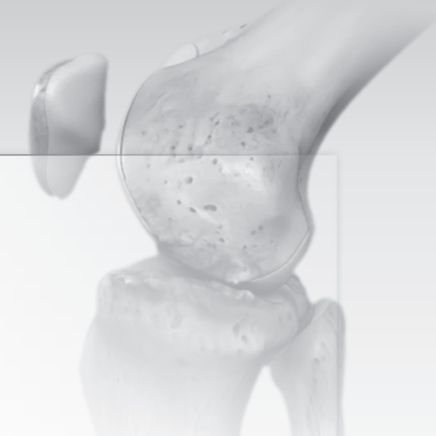
Chapter
1

Anatomy



Q1. Discuss in brief the development of skeleton.

Human skeleton has 206 bones. The parent connective tissue is *mesenchyme*. In intrauterine life the mesenchymal tissue, differentiate into *bone, cartilage, fascia and muscles*.

Important Points:
- *Cartilage* first appears at 5th wk of intrauterine life.
- *Ossification* of fetus starts in 5–6th wk of intrauterine life.
- *Synovial tissue* is seen earliest in 12th wk of intrauterine life.
- *Bone* first appears at 7th wk of intrauterine life.
- *Somites* undergo division into three parts:
  – *Dermatomes*: forms the dermis of the skin
  – *Myotomes*: forms the skeletal muscle
  – *Sclerotome*: helps to form the vertebral column.
- Bones of the limbs, including the bones of the shoulder and pelvic girdles, are formed from mesenchyme of the *limb buds*. With the exception of the clavicle, they are all formed by enchondral ossification.
- *Limb buds* are outgrowth that arises from the side-wall of the embryo at the beginning of the second month of intrauterine life.
- *Forelimb buds* appears about the 26th day and the *hindlimb bud* about the 28th day.

Q2. Write in short ossification and growth pattern in bone.

Development and Ossification of Bones

Bones are first laid down as mesodermal (connective tissue) condensations. Conversion of mesodermal models into bone is called *intramembranous or mesenchymal ossification* and the bones are called *membrane (dermal) bones*.
- However, mesodermal stage may pass through cartilaginous stage by chondrification during 2nd month of intrauterine life.
- A conversion of cartilaginous model into bone is called *intracartilaginous or endochondral* ossification and such bones are called *cartilaginous bones*.
- Ossification takes place by centres of ossification.
- The centres of ossification may be *primary or secondary*.
- The *primary centres* appear before birth, usually during 8th week of intrauterine life; the *secondary centres* appear after birth, with a few exceptions.
- Many secondary centres appear during puberty.
- A primary centre forms *diaphysis,* and the secondary centres form *epiphyses.*

- Fusion of epiphysis with the diaphysis starts at puberty and is complete by the age of 25, after which no more bone growth can take place.
- The *law of ossification* states that 'secondary centres of ossification which appear first are last to unite".
- The end of a long bone where epiphysial fusion is delayed is the growing end of the bone.

Growth of a Long Bone

- A growing bone increases both in length and in thickness.
- Bone grows in *length* by multiplication of cells in the epiphysial plate of cartilage.
- Depending upon the distribution/arrangement of cells following zones are recognized:
- *Zone of resting cartilage (or resting zone)*: Cells are small and irregularly arranged.
- *Zone of proliferating cells*: the cells are larger and are undergoing repeated mitosis. During the process of multiplication, they come to lie in parallel columns, separated by bars of intercellular matrix.
- *Zone of calcification or calcified matrix*: the cell becomes still larger and the matrix becomes calcified.
- *Zone of ossification*: here the cartilage cells dead and the calcified matrix is replaced by bone.
- Bone grows in *thickness* by active multiplication of cells in the zone of proliferation.
- Bone grows by deposition of new bone on the surface and at the ends. This process of bone deposition of osteoblasts is called *appositional growth or surface accretion*. However, in order to maintain the shape the unwanted bone must be removed. This process of bone removal by osteoclasts is called remodelling. This is how marrow cavity increases in size.

Q3. What are osteoblast, osteocytes and osteoclast.

Bone is a dynamic tissue that is remodeled constantly throughout life where osteoblasts are responsible for bone formation (osteogenesis) and osteoclasts for its resorption.

Osteoblasts

- Theses are bone-forming cells.
- Osteoblasts synthesize and secrete the organic matrix
- Osteoblasts are specialized mesenchymal cells with a single, usually eccentric, nucleus; contain large volumes of synthetic organelles: endoplasmic reticulum and Golgi membranes.
- They lie on bone surfaces and undergo a process of maturation where genes like core-binding factor α1 (Cbfα1) and osterix (Osx) play a very important role.
- Recently it was found that Wnt/β-catenin pathway plays a part on osteoblast differentiation and proliferation.
- When active, they assume a round, oval, or polyhedral form and a seam of new osteoid separate them from mineralized matrix.
- When stimulated, osteoblasts form new bone organic matrix and participate in controlling mineralization of matrix.
- Osteoblasts also play vital role in regulation of bone resorption through receptor activator of nuclear factor-κB (RANK) ligand (RANKL), that links to its receptor, RANK, on the surface of preosteoblast cells, inducing their differentiation and fusion.

- Osteoblasts secrete a soluble decoy receptor (osteoprotegerin, OPG) that blocks RANK/RANKL interaction by binding to RANKL and, thus, prevents osteoclast differentiation and activation.

Osteocytes

- These cells are seen in mature bone.
- Osteocytes descend from osteoblasts (and during this, the cells lose a large part of their cell organelles).
- They are formed by the incorporation of osteoblasts into the bone matrix.
- Present in lacunae.
- Osteocytes remain in contact with each other and with cells on the bone surface via *gap junction-coupled* cell processes passing through the matrix via small channels, the canaliculi that connect the cell body-containing lacunae with each other and with the outside world.

Functions

- Osteocytes are actively involved in *bone turnover*.
- Through its large cell-matrix contact surface involved in *ion exchange*.
- Osteocytes are the mechanosensory cells of bone and play a pivotal role in functional adaptation of bone.
- Also, function as regulators of mineralization and as regulators of phosphate homeostasis

Osteoclast

- These cells are responsible for bone removal.
- These are multinucleated giant cells with acidophilic cytoplasm responsible for *bone resorption* derived from hematopoietic stem cells.
- Seen at the site of bone resorption.
- Formation of osteoclast requires the presence of *RANK ligand* and *M-CSF*.
- Morphology: Osteoclasts lie in resorption bays *"eaten out cavities"* called *Howship's lacunae*.
- Produce enzymes like acid phosphatase, collagenase, acid hydrolases and various glycolytic enzymes.
- Parathyroid hormone, 1,25-dihydroxyvitamin D3, TGT-alpha, and EGF act permissively in their formation whereas *calcitonin* inhibits its formation.

Q4. What is ossification and discuss in brief the ossification centers.

All bone is of *mesodermal origin*. The process of bone formation is called ***ossification***.

Types of Ossification

Enchondral ossification

- In most part of the embryo, bone formation is preceded by the formation of cartilaginous model. This kind of bone formation is called *enchondral ossification*.
- Bones formed in this way are termed as *cartilage bones*.
- Example: *base of skull*, *trunk* and *limb bones*.

Intramembranous ossification

- If bone is laid down directly in fibrous membrane without the cartilaginous phase, this is called *intramembranous ossification*.

- Bones formed in this way are termed as *membrane bones*.
- Example: *Vault of skull, the mandible* and *the clavicle*.

Ossification Centers

An area where ossification starts is called *centre of ossification.*

Primary Center of Ossification

- Single or multiple
- Appear before birth b/w 6–8 wk of intrauterine life.
- When multiple, appear simultaneously.
- Diaphysis (shaft) of long bone develops from primary center.

Secondary Center of Ossification

- Multiple
- Appear after birth
- Epiphysis (ends) of long bone develops from secondary center.

Appearance of Important Ossification Centers

Bone	*Time of appearance of ossification centers*
Humerus head	Birth to 3 months
Scapula	First fetal week
Radial head	6 yr
Distal epiphyses of radius	1 yr
Lunate	4 yr
Scaphoid	5 yr
Olecranon	10 yr
Pisiform	12 yr
Distal epiphysis of femur	At birth (35–38 wk)
Capital epiphysis of femur	1 yr
Greater trochanter	3 yr
Lesser trochanter	11 yr
Upper tibial epiphysis	38 wk of intrauterine life
Talus	7th month
Calcaneum	5th month

Q5. Discuss the macroscopic and microscopic structure of bone.

Bone is a connective tissue, impregnated with calcium salts. The *inorganic* calcium salts (mainly calcium phosphate, partly calcium carbonate, and crystal of hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$ traces of other salts) make it hard and rigid, which can afford resistance to compressive forces of weight-bearing and impact forces of jumping. The *organic connective tissue* (collagen fibres) makes it tough and resilient (flexible), which can afford resistance to tensile forces.

Macroscopic structure

Macroscopically, the architecture of bone may be *compact* or *cancellous*.

Compact Bone

- It is dense in texture like ivory, but is extremely porous.
- It is best developed in the cortex of the long bones.
- This is an adaptation to bending and twisting forces (a combination of compression, tension and shear).

Cancellous Spongy or Trabecular Bone

- It is open in texture, and is made up of a meshwork of trabeculae (rods and plates) between which are marrow containing spaces.
- The trabecular mesh works are of three primary types, namely:
- Meshwork of rods
- Meshwork of rods and plates
- Meshwork compressive forces

Microscopically

The bone is of four types, namely lamellar (including both compact and cancellous), fibrous, dentine and cement.

- *Lamellar*: Most of the mature human bones, whether compact or cancellous, are composed of thin plates of bony tissue called lamellae.
- *Fibrous*: It is found in young fetal bones, but are common in reptiles and amphibia.
- *Dentine*
- *Cement* occurs in teeth.

Mineralized Bone

It could could be either:

- Woven bone (immature)
- Lamellar bone (mature)

Osteon

- The basic microscopic unit of bone is an 'osteon'.
- Haversian canals run through the entire length of the bone-carrying blood vessels.
- They are interlinked to each other through the Volkmann's canals.
- On a transverse section of the bone each of these Haversian canals is surrounded by a grouped of lacunae, which lodge an 'osteocytes'.
- The entire group of osteocytes link to each other and to the centrally located Haversian canal through cytoplasmic extensions that run through tiny channels called 'canaliculi'.

Q6. Discuss gross structure of an adult long bone.

Naked eye examination of the longitudinal and transverse sections of a long bone shows the following features:

Shaft

From without inwards it is composed of periosteum, cortex and medullary cavity.

Periosteum

- It is a thick fibrous membrane covering the surface of the bone.
- It is made up of an outer fibrous layer, and an inner cellular layer, which is osteogenic in nature.

- Periosteum is united to the underlying bone by Sharpey's fibres, and the union is particularly strong over the attachments of tendons and ligament.
- At the articular margin, the periosteum is continuous with the capsule of the joint.
- The abundant arteries nourish the outer part of the underlying cortex also.
- Periosteum has a rich nerve supply, which makes it the most sensitive part of the bone.

Cortex

It is made up of a compact bone, which gives it the desired strength to withstand all possible mechanical strains.

Medullary Cavity

- It is filled with red or yellow bone marrow.
- At birth, the marrow is red everywhere with widespread active hemopoiesis.
- As the age advances the red marrow at many places atrophies and is replaced by yellow, fatty marrow, with no power of hemopoiesis.
- Red marrow persists in the cancellous ends of long bones.
- In the llium, sternum, ribs, vertebrae and skull bones, the red marrow is found throughout life.

Articular End

The two ends of a long bone are made up of cancellous bone covered with hyaline cartilage (articular cartilage).

Q7. Discuss in brief the different part of a young bone.

Ans: A ***typical long bone*** ossifies in three parts, the two ends from secondary centres, and the intervening shaft from a primary centre.
Before ossification is complete, the following parts of the bone can be defined.

Epiphysis

- The tips and ends of a bone ossify from secondary centers are called epiphyses.
- Develop from secondary center
- Electropositive
- The epiphysis, which ossifies first, unites with the diaphysis last and epiphysis, which ossifies last fuses first (exception: distal end of fibula-ossifies first and fuse last).

These are of the following types:

Pressure Epiphysis

- It is articular and participates in transmission of the weight.
- Examples: Head of femur, lower end of radius, condyles of tibia, etc.

Traction Epiphysis

- It is also known as apophysis it is extra-articular and does not participate in the transmission of the weight.
- It always provides attachment to one or more tendons, which exert traction on the epiphysis.

- The pressure epiphyses ossify earlier than traction epiphyses.
- *Examples*: Trochanters of femur, tibial tuberosity tubercles of humerus, mastoid process, etc.

Atavistic Epiphysis

- It is phylogenetically an independent bone, which in man becomes fused to another bone.
- *Examples*: Coracoid process of scapula and os trigonum

Aberrant Epiphysis

- It is not always present.
- *Examples*: Epiphysis at the head of the first metacarpal and at the base of other metacarpal bones

Diaphysis

- It is the elongated shaft of a long bone between the two cartilaginous ends.
- Ossifies from a primary centre
- Contains marrow cavity
- Electropositive
- Site of muscle insertion

Metaphysis

- The ends of a diaphysis are metaphysis.
- Each metaphysis is the zone of active growth.
- Before epiphysial fusion, the metaphysis is richly supplied with blood through and arteries (*Circulus-Vasculosus of Hunter*) forming hair-pin bends.
- This is the commonest site of osteomyelitis in children because; the bacteria or emboli are easily trapped in the hair-pin bends, causing infraction.
- After the epiphysial fusion, vascular communications metaphysis contains no more end arteries, and is no longer subject to osteomyelitis.

Epiphysial Plate of Cartilage

- It separates epiphysis from metaphysis. Proliferation of cells in this cartilaginous plate is responsible for lengthwise growth of a long bone.
- After the epiphysial fusion, the bone can no longer grow in length. Both the epiphysial and metaphysial arteries nourish the growth cartilage.

Q8. Enumerate the functions of bone.

The first bone appears in the seventh embryonic week, it's the vertebra. The *clavicle* is the first bone in the skeleton to ossify.

Characteristics

- It is subject to disease and heals after a fracture.
- It has greater regenerative power than any other tissue of the body, except blood.
- It can mould itself according to changes in stress and strain it bears.
- It shows disuse atrophy and overuse hypertrophy.

Functions

- Bones give shape and support to the body, and resist all forms of stress.
- They provide surface for the attachment of muscles, tendons, ligaments, etc.
- They serve as levers for muscular actions.
- The skull, vertebral column and thoracic cage protect brain, spinal cord and thoracic viscera, respectively.
- Bone marrow manufactures blood cells.
- Bones store 97% of the body calcium and phosphorus.
- Bone marrow contains reticuloendothelial cells, which are phagocytic in nature and take part in immune responses of the body.
- The larger paranasal air sinuses affect the timber of the voice.

Q9. Discuss blood and nerve supply of bone.

BLOOD SUPPLY OF BONES

Long Bones

The blood supply of a long is derived from the following sources.

Nutrient Artery

- These enter the shaft through the nutrient foramen, run obliquely through the cortex, and divides into ascending and descending branches in the medullary cavity. Each branch divides into a number of small parallel channels, which terminate in the adult metaphysis by anastomosing with the epiphysial, metaphyseal, and periosteal arteries. The nutrient artery supplies medullary cavity, inner two-thirds of cortex and metaphysis.
- The nutrient foramen is directed away from the growing end of the bone; their directions are indicated by a jingle, *'To the elbow I go, from the knee' I flee*.
- The oblique direction of nutrient foramina opposite to the growing end of the bone is best explained by the growing-end hypothesis.
- Periosteal arteries are especially numerous beneath the muscular and ligamentous attachments. They ramify beneath the periosteum and enter the Volkmann's canals to supply the outer one-third of the cortex.

Epiphysial Arteries

These are derived from periarticular vascular arcades (circulus vasculosus) found on the non-articular bony surface.

Metaphyseal Arteries

- These are derived from the neighbouring systemic vessels.
- They reinforce the metaphyseal branches from the primary nutrient artery.
- In miniature long bones, the infection begins in the middle of the shaft rather than at the metaphysis because the nutrients artery breaks up into a plexus immediately upon reaching the medullary cavity.
- In the adults, however, the chances of infection are minimized because the nutrient artery is mostly replaced by the periosteal vessels.

Other Bones

- Short bones are supplied by numerous periosteal vessels, which enter their non-articular surfaces.

- In a vertebra, the body is supplied by anterior and posterior vessels, and the vertebral arch by large vessels entering the bases of transverse processes. Its marrow is drained by two large basivertebral veins.
- A rib is supplied by: (a) the nutrient artery, which enters it just beyond the tubercle, and (b) the periosteal arteries.

Veins

These are numerous and large in the cancellous, red marrow-bones (e.g. basivertebral veins). In the compact bone, they accompany arteries in the Volkmann's canals.

Lymphatics

- Present only in periosteum and haversian canal
- No lymphatics in bone marrow

Nerve Supply

- Nerves accompany the blood vessels. Most are sympathetic and vasomotor in function.
- Few are sensory which are distributed to the articular ends and periosteum of the long bones, to the vertebra, and to large flat bones.

Q.10 Discuss the classification of joints in brief.

Classification of Joints

Fibrous Joints (Synarthroses, Immovable)

- Sutures (in the skull)
- Syndesmoses
- Gomphoses

Cartilaginous Joints (Amphiarthroses Partially Movable)

- Synchondroses (hyaline cartilage)
- Symphyses (fibrocartilage)

Synovial joints (Diarthroses Freely Movable)

- Uniaxial
  - Ginglymus (hinge)
  - Trochoid (pivot)
- Biaxial
  - Condyloid
  - Saddle
- Triaxial
  - Ball and socket
  - Planar

Features and Examples

Fibrous Joints

This type of joint is held together by only a ligament.

Examples:
- *Sutures* in the sagittal and partial bones of skull
- Site where the teeth are held to their bony sockets *(Gomphoses)*
- Both the radio-ulnar and tibio-fibular joints *(Syndesmoses)*

Cartilaginous Joints

Cartilaginous (*Synchondroses and Symphyses*)
- These joints occur where the connection between the articulating bones is made up of cartilage.
- *Example*: Between vertebrae (intervertebral joint) in the spine and sacroiliac joint

Synchondroses are temporary joints, which are only present in children, up until the end of puberty.
Example: the epiphyseal plates in long bones

Symphysis joints are permanent cartilaginous joints.
Example: Pubic symphyses

Synovial Joints

Synovial (*Diarthrosis*):
- Synovial joints are by far the most common joint within the human body.
- They are highly movable and all have a synovial capsule (collagenous structure) surrounding the entire joint, a synovial membrane (the inner layer of the capsule) which secretes synovial fluid (a lubricating liquid) and cartilage known as hyaline cartilage which pads the ends of the articulating bones.
- There are 6 types of synovial joints which are classified by the shape of the joint and the movement available.
- Synovial joints are most evolved, and, therefore, most mobile type of joints.
- *Example*: Hip and knee joint, shoulder joint etc.

Q11. Discuss the characteristic features and different types of synovial joints with relevant examples.

Characteristic Features of a Synovial Joint

- *Hyaline (articular) cartilage* (occasionally *fibrocartilage* in certain membrane bones) covers the articular surfaces.
- *Articular cartilage* is avascular, non-nervous and elastic. Lubricated with synovial fluid, the cartilage provides slippery surfaces for free movements, like *'ice on ice'*.
- Between the articular surfaces there is a joint cavity filled with synovial fluid. An articular disc or meniscus divides the cavity partially or completely.
- An *articular capsule* encircling the joint, which is made up of a fibrous capsule lined by synovial membrane.
- Because of its rich nerve supply, the fibrous capsule is sensitive to stretches imposed by movements. This sets up appropriate reflexes to protect the joint from any sprain. This called the '*watch-dog*' action of the capsule.
- The *synovial membrane* lines whole of the interior of the joint, except for the articular surfaces covered by hyaline cartilage.
- The membrane secretes a slimy viscous fluid called the *synovial fluid*, which lubricates

the joint and nourishes the articular cartilage. The viscosity of fluid is due to hyaluronic acid secreted by cells of the synovial membrane.

- Varying degrees of movements are always permitted by the synovial joints.

Classification and Movements of Synovial Joints

S. no.	*Type of joint*	*Movements*
A.	Plane or gliding type	Gliding movement
B.	Uniaxial joints	
	a. Hinge jointb	Flexion and extension
	b. Pivot joint	Rotation only
C.	Biaxial joints	
	a. Condylar joint	Flexion and extension, and limited rotation
	b. Ellipsoid joint	Flexion, extension, abduction, adduction, and circumduction
D.	Multiaxial joints	
	a. Saddle joint	Flexion, and extension, abduction, adduction, and conjunct rotation
	b. Ball and socket joint	Flexion, extension, abduction, and adduction, circumduction, and rotation

Types of Synovial Joint

Plane Synovial Joints

- Articular surfaces are more or less flat (plane). They permit gliding movements (translations) in various directions
- *Examples:*
  - Intertarsal joints
  - Facet between superior and inferior articular process of vertebrae
  - Intercarpal joints
  - Jaw: Temporomandibular joint

Hinge Joints (Ginglymi)

- Articular surfaces are pulley-shaped. There are strong collateral ligaments.
- Movements are possible in one plane around a transverse axis.
- *Examples:*
  - Elbow joint
  - Ankle joint
  - Interphalangeal joints

Pivot (Trochoid) Joints

- Articular surfaces comprise a central bony pivot (peg) surrounded by an osteo-ligamentous ring. Movements are possible in one plane around a vertical axis
- Examples:
  - Median atlanto-axial joint
  - Superior and inferior radio-ulnar joints

Condylar (Bicondylar) Joints

- Articular surfaces include two distinct condyles (convex male surfaces) fitting into reciprocally concave female surfaces (which are also, sometimes, known as condyles, such as in tibia).

- These joints permit movements mainly in one plane around a transverse axis
- *Examples:*
  - Knee joint
  - Temporomandibular joints

Ellipsoid Joints

- Articular surfaces include an oval, convex, male surface fitting into an elliptical, concave female surface. Free movements are possible around the axes, flexion and extension around the transverse axis and abduction and adduction around the anteroposterior axis.
- Combination of movements produces circumduction.
- Typical rotation around a third (vertical) axis does not occur.
- *Examples:*
  - Wrist joint
  - Metacarpophalangeal joints
  - Atlanto-occipital joints

Saddle (Sellar) Joints

- Articular surfaces are reciprocally concavoconvex. Movements are similar to those permitted by an ellipsoid joint, with addition of some rotation (conjunct rotation) around a third axis, which, however, cannot occur independently.
- *Examples:*
  - First carpometacarpal joint
  - Sternoclavicular joint
  - Calcaneocuboid joint

Ball and Socket (Spheroidal) Joints

- Articular surfaces include a globular head (male surface) fitting into a cup-shaped socket (female surface). Movements occur around an indefinite number of axes, which have one common center. Flexion, extension, abduction, medial rotation, lateral rotation, and circumduction, all occur quite freely.
- *Examples:*
  - Shoulder joint
  - Hip joint
  - Talocalcaneonavicular joint