericardial cavity, cavities of gonads and kidneys (the excretory organs)
- Respiration by gills in aquatic forms and by lungs in terrestrial forms.
- The circulatory system is opened (except **class: Cephalopoda**) consists of a heart enclosed in a pericardial cavity and extends into a haemocoel.
- The nervous system contains 3 doubled ganglia: the cerebral, pedal and lateral ganglia and maybe visceral ganglion in some forms. Sense organs are eyes, tentacles and statocyst.
- Locomotion takes place by ventral muscular foot.
- The digestive system with salivary and digestive glands. The mouth with a hard chitinous structure, called radula or Odontophore (absent in **class: Bivalvia**).
- Sexes are usually separate and some are hermaphrodite. Development may be direct or indirect forming larvae.

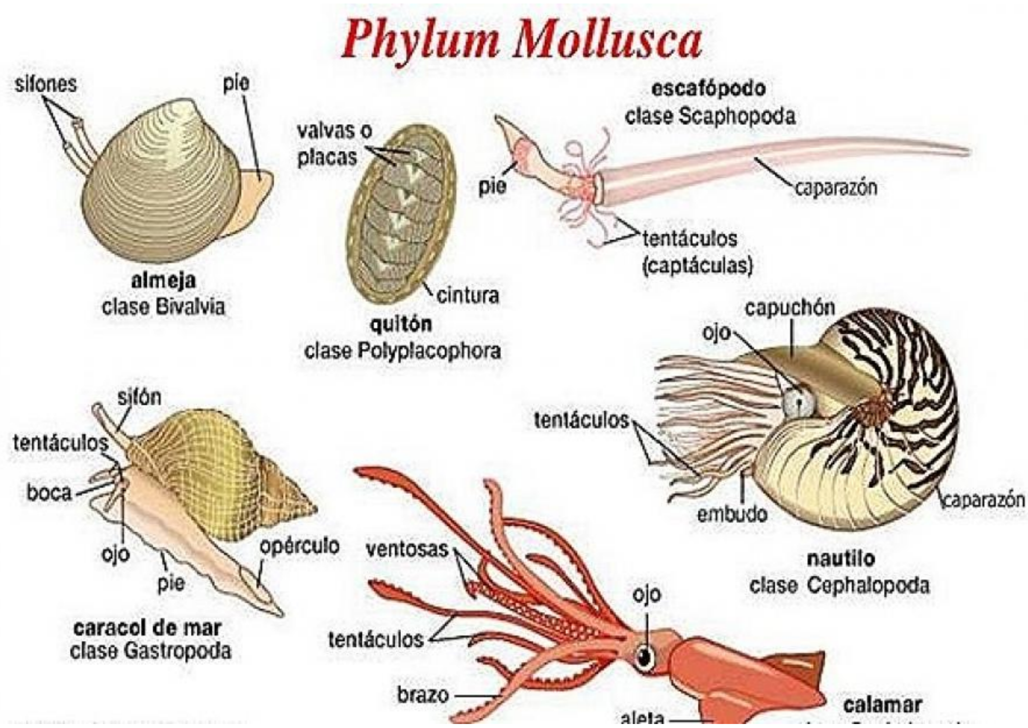


Figure 34: Groups of Mollusca

Class: Placophora

- 1- All are marine, present in all depths and contains all chitons.
- 2- Head is poorly developed without eyes or tentacles.
- 3- Mantle covers all dorsal surface and secrets calcareous spicules and usually also a shell.
- 4- Foot is flattened and large like a sucker.
- 5- Feeds on aquatic plants and algae.
- 6- Development includes a larvae called: trochophore

e.g.: ***Acanthochiton spinigera***

- It is common on our sea coasts, adhering to rocks, but when separated strongly from the rock, it rolls itself up to more or less spherical form like a ball.
- The body is elongated and oval in shape. The mantle secrets in the dorsal side a calcareous shell formed of 8 overlapped plates, enabling the animal to roll into a ball. The mantle edge with calcareous spicules.
- In the ventral side, the head is small with only a mouth. The foot is large acts as a creeping organ and as a sucker.
- The mantle cavity is a groove between head-foot and the mantle edge, within found the gills on each side. The anus opens on a papilla projecting behind the foot. In front of anus on each side, an excretory pore and a genital opening.

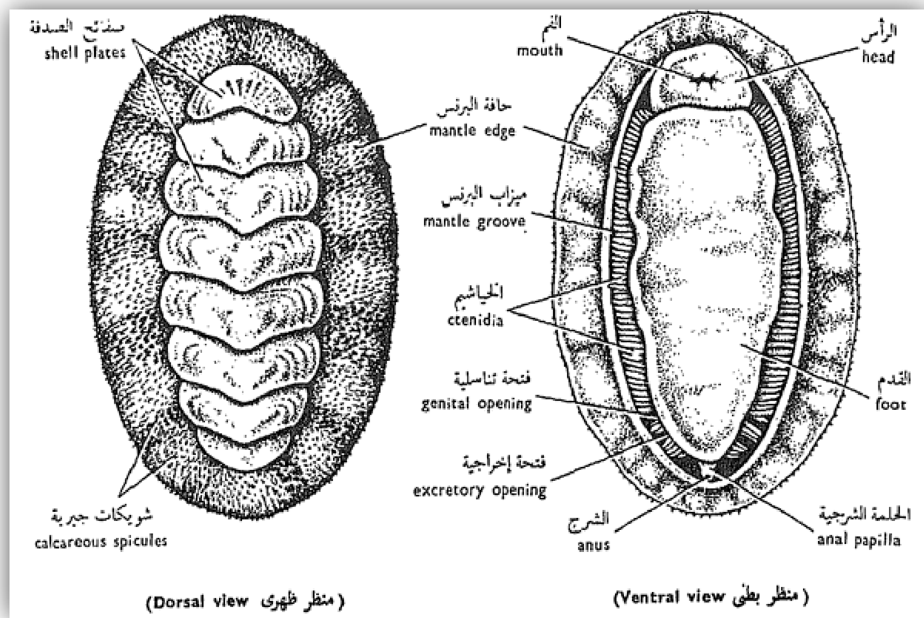


Figure 35: ***Acanthochiton spinigera***

Class: Gastropoda

- Gastropoda is the large class of molluscs, lives in marine water, freshwater and on land.
- The head and foot are fused in one structure (the head-foot), this part is bilaterally symmetrical, but the visceral hump is asymmetrical, due to two processes happened in the embryonic stages called: the torsion and the spiral coiling.
- The mantle form a coiled shell with different colours but sometimes disappear from some forms like slugs.
- Development is direct.
- It is herbivorous, and some species are predators or parasitic.
- Some species acts as intermediate hosts for some parasites like *Fasciola* and *Schistosoma*

Order: Pulmonata
e.g.: *Eremina desertorum*

- Common in the Egyptian desert, feeds on leaves and stems of desert plants. It is nocturnal hides in its shell during the day. It is active in winter.
- The shell with 4 whorls, and it is dextral.
- The headfoot mass bears anteriorly: the mouth, below it an opening of a gland (the pedal gland) produce a slimy secretion. There are 2 pairs of tentacles: the anterior pair is short, but the posterior one is long with two black eyes. A single genital opening found on the right side of head.

- <u>The visceral hump</u> is spirally coiled and occupies the shell whrols. The mantle form a thick ring called the mantle collar, bears on the right side: the pulmonary opening which leads internally to a cavity rich with blood vesels and acts as a lung. Note also the anus and the execretory opening on the mantle collar.

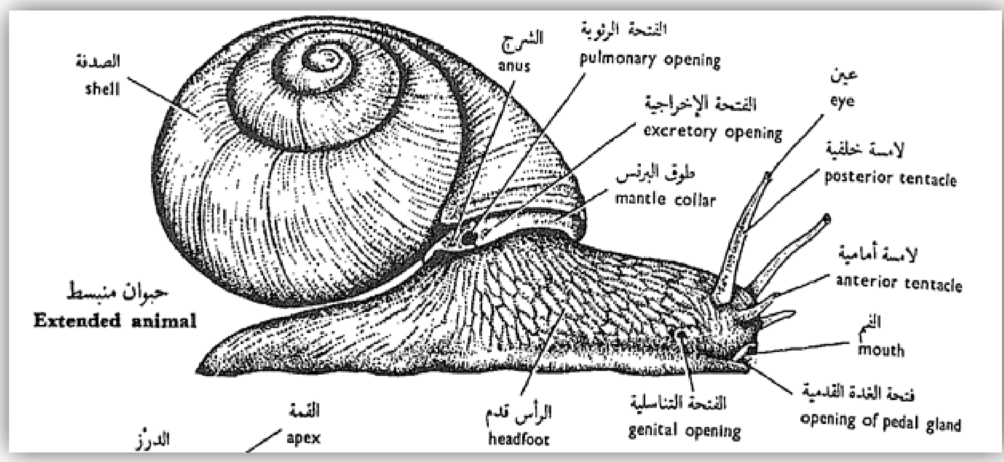


figure 36: ***Eremina desertoum***

Class: Pelecypoda

<u>(Bivalvia) or Lamellibranchiata</u>

- Most are marine and some are freshwater.
- The mantle consists of two lobes (right and left), so the shell is bivalved, the two valves hinged dorsally and jointed by a ligament.

- The head is reduced, only labial palps around the mouth. No radula because they are ciliary feeders.
- Moves very slowly by the foot, but mostly buried in the sand with its front.
- Sexes usually separated, but some are hermaphrodite. Development includes a larva called: veliger larva in marine forms.

e.g.: *Anodonta rubens*
(freshwater mussel or clam)

- Lives on the bottom of the river.
- The shell with 2 lateral valves, hinged dorsally. The umbo is a swollen apex found near the anterior part. Note the parallel lines of growth on the outer surface.
- Internally, the mantle consists of 2 lobes, which united together posteriorly to form two tubes: the exhalent siphon (small and smooth-walled) and the inhalent siphon (wider and papillated edges for testing water).
- The visceral hump is the compressed mid-dorsal portion of the body.
- The foot is a large mass, which drags the animal very slowly in the bottom mud.
- The labial palps are 2 pairs around the mouth carry cilia which drive food particles towards the mouth.
- The gills are 2 in number, very large and each one is formed of two plate-like folds.

- The muscles showing on the mantle surface are: the anterior and posterior adductor muscles which controlling the shell valves. The anterior and posterior retractor muscles which withdraw the foot inside the shell. The protractor muscle which forcing the foot outside the shell. Note the insertions of these muscles on the smooth inner surface of each valve.

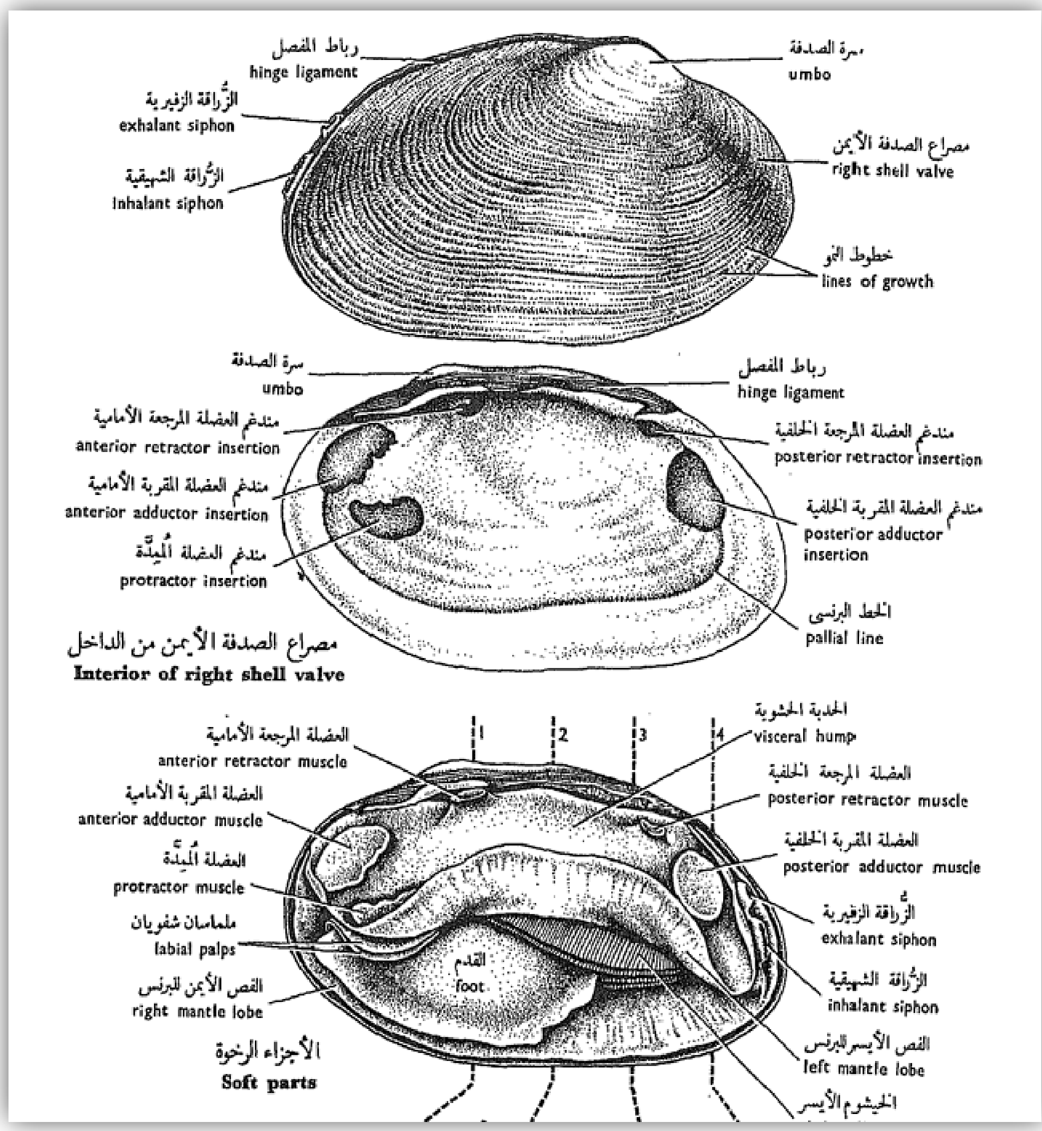


Figure 37: ***Anodonta rubens***

Class: Cephalopoda

- All are marine, it is the highest molluscs in development.
- The shell present internally or absent.
- The head is well-developed, with large eyes (as vertebrate eyes). The head bears a number of tentacles and arms (8-10) with strong suckers to capture the prey. These arms maybe are the modified anterior part of foot, thus called: Cephalopoda (head-foot).
- They are predators, so the mouth contains the radula and two sharp horny claws.
- The mantle cavity present in the ventral side contains the gills, anus, execretory and genital openings, also a muscular funnel opens in the cavity (it is the posterior part of foot).
- The circulatory system is closed.
- The nervous system is the highest system in all invertebrates, the ganglia are concentrated and fused together to form a brain enclosed in a cartilaginous capsule which contains statocysts.
- The sexs are separated and the development is direct.
- Cephalopods have several modes of defense. Some species can release light (Bioluminescence). Some species contains Chromatophores in their cells allow them to change colour. Lastly, most species have a sac which contains a black ink-like substance that can envelop and temporarily cloud the enemies' vision.

Order: Dibranchiata
Suborder: Decapoda
e.g.: *Sepia savignyi*

- The body is divided into a head and a visceral hump.
- The head with 2 large eyes similar to those of vertebrates. Also bears the mouth which surrounded by 8 arms (each arm is provided with 4 rows of suckers) and two long tentacles. The tentacles are used in catching the prey and the arms for holding it during eating.
- A muscular funnel found in the ventral side of the head, it opens in the mantle cavity. The water from the mantle cavity is forced out through the funnel opening causing the animal jerk backwards and emits a cloud of ink to escape from enemies.
- The visceral hump with 2 lateral fins, by which the animal swim. An internal shell present in the dorsal side of the visceral hump beneath the integument. Ventrally, occures the mantle cavity with a wide anterior mantle opening.

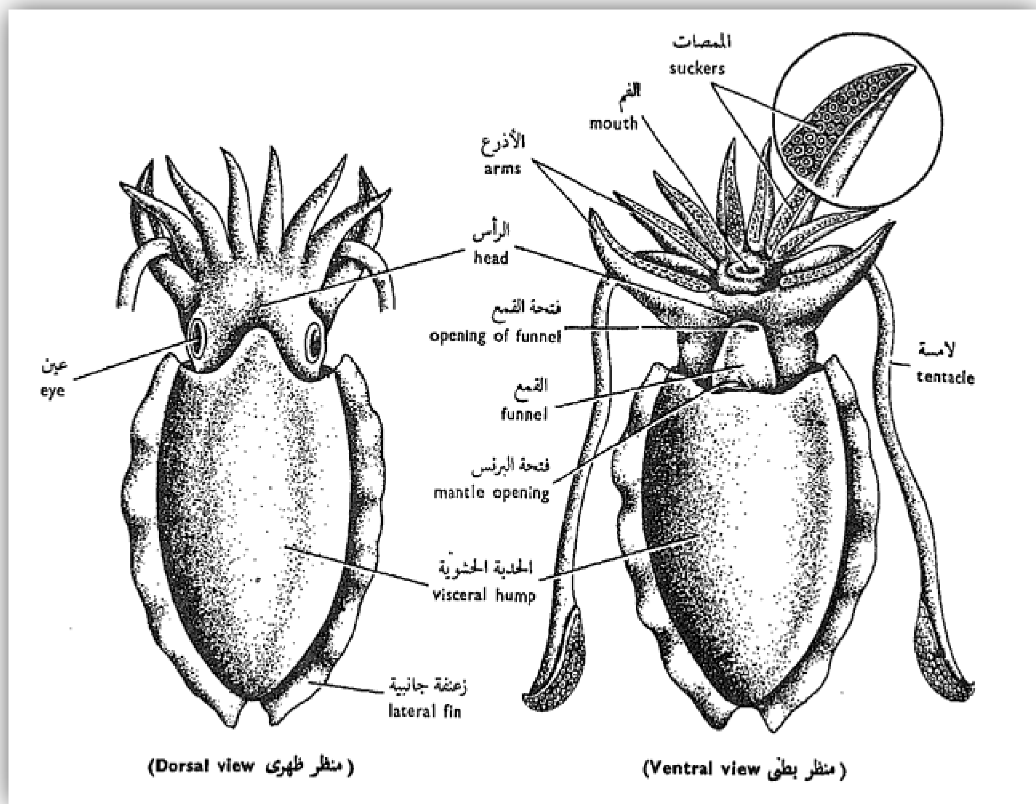


Figure 38: ***Sepia savignyi***

Phylum: Echinodermata

General characters:

- All are marine, found in the shores to the great depths. Includes forms quite different from the preceding invertebrates.
- Some are free living and some are sessile.
- Adults are radially symmetrical while larvae are bilaterally symmetrical.

- **The body** is not divided, with different shapes (star, rounded or cylindrical).
- They possess a dermal skeleton consists of calcareous ossicles which may develop into short or long spines pushes out on the surface, thus the name: Echinodermata.
- **The coelom** divided into several divisions (perivisceral coelom, perihaemal cavity and a water vascular system characterize this phylum).
- **The water vascular system** is connected to tube feet present on the outer body surface, these feet are the main locomotion organs but can also assist in sensation, respiration and food collecting.
- **Respiration** by dermal gills, tube feet or repiratory tree in class: Holothuroidea .
- **The nervous system** with circumoral nerve ring and radial nerves in all body.
- **The digestive system** is usually complete but in some forms there is no anus.
- **The circulatory system** is very reduced.
- No special execretory organs.
- **The sexes** is usually separated and the development maybe direct or including larva formation.
- Show high power of regeneration.

Class : Asteroidea

e.g.: ***Astropecten relitaris***

- Common in our seas, creeps slowly on the bottom but in rest it lies buried in the sand except the central part.
- **The body** is star-shaped, consisting of a central disc prolonged into 5 arms. The with two surfaces: a lower oral surface and an upper aboral surface.
- **On the aboral surface**, note the pointed spines on the edges of each arm and a blunt spines found in bundles called: the paxillae. Very minute dermal gills arise between the paxillae. Note also a plate with pores in the central disc, opposite to the angle between any two arms. This plate (the madreporite) lead into the water vascular system.

Watch video

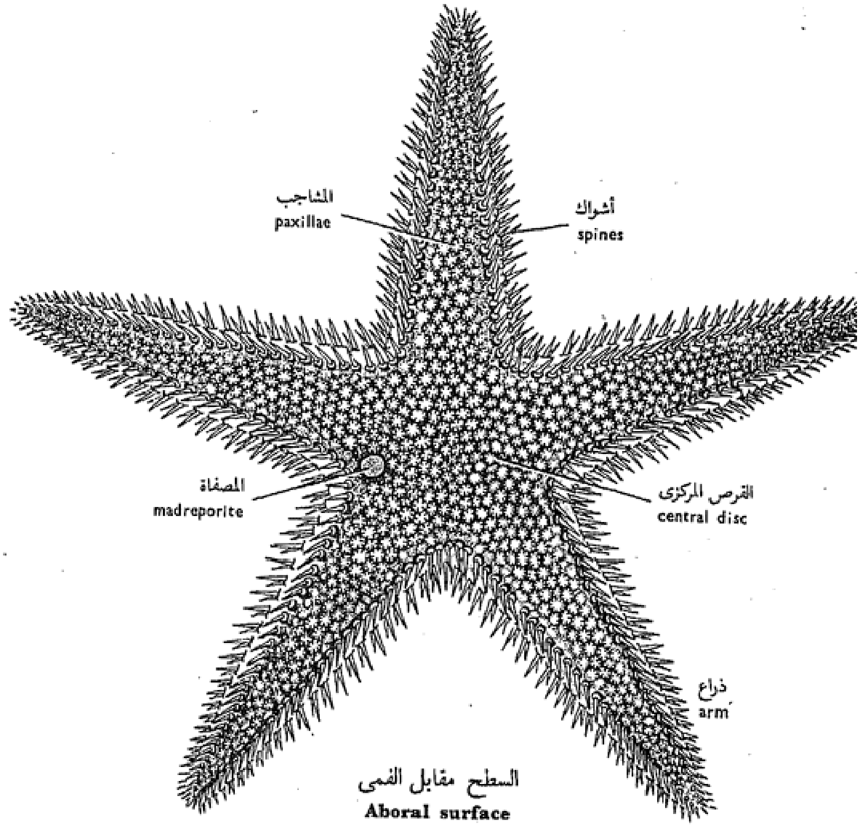


figure 39: ***Astropecten relitaris***

- **On the oral surface**, note the mouth in the centre, surrounded by a soft area (the peristome). Five ambulacral grooves extended out from the mouth along the entire length of each arm. Note, conical structures (the tube feet) project in 2 rows along each ambulacral groove. The terminal tube foot (called: the tentacle) has a pigmented spot (the eye) on its base. Note the different types of spines and the very small modified spines which known as pedicellariae, these small spines clean the body surface and the ambulacral grooves.

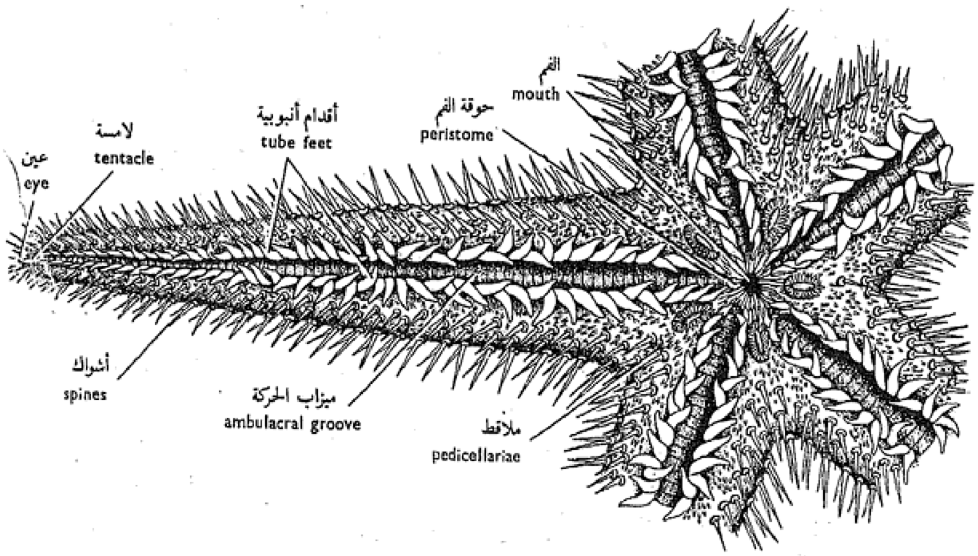


figure 40: Oral surface of *Astropecten*

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3- أحمد حماد الحسيني و أميل دميان (1969): بيولوجية الحيوان العملية (الجزء الثاني والثالث). دار المعارف- مصر.

Zoology Department

Zoology II

(Part 2: Physiology)

By/

Dr. Mariam A. Fawy

Teaching by

Dr. Mariam A. Fawy

Science faculty- Zoology department

Second Semester 2022-2023

Content

Introduction

Physiology: biological science dealing with how the body functions at the various levels of organization/study of the function of all living organisms. Physiology derived from two Greek words Physis= nature, logos= study

Physiology is the study of function

Levels of organization

The atom – e.g. hydrogen, carbon

The molecule –e.g. water, glucose

The macromolecule (large molecule) – e.g. protein, DNA

The organelle – e.g. nucleus, mitochondria

The tissues – e.g. liver – muscle

The organs – e.g. heart- kidney

The organ system – e.g. skeletal, cardiovascular

The organism – e.g. human, cat

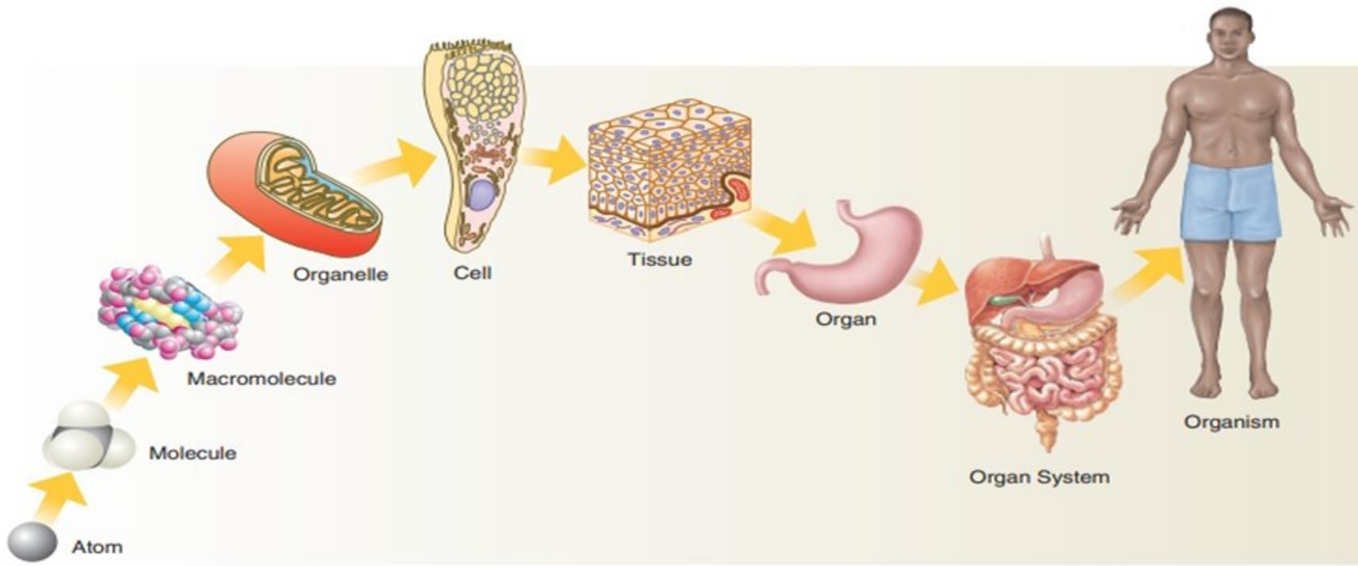


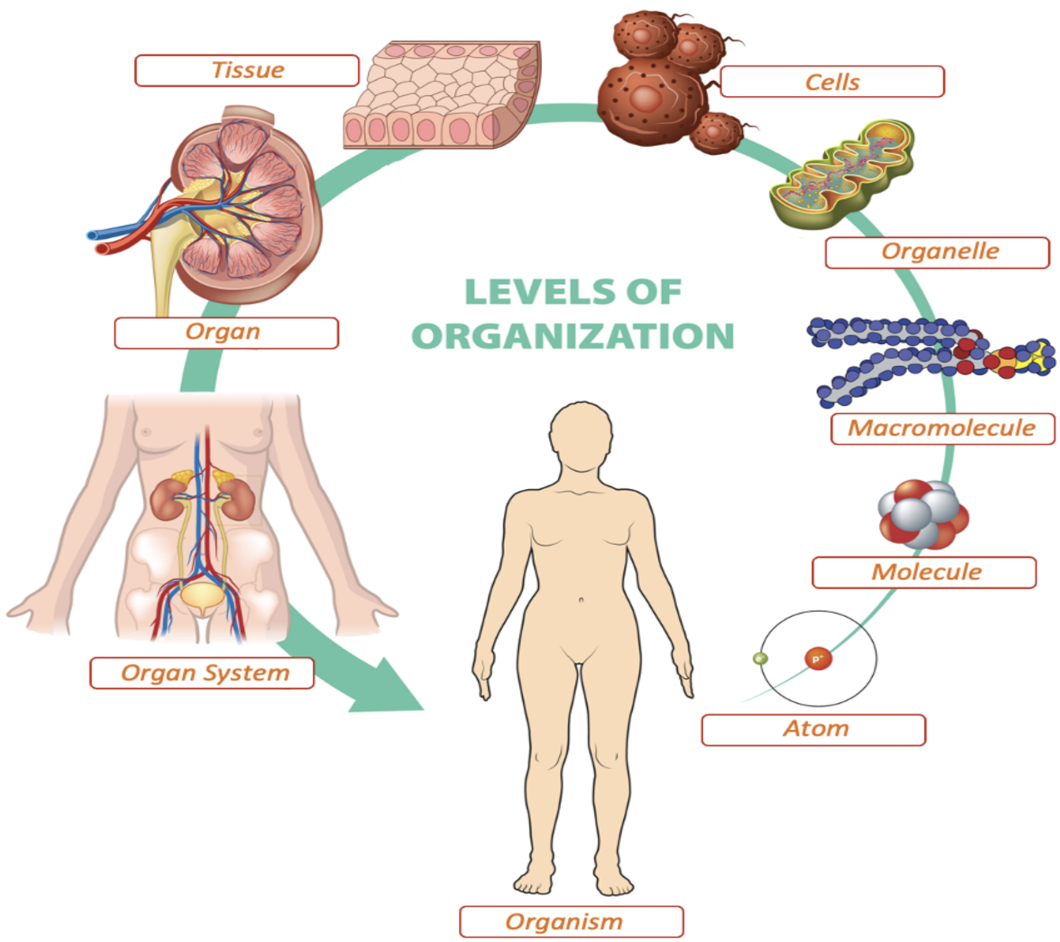
FIGURE 1-1 Organization levels of the body.

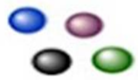
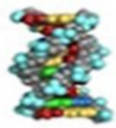
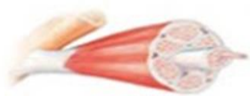
Adapted from Shier, D.N., Butler, J.L., and Lewis, R. Hole's Essentials of Human Anatomy & Physiology, Tenth edition. McGraw Hill Higher Education, 2009.

Levels of Organization (From Molecules to Organisms) - Worksheet - Answer Key

Q.1. Use the words in the box below to label the levels of the organization.

• Cells	• Organ	• Atom
• Organelle	• Macromolecule	• Organ System
• Tissue	• Molecule	• Organism



Level of Organization	Explanation	Example
 Atomic Level	Atoms are defined as the smallest unit of an element that still maintains the property of that element.	Carbon, Hydrogen, Oxygen
 Molecular Level	Atoms combine to form molecules which can have entirely different properties than the atoms they contain.	Water, DNA, Carbohydrates
 Cellular Level	Cells are the smallest unit of life. Cells are enclosed by a membrane or cell wall and in multicellular organisms often perform specific functions.	Muscle cell, Skin cell, Neuron
 Tissue Level	Tissues are groups of cells with similar functions	Muscle, Epithelial, Connective
 Organ Level	Organs are two or more types of tissues that work together to complete a specific task.	Heart, Liver, Stomach
 Organ System Level	An organ system is group of organs that carries out more generalized set of functions.	Digestive System, Circulatory System
 Organismal Level	An organism has several organ systems that function together.	Human

Characteristics of life:

Reproduction

Growth

Movement

Respiration

Responsiveness: this allows the organism to respond to changes

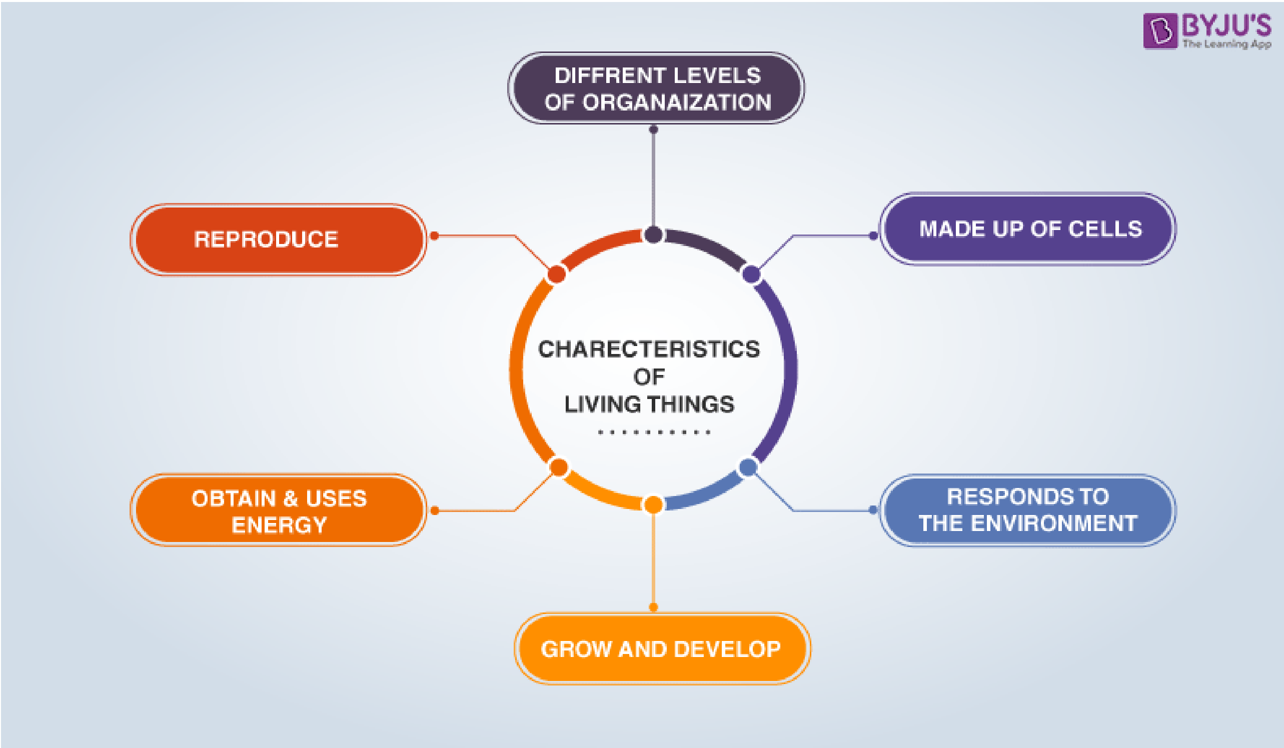
Digestion: produce the energy necessary for life

Absorption: blood and lymph, which then carry the substances to the parts of the organism requiring them

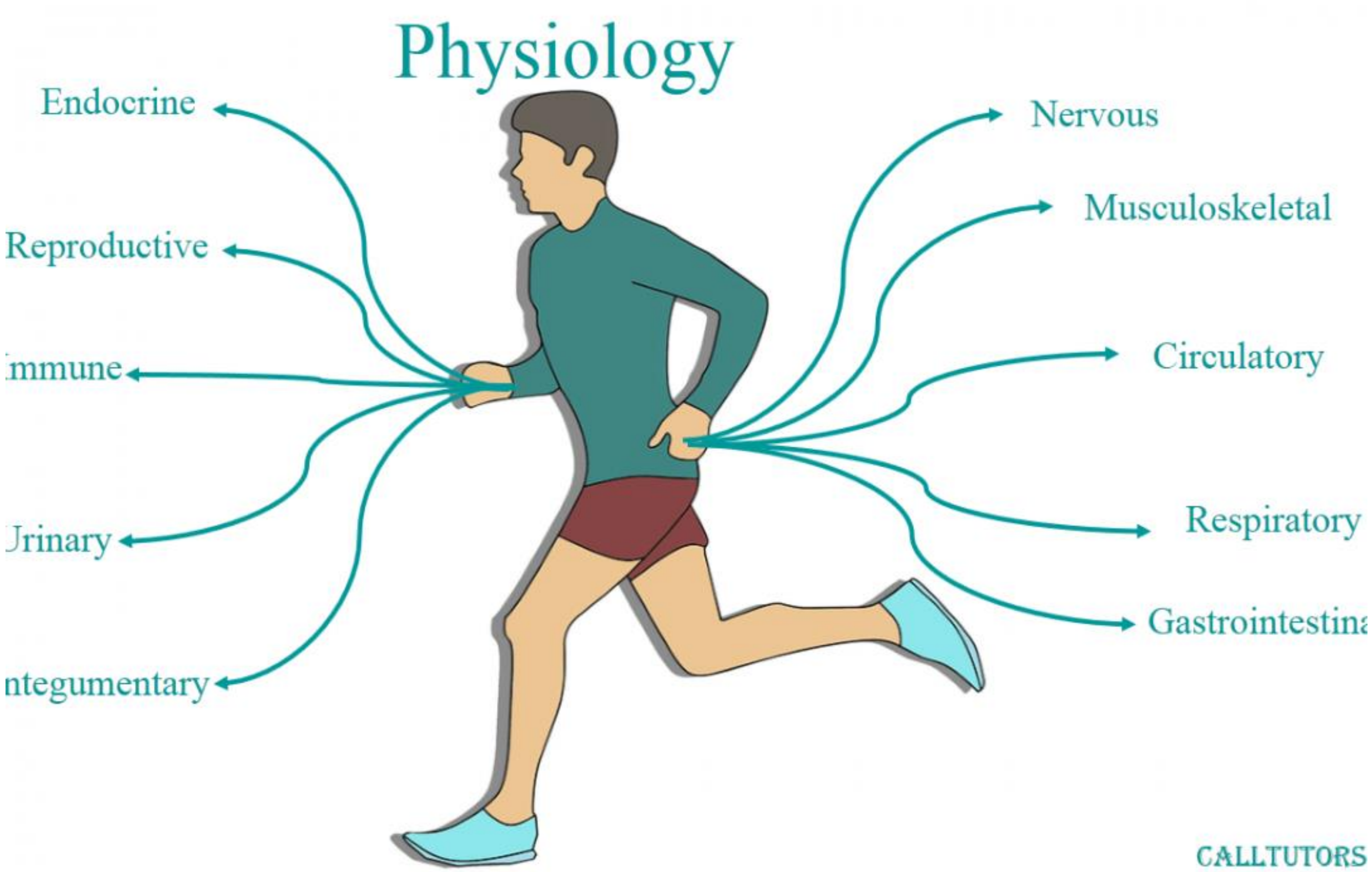
Circulation

Assimilation: the changing of absorbed substances into different substances, which can then be utilized by the tissue of the body.

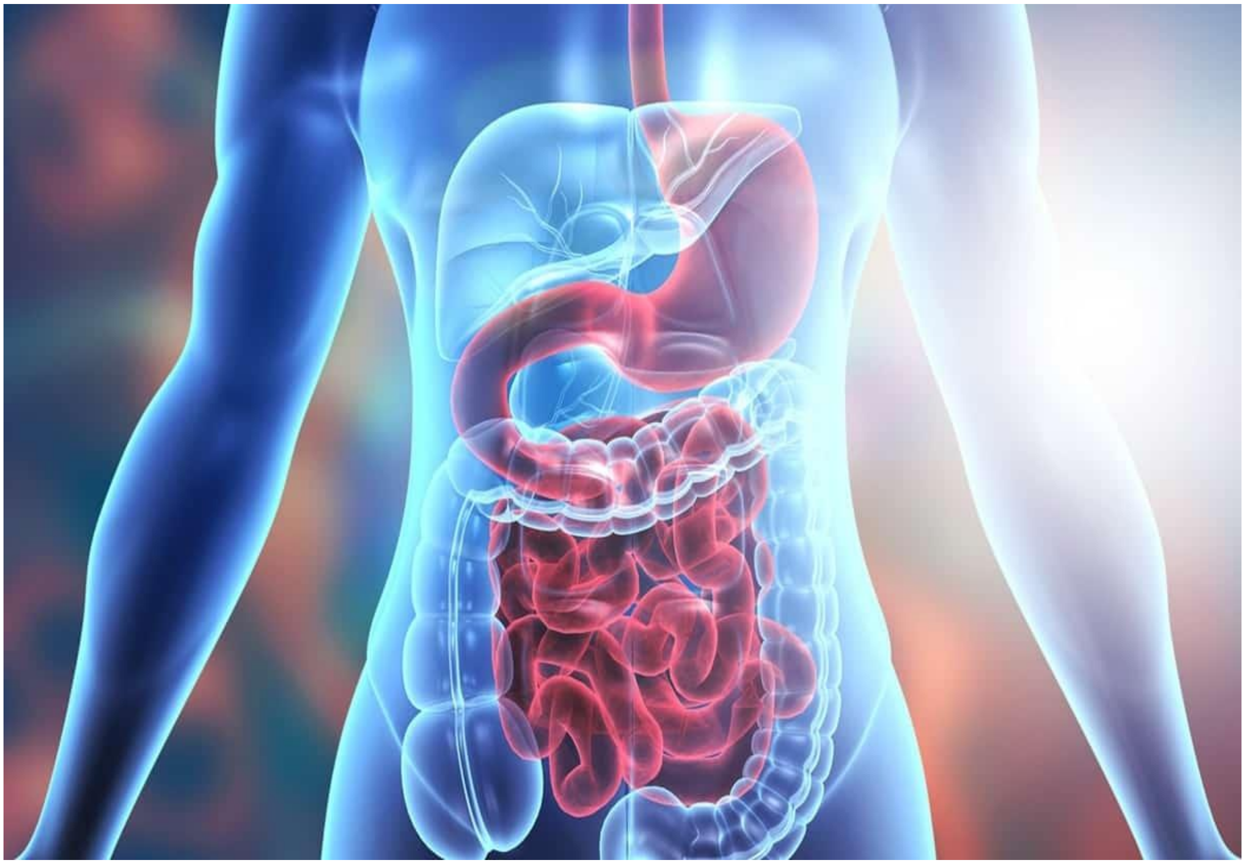
Excretion: the removal of waste substances from the body.



Physiology is the study of the function of each of these structures associated with the body. The body is often thought of as a complicated machine. For the machine to work, it must have all of its parts but each of these parts must function optimally. If organs or organ systems are not functioning properly, then the body is described as having the disease. Let's discuss a specific example. Some patients have a thinning (weakening) in the wall of an artery. This is referred to as an aneurysm. The blood in arteries is under very high pressure. This pressure becomes even greater when we are undergoing activities such as exercise. If the artery wall is weak and the pressure on the blood increases too much, the vessel may rupture (burst aneurysm) and the patient may bleed to death. The structure (vessel wall) has changed so that the artery can no longer carry out its function (containing the blood).



The Digestive System



People are probably more aware of their digestive system than of any other system, not least because of its frequent messages. Hunger, thirst, appetite, gas ☺, and the frequency and nature of bowel movements are all issues affecting daily life.

We need food for cellular utilization:

1- nutrients as building blocks for the synthesis

2- sugars, etc to break down for energy

most food that we eat cannot be directly used by the body

1- too large and complex to be absorbed

2- chemical composition must be modified to be useable by cells

Digestion is important for breaking down food into nutrients, which the body uses for energy, growth, and cell repair. Food and drink must be changed into smaller molecules of nutrients before the blood absorbs them and carries them to cells throughout the body. The body breaks down nutrients from food and drinks into carbohydrates, protein, fats, and vitamins.

The digestive system is formed of

1-Alimentary canal: the mouth, pharynx, esophagus, stomach, small intestine, and large intestine.

2-Digestive glands: the salivary gland, gastric gland, intestinal glands, liver, and pancreas.

The digestive system is made up of the gastrointestinal (GI) tract—also called the digestive tract or Alimentary canal and the liver, pancreas, and gallbladder. The GI tract is a series of hollow organs joined in a long, twisting tube from the mouth to the anus. The hollow organs that make up the GI tract are the mouth, esophagus, stomach, small intestine, large intestine—which includes the rectum—and anus. Food enters the mouth and passes to the anus through the hollow organs of the GI tract. The liver, pancreas, and gallbladder are the solid organs of the digestive system. The digestive system helps the body digest food.

→ organs of the digestive system form essentially:

a long continuous tube open at both ends

→the alimentary canal (gastrointestinal tract)

mouth→ pharynx → esophagus → stomach → small intestine → large intestine

→ attached to this tube are assorted accessory organs

and structures that aid in the digestive processes

salivary glands

teeth

liver

gall bladder

pancreas

mesenteries

→ The GI tract (digestive system) is located mainly in abdominopelvic cavity

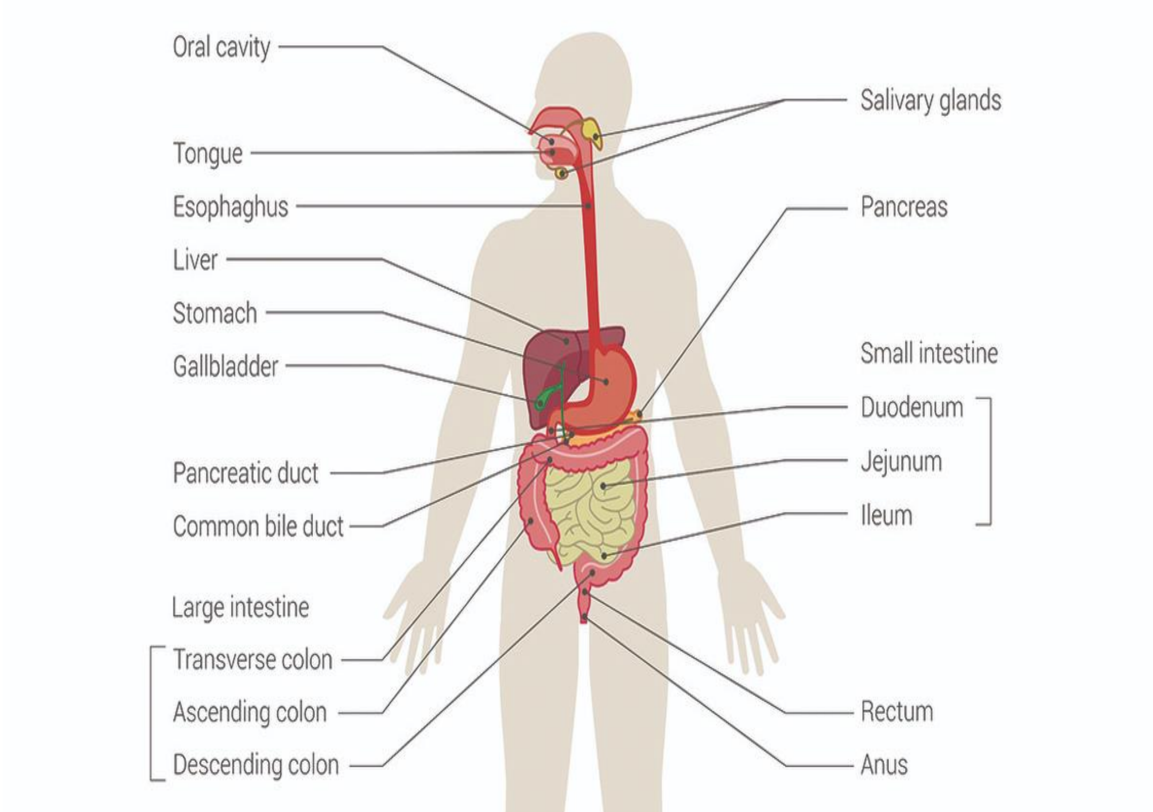
surrounded by serous membrane = visceral peritoneum

this serous membrane is continuous with the parietal peritoneum and extends

between digestive organs as mesenteries

→ hold organs in place, prevent tangling

Bacteria in the GI tract, also called gut flora or microbiome, help with digestion. Parts of the nervous and circulatory systems also play roles in the digestive process. Together, a combination of nerves, hormones, bacteria, blood, and the organs of the digestive system completes the complex task of digesting the foods and liquids a person consumes each day.



→ **Six Functions of the Digestive System:**

1. Ingestion
2. Mechanical processing
3. Digestion
4. Secretion
5. Absorption
6. Excretion

Characteristics of the GIT wall:

★ The cross-section of the wall of the GIT is formed of (5) layers:

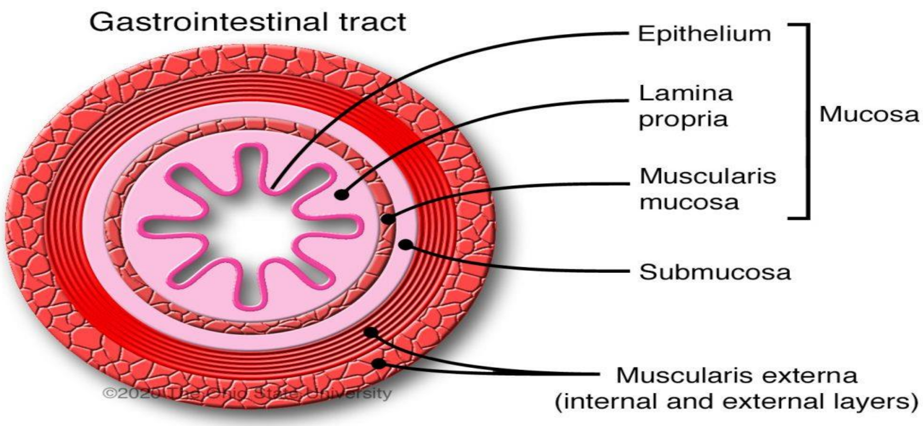
1- Mucosa: epithelial layer contains many mucus-secreting cells. The type of epithelium.

is simple columnar.

2- Submucosa: The layer of connective tissue contains blood vessels and some of the nerves that help regulate digestive activity.

3- Circular muscle layer and longitudinal muscle layer: The alternate contractions of these muscles create the wavelike movement that propels food through the digestive tract and mixes it with digestive juices. This movement is called peristalsis.

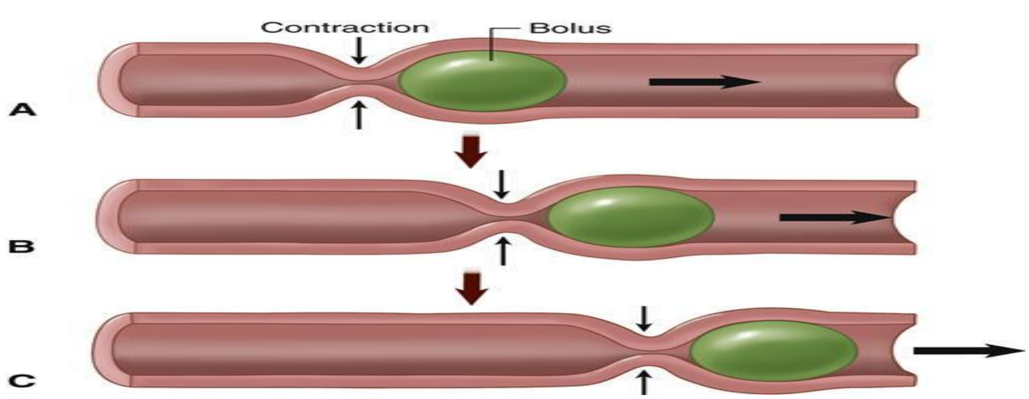
5- Serosa: fibrous connective tissue part of the peritoneum.



(1)- Propulsive movement (peristalsis):

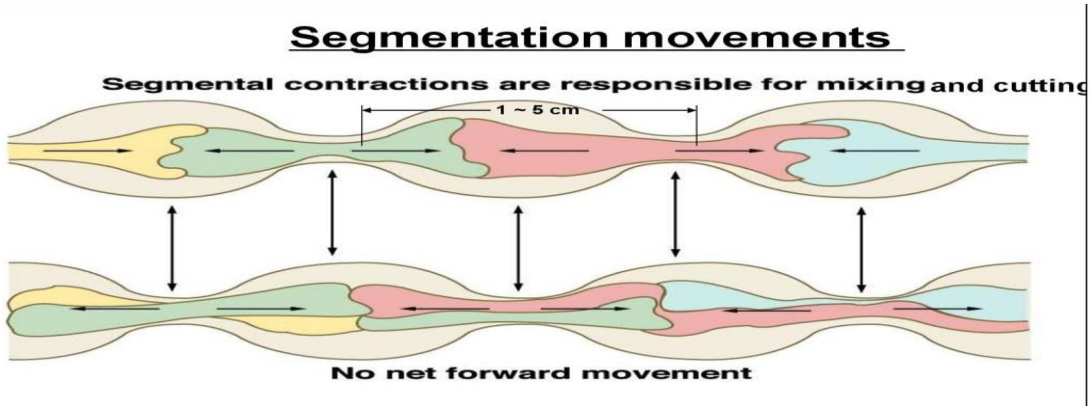
Aim: propelling the food forward along the GIT at a rate suitable for digestion and absorption.

Mechanism: A reflex initiated by a stretch of the gut wall → circular contraction behind the stimulus and relaxation in front of it → the wave of contraction moves in an oral to a caudal direction at rates (2- 25 cm/sec)



(2)- The mixing movements

The mixing movements are different in different parts of the alimentary canal sometimes, peristalsis causes most of the mixing when the forward progression of the intestinal contents is blocked by a sphincter. At other times, local constrictive contractions occur every few cms in the gut wall (only a few seconds), then new constrictions occur at other points of the gut → chopping off the contents.



Organ	Movement	Digestive Juices Used	Food Particles Broken Down
Mouth	Chewing	Saliva	Starches
Esophagus	Swallowing	None	None
Stomach	The upper muscle in the stomach relaxes to let food enter and lower muscle mixes food with digestive juice	Stomach acid	Protein
Small intestine	Peristalsis	Small intestine digestive juice	Starches, protein, and carbohydrates
Pancreas	None	Pancreatic juice	Starches, fats, and protein
Liver	None	Bile acids	Fats

★ Mastication (Chewing): Definition: It is the mechanical breakdown of large food particles into smaller ones in the mouth. Mastication helps digestion by increasing the exposed surface area to enzymes and helps to swallow.

Deglutition (swallowing): the propelling of food from the mouth to the stomach through the pharynx and esophagus.

Digestive Processes

The processes of digestion include six activities: ingestion, propulsion, mechanical or physical digestion, chemical digestion, absorption, and defecation.

The first of these processes, ingestion, refers to the entry of food into the alimentary canal through the mouth. There, the food is chewed and mixed with saliva, which contains enzymes that begin breaking down the carbohydrates in the food plus some lipid digestion via lingual lipase. Chewing increases the surface area of the food and allows an appropriately sized bolus to be produced.

Food leaves the mouth when the tongue and pharyngeal muscles propel it into the esophagus. This act of swallowing, the last voluntary act until defecation, is an example of propulsion, which refers to the movement of food through the digestive tract. It includes both the voluntary process of swallowing and the involuntary process of peristalsis. Peristalsis consists of sequential, alternating waves of contraction and relaxation of alimentary wall smooth muscles, which act to propel food along (Figure 1). These waves also play a role in mixing food with digestive juices. Peristalsis is so powerful that foods and liquids you swallow enter your stomach even if you are standing on your head.

Digestion includes both mechanical and chemical processes. Mechanical digestion is a purely physical process that does not change the chemical nature of the food. Instead, it makes the food smaller to increase both surface area and mobility. It includes mastication, or chewing, as well as tongue movements that help break food into smaller bits and mix food with saliva. Although there may be a tendency to think that mechanical digestion is limited to the first steps of the digestive process, it occurs after the food leaves the mouth, as well. The mechanical churning of food in the stomach serves to further break it apart and expose more of its surface area to digestive juices, creating an acidic "soup" called chyme. Segmentation, which occurs mainly in the small intestine, consists of localized contractions of circular muscle of the muscular layer of the alimentary canal. These contractions isolate small sections of the intestine, moving their contents back and forth while continuously subdividing, breaking up, and mixing the contents. By moving food back and forth in the intestinal lumen, segmentation mixes food with digestive juices and facilitates absorption.

chemical digestion, starting in the mouth, digestive secretions break down complex food molecules into their chemical building blocks (for example, proteins into separate amino acids). These secretions vary in composition but typically contain water, various enzymes, acids, and salts. The process is completed in the small intestine.

Food that has been broken down is of no value to the body unless it enters the bloodstream and its nutrients are put to work. This occurs through the process of absorption, which takes place primarily within the small intestine. There, most nutrients are absorbed from the lumen of the alimentary canal into the bloodstream through the epithelial cells that make up the mucosa. Lipids are absorbed into lacteals and are transported via the lymphatic vessels to the bloodstream (the subclavian veins near the heart). The details of these processes will be discussed later.

In defecation, the final step in digestion, undigested materials are removed from the body as feces.

Regulatory Mechanisms:

Neural and endocrine regulatory mechanisms work to maintain the optimal conditions in the lumen needed for digestion and absorption. These regulatory mechanisms, which stimulate digestive activity through mechanical and chemical activity, are controlled both extrinsically and intrinsically.

Hormone Regulators:

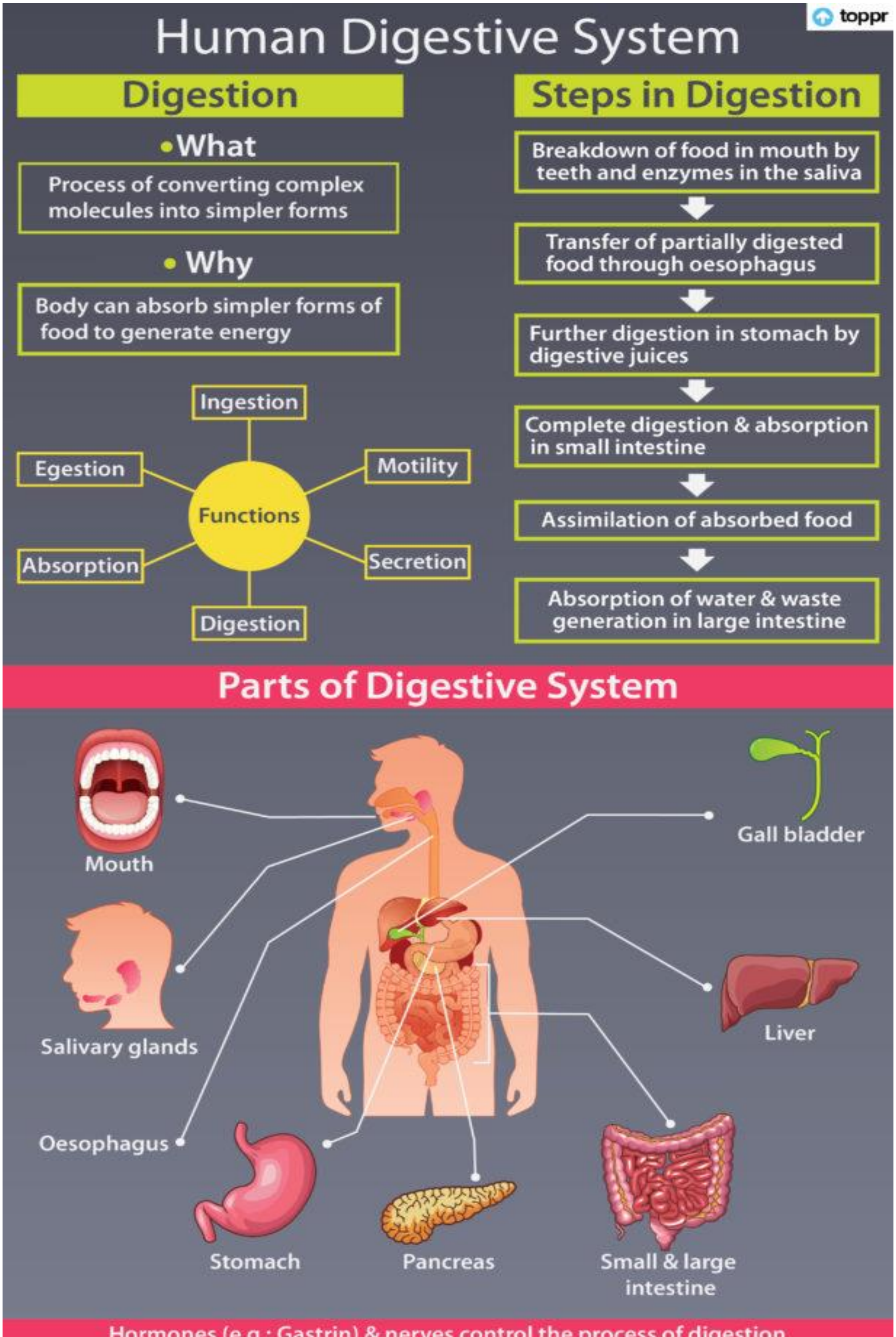
The cells in the lining of the stomach and small intestine produce and release hormones that control the functions of the digestive system. These hormones stimulate the production of digestive juices and regulate

appetite. The main digestive hormone of the stomach is gastrin, which is secreted in response to the presence of food. Gastrin stimulates the secretion of gastric acid by the parietal cells of the stomach mucosa. Other GI hormones are produced and act upon the gut and its accessory organs. Hormones produced by the duodenum include secretin, which stimulates a watery secretion of bicarbonate by the pancreas; cholecystokinin (CCK), which stimulates the secretion of pancreatic enzymes and bile from the liver and release of bile from the gallbladder; and gastric inhibitory peptide, which inhibits gastric secretion and slows gastric emptying and motility. These GI hormones are secreted by specialized epithelial cells, called endocrinocytes, located in the mucosal epithelium of the stomach and small intestine. These hormones then enter the bloodstream, through which they can reach their target organs.

Nerve Regulators

Two types of nerves help control the action of the digestive system: extrinsic and intrinsic nerves. Extrinsic, or outside, nerves connect the digestive organs to the brain and spinal cord. These nerves release chemicals that cause the muscle layer of the GI tract to either contract or relax, depending on whether food needs digesting. The intrinsic, or inside, nerves within the GI tract are triggered when food stretches the walls of the hollow organs. The nerves release many different substances that speed up or delay the movement of food and the production of digestive juices.

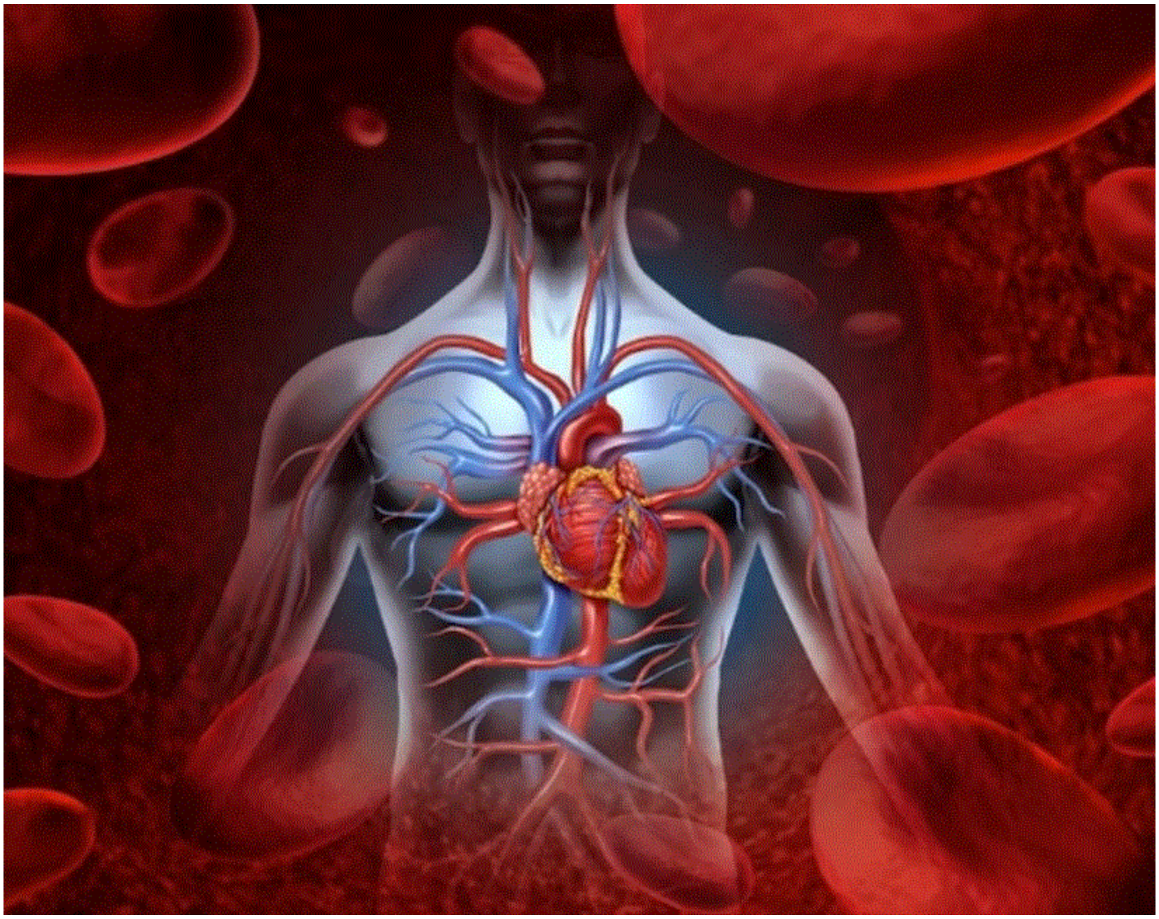
Also, the walls of the alimentary canal contain a variety of sensors that help regulate digestive functions. These include mechanoreceptors, chemoreceptors, and osmoreceptors, which are capable of detecting mechanical, chemical, and osmotic stimuli, respectively. For example, these receptors can sense when the presence of food has caused the stomach to expand, whether food particles have been sufficiently broken down, how much liquid is present, and the type of nutrients in the food (lipids, carbohydrates, and/or proteins). Stimulation of these receptors provokes an appropriate reflex that furthers the process of digestion. This may entail sending a message that activates the glands that secrete digestive juices into the lumen, or it may mean the stimulation of muscles within the alimentary canal, thereby activating peristalsis and segmentation that move food along the intestinal tract.


toppr
Human Digestive System
Digestion
•What
Process of converting complex molecules into simpler forms
• Why
Body can absorb simpler forms of food to generate energy
Functions
Ingestion
Motility
Secretion
Digestion
Absorption
Egestion
Steps in Digestion
Breakdown of food in mouth by teeth and enzymes in the saliva
Transfer of partially digested food through oesophagus
Further digestion in stomach by digestive juices
Complete digestion & absorption in small intestine
Assimilation of absorbed food
Absorption of water & waste generation in large intestine
Parts of Digestive System
Mouth
Salivary glands
Oesophagus
Stomach
Pancreas
Small & large intestine
Liver
Gall bladder
Hormones (e.g.: Gastrin) & nerves control the process of digestion

Region	Function	Enzymes structures and/or characteristic processes
Alimentary Canal		
Mouth	Mechanical maceration	Teeth
	Wetting action, beginning of carbohydrate digestion	Saliva containing enzymes (salivary amylase)
	Appetite stimulation	Taste buds
Pharynx and esophagus	Swallow	Esophageal peristalsis
	Transport of food to the stomach	
Stomach	Eliminate exogenous bacteria	Hydrochloric acid secreted by gastric glands and also pepsin
	Protein digestion	Muscle contractions
	Conversion of chewed food into semiliquid form	Stimulation and secretion of gastric juice
	Production of gastrointestinal hormone	
Small intestine	Completion of protein and carbohydrate digestion	Several enzymes released by the intestinal wall and pancreas
	Beginning and completion of lipid digestion	Pancreatic enzymes and hepatic bile
	Nutrient absorbed into the blood stream	Intestinal villi
	Production of secretin	Stimulation of bile secretion and pancreatic juice
Large intestine	Absorption of water and minerals	Microvilli on surface of cells lining the intestinal wall
Glands and accessory organs		
Pancreas	Two types of cells:	Pancreatic amylase, lipase
	Acinar cells produce many enzymes	Insulin, glucagon,
	Islet cells produce hormones	
	somatostatin that regulate blood sugar levels	
Liver	Storage and release of carbohydrates; conversion of amino acids into carbohydrates	All processes happen in all cells
	Fat packaging for transport	
	Regulation of cholesterol levels	
	HDL and LDL synthesis	
	Bile secretion	
	Fat-soluble vitamins storage	
	Synthesis of proteins present in blood plasma	
	Inactivation of hormones	
	Inactivation of foreign substances, e.g., alcohol, drugs	

Source: Adapted from Arking (2008).

Circulatory system



The cardiovascular system is composed of the heart and a closed system of blood vessels.

The heart:

- Consists of 4 chambers (the Rt. atrium and ventricle- the Lt. atrium and ventricle).
- Has 3 layers; endocardium, myocardium and epicardium (fibrous cover).

★ Is surrounded by a pericardial sac that contains 5 - 30 ml of clear fluid that lubricates the heart and allows it to contract with minimal friction.

The 2 main pumps are:

(1) The left ventricle: (pressure pump)

Pumps blood at a high resistance into the greater (systemic) circulation.

(2) The right ventricle: (volume pump)

Pumps the same volume of blood (at a lower resistance) to the pulmonary circulation.

The valves: (allow the passage of blood one direction only & not the reverse)

(1) Atrioventricular (A- V) valves: (2 valves)

Mitral valve (2 cusps): prevents backflow of blood from the left ventricle to the left atrium

Tricuspid valve (3 cusps): prevents backflow of blood from the right ventricle to the right atrium.

(2) Semilunar valves: (2 valves)

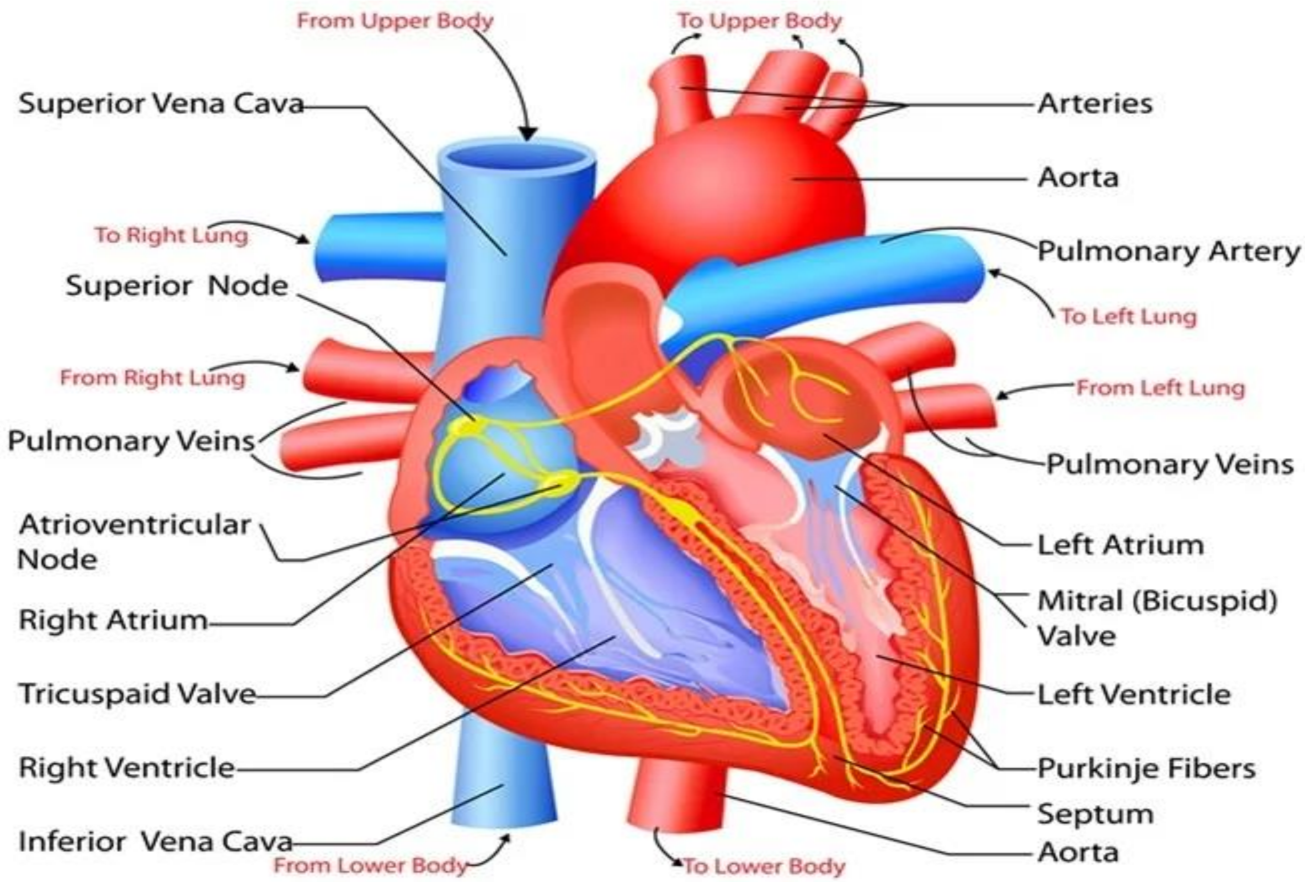
Aortic valve: prevents backflow of blood from the aorta to the left ventricle.

Pulmonary valve: prevents backflow of blood from the pulmonary artery to the right ventricle.

The papillary muscles:

These are ventricular muscles flaps attached to the cusps of the A- V valves by the cordae tendineae.

They contract with ventricular walls & pull the cusps of the valves toward the ventricles.



The heart is composed of:

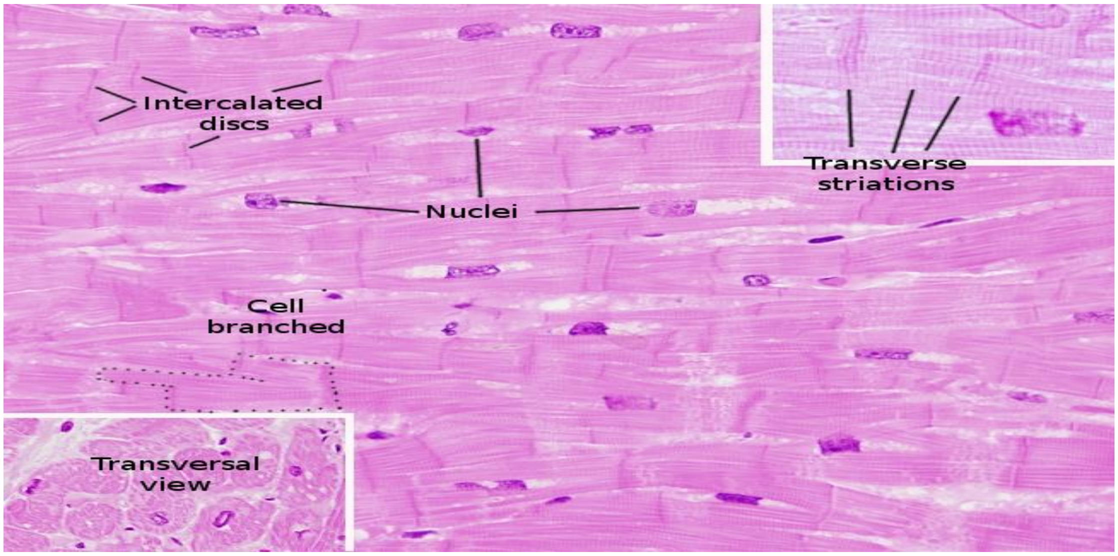
1- Cells full of contractile muscle proteins (e.g. ventricular muscle)

2- Cells with few contractile elements: (e.g. sinoatrial nodal "SAN")

The cardiac muscle fibers:

• Similar to skeletal muscle in striated structure

• Similar to smooth muscle in being involuntary & act as a syncytium



Types of cardiac muscle proteins:

As skeletal muscle (myosin, actin, troponin & tropomyosin) in addition to titin & dystrophin

Titin : A very large elongated protein Binds myosin to the Z line & keeps myosin filaments centered in the sarcomere Congenital anomalies in titin → abnormal dilated heart.

Dystrophin : A large protein, that connects actin to extracellular matrix → structural support to the muscle fiber and congenital defects in dystrophin → muscle weakness.

Properties of heart muscle :

1-Excitability

2-Contractility

3-Rhythmicity (automaticity)

4-Conductivity

Excitability: the ability to respond to an adequate stimulus by generating a propagating AP.

Rhythmicity (automaticity): is the ability of the heart to beat regularly & initiate its own regular repetitive beats independent on nerve supply.

★Due to the presence of automatic cells in the heart: SAN Sinoatrial node initiates cardiac impulses (pacemaker).

Conductivity the conduction of the cardiac impulse through the cardiac tissue.

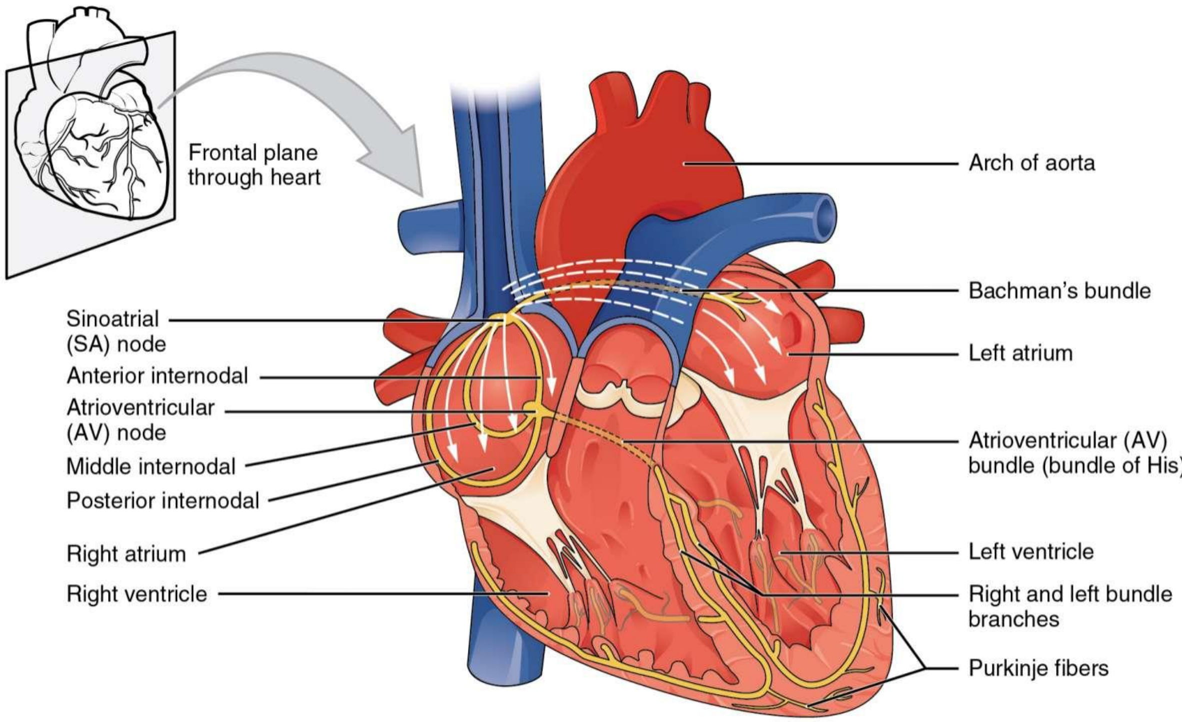
Cardiac cycle

Definition: (the changes from the beginning of one heart beat to the beginning of the next beat). It consists of diastole followed by systole.

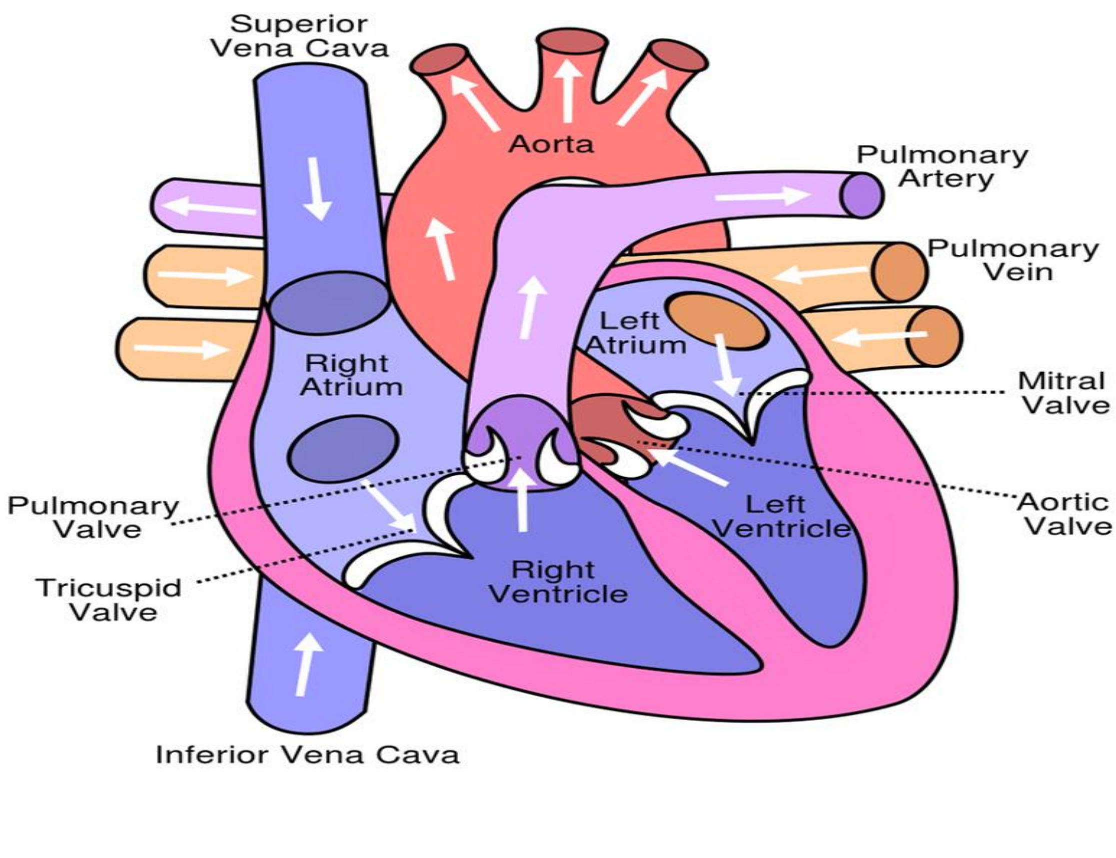
Pacemaker and Conducting System :

The heart beat is initiated by the pacemaker (SA Node) lying between the superior vena cava and the right atrium. The rhythmic depolarizations generated by the SA node are conducted through the atria to less rapidly firing AV node lying in the right atrium, close to the interventricular septum. After a short delay in the AV node, the cardiac impulses are conducted through the main conducting system of the heart, for the rapid conduction of electrical impulses. This is interventricular area conduction cells that radiate into the muscle wall of the ventricles.

Myocardium: The atrial myocardium is comprised of two thin muscular sheaths at right angles to each other, permitting the atria to act as receiving and pumping chambers. The ventricular myocardium is divided into spiral muscles and deep constrictor muscles, that looks like a sandglass; the result of complex twisting contraction is the direction of main stream of blood towards the openings of great vessels. The myocardium has specialized areas of sarcolemma called 'intercalated disk', that are cell-to cell junctions close enough to form a gap junction; these gap junctions offer very low electrical resistance, causing the myocardium to respond as 'functional syncytium' and not anatomical. There is no impediment to the passage of an action potential; therefore the excitation spreads to all fibers of a chamber.



Anterior view of frontal section



Circulation

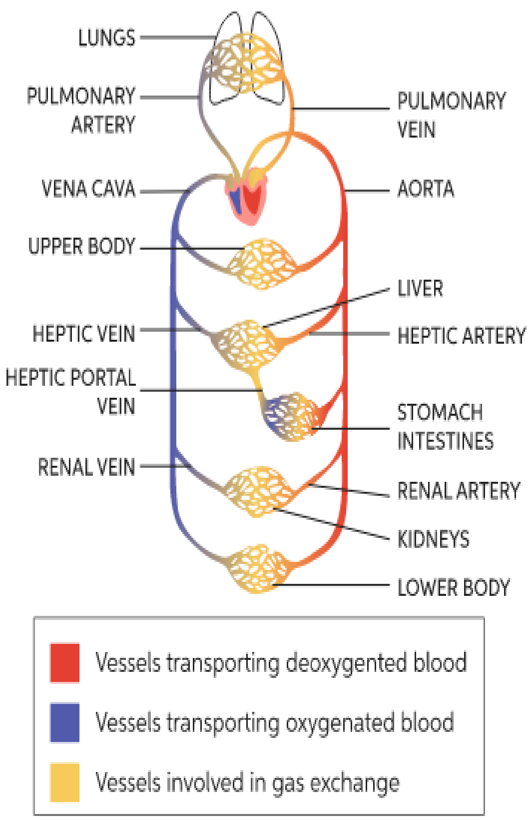
1-Systemic (general) circulation:

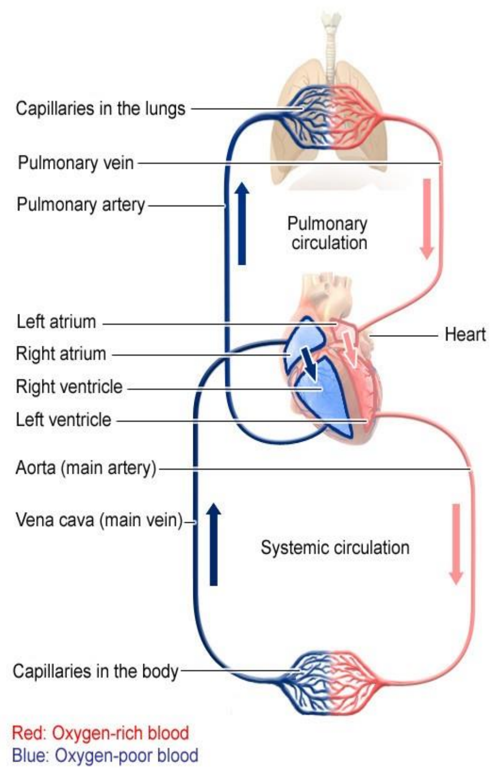
Carries oxygenated blood to all parts of the body

From Lt. ventricle → aorta → arteries → arterioles → capillaries(for exchange with ISF) → venules → veins → SVC & IVC → Rt. atrium.

2- Pulmonary circulation:

Carries deoxygenated blood to the lungs From Rt. ventricle → pulmonary artery → arterioles → pulmonary capillaries (gas exchange with alveoli) → 4 pulmonary veins → Lt. atrium.





Functional parts of the circulation:

	Wall properties	functions
Aorta and large arteries	Elastic (rich in elastic fibers) & contain smooth muscles	1-Transport blood under high pr. to tissues 2- Distend during systole & recoil during diastole 3- Maintain blood flow&prevent marked drop of pr.
Small arteries & arterioles	Strong muscular wall	1- Act as control vessels to bl. flow into capillaries 2- Responsible for the peripheral resistance
Capillaries	Flat endothelium with precapillary sphincter	Exchange fluids, nutrients & electrolytes between blood & ISF
Venules and veins	Thin venous wall	Major reservoir of blood (collect blood from capillaries to larger veins then to the heart)
Lymphatic system	Flat endothelium with pores	Accessory route for the fluid flow from the ISF spaces to blood.

Blood

Blood is the vital fluid tissue, that circulates with CVS. Total blood volume= 5600 ml (8% of body Wt.).

Functions of blood:

1-Transport function: for O^-_2 , CO_2, glucose, hormones and waste products

2-Defensive function: by WBCs & antibodies against pathogenic microorganisms

3-Hemostatic function: stoppage of bleeding after injury by clotting mechanism

4-Homeostatic function: keeping the composition of internal environment constant

Composition of blood:

Plasma: 55% total blood volume. Plasma is a yellow clear fluid

that clots on standing leaving the serum (plasma without clotting factors).

Cells: 45% total blood volume. RBCs (erythrocytes), WBCs (leucocytes), and Platelets (thrombocytes).

Composition of plasma:

1-Water:90% total plasma volume.

2-Inorganic substances: 0.9% total plasma volume. e.g. cation and anion

3-Organic substances: 9.1% total plasma volume. e.g plasma proteins and plasma lipid

4-Gases: O^-_2 , CO_2

Plasma proteins (conc. 1.2-7.4 gm /1dl)

1- Albumin

2- Globulins (α_1, α_2, β_1, β_2. y)

3- Fibrinogen

4- Prothrombin

Erythrocytes (RBCs):

Count: males: 5.5 million/mm^3 females. 4.8 million/mm^3. RBCs count is higher in newly born infants, athletes, people living at high altitudes,

less in growing children & old age.

Shape: circular, biconcave, nonnucleated discs

1-lt provides a large surface area for gas exchange

2-lt enhances cell flexibility (squeezing of RBCs in small capillaries)

3-lt results in minimal ↑ in tension on the membrane (if RBCs volume↑)

Life span120 days

Fate: old RBCs are destroyed in the tissue macrophage system (R.E.S) mainly in the spleen.

Structure:

(1) Erythrocyte membrane: semipermeable, plastic

(2) Cytoplasm:

• Hb: is the main content (34% of RBCs wt.)

• K+: is the main cation.

• Carbonic anhydrase: for C02 transport as $HC0_3^-$

• NO nucleus, NO ribosomes, NO mitochondria

It is function : RBCs are responsible for transporting oxygen from your lungs to your body's tissues.

Platelets

300,000 / mm^3 blood (normal range: 250,000 - 400,000 / mm^3 blood)

Life span: 4 days

Origin: in B.M. from megakaryocytes (giant cells derived from the myeloid stem cell line).

Function: hemostasis, thrombosis, and wound healing

White blood cells (leucocytes)

White blood cells (WBCs) are the mobile units of the body defensive system, acting in 2 ways:

(1) Phagocytosis (2) Formation of antibodies & sensitized lymphocytes
Count: 4000-11000 /mm 3.

Formation: in bone marrow

Types:

(1) Granulocytes
a- Neutrophils: (60 -70%) of WBCs
(their granules stain with acidic & basic dyes)
b- Eosinophils: (2- 6%) of WBCs
(their granules stain with acidic dyes)
c- Basophils: (0 -1%) ofWBCs
(their granules stain with basic dyes)

(2) Agranulocytes

a-Lymphocytes: (20- 30%) of WBCs

b- Monocytes: (2- 8%) of WBCs

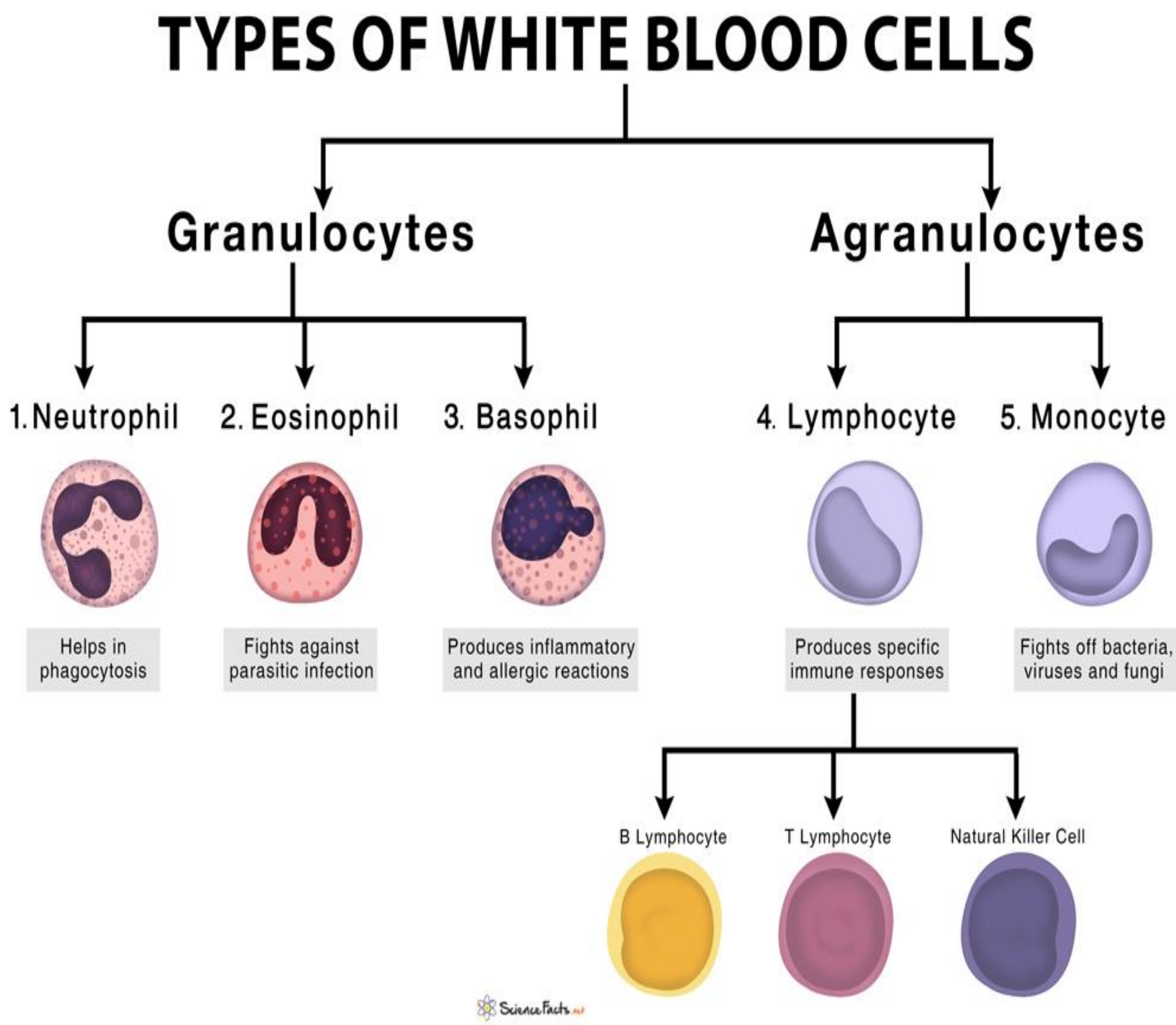
Function of leucocytes:

(1) Neutrophils
They are the first defensive line against invading organisms
→ingest & kill bacteria (phagocytosis)
(2) Eosinophils
a. Attack & kill parasites (by releasing certain substances)
b. Produce chemical mediators & prevent the toxic effects in allergic conditions.
c. They are weak phagocytes & show chemotaxis.
(3) Basophils
a. Contain histamine, heparin & leukotrienes.
b. Responsible for immediate type hypersensitivity reactions (as urticaria)
c. Have receptors that bind lgE-coated antigens~ degranulation of basophils.
(4) Lymphocytes
Formed in bone marrow, lymph node, thymus and spleen
The key cells of specific immunity (it is play important role in defending of the body)

(5) Monocytes

(a) Monocytes pass to areas of inflammation soon after neutrophils phagocytose & digest bacteria, dead neutrophils & remnants of tissue destruction

b. They are the precursors of tissue macrophages & together form the monocyte-macrophage system (have high defense & phagocytic function)



Respiratory system

The major functions of the respiratory system can be divided in two categories: respiratory and non-respiratory. The first function is to carry out the gas exchange. Metabolizing tissues utilize oxygen and produce carbondioxide. The respiratory system must obtain oxygen from the environment and must eliminate carbondioxide produced by cellular metabolism.

These processes must be coordinated so that the demand for oxygen is met and so that the carbondioxide that is produced is eliminated. The respiratory system is well-designed carryout gas exchange in an expeditious manner. The respiratory system is also involved in non-respiratory functions. It participates in maintaining acid-base balance since the increase in Co_2 in the body lead to increased H^+ the lungs also metabolize naturally occurring compounds such as angiotensin I, prostaglandins and epinephrine. The lungs are also responsible for protecting the body

from inhaled particles.

The function of the respiratory system:

The function of the respiratory system is the exchange of O2 and CO2 between the external environment and cells of the body.

Functional anatomy of the respiratory system

Functionally, the respiratory air passages are divided into two zones: a conductive zone and a respiratory zone. The airway tree consists of a series of highly branched hollow tubes that decrease in diameter and become more numerous at each branching. Trachea, the main airway in turn branches into two bronchi, one of which enters each lung. Within each lung, these bronchi branch many times into progressively smaller bronchi, which in turn branch into terminal bronchioles analogous to twigs of a tree. The terminal bronchioles redivide to form respiratory bronchioles, which end as alveoli,

analogous to leaves on a tree.

Conducting zone:

The conducting zone includes all of the anatomical structures through which air passes before reaching the respiratory zone. The conducting zone includes all of the anatomical structures through which air passes before reaching the respiratory zone. The conducting zone carries gas to and from the alveoli, i.e., it exchanges air between the alveoli and the atmosphere. The conducting zone of the respiratory system, in summary

consists of the following parts:

Mouth→ nose→ pharynx→ larynx→ trachea→ primary bronchi→ all successive branches of bronchioles including terminal bronchioles.

Functions

1- Warming and humidification of the inspired air:

Regardless of the temperature and humidity of the atmosphere, when the inspired air reaches the respiratory zone it is at a body temperature of 37o C (body temperature) and it is saturated with water vapor. This ensures that a constant internal body temperature will be maintained and that delicate lung tissue will be protected from desiccation.

2. Filtration and cleaning: Mucous secreted by the cells of the conducting zone serves to trap small particles in the inspired air and thereby performs a filtration function. This mucus is moved along at a rate of 1-2cm/min by cilia projecting from the tops of the epithelial cells that line the Conducting zone. There are about 300 cilia per cell that bend in a coordinated fashion to move the mucus toward the pharynx, where it can either be swallowed or expectorated. As a result of this filtration function, particles larger than about 6µm do not enter the respiratory zone of the lungs. The importance of this disease is evidenced by the disease called black lung, which occurs in miners who inhale too much carbon dust and therefore develop pulmonary fibrosis. The cleansing action of cilia and macrophages in the lungs is diminished by cigarette smoke.

3. Distribute air to the gas exchange surface of the lung.

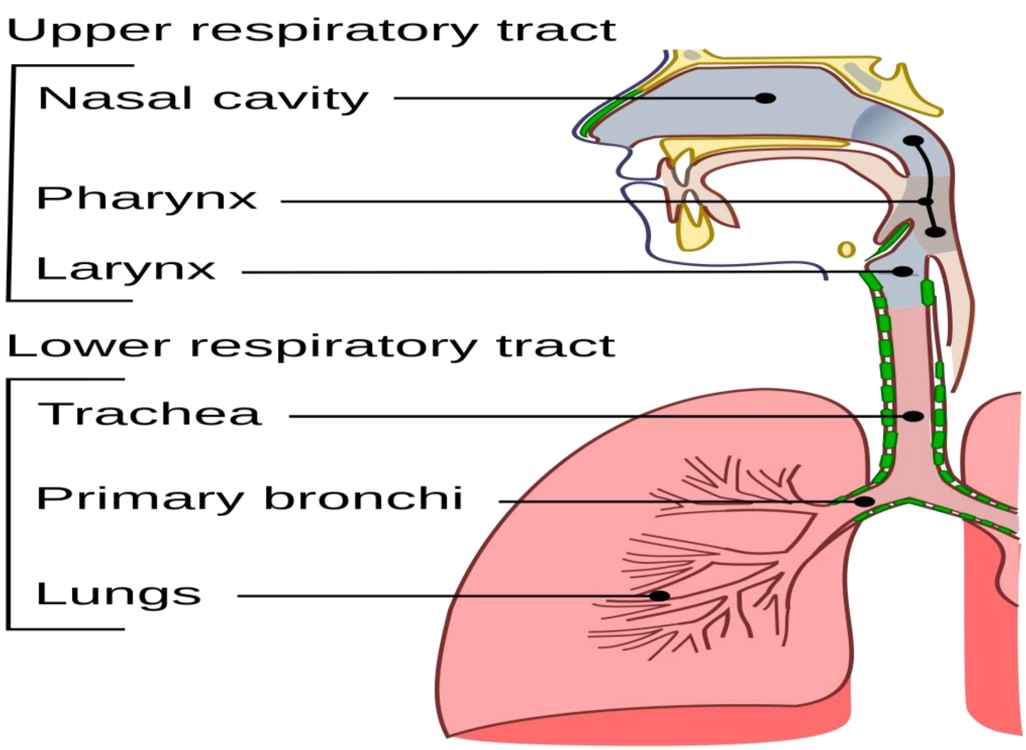
Respiratory zone the respiratory zone includes the respiratory bronchioles (because they contain separate out pouching of alveoli) and the alveoli. Alveoli are tiny air sacs, having a diameter of 0.25-0.50mm. There are about

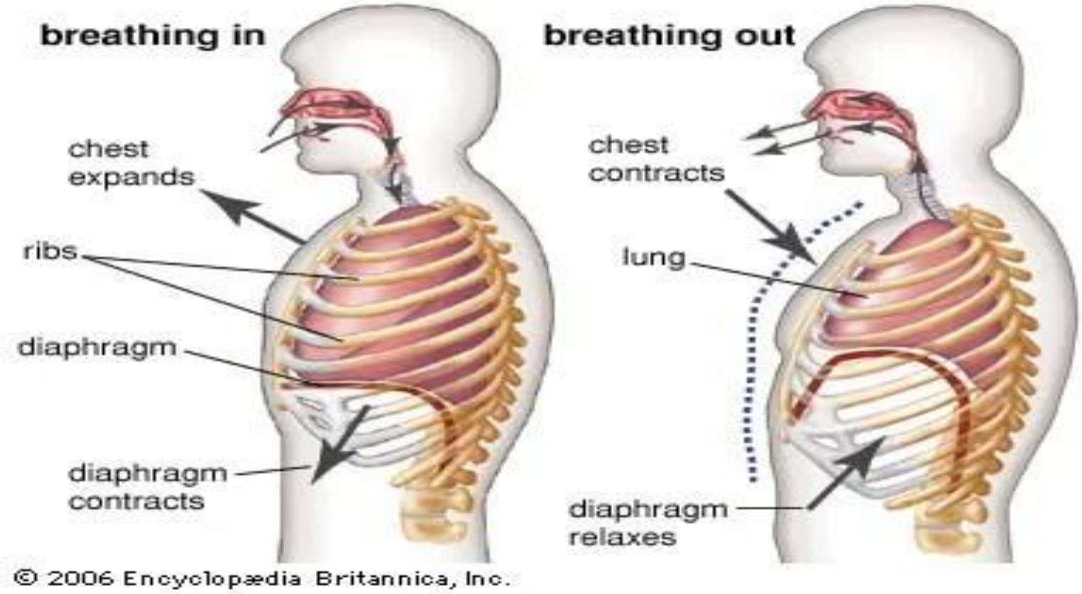
300-500 million alveoli in a lung. The numerous numbers of these structures provide a large surface area (60-80m^2 or 760ft^2) for the diffusion of gases.

Mechanics of breathing:

<u>Muscles used for breathing</u>:

Muscles of inspiration: The diaphragm is the most important inspiratory muscle. When the diaphragm contracts, abdominal contents are pushed downward and the ribs are lifted upward and outward. These changes increase intrathoracic volume and lower intrathoracic pressure. This initiates fthe low of air into the lungs. During exercise, when breathing frequency and TV increase, external intercostals muscles and accessory muscles are used for more vigorous inspiration. Muscles of expiration: Expiration is normally passive. During exercise or in diseases, in which airway resistance is increased (e.g. asthma) expiratory muscles are used such as abdominal muscles which compress abdominal cavity and push diaphragm up. Internal intercostals muscles pull ribs downward and inward.





Mechanics of breathing

The urinogenital system

⋆ Combination of the excretory and reproductive system

Kidney: is the main excretory organ of vertebrates. Concerned with the elimination of metabolic waste products.

Ovary: is the female reproductive organ or gonads.

Testis: is the male reproductive organ. These are concerned with the production of reproductive cells (egg and sperm).

Ducts: are passageways for the excretory waste products and reproductive outside.

Excretory System:

The paired kidneys which are metanephric are flat, elongated and lobulated. The ureters lead directly backward to open into the urodaeum or middle compartment of the cloaca; there is no urinary bladder. The nitrogenenous waste is excreted in the form of uric acid and discharged as a semi-solid mass. Adrenal bodies lie attached to the ventral surface of the kidneys as small yellowish elongated streaks.

Reproductive system:

The female reproductive organs: a pair of ovoid testes are attached to anterior end of the kidneys by peritoneum . From each testis leads the vas deferens which runs backwards along the outer side of the ureter of that side, and opens on a small papilla into the urodaeum. The vas deferens is dilated into a seminal vesicle at its hind end. There is no copulatory organ.

The female reproductive organs consist of a single ovary on the left side which is an adaptation to aerial life and an oviduct which opens into the body-cavity by a funnel-like aperture at the anterior end and posteriorly opens into the urodaeum.

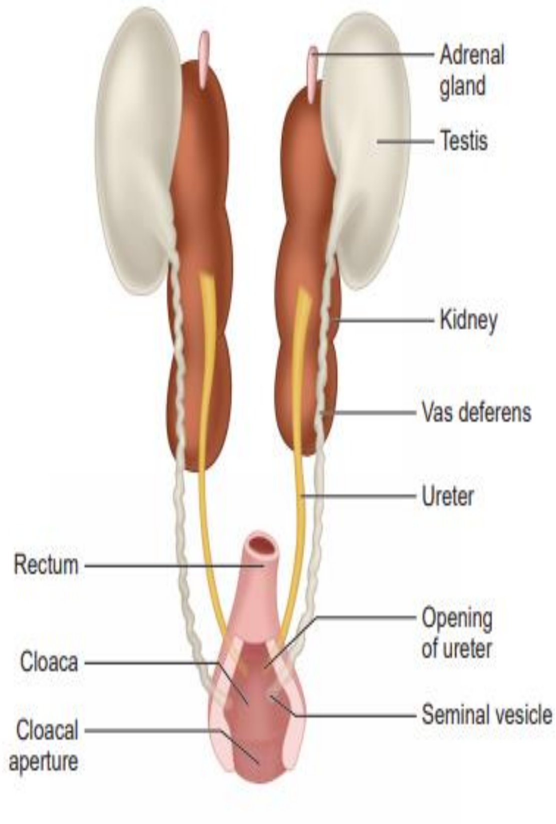


Figure 4.36 Pigeon –Male Urinogenital System

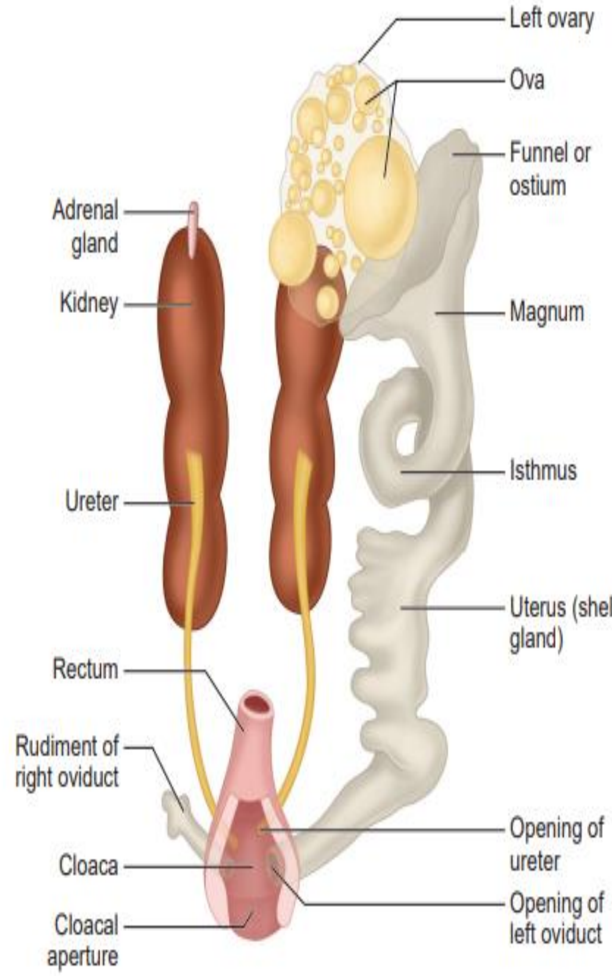


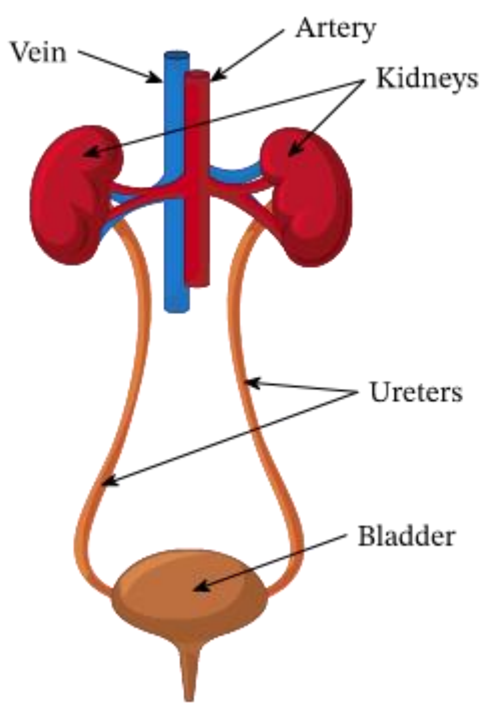
Figure 4.37 Pigeon –Female Urinogenital System

The urinary system

It is customary to link the organs of urinary excretion and reproduction as a urinogenital system. The suitability of this concept is questionable.

The urinary and reproductive organs differ in their embryological origin and development. In postnatal human beings, the association between the components of the urinary and the reproductive systems is very much limited. Hence the urinary and reproductive systems are considered separately.

The urinary organs comprise, two kidneys (renes), ureters, the urinary bladder (vesica urinaria) and the urethra.



human urinary system

The urinary system

The urinary system is one of the excretory systems of the body. It consists of the following structures:

• 2 kidneys, which secrete urine

• 2 ureters, which convey the urine from the kidneys to the urinary bladder

• urinary bladder where urine collects and is temporarily stored

• 1urethra through which the urine is discharged from the urinary bladder to the exterior.

The urinary system plays a vital part in maintaining homeostasis of water and electrolyte concentrations within the body. The kidneys produce urine that contains metabolic waste products, including the nitrogenous compounds urea and uric acid, excess ions and some drugs.

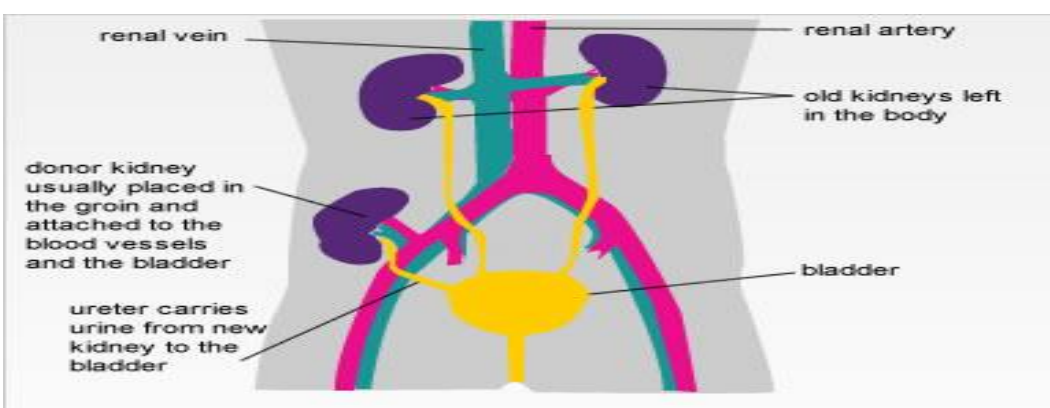
The main functions of the kidneys are:

• formation and secretion of urine

• production and secretion of erythropoietin, the hormone responsible for controlling the rate of formation of red blood cells.

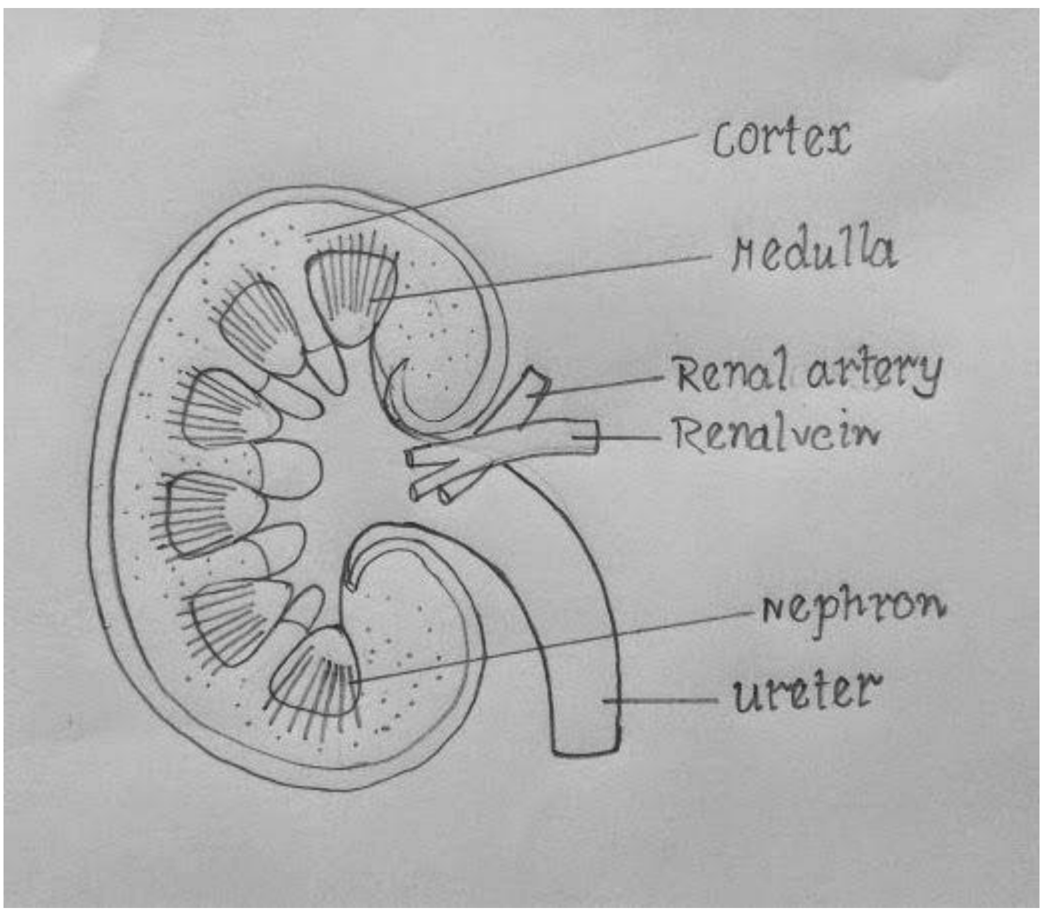
• production and secretion of renin, an important enzyme in the control of blood pressure.

Urine is stored in the bladder and excreted by the process of micturition.



The kidneys:

The kidneys lie on the posterior abdominal wall, one on each side of the vertebral column, behind the peritoneum and below the diaphragm. They extend from the level of the 12th thoracic vertebra to the 3rd lumbar vertebra, receiving some protection from the lower rib cage. The right kidney is usually slightly lower than the left, probably because of the considerable space occupied by the liver. Kidneys are bean-shaped organs, about 11cm long, 6 cm wide, 3 cm thick and weigh 150g. They are embedded in and held in position by, a mass of fat. A sheath of fibroelastic renal fascia encloses the kidney and the renal fat.



kidney

Right kidney

Superiorly —the right adrenal gland

Anteriorly —the right lobe of the liver, the duodenum and the hepatic flexure of the colon

Posteriorly —the diaphragm, and muscles of the posterior abdominal wall

Left kidney

Superiorly —the left adrenal gland

Anteriorly —the spleen, stomach, pancreas, jejunum and splenic flexure of the colon

Posteriorly —the diaphragm and muscles of the posterior abdominal wall

The microscopic structure of the kidney

The kidney is composed of about 1 million functional units, the nephrons, and a smaller number of collecting tubules. The collecting tubules transport urine through the pyramids to the renal pelvis giving them their striped appearance. The tubules are supported by a small amount of connective tissue, containing blood vessels, nerves and lymph vessels.

Functions of the kidney

Formation of urine : the kidneys form urine which passes through the ureters to the bladder for storage prior to excretion. The composition of urine reflects the activities of the nephrons in the maintenance of homeostasis. Waste products of protein metabolism are excreted, electrolyte balance is maintained and the pH (acid-base balance) is maintained by the excretion of hydrogen ions. There are three processes involved in the formation of urine:

- simple filtration
- selective reabsorption
- secretion

Simple filtration

Filtration takes place through the semipermeable walls of the glomerulus and glomerular capsule. Water and a large number of small molecules pass through, although some are reabsorbed later. Blood cells, plasma proteins and other large molecules are unable to filter through and remain in the capillaries. The filtrate in the glomerulus is very similar in composition to the plasma with the important exception of plasma proteins. Filtration is assisted by the difference between the blood pressure in the glomerulus and the pressure of the filtrate in the glomerular capsule. Because the diameter of the efferent arteriole is less than that of the afferent arteriole, a capillary hydrostatic pressure of about 7.3 kPa (55mmHg) builds up in the glomerulus. This pressure is opposed by the osmotic pressure of the blood, about 4 kPa (30 mmHg), and by filtrate hydrostatic pressure of about 2 kPa (15mmHg) in the glomerular capsule. The net filtration pressure is, therefore:

$7.3 - (4 + 2) = 1.3$ kPa, or

$55 - (30 + 15) = 10$ mmHg.

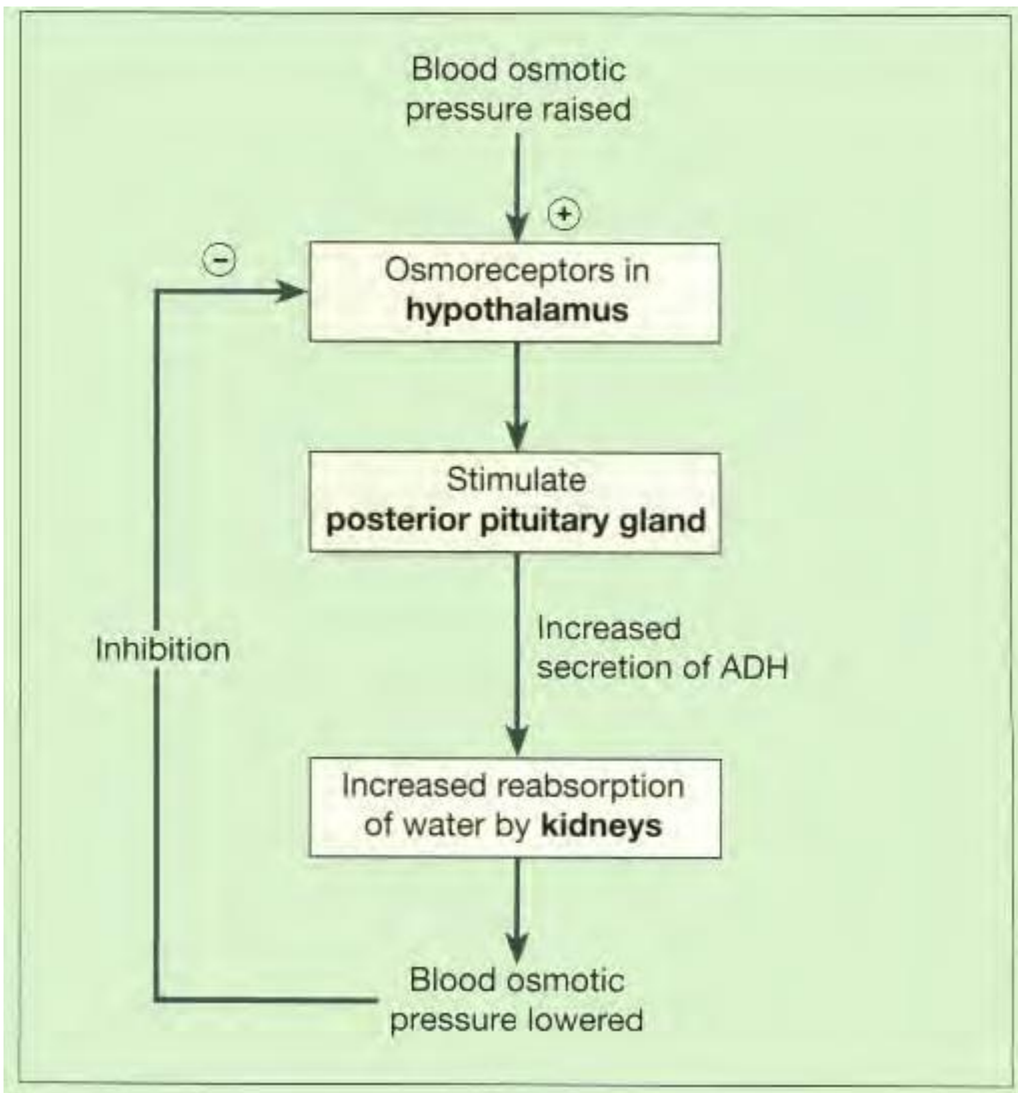
The volume of filtrate formed by both kidneys each minute is called the glomerular filtration rate (GFR). In a healthy adult, the GFR is about 125ml/min; i.e. 180litres of dilute filtrate is formed each day by the two kidneys. Most of the filtrate is reabsorbed with less than 1%, i.e. 1 to 1.5 liters, excreted as urine. The difference in volume and concentration is due to the selective reabsorption of some constituents of the filtrate and the tubular secretion of others.

Autoregulation of filtration: Renal blood flow is protected by a mechanism called autoregulation whereby renal blood flow is maintained at a constant pressure across a wide range of systolic blood pressures (from 80 to 200mmHg). Autoregulation operates independently of nervous control; i.e. if the nerve supply to the renal blood vessels is interrupted, autoregulation continues to operate. It is therefore a property inherent in renal blood vessels; it may be stimulated by changes in blood pressure in the renal arteries or by fluctuating levels of certain metabolites, e.g. prostaglandins. In severe shock when the systolic blood pressure falls below 80 mmHg, autoregulation fails and renal blood flow and hydrostatic pressure decrease, impairing filtration within the nephrons.

Selective reabsorption :

Selective reabsorption is the process by which the composition and volume of the glomerular filtrate are altered during its passage through the convoluted tubules, the medullary loop and the collecting tubule. The general purpose of this process is to reabsorb into the blood those filtrate constituents needed by the body to maintain fluid and electrolyte balance and the pH of the blood. Active transport is carried out at carrier sites in the epithelial membrane using chemical energy to transport substances against their concentration gradients. Some constituents of glomerular filtrate (e.g. glucose, amino acids) do not normally appear in urine because they are completely reabsorbed unless they are present in blood in excessive quantities. The kidneys' maximum capacity for reabsorption of a substance is the transport maximum, or renal threshold, e.g. normal blood glucose level is 2.5 to 5.3 mmol/l (45 to 95 mg/100 ml). If the level rises above the transport maximum of about 9 mmol/1 (160 mg/100 ml) glucose appears in the urine because all the carrier sites are occupied and the mechanism for active transfer out of the tubules is overloaded. Other substances reabsorbed by active transport include amino acids and sodium, calcium, potassium, phosphate and chloride. Some ions, e.g. sodium and chloride, can be absorbed by both active and passive mechanisms depending on the site in the nephron. The transport maximum, or renal threshold, of some substances varies according to the body's need for them at the time, and in some cases reabsorption is regulated by hormones. Parathyroid hormone from the parathyroid glands and calcitonin from the thyroid gland together regulate reabsorption of calcium and phosphate. Antidiuretic hormone (ADH) from the posterior lobe of the pituitary gland increases the permeability of the distal convoluted tubules and collecting tubules, increasing water reabsorption. Aldosterone, secreted by the adrenal cortex, increases the reabsorption of sodium and excretion of potassium. Nitrogenous waste products, such as urea and uric acid, are reabsorbed only to a slight extent.

Directions of selective reabsorption and secretion inthe nephron.



Negative feedback regulation of secretion of antidiuretic hormone (ADH).

Secretion

Filtration occurs as the blood flows through the glomerulus. Substances not required and foreign materials, e.g. drugs including penicillin and aspirin, may not be cleared from the blood by filtration because of the short time it remains in the glomerulus. Such substances are cleared by secretion into the convoluted tubules and excreted from the body in the urine. Tubular secretion of hydrogen (H+) ions is important in maintaining the homeostasis of blood pH.

Composition of urine

Water 96%

Urea 2%

Uric acid

Creatinine

Ammonia

Sodium

Potassium / 2%

Chlorides

Phosphates

Sulfates

Oxalates

Urine is clear and amber in color due to the presence of urobilin, a bile pigment altered in the intestine, reabsorbed and then excreted by the kidneys.

Water balance and urine output:

Water is taken into the body through the alimentary tract and a small amount (called 'metabolic water') is formed by the metabolic processes. Water is excreted in saturated expired air, as a constituent of the feces, through the skin as sweat and as the main constituent of urine. The amount lost in expired air and in feces is fairly constant and the amount of sweat produced is associated with the maintenance of normal body temperature. The balance between fluid intake and output is therefore controlled by the kidneys. The minimum urinary output, i.e., the smallest volume required to excrete the body's waste products, is about 500ml per day. The amount produced in excess of this is controlled mainly by antidiuretic hormone (ADH) released into the blood by the posterior lobe of the pituitary gland. There is a close link between the posterior pituitary and the hypothalamus in the brain.

Sensory nerve cells in the hypothalamus (osmoreceptors) detect changes in the osmotic pressure of the blood. Nerve impulses from the osmoreceptors stimulate the posterior lobe of the pituitary gland to release ADH.

When the osmotic pressure is raised, ADH output is increased and as a result, water reabsorption by the cells in distal convoluted tubules and collecting ducts is increased, reducing the blood osmotic pressure and ADH output. This feedback mechanism maintains the blood osmotic pressure (and therefore sodium and water concentrations) within normal limits. The feedback mechanism may be opposed when there is an excessive amount of a dissolved substance in the blood. For example, in diabetes mellitus when the blood glucose level is above the transport maximum of the renal tubules, excess water is excreted with the excess glucose. This polyuria may lead to dehydration in spite of increased production of ADH but it is usually accompanied by acute thirst and increased water intake.

Sodium balance

In addition to regulating total volume, the osmolarity (the amount of solute per unit volume) of bodily fluids is also tightly regulated. Extreme variation in osmolarity causes cells to shrink or swell, damaging or destroying the cellular structure and disrupting normal cellular function.

Regulation of osmolarity is achieved by balancing the intake and excretion of sodium with that of water. (Sodium is by far the major solute in extracellular fluids, so it effectively determines the osmolarity of extracellular fluids.)

An important concept is that the regulation of osmolarity must be integrated with the regulation of volume because changes in water volume alone have to dilute or concentrating effects on the bodily fluids. For example, when you become dehydrated you lose proportionately more water than solute (sodium), so the osmolarity of your bodily fluids increases. In this situation the body must conserve water but not sodium, thus stemming the rise in osmolarity. If you lose a large amount of blood from trauma or surgery, however, your loss of sodium and water are proportionate to the composition of bodily fluids. In this situation, the body should conserve both water and sodium.

As noted above, ADH plays a role in lowering osmolarity (reducing sodium concentration) by increasing water reabsorption in the kidneys, thus helping to dilute bodily fluids. To prevent osmolarity from decreasing below normal, the kidneys also have a regulated mechanism for reabsorbing sodium in the distal nephron. This mechanism is controlled by aldosterone, a steroid hormone produced by the adrenal cortex. Aldosterone secretion is controlled two ways:

1.The adrenal cortex directly senses plasma osmolarity. When the osmolarity increases above normal, aldosterone secretion is inhibited. The lack of aldosterone causes less sodium to be reabsorbed in the distal tubule. Remember that in this setting ADH secretion will increase to conserve water, thus complementing the effect of low aldosterone levels to decrease the osmolarity of bodily fluids. The net effect on urine excretion is a decrease in the amount of urine excreted, with an increase in the osmolarity of the urine.

2. The kidneys sense low blood pressure (which results in lower filtration rates and lower flow through the tubule). This triggers a complex response to raise blood pressure and conserve volume. Specialized cells (juxtaglomerular cells) in the afferent and efferent arterioles produce renin, a peptide hormone that initiates a hormonal cascade that ultimately produces

angiotensin II. Angiotensin II stimulates the adrenal cortex to produce aldosterone.

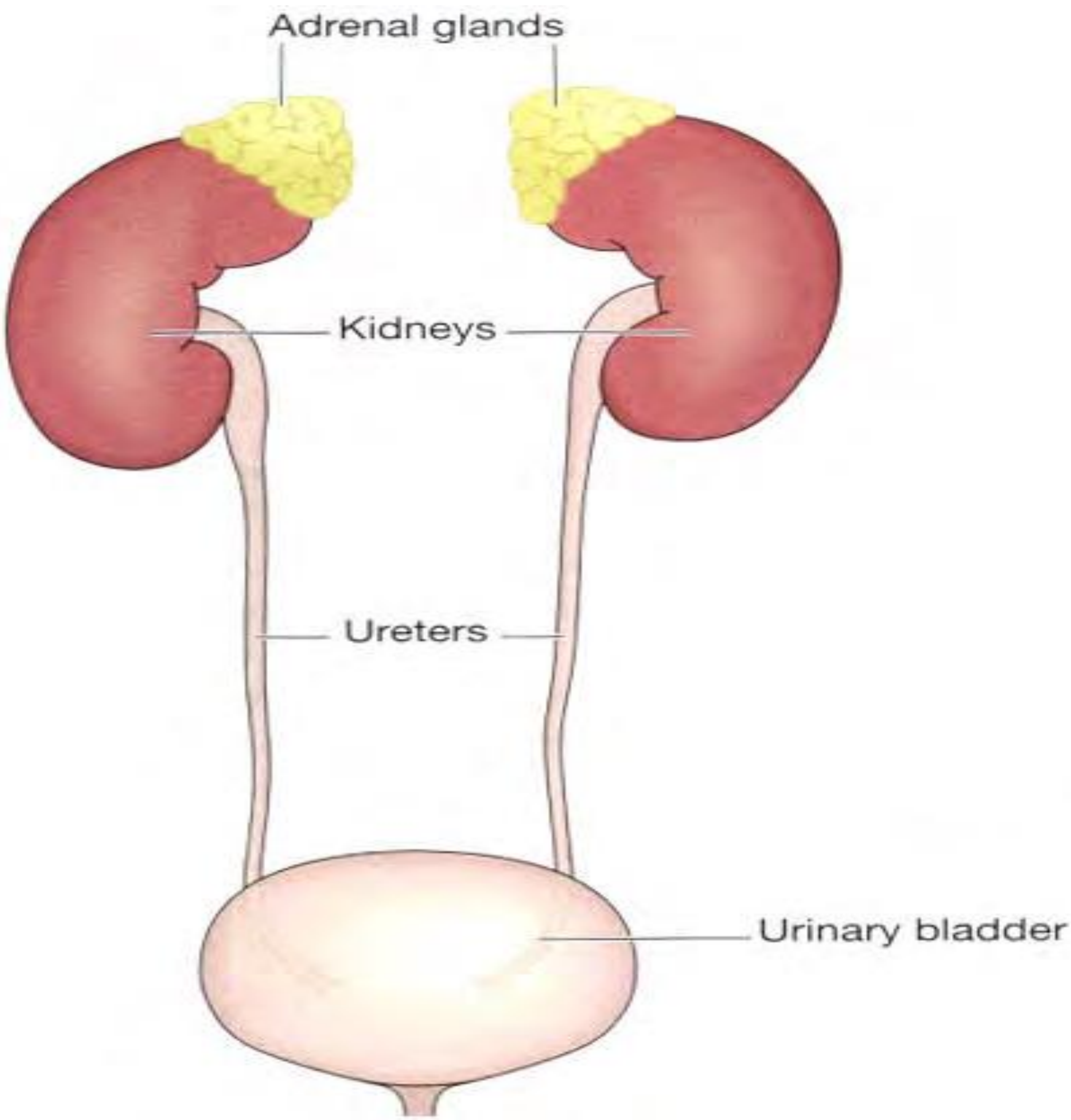
*Note that in this setting, where the body is attempting to conserve volume, ADH secretion is also stimulated and water reabsorption increases. Because aldosterone is also acting to increase sodium reabsorption, the net effect is the retention of fluid that is roughly the same osmolarity as bodily fluids. The net effect on urine excretion is a decrease in the amount of urine excreted, with lower osmolarity than in the previous example.

The ureters:

Function:

The ureters propel the urine from the kidneys into the bladder by peristaltic contraction of the smooth muscle layer. This is an intrinsic property of the smooth muscle and is not under autonomic nerve control. The waves of

contraction originates in a pacemaker in the minor calyces. Peristaltic waves occur several times per minute, increasing in frequency with the volume of urine produced, and send little spurts of urine into the bladder.



The ureters

The ureters are the tubes that convey urine from the kidneys to the urinary bladder. They are about 25 to 30 cm long with a diameter of about 3 mm. The ureter is continuous with the funnel-shaped renal pelvis. It passes downwards through the abdominal cavity, behind the peritoneum in front of the psoas muscle into the pelvic cavity, and passes obliquely through the posterior wall of the bladder arrangement, when urine accumulates and the pressure in the bladder rises, the ureters are compressed and the openings occluded. This prevents the reflux of urine into the ureters (towards the kidneys) as the bladder fills and during micturition when pressure increases as the muscular bladder wall contracts.

The urinary bladder

The urinary bladder is a reservoir for urine. It lies in the pelvic cavity and its size and position vary, depending on the amount of urine it contains. When distended, the bladder rises into the abdominal cavity. The bladder is roughly pear-shaped but becomes more oval as it fills with urine. It has anterior, superior, and posterior surfaces. The posterior surface is the base. The bladder opens into the urethra at its lowest point, the neck.

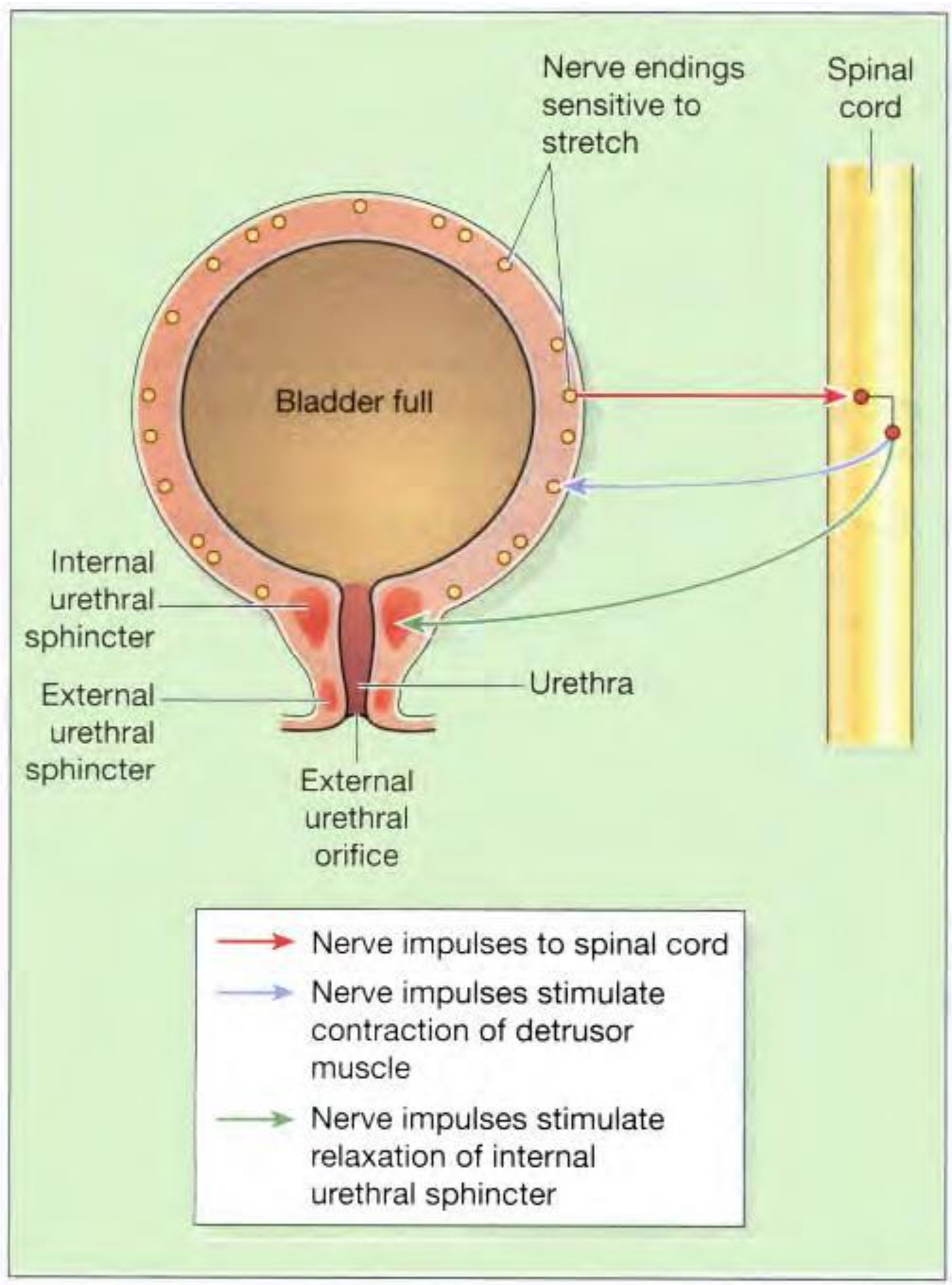
The urethra

The urethra is a canal extending from the neck of the bladder to the exterior, at the external urethral orifice. Its length differs in the male and in the female. The male urethra is associated with the urinary and productive systems.

MICTURITION

The urinary bladder acts as a reservoir for urine. When 300 to 400 ml of urine have accumulated, afferent autonomic nerve fibers in the bladder wall sensitive to stretch are stimulated. In the infant, this initiates a spinal reflex action and micturition occurs. Micturition occurs when autonomic efferent fibers convey impulses to the bladder causing contraction of the detrusor muscle and relaxation of the internal urethral sphincter. When the nervous system is fully developed the micturition reflex is stimulated but sensory impulses pass upwards to the brain and there is an awareness of the desire to pass urine. By conscious effort, reflex contraction of the bladder wall and relaxation of the internal sphincter can be inhibited for a limited period of time.

In adults, micturition occurs when the detrusor muscle contracts, and there is reflex relaxation of the internal sphincter and voluntary relaxation of the external sphincter. It can be assisted by increasing the pressure within the pelvic cavity, achieved by lowering the diaphragm and contracting the abdominal muscles (Valsalva's maneuver). Over-distension of the bladder is extremely painful, and when this stage is reached there is a tendency for involuntary relaxation of the external sphincter to occur and a small amount of urine to escape, provided there is no mechanical obstruction.



Simple reflex control of micturition when conscious effort cannot override the reflex action.

The reproductive systems

The ability to reproduce is one of the properties which distinguishes living from non-living matter. The more primitive the animal, the simpler the process of reproduction. In human beings, the process is one of sexual reproduction in which the male and female organs differ anatomically and physiologically. Both males and females produce specialized reproductive germ cells, called gametes. The male gametes are called spermatozoa and the female gametes are called ova. They contain the genetic material, or genes, on chromosomes, which pass inherited characteristics on to the next generation. In other body cells, there are 46 chromosomes arranged in 23 pairs but in the gametes, there are only 23, one from each pair. Gametes are formed by meiosis. When the ovum is fertilized by a spermatozoon the resultant zygote contains 23 pairs of chromosomes, one of each pair obtained from the father and one from the mother. The zygote embeds itself in the wall of the uterus

where it grows and develops during the 40-week gestation period before birth.

The functions of the female reproductive system are:

• formation of female gametes, ova

• reception of male gametes, spermatozoa

• provision of suitable environments for the fertilization of

the ovum by spermatozoa and the development of the

resultant fetus

• parturition (childbirth)

• lactation, the production of breast milk, which

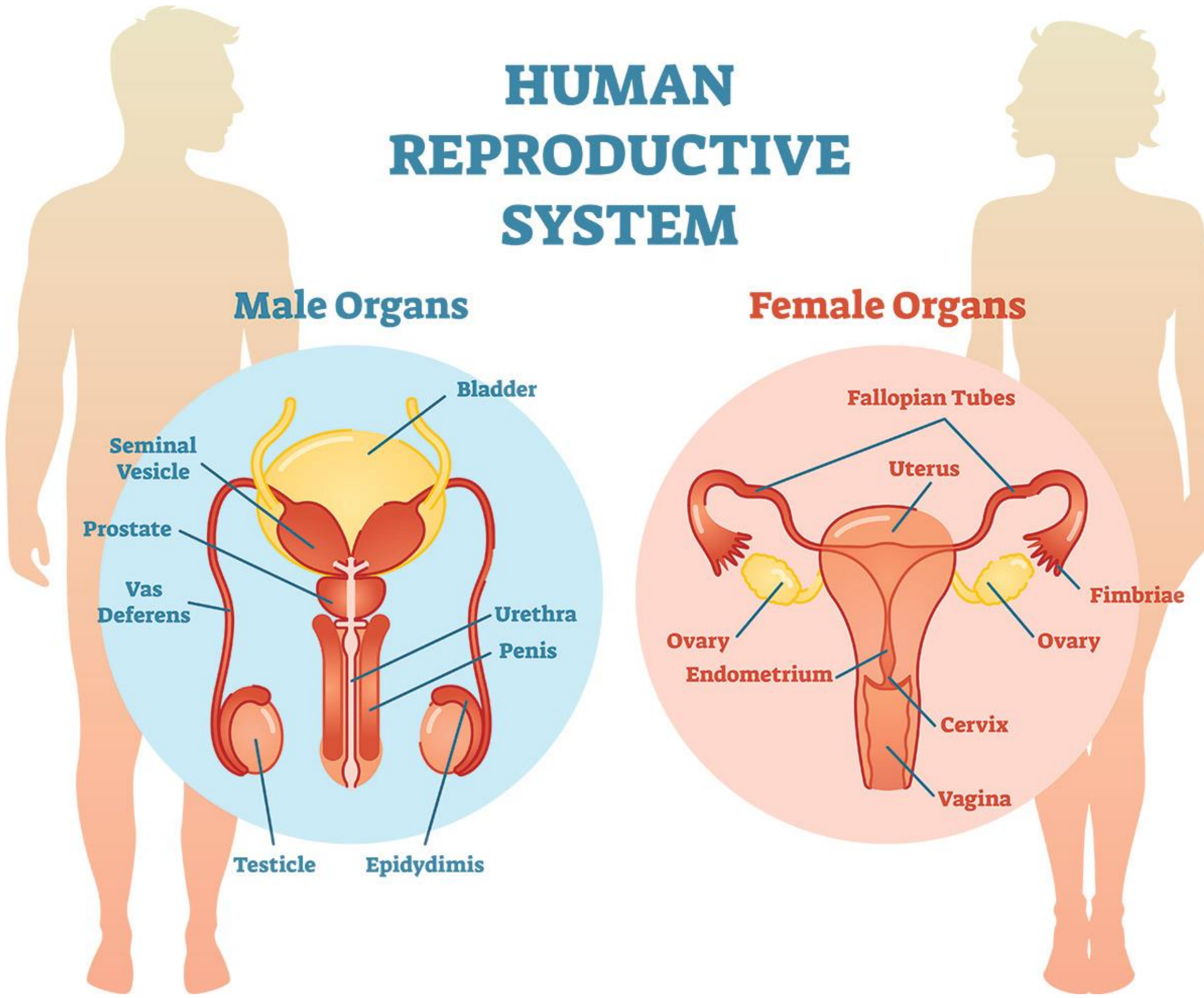
provides complete nourishment for the baby in its

early life.

The functions of the male reproductive system are:

• production of male gametes, spermatozoa

• transmission of spermatozoa to the female.



Male reproductive system

The male has reproductive organs, or genitals, that are both inside and outside the pelvis. The male genitals include:

- the testicles
- the duct system, which is made up of the epididymis and the vas deferens

- the accessory glands, which include the seminal vesicles and prostate gland
- the penis

In a guy who has reached sexual maturity, the two oval-shaped testicles, or testes make and store millions of tiny sperm cells. The testicles are also part of the endocrine system because they make hormones, including testosterone.

Testosterone is a major part of puberty in boys, and as a guy makes his way through puberty, his testicles produce more and more of it. Testosterone is the hormone that causes boys to develop deeper voices, bigger muscles, and body and facial hair. It also stimulates the production of sperm.

Alongside the testicles are the epididymis and the vas deferens, which transport sperm. The epididymis and the testicles hang in a pouch-like structure outside the pelvis called the scrotum. This bag of skin helps to regulate the temperature of testicles, which need to be kept cooler than body temperature to produce sperm. The scrotum changes size to maintain the right temperature. When the body is cold, the scrotum shrinks and becomes tighter to hold in body heat. When it's warm, it gets larger and floppier to get rid of extra heat. This happens without a guy ever having to think about it. The brain and the nervous system give the scrotum the cue to change size.

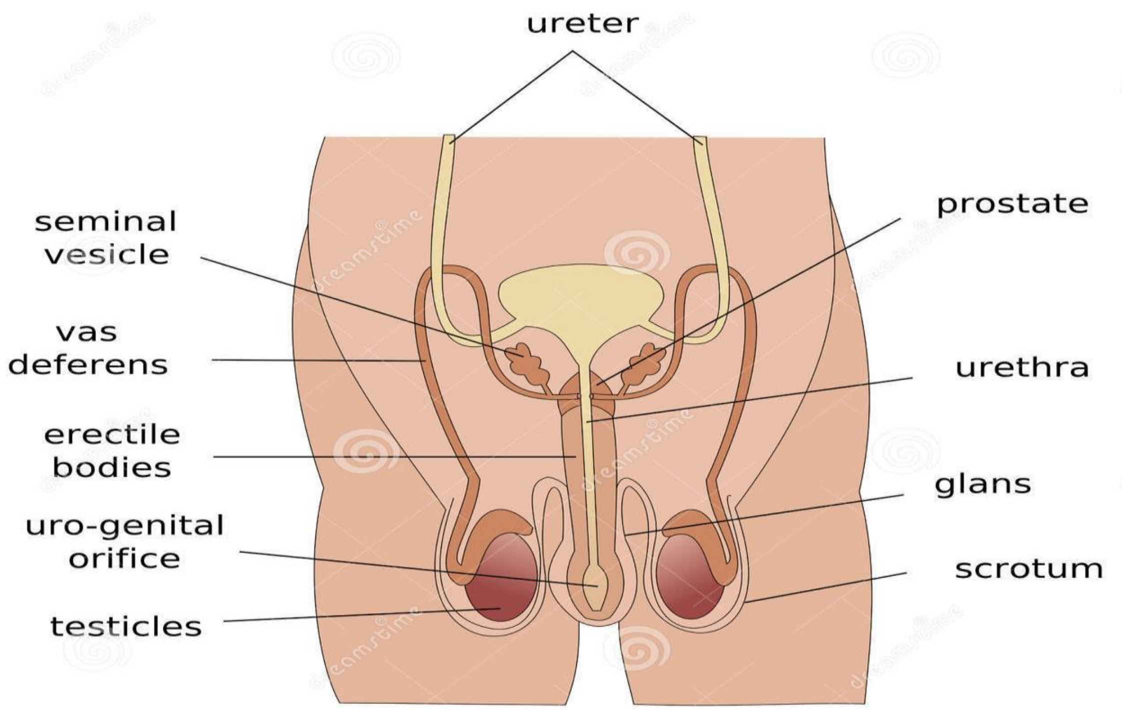
The accessory glands, including the seminal vesicles and the prostate gland, provide fluids that lubricate the duct system and nourish the sperm. The urethra is the channel that carries the sperm (in fluid called semen) to the outside of the body through the penis. The urethra is also part of the urinary system because it is also the channel through which pee passes as it leaves the bladder and exits the body.
The male reproductive system makes semen releases semen into the reproductive system of the female during sexual intercourse produces sex hormones, which help a boy develop into a sexually mature man during puberty When a baby boy is born, he has all the parts of his reproductive system in place, but it isn't until puberty that he is able to reproduce. When puberty begins, usually between the

ages of 9 and 15, the pituitary gland — located near the brain — secretes hormones that stimulate the testicles to produce testosterone. The production of testosterone brings about many physical changes.

Although the timing of these changes is different for every guy, the stages of puberty generally follow a set sequence:

During the first stage of male puberty, the scrotum and testes grow larger.
Next, the penis becomes longer and the seminal vesicles and prostate gland grow.
Hair begins to grow in the pubic area and later on the face and underarms. During this time, a boy's voice also deepens.
Boys also have a growth spurt during puberty as they reach their adult height and weight.

The penis is actually made up of two parts: the shaft and the glans. The shaft is the main part of the penis and the glans is the tip (sometimes called the head). At the end of the glans is a small slit or opening, which is where semen and urine exit the body through the urethra. The inside of the penis is made of spongy tissue that can expand and contract.


ureter
seminal vesicle
prostate
vas deferens
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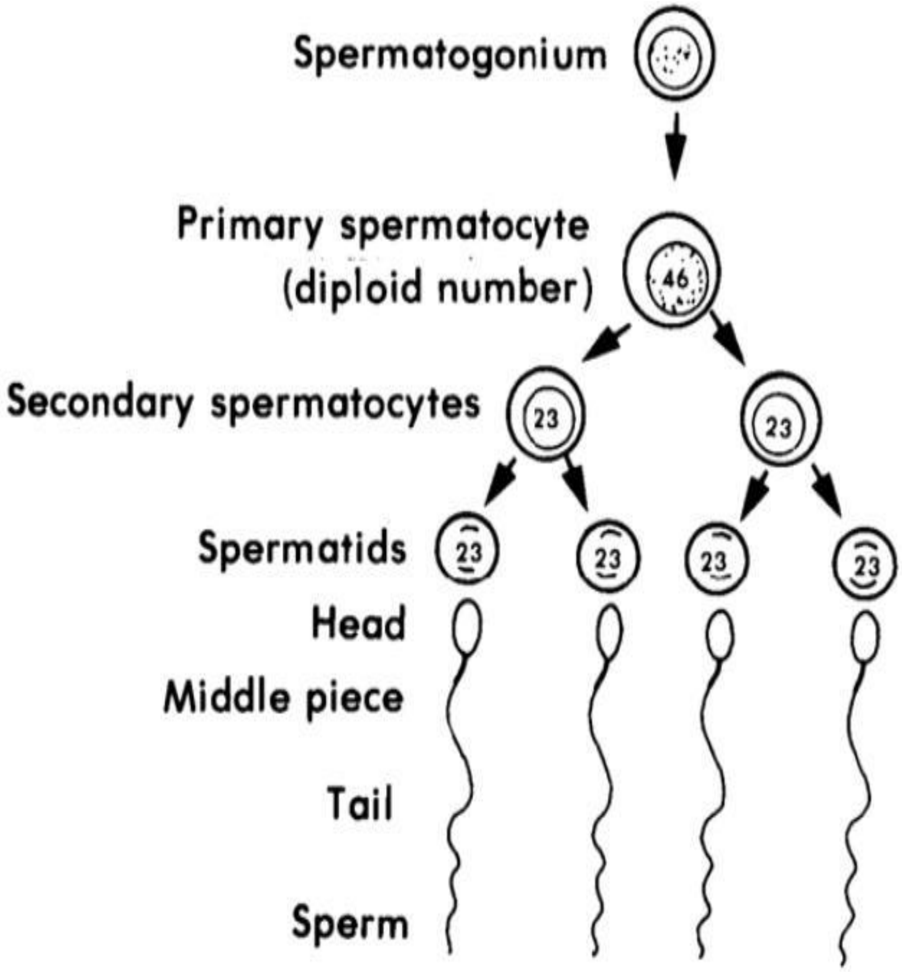
erectile bodies
glans
uro-genital orifice
scrotum
testicles



Spermatogenesis

Female reproductive system

While the following structures of the female reproductive system serve different purposes, together, they contribute to the creation and maintenance of an egg:

Ovaries – The ovaries are the female gonads – the primary organ in the female reproductive system. It is mainly responsible for producing egg cells, or ova, as well as hormones such as estrogen and progesterone. These hormones are responsible for controlling various reproductive processes in females and thickening and maintaining the uterus lining.

Fimbriae – The fimbriae are tissues attached to the ovaries that transfer the oocytes (immature eggs) from the ovaries to the fallopian tubes, or oviduct.

Fallopian tubes (oviduct) – The fallopian tubes are a pair of tubes that stretch from the ovaries to the uterus. They are responsible for transporting the oocytes to the uterus. Fertilization normally occurs here.

Uterus – The uterus is a muscular, pear-shaped organ where the fertilized egg will be implanted and developed.

Cervix – The cervix is the lower part of the uterus, a canal between the uterus and the vagina through which the fetus (developing baby) will exit during childbirth.

Vagina – The vagina is a passage leading to the uterus which accommodates the penis during sexual intercourse.

Oogenesis

Oogenesis is the process that produces egg cells. It occurs in the outer layers of the ovaries.

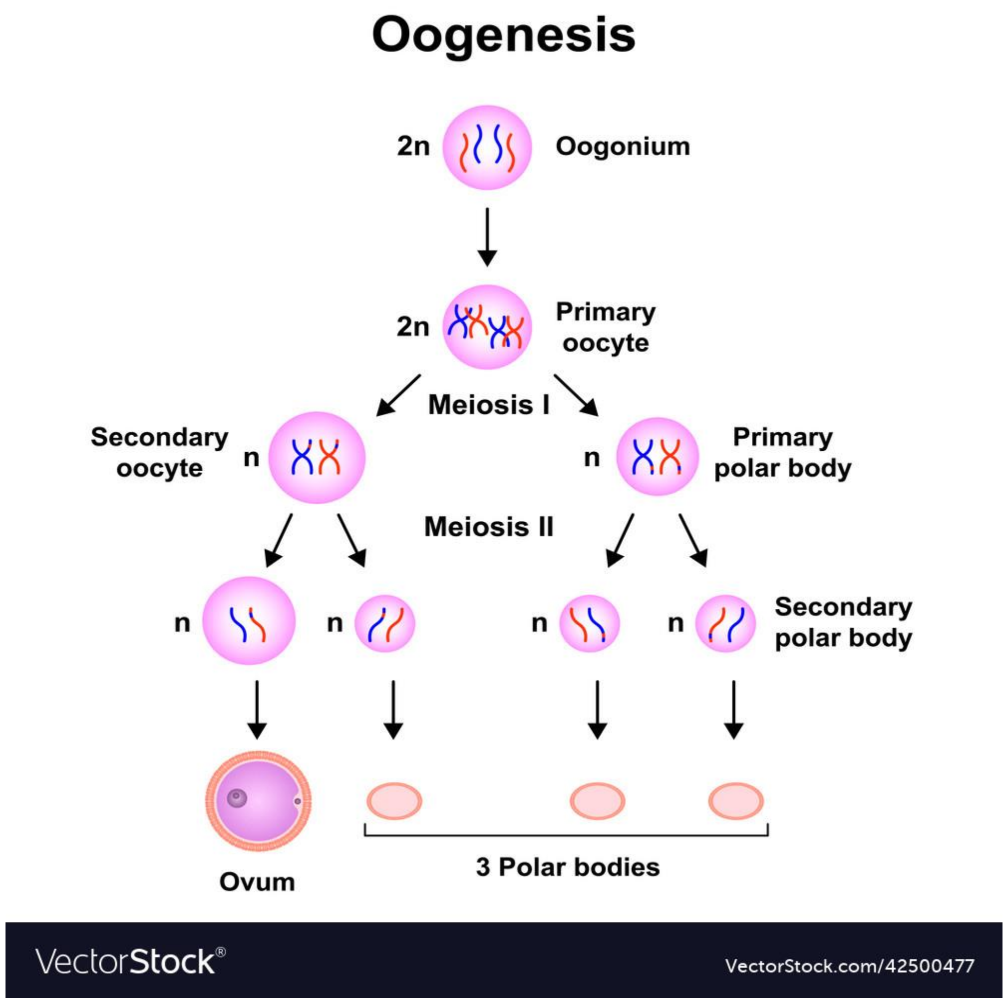
The process of oogenesis

1-Germ cells, which are the body's reproductive cells, undergo cell division several times by mitosis, forming two oogonia. Oogonia are immature reproductive cells containing two complete sets of chromosomes, one from each parent, i.e., they are diploid.

Remember that a diploid cell has two sets of chromosomes with two chromatids each. While chromatids are twins (they contain the same genetic information), paired chromosomes will code for the same traits but might have different alleles for those traits.

2-One oogonium continues to grow into a primary oocyte, an immature egg.

3-The cell (the primary oocyte) then undergoes division by meiosis (1st meiotic division), forming a secondary oocyte (if you need a refresher, check out our article Meiosis). This oocyte is a haploid cell containing only half of the original cell's chromosome. This is now the female set of chromosomes for the zygote. Additionally, small cell buds off the oocyte called a polar body.
Polar bodies are also haploid cells but are generally unable to be fertilized. It usually dies by apoptosis.
4-The secondary oocyte undergoes meiosis (2nd meiotic division), forming an ovum (egg cell) and another polar body. The polar bodies continue to divide and degenerate as the ovum develops. The maturation of the oocyte to form an ovum is arrested, or 'paused', in prophase until ovulation (after puberty). Then, it is allowed to continue until metaphase II, at which stage meiotic division is arrested again until the sperm fertilizes the egg.


Oogenesis
2n
Oogonium
2n
Primary oocyte
Meiosis I
Secondary oocyte
n
n
Primary polar body
Meiosis II
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Secondary polar body
Ovum
3 Polar bodies
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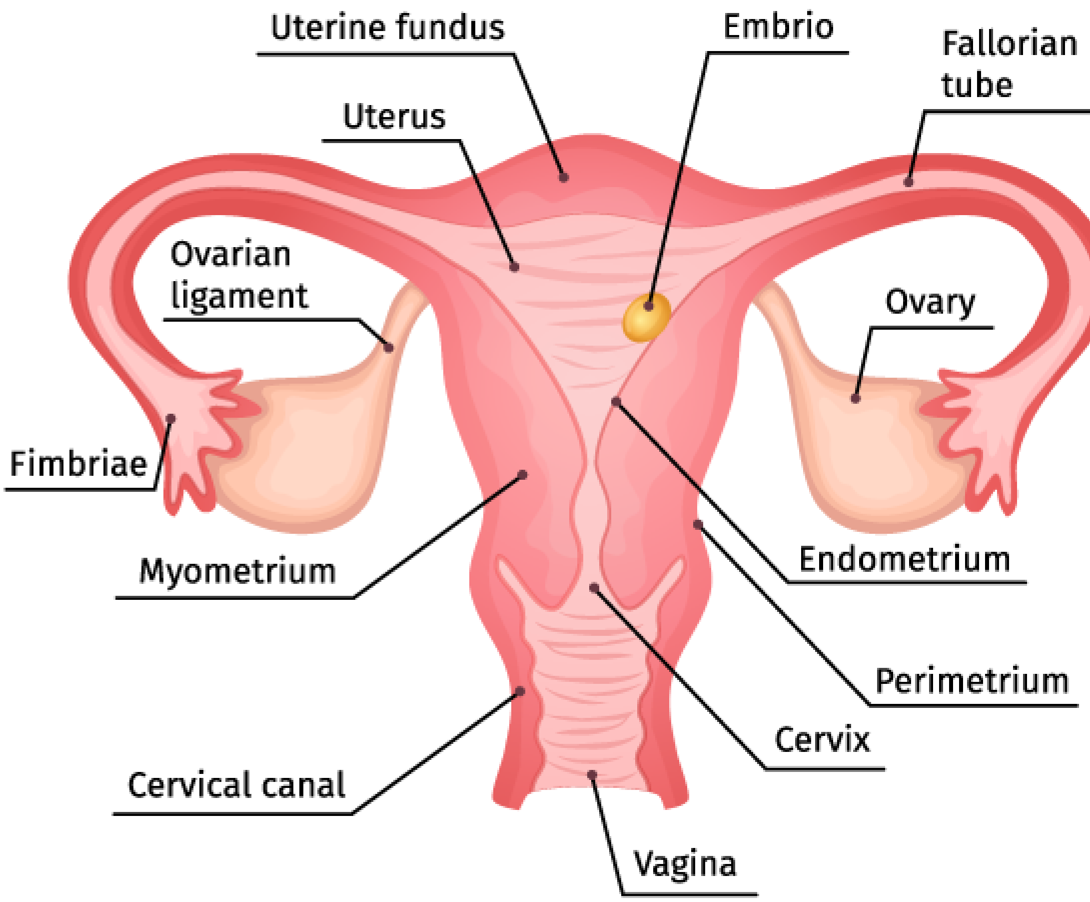
FEMALE REPRODUCTIVE SYSTEM



The skeletal system

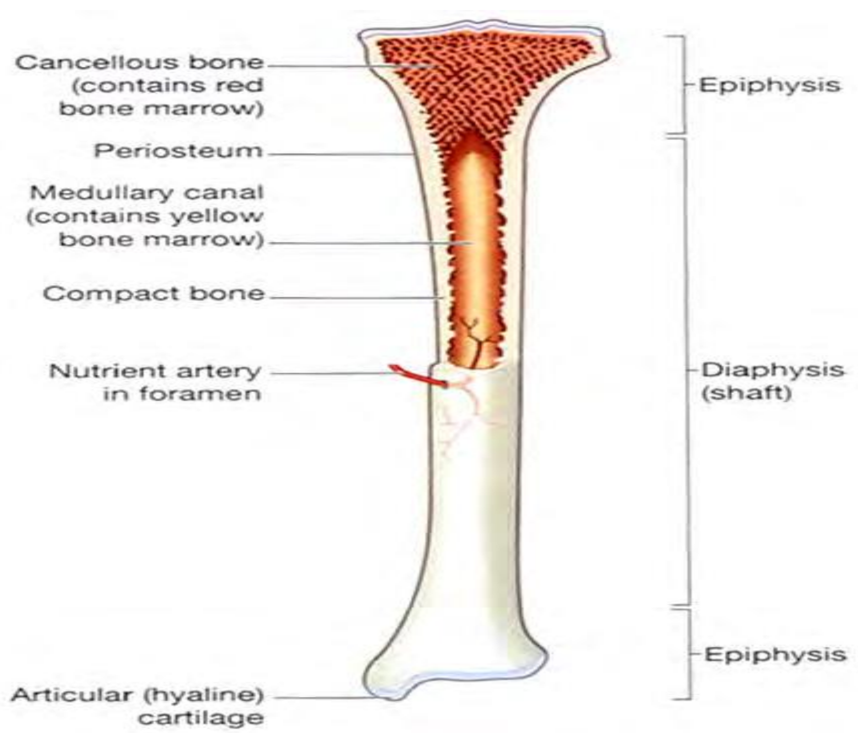
Bone is a strong and durable type of connective tissue.

It consists of:

• water (25%)

• organic constituents including osteoid (the carbon-containing part of the matrix) and bone cells (25%)

• inorganic constituents, mainly calcium phosphate (50%).



A mature long bone - partially sectioned.

Although bones are often thought to be static or permanent, they are highly vascular living structures that are
continuously being remodelled.

Types of bones

Bones are classified as long, short, irregular, flat and
sesamoid.

Long bones. These consist of a shaft and two extremities.
As the name suggests the length is much greater than the
width. Examples include the femur, tibia and fibula.

Short, irregular, flat and sesamoid bones. These have
no shafts or extremities and are diverse in shape and size.
Examples include:

• short bones —carpals (wrist)

• irregular bones—vertebrae and some skull bones

• flat bones —sternum, ribs and most skull bones

• sesamoid bones —patella (kneecap).

Bone cells

The cells responsible for bone formation are osteoblasts
(these later mature into osteocytes). Osteoblasts and chondrocytes (cartilage-forming cells) develop from the same parent fibrous tissue cells. Differentiation into osteogenic cells, rather than chondroblasts, is believed to depend upon an adequate oxygen supply. This may be a factor affecting the healing of fractures, i.e. if the oxygen supply is deficient there may be a preponderance of chondroblasts, resulting in a cartilaginous union of the fracture.

Osteoblasts

These are the bone-forming cells that secrete collagen and other constituents of bone tissue. They are present:

• in the deeper layers of periosteum

• in the centers of ossification of immature bone

• at the ends of the diaphysis adjacent to the epiphyseal

cartilages of long bones

• at the site of a fracture.

Osteocytes

As bone develops, osteoblasts become trapped and remain isolated in lacunae. They stop forming new bone at this stage and are called osteocytes. Osteocytes are nourished by tissue fluid in the canaliculi that radiate from the Haversian canals. Their functions are not clear but they may be associated with the movement of calcium between the bones and the blood.

Osteoclasts

Their function is the resorption of bone to maintain the optimum shape. This takes place on bone surfaces:

• under the periosteum, to maintain the shape of bones during growth and to remove excess callus formed during the healing of fractures

• round the walls of the medullary canal during growth and canalize the callus during healing.

A fine balance of osteoblast and osteoclast activity maintains the normal bone structure and functions.

Development of bone tissue (osteogenesis or ossification)

This begins before birth and is not complete until about the 21st year of life. Long, short and irregular bones develop from rods of cartilage, cartilage models. Flat bones develop from membrane models and sesamoid bones from tendon models. Bone development consists of two processes:

• secretion by osteoblasts of osteoid, i.e. collagen fibers in a mucopolysaccharide matrix which gradually

replaces the original cartilage and membrane models

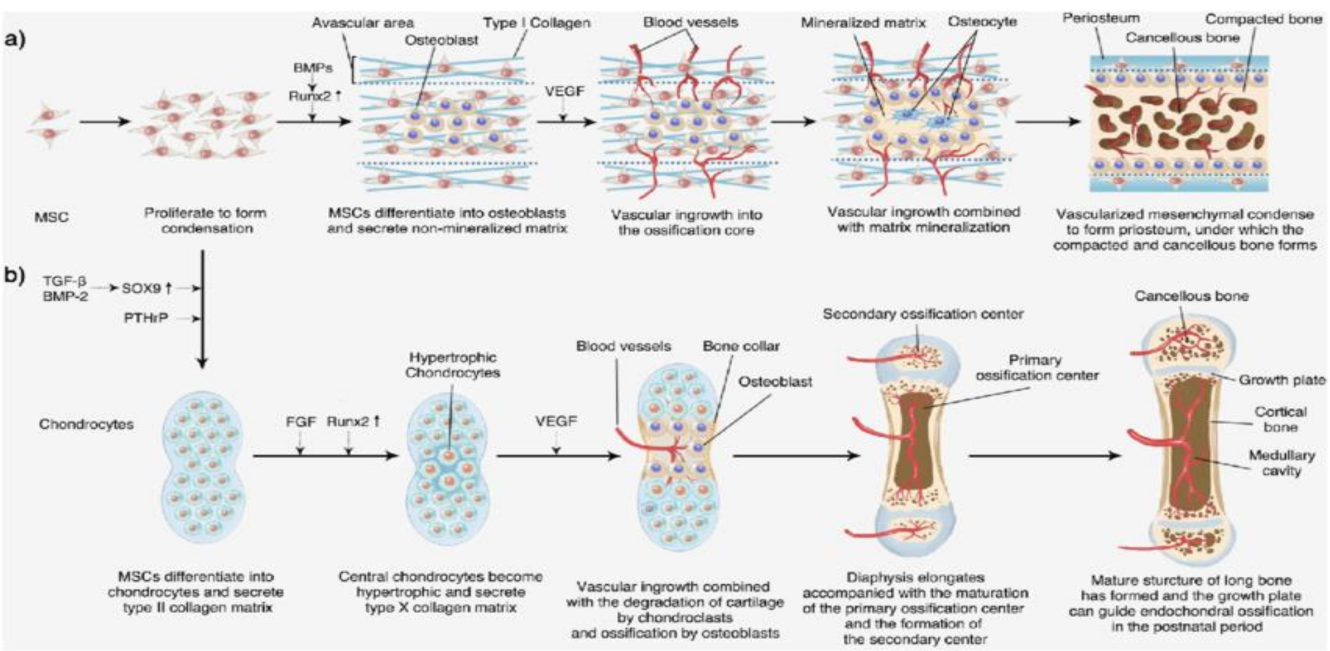
• calcification of osteoid immediately after its deposition.

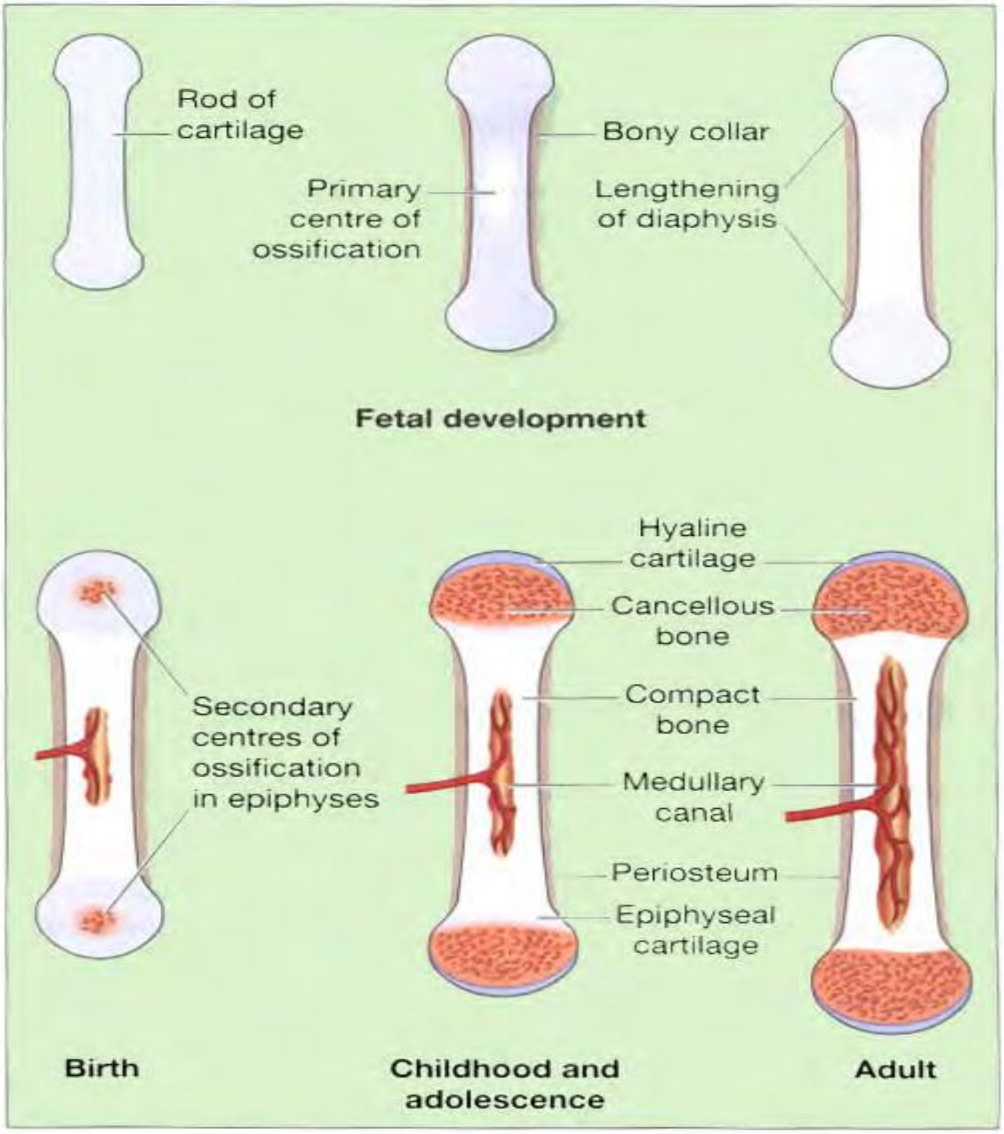
There are two types of arrangement of collagen in osteoid.

Woven (non-lamellar) bone. Collagen fibers are deposited in irregular bundles, then ossified.

This primitive bone structure is part of normal fetal development occurring during the ossification of bones that originate as membrane models, e.g. skull bones. In adults, it is also present in bone tumors and healing fractures. Lamellar bone. The collagen fibers are deposited as in woven bone, organized into characteristic lamellae found

in the compact and cancellous bone then ossified. This occurs when cartilage models are replaced by bone and in the healing of fractures.





The stages of development of a long bone.

Development of long bones

In long bones, the focal points from which ossification begins are small areas of osteogenic cells or centers of ossification in the cartilage model. This is accompanied by the development of a bone collar at about 8 weeks of gestation. Later the blood supply develops and bone tissue replaces cartilage as osteoblasts secrete osteoid components in the shaft. The bone lengthens as ossification continues and spreads to the epiphyses. Around birth, secondary centers of ossification develop in the epiphyses and the medullary canal forms when osteoclasts break down the central bone tissue in the middle of the shaft. After birth, the bone grows in length by ossification of the diaphyseal surface of the epiphyseal cartilages and growth is complete when the cartilages become completely ossified.

Hormonal regulation of bone growth

Hormones that regulate the growth and consistency of size and shape of bones include the following.

- Growth hormone and the thyroid hormones, thyroxine and triiodothyronine, are especially importantduring infancy and childhood; deficient or excessive secretion of these results in abnormal development of the skeleton.

• Testosterone and estrogens influence the physical changes that occur at puberty, i.e. the growth spurt and masculinizing or feminizing changes of specific parts of the skeleton, e.g. the pelvis.

• Calcitonin from the thyroid gland and parathyroid hormone from the parathyroid glands are involved in the homeostasis of blood and bone calcium levels required for bone development.

Although the length and shape of bones do not normally change after ossification is complete, bone tissue is continually being remodelled and replaced when damaged. Osteoblasts continue to lay down osteoid and osteoclasts reabsorb it. The rate in different bones varies, e.g. the distal part of the femur is replaced gradually over a period of 5 to 6 months.

Functions of bones

Bones have a variety of functions. They:

• provide the framework of the body

• give attachment to muscles and tendons

• permit movement of the body as a whole and of parts of the body, by forming joints that are moved by muscles

• form the boundaries of the cranial, thoracic and pelvic cavities, protecting the organs they contain

• contain red bone marrow in which blood cells develop hematopoiesis.

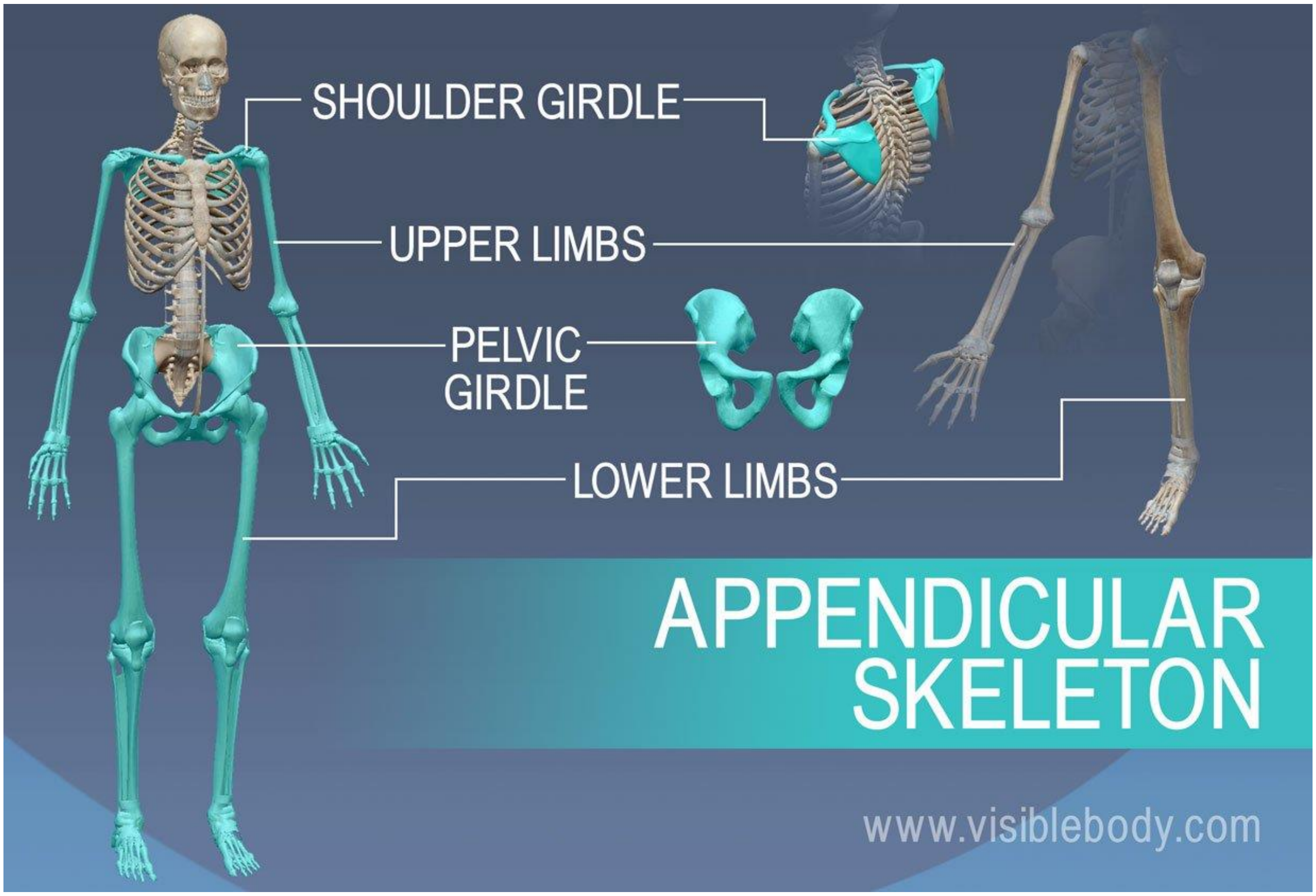
• provide a reservoir of minerals, especially calcium, phosphate.

AXIAL SKELETON:

This part consists of the skull, vertebral column, ribs and sternum. Together the bones forming these structures constitute the central bony core of the body, the axis.

APPENDICULAR SKELETON:

The appendicular skeleton consists of the shoulder girdle with the upper limbs and the pelvic girdle with the lower limbs.



Muscular System

Functions of the Muscular System

Producing movement is a common function of all muscle types, but skeletal muscle plays three other important roles in the body as well.

Producing movement. Mobility of the body as a whole reflects the activity of the skeletal muscles, which are responsible for all locomotion; they enable us to respond quickly to changes in the external environment.

Maintaining posture. We are rarely aware of the skeletal muscles that maintain body posture, yet they function almost continuously, making one tiny adjustment after another so that we can maintain an erect or seated posture despite the never-ending downward pull of gravity.

Stabilizing joints. As the skeletal muscles pull on bones to cause movements, they also stabilize the joints of the skeleton; muscle tendons are extremely important in reinforcing and stabilizing joints that have poorly fitting articulating surfaces.

Generating heat. The fourth function of muscle, generation of body heat, is a by-product of muscle activity; as ATP is used to power muscle contraction, nearly three-quarters of its energy escape as heat and this heat is vital in maintaining normal body temperature.

Muscles:

You control some muscles voluntarily with the help of your nervous system (your body's command center). You make them move by thinking about moving them.

Other muscles work involuntarily, which means you can't control them. They do their job automatically. In order to work, they take cues from other body systems, such as your digestive system or cardiovascular system.

There are three types of muscle tissue in the body. They are:

Skeletal: As part of the musculoskeletal system, these muscles work with your bones, tendons and ligaments. Tendons attach skeletal muscles to bones all over your body. Together, they support the weight of your body and help you move. You control these voluntary muscles. Some muscle fibers contract quickly and use short bursts of energy (fast-twitch muscles). Others move slowly, such as your back muscles that help with posture.

Cardiac: These muscles line the heart walls. They help your heart pump blood that travels through your cardiovascular system. You don’t control cardiac muscles. Your heart tells them when to contract.

Smooth: These muscles line the insides of organs such as the bladder, stomach and intestines. Smooth muscles play an important role in many body systems, including the female reproductive system, male reproductive system, urinary system and respiratory system. These types of muscles work without you having to think about them. They do essential jobs like move waste through your intestines and help your lungs expand when you breathe.

Function:

Muscles play a role in nearly every system and function of the body. Different kinds of muscles help with:

Breathing, speaking and swallowing.

Digesting food and getting rid of waste.

Moving, sitting still and standing up straight.

Pumping blood through the heart and blood vessels.

Pushing a baby through the birth canal as muscles in the uterus contract and relax.

Seeing and hearing.

Structure

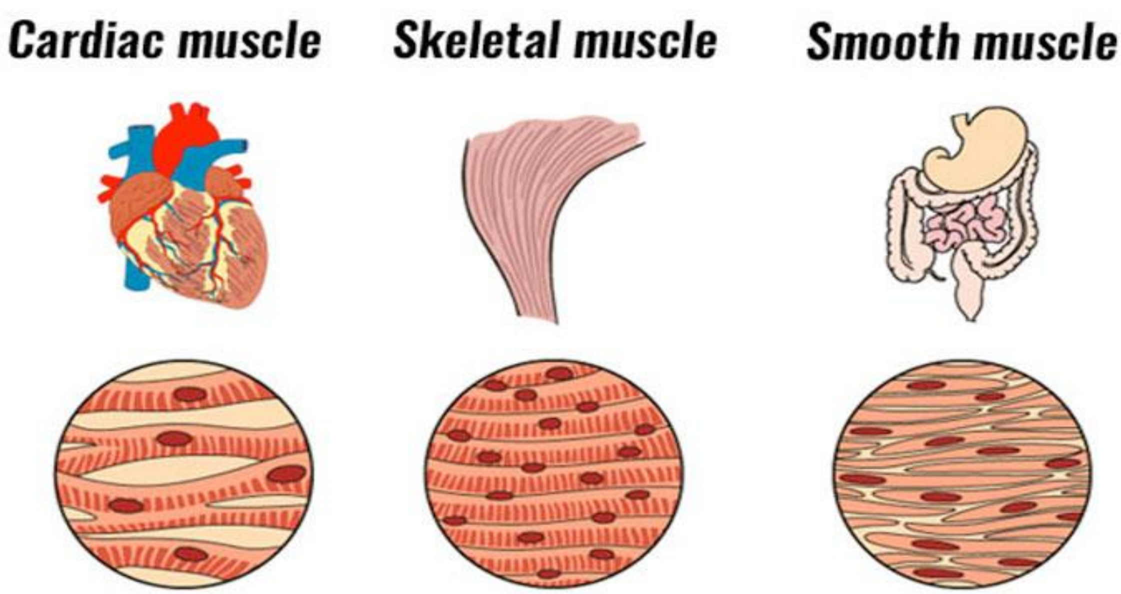
All types of muscle tissue look similar. But there are slight differences in their appearance:

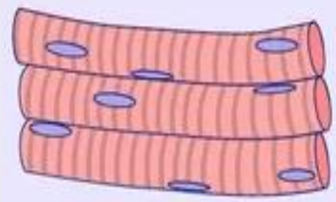
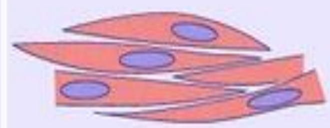
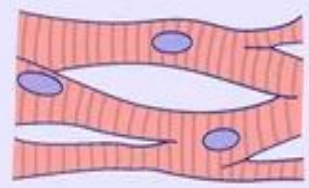
Skeletal muscles: Many individual fibers make up skeletal muscles. Actin and myosin are proteins that make up the fibers. The bundles of fibers form a spindle shape (long and straight with tapered ends). A membrane surrounds each spindle. Providers describe skeletal muscles as striated (striped) because of the striped pattern the spindles create together.

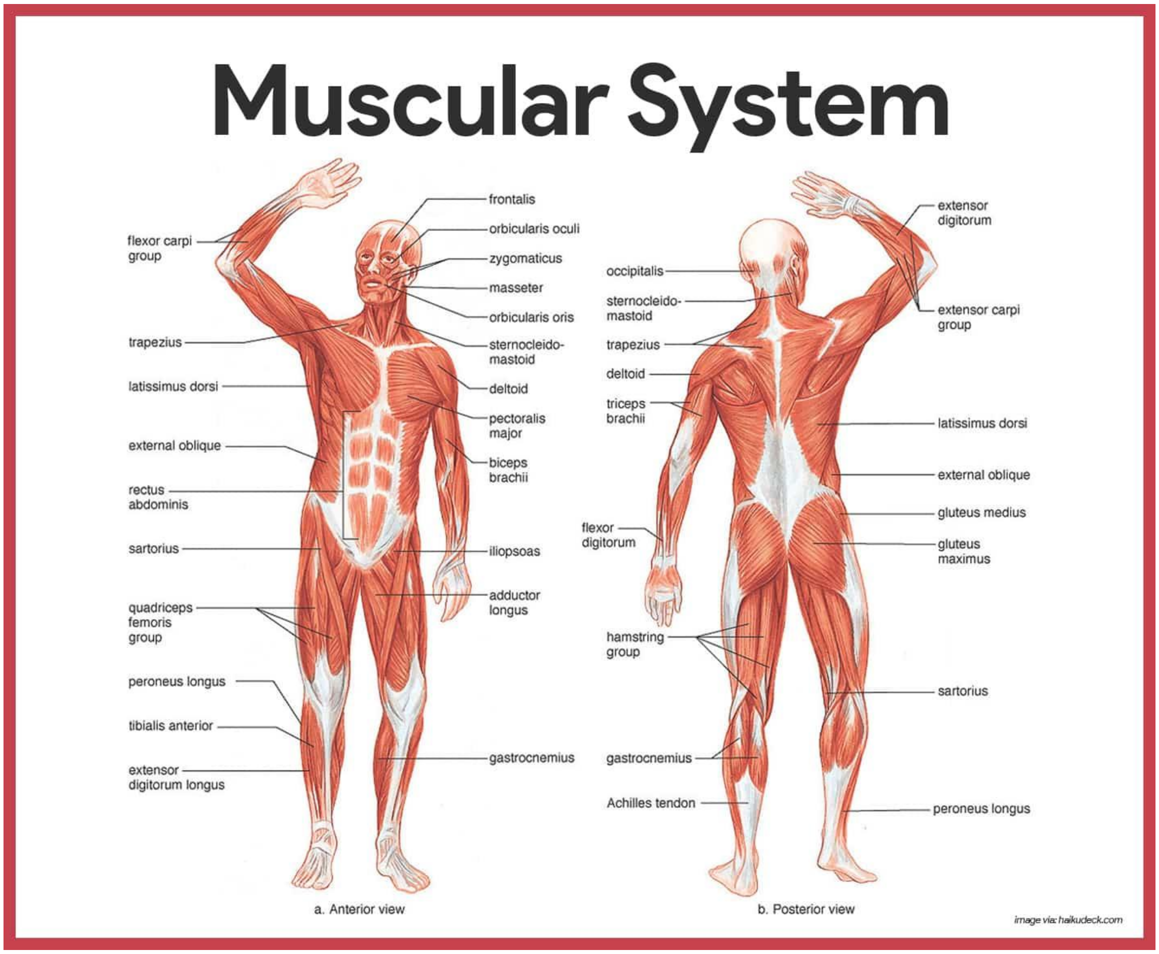
Cardiac muscles: These striated muscles look similar to skeletal muscles. Special cells called cardiomyocytes make up the fibers in cardiac muscles. Cardiomyocytes help your heart beat.

Smooth muscles: The proteins actin and myosin also make up smooth muscle fibers. In skeletal muscles, these proteins come together to form a spindle shape. In smooth muscles, these proteins appear in sheets. The sheets give this muscle tissue a smooth appearance.

You have all sizes of muscles in your body. The largest muscle is the gluteus maximus (the muscle that makes up your bottom). The smallest muscle is the stapedius, which is deep inside your ear. This tiny muscle helps you hear by controlling the vibration and movement of small bones in your ear.



	Main features	Histology
Skeletal muscle	• Fibers: striated, tubular and multi nucleated • Voluntary • Usually attached to skeleton	
Smooth muscle	• Fibers: non-striated, spindle-shaped, and uninucleated • Involuntary • Usually covering wall of internal organs	
Cardiac muscle	• Fibers: striated, branched and uninucleated • Involuntary • Only covering walls of the heart	



Skeletal muscle cells are multinucleate:

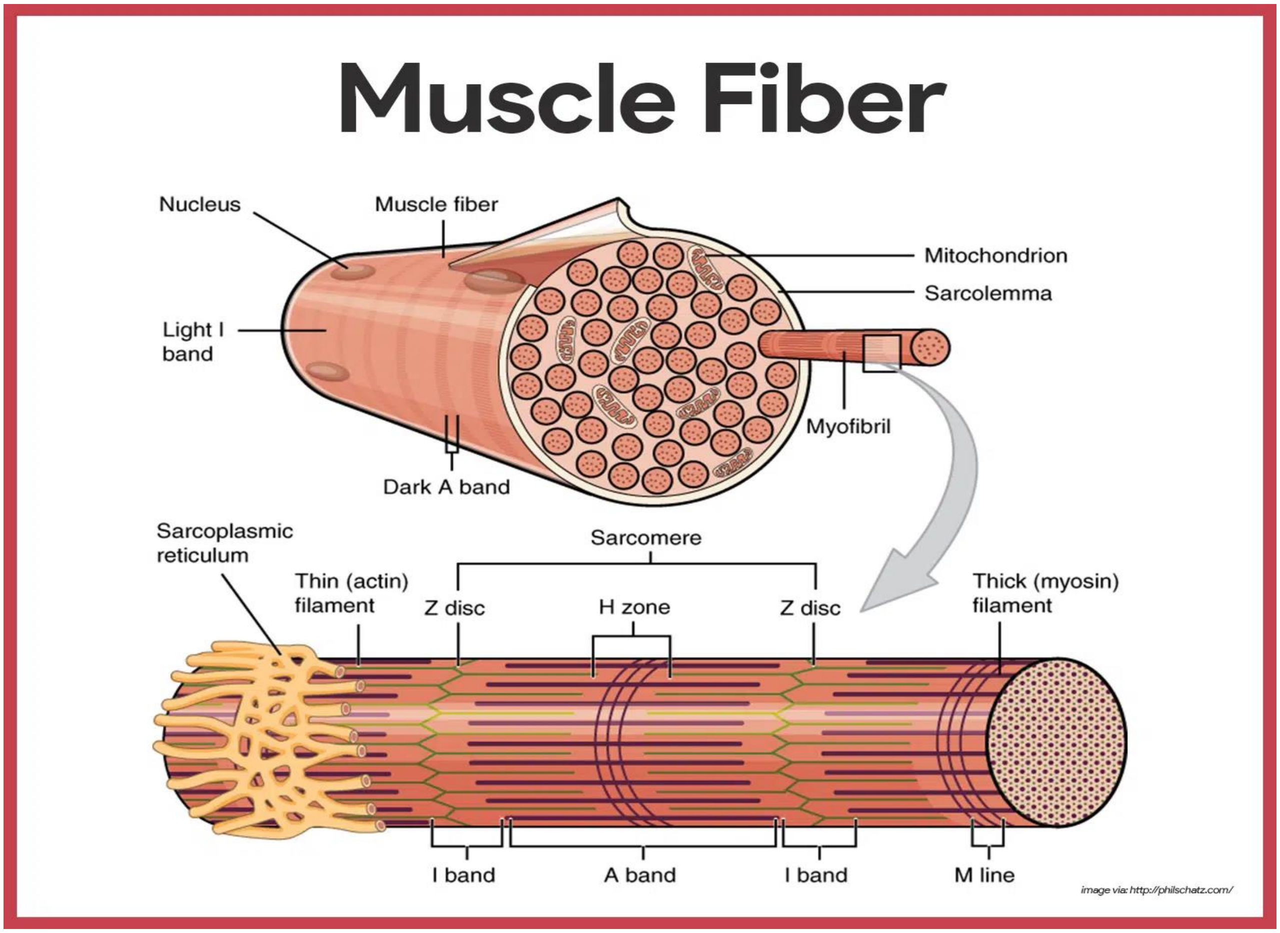
Sarcolemma. Many oval nuclei can be seen just beneath the plasma membrane, which is called the sarcolemma in muscle cells.

Myofibrils. The nuclei are pushed aside by long ribbonlike organelles, the myofibrils, which nearly fill the cytoplasm.

Light and dark bands. Alternating dark and light bands along the length of the perfectly aligned myofibrils give the muscle cell as a whole its striped appearance.

Sarcomeres. The myofibrils are actually chains of tiny contractile units called sarcomeres, which are aligned end to end like boxcars in a train along the length of the myofibrils.

Myofilaments. There are two types of threadlike protein myofilaments within each of our “boxcar” sarcomeres.



Thick filaments. The larger, thick filaments, also called myosin filaments, are made mostly of bundled molecules of the protein myosin, but they also contain ATPase enzymes, which split ATP to generate the power for muscle contraction.

Cross bridges. Notice that the midparts of the thick filaments are smooth, but their ends are studded with thick projections; these projections, or myosin beads, are called cross bridges when they link the thick and thin filaments together during contraction.

Thin filaments. The thin filaments are composed of the contractile protein called actin, plus some regulatory proteins that play a role in allowing (or preventing) myosin-bead binding to actin; the thin filaments, also called actin filaments, are anchored to the Z disc (a disclike membrane).

Sarcoplasmic reticulum. Another very important muscle fiber organelle is the sarcoplasmic reticulum, a specialized smooth endoplasmic reticulum; the interconnecting tubules and sacs of the SR surround each and every myofibril just as the sleeve of a loosely crocheted sweater surrounds your arm, and its major role is to store calcium and to release it on demand.

Muscle Contraction

The process of muscular contraction occurs over a number of key steps, including:

- Depolarisation and calcium ion release
- Actin and myosin cross-bridge formation
- Sliding mechanism of actin and myosin filaments
- Sarcomere shortening (muscle contraction)

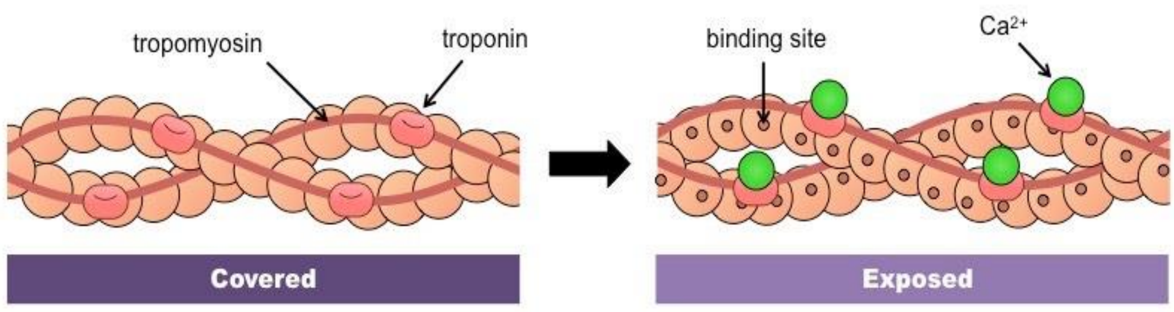
1. Depolarisation and Calcium Ion Release

- An action potential from a motor neuron triggers the release of acetylcholine into the motor end plate
- Acetylcholine initiates depolarisation within the sarcolemma, which is spread through the muscle fibre via T tubules
- Depolarisation causes the sarcoplasmic reticulum to release stores of calcium ions (Ca^{2+})
- Calcium ions play a pivotal role in initiating muscular contractions

2. Actin and Myosin Cross-Bridge Formation

- On actin, the binding sites for the myosin heads are covered by a blocking complex (troponin and tropomyosin)
- Calcium ions bind to troponin and reconfigure the complex, exposing the binding sites for the myosin heads
- The myosin heads then form a cross-bridge with the actin filaments

The Role of Calcium in Cross-Bridge Formation



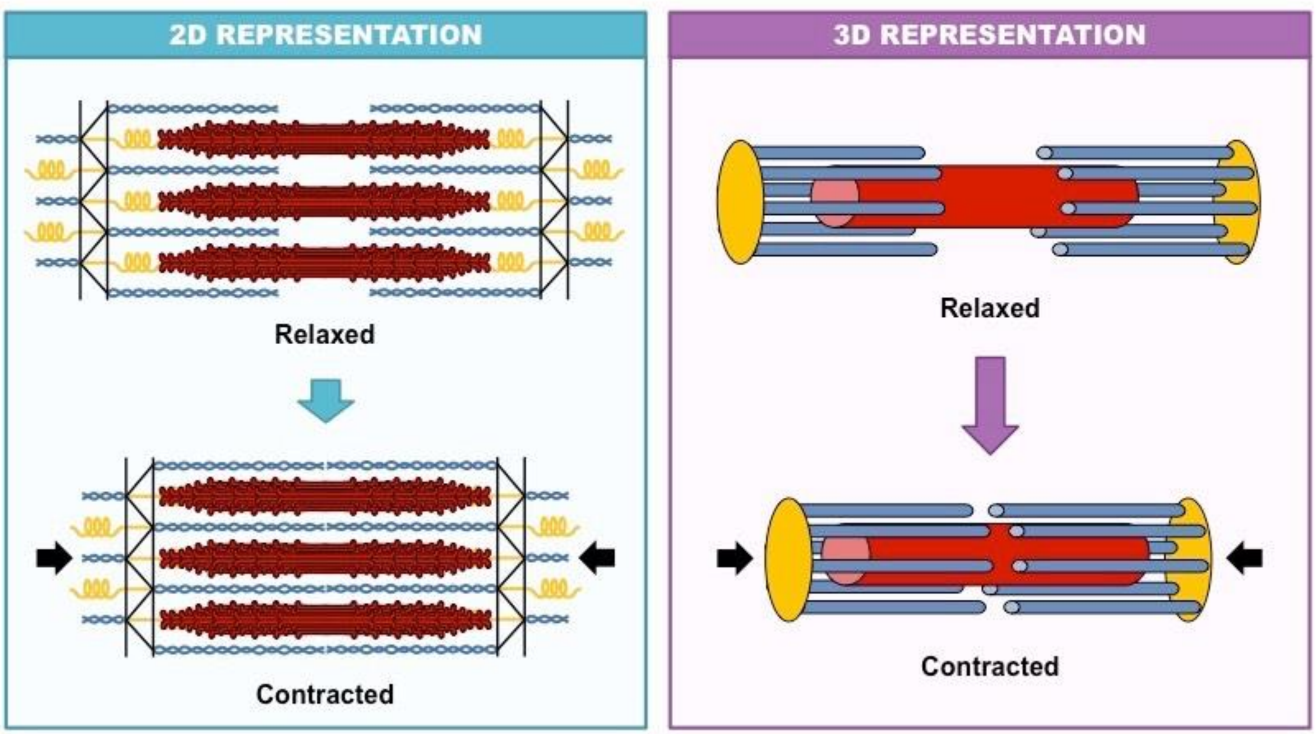
3. Sliding Mechanism of Actin and Myosin

- ATP binds to the myosin head, breaking the cross-bridge between actin and myosin
- ATP hydrolysis causes the myosin heads to change position and swivel, moving them towards the next actin binding site
- The myosin heads bind to the new actin sites and return to their original conformation
- This reorientation drags the actin along the myosin in a sliding mechanism
- The myosin heads move the actin filaments in a similar fashion to the way in which an oar propels a row boat

4. Sarcomere Shortening

- The repeated reorientation of the myosin heads drags the actin filaments along the length of the myosin
- As actin filaments are anchored to Z lines, the dragging of actin pulls the Z lines closer together, shortening the sarcomere
- As the individual sarcomeres become shorter in length, the muscle fibres as a whole contracts

Diagrams of Sarcomere Shortening



Summary of Muscle Contractions

- Action potential in a motor neuron triggers the release of Ca^{2+} ions from the sarcoplasmic reticulum
- Calcium ions bind to troponin (on actin) and cause tropomyosin to move, exposing binding sites for the myosin heads
- The actin filaments and myosin heads form a cross-bridge that is broken by ATP
- ATP hydrolysis causes the myosin heads to swivel and change orientation
- Swiveled myosin heads bind to the actin filament before returning to their original conformation (releasing ADP + Pi)
- The repositioning of the myosin heads move the actin filaments towards the centre of the sarcomere
- The sliding of actin along myosin therefore shortens the sarcomere, causing muscle contraction