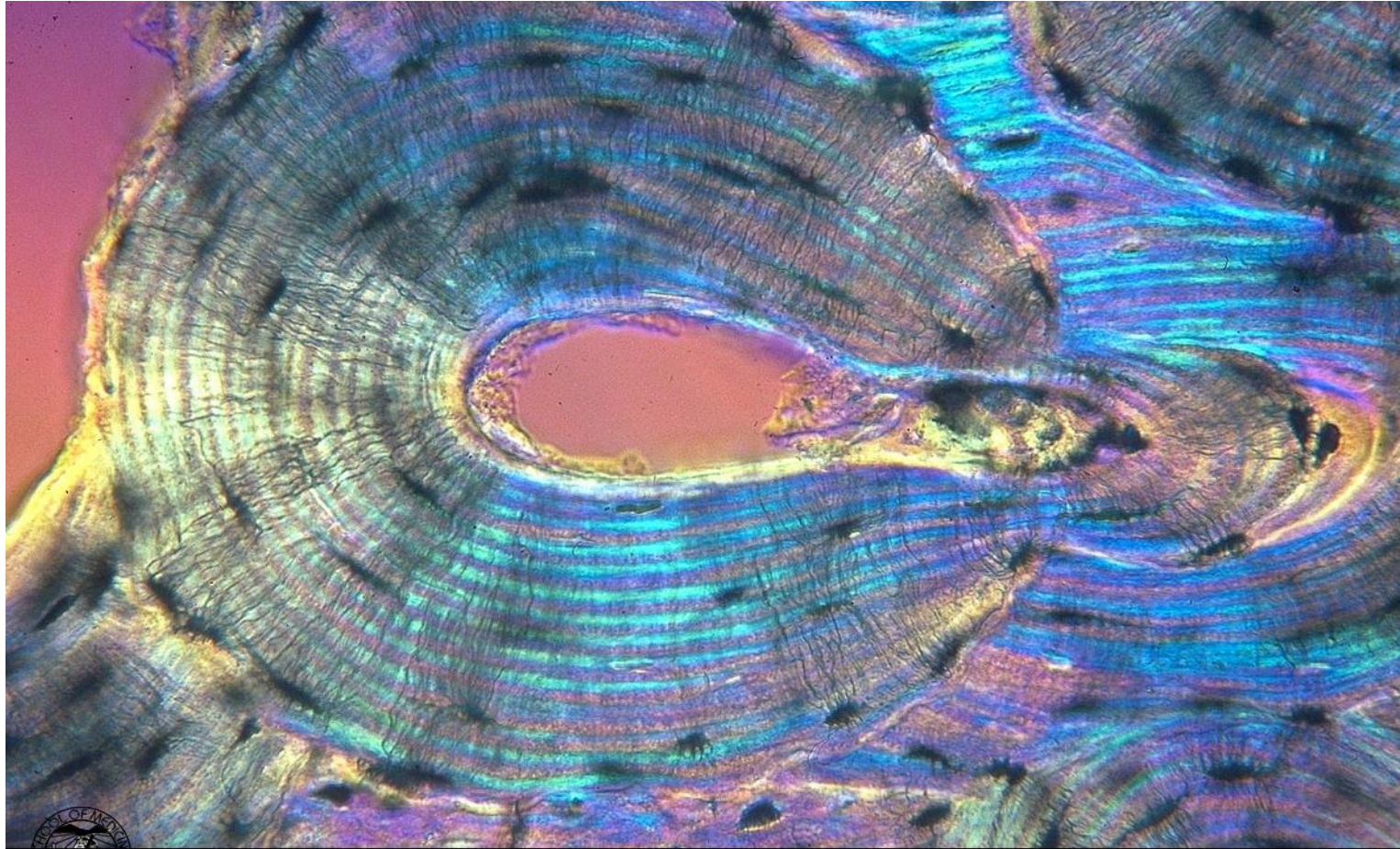


Bone

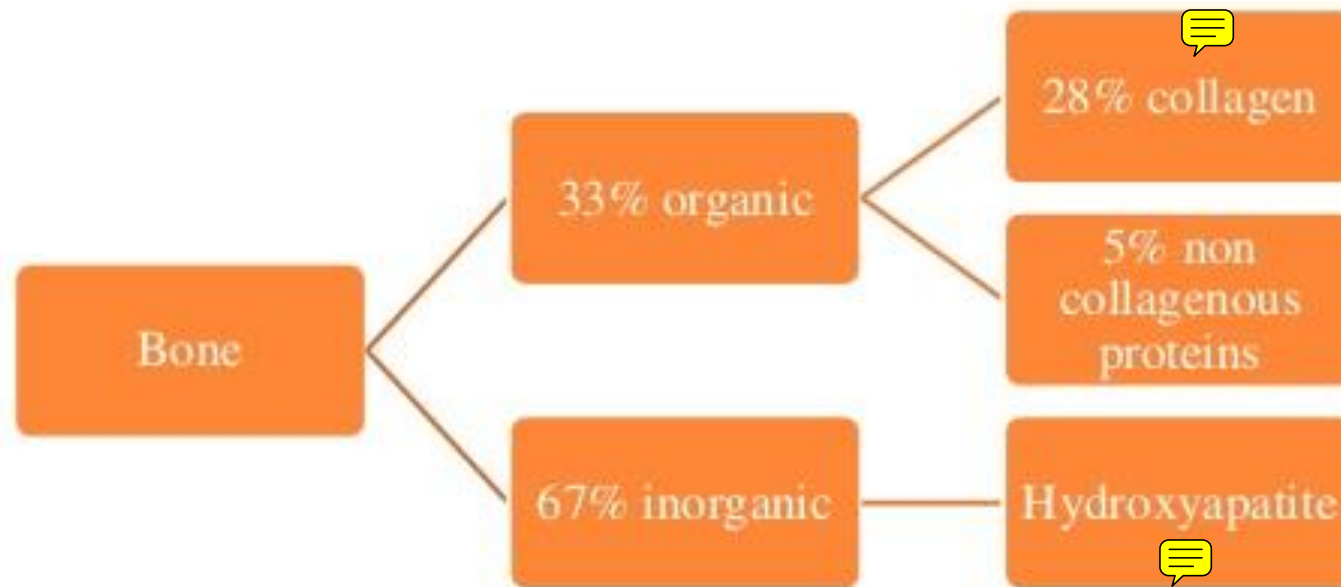


Functions of Bone

- ▣ **Primary structural framework** for **support** and **protection** of the organs of the body, ex. skull around brain
- ▣ Serve as **levers** for the muscles attached to them, thereby multiplying the force of the muscles to attain movement.
- ▣ Acts as a **reservoir** for calcium and phosphorous. Released or stored in a controlled fashion to maintain constant concentrations in body fluid.

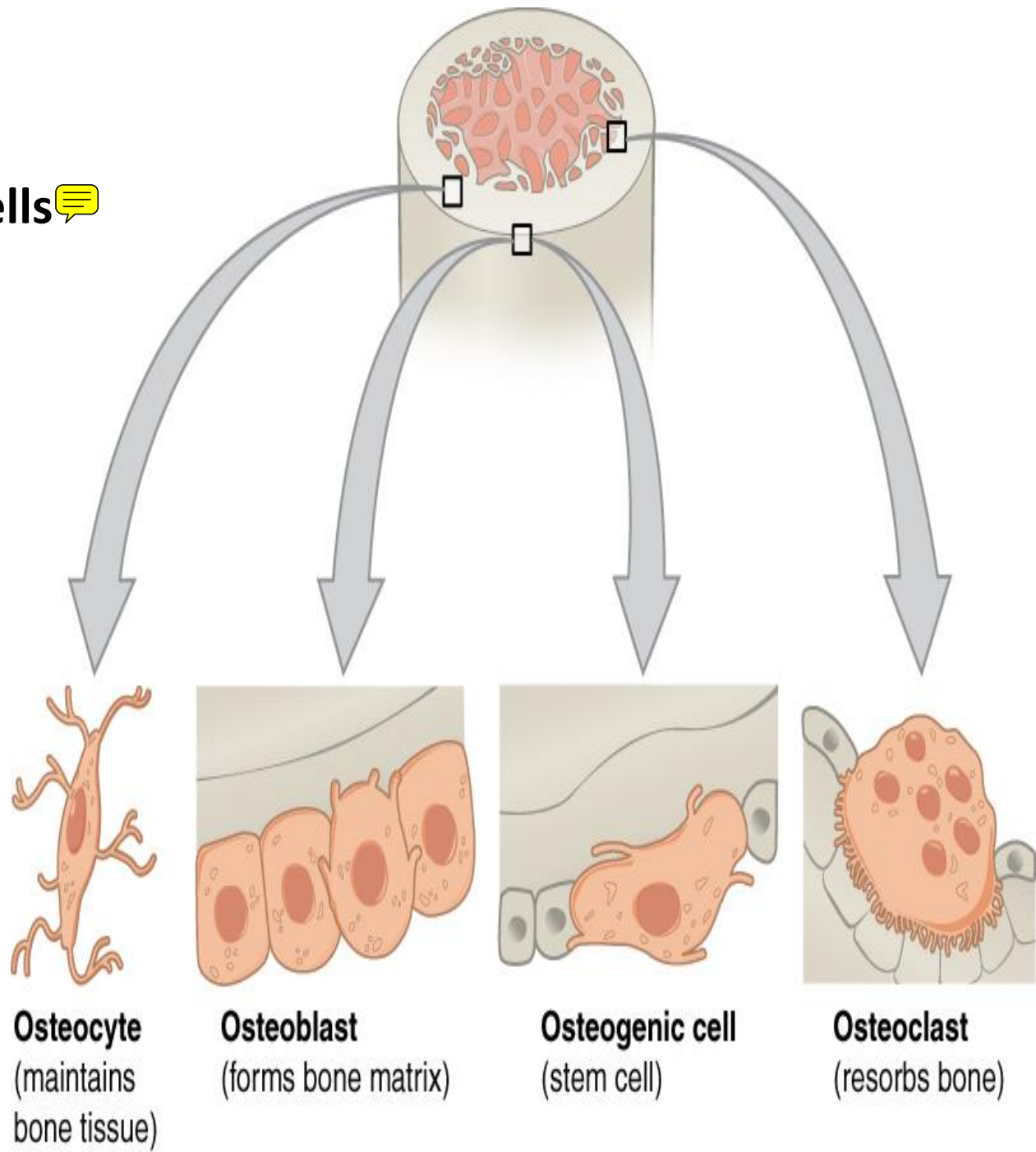
- Contain a central cavity, the **marrow cavity**, which houses the **bone marrow**, a hemopoietic organ. Bone marrow gives rise to blood cells and platelets (Hematopoiesis).
- Fat stored in marrow cavities.

COMPOSITION OF BONE:



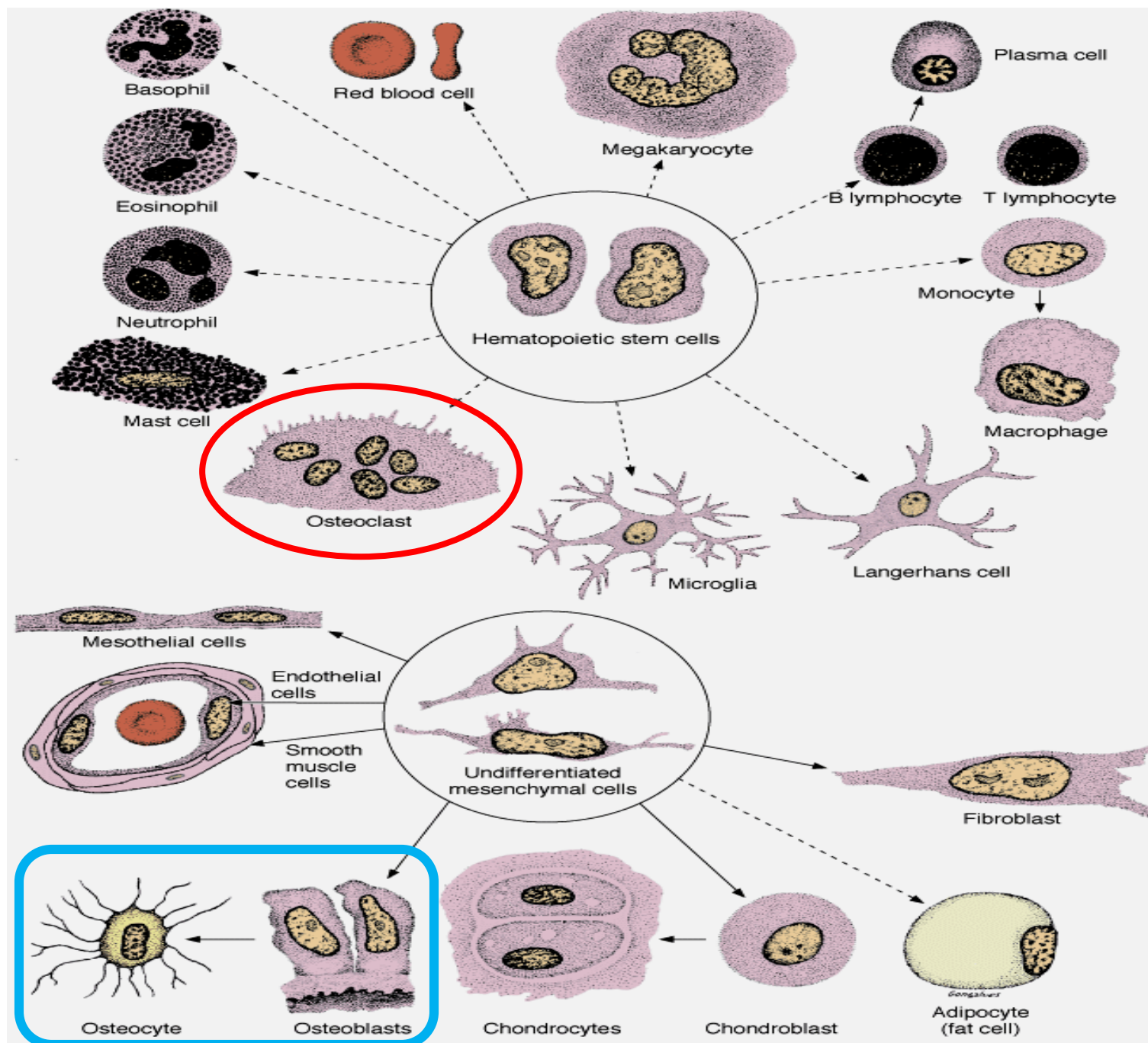
Cells of Bone

- **Osteoprogenitor cells**
- **Osteoblasts**
- **Osteocytes**
- **Osteoclasts**





Osteoprogenitor Cells

- Derived from **embryonic mesenchymal cells**
- Located in the inner cellular layer of the periosteum and in the endosteum.
- Have the potential to differentiate into osteoblasts.



OSTEOBLASTS

- ▣ 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.
- ▣  **Inactive** osteoblasts are flat cells that cover the bone surface. These cells resemble **bone lining cells** in both the endosteum and periosteum. 
- ▣ Secrete alkaline phosphatase (ALP) and osteocalcin, their circulating levels are used clinically as markers of osteoblast activity.

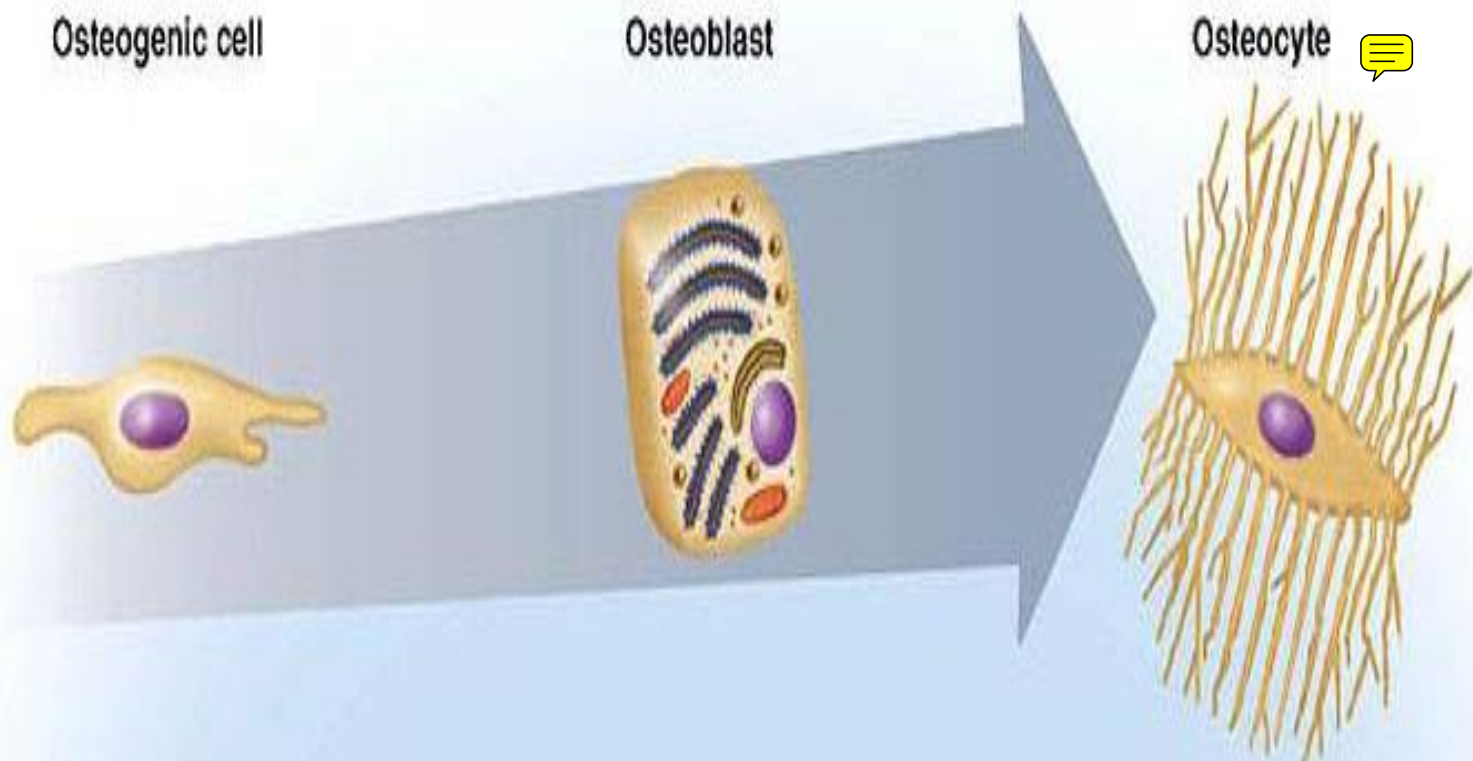
- **The osteoblast is also responsible for the calcification of bone matrix.**

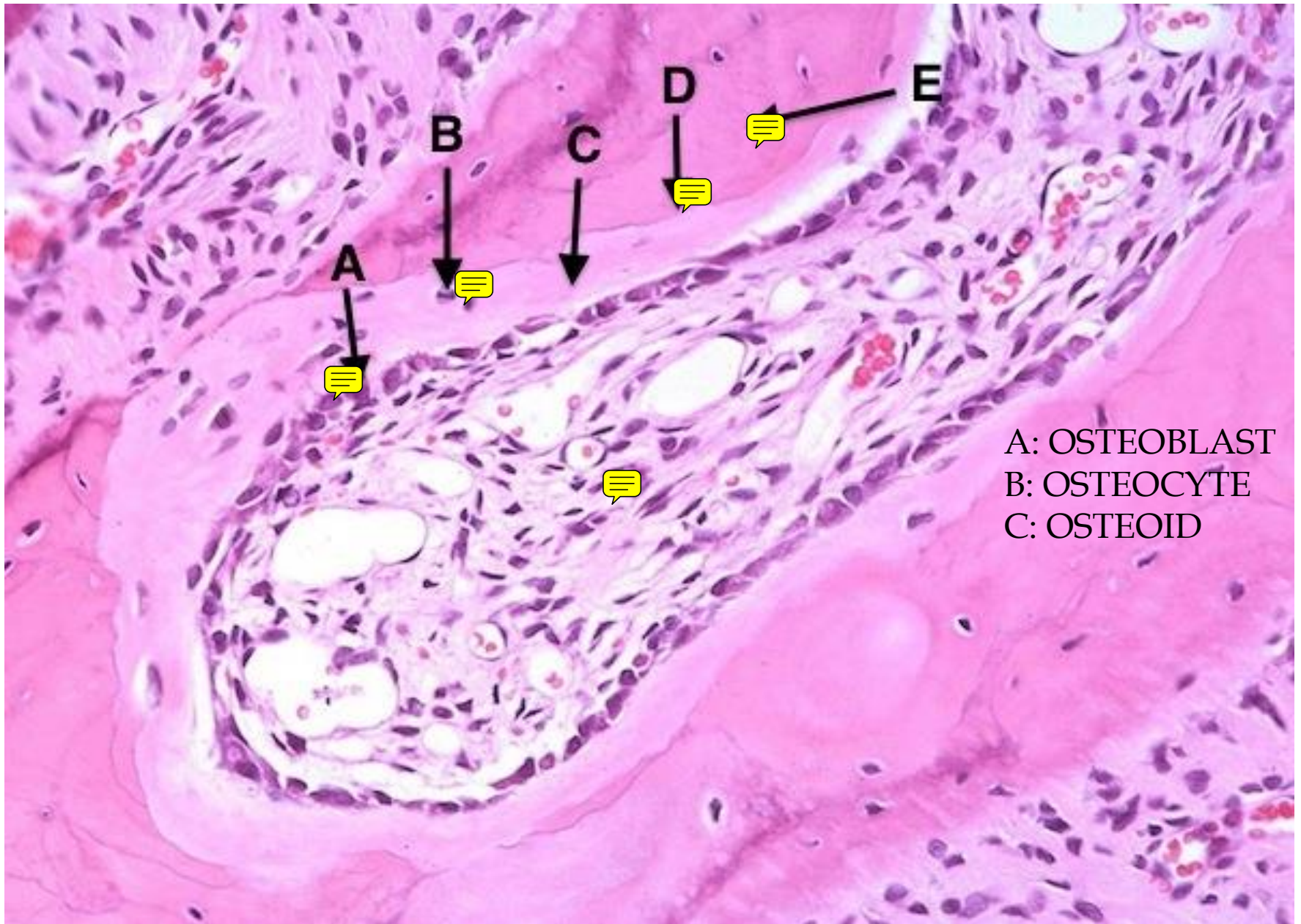
The calcification process appears to be initiated by the osteoblast through the secretion into the matrix the noncollagen proteins (small, vitamin k-dependent poly peptide) **osteocalcin**.

Small, membrane-limited matrix vesicles are rich in ALP and are actively secreted by osteoblast 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, between the osteoblast layer and the preexisting bone surface

- Osteoblast \Rightarrow Osteocyte



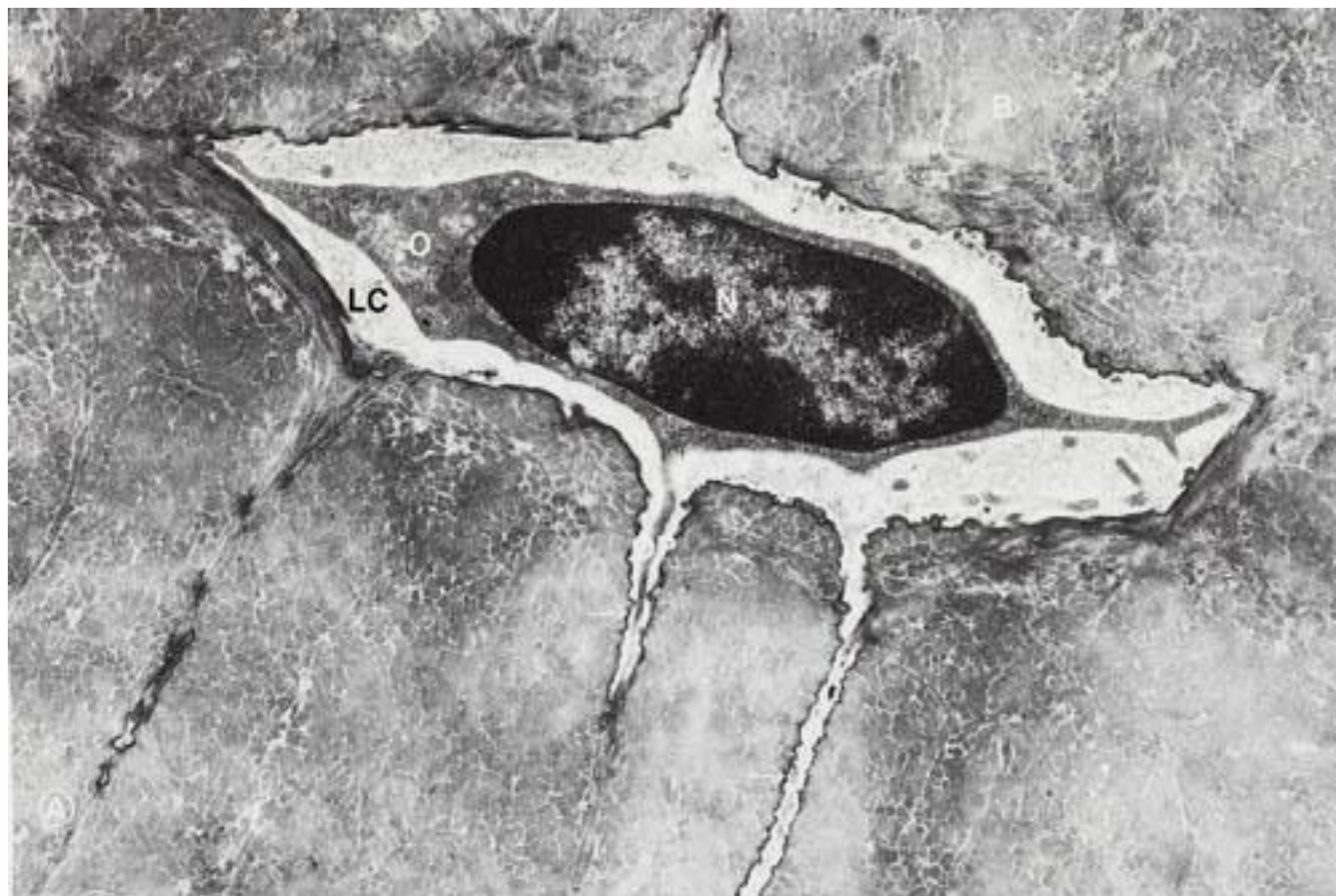


A: OSTEOLAST
B: OSTEOCYTE
C: OSTEOD


OSTEOCYTES

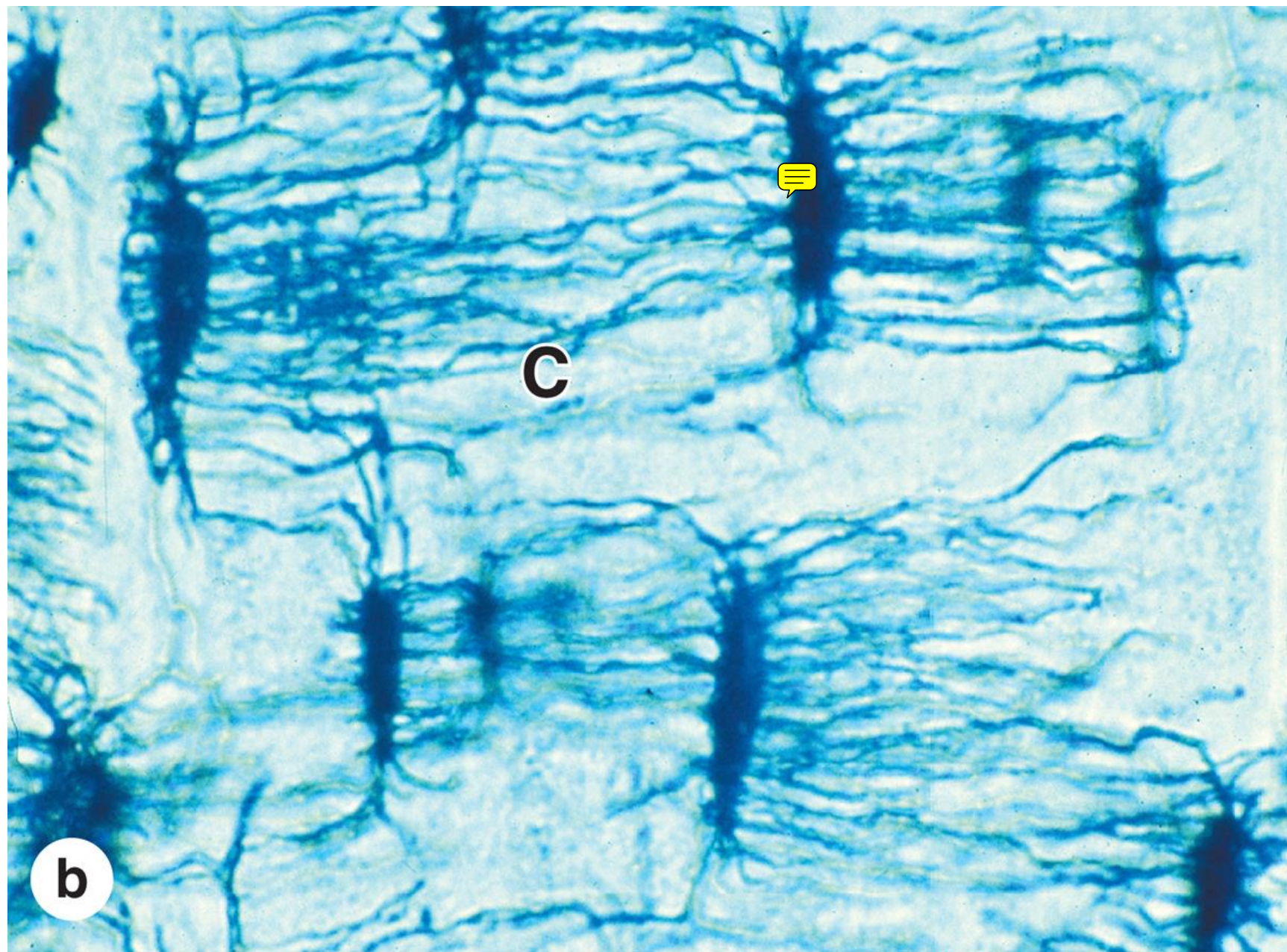
- Mature bone cells derived from osteoblasts that became trapped in their lacunae.
- Situated inside lacuna, one cell in each lacuna.
- Smaller than osteoblasts, almond shaped, with fewer RER, smaller Golgi complexes and more condensed nuclear chromatin.





OSTEOCYTES

- Radiating out in all directions from the lacuna are narrow, tunnel-like spaces (**canaliculi**) that contain cytoplasmic processes of the osteocyte.

- Processes make contact with similar processes of neighboring osteocytes, forming **gap junctions** through which ions and small molecules can move between the cells.



- Canaliculi also contain extracellular fluid carrying nutrients and metabolites that nourish the osteocytes.
- **Osteocytes actively involved in maintenance of matrix.**

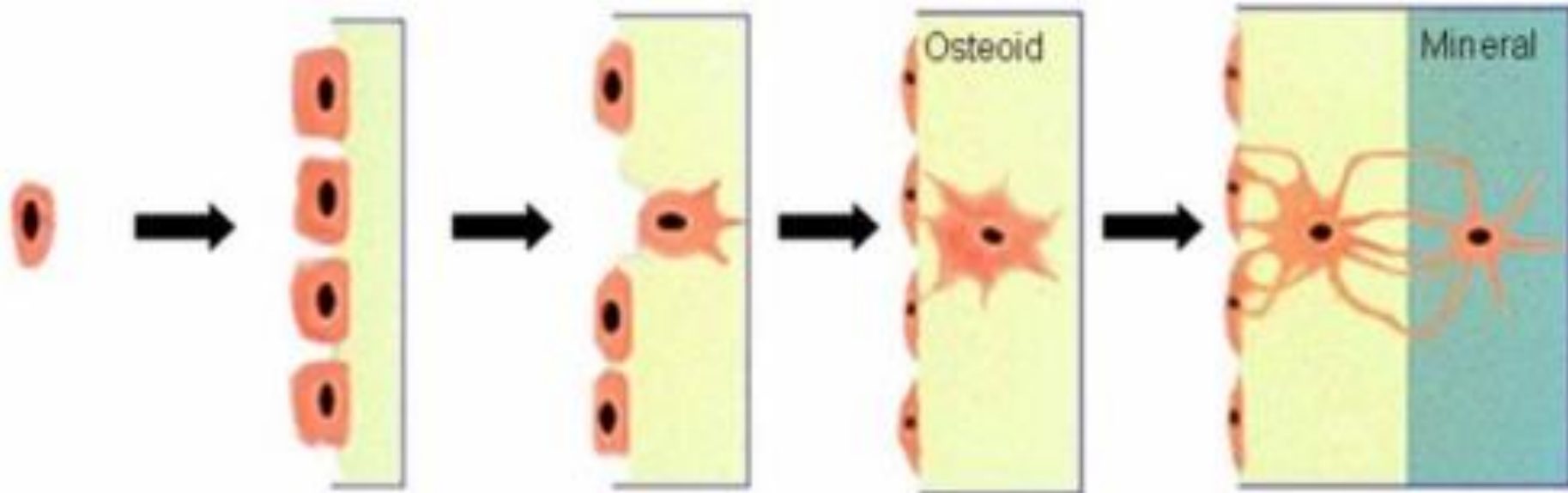
PRE-
OSTEOBLAST

OSTEOBLAST

OSTEOID
OSTEOCYTE

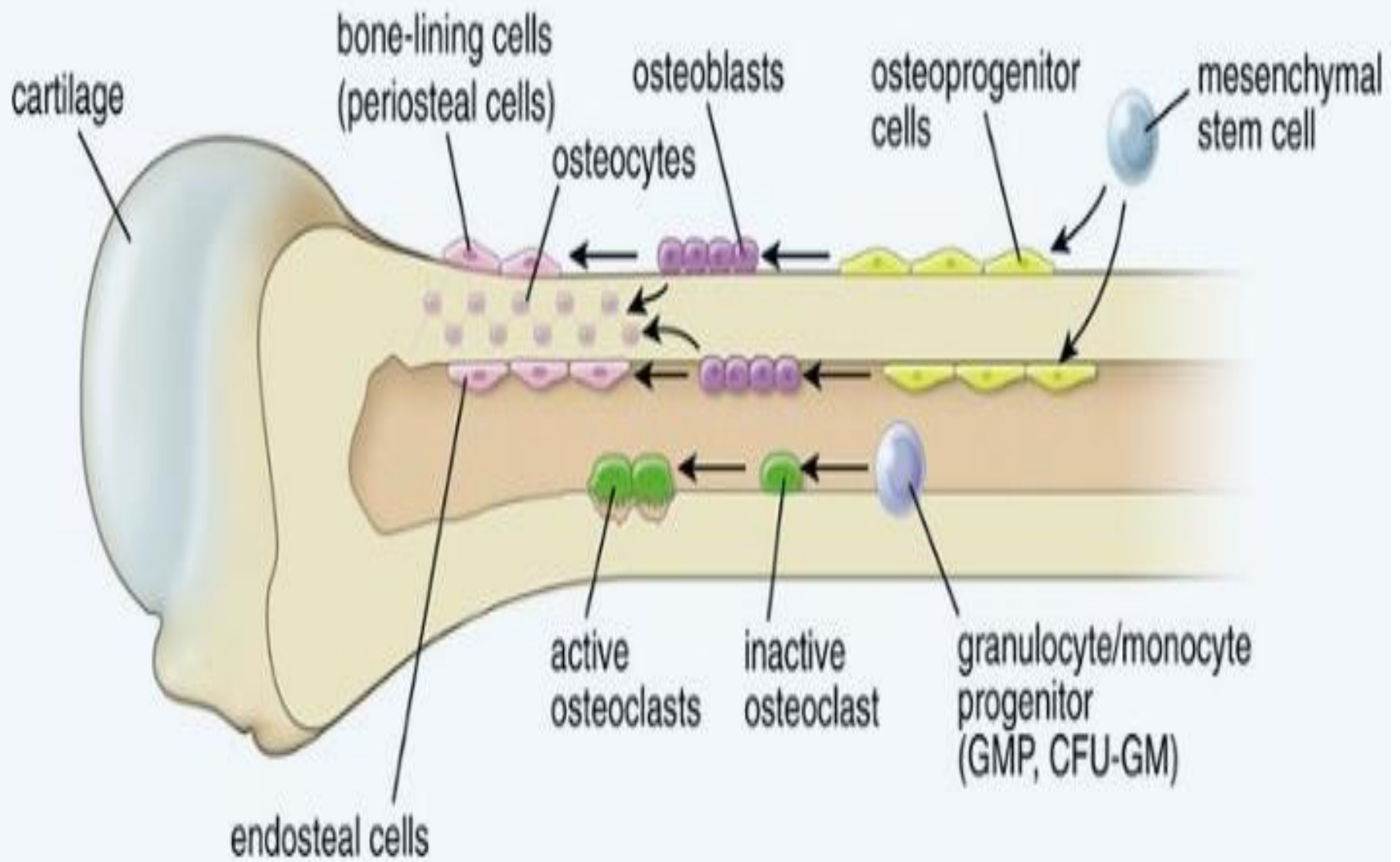
MINERALIZING
OSTEOCYTE

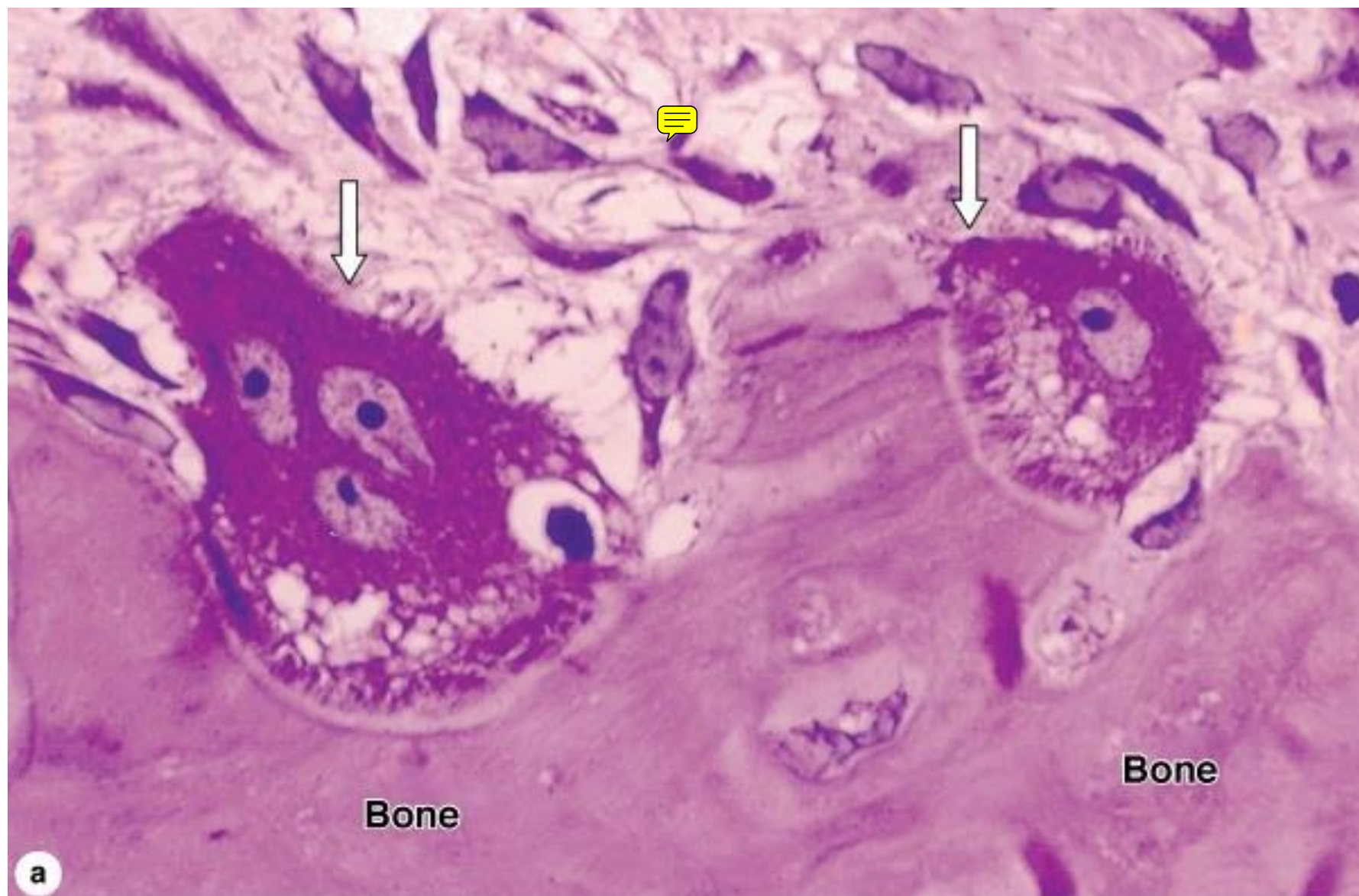
MATURE
OSTEOCYTE



OSTEOCLASTS

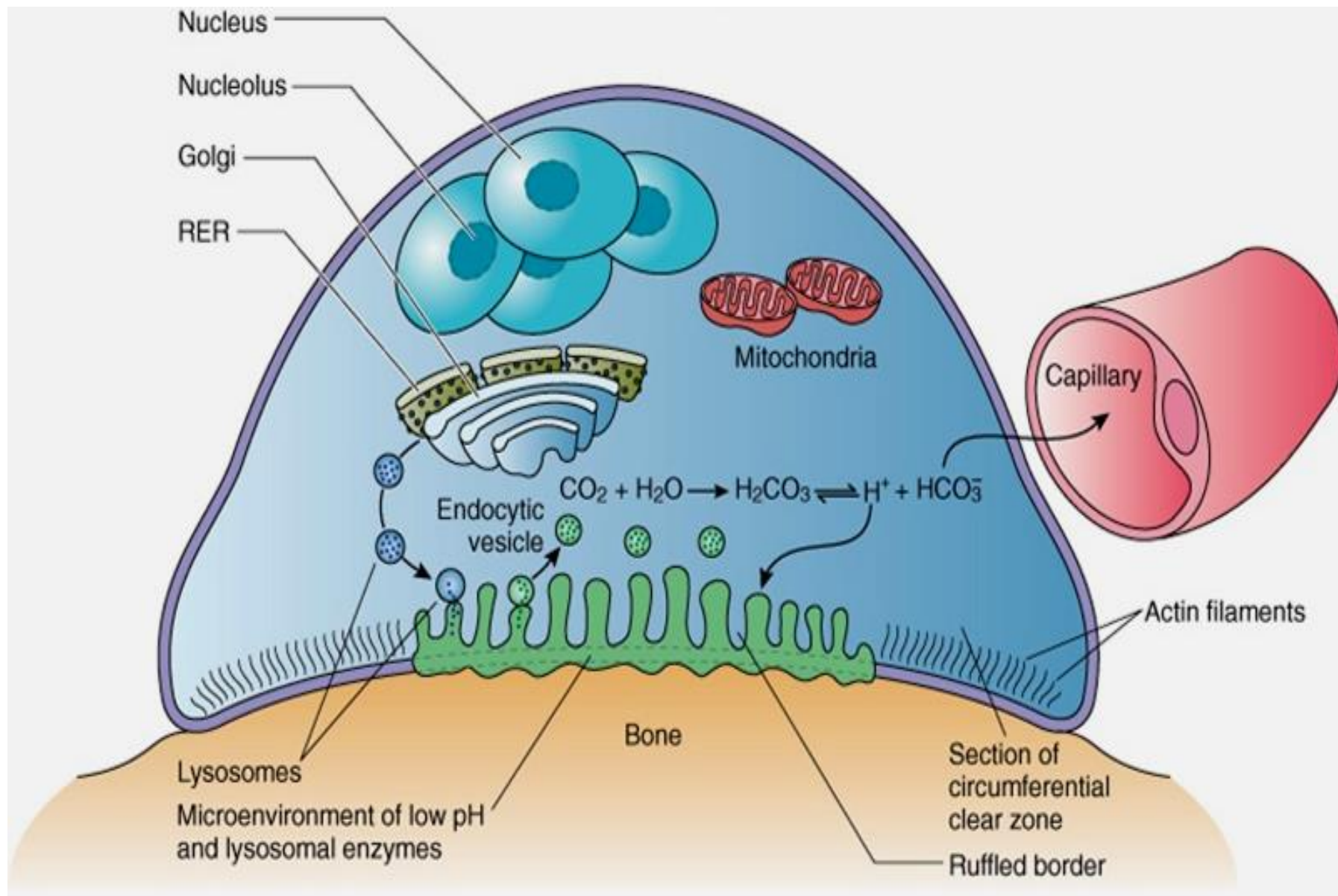
- ▣ Multinucleated cells originating from monocytes.
- ▣ Large, branched motile cells.
- ▣ Play a role in bone resorption and remodeling.
- ▣ Occupy shallow depressions, called **Howship's lacunae**, that identify regions of bone resorption.





- Osteoclast activity is controlled by local signaling factors and hormones:
- Osteoclasts have receptors for:
Calcitonin, a thyroid hormone.
- Osteoblasts activated by parathyroid hormone (PTH) produce M-CSF, RANKL, and other factors that regulate the formation and activity of osteoclasts.

- Secretes collagenase and some enzymes.
- **When active**, they lie in Howship's lacuna (resorption cavities):
 - 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 filaments.
 - Creates microenvironment for bone resorption.



Osteoblast

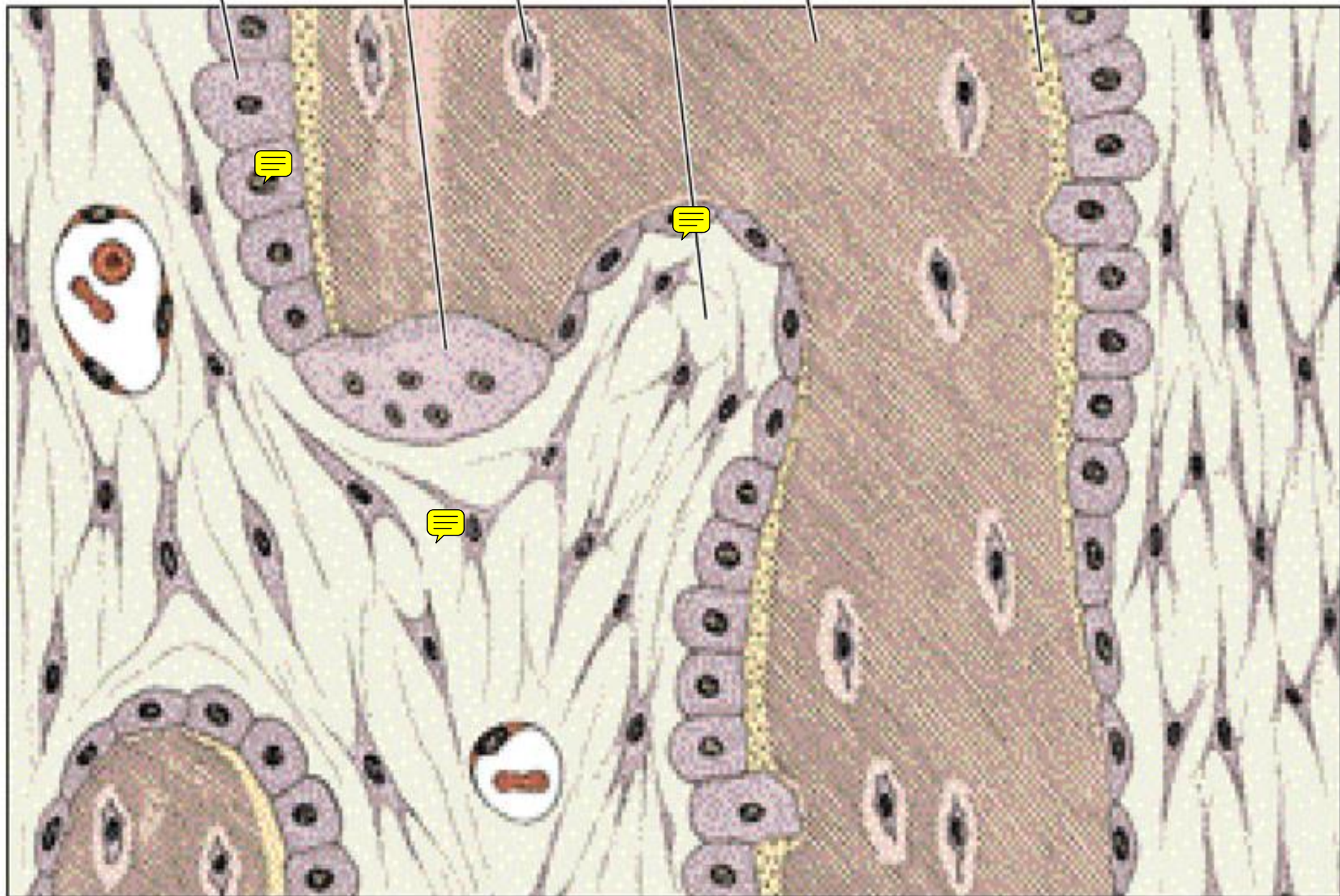
Osteoclast

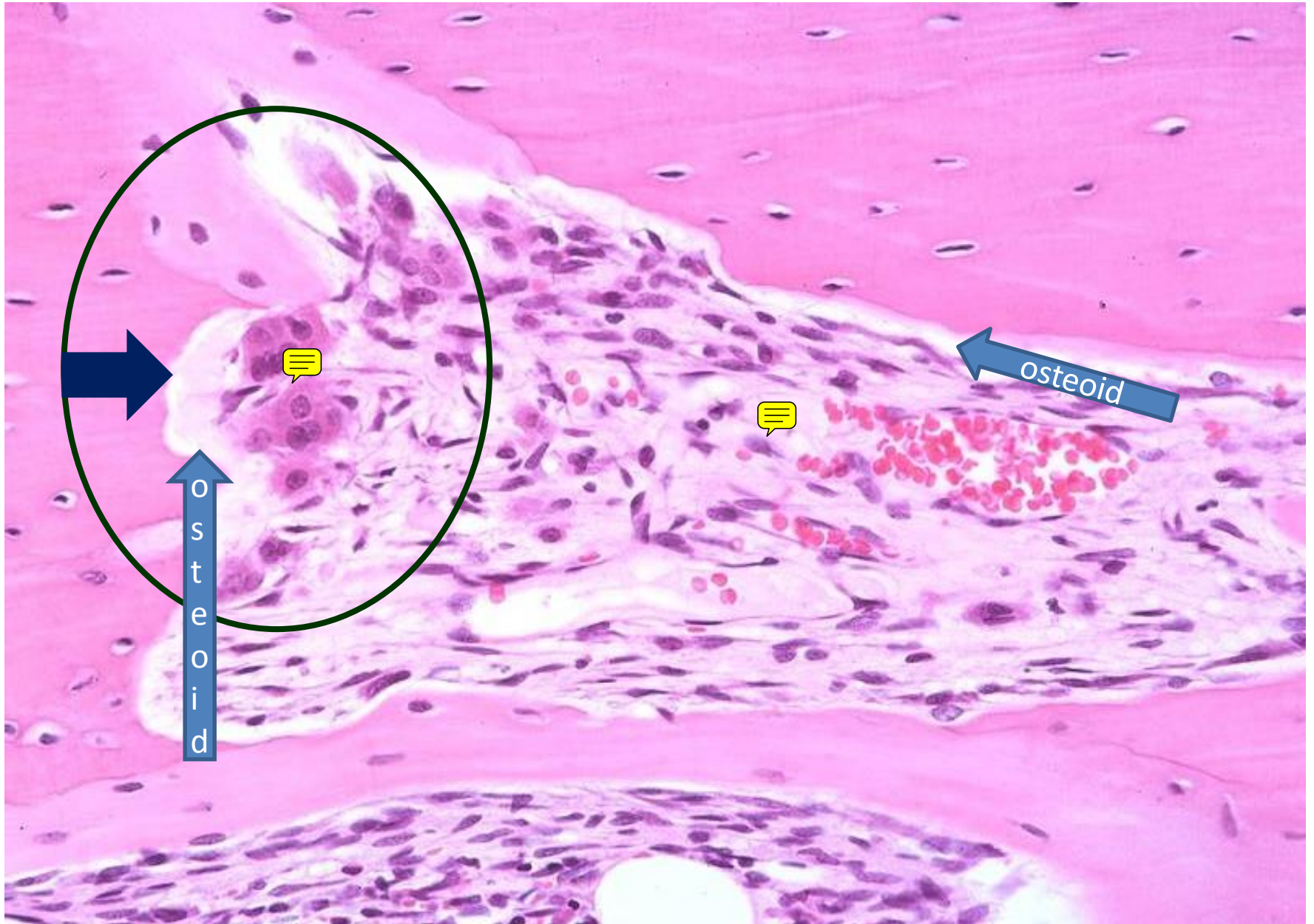
Osteocyte

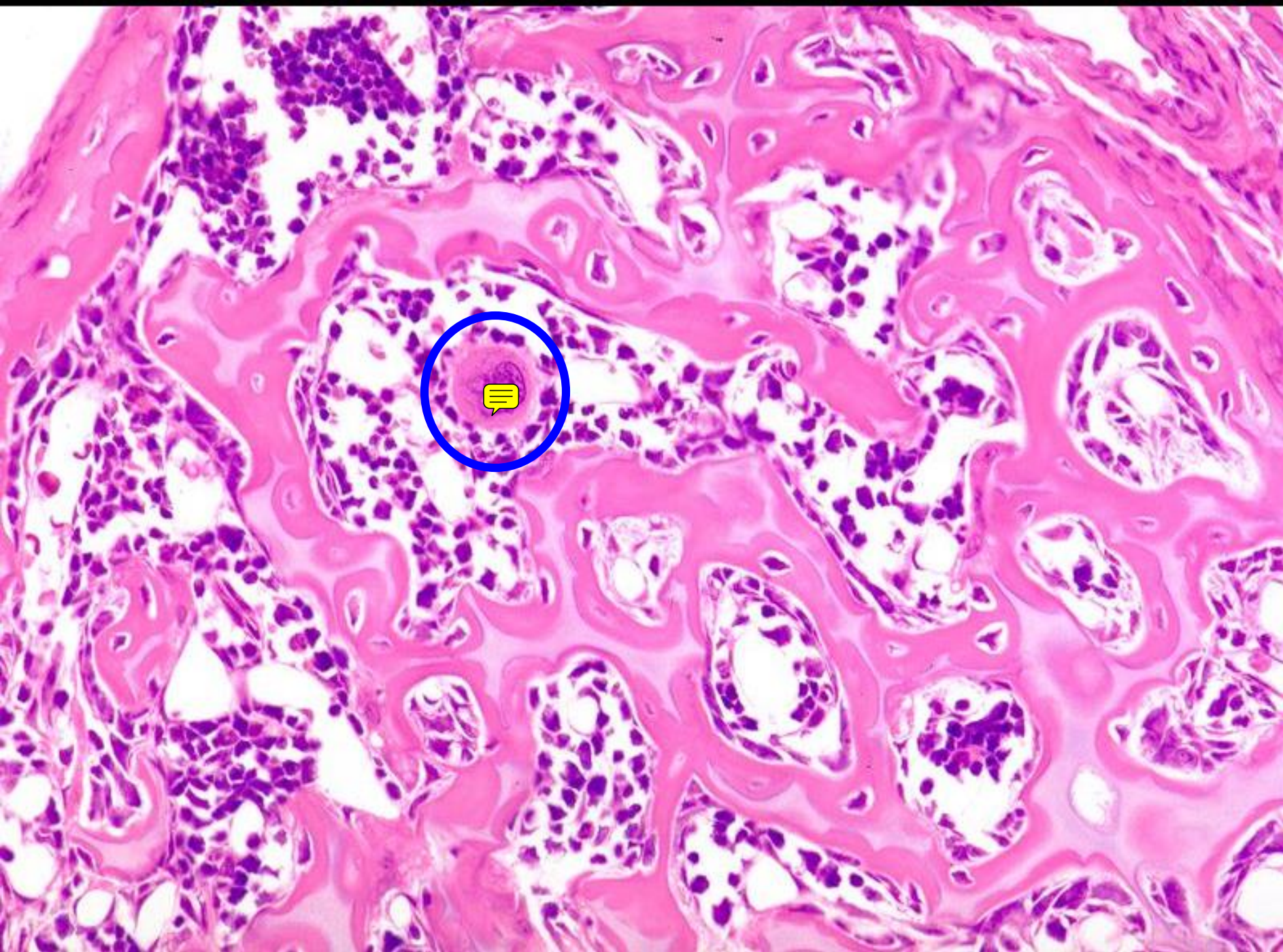
Mesenchyme

Bone matrix

Newly formed
matrix (osteoid)








BONE MATRIX

▣ Inorganic and organic constituents:

Inorganic Component:

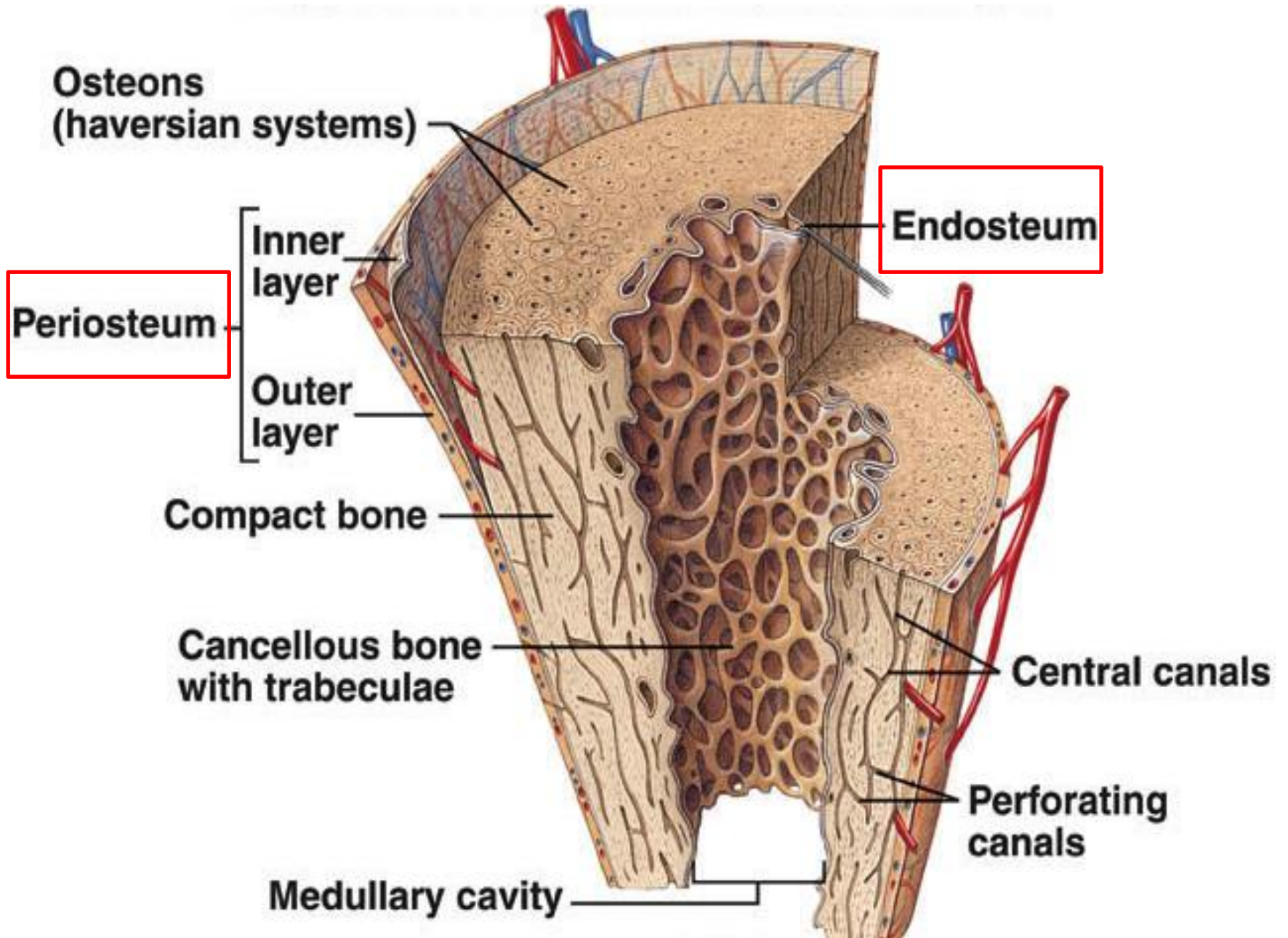
- About 67 % of dry weight.
 - Composed mostly of calcium and phosphorus, Crystals of calcium hydroxyapatite $[\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2]$.
 - Bicarbonate, citrate, magnesium, potassium and sodium ions are also found.
- ▣ Surface ions are hydrated \Rightarrow hydration shell.
- Facilitates fluid exchange

Organic Component:

- About 33% of dry weight.
- Embedded in the calcified matrix.
-  Predominantly type I collagen.
- Proteoglycan aggregates.
- Bone specific multiadhesive glycoproteins such as **osteonectin**.
- Calcium –binding glycoproteins , **osteocalcin**.

PERIOSTEUM & ENDOSTEUM


- Surfaces of bone are covered by tissue layers with bone forming cells.
- External surfaces: **Periosteum.**
- Internal surfaces: **Endosteum.**
- **Functions:**
 - Nutrition of bone.
 - Continuous supplying of osteoblasts from progenitor cells for bone growth or repair.



PERIOSTEUM

▣ Is organized much like the perichondrium.

▣ **Outer layer:**

- Is dense connective tissue, with small blood vessels, collagen bundles and fibroblasts.
- Some bundles penetrate through bone matrix binding the periosteum to bone, called **Perforating (Sharpey's) fibers.** 

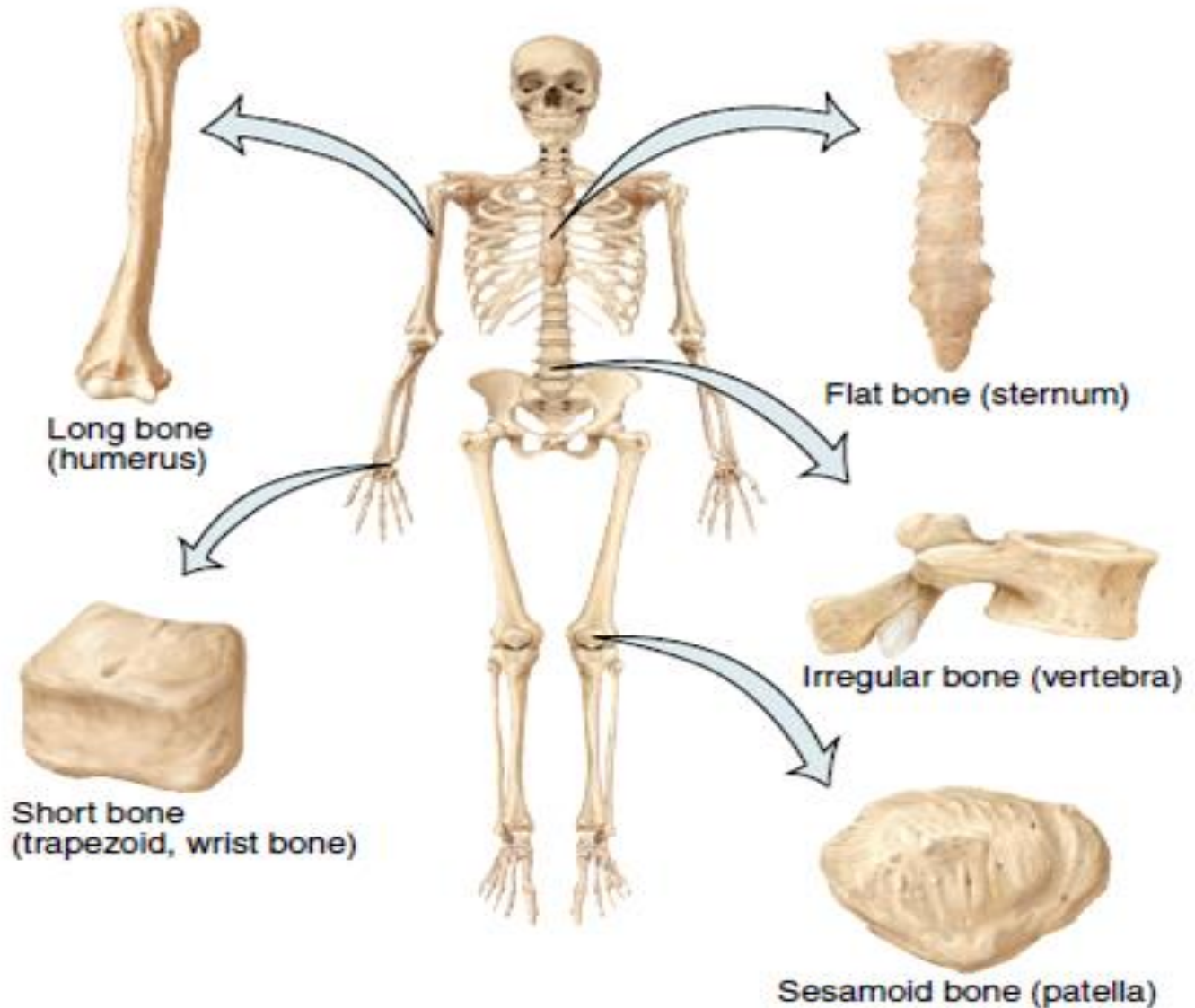
▣ **Inner layer:**

- Is a cellular contains bone lining cells, osteoblast and **osteoprogenitor cells.**

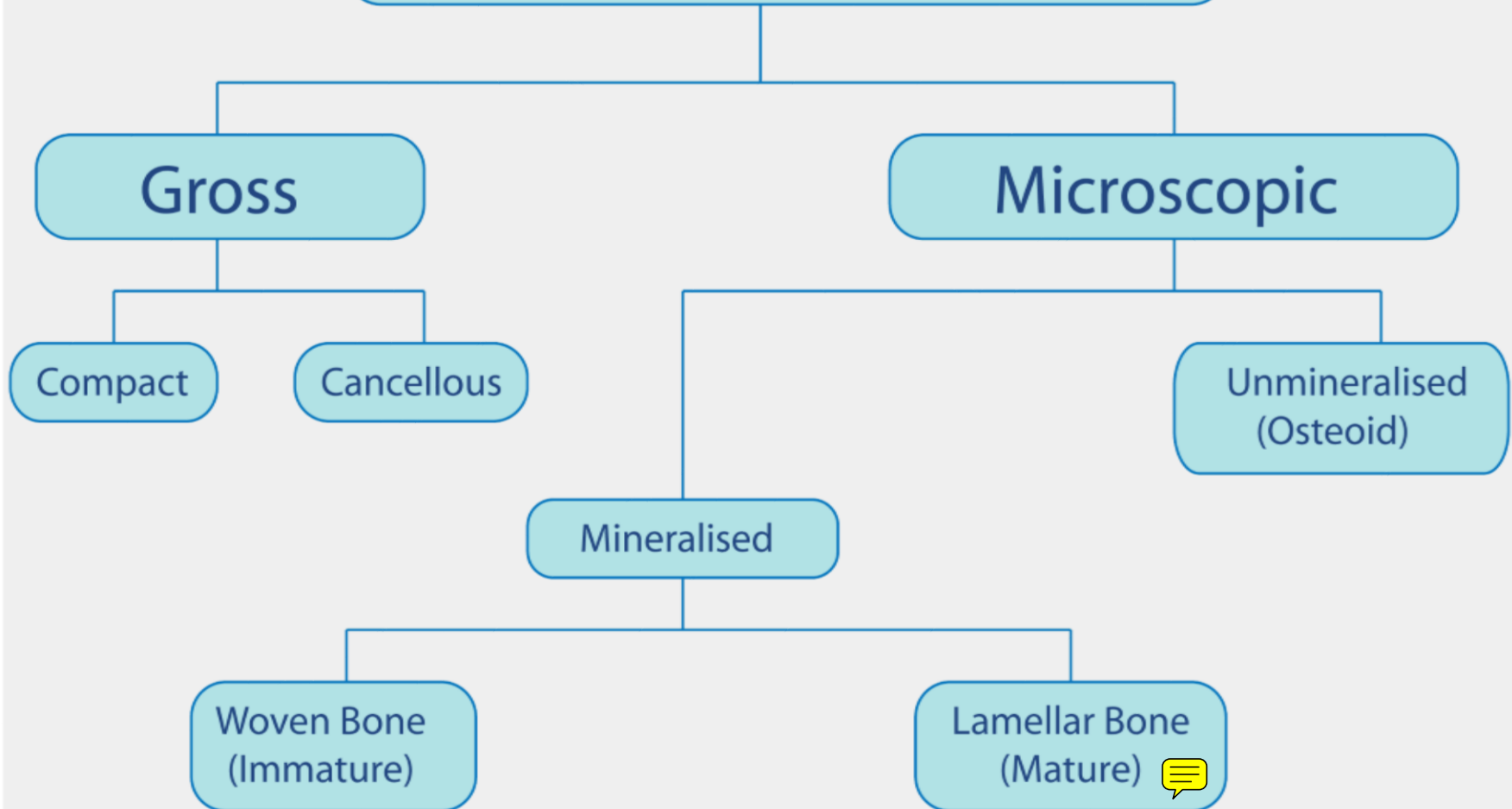
ENDOSTEUM

- Lines the internal cavity of the bone.
- Covers small trabeculae of bone matrix that project into marrow cavities.
- Thinner than the periosteum.
- Composed of a single layer of flat osteoprogenitor cells and osteoblasts.

Shape of bones



Structure of Bone



Types of bone

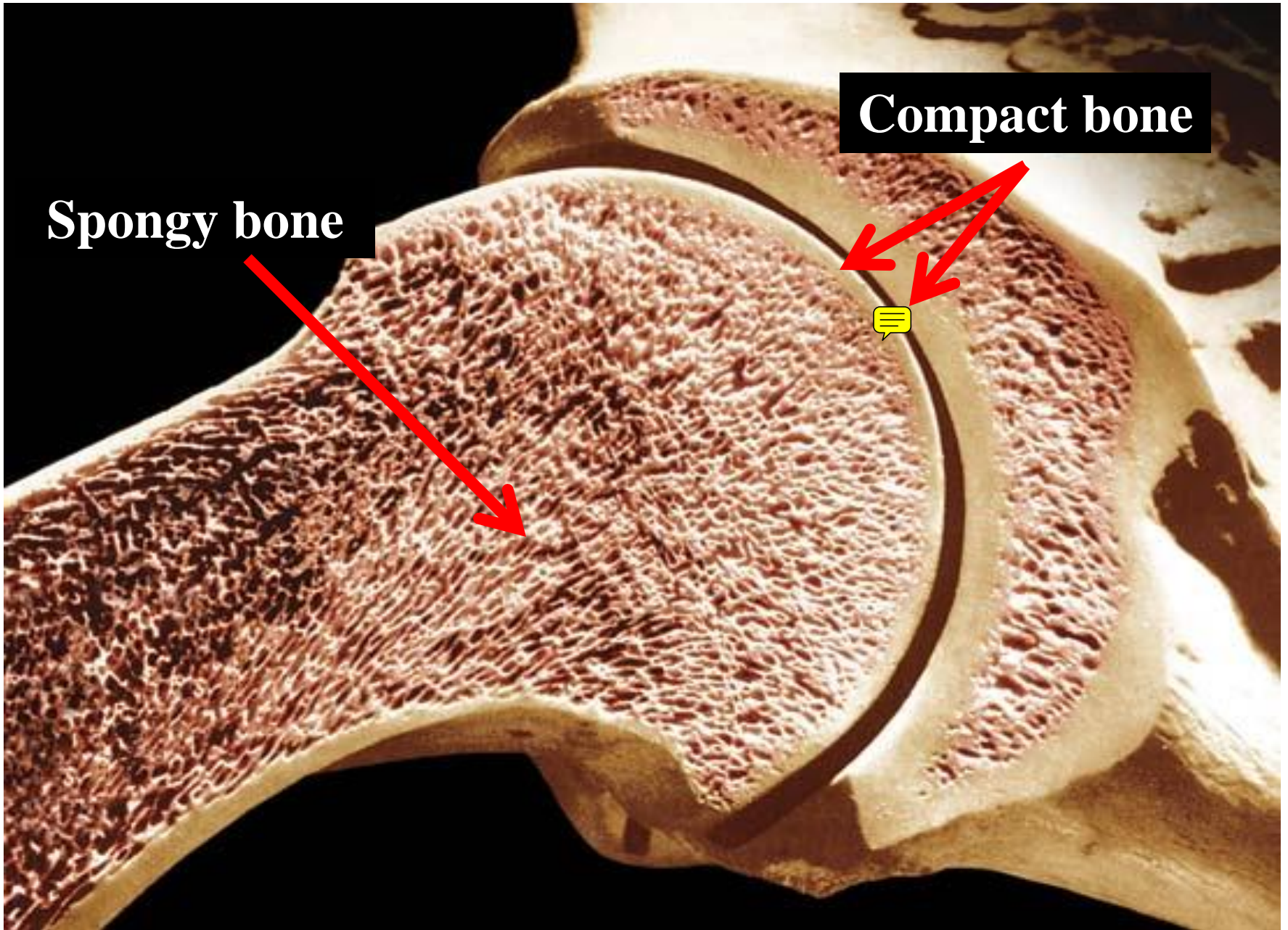
- **Gross observation** of a bone in cross section shows:

Compact (cortical) bone: a dense area near the surface , which represent 80% of the total bone mass.

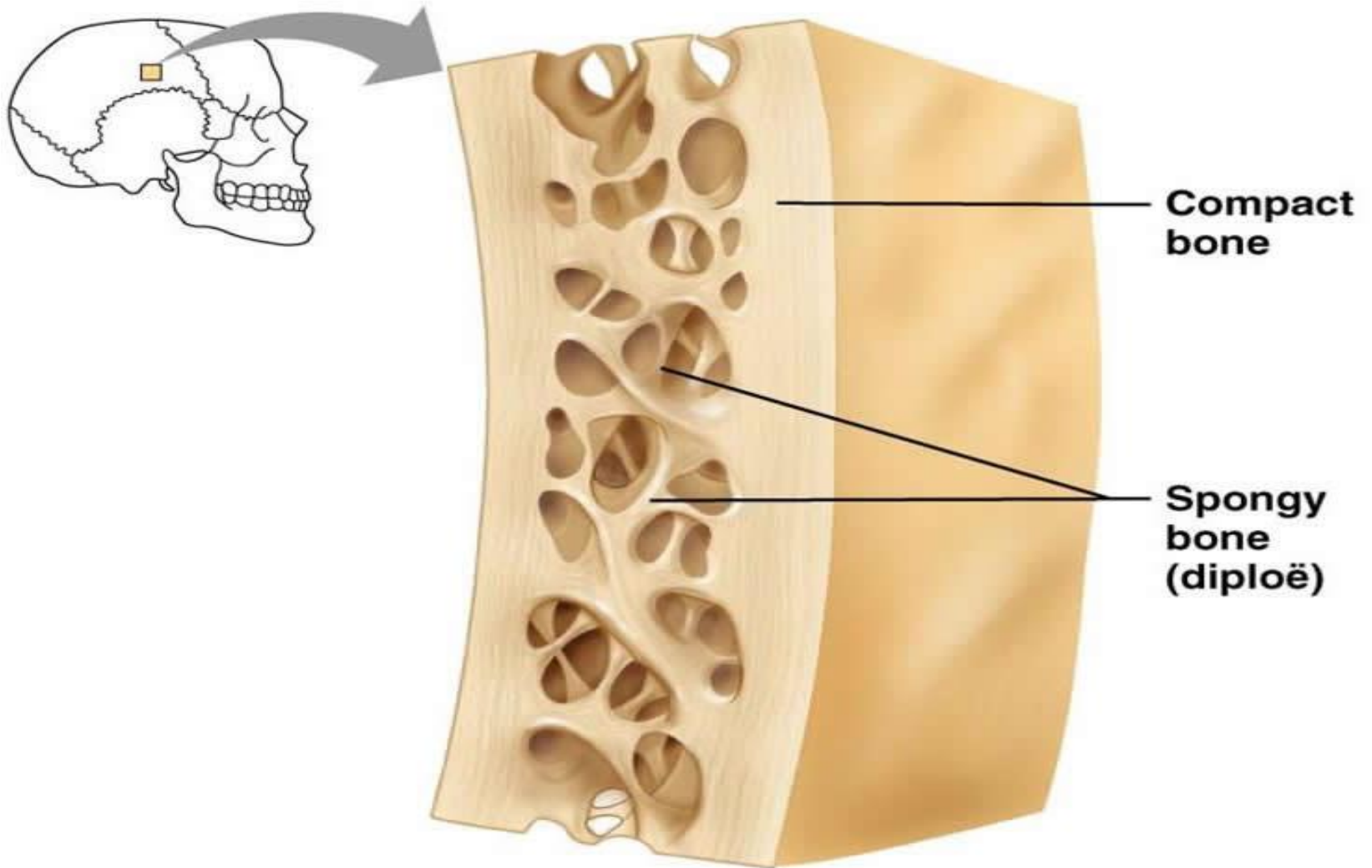
Cancellous (trabecular or spongy) bone: deeper areas with numerous interconnecting cavities, consisting about 20 %of total bone mass.

Spongy bone

Compact bone



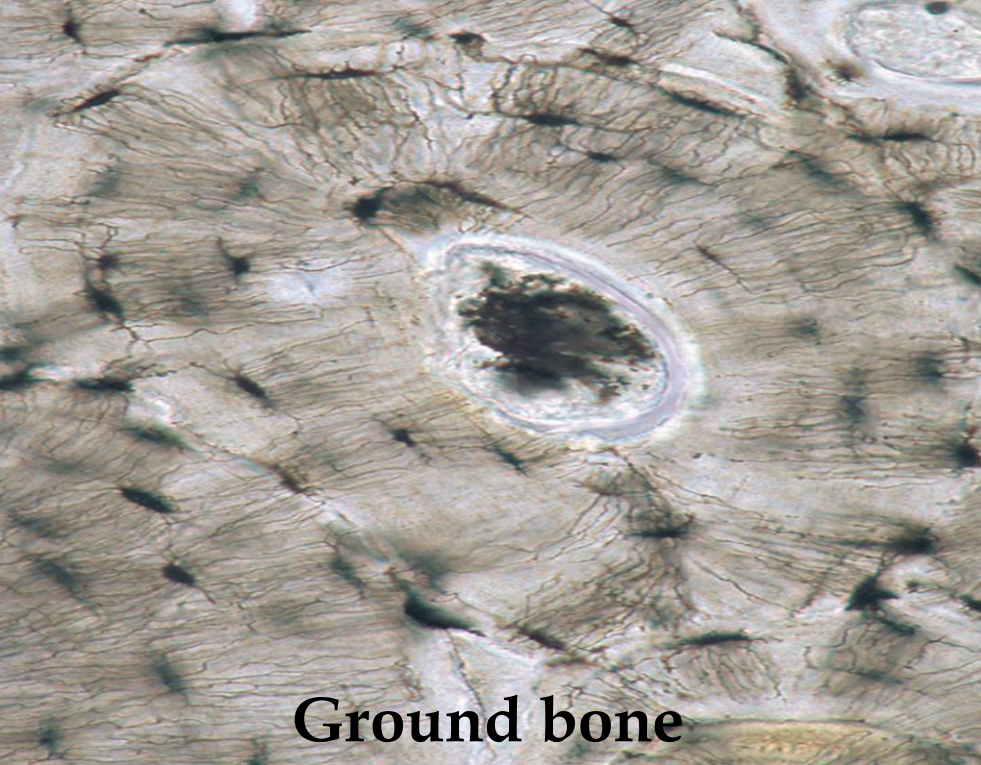
Flat bone



TECHNIQUE OF PREPARATION

- **Ground bone:**
- **Decalcified bone :** 

Because of its hardness, bone cannot be sectioned routinely. Bone matrix is softened by immersion in a decalcifying solution before paraffin embedding.



Ground bone



Decalcified bone

Types of bone

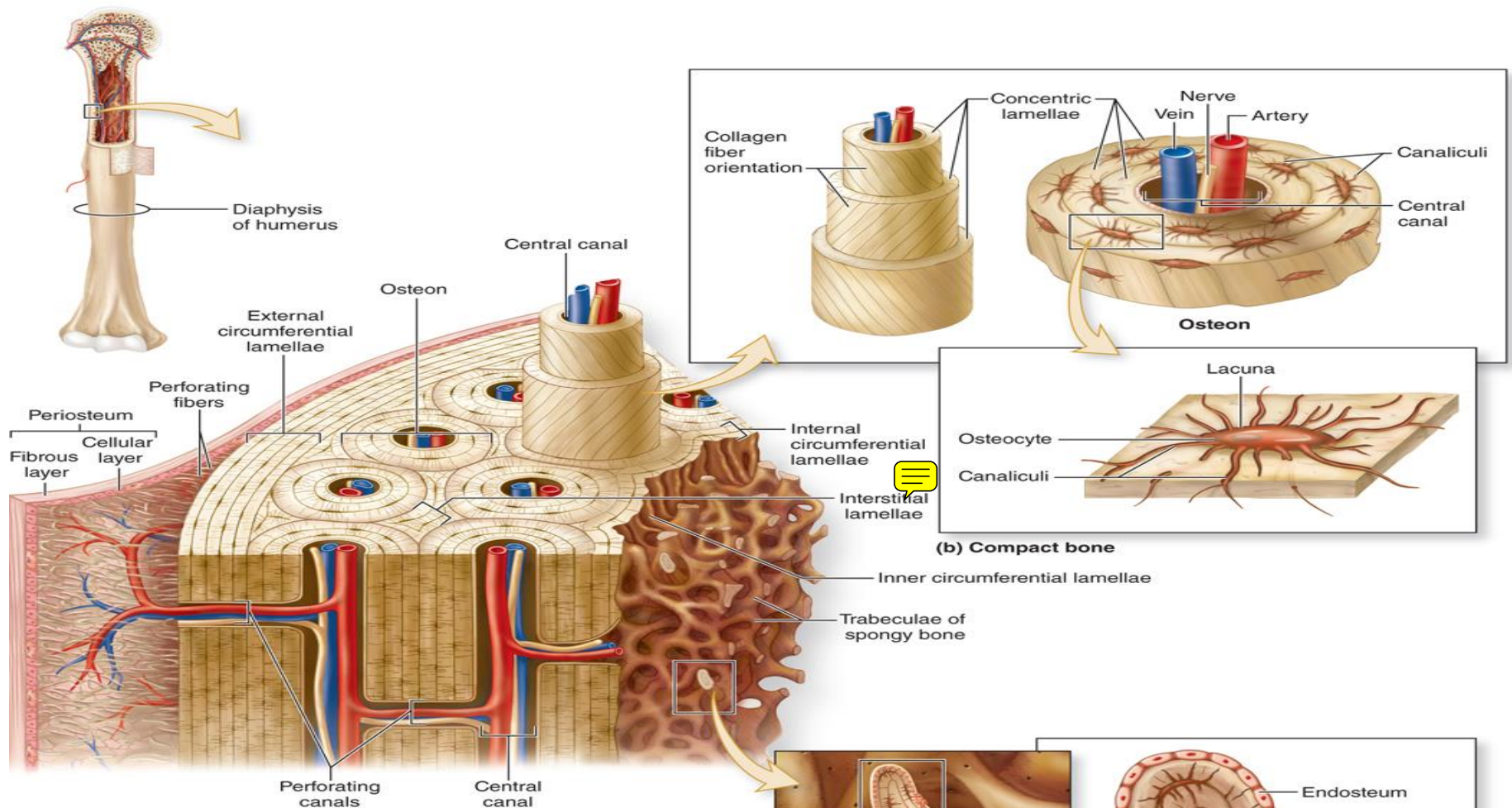
- **Microscopic examination** of bone tissue shows two types of organization :
 1. **Lamellar bone (mature).**
 2. **Woven bone (immature).**

Lamellar Bone

- ▣ Most bone in adults, **compact or cancellous** , is organized as **lamellar bone**.
- ▣ Is multiple layers or lamellae of calcified matrix.
- ▣ The lamellae are organized either parallel to each other (cancellous) or concentrically around a central canal (compact).
- ▣ In each lamella = mainly collagen fibers type I

**Compact
(cortical) bone**

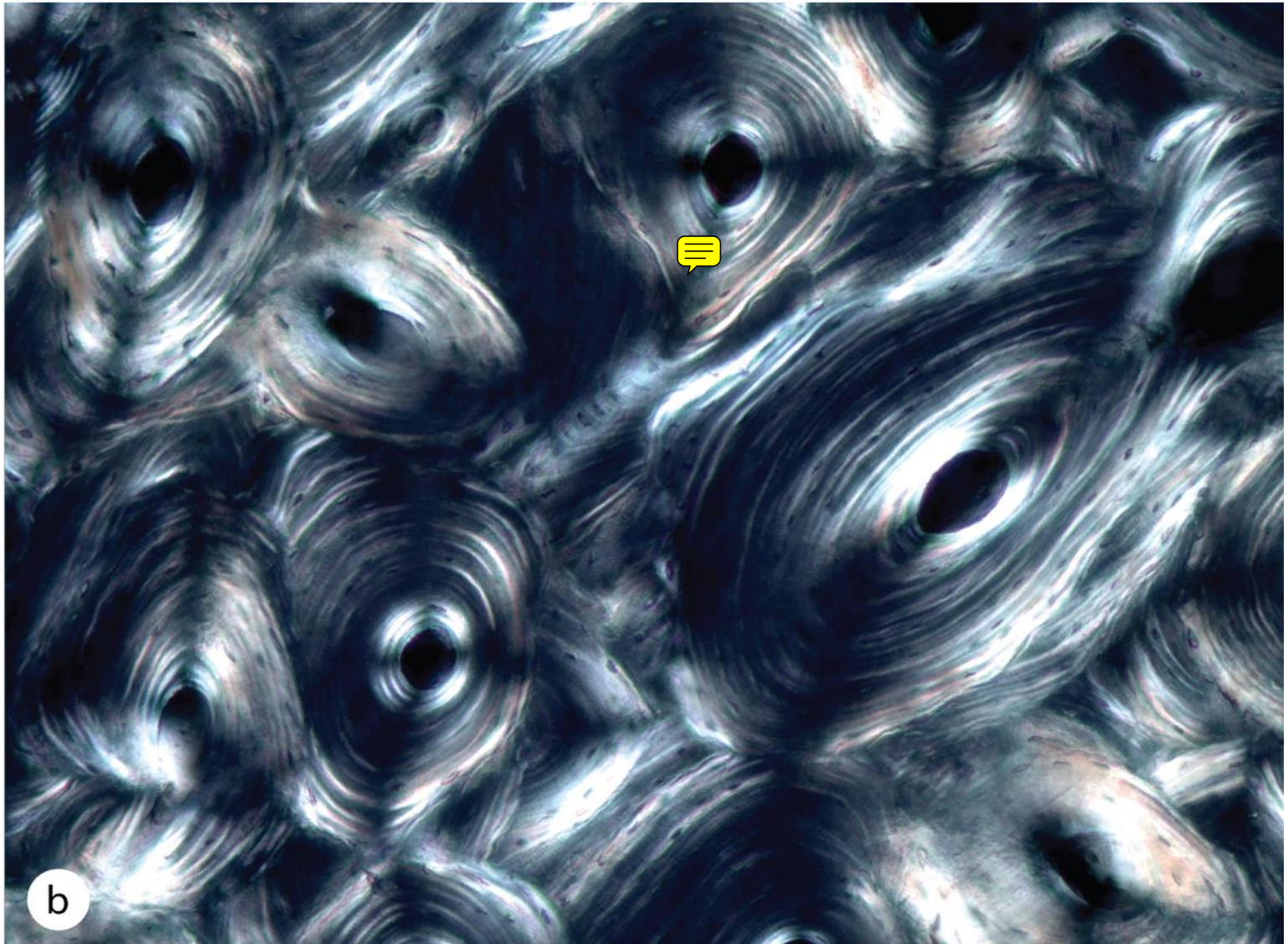
- ▣ An **osteon (or Haversian system)**: is the complex of concentric lamella surrounding a small canal containing blood vessels, nerves, loose CT and lined by endosteum.
- ▣ Between successive lamellae are lacunae (each with one osteocyte).
- ▣ The outer boundary of each osteon is called the **cement line**.
- ▣ The central canal communicate with the marrow cavity and the periosteum and with one another through transverse **Perforating canals (or Volkmann's canal)**.



(a) Section of humerus

(b) Compact bone

(c) Spongy bone



Alternating bright and dark bands indicate that collagen fibers in successive lamellae have different orientations.

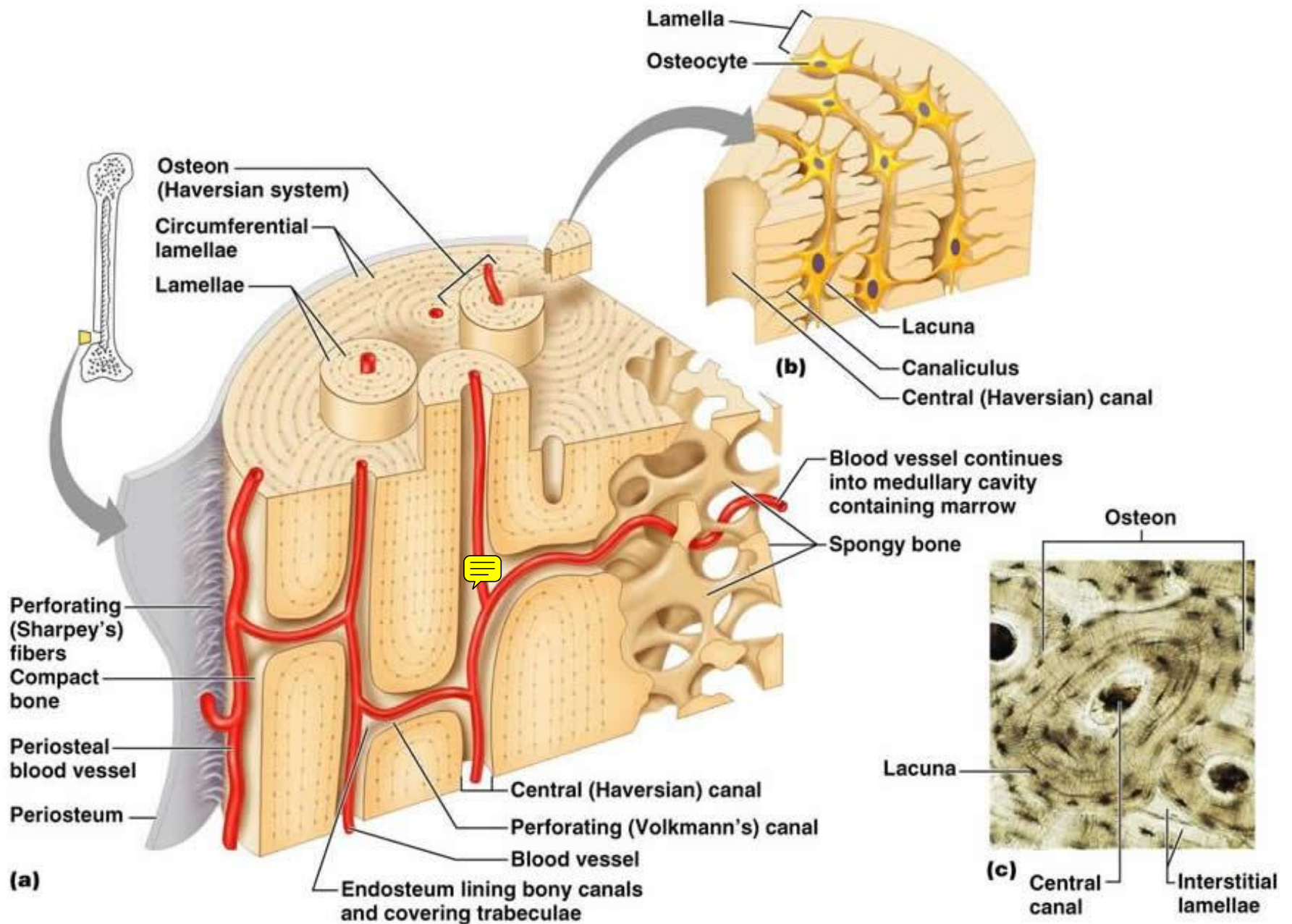
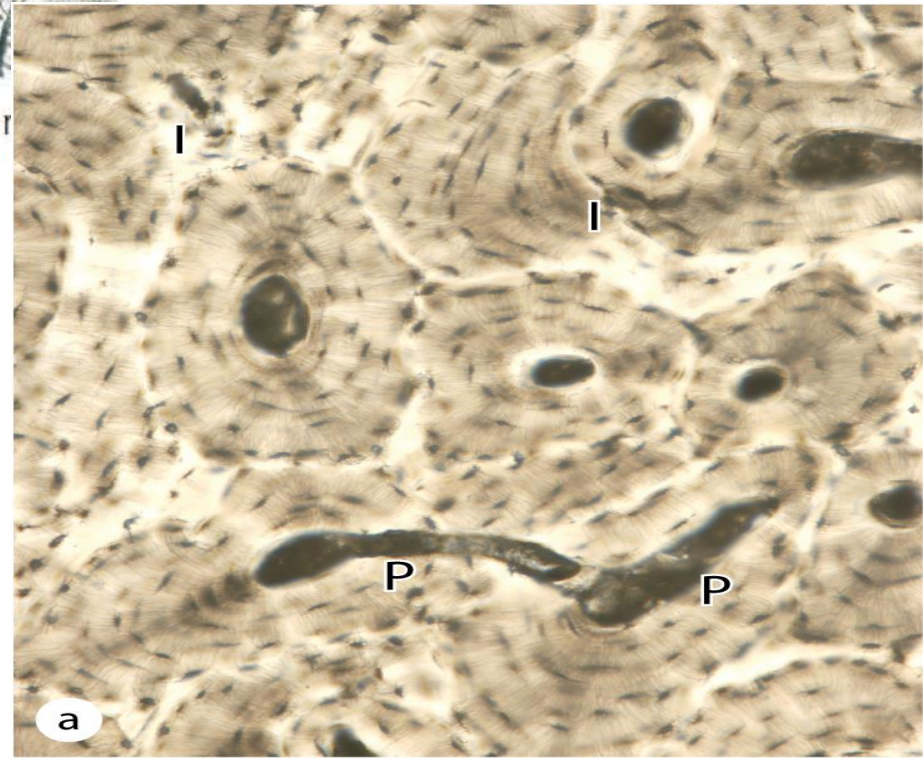
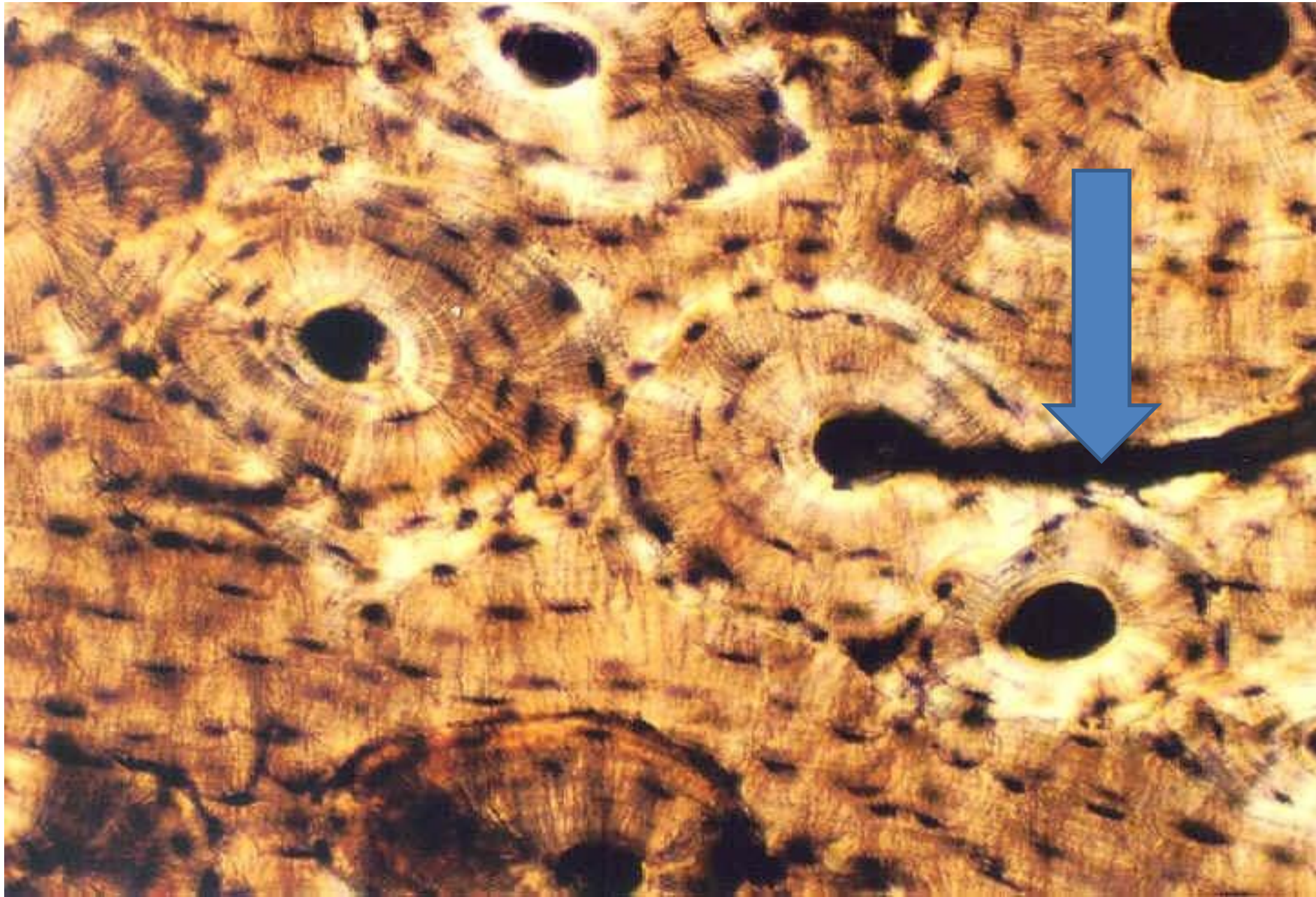




FIGURE 4.19 ■ Dry, compact bone: an osteon, transverse section. High r



VOLKMANN'S CANAL



Types of lamella:

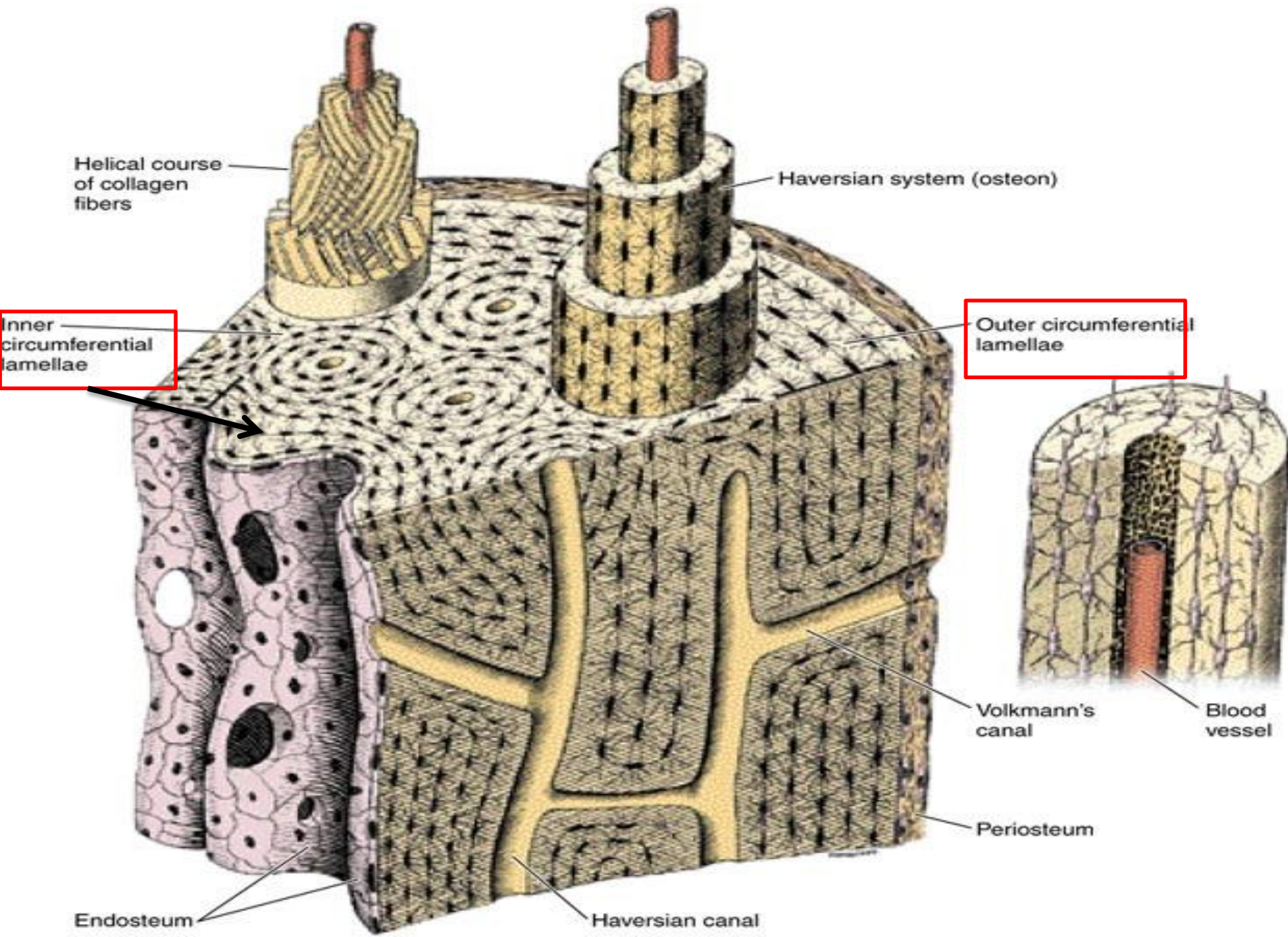
▣ Concentric:

▣ Interstitial:

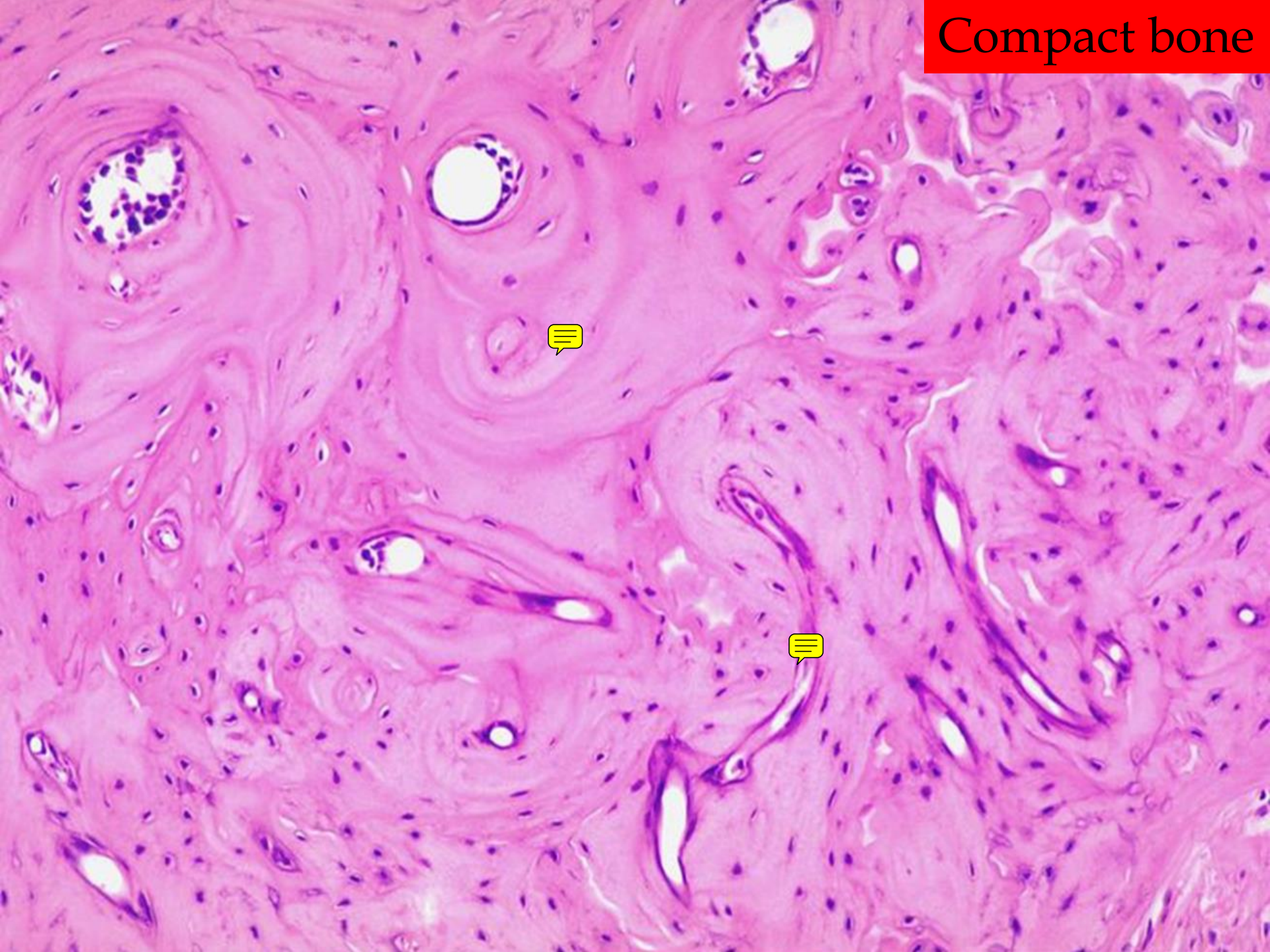
- Scattered among the intact osteon.
- Are numerous irregularly shaped groups of parallel lamellae.
- Are lamellae remaining from osteons partially destroyed by osteoclasts during growth and remodeling of bone.

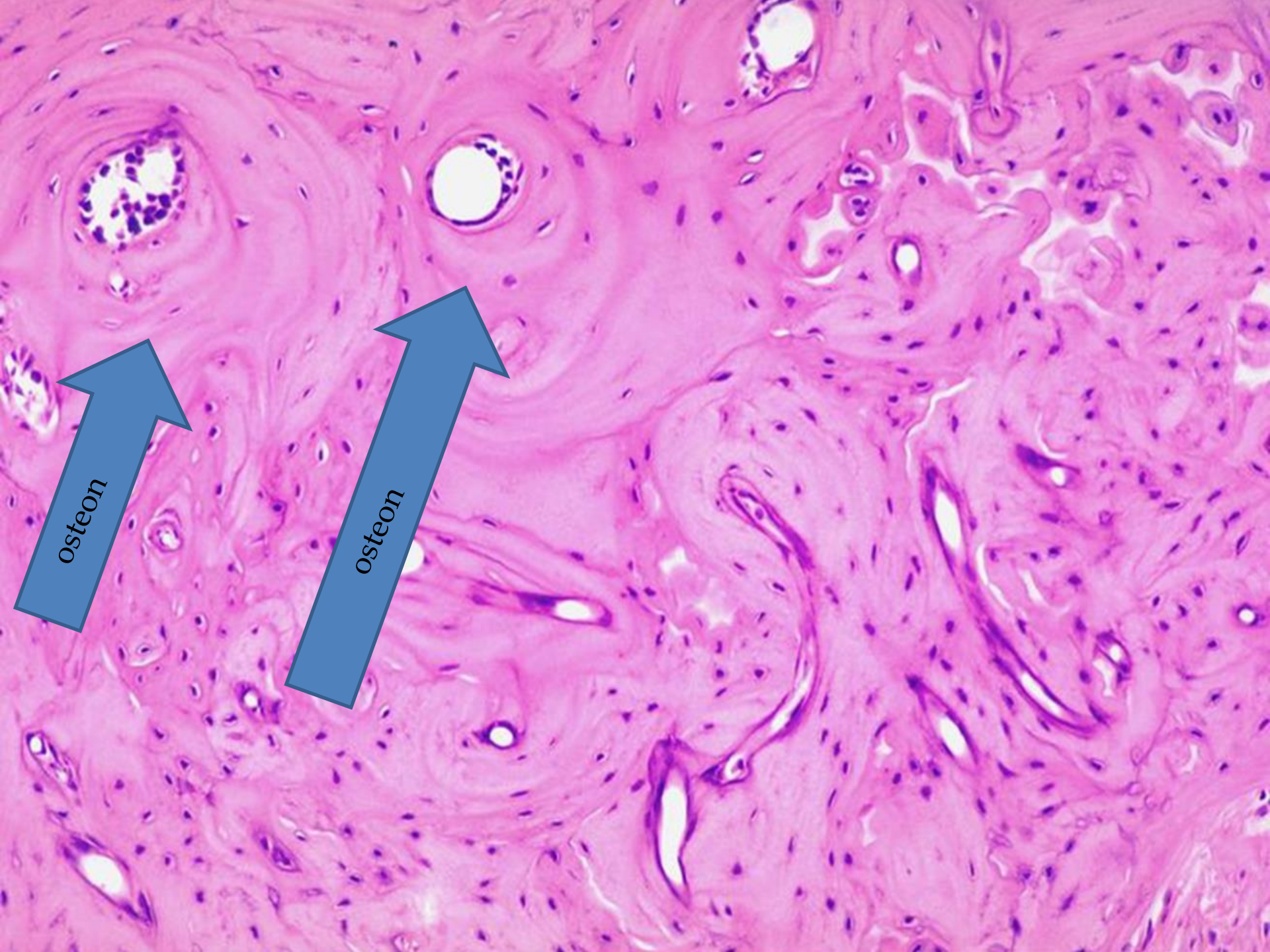
▣ Outer circumferential: located immediately beneath the periosteum.

▣ Inner circumferential: located around the marrow cavity.



Compact bone



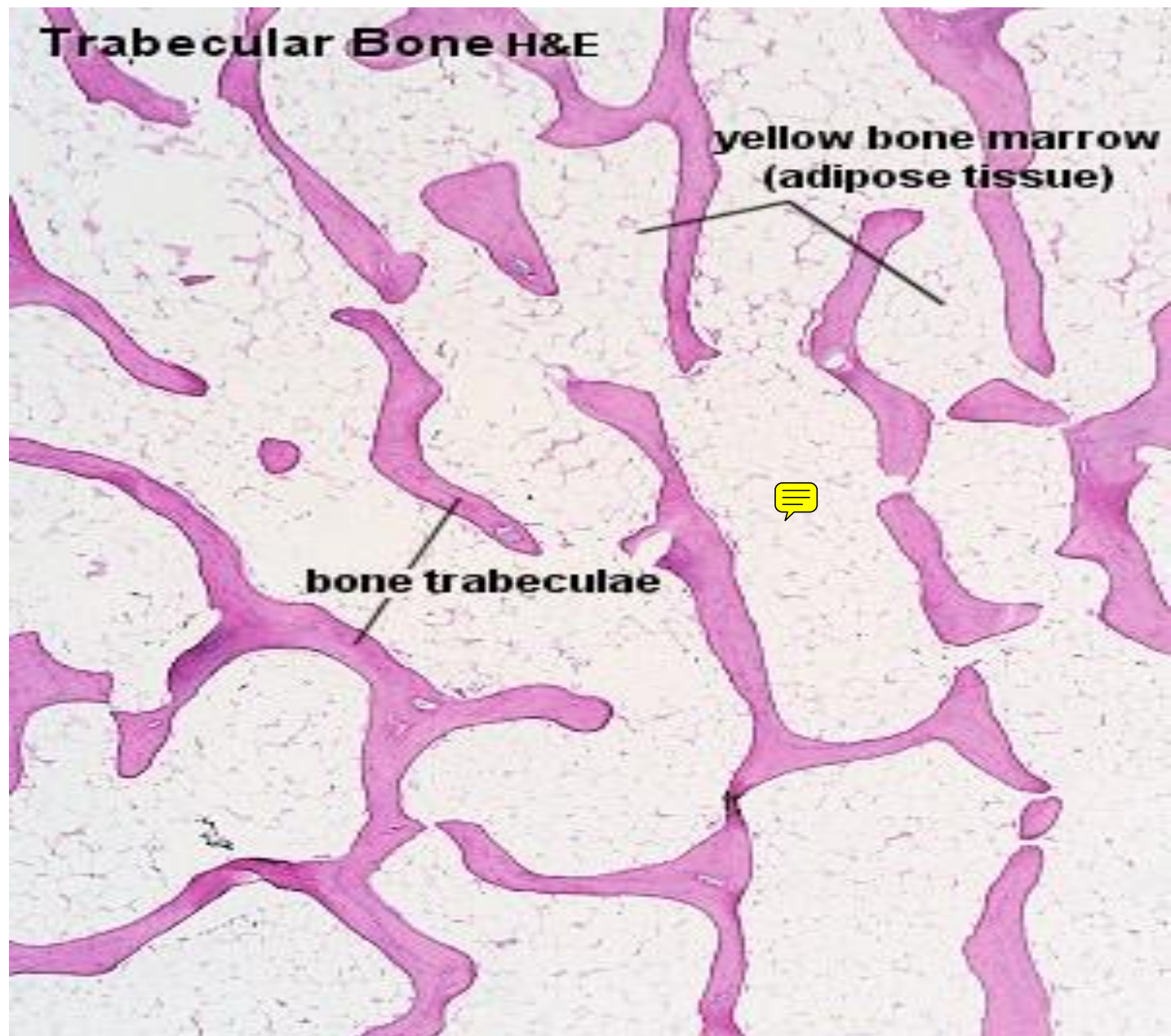


osteon

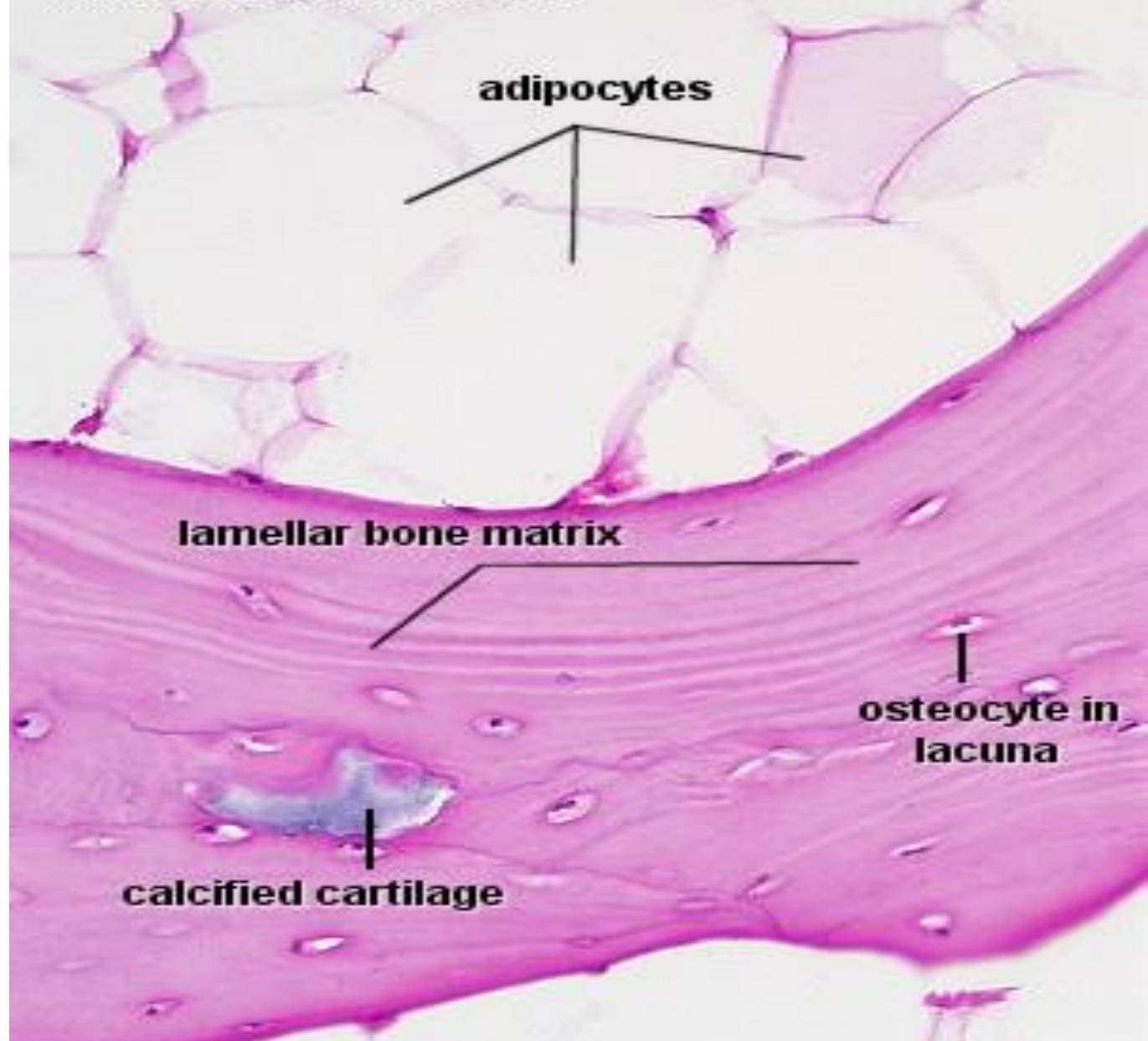
osteon

Cancellous
(trabecular or spongy)
bone

Trabecular Bone H&E



Trabecular Bone H&E



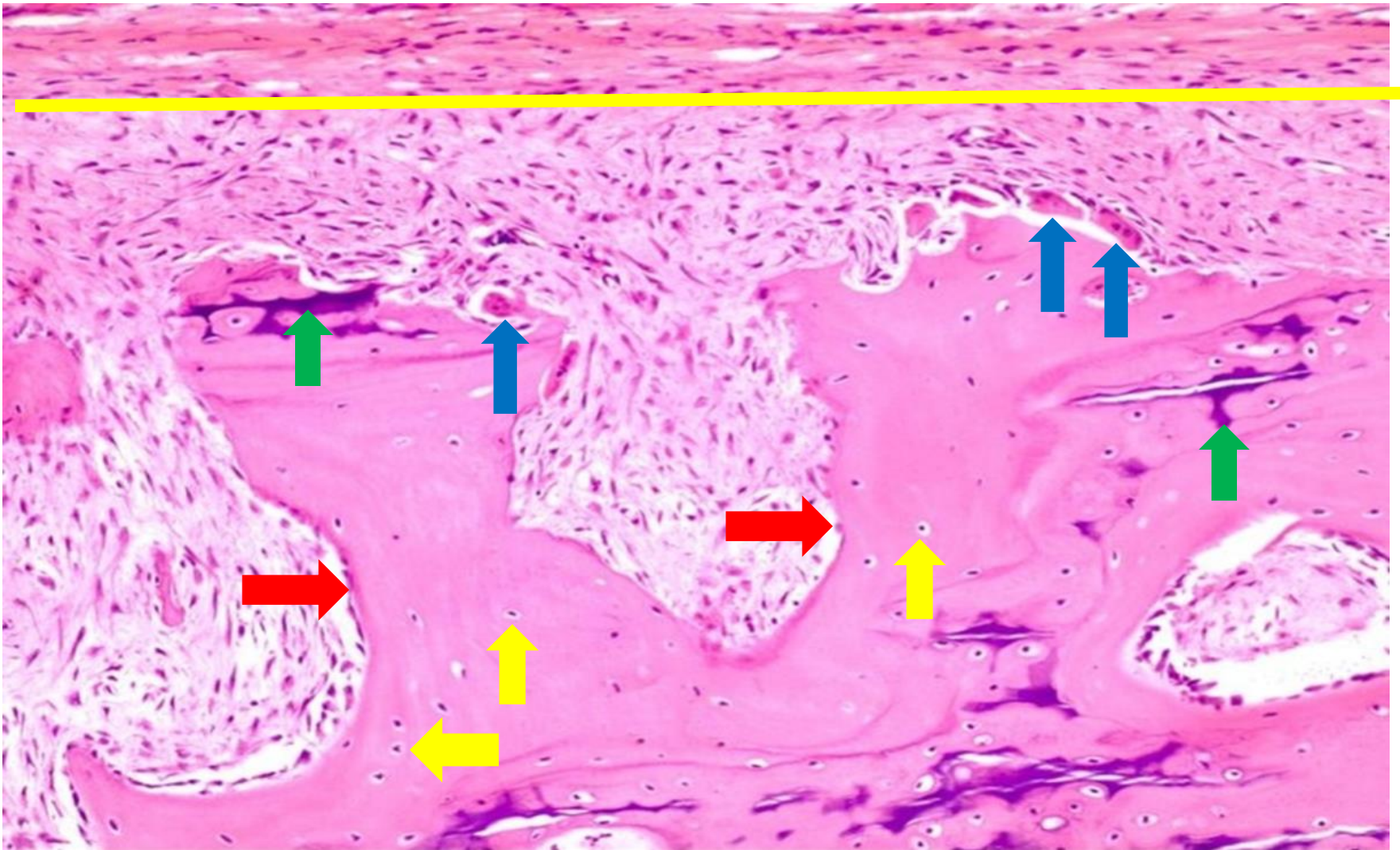
periosteum

osteoblasts



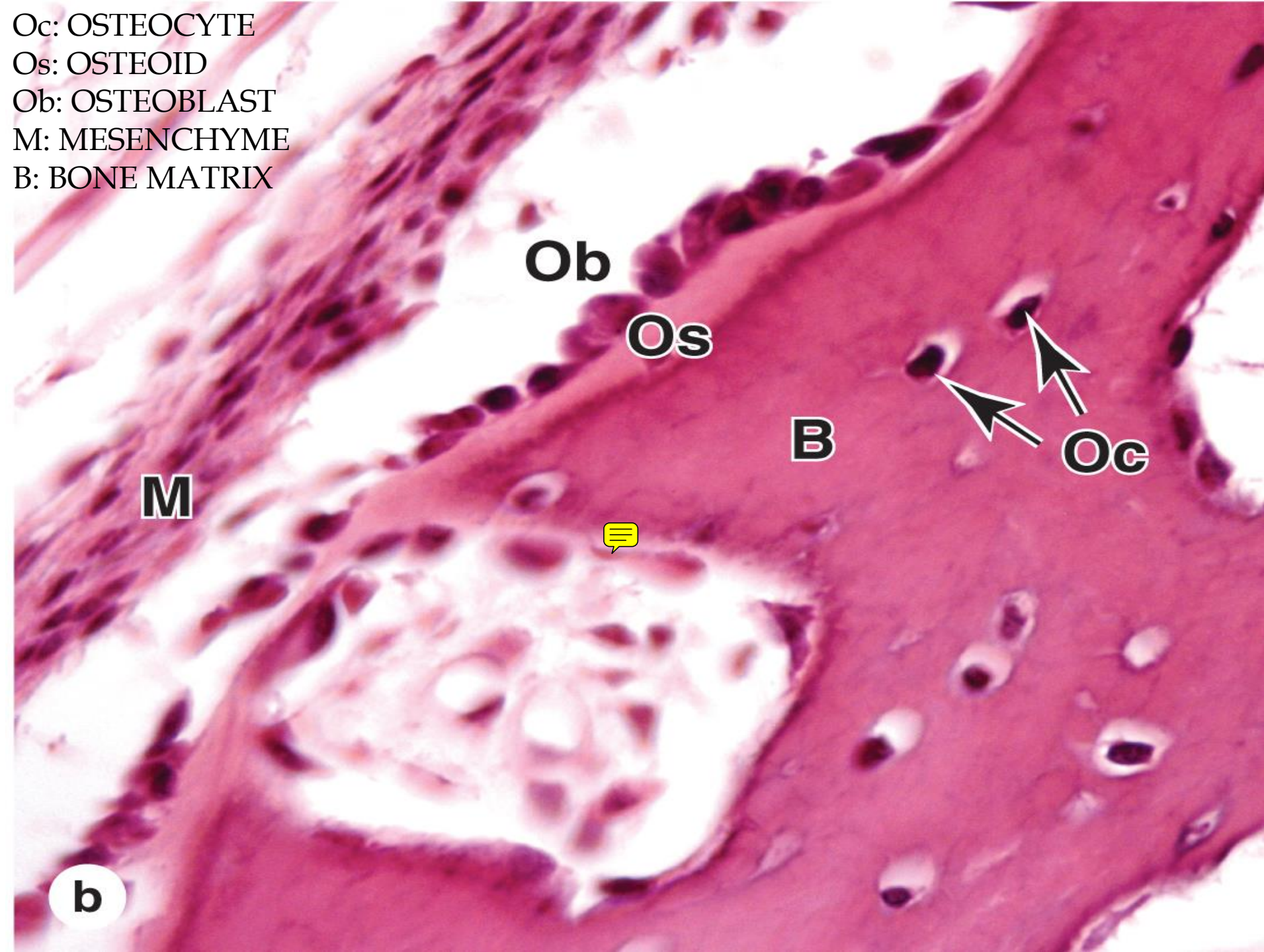
osteocytes

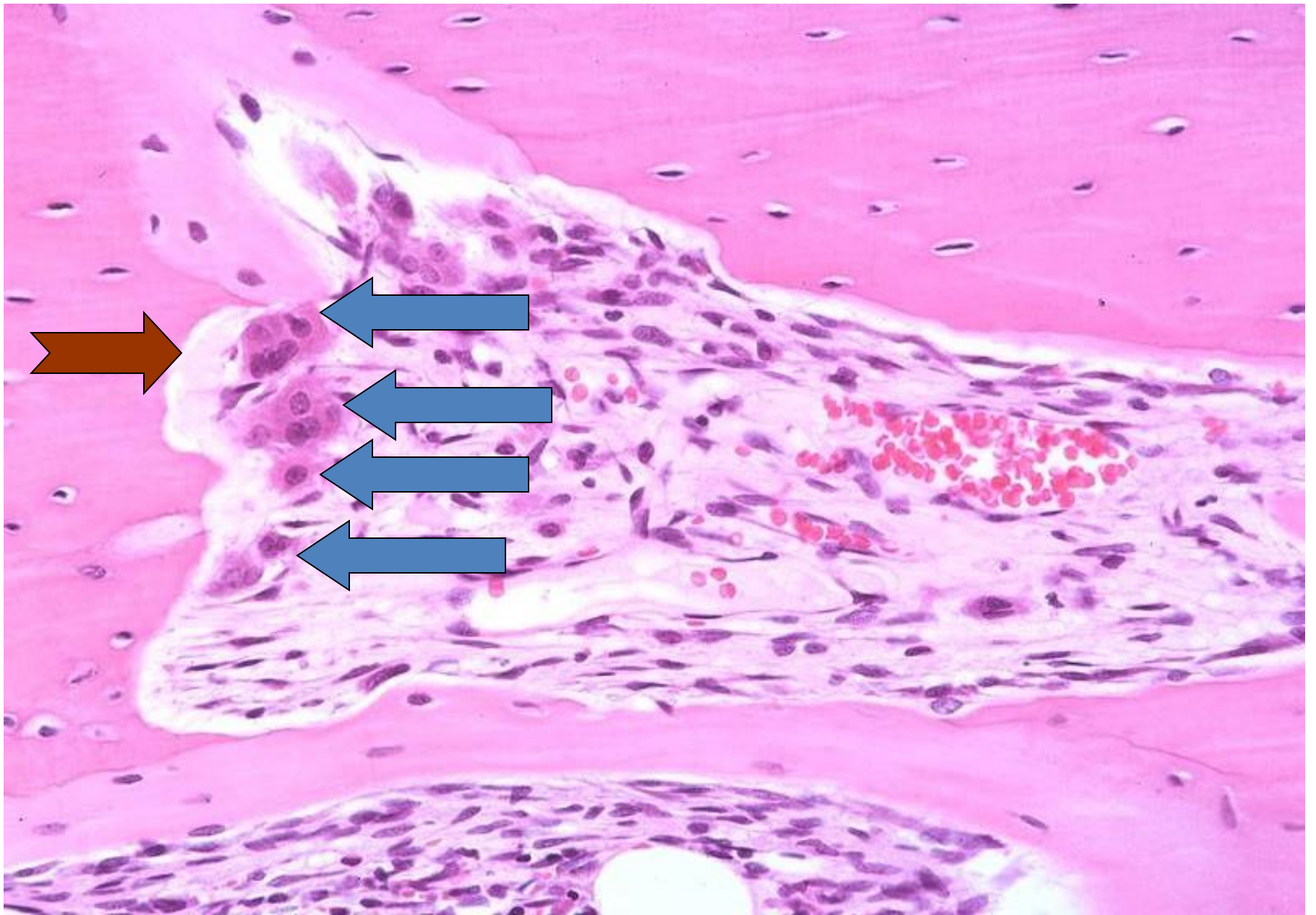
medullary spaces

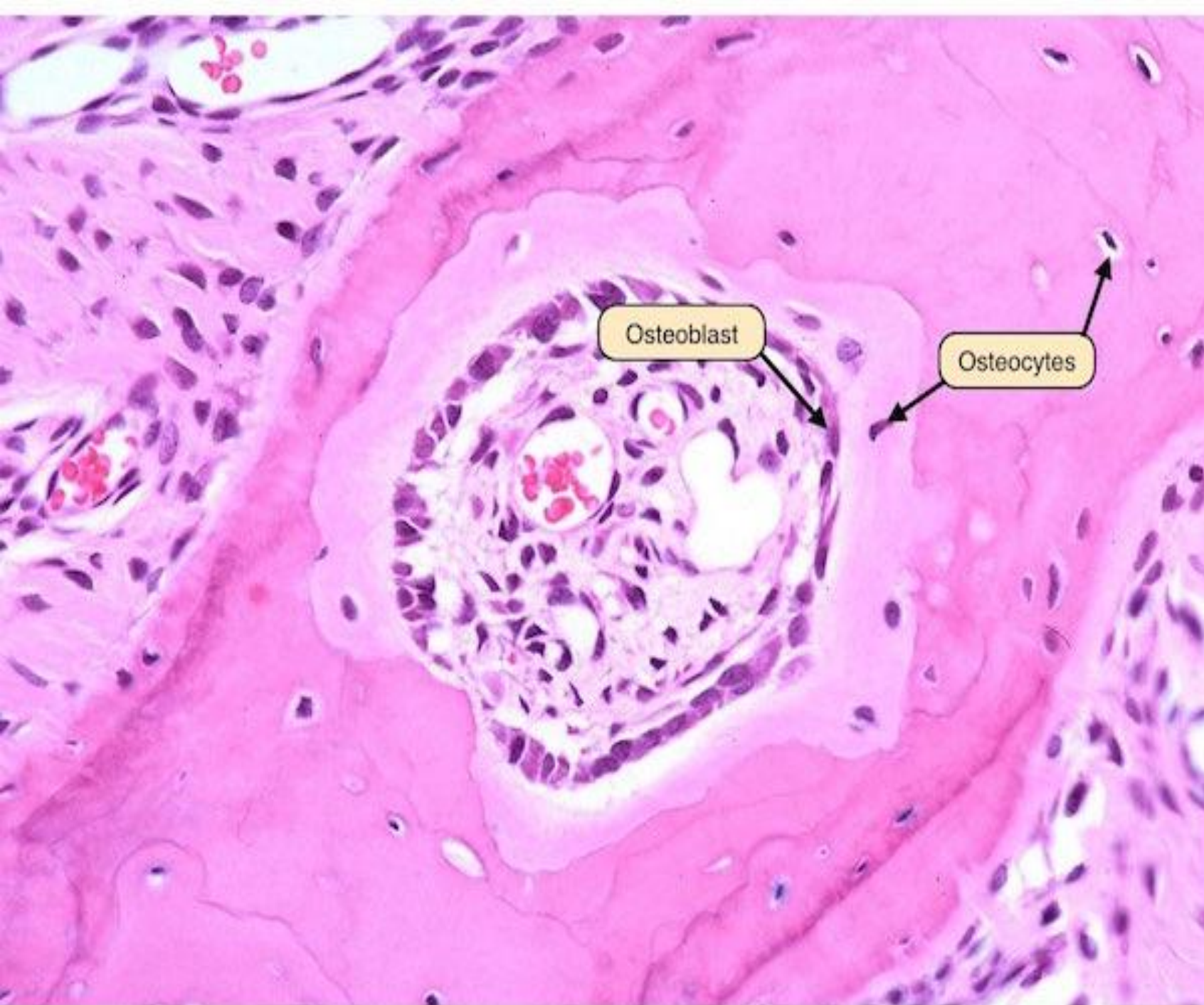


- ▣ **Periosteum**: an outer fibrous above the yellow line and inner cellular below the yellow line.
- ▣ **Blue arrow**: osteoclast.
- ▣ **Green arrow**: calcified cartilage.
- Red arrow**: osteoblast
- Yellow arrow**: Osteocyte

Oc: OSTEOCYTE
Os: OSTEOID
Ob: OSTEOLAST
M: MESENCHYME
B: BONE MATRIX

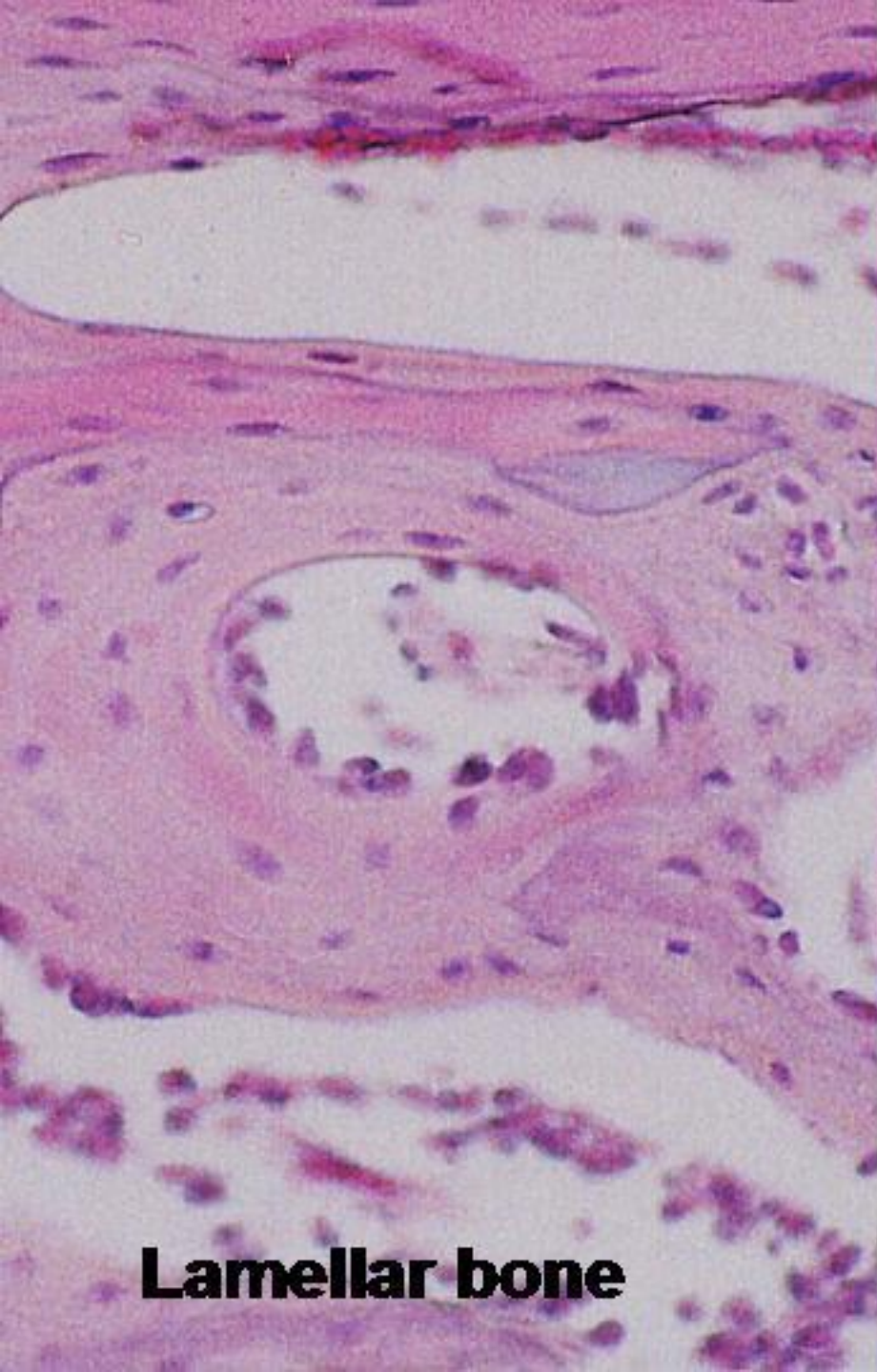




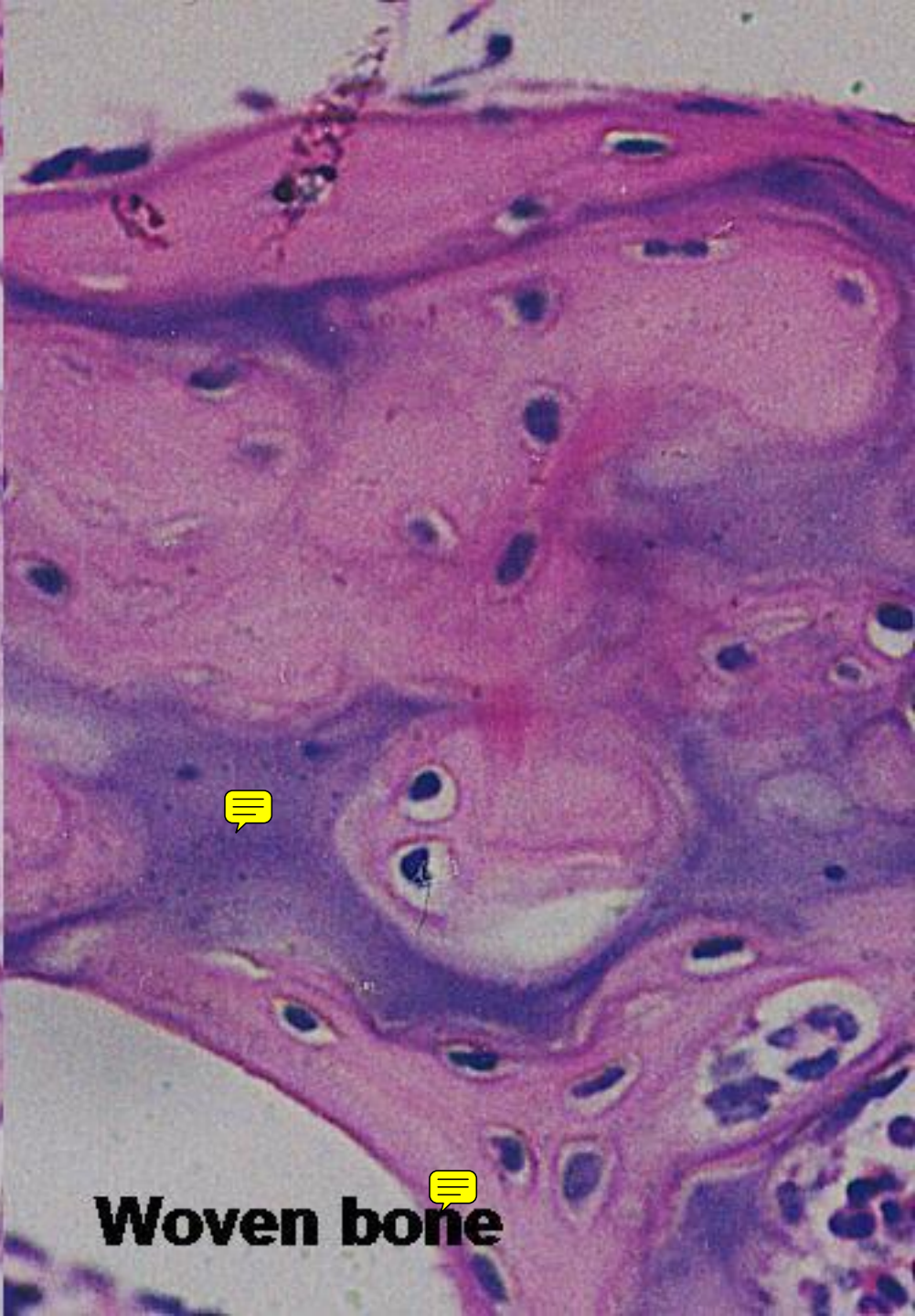


Woven Bone

- Is nonlamellar.
- Is the first bone tissue to appear in embryonic development and in fracture repair.
- Temporary, is replaced by in adult by lamellar bone.
- Random disposition of type I collagen fibers
- Lower mineral content.
- Easily penetrated by x-ray.
- Number of osteocytes is relatively high.



Lamellar bone



Woven bone

Woven vs. Lamellar bone

