BONE TISSUE AND HOMEOSTASIS

"Bone tissue is continuously growing, remodeling, and repairing itself. It contributes to homeostasis of the body by providing support and protection, producing blood cells, and storing minerals and triglycerides."

Introduction

Musculoskeletal System

The musculoskeletal system consists of:

- Bones of the skeleton
- Joints of the bones, and
- Skeletal muscles that move the body

Bone tissue is a **complex and dynamic living tissue**. It continuously undergoes **remodelling**, which includes the construction of new bone tissue and the breakdown of old bone tissue.

The **skeletal system** is the entire framework of bones and their cartilages, along with ligaments and tendons.

- **Osteology**: The study of bone structure and the treatment of bone disorders
- **Orthopedics**: The branch of medical science concerned with the prevention or correction of disorders of the musculoskeletal system

Functions of Bone and the Skeletal System

Support

- The skeleton serves as the structural framework of the body by supporting soft tissues
- Provides attachment to muscles and tendons

Protection

- The skeleton protects vital internal organs from injury
- Forms the boundaries of:
    - Cranium (brain)
    - Vertebrae (spinal cord)
    - Thorax or rib cage (heart and lungs)
    - Pelvis

Assistance in Movement

- Allows movement of the body as a whole and of individual body parts

- Bones form joints that are moved by muscles

Mineral Storage and Release (Mineral Homeostasis)

- Bone tissue stores minerals, especially:
  - Calcium (99%)
  - Phosphorus
- Essential for maintaining normal blood calcium levels

Blood Cell Production (Haemopoiesis)

- Within certain bones, **red bone marrow** produces:
  - Red blood cells
  - White blood cells
  - Platelets
- This process is called **haemopoiesis**

Triglyceride Storage

- **Yellow bone marrow** stores triglycerides
- Acts as a potential chemical energy reserve

Types of Bones

Classification Based on Shape

All bones of the body are classified into five types:

1. Long bones
2. Short bones
3. Irregular bones
4. Flat bones
5. Sesamoid bones

Additional Classification (Based on Location)

- Sutural bones

Long Bones

- Greater length than width
- Consist of a shaft and extremities (epiphyses)
- Slightly curved
- Vary in size
- Found in the limbs, such as:
  - Femur (thigh bone)

- Tibia and fibula (leg bones)
- Humerus (arm bone)
- Ulna and radius (forearm bones)
- Phalanges (finger and toe bones)

Short Bones

- Somewhat cube-shaped
- Nearly equal in length and width
- Examples:
  - Carpals (wrist bones)
  - Tarsals (ankle bones)

Irregular Bones

- Have complex shapes
- Examples:
  - Vertebrae (backbone)
  - Some skull bones

Flat Bones

- Generally, thin
- Examples:
  - Cranial (skull) bones – protect the brain
  - Sternum (breastbone)
  - Ribs – protect thoracic organs
  - Scapulae (shoulder blades)

Sesamoid Bones

- Shaped like a sesame seed
- Protect tendons from excessive wear and tear
- Example:
  - Patella (kneecap)

Sutural Bones

- Small bones located in sutures (joints) between certain cranial bones

Structure of Bone

Long Bone

A typical long bone consists of the following parts:

Diaphysis

- Shaft or body of the bone
- Long, cylindrical main portion
- Contains nerve and arterial supply
- Composed mainly of compact bone

Epiphyses

- Extreme ends of the bone
- Consist of an outer covering of compact bone with spongy bone inside

Metaphyses

- Regions between the diaphysis and epiphyses
- Contain epiphyseal cartilage (growth plate)
- Ossifies after growth to form the epiphyseal line

Articular Cartilage

- Thin layer of hyaline cartilage
- Covers the epiphyses where bones form joints

Periosteum

- Tough connective tissue sheath covering the entire bone except at joints
- Consists of:
    - Outer fibrous layer
    - Inner osteogenic layer
- Associated with blood supply

Medullary Cavity (Canal)

- Hollow cylindrical space within the diaphysis
- Contains fatty yellow bone marrow and numerous blood vessels in adults

Endosteum

- Thin membrane lining the medullary cavity
- Contains a single layer of bone-forming cells and small connective tissue

Short, Irregular, Flat and Sesamoid Bones

- Have a thin outer layer of compact bone
- Inner spongy bone contains red bone marrow
- Enclosed by periosteum

- In cranial bones, periosteum is replaced by dura mate

Microscopic Structure of Bone

Composition of Bone (Osseous Tissue)

- 55% inorganic matrix (mainly calcium phosphate)
- 29% collagen fibers
- 14% water
- 2% cells

Mineral salts are deposited in the collagen framework of the extracellular matrix. These salts crystallize, causing the tissue to harden. This process is called **calcification**.

Bone Cells

Four types of cells are present in bone tissue:

1. **Osteogenic cells**
    - Unspecialized bone stem cells
    - Only bone cells capable of cell division
    - Differentiate into osteoblasts
2. **Osteoblasts**
    - Bone-forming cells
    - Synthesize and secrete collagen fibers
    - Deposit inorganic salts and osteoid
    - Initiate calcification
    - Become osteocytes
3. **Osteocytes**
    - Mature bone cells
    - Do not divide
    - Monitor and maintain bone tissue
4. **Osteoclasts**
    - Break down bone tissue (resorption)
    - Release calcium and phosphate

Both osteoblasts and osteoclasts are found in areas of bone where active growth, repair, or remodeling occurs.

Compact and Spongy Bone

Compact Bone

- Makes up about 80% of total bone mass
- Composed of osteons (Haversian systems)

Spongy Bone

- Makes up about 20% of skeletal bone mass

Factors Affecting Bone Growth and Remodeling

1. Minerals
2. Vitamins:
    - A
    - C
    - D
    - K
    - B12
3. Hormones:
    - Growth hormone
    - Thyroid hormones
    - Sex hormones
    - Calcitonin
    - Parathyroid hormone

Divisions of the Skeletal System

- Adult human skeleton consists of **206 bones**
- Skeletons of infants and children contain **more than 206 bones**

Bones of the adult skeleton are divided into:

1. **Axial skeleton** – 80 bones
2. **Appendicular skeleton** – 126 bones

Axial Skeleton

The axial skeleton consists of:

- Skull
- Vertebral column
- Ribs
- Sternum

Together, these bones form the **central core (axis) of the body**.

Axial Skeleton – Number of Bones

Structure	Number
Cranium	8
Face	14

Hyoid	1
Auditory ossicles	6
Vertebral column	26
Sternum	1
Ribs	24
Total	**80**

Appendicular Skeleton

Pectoral (Shoulder) Girdle

- Clavicle – 2
- Scapula – 2

Upper Limbs

- Humerus – 2
- Ulna – 2
- Radius – 2
- Carpals – 16
- Metacarpals – 10
- Phalanges – 28

Pelvic (Hip) Girdle

- Hip (coxal) bone – 2

Lower Limbs

- Femur – 2
- Patella – 2
- Fibula – 2
- Tibia – 2
- Tarsals – 14
- Metatarsals – 10
- Phalanges – 28

THE AXIAL SKELETON AND HOMEOSTASIS

"The bones of the axial skeleton contribute to homeostasis by protecting many of the body's organs such as the brain, spinal cord, heart, and lungs. They are also important in support and calcium storage and release."

SKULL

- Bony framework of the head
- Rests on the upper end of the vertebral column
- Contains 22 bones
- Consists of:
    - Cranial bones (8)
    - Facial bones (14)

Sinuses

- Air-filled spaces present in:
    - Frontal
    - Sphenoid
    - Ethmoid
    - Maxillary bones
- Communicate with nasal cavity
- Lined with ciliated mucous membrane
- Provide resonance to the voice and reduce skull weight

CRANIUM

- Formed by flat and irregular bones
- Encloses and protects the brain
- Consists of two parts:
    1. Base – supports the brain
    2. Vault – surrounds and covers the brain

Additional features:

- Inner periosteum forms the outer layer of dura mater
- Sutures between bones are immovable in adults
- Numerous foramina and fissures allow passage of nerves and vessels

CRANIAL BONES (8)

- Frontal – 1
- Parietal – 2
- Temporal – 2
- Occipital – 1
- Sphenoid – 1
- Ethmoid – 1

Frontal Bone

- Forms the forehead

- Contributes to orbital cavities
- Forms supraorbital margins
- Contains frontal sinuses lined with ciliated mucous membrane
- Coronal suture joins frontal and parietal bones

Parietal Bones

- Form the sides and roof of the skull
- Articulate at:
    - Sagittal suture (with each other)
    - Coronal suture (with frontal)
    - Lambdoidal suture (with occipital)
    - Squamous suture (with temporal)
- Inner surface is concave and grooved

Temporal Bones

- Located on either side of the head
- Articulate with parietal, occipital, sphenoid, and zygomatic bones

Parts

1. Squamous part
2. Zygomatic process
3. Mastoid part
4. Petrous portion
5. Styloid process

- Squamous part: thin and fan-shaped
- Zygomatic process: forms zygomatic arch
- Mastoid part: contains mastoid air cells
- Petrous portion: houses organs of hearing and balance
- Styloid process: supports hyoid bone and muscles
- Forms temporomandibular joint with mandible
- External acoustic meatus located posteriorly

Occipital Bone

- Forms the back and base of the skull
- Articulates with parietal, temporal, and sphenoid bones
- Contains occipital condyles for articulation with atlas
- Allows nodding movements
- Foramen magnum allows passage of spinal cord

Sphenoid Bone

- Butterfly-shaped
- Located at the base of the skull
- Articulates with multiple cranial bones
- Contains sella turcica for pituitary gland
- Has air sinuses opening into nasal cavity
- Optic nerve passes through optic foramina

Ethmoid Bone

- Located in the anterior skull base
- Contributes to orbit, nasal septum, and nasal cavity
- Contains superior and middle conchae
- Has cribriform plate for olfactory nerves
- Contains multiple air sinuse

FACE

- Formed by 14 bones
- Form nasal and orbital cavities

Facial Bones

- Zygomatic – 2
- Maxilla – 2
- Nasal – 2
- Lacrimal – 2
- Vomer – 1
- Palatine – 2
- Inferior nasal conchae – 2
- Mandible – 1

Hyoid Bone

- Horseshoe-shaped bone in the neck
- Does not articulate with any other bone
- Attached to styloid process by ligaments
- Supports tongue and larynx

ORBITS

- Each orbit formed by seven bones:
    - Frontal
    - Sphenoid
    - Ethmoid
    - Palatine
    - Zygomatic

- Lacrimal
- Maxilla

Unique Features of Skull

1. Sutures
2. Paranasal sinuses
3. Fontanels

Fontanels

- Present in developing skull
- Filled with connective tissue
- Allow growth of brain
- Anterior fontanel closes at 12–18 months
- Posterior fontanel closes at 2–3 months

Functions of the Skull

1. Protects the brain
2. Protects eyes and supports eye muscles
3. Protects inner ear structures
4. Provides voice resonance
5. Forms air passages
6. Holds teeth
7. Enables chewing

Vertebral Column

- Also called spine or backbone
- Surrounds the spinal cord
- Composed of vertebrae
- Early development: 33 vertebrae
- Adult: 26 bones

Regions

Region	Number
Cervical	7
Thoracic	12
Lumbar	5
Sacrum	1
Coccyx	1

- Cervical, thoracic, lumbar – movable
- Sacrum and coccyx – immovable

TYPICAL VERTEBRA

A typical vertebra consists of:

1. Vertebral body
2. Vertebral (neural) arch
3. Several processes

Characteristics of a Typical Vertebra

Vertebrae in different regions of the vertebral column vary in size, shape, and specific details, but they are similar in basic structure and function.

A typical vertebra consists of:

1. A vertebral body
2. A vertebral arch
3. Several processes

Vertebral Body

- The vertebral body is the **broad, flattened, and largest part** of the vertebra
- When vertebrae are stacked together in the vertebral column, the flattened surfaces of the vertebral bodies articulate with the corresponding surfaces of the vertebrae above and below
- There is **no direct bone-to-bone contact** between vertebral bodies
- A tough pad of fibrocartilage called the **intervertebral disc** is present between each pair of vertebrae
- Vertebral bodies are located on the **anterior side** of the vertebral column
- The size of the vertebral bodies increases progressively toward the base of the spine

Vertebral (Neural) Arch

- The vertebral arch encloses a large **vertebral foramen**
- It lies behind the vertebral body
- Forms the posterior and lateral walls of the vertebral foramen

Structure:

- The lateral walls are formed by **pedicles**
- The posterior walls are formed by **laminae**

Processes:

- At the junction of pedicle and lamina, a **transverse process** projects laterally
- Where the two laminae meet posteriorly, a **spinous process** is formed

- Spinous processes can be felt through the skin along the length of the spine

Articular surfaces:

- The vertebral arch has **four articular surfaces**
- Two articulate with the vertebra above
- Two articulate with the vertebra below
- The series of vertebral foramina together form the **vertebral (neural) canal**, which contains the spinal cord

Region-Specific Vertebral Characteristics

Cervical Vertebrae

- The smallest vertebrae
- Designed to support only the weight of the head
- Transverse processes contain a **foramen transversarium**
- The vertebral artery passes through this foramen to supply the brain

First Cervical Vertebra (C1) – Atlas

- The bone on which the skull rests
- Ring-shaped vertebra
- Has **no body and no spinous process**
- Possesses two short transverse processes
- Has two flattened superior articular facets
- These articulate with the occipital condyles forming **condyloid joints**
- Permits **nodding movements** of the head

Second Cervical Vertebra (C2) – Axis

- Lies immediately below the atlas
- Has a small vertebral body
- Possesses a superior projection called the **odontoid process (dens)**
- The dens projects upward into the posterior foramen of the atlas
- It is held in place by the **transverse ligament**
- Allows **rotation of the head from side to side**

C3–C6

- Follow the structural pattern of a typical vertebra

C7 – Vertebra Prominens

- Has a long spinous process
- The process ends in a swollen tubercle

- Easily felt at the base of the neck

Thoracic Vertebrae

- Larger and stronger than cervical vertebrae
- Support greater body weight
- Have longer and larger transverse processes
- Vertebral bodies and transverse processes possess **facets** for articulation with ribs
- Facets are absent in **T11 and T12**

Lumbar Vertebrae

- Numbered **L1 to L5**
- The largest and strongest vertebrae
- Support the weight of the entire upper body
- Spinous processes are:
    - Thick
    - Broad
    - Quadrilateral in shape
- Well adapted for attachment of large lower back muscles

Sacrum

- Consists of **five rudimentary sacral vertebrae** fused together
- Forms a triangular or wedge-shaped bone
- Anterior surface is concave

Articulations:

- The base articulates with the **fifth lumbar vertebra (L5)**
- Laterally articulates with the ilium to form the **sacroiliac joints**
- Inferiorly articulates with the coccyx

Other features:

- The anterior edge of the base forms the **sacral promontory**, which projects into the pelvic cavity
- Contains a series of **foramina** on each side for passage of sacral spinal nerves

Coccyx

- Triangular in shape, similar to the sacrum
- Consists of **four fused coccygeal vertebrae**
- Forms a very small triangular bone
- The broad base articulates with the tip of the sacrum

Features of the Vertebral Column

Intervertebral Discs

- Located between the bodies of adjacent vertebrae
- Act as **shock absorbers**
- Form cartilaginous joints
- Contribute to flexibility of the vertebral column

Intervertebral Foramina

- A foramen is formed by the gap between adjacent vertebral pedicles
- An intervertebral foramen is present on each side between every pair of vertebrae
- Allows passage of:
    - Spinal nerves
    - Blood vessels
    - Lymph vessels

Ligaments

- Hold the vertebrae together
- Maintain the position of intervertebral discs

Curves of the Vertebral Column

- When viewed from the side, the vertebral column shows **four curves**
- Two are **primary curves**:
    - Thoracic curve
    - Sacral curve
- Primary curves are present in the fetus
- Two are **secondary curves**:
    - Cervical curve – develops when the child can hold the head upright (around 3 months)
    - Lumbar curve – develops when the child begins to stand (12–15 months)

Movements of the Vertebral Column

- Movement between individual vertebrae is limited
- Movement of the vertebral column as a whole is extensive and includes:
    - Flexion (bending forward)
    - Extension (bending backward)
    - Lateral flexion (side bending)
    - Rotation
- Maximum movement occurs in the **cervical and lumbar regions**

Functions of the Vertebral Column

- Vertebral foramina collectively form the vertebral canal
- Provides strong bony protection to the spinal cord
- Intervertebral foramina allow passage of spinal nerves, blood vessels, and lymph vessels
- Intervertebral discs permit movement and absorb shock
- Provides support for the skull
- Forms the axis of the trunk
- Provides attachment for:
    - Ribs
    - Shoulder girdle and upper limbs
    - Pelvic girdle and lower limbs

THORAX (THORACIC CAGE)

The thorax is made up of:

- **Sternum (1)** – anterior
- **Ribs (12 pairs)** – lateral walls
- **Thoracic vertebrae (12)** – posterior

Sternum (Breast Bone)

- Flat, narrow bone located in the center of the anterior thoracic wall
- Felt just beneath the skin in the middle of the chest
- Consists of three parts:
    1. Manubrium
    2. Body
    3. Xiphoid process

Manubrium

- Superior part of the sternum
- Articulates with the clavicles at the sternoclavicular joints
- Also articulates with the costal cartilages of the first and second ribs

Body

- Middle and largest part of the sternum
- Provides attachment to the ribs

Xiphoid Process

- Inferior and smallest part of the sternum
- No ribs are attached to it
- Provides attachment to:
    - The diaphragm
    - Muscles of the anterior abdominal wall

RIBS

- Twelve pairs of ribs form the lateral walls of the thoracic cage
- Elongated and curved bones
- Articulate posteriorly with the vertebral column

Classification of Ribs

True Ribs

- First **seven pairs**
- Articulate directly with the sternum
- Attached by costal cartilages

False Ribs

- Next **three pairs (8–10)**
- Articulate indirectly with the sternum

Floating Ribs

- Last **two pairs (11th and 12th)**
- Do not attach to the sternum
- Anterior ends are free

Parts of a Typical Rib

- **Head** – posterior projection with two facets; articulates with vertebral bodies to form the vertebrocostal joint
- **Neck** – narrow constricted region
- **Tubercle** – knob-like structure where the neck joins the body
- **Body (shaft)** – main portion of the rib
- **Costal angle** – point of abrupt curvature

Rib Articulations

Each rib forms up to **three joints** with the vertebral column:

1. Two joints between facets on the head of the rib and facets on the bodies of two adjacent vertebrae
2. One joint between the tubercle of the rib and the transverse process of the lower vertebra

Functional Features of the Rib Cage

- **Intercostal muscles** lie between the ribs and move the rib cage during breathing
- The arrangement of ribs and the amount of cartilage make the rib cage **flexible**

- The rib cage changes shape and size during respiration
- The first rib is firmly fixed to the sternum and first thoracic vertebra and does not move during inspiration
- Contraction of respiratory muscles pulls the rib cage upward toward the first ri

APPENDICULAR SKELETON AND HOMEOSTASIS

Appendicular Skeleton and Homeostasis

"The bones of the appendicular skeleton contribute to homeostasis by providing attachment points and leverage for muscles, which aids body movements; by providing support and protection of internal organs, such as the reproductive organs; and by storing and releasing calcium."

General Function of the Skeleton

- **Axial skeleton** – protection of internal organs
- **Appendicular skeleton** – movement

The appendicular skeleton includes:

- Bones that make up the **upper and lower limbs**
- Bones of the **two girdles** that attach the limbs to the axial skeleton

Bones are connected with one another and with skeletal muscles, permitting activities such as:

- Walking
- Writing
- Dancing
- Swimming
- Playing musical instruments

The appendicular skeleton consists of:

- **Shoulder girdle with the upper limbs**
- **Pelvic girdle with the lower limbs**

SHOULDER (PECTORAL) GIRDLE

The upper limb forms a joint with the trunk via the **shoulder girdle**.

It consists of:

- **Clavicles – 2**

- **Scapulae – 2** (one on each side)

Clavicle (Collar Bone)

- S-shaped long bone
- Has two ends:
  - **Acromial end**
  - **Sternal end**
- Articulates with the **manubrium of the sternum** at the **sternoclavicular joint**
- Forms the **acromioclavicular joint** with the **acromion process of the scapula**
- The clavicle is the **only bony link between the upper limb and the axial skeleton**

Scapula (Shoulder Blade)

- Flat, triangular-shaped bone
- Lies on the posterior chest wall
- Superficial to the ribs and separated from them by muscles

It consists of:

- **Glenoid cavity**
- **Spine**
- **Acromion process**
- **Coracoid process**

Glenoid Cavity

- Shallow articular surface present at the lateral angle
- Forms the **shoulder joint** with the head of the humerus

Spine

- A rough ridge on the posterior surface
- Extends beyond the lateral border of the scapula
- Overhangs the glenoid cavity

Acromion Process

- Prominent overhang
- Can be felt through the skin as the highest point of the shoulder
- Forms the **acromioclavicular joint** with the clavicle
- This joint is a slightly movable synovial joint
- Contributes to mobility of the shoulder girdle

Coracoid Process

- A projection from the upper border of the bone
- Gives attachment to muscles that move the shoulder joint

THE UPPER LIMB (UPPER EXTREMITY)

The upper limb has **30 bones** arranged in three locations:

- **Humerus** in the arm – 1
- **Ulna and radius** in the forearm – 2
- **Carpals** in the carpus (wrist) – 8
- **Metacarpals** in the metacarpus (palm) – 5
- **Phalanges** (bones of the digits) in the hand – 14

Humerus (Arm Bone)

- Longest and largest bone of the upper limb
- Consists of:
    - Proximal end (head)
    - Shaft
    - Distal end
- The head fits into the **glenoid cavity of the scapula**, forming the shoulder joint
- Distal to the head are two roughened projections:
    - **Greater tubercle**
    - **Lesser tubercle**
- Between them is a deep groove:
    - **Bicipital groove / intertubercular sulcus**
    - Occupied by one of the tendons of the biceps muscle
- The distal end has two surfaces that articulate with the radius and ulna to form the **elbow joint**

Ulna and Radius

- Two bones of the forearm
- Ulna is **longer than and medial** to the radius
- In anatomical position, the two bones are **parallel**
- They articulate:
    - With the humerus at the elbow joint
    - With carpal bones at the wrist joint
    - With each other at the **proximal and distal radioulnar joints**
- An **interosseous membrane**, a fibrous joint, connects the bones along their shafts
- This membrane stabilises their association and maintains their relative positions

Carpal (Wrist) Bones

- **8 bones** arranged in two rows of four

Proximal row (from lateral to medial):

- Scaphoid
- Lunate
- Triquetrum
- Pisiform

Distal row:

- Trapezium
- Trapezoid
- Capitate
- Hamate
- Bones fit closely together and are held by ligaments
- Allow limited movement between them
- Proximal row bones are associated with the wrist joint
- Distal row bones form joints with metacarpal bones
- Tendons of forearm muscles cross the wrist and are held close to bones by strong fibrous bands called **retinacula**

Metacarpal Bones (Bones of the Hand)

- **5 bones** forming the palm
- Numbered from the thumb side inwards
- Proximal ends articulate with carpal bones
- Distal ends articulate with phalanges

Phalanges (Finger Bones)

- **14 bones**
- Three in each finger
- Two in the thumb
- Articulate with metacarpal bones and with each other at **interphalangeal hinge joints**
- Each phalanx consists of:
    - Proximal
    - Middle
    - Distal

PELVIC (HIP) GIRDLE

- The lower limb forms a joint with the trunk at the **pelvic girdle**
- Formed from two **innominate (hip) bones**
- Also called:
    - Coxal bones
    - Pelvic bones
    - Os coxa

- Hip bones unite:
  - Anteriorly at the **pubic symphysis**
  - Posteriorly with the sacrum at the **sacroiliac joints**

Each hip bone consists of **three fused bones**:

- Ilium
- Ischium
- Pubis

A deep depression on the lateral surface called the **acetabulum** forms the hip joint with the head of the femur.

Ilium

- Upper flattened part of the hip bone
- Contains:
  - Iliac crest
  - Anterior superior iliac spine
  - Posterior superior iliac spine
  - Posterior inferior iliac spine
- Forms a strong synovial joint with the sacrum called the **sacroiliac joint**
- Designed to absorb stresses of weight bearing

Ischium

- Inferior and posterior part of the hip bone
- Has rough inferior projections called **ischial tuberosities**
- Bear the weight of the body in sitting position
- Commonly called **"sitting bones"**

Pubis

- Inferior and anterior part of the hip bone
- Articulates with the pubis of the opposite hip bone at the **pubic symphysis**
- Union and ossification of the three bones occur at the acetabulum

The Pelvis

- The complete ring formed by:
  - Hip bones
  - Pubic symphysis
  - Sacrum
  - Coccyx
- Forms a deep basin-like structure called the **bony pelvis**

The brim of the pelvis divides it into:

- **Greater (false) pelvis** – above the brim
- **Lesser (true) pelvis** – below the brim

Female pelvis:

- Lighter bones
- Shallower
- More rounded and roomier
- Adapted for childbirth

LOWER LIMB (LOWER EXTREMITY)

The lower limb has **30 bones** arranged in four locations:

- **Femur** in thigh – 1
- **Patella** (knee cap) – 1
- **Tibia and fibula** in the leg – 2
- **Tarsals** in the tarsus (ankle) – 7
- **Metatarsals** in the metatarsus – 5
- **Phalanges** in the foot – 14

Femur (Thigh Bone)

- Longest, heaviest, and strongest bone of the body
- Consists of:
    - Head
    - Neck
    - Shaft
    - Distal end
- Head is almost spherical and fits into the acetabulum forming the hip joint
- Neck extends outward and slightly downward from head to shaft
- Posterior surface of the lower third forms the **popliteal surface**
- Distal end has two articular condyles that articulate with tibia and patella to form the knee joint
- Femur transmits body weight to the bones below the knee

Tibia (Shin Bone)

- Medial bone of the lower leg
- Proximal end is broad and flat with two condyles for articulation with femur
- Head of fibula articulates with inferior aspect of lateral condyle to form proximal tibiofibular joint
- Distal end forms ankle joint with talus and fibula
- **Medial malleolus** projects downward and is palpable on inner ankle

Fibula

- Long, slender lateral bone of the leg
- Head articulates with lateral condyle of tibia
- Distal end forms **lateral malleolus**
- Helps stabilize the ankle joint

Patella (Knee Cap)

- Roughly triangular-shaped sesamoid bone
- Forms part of the anterior wall of the knee joint
- Posterior surface articulates with patellar surface of femur

Tarsal (Ankle) Bones

- **7 bones**:
  - Talus
  - Calcaneus
  - Navicular
  - Cuboid
  - Three cuneiform bones
- Talus articulates with tibia and fibula
- Calcaneus forms the heel
- Other tarsals articulate with each other and metatarsals

Metatarsals

- **5 bones** forming the dorsum (sole) of the foot
- Proximal ends articulate with tarsals
- Distal ends articulate with phalanges
- Head of the first metatarsal forms the **ball of the foot**

Phalanges (Toe Bones)

- **14 bones**
- Two in the great toe (hallux)
- Three in each of the remaining toes

Arches of the Foot

- Arrangement of bones, ligaments, and muscles gives the foot an arched shape

Longitudinal arch

- Runs from heel to toe
- Normal arch: only calcaneus and distal metatarsals touch the ground

- Flat foot occurs when ligaments sag and arch collapses

Transverse arch

- Runs across the foot
- Arched design acts as a shock absorber
- Distributes body weight evenly
- Most important muscular support:
    - **Posterior tibialis muscle**
    - Acts as a sling or suspension apparatus

DEFINITION OF A JOINT

A **joint (articulation)** is the site at which **two or more bones come together**, where the ends or edges of the bones are held together by **connective tissues**.

- Joints allow **flexibility and movement** of the skeleton
- In some joints, the participating bones are fastened together so firmly that **no movement is possible**

Classification of Joints (Structural Classification)

Based on the **type of binding tissue** that connects the bones, joints are classified into:

1. Fibrous joints
2. Cartilaginous joints
3. Synovial joints

Fibrous Joints

- Bones forming these joints are linked by **tough fibrous connective tissue**
- The arrangement often permits **no movement**

Examples

- Joints between skull bones (**sutures**) – immovable
- A healthy tooth cemented into the mandible by the **periodontal ligament**
- Tibia and fibula held together along their shafts by a sheet of fibrous tissue called the **interosseous membrane** – allows limited movement

Cartilaginous Joints

- Bones are connected by a pad of **tough fibrocartilage**
- The cartilage acts as a **shock absorber**

Types

- **Immovable cartilaginous joints**
  - Example: epiphyseal plates in growing children
- **Slightly movable cartilaginous joints**
  - Example:
    - Joints between vertebrae separated by **intervertebral discs**
    - **Pubic symphysis**

Synovial Joints

- Characterized by the presence of a **space or cavity** between articulating bones
- The ends of the bones are held together by a **fibrous capsule**
- Joints are lubricated by a small amount of **synovial fluid**
- These are the **most movable joints** in the body

Functional Classification of Joints

According to the **type and degree of movement** they allow, joints are classified as:

Synarthrosis

- Immovable joints
- Permit little or no movement
- Provide strong union between articulating bones
- Important where protection of internal organs is required

Examples:

- Fibrous joints between skull bones
- Cartilaginous joint such as the **manubriosternal joint**

Amphiarthrosis

- Permit **slight movement**
- Most are cartilaginous joints

Examples:

- Joints between bodies of vertebrae
- Pubic symphysis of pelvis

Diarthrosis

- Freely movable joints
- Include **all synovial joints** of the body

Types

- **Uniaxial joints** – allow movement in a single plane
  - Example: elbow joint
- **Biaxial joints** – allow movement in two planes
  - Example: metacarpophalangeal joint
- **Multiaxial joints** – allow movement in several directions
  - Example: shoulder joint, hip joint

Characteristics of a Synovial Joint

Articular (Hyaline) Cartilage

- Covers the parts of bones in contact with each other
- Provides a smooth articular surface
- Reduces friction
- Distributes weight
- Prevents damaging bone-to-bone contact
- Has **no blood supply**
- Receives nourishment from synovial fluid

Capsule (Capsular Ligament)

- Sleeve of fibrous tissue that holds the bones together
- Loose enough to allow freedom of movement
- Strong enough to protect the joint from injury
- Formed by an extension of the **periosteum** of participating bones

Synovial Membrane

- Delicate epithelial layer lining the capsule
- Covers all **non-weight-bearing surfaces** inside the joint
- Secretes synovial fluid

Synovial Fluid

- Thick, sticky fluid with egg-white consistency
- Fills the synovial cavity
- Nourishes joint structures
- Contains phagocytes that remove microbes and debris
- Lubricates moving parts of the joint
- Maintains joint stability
- Prevents separation of bone ends

Movements at Synovial Joints

Movements depend on:

- Tightness of ligaments
- How well the bones fit together
- Presence or absence of **intracapsular structures**

More stable joints are less mobile

Types of Movements

- Flexion
- Extension
- Abduction
- Adduction
- Circumduction
- Rotation
- Pronation
- Supination
- Inversion
- Eversion

Flexion

- Bending movement
- Usually forward, sometimes backward
- Example: knee joint

Extension

- Straightening movement or bending backward

Abduction

- Movement away from the midline of the body

Adduction

- Movement towards the midline of the body

Circumduction

- Movement of a limb or digit describing a cone-shaped path

Rotation

- Movement around the long axis of a bone

Pronation

- Turning the palm of the hand downward

Supination

- Turning the palm of the hand upward

Inversion

- Turning the sole of the foot inward

Eversion

- Turning the sole of the foot outward

Types of Synovial Joints

Based on **shape of articulating surfaces** and **range of movement**:

1. Ball and socket joints
2. Hinge joints
3. Gliding joints
4. Pivot joints
5. Condyloid joints
6. Saddle joints

Ball and Socket Joints

- Head of one bone is ball-shaped
- Fits into a cup-shaped socket of another bone
- Allow wide range of movements:
    - Flexion
    - Extension
    - Abduction
    - Adduction
    - Rotation
    - Circumduction

Examples

- Shoulder joint
- Hip joint

Shoulder Joint

- Formed by the **glenoid cavity** of scapula and head of humerus
- Capsular ligament is very loose inferiorly
- Allows extensive movement

Hip Joint

- Formed by the **acetabulum** of hip bone and head of femur
- Capsular ligament encloses head and most of the neck of femur
- Stabilised by strong ligaments and musculature

Hinge Joints

- Articulating ends fit together like a door hinge
- Movement restricted to:
    - Flexion
    - Extension

Examples

- Elbow joint
- Knee joint
- Ankle joint
- Interphalangeal joints of fingers and toes

Elbow Joint

- Involves three bones:
    - Humerus
    - Radius
    - Ulna

Humerus has two projections:

- Capitulum – articulates with head of radius (radiohumeral joint)
- Trochlea – fits into trochlear notch of ulna (humeroulnar joint)
- Joint is wrapped in ligaments and very stable
- Biceps produces flexion
- Triceps produces extension

Knee Joint

- Largest and most complex joint of the body
- Very stable hinge joint
- Formed by:

    - Condyles of femur
    - Condyles of tibia
    - Posterior surface of patella
- Associated with bursae and fat pads to reduce friction
- Allows flexion, extension, and slight rotation

Ankle Joint

- Formed by:
    - Distal end of tibia and medial malleolus
    - Distal end of fibula (lateral malleolus)
    - Talus
- Movements:
    - Dorsiflexion – lifting toes toward calf
    - Plantar flexion – standing on tiptoe

Gliding Joints

- Articular surfaces are flat or slightly curved
- Bones glide over each other
- Very limited movement
- Least movable synovial joints

Examples:

- Joints between carpal bones
- Joints between tarsal bones
- Joints between vertebral processes

Pivot Joints

- Allow rotation around a central axis
- One bone rotates within a ring formed by another bone and ligament

Examples

- Head rotation at atlanto-axial joint
- Proximal and distal radioulnar joints

Proximal and Distal Radioulnar Joints

- Proximal joint:
    - Head of radius rotates in radial notch of ulna
- Distal joint:
    - Distal end of radius articulates with head of ulna
- Allow pronation and supination

- Radius rotates around the ulna

Condyloid Joints

- Condyle is a smooth rounded projection
- Condyle fits into a cup-shaped depression

Examples

- Temporomandibular joint
- Metacarpophalangeal joints of hand
- Metatarsophalangeal joints of foot
- Allow:
    - Flexion
    - Extension
    - Abduction
    - Adduction
    - Circumduction

Wrist Joint

- A **condyloid joint**
- Formed between:
    - Distal end of radius
    - Proximal ends of scaphoid, lunate, and triquetrum
- A disc of white fibrocartilage:
    - Separates ulna from joint cavity
    - Separates inferior radioulnar joint from wrist joint
- Movements:
    - Flexion
    - Extension
    - Abduction
    - Adduction

Saddle Joints

- Articulating bones fit together like a saddle

Example

- Thumb joint
- Between trapezium and first metacarpal bone
- Range of movement similar to condyloid joint
- Provides additional flexibility

Thumb Movements

- Flexion
- Extension
- Abduction
- Adduction
- Circumduction
- Opposition (touching fingertips)