

Cartilage and bone

- Mechanic and supporting function
- Origin: embryonic mesenchyme
- Structure:
 - cells (chondrocytes – in cartilage
osteocytes, osteoblasts, osteoklasts – in bone)
 - Extracellular matter
 - homogenous, amorphous substance
 - fibers (collagen or elastic – in cartilage, only collagen – in bone)



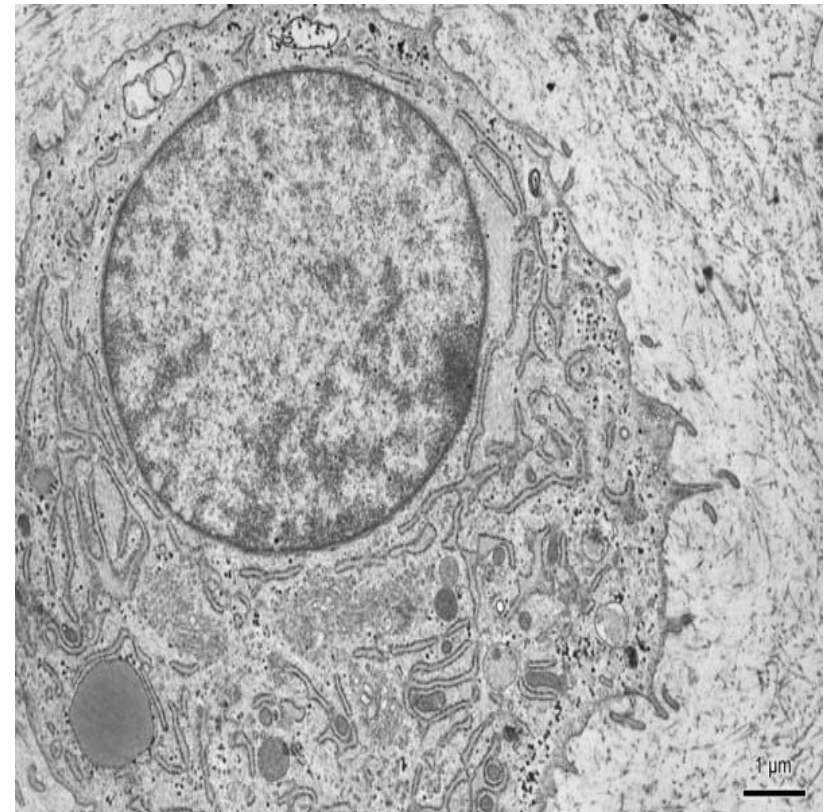
Cartilage properties

- Avascular tissue, without nerves,
- Decreased reparative ability, regeneration from perichondrium
- Perichondrium – dense collagen c. t. attached to cartilage
 - inner chondrogenic layer
 - outer c. t. layer



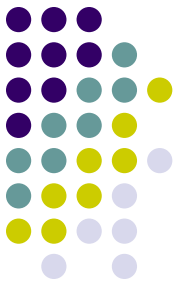
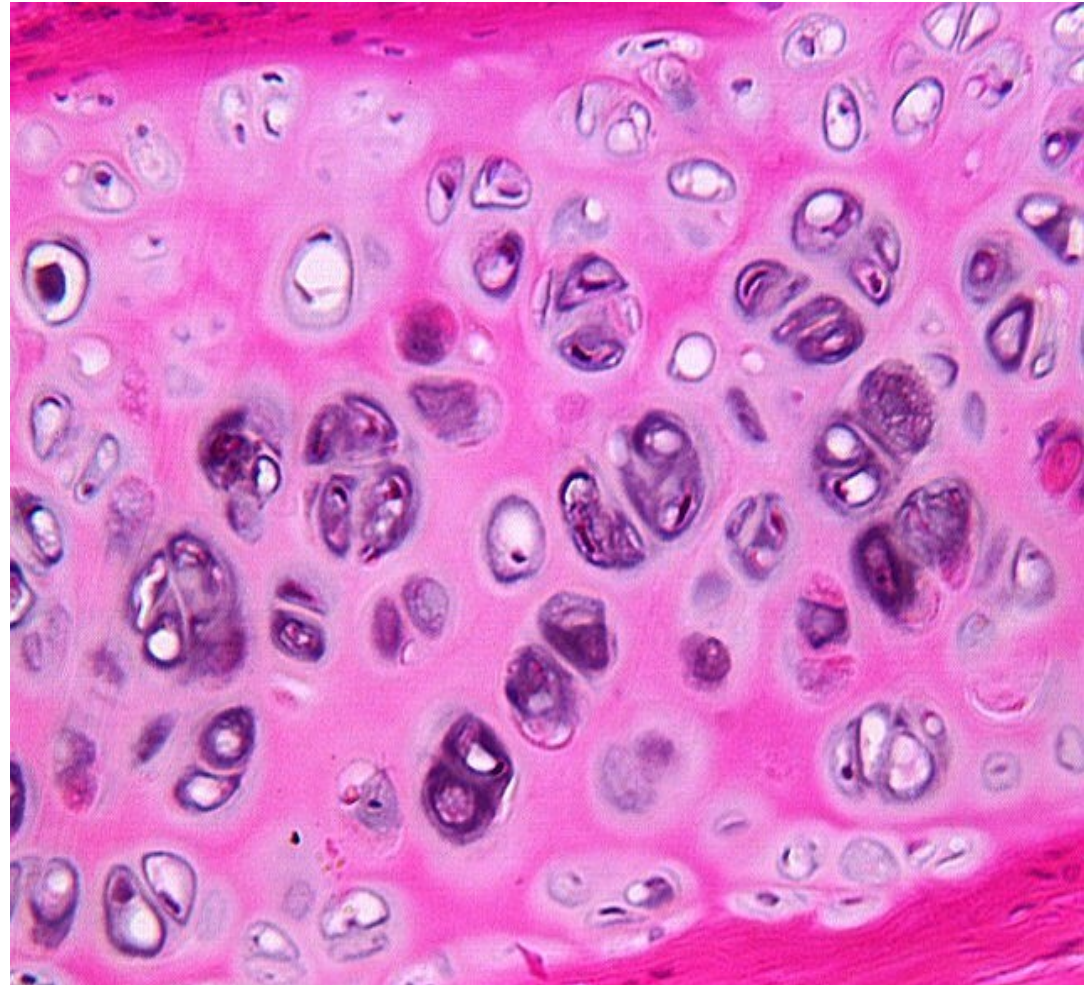
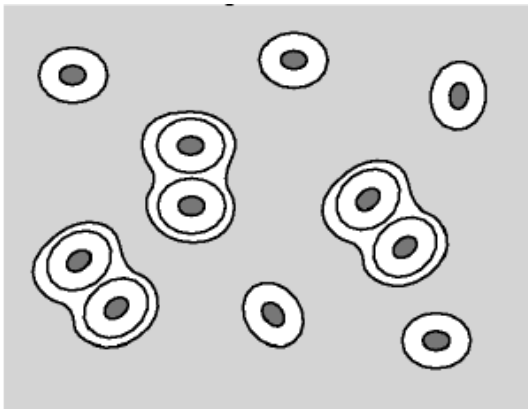
Cell of cartilage

- chondroblasts
 - immature chondrocytes in inner layer of perichondrium
- **chondrocytes** – in cartilage
 - basophilic cells → proteosynthesis, mitochondria, GER, Golgi apparatus, cytoskeleton.
 - produce amorphous matrix and fibers.



- Chondrocytes
 - *isogenous groups*,
 - *lacunae*,
 - *basophilic capsule*
of territorial matrix

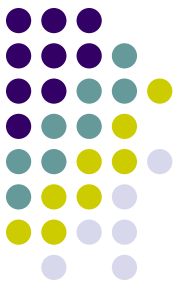
- Isogenous group + adjacent area of extracellular matter (territorial matter) = ***chondron***



Extracellular matter



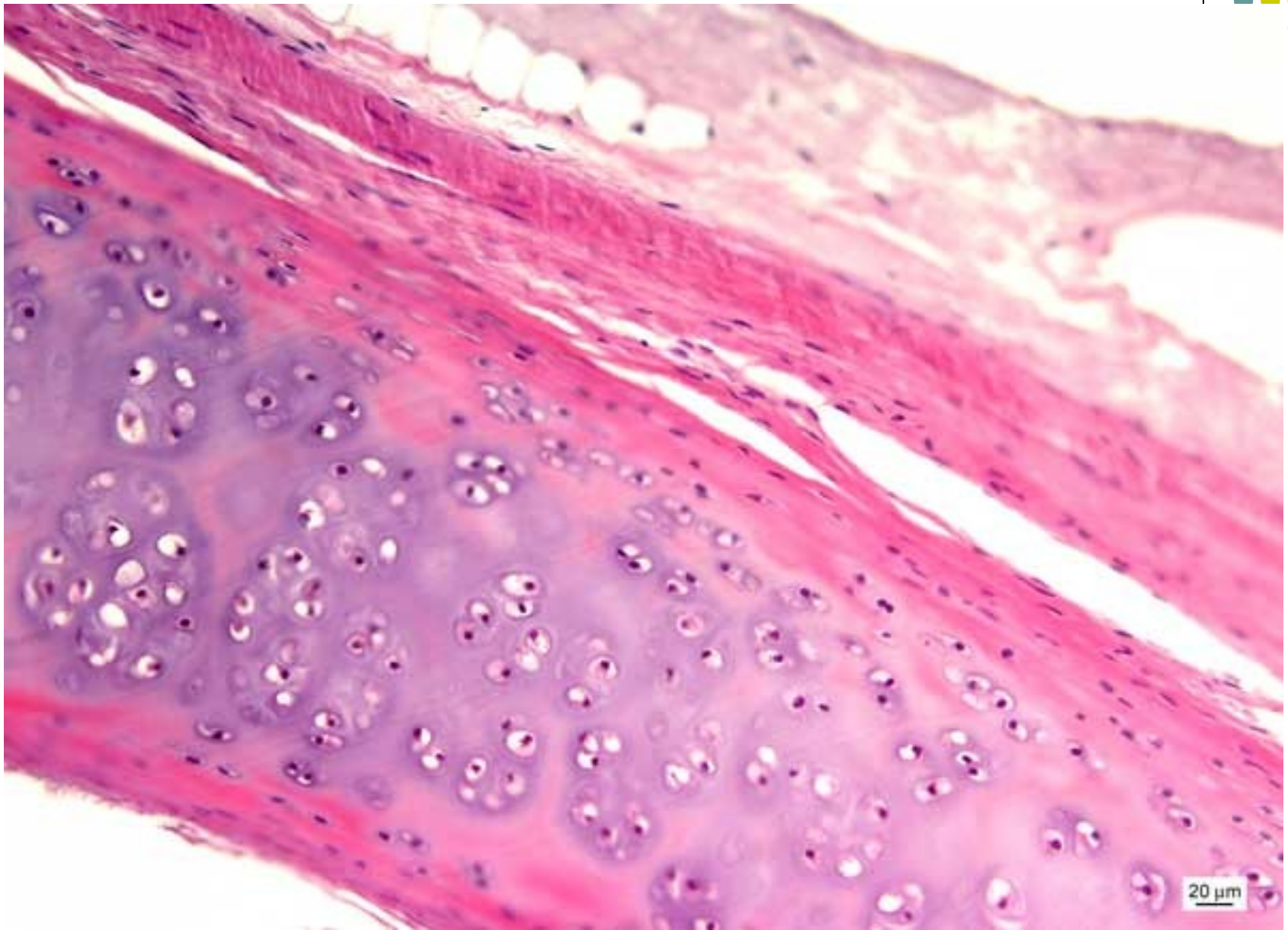
- ***Collagen*** II or I fibers
- ***Elastic*** fibers
- ***Glykosaminoglycans***
–hyaluronic acid,
chondroitin-sulphate
- Proteoglycans
- Glykoproteins



Types of cartilage

- **Hyaline** (*hyalos=glass*) – the most frequent, precursor of many bones in skeleton, covers articular surfaces, forms part of ribs skeleton of the nose, trachea, larynx
- **Elastic** - auricula, tuba auditiva, larynx, epiglottis
- **Fibrocartilage** - intervertebral discs, symphysis pubis, articular discs and meniscus

Hyaline cartilage, trachea, HE

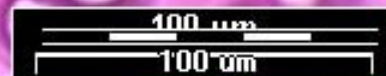


Hyaline cartilage, trachea

Perichondrium

Chondroblasts

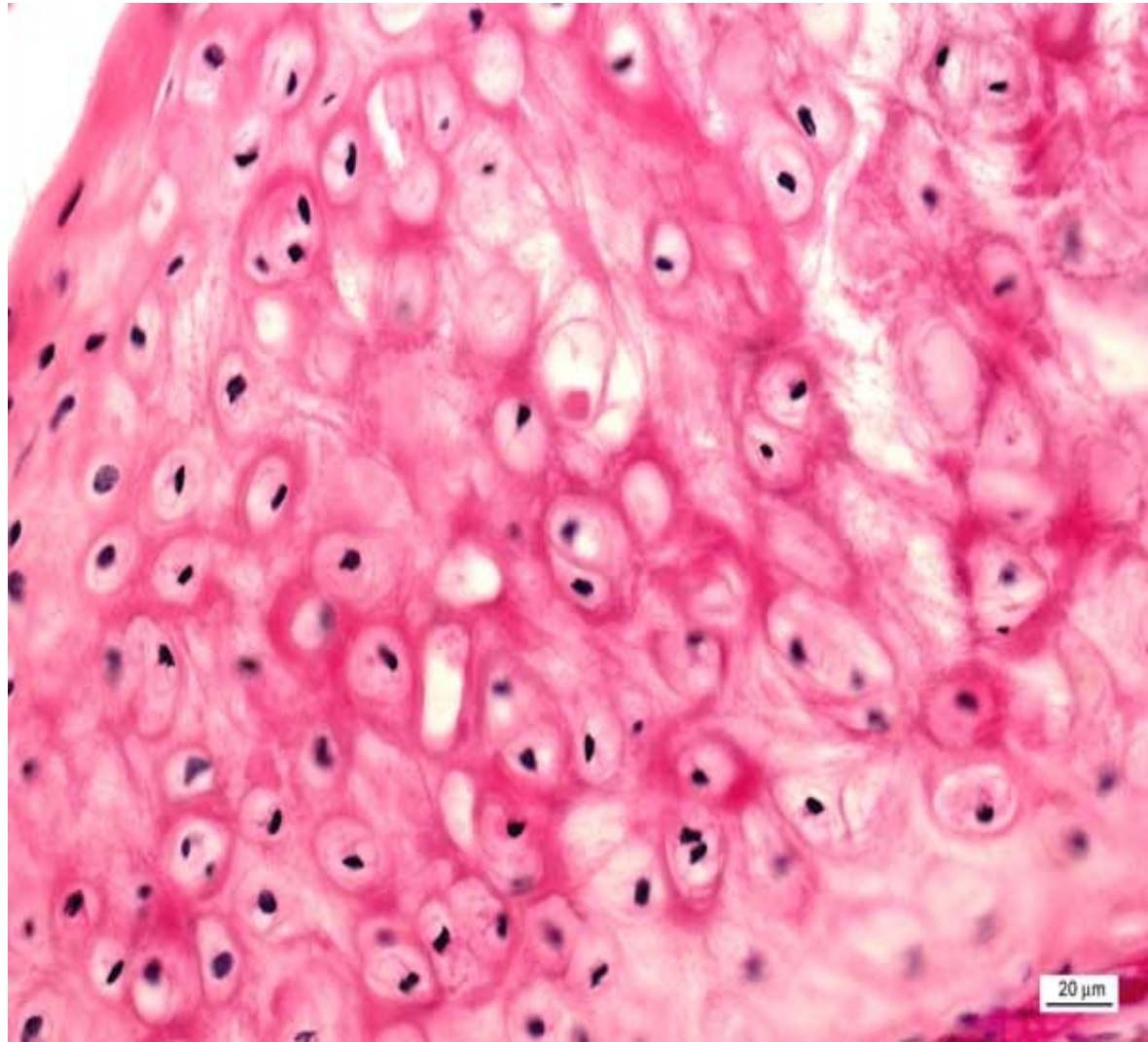
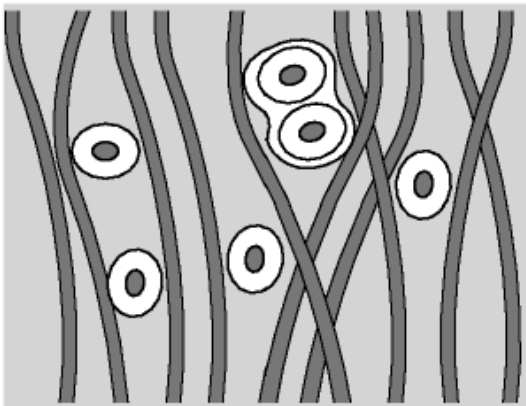
Isogenous (nest) cells

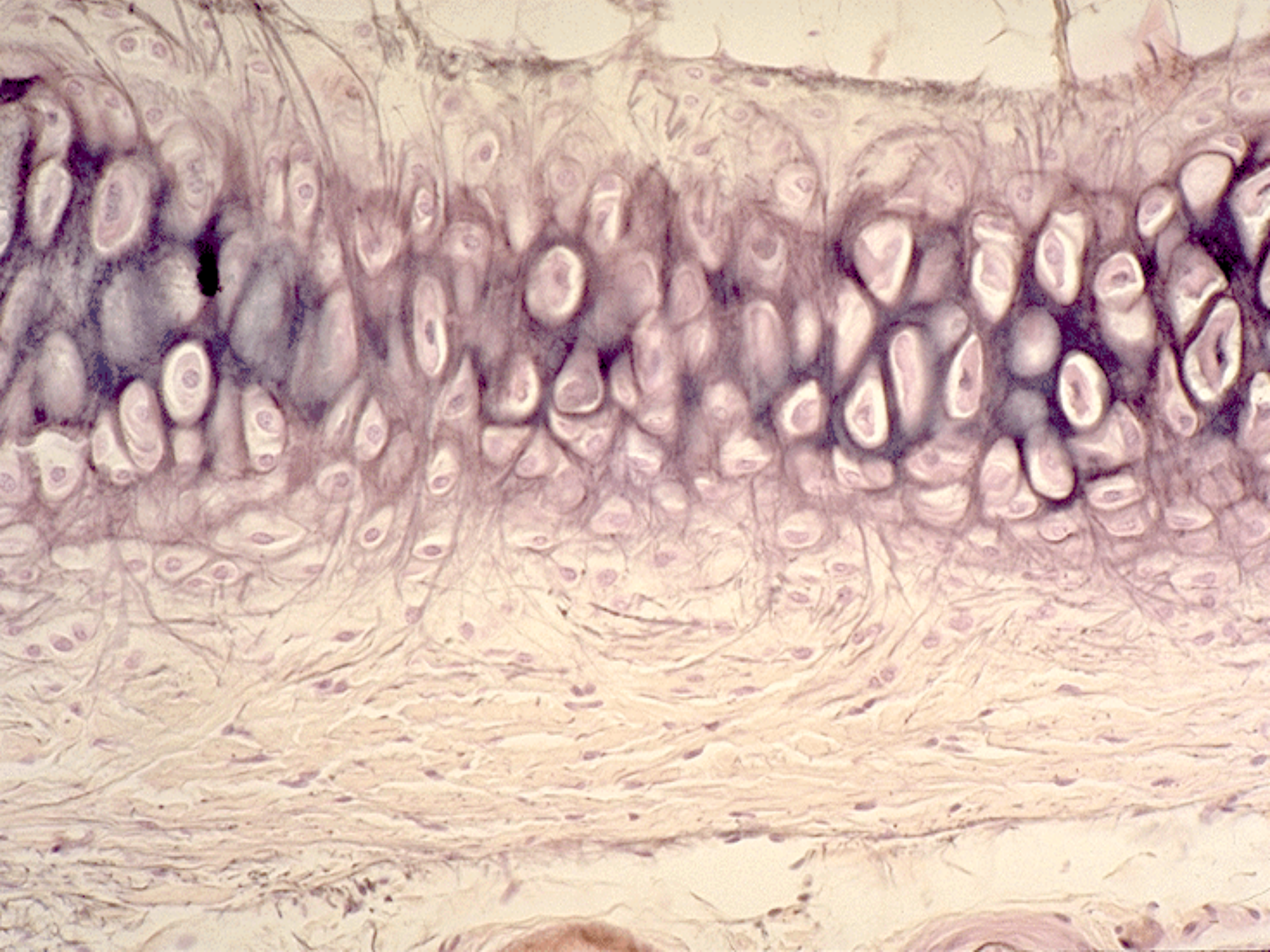


Elastic cartilage



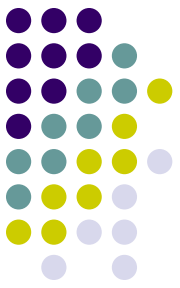
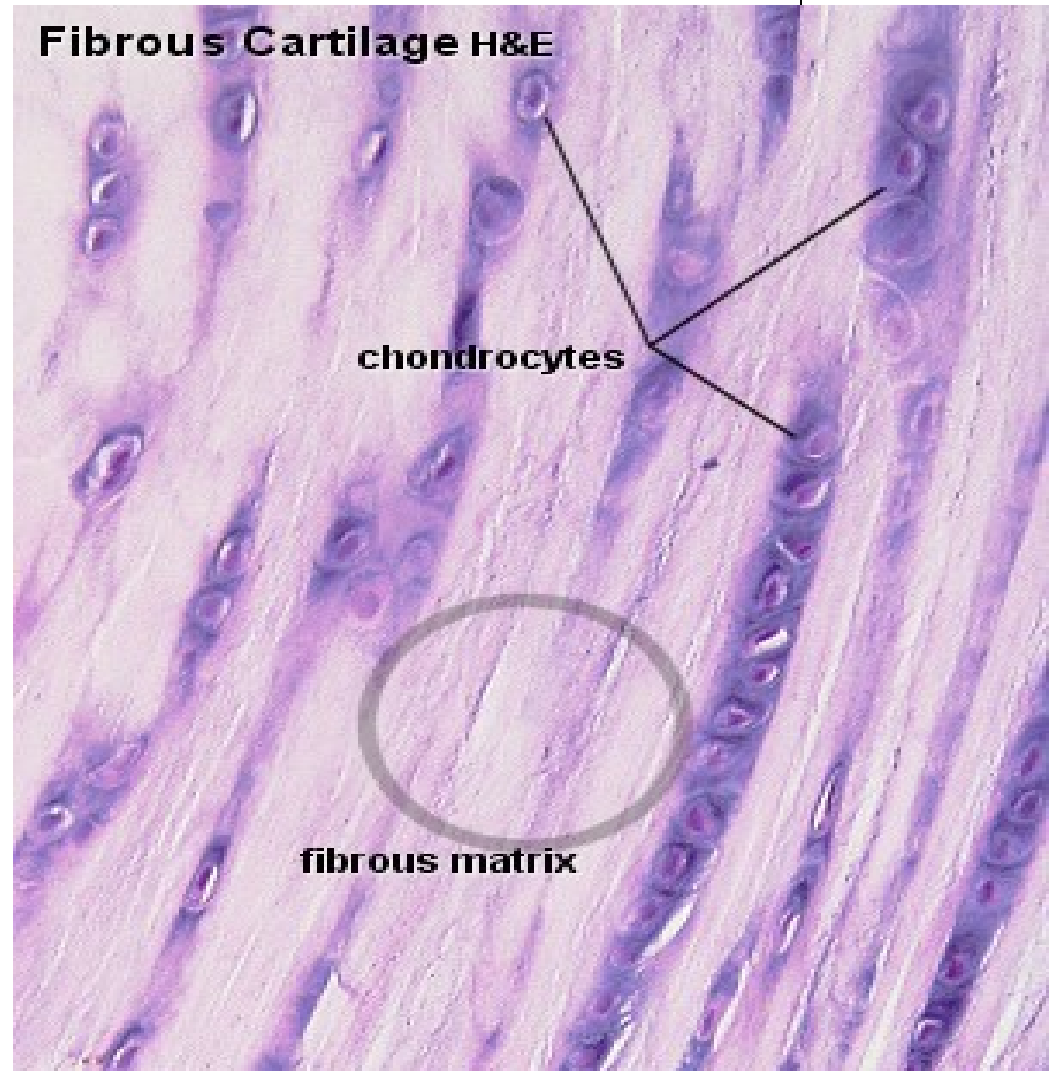
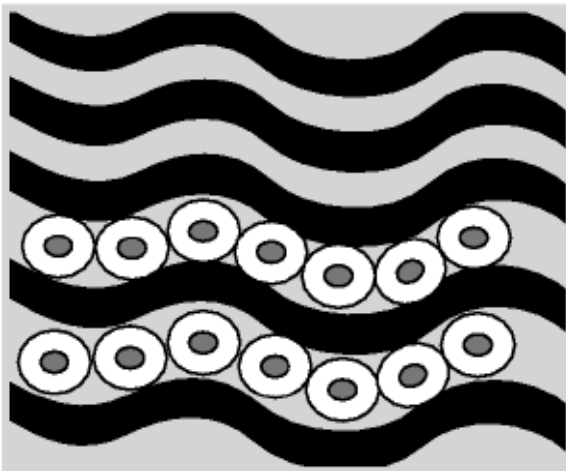
- *elastic fibers in amorphous matrix; special staining: resorcin, fuchsin and orcein.*
- Chondrocytes

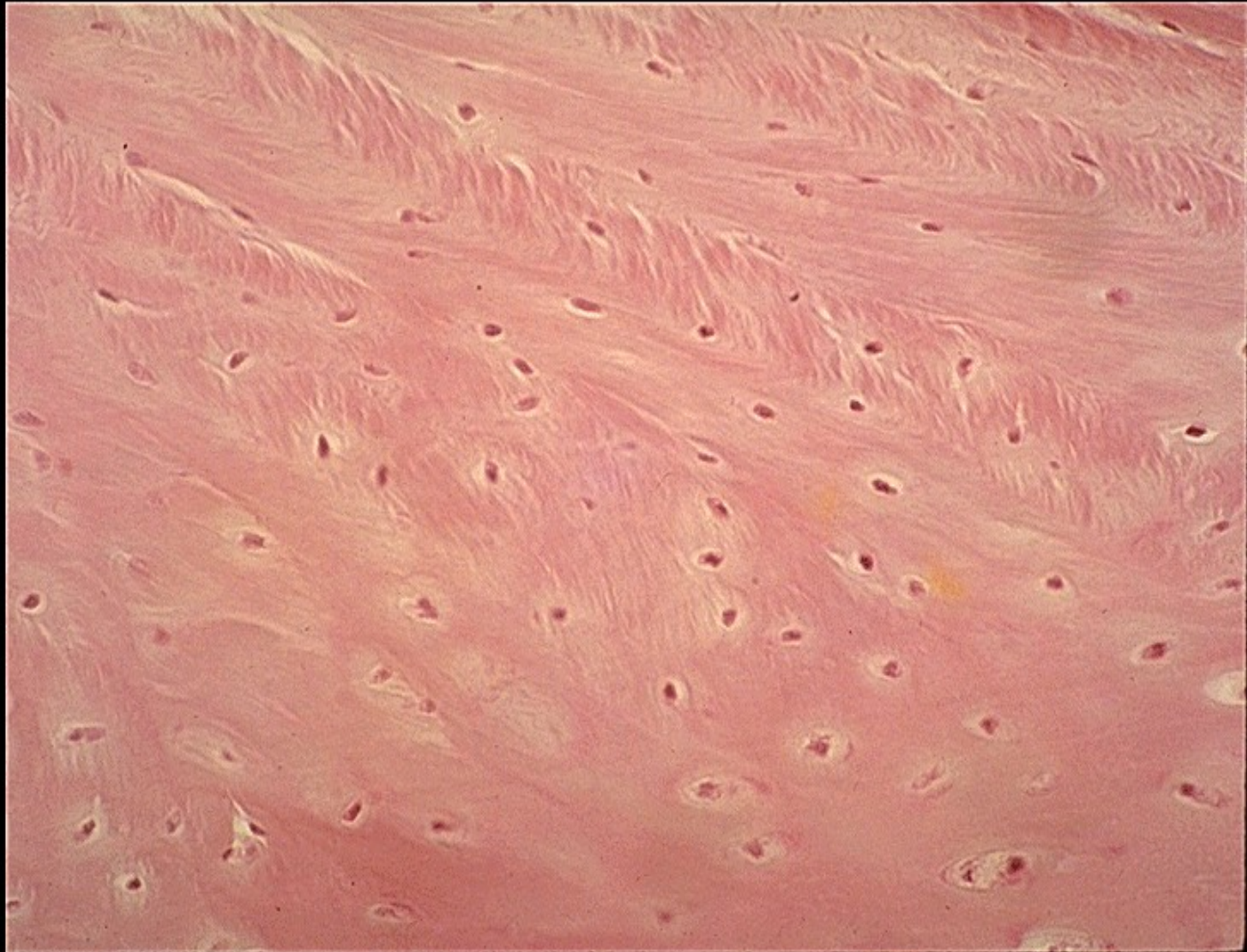




Fibrocartilage

- **Chondrocytes**
- Thick bundles of **collagenous fibers**
- **matrix**
- without perichondrium



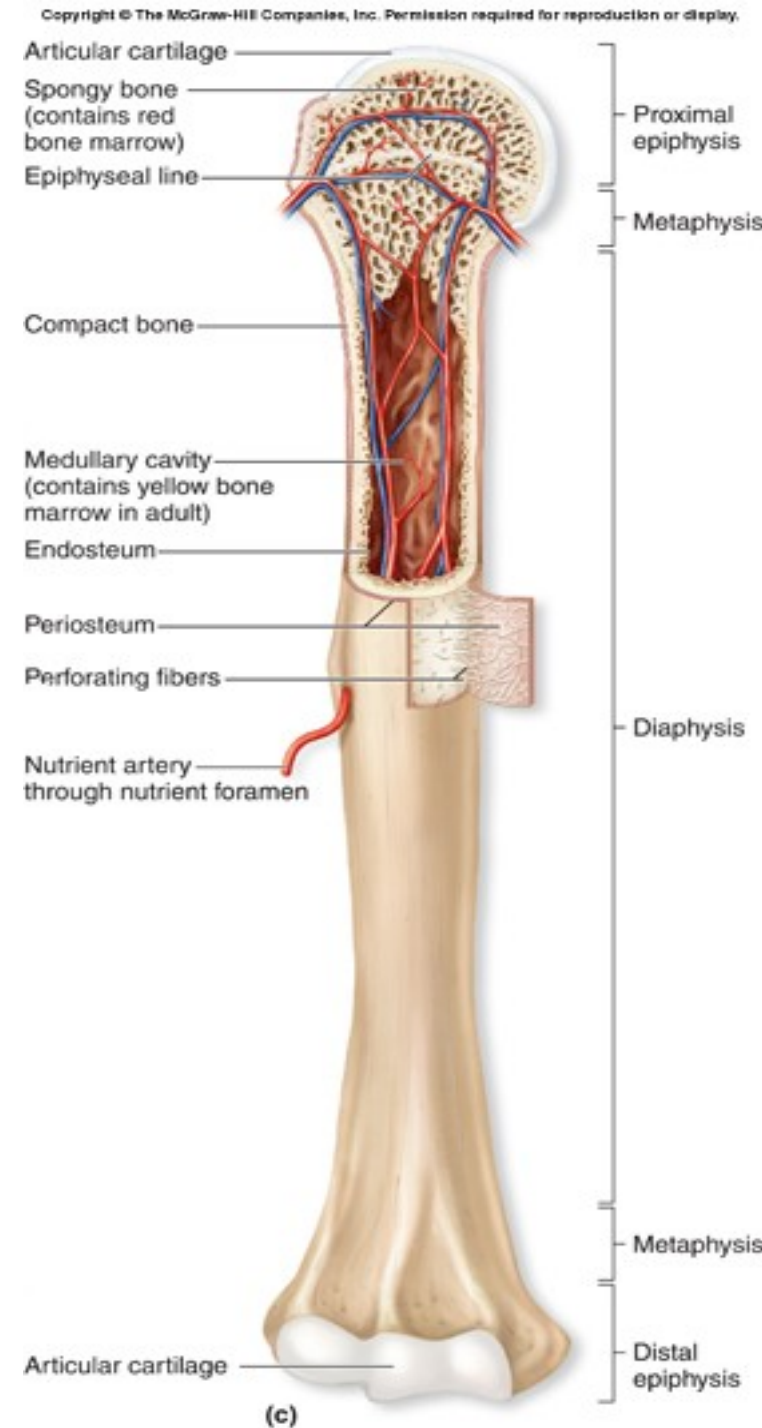


Bone

- specialized form of c. t.

Bone tissue structure

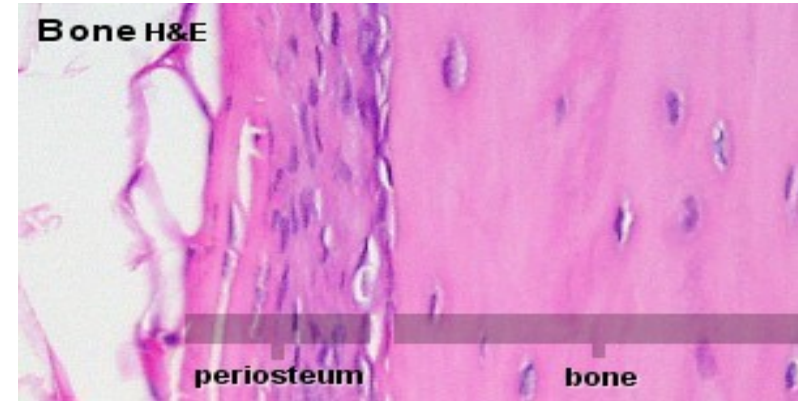
- Bone cells
- Extracellular matrix
 - Organic – collagen fibers
– amorphous matrix
 - Inorganic – minerals
- Periosteum





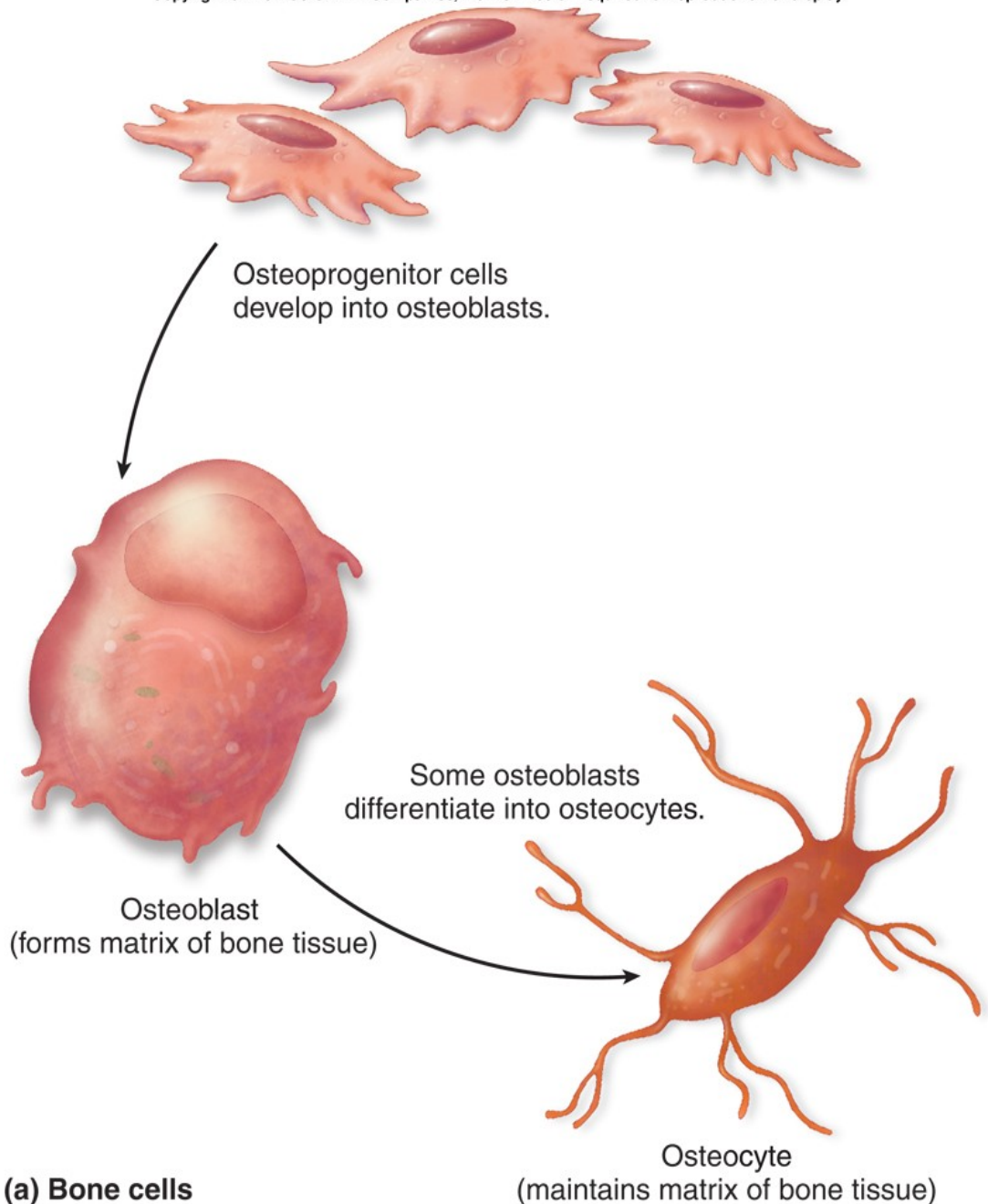
Bone tissue

- **Periosteum** – covers outer surface of bone:
 - Inner layer (osteoblasts, fibroblasts)
 - outer layer (only fibroblasts)Periosteum is attached by Sharpey's fibers.
- **Endosteum** – membrane with one layer of cells (osteoblasts, osteoclasts), covers inner surface of bone turned to the bone cavity)

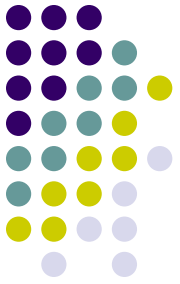
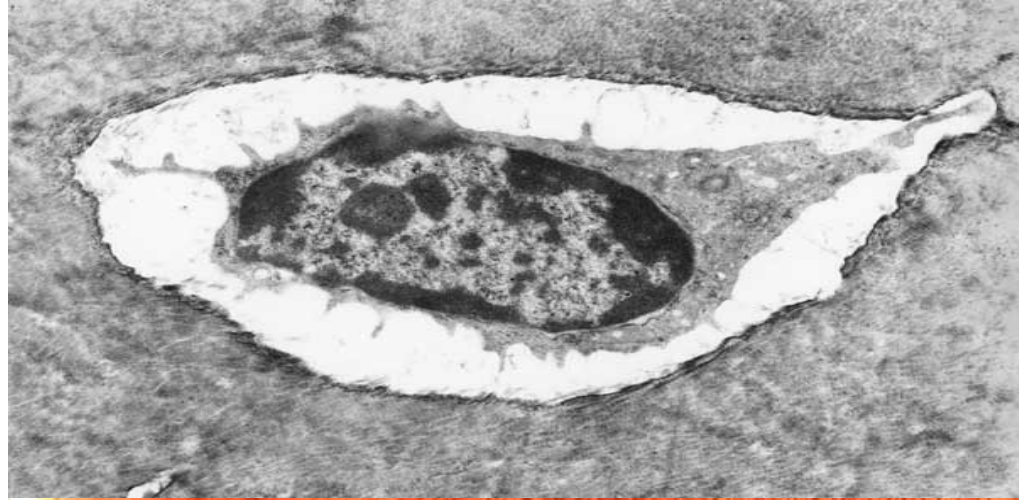


Bone cells

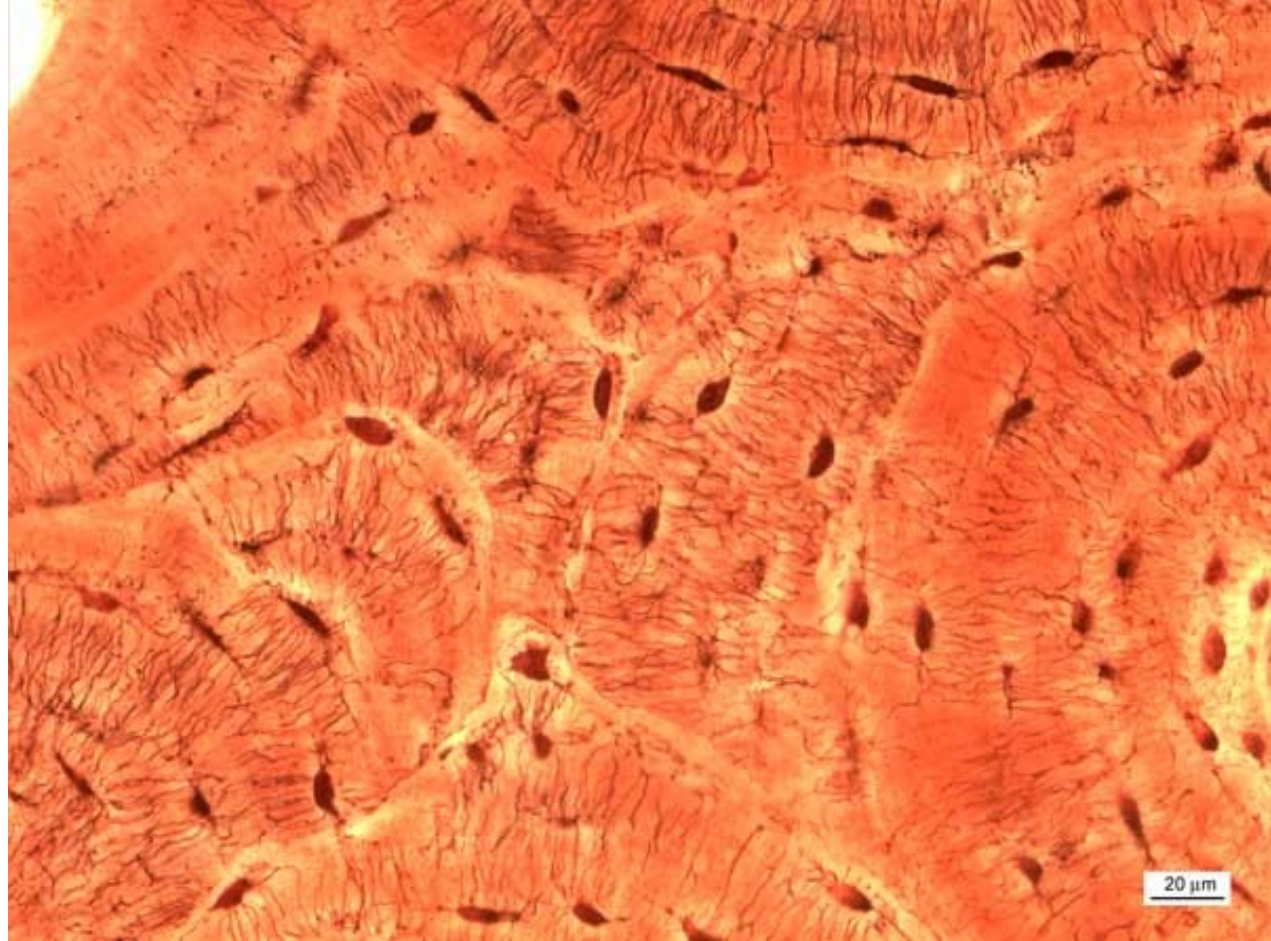
- **osteoprogenitor cells** – stem cells, in periosteum and endosteum
- **osteoblasts** produce organic matter, and transform into **osteocytes**



Osteocyte



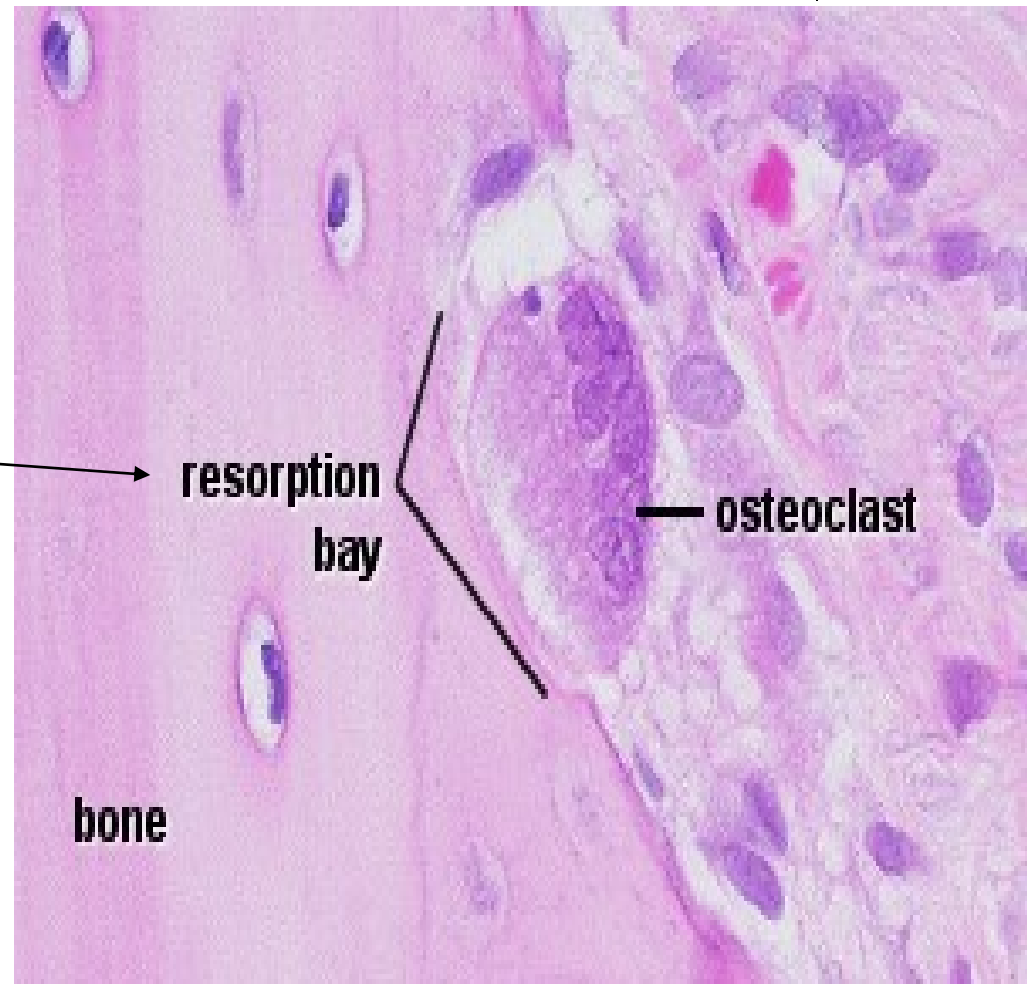
- In *lakuna*,
- Numerous processes in *canaliculi ossium* (cell communication)



Osteoclasts

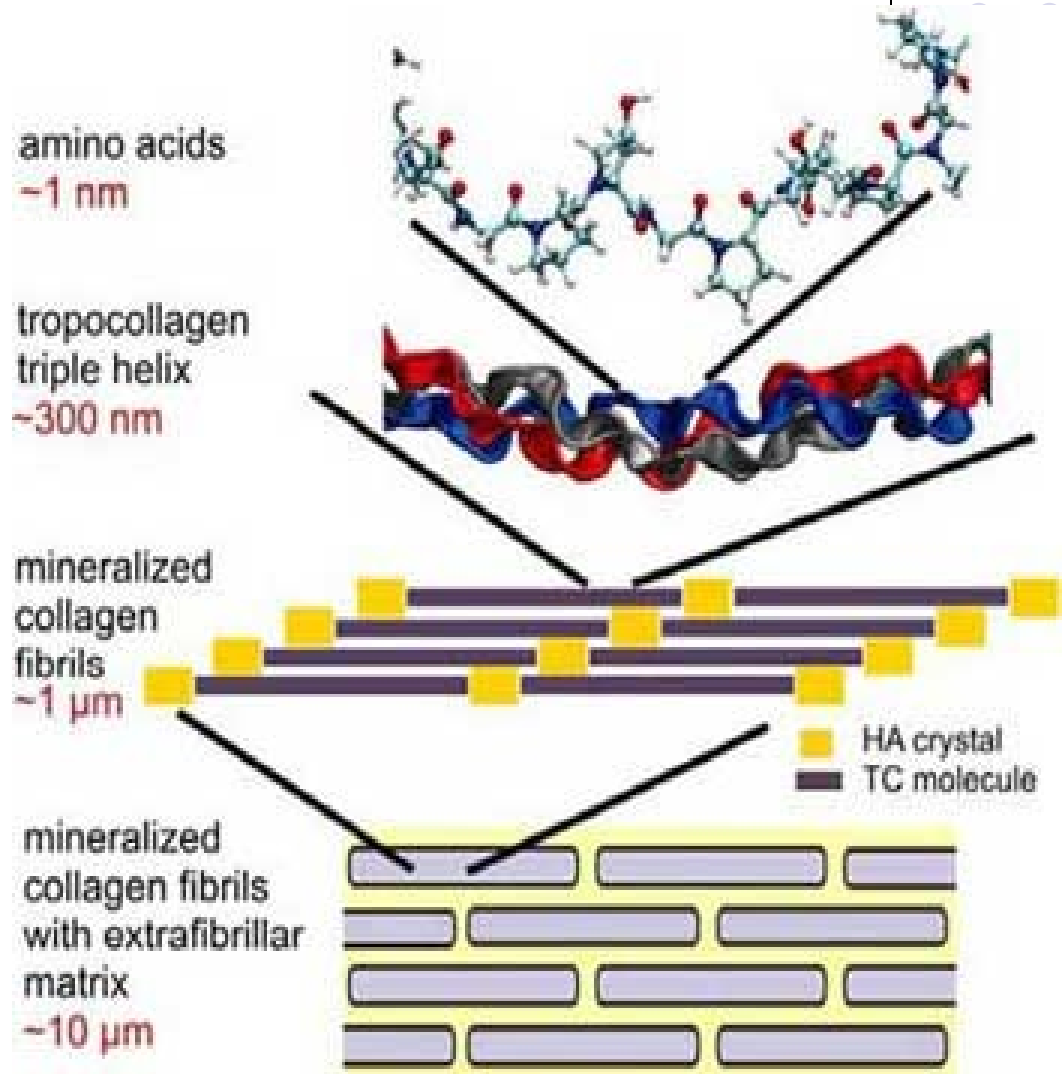


- large cells (up to 100 μm), polynucleated cells (up to 50 N), arise by fusion of monocytes
- in *Howship's lakuna*
- lysosomal enzymes digest collagenous fibers



Bone matrix

- collagen fibers – collagen I (cca 90 % of org. matter)
- amorphous matrix – osteoid.
- strength of matrix is caused by content of *inorganic salts* (hydroxyapatite).





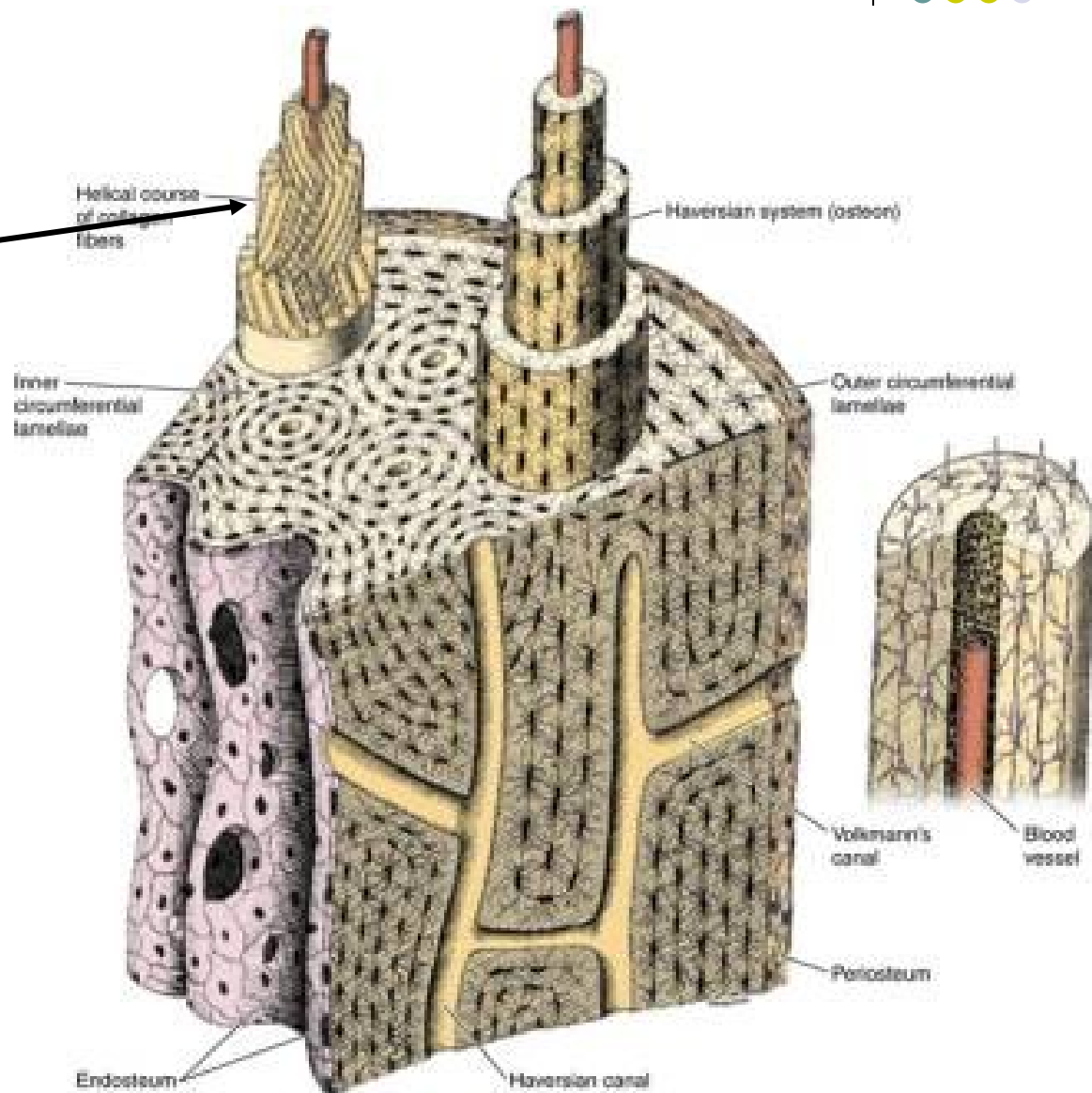
Types of bone tissue

- **2 types:** /according to arrangement of collagen fibers/
 - **Fibrillar (woven) bone** – primary
 - **Lamellar bone** – secondary
 - compact – wall of long bone diaphysis, surface layer of epiphysis
 - spongy /trabecular/ – inner part of epiphysis

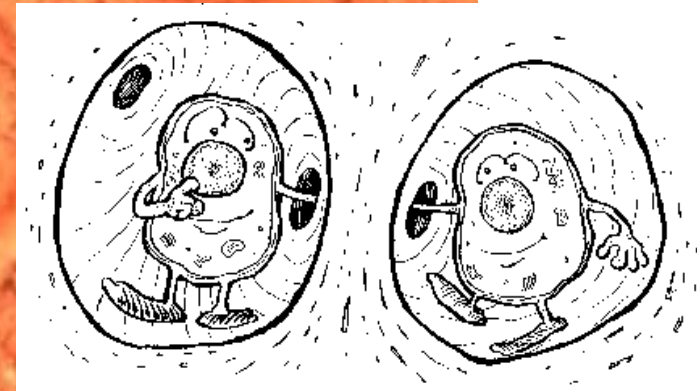
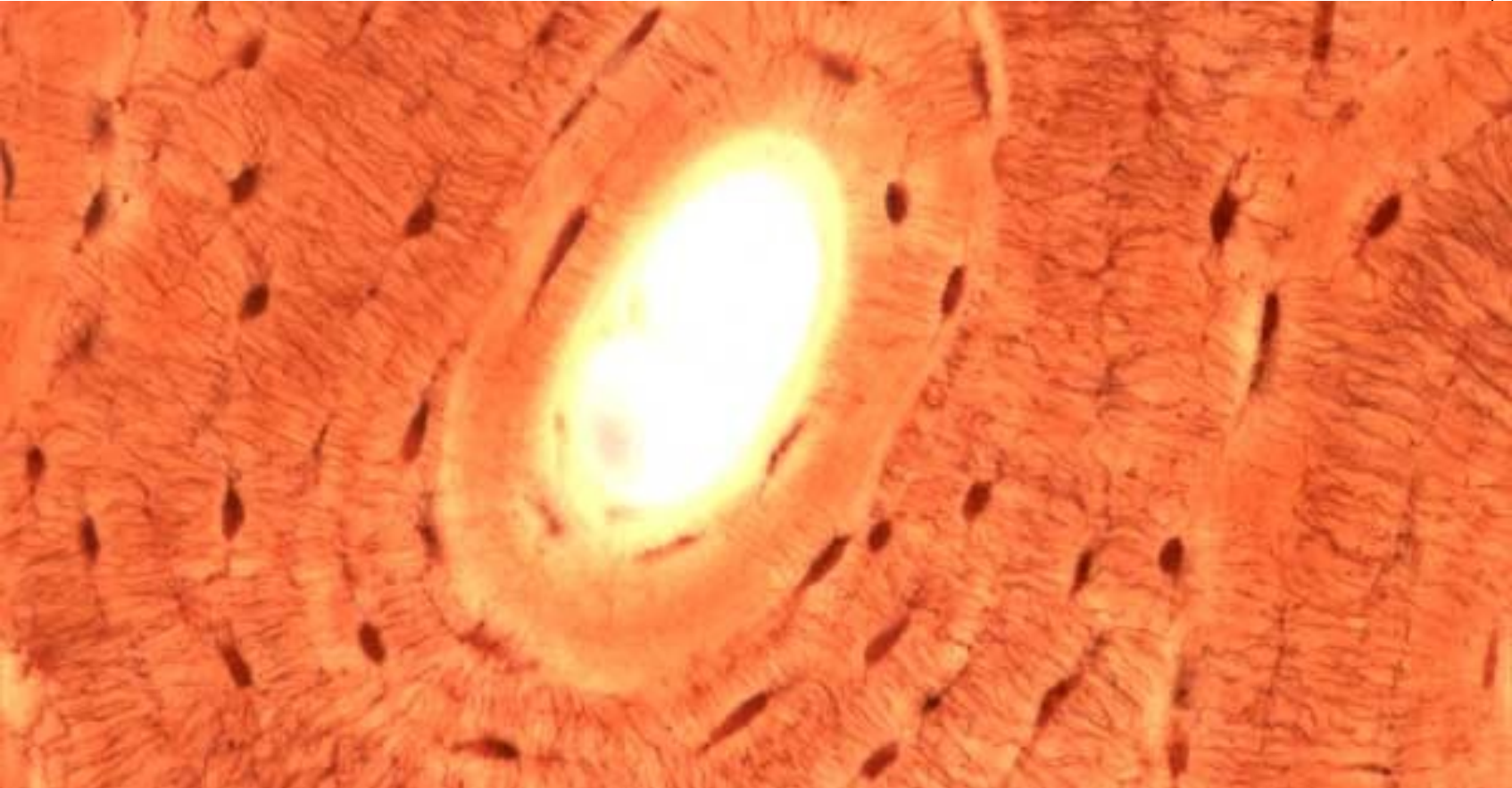
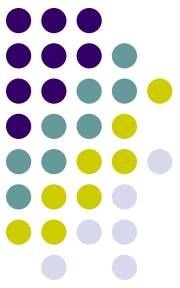
Lamellar bone



- **Lamellae** – thin plates with regularly arranged **collagen fibers**
- **Haversian systems - osteons**
- **Circumferential lamellae**
 - outer
 - inner
- **Interstitial lamellae**



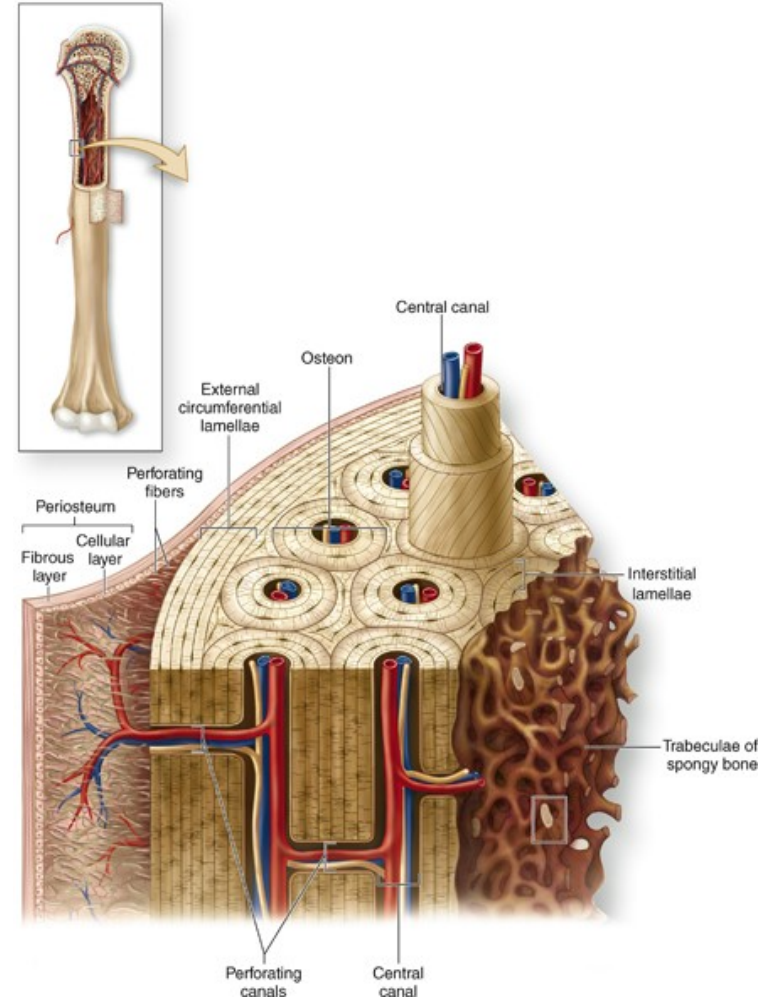
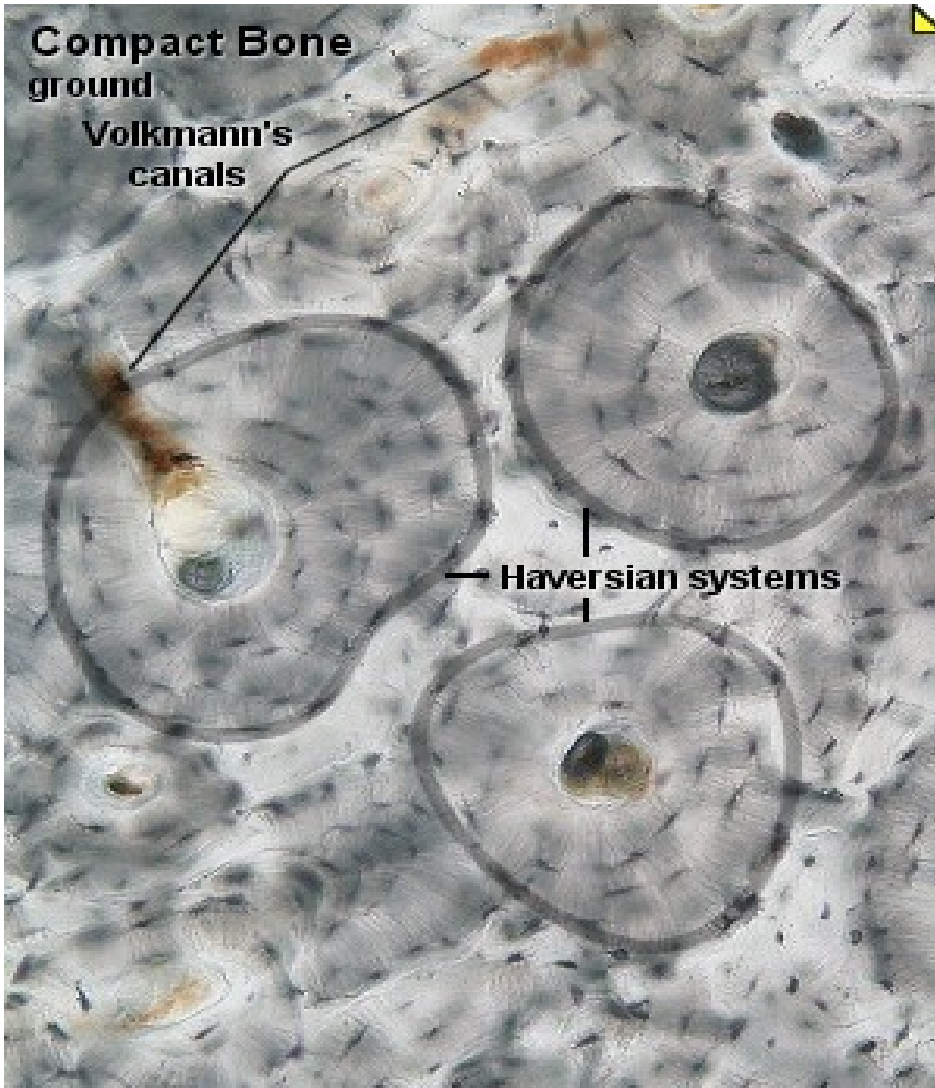
Haversian system – osteon



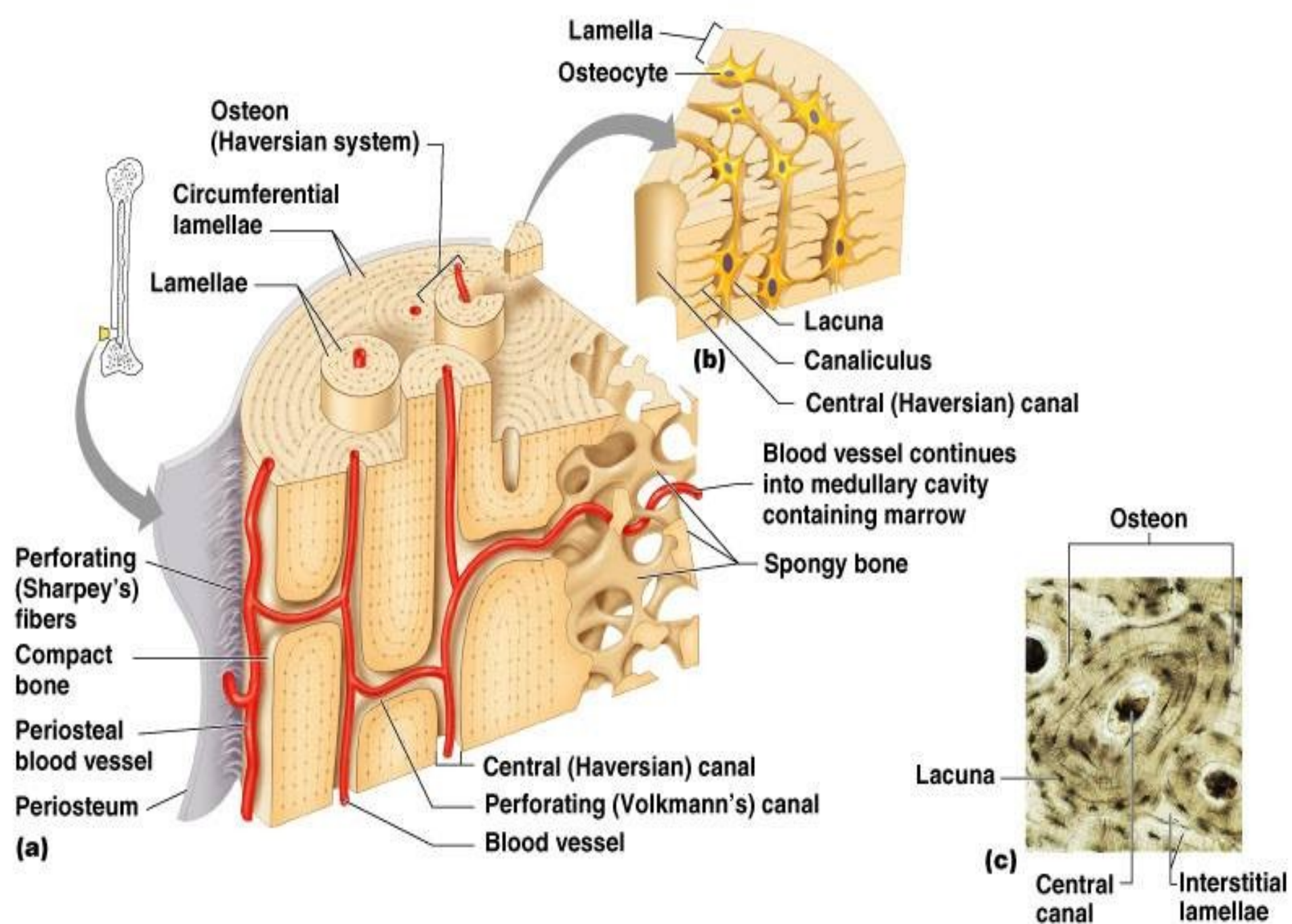
Lamellar bone



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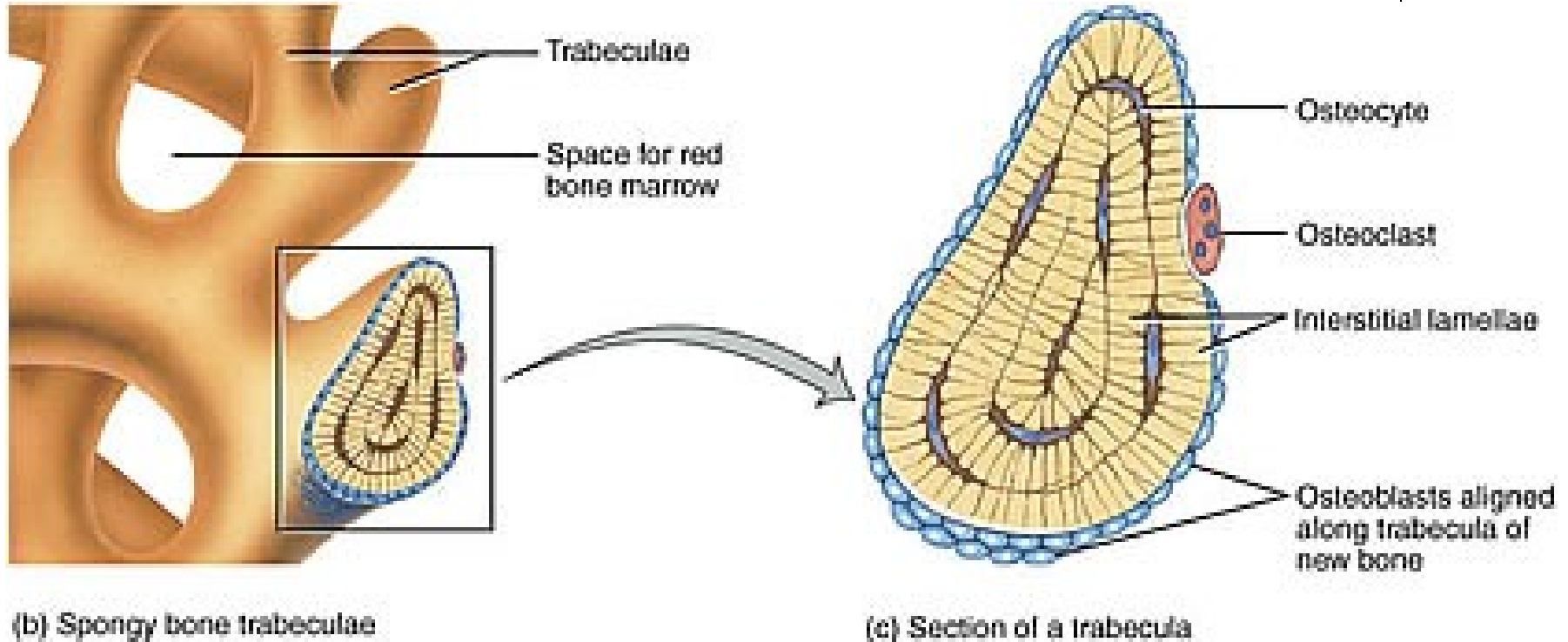


Haversian and Volkmann's canals



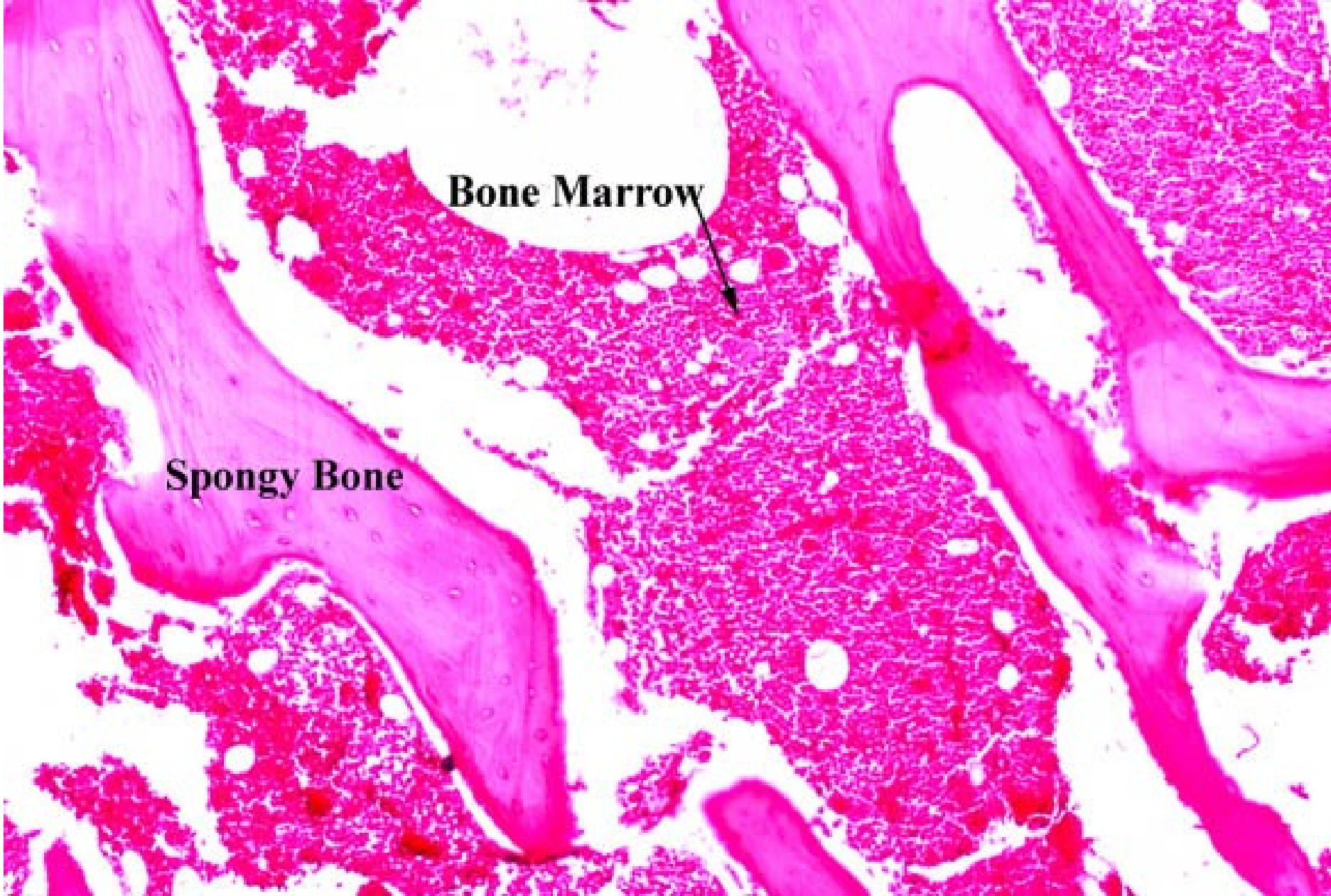


Lamellar bone – spongy type



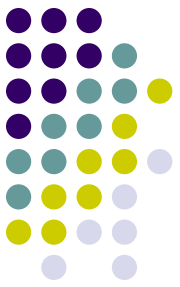
- Matrix is also organized into the ***lamellae***, but don't form Haversian systems.

Lamellar bone – spongy, HE



Bone Marrow

Spongy Bone



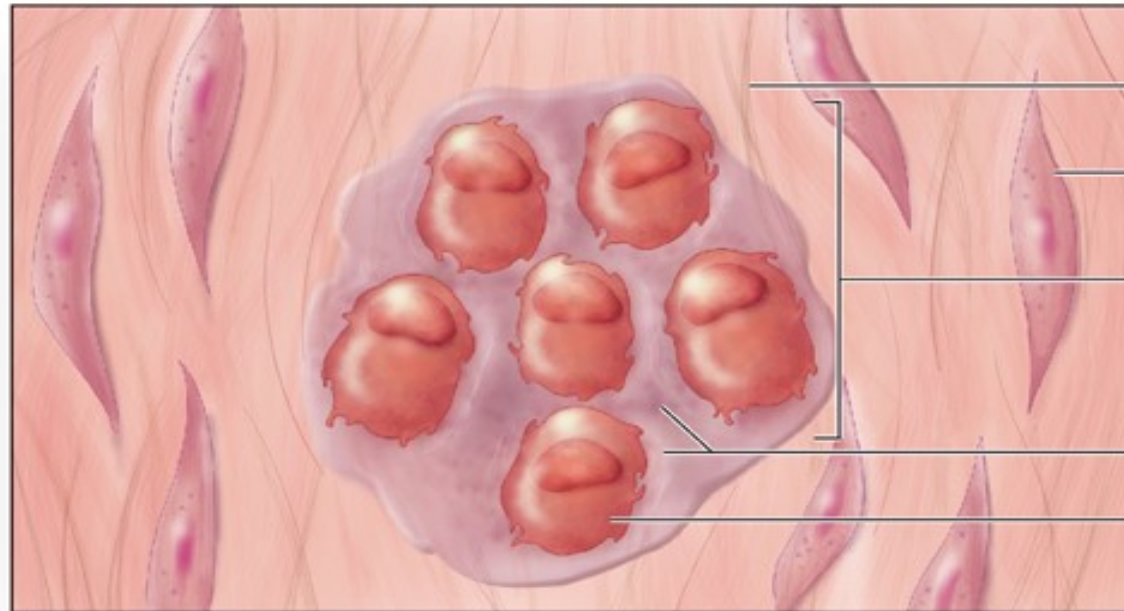
Histogenesis of bone tissue

- **Endochondral ossification** – hyaline cartilage is model for bone
(long bones)

- **Intramembranous ossification** – mesenchyme membrane is model, mesenchymocytes differentiate into osteoblasts
(skull bone, part of mandible and clavicle)

Intramembranous ossification

- ① Ossification centers form within thickened regions of mesenchyme



Collagen fiber

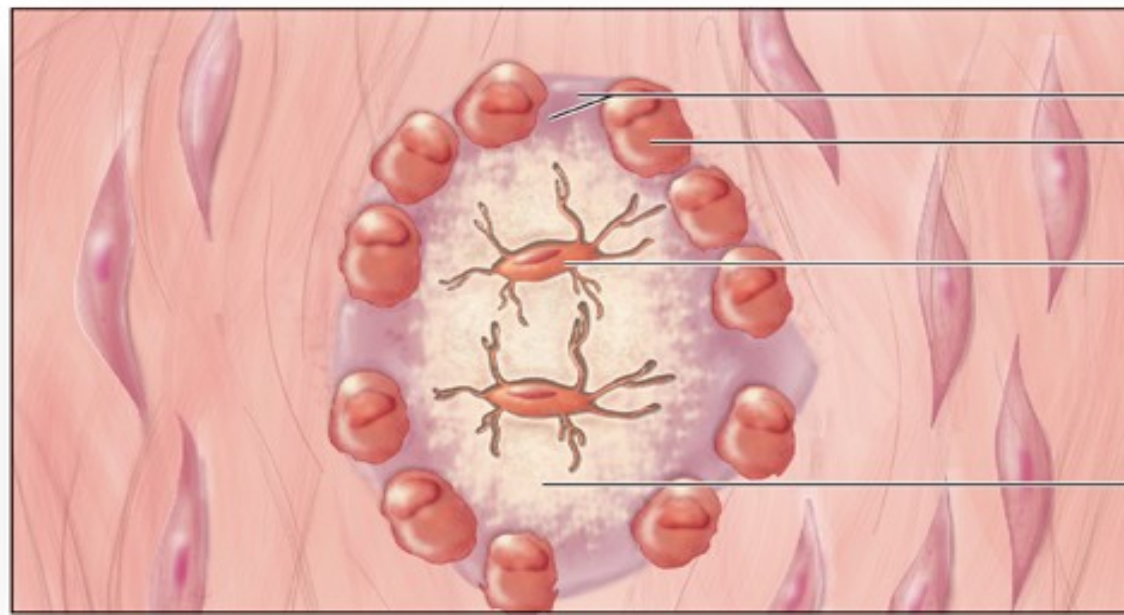
Mesenchymal cell

Ossification center

Osteoid

Osteoblast

- ② Bone matrix (osteoid) undergoes calcification.



Osteoid

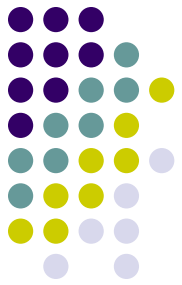
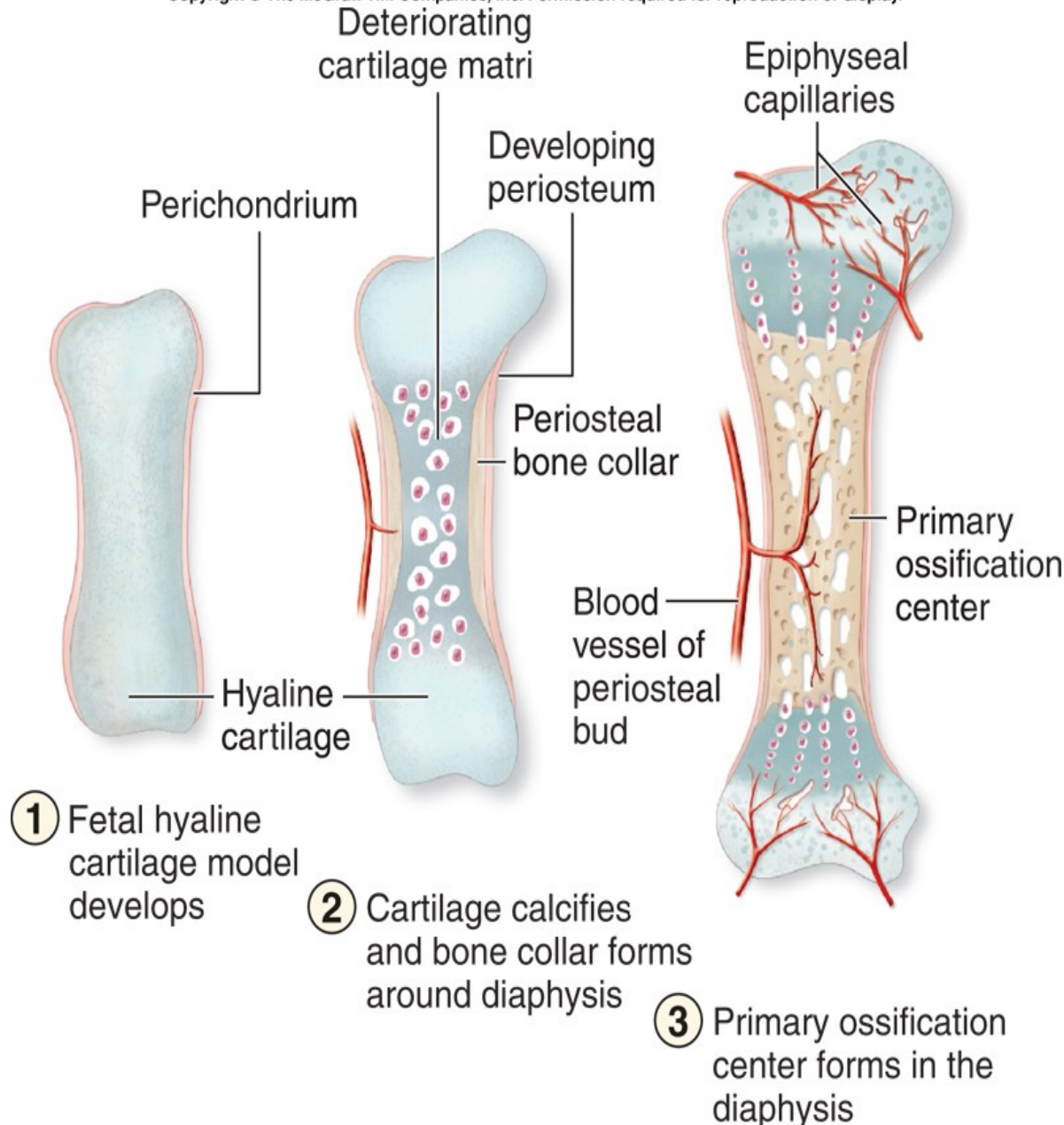
Osteoblast

Osteocyte

Newly calcified bone matrix

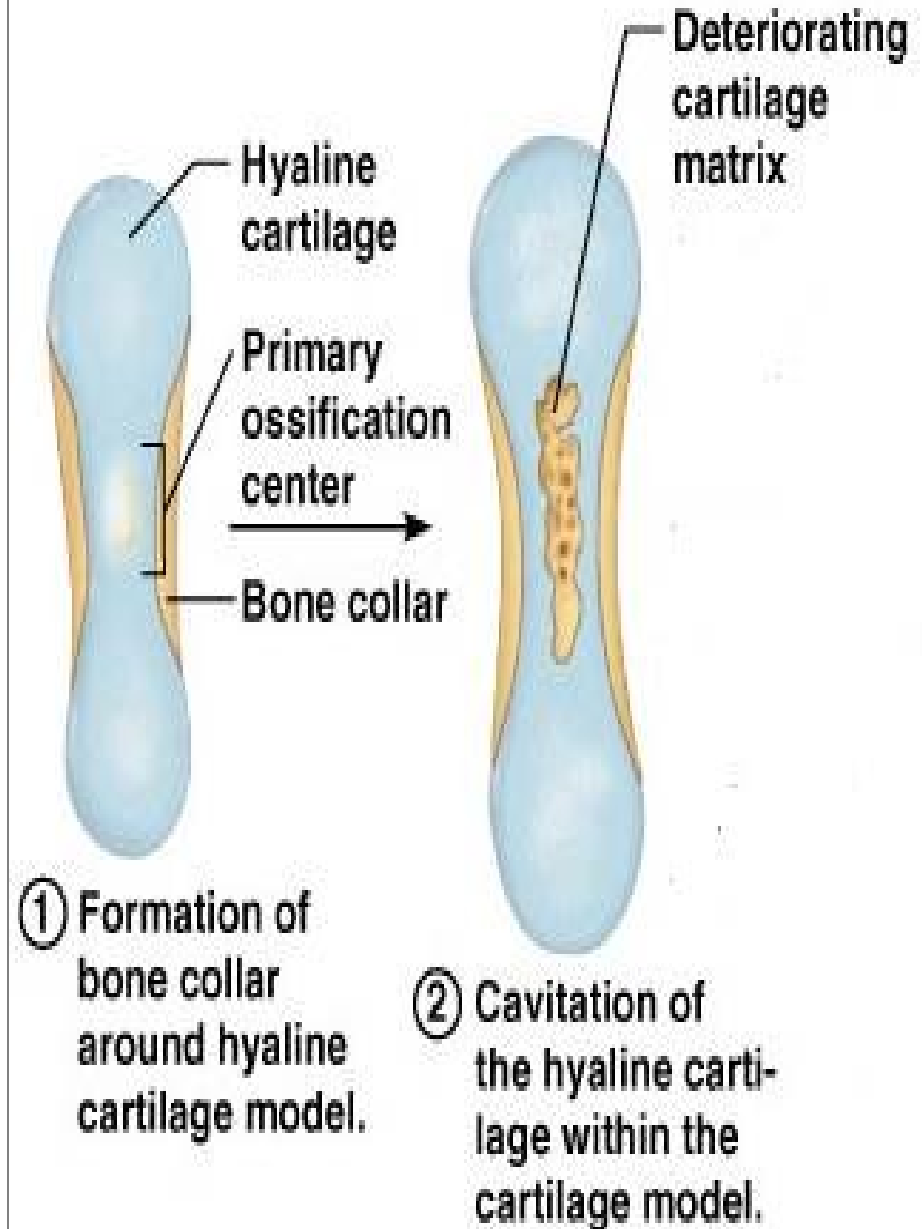
Endochondral ossification

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Periosteal bone collar

Undifferentiated cells in the perichondrium become osteoblasts, and the perichondrium is now the periosteum.

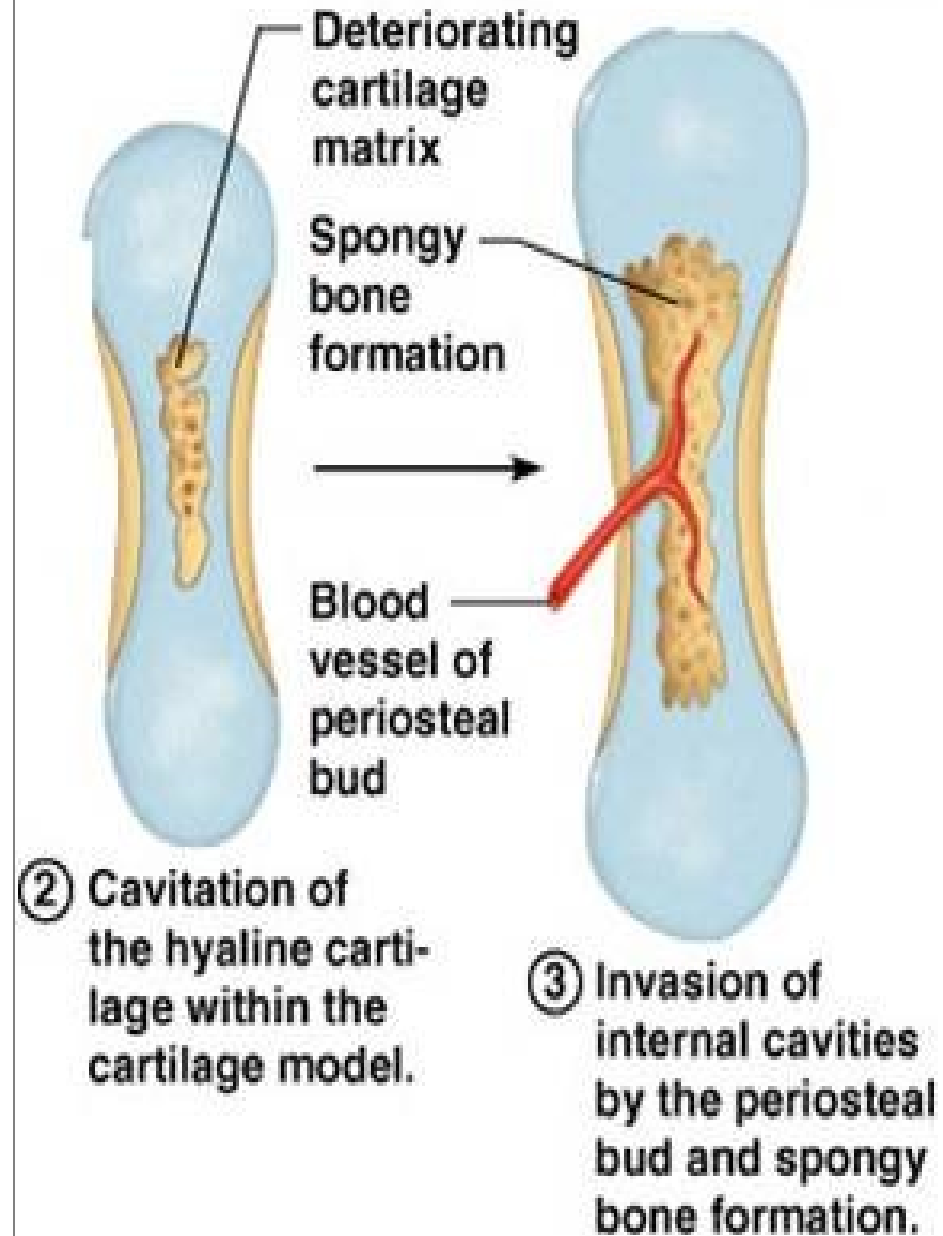


Chondrocytes at the center of the growing (**proliferating zone**) cartilage model enlarge (**zone of hypertrophy**).

The matrix calcifies (**zone of calcification**) and chondrocytes die. The rest of matrix form trabecular processes – spicules.

Blood vessels penetrate cartilage and carry the osteoblasts from periosteum. Osteoblasts cover the spicules and produce osteoid (**ossification zone**).

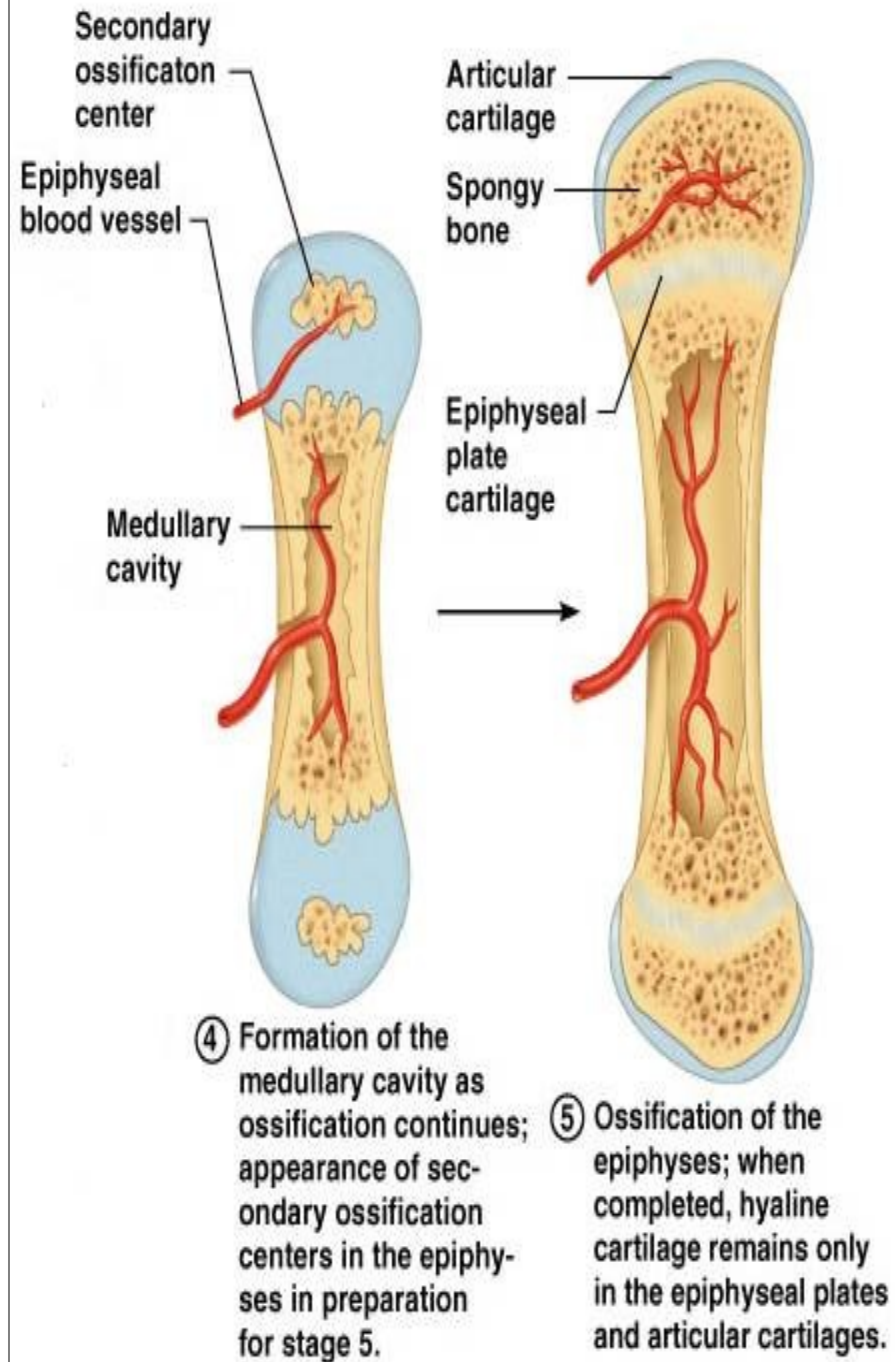
Ossification spreads in long axis of bone.



Osteoclasts resorb primitive bone (**zone of resorption**) and medullary cavity is formed.

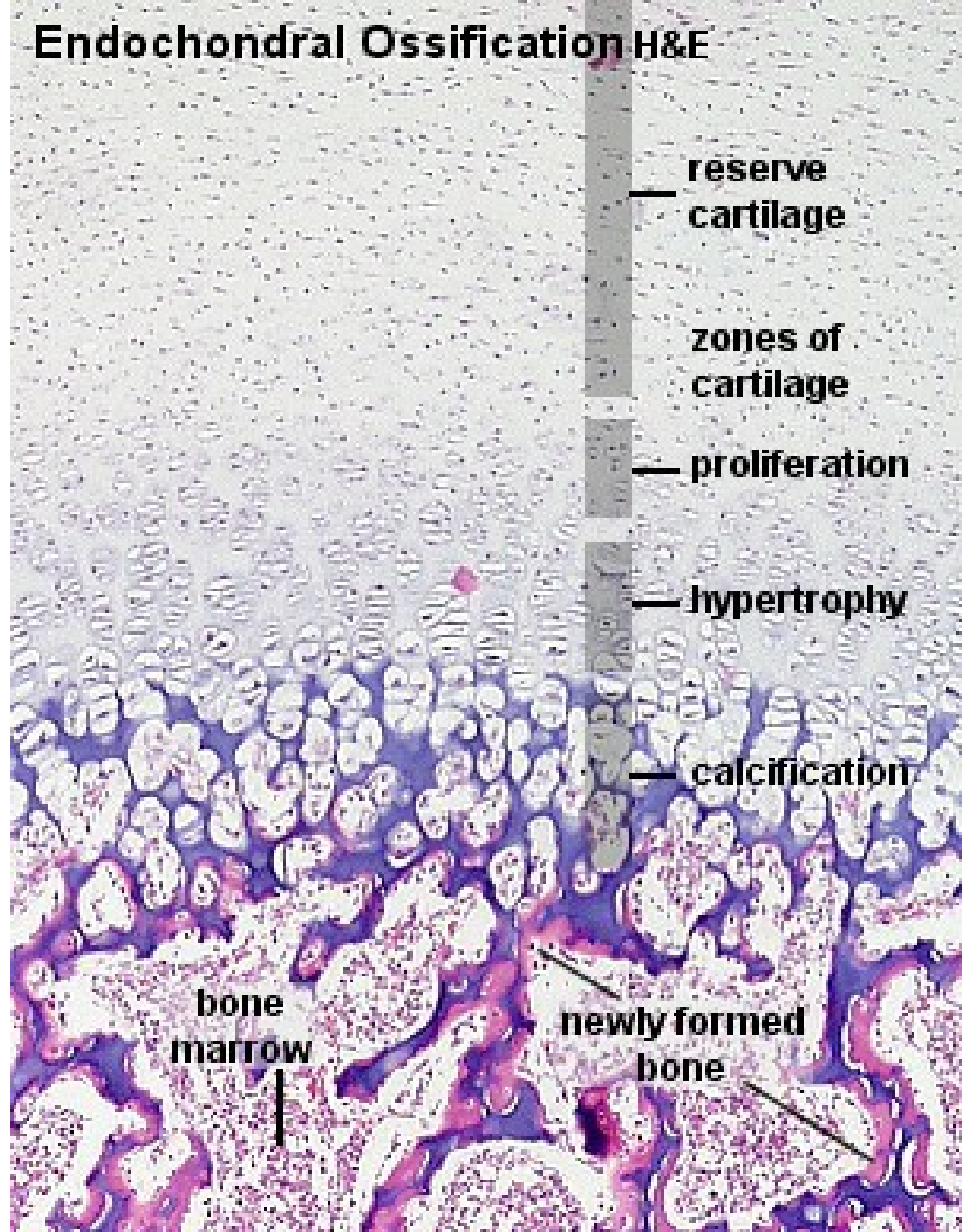
Similar process begins in epiphyses. Ossification spread radially.

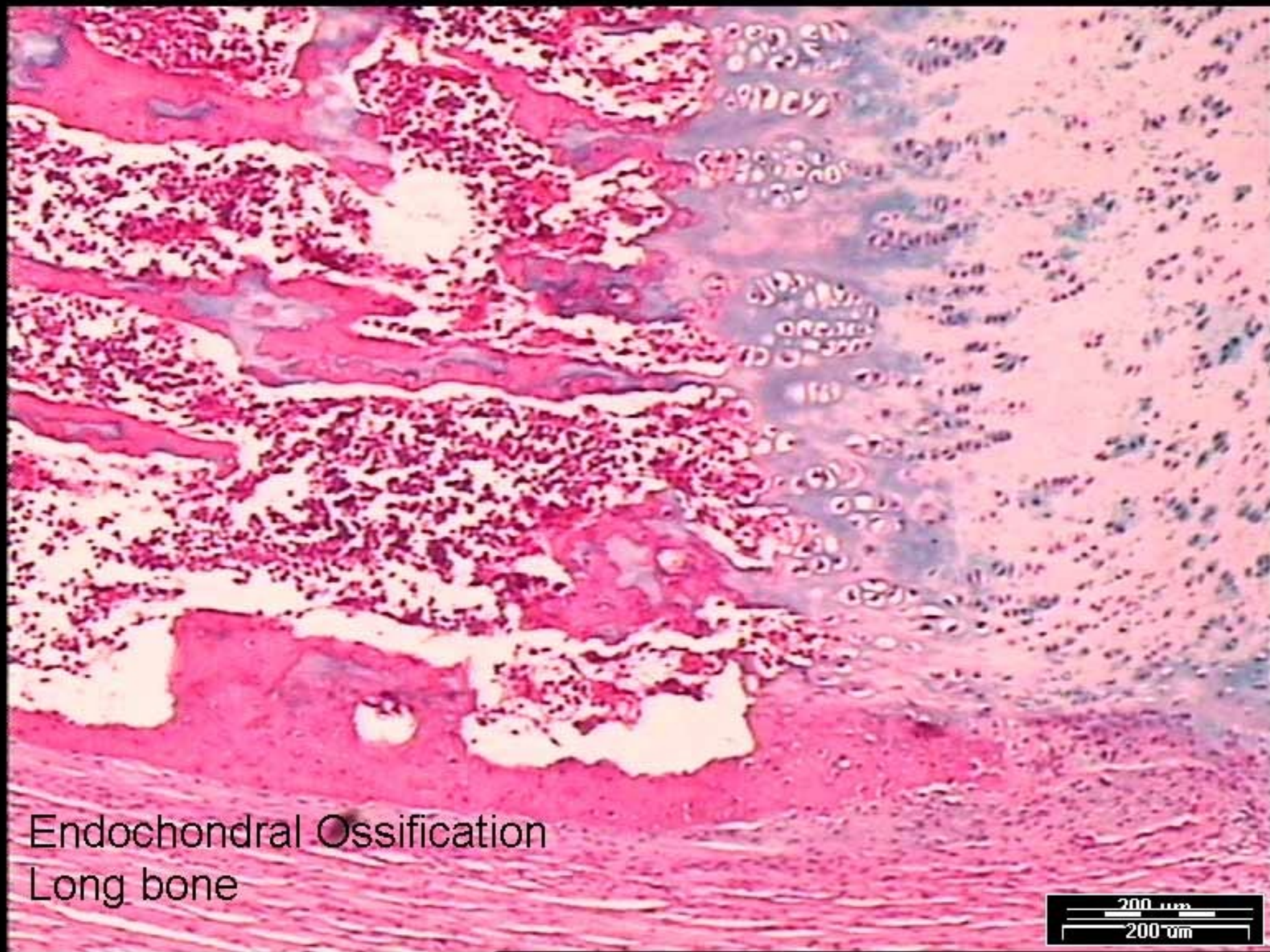
Also epiphyseal plates ossify at the end of body growth (cca 18 years).



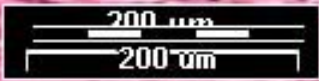
Endochondral ossification

- Zone of normal cartilage
- Zone of proliferated cartilage
- Zone of hypertrophic cartilage
- Zone of calcification
- Line of erosion
- Zone of ossification
- Zone of resorption





Endochondral Ossification
Long bone



Endochondral Ossification
Long bone

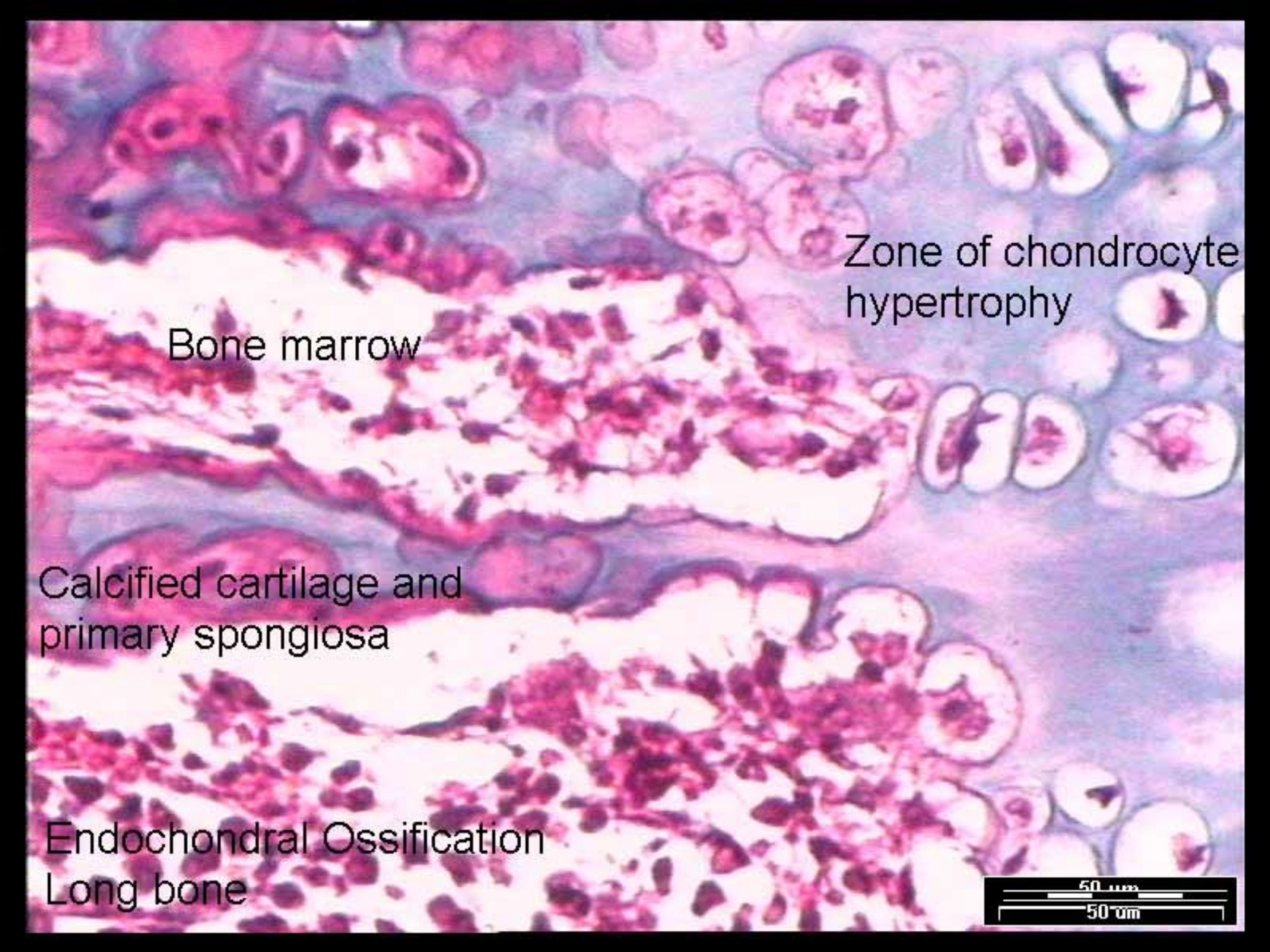




Growth Plate
Endochondral Ossification

This micrograph shows a cross-section of a developing bone. On the left, a growth plate is visible, characterized by a columnar arrangement of chondrocytes. To the right, the cartilage matrix is shown, with numerous small, dark-staining chondrocytes embedded within it. The overall structure is stained with hematoxylin and eosin (H&E), giving it a pinkish-purple hue.





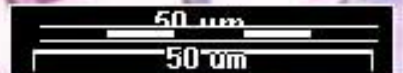
This histological image shows a cross-section of a long bone during endochondral ossification. The central part of the image is a large, irregularly shaped area of bone marrow, which is a collection of hematopoietic cells. This marrow is surrounded by a layer of calcified cartilage and primary spongiosa, which is the site of active bone formation. The outermost layer of the bone is composed of endochondral ossification, where cartilage is being replaced by bone tissue. The overall structure is a long bone, and the image is stained with hematoxylin and eosin (H&E).

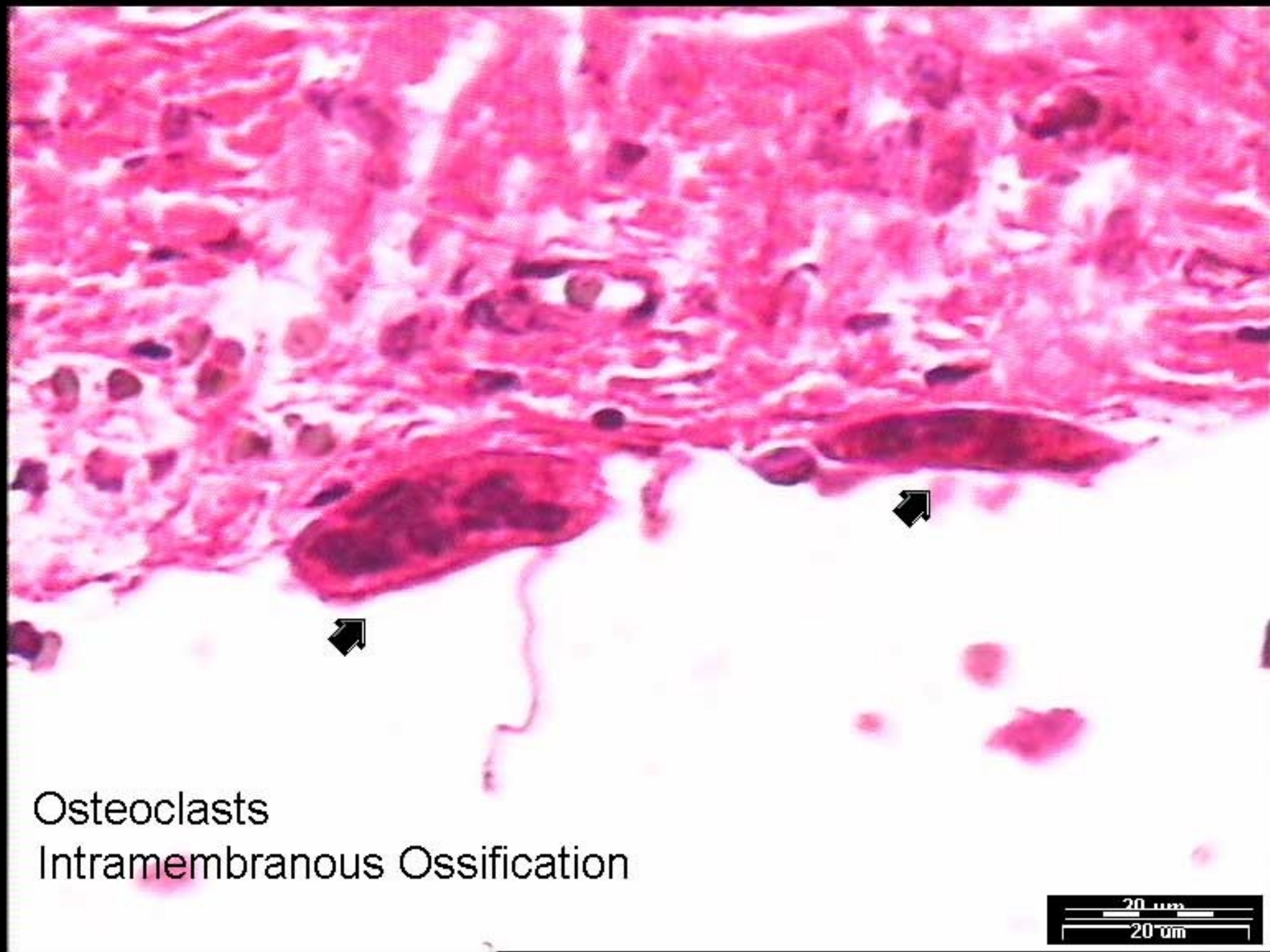
Bone marrow

Zone of chondrocyte hypertrophy

Calcified cartilage and primary spongiosa

Endochondral Ossification
Long bone





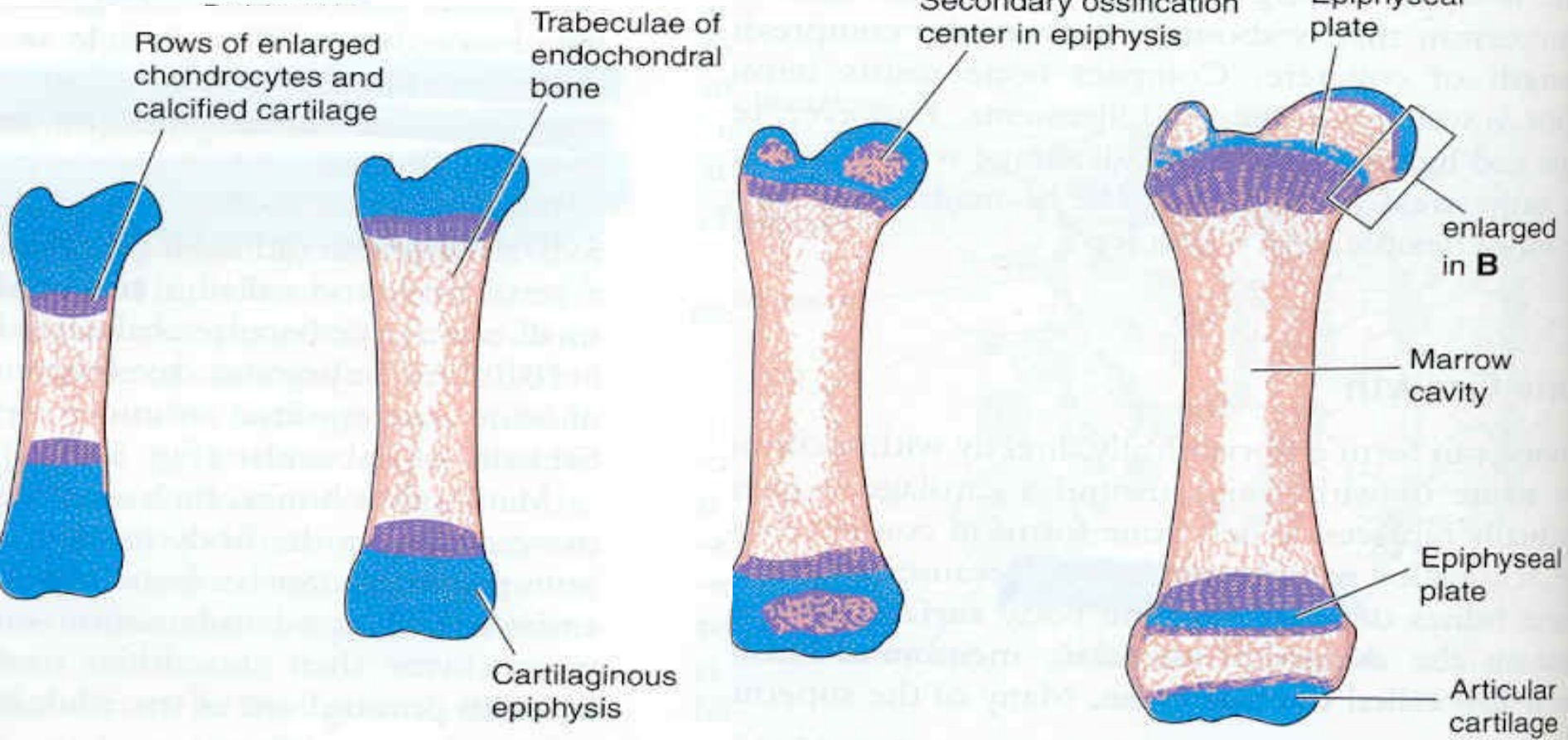
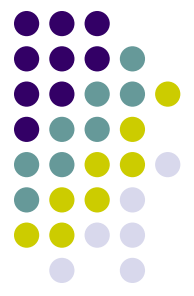
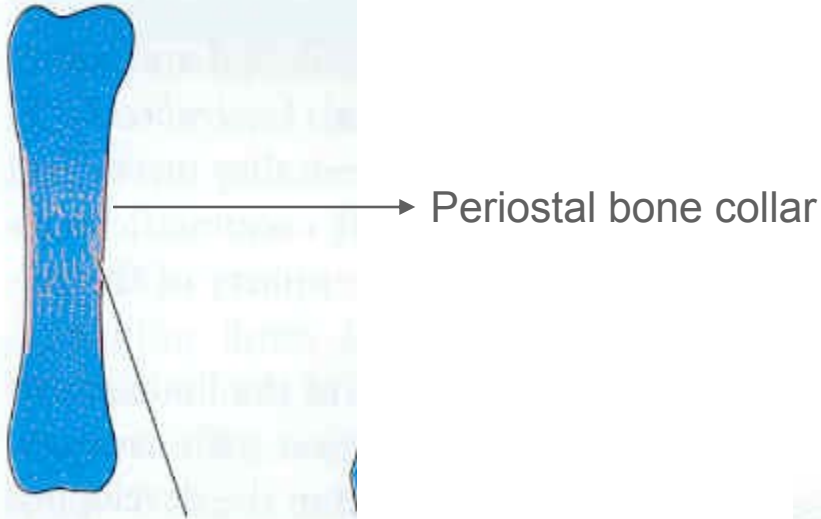
Osteoclasts
Intramembranous Ossification

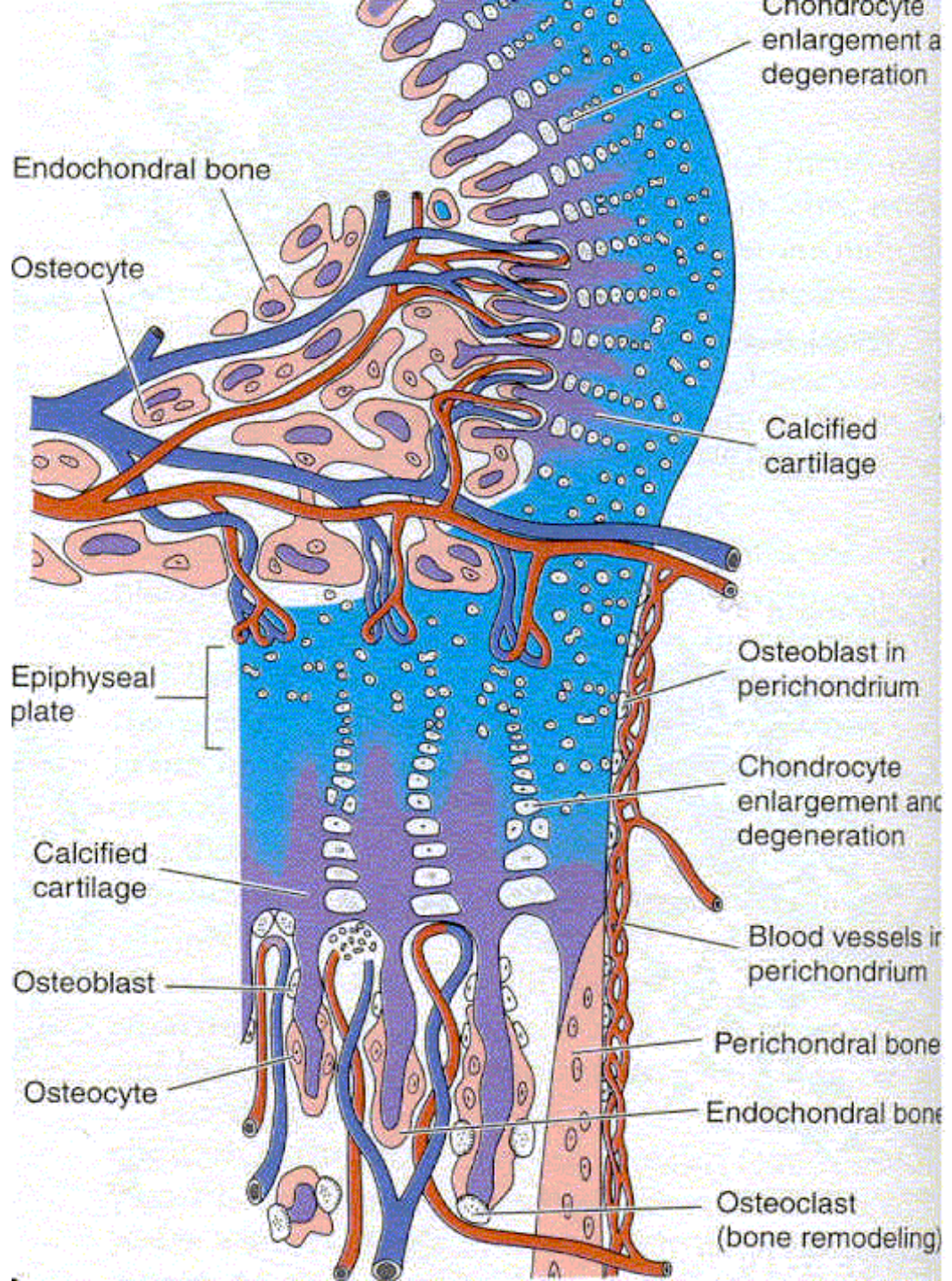
20 μm
20 μm



Bone growth

- cannot occur interstitially as cartilage growth does, because its rigid, mineralized matrix traps osteocytes and prevents them from dividing mitotically. Growth occurs in two directions:
- in length, by maintenance and growth of epiphyseal plate of cartilage. These plates allow a bone to expand lengthwise.
- in diameter, by continuous formation of bone around the periphery of the diaphysis.





Endochondral bone

Osteocyte

Chondrocyte enlargement and degeneration

Calcified cartilage

Epiphyseal plate

Osteoblast in perichondrium

Chondrocyte enlargement and degeneration

Calcified cartilage

Blood vessels in perichondrium

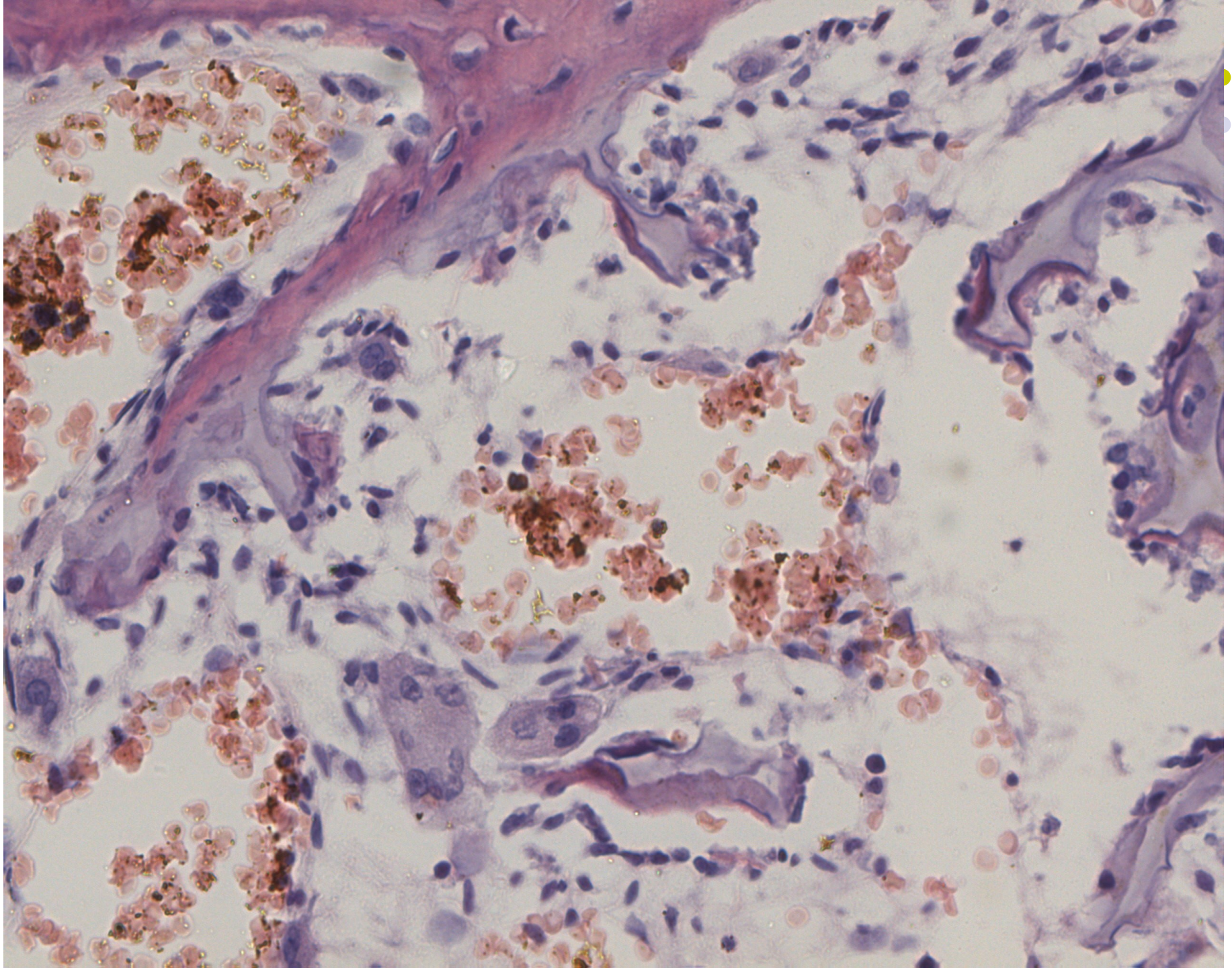
Osteoblast

Perichondral bone

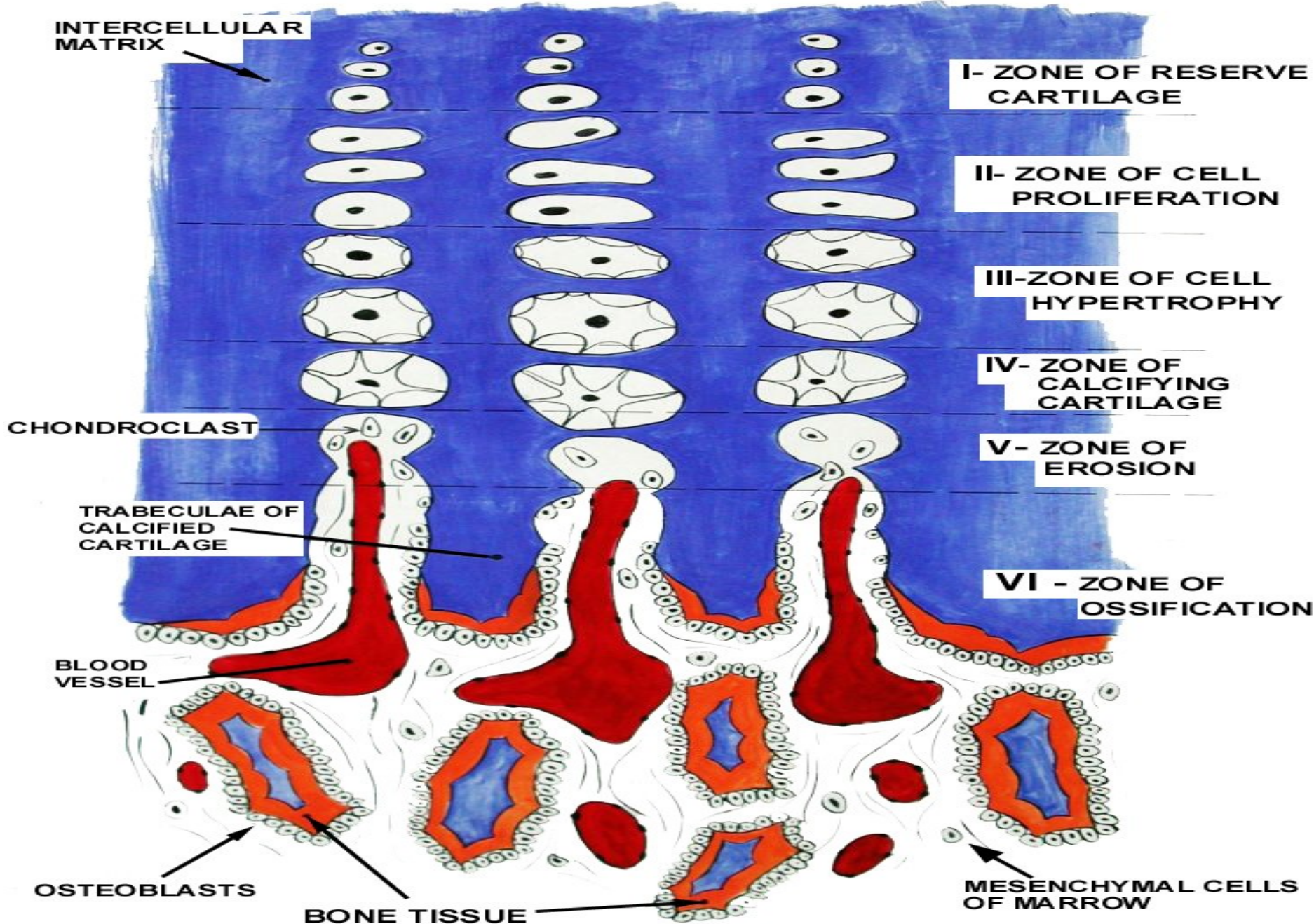
Osteocyte

Endochondral bone

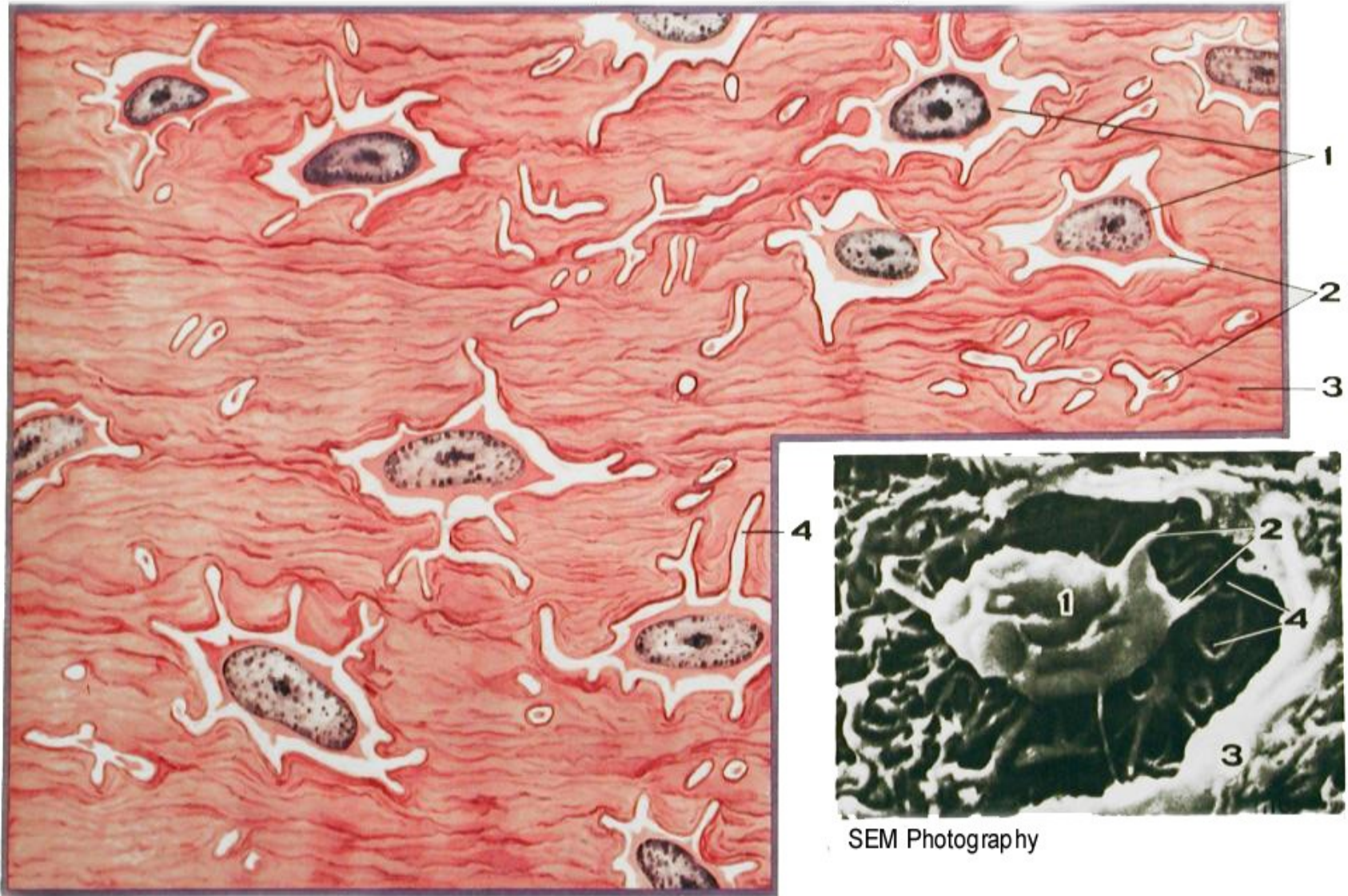
Osteoclast (bone remodeling)



ENDOCHONDRAL OSSIFICATION



PRIMARY (WOVEN) BONE



1- osteocytes 2-elongation of osteocytes 3-bone matrix 4-canalliculi from lacunae

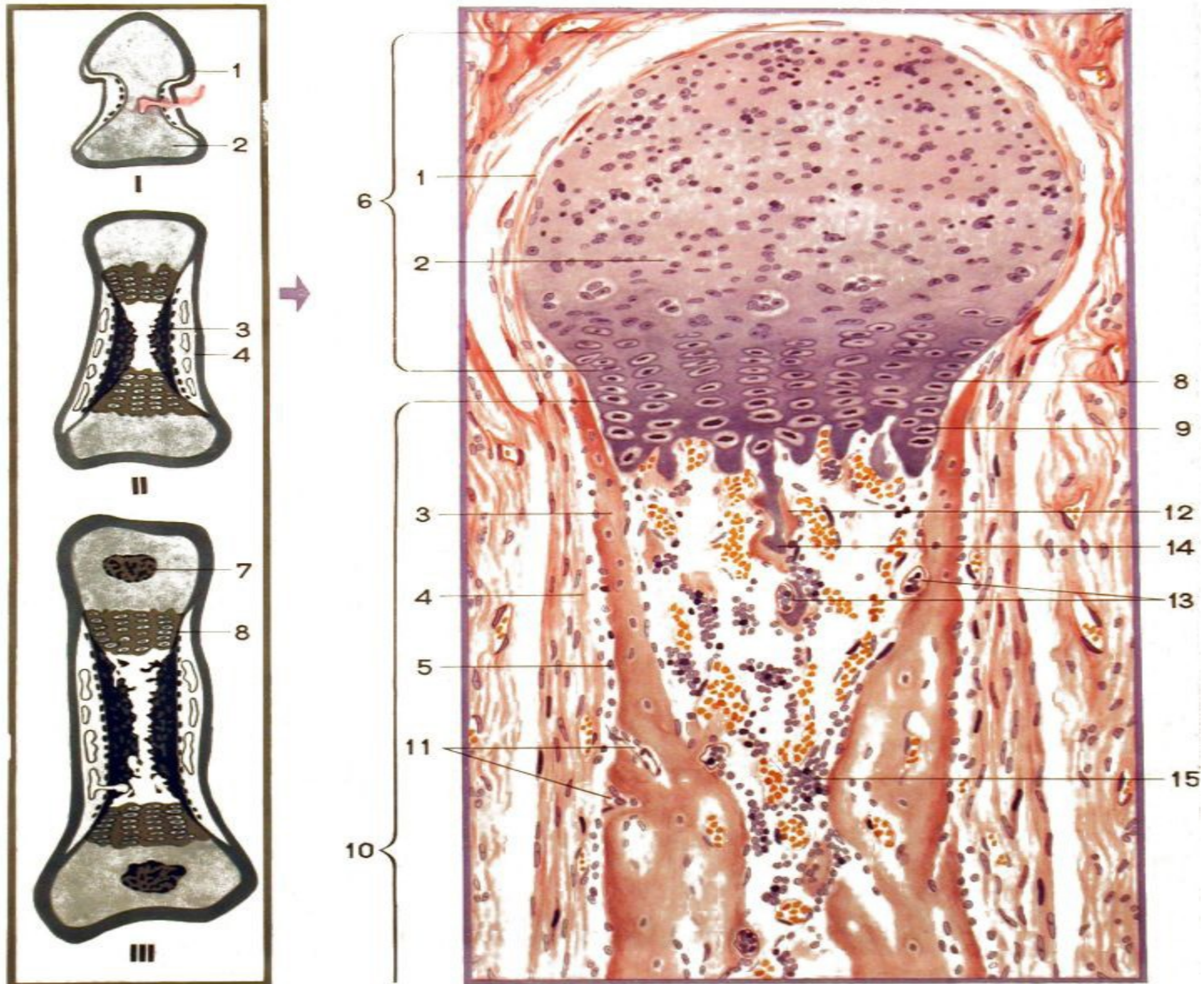


INTRAMEMBRANOUS (DESMOGENOUS) OSSIFICATION



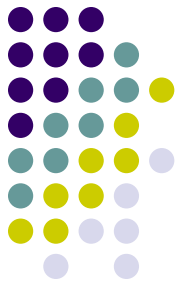
1-MESENCHYME 2-OSTEOBLASTS 3-OSTEOID 4-BONE MATRIX 5-OSTEOCYTES 6-OSTEOCLAST
7-BLOOD VESSELS 8-OSTEOGENOUS INSULA

ENDOCHONDRAL OSSIFICATION



I,II,III- STAGES OF OSTEOGENESIS

1-PERICHONDRIUM; 2-EMBRYONIC CARTILAGE; 3-BONE CUFF; 4-PERIOSTEUM;
 5-OSTEOBLASTS; 6-EPIPHYSIS; 7-SECONDARY OSSIFICATION CENTRE; 8-EPIPHYSEAL PLATE;
 9-CHONDROCYTIC DEATH; 10-DIAPHYSIS; 11-BLOOD VESSELS; 12-ENDOCHONDRAL BONE;
 13-OSTEOCLASTS; 14-CALCIFYING CARTILAGE; 15-MARROW



Normal hyaline cartilage

Endochondral ossification

Proliferating cartilage
(growth)

Hypertrophic cartilage

Calcified cartilage
* - calcified matrix

LINE of EROSION

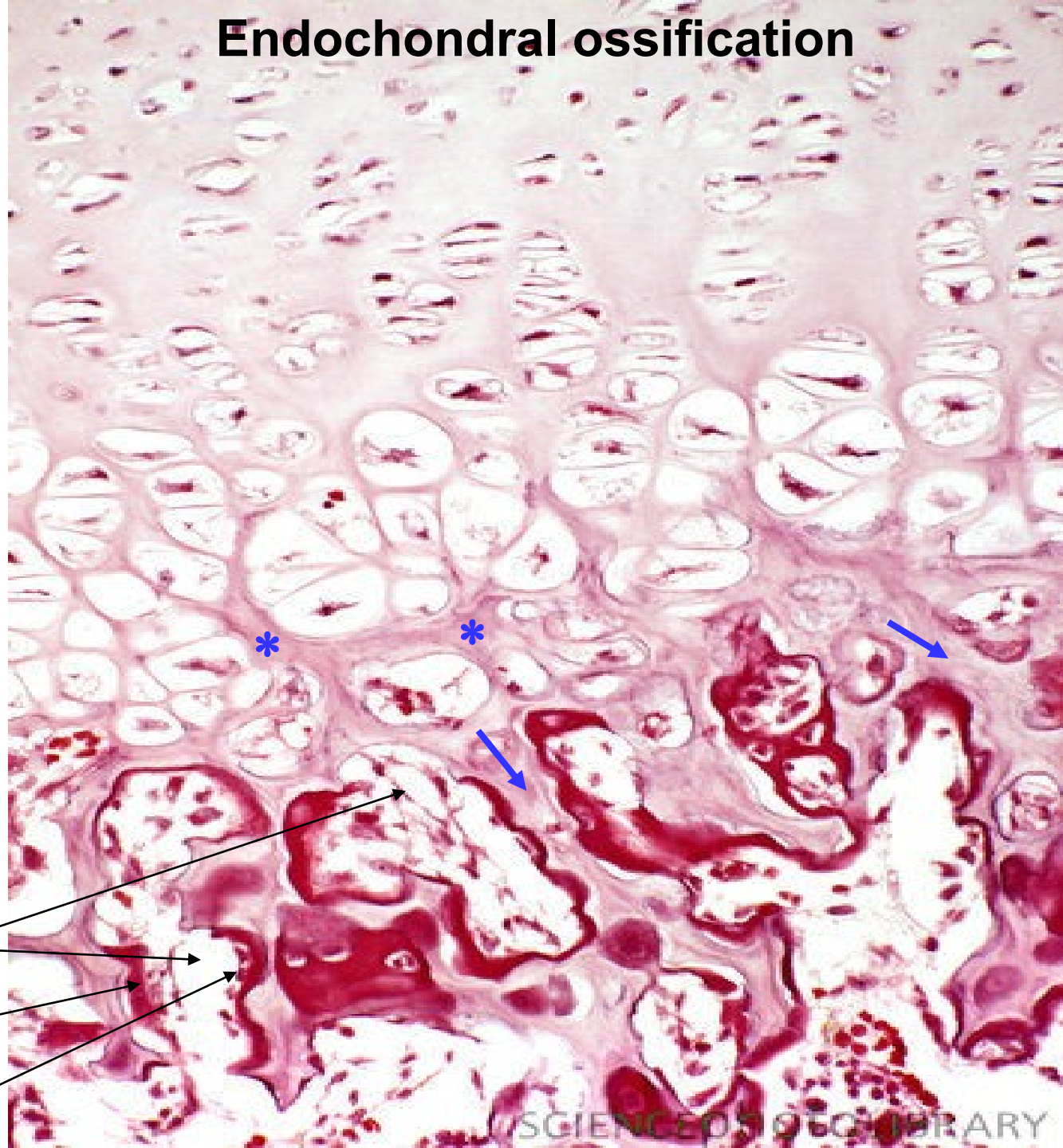
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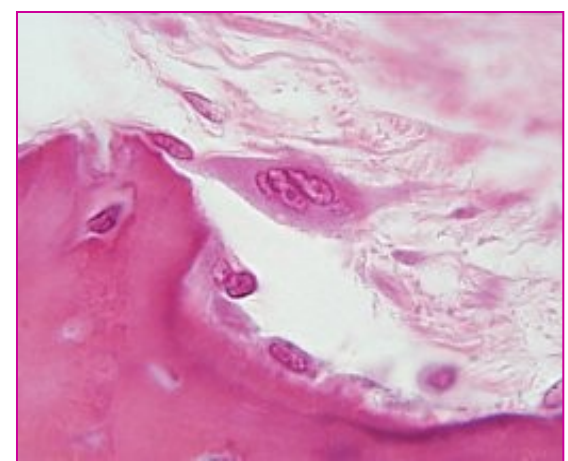
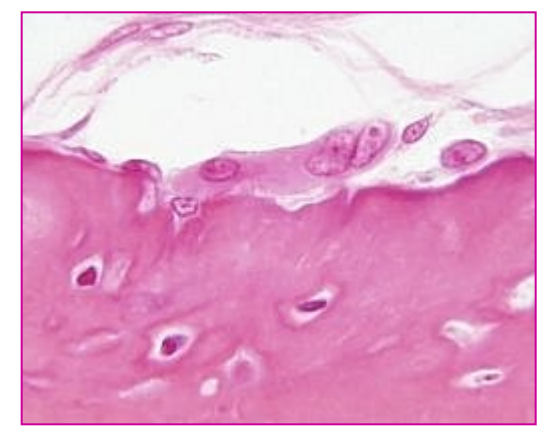
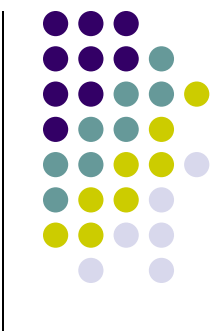
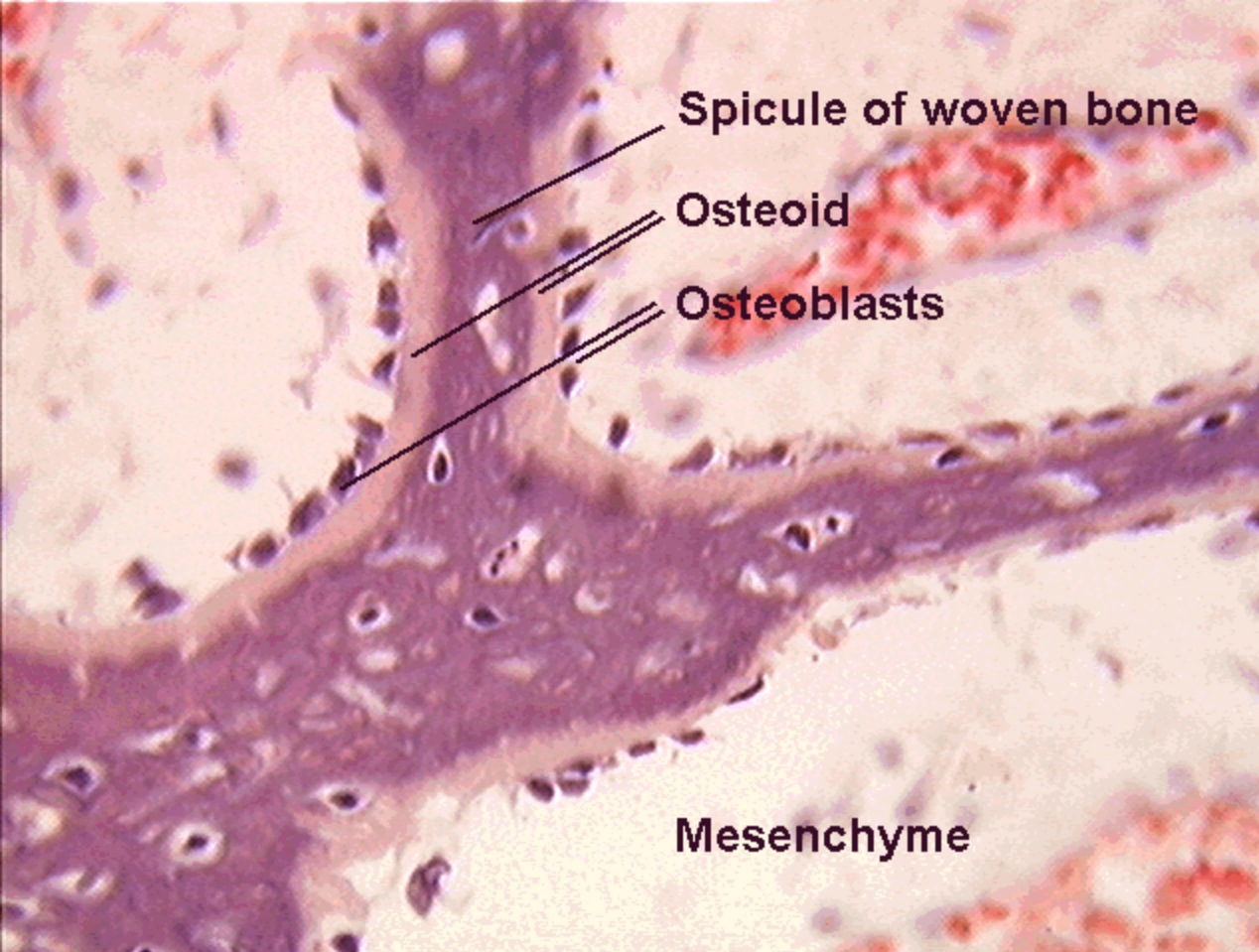
spicules

blood vessels

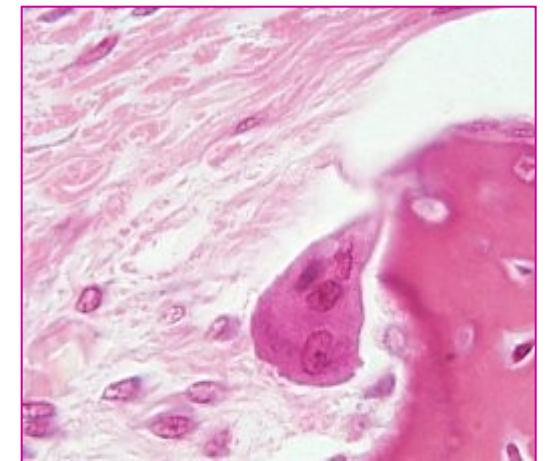
osteoid

osteoblasts





osteoklasty





Unexpanded chondrocytes

Expanding chondrocytes

Dying chondrocytes

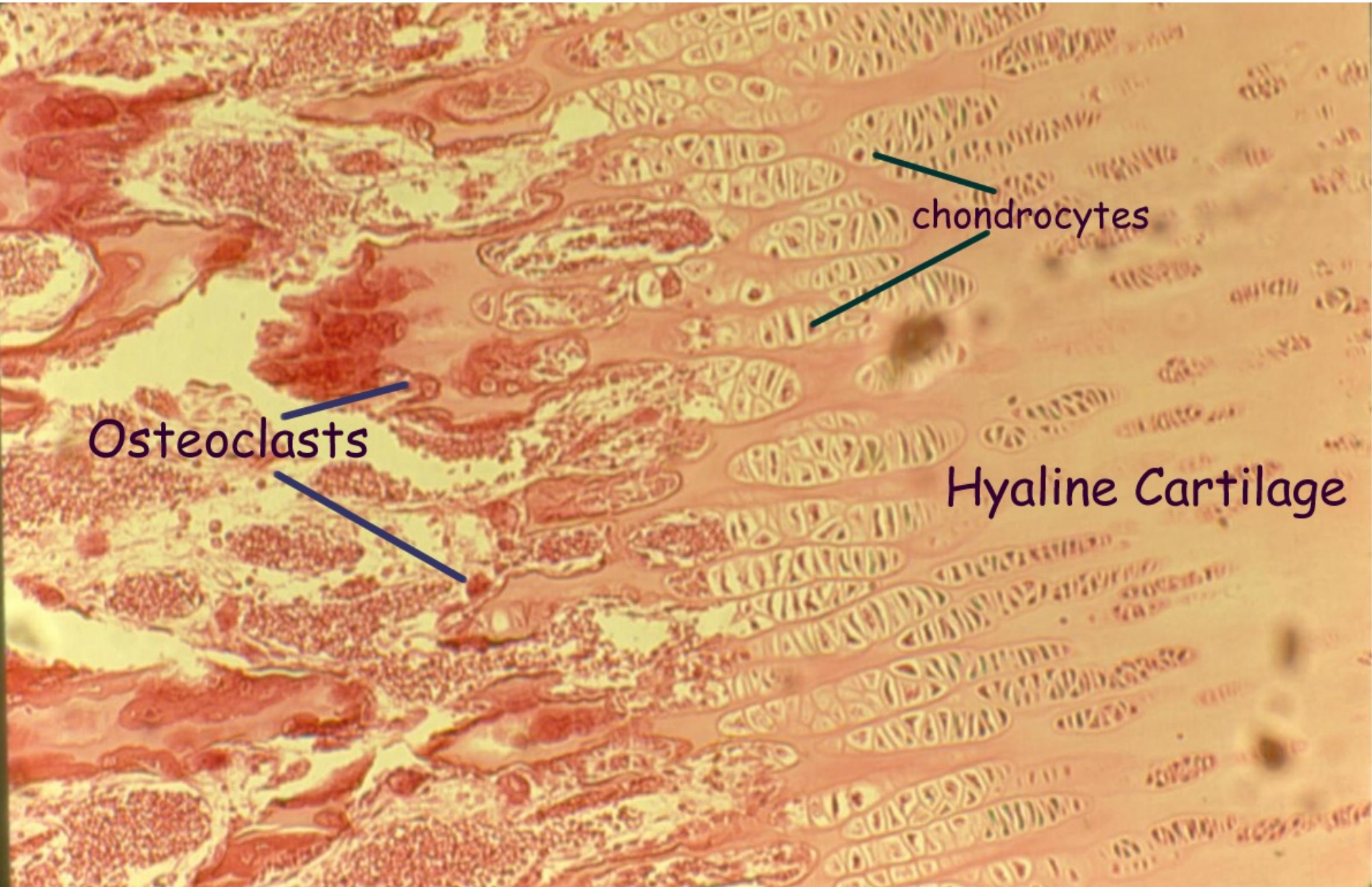
Empty lacunae

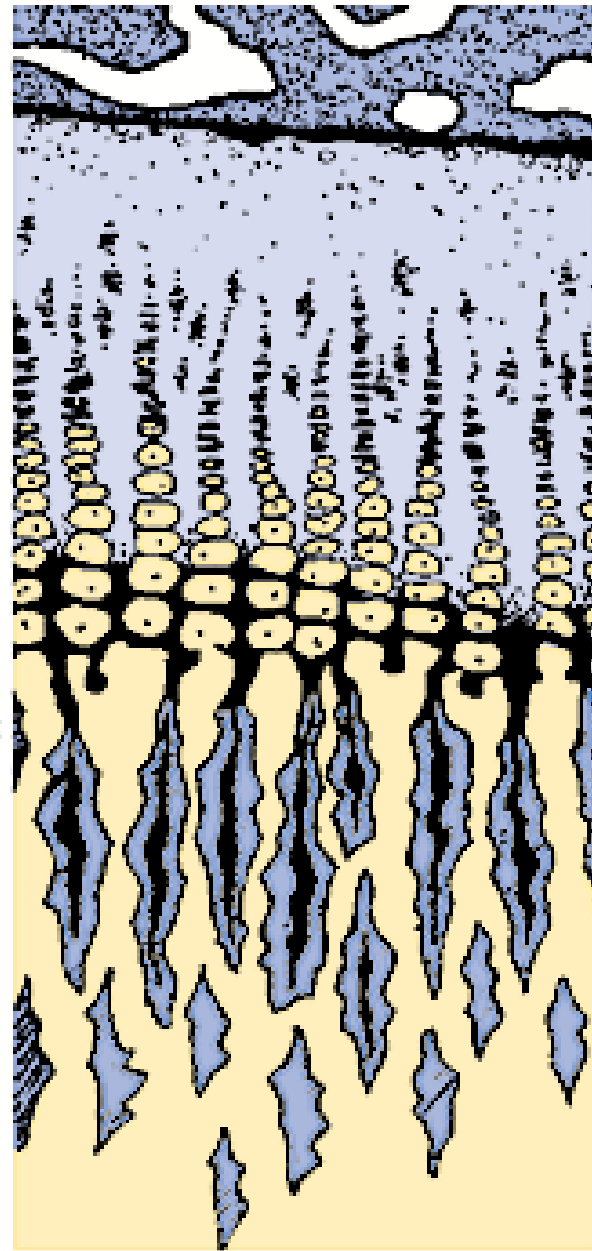
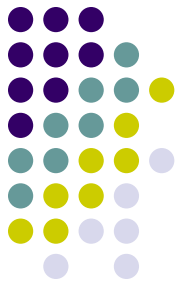
Calcifying matrix

Fully calcified matrix



Endochondrial Ossification





Chondrodys-
trophie,
Kretinismus

Rachitis

Osteochondritis
luetica

Osteogenesis
imperfecta

Marmor-
knochen-
krankheit

ruhender
Knorpel

wuchernder
Knorpel

Säulen-
knorpel

präpara-
torische
Verkalkungs-
zone

primäre
Spongiosa

sekundäre
Spongiosa