BONE TISSUE
&
OSSIFICATION

Functions of Bone

Support: Provides structural support for the entire body. A framework for attachment of soft tissues or organs.

Protection: Skull around brain and inner ear; ribs, sternum, vertebrae protect organs of thoracic cavity

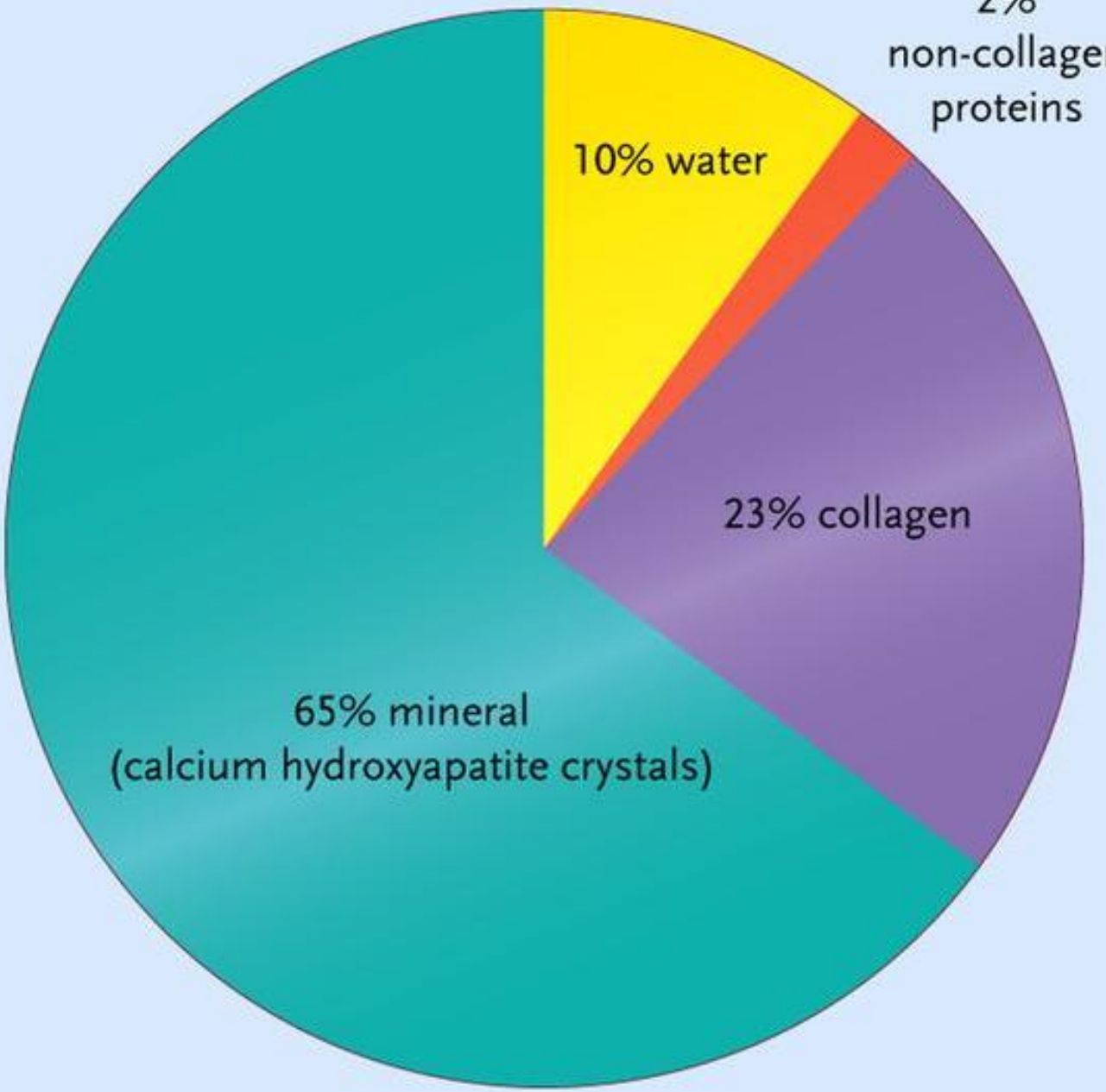
Leverage: Act as *levers* for muscles that contract and produce movement by pulling on bones via tendons.

Storage: Acts as a reservoir for calcium and phosphorous. Fat stored in marrow cavities

Blood cell production (Hematopoiesis):Bone marrow gives rise to blood cells and platelets

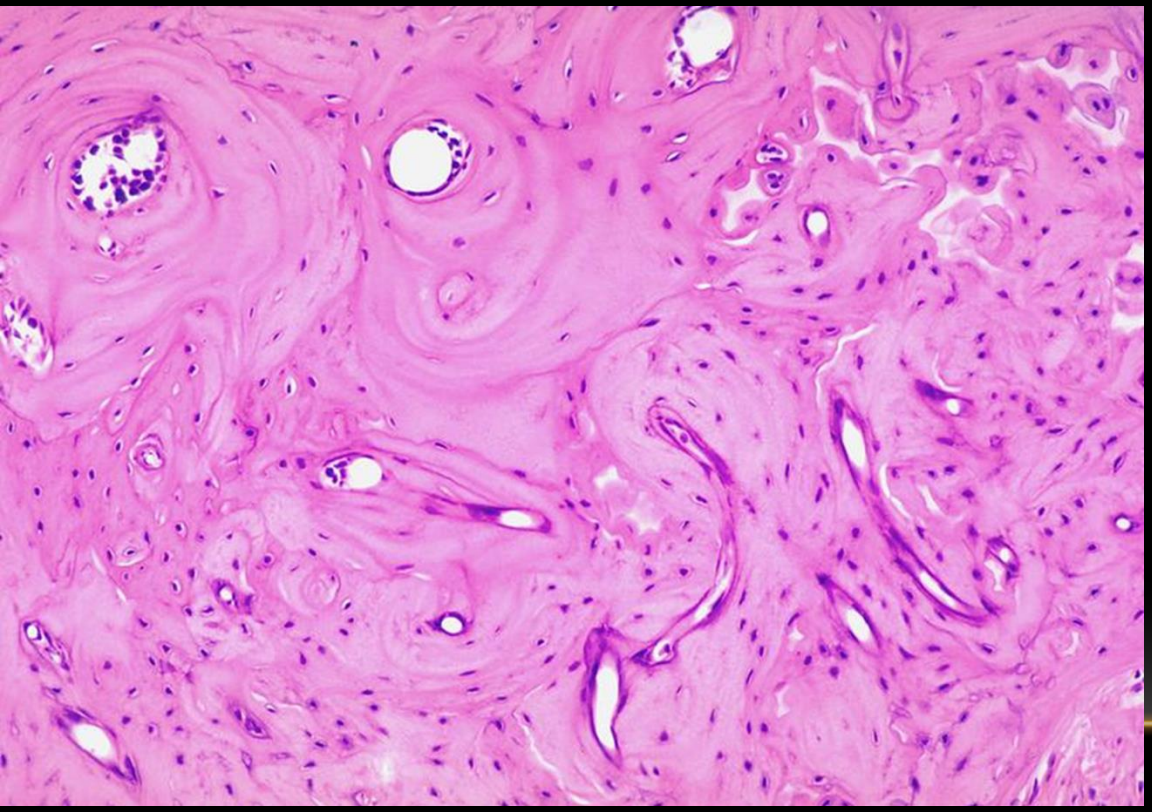
Terms:

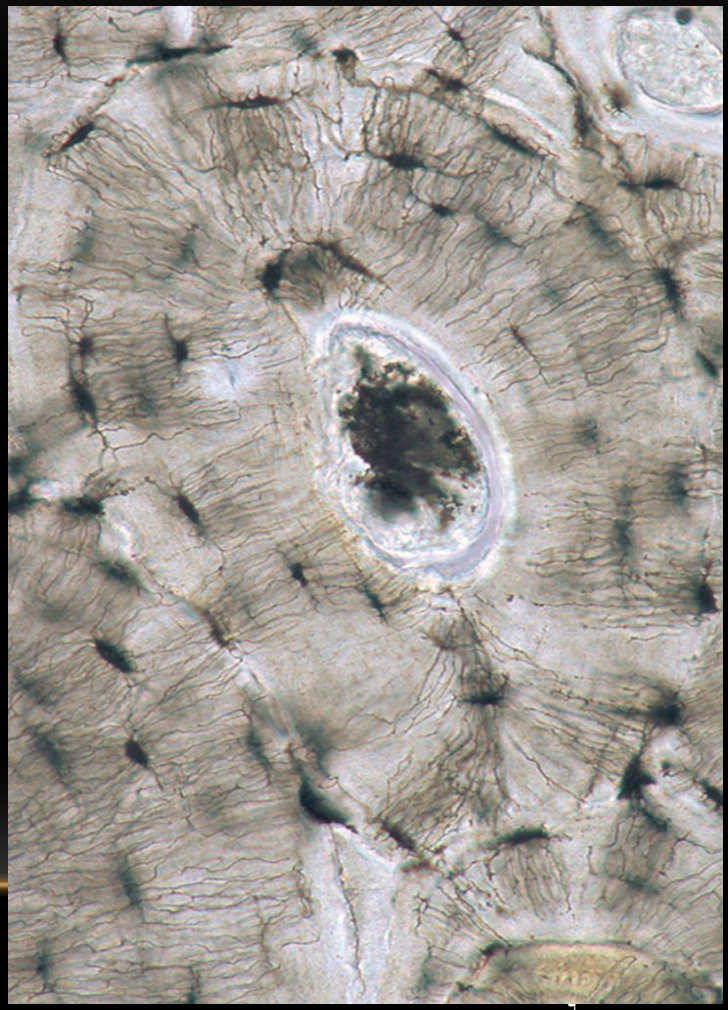
- Matrix
- periosteum
- Osteoprogenitor cells (osteogenic cells)
- Osteoblasts
- Osteocytes
- Lacuna
- Osteoclasts
- Canaliculi
- Filopodial process
- Haversian canal, system
- Osteon
- Volkmann canal
- Endosteum
- Osteoid


2%
non-collagen
proteins
10% water
23% collagen
65% mineral
(calcium hydroxyapatite crystals)

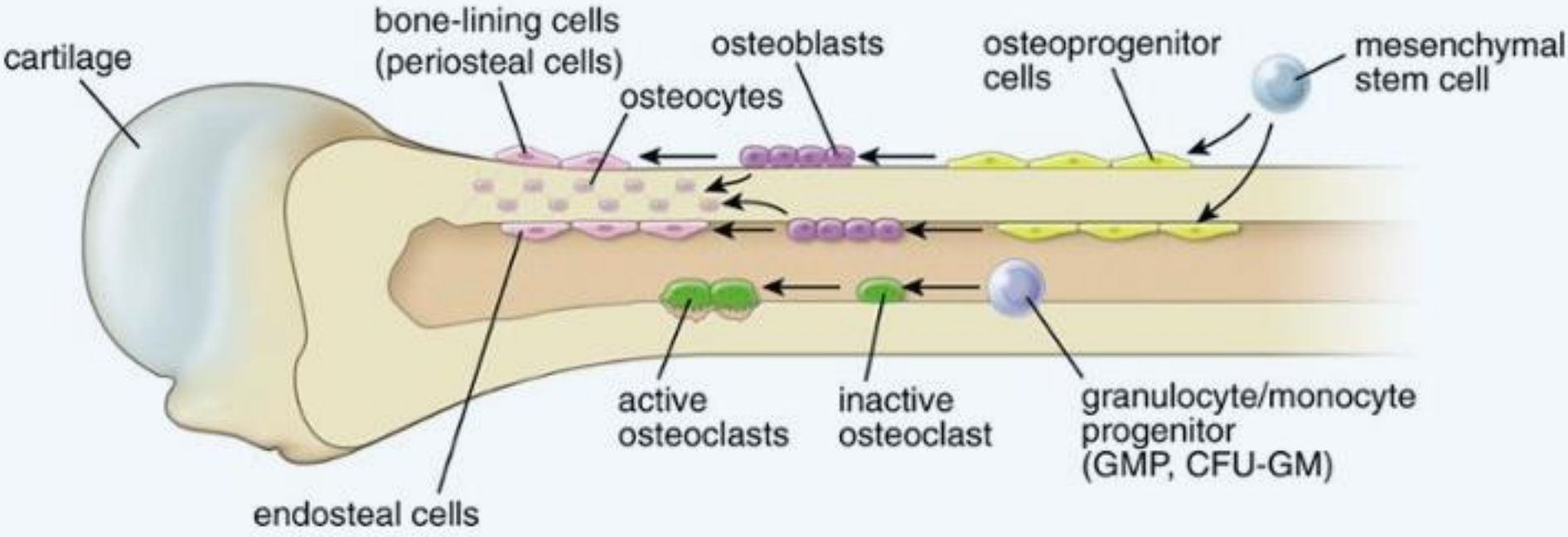
TECHNIQUE OF PREPARATION:

- Ground bone
- Declacified bone





Bone Cells


cartilage
bone-lining cells
(periosteal cells)
osteocytes
osteoblasts
osteoprogenitor
cells
mesenchymal
stem cell
active
osteoclasts
inactive
osteoclast
granulocyte/monocyte
progenitor
(GMP, CFU-GM)
endosteal cells

1- Osteoblast

Responsible for synthesis of the organic components of the matrix.

Deposition of inorganic components also depends on osteoblasts.

When active, appear cuboidal-columnar, typical protein synthesizing cells.

Secrete alkaline phosphatase and osteocalcin, their circulating levels are used clinically as markers of osteoblast activity.

The newly laid matrix is not calcified and called ***osteoid***.

Osteoblast ⇨ Osteocyte

The osteoblast is also responsible for the calcification of bone matrix. The calcification process appears to be initiated by the osteoblast through the secretion into the matrix of small, membrane-limited matrix vesicles. The vesicles are rich in ALP and are actively secreted only during the period in which the cell produces the bone matrix.

The newly deposited matrix is not immediately calcified. It stains lightly or not at all compared with the mature mineralized matrix, which stains heavily with eosin. Because of this staining property of the newly formed matrix, osteoblasts appear to be separated from the bone by a light band. This band represents the osteoid, the nonmineralized matrix.

The cytoplasm of the osteoblast is markedly basophilic, and the Golgi apparatus, because of its size, is sometimes observed as a clear area adjacent to the nucleus. Small, (PAS)-positive granules are observed in the cytoplasm.

In contrast to the secreting osteoblasts found in active matrix deposition, inactive osteoblasts are flat or attenuated cells that cover the bone surface. These cells resemble osteoprogenitor cells.

Osteoblasts respond to mechanical stimuli to mediate the changes in bone growth and bone remodeling. As osteoid deposition occurs, the osteoblast is eventually surrounded by osteoid matrix and then becomes an osteocyte.

Osteoblast processes communicate with other osteoblasts and with osteocytes by gap junctions.

2- Osteocyte

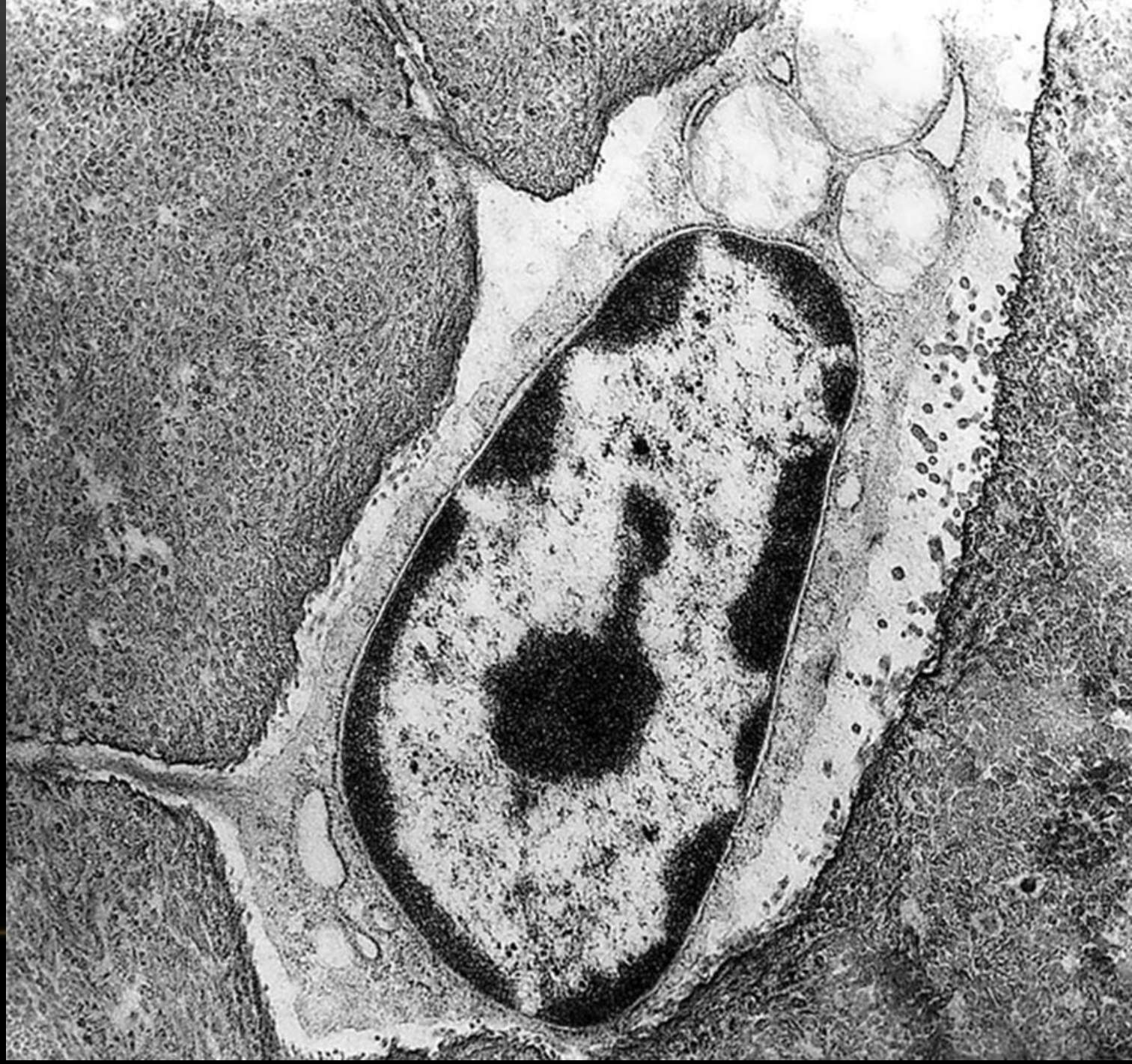
Smaller than osteoblasts, almond shaped, with fewer rER, and condensed Golgi.

Situated inside lacuna, one cell in each lacuna.

Cells have processes (filopodial) passing through canaliculi in the thin surrounding matrix.

Adjacent cells make contact through gap junctions in the processes.

Activrly involved in maintenance of matrix.



3- Osteoclast

Large, branched motile, multinucleated cells.

Secretes collagenase and some enzymes.

Activity is controlled by cytokines and hormones.

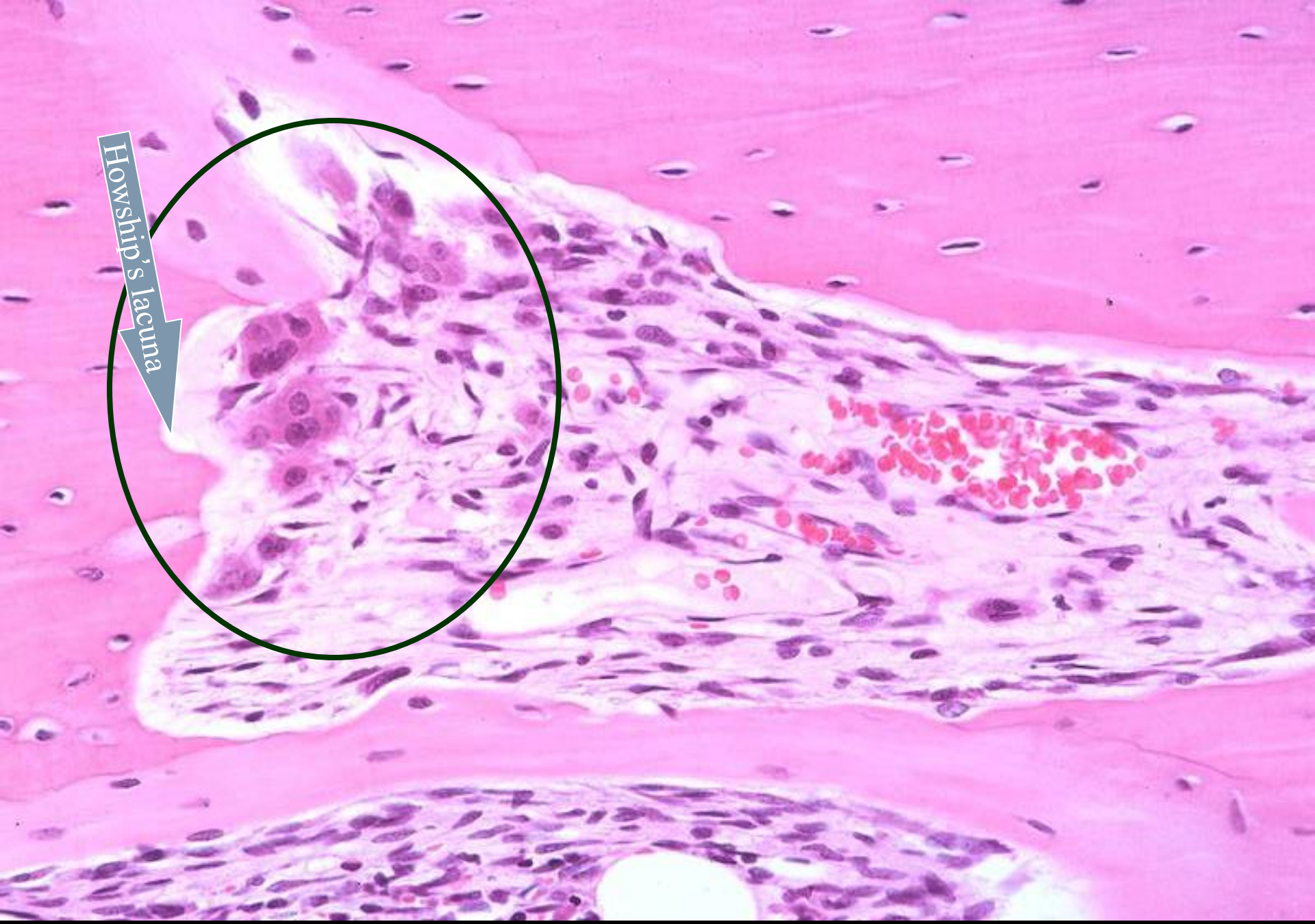
Has receptors for calcitonin.

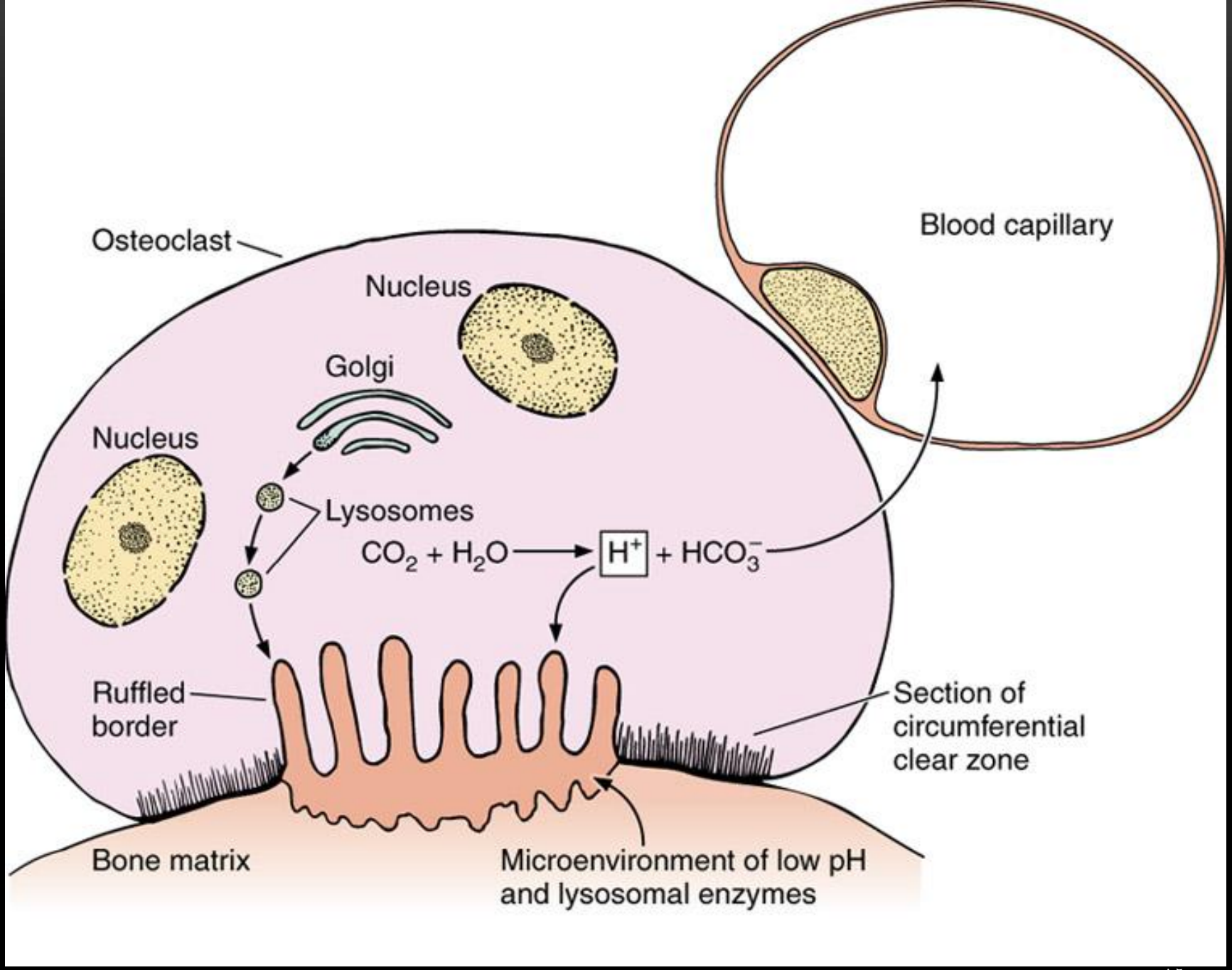
When active, they lie in Howship's lacuna:

- Enzymatically etched depression on the surface.

The surface facing the matrix shows irregular foldings; **ruffled border**.

- The ruffled border is surrounded by **clear zone**:
  - Clear of organelles, rich in actin.
  - Creates microvironment for bone resorption.


Howship's lacuna


Blood capillary
Osteoclast
Nucleus
Golgi
Nucleus
Lysosomes
$CO_2 + H_2O \rightarrow H^+ + HCO_3^-$
Ruffled border
Section of circumferential clear zone
Bone matrix
Microenvironment of low pH and lysosomal enzymes

BONE MATRIX:

Inorganic matter = ~ 50% of dry weight.

- Most of ions are: **Ca^{+2}** & **PO^{-4}**
- Others: Mg, K, HCO3, Citrate.
- Ca^{+2} & PO^{-4} form $C_{10}(PO_4)_6(OH)_2$ = ***hydroxyapatite***
  - Surface ions are hydrated ⇨hydration shell
    - Facilitates fluid exchange

Organic matter = collagen type I & ground substance.

Periosteum:

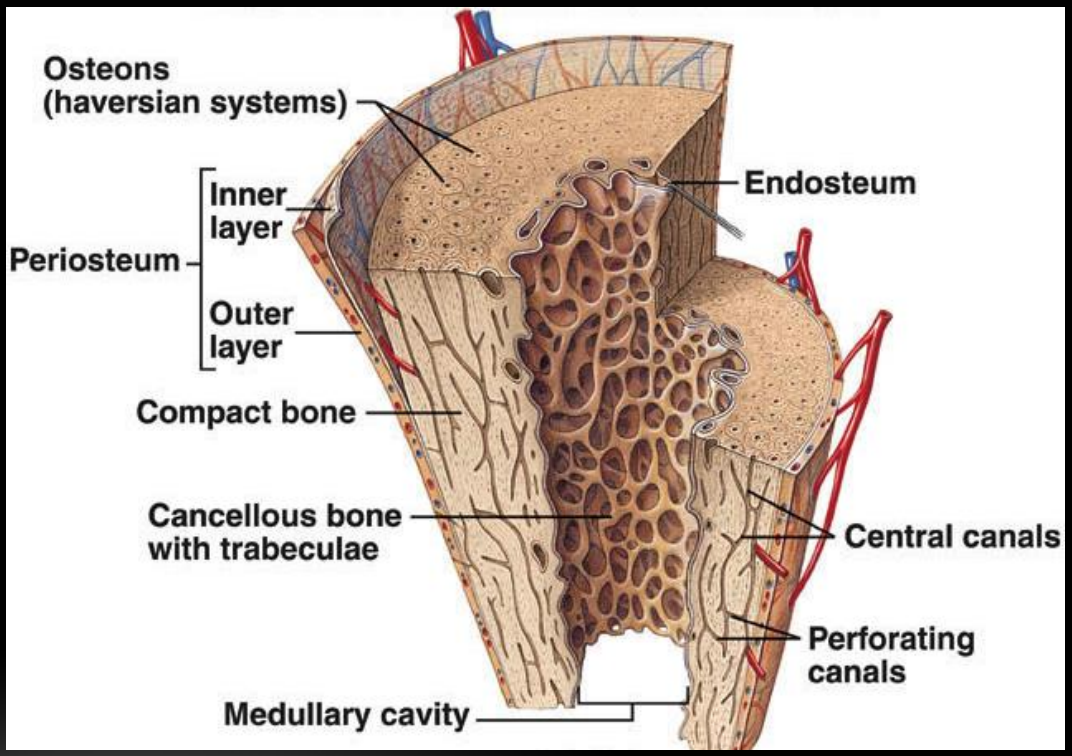
Outer fibrous

- Some fibers penetrate through bone substance ⇨Sharpey's fibers.

Inner cellular contains osteoprogenitor cells.

Functions:

- Nutrition of bone.
- Supplying osteoblasts from progenitor cells.

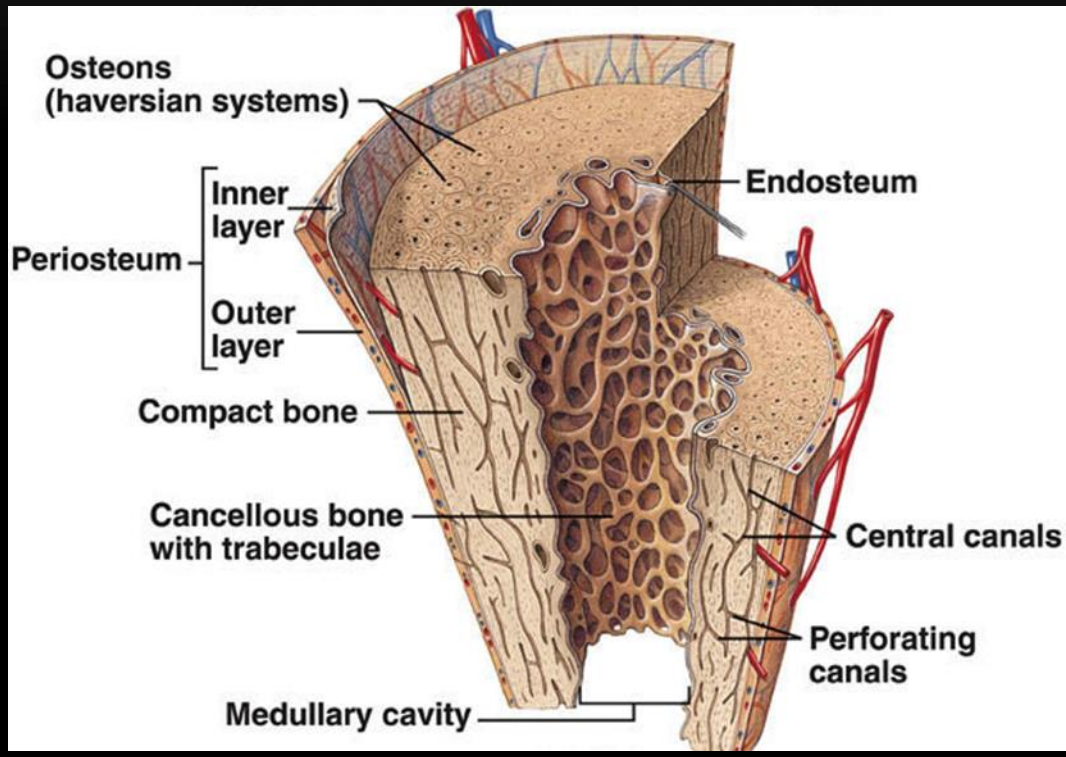


Endosteum:

Lines the internal cavity of the bone.

Composed of a single layer of flat osteoprogenitor cells.

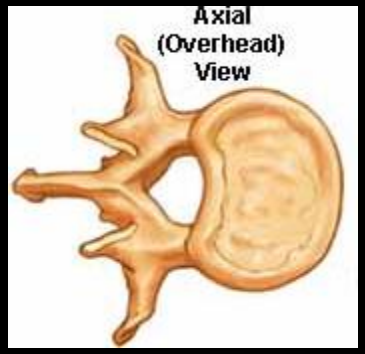
Has the same functions as periosteum.

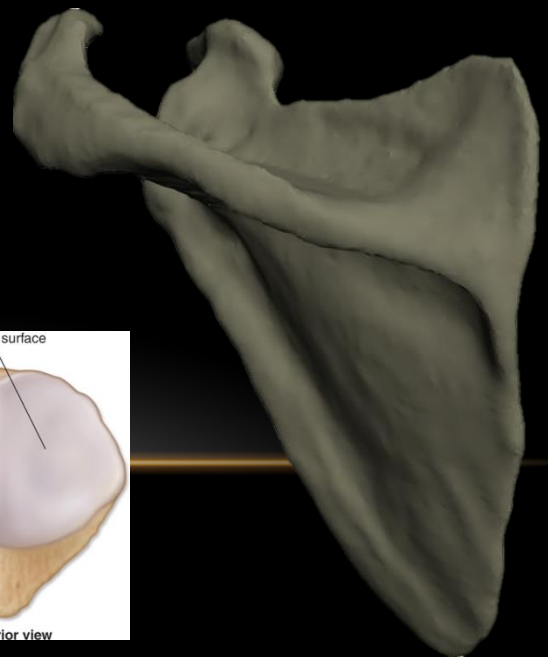


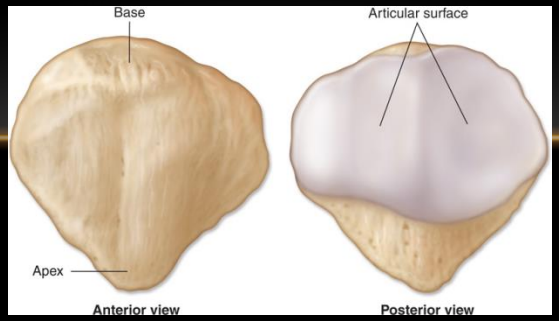
Types of Bone:

Anatomical:

- Long
- Short
- Flat
- Irregular
- Sesamoid

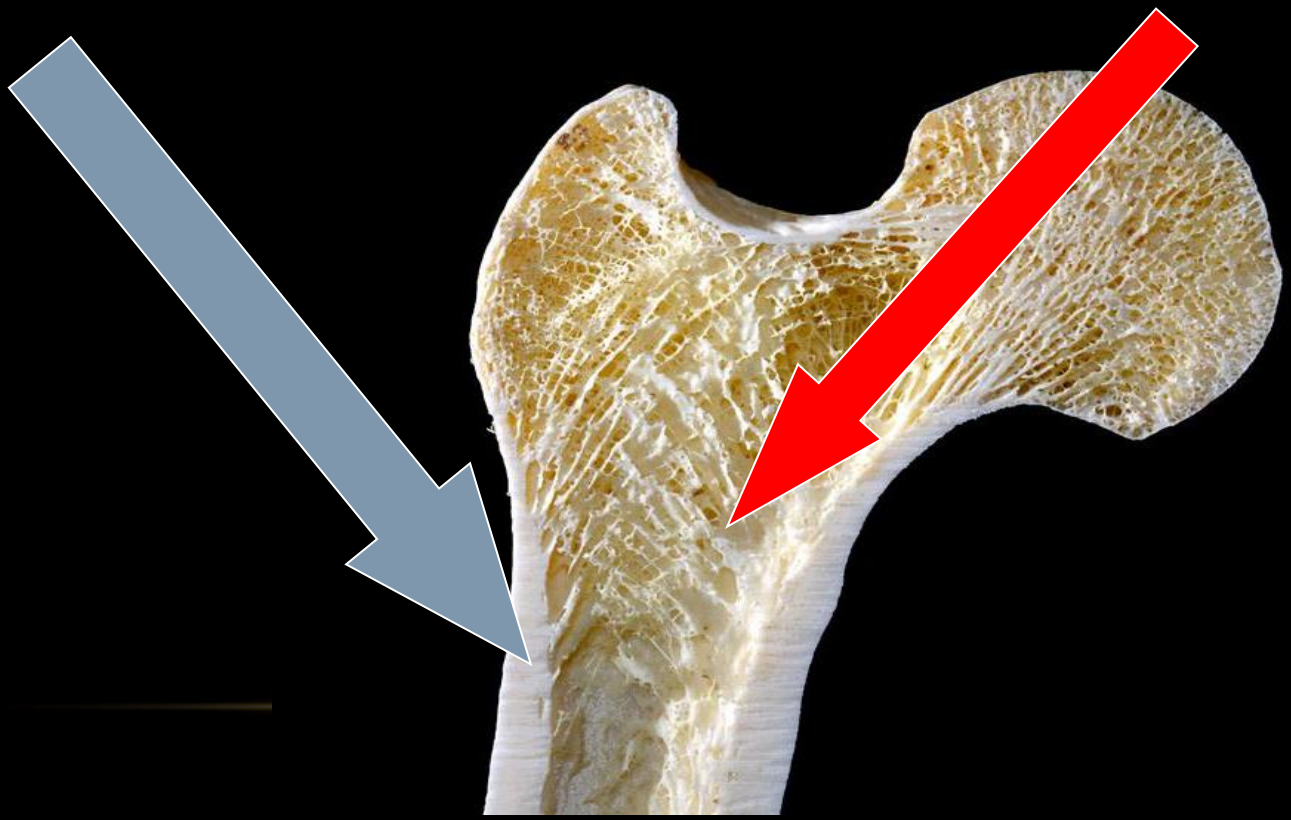






TYPES OF BONES:

- **Gross observation**:
  - Compact
  - Cancellous (spongy)



Histological Classification

Primary = Immature = Woven

Secondary = Mature = lamellar

Primary Bone Tissue:

- Temporary, replaced by secondary bone.
- Collagen fibres are irregularly arranged.
- Lower mineral content.
- Easily penetrated by x-ray.
- Number of osteocytes is relatively high.

Secondary Bone Tissue

Collagen fibers arranged in parallel or concentric lamellae.

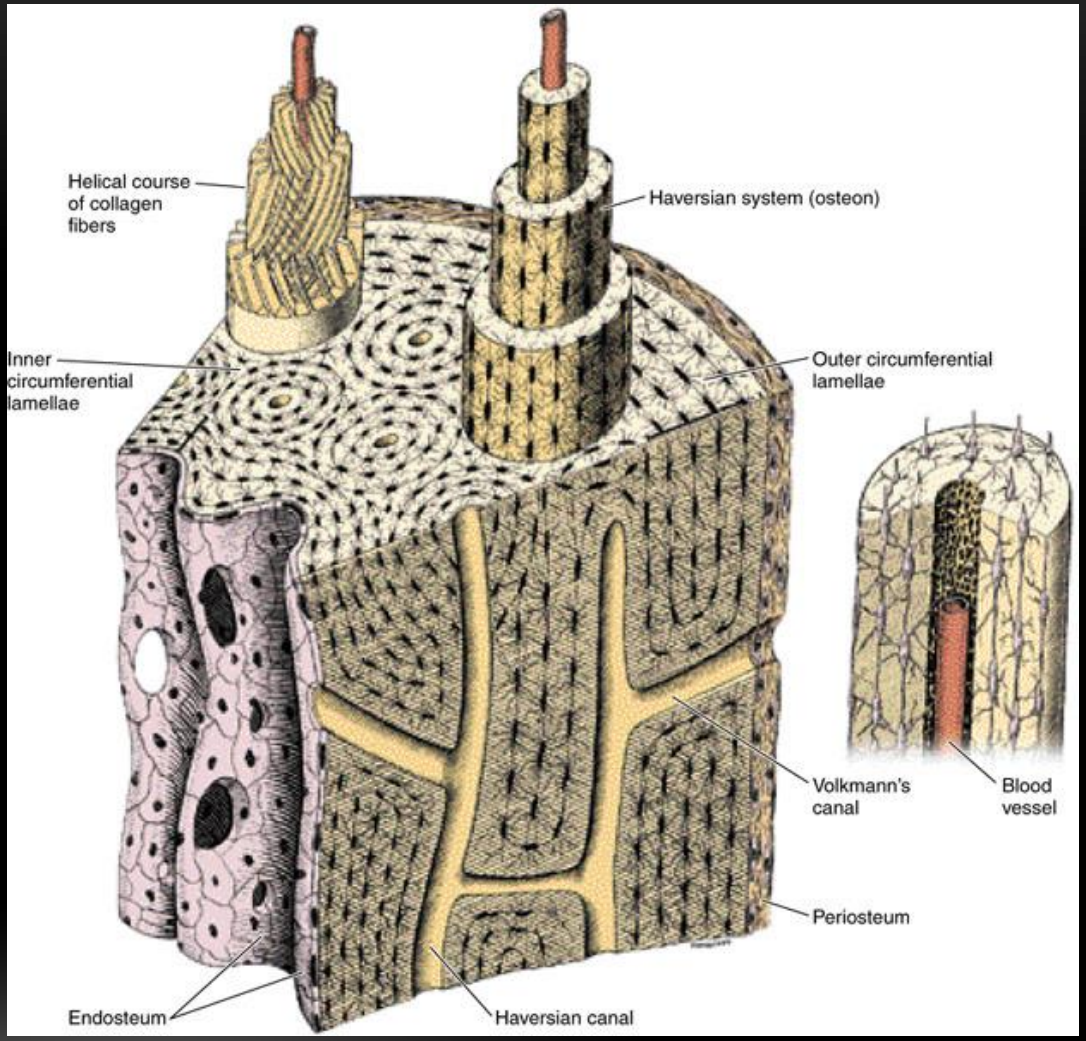
Concentric lamella surround a canal containing vessels and nerves = ***haversian system*** = ***osteon***.

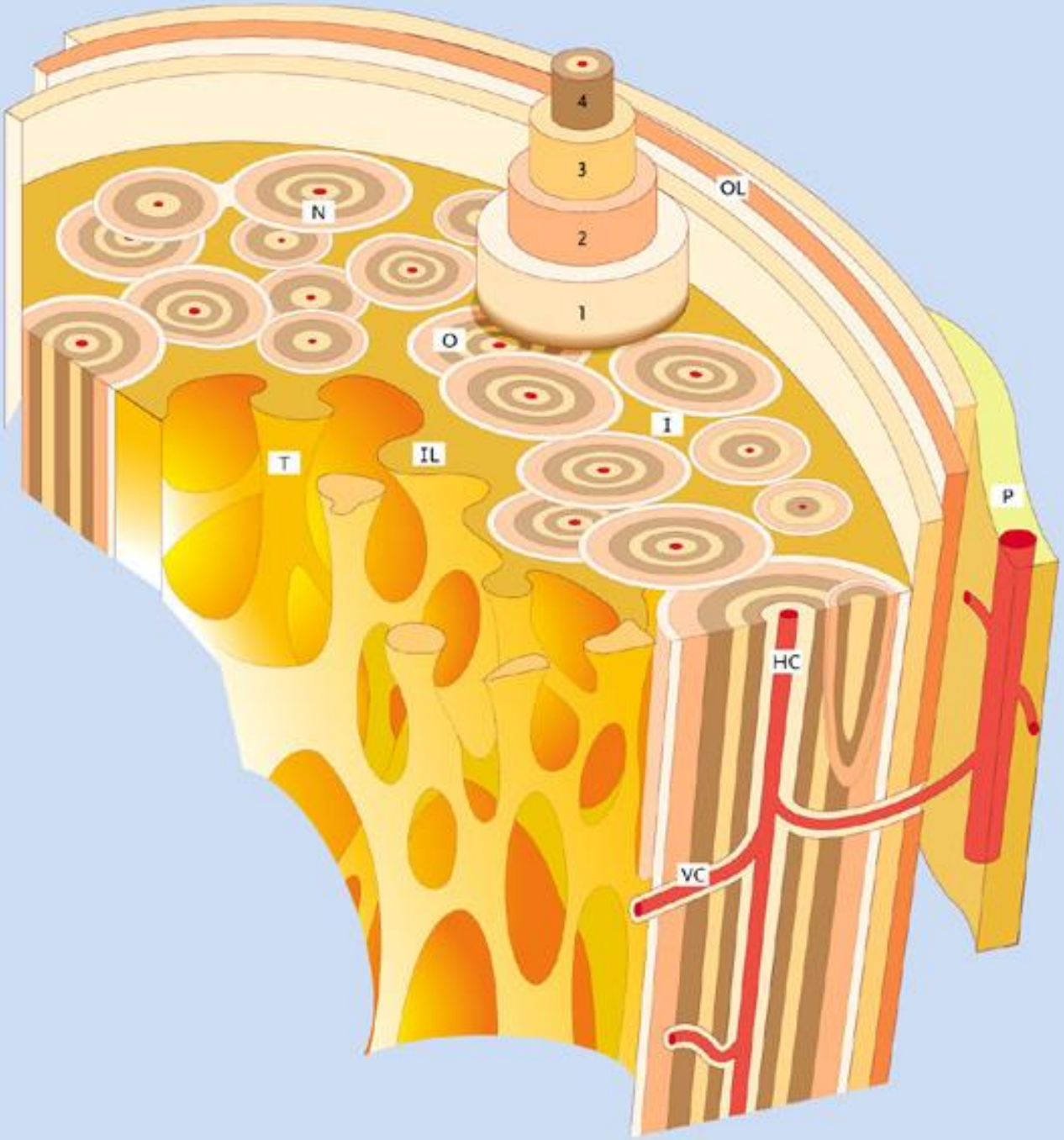
Osteons are lined with endosteum.

Osteons are connected together and to the endo-or-periosteum by Volkmann's canal.

Types of lamella:

- Outer circumferential
- Concentric
- Inner circumferential
- interstitial




4
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OSSIFICATION

Intramembranous

Endochondral

Intramembranous Ossification

- Takes place in mesenchymal condensations.
- The source of most flat bones.
- Contributes to the growth of short bones and thickening of long bones.
- The starting point is the ***primary ossification centre***.
- Osteoblasts become encapsulated in lacuna.

Several points of ossification occur and fuse forming spongy bone.

The spaces between the fusing islands are penetrated by blood vessels.

Ossification centers grow radially and eventually fuse.

Endochondral Ossification

- Responsible for the formation of short and long bones.
- Formation of the bone collar.
- Primary ossification center.
- Secondary ossification centre.

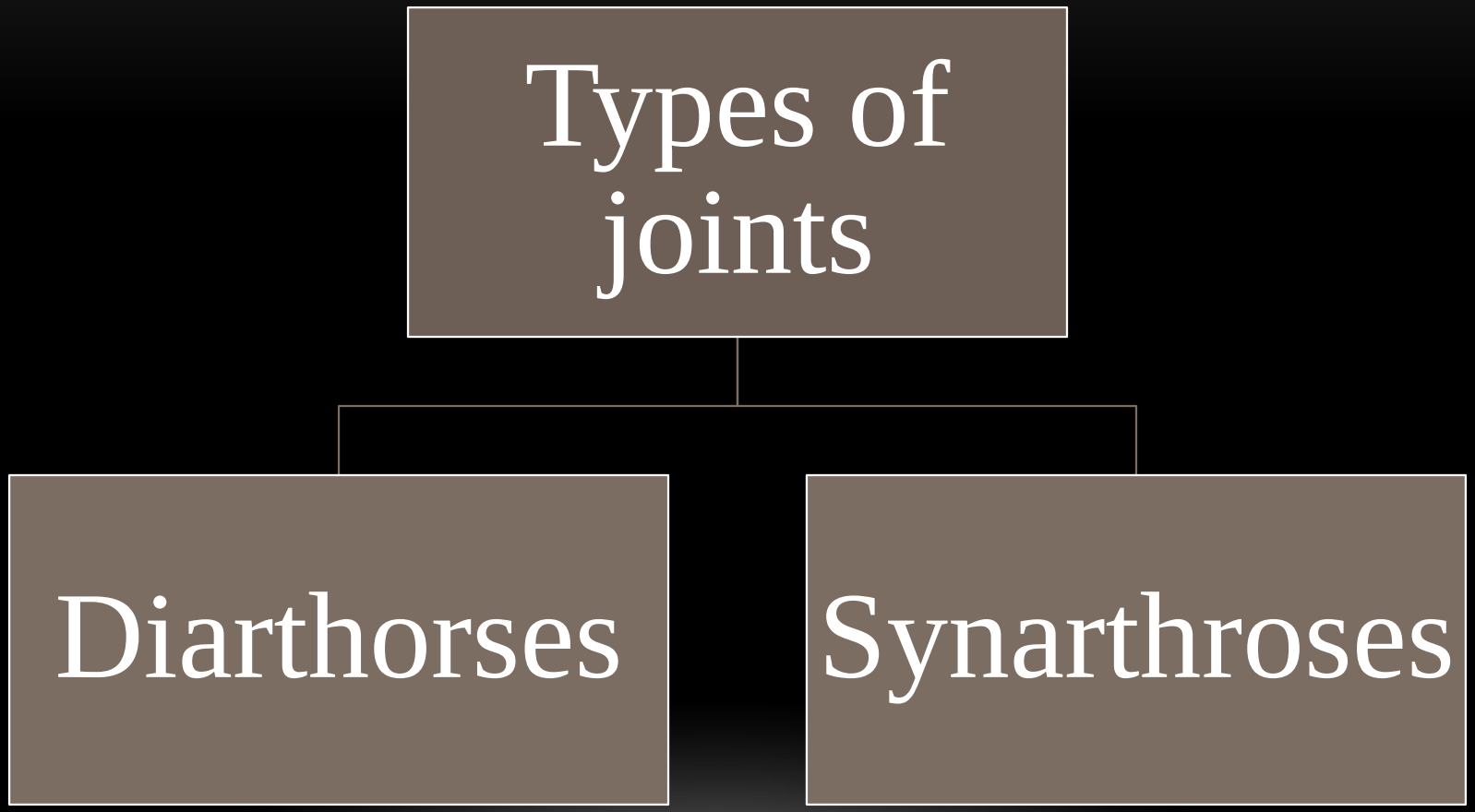
Calcification:

Begins by deposition of Ca^{+2} salts on collagen fibrils.

Aided by alkaline phosphatase.

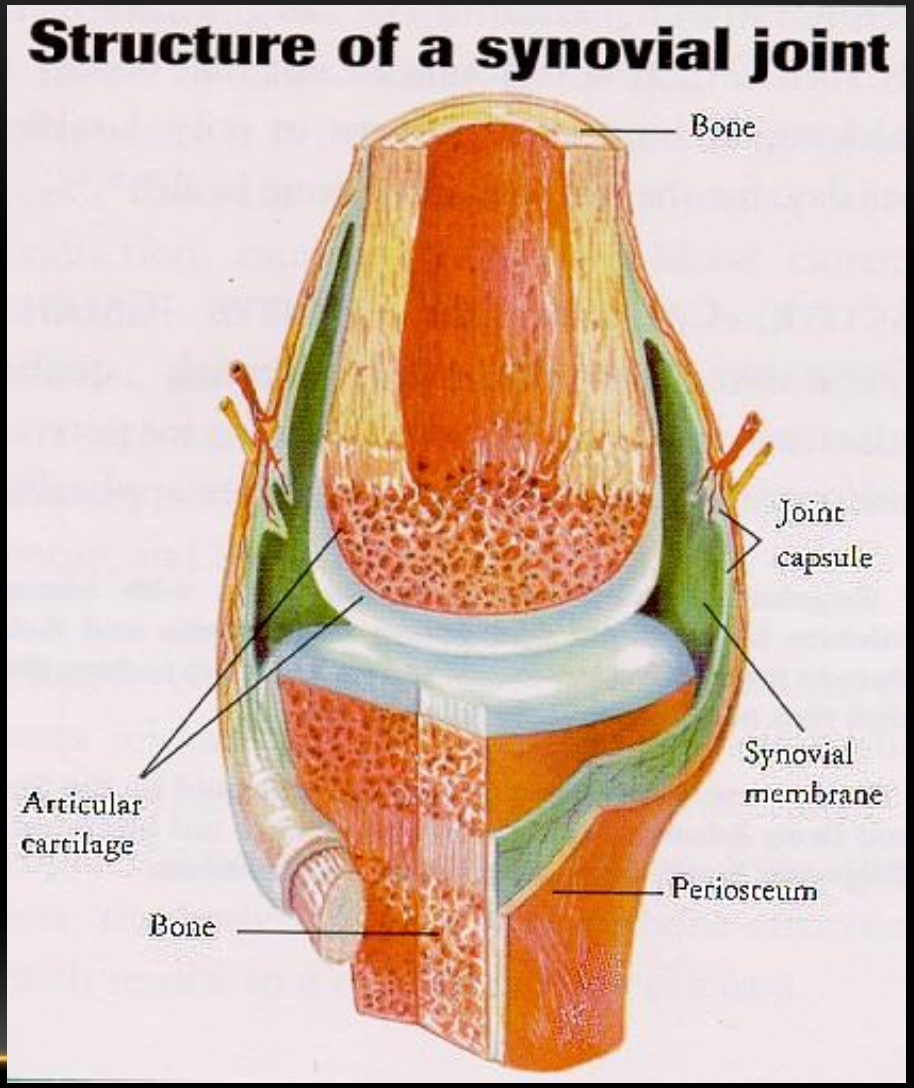
Deposition is accelerated by the ability of osteoblasts to concentrate Ca^{+2} salts intracellularly.

Joints

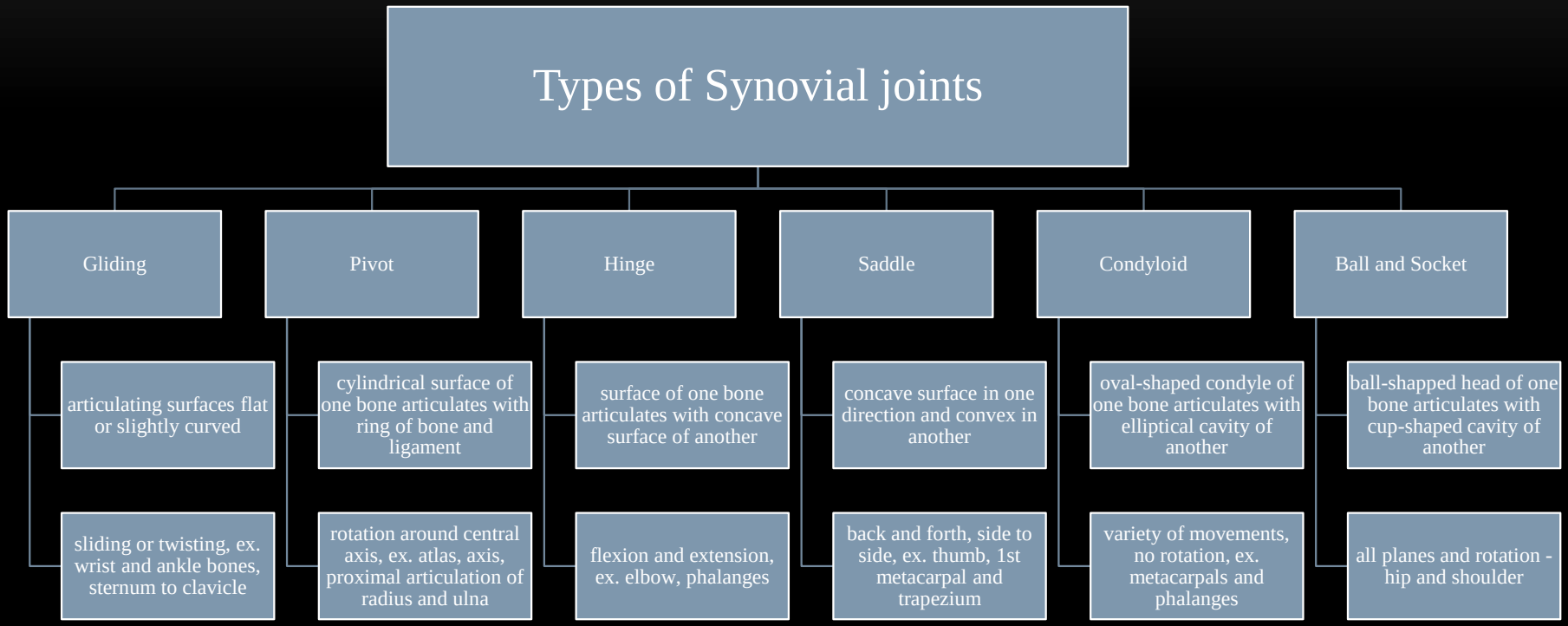

Types of joints
Diarthorses
Synarthroses

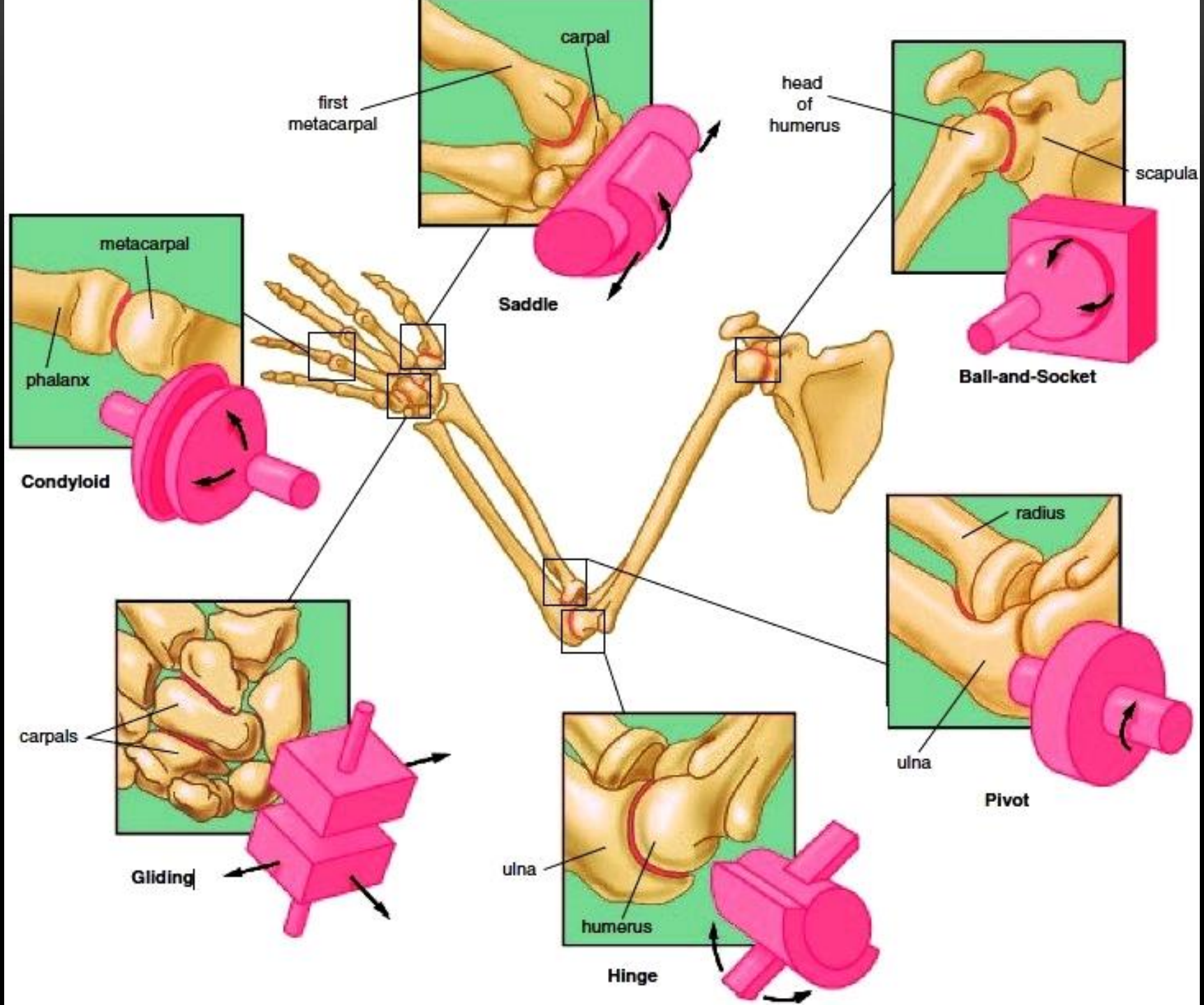
Diarthroses: permits free movement.

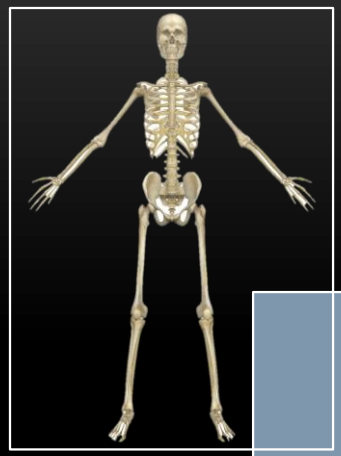
- Lined by synovial membrane (CT).
- Synovial fluid is derived from plasma.
- Capsule and ligaments align the bones.



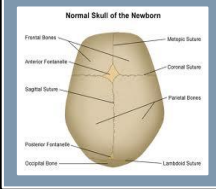
Types of Synovial joints




carpal
first metacarpal
Saddle
head of humerus
scapula
Ball-and-Socket
metacarpal
phalanx
Condyloid
radius
ulna
Pivot
carpals
Gliding
ulna
humerus
Hinge

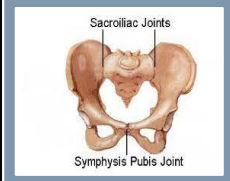


Synarthroses: limited or no movement.



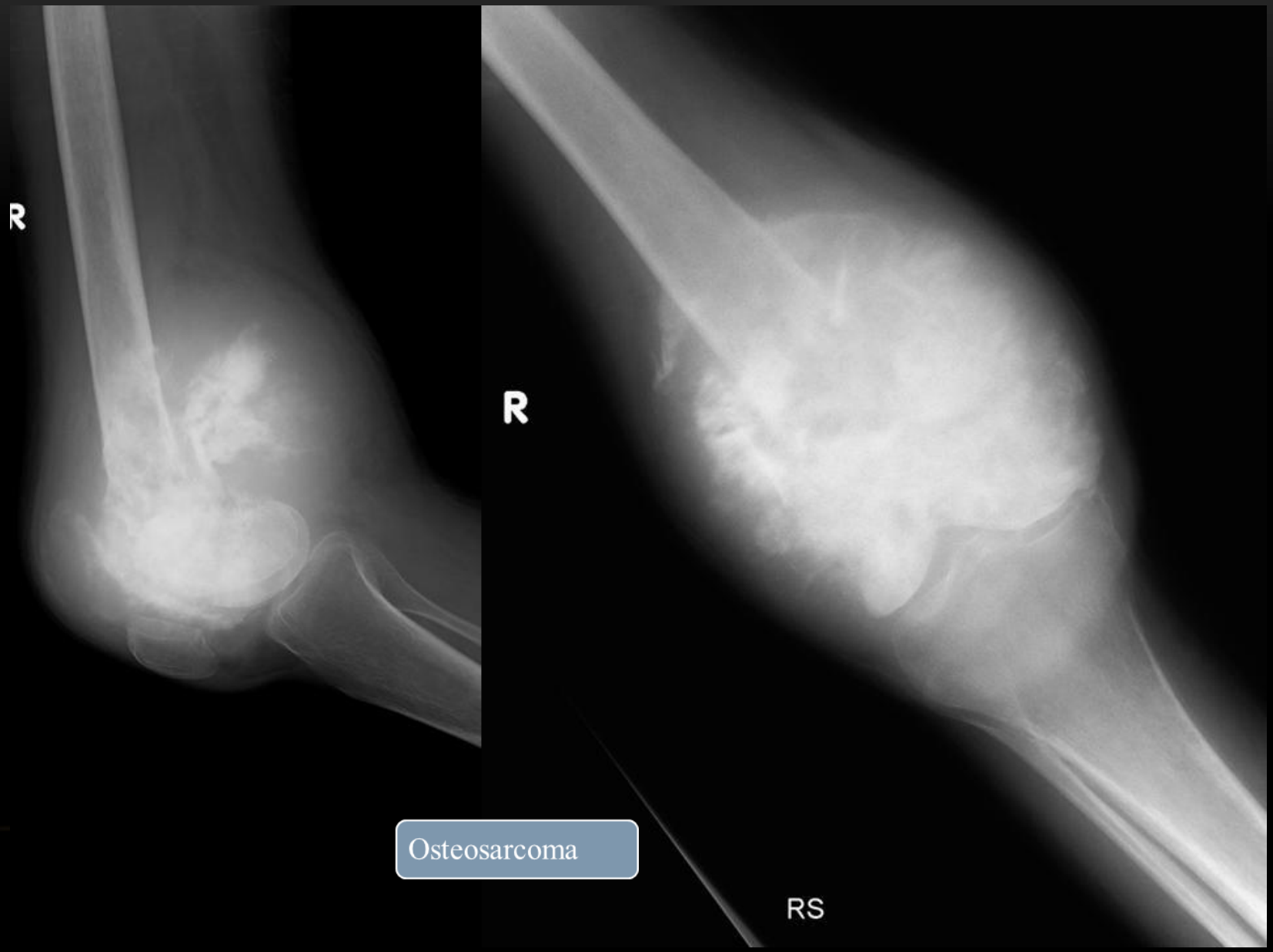
Synostosis: sutures.

Chondrosis: growth plates.



Syndesmosis: symphysis.

Clinical Problems



Osteosarcoma

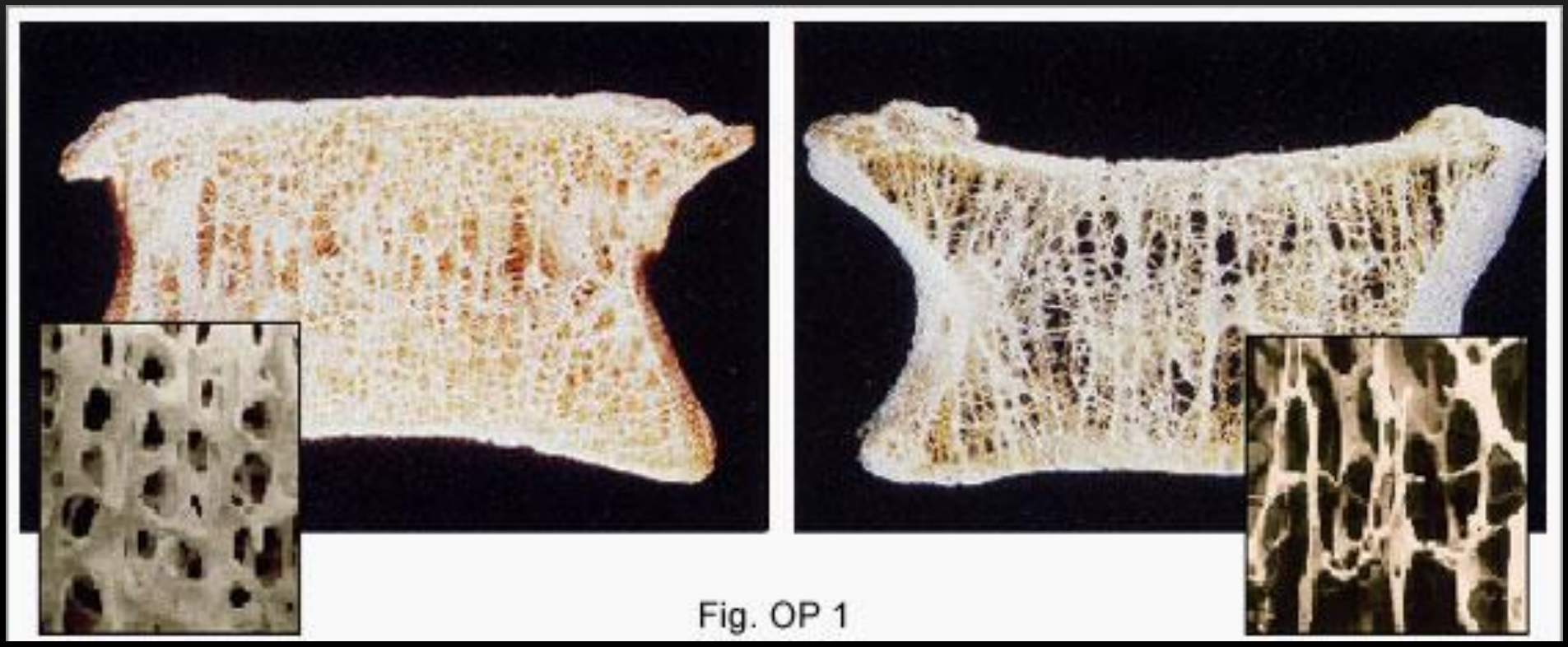


Fig. OP 1

Osteoporosis

Tetracycline deposition

Osteogenesis imperfects “Brittle bone disease”

Rickets

Osteoma

Rheumatoid arthritis