Introduction

Anatomy is the study of structure of human body. Study of anatomy helps in understanding the functions of body. Different aspects included in anatomy are Histology, Osteology, Myology, Arthrology and Neurology etc. Histology is study of tissues. Osteology is study of bones. Myology is study of muscles. Arthrology is study of joints. Neurology is study of nerves and nervous system. Understanding the functions of body different aspects included in anatomy help in reproduction to human anatomy.
4) Abduction: It is the movement taking the limb away from the midline.

5) Rotation: It is the movement around the central axis involving 360°.

6) Medial rotation: Rotation towards the medial direction is called medial rotation.

7) Lateral rotation: Rotation towards the lateral direction is called lateral rotation.

8) Flexion: It is the movement involving flexion, abduction, extension, and adduction, occurring in sequence.

Summary

Anatomy is the science dealing with the structure of the body. The subject matter includes Histology, Osteology, Myology, Arthrology, Neurology, etc. Various terms describing the human body are: Median line, medial, lateral, superior, inferior, anterior, posterior, proximal, distal, superficial, deep, etc. Terms describing the movements of the body are: Flexion, extension, adduction, abduction, rotation, medial rotation, lateral rotation, circumduction, etc.

Essay Questions

1) Define Anatomy and write the introduction of Anatomy.

2) Define Anatomy and describe its importance and relevance.

Short Answer Questions

1) Define anatomy and mention various subjects that enrich anatomy.

2) Write the definitions of:
   a) Histology
   b) Osteology.

3) What are:
   a) Myology
   b) Arthrology
   c) Neurology?

4) Explain terms:
   a) Median line, medial and lateral
   b) Superior and inferior
   c) Anterior and posterior
   d) Proximal and distal
   e) Superficial and deep

5) Define the movements:
   a) Flexion
   b) Extension
   c) Abduction
   d) Adduction
   e) Rotation
   f) Medial rotation
   g) Lateral rotation
   h) Circumduction

12) Define the term 'abduction' in medical language.

11) Explain the term 'rotation' in anatomy.

10) Define the terms of abduction and adduction.

9) Define the movements of flexion and extension.

8) Explain the terms: superficial and deep.

7) Give the definitions of: proximal and distal.

6) Write the definitions of: anterior, posterior, proximal, distal, superior, inferior, superior, and inferior.

1) Define anatomy and mention various subjects which enrich anatomy.
2. CELL and TISSUES

Cell is the smallest and basic structural and functional unit of living matter. It is capable of carrying life processes independently.

Properties of cell:
- Irritability
- Conductivity
- Contractility
- Absorption
- Excretion
- Growth and reproduction
- Motility
- Secretion

Types of cells of body:
- Somatic cells
- Gonadal cells

Somatic cells are diverse cells which make up somatic structures of body. They are two types of cells in body:
- (1) Somite cells
- (2) Conal cells

Gonadal cells are gametes which can unite to form new individual.

Structure of cell:
- Cell has a nucleus, which can unite to form new individual.
- Types of cells of body: They are two types of cells in body:
  - (1) Somite cells
  - (2) Conal cells

Every cell comprises the following parts:
- Cytoplasm
- Cell wall
- Nucleus

Cytoplasm:
- Cytoplasm is the mass of living matter between cell wall and nucleus.
- It contains stored foods, secretion granules, pigments and crystals. These are called cytoplasmic inclusions.
- Stored foods are carbohydrates, fats, proteins, minerals and vitamins.
- Pigments are two types - endogenous and exogenous.
- Endogenous pigments are haemoglobin and melanin.
- Exogenous pigments are carotenoids, dusts (carbon) and minerals (silver, lead etc.).

Cytoplasmic organelles are:
- Endoplasmic reticulum
- Golgi apparatus
- Mitochondria
- Lysosomes
- Ribosomes
- Centrosomes

Endoplasmic reticulum:
- Endoplasmic reticulum is a system that continues with infoldings of cell membrane and interlaces with the interior of cell.
- It is divided into two types:
  - Smooth ER
  - Rough ER
- Smooth ER is a network of smooth tubules.
- Rough ER is the site of synthesis of steroid hormones and glycogen.

Cell wall:
- It is also called as plasma membrane or cell membrane.
- Cell wall separates protoplasm from the environment.
- It consists of two layers: an inner and outer layer.
- The outer layer is the cuticle layer of cell, which is insoluble in water.
- The inner layer is the inner lining of cell membrane.
- The cell wall is composed of various substances like carbohydrates, proteins, cellulose, chitin, etc.
- It is about 80 A thick.
- It consists of a trilaminar structure of phospholipid bilayer sandwiched between two dense layers of protein layers.
- The outer layer of cell wall is the cuticle layer, which is insoluble in water.
- The inner layer is the inner lining of cell membrane.

Cytoplasm is the mass of living matter between cell wall and nucleus.
- It is capable of carrying life processes independently.
Functions of rough ER:
1) Protein synthesis
2) Translation of language of nucleic acids.

Golgi apparatus:
It is shaped like a network of threads.
Functions:
1) Synthesis of various secretions.
2) Storage of enzymes, ascorbic acid, and some other substances.

Mitochondria:
They are granular, filamentous, or rod-shaped solid bodies. They vary in size from 0.5 to 5 microns. They are surrounded by a trilaminar double membrane. The inner membrane remains folded to form partitions called cristae.
Functions:
1) Mitochondria are called powerhouses of cells. They supply 95% of a cell's energy requirements. In the presence of oxygen, the Kreb's cycle runs in mitochondria with the help of respiratory enzymes. These enzymes are called flavoproteins and cytochromes. These enzymes help in oxidative phosphorylation. They provide the energy for ATP synthesis. Mitochondria are called powerhouses of cells.
2) Synthesis of RNA and DNA.

Lysosomes:
They are digestive organs of cells. They contain powerful hydrolytic enzymes.
Functions:
1) Breaking down particles taken into the cell and digestion.
2) Autolysis
3) Phagocytosis
4) Killing of cells (planned way)
5) Cell division.

Ribosomes:
They are scattered throughout the cytoplasm singly or in groups.
Functions:
Protein synthesis.

Centrosome:
Centrosomes contain centrioles.
Function:
Centrioles control the orientation of spindle fibers. Centrioles are closely related to spindle formation during cell division (mitosis).

Differentiation of cellular mass:
Differential arrangement of cellular mass is evident when cells arrange in three layers. They are (1) Ectoderm (2) Mesoderm (3) Endoderm.

Ectoderm:
It gives rise to epithelial tissue, including bone, nerve, muscles, and connective tissue. The mesoderm gives rise to the bone and cartilage of the skeleton, the muscles of the body, and the connective tissue.

Mesoderm:
It contains various cell types and is the source of muscle, connective tissue, and blood cells.

Endoderm:
It gives rise to epithelial tissue, such as the lining of the digestive tract and lungs.

Differential arrangement of cellular mass:
Differentiation of cellular mass is evident when cells arrange in three layers. They are (1) Ectoderm (2) Mesoderm (3) Endoderm.

Ectoderm:
It gives rise to epithelial tissue, including bone, nerve, muscles, and connective tissue. The mesoderm gives rise to the bone and cartilage of the skeleton, the muscles of the body, and the connective tissue.

Mesoderm:
It contains various cell types and is the source of muscle, connective tissue, and blood cells.

Endoderm:
It gives rise to epithelial tissue, such as the lining of the digestive tract and lungs.

Differentiation of cellular mass:
Differential arrangement of cellular mass is evident when cells arrange in three layers. They are (1) Ectoderm (2) Mesoderm (3) Endoderm.

Ectoderm:
It gives rise to epithelial tissue, including bone, nerve, muscles, and connective tissue. The mesoderm gives rise to the bone and cartilage of the skeleton, the muscles of the body, and the connective tissue.

Mesoderm:
It contains various cell types and is the source of muscle, connective tissue, and blood cells.

Endoderm:
It gives rise to epithelial tissue, such as the lining of the digestive tract and lungs.

Differentiation of cellular mass:
Differential arrangement of cellular mass is evident when cells arrange in three layers. They are (1) Ectoderm (2) Mesoderm (3) Endoderm.

Ectoderm:
It gives rise to epithelial tissue, including bone, nerve, muscles, and connective tissue. The mesoderm gives rise to the bone and cartilage of the skeleton, the muscles of the body, and the connective tissue.

Mesoderm:
It contains various cell types and is the source of muscle, connective tissue, and blood cells.

Endoderm:
It gives rise to epithelial tissue, such as the lining of the digestive tract and lungs.

Differentiation of cellular mass:
Differential arrangement of cellular mass is evident when cells arrange in three layers. They are (1) Ectoderm (2) Mesoderm (3) Endoderm.

Ectoderm:
It gives rise to epithelial tissue, including bone, nerve, muscles, and connective tissue. The mesoderm gives rise to the bone and cartilage of the skeleton, the muscles of the body, and the connective tissue.

Mesoderm:
It contains various cell types and is the source of muscle, connective tissue, and blood cells.

Endoderm:
It gives rise to epithelial tissue, such as the lining of the digestive tract and lungs.
Tissues

Tissue is defined as a group of cells of similarity in structure, function and

1. Epithelial tissue
2. Connective tissue
3. Muscular tissue
4. Nervous tissue

Epithelial tissue gives rise to epithelium of digestive and respiratory tract, thyroid, parathyroid, thymus and bladder.

Epithelial tissue is defined as a group of cells of similarity in structure, function and genesis.

Basic tissues of human body: Human body contains following types of tissues.

1) Epithelial tissue
2) Connective tissue
3) Muscular tissue
4) Nervous tissue

Epithelial tissue gives covering to other tissues by forming epithelial membrane.

Functions of epithelial tissue are -
1) Protection to underlying surfaces
2) Providing surface for absorption
3) Secretory activity
4) Excretion

Types of Epithelial tissue:

1) Simple epithelium - consisting of single layer of cells
2) Compound epithelium - consisting of multiple layers of cells

Simple Epithelial tissue:

1) Simple epithelium - consisting of single layer of cells
   a) Squamous or pavement epithelium - consisting of single layer of flat cells.
   b) Cuboidal epithelium - consisting of single layer of cuboidal cells of same
   c) Columnar epithelium - consisting of single layer of columnar cells
   d) Ciliated epithelium - consisting of single layer of ciliated cells
   e) Glandular epithelium - lining the alveoli and ducts of glands

Functions of Simple Epithelial tissue:

1) Protection to underlying surfaces
2) Providing surface for absorption
3) Secretory activity
4) Excretion

Compound Epithelium:

Compound epithelium is classified into:

1) Columnar columnar epithelium - consisting of single layer of cells which are longer
2) Cuboidal columnar epithelium - consisting of single layer of cuboidal cells of same
3) Glandular columnar epithelium - lining the alveoli and ducts of glands

Functions of Compound Epithelial tissue:

1) Protection to underlying surfaces
2) Providing surface for absorption
3) Secretory activity
4) Excretion

Glands & glands:

A gland is an exocrine gland, the cells of which secrete a coating or support a coating membrane which in turn supplies secretions to epithelial membranes. Glands are divided into two types:

1) Exocrine glands
2) Endocrine glands
Transitional epithelium - consisting of four layers of cells, lying between simple epithelium and many layered stratified epithelium.

Stratified squamous cornified epithelium - consisting of many layers and horny due to deposition of keratin.

Stratified squamous non-cornified epithelium - consisting of stratified squamous epithelium, not keratinised.

Stratified columnar epithelium - consisting of several layers of columnar cells.

Stratified columnar ciliated epithelium - consisting of stratified columnar epithelium containing cilia.

Transitional epithelium is found in pelvis of kidney, ureter, urinary bladder, etc.


Stratified squamous cornified epithelium is found in skin, hairs, nails, horns, enamel of teeth, and canal walls, vagina, and cervix, etc.

Functions: 1) Protection from atmosphere 2) Protection from mechanical pressure 3) Protection from injury and friction.

Stratified squamous non-cornified epithelium is found in cornea, mouth, pharynx, oesophagus, and canal walls, vagina, and cervix, etc.

Functions: 1) Protection from atmosphere 2) Protection from mechanical pressure 3) Protection from injury and friction.

Stratified columnar epithelium is found in conjunctiva, pharynx, epiglottis, cavernous portion of urethra, etc.

Stratified columnar ciliated epithelium is found in larynx, soft palate, etc.

Connective tissue is also called mesenchymal tissue. It is developed from mesoderm. It serves the function of binding tissues together. Cells will be less and intercellular matrix will be abundant.

Several types of connective tissue are -

1. Squamous
2. Cuboidal
3. Stratified squamous non-cornified epithelium
4. Cuboidal
5. Columnar (with goblet cells)
6. Pseudostratified columnar epithelium with goblet cells
7. Stratified columnar epithelium with goblet cells
8. Pseudostratified ciliated columnar epithelium with goblet cells

Fig. 2.2
Epithelial tissues

1. Transitional epithelium
2. Columnar epithelium
3. Cuboidal epithelium
4. Stratified squamous epithelium
5. Goblet cell
6. Epithelial tissue
7. Basement membrane
8. Connective tissue
9. Gland
10. Epithelial lining

Fig. 2.3
Epithelial tissues

1. Transitional epithelium
2. Columnar epithelium
3. Cuboidal epithelium
4. Stratified squamous epithelium
5. Goblet cell
6. Epithelial tissue
7. Basement membrane
8. Connective tissue
9. Gland
10. Epithelial lining

Fig. 2.4
Epithelial tissues

1. Transitional epithelium
2. Columnar epithelium
3. Cuboidal epithelium
4. Stratified squamous epithelium
5. Goblet cell
6. Epithelial tissue
7. Basement membrane
8. Connective tissue
9. Gland
10. Epithelial lining
a) Areolar tissue  
b) Adipose tissue  
c) White fibrous tissue  
d) Yellow elastic tissue  
e) Reticular tissue  
f) Blood  
g) Hemopoietic tissue  
h) Cartilaginous tissue  
i) Osseous tissue  
j) Jelly like tissue  
k) Reticuloendothelial tissue  

Areolar tissue: It is supporting and packing tissue. It is distributed between muscular, vascular and nervous tissues. It is distributed in subcutaneous, subserous and submucous tissues. It is composed of fibres and cells. Spaces in the network of fibres is filled with ground substance. Fibres contained are white or collagenous fibres and yellow elastic fibres.

Types of cells found in areolar tissue are -
- Fibroblasts
- Histiocytes
- Basophilic cells
- Plasma cells
- Pigment cells
- Mast cells
- Lymphocytes
- Monocytes

Adipose tissue: It is also known as loose connective tissue. It contains fat inside fat cells. It is found below skin in mesentery, omentum etc. It prevents injury to organs. It gives shape to limbs. It stores energy in the form of fat. It helps in regulation of body temperature. It also serves to maintain circulation and blood pressure by its elastic recoil.

White fibrous tissue: It is made of white fibres formed by fibroblasts. These fibres are non branching and present in bundles. They are present in tendons and ligaments of limbs. It is made of collagen.

Yellow elastic tissue: It is another variety of fibrous tissue. It is yellow in colour. Fibres are thicker, bundles are wavy but follow a straight course. Fibres appear angular. Fibres are made of elastin. It is most resistant to many chemicals. It is digested by pancreatin.

Reticular tissue: Reticular tissue is similar to white fibrous tissue with certain differences. Reticular tissue is widely distributed and forms basement membrane of many epithelia. It is found in spleen, liver, lymph and bone marrow etc. Blood: Blood is fluid connective tissue of body. It is dealt in detail in Blood chapter.

Myeloid tissue: Myeloid tissue is blood forming tissue as well as phagocytic. Myeloid tissue is synonymously used for bone marrow. 'Myelos' means marrow.

Myeloid tissue is divided into two types -
- Red bone marrow - Active form
- Yellow bone marrow - Inactive form

Red cells are produced in red bone marrow. In fetal life, most of the bones contain red bone marrow. In postnatal life and with advancement of age red bone marrow is located only in upper ends of humerus and femur bones of skull, thorax, vertebrae and pelvic innominate bones. Yellow bone marrow occupies the space where red bone marrow will not be present. Although half of the bone marrow (red bone marrow) is active and half is inactive in adult, active half is enormously functional.

Lymphatic tissue: Lymphatic tissue is of two types -
- Non encapsulated lymph nodes present in loose connective tissue - thymus, tonsils.
- Encapsulated lymph nodes present in lymph organs - lymph nodes, spleen.

Hemopoietic tissue: There are two types of hemopoietic tissues. They are -
- Myeloid tissue
- Erythroblastic tissue: Erythroblastic tissue is blood forming tissue as well as phagocytic.
Cartilaginous tissue: It is connective tissue, which is intermediate between fibrous tissue and osseous tissue in firmness and elasticity. Components of cartilaginous tissue are cartilage cells, matrix, and ground substance. Matrix is made of chondrocytes and chondromucoid and chondroalbumoid. Chondromucoid on hydrolysis gives chondroitin sulphate.

Cartilaginous tissue is divided into three classes:

a) Hyaline cartilage
b) Fibrocartilage
c) Elastic cartilage.

Hyaline cartilage: It is made of cartilaginous cells and clear homogenous ground substance. Cartilage cells are also called hyaline cartilage. They are present in the articular end of bones.

Fibrocartilage: This type of cartilage has greater tensile strength with flexibility and rigidity. It can stand with shearing forces. It is found in intervertebral discs, menisci of knee joints, mandibular joints, pubic symphisis, linings of tendon, grooves in bones etc.

Elastic cartilage: It is between fibrous tissue and osseous tissue. It is yellow in colour and contains elastic fibres. It differs from hyaline cartilage as it contains large number of elastic fibres in the matrix. It is distributed in external ear, epiglottis, eustachian tube and some laryngeal cartilages.

Jelly-like connective tissue: It is an embryonic form of areolar tissue. Cells are large fibroblasts. A few macrophages and lymphocytes are also present. Ground substance is mucin in nature. It is found in umbilical cord, placenta, Wharton’s jelly of umbilical cord, tissues of eye, and vitreous humour of eye ball in adult life.

Reticuloendothelial tissue: It possesses various types of connective tissue cells, widely distributed in body. Main functions are phagocytosis, antibody formation, and destruction of foreign substances.

Osseous tissue: Osseous tissue consists of bone. It is the hardest connective tissue of body. It is composed of bone cells and intercellular ground substance. There are three types of bone cells. They are - Osteoblasts, osteocytes and osteoclasts. Interstitial fluid of bone is fluid-like ground substance. There are two types of proteins called osteopontin and osteocalcin. These proteoglycans are also called bone cement. Bone matrix is made of collagenous fibres and ground substance. There are two types of proteoglycans called chondrocalcin and chondrocalcin. These proteoglycans are also called bone cement and ground substance. Hydroxyapatite: It is made of collagenous fibres and ground substance.

(1) Hyaline cartilage
(2) Fibrocartilage
(3) Elastic cartilage

Cartilaginous tissue is divided into three classes.
There are two types of bone tissues according to density and hardness. They are:

1) Compact bone tissue.
2) Spongy bone tissue.

Compact bone tissue forms the outer layer of all bones and the shaft of long bones. Spongy bone tissue is found in the inner parts of flat bones, the rounded ends of long bones, and the body of vertebrae.

Bone is covered by a layer called periosteum, which has two layers: an outer layer and an inner layer called cambium. The cambium is osteogenic, meaning it produces osteoblasts and osteoclasts.

The endosteum is the lining membrane of the marrow cavity. It also has osteogenic and hematopoietic functions.

Bursae are small sacs of connective tissue with synovial fluid. They act as cushions to relieve pressure in moving parts.

Bone cavity is the hollow space inside the bone, which contains bone marrow. Bone marrow is divided into two types: red bone marrow and yellow bone marrow. Further details on bone marrow can be found in the myeloid tissue section.

Types of muscles:

- **Skeletal muscles** are voluntary muscles, under the control of the will. They are striated and show striations under the microscope.
- **Cardiac muscles** are found in the heart and are not striated.
- **Smooth muscles** are involuntary muscles, not under voluntary control. They are not striated.

**Composition of Bone**

Ossification refers to the process of forming bone from pre-existing tissues.

Types of bones:

- **Skeletal bones** are attached to the skeleton and are under the control of the will.
- **Spongy bone** is found in the inner parts of flat bones and is composed of bone tissue with a different density and hardness.
- **Compact bone** is the outer covering of skeletal muscles and is also osteogenic.

Muscular Tissue

Types of muscles based on striation:

1) Striated muscles
2) Non-striated muscles

Striated muscles have cross striations, while non-striated muscles do not.

Types of muscles based on control:

1) Skeletal muscle
2) Voluntary muscles
3) Cardiac muscle
4) Smooth muscle

Skeletal muscles are under voluntary control, while cardiac and smooth muscles are involuntary.

Types of muscles based on distribution:

1) Skeletal muscles
2) Cardiac muscles
3) Smooth muscles

Skeletal muscles are attached to bones and are under voluntary control. They show striations and are striated.

Cardiac muscles are found in the heart and do not show striations.

Smooth muscles are involuntary and do not show striations.

Fig. 2.4

Types of muscular tissue

Skeletal muscular tissue
Cardiac muscular tissue
Visceral muscular tissue
Muscle is divided into fasciculi. Each fasciculus contains muscle fibres. Each fibre is covered by endomysium. Histology of skeletal muscle fibres: Skeletal muscle fibres are cylindrical. They are elongated with several nuclei. Dimensions of skeletal muscle fibres are 1-40 x 0.01 - 0.1 mm². Sarcolemma is the transparent cell wall of muscle fibre. Myofibrils are bundles of myofilaments embedded in sarcoplasm inside the plasmalemma. Sarcoplasm contains sarcosomes (mitochondria), small Golgi apparatus, and nuclei. Neurone fibres (nerve fibres) arise from neurones originating in the nervous system. Neurone is the basic functional and structural unit of nervous system. Neuron is a cell that gives rise to neurone fibres and nerve cell bodies. Neurone fibres include dendrites, axon, and axon hillock. Neurone fibres pass through the nervous system and interact with muscles to cause movement. Neurone fibres are made of neurone fibres with myelin sheaths, axon hillock, and dendrites.

2) Neurone fibres (also called processes of neurone or nerve cells)

3) Neurone fibres (also called processes of neurone or nerve cells)

Neurone fibres: Two types of neurone fibres (also called processes of neurone or nerve cells) are present in neurone fibres, axons, and dendrites. Dendrites carry impulses from other neurones and carry them towards neurone fibres. Axon fibres carry impulses from neurone fibres and carry them away from neurone fibres. Dendrites and axon fibres are the parts of neurone fibres that receive and transmit impulses, respectively. Neurone fibres are divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neurone fibres are also divided into two main types: dendrites and axon fibres. Dendrites receive impulses from other neurones and pass them to the neurone fibre, while axon fibres transmit impulses away from the neurone fibre to other neurones or muscles. Neuron: Neuron is the basic functional and structural unit of nervous system. Neuron: Neuron is the basic functional and structural unit of nervous system. Neuron: Neuron is the basic functional and structural unit of nervous system. Neuron: Neuron is the basic functional and structural unit of nervous system. Neuron: Neuron is the basic functional and structural unit of nervous system. Neuron: Neuron is the basic functional and structural unit of nervous system. Neuron: Neuron is the basic functional and structural unit of nervous system. Neuron: Neuron is the basic functional and structural unit of nervous system. Neuron: Neuron is the basic functional and structural unit of nervous system. Neuron: Neuron is the basic functional and structural unit of nervous system. Neuron: Neuron is the basic functional and structural unit of nervous system.
are called myelinated fibres and fibres not covered by myelin are called non
myelinated fibres. Function of myelin sheath is insulation of nerve fibre. Nodes of
Ranvier are points of absence of myelin in the myelinated nerve fibres. Nonmyelinated nerve fibres do not have myelin. Nodes of Ranvier is the homogeneous nucleated covering over somatic and
autonomic nerve fibres outside C.N.S. Neurilemma is special type of interstitial tissue giving support and insulation. They are divided into- astrocytes, - oligodendrocytes
(or oligodendroglia) and microglia.

Fibres of peripheral nerve trunks are divided into bundles. Individual fibres
are held together by loose connective tissue called endoneurium. Each bundle is
covered by a sheath called perineurium. Epineurium is the tough enclosure of
whole nerve trunk.

Essay Questions
1. Write the structure of cell with diagram.
2. Explain Properties of cell.
3. Classify the tissues of human body and write about epithelial tissue.
4. What are different types of connective tissue? Explain myeloid tissue and
   osseous tissue.
5. Add note on Muscular tissue.
6. Discuss in brief about nervous tissue. Draw diagram of neuron.

Short Answer Questions
1. What is cell?
2. Mention the properties of cell.
3. Explain trilaminar structure of cell wall.
4. List cytoplasmic organelles.
5. Write the functions of a) Smooth E.R. b) Rough E.R.
6. What are the functions of Golgi apparatus?
7. Write about mitochondria.
8. What are a) Lysosomes and b) Ribosomes?
9. Write about endoplasmic reticulum.
10. Write about lysosomes.
11. What are the first evidence of differentiation of cellular mass.
15. Write about columnar epithelium.
16. Write the distribution of cuboidal epithelium.
17. Write the description of stratified epithelium.
18. Define the classes of compound epithelium.
19. What is tissue?
20. Write the functions of (a) Stratified squamous non-cornified epithelium.

21. What are the types of cells found in areolar tissue?

22. Write about white fibrous tissue.

23. Explain Myeloid tissue.

24. What are different types of cartilaginous tissue?

25. Write about Reticuloendothelial tissue.

26. What are types of bone tissue?

27. Give the T.S. of bone.

28. Mention different types of muscular tissues.

29. Explain a) Epimysium  
   b) Perimysium  
   c) Endomysium.

30. Define a) Sarcolemma  
    b) Sarcoplasm.

31. Differentiate between skeletal and cardiac muscular tissues.

32. Mention types of nerve processes.

33. What is nervous tissue?

34. Write different types of matters of nervous tissue.

35. Explain Histogenesis of nervous tissue.

36. What are parts of Neurone?

37. Mention types of nerve processes.

38. Define a) Recepting processes of nerve cell.  
    b) Discharge processes of nerve cell.

39. Write about Soma.

40. Define a) Myelinated nerve fibres.  
    b) Non-myelinated nerve fibres.

41. Explain (a) Endoneurium  
    (b) Perineurium  
    (c) Epineurium.

42. White adipose tissue.

43. While adipose tissue of bone.

44. What are different types of cartilaginous tissue?
DIGESTIVE SYSTEM AND HEPATO-BILIARY SYSTEM

Digestive system consists of gastrointestinal tract and various glands attached. Length of the tract is about 8-10 metres. It starts with mouth and ends with anus.

Various parts of the digestive tract:
- Mouth
- Pharynx
- Oesophagus
- Stomach
- Small intestine
- Large intestine
- Rectum
- Anus

Accessory organs of the digestive tract:
- Teeth
- Three pairs of salivary glands
- Liver and biliary system
- Pancreas

Mouth:
- It is the first part of the digestive tract. It opens through upper and lower lips. Roof of the mouth is called as palate. It is dome shaped. Front part of the roof is hard palate and back part is soft palate. Walls of the mouth are lined by mucous membrane and form floor of the mouth. Roof of the mouth is thickened at the back as pillar of fauces. Tonsils are present on either side of the mouth. Uvula is a fold of mucous membrane hanging from the soft palate.

Teeth:
- Man is provided with two sets of teeth in his life. Deciduous teeth or primary teeth are 10+10 in number. They erupt through the gums during first and second years of life. Second set starts replacing the first set at about sixth year and process is complete by twenty fifth year. Permanant teeth remain until old age and are called as permanent teeth. There are 16+16 in number. Four types of teeth are there:
  1) Incisor teeth
  2) Canine teeth
  3) Premolar teeth
  4) Molar teeth

Structure of tooth:
- Each tooth consists of three parts: root, neck, and crown. Root is embedded in the alveolus of maxilla or mandible. Neck is the constricted part between root and crown. Crown is the part projecting beyond the gum. Tooth is composed of three substances: dentine, enamel, and cementum.

Figure 3.1

Figure 3.2

HEPATO-BILIARY SYSTEM

Digestive system consists of gastrointestinal tract and various glands attached.
Dentine forms major part of tooth. Enamel is the outer covering of crown. It is the hardest substance. Cementum is in the neck. It is as hard as bone.

Crowns of Incisor teeth are chisel shaped. Crowns of canine teeth are large and conical. Crowns of premolar teeth are bicuspid and almost circular. Crowns of Molar teeth are broad and tetracispid or penta cuspid.

Salivary glands:
There are three pairs of salivary glands in the mouth. They are:
1) Parotid glands: They are the biggest salivary glands. One gland is present on each side of the face near the temple. It is responsible for the production of serous saliva.
2) Submandibular glands: They are just below the tongue and are the largest of the three glands. They produce mucous saliva.
3) Sublingual glands: They are the smallest salivary glands. They lie under the tongue and open into the mouth through several openings.

Pharynx:
Pharynx lies between mouth and oesophagus. It is divided into:
1) Nasopharynx
2) Oropharynx
3) Laryngopharynx
It serves as a common passage for both digestive and respiratory systems. It is lined by mucosa.

Oesophagus:
It is muscular tube extending between pharynx and stomach. It lies in both thoracic and abdominal cavities. It passes from thoracic cavity into abdominal cavity through the oesophageal opening of the diaphragm. Oesophagus is a muscular tube with two sphincters: the cardiac sphincter at the beginning and the pyloric sphincter at the end.

Cross section of oesophagus shows similar structure as remaining part of alimentary canal. It shows the following layers:
1) Mucous coat
2) Muscular coat
3) Submucous coat

Stomach:
Stomach is the most dilated part of digestive tract. It is J-shaped. It is situated between the end of the oesophagus and beginning of the small intestine. It lies below the diaphragm in the abdominal cavity. Its major part is to the left of the midline. It distends when it is filled with food. Average capacity of stomach is 1.5 L in an adult.

It has two surfaces, two curvatures, three parts, and two sphincters. They are as follows:
1) Anterior surface
2) Posterior surface
3) Lesser curvature
4) Greater curvature
5) Fundus
6) Body
7) Pylorus

Two sphincters of stomach are:
1) Cardiac sphincter (at the beginning)
2) Pyloric sphincter (at the ending)
Histologically, it shows
1) Outer serous coat, which is the visceral layer of peritoneum.
2) Muscular coat made of three layers consisting of longitudinal, circular, and oblique unstripped muscle fibres.
3) Submucous layer made of loose areolar tissue.
4) Macous membrane containing numerous folds called rugae.

Small intestine:
- It is a coiled tubular structure about 6 metres long, extending from pyloric sphincter to its junction with large intestine at the ileo-caecal valve.
- It lies within the curves of large intestine in the central and lower parts of abdominal cavity.
- It is divided into three parts: 1) Duodenum 2) Jejunum 3) Ileum.

Duodenum:
- It is the first part of small intestine.
- Duct from gall bladder, bile duct and pancreat pancreatic duct open into duodenum through hepatopancreatic ampulla.
- It lies within the curves of large intestine in the central and lower parts of abdominal cavity.

Jejunum:
- Jejunum is the upper two-fifth part of remainder of the small intestine.
- It contains goblet cells in addition to villi. They produce mucus.
- Lining of the mucous membrane has the following three features:
  1) Mucous membrane contains lymphoid tissues consistently. Macous membrane contains lymphoid follicles. They are most numerous in the lower part of ileum.
  2) It contains fine hair like projections called villi, each contains a lymph vessel called lacteal and blood vessels.
  3) It is supplied with glands of simple tubular type. They secrete intestinal juice.

Ileum:
- It contains solitary lymphatic follicles.
- It is 1.5 metres in length.
- It is continuous with ascending colon.
- It contains Brunner glands.

Large intestine:
- It contains submucous glands of simple tubular type. They secrete mucus.
- Lining of the mucous membrane has the following three features:
  1) The mucous membrane contains goblet cells in addition to villi. They produce mucus.
  2) Muscular coat with an external layer of longitudinal fibres and a thin internal layer of circular fibres.
  3) Submucous membrane contains blood vessels, lymph vessels and nerves (submucosa).
  4) Muscularis externa (Muscularis mucosa) and a thick internal layer of circular fibres.
  5) Submucous layer made of loose areolar tissue.
  6) Serous coat formed of peritoneum (Serosa) and a thin external layer of longitudinal fibres.
It is a vegetative organ in the human body.

3) Ascending colon:
It ascends upwards from the cecum and in front of the right kidney. It turns to the left below the liver. It forms into the transverse colon.

4) Transverse colon:
It lies transversely below the duodenum. It is in contact with the ascending and descending colon. It extends from the transverse colon and merges with the sigmoid colon.

5) Sigmoid colon:
It lies in the pelvis. Hence it is also called pelvic colon. It is situated at the left. It forms loops. It has a mesentery of its own. It continues below with the rectum.

Structure of large intestine:
Large intestine has the same structure as small intestine. The difference is: longitudinal muscles are arranged in three bands. Mucous membrane does not contain villi.

Rectum:
It is a straight tube lying in the lower posterior part of the pelvic region. It is 12 cm long and extends from the sigmoid colon to the anal canal. It is situated behind the urinary bladder, prostate and seminal vesicles. It has a valve called the internal sphincter. It contains many blood vessels and seminal vessels in and behind its walls. It is covered with smooth muscle. It continues below with the anal canal.

Anus:
Rectum ends in the anus. It is about 1 inch long. It is a small canal guarded by two sphincters. The internal sphincter is involuntary and the external sphincter is voluntary.

Peritoneum:
Peritoneum is a serous membrane. In males it is a closed sac lining the abdomen. In females, the free ends of the uterine tubes open into the peritoneal cavity. Peritoneum consists of two layers:
1) Parietal layer lining the walls of the abdominal cavity.
2) Visceral layer covering the abdominal organs.

Peritoneal cavity: It is the space between parietal and visceral layers of peritoneum.

1) Parietal layer lining the walls of the abdominal cavity.
2) Visceral layer covering the abdominal organs.

Peritoneum consists of two layers:
1) Parietal layer lining the walls of the abdominal cavity.
2) Visceral layer covering the abdominal organs.

Peritoneum is a serous membrane. It lines the abdominal wall.
Lobules of liver: Liver consists of a large number of hepatic lobules. They are hexagonal in shape. Diameter of each lobule is about 1 mm. Each lobule has a small central intra-lobular vein, which is a tributary of a hepatic vein. Portal canals are present around the edges of lobules. Each portal canal contains:
1) Interlobular vein.
2) A branch of the hepatic artery.
3) A small bile duct. These three structures together are called the portal triad.

Lobules consist of liver cells. These cells are large cells. Liver cells are arranged in sheets of one cell thick. Between these sheets are small veins with many anastomoses and small bile ducts. These bile ducts are called canaliculi.

Surfaces of liver:
1) Superior surface.
2) Inferior surface.
3) Anterior surface.
4) Posterior surface.

- Superior surface of liver is in contact with the inferior surface of the diaphragm.
- Inferior surface faces the abdominal viscera.
- Anterior surface is separated from the ribs and costal cartilages by the diaphragm.
- Posterior surface lies between the vertebral column and the lower end of the oesophagus.

Blood supply:
- Hepatic arteries supply oxygenated blood to the liver. They arise from the abdominal aorta. The right hepatic artery usually arises from the coeliac trunk.
- Portal veins carry blood from the intestines to the liver. They are the large veins that contain only venous blood. They form the portal system.
- The hepatic veins carry impure blood from the liver into the inferior vena cava.

Biliary system:
The biliary system consists of:
1) Common hepatic duct
2) Cystic duct
3) Common bile duct
4) Gall bladder
5) Pancreas

Gall bladder:
The gall bladder is a pear-shaped organ situated under the liver. It consists of three parts:
1) Fundus
2) Body
3) Neck

Layers of the gall bladder:
1) Outer serous coat
2) Middle muscular coat
3) Inner mucous coat

Pancreas:
The pancreas is a soft, grey, pinkish organ situated behind the stomach. It is about 12 to 15 cm long. It lies transversely across the posterior abdominal wall. The pancreas has three parts:
1) Head
2) Body
3) Tail

Portal veins:
- Portal veins are formed by the union of the splenic vein and the superior mesenteric vein. They drain the intestines and empty into the portal venous system of the liver.

Pancreatic duct:
The pancreatic duct joins the common bile duct at the head of the pancreas and opens together into the duodenum at the hepato-pancreatic ampulla.

Pancreatic lobules:
Pancreatic lobules are formed by the union of common pancreatic duct and exocrine ducts. Each lobule consists of a number of alveoli, which secrete digestive enzymes. These enzymes include trypsinogen, amylase, and lipase.

Islets of Langerhans:
Islets of Langerhans are present in the pancreas. They are composed of two types of cells: alpha cells and beta cells.

Alpha cells constitute 25% of the total number of islets, while beta cells constitute 75% of the total number of islets.

Summary:
The digestive system consists of the gastrointestinal tract and various glands attached to it. These glands include the mouth, pharynx, oesophagus, stomach, small intestine, large intestine, rectum, and anus. They are responsible for functions such as ingestion, deglutition, and digestion.
absorption and excretion. Accessory organs are teeth, salivary glands, liver and biliary system, pancreas etc.

**Essay Questions**

1) Define Digestive system. What are the various parts? Describe anatomy of mouth.
2) Describe the anatomy of pharynx and oesophagus. Draw the diagrams.
3) Write the anatomy of stomach. Draw the diagram and label.
4) What are different parts of small intestine? Explain their anatomy with figures wherever required.
5) Write the anatomy of large intestine. Draw the figure and label.
6) Explain the anatomy of liver. Draw figure.
7) Explain gall bladder and pancreas.

**Short answer questions**

1) List the main parts of Digestive system.
2) Mention different accessory organs of digestive system.
3) What are the various parts of salivary glands? How many pairs of salivary glands are there? What are they?
4) What are the locations of salivary glands.
5) Name the ducts of a) parotid glands b) submandibular glands.
6) Mention the parts of pharynx.
7) What are the layers in the structure of small intestine?
8) What are the layers in the structure of oesophagus?
9) Mention the parts of stomach.
10) Write the locations of salivary glands.
11) Name the ducts of a) parotid glands b) submandibular glands.
12) What are the layers in the structure of small intestine?
13) What are the surfaces of stomach?
14) What are the layers in the cross section of small intestine?
15) Name the cavities of stomach.
16) Write the names of sphincters of stomach.
17) List the layers of stomach.
18) Mention various parts of stomach.
19) Write the locations of salivary glands.
20) Define Rugae.
21) Write about vermiform appendix.
22) What are the lobes of liver when viewed from the inferior surface of liver?
23) What is a portal triad?
24) Define a) Laminae b) Canaliculi.
25) Name the surfaces of liver.
26) Name the parts of Biliary system?
27) Where is Gall bladder situated? What are its parts?
28) Name the layers of gall bladder.
29) Mention the locations of parts of pancreas.
30) What are islets of Langerhans?
4. RESPIRATORY SYSTEM

Definition: Respiration is defined as the process of gases exchange between body tissues and external environment.

Expiration: It is the process of expelling the air from the lungs.

Inhalation: It is the process of filling the lungs with air.

Respiration: It is the sum of expiration and inhalation.

Expiration process: They are similar operations at the back and lead into pharynx.

Inhalation process: They are the operations which lead in.

4.1. Nose

It is the part of respiratory system through which air is inhaled or exhaled.

1. External nose: It is the visible part of the nose. It is formed by the two nasal bones.
2. Nasal cavity: It is a large cavity divided by a septum. It is lined with ciliated respiratory mucosa.
3. Anterior nares: They are the openings which lead in.
4. Posterior nares: They are similar openings at the back and lead into pharynx.

4.2. Paranasal sinuses

They are the cavities in the bones that are connected to the nasal cavity.

1. Frontal sinus: It is located above the orbit.
2. Sphenoid sinus: It is located in the sphenoid bone.
3. Ethmoid sinus: It is located in the ethmoid bone.
4. Maxillary sinus: It is located in the maxillary bone.

4.3. Pharynx

It lies below the nasal cavity and above the larynx.

1. Nasopharynx: It lies between the nasal cavity and oropharynx.
2. Oropharynx: It lies between the nasopharynx and laryngopharynx.
3. Laryngopharynx: It lies behind the larynx.

4.4. Larynx

It is the part that connects the pharynx with the trachea.

1. Thyroid cartilage
2. Cricoid cartilage
3. Arytenoid cartilages
4. Epiglottis

4.5. Bronchi

They are the tubes that carry air from the trachea to the lungs.

1. Trachea
2. Bronchi
3. Bronchioles
4. Alveoli

4.6. Alveolar ducts

They are the small tubes that connect the bronchioles to the alveoli.

4.7. Alveoli

They are the tiny air sacs in the lungs.

4.8. Epiglottis

It is a flap of tissue that covers the larynx and prevents food from entering the respiratory system.

4.9. Vocal cords

They are the muscles that control the sound of speech.

4.10. Lungs

They are the organs that exchange oxygen and carbon dioxide with the blood.

4.11. Pleura

They are the membranes that cover the lungs and line the chest cavity.
thyroid cartilage is lined with stratified epithelium. Lower part is lined with ciliated epithelium.

**Cricoid cartilage:** It lies below the thyroid cartilage. Its shape is like a signet ring. It is broad at the back. It is lined with ciliated epithelium.

**Arytenoid cartilages:** They are a pair of small pyramids. They are made of hyaline cartilage. They are located on the broad portion of cricoid cartilage. Vocal ligaments are attached to them. Chink is the gap between vocal ligaments.

**Epiglottis:** Epiglottis is a leaf-shaped cartilage. It is attached to the inside of the front wall of the thyroid cartilage. During swallowing, the larynx moves upwards and forward and its opening is occluded by the epiglottis.

**Trachea:** It is also called the windpipe. It is a cylindrical tube. It is about 11 cm in length. It begins at the lower end of the pharynx. It divides into two bronchi at the level of the fifth thoracic vertebra. It is made of sixteen to twenty C-shaped incomplete cartilages. They are connected by fibrous tissue at the back. It is lined by ciliated epithelium. Ciliated epithelium contains goblet cells which secrete mucus.

**Bronchi:** Trachea divides into right and left bronchi. Trachea and bronchi, combinedly are inverted Y-shaped. Right bronchus leads into the right lung and left bronchus leads into the left lung. Right bronchus is shorter than left bronchus. Right bronchus is also wider.

**Bronchioles:** They do not have cartilage. They are lined by cuboidal epithelium. Bronchioles become further smaller to form terminal bronchioles. Terminal bronchioles are a single layer of columnar epithelium.

**Alveoli:** They are the final terminations of each bronchiole. They contain a thin layer of epithelial cells. They are surrounded by numerous capillaries. Capillary network is the site of exchange of gases between blood and air. Alveolar sacs and alveolar ducts are part of terminal bronchioles. Alveolar sacs are always closed. Alveolar ducts are minute passages and are lined by alveolar cells. Terminal bronchioles open into alveoli. Terminal bronchioles become primary bronchi. Primary bronchi lead into secondary bronchi. Secondary bronchi lead into bronchioles. Bronchioles lead into alveolar ducts. Alveoli are lined by alveolar cells. Terminal bronchioles and alveoli are supplied by bronchial arteries and bronchial veins.

**Respiratory muscles:** Intercostal muscles and diaphragm are respiratory muscles. However, during forced respiration, sternocleidomastoid, scalene, mylohyoid, and platysma muscles also participate.

**Pleura:** It is a serous membrane covering the lungs. It contains two layers. Inner layer close to the lungs is called the visceral layer. Outer layer is called the parietal layer. Pleural fluid lies in the space between these layers.

**Hilum:** It is a triangular shaped depression on the concave medial surface of the lung. It is a site for entrance or exit of blood vessels, nerves, and lymphatic vessels. It is also a site for entrance or exit of bronchi and bronchioles.

**Lung:** It is a spongy organ concerned with respiration. It is divided into two parts. Right lung is bigger than the left lung. Each lung is divided into lobes by means of fissures. Right lung is divided into three lobes. Left lung is divided into two lobes. Each lobe is divided into segments. Each segment contains a bronchus, blood vessels, and bronchioles. Pulmonary arteries carry deoxygenated blood from the heart to the lungs. Pulmonary veins carry oxygenated blood from the lungs to the heart. Bronchial arteries carry blood to the lungs. Bronchial veins carry blood away from the lungs.
Intercostal muscles: They are two series of muscles. Thus they are 11 pairs. They are external intercostal muscles and internal intercostal muscles. They are innervated by intercostal nerves.

Diaphragm: It is a large dome shaped sheath of muscle. It separates thoracic cavity from abdominal cavity. It is innervated by phrenic nerve on each side.

Summary

Respiratory system is system consisting of parts related with respiration. Parts of respiratory system are - nose, pharynx, larynx, trachea, bronchi, bronchioles, alveolar ducts and alveoli. Alveoli are the ultimate sites of gaseous exchange. Lungs are two in number. Right lung is divided into three lobes. Left lung is divided into two lobes. Bronchi and bronchioles deliver air to alveoli. Alveoli are the ultimate sites of gaseous exchange. Diphtheria: It is a huge dome shaped sheath of muscle. It separates thoracic cavity from abdominal cavity. It is innervated by intercostal nerves.
5. CARDIOVASCULAR SYSTEM

Cardiovascular system consists of the heart and vascular system. It is a well-organized blood transport system of the body.

Anatomy of Heart

Heart lies on the left upper part of the thoracic cavity, between the two lungs and under the sternum. It is broad above and conical below.

Histology of Heart:

The heart consists of three layers -

1) Pericardium (outermost layer consisting of a) Visceral pericardium b) Parietal pericardium
2) Myocardium (middle layer made of cardiac muscle cells and interstitial cells)
3) Endocardium (innermost layer)

Pericardium forms a bag-like structure between the visceral and parietal layers.

The two ventricles are separated by the interventricular septum. The two atria are separated by the interatrial septum. The two upper chambers are called atria or auricles. Lower two chambers are called ventricles. The two upper chambers are filling chambers and ventricles are pumping chambers. Compared to atria, ventricles are thicker since they are pumping chambers. Of the two ventricles, the wall of the left ventricle is three times thicker than that of the right ventricle since the left ventricle pumps oxygenated blood to all parts of the body and the right ventricle pumps deoxygenated blood to the lungs only.

Chordae tendinae and papillary muscles:
Papillary muscles arise from the ventricular walls. Chordae tendinae attach the apical end of the valves and papillary muscles. They prevent over-dilatation of the valves during diastole.

Tricuspid valve:

Opening between the right atrium and right ventricle is guarded by the tricuspid valve. It prevents backflow of blood from the right ventricle to the right atrium during ventricular diastole.

Mitral valve:

Opening between the left atrium and left ventricle is guarded by the mitral valve. It prevents backflow of blood from the left ventricle to the left atrium during ventricular diastole.

Pulmonary trunk:

Opening between the right ventricle and pulmonary trunk is guarded by the pulmonic valve. It prevents backflow of blood from the pulmonary trunk to the right ventricle during ventricular diastole.

Aorta:

Opening between the left ventricle and aorta is guarded by the aortic valve. It prevents backflow of blood from the aorta to the left ventricle during ventricular diastole.

Blood vessels attached to heart:

1) Superior and inferior vena cavae: Carry deoxygenated blood from parts of the body to the right atrium.
2) Pulmonary artery: Carries venous blood from the right ventricle to the lungs.
3) Pulmonary veins: Carry oxygenated blood from the lungs to the left atrium.
4) Aorta: Carries oxygenated blood from the left ventricle to all parts of the body.

Blood vessels of the body:

- Trachea
- Left common carotid artery
- Left internal jugular vein
- Left subclavian artery
- Left subclavian vein
- Arch of aorta
- Pulmonary trunk
- Left auricular appendage
- Left atrium
- Left lung
- Descending branch of left coronary artery
- Apex of heart
- Diaphragm
- Cut edge of pericardium
- Inferior vena cava
- Right ventricle
- Right coronary artery
- Bronchial tube
- Right common carotid artery
- Right internal jugular vein
- Right subclavian artery
- Right subclavian vein
- Brachiocephalic (Innominate) vein
- Pulmonary artery
- Superior vena cava
- Pulmonary vein
- Right auricular appendage
- Right atrium
- Right lung
- Cut edge of pleura

Fig. 5.1: Heart

Blood vessels of the body:

- Trachea
- Left common carotid artery
- Left internal jugular vein
- Left subclavian artery
- Left subclavian vein
- Arch of aorta
- Pulmonary trunk
- Left auricular appendage
- Left atrium
- Left lung
- Descending branch of left coronary artery
- Apex of heart
- Diaphragm
- Cut edge of pericardium
- Inferior vena cava
- Right ventricle
- Right coronary artery
- Bronchial tube
- Right common carotid artery
- Right internal jugular vein
- Right subclavian artery
- Right subclavian vein
- Brachiocephalic (Innominate) vein
- Pulmonary artery
- Superior vena cava
- Pulmonary vein
- Right auricular appendage
- Right atrium
- Right lung
- Cut edge of pleura

Fig. 5.1: Heart

Blood vessels of the body:

- Trachea
- Left common carotid artery
- Left internal jugular vein
- Left subclavian artery
- Left subclavian vein
- Arch of aorta
- Pulmonary trunk
- Left auricular appendage
- Left atrium
- Left lung
- Descending branch of left coronary artery
- Apex of heart
- Diaphragm
- Cut edge of pericardium
- Inferior vena cava
- Right ventricle
- Right coronary artery
- Bronchial tube
- Right common carotid artery
- Right internal jugular vein
- Right subclavian artery
- Right subclavian vein
- Brachiocephalic (Innominate) vein
- Pulmonary artery
- Superior vena cava
- Pulmonary vein
- Right auricular appendage
- Right atrium
- Right lung
- Cut edge of pleura

Fig. 5.1: Heart
Blood vessels supplying oxygenated blood to heart: Right and left coronary arteries arising from aorta supply oxygenated blood to heart.

Blood vessels draining heart: Coronary veins bring deoxygenated blood of heart to coronary sinus, which opens directly into right atrium.

Ductus arteriosus: Ductus arteriosus is the vestigial remnant of cord-like structure which existed in fetal life between arch of aorta and pulmonary trunk. In fetal life, it bypasses pulmonary circulation. After birth, it closes, becomes obsolete and atrophies.

Septum ovale: It is crescentic mark on interatrial septum. It is closed foramen ovale that existed in fetus.

Foramen ovale: It is the opening in interatrial septum in fetal life. It avoids blood entry into lungs in fetal life. After birth, it closes and forms septum ovale.

Cardiac centres: 1) Cardio inhibitory centre is dorsal motor nucleus of vagus in medulla. 2) Cardio accelerator centre is situated in lateral horn cells of upper thoracic segments of spinal cord.

Nerve supply to heart: Sympathetic and vagus nerves supply heart.

Conducting system of heart: System of conducting impulses of cardiac contraction consists of-1) Sinoatrial node (SA node) 2) Atrioventricular node (AV node) 3) Bundle of His. 4) Right and left branches of bundle of His. 5) Purkinje fibres.

SA node: It is present in the right atrium at the posterior part of interatrial septum. It is close to the opening of coronary sinus. Cells of AV node are cardiac muscle fibres. It measures about 5x20 mm. SA node is called pacemaker of heart.

AV node: It is present at the opening of superior vena cava into right atrium. AV node is made of modified cardiac muscle fibres. It passes through interventricular septum. It is about 20 mm long. AV node is the conduction system of heart.

Nerve supply to heart: Sympathetic and vagus nerves supply heart.

Foramen ovale: It is the opening in interatrial septum in fetal life. It avoids blood entry into lungs in fetal life. After birth, it closes and forms septum ovale.

Cardio inhibitory centre is situated in lateral horn of upper thoracic segments of spinal cord.

Cardiac centres: 1) Cardio inhibitory centre is dorsal motor nucleus of vagus in medulla. 2) Cardio accelerator centre is situated in lateral horn cells of upper thoracic segments of spinal cord.

Nerve supply to heart: Sympathetic and vagus nerves supply heart.

Conducting system of heart: System of conducting impulses of cardiac contraction consists of-1) Sinoatrial node (SA node) 2) Atrioventricular node (AV node) 3) Bundle of His. 4) Right and left branches of bundle of His. 5) Purkinje fibres.

SA node: It is present in the right atrium at the posterior part of interatrial septum. It is close to the opening of coronary sinus. Cells of AV node are cardiac muscle fibres. It measures about 5x20 mm. SA node is called pacemaker of heart.

AV node: It is present at the opening of superior vena cava into right atrium. AV node is made of modified cardiac muscle fibres. It passes through interventricular septum. It is about 20 mm long. AV node is the conduction system of heart.

Ductus arteriosus: Ductus arteriosus is the vestigial remnant of cord-like structure which existed in fetal life between arch of aorta and pulmonary trunk. In fetal life, it bypasses pulmonary circulation. After birth, it closes, becomes obsolete and atrophies.

Septum ovale: It is crescentic mark on interatrial septum. It is closed foramen ovale that existed in fetus.

Foramen ovale: It is the opening in interatrial septum in fetal life. It avoids blood entry into lungs in fetal life. After birth, it closes and forms septum ovale.

Cardiac centres: 1) Cardio inhibitory centre is dorsal motor nucleus of vagus in medulla. 2) Cardio accelerator centre is situated in lateral horn cells of upper thoracic segments of spinal cord.

Nerve supply to heart: Sympathetic and vagus nerves supply heart.

Conducting system of heart: System of conducting impulses of cardiac contraction consists of-1) Sinoatrial node (SA node) 2) Atrioventricular node (AV node) 3) Bundle of His. 4) Right and left branches of bundle of His. 5) Purkinje fibres.

SA node: It is present in the right atrium at the posterior part of interatrial septum. It is close to the opening of coronary sinus. Cells of AV node are cardiac muscle fibres. It measures about 5x20 mm. SA node is called pacemaker of heart.

AV node: It is present at the opening of superior vena cava into right atrium. AV node is made of modified cardiac muscle fibres. It passes through interventricular septum. It is about 20 mm long. AV node is the conduction system of heart.

BLOOD VESSELS

Arteries subdivide into arterioles. Arterioles end in capillaries. Capillaries are single layered thin vessels. Capillaries unite to form venules. Venules unite to form veins. Veins are the vessels carrying deoxygenated blood (except pulmonary veins).

Histology of arteries and veins: Arteries and veins consist of three layers-1) Tunica externa -outer layer made of fibrous tissue and elastic tissue and also called tunica adventitia. 2) Tunica media - middle layer of plain muscles and network of elastic fibres. 3) Tunica interna -innermost layer made of endothelial cells and also called tunica intima.

Anatomy of vascular system: Blood vessels constitute vascular system. There are two types of blood vessels: Arteries and veins. Arteries and veins consist of layers called tunica adventitia, tunica media, tunica interna. Arteries are the vessels carrying oxygenated blood to tissues (except pulmonary arteries). Veins are the vessels carrying deoxygenated blood to heart. Arteries subdivide into arterioles. Arterioles end in capillaries. Capillaries are single layered thin vessels. Capillaries unite to form venules. Venules unite to form veins. Veins are the vessels carrying deoxygenated blood to heart. Arteries and veins consist of three layers-1) Tunica externa - outer layer made of fibrous tissue and elastic tissue and also called tunica adventitia. 2) Tunica media - middle layer of plain muscles and network of elastic fibres. 3) Tunica interna - innermost layer made of endothelial cells and also called tunica intima.

Histology of arteries and veins: Arteries and veins consist of three layers-1) Tunica externa - outer layer made of fibrous tissue and elastic tissue and also called tunica adventitia. 2) Tunica media - middle layer of plain muscles and network of elastic fibres. 3) Tunica interna - innermost layer made of endothelial cells and also called tunica intima.

Anatomy of vascular system: Blood vessels constitute vascular system. There are two types of blood vessels: Arteries and veins. Arteries and veins consist of layers called tunica adventitia, tunica media, tunica interna. Arteries are the vessels carrying oxygenated blood to tissues (except pulmonary arteries). Veins are the vessels carrying deoxygenated blood to heart. Arteries subdivide into arterioles. Arterioles end in capillaries. Capillaries are single layered thin vessels. Capillaries unite to form venules. Venules unite to form veins. Veins are the vessels carrying deoxygenated blood to heart. Arteries and veins consist of three layers-1) Tunica externa - outer layer made of fibrous tissue and elastic tissue and also called tunica adventitia. 2) Tunica media - middle layer of plain muscles and network of elastic fibres. 3) Tunica interna - innermost layer made of endothelial cells and also called tunica intima. Arteries and veins consist of three layers-1) Tunica externa - outer layer made of fibrous tissue and elastic tissue and also called tunica adventitia. 2) Tunica media - middle layer of plain muscles and network of elastic fibres. 3) Tunica interna - innermost layer made of endothelial cells and also called tunica intima.
Tunica media in arteries is thicker than in veins.

Valves of Veins: Valves are present in veins, particularly in veins of lower limbs. They prevent backflow of blood from heart. These valves are semilunar pocket valves made by local folding of intima.

Vasovasorum: They are blood vessels supplying blood to large arteries and veins of above 0.1 mm diameter.

Sinusoids: Sinusoids and sinusoidal capillaries are not true capillaries. They have larger size than capillaries. Continuous endothelial lining is absent.

Arteries of the Body

1) Aorta, arising from left ventricle of heart is the main artery of body. It consists of three parts. They are-
   a) Ascending aorta, giving off two branches
      i) Right coronary artery
      ii) Left coronary artery. Coronary arteries supply blood to heart.
   b) Arch of the aorta, supplying blood to head and upper limbs.
   c) Descending aorta, divided into-
      i) Thoracic aorta, supplying blood to wall of chest cavity and viscera.
      ii) Abdominal aorta, supplying blood to wall of abdominal cavity and viscera.

2) Branches of the aorta:
   a) Right subclavian artery - gives rise to:
      i) Innominate artery - dividing into:
         a) Common carotid artery
         b) Right subclavian artery
      ii) Left common carotid artery
      iii) Left subclavian artery.
   b) Left subclavian artery - supplies:
      i) Thoracic aorta, supplying blood to wall of chest cavity and viscera.
      ii) Abdominal aorta, supplying blood to wall of abdominal cavity and viscera.

Branches of the internal carotid artery:
   a) Anterior cerebral artery, supplying brain
   b) Middle cerebral artery, supplying brain
   c) Ophthalmic artery, supplying eyes
   d) Facial artery, supplying face
   e) Occipital artery, supplying temporal parts in skull.

Arteries of the human body

Branches of the external carotid artery:
   a) Internal carotid artery
   b) Common carotid artery
   c) External carotid artery
   d) Maxillary artery
   e) Facial artery
   f) Occipital artery

Branches of the internal carotid artery:
   a) Anterior cerebral artery
   b) Middle cerebral artery
   c) Ophthalmic artery

Fig. 5.3
Circle of Willis: The Circle of Willis is formed by union of anterior and posterior inferior cerebellar arteries. It connects the anterior and posterior cerebral arteries, and is composed of the following arteries:

1. Left anterior cerebral artery
2. Right anterior cerebral artery
3. Left middle cerebral artery
4. Right middle cerebral artery
5. Left posterior cerebral artery
6. Right posterior cerebral artery

Veins of the Head, Neck, and Upper Limbs:
Veins of the head, neck, and upper limbs form a complex network of veins that drain blood into the subclavian veins. The subclavian veins drain blood from the upper limbs and are formed by the union of the cephalic and basilic veins in the axilla. They join with the axillary vein to form the brachiocephalic veins, which empty into the superior vena cava.

Course of Thoracic Aorta: The thoracic aorta begins as the descending aorta and continues as the thoracic aorta above the diaphragm. Branches of the thoracic aorta include:

1. Coeliac plexus
2. Superior mesenteric artery
3. Renal arteries
4. Final branches

The coeliac plexus divides into:
1. Hepatic artery - supplies liver
2. Gastric artery - supplies stomach
3. Splenic artery - supplies spleen

The superior mesenteric artery divides into:
1. Superior rectal artery
2. Inferior mesenteric artery

The renal arteries supply the kidneys.

Veins of the Body:
Veins of the body drain into the brachiocephalic veins and subclavian veins, which join to form the subclavian veins. The subclavian veins drain blood from the upper limbs and are formed by the union of the cephalic and basilic veins in the axilla. Radial and ulnar veins of the forearms join with those of the upper arms. Radial veins collect blood from the hand and forearm, while ulnar veins collect blood from the hand and forearm, and empty into the brachial artery. The brachial artery then continues as the axillary artery, which empties into the subclavian vein.

Veins of the Thorax:
In the thorax, the superior vena cava collects blood from the head, neck, and upper limbs, while the inferior vena cava collects blood from the lower limbs and abdomen. The inferior vena cava drains into the right atrium of the heart via the right atrial appendage.
Veins of the human body

1. Systemic circulation

- Oxygenated blood from the left ventricle of the heart is circulated to all parts of the body through the aorta.
- Deoxygenated blood from all parts of the body returns to the right atrium through the superior and inferior vena cava.

2. Pulmonary circulation

- Oxygenated blood from the lungs is circulated through the pulmonary arteries.
- Deoxygenated blood returns to the heart through the pulmonary veins.

Types of circulation

- Systemic circulation or greater circulation
- Pulmonary circulation or lesser circulation

There are mainly two circulatory networks in the body. They are:

- Systemic circulation: Circulates oxygenated blood to all parts of the body.
- Pulmonary circulation: Circulates oxygenated blood to the lungs for gas exchange.
Pulmonary circulation: Deoxygenated blood reaching the right atrium goes into the right ventricle and from here, it reaches the lungs through the pulmonary artery. After losing CO₂ in the lungs, it gets oxygenated and reaches the left atrium of the heart through pulmonary veins. This is called pulmonary circulation or lesser circulation.

Coronary circulation: It is the arterial network supplying oxygenated blood to the heart itself and draining deoxygenated blood from it. The right and left coronary arteries arise from the ascending aorta. They supply oxygen-rich blood to the heart muscles. Coronary veins, which collect deoxygenated blood from the heart, join the coronary sinus, which opens into the right atrium of the heart. This circulatory network of the heart is called the coronary circulation.

Portal circulation: It is the circulatory network through the liver. Portal vein and hepatic artery bring blood to the liver. Portal vein carries blood into the liver through the superior mesenteric and splenic veins. From the liver, oxygenated blood flows through the hepatic veins, which empty into the inferior vena cava. This circulatory network of the liver is called the portal circulation.

Summary

The cardiovascular system consists of the heart and the vascular system. The heart contains four chambers: the upper two (atria or auricles) and the lower two (ventricles). The histology of the heart includes cardiac muscle fibers and Purkinje fibers. The vascular system consists of arteries, arterioles, capillaries, venules, and veins. Arteries and veins have three layers: the tunica externa, tunica media, and tunica interna. The aorta is the main artery of the body, and the superior and inferior vena cava are the main veins of the body. The coronary arteries supply oxygen-rich blood to the heart, and the coronary veins carry deoxygenated blood from the heart. The portal circulation is the system through the liver, which receives blood from the spleen and pancreas. Different circulatory networks of the body, such as systemic circulation and pulmonary circulation, are essential for the proper functioning of the body.
Lymphatic System

Lymphatic system is a closed system consisting of:

1. Lymphatic capillaries
2. Lymphatic vessels
3. Lymph nodes
4. Lymph ducts

1) Lymphatic capillaries: They are fine hair-like vessels with porous walls. Their walls are formed by endothelial cells and supported by connective tissues. They arise in the tissue spaces and unite to form lymphatic vessels. Walls of the capillaries have permeability to substances of greater molecular size than the substances permeable through walls of blood capillaries. They drain into lymphatic vessels. They are fine hair-like vessels with porous walls.

2) Lymphatic vessels: They are lymphatic vessels made up of lymphatic capillaries.

6. Lymphatic System
2) Lymphatic vessels:

Lymphatic capillaries unite to form lymph vessels. They have one-sided valves. They are superficially and deeply located. They are found in skin, muscles, and several visceral organs. Lymph vessels pass through lymph nodes. They gradually increase in size. Finally, lymph collected from the body pours into right lymphatic duct and left lymphatic duct. The lymphatic vessels are connected by free anastomoses. Lymph vessels pass through lymph nodes. They gradually increase in size. Finally, lymph collected from the body pours into right lymphatic duct and left lymphatic duct. The lymphatic vessels are connected by free anastomoses.

3) Lymph nodes:

Lymph nodes are small bodies made of lymphatic tissue. They vary in size from tiny lymph nodes of lymphatic vessels to very large lymph nodes. They are important glandular structures spread at strategic points in the body. They are located both superficially and deeply. Lymphatic vessels bring lymph to lymph nodes. They divide within the node and discharge lymph. A lymph node is divided into two parts: the cortex and the medulla. The lymph nodes are named accordingly as they are located. They are:

- Cubital and axillary lymph nodes: They are situated in the arm.
- Popliteal and inguinal lymph nodes: They are situated in the leg.
- Submaxillary and cervical lymph nodes: They are situated in the neck.
- Mediastinal lymph nodes: These are present in the thorax.
- Abdominal lymph nodes: They are present in the abdomen.
- Pelvic lymph nodes: They are present in the pelvic organs.

4) Lymph ducts:

Efferent lymph vessels leaving lymph nodes pour lymph into right lymphatic duct and left lymphatic duct (thoracic duct). Thoracic duct is comparatively larger than right lymphatic duct. It begins at cisterna chyli. Cisterna chyli is a small pouch at the back of the abdomen. Lymphatic vessels from lower limbs, abdominal and pelvic organs empty into cisterna chyli and thoracic duct (thoracic duct). Thoracic duct joins into right lymphatic duct and left lymphatic duct (thoracic duct). Thoracic duct finally empties into left subclavian vein at its junction with left internal jugular vein. It is provided with uni-directional valves to prevent lymph from flowing in the wrong direction. Right lymphatic duct is smaller. It is formed by joining of lymphatic vessels from right side of the head, thorax and right upper limb at the root of neck. It joins into right lymphatic duct and empties into right subclavian vein.
enters into right subclavian vein, where it joins right internal jugular vein. Lymphatic ducts thus gather lymph from all the body and return it to bloodstream.

Spleen:
Spleen is the largest lymphoid tissue in the body. It is a bean-shaped, fist-sized organ. It is highly vascular organ. It is located in the left hypochondrium beneath the diaphragm. It is above the left kidney and descending colon and behind the stomach. It weighs about 150 g in adult human being and does not contain afferent lymphatic vessels. It is hematopoietic.

Histology of spleen:

Splenic pulp: Splenic pulp is the parenchymal tissue within the capsule of the spleen. It is divided into two types:
1) White pulp 2) Red pulp.

Splenic sinuses: Splenic sinuses are long vascular channels. They are 35 to 40 µ in diameter.

Marginal zone: It is the functional zone between white pulp and red pulp.

Tonsils:
Tonsils are well-defined organs of accumulated lymphoid tissue in the surrounding of pharynx, where nasal and oral passages unite. Tonsils do not possess afferent lymphatic vessels. They are divided into three groups
1) Palatine tonsils - covered by stratified squamous epithelium
2) Lingual tonsil - situated at the root of tongue.
3) Pharyngeal tonsils - one on each side in the median posterior wall of nasopharynx.

Thymus:
Thymus is partly endocrine gland and partly lymphoid structure. It is present in anterior and superior mediastinum of thorax. It extends from pericardium up into neck. It consists of two lobes.

Histology of thymus shows -
1) Capsule 2) Cortex & 3) Medulla

SUMMARY
Lymphatic system is a closed system consisting of lymphatic capillaries, lymphatic vessels, lymph nodes and lymph ducts. Spleen, tonsils and thymus are also lymphatic tissues. Spleen is hematopoietic organ. Splenic pulp is a parenchymal tissue within the capsule of the spleen.

Essay questions
1) Write the anatomy of lymphatic system.

Short Answer Questions
1) Define lymphatic system.
2) Explain lymphatic capillaries.
3) Describe lymphatic vessels.
4) What are a) Cubital and axillary lymph nodes. b) Mediastinal lymph nodes.
5) Mention the histological parts of lymph node.
6) Name the lymph ducts.
7) What is splenic pulp?

Q & A

Fig. 6.3
T.S. of Spleen

Histology of spleen: Histology of spleen shows -
1) Capsule 2) Trabeculae
Bones and Joints

Bones and Joints form the skeletal system of the body. There are about 206 bones in the human body. Main functions of the skeletal system are:
1) Giving support and protection to soft tissues and vital organs.
2) Giving attachment to muscles and assisting in body movements.
3) Formation of blood cells in the red bone marrow.
4) Storage of mineral salts like calcium and phosphorous.

Bone Composition:
- Water: 25%
- Ossin: 35%
- Ossinoid: 45%

Function of Bone Marrow:
- Formation of blood cells (hemopoiesis).
- Formation of bone cells (endochondral ossification).
- Functions of bone marrow include:
  - Reticuloendothelial system: Processing of blood cells.
  - Production of antibodies.
  - Storage of fat and minerals.

Types of Bones:
- Long bones
- Short bones
- Flat bones
- Irregular bones
- Sesamoid bones

Ossification:
- Intra membranous ossification
- Intra cartilaginous ossification

Bones and Joints form the skeletal system of the body. There are about 206 bones in the human body. Main functions of the skeletal system are:
1) Giving support and protection to soft tissues and vital organs.
2) Giving attachment to muscles and assisting in body movements.
3) Formation of blood cells in the red bone marrow.
4) Storage of mineral salts like calcium and phosphorous.

Bone Composition:
- Water: 25%
- Ossin: 35%
- Ossinoid: 45%

Function of Bone Marrow:
- Formation of blood cells (hemopoiesis).
- Formation of bone cells (endochondral ossification).
- Functions of bone marrow include:
  - Reticuloendothelial system: Processing of blood cells.
  - Production of antibodies.
  - Storage of fat and minerals.

Types of Bones:
- Long bones
- Short bones
- Flat bones
- Irregular bones
- Sesamoid bones

Ossification:
- Intra membranous ossification
- Intra cartilaginous ossification

Bones and Joints form the skeletal system of the body. There are about 206 bones in the human body. Main functions of the skeletal system are:
1) Giving support and protection to soft tissues and vital organs.
2) Giving attachment to muscles and assisting in body movements.
3) Formation of blood cells in the red bone marrow.
4) Storage of mineral salts like calcium and phosphorous.
Long bones: Long bones are found in limbs. A long bone has two ends. Ends of a long bone are called as epiphyses. These two ends are connected by shaft, which is called as diaphysis. Periosteum is the outer membrane covering the bone. Periosteum is followed by layer of compact bone. Central medullary canal is inside this. Through nutrient foramen, arteries enter. Medullary canal contains yellow bone marrow. Extremities consist of mass of spongy bone, which contains red bone marrow. Yellow bone marrow contains fat and blood cells, but is not rich in blood cells and blood cells may not rise in blood. Yellow bone marrow contains marrow cavity. Long bone can contain red bone which contains red blood cells and yellow bone marrow. Extremities consist of mass of yellow bone marrow. Yellow bone marrow is found at sites of concentration. Long bones develop from three centres called centres of ossification. Centre of ossification present in shaft is called diaphysis and centres of ossification present at the ends of bones are called epiphyses. Line of cartilage between epiphysis and diaphysis is called epiphyseal cartilage or epiphyseal plate. Epiphyseal plate separates epiphysis and diaphysis approximately until 25 years of age. After this age, the growth plate becomes impenetrable. At age of 25 years of age, the growth plate will be at the ends of the bones called epiphyses. Line of calcification present in shaft is called diaphysis and centre of ossification present at the ends of the bones is called epiphyses. Bones of the human body:

Total 206 bones forming the human skeleton can be divided into 1) Bones of Axial skeleton:
   i) Bones of skull:
      a) Bones of cranium: Cranium is called a brain box. It is a large, hollow bone of the head, protected by skull. Bones of the cranium are:
         1) Frontal bone
         2) Parietal bones
         3) Temporal bones
         4) Occipital bone
         5) Sphenoid bone
         6) Ethmoid bone
         7) Nasal bone
         8) Lacrimal bone
         9) Ethmoid bone
         10) Parietal bone
         11) Frontal bone
      ii) Bones of trunk:
         a) Sternum
         b) Ribs
         c) Vertebral column
   ii) Bones of upper limbs
      a) Shoulder bone
      b) Elbow bone
      c) Wrist bone
   iii) Bones of lower limbs
      a) Hip bone
      b) Knee bone
      c) Ankle bone

2) Bones of appendicular skeleton:
   i) Bones of upper limbs:
      a) Shoulder bone
      b) Elbow bone
      c) Wrist bone
   ii) Bones of lower limbs:
      a) Hip bone
      b) Knee bone
      c) Ankle bone

Bones of skull:
   Skull is a large bony structure containing cranium and bones of the face. Bones of the cranium are:
   - Frontal bone (1)
   - Parietal bones (2)
   - Temporal bones (2)
   - Occipital bone (1)
   - Sphenoid bone (1)
   - Ethmoid bone (1)
   - Nasal bone
   - Lacrimal bone
   - Ethmoid bone
   - Parietal bone
   - Frontal bone
   - Temporal bone
   - Sphenoid bone
   - Zygomatic bone
   - Maxilla
   - Mandible
   - Mastoid process
   - Occipital bone

Bones of the appendicular skeleton:
   - Shoulder bone
   - Elbow bone
   - Wrist bone
   - Hip bone
   - Knee bone
   - Ankle bone

Bones of the hand:
   - Phalanges
   - Metacarpals
   - Carpals

Bones of the leg:
   - Phalanges
   - Tarsals
   - Metatarsals
   - Carpals
   - Tibia
   - Fibula

3) Short bones:
   Short bones do not have shaft. They consist of spongy bone covered by shell of compact bone. Examples include:
   - Small bones of wrist
   - Small bones of ankle

4) Flat bones:
   Flat bones contain two layers of compact bone with spongy substance between the two layers. Examples include:
   - Bones of pelvis
   - Scapula

5) Irregular bones:
   Irregular bones are bones that do not fit into any category. Examples include:
   - Vertebrae
   - Bones of face

Seamoid bones:
   Seamoid bones are small bones that develop in tendons of muscles. Example:
   - Patella of knee joint
Coronal suture: Coronal suture is the immovable joint between frontal bone and parietal bones.

Sagittal suture: Sagittal suture is the immovable joint between the two parietal bones.

Lambdoid suture: Lambdoid suture is the immovable joint between the occipital bone and parietal bones.

Frontal bone: It is in the front central portion of the cranium. It is joined with two parietal bones. It extends to the forehead and forms the roof of the orbit and nasal cavities.

Features of frontal bone:
1. Supra orbital margins—forming the arches of the orbit.
2. Nasal notch—its bone projecting between supraorbital margins. Nasal bones are fitted to this.
3. Super ciliary arch—lies above these two structures.
4. Frontal tuberosities are the two prominences of the forehead.
5. Frontal sinuses are the two cavities in the frontal bone.

Parietal bones:
- Parietal bones are two in number. They form the roof and sides of the skull.
- They are of quadrilateral shape. Prominence of parietal bone is called parietal tuberosity.
- The inner surface of parietal bone is concave.
- Superior and inferior temporal lines run parallelly.
- A parietal bone has joints with:
  - Frontal bone anteriorly.
  - Occipital bone posteriorly.
  - Other parietal bone medially.
  - Temporal inferiorly.

Temporal bones:
- Temporal bones are two in number. They form the lower part of the sides of the skull.
- Temporal bones have joints with:
  - Sphenoid bone in front.
  - Parietal bones above.
  - Occipital bone behind.
  - Mastoid part: It forms the bone of the internal ear.
  - Tympanic part: It contains the external auditory meatus.

Occipital bone:
- Occipital bone is one in number. It is situated at the back and lower part of the cranial cavity.
- External occipital protuberance: It is a prominence of the occipital bone.
- Foramen magnum: It is a large oval opening below the external occipital protuberance. Cranial cavity communicates with vertebral canal through this opening.
- Occipital bone has the following features:
  - A temporal bone has the following parts:
    - Squamous part: It forms the flat part of the skull.
    - Mastoid part: It contains the bone of the internal ear.
    - Tympanic part: It contains the external auditory meatus.
    - Petrous part: It contains the bone of the internal ear.

Sphenoid bone:
- Sphenoid bone is one in number. It is situated at the base of the skull in front of temporal bones. It forms a large part of the skull infra-temporal bones.
- External occipital protuberance: It is a prominence of the occipital bone.
- Foramen magnum: It is a large oval opening below the external occipital protuberance. Cranial cavity communicates with vertebral canal through this opening.
- A parietal bone has the following features:
  - Superior and inferior temporal lines run parallelly.
  - A parietal bone has joints with:
    - Frontal bone anteriorly.
    - Occipital bone posteriorly.
    - Other parietal bone medially.
    - Temporal inferiorly.
middle cranial fossa. It is shaped like a bat with outstretching wings.

**a) Body:** Body contains two large air sinuses. They communicate with nasal cavity. Body also has a deep depression called hypophyseal fossa, which contains the pituitary gland. Hypophyseal fossa is also called as sella turica.

**b) Wings:** These wing-like structures are called greater and lesser wings. They have many openings for the passage of nerves and blood vessels.

### Ethmoid Bone:

It is one in number. It is cubical in shape. It fills the space between the orbits. Ethmoid bone consists of three parts.

1. **Cribriform Plate:** A small horizontal plate perforated with numerous fine openings through which the branches of olfactory nerve pass from the nose to the brain.
2. **Perpendicular Plate:** Descends from the cribriform plate. It forms the upper part of the nasal septum.
3. **Labyrinths:** Each consisting of a number of ethmoidal sinuses are thin-walled and communicate with the nasal cavity.

**Superior and middle nasal conchae:** Thin plates of ethmoid bone.

**Inferior nasal conchae:** Curved plates of bone which lie in the walls of the nasal cavity below the superior and middle nasal conchae of ethmoid bone.

### Cranial Fossae:

The base of the skull is divided into three fossae. They are:

1. **Anterior Cranial Fossa:** Formed by the horizontal plates of the frontal bone.
2. **Middle Cranial Fossa:** Formed by the sphenoid bone and petrous part of the temporal bone.
3. **Posterior Cranial Fossa:** Formed by the occipital bone.

### Fontanelles:

Due to incomplete ossification of the skull bones at birth, there are gaps between the bones. These gaps are called fontanelles. There are:

1. **Anterior Fontanelle:** It is the largest fontanelle present at the junction of the frontal and parietal bones where the coronal and sagittal sutures meet. It closes at the age of 1½ years.
2. **Posterior Fontanelle:** It is the fontanelle present at the junction of the parietal and occipital bones. It closes as soon as birth takes place.

### Sinuses:

These cavities in the bones of the skull communicate with the nose.

- **Frontal Sinuses:** A pair of sinuses present in the frontal bones. They are present one on each side of the root of the nose. They are large and communicate with the nasal cavity.
- **Maxillary Sinuses:** A pair of sinuses in the maxillary bones. They are present on each side of the nose. They communicate with the nasal cavity.
- **Ethmoidal and Sphenoidal Sinuses:** These sinuses are thin-walled and communicate with the nasal cavity.

### Functions of Sinuses:

1. **Lightening of bones of the face and cranium.**
2. **Giving resonance to the voice.**

### Bones of the Face:

There are 14 bones making the face.

- **Maxillae:** Two bones making the lower jaw.
- **Mandible:** One bone making the lower jaw.
- **Zygomatic Bones:** Two bones making the cheeks.
- **Nasal Bones:** Two bones making the root of the nose.
- **Lacrimal Bone:** Two bones making the eyelids.
- **Ethmoid Bone:** One bone making the nose.
- **Pterygoid Bone:** Two bones making the roof of the mouth and the floor of the orbit.
- **Palatine Bone:** Two bones making the hard palate.
- **Incisive Bone:** A bone making the incisive fossa of the maxilla.
- **Vomer Bone:** A bone forming the nasal septum.
- **Sphenoid Bone:** One bone making the sphenoid sinus.
- **Sphenoid Sinus:** A large air sinus in the sphenoid bone.
- **Mandibular Canal:** A canal in the mandible for the inferior alveolar nerve and artery.

### Figures:

- **Fig. 7.9** Cranial fossae
- **Fig. 7.10** Skull at birth showing fontanelles

---

**Fig. 7.9 Cranial Fossa**

1. **Posterior Cranial Fossa**
2. **Middle Cranial Fossa**
3. **Anterior Cranial Fossa**

**Fig. 7.10 Skull at birth showing fontanelles**

1. **Anterior Fontanelle**
2. **Posterior Fontanelle**
Palate bones:
-2 (roof of mouth cavity and hard palate)

Lacrimal bones:
-2

Nasal bones:
-2 (Nasal bridge)

Turbinate bones:
-2 (nasal conchae)

Vomer:
-1 (lower part of nasal septum)

Maxillae:
They are two in number.
They form upper jaw.

Features of maxillae:
1) Body is pyramidal in shape.
2) Zygomatic process, palatine process, alveolar process, and frontal process are present. Alveolar process contains upper teeth.
3) Maxillary sinus is present in internal aspect.

Mandible:
It forms the lower jaw.

Features of mandible:
1) Body is horizontal part in the center. It contains lower teeth.
2) Two rami are present on each side. Each ramus contains coronoid process in front. Condyle of jaw lies behind.

Zygomatic bones:
They are two in number. They are irregular bones forming part of the prominence of cheek and part of walls of orbit. Each of them contains temporal process which articulates with zygomatic process of temporal bone to form zygomatic arch.

Palate bones:
They are two in number. They form nasal cavity and floor of orbit.

Cheek bones:
They are two in number. They are irregular bones forming part of the malar prominence.

Vomer:
-1 (lower part of nasal septum)

Hyoid bone:
It is a 'U' shaped bone. It has a body and two horns (lesser horn and greater horn). It lies at the base of the tongue. Each horn is attached to the styloid process of the temporal bone.

Bones of trunk:
Sternum, ribs, vertebral column.

Sternum:
It is a long flat bone. It runs down the front of the thorax. It is divided into three parts:
- Manubrium sterni
- Body (also called mesosternum)
- Xiphoid process

Manubrium sterni:
Manubrium sterni is triangular and articulates on either side with clavicle.

Features of manubrium sterni:
- Clavicular notches - on both sides for articulation with clavicle.
- Suprasternal notch - between clavicular notches.
- Articular surfaces - on both sides for articulation with ribs.

Body:
It is longer and narrower than manubrium sterni.

Ribs:
They are 12 in number. They form the side and back of the thoracic cavity.

Vertebral column:
It is a vertical bone composed of individual vertebrae. It forms the backbone.

Fig. 7.11: Left Maxilla
- Zygomatic process
- Canine fossa
- Orbital surface
- Infraorbital foramen
- Zygomatic process
- Canine fossa
- Orbital surface

Fig. 7.12: Mandible (left half)
- Coronoid process
- Neck
- Ramus
- Angle
- Body
- Condyle
- Neck
- Ramus
- Angle
- Body
- Condyle

Fig. 7.13: Sternum (anterior aspect)
- Manubrium sterni
- Suprasternal notch
- Surface for clavicle
- 1st Rib
- 2nd Rib
- 3rd Rib
- 4th Rib
- 5th Rib
- 6th Rib
- 7th Rib
- Xiphoid process
notch where it joins the manubrium.

Xiphoid process: Xiphoid process is small. It is the lowest part of sternum. Diaphragm, linea alba and rectus abdominus muscles are attached to this part of sternum.

Ribs:
- They are 12 pairs of arched bones attached on back side to thoracic vertebrae.
- Features of rib:
  - a) Anterior or sternal end - having depressions for attachment of costal cartilage
  - b) Posterior or vertebral end - It has three parts
    1) Head
    2) Neck
    3) Tubercle
  - c) Shaft:
    1) Inner surface
    2) Outer surface
    a) Subcostal groove contains intercostal vessels and nerve.

Classification of ribs:
- True ribs: attached to the sternum directly. First seven pairs are true ribs.
- False ribs: attached to the sternum through costal cartilages. Remaining five pairs are false ribs. Of these, last two pairs are known as floating ribs.

Costal cartilages: They are bars of hyaline cartilage connecting ribs and sternum.

Vertebral column:
- Vertebral column is a powerful and flexible pillar made of a number of vertebrae which are connected to one another. Vertebral column provides central axis. It protects spinal cord and contains spinal nerves which are connected to one another. There are 33 vertebrae which are divided into five groups. They are classified as follows:
  - a) Cervical vertebrae - 7 in number forming the neck region.
  - b) Thoracic vertebrae - 12 in number forming thoracic region.
  - c) Lumbar vertebrae - 5 in number forming the lumbar region.
  - d) Sacral vertebrae - 5 in number forming the sacrum.
  - e) Coccygeal vertebrae - 5 in number forming the coccyx.

Vertebral column: Vertebral column is a powerful and flexible pillar made of a number of vertebrae which are connected to one another. Vertebral column provides central axis. It protects spinal cord and contains spinal nerves which are connected to one another. There are 33 vertebrae which are divided into five groups. They are classified as follows:

Classification of vertebra:
- Except atlas and axis, remaining vertebrae have common features. Each vertebra consists of:
  - a) Body - cylindrical in shape and lies to the front.
  - b) Articular processes - Two above, Two below.
  - c) Pedicles - Directed backwards and downwards.
  - d) Transverse processes - Protrude laterally for attachment of muscles and ligaments.
  - e) Spinous process - Forms a嵴 posterior to the vertebral foramen.
  - f) Laminae - Wide parts of arch carrying spinous process.
  - g) Vertebral foramen - Spinal cord passes through this foramen.
  - h) Intervertebral discs - They are discs of fibrocartilage for connecting one vertebra to another. Vertebral column is divided into five groups. They are:
    - a) Cervical vertebrae - 7 in number forming the neck region.
    - b) Thoracic vertebrae - 12 in number forming the thoracic region.
    - c) Lumbar vertebrae - 5 in number forming the lumbar region.
    - d) Sacral vertebrae - 5 in number forming the sacrum.
    - e) Coccygeal vertebrae - 5 in number forming the coccyx.
Atlas: It is the first cervical vertebra. Features:
1) It does not have a body.
2) It does not contain a spinous process.
3) It has two facets on the upper surface for articulation with the condyles of the occipital bone.

Axis: It is the second cervical vertebra. Features:
1) Odontoid process - an upward projection from the body.
2) Two facets - on the anterior surface for articulation with the atlas.
3) A spinous process - small and bifid.

Thoracic vertebrae: They are 12 in number. They carry ribs. Features:
1) Body - heart-shaped.
2) Facets - one on each side for attachment of ribs.
3) Transverse processes.
4) Vertebral foramen is not present.

Lumbar vertebrae: They are five in number. They are the largest vertebrae. Features:
1) They have no facets for articulation with ribs.
2) Spinous processes are large and strong. They give attachment to muscles.
3) Body is big and kidney-shaped.

Sacral vertebrae: They are five in number. They are fused to form the sacrum. Sacrum is triangular and forms a wedge between two hip bones which is enclosed. Features:
1) Four sacral foramina - openings on the anterior surface through which nerves pass.
2) Lateral masses on either side - formed by union of transverse processes.

Ligaments: Ligaments holding the vertebrae together are:
1) Anterior and posterior ligaments.
2) Ligamenta flava.
3) Supraspinous ligaments.

Curves of the vertebral column: When viewed from the side, the vertebral column has four curves.
1) Primary curves:
   a) Thoracic curve
   b) Pelvic curve
2) Secondary curves:
   a) Cervical curve
   b) Lumbar curve
Primary curves are present during fetal life. Cervical curve appears when the child begins to hold up the head and sit up. Lumbar curve appears when the child stands on its feet.

Bones of limbs: Appendicular skeleton consists of:
1) Bones of upper limbs (upper arm, forearm, wrist, and fingers).
2) Bones of lower limbs (thigh, leg, ankle, and foot).

Bones of upper limb:
1) Bones of shoulder girdle - scapula, clavicle (1+1) each side.
The bones of the upper limbs are:

- **Humerus**: The bone forming the upper arm on each side.
- **Radius and Ulna**: The bones of the forearm on each side.
- **Carpals**: The bones of the wrist on each side (8 total).
- **Metacarpals**: The bones of the palm on each side (5 total).
- **Phalanges**: Three phalanges for the fingers other than the thumb (12 total), and two phalanges for the thumb (2 total).

**Scapula**: The bone forming the shoulder blade on each side.

**Clavicle**: The collar bone on each side.

**Functions of Upper Limbs**: Handling objects, performing various types of work, and movement.

**Functions of Lower Limbs**: Locomotion, posture, and providing stability to the trunk.

**Scapula**: The large trianglular flat bone forming the shoulder blade.

- **Scapular Articulation**: Joint with the clavicle and spine.

**Clavicle**: The collar bone, not containing bone marrow cavity.

**Humerus**: The bone forming the upper arm, long bone of the upper limb.

**Anatomical Neck**: The narrow part of the humerus.

**Surgical Neck**: The broader part of the humerus.

**Glenoid Cavity**: The depression in the humerus for the head of the humerus.

**Acromion Process**: The point where the clavicle and scapula meet.

**Deltoid Tuberosity**: The point where the deltoid muscle attaches.

**Coracoid Process**: The prominent bone on the scapula.

**Olecranon Fossa**: The depression on the elbow joint.

**Surgical Neck**: The broad part of the humerus.

**Bone of Palm**: The metacarpals.

**Bone of Wrist**: The carpals.

**Bone of Forearm**: The radius and ulna.

**Bone of Upper Arm**: The humerus.

**Fig. 7.20**: The Scapula.

**Fig. 7.21**: The Clavicle.

**Fig. 7.22**: The Humerus.
Lower extremity contains:

- Trochlea - pulley shaped surface on inner side articulating with ulna.
- Capitulum - on outer side - It articulates with radius.
- Coronoid fossa - It is a depression located above articulating surface for ulna.
- Olecranon fossa - It lies at back and receives olecranon process of humerus.
- Medial and lateral epicondyle - lying on each side of articulating surfaces.

Upper extremity:

- Head - It is the inner bone of fore arm. It is shaped like a book and contains:
  - Deltoid tuberosity - rough tubercle on lateral aspect.
  - Spiral groove - also known as radial groove. Radial nerve passes through it.
- Neck - It lies below the head. It is a constricted portion.
- Shaft:
  - Deltoid tuberosity - rough tubercle on lateral aspect.
  - Spiral groove - also known as radial groove. Radial nerve passes through it.
- Lower extremity:
  - Head - rounded part which articulates with lower extremity of radius.
  - Neck - It is the outer bone of fore arm. It is a long bone. It contains two extremities and a shaft.

Radius:

- Head - disc shaped with hollow upper surface to articulate with capitulum of humerus.
- Neck - It lies below the head. It is a constricted portion.
- Radial tuberosity - on the ulna side, there is a projection, which is called radial tuberosity. Radial tuberosity gives insertion to biceps muscle.
- Lower extremity:
  - Narrow point between the two tuberosities.
  - Deltoid tuberosity - located at the front.
  - Greater tuberosity - located below the anatomical neck.
  - Proximal neck - below the anatomical neck.
  - Articular with glenoid cavity of scapula at shoulder joint.

Ulna:

- Head - hemisphere in shape.
- Neck:
  - Articulating with elbow.
- Shaft:
  - Deltoid tuberosity - rough tubercle on lateral aspect.
Bones of wrist:

- Bones of proximal row are: scaphoid, lunate, triquetral, and pisiform bones.
- Bones of distal row are: trapezium, trapezoid, capitate, and hamate bones.

Bones of palm:

- Bones of palm are called metacarpal bones. They are five miniature long bones each having a base and head.
- Bases of metacarpal bones articulate with distal row carpal bones and heads of metacarpal bones articulate with proximal row phalanges.

Bones of fingers:

- Bones of fingers are called phalanges. They are 14 miniature long bones arranged in rows. Thumb finger has two phalanges and the remaining fingers have three phalanges each.

Bones of lower limbs and pelvic girdle:

Bones of pelvic girdle:

- Pelvic girdle forms a link between the trunk and lower limbs.
- Pelvic girdle is formed by two innominate bones, one on each side with the sacrum and coccyx behind. Pelvic girdle is divided into two Greater pelvis (false) and Lesser pelvis (true).
- Pelvis is divided by lineaterminalis and promontory of sacrum. Greater pelvis is upper expanded portion. It is bounded on each side by Ilium and at back by base of sacrum. Lesser pelvis is upper expanded by iliacus and psoas major. It is bounded on each side by ilium and at back by base of sacrum.

Differences between male and female pelvis:

- Female pelvis is shorter than male pelvis. Female pelvis is wider than male pelvis. It is shallower than male pelvis. Sacrum is shorter and wider. Pubic arch forms obtuse angle in females whereas it forms acute angle in males. Sciatic notch is also wider. This variation in female pelvis adapts female pelvis for pregnancy and child birth.

Bones of the lower limb:

- Femur (thigh bone): one on each side
- Patella (knee cap): one on each side
- Tibia and fibula (leg bones): two on each side
- Tarsal bones (ankle bones): seven on each side
- Metatarsal bones (instep bones): five on each side
- Phalanges (bones of toes): (3 x 4) + 2 on each side

Femur:

- It is the longest and the strongest bone of the body. It resembles humerus of the upper arm.
- Features of femur: 1) Upper extremity 2) Shaft 3) Lower extremity

Innominate bone:

- Innominate bone is called as the pelvic bone or hip bone. Innominate bone is made of ilium, ischium, and pubis. Ilium, ischium, and pubis are united at the acetabulum, a deep cavity on the outer aspect of bone called acetabulum. Osseous structures in the acetabulum include the ilium, ischium, and pubis. It is named a hip bone. It is the bone of innominate bone.
Upper extremity: It has following features.

- **Head**: Spherical in shape and covered with hyaline cartilage.
- **Neck**: Long and flat lying below head.
- **Greater trochanter**: Located on the outer side where neck and shaft join.
- **Lesser trochanter**: Located on inner side where neck and shaft join.
- **Anterior and posterior intertrochanteric lines**: Unite greater and lesser trochanters.

Shaft: It has following features.

- **Linea aspera**: Ridge on posterior aspect.
- **Gluteal ridge**: Extends from linea aspera to the back of greater trochanter.
- **Spiral line**: Extends at the inner aspect from linea aspera to lesser trochanter.

Lower extremity: It has following features.

- **Medial and lateral condyles**: Two condyles.
- **Intercondylar notch**: Separating the two condyles.
- **Adductor tubercle**: Lying above medial condyle.
- **Popliteal surface**: Extending at the inner aspect from linea aspera to lesser trochanter.
- **Linea aspera**: Ridge on posterior aspect.
- **Intercondylar notch**: Extending from linea aspera to the back of greater trochanter.

Tibia and fibula:

- **Upper extremity**: It has following features.
  - **Head**: Located above medial condyle.
  - **Greater trochanter**: Separating the two condyles.
  - **Lesser trochanter**: Located on inner side where neck and shaft join.
  - **Intercondylar notch**: Extending at the inner aspect from linea aspera to lesser trochanter.
  - **Linea aspera**: Ridge on posterior aspect.

**Patella**: It is a small mobile disc located in front of the knee joint in the tendon of quadriceps muscle. It forms the knee cap. It is a sesamoid bone. It is triangular in shape with its apex facing downwards. Its posterior surface is smooth. It articulate with condyles of femur. Its anterior surface is rough.

Bones of the leg:

- **Tibia**: Inner bone of the leg. It is stronger than fibula.
  - **Upper extremity**: It has following features.
    - **Head**: Located above medial condyle.
    - **Greater trochanter**: Separating the two condyles.
    - **Lesser trochanter**: Located on inner side where neck and shaft join.
    - **Intercondylar notch**: Extending at the inner aspect from linea aspera to lesser trochanter.
  - **Shaft**: Triangular in shape. It has three borders and three surfaces. Crest of tibia is located at the middle third portion of anterior border. Soleal line is a ridge of bone. It is strong. It is present in the posterior surface.
  - **Lower extremity**: It is slightly expanded. Its surface articulates with talus and forms ankle joint.

- **Fibula**: Outer bone. It does not participate in weight bearing.
  - **Upper extremity**: It has following features.
    - **Head**: Located above medial condyle.
    - **Greater trochanter**: Separating the two condyles.
    - **Lesser trochanter**: Located on inner side where neck and shaft join.
  - **Shaft**: It has following features.
    - **Intercondylar notch**: Extending at the inner aspect from linea aspera to lesser trochanter.
    - **Linea aspera**: Ridge on posterior aspect.
Tarsal bones: Tarsal bones, meta tarsal bones, and phalanges are collectively called bones of the foot. Tarsal bones are seven bones in two rows.

- Talus
- Calcaneum
- Navicular
- Cuboid
- Three cuneiforms

Talus and calcaneum are the most prominent bones among tarsals. Talus is the main connecting link between the foot and the leg. Calcaneum is the largest bone of the foot. Navicular is disc-shaped.

Cuneiform bones are three in number:
- Medial
- Intermediate
- Lateral

Metatarsal bones are five bones.

Phalanges: They are 14 in number.

Classification of joints:
1. Fibrous joints (immovable)
2. Cartilaginous joints (slightly movable)
3. Synovial joints (freely movable)

Fibrous joints: These joints have fibrous cartilage and fibrous connective tissue as the connecting medium. Examples include:
- Sutures of the skull
- Tibiofibular joint
- Joints between teeth and jaws

Cartilaginous joints: These joints have cartilage covering bone surfaces. Examples include:
- Intervertebral joints
- Joints between manubrium sterni and body of sternum

Synovial joints: These joints are between two or more bones.

Definition: A junction of articulation is a function of movement between two or more bones.
3) Condyloid joint: It is the type of joint allowing movement in two planes.

4) Ball and socket joints: It is the type of joint allowing movement in all directions as a ball in cup-shaped socket cavity. Ex: Shoulder joint and hip joint.

5) Gliding Joints: It is also known as plane joint, Synovial joint. It is the type of joint allowing the joint forming surfaces of bones to glide over each other. Ex: Carpals joints, Tarsals.

6) Saddle Joint: It is the type of joint allowing free movement in all directions.

Types of movements at the joints:

1) Rotation movements: Movements due to one bone moving within another bone are rotation movements.

Ex: 1) Movements of femur in acetabulum of hip bone.
2) Movement of head rotation of radius over ulna.
3) Movement of ball of humerus in shoulder joints.

2) Angular movements:

a) Flexion: Bending of parts towards each other.

b) Extension: Straightening out of a part from each other.

c) Abduction: Movement of a part away from the body.

d) Adduction: Movement of a part towards the body.

e) Pronation: Bending of ventral surface downwards or turning of palm downwards as in blessing.

f) Supination: Turning of palm upwards as in begging.

g) Circumduction: Movement involving flexion, abduction, extension and adduction in sequence. Ex: Movement in shoulder.

3) Gliding movements: Gliding movement is type of movement in which two flat surfaces move over each other. Ex: Movement of carpal bones in wrist.

Movement of tarsal bones in foot.

Types of movements at the joints:

1) Rotation movements: Movements due to one bone moving within another bone are rotation movements.

Ex: 1) Movements of femur in acetabulum of hip bone.

2) Angular movements: They are different types.

a) Flexion: Bending of parts towards each other.

b) Extension: Straightening out of a part from each other.

c) Abduction: Movement of a part away from the body.

d) Adduction: Movement of a part towards the body.

e) Pronation: Bending of ventral surface downwards or turning of palm downwards as in blessing.

f) Supination: Turning of palm upwards as in begging.

g) Circumduction: Movement involving flexion, abduction, extension and adduction in sequence. Ex: Movement in shoulder.

3) Gliding movements: Gliding movement is type of movement in which two flat surfaces move over each other. Ex: Movement of carpal bones in wrist.

Movement of tarsal bones in foot.

Joints of human body:

Joints of human body can be classified on the basis of anatomical location into - 1) Joints of the Head 2) Joints of the trunk 3) Joints of the upper limb 4) Joints of the lower limb.

Joints of Head:

The only movable joint in head is temporomandibular joint. It lies between temporal bone and head of mandible. Sutures of the skull are immovable joints.

Sutures are already described in the previous sections of this chapter. Unossified membranous areas at the junctions of bones of skull are called fontanelles. They have also been dealt in the previous sections of this chapter.

Joints of the trunk:

1) Intervertebral joints: Joints of vertebrae are intervertebral joints. They allow gliding movements.

Between ribs and vertebrae are costovertebral joints. The joints between ribs and vertebrae are synovial joints where as joints between vertebrae are syndesmosis joints. They allow gliding movements.

Costovertebral joints: Joints between ribs and vertebrae are called costovertebral joints. They allow gliding movements.

Each vertebra is connected to all the vertebrae below it and above it by intervertebral joints. These joints are called discoid joints. They allow slight movement in all directions.

Joints of the upper limb:

1) Serradaculovertebral joint: Gliding type of joint between sternum and clavicle.

Movement is limited in all directions.

2) Acromioclavicular joint: Condylar joint between clavicle and scapula. Movement is limited in all directions.

3) Shoulder joint: It is a ball and socket joint between scapula and humerus. Movement is limited in all directions.

Joints of upper limb are - 1) Serradaculovertebral joint 2) Acromioclavicular joint 3) Shoulder joint.

Serradaculovertebral joints: Joints between ribs and vertebrae are called costovertebral joints. They allow gliding movements.

Costovertebral Joints: Joints between ribs and vertebrae are called costovertebral joints. They allow gliding movements.

Each vertebra is connected to all the vertebrae below it and above it by intervertebral joints. These joints are called discoid joints. They allow slight movement in all directions.

Joints of the lower limb:

1) Intervertebral joints: Joints of vertebrae are intervertebral joints. They allow gliding movements.

Between ribs and vertebrae are costovertebral joints. The joints between ribs and vertebrae are synovial joints where as joints between vertebrae are syndesmosis joints. They allow gliding movements.

Costovertebral joints: Joints between ribs and vertebrae are called costovertebral joints. They allow gliding movements.

Each vertebra is connected to all the vertebrae below it and above it by intervertebral joints. These joints are called discoid joints. They allow slight movement in all directions.

Joints of the upper limb:

1) Serradaculovertebral joint: Gliding type of joint between sternum and clavicle.

Movement is limited in all directions.

2) Acromioclavicular joint: Condylar joint between clavicle and scapula. Movement is limited in all directions.

3) Shoulder joint: It is a ball and socket joint between scapula and humerus. Movement is limited in all directions.

Joints of upper limb are - 1) Serradaculovertebral joint 2) Acromioclavicular joint 3) Shoulder joint.

Serradaculovertebral joints: Joints between ribs and vertebrae are called costovertebral joints. They allow gliding movements.

Costovertebral Joints: Joints between ribs and vertebrae are called costovertebral joints. They allow gliding movements.

Each vertebra is connected to all the vertebrae below it and above it by intervertebral joints. These joints are called discoid joints. They allow slight movement in all directions.

Joints of the lower limb:

1) Intervertebral joints: Joints of vertebrae are intervertebral joints. They allow gliding movements.

Between ribs and vertebrae are costovertebral joints. The joints between ribs and vertebrae are synovial joints where as joints between vertebrae are syndesmosis joints. They allow gliding movements.

Costovertebral joints: Joints between ribs and vertebrae are called costovertebral joints. They allow gliding movements.

Each vertebra is connected to all the vertebrae below it and above it by intervertebral joints. These joints are called discoid joints. They allow slight movement in all directions.

Joints of the upper limb:

1) Serradaculovertebral joint: Gliding type of joint between sternum and clavicle.

Movement is limited in all directions.

2) Acromioclavicular joint: Condylar joint between clavicle and scapula. Movement is limited in all directions.

3) Shoulder joint: It is a ball and socket joint between scapula and humerus. Movement is limited in all directions.

Joints of upper limb are - 1) Serradaculovertebral joint 2) Acromioclavicular joint 3) Shoulder joint.

Serradaculovertebral joints: Joints between ribs and vertebrae are called costovertebral joints. They allow gliding movements.

Costovertebral Joints: Joints between ribs and vertebrae are called costovertebral joints. They allow gliding movements.

Each vertebra is connected to all the vertebrae below it and above it by intervertebral joints. These joints are called discoid joints. They allow slight movement in all directions.
4) Elbow Joint:
Composed of humeroulnar joint, humeroradial joint. Hinge joint between humerus and ulna, humerus and radius. Flexion and extension occur at this joint.

5) Radio-ulnar Joints:
Pivot joints between radius and ulna. They are superior radio-ulnar joint and inferior radio-ulnar joint. Pronation and supination movements occur at these joints.

6) Wrist Joint:
Condyloid joint between radius and carpal bones. It is also known as radiocarpal joint. Flexion, extension, abduction and adduction occur at this joint.

7) Intercarpal Joints:
Gliding joints between carpal bones.

8) Carpometacarpal Joints:
Gliding joints between carpal bones and metacarpal bones. Carpometacarpal joint of thumb is saddle type joint.

9) Metacarpophalangeal Joints:
Condyloid type of joints between metacarpal bones and proximal row phalanges. Flexion, extension, adduction and abduction occur at these joints.

10) Interphalangeal Joints:
Gliding joints between phalanges.

11) Hip Joint:
Ball and socket joint between head of femur and acetabulum. Flexion, abduction, adduction, and circumduction occur at this joint.

12) Knee Joint:
Hinge joint between femur and tibia. Patella is present on smooth surface of femur. It helps in gliding movements. Flexion and extension occur at this joint.

13) Tibiofibular Joints:
Fibrous joints between tibia and fibula at their lower and upper extremities.

14) Ankle Joint:
Hinge joint between tibia and tarsals. Dorsiflexion and plantar flexion occur at this joint.

15) Tarsometatarsal Joints:
Gliding joints between tarsal bones and metatarsals.

16) Metatarso-phalangeal Joints:
Gliding joints between metatarsal bones and phalanges.

17) Intertarsal Joints:
Joints between talus with navicular and calcaneum with cuboid.

18) Talocalcaneal Joint:
Joint between talus and calcaneum. Movement is rocking type.

Summary:
Bone is the hardest connective tissue of body. Joint is any connection between two bones. Bones are classified into long bones, short bones, flat bones, irregular bones and sesamoid bones. Totally there are 206 bones in the human skeleton. They can be classified into bones of the skull, bones of the trunk, bones of upper limb and bones of lower limb. Joints are classified into fibrous joints, cartilaginous joints, and synovial joints. Synovial joints are further classified into gliding joint, hinge joint, pivot joint, ball and socket joint, condyloid joint and saddle joint.

Essay Questions:
1) Classify bones of human skeleton and write about bones of cranium.
2) Write about bones of face.
3) Write note on bones of upper limb, lower limb and bones of wrist and hand.
4) What are the bones of thorax? Write about ribs.
5) Write about bones of foot.
6) Classify joints. What are different synovial joints?
7) Write the joints of body.

Short Answer Questions:
1) What are the functions of skeletal system?
2) Where are the bones of body?
3) Classify joints. Where are different synovial joints?
4) Where are bones of thorax?
5) Where are bones of upper extremities?
6) Where are bones of lower extremities?
7) Where are bones of face?
8) Where are bones of trunk?
9) Where are bones of upper limb?
10) Where are bones of lower limb?

Fig. 7.32 Section of hip joint
2) Define ossification. What are the types?

3) What are various classes of bones?

4) Mention the bones of skull.

5) Give the list of bones of trunk.

6) Write the bones of upper limb.

7) Mention the bones of lower limb.

8) How many bones are there in cranium? Mention.

9) Mention the important sutures of cranium.

10) Write the features of frontal bone.

11) What are different parts of temporal bones?

12) What are fontanelles? Mention the types.

13) Mention the sinuses of skull.

14) Write the functions of sinuses.

15) Mention the bones of the face.

16) What is mandible? Name the parts.

17) Name the bones of upper limb.

18) What are the surfaces of scapula?

19) Write the bones of wrist.

20) Mention the number of (1) Thoracic vertebrae (2) Lumbar vertebrae

21) What are different classes of vertebrae?

22) Mention the number of (3) Sacral vertebrae

23) Mention the bones of pelvic girdle.

24) What are the features of pubis bone?

25) Write the parts of pelvis.

26) Differentiate between male and female pelvis.

27) Mention the bones of lower limb.

28) Describe the hip joint.

29) Define a) Gliding joint  b) Hinge joint

30) Write the functions of joints.

31) Mention the classes of joints.

32) What are the bones of foot? Mention with number.

33) Write the functions of upper extremity of foot.

34) Where the feet are of lower limb.

35) Mention the movements of (4) Wrist joint (b) Humeral joint (a) Gliding joint (d) Hinge joint
8. NERVOUS SYSTEM

The nervous system controls and integrates the functions of the human body.

Nervous system consists of neurons, its fibres, dendrites and axons.

Nervous tissue:
- It is composed of neurons and neuroglia.

Neuron:
- It is the structural and functional unit of the nervous system. It is made of the neuron cell body, dendrites and axons.
- The neuron cell body contains a large nucleus and receives impulses and transmits them to the nerve cell body.
- Axons carry impulses away from the nerve cell body.

Types of neurons:
- On the basis of the number of processes, they are classified into:
  1. Apolar neurons - Neurons having no processes.
  2. Unipolar neurons - Neurons having only one process, an axon.
  3. Bipolar neurons - Neurons having one axon at one pole and dendrites at the other pole.
  4. Pseudounipolar neurons - Neurons that are typically bipolar at first and then develop processes that converge towards one side of the cell body.
  5. Multipolar neurons - Neurons having the most varied form.

Types of nerve fibres:
- There are two types of nerve fibres:
  1. Medullated (myelinated) nerve fibres - Axon is covered by myelin sheath except at the nodes of Ranvier.
  2. Non-mediullated (non-myelinated) nerve fibres - Axons are not covered by myelin sheath.

Neuroglia:
- Neuroglia is a special type of interstitial tissue present both in grey and white matter.
- There are three types of neuroglia:
  1. Astrocytes:
     - Protoplasmic astrocytes
     - Fibrous astrocytes
  2. Oligodendroglia or oligodendrocytes:
     - Having few processes
  3. Microglia:
     - Having small size

Synapse:
- Synapse is the junction where one neuron ends and another neuron begins.
- Classification of synapses:
  1. Axosomatic synapse - Presynaptic terminal of the axon ends in the cell body of the neuron.
  2. Axodendritic synapse - Presynaptic fibres of any axon end in the dendrites of the neuron.
  3. Axo-axonic synapse - Presynaptic fibres of any axon end in the axon of the neuron.

Anatomy of the synapse:
- Microscopic anatomy of a motor neuron showing the main body of the neuron, dendrites, axon and multiple presynaptic terminals (synaptic knobs) ending in the soma and dendrites.
- Presynaptic terminals are the ends of the axon.

Neuromuscular junction:
- The junction where a motor nerve ends into muscle.

Fig. 8.1: A typical Neuron

Fig. 8.2: Axonodendritic synapse

Fig. 8.3: Axodendritic synapse

Fig. 8.4: Axo-axonic synapse

Fig. 8.5: Axosomatic synapse

Fig. 8.6: Axo-axonic synapse
**SOMATIC NERVES**

...When several cranial nerves arise from the spinal cord, and each nerve...
the spinal canal through an intervertebral foramen above the vertebra whose number it bears. The eighth spinal nerve emerges from the vertebral column below the seventh cervical vertebra. All the nerves from the thoracic and lumbosacral nerves enter the vertebral column below the vertebra whose number it bears. The coccygeal nerves pass from the lower extremity of the spinal canal.

Tracts:

Fibres carrying different sensations enter the spinal cord through the posterior roots. Inside the cord, a rearrangement takes place. Fibres carrying one kind of impulse tend to collect into a bundle. Such bundles are called sensory tracts. Motor tracts are also formed on similar lines. A tract may be defined as a bundle of fibres carrying one or a group of motor or sensory impulses in the central nervous system.

Brain stem:

Brain stem includes mid brain, medulla oblongata and pons varoli. Midbrain contains cerebral peduncles, corpora quadrigemina, red nucleus etc.

Midbrain:

Midbrain is the connection between fore brain and hindbrain. The dorsal part of midbrain is called the diencephalon. The ventral part is called the mesencephalon. The midbrain contains the corpus quadrigemina. The corpora quadrigemina are two pairs of nuclei located on either side of the midbrain. Each pair consists of a lateral nucleus and a medial nucleus. The lateral nucleus is the larger part of the pair and is formed by the cerebral peduncles. The medial nucleus is the smaller part and is formed by the internal capsules.

Medulla oblongata:

Medulla oblongata is also called the spinal bulb. It is the continuation of the cervical part of the spinal cord and is conically expanded. It extends from the lower border of the pons varoli to the foramen magnum. The medulla oblongata is divided into two parts: the anterior and posterior columns. The anterior column contains the spinal tract of the fifth cranial nerve. The posterior column contains the spinal tract of the trigeminal nerve. The medulla oblongata is separated from the pons varoli by the primary fissure.

Cerebellum:

Cerebellum is the largest part of the hindbrain. It lies behind the pons and medulla oblongata. The average weight of the cerebellum in adults is about 150 grams. Cerebellum consists of right and left cerebellar hemispheres. They are joined by the vermis. From a functional and morphological point of view, the cerebellum can be divided into two parts: the floculonodular lobe and the corpus cerebelli. The floculonodular lobe is separated from the corpus cerebelli by the posterior lateral fissure.

Phylogenetically, the cerebellum is divided into three regions:

1. Archicerebellum
2. Palaeocerebellum
3. Neocerebellum

Afferent and efferent fibres connecting the cerebellum with extracerebellar regions run through three large bundles. They are called the superior, middle, and inferior cerebellar peduncles. These can be divided into two classes: ascending and descending.

Ascending fibres are sensory fibres, descending fibres are motor fibres. A tract may be defined as a bundle of fibres carrying one or a group of motor or sensory impulses in the central nervous system.

Thalamus:

Thalamus is a large collection of nerve cells. It is located at the top of the midbrain. Five main nuclear masses of the thalamus are:

1. Medial nuclear mass
2. Lateral nuclear mass
3. Ventral nuclear mass
4. Posterior nuclear mass
5. Anterior nuclear mass

These nuclei carry different sensory information to the spinal cord, which is then transmitted to the cerebral cortex for further processing.
2) Lateral nuclear mass
3) Midline nuclei
4) Intralaminar nuclei
5) Pulvinar nuclei

Internal capsule:
It is a 'V' shaped band of fibres. It is bounded medially by thalamus and caudate nucleus. It is laterally bounded by lentiform nucleus. It is divided into:
- Anterior limb
- Posterior limb
- Genu.

Basal ganglia:
Basal ganglia includes corpus striatum, claustrum, red nucleus, body of Luys and substantia nigra. Corpus striatum includes caudate nucleus, globus pallidus and putamen.

Corpus striatum:
It is a mass of gray matter lateral and anterior to thalamus.

Anterior limb of internal capsule divides corpus striatum into two parts incom-

Substantia nigra:
It is a crescentic mass of nerve cells. It is located in the midbrain. It is connected to red nucleus, substantia nigra and globus pallidus. It is divided into:
- Lateral aspect
- Medial aspect

Body of Luys:
It is enclosed between thalamus and caudate nucleus. It is divided into:
- Anterior limb
- Posterior limb
- Genu.

Fig. 8.7 Lateral view of basal ganglia

It is divided into thalamus and caudate nucleus. It is bounded medially by lentiform and caudate nucleus. It is bounded laterally by lentiform nucleus.

Internal capsule:
It is a mass of gray matter lateral and anterior to thalamus.
rebrum consists of two symmetrical hemispheres. They are separated by a deep median furrow. They are connected by corpus callosum. Corpus callosum is a broad band of commissural fibres. The total surface area of the adult cortex is about 200 sq. cm. Each hemisphere has five main lobes:

1. Frontal lobe
2. Parietal lobe
3. Occipital lobe
4. Temporal lobe
5. Limbic area

Each hemisphere has four main fissures:

1. Central sulcus or Rolandic fissure
2. Parieto-occipital sulcus
3. Sylvian fissure
4. Callosomarginal fissure

Frontal lobe has four gyri:

1. Precentral gyrus
2. Superior gyrus
3. Middle gyrus
4. Inferior gyrus

Temporal lobe has three gyri:

1. Superior gyrus
2. Middle gyrus
3. Inferior gyrus

Cortex is divided into three main divisions:

1. Allocortex
2. Isocortex
3. Juxtallocortex or mesocortex

Precentral gyrus in frontal lobe is motor cortex, while postcentral gyrus is sensory cortex. Cortex has well-defined areas, each area surrounded by psycho-geometrical boundaries.

Meninges:

1. Pia mater
2. Arachnoid mater
3. Dura mater

The pia mater closely covers the brain and spinal cord, which is very delicate, highly vascular and dips down into the fissures of the cortex.

The arachnoid mater is a delicate layer lying between dura mater and pia mater. Cerebrospinal fluid fills up the space between arachnoid mater and pia mater, called the subarachnoid space.

The dura mater is the outermost, tough fibrous membrane extending down to the level of the second sacral vertebra. It consists of two layers: external and internal layers.

Cerebral Ventricles:

There are four ventricles: two lateral ventricles, a third ventricle, and a fourth ventricle.

Lateral ventricles are present in the cerebral hemispheres. The third ventricle lies in the interthalamic area. The fourth ventricle lies in the midbrain.

The dura mater is the outermost, tough fibrous membrane extending down to the level of the second sacral vertebra. It consists of two layers: external and internal layers.

2. Arachnoid mater and 3. Dura mater

Meninges:

1. Pia mater
2. Arachnoid mater
3. Dura mater

The pia mater closely covers the brain and spinal cord, which is very delicate, highly vascular and dips down into the fissures of the cortex.

The arachnoid mater is a delicate layer lying between dura mater and pia mater. Cerebrospinal fluid fills up the space between arachnoid mater and pia mater, called the subarachnoid space.

The dura mater is the outermost, tough fibrous membrane extending down to the level of the second sacral vertebra. It consists of two layers: external and internal layers.

Cerebral Ventricles:

There are four ventricles: two lateral ventricles, a third ventricle, and a fourth ventricle.

Lateral ventricles are present in the cerebral hemispheres. The third ventricle lies in the interthalamic area. The fourth ventricle lies in the midbrain.
**CRANIAL NERVES**

They are twelve pairs. They are-

1) Olfactory nerves
2) Optic nerves
3) Occulomotor nerves
4) Trochlear or pathetic nerves

**VI     Abducens general somatic sensory (af) lateral rectus
somatic motor (ef) lateral rectus**

**VII    Facial general somatic sensory (af) external ear, middle ear etc
special visceral motor (ef) facial muscles, neck, pinna, part of scalp**

**general visceral motor (ef) sublingual, submaxillary salivary glands, lacrimal glands**

**VIII  Vestibulo cochlear**

- Cochlear special somatic sensory (af) organ of corti
- Vestibular special somatic sensory (af) semi circular canals, utricle, saccule

**IX  Glosso general visceral sensory (af) mucous membrane of pharynx, pharyngeal posterior 1/3rd of tongue
special visceral sensory (af) taste buds of posterior 1/3rd of tongue**

**general somatic sensory (af) pharyngeal muscles, palatine tonsil and adjacent part of soft palate etc.
special visceral motor (ef) laryngeal muscles**

**general visceral motor (ef) secretory fibres to parotid**

**X   Vagus mixed pharynx, larynx, thoracic
and abdominal viscera**

**XI  Spinal accessory**

**XII  Hypoglossal somatic motor (ef) muscles of tongue**

**af: afferent                     ef: efferent**

**Autonomic nervous system:**

The autonomic nervous system controls the activity of organs except skeletal muscles, which are supplied with somatic nerves. Although it is independent of will, ANS is supplied to all the organs except skeletal muscles.

**Function of ANS:**

1) Controls the smooth muscles of organs.
2) Regulates blood vessels and glands.
3) Maintains body temperature.
4) Controls the sleep cycle.
5) Influences the digestive system.
6) Regulates the heart and blood pressure.

**Hypothalamus:**

Hypothalamus and Thalamus are present in Diencephalon. It is located at the interpeduncular space below thalamus. It has close relation with primary and secondary centres. Hypothalamus and Thalamus are present in Diencephalon. It is located at the interpeduncular space below thalamus. It has close relation with primary and secondary centres.

**S.No. & name            Type                        organs innervated**

1) Olfactory special somatic sensory (af) Olfactory epithelium
2) Optic special somatic sensory (af) retina
3) Occulomotor somatic motor (ef) medial & inferior rectus, motor inferior oblique muscles
4) Trochlear general somatic sensory (af) superior oblique muscle
5) Trigeminal special visceral motor (ef) pinna, lower face, teeth, gums of mandible
6) General somatic sensory (af) cornea, ciliary body and iris, lacrimal glands, conjunctiva etc
7) General visceral motor (ef) ciliary muscles
8) Olfactory tract
9) Hypophysis
10) Optic chiasma
11) Infundibulum
12) Cerebral Peduncle
13) Mammillary Bodies
14) Spinal Cord

**Fig. 8.12**

Under surface of brain showing central nerves.
The highest center for A.N.S. is derived from the basal plate of the diencephalon. It forms complex nuclei and fibres. It consists of the following nuclear masses: 1) Anterior group, 2) Middle group, and 3) Posterior group. The anterior group includes the preoptic nucleus and other related structures. The middle group contains the subthalamic nucleus and the zona incerta. The posterior group includes the habenular nuclei. For more details on the anatomy of the hypothalamus, refer to the hypothalamus topic in the ENDOCRINE GLANDS.

Summary

Nervous system consists of neurons, its fibres, dendrites and axons. Nervous tissue is made of neurons and neuroglia. Neuron is the structural and functional unit of the nervous system. A synapse is a microscopic gap between the ending of one neuron and the beginning of another. The post synaptic membrane receives the information and initiates a response. ANS is divided into craniosacral and thoracolumbar systems. Diencephalon contains the thalamus and hypothalamus.
The endocrine system consists of endocrine glands of the body. There are two types of glands in the body: exocrine glands and endocrine glands.

**Exocrine Glands**
- Mammary glands
- Sweat glands
- Lacrimal glands
- Salivary glands

**Endocrine Glands**
- Endocrine glands are ductless glands that pour their secretions directly into the bloodstream. These secretions are called hormones.

**Endocrine Glands in the Human Body**

- Hypothalamus
- Pituitary gland
- Thyroid gland
- Parathyroid glands
- Adrenal glands
- Pancreas
- Testes
- Ovaries
- Placenta

**Hypothalamus**
- Hypothalamus is a complex neurohormonal regulatory part. It contains hypothalamic nuclei and fibers. It forms the anterior wall of the third ventricle. It is situated at the interpeduncular space below the thalamus. It forms the median eminence of the hypothalamus.

**Pituitary Gland**
- It is called the master gland of the body. It is situated at the base of the brain in the sella turcica of the sphenoid bone. It is connected to the hypothalamus by the pituitary stalk.
- Dimensions: Anteroposteriorly, 10 mm; dorsoventrally, 6 mm; laterally, 13 mm.
- It has two lobes: the anterior lobe and the posterior lobe.

**Blood Supply**
- Anterior lobe is supplied by several arteries originating from the internal carotid artery and circle of Willis.
- Posterior lobe is supplied by the posterior inferior cerebellar artery.

**Types of Glands**
- There are two types of glands in the body: exocrine glands and endocrine glands.
set reaches capillary plexus of median eminence and infundibular stem. Capillary plexus is drained by a long portal vein.

Blood supply to neural lobe: Neural lobe is supplied blood by inferior hypophyseal arteries. Vessels form capillary network while ending in pars nervosa. Nerve supply: Few fibres from hypothalamohypophyseal tract or carotid plexus or from greater superficial petrosal nerves have control over this gland. Probably, they may be vasomotor nerves.

Thyroid

This gland is situated at the root of the throat. It has two fairly lateral lobes, which are symmetrical. Each measures 5 x 2 x 2 cm³ approximately. These lobes are present one on either side of trachea. They are connected by a thin portion of thyroid tissue called isthmus. Pyramidal lobe extends upwards from isthmus.

Thyroid gland moves upwards during swallowing. Weight in adults is between 20-25 g. It is highly vascular gland.

Microscopical examination of thyroid shows follicles of vesicles. They are lined by low cuboidal epithelium. Thyroid follicles are spherical or oval shaped with irregular size of 15-150 microns diameter. They are lined by single layer of epithelium. Blood supply: Superior and inferior thyroid arteries supply thyroid gland. Internal jugular vein and innominate vein drain the gland.


Parathyroid

It consists of four oval bodies embedded in posterior surface of thyroid. Each body measures 6 x 3 x 2 mm³. Each of the two pairs are present vertically behind each of the two lobes of thyroid. Total weight is about 40 mg. Gland is highly vascular. Superior and inferior thyroid arteries supply blood. Nerve supply is same as for thyroid. There are two types of cells in parathyroid.

1) Chief cells or principal cells
2) Oxyphil cells or eosinophil cells.

Adrenal glands

Adrenal glands are two in number. They are also called suprarenal glands. They are located on upper pole of each kidney. Right adrenal gland is smaller of the two. Dimensions of each gland are 50 x 30-40 x 10 mm. Average weight of each is 9-9 g. in adults.

There are two parts in adrenal gland.

1) Adrenal cortex - outer part consisting of
   a) Zona glomerulosa (outer)
   b) Zona fasciculata (middle)
   c) Zona reticularis (inner)

2) Adrenal medulla - Inner part consisting of irregular masses of polyhedral granular cells.

Pancreas

Human pancreas is large gland which is both exocrine and endocrine in its functions. It lies transversely across posterior abdominal wall behind the stomach at the level of 1st and 2nd lumbar vertebrae. It contains both exocrine cells and endocrine cells. Exocrine cells constitute about 90% of the gland. These cells are called A, B, and D cells, which secrete digestive enzymes. Endocrine cells, or islets of Langerhans, constitute about 10% of the gland. These cells are located in the pancreas and secrete hormones like insulin and glucagon.

There are mainly three distinct types of islet cells in human pancreas:

1) α-cells of islets of Langerhans.
2) β-cells of islets of Langerhans.
3) δ-cells of islets of Langerhans.

α-cells are also called A2-cells and constitute 10-15%, β-cells are also called B-cells and constitute 30-40%, and δ-cells are also called A1-cells and constitute 5%. In higher vertebrates, the ratio of α and β-cells of islets of Langerhans is 1:4. Other cell types are X cells, F cells, and C cells, etc.

Testes

Testes are the male reproductive organs concerned with spermatogenesis. For anatomy refer to Anatomy of Reproductive system.

Ovaries

Refer to Anatomy of Reproductive system.

Placenta

Refer to Anatomy of Reproductive system.

Thymus

Refer to Anatomy of Reproductive system.

Pineal body

Pineal body is also called epiphysis cerebri. It is flat, cone shaped and grey-colored. Its length is about 5-8 mm and breadth is about 3-5 mm. Pineal body is attached to the roof of the third ventricle by means of a short hollow stalk.

Histology of Thymus shows -

a) Capsule - dense connective tissue, rich in macrophages, mast cells, granulocytes.

b) Cortex - which is similar to lymph tissue of ordinary lymph nodes, but deficient of primary follicles.

c) Medulla - branched, branching band of lymphoid tissue.

There are two lobes in thymus gland. They are fused and asymmetrical. Right lobe is bigger than left lobe. Each lobe consists of numerous lobules. Follicles and medullary cords. Higher part of thymus consists of many lymphoid nodules and primary follicles.

Islets of Langerhans

These islets are made up of a group of cells which are usually present in the pancreas.

Pancreas

Pancreatic acini

β-cells

α-cells

δ-cells

A2-cells

B-cells

A1-cells

X cells

F cells

C cells

Interthalamic adhesion

Pineal body

Fig. 9.5 T.S. of Pancreas

Thymus in Newborn child

Fig. 9.6

Thymus gland

Fig. 9.7

Pineal gland

Fig. 9.8

106 105
Gastrointestinal tract as endocrine

Certain localised area of GIT acts as endocrine to secrete gastrointestinal hormones. Cells responsible for endocrine activity in GIT are not known with certainty. Gastrin I and II are produced in modified epithelial cells of glandular mucosa of pyloric part of stomach. Mucosa of upper part of small intestines secretes cholecystokinin - pancreozymin. Mucosa of upper small intestine produces villikinin. Intestinal lumen secretes enterocrinin.

Kidneys as endocrine

Juxtaglomerular cells produce renin. Erythropoietin is largely produced by kidneys. Prostaglandins are also produced by kidneys.

Summary

Endocrine system consists of endocrine glands of body. Endocrine glands are ductless glands. Endocrine glands of human body are pituitary, thyroid, parathyroid, adrenals, pancreas, testes (androgens and estrogens), ovaries, placenta (during pregnancy). Pituitary has two lobes - anterior and posterior lobes. Posterior lobe is connected to hypothalamus of brain by hypophyseal stalk. Anterior lobe is connected to hypothalamus by hypothyalamic portal vessels. Adrenal glands are located above kidneys. Adrenals secrete aldosterone, cortisol and sex hormones. Pancreas is the largest exocrine and endocrine gland. It secretes digestive enzymes and hormones. Four lobes of pancreas - exocrine and endocrine. Exocrine lobes secrete pancreatic juice and bicarbonate. Endocrine lobes secrete insulin and glucagon.

Essay Questions

1) What are different endocrine glands of body? Write the anatomy of pituitary.
2) Discuss anatomies of thyroid and parathyroid.
3) Describe the anatomies of adrenals and pancreas.
4) Write the anatomical descriptions of hypophysis and pituitary body.
5) What are the different endocrine glands of body? Where is the anatomy of pituitary.

Short Answer Questions

1) Define (a) Endocrine glands
2) Describe (b) Exocrine glands
3) Describe the anatomical descriptions of hypophysis and pituitary body.
4) Write the anatomical descriptions of adenohypophysis and neurohypophysis.
5) Where are the parts of adenohypophysis and neurohypophysis?
6) Where are the parts of anterior and posterior lobes of pituitary?
7) Where is hypophysis located?
8) Where is the hypophysis located?
9) Where are the parts of pituitary gland?
10) Where are the parts of pituitary gland located?
11) Where are the parts of pituitary gland located?
12) Where are the parts of pituitary gland located?
13) Where are the parts of pituitary gland located?
14) Where are the parts of pituitary gland located?
15) Where are the parts of pituitary gland located?
16) Where are the parts of pituitary gland located?
17) Where are the parts of pituitary gland located?
18) Where are the parts of pituitary gland located?
19) Where are the parts of pituitary gland located?
20) Where are the parts of pituitary gland located?
21) What are the parts of pituitary gland located?
22) What are the parts of pituitary gland located?
23) What are the parts of pituitary gland located?
24) What are the parts of pituitary gland located?
25) What are the parts of pituitary gland located?
26) What are the parts of pituitary gland located?
27) What are the parts of pituitary gland located?
28) What are the parts of pituitary gland located?
29) What are the parts of pituitary gland located?
30) What are the parts of pituitary gland located?
31) What are the parts of pituitary gland located?
32) What are the parts of pituitary gland located?
33) What are the parts of pituitary gland located?
34) What are the parts of pituitary gland located?
35) What are the parts of pituitary gland located?
36) What are the parts of pituitary gland located?
37) What are the parts of pituitary gland located?
38) What are the parts of pituitary gland located?
39) What are the parts of pituitary gland located?
40) What are the parts of pituitary gland located?
41) What are the parts of pituitary gland located?
42) What are the parts of pituitary gland located?
43) What are the parts of pituitary gland located?
44) What are the parts of pituitary gland located?
45) What are the parts of pituitary gland located?
46) What are the parts of pituitary gland located?
47) What are the parts of pituitary gland located?
48) What are the parts of pituitary gland located?
49) What are the parts of pituitary gland located?
50) What are the parts of pituitary gland located?
51) What are the parts of pituitary gland located?
52) What are the parts of pituitary gland located?
53) What are the parts of pituitary gland located?
54) What are the parts of pituitary gland located?
55) What are the parts of pituitary gland located?
56) What are the parts of pituitary gland located?
57) What are the parts of pituitary gland located?
58) What are the parts of pituitary gland located?
59) What are the parts of pituitary gland located?
60) What are the parts of pituitary gland located?
61) What are the parts of pituitary gland located?
62) What are the parts of pituitary gland located?
63) What are the parts of pituitary gland located?
64) What are the parts of pituitary gland located?
65) What are the parts of pituitary gland located?
66) What are the parts of pituitary gland located?
67) What are the parts of pituitary gland located?
68) What are the parts of pituitary gland located?
69) What are the parts of pituitary gland located?
70) What are the parts of pituitary gland located?
71) What are the parts of pituitary gland located?
72) What are the parts of pituitary gland located?
73) What are the parts of pituitary gland located?
74) What are the parts of pituitary gland located?
75) What are the parts of pituitary gland located?
76) What are the parts of pituitary gland located?
77) What are the parts of pituitary gland located?
78) What are the parts of pituitary gland located?
79) What are the parts of pituitary gland located?
80) What are the parts of pituitary gland located?
81) What are the parts of pituitary gland located?
82) What are the parts of pituitary gland located?
83) What are the parts of pituitary gland located?
84) What are the parts of pituitary gland located?
85) What are the parts of pituitary gland located?
86) What are the parts of pituitary gland located?
87) What are the parts of pituitary gland located?
88) What are the parts of pituitary gland located?
89) What are the parts of pituitary gland located?
90) What are the parts of pituitary gland located?
91) What are the parts of pituitary gland located?
92) What are the parts of pituitary gland located?
93) What are the parts of pituitary gland located?
94) What are the parts of pituitary gland located?
95) What are the parts of pituitary gland located?
96) What are the parts of pituitary gland located?
97) What are the parts of pituitary gland located?
98) What are the parts of pituitary gland located?
99) What are the parts of pituitary gland located?
100) What are the parts of pituitary gland located?
101) What are the parts of pituitary gland located?
102) What are the parts of pituitary gland located?
103) What are the parts of pituitary gland located?
104) What are the parts of pituitary gland located?
105) What are the parts of pituitary gland located?
106) What are the parts of pituitary gland located?
107) What are the parts of pituitary gland located?
108) What are the parts of pituitary gland located?
10. SENSE ORGANS

Sense Organs are the organs of special senses. They are eye, ear, nose and skin. Of these five organs, first four are organs of special senses. Skin is the organ of general sensations.

Eye:
- Eye is the organ of special sense of vision. It consists of eyeball, accessory structures of eye, and eyelids.
- Accessory structures of eye include: eyebrows, eyelashes, and conjunctiva.
- Eyebrows: Arching structures of the eyes.
- Eyelashes: Hair-like projections from the eyelids.
- Conjunctiva: Thin mucous membrane covering the exposed part of the eye.

Eye Ball:
- Structure of the eye ball:
  1. Vitreous humour
  2. Lens
  3. Aqueous humour
- Functions:
  - Aqueous humour: Fluid present in the anterior chamber of the eye.
  - Lens: Behind the iris and pupil, it is the organ of refraction of light onto the retina.
  - Vitreous humour: Jelly-like substance between the lens and retina. Responsible for maintaining the shape of the eye.

Accessory Structures:
- eyebrows
- eyelids
- conjunctiva

Lacrimal Apparatus:
- Glands:淚腺
- Routes:泪道

Optic Disc:
- The point where the optic nerve leaves the eye. It is also called the blind spot.

Macula:
- A small area of retina, also called the yellow spot or fovea centralis.

Clinical Labelling of Eye:
- Conjunctiva: INNER}

Fig. 10.1: Eye
Lacrimal gland situated in the lateral end of upper eyelid.

Lacrimal duct through which tears come out.

Lacrimal sac

Naso lachrymal duct through which tears flow into nasal cavity.

Extrinsic muscles of eye: There are six muscles moving the eyeball. They are:

1. Superior rectus - upward movement of eye.
2. Inferior rectus - downwards movement of eye.
4. Lateral rectus - outwards movement of eye. These four are straight muscles.
5. Inferior oblique - upward and outward movement of eye.
6. Superior oblique - downward and outward movement of eye. These two are oblique muscles.

Ear:

Ear is the organ of special sense of hearing. It is also responsible for equilibrium. It is divided into three parts.

Parts of ear are:
1. External ear: lying outside the skull
2. Middle ear: lying inside the skull
3. Internal ear.

External ear:
- It contains two parts. They are:
  a) Pinna - funnel shaped organ made of fibroelastic cartilage. It is the organ of collection of sound waves.
  b) External auditory meatus - small channel of about 3 cm length. It is lined with skin and wax creating glands are contained in this part. Hair and wax present in this part prevent dust particles. Its inner part is closed by a thin membrane called tympanic membrane or ear drum. This canal is the organ of conveyance of vibrations of sound to the tympanic membrane.

Middle ear:
- It is a small cavity in the temporal bone, anterior to the tympanic membrane.
- The middle ear contains a collection of air. The tympanic membrane is the main line between the tympanic membrane and the tympanic cavity. This canal is the external part of the tympanic cavity. It is divided into three parts: middle and inner ear. These two are divided into three parts. They are:

First part: Furca ovalis (oval window) and fenestra rotundum (round window). Round window is also called fenestra cochleae.

Second part: Eustachian tube - which communicates the middle ear posteriorly with mastoid antrum of temporal bone.

Third part: Auditory ossicles - Malleus, incus and stapes arranged across middle ear. These are minute bones of the middle ear and are bound by ligaments. They vibrate as a single unit when sound waves impinge on tympanic membrane.

Internal ear:
- It contains:
  1. Bony labyrinth - present in petrous portion of temporal bone.
  2. Membranous labyrinth - lying with the bony labyrinth.

Fluids of Internal ear:
- Perilymph is the fluid of bony labyrinth. Endolymph is the fluid of membranous labyrinth.

Structures of bony labyrinth:
- Vestibule: It is present between vestibule and semicircular canals. Vestibule contains:
  1. Sac of vestibule: containing membranous canal vestibule, cochlea and ampulla.
  2. Membranous labyrinth lying with the bony labyrinth.

- Utricle and saccule: They are two spherical organs lying in the floor of internal ear. These two are also called maculae.

- Basilar membrane: It is a thin membrane dividing cochlea into two parts. Organ of Corti is the neuroepithelium of cochlea. It is auditory receptor resting on basilar membrane. Cochlear nucleus is the major sensory neuron resulting from the basilar membrane dividing cochlea into two parts. Basilar membrane is membranous skin lining the cochlea into inner ear.

- Organ of Corti contains auditory receptor. The auditory nerve fibres enter the organ of Corti. Vestibulocochlear nerve collects sensation of equilibrium from vestibular division. It collects sensation of hearing from cochlear division. Auditory nerve fibres reach special nucleus on the back of thalamus and then cerebral cortex.
The semicircular canals are arranged at right angles to each other. They are superior, posterior, and lateral canals. The ampulla is the enlarged end of each canal. Vestibular nerve endings are present in the ampullae. The semicircular canals help the cerebellum in maintaining equilibrium.

The tongue is the organ containing taste buds. Taste buds are receptors of special sensation of taste. The epithelium of the tongue is modified into papillae and taste buds. Papillae are filiform, fungiform, and circumvallate. Taste buds are located on the sides of papillae. They are oval clusters of cells with a small pore on the surface in the epithelial layer. They measure 60-80 microns in length and 40 microns in diameter. Few taste buds are located on the soft palate, epiglottis, and pharynx. The cells within taste buds are two types: 1) Taste cells or gustatory cells or hair cells and 2) Supporting cells. Nerve fibres arise from hair cells and form a nerve plexus near the basement membrane. They finally join with glossopharyngeal or facial nerve to form nerves to the taste buds. Cells within these nerves are of two types: 1) Taste cells and 2) Supportive cells.

The nose contains olfactory receptors. Olfactory receptors are specialized bipolar nerve cells present in the olfactory area of the mucous membrane of the upper part of the nasal cavity. They are about 10-20 million in number. They receive the sensation of smell. The total surface area of olfaction on each side in man is about 250 mm². Olfactory area in man is comparatively small, and man is termed microsmatic animal. Olfactory area in dogs is large, and it is macrosmatic animal. Endings of olfactory nerves join to form the olfactory bulb. Olfactory bulb is connected to the olfactory centre in the brain. Some fibres of the trigeminal nerve are also present in the olfactory mucous membrane. They respond to irritating substances like ammonia. Surrounding the olfactory receptors in the olfactory area are supporting cells called sustentacular cells. Nerve fibres from these cells synapse in the olfactory area and then pass through the olfactory nerve (Ist cranial nerve) to the brain. Nerve fibres from the olfactory area pass through the olfactory bulb. The olfactory bulb is connected to the olfactory centre in the brain. There are four types of taste buds based on the sensation of taste - bitter, sour, salt, and sweet.

The skin consists of two layers: 1) Epidermis - outer layer and 2) Dermis - Inner layer. The epidermis is made of stratified epithelium. Layers of epidermis are:

1. Stratum corneum
2. Stratum lucidum
3. Stratum granulosum
4. Stratum germinatum.
Stratum corneum contains scale-like cells. They have keratin protein and these cells are constantly replaced.

Stratum lucidum is a glistening layer.

Stratum granulosum is made of spindle-shaped cells. They have granules in their cytoplasm.

Stratum germinatum is made of cuboidal cells. Multiplication of skin cells takes place in this layer.

Dermis: Dermis is the inner layer of skin. It contains:
- Melanophore cells containing melanin pigment.
- Arterial and venous capillaries.
- Sensory nerve endings.
- Sweat glands and sebaceous glands.
- Roots of hairs.
- Various sensory nerve endings of skin are organized in concentric rings, called Reissner's muscles (hair straightening muscles).
- Arrector pili muscles (hair straightening muscles).
- Sweaty glands and sebaceous glands.
- Smooth muscle fibres.
- Arterial and venous capillaries.
- Various sensory nerve endings of skin are organized in concentric rings, called Reissner's muscles (hair straightening muscles).
- Various sensory nerve endings of skin are organized in concentric rings, called Reissner's muscles (hair straightening muscles).
3. List the accessory structures of eye.

4. Explain (a) Sclera, (b) Cornea.

5. Write the extrinsic muscles of eye.

6. Describe choroid, ciliary body and iris.

7. Explain (a) Blindspot (b) Macula.

8. What are the light transmitting structures of eyeball?

9. Name the parts of lacrimal apparatus.

10. Mention the three main parts of ear.

11. What are the parts of external ear?

12. Mention parts of middle ear.

13. Name the main parts of external ear.

14. What are the parts of internal ear?

15. Name the main parts of internal ear.

16. Mention parts of middle ear.

17. Name the parts of external ear.

18. What are the parts of lachrymal apparatus?

19. What are the folds of internal ear?

20. Write about denmis.

21. Name different sensory epidermis of skin.
Excretory System

Excretory system consists of organs concerned with excretion of waste products formed in the cellular metabolism of body. Such channels concerned with excretion of waste products formed in the cellular metabolism of body are also called urinary tract.

**Channels of excretion**
- Kidneys
- Skin
- Liver
- Lungs
- Digestive Tract
- Salivary glands

**Urinary system**

Urinary system consists of:
- Kidneys
- Ureters
- Urinary Bladder
- Urethra
- Urinogenital tract

**Kidneys**

Kidneys are the main organs of the urinary system. They are bean shaped organs lying on the posterior wall of the upper abdomen, one on each side of the vertebral column. They lie at the level of the twelfth thoracic to third lumbar vertebrae.

- Right kidney is located slightly lower than the left kidney.
- Dimensions of each kidney: 11 x 5 x 3 cm. Each kidney weighs about 150g. The kidneys are embedded by a capsule of fibrous tissue called perirenal fat.

**Ureters**

Ureters transport urine formed in the kidneys to the urinary bladder. From urinary bladder, urine is passed to the exterior.

**Urinary Bladder**

In the center of the inner border of each bladder, there is a small pouch called trigone. The ureters open into the bladder through the openings of the renal pelvis. The urethra passes through the base of the bladder. The bladder is a hollow, muscular organ that stores urine.

**Urethra**

In males, the urethra is the passage for semen. In females, the urethra is the passage for the excretion of urine. The urethra in males is also called the urinogenital tract.

**Excretory System**

Excretory system consists of organs concerned with excretion of waste.
Malphigian body:
It is also called as renal capsule. It lies in cortex of kidney.

<table>
<thead>
<tr>
<th>Parts of nephron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowman’s capsule</td>
</tr>
<tr>
<td>Proximal convoluted tubule</td>
</tr>
<tr>
<td>Loop of Henle</td>
</tr>
<tr>
<td>Distal convoluted tubule</td>
</tr>
<tr>
<td>Collecting tubule</td>
</tr>
</tbody>
</table>

Renal Circulation:
There are two circulations in kidney.
1) Greater circulation
2) Lesser circulation

Greater circulation carries 85% of blood and lesser circulation carries 15% of blood. Renal arteries enter into kidneys through hilus at respective points. On or before entering the hilus, renal artery on each side divides into anterior and posterior divisions. Primary branches of divisions are called segmental arteries. Segmental arteries supply kidneys. They divide into lobar branches, one for each of the pyramids. Branches pass through the pyramids into the cortex.

(1) Bowman’s capsule
(2) Proximal convoluted tubule
(3) Loop of Henle
(4) Distal convoluted tubule
(5) Collecting tubule
(6) Venous blood returns through renal veins into inferior vena cava.
INTRODUCTION TO HUMAN PHYSIOLOGY

Physiology is the science of study of normal functions of body. This term originated from Greek word "physiologia" which means "natural knowledge." It was introduced by Jean Fernel in the year 1522. Physiology is the study of various processes that take place in the body and its functions. It is divided into different systems of body.

Different systems of body:

1. Haemopoietic system: It consists of blood. Main functions of blood include transport of respiratory gases, nutrients, hormones, etc.
2. Reticuloendothelial system: It consists of parts (monocytes, polymorphonuclears, etc.) related to the function of respiration.
3. Lymphatic system: It consists of parts (lymphatic capillaries, lymphatic vessels, lymph nodes, and lymph ducts) related to the function of respiration.
4. Skeletal system: It consists of bones of body. It is related with movements of organs and locomotion.
5. Muscular system: It consists of muscles. It is related with movements of organs and locomotion.
6. Circulatory system: It consists of heart and blood vessels. It is related with movements of organs and locomotion.
7. Respiratory system: It consists of parts related to the function of respiration.
8. Digestive system: It consists of parts related to the function of respiration.

Some important definitions:

1. Cell: It is the tiniest particle of body. It is the basic functional and structural unit of body.
2. Tissue: It is a group of cells of similarity in structure, function, and origin.
3. Organ: It is a group of different kinds of tissues for performing specific functions.
4. System: It is a collection of different organs of body to work collectively.
5. Organism: It consists of different systems.

Physiology is divided into descriptive and experimental physiological disciplines.

Descriptive physiology: It deals with the function of respiration, digestion, secretion, absorption, and reproduction. It includes morphological, functional, and biochemical aspects of physiology. It helps in study of body's structure and its functions.

Experimental physiology: It deals with the function of respiration, digestion, secretion, absorption, and reproduction. It includes morphological, functional, and biochemical aspects of physiology. It helps in understanding the working processes of living organisms. Experimental physiology is further explained by applying the principles of physiology's experimental discipline.

Haemopoietic system: It consists of blood. Main functions of blood include transport of respiratory gases, nutrients, hormones, etc.
Different parts related with excretion are kidneys, lungs, skin etc.

10) Endocrine system: It is the system of ductless glands which are related with production of hormones.

11) Reproductive system: It consists of reproductive organs and is related with the function of reproduction.

12) Nervous system: It consists of central and autonomic nervous systems. CNS is concerned with intellectual activity. ANS is concerned with involuntary functions of body and consists of sympathetic and parasympathetic nerves.

13) Special senses: Special senses of body are sight, hearing, taste, smell and touch. Parts related to these functions are eyes, ears, tongue, nose and skin.

Summary

Physiology is study of functions of body. Different systems of body are haemopoietic system, reticuloendothelial system, skeletal system, muscular system, circulatory system, respiratory system, digestive system, excretory system, endocrine system, reproductive system and special senses. Metabolism consists of anabolism and catabolism.

Essay Question

1. Write the introduction of Physiology. Define various terms related to physiology.

Short answer Questions

1. Define physiology.
2. Give the definitions of a) Cell b) Tissue
3. Write the definitions of a) Organ b) System
4. What are the functions of a) Endocrine system b) Reproductive system?
5. Define nervous system.
6. Mention the special senses.
7. Define metabolism.
Blood is defined as specialised fluid connective tissue of body containing blood cells suspended in plasma. It resembles sea water in its inorganic composition closely. This resemblance is explained by theory of evolution of life from sea water.

Functions of blood:
1) Transport of oxygen from lungs to tissues and carbon dioxide from tissues to lungs.
2) Transport of end products of digestion absorbed from intestines to cells for utilisation.
3) Carriage of essential chemicals like hormones, vitamins and other substances to the sites of their activities.
4) Transport of waste products of cellular metabolism to the excretory organs.
5) Maintenance of acid-base equilibrium.
6) Maintenance of water balance.
7) Maintenance of ionic balance.
8) Regulation of body temperature.
9) Regulation of blood pressure.
10) Guarding against haemorrhage by its property of coagulation.
11) Defence mechanism by means of phagocytosis by white cells and development of antibodies.
12) Maintenance of osmotic pressure due to presence of albumin (plasma protein) etc.

Physical properties:
- Colour: Red
- Reaction: Slightly alkaline
- pH: 7.36-7.45 (average 7.4)
- Specific gravity: 1.048-1.066 (average 1.057 in males, 1.053 in females)
- Consistency: Viscous
- Viscosity: 4.7 relative to water
- Volume: 1/11th of total body weight on average, 90ml/kg of body weight on average.
- 55% of whole blood.
- Total count of white cells: 4.5-12 thousand/mm³ for age group of 1-3 years, 6.5-15 thousand for age group of 4-7 years, and 4.5-13 thousand/mm³ for adults.
- Plate count: 2.5-4.5 thousand/mm³
- Total count of red cells: 4.5-15 million/mm³ in males, 4.0-12 million/mm³ in females, and 4.5-13 million/mm³ in children and infants.
- Haemoglobin: 14-18 g% in males, 11.5-16.5 g% in females, and 13.5-15 g% in infants (full term, cord blood).
- E.S.R.: 0-6.5 mm/hour in males, 0-3.7 mm/hour in females, and average being 9-12 mm/hour (Wintrobe's method)
- R.B.C. count: Normal average count in males is 5.5 million/mm³, in females is 4.5 million/mm³, and average being 15 million/mm³.
- Plasma volume: 52-55% in males, 45% in females.
- Packed cell volume: 45-48% in males, 40% in females.
- Total white cell count: 5-10 thousand/mm³ in adults, 10-25 thousand/mm³ in children and infants.
- Platelet count: 2.5-4.5 thousand/mm³.

Composition of blood:
Blood is composed of two parts: plasma and cells. Plasma contains 91-92% water and 8-9% solid components. Solid components of plasma are organic and inorganic in nature.

Plasma:
Plasma consists of 0.9% water and 9.1% solid components. The inorganic constituents of plasma are sodium, potassium, calcium, magnesium, phosphorous, iron, copper, etc.

Inorganic constituents of plasma:
- Sodium: 135-145 mmol/L
- Potassium: 3.5-5.5 mmol/L
- Calcium: 2.2-2.7 mmol/L
- Magnesium: 0.7-1.0 mmol/L
- Phosphorous: 0.8-1.4 mg/dL
- Iron: 50-150 mcg/dL
- Copper: 1.0-1.8 mcg/dL

Organic constituents of plasma:
- Glucose: 80-100 mg/dL
- Proteins: 6-8 g/dL
- Lipids: 100-200 mg/dL
- Lipoproteins: 50-150 mg/dL
- Bilirubin: 0.2-1.0 mg/dL
- Creatinine: 0.5-1.0 mg/dL
- Urea: 7-20 mg/dL
- Ketones: 0-0.5 mg/dL
- Urates: 3-7 mg/dL
- Immunoglobulins: 5-15 g/L

Blood cells:
- Red blood cells: 4.5-15 million/mm³
- White blood cells: 4.5-13 thousand/mm³
- Platelets: 2.5-4.5 thousand/mm³

Bleeding time: 2-5 minutes (average 3.25 minutes by Leech method). Clotting time: 11-16 minutes by capillary tube method.
Organic constituents of plasma: They are a)proteins b)nonproteinous nitrogen (NPN) substances c)carbohydrates d)lipids e)pigments

Plasma proteins are:
- Plasma proteins (7.5%) - Albumin, globulin, prothrombin, fibrinogen.
- Enzymes and hormones, antibodies (other substances) 

NPN substances - Urea, uric acid, creatinine, creatine, ammonia, aminoacids, xanthine, hypoxanthine etc.

Carbohydrates - glucose, galactose etc.

Lipids - Phospholipids, neutral fat, cholesterol, cholesterides etc.

Pigments - Bilirubin, carotene, xanthophyllin.

Cells:
- Blood cells are cells suspended in plasma. There are three types of blood cells.
  a) Red blood corpuscles (RBC) or erythrocytes.
  b) White blood corpuscles (WBC) or leucocytes.
  c) Platelets or thrombocytes.

Blood gases: They are oxygen and carbon dioxide.

Plasma proteins and their functions:
- Albumin: Albumin constitutes 52% of plasma proteins. It is the major plasma protein. Albumin is a homogeneous protein. Albumin is a mixture of several fractions. It is also present in serum. It is the fastest moving protein in electrophoretic fractionation. Albumin contains fibrinogen and prothrombin.
- Globulin: Globulin contains about 48,500 and isoelectric pH is 4.7.
- Prothrombin: Prothrombin is a component of plasma. It is converted to fibrin during clotting.
- Fibrinogen: Its molecular weight is 34,000. It is the major constituent of plasma. Fibrinogen is converted to fibrin during clotting.

Forms of Blood:
- Blood gases: They are oxygen and carbon dioxide.
- Blood cells: They are red blood cells, white blood cells, and platelets.
- Blood proteins: They are plasma proteins, enzymes, and hormones.

Forms of Blood used as specimens in diagnostic testing procedures are:
- Whole blood
- Plasma
- Serum
- Cells

Plasma proteins and their functions:
- Albumin: Albumin constitutes 52% of plasma proteins. It is the major plasma protein. Albumin is a homogeneous protein. Albumin is a mixture of several fractions. It is also present in serum. It is the fastest moving protein in electrophoretic fractionation. Albumin contains fibrinogen and prothrombin.
- Globulin: Globulin contains about 48,500 and isoelectric pH is 4.7.
- Prothrombin: Prothrombin is a component of plasma. It is converted to fibrin during clotting.
- Fibrinogen: Its molecular weight is 34,000. It is the major constituent of plasma. Fibrinogen is converted to fibrin during clotting.

Function of Albumin: Albumin: being the smallest plasma protein and having maximum symmetry, it exerts maximum osmotic pressure. 1% solution of albumin exerts 3.6 times more than globulin in same concentration. It is responsible for exerting 80% of total O.P. exerted by plasma proteins.

Globulin: Molecular weight of globulin is 90,000 to 130,000. It is insoluble in distilled water. But it is soluble in salt solutions. It is coagulated at 70°C. It is also present in serum. It is the faster moving protein in electrophoretic fractionation. It is coagulated by one fifth saturation with ammonium sulphate. Globulin contains two fractions. Globulin is a mixture of several functional proteins. Several other varieties of functionally different proteins are globulins.

Sources of globulins:
- Mesenchymal cells in embryo.
- Liver in adults.
- Lymphoid nodules.
- Reticulo endothelial system.

Functions:
- Globulins are responsible for viscosity and blood pressure of blood. It is attributed to their higher molecular weight and asymmetry.
- Immunoglobulins play important role in body’s defence mechanism.
- Prothrombin plays role in blood clotting.
- Fibrinogen plays role in blood clotting. It is converted to fibrin during clotting.

Fibrinogen synthesis is stimulated by systemic inflammation. Fibrinogen synthesis is inhibited by systemic inflammation.

Sources of fibrinogen:
- Mesenchymal cells in embryo.
- Liver in adults.
Blood cells is most dependent on fibrinogen, less on globulin and least on albumin. Increased fibrinogen levels raise sedimentation rate of blood cells by accelerating rouleaux formation. Other functions of plasma proteins:

1) Acting as reservoir.
2) Helping in CO$_2$ carriage by formation of carbamino proteins.
3) Transport of hormones, enzymes, clotting factors, iron, copper etc.
4) Protein binding of certain drugs helps their transport.

Red blood corpuscles (RBC):

Structure of RBC: Mature RBC of human being is circular biconcave disc shaped and not containing nucleus. It appears like a dumbell on viewing from side. Single RBC appears light brownish or yellow coloured under microscope. In bulk, RBCs appear red. There is no definite cell membrane of RBCs. A single RBC appears as a biconcave disc under microscope. The surface of RBC: Membrane of human being is circular, translucent and disc-like.

Composition of RBC:

- Water: 60-70%
- Solids: 30-40%
- Components in water:
  - Water: 60-70%
  - Solids: 30-40%
  - Hemoglobin: 33%
  - Protein: 2%
  - Phospholipid: 1%
  - Cholesterol: 0.3%
  - Cholesterides: 0.3%
  - Neutral fats: 0.3%
  - Amino acids: 0.2%
  - Urea: 0.1%
  - Adenyl pyrophosphates: 0.1%
  - Creatinine: 0.1%
  - Diphosphoglycerates: 0.1%

Other functions of plasma proteins: In addition to the above functions of plasma proteins, they also have the following functions:

1) Transport of hormones, enzymes, clotting factors, iron, copper etc.
2) Protein binding of certain drugs helps their transport.
2) For S-3 (Step-3) to take place, following are required.

- Metals: Iron, copper, manganese, and cobalt
- Bile salts
- Normal activity of thyroid, adrenal cortex
- Vitamin C, vitamin B6, vitamin B12, folic acid, riboflavin, pantothenic acid, and nicotinic acid.
- Pigments: Bile pigments, chlorophyl, other porphyrins.

3) Factors influencing in the step-3 are also operating for conversion of late normoblast (normoblast) to erythrocyte. Ultimately normal mature erythrocyte is formed.

Life span of R.B.C.: 120 days

Fate of R.B.C.: At the end of life span, erythrocytes disintegrate. RES swallows and digests the fragments. Haemoglobin is broken down into haem and globin. Globin breaks into amino acids. Haem breaks into... in haemoglobin synthesis. Green coloured biliverdin is formed from protoporphyrin... in haemoglobin.

4) Haemoglobin

Haemoglobin is the red pigment of blood. It is respiratory pigment of blood.

Parts of haemoglobin:

1) Non-specific prosthetic group - Haem (4%): Metalloporphyrin containing iron in ferrous form and non-iron residue i.e. protoporphyrin containing 4 pyrrole rings joined together.
2) Protein part called globin (96%).

Varieties of haemoglobin:

1) HbF (Fetal haemoglobin)
2) HbA (Adult haemoglobin)

Foetal haemoglobin has greater affinity for oxygen. It releases CO2 more readily.

Properties of Haemoglobin:

1) Ease of combining with oxygen to form oxyhaemoglobin and dissociating.
2) Combination of globin part of haemoglobin directly with CO2 to form carbamino haemoglobin.
3) Combination of globin part of haemoglobin with carbon monoxide directly with CO2. Then CO2 is carried by endogenous CO2 combining with CO2.

5) Haemoglobin offers rise to various pigments - bilirubin, biliverdin etc.
6) The presence of viscosity.
7) Joining of disc (s) to take place. Following are required.

- Metals: Iron, copper, manganese, cobalt, and calcium.
- Bile salts
- Normal activity of thyroid, adrenal cortex
- Phosphate, biogenic amines, other porphyrins, and mucous gland.

-Vitamin A, vitamin B12, vitamin C, folic acid, biotin, and other coenzymes.

6) Factors influencing in the step-3 are also operating for conversion of late normoblast (normoblast) to erythrocyte.
5) Porphyrins.

Methods of determination of Haemoglobin:
There are various methods of determination of haemoglobin. Some of them are-
1) Sahli’s method
2) Colorimetric method (Cyanmethaemoglobin method)
3) Von Slyke and Sadtler method (Highly accurate method)
4) Haldane’s modification of Gower’s method
5) Gower’s haemoglobinometer
6) Van Fleish’s haemometer
7) Tallqvist’s method
8) Spectrophotometric method (Cyanmethaemoglobin method)

Functions of haemoglobin:
1) Transport of respiratory gases - O₂ and CO₂
2) Maintenance of pH
3) Maintenance of ion balance.
4) Formation of pigments of bile, urine and stool.

Disorders related to RBC and Haemoglobin:
1) Anisocytosis: Variation in size of RBC is called anisocytosis.
2) Poikilocytosis: It is a condition in which there is deviation from shape.
3) Macrocytosis: Cells larger than normal size are called macrocytes.
4) Microcytosis: Cells smaller than normal size are called microcytes.

Polycythemia:
- It is a condition in which erythrocyte count is above normal.
- There is also increased Hb content and PCV.
- Raise in Hb is above 18g% in males and above 16.5g% in females.
- Raise in PCV is above 55% in males and above 47% in females.

Anaemia:
- It is a reduction in RBC count or Hb content or both below normal.

There are different types of anaemia.

1) Acute posthaemorrhagic anaemia
2) Chronic posthaemorrhagic anaemia
3) Anaemia caused by blood loss
4) Anaemia caused by bone marrow failure
5) Anaemia caused by deficiency of maturating factors
6) Anaemia caused by haemolysis
7) Anaemia caused by aplasia of bone marrow

S.No. Type of anaemia Cause Colour and size
1. Acute posthaemorrhagic anaemia
- Severe blood loss
- Normocytic, normochromic

2. Chronic posthaemorrhagic anaemia
- Normocytic (small size) type.

3. Anaemia caused by bone marrow failure
- Failure of bone marrow itself
- In aplastic anaemia, the bone marrow is underactive.

4. Anaemia caused by deficiency of maturating factors
- Iron deficiency anaemia
- Folic acid deficiency
- Pernicious anaemia
- Acute and chronic post haemorrhagic anaemia
- Macrocytic (big size), normochromic type.

5. Anaemia caused by haemolysis
- Haemolytic anaemia
- In thalassemia, the bone marrow is overactive.
- Hypochromic, microcytic type.

6. Anaemia caused by aplasia of bone marrow
- Failure of bone marrow itself
- In aplastic anaemia, the bone marrow is underactive.
- Normochromic, normocytic type.
b) Chronic posthaemorrhagic continued blood loss - hypochromic, anaemia microcytic

2. a) Sickle cell anaemia - abnormal formation of Sickle shaped RBC
b) Familial haemolytic anaemia - of RBC making them small and spherical
c) Mediterranean anaemia - fragile, very small.

3. Aplastic anaemia - aplasia of bone marrow - normochromic, normocytic

4. a) Pernicious anaemia - Vit B12, and folic acid deficiency - normochromic
b) Iron deficiency anaemia - inadequate intake of iron or enhanced requirement of iron - hypochromic, microcytic
c) Non tropical sprue - Failure of absorption of hypochromic vit B12 due to atrophy of intestinal mucosa

Some important indices of RBC and haemoglobin: They are colour index (CI), mean corpuscular diameter (MCD), mean corpuscular volume (MCV), mean corpuscular thickness (MCT), volume index (VI), relative volume of corpuscular haemoglobin (MHV), mean corpuscular haemoglobin concentration (MCHC), and mean haemoglobin (MCH).

White Blood Corpuscles (WBC):

They are also called leucocytes. They are colourless cells. They are nucleated and bigger than RBC. Number of leucocytes is very much less than RBC. Ratio of WBC to RBC is 1:700. They do not contain haemoglobin. They are not modified like RBC. They are extracellular. Several varieties of WBC are there, whereas RBC are of single variety only. They are actively engaged in movement, phagocytosis, excretion, and digestion. They are amoeboid.

Composition of WBC: They are composed of various elements:

- Nucleus (in leucocytes, they are again two types)
- Cytoplasm (granules, in neutrophils, eosinophils, and basophils, they are again two types)
- Granules - basic dye, eosin, and basic dye

<table>
<thead>
<tr>
<th>Values in differential leucocyte count:</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBC Type</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Neutrophils</td>
</tr>
<tr>
<td>Eosinophils</td>
</tr>
<tr>
<td>Basophils</td>
</tr>
<tr>
<td>Lymphocytes</td>
</tr>
<tr>
<td>Monocytes</td>
</tr>
</tbody>
</table>

Origin of Leucocytes: In early embryo, all blood cells originate from single primitive reticuloendothelial cell in the yolk sac. In postnatal life, they are derived extrinsically from red bone marrow. Granulocytes are derived extrinsically from red bone marrow, whereas monocytes and lymphocytes originate from spleen, thymus, and bone marrow. There are two theories explaining the genesis of blood cells:

- Monophyletic theory
- Polyphyletic theory

Fig. 2.2 Different types of Leukocytes

Varieties of leucocytes:

1) Granular leucocytes (also called granulocytes) - They are WBC containing granules in their cytoplasm. They are again three types.
   a) Neutrophils or polymorphs - Nucleus is multilobed. Granules take neutral dye.
   b) Eosinophils - Nucleus is two or three lobed. Granules take eosin (acidic dye).
   c) Basophils - Nucleus is lobed. Granules take basic dye.

2) Agranular leucocytes (also called agranulocytes) - They are WBC not containing granules in their cytoplasm. They are again two types.
   a) Lymphocytes - a) Small lymphocytes.
   b) Large lymphocytes.
   c) Monocytes

Values in different leucocyte count: (WBC)

<table>
<thead>
<tr>
<th>WBC Type</th>
<th>Percentage</th>
<th>Absolute number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutrophils</td>
<td>60-70%</td>
<td>3,000-6,000/mm³</td>
</tr>
<tr>
<td>Eosinophils</td>
<td>1-4%</td>
<td>150-400/mm³</td>
</tr>
<tr>
<td>Basophils</td>
<td>0-1%</td>
<td>0-100/mm³</td>
</tr>
<tr>
<td>Lymphocytes</td>
<td>25-30%</td>
<td>1,500-2,700/mm³</td>
</tr>
<tr>
<td>Monocytes</td>
<td>5-10%</td>
<td>350-800/mm³</td>
</tr>
</tbody>
</table>

Origin of Leucocytes: In early embryo, all blood cells originate from single primitive reticuloendothelial cell. In postnatal life, their origin is extrinsic. Several varieties of WBC are there, whereas RBC are of single variety only. They are actively engaged in movement, phagocytosis, excretion, and digestion. They are amoeboid.

Some important indices of RBC and haemoglobin: They are colour index (CI), mean corpuscular volume (MCV), mean corpuscular thickness (MCT), volume index (VI), relative volume of corpuscular haemoglobin (MHV), mean corpuscular haemoglobin concentration (MCHC), and mean haemoglobin (MCH).

White Blood Corpuscles (WBC): They are also called leucocytes. They are colourless cells. They are nucleated and bigger than RBC. Number of leucocytes is very much less than RBC. Ratio of WBC to RBC is 1:700. They do not contain haemoglobin. They are not modified like RBC. They are extracellular. Several varieties of WBC are there, whereas RBC are of single variety only. They are actively engaged in movement, phagocytosis, excretion, and digestion. They are amoeboid.

Composition of WBC: They are composed of various elements:

- Nucleus (in leucocytes, they are again two types)
- Cytoplasm (granules, in neutrophils, eosinophils, and basophils, they are again two types)
- Granules - basic dye, eosin, and basic dye

<table>
<thead>
<tr>
<th>Values in differential leucocyte count:</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBC Type</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Neutrophils</td>
</tr>
<tr>
<td>Eosinophils</td>
</tr>
<tr>
<td>Basophils</td>
</tr>
<tr>
<td>Lymphocytes</td>
</tr>
<tr>
<td>Monocytes</td>
</tr>
</tbody>
</table>

Origin of Leucocytes: In early embryo, all blood cells originate from single primitive reticuloendothelial cell. In postnatal life, their origin is extrinsic. Several varieties of WBC are there, whereas RBC are of single variety only. They are actively engaged in movement, phagocytosis, excretion, and digestion. They are amoeboid.

Some important indices of RBC and haemoglobin: They are colour index (CI), mean corpuscular volume (MCV), mean corpuscular thickness (MCT), volume index (VI), relative volume of corpuscular haemoglobin (MHV), mean corpuscular haemoglobin concentration (MCHC), and mean haemoglobin (MCH).

White Blood Corpuscles (WBC):

They are also called leucocytes. They are colourless cells. They are nucleated and bigger than RBC. Number of leucocytes is very much less than RBC. Ratio of WBC to RBC is 1:700. They do not contain haemoglobin. They are not modified like RBC. They are extracellular. Several varieties of WBC are there, whereas RBC are of single variety only. They are actively engaged in movement, phagocytosis, excretion, and digestion. They are amoeboid.

Composition of WBC: They are composed of various elements:

- Nucleus (in leucocytes, they are again two types)
- Cytoplasm (granules, in neutrophils, eosinophils, and basophils, they are again two types)
- Granules - basic dye, eosin, and basic dye

<table>
<thead>
<tr>
<th>Values in differential leucocyte count:</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBC Type</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Neutrophils</td>
</tr>
<tr>
<td>Eosinophils</td>
</tr>
<tr>
<td>Basophils</td>
</tr>
<tr>
<td>Lymphocytes</td>
</tr>
<tr>
<td>Monocytes</td>
</tr>
</tbody>
</table>

Origin of Leucocytes: In early embryo, all blood cells originate from single primitive reticuloendothelial cell. In postnatal life, their origin is extrinsic. Several varieties of WBC are there, whereas RBC are of single variety only. They are actively engaged in movement, phagocytosis, excretion, and digestion. They are amoeboid.
Life span of WBC:

Life spans of WBC vary from variety to variety. Varieties of WBC:

- Neutrophils: 2-4 days
- Eosinophils: 8-11 days
- Basophils: 12-15 days
- Lymphocytes: 2-3 days

Fate of WBC:

Fate of some varieties of WBC is similar and some is different. All the leucocytes disintegrate.

1. Granulocytes and fragments in blood and subjected to phagocytic action by reticuloendothelial cells.
2. Lymphocytes: pass through intestinal and other mucosa or subjected to phagocytic action of reticuloendothelial cells.

Functions of Leucocytes:

1. Phagocytosis: Engulfing of bacteria and foreign particles and their digestion by neutrophils is phagocytosis.
2. Manufacture of β and γ globulins: Important role is played by lymphocytes in body defense mechanism by manufacture of β and γ globulins.
3. Process of repair: Conversion of lymphocytes into fibroblasts in the area of inflammation helps in the process of repair.
5. Prevention of intravascular clotting: Secretion of heparin by basophils prevents intravascular clotting.

Disorders related to WBC count:

- Leucopenia: It is condition of decrease in WBC count below 4,000/mm³.
- Leucocytosis: It is condition of increase in WBC count above 11,000/mm³.
- Agranulocytosis: It is great fall of circulating granulocytes. It may be due to harmful effects of some drugs.

Leukaemia: It is malignant disease of one or more varieties of WBC.

Origin of Thrombocytes:

3) End of disintegration and release of thrombocytes.

Properties:

1. Stick to any surface.
2. Easy of clumping.

Synergism of platelets and coarse comminution of granules of nuclei and vesicles.

Section containing lamellar, glycogen, granules, and lipid bodies. Section containing micro bodies. Section containing microtubules and microfilaments.
Megakaryocytes introduce pseudopodia through walls of sinusoids. They are broken in a way so that, unit membrane envelopes individual fragment. These fragments with unit membranes are washed away into blood stream. These are platelets. Life span of thrombocytes: 5-9 days.

Fate of thrombocytes: They are destroyed in spleen and reticulo endothelial cells.

Functions of platelets:
1) Initiation of blood clotting by disintegration and liberation of thromboplastin.
2) Speedy repair of capillary endothelial lining.
3) Haemostatic mechanism by means of aggregation and coagulation.
4) Hastening the retraction of clot. It is dependent on thrombosthenin.
5) Liberation of 5-HT and Histamine to exert vaso constriction which helps in haemostasis.

Thrombocytopenic purpura: It is due to diminution of platelets in blood. In this disease, there is haemorrhage beneath skin and mucous membrane. Lesions are first red, then become gradually darker and finally fade to brownish yellow. It results in pigmentation disappearing in 2-3 weeks or remaining permanently. In this disease, coagulation time is normal. Bleeding time gets prolonged. Clot retraction does not take place.

Blood clotting (coagulation) and clotting factors:

Coagulation of blood is important for stopping further bleeding during injuries. Clotted blood plugs the bleeding point of blood vessels thus acting as haemostat.

Mechanism of blood clotting: When bleeding starts, blood comes into contact with rough surface. Platelets disintegrate and thromboplastin is released. Damaged tissues in the area of injury release prothrombin into plasma. Prothrombin in turn is converted into thrombin into thrombin by means of calcium. Thrombin interacts with fibrinogen to form fibrin (clot).

Clotting factors:

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Factor/Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prothrombin</td>
</tr>
<tr>
<td>2</td>
<td>Thromboplastin</td>
</tr>
<tr>
<td>3</td>
<td>Calcium</td>
</tr>
<tr>
<td>4</td>
<td>Fibrinogen</td>
</tr>
<tr>
<td>5</td>
<td>Factor X</td>
</tr>
<tr>
<td>6</td>
<td>Factor II</td>
</tr>
<tr>
<td>7</td>
<td>Factor IIA</td>
</tr>
<tr>
<td>8</td>
<td>Factor III</td>
</tr>
<tr>
<td>9</td>
<td>Factor IV</td>
</tr>
<tr>
<td>10</td>
<td>Factor V</td>
</tr>
<tr>
<td>11</td>
<td>Factor VI</td>
</tr>
<tr>
<td>12</td>
<td>Factor VII</td>
</tr>
<tr>
<td>13</td>
<td>Factor VIII</td>
</tr>
</tbody>
</table>

Complete thromboplastin or thrombokinase is a complex mechanism which helps in forming thrombin.

Thromboplastin is the mixture of prothrombin and tissue thromboplastin in the presence of calcium ions.

In normal plasma, prothrombin is single compound of calcium. When oxalated, two forms of prothrombin are found. They are 'A' and 'B'. Prothrombin is converted into thrombin by means of calcium and tissue thromboplastin

Coagulation does occur in a way (a) utilizing tissue thromboplastin and calcium ions in the plasma, and (b) utilizing tissue thromboplastin or thrombokinase, for further details refer to Plasma Proteins.
Hageman factor (factor XII): It is also called surface factor. It activates enzyme Christmas factor (factor XI): It is also called plasma thromboplastin component (PTC) or platelet factor. It is a coagulation factor that is not activated in the absence of tissue damage. It is activated by the contact activation pathway and is involved in the formation of the intrinsic pathway of coagulation.

Proaccelerin (factor XII): It is also called as accelerator globulin or Ac globulin or Ac G or thrombogene. It is necessary for the activation of coagulation factor I (prothrombin). It is heat labile and can be inactivated at 56°C in 30 minutes. It can also be inactivated by increasing pH to 10.5.

Accelerin (factor XII): It is a hypothetical activation product of factor XI. It is not used during clotting.

Antithrombin (factor XIII): It is also called stable factor or proconvertin or autoprothrombin-I. It accelerates tissue thromboplastin synthesis. It is not used during clotting. It is thermostable and can withstand up to 56°C. It is converted to proconvertin during clotting.

Antihaemophilic globulin (factor VIII): It is also called antihaemophilic factor (AHF) or platelet cofactor-I. It helps in intrinsic thromboplastin formation and intrinsic prothrombin conversion. Absence of this factor causes haemophilia disease. Haemophilia occurs in males. It is transmitted as sex linked recessive trait.

Hageman factor (factor XII): It is also called surface factor. It activates enzyme Christmas factor (factor XI): It is also called plasma thromboplastin component (PTC) or platelet factor. It is a coagulation factor that is not activated in the absence of tissue damage. It is activated by the contact activation pathway and is involved in the formation of the intrinsic pathway of coagulation.

Proaccelerin (factor XII): It is also called as accelerator globulin or Ac globulin or Ac G or thrombogene. It is necessary for the activation of coagulation factor I (prothrombin). It is heat labile and can be inactivated at 56°C in 30 minutes. It can also be inactivated by increasing pH to 10.5.

Accelerin (factor XII): It is a hypothetical activation product of factor XI. It is not used during clotting.

Antithrombin (factor XIII): It is also called stable factor or proconvertin or autoprothrombin-I. It accelerates tissue thromboplastin synthesis. It is not used during clotting. It is thermostable and can withstand up to 56°C. It is converted to proconvertin during clotting.

Antihaemophilic globulin (factor VIII): It is also called antihaemophilic factor (AHF) or platelet cofactor-I. It helps in intrinsic thromboplastin formation and intrinsic prothrombin conversion. Absence of this factor causes haemophilia disease. Haemophilia occurs in males. It is transmitted as sex linked recessive trait.

Hageman factor (factor XII): It is also called surface factor. It activates enzyme Christmas factor (factor XI): It is also called plasma thromboplastin component (PTC) or platelet factor. It is a coagulation factor that is not activated in the absence of tissue damage. It is activated by the contact activation pathway and is involved in the formation of the intrinsic pathway of coagulation.

Proaccelerin (factor XII): It is also called as accelerator globulin or Ac globulin or Ac G or thrombogene. It is necessary for the activation of coagulation factor I (prothrombin). It is heat labile and can be inactivated at 56°C in 30 minutes. It can also be inactivated by increasing pH to 10.5.

Accelerin (factor XII): It is a hypothetical activation product of factor XI. It is not used during clotting.

Antithrombin (factor XIII): It is also called stable factor or proconvertin or autoprothrombin-I. It accelerates tissue thromboplastin synthesis. It is not used during clotting. It is thermostable and can withstand up to 56°C. It is converted to proconvertin during clotting.

Antihaemophilic globulin (factor VIII): It is also called antihaemophilic factor (AHF) or platelet cofactor-I. It helps in intrinsic thromboplastin formation and intrinsic prothrombin conversion. Absence of this factor causes haemophilia disease. Haemophilia occurs in males. It is transmitted as sex linked recessive trait.

Hageman factor (factor XII): It is also called surface factor. It activates enzyme Christmas factor (factor XI): It is also called plasma thromboplastin component (PTC) or platelet factor. It is a coagulation factor that is not activated in the absence of tissue damage. It is activated by the contact activation pathway and is involved in the formation of the intrinsic pathway of coagulation.

Proaccelerin (factor XII): It is also called as accelerator globulin or Ac globulin or Ac G or thrombogene. It is necessary for the activation of coagulation factor I (prothrombin). It is heat labile and can be inactivated at 56°C in 30 minutes. It can also be inactivated by increasing pH to 10.5.

Accelerin (factor XII): It is a hypothetical activation product of factor XI. It is not used during clotting.

Antithrombin (factor XIII): It is also called stable factor or proconvertin or autoprothrombin-I. It accelerates tissue thromboplastin synthesis. It is not used during clotting. It is thermostable and can withstand up to 56°C. It is converted to proconvertin during clotting.

Antihaemophilic globulin (factor VIII): It is also called antihaemophilic factor (AHF) or platelet cofactor-I. It helps in intrinsic thromboplastin formation and intrinsic prothrombin conversion. Absence of this factor causes haemophilia disease. Haemophilia occurs in males. It is transmitted as sex linked recessive trait.

Hageman factor (factor XII): It is also called surface factor. It activates enzyme Christmas factor (factor XI): It is also called plasma thromboplastin component (PTC) or platelet factor. It is a coagulation factor that is not activated in the absence of tissue damage. It is activated by the contact activation pathway and is involved in the formation of the intrinsic pathway of coagulation.

Proaccelerin (factor XII): It is also called as accelerator globulin or Ac globulin or Ac G or thrombogene. It is necessary for the activation of coagulation factor I (prothrombin). It is heat labile and can be inactivated at 56°C in 30 minutes. It can also be inactivated by increasing pH to 10.5.

Accelerin (factor XII): It is a hypothetical activation product of factor XI. It is not used during clotting.

Antithrombin (factor XIII): It is also called stable factor or proconvertin or autoprothrombin-I. It accelerates tissue thromboplastin synthesis. It is not used during clotting. It is thermostable and can withstand up to 56°C. It is converted to proconvertin during clotting.

Antihaemophilic globulin (factor VIII): It is also called antihaemophilic factor (AHF) or platelet cofactor-I. It helps in intrinsic thromboplastin formation and intrinsic prothrombin conversion. Absence of this factor causes haemophilia disease. Haemophilia occurs in males. It is transmitted as sex linked recessive trait.

Hageman factor (factor XII): It is also called surface factor. It activates enzyme Christmas factor (factor XI): It is also called plasma thromboplastin component (PTC) or platelet factor. It is a coagulation factor that is not activated in the absence of tissue damage. It is activated by the contact activation pathway and is involved in the formation of the intrinsic pathway of coagulation.

Proaccelerin (factor XII): It is also called as accelerator globulin or Ac globulin or Ac G or thrombogene. It is necessary for the activation of coagulation factor I (prothrombin). It is heat labile and can be inactivated at 56°C in 30 minutes. It can also be inactivated by increasing pH to 10.5.

Accelerin (factor XII): It is a hypothetical activation product of factor XI. It is not used during clotting.

Antithrombin (factor XIII): It is also called stable factor or proconvertin or autoprothrombin-I. It accelerates tissue thromboplastin synthesis. It is not used during clotting. It is thermostable and can withstand up to 56°C. It is converted to proconvertin during clotting.

Antihaemophilic globulin (factor VIII): It is also called antihaemophilic factor (AHF) or platelet cofactor-I. It helps in intrinsic thromboplastin formation and intrinsic prothrombin conversion. Absence of this factor causes haemophilia disease. Haemophilia occurs in males. It is transmitted as sex linked recessive trait.

Hageman factor (factor XII): It is also called surface factor. It activates enzyme Christmas factor (factor XI): It is also called plasma thromboplastin component (PTC) or platelet factor. It is a coagulation factor that is not activated in the absence of tissue damage. It is activated by the contact activation pathway and is involved in the formation of the intrinsic pathway of coagulation.

Proaccelerin (factor XII): It is also called as accelerator globulin or Ac globulin or Ac G or thrombogene. It is necessary for the activation of coagulation factor I (prothrombin). It is heat labile and can be inactivated at 56°C in 30 minutes. It can also be inactivated by increasing pH to 10.5.

Accelerin (factor XII): It is a hypothetical activation product of factor XI. It is not used during clotting.

Antithrombin (factor XIII): It is also called stable factor or proconvertin or autoprothrombin-I. It accelerates tissue thromboplastin synthesis. It is not used during clotting. It is thermostable and can withstand up to 56°C. It is converted to proconvertin during clotting.

Antihaemophilic globulin (factor VIII): It is also called antihaemophilic factor (AHF) or platelet cofactor-I. It helps in intrinsic thromboplastin formation and intrinsic prothrombin conversion. Absence of this factor causes haemophilia disease. Haemophilia occurs in males. It is transmitted as sex linked recessive trait.

Hageman factor (factor XII): It is also called surface factor. It activates enzyme Christmas factor (factor XI): It is also called plasma thromboplastin component (PTC) or platelet factor. It is a coagulation factor that is not activated in the absence of tissue damage. It is activated by the contact activation pathway and is involved in the formation of the intrinsic pathway of coagulation.

Proaccelerin (factor XII): It is also called as accelerator globulin or Ac globulin or Ac G or thrombogene. It is necessary for the activation of coagulation factor I (prothrombin). It is heat labile and can be inactivated at 56°C in 30 minutes. It can also be inactivated by increasing pH to 10.5.

Accelerin (factor XII): It is a hypothetical activation product of factor XI. It is not used during clotting.

Antithrombin (factor XIII): It is also called stable factor or proconvertin or autoprothrombin-I. It accelerates tissue thromboplastin synthesis. It is not used during clotting. It is thermostable and can withstand up to 56°C. It is converted to proconvertin during clotting.

Antihaemophilic globulin (factor VIII): It is also called antihaemophilic factor (AHF) or platelet cofactor-I. It helps in intrinsic thromboplastin formation and intrinsic prothrombin conversion. Absence of this factor causes haemophilia disease. Haemophilia occurs in males. It is transmitted as sex linked recessive trait.
in mismatched blood transfusions. It is also needed in paternity testing, forensic medicine, blood diseases, experimental purposes etc. Blood transfusion is intravenous administration of blood to...corrects shock and vascular collapse. Agglutinogens: Erythrocytes contain antigens on the surface of their cell membrane. They are chemically lipoproteins. Surface antigens of red cells are also called agglutinogens. Types of agglutinogens: They are two types - A and B. Agglutinins: Agglutinins are antibodies present in plasma or serum. Types of agglutinins: They are two types α and β.

Haemagglutination reactions: Reactions between agglutinogens present on cells and their respective agglutinins are called haemagglutination reactions. These antigen - antibody reactions are made use of to detect the type of antigen.

Human blood group systems: There are around 300 blood group systems. These antigen - antibody reactions are made use of to detect the type of antigen. Hemagglutination reactions: Reactions between agglutinogens present on cells of erythrocytes and their respective antibodies are termed as hemagglutination reactions. Hemagglutination reactions are of two types: 1) Precipitation reactions, and 2) Agglutination reactions. They are two types - A and B.

ABO system of blood grouping: It was discovered by Karl Landsteiner. Some of the features of ABO system of blood grouping are - 1) ABO system of blood grouping is the most important system of human blood. 2) ABO system of blood grouping is the oldest system of human blood grouping. The ABO system of blood grouping is used in blood transfusion. There are six Rh agglutinogens. They are C, c, D, d, E, e. C, D and E are mendelian dominants. c, d and e are recessives. D and d are most common.

Rh group determination: The Rh status of a person is determined by using anti-D reagents. 

Clinical significance of Rh grouping in blood transfusion: When Rh +ve antibody reacts with Rh -ve cells, agglutination occurs. If the antibody is anti-D, agglutination occurs only when D antigen is present. If the antibody is anti-e, agglutination occurs only when E antigen is present. These reactions are used in blood transfusion. When Rh +ve blood is given to Rh -ve person, antibodies develop. However, this is no longer applicable.

Universal donor: O group blood can receive blood from all groups. It is called universal donor.

Universal recipient: As 'AB' group can receive blood from all, it is called universal recipient.
pregnancies, problem arises if the baby is again Rh +ve. This is due to passing of anti Rh antibodies from mother's blood through placenta into foetus, causing haemagglutination reaction. If the antibody titre is not high enough to cause death of foetus, child will be born alive and develops haemolytic jaundice. This condition is called erythroblastosis. If the case is severe, child may die if complete replacement of blood is not undertaken. Risks of blood transfusion: There is risk of transmission of Hepatitis and AIDS if blood is not properly screened and in proper containers. Rh incompatibility is significant in blood transfusion and pregnancy. Risks of blood transfusion: There is risk of transmission of Hepatitis and AIDS if blood is not properly screened and in proper containers. Rh incompatibility is significant in blood transfusion and pregnancy.

Summary

Blood is specialised fluid connective system of body. Main function of blood is transport of respiratory gases. Blood is composed of 55% plasma and 45% cells. Plasma proteins are albumin, globulin, prothrombin and fibrinogen. Blood cells are RBC, WBC and platelets. Blood has the property of clotting when exposed to rough surface. Various clotting factors are responsible for blood clotting.

Essay Questions

1) Write the functions, properties and composition of blood.
2) Discuss plasma proteins and their functions.
3) Write about coagulation, its mechanism and clotting factors.
4) Describe the structure of RBC. Write its composition, erythropoiesis and functions of RBC.
5) Write about Haemoglobin in detail.
6) Explain the disorders of RBC and Haemoglobin.
7) What are different types of WBC? Write different aspects related to WBC.
8) Write about platelets in detail.
9) Explain blood grouping.
10) Write about antihaemophilic globulin.

Short Answer Questions

1) Define blood.
2) Mention main functions of blood.
3) What are the parts of blood?
4) Write the forms of blood used as specimens in diagnosis.
5) List the protein and non-protein constituents of plasma.
6) Explain the different globulin fractions.
7) What are the plasma proteins?
8) When are the plasma proteins of interest?
9) What is the mechanism of blood clotting?
10) What are the factors inhibiting blood coagulation?
11) What are the factors accelerating blood coagulation?
12) What is the composition of RBC?
13) What are the stages of development of RBC according to extravascular theory?
14) What are the functions of RBC?
15) What is the composition of RBC?
16) When are the functions of RBC according to extravascular theory?
17) What are the stages of development of RBC according to extravascular theory?
18) What are the functions of RBC according to extravascular theory?
19) What are the stages of development of RBC according to extravascular theory?
24) What are different types of anaemia caused by haemolysis?
25) Write the fate of a) RBC b) WBC.
26) What is nontropical sprue? Write about size and colour of RBC in this condition.
27) Mention different types of leucocytes.
28) Write the values in total count of WBC.
29) Give any four functions of WBC.
30) Write lifespans of a) RBC b) WBC.
31) Explain structure of platelets by light microscope.
32) What are the properties of thrombocytes?
33) Give the a) lifespan &b) fate of thrombocytes.
34) What are the functions of thrombocytes?
35) Discuss thrombocytopenic purpura.
36) Mention few blood group systems.
37) What are different agglutinogens and antigens according to ABO system?
38) Mention different blood groups according to ABO and Rh systems.
39) How do you determine blood group by ABO system?
40) What is the significance of Rh factor in pregnancy?
41) Write the clinical significance of Rh grouping in blood transfusion.
3. CARDIOVASCULAR SYSTEM

Cardiovascular system is the system concerned with the functions of pumping oxygenated blood to various parts of the body, carrying deoxygenated blood back to the heart for pumping again to all parts of the body. Thus, it acts as the closed transport system of the body.

Properties of cardiac muscle:

1) Rhythmicity: It is one of the important properties of cardiac muscle. Rhythmicity is the ability of producing its own impulses throughout the cardiac muscle. It is evident from electrophysiological studies.

2) Conductivity: It is the ability of conduction of impulses through different parts of the heart. The impulse originates at the sino-atrial node, spreads over the atria, reaches the atrio-ventricular node, is transmitted to the bundle of His, its branches, Purkinje fibres, and ventricular muscle.

3) Excitability: It is the property of cardiac muscle to respond to adequate stimuli like other muscular tissues.

4) Contractility: It is the ability of cardiac muscle to respond to adequate stimuli like other muscular tissues.

5) All or none response: If a single muscle fibre contracts at all, it will contract to its maximum when conditions remain constant. The heart is a syncytium and thus, this rule applies to the whole heart.

6) Staircase phenomenon: It is also known as the Treppe phenomenon. It is found in quiescent heart and not in normal active heart. According to this phenomenon, if ventricular muscle is stimulated with induced current, first few contractions gradually increase in size and then become steady.

7) Tonicity: Cardiac muscle possesses tone. It is independent of nerves. It can maintain a fairly constant tension.

8) Refractory period: It is the period during which the heart will not respond to any external stimuli. The refractory period is 0.2 sec for rates up to 10 bpm.

Recovery Period is 0.2 sec for rates up to 101 bpm.

To overcome fatigue, long recovery periods give enough time to recover.

External stimuli: Recovery period of heart is long and it helps heart muscle to recover from fatigue after each beat. This is especially true when the heart is subjected to long periods of work, such as during exercise or during periods of emotional stress.

Recovery period is the period during which the heart will not respond to any external stimuli. It is a protective mechanism that prevents the heart from being overworked.

Conduction of cardiac impulse: Initiation of the impulse for heart beat is in the sino-atrial node. It is called the pacemaker of the heart. In the absence of the sino-atrial node, the atrio-ventricular node is a pacemaker, but at a lower rate.

Spread of cardiac impulses in the normal heart: Cardiac impulse spreads like this:

- Sino-atrial node
- Atrio-ventricular node
- bundle of bundle of Hiss
- Braches of bundle of Hiss
- Purkinje fibres
- Ventricular muscle.

Cardiac cycle:

Definition: Sequence of changes taking place during a heart beat from beat to beat is called the cardiac cycle.

Conduction of cardiac impulses: Initiation of impulses for heart beat is in the sino-atrial node.

Effect of ions on cardiac activity:

- Sodium ions initiate and maintain heart beat.
- Calcium ions strengthen systole.
- Potassium ions prolong diastole.

Energy requirements of cardiac muscle:

Cardiac muscle meets its energy requirements in the form of ATP. It obtains its energy requirements by oxidative pathways by oxidation of glucose, fatty acids, and amino acids in the presence of oxygen. ATP is an enzyme that provides energy for muscle contraction.
Normal heart rate: Number of heart beats per minute is 72 on average. Cardiac cycle time is the duration of completion of one cardiac cycle. Normal heart rate being 72 per minute, time taken for one cardiac cycle to take place is about 0.8 seconds. Hence, sequence of changes in a cardiac cycle occur every 0.8 sec.

Main events of cardiac cycle:

- **Atrial systole**: Atrial systole initiates cardiac cycle. During atrial systole, right and left atria contract to pour deoxygenated blood into right and left ventricles respectively. It lasts for 0.1 sec. and is followed by atrial diastole.

- **Atrial diastole**: During atrial diastole, right and left atria relax. Right atrium fills with deoxygenated blood from superior and inferior venae cavae. Left atrium fills with oxygenated blood from lungs through pulmonary veins. Atrial diastole lasts for 0.7 sec. and is followed by atrial systole.

- **Ventricular systole**: At the end of atrial systole, ventricular systole begins. During ventricular systole, right ventricle contracts to pump deoxygenated blood through pulmonary artery to lungs. Contraction of left ventricle pumps oxygenated blood into right ventricle. Contraction of left ventricle pumps oxygenated blood through aorta to parts of body. It lasts for 0.3 sec.

- **Ventricular diastole**: During ventricular diastole, right and left ventricles relax. They fill with blood from respective atria during this period. It is followed by ventricular systole. It lasts for 0.5 sec.

**Fundamental rules of cardiac action:**

1) Systoles of atrium and ventricle will never occur simultaneously.

2) Diastoles of the two chambers i.e. atria and ventricles always partly overlap.

**Ventricular systole** consists of two periods:

- **Isometric contraction period (0.05 sec)**: The interval between closing of A-V valves and opening of semilunar valves. Ventricles contract as closed cavities and intraventricular pressure rises steeply during this period.

- **Ejection period (0.25 sec)**: It starts when intraventricular pressure goes higher than pressure in pulmonary artery and systemic aorta causing opening of the semilunar valves. There are again two parts: a) Maximum ejection period (0.11 sec) - during which blood flows from right ventricle into pulmonary artery and left ventricle into systemic artery very rapidly, and b) Reduced ejection period (0.14 sec) - during which blood flow slows down due to ventricular systole coming to an end before beginning of diastole.

**Diastole** consists of two periods:

- **Prodiastolic period (0.04 sec)**: It is the brief interval between the beginning of diastole and closure of A-V valves. Ventricular diastole ends after isometric contraction period.

- **Ejection period (0.25 sec)**: It starts when intraventricular pressure goes higher than pressure in pulmonary artery and systemic aorta causing opening of the semilunar valves. There are again two parts: a) Maximum ejection period (0.11 sec) - during which blood flows from right ventricle into pulmonary artery and left ventricle into systemic artery very rapidly, and b) Reduced ejection period (0.14 sec) - during which blood flow slows down due to ventricular systole coming to an end before beginning of diastole.

**Atrial diastole** consists of two periods:

- **First half period of increased atrial pressure (0.1 sec)**: During this period, atrial pressure is higher than venous pressure in atria. Atrial veins are not opened during this period.

- **Second half period of decreased atrial pressure (0.4 sec)**: During this period, atrial pressure is lower than venous pressure in atria. Atrial veins are opened during this period.
of semilunar valves. 2) Isometric relaxation period (0.08 sec) which is the interval between closing of semilunar valves and opening of A.V. valves. Ventricles relax as closed cavities and intraventricular pressure and thus A.V. valves open and ventricular filling begins. There are three phases in ventricular filling. They are -

1) First rapid filling phase (0.113 sec) - A.V. valves open and blood rushes into ventricles rapidly. Most of the filling takes place in this phase.
2) Slow inflow phase (0.167 sec) - This is middle phase which is the longest phase. Amount of filling is minimum.
3) Last rapid filling phase (0.1 sec) - This period corresponds with atrial systole and ventricular filling becomes rapid again due to active contraction of atria.

Heart Sounds:
There are two types of heart sounds. They are -

1) Sounds which can be detected easily (which can be heard): They are two in number. They can be detected easily with a stethoscope. They are lub and dup. They are 1st and 2nd sounds.
2) Sounds which cannot be detected easily (which cannot be heard): They are also two in number. They are 3rd and 4th sounds.

Causes of heart sounds and their significance:
1) First heart sound is caused by sudden closure of A.V. valves on contraction of ventricular muscles. Its duration and intensity indicate the condition of myocardium.
2) Second heart sound is caused by sudden closure of semilunar valves in aorta and pulmonary artery. It indicates end of ventricular systole and beginning of ventricular diastole.
3) Third heart sound is caused by sudden rush of atrial blood into ventricles after A.V. valves open. It indicates beginning of ventricular filling.
4) Fourth heart sound is caused by atrial systole and consequently occurs during rapid filling phase (0.113 sec). A.V. valves open and blood rushes into ventricles rapidly. Most of the filling takes place in this phase.

Electrocardiogram (ECG):
Cardiac impulse generated in the pace maker of heart (SA node) and transmitted through other conducting tissues of heart are electrical in nature. These electrical impulses will be transmitted throughout body if suitable leads are placed on the body opposite to heart and connected to highly sensitive galvanometer containing recording device. Electrical potential can be recorded. This record is called as ECG and device used for this purpose is called ELECTROCARDIOGRAPH.

Leads: Electrical potential of heart can be recorded by connecting any two parts of body as positive and negative terminals. Specific arrangement of each pair of connections is called lead. Different leads: They are three types -

1) Standard limb leads: Lead I - Right arm, Left arm; Lead II - Right arm, Left leg; Lead III - Left arm, Left leg
2) Chest leads
3) Augmented unipolar limb leads - One limb is connected to positive terminal and other two limbs are connected together to negative terminal. Amplitudes are magnified by 50% in these leads.

Waves of Human ECG: Five consecutive waves of human ECG are P, Q, R, S, and T.
P is atrial complex and QRST are of ventricular complex.

Effect of nerves on heart:
1) Vagus has inhibitory effect on heart.
2) Sympathetic nerves have accelerating effect on heart.

Regulatory effect of cardiac centres on heart:
1) Cardioinhibitory centre: Stimulation of this centre has inhibitory effect on heart by causing bradycardia.
2) Cardioaccelerator centre: Stimulation of this centre increases sympathetic activity by causing tachycardia.

Heart rate: Heart rate is number of heart beats per minute.

Normal values:
- Teens: 70-90 per minute
- Adults: 60-80 per minute
- Elderly: 70-80 per minute

Factors affecting heart rate:
- Age and sex
- Metabolic rate
- Reproduction

Regulation of heart rate:
1) Local mechanism
2) Nervous mechanism

Local mechanism: Any factor which acts on S-A node and junctional tissue affects heart rate.

Nervous mechanism: Nervous mechanism includes sympathetic and parasympathetic regulation of heart rate.

Factors affecting heart rate:
- Age
- Sex
- Exercise
- Hormones
- Drugs
- Disease
- Anxiety

Blood Pressure:
Lateral pressure exerted by flowing blood on walls of blood vessels is called Blood Pressure.

Cardiac output:
Stroke volume times heart rate.

Normal values:
- Stroke volume: 50-70 ml
- Heart rate: 60-80 per minute

Factors affecting blood pressure:
- Age
- Sex
- Diet
- Exercise
- Stress

Cardiac output:
Stroke volume times heart rate.

Normal values:
- Stroke volume: 50-70 ml
- Heart rate: 60-80 per minute

Blood pressure
- Systolic: 120-140 mmHg
- Diastolic: 80-90 mmHg

Factors affecting blood pressure:
- Age
- Sex
- Diet
- Exercise
- Stress

Electrocardiogram:
Fig. 3.2 Normal Electrocardiogram

Voltage
- P wave: 0.1-0.2 mV
- Q wave: 0.1 mV
- R wave: 1.0-1.5 mV
- S wave: 0.05-0.1 mV

Duration
- P wave: 0.08-0.20 sec
- QRS complex: 0.06-0.10 sec
- ST segment: 0.02-0.08 sec
- T wave: 0.08-0.20 sec

T wave
- Presence
- Absence

Stress
- Acute
- Chronic

Effects of drugs:
- Beta blockers
- Calcium channel blockers
- Diuretics
- ACE inhibitors

Cardiac index:
Cardiac output per minute per m² of body surface area.

Normal values:
- Average: 2.5-4.0 L/min/m²

Stroke volume index:
Stroke volume per m² of body surface area.

Normal values:
- Average: 3.2-4.7 ml/m²
**Summary**

1. **Hypotension**: It is decrease of blood flow or cardiac output.
2. **Hypertension**: It is cause of blood flow or cardiac output.
3. **Shock**: It is decrease of blood flow or cardiac output.
4. **Atherosclerosis**: It is hardening and narrowing of arteries.
5. **Cardiac arrhythmias**: It is condition of disorder of rhythm of heart.
6. **Heart block**: It is condition of delay or failure of conduction of nerve impulses.
7. **Hypotension**: It is decrease of arterial pressure (A.P.) ^\textgreater 100/60
8. **Hypertension**: It is increase of arterial pressure (A.P.) ^\textlt 150/90

**Cardiovascular disorders**:

1. **Hypertension**: It is chronic increase in arterial B.P.
2. **Hypotension**: It is decrease in arterial B.P.
3. **Ischaemia**: It is loss of blood supply to a particular part of body.

**Vascular disorders**:

1. **Hypertension**: It is chronic increase in arterial B.P.
2. **Hypotension**: It is decrease in arterial B.P.

**Disorders of heart**

1. **Angina pectoris**: It is clinical disorder of heart caused by myocardial ischaemia. Symptoms are precardial chest pain, discomfort, pressure, etc.
2. **Myocardial infarction**: It is ischaemic type of myocardial necrosis caused by reduced coronary blood flow. Clinical picture is similar to angina pectoris.
3. **Congestive cardiac failure**: It is failure of heart to maintain adequate cardiac output. Clinical picture is similar to angina pectoris.
4. **Heart failure**: It is functional inability of heart to supply metabolic needs of the body.
5. **Cardiac arrhythmias**: It is condition of disorder of rhythm of heart.
6. **Heart block**: It is condition of delay or failure of conduction of nerve impulses.

**Measurement of B.P.**

1. **Systolic pressure (Sp)**: It is the maximum pressure during systole, also called the high pressure or diastolic pressure.
2. **Diastolic pressure (Dp)**: It is the minimum pressure during diastole, also called the low pressure or coronary pressure.
3. **Mean pressure**: It is defined as the mean of diastolic and systolic pressures.
4. **Pulse pressure**: It is the difference between systolic pressure and diastolic pressure.

**Impulse spreads from S/V node. Conduction cycle is sequence of changes leading to rhythm, conductivity, contractility etc. S/V node is pacemaker of heart.**

**Mean pressure** is defined as the pressure of myocardiun necrosis caused by precardial chest pain, discomfort, pressure, etc.
Events of cardiac cycle are atrial systole, atrial diastole, ventricular systole, and ventricular diastole. Heart sounds are four. Two of them can be detected easily and the other two cannot be detected easily. ECG is recording of electrical impulses of heart using suitable leads. Heart rate is number of heart beats/minute. Cardiac output is amount of blood pumped out by each heart beat per minute. Arterial BP is measured using sphygmomanometer. Some of the disorders of heart are angina pectoris, myocardial infarction, congestive cardiac failure, heart failure, etc. Some of the vascular disorders are hypertension, hypotension, ischaemia, etc.

**Essay Questions**

1. Write the properties of cardiac muscle.
2. Explain cardiac cycle.
3. Write short notes on:
   a) conduction of cardiac impulse
   b) heart sounds
4. Write about ECG.
5. Define B.P. and explain the method of measurement.
6. List out various cardiac disorders.
7. Define B.P. and explain the method of measurement.
8. Write about ECG.
9. Define all or none response.
10. Define cardiac cycle?
11. Define the properties of cardiac muscle.

**Short Answer Questions**

1. Define rhythmicity.
2. What is conductivity?
3. Explain all or none response.
4. Write the effect of following ions on heart
5. Explain all or none response.
6. List out various cardiac disorders.
7. Define B.P. and explain the method of measurement.
8. Write about ECG.
9. Define B.P. and explain the method of measurement.
10. Write about ECG.
11. Define B.P. and explain the method of measurement.
12. Explain cardiac cycle.
13. Define B.P. and name the instrument for measuring B.P.
14. What is mean of heart rate by indirect method?
15. What is mean of heart rate by direct method?
16. What are different methods of measuring B.P. by indirect method?
17. What are different methods of measuring B.P. by direct method?
18. Define B.P. and name the instrument for measuring B.P.
19. What is mean of heart rate by indirect method?
20. What is mean of heart rate by direct method?
21. What are different methods of measuring B.P. by indirect method?
22. What are different methods of measuring B.P. by direct method?
23. Define B.P. and name the instrument for measuring B.P.
24. What is mean of heart rate by indirect method?
25. What is mean of heart rate by direct method?
26. What are different methods of measuring B.P. by indirect method?
27. What are different methods of measuring B.P. by direct method?
28. Define B.P. and name the instrument for measuring B.P.
29. What is mean of heart rate by indirect method?
30. What is mean of heart rate by direct method?
31. What are different methods of measuring B.P. by indirect method?
32. What are different methods of measuring B.P. by direct method?
33. Define B.P. and name the instrument for measuring B.P.
34. What is mean of heart rate by indirect method?
35. What is mean of heart rate by direct method?
36. What are different methods of measuring B.P. by indirect method?
37. Define B.P. and mention the instrument.
38. Define B.P. and mention the instrument.
39. Define B.P. and mention the instrument.
40. Define B.P. and mention the instrument.
41. Define B.P. and mention the instrument.
42. Define B.P. and mention the instrument.
43. Define B.P. and mention the instrument.
44. Define B.P. and mention the instrument.
45. Define B.P. and mention the instrument.
46. Define B.P. and mention the instrument.
47. Define B.P. and mention the instrument.
48. Define B.P. and mention the instrument.
49. Define B.P. and mention the instrument.
50. Define B.P. and mention the instrument.
51. Define B.P. and mention the instrument.
52. Define B.P. and mention the instrument.
53. Define B.P. and mention the instrument.
54. Define B.P. and mention the instrument.
55. Define B.P. and mention the instrument.
56. Define B.P. and mention the instrument.
57. Define B.P. and mention the instrument.
58. Define B.P. and mention the instrument.
59. Define B.P. and mention the instrument.
60. Define B.P. and mention the instrument.
61. Define B.P. and mention the instrument.
62. Define B.P. and mention the instrument.
63. Define B.P. and mention the instrument.
64. Define B.P. and mention the instrument.
65. Define B.P. and mention the instrument.
66. Define B.P. and mention the instrument.
67. Define B.P. and mention the instrument.
68. Define B.P. and mention the instrument.
69. Define B.P. and mention the instrument.
70. Define B.P. and mention the instrument.
71. Define B.P. and mention the instrument.
72. Define B.P. and mention the instrument.
73. Define B.P. and mention the instrument.
74. Define B.P. and mention the instrument.
75. Define B.P. and mention the instrument.
76. Define B.P. and mention the instrument.
77. Define B.P. and mention the instrument.
78. Define B.P. and mention the instrument.
79. Define B.P. and mention the instrument.
80. Define B.P. and mention the instrument.
81. Define B.P. and mention the instrument.
82. Define B.P. and mention the instrument.
83. Define B.P. and mention the instrument.
84. Define B.P. and mention the instrument.
85. Define B.P. and mention the instrument.
86. Define B.P. and mention the instrument.
87. Define B.P. and mention the instrument.
88. Define B.P. and mention the instrument.
89. Define B.P. and mention the instrument.
90. Define B.P. and mention the instrument.
91. Define B.P. and mention the instrument.
92. Define B.P. and mention the instrument.
93. Define B.P. and mention the instrument.
94. Define B.P. and mention the instrument.
95. Define B.P. and mention the instrument.
96. Define B.P. and mention the instrument.
97. Define B.P. and mention the instrument.
98. Define B.P. and mention the instrument.
99. Define B.P. and mention the instrument.
100. Define B.P. and mention the instrument.
LYMPHATIC SYSTEM

Lymphoid system is a closed system consisting of lymphatic capillaries, lymph vessels, lymph nodes and lymph ducts carrying lymph from all parts of the body and pouring into the bloodstream again. Lymph is the carrying medium between blood and tissues at the tissue level. For gaseous exchange, nutrient supply and waste product exchange to take place, fluid escapes from capillaries into tissues. Certain amount of fluid escapes from the capillaries into the tissues. The fluid does not enter back into the blood stream. Remaining fluid which cannot enter back into the bloodstream returns to the blood stream through the lymphatic system.

Lymph:
Lymph is the carrying medium between blood and body tissues. It is thin, watery and clear modified tissue fluid similar to plasma.

Composition of Lymph:

- **Cellular part:**
  - Consists of large number of leucocytes. They are mainly lymphocytes. The normal range is 1,000 - 20,000/mm³. RBC and platelets are absent in lymph.
  - Absorption of fluids from tissue spaces. Blunting and lymphatics of intestinal villi.
  - Return of proteins and excess plasma proteins from the tissues.
  - Reduced capillary permeability of capillary walls.

- **Non-cellular part:**
  - Consists of solids dissolved in water. Water constitutes 94% of non-cellular part. Main solids of lymph are proteins, fats, carbohydrates, non-proteinous nitrogenous substances like urea and creatinine, chlorides, phosphorous, etc.

Lymph formation:
Lymph is formed from tissue fluid. Lymph formation depends on physical factors such as:

1. Capillary pressure
2. Permeability of capillary walls
3. Substances which alter osmotic pressure
4. Increased metabolic activity of an organ
5. Massage
6. Anoxia
7. Metabolites
8. Passive movements

Factors increasing permeability of capillary walls:
- Increase in temperature
- Histamine and peptone which injure capillaries
- Reduced oxygen supply

Factors influencing circulation of lymph:
1. Pressure gradient
2. Valves
3. Muscular action
4. Respiratory movements
5. Lymphagogues.

Lymph nodes:
Lymph nodes are important glandular structures spread at strategic points of the body. They filter lymph and lymphocytes. They prevent spread of cancer cells. They give birth to lymphocytes and monocytes. They aid immunological responses. They also manufacture gamma-globulin.

Functions of lymph nodes:
- Filter microbes, their toxins and foreign bodies.
- Give birth to lymphocytes.
- Aid immunological responses.
- Manufacture gamma-globulin.

Spleen:
Spleen is an encapsulated lymphoid structure.

- **Haemopoiesis:**
  - In foetal life, RBCs are formed by spleen and in certain conditions, spleen develops mature blood cells. spleen develops lymphoid tissue, spleen develops lymphatic sinuses.
  - Malphigian corpuscles of spleen produce lymphocytes.

Functions of spleen:
- Haemopoietic functions: In foetal life, RBCs are formed by spleen and in certain conditions, spleen develops lymphoid tissue, spleen develops lymphatic sinuses.
- Lymphocytes: In lymphoid tissues, lymphocytes are produced by lymphocytes.

Functions of lymph nodes or lymph glands:
Lymph nodes are important glandular structures spread at strategic points of the body. They filter lymph and lymphocytes. They prevent spread of cancer cells. They give birth to lymphocytes. They aid immunological responses. They also manufacture gamma-globulin.

Functions of spleen:
- Haemopoiesis: In foetal life, RBCs are formed by spleen and in emergency after birth, it produces RBCs only during emergency after birth.
- Malphigian corpuscles of spleen produce lymphocytes.
- Spleen develops monocytes.
- Spleen produces platelets.

Functions of lymph:
- Supply of oxygen and nutrients to parts where blood cannot reach.
- Maintenance of constant volume of tissue fluid.
- Return of proteins from tissue spaces to blood.
- Absorption of fats from intestine. Blind end lymphatics of intestinal villi (lacteals) absorb fat.
- Lymphocytes and monocytes act as defensive cells of body. Lymphatic system is also responsible for removal of bacteria from tissues.
- Lymph also helps in transport of proteins from interstitial fluid to blood.
- It drains extra interstitial fluid to circulation system.

Functions of lymph nodes or lymph glands:
Lymph nodes filter microbes, their toxins and foreign bodies. They give birth to lymphocytes. They aid immunological responses. They also manufacture gamma-globulin.

Functions of spleen:
- Haemopoiesis: In foetal life, RBCs are formed by spleen and in emergency after birth, it produces RBCs only during emergency after birth.
- Malphigian corpuscles of spleen produce lymphocytes.
- Spleen develops monocytes.
- Spleen produces platelets.

Functions of lymph:
- Supply of oxygen and nutrients to parts where blood cannot reach.
- Maintenance of constant volume of tissue fluid.
- Return of proteins from tissue spaces to blood.
- Absorption of fats from intestine. Blind end lymphatics of intestinal villi (lacteals) absorb fat.
- Lymphocytes and monocytes act as defensive cells of body. Lymphatic system is also responsible for removal of bacteria from tissues.
- Lymph also helps in transport of proteins from interstitial fluid to blood.
- It drains extra interstitial fluid to circulation system.
destroyed by RES of splenic pulp. Bilirubin is produced from haemoglobin released by lysed RBC. Bilirubin is partly oxidised to biliveridin on its way to liver via splenic vein. Iron separated from haemoglobin in this process is transferred to bone marrow and liver via RES cells.

4) Immune bodies are produced by RES of spleen. Spleen also traps bacteria, their toxins, foreign particles and debris etc.

**Tonsils:**
1) Supply of lymphocytes to the blood and lymph.
2) Defence against bacterial infection.
3) Other functions of RES.

**Thymus:**
1) It is the source of lymphocytes.
2) It develops immunological competence.
3) It controls immunological phenomena.
4) Thymus is associated with leukaemia.
5) Thymus secretes a hormone thymosin. It is involved in regulation of neuromuscular transmission.
6) It helps in deposition of mineral salts on bones.
7) Thymus is partly endocrine and partly lymphoid tissue.
8) Thymus is partly endocrine and partly lymphoid tissue.

**SUMMARY**
Lymph is a clear, thin, watery fluid similar to plasma. Lymphatic system is a closed system of vessels, sinuses and capillaries. Functions of lymphatic system are - defence, transport of respiratory gases, nutrients and waste products. Lymph is involved in several immune conditions. Lymphocytes and plaque-shaped plasma cells are involved in immune responses. Other functions of RES include:

*Defensive function of RES:
1) Phagocytosis by macrophages.
2) Complement formation.
*Uptake of nutrients:
3) Uptake of nutrients and waste products.
*Transport of respiratory gases:
4) Transport of respiratory gases to the blood and tissue.
*Transport of lymphocytes:
5) Transport of lymphocytes to the blood and tissue.
*Transport of lymphocytes:
6) Transport of lymphocytes to the blood and tissue.

**Essay Questions**
1) Write the physiology of lymphoid system.
2) Define lymph.
3) Define lymphatic system.
4) What is the composition of lymph?
5) Differentiate between lymph and plasma.
6) What are the factors increasing permeability of capillary walls?
7) Mention the factors helping the lymph circulation.
8) Write the functions of lymph glands.
9) Mention the functions of spleen.
10) What is Ascites?
11) Define tonsilitis.
12) What is Oedema?

**Short Answer Questions**
1) What is a) lymph b) lymphatic system?
2) What is the composition of lymph?
3) Differentiate between lymph and plasma.
4) What are the factors increasing permeability of capillary walls?
5) Mention the factors helping the lymph circulation.
6) Write the functions of lymph glands.
7) Mention the functions of spleen.
8) What is Ascites?
9) Define tonsilitis.
10) What is Oedema?
5. DIGESTIVE SYSTEM

Digestive system is the system concerned with digestion. Digestion is the process of conversion of complex molecules like proteins, fats and carbohydrates into simple molecules. End products of carbohydrates, fats and proteins are monosaccharides, fatty acids and amino acids respectively.

Functions of digestive system:
1) Ingestion of food
2) Mastication of ingested food
3) Deglutition of bolus
4) Secretion of digestive juices
5) Digestion
6) Absorption of water and end products of digestion
7) Defaecation
8) Manufacture of intrinsic factor which aids in erythropoiesis
9) Regulation of blood reaction
10) Regulation of blood sugar
11) Maintenance of water balance

Mouth:
Ingestion, mastication and digestion to some extent take place in mouth. Process of taking food into mouth is called as ingestion. Ingested food is torn, ground and mixed with saliva. Process of tearing, grinding and mixing with saliva involves the movements of jaws, the tongue and the teeth. Process of mastication to form a bolus is called as bolus formation.

Digestion in mouth: During the process in the mouth, salivary amylase converts starch into a soluble disaccharide sugar called maltose.

Absorption in mouth: Absorption of food does not take place in mouth. Drugs like nitroglycerine and isoprenaline are absorbed through buccal mucosa.

Composition of saliva: Saliva contains water, mucus, sodium chloride, sodium bicarbonate.

Pharynx and oesophagus:
Bolus formed in the mouth passes into stomach. Passage of food from mouth to stomach is called as swallowing or swallowing or pharyngeal swallowing. Process of swallowing includes the pharyngeal stage and the esophageal stage. Swallowing occurs in three stages. They are as follows:

1) Anterior or pharyngeal stage: The soft palate is raised and the larynx is closed at this stage to prevent food from entering the respiratory tract.
2) Pharyngeal stage: The pharynx is constricted and the food is forced into the oesophagus.
3) Oesophageal stage: The food moves down the oesophagus into the stomach.

Functions of teeth:
1) Incisors are for cutting food.
2) Canines are for tearing food.
3) Premolars are for grinding and crushing food.
4) Molars are for grinding and mastication of food.

Functions of tongue:
1) Tasting of food.
2) Assistance in mastication of food.
3) Assistance in swallowing.
4) Assistance in speech.

Functions of saliva:
1) It helps to keep the mouth moist and facilitates speech.
2) It helps in mastication and formation of bolus.
3) It dilutes and neutralizes pungent substances in the mouth.
4) It helps in hydration and cleansing of mouth.
5) It acts as a solvent for soluble substances.
6) It helps in mastication and formation of bolus.
7) It helps to keep the mouth moist and the pharyngeal muscles relaxed.
8) It helps in maintenance of water balance by action of the macula densa.
9) It helps in maintenance of body fluids, sugar and certain drugs.
10) It helps in hydration of saliva and conversion of food into a bolus.

Functions of digestive system:
1) Preparation of food: Simple molecules and products of carbohydrates, fats and proteins are produced by the process of digestion. These molecules are further absorbed in the small intestine.
2) Absorption of water and products of digestion.
3) Absorption of fats and products of digestion.
4) Secretion of digestive juices.
5) Secretion of pepsinogen.
6) Secretion of intrinsic factor.
7) Secretion of intrinsic factor.
8) Secretion of intrinsic factor.
9) Secretion of intrinsic factor.
10) Secretion of intrinsic factor.

Pharynx and oesophagus:
Bolus formed in the mouth passes into stomach through the pharynx and oesophagus. Passage of food from mouth to stomach is called as swallowing or swallowing or pharyngeal swallowing. Process of swallowing includes the pharyngeal stage and the esophageal stage. Swallowing occurs in three stages. They are as follows:

1) Anterior or pharyngeal stage: The soft palate is raised and the larynx is closed at this stage to prevent food from entering the respiratory tract.
2) Pharyngeal stage: The pharynx is constricted and the food is forced into the oesophagus.
3) Oesophageal stage: The food moves down the oesophagus into the stomach.

Functions of tongue:
1) Tasting of food.
2) Assistance in mastication of food.
3) Assistance in swallowing.
4) Assistance in speech.

Pharynx and oesophagus:
Bolus formed in the mouth passes into stomach through the pharynx and oesophagus. Passage of food from mouth to stomach is called as swallowing or swallowing or pharyngeal swallowing. Process of swallowing includes the pharyngeal stage and the esophageal stage. Swallowing occurs in three stages. They are as follows:

1) Anterior or pharyngeal stage: The soft palate is raised and the larynx is closed at this stage to prevent food from entering the respiratory tract.
2) Pharyngeal stage: The pharynx is constricted and the food is forced into the oesophagus.
3) Oesophageal stage: The food moves down the oesophagus into the stomach.

Functions of tongue:
1) Tasting of food.
2) Assistance in mastication of food.
3) Assistance in swallowing.
4) Assistance in speech.
3) Peristaltic movement moves the bolus down the oesophagus into the stomach.

Stomach:

Functions of the stomach are:

1) It acts as a reservoir of food temporarily.
2) It secretes gastric juice.
3) It has churning motility by which food is further broken and mixed with gastric juice.
4) The action of the peristaltic wave involves the contraction of muscle fibers in the stomach wall.
5) With the help of gastric juice, food is partially digested.
6) Absorption of small quantities of water, salt, alcohol, glucose and certain drugs takes place in the stomach.
7) Excretion of certain toxins, heavy metals and certain alkaloids like morphine takes place in the stomach.
8) It produces gastrin which stimulates gastric secretion.
9) It produces Castle's intrinsic factor, which is required for the absorption of vitamin B12.
10) Reflex functions:

   - Gastric juice contains hydrochloric acid, which helps in the digestion of food.
   - Gastric juice contains pepsinogen, which is converted into pepsin.
   - Gastric juice contains renin, which converts caseinogen into casein.
   - Gastric juice contains gastrin, which stimulates gastric secretion.
   - Gastric juice contains intrinsic factor, which is required for the absorption of vitamin B12.

Mechanism of gastric digestion:

1) Hydrochloric acid (0.4%) in gastric juice produces a pH of 1.5 to 2.5.
2) Pepsinogen is converted into pepsin. Pepsin is an enzyme that digests proteins.
3) Renin converts caseinogen (milk protein) into casein. Pepsin digests casein.
4) Gastric juice contains intrinsic factor. It is required for the absorption of vitamin B12.

Composition of gastric juice:

Gastric juice contains hydrochloric acid (0.4%), water, minerals and mucus, pepsin, gastrin, renin, and gastrin peptidase. The composition of gastric juice is similar to that of the stomach contents. The stomach is the largest organ of the digestive system.
Gastric juice makes the food more liquid and acidic. Acidification of food takes about 15 to 30 minutes in the cardiac end of the stomach until which time, action of ptyalin is in progress. Peristaltic action is very much marked in the pyloric part of the stomach. Food is quickly acidified in the pyloric end of the stomach. Mixing with gastric juice takes place due to churning motility. Food stays in the stomach for half an hour to 3 hours or more. Time of stay of food in the stomach depends upon the rate of gastric emptying and the rate of assimilation. Pyloric part of the stomach is normally contracted. When the food is acidified to a certain degree, pylorus relaxes to allow little food into the duodenum. Gradually, food in the duodenum becomes alkaline and food in the pylorus becomes more acidic. This causes pylorus to reopen. Food is converted into a greyish white fluid called chyme in the stomach.

1) In the stomach, proteins are acted upon by pepsin (active form of pepsinogen, conversion brought about by gastric HCl) and converted into peptones.
2) Milk protein caseinogen is acted upon by renin and converted to casein. In the form of casein only, it is acted upon by pepsin.

Gastric juices containing HCl and digestive enzymes are produced in three phases as described in the mechanism of gastric secretion.

**Functions of the small intestine:**

1) Digestion
2) Absorption.

Digestive process taking place in the small intestine:

- Chyme is propelled into the duodenum from the stomach due to relaxation of pyloric sphincter.
- Here it is alkalinised due to the action of pancreatic and intestinal juices.
- Intestinal juices are produced in the jejunum. Bile juice is useful for emulsification of fats. Pancreatic juice contains trypsin, amylase, and lipase enzymes. Trypsin is responsible for conversion of proteins into polypeptides. Amylase converts all starch into maltose and dextrin. Lipase acts on fats and converts them to fatty acids and glycerol.

Intestinal juice is also called succus entericus. It contains water, salts and enzymes.

Enzymes present in sucus entericus are:

1) Enterokinase
2) Peptidase
3) Maltase
4) Sucrase
5) Lactase
6) Lipase

Enterokinase is responsible for conversion of trypsinogen secreted by the pancreas into trypsin. Peptidase converts polypeptides into amino acids. Maltase converts maltose into glucose molecules. Sucrase converts sucrose into glucose and fructose molecules. Lactase converts lactose into glucose and galactose molecules. These enzymes are mixed with food by peristalsis and muscular action of the walls of the small intestine.

### Small Intestine:

- Lumen - the central cavity of the intestine
- Villi - finger-like projections in the small intestine
- Mucosal layer - the innermost layer of the small intestine
- Submucosal layer - the middle layer of the small intestine
- Muscularis layer - the outermost layer of the small intestine
- Serosa - the outermost layer of the small intestine

In the small intestine, absorption occurs due to pepsin (active form of pepsinogen) and converted into peptogenesis.

1) In the stomach, proteins are acted upon by pepsin (active form of pepsinogen) and converted into peptones.
2) Milk protein caseinogen is acted upon by renin and converted to casein. In the form of casein only, it is acted upon by pepsin.

Digestive process takes place in the small intestine:

- Chyme is propelled into the duodenum from the stomach due to relaxation of pyloric sphincter.
- Here it is alkalinised due to the action of pancreatic and intestinal juices.
- Intestinal juices are produced in the jejunum. Bile juice is useful for emulsification of fats. Pancreatic juice contains trypsin, amylase, and lipase enzymes. Trypsin is responsible for conversion of proteins into polypeptides. Amylase converts all starch into maltose and dextrin. Lipase acts on fats and converts them to fatty acids and glycerol.

Intestinal juice is also called succus entericus. It contains water, salts, and enzymes.

Enzymes present in succus entericus are:

1) Enteroxine
2) Peptidase
3) Maltase
4) Sucrase
5) Lactase
6) Lipase

Enterokinase is responsible for conversion of trypsinogen secreted by the pancreas into trypsin. Peptidase converts polypeptides into amino acids. Maltase converts maltose into glucose molecules. Sucrase converts sucrose into glucose and fructose molecules. Lactase converts lactose into glucose and galactose molecules. These enzymes are mixed with food by peristalsis and muscular action of the walls of the small intestine.

These processes occur first at one place, next in another place and then followed by relaxation. This has a churning effect on food. Digestive process in the stomach is incomplete. It is complete in the small intestine. End products of digestion are:

- Proteins - amino acids
- Carbohydrates - monosaccharides
- Fats - fatty acids

Absorption: Very little food is absorbed in the stomach. Almost entire absorption takes place in the small intestine. Very little food is absorbed in the stomach. Almost entire absorption takes place in the small intestine. Vitamin C and K are absorbed in the small intestine. Bile and vitamin A, D, E, and K are absorbed in the small intestine. Bile and vitamin A, D, E, and K are absorbed in the small intestine.

**Functions of the small intestine:**

1) Digestion
2) Absorption.

- Chyme is propelled into the duodenum from the stomach due to relaxation of pyloric sphincter.
- Here it is alkalinised due to the action of pancreatic and intestinal juices.
- Intestinal juices are produced in the jejunum. Bile juice is useful for emulsification of fats. Pancreatic juice contains trypsin, amylase, and lipase enzymes. Trypsin is responsible for conversion of proteins into polypeptides. Amylase converts all starch into maltose and dextrin. Lipase acts on fats and converts them to fatty acids and glycerol.

Intestinal juice is also called succus entericus. It contains water, salts, and enzymes.

Enzymes present in succus entericus are:

1) Enteroxine
2) Peptidase
3) Maltase
4) Sucrase
5) Lactase
6) Lipase

Enterokinase is responsible for conversion of trypsinogen secreted by the pancreas into trypsin. Peptidase converts polypeptides into amino acids. Maltase converts maltose into glucose molecules. Sucrase converts sucrose into glucose and fructose molecules. Lactase converts lactose into glucose and galactose molecules. These enzymes are mixed with food by peristalsis and muscular action of the walls of the small intestine.

These processes occur first at one place, next in another place and then followed by relaxation. This has a churning effect on food. Digestive process in the stomach is incomplete. It is complete in the small intestine. End products of digestion are:

- Proteins - amino acids
- Carbohydrates - monosaccharides
- Fats - fatty acids

Absorption: Very little food is absorbed in the stomach. Almost entire absorption takes place in the small intestine. Very little food is absorbed in the stomach. Almost entire absorption takes place in the small intestine. Vitamin C and K are absorbed in the small intestine. Bile and vitamin A, D, E, and K are absorbed in the small intestine. Bile and vitamin A, D, E, and K are absorbed in the small intestine.

**Functions of the small intestine:**

1) Digestion
2) Absorption.

- Chyme is propelled into the duodenum from the stomach due to relaxation of pyloric sphincter.
- Here it is alkalinised due to the action of pancreatic and intestinal juices.
- Intestinal juices are produced in the jejunum. Bile juice is useful for emulsification of fats. Pancreatic juice contains trypsin, amylase, and lipase enzymes. Trypsin is responsible for conversion of proteins into polypeptides. Amylase converts all starch into maltose and dextrin. Lipase acts on fats and converts them to fatty acids and glycerol.

Intestinal juice is also called succus entericus. It contains water, salts, and enzymes.

Enzymes present in succus entericus are:

1) Enteroxine
2) Peptidase
3) Maltase
4) Sucrase
5) Lactase
6) Lipase

Enterokinase is responsible for conversion of trypsinogen secreted by the pancreas into trypsin. Peptidase converts polypeptides into amino acids. Maltase converts maltose into glucose molecules. Sucrase converts sucrose into glucose and fructose molecules. Lactase converts lactose into glucose and galactose molecules. These enzymes are mixed with food by peristalsis and muscular action of the walls of the small intestine.

These processes occur first at one place, next in another place and then followed by relaxation. This has a churning effect on food. Digestive process in the stomach is incomplete. It is complete in the small intestine. End products of digestion are:

- Proteins - amino acids
- Carbohydrates - monosaccharides
- Fats - fatty acids

Absorption: Very little food is absorbed in the stomach. Almost entire absorption takes place in the small intestine. Very little food is absorbed in the stomach. Almost entire absorption takes place in the small intestine. Vitamin C and K are absorbed in the small intestine. Bile and vitamin A, D, E, and K are absorbed in the small intestine. Bile and vitamin A, D, E, and K are absorbed in the small intestine.
again into fat droplets. These fat droplets pass into lymph within villi and are drained away by lacteals. Fat passes through lymphatic vessels to cisternachyli. Thoracic duct carries it into blood stream.

Large intestine:

1) Absorption of water and formation of solid stools.
2) Absorption of salts, glucose, amino acids and certain drugs.
3) Secretion of mucus by goblet cells which lubricate large intestine.
4) Excretion of heavy metals.
5) Biosynthesis of vitamins like cyanacobalamin (B₁₂), folic acid, Vit K by microflora of colon.
6) Digestion of pathogenic microbes by microbes harbouring colon.
7) Mass peristalsis pushing away stools into rectum.
8) Relaxation of muscles of rectum, pelvic floor, abdominal wall and diaphragm.
9) Convulsion of peritoneum.
10) Convulsion of rectum. When pressure in rectum reaches 40-50 mm of Hg, faeces are passed to the exterior through anus. This process is called defaecation. During defaecation, faeces are passed to the exterior through anus. This process is called defaecation.
11) Bladder evacuation facilitates the process. It is involuntary, once started. Increased intra-abdominal pressure during defaecation facilitates the process.
12) Convolution of peritoneum, external sphincter gives stretch sensation and defaecation.

Functions of Liver:

1) Secretion of bile.
2) Detoxication of drugs and certain drugs.
3) Deamination of amino acids to form urea.
4) Absorption of carbohydrates and proteins.
5) Miscellaneous: Production of plasma proteins - Albumin, globulin, fibrinogen and prothrombin.
6) Absorption of amino acids to form urea.
7) Secretion of mucus by goblet cells which lubricate large intestine.
8) Absorption of fats, glucose, amino acids and certain drugs.
9) Absorption of water and formation of solid stools.
Functions of Gall bladder:
1) It acts as reservoir of bile.
2) It concentrates bile.
3) It secretes mucus and excretes cholesterol.
4) It maintains pressure in biliary tract.

Functions of Gallbladder:
1) It acts as a reservoir of bile.
2) It concentrates bile.
3) It secretes mucus and excretes cholesterol.
4) It maintains pressure in the biliary tract.

Functions of Bile:
1) It helps in emulsification of fats by reducing their surface tension. It helps in their digestion.
2) Bile salts help in absorption of A, D, E, K vitamins, fats, iron and calcium.
3) Bile stimulates peristalsis and exerts a laxative effect.
4) Bile has buffer action.
5) It has cholagogue and secretogogue action. Cholagogue action means biliary secretion and secretogogue action means secretion of all enzymes.
6) Bile salts help in digestion by reducing their surface tension.
7) Bile stimulates peristalsis and exerts a laxative effect.
8) Bile has buffer action.
9) It has cholagogue and secretogogue action. Cholagogue action means biliary secretion and secretogogue action means secretion of all enzymes.

Functions of Pancreas:
1) It has both exocrine and endocrine functions.
2) As part of exocrine function, it produces pancreatic juice containing digestive enzymes for digestion of carbohydrates, proteins, and fats. Cells lining the alveoli produce the enzymes.
3) As part of endocrine function, it secretes insulin and glucagon, used in carbohydrate metabolism. α-cells of islets of Langerhans secrete glucagon hormone and β-cells of islets of Langerhans produce insulin.

Disorders of Digestive system:
1) Nausea: It is a distressing feeling of vomiting before vomiting.
2) Vomiting: It is a sudden, spasmodic expulsion of the contents of the stomach.
3) Anorexia: It is a loss of appetite.
4) Constipation: It is a delay in defecation.
5) Diarrhoea: It is frequent defaecation, usually with fluid stools.

Composition of Pancreatic Juice:
Pancreatic juice contains enzymes - trypsinogen, amylase, and lipase. Trypsinogen is converted into its active form by an intestinal enzyme, enterokinase. Trypsin converts peptones and proteins into amino acids. Trypsin is the active form of trypsinogen. Trypsinogen is converted into its active form by the enzyme enterokinase. Amylase acts on cooked and uncooked starch and converts it into maltose. Lipase splits fats into fatty acids and glycerol. The surface area is increased when surface area is increased. Increased surface area is brought about by emulsifying action of bile on fats.
Gastroenteritis: It is a disorder symptomatised by nausea, anorexia, vomiting, abdominal discomfort and diarrhoea. It may be due to bacterial, fungal infections or poisoning.

Peptic ulcer: It is a circumscribed ulceration of mucous membrane. It occurs in the area bathed by acid and pepsin. Peptic ulcers occurring in stomach is gastric ulcer and peptic ulcer occurring in duodenum is duodenal ulcer.

Dysphagia: It is difficulty in swallowing.

Appendicitis: It is inflammation of appendix.

Peritonitis: It is acute inflammation of peritoneal layer.

Hepatitis: It is inflammation of liver.

Cirrhosis: It is hardening of liver and blocking the sinusoids of liver affecting its functions adversely.

Movement of gastrointestinal tract:

Movements of digestive tract are brought about by muscular tissue present in the digestive tract.

Functions of movements of alimentary canal:

1) Secretion of digestive juices.
2) Thorough mixing with digestive juices.
3) Digestion of ingested food.
4) Absorption of digested food.
5) Defaecation.

Types of movements of GIT:

There are two types of movements in GIT. They are:

1) Translatory movements: They travel onwards. Ex: peristalsis, antiperistalsis.
2) Stationary movements: They are localised movements. They do not move onwards. Ex: segmentation, tonic contraction etc.

Summary

Main functions of digestive system are ingestion, secretion, digestion, absorption and defaecation. Digestion starts by the action of ptyalin in mouth. Action of ptyalin continues until it is acidified in stomach. Acidification by HCl present in gastric juice favours the action of gastric enzymes. Digestion is incomplete in stomach. In small intestine, digestion is completed and end products of digestion are formed. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in stomach is limited to certain substances. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.

Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol. Absorption in small intestine is limited to certain substances. End products of digestion of proteins are amino acids. End products of digestion of carbohydrates are monosaccharides. End products of digestion of fats are fatty acids and glycerol.
Short Answer Questions

1) What are different processes taking place in mouth?
2) Explain mastication.
3) What is bolus? How is it formed?
4) Write the steps of deglutition.
5) Give the composition of saliva.
6) Write the composition of bile juice.
7) What is the function of liver?
8) What are the end products of digestion?
9) What are the enzymes present in succus entericus?
10) What are the enzymes present in gastric juice?
11) Mention the phases of gastric secretion.
12) Mention the functions of gall bladder.
13) Give the functions of gall bladder.
14) What are the enzymes present in saliva?
15) Give the function of tongue.
16) Mention the functions of pancreatic juice.
17) Mention secretory cells of gastric mucosa and substances produced.
18) What are the end products of digestion?
19) How does absorption in small intestine take place?
20) How do various disorders of digestive system behave?
21) Define a) Gastritis. b) Anorexia.
22) What are the enzymes present in pancreatic juice.
23) What are the functions of gall bladder?
24) Define defaecation and mention the events.
25) How does absorption in small intestine take place?
26) What are the functions of liver?
27) Define defaecation and mention the events.
28) What are the enzymes present in succus entericus.
29) What are the enzymes present in gastric juice?
30) Mention the phases of gastric secretion.
31) Mention secretory cells of gastric mucosa and substances produced.
32) What are the enzymes responsible for (a) production of saliva (b) mass peristalsis in the colon.
33) Define defaecation and absorption taking place in mouth.
6. RESPIRATORY SYSTEM

Respiration is defined as the process by which oxygen in the external atmosphere is exchanged by blood in the lungs, carried to the tissues, and carbon dioxide formed in the tissues is carried by blood to the lungs and expired.

Functions of the Respiratory Tract:
1. Filteration of dust particles: Dust particles are filtered out by hairs in the nose. Cilia of the trachea and bronchi help in propulsion of mucus with entangled foreign particles, thus keeping the respiratory passages free of foreign particles.
2. Cold and dry inspired air is brought to body temperature and humidified during its passage through the respiratory tract before it reaches the lungs.

Functions of Respiration:
1. Carriage of oxygen to the tissues and elimination of carbon dioxide formed in the tissues.
2. Excretion of volatile substances like ammonia, ketone bodies, water vapor, and drugs like ether.
3. Regulation of body temperature by losing heat through expired air.
5. Water balance through excretion of water vapor.
6. Maintenance of circulation by affecting heart rate and cardiac output.
7. Rhythmic movement of the diaphragm and chest wall helps in venous inflow into the heart.
8. Homeostasis of metabolism in the tissues.

Reflexes of the Respiratory Tract:
1. Cough reflex: Cough is a protective reflex mechanism by which respiratory passages are kept clean.
2. Sneezing reflex: Sneezing is a protective reflex mechanism by which respitory passages are kept clean.

Mechanism of Inspiration: There are two stages in inspiration - 1) Expiratory Centre (expiratory) in the medulla oblongata and 2) Inspiration Centre (innervation) in the medulla oblongata. Nerve impulses pass through the phrenic and intercostal nerves to the diaphragm and intercostal muscles. These muscles contract and increase the size of the thoracic cavity, causing negative intrapleural pressure which draws air into the lungs.

Mechanism of Expiration: Expiration is a passive process. After inspiration, the expiratory centre in the medulla oblongata sends impulses to the diaphragm and intercostal muscles to relax, causing the thoracic cavity to contract and the intrapleural pressure to rise, expelling air from the lungs.

In women, respiration is thoracoabdominal, with both the thoracic and abdominal cavities involved. In men, respiration is abdominal. The lungs of the foetus in the mother's womb are solid, and the pleural pressure is zero.

First Breath: At the start of parturition, as the head of the baby comes out of the mother’s womb, a change in temperature is felt in the medulla oblongata, which sends impulses to the diaphragm and intercostal muscles through the phrenic and intercostal nerves, causing them to contract and increase the size of the thoracic cavity, drawing air into the lungs.
Control of Respiration

Respiration is under both autonomic and voluntary control. Voluntary control system is present in cerebral cortex. It sends impulses to the respiratory motor neurons through corticospinal tracts. Autonomic control system is present in pons and medulla oblongata. It sends impulses to the respiratory motor neurons through the vagus nerve.

Pons in the brain consists of apneustic centre and pneumotaxic centre. Stimulation of the apneustic centre stimulates respiratory centres and results in arrest of respiration during inspiration. The pneumotaxic centre is located above the apneustic centre. It inhibits the apneustic centre and prevents inspiration arrests.

Chemical Control: It is mainly affected by CO₂ tension. Respiration centre being extremely sensitive to it, increased CO₂ tension stimulates respiration. High increase of CO₂ tension causes asphyxia and death also. Lack of oxygen stimulates respiration. Decreased O₂ tension is another stimulus for respiration.

Stages of Respiration: There are four stages in respiration. They are:

1. Ventilation
2. Intrapulmonary gas mixing
3. Diffusion
4. Perfusion

Ventilation refers to the passage of air into and out of the lungs during inspiration and expiration. Intrapulmonary gas mixing refers to the mixing of inhaled air with the air already present in the lungs. Diffusion refers to the transfer of gases across the alveolar capillary membrane. Perfusion means the flow of adequate quantity of blood through the lungs.

Gaseous exchange: Gaseous exchange occurs at two places.

1. Lungs: Oxygen is taken up by the blood and carbon dioxide is given off by the blood.
2. Tissues: Oxygen is released to the tissues and carbon dioxide is taken up by the blood.

Mechanism of Transport of Oxygen:

Oxygen combines with haemoglobin to form oxyhaemoglobin. It is a reversible combination. At the tissue level, oxygen is released and haemoglobin is called as reduced haemoglobin.

Mechanism of Transport of Carbon Dioxide:

Carbon dioxide is transported in two ways:

1. In dissolved state in plasma as bicarbonate.
2. In combination with haemoglobin as carbamino carbon dioxide.

Mechanism of Speech:

Vocal ligaments are fixed to the thyroid cartilage in front and to the arytenoid cartilages behind. Vocal ligaments are stretched and relaxed by the action of the laryngeal muscles.

Composition of Inspired Air:

- Nitrogen: 79%
- Oxygen: 21%
- Carbon Dioxide: 0.04%
- Water vapour: 16%
- Other gases: 79%

Composition of Expired Air:

- Nitrogen: 79%
- Oxygen: 16%
- Carbon Dioxide: 4.5%
- Water vapour: 16%
- Other gases: 79%

Phrenic Nerve: The phrenic nerve is a mixed nerve that contains motor and sensory fibres. It innervates the diaphragm, a large sheet of muscle that separates the thoracic and abdominal cavities. The phrenic nerve originates from the cervical nerves C3 to C5.
is called as asphyxia.

Anaphylactic reactions: Immediate reactions of blood leads to death. This condition is due to release of histamine and other chemicals which cause narrowing of bronchi.

Dissection of larynx: It is a surgical procedure to remove the larynx and the voice box. It is performed when there is a severe narrowing of the larynx due to cancer or other conditions.

Respiratory volumes:

Tidal Volume: It is the volume of air breathed in or expired out during normal quiet breathing. Normal value is 500 ml.

Inspiratory Reserve Volume: It is the volume of air which is inhaled above the tidal volume in forced inspiration. Normal value is 2-3.3 litres.

Expiratory Reserve Volume: It is the volume of exhaled air above the tidal volume in forced expiration. Normal value is 1 litre.

Vital Capacity: It is the volume of air breathed out by forced expiration after taking forced inspiration. Normal value is 4.3 L in males and 3.1 L in females.

Residual Volume: It is the volume of air remaining in the lungs after maximum expiration. Normal value is 1.2 L.

Normal rate of respiration: 14 - 18 per minute in adults.

Artificial respiration:

Methods of artificial respiration:

1) Manual methods: They are 1) Schaefer’s method
2) Instrumental methods

Artificial respiration: It is indicated when there is respiratory failure but the heart continues to beat. During this process, lungs are subjected to alternate inflation and deflation. Artificial inflation and deflation of lungs reflexly stimulates respiratory centres.

Methods of artificial respiration:

1) Manual methods: They can be divided into 1) Manual methods
2) Instrumental methods

1) Manual methods: They are 1) Schaefer’s method
2) Instrumental methods

Artificial respiration: It is indicated when there is respiratory failure but the heart continues to beat. During this process, lungs are subjected to alternate inflation and deflation. Artificial inflation and deflation of lungs reflexly stimulates respiratory centres.

Methods of artificial respiration:

1) Manual methods: They are 1) Manual methods
2) Instrumental methods

1) Manual methods: They are 1) Schaefer’s method

Artificial respiration:

Methods of artificial respiration:

1) Manual methods: They are 1) Schaefer’s method
2) Instrumental methods

Methods of artificial respiration:

1) Manual methods: They are 1) Schaefer’s method
2) Instrumental methods

Methods of artificial respiration:

1) Manual methods: They are 1) Schaefer’s method
2) Instrumental methods

Methods of artificial respiration:

1) Manual methods: They are 1) Schaefer’s method
2) Instrumental methods

Methods of artificial respiration:

1) Manual methods: They are 1) Schaefer’s method
2) Instrumental methods
6) Anoxia: It is a condition of lack of oxygen availability to body in general. It is also called as hypoxia.

7) Cyanosis: Taking up of blue colour by skin and mucous membranes is called as cyanosis. It occurs from anoxaemia, respiratory obstruction, lung diseases, heart failure, venous obstruction etc.

Disorders of respiratory system:

Pharyngitis: It is inflammation of pharynx due to bacterial or viral infection or allergic condition.

Laryngitis: It is the inflammation of larynx due to bacterial or viral infection or allergy.

Pneumonia: It is acute infection of alveoli of lungs due to bacterial or viral infections.

Asthma: It is spasmodic contraction of bronchi and bronchioles. Patient feels more difficulty in expiration than for inspiration.

Bronchitis: It is acute or chronic inflammation of bronchi due to microbial, chemical or mechanical causes.

Emphysema: It is a disease of lungs in which, some of the walls of alveoli break to create larger alveoli. It causes reduced surface area for gaseous exchange. Vital capacity is decreased in such case.

Pneumothorax: It is clinical disorder in which free air is present between visceral and parietal layers, which may lead to collapse of lungs.

Pleurisy: It is a condition of inflammation of pleura. In dry pleurisy, it is dry visceral and parietal layers, which may lead to collapse of lungs.

Pulmonary tuberculosis: It is a chronic infectious disease caused by mycobacterium tuberculosis. It is symptomatised by low fever, cough, blood in sputum.

Summary

In spumnm, myocarditis is caused by lymphocytes. It is symptomatised by low fever and cough.

Pulmonary tuberculosis: It is a chronic infectious disease caused by mycobacterium tuberculosis. It is symptomatised by low fever, cough.

Promethazine: It is a condition of inflammation of pleura. In dry pleurisy, it is dry visceral and parietal layers, which may lead to collapse of lungs.

Promethazine: It is a clinical disorder in which free air is present between visceral and parietal layers, which may lead to collapse of lungs.

Emphysema: It is a disease of lungs in which, some of the walls of alveoli break to create larger alveoli. It causes reduced surface area for gaseous exchange. Vital capacity is decreased in such case.

Artificial respiration can be given by manual and instrumental methods.
12. What is inspiratory reserve volume?

13. Define vital capacity.

14. Write the normal values of
   a) Expiratory reserve volume.
   b) Rate of respiration.

15. Define
   a) Hyperpnoea
   b) Cyanosis
   b) Rate of respiration.

16. Explain
   a) Asthma
   b) Emphysema

17. Name the methods of artificial respiration.

NERVOUS SYSTEM

Nervous system controls and integrates the functions of the human body. It is divided into the central nervous system (CNS) and the peripheral nervous system (PNS).

Central Nervous System
- Consists of the brain and spinal cord.
- Controls and integrates the body's functions.

Peripheral Nervous System
- Divided into somatic nervous system (SNS) and autonomic nervous system (ANS).

Somatic Nervous System
- Controls voluntary movements.

Autonomic Nervous System
- Controls involuntary functions like heart rate, blood pressure, and digestion.

Physiological characteristics of nerve fibres:
1. Excitability or irritability: It is the property of a nerve fibre to respond to stimuli.
2. Conductivity: It is the ability of a nerve to transmit impulses.
3. All or none law: A nerve fibre either responds to its maximum or there will be no response at all.

Transmission of impulses in nerves is electrical in nature. It is due to electrical potential differences in the concentration of sodium and potassium ions on either side of the membrane.

Ganglion: A ganglion is a collection of nerve cells and their fibres lying away from the central nervous system.

Synapse: A synapse is the junction where one neuron ends and the other begins.

Physiological characteristics of nerve fibres:
1. Excitability or irritability: It is the property of a nerve fibre to respond to stimuli.
2. Conductivity: It is the ability of a nerve to transmit impulses.
3. All or none law: A nerve fibre either responds to its maximum or there will be no response at all.

Types of nerves:
1. Afferent or sensory nerves: Afferent nerves are those which bring impulses from various organs or periphery to the brain or spinal cord.
2. Efferent or motor nerves: Efferent nerves are those which carry the impulses from the brain or spinal cord to the periphery.

Chemical Transmission at Synapse:
Nerve impulse over nerve fibre is electrical at the terminal end of axon where it is to be transmitted to another neuron or muscle. Through the synaptic cleft, it becomes chemical due to release of a chemical called neurotransmitter.

Neurotransmitter: Neurotransmitter is defined as a chemical substance released from a neuron, which acts rapidly, briefly and at short range. Examples of neurotransmitters are acetylcholine, dopamine, serotonin, GABA, glutamate, glycine, noradrenaline, adenosine, etc.

Action potential: Changes in the membrane potentials causing depolarisation and repolarisation in the membrane potentials are called action potential.

Factors affecting nerve conduction:
1. Conductive strength of nerve.
2. Intra-cellular resistance.
3. Myelination.
4. Temperature.

Factors affecting nerve transmission:
1. Chemical transmission at synapse.
2. Receptor sensitivity.
3. Temperature.

Action potential: Changes in the membrane potentials causing depolarisation and repolarisation in the membrane potentials are called action potential.

Membrane potential is caused by differences in the concentrations of sodium and potassium ions on either side of the membrane. If the concentrations of sodium ions outside are greater than the concentrations of potassium ions inside, the nerve is in its resting state and is said to be polarised. In depolarised state, the permeability of sodium ions increases, and potassium ions are actively pumped out.

Polarisation: In a stimulated neuron, number of sodium ions transported out is greater than the number of potassium ions moving in. Membrane is said to be depolarised. In depolarised state, it has negative charge inside and positive charge outside.

Repolarisation: A ten-thousandth of a second after depolarisation, the membrane again becomes impermeable to sodium ions and potassium ions can still move through the membrane. Because of the high concentrations of potassium ions on the outside, potassium ions diffuse outwardly causing repolarisation. This process is called repolarisation.
Ion channels:

Ion channels are components of both intracellular and extracellular membranes. They are selectively permeable to various ions—mainly Na⁺, K⁺, Ca²⁺, Mg²⁺, and Cl⁻. This selectivity is in response to cell stimuli. Each ion channel consists of a pore, gate, and sensors responding to cell signals. The relative activity of ion channels is regulated by several factors, including voltage, chemical signals, and intracellular mechanisms.

Division of Nervous System:

Physiological nervous system is divided into voluntary and involuntary nervous systems. The voluntary nervous system is responsible for conscious control of movements, while the involuntary nervous system controls unconscious functions such as heart rate and digestion.

**Functions of the Brain**

1. Detection and processing of sensory information from inside and outside the body.
2. Orientation and control of movement and posture.
3. Integration and coordination of skeletal muscle contractions.

**Lesions of the Brain:**

Lesions of the brain can cause deficits of posture and voluntary movement.

**Functions of Spinal Cord**

Spinal cord is the main component of the peripheral nervous system. It is responsible for transmitting information between the brain and the body. The spinal cord is divided into different segments, each responsible for different functions. For example, the thoracic segments control movements of the trunk and limbs, while the lumbar segments control movements of the lower body.

**Types of Reflexes:**

There are two main types of reflexes:

1. **Unconditioned or Inborn Reflexes**
   - Superficial reflexes (e.g., corneal reflex, abdominal reflex)
   - Deep reflexes (e.g., knee jerk, bicep jerk, ankle jerk)
   - Visceral reflexes (e.g., digestive reflexes like vomiting and defecation)

2. **Conditioned or Acquired Reflexes**

Conditioned reflexes are induced by external stimuli and cannot be elicited normally.

**Reflex Actions:**

Reflex actions are involuntary responses to stimuli. They are mediated by the spinal cord and are essential for maintaining homeostasis and survival.

**Functions of the Brain:**

1. Detection and processing of sensory information from inside and outside the body.
2. Orientation and control of movement and posture.
3. Brain is also the seat of consciousness.
4. Integration and coordination of skeletal muscle contractions.

**Lesions of the Brain:**

Lesions of the brain can cause deficits of posture and voluntary movement.
Functions of Thalamus:
- Thalamus is an important relay station for sensory and motor impulses. It processes information and routes it to the appropriate areas of the cortex.
- Lesions to the thalamus can cause deficits in sensory perception and motor control.

Mid Brain:
- It forms the connecting link between the forebrain and hindbrain. Crus cerebri are concerned with righting reflexes triggered by auditory and visual impulses. Tegmentum is also concerned with sub-conscious motor functions.
- Substantia nigra plays an important role in controlling muscle tone and rigidity. Damage to this portion or deficiency of neurotransmitter (dopamine) in this region causes Parkinson's disease (Parkinsonism).
- Red nucleus receives and conveys impulses through the spinal cord, hypothalamus, cerebral cortex and brainstem.

Substantia nigra plays an important role in controlling muscle tone and rigidity. Damage to this portion or deficiency of neurotransmitter (dopamine) in this region causes Parkinson's disease (Parkinsonism).

Mid Brain besides being the connecting link between the fore-brain and hind brain, is also an important centre for various righting and postural reflexes. These reflexes are directed through visual and auditory impulses.

Functions of hypothalamus:
- Functions of hypothalamus are as follows:
  1. It exerts highest control over autonomic nervous system.
  2. It acts as a reflex centre for the control of emotional changes.
  3. It controls sleep and wakefulness.
  4. It regulates body temperature.
  5. It controls hunger, feeding, obesity, and thirst.
  6. It controls gastric acid secretion.
  7. It secretes posterior pituitary hormones.
  8. It secretes anterior pituitary hormones.
  9. It controls sexual behaviour.

Functions of Limbic System:
- Emotional changes such as love, hate, envy, revenge, selfishness and altrusim etc. are controlled by this system. The stimulation of limbic system also produces visceral, somatic and endocrinal changes. Lesions to the amygdaloid nucleus cause hypersexuality and hyperphagia in animals.
- The limbic system also serves as the biological clock. It is concerned with the diurnal variations. It acts as a sort of system for emotional homeostasis.
- The limbic system also recognizes threats and danger. It helps the brain to recognize the problems and take steps to restore proper equilibrium.

Functions of reticular formation:
- Chief function of this mass is to co-ordinate muscle activity and arouse the cerebral cortex via wakefulness center in the hypophysis.

THE CEREBRUM:

Motor Functions:
- General motor functions which are volitional.
- Special motor functions like regulation of muscle tone, equilibrium and control of postural activity.
- Lesions to some part of basal nuclei (corpus striatum) can produce Parkinson's disease. Basal nuclei also control automatic movements associated with the control of movement of skeletal muscles.

Sensory Function:
- It helps in analysing sensation of touch, tactile discrimination, temperature, pain, pressure, vibration and stereognostic sensation.
- It also governs special senses like taste, smell, vision and hearing.
- Cerebral hemisphere is the seat for various functions of intelligence e.g. memory, planning, judgement etc.
6. Cortex has well-defined sites, called areas. Psycho-area analyses and interprets the various impressions—psychosensory, psychosensor auditory, etc.

7. Damage to the sensory cortex makes the subject unable to identify the exact site of stimulation though he is still aware of the stimulus.

8. The motor cortex is concerned with control of movements of body. Damage to this part causes paralysis of movements that occur as a willful act. Reflex and involuntary movements can still occur.

8. In speech center present in frontal lobe, thoughts are formulated into words.

9. In auditory cortex present in temporal lobe, speech heard is decoded and understood. Local injury can cause strange behavior associated with complex visual and auditory hallucinations.

10. Parietal cortex is concerned with the high appreciation of sensation such as the ability to assess the weight, texture, and identity of an object. It is called stereognostic sensation.

11. Occipital lobe consists of visual cortex. It receives light impulses from the opposite visual field. Damage to this part causes blindness.

Functions of pyramidal and extrapyramidal tracts (descending tracts):

1. They carry impulses to the brain from muscles and from higher centers.

2. They control the muscles of the body in a coordinated manner.

3. They are involved in the regulation of posture, balance, and equilibrium.

Functions of ascending tracts:

1. They carry impulses from the muscles, joints, and sense organs to the brain.

2. They carry impulses from the spinal cord to the brain.

3. They carry impulses from the brain to the spinal cord.

4. They carry impulses from the brain to the muscles.

5. They carry impulses from the brain to the autonomic nervous system.

6. They carry impulses from the brain to the endocrine system.

7. They carry impulses from the brain to the sympathetic nervous system.

8. They carry impulses from the brain to the parasympathetic nervous system.

9. They carry impulses from the brain to the sensory system.

10. They carry impulses from the brain to the motor system.

11. They carry impulses from the brain to the autonomic nervous system.

Electroencephalogram (EEG):

The electroencephalogram (EEG) is a graphic record of changes in the electrical activity of the brain. It is produced by the cerebral cortex and is recorded by electrodes placed on the scalp. The EEG is used to monitor the electrical activity of the brain in health and illness.

Types of waves:

1. Alpha waves: These waves are produced when the eyes are closed and the subject is in a relaxed state. They are associated with relaxation and sleep.

2. Beta waves: These waves are produced when the eyes are open and the subject is alert and focused. They are associated with wakefulness and concentration.

3. Theta waves: These waves are produced when the subject is in a relaxed state and is engaged in a repetitive or stereotyped activity. They are associated with daydreaming and meditation.

4. Delta waves: These waves are produced when the subject is in a deep state of sleep. They are associated with dreaming.

Factors influencing EEG pattern:

1. Age: EEG patterns change with age. For example, slow waves become more prominent in infants and young children, while high-frequency waves become more prominent in adults.

2. Blood glucose level: Decreased blood glucose levels can cause an increase in the frequency of delta waves.

3. Hypoxia: A decrease in oxygen levels can cause a decrease in cerebral blood flow and a decrease in EEG activity.

4. Sleep: During sleep, the frequency of the EEG waves decreases, and there is an increase in the amplitude of the waves.

The EEG is used to diagnose and treat a variety of neurological conditions, including epilepsy, brain tumors, and stroke.
Cerebrospinal fluid (CSF) is a modified tissue fluid present in the sub-arachnoid space, cerebral ventricles, and the central canal of the spinal cord. It is about 150 ml in adults. It is a clear, colourless, watery fluid formed by the blood vessels of the choroid plexuses, which are situated in the cerebral ventricles. The composition of CSF contains about 40-60 mg% of glucose, which varies with the blood sugar level. It contains traces of proteins and other nitrogenous substances as well as electrolytes such as sodium, potassium, calcium, chloride, bicarbonates, etc. CSF can be withdrawn by a lumbar puncture technique from the sub-arachnoid space which is at the level below the second lumbar vertebra.

Functions of CSF:
1. Bathing of the brain and spinal cord.
2. It acts as a shock absorber or buffer to the brain and the spinal cord.
3. It supplies nutrition and takes away the waste products from the brain and spinal cord.
4. It protects the brain and spinal cord against infections and acts as a buffer.

Cranial nerves:

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Olfactory</td>
<td>Smell</td>
</tr>
<tr>
<td>II</td>
<td>Optic</td>
<td>Vision</td>
</tr>
<tr>
<td>III</td>
<td>Oculomotor</td>
<td>Accommodation and direction (VIII)</td>
</tr>
<tr>
<td>IV</td>
<td>Trochlear</td>
<td>Movement of eyeball</td>
</tr>
<tr>
<td>V</td>
<td>Trigeminal</td>
<td>Sensation from face and scalp, HEAD</td>
</tr>
</tbody>
</table>
Parasympathetic system: It is a diffuse nervous system characterized by its widespread distribution to all organs of the body. It is excitatory in nature and is concerned with the maintenance of bodily functions at rest. Functions of the parasympathetic system include:

- Stimulation of digestive organs
- Increased heart rate
- Increased blood flow to the skin
- Increased salivary and gastric secretion
- Increased renal blood flow
- Increased peristalsis

Sympathetic system: It is a nervous system that innervates the muscles of the heart and blood vessels, as well as the sweat glands and hair follicles. It is inhibitory in nature, and its functions are characterized by:

- Increased heart rate
- Increased blood pressure
- Increased blood flow to the muscles
- Decreased salivary and gastric secretion
- Decreased renal blood flow
- Decreased peristalsis

Disorders of the Nervous System:

- Meningitis: It is an inflammation of the meninges, the protective layer of the brain and spinal cord. It is caused by various pathogens, including bacteria, viruses, and fungi.
- Encephalitis: It is a viral infection of the brain, characterized by fever, headache, and confusion.
- Poliomyelitis: It is a viral infection of the spinal cord, characterized by weakness and paralysis of the muscles.
- Hydrocephalus: It is a condition in which the brain has an abnormal accumulation of cerebrospinal fluid (CSF), leading to increased pressure on the brain.
- Myotonia: It is a condition characterized by muscle stiffness and difficulty in relaxing after contraction.
- Narcolepsy: It is a sleep disorder characterized by sudden and irresistible episodes of sleep.
- Neuralgia: It is a condition characterized by pain in a particular area of the body.
- Neuritis: It is a condition characterized by inflammation of the nerves, which can be caused by a variety of factors, including infection or injury.
- Delirium: It is a state of confusion characterized by disorientation and agitation.
- Epilepsy: It is a chronic condition characterized by seizures.
- Schizophrenia: It is a chronic, severe mental illness characterized by hallucinations, delusions, and disorganized behavior.
- Mania: It is a condition characterized by extreme mood swings and heightened energy levels.
- Parkinson's disease: It is a neurological disorder characterized by tremors, rigidity, and bradykinesia.
- Hemiplegia: It is a condition characterized by paralysis of one side of the body, usually as a result of a stroke.
Summary

Transmission of impulses in nerves is due to membrane potential. Factors affecting nerve conduction are 1) Conduction velocity 2) Intracellular resistance 3) Myelination etc. Transmission at the synapses of the nervous system are meningitis, encephalitis, poliomyelitis, neuralgia, neuritis, schizophrenia etc.

Essay Questions
1) Write about transmission of impulses.
2) Explain the physiology of brain.
3) Write about EEG. Explain specialised functions of brain.
4) What are the functions of cranial nerves? Write about physiology of ANS.
5) Discuss disorders of nervous system.

Short Answer Questions
1) Define polarisation, depolarisation and repolarisation.
2) What is neurotransmitter? Give examples.
3) Explain ion channels.
4) What are divisions of nervous system?
5) Mention the functions of spinal cord.
6) Explain reflex action.
7) What are the types of reflexes?
8) Mention the functions of brain.
9) Write the functions of medulla oblongata.
10) What are the functions of pons?
11) Write the physiology of cerebellum.
12) What are the functions of midbrain?
13) Give the functions of hypothalamus.
14) Give the functions of hypophysis.
15) Write the physiology of cerebrum.
16) What are the functions of medulla oblongata?
17) Mention the function of spinal cord.
18) What are the types of reflexes?
19) Explain conditioning and conditioned reflexes.
20) Define memory and types of memory.
21) What is CSF?
22) Define memory and types of memory.
23) Mention the factors influencing EEG pattern.
24) Define EEG and mention types of waves.
25) Define the functions of CNS.
26) Define the functions of brainstem.
27) Define the functions of spinal cord.
28) Define the functions of peripheral nerves.
29) What are the effects of sympathetic stimulation over heart?
30) What are the effects of parasympathetic stimulation over heart?
Endocrine System

Endocrine glands secrete chemical substances known as hormones, which in minute concentrations exert significant physiological action on the target organs. Endocrine glands being ductless glands pour their secretions into bloodstream directly. There are two systems in the body, which are related with co-ordination of functions of different systems. They are a) Nervous system b) Endocrine system. Endocrine system is concerned with control and co-ordination of functions of different systems. There are two systems in the body, which are related with co-ordination of functions of different systems.

Methods of investigation of endocrine glands:

8.1 Negative feed back mechanism

8.2 Positive feed back mechanism

Chemical nature of hormones: Chemically, hormones are proteins, glycoproteins, peptides, amino acid derivatives or steroids.

Mechanism of action of hormones: Hormones are believed to act by binding to the receptors present on plasma membranes of target cells.

Storage of hormones: They are not stored except in the organ of synthesis. They get destroyed and eliminated as soon as they exert their effect.

Transport of hormones: They are normally transported by binding themselves to plasma proteins.

Endocrine regulation: Endocrine regulation are inter related and inter dependent. If a gland 'A' stimulates gland 'B', gland 'B' directly or indirectly, stimulates gland 'C', gland 'C' in turn inhibits gland 'B'. This is called feedback.

Endocrine regulation: Endocrine regulation are inter related and inter dependent. If a gland 'A' stimulates gland 'B', gland 'B' directly or indirectly, stimulates gland 'C', gland 'C' in turn inhibits gland 'B'. This is called feedback.

Methods of investigation of endocrine glands:

1. Clinical methods
2. Experimental methods
3. Chemical methods
4. Autoradiographic methods

Essential properties to be possessed by hormones:
1. Water solubility/Carriability: As they have to be transported via blood, they must be water soluable/transportable.
2. Low molecular weight: Hormones have low molecular weight.
3. Non cumulative: Hormones are not stored except in the organ of synthesis.
4. Functional properties of endocrine glands:
   a) Growth
   b) Metabolism
   c) Resistance to stress
   d) Reproduction
   e) Stability of internal environment

Endocrine system is concerned with control and co-ordination of functions of different systems. There are two systems in the body, which are related with co-ordination of functions of different systems. Endocrine glands secrete chemical substances known as hormones, which in minute concentrations exert significant physiological action on the target organs. When
should be water soluble or should be of form, in which, they can be carried to the target organs.

2) Low molecular weight: They should have low molecular weight so as to readily diffuse out of capillaries. This is true in case of almost all hormones except insulin, thyroglobulin etc., which have bigger molecules.

3) Non cumulation: They should be inactivated or destroyed and eliminated to prevent cumulative action.

Hypothalamus

Hypothalamus regulates secretory functions of anterior lobe of pituitary. Hormones of posterior lobe of pituitary are produced in hypothalamic nuclei and transported to posterior pituitary through hypothalmico hypophyseal tract.

Regulation of secretory functions of anterior Pituitary: Hypothalamus regulates secretory functions of anterior pituitary by means of releasing and inhibiting factors liberated by hypothalamic axons.

Releasing & inhibiting hormones produced by hypothalamus:

Releasing hormones produced by hypothalamus:
1) Corticotrophin releasing hormone or factor (CRH or CRF)
2) Thyrotrophin releasing hormone or factor (TRH or TRF)
3) Leutinising hormone releasing hormone or factor (LH-RH or LH-RF)
4) Follicle stimulating hormone releasing hormone or factor (FSH-RH or FSH-RF)
5) Growth hormone releasing hormone or factor (GH-RH or GH-RF)
6) Prolactin releasing hormone or factor (PRH or PRF)

Inhibiting hormones produced by hypothalamus:
1) Growth hormone release inhibiting hormone or factor (GH-RIH or GH-IF)
2) Prolactin release inhibiting hormone or factor (PR-IF)
3) Melanocyte stimulating hormone release inhibiting hormone or factor (MSH-RIH or MSH-IF)

Posterior pituitary functions: Vasopressin also called antidiuretic hormone (ADH) and oxytocin are secreted by hypothalamus and transported to posterior pituitary where they are stored and released.

Hypothalamus secretes some hormones which have control over other endocrine glands. They are called releasing hormones and inhibiting hormones. These hormones control the release of other endocrine glands.

Releasing & inhibiting hormones produced by hypothalamus:

Primary gland

Adrenocorticotropic hormone (ACTH)
Thyrotrophic hormone (TSH)
Luteinising hormone (LH)
Follicle stimulating hormone (FSH)
Prolactin
Growth hormone (GH)

Growth hormone (GH): It is also called somatotrophic hormone (STH)

Functions of growth hormone: They can be divided into:

1) Growth stimulating hormone (GSH) or (GHRH or GHRP)
2) Growth hormone releasing hormone (GHRH or GHRP)
3) Adrenocorticotropic hormone (ACTH)
4) Luteinizing hormone releasing hormone (LH-RH or LH-RF)
5) Follicle stimulating hormone (FSH)-RH or FSH-RF
6) Growth hormone releasing hormone (GH-RH or GH-RF)
7) Prolactin releasing hormone (PRH or PRF)
8) Growth hormone release inhibiting hormone (GH-RIH or GH-IF)
9) Prolactin release inhibiting hormone (PRF or PR-IF)
10) Melanocyte stimulating hormone release inhibiting hormone (MSH-RIH or MSH-IF)

Hypothalamic hormones produced by hypothalamus:


Provisional function by anterior pole of hypothalamus:

Primary gland

Adrenocorticotropic hormone (ACTH)
Thyrotrophic hormone (TSH)
Luteinising hormone (LH)
Follicle stimulating hormone (FSH)
Prolactin
Growth hormone (GH)

Growth hormone (GH): It is also called somatotrophic hormone (STH)

Functions of growth hormone:

a) Growth functions
b) Metabolic functions
c) Lactogenic functions

a) Growth functions:
Growth hormone is needed for normal growth of body. It stimulates skeletal growth, muscular growth, visceral growth and growth of thymus.

b) Metabolic functions:
Growth hormone has also effects on metabolism of proteins, carbohydrates, fats and minerals.

Hypothalamic hormones produced by hypothalamus:

1) Corticotrophin releasing hormone or factor (CRH or CRF)
2) Thyrotrophin releasing hormone or factor (TRH or TRF)
3) Leutinising hormone releasing hormone or factor (LH-RH or LH-RF)
4) Follicle stimulating hormone releasing hormone or factor (FSH-RH or FSH-RF)
5) Growth hormone releasing hormone or factor (GH-RH or GH-RF)
6) Prolactin releasing hormone or factor (PRH or PRF)
7) Growth hormone release inhibiting hormone or factor (GH-RIH or GH-IF)
8) Prolactin release inhibiting hormone or factor (PR-IF)
9) Melanocyte stimulating hormone release inhibiting hormone or factor (MSH-RIH or MSH-IF)
10) Corticotrophin releasing hormone or factor (CRH or CRF)
4) Lactogenic function: It also increases secretion of milk during lactation.

Disorders resulting from Hyper and Hypo secretions:

Hyperpituitarism:
- Hyperpituitarism in youngs causes gigantism. Hyperpituitarism in adults causes acromegaly. 
  - Gigantism is characterised by unusual tall structure due to increased skeletal growth.
  - Acromegaly is characterised by thickening of bones giving gorilla type appearance.

Hypopituitarism:
- Hypopituitarism in children and infants causes dwarfism.
- Pituitary dwarfs are unusually shorter than normal subjects of same age.
- Hypopituitarism in children retards sexual development.
- In adults, it causes sexual degeneration i.e. impotency and amenorrhoea etc.

Regulation of growth hormone:
- Secretion of growth hormone by acidophil cells of pars distalis is mainly regulated by a hormone produced by hypothalamus known as growth hormone releasing factor (GHRF).

2) Thyrotrophin or thyroid stimulating hormone (TSH):
- It controls the growth of thyroid gland and its activity.
- Hyperpituitarism and hypopituitarism have influence over thyroid.
- Hyperpituitarism causes hyperactivity of thyroid and hypopituitarism causes retardation of thyroid development.
- Release of thyrotrophin is mainly controlled by thyrotrophin releasing factor (TRH) by hypothalamus.

3) Adrenocorticotrophic hormone (ACTH): 
- It is also called as adrenocorticotrophin or adrenotrophic hormone.
- It controls the growth of adrenal cortex and release of cortisol by adrenal cortex.
- Hypothalamus mainly controls release of ACTH through CRF (Corticotropin releasing factor).

4) Follicle stimulating hormone (FSH):
- FSH causes maturation of Graafian follicles in females and preparation for ovulation.
- It develops ovarian follicles to secrete oestrogen.
- FSH causes maturation of Graafian follicles in females and prepares them for ovulation.

5) Leutinising hormone (LH):
- It develops ovarian follicles to secrete oestrogen and causes ovulation.
- LH develops ovarian follicles to secrete oestrogen in females and causes ovulation in males.

6) Prolactin:
- It is also called leutotrophin or leutotrophic hormone or mammotrophic hormone.
- It is responsible for lactation in postpartum women.
- Suckling of nipple by baby stimulates secretion of prolactin. This is called suckling stimulus.
- Suckling stimulus also evokes secretion of oxytocin.

Hormonal function of pars tuberalis:
- It is not known.

Hormonal function of pars intermedia:
- Pars intermedia secretes a hormone called melanocyte stimulating hormone (MSH).
- It is also called intermedin.
- It affects the synthesis of melanin.
- Secretion of MSH is inhibited by hydrocortisone and cortisone.
- Action of MSH is inhibited by epinephrine and norepinephrine.

Functions of Neuro Hypophysis:

Hormonal function of Pars nervosa:
- Physiologically, posterior lobe means pars nervosa though anatomically, it consists of pars nervosa and pars intermedia.
- Neurohypophysis consists of pars nervosa and infundibulum.
- Hormones of neurohypophysis are vasopressin and oxytocin.
- Vasopressin is also called antidiuretic hormone (ADH). Actually, vasopressin and oxytocin are synthesized in the hypothalamus, transported to posterior lobe and are released in association with antidiuretic factor (ADH) and oxytocin releasing factor.
- Oxytocin causes appearance, growth and persistence of corpus luteum.
- In males, LH or ICSH (Interstitial cell stimulating hormone) stimulates Leydig cells (Interstitial cells) to produce androgen.
- FSH and LH are called gonadotrophins or gonadotrophic hormones.
- Actually, FSH and LH are called gonadotrophins or gonadotrophic hormones.
- In males, LH or ICSH (Interstitial cell stimulating hormone) stimulates Leydig cells to produce androgen.
Oxytocin: Oxytocin is a hormone causing contraction of the uterus. It contracts the smooth muscle of the mammary gland, leading to milk ejection. It also stimulates the release of prolactin from the anterior pituitary, which further aids in milk ejection. Oxytocin plays a role in the onset of labor, milk ejection, and sexual behavior.

Thyroid Gland

Hormones produced by the thyroid gland: T3, T4

Hyperthyroidism: Hyperthyroidism causes an increase in body temperature and metabolic rate. It leads to symptoms like weight loss, increased heart rate, and restlessness.

Hypothyroidism: Hypothyroidism causes fatigue, weight gain, and decreased metabolic rate. Symptoms include dry skin, constipation, and cold intolerance.

Thyroxine (T4) and Triiodothyronine (T3) Functions:
- Growth and development: T4 and T3 are crucial for normal growth and development in children.
- Metabolism: They influence carbohydrate, protein, and lipid metabolism. T3 is more potent than T4.
- Calorogenesis: T3 stimulates the basal metabolic rate (BMR).
- Heart rate: T3 increases heart rate and contractility.

Disorders resulting from hypo and hypersecretions of thyroxine and triiodothyronine:

Hypothyroidism: Hypothyroidism causes cretinism in children and myxedema in adults. Symptoms include mental retardation, delayed speech, and reduced motor activity.

Cretinism: Symptoms include delayed motor development, mental retardation, and characteristic physical features.

Myxedema: Symptoms include dry skin, hair loss, cold intolerance, and slow metabolism.

Thyroid Hormones: Thyroid hormones influence growth and development, metabolism, and cardiovascular function.

Effect on heart rate: Thyroxine increases heart rate and contractility.

Hormones produced by the thyroid gland:

1. Thyroxine (T4)
2. Triiodothyronine (T3)
3. Calcitonin

Endocrine System: Hormones control the activities of other cells in the body by communicating information through the bloodstream.

Hormones: Thyroid hormones are produced in the thyroid gland and released into the bloodstream to be transported to various tissues throughout the body.

Thyroid Hormones: Thyroid hormones control the metabolic rate, growth, and development of various tissues in the body.

Disorders: Hypothyroidism and hyperthyroidism can manifest as various symptoms, including weight changes, fatigue, and altered mood.

Hormones: Oxytocin is essential for milk ejection, and T3 and T4 are critical for growth and metabolism.
6) Slowed heart rate & cardiac output etc.
7) Lethargy & apathy etc.

Goitre: Goitre is enlargement of thyroid gland. It is non-inflammatory, non-neoplastic disease. Colloid goitre, diffuse parenchymatous goitre and nodular goitre are due to 1) iodine deficiency 2) goitrogenic substances 3) drugs etc. In toxic goitre, thyroid gland is enlarged and also there is hypersecretion of thyroid hormones produced by the gland. This condition is called hyperthyroidism. Hormones secreted by the gland include:

- Triiodothyronine (T3)
- Thyroxine (T4)
- Calcitonin
- Parathyroid hormone

Hyperthyroidism is caused by overproduction of thyroid hormones, leading to increased metabolic rate and symptoms such as weight loss, increased sweating, and nervousness.

Hypothyroidism: It is characterized by weakness, loss of muscle tone, nausea, and other symptoms.

Parathyroid gland: The parathyroid glands are essential for life. They secrete parathyroid hormone (PTH), which is involved in maintaining normal calcium and phosphate levels.

Adrenal glands: The adrenal glands secrete two main types of hormones:

1. Steroidal hormones: These include:
   - Glucocorticoids: Cortisol, cortisone, hydrocortisone, dehydroepiandrosterone
   - Mineralocorticoids: Aldosterone, 11-deoxycorticosterone

2. Non-steroidal hormones: These include:
   - Androgens: Androstenedione, dehydroepiandrosterone
   - Estrogens: Estradiol, progesterone

Functions of adrenal cortex: The adrenal cortex secretes hormones in response to ACTH.

- Mineralocorticoids: Regulate electrolyte balance
- Glucocorticoids: Regulate stress response, immune function, and metabolism
- Androgens: Involved in sex hormone production

Hyperparathyroidism: It is characterized by high blood calcium levels due to increased secretion of parathyroid hormone (PTH).

Hypoparathyroidism: It is characterized by low blood calcium levels due to decreased secretion of parathyroid hormone (PTH).

Disorders resulting from hyper and hypo activities of parathyroids:

- Hyperparathyroidism: Commonly caused by tumor or hyperplasia of parathyroid gland.
- Hypoparathyroidism: Commonly occurs after thyroid surgery.

Adrenal cortex: The adrenal cortex secretes glucocorticoids and mineralocorticoids.

- Glucocorticoids: Involved in stress response and immune function
- Mineralocorticoids: Involved in electrolyte balance

Disorders of adrenal cortex:

- Addison's disease: Hyposecretion of adrenal cortex hormones, leading to low blood pressure, weakness, and fatigue.
- Cushing's syndrome: Hypersecretion of adrenal cortex hormones, leading to weight gain, moon face, and other symptoms.

Hypothyroidism: Causes: Autoimmune thyroiditis, Hashimoto's thyroiditis, postpartum thyroiditis, and other causes.

Hyperthyroidism: Causes: Graves' disease, toxic multinodular goiter, and other causes.
Sex characters.

Disorders resulting from hypo and hyper functioning of adrenal cortex:

Chronic insufficient adrenal cortical secretion causes Addison's disease. Acute insufficiency sometimes occurs in which there is absence of secretion by the cortex.

Addison's disease: Addison's disease is caused by tuberculosis of adrenal cortex and medulla. Addison's disease is characterised by:
- Muscular weakness, easy fatiguability, low diastolic B.P., gastrointestinal disturbances, pigmentation of skin and mucous membranes, low BMR, sub normal temperature, concentration defects, sub normal sexual functions, etc.

Disorders of hyper secretion are:
- Cushing's syndrome
- Hyper aldosteronism
- Adrenogenital syndrome

Cushing's syndrome: In Cushing's syndrome, there is excessive secretion of cortisol. The underlying cause may be excessive secretion of ACTH, either from a pituitary adenoma or due to metastasis of a pituitary adenoma. The resultant hypertension, muscular weakness, diabetes, hypertension, hyperglycaemia, and weight loss characterise this disease.

Hyper aldosteronism: Hyper aldosteronism is due to over activity of the adrenal cortex. The disease is characterised by:
- Hypertension, muscular weakness, mental confusion, nausea, vomiting, polyuria, hypokalaemia, hypoxia, hyperviscosity of blood, etc.

Adrenogenital syndrome: Hyper aldosteronism results from over activity of the adrenal cortex.

Control of adrenal cortex:
- Corticotrophin (ACTH) is secreted by corticotrophin releasing factor secreted by hypothalamus.
- Aldosterone is controlled by glomerulotrophin released by pituitary.
- ACTH is controlled by concentration of sodium in plasma.

Adrenal medulla:

- Produces adrenaline and noradrenaline.
- Adrenal medulla is sensitive to changes in blood pressure and circulating catecholamines.
- Adrenal medulla produces adrenaline and noradrenaline.
- The secretion of adrenaline is controlled by the sympathetic nervous system.
- Noradrenaline is controlled by the parasympathetic nervous system.

Hormones of pancreas:

- Alpha cells of islets of Langerhans produce glucagon.
- Beta cells of islets of Langerhans produce insulin.

Insulin is the main pancreatic hormone. It lowers blood sugar levels by following pathways.

Pancreas:

- Alpha cells: alpha cells produce glucagon, which helps to increase blood sugar levels.
- Beta cells: beta cells produce insulin, which helps to decrease blood sugar levels.
- Glucagon stimulates the liver to release glucose into the bloodstream.
- Insulin promotes the uptake of glucose into cells, especially muscle and fat cells.

Diabetes mellitus:

- Hyperglycaemia: High blood sugar levels due to lack of insulin or resistance to insulin.
- Hypoglycaemia: Low blood sugar levels due to excess insulin.

Adrenal cortex:

- Nerve fibres terminate in the adrenal cortex.
- Adrenal cortex secretes sex hormones.
- Sex hormones are important in the development of secondary sex characteristics.
- Adrenal cortex secretes adrenaline and noradrenaline.

Pancreas:

- Alpha cells: produce glucagon, which promotes the breakdown of glycogen into glucose.
- Beta cells: produce insulin, which promotes the uptake of glucose into cells and the storage of glycogen.

Blood glucose levels are maintained by the interplay of these hormones.
Preventing gluconeogenesis.

Glucagon is hyperglycaemic hormone. It raises blood sugar levels by glycogenolysis and gluconeogenesis.

Hypoglycaemia: Hypoglycaemia is a condition in which blood sugar level is lowered below 80 mg%. Between 70-50 mg% of blood sugar, symptoms of hypoglycaemia start. In diabetics, these symptoms may start at a level well above normal.

Symptoms of hypoglycaemia:
- Weakness, fatigue and hunger.
- Anxiety and irritability.
- Behavioural abnormality similar to those seen in alcohol poisoning.
- Tremors, flushing.
- Delirium, coma, convulsions.
- Loss of deep reflexes.

Hyperglycaemia: Hyperglycaemia is a condition in which blood sugar level is raised above normal.

Renal threshold and glycosuria: Renal threshold for blood sugar is 180 mg%. Though blood sugar level raises above 120 mg%, it does not appear in urine. It appears in urine after it raises above 180 mg%. This appearance of sugar in urine is called glycosuria. Normally, renal tubular cells are able to reabsorb glucose back into blood. When blood sugar level is low, renal tubular cells are unable to reabsorb glucose back into blood. Thus, glycosuria occurs.

Diabetes mellitus: Diabetes mellitus is disease resulting from abnormal carbohydrate metabolism.

Diabetes mellitus occurs when blood sugar level is raised above normal.

Insulin deficiency or hyperpituitarism or hyperthyroidism or hyperactivity of adrenal cortex results in diabetes mellitus.

Diabetes mellitus is divided into four stages.

Stage I - Prediabetes, insulin resistance.
- Weight loss.
- Polyphagia.
- Polyuria.
- Polydipsia.
- Ketosis.
- Acute or chronic.

Stage II - Subclinical diabetes, carbohydrate metabolism becomes abnormal under stress.
- Glucose tolerance is normal.
- Glucose is excreted in urine.
- Kidneys can still reabsorb glucose.

Stage III - Overt diabetes, carbohydrate metabolism becomes abnormal.
- Glucose intolerance.
- Renal threshold raised.
- Glucose appears in urine.
- Glucose is not reabsorbed.
- Polyuria.
- Polydipsia.
- Polyphagia.
- Acute or chronic.

Stage IV - Chronic diabetes, glucose metabolism becomes abnormal.
- Renal threshold raised.
- Glucose appears in urine.
- Glucose is not reabsorbed.
- Polyuria.
- Polydipsia.
- Polyphagia.
- Acute or chronic.

Diabetes mellitus: Diabetes mellitus is disease resulting from abnormal carbohydrate metabolism.

Diabetes mellitus causes hyperglycaemia, polyuria, glycosuria, polydipsia, polyphagia, ketosis, acidosis, and coma.

Diabetes mellitus may be divided into four stages.

Stage I - Prediabetes.
- Insulin resistance.
- Weight loss.
- Polyphagia.
- Polyuria.
- Polydipsia.
- Ketosis.
- Acute or chronic.

Stage II - Subclinical diabetes.
- Carbohydrate metabolism becomes abnormal under stress.
- Glucose tolerance is normal.
- Renal threshold is normal.

Stage III - Overt diabetes.
- Glucose intolerance.
- Renal threshold raised.
- Glucose appears in urine.
- Glucose is not reabsorbed.
- Polyuria.
- Polydipsia.
- Polyphagia.

Stage IV - Chronic diabetes.
- Glucose metabolism becomes abnormal.
- Renal threshold raised.
- Glucose appears in urine.
- Glucose is not reabsorbed.
- Polyuria.
- Polydipsia.
- Polyphagia.

Diabetes mellitus: Diabetes mellitus is disease resulting from abnormal carbohydrate metabolism.

Diabetes mellitus causes hyperglycaemia, polyuria, glycosuria, polydipsia, polyphagia, ketosis, acidosis, and coma.

Diabetes mellitus may be divided into four stages.

Stage I - Prediabetes.
- Insulin resistance.
- Weight loss.
- Polyphagia.
- Polyuria.
- Polydipsia.
- Ketosis.
- Acute or chronic.

Stage II - Subclinical diabetes.
- Carbohydrate metabolism becomes abnormal under stress.
- Glucose tolerance is normal.
- Renal threshold is normal.

Stage III - Overt diabetes.
- Glucose intolerance.
- Renal threshold raised.
- Glucose appears in urine.
- Glucose is not reabsorbed.
- Polyuria.
- Polydipsia.
- Polyphagia.

Stage IV - Chronic diabetes.
- Glucose metabolism becomes abnormal.
- Renal threshold raised.
- Glucose appears in urine.
- Glucose is not reabsorbed.
- Polyuria.
- Polydipsia.
- Polyphagia.

Diabetes mellitus: Diabetes mellitus is disease resulting from abnormal carbohydrate metabolism.

Diabetes mellitus causes hyperglycaemia, polyuria, glycosuria, polydipsia, polyphagia, ketosis, acidosis, and coma.

Diabetes mellitus may be divided into four stages.

Stage I - Prediabetes.
- Insulin resistance.
- Weight loss.
- Polyphagia.
- Polyuria.
- Polydipsia.
- Ketosis.
- Acute or chronic.

Stage II - Subclinical diabetes.
- Carbohydrate metabolism becomes abnormal under stress.
- Glucose tolerance is normal.
- Renal threshold is normal.

Stage III - Overt diabetes.
- Glucose intolerance.
- Renal threshold raised.
- Glucose appears in urine.
- Glucose is not reabsorbed.
- Polyuria.
- Polydipsia.
- Polyphagia.

Stage IV - Chronic diabetes.
- Glucose metabolism becomes abnormal.
- Renal threshold raised.
- Glucose appears in urine.
- Glucose is not reabsorbed.
- Polyuria.
- Polydipsia.
- Polyphagia.

Diabetes mellitus: Diabetes mellitus is disease resulting from abnormal carbohydrate metabolism.

Diabetes mellitus causes hyperglycaemia, polyuria, glycosuria, polydipsia, polyphagia, ketosis, acidosis, and coma.

Diabetes mellitus may be divided into four stages.

Stage I - Prediabetes.
- Insulin resistance.
- Weight loss.
- Polyphagia.
- Polyuria.
- Polydipsia.
- Ketosis.
- Acute or chronic.

Stage II - Subclinical diabetes.
- Carbohydrate metabolism becomes abnormal under stress.
- Glucose tolerance is normal.
- Renal threshold is normal.

Stage III - Overt diabetes.
- Glucose intolerance.
- Renal threshold raised.
- Glucose appears in urine.
- Glucose is not reabsorbed.
- Polyuria.
- Polydipsia.
- Polyphagia.

Stage IV - Chronic diabetes.
- Glucose metabolism becomes abnormal.
- Renal threshold raised.
- Glucose appears in urine.
- Glucose is not reabsorbed.
- Polyuria.
- Polydipsia.
- Polyphagia.

Diabetes mellitus: Diabetes mellitus is disease resulting from abnormal carbohydrate metabolism.

Diabetes mellitus causes hyperglycaemia, polyuria, glycosuria, polydipsia, polyphagia, ketosis, acidosis, and coma.

Diabetes mellitus may be divided into four stages.

Stage I - Prediabetes.
- Insulin resistance.
- Weight loss.
- Polyphagia.
- Polyuria.
- Polydipsia.
- Ketosis.
- Acute or chronic.

Stage II - Subclinical diabetes.
- Carbohydrate metabolism becomes abnormal under stress.
- Glucose tolerance is normal.
- Renal threshold is normal.

Stage III - Overt diabetes.
- Glucose intolerance.
- Renal threshold raised.
- Glucose appears in urine.
- Glucose is not reabsorbed.
- Polyuria.
- Polydipsia.
- Polyphagia.

Stage IV - Chronic diabetes.
- Glucose metabolism becomes abnormal.
- Renal threshold raised.
- Glucose appears in urine.
- Glucose is not reabsorbed.
- Polyuria.
- Polydipsia.
- Polyphagia.
Thymus acts as a source of lymphocytes. It develops immunological competence. This gland plays an important role in countering environmental stress. This gland helps in the deposition of minerals on bones.

Disorders: Neonatal anaemia is due to passage of thymus stimulating hormone through the placenta into the foetal thymus.

Pineal body is neuroendocrine in function. It regulates rhythmic activity of the endocrine system. Pineal body or epiphysis cerebri contains high concentration of melatonin. Melatonin's precursor is serotonin. Melatonin can lighten the skin of tadpoles, thus the name. In mammals, melatonin acts on the brain tissue and other tissues to influence the development and functioning of the gonads, pituitary, thyroid, and other organs. Pineal body also produces adrenocorticotropic hormone and anti-A.C.T.H. factor. Pineal tumour in children delays puberty. Pineal body also produces a compound that can cure schizophrenia.

Gastrointestinal tract as endocrine:

Gastrin I and II are produced in the pyloric part of the stomach. Upper part of the small intestine produces cholecystokinin - pancreozymin hormone. Duodenal mucosa produces secretin. Wall of the stomach and small intestine produce gut glucagon. Gastric mucosa produces gastrone. Upper part of the small intestine produces villikinin. Intestinal lumen also secretes enterocrinin.

Gastrins:

1) Stimulation of gastric motility
2) Stimulation of oxyntic cells to secrete HCl and pepsinogen
3) Stimulation of gastric fluid
4) Stimulation of duodenal mucosa to release secretin

Cholecystokinin - Pancreozymin (CCK):

1) Stimulation of gall bladder
2) Stimulation of pancreatic cells to secrete HCl and enzymes
3) Stimulation of gastric fluid
4) Stimulation of duodenal mucosa to release secretin

Secretin:

It stimulates the secretion of pancreatic juice but not enzymes. Removal of vagus has no effect on the release of secretin. Removal of pituitary lowers the secretion. If the mucosa of the stomach secretes hydrochloric acid, then the activity of the enzyme is secreted by the wall of the stomach.

Gut glucagon:

It is immunoreactive with glucagon-like activity. It is secreted by the wall of the stomach and small intestine in response to glucose ingestion. Its physiological actions are most similar to those of glucagon, though it is not identical to glucagon. Its release is not regulated by vagus or other means. Glucose ingestion also releases adrenocorticotropic hormone and other hormones.

ACVHL's effect on the body is through the hypothalamo-pituitary-adrenal axis.

Pituitary hormone is the body's first line of defence. It releases anti-A.C.T.H. factor, which, in turn, releases cortisol, a powerful anti-inflammatory hormone. This hormone helps in deposition of minerals on bones. This gland plays an important role in the endocrine and immunological systems of the body. Pituitary hormone is the body's first line of defence. It releases antioestrogen, which, in turn, releases prolactin, a powerful anti-inflammatory hormone. This hormone helps in deposition of minerals on bones. This gland plays an important role in the endocrine and immunological systems of the body.

Pituitary hormone is the body's first line of defence. It releases antioestrogen, which, in turn, releases prolactin, a powerful anti-inflammatory hormone. This hormone helps in deposition of minerals on bones. This gland plays an important role in the endocrine and immunological systems of the body.

Pituitary hormone is the body's first line of defence. It releases antioestrogen, which, in turn, releases prolactin, a powerful anti-inflammatory hormone. This hormone helps in deposition of minerals on bones. This gland plays an important role in the endocrine and immunological systems of the body.
Prostaglandins possess the properties of contraction and relaxation of smooth muscle, effects on reproductive system and many other effects. Renal erythropoietic factor is also called as EPO, as it acts on the bone marrow and promotes haemoglobin synthesis. It augments haemoglobin content and increases red cell volume also.

**Summary**

Endocrine glands are ductless glands whose secretions pour into the blood stream directly. Endocrine glands are different from exocrine glands because they produce and release hormones into the blood stream to affect the functioning of other organs. Endocrine glands are involved in the regulation of body functions such as metabolism, growth, reproduction, and stress response.

**Essay Questions**

1) What are endocrine glands? Write about endocrine regulation mechanisms.
2) What is a hormone? Write notes on mechanism of action, and properties to be possessed by hormones.
3) Write the physiology of pars distalis.
4) Write about functions of Neurohypophysis.
5) Explain the physiology of thyroid gland and clinical disorders related to hypo and hyper activities of this gland.
6) Discuss the physiology of anterior glands.
7) Explain the physiology of posterior glands.
8) Write about posterior pituitary.
9) Examine the physiology of pars nervosa.
10) Explain the physiology of pars intermedia.
11) Write about posterior pituitary.
12) Name the hormones of pars intermedia.
13) Discuss oxytocin.
14) Name the hormones of pars nervosa.
15) Name the hormones of pars distalis.
16) Discuss adrenocortical hormones and their functions.
17) Explain hydrocortisone.
18) Write about vasopressin.
19) Discuss oxytocin.
20) Name the hormones of adrenal cortex.
21) Name the hormones of adrenal medulla.

**Short Answer Questions**

1) Define a) hormone b) endocrine gland.
2) Name the systems concerned with co-ordination of systems of body.
3) Write about a) storage of hormones. b) transport of hormones.
4) What is negative feedback mechanism?
5) Explain positive feedback.
6) Mention the methods of investigation of endocrine glands.
7) What do you mean by tropic hormones? Mention few.
8) What are the effects of hyperplasia of hormone(s) in young (p) adults?
9) Why is glycogen stored as a hormone (p) transporter of hormones?
10) Name the systems concerned with co-ordination of systems of body.
11) Define (a) hormone (b) endocrine gland.
12) What is the function of endocrine glands?
22) Name the disorders of hyper secretion of adrenal cortex.

23) Write the symptoms of Cushing's syndrome.

24) Write about Addison's disease.

25) Differentiate between primary and secondary forms of aldosteronism.

26) Write about control of adrenal cortex.

27) Explain hyper and hypo activities of adrenal medulla.

28) Name the hormones produced by a) Thyroid b) Pineal body.

29) What is hypoglycemia?

30) How does insulin lower blood sugar levels?

31) What is meant by hypoglycemia?

32) Write the symptoms of hypoglycemia.

33) What is hyperglycemia?

34) How does glucagon act as hyperglycaemic?

35) Mention the types of diabetes mellitus and explain.

36) Define hypoglycaemia and hypoglycaemia.

37) Mention the symptoms of hyperglycaemia.

38) What is meant by hyperglycaemia?

39) How does insulin lower blood sugar levels?

40) What is hyperglycemia?

41) Name the hormones produced by a) Thymus b) Pineal body.

42) Name gastrointestinal hormones.

43) What are functions of a) gastrin b) secretin.

44) What are functions of a) Villikinin b) Enterocrinin.

45) What are functions of a) gastrin b) secretin.

46) What are secondary sex characters in males?

47) Mention male sex hormones.

48) Mention male sex hormones.

49) What are the symptoms of diabetes mellitus?

50) Mention the symptoms of diabetes mellitus and explain.

51) Define hypoglycaemia and hypoglycaemia.

52) What is hypoglycemia?

53) What is hyperglycemia?

54) How does glucagon act as hyperglycaemic?

55) Name the hormones produced by a) Thyroid b) Pineal body.

56) Explain hyper and hypo activities of adrenal medulla.
Kidneys are the chief organs of excretion. They perform excretory as well as homeostatic and endocrine functions. Urinary system consists of 2 kidneys, 2 ureters, 1 bladder and 1 urethra.

Functions of kidney:

1) Excretion of waste products of cellular metabolism - especially nitrogenous and sulphur containing waste products of protein metabolism.
2) Maintenance of pH.
3) Maintenance of water balance and thus plasma volume.
4) Elimination of drugs and toxic substances from body.
5) Maintenance of optimum concentration of certain blood constituents by means of selective reabsorption.
6) Regulation of blood pressure by its endocrine function of secreting renin hormone. It occurs during hypoxia in emergency. Renin is produced in the cortex of kidney by juxtaglomerular cells of juxtaglomerular apparatus. Production of prostaglandin also helps in blood pressure regulation.
7) Maintenance of osmolality.
8) Maintenance of acid-base equilibrium.
9) Maintenance of osmotic pressure in blood and tissues.
10) Regulation of erythropoiesis through formation of erythropoietin.
11) Playing important role in vitamin-D metabolism.
12) Maintenance of optimum concentrations of certain substances by process of selective reabsorption.
13) Production of kininogen takes place in kidneys. Kininogen has also antihypertensive effect.
14) Destruction of insulin and glucagon hormones takes place in kidneys.

Renal system consists of 2 kidneys, 2 ureters, 1 bladder and 1 urethra. They perform excretory as well as homeostatic and endocrine functions. Kidneys are the chief organs of excretion.
Reabsorption of sodium and chloride:

Reabsorption of sodium and chloride occurs together. Glomerular filtrate contains about 560 g of Na\(^+\) out of which, about 490 g is reabsorbed in the proximal tubule. About 65 g is reabsorbed in the distal tubule and 5 g is excreted in urine. Reabsorption of sodium is influenced by aldosterone. Aldosterone is an adrenocortical hormone.

Reabsorption of chloride through ascending limb of loop of Henle occurs by active transport. Reabsorption of sodium ions through the proximal tubule, ascending limb of loop of Henle, and distal tubule is passive through the process of diffusion. Chloride is also reabsorbed through sodium ions into the renal tubule by active process.

Reabsorption of potassium:

Most of potassium is reabsorbed in the proximal tubule by active process. Secretion of potassium takes place in the distal convoluted tubule. Reabsorption of sodium ions and secretion of potassium takes place simultaneously.

Reabsorption of bicarbonate:

Bicarbonate is completely reabsorbed in the renal tubule. It occurs by bicarbonate transport. Reabsorption of bicarbonate increases with increasing CO\(_2\) concentration in blood and decreases with depletion of potassium and chloride. Bicarbonate reabsorption is influenced by secretion of aldosterone. Hypersecretion of aldosterone increases bicarbonate reabsorption.

Reabsorption of phosphate:

Phosphate is reabsorbed in the proximal tubule. Reabsorption of phosphate is an active process. Parathyroid hormone depresses transport. Acids increase phosphate excretion in the renal tubule, whereas the reabsorption of phosphate increases.

Formation of phosphoglucomutase:

Formation of phosphoglucomutase is an active process. Phosphoglucomutase increases with the reabsorption of phosphate. Phosphoglucomutase is increased by the reabsorption of phosphate.

Reabsorption of sulphate, uric acid, ascorbic acid, β-hydroxy butyric acid, aceto acetic acid, creatine, some of amino acids etc. takes place in the tubules.

Tubular secretion:

Renal tubular cells secrete some substances. Tubular secretion is an active process. Ethereal sulphates, steroids, glucuronides, 5 hydroxy indole acetic acid etc. are secreted by tubules. Certain substances like phenol red, diodrast, penicillin, para amino hippuric acid are actively transferred from blood stream into tubules.

Tubules also secrete potassium, creatinine, and hydrogen ions. Potassium and hydrogen ions are secreted in the tubules when sodium ions are reabsorbed.

Micturition:

Micturition is the process of filling up of bladder and emptying of same from it. It involves co-ordinated contraction of the bladder, abdominal wall, muscles of pelvic floor, fixation of chest wall and diaphragm and relaxation of internal and external urethral sphincters.

Micturition depends on integrity of nerves of the bladder. Voluntary eff ort increases micturition and the process of micturition. Micturition increases with the reabsorption of phosphate. Phosphoglucomutase increases with the reabsorption of phosphate.
has enormous control over this process. It can influence both sympathetic and parasympathetic supply to bladder.

Central control of micturition: Cortical centre, hypothalamic centre, brain stem centre and spinal centres control this process centrally.

Dialysis: It is the process of diffusing the incompatible substances out of blood by means of artificial device. Arterial blood is passed through this device and after filtration, blood is returned back into the body through the vein. Coagulation is prevented by heparin during dialysis.

Abnormal conditions of urinary system:

Nephritis: It is the condition which represents diffuse inflammation of glomeruli. This condition is associated with albumin, casts, haemoglobin etc. In glomerulonephritis, secondary changes in tubule accompany.

Nephrosis: It is also called degenerative nephritis. It is characterised by degenerative changes in glomeruli and tubules.

Nephrosclerosis: There are pathological changes in glomeruli and also arteriosclerosis of renal arteries and veins.

Calculi: Precipitation of urinary salts causes formation of calculi. It is caused by alkaline urine. Patients with calculi have haematuria, pyuria, retention of urine. Severe renal colic follows when stone is located in ureter or on passing through urethra.

Cystitis: It is inflammation of urinary bladder. Symptoms include frequent urination, burning sensation, urgency, dysuria and haematuria.

Summary: The renal system consists of two kidneys. Main functions of kidneys include:

1) Excretion of waste products
2) Water balance
3) Acid-base balance
4) Other functions like formation of B.P., regulation of erythropoiesis etc.

Formation of urine takes place by glomerular and tubular functions i.e. glomerular filtration, tubular reabsorption, tubular secretion and formation of new substances.

Processes taking place in glomeruli and tubules also contribute to other renal functions.

Essay Questions

1. Write the functions of kidneys.
2. Explain glomerular and tubular functions.
3. Write about reabsorption of phosphate.
4. Name the centre controlling micturition.
5. When are the muscles involved in micturition?
6. Define micturition.
7. Where do renal receptors of phosphate lie?
8. Where is tubular reabsorption?
9. What is the urine alkaline after dialysis?
10. What are the changes involved in micturition?
11. Name the centres involved in micturition.
12. Define micturition.
13. Where do renal receptors of phosphate lie?
14. What is the urine alkaline after dialysis?
15. What are the changes involved in micturition?
17. Where do renal receptors of phosphate lie?
18. What is the urine alkaline after dialysis?
19. What are the changes involved in micturition?
20. Define micturition.
21. Where do renal receptors of phosphate lie?
22. What is the urine alkaline after dialysis?
23. What are the changes involved in micturition?
24. Define micturition.
25. Where do renal receptors of phosphate lie?
26. What is the urine alkaline after dialysis?
27. What are the changes involved in micturition?
29. Where do renal receptors of phosphate lie?
30. What is the urine alkaline after dialysis?
31. What are the changes involved in micturition?
32. Define micturition.
10. REPRODUCTIVE SYSTEM

Reproduction is the process of producing same type of offsprings. There are two sexes - male and female. In males masculine characters are dominant and feminine features are rudimentary. In females, feminine characters dominant and masculine features remain rudimentary. Balance of male and female sex hormones is essential for physical and mental get up of male or female.

Puberty: Puberty is onset of reproductive life. It is about 2 years earlier in females than in males. Usually, onset of puberty is between 12 and 16 years.

Menarche: It is the first appearance of menstruation in females.

Menopause: It is cessation of menstruation in females. It is usually between 45th and 55th years of age. There is degeneration of both primary and secondary sex organs at this stage.

Differentiation of sex:
Male spermatogonia and female oogonia also contain 23 pairs of chromosomes as in somatic cells. Of these 22 pairs do not play any role in sex determination and hence are called autosomes. Last pair of chromosomes will be different and called sex chromosomes. In females these are 2 X chromosomes (XX), they are called homoglogous type, and in males sex chromosomes are one X and one Y, and hence called heterologous type. In the process of fertilization, Y chromosome from male is involved, and X can be from either parent. Hence, XY is male and XX is female.

Sex chromosome in females are 2 X chromosomes i.e. XX. In males they are one X and one Y and hence called heterologous type. In the process of fertilization, Y chromosome from male unites with ovum (X), two sex chromosomes will be different and resulting offspring is male (XY).

Functions of testes:
1) Spermatogenesis:
Spermatogenesis is the process of formation of spermatozoa.

2) Secretion of testosterone by interstitial cells of Leydig:
Leydig cells occupy less than 10% of volume of testes. They secrete androgens, progesterone, corticosteroids, and DHEA. Interstitial cells of Leydig are stimulated by LH and FSH.

Semen:
Semen is a mixture of spermatozoa and secretions of various glands. Volume of semen is about 3-4 ml. Reaction ranges from 7.2-8.9 (alkaline). Average pH is 7.8. Self liquefaction of semen takes place and is complete after 30 minutes. Absence of liquefaction inhibits motility of spermatozoa. Normal sperm count is 40-300 millions/ml of semen. Count of spermatozoa less than 20 millions/ml of semen can generally cause infertility. For abnormal spermatozoa, more than 20% abnormalities is more doubtful to cause fertility.

Dihydrotestosterone:
Dihydrotestosterone is more potent androgen. It is identical with testosterone. About 7.8 mg of testosterone is secreted by Leydig cells per day.

Conversion of testosterone to dihydrotestosterone in androgen responsive tissues:
Testosterone is converted into dihydrotestosterone by action of aromatase enzyme. Leukocyte is the first enzyme to convert testosterone into dihydrotestosterone. It is the most potent androgen.

Secretion of Testosterone by Interstitial Cells of Leydig:
Leydig cells secrete testosterone in response to LH. Testosterone is secreted in pulses.

Interstitial cells of Leydig secrete testosterone and LH. They are stimulated by LH and FSH and are regulated by GnRH.

Semen contains spermatozoa, secretions of various glands, and a number of hormones. It is a suspension of spermatozoa in the fluid secreted by accessory glands.
Composition of semen: Constituents of semen are -

- Fructose - principal source of energy for ejaculated sperm.
- Phosphatases - acid phosphatase in high amounts and alkaline phosphatase in low amounts.
- Spermine - nitrogenous base of prostatic secretion, found in large amounts. It differentiates semen from other body fluids.
- Choline - nitrogenous base found in high concentrations. It may have action on female genital organs or on sperm motility.
- Ergothioneine - nitrogenous base ensuring motility of spermatozoa and fructose utilisation.
- Citric acid - derived from prostatic secretion facilitating semen coagulation and liquefaction. It activates prostatic acid phosphatase.
- Lipids - phospholipids and cholesterol derived from prostatic secretion account for opalescence of semen.
- Protein materials - 3.5 to 5 g. of protein/100 ml. is present. It is responsible for coagulation.
- Hyaluronidase - facilitating fertilisation.
- Other substances - they include creatine, creatinine, epinephrine, nor epinephrine and inositol. Their function is not clearly known.

Functions of ovaries:

- Formation of mature ova & secretion of hormones. Hormones secreted are:
  - a) Oestrogens by graffian follicles.
  - b) Progesterone by corpus luteum and corpus albicans.
  - c) Androgens and relaxin.
  - d) Ovarian (follicular) and lutein (corpus luteum) hormones.

Formation of mature ova:

Germinal epithelium is the outermost covering of ovaries. It sends down genital cords. Genital cords are finger-like processes that cut off from the surface and break into small islands of cells. One of these cells enlarges and gets differentiated from the neighbouring cells. It is called a primary oocyte. Rest of the cells surround this primary oocyte and form primordial follicles. Immature primordial follicles are 2-50,000 in number in the newborn baby. They reach 1,000,000 to 2,000,000 in number and all are mature by the age of 30 years. Ovaries consist of four main components:

1. Cortex - a large mass of follicles, the layer of which is made up of large and small follicles.
2. Medulla - a large mass of connective tissue, blood vessels, and nerves that are usually found in the inner part of the ovary.
3. Pedicles - a network of blood vessels, nerves, and lymphatic vessels that supply the ovary.
4. Pelvis - a large cavity that surrounds the ovary and is connected to the uterus by the uterine tube.

Formation of mature ova:

Ovulation occurs between 13 to 17 days after the first day of menstruation. Primordial follicles undergo a process of maturation called ovulation. This process involves the release of the oocyte from the Graafian follicle. A follicle matures in 10-14 days. At this stage, it is called a Graafian follicle. The Graafian follicle increases in size and becomes more prominent from the surrounding tissue. The Graafian follicle reaches 10 mm in size. The follicle ruptures, allowing the oocyte to escape and enter the fallopian tube. This process of rupture causing the release of the oocyte is called ovulation. It occurs between 13th to 17th day of the menstrual cycle in humans. The ovum will not remain functional after 12-14 hours. If it does not fertilise, it will degenerate and disappear.

Secretion of hormones: Ovaries secrete four hormones. They control the whole reproductive life of the female. It is responsible for:

- Puberty changes: Appearance of secondary sexual characters.
- Pregnancy and associated changes.
- Secretion of hormones: Ovaries secrete four hormones. They are -
  - a) Oestrogens
  - b) Progesterone
  - c) Androgens
  - d) Relaxin

For the occurrence of ovulation:

- Luteinising hormone (LH) - released by the pituitary gland, causing the Graafian follicle to rupture and release the oocyte.
- Follicle-stimulating hormone (FSH) - released by the pituitary gland, causing the Graafian follicle to mature.

Ovulation:

- Maturity of follicle takes place in 10-14 days. At this stage, it is called a Graafian follicle. The Graafian follicle increases in size and becomes more prominent from the surrounding tissue. The Graafian follicle reaches 10 mm in size. The follicle ruptures, allowing the oocyte to escape and enter the fallopian tube. This process of rupture causing the release of the oocyte is called ovulation. It occurs between 13th to 17th day of the menstrual cycle in humans. The ovum will not remain functional after 12-14 hours. If it does not fertilise, it will degenerate and disappear.

Puberty changes:

- Appearance of secondary sexual characters.
- Puberty changes - responsible for (1) Development of secondary sexual characters (2) Fertility and reproductive changes (3) Psychological and associated changes.

With these four hormones, ovary controls the reproductive life of females. They are -

- a) Oestrogens
- b) Progesterone
- c) Androgens
- d) Relaxin

Formation of mature ova:

- Formation of mature ova involves the process of ovulation. This process involves the release of the oocyte from the Graafian follicle. A follicle matures in 10-14 days. At this stage, it is called a Graafian follicle. The Graafian follicle increases in size and becomes more prominent from the surrounding tissue. The Graafian follicle reaches 10 mm in size. The follicle ruptures, allowing the oocyte to escape and enter the fallopian tube. This process of rupture causing the release of the oocyte is called ovulation. It occurs between 13th to 17th day of the menstrual cycle in humans. The ovum will not remain functional after 12-14 hours. If it does not fertilise, it will degenerate and disappear.
Ovarian Cycle: Adult ovary undergoes recurring cyclic process of ovulation and menstruation. It occupies about 28 days. The cycle begins on the first day of menstruation. Ovarian cycle consists of two phases.

1) Follicular phase
2) Luteal phase

Ovulation occurs normally between 13th to 17th days of cycle, separating the two phases. Menstruation takes place 14 days after ovulation, if fertilisation does not take place.

Coitus: It is the biological act of introduction of erected penis of male into vagina of female and withdrawing after ejaculation. It is influenced by testosterone.

Erection: Erection is the act of thickening, elongation and stiffening of penis. It is brought about by distension of venous sinuses in response to sexual excitement, being initiated by psychological and hormonal stimulation. Parasympathetic impulses released by parasympathetic nerve fibres cause vasodilatation of arterioles of corpora cavernosa and constriction of main dorsal vein. Corpora cavernosa and spongiosa of penis fill with blood under high pressure. Penis which is small, flabby with wrinkled skin becomes thick, elongated and rigid.

Emission: Emission is the act of movement of semen into urinogenital tract. It is a sympathetic responsive act.

Ejaculation: It is the act of sudden ejection of semen out of urethra at the time of orgasm. It is a sympathetic activity. At the time of ejaculation, sympathetic impulses prevent micturition by causing:

a) Relaxation of detrusor muscle
b) Constriction of internal sphincter.

This act also prevents reflux of semen into bladder.

Orgasm: It is the act of sudden reception of semen on genital organs at the time of emission.

Physiological changes during coitus:

- Increase of heart rate
- Increase of blood pressure
- Increase of respiration
- Increase of body temperature
- Increase of sex hormones
- Increase of excitement

Fertilisation: Fertilisation is the process of penetration of ovum by spermatozoa recently deposited in the genital tract. Fertilisation usually occurs by ovum of secondary oocytes before ovulation. Once fertilisation of ovum takes place, it is followed by division of cytoplasmic processes. The resulting cells then differentiate into the blastocyst, which eventually becomes the embryo.

Implantation: Implantation is the process of formation of blastocyst, which usually occurs between 6th and 9th day after ovulation. Implantation occurs by erosion of uterine epithelial cells and penetration of blastocyst. It usually occurs between the 6th and 9th day after ovulation.

Menstruation: Menstruation is the process of cyclical discharge of the endometrium, along with blood, mucus, strips of endometrium and leucocytes. After discharge, clotting takes place due to rapid formation of fibrin. In each ovarian cycle, endometrium proliferates to prepare suitable bed to receive and implant blastocyst. If pregnancy does not take place, this hyperplastic mucosa breaks down along with the unovulated ovum, blood and mucus. This process is known as menstruation.

In case of conception, the endometrium is converted into decidua by formation of chorionic villi. The decidua is invaded by the blastocyst, which begins to implant in the endometrium. Alkalinity of the uterus facilitates implantation.
1) Resting phase or follicular phase of healing of endometrium (1st-5th day)
2) Proliferative phase of maturation of Graafian follicle (6th-14th day)
3) Premenstrual or luteal phase of growth of corpus luteum (15th-28th day)
4) Destructive or menstrual phase of degeneration of corpus luteum (starting on 28th day and lasting up to 4-6 days)

Pregnancy:
Conception occurs if ovum is fertilised. At the end of pregnancy, parturition takes place. It normally 280 days of gestation period in human females

Physiological changes during pregnancy are:
1) Hypertrophy and thus enlargement of uterus
2) Increased water retention in the later months of pregnancy causing glycosuria
3) Increased secretion of prolactin
4) Increased thyroid gland and placental growth and enlargement
5) Increased secretion of thyroxine
6) Cessation of ovulation
7) Increase of blood volume, blood cholesterol, plasma fibrinogen, plasma globulin etc.
8) Lowered plasma albumin, plasma iron levels
9) Increased erythrocyte sedimentation rate
10) Increased cardiac output
11) Increased vital capacity, tidal volume and pulmonary ventilation
12) Nausea and vomiting in early months
13) Increased sodium retention
14) Excretion of oestrogen, pregnanediol and placental gonadotrophins
15) Cessation of menstruation
16) Increased thyroid gland activity
17) Increased parathyroid hormone
18) Increased secretion of cortisol
19) Increased parathyroid hormone
20) Increased synapses of hormone binding proteins by liver
21) Increased formation of renin substrate by liver
22) Increased formation of renin substrate by liver
23) Increased formation of renin substrate by liver

Placenta:
It is the functional connection between embryo and uterus. It is necessary in mammals as the foetus is developed in uterus. It is derived from yolk sac, foetal, maternal blood and other tissues.

Functions of Placenta:
1) Supply of nutrients from maternal blood to foetus
2) Excretion of fetal metabolites by diffusion into maternal blood
3) Passage of O2 from maternal blood to foetal blood and CO2 from foetal blood to maternal blood
4) Passage of water across the placental barrier
5) Formation and development of thyroid glands
6) Development of placenta
7) Cessation of ovulation
8) Increase of blood volume, blood cholesterol, plasma fibrinogen, plasma globulin etc.
9) Lowered plasma albumin, plasma iron levels
10) Increased erythrocyte sedimentation rate
11) Increased cardiac output
12) Increased vital capacity, tidal volume and pulmonary ventilation
13) Nausea and vomiting in early months
14) Excretion of oestrogen, pregnanediol and placental gonadotrophins
15) Cessation of menstruation
16) Increased thyroid gland activity
17) Increased parathyroid hormone
18) Increased secretion of cortisol
19) Increased parathyroid hormone
20) Increased synapses of hormone binding proteins by liver
21) Increased formation of renin substrate by liver
22) Increased formation of renin substrate by liver
23) Increased formation of renin substrate by liver

Parturition:
Parturition is the process of childbirth at the end of gestation. It occurs at about 38th day after last menstrual period. Periodic contraction of smooth muscles of uterus and skeletal muscles of abdomen and parturition. Oestrogen stimulates uterine contraction. Oxytocin secreted by posterior lobe of pituitary gland brings about vigorous contraction of uterine wall. Relaxation of pubic ligaments and placenta enlarges birth canal by means of relaxing pubic ligaments.

Stages of Labour:
1) First stage of labour: Duration of labour varies from 12-18 hours. Following are the stages of labour:
   1) First stage of dilatation of cervix and dilatation of the membranes of the amnion and expulsion of amniotic fluid
   2) Second stage of descent of child through vagina and expulsion of placenta
   3) Third stage of expulsion of placenta
2) Second stage of dilation of cervix and expulsion of placenta
3) Third stage of expulsion of placenta

Multiple Births:
Giving birth to more than one child at a time is called multiple births. Twins can be divided into two types:
1) Monozygotic twins: In this case, one zygote is formed by penetration of single sperm into single ovum. Zygotic material divides into two halves and gives rise to two separate embryos. This type of twins develop from the same sex, same blood group and tissues. They are called monozygotic twins.
2) Dizygotic twins: In this case, two zygotes are formed by penetration of two sperm into two separate ova. Two separate embryos develop. This type of twins may be of same or different sex. They are called dizygotic twins.
Dizygotic twins: In this case, two ova are discharged at a time and they are fertilised by two sperms. Two zygotes are formed. In such case, twins are not identical and called dizygotic twins.

Multiple births: Triplets, quadruplets or quintuplets may be born from any of above processes or combination.

Methods of controlled reproduction

Populatin explosion is a major problem in the today world. It is necessary to follow contraceptive measures to bring the population to a balance. In a country like India, people have to be mass educated regarding population control.

Some of the contraceptive methods are:

1) Temporary methods 2) Permanent methods

1) Temporary methods include -

- Natural methods
- Methods using barriers: a) IUCD b) Oral contraceptives c) Spermicidal jellies, sponges, tampoons, powders d) Implant

2) Natural methods:

a) Spermicidal jellies, creams and foam tablets: They are smeared in vagina deeply inside. They are to be used before coitus. Sperms, tampoons and powders. Sperm should be soaked in spermaicidal jelly before use or powder be sprinkled over sponge. Sponge should be inserted in spermiadic jelly. Tampoons should be introduced in vagina before coitus and withdrawn 8 hours after coitus.

b) Spermicidal jellies: Sperm should be introduced in vagina before coitus. Withdraw after 8 hours.

c) Oral contraceptives: There are three regimes of oral contraceptives. They are - 1) Classical pills 2) Sequential pills 3) Local supplementation pills.

- Implants: Progesterin capsules are implanted in body. Action lasts for months or years. Progestasert is such an implant. It can be taken out when pregnancy is needed.

- Douching

2) Methods using barriers:

a) Condom: Condom should be rolled over erect penis leaving one cm at the end after expelling the air in the tip. After ejaculation, penis should be withdrawn, holding the condom at base. Inner of the condom is felt, vagina should be swabbed with soap water.

Full sexual pleasure may not be felt with barrier methods. Interruption of foreplay is also a demerit. Condom may slip or tear during use.

b) Methods for insertion of foreign body in uterus: A foreign body is placed in uterus. 1) Use of Condom: Condom should be unrolled over erect penis leaving one cm at the end after expelling the air in the tip. After ejaculation, penis should be withdrawn, holding the condom at base. If the condom is felt, vagina should be swabbed with soap water.

2) Methods using barriers: a) Condom, b) Barriers, c) IUCD, d) Oral contraceptives e) Spermicidal jellies, sponges, tampons, powders. f) Implant

- Spermicidal jellies, creams and foam tablets: They are smeared in vagina deeply inside. They are to be used before coitus. Sperms, tampoons and powders. Sperm should be soaked in spermiadic jelly before use or powder be sprinkled over sponge. Sponge should be inserted in spermiadic jelly. Tampoons should be introduced in vagina before coitus and withdrawn 8 hours after coitus.

- Implants: Progesterin capsules are implanted in body. Action lasts for months or years. Progestasert is such an implant. It can be taken out when pregnancy is needed.
G) Douching: It is washing vagina with irritating fluid like salt solution, lactic acid solution, lemon juice or alum solution after coitus. Tap water can also be used for douching.

Termination of pregnancy: It is also a method of contraception when conception has already occurred. It should be conducted in accordance with MEDICAL TERMINATION OF PREGNANCY ACT, enacted in 1971.

Permanent methods: They are - vasectomy for males, tubectomy for females and laparoscopic methods for women.

In vasectomy, vas deferens is cut on both sides and ligated. It is 100 percent reliable. In tubectomy, fallopian tubes are ligated. It requires opening of abdomen. Woman should not be pregnant at the time of operation. In laparoscopic method, fallopian tubes are viewed using laproscope and ligated or hysteroscopy is sealed. It is usually done after 5th day of menstruation. A small incision is made on abdomen for this operation near umbilicus. This procedure requires 10 to 15 minutes.

Sex hormones

They are - a) Male sexual hormones (d) Female sexual hormones.

Male sexual hormones: They are - 1) Testosterone 2) Androstenedione 3) Dehydroepiandrosterone (DHEA). Testes mainly produce testosterone. It is eliminated in urine directly or as metabolites. Metabolites of testosterone are androstenedione and DHEA. Even though androstenedione and DHEA are metabolites, they are physiologically active. Male sexual hormones and compounds with similar activity are called androgens. Androgens are also produced in small concentrations in females.

Testosterone is primarily produced by Leydig cells of testes. Ovaries and adrenal cortex also produce the precursors of testosterone, which can be converted into testosterone in many tissues. Testosterone is produced in testes in androgen and adrenal cortex. Male sexual hormones and compounds with similar activity in both sexes are called androgens. Androgens are also produced in small concentrations in females.

Testosterone is released from the testes in response to FSH and LHRH released by anterior lobe of pituitary gland. Testosterone is then converted into other androgens. Testosterone in plasma is 90% bound to sex hormone binding globulin (SHBG) and 10% free. This free testosterone is responsible for the physiological actions of male sex hormones.

Levels of testosterone in plasma of men are 5 to 100 times greater than the levels in plasma of women. About 4-12 mg. is produced in young males per day whereas 0.5-2.9 mg. is produced in young females per day. Testosterone is converted by androgen responsive tissues in the body to highly active metabolite dihydrotestosterone. It is believed to be the active form of the hormone. Dihydrotestosterone binds to cytoplasmic protein receptor before acting on the nucleus.

In males, secretion of testosterone by testes increases greatly at puberty. At this stage androgens are responsible for -

- Growth of male sex organs: Development of male sexual organs takes place.
- Increase in the activity of these organs: Spermatogenesis by testes begins. Sertoli cells develop and support the growth of spermatids. Seminal vesicles, seminal vesicles, and Cowper’s glands start secreting.
- Increase of male sex hormones:

Secondary sexual character develop. They are 1) growth of moustache and beard; pubic hair and hair in other parts of body like back, etc. The physiological actions of male sex hormones are -

1) Androgenic functions:

- Physiological functions of male sex hormones:

- In males, dihydrotestosterone causes masculinizing effects in male sexual characters also. They cause development of prostate, penis and related sexual tissues.

Levels of testosterone in plasma of men are 5 to 100 times greater than the levels in plasma of women. About 4-12 mg. is produced in young males per day whereas 0.5-2.9 mg. is produced in young females per day. Testosterone is converted by androgen responsive tissues in the body to highly active metabolite dihydrotestosterone. It is believed to be the active form of the hormone. Dihydrotestosterone binds to cytoplasmic protein receptor before acting on the nucleus.

1) Androgenic functions:

- Androgenic functions:

- In males, dihydrotestosterone causes masculinizing effects in male sexual characters also. They cause development of prostate, penis and related sexual tissues.

Levels of testosterone in plasma of men are 5 to 100 times greater than the levels in plasma of women. About 4-12 mg. is produced in young males per day whereas 0.5-2.9 mg. is produced in young females per day. Testosterone is converted by androgen responsive tissues in the body to highly active metabolite dihydrotestosterone. It is believed to be the active form of the hormone. Dihydrotestosterone binds to cytoplasmic protein receptor before acting on the nucleus.
Female sex hormones:

- Oestrogens, progesterone, relaxin, androgens.

Oestrogens: Oestradiol is the most important member of this group. It is produced by graafian follicle of ovaries. It is excreted as such or as metabolites. Its metabolites are oestrone and oestriol. In these forms also physiological activity is exhibited. In pregnancy, placenta produces large amounts of oestrone.

Progesterone: progesterone is secreted by corpus luteum of ovaries and placenta. Pregnanediol is the metabolic product of progesterone and it is biologically inactive. It is also found in adrenal cortex.

Functions of oestrogens and progesterone:

- Growth of female sex organs: Oestrogen stimulates development and maintains morphological and functional state of female sex organs—vagina, uterus, fallopian tubes. Oestrogen is responsible for enlargement of vagina to adult size.

Secondary sexual characters: Mainly oestrogens and to a lesser extent, progesterone are responsible for development of secondary sexual characters. Growth of female sex organs: Oestrogen stimulates development and maintains physiological activity of female sex organs. Growth of female sex organs:

- Development of breast:
  - At puberty, both oestrogens and progesterone are involved in the development of breast. Oestrogens cause proliferation of ductile system of breast. Progesterone stimulates development of alveolar system. Oestrogens contribute to the shape of breast and function. Progesterone causes proportional changes in endometrium after pregnancy is established.

- Rapid growth of long bones:

Androgens: They are important in development of secondary sexual characters.

- Development of secondary sexual characters:
  - Increase in protein and muscle activity.
  - Increase in muscle mass.

- Psychological aspect: Androgens play important role in development of male psychology and behaviour. Functionalized and functional role of androgens makes them different from oestrogens.
Summary

Reproduction is the process of producing same type of offsprings.

Functions of testes are 1) Spermatogenesis  2) Secretion of testosterone. Semen is suspension of spermatozoa in the fluid secreted by epididymis, prostate, seminal vesicles and Cowper's glands. Functions of ovaries are 1) formation of matureova  2) secretion of hormones. Fertilisation is the union of spermatozoa with ovum. Conception is the entrance of fertilised ovum into the uterus. Pregnancy is the pregnancy of fertilised ovum to child birth. Methods of family planning are i) Temporary methods  ii) Permanant methods.

Male sex hormones are i) Testosterone ii) Androsterone iii) Dehydro epiandrosterone. Female sex hormones are - oestrogens, progesterone and relaxin. Small quantities of androgens are also present in women and are responsible for libido.

Essay Questions

1) Write the functions of testes in detail.
2) Explain the functions of ovaries.
3) Write about pregnancy and physiological changes during pregnancy.
4) Discuss the methods of controlled reproduction.
5) What are the male sex hormones? Write note on them.
6) List out female sex hormones. Add a note on them.

Short Answer Questions

1) Explain a) Male sex b) Female sex.
2) What is puberty?
3) Define a) Menarch b) Menopause
4) Differentiate between male and female sexes.
5) Mention the functions of testes.
6) What is spermatogenesis?
7) What is semen?
8) Mention the functions of interstitial cells of Leyde.
9) Mention the functions of mesenchymal cells of Leyde.
10) What is semen?
11) What is spermatozoa?
12) Mention the functions of male sex hormones at puberty.
13) What is hyaluronidase?
14) Write the basis on which LUCs are influenced.
15) Mention the extramammary methods of controlled reproduction in women.
16) Explain the basis of rhythm method based on body temperature.
17) When are the menopause marks of controlled reproduction.
18) Define spermatogenesis and write the stages of puberty.
19) What is pregnancy?
20) What are the menopause marks of controlled reproduction in women?
21) When are the menopause marks of controlled reproduction?
22) When is menstruation?
23) When is menstruation?
24) What is menstruation?
25) What is menstruation?
26) What is menstruation?
27) What is menstruation?
28) What is menstruation?
29) What is menstruation?
30) What is menstruation?
31) What is menstruation?
32) What is menstruation?
33) What is menstruation?
34) What is menstruation?
35) What is menstruation?
36) What is menstruation?
37) What is menstruation?
38) What is menstruation?
39) What is menstruation?
40) What is menstruation?
41) What is menstruation?
42) What is menstruation?
43) What is menstruation?
44) What is menstruation?
45) What is menstruation?
46) What is menstruation?
47) What is menstruation?
48) What is menstruation?
49) What is menstruation?
50) What is menstruation?
51) What is menstruation?
52) What is menstruation?
53) What is menstruation?
54) What is menstruation?
55) What is menstruation?
56) What is menstruation?
57) What is menstruation?
58) What is menstruation?
59) What is menstruation?
60) What is menstruation?
61) What is menstruation?
62) What is menstruation?
63) What is menstruation?
64) What is menstruation?
65) What is menstruation?
66) What is menstruation?
67) What is menstruation?
68) What is menstruation?
69) What is menstruation?
70) What is menstruation?
71) What is menstruation?
72) What is menstruation?
73) What is menstruation?
74) What is menstruation?
75) What is menstruation?
76) What is menstruation?
77) What is menstruation?
78) What is menstruation?
79) What is menstruation?
80) What is menstruation?
81) What is menstruation?
82) What is menstruation?
83) What is menstruation?
84) What is menstruation?
85) What is menstruation?
86) What is menstruation?
87) What is menstruation?
88) What is menstruation?
89) What is menstruation?
90) What is menstruation?
91) What is menstruation?
92) What is menstruation?
93) What is menstruation?
94) What is menstruation?
95) What is menstruation?
96) What is menstruation?
97) What is menstruation?
98) What is menstruation?
99) What is menstruation?
100) What is menstruation?
101) What is menstruation?
102) What is menstruation?
103) What is menstruation?
104) What is menstruation?
105) What is menstruation?
106) What is menstruation?
107) What is menstruation?
108) What is menstruation?
109) What is menstruation?
110) What is menstruation?
111) What is menstruation?
112) What is menstruation?
113) What is menstruation?
114) What is menstruation?
115) What is menstruation?
116) What is menstruation?
117) What is menstruation?
118) What is menstruation?
119) What is menstruation?
120) What is menstruation?
1. SENSE ORGANS

The system of sense organs contains the eye, ear, tongue, nose, and skin. They are the organs of vision, auditory sense, gustation, olfaction, and tactile sense. The first four are special senses. Taste and smell are called chemical senses.

**Eye:** Physiology of vision includes the following steps:
- Entry of light into the eye through the cornea
- Regulation of the amount of light by the iris and pupil
- Focusing of the image on the retina through the lens
- Darkening of the interior of the eye by the pigmented choroid
- Stimulation of the photo receptors of rods and cones of the retina by the image formed
- Carriage of impulses to the visual cortex present in the occipital lobe of the brain through the optic nerve.

**Accommodation:** When the image of a near object is brought to focus on the retina, the optical apparatus adjusts to change the refractive power of the eye. This process is called accommodation. The normal resting eye is set for parallel rays beyond 20 ft. without accommodation. Accommodation occurs by increasing the curvature of the lens and raising its refractive power.

- **Stimulation of photo receptors of rods and cones:** Image formed on the retina stimulates the photo receptors of rods and cones. The optic nerve carries these impulses.
- **Binocular vision:** Long sighted person can see objects at a distance well. Those impulses are carried through both eyes.
- **Regulation of pupillary dilatation:** Pupil constriction reflexes include:
  - Light reflex: caused by falling of light
  - Lid closure reflex: caused when effort is done to close the eyelid
  - Near reflex: caused when viewing near objects
  - Oculosensory reflex: caused when the conjunctiva is irritated
  - Psychosensory reflex: caused by emotions
  - Labyrinthine pupillary reflex: caused by rotating the body around its axis
  - Withdrawal reflex: caused by withdrawal of light from the eyes

- **Myopia:** It is also called nearsightedness. A short-sighted person cannot see distant objects easily. In myopia, the eyeball is longer than normal.平行 rays instead of being focused on the retina get focused in front of the retina. A convex lens can correct this problem.
- **Hypermetropia and presbyopia:** A far-sighted person cannot see objects at a distance well. They are also called long-sighted or presbyopia.
- **Hypermetropia:** It is also called long-sightedness. A long-sighted person can see distant objects very well. Those impulses are carried through the posterior part of the eye. Near objects are not clear. This can be corrected by wearing convex lenses (+).

**Fig. 11.1**

**Optic nerve**

**optic tract**

**visual cortex**

**Optic chiasma**

**Lateral geniculate body**

**Retina**

**Lens (++)**

**Iris**

**Pupil**

**Cornea**

**conjunctiva**

**eyelid**
It is rare in children and is due to disproprotionate growth of structures of eye ball. It may be corrected with age. Common cause of hypermetropia is presbiopia occurring in the age between 40 and 50 years age.

Astigmatism: In this type of error, rays do not focus sharply on retina. Oblong shape of cornea and lens causes this problem. It is corrected by wearing cylindricallens or by combining cylindrical and spherical lenses.

Cataract: It is caused due to lens becoming opacified. It is cured by removing the lens and fitting artificial transparent plastic lens in its place.

Glaucoma: It is caused by increased intraocular pressure resulting from disturbed balance in production and drainage of aqueous humour. It is most common after 40 years age. Early diagnosis and treatment prevent loss of vision.

Night blindness: Condition resulting in inability to view in dim light is called night blindness and is caused by vitamin deficiency or pathological cause.

Mechnism of hearing: Ears are the organ of hearing and equilibration of body. It is controlled by VIII cranial nerve (also called vestibulocochlear nerve).

Physiology of hearing and equilibration:

- Events of hearing are -
  a) Sound waves reaching the ear are collected by pinna.
  b) They are directed by pinna into external auditory meatus.
  c) External auditory meatus directs these waves to strike the tympanic membrane.
  d) Tympanic membrane, being connected to malleus also vibrates.
  e) These vibrations are passed to the membrane covering fenestra ovalis through incus and stapes.
  f) Vibrations are passed to organ of corti from the inner surface of fenestra ovalis through perilymph and endolymph.
  g) Impulses produced by vibrations are carried to brain stem through cochlear nerve.
  h) They reach the auditory centre present in temporal lobe of opposite side.

Disorders of ear:
- Deafness: Deafness is caused by loss of function of organ of corti and also due to interference in transmission of impulses by auditory nerve.
- Deafness is of following types -
  1) Conductive deafness caused by -
     a) External ear obstruction
  2) Middle ear disease
  3) External ear obstruction

Physiology of gustation -
Sense of taste is closely related to sense of smell.

Flavour: Flavour is complex sensation caused by taste, odour, degree of heat, pungency / blandness, roughness / smoothness.
Primary taste sensations:

Primary taste sensations are four in number. They are:
1) Sweet at the tip
2) Bitter at the dorsum anteriorly
3) Sour at the sides
4) Salt at the back

Factors influencing taste sensation:
1) Total surface area stimulated
2) Temperature (30-40°C is optimum)
3) Olfaction
4) Individual variation
5) Adaptation
6) Food habits etc.
7) State of substance

Mechanism of taste sensation:
Branch of the facial nerve innervates the anterior 2/3 portion of the tongue, the posterior 1/3 portion is innervated by the glossopharyngeal nerve. The vagus nerve receives impulses from the throat and the pharynx. Nerve impulses are carried by these tracts to the taste center present in the medulla. Sensation of taste is interpreted in the cortex.

Nose: Physiology of olfaction

Smell is also a chemical sensation like taste. For perception of olfactory sensation, vapors of a substance are required. These vapors get dissolved in the local secretions of the nose. Smell is the most primitive sensation. It is more acute than taste. The total surface area of olfaction on each side in man is about 250 square cm.

Classification of odours:
Odours are classified into nine types by Zwaarde maker. They are:
1) Alliaceous
2) Ambrosial
3) Aromatic
4) Caprillic
5) Empyreumatic
6) Etherial
7) Fragrant
8) Repulsive
9) Nauseative

Volatile substances produce strong odour. Non-volatile substances are non-odorous. Odorous particles emitted by odoriferous substances ascend up and reach the olfactory area. Odoriferous substances show specificity to be adsorbed on the olfactory area. After adsorption, generator potentials of 4-6 seconds duration are developed. When the generator potentials reach threshold value, action potential is passed along axons to the olfactory bulb. From the olfactory bulb, sensations are carried to the olfactory centre in the cerebrum through the olfactory tract. Perception of smell occurs in this centre.

Skin: Physiology of its sensations

Skin functions as a medium for perception of general senses. They are:
1) Touch
2) Pressure
3) Temperature
4) Pain

Sensation of pain causes maximum sensation.

Classification of odours:
Odours are classified into nine types by Zwaarde maker.

Volatile substances produce strong odour. Non-volatile substances are non-odorous. Odorous particles emitted by odoriferous substances ascend up and reach the olfactory area. Odoriferous substances show specificity to be adsorbed on the olfactory area. After adsorption, generator potentials of 4-6 seconds duration are developed. When the generator potentials reach threshold value, action potential is passed along axons to the olfactory bulb. From the olfactory bulb, sensations are carried to the olfactory centre in the cerebrum through the olfactory tract. Perception of smell occurs in this centre.

Skin: Physiology of its sensations

Skin functions as a medium for perception of general senses. They are:
1) Touch
2) Pressure
3) Temperature
4) Pain

Sensation of pain causes maximum sensation.

Classification of odours:
Odours are classified into nine types by Zwaarde maker.

Volatile substances produce strong odour. Non-volatile substances are non-odorous. Odorous particles emitted by odoriferous substances ascend up and reach the olfactory area. Odoriferous substances show specificity to be adsorbed on the olfactory area. After adsorption, generator potentials of 4-6 seconds duration are developed. When the generator potentials reach threshold value, action potential is passed along axons to the olfactory bulb. From the olfactory bulb, sensations are carried to the olfactory centre in the cerebrum through the olfactory tract. Perception of smell occurs in this centre.
4) Headache - caused by anxiety, intracranial vascular changes etc. Sensation of pain is carried by non-myelinated afferent nerves originating from area of pain. They carry sensation to dorsal horn of gray matter of spinal tract. It is carried to thalamus from here. From thalamus, pain impulses are carried to subcortical area and finally to cerebral cortex where sensation is interpreted.

Summary

Skin is organ of senses of touch, pressure, temperature, pain and itch etc.

When are class of pain?
1. Acute pain
2. Chronic pain

Essay Questions

1) Write about physiology of vision and visual disorders.
2) Explain physiology of hearing and auditory disorders.
3) Write about physiology of taste and gustatory sensation.
4) Write about physiology of olfaction and olfactory sensations.

Short Answer Questions

1) Name general senses.
2) Name general senses and their organs.
3) What is accommodation?
4) Name the reflexes of pupil.
5) What is glaucoma?
6) What are functions of ear? Write about balance and equilibrium.
7) What are functions of ear? Write about balance and equilibrium.
8) What is equilibrium?
9) What are the phases of pupil?
10) Why are pain impulses from skin carried to spinal cord through non-myelinated fibers?