



BONE TISSUE

# Components

## Bone matrix

### Organic

- Collagen++
- Proteoglycans
- Glycoproteins

### Inorganic

- Calcium hydroxyapatite +++

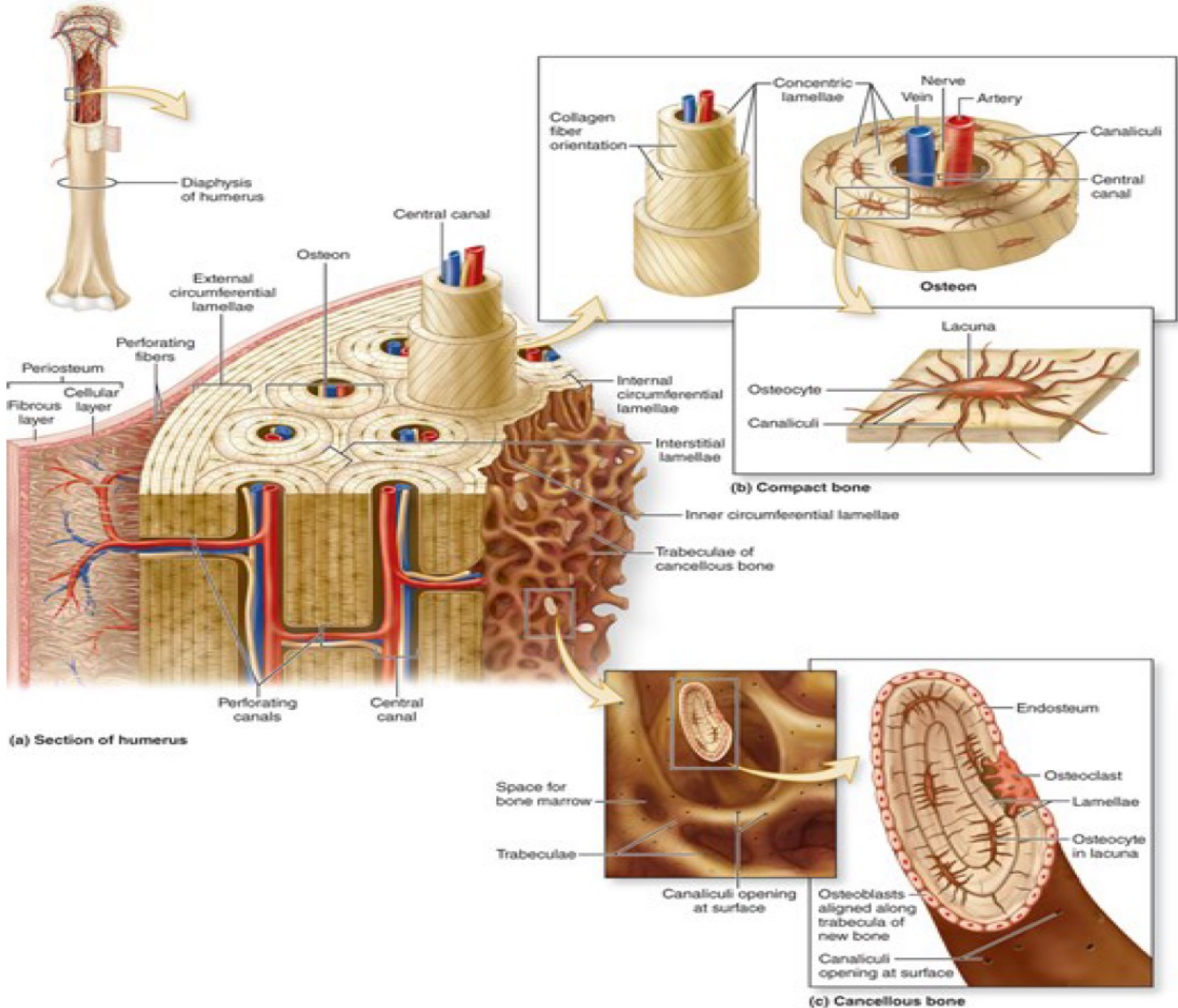
## Cells

- Osteoblast
- Osteocytes
- Osteoclasts

# Functions

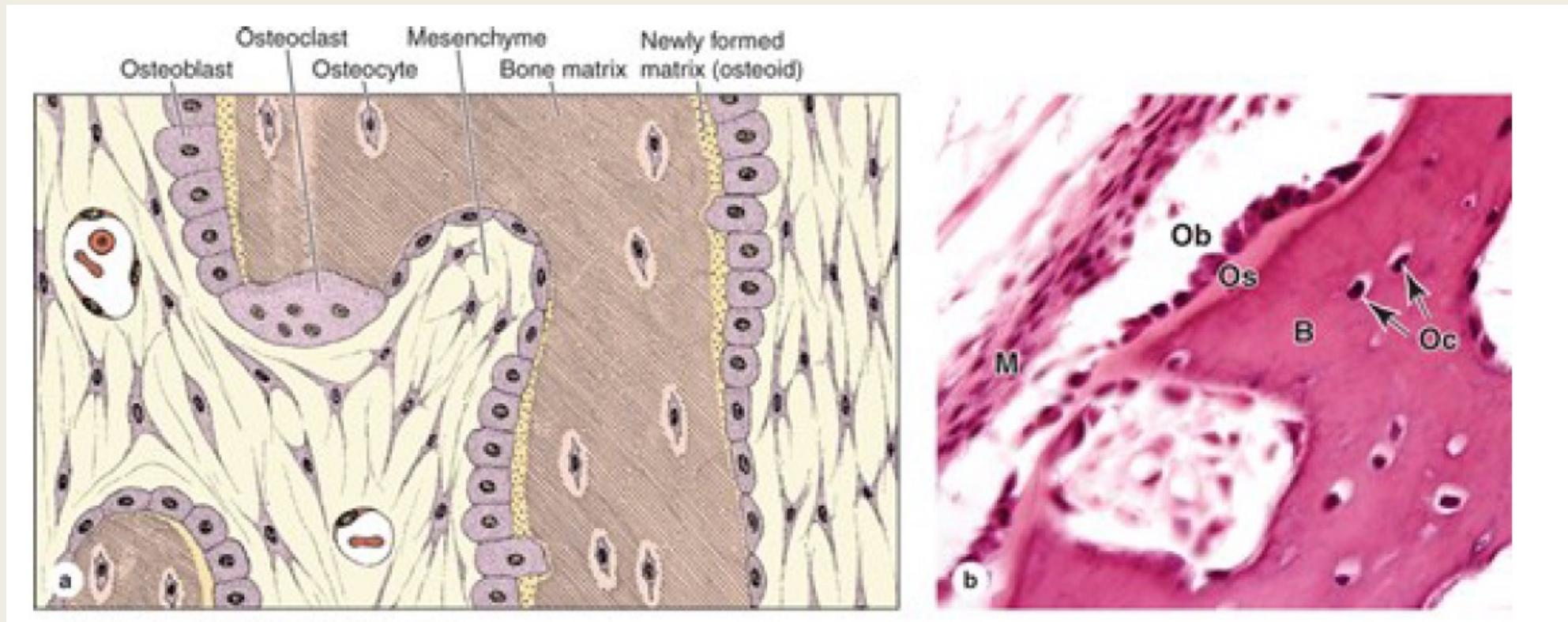
- Main constituent of the adult skeleton
- Provides solid support for the body, protects vital organs such as those in the cranial and thoracic cavities,
- Encloses internal (medullary) cavities containing bone marrow.
- Bone tissue also serves as a reservoir of calcium, phosphate, and other ions.

# Bone



# Bone cells

1. Osteoblast
2. Osteocytes
3. Osteoclasts



# Cells

- Osteocytes are found in cavities (lacunae) between bone matrix layers (lamellae), with cytoplasmic processes in small canaliculi that extend into the matrix.
- Osteoblasts growing cells which synthesize and secrete the organic components of the matrix
- Osteoclasts which are giant, multinucleated cells involved in removing calcified bone matrix and remodeling bone tissue

# Osteoblasts

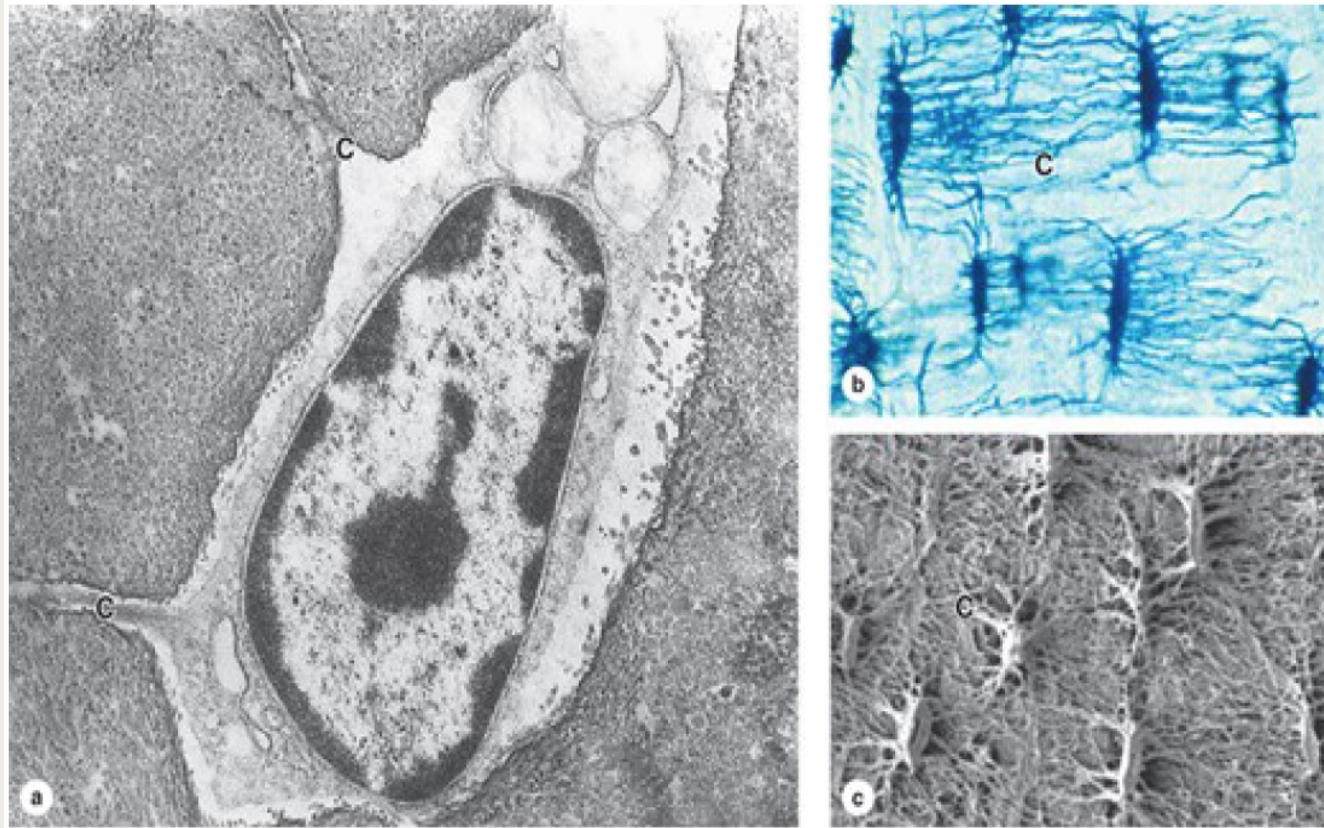
- Originating from mesenchymal stem cells.
- Produce the organic components of bone matrix
- Located exclusively at the surfaces of bone matrix.
- Active ones are located exclusively at the surfaces of bone matrix (integrins)

# Osteoblasts

## **When their synthetic activity is completed:**

- Some osteoblasts differentiate as osteocytes entrapped in matrix-bound lacunae.
- Some flatten and cover the matrix surface as bone lining cells
- The majority undergo apoptosis.

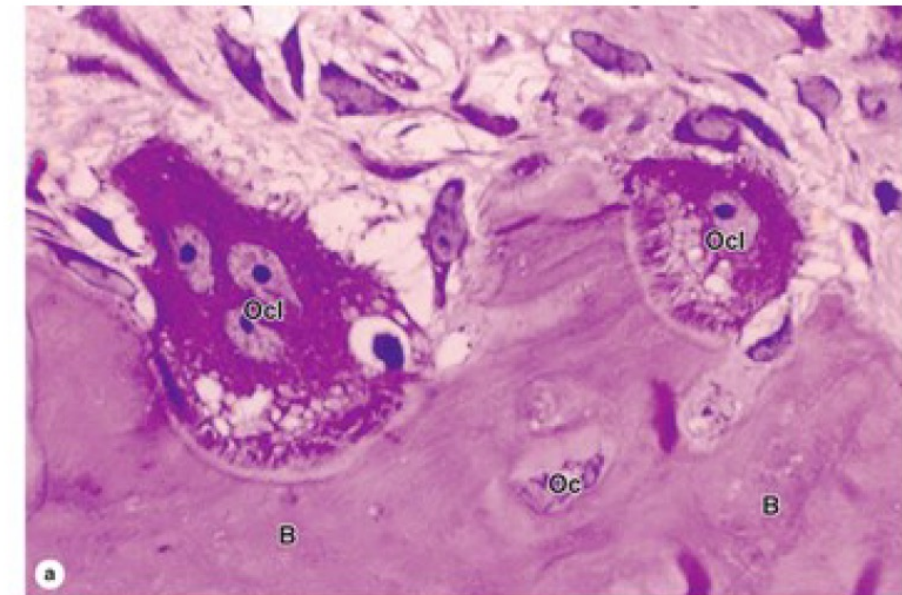
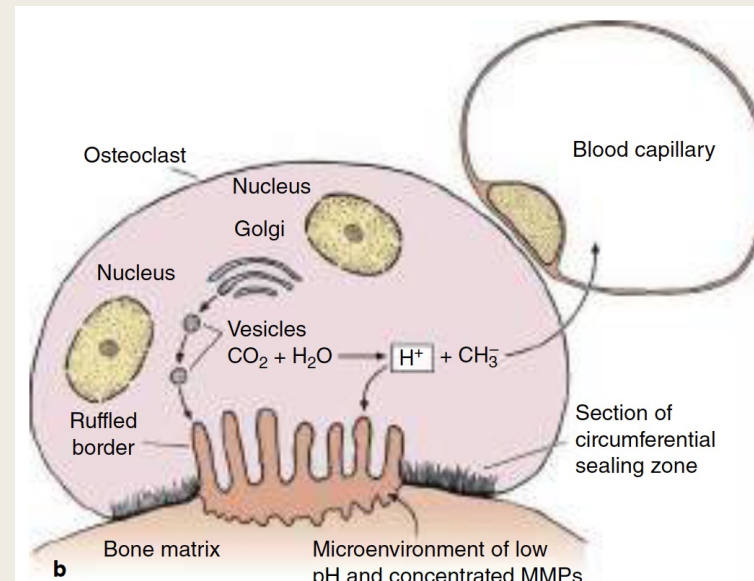
# Osteocytes



- Surrounded by the material they secrete and then differentiate as osteocytes.
- Processes in canaliculi 250-300 nm.
- Osteocytes communicate with one another and with nearby osteoblasts and bone lining cells via gap junctions at the ends of their processes
- The most abundant cells in bone,
- Exhibit significantly less RER, smaller Golgi complexes, and more condensed nuclear chromatin than osteoblasts
- Maintain the calcified matrix, and their death is followed by rapid matrix resorption

# Osteoclast

- Very large, motile cells with multiple nuclei.
- Resorption cavities (Howship lacunae)
- Osteoclast's circumferential **sealing zone** where integrins tightly bind the cell to the bone matrix.
- The sealing zone surrounds a **ruffled border** of microvilli and other cytoplasmic projections close to this matrix.



# Osteon

## Osteon (Haversian system):

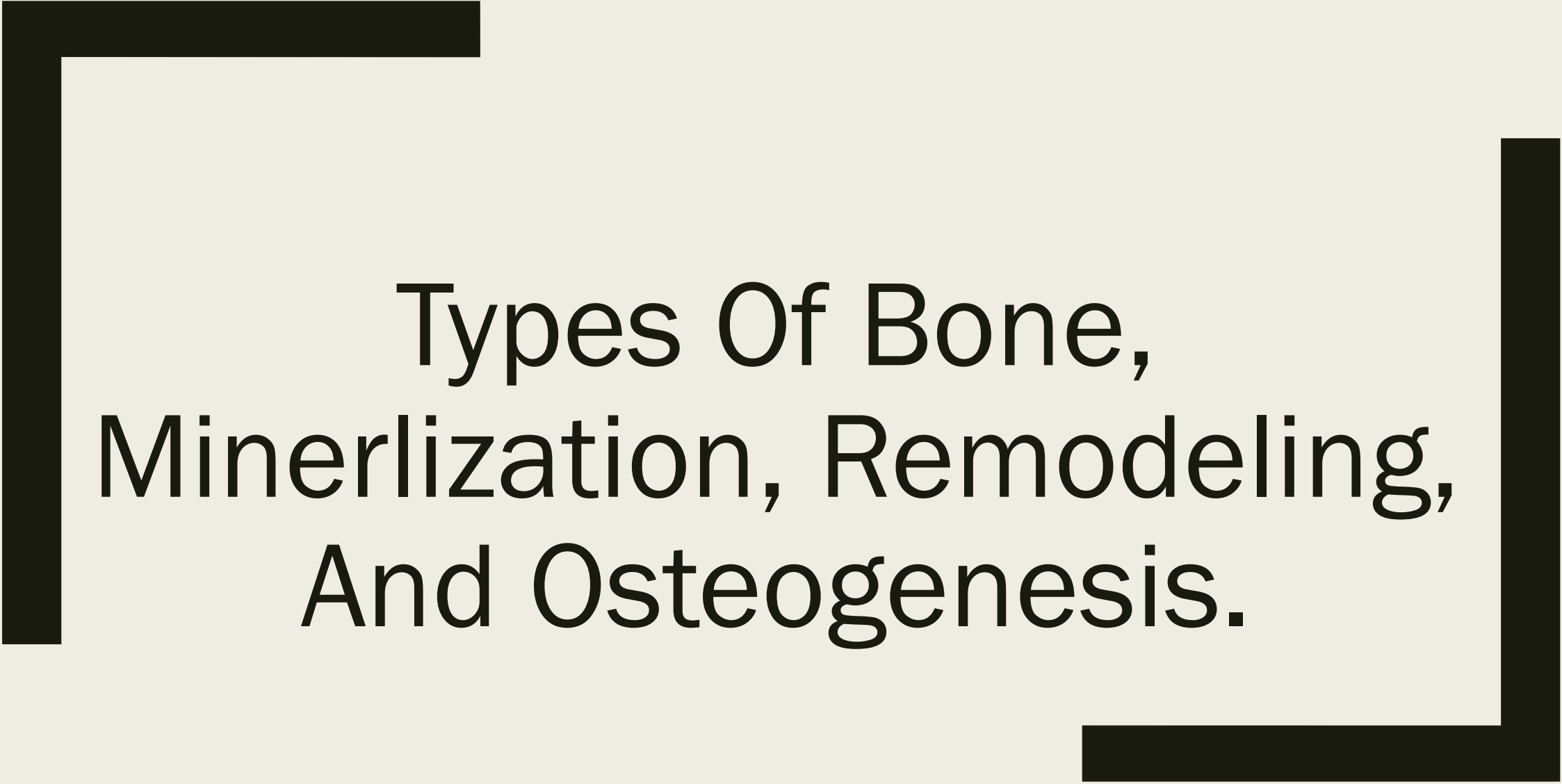
- Complex of concentric lamellae
- 100-250  $\mu\text{m}$  in diameter
- Surrounding a central canal that
- Contains small blood vessels, nerves, and endosteum

# Periosteum & Endosteum

- External and internal surfaces of all bones
- Periosteum is a dense connective tissue, containing mostly bundled type I collagen, but also fibroblasts and blood vessels
- Type I collagen (Fibrillar collagens types I, II, and III).
- Bone is vascularized by small vessels that penetrate the matrix from the periosteum.
- Endosteum covers all trabeculae around the marrow cavities.

# Types Of Bone

Type of Bone	Histological Features	Major Locations
<b>Woven bone</b> , newly calcified	Irregular and random arrangement of cells and collagen; lightly calcified	Developing and growing bones; hard callus of bone fractures
<b>Lamellar bone</b> , remodeled from woven bone	Parallel bundles of collagen in thin layers (lamellae), with regularly spaced cells between; heavily calcified	All normal regions of adult bone
<b>Compact bone</b> , ~80% of all lamellar bone	Parallel lamellae or densely packed osteons, with interstitial lamellae	Thick, outer region (beneath periosteum) of bones
<b>Cancellous bone</b> , ~20% of all lamellar bone	Interconnected thin spicules or trabeculae covered by endosteum	Inner region of bones, adjacent to marrow cavities

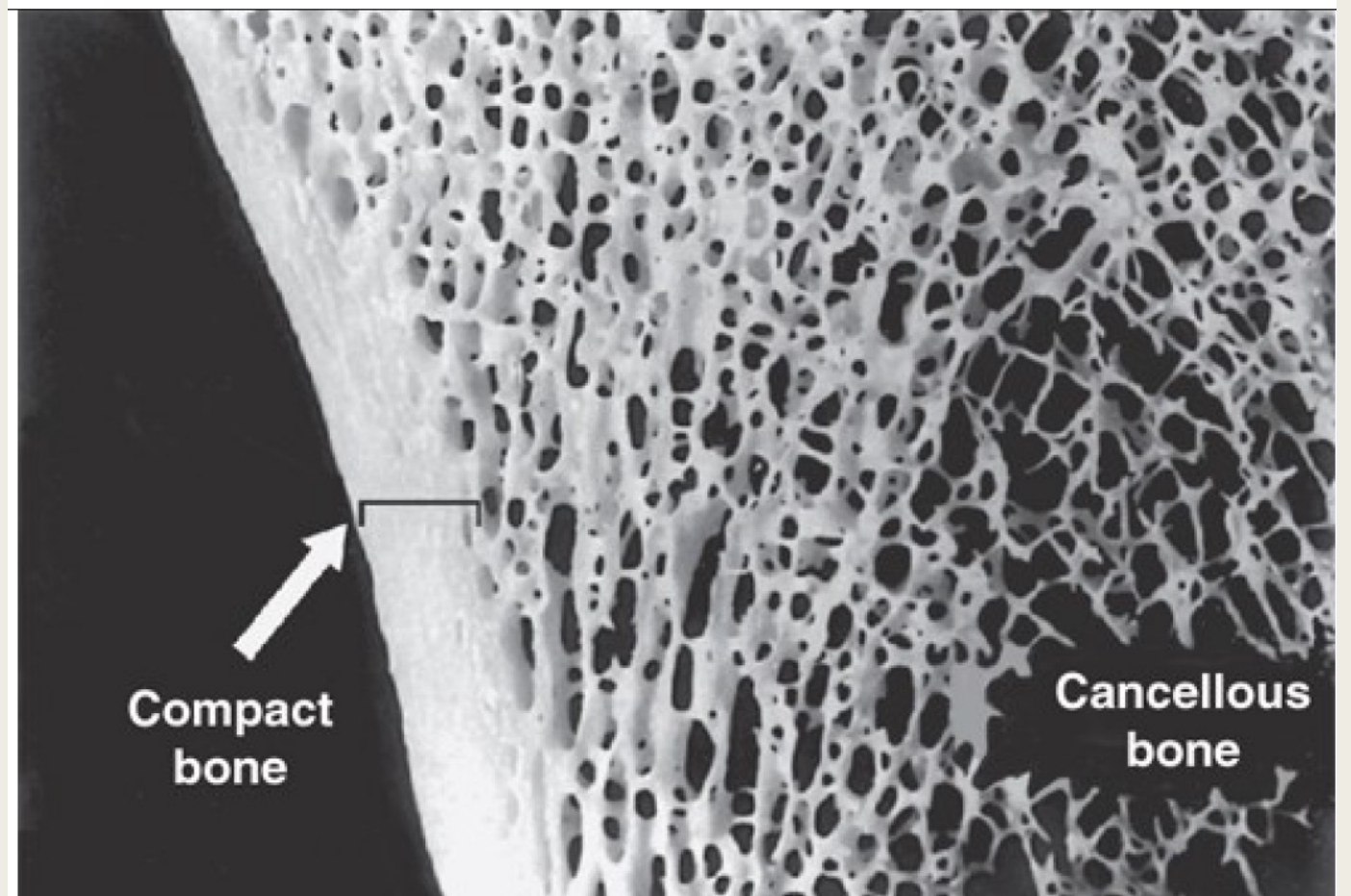
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# Types Of Bone, Minerlization, Remodeling, And Osteogenesis.

# Types Of Bone

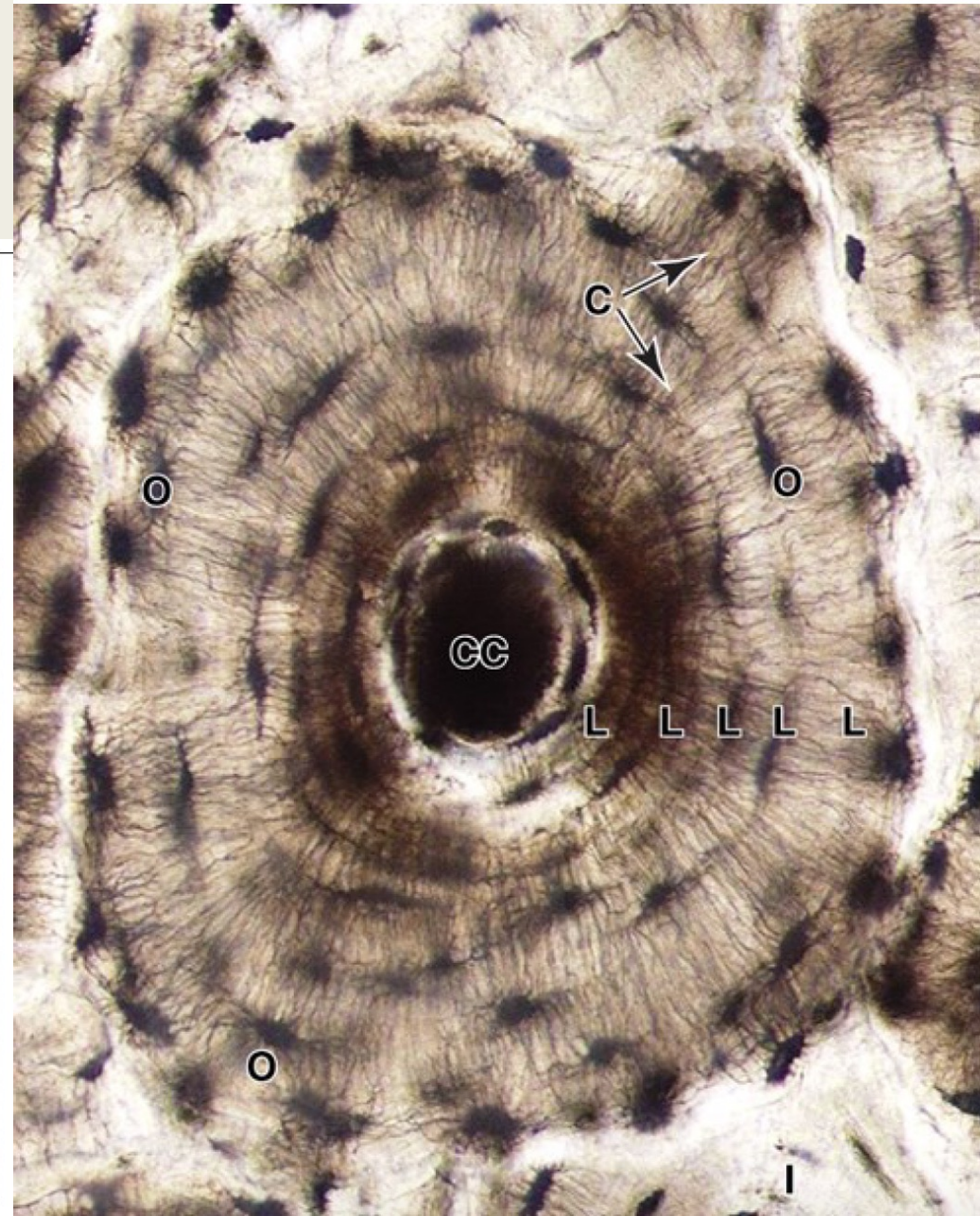
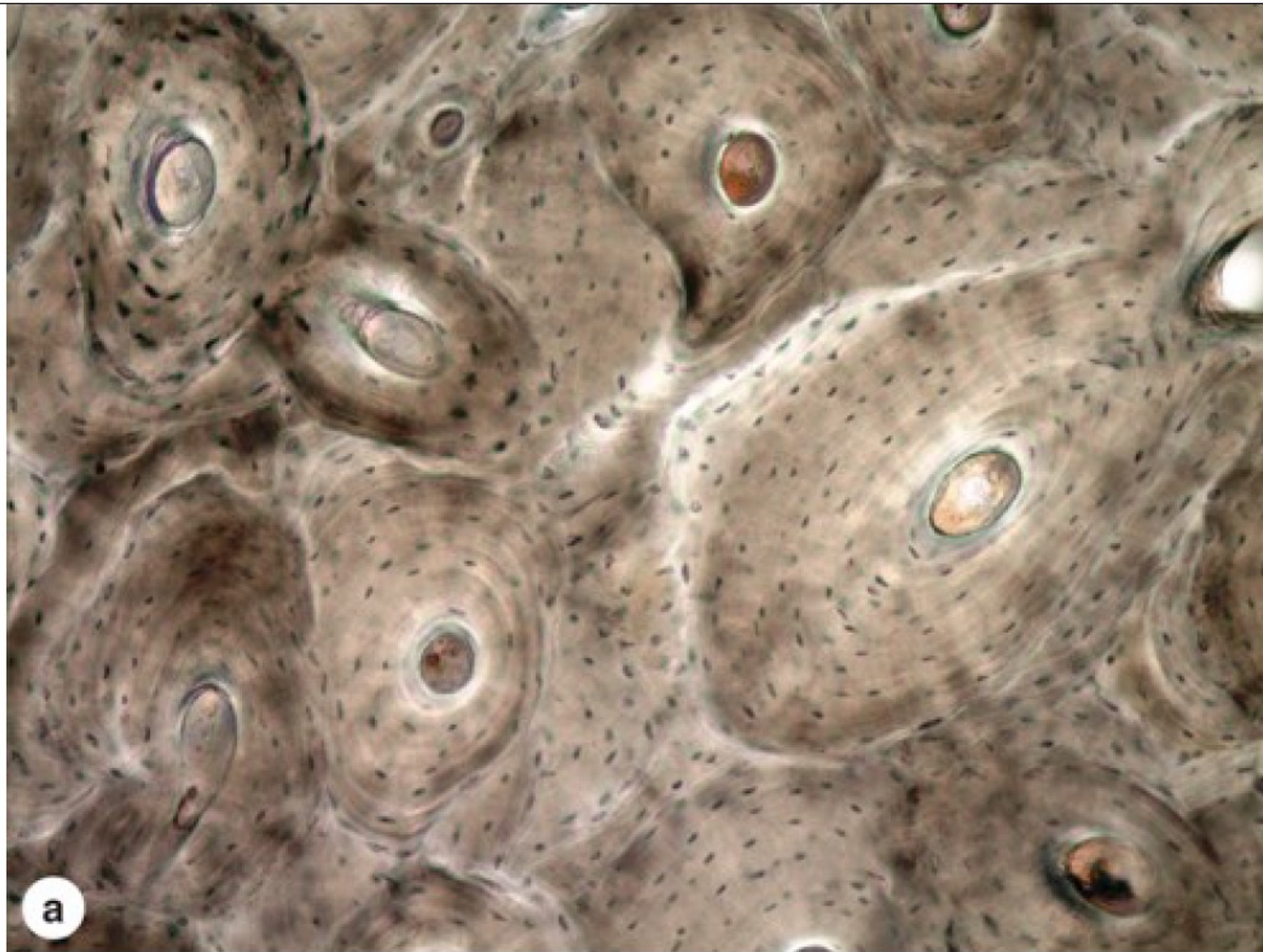
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# Compact Bone



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# Compact Bone- Osteons



# Mineralization in bone matrix

- **Osteoid**

Collagen I ++++

Glycoproteins

proteoglycans

- **Osteocalcin**

Vit. K-dependant polypeptid.

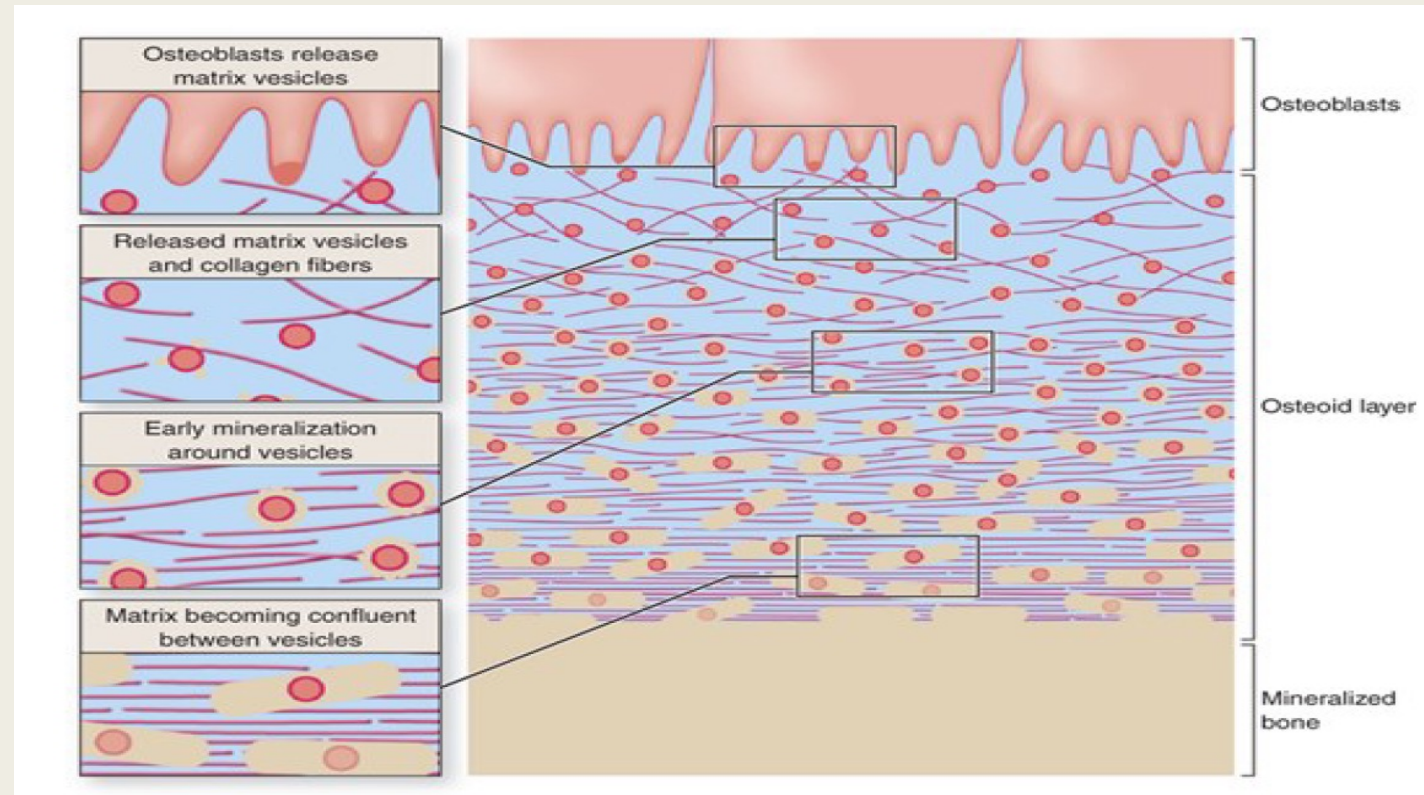
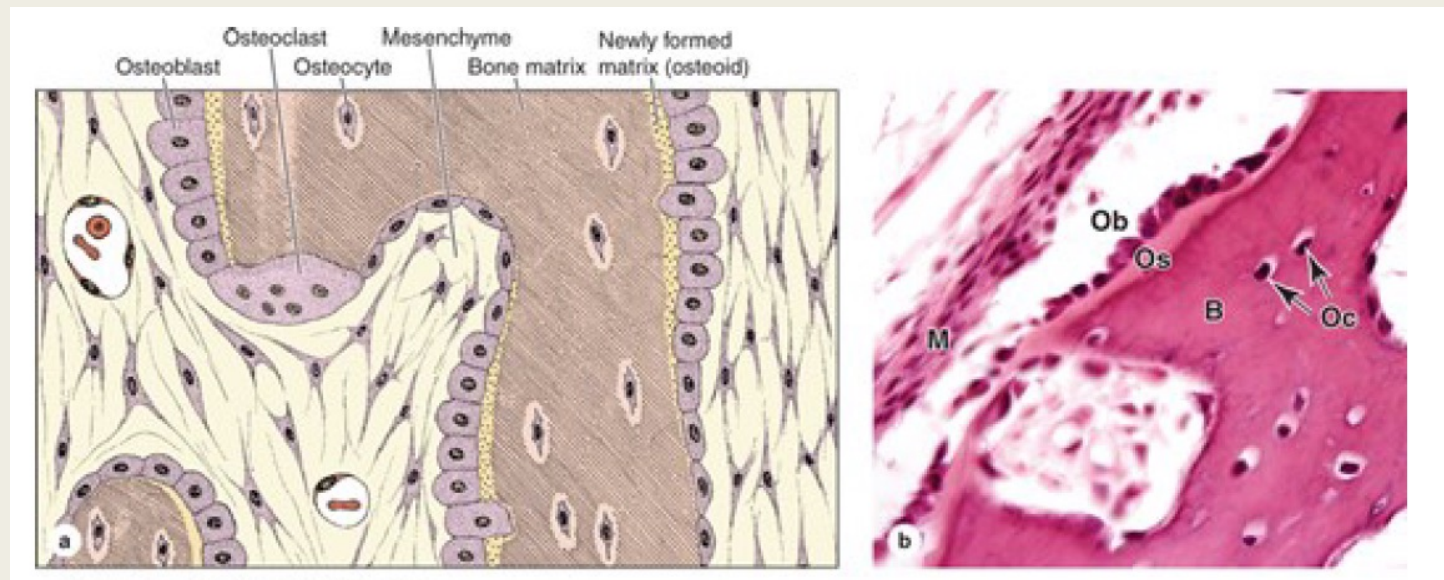
Binds  $\text{Ca}^{2+}$  (with other GPs)

- **Matrix vesicles.**

Rich with Alkaline phosphatase.

Raises  $\text{PO}_4^{3-}$

Formation of hydroxyapatite

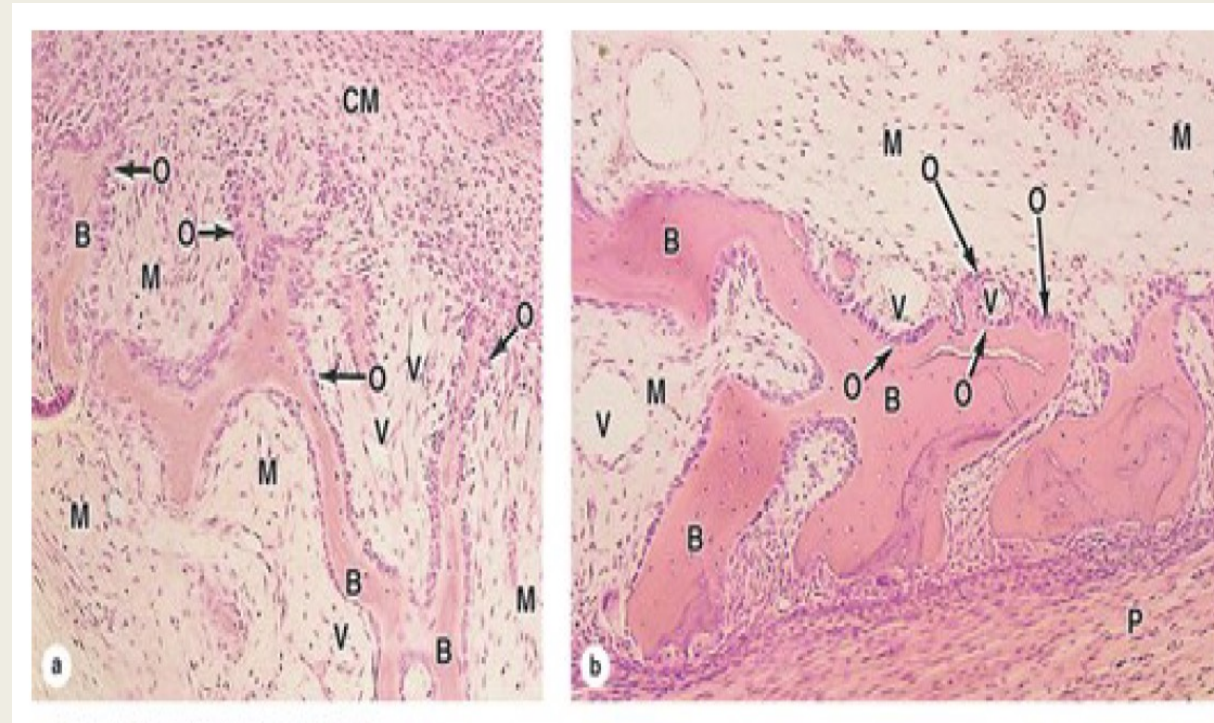


# Osteogenesis—bone formation

- **Intramembranous ossification:** osteoblasts differentiate directly from mesenchyme
- **Endochondral ossification:** a preexisting matrix of hyaline cartilage is eroded and invaded by osteoblasts

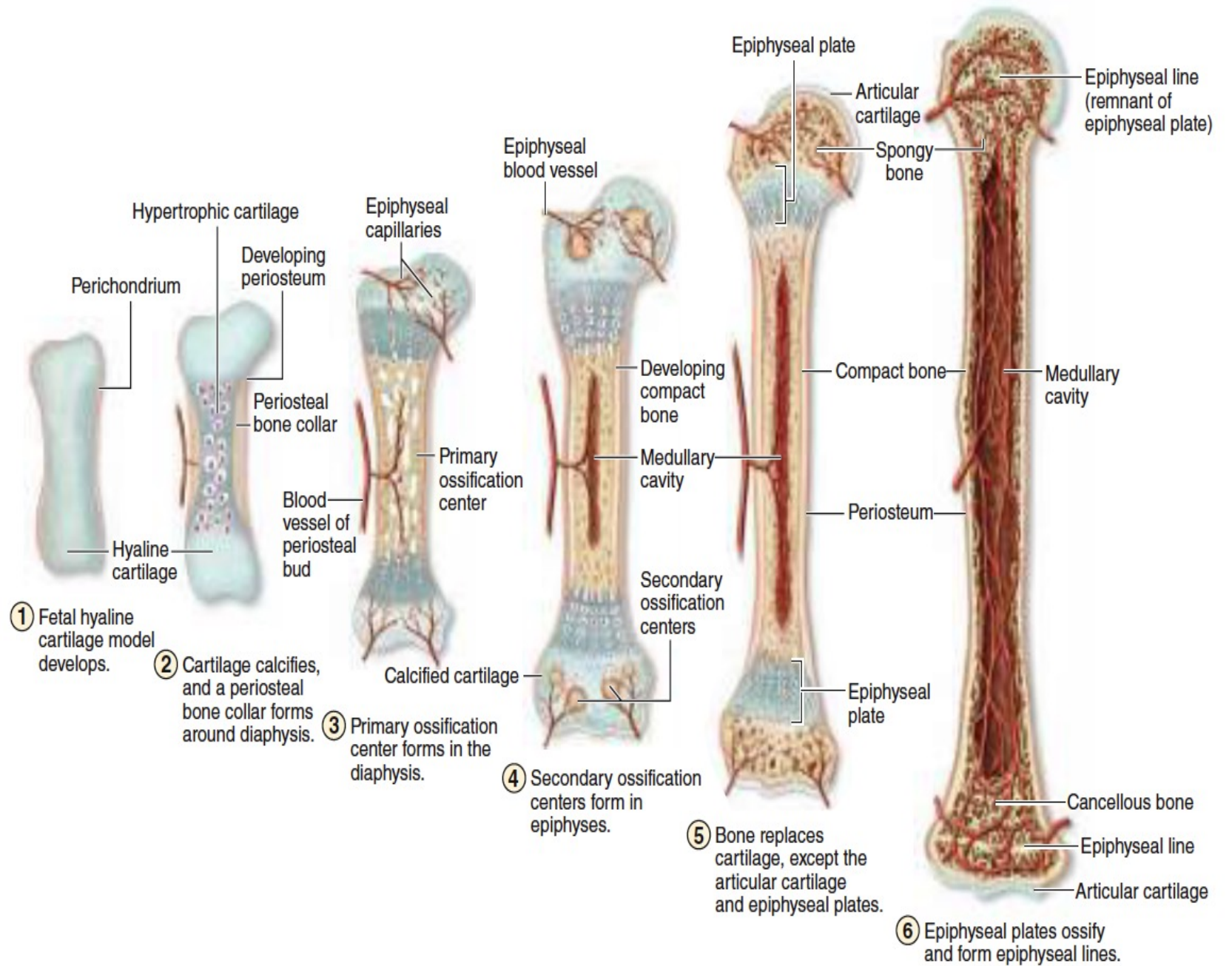
# Intramembranous Ossification

- Most flat bones form this way (bones of the skull, jaws, scapula and clavicle)
- Within the condensed mesenchyme begins in ossification centers—osteoblasts around developing capillaries—Osteoid—Calcification—woven bone with osteocytes in lacunae and canaliculi.



- The anatomical bone forms gradually as woven bone matrix is replaced by compact bone that encloses a region of cancellous bone with marrow and larger blood vessels.
- Mesenchymal regions that do not undergo ossification give rise to the endosteum and the periosteum.
- The fontanelles or “soft spots” on the heads of newborn infants are areas of the skull in which the membranous tissue is not yet ossified.

# Endochondral ossification



# Endochondral ossification

- Takes place within hyaline cartilage shaped as a small version of the bone to be formed.
- Forms most bones of the body (well studied in developing long bones).
- First occurs within a bone collar (osteoblasts that differentiate within the perichondrium (transitioning to periosteum)).
- The collar impedes diffusion of oxygen/nutrients into the underlying cartilage--local chondrocytes hypertrophy-- compress the matrix--calcification (osteocalcin and alkaline phosphatase)--death (chondrocytes).

# Endochondral ossification

- The hypertrophic chondrocytes eventually die, creating empty spaces within the calcified matrix.
- **Primary ossification center:** blood vessels from the perichondrium (periosteum) penetrate the bone collar— osteoprogenitor cells— produce woven bone (first trimester)
- **Secondary ossification centers:** appear later at the epiphyses.

## Cartilage remains as:

- Articular cartilage: persists through adult life.
- Epiphyseal cartilage (epiphyseal plate or growth plate): connects each epiphysis to the diaphysis— longitudinal growth.

# Epiphyseal plate

## Zone of reserve cartilage:

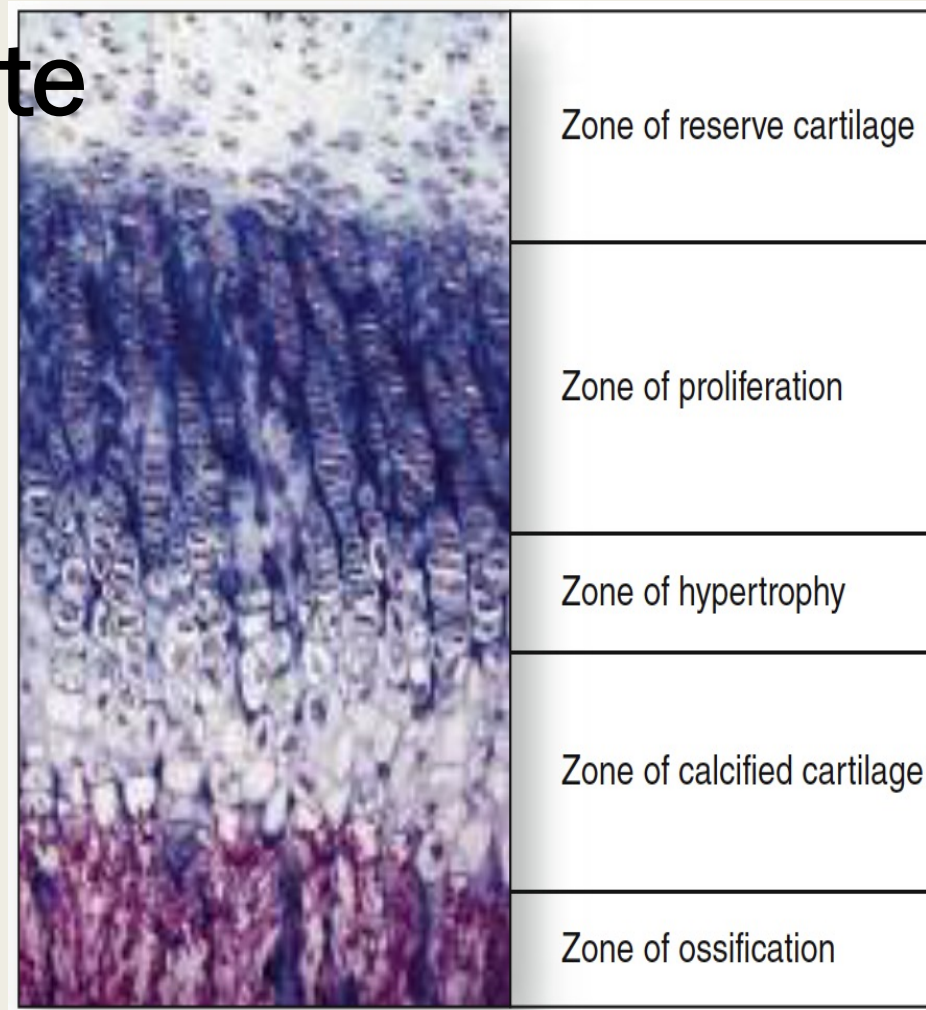
- Composed of typical hyaline cartilage.

## Proliferative zone:

- The cartilage cells divide—enlarge— matrix release.
- Become organized into columns.

## Zone of ossification:

- Bone tissue first appear
- Capillaries and osteoprogenitor cells invade the vacant chondrocytic lacunae.
- Osteoblasts settle in a layer over the spicules of calcified cartilage matrix and secrete osteoid (becomes woven bone)
- Woven bone is then remodeled as lamellar bone.



## Zone of hypertrophy:

- Contains swollen terminally differentiated chondrocytes.
- Compressed matrix and stiffened by collagen X.
- Increased vascularization.

## Zone of calcified cartilage:

- Chondrocytes about to undergo apoptosis.
- Release matrix vesicles and osteocalcin—calcification.

# Bone remodeling

- Bone growth involves: 1) the continuous resorption of bone tissue formed earlier, and 2) the simultaneous laying down of new bone at a rate exceeding that of bone removal.
- The sum of osteoblast and osteoclast activities in a growing bone constitutes osteogenesis or the process of bone modeling, which maintains each bone's general shape while increasing its mass.
- 5-10% of bone turns over annually.

# Bone remodeling

- **Bone turnover:** is very active in young children, where it can be 200 times faster than that of adults.
- **Bone remodeling:** in adults the skeleton is also renewed continuously, which involves the coordinated, localized cellular activities for bone resorption and bone formation—**tissue remains plastic and capable of adapting its internal structure in the face of changing stresses**

# Bone repair

- Excellent capacity for repair:
  1. It contains osteoprogenitor stem cells in the periosteum, endosteum, and marrow.
  2. Is very well vascularized.
- The major phases that occur typically during bone fracture repair include initial formation of fibrocartilage and its replacement with a temporary callus of woven bone.

# Osteoporosis

- Frequently found in immobilized patients and in postmenopausal women.
- Is an imbalance in skeletal turnover so that bone resorption exceeds bone formation---calcium loss---reduced bone mineral density (BMD).
- Individuals at risk are routinely tested for BMD by dual-energy x-ray absorptiometry (DEXA scans).

# Osteopetrosis

- Genetic disease.
- Characterized by dense, heavy bones (marble bones).
- The osteoclasts lack ruffled borders and bone resorption is defective.
- Overgrowth and thickening of bones---obliteration of the marrow cavities---depressing blood cell formation----anemia and the loss of white blood cells.

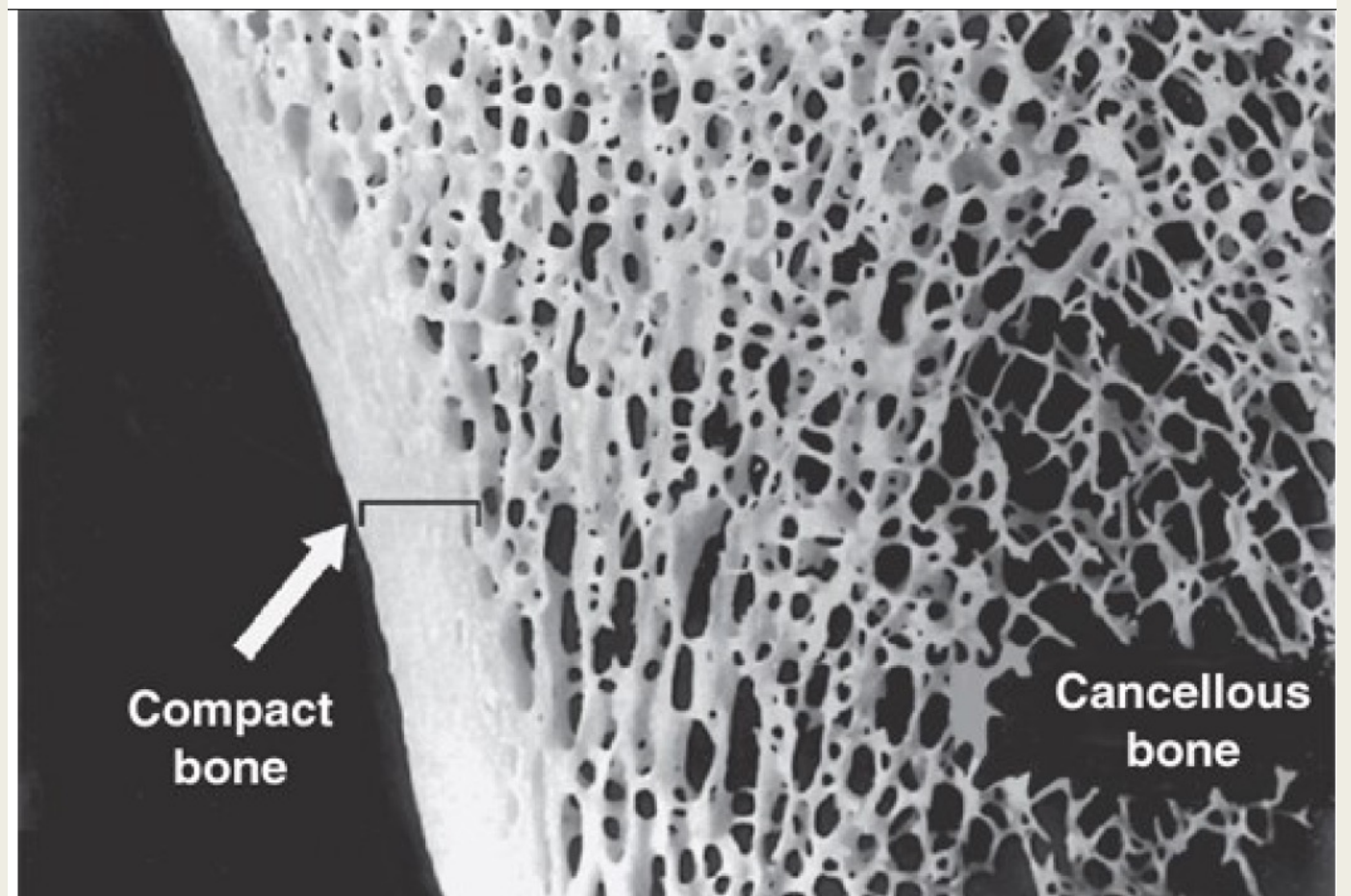
## »» MEDICAL APPLICATION

The network of dendritic processes extending from osteocytes has been called a “mechanostat,” monitoring areas within bones where loading has been increased or decreased, and signaling cells to adjust ion levels and maintain the adjacent bone matrix accordingly. **Lack of exercise** (or the weightlessness experienced by astronauts) leads to **decreased bone density**, due in part to the lack of mechanical stimulation of these cells.

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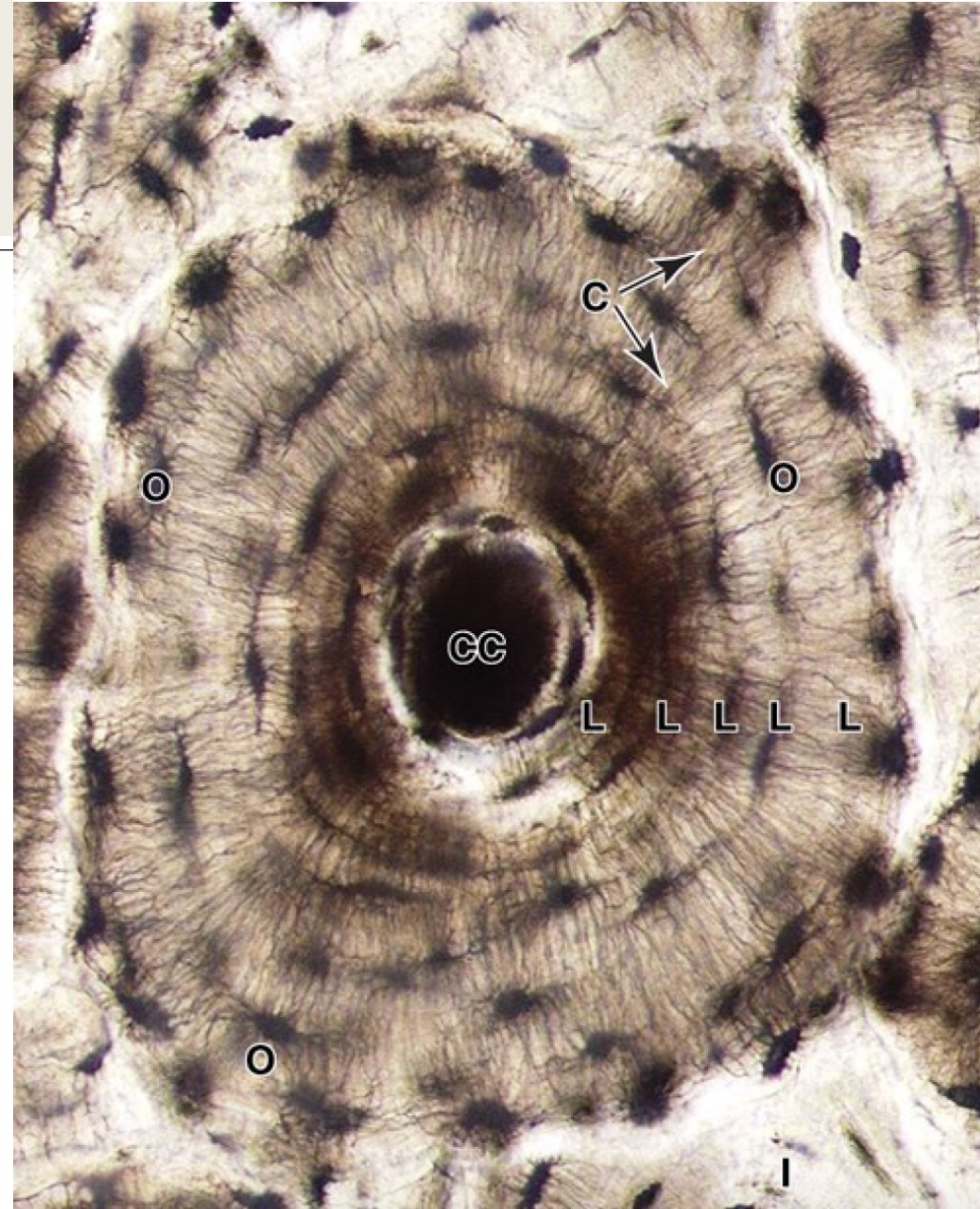
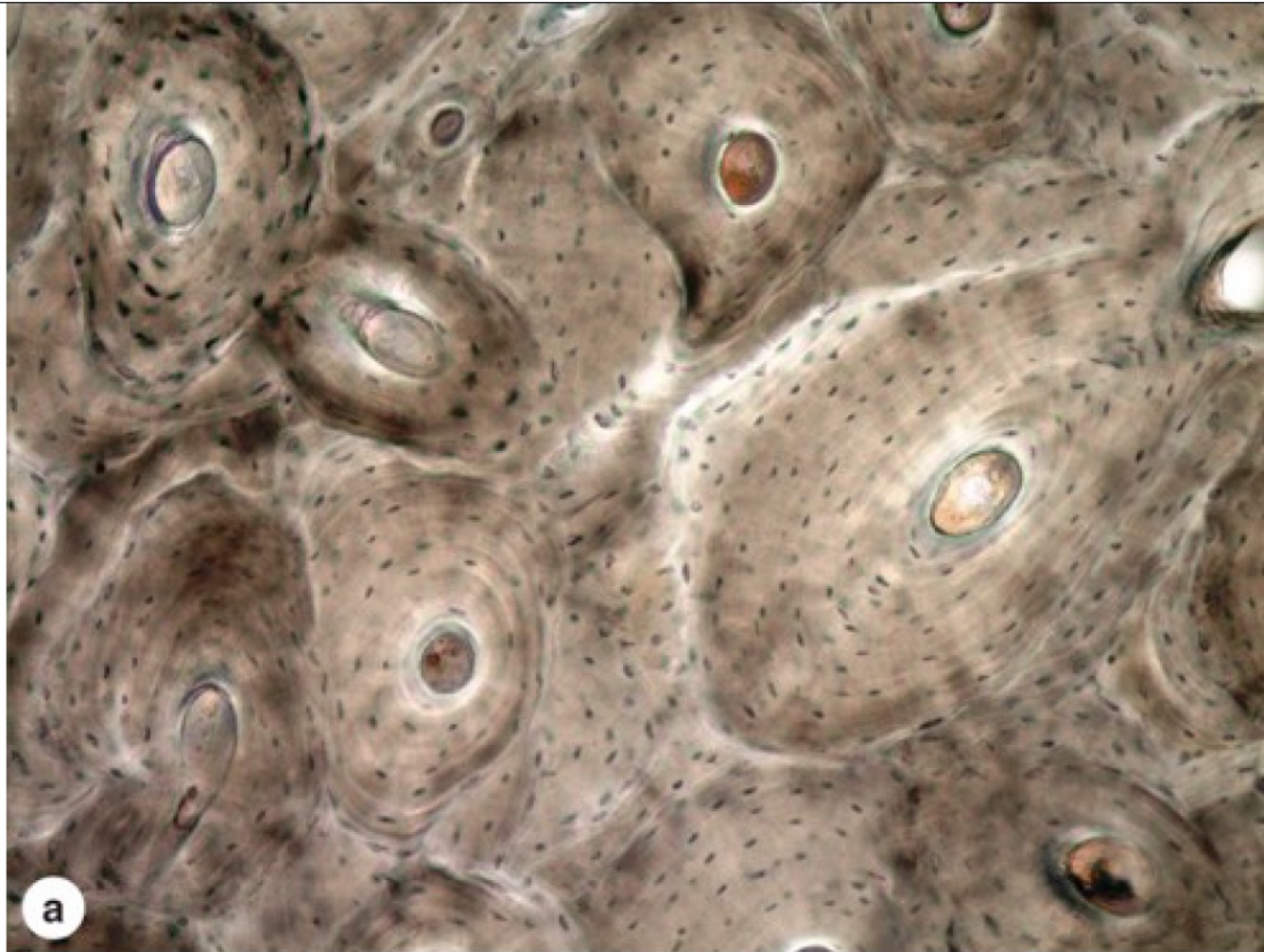
**Osteogenesis imperfecta**, or “brittle bone disease,” refers to a group of related congenital disorders in which the osteoblasts produce deficient amounts of type I collagen or defective type I collagen due to genetic mutations. Such defects lead to a spectrum of disorders, all characterized by significant fragility of the bones. The fragility reflects the deficit in normal collagen, which normally reinforces and adds a degree of resiliency to the mineralized bone matrix.

# Compact Bone



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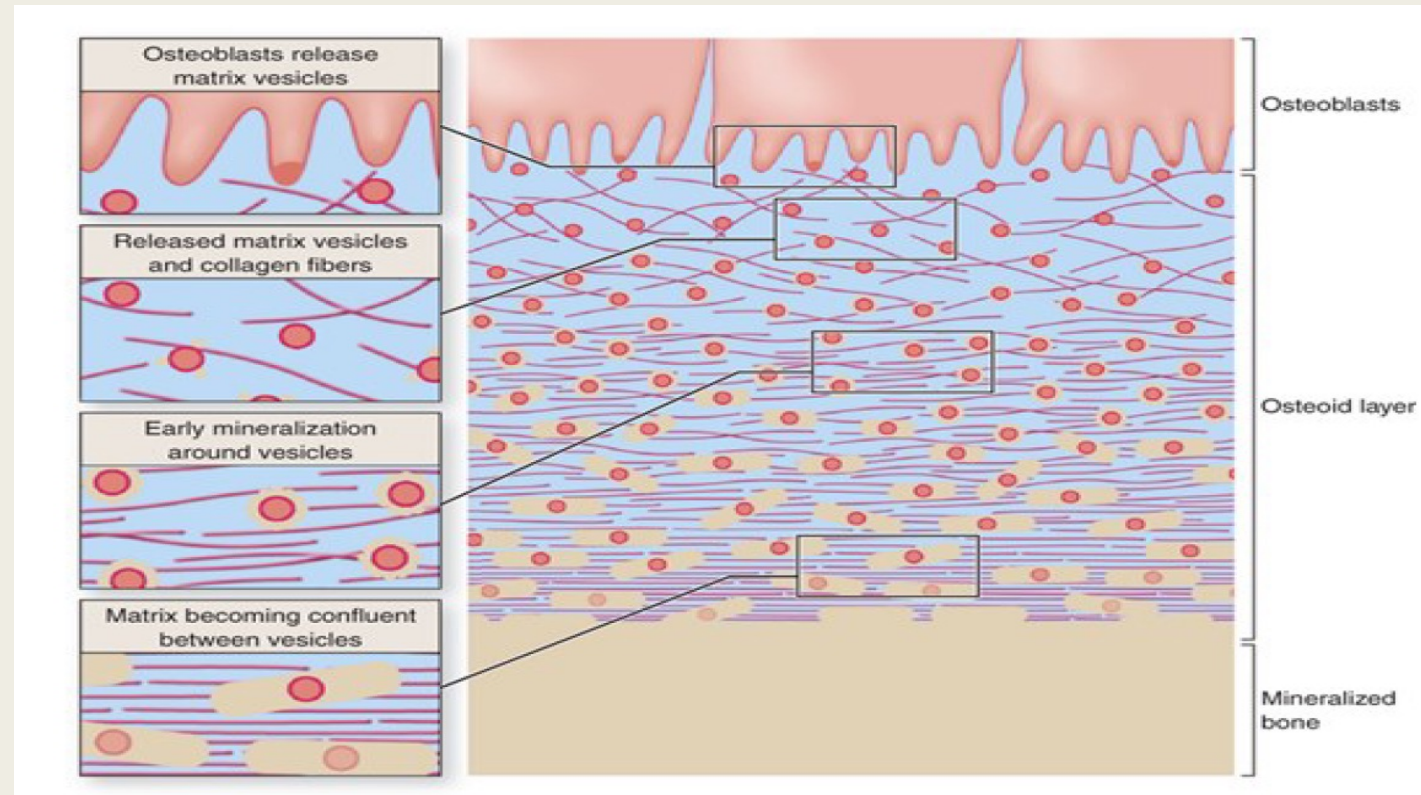
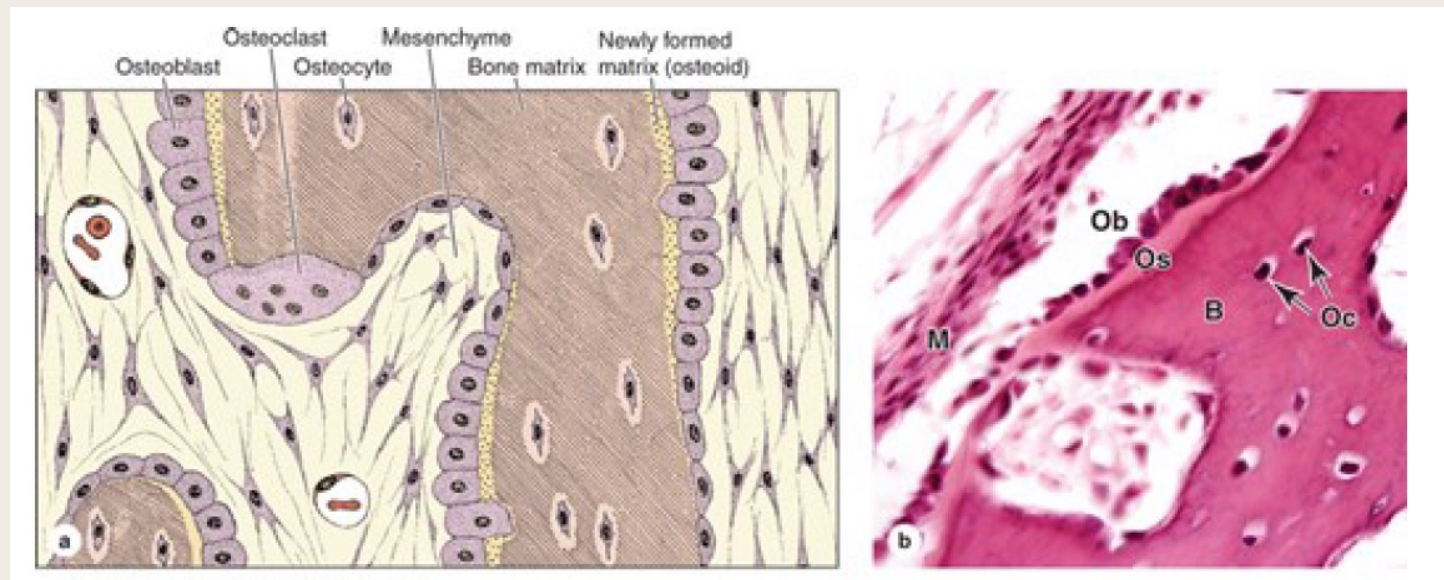
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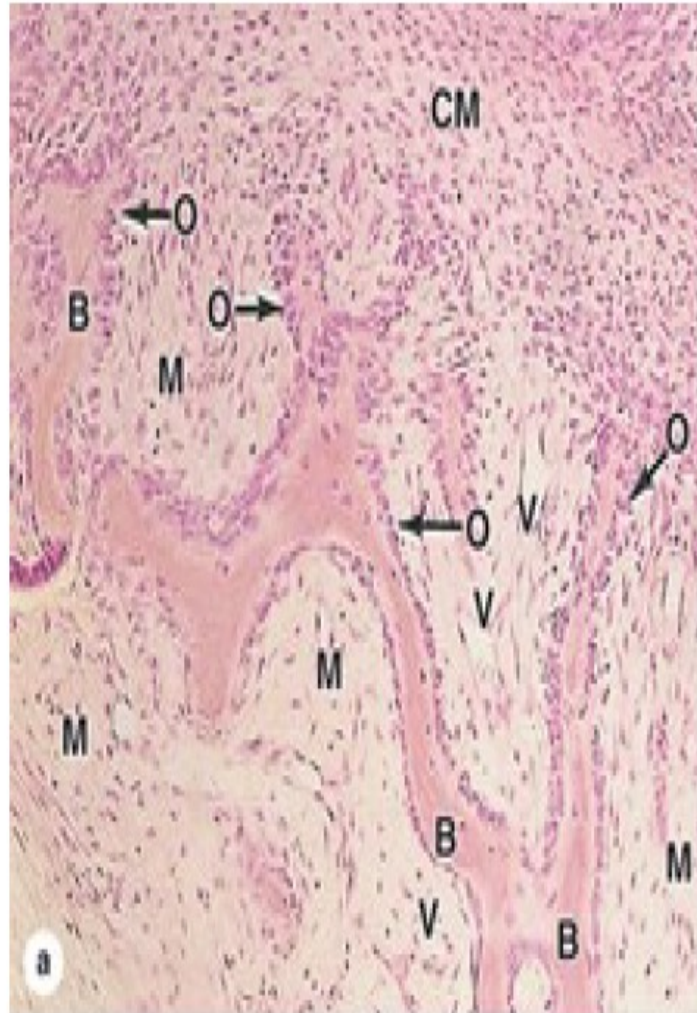
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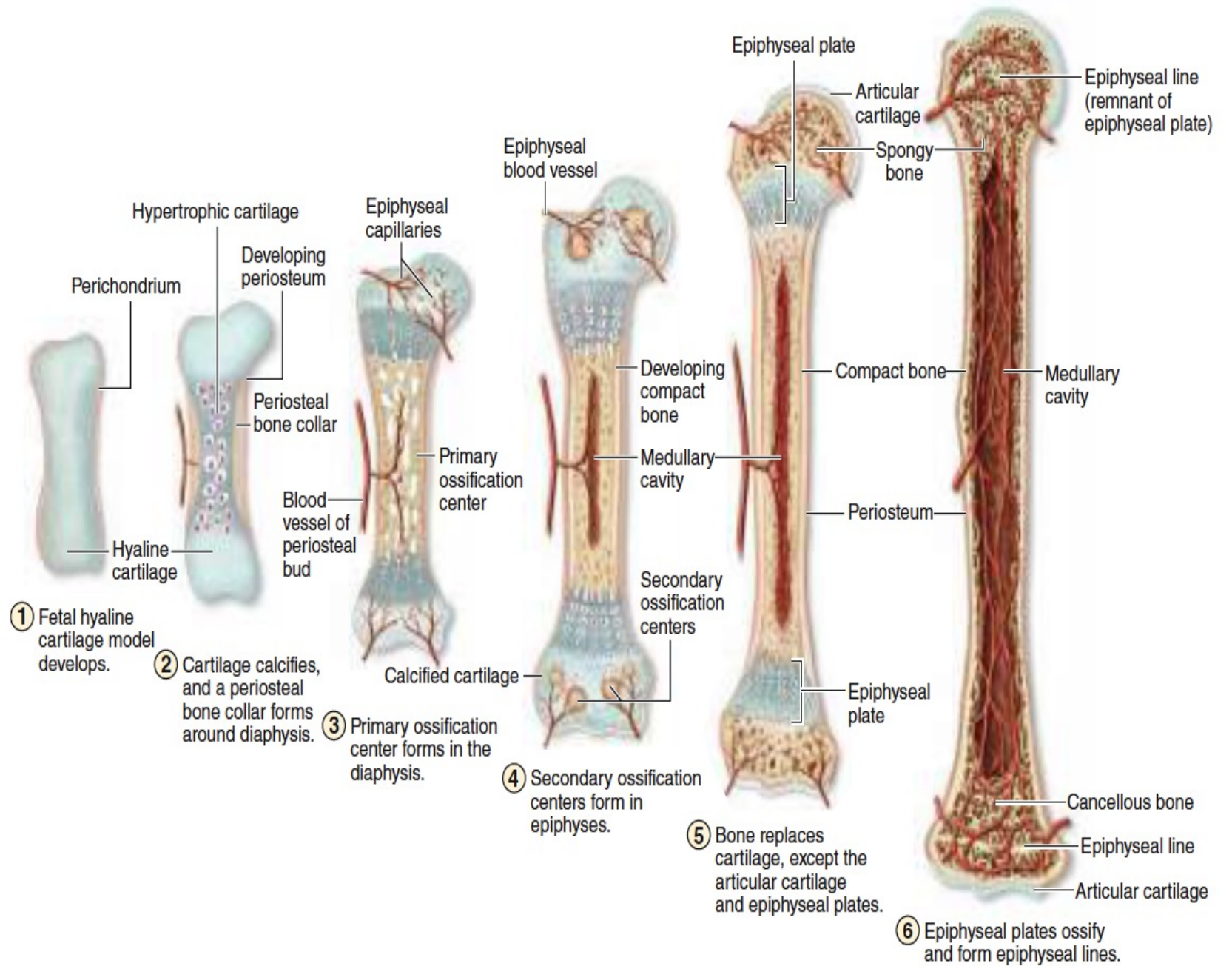
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# Endochondral ossification



① Fetal hyaline cartilage model develops.

② Cartilage calcifies, and a periosteal bone collar forms around diaphysis.

③ Primary ossification center forms in the diaphysis.

④ Secondary ossification centers form in epiphyses.

⑤ Bone replaces cartilage, except the articular cartilage and epiphyseal plates.

⑥ Epiphyseal plates ossify and form epiphyseal lines.

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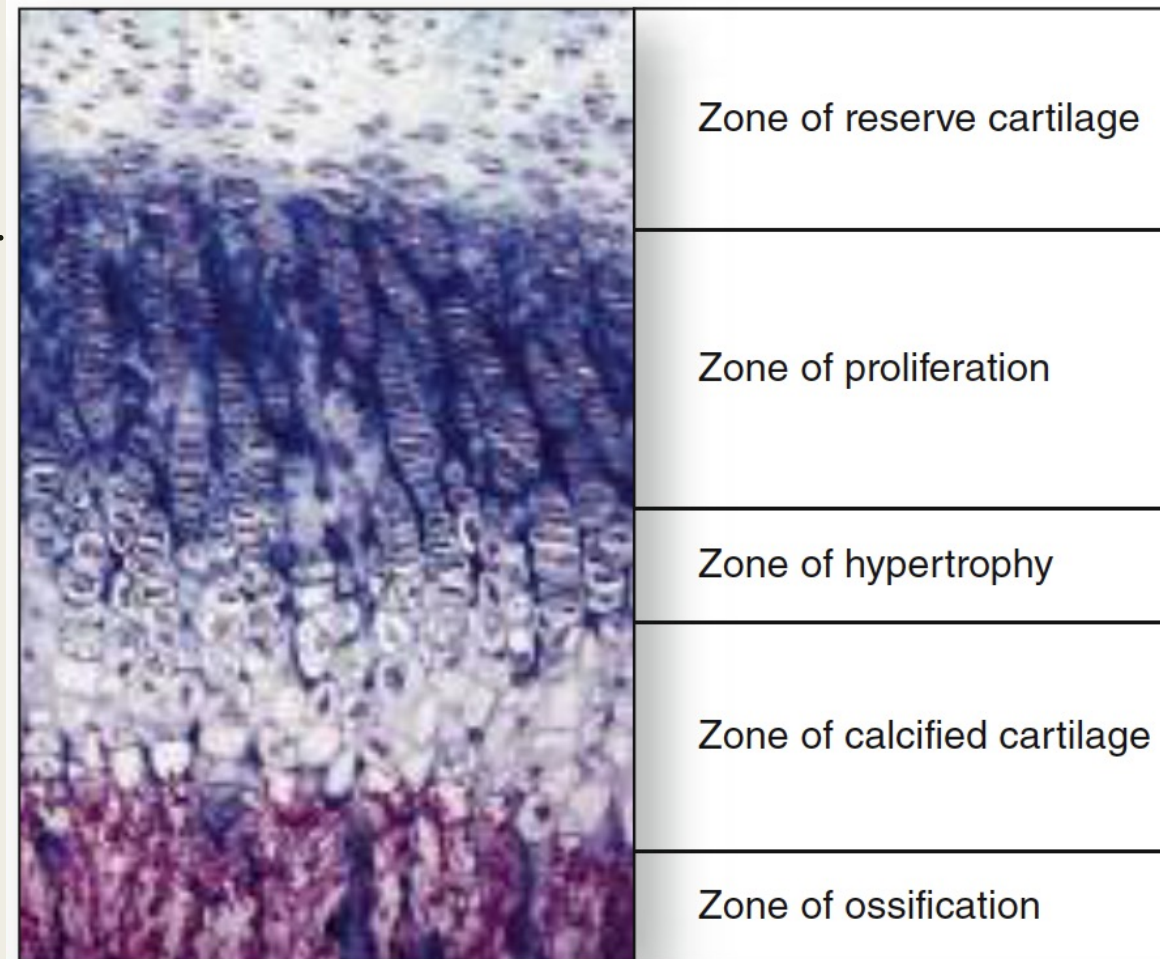
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