Chapter

1

Anatomical Terminology

1.1 DEMONSTRATE NORMAL ANATOMICAL POSITION, VARIOUS PLANES, RELATION, COMPARISON, LATERALITY AND MOVEMENT IN OUR BODY

SHORT ESSAYS

1. Describe the terms of relationship and comparison in human body.

Term	*Meaning*
Superior	Nearer to the vertex of the skull
Inferior	Nearer to the sole of the foot
Cranial	Nearer to the skull
Caudal	Nearer to the tail/feet
Anterior	Nearer to the front of the body
Posterior	Nearer to the back of the body
Ventral	Nearer to the belly/front
Dorsal	Nearer to the back
Rostral	Nearer to the front (particularly used for describing structures in brain)
Medial	Nearer to midline of the body
Lateral	Farther from the midline of the body
Superficial	Nearer to the skin
Intermediate	In between superficial and deep
Deep	Farther from the skin
External	Outside of an organ/part of the body
Internal	Inside of an organ/part of the body
Proximal	Nearer to the root of a structure or a limb
Distal	Farther to the root of a structure or a limb

2. Describe the terms of movement.

Term	*Meaning*
Flexion	Movement that decreases in the angle between the anterior surface of two bones or bending
Extension	Movement that increases in the angle between the anterior surface of two bones or straightening
Right/left lateral flexion	Movement that causes bending towards right or left side of the body (possible only with neck and trunk)
Adduction	Moving towards the median plane
Abduction	Moving away from the median plane
Circumduction	A sequential movement involving flexion, abduction, extension, and adduction so that distal part of the structure moves in a circle
Rotation	Revolving of a part of the body around its own axis
Elevation	Raises a part upwards/superiorly
Depression	Lowers a part downwards/inferiorly
Medial rotation	Movement that brings the anterior surface of a limb closer to the midline
Lateral rotation	Movement that takes the anterior surface of the limb away from midline
Protrusion	Forward movement (as in scapula and mandible)

Term	*Meaning*
Retrusion/ retraction	Forward movement (as in scapula and mandible)
Pronation	*Occurs exclusively in forearm:* Movement that causes palm to face posteriorly and dorsum of the hand to face anteriorly
Supination	*Occurs exclusively in forearm:* Movement that causes palm to face anteriorly and dorsum of the hand to face posteriorly
Opposition	Movement that allows the tip of the thumb to touch tips of other fingers across the palm
Reposition	Movement that brings the tip of the thumb from opposition to normal position
Inversion	*Occurs exclusively in foot:* Movement that causes medial border of the sole to face upwards
Eversion	*Occurs exclusively in forearm:* Movement that causes lateral border of the sole to face upwards

SHORT ANSWERS

1. Describe the anatomical position of the human body.

In the anatomical position, the human body is:

- Standing straight with looking straightforward (Figs 1.1.1 and 1.1.2)

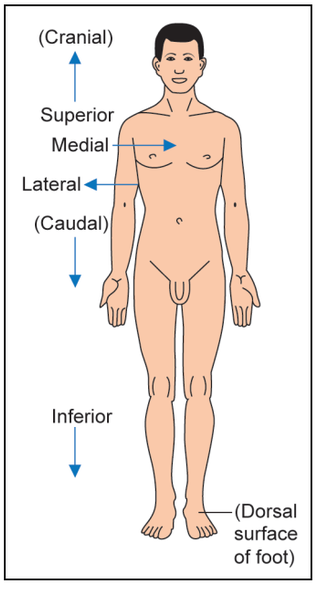


Fig. 1.1.1: Anatomical position of the human body

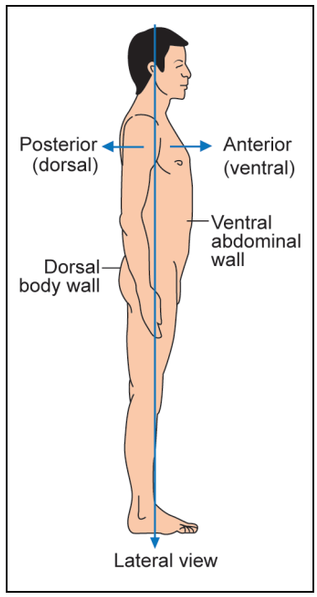


Fig. 1.1.2: Anatomical position of the human body

- Both the upper limbs by the bodyside with palms forward-facing
- Feet approximated together with the toes pointing forwards

2. An Intern enters the casualty department, where a Consultant is looking at a CT scan of the head. The Consultant asks the Intern to describe the meaning of coronal, median, sagittal and transverse planes. Define all the above mentioned anatomical planes.

Anatomical Planes (Fig. 1.1.3)

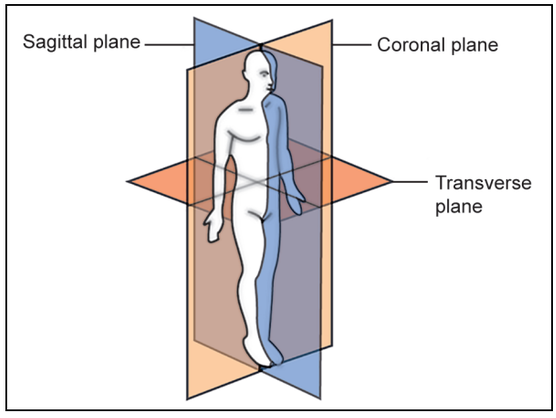


Fig. 1.1.3: Anatomical planes of the human body

1. **Midsagittal plane or median plane**
   - Passes through the center of the body
   - The body is divided into two equal halves—right and left
2. **Sagittal plane:** Any longitudinal plane which is parallel to the midsagittal plane
3. **Coronal plane**
   - This plane is perpendicular to the sagittal plane
   - The body is divided into two halves—anterior and posterior
4. **Transverse plane**
   - Perpendicular plane to the sagittal and coronal planes
   - The body is divided into two parts—upper and lower

3. Describe the use of anatomical planes in practice of medicine.

Anatomical planes are used to describe sections:

1. **Transverse/cross section:** In this section, the slices of the body are cut in a plane perpendicular to the longitudinal axis of the body or parts of the body (as in a CT scan)
2. **Longitudinal section:** This section passes parallel to the longitudinal axis of the body or parts of the body
3. **Oblique section:** Refers to section of the body cut in planes/direction excluding the transverse and longitudinal sections
4. **Describe the terms of laterality.**

Term	*Meaning*
Unilateral	Structures present on one side of the body only (E.g.: spleen, liver)
Bilateral	Structures present on both sides of the body (E.g.: kidneys, lungs)
Ipsilateral	Structures present on same side of the body (E.g.: right thumb and right toe)
Contralateral	Structures present on different sides of the body (E.g.: right thumb and left thumb)

1.2 DESCRIBE COMPOSITION OF BONE AND BONE MARROW

SHORT ESSAY

1. Describe the composition of bone.

Bone is a highly vascularised, mineralized, living and specialized connective tissue made of cells embedded in an extracellular matrix.

Composition of Bone

A. Cells

B. Extracellular matrix
   - Ground substance
   - Fibers

A. Cells: Five Types

1. **Osteoprogenitor cells**
   - These are the stem cells which can give rise to other types of cells
   - They are derived from mesenchymal stem cells
   - These are present on the external and internal surfaces of the bone
2. **Osteoblasts**
   - These are cells which produce the bone matrix
   - Arise from the osteoprogenitor cells
   - These give rise to the osteocytes (only 10–20% of osteoblasts give rise to osteocytes)
   - Produces an unmineralized matrix known as osteoid
   - Produces osteocalcin, alkaline phosphatase, and matrix vesicles, which assist in mineralization of the osteoid
3. **Osteocytes**
   - Formed when an osteoblast is surrounded by matrix
   - Flattened cells with cytoplasmic processes which communicate with each other by gap junctions
   - Located in space called lacunae and canaliculi
   - The nutritive material diffuses through the canaliculi radiating from lacuna
   - Apart from maintaining bone, these also play a role in mechanotransduction (increased and decreased mechanical stimuli will lead to bone formation and bone loss, respectively)

4. **Osteoclasts**
   - Derived from the fusion of uncommitted cells of red bone marrow
   - Large cells with many nuclei
   - Vital role in bone remodeling by resorbing the bone
   - Present in Howship's lacunae—which are shallow depressions of the bone
5. **Bone lining cells**
   - Two types—periosteal and endosteal cells
   - Derived from the osteoblasts
   - Provide nutrition to osteocytes

B. Extracellular Matrix

Ground substance

- Proteoglycans—chondroitin sulfate, keratan sulfate
- Glycoproteins—osteonectin, osteocalcin
- Mineral component—hydroxyapatite, citrate ions, bicarbonate ions
- Water—7%

Fibers

- Type I collagen fibers
- Gives tensile strength

SHORT ANSWERS

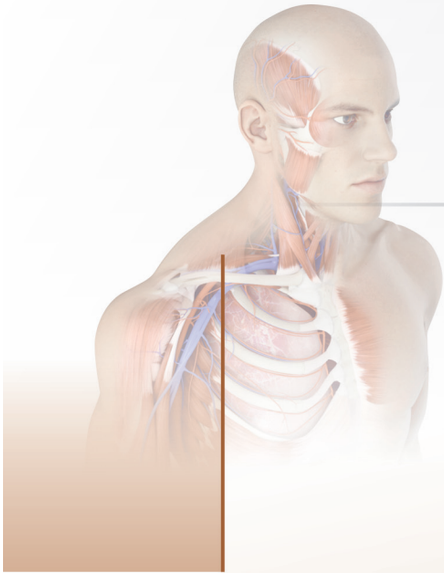
1. Enumerate the bone cells and mention at least one function of each cell.

Bone cells	*Functions*
Osteoprogenitor cells	• Give rise to osteoblasts and other bone cells
Osteoblasts	• Produce osteoid—unmineralized matrix, made of proteoglycans, glycoproteins, type I collagen fibers • Produce osteocalcin, alkaline phosphatase cause the release of calcium and phosphate • Produce matrix vesicles—concentrate calcium and phosphate—vital for mineralization
Osteocytes	• Have balanced osteogenic and osteoclastic activity—maintain the bone • Alkaline phosphatase secreted—maintain calcification
Osteoclasts	• Vital role in bone remodeling by resorbing the bone
Bone lining cells	• Provide nutritional support to the osteocytes

2. Compare and contrast the features of compact/dense and cancellous/spongy bone.

- The classification into compact and spongy bone depends on the amount of solid bony tissue present and the size and number of spaces present within bony tissue
- Compact bone has more solid bony tissue, less and smaller spaces within and vice versa in case of cancellous bone

Feature	*Compact bone*	*Cancellous bone*
Density	Dense	Porous
Location	Outer part of the bone	Inner part of the bone
Lamellae	Regular	Irregular
Haversian system	Present	Absent
Bone marrow	Absent	Present
Percentage in the body by weight	75%	25%



Chapter

2

General Features of Bones and Joints

2.1 DESCRIBE PARTS, BLOOD AND NERVE SUPPLY OF A LONG BONE

SHORT ESSAYS

1. Classify bones according to shape. Give an example for each type.

Type of bone	*Feature*	*Example*
Long bones (Fig. 2.1.1)	Length of the bone is greater than breadth and thickness	Typical long bone—femur, humerus Short/miniature long bone—phalanges
Short bones (Fig. 2.1.2)	Smaller in size, typical cuboid shaped	Carpal bones
Flat bones (Fig. 2.1.3)	Flat/plate-like bone, shallow	Frontal bone, rib
Irregular bones (Fig. 2.1.4)	Irregular shaped	Vertebrae
Sesamoid bones (Fig. 2.1.5)	Develops in muscle tendons	Patella
Pneumatic bones	Irregular shaped, composed of air-filled cavity within	Maxilla
Accessory bones	Not present in the body usually	Sutural or wormian bones

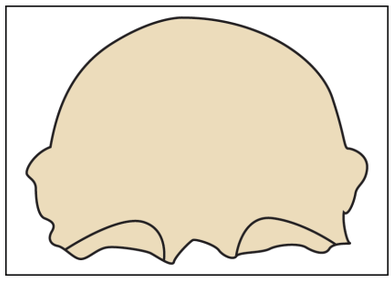


Fig. 2.1.1: Frontal bone (flat bone)

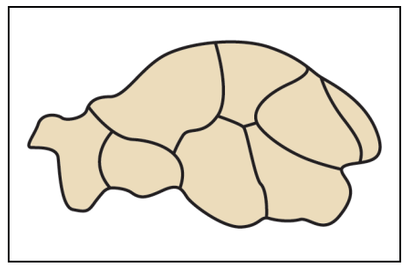


Fig. 2.1.2: Carpals (short bone)

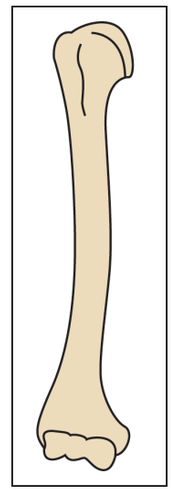


Fig. 2.1.3: Humerus (long bone)

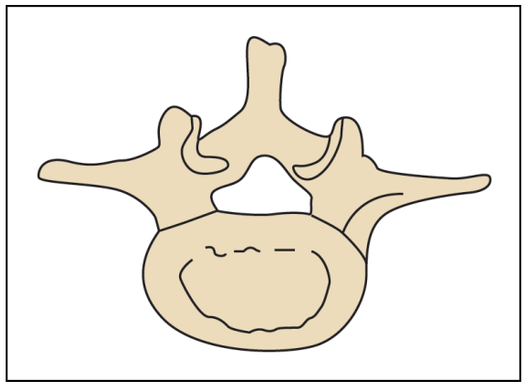


Fig. 2.1.4: Vertebra (irregular bone)

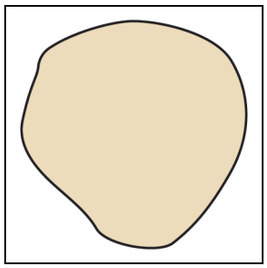


Fig. 2.1.5: Patella (sesamoid bone)

2. Describe the parts of a growing long bone.

Parts of growing long bone (Fig. 2.1.6)

1. **Epiphysis**
   - Refers to the ends of long bones ossifying from secondary centers
   - 4 types:
     1. *Pressure epiphysis*
        - Covered by articular cartilage
        - Transmits body weight
        - E.g.—femoral head
     2. *Traction epiphysis*
        - Caused by muscle pull
        - Non-articular
        - Provides attachment to the muscle
        - Ossification occurs after pressure epiphysis
        - E.g.—trochanters of femur
     3. *Atavistic epiphysis*
        - Found as an independent bone in lower mammals
        - Fuses to the nearby bone in humans, receiving the nutrition from it
        - E.g.— coracoid process of scapula
     4. *Aberrant epiphysis*
        - Appears at unusual end of a short long bone
        - E.g.—Epiphysis at the head of the first metacarpal
2. **Epiphyseal plate**
   - Hyaline cartilage plate
   - Between the epiphysis and diaphysis of growing bone
   - It presents as long as the bone grows in length
   - Once bone growth is complete, the cartilage is replaced by bone
   - Nourished by epiphyseal and metaphyseal arteries
3. **Metaphysis**
   - The diaphyseal end towards epiphyseal cartilage
   - This is the most actively growing area of the long bone
   - Close to the metaphysis, capsule of the joint, ligaments and muscles are attached
   - Metaphysis has profuse blood supply. The nutrient arteries form hairpin-like bend here and

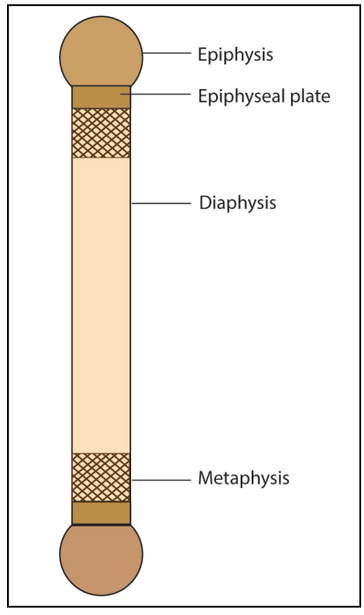


Fig. 2.1.6: Parts of a growing long bone

favour the settling of microorganisms. Hence metaphysis is the common site of infection in a growing bone

4. **Diaphysis**
   - It is the elongated part of the bone between the two metaphyseal ends
   - Develops from primary ossification center

3. Describe epiphysis. Mention the types with an example for each.

Epiphysis

- Ends of long bones ossifying from secondary centers
- 4 types:
  1. *Pressure epiphysis* (Fig. 2.1.7)
     - Covered by articular cartilage
     - Transmits body weight
     - E.g.—femoral head
  2. *Traction epiphysis* (Fig. 2.1.7)
     - Caused by muscle pull
     - Non-articular
     - Provides attachment to the muscle
     - Ossification occurs after pressure epiphysis
     - E.g.—trochanters of femur
  3. *Atavistic epiphysis* (Fig. 2.1.8)
     - Found as an independent bone in lower mammals
     - Fuses to the nearby bone in humans, receiving the nutrition from it
     - E.g.—coracoid process of scapula

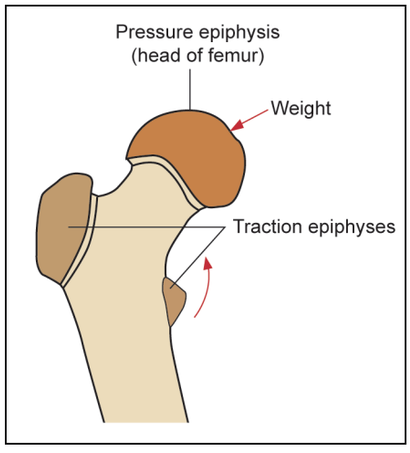


Fig. 2.1.7: Pressure and traction epiphyses

4. *Aberrant epiphysis* (Fig. 2.1.9)
   - Appears at unusual end of a short long bone
   - E.g.—1st metacarpal bone head epiphysis

4. Describe the blood supply of the long bone.

Supplied by 4 sets of arteries—nutrient, periosteal, metaphyseal, epiphyseal (Fig. 2.1.10)

1. **Nutrient artery**
   - Enters the shaft in the middle
   - Enters through the nutrient foramen
   - Has an oblique course in the cortex of the bone
   - In the medullary cavity, it divides into ascending and descending branches

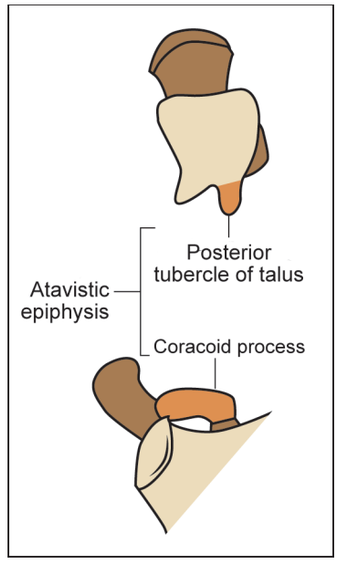


Fig. 2.1.8: Atavistic epiphysis

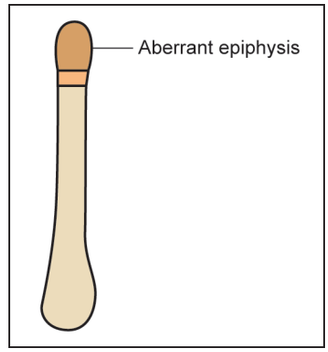


Fig. 2.1.9: Aberrant epiphysis

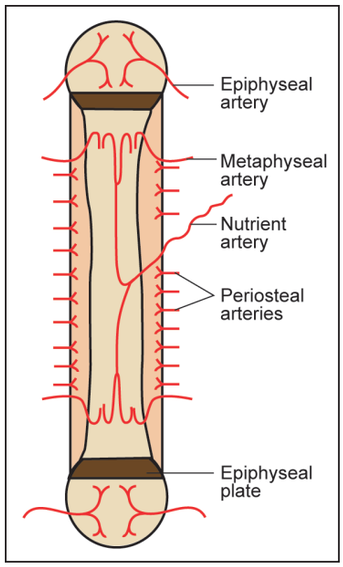


Fig. 2.1.10: Blood supply of a growing long bone

- The branches subdivide into numerous smaller parallel vessels
- These vessels form hairpin loops in the metaphysis
- The loops anastomose with epiphyseal, juxta-epiphyseal, and periosteal arteries
- Supplies the medullary cavity which contains the bone marrow and inner two-thirds of the outer shell of diaphysis and metaphysis

2. **Periosteal arteries**
   - They are numerous
   - Ramify below periosteum
   - Supply the outer third of the cortex by entering the Volkmann's canals
   - More numerous below the ligamentous and muscular attachments
3. **Metaphyseal/Juxtaepiphyseal arteries**
   - Derived from anastomosis around the joint and enter the bone by piercing the joint capsule
   - Directly enters the metaphysis along joint capsule attachments
4. **Epiphyseal arteries:** Derived from circulus vasculosus, i.e., arterial anastomosis around the joint

There are Two Types of Epiphyseal Arteries

1. When articular cartilage and epiphyseal cartilage is a single continuous structure (as in head of femur), the epiphyseal artery pierces the epiphyseal cartilage before supplying epiphysis. These types of arteries when injured produce avascular necrosis
2. When articular cartilage and epiphyseal cartilage is not continuous, the epiphyseal artery enters without piercing the epiphyseal cartilage. Injury of such arteries does not result in avascular necrosis

5. Compare and contrast membranous and cartilaginous ossification.

	Membranous ossification	*Cartilaginous ossification*
Step 1	Condensation of mesenchymal tissue to form membranous sheet model Osteoblasts are formed from the osteoprogenitor cells The site of appearance of osteoblasts is termed as ossification center	Chondroblasts of cartilaginous model enlarge and calcification of surrounding matrix occurs due to alkaline phosphatase secreted
Step 2	Ground substance and collagen fibers are secreted by the osteoblasts into the intercellular spaces forming the osteoid tissue or bone matrix	The death and disappearance of the chondroblasts leads to formation of empty spaces called primary areolae
Step 3	Osteoid tissue gets mineralized with calcium salts under the influence of alkaline phosphatase secreted by osteoblasts, leading to bone formation The osteoblasts trapped in mineralized matrix are called osteocytes	Osteoblasts are formed by differentiation of cells on the periosteal surface They enter at the ossification site (periosteal bud) along with blood vessels
Step 4		Majority of the calcified matrix is absorbed to form secondary areolae, which are large empty spaces A thin bar of calcified matrix is left behind
Step 5		Osteoid (new bone) is laid on the surface of calcified bar of matrix
Step 6		Mineralization of osteoid

6. Hyoid bone belongs to the axial skeleton of human skeletal system. Is this statement true? Classify human skeletal system with examples.

Yes, hyoid bone is included as a part of the axial skeleton.

Classification of Human Skeletal System with Examples

Human skeletal system is classified into two parts

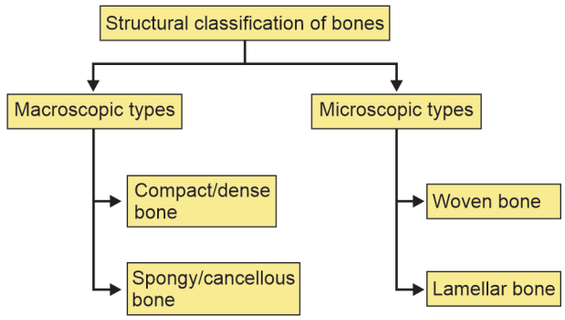
- **Axial skeleton:** Includes bones that form the central axis of the body and is made up of:
  1. Skull (28 bones)
  2. Hyoid bone (1)
  3. Vertebral column (7 cervical, 12 thoracic, 5 lumbar, 5 sacral and 3–4 coccygeal vertebrae)
  4. Ribs (12 pairs)
  5. Sternum (1)
- **Appendicular skeleton:** Includes bones of the limbs
  a. ***Girdle bones***
     1. *Upper limb:* Clavicle (2) and scapula (2)
     2. *Lower limb:* Hip bone (2)
  b. ***Bones of free limb***
     1. *Upper limb:* Humerus (2), radius (2), ulna (2), skeleton of hand (8 carpals, 5 metacarpals, 2 phalanges in thumb and 3 phalanges in rest of the fingers of each hand)
     2. *Lower limb:* Femur (2), tibia (2), fibula (2), patella (2), skeleton of foot (7 tarsals, 5 metatarsals, 2 phalanges in great toe and 3 phalanges in rest of the toes of each foot)

7. Metacarpal bone is an example for a modified long bone. Is this statement true? Classify the bones based on their shape.

- Yes, metacarpal bone is an example for modified long bone
- Based on the shape, bones are classified as,

Type of bone	*Feature*	*Examples*
Long bones 1a. Typical long bones	These are tubular bones with length more than width These bones have two ends (epiphysis) and a shaft (diaphysis)	Long bones of the limbs (humerus, radius, ulna, femur, tibia and fibula)
1b. Modified long bones	These bones have epiphysis at only one end and a shaft	Metacarpal
Short bones	These are short, cuboidal shaped bones with length almost equal to width	Carpal and tarsal bones
Flat bones	These are flat, plate like bones	Bones forming vault of the skull, ribs, sternum
Irregular bones	These bones do not have a characteristic shape	Vertebra and hip bone
Sesamoid bones	These bones develop within the tendons of the muscles	Patella, pisiform
Pneumatic bones	These bones are filled with air to make them lighter	Maxilla, ethmoidal, frontal and sphenoidal bone
Accessory bones	These bones are not always present	Wormian bones of the skull

8. Describe the structural classification of bones.



Bones can be classified based on their macroscopic (gross) and microscopic appearance.

1. **Macroscopic classification:** Based on the structure as seen with naked eyes.
   i. *Compact/dense bone:* Refers to the outer part of the bone that is dense and compact, (e.g. cortex of the bone)
   ii. *Spongy/cancellous bone:* Refers to the sponge like meshwork found inside the bone forming the medullary cavity and filled with bone marrow
2. **Microscopic classification:** Based on the structure as seen with the help of a microscope.
   i. *Immature/Woven bone*
      - Also called bundle/non-lamellar bones
      - These bones are found in fetus during development
      - They do not have an organised/lamellated appearance
      - These contain more cells than per unit area than in mature bone
      - The cells are irregularly/randomly arranged
      - The matrix has more ground substance
      - The matrix stains with haematoxylin
   ii. *Mature/Lamellar bone*
      - Composed of units called osteons/Haversian systems
      - They have an organised/lamellated appearance
      - These contain less cells than per unit area than in mature bone
      - The cells are regularly arranged
      - The matrix has less ground substance
      - The matrix stains with eosin

SHORT ANSWERS

1. Compare and contrast the features of a long bone with a miniature long bone.

Long bone	*Miniature long bone*
Long, with length more than breadth and thickness	Shorter than typical long bone, but length more than breadth and thickness
Has two epiphysis at the ends and an intervening diaphysis	Has epiphysis at one end only
E.g.—femur, humerus, radius	E.g.—metacarpals, metatarsals, phalanges

2. What are pneumatic bones? What are their functional roles? Give one example.

Pneumatic Bones

- Type of irregular bone
- Contains cavity filled with air and lined by mucous membrane
- Mostly found in the face, around the nose

Functional Role

- Lighten the skull
- Resonance added to the voice
- Condition the inspired air

Example

Maxilla

3. What are accessory bones? How do they differ from heterotopic bones?

Accessory/Supernumerary Bones

- These bones are not found in the body usually.
- These bones usually results because of appearance of extra center of ossification and failure of this center to fuse with the main bone
- E.g.—sutural or wormian bones

Heterotopic Bones

- Formed pathologically in a muscle or soft tissue following trauma or surgery
- Usually occurs due to the ossification of the clot that is produced as a result of trauma.

4. How bones are classified according to the process of development? Give example for each.

- Membranous bones—bones of the cranial vault
- Cartilaginous bones—vertebrae
- Membrano-cartilagenous bones—mandible

5. What is periosteum? What is its functional significance?

Periosteum

- Thick fibromembranous external covering of the bone
- It has two layers—outer fibrous and inner cellular

Functional Significance

- Protection and maintenance of bone shape
- Nourishment of outer part of cortex
- Ligaments, tendons, intermuscular septa attached to it
- Helps in bone regeneration

6. Compare and contrast pressure epiphysis and traction epiphysis.

Pressure epiphysis	*Traction epiphysis*
Found in the joints	Not involved in the joints
The bone is subjected to pressure	The bone is subjected to muscle pull
Assist in weight transmission	Provide attachment to muscles
Ossify earlier	Ossify after the pressure epiphysis
E.g.—head of femur	E.g.—trochanters of femur

7. What is atavistic epiphysis and how does it differ from the aberrant epiphysis?

Atavistic Epiphysis

- Found as an independent bone in lower mammals
- Fuses to the nearby bone in humans, receiving the nutrition from it
- E.g.—coracoid process of scapula

Aberrant Epiphysis

- Appears at unusual end of a short long bone
- E.g.—1st metacarpal bone head epiphysis

8. Metaphysis is a common site of osteomyelitis in children. Explain its anatomical basis.

- Prior to epiphysis fusion, metaphysis has abundant blood supply by nutrient, metaphyseal, periosteal arteries
- The nutrient arteries form a hairpin bend close to the metaphysis
- The emboli or bacteria tend to get trapped at these bends leading to osteomyelitis in children
- In adults, after epiphyseal fusion, the arteries communicate with epiphyseal arteries. Thus, it is a rare site for osteomyelitis in adults.

9. Classify the bones based on their development.

Based on the development, bones are classified as:

1. **Membranous bones**
   - These bones develop by membranous ossification
   - Example—bones of the vault of skull
2. **Cartilaginous bones**
   - These bones develop by cartilaginous ossification
   - E.g.—long bones of the limbs (humerus, femur)
3. **Membrano-cartilaginous bones**
   - These bones develop by both membranous and cartilaginous ossification
   - E.g.—clavicle, mandible

2.2 ENUMERATE LAWS OF OSSIFICATION

SHORT ANSWERS

1. Enumerate the laws of ossification.

Laws of Ossification

- Primary centers of ossification always appear before birth (exceptions are carpal bones, navicular bone and cuneiform which appear after birth)
- Secondary centers of ossification always appear after birth [exceptions are the lower end of the femur and occasionally the upper end of the tibia for which secondary centers appear before birth]
- As a rule, ossification centers which appear first fuses last and vice versa
- Centers for pressure epiphysis fuse first compared to centers for traction epiphysis
- The foramen for the nutrient artery is always directed away from the growing end of the bone. (can be remembered as "to the elbow I go and from the knee, I flee").

2. Describe the law of union of epiphysis.

Law of the Union of Epiphysis

- Ossification centers which appear first fuses last, and centers which appear last will fuse first
- Exception: In fibula, the center for the lower end appears first and fuses first. This is because the upper end of the fibula is an example for traction epiphysis, whereas the lower end is a pressure epiphysis. As per the laws of ossification centers for pressure epiphysis fuses first.

2.3 ENUMERATE SPECIAL FEATURES OF A SESAMOID BONE

SHORT ANSWER

1. Describe the features of a sesamoid bone.

Sesamoid Bone (Fig. 2.1.5)

Sesamoid bones are small seed-like bones which develops within the muscle tendons.

Features

- Lacks periosteum
- Is avascular (derives the nutrition from the synovial fluid)
- The rubbing surface is covered with articular cartilage
- Ossification occurs post-birth, commonly by multiple centers
- No Haversian system

Functions

- Pulley for muscle contraction
- Changes the direction of muscle pull
- The friction of tendon against the bone is minimized

Examples

- Patella—in the tendon of quadriceps femoris
- Pisiform—within the tendon of flexor carpi ulnaris

2.4 DESCRIBE VARIOUS TYPES OF CARTILAGE WITH THEIR STRUCTURE AND DISTRIBUTION IN BODY

SHORT ESSAY

1. Compare and contrast the features of hyaline and elastic cartilage.

Feature	*Hyaline cartilage (Fig. 2.4.1)*	*Elastic cartilage (Fig. 2.4.2)*
Location	Fetal life: All skeletal tissue Adults: Nasal cartilages, articular cartilages, thyroid, cricoid and part of the arytenoid cartilages	External ear, epiglottis Auditory tube, apex of the arytenoid, corniculate and cuneiform cartilages
Appearance	Glossy bluish, translucent	Yellowish, opaque
Perichondrium	Present	Present
Chondrocytes	Abundant and present within the lacunae Arranged in group as isogenous cell nests	More numerous and bigger, packed more closely in the lacunae
Matrix	Homogenous, basophilic, matrix with ground glass appearance arranged as—capsular, territorial and interterritorial matrix Type II collagen fibers—delicate and not visible,	Eosinophilic matrix, rich in elastic fibers Type II collagen fibers are also present
Calcification tendency	Common	Less common
Elasticity	Flexible	Most flexible
Functions	Forms the foundation for development of all cartilaginous bones Resists compression Forms the skeleton of the respiratory tract and provides structural support	Provides flexibility

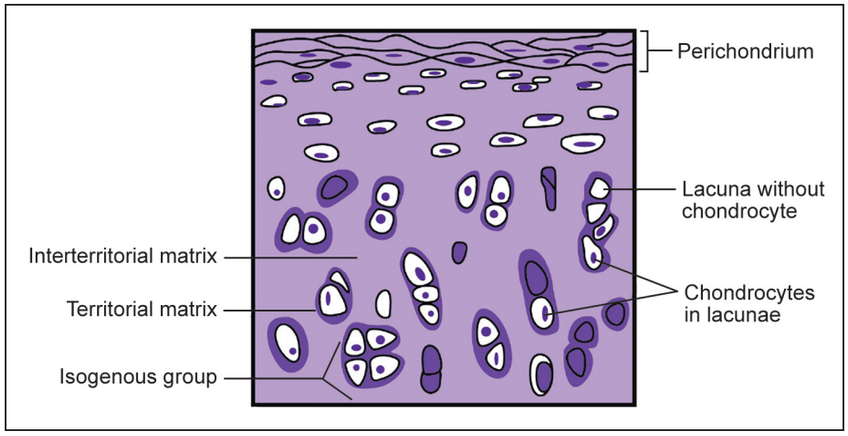


Fig. 2.4.1: Hyaline cartilage

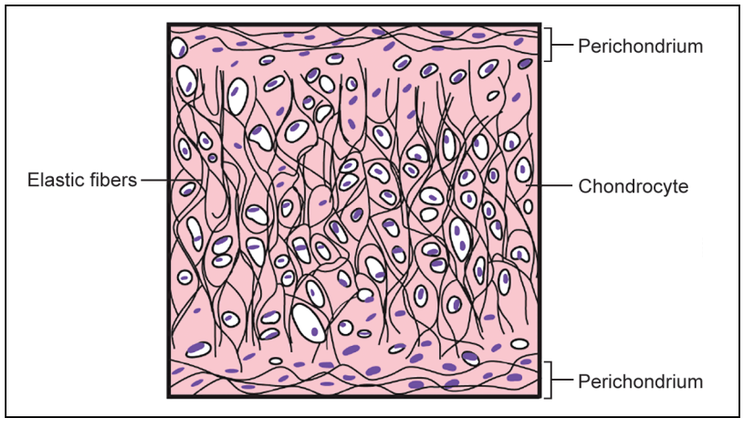


Fig. 2.4.2: Elastic cartilage

SHORT ANSWERS

1. What is perichondrium? What is its functional role?

Perichondrium

- Dense fibroconnective tissue layer covering the external surface of the cartilage
- Has following two layers:
  - An outer fibrous layer
  - Inner cellular layer

Functional Role

- Protection from injury—especially in the growth and development phase
- In children, it promotes cell regeneration thus reducing recovery time post-injury
- Reduces friction
- Provides elasticity
- Allows the blood flow to the cartilage

2. Describe the peculiar features of fibrocartilage.

Fibrocartilage (Fig. 2.4.3)

- Appearance and color—opaque, glistening white
- Perichondrium—absent
- Chondrocytes—few, scattered, arranged singly or in rows
- Matrix—parallel running thick collagen fiber bundles within the matrix
- Calcification—does not occur
- Elasticity—firm, strongest type of cartilage

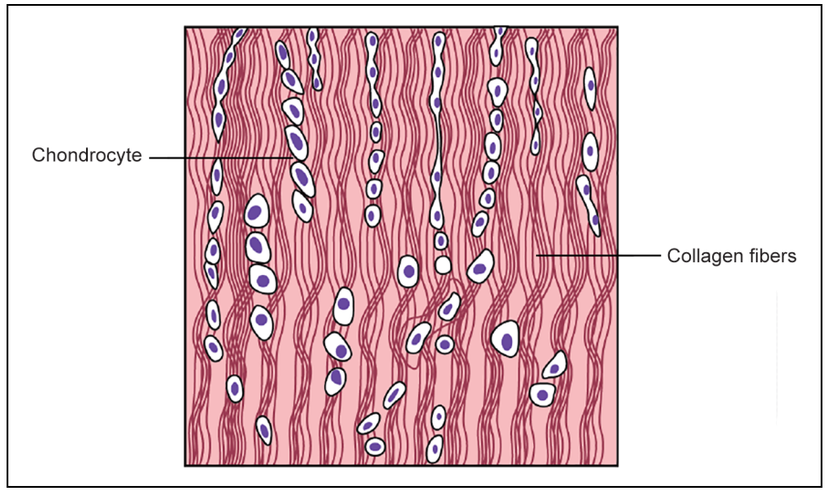


Fig. 2.4.3: Fibrocartilage

2.5 DESCRIBE VARIOUS JOINTS WITH SUBTYPES AND EXAMPLES

SHORT ESSAYS

1. Classify the joints. Give an example for each.

Joints' Classification

Depending on the Amount of Movement Allowed and Structure of Joint

A. **Synarthroses/fibrous joints/immovable joints**

Here articular surfaces are connected by fibrous connective tissue. Subtypes include

1. *Sutures (these are restricted to skull only) (Fig. 2.5.1)*
   - Serrate suture—sagittal suture
   - Denticulate suture—lambdoid suture
   - Squamous sutures—between squamous part of temporal bone and parietal bone
   - Plane suture—between palatine process of 2 maxillae
   - Wedge and groove (schindylesis)—between rostrum of sphenoid and upper part of vomer
2. *Syndesmosis (bones are connected by a dense fibrous membrane or cord) (Fig. 2.5.2):* Inferior tibio-fibular joint
3. *Gomphosis (a peg and socket type of articulation) (Fig. 2.5.3):* Roots of teeth

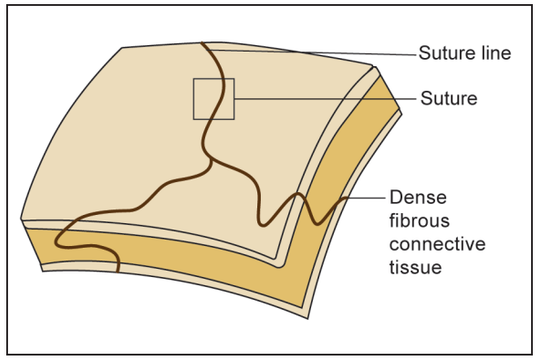


Fig. 2.5.1: Sutures

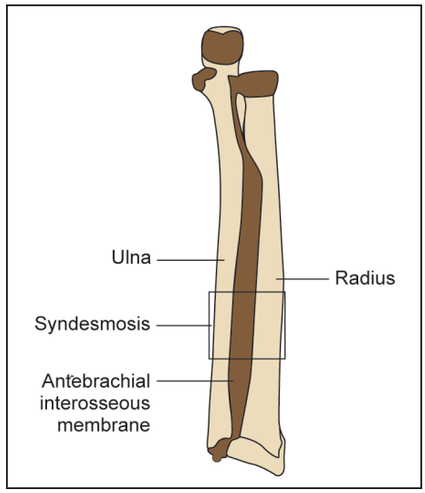


Fig. 2.5.2: Syndesmosis (e.g. middle radioulnar joint)

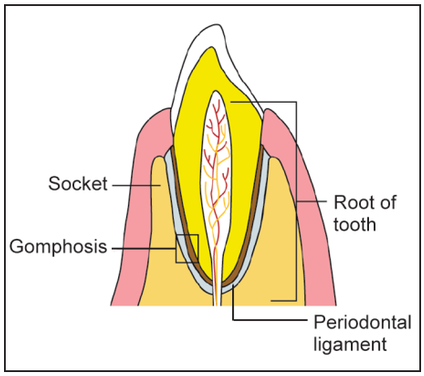


Fig. 2.5.3: Gomphosis

B. **Amphiarthrosis**

1. *Synchondroses/primary cartilaginous joints (the centres of ossification are separated by hyaline cartilage)*: Junction between epiphysis and diaphysis
2. *Symphyses/secondary cartilaginous joints (the articular surfaces are connected by fibrocartilage) (Fig. 2.5.4)*
   - Intervertebral discs
   - Manubriosternal and xiphisternal joints
   - Pubic symphysis

C. **Diarthroses/synovial joint (these are freely movable joints) (Fig. 2.5.5)**

a. *According to number of articulating joints*
   1. Simple joint: Two articular surfaces are involved in formation of a joint
      E.g.—interphalangeal joint
   2. Compound joint: More than two articular surfaces are involved in formation of a joint
      E.g.—ankle joint
   3. Complex joint: Here the joint cavity is divided into two distinct compartments
      E.g.—knee joint

b. *According to axis of movement/shape of articular surface*
   1. Uniaxial (movement is possible in only one axis/direction)
      - Hinge/ginglymus—elbow
      - Pivot/trochoid—atlanto-axial joint
      - Condylar joint—knee
   2. Biaxial (movement is possible in two axis/direction)
      - Ellipsoid joint—radiocarpal joint
      - Saddle joint—sternoclavicular joint
   3. Polyaxial (movement is possible in multiple axis/direction)
      - Ball and socket/spheroidal joint—hip joint
      - Plane joint—intertarsal joint

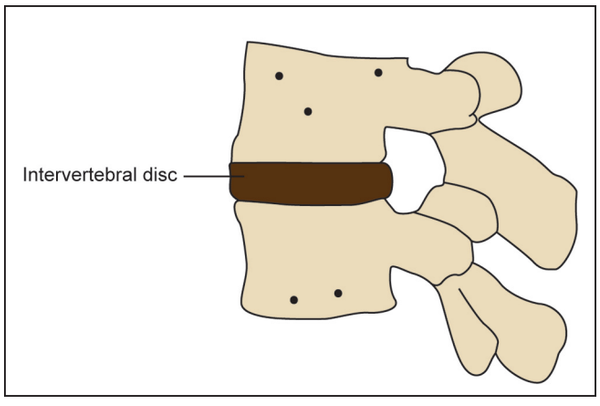


Fig. 2.5.4: Symphyses

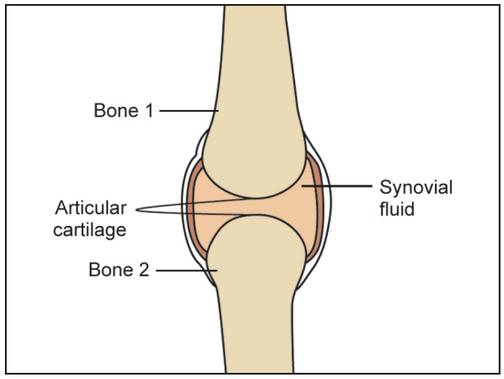


Fig. 2.5.5: Diarthroses

2. Classify the synovial joints. Give an example for each type.

Synovial Joints' Classification

According to Number of Articulating Joints

1. Simple joint—interphalangeal joint
2. Compound joint—ankle joint
3. Complex joint—knee joint

According to Axis of Movement/Shape of Articular Surface

1. **Uniaxial**
   - Hinge/ginglymus—elbow (Fig. 2.5.6)
   - Pivot/trochoid—atlanto-axial joint
   - Condylar joint—knee, TMJ

2. **Biaxial**
   - Ellipsoid joint—radiocarpal joint
   - Saddle joint—sternoclavicular joint (Fig. 2.5.7)
3. **Polyaxial**
   - Ball and socket/spheroidal joint—hip joint (Fig. 2.5.8)
   - Plane joint—intertarsal joint

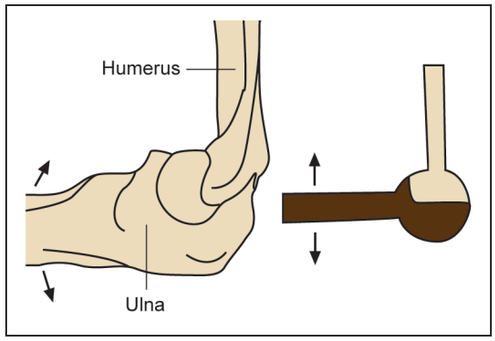


Fig. 2.5.6: Uniaxial joint

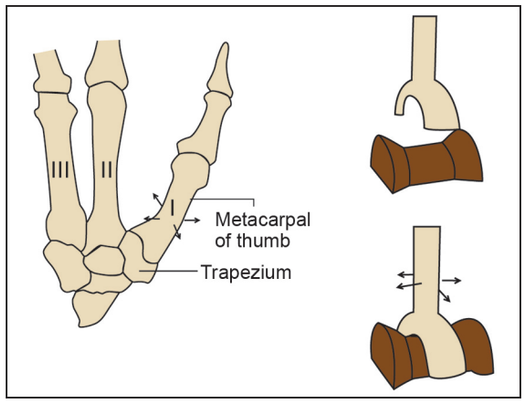


Fig. 2.5.7: Biaxial joint

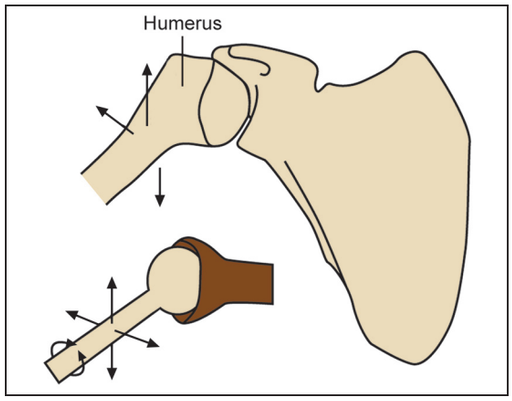


Fig. 2.5.8: Polyaxial joint

3. Describe the components of a synovial joint. Mention functional significance of each.

Synovial Joints' Components (Fig. 2.5.9)

Fibrous Capsule

- Completely covers and encloses the synovial cavity
- Constitutes longitudinal and interlacing white connective tissue fiber bundles
- It forms the articular capsule along with the synovial membrane

Functions

1. Stabilizes the joint and prevents dislocation
2. Has numerous nerve endings, stimulation of which leads to contraction of the muscle such that the joint is brought to the position with maximum comfort.

Ligaments

- Thickened collagen fiber bands
- Two types—true and accessory

1. **True ligament**
   - Local thickenings of parallel fiber bundles of capsular ligament
   - Intrinsic ligaments—since they are not separate from the capsular ligament

   Function: Stabilizes the joint by permitting movement in one plane, and preventing in others

2. **Accessory ligament**
   - Separate from the capsule
   - Can be intracapsular or extracapsular

   Function: Gives reinforcement to the joint, limiting the range of movements

Synovial Membrane

A highly vascular, thin, connective tissue membrane which lines the inner aspect of the fibrous capsule

Function: Produces synovial fluid which lubricates the joint

Articular Cartilage

Made of hyaline cartilage.

Function: Aids in smooth and frictionless joint movements and resist the compression forces

Meniscus or Articular Disc

- Fibrocartilagenous pads in between the articular surfaces of some joints

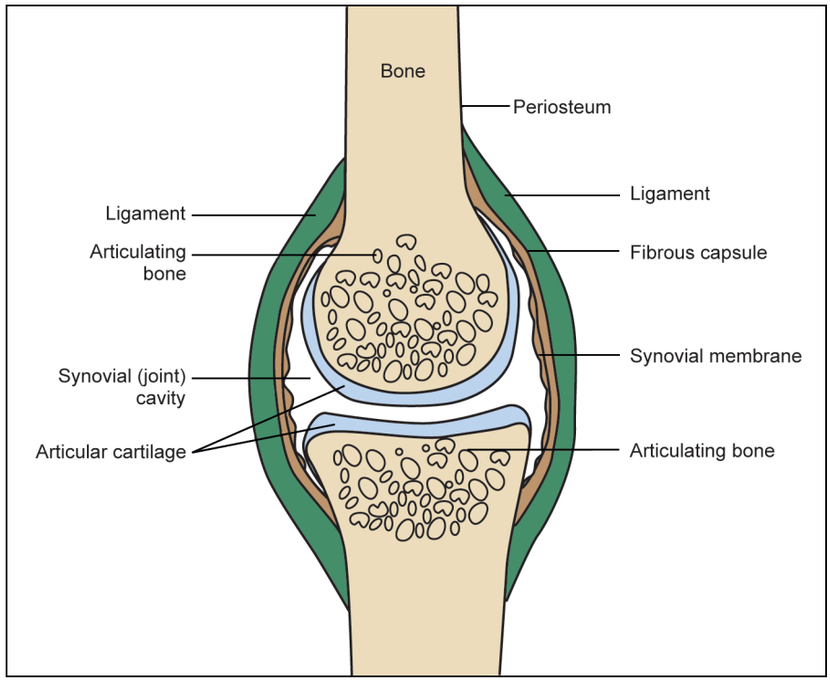


Fig. 2.5.9: Synovial joint components

Function

1. Lubrication
2. Division of the joint into two components
3. Function as a ligament by modifying some movements
4. Provides cushioning to the articular cartilage and prevents its wear and tear

Bursae

- Pouch-like sacs near some joints
- Filled with synovial fluid

Function

1. Cushioning the muscles
2. Aid in the movement of muscle or tendon over bone or ligamentous surfaces

Fat Pads (Haversian Glands)

- Found between the fibrous capsule and synovial membrane or between the synovial membrane and bone
- Function—accommodate to the changing conditions of the joint during movement

SHORT ANSWERS

1. Compare and contrast primary and secondary cartilaginous joints.

Primary cartilaginous joints	*Secondary cartilaginous joints*
Also known as synchondroses	Also known as symphyses
Hyaline cartilage connects the bones	Hyaline cartilage covers the bone, fibrocartilage connects the bones
Movement not possible	Minimal movement possible
Temporary joint, replaced completely by bone in later life	The fibrocartilage persists throughout life
Occurrence in midline is rare	Always seen in midline

2. Describe syndesmosis. Give an example.

Syndesmosis

- Joint between 2 bones connected by greater amount of connective tissue
- Connective tissue forms interosseous ligament and membrane
- Permits slight movement at the joint

Example

Interosseous radio–ulnar joints

3. List any three ball and sockets joints in the body

1. Hip joint
2. Shoulder joint
3. Incudostapedial joint

4. List the movements occurring at a ball and socket joint.

1. Flexion
2. Extension
3. Adduction
4. Abduction
5. Medial rotation
6. Lateral rotation
7. Circumduction

5. Mention the factors maintaining the stability of a synovial joint.

- Bones—fitting into each other
- Ligaments—intracapsular and extracapsular ligaments
- Muscles—strength and tone of various muscles-most important factor

2.6 EXPLAIN THE CONCEPT OF NERVE SUPPLY OF JOINTS AND HILTON'S LAW

SHORT ANSWER

1. Define the Hilton's law. Mention its functional significance.

Hilton's Law

Nerve which supplies a joint will also innervate the muscles regulating the movements of that joint and the skin over the joint.

Functional Significance

- When the joint is injured or damaged, the nerve supplying it will stimulate the muscle to contract in a way as to bring the joint to a position of maximum comfort, thus protecting the joint.
- The joint pain is referred to the skin over the joint.

Chapter

3

General Features of Muscle

3.1 CLASSIFY MUSCLE TISSUE ACCORDING TO STRUCTURE AND ACTION

SHORT ESSAYS

1. Compare and contrast the features of skeletal and cardiac muscles.

Feature	*Skeletal muscle (Fig. 3.1.1)*	*Cardiac muscle (Fig. 3.1.2)*
Synonyms	Striated muscle Somatic muscle Voluntary muscle	Myocardium
Location	Attached to skeleton Tongue Proximal and middle third of esophagus	Heart and base of the great vessels of heart
Connective tissue	Three coverings, from outside inwards arranged as, epimysium, perimysium and endomysium	Presence of endomysium
Structure of the muscle fiber	Single elongated muscle cell	Several cardiac muscle arranged as branching fibers
Nucleus	Multiple and peripherally situated	Single and centrally situated
Ultrastructure	T tubules arranged as triad (have two terminal cisternae)	T tubules arranged as diad (have one terminal cistern)
Presence of cell junctions	Absent	Intercalated discs are present
Type of innervation	Somatic	Autonomic/visceral
Response to exercise	Hypertrophy	Hypertrophy
Response to injury	Regeneration is limited	Regeneration is absent

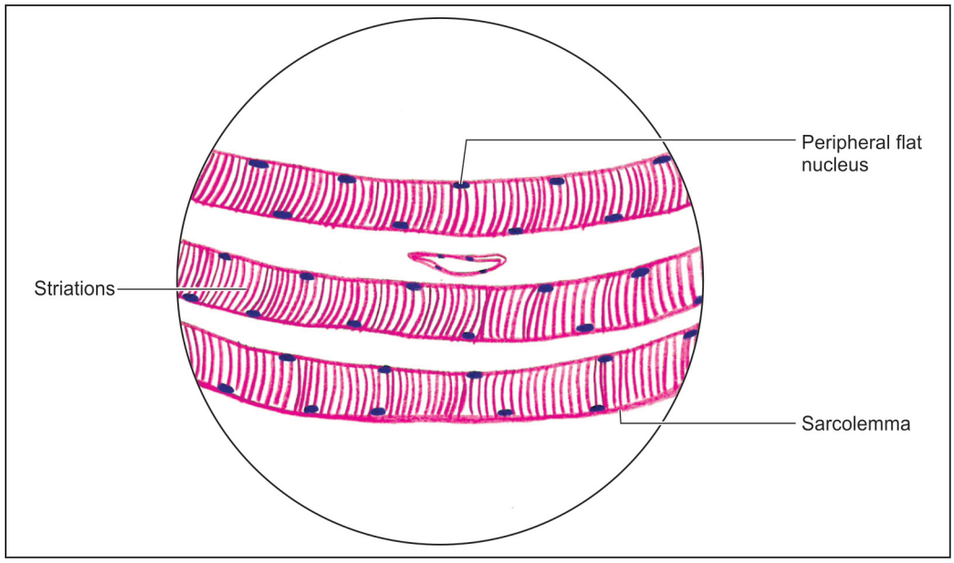


Fig. 3.1.1: Skeletal muscle

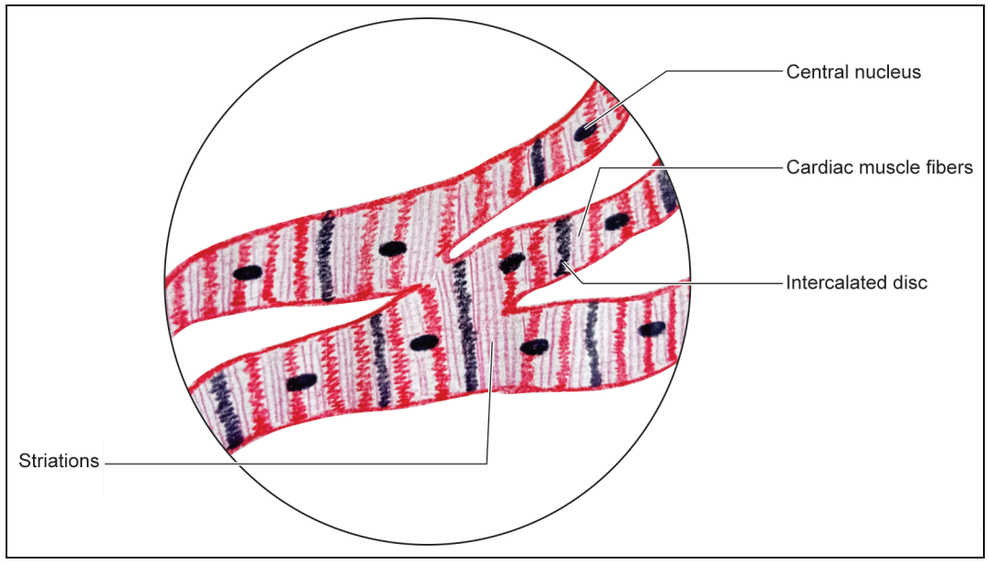


Fig. 3.1.2: Cardiac muscle

2. Compare and contrast the features of skeletal and smooth muscles.

Feature	*Skeletal muscle (Fig. 3.1.1)*	*Smooth muscle (Fig. 3.1.3)*
Synonyms	Striated muscle Somatic muscle Voluntary muscle	Involuntary
Location	Attached to skeleton Tongue Proximal and middle third of esophagus	Tunica media of vessels Muscular layer of tubular organs in gastrointestinal tract and urinary tract
Connective tissue	Three coverings, from outside inwards arranged as, epimysium, perimysium and endomysium	Presence of endomysium
Structure of the muscle fiber	Single elongated muscle cell	Short, spindle-shaped cell
Nucleus	Multiple and peripherally situated	Single and centrally situated
Ultrastructure	T tubules arranged as triad (have two terminal cisternae)	None
Presence of cell junctions	Absent	Gap junctions are present
Type of innervation	Somatic	Autonomic/visceral
Response to exercise	Hypertrophy	Hypertrophy and hyperplasia
Response to injury	Regeneration is limited	Regeneration is present

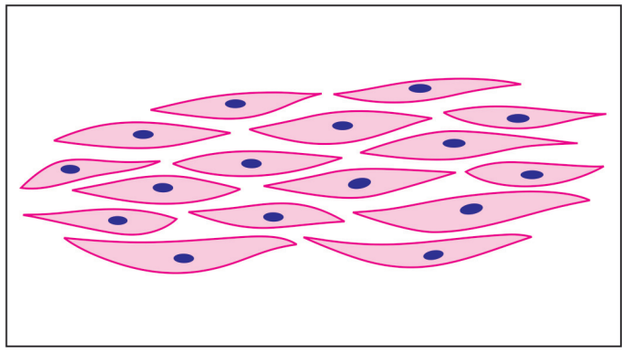


Fig. 3.1.3: Smooth muscle

3. Classify the muscles based on the arrangement of fibers.

1. **Parallel fasciculi**
   - Muscle fibers are parallel to the muscle pull
   - Have maximum range of movement
   - They may be:
     - Quadrilateral—thyrohyoid
     - Strake-like—sartorius
     - Strap-like—rectus abdominis
     - Fusiform—biceps
2. **Convergent fasciculi**
   - Muscle fibers are converging to the point of insertion
   - Powerful but with restricted range of movements
   - Triangular—adductor longus
   - Fan-shaped—temporalis
3. **Twisted or spiral fasciculi**
   - Muscle fibers are arranged spirally
   - E.g.—trapezius
4. **Cruciate fasciculi**
   - Muscle fibers are arranged in two different planes and are arranged in the form of the letter 'X'
   - E.g.—sternocleidomastoid
5. **Sphincteric fasciculi**
   - Muscle fibers are arranged around an opening or orifice circumferentially
   - E.g.—orbicularis oculi, orbicularis oris

6. **Pennate fasciculi**
   - Muscle fibers resemble feather
   - They may be:
     - Unipennate: Muscle fibers are attached to one side of the tendon only. E.g. Flexor pollicis longus, extensor digitorum longus
     - Bipennate: Muscle fibers are attached to both sides of the tendon only. E.g. Rectus femoris, dorsal interossei muscles of hand and foot
     - Multipennate: Series of bipennate muscles attached together. E.g. middle fibers of deltoid
     - Circumpennate—muscle fibers are arranged as convergence of fibers from the walls of cylindrical space on to tendon. E.g. tibialis anterior

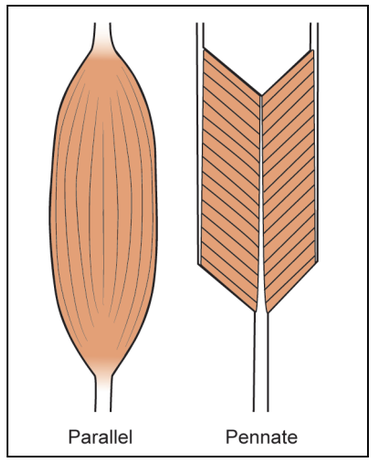


Fig. 3.1.4: Parallel and pennate muscle fibers

SHORT ANSWERS

1. Compare and contrast parallel and pennate muscle fibers.

Parallel muscle fiber (Fig. 3.1.4)	*Pennate muscle fiber (Fig. 3.1.4)*
Arranged parallel to the muscle pull	Arranged in the shape of feather
Has maximum range of movement	Has lesser range of movement but stronger
Types—quadrilateral, strake-like, strap-like, fusiform	Types—unipennate, bipennate, multipennate, circumpennate
E.g.—biceps	E.g.—deltoid

2. Describe cruciate muscle. Mention an example.

Cruciate Muscle

- The muscle fibers are arranged in two planes—superficial and deep
- Muscle fibers cross each other in the form of the letter 'X'

Example

Sternocleidomastoid, masseter, adductor magnus

3.2 ENUMERATE PARTS OF SKELETAL MUSCLE AND DIFFERENTIATE BETWEEN TENDONS AND APONEUROSES WITH EXAMPLES

SHORT ANSWER

1. Compare the different modes of insertion of a skeletal muscles.

Tendon	*Aponeurosis*
Rounded cord-like structure made up of connective tissue	Thin, flattened sheath like structure
Attaches muscle to bone	Provides broader attachment for muscle to bone
Allows proper contraction, provides support and strength, more endurance and stretching capacity	It bears extra pressure and tension since it is having property of recoiling, they act as shock absorber and allow to bear weight
Provides flexibility and motility	Provides strength and durability
E.g.—tendon of biceps	E.g.—bicipital aponeurosis

3.3 EXPLAIN SHUNT AND SPURT MUSCLES

SHORT ANSWER

1. Compare and contrast the features of spurt and shunt muscles.

Spurt muscle (Fig. 3.3.1)	*Shunt muscle (Fig. 3.3.1)*
Produce force during a movement across the joint	Stabilizes the joint during the movement
Origin is at a distance from the joint	Originates near the joint
Inserts near the joint	Insertion is away from the joint
E.g.—brachialis	E.g.—brachioradialis

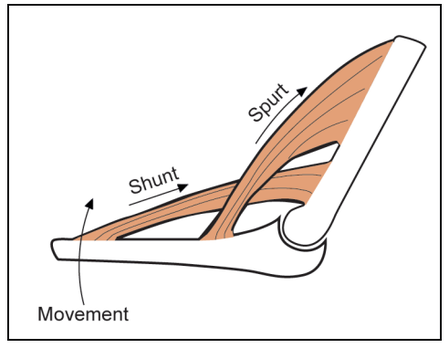
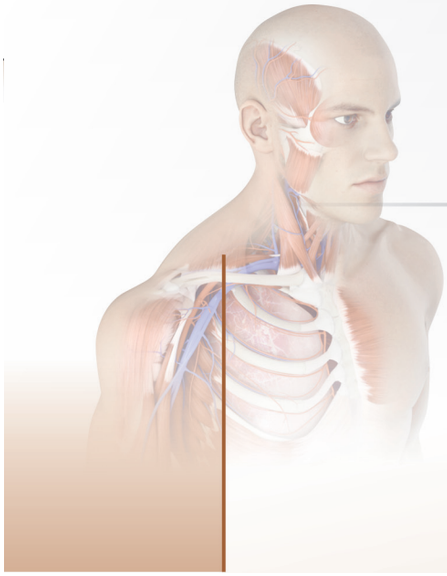


Fig. 3.3.1: Shunt and spurt muscles



Chapter

4

General Features of Skin and Fascia

4.1 DESCRIBE DIFFERENT TYPES OF SKIN AND DERMATOMES IN BODY

SHORT ESSAY

1. Compare and contrast the features of thick skin and thin skin.

Feature	*Thick skin (Fig. 4.1.1)*	*Thin skin (Fig. 4.1.2)*
Synonyms	Non-hairy skin Glabrous skin	Hairy skin
Location	Palms and soles Flexor surface of digits	Skin over almost all parts of the body except at palm and soles
Thickness	400–600 μm	75–150 μm
Layers	Epidermis Dermis Hypodermis	Epidermis Dermis Hypodermis
Stratum corneum	Very prominent	Less prominent
Stratum lucidum	Present	Absent
Stratum granulosum	Well developed	Poorly developed
Hair follicles	Absent	Present
Sweat gland	Present	Present
Sebaceous gland	Absent	Present
Arrector pilorum	Absent	Present

SHORT ANSWER

1. Define dermatome. Mention the areas of dermatomal discontinuity in human body.

Dermatome

Dermatome is the area of the skin supplied by an individual/single spinal segment.

Areas of Dermatomal Discontinuity

Observed in human beings at the level of the sternal angle. The area of the trunk above the level of the sternal angle is supplied by the C5 dermatome and the area immediately below is supplied by T1 dermatome. This is because the intervening dermatomes are 'pulled' to supply the upper limb.

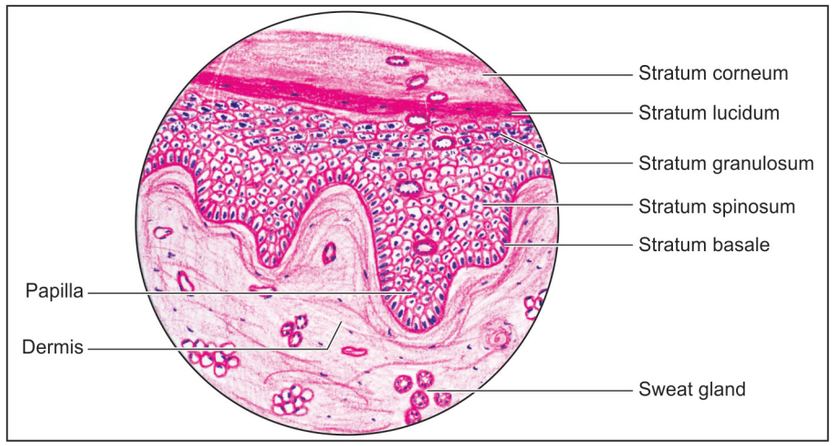


Fig 4.1.1: Thick skin

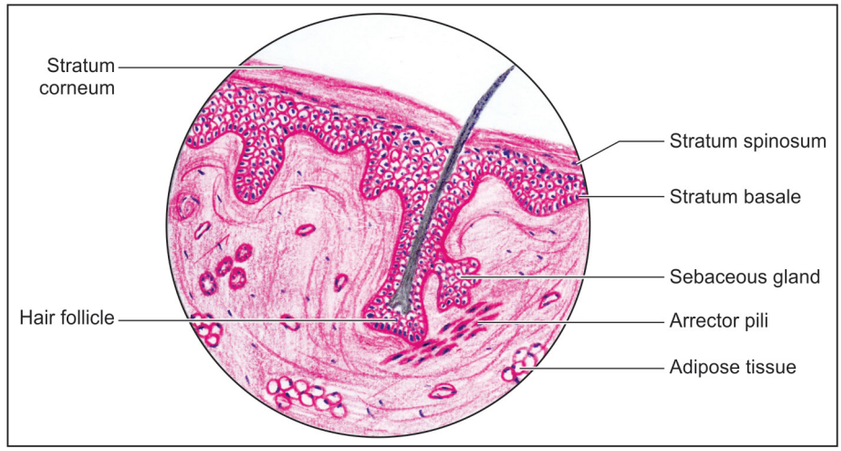


Fig 4.1.2: Thin skin

4.2 DESCRIBE STRUCTURE AND FUNCTION OF SKIN WITH ITS APPENDAGES

SHORT ESSAY

1. Describe the structure of skin.

Structure of Skin (Figs 4.2.1 and 4.2.2)

Skin has 2 principal layers—epidermis and dermis

1. **Epidermis**
   - It is the superficial surface epithelium of skin
   - Made of stratified squamous keratinized epithelium
   - Avascular, derived from surface ectoderm
   - Thickness—0.007 to 0.12 mm
   - Constitutes 4–5 layers, from deep to superficial they are:
     - Stratum basale
       - Also called *stratum germinatum, basal layer, Malpighian layer*
       - A single layer of columnar or cuboidal cells
       - Also contains melanocytes
     - Stratum spinosum
       - Also called *spiny layer, prickle cell layer*
       - Has several layer of polygonal cells
       - Desmosomes hold the cells together

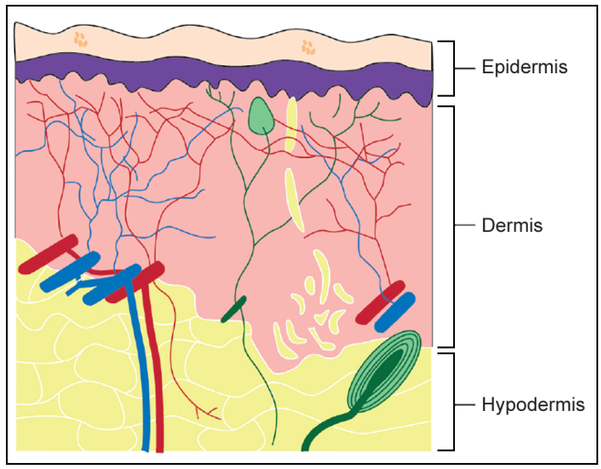


Fig. 4.2.1: Thick skin

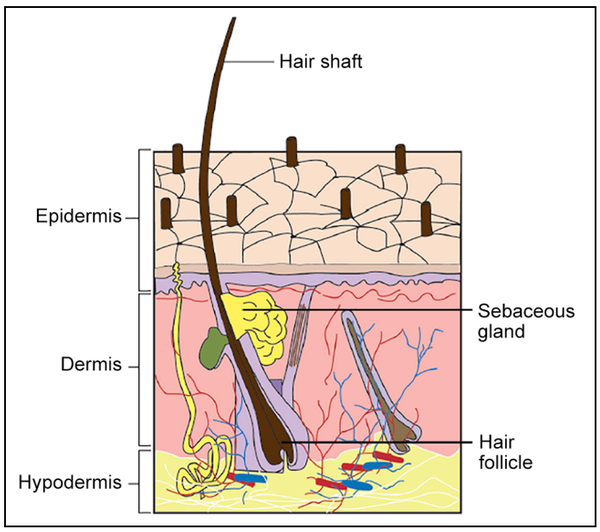


Fig. 4.2.2: Thin skin

- Stratum granulosum
  - Also called *granular layer*
  - 3–4 layers of flattened cells
  - Has pyknotic nuclei with signs of degeneration
  - Keratohyalin granules are seen in cytoplasm
- Stratum lucidum
  - Also called *clear layer*
  - Seen in the thick skin over palms and soles
  - A thin homogenous glassy layer
  - Highly refractile
- Stratum corneum
  - Most superficial layer
  - Made of 25–30 layers of fully keratinized flattened scale like dead cells filled with keratin
  - Cornified

2. **Dermis**
   - Present beneath the epidermis and derived from mesoderm
   - Made of type I collagen and elastic fibers
   - Harbours glands, lymphatics, blood vessels, nerves

- Arrector pili—dermal muscle associated with hair follicles
- Has 2 layers:
  1. Superficial papillary layer
     - Constitutes one-fifth of dermal thickness
     - Dermal papillae—blunt conical projections into epidermis
  2. Deep reticular layer
     - Mostly comprises of collagen fibers arranged in parallel bundles
     - Langer's lines or cleavage lines—caused by direction of the bundles
     - Cleavage line—horizontal in trunk and neck, vertical in limbs

SHORT ANSWERS

1. Compare and contrast the features of eccrine and apocrine sweat glands.

Feature	*Eccrine sweat gland*	*Apocrine sweat gland*
Location	Entire body except lips and parts of external genitalia	Axilla Nipple and areola External genitalia Skin around anus
Type	Simple coiled tubular	Simple tubular gland with large lumen Occasionally branched
Association with hair follicle	Independent structure Not associated with hair follicle	Associate with hair follicle
Component parts	Secretory segment Duct segment	Secretory segment Duct segment
Secretory segment	Narrow lumen and is made up of three types of cells Clear cells Dark cells Myoepithelial cells	Wider lumen but made up of only one type of cell
Duct segment	Lined by stratified cuboidal epithelium Lack myoepithelial cells	Lined by stratified cuboidal epithelium Lack myoepithelial cells
Mode of secretion	Merocrine	Merocrine/apocrine/holocrine
Type of secretion	Resembles ultrafiltrate of blood	Protein and pheromone rich fluid
Excitatory stimulus	Cholinergic	Adrenergic
Age of functioning	Throughout life	Becomes active at puberty
Function	Temperature regulation	Regeneration is present

2. Describe the structure and list the location of sebaceous gland.

Structure

- They are simple branched glands
- Associated with hair follicles and each follicle has 1–6 glands
- Secrete sebum, an oily material onto the hair shaft

Location

- They are present all over the body except palms and soles
- They open directly onto the skin surface at the following sites:
  - Nose
  - Genital and perianal regions
  - Areola of breast
  - Eyelids

3. List the functions of skin.

1. Protection
2. Thermoregulation
3. Sensory reception
4. Hydroregulation
5. Absorption of lipid-soluble substances
6. Vitamin D synthesis
7. Excretion of waste material
8. Emotional communication

4.3 DESCRIBE SUPERFICIAL FASCIA ALONG WITH FAT DISTRIBUTION IN BODY

SHORT ESSAY

1. Describe the structure of superficial fascia.

Structure of Superficial Fascia

- It is the layer of loose areolar tissue found subcutaneously
- Unites the dermis with the underlying deep fascia
- It is abundant in fat
- The fat content varies in various body parts
- The fat in the superficial fascia is absent in
  - Eyelids
  - Pinna
  - Flexor creases of the fingers
  - Penis
  - Scrotum
- The fat content is more in children and females
- The fat deposition in particular sites in females leads to their secondary sexual characteristics
  - Breast
  - Anterior abdominal wall below umbilicus
  - Cervical thoracic region
  - Post-deltoid region
  - Gluteal and lumbar region
  - Anterior thigh
- The blood vessels, lymphatics, and nerves travel in the superficial fascia before reaching dermis.

SHORT ANSWERS

1. Define panniculus carnosus. List the muscles in human body which represent panniculus carnosus.

Panniculus Carnosus

Panniculus carnosus is a thin layer of muscle found in the superficial fascia in animals.

Muscles which Represent Panniculus Carnosus

1. Muscles of facial expression
2. Platysma in the neck
3. Palmaris brevis
4. Corrugator cutis ani
5. Subareolar muscle in the breast
6. Dartos in the scrotal wall

2. List the functions of superficial fascia.

1. Forms an insulating layer beneath the skin
2. Leads to a smooth external contour, seen in children and females
3. Permits skin to move on the underlying structures
4. Let's an easy passage to blood vessels, lymphatics nerves
5. Causes cushioning effect in certain sites

4.4 DESCRIBE MODIFICATIONS OF DEEP FASCIA WITH ITS FUNCTIONS

SHORT ESSAYS

1. Describe the structure of deep fascia.

Structure of Deep Fascia

- A tough, inelastic membrane of fibrous tissue
- Encloses the body deep to subcutaneous tissue
- The soft tissues are held in place
- The body shape is maintained
- Prominent in neck and limbs
- Neck has 3 layers:
  1. **General investing layer:** Encloses the neck structure like collar
  2. **Pretracheal fascia:** Present anterior to trachea
  3. **Prevertebral fascia:** Anterior to cervical vertebrae
  4. The neck is thus divided into visceral compartment and musculoskeletal compartment
- Limbs
  1. The deep fascia gives rise to intermuscular septa, which attach to the periosteum
  2. The septa allow the muscle group to contract individually
  3. Enables the muscles to slide freely over other groups

2. Describe the modifications of deep fascia.

1. **Retinacula**
   - Thickened band like, retaining the tendons of long muscles in place
   - Bowstringing during contraction of muscles is prevented

2. **Aponeurosis**
   - A thick, wide sheet of fibrous tissue in palms and soles
   - Protects the underlying structures
   - Provided attachment to muscles
3. **Fibrous sheaths**
   - Deep fascia forms sheath around neurovascular bundles at certain sites
   - Carotid sheath—encloses the common carotid artery, vagus nerve, internal jugular vein
   - Axillary sheath—encloses axillary artery and vein
4. **Fibrous capsule**
   - Deep fascia splits to enclose certain glands by forming their capsule
   - E.g.—parotid gland capsule
5. **Interosseous membrane:** Connecting bones in forearm and leg
6. **Intermuscular septa**
   - The deep fascia gives rise to intermuscular septa in limbs, which attach to the periosteum
   - The septa allow the muscle group to contract individually
   - Enables the muscles to slide freely over other groups
7. **Fibrous flexor sheath**
   - Formed around the flexor tendons of fingers and toes
   - Prevent the tendons from bowing out of position
8. **Ligaments:** Localized thickened bands of deep fascia
9. **Fascial sheath:** Sheath around certain muscles, like psoas sheath

SHORT ANSWERS

1. Mention the sites in human body where deep fascia is absent.

1. Face
2. Breast
3. Anterior abdominal wall
4. Penis
5. Scrotum
6. Ischiorectal fossa

2. List the functions of deep fascia.

1. Keeps the underlying structures in position
2. Provides attachment to muscles
3. Facilitates venous and lymphatic drainage
4. Binding bones
5. Retains the tendons in position and prevents bowstringing

4.5 EXPLAIN PRINCIPLES OF SKIN INCISIONS

SHORT ANSWERS

1. Define Langer's line. Describe its importance in planning surgical incisions.

Langer's line

Langer's lines are the topological lines on the body caused by the arrangement of the collagen fibers in the reticular layer of the dermis.

Importance in Planning Surgical Incisions

- Surgical incisions made parallel to these lines heal faster and leaves lesser scar.
- Surgical incisions across these lines heals slower and leaves ugly scar.

2. Define dermatoglyphics. Mention its clinical application.

Dermatoglyphics

Dermatoglyphics is the study of the ridges of the skin or fingerprints.

Clinical Application

- Provides identity to an individual as it is unique to every individual
- Medicolegal purpose to identify the criminal
- In certain diseases, there is deviation from the normal pattern.

Chapter

5

General Features of the Cardiovascular System

5.1 DIFFERENTIATE BETWEEN BLOOD VASCULAR AND LYMPHATIC SYSTEM

SHORT ESSAY

1. Compare and contrast the features of blood vascular system and lymphatic system.

Blood vascular system	*Lymphatic system*
Constitutes blood vessels	Constitutes lymph vessels
Blood is the circulating fluid—reddish colour	Lymph is the circulating fluid—colourless
Transportation of blood through heart, blood vessels and platelets	Transportation of lymph through lymphatic vessels
Contains plasma, erythrocytes, leukocytes and platelets	Contains lymphocytes
Aids in transport of gases	Cannot transport gases
Carries digested food material, waste from cells	Carries digested fat
Definite basal lamina and pericytes are present in blood capillaries	Basal lamina and pericytes are absent. Flap valves are present between endothelial cells in lymph capillaries
Capillaries are permeable to soluble crystalloids	Capillaries permeable to macromolecules of colloids and particulate matters
Capillaries collapse in increase tissue fluid pressure	Capillary wall is anchored to connective tissue, so the lumen remains patent

SHORT ANSWERS

1. List the components of cardiovascular system.

- Blood
  - Blood cells
    - Erythrocytes
    - Leukocytes
    - Platelets
- Plasma
- Heart
- Blood vessels
  - Arteries
  - Capillaries
  - Veins

2. List the functions of blood vascular system.

1. Transportation of nutrients to various body parts
2. Removal of waste products from various body parts
3. Gaseous exchange of oxygen and carbon dioxide
4. Carrying hormones and other regulatory molecules
5. Protection from infection

5.2 DIFFERENTIATE BETWEEN PULMONARY AND SYSTEMIC CIRCULATION

SHORT ESSAY

1. Compare and contrast the features of pulmonary and systemic circulation.

Pulmonary circulation (Fig. 5.2.1)	*Systemic circulation (Fig. 5.2.1)*
Composed of pulmonary artery and pulmonary vein	Composed of superior and inferior vena cava, aorta and other small vessels
Pulmonary artery carries the deoxygenated blood from the right ventricle to the lungs	Aorta carries the oxygenated blood from left ventricle of heart to the rest of the body
Pulmonary veins carry oxygenated blood from lungs to the left atrium	The vena cava—superior and inferior, carry deoxygenated blood from different parts of body to right atrium
Carries blood to lungs	Carries blood throughout body
Release carbon dioxide from blood and dissolve oxygen in blood	Provides nutrition and oxygen to metabolizing cells in the body

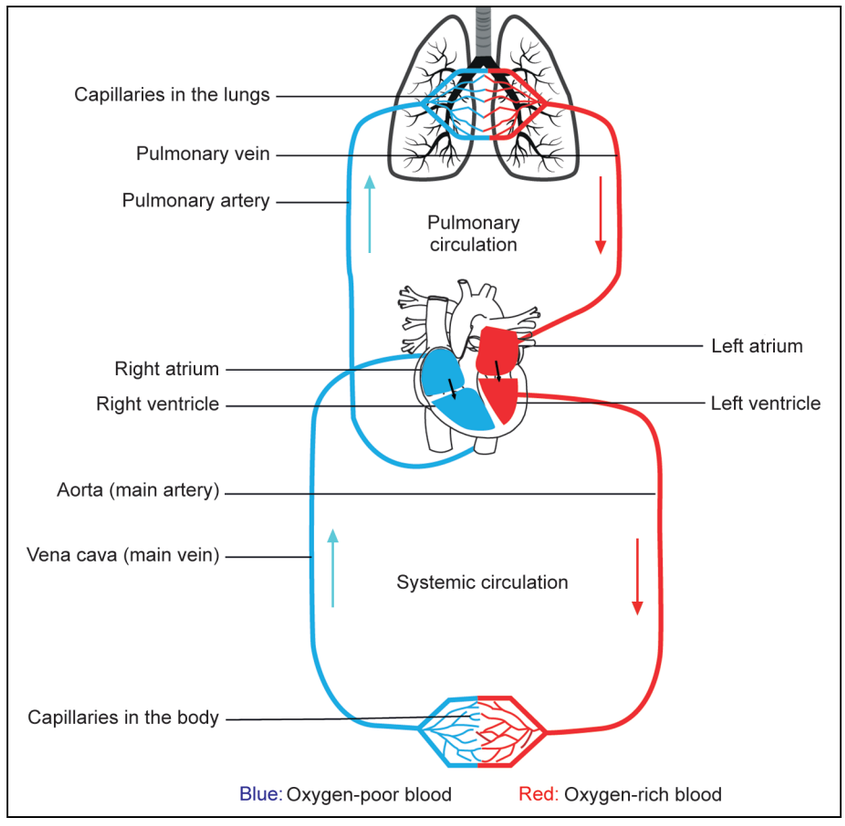


Fig. 5.2.1: Pulmonary and systemic circulations

5.3 LIST GENERAL DIFFERENCES BETWEEN ARTERIES AND VEINS

69.1 IDENTIFY ELASTIC AND MUSCULAR BLOOD VESSELS, CAPILLARIES UNDER THE MICROSCOPE

69.2 DESCRIBE THE VARIOUS TYPES AND STRUCTURE–FUNCTION CORRELATION OF BLOOD VESSEL

69.3 DESCRIBE THE ULTRASTRUCTURE OF BLOOD VESSELS

SHORT ESSAYS

1. Classify blood vessels with examples.

Blood Vessels Classification

1. **Conducting vessels**
   - Also called elastic arteries
   - Constitute the large arteries and their branches
   - E.g.—aorta
2. **Distributing vessels**
   - Also called muscular arteries
   - E.g.—renal artery
3. **Resistance vessels**
   - Arterioles
   - Diameter of less than 100 μm
   - They are of 3 types:
     - Large arterioles
     - Terminal arterioles
     - Meta-arterioles
4. **Exchange vessels**
   - Capillaries
   - Sinusoids
   - Post-capillary venules
5. **Capacitance or reservoir vessels**
   - Veins
   - They are of 3 types:
     - Large veins—superior vena cava
     - Medium veins—splenic vein
     - Small veins
       - o Post-capillary venules (exchange vessel)
       - o Muscular venules

2. Describe the structure of a blood vessel.

Structure of Artery (Fig. 5.3.1)

Made of 3 layers—tunica intima, tunica media and tunica adventitia

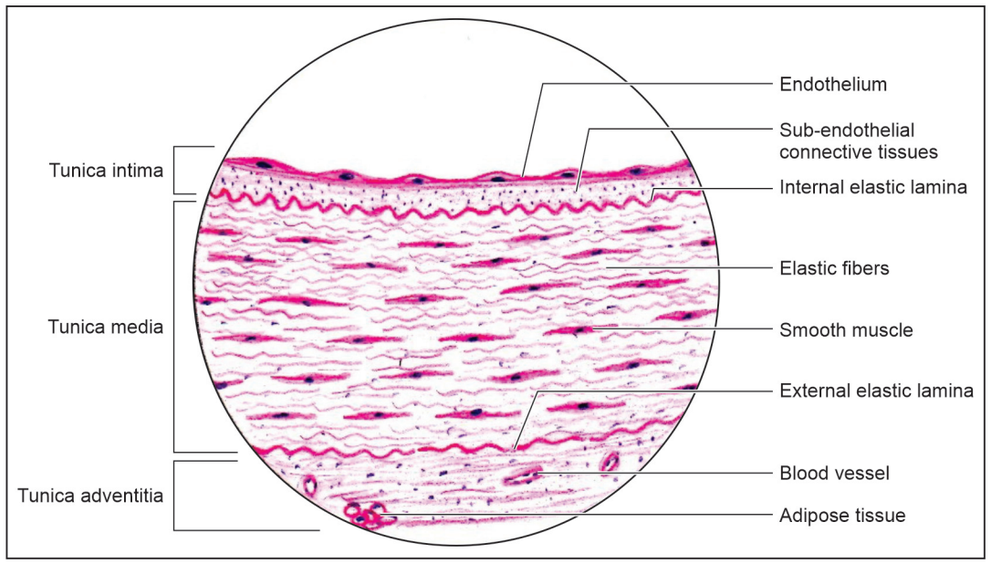


Fig. 5.3.1: Schematic diagram of blood vessel

1. **Tunica intima**
   - Innermost layer
   - Consists of endothelium—flattened cells and basal lamina
   - Sub-endothelial loose connective tissue and internal elastic lamina support the endothelium externally
   - Internal elastic lamina is a fenestrated membrane of elastic tissue
2. **Tunica media**
   - Thickest layer of the arterial wall
   - Consists of alternate layer of elastic fibers and circularly arranged smooth muscle fibers
   - External elastic lamina
     - o Fenestrated membrane of elastic tissue
     - o Limits the tunica media externally
3. **Tunica adventitia**
   - Outermost layer
   - Thin, but strongest of the 3 layers
   - Consists of longitudinal connective tissue fibers and connective tissue cells
   - Connective tissue comprises of both elastic and collagen fibers
   - Merges with the perivascular sheath

Structure of Capillary

Made up of single cell layer of squamous epithelium, known as endothelium.

Structure of Vein (Fig. 5.3.4)

- Consists of the same 3 layers as artery
- Differences are:
  - Tunica intima—internal elastic lamina is absent
  - Tunica media—poorly developed
  - Tunica adventitia—thickest of the 3 layers. Made of muscle, elastic and collagen fibers

3. Compare and contrast the microscopic features of large-sized artery and medium-sized artery.

Microscopic feature	*Large-sized artery (Fig. 5.3.2)*	*Medium-sized artery (Fig. 5.3.3)*
Tunica adventitia	Thin and has greater proportion of elastic fibers	Thin layer of fibroelastic tissue
Tunica media	Consists mainly of elastic fibers arranged in fenestrated concentric membranes	Consists mainly of circular smooth muscles
Tunica intima	Consists of endothelium, subendothelial connective tissue, internal elastic lamina	Consists of endothelium, subendothelial connective tissue, internal elastic lamina
	Subendothelial tissue has more elastic tissue	Subendothelial tissue has lesser elastic tissue
	Internal elastic lamina is not distinct	Internal elastic lamina is prominent

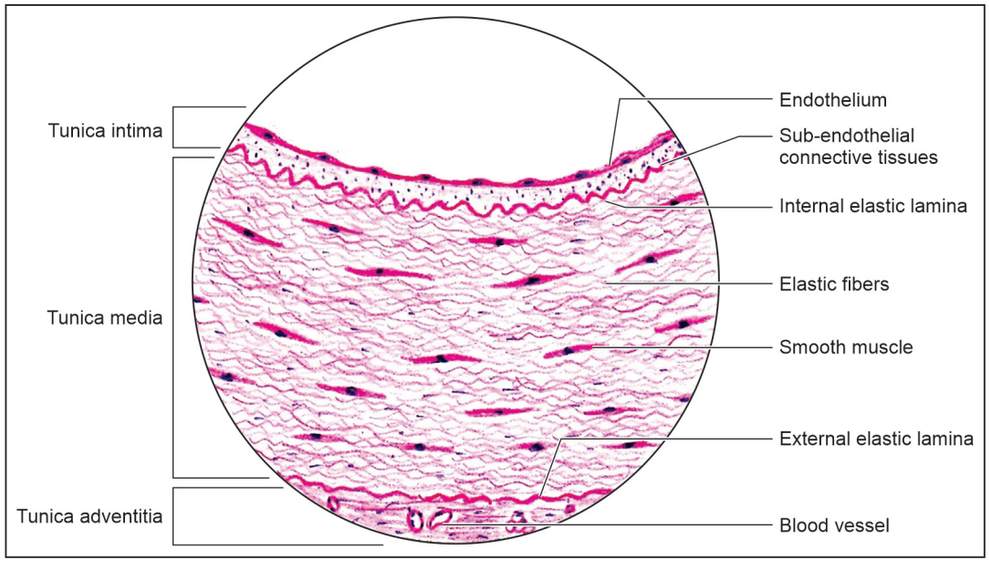


Fig. 5.3.2: Large-sized artery

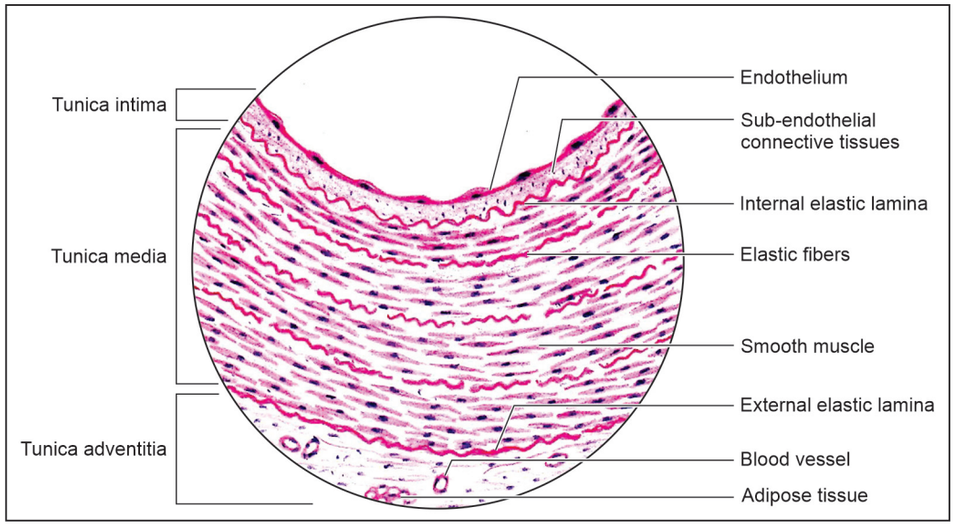


Fig. 5.3.3: Medium-sized artery

4. Describe the microscopic structure of large-sized vein.

Microscopic Structure of Large-sized Vein (Fig. 5.3.4)

Made of 3 layers—tunica intima, tunica media, tunica adventitia

- **Tunica intima**
  - Innermost layer
  - Consists of endothelium—flattened cells and basal lamina
  - Sub-endothelial loose connective tissue supports the endothelium externally
- **Tunica media**
  - Consists of collagen and elastic fibers and muscle
  - Has more collagen fibers and lesser elastic fibers and muscle
- **Tunica adventitia**
  - Outermost layer
  - Thickest of the 3 layers
  - Elastic and muscle fibers—arranged longitudinally
  - Collagen fibers—form a meshwork, spiralling around the vessel

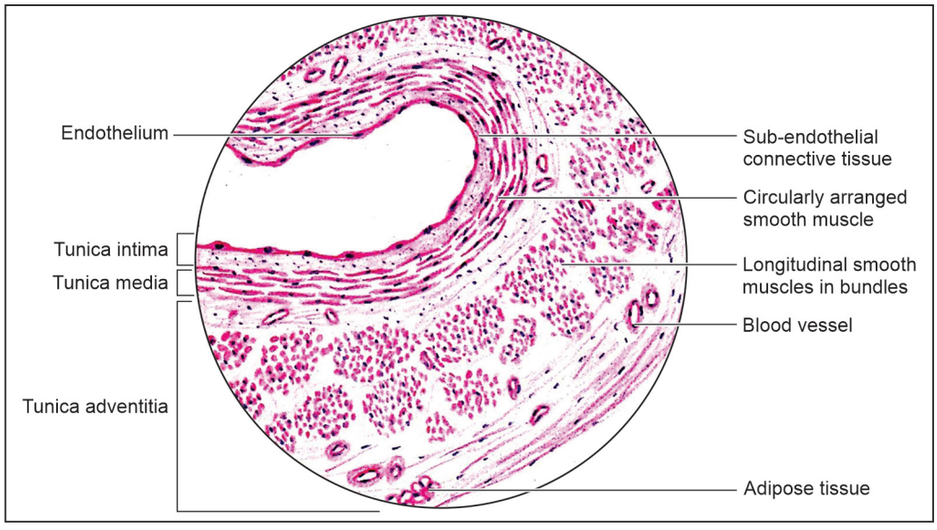


Fig. 5.3.4: Large-sized vein

SHORT ANSWERS

1. Compare and contrast the characteristic features of arteries and veins.

Features	*Arteries*	*Veins*
Definition	Vessels that deliver blood to capillaries	Vessels that collect blood from capillaries
Layers (from inside out)	Tunica intima	Tunica intima
	Tunica media	Tunica media
	Tunica adventitia	Tunica adventitia
Vascular tree	Large artery	Post-capillary venule
	Medium-sized artery	Muscular venule
	Small artery	Small vein
	Arteriole	Medium vein
	Capillary	Large vein
Thickness of the wall	Thick-walled	Thin-walled
Lumen	Narrower	Wider
Thickest layer	Tunica media	Tunica adventitia
Presence of longitudinal smooth muscle in adventitia	Absent	Present
Valves within the lumen	Absent	Present

2. Describe the blood supply of arteries.

Blood Supply of Arteries

- Vasa vasorum supplies tunica adventitia and outer two-thirds of tunica media by forming a dense plexus in tunica adventitia
- Luminal blood supplies the tunica intima and inner third of tunica media via diffusion
- Venous drainage is via the minute veins corresponding the arteries

3. List the common sites palpation of arterial pulse in human body.

Common Sites Palpation of Arterial Pulse in Human Body

Artery	*Site of palpation*
Carotid	At the level of cricoid cartilage, along anterior border of sternocleidomastoid
Brachial	Anterior aspect of elbow, medial to tendon of biceps
Radial	At the wrist, on the radial aspect of forearm, lateral to flexor carpi radialis tendon
Femoral	Inferior to the inguinal ligament, between anterior superior iliac spine and pubic symphysis
Popliteal	In the popliteal fossa
Posterior tibial	In the ankle, on the medial aspect, between the tendocalcaneus and medial malleolus
Dorsalis pedis	Dorsum of the foot, medial to extensor hallucis longus tendon

4. List the different types of capillaries with examples.

Types of Capillaries

1. **Continuous capillaries**
   - The endothelial cells are continuous
   - Tight junctions hold the cells together
   - Selective transport of materials takes place through pinocytic vesicles
   - Found in skin, lungs, muscle and brain
2. **Fenestrated capillaries**
   - The endothelial cells have pores in between
   - Diaphragm, made of mucoprotein, closes the pores
   - Diffusion of materials takes place through the diaphragm
   - Found in intestinal villi, endocrine glands, etc

5. Compare and contrast the structure and function of capillary and sinusoid.

Feature	*Capillary*	*Sinusoid*
Definition	Vessels that lie closet to the tissue that they supply	Large, irregular and expanded capillaries
Size	4–8 μm in diameter Can allow passage of single blood cell and that too with considerable deformity	30–40 μm in diameter
Continuity of endothelium	Endothelium is continuous. Adjacent cells are connected by tight junctions and act as true barrier (fenestrations are seen in fenestrated capillaries)	Endothelium exhibits true discontinuity

5.4 EXPLAIN FUNCTIONAL DIFFERENCE BETWEEN ELASTIC, MUSCULAR ARTERIES AND ARTERIOLES

SHORT ESSAY

1. Classify arteries with examples. Compare and contrast the structures of elastic and muscular artery.

Classification of Arteries

1. **Conducting vessels**
   - They measure more than 10 mm in diameter
   - Constitute the large arteries and their branches
   - E.g.—aorta
2. **Distributing vessels**
   - They measure 2–10 μm in diameter
   - E.g.—renal artery
3. **Resistance vessels**
   - Arterioles
   - Their diameter varies between 10–100 microns
   - They are of 3 types:
     - Large arterioles
     - Terminal arterioles
     - Meta-arterioles

Elastic artery	*Muscular artery*
Also known as conducting vessel	Also known as distributing vessel
Large arteries	Medium-sized arteries
Tunica media constitutes of elastic fibers	Tunica media constitutes of muscular tissue (75%) mainly and elastic fibers
Function is to conduct blood from heart to the muscular artery	Function is to supply blood to organs or limbs
E.g.—aorta	E.g.—renal artery

SHORT ANSWERS

1. Compare and contrast the structure of a muscular artery and an arteriole.

Muscular artery	*Arteriole*
Also known as distributing vessel	Also known as resistance vessel
Diameter is 2–10 μm	Diameter is 10–100 μm
Tunica media constitutes of muscular tissue (75%) mainly and elastic fibers	Tunica media is made up of smooth muscles
Function is to supply blood to organs or limbs	Function is to supply blood and also provide peripheral resistance to blood flow
E.g.—renal artery	3 types—large arterioles, terminal arterioles, meta-arterioles

2. Compare and contrast the structure of continuous and fenestrated capillaries.

Continuous capillaries	*Fenestrated capillaries*
The endothelial cells are continuous	The endothelial cells have pores in between
Tight junctions hold the cells together	Diaphragm, made of mucoprotein, closes the pores
Selective transport of materials takes place through pinocytic vesicles	Diffusion of materials takes place through the diaphragm
Found in skin, lungs, muscle and brain	Found in intestinal villi, endocrine glands, etc.

5.5 DESCRIBE PORTAL SYSTEM GIVING EXAMPLES

SHORT ANSWERS

1. Define portal system. Give examples.

Portal System

- Portal system is a type of circulatory system which begins with capillaries and terminates with capillaries.
- Hepatic portal system—venous blood of the gut, pancreas and spleen reach the liver via the portal vein. In liver, secondary capillary bed is formed, known as hepatic sinusoids

Examples

- Hypothalamo-hypophyseal portal circulation—between the capillaries of hypothalamus and anterior pituitary
- Renal portal circulation—efferent arterioles between the glomerular capillaries and capillary plexus around the proximal and distal convoluted tubules.

2. Compare and contrast systemic and portal circulation.

Systemic circulation	*Portal circulation*
Blood is carried from left ventricle of the heart via arteries and then capillaries, veins carry the blood back to right atrium of the heart	Portal vessel carries blood from a capillary network and than branches to form the terminating capillary network or sinusoids
Main function is the oxygenation of various parts of the body	Function is to aid in absorption of nutrients, carrying hormones, reabsorption of salts and other constituents
Present throughout the body	Present in hepatic portal system, hypothalamo-hypophyseal system, renal portal circulation

5.6 DESCRIBE THE CONCEPT OF ANASTOMOSES AND COLLATERAL CIRCULATION WITH SIGNIFICANCE OF END-ARTERIES

SHORT ESSAY

1. Define anastomosis. Describe different types of anastomosis.

Anastomosis

Communication between the blood vessels is known as anastomosis.

Types of Anastomosis

1. **Arterial anastomosis**
   - Communication between branches of two arteries forming anastomosis
   - Functions as collateral channel in case of blockage of one of the arteries
   - It may be actual or potential anastomosis
     i. Actual anastomosis
        – Can occur in the following way:
          o End-to-end anastomosis
          o Ends of the arteries join to form anastomosis
          o E.g.—facial arteries
        – Convergent anastomosis
          o Convergence of two smaller arteries to form a larger artery
          o E.g.—anastomosis of vertebral arteries to form basilar artery

     ii. Potential anastomosis
        – Occurs between terminal arterioles
        – In case of sudden blockage of one of the arteries, a collateral circulation cannot be formed
        – But over a period, the arterioles can dilate to form a collateral circulation
        – E.g—coronary arteries
2. **Arteriovenous anastomosis**
   - Communication between an artery and a vein without the capillaries in between

- Also called arteriovenous shunts
- The shunts are usually formed between a terminal arteriole and a venule
- The wall of the shunt is thick, muscular, with rich vasomotor sympathetic nerve supply
- They can act like a sphincter, and allow direct passage of blood, bypassing the capillaries
- Sites of arteriovenous shunts
  - Skin over lips, nose and external ear
  - Tongue
  - Thyroid gland
  - Mucosal membrane of nose, alimentary canal
  - Erectile tissue of sex organs
- Function—regulates temperature, blood pressure, and regional blood flow

3. **Venous anastomosis**
   - Communication between the tributaries of veins
   - E.g.—dorsal venous arch of hand and the foot

SHORT ANSWERS

1. Define collateral circulation. Describe its function.

Collateral Circulation

- Circulation that occurs through the anastomosis is referred to as the collateral circulation
- Can be present normally to supply a particular region. E.g.—circle of Willis in brain

Function

- Helps in maintaining blood supply in case of blockage of one of the arteries
- Potential anastomosis is where the collateral circulation is formed by the arterioles if sufficient time is given. E.g.— coronary arteries

2. Define end arteries. Mention their types and clinical significance.

End Arteries

- Arteries with no pre-capillary anastomosis
- They are found in
  - Central artery of retina
  - Arteries of spleen, kidney and liver
  - Arteries of metaphysis of long bone
  - Central branches of cerebral arteries

Types

1. Anatomic or true end artery
2. Functional end artery

Clinical Significance

Blockage of the end arteries leads to ischemia and cell necrosis of the area supplied.

5.7 EXPLAIN FUNCTION OF META-ARTERIOLES, PRECAPILLARY SPHINCTERS, ARTERIOVENOUS ANASTOMOSES

SHORT ESSAY

1. Define arteriovenous anastomosis. List the sites where these are present. Mention its functions.

Arteriovenous Anastomosis (Fig. 5.7.1)

- Direct connection between the smaller arteries and veins is referred to as arteriovenous anastomosis
- Also called arteriovenous shunts
- The wall of the shunt is thick, muscular with rich vasomotor sympathetic nerve supply
- They can act like a sphincter, and allow direct passage of blood, bypassing the capillaries
- The number of arteriovenous anastomosis is less at the extremes of age (newborns and old age), and hence temperature regulation is less efficient in these age.

Sites of Arteriovenous Shunts

- Skin over lips, nose, external ear
- Tongue
- Thyroid gland
- Mucosal membrane of nose and alimentary canal
- Erectile tissue of sex organs

Functions

1. Regulates temperature by regulating the flow of blood across the capillary bed
2. Regulates blood pressure in portal venous system
3. Regulates regional blood flow

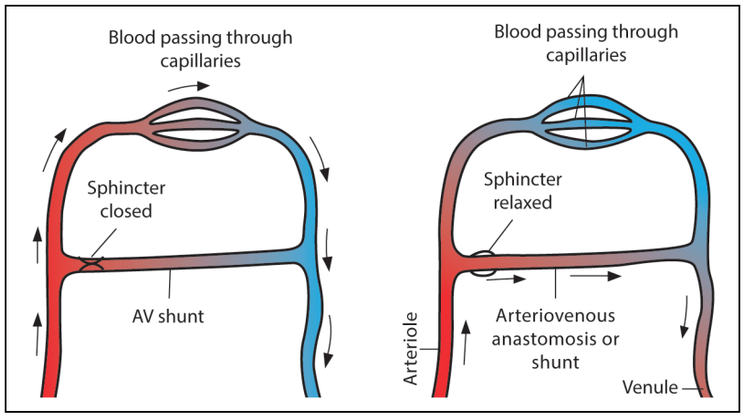


Fig. 5.7.1: Arteriovenous anastomosis

SHORT ANSWER

1. Compare and contrast structure and function of terminal and meta-arterioles.

Terminal arteriole	*Meta-arteriole*
Larger diameter— 15–20 μm	Smaller diameter— <15 μm
Walls have smooth muscle	Walls devoid of smooth muscle
Internal elastic lamina absent	Internal elastic lamina absent
Pericytes absent	Pericytes or Rouget cells present

5.8 DEFINE THROMBOSIS, INFARCTION AND ANEURYSM

SHORT ANSWERS

1. Define thrombosis. Mention its clinical significance.

Thrombosis

Thrombosis is defined as the formation or presence of blood clot in any part of circulatory system.

Clinical Significance

- Thrombosis in the coronary arteries can lead to myocardial infarction
- Thrombosis in the branches of cerebral arteries can lead to stroke
- Thrombosis in the retinal arteries can lead to blindness
- Thrombosis in the arteries supplying the gut can lead to bowel ischemia
- Thrombosis in the arteries supplying the extremities can lead to gangrene

2. Define infarction. Describe its anatomical basis and mention its clinical significance.

Infarction

Infarction is the tissue death due to inadequate blood supply to the affected area due to arterial blockages by thrombus/emboli, rupture of vessel or mechanical compression or vasoconstriction.

Anatomical Basis

- Sudden reduction in blood supply to a tissue occurs
- The collaterals are not formed due to acute onset
- This leads to hypoxia and death of the tissue

Clinical Significance

- Infarction of the tissues is common and can have significant consequences such as
  - Myocardial infarction
  - Cerebral infarction

- Pulmonary infarction
- Bowel infarction
- Gangrene—ischemic necrosis of the extremities

3. Define aneurysm. Describe its anatomical basis and mention its clinical significance.

Aneurysm

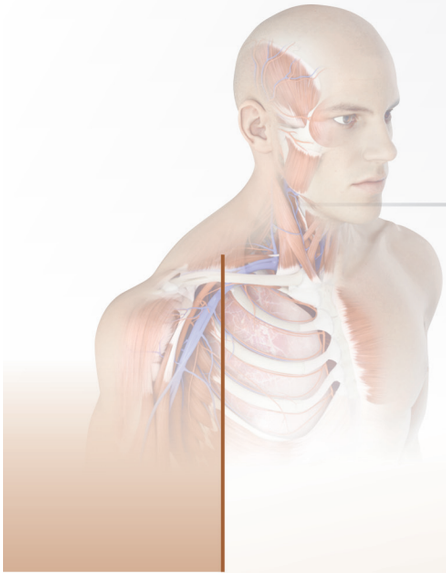
An aneurysm is the enlargement of the artery due to weakness in the arterial wall.

Anatomical Basis

- True aneurysm—attenuated but intact arterial wall or thinned ventricular wall of the heart
- Pseudo-aneurysm—defect in the vascular wall leading to extravascular hematoma freely communicating with the intravascular space

Clinical Significance

- Aneurysms in brain can rupture leading to stroke
- Abdominal aorta aneurysms can remain asymptomatic or cause back pain or lower limb ischemia
- Renal aneurysm can lead to flank pain, or features of hypertension or shock
- Peripheral aneurysms are usually asymptomatic.



Chapter

6

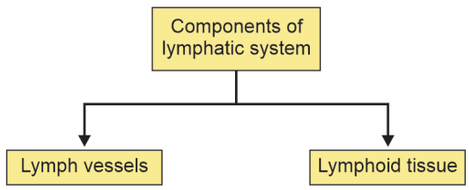
General Features of Lymphatic System

6.1 LIST THE COMPONENTS AND FUNCTIONS OF THE LYMPHATIC SYSTEM

SHORT ESSAY

1. List the components of lymphatic system. Describe the structure of lymphatic vessels in detail.

Components of Lymphatic System



1. Lymph capillaries
2. Lymph vessels proper
3. Terminal lymphatic duct

1. Primary lymph follicles
2. Primary lymphoid organs
3. Secondary lymphoid organs

Structure of Lymphatic Capillaries

- The lymphatic capillaries are blind-ended, dilated tubes forming a wide-meshed plexus in extracellular matrix
- They have incomplete basal lamina or are totally absent
- The associated pericytes are also absent
- They have diameter of 0.5–1.0 μm
- Endothelial cells line the smaller lymphatic vessels
- The endothelium is discontinuous with lack of gap junctions
- Joining of lymphatic capillaries leads to formation of larger lymph vessels

Structure of Lymphatic Vessels

- The larger lymph vessels have a thin external connective tissue coat supporting the endothelium
- Numerous valves are present in the lumen
- Semilunar-shaped
- Paired
- Extension of tunica intima
- Edges of the valve point in the direction of the current
- They have a beaded appearance due to the sinus like expansion of the vessel wall downstream of a valve
- The lymph vessels merge to form lymph ducts
- Two lymph ducts—thoracic duct, right lymphatic duct
- The wall of lymphatic duct has 3 layers:
  1. **Tunica adventitia:** Constitutes of external elastic lamina
  2. **Tunica media:** Made of circumferentially-arranged smooth muscles
  3. **Tunica intima**
     - Has sparse elastic fibers
     - Cisterna chyli—initial large sac-like dilatation in the thoracic duct.

SHORT ANSWER

1. List the functions of lymphatic system.

1. Drainage of excessive fluid in the tissue into the venous system
2. Absorption and transportation of fat from intestine to blood
3. Boost immunity by defending against infective agents
4. Helps in filtration of particulate matter
5. Lymphoid organs produce lymphocytes

6.2 DESCRIBE STRUCTURE OF LYMPH CAPILLARIES AND MECHANISM OF LYMPH CIRCULATION

SHORT ESSAY

1. Describe the normal pathway of lymphatic drainage in human body (Fig. 6.2.1).

- Lymph capillaries form a vast network in intercellular spaces
- The tissue fluid enters these capillaries and is then termed as lymph
- The lymph capillaries unite and form the lymphatic vessels
- Lymphatic vessels pass through multiple lymph nodes
- The small lymph vessels join to form larger vessels
- The lymph vessels eventually form lymph ducts
- Lymph ducts drain into subclavian vein

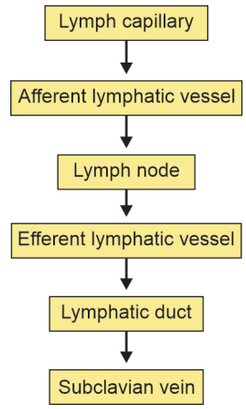


Fig. 6.2.1: Normal pathway of lymphatic drainage

SHORT ANSWERS

1. Compare and contrast the structure of a lymph capillary with a blood capillary.

Lymph capillary	*Blood capillary*
Colorless	Reddish color
Closed at the tip	Connected to arterioles at one end and venules at the other
Wider	Narrower
The lining endothelium is thin and the basement membrane is poorly developed	Lined by normal endothelium and basement membrane
Contains lymph	Contains blood
The pressure is relatively low	The pressure is relatively high
Absorbs fluid from intercellular space	Adds fluid to intercellular space

2. List the areas in the body where lymph capillaries are absent.

1. Hair
2. Nails
3. Cornea
4. Epidermis
5. Brain
6. Spinal cord
7. Articular cartilage
8. Splenic pulp
9. Bone marrow

3. Compare and contrast the area drained by the thoracic duct and right lymphatic duct.

Areas drained by thoracic duct	*Areas drained by right lymphatic duct*
Left thoracic region	Right thoracic region
Left upper limb	Right upper limb
Left side of head	Right side of head
Left side of neck	Right side of neck
Bilateral lower extremities	
Abdomen	

4. List the factors which facilitate lymphatic drainage.

1. Smooth muscle present in the lymphatic vessel wall
2. Pulsation of adjacent arteries
3. Valves in the lymphatic vessel lumen

4. Contraction of surrounding muscles leads to massaging action
5. Filtration pressure generated in the tissue spaces
6. Respiratory movements
7. Negative pressure built in the brachiocephalic veins

5. Describe the pathway of lymphatic drainage through the lymph node.

See Fig. 6.2.2.

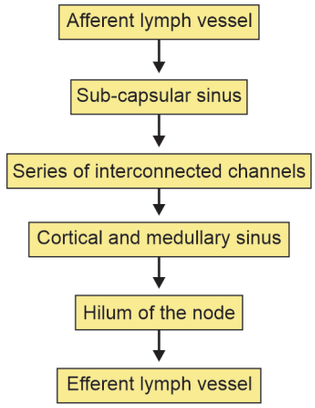


Fig. 6.2.2: Pathway of lymphatic drainage through the lymph node

6.3 EXPLAIN THE CONCEPT OF LYMPHEDEMA AND SPREAD OF TUMORS VIA LYMPHATICS AND VENOUS SYSTEM

SHORT ESSAY

1. Define lymphedema. Describe the anatomical basis for lymphedema.

Lymphedema

Lymphedema may be defined as the localized fluid retention and tissue swelling due to compromised or obstructed lymphatic system.

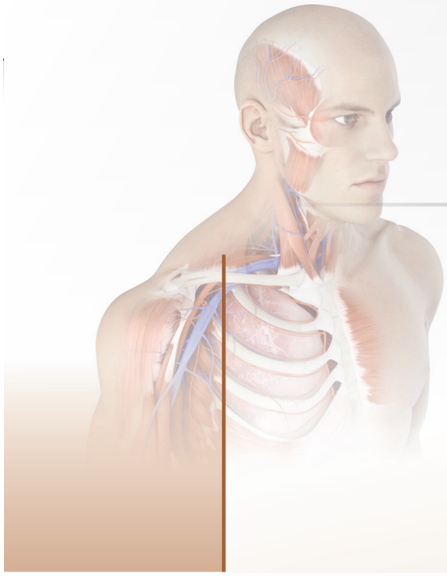
Anatomical Basis

- Fluid which leaks from capillaries into the tissue space is mainly absorbed back into the blood-stream
- About 30 litres of fluid passes into intercellular space in a day
- 27 litres are absorbed into the venous system
- The remaining 3 litres is absorbed by lymph capillaries
- The lymph is then pumped into the lymph vessels and it passes through various lymph nodes and finally the lymph ducts draining into subclavian vein
- When part of the lymph system is damaged or blocked, fluid cannot drain from nearby body tissues
- Fluid accumulates in the tissues and causes swelling

SHORT ANSWER

1. Describe the anatomical basis for spread of cancer through lymphatic system.

- Lymphatic spread is the most common route of spread of cancer
- The cancer cells are trapped in the lymph node after they enter into the lymphatic system
- The cancer cells proliferate in the lymph node leading to nodal spread of cancer
- The first lymph node draining a site of cancer is called sentinel lymph node
- Cancer cells escaping from the lymph node can spread further to other lymph nodes or reach the blood circulation to cause distant organ metastases.



Chapter 7

Introduction to the Nervous System

7.1 DESCRIBE GENERAL PLAN OF NERVOUS SYSTEM WITH COMPONENTS OF CENTRAL, PERIPHERAL AND AUTONOMIC NERVOUS SYSTEMS

SHORT ESSAY

1. Describe the anatomical and functional organization of the human nervous system.

Anatomical Organization

1. **Central nervous system (CNS)**
   - Comprises of brain and spinal cord
2. **Peripheral nervous system (PNS)**
   - Comprises of all neural tissues other than CNS
   - Consists of:
     - Peripheral nerves
       - Cranial nerves—12 pairs
       - Spinal nerves—31 pairs
     - Ganglia
       - Sensory
       - Autonomic
     - Autonomic nervous system (ANS)
       - Sympathetic nervous system
       - Para-sympathetic nervous system
     - Special senses
       - Taste
       - Olfaction
       - Vision
       - Hearing
       - Balance

Functional Organization

- Afferent division or sensory system
  - The information is brought to CNS
- Efferent division or motor system
  - The information is carried from CNS
  - Divided into:
    - Somatic nervous system
      - Innervates somatic structures, mainly skeletal muscles
      - Causes voluntary motor activities
    - Autonomic nervous system
      - Innervates visceral structures
      - Causes involuntary movements

SHORT ANSWERS

1. List the components of central and peripheral nervous system.

Anatomical Organisation of the Nervous System

Figure 7.1.1

2. List the functions of human nervous system.

1. Motor function—voluntary movements
2. Sensory function—receiving and perception of information
3. Integration
4. Cognition-learning, memory, emotions
5. Autonomic function—involuntary body functions

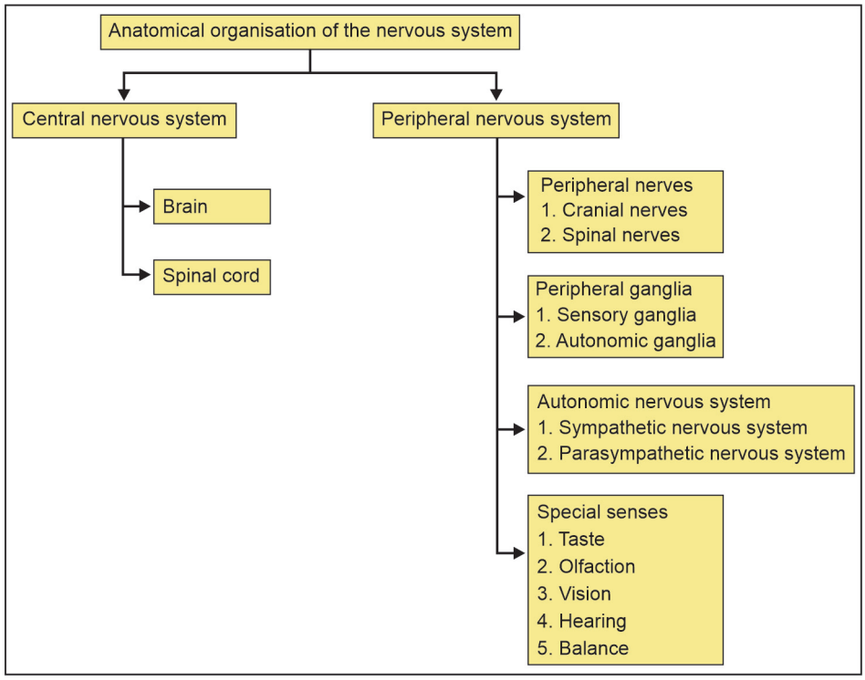


Fig. 7.1.1: Anatomical organisation of the nervous system

3. Define autonomic nervous system. Describe the formation of its subdivisions.

Autonomic Nervous System

Autonomic nervous system is the visceral efferent component of the human nervous system.

It supplies three structures in the body:

1. Smooth muscles
2. Cardiac muscles
3. Glands

Formation of its Sub-divisions

1. **Sympathetic nervous system**
   - Arise from the T1 to L2 spinal segments
2. **Parasympathetic nervous system**
   - Arise from brain in visceral efferent nuclei and exit via cranial nerves - III, VII, IX, X
   - Arise from the 2nd, 3rd, 4th sacral segments

7.2 LIST COMPONENTS OF NERVOUS TISSUE AND THEIR FUNCTIONS

SHORT ESSAYS

1. Classify the components of nervous tissue with examples.

Classification of Components of Nervous Tissue

1. Neurons
2. Neuroglial cells

Classification of Neurons

According to Polarity

1. *Apolar neurons:* Neuroblasts present in the neural tube during early development
2. *Unipolar:* Existence of true unipolar neurons is not clear in human beings. But transient true unipolar neurons are seen during early differentiation of the neural tube
3. *Pseudo-unipolar neurons:* Nerves in sensory ganglia of cranial nerves
4. *Bipolar neurons:* Nerves in the olfactory epithelium, retina, auditory epithelium
5. *Multipolar neurons:* Motor neurons forming a tract in the brain

According to the Function

1. **Motor neurons**
   i. *Upper motor neurons:* Neurons that originate in higher cortical center and terminate in the nuclei
   ii. *Lower motor neurons:* Neurons that originate in the nuclei and terminate in the target organ
2. **Sensory neurons**
   i. *First order neurons:* Neurons that begin from the receptor or the target organ and terminates in a nuclei
   ii. *Second order neurons:* Neurons that begin from the nuclei and terminate in the thalamus
   iii. *Third order neurons:* Neuron that begins from the thalamus and terminate in the primary sensory cortex of brain

According to the Relative Length of Axons and Dendrites

1. *Golgi type I neurons:* Pyramidal cells of the cerebral cortex
2. *Golgi type II neurons:* Cells of the cerebral cortex

According to the Shape of the Cell Body

1. *Pyramidal cells:* Pyramidal cells of motor cortex
2. *Fusiform cells:* Fusiform cells of motor cortex
3. *Pyriform cells:* Purkinje cells of the cerebellum

Other Types

1. *Stellate cells:* Stellate cells of the cerebellar cortex
2. *Glomerular cells:* Granule cells of the cerebellum
3. *Amacrine cells:* Amacrine cells of the retina

Classification of Neuroglial Cells

According to Location, Origin, Function

- Neuroglia in CNS
  1. Astrocytes
  2. Oligodendrocytes
  3. Ependymal cells
  4. Microglia
- Neuroglia in PNS
  1. Satellite cells
  2. Schwann cells

According to Structure

1. **Macroglia:** Astrocytes, oligodendrocytes, ependymal cells
2. **Microglia:** Phagocytic cells derived from mesoderm

2. Classify neuroglial cells. Mention their functions.

Glial cell type	*Origin*	*Location*	*Functions*
Oligodendrocyte	Neural tube	CNS	Myelin production
Astrocytes	Neural tube	CNS	Provides structural support
1. Fibrous astrocytes			Metabolic exchanges
• Contains gliofibrils which extend into processes			Repair processes
• Located in CNS white matter			Blood-brain barrier
2. Protoplasmic astrocytes			
• Gliofibrils are absent			
• Located in CNS grey matter			
Ependymal cell	Neural tube	CNS	Epithelial lining cavities of CNS
Microglia	Bone marrow	CNS	Macrophagic activity
Schwann cell	Neural tube	PNS	Myelin production
Satellite cell	Neural tube	PNS	Preserves neuron cell bodies

3. Define the blood–brain barrier. Describe its formation. Mention its function and clinical significance.

Blood–brain Barrier

Blood–brain barrier is a highly-selective semi-permeable membrane that regulates the passage of substances into the central nervous system.

Formation

It is located at the capillary endothelium in the brain and constitutes the following:

- Capillary endothelium with tight junctions
- The basement membrane of endothelium
- Astrocytes—end-feet

Functions

1. Protection of brain from infective agents
2. Prevent the entry of harmful substances into the brain

Clinical Significance

- It may be disrupted in certain infections or ischemia
- Primary or metastatic brain tumors can cause its breakdown
- As the blood–brain barrier is poorly developed in neonates, high bilirubin levels can reach the brain leading to a condition known as kernicterus.

4. Describe blood–CSF barrier. Describe its formation. Mention its function and clinical significance.

Blood–CSF Barrier

Forms an interface between blood and CSF

Formation

- Capillary endothelial cells which are fenestrated
- Basement membrane
- Astrocyte-end feet
- Choroidal epithelial cells with tight junctions

Functions

1. Protection of brain from infective agents
2. Prevent the entry of harmful substances into the brain
3. Selectively permits entry of certain substances into brain
4. Facilitates removal of metabolic products from brain

Clinical Significance

- Disruption can lead to infection of CNS
- Can be disrupted in certain infections or tumors of the brain

SHORT ANSWERS

1. Compare the structure of a fibrous and protoplasmic astrocyte.

Fibrous astrocyte	*Protoplasmic astrocyte*
Originates from the neural tube	Originates from the neural tube
Contains myofibrils which extend into processes	Gliofibrils are absent
Located in CNS white matter	Located in CNS grey matter
Processes are parallel to its axon	Processes form a complex network

2. Which neuroglial cell is responsible for formation of myelin sheath in central nervous system? Describe its structure.

Neuroglial Cell Responsible for the Formation of the Myelin Sheath

Oligodendrocytes form myelin sheath in the central nervous system.

Structure of Oligodendrocyte

- They are smaller cells with lesser number of processes
- They possess round nuclei
- The cytoplasm has numerous mitochondria, glycogen and microtubules
- Have morphological variation and can be cells with,
  - Large euchromatic nuclei and pale cytoplasm
  - Heterochromatic nuclei and dense cytoplasm

7.3 DESCRIBE PARTS OF A NEURON AND CLASSIFY THEM BASED ON NUMBER OF NEURITES, SIZE AND FUNCTION

SHORT ESSAYS

1. Describe the structure of a typical multipolar neuron.

Structure of a Typical Multipolar Neuron (Fig. 7.3.1)

- A neuron consists of a cell body and 2 processes
- Cell body/soma/perikaryon
- Made up of a mass of cytoplasm, bounded by plasma membrane
- The nucleus is large and vesicular with prominent nucleolus
- The cytoplasm has Nissl substances, which are large aggregations of rough endoplasmic reticulum
- Neurofibrils are present in cytoplasm, which are filamentous protein strands
- Centrosomes and centrioles are absent
- Processes/neurites
- Axon
  - Carries the impulse away from the cell body
  - A single long process
  - Does not branch except at its end
  - Telodendria—present at the end of axon and have terminal buttons or presynaptic knobs
- Dendrites
  - Carry the impulse towards the cell body
  - Multiple short processes

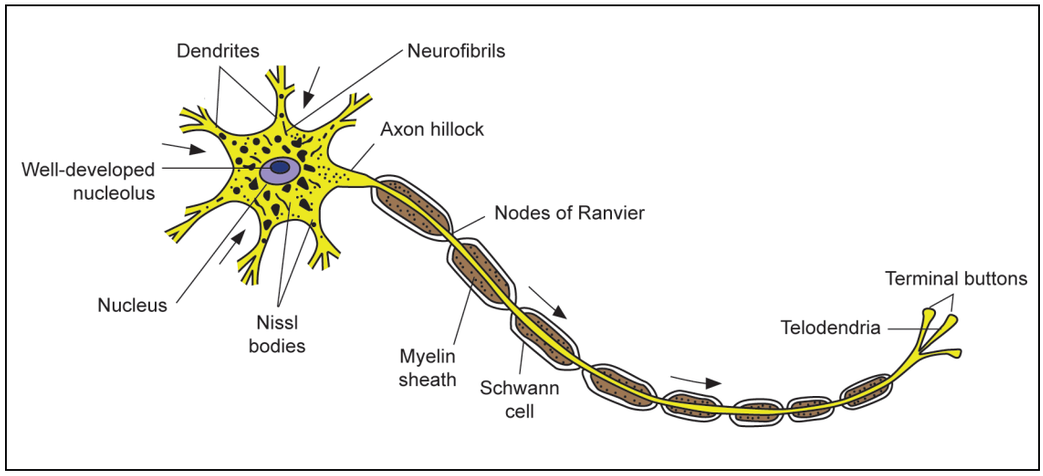


Fig. 7.3.1: Structure of a typical multipolar neuron

2. Classify neurons based on the number of neurites. List examples for each type.

Type of neurons (Fig. 7.3.2)	*Features*	*Examples*
Apolar neurons	• No processes	Neural tube
Unipolar	• It has only one process	Early differentiation of neural tube
Pseudo-unipolar neurons	• Only 1 process • It divides into a central and a peripheral branch • Central branch serves as axon • Peripheral branch serves as dendrite	Dorsal root ganglia of spinal nerves
Bipolar neurons	• Has 2 processes, one on each pole • One process is the axon and the other is dendrite	Olfactory epithelium, retina, vestibulocochlear ganglia
Multipolar neurons	• Has 1 axon and multiple dendrites • Most common type of neuron	Motor neurons of brain, spinal cord, anterior horns cells and of autonomic ganglia

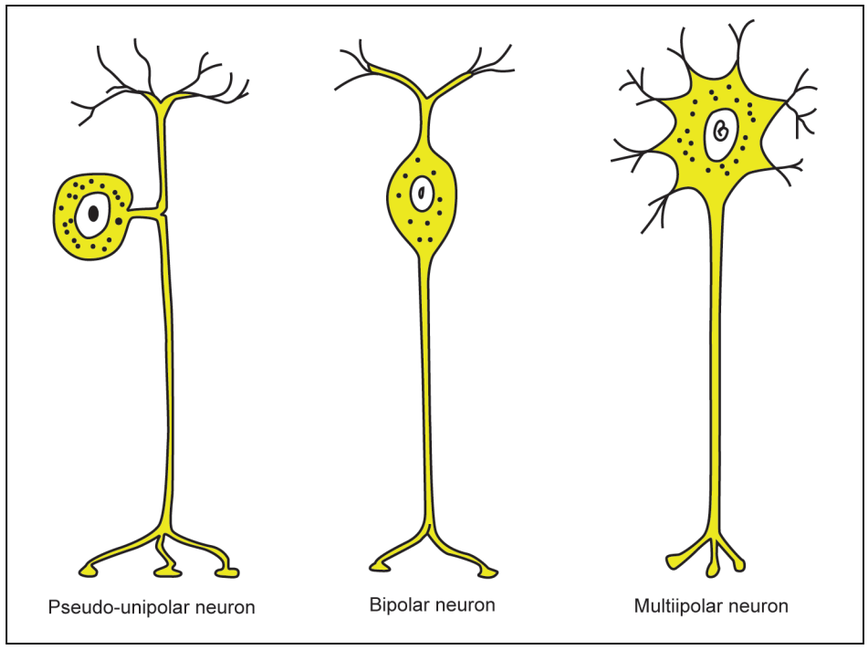


Fig. 7.3.2: Types of neurons

3. Classify neurons based on the functions. Mention examples.

Type of neuron	*Features*	*Examples*
Motor neuron	• Carries impulses away from CNS—efferent nerve • Supplies peripheral organs, like muscles • Consists of a long axon and short dendrite	Alpha motor neurons which arise from the anterior grey horn of the spinal cord
Sensory neuron	• Carries impulses to CNS—afferent nerve • Transmits impulses from peripheral organs • Consists of short axon and long dendrites	Pseudounipolar neurons present in the dorsal root ganglion of the spinal nerve
Interneuron	• Connects the sensory and motor neuron	Small neurons which connect the sensory and motor neurons in the spinal cord

SHORT ANSWERS

1. Compare and contrast the structure of dendrites and axons.

Axons	*Dendrites*
Only one in number	Multiple in number
Thin long, uniform thickness, smooth surface	Short, thickness diminishes with repeated divisions, spiny projections present on branches
Fewer branches and at right angles	Multiple branches and at acute angles
Neurofibrils are present but Nissl granules are absent	Both neurofibrils and Nissl granules are present
Efferent component of an impulse	Afferent component of an impulse

2. Describe the structure and function of Nissl substance.

Structure

- Comprises of rosettes of polysomes and rough endoplasmic reticulum
- They are characteristic of nerve cells
- Absent in axons
- More in motor nerves

Functions

1. Protein synthesis
2. Maintains continuous axonal flow

3. Describe chromatolysis and its functional significance.

Chromatolysis

- Process of disappearance of Nissl bodies when a nerve cell is injured
- Also associated with movement of the nucleus to the cell periphery and increased size of cell body, nucleus and nucleolus

Functional Significance

Chromatolysis is associated with

- Axotomy
- Acrylamide intoxication
- Lithium toxicity
- Amyotrophic lateral sclerosis (ALS)
- Alzheimer's disease
- Pick's disease
- Alcoholic encephalopathy
- Idiopathic brainstem neuronal chromatolysis

4. Compare and contrast the structure of Golgi type I and type II neuron.

Golgi type I neuron	*Golgi type II neuron*
Has long axon Sends branches outside CNS	Has short or no axon Does not send branches outside CNS
E.g.—Purkinje cells of cerebellum	E.g.—neurons of cerebral cortex

5. List the sites in the human body where bipolar neurons are present.

1. Retina
2. Olfactory epithelium
3. Vestibulocochlear ganglia

7.4 DESCRIBE STRUCTURE OF A TYPICAL SPINAL NERVE

SHORT ESSAY

1. Describe structure of a typical spinal nerve.

- A peripheral nerve attached to the spinal cord is called spinal nerve.
- There are 31 pairs of spinal nerves, arranged as 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and one coccygeal pair (Fig. 7.4.1).
- Each nerve is connected to the spinal cord by two roots
- The two roots pass in the intervertebral foramen, uniting there to form spinal nerve
  1. Anterior root
  2. Posterior root

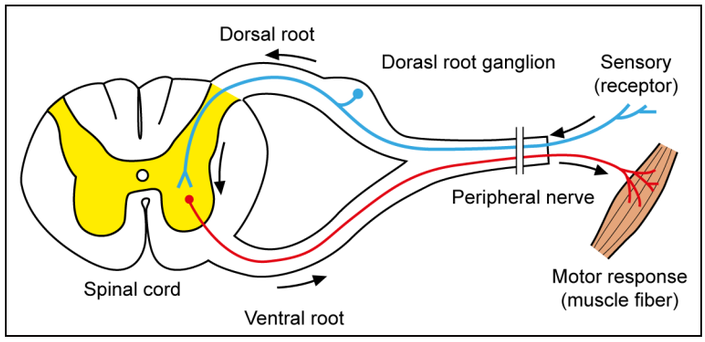


Fig. 7.4.1: Structure of a typical spinal nerve

1. **Anterior root**
   - Also called motor or efferent root
   - Attached to the anterior part of the spinal cord
   - Contains efferent fibers that arises from the ventral horn of the spinal cord
2. **Posterior root**
   - Also called sensory or afferent root
   - Attached to the posterior part of the spinal cord
   - Contains afferent fibers that arises from the posterior horn of the spinal cord

- The 2 roots emerge out of the vertebral canal through intervertebral foramen
- They form the nerve trunk after joining each other
- The nerve trunk divides into:

1. **Posterior rami**
   - Small
   - Curve posteriorly
   - Supply the back muscles and skin over the muscles
2. **Anterior rami**
   - Large
   - Traverse antero-laterally along the body wall
   - Supply the antero-lateral body wall muscles and skin

- The corresponding sympathetic ganglion gives rise to gray ramus communicans which joins the anterior ramus
- It carries the post-ganglionic sympathetic fibers which supply
  - Smooth muscles of blood vessels
  - Sweat glands
  - Arrectores pilorum

SHORT ANSWER

1. Compare and contrast the structure and function of grey and white rami communicans.

Feature	*White rami communicans*	*Gray rami communicans*
Type of fibers	Myelinated	Non-myelinated
Source of origin	Lateral horn cells of spinal cord	Cells of sympathetic ganglion
Function	Relay in sympathetic ganglion	Distributed to blood vessels, hair and sweat glands through branches of anterior and posterior rami of spinal nerves

7.5 DESCRIBE PRINCIPLES OF SENSORY AND MOTOR INNERVATION OF MUSCLES

SHORT ESSAY

1. Compare and contrast the features of sensory and motor innervation of muscles.

Sensory innervation of muscle	*Motor innervation of muscle*
• 2 types	• 2 types
Annulospiral (primary) endings	Large alpha myelinated fibers
• Wind spirally around the equator of intrafusal fibers	• Axon of alpha anterior horn cells
• Thickly myelinated (type Ia) neuron	• Supply the extrafusal muscle fibers
Flower spray (secondary) endings	Small gamma myelinated fibers
• Located at a distance from equator	• Axons of gamma anterior horn cells
• Thinly myelinated (type II) neuron	• Supply the intrafusal muscle fibers
• End as varicosities resembling a spray of flowers	
• Have a short axon	• Have a long axon
• Dendrite is usually single and long	• Dendrites are multiple and short
• Have a receptor	• Do not have a receptor
• Carry signal from muscle to CNS	• Carry signal from CNS to muscle
• Follow the afferent pathway	• Follow the efferent pathway

7.6 DESCRIBE CONCEPT OF LOSS OF INNERVATION OF A MUSCLE WITH ITS APPLIED ANATOMY

SHORT ESSAY

1. Describe the anatomical basis for effects of loss of innervation to a muscle.

- Lesions of the peripheral nerve that supplies the muscle or involvement of anterior horn cells in diseases (E.g. poliomyelitis) reduce the power of the muscle or paralyze the muscle involved
- Muscular wasting occurs within 2–3 weeks after peripheral nerve lesion
- Muscular fasciculation, i.e. twitching of group of muscle fibers is commonly seen in patients with chronic disease that affects the anterior horn cells
- Muscular contracture occurs most commonly in the muscles that normally oppose the paralyzed muscles
- This contracture leads to permanent shortening of muscle
- Localized wasting of muscles is associated with lower motor neuron type of paralysis and disuse atrophy
- Generalized wasting of muscle occurs in debilitating diseases such as cancer, pulmonary tuberculosis, etc.
- The muscle rigidity is of 3 types:
  1. **Clasp-knife type**
     - Initial resistance to the movement is suddenly overcome
     - Seen in upper motor neuron lesion
  2. **Lead-pipe type**
     - A steady increase in resistance throughout the movement
     - Seen in extrapyramidal lesion
  3. **Cogwheel type**
     - Ratchet-like (intermittent) increase in resistance to movement
     - Seen in extrapyramidal lesion

7.7 DESCRIBE VARIOUS TYPE OF SYNAPSE

SHORT ESSAY

1. Define synapse. Describe different types of synapse.

Synapse

Synapse is the neuronal junction at which the nerve impulse passes from one neuron to another.

Types of Synapse

1. **Axodendritic (Fig. 7.7.1):** Synapse between an axon and a dendrite
2. **Axosomatic (Fig. 7.7.2):** Synapse between an axon and a soma
3. **Axoaxonic (Fig. 7.7.3):** Synapse between 2 axons
4. **Dendrodendritic (Fig. 7.7.4):** Synapse between two dendrites
5. **Somatodendritic:** Synapse between a soma and a dendrite
6. **Somatosomatic:** Synapse between two somas

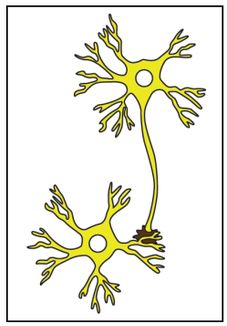


Fig. 7.7.1: Axodendritic synapse

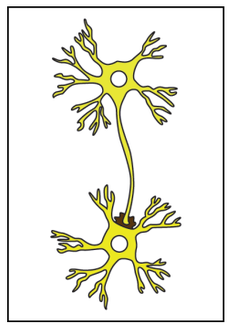


Fig. 7.7.2: Axosomatic synapse

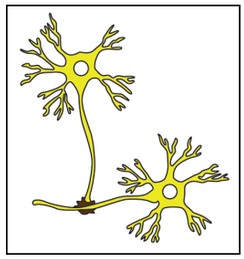


Fig. 7.7.3: Axoaxonic synapse

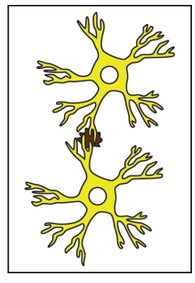


Fig. 7.7.4: Dendrodendritic synapse

7.8 DESCRIBE DIFFERENCES BETWEEN SYMPATHETIC AND SPINAL GANGLIA

SHORT ESSAY

1. Define ganglia. Compare and contrast the features of sensory and autonomic ganglia.

Ganglia

Aggregation of cell bodies of neurons within the peripheral nervous system is referred to as ganglion.

Sensory ganglia	*Autonomic ganglia*
• Thick capsule	• Thin capsule
• Big, round, pseudo-unipolar neurons arranged peripherally	• Multipolar neurons arranged irregularly
• Nucleus is central	• Star-shaped in varying sizes in sections
	• Eccentric nucleus
• Satellite cells enclose every neuron	• Cell body is incompletely covered by satellite cells
• Neurons in groups separated by bundles of nerve fibers	• Neurons widely spaced and separated by axons/dendrites which pass without being involved in synapse
• Regularly arranged nerve fibers entering and leaving the ganglion	• Nerve fibers are irregularly scattered
• No synapse	• Synapse present
• E.g.—dorsal roots of the spinal nerves; sensory ganglia of cranial nerves—V, VII, IX, X	• E.g.—sympathetic ganglia along sympathetic chain; otic ganglion; ciliary ganglion; submandibular ganglion