BONE

Functions of Bone:

- Allows body to move by giving attachment to different body muscles
- Supports soft tissues
- Protects vital organs (cranium, thoracic cavity)
- Contains bone marrow → Blood formation
- Metabolic function : Reservoir of Ca++, PO4 to maintain constant concentrations in body fluids

Bone covering

❑**Periosteum:**

cover the external surface of bone , formed of two layers

❑Outer fibrous

This layer support the bone & gives attachment to the tendon of muscles , at these site collagen fibers are more thickened forming sharpey's fibers that penetrate deep into the bone substance to fix periosteum and prevent its separation

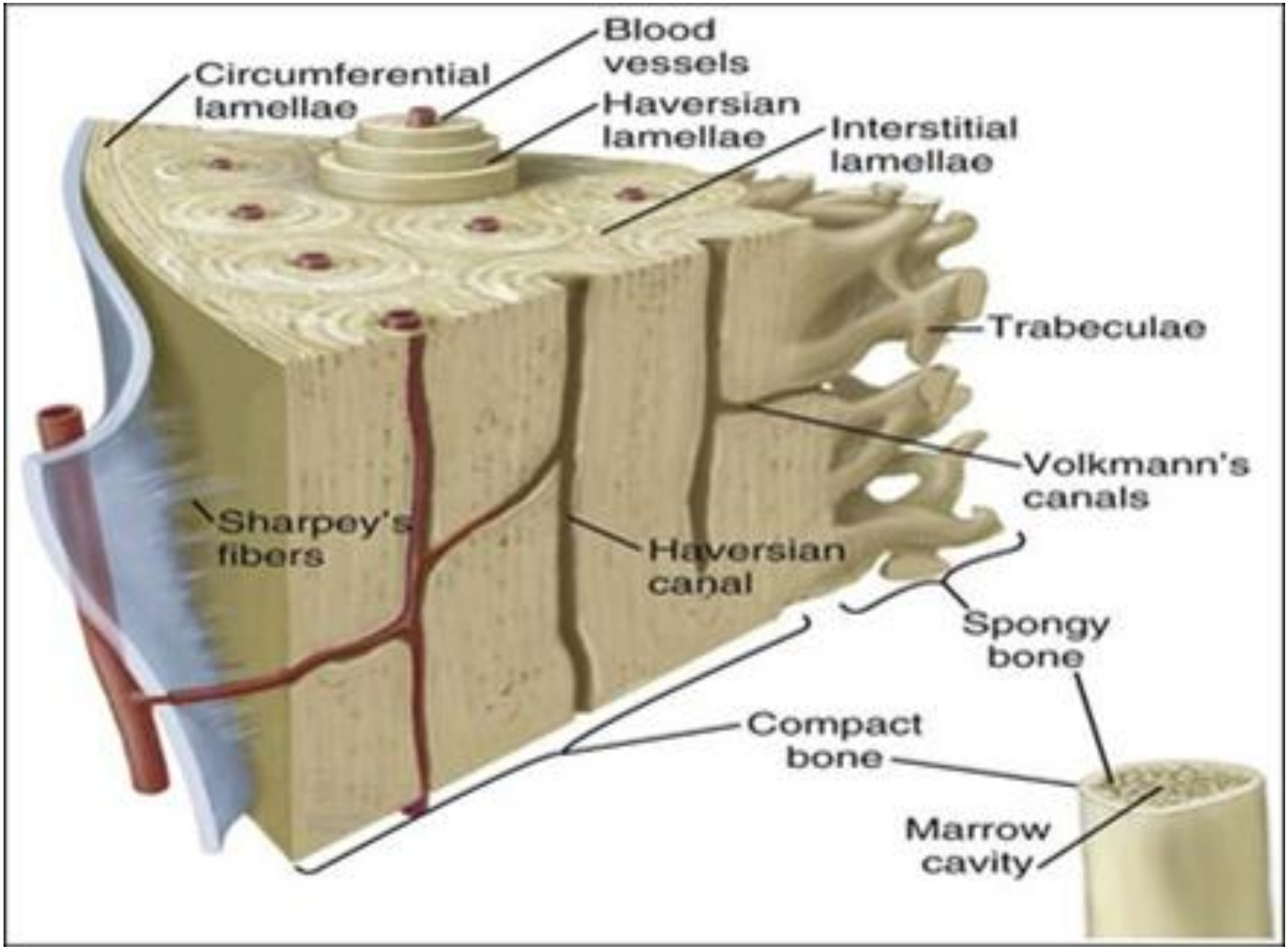
❑Inner vascular & cellular formed of osteogenic cells

(osteoprogenitor & osteoblasts) and blood vessels important for

Nutrition of bone & supply of osteoblasts

❑**Endosteum:**

lines the bone marrow cavity formed **only of cellular** layer of osteogenic cells


Blood vessels
Circumferential lamellae
Haversian lamellae
Interstitial lamellae
Trabeculae
Volkmann's canals
Sharpey's fibers
Haversian canal
Spongy bone
Compact bone
Marrow cavity

Bone Components

Bone is composed of cells lying in extracellular calcified matrix

❑**Bone matrix:** composed of :

❖**Water** :**25%** of bone weight permits ion exchanges

❖ **Organic components** = **30%** of bone weight include :

➢**Ground substance** formed of :

- proteoglycans bound to hyaluronic acid
- Adhesive glycoproteins e.g. osteocalcin & osteonectin

➢**Matrix fibers**

- type I collagen fibers
- Collagen forms osteoids: strands of spiral fibers that form matrix

❖**Inorganic components:** **45%** of bone weight

Calcified material in the form of calcium phosphates (Calcium hydroxyapatite) & calcium carbonates (calcium salts are responsible for the hardens of bone)

❑ Bone cells (4)

1. Osteoprogenitor cells (mother cells of bone)

arise from UMCs in the connective tissue present where bone formation is initiated

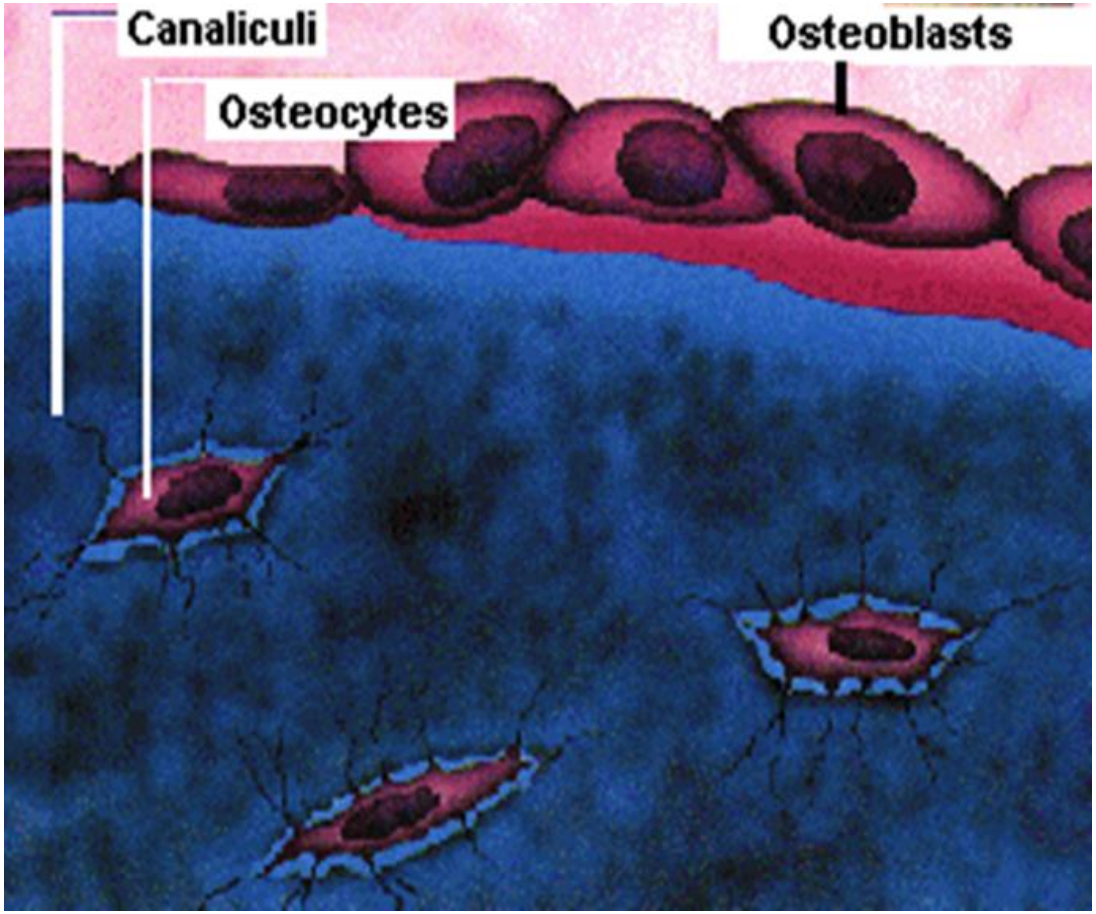
- present in cellular layer of periosteum
- Endosteum
- Lining Haversian canals

Function

Proliferate and differentiate to osteoblasts

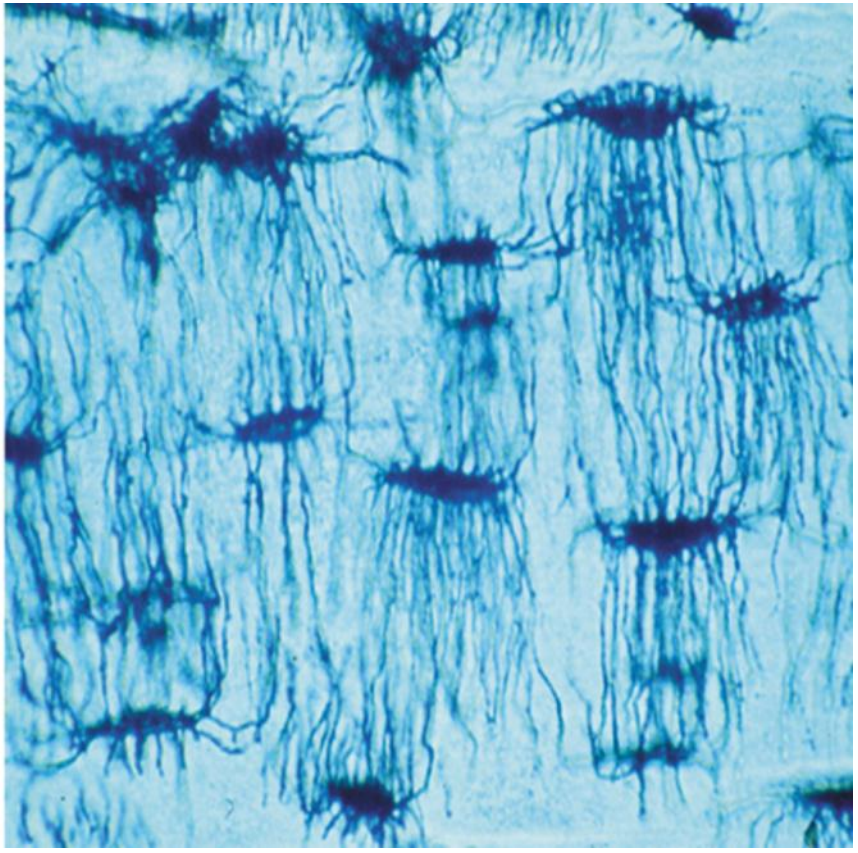
2.Osteoblasts are bone-forming cells

- Synthesize organic components of matrix (collagen fibers type I, proteoglycans, glycoproteins.)
- Secretion of alkaline phosphatase enzyme essential for deposit of Ca++, PO4.



3.Osteocytes = called unit bone cells

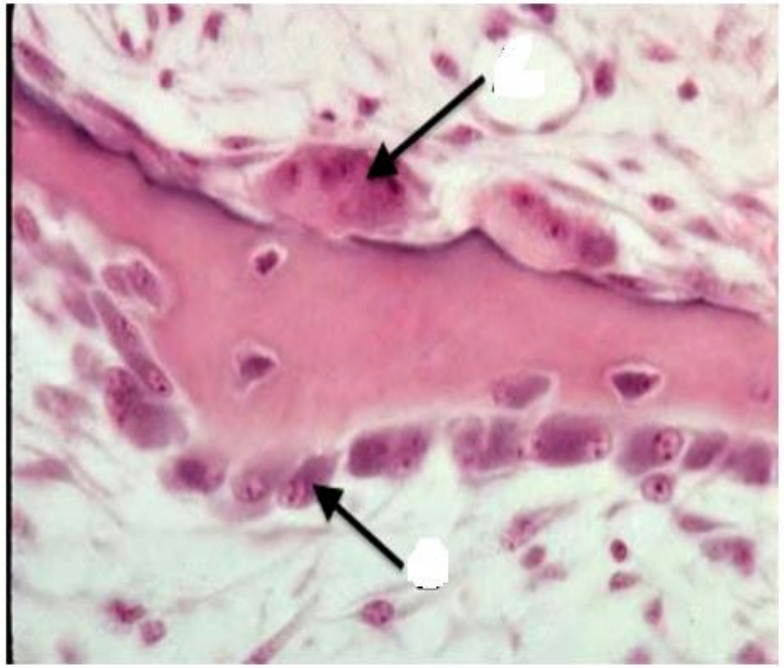
- Mature bone cells that sit in lacunae
- Osteocyte with cytoplasmic extensions in the canaliculi
- Gap junctions between osteocytes provide nutrition
- Maintain bony matrix, long living cells

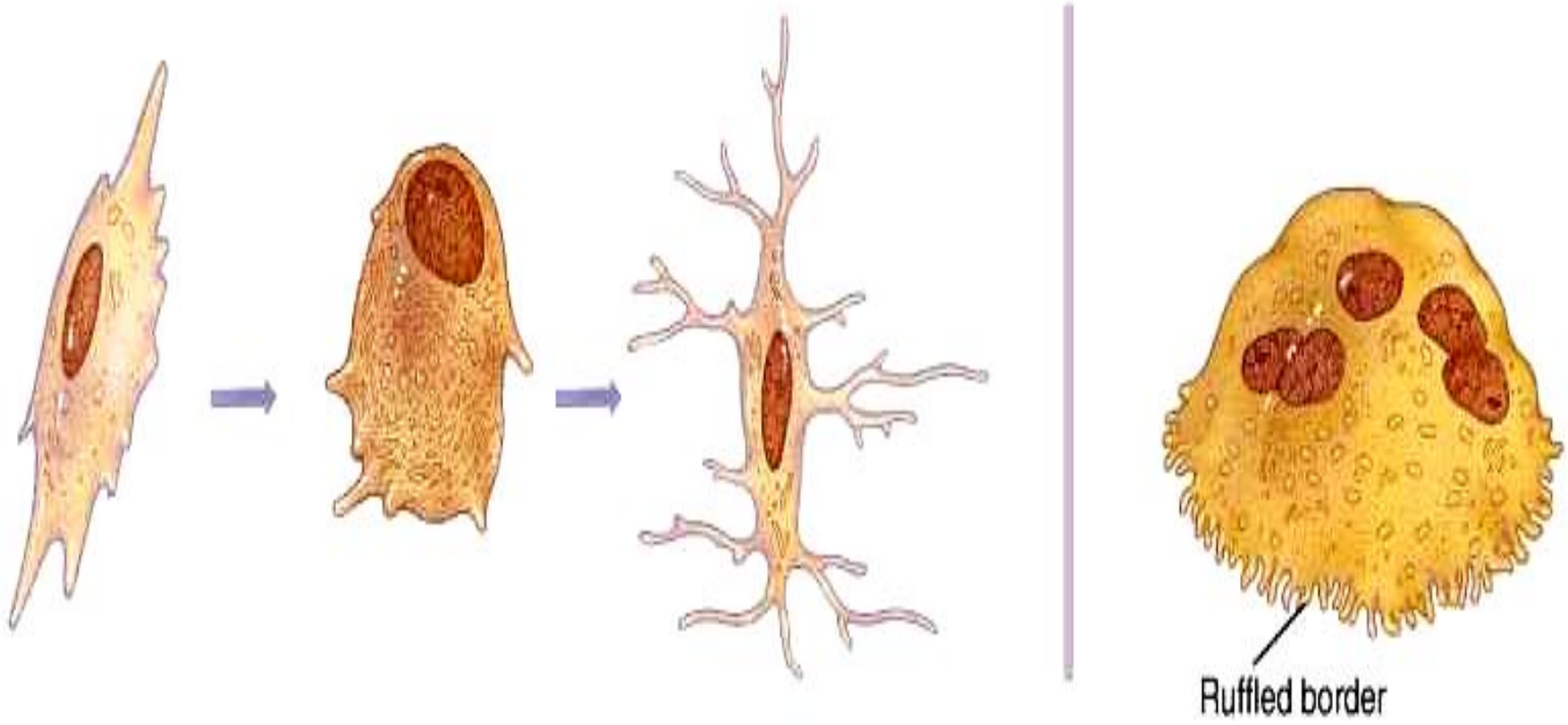


4.Osteoclasts = bone macrophages are bone-eating cells

= Derived from monocytes; engulf bony material

- Active osteoblasts stimulate osteoclast activity
- Large, branched, motile, multinucliated cells lying in Howship's lacunae
- Secrete enzymes that digest matrix = bone resorption & removal of inorganic & organic matrix





Osteogenic cell (develops into an osteoblast)

Osteoblast (forms bone tissue)

Osteocyte (maintains bone tissue)

Osteoclast (functions in resorption, the destruction of bone matrix)

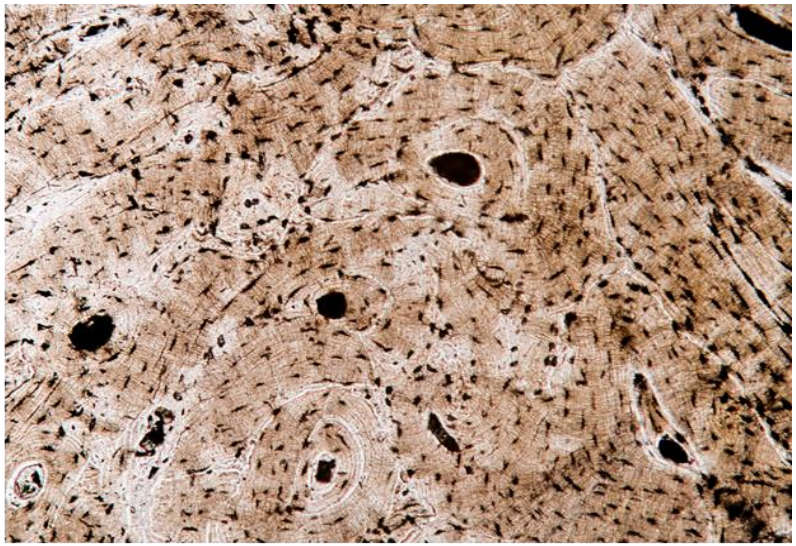
Cell	Origin	Function
1. Osteoprogenitor cells **Mother cells of bone**	From UMC in the CT	Proliferate & differentiate to osteoblast
2. Osteoblast **Bone forming cells**	From osteoprogenitor cells	Secretion of organic component of bone matrix Secretion of alkaline phosphatase essential for Calcium salts deposition
3. Osteocytes **Unit bone cells**	From osteoblast after being entrapped by calcified matrix	Maintenance of the bone matrix
4. Osteoclast **Bone macrophages** **Bone eating cells**	From blood momocytes	Bone resorption = removal of the inorganic & organic bone matrix

Methods of histological study of bone

There are **two methods** :

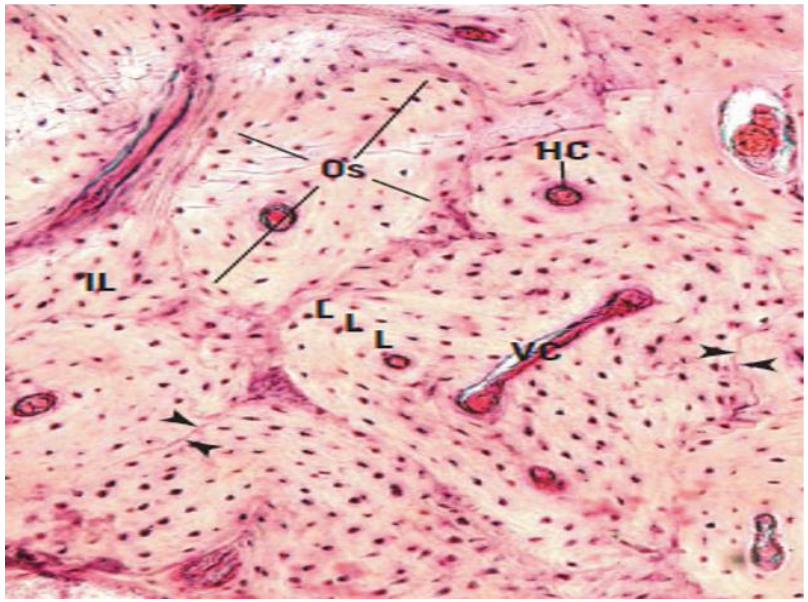
1. **Unstained ground bone**

In which the bone is grinned by special bone – grinding machine to produce very thin slices of bone the bone is mounted on glass slide , covered with a glass coverslip then examined directly by LM



2. **Stained decalcified sections** :

The calcium salts are removed from bone using strong acid solution e.g. nitric acid or chelating agent e.g. EDTA thus the bone became soft and is embedded sectioned & stained as usual with routine H&E stain



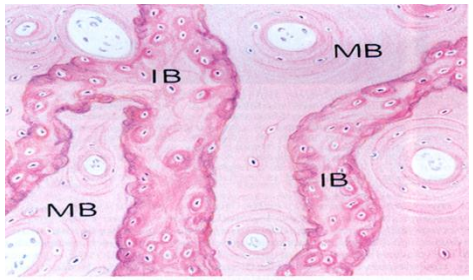
Types of bones

1. Primary bone = woven bone

- Immature weak bone
- Deposited during prenatal development & bone repair
- It is temporary and replaced later on by secondary bone

Characters

1. Low calcium
2. Irregular collagen
3. Abundant irregular osteocytes



2. secondary bone = lamellar bone

Mature strong bone that replaces primary bone

Characters

1. High calcium content so it is stronger
2. Regular collagen form lamellae
3. Less abundant osteocytes regularly arranged along the lamellae

Articular cartilage: covers epiphysis

Epiphysis: ends of bone

Epiphyseal plate: growth plate

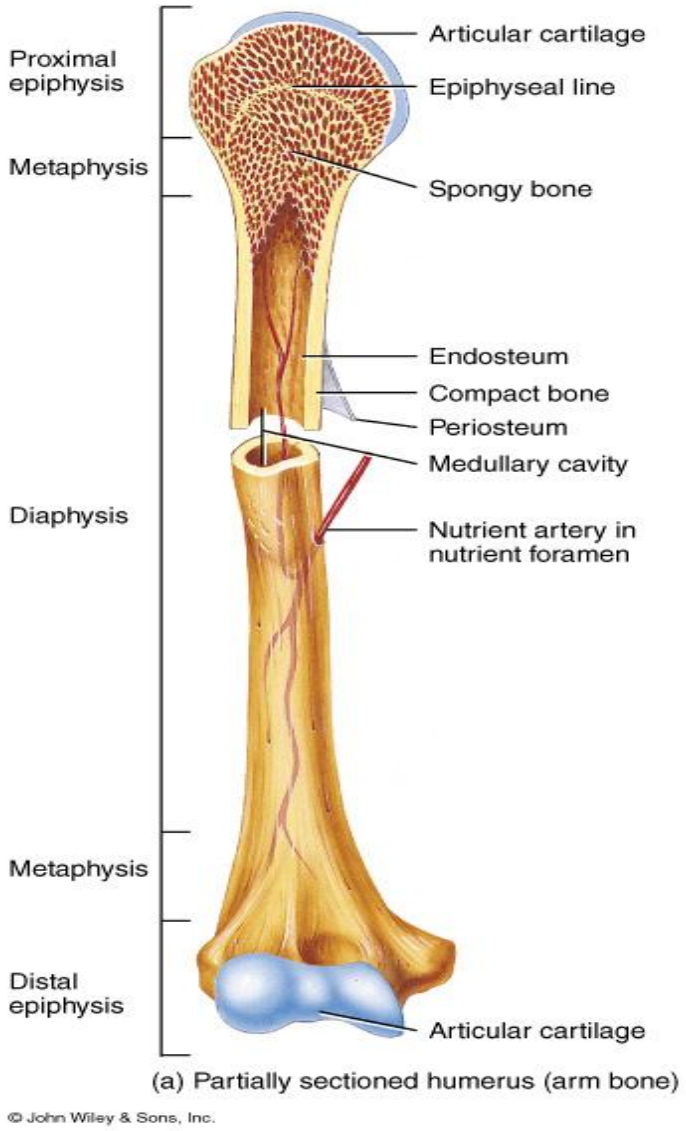
Metaphysis: b/w epiphysis and diaphysis

Diaphysis: shaft of long bone

Periosteum: bone covering
Sharpey's fibers: periosteum attaches to underlying bone

Endosteum: thin layer lining the medullary cavity

Medullary cavity: Hollow chamber in bone
- red marrow produces blood cells
- yellow marrow is adipose



(a) Partially sectioned humerus (arm bone)

Mature bone

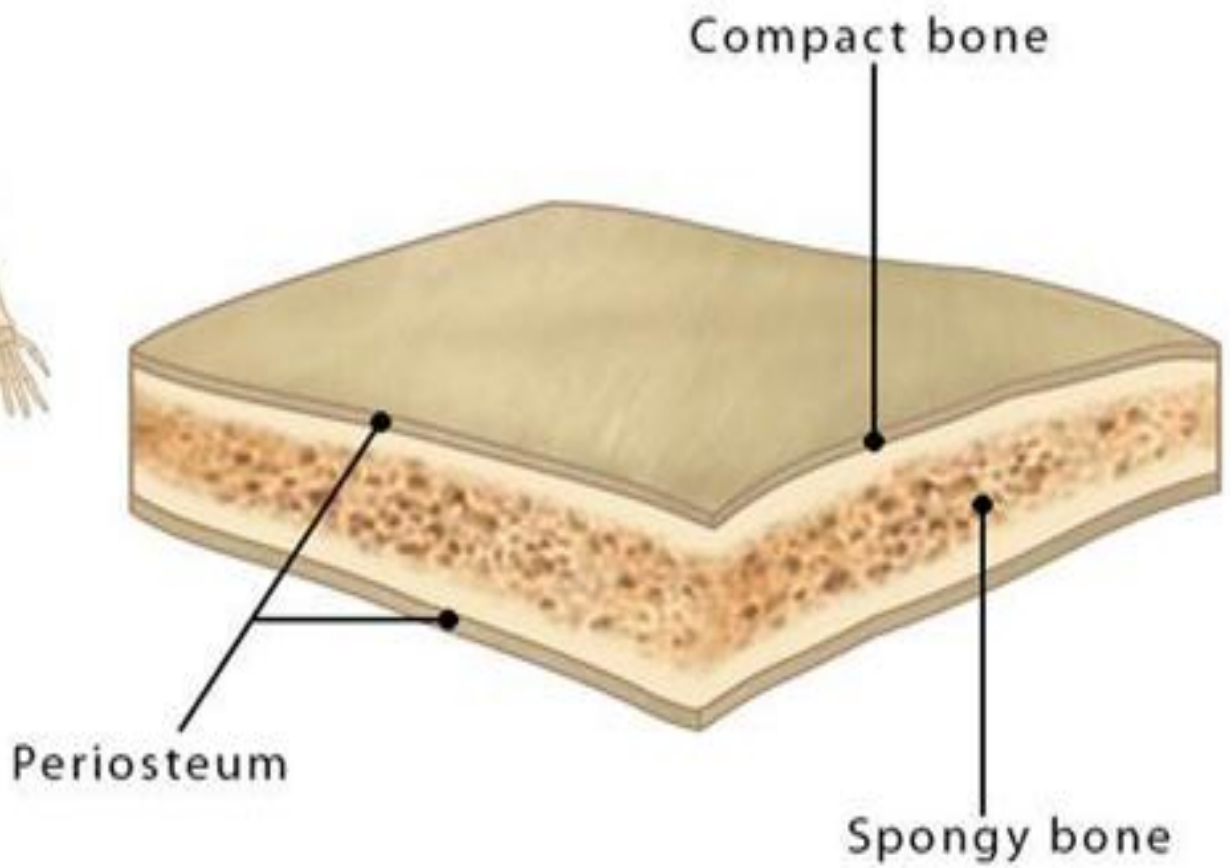
❑ Compact bone

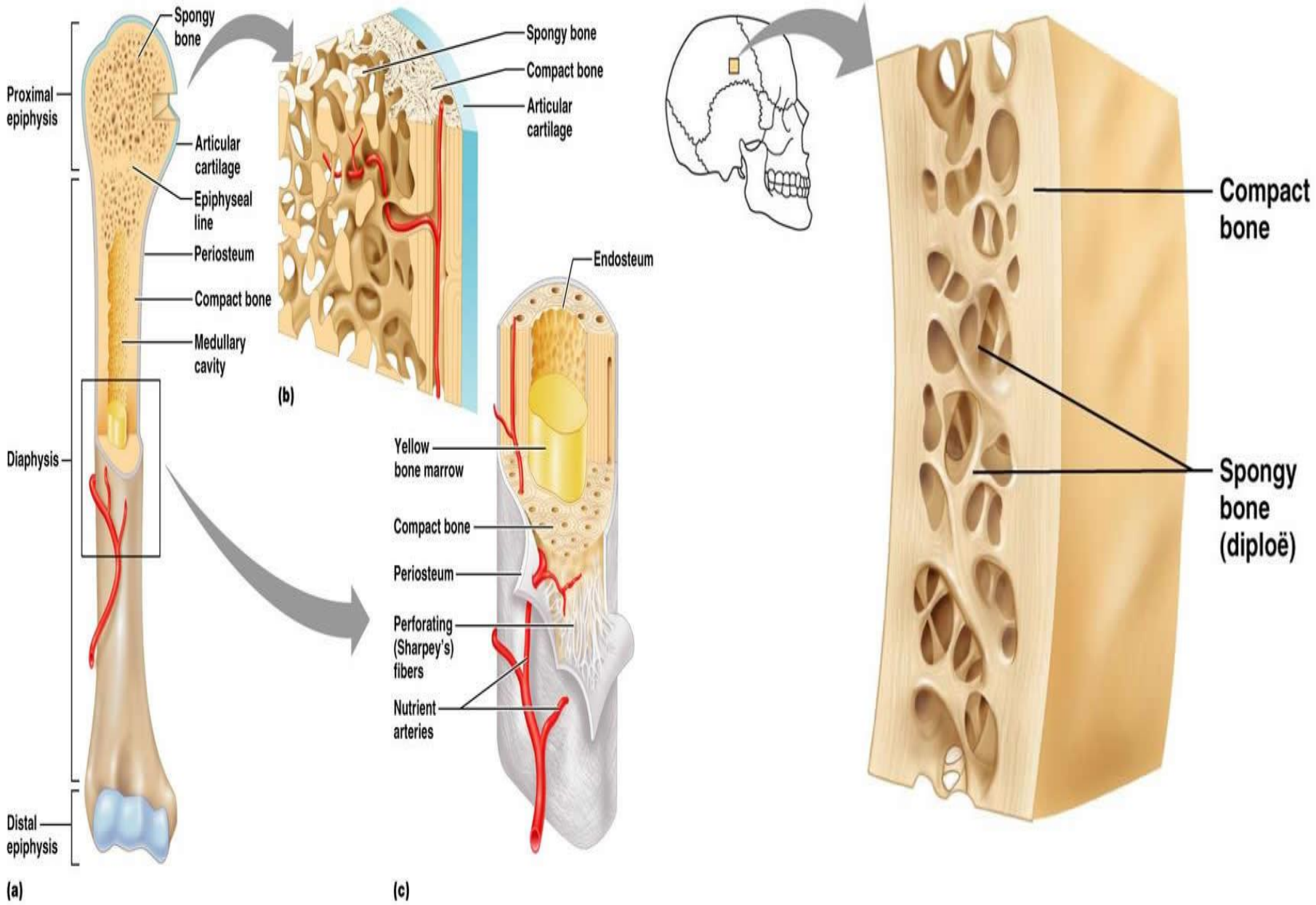
- Is also called **dense bone** = Lamellar bone
- Found in:
  - ❖ metaphysis & diaphysis of long bone
  - ❖ Outer & inner tables of flat bone
- Compact bone is composed of closely packed osteons.
- An osteon is also called a **Haversian system**.
- Haversian system or osteon is a Structural and functional unit of the Compact Bone

❑ Spongy bone

- is also referred to as cancellous (trabecular) bone, It is non-lamellar bone or bundle bone
- Found in :
  - ❖ Epiphysis of long bone
  - ❖ Diploe of flat bone
- The mineralized tissue is seen as plates and bars.
- Trabeculae are the bars seen in the spongy bone.
- Multiple marrow spaces are also present.

Flat Bone




Spongy bone
Proximal epiphysis
Articular cartilage
Epiphyseal line
Periosteum
Compact bone
Medullary cavity
Diaphysis
Distal epiphysis
(a)
Spongy bone
Compact bone
Articular cartilage
(b)
Endosteum
Yellow bone marrow
Compact bone
Periosteum
Perforating (Sharpey's) fibers
Nutrient arteries
(c)
Compact bone
Spongy bone (diploë)

Histology of Compact Bone

Site : it is found in :

1. Diaphysis (shaft) of long bones e.g. humerus & femur
2. Outer & inner tables of flat bone e.g. skull

• Has a single centrally located bone marrow cavity

Covering :

❑ **Periosteum.** The outer surface of the bones is covered by a double-layered coat.

➢**The outer fibrous** layer of periosteum is dense connective tissue.

➢ Support osteogenic layer

Function : Nutrition , supply osteoblast for bone formation (repair- Growth he bone

❖ Gives attachment to tendons of muscle

❖At these site collagen fibers penetrate deep into the bone forming sharpey‘ s fibers fix periosteum to inside of the bone

➢**The inner cellular** is a loose CT containing osteoprogenitor cells.

❑**Endosteum :** lines the internal surface of bone formed of osteogenic cells & blood vessels

The same function as the cellular layer of periosteum

Bone tissue: it is called bone lamellae , it is regular

In compact bone

Formed of collagen fibers and osteocytes in lacunae

Osteocytes communicate together through bony canaliculi to maintain nutrition

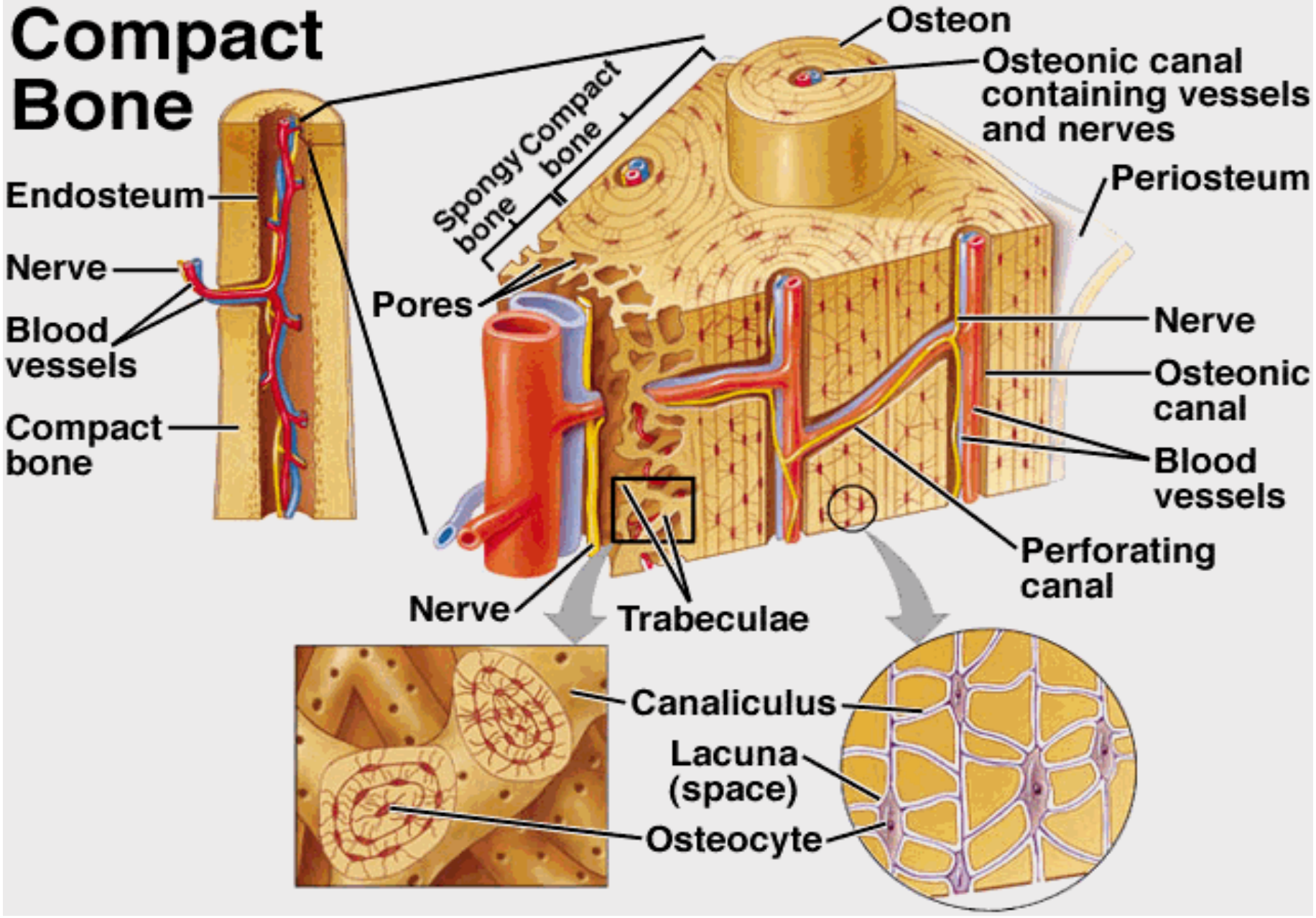
In compact bone :

1. External (outer) circumferential lamella
2. Internal (inner) circumferential lamella
3. Haversion system (osteon)
4. Interstitial lamella

Filling the spaces between Haversian system

Represent the that left behind during the process of continuous renewal of bone

Compact Bone



OSTEONS
=Haversian system

Definition :

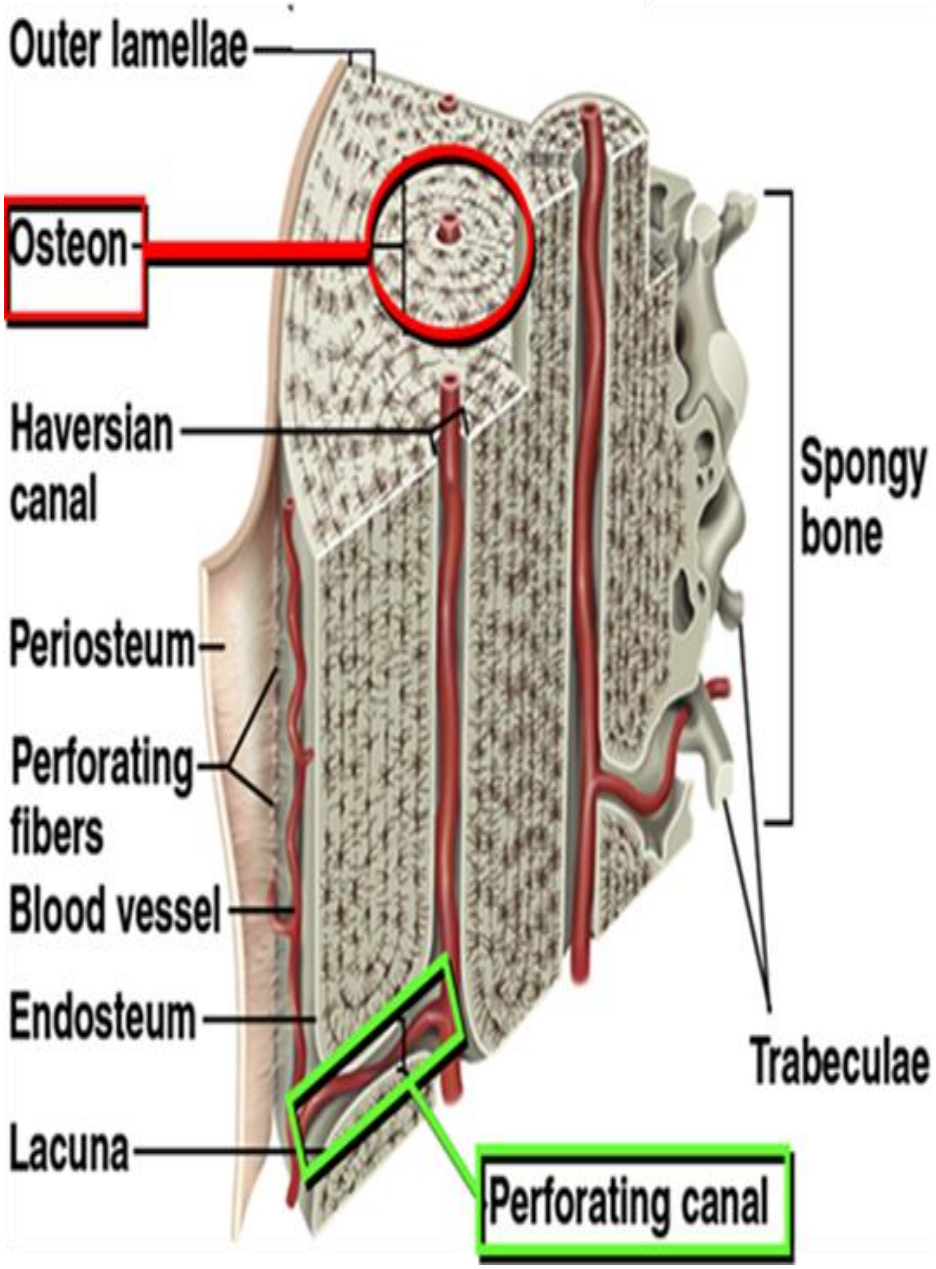
Osteon (Haversian system) is the whole complex of concentric lamellae of the bone surrounding a canal containing blood vessels, nerves, and loose connective tissue is called a **Haversian system,** or **osteon** .

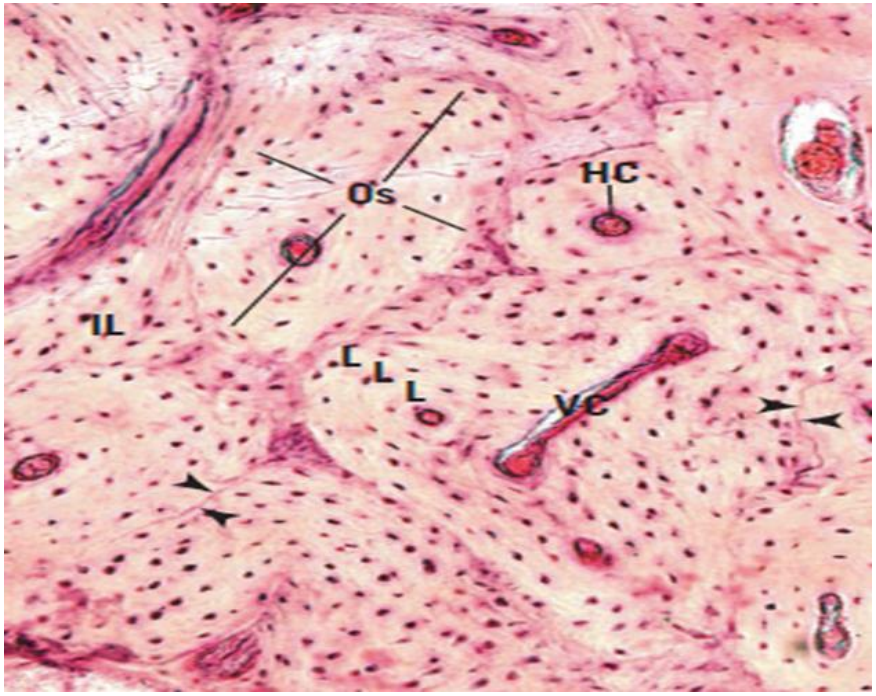
Lacunae containing osteocytes are found between , and occasionally within, the lamellae. In each lamella, collagen fibers are parallel to each other.

- Haversian canals communicate with marrow cavity, periosteum, other canals through Volkmann's canals

One bone marrow cavity in young age contain active bone marrow (Red BM)

- In adult contain yellow inactive bone marrow


Outer lamellae
Osteon
Haversian canal
Periosteum
Perforating fibers
Blood vessel
Endosteum
Lacuna
Spongy bone
Trabeculae
Perforating canal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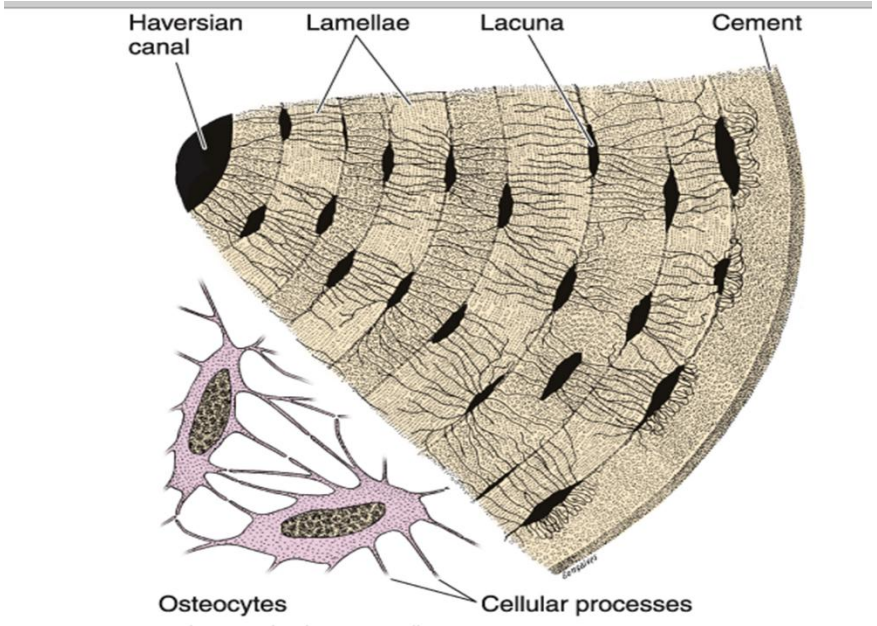
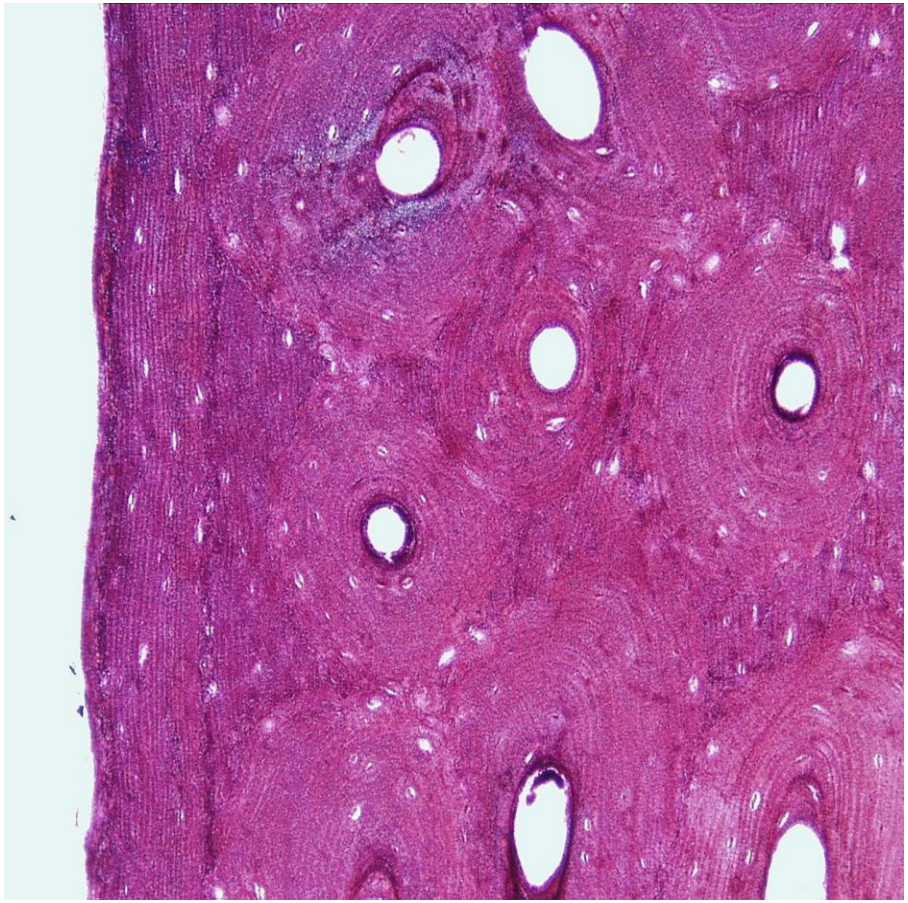
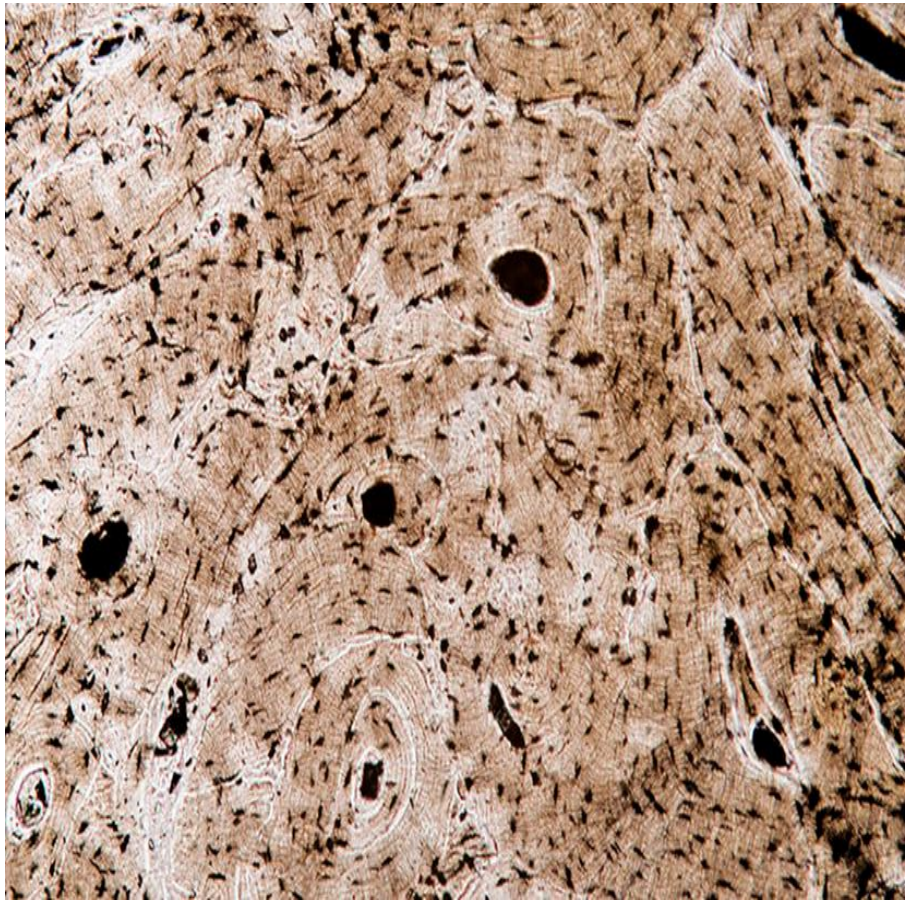

Haversian canal
Lamellae
Lacuna
Cement
Osteocytes
Cellular processes

OSTEONS





Cancellous bone
= Spongy bone

- It contains many bone marrow cavities giving the bone a spongy appearance

Structure:

Bone covering :

1. **Periosteum**
2. **Endosteum**

Bone tissue : Formed of two main components

1. **Bone trabeculae**

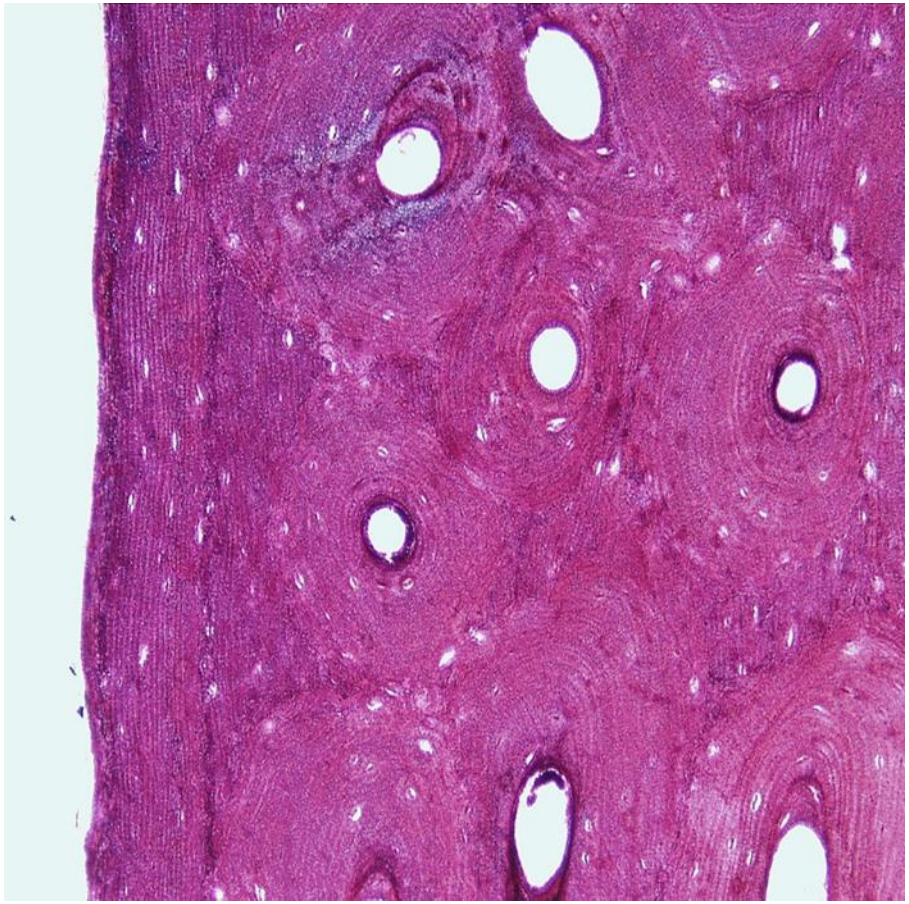
➢ irregular & anastomosing irregular bone lamellae with scattered osteocytes in lacunae

➢Poorly developed Haversian system

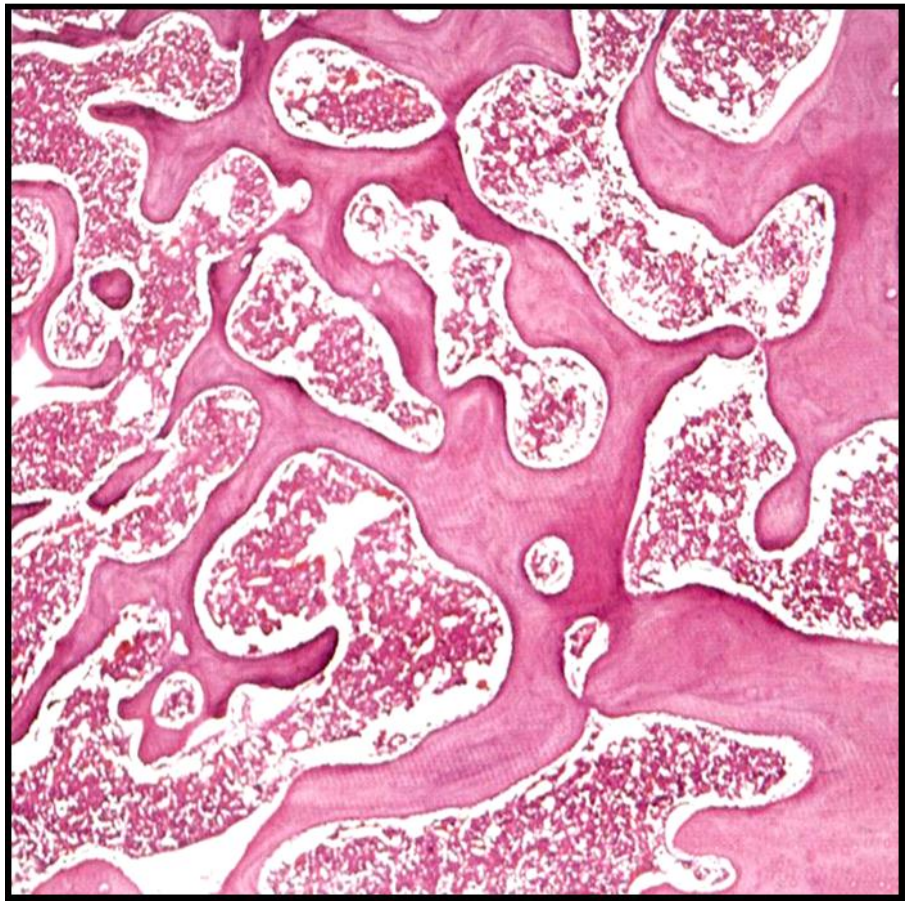
2. **Bone marrow cavities :**

Multiple irregular BM cavities contain active red bone marrow

Compact bone



Cancellous bone



	Compact bone	Cancellous bone
Naked eye appearance	Dense with no hole	Spongy with many hole
Sites	Shaft of long bones Outer & inner tables of flat bones	Flat bone Epiphysis of long bone
Periosteum	Present	Present
Endosteum	Lines central single marrow cavity	Lines multiple marrow cavities
Marrow cavity	Central single	Multiple cavities
Bone lamellae	Regular , parallel form Haversian system , circumferential and interstial lamellae	Irregular , incomplete lamellae Form bone trabeculae
Haversian system	Mature , well developed	Immature , primitive Haversian
Matrix	Well organized collagen	Irregular collagen
Nutrition	Bone nutrient vessels , periosteal vessels . Volkman canal , Haversian canals, canaliculi of all osteocytes	Bone nutrient vessels , periosteal vessels, multiple marrow cavities, bone canaliculi

	Bone	Cartilage
Characters	Hard , inflexible	Firm & flexible
Covering	Periosteum & endosteum	Perichondrium Except White fibrocartilage & articular surface of hyaline
Matrix	Rich in Ca ++ , less hydrated 25% water	Well hydrated 70-80 % water
CT fibers	Collagen I well organized into lamellae	Collagen II Elastic fibers Collagen I in WFC
Cells	5 Types Osteocytes single inside lacunae communicating by processes	2 Types Chondrocytes single or in group inside lacune forming cell nest
Vascularity	Vascular	Avascular

BONE FORMATION

- Bone may develop (**directly**) from mesenchyme or by the replacement of cartilage (**indirectly**).
- The process of replacing other tissues with bone is called **ossification**
- The process of bone formation is called **ossification**

Bone formation occurs in four situations:

- Formation of bone in an embryo
- Growth of bones until adulthood
- Remodeling of bone
- Repair of fractures

BONE FORMATION

Formation of Bone in an Embryo

begins at the 6th week of embryo development and continues up to age of 25

two patterns

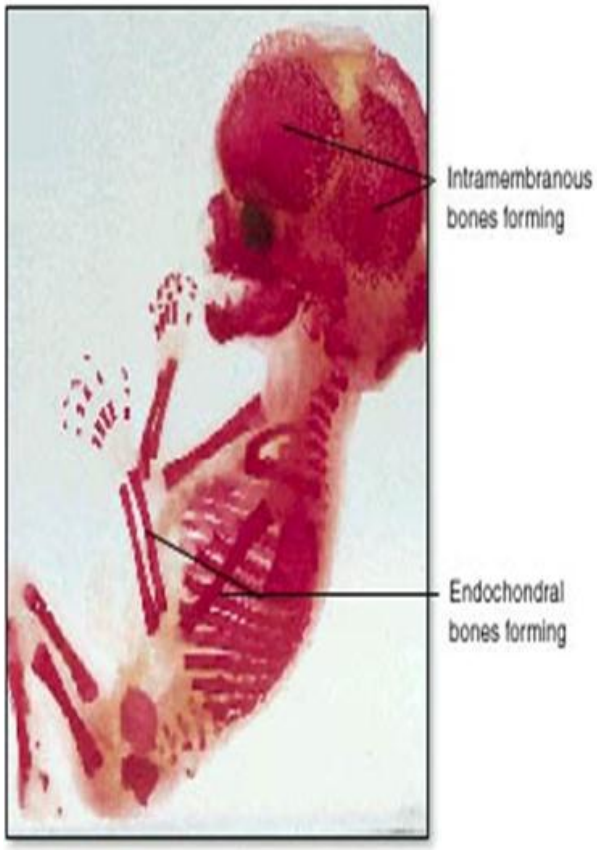
- **Intramembranous ossification**

  Flat bones of the skull , mandible & clavicle are formed in this way

- **Endochondral ossification**

  cartilage formation and ossification occurs during the sixth week of embryonic development

  - The replacement of cartilage by bone
  - Most bones of the body are formed in this way including long bones

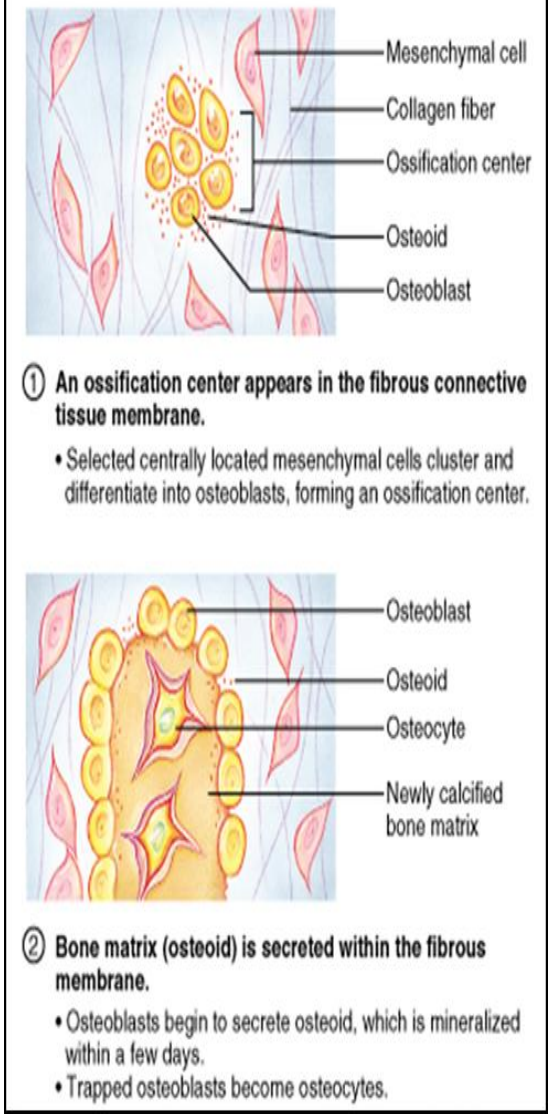


Intramembranous Ossification

- An ossification center appears in the mesenchymal connective tissue membrane
- Mesenchyme cells differentiate into osteoblasts. **Osteogenic islands.**
- Osteoblasts secrete bone matrix within the fibrous membrane
- Osteoblasts surround themselves with bone matrix, forming osteocytes = Osteoblasts mature into osteocytes

= It is **osteoid stage.**

- Osteoid becomes mineralized through crystallization of Ca++ salts using enzyme alkaline phosphatase and is called primary ossification center(OC). It is **ossification stage and formation of spicules.**
- Blood vessels begin to grow spicules that meet and fuse together.
- **Woven Bone (primary spongy bone).**
- Osteoclasts erode the primary bone matrix . **It is remodeling or Secondary bone formation.**



Endochondral (indirect) Ossification

- Bone develops from pre-existing model perichondrium and hyaline cartilage
- Formation of primary ossification center (**OC**) and marrow cavity in shaft of model

1.Cartilage modelstem cells give rise to osteoblasts and clasts

2.The periosteal bone collar (perichondral ossification) bony collar developed by osteoblasts

3.Proliferation,hypertrophy,calcification of the cartilage (chondrocytes swell and die) = bone laid down and marrow cavity created

4. Formation of primary marrow cavity and Periosteal bud- small cluster of blood vessels

4. Primary ossification center

5.Secondary ossification center

7.Secondary bone formation and remodeling

8.Bone growth in length and girth

Stages of Endochondral Ossification

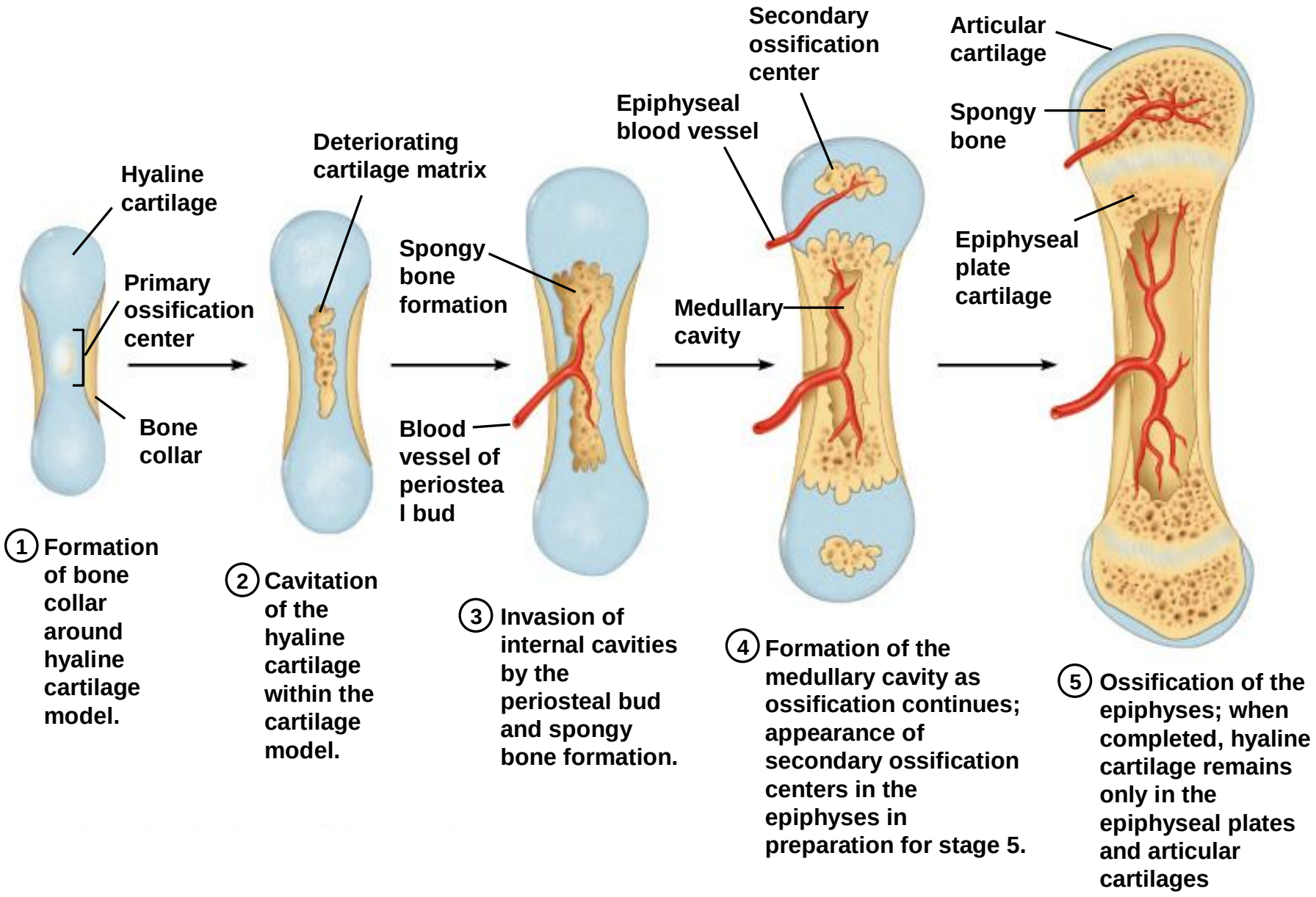
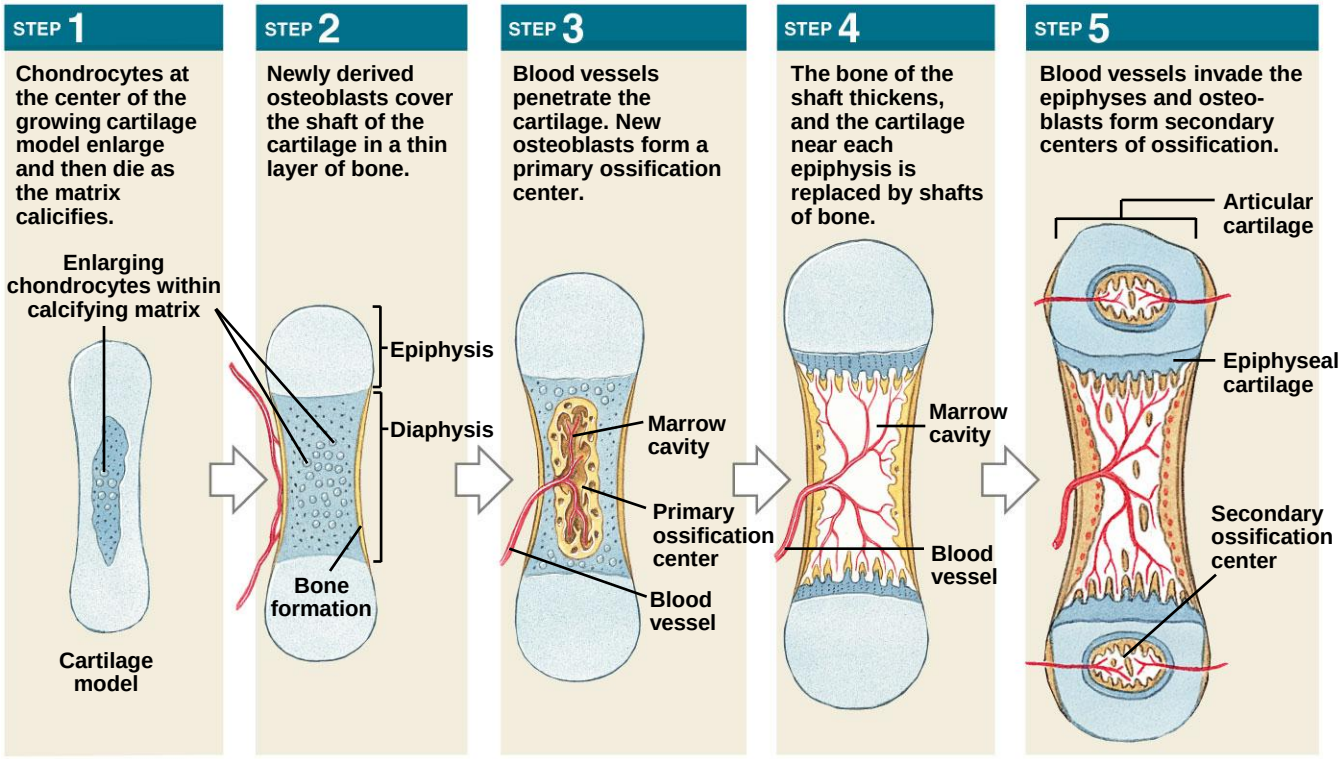


Figure 6.8

Endochondral Ossification



Replacement of hyaline cartilage with bone
Most bones are formed this way (i.e. long bones).

Bone Growth

- Bones increase in length = **interstitial growth** of epiphyseal plate

- Bones increase in width = **appositional growth**

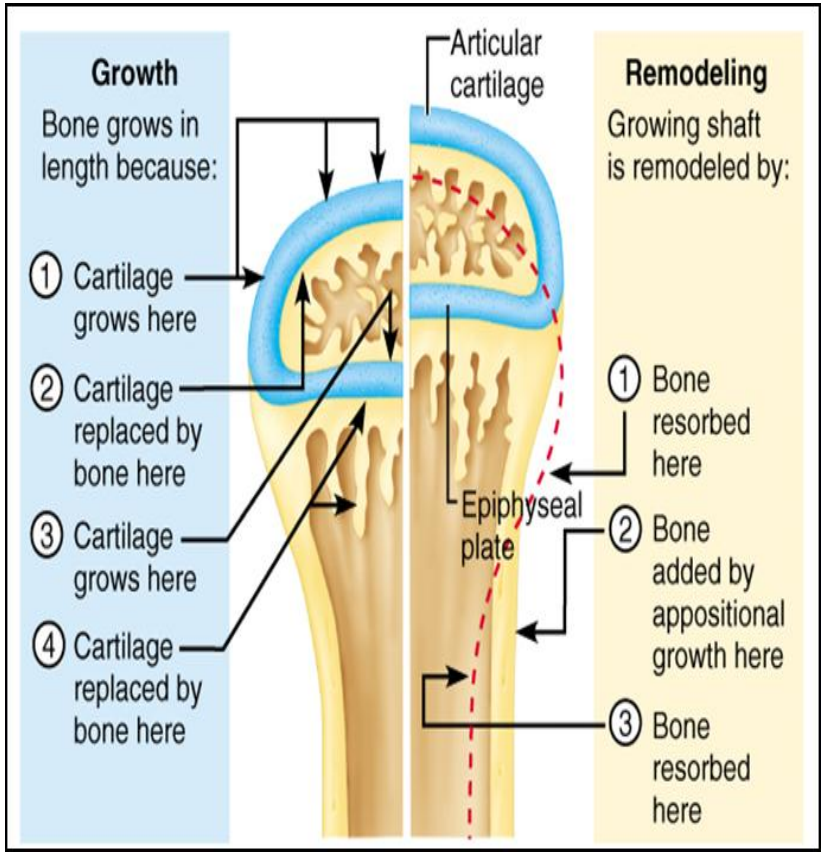
osteoblasts lay down matrix in layers on outer surface and osteoclasts dissolve bone on inner surface

- Secondary ossification centers and secondary marrow cavities are formed in the ends of the bone
- primary and secondary marrow cavities united

- Cartilage remains as articular cartilage and epiphyseal (growth) plates
- growth plates provide for increase in length of bone during childhood and adolescence

Longitudinal Bone Growth

- Longitudinal Growth (interstitial)
- cartilage continually grows and is replaced by bone
- Bones lengthen entirely by growth of the **epiphyseal plates**
- Cartilage is replaced with bone as quickly as it grows



GROWTH IN LENGTH
GROWTH OF CARTILAGE ON THE EPIPHYSEAL PLATE

- The growth in length of long bones involves two major events:
  - Growth of cartilage on the epiphyseal plate
  - Replacement of cartilage by bone tissue in the epiphyseal plate

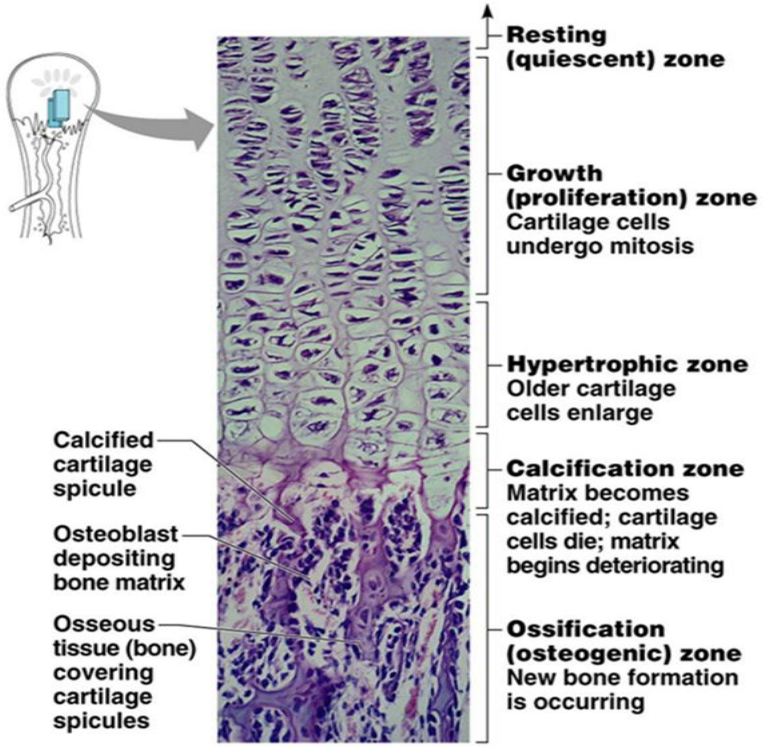
- osteoblasts located beneath the periosteum secrete bone matrix and build bone on the surface osteoclasts located in the endosteum resorbs (breakdown) bone.

- epiphyseal plate (bone length)

- 4 zones of bone growth.

1- Zone of resting cartilage (quiescent):

- no bone growth
- located near the epiphyseal plate
- scattered chondrocytes
- anchors plate to bone



2- Zone of proliferating cartilage (proliferation zone)

- chondrocytes stacked like coins , chondrocytes divide

3- Zone of hypertrophic (maturing) cartilage

- large chondrocytes arranged in columns ,lengthwise expansion of epiphyseal plate

- 4- Zone of calcified cartilage

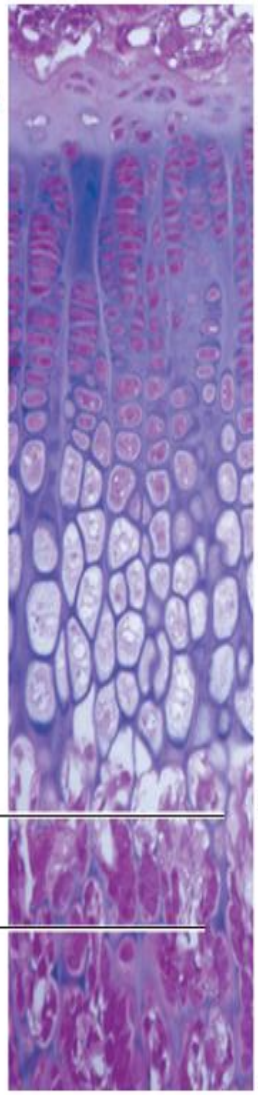
- cells lay down bone

- dead chondrocytes surrounded by a calcified matrix.

Matrix resembles long spicules of calcified cartilage.

Spicules are partly eroded by osteoclasts and then covered in bone matrix from osteoblasts: spongy bone is formed.

Organization of Cartilage within Epiphyseal Plate of Growing Long Bone



Resting zone – small, inactive cartilage cells

① **Proliferation zone**
Chondroblasts quickly divide and push the epiphysis away from the diaphysis, lengthening the bone.

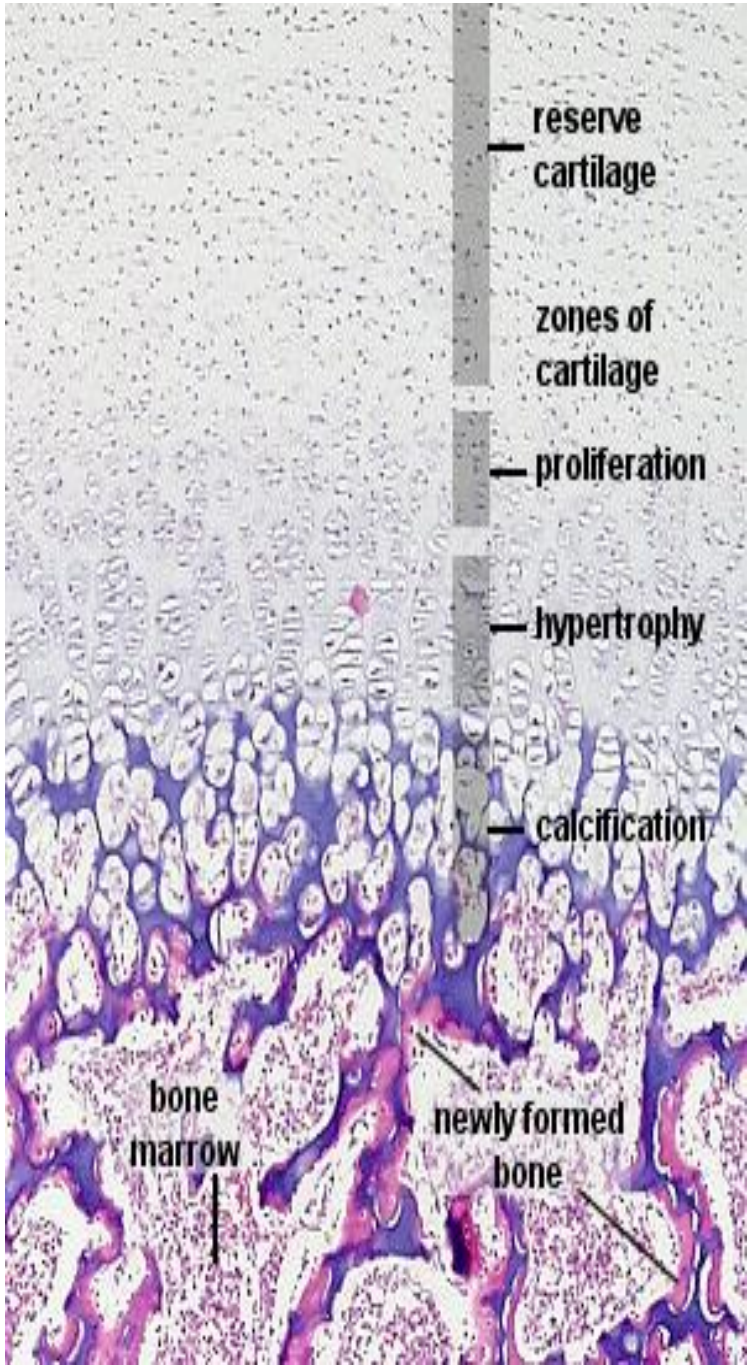
② **Hypertrophic zone**
Older chondrocytes enlarge and signal the surrounding matrix to calcify.

③ **Calcification zone**
Matrix becomes calcified; chondrocytes die, leaving behind trabeculae-shaped calcified cartilage. THIS IS NOT YET BONE!
.

Calcified cartilage spicule

Osseous tissue

④ **Ossification zone**
Osteoclasts digest the calcified cartilage, and *osteoblasts* replace it with actual bone tissue in the shape of the calcified cartilage – resulting in bone trabeculae.



Structure of the epiphyseal plate

1. Zone of reserve cells (resting cartilage): A thin layer of small, randomly oriented chondrocytes adjacent to the bony trabeculae on the articular side of the growth plate.

2. Zone of proliferation: Chrondrocytes are stacked in prominent rows, mitotic figures and the cartilage matrix becomes more basophilic

3. Zone of maturation: No mitoses; gradual cellular enlargement.

4. Zone of hypertrophy:

Chrondrocytes and their lacunae increase in size.

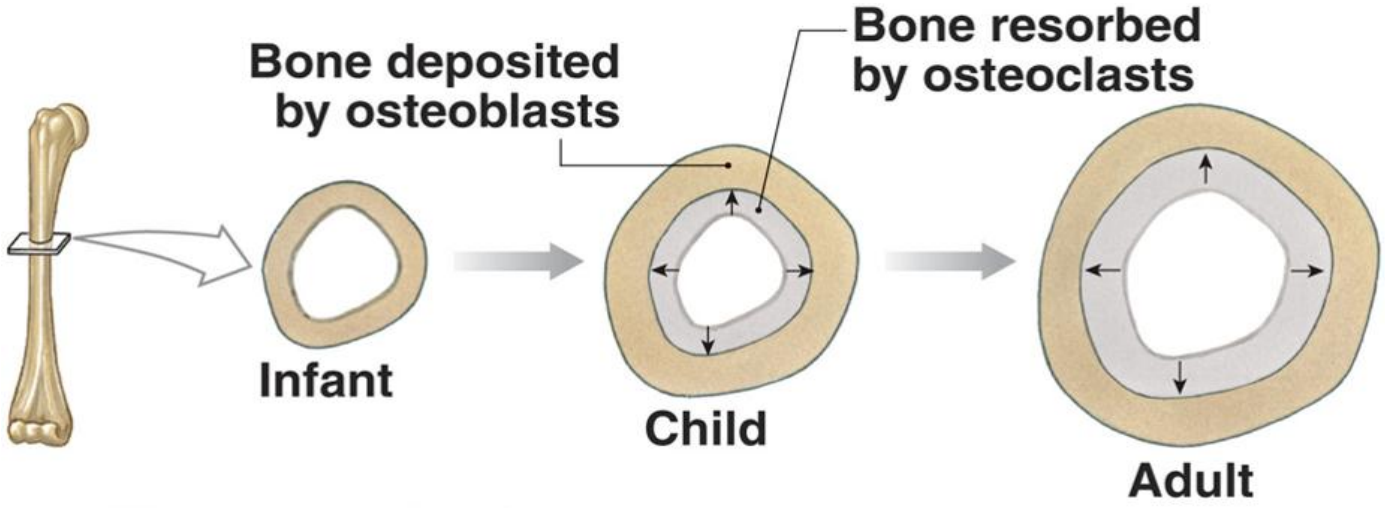
5. Zone of calcification: Deposition of minerals in the matrix surrounding the enlarged lacunae causing cell death.

6. Zone of ossification: Osteoblasts deposit bone matrix on the exposed plates of calcified cartilage.

7. Zone of resorption: Osteoclasts absorb the oldest bone spicules.

APPOSITIONAL BONE GROWTH

- Growing bones widen as they lengthen
- Appositional growth – growth of a bone by addition of bone tissue to its surface
- Bone is resorbed at endosteal surface and added at periosteal surface
  - Osteoblasts – add bone tissue to the external surface of the diaphysis
  - Osteoclasts – remove bone from the internal surface of the diaphysis



BONE REMODELING
Remodeling is secondary bone formation

bone continually renews itself

- never metabolically at rest
- enables Ca++ to be pulled from bone when blood levels are low
- osteoclasts are responsible for matrix destruction
- produce lysosomal enzymes and acids

Function :

Remodeling helps, continous renewal of old osteon and formation new one, replacement of immature bone by mature one reshape growing bones to adapt to changing loads

- spongy bone replaced every 3-4 years
- compact bone every 10 years

Repair of Fractures

Any bone breakleads to Hemorrhage

❖Closed reduction into place by manipulation

❖ Open reduction by surgery

Phases of fracture healing

1. Clot formation : blood clot will form around break= fracture hematoma

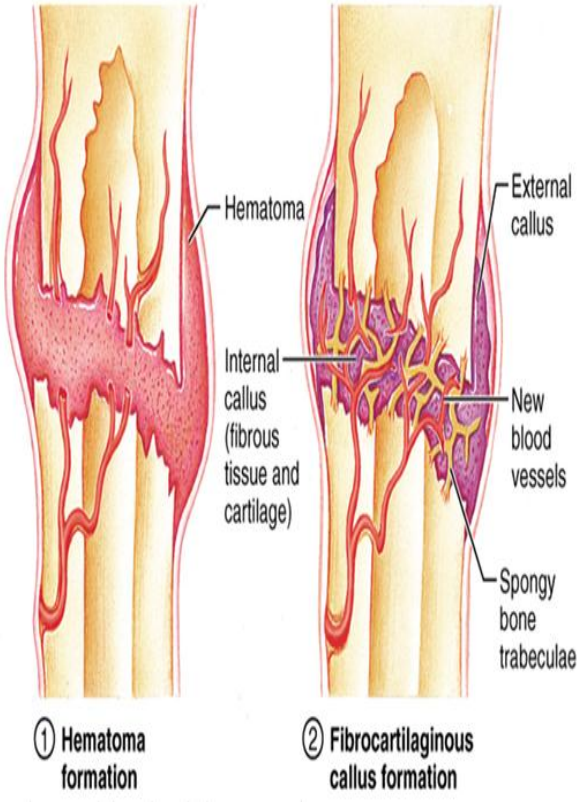
To stop hemorrhage

- inflammatory process begins
- blood capillaries grow into clot

2. Callus formation = soft callus

Blood clot is removed by macrophages and osteoclasts remove adjacent bone

Enhanced activity of osteoprogenitor cells from periosteum & endosteum form soft callus of fibrocartilage like tissue = (soft) callus



3. Callus ossification (Hard callus)

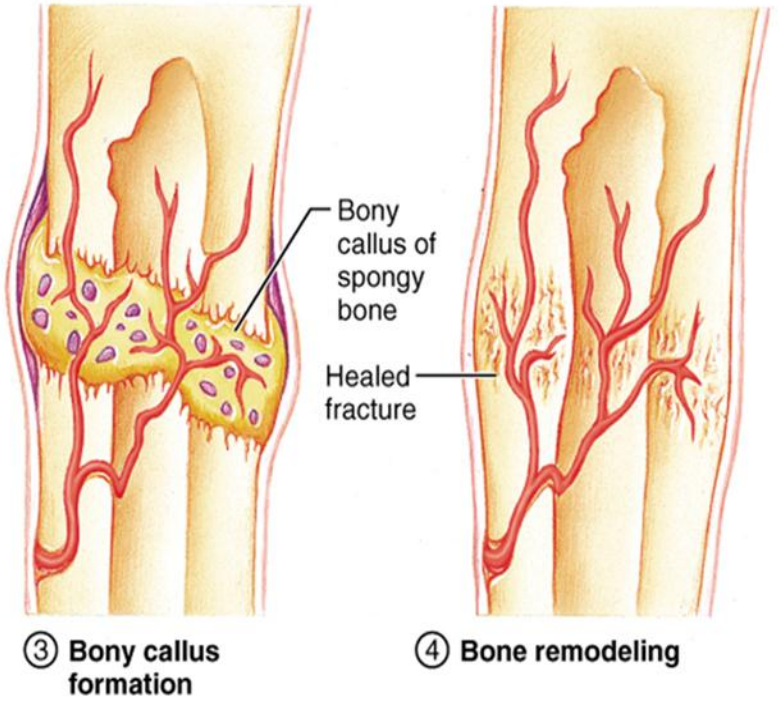
Primary bone formation is initiated by imtramembranous ossification , mesenchymal cells give rise to cartilage

Some mesenchymal cells changed to bone by intracartilaginous ossification and hard callus is formed of irregular bone trabeculae of primary immature temporary bone

4. Bone remodeling

Primary bone is resorbed and replaced by secondary bone

Further remodeling restore the original bone structure & contour



Types of Bone Tissue
(Classification)

According to its architecture:

- Spongy (cancellous)
- Compact (dense)

According to its fine structure:

- Primary (woven)
- Secondary (lamellar)

According to its histogenesis:

- Intramembranous
- Endochondral