Histology of the bone

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Bone function

- Support
- Protection (protect internal organs)
- Movement (provide leverage system for skeletal muscles, tendons, ligaments and joints)
- Mineral homeostasis (bones act as reserves of minerals important for the body like calcium or phosphorus)
- Hematopoiesis: blood cell formation
- Storage of adipose tissue: yellow marrow

Bone anatomy

Diaphysis: long shaft of bone

Epiphysis: ends of bone

Epiphyseal plate: growth plate

Metaphysis: b/w epiphysis and diaphysis

Articular cartilage: covers epiphysis

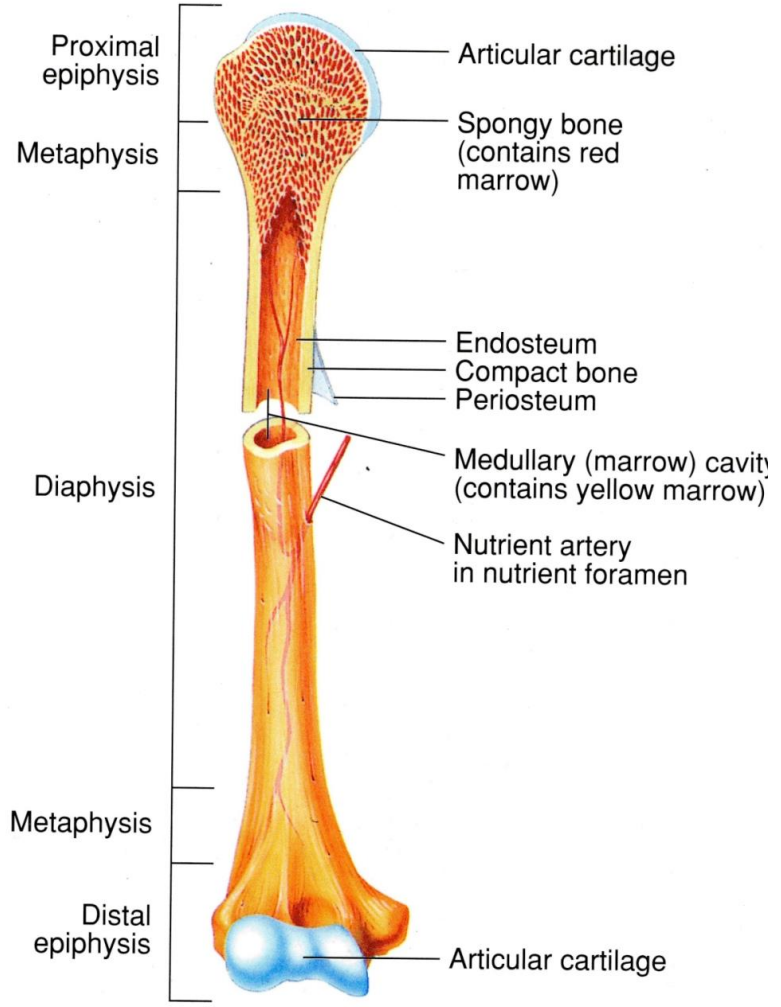
Periosteum: bone covering (pain sensitive)

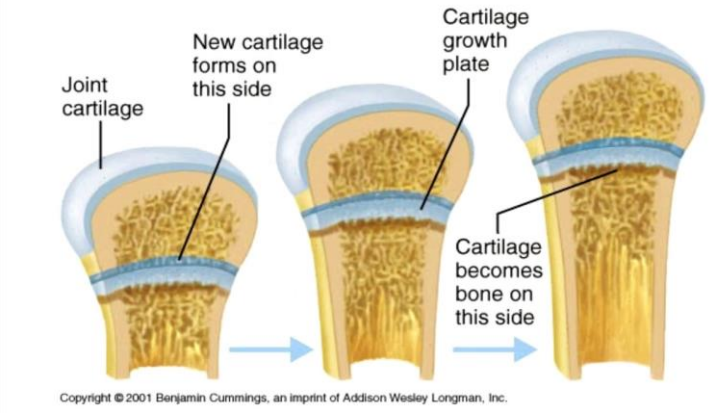
Sharpey's fibers: periosteum attaches to underlying bone

Medullary cavity: Hollow chamber in bone

- Red marrow produces blood cells
- Yellow marrow is adipose

Endosteum: thin layer lining the medullary cavity





Blood and nerve supply of bone

- Bone is supplied with blood by:
  - **Periosteal arteries /veins**-supply the periosteum and compact bone

- Nerves accompany the blood vessels that supply bones
  - The periosteum is rich in sensory nerves sensitive to tearing or tension
  - Accompanied by periosteal arteries

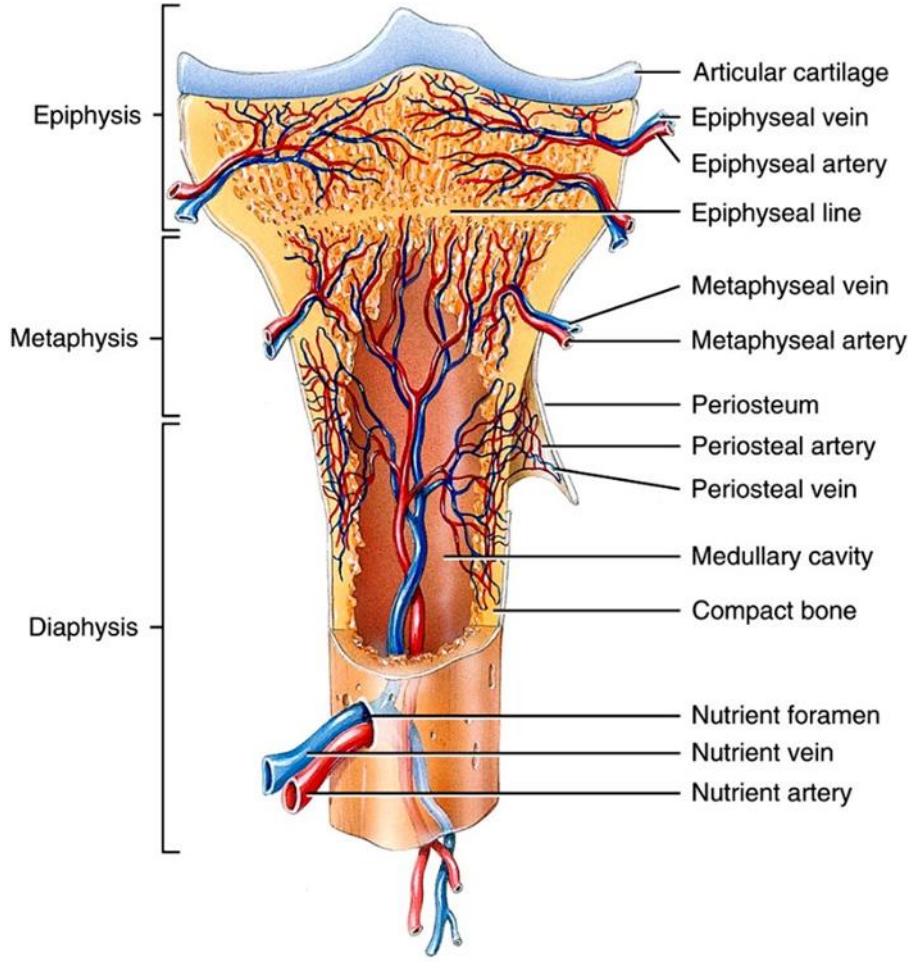
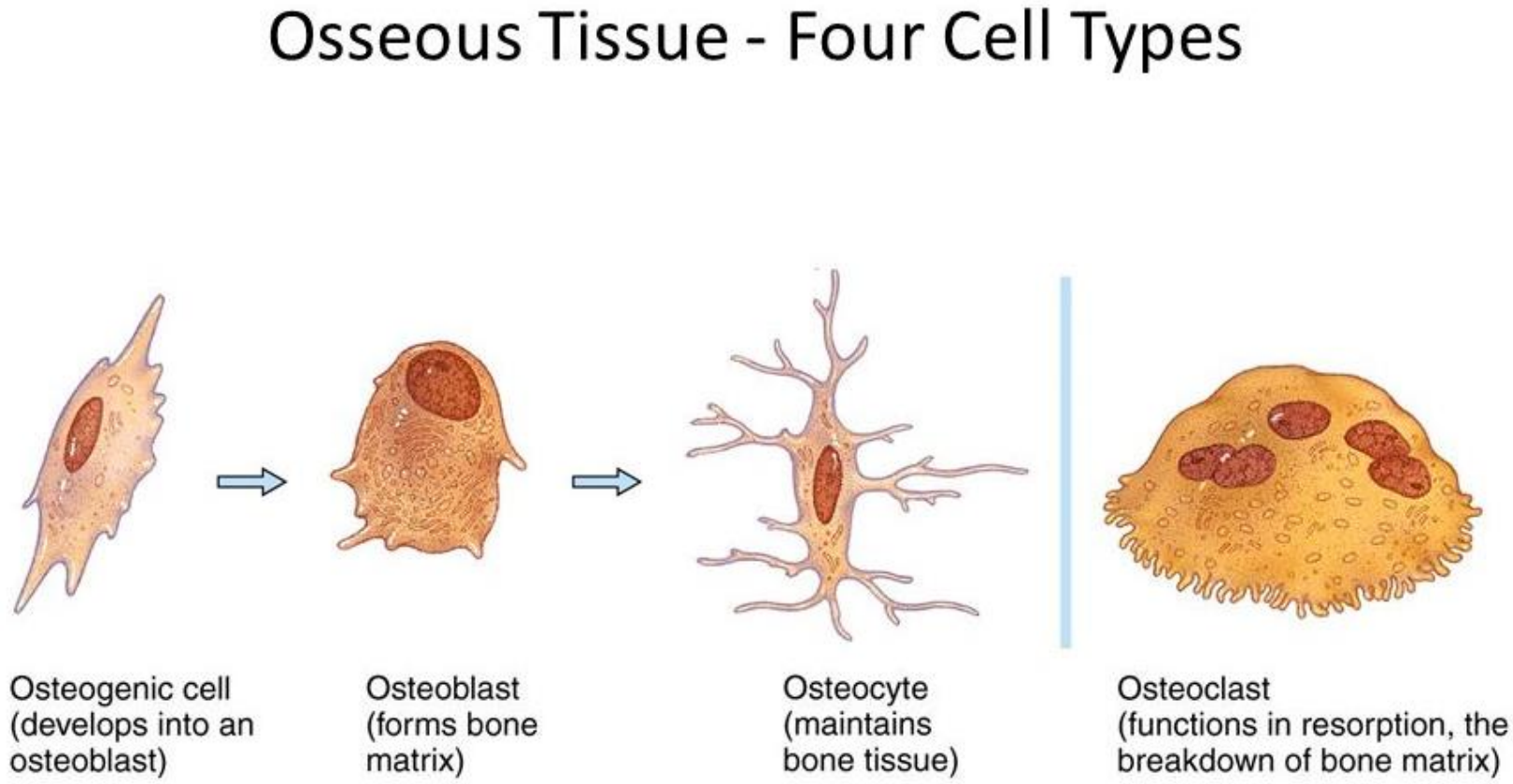


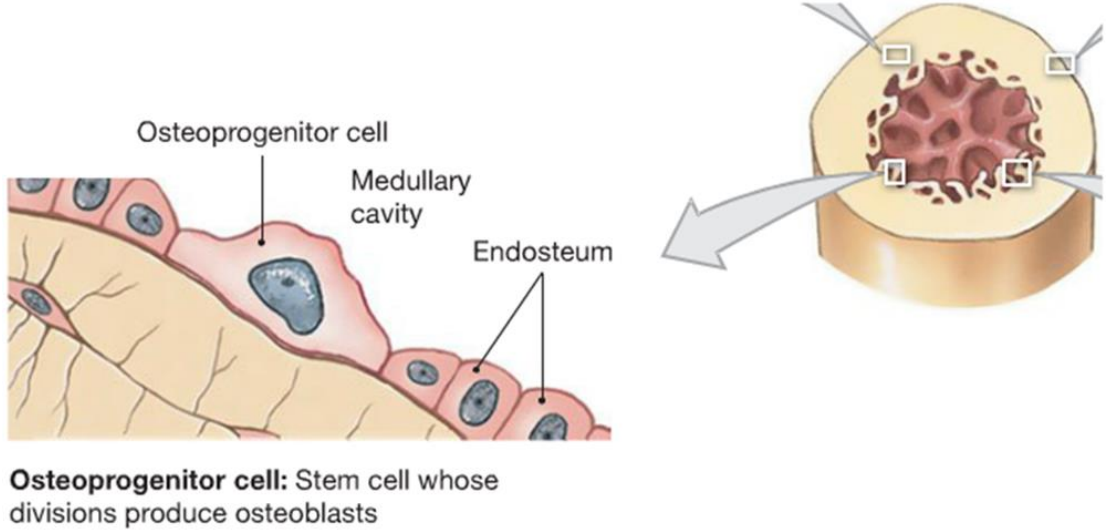
Figure 06.04 Tortora - PAP 12/e

4 cell types

- 4 cell types make up osseous tissue
  -Osteoprogenitor cells
  -Osteoblasts
  -Osteocytes
  -Osteoclasts



Osteoprogenitor cells



Osteoprogenitor cell: Stem cell whose divisions produce osteoblasts

-A mesenchymal stem cell -undergo mitotic division and differentiate into an osteoblast.

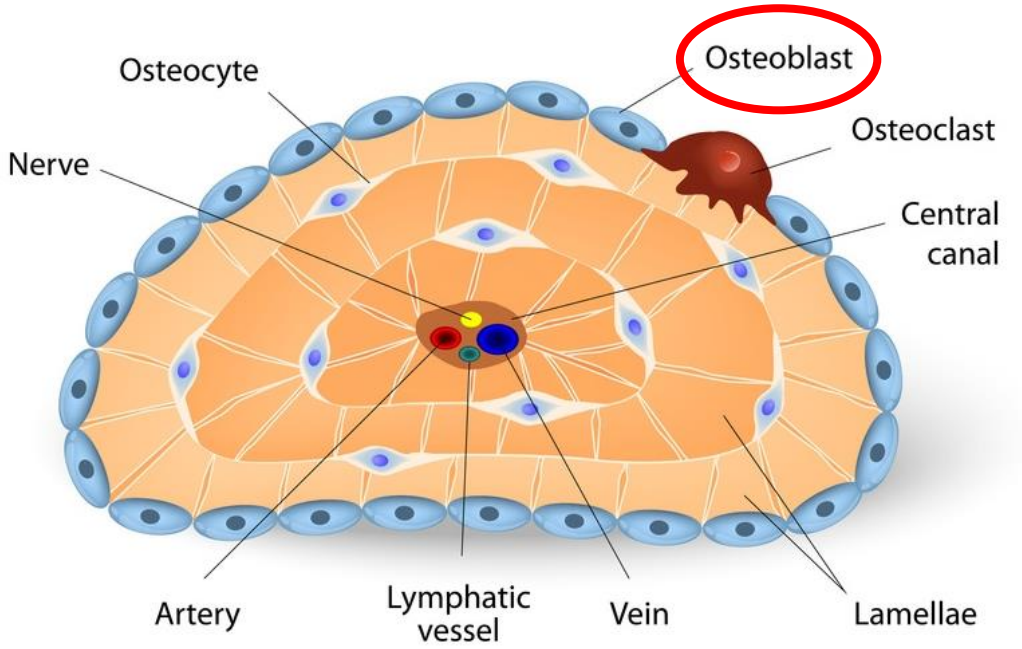
-Located in the inner cellular layer of the periosteum, the endosteum

-Most active during bone growth

-Large numbers are reactivated in adult life in repair of fractures.

-Differentiate into osteoblasts during the continuous process of bone remodeling.

Osteoblasts



- Bone forming cells
- found **exclusively on surface** of bone
- No ability to mitotically divide
- Synthesize & secretors
  - –Organic components of bone matrix
    - Eg : collagen, proteoglycans, glycoproteins etc.
  - –Inorganic components

-When **active** stage - cells are **cuboidal to columnar** shape and **basophilic**

-When **activity reduced-** cells are **flattened** and basophilia reduces.

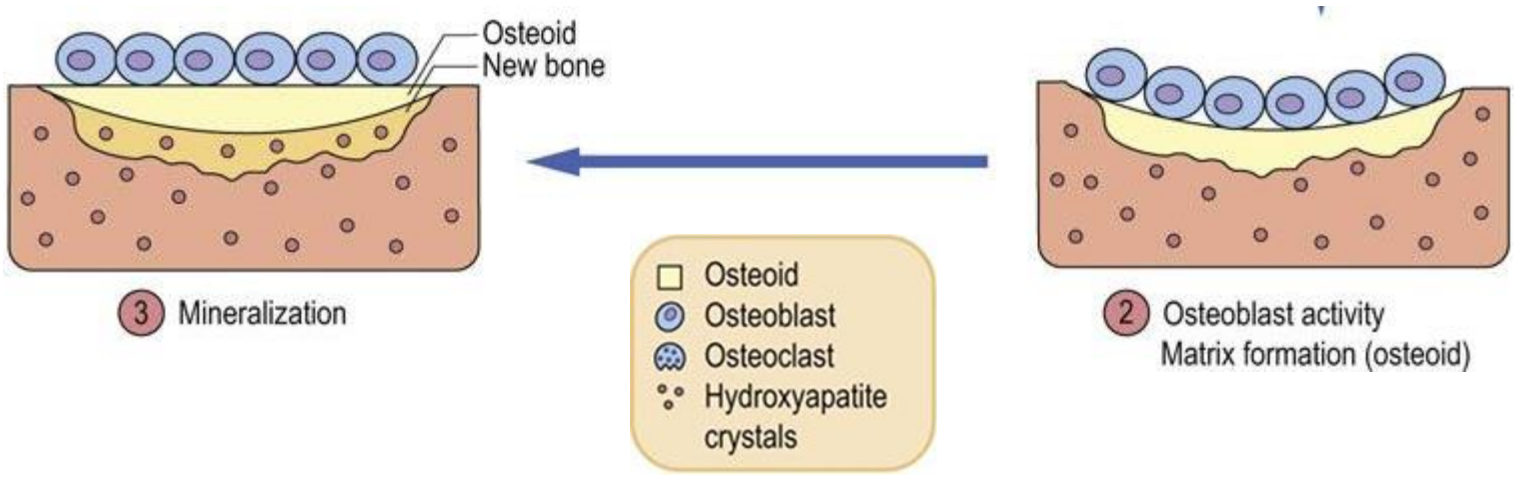
Osteoblasts

-Located on the surface of bone tissue and resemble epithelium(endosteum and periosteum)

-Matrix material are secreted at the cell surface in contract with excising matrix.

-This new unclarified bone called-<u>Osteoid.</u>

-Bone forming process completed when Ca salts deposits in new matrix.



Osteocytes:

-Inactive osteoblasts are surrounded by the material they have secreted.

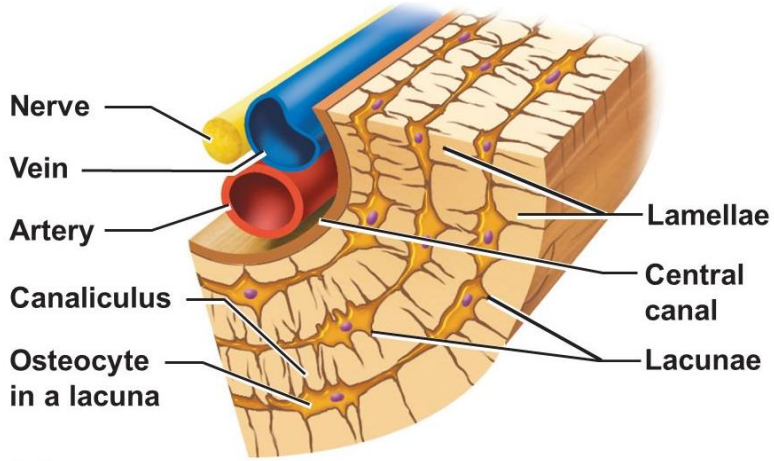
-Further differentiate as <u>osteocytes.</u>

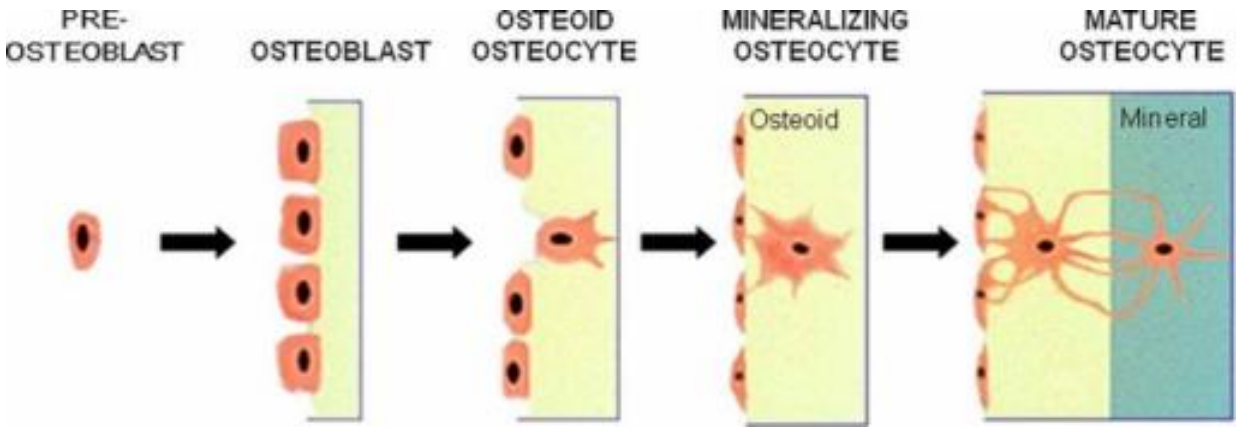
-Trapped within a cavity called <u>lacunae</u>

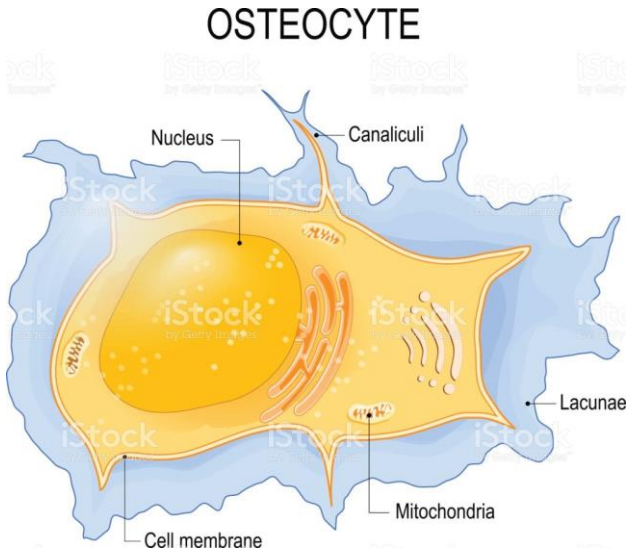
-Osteocytes <u>do not secrete matrix</u> material

-During transition acquire many <u>dendritic</u> processes.

-Exchange of nutrients and waste through extracellular fluid.





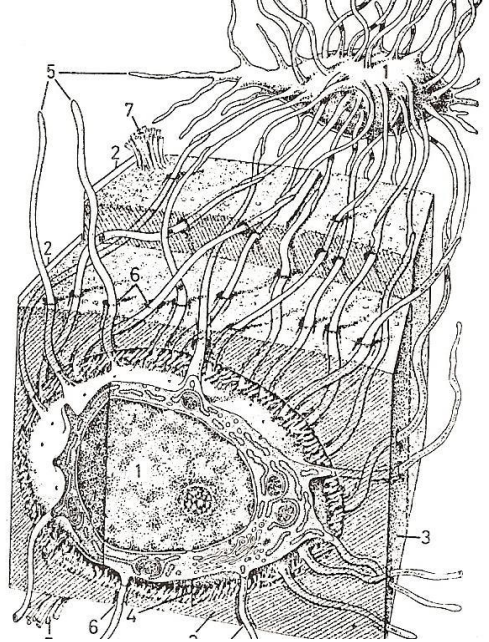


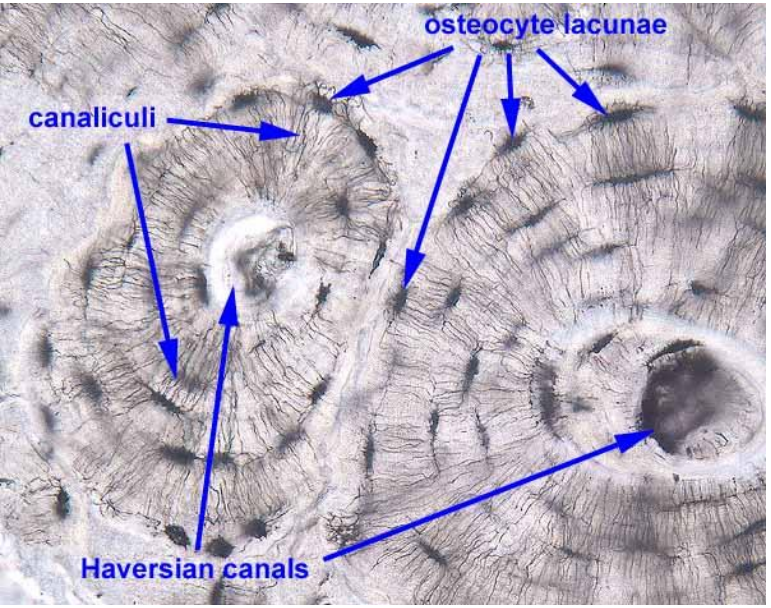
Osteocytes:

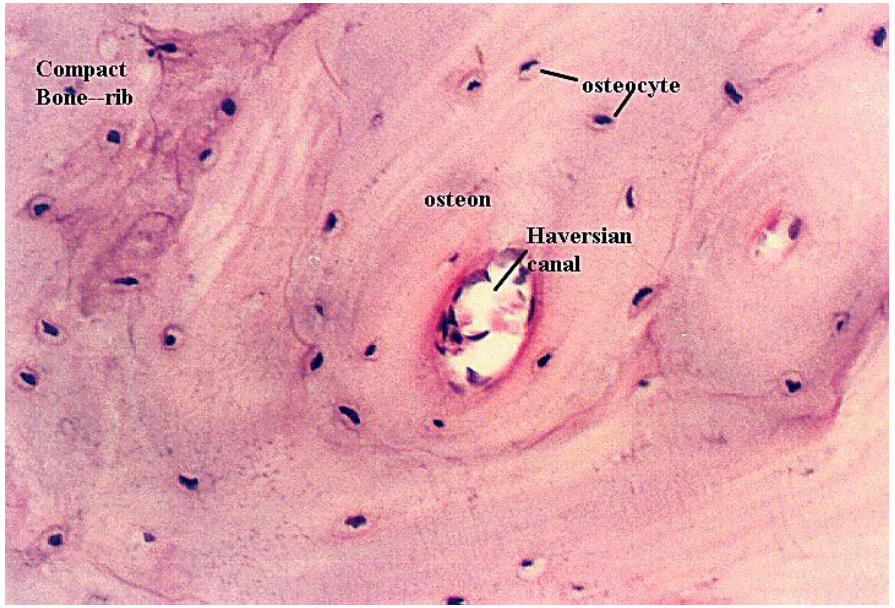
-Communicate one another through dendritic processes.

-Have less RER, smaller Golgi and condensed nuclear chromatin.

-Dead osteocytes- resorb in to the matrix







Source: Mescher AL: *Junqueira's Basic Histology: Text and Atlas, 12th Edition:* http://www.accessmedicine.com

Osteoclasts

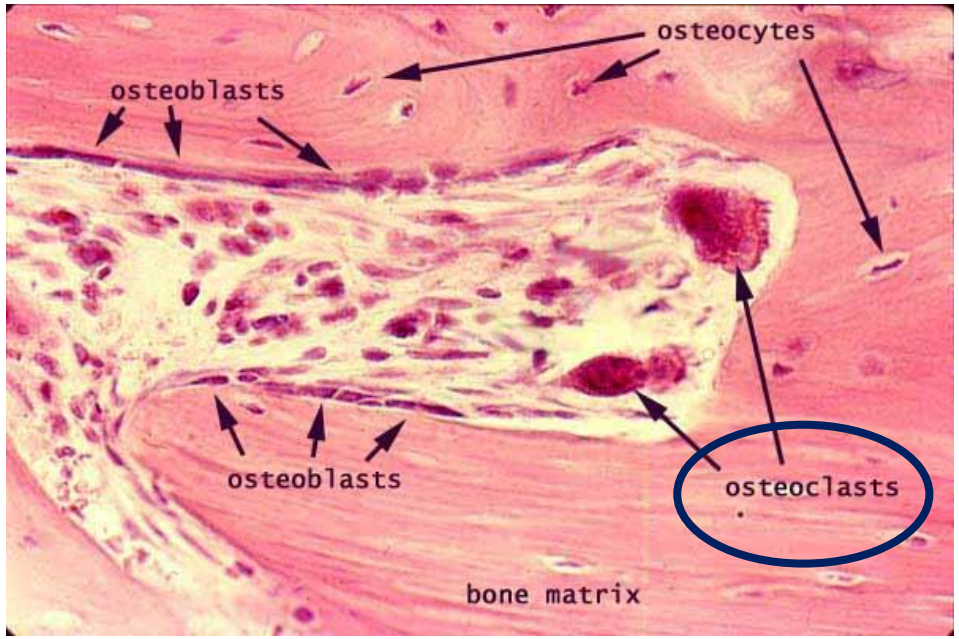
-Derived from blood monocytes

-Bone resorbing cells

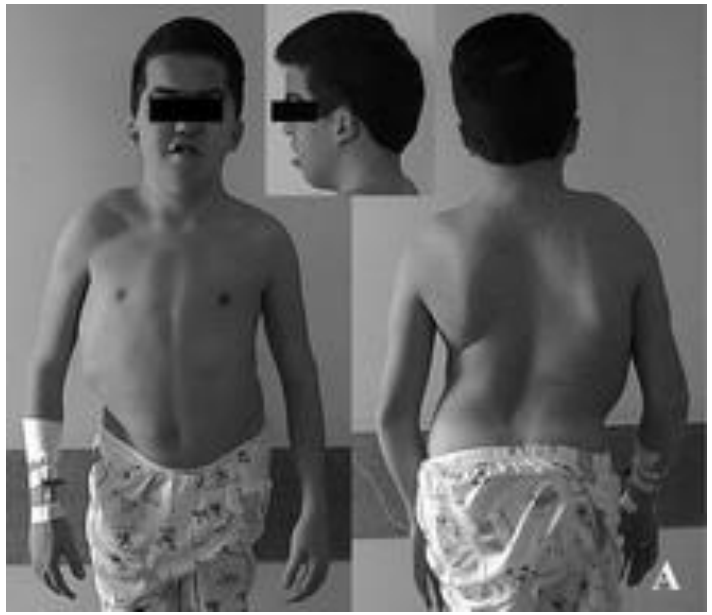
-Lies in bone surface

-Very large, motile cells with multiple nuclei

-Main function : Matrix resorption during bone growth and remodeling.

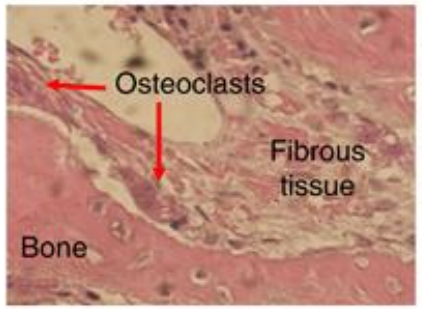


Osteopetrosis (Marble bone disease)

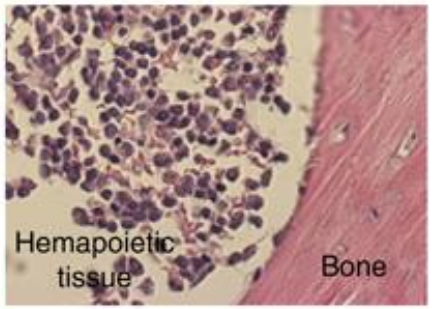


Ostepetrosis

- Defect in osteoclastic activity
- Bone resorption is poor
- Excessive deposition of bone matrix
- Marrow cavity get narrowed ➡ Less bone marrow ➡ Anemia



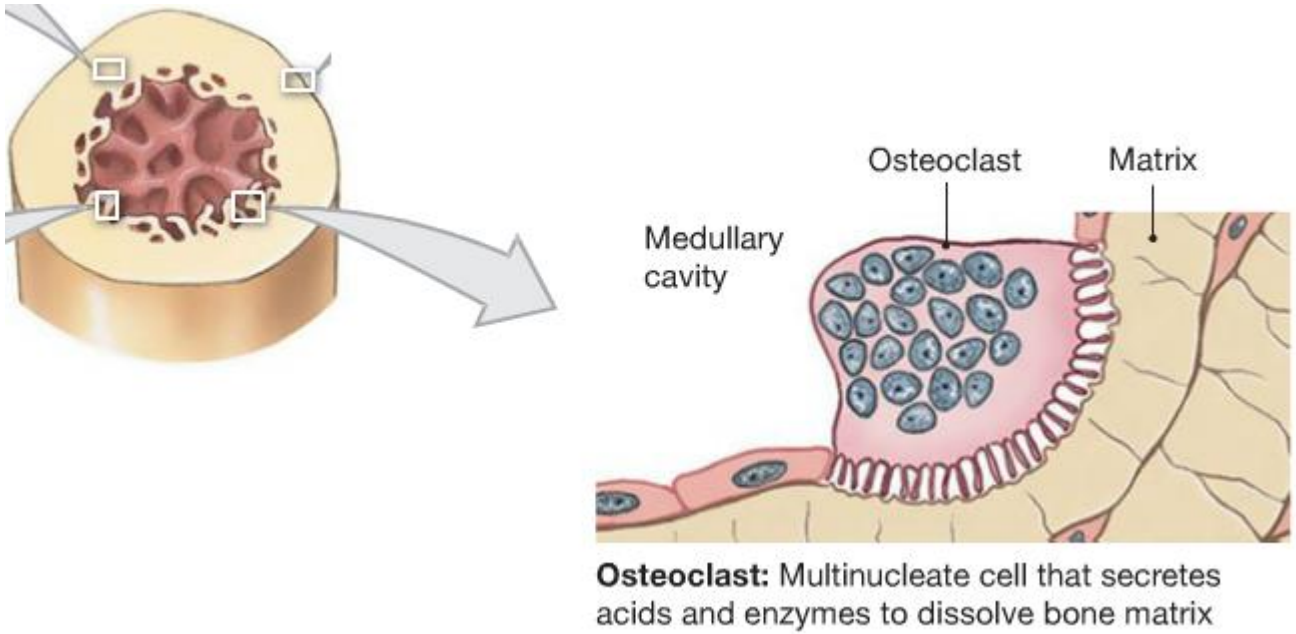
Osteoclast-rich



Osteoclast-poor

What is bone matrix ?

- Bone is specialized connective tissue
- Composed of calcified extracellular material –called bone matrix
- Compact bone consists almost entirely of extracellular substance
- Osteoblasts deposit the matrix in the form of thin sheets which are called *lamellae*



Osteoclast: Multinucleate cell that secretes acids and enzymes to dissolve bone matrix

Type of bones

A -Primary bone(immature bone, woven bone)

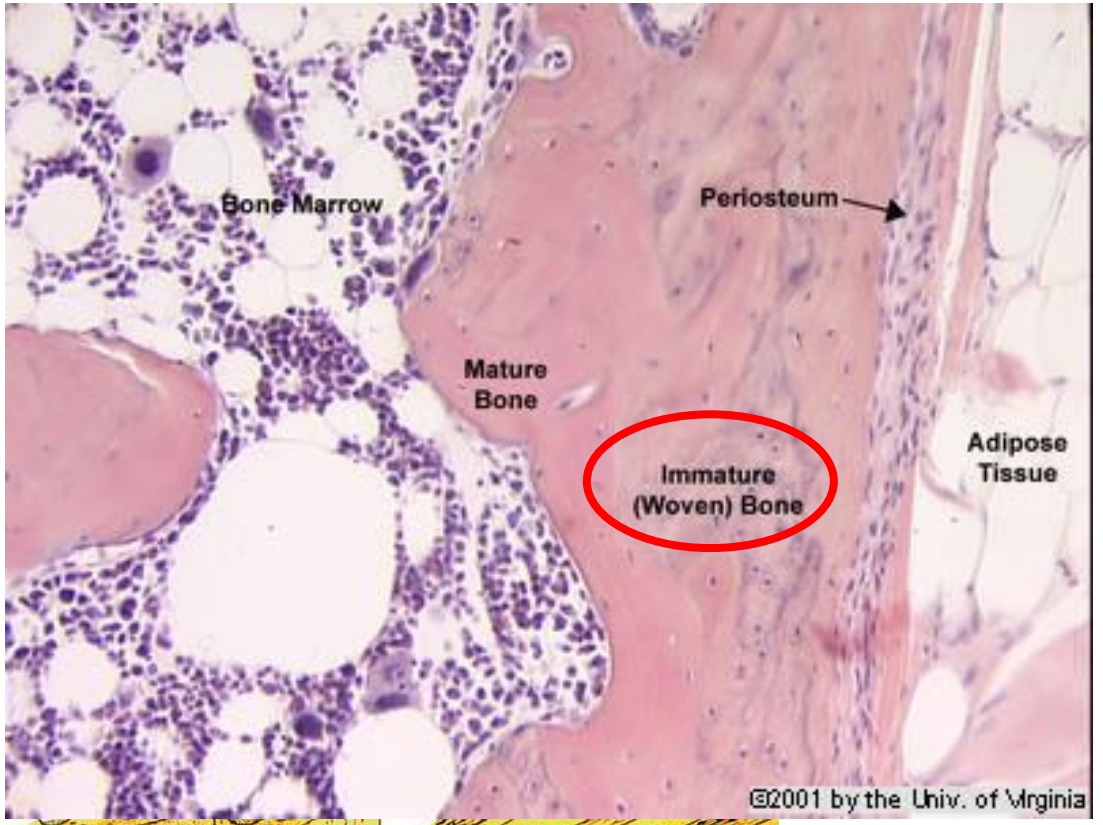
B-Secondary bone (mature bone, lamellar bone)

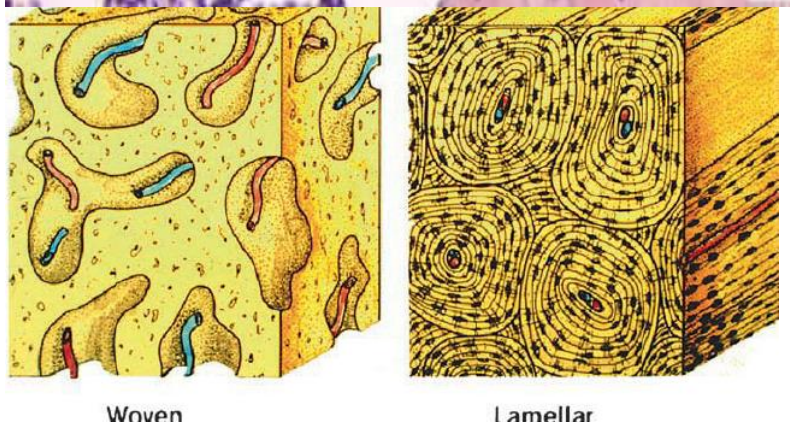
I.Compact bone

II.Spongy bone

Primary bone(immature bone, woven bone)

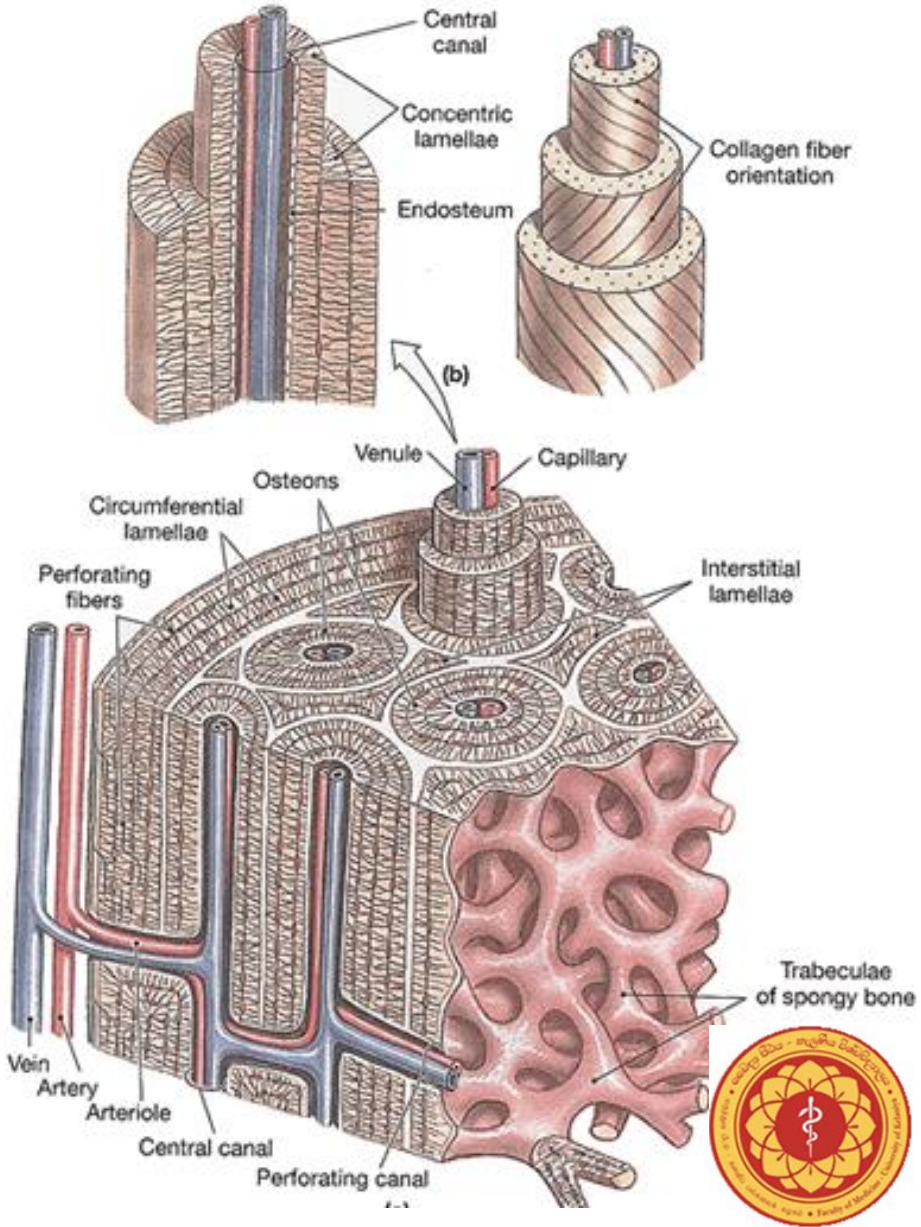
- First type of bone formed during fetal development, fracture repair, and tissue turnover.
- Characteristics –
  - Abundant osteocytes
  - A low mineral content (Therefore more easily penetrated by X Rays)
  - An irregular array of collagen fibers.
- It is temporary and is replaced by secondary bone tissue.





Secondary bone (mature bone, lamellar bone)

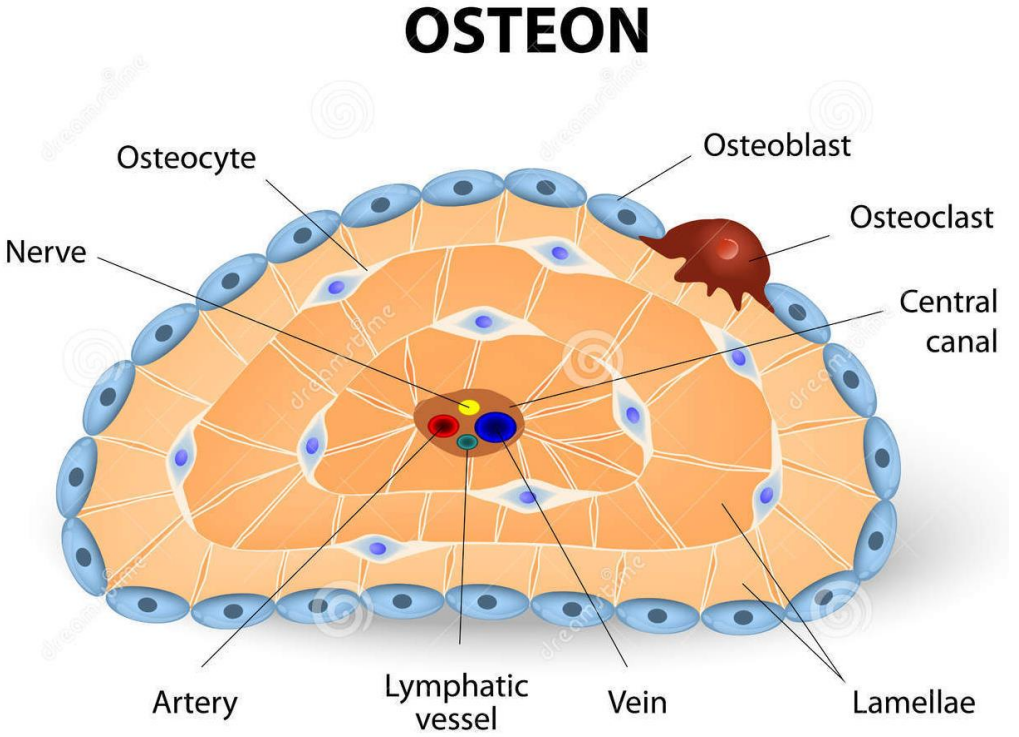
- Characteristically contains <u>collagen</u> fibers <u>arranged in lamellae</u>
- <u>Parallel</u> to each other or <u>concentrically</u> organized around a vascular channel.

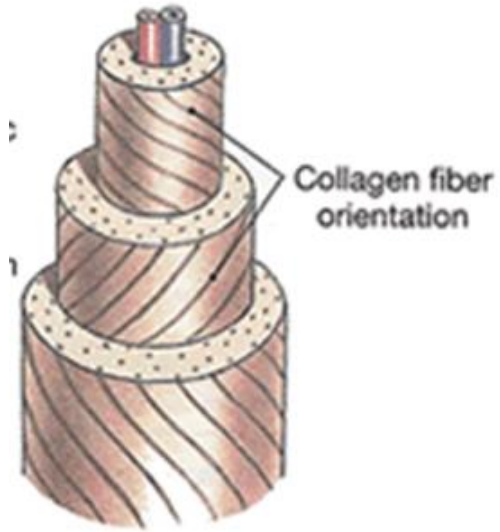


Compact bone

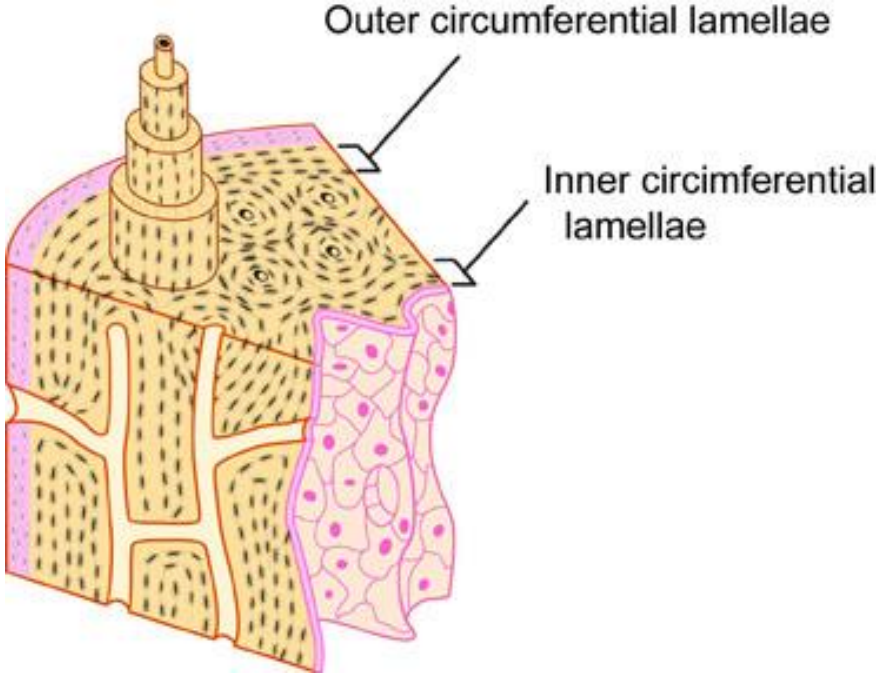
- Lamellae are arranged into <u>osteons</u> (Haversion systems) around a <u>haversion canal</u>

  (osteon basic unit of compact bone)
- Collagen fibers are parallel to each other within a lamella, but collagen fibers in adjacent lamellae lie perpendicular to one another providing the bone with great strength.
- Lacunae containing osteocytes- are found between the lamellae.
- **Haversian canal** generally contains one or two capillaries , nerve fibers and lymphatic channels





Organization of lamellae

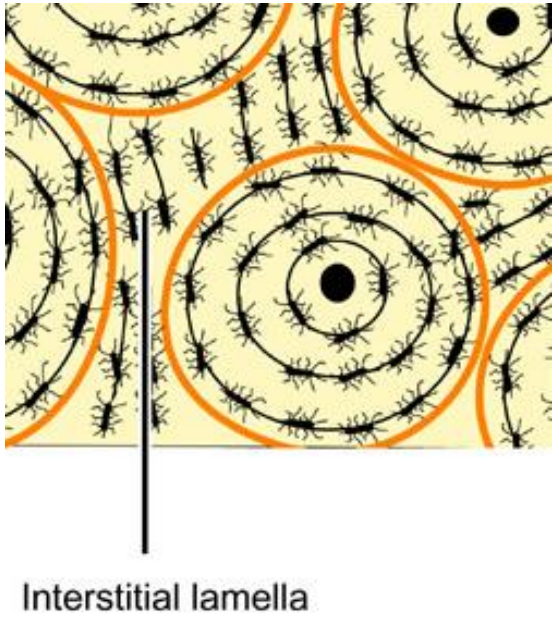


Outer circumferential lamellae:

-Lamellae that are deep to the periosteum and form the outermost region of the diaphysis.

Inner circumferential lamellae:

-Lamellae that completely encircle the marrow cavity

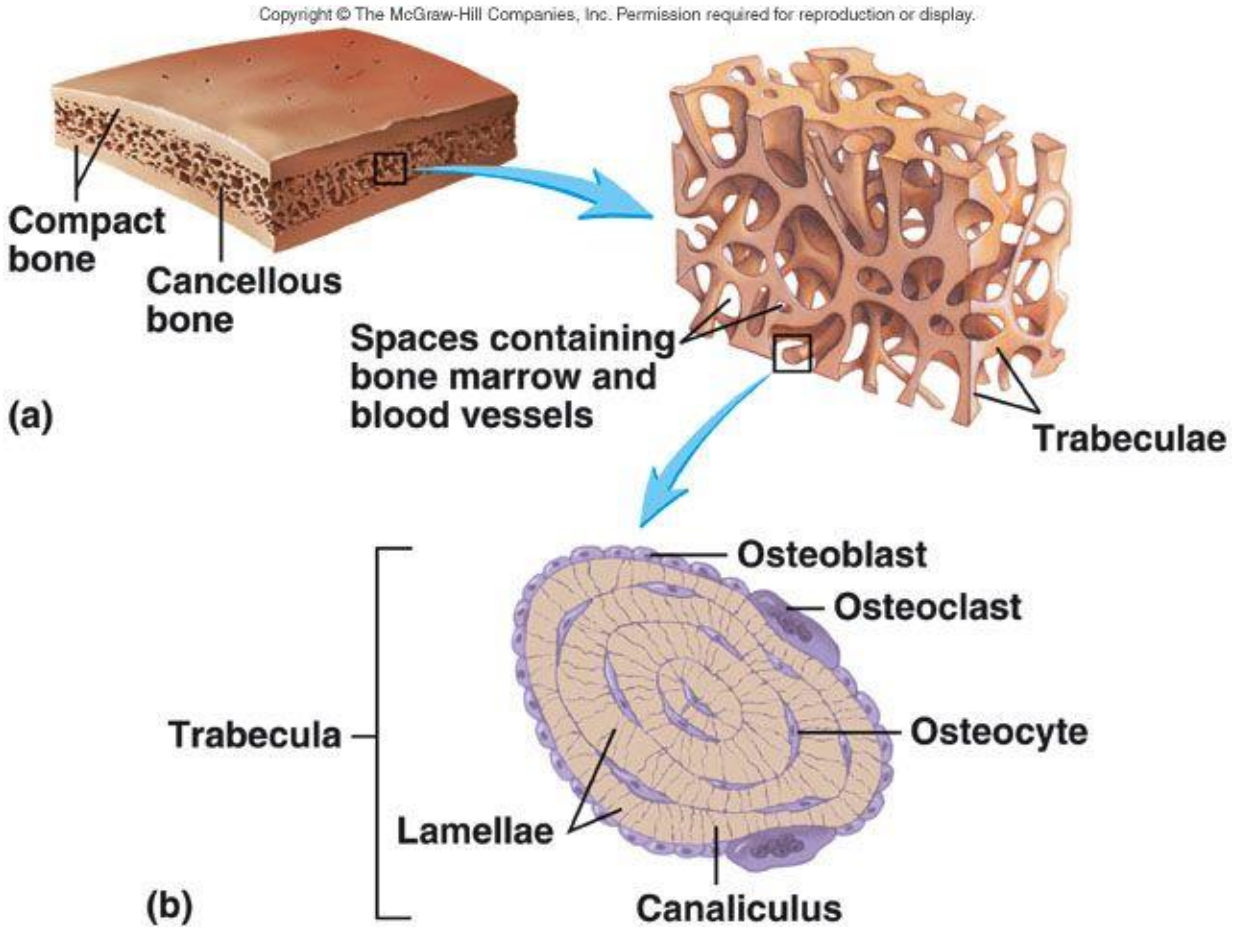


Interstitial lamellae:

Triangular or irregularly shaped groups of parallel lamellae leftover by osteons destroyed during growth and remodeling.

Spongy bone (cancellous bone or trabecular bone)

- Branching bone trabeculae project out from the internal surface of compact bone into the marrow cavity.
- Spongy bone typically does not contain osteons.
- Trabeculae are only a few cell layers thick and contain irregularly arranged lamellae.
- The lamellae contain lacunae housing osteocytes, which are nourished by diffusion of nutrients that travel through canaliculi from the marrow cavity.



Osteogenesis

-The process of bone formation is called **ossification**

-Bone formation occurs in four situations:

1) Formation of bone in an embryo
2) Growth of bones until adulthood
3) Remodeling of bone
4) Repair of fractures

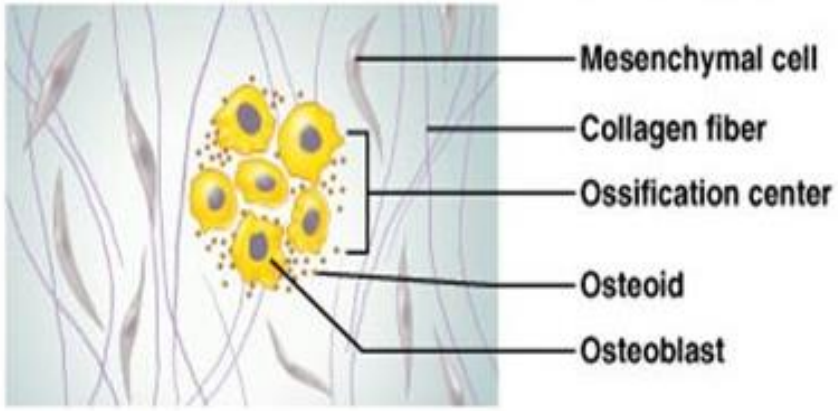
Formation of Bone in an Embryo

- Cartilage formation and ossification start during the 6th week of embryonic development
- Two patterns
    - **Intramembranous ossification**
    - **Endochondral ossification**
- In both processes the developing bone tissue - is woven bone (primary or immature bone).

Intramembranous ossification

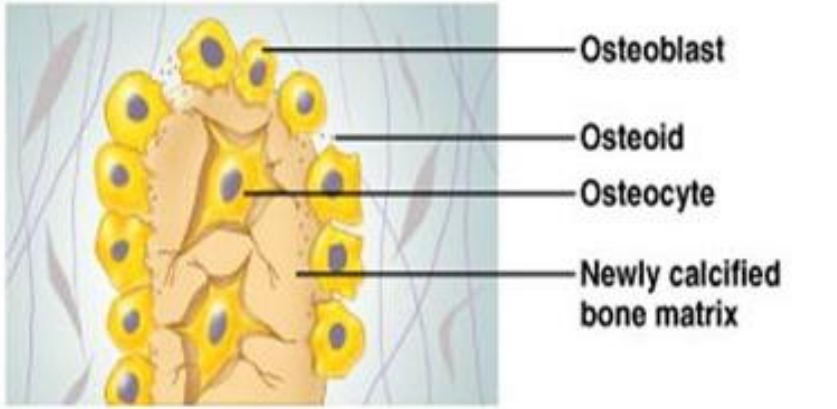
- Flat bones of the skull and mandible are formed in this way
- Takes place in highly vascularized mesenchymal tissues.
- Mesenchymal cells in connective tissue differentiate to osteoblast
- Osteoblasts secrete bone matrix -quickly followed by calcification
- Region of initial osteogenesis termed - primary ossification center
- Some trapped osteoblast within matrix termed- osteocytes
- Islands of developing bone are formed; these are termed spicules

Intramembranous ossification



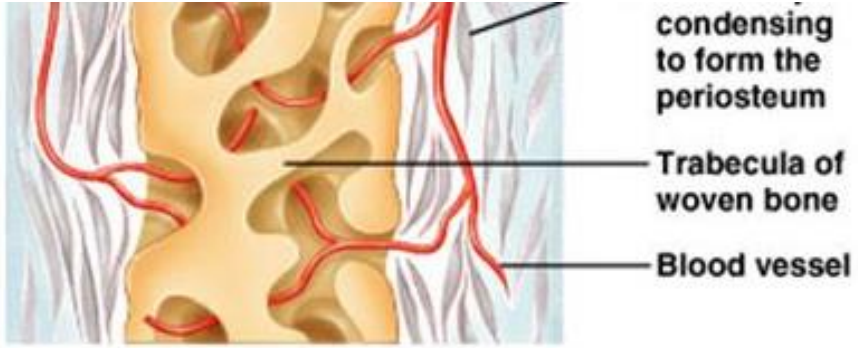
① **An ossification center appears in the fibrous connective tissue membrane.**

- Selected centrally located mesenchymal cells cluster and differentiate into osteoblasts, forming an ossification center.



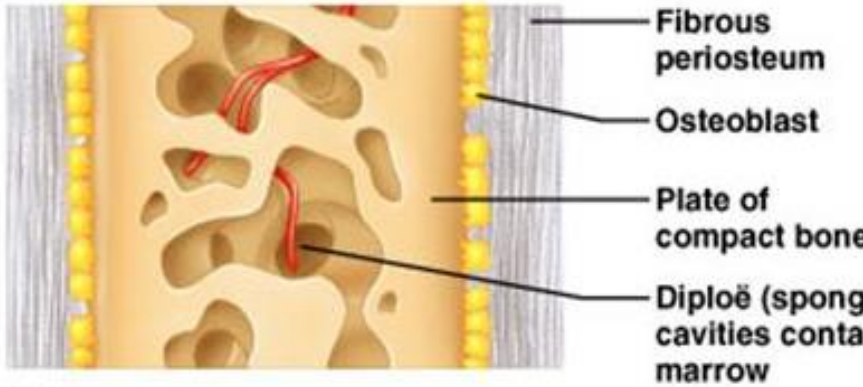
② **Bone matrix (osteoid) is secreted within the fibrous membrane.**

- Osteoblasts begin to secrete osteoid, which is mineralized within a few days.
- Trapped osteoblasts become osteocytes.



③ **Woven bone and periosteum form.**

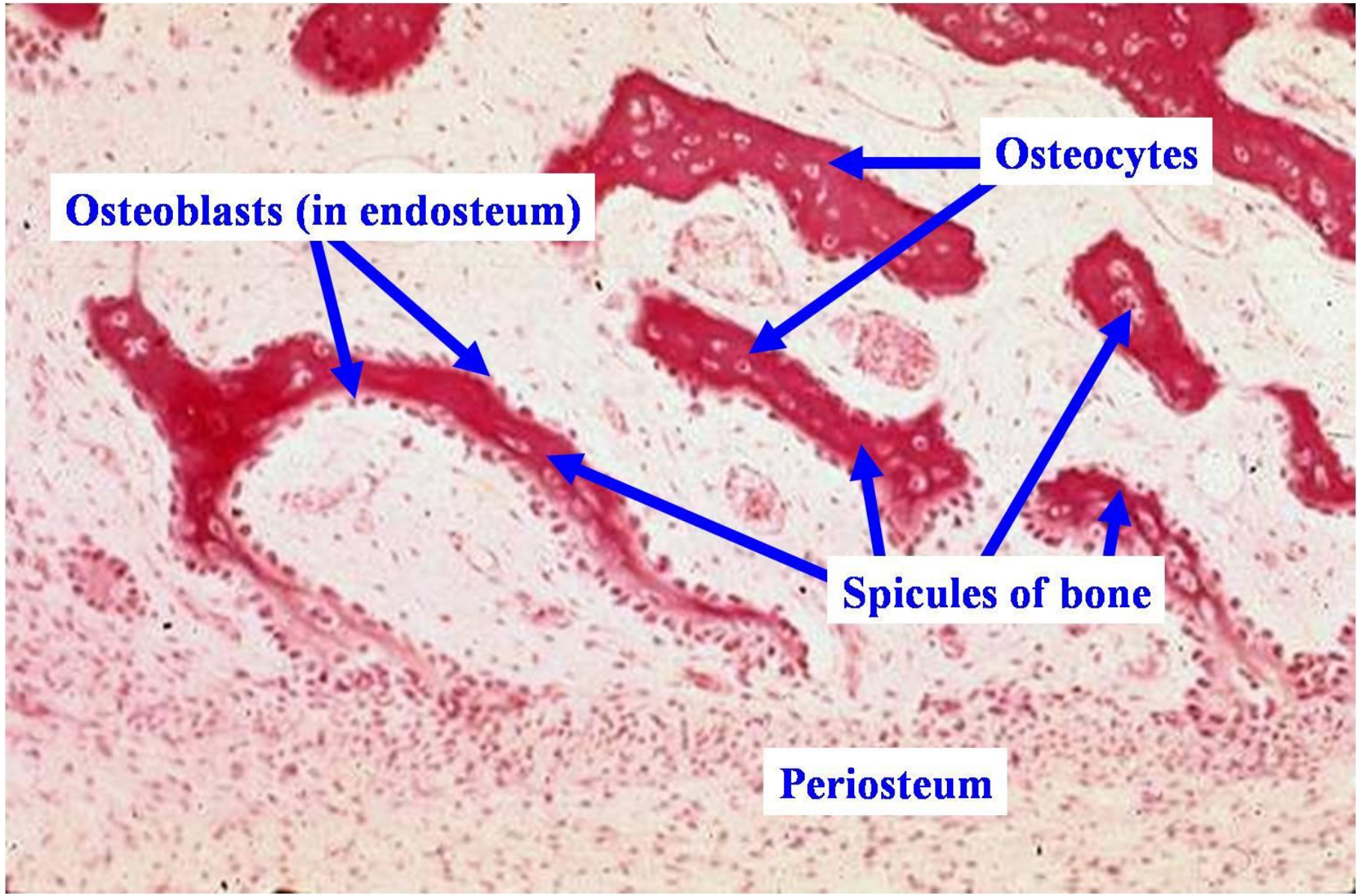
- Accumulating osteoid is laid down between embryonic blood vessels, which form a random network. The result is a network (instead of lamellae) of trabeculae.
- Vascularized mesenchyme condenses on the external face of the woven bone and becomes the periosteum.



④ **Bone collar of compact bone forms and red marrow appears.**

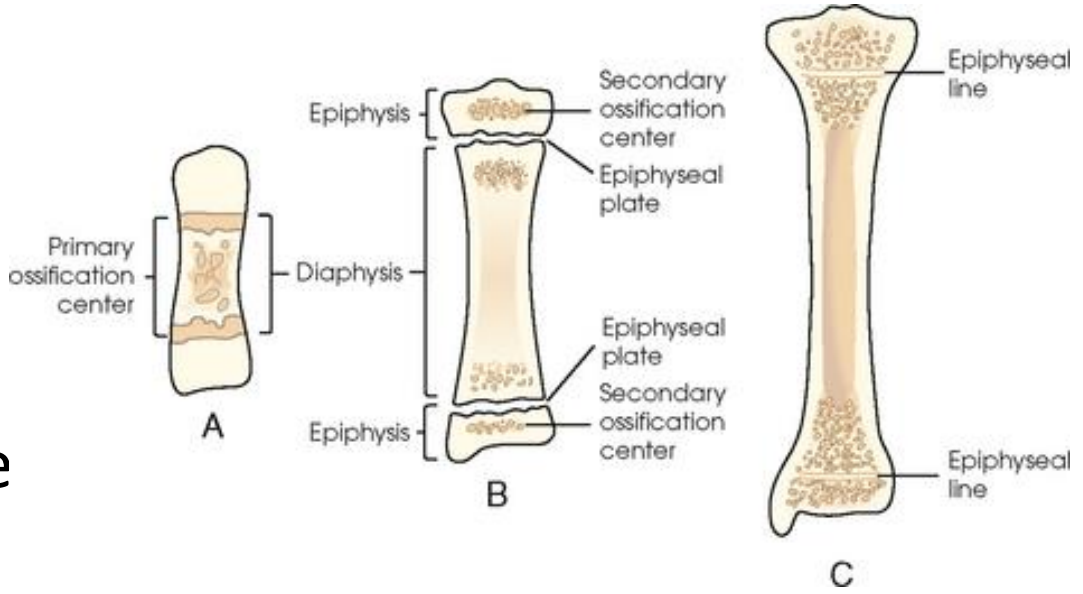
- Trabeculae just deep to the periosteum thicken, forming a woven bone collar that is later replaced with mature lamellar bone.
- Spongy bone (diploë), consisting of distinct trabeculae, persists internally and its vascular tissue becomes red marrow.

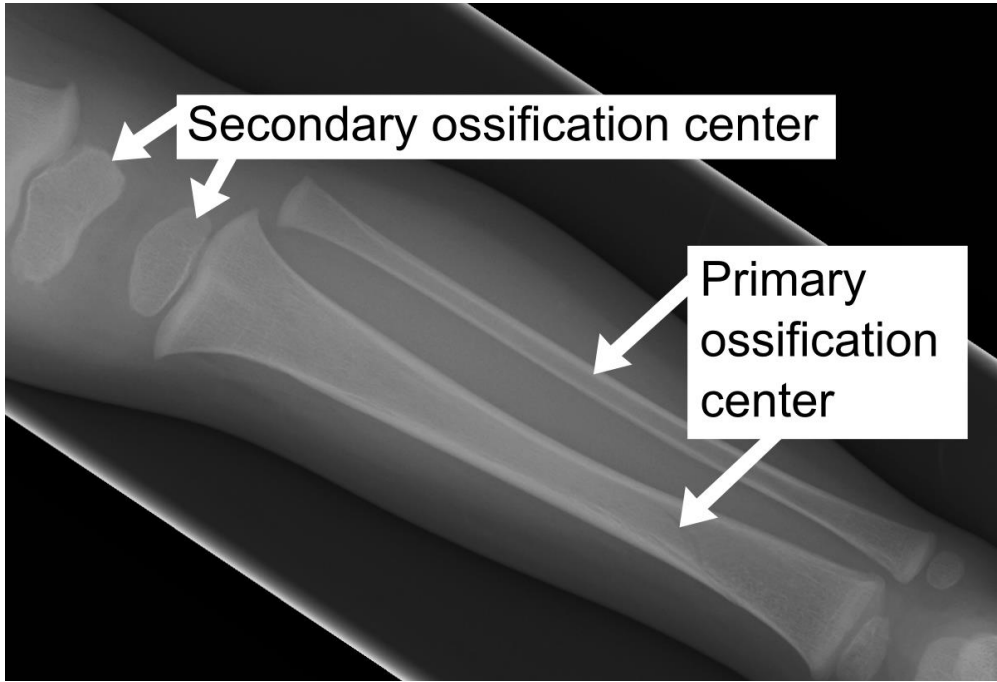
Intramembranous ossification



Endochondral ossification

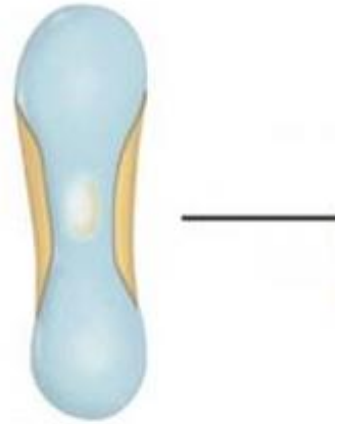
- Responsible for the formation of short and long bones
- The replacement of cartilage by bone
- This cartilage resembles small version of bone to be formed
- Preexisting hyaline cartilage is invaded by osteoblasts
- Primary ossification occurs at diaphysis during fetal life (first trimester)
- Secondary ossification start in same manner but at epiphysis, but without bone collar





Endochondral ossification

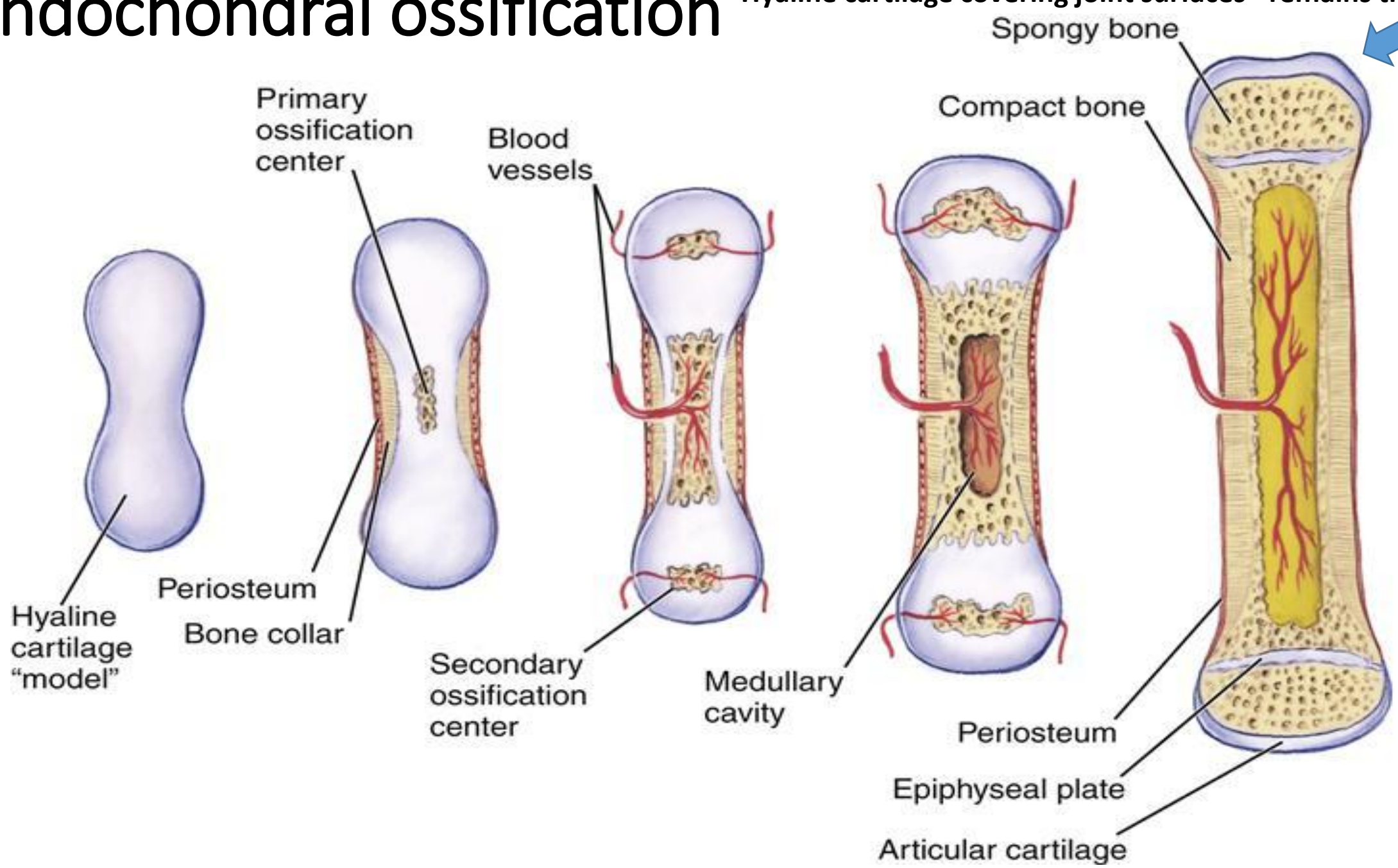
- Perichondrium of shaft (diaphysis) becomes vascularized and develops osteogenic potential
- Osteogenic cells become osteoblasts that secrete bone
- Forms a bone collar.
- Perichondrium is now called periosteum.
- Periosteum prevents diffusion of nutrients to the chondrocytes .
- Chondrocytes die - forms a central cavity in the cartilage
- Osteoclasts form holes in the bone collar
- Allow osteogenic bud (composed of osteoprogenitor cells, hematopoeitic cells, and blood vessels) to enter in to the cartilage
- Osteoprogenitor cells ➡ Osteoblasts ➡ Continuous secretion of osteoid



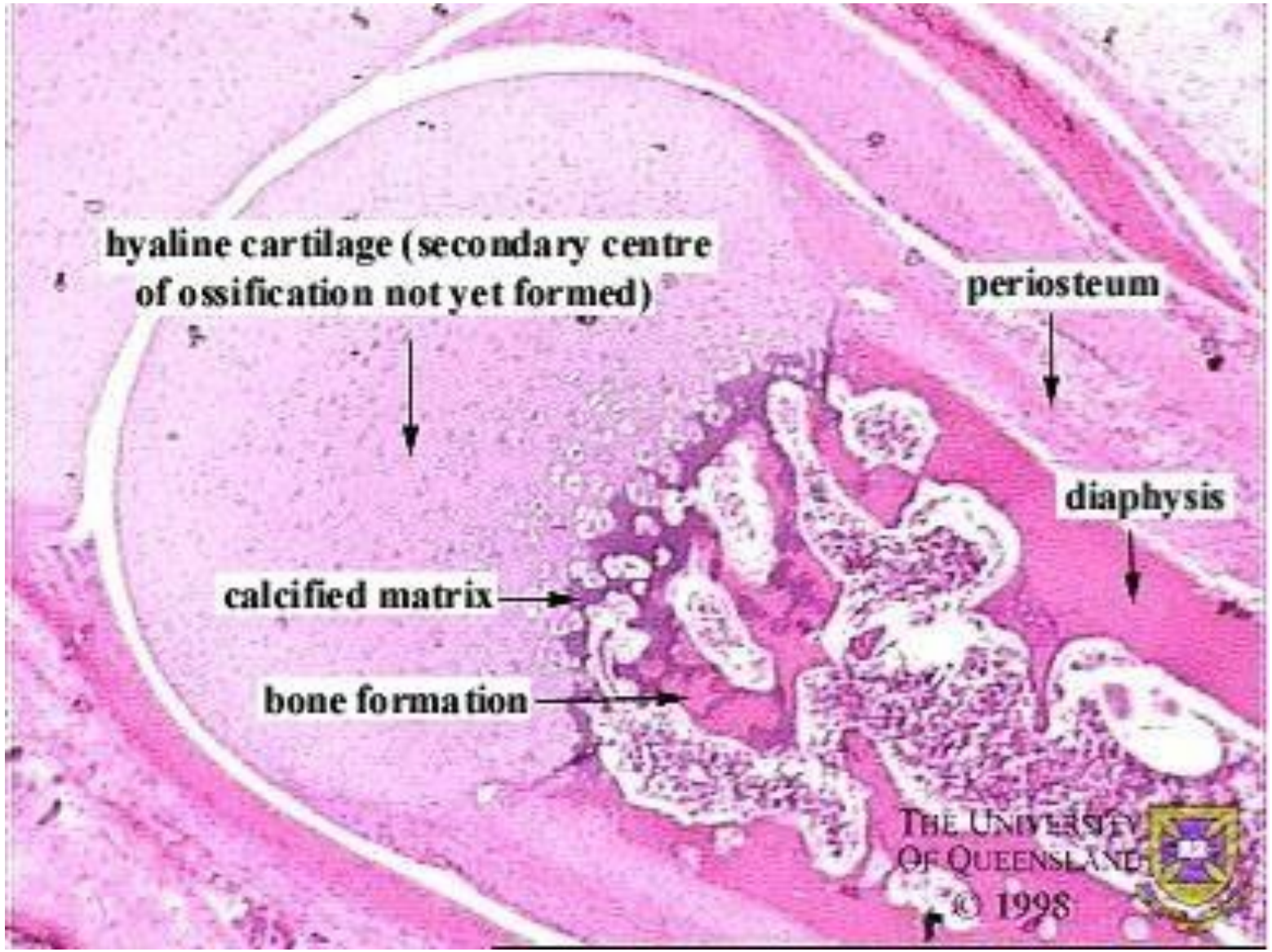
① Formation of bone collar around hyaline cartilage model.

Endochondral ossification

Hyaline cartilage covering joint surfaces - remains throughout life.



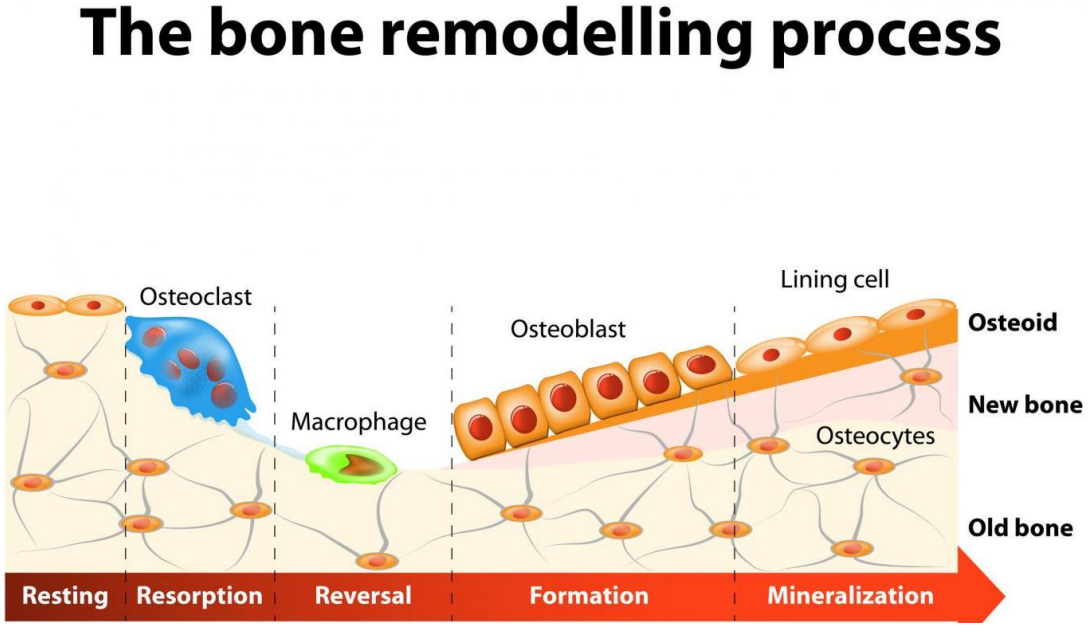
Endochondral ossification



Bone remodeling

Bone continually renews itself

- Bone is always metabolically active
  -Sum of osteoblastic and osteoclastic activity leads to bone growth
- Osteoclasts are responsible for matrix destruction
- Osteoclasts produce lysosomal enzymes and acids
- Spongy bone replaced every 3-4 years
- Compact bone every 10 years



Bone remodeling-Fracture healing

-Blood clot will form around break (fracture hematoma)

-Inflammatory process begins in clot

-Blood capillaries grow into clot

-Phagocytes and osteoclasts remove damaged tissue

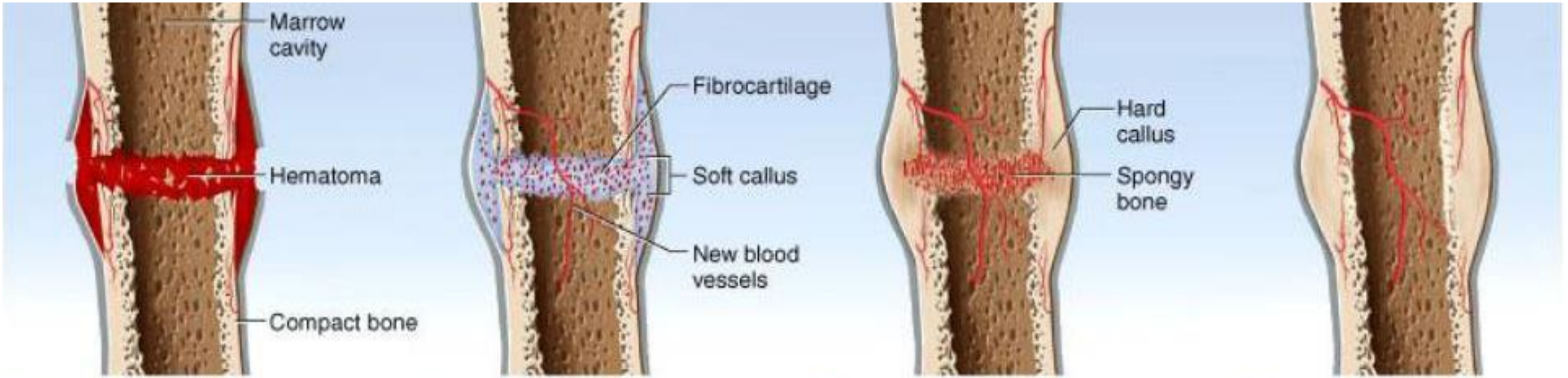
Procallus forms

Invaded by osteoprogenitor cells and fibroblasts

Secrete collagen and fibrocartilage

Turns Procallus to fibrocartilaginous (soft) callus

Bone remodeling-Fracture healing



1. **Hematoma formation**
The hematoma is converted to granulation tissue by invasion of cells and blood capillaries.

2. **Soft callus formation**
Deposition of collagen and fibrocartilage converts granulation tissue to a soft callus

3. **Hard callus formation**
Osteoblasts deposit a temporary bony collar around the fracture to unite the broken pieces while ossification occurs

4. **Bone remodeling**
Small bone fragments are removed by osteoclasts, while osteoblasts deposit spongy bone and then convert it to compact bone

Bone remodeling-Fracture healing

- Broken ends of bone are bridged by callus

↓

- Osteoprogenitor cells are replaced by osteoblasts and form spongy bone

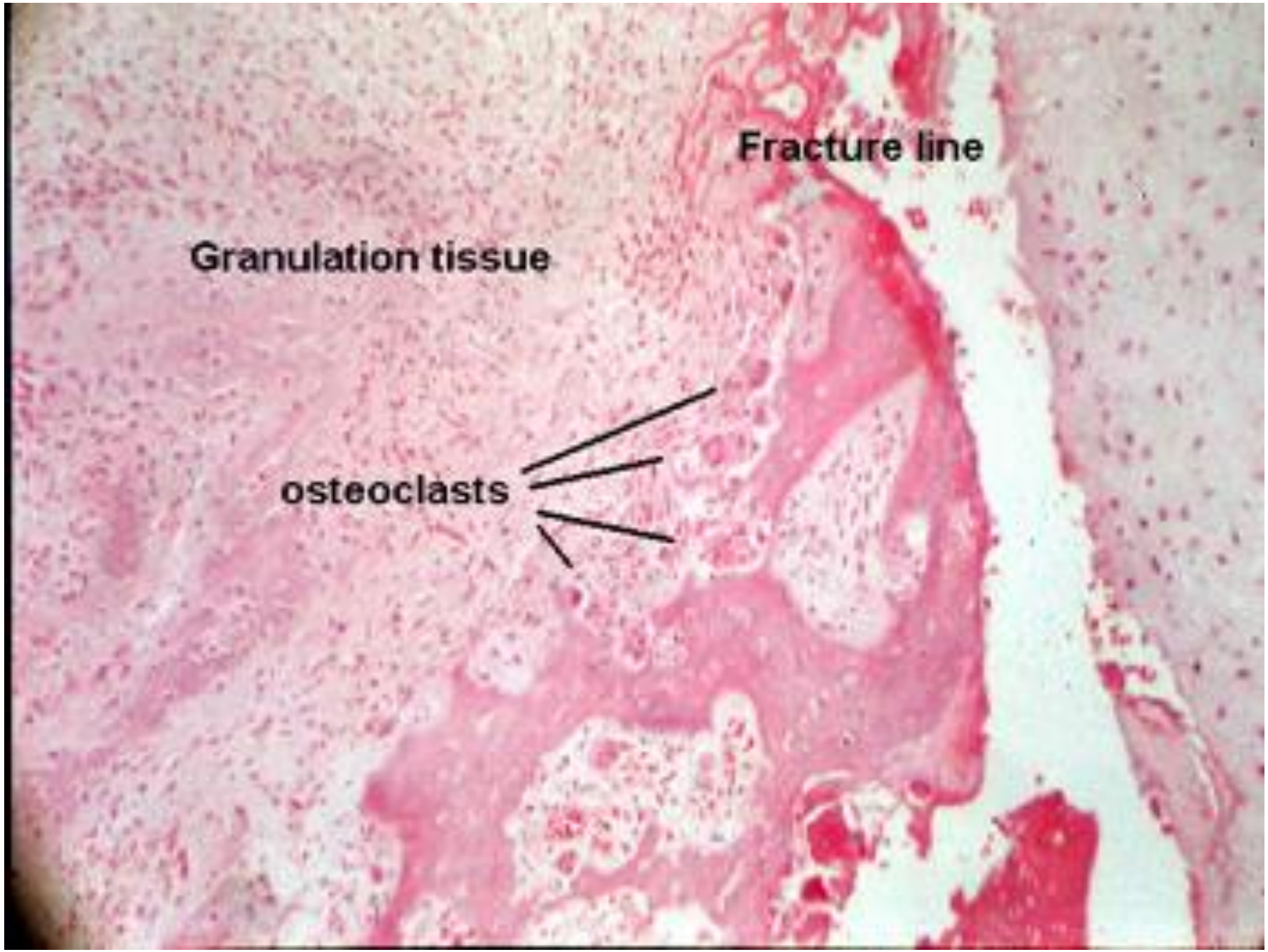
↓

Bony (hard) callus is formed

↓

Callus is resorbed by osteoclasts and spongy bone → compact bone

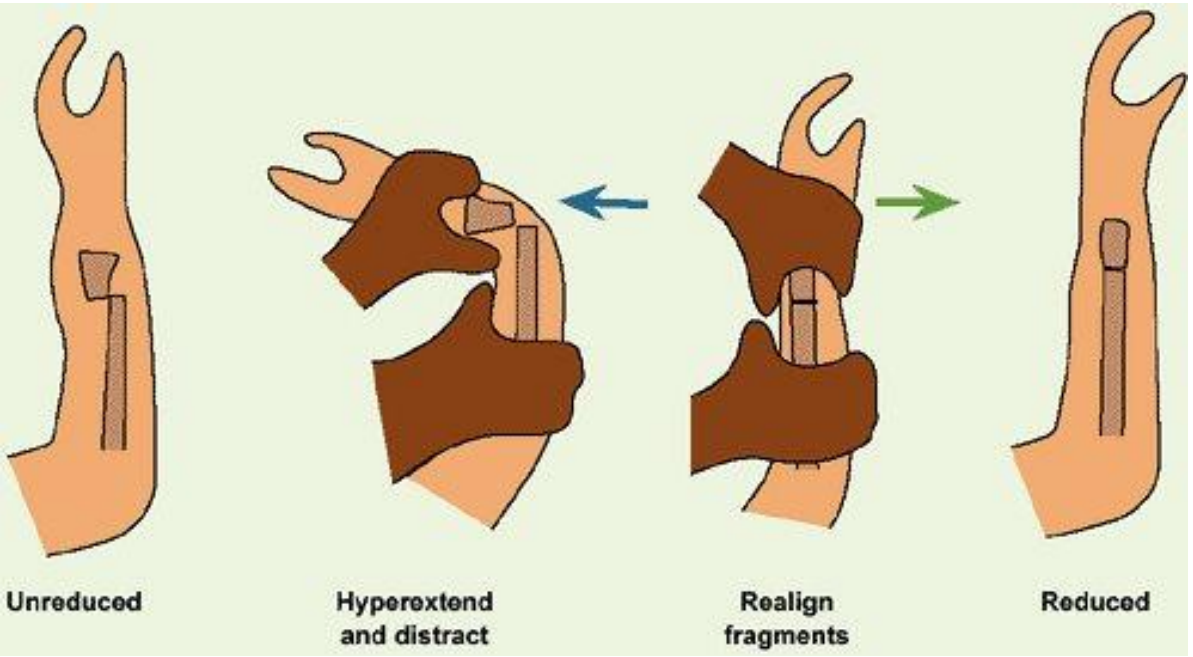
Remodeling : the shaft is reconstructed to resemble original unbroken bone.


Fracture line
Granulation tissue
osteoclasts

Bone remodeling-Fracture healing

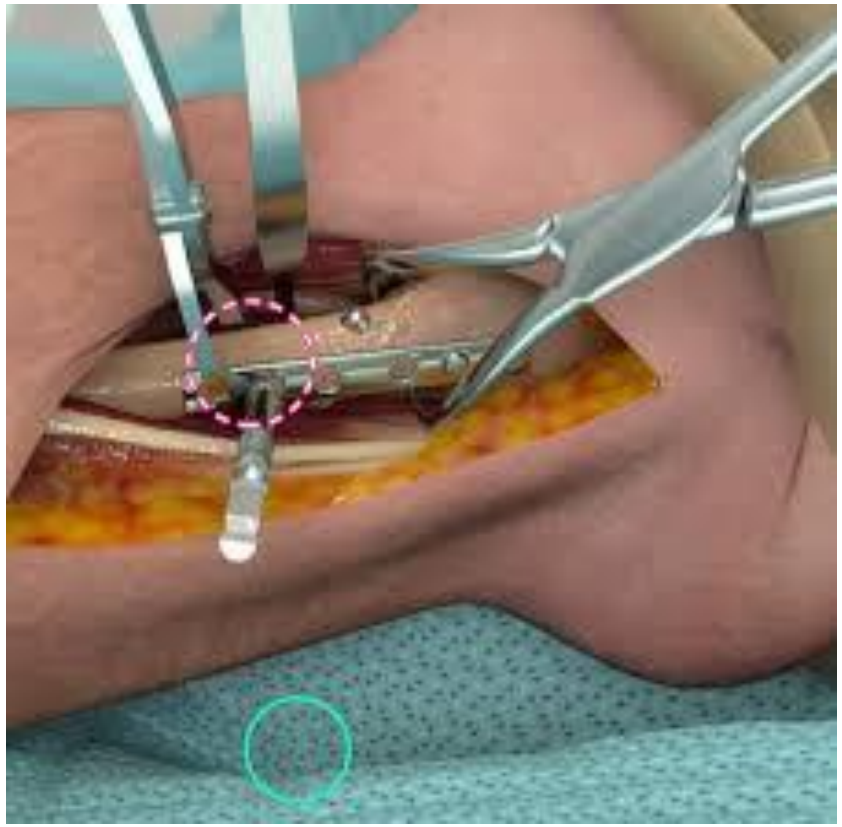
Surgical interventions to facilitate bone healing

Closed reduction - Manipulation of the bone fragment without surgical exposure of the fragments.



Surgical interventions to facilitate bone healing

Open reduction - Fracture fragments are exposed surgically and bone ends secured together with pins or wires

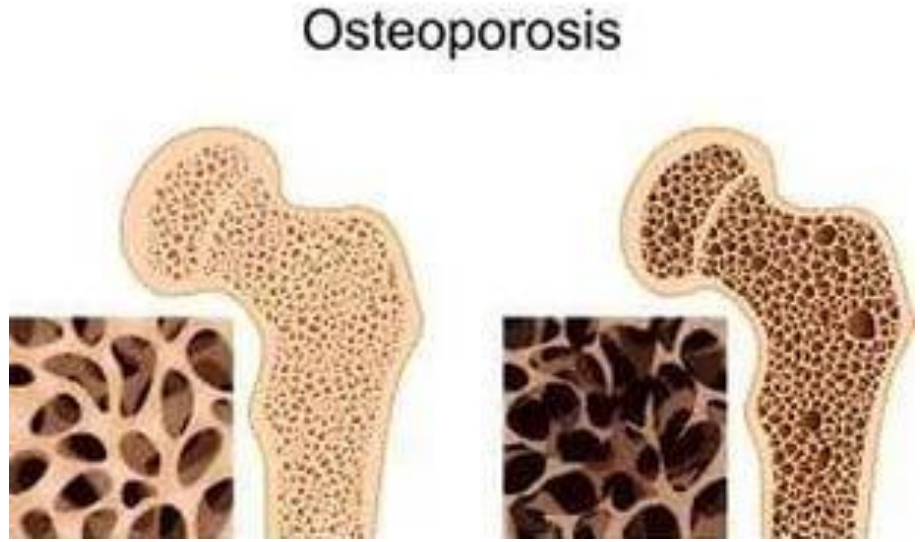


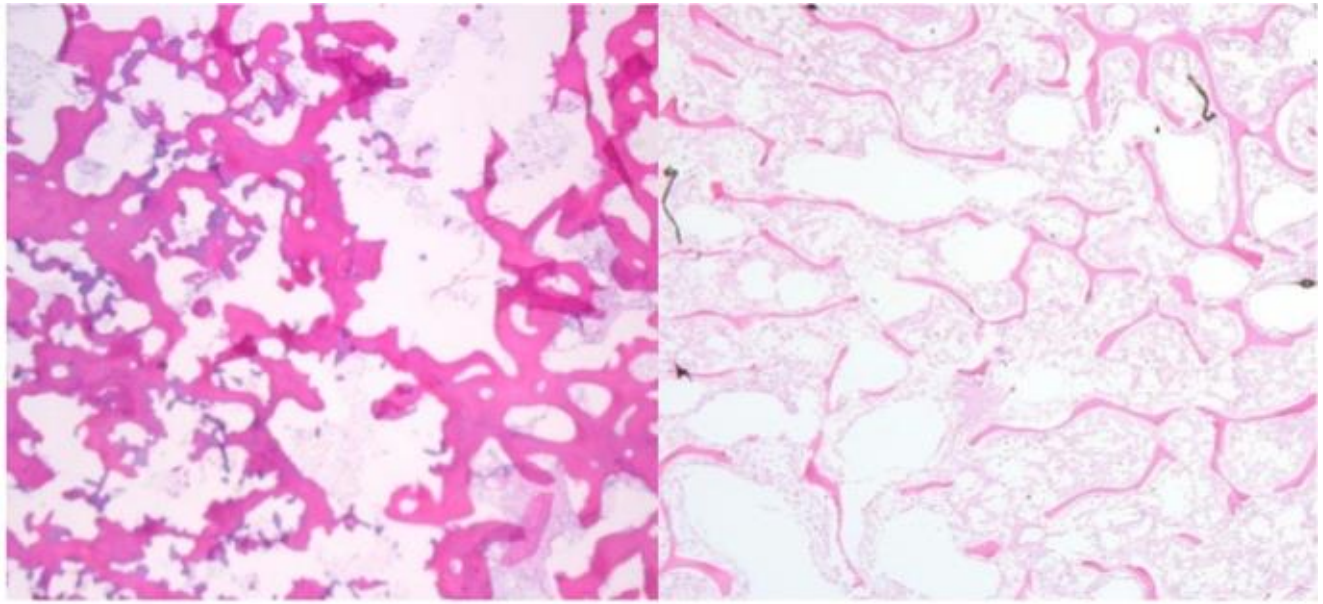
Osteoporosis

Loss of both bone salts and collagen fibers.

Increased osteoclast activity

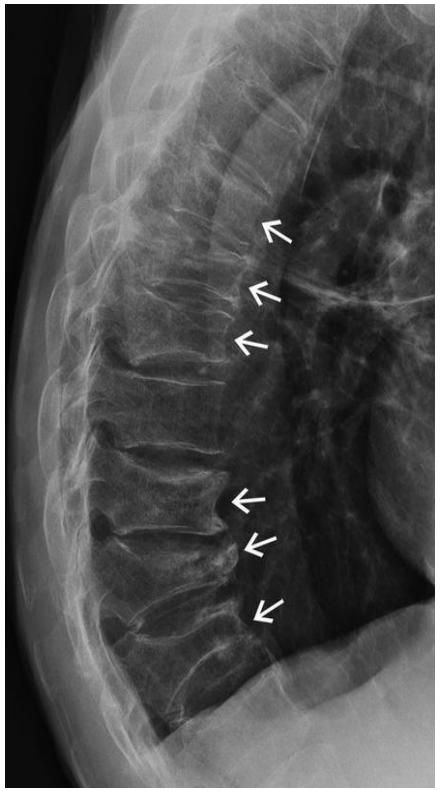
decreased osteoblast activity





Normal Medullary bone (trabecular/ cancellous bone)

Osteopenia- thin trabeculae, reduced bone mass



Thank you !!