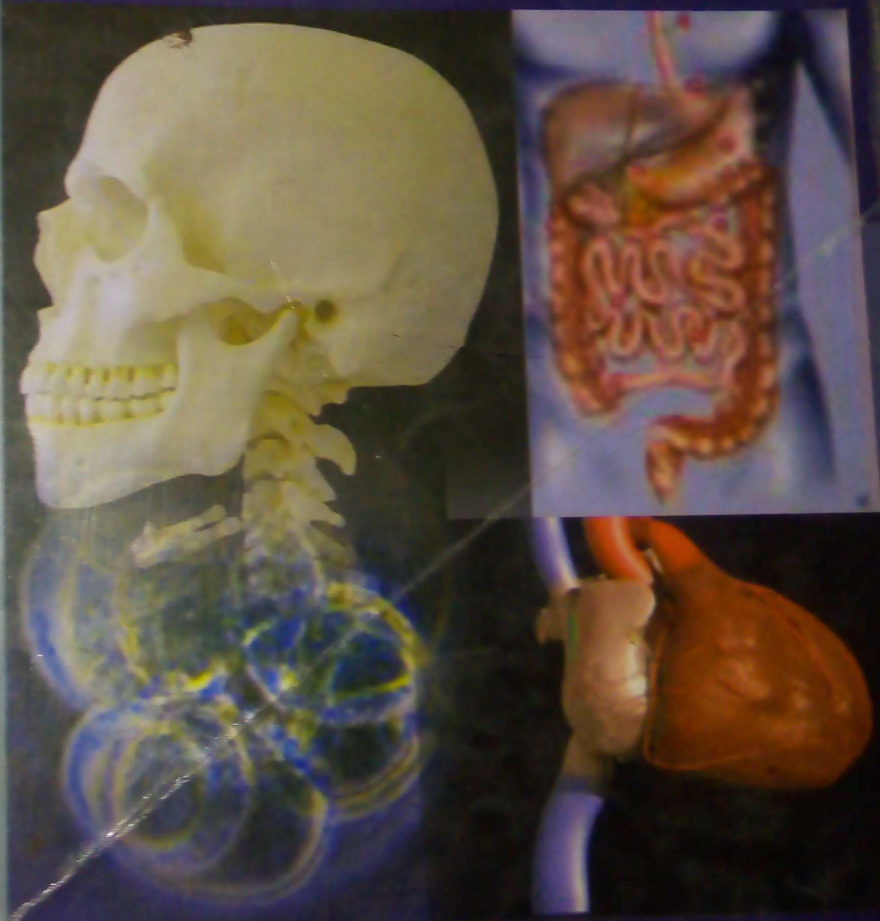


Human Anatomy and Physiology

S. B. BHISE
A. V. YADAV



NIRALI PRAKASHAN

TEXT BOOK OF
**HUMAN ANATOMY
AND
PHYSIOLOGY**

For

**First Year Diploma in Pharmacy
As Per E. R. 1991
and also useful for B.Sc. Nursing Students**

Dr. S. B. BHISE

Principal, Govt. College of Pharmacy
KARAD.

Dr. A. V. YADAV

Head of Pharmacy Deptt;
Government College of Pharmacy
KARAD.

Price ₹ 125.00



NIRALI PRAKASHAN

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INTRODUCTION

The human being is a very complex multicellular organism. The study of human body is divided under two major headings, viz., Anatomy and Physiology.

- (1) **Anatomy** : It is the study of the structure of the body as a whole, and also the study of its individual parts and their relations to one another.
- (2) **Physiology** : It is concerned with the way in which the various parts work and how they are integrated to produce a co-ordinated action of the whole body.

A cell is the smallest functional unit of an organism. Groups of cells having the same physical characteristics and performing similar specialized functions, are described as tissues. Various types of tissues join to form an organ, and a system consists of a number of such organs and tissues. Although each system carries out one or more of the vital functions of the body, none of the systems can exist in isolation because of specialization of cells.

Different body organs have different structures. The variation in structures is due to the variations in the functions they perform. For example, the bony skeleton provides support to various organs; therefore, bones are rigid in structure. The heart has to pump blood through the blood vessels; hence, walls of the heart are highly muscular. In the alveoli of lungs, transfer of gases across the wall is continuous; therefore, the alveolar membrane is very thin. The small intestine is responsible mainly for digestion and absorption of food; as it contains many secretions and villi which assist in effective absorption.

Before discussing these specialities in structures, the various systems are briefly described below :

VARIOUS SYSTEMS OF HUMAN BODY

The human body consists of the following systems :

- (1) **Skeletal System** : It consists of the bony framework. It acts as the supporting structure and offers protection to other organs.
- (2) **Muscular System** : The muscles and tendons are attached to the bones. They help to give the body its shape and power to move in all directions.
- (3) **Nervous System** : It serves to control and to co-ordinate the functions of the various parts of the body. It also makes an individual keenly aware of the environments in which he lives.
- (4) **Circulatory System** : It distributes the essential supplies of oxygen and nutrient materials to all the parts of the body and also removes the waste products from the body.

- (5) **Respiratory System** : It supplies oxygen to the body from the atmosphere and at the same time disposes off carbon dioxide and water vapour from the body.
 - (6) **Digestive System** : It is concerned with the intake of food, its digestion and absorption.
 - (7) **Excretory System** : It removes waste products from the body. It comprises of the organs like kidneys, large intestine, skin, and lungs.
 - (8) **Endocrine System** : It produces certain chemical substances through endocrine glands. These chemical substances are termed as hormones and they regulate body processes.
 - (9) **Reproductive System** : It is the means by which life is transmitted from one generation to another in order to continue the life cycle on the earth.
- All these systems work as an integrated whole producing the co-ordinated effort necessary for the maintenance of health and well-being.
- The human body is built round the bony framework or skeleton which consists of the following parts :

- (a) The head and neck;
 - (b) The trunk divided into thorax, abdomen, and pelvis;
 - (c) The limbs, both upper and lower.
- For the simplicity of description, the body is divided into four cavities, viz.:
- (1) Cranial
 - (2) Thoracic
 - (3) Abdominal and
 - (4) Pelvic.

The *cranial cavity* contains brain. Its boundaries are formed by the bones of the skull. The *thoracic cavity* contains lungs, heart, trachea, bronchi, oesophagus, aorta, superior and inferior vena cavae. The boundaries of thoracic cavity are formed by ribs, sternum and supporting muscles. The *abdominal cavity* contains stomach, small intestine, most of the large intestine, liver, gall bladder, pancreas, spleen, kidneys, upper part of the uterus and suprarenal glands. The *abdominal cavity* is lined by a dome-shaped muscle called diaphragm on the superior side and lumbar vertebrae and muscles on the posterior side. On inferior side, it is continuous with the *pelvic cavity*. The pelvic cavity contains lower part of the large intestine, few loops of small intestine, urinary bladder, lower part of the ureters, urethra and reproductive organs. The pelvic cavity is lined by pelvis, sacrum and coccyx and muscles of the pelvic floor.

VARIOUS PARTS OF SKELETAL SYSTEM

Following are some of the terms used for the anatomical description of the various parts of the skeletal system :

1. **Anatomical Position** : This is the upright position of the human body with the head facing forward, the arms at the sides with palms of the hands facing forward and the feet together.
2. **Median Plane** : When the body in the anatomical position is divided longitudinally in two equal parts, it is divided in the median plane. Any structure towards the mid-line is termed 'medial' and the structure away from the mid-line is called as 'lateral'.
3. **Proximal and Distal** : These terms are used for describing bones of the limbs. The proximal end is nearest to the point of attachment of the limb and the distal end is farthest away.

4. **Anterior or Ventral** : It indicates that the part being described is nearer to the front of the body.
5. **Posterior or Dorsal** : It indicates that the part being described is nearer to the back of the body.
6. **Superior** : It indicates a structure near the head.
7. **Inferior** : It indicates a structure away from the head.
8. **Border** : It is a ridge of bone which separates two surfaces.
9. **Spine, Spinous Process or Crest** : It is a sharp ridge of bone.
10. **Tubercle** : These are small, roughened bony projections for attachment of muscles or ligaments.
11. **Fossa** : It is a depression or a hollow.
12. **Foramen** : It is a hole in a structure.
13. **Sinus** : It is a cavity within a bone.
14. **Meatus** : It is a tube-shaped cavity within a bone.
15. **Articulation** : It is a joint between two or more bones.
16. **Suture** : It is an immovable joint between two or more bones.
17. **Articulating Surface** : It is that part of a bone which enters into the formation of a joint.
18. **Facet** : It is a small, flat, articulating surface.
19. **Condyle** : It is a smooth rounded projection of a bone which takes part in a joint.
20. **Septum** : It is a partition separating two cavities.
21. **Fissure or Cleft** : It indicates a narrow slit.

SUMMARY

The study of human body is divided into :

Anatomy and Physiology:

Organ : A physiological unit composed of two or more tissues associated in performing some special function.

System : An arrangement of organs closely allied and concerned with the same function.

Systems found in the body are :

Skeletal, Endocrine, Reproductive, Muscular, Respiratory, Nervous, Digestive, Circulatory, Excretory.

QUESTIONS

1. Define the terms "Anatomy" and "Physiology".
2. Name various body cavities. Give the names of two organs placed asymmetrically in the body.
3. "Structure of organ is adopted to the function it performs". Explain the statement.

THE CELL

INTRODUCTION

The cell is the basic unit of all body tissues. The living cells are made up of a substance called protoplasm which is slightly opaque, colourless, soft jelly-like substance consisting of water and a large number of substances in solution or suspension. The outermost layer consists of cytoplasmic membrane. Within the cell there is a central mass called nucleus which is surrounded by nuclear membrane. Protoplasm inside the cell and outside the nucleus is called as cytoplasm and the protoplasm inside the nucleus is termed as nucleoplasm.

Cytoplasmic membrane is composed of various layers. It acts as a selective sieve through which certain substances are allowed to enter into the cell and the transport outside the cell few other substances in the form of excretion. Many active transport processes occur across the cytoplasmic membrane. At some places, layers of the cytoplasmic membrane are folded inwards forming vesicles close to the surface and inward projections penetrate into the centre of the cell in the form of channels which widen out into vesicles. This complex within the cell is called endoplasmic reticulum (See Fig. 2.1). In many places, the endoplasmic reticulum carries granules known as

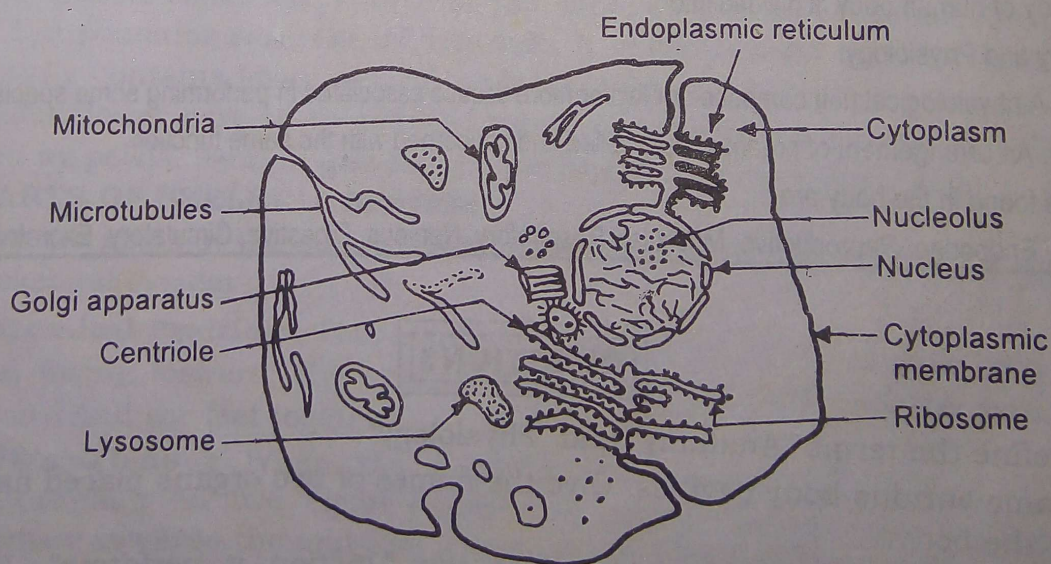


Fig. 2.1 : Components of the Cell

ribosomes. It is also linked with the tightly packed system of smooth-surfaced vesicles near the nucleus called Golgi apparatus. Ribosomes are composed mainly of ribonucleic acid (RNA).

acid which participates in the synthesis of protein in the cells. The endoplasmic reticulum without ribosomes helps in the synthesis of lipid substances. The endoplasmic reticulum and Golgi apparatus have direct and fine connections. The function of Golgi apparatus is to store the secretory substances and prepare for the final secretion. When the endoplasmic reticulum is disrupted by homogenisation, it forms vesicles known as microsomes.

The cytoplasm also contains two more important organelles called mitochondria and lysosomes.

Mitochondria are small intracellular organelles which are surrounded by a double-unit membrane. Many infoldings of the inner unit membrane form shelves on which oxidative enzymes of the cell are adsorbed. When nutrients and oxygen come in contact with these enzymes, they combine to form carbon dioxide, water and liberated energy is utilized to synthesize adenosine triphosphate (ATP). The ATP then diffuses throughout the cell and releases its stored energy for performing cellular functions. The mitochondria contains a special type of deoxyribonucleic acid and are probably self-replicative. Their main function is, therefore, as a store-house of energy.

Lysosome is another intracellular structure surrounded by a lipoprotein unit membrane. It is filled with a large number of small granules which are aggregates of digestive enzymes. These enzymes can digest proteins, nucleic acids, mucopolysaccharides and glycogen. Ordinarily, the membrane surrounding lysosome prevents the enclosed digestive enzymes from coming in contact with other substances in the cell.

Many cells contain fine tubular structures called microtubules which are arranged in bundles. These are stiff structures that break if bent too severely. The primary function of microtubules is to provide rigid physical structures for certain parts of cells like cilia. They are also used for movement of cytoplasm. The cytoplasm of each cell contains two centrioles which are small cylindrical structures. They play an important role in cell division.

Besides these organelles, the cells also contain organic and inorganic salts, carbohydrates, fatty substances and proteins.

A nucleus is the control of the cell. It contains large quantities of deoxyribonucleic acid (DNA). The nuclear membrane has characteristics similar to those of the cell membrane except that very large holes or pores are present in nuclear membrane. The nucleus also contains one or more lightly staining structures called nucleoli. The nucleolus does not have a limiting membrane. It is an aggregate of loosely bound granules composed mainly of ribonucleic acid (RNA). It becomes usually enlarged when the cell is actively synthesizing proteins. The RNA stored in nucleolus disperses to cytoplasm where it controls cytoplasmic functions.

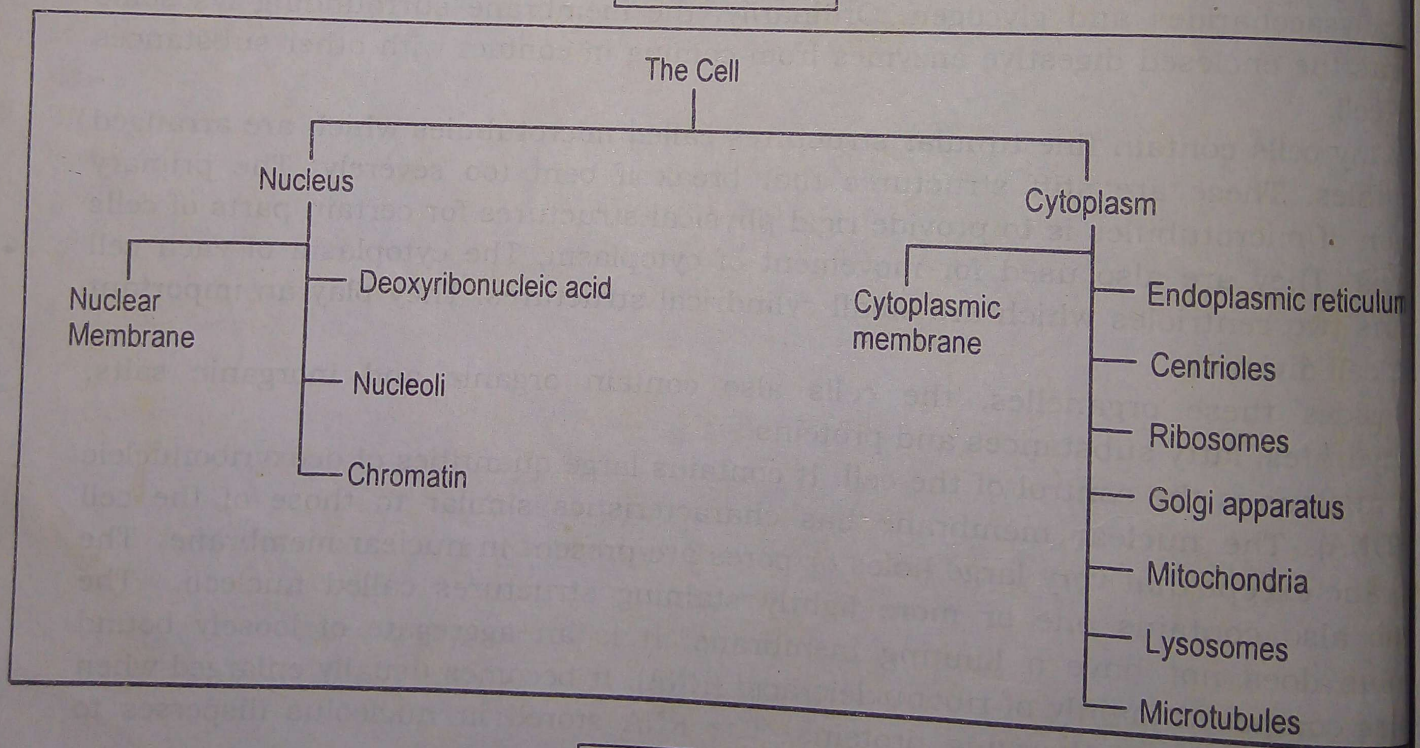
Reproduction of Cells :

Reproduction of cells helps in the continuation of that species. The genetic material present inside the nucleus exists as thread-like structures known as chromosomes. They contain genes. The number of chromosomes is a characteristic of that species. Human cells contain 46 chromosomes arranged in 23 pairs. In a cell division, 'daughter cells' are identical to 'parent cells' and contain the same number of chromosomes, it is called mitosis. In a cell division, when the number of chromosomes is reduced to half, it is called as meiosis. Formation of sexual gametes takes place by meiosis.

There are various well defined stages in the process of meiosis. They are as follows :

- (a) **Prophase** : This is the phase during which the centrosome divides into two parts and migrates to either of the poles of the cell. They form spindles between them. Each chromosome then gets divided into two and the pair is held together by a centromere. *chr*
- (b) **Metaphase** : This is the phase during which the nuclear membrane disappears and the chromosomes arrange themselves at the centre of the cell and are attached to the spindles between the centrosomes. *chromoso*
- (c) **Anaphase** : This is the phase, during which the centromere divides and the identical chromosomes move apart. They arrange themselves at the opposite poles of the cell. Now the spindles break.
- (d) **Telophase** : This is the phase during which the nuclear membrane reappears, the spindles disappear and the constriction develops round the middle of the cell body. This finally leads to two daughter cells.

SUMMARY



QUESTIONS

1. Define cell. Draw a diagram of a typical cell with proper labelling.
2. Describe the physiology of mitochondria and microsome.
3. Describe the cell physiology.

THE TISSUES

INTRODUCTION

A tissue consists of cells and products of cells specially developed for carrying out certain specific functions. The tissues are classified according to the size, shape and functions. There are four main types of tissues viz. :

- (1) Epithelial tissue or epithelium
- (2) Muscular tissue
- (3) Nervous tissue and
- (4) Connective tissue.

1. EPITHELIAL TISSUE (Epithelium)

Epithelium is the type of tissue, covering outer side of the body and lining various cavities within, including air passages and digestive tube. It performs two main functions viz.; (a) Protection of the underlying tissues against friction or injury and (b) Secretion of special chemical substances which are either used elsewhere in the body or excreted as waste products. On the outer side of the body, epithelial tissues form skin and within the body, the epithelial tissues form membranes and glands. As the cells forming epithelial tissues are very closely packed together, the intercellular substance "matrix" is minimal. The cells usually lie on a basement membrane which is an inert connective tissue.

Epithelial tissue is divided into two types : (i) Simple Epithelium, (ii) Compound Epithelium.

Simple Epithelium :

It consists of a single layer of cells resting on a basement membrane. It is subdivided into four types. These types are named according to the shape of the cells which differ according to the functions they perform. The four sub types are :

- (a) Squamous or pavement epithelium;
- (b) Cuboidal epithelium;
- (c) Columnar epithelium; and
- (d) Ciliated epithelium.

(a) *Squamous or Pavement Epithelium* : This is composed of a single layer of flattened cells (Fig. 3.1). The cells fit closely like flat stones and form a very smooth membrane. This tissue provides a thin, smooth, inactive lining for the following structures :

Heart, Blood vessels, Alveoli of the lung and Lymph vessels.

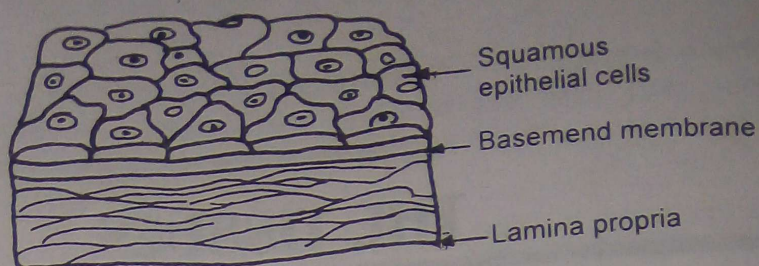


Fig. 3.1 : Squamous Epithelium

(b) *Cuboidal Epithelium* : This is composed of cube-shaped cells fitting closely together on a basement membrane in tubules of kidney and some glands. This tissue is actively involved in secretion or absorption. Since, it is present in simple glands producing glandular secretions, it is also called as secretive epithelium.

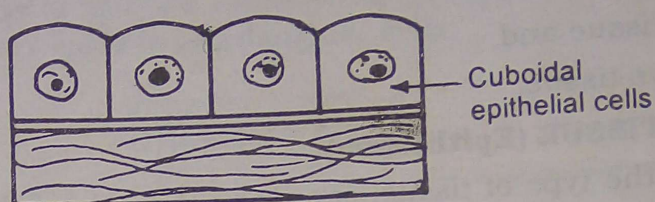


Fig. 3.2 : Cuboidal Epithelium

(c) *Columnar Epithelium* : This is formed by a single layer of cylindrical cells resembling tiny columns and is situated on a basement membrane. It is found lining the organs of the alimentary tract. Special columnar cells called 'goblet cells' in the gastro-intestinal tract, secrete a thick sticky substance called mucous.

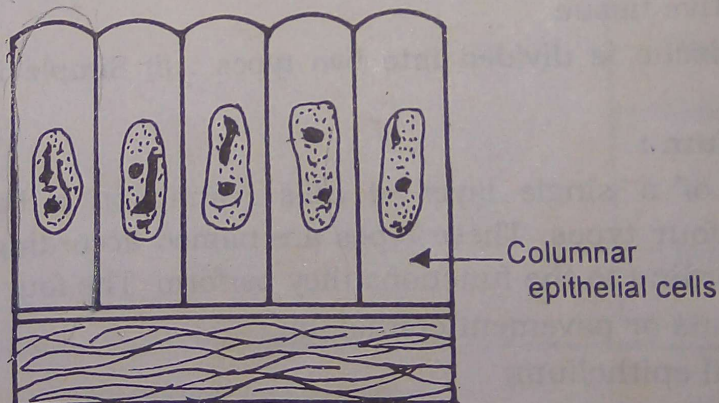


Fig. 3.3 : Columnar Epithelium

(d) *Ciliated Epithelium* : This is formed by columnar cells with fine, hair like protoplasmic processes called cilia on their free surface. The cilia are capable of moving and beating in one particular direction. The wave-like movement of cilia moves the contents of the tubes they line, in one direction only. It is found lining most of the respiratory passages and the uterine tubes. In the respiratory passages, it propels mucous towards the throat, and in the uterine tube, it propels the ova towards the uterus.

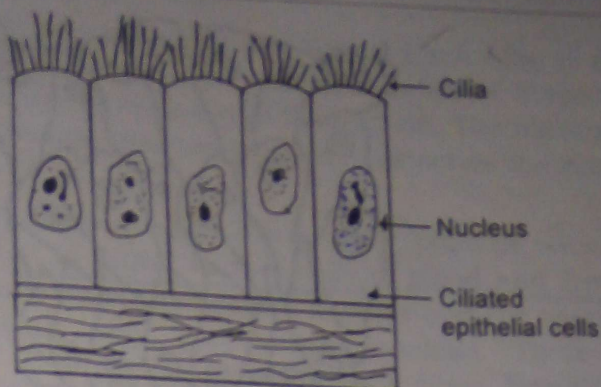


Fig. 3.4 : Ciliated Epithelium

Compound Epithelium :

This consists of a number of layers of cells. The main function of this tissue is to protect underlying structures. There are two main types : Stratified and Transitional epithelium.

(a) *Stratified Epithelium* : The deepest layers of the cells are columnar in shape and as they grow towards the surface, they become flattened (Fig. 3.5). This is because of the constant migration of cells from deeper layer towards the surface. When the surface

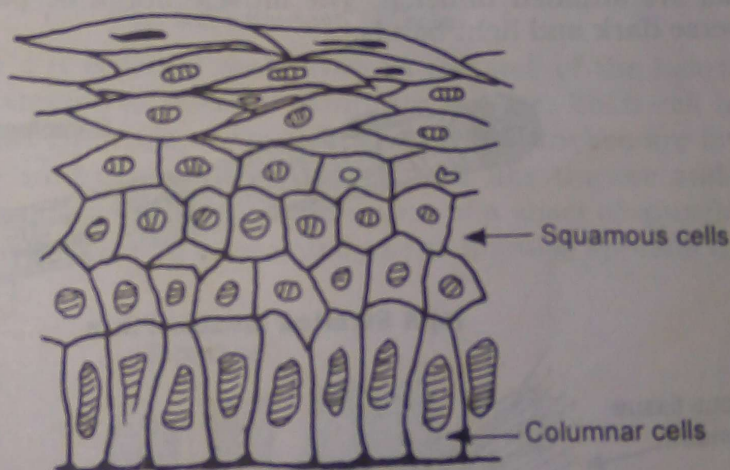


Fig. 3.5 : Stratified epithelium

is reached, the cells die and lose their nuclei. In some cases, superficial layers are hardened to form a substance 'keratin'. Such cells are called keratinized epithelial cells. Non-keratinized epithelium is found on wet surfaces such as conjunctiva of the eyes, lining of mouth, pharynx and oesophagus. Keratinized epithelium is found on dry surfaces like skin, hair and nails.

(b) *Transitional Epithelium* : This is composed of several layers of pear-shaped cells and represents a stage between simple and stratified epithelium. Its superficial layer is of cubical cells beneath which are three or four layers of oval shaped cells (Fig. 3.6). They are held together by an intercellular cement, which is slimy in nature and allows the cells to slip over one another. This tissue is found lining accessory structures of urogenital system viz., ureters, bladder and urethra.

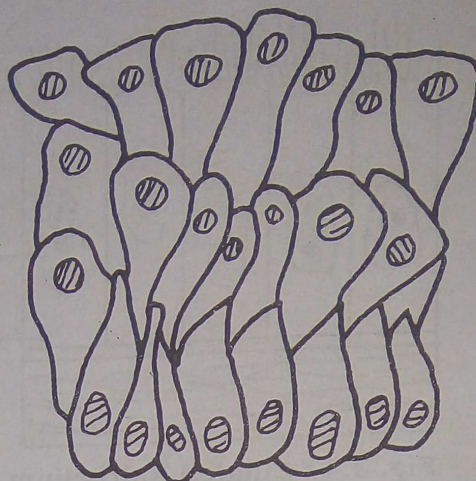


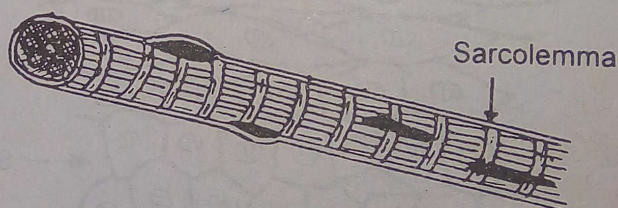
Fig. 3.6 : Transitional Epithelium

2. MUSCULAR TISSUE

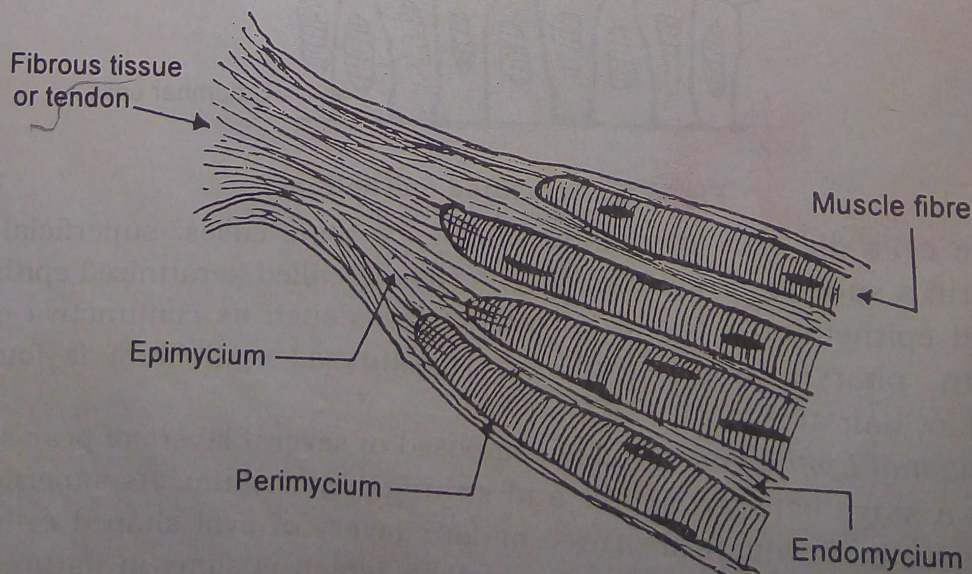
It is contractile and therefore able to produce movements. It consists of muscle fibres, each one able to shorten or contract. There are three types of muscular tissue:

- (a) Striated or voluntary muscle;
- (b) Smooth or involuntary muscle; and
- (c) Cardiac muscle.

(a) Striated Muscle : It is described as skeletal, striated, stripped or voluntary muscle. It works under the control of the will. It is found in skeletal muscle. The cells of voluntary muscle are about 10 to 40 millimetres in length and are roughly cylindrical in shape (Fig. 3.7). Sarcolemma is the fine sheath surrounding each muscle fibre. Several nuclei are situated under it. The muscle fibres lie parallel to one another and show transverse dark and light bands.



(a) A Striated Muscle Fibre



(b) A Bundle of Striated Muscle Fibres and their Connective Tissue

Fig. 3.7

Muscle is attached to the perimysium beyond the skin.

(b) Smooth muscle is not under voluntary control. It is found in the alimentary canal, blood vessels, and other organs. It consists of spindle-shaped cells with a single nucleus. The sarcolemma is the fine sheath surrounding each muscle fibre. The muscle fibres lie parallel to one another and show transverse dark and light bands.

(c) Cardiac muscle cells show striations and one nucleus with each cell. This arrangement of fibres. Each fibre is surrounded by a layer of connective tissue.

Muscle consists of a large number of muscle fibres. Each fibre is enclosed in and attached to fibrous tissue called endomysium. Small bundles of fibres are enclosed in perimysium and the whole muscle is enclosed in epimysium. The fibrous tissue extends beyond the muscle fibres to become the tendon which attaches the muscle to bone or skin.

(b) Smooth Muscle : It is described as involuntary, plain or visceral muscle. It is not under control of the will. It is found in the walls of blood and lymph vessels, the alimentary tract, the respiratory tract, the urinary bladder and the uterus. The cells are spindle shaped (Fig. 3.8) with only one central nucleus. There is no distinct sarcolemma; but a very fine membrane surrounds each fibre. Bundles of fibres form sheets of muscles which form parts of the walls of above structures. During contraction and relaxation, the fibres glide over one another.



Fig. 3.8 : Smooth Muscle

(c) Cardiac Muscle : It is found exclusively in the wall of the heart. The cardiac cells show cross-stripes similar to those of voluntary muscle. Each cell has a nucleus and one or more branches. The ends of the cells and their branches are in close contact with each other forming 'intercalated discs' which look like thicker and darker lines. This arrangement gives cardiac muscle an appearance of a sheet of muscles rather than fibres. Each fibre does not need to be stimulated as the impulse spreads from cell to cell across intercalated discs.

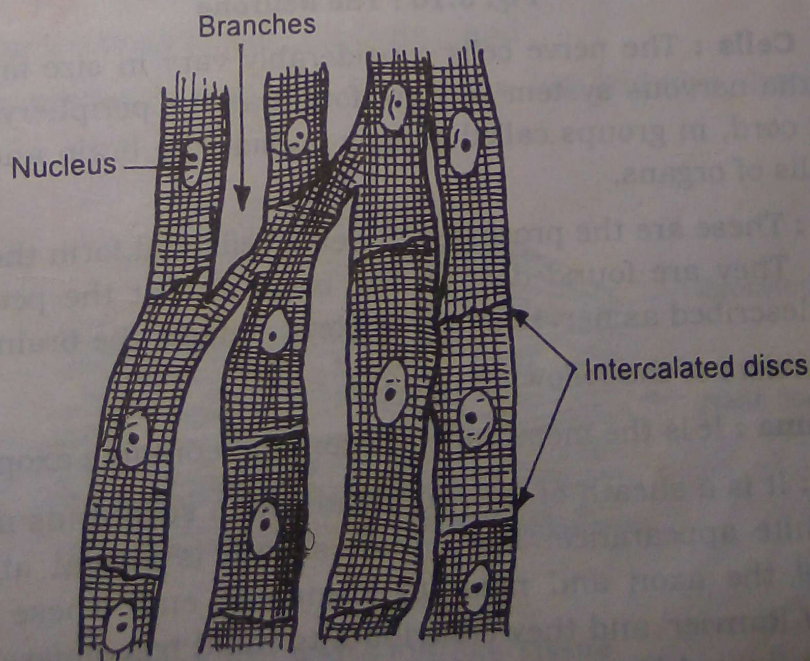


Fig. 3.9 : Cardiac Muscle

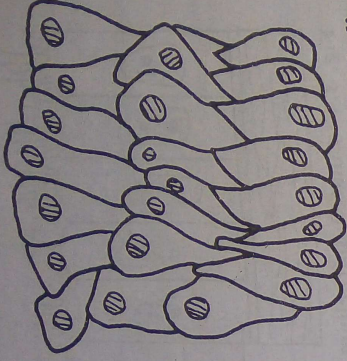
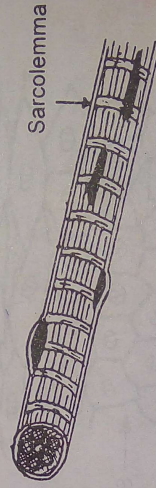


Fig. 3.6 : Transitional Epithelium

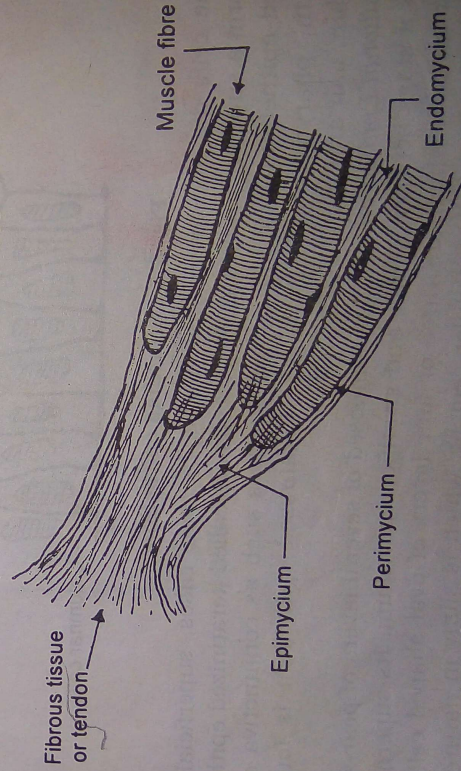
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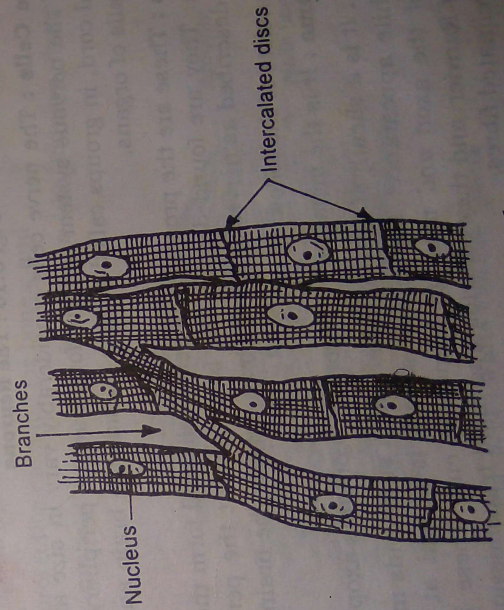


Fig. 3.9 : Cardiac Muscle

3. NERVOUS TISSUE

The nervous tissue carries out the special function of carrying messages of stimuli within the body. The properties of irritability and conductivity are specially developed in the nervous tissue. The impulses are conducted along the special cells 'neurons' which form a unit structure of the nervous tissue. Each neurone consists of a nerve cell and its processes called axons and dendrites (Fig. 3.10).

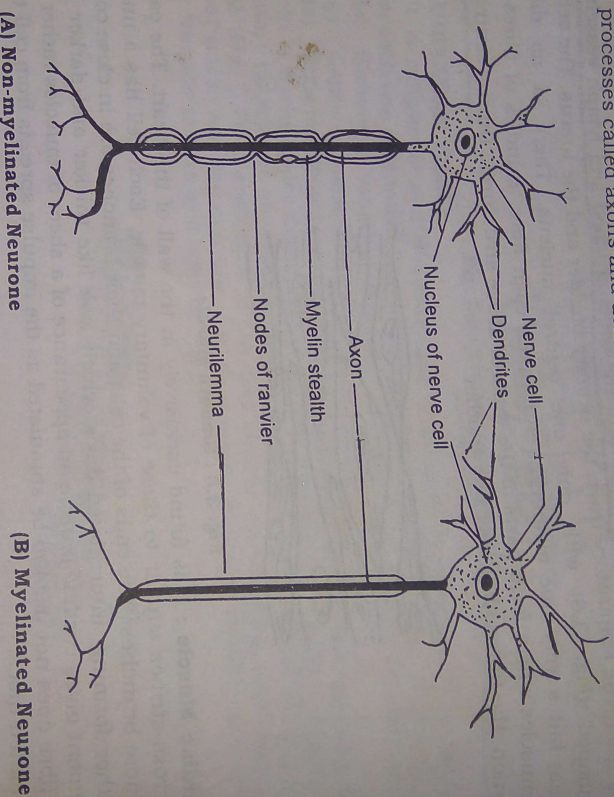


Fig. 3.10 : The Neuron

(i) **Nerve Cells** : The nerve cells considerably vary in size and shape. They form the gray matter of the nervous system and are found at the periphery of the brain, in the centre of spinal cord, in groups called ganglia outside the brain and spinal cord and as single cells in walls of organs.

(ii) **Axons** : These are the processes of nerve cells and form the white matter of the nervous system. They are found deep in the brain and at the periphery of the spinal cord. These are described as nerves or nerve fibres outside the brain and spinal cord.

The axon consists of the following parts :

- (a) **Axolemma** : It is the membrane of axon and contains axoplasm.
- (b) **Myelin** : It is a sheath of fatty material which surrounds most axons and gives them white appearance. The myelin sheath is absent at intervals along the length of the axon and near its branching end. These intervals are called 'Nodes of Ranvier' and they contribute to rapid transmission of nerve impulses along myelinated fibres.

(c) **Neurilemma** : It is a very fine, delicate membrane surrounding the axons of all peripheral nerves. It consists of a series of 'Schwann cells' which surround the axon and the myelin sheath.

(iii) **Dendrites** : These are the processes on nerve cells which carry impulses towards nerve cells. These are shorter as compared to axon and each neurone have many dendrites.

Types of Neurones :

(1) **Sensory or Afferent Neurones** : These neurones transmit impulses from the periphery of the body to the spinal cord and then to the brain where they are interpreted and sensed e.g. sense of taste, sight, touch etc.

(2) **Motor or Efferent Neurones** : These neurones convey impulses from the brain and spinal cord to other parts of body stimulating glandular secretion or causing muscle contraction.

(3) **Intercalated Neurones** : These are found between sensory and motor neurones and form links in the pathways of nerves.

Synapse : In the transmission of a nerve impulse, whether sensory or motor more than one neurone is always involved. The point at which the nerve impulse passes from one to another is called synapse. Various chemicals known as transmitters are secreted in the synapse and are involved in the transmission of information across the synapse.

4. CONNECTIVE TISSUE

This tissue binds together and supports more active and delicate tissues of the body. In structure, these tissues consists of tiny threads or fibres. These fibres are specially developed cells and are of two types : White and Yellow.

(a) **The White Fibres** : These are wavy and run in bundles with very little matrix. (Fig. 3.11). They are inelastic but can be slightly stretched because of their wavy nature. They contain protein 'collagen' and yield gelatin on boiling. These fibres are found :

- (1) Forming the ligaments which bind bones together;
- (2) As an outer protective covering for bones; and
- (3) As an outer protective covering for organs like kidneys, lymph nodes and brain.

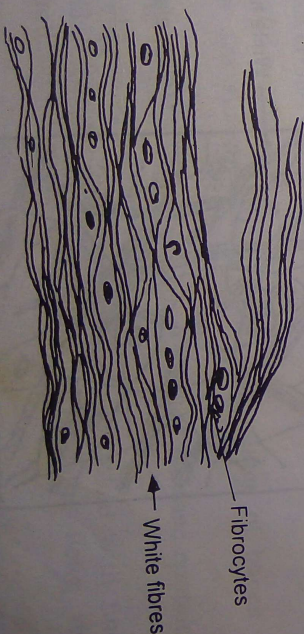


Fig. 3.11 : White Fibrous Tissue

(b) **Yellow elastic fibres** : These run either single or branched. They are composed of highly elastic material and permit considerable stretching (Fig. 3.12). These fibres are found in such organs as large arteries, trachea, bronchi, lungs etc. where alteration of shape is required.

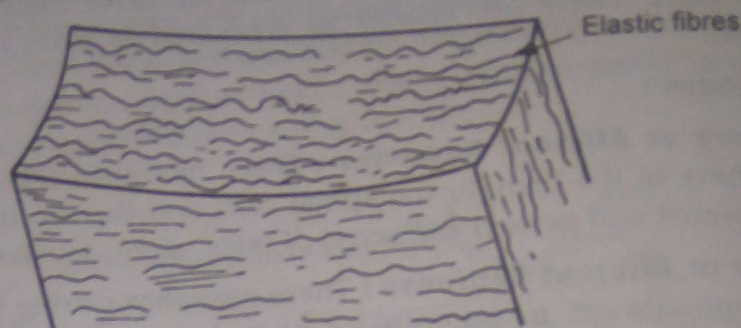


Fig. 3.12 : Yellow Elastic Fibres

From these fibres the following varieties of connective tissues are formed :

- (1) Loose connective or Areolar tissue;
- (2) Fatty or Adipose tissue;
- (3) Fibrous tissue;
- (4) Bone and
- (5) Cartilage.

Two special connecting tissues, viz., blood and lymphoid tissues are discussed separately.

(1) **Areolar tissue** : It consists of a loose network of fibres. It has a semi-solid matrix with the cells (Fig. 3.13) called fibrocytes widely separated by yellow elastic and white fibres. Few blood vessels and nerves may be found running through the tissue. It is found in almost every part of the body connecting and supporting other tissues e.g. under the skin, between muscles, supporting blood vessels and nerves, in the alimentary canal, in glands supporting secretory cells etc.

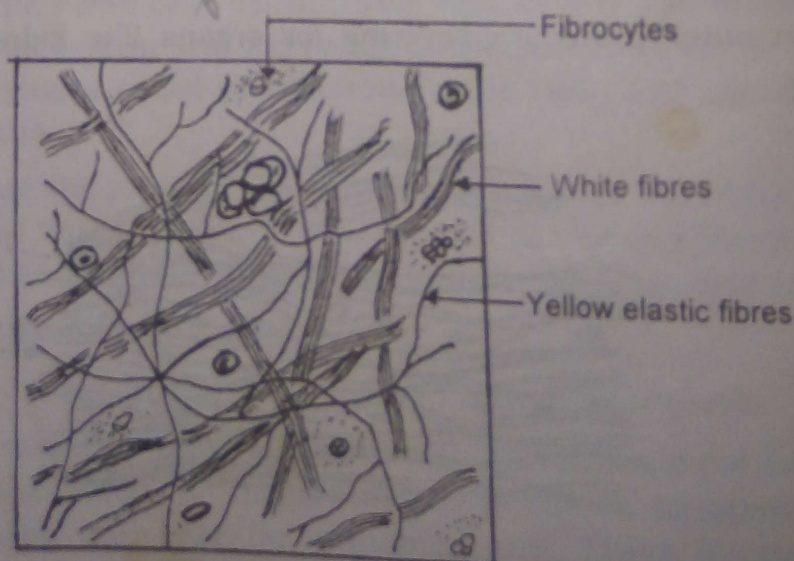


Fig. 3.13 : Areolar Tissue

(2) **Adipose Tissue** : It consists of a collection of fat cells containing fat globules. (Fig. 3.14). The cells are present in the matrix of adipose tissue in varying numbers. The tissue is found supporting organs such as kidneys and the eyes, between bundles of muscle fibres, with areolar tissues under the skin etc.

It has three special uses :

- (a) It forms a food reserve from which the body can draw food when needed;
- (b) Fat being poor conductor of heat serves to retain the body heat and
- (c) It protects the delicate organs.

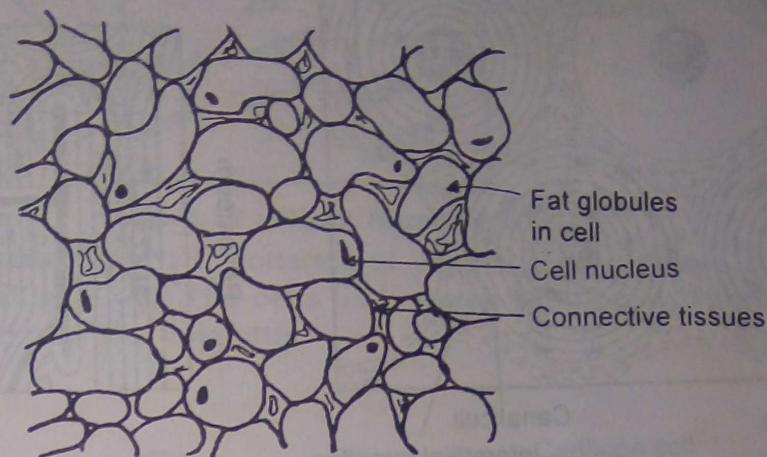


Fig. 3.14 : Adipose Tissue

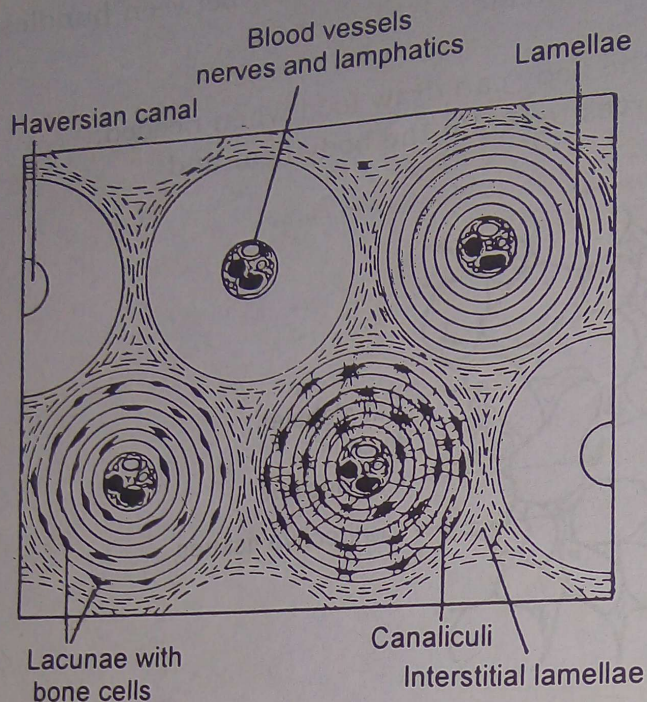
(3) **Fibrous Tissue** : It consists of either white or yellow fibres densely massed together. It is strong as compared to the loose connective and fatty tissue. It is found forming skins in tendons and ligaments. Tendon is a strong cord of white fibrous tissue joining muscle to bone. A ligament is a strong fibrous cord joining bone to bone. The tissue forms deep or true skin of the body.

(4) **Bone** : It is one of the hardest connective tissues in the body. It consists of a specialized type of fibrous material e.g. fibrous tissue hardened by deposits of material salts chiefly calcium phosphate derived from plasma. The fibrous material gives it toughness, while the mineral matter gives it rigidity. This tissue forms the skeletal system. There are two types of bone tissues : (a) Compact and (b) Cancellous.

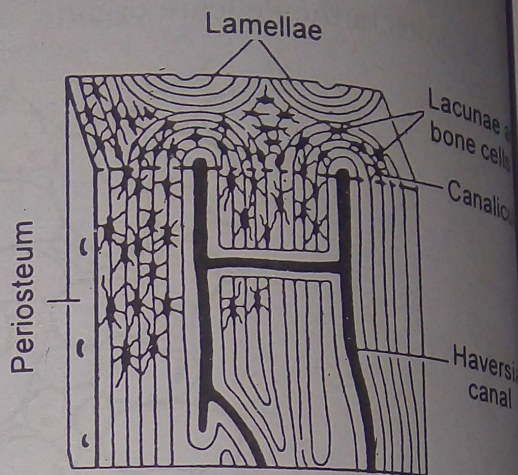
(a) **Compact Bone** : It consists of a large number of units called haversian systems which have well-defined characteristics.

- (1) A central haversian canal runs longitudinally and contains blood, lymph, capillaries and nerves.
- (2) The canals are surrounded by concentric plates of bones known as lamellae.
- (3) Between the lamellae there are spaces called lacunae containing lymph and bone cells called osteocytes.
- (4) The haversian canals and the lacunae are linked with fine channels called canaliculi. Lymph carrying nourishment flows through the canaliculi.
- (5) In the spaces between the haversian system there are interstitial lamellae.

(b) **Cancellous Bone** : It looks like a sponge. The haversian canals are larger and there are fewer lamellae as compared to compact bone. Red marrow is always present with cancellous tissue.



(A) Cross Section



(B) Longitudinal Section

Fig. 3.15 : The Bone

(5) **Cartilage** : It is a specialized type of fibrous tissue. It is very strong and forms a framework for the outer parts of ear and nose. It also provides a firm wall to the parts of air passage e.g. larynx and trachea. It has a solid matrix. It is divided into three types :

- Hyaline cartilage;
- White fibrocartilage; and
- Yellow or elastic fibrocartilage.

(a) **Hyaline Cartilage** : It appears as a smooth bluish-white tissue. The cells appear in groups of two or more and where they come in contact, the edges appear to be flattened. (Fig. 3.16). The matrix is solid and smooth. It is found :

- On the surface of the parts of the bones which form joints;
- Forming the costal cartilages which attach ribs to the sternum; and
- Forming part of the larynx, trachea and bronchi.

(b) **White Fibrocartilage** : It consists of dense masses of white fibres in a solid matrix with the cells widely dispersed (Fig. 3.17). It is a tough, slightly flexible tissue.

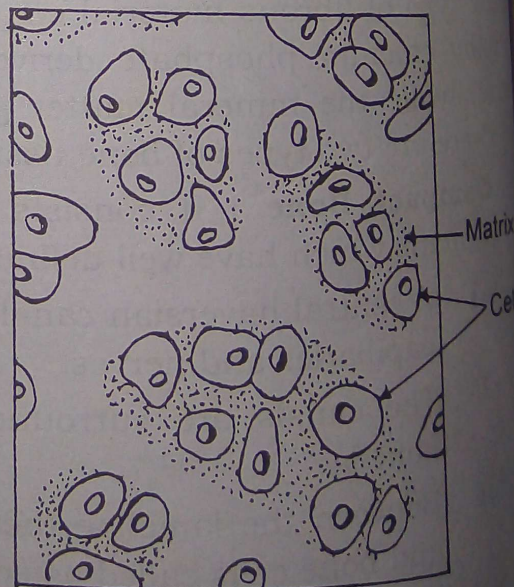


Fig. 3.16 : Hyaline Cartilage

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It is found :

- (i) As pads between the bodies of the vertebrae called inter-vertebral discs,
- (ii) Between articulating surfaces of bones of the knee joint and
- (iii) Surrounding the rim of the bony sockets of the hip and shoulder joints.

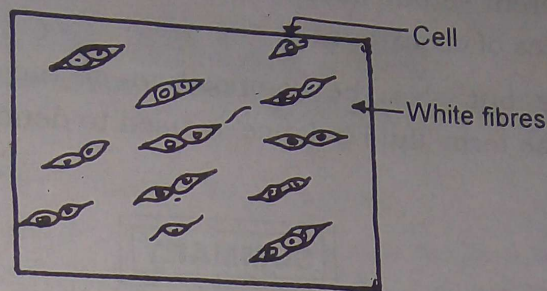


Fig. 3.17 : White fibrocartilage

- (c) **Yellow Fibrocartilage** : It consists of yellow, elastic, fibres running through solid matrix (Fig. 3.18). The cells lie between the fibres. It forms the pinna or lobe of the ear and the epiglottis.

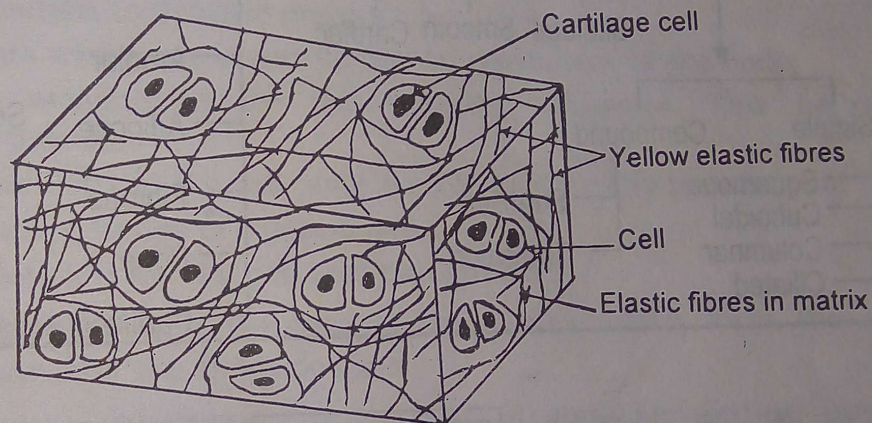


Fig. 3.18 : Yellow Elastic Fibrocartilage

Body Fluids : Water is the universal medium in which all metabolic reactions occur. About 60% of our body weight is made up of water. Water along with dissolved substances in it, constitute body fluids. A major proportion of body fluid is found intracellularly i.e. in the form of protoplasm. There are four body fluid compartments as follows :

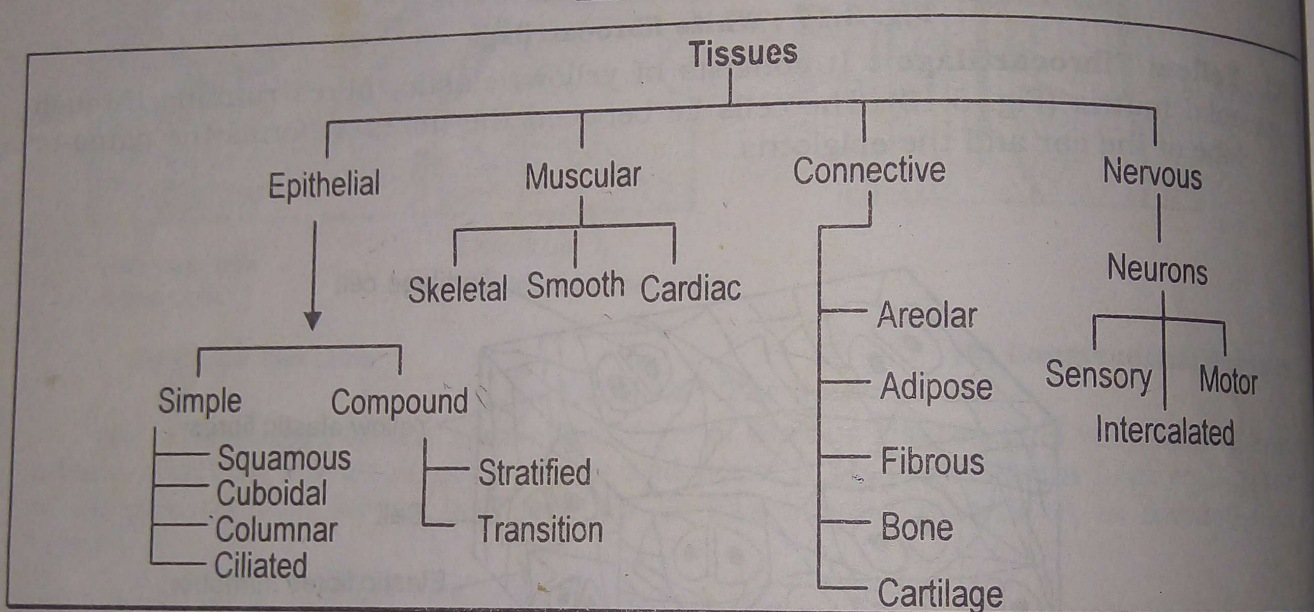
- (1) Intracellular,
 - (2) Extracellular (Tissue fluid),
 - (3) Circulatory system (Blood plasma and lymph) and
 - (4) Transcellular fluid compartment e.g. (CSF, synovial fluid, serous fluid etc.).
- (1) **Intracellular fluid** : About 65% of body water is present intracellularly. It contains food materials like glucose, amino acid, and electrolytes like potassium, phosphates etc. All metabolic reactions occur here.
- (2) **Extracellular fluid** : All the cells of the body are bathed in this fluid. It acts as a medium from which the cells obtain their nourishment and waste materials from cells are washed away.

(3) **Plasma fluid (Circulatory system)** : It acts as a transport system and through the medium of extracellular fluid, serves the cells of the body.

(4) **Transcellular fluids** : These include cerebrospinal fluid (CSF) present in subarachnoid space in the meninges of central nervous system; and serous fluid in different serous membranes. These fluids perform specialised functions at their places of occurrence.

Not only volume but also the composition of these body fluids is maintained relatively constant. The term 'fluid balance' is used to denote this property.

SUMMARY



QUESTIONS

1. Define cartilage. What are the various types of cartilages ? Name the places in the body where white fibrocartilage is found.
2. What is tissue ? List the primary tissues of the body and their functions.
3. What are cilia and what is their function ? In what areas of the body is ciliated epithelium present ?
4. Mention the areas of the body where the nerve cells (cell bodies) of neurons are found.
5. Name the organs in which the following tissues are found : transitionary epithelium, areolar tissue, white fibrous tissue, hyaline cartilage and cardiac muscle.

INTRODUCTION

Skeleton of the body provides a framework for the organs and they form joints of various types.

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THE SKELETON

INTRODUCTION

Skeleton constitutes the bony framework of the body.

The skeletal system consists of about 206 bones to make a strong, movable living framework for the body. It supports and protects softer, delicate tissues and organs and they form joints for the movement of the body. The bones making up the skeleton are of various types e.g. long bones, short bones, flat bones, irregular bones etc.

The bones perform the following important functions :

- (1) They form the supporting framework of the body;
- (2) They form boundaries for the cranial, thoracic and pelvic cavities;
- (3) They give protection to delicate organs;
- (4) They form joints which are essential for the movement of the body;
- (5) They provide attachment for the voluntary muscles. This helps in the movements of joints;
- (6) They form blood cells in the red bone marrow in cancellous bone; and
- (7) They act as a store house of calcium salts.

The bones of the skeleton are divided into two groups :

- (1) **The Axial Skeleton** : It consists of the bones which form the skull, the vertebral column and the thoracic cage.
- (2) **The Appendicular Skeleton** : It consists of shoulder girdles, upper limbs, pelvic girdle and lower limbs.

THE AXIAL SKELETON

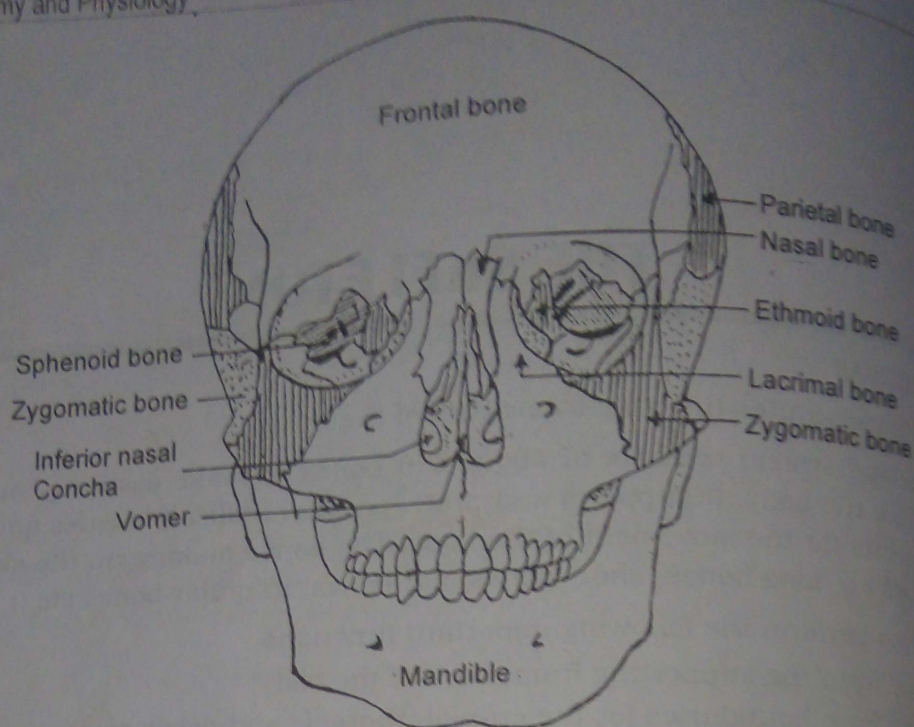
The bones of the axial skeleton constitute the central bony core of the body.

THE SKULL

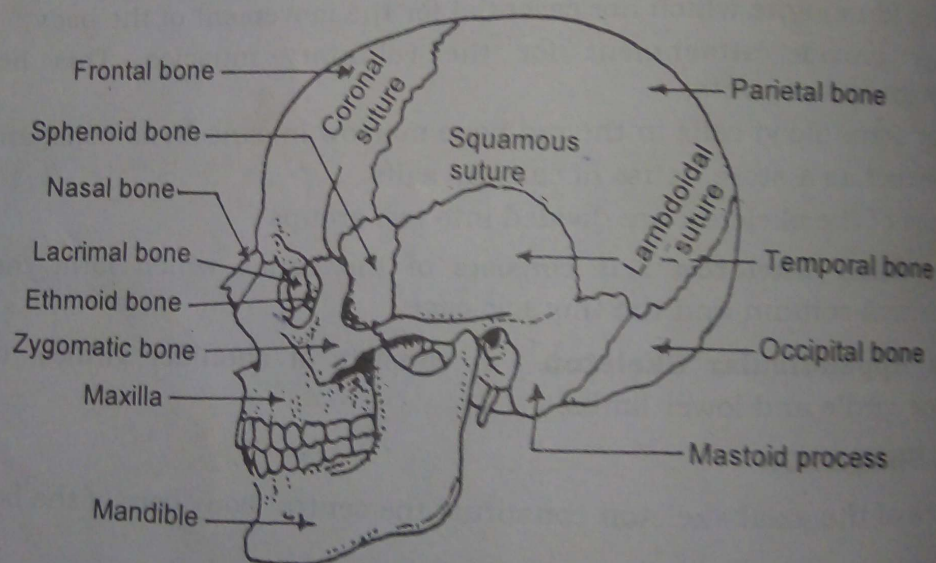
It rests upon the upper end of the vertebral column and its bony structure is divided into two parts viz., cranium and face.

The Cranium : It provides bony protection to the brain. It is described in two parts : base and vault. The base is a part on which the brain rests and the surrounding part is termed as the vault. The base is divided into the anterior, middle and posterior cranial fossae. The inner surfaces of all the cranial bones are supplied with blood vessels. The bones which form the cranium [Fig. 4.1 (a) and (b)] are : one frontal bone; two parietal bones; one occipital bone; one sphenoid bone; one ethmoid bone and two temporal bones.

(4.1)



(a) The Bones of the Skull (Anterior View)



(b) The Bones of the Skull (Lateral View)

Fig. 4.1

1. The Frontal Bone :

The frontal bone is a large flat bone which forms the forehead and also the upper part of the orbital cavities. It develops in two parts which gradually fuse into one. It contains two cavities called the frontal sinuses which lie one over each orbit. It contains air which enters by a small opening leading from nasal cavities. These sinuses give lightness to the bone and resonance to the voice, acting as sounding chambers.

2. The Parietal Bones :

The parietal bones are two flat bones forming sides and roof of the skull. They articulate with each other and with frontal, occipital and temporal bones. The external surface is concave and is grooved by the brain and blood vessels.

3. The Occipital Bone :

The occipital bone is a large flat bone which forms the back of the skull. It is immovable joint with the parietal bones. There is a rough opening known as the foramen magnum.

4. The Temporal Bone :

The temporal bone is a large flat bone which forms the side of the skull. It is divided into four parts:

- (1) The squamous part
- (2) The zygomatic process
- (3) The mastoid process
- (4) The styloid process

5. The Sphenoid Bone :

The sphenoid bone is a large flat bone which forms the base of the skull. It is an outstretched bone. The surface of the bone is smooth. The sphenoid bone is a large flat bone which forms the base of the skull. It is an outstretched bone. The surface of the bone is smooth. The sphenoid bone is a large flat bone which forms the base of the skull. It is an outstretched bone. The surface of the bone is smooth.

3. The Occipital Bone :

The occipital bone forms back of the head and part of the base of the skull. It forms immovable joints with parietal, temporal and sphenoid bones. On the outer surface, there is a roughened area called occipital protuberance. In this bone, there is a large opening known as the foramen magnum, for the passage of spinal cord.

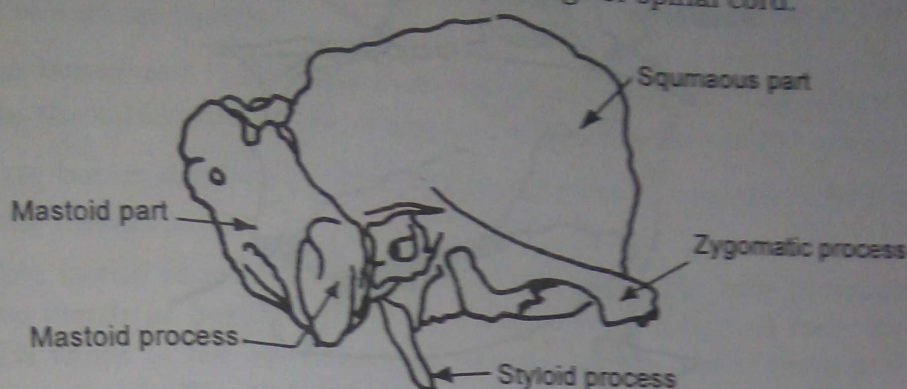


Fig. 4.2 : The Temporal Bone (Lateral View)

4. The Temporal Bones :

The temporal bones lie on each side of the head (Fig. 4.2). Each temporal bone is divided into four parts. They are :

- (1) The squamous part is the fan shaped portion.
- (2) The mastoid process is a thickened part of bone and can be felt just behind the ear. It contains a large number of small air sinuses which communicate with middle ear. A styloid process projecting from it gives attachment to muscles.
- (3) The petrous portion is thick and forms a part of the base or floor of the skull and contains the organ of hearing.
- (4) The zygomatic process is directed forward and articulates with the zygomatic bone to form zygomatic arch.

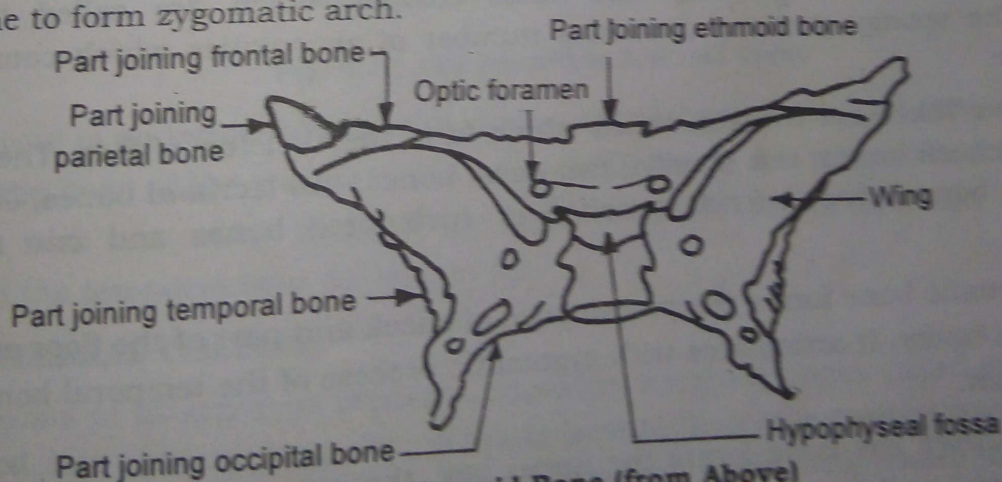


Fig. 4.3 : Sphenoid Bone (from Above)

5. The Sphenoid Bone :

The sphenoid bone is an irregular bone in the shape of a bat with its wings outstretched and lies in the centre of the base of the skull (Fig. 4.3). On the superior surface of the middle of the bone, there is a depression in which the pituitary gland sits. The wings are perforated by many openings for the passage of nerves and blood vessels.

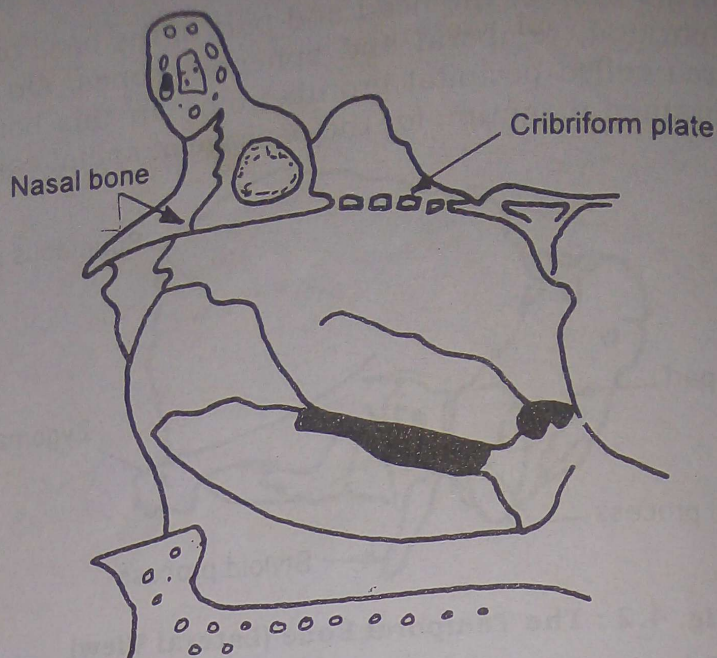


Fig. 4.4 : Ethmoid Bone

6. The Ethmoid Bone :

The ethmoid bone is a very light, fragile, irregular bone and occupies an anterior part of the base of the skull and helps to form the orbital cavity, the nasal septum and the lateral walls of the nasal cavity (Fig. 4.4). It has a horizontal flattened part called cribriform plate which has many fine openings like a sieve. The openings are for the passage of the nerves of smell called the olfactory nerves. It also contains a flat vertical portion between the two nasal cavities. Two spongy portions form an outer wall of the upper part of the nasal cavity and inner wall of the orbit. On each side, the spongy portions present two projections into nasal cavities which are called turbinate processes. The spongy portions contain a number of air cavities which communicate with the nose.

The Face : There are thirteen bones which form the skeleton of face. They are the zygomatic or cheek bones; one maxilla; two nasal bones; two lacrimal bones; one vomer; two palatine bones; two inferior conchae or turbinated bones and one mandible (Fig. 4.1).

Each zygomatic bone forms the prominence of cheek and part of the floor and lateral walls of orbital cavity. It articulates with zygomatic process of the temporal bone to form a zygomatic arch.

Maxilla or upper jaw bone forms the upper jaw, the anterior part of the roof of the mouth, the lateral walls of the nasal cavities and part of the floor of orbital cavities. It presents the alveolar ridge which projects downwards and carries the upper teeth. On each side, there is a large air sinus, the maxillary sinus which is lined with ciliated mucous membranes and communicates with the nasal cavity.

The nasal bones are two small bones which form greater part of the lateral and superior surfaces of the bridge of the nose. They articulate with each other medially.

The lacrimal bones are two very small bones located in a position posterior and lateral to the nasal bones. They also form the inner wall of the orbit. They are grooved and the groove contains lacrimal sac and nasal duct. It carries tear or lacrimal fluid from eye down to the nasal cavity.

The vomer is a thin flat bone which extends upwards from middle of the hard plate to separate the two nasal cavities.

The palatine bones are two irregular bones which form the back of the hard palate and extend upto the outer wall of the nasal cavity into the floor of the orbit.

The turbinate bones are two small scroll-shaped flat bones which form a part of the lateral wall of the nasal cavity.

The mandible is the strongest bone of the face and is the only movable bone of the skull. It has two identical parts. Each part consists of (1) a curved body on the superior surface of which there is the alveolar ridge containing the lower teeth and (2) a ramus which projects upward (Fig. 4.5). At the upper end, the ramus is divided into two processes; the condyloid process which articulates with the temporal bone and the coronoid process which gives attachment to muscles and ligaments. The point where the ramus joins the body is called the angle of the jaw.

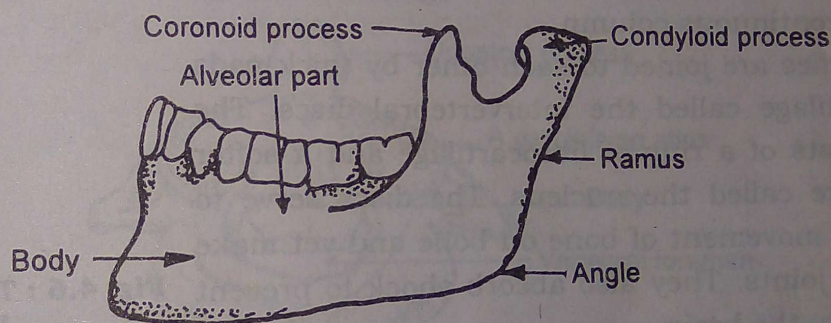


Fig. 4.5 : The Mandible (Lateral View)

The hyoid is an isolated horse-shoe-shaped bone lying in the soft tissue of the neck. It lies at the base of the tongue and gives attachment to the tongue muscle. It does not articulate with any other bone of the head or trunk but is attached to the styloid process of the temporal bone by ligaments.

THE VERTEBRAL COLUMN

It consists of twenty-four separate, movable, irregular bones called vertebrae which are divided into three groups viz.; cervical (seven); thoracic (twelve) and lumbar (five). (Fig. 4.6). In addition, the sacrum consisting of five fused bones and the coccyx consisting of four fused bones which also form a part of the vertebral column. When viewed from the side, the vertebral column shows four anteroposterior curves. They are : cervical curve, in the neck which is convex forwards; thoracic curve, convex backwards; lumbar curve, convex forwards and the pelvic curve convex backwards. Posteriorly convex curves, thoracic and pelvic, are called primary curves and anteriorly convex curves are called secondary curves.

Each vertebra consists of : (1) A disc-shaped body lying in the front and (2) An arc of bone pointing backwards from the body and enclosing a space between body and arch called the neural or spinal canal through which the spinal cord passes. This arch carries three rough processes for muscle attachment. One spinous process which projects backwards and two transverse processes one on either side. On the superior and inferior surfaces of the neural arch, there are two articular processes (Fig. 4.7), which carry smooth surfaces to articulate with similar processes on the vertebrae above and below. The arch carries a notch on either side on the under surface. The narrow part of the arch above the notch is known as the pedicle (Fig. 4.7). The wide part of the arch carrying the spinous process is known as the lamina, which forms the back wall of the vertebral column. The vertebrae lie body over body and arch, over arch forming a continuous column.

The bodies are joined to each other by thick pads of fibrocartilage called the intervertebral discs. The discs consists of a ring of fibrocartilage and a softer pulpy centre called the nucleus. The discs serve to allow slight movement of bone on bone and yet make very strong joints. They also absorb shock to prevent its passage to the brain.

The Cervical Vertebrae : These are the smallest separate vertebrae with relative large openings; they run down the neck forming a slightly forward curve. They have special features : (a) Each transverse process carries an opening through which vertebral artery passes upwards to the brain. (b) The spinous process is forked or bifid giving attachment to muscles and ligaments.

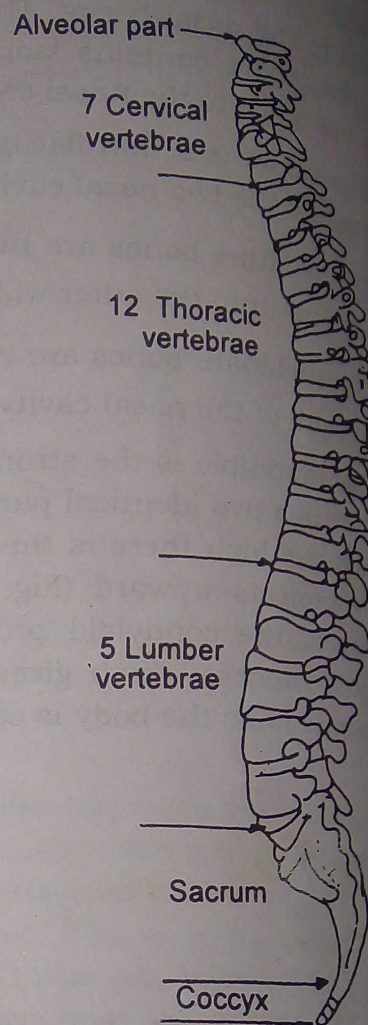


Fig. 4.6 : The Vertebral Column Lateral View

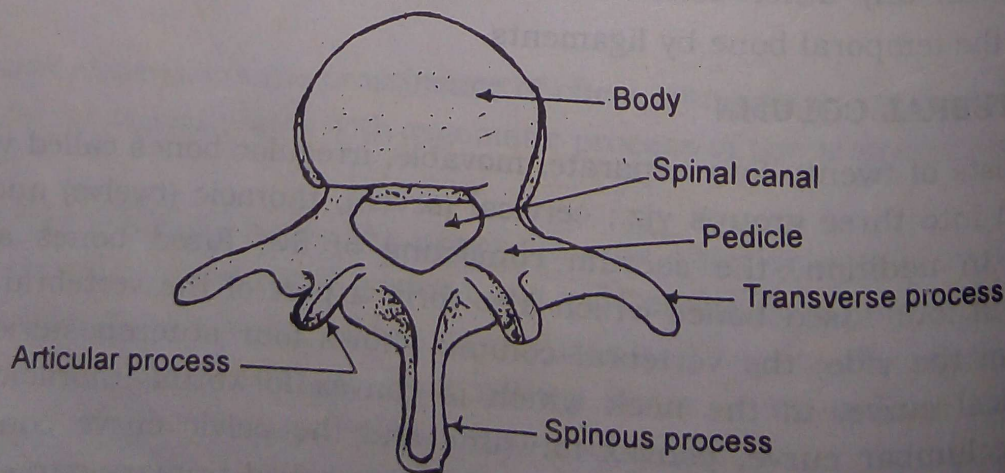


Fig. 4.7 : A Typical (Lumbar) Vertebra

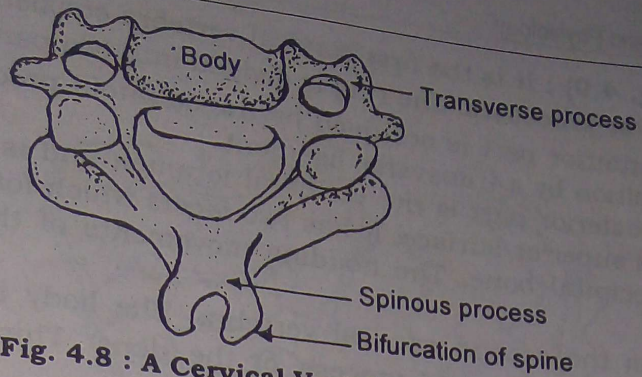


Fig. 4.8 : A Cervical Vertebra

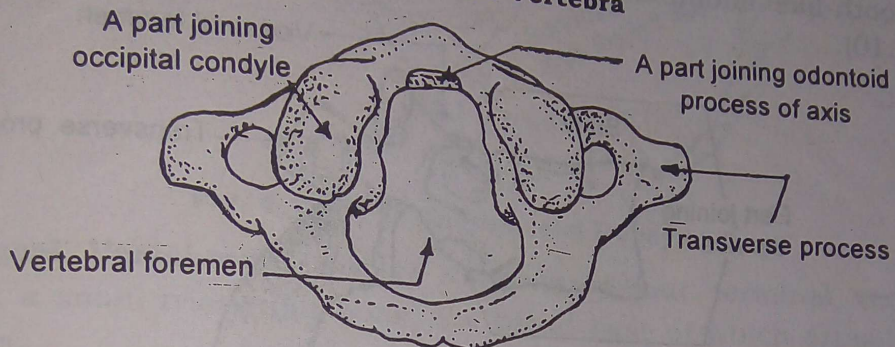


Fig. 4.9 : The Atlas

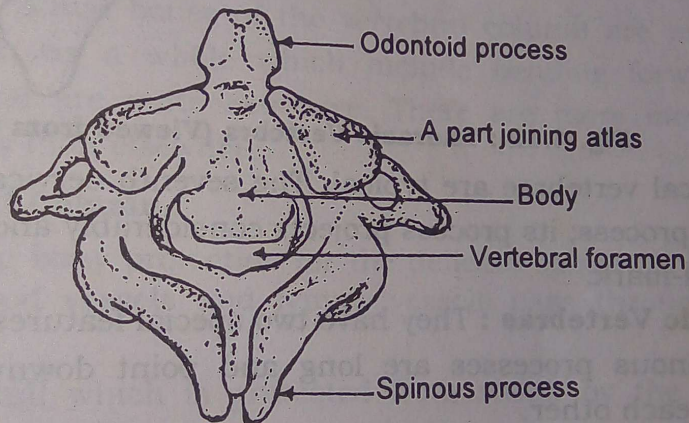


Fig. 4.10 : The Axis

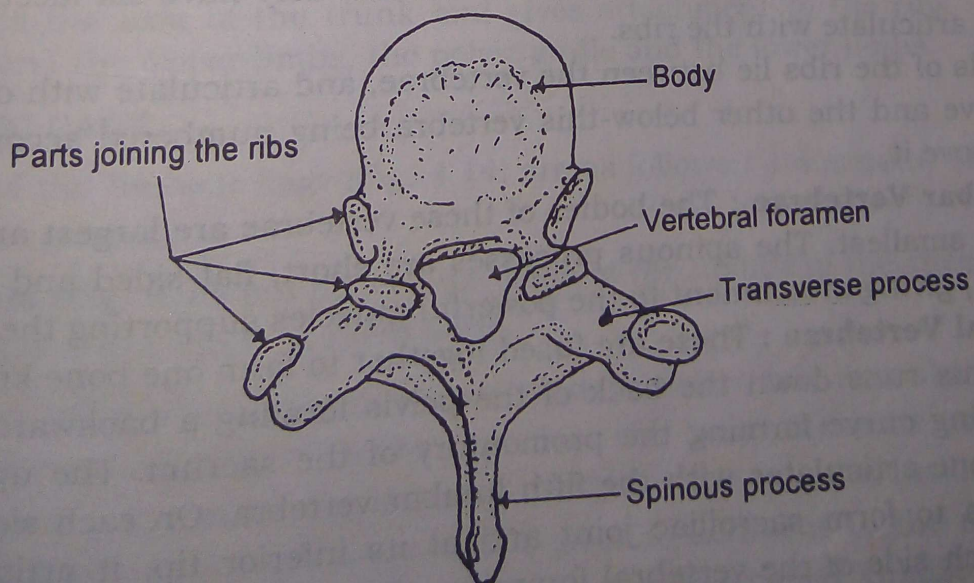


Fig. 4.11 : A Thoracic Vertebra

Atlas (Fig. 4.9) : It is the first cervical vertebra consisting of a ring of bone with short transverse processes. The ring is divided into two parts.

- The anterior part is occupied by the odontoid process of the axis which is in position by a transverse ligament.
- The posterior part is the vertebral foramen and is occupied by the spinal cord. On its superior surface, it has two facets which form joints with the condyles of the occipital bone. The nodding movements of the head takes place at these joints.

Axis : It is the second cervical vertebra. The body is small and has an upward projecting tooth-like 'odontoid process' or the 'dens'. This process articulates with the atlas (Fig. 4.10).

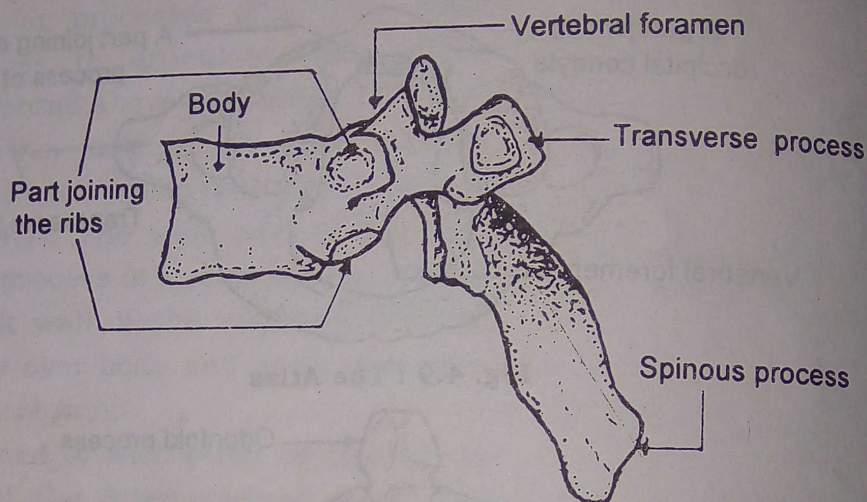


Fig. 4.12 : Thoracic Vertebra (Viewed from the Side)

Other cervical vertebrae are typical. The seventh cervical vertebra does not have a forked spinous process; its process projects considerably and is, therefore, an important anatomical land-mark.

The Thoracic Vertebrae : They have two special features (Figs. 4.11 and 4.12) :

- The spinous processes are long and point downwards, so that they overlap each other.
- Since, the vertebrae articulate with the ribs, they have six facets, out of which four articulate with the ribs.

The heads of the ribs lie between the vertebrae, and articulate with one facet on the vertebra above and the other below—this vertebra being numbered according to the one which lies above it.

The Lumbar Vertebrae : The bodies of these vertebrae are largest and the vertebral foramina are smallest. The spinous processes are short, flat-sided and project straight back (Fig. 4.7) giving attachment to the powerful muscles supporting the back.

The Sacral Vertebrae : These are fused together to form one bone known as the sacrum (Fig. 4.13). This runs down the back of the pelvis forming a backward curve and an upper projecting curve forming the promontory of the sacrum. The upper part of the base of the bone articulates with the fifth lumbar vertebra. On each side, it articulates with the ilium to form sacroiliac joint and at its inferior tip, it articulates with the coccyx. On each side of the vertebral foramina, there is a series of foramina, one for the other for the passage of the nerves.

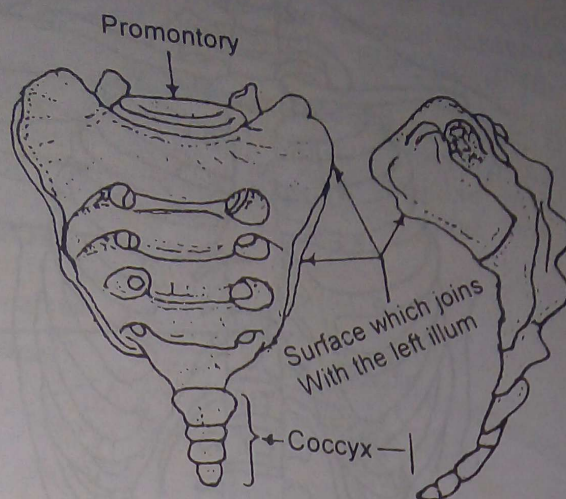


Fig. 4.13 : The Sacrum and Coccyx

The Coccygeal Vertebrae : Coccyx consists of four terminal vertebrae fused together to form a small triangular bone, the broad base of which articulates with the tip of the sacrum.

The movements of individual bones of the vertebral column are very limited. The movements of the column as a whole which include bending forward, backward, sidewise or turning around are quite extensive. There are more movements in the cervical and lumbar regions than elsewhere.

Functions of the Vertebral Column :

- (1) It provides a strong bony protection for the delicate spinal cord lying within it. Spinal nerves, blood vessels and lymph vessels pass through intervertebral foramina.
- (2) It supports the skull which is protected from shock by the presence of the intervertebral discs.
- (3) It forms the axis of the trunk and gives attachment to the ribs, the shoulder girdle and the upper limbs, the pelvic girdle and the lower limbs.

THE THORACIC CAGE

The bones of the thoracic cage (Fig. 4.14) are as follows : 1 sternum; 12 pairs of ribs and 12 thoracic vertebrae.

The Sternum [Fig. 4.15 (a)] : It is a flat bone in the middle of the chest. It is shaped like a dagger and is described in three parts.

The manubrium is the uppermost part and presents two articular facets on its lateral borders for articulation with the clavicles. The body or middle portion is called gladiolus. It presents facets on the lateral borders for the attachment of the ribs. The Xiphoid process is the tip of the bone which gives attachment to the diaphragm and muscles of the anterior abdominal wall. The process is also called Xiphisternum.

The ribs join the sternum by strips of cartilage.

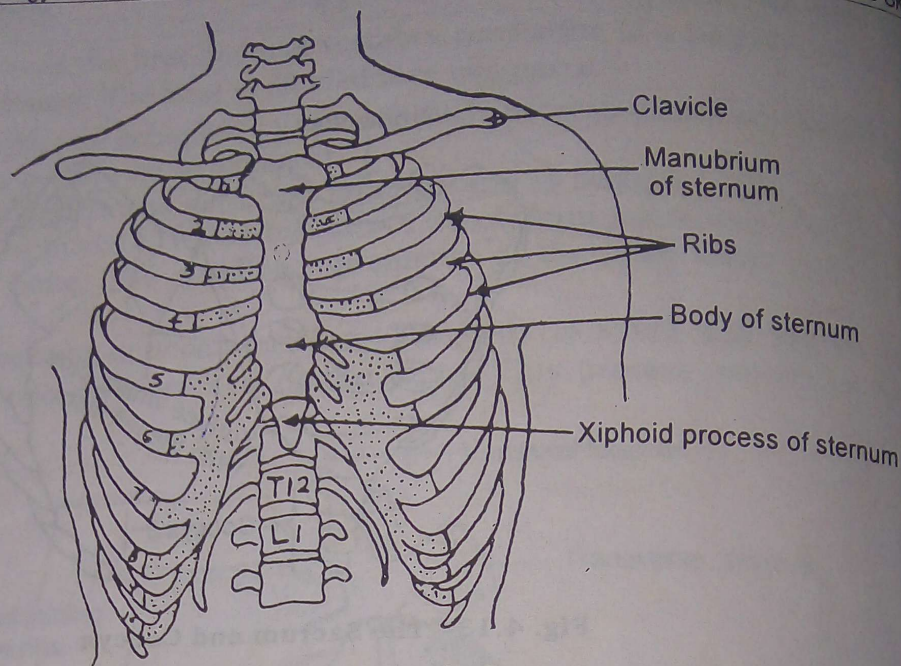
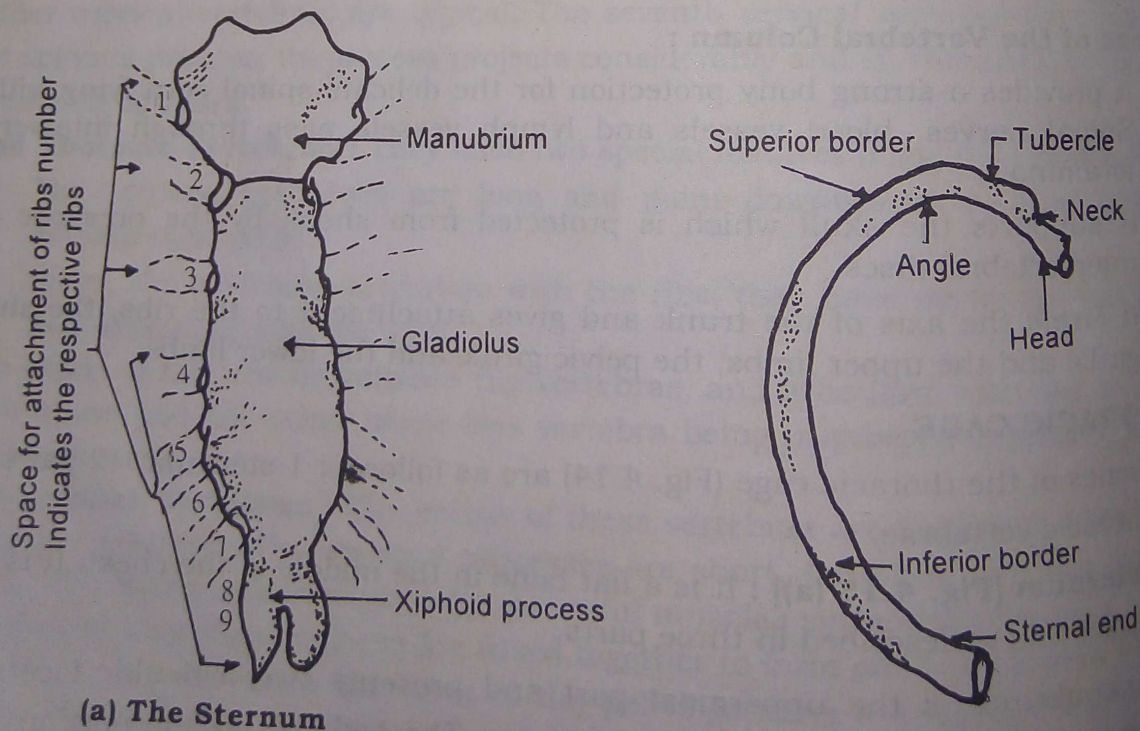


Fig. 4.14 : The Thoracic Cage

The Ribs : There are twelve pairs of ribs which form bony lateral walls of the thoracic cage. The first seven are described as true ribs; the eighth, ninth and tenth are called false ribs and the last two are called floating ribs. All the pairs articulate posteriorly with thoracic vertebrae. Anteriorly, the first seven ribs are directly attached to the sternum; the latter three are only indirectly attached to the sternum and the last two pairs have no anterior attachment.

Each rib is a flat curved bone having a head, neck, tubercle, angle, sternal end, anterior and posterior surface and a superior and inferior border. Fig. 4.15 (b). The head



(a) The Sternum

(b) A typical rib

Fig. 4.15

articulates posteriorly with bodies of two adjacent vertebrae. The neck is a constricted portion next to head and between the head and the tubercle. The tubercle articulates with the transverse process of thoracic vertebra. The angle is the point at which

bone bends. The sternal end is attached to the sternum by a costal cartilage. The superior border is rounded and smooth while the inferior border exhibits a marked groove occupied by blood vessels and nerves. The first rib does not move during respiration.

Spaces between the ribs are occupied by intercostal muscles. During respiration, when these muscles contract, the ribs and sternum are lifted upwards and downwards increasing the capacity of thoracic cavity. The ribs increase in size from above to downwards so that the thoracic cavity is roughly cone-shaped. The thoracic vertebrae are described earlier.

THE APPENDICULAR SKELETON

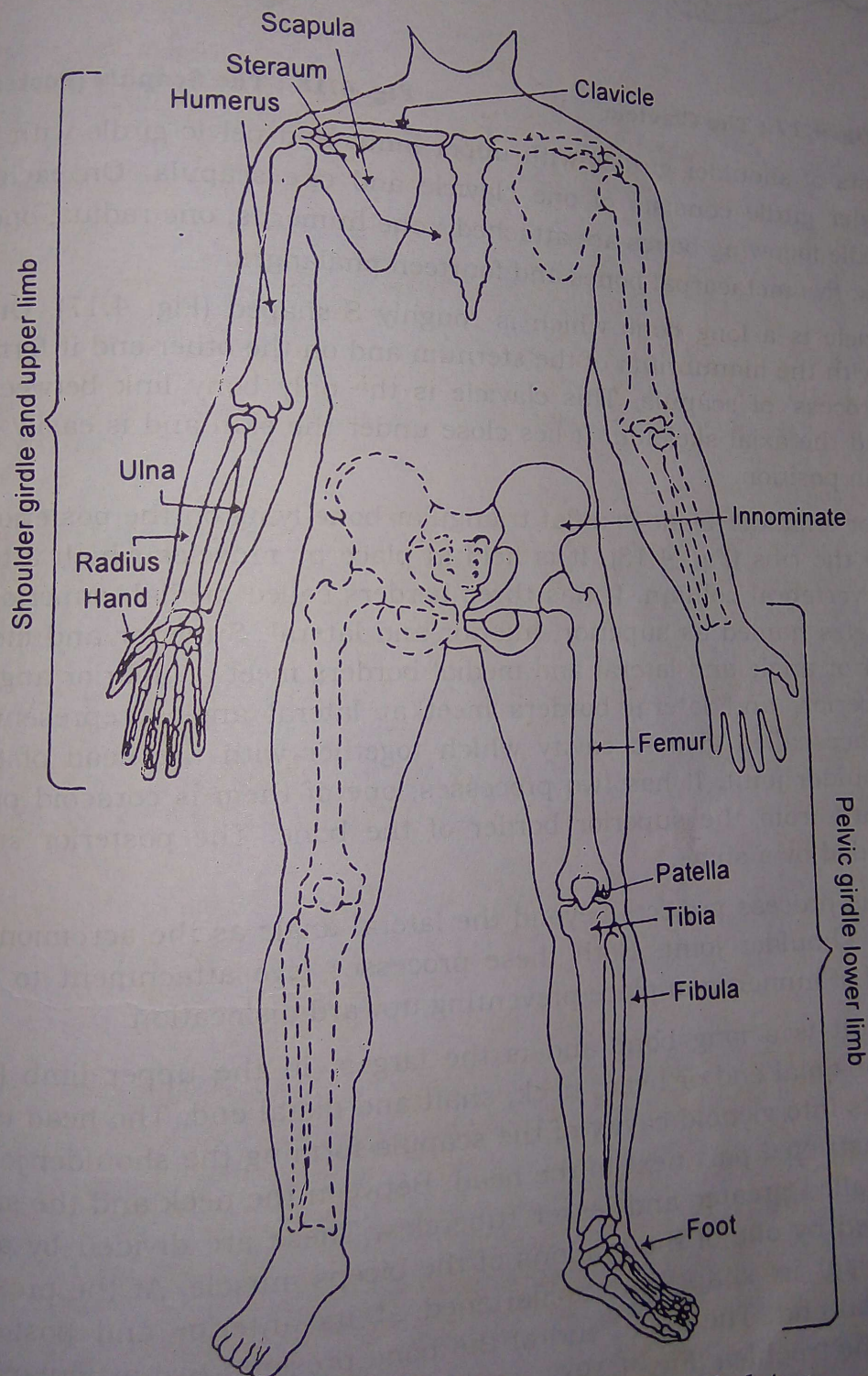


Fig. 4.16 : The Bones of the Appendicular Skeleton

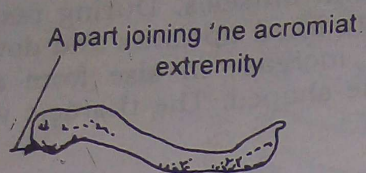


Fig. 4.17 : The Clavicle

It consists of shoulder girdles with upper limbs and pelvic girdle with lower limbs. Each shoulder girdle consists of one clavicle and one scapula. On each side of the shoulder girdle following bones are attached : one humerus, one radius, one ulna, eight carpal bones; five metacarpal bones and fourteen phalanges.

The clavicle is a long bone which is roughly S-shaped (Fig. 4.17). On one end it articulates with the manubrium of the sternum and on the other end it forms joint with the 'acromion process' of scapula. This clavicle is the only bony link between the upper extremity and the axial skeleton. It lies close under the skin and is easily felt. It keeps the scapula in position.

Scapula or shoulder blade is a flat triangular bone lying on the posterior chest wall superficial to the ribs (Fig. 4.18). It is held in place by muscles which attach it to the ribs and the vertebral column. It has three borders called medial, superior and lateral and three angles named as superior, inferior and lateral. Superior and medial borders meet at superior angle and lateral and medial borders meet at inferior angle. The point at which superior, and lateral borders meet at lateral angles represents a shallow articular surface called glenoid cavity which together with the head of the humerus forms the shoulder joint. It has two processes, one of them is coracoid process which projects forward from the superior border of the bone. The posterior surface of scapula is divided by a spine.

The spinous process projects beyond the lateral angle as the acromion process overhangs the shoulder joint. Both these processes give attachment to muscles which keeps the head of humerus in place preventing upward dislocation.

Humerus : It is a long bone and is the largest in the upper limb (Fig. 4.19). It consists of a proximal end or head, neck, shaft and distal end. The head is smooth rounded and fits into glenoid cavity of the scapula forming the shoulder joint. The neck is a slightly constricted part next to the head. Between the neck and the shaft there are two tubercles called greater and lesser tubercles. These are divided by a deep groove which is occupied by one of the tendons of the biceps muscle. At the proximal end the shaft is cylindrical in shape but is flattened at its anterior and posterior surfaces towards the distal end. The distal end of the bone presents two articular surfaces, the capitulum and the trochlea (Fig. 4.19).

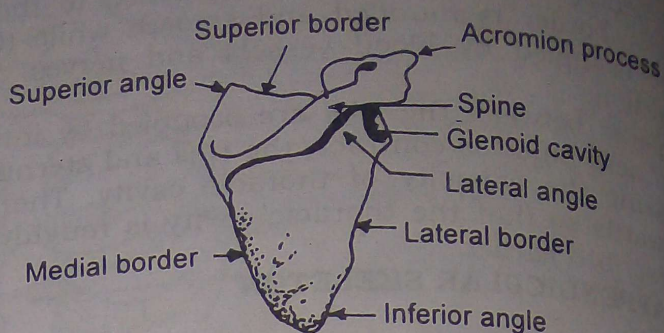


Fig. 4.18 : The Scapula (Posterior View)

Immedi
coronoid fo
end of the
respectively
(Fig. 4.19).

Ulna and
membrane

Ulna : It is a long bone (Fig. 4.20). It articulates with the radius. The olecranon process of the humerus articulates with the coronoid process of the ulna. A small bursa is present between the olecranon and the humerus to facilitate movements.

Shaft of the ulna is attached to the sheet of the wrist joint by the posterior end.

Radius : It is a long bone, neck, tuberosity of the radius on the top articular surface.

The circumference of the shaft carries the articular surface which articulates with the radiolunar joint of the thumb. It

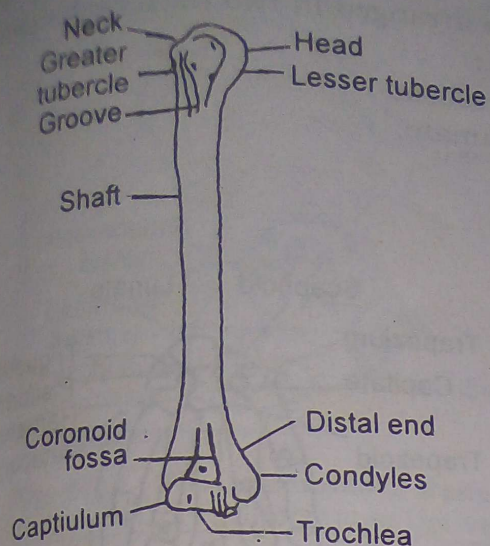


Fig. 4.19 : The Humerus

Immediately above the articular surface, the anterior side of the bone contains coronoid fossa and the posterior surface contains olecranon fossa (Fig. 4.19). The lower end of the bone also contains two condyles for articulation with the radius and ulna respectively. Above the condyles on either side are median and lateral epicondyles (Fig. 4.19).

Ulna and radius are the two bones of the forearm. There is an interosseous membrane between the bones.

Ulna : This is a long bone consisting of proximal end, shaft and distal end or head (Fig. 4.20). It is located on the inner side of the forearm and is slightly bigger than radius. The proximal end contains a semilunar notch called trochlear notch (Fig. 4.20), which articulates with the trochlea of the humerus. At its proximal end, there is the olecranon process which forms the point of an elbow and fits into the olecranon fossa of the humerus when the arm is straight. At its distal end of the trochlear notch lies the coronoid process which fits into the coronoid fossa of the humerus when the arm is bent. A smaller joint cavity, the radial notch, faces outwards and forms a pivot joint with the head of the radius which rotates against it. This joint produces turning movements of a hand.

Shaft of the bone is triangular in shape and carries a sharp ridge for its attachment to the sheet of fibrous tissue. The lower extremity is much smaller and is joined to a wrist joint by a pad of white fibrous tissue. It also carries a styloid process from the posterior end which gives attachment to ligaments.

Radius : It is a long bone and is the outer bone of a forearm. It consists of head, neck, tuberosity, shaft and distal extremity (Fig. 4.20). The head is disc-shaped and flat on the top and articulates with the capitulum of the humerus.

The circumference of head articulates with the radial notch of ulna. At the upper end of the shaft, there is a radial tuberosity which gives attachment to muscles. The shaft carries a sharp ridge facing ulna. The distal end of the bone is expanded. It articulates with the carpal bones to form a wrist joint and with the ulna to form a radioulnar joint (Fig. 4.20). It also carries a styloid process which is felt at the base of the thumb. It gives attachment to ligaments and muscles.

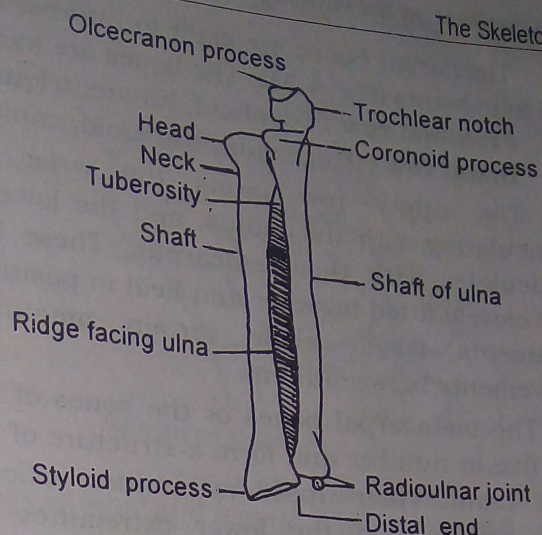


Fig. 4.20 : The radius and ulna

The carpal bones are eight in number and are arranged in two rows each consisting of four bones (Fig. 4.21). The bones are as follows :

Proximal row : Scaphoid, lunate, triquetrum, pisiform.

Distal row : Trapezium, trapezoid, capitate, hamate.

The upper row forms the wrist joint, articulating with the radius, and the lower row articulates with the metacarpus. These bones are closely fitted together and held in position by ligaments which allow certain amount of movements between them.

The metacarpal bones or the bones of hand are five in number and form a structure of palm of a hand. Their upper extremities articulate with carpus and the lower extremities with phalanges.

Phalanges or bones of the fingers are fourteen in number and are so arranged that there are three in each finger and two in the thumb. The upper end of these bones is the largest and articulates with the corresponding metacarpal bone at one end and with the middle phalanges at the other end. The lower phalanges are the smallest and form tips of fingers.

The Pelvic Girdle and Lower Limb : Bones of pelvic girdle are two innominate bones and one sacrum. The bones of the lower extremity are as follows :

One femur; one tibia; one fibula; one patella; seven tarsal bones; five metatarsal bones and fourteen phalanges.

Innominate bone :

Each of the innominate or the hip bones consists of three bones : ilium, ischium and pubis, fused together to form one large irregular bone (Fig. 4.22). On its outer surface, it has a deep depression called acetabulum with which the head of femur forms the hip joint. Ilium is the upper flattened part of the bone and contains the iliac crest (Fig. 4.22). Pubis is an anterior part of the bone and articulates with the pubis of other hip bone at a cartilagenous joint called symphysis pubis. It also contains a large opening called obturator foramen (Fig. 4.22). Ischium is an inferior and posterior part of the bone which contains ischial tuberosity. The external surfaces of the innominate bones are markedly ridged for the attachment of muscles.

Pelvis (Fig. 4.23) is formed by innominate bones which articulate anteriorly at symphysis pubis and posteriorly with sacrum. The two pubic bones join one another at the middle line. It is divided into greater or false pelvis above and lesser or true pelvis below. The ridge of the bone (Fig. 4.23) called the brim of the pelvis is a separating line for these two parts.

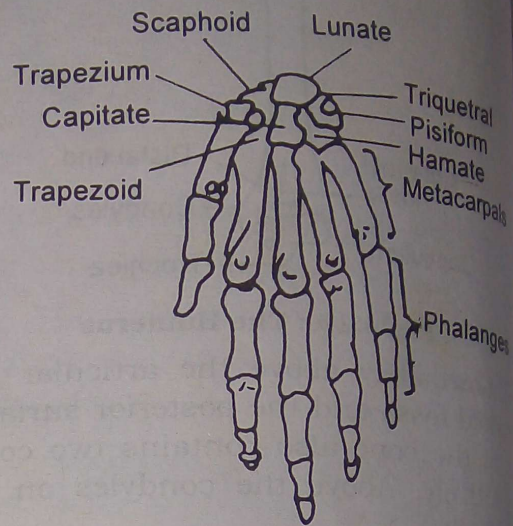


Fig. 4.21 : The Carpal Bones

Bones
Cavity
Sacrum

Pubic-arch

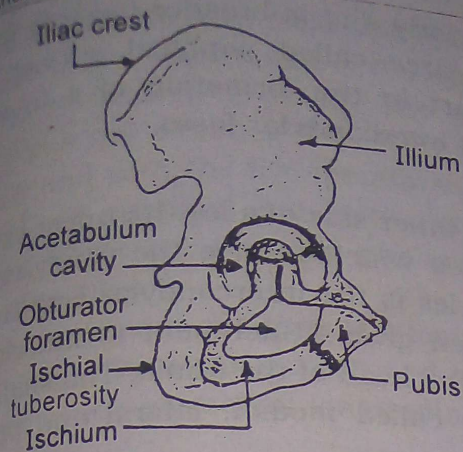
Femur :

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(Fig. 4.24)
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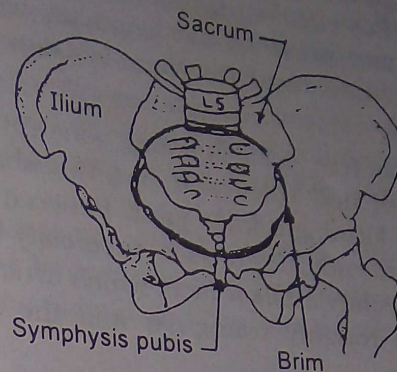
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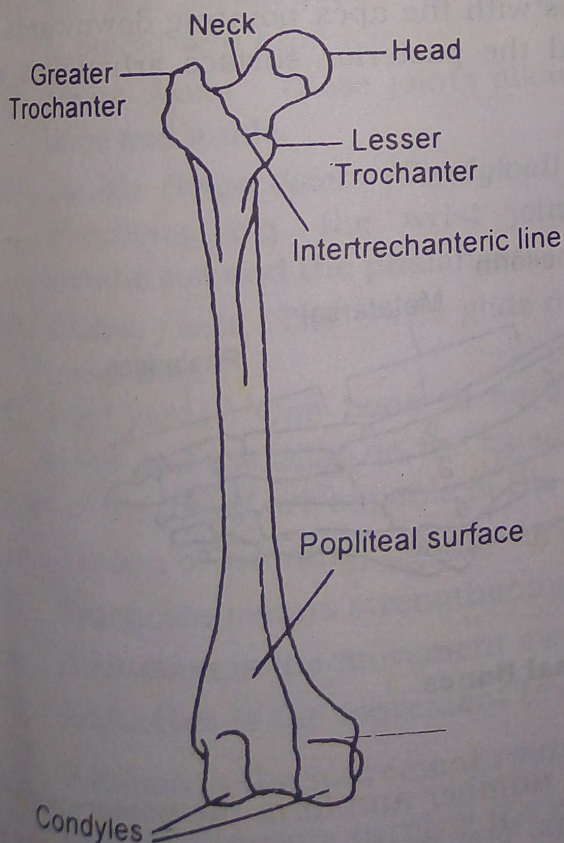
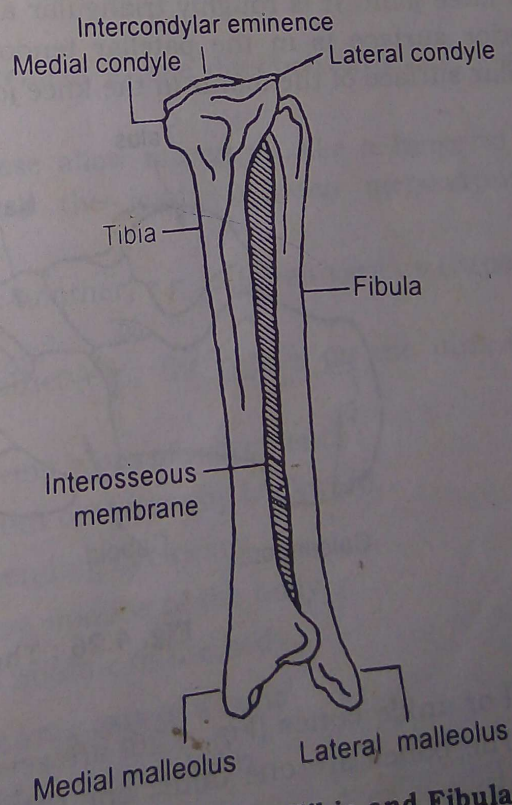
**Fig. 4.22 : The Innominate Bone**

There are distinct differences between pelvis of male and female. They are as follows :

	Female	Male
Bones	Lighter and smaller	Heavier and longer
Cavity	Shallow and round	Deep and funnel-shaped
Sacrum	More concave anteriorly, making the true pelvis broader	Less concave, making the true pelvis narrower at the outlet.
Pubic-arch	The angle made at the symphysis pubis is wider. The bones are movable for convenience in delivery	The angle of the pubic arch is narrower. The bones are immovable.

**Fig. 4.23 : The Pelvis****Femur :**

Femur or a thigh bone is the longest and strongest of all the bones of the body (Fig. 4.24). Proximal extremity consists of head, neck and greater and lesser trochanters. The head is almost spherical and fits into acetabulum of the hip bone. Two trochanters and intertrochanteric line (Fig. 4.24) give attachment to muscles which move hip joint.

**Fig. 4.24 : The Femur****Fig. 4.25 : The Tibia and Fibula**

The shaft of the bone is slightly convex anteriorly and is broader towards its distal end. Posterior surface forms a flat triangular area called popliteal surface. Distal extremity presents two condyles which take part in the formation of a knee joint. Between the condyles, there is a depression called intercondylar fossa.

Tibia :

Tibia (Fig. 4.25) is a long bone running on the inner side of a leg. Its upper extremity is broad and thick and has two shallow condyles which receive the condyles of the femur, forming a knee joint. Between these condyles is the intercondylar eminence. On the front side, there is a tuberosity of tibia which gives attachment to muscles. The lateral condyle has a facet which articulates with the head of the fibula. The shaft of the bone is roughly triangular and the surfaces are called medial, lateral and posterior surfaces.

The crest of tibia is a ridge which can be felt very close to the surface on anterior aspect of leg. Distal extremity of tibia forms an ankle joint with talus. Tibia carries a process which projects downwards forming the prominence on the inner side of the ankle joint called the medial malleolus.

Fibula :

Fibula is a long slender bone which is lateral to tibia (Fig. 4.25). The proximal end articulates with the lateral condyle of tibia and the lower extremity articulates with the tibia and projects further to form lateral malleolus, and takes part in the formation of the ankle joint. The shaft of the bone is ridged for the attachment of muscles.

Patella :

Patella or knee cap is a sesamoid (developed in a muscle tendon) bone associated with knee joint. It is roughly triangular and lies with the apex pointing downwards. Its anterior surface is in the patellar tendon and the posterior surface articulates with the patellar surface of the femur in the knee joint.

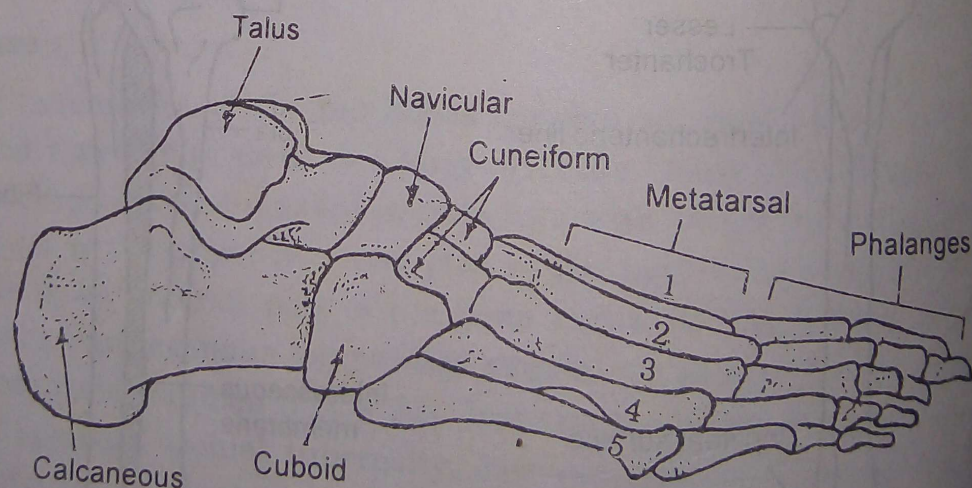


Fig. 4.26 : The Tarsal Bones

Tarsals :

Tarsal or ankle bones (Fig. 4.26) are seven in number and form the posterior part of the foot. The bones are one talus; one calcaneous; one navicular; three cuneiform; one cuboid.

Talus articulates with tibia and fibula at the ankle joint. Calcaneus or heel bone is roughened for the attachment of muscles. Navicular is situated on the medial side of the foot distal to talus (Fig. 4.26). The medial, intermediate and lateral cuneiform and cuboid form a row of bones (Fig. 4.26) which articulate with the other three tarsal bones proximally and with the five metatarsal bones distally. The metatarsal bones are five in number. Their proximal ends articulate with the tarsal bones and the distal ends with phalanges. There are fourteen phalanges in each foot, two in the great toe and three each in other toes.

The arrangement of bones of a foot is such that it is not a rigid structure. The bones have a bridge-like arrangement and are supported by muscles and ligaments so that four arches such as medial longitudinal, lateral longitudinal and two transverse arches are formed.

The Joints : A joint is the site at which any two or more bones come together. The joints are classified as fibrous, cartilagenous and synovial. In fibrous or fixed joint, there is no movement between the bones concerned. There is a fibrous tissue between their ends e.g., the joints between the bones of the skull and the joints between the teeth and the maxilla and mandible. In cartilagenous joints, there is a pad of white fibrocartilage between the ends of the bones. Movement is possible because of the compression of the pad of cartilage, e.g. symphysis pubis and joints between the bodies of the vertebrae.

Synovial joints are characterized by the presence of synovial membrane. A considerable amount of movement is possible. Limitations on movement is mainly due to the shape of the bony surface which forms the joint. They are subdivided according to the movements possible.

- (1) *Ball and Socket Joint* : A hemispherical head fits into a cup-shaped socket e.g., shoulder and hip.
- (2) *Hinge Joints* : These joints allow movement in one direction only, e.g. elbow, knee and ankle.
- (3) *Double Hinge Joints (Condylloid)* : These allow movement like a hinge in two directions, e.g. the wrist joints and the joints between metacarpus or metatarsus and the phalanges.
- (4) *Gliding joints* : The bones glide on one another, e.g. between various carpal and tarsal bones.
- (5) *Pivot joints* : One bone turns on another e.g., the radius on the ulna at the elbow and the atlas on the axis.

Some of the joints are capable of the following types of movements :

- (1) Flexion or bending, usually forward but occasionally backward.
- (2) Extension means strengthening or bending backward.
- (3) Abduction is the movement away from midline of the body.
- (4) Adduction is the movement towards midline of the body.
- (5) Rotation is the movement round the long axis of a bone.
- (6) Pronation means turning the palm of the hand down.
- (7) Supination means turning the palm of the hand up.

(8) Circumduction is the combination of flexion, extension, abduction, and adduction. It involves movements of the limbs through a circle.

(9) Inversion is the turning the sole of the foot inwards.

(10) Exversion is turning the sole of the foot outward.

Different types of joints help to make different kinds of movements. The ball-and-socket joints are freely movable allowing flexion and extension, abduction, adduction, circumduction and external and internal rotation. The hinge joints allow flexion and extension only. Double hinge joints allow flexion, extension, adduction, abduction and circumduction. In the gliding joints, there is only a slight movement increasing the range of movement in all directions. The pivot joints permit rotation around the point where they are pivoted.

The joints are movable, but the movements are carried out by the various muscles. The muscles also run from bone to bone and help to hold the bones in position and give support to the joint capsule, as long as the normal tone is sustained.

Disorders of joints : Any or all of the structures of joints may be damaged by disease.

Inflammation of the joints is called arthritis. Arthritis is of two types; acute and chronic.

Acute Arthritis : In Rheumatic arthritis, there is an acute synovitis with the exudate of turbid fluid in the joint. Extreme tenderness is the characteristics of a swollen and acutely inflamed joint. In the case of traumatic synovitis, the inflammation is confined to the synovial membrane without any destruction of tissue.

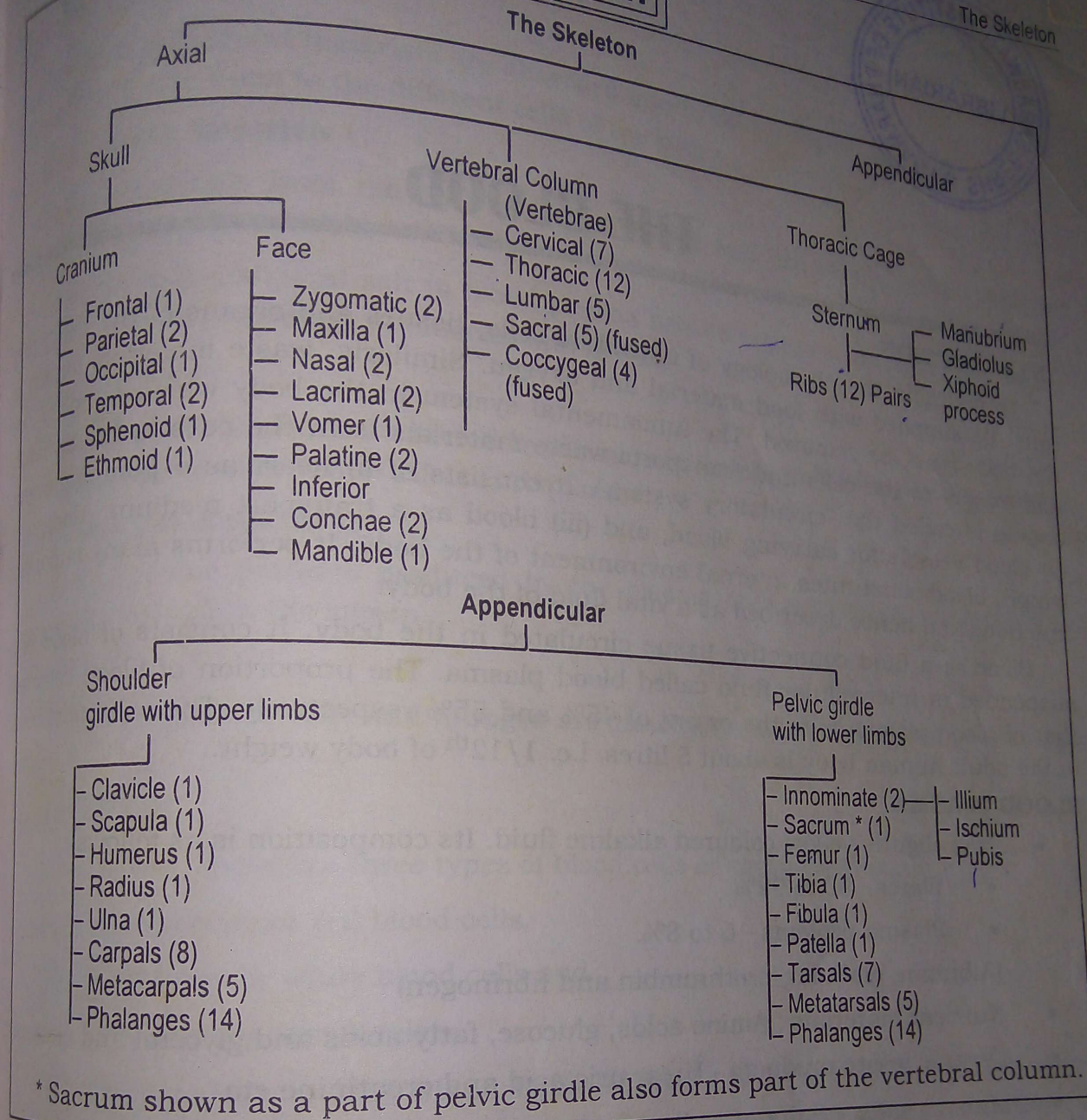
Chronic Arthritis : There are various types of chronic arthritis. Tuberculous arthritis is a disease very commonly in children. When it occurs in an adult, it is more likely to be primary in the synovial membrane. The synovial fluid is usually scanty but highly fibrous so that it contains flakes of fibrin which may develop into foreign bodies. Rheumatoid arthritis is a common, tragic and crippling disease particularly affecting small joints of hands and feet; the larger joints may affect later. It causes pains and swelling of the joints together with increasing stiffness and disability. In the later stages, the joints become distorted and deformed. During this condition, the patient may suffer from mild fever, anemia, sweating etc. Osteoarthritis involves degeneration of articular cartilage and bone. This is a disease which normally occurs in the old age. Large joints are commonly affected, very often only one joint, i.e. particularly the knee joint. Gout is yet another disease involving joints. The disease involves over-production of uric acid which is deposited in the joint and the surrounding soft tissues. These deposits occur in the synovial membrane and capsule. Kidneys may also suffer from the deposits.

The intervertebral disc also can be a site of disorder. The disc may be protruded or herniated into the vertebral canal and press the spinal cord or stretch the nerves. This disorder causes low back pain and sciatica or pain passing down the back of the leg along the course of the sciatica nerve.

A few other dysfunctions related to the joint may occur. If the bone from a joint is displaced, the condition is called dislocation. Individuals especially women past middle age, are frequently depleted of calcium. Bones of such individuals lack in calcium and therefore become relatively more fragile. This condition is called osteoporosis.

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SUMMARY



QUESTIONS

- Name the bones in the appendicular skeleton. Describe a shoulder joint.
- Differentiate between male and female pelvic girdle.
- Name the bones of axial skeleton.
- Define skeleton, bone and articulation (Joint). Classify the bones with suitable examples.
- Classify the joints with examples of each class.
- Name the primary and secondary curves of vertebral column. Describe each.
- What are the functions of bones?
- Mention the functions of vertebral column.
- What is dislocation?
- What is osteoporosis and rheumatic disorder?



THE BLOOD

INTRODUCTION

To maintain the physiology of individual cells, tissues and organs of the body, the body must be supplied with food material and oxygen. Similarly, waste materials formed in the body must be removed. The fundamental system in the body which supplies food and oxygen to the cells and transports waste materials from the cells to the excretory organs is called the "circulatory system". It consists of (i) heart as a pumping organ, (ii) blood vessels for carrying blood; and (iii) blood as a transport medium. Along with lymph, blood constitutes internal environment of the body. It performs many important functions and hence described as a vital fluid of the body.

Blood is a fluid connective tissue circulated in the body. It consists of blood cells suspended in intercellular fluid called blood plasma. The proportion of blood cells to that of blood plasma is to the extent of 45% and 55% respectively. The volume of blood in the adult human body is about 5 litres. i.e. $1/12^{\text{th}}$ of body weight.

BLOOD PLASMA

- It is slightly yellow coloured alkaline fluid. Its composition is as follows :
 - Water - 90 to 92%.
 - Plasma proteins - 6 to 8%.
(Albumin, globulin, prothrombin and fibrinogen)
- Nutrient materials : Amino acids, glucose, fatty acids and glycerol and vitamins.
- Organic waste products - Urea, uric acid and creatinine etc.
- Mineral salts - Salts of sodium, potassium, magnesium, calcium, iron, copper, phosphorus and iodine.
- Hormones and enzymes - Antibodies and antitoxins.
- Gases - Oxygen, carbon dioxide and nitrogen.

Plasma Proteins :

- (i) Plasma proteins are responsible for osmotic pressure of blood which prevents complete emptying of blood vessels.
- (ii) They are also responsible for viscosity of blood and help in the maintenance of blood pressure.
- (iii) Plasma globulin helps in the formation of antibodies which give protection against infection.
- (iv) Prothrombin and fibrinogen helps in the clotting of blood.

(v) Some substances are transported around the body, while they are bound to plasma proteins.

Nutrient Materials :

The above nutrient materials are absorbed into blood through digestive system. The blood transports them to the different cells of the body.

Organic Waste Materials :

Waste materials from the cells enter into blood and are carried to the excretory organs for their excretion.

Mineral Salt : Mineral salt in blood plasma help to maintain the acid base balance of the body, and physiology of muscles and nerves.

Body Secretions :

Enzymes and hormones secreted by the glands, enter into blood and are carried to the target organs where their effect is required.

Antibodies and Antitoxins :

These are the proteins produced by the plasma cells which are found mainly in lymph glands and in the spleen.

Gases :

Oxygen, carbon dioxide and nitrogen are dissolved in and transported by the plasma water.

BLOOD CELLS

In the blood, there are three types of blood cells or corpuscles viz.,

- Erythrocytes or red blood cells.
- Leucocytes or white blood cells and
- Thrombocytes or platelets.

(a) Erythrocytes or Red Blood Cells (R.B.C.) : Red blood cells are small circular biconcave disc-shaped cells suspended in blood plasma. In masses together, they appear red in colour. The number of R.B.Cs. differs according to age, sex and physiological conditions of the body. In adult male, the normal R.B.Cs. count is 5 to 5.5 millions per cubic mm, while in female, the count is 4 to 4.5 millions per cubic mm. Erythrocytes are produced in liver in foetal life. After birth, they are produced in the red bone marrow of extremities of long bones, between layers of compact bone in flat and irregular bones such as the sternum, skull, ribs and vertebrae. The process of formation of erythrocytes in the red bone marrow is called erythropoiesis. In the red bone marrow, the original cells from which the R.B.Cs. are developed, are called megakaryocytes. They are large cells with large nucleus and cytoplasm containing granules. The developmental changes occur in megakaryocyte in the presence of iron and vitamin B₁₂ forming erythrocytes.

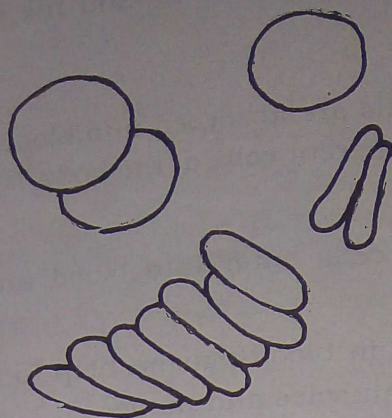
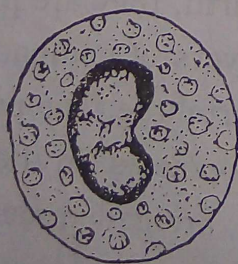


Fig. 5.1 : Red Blood Corpuscles

The R.B.C. is a mass of haemoglobin enclosed in a membrane called stroma. Haemoglobin is a complex protein with high molecular weight. It consists of protein material called globin and non-protein material called haem. The haem component contains iron which gives red colour to haemoglobin. It has attraction towards oxygen and their combination forms oxyhaemoglobin. It has also attraction towards carbon dioxide and their combination forms carboxy-haemoglobin. The normal amount of haemoglobin in the body varies with age, sex and conditions of the body. The normal average haemoglobin count is 15 grams per 100 ml of blood, it is 14-17 grams per 100 ml in men, while it is 12-16 grams per 100 ml in women.

The total life span of R.B.C. is from 115 to 120 days. When they become old, they are destroyed in the spleen, liver and reticuloendothelial system. During destruction (haemolysis), the stroma gets dissolved and haemoglobin is set free. It is split to form haem and globin. Globin is used by the body cells while haem is split further into iron and waste materials (bilirubin and biliverdin). Iron is stored and reused for the formation of haemoglobin. The waste materials are secreted in bile and are excreted. The function of erythrocytes is to transport oxygen and carbon dioxide.

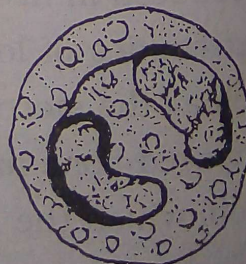
(b) Leucocytes or White Blood Cells (W.B.Cs.) : White blood cells are irregularly shaped nucleated large cells. They are colourless mobile units in the blood. The normal W.B.C. count in the adult human being is from 6000 to 10000 per cubic mm of blood. On the basis of presence of granules in their cytoplasm, these are classified into two classes, viz., (1) Granulocytes and (2) Agranulocytes.



Basophil



Neutrophil



Eosinophil

(a) The Granular Leucocytes

(1) **Granulocytes** grow in the bone marrow on the basis of the presence of granules. Basophils.

(i) Neutrophils

They are the most common type of granulocytes.

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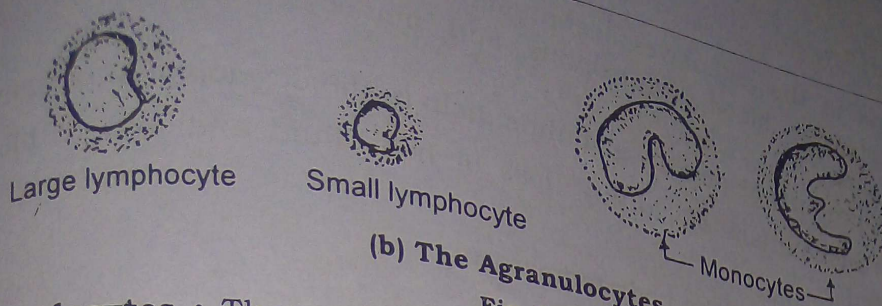
They are found in the blood.

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(b) The Agranulocytes
Fig. 5.2

(1) **Granulocytes** : They constitute about 75 per cent of total W.B.C. These cells grow in the red bone marrow and show the presence of granules in their cytoplasm. On the basis of staining, they are further classified as Neutrophils, Eosinophils and Basophils.

(i) **Neutrophils** : These constitute about 70 per cent of total W.B.C. in the blood. The granules of these cells are stained with neutral dye and appear purple in colour. These are responsible for defence mechanism of the body. They ingest the infecting micro-organisms and destroy them by phagocytosis. The life-span of neutrophils which remain in the blood vessels is believed to be about 30 hours and those which leave the blood do not return.

(ii) **Eosinophils** : These constitute about 4 per cent of the total W.B.C. in the blood. The granules of these cells take red acid dye called eosin. The granules are larger in size. It is thought that the eosinophils phagocytose the particles which are formed when antigens and antibodies react.

(iii) **Basophils** : These constitute about 1 per cent of the total W.B.C. in the blood. The granules of these cells take basic dye and appear blue in colour. They are found in large numbers in allergic reactions. They are responsible for the destruction of products of antigen and antibody reactions.

(2) **Agranulocytes** : These are mononuclear cells. They do not show the presence of granules in their cytoplasm. As they are produced in lymph-glands, they are also called lymphocytes. These constitute about 25% of all leucocytes. There are two varieties of agranulocytes, viz., Lymphocytes (about 23%) and Monocytes (about 2%). The lymphocytes are responsible for the development of immunity against foreign substances or antigens such as micro-organisms. The monocytes are large cells with large nucleus and are bigger than lymphocytes. The function of monocytes closely resembles with that of neutrophils and are actively phagocytic in action.

(c) **Thrombocytes** : These are the smaller fragments of megakaryocytes. The normal count is about 3 to 4 lakhs per cubic mm of blood. They help in clotting blood.

Functions of blood :

- (1) It transports oxygen in the form of oxyhaemoglobin from the lungs to the body cells and returns carbon dioxide from the cells to the lungs for excretion.
- (2) It acts as an important transport system for nourishment. The nutrients absorbed from digestive system are supplied by the blood to the body cells.
- (3) It removes waste products from the tissues and cells. These waste materials are transported to the appropriate organs for excretion.
- (4) It transports hormones and enzymes from their cells of origin to their target organs and tissues.

- (5) It helps in the defensive mechanism of the body. This is by means of the leucocytes in blood. Neutrophils and monocytes destroy infecting micro-organisms. Plasma proteins, especially globulins, help in the development of immunity.
- (6) By the mechanism of clotting, loss of body fluid and loss of blood cells is prevented.
- (7) It helps to maintain the body temperature.

Blood Groups :

Blood of one person is not always compatible with that of another. Hence, before transfusion of blood, it must be tested for its compatibility with the acceptor's blood. Only compatible blood is to be transfused. If incompatible blood is transfused, agglutination of the erythrocytes occurs which leads to haemolysis.

Membrane of erythrocytes contain antigens called agglutinogens and people have natural antibodies, i.e. agglutinins. Agglutinogens are genetically determined and are of two types A and B. It is possible to have antigen A in the red cells (Group A) or antigen B in the red cells (Group B) or both A and B antigens in the red cells (Group AB) or no antigen in red cells (Group O).

Agglutinins in the plasma are globulins and are of opposite type. Thus, type A blood contain 'b' agglutinin and type B blood contain 'a' agglutinin. While type AB contains no agglutinins and type O contains both 'a' and 'b' agglutinins. The compatibility of blood groups is shown below.

While determining compatibility, RBCs of donor must remain intact i.e. the agglutination due to acceptors agglutinin must be avoided. Agglutination of acceptor's RBC due to donor's agglutinin is not to be considered as it does not happen.

Blood Group	Agglutinin in RBC	Agglutinin in Plasma
'A'	'A'	'b'
'B'	'B'	'a'
'AB'	'A', 'B'	No agglutinin
'O'	No agglutinin	'a', 'b'

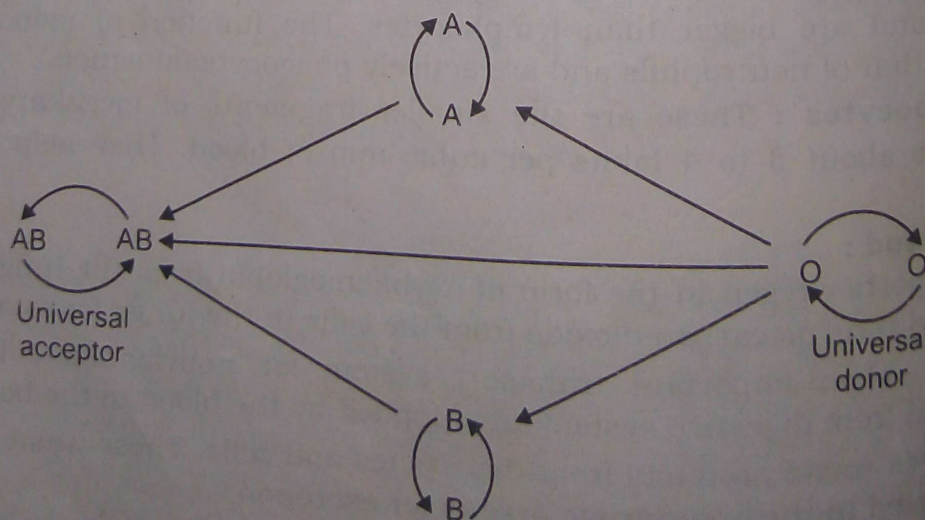


Fig. 5.3 : Blood Groups showing their Compatibility

Thus, group AB is a universal acceptor and group O is a universal donor.

There is another antigen, called 'Rh' antigen, present in some person's blood. Persons with 'Rh' antigen in the red cells are called Rh + ve and those without it are called Rh - ve. It has a great significance in pregnancy. If the mother be Rh - ve and the baby in the womb be Rh + ve (which is a possibility if the father be Rh + ve), the 'Rh' antibodies will be produced in the mother's serum and such blood flowing through the placenta into the foetus may cause haemolysis and jaundice in the baby endangering its life in the womb or soon after birth. The risk becomes greater in successive pregnancies.

Blood Clotting :

When blood is shed, it soon loses its fluidity and red coloured, soft jelly like sticky mass is formed. This mass plugs the broken surface of blood vessels and avoids further loss of blood from the body. The soft mass thus formed is called 'blood clot' and the process of forming blood clot is called 'clotting of blood' or 'coagulation of blood'. The mechanism of blood clotting is complicated one and involves many factors. The mechanism can be briefly described as follows :

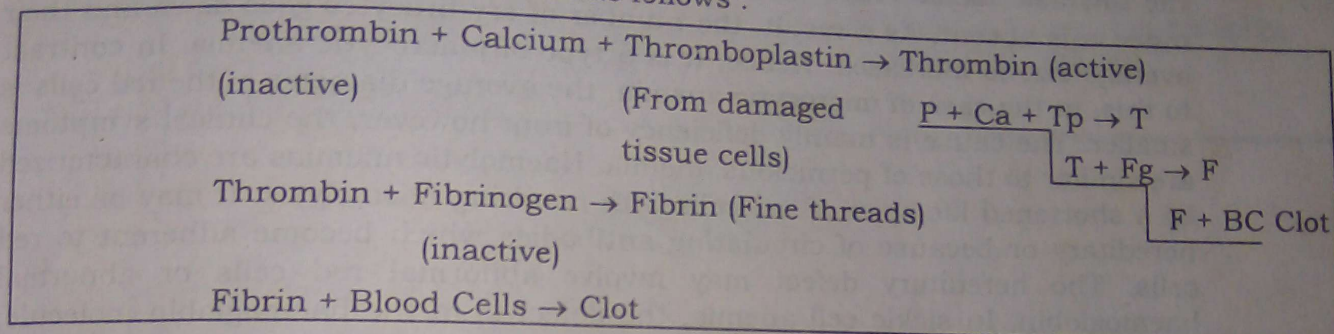


Fig. 5.4 : Mechanism of Blood Clotting

Whenever, there is an injury to a blood vessel, there is formation of rough surface (the inner smooth lining of blood vessel is disturbed). When blood platelets come in contact with such a rough surface, they are injured. Due to injury, they release the substance called thromboplastin (Thrombokinas). The injured tissues also secrete thromboplastin. In the presence of thromboplastin and calcium in the blood plasma, prothrombin (naturally occurring plasma protein) is converted into thrombin which helps in conversion of fibrinogen to fibrin. The fibrin is insoluble and forms threads. The threads of fibrin form a net. In the holes of this net, blood cells are entangled. This mass then contracts to form a blood clot. The fluid that remains after clotting of blood is called blood serum. The normal clotting time of blood is 3 to 6 minutes. It is defined as the length of time between the moment of escape of blood outside the vessel and the moment of development of fibrin thread. The time required for cessation of bleeding is called bleeding time. Normal bleeding time is 1 to 4 minutes.

Factors hastening coagulation of blood are as follows :

- (i) Temperature slightly excess than body temperature;
- (ii) Contact of blood with rough surface and injury to the blood platelets;
- (iii) Excessive slowness of blood flow and
- (iv) Snake venom.

Factors retarding coagulation of blood :

- (i) Low temperature;
- (ii) Contact of blood with smooth surface;
- (iii) Presence of sodium or potassium citrate. Normally, a blood clot is formed on the surface where the injury has occurred. When such a clot is formed in the circulation, it is called thrombus. Whenever a portion of a clot is detached and enters the circulating blood, it is called embolus.

Disorders of blood : Major disorders of blood are -

- (i) Anemias,
 - (ii) Polycythemia,
 - (iii) Bleeding disease,
 - (iv) Leukemias and
 - (v) Agranulocytosis,
 - (vi) Thalassemia.
- (i) Anemia signifies reduction in the amount of oxygen - carrying haemoglobin in a given volume of blood. There are several types of anemia. In pernicious anemia, the intrinsic factor responsible for the absorption of vitamin B₁₂ from the small intestine mucosa is absent. As a result, the number of erythrocytes goes down and the average size is increased. Hence, it is a type of macrocytic anemia. In contrast to this, in the case of microcytic anemia, the average diameter of the red cells is smaller. The cause is mainly deficiency of iron; however, the clinical symptoms are similar to those of pernicious anemia. Haemolytic anemias are characterized by a shortened life span of red cells with resulting haemolysis. It may be hereditary or because of circulating antibodies which become adherent to red cells. The hereditary defect may involve abnormal red cells or abnormal haemoglobin. In sickle cell anemia, the defect is in the haemoglobin molecule. The shape of a large number of the red cells is crescentic or sickle and the life span is, considerably shortened.
- (ii) In Thalassemia, the haemoglobin defect results in a decreased life span of circulating red cells. The shape of red cells is altered, but a large number of nucleated cells are also observed. Many haemolytic anemias are caused by certain drugs, bacterial toxins, malarial parasite etc. Rh incompatibility can cause haemolytic disease of the newborn. Aplasia or atrophy of the bone marrow can cause aplastic anemia which results in the reduction of the number of red cells, leukocytes and blood platelets.
- (iii) Polycythemia refers to increase in the number of blood cells, especially red blood cells. In primary polycythemia, along with increased number of red cells, the bone marrow is also markedly hyperplastic; skin and mucous membranes of the mouth are red and conjunctiva is red. In secondary polycythemia, there is a compensating increase in red cells in the conditions of sufficient oxygen.
- (iv) Bleeding diseases are those in which the normal mechanism for the control of haemorrhage is deficient or deranged. The bleeding time and coagulability are the tests used to confirm this disease. Haemophilia is characterized by prolonged bleeding following a cut. It is hereditary in nature.
- (v) The important feature of leukemia is proliferation of leukoblastic cells, resulting in a great increase in the white blood cells. It is essentially a disease of the bone marrow.

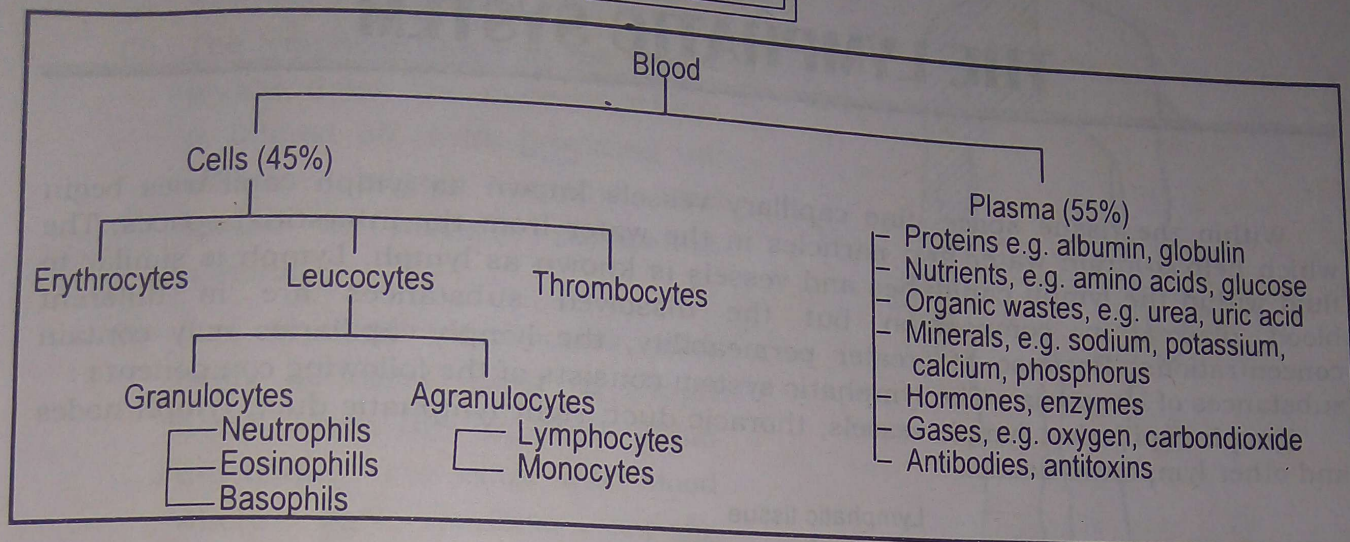
Erythrocytes

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- (vi) Agranulocytosis is a remarkable disappearance of granulocytic leukocytes from blood. It may be associated with lesions of the mouth involving gums, tonsils and even the bones of a jaw.

SUMMARY



QUESTIONS

- Write a note on 'Blood groups'.
- What do you mean by 'Rh factor' ? What is its significance ?
- Describe the functions of leucocytes.
- What is haemoglobin ? What is its function ? Mention its normal count.
- What is thrombosis ? Name the blood vessel supplying oxygenated blood to myocardium.
- What is anemia ? What is its important symptom ?
- Define the terms - Leucopenia, Leucocytosis, Erythrocytosis and Haemorrhage.
- Which organs have constant blood flow ?
- What is E.S.R. ? What is its significance ?
- Define and describe in brief the following terms :
Phagocytosis, Erythropoiesis and Embolism.
- Without going in great details describe the process of blood coagulation.
- What are the factors which accelerate and retard clotting of blood ?
- Outline the life cycle of red cell.
- Give the composition of blood.
- Summarize the functions of blood.
- Define and give the normal values for 'bleeding time' and 'clotting time'. What do you mean by blood serum ?

THE LYMPHATIC SYSTEM

Within the tissue space, fine capillary vessels known as lymph capillaries which help to drain water and particles in the water from the interstitial spaces. fluid within the lymph capillaries and vessels is known as lymph. Lymph is similar to blood plasma in composition but the dissolved substances are in different concentrations. Because of greater permeability, the lymph capillaries may contain substances of larger size. The lymphatic system consists of the following components:

Lymph capillaries; lymph vessels; thoracic duct; right lymphatic duct; lymph nodes and other lymphatic tissue.

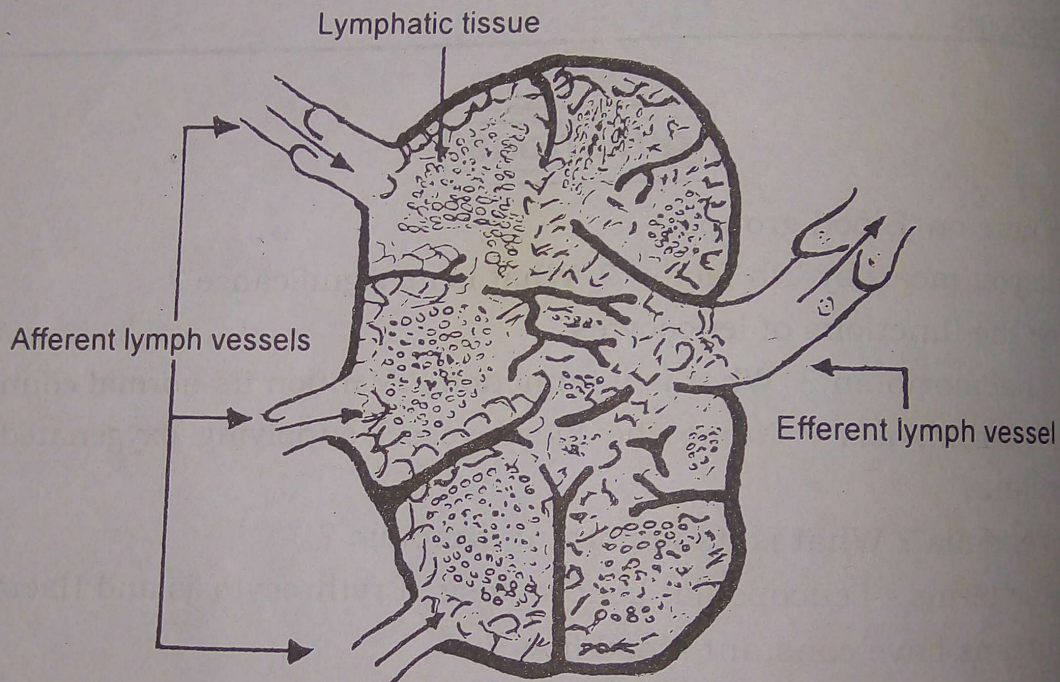


Fig. 6.1 : T. S. of Lymph Node

Most of the lymph vessels open into lymph nodes. The lymph drains through one node before returning to blood. The lymph nodes are situated in various positions throughout the body. The lymph from head and neck passes through lymph nodes. The lymph from upper limbs passes through axillary nodes. The important groups of lymph nodes in the thoracic cavity are tracheobronchial and intercostal lymph from pelvic and abdominal cavities passes through pelvic and abdominal nodes respectively. The lymph from the lower limbs is drained through popliteal and iliac nodes. The lacteals are the lymph capillaries which drain lymph from the intestine.

The lymph nodes perform the following functions :

- (1) Lymph is filtered as it passes through lymph nodes leaving behind no particles.
- (2) The lymphoid tissue in the nodes breaks down the material which is filtered off, thus providing an effective barrier against the spread of noxious particulate material.
- (3) One type of lymphocytes after being activated, pass to lymph nodes where they multiply. From the nodes, they enter into blood where they perform specific protective activities.

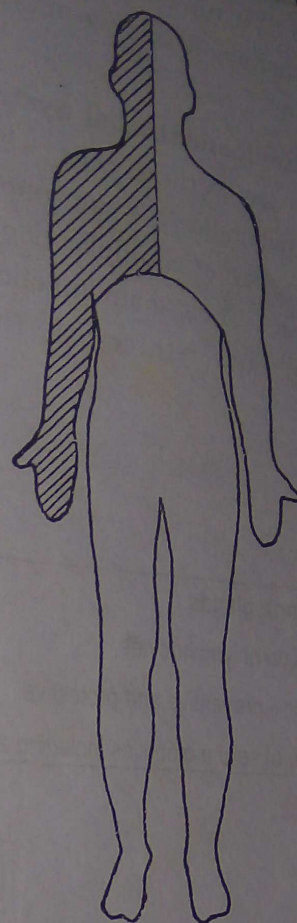


Fig. 6.2 : The diagram showing location of regions from which lymph collects in the thoracic duct and right lymphatic duct (The region of the latter is shaded)

There are two lymphatic ducts which collect lymph from the whole body and return it to the blood. They are called the thoracic duct and the right lymphatic duct. The thoracic duct collects lymph from all the left side parts of the body, right leg, right abdomen, while the right lymphatic duct collects lymph from the rightside of chest, neck, head and arm. The thoracic duct empties its contents into left subclavian vein and the right lymphatic duct into right subclavian vein.

Two important lymphatic tissues, viz., spleen and the thymus, have special functions :

Spleen : Erythrocytes are destroyed in the spleen and the breakdown products viz. bilirubin and iron are passed to the liver via splenic and portal veins. Other cellular material like micro-organisms are phagocytosed. The spleen also acts as a reservoir of erythrocytes and in states of emergency, such as hypoxia, they pass into circulation. The spleen forms lymphocytes some of which stay in the spleen and few other pass into circulating blood. The spleen forms a considerable amount of specific antibodies and antitoxins which are passed into blood.

Thymus : Thymus gland is the site of activation of T-lymphocytes which originate in red bone marrow. It is very active in early stages of life. The activity declines with advancing age.

The Reticuloendothelial System : Throughout all the tissues and organs of the body there are certain cells which ingest foreign particles and bacteria. They concentrate particularly in the lymph glands, spleen, liver and bone marrow. These cells have great power of multiplication and are related to both lymphocytes and blood-forming organs. Their main function is to protect the body from infection. They also destroy worn out erythrocytes. Those phagocytic cells form the reticuloendothelial system.

SUMMARY

Functions of Lymph glands :

1. Formation of lymphocytes.
2. Filtration - preventive and protective.
3. Addition of serum globulins including antibodies.

QUESTIONS

1. Define and describe the formation of lymph. Give its functions.
2. What is the composition of lymph ? Name two main lymphatic ducts. Where do they communicate with the blood circulatory system ?
3. Draw a transverse section of lymph gland and mention its functions.
4. What is reticuloendothelial system ? Describe the functions of spleen.

THE CARDIOVASCULAR SYSTEM

INTRODUCTION

There is a continuous flow of blood throughout the human body. This process is known as blood circulation. It is carried out and maintained by a hollow muscular organ with the help of various vessels linked with it. The hollow muscular organ is called heart and it is linked to blood vessels. The blood vessels are of two types : The vessels which collect blood from different parts of the body and empty their contents in the heart are called veins and the vessels which supply blood from the heart to other parts of body are termed as arteries.

THE HEART

The heart is a hollow, muscular organ. It lies in the centre of thorax and between the two lungs; but is more to the left of the middle. It is cone-shaped and presents a base above and an apex below. It is of the size of a closed fist of the individual. It is composed of three layers of tissues.

- (1) **The Pericardium** : It is made of two sacs. The outer sac consists of fibrous tissue and the inner of a double layer of serous membrane. The fibrous nature of the outer sac prevents over distension of the heart. The cells of the serous membrane secrete serous fluid into the space between the two layers. This fluid allows smooth movement between the layers during the heart beats.
- (2) **The Myocardium** : It is the muscular coat through the action of which the blood is circulated. It is made up of a specialized tissue known as cardiac muscle. The myocardium is the thickest at the apex and thins out towards the base.
- (3) **The Endocardium** : It forms a lining to the myocardium. It is a smooth membrane consisting of flattened epithelial cells continuous with the lining of the blood vessels and also the valves.

The interior of the heart is divided into right side and left side, by a vertical septum. Each side is further subdivided into an upper chamber and a lower chamber by a valve. The upper chambers are called atria and the lower chambers as ventricles. The valves between the atria and the ventricles ensure that the flow of blood is in one direction only. The valve separating the right atrium from the right ventricle is called tricuspid valve and consists of three flaps or cusps. The left atrioventricular valve is called

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LA : Left atrium
RA : Right atrium
LV : Left ventricle
RV : Right ventricle

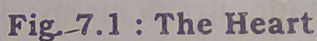


Fig-7.1 : The Heart

Blood supply to the Heart : The heart is supplied with arterial blood by the right and left coronary arteries. The venous return is by the coronary sinus which empties into the right atrium.

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Fig. 7.

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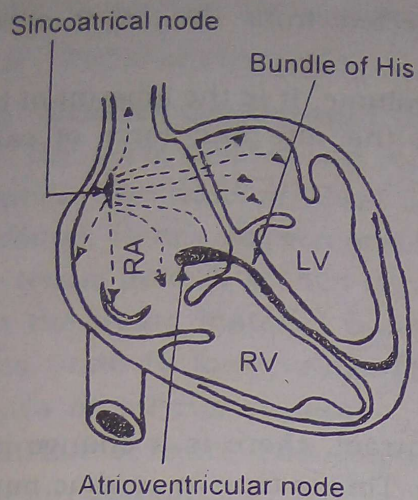


Fig. 7.2 : Conducting System in Heart

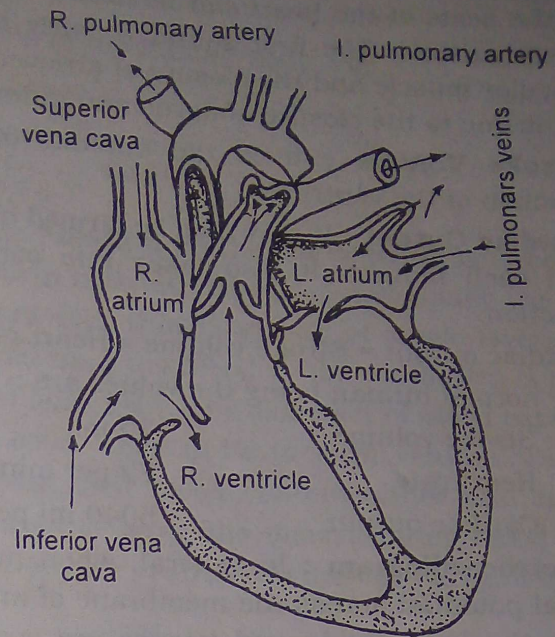


Fig. 7.3 : Circulation through Heart

Cardiac Cycle : The events which occur in the heart during the circulation of blood are known as the cardiac cycle. The heart action originates in the special type of myocardium called the sinoatrial node (S.A. node) (pace-maker). It is situated near the opening of superior vena cava in the right atrium. The wave of contraction starts from S.A. node. This wave is conducted by the atrial myocardium causing atrial contraction (atrial systole). The wave is transmitted to another node called atrioventricular node (AV node) situated on the atrioventricular septum. It is then conducted by the tissue in the interventricular septum called the bundle of HIS. It divides at the bottom of ventricles passing the wave over right and left ventricles. This causes contraction of ventricles i.e., ventricular systole. When there is a ventricular systole there is no wave of contraction over the atria, hence the atria relax; i.e., there is atrial diastole. When there is an atrial systole the ventricles relax showing ventricular diastole. The atria contract simultaneously, so also they relax simultaneously, and the same happens in the case of ventricles. Thus, a cardiac cycle consists of four events viz., atrial systole, atrial diastole, ventricular systole and ventricular diastole. These events occur cyclically in the heart. Thus, the heart beats continuously throughout the life. The cardiac muscles get rest only during diastole.

The contraction of atria is for a very short time and that of the ventricles is for a longer duration and more forcible. The time required for one cardiac cycle is 0.8 seconds. Thus, in a minute, about 70 cardiac cycles take place in an adult.

Heart Sounds : Contraction and relaxation of heart produces sounds.

If the ear or the receiver of stethoscope is placed upon left upper side of the chest wall, the beats of the heart can be heard. Two sounds, separated by a short pause can be distinguished. The first sound is fairly loud and is due to the contraction of the ventricular muscle and the closure of atrioventricular valves. The second sound is softer and it is due to the closure of aortic and pulmonary valves.

Stroke Volume : It is the amount of blood ejected from the heart at each contraction of the ventricles.

Cardiac Output : It may also be termed as minute volume. It is the amount of blood ejected each minute. It also takes into consideration the rate and force of cardiac contraction.

$$\text{Cardiac output} = \text{Stroke volume} \times \text{Heart rate}$$

For normal human being the values are :

Stroke volume	70 ml
Heart rate	72 per minute
Cardiac output	5040 ml per minute

Electrocardiogram : In general, when muscles contract, there is a change in the electrical potential across the membrane of muscle fibre. This is true in cardiac muscles also. As the body fluids and tissues are good conductors of electricity, the electrical changes occurring in the contracting myocardium can be detected by attaching electrodes to the surface of the body. The pattern of electrical activity may be displayed on the oscilloscope screen or printed out on paper. This tracing is called an electrocardiogram (ECG).

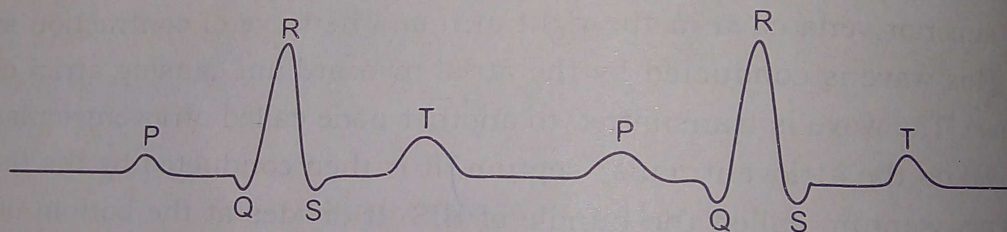


Fig. 7.4 : Electrocardiograph Tracing of Cardiac Cycle

The normal ECG tracing shows five waves which are named as P, Q, R, S, and T (Fig. 7.4).

The P wave is caused by the impulse of contraction within the atria. The Q, R, and S waves indicate spread of the impulse of contraction through the conducting tissue of the ventricular muscle. The T wave represents the relaxation of the ventricular muscle. Examination of ECG gives information regarding state of myocardium and conducting system within the heart.

The different waves are associated with excitation and contraction of the different parts of the heart.

Changes in the cardiogram are observed in the cases of disorders of heart. Change in the cardiogram is an indication of a particular disease. Thus ECG has a diagnostic value. The instrument used in recording the ECG is called electrocardiograph.

Circulation of Blood : Liver, kidneys and brain are the organs which get constant blood supply.

There are three types of blood circulations in the human body, viz.,

- (i) Greater circulation or systemic circulation;
- (ii) Pulmonary circulation or lesser circulation; and
- (iii) Portal circulation.

(i) Greater circulation : The oxygenated blood from the left ventricle is forced into aorta. The aorta divides and redivides to form arteries, arterioles and finally the blood capillaries. The walls of blood capillaries are very thin (made up of single layer of flat epithelium). Hence, oxygen and food material from the blood in the capillaries is passed to the tissue fluid. It is then supplied to the body cells. The same set of blood capillaries collect the waste material from the body cells. They unite to form venules. Different venules unite to form veins. The veins pour their blood content either into superior venacava or inferior venacava. These venacavae bring the deoxygenated blood to the right atrium of heart. This course of blood from left ventricle to the right atrium is called greater circulation.

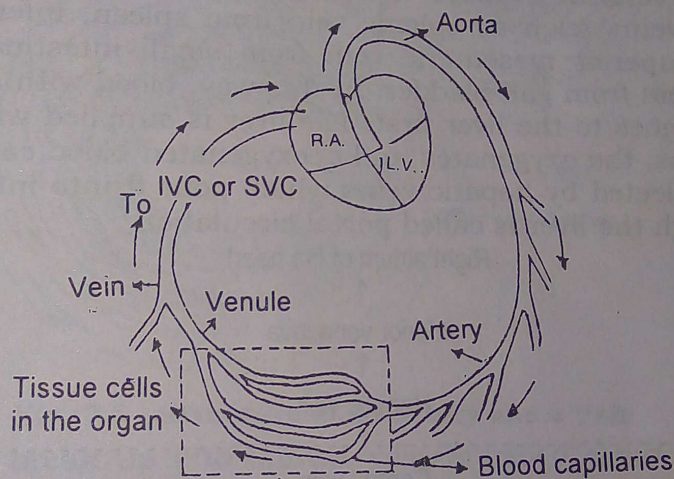


Fig. 7.5 : Systemic (Greater) circulation

(i) Pulmonary Circulation : The deoxygenated blood from the right ventricle is forced into the pulmonary artery. The pulmonary artery divides into two branches each carrying blood to right and left lungs. In the lung tissue, the artery divides and redivides to form a net of blood capillaries surrounding the alveoli. Thus, the blood in blood capillaries and oxygen in the alveoli are separated by a double layer of flat epithelium (one layer is due to wall of blood capillary and another due to wall of alveoli). This membrane is called alveolar capillary membrane. The oxygen from alveoli diffuses through this membrane and passes to the blood in the capillaries. The carbon dioxide from blood capillaries diffuses into alveoli. Thus, the exchange of gases occurs in the lungs causing oxygenation of blood. The oxygenated blood from right and left lung is collected by four pulmonary veins and poured into the left atrium. This course of blood from right ventricle to the left atrium is called pulmonary circulation. As it is related only with oxygenation of blood occurring in the lungs, it is called lesser circulation.

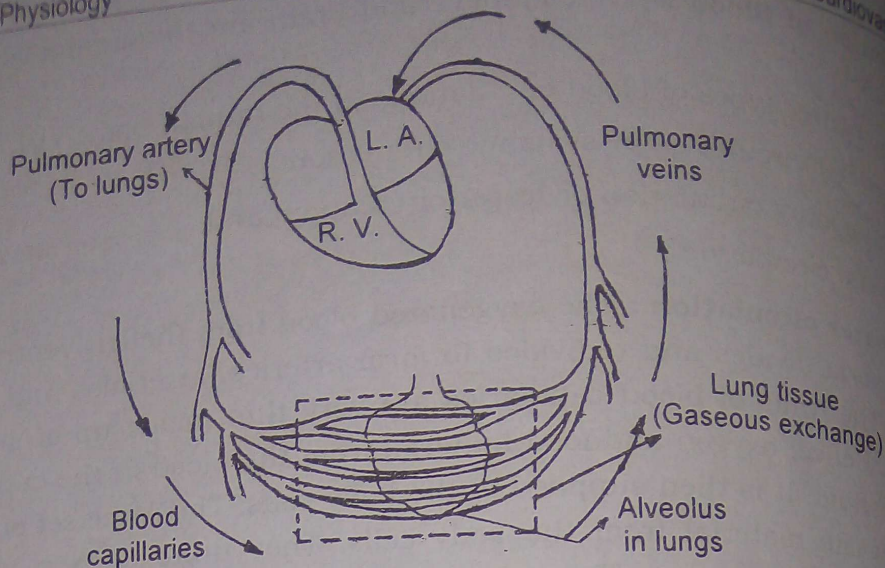


Fig. 7.6 : Pulmonary Circulation (Lesser Circulation)

(iii) **Portal Circulation** : The venous blood from the digestive organs such as intestine, stomach and pancreas is collected by the portal vein. It, instead of pouring its content into inferior venacava, pours it into the liver. The portal vein is formed by joining together the veins such as splenic vein from spleen, inferior mesenteric vein from rectum and colon, superior mesenteric vein from small intestine, gastric vein from stomach and cystic vein from gall bladder. In this way, blood with a high concentration of nutrient materials goes to the liver first. The liver is supplied with oxygenated blood by hepatic artery. Thus, the oxygenated and deoxygenated blood carried into the liver is mixed and further collected by hepatic veins which pour it into inferior venacava. The course of blood through the liver is called portal circulation.

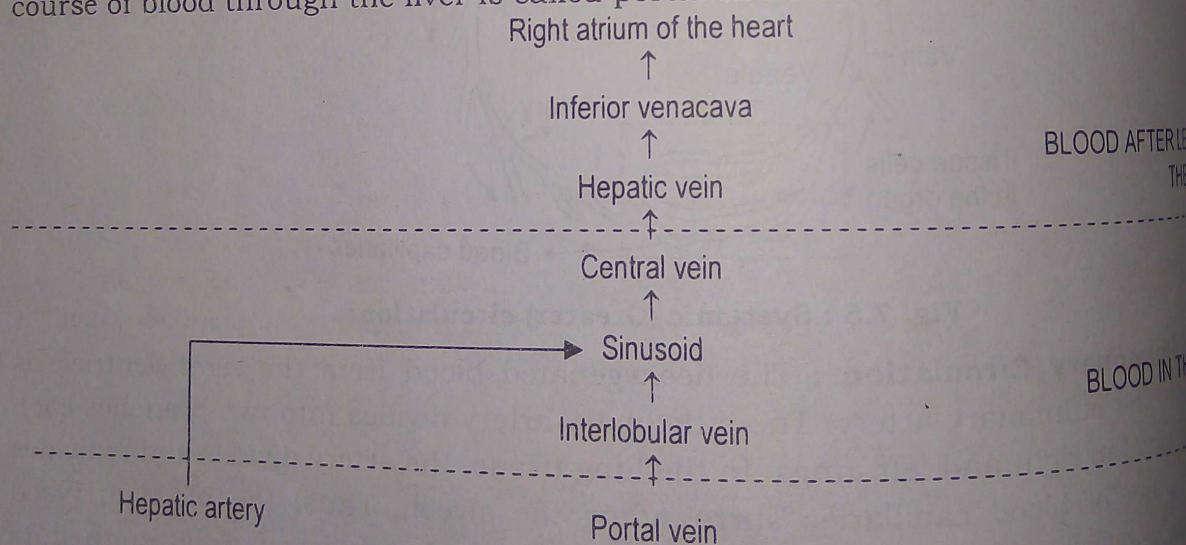


Fig. 7.7 : Portal Circulation

In general, venous blood passes from the tissues to the heart by the most direct route. The only exception is the blood passing from abdominal part of the digestive system and spleen, in which case, it initially passes via liver and then to the inferior venacava. Because of this 'portal circulation', nutrients present in the blood from digestive organs are modified in the liver. This helps in the regulation of materials to other parts of the body.

The Blood Vessels :

Arteries are the blood vessels which transport blood away from the heart. They consist of three layers of tissue (Fig. 7.8). Outer layer consists of fibrous tissue called tunica adventitia. The middle layer consists of smooth muscle and elastic tissue.

tunica media. The tunica media is the larger arteries and the smaller arteries.

Veins are the blood vessels which transport blood back to the heart. They have three layers similar to arteries, but the middle layer is thinner because there is no need for valves, which prevent backflow of blood. The intima is strengthened by elastic tissue.

The small arteries and capillaries are composed of a single layer of cells. The passage of water and small substances do not require a network and link a network of capillaries. The arterial and venous systems are the main components of the circulatory system.

The arterial system is the part of the circulatory system that carries blood away from the heart. It is composed of arteries and arterioles. The arterial system is a branching network that carries blood from the heart to the rest of the body. The arterial system is the part of the circulatory system that carries blood away from the heart. It is composed of arteries and arterioles. The arterial system is a branching network that carries blood from the heart to the rest of the body.

tunica media. The inner lining consists of squamous epithelium called endothelium. In the larger arteries, the tunica media consists of more elastic tissue and less muscle. In the smaller arteries, the tunica media consists almost entirely of smooth muscle.

Veins are the blood vessels which transport blood to the heart. They also contain three layers similar to these of arteries. In the case of veins, the walls are much thinner because there is less muscle and elastic tissue in the tunica media. Some veins possess valves, which prevent the back flow of blood. The valves are formed by a fold of tunica intima strengthened by connective tissues.

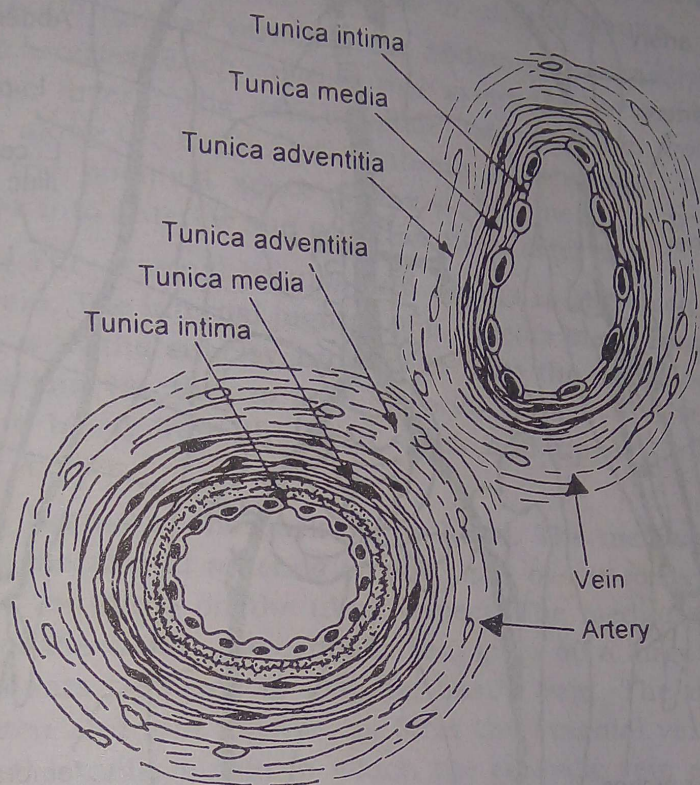


Fig. 7.8 : Structure of an Artery and a Vein

The small arteries break up into minute vessels called capillaries. The wall of the capillary is composed of a single layer of endothelial cells which is very thin and permits the passage of water and other small molecules. Blood cells and large molecular weight substances do not normally pass through capillary walls. Capillaries form a vast network and link arterioles to venules.

ARTERIAL AND VENOUS SYSTEMS

Arterial System : The aorta after passing upwards for a short distance arches backwards and to the left. Two common carotid arteries, viz., left and right arise from the arch of aorta and the aorta. The left common carotid artery arises directly from the arch of aorta and the right one arises as a branch of brachiocephalic artery. There are two subclavian arteries out of which the right subclavian artery arises from the brachiocephalic artery and directly from the arch of the aorta. The axillary artery is a continuation of the subclavian artery and lies in the axilla. The first part is deep and then it runs superficially to become the brachial artery. It runs down the medial aspect of the upper arm and extends below the elbow joint where it divides into a radial and an ulnar artery. Together, the radial and ulnar arteries form palmar arches in the hand. Branches from the axillary, brachial, radial and ulnar arteries supply all the structures in the upper limb.

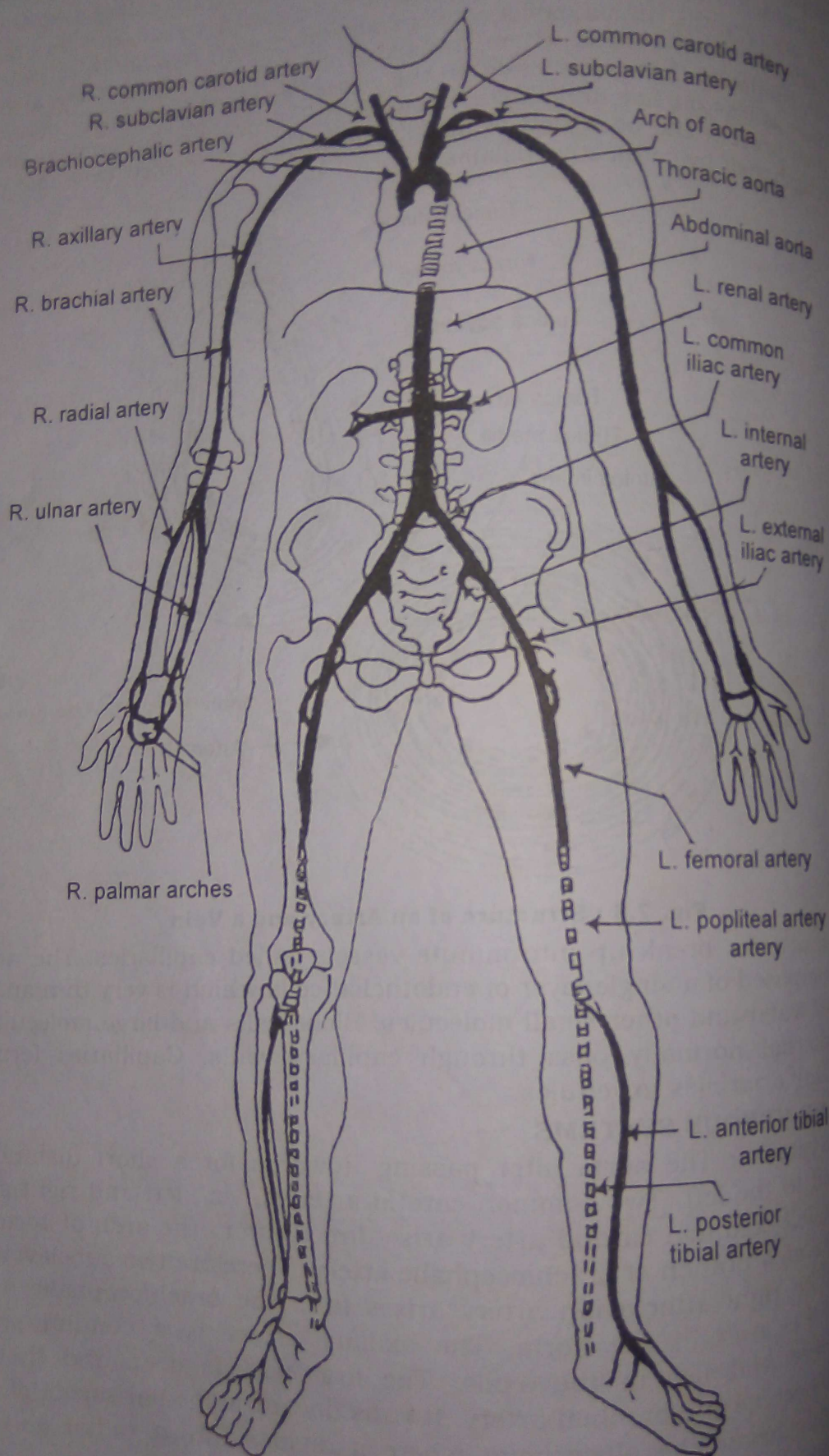


Fig. 7.9 : Arterial System : Deep Arteries Shaded, Superficial Arteries Unshaded

The descending aorta continues downwards to the diaphragm to become the abdominal aorta, which gives off branches which supply blood to the abdominal organs.

The abdominal aorta gives off the important pair of arteries which supply blood to the kidneys.

At the level of the diaphragm, the descending aorta divides into the right and left common iliac arteries. The right common iliac artery divides into the right internal iliac artery which extends to the femur to enter the femoral artery. The left common iliac artery divides into the left internal iliac artery which extends to the femur to enter the femoral artery.

Venous system :

The venous system carries blood from the body back to the heart. The venous system is divided into the superficial and deep venous systems. The superficial venous system is located in the skin and subcutaneous tissue, while the deep venous system is located in the muscles and bones.

The cephalic vein is one of the superficial veins of the upper limb. It begins at the back of the hand and runs along the thumb side of the forearm. The basilic vein is another superficial vein of the upper limb. It begins at the back of the hand and runs along the little finger side of the forearm. The axillary vein is formed by the union of the cephalic and basilic veins. It then joins the venous system at the junction of the internal jugular vein and the common carotid vein.

Most of the venous system is formed by the union of the superficial and deep venous systems. The superficial venous system is formed by the union of the cephalic and basilic veins. The deep venous system is formed by the union of the femoral and popliteal veins.

In the abdominal cavity, the common iliac veins join the internal iliac veins. The internal iliac veins drain the pelvic organs, including the testes, ovaries, kidneys, and the remaining organs in the pelvic cavity.

In the lower limbs, the long saphenous vein and the great saphenous vein join to form the popliteal vein. The popliteal vein then joins the femoral vein. The femoral vein is formed by the union of the popliteal vein and the great saphenous vein. The femoral vein then joins the venous system at the junction of the internal jugular vein and the common carotid vein.

The descending aorta is continuous with the arch of the aorta. It extends downwards to the level of the 12th thoracic vertebra where it passes behind the diaphragm to become the abdominal aorta. The thoracic aorta gives off many paired branches which supply walls of the thoracic cavity and the organs within it.

The abdominal aorta extends from the 12th thoracic to the 4th lumbar vertebra. One of the important paired branches of the abdominal aorta is that of renal arteries which supply blood to the kidneys and give off branches to adrenal glands.

At the level of the 4th lumbar vertebra, the abdominal aorta divides into the right and left common iliac arteries. Each common iliac artery further divides into an external iliac and internal iliac artery. The external iliac artery further becomes the femoral artery which extends along the thigh and eventually passes round the medial aspect of the femur to enter the popliteal space where it becomes the popliteal artery. The popliteal artery divides into anterior and posterior tibial arteries.

Venous system : The external jugular vein begins in the neck and finally passes into the subclavian vein. The internal jugular vein collects blood from various regions of the brain and unites with the subclavian veins to form the brachiocephalic veins. Two brachiocephalic veins join together to form superior venacava. The superior venacava drains all the venous blood from the head, neck and upper limbs and empties its content into the right atrium.

The cephalic vein begins at the back of the hand. The median vein begins at the palmar surface of the hand and ascends on the front of the forearm. The basilic vein begins at the back of the hand on the ulnar aspect. The median veins ends with the basilic vein. In front of the elbow, the cephalic vein gives off a large branch, the median cubital vein, which slants upwards to join the basilic vein. The ulnar and the radial veins are deeply located and join together to form the brachial vein. The brachial vein further continues as the axillary vein in which the cephalic vein empties its contents. The axillary vein further continues as the subclavian vein which ultimately forms brachiocephalic vein.

Most of the venous blood from the organs in the thoracic cavity is drained into the azygos and the hemiazygos veins which empty into the superior venacava and the left brachiocephalic vein respectively.

In the abdominal region, the inferior venacava is formed when right and left common iliac veins join at the level of the 5th lumbar vertebra. Paired veins from the testes, ovaries, kidneys and adrenal glands join the inferior venacava. Blood from the remaining organs in the abdominal cavity enters portal circulation.

In the lower limbs there are two main superficial veins called short saphenous vein and long saphenous vein. The posterior and the anterior tibial veins are the deep veins which join to form the popliteal vein. The short saphenous vein ascends superficially to join the deep popliteal vein, which ultimately becomes the femoral vein and ascends in the thigh. The external iliac vein is the continuation of the femoral vein and also receives the long saphenous vein in its path. The internal iliac vein receives tributaries from several veins which drain the organs of the pelvic cavity. The external and the internal iliac veins join to form common iliac vein. Two common iliac veins from either side of the body ascend and unite to form the inferior venacava.

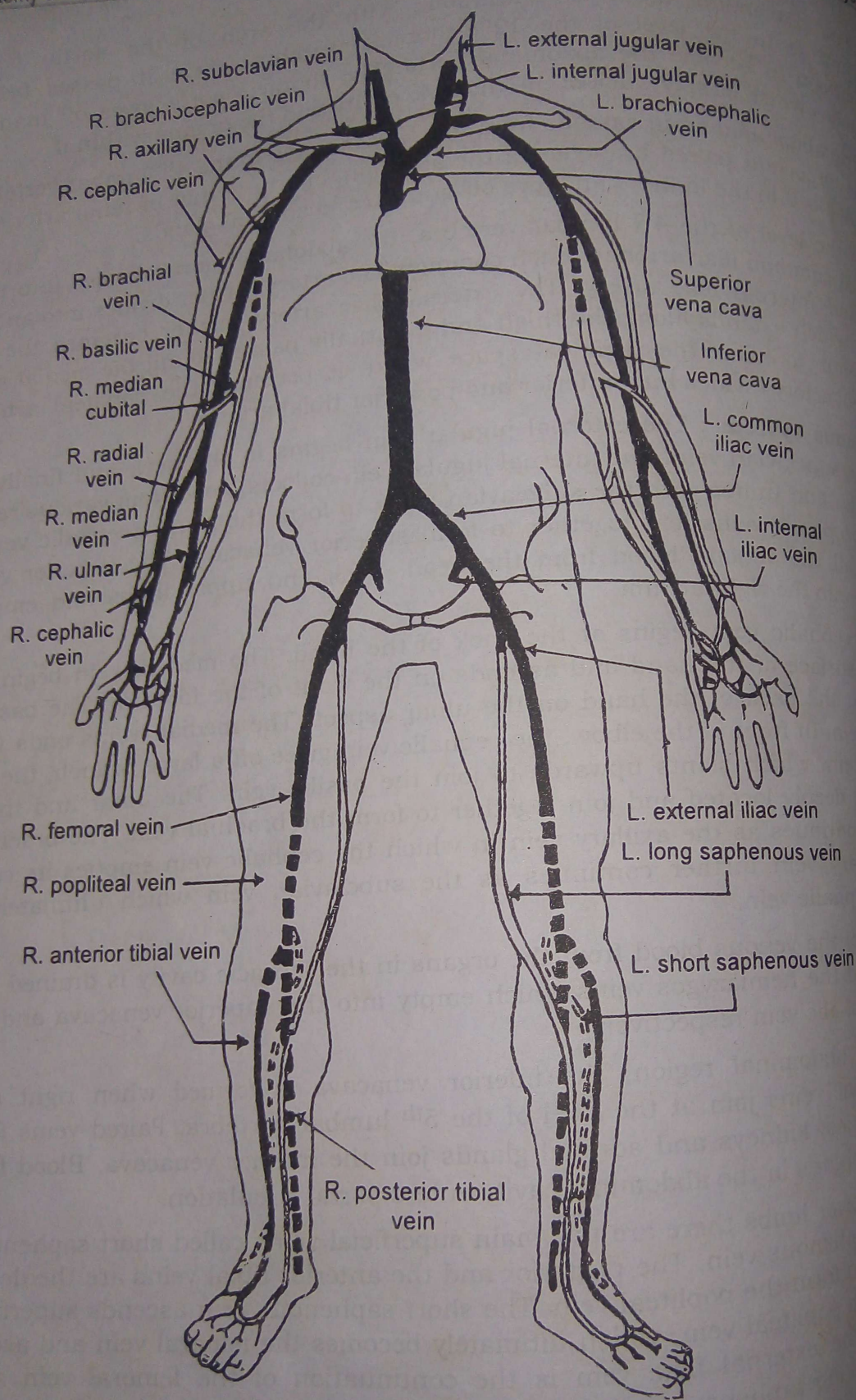


Fig. 7.10 : The Venous System : Deep Veins Shaded, Superficial Veins Unshaded

BLOOD PRESSURE (B.P.)

It is the force exerted on the walls of blood vessels. There are two types of blood pressure: systolic and diastolic. The systolic pressure is the pressure exerted during systole, and the diastolic pressure is the pressure exerted during diastole. The normal systolic pressure is 120 mm of Hg and the normal diastolic pressure is 80 mm of Hg. The difference between systolic and diastolic pressure is called the pulse pressure.

Factors Maintaining Blood Pressure

- (1) **Contractile force of the heart**: The heart contracts and pumps blood into already full vessels. The pressure is systolic B.P. The volume and thus the pressure is maintained.
- (2) **Cardiac output**: The volume of blood pumped by the heart per minute.
- (3) **Elasticity of wall of blood vessels**: The blood vessels are elastic and can stretch to accommodate the flow of blood.
- (4) **Volume of blood**: The total volume of blood in the body.
- (5) **Peripheral resistance**: The resistance to the free flow of blood through the blood capillaries. It is the pressure on the walls of the blood vessels.

Factors Affecting Blood Pressure

- (1) **Physiological condition**: For example, during exercise, the blood pressure increases.
- (2) **Emotional condition**: Emotional stress can increase blood pressure.
- (3) **Age of the individual**: Blood pressure increases with age.
- (4) **Body weight**: Obesity is associated with high blood pressure.

Measurement of Blood Pressure

Blood pressure is measured by a sphygmomanometer. It consists of a pressure pump and a mercury manometer. The pump is used to inflate a rubber bag until the pressure is above the systolic pressure.

BLOOD PRESSURE (B.P.)

It is the force called radial pressure, exerted by blood on the walls of the blood vessels. There are two types of pressures viz., systolic and diastolic. The pressure exerted during systole is called systolic blood pressure, while the pressure exerted by the blood during diastole is called diastolic blood pressure. The systolic blood pressure is produced due to the contraction of heart muscles which forces the blood into the already full aorta. Blood pressure is measured in terms of mm of Hg. The systolic blood pressure in the normal adult human being is 120 mm of Hg and the diastolic blood pressure is 80 mm of Hg. There are physiological variations in the normal B.P. Thus, in the case of normal individual the systolic blood pressure may vary from 100 to 150 mm of Hg and diastolic blood pressure may vary from 60 to 90 mm of Hg. The difference between systolic and diastolic blood pressure is called pulse pressure.

Factors Maintaining Blood Pressure :

- (1) **Contractile force of heart** : During the ventricular systole, the blood is forced into already full aorta. This exerts maximum force on the walls of arteries. This is systolic B.P. Greater the contractile force of heart, greater will be the stroke volume and thus the greater B.P.
- (2) **Cardiac output** : Greater the cardiac output, greater will be the blood pressure.
- (3) **Elasticity of wall of blood vessels.**
- (4) **Volume of blood circulated in the circulatory system.**
- (5) **Peripheral resistance** : It is the resistance offered by the blood capillaries to the free flow of blood. The resistance is due to the decrease in the lumen size of blood capillaries. Because of this resistance, some amount of blood is present in the arterial system even during the diastole. This blood exerts minimum pressure on the walls of blood vessels which is called diastolic B.P.

Factors Affecting Blood Pressure :

- (1) **Physiological condition** : Physiological condition of the body also affects B.P. For example, during heavy exercise, the B.P. is increased, while during the resting period the B.P. slightly falls.
- (2) **Emotional conditions.**
- (3) **Age of the individual.**
- (4) **Body weight.**

Measurement of Blood Pressure :

Blood pressure is measured with the help of an instrument called 'Sphygmomanometer'. It consists of a rubber bag connected by rubber tubings to a pressure pump and a mercury manometer. The rubber bag is wrapped round the upper arm of the individual. With the help of pressure pump, the air is pumped into the rubber bag until the pressure is 200 mm of Hg (which can be seen on the mercury

manometer). This pressure is sufficient to obliterate the brachial artery. Thus, at condition, the pulse disappears when observed at elbow joint. The chest piece of stethoscope is kept at the elbow and the heart sounds are observed. Now the chest piece bag is slowly released. The stage at which the pulse is first heard at elbow, the reading on the manometer is noted as systolic B.P. The air from the rubber bag is still released further and the stage at which the heart sounds stops, the reading on the manometer is noted as diastolic B.P. (Also refer to page No. P-II.1) B.P. is generally measured when individual is at rest, both mentally and physically.

CARDIOVASCULAR DISORDERS

These are divided into : (a) Disorders of heart and (b) Disorders of blood vessels.

(a) Disorders of Heart : There are three main ways in which the action of the heart may be interfered with :

- (1) The valves may be damaged by inflammation;
- (2) The cardiac muscles may not receive sufficient nourishment on account of narrowing of the coronary arteries;
- (3) The heart may have too much work to do and finally gives way to exhaustion.

There are five forms of the diseases :

- (1) Rheumatic heart disease,
- (2) Bacterial endocarditis,
- (3) Coronary artery occlusion,
- (4) Hypertensive heart disease and
- (5) Congenital heart disease.

(1) Rheumatic Heart Disease : Rheumatic heart disease is caused by streptococcal infection. The mitral valve is the common site of infection. In addition to the valves, heart muscles and pericardium may also be affected. The inflammation of pericardium is called pericarditis.

(2) Bacterial Endocarditis : Bacterial endocarditis is caused by a variety of bacteria, especially hemolytic streptococci. Formation of a large number of emboli is a common consequent effect is called pericarditis. Bacterial endocarditis is caused by a variety of non-haemolytic antibiotics, incidence of the disease has been controlled.

(3) Coronary Artery Occlusion : In coronary artery occlusion, myocardial infarct is an essential feature. The infarct is a soft, pale area of dead muscles in the wall of the left ventricle, varying greatly in size. It is caused by a thrombus entering in coronary artery or narrowing of the coronary arteries may be the cause of the infarct. It leads to severe chest pain, sudden pain is felt in the region of the heart and it frequently passes to the left arm.

(4) Hypertension : It is a condition for which there is a high blood pressure.

(5) Congenital defects : These are defects of the heart and blood vessels which are present from birth.

Cardiac disorders

The cardiovascular system is disturbed when the heart is disturbed. This condition within the heart leads to the deposition of fatty substances. As a result, blood constituents, deposited in the heart.

(b) Disorders of blood vessels : Disorders of blood vessels are of two types.

- (1) Degenerative diseases
- (2) Inflammatory diseases

In arteriosclerosis, there is degeneration of the walls of the smaller visceral arteries. There are two types of arteritis appearing.

The pathology of these disorders has the following features.

- (1) The veins have a tendency to become varicose.
- (2) They also have a tendency to become haemorrhoidal.

Two conditions, are common in the veins.

- (1) Varicose vein
- (2) Haemorrhoids

A varicose vein is a condition in which the blood accumulates in such a way that the surrounding tissue. This is one of the important factors in the condition in which the blood is enlarged. The possible effects are embolism and thrombosis.

- (4) **Hypertensive Heart Disease** : In a hypertensive patient, the heart has to work for years against a greatly increased resistance in the form of high blood pressure. The symptoms are similar to other forms of heart failure.
- (5) **Congenital Heart Disease** : Heart disease may be congenital. Most of the defects lie in variations in the formation of the septum dividing heart into a right and a left side. Congenital defects are points of weakness against bacterial infection, cyanosis, dyspnoea, polycythemia observed in a child with congenital heart disease.

Cardiac disorders in Arrhythmia and Artherosclerosis the function of cardiovascular system is disturbed. In arrhythmia the rhythm of contraction and relaxation of the heart is disturbed. It may be because of defective generation of impulses or defective condition within conducting tissues of the myocardium. In artherosclerosis, there is a deposition of fatty material in the walls of arteries. This leads to thickening of arteries. As a result, blood pressure is found to be increased. Cholesterol is one of the important constituents, deposition of which is a causative factor for artherosclerosis.

(b) **Disorders of Blood Vessels** : These are classified in arterial and venous disorders. Disorders of arteries are :

- (1) Degenerative; called arteriosclerosis or
- (2) Inflammatory; termed as arteritis.

In arteriosclerosis, there may be a patchy, fatty degeneration inside arteries, or degeneration of the media of the middle sized vessels or a diffused thickening of the smaller visceral arteries. Inflammatory changes in arteries are less common. Various types of arteritis appear to be manifestations of allergy or hypersensitivity.

The pathology of veins is different from that of arteries because of their two special features.

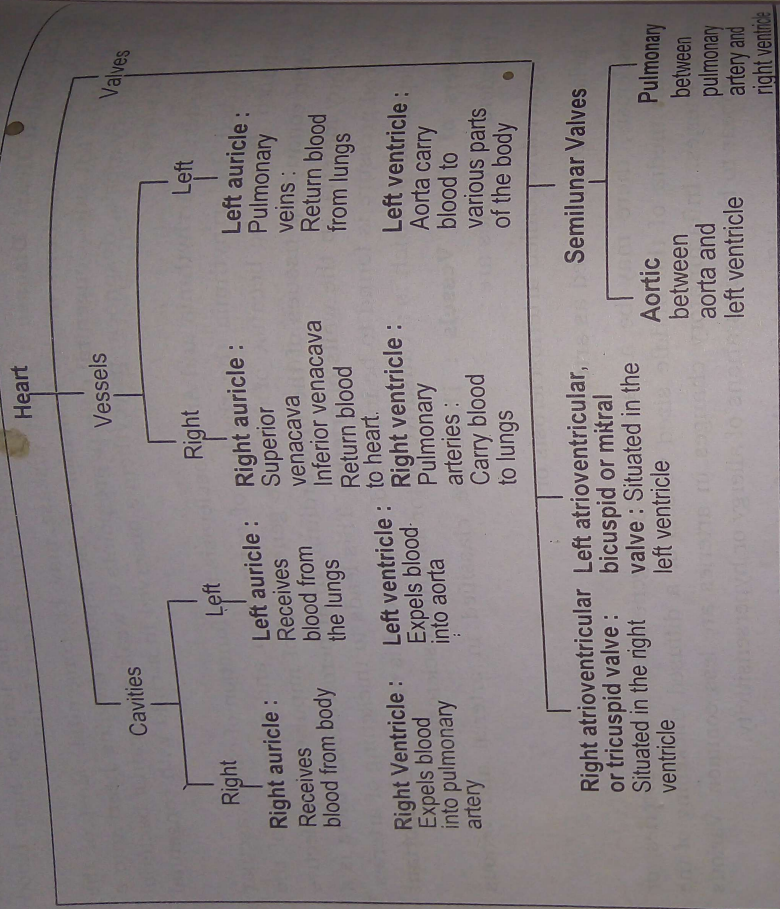
- (1) The veins have valves; and
- (2) They also have lymphatics.

Two conditions, affecting the veins in which thrombosis is common are -

- (1) Varicose vein and
- (2) Haemorrhoids.

A varicose vein is one that is dilated and tortuous. The dilation may be extreme because of which the valves become incompetent and cease to function. The blood accumulates in such veins. Injury to the varicose vein causes haemorrhage into the surrounding tissue. Thrombosis is liable to occur. Heredity plays a part in its causation but the important factor is increase of pressure in the vein. Haemorrhoids or piles is a condition in which the veins at the lower end of the rectum become varicose and enlarged. The possible effects which may render the condition serious are haemorrhage, phlebitis and thrombosis.

SUMMARY



QUESTIONS

- Describe in short cardiac cycle.
- What are the heart sounds?
- Define and give normal values for –
 - Pulse
 - Cardiac output
 - Stroke volume and
 - Heart rate.
- Draw and label the figure of arterial system.
- Draw and label the figure of venous system.
- Define the terms – blood pressure, hypertension, hypotension, arrhythmia and heart failure.

THE RESPIRATORY SYSTEM

INTRODUCTION

Energy is released from food material when it undergoes oxidation in the cell. Oxygen is necessary for the process of oxidation. During oxidation reaction, energy is created. In addition to energy, waste material such as carbon dioxide is also produced in the cells. The carbon dioxide is eliminated from the body. (There is a continuous interchange of gases (oxygen and carbon dioxide) between the organism and the external environments. A system of specialized structure performing this function is called "Respiratory System".)

The term respiration is defined as, "the exchange of gases (O_2 and CO_2) occurring between atmosphere and body cells". It involves two stages viz., external respiration and internal respiration. (The exchange of gases occurring between atmosphere and blood, taking place in lungs, is described as the external respiration, and the exchange of gases occurring between blood and body cells is called internal respiration or tissue respiration.)

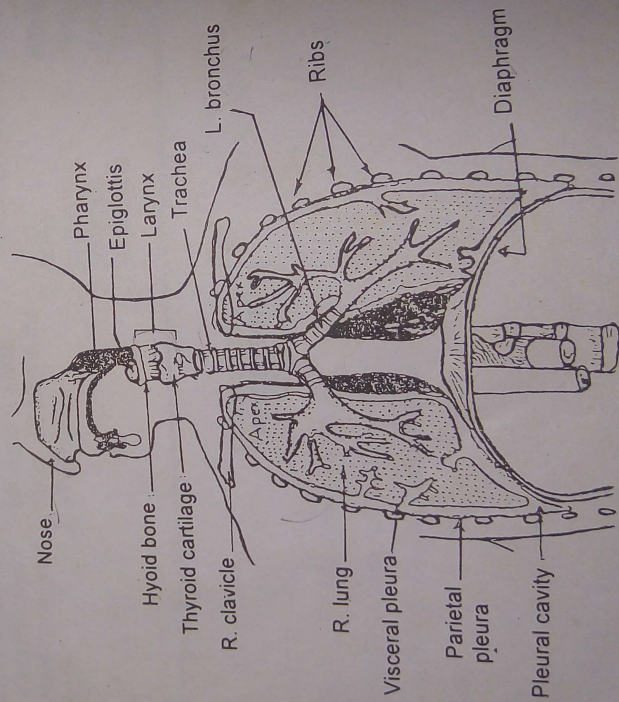


Fig. 8.1 : The Respiratory System

(8.1)

Human Anatomy

RESPIRATORY SYSTEM

The oropharyngeal cavity is the common passage for food and air. The bronchioles and the alveoli are the terminal parts of the respiratory system.

Nose: The nose is the organ of smell. It ensures that the air passing through it is free from dust and mucus. The mucous membrane of the nose is moist.

Pharynx: The air passes through the pharynx. The pharynx is a common passage for food and air. It is the point where the respiratory and digestive tracts meet.

Larynx: The larynx is the voice box. It is the point where the respiratory and digestive tracts meet.

- (a)
- (b)
- (c)
- (d)

On the tongue, the epiglottis helps to close the glottis.

The vocal cords are located in the larynx. They are the point where the respiratory and digestive tracts meet.

It provides a passage for the air. The sound of the voice is produced by the vibration of the vocal cords.

Trachea: The trachea is the windpipe. It is the point where the respiratory and digestive tracts meet. It is the point where the air enters the lungs.

Intercostal: The intercostal space is the space between the ribs. It is the point where the respiratory and digestive tracts meet.

RESPIRATORY SYSTEM

The organs of the respiratory system are : Nose, pharynx, larynx, trachea, bronchi, bronchioles, two lungs and their coverings, pleura and muscles of respiration viz. intercostal muscles and diaphragm (Fig. 8.1). The various organs of the respiratory system are listed in Fig. 8.1.

Nose : It is the first respiratory passage through which incoming air passes. It ensures warm, moistened and filtered air to the respiratory system. The air is warmed as it passes over the surface of the nose; it is moistened by its contact with moist mucous. Particles of dust stick to the mucous. The nose is an organ of the sense of smell. The olfactory nerves are responsible for the smelling sense.

Pharynx : It is an organ involved in the respiratory as well as the digestive systems. The air passing through the nose is further moistened and warmed here. The auditory tubes pass between the nasal part of the pharynx and the middle ear. The auditory tubes air passes to the middle ear, which is essential for proper hearing. The lymphatic tissue of the pharyngeal tonsils help to prevent microbes from entering into the body.

Larynx : Larynx is composed of pieces of cartilage connected by ligaments and membranes. The cartilages are as follows :

- (a) Thyroid Cartilage (one)
- (b) Cricoid Cartilage (one)
- (c) Arytenoid Cartilages (two)
- (d) Cuneiform and Corniculate Cartilage (two each)

On the top of the thyroid cartilage is the epiglottis, which is a cartilagenous flap and helps to close larynx during swallowing.

The vocal cords lie inside the larynx. They pass from thyroid cartilage in front to the arytenoids behind. It is by the vibration of the cords due to the air passing through the glottis that the voice is produced. Various muscles attached to the larynx control the production of voice.

It provides a passage for air between the pharynx and the trachea. During the passage, the air is further moistened, filtered and warmed. The vocal cords produce sound of varying loudness and pitch. During swallowing, the larynx moves upwards occluding the opening into it from the pharynx ensuring passage of food into the digestive system.

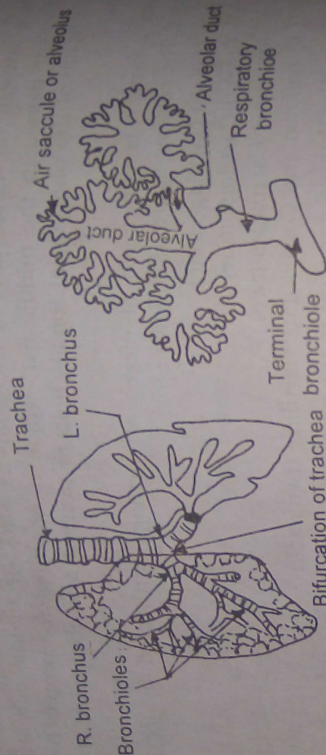
Trachea, Bronchi and Bronchioles : Because of the presence of the cartilage in the larger air passage, they remain permanently open allowing free passage of air between the atmosphere and alveoli of lungs. The mucous coating of the membrane is sticky and dust or bacteria adhere to it. The particulate matter in inspired air is thus removed before it reaches the alveoli. The motion of cilia lining the membrane helps the mucous with adherent particle reaching the pharynx from where it may either be swallowed or expectorated. The diameter of the respiratory passages may be altered by contraction or relaxation of involuntary muscles. This alters the volume of air entering the lungs.

Intercostal Muscles and Diaphragm : They contract simultaneously which enlarges the thoracic cavity in all directions. This occurs during inspiration. The reverse process occurs during expiration.

Lungs : Lungs are the principal organs of respiration. They are two in number, fill the cavity lying one on each side. They are cone-shaped with the apex above the base rests on the floor of the thoracic cavity on the diaphragm. The lungs are divided into lobes by tissues. The right lung has three lobes and the left lung has two lobes. Each of the bronchial tube which is an extension of bronchi. Lung tissue is spongy and porous. The lung tissue is thickly supplied with blood vessels.

Each lung is surrounded by a double serous membrane called pleura. Pleura composed of outer parietal and inner visceral layers. Between the pleural layers, there is a slight exudate which lubricates the surface and prevents friction between the lungs and the chest wall, during the respiratory movements.

Alveolar lining of the lungs is very thin. It is the main site for the exchange of gases, viz., oxygen and carbon dioxide.



(a) Trachea and Bronchi

(b) The Alveoli

Fig. 8.2

MECHANISM OF RESPIRATION

It is the process by which the lungs are expanded to take air in and then contract to expel it out. The cycle of respiration consists of three phases, viz., inspiration, expiration and pause. Per minute, sixteen to seventeen cycles of these phases occur in normal adults. The expansion of chest during inspiration occurs due to muscular activities of the respiratory muscles. This muscle activity is partly voluntary and partly involuntary. The main muscles of respiration, in normal quiet breathing, are intercostal muscles and diaphragm.

Physiology of Respiration : The process of respiration is divided into two parts, external respiration and internal respiration. During external respiration, air containing oxygen is taken in. It flows along the trachea and bronchial tubes to the alveoli, where it intimately comes into contact with the blood in the pulmonary capillaries. Through the alveolar-capillary membrane, oxygen passes across and is taken up by the haemoglobin of red blood cells. It is then carried to the heart, pumped in arteries for circulation to all parts of the body. Simultaneously, carbon dioxide, which is a waste product of metabolism, passes across the membrane of the blood capillaries to the alveoli. From alveoli, it passes through the bronchial tubes to the trachea and is breathed out through nose and mouth. The processes of taking

Human Anatomy and Physiology

i.e. inspiration centre in the brain present in blood with oxygen circulates from the oxygen i.e. carbon dioxide

Intercostal

which occupy the intercostal muscles extend downwards intercostal muscles of the shape of the thoracic cavity

Diaphragm

abdominal cavity lower ribs, vertebral central tendon contracts, its muscle enlarging the thoracic

The intercostal due to contraction in the lungs is respiration air into the lungs

During expiration into the place; the expiration, there is

Following are

Vital Capacity

most forcible inspiration Once the lungs are air that a person can as vital capacity

i.e. inspiration and throwing it out i.e. expiration are controlled by the respiratory centre in the brain. The centre is sensitive to the amount of oxygen and carbon dioxide present in blood. During internal respiration, the blood with its haemoglobin saturated with oxygen circulates throughout the body. Various tissues of the body take oxygen from the oxygen rich haemoglobin and the blood receives the waste product of oxidation i.e. carbon dioxide.

Intercostal Muscles : There are eleven pairs of muscles called intercostal muscles which occupy the space between the ribs. These are arranged in two layers, the external intercostal muscles extend downwards and forwards and internal intercostal muscles extend downwards and backwards. The first pair of ribs is fixed. Hence, when the intercostal muscles contract the other pairs of ribs are pulled towards first rib. Because of the shape of the ribs, they move outwards when they are pulled upwards. Because the thoracic cavity is enlarged anterior-posteriorly and laterally.

Diaphragm : It is a muscular flap which separates the thoracic cavity from the abdominal cavity. It consists of central tendon from which the muscle fibres radiate to lower ribs, vertebral column and xiphoid process. When the diaphragm is relaxed, the central tendon is at the level of the eighth thoracic vertebra. When the diaphragm contracts, its muscle fibres are shortened and the central tendon is pulled downwards, enlarging the thoracic capacity in length.

The intercostal muscles and the diaphragm contract and relax simultaneously. Thus due to contraction of respiratory muscles, the thoracic cavity is enlarged. The pressure in the lungs is reduced to a level lower than the atmospheric pressure which brings the air into the lungs to equalise the atmospheric and alveolar air pressure.

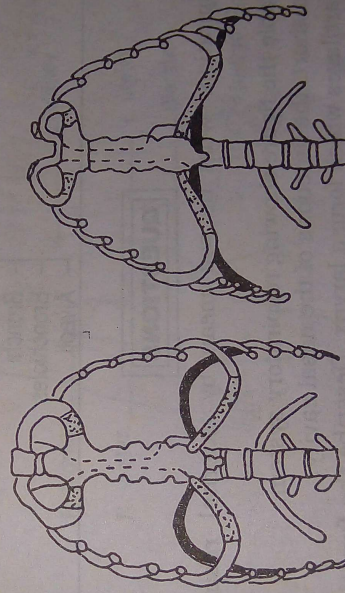


Fig. 8.3 : The Thoracic Cavity during Breathing

During expiration, the intercostal muscles and diaphragm relax; the ribs fall back into the place; the diaphragm ascends; the lungs contract and air is given out. After expiration, there is a small pause.

Following are some of the physiological values :

Vital Capacity : It is the volume of air that passes into and out of the lungs by the most forcible inspiration and expiration. The value of a normal human is 3 to 5 litres.

Once the lungs are filled with air, they are never completely emptied. The quantity of air that a person can expel by forcible expiration after the deepest inspiration is termed as vital capacity. There are several factors on which vital capacity of a man depend.

Anatomical build of a person, position of the person, the strength of respiratory muscles and the distensibility of the lungs are some of these factors. A tall, thin person has higher vital capacity than an obese person. A well developed man may have higher vital capacity. Factors like paralysis of respiratory muscles, pulmonary congestion reduce the vital capacity.

Tidal Volume : It is the amount of air which is inspired and expired in an ordinary quiet breathing. The normal value is about 500 ml.

Inspiratory Reserve Volume : It is the amount of air that can be breathed in above the tidal volume, by the deepest possible inspiration. It is estimated to be about 1800 to 2000 ml.

Expiratory Reserve Volume : It is the amount of air that can be breathed out after a quite expiration by the most forcible expiration. It is equal to about 1400 ml.

Residual Volume : It is the amount of air that remains in the lungs after the most powerful expiration. It is about 1200 to 1500 ml.

SUMMARY

The Respiratory System

- Nose
- Pharynx
- Larynx
- Trachea
- Bronchi
- Bronchioles
- Alveoli

QUESTIONS

1. Define respiration. What do you mean by external respiration and internal respiration?
2. Draw and label the figure showing respiratory system.
3. Describe, in short, the functions of the nasal cavity.
4. Name the cartilages which form a larynx. Describe the functions of the larynx.
5. What do you know about vocal cords?
6. Define and give normal values for vital capacity, tidal volume, inspiratory reserve volume, expiratory reserve volume and functional residual capacity.
7. What is the normal rate of respiration in adults? What are the normal changes during respiration?
8. What structural changes occur from trachea upto alveoli?
9. Explain how intercostal muscles and diaphragm help in the mechanism of respiration.
10. Describe, in short, the physiology of respiration.

INTRODUCTION

During the process of respiration, oxygen is taken up by the body tissues and carbon dioxide is released. The exchange of these gases is called external respiration. The exchange of gases between the blood and the body tissues is called internal respiration. The exchange of gases between the blood and the lungs is called pulmonary respiration.

(a) External respiration

(b) Internal respiration

(c) Pulmonary respiration

(d) Cellular respiration

The urinary system consists of the kidneys, ureters, bladder and urethra. The kidneys filter the blood and remove waste products from the body. The ureters carry the urine from the kidneys to the bladder. The bladder stores the urine until it is ready to be excreted from the body through the urethra.

Kidneys
the bladder

THE URINARY SYSTEM

INTRODUCTION

During normal metabolic reactions, certain waste products are produced in the tissue cells. These products enter the blood and are carried to the excretory organs for their excretion. Following are the main excretory organs in the human body :

- (a) **Kidneys** : They excrete water and soluble salts, resulting from metabolism of proteins, neutralization of acids etc. in the form of urine.
- (b) **Lungs** : They excrete carbon dioxide and water vapour.
- (c) **Skin** : It excretes water, carbon dioxide and salts in the form of sweat.
- (d) **Alimentary canal** : It excretes solids and secretes the material in the form of faeces.

The urinary system consists of the following structures : two kidneys; two ureters; one urinary bladder; and one urethra.

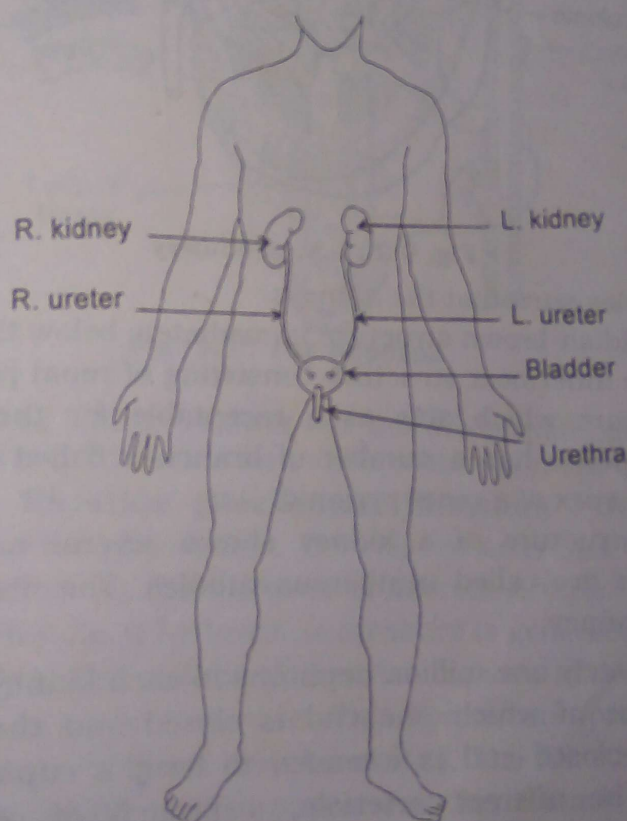


Fig. 9.1 : The Urinary System

Kidneys perform the function of forming urine which passes through the ureters to the bladder for excretion. This helps in maintaining the fluid and electrolyte balance

Henle and the distal convoluted tubule which leads into collecting tubule. The wall of glomerular capsule consists of single layer of flat epithelial cells. The remainder of the nephron and the collecting tubule are formed by a single layer of highly specialized cells. The function of nephron is to form urine.

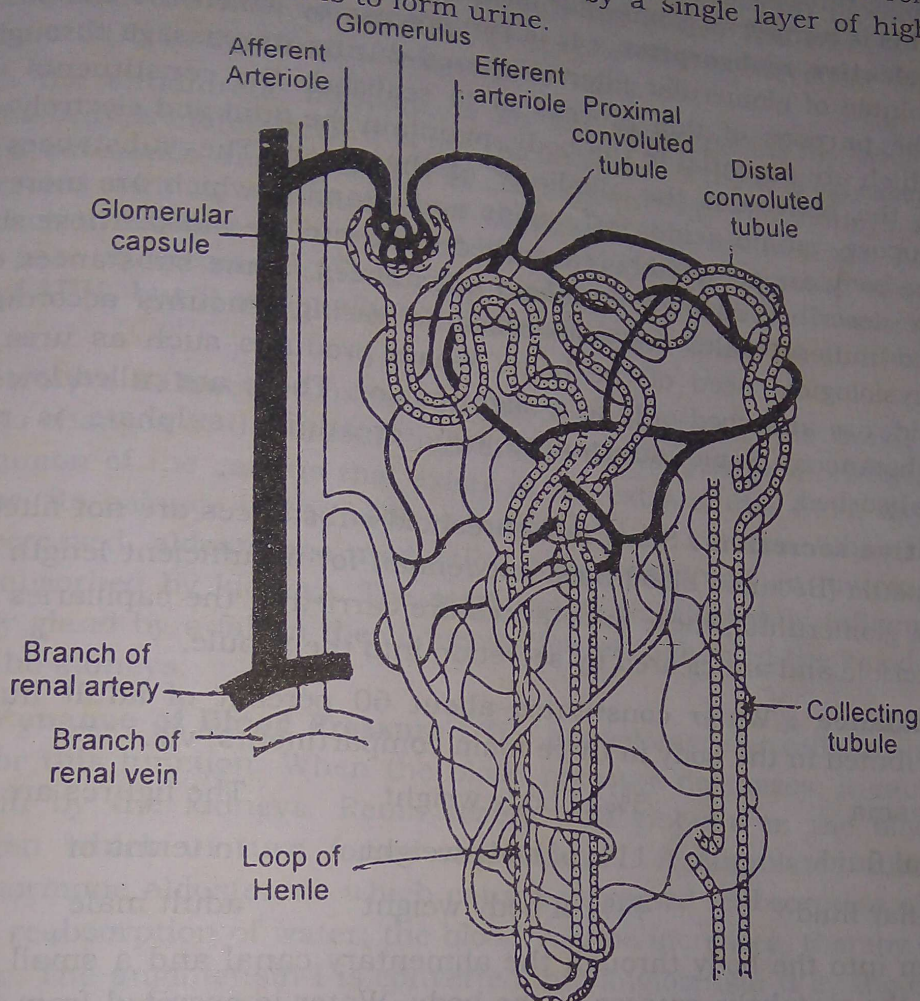


Fig. 9.3 : The Nephron

Functions of Kidneys :

(1) **Formation of Urine :** Kidneys filter out the waste material from the blood and secrete it in the form of urine. The urine formation occurs in three stages.

- (a) **Glomerular filtration (Mechanical filtration) :** The afferent arteriole carry blood to the glomerulus. The efferent arterioles carry the blood away from glomerulus. As the diameter of afferent arteriole is greater than that of efferent arteriole, a hydrostatic pressure is generated in the glomerulus (90 mm of Hg.). The wall of glomerular capsule acts as a filter and hence the filtration is under pressure. This hydrostatic pressure is opposed by osmotic pressure of blood (25 mm of Hg.). The filtrate exerts a pressure of 15 mm of Hg which is also opposite to hydrostatic pressure. Thus, the resultant filtration pressure is $90 - 25 - 15 = 50$ mm of Hg. Due to this pressure, the constituents of blood are filtered in the nephron. Filtration of constituents depends on their molecular weight. The high molecular weight constituents are not filtered. Except the blood cells and plasma proteins, all the constituents of blood are filtered.

Every minute, about 1 litre of blood containing 500 ml of plasma flows through all the glomeruli and about 100 ml (10%) of it is filtered. This is termed as glomerular filtration rate.

(b) **Selective reabsorption** : It is the process by which the composition of volume of glomerular filter is altered during its passage through tubules. The purpose of this process is to reabsorb the constituents of filtrate which are essential to the body, maintain the fluid and electrolyte balance of the body and the alkalinity of the blood. The substances such as glucose, amino acids, fatty acids and vitamins which are more useful to the body are completely reabsorbed back into the blood. These substances are described as high threshold substances. Some substances such as and mineral salts are reabsorbed in varying amounts according to physiological need of the body. Waste products such as urea and acid, are absorbed only to a slight extent. These are called low threshold substances. Some substances e.g., creatinine sulphate is not at all reabsorbed.

(c) **Active secretion** : Some non-threshold substances are not filtered by the capsule (Because blood does not remain for a sufficient length of time in the glomerulus); these substances are carried in the capillaries of efferent arteriole and are cleared by secretion into the tubule.

(2) **Water Balance** : Water constitutes about 60 percent of adult human body weight. It is distributed in the body in three main compartments, viz.

Blood plasma	5% of body weight	The figures are in terms of adult male
Interstitial fluid	11% of body weight	
Intracellular fluid	44% of body weight	

Water is taken into the body through the alimentary canal and a small quantity is also produced by the metabolic process in the body. Water is excreted from the body through the expired air, as a constituent of faeces, as sweat, through the skin and through the urine. The amount of water excreted in expired air and in faeces is fairly constant. Water excreted in the sweat is associated with the maintenance of body temperature. The balance between intake and output is maintained by the kidneys. Normally, water output is directly related to fluid intake. Water loss through kidneys is rigorously controlled and varies from 1000 to 1500 ml in 24 hours. This output is controlled by the antidiuretic hormone (ADH). This hormone is produced and released into the blood by the posterior lobe of pituitary gland. The osmotic pressure of blood is always maintained constant. Any increase or decrease in the intake of water, affects the osmotic pressure of blood.

If the osmotic pressure of the blood is raised, the osmoreceptors in the hypothalamus are stimulated. There is a close link between hypothalamus and posterior lobe of pituitary gland. The stimulation of osmoreceptors in hypothalamus results in increased output of ADH by the pituitary gland. Conversely, if osmotic pressure of blood is reduced, the release of ADH in the blood is reduced. The ADH acts on the distal tubules of the kidneys which increase the permeability of distal and collecting tubules. This

leads to an increase in reabsorption of water, resulting in a decrease in the concentration of dissolved substances in the blood. The main function of ADH is to reduce the concentration of ADH in the blood.

Although the antidiuretic hormone helps to maintain the balance of the body is maintained, any dissolved substance such as water is excreted with the urine. The amount of electrolytes in the urine for this purpose is increased. The production of ADH, but not its intake.

(3) **Electrolyte Balance** : The balance of electrolytes may be due to changes in the concentration of the most common of them. Sodium is the most common of them. Through urine, its balance is maintained. If sodium is decreased, aldosterone is released from the posterior lobe of pituitary gland by the posterior lobe of pituitary gland by the posterior lobe of pituitary gland produced in the kidneys.

(4) **Maintenance of Blood Pressure** : The maintenance of blood pressure is responsible for this function. The hormone renin by the kidneys converts angiotensinogen which is produced by the liver into angiotensin. Angiotensin is followed by reabsorption of water and electrolytes to increase blood pressure. The angiotensin II is produced in the lungs. Angiotensin-II is a powerful vasoconstrictor which increases the blood pressure is maintained.

Composition of Normal Urine

Water
Urea
Uric acid
Creatinine
Ammonia
Sodium
Potassium
Chlorides
Phosphates
Sulphates
Oxalates

Urine is amber in color. It has a strong action. A healthy adult

into increase in reabsorption of water from tubule into the circulating blood. Increase in the concentration of dissolved substances in the blood increases the production of ADH, resulting in reabsorption of water which dilutes the blood. The effect of diluting the blood is to reduce the amount of ADH produced. The cyclic effect maintains the concentration of ADH in the blood within narrow limits.

Although the antidiuretic hormone is an important means by which the water balance of the body is maintained, it is not the only one. If there is an excess amount of any dissolved substance in the blood it is excreted through the kidneys and excess of water is excreted with it; e.g. in case of untreated diabetes mellitus. Also, if excess amount of electrolytes have to be excreted from the body, the amount of water required for this purpose is increased. This may lead to dehydration, in spite of increased production of ADH, but it is usually accompanied by acute thirst and increased water intake.

(3) Electrolyte Balance : Changes in the concentration of electrolytes in the body may be due to changes in the amount of water or the amount of electrolytes. Sodium is the most common of the cations that exists in the extracellular fluid. As it is excreted through urine, its balance in the body is maintained by kidneys. When the amount of sodium is decreased, aldosterone production is increased and an increased amount of sodium is reabsorbed by kidneys. The secretion of aldosterone is influenced by ACTH from pituitary gland by a fall in the concentration of sodium in the blood and by renin produced in the kidneys.

(4) Maintenance of Blood Pressure : The juxtaglomerular cells in the kidneys are responsible for this function. When the blood pressure decreases, it causes release of hormone renin by the kidneys. Renin reacts with globulin in the blood and forms angiotensinogen which in turn forms angiotensin-I. It stimulates adrenal cortex to produce the hormone aldosterone which causes increased reabsorption of sodium. This is followed by reabsorption of water; the blood volume increases, thereby increasing the blood pressure. The angiotensin-I is converted into angiotensin-II by the enzymes in the lungs. Angiotensin-II is a powerful vasoconstrictor and increases blood pressure. Thus, the blood pressure is maintained.

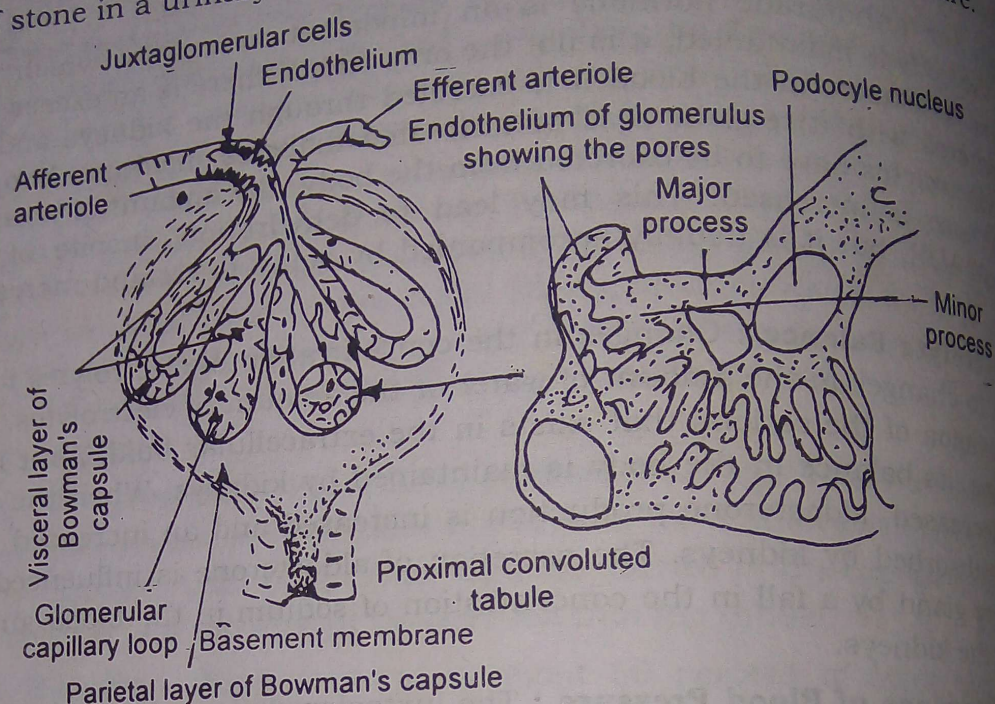
Composition of Normal Urine :

Water	96%
Urea	2%
Uric acid	
Creatinine	
Ammonia	
Sodium	
Potassium	2%
Chlorides	
Phosphates	
Sulphates	
Oxalates	

Urine is amber in colour. It has a specific gravity of 1.020 to 1.030 and is acidic in reaction. A healthy adult passes about 1000 to 1500 ml of urine per day.

Proteins, sugar, ketone bodies, bile and blood are the abnormal constituents occasionally found in urine. The presence of sugar in urine is called glycosuria, which occurs during diabetes.

Damage to the kidneys, impairing its functioning, is called renal failure. Infection or formation of stone in a urinary tract is also one of the causes for renal failure.



(a) L. S. of Glomerulus

(b) A Portion Magnified

Fig. 9.4

PATHOPHYSIOLOGY OF RENAL DISEASES

Glomerulonephritis is an inflammatory condition, possibly of allergic origin. Glomeruli are the main targets. Oedema may be present in both the acute and chronic stages of nephritis. This stage is called dry nephritis. The cause of oedema follows: Two, more or less equal but opposite, forces are always at work in the capillaries. (a) Blood pressure, which tries to force the fluid part of the blood through the vessel wall into the tissues. (b) The osmotic pressure of the blood proteins holds the fluid back with the vessels.

In nephritis, the blood proteins are seriously diminished because of albuminuria. This reduces the osmotic pressure. As a result, more fluid is forced through the vessel wall into the tissues resulting in oedema. If the site of damage is tubules, rather than glomeruli, it is called tubular nephrosis. It involves combination of albuminuria and massive oedema. Pyelonephritis involves inflammation of the kidney and the renal pelvis. The inflammation is primarily of the interstitial tissue. The cause is usually pyogenic bacteria, particularly *E. coli*, *Streptococci* and *Staphylococci*. It is one of the commonest forms of renal diseases. In chronic conditions, hypertension may develop. The hypertension caused by glomerulonephritis or pyelonephritis is called secondary hypertension.

A urinary calculus is a stone that is formed in the urinary tract. It may be formed either in the kidney or in the bladder. The symptoms include pain, the passage of blood through urine and is an evidence of renal failure.

OEDEMA

All the fluid that is exchanged between the plasma and the tissue fluid goes out into the tissue space by the plasma membrane. As to the fluid that goes into the capillaries, it is pulled back by the osmotic pressure of the blood proteins. If there is a disturbance in the balance of these forces, fluid enters the tissue space. This is called oedema.

- (1) E
- (2) D
- (3) B
- (4) D
- (5) A

The balance of these forces is maintained by drugs that

OEDEMA

All the cells in the body are bathed in the tissue fluid. It serves as a medium of exchange between blood plasma and the cells. The tissue fluid is derived from the plasma of the blood. As the walls of blood capillaries are thin, some of the fluid passes out into the space between the tissue cells. This occurs by means of diffusion and by capillary hydrostatic pressure. Another force, called protein osmotic pressure is formed by the plasma protein which acts as a pulling force of hold the fluid in the vessel as well as to attract fluid in. This opposite force prevents undue loss of fluid from the capillaries. As blood moves through the capillary network and some fluid is lost in the tissue space, the plasma protein concentration is slightly increased and hence the pulling force is increased. As a result, the water and crystalloids re-entering in the capillaries colloids with water and enter the lymph capillaries. Thus, normally there is a delicate balance between the fluid leaving and re-entering the capillaries. The disturbance in this balance causing decrease in fluid return in the capillaries results into the excess accumulation of tissue fluid called oedema. The oedema may arise from the following reasons –

- (1) Excessive mechanical hydrostatic pressure in the capillaries, if venous drainage is blocked;
- (2) Decrease in osmotic pressure due to insufficient plasma proteins;
- (3) Blockage of lymphatics;
- (4) Damage to the capillary walls so that plasma proteins leak out into tissue spaces and
- (5) An important factor causing oedema is the inability of kidneys to excrete sodium.

The basic treatment for oedema is the administration of diuretics, which are the drugs that increase the quantity of urine production.

SUMMARY**Excretory Organs and Excretory Products**

Kidneys
(Urine)

Respiratory System
(Carbon dioxide)

Skin
(Sweat)

Alimentary canal
(Faeces)

Urinary System :

- 2 Kidneys
- 2 Ureters
- 1 Urinary bladder
- 1 Urethra

Functions of Kidneys :

- (a) Urine formation
- (b) Water balance of body
- (c) Electrolyte balance of body
- (d) Long-term maintenance of blood pressure

Edema : Accumulation of tissue fluid.
Diuretics are used to treat oedema.

QUESTIONS

1. What are the excretory organs ? Mention the excretory products excreted by them.
2. Draw and label the figures -
(a) Urinary system, (b) L.S. of kidney and (c) Nephron.
3. Mention the functions of kidneys. Explain how kidneys help in water balance in the body.
4. Explain the meaning of oedema, nephritis, glycosuria and diuretics.
5. What is the composition of normal urine ? What amount of urine is produced per day ?
6. Define Glomerular Filtration Rate (GFR) and give its average value for a normal man.
7. Explain what is acute renal failure and name two of its common causes.
8. How kidneys help in maintaining electrolyte balance ?
9. Explain the role of kidneys in long term maintenance of blood pressure.
10. What are the components of blood that are liberated in glomerular filtration ? Do they all appear in urine ? If not, why ?
11. What do you mean by "juxtaglomerular apparatus" ? What is its primary function ?
12. What abnormal constituents may be found in urine ? Mention the diseases in which such constituents are found in urine.

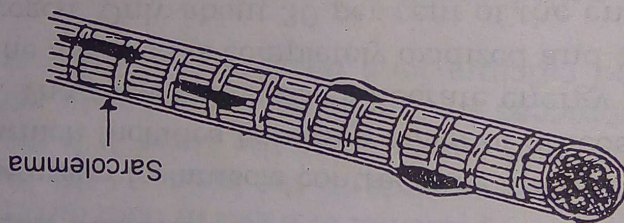
THE STRUCTURE

It consists of two cells, the parietal and the visceral, which are separated by a space called the peritoneal cavity. The parietal layer is continuous with the lining of the abdominal wall, while the visceral layer covers the surface of the organ. The space between them is filled with a lubricating fluid called peritoneal fluid.

SKELETAL MUSCLES

THE STRUCTURE OF SKELETAL MUSCLE

It consists of muscle cells which are elongated and are often tapering to the ends. These cells show several nuclei situated just under covering of the cell called sarcolemma. Such muscle cells are described as muscle fibres. The length of fibres varies from 10 to 40 millimeters. The muscle fibres lie parallel to one another and when viewed under microscope, they show well marked transverse dark and light bands, hence the name striated or striped muscle. Each muscle fibre is covered by a fibrous tissue called endomysium. Small bundles of fibres are enclosed in perimysium and the whole muscle in epimysium. The fibrous tissue enclosing the fibres,



(a) A Striated Muscle Fibre

(b) A Bundle of Striated Muscle Fibre and their Connective Tissue

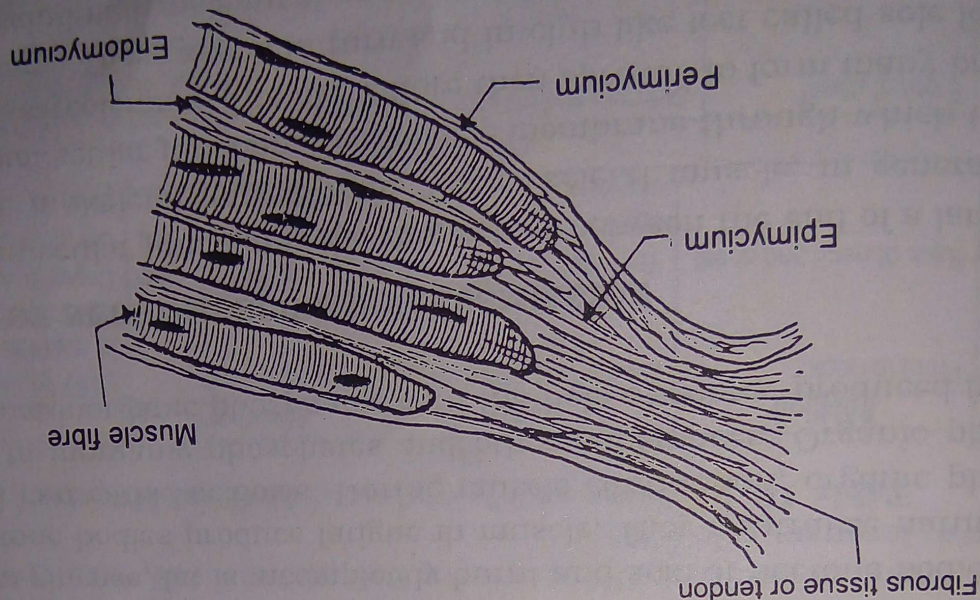


Fig. 10.1

(10.1)

Human And

the stimulus progressively decreases. Finally, if they are not contract by stimulus, such a condition is called muscle fatigue. The muscle fatigue is usually inadequate blood supply.

(2) **Muscle Tone** : Muscle is never relaxed. It is always in a state of partial contraction which is described as muscle tone. Muscle tone is a posture of the body. A degree of muscle tone is responsible for the contraction of cardiac muscles.

(3) **Muscle Fatigue** : If a muscle is frequently stimulated to contract, its stimulus progressively decreases. Finally, it may not contract by stimulus. Such a condition is called muscle fatigue. The muscle fatigue is usually due to inadequate blood supply.

the stimulus progressively decreases. Finally, if they are not contract by stimulus, such a condition is called muscle fatigue. The muscle fatigue is usually inadequate blood supply.

changes in the muscle which includes breaking down of glucose, glycogen and the result of their oxidation. The chemical changes liberate energy required for contraction. Only about one-fifth of the fuel food is completely oxidized and the remainder is stored in the form of glycogen. Only about 30 per cent of the energy produced in the muscle is available for the work of contraction. The remainder being released in the form of heat.

Glucose is a better fuel, because it is more easily burnt and burnt completely. There is lack of glucose, fat is incompletely burnt and acid or acetone bodies are produced. Acetone bodies produce fatigue in muscle. They neutralize natural alkali in blood and can cause acidosis. During muscle contraction, organic phosphates are taken down to inorganic phosphates and other substances. Organic phosphates are generated from inorganic phosphates with the help of energy produced from food.

PHYSIOLOGY OF NEUROMUSCULAR TRANSMISSION

PHYSIOLOGY OF NEUROMUSCULAR TRANSMISSION

The neuromuscular junction is the connection between the end of a large motor nerve fibre and a skeletal muscle fibre. Each skeletal muscle, in general, is innervated by one neuromuscular junction. The muscle membrane through which the nerve fibre enters is called sarcolemma. The nerve fibre then spreads to form many branches called axons. These axons in turn end in club like feet called sole feet. The sole foot, is a small space called the hypolemmal axons and the sole foot is called end plate. The space between the sole foot and the muscle fibre membrane is called synaptic cleft. The synaptic cleft below which there are many folds called acetylcholine which is responsible for stimulating the muscle fibre.

Trapezius
Pectoralis m
Latissimus m
Serratus ma

Name
Sternomastoid
Trapezius
Pectoralis m
Latissimus d
Serratus ma

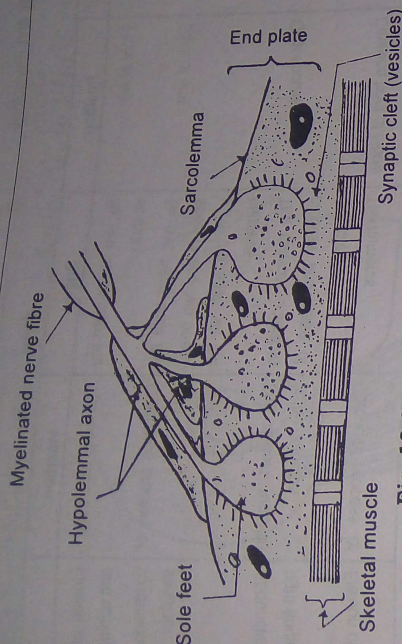


Fig. 10.2 : Neuromuscular Junction

When a nerve impulse reaches neuromuscular junction, passage of the action potential over the sole feet causes many of the small vesicles of acetylcholine to rupture into the synaptic cleft. The acetylcholine acts on the plasma membrane to increase its permeability. This in turn allows spontaneous leakage of sodium causing end plate potential. When the end plate potential becomes great enough, it stimulates the entire muscle fibre causing an action potential to travel in both directions along the fibre.

When the action potential spreads to the inside of the muscle fibre, then calcium ions are released into the fluid surrounding the fibres. It is the presence of calcium ions that elicits contractile process in the fibres. Immediately after the action potential is over, previously released calcium ions recombine with the reticulum and the muscle contraction ceases.

There is an enzyme called acetylcholinesterase which is responsible for splitting of acetylcholine. The enzyme is present in synaptic cleft. Because of immediate hydrolysis of acetylcholine, the membrane is repolarized again to receive successive stimuli. Acetylcholine provides an amplifying system that allows a very weak nerve impulse to stimulate a very large muscle fibre.

Table 10.1 : Name and Location of Skeletal Muscles

Neck				
Name	Position	Origin	Insertion	Action
Sternomastoid	Front to neck	Sternum and clavicle	Mastoid process	Used separately, turn the head to opposite side; used together, flex the neck
Trapezius	Back of neck and chest	The occiput and the spines of the dorsal vertebra	The spine of the scapula and the clavicle	Draws the scapula back, raises the shoulder, pull on the occiput extending the neck
Shoulder				
Pectoralis major	Front of chest	Sternum and clavicle	Humerus	Adduction of the shoulder drawing the arm across front of thorax, internal rotation of shoulder
Latisimus dorsi	Lumbar to shoulder region	Lumbar vertebrae, sacrum and back of iliac crest	Humerus	Adduction of the shoulder drawing the arm backwards and downwards internal rotation of the shoulder
Serratus magnus	Sides of thorax under scapula	The ribs in the front of the thorax	Vertebral border of scapula	Draws the scapula forward, antagonistic to the trapezius.

Arm

Name	Position	Origin	Insertion	Action
Biceps	Front of arm	By two heads from the scapula	The radial tuberosity	Flexion of elbow and supination of forearm
Triceps	Back of arm	By one head from the scapula and two heads from the shaft of the humerus	Olecranon process of ulna	Extension of elbow
Deltoid	Over shoulder	The clavicle, acromion process and spine of the scapula	The deltoid tubercle of the humerus	Abduction of the arm at right angle
Brachialis	Crossing front of elbow	The humerus	Coronoid process of ulna	Flexion of elbow

Trunk Muscles Moving the Hip

Psoas	Crosses front of groin	Bodies of lumbar vertebrae	The lesser trochanters	Flexes the hip and laterally rotates it
Iliacus	Crosses the groin with psoas	Front surface of the iliac bone	The lesser trochanter	Similar to psoas
Gluteal muscles	Crosses back of hip forming buttocks	Back surface of iliacus and sacrum	The greater trochanter and gluteal line of femur	Extend, abduct and rotate the hip

Muscles of The Thigh

Quadriceps extensor	Front of thigh	Iliacus and femur	Patella	Extension of knee and hip
Hamstrings	Back of thigh	Isochial tuberosity and femur	Tibia and fibula at either side of popliteal space	Flexion of knee and of hip

Name	Position	Origin	Insertion	Action
Sartorius	Crosses front of thigh	Anterior superior iliac spine	Tibia at inner side below knee	Flexion of hip and abduction and extension of hip
Adductor of hip	Inner side of thigh	Pubis and ischium	Femur and medial epicondyle	Adducts the hip

Muscles of Leg

Gastrocnemius	Back of calf	Epicondyles of femur	Calcaneus	Plantar flexion of the heel
Goleus	Front of calf	Tibia and fibula	Calcaneus	Plantar flexion of the heel
Tibialis anterior	Front of leg	Tibia	Tarsus and metatarsus	Dorsiflexion of the foot

The main muscles of body are shown in the following Fig. 10.3, 10.4, 10.5, 10.6 and 10.7.

Skeletal Muscles

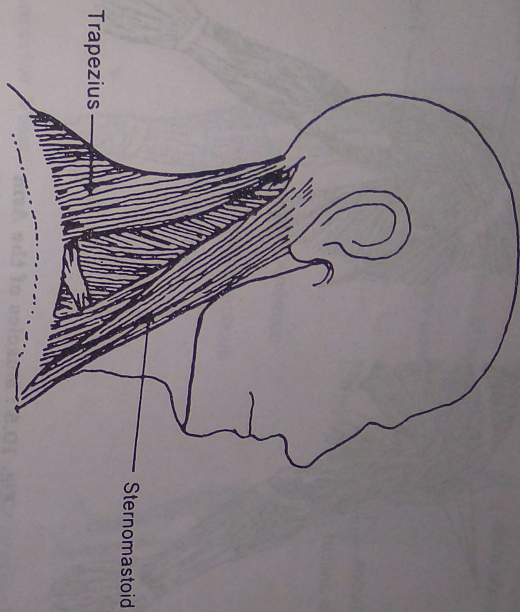


Fig. 10.3 : Muscles of the Neck

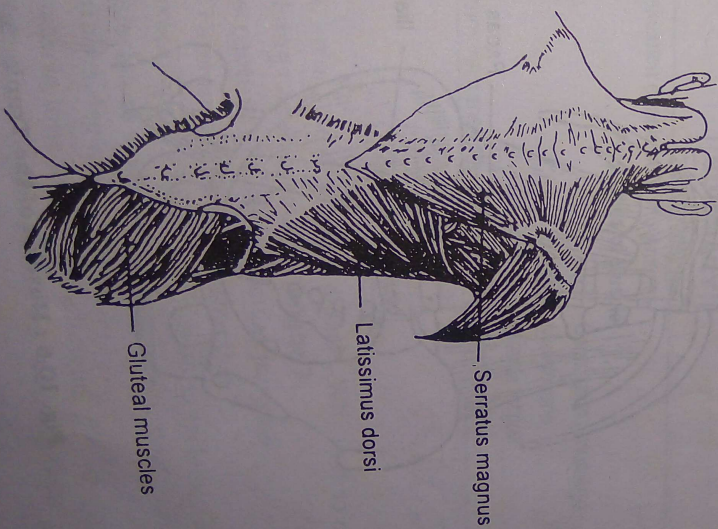


Fig. 10.4 : Muscles of the Shoulder

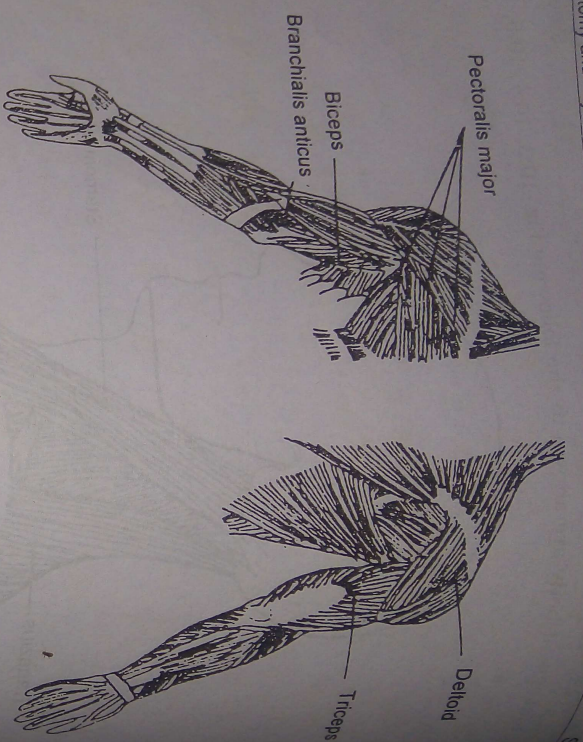


Fig. 10.5 : Muscles of the Arm

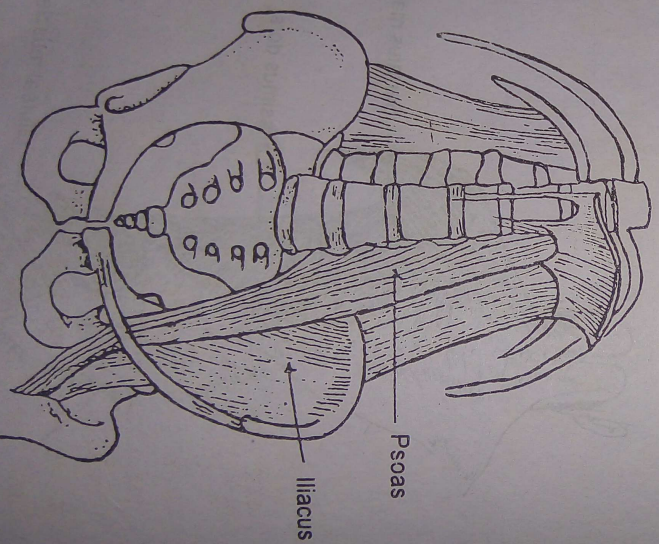
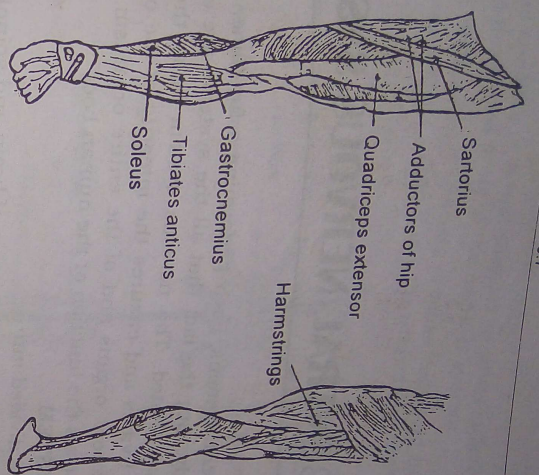


Fig. 10.6 : Muscles of the Trunk

Skeletal muscle

Acetylcholine at

1. Draw a
2. What is
3. Descri
4. What is
5. Discus
6. Name t
7. forearn
8. Descri
- What is



(a) Anterior View

(b) Posterior View

Fig. 10.7 : Muscles of the Thigh and Leg

SUMMARY

Skeletal muscles attached to skeleton enable body movements.

Properties of Muscle

- (a) Contraction (irritability)
- (b) Muscle tone
- (c) Muscle fatigue

Acetylcholine acts as a neurohumoral transmitter at Skeletal myoneural junction.

QUESTIONS

1. Draw and label the structure of skeletal muscle. Why is it so called ?
2. What is the underlying cause of muscle fatigue ?
3. Describe the ultrastructure of neuromuscular junction.
4. What is the role of calcium in muscle contraction ?
5. Discuss and give examples of energy sources for muscle activity.
6. Name the main muscles of back, chest, abdomen, neck, shoulder, upper arm, forearm, thigh, buttocks, leg and pelvic floor.
7. Describe in short muscle tone and muscle fatigue.
8. What is muscle ? Name the types of muscles; mention their properties.

THE CENTRAL NERVOUS SYSTEM

INTRODUCTION

It is true that different systems, each performing a fundamental function, constitute a human body. But the fact that all the systems are entirely dependent on each other must be appreciated. The nervous system links these various co-ordinates all their activities and ensures the integrity of the organism. It is the activities of the different organs and of the entire organism. In conjunction with the endocrine system, it controls the function of the human body.

CENTRAL NERVOUS SYSTEM

The nervous system is divided into -

- (1) The Central Nervous System consisting of brain and spinal cord, and
- (2) The Peripheral Nervous System consisting of :
 - (a) 31 pairs of spinal nerves arising from spinal cord,
 - (b) 12 pairs of cranial nerves arising from brain and
 - (c) The autonomic nervous system which is divided into :
 - (i) Sympathetic nervous system,
 - (ii) Parasympathetic nervous system.

The Central Nervous System (CNS) and the Autonomic Nervous System (ANS) are distinguished as follows :

Central Nervous System CNS	Autonomic Nervous System ANS
(1) It is related with sensory and motor activity.	(1) It is related with the activity of heart, various glands and the muscles.
(2) It enables a person to adjust with external environment.	(2) It enables the person to adjust with internal environment.
(3) The functions of CNS occur according to the will power of the person.	(3) The functions of ANS do not occur according to the will power of person.
(4) It supplies nerves to skeletal muscles (motor nerves) and sensory nerves carry impulses from sense organs to brain.	(4) It supplies nerves to smooth muscles of visceral organs e.g. ureters, tubes, bronchi, trachea etc. and glands.

Human Anatomy and Physiology
The nervous system consists of the brain, spinal cord and nerves. The parts of the nervous system are the structure of the brain, spinal cord and nerves. The parts of the nervous system are the structure of the brain, spinal cord and nerves.

Nerve Cell
The nerve cell consists of a cell body (soma) and a long process called the axon. The axon is covered by a sheath of fat called the myelin sheath. The myelin sheath is made up of a substance called the myelin. The myelin is made up of a substance called the myelin. The myelin is made up of a substance called the myelin.

The nervous tissue consists of a vast number of units called neurons. The neurons are the structural and functional units of the nervous system.

Parts of Neuron : Each neuron consists of nerve cells and its processes called axon and dendrites. The processes are nothing but the projections of the cytoplasm.

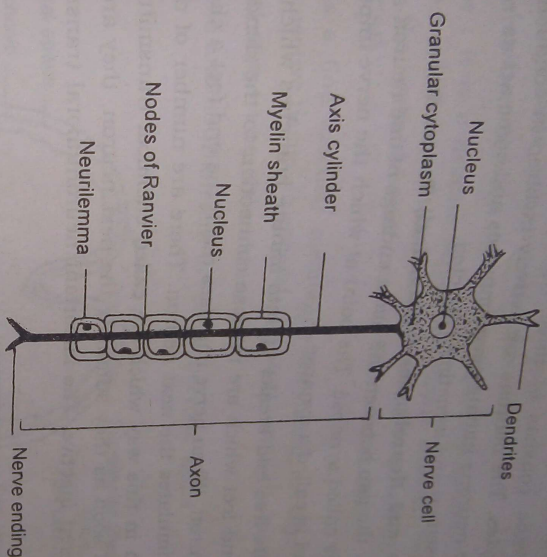


Fig. 11.1 : Parts of Neuron

Nerve Cell : It varies in size and cannot be seen with a naked eye. A nerve cell consists of a central large nucleus and cytoplasm containing granules. Granules are made up of a chemical transmitter which transmits the impulse. They form the grey matter of the nervous system and are found at the periphery of the brain, centre of the spinal cord, in groups called ganglia outside the brain and spinal cord, and as a single cell in the wall of organs.

Axon : It is called nerve fibre. It has a central long axis. Axon is covered with a sheath of fatty material myelin or medullary sheath. The axon which is not covered with myelin, is called non-myelinated nerve fibre. Myelin is a deposition of fat covered with neurilemma. It :

- (1) Acts as an insulator,
- (2) Protects the axon from pressure of injury, and
- (3) Speeds up the flow of nerve impulses through the axon. The myelin sheath is absent at intervals along the length of the axon and near its branching end. The breaks in the myelin sheath are called the nodes of Ranvier and their presence contributes to the rapid transmission of nerve impulses along myelinated fibres.

The axon carries nerve impulses away from the cell and are usually longer than dendrites.

Dendrites : They are nerve fibres which carry impulses towards nerve cell body. They have the same structure as that of axon, but they are usually shorter. Each neuron has many dendrites.

All the neurons are held together by a connective tissue in the nervous system called neuroglia. Neuroglia consists of three types of cells (1) Astrocytes, (2) Oligodendrocytes, (3) Ependymocytes. The neurons are actively involved in conducting nerve impulses. The cells of some neurons initiate nerve impulses and some act as 'relay stations' where impulses are passed on and sometimes directed.

The Synapse and Neurohumoral (Chemical) Transmitters : When a chain of neurons, the gap between the nerve endings of one neuron and the dendrite of the next neuron is called synapse. The point at which the nerve impulses pass from one neuron to another end is called a synapse.

The axon, at its free end breaks up into minute branches which terminate in swellings called end feet which are in close connection to the dendrites and the cell of the next neuron. When nerve impulses reach the end feet a chemical substance is released which stimulates the next neuron. There are number of different substances known to function in this way which are called chemical transmitters. They are short lived and as soon as they stimulate the next neuron, they are neutralized by an enzyme and rendered inactive. The important neurohumoral transmitters or neurotransmitters are :

- (1) Acetylcholine,
- (2) Adrenaline,
- (3) Noradrenaline.

Since, they transmit nerve impulses, they are called transmitters.

Central Nervous System : The central nervous system consists of brain and spinal cord. The brain is the cranial cavity and the spinal cord present in the vertebral column.

Brain : The peripheral part of brain is made of grey matter and the medulla is made of white matter. The brain and the spinal cord are completely surrounded by three meninges or membranes which lie between the skull and the brain. They are named as :

- (1) The Dura mater,
- (2) The Arachnoid mater,
- (3) The Pia mater.

The dura mater and the arachnoid mater are separated by a space called subdural space. The arachnoid and the pia mater are separated by a space called subarachnoid space which contains Cerebro Spinal Fluid (CSF).

Dura mater

It is the outermost membrane which covers the brain and spinal cord. It is made of two layers, the outer layer is called the dura mater and the inner layer is called the arachnoid mater.

- (a) Cerebrum
- (b) Cerebellum
- (c) Brainstem
- (d) Spinal cord

Arachnoid

It is the middle layer of the meninges. It is made of two layers, the outer layer is called the arachnoid mater and the inner layer is called the pia mater.

Pia mater

It is the innermost layer of the meninges. It is made of two layers, the outer layer is called the pia mater and the inner layer is called the arachnoid mater.

- (1) To protect the brain
- (2) To support the brain

The Ventricles

The ventricles are the fluid-filled cavities in the brain. They are named as follows :

- (1) Right ventricle
- (2) Left ventricle
- (3) The Foramen of Monro

Dura mater : It is the fibrous covering over the brain and spinal cord. It has two membranes which are in close contact with each other, except at the four different places where they are seen to be separated from each other. The four places are :

- (a) Cerebral hemisphere to form falx cerebri.
- (b) Cerebellar hemisphere to form falx cerebelli.
- (c) Cerebrum and cerebellum to form tentorium cerebelli.
- (d) Behind the cerebellum between the two cerebellar hemisphere.

Arachnoid mater : It is a delicate serous membrane situated between the dura mater and the pia mater. It is separated from dura mater by subdural space and from the pia mater by the subarachnoid space. The subarachnoid space contains cerebrospinal fluid (CSF).

Pia mater : It is a fine vascular membrane consisting mainly of blood vessels supported by fine connective tissue. In general, the functions of the meninges are :

- (1) To protect and support nervous tissue, and
- (2) To supply blood and nourishment to central nervous tissue.

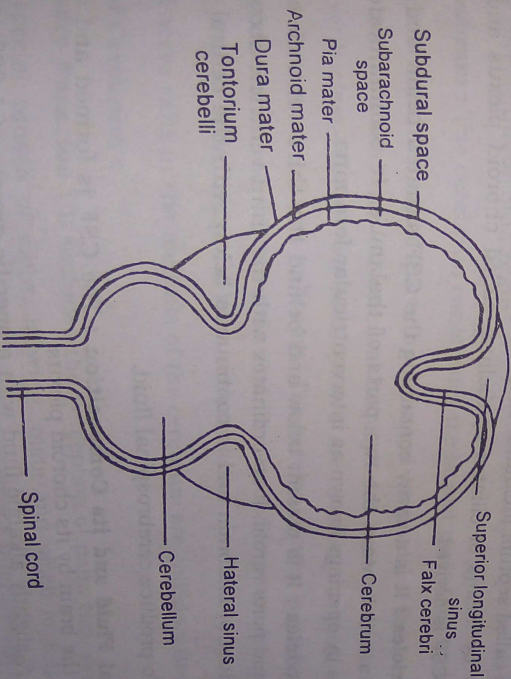


Fig. 11.2 : The Meninges

The Ventricles of the Brain and the CSF : Within the brain there are four irregular shaped cavities or ventricles containing CSF (Cerebrospinal fluid). The four ventricles are :

- (1) Right and Left Lateral Ventricles.
- (2) The Third Ventricle.
- (3) The Fourth Ventricle.

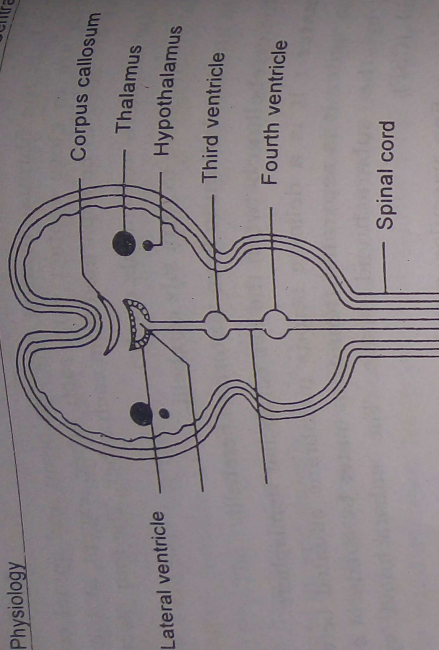


Fig. 11.3 : The Ventricles of the Brain

Lateral Ventricles : They lie within the cerebral hemispheres (cerebrum is divided into two equal hemispheres by central longitudinal fissures) one on either side of median plane just below the corpus callosum. They are separated from each other by a thin membrane called septum lucidum. They show presence of blood capillaries and are lined internally by means of ciliated epithelium called choroid plexus and from choroid plexus CSF is derived.

Third Ventricles : It is a cavity containing the CSF situated below and behind the lateral ventricles and between the two parts of thalamus. It communicates with lateral ventricles by openings known as interventricular foramina.

Fourth Ventricles : It is present below and behind the third ventricle and between the cerebellum and pons varolii. It co-ordinates with the third ventricle above by a narrow opening known as aqueduct of midbrain and is continuous below with the central canal of spinal cord.

Function : To produce cerebrospinal fluid.

Cerebrospinal Fluid and its Composition : The CSF is formed and secreted into each ventricle of the brain by its choroid plexus.

CSF is a clear, slightly alkaline fluid with a specific gravity of 1.005 and consists of water, amino acids, glucose, mineral salts, and urea, creatinin in small amounts. The normal hydrostatic pressure of CSF is about 130 mm of water (10 mm of Hg).

From the roof of fourth ventricle, the CSF flows through the two foramina (medial and lateral foramina) into the subarachnoid space and completely surrounds the brain and the spinal cord. It also flows from the floor of fourth ventricle downwards through the central canal of the spinal cord. The CSF is reabsorbed into the capillaries in the arachnoid mater and in this way is returned to the circulating blood.

Functions of Cerebrum

- (1) It supplies oxygen and nutrients to the brain.
- (2) It maintains the body temperature.
- (3) It acts as a control centre for the body.
- (4) It keeps the body in a state of alertness.

Brain :

The brain is the central part of the nervous system. It is the control centre of the body.

The brain is divided into three main parts:

- (1) Cerebrum
- (2) The cerebellum
- (3) The brainstem
- (4) The spinal cord
- (5) The meninges

1. Cerebrum

It is the largest part of the brain. It is divided into two halves called hemispheres. Each hemisphere is further divided into four lobes: frontal lobe, parietal lobe, temporal lobe, and occipital lobe.

Group of

Functions of Cerebrum

- (1) Sensory functions: The cerebrum receives and interprets sensory information from the body and the environment.
- (2) Motor functions: The cerebrum controls voluntary movements of the body.
- (3) Association functions: The cerebrum is involved in higher mental functions such as learning, memory, and reasoning.

Functions of CSF :

- (1) It supports and protects the delicate structures of brain and spinal cord.
- (2) It maintains uniform pressure around these delicate structures.
- (3) It acts as a cushion and shock absorber for the brain and spinal cord.
- (4) It keeps the brain and spinal cord moist as there may be an interchange of substances between the fluid and nerve cells.

Brain :

The brain constitutes about $1/50^{\text{th}}$ of the body weight and lies within the cranial cavity. The brain is formed of :

- (1) Cerebrum or forebrain.
- (2) The midbrain.
- (3) The pons varolii.
- (4) The medulla oblongata.
- (5) The cerebellum or hind brain.

1. **Cerebrum** : The cerebrum constitutes the largest part of the brain.

It is divided into two equal parts by a central longitudinal fissure. The two parts formed are the right and the left cerebral hemispheres (each of which contains one of the lateral ventricles). These two hemispheres are internally connected by a mass of white matter known as corpus callosum. The cerebral cortex is made of grey matter. Each hemisphere of the cerebrum is divided for descriptive purposes into lobes called : frontal lobe, parietal lobe, temporal lobe, occipital lobe.

Group of nerve cells in the medulla of the cerebrum are called as Ganglia.

Functions of Cerebrum :

- (1) **Sensory Function** : It includes the perception of pain, temperature, touch and the special senses of sight, hearing, taste and smell impulses from sensory organs. They are carried to the cerebrum where interpretation of senses takes place and response is given accordingly.
- (2) **Motor Function** : It is associated with initiation and control of voluntary muscle contraction.
- (3) **Association** : It includes all mental activities like memory, intelligence, sense of responsibility, reasoning, moral sense and learning are attributed to the higher centres.

Parts of Central Nervous System :

The Central Nervous System

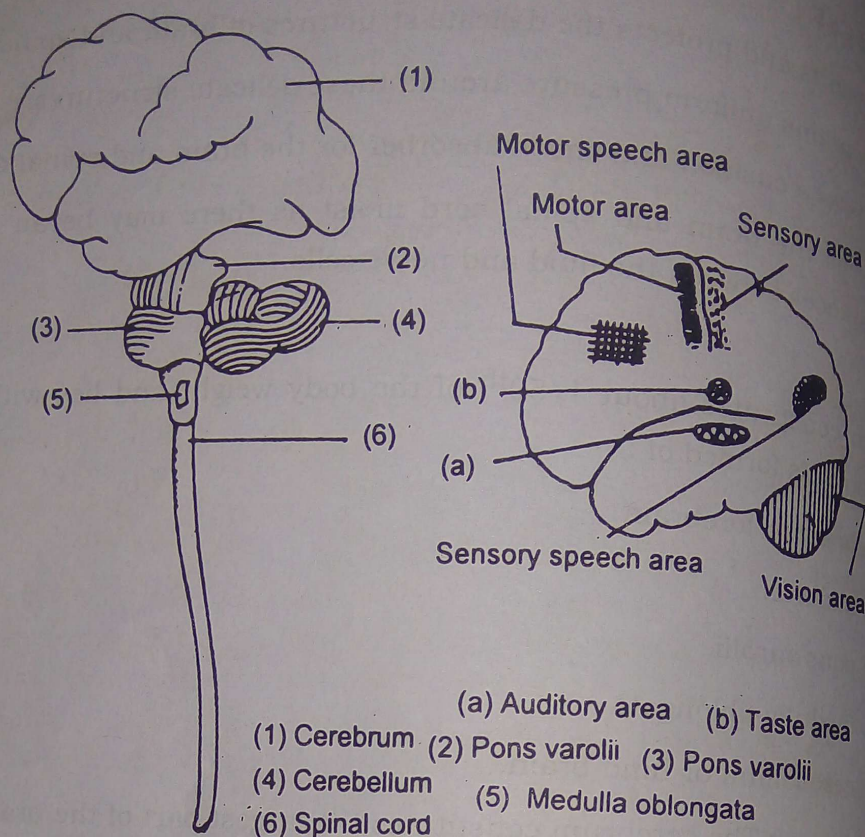


Fig. 11.4 : Lateral View of Cerebrum showing Functional Areas

2. Midbrain : It is the connection between cerebrum and other parts of nervous system. The nerve cells act as relay stations for the ascending and descending nerve fibres.

3. Pons Varolii : It is present in front of cerebellum and below the midbrain above the medulla oblongata. The pons varolii act as a relay station for the ascending and descending nerve impulses.

4. Medulla Oblongata : It is an important part of the brain because all the vital centres of the body are present in the medulla oblongata. The vital centres are :

- (1) The cardiac centre.
- (2) The respiratory centre.
- (3) The vasomotor centre.
- (4) Reflex centres of vomiting, coughing, sneezing, swallowing.

Functions :

- (a) The cardiac centre controls the rate and force of cardiac contraction. When impulses are carried from cardiac centre to heart, the heart activity increases and maintains contractility.

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(b) The respiratory centre, nerve impulses stimulate contraction of diaphragm for inspiration.

(c) The vasomotor centre impulses reach the blood vessels. Stimulation may cause constriction or dilation.

(d) Reflex centres protect the body. Deep within the cerebral hemispheres are 'ganglia' which act as relay stations.

(1) Basal ganglia.

(2) Thalamus.

(3) Hypothalamus.

(1) Basal Ganglia : It is located in the cerebrum. It influences the tone of the muscles.

(2) Thalamus : Thalamus is located in the cerebral hemispheres just below the cerebrum. It is the periphery of the body association. All sensory impulses are conveyed to the thalamus. The thalamus is unable to interpret all the senses.

(3) Hypothalamus : It is located in the third ventricle. Hypothalamus controls the activities of the endocrine system.

(a) Hypothalamus controls the pituitary gland.

(b) It shows the part of the nervous system which controls the activities of the endocrine system.

Reticular Formation : Located in the brain stem, there are a number of nuclei which play the following roles :

- (1) It helps in the co-ordination of motor movement and posture.
- (2) It is involved in the regulation of the nervous system such as sleep and wakefulness.
- (3) It is related with the emotional and motivational activities.

5. Cerebellum : It is located in the posterior portion of the cerebrum.

(a) It maintains muscle tone and posture.

(b) It controls and co-ordinates precise actions.

(c) It co-ordinates activities and maintains equilibrium of the body.

- (b) The respiratory centre controls the rate and depth of respiration. From this centre, nerve impulses pass to the phrenic and intercostal nerves which stimulate contraction of the diaphragm and intercostal muscles, thus initiating inspiration.
- (c) The vasomotor centre control the calibre of the blood vessels. Vasomotor impulses reach the blood vessels through the autonomic nervous system. Stimulation may cause either contraction / or dilation of blood vessels.
- (d) Reflex centres protect the body from uneven situations.

Deep within the cerebral hemisphere, there are masses of nerve cells known as 'ganglia' which act as relay stations. Important masses of grey matter include :

- (1) Basal ganglia.
- (2) Thalamus.
- (3) Hypothalamus.

(1) **Basal Ganglia** : It is a group of nerve cells present in the medulla of the cerebrum. It influences the tone of skeletal muscles.

(2) **Thalamus** : Thalamus consists of a mass of nerve cells situated within the cerebral hemispheres just below the corpus callosum. All sensory nerves from the periphery of the body associated with the impulses of pain, temperature, pressure and touch are conveyed to the thalamus and from there to the sensory part of the cerebrum. The thalamus is unable to distinguish crude sensations. Except the sensation of vision, it interprets all the senses.

(3) **Hypothalamus** : It is situated below and in front of the thalamus at the level of the third ventricle. Hypothalamus performs the following functions :

- (a) Hypothalamus regulates and controls the release of hormones from pituitary gland.
- (b) It shows the presence of centres controlling the activity of autonomic nervous system. The autonomic centre present in the hypothalamus controls the activity of autonomic nervous system.

Reticular Formation : It contains a large number of nerve cells and nerve fibres. In the brain stem, there are collection of neurons referred to as the reticular formation. It plays the following roles :

- (1) It helps in the co-ordination of skeletal muscle activity which involves voluntary motor movement and maintenance of balance.
- (2) It is involved in the regulation of the activities controlled by the autonomic nervous system such as cardiovascular, respiratory etc.
- (3) It is related with the sleep and wakefulness of a person.

5. **Cerebellum** : It is situated behind pons varolii and immediately below the posterior portion of cerebrum. It performs the following functions :

- (a) It maintains muscle tone.
- (b) It controls and co-ordinates the movements of muscles ensuring smooth, even and precise actions.
- (c) It co-ordinates activities associated with the maintenance of balance and equilibrium of the body.

Spinal Cord : It is an elongated and almost cylindrical part of the central nervous system. It is situated in the neural canal of vertebral column and extends from the base of the medulla oblongata to the first lumbar vertebra below. It continues with the medulla oblongata above to the first lumbar vertebra below. It is about the thickness of little finger. It is about 45 cm long and is about the thickness of little finger. It is surrounded by dura, arachnoid and pia mater. CSF is present in the central canal of the spinal cord and in the subarachnoid space.

The spinal cord is a link of nervous tissue between brain and other organs of the body. The nerves conveying impulses from and to the organs enter and leave the spinal cord at the appropriate level and convey the impulses. Thirty one pairs of nerves arise from the spinal cord which are known as spinal nerves. Each nerve has a posterior root and an anterior nerve root. Many nerves arise at the level of second lumbar vertebra and extend downwards and enter the vertebral column. They look like a horse tail and are called cauda equina. These nerves leave the neural canal at the appropriate level.

The transverse section of the spinal cord shows that it is composed of grey matter in the centre, surrounded by white matter. The grey matter is arranged in the shape of the letter 'H' showing anterior and posterior horns of grey matter. In the centre, there is a canal called central canal which contains cerebrospinal fluid. The grey matter of the spinal cord contains nerve cells which link the sensory and motor neurons in the form of reflex arc.

Posterior Horns of Grey Matter : It is composed of nerve cells which are stimulated by sensory nerve impulses from periphery of the body. The nerve fibres of these cells contribute to form white matter, transmit the impulses to the brain.

The white matter is arranged in the following three bands :

- (1) Lateral band,
- (2) Anterior band, and
- (3) Posterior band.

T. S. of Spinal Cord :

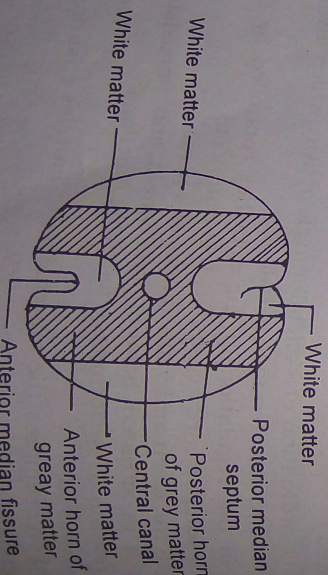


Fig. 11.5 : T. S. of Spinal Cord

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Functions :

- (1) It is the main pathway for the transmission of nerve impulses.
- (2) Reflex actions are protected by the spinal cord. The action can be carried out without the need for movement of the body. This is necessary for a simple reflex.
- (a) A sensory ganglion is a cluster of nerve cells in the spinal cord.
- (b) A connective tissue spinal cord.
- (c) A motor nerve of grey matter terminates in the muscles.

The important functions of the spinal cord are :

- (1) The quick response to touch it.
- (2) The sudden response to pain.
- (3) The quick response to light.
- (4) A sudden response to sound.

In the infants, the spinal cord grows older, and these acts become more complex.

protection:

- (1) It is the means of connection between the peripheral organs and the brain.
- (2) **Reflex action** : It is the automatic motor response given by the brain. sensory stimulus without involving brain in action. Most of the reflex actions are protective in nature. Reflex actions are the part of defense mechanism of the body. These actions occur very rapidly than the voluntary actions. The reflex action can be inhibited by the voluntary control. Many of such actions occur without consideration on the part of the individual consciousness e.g. the movement of the stomach, small intestine, etc. Formation of complete reflex arc is necessary for the reflex actions to occur.

A simple reflex arc has the following components :

- (a) A sensory neuron in the sensory organ, the sensory nerve, posterior root ganglion and its nerve fibre which passes to a posterior horn of grey matter in the spinal cord.
- (b) A connector neuron which consists of a nerve cell, its dendrites and axon in the spinal cord.
- (c) A motor neuron consisting of a nerve cell and its dendrites in the anterior horn of grey matter, the axon of this nerve cell and the motor end plates which terminate in muscle.

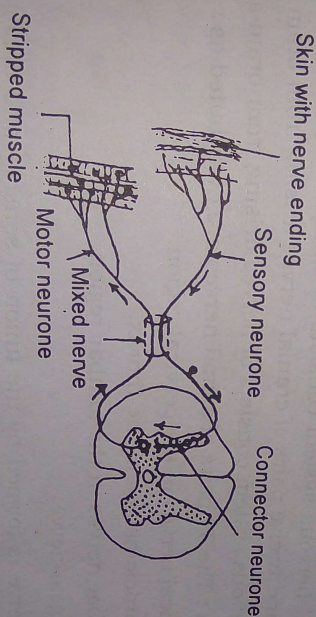


Fig. 11.6 : The Reflex Arc

The important reflex actions are :

- (1) The quick closing of an eyelid if the eye is touched or when something threatens to touch it.
 - (2) The sudden withdrawal of the hand if the fingers touch something hot.
 - (3) The quick recovery of the balance of the body to prevent falling after a slip.
 - (4) A sudden coughing attack, if a crumb is inhaled.
- In the infants, the act of micturition and defaecation is carried out reflexly. As the child grows older, the sensory nerve tracts of the spinal cord become fully developed and these acts become conscious voluntary acts.

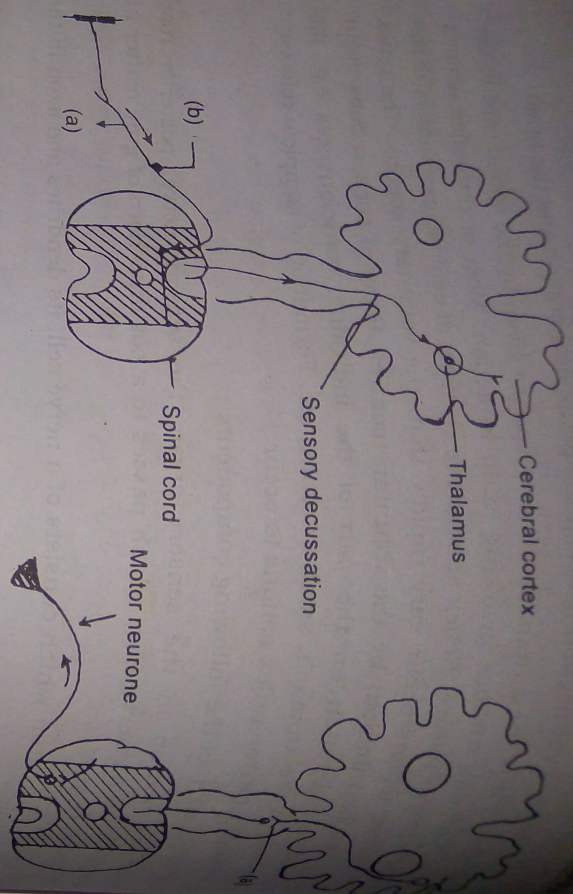


Fig. 11.7 : Sensory (Ascending) Nerve Tract

Fig. 11.8 : Motor (Descending) Nerve Tract

PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system consists of thirty one pairs of spinal nerves from spinal cord and twelve pairs of cranial nerves arising from brain. Autonomic nervous system consists of nerves arising from brain and spinal cord.

Spinal Nerves : The 31 pairs of spinal nerves are distributed as :

- 8 pairs of cervical nerves in the cervical region.
- 12 pairs of thoracic nerves in the thorax.
- 5 pairs of lumbar nerves in the lumbar region.
- 1 pair of coccygeal nerve.

Each spinal nerve is formed by the union of sensory and motor nerves. Hence, it is a mixed type of nerve.

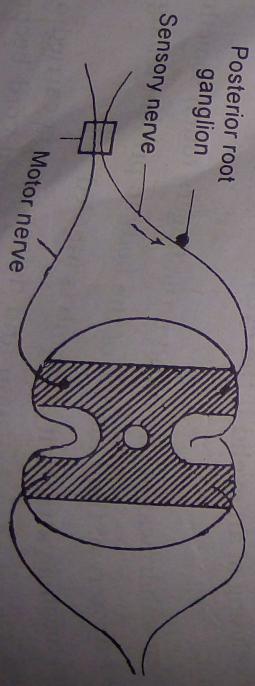


Fig. 11.9

Cranial Nerves

Name of Cranial Nerve

1. Olfactory
2. Optic nerve
3. Oculomotor
4. Trochlear
5. Trigemina (largest)

Human Brain
Nerve plexuses
(1)

- (2)
- (3)
- (4)
- (5)

Types of Nerve

they are 1

(a) A

(b) S

(c) M

cc

cc

cc

cc

cc

cc

cc

cc

cc

cc

cc

cc

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cc

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cc

cc

cc

Nerve Plexuses : The branches of various nerves unite to form a structure called plexuses.

- (1) The cervical plexus is formed of 1st, 2nd, 3rd and 4th spinal nerves. It supplies nerves to the head and thorax region.
- (2) The thoracic spinal nerves (2 - 12) do not form any plexus. It supplies and are supplied to the diaphragm.
- (3) The brachial plexus is formed of 5th, 6th, 7th, 8th cervical spinal nerves and 1st thoracic spinal nerve. The brachial plexus supplies to the shoulder girdle and upper limb.
- (4) Lumbar plexus is formed of 1st, 2nd, 3rd and 4th lumbar nerves and supply nerves to pelvic organs.
- (5) 5th lumbar and 1st, 2nd, 3rd, 4th and 5th sacral nerves unite to form sacral plexus which supply nerves to lower limbs.
- Nerves :** Nerves are made up of a single neuron which carries nerve impulses or they are made up of a chain of neurons.

Types of Nerves :

- (a) **Motor or efferent or descending nerves :** These nerves convey impulses from the brain and spinal cord to the other parts of the body.
- (b) **Sensory or afferent nerves or ascending nerves :** These nerves transmit impulses from the periphery of the body to the spinal cord and then to the brain where they are interpreted. They arise at sense organs and terminate at brain.
- (c) **Mixed nerves :** In the spinal cord sensory nerves are arranged in the groups called tracts and are separated from the tracts of motor outside the spinal cord where afferent and efferent nerves are enclosed within the same tube of connective tissue. They are called mixed nerves.

Cranial Nerves :

Name of Cranial Nerve	Type	Origination	Terminate at	Function
1. Olfactory	Sensory	Smell area in the roof of nose (olfactory lobe)	Smell area in the temporal lobe of cerebrum	Sense of smell
2. Optic nerve	Sensory	Retina of eyes	Vision area of the occipital lobe of cerebrum	Sense of light
3. Oculomotor	Motor	Nerve cells of mid brain	Superior, inferior and medial rectus, muscle of eye, also to ciliary muscles, muscle fibre of iris.	Moving of eye-ball, Focussing, Regulating the size of pupil.
4. Trochlear	Motor	Nerve cells in mid brain	Superior oblique muscles of the eye.	Movement of eyeball.
5. Trigeminal (largest)	Mixed	Motor nerve starts from pons varolii Sensory nerve from the gums, cheek, lips, lower jaw, cornea.	Muscle of Mastication Trigeminal ganglion in the brain.	Chewing Sensation from face.

Name of Cranial Nerve	Type	Origination	Terminate at	Function
6. Abducens	Motor	Floor of fourth ventricle	Lateral rectus muscle of eye	Movement of eye
7. Facial	Mixed	Motor fibres from Pons Ventral sensory nerves from tongue.	Muscle of face	Movement of face expression, sensation
8. Vestibulocochlear	Sensory	Semicircular canals of inner ear from cochlea.	Cerebellum	Sense of hearing
9. Glossopharyngeal	Mixed	Motor branch from medulla oblongata. Sensory branch from parotid glands.	Back of tongue and pharynx, Medulla oblongata.	Movement of Pharynx secretion of Saliva and taste
10. Vagus	Mixed	Motor branch of medulla oblongata. Sensory branch originating from larynx, pharynx, thorax and abdomen.	Digestive glands, kidneys, heart, etc. Trigeminal ganglion in the brain.	Secretion and movement of the organs.
11. Accessory	Motor	Medulla oblongata	Larynx, Pharynx, sternomastoid, trapezius muscles	Movement in these regions
12. Hypoglossal	Motor	Medulla oblongata	Muscles of tongue.	Movement of tongue

AUTONOMIC NERVOUS SYSTEM (ANS)

Central nervous system makes persons aware of external environments and the is mainly related with receiving the sensations from external environments. Interpretation of senses, processing, association and response to the sensations. It also stores information for future use. Understanding and initiating thoughts are the important activities of CNS.

Yet the unconscious activities of the body are also to be controlled for functional need of the body (CNS controls the activities which reach to the consciousness of person). Many activities which do not reach the consciousness of the person are regulated and controlled by autonomic nervous system (ANS). The activities are involuntary. Thus the ANS controls and regulates the involuntary visceral functions is called autonomic because it is not under the control of will.

Two broad divisions of ANS are the sympathetic nervous system (SNS) and parasympathetic nervous system (PSNS). Usually, these two systems are in a state of dynamic equilibrium (i.e. working hand in hand). Sympathetic nervous system controls the individual to adjust to stress while the parasympathetic participate in relaxation building.

Sympathetic Nervous System (Thoracolumbar) : It originates in the thoracic and the lumbar region of the spinal cord.

Parasympathetic Nervous System (Craniosacral) : It originates in the cranial and sacral region of the spinal cord.

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The autonomic nervous system arises from the brain and spinal cord. It forms a network of such sympathetic and parasympathetic ganglia around muscle and organs.

Sympathetic Stimuli

Dilates the pupil
No effect
No effect
Dilates the bronchodilation
Increases heart rate contraction.

Vasodilation
Vasodilation

Vasoconstriction

Relaxation of muscles
sphincters constrict

Increase the sweat

Decrease the salivary

Secretion inhibits

Inhibits bile flow

Increased secretion

Vasoconstriction, Vasoconstriction, Vasoconstriction

Muscle wall relaxation

Metabolism increases

Contraction of uterine

defenses, seminal

Note : In the sympathetic nervous system, the adrenal medulla secretes epinephrine and norepinephrine.

Note : In the parasympathetic nervous system, the vagus nerve (X) is the main nerve.

Note : In the sympathetic nervous system, the thoracic and lumbar regions of the spinal cord are involved.

Note : In the parasympathetic nervous system, the cranial and sacral regions of the spinal cord are involved.

Note : In the sympathetic nervous system, the adrenal medulla secretes epinephrine and norepinephrine.

The autonomic nerves of both SNS and PSNS consist of myelinated nerve fibres arising from the lateral horn cell of the spinal cord. The nerve is called preganglionic nerve. It forms a synapse with nerve cell of another neuron (non-myelinated). A number of such synapses together form a noticeable anatomical swelling which is called ganglion. This second fibre is called the postganglionic fibre. It ends in fibre terminals around muscles or gland cells called the effector cells.

Table 11.2 : Physiology of ANS

Sympathetic Stimulation (adrenergic effect)	Organ	Parasympathetic Stimulation (cholinergic effect)
Dilates the pupil causing mydriasis No effect No effect Dilates the bronchial tubes (bronchodilation) Increases heart rate, increases the force of contraction.	Eye (iris) Ciliary muscles Lacrimal glands Bronchi Heart	Constrict the pupil causing miosis Constrict the muscles and causes accommodation of lens for near vision. Stimulates secretion Constrict the bronchial tubes (Bronchospasm) Slow the heart rate. Decreases the force of contraction
Vasodilation Vasodilation Vasoconstriction Relaxation of muscles, reduces motility, sphincters constricted	Blood Vessels (i) Coronary artery (ii) Skeletal blood vessels (iii) All other blood vessels Smooth muscles of gastrointestinal tract	Vasoconstriction Vasoconstriction Vasodilation Increase the movement and the sphincters relax
Increases the sweating Increases the salivation Secretion inhibits Inhibits bile flow Increased secretion Vasoconstriction, which leads to decrease blood flow Muscle wall relaxed, internal sphincter contracted Metabolism markedly increased, liver secretes glycogen Contraction of uterine muscles, ductus, vesicles, seminal vesicle, vasoconstriction	Glands (i) Sweat glands (ii) Salivary glands (iii) Gastric and intestinal glands (iv) Bile (v) Adrenal glands Kidney (i) Blood flow (ii) Urinary bladder Metabolic effect Sex organs	No innervation Increase the salivation Secretion increases Stimulates bile flow No innervation No effect Muscle wall contracted, internal sphincter relaxed No effect Vasodilation and erection

Note : Increased sweating and increased secretion of adrenal glands is cholinergic and not sympathetic stimulation. Although it is sympathetic stimulation.

10. What is reflex action ? Name the parts of reflex arc.
11. What is CSF ? What are its functions ?
12. Draw and label T.S. of spinal cord and mention its functions.
13. List the neurohumoral transmitters acting centrally and peripherally.
14. What are cranial nerves ? Prepare a list.
15. Which cranial nerves transmit impulses that result in vision ? In eye movement ? Hearing ? Taste sensation ? and slowing of heart ?
16. Name the biggest cranial nerve. What are its functions ?
17. With a diagram show how sensory impulse is carried to brain and how motor impulse is carried to the effector organ.
18. Explain in short functions of medulla oblongata.
19. Explain in short the functions of either cerebrum or cerebellum.
20. Compare autonomic nervous system with that of central nervous system.
21. What are the organs which are supplied with autonomic nerves ?
22. What are the branches of ANS ? Explain their relationship with each other.
23. Compare the anatomy of SNS with that of PSNS.
24. What is the effect of sympathetic stimulation on heart, bronchi and GIT ?

THE SPECIAL SENSES

Taste, smell, hearing, vision and touch are the important special senses.

TASTE

Tongue is the organ of taste. Taste buds are the organs of the sense of taste and are numerous in the papillae of the tongue. There are three types of papillae on the tongue. They are :

Vallate : They form an inverted 'V' - shape at the base.

Fungiform : These are situated on the sides and the tip.

Filiform : These are found mainly on the anterior two-thirds of the tongue. Four fundamental sensations of taste are sweet, sour, bitter and salt. Other tastes are either a combination of two or more of the fundamental tastes or are associated with the sense of smell. The substances in solution form enter the pores of the taste buds and stimulate the hair-like endings of the cells. The impulses are transmitted to the thalamus and then to the taste area in the cerebral cortex where taste is perceived. Taste buds are not evenly distributed over the tongue. The stimulation for various tastes takes place at different parts of the tongue.

- (i) Sweet and salty tastes at the tip of the tongue.
- (ii) Sour taste at the sides of tongue.
- (iii) Bitter taste at the back of the tongue.

The tongue is also sensitive to temperature, pain, touch and pressure.

SMELL

An odorous material gives off particles which are carried into the nose with the inhaled air. They dissolve in the secretions of the mucous membrane and stimulate the nerve cells of the olfactory region. The convection currents carry the inspired air to the olfactory portion of the nose. The air entering into the nose is heated and above cribriform plate of the ethmoid bone forms olfactory bulb. This part is termed as bulb, sensation is passed along the olfactory tract by several relaying stations until it reaches the final receiving area in the olfactory centre which lies in the temporal lobe of the cerebral hemisphere where the sensation is interpreted.

Sniffing concentrates more particles more quickly in the roof of the nose. This increases the number of special cells stimulated and the perception of the smell.

(12.1)

When an individual is continuously exposed to an odour, perception of the odour decreases and eventually ceases. This loss of perception affects only specific odour. This can become dangerous with escape of unpleasant smelling poisonous gases.

The Special Senses

HEARING

Ear is the organ of hearing. For the purpose of description, it is divided into three parts viz., external, middle and internal.

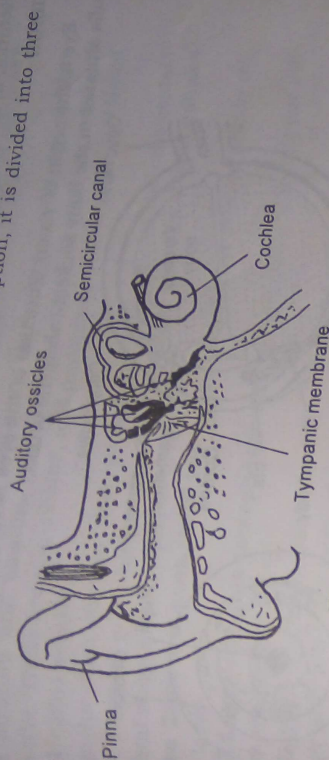


Fig. 12.1 : The Parts of the Ear

External Ear : It helps to collect the sound waves. The external auditory meatus

conveys the sound waves to the tympanic membrane. The pinna of ear is irregularly shaped and is composed of cartilage and fibrous tissue.

Middle Ear : It is a small chamber internal to the tympanic membrane and contains

air. The eustachian tube runs forward from the cavity of the middle ear into the nasopharynx where it opens. Thus, the air pressure may be equalized on each side of the drum. The auditory ossicles are three small bones arranged across the middle ear like a chain reaching from the tympanic membrane to the inner ear. The external bone is the malleus, shaped like a hammer. The middle bone is incus which articulates with the malleus on the outer side and with the stapes on the inner side. The innermost is the stapes which is attached by its oval base with the membrane closing the vestibular fenestra, or oval window. This chain of bones transmits the sound from the drum to the internal ear.

Internal Ear : It consists of several cavities which channel the temporal bone. The cavities are called the outer bony labyrinth inside which is the membranous labyrinth. These cavities contain fluid and nerve endings for hearing and balance. The bony labyrinth contains fluid called perilymph. The labyrinth consists of three parts :

- The vestibule to which all the other parts communicate;
 - The semicircular canals; three in number : superior, posterior and lateral.
- Each canal has a swelling at one end called the ampulla. The function of this part is to assist the cerebellum in the control of equilibrium and the sense of position of the body.

The cochlea is spiral tube twisted on itself resembling a snail shell. The membranous labyrinth contains fluid called endolymph. The vibrations from the middle ear are transferred to the perilymph which are then transmitted to the endolymph stimulating the nerve endings of the auditory nerve.

The auditory nerve finally conveys the information to the cerebral cortex. The sensation of hearing is interpreted by the brain. The vestibular distributed to the semicircular canals convey to the brain the impulses alteration in the position of the fluid in these canals.

VISION

Eye is the organ of vision. Function of the eyes is vision or seeing. There are two balls situated in the bony sockets called the orbits.

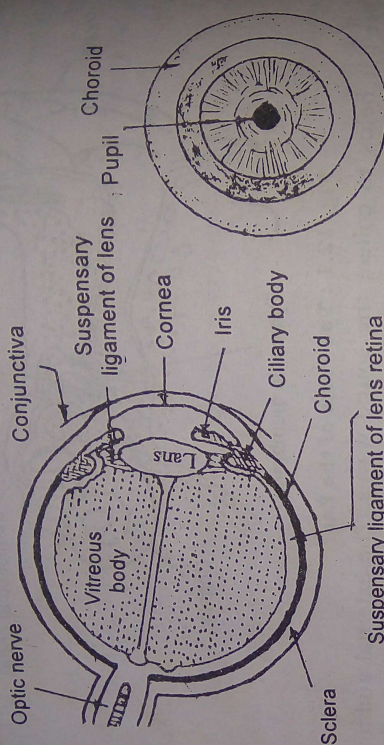


Fig. 12.2 : Section of the Eye

The eye ball consists of three coats or layers as follows :

- (1) *Outermost fibrous coat or sclera* : The central transparent region of the anterior part is called the cornea. Over the exposed part of the eye ball, there is a superficial mucous membrane called the conjunctiva which is also reflected along the inner surface of the eye-lids.
- (2) *Middle vascular coat or uvea (choroid)* : The anterior most or foremost part of it is called iris.

The central adjustable opening in the iris just behind the cornea is called the Pupil or pupillary aperture. The pupil varies in size depending upon the intensity of light present. In bright light, it is constricted while in dim light it is dilated. The iris is continued behind as ciliary body. The ciliary body is continued behind as the choroid. It forms a major part of the uvea or vascular coat of the eye ball.

- (3) *Innermost nervous coat or retina* : Anteriorly or in front, it extend upto the limbus of the choroid and posteriorly or behind it is continued as the optic nerve or the second cranial nerve to the brain.

The cavity of the eye ball is divided by the lens and the suspensory ligaments into two compartments - one anterior compartment and the other posterior compartment called the vitreous chamber containing jelly like vitreous humour. The anterior chamber is subdivided by the iris into anterior and posterior chambers. Both these chambers contain water fluid called aqueous humour and communicate with each other through the pupillary aperture.

Secretion and circulation of aqueous humour : Aqueous humour is secreted by the ciliary bodies into the posterior chamber and through the pupillary aperture it flows into the anterior chamber and at the angles of the anterior chamber, via the canal of Schlemm, it is drained into the veins.

Fig. 12.3 : The Front View of Eye

The eye ball consists of three coats or layers as follows :

- (1) *Outermost fibrous coat or sclera* : The central transparent region of the anterior part is called the cornea. Over the exposed part of the eye ball, there is a superficial mucous membrane called the conjunctiva which is also reflected along the inner surface of the eye-lids.
- (2) *Middle vascular coat or uvea (choroid)* : The anterior most or foremost part of it is called iris.

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Secretion and circulation of aqueous humour : Aqueous humour is secreted by the ciliary bodies into the posterior chamber and through the pupillary aperture it flows into the anterior chamber and at the angles of the anterior chamber, via the canal of Schlemm, it is drained into the veins.

TOUCH

The skin is the organ of sensation of touch. The skin covers and protect human body.

It is divided into two layers, epidermis and dermis.

Epidermis : It consists of stratified epithelium consisting of a number of cell layers arranged in two zones viz., horny zone and germinative zone.

1. **Horny Zone** : It lies superficially containing three upper layers viz., stratum corneum, stratum lucidum and stratum granulosum. Cells of stratum corneum are thin, flat and scale like. These are non-ciliated, and protoplasm of these cells is replaced by horny substance called keratin.

Cells of stratum lucidum contain clear protoplasm and some of the cells contain nuclei. The cells of stratum granulosum contain nuclei and granules. These granules are known to be initial stage of development of keratin.

2. **Germinative Zone** : It consists of two layers of epithelial cells as prickle cell layer and basal cell layer.

Prickle Cell Layer : Minute protoplasmic threads (strands) connecting one cell with another are present.

Basal Cell Layer : The cells are arranged in wave-like order. They are packed close together and form the layer of cells which rest on papillae of dermis. The cells reproduce rapidly and replace the cells from the superficial layer. In this layer, there are cells called melanoblasts which contain granules of pigment giving colour to the skin. Epidermis does not contain any blood vessels but the cells of epidermis are bathed in a fluid called lymph which is collected by different lymphatic vessels.

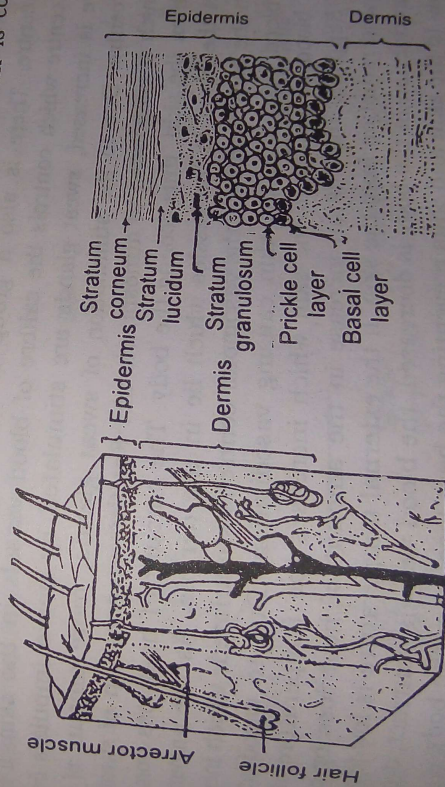


Fig. 12.4 : The Skin

Fig. 12.5 : The Layers of Epidermis

True Skin : It is made up of fibrous and elastic connective tissue. The dermis is arranged in small papillae. There are many structures in dermis : blood capillaries, blood vessels, nerve endings of sensory nerves, tubules of sweat glands, sebaceous glands. The sebaceous glands are small flask shaped and open into the hair follicle. The dermis are numerous around the nose, mouth, ear and do not occur in the skin of sole of feet. These glands secrete oily secretion called sebum. The sebum also acts as a lubricant to the hairs. It also acts as a protective layer.

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Arrector Muscles: When these muscles contract, they pull the hair follicle into the state of fear and in response to cold. The special sense of fear is called pilo-erection. The special sense of cold is called pilo-erection.

Hair Follicle : It is a small cluster of cells called hair bulb from which the hairs grow.

Physiology of Skin : Skin is one of the most active organs of the body. It consists of many sensory nerves which act as organ of sensation of touch, pain, heat and cold. It is one of the main excretory organs of the body. It reacts to the unpleasant or painful stimulation. It protects deeper tissues from injury and acts as a barrier against infection by bacteria and excretes out the waste products in the form of sweat. The skin also produces vitamin D. It contains delicate organs of the body from injury and acts as a barrier against infection by bacteria and excretes out the waste products in the form of sweat. The skin also produces vitamin D.

Temperature : Human beings are warm blooded animals. They maintain a constant temperature of about 98.6°F (37°C). The temperature of the sun act on this substance producing vitamin D.

Regulation of Body Temperature For maintaining this temperature their body temperature is maintained at 37°C . For maintaining this temperature is a fine balance between heat production and heat loss from the body. Heat is produced by several body activities such as muscles contraction, chemical reactions by activities in digestive organs and utilization of food stuff. Heat is also lost from the body by different ways such as, 90% by skin, 2% in expired air, 1% in urine and faeces.

The centre controlling the temperature is situated in hypothalamus called regulating centre. There is also a group of cells in medulla oblongata called vasomotor centre which controls the calibre of blood vessels in the skin. If the temperature is increased, sweat glands are stimulated by nerve impulses from regulating centre. Due to the stimulation of sweat glands, more amount of sweat is secreted which is evaporated to atmospheric air. For the evaporation of sweat, heat is taken out from the skin, thus cooling the body. The amount of heat loss from the body depends on the blood in the vessels which lie in the dermis. As the amount of blood in the body increases, the vasomotor centre is stimulated, which increases the calibre of blood vessels in the skin causing vasodilation. Due to vasodilation, more amount of blood is passed to the skin which increases the temperature of the skin. When this happens, there is an increase in the amount of heat loss by convection and radiation from the skin. If the external temperature is low (e.g. in winter), the blood supply to the skin and thus the heat loss is decreased. The blood vessels contract, decreasing the heat loss from the body.

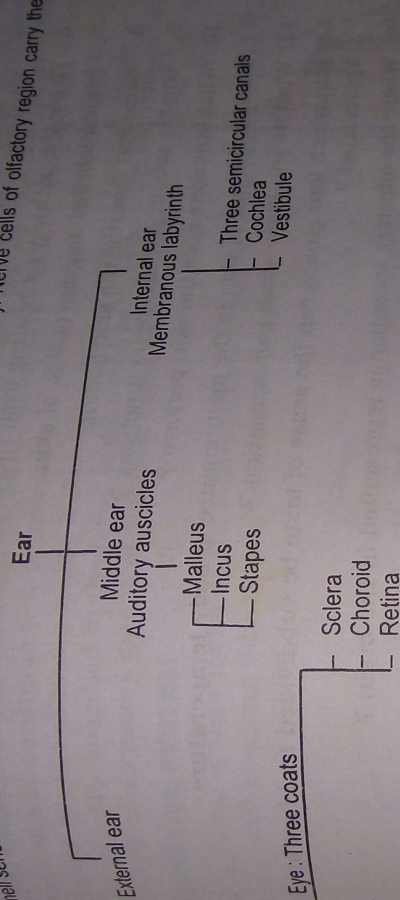
Physiology of Pain : The sense of pain apprises the individual about any damaging process and causes necessary muscular reactions to remove the contact with the damaging stimuli. Pain receptors are stimulated when tissues of the body are being damaged. The types of damaging stimuli causing pain are trauma, issues, ischaemia of the tissues which releases a substance from the area of the body rather than being localized in the organ itself. This is called as pain. The areas in the brain where sensory stimuli are carried and are interpreted are thalamus and hypothalamus.

SUMMARY

The special senses and organs are :

Taste	- Tongue
Smell	- Nose
Hearing	- Ears
Vision	- Eyes
Touch	- Skin

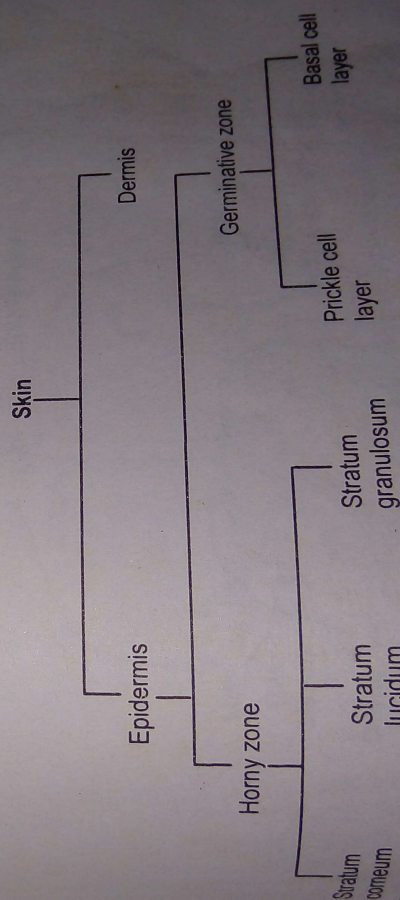
Four fundamental sensations of taste are sweet, sour, bitter and salty. Nerve cells of olfactory region carry the smell sensation.



Eye : Three coats

- Sclera
- Choroid
- Retina

Optic nerve conveys the sensation of vision



Physiology of Skin :

- (a) Sensation of touch
- (b) Excretion of sweat
- (c) Protection
- (d) Formation of vitamin D
- (e) Regulation of body temperature

QUESTIONS

1. Draw a sagittal section of the eye.
2. Describe rods and cones and indicate through which regions light enters before reaching them.
3. Explain how the eye accommodates near and far vision.
4. Draw a labelled diagram of an ear.
5. What are auditory ossicles? What is their function?
6. Trace the pathway for hearing from the external ear to the cerebral cortex.
7. Draw a labelled diagram of V.S. of skin.
8. Name and describe the skin glands.
9. What is sebum? What are its functions?
10. What functions does the skin perform?
11. Explain the role of skin in the maintenance of body temperature.
12. What do you know about pain sensation?
13. Into which four groups can the sense of taste be subdivided and how are they appreciated?
14. Where the olfactory sensation is represented in the brain?

INTRODUCTION

The cell life activities and a purposes. Hence contains complex form, so simple form, so that it is easy with the help of

THE DIGESTIVE

The digestive alimentary tract

THE DIGESTIVE SYSTEM

INTRODUCTION

The cell life requires essential materials for growth, for carrying out other structural activities and as a source of energy for these activities. Hence, human organism needs a regular supply of food. The food material serves these purposes. It is necessary to convert these complex substances into simple form, so that cells can utilize it. The conversion of complex substances into simple form is described as digestion. The alimentary canal with the help of accessory glands of digestion performs this function.

THE DIGESTIVE SYSTEM

The digestive system includes the alimentary canal and some accessory organs. The alimentary tract is a long tube through which food passes.

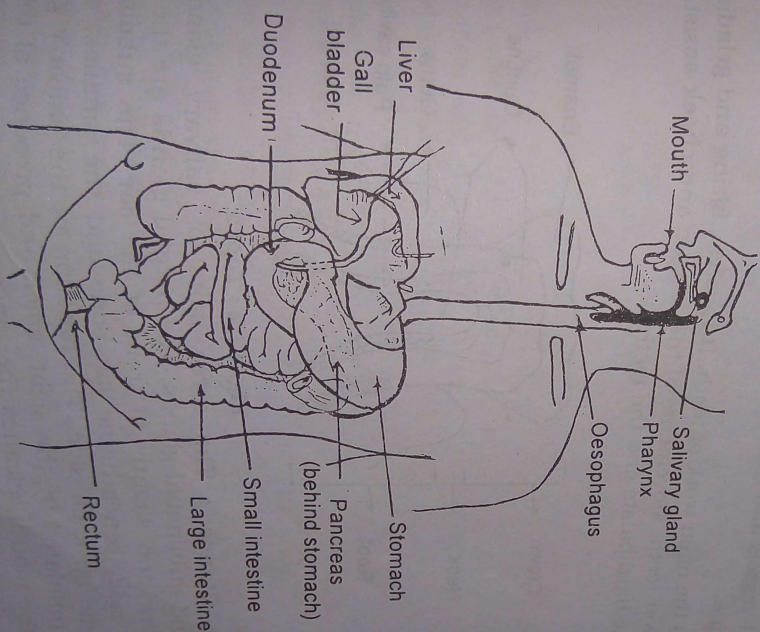


Fig. 13.1 : Digestive System
(13.1)

It begins at the mouth and terminates at the anus. The parts of the alimentary canal are : Mouth, pharynx, oesophagus, stomach, small intestine and large intestine and anal canal. The accessory organs are the three pairs of salivary glands, the pancreas.

All these organs and glands are both physiologically as well as anatomically interdependent. Digestion and absorption occur in stages, each stage being dependent on the previous stage or stages.

The mouth or oral cavity is bounded by lips, muscles of the cheeks and a hard palate. The tongue is a voluntary muscular structure which occupies the floor of the mouth. It contains numerous papillae which contain nerve endings of the sense of touch. The mouth also contains teeth which are embedded in the sockets of the alveolar process of the mandible and the maxilla.

Teeth and Mastication : In an adult, the total number of teeth are thirty-two, sixteen in each jaw. Their names and numbers beginning from the centre are as follows. Two incisors, one canine, two pre-molars and three molars. A tooth possesses a crown, neck and root. The crown projects above the gum, the neck is surrounded by the gingiva and the root lies beneath it. A tooth is made up of a very hard material called dentine. In the central part of the structure lies the pulp cavity. The pulp contains connective tissue cells, blood vessels and nerves. The crown is covered with enamel which is harder than dentine.

Mastication is the main work of teeth. It involves biting and grinding of food between the upper and lower teeth. Movements of the tongue and cheek assist, by the pressure of food against the hard palate and the teeth.

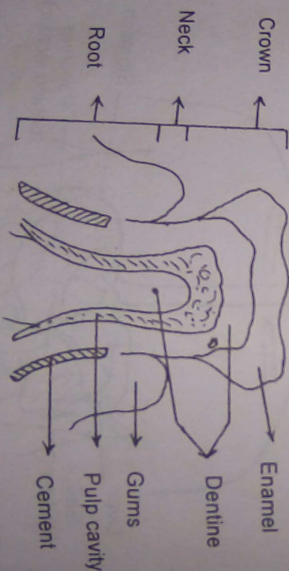


Fig. 13.2 : Tooth

The Salivary Glands : The three pairs of salivary glands are the parotid, submandibular and sublingual glands. The parotid glands are the largest. They are present on each side below and slightly in front of the ear. The submandibular glands are present on each side, beneath the jaw-bone and the smallest sublingual glands are present beneath the tongue on each side. The function of the salivary glands is to secrete saliva which moistens the mouth, cleanses the tongue and makes speech easier. Saliva moistens the mouth, cleanses the tongue and makes speech easier. The enzyme ptyalin acts on cooked starches in alkaline medium and converts them to a soluble form called maltose. The action of the enzyme continues till the food is rendered acidic by the action of gastric fluid.

Human Anatomy and Physiology

The structure of the oesophagus consists of the following layers of tissue.

- (1) Outer coat
- (2) Muscle layer
- (3) Submucosa
- (4) Mucous membrane

(Fig. 13.1) The duodenum is connected to the stomach and is termed as greater and lesser curvature. The pyloric orifice is the opening into the duodenum.

At the distal end of the stomach and the pylorus, the food is allowed to churn in the numerous gastric pits, where the mineral salts, mucus and enzymes are secreted.

The small intestine continues upto the ileum and is divided into three parts: the duodenum (3 metres), the jejunum (5 metres) and the ileum (3 metres). The jejunum and ileum are present below the stomach and are called enterokinins. The pancreas is present inside the duodenum. It consists of a head, body and tail. The pancreatic duct is formed by the union of the main duct and the accessory duct.

The structure of the alimentary canal follows a consistent pattern from the oesophagus onwards. The walls of alimentary canal are made up of the following four layers of tissue.

- (1) Outer covering consisting of peritoneum in the abdomen.
- (2) Muscle layer of both circular and longitudinal muscles.
- (3) Submucous layer of loose connective tissue.
- (4) Mucous membrane lining consisting of epithelial cells.

(Fig. 13.1) The oesophagus opens into the stomach at the pyloric orifice. The part of the stomach above the pyloric orifice is called the fundus, the main part is the body and the lower part is the pyloric antrum.

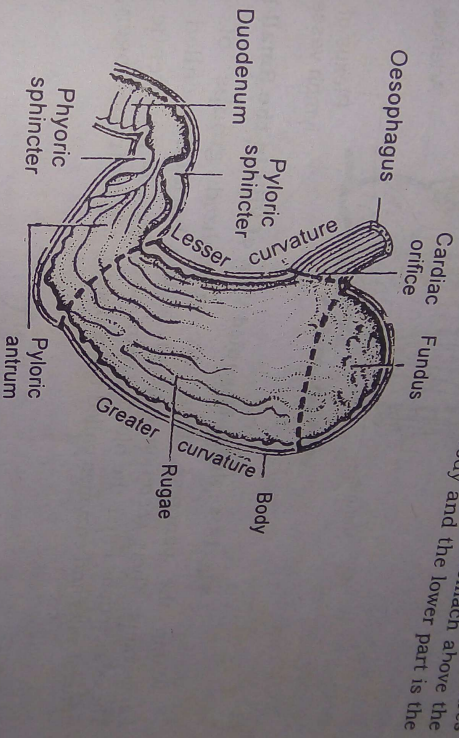


Fig. 13.3 : Longitudinal Section of the Stomach

At the distal end, there is pyloric sphincter which guards the opening between the stomach and the duodenum. The muscular layer in the stomach is very strong and has churning motion and peristaltic movements. The mucus membrane contains numerous gastric glands which secrete gastric juice. The gastric juice consists of water, mineral salts, mucous, hydrochloric acid, enzymes called pepsinogen and rennin.

The small intestine is continuous with the stomach at the pyloric sphincter and continues upto ileocecal valve opening into large intestine. It is about 5 metres in length and is divided into the duodenum (25 cm) followed by jejunum (2 metres) and ileum (metres). The inner surface of the small intestine is greatly increased by the circular and finger like projections called villi (Fig. 13.3). Large number of tubular glands are present below the surface between the villi. Blood vessels and lymph vessels are also present inside the villi. The intestinal juice consists of water, mucus, and enzymes like amylase, pepsinase, lipase, sucrase, maltase and lactase.

The pancreas is a pale grey gland consisting of a broad head, a body and a narrow tail. It is a large number of lobules. Each lobule is drained by a small duct and they form a larger pancreatic duct. Just before entering the duodenum, the pancreatic duct joins the bile duct. The common opening of pancreatic and bile duct is called by the sphincter of Oddi.

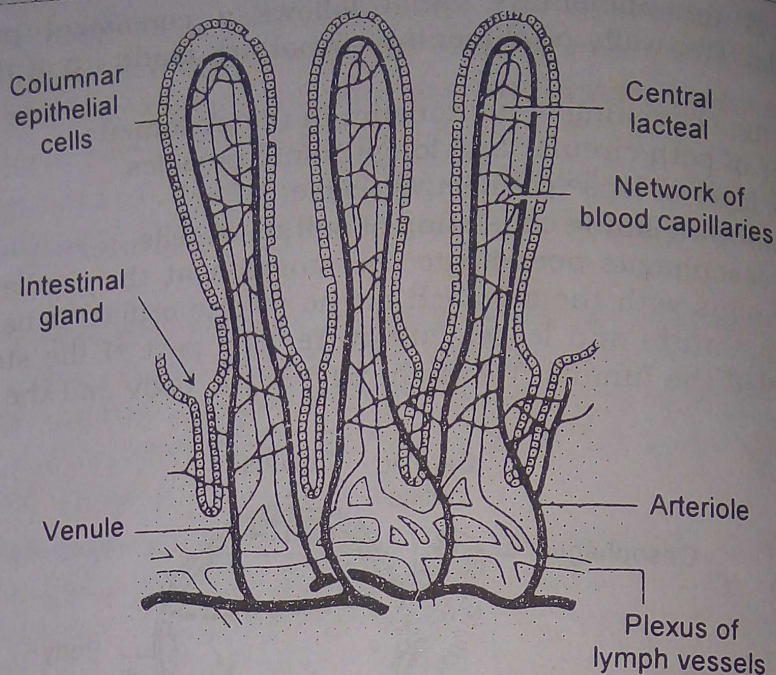


Fig. 13.4 : Highly Magnified View of Villi in the Small Intestine

Within the pancreas, there are specialized groups of cells called islets of Langerhans. Their secretion consists of two hormones called insulin and glucagon. These secretions enter the blood stream directly. The pancreatic juice consists of water, mineral salts and enzymes called trypsinogen, chymotrypsinogen, amylase and lipase.

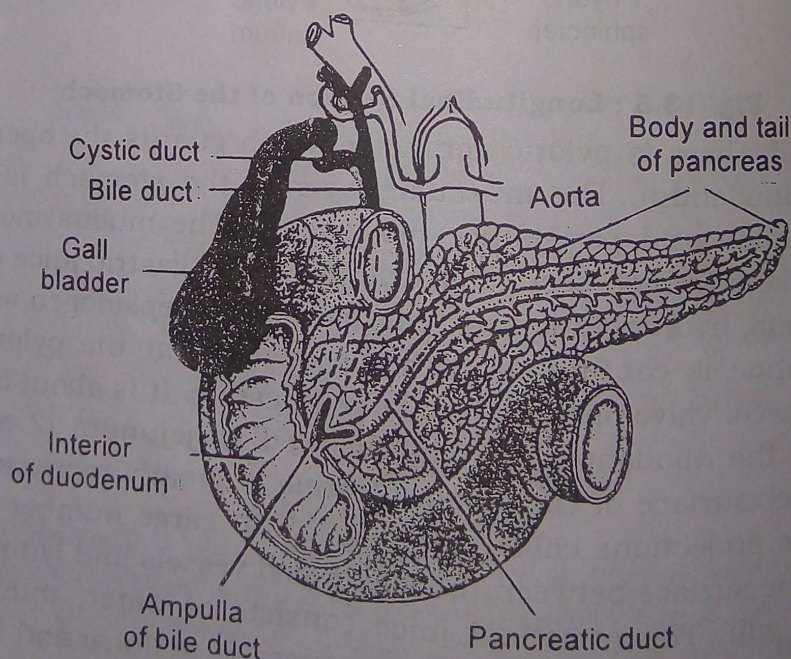


Fig. 13.5 : The pancreas in relation to the duodenum and biliary tract.
Part of the anterior wall of the duodenum removed

The last part of the small intestine further continues as the large intestine. The large intestine is about 1.5 metres long. It begins at the caecum, continues as colon, rectum and ends in anal canal. It forms an arch round the coiled up small intestine.

Human Anatomy and Physiology
longitudinal muscle, but a
tissue, but a
longitudinal
are formed by
colon and up
**FUNCTIONS
AND ABSORPTION**

The food
tongue and
mass or bolus
enzyme 'ptyalin'
moistens and
within the mouth
the upward movement
into the oesophagus
peristalsis and
the oesophagus
peristaltic contraction

The stomach
juices to act on
mucus, hydrochloric
Water in the stomach
acidifies the food
the active enzyme
Pepsin converts
milk to insoluble
present in the
absorption of
the stomach
as a barrier
action of the
intestine. Alcohol and
alcohol and
circulation.

The small intestine
peristaltic, the
consists of three
The enzyme ptyalin
inactive ptyalin
chymotrypsinogen
Intestinal juice
convert pepsin
and glycerol
convert the

longitudinal muscle fibres of large intestine do not form a smooth continuous layer of tissue, but are collected into bands located at regular intervals round the colon. The longitudinal muscle fibres surround the rectum and the anal canal. The anal sphincters are formed by thickening of the circular muscle layer. The mucus membrane lining the colon and upper part of rectum contain glands which secrete mucus.

FUNCTIONS OF THE VARIOUS ORGANS AND THE PHYSIOLOGY OF DIGESTION AND ABSORPTION

The food is masticated or chewed by the teeth and moved around the mouth by the tongue and the muscles of the cheeks. It is mixed with saliva and formed into a soft mass or bolus ready for swallowing. The secretions of the salivary glands contain an enzyme 'ptyalin' which converts starches into maltose. The salivary secretion also moistens and lubricates the food. It also cleans the mouth and keeps the structures within the mouth soft and pliable. The bolus of food is pushed back into the pharynx by the upward movement of the tongue. The muscles of the pharynx further propel it down into the oesophagus. The presence of bolus in the pharynx stimulates a wave of peristalsis and propels the bolus through the oesophagus to the stomach. The walls of the oesophagus are lubricated by mucus which assists the passage of the bolus during peristaltic contraction of the muscular wall.

The stomach acts as a temporary reservoir for food thus following the digestive juices to act on food. It also produces gastric juice which contains water, mineral salts, mucus, hydrochloric acid, enzymes viz., pepsinogen, rennin and the intrinsic factor. Water in the gastric juice further liquefies the swallowed food. Hydrochloric acid modifies the food and stops the action of salivary ptyalin. It also converts pepsinogen to the active enzyme pepsin and kills many microbes which may be harmful to the body. Pepsin converts proteins into peptones and rennin changes soluble caseinogen from the milk to insoluble casein which in turn is converted by pepsin into peptones. Rennin is present in gastric juice of infants only. The intrinsic factor is necessary for the absorption of vitamin B₁₂. The mucus in the gastric juice prevents mechanical injury to the stomach wall by lubricating the contents. It also prevents chemical injury by acting as a barrier between the stomach wall and other constituents of gastric juice. Muscular action of the stomach mixes the food with gastric juice and moves it to the small intestine. Absorption takes place in the stomach to a limited extent. Water, glucose, alcohol and some drugs are absorbed through the walls of the stomach into the venous circulation.

The small intestine further progresses the movement of its contents by its peristaltic, segmental and pendular movements. It also secretes intestinal juice which consists of water, mucus and various enzymes. The intestinal juice is alkaline in nature. Enzymes in the intestinal juice perform various functions. Enteropeptidase converts pancreatic trypsinogen and chymotrypsinogen to active trypsin and chymotrypsin which further converts peptones into peptides and polypeptides. Pancreatic and pancreatic amylase convert polysaccharides to disaccharides. Peptidases convert peptides and polypeptides into amino acids. Lipase converts fats into fatty acids and glycerol. Sucrase, maltase and lactase act on corresponding disaccharides to convert them into monosaccharides.

The intestinal juice, thus completes digestion of carbohydrates, proteins and fats. The solitary lymph follicles and aggregated lymph follicles in the villi of small intestine help in protection against infection by micro-organisms. All the digested material is also absorbed in the small intestine.

The end products of digestion of carbohydrates, proteins and fats are monosaccharides (mainly glucose), amino acids, fatty acids and glycerol and are absorbed into the capillaries of the villi and transported in the blood to the liver. Amino acids also follow the same path. Fatty acids are absorbed into the lacteals of the villi and are transported via the thoracic duct to the left subclavian vein. Then, they are carried to the liver where they are reabsorbed and recombined.

[Chemical digestion of food - See Table 13.1 on Page No. 13.8].

The food passing through the small intestine enters the large intestine. In the intestine, absorption of water continues till semisolid consistency is achieved. In the large intestine, some drugs are also absorbed into the blood capillaries from the villi. This forces its contents into the descending and pelvic colon and finally to the anus.

STRUCTURE AND FUNCTIONS OF LIVER

It is the largest gland in the body situated in the uppermost part of the abdominal cavity on the right side beneath the diaphragm. It is about 1500 gm in weight. Its irregular in structure. The upper surface is convex and lies beneath the diaphragm. Its under surface is irregular. Liver is mainly divided into two lobes right and left by a longitudinal fissure separates caudate lobe from the left lobe. The liver is subdivided into four lobes viz., right, left, caudate and quadrate.

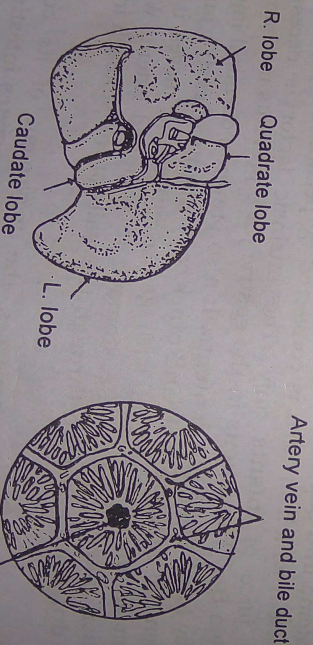


Fig. 13.6 : The Liver Lobes

Liver is made up of lobules which are polyhedral in shape. Each lobule is composed of cubical cells arranged radially and the vessels of the liver are connected by liver sinusoids. The portal canals of which contains many enzymes. Masses of such cells which are covered by a thin layer of connective tissue called Glisson's capsule which forms portal canal. These portal canals are present surrounding lobules. The blood from portal vein comes in close contact with the sinusoids.

Fig. 13.7 : T.S. of Liver Lobules

- Human Anatomy**
- The liver cells. The liver lobule is the basic functional unit of the liver. It is composed of hepatocytes which are arranged in cords around a central vein. The portal canals are located at the periphery of the lobule and contain the portal triad (portal vein, hepatic artery, and bile duct). The portal vein carries blood from the gastrointestinal tract to the liver. The hepatic artery carries oxygenated blood to the liver. The bile duct carries bile from the liver to the gallbladder.
- (1) Secretory Function**
- The liver secretes bile, which is composed of water, bile salts, bile pigments (bilirubin and biliverdin), and bile acids. Bile salts are responsible for the emulsification of fats, which makes them easier to digest. Bile pigments are the breakdown products of hemoglobin. Bile acids are the conjugates of bile salts and bile acids.
- (2) Glycogen Storage**
- The liver stores glycogen, which is a form of stored energy. Glycogen is made up of glucose units and is stored in the cytoplasm of liver cells. When the body needs energy, the glycogen is broken down into glucose and released into the bloodstream.
- (3) Protein Synthesis**
- The liver synthesizes many proteins, including albumin, which is the most abundant protein in the blood. Albumin helps to maintain the osmotic pressure of the blood and transport various substances. The liver also synthesizes clotting factors, which are essential for blood clotting.
- (4) Detoxification**
- The liver plays a crucial role in detoxifying the body. It breaks down toxins and drugs into less harmful substances that can be excreted from the body. The liver also converts ammonia into urea, which is then excreted in the urine.
- (5) Fatty Acid Metabolism**
- The liver is involved in the metabolism of fatty acids. It can break down fatty acids into ketone bodies, which can be used as an energy source by other tissues. The liver can also synthesize fatty acids and store them as triglycerides.
- (6) Maintenance of Blood Glucose Levels**
- The liver helps to maintain the blood glucose levels. It can release glucose from its glycogen stores when the blood glucose level is low. It can also synthesize glucose from non-carbohydrate sources (gluconeogenesis) when the blood glucose level is low.

The small capillaries collect the blood and unite to form vein in the centre of the lobule. The hepatic vein, passing directly into inferior vena cava, is formed by the union of the hepatic portal vein and the inferior vena cava. Bile is formed by the hepatic cells and is secreted into the bile ducts. Large bile ducts have lining of columnar epithelium and outer layer of smooth muscle. Bile is temporarily stored in the gall bladder.

Physiology of Liver :

(1) **Secretion of Bile :** Hepatic cells secrete an alkaline fluid called bile. It is composed of 90% water, bile salts (sodium glycocholate, sodium taurocholate), bile pigments (bilirubin, biliverdin), cholesterol and mucin. Bile salts are helpful in digestion and absorption of fats. They reduce surface tension of fats and help in their emulsification. R.B.Cs. are destroyed in the liver and spleen. The haemoglobin of R.B.C. is broken down into globin and Haem. Haem is again broken down into iron and urobilinogen, which form bile pigments later on.

(2) **Glycogenic Functions :** The portal vein carries the blood from the digestive tract which contains glucose and amino acids. It pours the blood into liver. The hepatic cells, by the action of enzymes, convert glucose into glycogen and it is then stored in the liver. Whenever, there is need of energy to body, hepatic cells convert glycogen to glucose and pass it to body cells through blood circulation. Thus, this glycogenic action helps to maintain the sugar level constant in the blood.

(3) **Formation of Urea :** Portal vein carries blood containing amino acids to the liver. Hepatic cells by the action of their enzymes cause deamination of amino acids, i.e. amino group is set free which forms urea. Urea is carried away to kidneys by the blood and is given out of the body through urine.

(4) **Desaturation of Fats :** The digested fats in the form of the fatty acids and triglycerides are absorbed in the central lacteal duct. The fatty acids and glycerol again unite to form chylomicrons. This fat is carried away by the blood and is stored in the different tissues in the form of fat. Whenever, the energy is needed, this saturated stored fat is carried to liver by blood. Then the hepatic cells cause the desaturation of this fat and pass it to different tissues for utilisation.

Functions Related to Blood :

- (i) Formation of R.B.Cs. in foetal life.
- (ii) Destruction of R.B.Cs. forming bile pigments and iron.
- (iii) Formation of plasma proteins viz., albumin and globulin.
- (iv) Formation of prothrombin and fibrinogen responsible for blood clotting.
- (v) Formation of heparin, a natural anticoagulant in the blood.
- (vi) Storage of iron, vitamin B₁₂.

Maintenance of Body Temperature : As a number of chemical reactions occur in the body, heat is generated which is helpful in maintaining body temperature.

(7) Excretion of Toxic Substances : The toxic substances entering the body through alimentary canal are destroyed in the liver e.g., alcohol, some drugs, etc. As liver is responsible for a number of intermediate metabolic reactions, it is called the chemical factory in the body.

Metabolism :

When nutritional materials which are end products of digestion are oxidized in the cells of the body, energy is released. All such chemical changes necessary for the fulfillment of vital functions of body are termed as metabolic changes. They are the sources of energy for activities of the body. The minimum energy requirement per day is described as the Basal Metabolic Rate (BMR). This is the rate at which the sum of all metabolic processes takes place, when an individual is at rest and has eaten no food for 12 hours. The normal BMR values are :

Men : (170 kJ/m²/hr.).

Women : (155 kJ/m²/hr.).

The units for measurement of BMR are kilojoules/metre²/hour.

Table 13.1 : Chemical Digestion of Food

		ACTION ON					
Organ in the Alimentary Canal	Digestive Juice and Enzymes	Carbohydrates	Proteins	Fats			
1. Mouth	Saliva Salivary amylase	Cooked Starches → Maltose	No action	No action			
2. Stomach	Gastric Juice (i) Pepsin (ii) Renin (iii) Gastric lipase	No action	Proteins → Peptones Casein → Paracasein (Milk Protein)	Fats → Fatty acids and glycerol			
3. Small intestine	Pancreatic Juice (i) Trypsin and Chymotrypsin (ii) Pancreatic amylase (iii) Pancreatic lipase Bile Bile Salts (No enzyme) Intestinal Juice (i) Peptidase (ii) Sucrase Maltase Lactase (iii) Enteric Lipase	Starch → Disaccharides Disaccharides Sucrose → Glucose + Fructose Maltose → Glucose + Glucose Lactose → Glucose + Galactose	Peptones → Poly-peptides Poly-peptides → Amino acids	Fats → Fatty acids and glycerol Unemulsified lip → Emulsified lip			
		Emulsified lip + Fatty acids + glycerol					
		Gastric Juice					
(i) Volume	1.5 to 2.5 lit / day	Intestinal	2 to 3 lit / day	Pancreatic	600 to 800 ml / day	Bile	800 to 1000 ml / day
(ii) pH	1.6 to 3.2	7.5 to 8	4.5 to 7.0	6.8 to 7.7			

Duodenum
Jejunum
Ileum

Composition of d

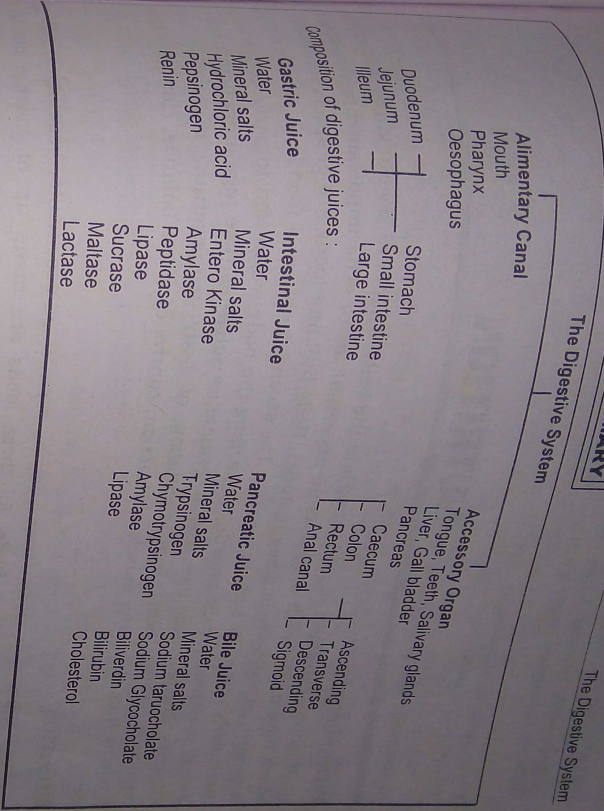
Gastric juice
Water
Mineral salts
Hydrochloric acid
Pepsinogen
Renin

1. Define the term digestion.
2. Draw a diagram of the human digestive system.
3. Name the organs of the human digestive system.
4. What are the functions of the human digestive system?
5. Give the names of the organs of the human digestive system.
6. List the functions of the human digestive system.
7. What are the functions of the human digestive system?
8. Name the organs of the human digestive system.
9. List the functions of the human digestive system.
10. Give the names of the organs of the human digestive system.
11. What are the functions of the human digestive system?
12. Describe the human digestive system.

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oxidized in the
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SUMMARY



QUESTIONS

1. Define the terms - Digestion and mastication. Where do they occur ?
2. Draw and label the diagram of digestive system.
3. Name and describe the coats that compose the walls of the oesophagus, stomach and intestines.
4. What are the normal end products of digestion and how do they reach the blood circulation ?
5. Give the composition of gastric juice and bile.
6. List the functions of liver.
7. What are the four main activities of GIT ?
8. Name the functions of stomach and colon.
9. List the enzymes that act on carbohydrate, protein and fat.
10. Give the composition and functions of saliva.
11. What is metabolism ? Explain the meaning of BMR.
12. Describe the exocrine function of pancreas.

NUTRITION

INTRODUCTION

Nutrition is defined as food at work in the body. There are several kinds of functions which have involvement of food as an important factor. The important function of food is to work as the body-building material. Body building foods are of special importance particularly when the body is growing. The second function of food is to provide energy. Energy is utilized for the growth, for keeping the body warm and to perform day-to-day activities. The body also uses food to regulate its activities. The regulatory activities are regulation of the heart beat, regulation of body temperature, removal of waste products from the body, muscle contraction, control of water balance, clotting of blood etc.

NUTRITION

Food appears in many forms such as cereals, pulses, fruits, vegetables, milk and milk products and flesh foods. All these foods are made up of a large number of components called nutrients and can be grouped into six main classes, viz.,

- | | |
|--------------------|---------------|
| (a) Water, | (b) Proteins, |
| (c) Carbohydrates, | (d) Fats, |
| (e) Minerals and | (f) Vitamins. |

Most of the foods are composed of more than one class of nutrients. The nutrients are discussed with a special reference to the functions they perform.

Body-building Nutrients : Proteins, minerals and water come in this category. They are used in forming muscles, blood, hair and other tissues. The largest part of the protein in Indian diet comes from cereals and pulses. Animal proteins like milk products, eggs, fishes and meat also act as source of proteins.

The highest concentration of minerals is found in the bones and the teeth. Minerals are also present in other body tissues. Some minerals are present in only a few foods. If the food lacks in those minerals, then the effects due to their deficiency are observed in the human body.

Water is present in all the tissues. It is especially important in building lymph, blood and many secretions of body.

Energy giving Nutrients : Carbohydrates and fatty foods come in this category. Proteins may also be used as the source of energy. This, however, happens only when enough energy is not available from carbohydrates and fats.

The most common source for carbohydrates are starch, sugar and cellulose. Fatty foods like vegetable oils, vanaspati, butter and ghee, nuts, oils, and animal fats are the sources of high amount of energy.

Regulating Nutrients : Many nutrients work together to regulate the functions of the body. This is true of proteins, minerals, water and vitamins.

Food Groups : Foods can be classified into different groups on the basis of the predominant nutrients they supply. This classification serves as a guideline for the selection and use of proper foods and as a means of estimating the extent to which diets are adequate or inadequate.

Various groups of foods and the types of Indian foods in each class are presented below :

- (1) **Protein Foods :** Milk and milk products, e.g., curds, butter-milk, panir, khoa. Pulses, e.g. dal, gram, lentils, dried beans and peas. Nuts and oil seeds e.g., groundnut, tree nuts, sesame. Eggs, fish, meat, like mutton, poultry, pork, beef.
- (2) **Protective Vegetables and Fruits :**
 - (a) Leafy green vegetables e.g. spinach, fenugreek, drumstick leaves, cabbage.
 - (b) Yellow or orange fruits and vegetables, e.g., carrot, pumpkin, papaya, mango.
 - (c) Vitamin C rich fruits and vegetables, e.g., amla, guava, orange, grape fruit, sweetlime, pineapple, tomato, ber (bor), cabbage, cauliflower.
- (3) **Other Vegetables :** e.g. brinjal, lady's finger, beans and peas, cucumber, onions, etc.
- (4) **Cereals, Roots and Tubers :** e.g. rice, wheat, jowar, bajra, ragi, potato, etc.
- (5) **Fats, Oils, Sugar and Jaggery :** e.g. vegetable oils, vanaspati, ghee, butter, sugar, jaggery, honey.

Vitamins : Vitamins are organic substances present in small amounts in natural materials, which are essential for growth and normal metabolism. They are considered essential to all cells and are needed in the diet in minute amounts.

Essentials of diet : These includes carbohydrates, proteins, fats, vitamins, mineral water and roughages. These necessities must be in correct proportion for the body to function efficiently.

A diet which satisfies these requirements and helps important functions of the body such as providing energy, building tissues and regulating the body adequately is termed as a balanced diet. It contains food from all the subgroups described earlier. The essential vitamins, their sources, physiological role and diseases caused because of deficiency are presented in the following table.

Table 14.1

Vitamins		Sources	Physiological Role	Deficiency Diseases
1. Fat Soluble				
(i) A		Milk, butter, eggs, fish-liver oils, green vegetables (provitamins)	A factor in decreasing susceptibility to skin infections. Preserving general health and vigor. Effecting chemistry necessary for vision, promoting growth	Failure to gain weight, xerophthalmia, night blindness, skin, impaired epithelial cells (dry skin), increased incidences of inflammatory diseases of ear and sinuses, degenerative changes in internal organs
(ii) D		Egg yolk, whole milk, butter, fish-liver oils	A factor in well-developed bone and teeth, calcium and phosphorus metabolism	Rickets (in children) Osteomalacia (in adults), bone demineralization
(iii) E		Seeds of plants, eggs, lettuce, spinach, meat	A factor in normal gestation in rats	Sterility in rats
(iv) K		Wide distribution, especially green leaves	A factor in normal functioning of liver and normal clotting time	Delayed clotting time
(2) Water Soluble				
(i) B ₁ (Thiamine)		Whole-grain cereals, legumes, eggs, pork	A factor in normal carbohydrate metabolism. Maintenance of normal appetite, digestion, absorption	Beriberi, polyneuritis, shunted growth in children, lowered appetite, intestinal motility
(ii) B ₂ (Riboflavin)		Milk, eggs, green vegetables, liver, heart	A factor in tissue respiration	Dermatitis, pellagra, welldescribed lesions
(iii) Niacin		Liver, milk, poultry products	Essential in metabolic processes that release energy	Low nutritional level
(iv) B ₆ (Pyridoxine)		Whole-grain cereals, yeast, milk, eggs, pork, liver, legumes	A factor in normal metabolism of fats, amino acids	Dermatitis (experimental Pellagra in rats), Nervousness, irritability, insomnia
(v) B ₁₂ (Cyanocobalamin)		Liver, kidney, meat, milk, cheese	A factor in Red Blood Cell formation.	Anaemia
(vi) Pantothenic acid		Egg yolk, kidney, liver, yeast, bean, meat, heart	Essential for synthesis of acetyl coenzyme A, metabolism of fats, carbohydrates and certain aminoacids	Rarely occurs in man
(vii) Folic acid		Fresh green leafy vegetables, liver, legumes	A factor in functioning of enzyme systems essential in metabolic processes-growth and development.	Anaemia
(viii) Ascorbic acid		Citrus fruits (raw or canned), tomatoes (raw or canned), broccoli	A factor in Red Blood Cell formation.	Low nutritional level, fragility of capillary networks.
			Normal integrity of capillaries. Normal development of teeth and maintenance of health of gums. Healing of wounds and protection against infections.	Scurvy and possibly predisposition to dental caries and systematic type of pyorrhea.
			Normal cellular chemistry of all tissues.	

Food :

Vitamin

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.

SUMMARY

Performs the following activities :

- (a) Acts as body building material.
- (b) Provides energy.
- (c) Regulatory activities of the body.

Vitamins :

- (1) Fat soluble vitamins e.g. Vitamins A, D, E, K.
- (2) Water soluble vitamins e.g. Vitamins C, B₁, B₂, B₆, B₁₂

QUESTIONS

1. What are vitamins ? Classify them.

2. What are the effects of Vitamin D deficiency ?

3. What is the importance of minerals in the body ?

4. Why and how does Vitamin K deficiency affect clotting of blood ?

5. Name the deficiency diseases of Vitamin A, D, E and B₁₂. Explain the sources and uses of vitamin C.

6. What is meant by a balanced diet ?

THE ENDOCRINE SYSTEM

INTRODUCTION

The endocrine system (Fig. 15.1) consists of glands which are widely separated from one another and does not possess any anatomical relationship. These glands are called ductless glands because the secretions which they produce do not leave the glands through a duct but pass directly from the cells into the blood stream. The secretions are called hormones.

The secretion of hormones by other endocrine glands is mostly controlled by the pituitary gland. Hence, it is called master-gland of the body. The release of anterior pituitary hormones follows stimulation of the gland by 'releasing factor' produced by the hypothalamus. The whole system is controlled by a negative feedback mechanism. Whenever, there is a low level of hormones in the blood, hypothalamus produces appropriate releasing factor which stimulates release of hormones by the anterior pituitary which in turn stimulates the target gland to produce and release its hormone. As a result, blood level of the hormones rises and this in turn inhibits secretion of releasing factor by the hypothalamus.

Hormones :

These are the chemical substances which are formed in one particular organ or gland and are carried by blood stream to another organ where it has an effect on the organ functions, growth and nutrition.

Important endocrine glands are as follows :

- (1) Pituitary
- (2) Thyroid
- (3) Parathyroid
- (4) Adrenal
- (5) Islets of Langerhans
- (6) Ovaries
- (7) Testes
- (8) Pineal.

The brief account of various endocrine glands, their situations, hormones they secrete and their physiological role and hyper, hyposecretion effect is given in the table titled Endocrinology.

Table 15.1 : Endocrinology (Endocrine System)

Name of Gland

Situation

Hormones

Physiological Role

Hypothalamus

ated from are also leave the am. Their rolled by f anterior ed by the echanism. produces e anterior ormones. cretion of organ or ect on the	ones they ones the n the table	the hypothalamus of brain and connected to sphenoid bone at the base of hypophyseal fossa of	(1) Anterior lobe Hormones (a) Growth hormone (G.H.) (b) Somatotrophic hormone (c) Thyrotrophic hormone (TSH) (d) Adrenocorticotrophic hormone (ACTH) (e) Gonadotrophic hormones (f) Follicle stimulating hormone (FSH) (g) Luteinising hormone (L.H.) Also named as ICSH in male (h) Lactogenic Hormone (Prolactin) (2) Posterior lobe (a) Oxytocin (b) Antidiuretic hormone (Vasopressin) (ADH) (3) Middle lobe : Unknown hormone
Hyposecretion - (i) Before puberty it leads to dwarfism. (ii) After puberty the hyposecretion causes Acromegaly in which the bone and soft tissues of organs thicken and coarsen particularly it affects the hands and skull.	(1) Hyposecretion - (i) Before puberty it stimulates growth directly and in conjunction with other hormones. It controls the growth and activity of thyroid gland and stimulates its secretion. (2) Hyperecretion - (i) Before puberty it causes Gigantism (Sheehan's disease) (ii) After puberty it causes Acromegaly in which the bone and soft tissues of organs thicken and coarsen particularly it affects the hands and skull.	It stimulates growth directly and in conjunction with other hormones. It controls the growth and activity of thyroid gland and stimulates its secretion. It stimulates the cortex of adrenal glands to produce their hormones. In female, it stimulates the ovarian follicle to produce mature ovum. In male, it stimulates the formation of spermatozoa in testes. In female, it stimulates the corpus luteum to produce progesterone. In male, it stimulates interstitial cells to produce testosterone. It has direct effect on mammary glands and with help of other hormones it stimulates mammary glands to secrete milk. It causes expulsion of placenta after the delivery. It promotes contraction of uterine muscles during the birth of baby and helps in the release of milk during breast feeding. It increases the water reabsorption by kidneys and pressor effect stimulates involuntary muscles. It is associated with growth and development of melanocytes which gives the skin its colour.	Hyperecretion of ADH decreases formation of urine. Hyposecretion result in diabetes insipidus.

Name of Gland	Situation	Hormones	Physiological Role	Hypo/Hypersecretion Effect
2. Thyroid	It is situated in the neck in front of trachea and besides the thyroid cartilage. It consists of two lobes which are connected anteriorly by the tissue called isthmus of thyroid.	(a) Thyroxine (b) Tri-iodothyronine	These are essential for mental and physical growth, for healthy skin and hair, for nerve stability, and for controlling basal metabolic rate. They influence general oxidation rate in the body.	(1) Hyposecretion – (i) In early life, mental and physical growth is retarded resulting in cretinism (ii) In adult life, hyposecretion leads to myxedema (The general metabolic rate is low, movements are lethargic, skin becomes thick and dry, the temperature is subnormal and pulse is slow). (2) Hypersecretion : It causes increase in metabolic rate, weight loss, the eye balls protrude hence called exophthalmic goitre also called graves disease.
3. Parathyroid glands	These are small glands, two on each side of thyroid gland in the neck on the posterior side.	(c) Thyrocalcitonin Parathormone	It controls the amount of calcium in the blood. It decreases the blood calcium level. It regulates the blood calcium level. It causes the release of calcium from bone into the blood. It also increase absorption of calcium from intestine. It influences the irritability of nervous tissue and muscles	(1) Hyposecretion : It causes decrease in blood calcium level (hypocalcemia). It causes the disorder described as tetany in which there is muscular twitching particularly in hands and feet. (2) Hypersecretion : The balance of calcium is disturbed, calcium in the bone decreases which results in bone disease. Calcium is deposited in kidneys causing renal stone and kidney failure.
4. Adrenal glands	The two adrenal glands are situated on the upper pole of each kidney	1. Adrenal Cortex (a) Glucocorticoids Hydrocortisone and Corticosterone (b) Mineralo corticoids - Aldosterone	They control and regulate carbohydrate metabolism are responsible for changing glycogen to glucose. They also influence metabolism of fats and proteins. They promote protein anabolism and shift carbohydrate metabolism to fat metabolism. It maintains electrolyte balance in the body. It causes reabsorption of sodium in the kidneys.	(1) Hyposecretion : The patient becomes wasted and gradually weakens. The kidneys fail to conserve sodium, which therefore is excreted in too large amounts (Addison's disease). (2) Hypersecretion : It causes cushings syndrome and virilism in the adult female.

Name of Gland	Situation	Hormones	Physiological Role	Hypo/Hypersecretion Effect
5. Islets of Langerhans	These cells are irregularly distributed throughout the pancreas	(c) Sex hormones Androgen, Progesterone 2. Adrenal Medulla : Adrenaline, noradrenaline (a) Insulin (b) Glucagon	They are responsible for development and maintenance of secondary sexual characters in male and female. It prepares body for fight. It dilates bronchi, blood vessels to skeletal muscles and pupil. It constricts blood vessels to the skin. It increases breakdown of glycogen to glucose. It reduces blood glucose level, enables glucose to enter cells, promotes conversion of glucose to glycogen, promotes storage of fat and promotes synthesis of protein. It raises blood glucose level, converts glycogen to glucose in liver and promotes gluconeogenesis. Acts by maintaining nutrition and mature size of female reproductive organs. Sensitizes the mucous membrane of the uterus, so that it responds to the contact of the developing ovum and assists in implantation. Influences the development of secondary sex characteristics in the male. It may be associated with the development of gonads by influencing the release of gonadotrophic hormones from anterior lobe of pituitary gland.	Hypersecretion : Increases blood pressure. Hyposecretion : Decreases blood pressure. Hyposecretion : Deficiency results in hyperglycemia. There is an increase in the blood sugar level, loss of weight, skin, mouth, tongue becomes dry and there is increase in the rate of breathing (Glucose is passed in urine (Diabetes mellitus)). Excessive ovarian function produces precocious puberty. Diminished ovarian function characterized by late onset of menstruation, faulty development of genital organs, delayed menstruation. The tendency to become obese after castration.
6. Ovaries (2) in female	One on each side of uterus, attached to the broad ligament and below the uterine tubes.	(a) Oestrogen (b) Progesterone		
7. Testes (2) in male	In scrotum	Testosterone		
8. Pineal gland	Situated near the corpus collosum in the brain	Unknown		

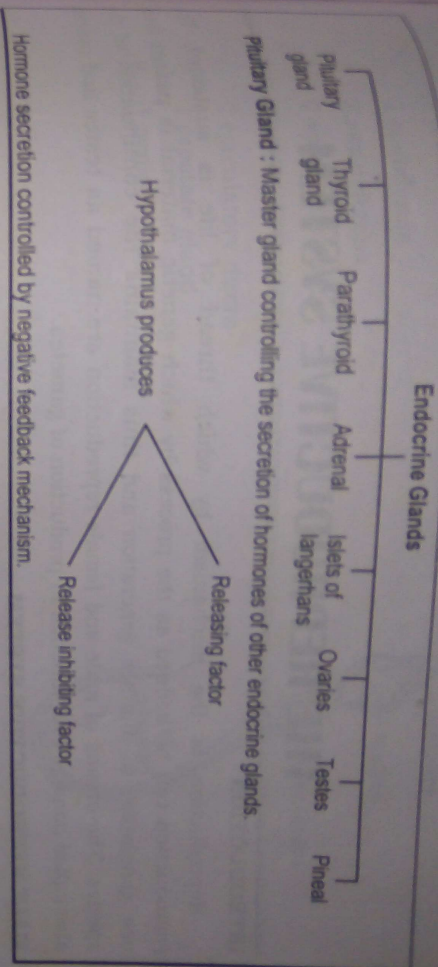
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Hormone

Pituitary gland

Human Anatomy

SUMMARY



QUESTIONS

1. What do you mean by endocrine gland? Define the term hormone. List the endocrine glands with their locations.
2. What is the simplest way in which secretion of a hormone may be controlled?
3. Which gland is called master gland? Why?
4. What hormone enhances and prolongs sympathetic effect?
5. Describe in short hyperthyroidism and hypothyroidism.
6. Point out the difference between diabetes mellitus and diabetes insipidus.
7. What are the hormones that control blood calcium level?
8. What is mineralocorticoid? Why is it so called?
9. Outline the action of vasopressin on the kidney.
10. Summarise the hyposecretion and hypersecretion effects of pituitary gland.
11. Name the hormones from adrenal cortex and mention their functions.

THE REPRODUCTIVE SYSTEM

INTRODUCTION

Reproduction is the mechanism by which thread of life is sustained. The reproduction can be defined as the process by which genetic material is passed from one generation to another generation and thus maintains the continuation of the species. The organs of male and female reproduction are named as testes and ovaries also called *gonads*, and function in production of gametes.

MALE REPRODUCTIVE SYSTEM

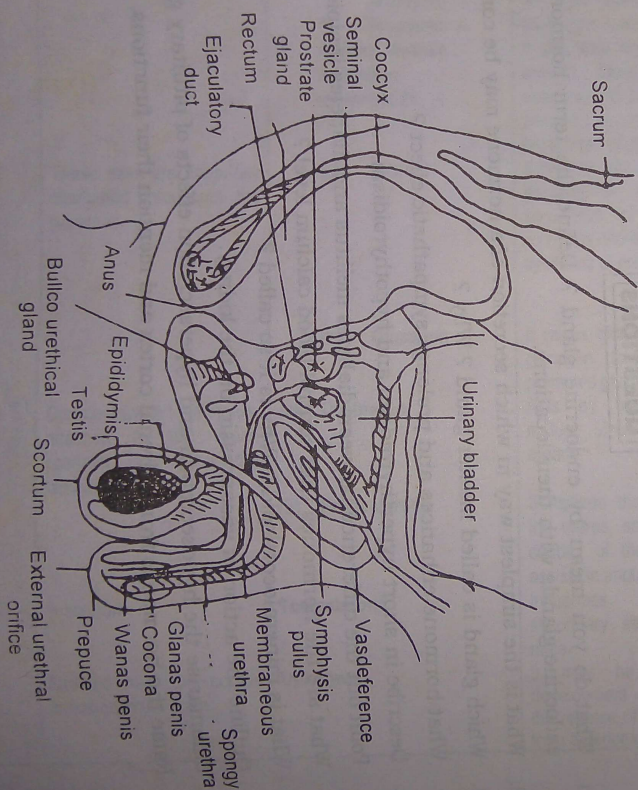


Fig. 16.1

(16.1)

Scrotum

It lies in the scrotum. It is a sac-like structure which contains the testes. It is composed of two layers of skin and contains a network of blood vessels and nerves.

1.

endocrine glands, the testes, which produce and secrete male sex hormones (testosterone) and also produce sperm cells. The testes are located in the scrotum, a sac-like structure that hangs outside the body. The scrotum is composed of two layers of skin and contains a network of blood vessels and nerves.

2.

The epididymis is a coiled mass of tubules that sits on top of the testis. It is responsible for storing and maturing sperm cells. The epididymis is composed of three parts: the head, body, and tail.

It consists of the following organs :

1. 2 testes
2. 2 epididymis
3. 2 vas deferens
4. 2 spermatic cords
5. 2 seminal vesicles
6. 2 ejaculatory ducts
7. 1 prostate gland
8. 1 penis

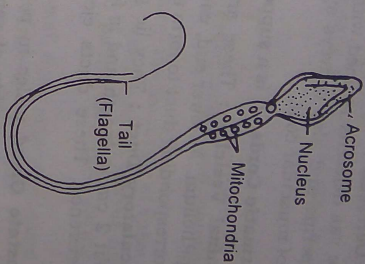


Fig. 16.2

Scrotum :

It lies below the symphysis pubis, in front of upper part of thighs and behind the penis. It is a cutaneous pouch, consisting of loose skin and divided into two components each of which contains testes, suspended by spermatic cord. The muscle of scrotum either contracts or relaxes in response to cold or warmth in order to maintain optimal temperature for formation of spermatozoa.

1. Testes : The testes are reproductive organ of males which is one of the endocrine gland. These are about 5 cm in length, 2.5 cm in diameter and weighs about 10 to 15 gm. These are surrounded by three layers of tissue. The outermost is covered by serous membrane tunica vaginalis. Internal to tunica vaginalis is dense layer of white fibrous tissue tunica albuginea which extends inward and divides the testes into numerous internal compartments called lobules. A group of 200 to 300 cells combine and form a seminiferous tubules lined by germinal epithelial cells that produce sperms by spermatogenesis. In between germinal cells, there are cells of sertoli, which provide nourishment and attachment for developing sperms. There is also realisation that sertoli cells maintain blood testes-barrier, which is important as sperms and developing cells, produce surface antigens which are recognised as foreign particle and body thus destroys the same because of immune response. It is also postulated that sertoli cells has a capacity to synthesize steroids i.e. oestradiol. Between seminiferous tubules are clusters of interstitial endocrinocytes (i.e. interstitial cells of Leydig) which secrete male hormone testosterone which controls the development, growth and maintenance of the male sex organ and their secondary sex character.

The innermost layer of testes is tunica vasculosa which consists of a network of capillaries supported by delicate connective tissue.

2. Epididymis : The sperms are transported out of testes into a tube called epididymis. It is a comma shaped organ, that lies along the posterior border of testes. Functionally, it is the site of sperm maturation which takes about 10 to 14 days. During

this period, sperm undergoes complete maturation, under the influence of testosterone, thereby spermatozoa becomes mobile and capable of fertilizing ovum.

3. Vas Deferens : This is continuation of epididymis. They get dilated to form ampulla. The vas deferens is lined with pseudostratified epithelium and its function is storage of sperms and also conveys sperms from epididymis to urethra by peristaltic contraction of muscular coat.

4. Spermathecal Cords : It is a supporting structure of male reproductive system.

5. Seminal Vesicles : These are two small fibromuscular pouches lined with columnar epithelium. At lower end, each seminal vesicle opens into a short duct which joins with corresponding duct to form an ejaculatory duct.

6. Ejaculatory Duct : They lie posterior to urinary bladder, 2 in number. Each duct is about 2 cm in length and is formed by the union of duct from seminal vesicle and vas deference. These ducts eject spermatozoa into prostatic urethra prior to ejaculation.

7. Prostate Gland : Lies in pelvic cavity. They secrete an alkaline milky fluid which neutralises the acidity of semen and vaginal secretions and thereby greatly increases motility and fertility of spermatozoa. The prostate gland slightly increases from birth to puberty.

The paired bulbourethral or Cowper's glands are about size of peas, located beneath prostate. The bulbourethral gland secretes an alkaline substance that protects sperm by neutralizing the acidic environment of the urethra and sexual intercourse.

Penis : It consists of root and body. It is used to introduce spermatozoa into vagina. The vascular changes result in erection which is a parasympathetic effect after which follows ejaculation which is sympathetic reflex during which smooth muscle sphincter at base of urinary bladder is closed and thus urine is not expelled during ejaculation.

The expanded portion at the tip of penis is called glans penis which is farther covered by skin called foreskin or prepuce. The penis is supplied by autonomic and somatic nerves.

Constituent of Semen (Alkaline pH 7.20 - 7.60) : Semen is the fluid ejaculated during intercourse from urethra. It consists of :

- Spermatozoa.
- A viscid fluid secreted by seminal vesicle which helps to nourish spermatozoa.
- A thin lubricating fluid produced by prostate gland.
- Mucus secreted by lining of glands.
- Antibiotic seminal plasmin which has the ability to destroy a number of bacteria.

Puberty in Males : Occurs between the age group 10 to 14 years. LH from anterior pituitary stimulates interstitial cells of testes to increase the production of testosterone which influences the following characters :

- Growth of muscles and marked increase in height and weight.
- Enlargement of larynx and voice 'breaks'.
- Growth of hair on face, chest, abdomen and pubis.

FEMALE

The
for expl

Ext
followi
(a)

- (a)
- (b)
- (c)
- (d)
- (e)

- (4) Enlargement of penis, scrotum and prostate gland.
- (5) Production of sperms.

FEMALE REPRODUCTIVE SYSTEM

The female reproductive organs also called genitalia are divided into two categories for explanation purpose :

- (a) External genitalia.
- (b) Internal genitalia.

External Genitalia : These are collectively called vulva and consists of the following :

- (a) Labia majora are the two large folds which form the boundary of vulva. They are composed of skin and fat, muscular tissue, blood vessels, nerves and a large number of sebaceous glands. It is about 3 inches long and during puberty, hairs grow on lateral aspect of labia majora.
- (b) The nymphae or labia minora are the two small folds of skin situated between the upper part of labia majora. The labia contains erectile tissue.
- (c) The clitoris is homologous to penis in male, situated anteriorly in vestibule and contains erectile tissue.
- (d) **Hymen :** It is a thin layer of mucous membrane and is perforated centrally to allow the menstrual discharge to drain away. An abnormal absence of perforation is described as imperforate hymen.
- (e) Greater vestibular gland (Bartholin's gland) lie in labia majora one on each side near vaginal opening and secrete mucus that prevents vulva from drying.

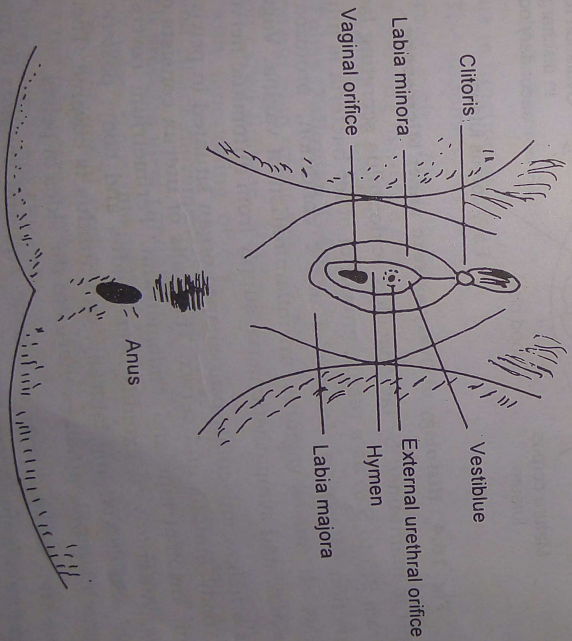


Fig. 16.3 : External Genital in Female

Internal Organs : These lie in pelvic cavity and consists of vagina, uterus, uterine tubes and two ovaries.

Vagina : It is fibromuscular tube lined with stratified epithelium, supplied with blood vessels and nerves and connecting the external and internal organs of reproduction. It extends from vestibule to uterus.

It consists of three layers. They are :

- (1) Outer covering of areolar tissue,
- (2) Middle layer of smooth muscles, and
- (3) Inner lining of squamous epithelium.

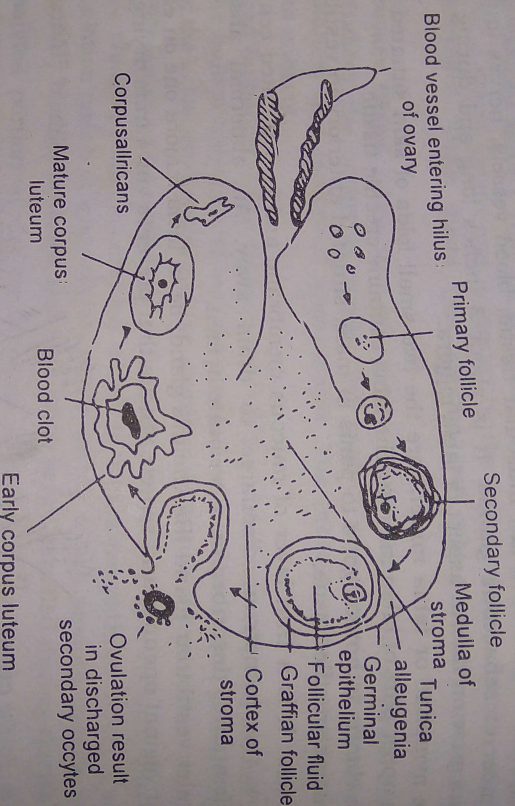


Fig. 16.4 : Histology of Ovary as seen under Microscope

The acidic pH is maintained by lactobacillus acidophilus secreting lactic acid which maintains pH from 3.5 to 5.0; as a result, growth of other bacteria is inhibited which is a protective function of vagina. In spite of acidic condition, protozoa trichomonas vaginalis grows which causes vaginitis, an inflammation of vagina. Vagina consists of both parasympathetic and sympathetic nerve supply from autonomic nervous system.

Uterus : It is a hollow muscular, pear-shaped organ situated in pelvis. It consists of three parts viz., body, fundus and cervix. The walls of uterus consists of three layers viz., perimetrium, myometrium and endometrium. Perimetrium covers most of the surface of uterus. Anteriorly, it extends over fundus and body; posteriorly it extends over fundus, body and cervix, and laterally, only fundus is covered. There is a double fold of ligament which laterally attaches uterus to the sides of pelvis.

Myometrium is the thickest layer of uterine wall and consists of mass of smooth muscle fibres. Endometrium consists of columnar epithelium and contains a large number of mucus secreting tubular gland.

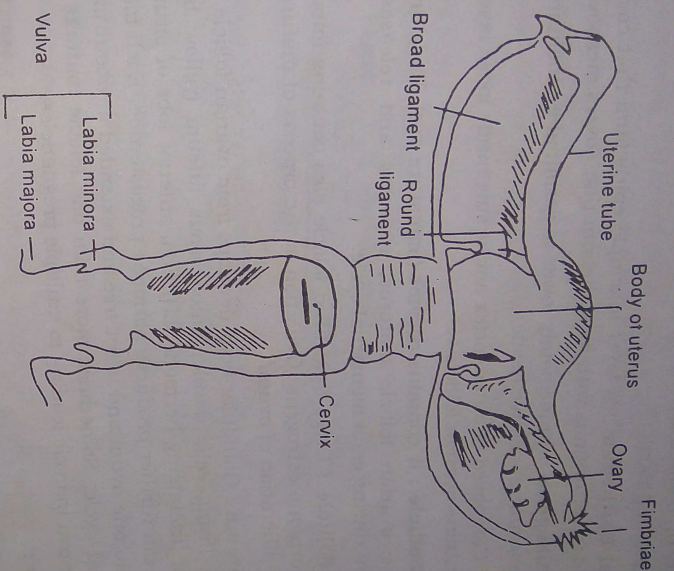


Fig. 16.5 : Female Reproductive System (Genital Organ-Vagina Section)

The uterus is functionally a place where embryo grows and develops until the time of delivery. The endometrium is prepared for the reception of fertilized ovum during each menstrual cycle. Also during pregnancy, the size of uterus increases to accommodate growing foetus. When cervix is fully dilated, the mother assists the birth of a baby by holding her breath.

Uterine Tubes (Fallopian Tubes) : These are muscular tubes and are four inches in length and extend from upper side of uterus to ovary. The end of each tube has a finger like projection called fimbriae. The longest of this is ovarian fimbriae which is in close association with functioning of ovary. They convey ovum from ovary to uterus by peristalsis and ciliary movement with the help of ciliated membrane. Also it secretes mucus which provides ideal condition of movement of ova and sperms. Fertilization of ovum usually takes place into uterine tube and then the zygote moves into uterus. During birth control, one of sterilization method called tubectomy, the principle utilized is that either the two uterine tubes are totally removed, or their open ends are ligated. As a result, the ovum is not allowed to reach uterus for fertilization.

Ovaries : These, also called female gonads, are the homologous to testes in males. They are two in number and are maintained in position by series of ligaments and by

double layer fold of peritoneum called mesoovarian. Microscope reveals that ovary consists of the following parts :

- (a) **Germinal Epithelium** : A layer of simple epithelium that covers the surface of ovary and is continuous with mesothelium that covers mesoovarian.
- (b) **Tunica Albuginea** : Immediately lower to germinal epithelium and is a capsule of collagenous connective tissue.
- (c) **Stroma** : Composed of outer cortex and it surrounds loose layer of medulla. The cortex contains ovarian follicle.
- (d) **Ovarian Follicle** : It contains oocytes (immature ova). But during child bearing years, one ovarian follicle matures, ruptures and releases its ovum into peritoneum during each menstrual cycle.
- (e) **Graafian Follicle** : Large fluid filled follicle also contains immature ovum and secretes hormone estrogens. Ovulation is the process of maturation of graafian follicle and liberation of ovum.
- (f) **Corpus Luteum** : Glandular body develops from ovarian follicle. After ovulation, the follicle lining cells develop into corpus luteum (yellow body) under the influence of luteinising hormone (LH) from anterior lobe of pituitary gland. The corpus luteum further produces hormone progesterone. Each month one follicle develops into one ovum and is set free and extended at about middle (day 14th) of menstrual cycle. Sometimes more than one follicle matures thus releasing two or more ova in cycle leading to multiple pregnancies.

Functions of Ovary :

- (a) **Production of ova by ovulation**. During this matured graafian follicle breaks and liberates ova. When graafian follicle ruptures, a little bleeding occurs and a clot is formed in the cavity of follicle, and cells which have yellow coloured appearance, grow into this clot and form corpus luteum as specified earlier.
- (b) **Production of oestrogen**.
- (c) **Production of progesterone**.

Puberty in Females : Following features are observed :

- (a) Uterus, uterine tubes and ovaries reach maturity.
- (b) Menstrual cycle and ovulation begins.
- (c) Breast develop and enlarge.
- (d) Pelvic hair begins to grow.
- (e) Increase in growth rate and widening of pelvis.

Menstrual Cycle : It is defined as a series of changes in endometrium of a non-pregnant female. Parallel to menstrual cycle is ovarian cycle which is monthly series of events associated with maturation of an ovum. It is a hormonal control and controlled by regulating factors from hypothalamus called gonadotropin releasing hormone (Gn RH).

It stimulates anterior pituitary to release following hormones :

- (1) Follicle stimulating hormone (FSH) which promotes maturation of ovarian follicle and secretion of oestrogen leading to ovulation.
- (2) *Luteinising Hormone (LH)* : Stimulates development of corpus luteum and secretes progesterone.

Phases of menstrual cycle are divided into :

Proliferative phase : 10 days

Secretory phase : 14 days

Menstrual phase : 4 days

Proliferative Phase : It is characterized by release of oestrogen. During this, endometrium gets proliferated and it gets renewed. In this period also, graafian follicle is maturing and this phase lasts for ten days and is terminated when ovulation occurs and oestrogen production is inhibited.

Secretory Phase : Immediately after ovulation, the cells lining ovarian follicle are stimulated by LH to develop corpus luteum which further produces progesterone. Under the influence of progesterone, the endometrium becomes oedematous and secretory glands produce an increased amount of watery mucus which is also called luteal phase. If the implantation of fertilized ovum occurs, then endometrium grows further and then the menstrual cycle is interrupted during the period of lactation. If ovum is not fertilized, the cycle enters in the next phase.

Menstrual Phase : It is characterized by periodic discharge of 25 to 65 ml of blood, tissue fluid, mucus, and epithelial cells. It is caused by sudden reduction in oestrogen and progesterone and lasts for approximately four to five days. During menstrual phase, ovarian cycle is also in operation and primary follicle begins its development. At birth, each ovary contains 200,000 follicles each consisting of primary ovum surrounded by single epithelium. Towards the end of menstrual phase, about 20 primary follicles develop into secondary follicle which consists of secondary ova. The production of oestrogen by secondary follicle elevates the level of oestrogen in blood. Although 20 follicles begin development, each cycle, usually one, attains maturity and the others die out. Also, placenta which is developed during pregnancy, produces oestrogen, progesterone and gonadotrophins. The placenta is an organ which provides foetus with nutritional material, oxygen, antibodies. Antibodies transported are IgM type of antibodies which helps in natural passive immunity in foetus.

Menopause : It is the period which occurs between age group of 45 and 55 years marking the end of child bearing period. This is due to ovaries normally become less responsive to FSH and LH stimulation and is characterised by -

- (a) The breast shrink.
- (b) Sex organ atrophy.
- (c) Pelvic hair become sparse.
- (d) Sweating, palpitation, causing discomfort and disturbances of the normal sleep pattern.

SUMMARY**Male Reproductive System :**

- 2 Testes
- 2 Epididymis
- 2 Vas deferens
- 2 Spermatic cords
- 2 Seminal vesicles
- 2 Ejaculatory ducts
- 1 Prostate gland
- 1 Penis

Female Reproductive System :

- 2 ovaries
- 2 uterine tubes
- 1 uterus
- 1 vagina

Puberty : It is the age at which the reproductive organs start functioning.

Menstrual Cycle :

- Proliferative Phase
- Secretory Phase
- Menstrual Phase

Menopause : It is the end of child bearing period in women.

QUESTIONS

1. Define the terms : (a) Reproduction (b) Puberty (c) Menstruation (d) Menopause
2. Draw and label the male reproductive system.
3. Draw and label the female reproductive system.
4. Describe the functions of (a) Testes and (b) Ovaries.
5. What is menstruation ? Describe in detail the phases of menstruation.
6. Describe in detail the structure and functions of testes.
7. Describe in detail the structure and functions of ovaries.



NIRALI PRAKASHAN

Abhyudaya Pragati, 1312 Shivaji Nagar, Off J.M. Road,
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