Structural Organisation in Animals

LEVELS OF STRUCTURAL ORGANISATION IN A MULTICELLULAR ANIMAL

- A multicellular organism exhibits various levels of structural organisation which work in an integrated manner to contribute to its survival.

Cellular Level

- Cells are the structural and functional unit of life. In multicellular animals, cells show a considerable degree of division of labour among themselves due to specialisation and differentiation.

Tissue Level

- A group of one or more types of cells, similar in origin and specialised to perform a specific function, held together in specific extra-cellular materials constitute a tissue. Only four basic types of tissues are present in all complex animals.

Organ Level

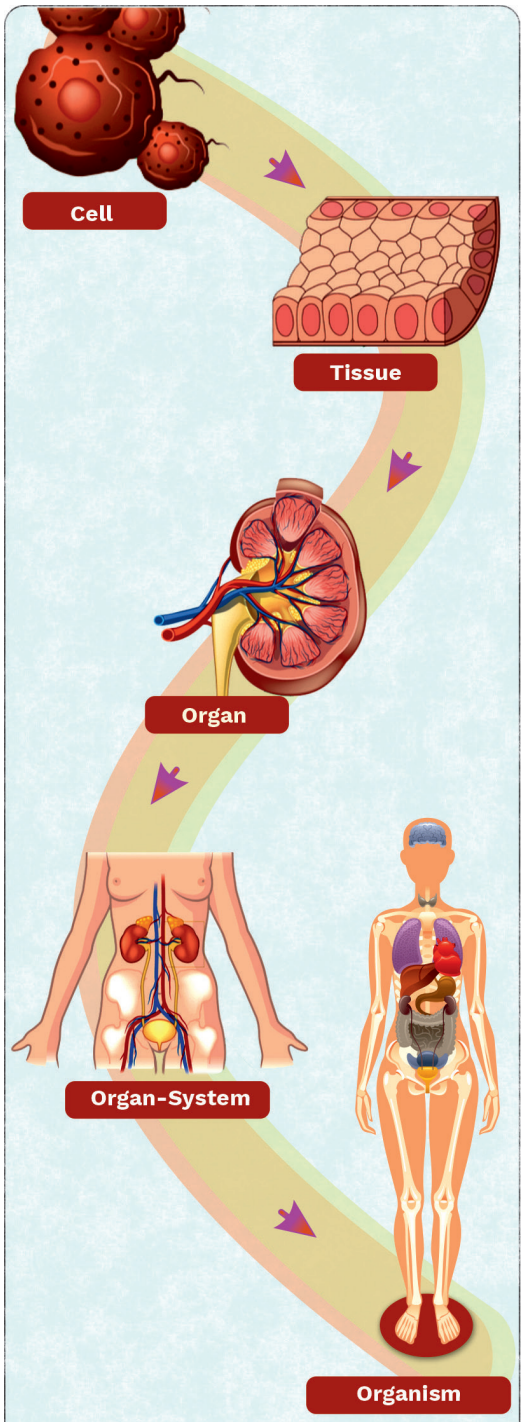
- Animal tissues are organised in specific proportions and patterns to form an organ. It performs specific functions with the help of integrated activities of its tissues, e.g., stomach, liver, urinary bladder, etc.

Organ-System Level

- An organ system comprises of two or more organs which function together by interacting physically or chemically in a coordinated manner to carry out major life processes, e.g., the digestive system performs a major life process of digestion and absorption of the digested food.

Organism

- An organism or an individual consists of several organ-systems which perform their functions in unison to sustain the individual. It is the highest level of structural organisation.

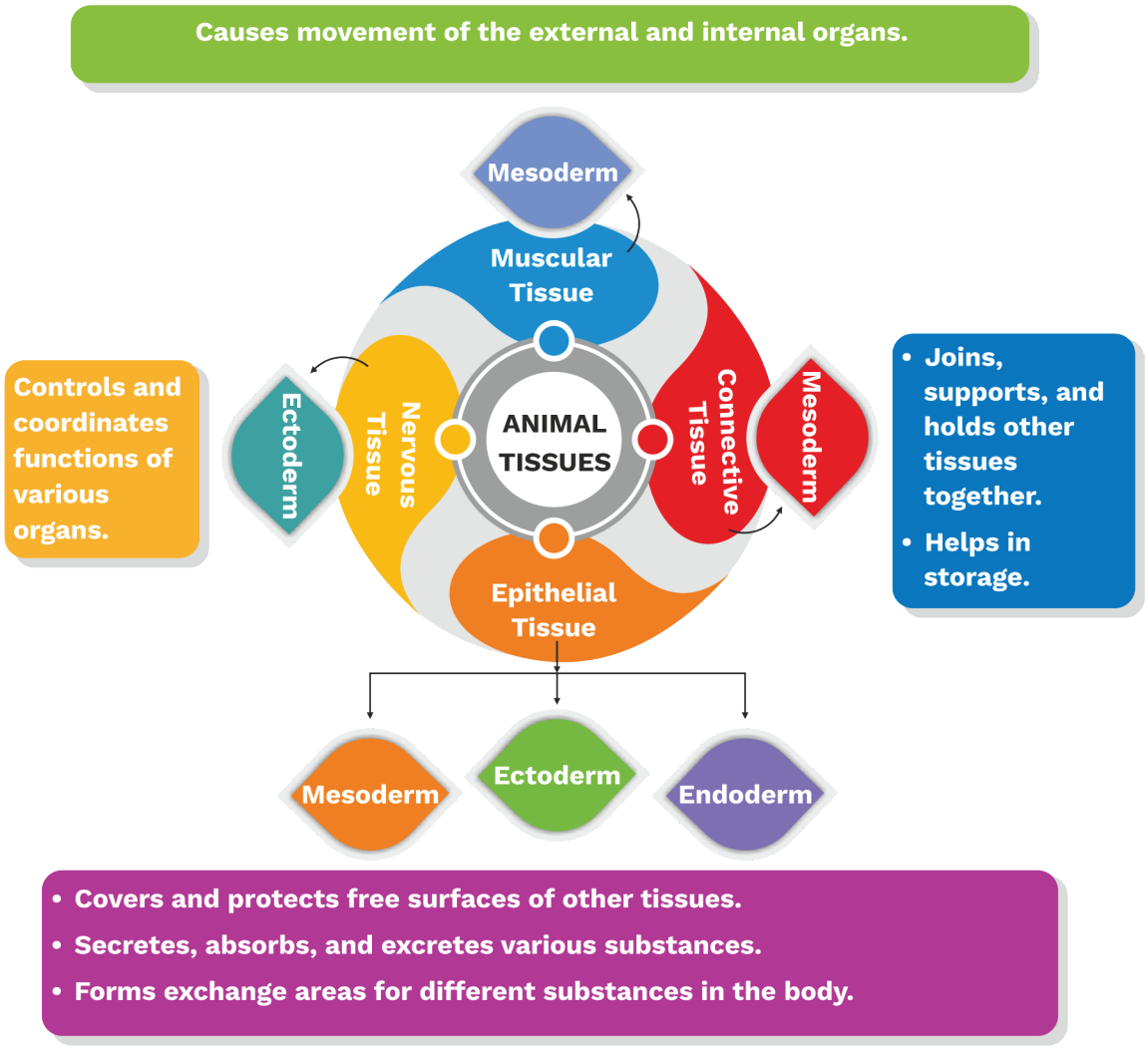


ANIMAL TISSUES

- Animal tissues are classified into four major classes based on the functions performed by their cells.
- These are epithelial tissue, connective tissue, muscular tissue, and neural tissue.

Gray Matter Alert!!!

The term 'Tissue' was coined by Bichat. He is considered as the 'Father of animal histology'.



EPITHELIAL TISSUE

- An epithelial tissue is commonly called as epithelium (pl.: epithelia).
- Ruysch coined the term 'epithelium' (Gr. *epi-* upon, *thelio-* grows) which means a tissue that grows upon other tissues.

- It consists of one or more layers of compactly arranged similar cells which provide a covering or a lining on the external and internal surfaces of many body parts.
- Epithelial tissue is the first tissue to be formed in the embryo and the first tissue to evolve in the animal kingdom.

Characteristics

- Epithelial cells are compactly packed with little intercellular matrix and are arranged in one or more layers.
- The cells of a single-layered epithelial tissue or the cells of the lowermost layer of a multi-layered epithelial tissue always rest on a extra-cellular basement membrane which separates the epithelial tissue from the underlying connective tissue.
- It consists of an outer, thin layer of muco-polysaccharides and glycoproteins situated close to the epithelial cells and an inner, thick layer of collagen or reticular fibres.
- The free surface of the epithelial tissue faces either a body fluid or the outside environment.
- Epithelial cells are separated by very thin films of extra cellular materials. All epithelial cells are held together by specialised junctions which provide them with both structural and functional links.
- They include tight junctions to stop leaking of substances across a tissue, adhering junctions to keep neighbouring cells cemented together, and gap junctions to connect the cytoplasm of adjoining cells for easy transfer of substances.
- Blood vessels are absent in the epithelial tissue. The exchange of materials takes place by diffusion through basement membrane from the blood vessels of underlying connective tissue.
- It shows a very high capacity of mitotic cell division.

Definitions

Tissue: A group of cells of same origin along with intercellular substances that perform a specific function is called a tissue.
Histology: The study of microscopic anatomy of tissues is called histology.

Previous Year's Question

Basement membrane is made up of:
(1) no cell product of epithelial cell
(2) epidermal cell only
(3) endodermal cell
(4) both (2) and (3)

Gray Matter Alert!!!

Tight junctions: Plasma membranes of adjacent cells are fused at intervals by cell junctions called tight junctions. They help to stop substances from leaking across a tissue.
Adhering junctions: Cell junctions which perform cementing functions to keep neighbouring cells together.
Gap junction: Cell junctions which facilitate the cells to communicate with each other by connecting the cytoplasm of adjoining cells for rapid transfer of ions, small molecules, and sometimes big molecules.

Types of Epithelial Tissue

- On the basis of arrangement of cells, epithelium is classified into two types–simple and compound epithelium.

Simple Epithelium

- A single layer of epithelial cells which directly rest on the basement membrane and function as a lining for body cavities, tubes, and ducts.
- Simple epithelium is classified into three types based on the structural modification of the cells- squamous epithelium, cuboidal epithelium, columnar epithelium.

Squamous Epithelium

- It is formed of a single thin layer of flattened cells with prominent centrally located nuclei. The cells have irregular boundaries and usually appear polygonal in shape.
- It is found in the terminal bronchioles and alveoli of the lungs, walls of blood vessels, lymph vessels, Bowman's capsules, thin segment of the descending limb of Henle's loop, internal ear, heart, coelomic cavities, and rete testis.
- Simple squamous epithelium is involved in forming exchange boundaries in the body for the diffusion of substances. It also performs protective, excretory, and secretory functions.

Cuboidal Epithelium

- Made up of a single layer of cube-like cells resting on a basement membrane. The cells have prominent centrally located rounded nuclei and appear polygonal in surface view.
- It is commonly found in ducts of glands, proximal convoluted tubules, thick segment of descending limb of Henle's loop, thick segments of the ascending limb of Henle's loop and distal convoluted tubules of the nephrons of kidneys, parts of inner ear, thyroid follicles, ovaries, seminiferous tubules, sweat glands of

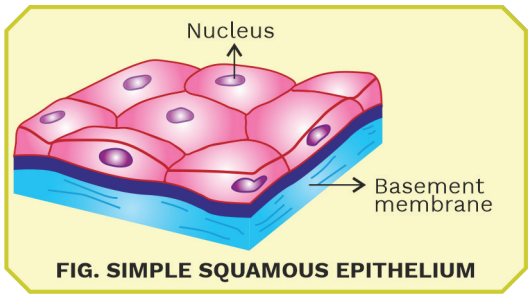


FIG. SIMPLE SQUAMOUS EPITHELIUM

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The squamous epithelium of the blood vessels, lymph vessels and heart is called endothelium. Mesothelium is the squamous epithelium of the coelom.

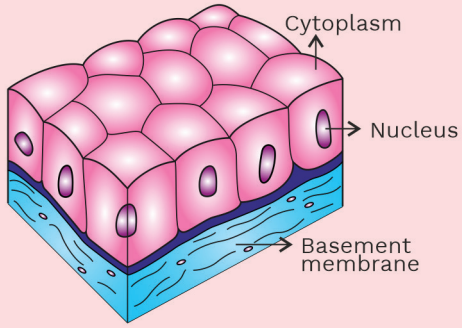

FIG. SIMPLE CUBOIDAL EPITHELIUM

Definition

Microvilli: Finger-like protrusions of cell membrane present at the free surface of various cells for increasing their surface area, often giving a brush-border appearance.

mammalian skin, thin bronchioles, ciliary bodies, choroid, and iris of eyes. It is also present in the inner surface of the lens, and pigment cell layer of the retina.

- Often, the free surface of the cells of cuboidal epithelium shows brush-border appearance due to the formation of microvilli. Microvilli increase the surface area for absorption.
- The main functions of the cuboidal epithelium

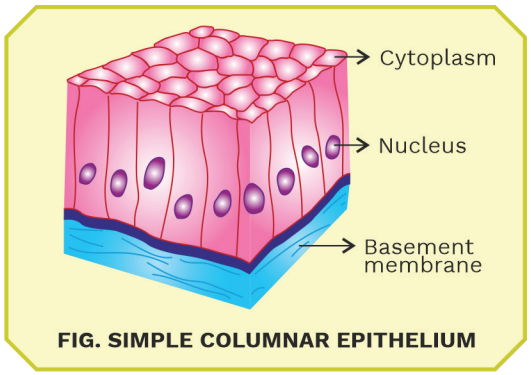

FIG. SIMPLE COLUMNAR EPITHELIUM

are secretion and absorption. It also functions to provide protection, perform excretion and gamete formation.

Columnar Epithelium

- It is composed of a single layer of tall and slender cells arranged side by side like a column. The nuclei lie at the base of the cells.
- It is found in the lining of stomach, intestine, gall bladder and bile duct. The columnar epithelium of the stomach and intestine contain mucus-secreting cells (goblet cells), hence also called mucous membrane. The mucous membrane of the intestine has microvilli (brush-border epithelium) for increasing the absorptive surface area.
- Columnar epithelium forms the glandular epithelium of gastric glands, intestinal glands, and pancreatic lobules where it mainly helps in secretion.
- Its main function is secretion and absorption.

Ciliated Epithelium

- If the cuboidal and columnar cells bear cilia on their free surface, they are called as ciliated cuboidal epithelium and ciliated columnar

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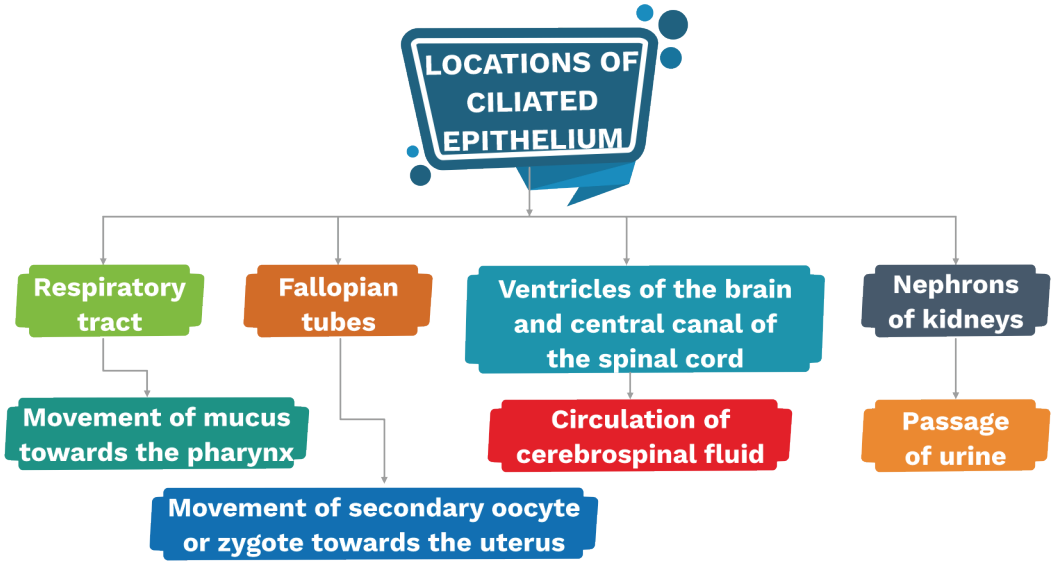
Pseudostratified Epithelium: It consists of a single layer of unequal columnar cells. The normal columnar cells have oval-shaped nuclei whereas the shorter cells have spherical nuclei present at different levels, thus appearing to be multi-layered. The shorter cells may secrete mucus and lack cilia. The longer cells may have cilia on their free surfaces. It is found in trachea, larger bronchi, a part of pharynx, vas deferens, epididymis, male urethra, and large ducts of certain glands like parotid glands.



epithelium, respectively.

- Ciliated cuboidal epithelium is present in certain parts of nephrons of the kidneys whereas ciliated columnar epithelium is mainly present in the inner surface of most of the respiratory tract including bronchioles, fallopian tubes, ventricles of the brain, central canal of the spinal cord, tympanic cavity of middle ear and Eustachian tube.
- The cilia mainly function to move mucus or particles constantly in a specific direction over the epithelium.

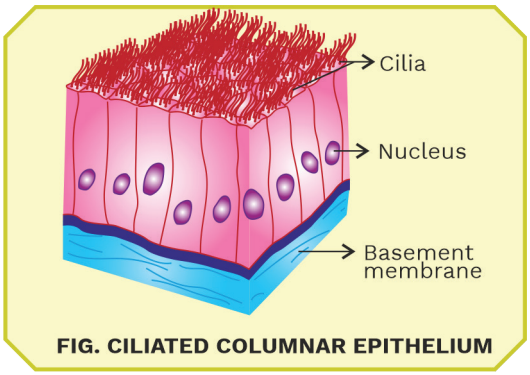


FIG. CILIATED COLUMNAR EPITHELIUM

Glandular Epithelium

- Some of the cuboidal and columnar cells modify to become secretory and form glandular epithelium and glands.
- Glands are classified as unicellular glands and multicellular glands based on the number of cells; exocrine glands, endocrine glands, and heterocrine glands based on the mode of pouring their secretion (presence or absence of ducts); and merocrine glands, apocrine glands, and holocrine glands based on the process of releasing their secretion.

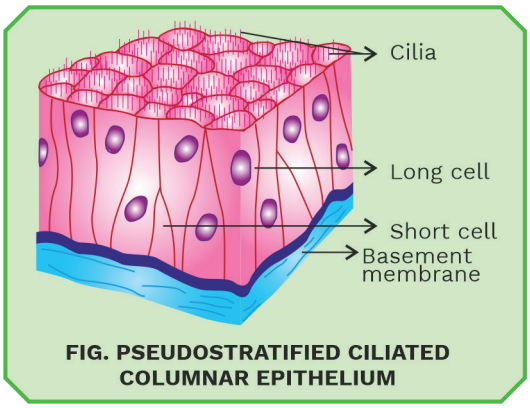


FIG. PSEUDOSTRATIFIED CILIATED COLUMNAR EPITHELIUM

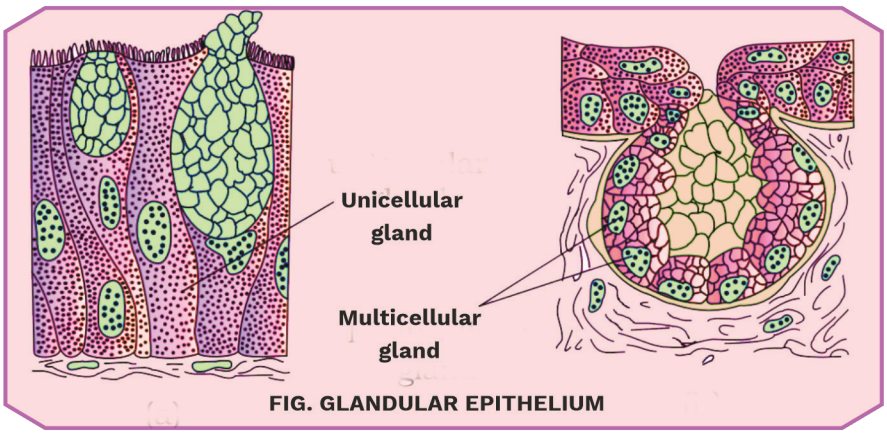


FIG. GLANDULAR EPITHELIUM

CLASSIFICATION OF GLANDULAR EPITHELIUM	
BASED ON THE NUMBER OF CELLS	
Unicellular gland	Multicellular gland
Consist of isolated glandular cells e.g., Goblet cells of alimentary canal.	Consist of cluster of cells e.g., Salivary glands, gastric and intestinal glands.

BASED ON THE PRESENCE AND ABSENCE OF DUCTS		
Exocrine glands	Endocrine glands	Heterocrine glands
Secrete mucus, saliva, earwax, oil, milk, enzymes, and other cell products.	Secrete hormones	Secrete both enzymes and hormones
Situated close to their target site	Situated far from their target site	Release enzymes for target sites present near and hormones for target sites present far
Glands with ducts	Ductless glands	Ducts present for delivering enzymes; hormones poured directly in the blood
E.g., Salivary glands, gastric glands, intestinal glands, tear glands, sweat glands, oil glands, etc.	E.g., Thyroid gland, adrenal gland, thymus gland, etc.	E.g., Pancreas.

BASED ON THE PROCESS OF RELEASING THEIR SECRETION		
Merocrine glands	**Apocrine glands**	**Holocrine glands**
Cell secretion discharged by exocytosis	**The apical part of the cell carrying the secretion breaks off as discharge**	**The entire cell is filled with its secretion and is discharged.**
No loss of entire cell or its part	**Apical part of the cell is lost.**	**Entire cell is lost**
E.g., Goblet cells, salivary glands, etc.	**E.g., Mammary glands**	**E.g., Sebaceous glands**

Compound Epithelium

- It consists of more than one layer of cells (multi-layered). The cells of the deepest layer rest on the basement membrane.
- The compound epithelium is present where protection for underlying tissue against mechanical, chemical, or osmotic stresses is required. It has a limited role in secretion and absorption.
- Compound epithelium is of two major types, namely, stratified epithelium and transitional epithelium.

COMPOUND EPITHELIUM

Stratified Epithelium

- Epithelial cells are arranged in many layers.
- Mostly columnar cells or cuboidal cells are present in the deepest layer.
- Classified into four types based on the shape of cells in the superficial layer.

1. **Stratified squamous epithelium:**
   The cells of the deepest layer divide mitotically to form new cells.
   a. **Keratinised stratified squamous epithelium:** The superficial cells lose their cytoplasm and deposit keratin to become hard and waterproof, e.g., epidermis of human skin.
   b. **Non-keratinised stratified squamous epithelium:** The superficial cells do not have keratin deposition and thus are not waterproof. They provide moderate protection, e.g., epithelium of buccal cavity, tongue, pharynx, vocal cords, oesophagus, lower parts of urethra, cervix, vagina, conjunctiva, cornea of eye, middle part of anal canal.
2. **Stratified cuboidal epithelium:** Superficial cells are cuboidal in shape, e.g., lining of the inner surfaces of large salivary and pancreatic duct, and ducts of sweat glands.
3. **Stratified columnar epithelium:** Superficial cells are columnar in shape, e.g., Lining of epiglottis, ducts of mammary glands, and parts of urethra.
4. **Stratified ciliated columnar epithelium:** Superficial columnar cells have cilia, e.g., lining of larynx and upper parts of the soft palate.

Transitional Epithelium

- Epithelial cells are arranged in four to six layers.
- It does not have a basement membrane.
- Cells of the deepest layer are cuboidal or columnar.
- Cells of the middle layer are pear-shaped.
- Cells of the superficial layer are large and globular.
- It has the ability to stretch without undergoing any damage.
- It does not bear cilia.
- It is found in renal calyces, renal pelvis, ureters, urinary bladder and parts of the urethra.

CONNECTIVE TISSUE

- These tissues are the most abundant and widely distributed in the body of higher animals.
- They link and support other tissues or organs of the body.
- The cells of the connective tissue are always present in a ground substance or an extra-cellular matrix.
- The extra-cellular matrix may be solid, liquid, or gel, i.e., it can be soft, dense, and mineralized, fluidly, or fibre-free.
- Some cells of connective tissue secrete proteins and modified carbohydrates

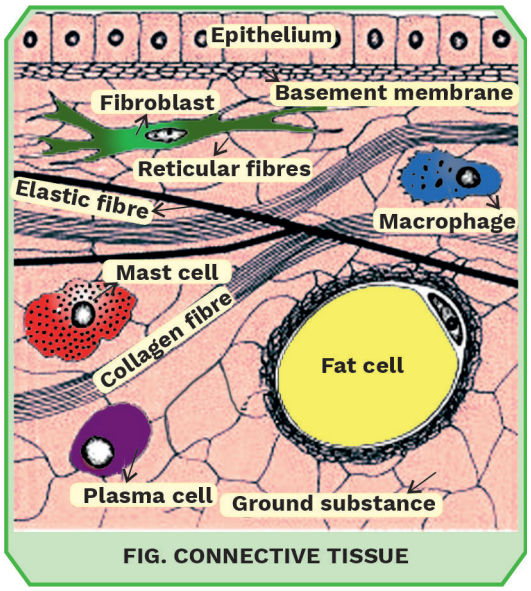
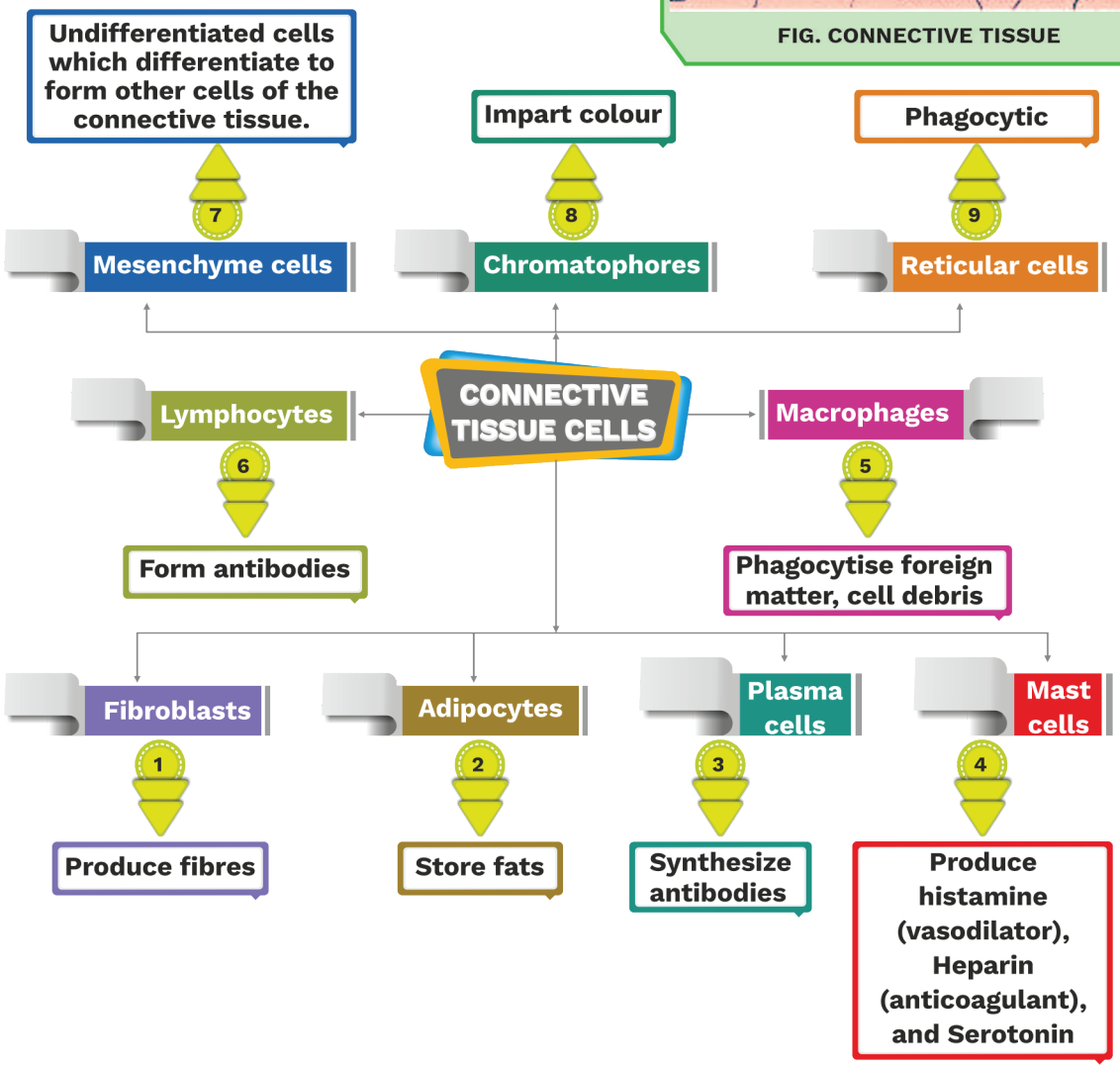
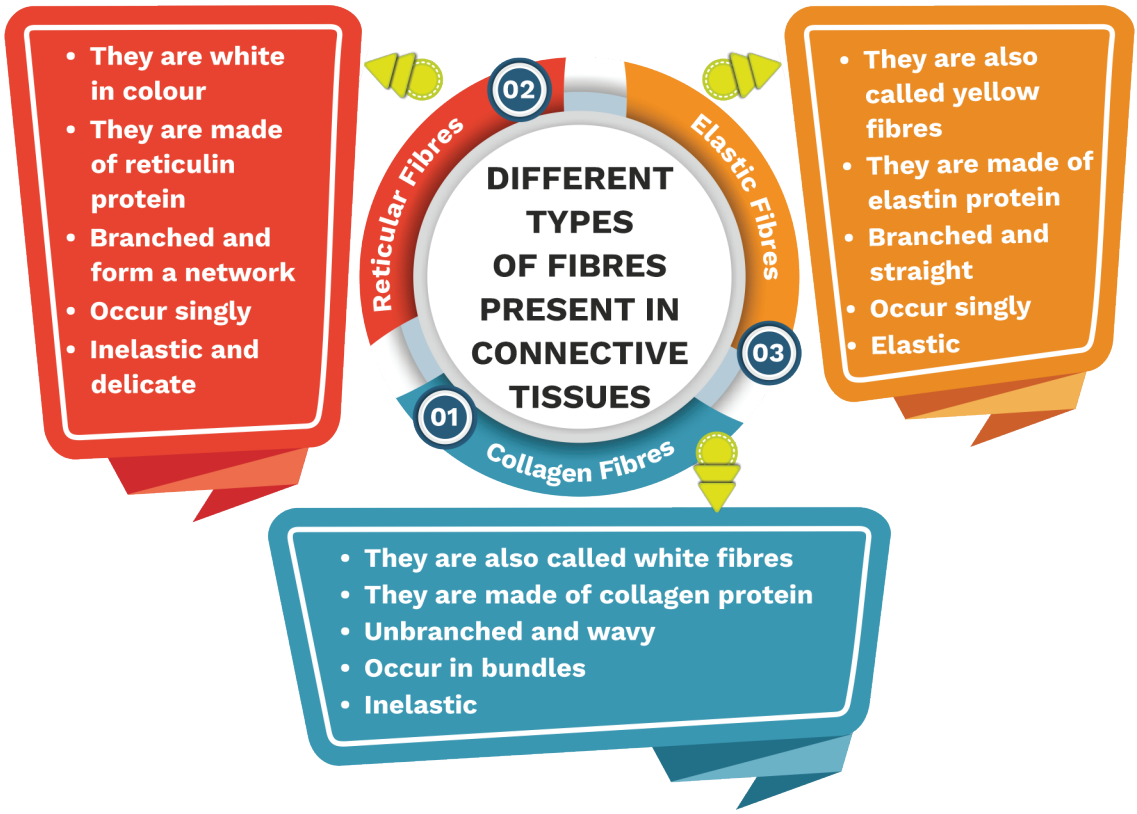


FIG. CONNECTIVE TISSUE



(mucopolysaccharides) such as hyaluronic acid, which accumulate between cells and fibres to form the matrix.

- The connective tissue contains different types of cells and fibres in the matrix.



Types of Connective Tissues

- Connective tissues are of the followng three types, i.e., loose connective tissue, dense connective tissue and specialised connective tissue.

Loose Connective Tissue

- The cells and fibres of the loose connective tissue are loosely arranged in a semi-fluid ground substance. They are of two types, namely, areolar, and adipose loose connective tissue.

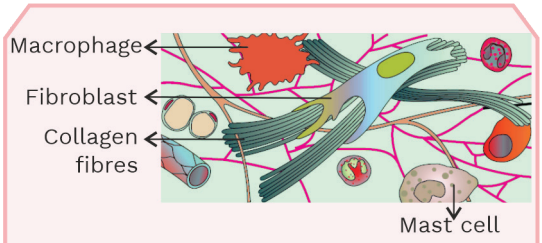


FIG. AREOLAR TISSUE

Areolar Tissue

- It is the most widely distributed connective tissue in the body of higher vertebrates.
- It occurs beneath the epithelia of many hollow visceral organs, skin and on the walls of arteries and veins.
- It contains matrix, fibroblasts, mast cells, macrophages, collagen fibres, elastin fibres, plasma cells, mesenchyme cells, chromatophores.
- Areolar tissue binds skin with the muscles and mesenteries, thus acting as a support framework for the epithelium.
- It acts as a packing tissue in almost all the organs to keep the organs in place and in normal shape. It provides a medium for rapid diffusion of materials. It helps in healing wounds.
- Histamine attracts phagocytes to the site of infection. Heparin avoids blood coagulation. Histamine of mast cells is involved in allergic and inflammatory reactions.

Adipose Tissue

- Adipose tissue stores fat in cells called adipocytes. Its matrix also includes fibroblasts, macrophages, collagen fibres and elastin fibres. The excess nutrients which are not converted to fats immediately are also stored in this tissue.
- It is found mainly beneath the skin, around kidneys, eyeballs, heart and blood vessels, in mesentery, and bone marrow. It prevents heat loss and forms shock-absorbing cushions around kidneys and eyeballs.

Dense Connective Tissue

- In dense connective tissues, the fibroblasts, and the fibres are compactly packed.
- There are two types of dense connective tissues based on regular or irregular orientation of the fibres.

Previous Year's Question

Histamine secreting cells are found in
(1) connective tissues
(2) lungs
(3) muscular tissue
(4) nervous tissue

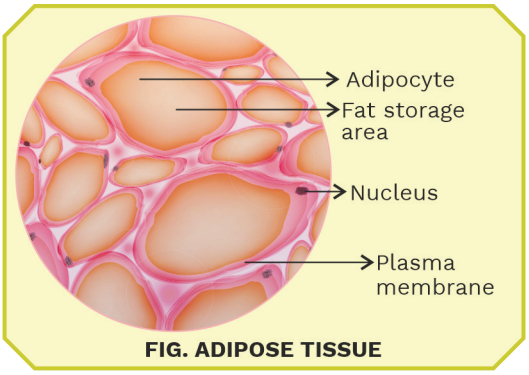


FIG. ADIPOSE TISSUE

Gray Matter Alert!!!

When boiled in water, collagen changes into gelatin.

DENSE REGULAR CONNECTIVE TISSUE

- Collagen fibres are present in rows between many parallel bundles of fibres, i.e., fibres have a regular orientation.
- E.g., Tendons are bundles of white or collagen fibres which attach skeletal muscles to bones.
- Ligaments are bundles of yellow fibres which joins one bone to another.

DENSE IRREGULAR CONNECTIVE TISSUE

- Fibroblasts and many collagen fibres are oriented differently, i.e., fibres have irregular orientation.
- E.g., The dense connective tissue present in the skin.

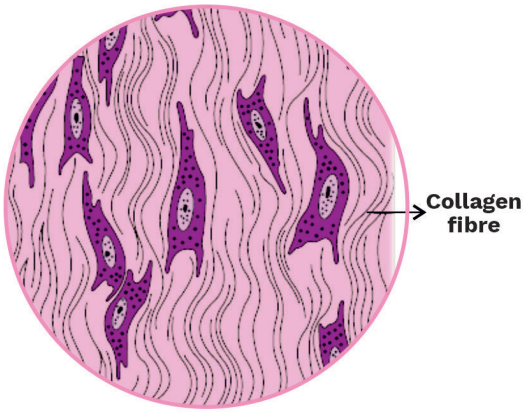


FIG. DENSE REGULAR CONNECTIVE TISSUE

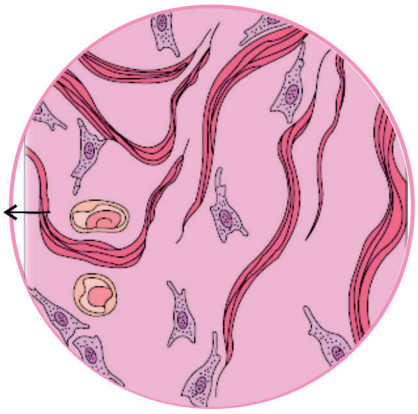


FIG. DENSE IRREGULAR CONNECTIVE TISSUE

Specialised Connective Tissue

- The various specialised connective tissues are cartilage, bone, blood, and lymph.

Cartilage

- The cells of the cartilage are called chondrocytes and they are enclosed in small fluid-filled cavities called lacunae, present within the matrix secreted by them.
- The matrix consists of water, proteoglycans, lipids, collagen fibres, etc. The main mucoprotein

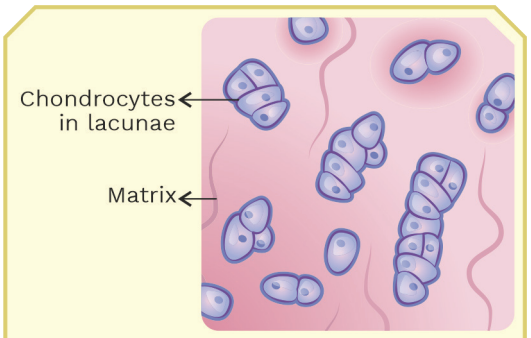


FIG. HYALINE CARTILAGE

is aggrecan and main carbohydrates are glycosaminoglycans like chondroitin sulphate, keratin sulphate and hyaluronic acid. It resists compression.

- Cartilage matrix including its content is externally covered by a sheath of white fibrous connective tissue called Perichondrium. Due to the presence of outermost perichondrium sheath, the growth of cartilage is peripheral (unidirectional).
- Blood vessels form a network of capillaries from which nutrients diffuse into the matrix and consequently to chondrocytes.

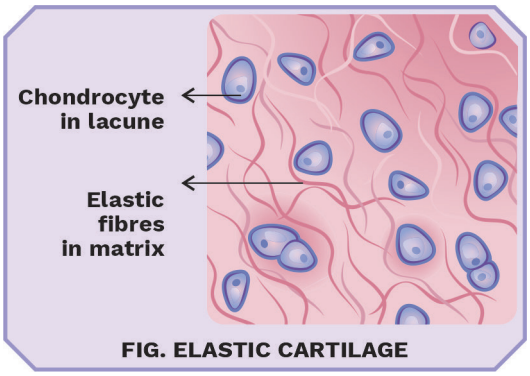


FIG. ELASTIC CARTILAGE

Previous Year's Question

During an injury, nasal septum gets damaged and for its recovery which cartilage is preferred?
(1) Elastic cartilage
(2) Hyaline cartilage
(3) Calcified cartilage
(4) Fibrous cartilage

Hyaline cartilage

- It is translucent, elastic, firm and bluish in colour.
- It is the commonest cartilage in the body due to its qualities of elasticity and resistance to crushing and shock absorbing property.
- Consist of less collagen fibres.
- It is present at the ends of long bones on the articular surface (articular cartilage), as costal cartilage that attaches the ribs to the sternum, as tracheal and bronchial rings, in hyoid apparatus, nasal septum, parts of larynx and most of the embryonic skeleton.

White fibrocartilage

- Matrix is opaque as it contains thick bundles of collagen fibres.
- It is the strongest cartilage.
- It has scattered lacunae containing chondrocytes.
- Occurs in the intervertebral disc (cushions between vertebra), pubis symphysis and articular discs in the knee joint.

Yellow fibrocartilage

- Matrix is opaque as it contains yellow elastic fibres.
- Matrix also contains chondrocytes in lacunae between yellow fibres.
- Due to presence of yellow fibres, it is very flexible.
- It is present in the pinna of ear, wall of eustachian tubes, external auditory canal, epiglottis, and at the tip of nose.

Calcified cartilage

- It is similar to hyaline cartilage, but its matrix is impregnated with calcium salts. It is hard, inelastic, and brittle due to presence of calcium carbonate.

  Example, supra scapula of pectoral girdle of frog, and vertebrae of shark.

- Cartilage is classified into the following four types:

Bone

- Bones have a hard and non-pliable matrix rich in calcium salts and collagen fibres which give them strength to give a structural frame to the body.
- Long bones of the hindlimbs bear the weight of the body, whereas other bones support and protect softer tissues and organs. Along with the skeletal muscles, bones help to bring about movements.
- A mammalian bone is enveloped by a sheath of white fibrous collagenous tissue called periosteum which contains blood vessels and bone-forming cells called osteoblasts.
- The matrix is composed of inactive osteocytes (in fluid-filled space called bone lacuna), ossein protein, and salts like calcium phosphate, calcium carbonate, magnesium phosphate, etc.
- The bone matrix also consists of many Haversian canals, each of which contains an artery, a vein, a lymph vessel, a nerve, and bone cells.
- The bone cavity of long bones is called bone marrow cavity and it is covered by a layer called endosteum (made of white fibrous tissue and osteoblasts). The bone marrow cavity is filled with a semisolid fatty neurovascular tissue called as bone marrow.
- Bone marrow is of two types, i.e., red bone marrow and yellow bone marrow. The red bone marrow is highly vascular reticular tissue which synthesises erythrocytes (haemopoiesis) and granular leucocytes.
- The yellow bone marrow mainly stores fats. It performs haemopoiesis only in case of an emergency.

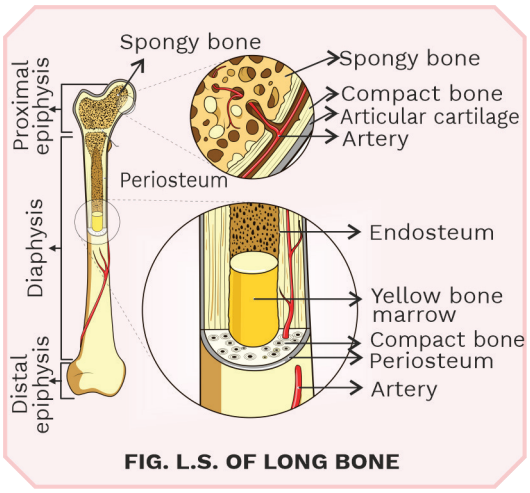
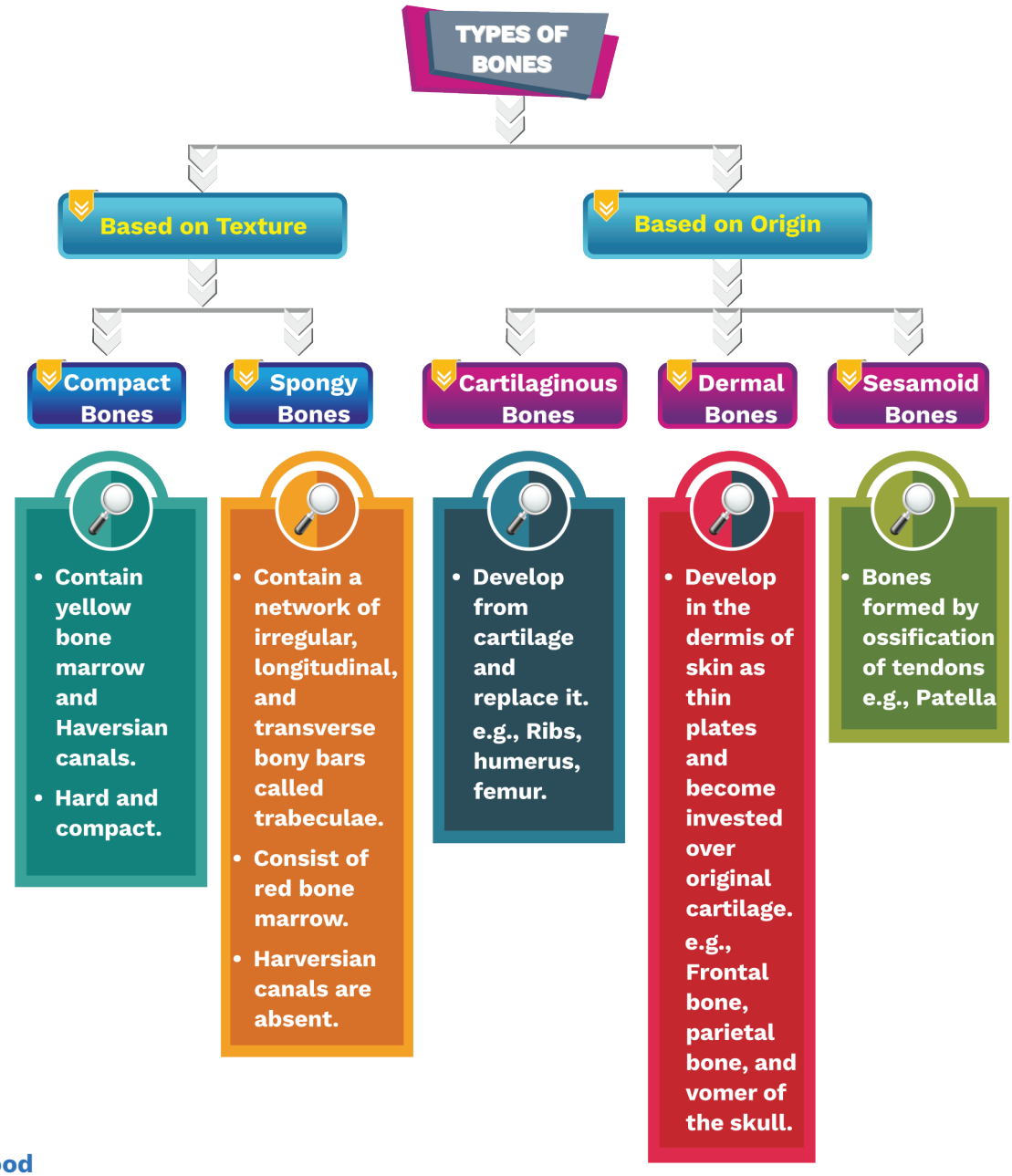


FIG. L.S. OF LONG BONE

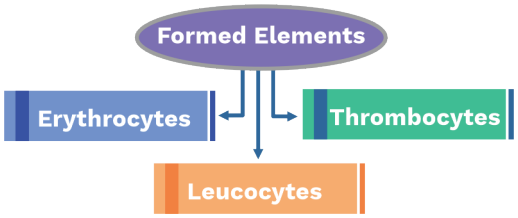
Previous Year's Question

Bone is mainly composed of
(1) Iron and phosphorus
(2) Sulphur and calcium
(3) Calcium and phosphorus
(4) Calcium and magnesium



Blood

- Blood is a vascular or fluid (motile) connective tissue containing plasma and formed elements (free blood corpuscles or cells).
- The matrix is not formed by tissue cells and is devoid of fibres. The cells of blood do not have the power of multiplication (cell division).



- Blood is heavier than water and slightly alkaline in nature (pH range –7.36 to 7.54; average pH 7.4).
- Blood forms about 6–10% of the body weight. A healthy adult human has about 5.5 litres of blood.
- Haemopoiesis is the process of formation of the blood. In a mammalian embryo, yolk sac, liver, bone marrow, lymph nodes, spleen and thymus are haemopoietic organs.
- However, in adults, most of the blood cells are formed in the red bone marrow.
- Blood transports food materials, respiratory gases, hormones, excretory wastes, and heat. It also maintains the pH, balance the amount of water, helps in healing, etc.

Composition of Blood

- Blood is composed of 55% plasma and 45% formed elements.
- **Plasma**
  - It is a light yellow (straw-coloured) liquid consisting of 90-92% water and 6-8% proteins.
  - Major proteins present in blood plasma are fibrinogen (for clotting of blood), globulins (involved in defence mechanism), and albumins (maintain osmotic balance).
  - Plasma contains mineral salts (0.9% of plasma) like chlorides, bicarbonates, sulphates, and phosphates of sodium, potassium, calcium, iron, and magnesium.
  - Many cellular products like enzymes and hormones, cellular wastes like urea, gases like O_2, CO_2 and nitrogen, and nutrients like glucose, fatty acids, amino acids, nucleosides, etc., and anticoagulant heparin are also found in the blood plasma.
- **Formed Elements**
  - The formed elements of blood consist of two types of corpuscles (blood cells) namely erythrocytes (red blood cells) and leucocytes

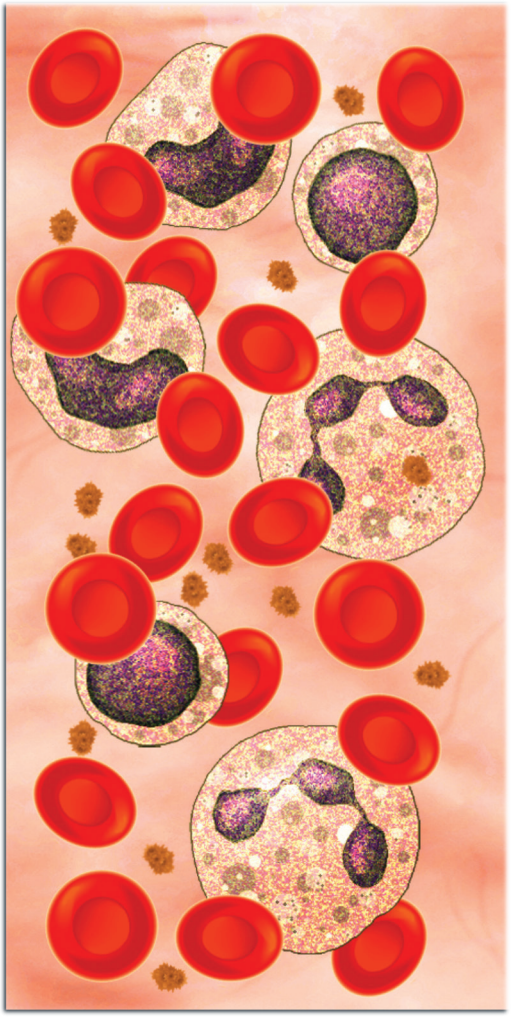


FIG. PLASMA AND FORMED ELEMENTS

(white blood cells), and thrombocytes (platelets).

- **Erythrocytes (Red Blood Cells, RBCs)**
  - They are the most abundant blood cells (5 million to 5.5 million per cubic mm of blood in a healthy adult human).
  - Human erythrocytes are small, rounded, biconcave and measure 7–8 μ in diameter and 2 μ in thickness near the rim.
  - Mature erythrocytes do not contain cell organelles such as nucleus, mitochondria, endoplasmic reticulum, etc.
  - The entire cell space is filled with a red coloured, iron-containing complex protein called haemoglobin causing an increase in O_2 carrying capacity.
  - Haemoglobin is formed of globin protein and an Fe^{2+} porphyrin complex. Globin protein is formed of 4 polypeptide chains –2 α and 2 β chains. Each haemoglobin molecule contains 4 heme groups attached to each molecule of globin.
  - Each heme group consists of an iron-containing porphyrin ring. The porphyrin ring contains an atom of iron and 4 pyrrole rings. An erythrocyte has about 280 million haemoglobin molecules in its cytoplasm and only haemoglobin constitute 36% of total weight of RBC (90% of dry weight). A healthy individual has 12-16 gms of haemoglobin in every 100 ml of blood.
  - In humans, erythrocyte has a lifespan of 120 days. Worn out RBCs or fragments of RBCs are disposed off by phagocytosis by macrophages in the liver and spleen (graveyard of RBCs).
  - On exposure to a high partial pressure of O_2 in the lungs, 4 molecules of O_2 loosely bind to 4 Fe^{2+} ions of haemoglobin to form oxyhaemoglobin.
  - Oxyhaemoglobin releases O_2 at low partial pressure of O_2 in the tissue. Some of the

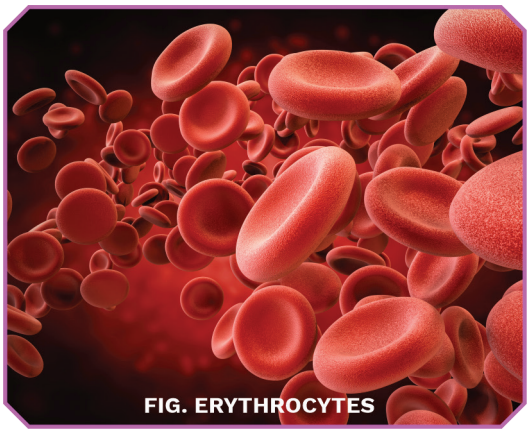


FIG. ERYTHROCYTES

Gray Matter Alert!!!

It is the chemical breaking up of the haemoglobin that gives blue, green and yellow colouration to a bruise in which the blood escapes from the ruptured blood vessel into the subcutaneous tissue.

CO_2 combines with globin of haemoglobin of erythrocytes and is carried to lungs. RBCs carry CO_2 as bicarbonate ions formed in them by catalytic activity of carbonic anhydrase enzyme.

- **Leucocytes (White Blood Cells, WBCs)**
  - These are the nucleated, colourless blood cells with comparatively short life span.
  - They are relatively less in number which averages 6000-8000 per cubic mm of blood.
  - Based on size, granules, staining reactions, shape of nuclei, etc., leucocytes are classified into - granulocytes (having granules in the cytoplasm) and agranulocytes (absence of granules in the cytoplasm).
- **Thrombocytes (Blood Platelets)**
  - These are biconvex or rounded, small cell fragments produced by megakaryocytes in the bone marrow.
  - They are smallest in size having a diameter of 2 to 3 μ. The life span of platelets is about a week.
  - The colourless platelets number varies from 1,50,000-3,50,000 per cubic mm of blood.
  - The platelets release several platelet factors

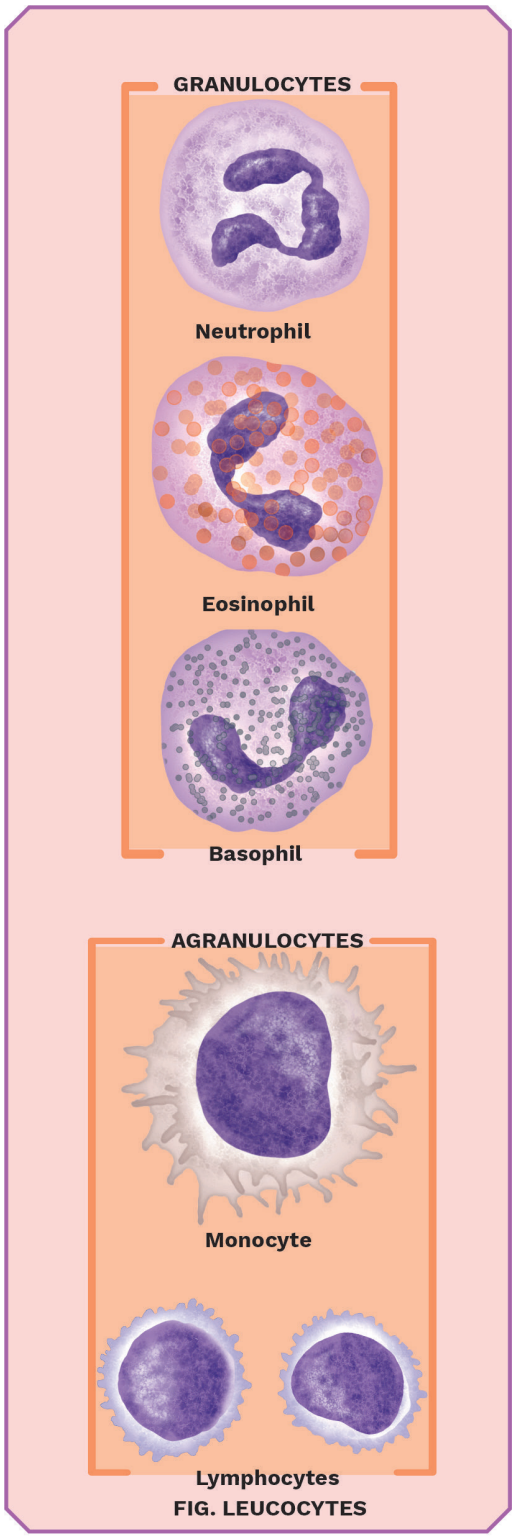
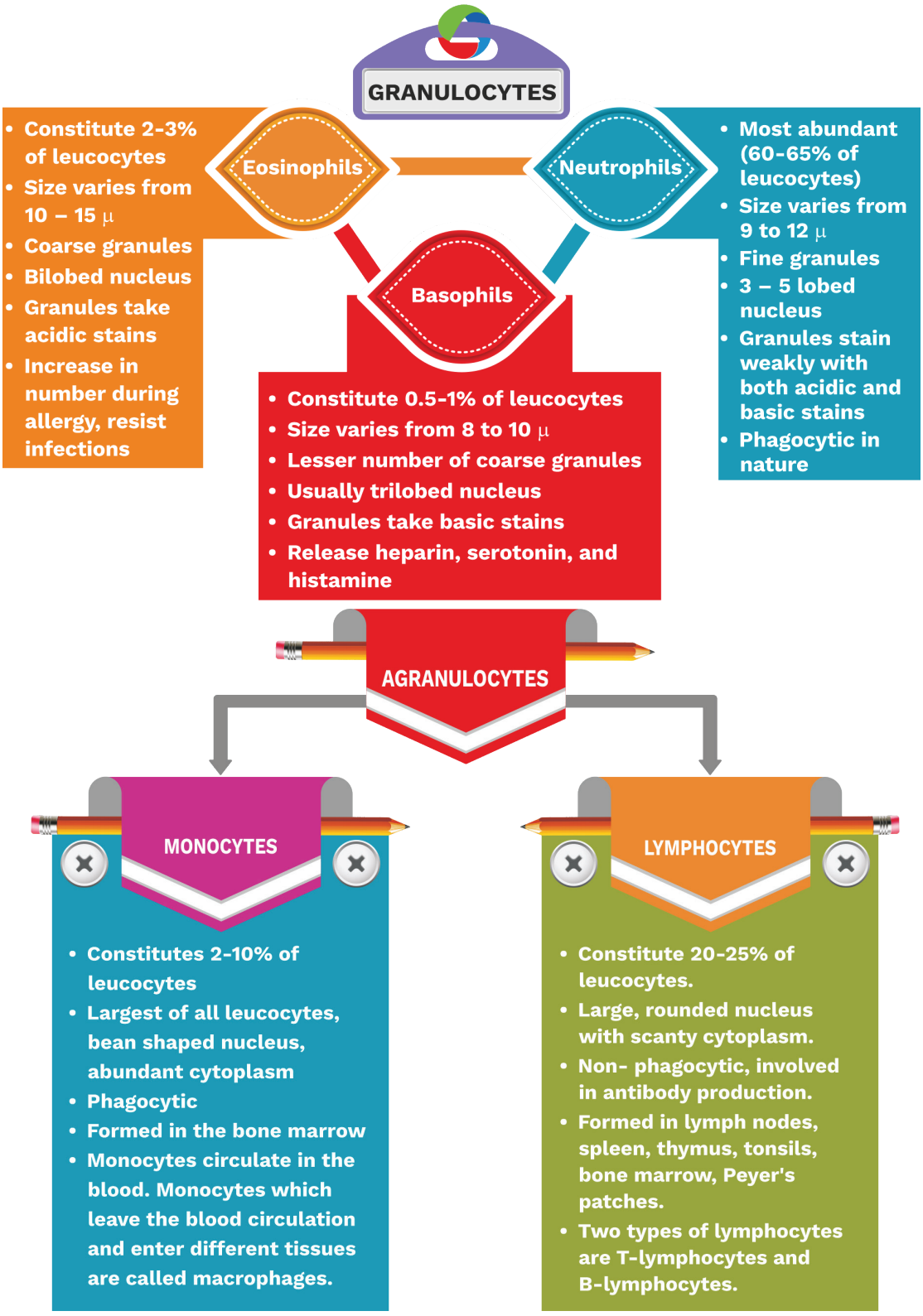


FIG. LEUCOCYTES


GRANULOCYTES
Eosinophils
Neutrophils
Basophils
• Constitute 2-3% of leucocytes
• Size varies from 10 – 15 μ
• Coarse granules
• Bilobed nucleus
• Granules take acidic stains
• Increase in number during allergy, resist infections
• Most abundant (60-65% of leucocytes)
• Size varies from 9 to 12 μ
• Fine granules
• 3 – 5 lobed nucleus
• Granules stain weakly with both acidic and basic stains
• Phagocytic in nature
• Constitute 0.5-1% of leucocytes
• Size varies from 8 to 10 μ
• Lesser number of coarse granules
• Usually trilobed nucleus
• Granules take basic stains
• Release heparin, serotonin, and histamine
AGRANULOCYTES
MONOCYTES
LYMPHOCYTES
• Constitutes 2-10% of leucocytes
• Largest of all leucocytes, bean shaped nucleus, abundant cytoplasm
• Phagocytic
• Formed in the bone marrow
• Monocytes circulate in the blood. Monocytes which leave the blood circulation and enter different tissues are called macrophages.
• Constitute 20-25% of leucocytes.
• Large, rounded nucleus with scanty cytoplasm.
• Non- phagocytic, involved in antibody production.
• Formed in lymph nodes, spleen, thymus, tonsils, bone marrow, Peyer's patches.
• Two types of lymphocytes are T-lymphocytes and B-lymphocytes.

and an enzyme thromboplastin on injury which plays a vital role in blood clotting.

LYMPH (TISSUE FLUID)

- Some water and water-soluble substances move out of the blood into the interstitial space when the blood flows through the capillaries in the tissues.
- This fluid is called tissue fluid or interstitial fluid or lymph. Its mineral distribution is the same as that in blood plasma. Lymph does not have RBC and platelets.
- It has floating WBCs, mostly lymphocytes, which come out of the blood by diapedesis (the process by which WBCs pass through capillary wall).
- Lymph acts as an exchange medium which transports oxygen, food materials, hormones, etc., to the body cells from the blood and brings carbon dioxide and other metabolic wastes from the body cells to the blood. It keeps the body cells moist.
- Lymphatic vessels collect lymph and drain it back to the major veins.
- Lymph nodes produce lymphocytes. Lymph in the lacteals of the intestine absorbs and transports digested fat products and fat-soluble vitamins from the intestine.

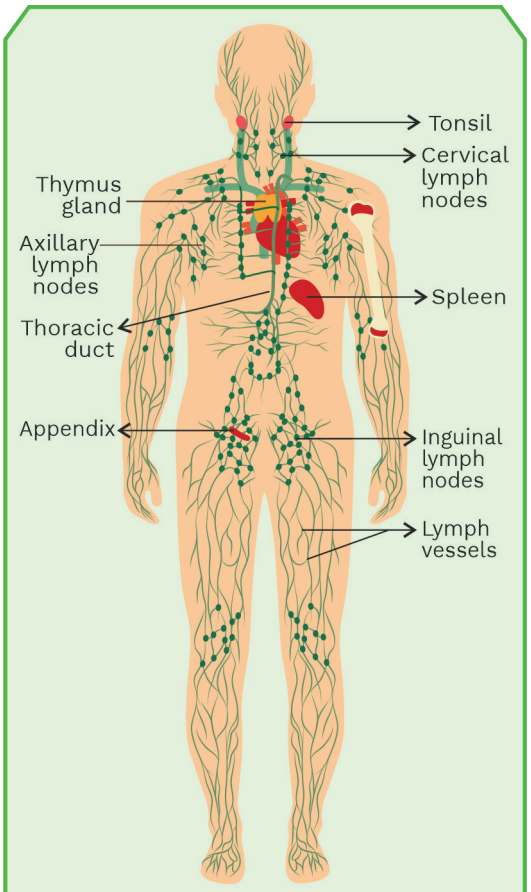


FIG. LYMPHATIC SYSTEM

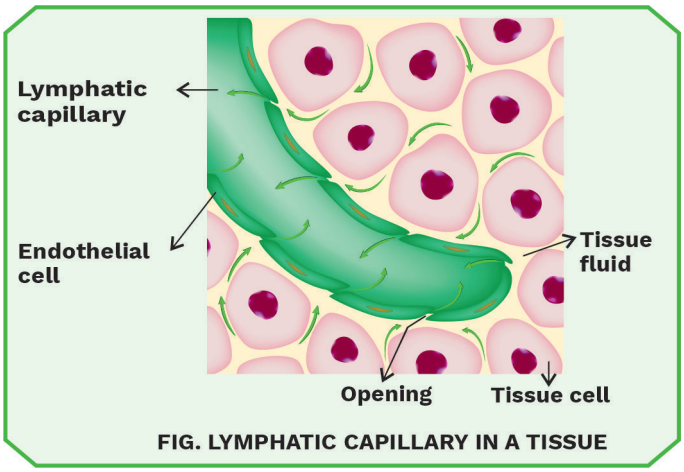


FIG. LYMPHATIC CAPILLARY IN A TISSUE

Gray Matter Alert!!!

Muscular tissue, in general, develops from the embryonic mesoderm but the myoepithelial cells of the salivary glands, mammary glands, sweat glands and muscles of the iris of the eye arise from the embryonic ectoderm.

MUSCLE TISSUE

- The muscular tissue is made of muscle cells or muscle fibres of variable lengths which are contractile in nature. Although the muscle fibres are bound together by connective tissues, they do not have any intercellular substance.
- Muscles help in the movements of the body. They help the body to adjust to the changes in the environment and to maintain the positions of the various parts of the body.

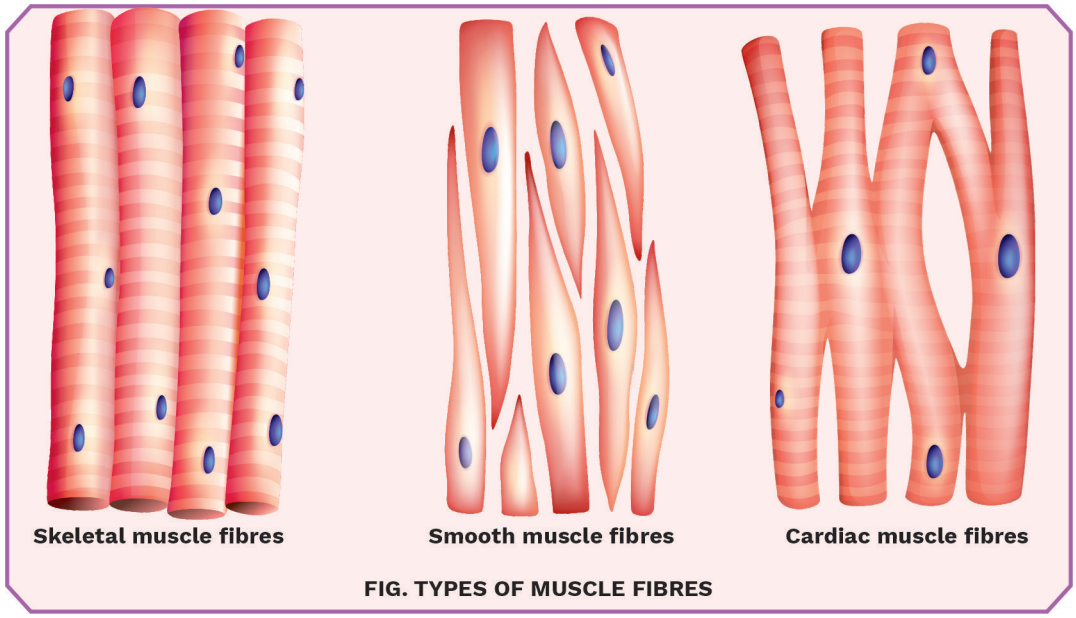


FIG. TYPES OF MUSCLE FIBRES

- Each muscle is made of many long muscle fibres arranged parallelly. These fibres are made of numerous fine fibrils, called myofibrils present in the cytoplasm (sarcoplasm).
- A skeletal muscle (covered by a connective tissue sheath called epimysium) consists of many bundles of muscle fibres called fasciculi or fascicles (covered by perimysium). Each muscle fibre present in a fasciculus is surrounded by a thin connective tissue sheath called the endomysium.
- Based on the location, there are three types of muscles: skeletal, smooth, and cardiac muscles.

Skeletal Muscle Fibres	Smooth Muscle Fibres	Cardiac Muscle Fibres
• Associated with skeletal system • Cylindrical • Unbranched • Multinucleated (Syncytial) • Striated (with light and dark bands) • Voluntary • Fatigue faster **Examples:** Muscles associated with bones like biceps, triceps, quadriceps, upper part of oesophagus, pharynx, and tongue, etc.	• Associated with Visceral organs • Spindle-shaped • Unbranched • Uninucleated • Unstriated • Involuntary • Do not fatigue **Examples:** Muscles present in visceral organs.	• Associated with heart • Cylindrical • Branched (Oblique bridges) • Uninucleated • Striated (with intercalated discs) • Involuntary • Never Fatigue **Example:** Muscles of the heart.

NEURAL TISSUE

- Neural tissue help in body's responsiveness to changing conditions. It coordinates and integrates the functioning of various body parts.

Previous Year's Question

Characteristics of smooth muscle fibres are:

(1) spindle-shaped, unbranched, non-striated and uninucleate
(2) spindle-shaped, unbranched, unstriped and multi-nucleate
(3) cylindrical, unbranched, unstriped and multinucleate
(4) cylindrical, unbranched, striated and multinucleate

- The neural system consists of neurons, neuroglial cells (neuroglia), ependymal cells and neurosecretory cells.

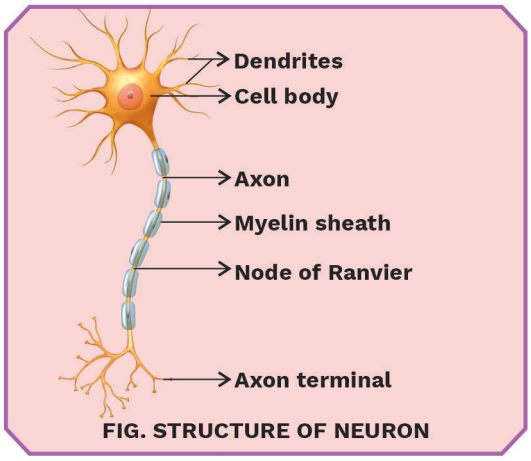
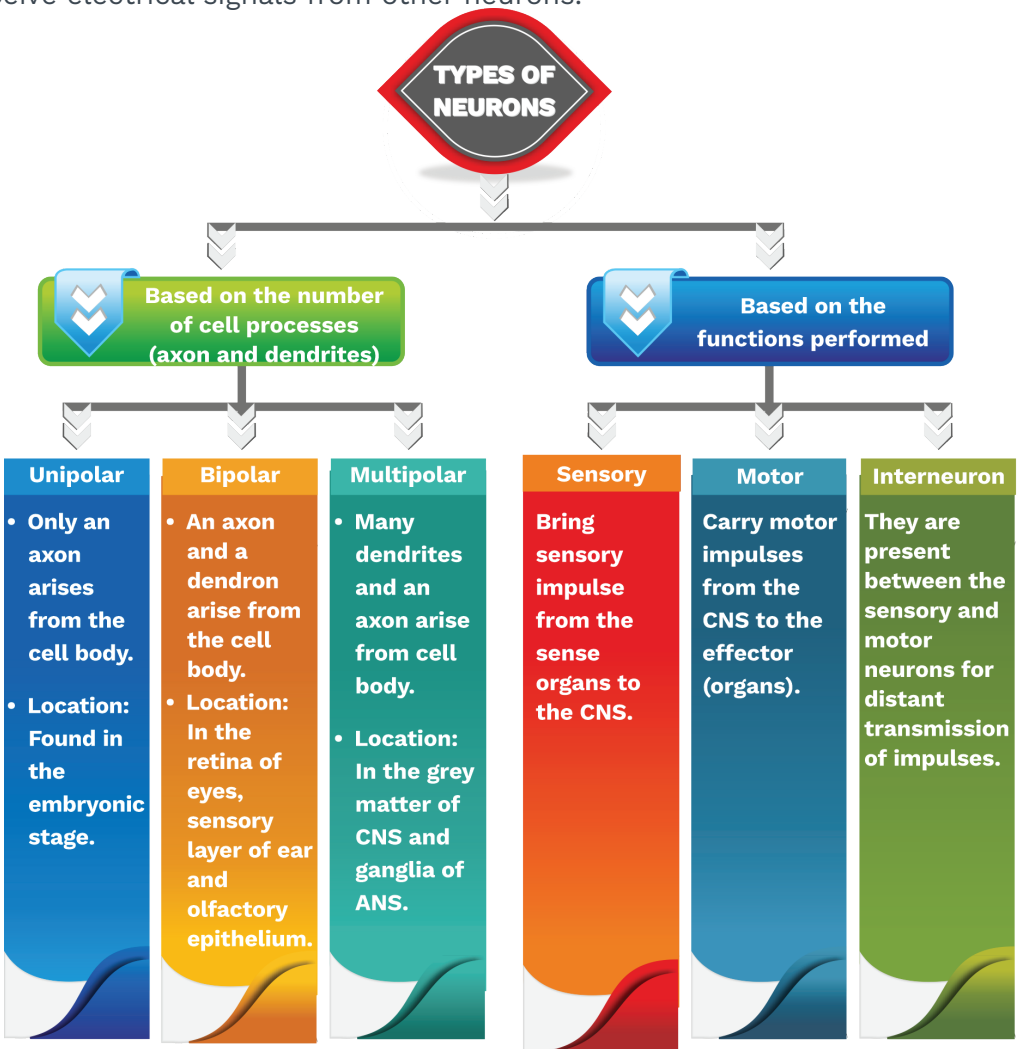


FIG. STRUCTURE OF NEURON

Neuron

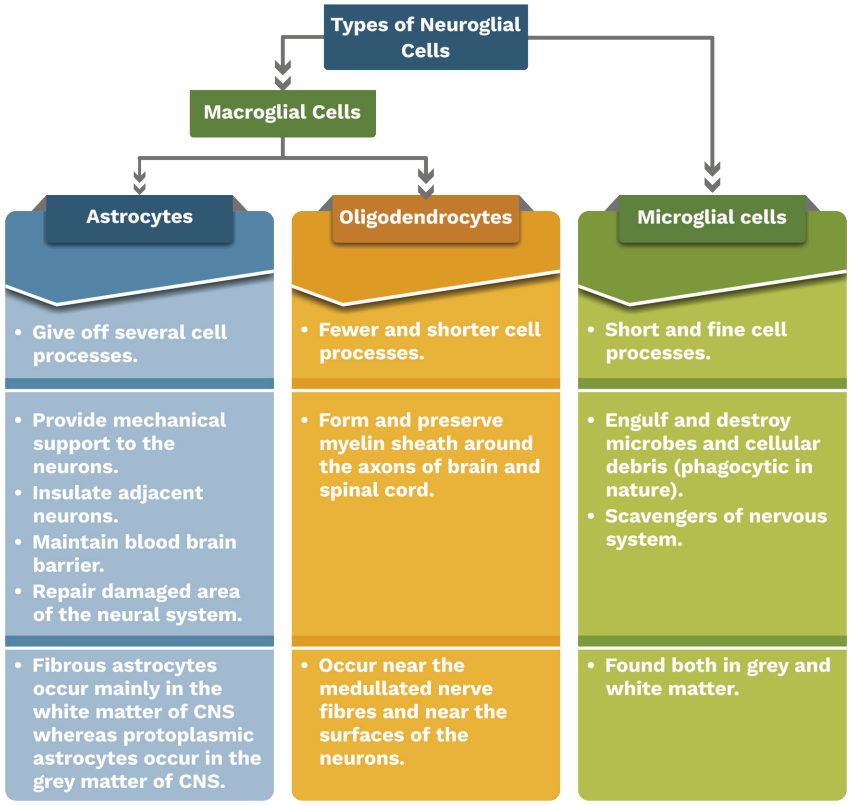
- Neurons are the structural and functional unit of neural system. A neuron consists of three major parts – cell body, dendrites, and axon.
- **Cell Body:** The cell body consists of nucleus, mitochondria, endoplasmic reticulum, Golgi bodies, lysosomes, ribosomes, Nissl's granules and neurofibrils in the cytoplasm.
- **Dendrites:** Dendrites are usually shorter and tapering processes of a multipolar neuron. They receive electrical signals from other neurons.



- **Axon:** Axon is a long process arising from the cell body. Its neuroplasm contains abundant neurofibrils and mitochondria but lacks Nissl's granules and other cell organelles. The axon ends into terminal pre-synaptic knobs. The electric impulse travels along the length of the axon towards their endings.

Gray Matter Alert!!!

Microglial cells are formed from the embryonic mesoderm.



Neuroglia

- Neuroglia makes up more than one-half the volume of neural tissue in our body. The neuroglial cells protect and support neurons.
- Neuroglial cells are majorly of two types – Macroglial cells (astrocytes and oligodendrocytes) and microglial cells.

Ependymal Cells

- Brain and spinal cavities are lined by a single layer of ependymal cells.

Previous Year's Question

Which one of the following pairs of structures distinguishes a nerve cell from other types of cell?

(1) Vacuoles and fibres
(2) Flagellum and medullary sheath
(3) Nucleus and mitochondria
(4) Perikaryon and dendrites

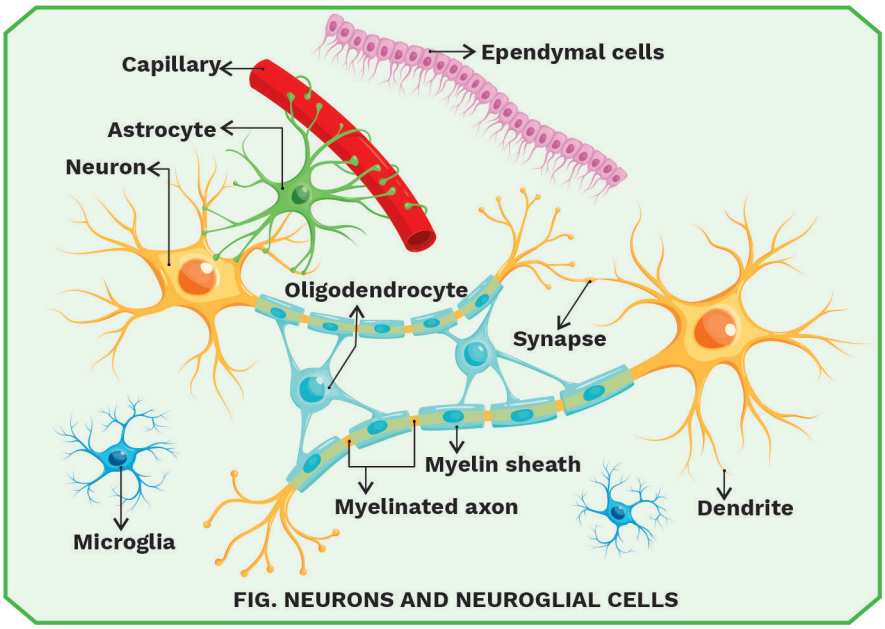


FIG. NEURONS AND NEUROGLIAL CELLS

- They may be squamous or columnar and bear microvilli and cilia at free ends. The cilia and microvilli help in movement and absorption of the cerebrospinal fluid, respectively.

Neurosecretory Cells

- Some nerve cells modify to secrete hormones in the blood. The neurosecretory cells of hypothalamus secrete many neurohormones which stimulates anterior pituitary.
- When a neuron is suitably stimulated, an electrical disturbance is generated which swiftly travels along its plasma membrane.
- Arrival of the disturbance or impulse at the neuron's endings, or output zone, triggers events that may cause stimulation or inhibition of adjacent neurons and other cells.

COCKROACH

Classification

Kingdom - Animalia

Previous Year's Question

Four healthy people in their twenties got involved in injuries resulting in damage and death of few cells. Of the following, which cells are least likely to be replaced by new cells?
(1) Liver cells
(2) Neurons
(3) Malpighian layer of the skin
(4) Osteocytes

Phylum - Arthropoda
Class - Insecta
Order - Blattodea
Family - Blattidae
Genus - *Periplaneta*
Species - *americana*

Habitat

- Cockroaches are cosmopolitan in distribution. They live in dark and damp places throughout the world. They are residents of human homes and thus are serious pests and vectors of several diseases.

Colour

- They bear brown or black coloured bodies. Bright yellow, green and red coloured cockroaches have also been reported in tropical regions.

Size

- Their size is from ¼ inches to 3 inches (0.6-7.6 cm). The adults are about 34-53 mm long with wings that extend beyond the tip of the abdomen in males.

Nature

- Cockroaches are nocturnal in nature and

Previous Year's Question

Which of the following feature is not present in *Periplaneta americana*?

(1) Exoskeleton composed of N-acetylglucosamine
(2) Metamerically segmented body
(3) Schizocoelom as body cavity
(4) Indeterminate and radial cleavage during embryonic development

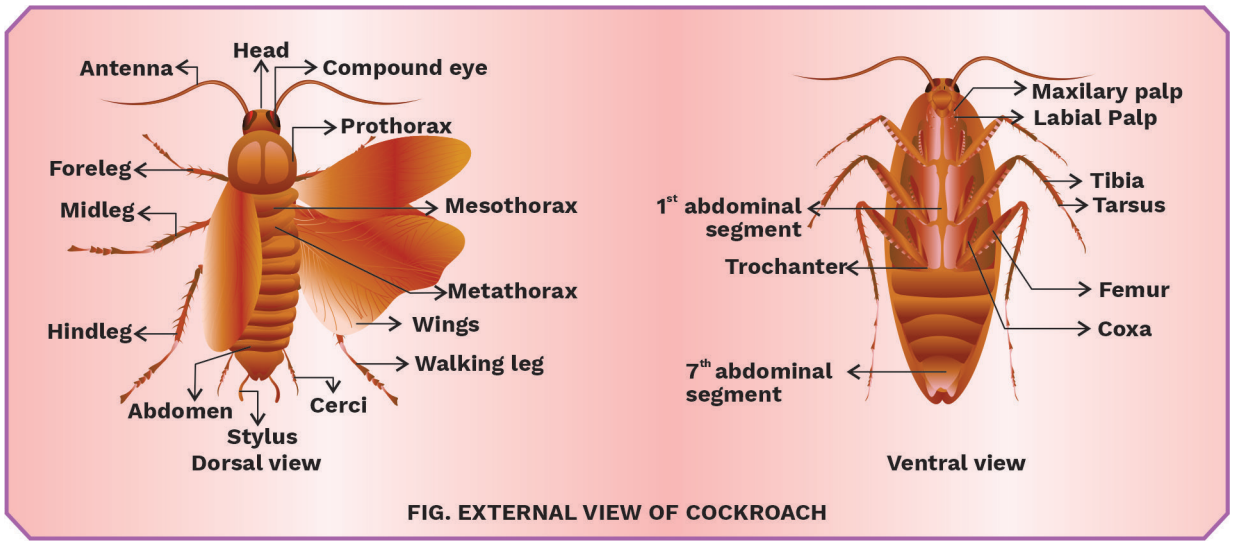


FIG. EXTERNAL VIEW OF COCKROACH

omnivorous in diet.

Morphology

- **Exoskeleton:** A hard, brown-coloured, chitinous exoskeleton covers the entire body. Exoskeleton is made of sclerites which are hardened plates present in each body segment.
- Dorsal sclerites are called tergites while ventral sclerites are called sternites. Sclerites are joined to each other by a thin and flexible articular membrane (arthrodial membrane).
- The body is segmented and divided into three regions – head, thorax, and abdomen.

Head

- Anteriorly placed, triangular head lies at right angles to the longitudinal body axis.
- It shows great mobility in all directions due to its flexible neck. It is formed due to the fusion of six body segments.
- The head consists of:
  - a pair of compound eyes as the organs of sight.
  - a pair of antennae arising from the membranous or antennal sockets present in front of the eyes.
  - a pair of small, rounded, light-sensitive ocellus or fenestra (undeveloped simple eyes) situated just towards the inner and upper side of each antennal socket.
  - appendages forming mouthparts for biting and chewing which consist of a labrum, a pair of mandibles, a pair of maxillae and a labium, and hypopharynx.
- Labrum (upper lip) bears the organs of taste and holds the food particles during feeding.
- Each mandible is divided into a grinding region and an incising region. The inner margin of each mandible bears teeth for cutting and masticating the food.

Rack Your Brain

The terga, sterna, and pleura in a cockroach are joined by which membrane?

Gray Matter Alert!!!

Cockroach has a hypognathous type of head as the proximal semi-circular broader end of the head is directed upwards, and the mouth bearing distal narrow end is directed downwards.

Rack Your Brain

Which part of the mouth of cockroach does not take an active part in feeding?

- Maxillae lie beneath the mandibles and help in holding the food and giving it to the mandibles for mastication. They are also used for cleaning the antennae and the first pair of legs. Maxillae bear sensory bristles which respond to touch, taste, and smell.
- Labium (lower lip) does not take active part in feeding. However, it prevents any loss of food particles from mandibular action. They also have sensory bristles which respond to taste and smell.
- Hypopharynx is a median flexible lobe that lies within the cavity enclosed by the mouthparts. It directs the saliva towards the food.
- Mouth is a narrow opening bounded by the mouth parts. Mouth leads into pharynx.

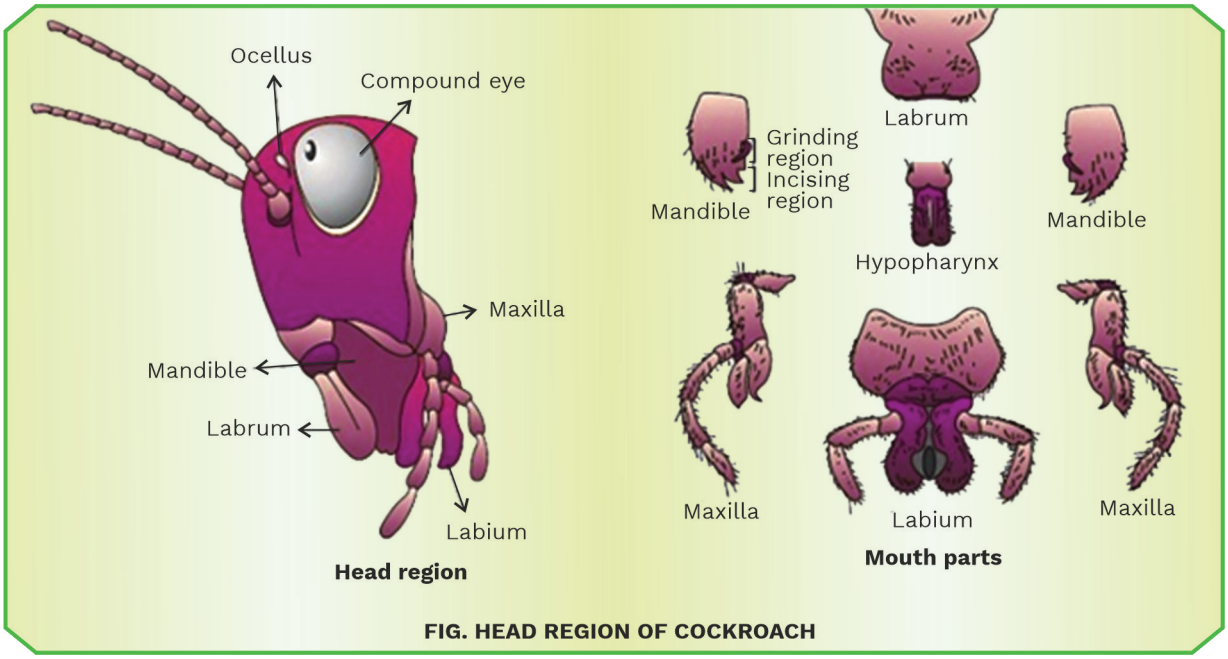


FIG. HEAD REGION OF COCKROACH

Thorax

- Thorax is connected with the head by a short extension of the prothorax (neck). It consists of three parts – anterior prothorax, middle mesothorax and posterior metathorax.

Gray Matter Alert!!!

The hypopharynx of cockroach is also called lingua or tongue.

Rack Your Brain

Assertion: Cockroaches can fly up to considerable distances.
Reason: Cockroaches have a pair of wings in each thoracic segment.

- Thorax bears a pair of walking, jointed legs in each segment, two pairs of wings, and two pairs of thoracic spiracles.
- The first pair of wings (forewings) arise from mesothorax (mesothoracic wings) called tegmina or elytra are opaque, dark, and leathery, and larger than the second pair of wings. They are not used for flight and cover the hind wings when at rest.
- The second pair of wings (hind wings) from metathorax (metathoracic wings). They are transparent, membranous and are used in flight.
- The first pair of thoracic spiracles lie between the bases of first and second pairs of legs. The second pair of spiracles lies between the bases of second and third pairs of legs. Spiracles help in intake of air from the atmosphere and releasing out of carbon dioxide rich air from the body.

Abdomen

- There are 10 segment in the abdomen of both male and female.
- Only male cockroaches bear a pair of short, thin, thread-like, unhinged, touch-sensitive outgrowths called anal styles projecting backwards from the 9^{th} sternum.
- 10^{th} segment has a pair of jointed filamentous outgrowths called anal cerci which are sensitive to touch and sound in both the sexes.
- The genital aperture in both the sexes is surrounded by gonapophysis (9^{th} segment in males and 8^{th} and 9^{th} segments in females). In male, gonapophysis forms the external genitalia for copulation.
- In gonapophysis forms the ovipositor which guides the fertilised eggs towards the oothecal chamber.
- The 7^{th} sternum is boat shaped and along with the 8^{th} and 9^{th} sterna forms a brood or genital pouch. The anterior part of the genital pouch contains spermathecal pores, female gonopore

Previous Year's Question

In cockroach, the anterior wings are called
(1) Elytra
(2) Pedipalps
(3) Antenna
(4) Chelicerae

Previous Year's Question

The abdomen of an adult cockroach has _____ segments.
(1) 4
(2) 6
(3) 8
(4) 10

Previous Year's Question

A pair of stink glands is found in
(1) 4^{th} and 5^{th} terga of cockroach
(2) 5^{th} and 6^{th} terga of cockroach
(3) 5^{th} and 6^{th} sterna of cockroach
(4) 4^{th} and 5^{th} sterna of cockroach

and collateral glands.

- The genital pouch or chamber in the males lie at the hind end of abdomen. It is bounded dorsally by 9th and 10th terga and bounded ventrally by the 9th sternum and It contains dorsal anus, ventral male genital pore and gonapophysis.
- A pair of stink glands is situated between the 5th and 6th abdominal terga which produce a stinky (foul-smelling) secretion.
- There are eight pairs of abdominal spiracles. The first pair of abdominal spiracles lie dorsally on the margins of the 1st abdominal tergum. The rest are present on both the sides of their corresponding segments between the terga and sterna.

ANATOMY

Digestive System

- The alimentary canal present in the body cavity is divided into three regions: foregut, midgut, and hindgut.
- **Foregut**
  - The foregut is lined by cuticle and comprises of the mouth which opens into a short tubular pharynx, leading to a narrow tubular, thin walled oesophagus.
  - Oesophagus continues into a sac-like, pear-shaped structure called crop which stores food.
  - Proventriculus lies after the crop. It has thick wall with an outer layer of thick circular muscles and thick inner cuticle forming six highly chitinous plate called teeth which are used for grinding the food particles.
- **Midgut**
  - Midgut is somewhat coiled tube with almost uniform thickness.
  - The main site where digestion and absorption of food takes place. The midgut is lined by glandular epithelium which secretes digestive enzymes.
  - A ring of 6-8 blind tubules known as hepatic

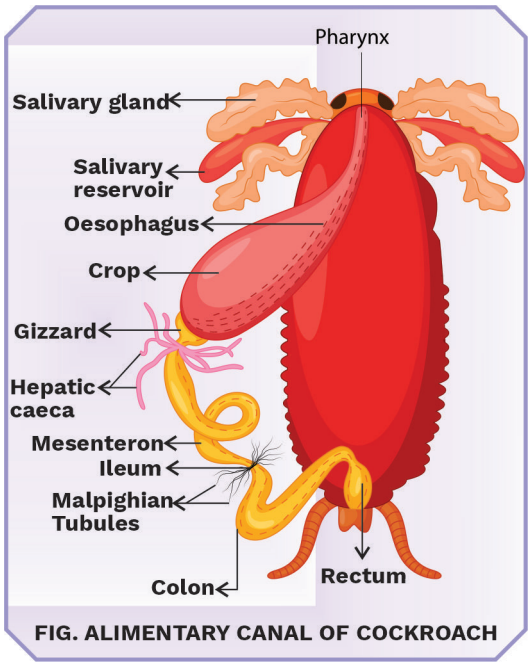


FIG. ALIMENTARY CANAL OF COCKROACH

Definition

Malpighian tubules: Yellow coloured, thin, filamentous tubules present at the junction of midgut and hindgut in cockroach which help in excretion.

or gastric caeca (lined by glandular cells) is present at the junction of foregut and midgut, which secrete digestive juices containing amylolytic, proteolytic, and lipolytic enzymes.
    - At the junction of midgut and hindgut is present another ring of 100-150 yellow coloured thin filamentous Malpighian tubules. They help in removal of excretory products from haemolymph.
- **Hindgut**
    - The hindgut is broader than midgut. It is divided into ileum, colon, and rectum. The rectum opens out through anus.
- A pair of salivary glands lie on each side of the oesophagus and crop.
- They store their secretion called saliva in reservoirs, which is carried to the preoral cavity through salivary ducts.
- Saliva consists of amylase, chitinase, and cellulase enzymes.

Blood Vascular System

- Cockroaches have an open blood vascular system as the blood vessels are poorly developed and the blood moves through the internal open spaces and is in direct contact with the visceral body organs.
- The haemolymph (blood) is composed of haemocytes flowing in a colourless plasma with no respiratory pigment.
- In the thorax and abdomen, the haemocoel (body cavity filled with haemolymph) is divided into blood-filled spaces called sinuses.
- Heart of cockroach consists of elongated muscular tube lying along mid dorsal line of thorax and abdomen below the terga.
- It is differentiated into thirteen funnel-shaped contractile chambers.
- The first three chambers are present in the thorax while the rest ten chambers are situated in the abdomen.

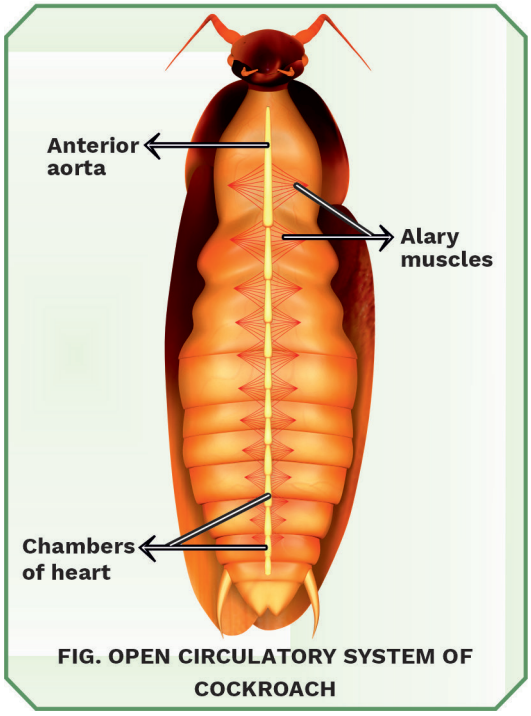


FIG. OPEN CIRCULATORY SYSTEM OF COCKROACH

Gray Matter Alert!!!

Cockroach has a neurogenic heart as the heartbeat is initiated by a nerve impulse.

- All the chambers are inter connected, and their openings have ventricular valves to allow the blood flow in anterior direction only.
- The last chamber is closed posteriorly.
- An anterior aorta arises from the first chamber of the heart and leads into the head sinuses.
- A pair of lateral apertures called ostia are present on either side on the posterior end of each chamber.
- Blood from sinuses enters the heart through ostia and is pumped anteriorly to sinuses again.
- Twelve pairs of triangular alary muscles are present which help in blood flow from the heart to other sinuses.

Respiratory System

- The respiratory system consists of 10 pairs of small holes called spiracles, tracheae, and tracheoles.
- Sphincters regulates the opening of the spiracles.
- There are three pairs of longitudinal tracheal trunks which are connected with each other by transverse tracheae.
- Tracheal tubes subdivide into tracheoles which carry oxygen from the air to all the parts. By diffusion the exchange of gases take place at the tracheoles.

Excretory System

- Excretion is performed by fine, unbranched, yellow coloured, blind-ended Malpighian tubules.
- The closed end of each Malpighian tubule floats freely in the blood and the proximal end opens into the hindgut.
- Glandular and ciliated cells lines each tubule.
- They absorb waste products like potassium and sodium urate, water, and carbon dioxide from the blood.
- Most of the water and bicarbonates of potassium and sodium are reabsorbed. Cockroaches are

uricotelic as they excrete out uric acid formed in the malpighian tubules through the hindgut (anus).

- In addition, the fat body, nephrocytes (arranged on each side of the heart) and urecose glands (long tubules of utricular gland of the male cockroach) also help in excretion.
- Fat body lies below the body wall and fills almost all the space within the body. Some fat cells of the fat body get excretory matter from the blood.

Nervous System

- The nervous system of cockroach is ventrally placed and spread throughout the body, the head holding only a bit of a nervous system while the rest running along the ventral part of its body.
- That is why, if the head of a cockroach is cut off, it will still live for as long as one week.
- It consists of a series of fused, segmentally arranged ganglia joined by paired longitudinal connectives.
- The brain is represented by supra-oesophageal (above oesophagus) ganglion which is formed by the fusion of three pairs of ganglia.
- It supplies optic nerves to the two compound eyes, antennary nerves to the antennae, and labro-frontal nerves which divide to form the frontal connective (runs to the frontal ganglion) and labral nerve (runs to the labrum).
- A short and broad circum-oesophageal connective is given off from either side of the brain.
- The circum-oesophageal connectives meet the sub-oesophageal ganglion (below oesophagus) which is formed by the fusion of three pairs of ganglia. A pair of mandibular nerve, maxillary nerve, and labial nerve arise from the sub-oesophageal ganglion which supplies the mandibles, maxillae, and labium, respectively.
- A double ventral nerve cord extends from

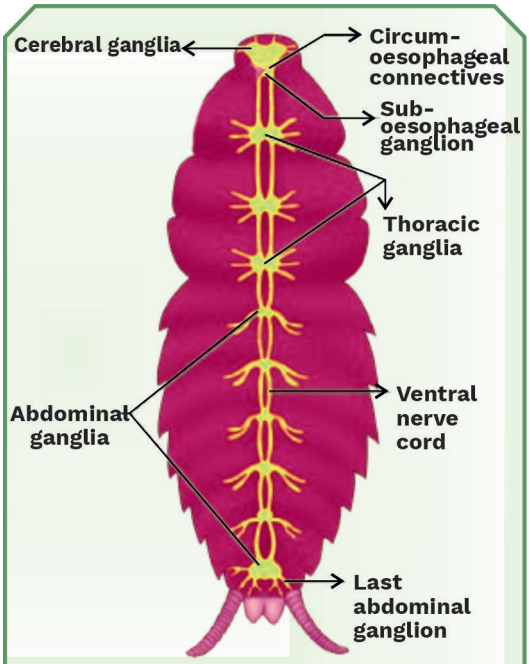


FIG. NERVOUS SYSTEM OF COCKROACH

Gray Matter Alert!!!

The supraoesophageal ganglion (brain), circumoesophageal connectives and sub-oesophageal ganglion constitute a nerve ring in the head capsule of a cockroach.

the sub-oesophageal ganglion, ventral to the alimentary canal. It has three ganglia that lie in the thorax (one in each thoracic segment) and six abdominal ganglia (in 1st, 2nd, 3rd, 4th, 6th, and 7th abdominal segments).

Sense Organs

- In cockroach, the sense organs include:
  - Antennae (a pair of thread-like structures which arise from membranous sockets lying in front of eyes). Antennae have sensory receptors that respond to smell, touch along with monitoring the environment (humidity and temperature).
  - Compound eyes are present at the dorsal surface of the head and each eye consists of about 2000 hexagonal facets externally called ommatidia (sing.: ommatidium). An ommatidia consist of a dioptric part to focus the light rays and a receptive part to convert image into an impulse to be conveyed to the brain through optic nerves.
  - With the help of several ommatidia, a cockroach can receive several images of an object. This kind of vision is known as mosaic vision with more sensitivity but less resolution, being common during night (hence called nocturnal vision).
  - Maxillary palps and labial palps bear sensory receptors for taste and smell.
  - Anal cerci consists of sensory receptors which respond to touch and sound.

Reproductive System

- Cockroaches are dioecious animals. Both males and females have well-developed reproductive organs.

Male Reproductive System

- The male reproductive system of cockroaches consists of a pair of testes one lying on each

Rack Your Brain

Which type of vision is found in cockroach?

Previous Year's Question

The taste receptors of cockroach are
(1) Tactile hairs
(2) Compound eyes
(3) Companiform sensillae
(4) Maxillary palps and labium

lateral side in the 4th-6th abdominal segments.

- From each testis arises a thin vas deferens, which opens into ejaculatory duct through seminal vesicle.
- A mushroom shaped gland called utricular gland is present at the junction of vas deferens and ejaculatory duct in the 6th-7th abdominal segments.

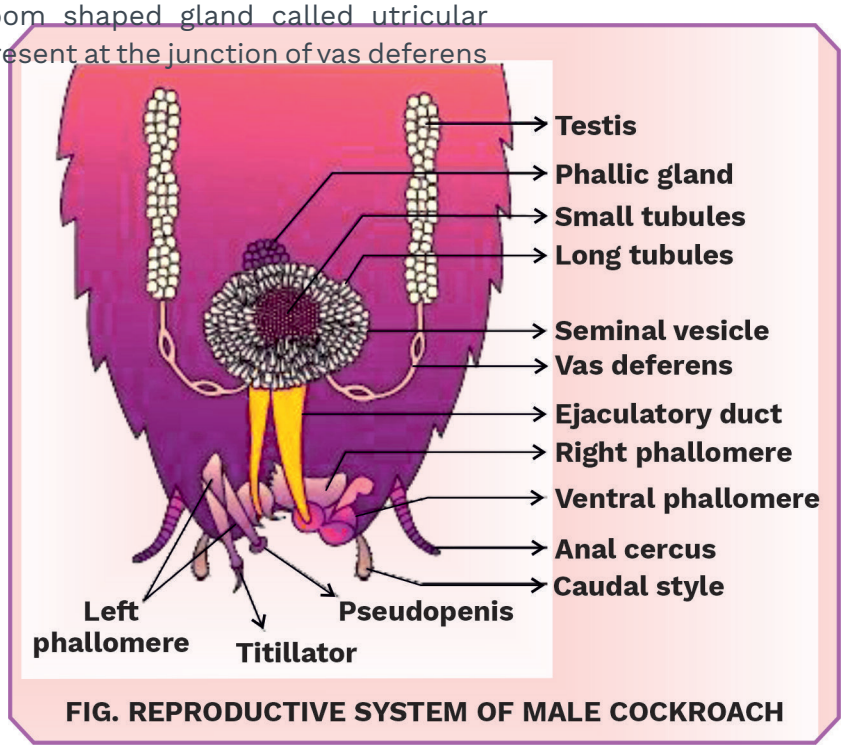


FIG. REPRODUCTIVE SYSTEM OF MALE COCKROACH

- It has long tubules at the periphery, small tubules which nourish the sperms, and seminal vesicles which function as an accessory reproductive gland to store the sperms and gluing them together in form of bundles called spermatophores which are discharged during copulation.
- The ejaculatory duct, arising from the base of the utricular gland, opens into male gonopore (male genital pore) situated ventral to anus.
- A large, elongated sac-like structure called phallic gland lies beneath the utricular gland and the ejaculatory duct. It narrows posteriorly and terminates into a duct near the male gonopore

Previous Year's Question

Phallomeres in male Periplaneta arise from

(1) 7th sternum
(2) 8th sternum
(3) 9th sternum
(4) 8th and 9th sterna

on the left phallomere.

- The external genitalia is represented by male gonapophysis or phallomeres (chitinous asymmetrical structures, surrounding the male gonopore).
- They include the right, left and ventral phallomere. Phallomeres help in transfer of sperms into the female cockroach.
- The sperms are produced by the sperm follicles of the testes. They are passed to the vas deferens via vasa efferentia.
- Vas deferens transfer the sperms to the seminal vesicles.
- The sperms are then transferred to the ejaculatory duct and passed outside through the gonopore into the female genital chamber with the help of the male phallomeres.
- Spermatophores are three-layered structures. The secretion of the long tubules, ejaculatory duct, and phallic gland forms the innermost, middle, and outermost layer of the spermatophore, respectively.

Female Reproductive System

- The female reproductive system consists of two large yellowish ovaries, lying laterally in the 2nd – 6th abdominal segments embedded in the fat bodies.
- Each ovary consists of a group of eight ovarian tubules or ovarioles, containing a chain of developing ova.
- Oviducts of each ovary unite into a single median oviduct (also called vagina) which opens into the genital chamber by a vertical slit called the female genital pore.
- A genital pouch encloses a boat shaped cavity having the genital chamber anteriorly and a vestibulum or oothecal chamber posteriorly.
- A pair of spermatheca lies in the 6th abdominal segment which opens into the genital chamber.

Previous Year's Question

Male and female cockroaches can be distinguished externally through

(1) anal styles in male
(2) anal cerci in female
(3) anal style and antennae in females
(4) both (2) and (3)

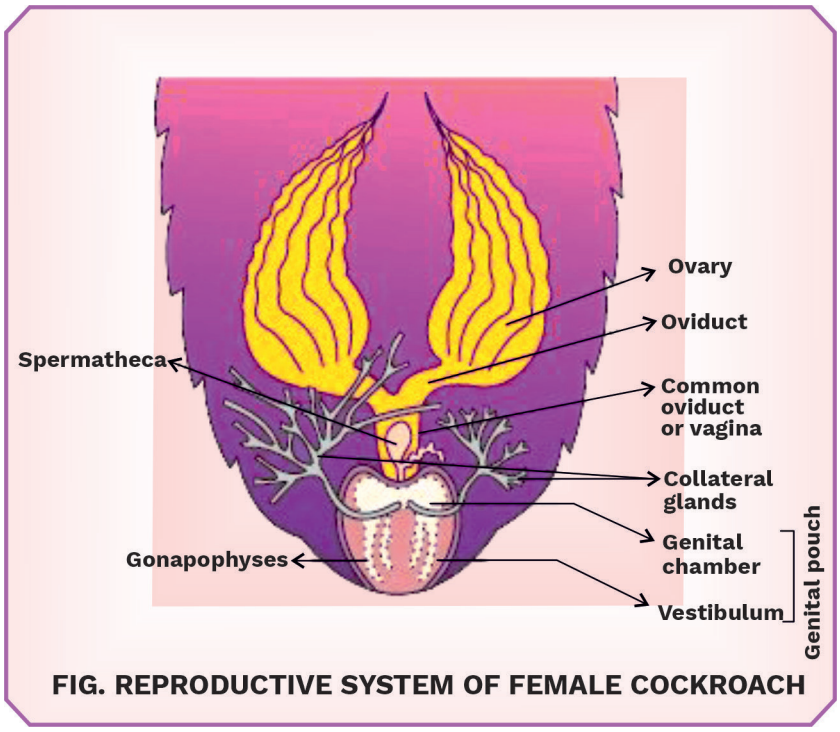


FIG. REPRODUCTIVE SYSTEM OF FEMALE COCKROACH

The left spermatheca stores the sperms received from the male during copulation.

- The female phallomeres called female gonapophysis surrounds the female genital pore and consist of six chitinous plates. They are used to carry eggs to the oothecal chamber.
- Two branched tubular glands called collateral glands open on the dorsal side of the genital chamber. Their secretion forms the oothecal case of the ootheca.
- During copulation, the spermatophores are transferred to the female genital chamber with the help of male phallomeres.
- The sperms are liberated from the spermatophores in the genital chamber and reach the left spermatheca. The eggs from both the ovaries are passed into the vagina from where they reach the genital chamber via the female genital pore.
- In the genital chamber, the eggs are fertilised by the sperms coming from the left spermatheca.
- In the oothecal chamber, the fertilised eggs are encased in capsules called oothecae. Ootheca is

Previous Year's Question

What external changes are visible after the last moult of a cockroach nymph?

(1) Both forewings and hind wings develop
(2) Labium develops
(3) Mandibles become harder
(4) Anal cerci develop

a dark reddish to blackish brown capsule, about 3/8" (8 mm) long.

- On an average, females produce 9-10 oothecae, each containing 14-16 fertilised eggs. They are dropped or glued to a suitable surface, usually in a crack or crevice of high relative humidity near a food source.
- The development of cockroach is paurometabolous, i.e., there is development through gradual nymphal stages.
- The nymphs look very much like adults. The nymph grows by moulting about 13 times to reach the adult form. The next to last nymphal stage has wing pads but only adult cockroaches have wings.

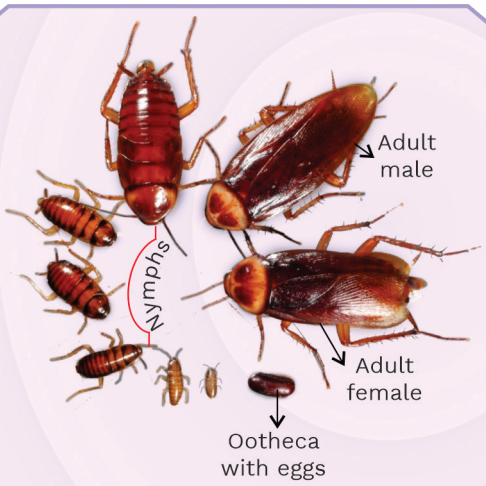


Fig. PAUROMETABOLOUS DEVELOPMENT IN COCKROACH

Interaction with Human Beings

- Many species of cockroaches are wild and are of no known economic importance yet. A few species thrive in and around human habitat.
- They are pests because they spoil food and contaminate it with their smelly excreta. Since they also dwell in sewage pipes and gutter holes, they can transmit a variety of bacterial diseases like cholera, diarrhoea, typhoid, etc., by contaminating food material.

EARTHWORM (A BRIEF ACCOUNT)

Common Indian earthworm	***Pheretima posthuma***
Habitat	Inhabits the upper layer of the moist soil.

Common Indian earthworm	*Pheretima posthuma*
Morphology	• Body is divided into 100-120 metameres. • Dorsal blood vessel makes a median mid-dorsal line. • Ventral surface consists of genital pores. • Mouth and prostomium are present at the anterior end. • The Ist body segment is peristomium (bears mouth) • Clitellum is present in the 14th-16th segments. • Four pairs of spermathecal apertures are present on the ventro-lateral sides of the intersegmental grooves, i.e., 5th -9th segments. • A single female genital pore is present in the mid-ventral line of 14th segment. • A pair of male genital pores are present on the ventro-lateral sides of the 18th segment. • Nephridiopores open on the surface of the body. • Rows of S-shaped setae are embedded in the epidermal pits in the middle of each segment except the first, last and clitellum. Their principal role is locomotion.
Body wall	Consist of outer thin non-cellular cuticle, the epidermis is made up of a single layer of columnar epithelial cells containing secretory gland cells, two muscle layers (circular and longitudinal) and an innermost coelomic epithelium.
Digestive System	• The alimentary canal runs between first to last segment of the body. • Mouth opens into the buccal cavity (1st-3rd segments) which leads to a muscular pharynx. • Oesophagus (5th-7th segments) continues into a muscular gizzard (8th-9th segments). It helps in grinding the soil particles and decaying leaves, etc. • The stomach extends from 9-14 segments. Calciferous glands of stomach neutralise the humic acid present in humus. • Intestine starts from the 15th segment and continues till the last segment. A pair of short and conical intestinal caecae project from the intestine on the 26th segment. Typhlosole (internal median fold of dorsal wall which increases absorptive surface area) present after 26th segment except the last 23rd-25th segments. • The alimentary canal opens to the exterior by anus.

Common Indian earthworm	*Pheretima posthuma*
Blood vascular system	• Closed type of blood vascular system present, consisting of blood vessels, capillaries, and heart. • Blood glands are present on the 4th, 5th and 6th segments. They produce blood cells and haemoglobin which is dissolved in blood plasma. Blood cells are phagocytic in nature.
Respiratory System	• Specialised breathing organs are absent. • Respiratory exchange occurs through moist body surface into their bloodstream.
Excretory System	• Segmentally arranged coiled tubules called nephridia regulate the volume and composition of the body fluids. • Septal nephridia - present on both the sides of intersegmental septa of segment 15th to the last that open into the intestine. • Integumentary nephridia - attached to the lining of the body wall of segment 3rd to the last that open on the body surface. • Pharyngeal nephridia - present as three paired tufts in the 4th, 5th, and 6th segments.
Nervous System	• Represented by ganglia arranged segment-wise on the ventral paired nerve cord. • The nerve cord in the anterior region (3rd and 4th segment) bifurcates, laterally encircling the pharynx and joins the cerebral ganglia dorsally to form a nerve ring.

Common Indian earthworm	*Pheretima posthuma*
Reproductive System	• Earthworm is hermaphrodite (bisexual). • Two pairs of testes are present in the 10th and 11th segments. • Vasa deferentia run-up to the 18th segment where they join the prostatic duct. • Two pairs of accessory glands are present one pair each in the 17th and 19th segments. • The common prostate and spermatic duct (vasa deferentia) opens to the exterior by a pair of male genital pores on the ventro-lateral side of the 18th segment. • Four pairs of spermathecae are present in 6th-9th segments (one pair in each segment). They receive and store spermatozoa during copulation. • One pair of ovaries is attached at the inter-segmental septum of the 12th and 13th segments. • Ovarian funnels are present beneath the ovaries which continue into oviduct, joins together and open on the ventral side as a single median female genital pore on the 14th segment. • During mating, there is a mutual exchange of packets of sperms (called spermatophores) between two worms. • Mature sperm and egg cells and nutritive fluid are deposited in cocoons produced by the gland cells of clitellum. • Fertilisation and development occur within the cocoons which are deposited in soil. After about 3 weeks, each cocoon produces two to twenty baby worms with an average of four. • Development of earthworm is direct, i.e., there is no larva formed.
Interaction with Mankind	• Earthworms are called 'friends of farmers' as they make burrows in the soil and make it porous which helps in respiration and penetration of the developing plant roots. • The process of increasing fertility of soil by the earthworms is called vermicomposting. • They are also used as bait in game fishing.

FROGS (A BRIEF ACCOUNT)

Common Indian Frog	*Rana tigrina*
Habitat and habits	• They live both on land and in freshwater. • They do not have a constant body temperature (cold-blooded or poikilotherms). • They can change their colour to hide them from enemies (camouflage). During peak summer and winter, they take shelter in deep burrows, i.e., summer sleep (aestivation) and winter sleep (hibernation) respectively.
Morphology	• The skin is moist, smooth, and slippery due to the presence of mucus. • Dorsally, the body is generally olive green with dark irregular spots. Ventrally, the skin is uniformly pale yellow. • The frog never drinks water but absorbs it through the skin. • Body is divisible into head and trunk. A neck and tail are absent. • A pair of nostrils is present above the mouth. • Eyes are bulged and covered by a nictitating membrane that protects them while in water. • Membranous tympanum or ear (on either side of eyes) receives sound signals. • The forelimbs (ends in four digits) and hind limbs (ends in five digits) help in swimming, walking, leaping, and burrowing. • Feet have webbed digits that help in swimming.

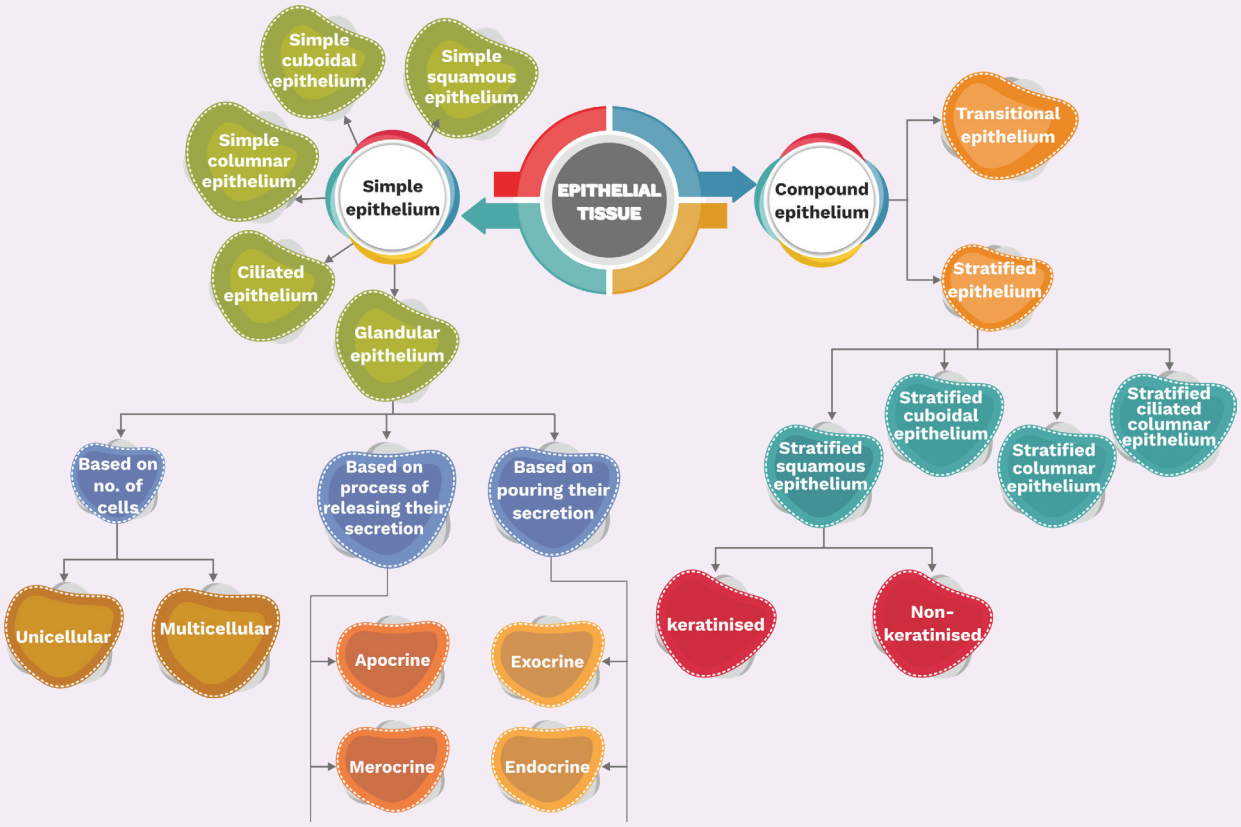
Common Indian Frog	*Rana tigrina*
Digestive System	• Consists of alimentary canal and digestive glands. • The length of intestine is reduced as frogs are carnivores. • The mouth opens into the buccal cavity that leads to the oesophagus through pharynx. • Food is captured by the bilobed tongue at anterior end. • Oesophagus opens into the stomach which in turn continues as the intestine, rectum and finally opens outside by the cloaca. • Liver secretes bile that is stored in the gall bladder. • Pancreas produces digestive enzymes. • Digestion of food takes place by the action of HCl and gastric juices secreted by the walls of the stomach. • Partially digested food called chyme is passed from stomach to the duodenum. The duodenum receives bile from gall bladder and pancreatic juices from the pancreas through a common bile duct. • Bile emulsifies fat and pancreatic juices digest carbohydrates and proteins. • Final digestion takes place in the intestine. • Digested food is absorbed by the numerous finger-like folds in the inner wall of intestine called villi and microvilli. • The undigested solid waste moves into the rectum and passes out through cloaca.
Respiratory System	• Skin acts as aquatic respiratory organ (cutaneous respiration). Dissolved oxygen in the water is exchanged through the skin by diffusion. • On land, the buccal cavity, skin, and lungs (pulmonary respiration) act as the respiratory organs. • A pair of lungs are present in the upper part of the trunk region (thorax). • Air enters through the nostrils into the buccal cavity and then to lungs. • During aestivation and hibernation gaseous exchange takes place through skin.

Common Indian Frog	*Rana tigrina*
Blood Vascular System	• Closed type of blood vascular system is present involving heart, blood vessels and blood. • Lymphatic system consists of lymph, lymph channels and lymph nodes. • Heart (covered with pericardium) is situated in the upper part of the body cavity and has three chambers, two atria and one ventricle. • A triangular sinus venosus joins the right atrium. It receives blood through vena cava. • The ventricle opens into conus arteriosus on the ventral side of the heart. Arteries carry the blood from the heart to all parts of the body (arterial system) and veins collect blood from different body parts to the heart (venous system). • Hepatic portal system is present between liver and intestine, whereas renal portal system is present between the kidney and lower parts of the body. • The blood is composed of plasma and blood cells (erythrocytes, leucocytes and platelets) and circulates in the body by pumping of heart. • Erythrocytes are nucleated and contain red coloured pigment namely haemoglobin. • The lymph lacks few proteins and RBCs. • The blood carries nutrients, gases, and water to the respective sites during the circulation.
Excretory System	• It consists of a pair of kidneys, ureters, cloaca and urinary bladder. • Each kidney is composed of uriniferous tubules or nephrons (structural and functional units). • Two ureters emerge from the kidneys in the male frogs and act as urinogenital duct which opens into the cloaca. • In females the ureters and oviduct open separately in the cloaca. • The thin-walled urinary bladder is present ventral to the rectum which also opens in the cloaca. • The frog excretes urea (ureotelic animal).

Common Indian Frog	*Rana tigrina*
Nervous System and Control and Coordination System	• The nervous system consists of a central nervous system (brain and spinal cord), a peripheral nervous system (cranial and spinal nerves) and an autonomic nervous system (sympathetic and parasympathetic). • Brain is enclosed in a bony structure called brain box (cranium). The brain is divided into fore-brain (having olfactory lobes, paired cerebral hemispheres and unpaired diencephalon), midbrain (characterised by a pair of optic lobes) and hind-brain (consists of cerebellum and medulla oblongata). • The medulla oblongata passes out through the foramen magnum and continues into spinal cord, which is enclosed in the vertebral column. • There are ten pairs of cranial nerves. • The prominent endocrine glands are pituitary, thyroid, parathyroid, thymus, pineal body, pancreatic islets, adrenals, and gonads.
Sense Organs	• Sense organs include sensory papillae (touch), taste buds (taste), smell nasal epithelium (smell), eyes (vision) and tympanum with internal ears (hearing). • Out of these, eyes and internal ears are well-organised structures, and the rest are cellular aggregations around nerve endings. • Eyes are a pair of spherical structures situated in the orbit in skull. These are simple eyes (possessing only one unit). • External ear is absent in frogs and only tympanum can be seen externally. • The ear is an organ of hearing as well as balancing (equilibrium).

Common Indian Frog	*Rana tigrina*
Reproductive System	• Frogs exhibit sexual dimorphism. Male frogs can be distinguished by the presence of sound-producing vocal sacs and a copulatory pad on the first digit of the fore limbs which are absent in female frogs. • Male reproductive organs consist of a pair of yellowish ovoid testes, adhered to the upper part of kidneys by a double fold of peritoneum called mesorchium. • Vasa efferentia are 10-12 in number that arise from testes. They enter the kidneys on their side and open into Bidder's canal. It communicates with the urinogenital duct that comes out of the kidneys and opens into the cloaca. • The cloaca passes faecal matter, urine, and sperms to the exterior. • The female reproductive organs include a pair of ovaries. • The ovaries are situated near kidneys and there is no functional connection with kidneys. • A pair of oviducts arising from the ovaries opens into the cloaca separately. A mature female can lay 2500 to 3000 ova at a time. • Fertilisation is external and takes place in water. • Development involves a larval stage called tadpole. Tadpole undergoes metamorphosis to form the adult.
Interaction with Mankind	• They eat insects and protect the crop. • They maintain ecological balance as they serve as an important link of food chain and food web in the ecosystem. • In some countries, the muscular legs of frog are used as food.

Summary


EPITHELIAL TISSUE
Simple epithelium
Simple cuboidal epithelium
Simple squamous epithelium
Simple columnar epithelium
Ciliated epithelium
Glandular epithelium
Based on no. of cells
Unicellular
Multicellular
Based on process of releasing their secretion
Apocrine
Merocrine
Based on pouring their secretion
Exocrine
Endocrine
Compound epithelium
Transitional epithelium
Stratified epithelium
Stratified squamous epithelium
keratinised
Non-keratinised
Stratified cuboidal epithelium
Stratified columnar epithelium
Stratified ciliated columnar epithelium

SOLVED EXERCISE

1. **Which of the following tissue is ectodermal in origin?**

(1) Connective tissue **(2) Muscular tissue**

(3) Neural tissue **(4) Both (1) and (3)**

Sol. **(3)**

Neural tissue is derived from the embryonic ectoderm.

2. **Presence of a basement membrane is a characteristic feature of**

(1) Neural tissue **(2) Connective tissue**

(3) Muscular tissue **(4) Epithelial tissue**

Sol. **(4)**

The cells of a single-layered epithelial tissue or the cells of the lowermost layer of a multi-layered epithelial tissue always rest on a non-cellular basement membrane which separate the epithelial tissue from the underlying connective tissue.

3. **The main function of simple columnar epithelium is**

(1) Protection **(2) Secretion**

(3) Absorption **(4) Both (2) and (3)**

Sol. **(4)**

The main function of simple columnar epithelium is secretion and absorption. It is found in the lining of stomach, intestine, gall bladder and bile duct. The columnar epithelium of the stomach and intestine contain mucus-secreting cells (goblet cells), hence also called mucous membrane. The mucous membrane of the intestine has microvilli (brush-border epithelium) for increasing the absorptive surface area.

4. **Goblet cells of alimentary canal are**

(1) Multicellular glands **(2) Unicellular glands**

(3) Endocrine glands **(4) Holocrine glands**

Sol. **(2)**

Goblet cells of alimentary canal are unicellular glands as they consist of isolated glandular cells.

5. **The most widely distributed connective tissue in the body of higher vertebrates is**

(1) Bone
(2) Areolar tissue
(3) Cartilage
(4) Dense regular connective tissue

Sol. **(2)**

The most widely distributed connective tissue in the body of higher vertebrates is areolar tissue. It occurs beneath the epithelium of many hollow visceral organs, skin and on the walls of arteries and veins. Areolar tissue binds skin with the muscles and mesenteries, thus acting as a support framework for the epithelium. It acts as a packing tissue in almost all the organs to keep the organs in place and in normal shape. It provides a medium for rapid diffusion of materials.

6. **Which of the following statements is not correct about white fibro-cartilage?**

(1) It is the strongest cartilage.
(2) Matrix is opaque as it contains thick bundles of collagen fibres.
(3) It has scattered lacunae containing chondrocytes.
(4) It is present as tracheal and bronchial rings.

Sol. **(4)**

White fibro-cartilage occurs in the intervertebral disc (cushions between vertebrae), pubis symphysis and articular discs in the knee joint.

7. **Blood cells which are phagocytic in nature are**

(1) Lymphocytes and neutrophils
(2) Eosinophils and basophils
(3) Monocytes and neutrophils
(4) Neutrophils and eosinophils

Sol. **(3)**

Monocytes and neutrophils are phagocytic in nature.

8. **_____ makes up more than one half the volume of neural tissue in human beings.**

(1) Non-myelinated neurons **(2) Ependymal cells**

(3) Neuroglia **(4) Neurosecretory cells**

Sol. **(3)**

Neuroglia makes up more than one-half the volume of neural tissue in our body. The neuroglial cells protect and support neurons.

9. **Select the correct statement.**

(1) Cockroach bears a pair of jointed legs in each thoracic segment, two pairs of thoracic wings, and two pairs of thoracic spiracles.

(2) Cockroach bears two pairs of jointed legs in each thoracic segment, two pairs of thoracic wings, and three pairs of thoracic spiracles.

(3) Cockroach bears a pair of jointed legs in each thoracic segment, two pairs of thoracic wings, and three pairs of thoracic spiracles.

(4) Cockroach bears two pairs of jointed legs in each thoracic segment, three pairs of thoracic wings, and two pairs of thoracic spiracles.

Sol. **(1)**

Cockroach bears a pair of jointed legs in each thoracic segment, two pairs of thoracic wings, and two pairs of thoracic spiracles.

10. **What is true about the reproductive system of a female cockroach?**

(1) It consists of two large yellowish ovaries, lying laterally in the 2^{nd} – 4^{th} abdominal segments embedded in the fat bodies.

(2) Each ovary consists of a group of four ovarian tubules or ovarioles, containing a chain of developing ova.

(3) A pair of spermatheca lies in the 3^{rd} abdominal segment which opens into the genital chamber.

(4) The female phallomeres surrounds the 3^{rd} female genital pore and consist of six chitinous plates.

Sol. **(4)**

It consists of two large yellowish ovaries, lying laterally in the 2^{nd} – 6^{th} abdominal segments embedded in the fat bodies. Each ovary consists of a group of eight ovarian tubules or ovarioles, containing a chain of developing ova. A pair of spermatheca lies in the 6th abdominal segment which opens into the genital chamber.