Structure
1.0 Introduction
1.1 Planes of the Human Body
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1.3 The units of Structure and Functions of Cell

1.0 Introduction

ANATOMY is a science that deals with the structures of the body and the relation of various parts to each other. A knowledge of these structures is necessary to understand their functions.

The subject matter of Anatomy includes:

1. Cytology – study of cells
2. Histology – study of tissues
3. Osteology – study of bones
4. Myology – study of muscles
5. Arthrology - study of joints
6. Splanchnology – study of organs
7. Neurology – study of nervous system

Descriptive terms used in Anatomy: The arrangement of various parts of body may be:

i. Symmetric e.g. limbs, eyes, ears and lungs. Their arrangement on the right side and left side are similar.

ii. Asymmetric e.g. spleen and liver. The spleen lies entirely in the left side. Liver lies mostly on the right side.

The study of the human body is done in anatomical position. In this position, the body is erect, the head facing forwards, arms by the sides and palms of the hand facing forward.

The following are the few important terms which are used to describe the human body:

1. Median line (mid sagittal plane): The central plane which divides the body into two halves i.e. right and left.

2. Medial: nearer to the median line.

3. Lateral: away from the median line.

4. Superior: nearer to the head.

5. Inferior: nearer to the foot.

6. Anterior: nearer to the front surface of the body.

7. Posterior: nearer to the back surface of the body.


10. Superficial: nearer to the skin surface.

11. Deep: deeper from the skin surface.

1.1 Planes of the Human Body

Planes and Axis

Human movements are described in three dimensions based on a series of planes and axis. There are three planes of motion that pass through the human body.
1. The sagittal plane
2. The frontal plane
3. The transverse (horizontal) plane
   - The sagittal plane lies vertically and divides the body into right and left parts.
   - The frontal plane also lies vertically however divides the body into anterior and posterior parts.
   - The transverse plane lies horizontally and divides the body into superior and inferior parts.

![Fig 1.1]

**Axis**

An axis is a straight line around which an object rotates. Movement at the joint take place in a plane about an axis. There are three axis of rotation.

1. Sagittal axis
2. Frontal axis
3. Vertical axis
   - The sagittal axis passes horizontally from posterior to anterior and is formed by the intersection of the sagittal and transverse planes.
   - The frontal axis passes horizontally from left to right and is formed by the intersection of the frontal and transverse planes.
• The vertical axis passes vertically from inferior to superior and is formed by the intersection of the sagittal and frontal planes.

Fig 1.2 Movement in the sagittal plane about the frontal axis
Fig 1.3 Movement in the frontal plane about the sagittal axis
Fig 1.4 Movement in the transverse (horizontal) plane about the vertical axis.
PHYSIOLOGY is the science of life which deals with normal functions of the body. It explains how various systems in the body function together normally as a single unit.

The subject matter of physiology includes the study of various systems like:

1. Skeletol system
2. Muscular system
3. nervous system
4. Circulatory system
5. Respiratory system
6. Digestive system
7. Endocrine system
8. Excretory system
9. reproductive system

Organs of the body: An organ is a group of tissues arranged in a certain way to carry out a specific function e.g. stomach, heart, kidneys. The human body is highly developed multicellular organism containing various organs which perform different functions. The organs are again grouped together to form systems.

1.2 Systems of the Body

A system is a group of organs which together carry out one of the essential functions of the body. The following are some important systems.

1. Cardiovascular system

   Components: Heart, blood vessels, and blood.

   Functions: Transport of blood; including cells, nutrients, wastes, gases, hormones, etc.

2. Digestive system

   Components: Digestive tract which includes mouth, esophagus, stomach, small intestine, large intestine, anus, and accessory organs such as salivary gland, pancreas, liver and gallbladder

   Functions: Processing and absorption of nutrients
3. Endocrine system

**Components:** Organs which produce hormones (chemical messengers) which include pituitary, thyroid, thymus, testes, ovaries, etc.

**Functions:** Long-term regulation of systems by production and release of hormone

4. Integumentary system

**Components:** Includes the skin, hair, nails, sweat glands and oil glands

**Functions:** Protection (by skin, hair, etc.), site of sensory receptors, involved in body temperature control, etc.

5. Lymphatic system

**Components:** Includes lymph nodes, lymphatic vessels and their fluid called lymph, tonsils, spleen, and thymus

**Functions:** Production of lymphocytes for immunity, and collects, filters, and transports fluid (lymph)

6. Muscular system

**Components:** Includes the skeletal muscles

**Functions:** Movement of the body and involved in body temperature regulation

7. Nervous system

**Components:** Includes the brain, spinal cord, nerves, and receptors

**Functions:** Immediate control of systems, personality, emotions, etc.

8. Reproductive system

**Components:** Male: Includes testes, ductus (vas) deferens, prostate, seminal vesicles, penis.

**Female:** Includes ovaries, fallopian tubes, uterus, and vagina.

**Functions:** Production of gametes (sperm, egg), implantation and development

9. Respiratory system

**Components:** Includes the nasal cavity, voice box (larynx), windpipe (trachea), and lungs
**Functions:** Delivery of air to lungs for oxygen and carbon dioxide exchange

10. **Skeletal system**

**Components:** Bones which form the skeleton

**Functions:** Includes the skeleton which supports, protects, provides for storage of calcium, and serves as a site of blood cell production.

### 1.3 The Units of Structure and Functions of Cell

All organisms are composed of structural and functional units of life called ‘cells’. The body of some organisms like bacteria, protozoans and some algae is made up of a single cell while the body of fungi, plants and animals are composed of many cells. Human body is built of about one trillion cells.

Cells vary in size and structure as they are specialized to perform different functions. But the basic components of the cell are common to all cells. The cell is the smallest unit of living tissues. Cells of different tissues perform different functions. A cell is made up of the following structures:

1. **Cell wall:** It is the external boundary of the living cell. It is a three layered structure made up of lipids and proteins. It measures approximately 70 Å in thickness. The cell wall allows the diffusion of substances into and out of the cell.

2. **Nucleus:** It is the largest structure present almost in the centre of a cell. It is more or less spherical in shape. It is bounded by nuclear membrane, the nucleus contains: a) nucleolus b) chromatin
   
   a. **Nucleolus:** It is highly coiled filamentous structure present in the nucleus. It is not surrounded by a membrane. But it contains numerous granules. Nucleolus is the site of ribosomal RNA (ribo nucleic acid) synthesis.
   
   b. **Chromatin:** These are fibrous threads present in the nucleus. They are composed of DNA (deoxy ribonucleic acid) and proteins. The chromatin threads carry genetic information. At the time of cell division, chromatin condenses into chromosomes. The number of chromosomes is constant for a particular species of organism. In man, there are 23 pairs of 46 chromosomes.

3. **Cytoplasm:** It is the region lying between the cell membrane and nucleus. The cytoplasm contains cell organelles like endoplasmic reticulum, golgi apparatus, mitochondria, lysosomes and centrosome.
Microsomes: they are extremely small bodies present in the cytoplasm. They can be separated by centrifuging a tissue homogenate at very high speed (10000 rpm). Microsomes contain 1) ribosomes 2) granular matrix. Ribosomes are concerned with protein synthesis. Granular matrix contain i. “oxidase” which generate hydrogen peroxide. ii. “catalase” which converts hydrogen peroxide into water.

![Fig 1.5 Structure of a Cell](image)

**Organelles of cytoplasm:** following are the important organelles present in the cytoplasm:

i. **Endoplasmic reticulum:** it is the most extensive cell organelle present in cytoplasm. It consists of two membranes which are separated by a space. They are:

   a. **Granular or rough surfaced endoplasmic reticulum** containing ribosomes. The ribosomes are the sites of protein synthesis.

   b. **Agranular or smooth surfaced endoplasmic reticulum.** This does not contain ribosomes. This type of endoplasmic reticulum is concerned with fatty acid and steroid synthesis. Also, they store and release calcium.

ii. **Golgi apparatus:** it is a cup shaped structure contains vesicles. It is situated between the nucleus and the apex of the cell. It is concerned with concentration of proteins prior to their secretion.

iii. **Mitochondria:** they occur in the cytoplasm at variable numbers e.g. few hundreds to few thousands. The mitochondrion is composed of two layers of membranes.

They are:

a. An outer layer which is smooth.
b. An inner layer folded into sheets of tubules called cristae.

Both this layers enclose a central cavity called matrix.

**Lysosomes**

1. Lysosomes are small spherical organelles that enclose hydrolytic enzymes within a single membrane.

2. Lysosomes are the site of protein digestion – thus allowing enzymes to be re-cycled when they are no longer required. They are also the site of food digestion in the cell, and of bacterial digestion in phagocytes.

3. Lysosomes are formed from pieces of the Golgi apparatus that break off.

4. Lysosomes are common in the cells of Animals, Protoctista and even Fungi, but rare in plants.

**Cytoskeleton**

1. Just as your body depends on your skeleton to maintain its shape and size, so a cell needs structures to maintain its shape and size.

2. In animal cells, which have no cell wall, an internal framework called the cytoskeleton maintains the shape of the cell, and helps the cell to move.

3. The cytoskeleton consists of two structures:
   
   a. **microfilaments** (contractile). They are made of actin, and are common in motile cells.
   
   b. **microtubules** (rigid, hollow tubes – made of tubulin).

4. Microtubules have three functions:
   
   a. To maintain the shape of the cell.

   b. To serve as tracks for organelles to move along within the cell.

   c. They form the centriole.

**Centrosomes**: it is a small rod shaped body found near the nucleus. It plays an important role during cell devision. The centrosome is surrounded by a radiating thread like structure. It contains two centrioles.

**Cilia and Flagellae**

1. Cilia and Flagellae are structures that project from the cell, where they assist in movement.
2. **Cilia** (sing. *cilium*) are short, and numerous and hair-like.

3. **Flagellae** (sing. *flagellum*) are much longer, fewer, and are whip-like.

4. The cilia and flagellae of all Eukaryotes are always in a ‘9 + 2’ arrangement that is characteristic (see diagram).

5. Protoctista commonly use cilia and flagellae to move through water.

6. Sperm use flagellae (many, all fused together) to swim to the egg.

7. Cilia line our trachea and bronchi, moving dust particles and bacteria away from the lungs.

**Functions of Cell**

The following are the important functions performed by a cell.

1. **Ingestion and assimilation**: the cell ingests chemical substances like amino acids from intercellular or interstitial fluid. These substances are used to build up complicated substances like proteins.

2. **Growth and repair**: the ingested and assimilated materials are used to synthesise new protoplasm. This leads to increase in size and growth of the cell. Also worn out parts of the cell are replaced by this process.

3. **Metabolism**: this involves two processes:
   i. Anabolism in which the ingested and assimilated food material is used for growth and repair.
   ii. Catabolism in which food material is broken down to release energy for various functions of the cell.

4. **Respiration**: it involves transport of oxygen from lungs through blood to the tissues and removal of waste products like carbon dioxide. This is essential for the survival and functions of a cell.

5. **Excretion**: the cell eliminates waste products resulting from catabolism into interstitial fluid. These products are carried by blood for elimination through lungs and kidneys.

6. **Irritability and contractility**: the cell is active by means of these two functions. The cell responds to any stimulus by contracting. Or, the impulse is conducted as that occurs in a nerve cell.

7. **Reproduction**: after growing to an optimum size, the cell divides into daughter cells. Reproduction of cells occurs by mitosis and meiosis.
Kinds of cell division

There are two kinds of cell division- mitosis and meiosis.

1. **Mitosis**: Cell division for growth and replacement wherein the two daughter cells are identical and similar to mother cell in all respects.

2. **Meiosis**: It occurs in the gonads for sexual reproduction to produce gametes. The resultant cells, egg (in female) and sperms (in male), possess half the chromosome number of the parent cell.

![Fig 1.6: Stages of mitosis](image)

**Stages of mitosis**

1. **Mitosis** *(mitos = thread)* Mitosis is divided into 4 phases or stages termed as

   (i) Prophase (ii) Metaphase

   (iii) Anaphase (iv) Telophase

   The nucleus divides first and then the whole cell divides. Division of one nucleus to give two daughter nuclei (karyokinesis). Division of cytoplasm to give two daughter cells *(cytokinesis)*.

**Prophase**

It shows three subphases:
(i) **Early Prophase**

(a) Centrioles start moving towards opposite poles of the Nucleolus cell.
(b) Chromosomes appear as long threads.
(c) Nucleus becomes less distinct (Fig. 4.13a)

(ii) **Middle Prophase**

(a) Chromosomes condensation is complete
(b) Each chromosome is made up of two chromatids held together at their centromeres.
(c) Each chromatid contains newly replicated daughter DNA molecule.

(iii) **Late Prophase**

(a) Centrioles reach the pole.
(b) Some spindle fibres extend from pole to the equator of the cell.
(c) Nuclear membrane disappears.
(d) Nucleolus is not visible.

**Metaphase**

(a) Chromosomes move towards the equator of the cell.
(b) Each chromosome becomes attached to the spindle fibre by centromere.
(c) The sister chromatids are not yet separated. (Fig.

**Anaphase**

(a) Centromeres divide
(b) Two daughter chromatids separate
(c) Each chromatid now contains a centromere and is now termed a chromosome.
(d) Half the number of new chromosomes (daughter chromatids) move toward one pole and the other half to the other pole.
(e) Cytokinesis begins as the cleavage furrow starts in animal cells.

**Telophase**

(a) Chromosomes begin to form a chromatin network as in a nucleus.
(b) New nuclear membrane is formed around each daughter nucleus

(c) Nucleolus becomes visible again.

**Cytokinesis**

It is the process of the division of cytoplasm into two. It is initiated in the beginning of telophase and is completed by the end of telophase. The cytokinesis is different in plant cell and animal cell. In an animal cell, invagination of plasma membrane proceeds from the periphery of the cell towards the interior. In plant cell phragmoplast (cell plate) begins to form in the centre of cell and then expands towards the periphery.

**Significance of Mitosis**

It is an equational division, and the two daughter cells are identical in all respects. They receive the same number and kind of chromosomes as were in the mother cells.

- It is the only mode of reproduction in unicellular organisms.
- It is the process by which growth takes place in animals and plants by constantly adding more and more cells.
- It also plays a role in repair by growth, example in wound healing, regeneration of damaged parts (as in the tail of lizard), and replacement of cells lost during normal wear and tear (as the surface cells of the skin or the red blood cells).

**Mitosis (Limited or unlimited)**

Growth by mitosis occurs in a limited or controlled manner to the extent it is required in the body. But at times due to some special causes it may continue to unlimited situation which may cause **Cancer**.

**Meiosis**

Meiosis is characterized by two successive divisions of the nucleus (meiosis I and II) and cytoplasm, while the chromosomes divide only once. The phases of meiotic division are given in the flow chart drawn here.

**The interphase** which precedes the onset of meiosis is similar to the interphase which precedes mitosis. At S-phase, the DNA molecule of each chromosome duplicates to give two DNA molecule and hence two chromatids are found in one chromosome.

Meiosis-I and meiosis-II are continuous and have sub-stages.
Physiotherapy

Fig 1.7

Meiosis - I

Like mitosis, meiosis also consists of four stages; prophase, metaphase, anaphase and telophase.

Prophase-I

The prophase of meiosis-I is much longer as compared to the prophase of mitosis.

It is further sub-divided into the following five sub-stages:

(i) **Leptotene** (GK ‘leptos’ - thin; ‘tene - thread).
(ii) **Zygotene** (GK. ‘Zygos’-pairing)
(iii) **Pachytene** (GK. ‘pachus’ - thick):
(iv) **Diplotene** (‘Diplous’-double)
(v) **Diakinesis** (GK dia = through, in different directions, kinesis = motion)

Metaphase-I

- The bivalents arrange themselves at the equator.
- The spindle fibres are attached at the centromere of the chromosomes.

Anaphase-I (Fig. 1.7g)

- The spindle fibres shorten.
• The centromeres of homologous chromosomes are pulled along by the spindle fibres towards the opposite poles (no division of centromere).

• Thus, half of the chromosome (each with two chromatids) of the parent cell go to one pole and the remaining half to the opposite pole.

• Each set of chromosomes that moves to one pole consists of a mixture of paternal and maternal chromosome parts (new gene combination).

**Telophase-I**

The separated chromosomes form nuclei.

**Meiosis - II**

It has the same four stages;

(i) *Prophase II* (ii) *Metaphase II*

(iii) *Anaphase II* (iv) *Telophase II*

(i) **Prophase II**

• The chromosomes shorten and reappear. The two chromatids are attached to the single centromere.

• Formation of spindle starts.

• Nucleolus and nuclear membrane begin to disappear.

(ii) **Metaphase II**

• The chromosomes arrange themselves along the equator.

• Formation of spindle apparatus is completed.

• The centromere of each chromosome is attached to the spindle fibre.

(iii) **Anaphase II**

• The centromere in each chromosome divides.

• The chromatids get their centromere and become daughter chromosomes and begin to move towards the opposite poles.

(iv) **Telophase II**

• On reaching the poles the chro-mosomes organize themselves into haploid daughter nuclei.

• The nucleolus and the nuclear membrane reappear.
Cytokinesis

This may occur in two successive stages, once after meiosis I and then after meiosis II, or in some instances it occurs only after meiosis II.

Meiosis results in four haploid cells.

Significance of Meiosis

(i) It helps to maintain constant number of chromosomes in a species undergoing sexual reproduction.

(ii) Meiosis occurs during gamete formation (gemetogenesis) and reduces the number of chromosomes from diploid (2n) to haploid (n) in the gametes. These haploid gametes fuse to form diploid zygote during fertilization. The diploid zygote develops into a normal diploid individual.

(iii) Meiosis establishes new combination of characters due to

(i) mixing of paternal and maternal chromosomes and

(ii) crossing over during prophase

Short Answer Type Questions

1. Define Anatomy?
2. Define physiology?
3. Write any six movements occurring at joints?
4. Define cell?
5. What are the functions of cell?
6. Write the different planes and axis of human body?
7. What are the functions of mitochondria?
8. Write different organelles of cytoplasm?
9. Define mitosis and meiosis?
10. Define system and mention systems of body?
11. Draw the structure of cell?
12. What is neurology and nephrology?
13. Name the sense organs.
Long Answer Type Questions

1. Define system and explain any six systems.
2. Explain the structure and functions of the cell.
3. Explain in detail about the organelles of the cell.
Structure

2.1 Terms used for describing the position of the Body

2.2 Skeletal System

2.3 Bones of the Skull

2.4 Bones of the Upper Limb

2.5 Bones of Wrist and Hand

2.6 Bones of Thorax

2.7 Bones of Lower Limb

2.8 Bones of Foot

2.1 Terms used for describing the position of the Body

a. Anatomical Position

In this position, the body is erect, the eyes look straight to the front, the upper limbs hang by the side of the trunk with the palms directed forwards, and the lower limb are parallel with the toes pointing forwards.

All Structures are described presuming the body in anatomical position, although during study the body may be placed in any position.
b. Supine Position

Lying down (Recumbent) position with the face directed upwards.

c. Prone Position

Lying down (Recumbent) position with the face directed downwards.

d. Lithotomy Position

Lying supine with the buttocks at the edge of the table, the hips and knees fully flexed, and the feet strapped in position.

Terms of Relation Commonly used in Gross Anatomy

- Anterior - Towards the front
- Posterior - Towards the back
- Superior - Towards the head
- Inferior - Towards the feet
- Medial - Towards the median plane
- Lateral - Away from the median plane

Terms of Relation Commonly used in Embryology and Comparative Anatomy, but sometimes in Gross Anatomy

- Ventral - Towards the belly (like anterior)
- Dorsal - Towards the back (like posterior)
- Cranial or Rostral - Towards the head (like superior)
- Caudal - Towards the tail

Special Terms for Limbs

- Proximal - Nearer to the trunk
- Distal - Away from the trunk
- Radial - The outer border in the upper limb
- Ulnar - The inner border in the upper limb
- Tibial - The inner border in the lower limb
- Fibular - The outer border in the lower limb
g. Preaxial border - The outer border in the upper limb, and the inner border in the lower limb.

h. Postaxial border - The inner border in the upper limb, and the outer border in the lower limb.

i. Flexor surface - The anterior surface in the upper limb, and the posterior surface in the lower limb.

j. Extensor surface - The posterior surface in the upper limb, and the anterior surface in the lower limb.

k. Palmar or Volar - Pertaining to (towards) the palm of the hand.

l. Plantar - Pertaining to (towards) the sole of the foot.

**Certain Other Terms**

A. Terms used for hollow organs
   a. Interior or inner
   b. Exterior or outer
   c. Invagination or inward protrusion, and
d. Evagination or outward protrusion

B. Terms used for solid organs
   a. Superficial, towards the surface, and
   b. Deep, inner to the surface

C. Terms used to indicate the side
   a. Ipsilateral - of the same side, and
   b. Contralateral - of the opposite side

**Terms used for Describing Muscles**

a. Origin The end of a muscle which is relatively fixed during its contraction.

b. Insertion The end of a muscle which moves during its contraction. The two terms, origin and insertion, are sometimes interchangeable, when the origin moves and the insertion is fixed.

c. Belly The fleshy and contractile part of a muscle. d. Tendon The fibrous, noncontractile and cord-like part of a muscle.
e. Aponeurosis: The flattened tendon.

f. Raphe: The fibrous band made up of interdigitating fibres of the tendons or aponeuroses. Unlike a ligament, it is stretchable. Ligaments are fibrous, inelastic bands which connect two segments of a joint.

Terms Used for Describing Movements

a. Flexion: Approximation of the flexor surfaces whereby the angle of the joint is reduced.

b. Extension: Approximation of the extensor surfaces whereby the angle of the joint is increased. It is opposite to flexion.

c. Adduction: Movement towards the central axis.

d. Abduction: Movement away from the central axis. It is opposite to adduction.

e. Medial rotation: Inward rotation.

f. Lateral rotation: Outward rotation.

g. Circumduction: Various combinations of the foregoing movements (a to d).

h. Pronation: Rotation of the forearm so that the palm is turned backwards.

i. Supination: Rotation of the forearm so that the palm is turned forwards.

j. Protraction: Forwards protrusion.

k. Retraction: Movement reverse of protraction.

Terms used for Describing Vessels

a. “Arteries” carry oxygenated blood away from the heart, with the exception of the pulmonary and umbilical arteries which carry deoxygenated blood. Arteries resemble trees because they have branches (arterioles).

b. “Veins” carry deoxygenated blood towards the heart, with the exception of the pulmonary and umbilical veins which carry oxygenated blood. Veins resemble rivers because they have tributaries (venules).

c. “Capillaries” are networks of microscopic vessels connecting arterioles to venules.
d. "Anastomosis" is a precapillary or post capillary communication between the neighbouring vessels.

### 2.2 Skeletal System

The bony framework of the human body is known as skeleton.

Bones and joints form the skeletal system of the body. Functions of the skeletal system are:

1. Support and protection of soft tissues and vital organs.
2. To give attachment to muscles.
3. Formation of red blood corpuscles in the bone marrow.
4. Storage of mineral salts like phosphorus and calcium.

![Human Skeleton Diagram](Fig 2.1 Human Skeleton)
Bone

The hardest tissue of the body is called bone.

Classification of Bones

Bones of the skeleton are classified as:

1. **Long Bones**: They are found in the limbs. A long bone contains a shaft and two extremities. The long bones act as levers and help in various movements of the body. Eg. Humerus, radius, ulna, femur, tibia, fibula.

2. **Short Bones**: These have no shaft. But they contain a spongy substance covered by a shell of compact bone e.g. small bones of wrist and ankle. Eg. Carpals bones and tarsal bones.

3. **Flat Bones**: They contain two layers of compact bone with a spongy substance in between e.g. pelvic bones and scapula.

4. **Irregular Bones**: They do not fall in any category. Eg. pelvic bone and scapula.

5. **Sesamoid bones**: These are small bones which develop in the tendons of muscles e.g. patella of knee Joint.

Structure of Bone

Bone is the hardest of the connective tissues. It consists of two kinds of connective tissues 1) Compact bone 2) Cancellous bone.

Cancellous Bone

![Cancellous Bone Diagram](image-url)
Compact Bone

It is hard and dense. It is found in flat bones, in the shafts of long bones and as a thin covering of all bones.

A long bone (longitudinal section)

Gross structure of a Long Bone

A long bone has two ends (epiphysis) connected by a shaft (diaphysis). The outer membrane covering the bone is periosteum. It is followed by a thick layer of compact bone. Inside this is a central medullary canal. Nutrient foramen is the opening through which arteries pierce the medullary canal.

Microscopic structure of Bone

Cross section of a bone under the microscope shows the following structures

1. *Haversian canal* which lies at the centre. It contains blood vessels, nerves and lymphatics.

2. *Lamellae* which are plates of bone arranged concentrically around the Haversian canal.

3. *Lacunae* which are spaces between the lamellae and they contain bone cells.
4. *Canaliculi* which are fine channels. They radiate between the lacunae and the central *Haversian canal*.

All the structures together form a unit. This unit is called as the *Haversian system*.

**Development and Growth of Bones**

Formation of the bone is called *ossification*. Bones of the skeleton are developed in two ways:

1. Some bones develop in sheets of fibrous tissue (intra-membranous ossification).
2. Other bones develop in bars of cartilage (intracartilagenous ossification).

In both cases, bone cell called osteoblast invade the area of ossification. Here, calcium salts are deposited to give the necessary hardness. This process of bone development occurs before birth.

After birth, the bone grows from certain centers in it. The centre in the shaft is called *diaphysis*. The two centers in the ends are called as *epiphysis*. The layer of cartilage in between the epiphysis and diaphysis is called as *epiphyseal cartilage*. This is gradually replaced by bone. This replacement occurs till the epiphysis and diaphysis unite to form a single bony structure. After this, growth of bone stops.

**Bones of the Human Skeleton**

A total of 206 bones form human skeleton. These bones can be classified as:

1. Bones of the skull : Bones of cranium, face and lower jaw
2. Bones of the trunk : Ribs
   Sternum
   Vertebral column
3. Bones of upper limb : Scapula (shoulder girdle)
   Humerus (arm bone)
   Radius and ulna (forearm bones)
   Phalanges (finger bones)
4. Bones of lower limb : Pelvic girdle (hip bone)
Bones of the skull and trunk form the axial skeleton. Bones of the upper and lower limbs form the *appendicular* skeleton.

### 2.3 Bones of the Skull

Bones of the skull are divided into two groups:

1. Bones of cranium (or brain box)
2. Bones of face

**Bones of Cranium**

Cranium is formed by 8 bones. They are:

1. One frontal bone
2. Two parietal bones

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*Fig 2.4 Skull image*
3. Two temporal bones
4. One occipital bone
5. One sphenoid bone
6. One ethmoid bone

**Sutures of the Cranium**

Sutures are the immovable joints which unite the bones of the skull. The important sutures are:

1. Coronal suture: between the frontal bone and the two parietal bones
2. Sagittal suture: between the two parietal bones.
3. Lambdoid suture: between the occipital bone and the two parietal bones

**Frontal Bone**

If forms the forehead and the roof of the orbit. The features of frontal bone are:

1. **Supraorbital margins** form the arches of orbit.
2. **Nasal notch** - bone projecting between supraorbital margins. Nasal bones are fitted to this.
3. **Superciliary arch** - lies above these two structures. Frontal tuberosities - the two prominences of forehead.
4. **Frontal tuberosities** - the two prominences of forehead.
5. **Frontal sinus** - a space behind the forehead. It contains air and is lined by mucous membrane.
Parietal Bone

They are two in number. Both form the roof and sides of the skull. It has four borders, four angels and two surfaces.

1. The articulation of this bone are anteriorly with frontal bone posteriorly with occipital bone medially with the other parietal bone below with the temporal bone.

2. It contains an eminence called parietal tuberosity.

3. Superior and inferior temporal lines are the two lines which run parallel to each other.

4. The inner surface is concave. It has impressions for meningeal vessels.

Fig 2.5 Parietal Bone

Temporal Bone

They are two in number. They form lower part of the sides of the skull. The parts of temporal bone are:

1. **Mastoid part**-contains mastoid process.

2. **Squamous part**-a flat part having the zygomatic process which is connected to zygomatic bone.

3. **Petrosus part**-forms the bone of the internal ear.

4. **Tympanic part**-contains the external auditory meatus.
Occipital Bone

It is at the back and lower part of the cranial cavity. The features of occipital bone are:

1. A prominence above called as *external occipital protuberance*.
2. *Condyles*, two in number which articulate with atlas.
3. An opening at the base of skull called *foramen magnum*. The spinal cord passes through this opening.
Sphenoid Bone

It lies at the base of the skull. It forms a large part of middle cranial fossa. It contains

1. Two pairs of wing-like structures called “greater” and “lesser” wings.
2. “Sella turcica” or “hypophyseal fossa” which is a facet for the pituitary glands.

Ethmoid Bone

Fig 2.8 Sphenoid bone viewed from above

Fig 2.9 Ethmoid Bone viewed from above
It is cubical in shape. It is very light and thin. It is situated at the roof of nose and in between the orbits. It contains:

1. Two *labyrinths* composed of ethmoidal sinuses.
2. A *perpendicular* plate forming the upper part of nasal septum.
3. *Cribiform* plate fitting into a notch of frontal bone. Olfactory nerves pass through perforations in this plate.

**Cranial Fossae**

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

1. **Anterior cranial fossa**: It is formed by horizontal plates of frontal bone.
2. **Middle cranial fossa**: Formed by sphenoid bone and *petrous* portion of temporal bones.
3. **Posterior cranial fossa**: Formed mainly by the occipital bone.

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*Fig 2.10 Outline of skull seen from below*
The Fontanelles

At birth, skull bones of the child are not completely ossified. The space between the bones are filled by membranes. These membranes at the angles of bones are called fontanelles. These fontanelles are:

1. **Anterior Fontanelle**: It is the largest of the fontanelles. It is diamond shaped. It is situated at the junction of frontal and two parietal bones. Here, the coronal and sagittal sutures meet. This fontanelle closes at the age of 1 year and 6 months.

2. **Posterior fontanelle**: It is at the back. It occurs -at the junction of two parietal and the occipital bones. It closes soon after birth.

![Fig 2.11 The fetal skull from above (left) and from behind.](image)

Sinuses of the Skull

These are cavities or chambers present in the bones the skull. The important sinuses are:

1. **Frontal Sinus**: They are two in number present in the frontal bones. They are present on each side at the root of the nose.

2. **Maxillary sinuses**: Two in number present in the maxillary bones. They lie on each side of the nose.

3. **Ethmoidal and sphenoidal sinuses**: They are the other sinuses present in the skull. All these sinuses communicate with the nose.
Functions of Sinuses

1. They give resonance to the voice.
2. They lighten the bones of face and cranium.

Bones of the Face

The bones which make the face are 14 in number. These bones are:
1) Two maxillae (upper jaw) 2) one mandible (lower jaw) 3) two palate bones 4) two zygomatic bones 5) two lacrimal bones 6) two nasal bones 7) two inferior turbinate bones 8) one vomer

Maxillae

They are two in number. These bones form the upper jaw. The essential features of maxilla are:

1. A body which is pyramidal in shape.
2. Four processes namely zygomatic process alveolar process, frontal process and palantine process.
3. Maxillary sinus present in the internal aspect.
Mandible

This bone forms the lower jaw and is the only movable bone of skull. It contains:

1. A *body* which is the horizontal part in the centre. It contains the lower teeth and forms the chin.

2. Two *rami*, one on each side. Each ramus contains the *coronoid process* in the front and *condyle of jaw* (head) which lies behind.

*Temporo-inandibular joint* is formed by the articulation of condyle with the temporal bone *process, frontal process and palantine process*. 3. *Maxillary* sinus present in the internal aspect.

![Mandible Diagram](image)

**Fig 2.13 Mandible**

**Palate Bones**: They are two in number. They form the roof of the mouth cavity and the hard palate.

**Zygomatic Bones**: Two bones. They form a part of the floor of the orbit. Each of them contains a temporal process. This process joins with the zygomatic process of temporal bone and forms the zygomatic arch.

**Lacrimal Bones**: They are two bones found in the interior of the orbit. It contains the lacrimai sac which secretes the lacrirnal fluid.

**Nasal Bones**: They are two in number. They form the nasal bridge.

**Inferior Turbinate Bones**: Two in number. They are also called as nasal conchae. They are found in the interior of the nasal cavit

**Vomer**: It forms the lower part of nasal septum.

**Hyoid Bone**: It is V shaped bone. It has:
1. a *body*

2. two horns called as *lesser horn* and greater horn. The hyoid bone is attached to the base of the tongue and to styloid process by means of ligaments.

### 2.4 Bones of the Upper Limb

**Scapula**

It lies at the back of the thorax. It forms the posterior part of the shoulder girdle. It has two surfaces, three angles and three borders.

The surfaces of scapula are

1. **Anterior or costal surface**: It is called as the suprascapular fossa. It lies nearest to the ribs. Subscapularis muscle is attached to this surface.

![Fig 2.14 Posterior surface of left scapula](image)

2. **Posterior or dorsal surface**: It is divided into two fossae by spine of scapula which ends with acromion process. The fossae are:

   a. **Supraspinous fossa** which is the upper one. It gives attachment to supraspinatus muscle.
b. **Infraspinous fossa** which is below. It gives attachement to infraspinatous muscle.

**The borders of scapula are**

1. **Superior border**: It lies in the upper part. It extends from the superior angle to the base of corocoid process. Supras capular notch is at the inner extremity of this border. The suprascapular vessels pass through this notch.

2. **Medial or vertebral border**: It is nearest to vertebral column. It extends between superior and inferior angles.

3. **Lateral or axillary border**: It is nearest to axilla. It lies between inferior angle and glenoid cavity.

**The angles of scapula are**:

1. **Superior angle**: It lies at the junction between superior and medial borders. 2. 2.

2. **Inferior angle**: It is the junction between medial and lateral borders. It is the lowest point of the scapula.

3. **Lateral or external angle**: It contains glenoid cavity which receives the head of humerus (to form shoulder joint). Corocoid process of scapula arises internal to glenoid cavity.

**Clavicle**

![Fig 2.15 Left clavicle above (top) and from below.](image-url)
It is also called as collar bone. It is a long and curved bone. It forms the anterior part of shoulder girdle. It contains a shaft, two ends and four borders.

The ends are

1. Medial or sternal end. It articulates with sternum.
2. Lateral or acromial end. It articulates with acromion process of scapula.

The borders of clavicle are superior, inferior, anterior and posterior borders.

Humerus

It is the longest bone of upper limb. It contains two extremities and a shaft.

Upper extremity

It contains:

1. A hemispherical head which articulates with glenoid cavity of scapula (at the Shoulder joint).
2. Anatomical neck which is below the head.
3. Greater tuberosity which is below the anatomical neck. It is in the outer side of upper extremity.
4. Lesser tuberosity which is also below the anatomical neck. But it is at the front.
5. Bicipital groove or intertubercular sulcus: It lies in between these two tuberosities.
6. Surgical neck: It is a narrow point of the bone below the two tuberosities.

Shaft

It contains

1. Deltoid tuberosity which is a rough tubercle on the lateral aspect of the shaft. It receives the insertion of deltoid muscle.
2. Spiral or radial groove which is an oblique groove across the back of the shaft. The radial nerve passes through this groove.

Lower extremity

It contains:

1. Trochlea which is a pulley-shaped surface on the insides. It articulates with nina.
2. *Capitulum* on the outer side. It articulates with radius.

3. *Coronoid fossa* which is a depression. It lies above the articulating surface for ulna.

4. *Olecranon fossa* which lies at the back. It receives the olecranon process of ulna.

5. *Medial and lateral epicondyles* which lie on each side of the articulating surfaces.

![Fig 2.16 Posterior (left) and anterior views of right humerus](image)

**Ulna**

It is the inner most bone of the forearm. It contains two extremities and a shaft.

**Upper extremities**

It contains
1. **Coronoid process** which is a projection in front. It fits into the coronoid fossa of humerus.

2. **Olecranon process** which is an upward projection at the back. It fits into olecranon process of humerus.

3. **Trochlear notch** which is formed by these two processes. It articulates with trochlear surface of humerus.

4. **Radial notch** which is on the outer or lateral aspect. It articulates with head of radius.

**Shaft**

It is tapering towards the lower end. If contains surfaces and borders. It gives attachment to:

1. Muscles which control movements of wrist and fingers.
2. Flexor and extensor muscles of forearm.

**Lower extremity**

It contains

1. **Head of ulna** which is a small rounded eminence. It articulates with lower extremity of radius.
2. **Styloid process** which projects downwards from back of lower extremity.
Radius

It is the lateral or outer most bone of forearm. It contains two extremities and a shaft.

Upper extremity

It contains;

1. A head which is more or less button-shaped.
2. Neck which lies below the head.
3. Biceps tubercle which lies below and to the medial side of neck. It gives insertion to biceps muscle.

Shaft

It is narrower above and wider below. It contains surfaces which give attachment to a variety of muscles.

Lower extremity

It contains styloid process which is on the outer or lateral aspect.

2.5 Bones of Wrist and Hand

Bones of Wrist

The bones of carpus or arranged in two rows. They are

1. First or proximal row made of **scaphoid, lunate, triquetral and pisiform bones**.
2. Second or distal row made of \textit{trapezium, trapezoid, capitate and hamate bones}.

\textbf{Bones of Palm}

They are made of metacarpal bones. They are long bones which contain a head, a shaft and a base. The bases articulate with the distal row of carpal bones. The heads articulate with the proximal row of phalanges.

\textbf{Bones of Fingers}

They are made of phalangial bones. These are long bones. The thumb has two phalanges. Other fingers have three phalanges. They are proximal, middle and distal phalanges.

\textbf{Metacarpo-phalangial} joints are the joints between meta carpal and phalangial bones.

\textbf{Interphalangial} joints are the joints between the phalangial bones themselves.

\textbf{2.6 Bones of Thorax}

The skeleton of the thorax is made of the following bones:

1. \textbf{Stemum} in the front
2. Twelve parts of ribs at the sides.
3. Twelve thoracic vertebrae at the back.

\textbf{Sternum}

It is also called as breast bone. It is a flat bone which is divided into three parts namely \textit{manubrium sterni, body of sternum and xiphoid bone}.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{sternum.png}
\caption{Fig 2.18 Sternum}
\end{figure}
Manubrium Sterni

It is the upper part which is triangular in shape. It contains:

1. Clavicular notches on both sides. These notches articulate with clavicle.

2. Suprasternal notch which is present in between the two clavicular notches.

3. Articular surfaces ‘on both sides for the first rib.

Body of Sternum (gladiolas) : The second rib is attached at the junction between manubrium sterni and body of sternum. This junction is called as Angle of Ludwig. The body of sternum has attachments for 3rd, 4th, 5th, 6th and 7th ribs.

Xiphoid bone (ensiform process) : It is the lowest part of sternum. To this are attached the diaphragm, linea alba and rectus abdominis muscle.

Ribs

They are arranged in twelve pairs. On the back side, all of them are attached to thoracic vertebrae. Depending on their attachment in the front, they are classified as:

1. True ribs which are the upper seven pairs. They are attached to the sternum directly.

2. False ribs which are the lower five pairs. They are attached to the sternum indirectly (through costal cartilages).

3. Floating ribs are the lowest two pairs. They are not attached in front.

![Fig 2.19 A typical rib](image-url)
A rib consists of the following parts

1. **Anterior or sternal end**: It has depressions for attachment of costal cartilage.

2. **Posterior or vertebral end**: It has a head, neck and tubercle.

3. **Shaft** which has
   a. Two surfaces namely inner and outer surfaces
   b. Two borders namely upper and lower borders.
   c. Subcostal groove present in the inner surface. It contains intercostal vessels and nerves.

**Costal Cartilages**

These are bars of hyaline cartilage. They connect the ribs and sternum.

**Vertebral Column**

The vertebral column (or spinal column) is made of a number of bones. These bones are called vertebrae. In all, there are 33 vertebrae.

**Classification of vertebrae**: According to the region they occupy, the vertebrae are classified as

1. *Cervical vertebrae*: 7 in number. They form the neck region.
2. **Thoracic vertebrae**: 12 in number. They form back of thorax.

3. **Lumbar vertebrae**: 5 in number. They form lumbar region.

4. **Sacral vertebrae**: 5 in number. They form the sacrum.

5. **Coccygeal vertebrae**: 4 in number. They form coccyx. Except the first and second cervical vertebrae (axis and atlas), other vertebrae have similar characteristics. So these other vertebrae are called as typical vertebrae.

**Structure of a Typical Vertebra**

A typical vertebra contains

1. A **body** which is a box-shaped anterior part. It is slightly concave in the upper and lower surface.

2. **Neural arch** which is the posterior part. It contains
   a. two pedicles which project backward and
   b. two **laminae** which are directed backward to meet behind in the mid-line.

3. **Two transverse processes**, one on each side. They lie in the junction between pedicle and lamina.

4. **One spinous process** which is a backward projection. It occurs where the two laminae unite in the mid-line.

5. **Two articular processes**, in the upper and lower surface. They lie at the junction between pedicle and laminae (near the transverse process).

6. **Neural canal** which is a circular opening. The spinal cord passes through this.

**Cervical Vertebrae**

![Fig 2.21 A typical cervical vertebrae viewed from above](image)
They are seven in number.

The first cervical vertebra is called as atlas. The second cervical vertebra is called as axis. These two cervical vertebrae have different structures when compared with others.

**Atlas**

1. It does not have a body.
2. It does not have spinous process.
3. On the upper surface, it has two facets. These facets articulate with the condyles of occipital bone (to form atlantooccipital joint).

**Axis**

It is the second cervical vertebra. It contains:

1. *Odontoid process* which is an upward projection from the body. It articulates with anterior arch of atlas.
2. *Two facets* on the anterior surface. They articulate with atlas.
3. *A spine* which is small and bifid.

**Other cervical Vertebrae**

They are the lower five. Their features are: 1. a smaller body 2. oblong shape 3. triangular neural canal 4. bifid spinous process 5. vertebral foramen in the transverse process.
Thoracic Vertebrae

They are twelve in number. These vertebrae carry the ribs. The characteristic features of these vertebrae are:

1. Body is heart shaped.
2. Body has facets, one on each side for the attachment of head of ribs.
3. The transverse process has facets at the tips for articulation with tubercle of ribs.
4. Vertebro foramen is absent.
5. Pedicle and laminar are absent.
6. Spinous process is long and projects downwards.

Fig 2.22 Thoracic vertebrae with ligaments and articulations of ribs.

Fig 2.23 A thoracic or dorsal vertebra seen from the side
Lumbar Vertebrae

They are five in number. They have the following characteristics.

1. Body is big and kidney shaped.
2. Spinous process is short, stout and directed backwards.
3. No articular facets for ribs.
4. Pedicles and laminæ are present.

Sacral Vertebrae

They are five in number. All of them unite to form a single bone called sacrum. The sacrum joins with the pelvic bone and takes part in the formation of pelvic cavity. The features of sacrum are:

1. *Sacral foraminae* which are four openings present in the anterior surface. Nerves pass through these openings.
2. *Lateral masses* on either side. They are formed by the union of transverse processes.
3. *Sacral promontary* which is the projection of the upper part of sacrum.

Coccygeal Vertebrae: They are four in number. All of them unite to form a single bone called Coccyx.
Ligament

The vertebrae are held together by the following ligaments.

1. *Anterior and posterior ligaments*: They run the whole length of spine. They connect the anterior and posterior aspects of the bodies respectively.

2. *Ligamenta flava*: They connect the laminac of vertebral arches.

3. *Supraspinous ligaments*: They lie between the spines and connect them.

*Intervertebral discs*: They are made of fibrocartilage

Bones of the Pelvis Girdle

The pelvic girdle is the connection between the trunk and lower extremities. It is formed by:

1. Two inominate bones, one on each side.

2. The sacrum and coccyx in between.

Inominate Bone

It is called as pelvic bone or hip bone. It is made of three parts namely *ilium, ischium and pubis*. All these three bones unite to form a large cup shaped cavity on the outer surface called *acetabulum*. The head of femur fits into acetabulum forming the hip joint.

![Fig 2.25 The left innominate bone. External (left) and internal surfaces](image)
Ilium

It is the upper expanded and flat part of inominate bone. It contains:

1. **External or gluteal surface**: This surface contains three ridges namely superior, middle and inferior gluteal ridges. They give attachment to gluteal muscles.

2. **Internal surface which is concave**: It forms part of iliac fossa and it gives attachment to iliac muscles.

3. An upper margin called as crest of ilium. The crest of ilium contains four spines. They are:
   a. Anterior superior iliac spine
   b. Posterior superior iliac spine
   c. Anterior inferior iliac spine
   d. Posterior inferior iliac spine

4. Great sciatic notch which is below the articulating surface for sacrum.

Pubis

It is the front portion of inominate bone. It contains:

1. **A body** which is more or less square in shape.

2. **Symphysis pubis** which is the union of the pubic bones in the front.

3. **Superior ramus** which is a bridge of bone projecting from the outer part of body and joins it to ilium.

4. **Inferior ramus** which is the lower part of the body and joins it to ischium.

Ischium

It is the solid, broad portion at the lower and back part of inominate bone. It contains:

1. A body which forms acetabulum on the outer surface.

2. Tuberosity of ischium present at the lowest point. It supports the body weight while sitting.

3. Spine of ischium which arises from the back of ischium.

Obturator foramen is a roughly triangular opening which is bounded by:

1. Public bone in front and above.
2. Ischium behind and below.
**Parts of Pelvis**

Pelvis can be divided into:

1. *False pelvis* which is the upper part. It is formed by the two iliac bones.
2. *True pelvis* which is the lowest part. It is formed by ischium and pubis (in the front and on each side) and by sacrum (behind). Pelvic brim is the upper opening of true pelvis.

Iliopectineal line is the line present at the junction of ilium with ischium.

**Differences between Female and Male Pelvis**

The female pelvis is adapted for pregnancy and child birth. It differs from male pelvis in the following aspects.

1. It is shallow and wider than male pelvis.
2. Inlet and outlet are longer and nearly oval in shape.
3. Bones are lighter and smoother.
4. Pubic arch is wider.
5. Ischial tuberosities are further apart.
6. The coccyx is more movable.
2.7 Bones of Lower Limb

FEMUR: It is also called as thigh bone. It is the longest and strongest bone of the skeleton. It contains two extremities and a shaft.

Upper extremity

It contains

1. A head which is spherical and covered with hyaline cartilage.
2. A neck which lies below the head. It is long and flattened.
3. Greater trochanter which is on the outer side where the neck joins the shaft.
4. Lasser trochanter which is on the inner side where the neck joins the shaft.

Anterior and posterior intertrochantric lines are two lines which unite greater and lesser trochanters.

Shaft

It is smooth, cylindrical and rounded in front and at the sides. It contains

1. Linea aspera which is a ridge on the posterior aspect femur.

Fig 2.27
2. Gluteal ridge which extends from linea aspera to the back of greater trochanter.

3. Spiral line which extends at the inner aspect from linea aspera to lesser trochanter.

**Lower extremity**: It contains:

1. *Medial and lateral condyles* lying one on each side.
2. *Intercondylar notch* which lies behind. It separates these two condyles.
3. *Adductor tubercle* which is a small tubercle above the medial condyle.
4. *Patellar surface* which separates the two condyles in front. Patella rests on this surface.
5. *Popliteal surface* which is above the condyles at the back. Popliteal vessels and nerves lie on this surface.

**Patella**

It is a sesamoid bone developed in the tendon of quadriceps femoris muscle. It contains:

1. An apex pointing downwards. The ligamentum patellae is attached to the apex.
2. An anterior surface which is rough and covered with a bursa.
3. Posterior surface which is smooth. It articulates with patellar surface of femur (to form knee point).

**Tibia**

It is the innermost bone of the leg. It is a long bone containing two extremities and a shaft.

**Upper extremity**: it contains:

1. *A head* which contains two condyles namely *medial condyle* and lateral condyle. The upper surfaces of these condyles articulate with the corresponding condyles of femur.
2. *Popliteal notch* which separates the two condyles at the back.
3. *Tubercle of tibia* which lies below the condyles in the front.
Shaft

It is triangular in shape having three borders and three surfaces. The shaft contains:

1. *Crest of tibia* which is present in the middle third of the anterior border.
2. *Soleal line* which is a strong ridge of bone present in the posterior surface.

**Lower Extremity**: It is slightly expanded. It has an articular surface for talus to form the ankle joint. *Medial malleolus* is a downward projection present in the medial aspect.

![Fig 2.28 Tibia and fibula](image)

Fibula

It is the lateral or outermost bone of the leg. It is a long and slender bone. It contains two extremities and a shaft.

**Upper extremity**: It contains:

1. *A head* which is expanded. It articulates with the back of lateral condyle of tibia. It does not take part in the formation of knee joint.
2. *Styloid process* present in the apex of head. One ligament of knee joint is attached to this.
**Shaft:** It is thin and gives attachment to several muscles.

**Lower extremity:** It contains:

1. *Lateral malleolus* which is a downward prolongation of the lower extremity.

2. *Malleolar fossa* which is a rough depression behind the malleolus.

### 2.8 Bones of Foot

Bones of foot can be classified as:

1. Tarsal bones (7 bones)
2. Metatarsal bones (5 bones)
3. Phalangial bones (14 bones)

![Fig 2.28 Bones of Foot](image)

**Tarsal Bones**

They include *calcaneum, talus, navicular, cuboid* and three *cuneiform bones*.

**Calcaneum**

It is the largest bone of the foot. It lies at the back of foot. Above, it articulates with talus and in front with cuboid. Calcaneum gives attachment to *tendo calcaneus* of calf muscle.
Talus

It forms the central and highest point of foot. It articulates at the sides with medial and lateral malleoli and below with calcaneum.

Navicular (or scaphoid):

It is a disc shaped bone. It is present in the medial aspect of foot. It lies between talus at the back and three cuneiform bones in front.

Cuboid

It is in the lateral aspect of foot. Behind, it articulates with calcaneum. In front, it articulates with two lateral metatarsal bones.

Cuneiform Bones

They are three in number namely medial, intermediate and lateral cuneiform bones. Posteriorly they articulate with navicular bone. Anteriorly they articulate with three metatarsal bones.

Metatarsal Bones

They are five in number. They correspond with the five toes. All of them are long bones. They contain a head, shaft and base. The first metatarsal is thick and stout.

• The first metatarsal is thick and stout.
• The second metatarsal is longer than others.
• The fifth one has a projection at the lateral side of the base.

Phalanges

They are 14 bones, two for the first toe and three for the rest. All of them are long bones.

Arches of Foot

In the foot, the bones are so arranged that there are four different arches. There are two longitudinal arches and two transverse arches. These arches are

a. Medial or internal longitudinal arch: For this

1. Posterior support is given by calcaneum.

2. Anterior support is given by navicular, three cuneiforms and heads of three inner metatarsal bones.
3. Summit is provided by the talus.

b. **Lateral or outer longitudinal arch**: This is formed by calcaneum, cuboid and two outer metatarsal bones.

c. **Transverse tarsal arch** It is formed by the tarsal bones.

d. **Transverse metatarsal arch**: It is formed by the heads of metatarsal bones.

---

**Short Answer Type Questions**

1. Define osteology.
2. Define anatomical position.
3. Define the words proximal, distal and median line.
4. Define bone and write its functions.
5. What are the functions of skeletal system?
6. Mention the bones of upper limb.
7. Write the names of capal bones.
8. Write the names of lower limb bones.
9. Write the names of tarsal bones.
10. Write the names of cranial bones.
11. Write the names of facial bones.
12. Write about humerus bone.
13. Write about femur bone.
14. Write about hip bone.
15. Write the structure of long bone.
16. Write the names of vertebral bones.
17. What are the functions of thorax?
18. Write the arches of foot.
19. Write about sternum.
Long Answer Type Questions

1. Classify bones. Write the process of repair.

2. Write the structure and functions of thorax.
3.0 Introduction

Any connection between bones of the skeleton is called as a *joint or articulation*. *Arthrology* is the term applied for the study of joints.

![Image of a fixed joint or Suture](image)

**Fig 3.1 A fixed joint or Suture**
3.1 Classification of Joints

Joints are classified as:

1. Fibrous joints
2. Cartilagenous joints
3. Synovial joints

Fibrous Joints (or Synarthroses)

They are also called as fixed or immovable joints. In these joints, there is a tight union between the bones. So no movement is possible at these joints e.g. sutures of the skull and teeth in their sockets.

Cartilagenous Joints (or amphiarthroses)

They are also called as movable joints. In this type

1. The articular ends of the bones are covered by hyaline cartilage.
2. There is a pad of fibrocartilage between the joint.
3. The joint is covered by ligaments.

Symphysis pubis and intervertebral joints are examples of cartilagenous joints.

Synovial Joints (or diarthroses)

They are also called as freely movable joints.
The characteristics of these joints are:

1. Articular ends of bones are covered by hyaline cartilage.
2. Bones are bound together by ligaments.
3. Joint is enclosed by fibrous capsule.
4. Capsule of the joint is lined by synovial membrane.
5. The cavity of the joint contains synovial fluid.

**Synovial joint**

1. **Gliding joint (plane joint):** Here two flat surfaces of bones glide on each other, e.g. joint between carpal and tarsal bones.
2. **Hinge joint:** Here, movement is possible in one plane only e.g. elbow joint.
3. **Pivot joint:** In this joint, rotation is the only possible movement, e.g. joint between radius and ulna.
4. **Ball and socket joint:** Articular end of one bone is ball like. It fits into the socket like cavity of another bone. Movement in all directions is possible in this type e.g. shoulder joint and hip joint.
5. **Condyloid joint:** It is similar to hinge joint but movement occurs in two planes e.g. wrist joint.
6. **Saddle joint:** It has one concave surface. This results in free movement in all directions e.g. joint between metacarpal bone of thumb and trapezium.

**Movements Occuring at Joints**

The movement which occur at joints are classified into three major types

1. Gliding movements
2. Angular movements
3. Rotation or circular movements

**1. Gliding Movements:** They occur when two flat surfaces move on each other, e.g. movements between carpal and tarsal bones.

**2. Angular movements:** They bring about an increase or decrease in the angle between bones. Depending on the direction in which the movement occurs, they are further classified into
i. **Flexion**: A movement where similar surfaces come nearer to each other. This reduces the angle between two bones e.g. bending the forearm at elbow.

ii. **Extension**: A movement where similar surfaces go apart. Here the angle between two bones is increased. It is the opposite of flexion e.g. straightening of the bent forearm.

iii. **Adduction**: A movement which brings the limb towards midline.

iv. **Abduction**: It is the opposite of adduction. ‘The limb is drawn away from the mid line.

3. **Rotation or circular movements**: They occur when one bone moves around or within another bone. The movement occurs around a central axis. It is further classified into

   i. **Medial rotation** which occurs towards medial direction.

   ii. **Lateral rotation** which occurs towards lateral direction.

   **Circumduction** is a combination of rotation and angular movements. It involves flexion, abduction, extension, adduction and some rotation. This movement occurs in shoulder, hip etc.

### 3.2 Joints of Upper Limb

**Sterno-clavicular Joint**: It is a gliding joint between sternum and clavicle. A pad of cartilage is present in the joint cavity between the bones.

**Acromio-clavicular joint**: Formed by outer end of clavicle articulating with acromion process of scapula. There is a pad of cartilage between the ends of bones. There is a limited amount of movement in all directions.

**Shoulder joint**

---

Fig 3.3 Shoulder joint
It is a ball and socket type of joint. It occurs between head of humerus and glenoid cavity of scapula. The bones are united together by ligaments. These ligaments form a very loose capsule. Also, the shoulder joint has a synovial cavity. The tendon of long head of biceps passes through this.

**Movements**: All types of movements like flexion, extension, abduction, adduction, rotation and circumduction are possible at this joint.

**Elbow Joint**

It is a hinge joint. It is formed by humerus above and radius and ulna below. It is composed of two different joints They are

1. *Humero-ulnar joint* formed by trochlear notch of ulna and trochlear surface of humerus.

2. *Humero - radial joint* formed by head of radius and capitulum of humerus.

These four articulating surfaces are covered by a joint capsule.

**Movements**: Flexion and extension occur at this joint.

**Radio - ulnar joint**

This is formed by the articulation of radius and ulna at their upper and lower extremities. The interosseous membrane joins them throughout their shaft. This joint is further classified as

1. Superior radio-ulnar joint formed by head of radius and radial notch of ulna.

2. Inferior radio-ulnar joint formed by head of ulna and lower end of radius.

**Movements**: Pronation and supination occur at these joints.

**Wrist joint**

It is a condyloid joint. It is formed by the lower end of radius and three carpal bones (navicular, lunate and triquetral).

**Movements**: Flexion, extension, abduction and adduction are the movements which occur at this joint.

**Metacarpo- phalangeal Joints**

They occur between meta carpal and phalangeal bones. The movements at these joints are flexion, extension, adduction and abduction.
Interphalangeal Joints

They occur between phalangeal bones of the same finger. Flexion and extension are the movements possible.

3.3 Joints of Lower Limb

Hip Joint

It is a ball and socket type of joint. It occurs between acetabulum of inominate bone and head of femur. The acetabulum is deepened by a ring of fibro cartilage called acetabular larbrum.

![Diagram of Hip Joint]

Fig 3.4 The Auterior ligaments of the Hip Joints

The joint capsule is strengthened by three ligaments. They are

1. *ilio-femoral ligament* in the front.
2. *pubo-femoral ligament* below.
3. *ischio-femoral ligament* at the back. The head of femur is connected to the sides of acetabular by means of a ligament. It is called as ligamentum leres.

Movements: Flexion, extension, abduction, adduction, rotation and circumduction occur at this joint.

Knee Joint

It is a hinge joint formed by
1. Two condyles of femur articulating with the condyles of tibia.

2. Patella.

The structures of knee joint are

1. Medial and lateral semi lunar cartilages: They are attached to the upper surface of tibia. They deepen the articular surface.

2. Cruciate ligaments: Upper attachment is intercondylar notch of femur. Lower attachment is the upper surface of tibia. They receive blood from smaller arteries (arterioles) and deliver.

Fig 3.5 The right knee joint viewed from behind

The capsule of the joint is strengthened by medial and lateral ligaments.

**Movements**

1. Dorsiflexion (bending the foot up towards the leg).

2. Plantar flexion (bending the foot downwards).
Joints of the Foot

They are

1. **Tarsal joints**: They occur between talus and calcaneum and also between other tarsal bones.

2. **Tarso-metatarsal joints**: Occur between tarsal and metatarsal bones.

3. **Metatarso phalangeal joints**: Occur between metatarsal and phalangeal bones.

4. **Inter phalangeal Joints**: They occur between phalangeal bones themselves.

### 3.4 Joint Disorders

**Arthritis**

It is an inflammation occurring at a joint or joints. It can occur at any age but commonly occurs in middle and old age groups. The common type of arthritis are:

1. Rheumatoid arthritis
2. Osteo - arthritis.

**Rheumatoid Arthritis**

It is a polyarthritis. It is bilateral and symmetrical in distribution. The commonly affected joints are those of hands and feet. In severe cases, most of the synovial joints are involved. The cause for rheumatoid arthritis is not known. It is an autoimmune disease initiated by microbial infection, probably viruses. As the disease progresses, it leads to intermittent fever. Later, there is deformity of joint leading to decrease in movement and pain. Steroids are usually given to treat this condition.

**Osteoarthritis**

It is a disease occurring due to degenerative changes in the cartilages of joints. The articular cartilage becomes thinner. So the articular surfaces of bones come in contact with each other. Later the bones start degenerating. This produces pain, stiffness and decrease in movement. Physiotherapy and reduction in body weight are advised in this condition. Also steroids are beneficial.

**Gout**

It is caused by the deposition of sodium urate crystals in joints and tendons. It occurs in people with high uric acid levels due to overproduction or decreased
excretion by the kidneys. There is arthritis lasting for several days or weeks with some remission in between. After repeated attacks, permanent damage may occur. Joints commonly affected are ankle, wrist, knee and elbow.

Dislocations

A dislocation is a complete separation of joint surfaces due to tearing of the joint capsule. Dislocation commonly occurs at shoulder and hip joint.

Shoulder Joint

It is more liable for dislocation than any other joint because of:

1. Shallow articulating cavity
2. Large size of the head of humerus
3. Laxity of the capsular ligament

Dislocation of shoulder joint may complicate fractures of upper extremity of humerus.

Sternoclavicular Joint

A forward or backward dislocation may occur as a result of a heavy fall on the shoulder e.g. horse riding.

Elbow Joint

Backward dislocation can occur at elbow joint. It may be accompanied by fracture of the coronoid process.

Hip Joint

Dislocation of hip joint may occur in any direction. But backward and medial dislocation is more common since the capsule is weak at these sites.

Forward dislocation is rare since the ileofemoral ligament crossing the front of hip joint is very strong. Congenital dislocation of hip joint may also occur.

Knee Joint

Knee joint is surrounded by strong ligaments and powerful muscles. So it is one of the strongest and most stable joints in the body. So dislocation of knee joint is very rare.

But the following disorders may occur at knee joint.

1. Slipped cartilage: It occurs due to tearing, detachment or displacement of one of the semilunar cartilages of knee joint.
2. **Acute synovitis**: It may occur at knee joint due to trauma. Since the synovial membrane of the knee joint is extensive, swelling occurs on each side above the patella.

3. **Bursitis**: Enlargement and inflammation of one of the bursae may occur. The bursa between patella and skin is mostly affected.

### Short Answer Type Questions

1. Define joint and write its functions.
2. Write the functions of synovial joints.
3. Mention different movements occurring at joints.
4. Write the name of upper limb and lower limb joints.
5. Write the movements occurring at the shoulder joint.
6. Write about elbow joint.
7. Write the joints of foot.

### Long Answer Type Questions

1. Classify joints and explain the structure of the synovial joints.
2. Explain the structure of the shoulder joint.
3. Explain the structure of the knee joint.
The muscular system consists of a large number of muscles (more than 300). They bring about various movements in the body. Muscles are attached to bones, cartilages, ligaments, skin or other muscles by fibrous structures called tendons or aponeurosis. Tendon is a cord-like structure, whereas aponeurosis is a strong fibrous sheet. Muscles are richly supplied by blood vessels and nerves.
Each muscle has an origin and insertion. Origin is the end which remains stationary when the muscle contracts. The end which moves the end is called insertion. But it is not the same in all cases. In some cases, both ends of the muscle may move.

4.1 Types of Muscles

Muscular tissue can be classified into:

1. Smooth, non-striated or involuntary muscles.
2. Cardiac muscle or myocardium.
3. Skeletal, striated or voluntary muscles.

Smooth Muscles

- These muscles are often encircle or surround the viscera.
- Do not exhibit cross striation under microscope, being plain and smooth in form.
- They are supplied by autonomic nerves, and therefore, are not under voluntary control.
- Respond slowly to stimuli, being capable of sustained contraction and do not fatigue easily.
- Provide power of regulating the internal environment, related to digestion, circulation, secretion and excretion.
- They are less dependent on nervous control, being capable of contracting automatically, spontaneously and often rhythmically.
- Each muscle is an elongated, spindle-shaped cell, with a single nucleus placed centrally, the myofibrils. Show longitudinal striations. Ex. Muscles of the blood vessels, and the arrector pili muscles of the skin.

Cardiac Muscles

- It forms myocardium of the heart.
- It is intermediate in structure, being striated and at the same time involuntary.
- It is meant for automatic and rhythmic – contractions and
• Each muscle muscle fibre, having a single nucleus placed centrally, branches and anastomoses with the neighbouring fibres at intercalated discs (apposed cell membranes), the cross striations are less prominent than those in the skeletal muscle.

**Skeletal Muscles**

The skeletal muscle is attached to the skeleton. The movement of skeletal muscles can be controlled by will.

**Functions of the skeletal muscles**

i. They give shape, form and appearance to the body.

ii. They protect the vital organs of the body.

iii. They keep the joints in proper position.

iv. They help in venous return and lymphatic drainage.

**Structure of the Skeletal Muscle**

Skeletal muscles are composed of a large number of muscle fibres. Each muscle fibre has one are more nuclei which lie in the periphery. The cytoplasm of the muscle cell is called as sacroplasm.

Myofibrils are very small parallel filaments which lie in the cytoplasm. The membrane of the muscle fibre is called as sarcolemma. Each muscle fibre is embedded in a connective tissue called endomysium. The fibres within a muscle are arranged in bundles. Each bundle is enclosed in a sheath called perimysium.

**Properties of Skeletal Muscle**

1. **Excitability and irritability**: it is the property of a muscle to respond to a stimulus. If the response occurs in the form of contraction, it is called as contractility.

2. **Tonicity**: muscles of a living organism are in partially contracted state, even at rest. The resistance to stretch is called as tonicity.

3. **All or none response**: when a stimulus given to a muscle i) the muscle either contracts to maximum or ii) it does not contract at all.

4. **Summation**: when a second stimulus is given to a muscle even while it is contracting due to the first stimulus, the degree of contraction is more. This phenomenon is called summation. The increased response is due to stimulation of more and more motor units by repetitive stimuli.
5. **Trappe or staircase phenomenon**: stimulation of a muscle at regular short intervals increases the amplitude of contraction. This occurs due to increased irritability of the muscle produced by chemical products of the earlier contractions.

6. **Tetanus**: when a muscle is stimulated repeatedly at a very faster rate, the muscle contracts maximally. The muscle remains at this state of contraction till i) the stimulus continues or ii) it gets fatigued. This sustained maximal contraction is called tetanus.

7. **Refractory period**: it is a period when muscle loses its excitability. During refractory period, the muscles do not respond to any stimulus, however strong it may be.

8. **Isotonic contraction**: it is the contraction in which the muscle shortens under constant load. It occurs in muscles during walking, running or lifting.

9. **Isometric contraction**: in this type of contraction, the muscle develops tension but it does not shorten in length eg. Maintaining the posture against gravity.

10. **Fatigue**: it is a state of reduce excitability and contractility of a muscle. It is produced by rapid and repeated stimulation of the muscle. Fatigue may occur due to depletion of energy and accumulation of metabolites like lactic acid.

Muscle Spindle

These are the spindle shaped sensory end organs of the skeletal muscle. Each spindle contains 6-14 intrafusal muscle fibres which are of two types, the larger nuclear bag fibres, and the smaller nuclear chain fibres. The spindle is innervated by the sensory and motor nerves. Muscle spindles acts as a stretch receptors.

![Nuclear bag fibre](image1)

**Fig 4.1 Structure and nerve supply of the muscle spindle**
They record and help in regulating the degree and rate of muscle contraction of the extra fusual fibres by influencing the alpha neurons. Recent evidence shows that the spindle activity is represented in the sensory cortex, which plays a part in conscious appreciation of the position and movements of the joints.

### 4.2 Muscles of Upper Limb

Which connected upper limb to vertebral column

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Verte Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Trapezius</strong></td>
<td>Upper Posterior border of lateral 1/3rd of clavicle. Middle - Medial border of acromion and upper lip of crest of spine of scapula lower Deltoid tubercle at medial end of spine of scapula.</td>
<td>Moter -Spinal accessory Proprioceptive -ventral rami of C and C₄.</td>
<td>Rotate the scapula Elevate scapula (along with levator scapular) - Retract scapula (along with Rhomboids)</td>
</tr>
<tr>
<td>Medical 1/3rd Of superior muchal line of occipital bone. Ligamentum Nuchae Spinous process &amp; superspomous ligament of T₁, T₁₂.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. Latissimus Dorsi</strong></td>
<td>Floor of intertubercular sulcus of humerus</td>
<td>Thoraco-dorsal (C₆, C₇, C₈)</td>
<td>Extendes shoulder joint. Adduction Elevates Trunk during climbing Costal fibres for inspiration rest for expiration</td>
</tr>
<tr>
<td>Lower six thoracic spines and supra Spinous Ligament All lumbar and sacral vertabrae Outer lip of iliac crest. Inferior angle of Scapula</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. Levator Scapula</strong></td>
<td>Medial or vertebral border from upper angle to apex of scapular spine.</td>
<td>Ventral rami of C₃, C₄</td>
<td>Elevates Scapula</td>
</tr>
<tr>
<td>Posterior tubercles of Transverse four cervical Vertebrae</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Rhomboidus Major**

<table>
<thead>
<tr>
<th><strong>Spinous Process</strong></th>
<th><strong>Dorsal aspect of medial border of scapula from inferior angle to root of spine.</strong></th>
<th><strong>Dorsal Scapular C₅</strong></th>
<th><strong>Retract Scapula depress shoulder</strong></th>
</tr>
</thead>
</table>

**R.Minor**

<table>
<thead>
<tr>
<th><strong>Ligamentum nuchae and spinous process of C₇ and T₁</strong></th>
<th><strong>Medial border of scapula at apex of spine.</strong></th>
<th><strong>Dorsal Scapular C₅</strong></th>
<th><strong>Retract scapula depress shoulder</strong></th>
</tr>
</thead>
</table>

![Fig 4.2](image)

**Pectoralis major**

<table>
<thead>
<tr>
<th><strong>Origin</strong></th>
<th><strong>Insertion</strong></th>
<th><strong>Verve Supply</strong></th>
<th><strong>Action</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Clavicular head</td>
<td>As bilaminar tendon into lateral lip of intertubercular sulcus of humerus</td>
<td>Medial (C₈, T₁) Lateral (C₅, C₆, C₇) Pectoral nerves.</td>
<td>Medial rotation and adduction of Shoulder joint Clavicular -flexion Sternocostal head extension to bring the flexed humerus to side Accessory Inspiratory muscle</td>
</tr>
<tr>
<td>Medial half of anterior surface of clavicle.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stermocostal head - Lateral part of Anteral part of Anterior surface of sternum upto 6th costal cartilage 2nd - 6th costal cartilage. Aponeurosis of External oblique.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 4.3 Muscles of Shoulder

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Verve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2. Subscapularis</strong></td>
<td>Subscapular fossa medial 2/3rd</td>
<td>Lesser humeral tubercle front of articular capsule</td>
<td>Upper and lower subscapular nerve C5, C6, C7</td>
</tr>
<tr>
<td><strong>3. Supraspinatus</strong></td>
<td>Medial 2/3rd of supraspinous fossa and supraspinus Fascia</td>
<td>Highest facet of greater humeral tubercle</td>
<td>Suprascapular nerve C4, 5, 6.</td>
</tr>
<tr>
<td><strong>4. Infraspinatus</strong></td>
<td>Medial 2/3rd of lateral border on dorsal surface of Scapula</td>
<td>Medial facet of greater humeral tubercle</td>
<td>Suprascapul C4, C5, C6</td>
</tr>
<tr>
<td><strong>5. Teres minor</strong></td>
<td>Upper 2/3rd of lateral border on dorsal surface of Scapula</td>
<td>Lowest facet of greater humeral tubercle</td>
<td>Axillary Nerve C4, C5, C6</td>
</tr>
<tr>
<td><strong>6. Teres major</strong></td>
<td>Dorsal oval area near the inferior scapula angle.</td>
<td>Medial lip of the humeral intertubercular sulcus</td>
<td>Lower subscapular Nerve C6, C7</td>
</tr>
</tbody>
</table>
### 4.4 Muscles of Arm

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Biceps brachii</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short hand - Tip of coracoid process long head - supra Glenoid tubercle of scapula and Adjacent Glenoidal Lobraum</td>
<td>Posterior part of radial tuberosity Bicipital aponeurosis into posterior border of ulna</td>
<td>Musculocutaneous nerve $C_5, C_6, C_7$</td>
<td>Flexion of elbow joint. Long head keep the humeral head in glenoid cavity during abduction of shoulder joint</td>
</tr>
<tr>
<td><strong>2. Brachialis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anteromedial And anterolateral surface of lower half of shaft of Humerus medial intermuscular septum</td>
<td>Anterior surface of coronoid process and tuberosity of ulna</td>
<td>Musculocutaneous radial nerve $C_7$</td>
<td>Flexion of elbow joint</td>
</tr>
<tr>
<td><strong>3. Triceps</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long head - infraglenoid tubercle of scapula lateral - Oblique posterior ridge on humeral Shaft Lateral - intermuscular Septum Medial - Posterior surface of shaft of humerus, medial border of humerus, medial and Lateral intermuscular Septum</td>
<td>Posterior part of upper surface of olecranon process</td>
<td>Radial nerve $C_6, C_7, C_8$</td>
<td>Extensor of elbow joint Adducts the humerus to thorax</td>
</tr>
</tbody>
</table>
**Muscles of Forearm**

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Pronator teres</strong>&lt;br&gt;Humeral head - Lower part of Medial supracondylar ridge&lt;br&gt;Epicondyle&lt;br&gt;Ulnar - medial side of coroid process.</td>
<td>Middle of the lateral surface of shaft of radius</td>
<td>Median nerve C₆, C₇</td>
<td>Promotion of forearm, weak flexor of elbow joint</td>
</tr>
<tr>
<td><strong>2. Flexor carpi ulnaris</strong>&lt;br&gt;Humeral - Medial Epicondyle&lt;br&gt;Ulnar - medial margin of Olecranon process and upper 2/3rd of posterior border of ulna.</td>
<td>Pisiform Hook of hamate and base of 5th metacarpal through pisohamate and pisometacarpal ligament</td>
<td>Ulnar nerve C₇, C₈</td>
<td>Flexor of wrist adduction at wrist joint</td>
</tr>
</tbody>
</table>
### Deep Flexor Muscles

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Verve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Flexor digitorum profundus</td>
<td>Anterior and medial surface of upper 3/4th of shaft of ulna</td>
<td>4 tendons into palmar surface of base of distal phalanges</td>
<td>Medial part by Ulnar Lateral by anterior interosseous branch of median Nerve</td>
</tr>
</tbody>
</table>

### Deep Group Muscles

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Verve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Supinator</td>
<td>Lateral epicondyle Radial collateral ligament, Annular Ligament supinator crest of ulna</td>
<td>Upper 1/3rd of lateral surface of radius - Between anterior and posterior oblique lines</td>
<td>Posterior interosseous Nerve</td>
</tr>
<tr>
<td>2. Abductor</td>
<td>Pollicus longus</td>
<td>Radial side of base of first metacarpal</td>
<td>Posterior interosseous Nerve</td>
</tr>
</tbody>
</table>

![Fig 4.5](image-url)
### Posterior compartment of Forearm

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Brachioradialis</strong></td>
<td>Upper 2/3rd of lateral supracondylar ridge lateral inter muscular septum</td>
<td>Base of styloid process of radius</td>
<td>Radial nerve</td>
</tr>
<tr>
<td><strong>2. Extensor Carpi Radialis Longus</strong></td>
<td>Lower 1/3rd of the lateral supracondylar ridge lateral inter muscular septum</td>
<td>Dorsal surface of base of 2nd metacarpal</td>
<td>Radial nerve</td>
</tr>
<tr>
<td><strong>3. Extensor Digiti Minimi</strong></td>
<td>Lateral epicondyle of Humerus</td>
<td>Dorsal digital expansion of little finger</td>
<td>Posterior interosseous nerve of radial C7</td>
</tr>
<tr>
<td><strong>4. Extensor Carpi Ulnaris</strong></td>
<td>Lateral epicondyle of Humerus Posterior border of ulna aponeurosis.</td>
<td>Tubercle on the medial side of base of 5th metacarpal bone</td>
<td>Posterior interosseous nerve of radial C7</td>
</tr>
</tbody>
</table>
### 4.5 Muscles of Hand

<table>
<thead>
<tr>
<th><strong>Origin</strong></th>
<th><strong>Insertion</strong></th>
<th><strong>Nerve Supply</strong></th>
<th><strong>Action</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Flexor pollicis brevis</strong></td>
<td>Radial side of base of proximal phalanx ulnar nerve.</td>
<td>Recurrent branch of median nerve Deep branch of ulnar nerve.</td>
<td>Flexes the proximal phalanx of thumb</td>
</tr>
<tr>
<td>Superficial - Flexor retinaculum and trbrcle of trapezium deep - Trapezoitd and capitate bones</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **2. Adductor pollicis** | Ulnar side of base of proximal phalanx of thumb | Deep branch of ulnar nerve | Approximates the thumb to index finger |
| Transverse - longitudinal ridge on palmar surface of 3rd Metacarpal bone oblique - bases of 2nd and 3rd metacarpal, Trapezoid capitate by Crescentic Origen | | | |

### Lumbricals

<table>
<thead>
<tr>
<th><strong>Origin</strong></th>
<th><strong>Insertion</strong></th>
<th><strong>Nerve Supply</strong></th>
<th><strong>Action</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1st and 2nd - Unipennate from radial side or profundus tenduns for index and middle finger 3rd and 4th Bipennate &amp; arise sides for middle, ring and little Fingers</td>
<td>Radial side of dorsal digital expansion of medial four fingers</td>
<td>Median - Deep branch of ulnar never</td>
<td>Flex the digits at metacapphalangeal &amp; extend at Interphalan geal joints</td>
</tr>
</tbody>
</table>
### Hypotenar

<table>
<thead>
<tr>
<th><strong>Origin</strong></th>
<th><strong>Insertion</strong></th>
<th><strong>Vere Supply</strong></th>
<th><strong>Action</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Palmaris brevis</strong></td>
<td>Skin on ulnar side of palm</td>
<td>Superficial branch of ulnar nerve C₆, T₁</td>
<td>Wrinkles the skin on ulnar side of palm of deepens the hollow of palm</td>
</tr>
</tbody>
</table>

**2. Flexor digiti minimi**

<table>
<thead>
<tr>
<th><strong>Origin</strong></th>
<th><strong>Insertion</strong></th>
<th><strong>Vere Supply</strong></th>
<th><strong>Action</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial side of hook of hamate + flexor retinaculum</td>
<td>Ulnar side or proximal phalanx of little finger</td>
<td>Deep branch of ulnar nerve</td>
<td>Flexor of proximal phalanx of little finger. Flexes the fifth metacarpal rotating it laterally at Carpometacarpal joint</td>
</tr>
</tbody>
</table>

### 4.6 Muscles of Lower Limb

#### Muscles of Iliac Region

<table>
<thead>
<tr>
<th><strong>Origin</strong></th>
<th><strong>Insertion</strong></th>
<th><strong>Vere Supply</strong></th>
<th><strong>Action</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Iliacus</strong></td>
<td>Into psoas tendon and to the shaft of femur for 2.5cm below and in front of lesser trochanter.</td>
<td>Femoral nerve L₂, L₃</td>
<td>Flexor of hip joint</td>
</tr>
</tbody>
</table>

**Psoas major**

<table>
<thead>
<tr>
<th><strong>Origin</strong></th>
<th><strong>Insertion</strong></th>
<th><strong>Vere Supply</strong></th>
<th><strong>Action</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior surface and lower border By five digitations from T₁₂ - L₁ vertebal bodies and intervening discs. Tendrous arches across the concave lumbar bodies.</td>
<td>Lesser trochanter of femur</td>
<td>Ventral rami of lumbar spinal nerves L₁, L₂, L₃</td>
<td>Flexor of hip joint</td>
</tr>
</tbody>
</table>
Anterior Thigh/Femoral Muscles

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Rectus femoris - straight - anterior inferior iliac spine reflected - Groove above acetabulum and fibrous capsule of hip joint</td>
<td>Base of patella</td>
<td>Femoral nerve L2,3</td>
<td>Extend the knee and flexes the hip</td>
</tr>
<tr>
<td>b) Vastus lateralis - Intertrochanteric line, anterior and inferior borders of greater trochanter, lateral lip of gluteal tuberosity, proximal half of lateral lip of linea aspera</td>
<td>Patellar base and lateral border</td>
<td>Femoral nerve L2,3</td>
<td>Prevents lateral displacement patella in extended knee.</td>
</tr>
<tr>
<td>c) Vastus medialis - Intertrochanteric line, spiral line medial lip of linea aspera proximal part of medial supracondylar line</td>
<td>Medial and upper bord of patella and to tuberosity of tibia.</td>
<td>&quot;</td>
<td>Prevents medial displacement patella in extended knee.</td>
</tr>
<tr>
<td>d) Vastus intermedius - Proximal 2/3rd of anterior and lateral surface of femoral shaft and distal part of lateral intermuscular septum.</td>
<td>Lateral patellar border lateral tibial condyle</td>
<td>&quot;</td>
<td>Extensor of knee.</td>
</tr>
</tbody>
</table>
### Medial/Adductor Muscles of Teeth

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gracilis</td>
<td>Medial margin of lower half of body of pubis, ramus and adjoining ischial ramus</td>
<td>Upper part of Obturator nerve medial surface of tibia</td>
<td>Flexes the leg L₂, L₃ medially Femoral adductor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Adductor brevis</td>
<td>Front of pubic body and inferior ramus between gracilis and obturator externus</td>
<td>Along a line extending from lesser trochanter to linea aspera</td>
<td></td>
</tr>
</tbody>
</table>

### Muscles of Gluteal Region

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gluteus maximus</td>
<td>Iliums posterior gluteal line outer surface of drosal segment of iliac crest. Aponeurosis of erector spinae Dorsal surface of lower sacrum side of coccyx sacrotuberous ligament gluteal</td>
<td>Upper fibres into iliotibial tract Deeper into the femoral gluteal tuberosity</td>
<td>Inferior gluteal nerve L₅ S₁ S₂ Extends the flexed thigh flexion of hip joint lateral rotator of hip maintains extended position of knee joint abductor of hip joints.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Piriformis</td>
<td>By 3 digitations from the bone between of anterior sacral foramina and area lateral to it. Ileal gluteal surface capsule of sacra iliac joint. upper surface of sacrotuberverus ligament</td>
<td>Upper border of greater trochanter</td>
<td>Branches from C₅ S₁ S₂ Lateral rotation of extended thigh and abduction of flexed thigh</td>
</tr>
</tbody>
</table>
### Posterior Femoral Muscles

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biceps femoris Long</td>
<td>Head of fibula, lateral condyle</td>
<td>Sciatic nerve L₂, S₁, S₂</td>
<td>Flexion of knee on ischial tuberosity, extension of lower part of condyle</td>
</tr>
</tbody>
</table>

4.7 Muscles of Leg - Anterior Crural

Muscles

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tibialis anteriors</td>
<td>Medial and inferior surface of medial cuneiform and 1st metatarsal bone</td>
<td>Deep peroneal L₄-₅</td>
<td>Dorsi flexor of telocural joint, inverter of foot, maintains balance of body</td>
</tr>
</tbody>
</table>

| Extensor digitorum longus | 4 slips into dorsal digital expansion opposite proximal phalanx divides into 3 slips middle to base of middle phalanx, 2 to base of distal phalanx | Deep peroneal L₄, S₁ | Extend the toes dorsiflexes the foot |
**Lateral Leg Muscles**

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Verve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Peroneus longus</td>
<td>Upper 2/3rd of lateral surface of fibula fascial crus anterior and posterior crucial intermuscular septum</td>
<td>By 2 slips to lateral sides of 1st metatarsal base and adjacent cuneiform, 3rd slip - 2nd metatarsal base</td>
<td>Superficial peroneal nerve L₅, S₁, S₂</td>
</tr>
</tbody>
</table>

**Posterior Cranial Muscles - Superfacial**

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Verve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gastronemius</td>
<td>Medial head - upper and posterior of medial condyle of femur femoral popliteal surface above medial condyle Lateral-lateral surface of lateral condyle and adjoining superocondyler line</td>
<td>Forms tendocalcaneus us and joints at middle of posterior surface of calcaneus</td>
<td>Tibial nerve S₁₂</td>
</tr>
<tr>
<td>2. Soleus</td>
<td>Posterior aspect of head and proximal quarter of shaft of fibula. Soleal line of tibia. Medial 1/3rd of medial border of shaft tibia. Fibrous arch between tibia and fibula</td>
<td>Forms tendocalcaneus us and joints at middle of posterior surface of calcaneus</td>
<td>Tibial nerve S₁₂</td>
</tr>
</tbody>
</table>
### Dorsal, Muscle of Foot

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Verve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Extensor digitorum brevis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior part of superolateral surface of calcaneus</td>
<td>Four tendons</td>
<td>Lateral branch of deep peroneal nerve S1-2</td>
<td>Extension of phalanges</td>
</tr>
<tr>
<td>interosseous membrane</td>
<td>Medial to the dorsal side of base of proximal phalanx</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ligament, stem of inferior extensor retinaculum</td>
<td>Other joint the lateral side of tendon of extensor digitorum longus</td>
<td></td>
<td>for 2,3,4 toes.</td>
</tr>
</tbody>
</table>

### Plantar Muscles of Foot/Sole

#### First Layer

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Verve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Abductor hallucis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexor retinaculum</td>
<td>Medial side of proximal phalanx base of hallux</td>
<td>Medial planter Nerve S2-3</td>
<td>Plantar flexor lateral rotation Toes</td>
</tr>
<tr>
<td>Medial process of calcaneus tuberosity planter aponeurosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermuscular septum</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Second Layer

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Verve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Flexor digitorum accessorius</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midial - Midial concave surface of calcaneus</td>
<td>Lateral side of tendons of flexor digitorum longus</td>
<td>Lateral plantar S2-3</td>
<td>Plantar flexion of lateral 4 toes</td>
</tr>
<tr>
<td>Lateral - lateral tubercle of calcaneus long plantar ligament</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Cranio Facial Muscles

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Verve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Occipitofrontalis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occipitalis - lateral 2/3 of</td>
<td>Medial fibres are continuous</td>
<td>Posterior auricular branch.</td>
<td>Retract the scalp Frontalis raise the</td>
</tr>
<tr>
<td>highest nuchal line and</td>
<td>with corrugator supercilli and</td>
<td>Temporal branch of facial nerve</td>
<td>eyebrows and nasal skin Acting</td>
</tr>
<tr>
<td>mastoid temporal bone.</td>
<td>orbicularis oculi, lateral</td>
<td></td>
<td>Alternatively move entire scalp back and</td>
</tr>
<tr>
<td>Frontalis - has no bony</td>
<td>with orbicularis over the</td>
<td></td>
<td>Forwards</td>
</tr>
<tr>
<td>attachments arise from front</td>
<td>zygomatic process of frontal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>of gale aponeurotica</td>
<td>bone. All fibres join</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>epicranial, aponeurosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>anterior to coronal suture</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Circumorbital and Palebral Musculature

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Verve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Orbicularis Occuli orbital</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nasal part of front bone,</td>
<td>They form complete loop</td>
<td>Orbital closes eyelids tightly</td>
<td></td>
</tr>
<tr>
<td>frontal process of maxilla and</td>
<td>and upper fibres blend</td>
<td>as in protecting the eye from</td>
<td></td>
</tr>
<tr>
<td>to medial palpebral ligament.</td>
<td>with frontalis and corrugator</td>
<td>bright light.</td>
<td></td>
</tr>
<tr>
<td>Palpebal - medial palpebal</td>
<td>supercilli. Its fibres</td>
<td>Closes the lids gently in sleep</td>
<td></td>
</tr>
<tr>
<td>ligament and bone just above</td>
<td>swap cross the eyelids anterior</td>
<td>of rapidly in blinking. Draws</td>
<td></td>
</tr>
<tr>
<td>the ligament</td>
<td>to orbital septumr interlaxting at the lateral commissure as lateral palpebral raphe. Attached to torsi near the lacrimal conaliculi and lateral palpebral raphe.</td>
<td>the lids and lacrimal papillae and dilates the sac. When the entire muscle contracts the frontal temporal and molar skin is down towards the medial orbital angle</td>
<td></td>
</tr>
</tbody>
</table>
### Buccolabial Musculature

<table>
<thead>
<tr>
<th><strong>Origin</strong></th>
<th><strong>Insertion</strong></th>
<th><strong>Verve Supply</strong></th>
<th><strong>Action</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Mantalis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inferior labial</td>
<td>Mandibles</td>
<td>Mandibular marginal branch of facial nerve</td>
<td>Raises the mental tissues Mentolabial sulcus and ase of lower lip - aid in protection / excision.</td>
</tr>
<tr>
<td>frenulum</td>
<td>incisive fossa and mental skin.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. Buccinator</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper surface</td>
<td>Upper fibre straight to upper lip lower straight to lower lip intermediate chiasmatic decussation at modiolus and upper join with orbucularis oris of lower with upper lip</td>
<td>Lower buccal branches of facial nerve</td>
<td>Compress the cheeks against Teeth Forcibly expels the air between the lips from Inflated Vestibule</td>
</tr>
<tr>
<td>of alveolar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>process of</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>maxilla mandible</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>opposite the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>molar teeth.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ptery gomondibul</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ar raphe. A fibrous bend extends from pterygoid hamulus to maxillary tubersity</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Muscles of Mastication

<table>
<thead>
<tr>
<th><strong>Origin</strong></th>
<th><strong>Insertion</strong></th>
<th><strong>Verve Supply</strong></th>
<th><strong>Action</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Masseter</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superficial -</td>
<td>To mandibular angle and lower posterior half of lift real surface of its rami. Central part of mandibular ramus Upper part of mandibular racus and its cornoid process</td>
<td>Anterior trunk of mandibular nerve</td>
<td>Occlusion of teeth in Mastication Help in side to side movement of mandible</td>
</tr>
<tr>
<td>maxillary process</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of zygomatic arch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle-Medial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>side of anterior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/3 of zygomatic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>arch lower border</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of posterior 1/3rd</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep-Deep</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>surface of zygomatic arch</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Deep muscles of Back

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Erector spinae</strong></td>
<td>Divide in upper lumbar region</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>lateral - Ilio cervicalis</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>intermediate – Lonissimus</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medial – spinalis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median sacral crest</td>
<td>lumbar and eleventh and twelfth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>thoracic spines</td>
<td>and superaspinous ligaments.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medial side of dorsal part</td>
<td>of iliac lateral sacral crest</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Orbital Muscles

Extrinsic Muscles of Eyeball

<table>
<thead>
<tr>
<th>Origin</th>
<th>Insertion</th>
<th>Nerve Supply</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Superior oblique</strong></td>
<td>Sclera behind the equator in</td>
<td>Trochlear</td>
<td>Depression, adductor,</td>
</tr>
<tr>
<td></td>
<td>posterosuperior quadrant of eye</td>
<td>nerve</td>
<td>Extorsion</td>
</tr>
<tr>
<td></td>
<td>ball</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undersurface of lesser wing</td>
<td>Sclera behind the equator in</td>
<td>Trochlear</td>
<td>Depression, adductor,</td>
</tr>
<tr>
<td>of sphenoid medial to</td>
<td>posterosuperior quadrant of eye</td>
<td>nerve</td>
<td>Extorsion</td>
</tr>
<tr>
<td>common tendinous ring</td>
<td>ball</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Short Answer Type Questions

1. Write the types of muscle tissue.
2. What are the functions of muscle tissue?
3. Write the origin, insertion, nerve supply and actions of deltoid, biceps, quadriceps, hamstrings muscles?
4. Write the names of the muscles of facial expression?
5. What is muscle spindle?
6. Write the properties of skeletal muscle?
7. What are the rotator cuff muscles?
8. What is fatigue?
9. Write about diaphragm?

**Long Answer Type Questions**

1. Write the types and functions of muscle tissues.
2. Write the structure and functions of skeletal muscle.
**Blood**

**Structure**

5.0 Introduction

5.1 Functions of Blood

5.2 Cellular elements of Blood

5.3 Platelets

**5.0 Introduction**

Blood is a specialized connective tissue which is fluid in nature, which plays a very important part in the maintenance of life. It is a fluid tissue composed of two parts. The intracellular substance is called plasma. The Blood is red in colour due to the presence of Hemoglobin pigment. The average volume of blood in the body is about 6 Lts. Blood is slightly alkaline with a Ph of about 7.4. The specific gravity of blood is about 1.055.

**5.1 Functions of Blood**

1. It transports oxygen and nutrients to various tissues.
2. It transports waste products to excretory organs.
3. It carries endocrine hormones to various tissues.
4. It regulates water balance of the body.
5. It maintains immunity power of the body.

6. Through clotting factors it prevents haemorrhage.

**Composition**

Although it appears as a faint yellow fluid, actually it consists of two parts-a liquid part, the plasma and a solid part- the formed elements or different type of cells, which remain suspended in the plasma. The cells are called as the blood corpuscles- R.B.C. W.B.C. and blood platelets. The cells form 45% and the plasma 55% of the total volume of blood.

**The Plasma**

The blood consists of a suspension of special cells in a liquid called **plasma**

It is a clear, straw-colored watery liquid. It consists of:

1. Water 90 to 92%
2. Solid 8-10%. The solids include:
   (a) Proteins: 7% of albumins, globulins, fibrinogen, prothrombin and heparin.
   (b) Inorganic constituents: 0.9% of Sodium, Calcium, Potassium, Magnesium etc.
   (c) Organic Constituents: glucose, amino acids, fatty acids, glycerol, vitamins and non-nitrogenous substances like urea, uric acid, creatinine, ammonia etc.
4. Anti-bodies and anti toxins which protect the body against bacterial infection.
5. Certain hormones and enzymes.
6. Coloring matter: Yellow colour of plasma is due to the presence of small amount of bilirubin, carotene etc.

**Plasma Proteins**

**Albumin**: it is the key plasma protein which helps in maintaining the osmotic pressure of the blood. It is synthesized in liver.

**Globulin**: which is of three types namely alpha, beta and gamma, produced in lymphoid tissue? it helps in maintaining immunity by producing antibodies and immune substance.
Fibrinogen: which responsible for coagulation of blood. It is synthesized in liver

**Functions of Blood Plasma**

1. Essential for blood clotting: The presence of fibrinogen and prothrombin in the plasma takes part in blood clotting, which are produced in the liver.

2. Plasma maintains colloidal osmotic pressure of blood and help in regulating the distribution of fluid between the blood and tissues.

3. The protein which plasma contains gives the blood the sticky consistency called viscosity, which is necessary to prevent too much fluid passing through the capillary wall into the tissues. This viscosity of blood assists in the maintenance of blood pressure.

4. Plasma is concerned with erythrocytes (R.B.C.) sedimentation rate. An increase in fibrinogen raises the sedimentation rate of red blood cells.

5. Acts as a buffer: The salts in the plasma are necessary or the building of protoplasm and they act as buffer substances neutralizing acids or alkalis in the body and maintaining the correct reaction of blood.

6. Acts as a protein reserve: During starvation the tissue can draw protein from the plasma store.

7. Protects against infection: The anti-bodies and antitoxins provide protection against infection and neutralize the poisonous bacterial toxins.

8. Help in transportation: Plasma protein combines with certain substances can help to carry them in the blood stream.

### 5.2 Cellular Elements of Blood

In the blood are present special cells, classified in: **erythrocytes** and **leukocytes**. There are also **platelets** which are not considered real cells. In the following, we will deal the different categories of blood cells. dia

**Erythrocytes (Red Cells)**

The erythrocytes are the most numerous blood cells i.e. about 4-6 millions/mm³. They are also called red cells. In man and in all mammals, erythrocytes are devoid of a nucleus and have the shape of a biconcave lens. The red cells are rich in **hemoglobin**, a protein able to bind in a faint manner to oxygen. Hence, these cells are responsible for **providing oxygen to tissues** and partly
for recovering carbon dioxide produced as waste. However, most CO$_2$ is carried by plasma, in the form of soluble carbonates.

![Fig. 1- Erythrocytes](image)

**Erythropoiesis**

It is the process by which RBC’s are formed in the foetus, RBC’s are formed in liver, spleen and red bone narrow. After birth, they are formed only in the red bone narrow of sternum, ribs, vertebrae etc. the stages of development of RBC’s are as follows.

1. Proerythroblast
2. Normoblast
3. Reticulocyte
4. Erthrocyte.

Both vitamin B12 and folic acid are necessary for the development of RBC’s.

**Hemoglobin**

It is the respiratory pigment of erythrocytes. The red colour of blood due to hemoglobin. It contains globin a protein which is conjugates with heme. Heme molecule contains four pyrrole rings with iron in the centre. The hemoglobin content of body is about 15 G per 100 ml of blood. Anemia occurs due to a decrease in hemoglobin.

**Functions of Hemoglobin**

1. Transport of oxygen and carbondioxide
2. Maintenance of acid base equilibrium
3. As a source for the formation of bilirubin
Leukocytes (White Cells)

Leukocytes, or white cells, are responsible for the defense of the organism. In the blood, they are much less numerous than red cells. The density of the leukocytes in the blood is 5000-7000 /mm³. Leukocytes divide in two categories: granulocytes and lymphoid cells or agranulocytes. The term granulocyte is due to the presence of granules in the cytoplasm of these cells. In the different types of granulocytes, the granules are different and help us to distinguish them. In fact, these granules have a different affinity towards neutral, acid or basic stains and give the cytoplasm different colors. So, granulocytes distinguish themselves in neutrophil, eosinophil (or acidophil) and basophil. The lymphoid cells, instead, distinguish themselves in lymphocytes and monocytes. As we will see later, even the shape of the nucleus helps us in the recognition of the leukocytes.

Each type of leukocyte is present in the blood in different proportions:

- neutrophil 50 - 70 %
- eosinophil 2 - 4 %
- basophil 0,5 - 1 %
- lymphocyte 20 - 40 %
- monocyte 3 - 8 %

**Neutrophils** are very active in phagocytizing bacteria and are present in large amount in the pus of wounds. Unfortunately, these cells are not able to renew the lysosomes used in digesting microbes and dead after having phagocyted a few of them.
**Eosinophils** attack parasites and phagocyte antigen-antibody complexes.

![Fig. 3 - Eosinophil]

**Basophil** secrete anti-coagulant and vasodilatory substances as histamines and serotonin. Even if they have a phagocytory capability, their main function is secreting substances which mediate the hypersensitivity reaction.

![Fig. 4 - Basophil]

**Lymphocytes** are cells which, besides being present in the blood, populate the lymphoid tissues and organs too, as well as the lymph circulating in the lymphatic vessel. In the blood, lymphocytes are 20-40% of all leukocytes and are slightly larger than red blood cells.

**Monocytes** are the precursors of **macrophages**. They are larger blood cells, which after attaining maturity in the bone marrow, enter the blood circulation where they stay for 24-36 hours. Then they migrate into the connective tissue, where they become macrophages and move within the tissues. In the presence of an inflammation site, monocytes quickly migrate from the blood vessel and
start an intense phagocytory activity. The role of these cells is not solely in phagocytosis because they have also have an intense secretory activity. They produce substances which have defensive functions such as lysozime, interferons and other substances which modulate the functionality of other cells.

Fig 5.5

Functions of WBC's

1. Protection against infection: This is done by neutrophils and monocytes which engulf bacteria. This process is called as phagocytosis.

2. To aid in the repair of injured tissues.

3. To produce immune substances which defend against diseases. This is done by lymphocytes through the synthesis of Gammaglobulin.


5.3 Platelets

The main function of platelets, or thrombocytes, is to stop the loss of blood from wounds (hemostasis). To this purpose, they aggregate and release factors which promote the blood coagulation. Among them, there are the serotonin which reduces the diameter of lesioned vessels and slows down the hematic flux, the fibrin which trap cells and forms the clotting.

Even if platelets appears roundish in shape, they are not real cells. they have an intense purple color. Their diameter is 2-3 μm about, hence they are much smaller than erythrocytes. Their density in the blood is 200000-300000 / mm³. THEIR LIFE SPAN IS ABOUT 3-5 DAYS.
Functions of Platelets

1. Thromboplastin liberated from platelets is essential for clotting.
2. They close minute lesions in the wall of blood vessels.
3. They aid in body’s defense mechanism against bacteria.
4. They contain histamine and serotonin.
5. They contain some antigenic substance also “Thrombocytopenia”. It is a condition where there is a decrease in platelet count.

Mechanism of Clotting

When there is an injury and blood flows, a mechanism is provided within the body whereby blood loss is prevented. This is termed as the coagulation or clotting of blood.

The actual mechanism of blood coagulation is a complicated one, but the general principles are simple and important. Before clotting, there are some substances which must be present in the blood. They are prothrombin, calcium, fibrinogen and thromboplastin.

Prothrombin, calcium and fibrinogen are all normal constituents of blood. But thromboplastin is released only when there is a damage in a blood vessel or tissue cell the release of thromboplastin from thrombocytes or blood platelets brings about a series of changes or events which finally produces a blood clot.

Normally, prothrombin (protein present in the plasma) as such is inactive, but when acted upon thromboplastin in the presence of calcium is converted to an active substance thrombin.

Thrombin in turn acts on fibrinogen, another plasma protein, to produce an insoluble thread-like substance called fibrin.

The fibrin threads entrap blood cells to form a solid mass, the clot. After sometimes the clot shrinks’, and a clear stickle fluid, serum is released, (Serum=plasma-fibrinogen).

The mechanism of clotting can be expressed in a simple formula:

1. Prothrombin + Calcium+thromboplastin = Thrombin (active) (inactive) (from damaged tissue cells and platelets)
2. Thrombin + fibrinogen = Fibrin (fine threads) (inactive)
3. Fibrin + blood cells = CLOT
Clotting Factors

The various factors involved in the scheme of clotting described above are designated by numbers as factors I, II. These factors are:

- **Factors I** - Fibrinogen
- **Factors II** - Prothrombin
- **Factors III** - Thromboplastin
- **Factors IV** - Calcium
- **Factors V** - Quicks labile factor
- **Factors VI** - Existence of these factors not accepted
- **Factors VII** - Quicks stable factor
- **Factors VIII** - Antihenophilic factor
- **Factors IX** - Christmas factor

Factors V and VII are required for the conversion of damaged tissue into thromboplastin factor VIII. Factor VIII is the antithemophilic factor called as haemophilia. Factors IX is called Christmas factor in an American Negro named Christmas, all the other factors were present. But his blood did not clot. So this factors was called as Christmas.

Factors Hastening Clotting

1. Calcium salts acts as good coagulants.
2. Vitamin K has a coagulant action because it helps in the formation of prothrombin, which is necessary for blood clotting.
3. Injury to the tissues or vessel wall helps in coagulation, so that a clean cut with a sharp knife bleeds more freely than a crushed wound in which there is bruising and damage to the surrounding tissues.
4. Contact with a foreign body as the application of surgical dressings help in the speedy formation of a clot and arrest of hemorrhage.
5. Slightly higher temperature than that of the body helps clotting and hence the use of hot swabs to stop surgical bleeding.

Factors Retarding Clotting

1. Heparin is a protein normally present in the blood is formed in the liver and prevents blood clotting in the vessels.
2. Addition of sodium citrate and potassium Oxalate to the blood will combine with calcium and form insoluble salts, thereby make it inactive. These prevent coagulation. In this method, blood is preserved in the blood banks without coagulation.

3. Contact with oil, grease or paraffin wax, would retard clotting.

4. Local Cold.

5. Snake venom is another anticoagulant.

Clotting Time

It is the time taken for the clotting of human blood removed from circulation the average clotting time varies from 5 to 15 minutes.

Blood Groups

The most common type of grouping is the ABO grouping. The varieties of protein coating on red blood cells divides blood into four groups:

- A (A oligosaccharide is present)
- B (B oligosaccharide is present)
- AB (A and B oligosaccharides are present)
- O (neither A nor B, only their precursor H oligosaccharide present)

There are subtypes under this grouping (listed as A1, A2, A1B or A2B...) some of which are quite rare. Apart from this there is a protein which plays an important part in the grouping of blood. This is called the Rh factor. If this is present, the particular blood type is called positive. If it is absent, it is called negative. Thus we have the following broad categories:

- A1 Negative (A1 -ve)
- A1 Positive (A1 +ve)
- A1B Negative (A1B -ve)
- A1B Positive (A1B +ve)
- A2 Negative (A2 -ve)
- A2 Positive (A2 +ve)
- A2B Negative (A2B -ve)
- A2B Positive (A2B +ve)
Rare blood types

In the “ABO” system, all blood belongs to one of four major groups: A, B, AB, or O. But there are more than two hundred minor blood groups that can complicate blood transfusions. These are known as rare blood types. Whereas common blood types are expressed in a letter or two, with maybe a plus or a minus, a smaller number of people express their blood type in an extensive series of letters in addition to their ‘AB-’ type designation.

**Short Answer Type Questions**

1. Define blood.
2. Write the functions of blood.
3. Write the composition of blood.
4. Write about plasma.
5. Write the functions of plasma proteins.
6. What are the cellular components of blood?
7. Write the functions of RBCs?
8. Write the functions of WBCs?
9. Write the functions of platelets.
10. Write the difference between RBCs and WBCs?
11. Write about hemoglobin.
12. What is clotting time?
13. Write the clotting mechanism.
14. Mention the clotting factors.
15. Write the blood groups.
16. Which blood group is named as universal donor and why?
17. Which blood group is named as universal recipient and why?

18. What is ESR?

Long Answer Type Questions

1. Write about the cellular components of the blood with its functions.

2. Explain the composition of plasma with its functions?

3. Explain the clotting mechanism in detail?
The Lymphatic System

Structure

6.0 Introduction

6.1 Functions of Lymphatic System

6.2 Lymphoid Organs

6.0 Introduction

The Lymphatic System is composed of lymph nodes, lymphatic vessels and specialized lymphatic organs such as tonsils, thymus and spleen. The function of the lymphatic system is to clean plasma and prevent toxins from taking over the body. This system is essential to the body’s defense mechanism, filters out organisms that cause disease, produces certain white blood cells, and generates antibodies. It is also important for the distribution of fluids and nutrients in the body. It drains excess fluids and protein so that tissues don’t swell up. The lymphatic vessels are present whenever there are blood vessels and they transport excess fluid to the end vessels without the assistance of any pumping action. The lymphatic system and the cardiovascular system are closely related structures that are joined by a capillary system. The body is able to eliminate the products of cellular breakdown and bacterial invasion through the blood flow, the lymph nodes and into the lymph.
There are more than 100 lymph nodes, located mainly in the neck, groin, armpits, and scattered all along the lymph vessels. These act as barriers to infection by filtering out and destroying toxins and germs. The largest body of lymphatic quarter which drains lymph fluids from the upper right quarter of the body above the diaphragm and down the midline, and the thoracic duct which drains the rest of the goby. It is through the actions of this system that our body is able to fight infection and to ward off foreign invaders diagram.

![Lymphatic System Diagram]

**Fig 6.1 Lymphatic System**

### 6.1 Functions of Lymphatic System

- *Draining excess interstitial fluid*: lymphatic vessels drain excess fluid from tissue spaces & return it to the blood

- *Transporting dietary lipids*: lymphatic vessels transport lipids & lipid-soluble vitamins (A,D,E & K) absorbed by GI tract to the blood

- *Carrying out immune responses*: lymphatic tissue initiates specific immune responses to microbes or abnormal cells
Lymphatic Vessels (Lymphatics)

System of drainage vessels that collects excess protein-containing interstitial fluid (fluid between cells) & returns it to blood used to return fluid escaped from blood into tissue spaces back to blood

Lymph is interstitial fluid that has entered lymphatic vessels form one-way system; blood flows toward heart.

Lymph Capillaries

Occur almost everywhere blood capillaries occur (except bones & teeth, bone marrow, & central nervous system (uses CSF to collect fluid))

- The edges of endothelial cells in walls of lymph capillaries loosely overlap forming minivalves to prevent backflow.
- Collagen filaments anchor the endothelial cells to connective tissue outside, allow the flaps to open when interstitial fluid volume increases such that fluid enters the lymphatic capillaries
- Lymphatic capillaries (unlike blood capillaries) can easily take up proteins, foreign cells & debris… fortunately lymph is circulated through lymphoid organs with immune cells to examine the fluid for undesirables
- Lacteals are specialized lymphatic capillaries in the intestinal mucosa that carry a thick white fatty lymph (chyle) to the blood
- Lymph flows from lymphatic capillaries to collecting vessels, trunks, and ducts.

Lymphangitis: inflammation of lymphatics

- Lymphatic ducts: right lymphatic duct drains lymph from right upper arm, right side of head & thorax; thoracic duct arising from the sac-like cisterna chyli drains the rest of the body

Lymph transport: slow transport; lymph is not pumped, but flows by smooth muscle contraction in the walls of the vessels, pressure changes in the thorax during breathing & valves to prevent backflow

- Also, bundling with blood vessels helps along with movements in adjacent tissues.
Lymphoid Cells

Lymphocytes: \textit{T cells} \& \textit{B cells}

- \textbf{T cells} direct the immune response against virally-infected cells \& cancer cells.
- \textbf{B cells} produce plasma cells that synthesize antibodies
- \textbf{Macrophages}: phagocytize foreign substances \& help activate T cells (along with \textit{dendritic cells})
- \textbf{Reticular cells}: provide stroma to nourish cells of lymphoid organs

Lymphoid Tissue

- Reticular connective tissue: forms a network around macrophages \& lymphocytes in lymphoid organs.
- Diffuse lymphatic tissue: scattered reticular tissue elements
- \textbf{Lymphatic nodules}: tightly packed reticular elements \& cells
- \textbf{Germinal centers}: actively dividing B cells \& T cells

6.2 Lymphoid Organs

Lymph nodes, Spleen \& Thymus

Thymus

Bilobed organ in inferior neck extending into mediastinum
- functions in maturation of T cells; mostly in childhood
- size decreases with age as most tissue replaced by connective tissue
- thymic lobules each contain a cortex and medulla with lymphocytes (T cells); medulla contains Hassal’s corpuscles (appear red)
- thymocytes (epithelial cells in stroma) secrete hormones (thymosins) for development of T cells

Lymph Nodes

- Hundreds of small organs that cluster along lymphatic vessels
- Filter lymph: macrophages in lymph nodes remove debris \& destroy microorganism.
- Activate immune system: lymphocytes within follicles monitor lymph for foreign antigens & mount responses against them.
- T cells circulate between blood, lymph nodes & lymphatic vessels for continuous exposure to foreign substances.
- Lymph sinuses: large capillaries surrounded by reticular fibers with macrophages.

**Structure**

- Capsule: dense connective tissue surrounding lymph node with trabeculae that extend inward to divide the node into compartments.
- Cortex: outer region of lymph node (just inside capsule) containing follicles; germinal centers of follicles contain dividing B cells.
- Medulla: medullary cords from cortical tissue contain lymphocytes & plasma cells.
- Circulation: afferent lymphatic vessel -> subcapsular sinus -> cortical & medullary sinuses -> efferent lymphatic vessel at hilus.
- Lymph nodes can become inflamed when overwhelmed with foreign substances & can become secondary cancer sites.

**Spleen**

Largest lymphoid organ; located in left side of abdominal cavity just below diaphragm.

![Fig 6.2 Spleen](image)
blood flows through sinuses; spleen removes aged & defective blood cells from circulation & contains macrophages to cleanse blood of foreign matter.

stores breakdown products of red blood cells for later use

in fetus, produces erythrocytes

stores blood platelets

red pulp: most of mass of spleen; concerned with blood-cleansing & removal of old RBCs.

white pulp: contains lymphocytes (B cells)

direct spleen injury can cause it to rupture; treatment = removal (splenectomy).

**Tonsils**

Small organs around the entrance to the pharynx

contain follicles with germinal centers with dividing B cells

palatine tonsils: paired at posterior end or oral cavity; most likely to be infected.

lingual tonsils: at base of tongue

tubal tonsils: at openings of auditory tubes into pharynx

**Lymphoid Follicle Aggregates**

- Mucosa-associated Lymphatic tissue (MALT)
- Peyer’s Patches in intestine (ileum)
- Appendix

**Short Answer Type Questions**

1. Write the composition of lymph?

2. What are the functions of lymphatic system?

3. Write the names of the lymphoid organs?

4. What are the functions of spleen?

5. What are the functions of thymus?
UNIT 7

Cardio Vascular System

Structure

7.0 Introduction
7.1 Structure and Function of the Heart
7.2 Cardiac Cycle
7.3 Blood Pressure

7.0 Introduction

The cardiovascular system can be thought of as the transport system of the body. This system has three main components: the heart, the blood vessel and the blood itself. The heart is the system’s pump and the blood vessels are like the delivery routes. Blood can be thought of as a fluid which contains the oxygen and nutrients the body needs and carries the wastes which need to be removed. The following information describes the structure and function of the heart and the cardiovascular system as a whole.

7.1 Structure and Function of the Heart

Function and Location of the Heart

The heart’s job is to pump blood around the body. The heart is located in between the two lungs. It lies left of the middle of the chest.
The heart is a muscle about the size of a fist, and is roughly cone-shaped. It is about 12cm long, 9cm across the broadest point and about 6cm thick. The pericardium is a fibrous covering which wraps around the whole heart. It holds the heart in place but allows it to move as it beats. The wall of the heart itself is made up of a special type of muscle called cardiac muscle.

**Chambers of the Heart**

The heart has two sides, the right side and the left side. The heart has four chambers. The left and right side each have two chambers, a top chamber and a bottom chamber. The two top chambers are known as the left and right atria (singular: atrium). The atria receive blood from different sources. The left atrium receives blood from the lungs and the right atrium receives blood from the rest of the body.

The bottom two chambers are known as the left and right ventricles. The ventricles pump blood out to different parts of the body. The right ventricle pumps blood to the lungs while the left ventricle pumps out blood to the rest of the body. The ventricles have much thicker walls than the atria which allows them to perform more work by pumping out blood to the whole body.
Blood Vessels

Blood vessels are tubes which carry blood. Veins are blood vessels which carry blood from the body back to the heart. Arteries are blood vessels which carry blood from the heart to the body. There are also microscopic blood vessels which connect arteries and veins together called capillaries. There are a few main blood vessels which connect to different chambers of the heart. The aorta is the largest artery in our body. The left ventricle pumps blood into the aorta which then carries it to the rest of the body through smaller arteries. The pulmonary trunk is the large artery which the right ventricle pumps into. It splits into pulmonary arteries which take the blood to the lungs. The pulmonary veins take blood from the lungs to the left atrium. All the other veins in our body drain into the inferior vena cava (IVC) or the superior vena cava (SVC). These two large veins then take the blood from the rest of the body into the right atrium.

Valves

Valves are fibrous flaps of tissue found between the heart chambers and in the blood vessels. They are rather like gates which prevent blood from flowing in the wrong direction. They are found in a number of places. Valves between the atria and ventricles are known as the right and left atrioventricular valves, otherwise known as the tricuspid and mitral valves respectively. Valves between the ventricles and the great arteries are known as these semilunar valves. The aortic valve is found at the base of the aorta, while the pulmonary valve is found the base of the pulmonary trunk. There are also many valves found in veins throughout the body. However, there are no valves found in any of the other arteries besides the aorta and pulmonary trunk. The main arteries which branch off the aorta and take blood to specific parts of the body are:

- Carotid arteries, which take blood to the neck and head
- Coronary arteries, which provide blood supply to the heart itself
- Hepatic artery, which takes blood to the liver with branches going to the stomach.
- Mesenteric artery, which takes blood to the intestines
- Renal arteries, which takes blood to the kidneys
- Femoral arteries, which take blood to the legs
- The body is then able to use the oxygen in the blood to carry out its normal functions. This blood will again return back to the heart through the veins and the cycle continues
7.2 Cardiac Cycle

The cardiac cycle is the sequence of events that occurs in one complete beat of the heart. The pumping phase of the cycle, also known as systole, occurs when heart muscle contracts. The filling phase, which is known as diastole, occurs when heart muscle relaxes. At the beginning of the cardiac cycle, both atria and ventricles are in diastole. During this time, all the chambers of the heart are relaxed and receive blood. The atrioventricular valves are open. Atrial systole follows this phase. During atrial systole, the left and right atria contract at the same time and push blood into the left and right ventricles, respectively. The next phase is ventricular systole. During ventricular systole, the left and right ventricles contract at the same time and pump blood into the aorta and pulmonary trunk, respectively. In ventricular systole, the atria are relaxed and receive blood. The atrioventricular valves close immediately after ventricular systole begins to stop blood going back into the atria. However, the semilunar valves are open during this phase to allow the blood to flow into the aorta and pulmonary trunk. Following this phase, the ventricles relax that is ventricular diastole occurs. The semilunar valves close to stop the blood from flowing back into the ventricles from the aorta and pulmonary trunk. The atria and ventricles once again are in diastole together and the cycle begins again.

Events of Cardiac Cycle

Atrial systole – time : 0.1 sec
Atrial diastole – time : 0.7 sec
Ventricular systole – time : 0.3 sec
Ventricular diastole – time : 0.5 sec
Therefore, time taken for each beat is 0.8 sec

Conducting System of the Heart

The impulses for cardiac contraction are transmitted through the conduction system of the heart. This system is made of 1) Sino atrial node 2) Atrioventricular node 3) Bundle of His 4) Purkinje fibres. The conduction of impulses occurs in the following sequences

1. The impulses for cardiac contraction start at “sinoatrial node” (SA node). It is present at the opening of superior vena cava into the right atrium. SA node is called as pace maker of heart.
2. The impulses then pass through the atrial muscle.
3. Later, the impulses pass to “atrio-ventricular node” (AV node). It lies in the upper part of atrio-ventricular septum.

4. From here, the impulses pass to “bundle of His”. It is a special bundle of nerve and muscle tissue. Also, it is the only muscular connection between the atria and ventricles.

5. The bundle of his passes through the interventricular septum. Later it divides into branches called purkinje fibers. The right and left branches of this fiber supply the two ventricles.

This specialized conduction system of heart provides greater conductivity of cardiac impulses.

**Properties of Cardiac Cycle**

The cardiac muscle has certain characteristics. They are:

1. **Contractility**
   
   By contraction of the cardiac muscles the heart pumps the blood out of its chambers.

2. **Conductivity**
   
   The impulses for cardiac contraction are conveyed through a specialised conduction system.

3. **Rhythmicity**
   
   Heart muscle has the inherent property of rhythmic contraction. Cardiac contraction occur in a regular fashion. The two atria and ventricles contract alternately.

4. **Refractory Period**
   
   During systole, the heart does not respond to any other stimuli, however strong it may be. This is called as refractory period.

**Heart Sounds**

Totally four sounds are produced by the heart. The first sound as LUB and the second sound as DUB can be heard with a stethoscope. The third and fourth sounds cannot be heard.

**First sound** is produced by the closure of atrioventricular valves. This is loud and of a long duration.
Second sound is produced by the closure of semi lunar valves (aortic and pulmonary). It is shrill and of a short duration.

**Pulse**

Pulse is the throbbing sensation felt over the walls of arteries. It is defined as the pressure difference transmitted in the form of a wave over the arterial walls. Pulse rate is almost the same as heart rate (60 to 80 per minute).

The wrist is the common site where pulse is usually felt. At this site, the radial artery is very superficial. This pulse is called as radial pulse. Other arteries where pulse can be felt are carotid artery, facial artery and temporal artery. In case of fever, the rate of pulse increases at the rate of 10 per every rise of 1°F.

Generally veins do not exhibit pulsation. The only vein which exhibits pulsation is jugular vein (which is nearer to heart).

**Electrocardiogram (ECG)**

It is the recording of electrical activity of the heart. Electrocardiograph is the instrument which is used to record the electrical current generated in the heart. By means of this instrument, the electrical current generated in the heart is conducted to remote parts of the body. The heart current can be recorded by connecting any two parts of the body with this instrument. The connections are called as leads. They are

- Lead I Right arm and left arm.
- Lead II: Right arm and left leg.
- Lead III Left arm and left leg.

Connections Over the chest with indifferent electrodes are also sometimes used. The ECG recordings are designed by letters P, Q, R, S, and T.

- The wave P is caused by contraction of atria.
- The wave Q, R and S are produced by the contraction of ventricles.
• The wave T is produced by the relaxation of ventricles.

• During diseases of the heart, these waves are abnormal in shape and position.

**Cardiac Output**

It is defined as the quantity of blood pumped by the heart in one minute.

Stroke volume is the amount of blood ejected per beat of the heart. It is about 70ml. So, every minute some 5040 ml (nearly 5 liters) of blood is pumped by the heart.

Cardiac output depends on the following factors:

1. Amount of blood returned to the heart through veins (venous return).
2. Force and rate of contraction of the heart.
3. Peripheral resistance offered by blood vessels.

### 7.3 Blood Pressure (BP)

It is defined as the lateral pressure exerted by blood on blood vessels. The blood pressure which is normally expressed is arterial blood pressure. It has two phases:

1. **Systolic blood pressure**: It is the maximum blood pressure, This occurs during the systole of the heart. (range 100 to 120 mm Hg.)

2. **Diastolic blood pressure**: It is the minimum pressure. It occurs during the diastole of the heart (range 60 to 80 mm Hg.)

Pulse pressure is the difference between systolic and diastolic blood pressure (It is nearly 40 mm Hg.)

**Factors affecting Blood Pressure**

1. Blood volume
2. Cardiac output
3. Peripheral resistance
4. Elasticity of blood vessels
5. Diameter of the lumen of blood vessels
6. Viscosity of blood
1. **Blood volume** is the total amount of blood in circulation. A sufficient amount of blood in blood vessels is necessary to maintain normal blood pressure. Loss of blood as in hemorrhage produces a fall in blood pressure.

2. **Cardiac output** is the quantity of blood pumped by the heart in one minute. It is the product of stroke volume (the amount of blood ejected per beat of the heart) and rate of the heart. An increase in stroke volume increases systolic blood pressure. An increase in cardiac output increases both systolic and diastolic blood pressure.

3. **Peripheral resistance** is the resistance offered by blood vessels for the flow of blood. Resistance is offered mainly by small blood vessels, especially arterioles.

4. **Elasticity** of the arterial walls distends the aorta when the ventricle contracts. The elastic recoils when the ventricle relaxes. This recoil pushes the blood downwards. Decrease in elasticity as in atheroma produces a rise in blood pressure.

5. **Diameter of the lumen of blood vessels** can be altered. Narrowing of the lumen increases the resistance to blood flow and this increases blood pressure. Enlargement of the lumen has the opposite effect.

6. **Viscosity of blood** is its stickiness. The viscosity of blood depends on plasma, plasma proteins and number of the red blood cells. An increase in viscosity increases blood pressure.

**Measurement of Blood Pressure**

Blood pressure is usually measured by an instrument called “sphygmomanometer”. It consists of a mercury manometer, cuff and hand pump. The cuff is tied around the cubital fossa of the individual. Then the hand pump is pressed so that air is inflated in the cuff. When the cuff is fully inflated, air pressure is more than blood pressure. So blood flow in the brachial artery is completely obstructed. Now the hand pump is slowly released, till the time the appearance of the first sound is heard (by means of a stethoscope put in the cubital fossa). The manometric reading is now noted. This reading is the systolic blood pressure.

Later, the hand pump is slowly released till the time the sound becomes louder and louder. Later it stops. The manometric reading is noted when the sound disappears. This reading is the diastolic blood pressure.
Cardiovascular Disorders

Disorders of Heart

**Cardiac Failure**: It is a condition in which the myocardium of ventricle is unable to maintain sufficient circulation of blood to meet the needs of the body. Depending on onset it may be classified as:

1. Acute cardiac failure: When the onset is sudden.
2. Chronic cardiac failure: When the onset is gradual.

**Stenosis of valves**: It is the narrowing of the valves of the heart. In this condition, the edges of the cusps (of the valves) become rough. So they stick together and narrow the valvular opening.

**Incompetence of valves**: It is a functional defect caused by the failure of the valve to close completely. This allows blood to flow back into the ventricle when it relaxes.

**Ischemic Heart Disease**: It occurs due to narrowing or occlusion of one or more branches of coronary arteries. It may lead to angina pectoris.

**Angina pectoris (angina of effort)**: It is pain occurring due to myocardial ischemia. It occurs due to narrowing of coronary arteries. Because of this, physical effort causes severe ischemic pain.

**Myocardial infarction**: It is the death of an area of cardiac tissue due to lack of coronary blood supply to that segment of the myocardium. It occurs due to occlusion of coronary artery.

**Cardiac arrhythmia**: It is a disorder in cardiac rate and rhythm. It occurs due to defective impulse formation and defective impulse conduction in the heart.

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**Short Answer Type Questions**

1. Define cardiovascular system.
2. What are the functions of heart?
3. Write the difference between arteries and veins.
4. Write about capillaries.
5. What are the properties of the cardiac muscle?
6. Write the valves of heart?
7. Write the differences between arteries and pulmonary arteries?
8. Write the differences between veins and pulmonary veins?
9. Define cardiac cycle?
10. Define cardiac output?
11. What is blood pressure and mention the factors effecting BP?
12. Write about heart sounds.
13. What is pulse?
14. What do you mean by ECG?

**Long Answer Type Questions**

1. Write the structure and functions of heart.
2. Explain different types of circulations of the body.
3. Explain in detail about cardiac cycle?
4. Draw the diagram of the heart and label its parts.
8.0 Introduction

It consists of brain, spinal cord and nerves. This system creates awareness of the environment such that the body can respond by adapting.

Functions of the Vascular System

1. monitoring body=sensory
2. processing info=integrative
3. initiate a response=motor
4. homeostasis=maintaining balanced internal environment
5. Divisions of the nervous system
Central Nervous System

6. Brain and spinal cord

7. All sensory impulses travel to here, all motor responses originate here

Peripheral Nervous System

8. Organs
   a. Cranial nerves
   b. Spinal nerves

9. Somatic
   a. Sensory organs of skin, head,
   b. Motor nerves to skeletal muscle
   c. Voluntary control

10. Autonomic
    a. Motor nerves to visceral organs, blood vessels, glands
    b. Sympathetic—respond to stress
    c. Parasympathetic—normal functioning

8.1 Nerve Tissue

There are two types of nervous tissues—the neurons (nerve cells) and glia (neuroglia). The neuron is the basic structural unit of the nervous system. The glia are cells of supporting tissue for the nervous system. There are several different types of glia, but their general function is support (physical, nutritive, etc.).

Specialization

Nervous tissues are specialized to:

a. **Receive Stimuli**. Cells receiving stimuli are said to be “irritable” (as are all living cells to a degree).

b. **Transmit Information**.

c. **"Store" Information**. The storing of information is called memory.
The Neuron

Definition

A neuron is a nerve cell body and all of its processes (branches).

Neuron Cellbody: The neuron cell body is similar to that of the “typical” animal cell.

Neuron Processes

There are two types of neuron processes—dendrites and axons.

a. Dendrite. A dendrite is a neuron process which carries impulses toward the cell body. Each neuron may have one or more dendrites. Dendrites receive information and transmit (carry) it to the cell body.

b. Axon. An axon is a neuron process which transmits information from the cell body to the next unit. Each neuron has only one axon.

Information Transmission. Information is carried as electrical impulses along the length of the neuron.

Coverings. Some neuron processes have a covering which is a series of Schwann cells, interrupted by nodes (thin spots). This gives the neuron process the appearance of links of sausage. The Schwann cells produce a lipid (fatty) material called myelin. This myelin acts as an electrical insulator during the transmission of impulses.

Types of Neurons

Neurons may be identified according to shape, diameter of their processes, or function.

a. According to Shape. A pole is the point where a neuron process meets the cell body. To determine the type according to shape, count the number of poles.

(1) Multipolar neurons. Multipolar neurons have more than two poles (one axon and two or more dendrites).

(2) Bipolar neurons. Bipolar neurons have two poles (one axon and one dendrite).

(3) Unipolar neurons. Unipolar neurons have a single process which branches into a T-shape. One arm is an axon; the other is a dendrite.
b. **According to Diameter (Thickness) of Processes.** Neurons may be rated according to the thickness of myelin surrounding the axon. In order of decreasing thickness, they are rated A (thickest), B, and C (thinnest). The thickness affects the rate at which impulses are transmitted. The thickest are fastest. The thinnest are slowest.

c. **According to Function.**

(1) Sensory neurons. In sensory neurons, impulses are transmitted from receptor organs (for pain, vision, hearing, etc.) to the central nervous system (CNS).

(2) Motor neurons. In motor neurons, impulses are transmitted from the CNS to muscles and glands (effector organs).

(3) Interneurons. Interneurons transmit information from one neuron to another. An interneuron “connects” two other neurons.

(4) Others. There are other, more specialized types, for example, in the CNS.

8.2 **The Brain**

The brain is an organ located in the skull. It weighs about 3 pounds. The senses (taste, smell, sight, hearing, touch), emotions, thoughts, and movement are controlled by the brain. The right side of the brain controls the left side of the body and the left side of the brain controls the right side of the body.

**The Different Parts of the Brain**

It develops from a single tube which initially shows three enlargements, the fore-runners of the brain, termed, fore-brain mid-brain and hind-brain. Thus:

The Fore-Brain, becomes the cerebral hemispheres, corpus straitium and the thalami.

The Mid-Brain, the mid-brain These three

The Hind-Brain, the pons Varolli, form the
medulla oblongata,

The Cerebrum fills the front and upper portion of the cranial cavity, termed respectively the anterior and middle cranial fossa. It consists of two large hemispheres of nerve cells (grey matter) and nerve fibres (white matter). The outer layer of grey matter is termed the cortex. The two cerebral hemispheres are separated by a deep cleft, but united at their bases by the corpus callosum,
a mass of white matter consisting of nerve fibres. Beneath this are islands of grey matter, the basal ganglia.

**Fig 8.1 Brain**

**Areas of the Brain.** Fissures and sulci divide the cerebral hemisphere into areas. The cerebral cortex is arranged in convolution or irregular folds in order to increase the expanse of grey matter. The depressions between the convolutions are called sulci and the deepest sulci form the longitudinal and lateral fissures. These fissures or sulci divide the brain into named areas or ‘lobes’ which correspond in position to the bones beneath which they lie, e.g. the frontal, temporal parietal and occipital lobes.

The longitudinal fissure is a deep cleft in the medical plane separating the cerebrum into right and left cerebral hemispheres; into it dips a thin plate of dura mater called the falx cerebri. Similarly a thin partition of dura mater, the falx cerebelli, divides the cerebellum into right and left hemispheres.

The lateral sulcus, or the fissure of Sylvius, separates the temporal lobe from the frontal lobe (anteriorly) and from the parietal lobe more posteriorly.

The central sulcus or fissure of Rolando separates the frontal from the parietal lobes. The occipital lobes of the cerebrum are situated behind the parietal lobes and rest upon the tentorium cerebelli - a fold a dura mater which separates the middle cranial fossa from the posterior cranial fossa below.

**Frontal lobe:** executive function, decisions, personality, language, planning, movement
Parietal lobe: intelligence, reasoning, sensation, reading

Occipital lobe: vision

Temporal lobe: language, behavior, hearing, vision, emotions, memory

The Cerebral Cortex is composed of many layers of nerve cells; it is the grey matter of the cerebrum. It is arranged in irregular folds or convolutions, an arrangement which increases the surface area of the cerebral cortex, as scalloping a piece of material increases the length cortex, as scalloping a piece of material increases the length of its exact edge.

The white matter lies more deeply and consists of the nerve fibres belonging to the cells of the cortex.

The motor area lies just in front of the central sulcus, extending down as far as the lateral sulcus. This area of the cortex contains large cells which form the beginning of the motor pathway which controls movement of the opposite side of the body. The body is represented upside down the lower limb, trunk, upper limb, neck and finally head controlling areas lie, from above down, in the motor area as indicated in

The lowest part of the motor cortex is called Broca’s area and is concerned with speech. Broca’s area and is concerned with speech. Broca’s area lies in the left cerebral hemisphere in right-handed people, and on the opposite side in those who are left-handed.
The sensory cortex lies immediately behind the central sulcus. Here the various modalities of sensation are appreciated and interpreted.

The auditory area lies in the temporal lobe just below the longitudinal fissure. Here sound impressions are received and interpreted.

The visual area lies at the tip of the occipital lobe and receives images and impressions for interpretation.

The centres of taste and smell lie well forward in the temporal lobe.

The white matter of the cerebral hemispheres consists of nerve fibres running to and from the cortex linking up the various ‘centres’ of the brain with the spinal cord.

Basal Ganglia. As already mentioned, embedded in the mass of white matter of each cerebral hemisphere are certain small areas of grey matter, termed the basal ganglia or nuclei. Two of these are the caudate and lentiform nuclei and together form the corpus striatum. These structures are closely related to another mass of grey matter, the thalamus, which lies medially to them. It is likely that this system in some way influences tone and posture, integrates and co-ordinates the main voluntary muscle movements which are the concern of the great descending motor pathway, or the pyramidal system.

The Thalamus is chiefly concerned with the reception of sensory impulses, which may be either interpreted at a subcortical level, or relayed on to the sensory area of the cerebral cortex. It appears to have an important regulating action on many of the highest centres for sensation and movement.
The Hypothalamus. In the region of the floor of the third ventricle are certain nuclei which have definite physiological activity. Some of them are related to the autonomic nervous system forming the ‘highest part of that system’. Some nuclei also have connections with the posterior lobe of the pituitary gland of the endocrine system on which they exert control. Functions such as body temperature regulations, hunger and thirst are regulated by centres in the hypothalamus.

The Internal capsule is formed by fibres of the great motor and sensory pathways which link the cerebral cortex with the brain stem and spinal cord. In this part of their course these nerve fibres are closely packed together as they pass between the islands of grey matter. Thrombosis of the artery supplying the internal capsule may lead to damage of the opposite side of the body (hemiplegia); such a cerebrovascular catastrophe constitutes a ‘stroke’.

The Functions of the Cerebrum.

- The cerebral cortex contains the higher centres controlling mental behaviour, thought, consciousness, moral sense, will, intellect, speech, language, and the special senses.
- The cortex is the origin of all voluntary motor impulses controlling the skeletal muscles.
- It is the final area for the reception of all incoming sensory nerve impulses and for their appreciation and interpretation, including skin sensation, touch, pain, pressure, temperature, vibration, texture, shape, and size, and muscle and joint sense.

The Brain Stem is composed of the mid-brain, pons varolii and medulla oblongata. The mid-brain forms the upper part of the brain stem. Through it runs the cerebral aqueduct connecting the third and fourth ventricles.

![Fig 8.3 A Section of the Mid-brain showing main tracts of fibres](image_url)
The mid-brain contains centres for the control of balance and the movements of the eyes.

The **pons Varolii** forms the middle portion of the brain stem and thus contains the same ascending and descending pathways as the mid-brain. There are many fibres running transversely through the pons which link the two lobes of the cerebellum; and the cerebellum with the cerebral cortex.

The **medulla oblongata** forms the lower portion of the brain stem linking the pons with the spinal cord. The medulla lies in the posterior cranial fossa and joins the spinal cord just below the foramen magnum of the occipital bone.

The main features of the medulla are that here the descending motor pathways cross from one side of the brain stem to the other. This is called the motor decussation. A similar arrangement of the sensory pathways occurs in the medulla and is referred to as the sensory decussion. The medulla contains the nuclei of several important cranial nerves. It also contains certain "vital centres" which control respiration and the cardiovascular system. Injury to this part of the brain stem is therefore liable to have very serious consequences.

**The Cerebellum** is the largest part of the hind-brain. It occupies the posterior cranial fossa and is roofed over by the tentorium cerebelli, a fold of dura mater which separates it from the occipital lobes of the cerebrum.

It is separated from the pons and medulla by the cavity of the fourth ventricle. It is divided into two hemispheres, right and left, by a deep cleft into which dips another fold of dura mater, the falx cerebelli.

The arrangement of grey and white matter is similar to that found in the cerebrum with the grey matter arranged at the surface. The surface is ridged rather than folded into convolutions, the fissures between the ridges being very much closer together than the sulci of the cerebral cortex.

The cerebellum has connections with many other parts of the nervous system. Its principal connections are with the cerebral hemisphere of the opposite side and with the brain stem. It also receives fibres from the spinal cord and is connected with the reflex centres of sight in the roof of the mid-brain, with the thalamus and with the auditory or acoustic nerve of hearing.

**The functions of the cerebellum**

- It regulates posture and postural activities.
- It plays an important part in muscular co-ordination and the maintenance of balance.
• Whereas the cortico-spinal fibres running between the cerebral cortex and the spinal cord cross (see above), and thus the cerebral cortex controls the movement of the opposite side of the body, the cerebellar hemisphere controls muscle tone and posture on its own side.

A unilateral lesion of the cerebellum causes disturbance of posture and muscle tone. Movement is very inco-ordinate, a patient may be unable to put food into his mouth and smears it across his face; he sways in walking and tends to fall towards the affected side. All voluntary movement is slow, and the muscles of the limbs are limp and flail-like. Speech is slow.

8.3 The Spinal Cord

The spinal cord has two Functions

Transmission of nerve impulses. Neurons in the white matter of the spinal cord transmit sensory signals from peripheral regions to the brain and transmit motor signals from the brain to peripheral regions.

Spinal reflexes. Neurons in the gray matter of the spinal cord integrate incoming sensory information and respond with motor impulses that control muscles (skeletal, smooth, or cardiac) or glands.

The spinal cord is an extension of the brainstem that begins at the foramen magnum and continues down through the vertebral canal to the first lumbar vertebra (L1). Here, the spinal cord comes to a tapering point, the conus medullaris. The spinal cord is held in position at its inferior end by the filum terminale, an extension of the pia mater that attaches to the coccyx. Along its length, the spinal cord is held within the vertebral canal by denticulate ligaments, lateral extensions of the pia mater that attach to the dural sheath.

The following are external features of the Spinal Cord

• Spinal nerves emerge in pairs, one from each side of the spinal cord along its length.

• The cervical nerves form a plexus (a complex interwoven network of nerves—nerves converge and branch).

• The cervical enlargement is a widening in the upper part of the spinal cord (C4–T1). Nerves that extend into the upper limbs originate or terminate here.

• The lumbar enlargement is a widening in the lower part of the spinal cord (T9–T12). Nerves that extend into the lower limbs originate or terminate here.
Fig 8.4 External features of the spinal cord

- The anterior median fissure and the posterior median sulcus are two grooves that run the length of the spinal cord on its anterior and posterior surfaces, respectively.

- The cauda equina are nerves that attach to the end of the spinal cord and continue to run downward before turning laterally to other parts of the body.

- There are four plexus groups: cervical, brachial, lumbar, and sacral. The thoracic nerves do not form a plexus.

A cross section of the spinal cord reveals the following features

Roots are branches of the spinal nerve that connect to the spinal cord. Two major roots form the following:

- A ventral root (anterior or motor root) is the branch of the nerve that enters the ventral side of the spinal cord. Ventral roots contain motor nerve axons, transmitting nerve impulses from the spinal cord to skeletal muscles.
• A dorsal root (posterior or sensory root) is the branch of a nerve that enters the dorsal side of the spinal cord. Dorsal roots contain sensory nerve fibers, transmitting nerve impulses from peripheral regions to the spinal cord.

• A dorsal root ganglion is a cluster of cell bodies of a sensory nerve. It is located on the dorsal root.

**Gray matter** appears in the center of the spinal cord in the form of the letter H (or a pair of butterfly wings) when viewed in cross section:

• The gray commissure is the crossbar of the H.

• The anterior (ventral) horns are gray matter areas at the front of each side of the H. Cell bodies of motor neurons that stimulate skeletal muscles are located here.

• The posterior (dorsal) horns are gray matter areas at the rear of each side of the H. These horns contain mostly interneurons that synapse with sensory neurons.

• The lateral horns are small projections of gray matter at the sides of H. These horns are present only in the thoracic and lumbar regions of the spinal cord. They contain cell bodies of motor neurons in the sympathetic branch of the autonomic nervous system.

• The central canal is a small hole in the center of the H crossbar. It contains CSF and runs the length of the spinal cord and connects with the fourth ventricle of the brain.

**White columns** (funiculi) refer to six areas of the white matter, three on each side of the H. They are the anterior (ventral) columns, the posterior (dorsal) columns, and the lateral columns.

• Fasciculi are bundles of nerve tracts within white columns containing neurons with common functions or destinations.

• Ascending (sensory) tracts transmit sensory information from various parts of the body to the brain.

• Descending (motor) tracts transmit nerve impulses from the brain to muscles and glands.
Coverings of the CNS

The coverings of the CNS are skeletal and fibrous.

a. **Skeletal Coverings.**

(1) Brain. The bones of the cranium form a spherical case around the brain. The cranial cavity is the space inclosed by the bones of the cranium.

(2) Spinal cord. The vertebrae, with the vertebral foramina, form a cylindrical case around the spinal cord. The overall skeletal structure is the vertebral...
column (spine). The vertebral (spinal) canal is the space inclosed by the foramina of the vertebrae.

b. Meninges (Fibrous Membranes). The brain and spinal cord have three different membranes surrounding them called meninges. These coverings provide protection.

(1) Dura mater. The dura mater is a tough outer covering for the CNS. Beneath the dura mater is the subdural space, which contains a thin film of fluid.

(2) Arachnoid mater. To the inner side of the dura mater and subdural space is a fine membranous layer called the arachnoid mater. It has fine spiderweb-type threads which extend inward through the subarachnoid space to the pia mater. The subarachnoid space is filled with cerebrospinal fluid (CSF).

ARACHNOID = spider-like

(3) Pia mater. The pia mater is a delicate membrane applied directly to the surface of the brain and the spinal cord. It carries a network of blood vessels to supply the nervous tissues of the CNS.

Blood Supply of the CNS

a. Blood Supply of the Brain. The paired internal carotid arteries and the paired vertebral arteries supply blood rich in oxygen to the brain. Branches of these arteries join to form a circle under the base of the brain. This is called the cerebral circle (of Willis). From this circle, numerous branches supply specific areas of the brain.

(1) A single branch is often the only blood supply to that particular area. Such an artery is called an end artery. If it fails to supply blood to that specific area, that area will die (stroke).

(2) The veins and venous sinuses of the brain drain into the paired internal jugular veins, which carry the blood back toward the heart.

b. Blood Supply of the Spinal Cord. The blood supply of the spinal cord is by way of a combination of three longitudinal arteries running along its length and reinforced by segmental arteries from the sides.

Cerebrospinal Fluid (CSF)

A clear fluid called cerebrospinal fluid (CSF) is found in the cavities of the CNS. CSF is found in the ventricles of the brain, the subarachnoid space, and
the central canal of the spinal cord. CSF and its associated structures make up the circulatory system for the CNS.

a. **Choroid Plexuses.** Choroid plexuses are special collections of arterial capillaries found in the roofs of the third and fourth ventricles of the brain. The choroid plexuses continuously produce CSF from the plasma of the blood.

b. **Path of the CSF Flow.** Blood flows through the arterial capillaries of the choroid plexuses. As CSF is produced by the choroid plexuses, it flows into all four ventricles. CSF from the lateral ventricles flows into the third ventricle and then through the cerebral aqueduct into the fourth ventricle. By passing through three small holes in the roof of the fourth ventricle, CSF enters the subarachnoid space. From the subarachnoid space, the CSF is transported through the arachnoid villi (granulations) into the venous sinuses. Thus, the CSF is formed from arterial blood and returned to the venous blood.

**The functions of the cerebrospinal fluid.** It acts as a buffer, protecting the brain and spinal cord. It conveys nourishment to the tissues of the central nervous system.

Lumbar puncture. Because the spinal cord ends at the level of the first of second lumbar vertebrae and the sub-arachnoid space extends to the level of the second sacral vertebra, a sample of cerebrospinal fluid may be drawn off by introducing a lumbar puncture needle into the sub-arachnoid space between these points a process called lumbar puncture.

The examination of the cerebrospinal fluid thus obtained may reveal important information in conditions such as meningitis and sub-arachnoid cerebral haemorrhage.

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**8.4 The Peripheral Nervous System (PNS)**

**General**

a. **Definitions.**

(1) The peripheral nervous system (PNS) is that portion of the nervous system generally concerned with commands for skeletal muscles and other muscles made up of striated muscle tissue, as well as sensory information from the periphery of the body. The sensory information is carried to the CNS where it is processed. The PNS carries commands from the CNS to musculature.
(2) A nerve is a collection of neuron processes, together and outside the CNS. (A fiber tract is a collection of neuron processes, together and inside the CNS.)

b. **General Characteristics of the Peripheral Nerves.** The PNS is made up of a large number of individual nerves. These nerves are arranged in pairs. Each pair includes one nerve on the left side of the brainstem or spinal cord and one nerve on the right side. The nerve pairs are in a series, each pair resembling the preceding, from top to bottom.

c. **Categories of PNS Nerves.** PNS nerves include cranial nerves and spinal nerves.

(1) Cranial nerves. The 12 pairs of nerves attached to the right and left sides of the brainstem are called cranial nerves. Each cranial nerve is identified by a Roman numeral in order from I to XII and an individual name. For example, the Vth (“fifth”) cranial nerve is known as the trigeminal nerve (N.).

\[
\text{TRI} = \text{three} \\
\text{GEMINI} = \text{alike} \\
\text{TRIGEMINAL} = \text{having three similar major branches}
\]

(2) Spinal nerves. Attached to the sides of the spinal cord are 31 pairs of spinal nerves. The spinal nerves are named by:

(a) The region of the spinal cord with which the nerve is associated.

(b) An Arabic numeral within the region. For example, T-5 is the fifth spinal nerve in the thoracic region.

**Cranial Nerves**

- 12 pairs of cranial nerves
- Each attaches to the ventrolateral surface of the brainstem near the associated sensory or motor nuclei

**Olfactory nerves (I)**

- Carry sensory information responsible for the sense of smell
- Synapse within the olfactory bulb

**Cranial nerves II, III, IV**

- Optic nerves (II)
Carry visual information from special sensory receptors in the eyes
- Occulomotor nerves (III)
- Primary source of innervation for 4 of the extraocular muscles
- Trochlear nerves (IV)
- Innervate the superior oblique muscles

**Cranial nerves V, VI, VII**
- Trigeminal nerves (V)
- Missed nerves with ophthalmic, maxillary and mandibular branches
- Abducens nerve (VI)
- Innervates the lateral rectus muscles
- Facial nerves (VII)
- Mixed nerves that control muscles of the face and scalp
- Provide pressure sensations over the face
- Receive taste information from the tongue

**Cranial nerves VIII, IX**
- Vestibulocochlear nerves (VIII)
- Vestibular branch monitors balance, position and movement
- Cochlear branch monitors hearing
- Glossopharyngeal nerves (IX)
- Mixed nerves that innervate the tongue and pharynx
- Control the action of swallowing

**Cranial nerves X**
- Vagus nerves (X)
- Mixed nerves
- Vital to the autonomic control of visceral function

**Cranial nerves XI, XII**
- Accessory nerves (XI)
• Internal branches

• Innervate voluntary swallowing muscles of the soft palate and pharynx.

• External branches

• Control muscles associates with the pectoral girdle

• Hypoglossal nerves (XII)

• Provide voluntary motor control over tongue movement

The Main Nerve Plexuses and their Trunks

The anterior primary divisions of the spinal nerves, other than those which arise in the thoracic region and form the intercostal nerves, are arranged into four main plexuses.

The Cervical Plexus is formed by the first four cervical nerves. It lies in the neck beneath the sternomastoid muscle. Many branches arise from it to supply some of the muscles of the neck. The phrenic nerves which supply the diaphragm arise from the plexus.

The Brachial Plexus is formed by the four lower cervical nerves and the first thoracic nerve. It is situated in the posterior triangle of the neck behind the clavicle and in the axilla. At first, three trunks are formed; these then divide and unite again to form three cords, lateral, medial, and posterior. From these cords 5 principal nerves arise which supply the arm and some of the neck and chest muscles (see Fig. below).

The Lumbo-Sacral Plexus provides the principal spinal nerves to the lower limb.

![Diagram of the Brachial Plexus](image)

Fig 8.5 22/19 - The Brachial Plexus (left) showing the origin of the principal nerves of the upper limb.

The Lumbar Plexus from the first 4 lumbar nerve roots lies in the psoas muscle supplying it and divides into two branches, the femoral nerve passing beneath the inguinal ligament, through the femoral triangle to supply the muscles
on the front of the thigh, and the obturator nerve which enters the thigh through the obturator foramen to supply the muscles on the inner side of it.

The Sacral plexus consists of the 4th and 5th lumbar nerves and the sacral nerves uniting to form the great sciatic nerve which passes into the thigh through the great sciatic notch supplying the hamstring muscles. It then divides into the medial and lateral popliteal nerves which supply the muscles on the back of the thigh and all the muscles, back and front, below the knee.

Fig 8.6

Lumbo sacral Plexus

The motor Nerve pathways. Impulses travel in descending tracts called the cerebrospinal of pyramidal tracts, from the cerebral cortex to the spinal cord. The first neurones, upper motor neurones, have their cell bodies in the pre-Rolandic area of the cerebral cortex and many fibres converge to be closely grouped together as they pass between the caudate and lentiform nuclei, in the internal capsule.

The lower motor neurones, which begin as cell bodies in the anterior horn of the spinal cord pass out in the anterior root of a spinal nerve to be distributed to the periphery, ending in a motor organ such as a muscle.

Motor neurone lesions. In considering the clinical aspect, it is necessary to differentiate between a lesion of an upper motor neurone, i.e., of the central motor pathway and a lesion of a lower motor neurone.

In an upper motor neurone lesion - hemiplegia is an example - the muscles are not paralysed but are weak and control of them is lost. The muscles of the limbs may be spastic and involuntary movements may occur which are uncontrollable and often lead to severe rigidity in spasm. Reflexes are exaggerated. There is no loss of muscle tone and no wasting of the affected muscles.
In a lower motor neurone lesion, as in poliomyelitis, the affected muscles are paralysed, being limp and flaccid, there is wasting and normal reflexes are lost, if the subject is a child the limb may not develop.

**Sensory Nerve Pathway.** The sensory nerve impulses travel in ascending tracts which consist of a three-neurone pathway.

The first or most peripheral neurone has its cell body in the sensory ganglion of the posterior nerve root of a spinal nerve; one branch, a dendron, passes to the periphery to end in some sensory organ such as the skin; the other branch, the axon, passes into the spinal cord and ascends in the posterior column to arborize round a nucleus in the medulla.

The second neurone cell arises in the same nucleus and then crosses the mid-line in a similar way as the descending motor pathway, to form the sensory decussation, ascends through the pons and mid-brain to reach the thalamus.

The third and final neurone commencing in the thalamus passes through the internal capsule to reach the sensory area of the cerebral cortex.

These ascending tracts convey impulses of touch, joints position and vibration sensation; others convey impulses of touch, pain and temperature.

**Sensation.** A peripheral sensory nerve will carry some ‘afferent’ impulses to be interpreted by the sensory area in the cerebral cortex as touch, pain, itch, temperature and warm and cold sensations from superficial structures, and other ‘afferent’ impulses arising from deeper structures as in pain, pressure etc. and the sense of the movement and the position of joints and muscles. The interpretation of sensation therefore depends on stimuli from the periphery, relayed by several neurones reaching eventually the central interpreting station in the brain.

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**Fig 8.6** A diagram showing the varieties of sensations collected from superficial and deep structures.
A Reflex Action requires the following structures which form a reflex arc:

- A sensory organ which receives the impulse, e.g. the skin.
- A sensory nerve fibre which conducts this impulse to the cells in the posterior root ganglion and thence by their fibres to the grey matter of the posterior horn of the spinal cord.
- The spinal cord where connector nerves pass impulses on to the anterior horn of the cord.

A motor nerve cell in the anterior horn of the spinal cord which received and transmitted the impulse along motor nerve fibres.

A motor organ, e.g. a muscle, which, stimulated by the motor nerve impulse, performs the action.

Upper motor nerves commence in the cerebral cortex and pass into the spinal cord, crossing at the medulla. As indicated, these nerves coverage to pass, closely packed together with the nerves of the ascending sensory tract, through the internal capsule.
Lower motor nerves begin as cells in the grey matter of the cord, and pass out from the anterior horns to supply the muscles and other structure.

**Short Answer Type Questions**

1. Classify nervous system?
2. Write the parts of brain?
3. Write the lobes of cerebrum?
4. What are the functions of cerebrum?
5. What is cortex?
6. What are the functions of basal ganglia?
7. What are the functions of sensory cortex?
8. What are the functions of thalamus and hypothalamus?
9. Write the functions of cerebellum?
10. Write about pons?
11. Write about brain stem?
12. Write about mid brain?
13. Write about medulla oblongata?
14. Write the position of spinal cord?
15. What are the functions of spinal cord?
16. Write about meninges?
17. Write about ventricles of brain?

**Long Answer Type Questions**

1. Explain in detail about the structure and functions of brain.
2. Mention the names of cranial nerves.
3. Explain in detail about the structure and functions of spinal cord.
9.1 Physiology of Muscle Contraction

Events of muscle contraction:

1. During normal resting state of a muscle, the muscle membrane is in a polarised state. This occurs because:
   a. The interior of the muscle cell is negatively charged. It contains a large concentration of K+ ions.
   b. The exterior of the muscle cell is positively charged. It contains a large concentration of Na+ ions.

2. When a nerve is stimulated, acetylcholine is liberated at the neuromuscular junction.
3. Acetylcholine increases the permeability of the muscle membrane. So Na+ ions enter into the cell and K+ ions come out of the cell. This produces a change in electrical charge. Both the interior and exterior of the muscle become positively charged. Now the membrane becomes depolarised. This depolarization produces a muscle contraction.

4. When the muscle contraction is over, acetylcholine is destroyed by the enzyme acetylcholinesterase.

5. Now, K+ ions move into the cell and Na+ ions out of the cell. This produces repolarisation of the muscle membrane. Now the muscle is ready for a second contraction.

9.2 The Neuromuscular Junction

A neuromuscular junction is a “connection” between the terminal of a motor neuron and a muscle fiber. The neuromuscular junction has an organization identical to a synapse. However, the bulb is larger. The postsynaptic membrane is also larger and has foldings to increase its surface area.

Fig 9.1 Neuro muscular junction

(1) Motor neuron. The axon of a motor neuron ends as it reaches a striated muscle fiber (of a skeletal muscle). At this point, it has a terminal bulb. Within this bulb are synaptic vesicles (bundles of neurotransmitter). The presynaptic membrane lines the surface of the terminal bulb and lies close to the muscle fiber.
(2) Synaptic cleft. The synaptic cleft is a space between the terminal bulb of the motor neuron and the membrane of the muscle fiber.

(3) Muscle fiber. The terminal bulb of the motor neuron protrudes into the surface of the muscle fiber. The membrane lining the synaptic space has foldings and is called the postsynaptic membrane. Beneath the postsynaptic membrane is a chemical which inactivates the used neurotransmitter.

9.3 Physiological Changes during Exercises

(a) Immediate changes during exercise:
    • Increased blood flow to muscle because of increased demands for oxygen.
    • Increased heart rate.
    • Increased arterial pressure with heavy exercise. This is due to increase stroke volume, increase cardiac output, increase heart rate and increase peripheral resistance to blood flow.
    • Increase oxygen demand and consumption.
    • Increase depth of respiration, secondary muscle of respiration contract to assist the respiration process.

(b) Adaptive (long term) changes:

Muscle changes: the vascularization of the muscle or the density of the capillary bed increases. When a muscle contracts at low intensity for many respirations to the point of fatigue, aerobic activity occurs in the muscle to provide energy for muscle contraction. Oxygen is necessary for this process to occur. Greater amounts of oxygen can be made available to the muscle as the capillary bed becomes more dense and blood supply to the muscle increases. Adaptive changes in the type I and type IIa muscle fibres are associated with increases in muscular endurance.

Cardiac and Vascular Changes

a. Cardiac and stroke volume increases. This leads to an increase in the efficiency of the working capacity of the heart.

b. Resting heart rate decreases. During exercise, of course the heart rate increases, but as endurance improves, the heart rate returns to a resting level more rapidly after exercise.
Note: cardiac reserve (the difference between the capacity to do work and the demand for cardiac work) decrease with age and with heart and lung disease. Therefore the implementation and progression of a condition program for the normal young individual versus the patient with cardio pulmonary and circulation disease will vary greatly.

9.4 The Synapse

A synapse is a “connection” between two neurons.

(1) First neuron. An axon terminates in tiny branches. At the end of each branch is found a terminal bulb. Synaptic vesicles (bundles of neurotransmitter) are located within each terminal bulb. That portion of the terminal bulb which faces the synaptic cleft is thickened and is called the presynaptic membrane. This is the membrane through which neurotransmitters pass to enter the synaptic cleft.

(2) Synaptic cleft. The synaptic cleft is the space between the terminal bulb of the first neuron and the dendrite or cell body of the second neuron.

(3) Second neuron. The terminal bulb of the first neuron lies near a site on a dendrite or the cell body of the second neuron. The membrane at this site on the second neuron is known as the postsynaptic membrane. Within the second neuron is a chemical that inactivates the used neurotransmitter.

9.5 Degeneration and Regeneration of Nerves

Traumatic injury to nerves in the PNS (peripheral nervous system) results in the loss of neural functions. Repair is achieved through regeneration of severed axons and reinnervation of target tissues. Successful functional recovery depends on the ensemble of cellular and molecular events that develop distal to lesion sites all the way towards denervated target tissues. Those represent the PNS response to traumatic nerve injury and are termed collectively Wallerian degeneration.

The term Wallerian degeneration has been adopted to describe events that follow traumatic injury to CNS (central nervous system) axons (e.g. spinal cord injury). However, Wallerian degeneration in PNS and CNS differ with respect to the types of cells involved (e.g. Schwann cells and macrophages in PNS versus oligodendrocytes and microglia in CNS) and outcome (e.g. removal of degenerated myelin during PNS Wallerian degeneration but not during CNS Wallerian degeneration).
Short Answer Type Questions

1. What is CSF and write its composition?
2. Write the functions of CSF?
3. Write the types of sensations?
4. What are the differences between UMN and LMN?
5. What are the differences between UMN and LMNL?
6. What do you mean by reflex arc?
7. Write the importance of reflex action.
8. Write the functions of autonomic nervous system?
9. Write the difference between nerve and nerve fibre?
10. Name the plexus?
11. What is neuromuscular junction?
12. What is wallerian degeneration?
13. What is synapse?
14. What are the functions of autonomic nervous system?
Long Answer Type Questions

1. Explain briefly about reflex action and reflex arc and state its importance.

2. Explain in detail about brachial plexus.

3. Explain the phenomenon of the muscle contraction?
Respiration is defined as the exchange of gases between body tissues and the external environment. Supply of oxygen to the tissues and excretion of carbon dioxide occur only through respiration.

**Functions of the Respiratory system**

- Gas exchange between air and circulating blood
- Moving air from the exchange surface of the lungs
- Protection of respiratory surfaces
- Production of sound
- Provision for olfactory sensations
Organization of the Respiratory System

- Upper respiratory system
  Nose, nasal cavity, paranasal sinuses, pharynx
- Lower respiratory system
  Larynx, trachea, bronchi, bronchioles, alveoli

The Respiratory Tract

- Conducting passageways carrying air to and from the alveoli
- Upper respiratory passages filter and humidify incoming air
- Lower passageways include delicate conduction passages and alveolar exchange surfaces.

Respiratory Mucosa

- Respiratory epithelium and underlying connective tissue
• Respiratory membrane, supported by lamina propria, changes along tract
• Lines conducting portion of respiratory tract
• Protected from contamination by respiratory defense system

The Upper Respiratory System

1. The nose and nasal cavity consists of

   It is divided into right and left portions by means of nasal septum. The nasal cavity is lined by mucous membranes. The entrance to nasal cavity is formed by “anterior nares” (nostrils). They contain small hairs which act as filters for dust. The back of nasal cavities contain posterior nares. They form the entrance to nasopharynx.

2. The pharynx

   • Shared by the digestive and respiratory systems
   • Divided into three sections:
     Nasopharynx – superior portion
     Oropharynx – continuous with the oral cavity
     Laryngopharynx – between the hyoid bone and the esophagus

3. The Larynx

   Its lies between pharynx above and trachea below. It is formed by the following cartilages:
   • “Thyroid cartilage” which is the largest.
   • “Cricoid cartilage” which lies below the thyroid cartilage
   • “Two aretenoid cartilages” at the back of cricoid.
   • “Epiglottis” attached to the top of thyroid cartilage

Folds of the Larynx

   • Inelastic vestibular folds
   • Delicate vocal folds

Sound production

   • Air passing through the glottis vibrates the vocal folds producing sound waves.
• Pitch depends on conditions of vocal folds
• Diameter
• Length
• Tension

The Laryngeal Musculature
• Muscles of the neck and pharynx position and stabilize the larynx
• When swallowing, these muscles
• Elevate the larynx
• Bend the epiglottis over the glottis
• Intrinsic muscles control tension on the vocal folds and open the glottis

4. The trachea
• It is a cylindrical tube which is about 11 cm. in length. It beings at the lower end of pharynx.
• Extends from the sixth cervical vertebra to the fifth thoracic vertebra
• At the level of 5th thoracic vertebra, it divides into two bronchi.
• Trachea is made of sixteen to twenty C-shaped incomplete cartilages.
• These cartilages are connected by fibrous tissue at the back.
• The trachea is lined by mucous membrane made of ciliated epithelium. diagram.

![Fig 10.2 Structure of respiratory system](image-url)
The Primary Bronchi

They are formed by the division of bronchi. Bronchioles are the finest branches of bronchi. Bronchioles do not have cartilage. They are lined by cuboidal epithelium.

The Lungs

Lungs are the principal organs of respiration. They are two in number lying one on each side of the chest cavity. The two lungs are separated in the middle by heart and other structures of mediastinum.

Shape

Lungs are conical in shape. The apex of lungs is above, rising slightly over the clavicle. The base of lungs is near the diaphragm.
Lobes

Each lung is divided into lobes by means of fissures. The right lung which is bigger has three lobes. The left lung has two lobes. Each lobe is composed of a number of lobules. Each lobe contains a small bronchial tube. This tube divides and sub divides and ends finally in air sacs.

Pleura

It is a serous membrane which covers the lungs. It is made of two layers. The inner layer is called as visceral layer. It is very close to the lungs. “Parietal layer” is the outer layer. The space between these two layers is filled with pleural fluid.

Root of the Lungs

The medial surface of each lung has a vertical slit called hylum. Structures like blood vessels, nerves and lymphatics pass through the hylum. These structures together constitute the root of lung. The root of lung is formed by:

1. “Pulmonary arteries” which carry impure blood to the lungs from heart.
2. “Pulmonary veins” which carry oxygenated blood from lungs to the heart.
3. “Bronchial arteries” which are branches of thoracic aorta. They carry arterial blood which nourishes the substance of lung tissue.
4. “Bronchial veins” which return venous blood of lungs to superior vena cava.
5. “Bronchi” which divide into bronchioles.
7. Nerves: Sympathetic and vagus nerve which supply the lungs.

Each of the tertiary bronchi serves a specific bronchopulmonary segment. These segments each have their own artery. Thus, each bronchopulmonary segment is supplied by a bronchus, and two arteries, a pulmonary artery and a bronchial artery which run together through the center of the segment. Veins and lymphatics drain along the edges.

There are 10 bronchopulmonary segments in the right lung (3 in superior lobe, 2 in middle lobe, 5 in inferior lobe) and 8-10 segments on the left (4-5 in upper lobe, 4-5 in lower lobe). Each segment is separated from the others by a layer of connective tissue.
This means that each bronchopulmonary segment is a discrete anatomical and functional unit, and this separation means that a bronchopulmonary segment can be surgically removed without affecting the function of the other segments.

Delineation of the bronchopulmonary segments was made by Dr. John Franklin Huber at Temple University Hospital

**Bronchopulmonary Segments**

**Right Lung**

**A PALM Seed Makes Another Little Palm**

**Superior lobe**
- Apical
- Posterior
- Anterior

**Middle lobe**
- Lateral
- Medial

**Inferior lobe**
- Superior
- Medial-basal
- Anterior-basal
- Lateral-basal
- Posterior-basal

**Left Lung**

**ASIA ALPS**

**Apoptotic Ant lions Stop In, Suddenly Amalgamating Laboratory Posts**

**AP And Supine alignment Increases Limited Studies And Makes Baseline Pulmonary Bases Look Bad** (a radiology mnemonic)

**Superior lobe**
- Apico-posterior (merger of “apical” and “posterior”)
- Anterior
Lingula of Superior lobe

- Inferior lingular
- Superior lingular

Inferior Lobe

- Superior
- Anteromedial basal (merger of “anterior basal” and “medial basal”)
- Posterior basal
- Lateral basal

Blood Vessels of Lungs

1. **Pulmonary arteries** which carry impure blood from the right ventricle to the lungs. These arteries divided and sub divided to from arterioles ultimately from a network of capillaries. The thin membrane of these capillaries enables exchange of gases which is a function of respiration.

2. **Pulmonary veins** formed by the union of capillaries. The pulmonary veins carry oxygenated blood to left atrium of heart.

3. **Bronchial arteries** which carry oxygenated blood from thoracic aorta directly to lungs. This blood nourishes the substance of lung tissue.

4. **Bronchial veins** which return the venous blood of lungs to superior vena cava.

The bronchial tree

- These are the System of tubes formed from the primary bronchi and their branches.
- Primary bronchi branch into secondary or lobar bronchi
- Secondary bronchus goes to each lobe of the lungs
- Secondary bronchi branch into tertiary bronchi
- Tertiary bronchi supply air to single bronchopulmonary segment

The Bronchioles

- They are formed by the division of bronchi.
- Bronchioles are the finest branches of bronchi.
- Bronchioles do not have cartilage. They are lined by cuboidal epithelium.
Alveoli (Air sacs)

- They are the final termination of each bronchi.
- They contain a thin layer of epithelial cells surrounded by numerous capillaries.
- Exchange of gases takes place through the walls of these capillaries.

The pleural cavities and pleural membranes

- Each lung covered by one pleura
- Pleura – serous membranes lining the pleural cavity
- Parietal - attaches to the walls of the pleural cavity
- Visceral - adheres to the surface of the lungs
- Pleural fluid – fills and lubricates the space between the pleura

10.2 Mechanics of Breathing

Inspiraton: Inspiration is the active part of the breathing process, which is initiated by the respiratory control centre in medulla oblongata (Brain stem). Activation of medulla causes a contraction of the diaphragm and intercostal muscles leading to an expansion of thoracic cavity and a decrease in the pleural space pressure. The diaphragm is a dome-shaped structure that separates the thoracic and abdominal cavities and is the most important muscle of inspiration.

When it contracts, it moves downward and because it is attached to the lower ribs it also rotates the ribs toward the horizontal plane, and thereby further expands the chest cavity. In normal quite breathing the diaphragm moves downward about 1 cm but on forced inspirationexpiration total movement could be up to 10 cm.

When it is paralysed it moves to the opposite direction (upwards) with inspiration, paradoxical movement. The external intercostal muscles connect adjacent ribs. When they contract the ribs are pulled upward and forward causing further increase in the volume of the thoracic cavity. As a result fresh air flows along the branching airways into the alveoli until the alveolar pressure equals to the pressure at the airway opening.

Expiration: Expiration is a passive event due to elastic recoil of the lungs. However, when a great deal of air has to be removed quickly, as in exercise, or when the airways narrow excessively during expiration, as in asthma, the internal intercostal muscles and the anterior abdominal muscles contract and accelerate
expiration by raising pleural pressure. The rate of respiration is 16 to 18 per minute in adults. The rate is higher in children.

10.3 Lung Volumes and Capacities

Pulmonary function can be examined by the spirometry technique. Spirometers are the traditional tools of the respiratory physiologists. The subject breathes into a closed system in which air is trapped (bell). As the subject breathes air movement into or out of the mouthpiece causes the bell to rise (inspiration) or fall (expiration). Corresponding movements of an attached pen register the change in volume on a rotating drum recorder. From such a recording we could measure

**Tidal volume (TV):** Volume of air inhaled or exhaled with each breath during normal breathing (0.5 L).

**Inspiratory reserve volume (IRV):** Maximal volume of air inhaled at the end of a normal inspiration (3 L).

**Expiratory reserve volume (ERV):** Maximal volume of air exhaled at the end of a tidal volume (1.2 L).

**Inspiratory capacity (IC):** Maximal volume of air inhaled after a normal expiration (3.6 L) (TV+IRV).

**Functional Residual Capacity (FRC):** The volume of gas that remains in the lung at the end of a passive expiration. (2-2.5 L or 40% of the maximal lung volume) (ERV+RV).

**Residual Volume (RV):** The volume of gas remains in the lung after maximal expiration. (1-1.2 L)

FRC and RV can not be measured with an ordinary spirometer.
Physiotherapy

**Total Lung Capacity (TLC):** The maximal lung volume that can be achieved voluntarily. (5-6 L) (IRV+ERV+TV+RV)

**Vital capacity (VC):** The volume of air moved between TLC and RV. (4-5 L) (IRV+ERV+TV).

Multiplying the tidal volume at rest by the number of breaths per minute gives the total minute volume (6 L/min). During exercise the tidal volume and the number of breaths per minute increase to produce a total minute volume as high as 100 to 200 L/min.

### 10.4 Regulation of Respiration

Respiration is regulated by two controls: 1) Nervous control 2) Chemical control.

**1. Nervous control**

It is exerted by “respiratory center” present in the medulla oblongata of brain. From this centre afferent impulses pass to:

1. Diaphragm through phrenic nerve.
2. Intercostal muscles through intercostal nerves.

These impulses cause rhythmic contraction of diaphragm and intercostal muscles.

Afferent impulses arise due to the distention of air sacs. They are carried by vagus to the respiratory centre.

**2. Chemical Control**

This is effected through carbon dioxide content of blood. An increase in the level of carbon dioxide produces stimulation of the respiratory centre. A decrease in carbon dioxide level produces the opposite effect.

**Reflex Mechanism**

**Carotid body and aortic body chemoreceptors:** Some chemoreceptors also regulated respiration reflexly. These receptors are present in:

1. “Carotid body” which lies in the bifurcation of common carotid artery.
2. “Aortic body” which is at the foot of subclavian artery.

These two bodies contain the ending of sensory nerve which run in vagus nerves. Increase in carbon dioxide level of blood stimulates these bodies. The impulses are then carried to the respiratory centre which is also stimulated.
Hering-Breuer reflex

The lungs contain some stretch receptors. Expansion of the lungs stimulates these receptors. These impulses now inhibit the respiratory centre. So inspiration stops. Now the lungs collapse and there is no stretch. So inhibition of the respiratory centre through vagus also stops. Inspiration starts again. This reflex is called Hering-Breuer reflex.

Abnormal Types of Respiration

1. Cheyne-stokes Breathing: It is a form of periodic breathing in which groups of breaths are separated by periods of apnea. This occurs because the C02 tension of arterial blood is reduced to a very low level. So the respiratory centre can not be stimulated. Respiration starts again, only when the C02 tension increases. Cheyne-stokes breathing occurs in uremia, opium poisoning and increased intracranial pressure.

2. Apnea - stopping of respiration for short intervals.

3. Hyperpnea - increase in depth of respiration.

4. Dyspnea - difficulty in breathing.

5. Polypnea - respiration characterised by rapid rate.

6. Tachypnea - exceedingly high rate of respiration.

Artificial Respiration

It is employed when respiration fails due to drowning, carbon monoxide poisoning etc. Artificial respiration must be given immediately when respiration fails. Most methods employed are designed to increase and decrease the capacity of thorax. So air can be drawn into the lungs and expelled. The follow are a few methods of artificial respiration:

1. Schafer’s method and Holger Nialson method

   Both involve compression of thoracic cavity by pressure against ribs.

2. Mouth to mouth method

   It involves blowing air into lungs through mouth.

3 Instrumental methods

   They are Drinker’s method, Bragg-Paul’s method and Iron lung method. These methods can be carried out only in hospitals.
Short Answer Type Questions

1. Define respiration.
2. State the functions of respiration.
3. Write the parts of respiratory system.
4. Write about pharynx.
5. Write about larynx.
6. Mention the difference between right and left lung.
7. Write the position and shape of the lungs.
8. Write about the lobes of the lungs.
10. Write about nervous control of the respiration.
11. Write about the chemical control of the respiration.
12. What is dyspnoea?
13. What is meant by artificial respiration?
14. Write about trachea.

Long Answer Type Questions

1. Explain the parts of the respiratory system.
2. Explain in detail about the structure of the lungs.
3. Write about the mechanism of the respiration.
4. Mention briefly respiratory volumes and capacities.
5. Explain briefly how gases exchange take place.
6. Write about broncho pulmonary segments.
7. Explain the structure of the upper respiratory tract.
8. Explain the structure of the lower respiratory tract.
11.0 Introduction

Alimentary canal (gastrointestinal (GI) tract): continuous muscular digestive tube that is open to the outside environment at both ends

- **digests** (breaks down) food & **absorbs** digested fragments into blood
- **organs**: mouth, pharynx, esophagus, stomach, small intestine, large intestine (leads to terminal opening or anus)
- **accessory digestive organs**: teeth, tongue, gall bladder.
- large digestive glands in: salivary glands, liver & pancreas.
- produce secretions that help in breakdown of food

11.1 Digestive Processes

- **Ingestion**: taking food into digestive tract
- **Propulsion**: moves food along alimentary canal
- **swallowing**

- **peristalsis**: alternate waves of contraction & relaxation of muscles in organ (esophagus, stomach) walls.

- **mechanical digestion**: physically prepares food for enzymatic (chemical) digestion.
  
  - includes chewing, mixing with saliva, churning food in stomach & **segmentation** (rhythmic local constrictions of small intestine).

- **chemical digestion**: complex food molecules broken down by enzymes released by glands of digestive organs.

- **absorption**: passage of digested products from GI tract into blood or lymph.

- **defecation**: elimination of indigestible substances in form of feces.

### Basic Functional Concepts

Regulation of digestive system...

- Digestive activity is provoked by a range of chemical & mechanical stimuli (sensory receptors located in the walls of the GI tract organs.

- Controls of digestive activity are both intrinsic & extrinsic (local nerve plexuses.

- Hormones as well as hormones released into blood).

### Blood Supply: The Splanchnic Circulation

Splanchnic circulation includes arteries that branch off abdominal aorta & serve digestive organs & **hepatic portal circulation**

- **Celiac trunk**: branches to stomach (left gastric artery), spleen & pancreas (splenic artery; branches to pancreatic artery) and liver (common hepatic artery)

- **Superior mesenteric artery**: branches serve all regions of the small intestine and ascending & transverse colon

- **Inferior mesenteric artery**: branches serve transverse, descending & sigmoid colon, and rectum

- **Hepatic portal vein** receives blood from the splenic vein & superior mesenteric vein & carries blood (containing absorbed nutrients as well as waste) to **liver** for storage & processing of nutrients & detoxification of waste
Enteric Nervous System of GI tract

- **Enteric neurons** of intrinsic nerve plexuses regulate digestive system activity.

- **Submucosal nerve plexus** controls glands & smooth muscle of mucosa

- **Myenteric nerve plexus** (located between circular & longitudinal muscle layers of muscularis externa) control GI tract mobility (segmentation & peristalsis).

- Enteric nervous system linked to CNS by afferent visceral fibers & ANS (extrinsic control, or control outside GI tract).

**Functional Anatomy of Digestive System**

Mouth & Associated Organs

1. **Mouth (oral or buccal cavity)**: anterior opening is oral orifice; continuous with oropharynx posteriorly

   1. Epithelium of mouth, hard palate & tongue is slightly keratinized stratified squamous epithelium oral mucosa produces antimicrobial peptides called defensins to prevent infection.

2. **Lips & Cheeks**

   **Lips (labia)**: Formed by orbicularis oris muscle

   **Red margin**: Reddish area visible externally; redness due to blood within blood vessels showing through (poor keratinization)

   **labial frenulum**: median fold that joins lips to gums

   **Cheeks**: Formed by buccinator muscles

   **Vestibule**: Recess between cheeks & gums (& lips & gums)

   **Oral cavity proper**: Cavity within teeth & gums

   - **Palate**: Forms roof of mouth

   **Hard palate**: formed from palatine bone & palatine process of maxilla

   **Soft palate**: Formed mostly of skeletal muscle

   **Uvula**: Projects downward from free edge of soft palate; closes off nasopharynx during swallowing

   **Fauces**: Arched area (opening) of oropharynx that contains palatine tonsils

2. **Tongue**: Occupies floor of mouth & fills most of oral cavity composed of skeletal muscle that grips & mixes food with saliva to form a **bolus** intrinsic muscles: change shape of tongue.

   **Extrinsic muscles**: Change position of tongue (protrude, retract, move side to side)

   - **Lingual Frenulum**: Mucosal fold that secures tongue to floor of mouth

   - **papillae**: peglike projections of tongue mucosae, some of which contain taste buds

   **Filiform papillae**: small rough conical projections that provide friction for food manipulation
**Fungiform papillae**: Mushroom-shaped papillae scattered over tongue surface

![Tongue Diagram](image)

Fig. 11.2 Tongue

**Circumvallate (vallate) papillae**: In V-shaped row at back of tongue

**Sulcus Terminalis**: Groove that divides anterior 2/3 of tongue in oral cavity from posterior 1/3 of tongue in oropharynx

2. **Salivary Glands**: Glands inside & outside oral cavity that secrete saliva

- **Intrinsic salivary glands or buccal glands**: Throughout oral mucosa
- **Extrinsic salivary glands**

**Parotid glands**: Paired glands anterior to ear between masseter muscle & skin.

![Salivary Gland Diagram](image)

Fig. 11.3 Salivary glands

**Mumps**: Inflammation of parotid glands; caused by mumps virus

**Submandibular glands**: Walnut-sized glands that lie along medial aspect
of mandible

**Sublingual gland**: anterior to submandibular gland under tongue

- Salivary glands composed of mucous & serous cells

- **Saliva**: mostly water; slightly acidic secretion containing electrolytes (sodium, chloride, bicarbonate... ions), salivary amylase (digestive enzyme), mucin, lysozyme, IgA & metabolic wastes (urea & uric acid). Protection against infection provided by IgA, lysozyme, defensins & a cyanide compound. Bacteria at back of tongue convert nitrites into nitric oxide, which acts as an antibiotic.

1. **control of salivation**: primarily controlled by parasympathetic division of ANS. Salivatory nuclei in brain stem stimulated by sensory receptors in mouth, which trigger.

**Teeth**: Lie in sockets (alveoli) in gum-covered margins of maxilla & mandible

- Primary function is mastication (chewing)

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<td>8-9 Years</td>
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<tr>
<td>Canine (Cuspid)</td>
<td>11-12 Years</td>
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<tr>
<td>First Premolar (first bicusp)</td>
<td>10-11 Years</td>
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<td>12-13 Years</td>
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<tr>
<td>Central Incisor</td>
<td>6-7 Years</td>
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*Fig. 11.4 Tooth Structure*

- **Dentition**: 2 sets of teeth

- **Primary dentition**: deciduous (milk or baby) teeth; set of 20 teeth that first appear at about 6 months & generally last from 6 to 12 years.
**Permanent teeth**: Usually 32 teeth including wisdom teeth

Each half of the upper and lower jaw contain 8 teeth. They are: 2 incisors, 1 canine, 2 premolars and 3 molars.

**Tooth structure:**

- **Gingiva (gum)**: oral mucosa that surrounds tooth
- **Crown**: exposed part of tooth above gingiva
- **Enamel**: acellular brittle material composed of hydroxyapatite crystals (mostly calcium salts)
- **Root**: Portion of tooth embedded in jawbone (teeth can have from 1 to 3 roots)
- **Cementum**: Calcified connective tissue covering outer surface of root
- **Periodontal ligament**: Anchors the tooth to the bony alveolus of the jaw within joint (gomphosis)
- **Dentin**: bonelike material under enamel forming bulk of tooth
- **Pulp cavity**: Central cavity containing pulp (connective tissue, blood vessels, nerves)

**Root canal**: Where pulp cavity extends into root?

Fig. 11.5 Tooth Anatomy
Tooth & Gum Disease

- **Dental caries (cavities)**: Result from demineralization of enamel by bacteria in dental plaque

- **Gingivitis**: Inflammation of gingival caused by dental plaque & tartar accumulation

- **Periodontitis (periodontal disease)**: Bacteria invade the bone surrounding a tooth, & immune system response further erodes bone & tooth

**Pharynx**: Food passes from mouth into oropharynx & then laryngopharynx stratified squamous mucosa surrounded by 2 skeletal muscle layers to propel food into esophagus.

Pharynx lies between the mouth and oesophagus. Pharynx consists of three parts:

i. Nasopharynx

ii. Oropharynx

iii. Laryngopharynx

**Nasopharynx**

It lies behind the nasal cavatiy. It extends from base of skull to the level of

**Nasopharynx**

It lies behind the nasal cavatiy. It extends from base of skull to the level of soft palate. On either side, it has an opening for Eustachian tube.

**Oropharynx**

It lies behind the mouth. It extends between soft palate above and upper opening of larynx below. The lateral walls of oropharynx contain the tonsils.

**Laryngopharynx**

It is the lowest part and it lies behind the larynx.

Oropharynx and laryngopharynx serve as a common channel for the passage of food and air. Through both these parts, food is conducted from mouth to oesophagus and air from nasopharynx to larynx.

**Esophagus**: Food moving through laryngopharynx is routed into the esophagus as the epiglottis closes off the larynx. Esophagus extends about 25 cm from pharynx to stomach; route is through thoracic cavity posterior to trachea & then piercing diaphragm at esophageal hiatus to extend into abdominal cavity.
esophagus joins stomach at cardiac orifice

**Cardiac (gastroesophageal) sphincter**: smooth muscle valve preventing backflow of food from stomach into esophagus

**Heartburn**: symptom of gastroesophageal reflux disease (GERD); backflow of acidic gastric juice from stomach into esophagus

**Digestive Processes Occurring in Mouth, Pharynx & Esophagus**:

**Mastication (chewing)**

**Deglutition (swallowing)**

- Buccal phase: voluntary phase in mouth

- Pharyngeal-esophageal phase: involuntary phase in pharynx & esophagus (controlled by medulla & pons)

**Deglutition (the act of swallowing)**

In the mouth, food is masticated and mixed well with saliva. The action of tongue and cheeks convert food into a round mass called bolus. This bolus is swallowed.

**Abdominal Cavity and its Contents**

Abdomen is the largest cavity in the body. It is oval in shape and contains a variety of organs. It can be divided into two parts

1. Abdumen proper - an upper larger cavity
2. Pelvis - a lower smaller cavity

**Boundaries of abdomen**: Abdomen is bounded

1. Above by the lower surface of diaphragm
2. Below by the brim of true pelvis
3. In the front and sides by abdominal muscles, ribs and iliac bones.
4. At the back by vertebral column, psoas and quadratus lumborum muscles.

**Contents of abdomen**

The abdomen contains stomach, intestines, liver, spleen, pancreas, kidney, adrenal glands, abdominal aorta, inferior vena cava, peritoneum, fat etc.
11.2 Stomach and its Digestive Function

Stomach is the dilated portion of alimentary canal and it receives food from oesophagus. It lies in the upper part of abdominal cavity below the left half of diaphragm.

**Parts of Stomach**: Stomach has

1. Two surfaces: An anterior and a posterior surface
2. Two borders: An upper border called lesser curvature, and a lower border called greater curvature.
3. Two ends: Upper end called cardial end and it is guarded by cardiac sphincter. Lower end called pyloric end and it is guarded by pyloric sphincter.
4. Fundus: A dome shaped upper part lying to the left of cardiac end.
5. Body: The main part of stomach
6. Pyloric antrum: The lower part

**Structure of Stomach**

Stomach contains the following four coats:

1. Peritoneal coat (made of serous covering)
2. Muscular coat (made of longitudinal, circular and oblique fibres)
3. Submucous coat (made of areolar tissue)
4. Mucous coat (made of mucous membrane)

**Secretions of Stomach**

The mucous membrane of stomach contains glands which secrete gastric juice continuously. The secretion of gastric juice occurs due to:

1. A reflex mechanism through vagus nerve
2. Gastrin, a hormone secreted by the action of food stuffs on gastric mucous membrane.
3. Psychological effects produced by taste or smell of food. Gastic juice contains pepsin, rennin, hydrochloric acid and intrinsic factor.

**Small Intestine and Its function of digestion and absorption**

Small Intestine is the part of alimentary canal which extends from the pyloric end of the stomach to caecum (the first part of large intestine).

Parts: Small intestine consists of three parts:

1. Duodenum
2. Jejunum
3. Ileum

**Duodenum**

It is C-shaped fixed part which is attached to posterior abdominal wall by peritoneum. The head of pancreas lies in the concavity of duodenum. Also the bile duct and pancreatic duct open together at the concave surface. A small eminence at this opening is called ampula of Vater.

**Jejunum**

It is the continuation of duodenum and it is the middle portion of small intestine.

**Ileum**

It forms the last part of the small intestine.

**Digestion in small intestine**

The acidic chyme from the stomach enters into the duodenum. There it mixes with:

1. The alkaline intestinal juice called “succus entericus”
2. Alkaline secretions from liver and pancreas

In the small intestine, digestion is carried out by the following enzymes of intestinal juice.

1. “Enterokinase” which converts trypsinogen
2. “Erepsin” which converts polypeptides into amino acids
3. “Sucrase”, maltase and lactase which convert the corresponding disaccharides into monosaccharides.

Absorption in Small Intestine

The absorption of digested food occurs in small intestine through villi.

Villi

Villi are minute projections which are present in the inner mucous coat of the intestine. The villi give a velvety appearance to the intestinal mucous membrane. Each villus has:

1. A central lymphatic vessel called lacteal. Fats are absorbed into lacteal and carried to thoracic duct.
2. A network of capillaries surrounding the lacteal. Digested products of carbohydrates and protein are absorbed into these capillaries. They are carried to liver by portal vein.
3. Lymphoid tissue which holds together the lacteals and capillaries.

Fig. 11.7 Small Intestine and Villi
Large Intestine and its functions

Large intestine (colon) extends from the end of ileum to rectum. Large intestine consists of the following parts: caecum, appendix, ascending colon, transverse colon and sigmoid colon.

1. Caecum

It is a short rounded sac which lies in the right iliac fossa. It commences at ileocaecal valve where the ileum joins the caecum.

2. Vermiform appendix

It springs out from the caecum at about an inch from the ileocaecal junction. It is present in the right iliac fossa. The lumen of appendix communicates with that of caecum. The appendix is composed of the same four coats as intestine but the submucous coat contains lymphoid tissue.

3. Ascending Colon

It ascends upwards from caecum and in front of right kidney. It turns to the left below the liver and forms the transverse colon.

4. Transverse Colon

It is the loop of large intestine which extends between the lower surfaces of liver and spleen. At the lower surface of spleen, it turns downwards to form descending colon.

5. Descending Colon

It extends from the lower surface of spleen to brim of pelvis. It lies in the left lumbar region.

6. Sigmoid Colon

It is the continuation of descending colon and it continues below with rectum.

Functions of large intestines:

1. Digestion: This is carried out by micro organisms of colon. They act on the undigested and unabsorbed residue from small intestine.

2. Absorption: All carbohydrates, proteins and fat are already absorbed in small intestine. Only water and glucose are absorbed in the colon.

3. Secretion: Mucin is the only secretion. It lubricates colon and facilitates the passage of fecal matter.
Rectum: It occupies the lower posterior part of the pelvis. It extended between sigmoid colon and anus.

The lower part of rectum is dilated and it is called rectal ampula.

Anus: It is a small canal measuring about one inch in length. The opening of anus is guarded by a sphincter called anal sphincter. This sphincter is under voluntary control.

Defecation: It is defined as evacuation of fecal matter of rectum. Defecation is a reflex mechanism. But this reflex is under voluntary control. This reflex for defecation occurs when a sufficient quantity of feces accumulates in the rectum. This produces stretching of rectal walls and also increases pressure in the rectum. When the pressure exceeds 40mm Hg the nerve ending sofrectum are stimulated.

The impulses reach the spinal cord. From the spinal cord, impulses for defecation are carried to the rectum through motor nerves.

The act of defecation involves the following events:
1. Relaxation of anal sphincter which is the first voluntary act.
2. This is followed by contraction of:
   · Muscles of rectum
   · Muscles of pelvic floor
   · Muscles of abdominal walls
   · Diaphragm

11.3 Digestion of food in the alimentary canal

Food contains

All these constituents of food are digested in the alimentary canal as follows

1. Carbohydrates

Ptyalin (salivary amylase) present in saliva converts cooked starches in food into a sugar called maltose. This conversion occurs in the mouth. All sugars are converted to simple monosaccharides like glucose by the action of enzymes in the small intestine. Glucose is absorbed through the capillaries of villi in the small intestine. It is then carried to liver by portal vein where it is stored as glycogen.
2. Proteins

The digestive enzymes convert proteins into peptones, polypeptides and finally into amino acids. The aminoacids are absorbed through villi of small intestine and carried to liver.

3. Fats

Lipase, an enzyme of pancrease which is poured into small intestine converts fats into fatty acids and glycerol. These two products are absorbed through lacteals of villi.

They are carried to thoracic duct through cisterna chylit. From the thoracic duct they enter into blood through left brachiocephalic vein.

Peritoneum

Peritoneum is a serous membrane which lines the abdomen and covers the abdominal organs. It consists of the following two layers.

1. Parietal peritoneum which lines the walls of abdominal cavity
2. Viceral peritoneum which covers the abdominal organs. The space between these two layers is called as peritoneal space.

Organs completely covered by peritoneum are stomach, liver and intestines. Organs partly covered by peritoneum are kidney.

Omenta

The folds of peritoneum connected to the stomach are called omenta. They are divided into:

1. Greater omentum which hangs from the lower border of stomach to the front surface of small intestine.
2. Lesser omentum which extends from the lower border of liver to the lesser curvature of stomach.

Mesentry

It is the fold of peritoneum which attaches the different parts of small intestine to the posterior abdominal wall. Blood vesels, nerves and lymphatics enter the intestines only through mesentry.

Peritoneal ligaments

They are folds of peritoneum which connect organs (like liver and uterus) to the posterior abdominal wall.)
Pelvic Peritoneum

It is the part of the peritoneum present in the pelvic region. The pelvic peritonum is actually the continuation of peritoneum in the abdominal cavity. The arrangement of pelvic peritoneum is different in males and females due to the presence of uterus and fallopian tubes in females.

Arrangement in males

In males, the peritoneum covers the upper part of rectum. Then it passes over the posterior and upper surface of bladder. Later, it becomes continuous with the peritoneum of anterior abdominal wall.

Arrangement in females

In females the peritoneum covers the rectum as in males. But it covers the anterior and posterior surfaces of uterus before reaching the bladder. The sac of peritonium between the rectum and uterus is called the Pouch of Douglas. In the females, the peritoneum covers the fallopian tubes also. the fallopian tubes open directly into the peritoneal cavity. The mucous membrane of fallopian tubes is continuos with peritoneum.

Functions of Peritoneum

1. It forms a complete or partial covering for abdominal organs
2. It forms a smooth lining which enables the abdominal organs to move over each other without friction.
3. The ligaments and mesentries of peritoneum hold the abdominal organs in position.
4. Omentum and mesentry serve as store house for fat
5. The fat of peritoneum prevents infections being carried to abdominal organs.
6. The peritoneum contains some fluid which absorbs shock and prevents it from getting transmitted to abdominal organs.
7. The peritoneum itself can absorb large quantities of fluids.

Short Answer Type Questions

1. What are the functions of GI tract?
2. What are the parts of digestive system?
3. Write the types of teeth.
4. Write the types of salivary glands.
5. What are the functions of saliva?
6. What is peristalsis?
7. Write about esophagus.
8. Write the contents of abdomen.
9. What are the secretions of stomach?
10. What is chyme?
11. What are the functions of small intestine?
12. What are the functions of large intestines?

**Long Answer Type Questions**

1. Explain the structures of digestive system.
2. Explain the structure of stomach and its digestive functions.
3. Explain the structure, digestion and absorption of small intestine.
4. Explain the structure, digestion and absorption of large intestine.
5. Explain the process of digestion and absorption of food in alimentary canal.
12.0 Introduction

Digestion of food is aided by the following abdominal organs which are situated outside the alimentary canal. They are:

1. Liver
2. Gall bladder
3. Pancreas

12.1 Liver

Position: largest gland in body; it lies under diaphragm & mostly within rib cage; occupies most of right hypochondriac & epigastric regions.

4 primary lobes: right (largest lobe), left, quadrate & caudate

- falciform ligament: separates left & right lobes & suspends liver from diaphragm & anterior abdominal wall
- **Round ligament (ligamentum teres)**: fibrous remnant of fetal umbilical vein (ductus venosus)

- **Hepatic artery & hepatic portal vein** travel through lesser omentum & enter liver at porta hepatis & common hepatic duct

- **Bile** travels through right & left hepatic ducts, which lead into **common hepatic duct** or **common hepatic duct** fuses with **cystic duct** to form (common) **bile duct**.

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**Fig. 12.1 Liver and structures passing through the hylum**

**Four Surfaces:** They are:

1. **superior surface** which is in contact with the under surface of diaphragm.

2. **Inferior surface** which is facing the abdominal viscera. The hylum or portal fissure is present in the inferior surface. The blood vessels of liver and bile duct pass through the hylum.

3. **Anterior surface** which is separated from ribs and coastal cartilages by the diaphragm.

4. **Posterior surface** which lies in front of vertebral column, aorta, inferior vena cava and lower end of oesophagus.

**Internal (minute or microscopic structure):** the liver consists of a large number of liver cells called **lobules**. Each lobules has a central vein. The connective tissue lying in between the lobules contains the branches of:
1. Portal vein
2. Hepatic artery
3. Bile duct

Fig. 12.2 Internal structure of liver

Blood supply: blood is brought to liver by: i) hepatic artery  ii) portal vein.

But blood is carried from liver to inferior vena cava through hepatic veins.

Bile ducts: the secretion of liver( bile) is carried through bile ducts which are formed by the union of biliary canaliculi. The biliary canaliculi are small biliary channels present in between the lobules of liver.

- **Composition of bile**: bile is a yellow-green alkaline solution consisting of bile salts, bile pigments, cholesterol, neutral fats, phospholipids & a variety of electrolytes

  Bile salts: cholesterol derivates that emulsify fats (suspend in water), aiding in digestion & absorption of fats

  *bilirubin*: bile pigment produced as a waste product of heme of hemoglobin during red blood cell breakdown.

**Functions of the Liver:**

1. Secretion of bile.
2. Synthesis and storage of glycogen.
3. Formation of urea by the de-amination of amino acids.
5. Conversion of unsaturated fats into saturated fats.
7. Synthesis of prothrombin and fibrinogen which are necessary for blood coagulation.
8. Synthesis of heparin, the natural anti coagulant.
9. Production of heat as a result of metabolic reaction.
10. Inactivation of toxic substances and drugs.
11. Storage of vitamins A, D, E and K.

Fig. 12.3 Gallbladder

Gall bladder is pear shaped storage sac for bile. It is situated in the under surface of the right lobe of liver. It consists of a fundus, body and neck.

Functions of gall bladder: The gall bladder stores the bile that is secreted in liver. Also it concentrates the bile stored in it.

Bile: It is an alkaline fluid secreted by the liver and stored in gall bladder. About 500 to 1000 ml of bile is secreted by liver per day. But the capacity of gall bladder is only 30 ml. So bile is concentrated in gall bladder. Bile contains 86% of water, bile salts, bile pigments, mucin, cholesterol and other substances.

Bile salts: Bile salts are sodium taurocholate and sodium glycocholate. The bile salts increase the digestive activity of lipase, a pancreatic enzyme. Also they help in the absorption of fats (like glycerol, fatty acids and cholesterol) and fat soluble vitamins (A, D, E and K).
**Bile pigments:** They are bilirubin and biliverdin. They are formed from hemoglobin which is released in the destruction of worn out red blood cells in the spleen.

### 12.3 Pancreas

**Position:** Pancreas is a long, slender gland which lies transversely across the posterior abdominal wall. It lies behind the stomach at the level of 1st and 2nd lumbar vertebrae.

**Parts:** It consists of the following:

- **Head** lies in the C-shaped curve of duodenum.
- **Body** lies in front of the body of lumbar vertebrae
- **Tail** lies in contact with the hylum of spleen.

![Fig. 12.4 Pancreas](image)

**Secretions:** the secretions of pancreas can be classified into: (1) Exocrine secretion (2) Endocrine secretion.

1. **Exocrine secretion:** It is pancreatic juice which is digestive in function. It is conveyed to duodenum through pancreatic duct. Pancreatic juice contains the following digestive enzymes:

   - (i) *Lipase*, which converts fats into fatty acids and glycerol.
   - (ii) *Amylase*, which converts starch into maltose.
   - (iii) *Trypsin* which converts peptones into aminoacids.
2. Endocrine secretions: it is secreted by the islets of Langerhans and directly poured into circulation. This secretion contains two different hormones which are secreted by the two different cells of islets of Langerhans. These hormones are:

(i) **Glucagon** – secreted by alpha cells

(ii) **Insulin** – secreted by beta cells

### Short Answer Type Questions

1. Write the position of liver.
2. Write the blood supply of liver.
3. What are the functions of liver?
4. Write about gallbladder?
5. Write the composition of bile.
6. What are bile salts?
7. What are bile pigments?
8. Write the secretions of pancreas.
9. What are the accessory organs of digestion?

### Long Answer Type Questions

1. Write the structure and function of liver.
2. Write the structure and functions of gall bladder.
3. Write the structure and functions of pancreas.
UNIT 13

Nutrition, Metabolism & Body Temperature Regulation

Structure

13.0 Introduction
13.1 Metabolism
13.2 Body energy balances

13.0 Introduction

- **Nutrient**: Substance in food that is used by the body to promote normal growth, maintenance & repair

  **Major nutrients**: Carbohydrates, lipids, proteins, vitamins, minerals & water

  **Essential nutrients**: Nutrients that cannot be synthesized by chemical reactions in the body, & must be obtained from the diet

**Carbohydrates**

  **Dietary sources**: Sugars from fruits, sugar (cane), honey, milk; starch from grains, vegetables; cellulose from most plants (cellulose is indigestible = fiber)

  **Uses in the body**: Glucose is major body fuel; used to make ATP (other sugars such as fructose & galactose are converted to glucose by liver)

  **Dietary requirements**: 200-300 grams/day recommended (40% of total calories)
Lipids

**Dietary sources:** Saturated fats in meats & dairy products (& some plants); unsaturated fats in seeds, nuts & vegetable oils; cholesterol in egg yolks, milk products, meats

**Uses in the body:** Fats help the body absorb fat-soluble vitamins; triglycerides are major source of energy for hepatocytes & skeletal muscle; phospholipids used to synthesize cellular membranes; fats used as cushioning & insulation in adipose tissue; cholesterol used in plasma membrane, steroid hormone synthesis & bile salts

**Dietary requirements:** Fats should represent 30% or less of total calories; saturated fats should be 10% or less of total fats; less than 200 mg/day cholesterol

Proteins

**Dietary sources:** Eggs, milk & most meats are complete proteins (contain all essential amino acids); vegetables must be used in combination to obtain all essential amino acids (cereal grains and legumes)

**Uses in the body:** Functional proteins regulate most chemical reactions in cells; structural proteins important for skin, connective tissue fiber & muscle contraction; nitrogen balance (nitrogen in protein intake = nitrogen in urine & feces); energy source only if in excess or insufficient carbs or fats

**Dietary requirements:** 0.8 g/kg body weight recommended (~ 55 g/day for a 150 lb. Individual)

Vitamins: Organic compounds needed in small amounts for growth & metabolism

Vitamins not used for energy, but are critical in energy-producing reactions

Most vitamins function as **coenzymes** (assist enzyme in its activity)

B vitamins niacin & riboflavin act as coenzymes NAD+ & FAD) in oxidative

Phosphorylation

Most vitamins must be obtained from diet; exceptions are vitamin D made in the skin, vitamin K & some B vitamins synthesized by intestinal bacteria, & vitamin A which can be synthesized from beta-carotene (orange-yellow pigment in some vegetables)
**Water-soluble vitamins**: Absorbed along with water from GI tract includes **vitamin C & the B vitamins**

**Fat-soluble vitamins**: Bind to ingested lipids & absorbed along with their digestion products includes **vitamins A, D, E & K**

**Vitamin A** can be synthesized from **beta-carotene** (antioxidant in orange vegetables) required for synthesis of visual pigments, normal development of bones, teeth & maintenance of epithelia

**Vitamin D** required for calcium & phosphorus absorption during digestion

**Vitamin E** is antioxidant (prevents oxidation of vitamin A & polyunsaturated fatty acids)

**Vitamin K** required for blood clotting

**B vitamins** (B1-B12) required for cellular metabolism

**Vitamin C** (ascorbic acid) required for collagen production, storage of folic acid, & metabolism of some amino acids; promotes iron absorption & synthesis of steroid hormones

Vitamins A, C, & E are **antioxidants** that neutralize harmful free radicals in body

Balanced diet necessary to obtain all required vitamins

**Minerals**: also not used for energy, but used by other nutrients to carry out necessary cellular reactions 7 minerals required in moderate amounts: calcium, phosphorus, potassium, sulfur, sodium, chloride & magnesium

Several minerals also required in trace amounts (e.g.: fluorine, iodine, iron, zinc)

### 13.1 Metabolism

- **Metabolism**: all chemical reactions occurring in the body & necessary to maintain life

  **Anabolism**: reactions that build up molecules (larger molecules are built from smaller molecules)

  Example : Bonding of amino acids to make a protein

  **Catabolism**: Reactions that break down molecules (complex structures are broken down into simpler ones)
Example: Cellular respiration (food fuels broken down in cells & energy released is captured to make ATP)

- **Phosphorylation**: addition of a phosphate molecule to another molecule (usually a protein or nucleotide (ADP)) Often used to activate a protein or chemical (sometimes used to inactivate)

**Oxidation**: the gain of oxygen or the loss of hydrogen (or electrons)

**Reduction**: the loss of oxygen or the gain of hydrogen (or electrons)

**Oxidation-reduction (redox) reactions**: one molecule is oxidized (loses electrons & energy) while another molecule is reduced (gains electrons & energy)

**Dehydrogenases**: enzymes that catalyze transfer of hydrogen

**Oxidases**: enzymes that catalyze transfer of oxygen

Use coenzymes NAD+ & FAD

**Mechanisms of ATP synthesis**

**Substrate-level phosphorylation**: high-energy phosphate transferred directly from a substrate molecule to ADP

**Oxidative phosphorylation**: a chemiosmotic process where hydrogen ion transport across the mitochondrial membrane (chemiosmosis) provides the energy required for the enzyme ATP synthase to synthesize ATP from ADP and phosphate

**Carbohydrate metabolism**

**Oxidation of glucose**: glucose + oxygen -> water + carbon dioxide + 36 ATP + heat

**Glycolysis**: glucose broken down to 2 molecules of pyruvic acid

• Occurs in the cytoplasm of cells

• Net gain of 2 ATP

• Following glycolysis, if oxygen is available pyruvic acid is converted to acetyl coA on the way into the mitochondrion (transition reaction) to go into the Krebs cycle.

Pyruvic acid is converted to acetic acid, which is then combined with coenzyme A (a pantothenic acid derivative)
Carbon dioxide is released in the conversion

- If oxygen is in short supply, pyruvic acid is reduced to lactic acid (anaerobic respiration or fermentation)

Some lactic acid is transported to liver & can be converted back to pyruvic acid when oxygen becomes available; lactic acid remaining in cells impairs cellular activity (muscle cell fatigue during exercise)

**Krebs Cycle**: An 8-step cycle that shuffles carbon atoms while oxidizing sugars to reduce NAD+ & FAD

- Occurs in the mitochondrial matrix
- The resulting 3 NADH molecules and 1 FADH2 molecule per acetyl coA will enter the electron transport chain
- Net gain of 1 ATP per acetyl coA

**Electron Transport Chain & Oxidative Phosphorylation**: NADH & FADH2 are oxidized, & the hydrogen ions removed are sent across the inner mitochondrial membrane while electrons are transported from protein to protein on the inner mitochondrial membrane

- The **hydrogen ions** are sent back across the mitochondrial membrane through an ATP synthase enzyme, releasing **energy** that is used by the enzyme to produce ATP from ADP & phosphate
- Occurs on the inner mitochondrial membrane
- **Oxygen** acts as an electron acceptor, & uses the transported electrons with available hydrogen atoms to form water

**Aerobic Cellular Respiration: ATP generation summary**

36-38 ATP yield from the complete breakdown of 1 glucose molecule

**Glycolysis**: 2 ATP (net yield) & 2 NADH

**Formation of Acetyl Coenzyme A**: 2 NADH

**Krebs Cycle**: 2 ATP, 6 NADH & 2 FADH2

So far: 4 ATP, 10 NADH & 2 FADH2

**Electron Transport Chain**: yields 3 ATP per NADH & 2 ATP per FADH2
• This would typically result in 30 ATP from the 10 NADH & 4 ATP from the 2 FADH2, or 34 ATP

• 34 ATP from electron transport, added to the 4 ATPs produced previously yields a total of 38 ATP from aerobic respiration

• However, the 2 NADH from glycolysis were produced in the cytoplasm. These NADH molecules cannot enter the mitochondrion, but transfer their electrons to shuttle molecules, which then transfer the electrons to NAD+ or FAD molecules inside the mitochondrion. Most cell types use the glycerol phosphate shuttle, which transfers its electrons to FAD to form FADH2 & only yields 2 ATP per NADH; in heart, liver & kidney cells, the malate-aspartate shuttle transfers its electrons to NAD+ to form NADH & yields 3 ATP per NADH – hence the 36-38 ATP yield, depending on the cell type

  **Glycogenesis**: when more glucose is available than is needed for energy, glucose molecules are combined in long chains to form glycogen. It occurs in liver & skeletal muscle cells

  **Glycogenolysis**: When blood glucose levels drop, glycogen lysis occurs, releasing glucose molecules from glycogen

  **Gluconeogenesis**: When too little glucose is available, glycerol & amino acids are converted to glucose. It occurs in liver.

  - **Lipid metabolism**: Fats are concentrated energy source; about twice as much energy can be gained from fats as from glucose (most cell types can use fats as an energy source, but some cell types (neurons & red blood cells) rely almost exclusively on glucose for energy

  **Oxidation of glycerol & fatty acids**: triglycerides are broken down into fatty acids and glycerol; glycerol enters glycolytic pathway while fatty acids are oxidized to acetic acid

  **Beta oxidation**: Fatty acids oxidized to acetic acid, to which coenzyme A is added & the acetyl coA enters the Krebs cycle

  **Lipogenesis**: Triglyceride synthesis from acetyl coA & glycerol

  Occurs when cellular ATP & glucose levels are high (one of the problems with diets very high in sugars/carbohydrates)

  **Lipolysis**: Breaking of stored fats into fatty acids & glycerol

  - **Protein metabolism**: When more protein is ingested than needed for protein replacement, amino acids can be oxidized for energy or converted to fat
Oxidation of amino acids: Amino acids are converted to keto acids, which can then be converted to pyruvic acid & acetyl coA; occurs in liver & requires 3 steps:

Transamination: transfer of amine group from amino acid to α-ketoglutaric (keto) acid to form glutamic acid

Oxidative deamination: amine group of glutamic acid is removed as ammonia (which is combined with carbon dioxide & excreted as urea in urine) & keto acid

Keto acid modification: keto acid modified as necessary (to form pyruvic acid, acetyl coA...) to enter energy pathways

Synthesis of Proteins: protein synthesis is first priority for amino acids absorbed.

8 essential amino acids must be absorbed through digestive system from food.

Nonessential amino acids can be synthesized from other molecules in liver

- Catabolic-Anabolic Steady State of Body: organic molecules (proteins, carbohydrates, lipids) are continuously broken down & rebuilt

Nutrient pools: the body’s total supply of nutrients; most nutrients are interconvertible

Amino acid pool: the body’s total supply of free amino acids; must be converted to carbohydrate to be used for energy

Carbohydrate pool: Can be used directly for energy or stored

Fat pool: Can be used directly for energy or stored

Absorptive State: The time during & shortly after eating when nutrients are actively being absorbed from GI tract

Carbohydrates: Absorbed monosaccharides are delivered to liver; fructose & galactose are converted to glucose; glucose is used for energy if necessary & excess is stored in liver as glycogen or converted to fat & stored in adipose tissue.

Triglycerides: Collected in lymph & converted to fatty acids & glycerol; fatty acids & glycerol are used for energy if necessary or converted back to triglycerides & stored in adipose tissue.
Amino Acids: Delivered to liver; remain in blood if needed for protein synthesis; otherwise, amino acids are deaminated to keto acids for use as energy

Hormonal control: Insulin released by pancreatic islets directs events of absorptive state

Insulin is primarily a hypoglycemic hormone; it removes glucose from blood into tissue cells, lowering blood sugar levels

Deficiency in insulin or malfunctional insulin receptors can lead to diabetes mellitus

Postabsorptive state: Between meals when blood sugar levels are falling

- Goal is to maintain blood glucose levels within normal limits (80-100 mg/100 ml)

Sources of glucose: Glycogenolysis in liver & skeletal muscle cells; lipolysis in adipose tissue & liver (released glycerol is converted to glucose); catabolism of cellular protein (deamination of amino acids to keto acids & conversion of keto acids to glucose)

Glucose sparing: use of noncarbohydrate molecules for fuel to conserve glucose.

Hormonal control: Glucagon released by pancreatic islets is a hyperglycemic hormone; it raises blood glucose levels

Neural control: epinephrine released by sympathetic fibers mobilizes fat stores for energy & promotes glycogenolysis

Role of Liver in Metabolism:

Hepatocytes carry out many (~500) metabolic functions

Cholesterol metabolism & regulation of plasma cholesterol levels

Cholesterol is used in synthesis of bile salts, steroid hormones, vitamin D & plasma membrane in all cells; also part of embryonic hedgehog protein.

15% of cholesterol comes from diet; rest is synthesized from acetyl coA

Lipoproteins & cholesterol transport

- Very low density lipoproteins (VLDLs): Transport triglycerides from liver to tissues (primarily adipose tissue)
• **Low-density lipoproteins (LDLs):** Transport cholesterol to tissues (bad cholesterol)

• **High-density lipoproteins (HDLs):** Transports excess cholesterol from tissues to liver for use in bile salts

## 13.2 Body energy balance

### Regulation of Food Intake:

**Neural signals:** vagal nerve fibers communicate between gut & brain

**Nutrient signals:** increases in plasma levels of glucose, amino acids, fatty acids & **leptin** (satiety-related hormone released by adipose tissue) depress eating also, insulin appears to be an important satiety signal, & body temperature & psychological factors affect eating habits

### Regulation of Body Temperature:

**Hypothalamus** is main integrating center for thermoregulation

**Thermoregulatory centers** include heat-loss center & heat-promoting center

**Heat-promoting mechanisms:** Hypothalamic heat-promoting center activated

- Vasoconstriction of cutaneous blood vessels (blood rerouted to internal organs)
- Increase in metabolic rate
- Shivering (contraction of skeletal muscle)
- Enhanced thyroxine release (increases metabolism & heat)

**Heat-loss mechanisms:** Hypothalamic heat-loss center activated

- Vasodilation of cutaneous blood vessels (heat lost through skin)
- Enhanced sweating

### Short Answer Type Questions

1. What is metabolism?
2. What are the sources of energy present in food?
3. What is basal metabolism?
4. Write the requirements of normal diet.
5. Define diet.

**Long Answer Type Questions**

1. Explain in detail about carbohydrate metabolism.
2. Explain in detail about protein metabolism.
3. Explain in detail about fat metabolism?
Structure

14.0 Introduction

14.1 Kidney

14.2 Formation of urine

14.3 Diseases of urinary system

14.0 Introduction

The urinary system is the main excretory system of the body. It consists of (1) two kidneys (2) two ureters (3) an urinary bladder (4) an urethra.

Fig. 14.1 Parts of urinary system
14.1 Kidney

They are two bean shaped organs lying on the posterior abdominal wall, on each side of the vertebral column.

Functions of the kidneys:

1. Excretion of water and waste products of protein metabolism.
2. Excretion of excess salt.
3. Excretion of harmful substances, drugs and toxins.
4. Regulation of pH of blood.

Positions of the kidneys

The kidneys extend from the level of last thoracic vertebra to the third lumbar vertebra. The right kidney is smaller than the left kidney. Each kidney measures 11 cm in length, 5 cm in width and 3 cm in thickness. Each kidney weighs about 150 grams.

The outer border of kidney is “convex”. The inner border is concave and it is called as “hylum”. Blood vessels enter and leave the kidney through the hylum. A suprarenal gland is situated at the apex of each kidney.

Structure of kidney

Kidney is surrounded by an outer fibrous capsule. Below this lies the substance of the kidney which consists of:

1. An outer cortex which is reddish-brown in colour.
2. Inner medulla which contains “pyramids” of the kidney.

Fig. 14.2 Internal structure of kidney
3. An upper expanded end or ureter called “pelvis”. Microscopically the kidneys are made of a number of structural and functional units called “nephrons”. There are about one million nephrons in each kidney. A nephron consists of two parts:

1. Malphigian bodies made of Bowman’s capsule and glomerulus.
2. Renal tubules.

**Malphigian bodies**

It is made of 1) an upper expanded end of the renal tubule called “Bowman’s capsule” 2) a bunch of capillaries called “glomerulus” which are packed in Bowman’s capsule. The malphigian bodies are present in the cortex.

**Renal tubules**

They consist of four parts:

1. Proximal convoluted tubule situated in the cortex.
2. Loop of Henle present in the medulla.
3. Distal convoluted tubule present in the cortex.
4. Collecting tubules which pass through the medulla and open into the pelvis of kidney.

![Diagram of nephron](image)

**Fig. 14.3 Structure and different levels of absorption of nephron**
Blood supply to kidney

Kidneys are supplied by renal arteries which are branches of abdominal aorta. Venous blood of kidney is drained by renal veins which open into inferior vena cava.

14.2 Formation of Urine

The formation of urine by kidneys involves three processes:

1. Glomerular filtration
2. Tubular secretion
3. Tubular reabsorption

1. Glomerular filtration

Filtration of water, salts and other substances occurs in the glomeruli. Glomerular filtrate is the fluid that is formed after filtration. About 100 ml of glomerular filtrate is formed per minute. This filtrate passes into the proximal convoluted tubule.

2. Tubular secretion

It is an active process which occurs in the convoluted tubules. Abnormal substances or normal substances present in excess in blood are eliminated by this process. Potassium, hydrogen and drugs like penicillin are excreted by tubular secretion.

3. Tubular reabsorption

The rate of glomerular filtration is about 100 ml per minute. So about 6 litres of glomerular filtrate can be formed in one hour. But the volume of urine eliminated per day is only about 1.5 litres. It is so, because nearly 99 percent of the glomerular filtrate is reabsorbed. Reabsorption of water occurs in the convoluted tubules and collecting tubule. In addition to water, some salts are also reabsorbed in the renal tubules. Urine is the fluid that results from the above three processes. It enters the collecting tubules and then into the pelvis of kidney. From there, it enters the urinary bladder through ureter.

Ureter

It is the duct which carries urine from the kidney to bladder. It is a tube like structure measuring about 26 cm in length. It commences from the pelvis of kidney. Later it passes down in the abdominal cavity and opens in the posterior aspect of urinary bladder. Ureter is made of (1) an outer fibrous layer (2) middle
muscular layer (3) inner mucous layer.

**Urinary Bladder**

It is a pear shaped muscular sac which acts as a reservoir for urine. It lies in the pelvic cavity behind symphysis pubis. The lowest part of bladder is called as base and the upper part is called “fundus”.

Bladder has three openings, two for ureters and one for urethra. The triangular area between these openings is the “trigone of the bladder”.

Bladder is made of four layers 1) outer serous coat 2) muscular coat 3) sub-mucous coat 4) mucous lining made of transitional epithelium. The bladder is controlled by pelvic nerves and sympathetic fibres from hypogastric plexus.

**Urethra**

It is a canal through which urine passes from the bladder to the outside. It differs in the males and females. But a sphincter is present in both.

**Male urethra**

It is about 20cm in length. It consists of three parts (1) Pelvic part (2) Perineal part (3) Pineal part.

**Female urethra**

It is short and measures about 4 cm in length. It starts from the base of bladder at the trigone. It opens externally in front of vaginal opening.

**Micturition**

It is the act of passing urine. When urine accumulates in the bladder, it produces stretching of its walls. This raises the pressure within the bladder. This occurs when 170 to 230 ml of urine has collected in the bladder. This in turn stimulates the afferent nerves of the bladder. The impulses are carried to higher centres which control micturition.

Micturition occurs due to contraction of muscular coat of the bladder and relaxation of the sphincter. It is also assisted by contraction of abdominal muscles.

**Composition of urine**

The volume of urine excreted in man varies from 1 to 2 litres daily. The colour of urine is pale amber odour is aromatic and reaction is slightly acidic (pH 6). Specific gravity varies from 1010 to 1025.
Urine consists of

1. Water - 96%
2. Urea - 2%
3. Uric acid and salts - 2%

### 14.3 Diseases of the Urinary System

1. **Glomerulo nephritis** - An infection of kidney leading to inflammation of glomeruli.
2. **Pyelitis** - An inflammation in pelvis of kidney due to infections.
3. **Polyurea** - Secretion of large quantities of urine.
4. **Anurea** - Cessation of urine secretion.
5. **Renal calculi** - Deposition of insoluble substance in urinary tract.
6. **Cystitis** - Inflammation of urinary bladder.

**Oedema**

It is water logging of the tissues. It occurs as swelling of the body or any part of the body due to retention of fluid. Oedema can occur due to a variety of causes.

**Oedema of renal failure**

It occurs as follows: Plasma proteins are excreted in kidney failure. This produces a decrease in osmotic pressure of blood. So entry of fluid at the venous side is decreased. This leads to accumulation of fluid in tissue spaces. It results in swelling leading to oedema.

**Cardiac oedema**

It occurs in congestive cardiac failure. Because of inefficient contraction of the heart, venous fluid is not effectively mobilised to the heart. So fluid accumulates in tissues producing oedema.

**Oedema of lymphatic obstruction**

It occurs mostly after radical mastectomy (removal of breast). In this procedure, the lymph glands which drain the axilla are also removed. So oedema occurs because of obstruction to lymphatic flow.
Oedema also occurs in elephantiasis caused by filariasis. Oedema is due to obstruction of the lymphatics by the parasite.

**Oedema of Thrombosis**

It is seen in thrombosis of deep veins of legs. It is due to prolonged, confinement to bed due to which flow of blood is sluggish. So clots form which further obstruct blood flow producing oedema.

**Short Answer Type Questions**

1. Write the main parts of excretory system.
2. What are the functions of kidneys?
3. Write the position of kidneys?
4. Draw the diagram of nephron.
5. Write the parts of nephron.
6. Write about ureter.
7. Write about urethra.
8. What is micturation?
9. Write the composition of urine.
10. What is oedema?
11. Draw the urinary system diagram.
12. Draw the diagram of nephron.

**Long Answer Type Questions**

1. Explain in detail about urinary system.
2. Explain in detail about the formation of urine.
The Endocrine System

Structure

15.0 Introduction

15.1 Major Endocrine glands

15.0 Introduction

Endocrine System: a system of small glands scattered throughout the body that influences the metabolic activities of cells through hormones

Hormones: chemical messengers released to the blood by the cells of endocrine glands that regulate the metabolic activities of other cells in the body

Hormones signal target cells to perform specific chemical reactions

Endocrine Glands: pituitary, thyroid, parathyroid, adrenal, pineal and thymus glands.

Organs with major functions outside the endocrine system containing endocrine tissue/cells: pancreas, gonads, hypothalamus (neuroendocrine organ)

Tissues that produce hormones also found within: adipose cells, small intestine, stomach, kidneys, heart

Hormones

Amino acid-based hormones: contain from a couple to many amino acids, vary in size from simple amino acid derivatives (amines, thyroid hormone, peptides) to proteins (polypeptides).
Steroid hormones: synthesized from cholesterol (includes hormones from the gonads and adrenal cortex (outer region of the adrenal gland))

Eicosanoids: local hormones (paracrines); biologically active lipids released from nearly all cell membranes

Effects are highly localized, different from circulating hormones

Leukotrienes: chemicals that mediate inflammation & some allergic reactions

Prostaglandins: many targets/effects... raise blood pressure, stimulate uterine

Contractions during birth, enhance blood clotting & inflammation

Eicosanoids are generally not considered part of the endocrine system.

Mechanisms of hormone action

- Alter plasma membrane permeability or electrical state
- Stimulate synthesis of proteins within cells
- Activate or deactivate enzymes
- Induce secretory activity
- Stimulate mitosis/cell division

Control of hormone release

Negative feedback: hormone secretion triggered by an external stimulus; as hormone levels rise, the hormones feed back to the metabolic pathway that produces them & inhibit their further release

Humoral stimuli: hormone release controlled by blood levels of specific ions and nutrients (e.g.: calcium or glucose)

Neural stimuli: nerve fibers stimulate hormone release (sympathetic neurons stimulate secretion of catecholamines (epinephrine & norepinephrine) fro the adrenal medulla))

Hormonal stimuli: other hormones regulate release of a hormone (e.g.: releasing & inhibiting hormones released by hypothalamus regulate release of hormones from pituitary)

Nervous system modulation: the nervous system can override normal homeostatic mechanisms for hormonal control (for example, to allow more glucose for fuel to be released during excitement (“fight or flight response”))
15.1 Major Endocrine Glands

1. Pituitary gland
2. Thyroid gland
3. Parathyroid gland
4. Adrenal glands
5. Pancreas
6. Sex glands (gonads)
7. Thymus
8. Pineal gland
Pituitary Gland

(Hypophysis): the pituitary gland is situated at the base of brain in a hollow called sella turcica of sphenoid bone. It consists of two main lobes:

1. Anterior lobe (anterior pituitary)
2. Posterior lobe (posterior pituitary)

Anterior Pituitary (Adenohypophysis): the anterior lobe of pituitary contains three types of cells namely chromophobe, eosinophil, and basophil.

Hormones of anterior pituitary: the anterior lobe of pituitary secretes the following hormones:

1. Growth hormone (GH)
2. Prolactin (PRL)
3. Follicle-stimulating hormone (FSH)
4. Leutinizing hormone (LH)
5. Thyroid-stimulating hormone (TSH)
6. Adrenocorticotropic hormone (ACTH)

1. Growth Hormone (GH): stimulates cell division in most cells (major targets are bone & skeletal muscle) IGFs (insulin-like growth factors or somatomedins) mediate most effects of GH


3. Follicle-stimulating hormone (FSH): stimulates gamete production in gonads (ovaries & testes)

4. Leutinizing hormone (LH): promotes production of gonadal hormones (testosterone, estrogen & progesterone)

5. Thyroid-stimulating hormone (TSH): stimulates normal development of & secretion of hormones from thyroid gland

6. Adrenocorticotropic hormone (ACTH or corticotropin): stimulates release of corticosteroid hormones from adrenal cortex
Disorders of anterior pituitary

Hypersecretion: In children, can lead to gigantism; after long bones have developed, can lead to acromegaly.

Hyposecretion: In children, can lead to pituitary dwarfism.

Posterior pituitary (Neurohypophysis): Receives & stores hormones from hypothalamus for later release.

Oxytocin: produced by paraventricular nucleus of hypothalamus; stimulates uterine contraction during childbirth & milk ejection during nursing

Antidiuretic hormone (ADH): produced by supraoptic nucleus of hypothalamus; stimulates kidney tubules to retain water

Deficiency of ADH secretion leads to diabetes insipidus

Thyroid Gland

The thyroid gland is situated in the lower part of neck on the thyroid cartilage. The thyroid gland contains two lobes, one on each side of the trachea. These two lobes are connected by an isthmus which lies in front of the trachea.

Secretions of thyroid hormones: the thyroid gland synthesizes and secretes two hormones: thyroxine and tri-iodothyronine.

Thyroxine (T4): Major hormone released from thyroid follicles (contains 4 iodine molecules)
Triiodothyronine (T3): (contains 3 iodine molecules); generally formed from T4 by leaving an iodine molecule
- Thyroid hormone formed by joining 2 tyrosine-iodine complexes.

Regulation of secretion: the secretion of thyroid hormone is controlled by thyroid stimulating hormone of anterior pituitary.

Functions of thyroid hormones:
1. Increases oxygen consumption and heat production in tissues.
2. Increases basal metabolic rate (BMR).
3. Increases the absorption and utilization of glucose.
4. Anabolic effects like growth promotion and protein synthesis.
5. Increases the rate of cholesterol synthesis in liver.
6. Mylinaton of central nervous system.
7. Storage of iodine.

Disorders of thyroid function:

Hypothyroidism:
2. Myxodema: Which is due to thyroid deficiency occurring after birth. It produces retardation of physical growth.
3. Endemic goitre: Which occurs due to deficiency of iodine in food. It produces enlargement of the thyroid gland.

Hyperthyroidism
Grave’s disease which is due to excessive production of TSH. It produces protrusion of eye balls, rapid pulse and nervousness.

Parathyroid Glands
The parathyroid glands are four in number. They embedded on the posterior surface of the thyroid gland, two lying on each side.
Functions of Parathyroid hormone (Parathormone or PTH):

1. raises blood calcium levels by stimulating osteoclasts, enhancing absorption of calcium by kidneys, & increasing absorption of calcium by cells of intestine

2. PTH activates the inactive form of vitamin D in the kidneys; vitamin D enhances absorption of calcium by intestine.

Disorders of parathyroid hormone

1. Hyper secretion : Produces osteitis fibrosa. It is characterized by decalcification of bone leading to loss of strength and fibrous appearance.

2. Hypo secretion : Produces hypocalcemia which leads to tetany.

Adrenal Glands

Also called as Suprarenal Glands: they are pyramid-shaped glands situated on the top of the each kidney. The adrenal gland can be devided into two parts which are different in structure and function.

They are 1. Adrenal cortex 2. Arenal medulla.

- Adrenal Cortex: releases corticosteroid hormones. They are:

1. Mineralocorticoids: They are Aldosterone and desoxy-corticosterone. They help to maintain electrolyte and water balance of the body.

2. Glucocorticosteroids: They are cortisol, cortisone and corticosterone.

Their important functions are

1. To increase the synthesis of glycogen.

2. To increase the break down of protein into aminoacids.


4. Decreasing the production of eosinophils and lymphocytes.

5. Anti-inflammatory and anti-allergic effect.

3. Gonadocorticoids: secondary source of sex hormones;

They are androgens(in males), and oestrogen(in females).
Disorders

- **Addison’s disease**: low level of adrenal cortex hormones resulting in bronzing of skin, low blood sugar (low energy & weak immunity) & low blood sodium (low blood pressure)

- **Cushing syndrome**: high level of adrenal cortex hormones resulting in high blood sugar (& possibly diabetes mellitus), high blood sodium (hypertension), swelling & obesity & possible masculinization in women

2. **Adrenal medulla**: releases **catecholamines** (norepinephrine & epinephrine)

   Release is stimulated by **sympathetic nervous system** (“fight or flight” response)

   1. **Epinephrine**: stimulates heart rate & metabolism

   2. **Norepinephrine**: influences peripheral vasoconstriction & blood pressure.

Pancreas

The pancreas lies on the posterior abdominal wall in front of abdominal aorta and lumbar vertebrae.

The endocrine cells present in pancreas are the **islets of Langerhans**. **They secrete**: insulin and glucagon.

1. **Insulin**: released by beta cells of islets; lowers blood glucose levels by stimulating glucose storage & uptake of glucose by cells for energy.

   Insulin deficiency may leads to **diabetes mellitus**

   Insulin-dependent diabetes mellitus (IDDM) : Autoimmune disease where immune cells attack & destroy beta cells

   Non-insulin-dependent diabetes mellitus (NIDDM): insulin receptors do not properly respond to insulin

2. **Glucagon**: Raises blood glucose levels by stimulating glucose removal from glycogen storage deposits in liver cells & gluconeogenesis

Gonads (sex glands)

The sex glands are **(ovaries & testes)**: produce steroidal sex hormones

1. **Ovaries**: produce estrogens, progesterone, inhibin & relaxin
**Estrogens** (estrone & estradiol) & **progesterone**: produced by ovary cells are responsible for maturation of female reproductive organs & regulation of menstrual cycle also, maintain pregnancy & prepare mammary glands for lactation.

**Inhibin** inhibits FSH during ovarian cycle; **relaxin** released during pregnancy. It increases flexibility of pubic symphysis & helps dilate uterine cervix

**Testes**: Produce testosterone, an **androgen** (male sex hormone)

**Testosterone**: Produced by cells of testes is responsible for maturation of male reproductive organs & sperm cell production

**Inhibin** inhibits FSH to regulate spermatogenesis

**Pineal Gland**

It is a very small gland situated in the brain.

It secretes melatonin.

**Melatonin** appears to be involved in maintenance or sleep/wake (day/night) cycles

Melatonin derived from the amino acid serotonin

More melatonin released in darkness, less in light; norepinephrine from sympathetic fibers stimulate secretion of melatonin (may cause sleepiness)

During sleep, plasma levels of melatonin increase & then decrease before awakening; therapeutic use to induce sleep still under investigation

**Thymus**

It is a gland present in the upper chest cavity on the trachea. It secretes thymopoietins & thymosins. They involved with normal development of T cells (lymphocytes); may slow aging.

**Other Hormone-Producing Structures:**

**Heart**: specialized cardiac muscle cells of atria secrete atrial natriuretic peptide (ANP), which reduces blood volume, blood pressure, & blood sodium levels.

**GI tract**: enteroendocrine cells secrete hormones that aid in digestion.

**Placenta**: secretes steroid hormones that help during pregnancy & human chorionic gonadotropin (hCG).
Kidney: secretes erythropoietin that stimulates red blood cell synthesis in bone marrow.

Skin: secretes inactive vitamin D (cholecalciferol), which is activated by PTH in kidneys.

Adipose Tissue: secretes leptin, which binds to neurons regulating appetite control & leads to sensation of satiety.

**Short Answer Type Questions**

1. What is hormone?
2. Write the names of endocrine glands.
3. Write the hormones of anterior pituitary gland.
4. What are the functions of thyroid hormones?
5. What are the functions of parathyroid hormones?
6. What are the actions of alkaline?
7. Write about insulin.
8. What are the sex glands?
9. Write about estrogen.
10. What are the functions of progesterone?
11. Write about thymus.
12. Write about pineal body.
13. What are exocrine glands?
14. Write the functions of thyroid gland?

**Long Answer Type Questions**

1. Explain the structure and functions of pituitary glands.
2. Explain the structure and functions of thyroid glands.
3. Explain the structure and functions of Parathyroid glands.
**16.1 Male reproductive system**

Reproductive system can be classified into:

1. External genital organs: Penis containing the urethra.
2. Internal genital organs: Testes
   - Vas deferans
   - Seminal vesicles
   - Prostate glands.

**Penis**: It is the copulatory organ and also it contains the terminal part of urethra. The parts of penis are

1. Corpora cavernosa which are two pillars of erectile tissue lying side by side under the skin of penis.
2. Corpora spongiosum contains the urethra and it lies below corpora cavernosa.

3. Glans penis which is the epiglottis tip of penis.

4. Propuce which is a fold of skin covering the glans penis.

**Testes**

![Fig. 16.1 Testes](image)

**Position** : Testes are the male reproductive organs which produce spermatozoa. The testes are two oval shaped bodies lying one on each side in the “scrotum”. The scrotum forms a bag of puch for the two testes. Each testes is enclosed in a sac called tunica vaginalis which is derived from peritoneum.

The testes are actually suspended in the scrotum by means of spermatic cord.

**Structure** : Each testis (or Testicle) contains a number of tubules called seminiferous tubules. The seminiferous tubules unit at the upper end of these seminiferous the upper end form epididymis. The epididymis forms the commencement of vas deferens (or seminal duct).

In between the seminiferous tubules there are interstitial cells (Ledig cells) which secrete testosterone.

**Vas Deferens** : (Seminal duct) : They are two in number one for each testis. The vas deferens commences from the epididymis at the upper end of testis. It travels upwards within the spermatic cord and enters the abdominal
cavity through the inguinal canal.

From the abdominal cavity, the vas deferens enters the pelvis and joins of the bladder.

![Diagram of male reproductive system]

**Fig. 16.2 Seminal vesicles**

They are two in number, each one lies at the side of the terminal part of vas deferens.

The seminal vesicle joins with the terminal portion of vas deferens and the ejaculatory duct. The ejaculatory duct pierces the prostate gland and opens into the ejaculations.

Prostate Gland: The prostate gland lies below the bladder and it surrounds the first part of urethra. It is pyramidal in shape. Its base is directed above and it is in contact with the inferior surface of bladder. The apex is directed downward. The prostate consists of glands, ducts and involuntary muscles. The prostate secretes a fluid which is conveyed to the urethra through ducts.

**Semen:** Semen is the compound secretion of testes, prostate and seminal vesicles. Semen acts as a vehicle for spermatozoa and also it provides nutrition to the spermatozoa.

Semen is a thick, Whitish fluid which is very viscous in nature. It is slightly alkaline and has a pH of about 7.4. Each ejaculation produces 3ml of semen. Each ml. of semen normally contains about 60 to 100 millions spermatozoa.

**Spermatozoa:** Spermatozoa are produced by the seminiferous tubules of testes. Each spermatozoan contains a head, body and tail. The spermatozoa are highly motile and their function is to fertilise the ovum in the female genital tract.
16.2 Female Genital Organs

The female genital organ can be classified into:

1. Secondary organ: Breast (or mammary glands)
2. External genital organs: Mons veneris
   - Labia majora
   - Labia minora
   - Clitoris
   - Hymen
3. Internal genital organ: Vagian Uterus Oraries
   - Fallopian tubes

**Breast (Mammary glands):** They are accessory of secondary reproductive organ in the female. They secrete milk. The mammary glands are rudimentary in the males.

**Position:** The breasts lie on the pectoralis major muscle of both sides. On the sides, they extend between sternum and axilla. From above downwards, they extend between the 2nd and 6th rib.

**External features:** The breasts are more or less hemispherical in shape. They contain a small prominence in the middle called nipple.

Areola is a coloured area which surrounds the nipple.

![Breast Diagram](gland-fat-ampulla-nipple-deep-fascia-pectoralis-major)

**Fig. 16.3 Breast**

**Internal Structure:** The breast consist of a number of lobules which are made of columnar epithelium. these lobules are surrounded by fat. The lobules
give rise to lactiferous ducts which pass towards the nipple. These ducts have an enlargement at the end which is called ampulla.

**Development**: At birth, the breast is poorly developed and it contains only a rudimentary nipple. At puberty, the breast starts developing and the gland tissue increases. This is due to the action of oestrogen and progesterone secreted by the ovaries. The active development commences at the starting of menstrual life when there is deposition of fat and starting of menstrual life when there is deposition of fat and increase in size. After menopause, the ovaries lose their function and the breast also shrinks.

**Secretion of milk**: During pregnancy, oestrogen and progesterone secreted by the ovary, stimulate the growth of ducts and lobules of breast. Later, these two hormones are secreted by placenta and produce the same effect. After child birth, the secretion of these two hormones decreases. Now, milk secretion is stimulated by prolactin of anterior pituitary. Oxytocin of posterior pituitary is responsible for milk ejection.

**External Genital Organs**

![Fig. 16.4 External genital organs]

These organs are collectively known as vulva and it consists of the following parts:

1. **Mons veneris** (Mons pubis): It is a pad of fat in the female, lying in front of symphysis pubis. At puberty, this area is covered with hair (public hair).

2. **Labia majora**: They are two round thick folds of skin which form the sides of vulva.
3. **Labia minor** (nymphae) : They are two thin folds of skin which lie in the space enclosed by labia major. Vestibule is a triangular area which is enclosed by labia minora. The vestibule contains the opening of urethra and vagina.

4. **Clitoris** : It is a small erectile body which is situated at the apex of the vestibule. It is a highly sensitive structure and it corresponds with the penis in males.

5. **Hymen** : It is a thin membrane which covers the vaginal orifice of virgin women. It is usually perforated so as to allow menstrual flow.

**Internal genital organs**

- **Vagina** : It is a canal made of muscular walls. It extends from the vaginal orifice (in vestibule) below to the cervix of uterus above. The vagina is lined by a thin skin which is thrown into a number of folds. A small projection of the vagina above the outer surface of cervix of uterus is called as fornix.

- **Uterus**

  **Position** : Uterus or womb is a hollow muscular organ situated in the pelvis. It is covered by peritoneum and lies between the bladder in front and rectum behind.

![Fig. 16.5 Uterus](image.png)

- **Parts** : The uterus can be divided into three parts : 1) fundus 2) body 3) cervix.

  Funds is the upper part which lies above the two openings of fallopian tubes. Body is the part which lies between the fundus and cervix. Cervix is the lower constricted part. The cervix is continuous above with the body of uterus through an orifice called internal os. It is continuous below with the vagina through external os.

  Fallopian tubes are attached on either sides of the fundus of uterus. Ligaments
of uterus: The uterus is supported and held in position by means of two ligaments. They are:

(i) Two broad ligaments which are folds of peritoneum. They extend between the sides of uterus and the pelvic wall. The layers of broad ligaments contain 1) fallopian tube 2) round ligament 3) blood vessels, nerves and lymphatics.

(ii) Two round ligaments which extend from the uterus (below the fallopian tube) to labia majora.

Structure: The walls of the uterus are thick and consist of three layers. They are:

1. Outer peritoneal layer called perimetrium.
2. Middle muscular layer called myometrium.
3. Inner muscular layer called endometrium.

Functions of uterus

1. Plays an active part in menstruation.
2. Receives the fertilised ovum and retains it during pregnancy.
3. Expels the foetus by contraction of its muscular walls.

Ovaries

Position: The ovaries are two in number. They lie on either side of the uterus. A fold of peritoneum attaches the ovaries to posterior aspect of broad ligament. The ovaries lie below the fallopian tube of each side. Structure: The ovary contains:

1. A central soft tissue called stroma.
2. An outer surface called germinal epithelium.
   
   The germinal epithelium contains the graffian follicles. The graffian follicles contain the ova. The ova are surrounded by a fluid called liquor folliculi.
   
   Ovalation occurs due to the rupture of the graffian follicles. Corpus luteum is the graffian follicle which has liberated its ovum.

Functions of the ovary

1. Formation, development and liberation of ova.
2. Secretion of oestrogen (by graffian follicle).
3. Secretion of progesterone (by corpus follicle).

Fallopian Tubes (Uterine tubes): The fallopian tubes are two in number. They arise one on each side from the upper angles of uterus. They lie in the upper margin of broad ligament of uterus.

**Parts:** The fallopian tube has 1) an uterine end 2) an ampulla 3) a fimbrial end.

1. The uterine end is attached to the walls of uterus. The opening at this end continues with the cavity of uterus.
2. The ampulla is a slight enlargement near the fimbrial end.
3. The fimbrial end is the terminal portion of fallopian tube. This end has (i) finger like processes called fimbriae (ii) an opening which gives access to the peritoneal cavity.

**Structure:** The fallopian tube consists of
1. Outer peritoneal layer
2. Middle muscular layer
3. Inner mucous layer

**Functions:** The fallopian tube acts as a passage for ova from the ovary to uterus. Usually, the fertilisation of ovum by spermatozoa occurs in the fallopian tube.

**Puberty in females:** Puberty is the age at which internal reproductive organs mature. It usually occurs at the age of 10 to 14 years in girls. It is marked by the onset of menstruation (the menarche). The physical and physiological changes which occur at puberty are:

1. Maturation of ovaries, uterus and uterine tubes.
2. Enlargement of vagina and breasts.
3. Growth of axillary and public hair.
4. Increased growth and widening of pelvis.
5. Inset of menstruation and ovulation.
6. Increased deposition of fat in subcutaneous tissue.
7. Mental and emotional maturity.
Ovulation: Maturation of the graffian follicle and liberation of ovum is termed as ovulation. The ovary contains graffian follicles. These follicles are about 40,000 in number. They are formed even during foetal life.

Fig. 16.6 Ovary showing primordial follicle graffian follicle and corpus albicans

The rest get degenerated. But all the follicles are lost at menopause.

Ovary showing primordial follicle, graffian follicle and corpus albicans.

Ovulation occurs due to the rupture of the graffian follicles. This is stimulated by luteinising hormone (LH) of anterior pituitary. After discharging the ovum, the graffian follicle forms the corpus luteum. Estrogen is produced by the corpus luteum. If pregnancy takes place, the corpus luteum persists upto 5th or 6th month of pregnancy. If pregnancy does not take place, the corpus luteum and gets atrophied and forms Corpus albicans.

Ovulation occurs at about the 14th day of menstrual cycle. The ovum is discharged into the peritoneal cavity. It is carried to the fallopian tube by the action of fimbriae. The ovum gets fertilised in the fallopian tube and later gets embedded in the uterine wall. If the ovum is not fertilised, it is discharged through menstrual flow.

Menstruation: Menstruation starts at puberty. It stops temporarily during pregnancy but permanently at menopause. It occurs almost every 28 days. Menstruation involves periodic discharged of blood from uterine cavity. During menstrual cycle, the endometrium undergoes cyclic changes and is prepared to receive the fertilised ovum. These endometrial changes are also associated with changes in the ovary.

Changes in the endometrium during menstrual cycle be divided into the following phases based on changes occurring in the uterus:

1. Destructive phase (Menstrual phase): It is the phase lasting for the first five days of the cycle during which menstrual bleeding occurs.
Fig. 16.7 Changes in endometrium during menstrual cycle

2. Follicular phase (Proliferative phase): If extends for the next 9 days. During this time, repair of the endometrium occurs. At this stage, the graffian follicle of ovary matures (for this FSH of anterior pituitary is necessary) and ova develop inside. The graffian follicle now secretes oestrogen. Around the 14th day of the menstrual cycle, the graffian follicle ruptures and releases the ova. The graffian follicle now becomes corpus luteum.

3. Luteal phase (Secretory phase): It is the phase lasting for the next 14 days. During this phase, the endometrium becomes thick and vascular so as to receive the fertilised becomes thick and vascular so as to receive the fertilised ovum. Now the corpus luteum secretes progesterone (For this LH of anterior pituitary is necessary). If conception occurs by implantation of the fertilised ovum, the secretion of progesterone continues throughout pregnancy. Otherwise the corpus luteum begins to degenerate and does not produce progesterone. Later, the capillaries of endometrium burst and menstruation occurs (The first day of menstrual flow is designated as Day 1 of menstrual cycle).

Menopause (Climacteric): It is the cessation of menstruation which occurs in a women’s life at about years of age. It is caused by changes in the concentration of sex hormones. The ovaries becomes less responsive to FSH and LH. So ovulation and menstrual cycle become irregular and stop ultimatey. Menopause is accompanies by certain changes like 1. flushing and sweating 2. shrinkage of breast 3. atrophy
16.3 Physical changes during pregnancy

Gynecology:

Labour (child birth, Parturation)

Full term labour takes place up to 40 weeks of pregnancy, but normal limits are within 2 weeks either side of this estimated delivery date (EDD).

Signs of labour

1. Cervix is dilated more than 2 cm.
2. Contraction are strong, regular and frequent.
3. During early cervical dilatation, Mucus discharge called “the Show” is discharged.
4. Natural rupture of the amniotic membranes termed “waters breaking” usually occurs in labour.

Various stages of labour

There are 3 stages of labour

1. First stage - Cervical dilatation:

   This takes 12 hours in primary gravida, 7 1/2 hours in secondary gravida.
   - Contractions increase variability, until cervix is fully dilated
   - Each contraction produces a wave of sensation, starting with a feeling of tightening in the abdomen and reaching the peak of intensity before dying away.
   - Pain also felt in the lumbar, public and often the thighs.

Second stage:

The birth primagravida

- Thus takes of 1 hour in 8-15 minutes in multigravida.
- Pushing and straining of diaphragm and abdominal muscle reflexly osirnt uterus to expel the baby through the curved birth canal.
- Expulsion effort delivers anterior shoulder first from under public and then posterior shoulder, trunk & legs. The baby is born.
3. **Third Stage**

The cord divided near the baby abdomen and with in 5 minutes of so of birth the placenta has sperated from the uterus. Placenta is enpelled with the cord and membrane. Thos Completes the labour.

**Clinical Managment**

1. **Episiotomy**: A small incision in the prinieum will make a much larger space for baby to deliver.

2. **Forceps entraction**: The blades of foreceps fot the sides of the baby’s head & gentle smooth movements are used with uterine contractions to lift the baby out.

3. **Calsarean section**: A transverse intision is made through the skin and muscles of the lower abdomen known as “Bikimi Incision” so that baby and placenta may be removed.

**Clinical Management for Pain During Labour**

1. **Aunalgesics**: Pethidine is a muscle relavant and also induces drowsiners. It also helps in controlling pain during labour.

2. **Epidural analgesia**: Anadesthestic agent intraduced into dural space between the durameter & the perisosteum. It also helps in controlling pain.

**Physiotherapy Management During Labour**

Application of TNS, in the lawer abdominal ragion helps in controlling the pain.

**Physiological changes during Pregnancy**:  

Different Physiolgical changes are:

1. Uterus grows from a weight of 50gms. to 950gms. at term.
2. Endometrium Thickness as blood supply increases.
3. The cervik and vagina are more vasucular and sgter with increased secretion of mucus.
4. Abdominal muscle fibers lengthen and as the liner alba seperates (diastheses).
5. Skin pigmentation causes the nipples and ageola to darken and a fine brown line.
6. Tadalafil called ralane is released into body, it causes hypermobility of joints.

7. There is 50% increase in blood plasma-volume by 34th week.

8. White cell count increases to give protection against infection.

9. Urinary tract infections sometimes occur due to the bladder and uterus encouraging urinary stasis.

10. Thyroid, Suprarenal and pituitary endocrine glands enlarge to improve their metabolic function.

11. Posture and gait changes as the weight increases in the abdomen and pelvic joints relax.

12. Center of gravity shifts forwards resulting in strain on the lumbar spine as abdominal muscles lengthen.

16.4 Family planning and types of contraceptives

Population problem: Increase in population is an important problem of India. India is the second populated country in the world next to China. India’s population is nearly 700 millions. If growth rate is not checked, the population is expected to reach 1000 millions by 2000 A.D. The increase in population is due to advances in medical sciences, nutrition and control of various diseases. Increase in birth rate is due to lack of family planning.

Family planning: Family planning is a family health and welfare programme with the following objectives. 1) To limit child birth 2) to have proper interval between two successive children 3) health care of mother and child.

Contraceptive methods: The methods by which pregnancy can be prevented are classified as follows:

1. Temporary methods
   1. Natural: Rhythm method
      Carvical mucus method
      Coitus interruptus
      Abstinence
   2. Chemical: Foam tablets
      Jellies and pastes
3. Mechanical: Condom
   Diaphragm

Intra uterine contraceptive devices (UCD)

4. Hormonal: Oral contraceptives


ii. Permanent methods (Sterilisation)

1. Males: Vasectomy
2. Females: Laprascopy

Natural Methods

Rhythm method (Safe period method): A week before and week after
menses in considered tobe a safe period which can avoid conception. During
these days, ovulation does not occur and so pregnancy can be prevented. A few
disadvantages of this method are: (1) In case of irregular menstrual cycle,
prediction of safe period is difficult (2) Failure can occur to the extent of 20%

Cerical muscus method: At the time of ovulation, the cervical muscus
becomes thin, clear and watery. Days between the 3rd and 7th day of muscus
secretion is the period of conception. Coitus can be avoided during these days
to prevent pregnancy.

Colitus Interruptus: Withdrawl of the penis before ejaculation is called
coitus interrupts. This method is difficult to practice. Also it is not reliable method.

Abstinence: Keeping away from sexual contact is the best method which
can prevent pregnancy. But this method is impractical.

Chemical Methods

Foam tablets: These tablets generate foam when moistened and introduced
into the vagina. The foam interferes with the free movement of sperm. Also the
tablets contain some chemical substances which destroy the sperm.

Advantages: These tablets are cheap and easy to use. Disadvantages:
Irritation or burning sensation in the vagina.

Jellies, creams and pastes: These substances are applied into the vagina by
a special appicator. They melt and a spread into the vagina producing a
spermicidal action. Again these substances should not be used in case of irritation.
Mechanical Methods

**Condom**: Condoms are made of latex and can be rolled over the penis before sexual intercourse. The condom collects the semen and therefore prevents the entry of sperm into the vagina. Use of condom is a very safe, easy and cheap method. Also it can provide safety against sexually transmitted diseases. The only disadvantage is interference with local sex sensation.

**Diaphragm**: It is rubber dome with a flexible rim made of metal or spring. The diaphragm is fitted into the vagina before sexual intercourse. It should remain in place at least 5 hours after intercourse. The diaphragm prevents the entry of sperm into the vagina. It is relatively as safe method, but a doctor or nurse is required to fit the diaphragm. Intra Uterine contraceptive devices (IUCD).

The intra uterine contraceptive devices are inserted into the uterine cavity. The do not prevent the fertilisation of ovum. But the fertilised ovum is prevented from implantation in the uterus. The two devices commonly used are : (1) Lippes loop (2) Copper - T.

**Lippes loop**: It double - S shaped device made of polyethylene. It has attached threads which project into the vagina. The threads can be easily felt which assures that the loop is in place. The advantages of Lippes loop are :

1. Easy insertion  
2. Inexpensive  
3. Reversible  
4. Prolonged safety.

**Copper - T**: Metallic copper has strong antifertility effect. Copper - T when introduced into the uterine cavity dissolves slowly and prevents conception.

**Oral Contraceptives**

Oral contraceptives commonly called as ‘pill’ prevent conception by preventing ovulation. The following is the principle behind the use of oral contraceptives. During pregnancy there is a high level of oestrogen and progesterone which are ovarian hormones. These prevent ovulation. So ovulation and therefore conception can be prevented by administering these hormones. The oral contraceptives contain oestrogen and progesterone is the form of tablets. The tablets should be taken for 21 days starting from the 5th day of the menstrual cycle. Advantages of oral contraceptives are : easy administration, reversibility and less failure (0.7%).

**Pregnancy - Termination**

These methods are used after conception has occurred. These methods include menstrual regulation and abortion.
Menstrual regulation: It involves aspiration of uterine contents within 6 days a missed period.

Abortion: It is termination of pregnancy before the 28th week of gestation. The first 10 weeks is the safest period for inducing abortion. Abortion can be done by two techniques: 1. Dilatation and curettage (D & C) 2. Vacuum aspiration. The disadvantages of abortion are bleeding, infection and perforation of uterus.

Permanent methods (Sterilisation)

Sterilisation is the method by which a male or female is rendered permanently infertile. The procedure of sterilisation in male is called vasectomy and that in female is called tubectomy.

Vasectomy: It is the sterilisation procedure in males. In this method, a piece of vas deferens is cut and clamped. It is usually done through scrotal route.

Advantages:

1. It is a simple surgical procedure.
2. No hospitalisation is required
3. Most effective and successful method.

Disadvantages

1. Occasional infections and sperm granuloma.

Tubectomy: It is a sterilisation procedure in the females. It this method, the fallopian tubes of both sides are cut and clamped. This prevents the transport of ovum. The best time for tubectomy is after delivery. At this time, the fallopian tubes are easily approachable. Also an extended stay in the hospital can be avoided when tubectomy is done at this time.

Laparoscopy: It is the recent method of sterilisation in females. By this method, the fallopian tubes are sealed by passing a beam of light from a device. It is a simple and effective method and the patient can be discharged on the same day.

Short Answer Type Questions

1. Write the names of male reproductive system.
2. Write the names of female reproductive system.
3. Write about testis.
4. Write about functions of uterus.
5. Write about ovaries.
6. What are the functions of ovaries?
7. Write the parts of fallopian tubes.
8. What is ovulation?
9. What is menopause?
10. What is fertilization?
11. Write about placenta.
12. What are the functions of umbilical cord?
13. Write the different types of contraceptive methods?

**Long Answer Type Questions**

1. Explain the structure of male reproductive system.
2. Explain the structure of female reproductive system.
3. Explain the phases of menstrual cycle.
4. What are the physiological changes that occur during pregnancy?
5. What are sex hormones and write their functions?