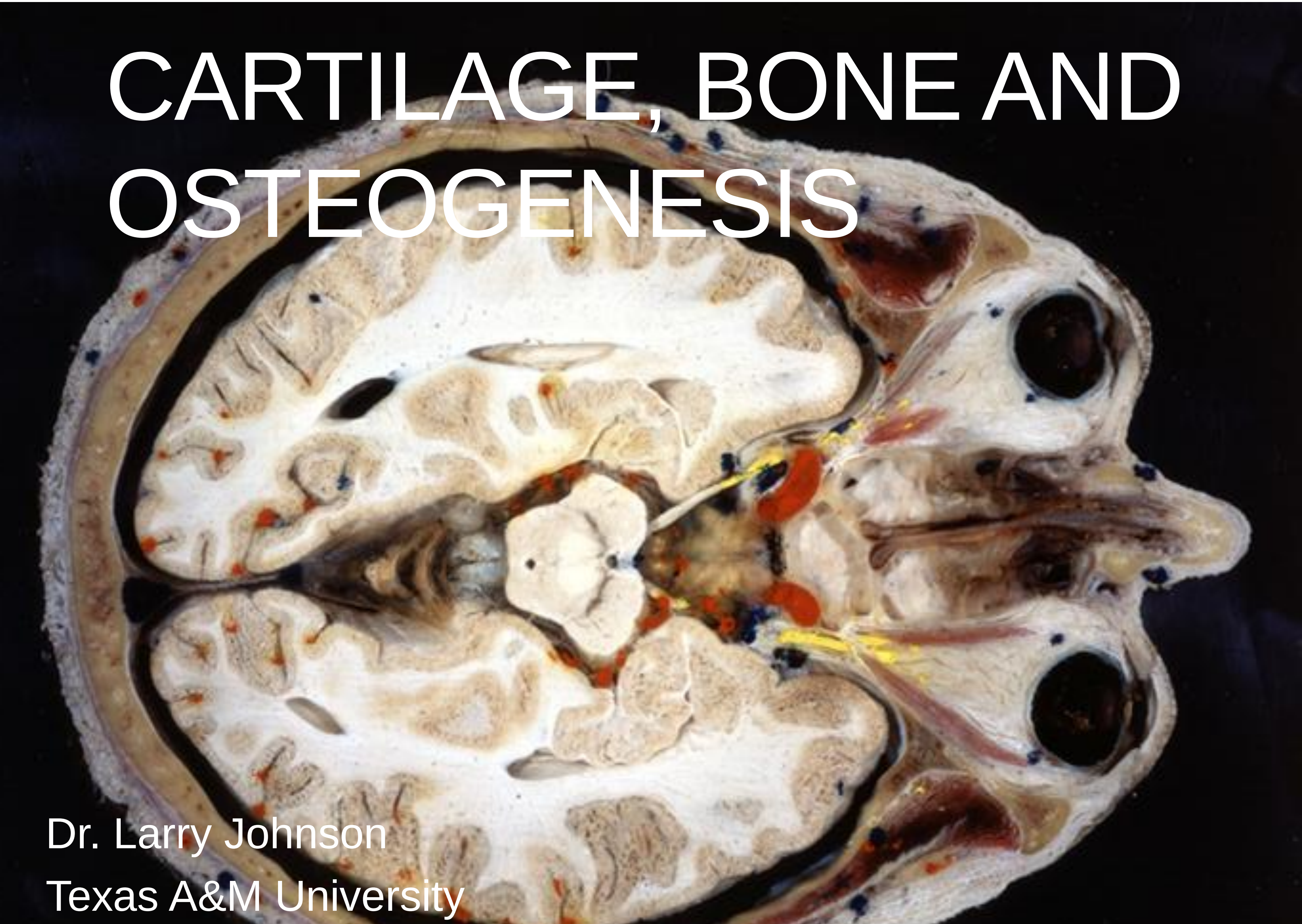
CARTILAGE, BONE AND OSTEOGENESIS



Dr. Larry Johnson
Texas A&M University

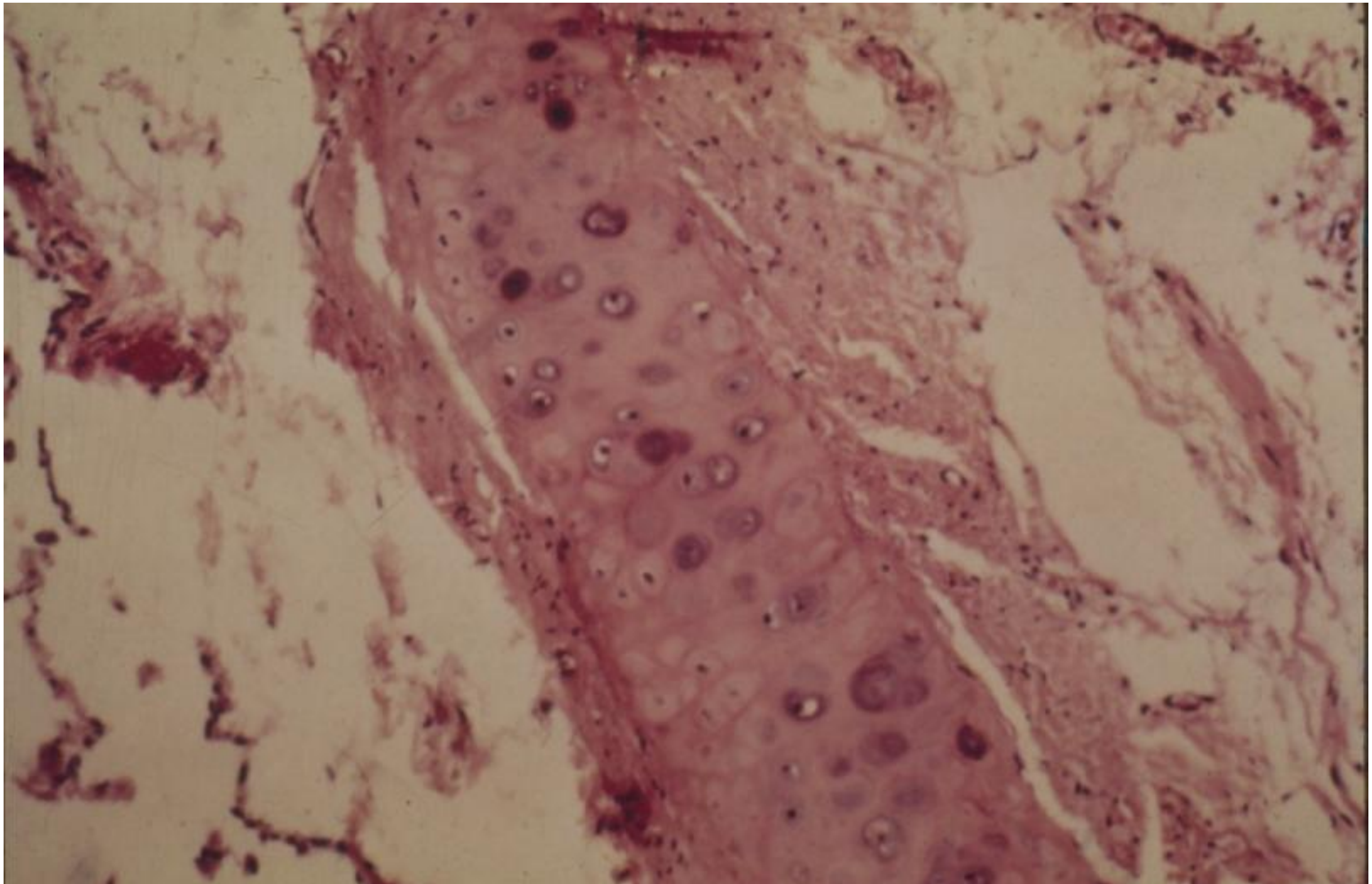
Objectives

- Histologically identify and functionally characterize each of the various forms of supporting connective tissue.
- Recognize the structure and characterize the function of cells, fibers and ground substance components of each of the supporting connective tissues examined.
- Describe the cellular mechanisms that provide for intramembranous and endochondrial bone development.
- Compare and contrast the structure and function of compact and sponge bone.

From: Douglas P. Dohrman and TAMHSC Faculty 2012 Structure and Function of Human Organ Systems, Histology Laboratory Manual

FUNCTIONS OF CARTILAGE

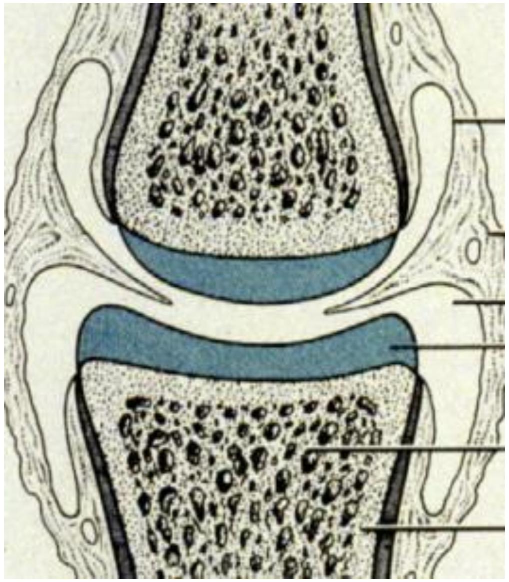
FLEXIBLE SUPPORT - RETURN TO ORIGINAL SHAPE (EARS, NOSE, AND RESPIRATORY)

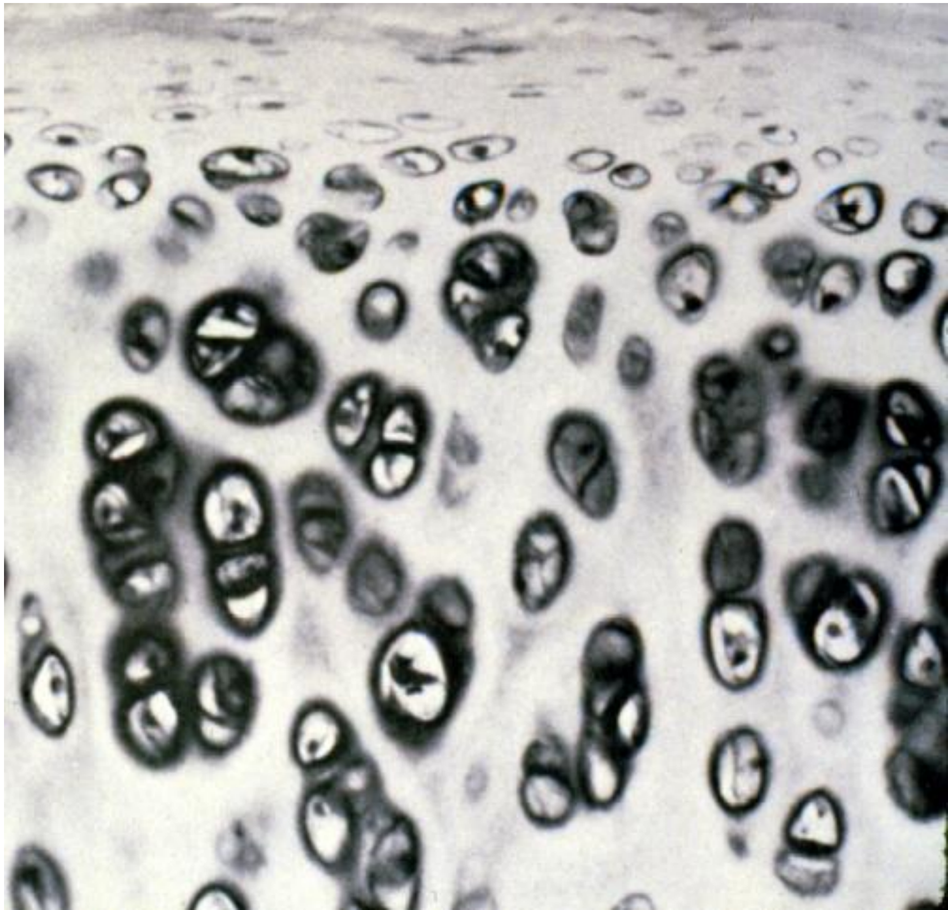


FUNCTIONS OF CARTILAGE

SLIDES ACROSS EACH OTHER EASILY WHILE BEARING WEIGHT (JOINTS, ARTICULAR SURFACES OF BONES)

CUSHION - CARTILAGE HAS LIMITED COMPRESSIBILITY (JOINTS)





No nerves and, thus, no pain during compression of cartilage.

CONNECTIVE TISSUE

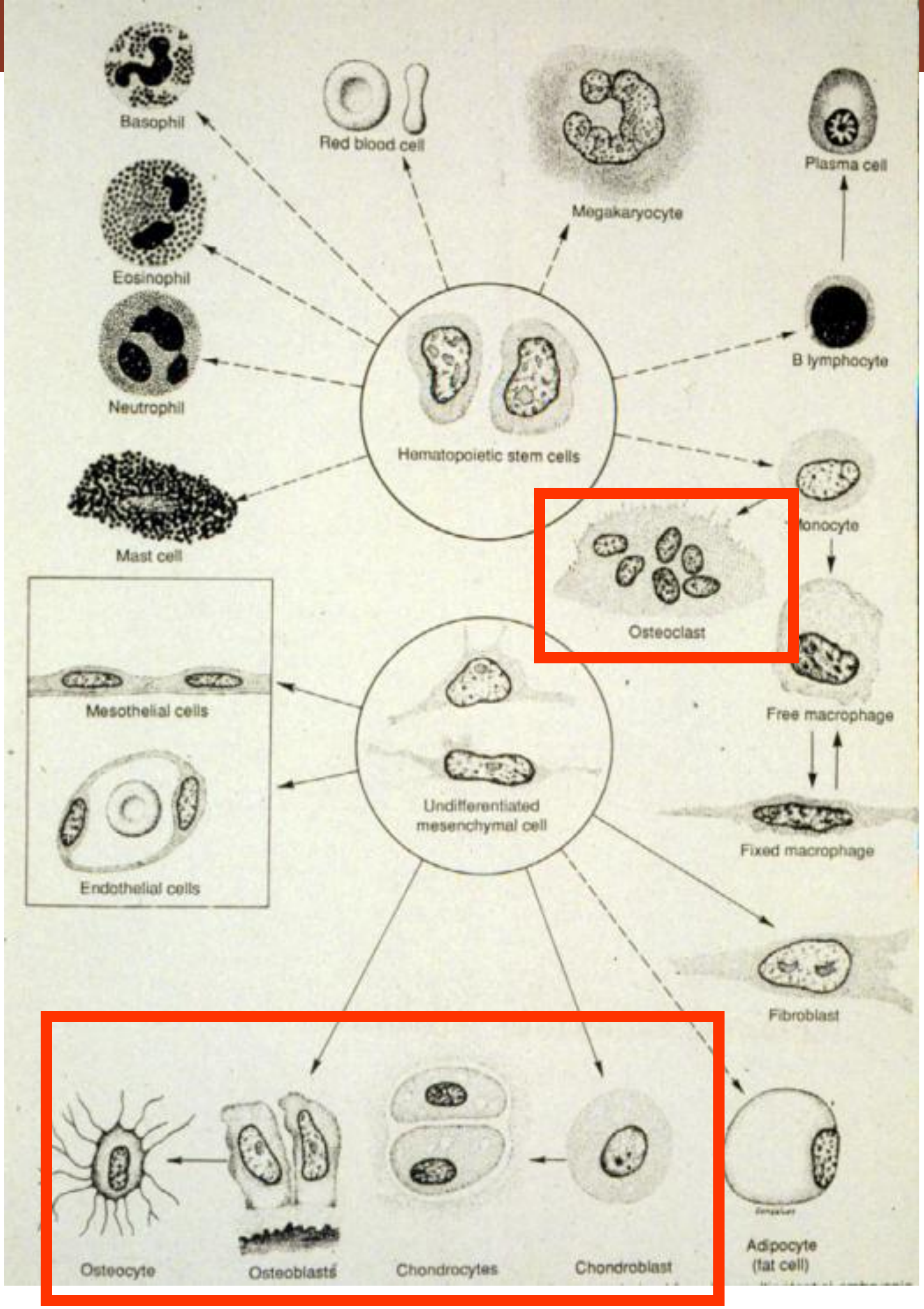
- Connective tissue
  - Connective tissue proper
    - Loose (areolar)
    - Dense
      - Regular
      - Irregular
  - Connective tissue with special properties
    - Adipose tissue (Chapter 6)
    - Elastic tissue
    - Hematopoietic (lymphatic and myeloid) tissue (Chapter 14)
    - Mucous tissue
  - Supporting connective tissues
    - Cartilage (Chapter 7)
    - Bone (Chapter 8)

CELLS OF CT

FIBROBLASTS
MESENCHYMAL
CELLS and RBC
ADIPOSE CELLS
MACROPHAGE
PLASMA CELLS
MAST CELLS and WBC

CHONDROBLASTS
CHONDROCYTES

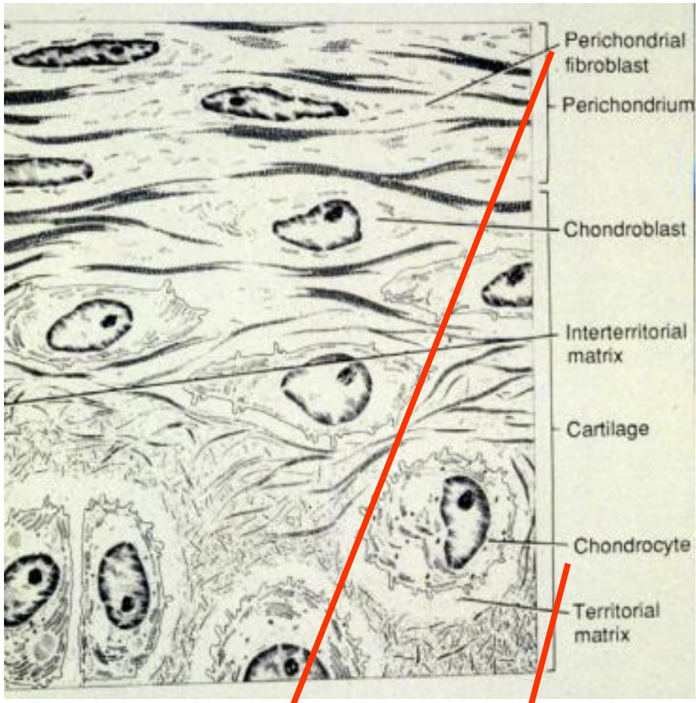
OSTEOBLASTS
OSTEOCYTES
OSTEOCLASTS

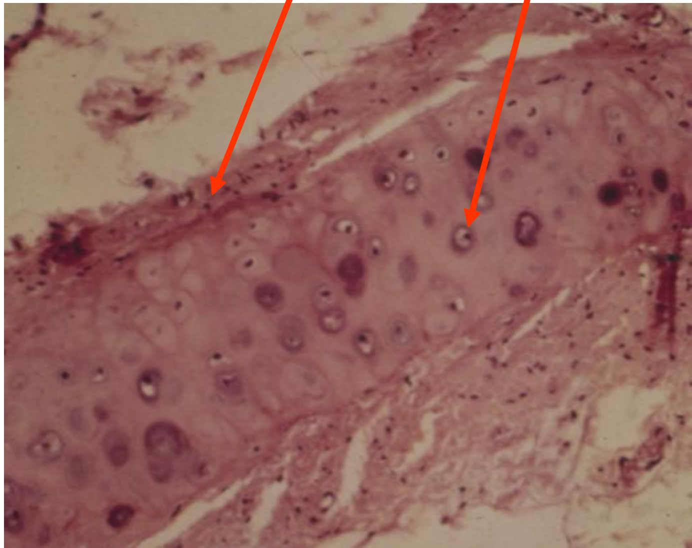


GENERAL ORGANIZATION OF CARTILAGE

PERICHONDRIUM

- CAPSULE-LIKE SHEATH OF DENSE IRREGULAR CONNECTIVE TISSUE THAT SURROUNDS CARTILAGE (EXCEPT ARTICULAR CARTILAGE)
- FORMS INTERFACE WITH SUPPORTED TISSUE
- HARBORS A VASCULAR SUPPLY

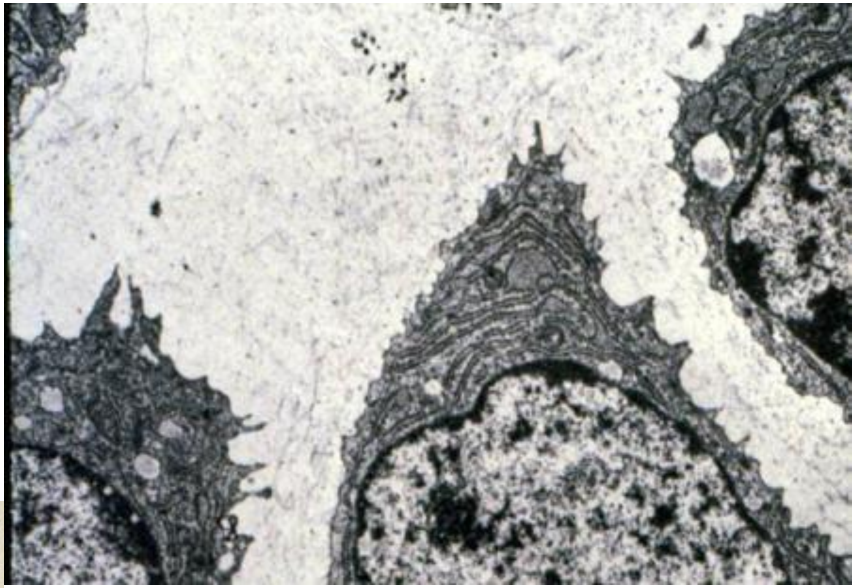


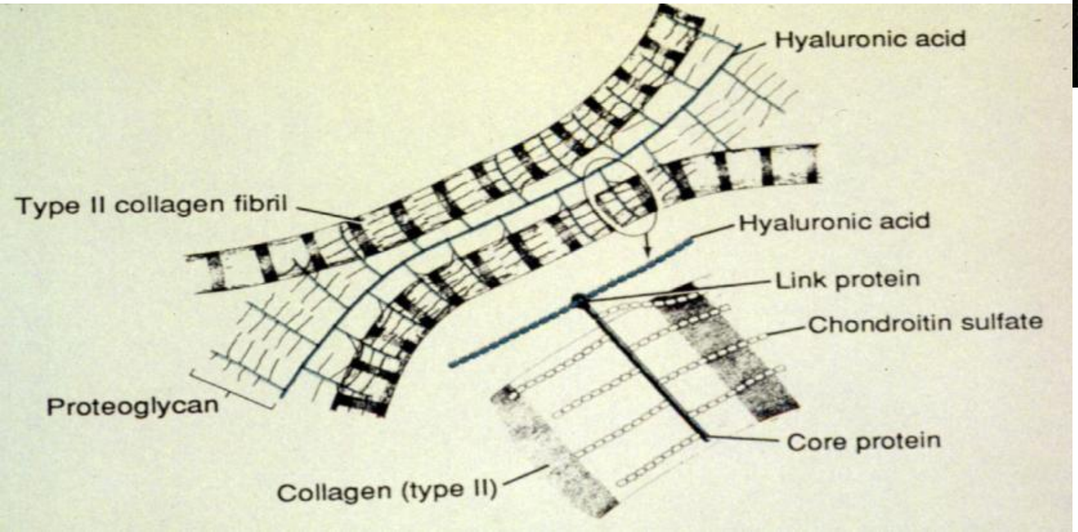


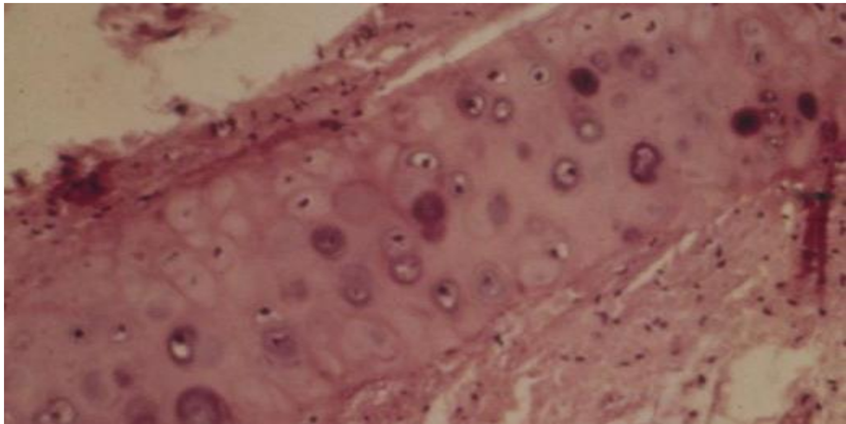
GENERAL ORGANIZATION OF CARTILAGE

MATRIX

TYPE II COLLAGEN (LACK OF OBVIOUS PERIODICITY)



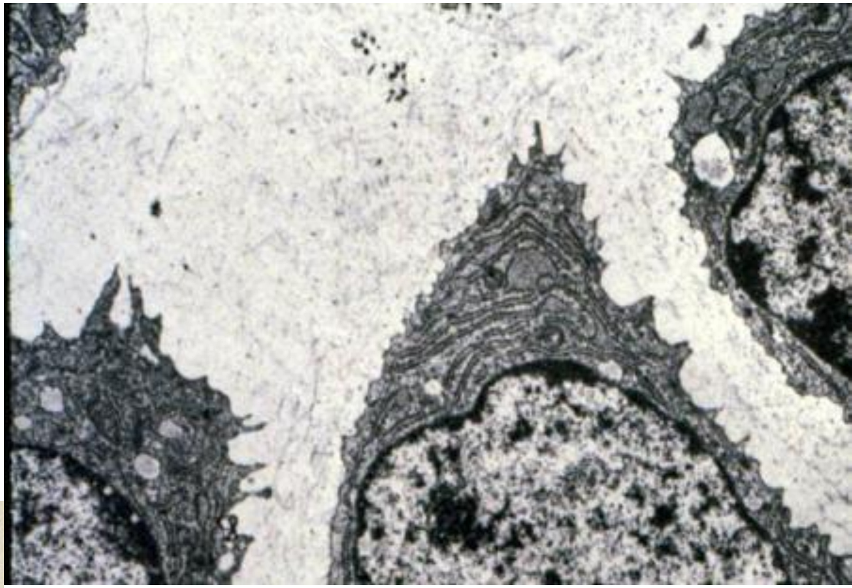


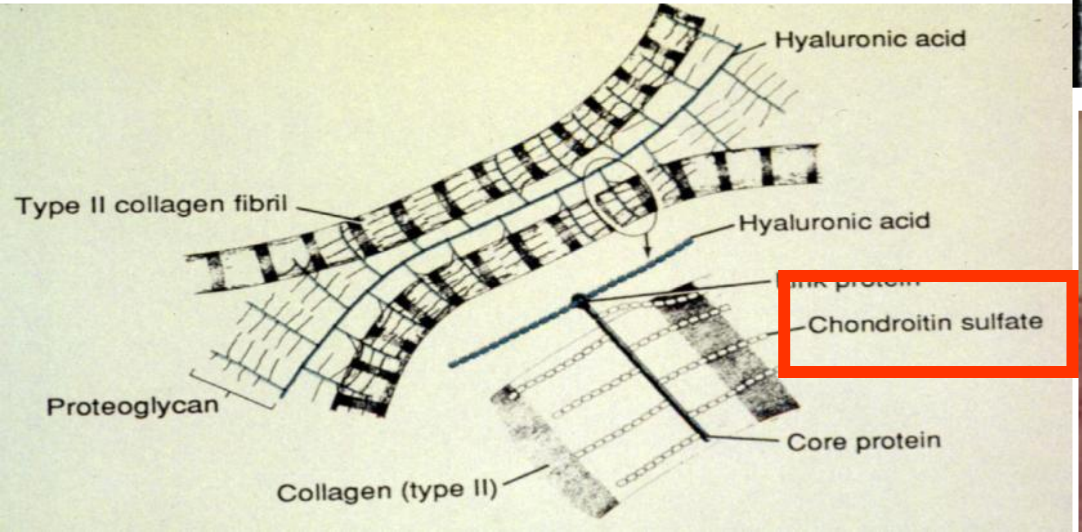


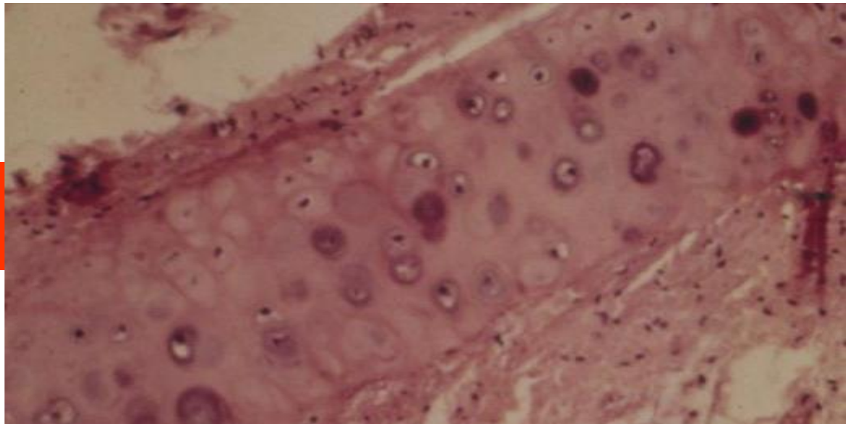
GENERAL ORGANIZATION OF CARTILAGE

MATRIX

- TYPE II COLLAGEN (LACK OF OBVIOUS PERIODICITY)
- SULFATED PROTEOGLYCANS (CHONDROITIN SULFATE AND KERATAN SULFATE) - STAIN BASOPHILIC







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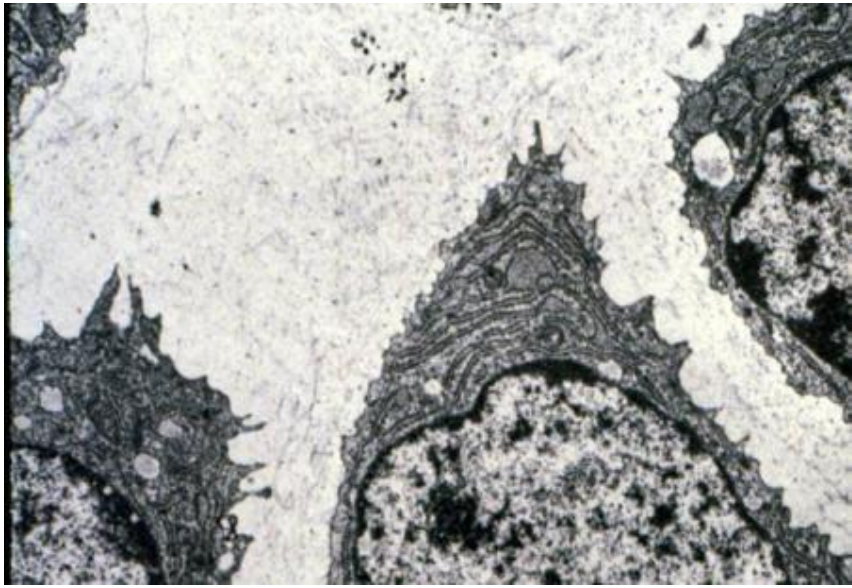
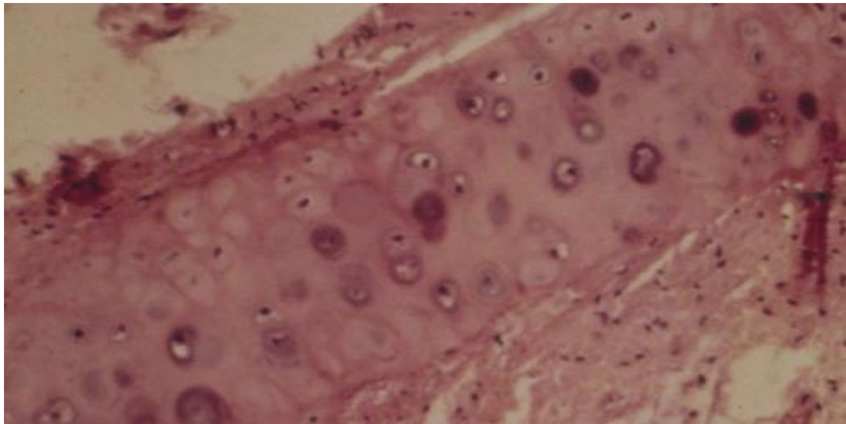
MATRIX

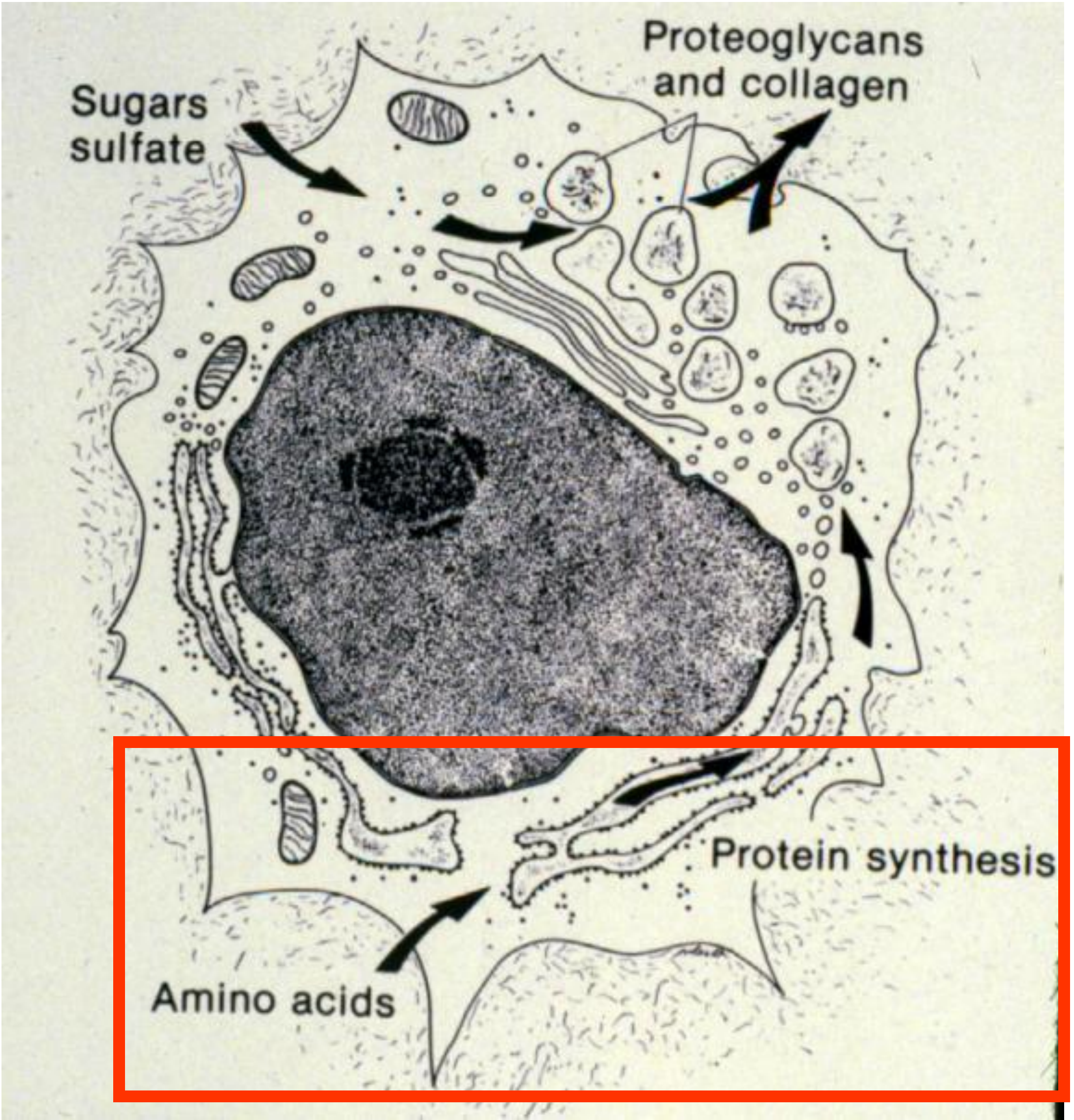
- TYPE II COLLAGEN (LACK OF OBVIOUS PERIODICITY)
- SULFATED PROTEOGLYCANS (CHONDROITIN SULFATE AND KERATAN SULFATE) - STAIN BASOPHILIC
- CAPABLE OF HOLDING WATER / DIFFUSION OF NUTRIENTS
- AVASCULAR - GETS NUTRIENT/WASTE EXCHANGE FROM PERICHONDRIUM





GENERAL ORGANIZATION OF CARTILAGE

CHONDROCYTES / CHONDROBLASTS



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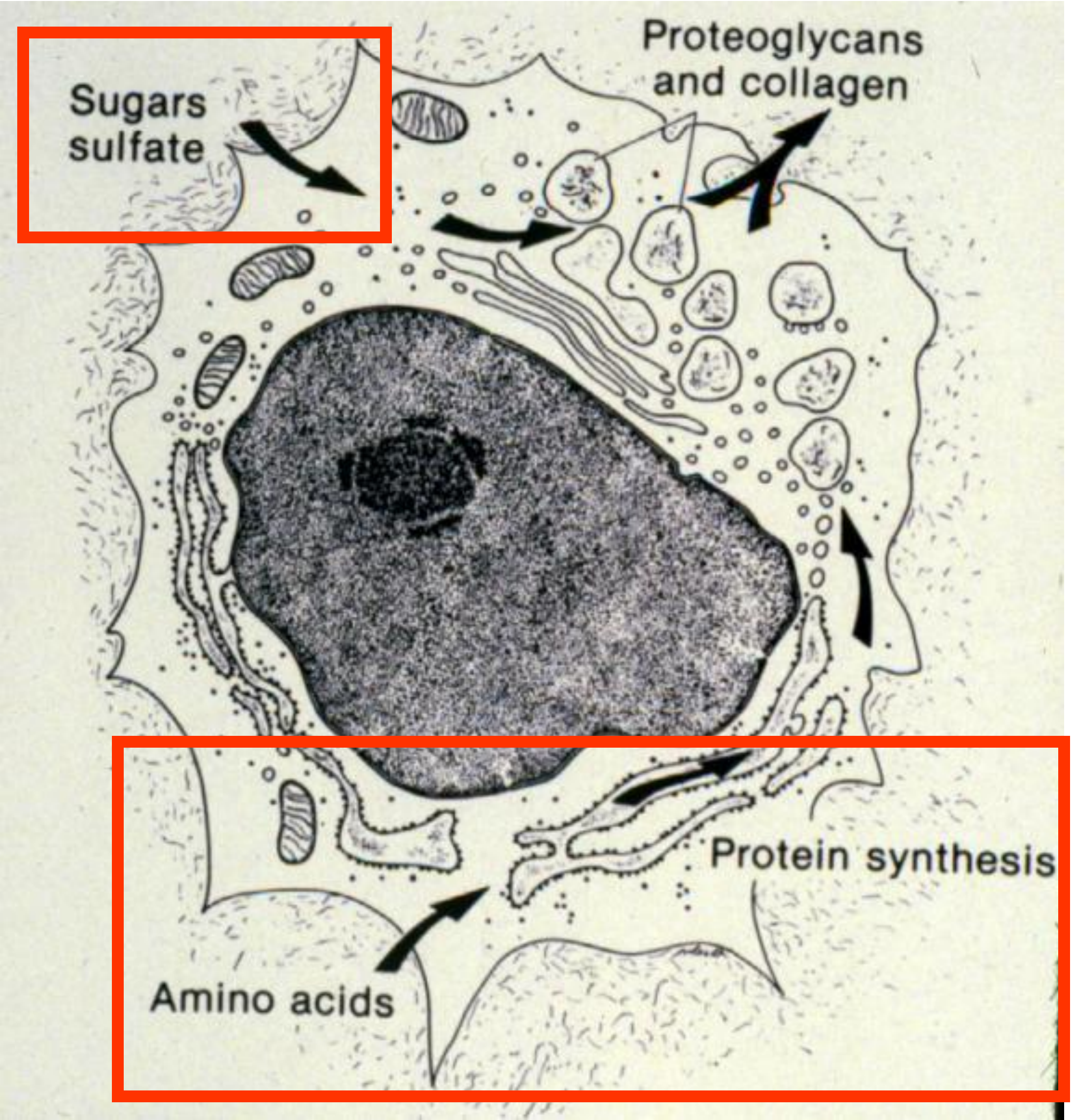

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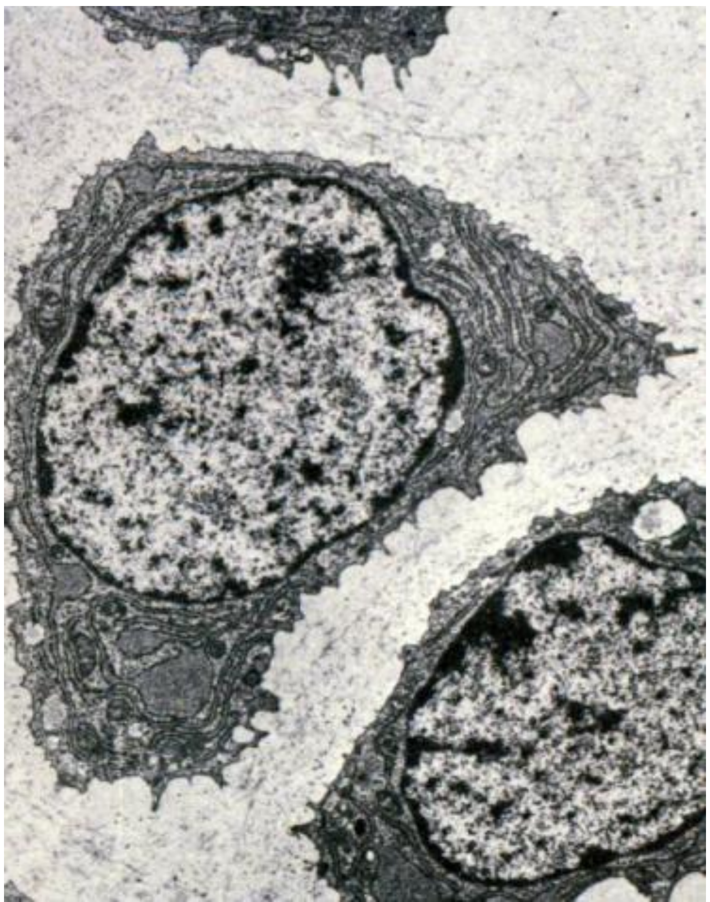

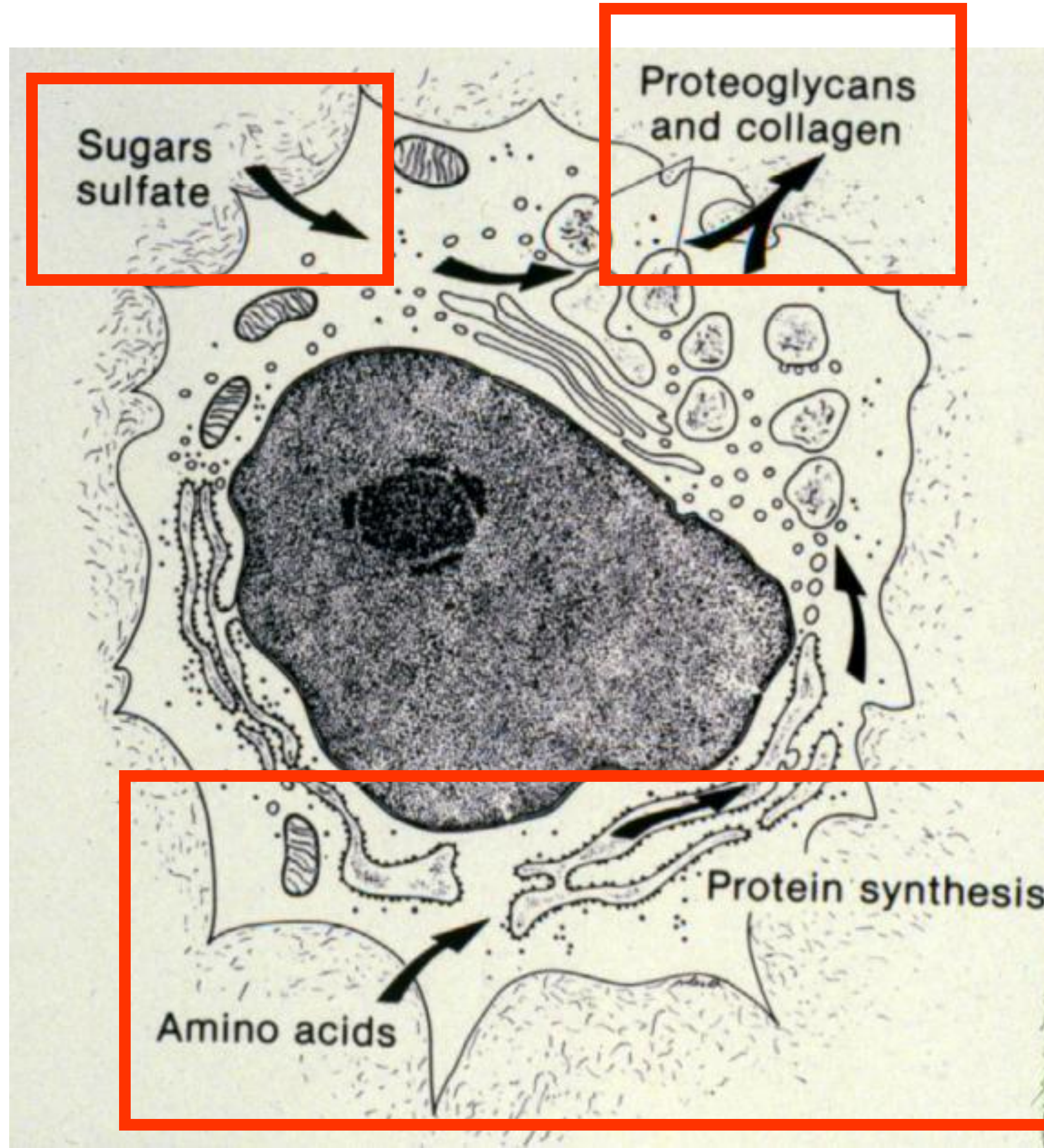

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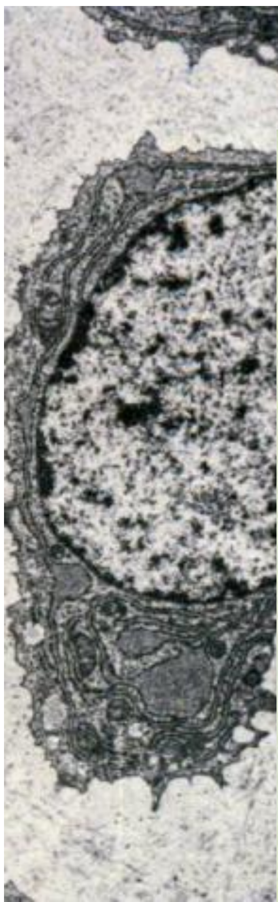
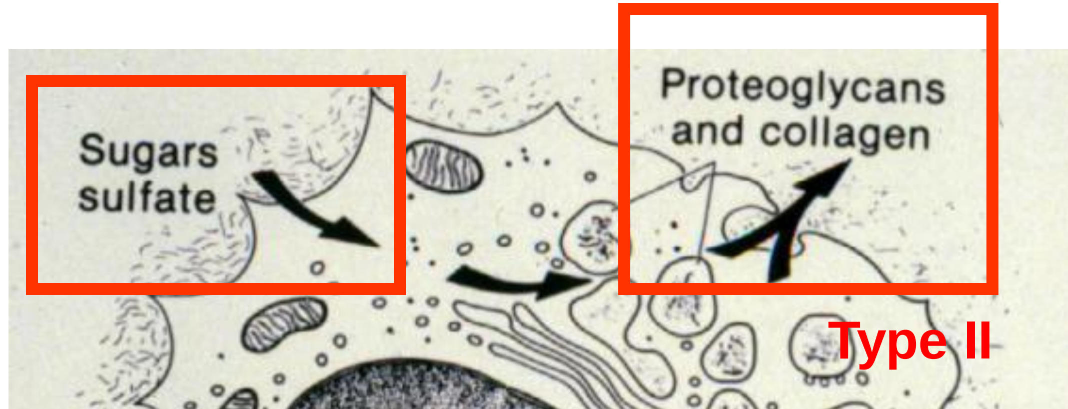
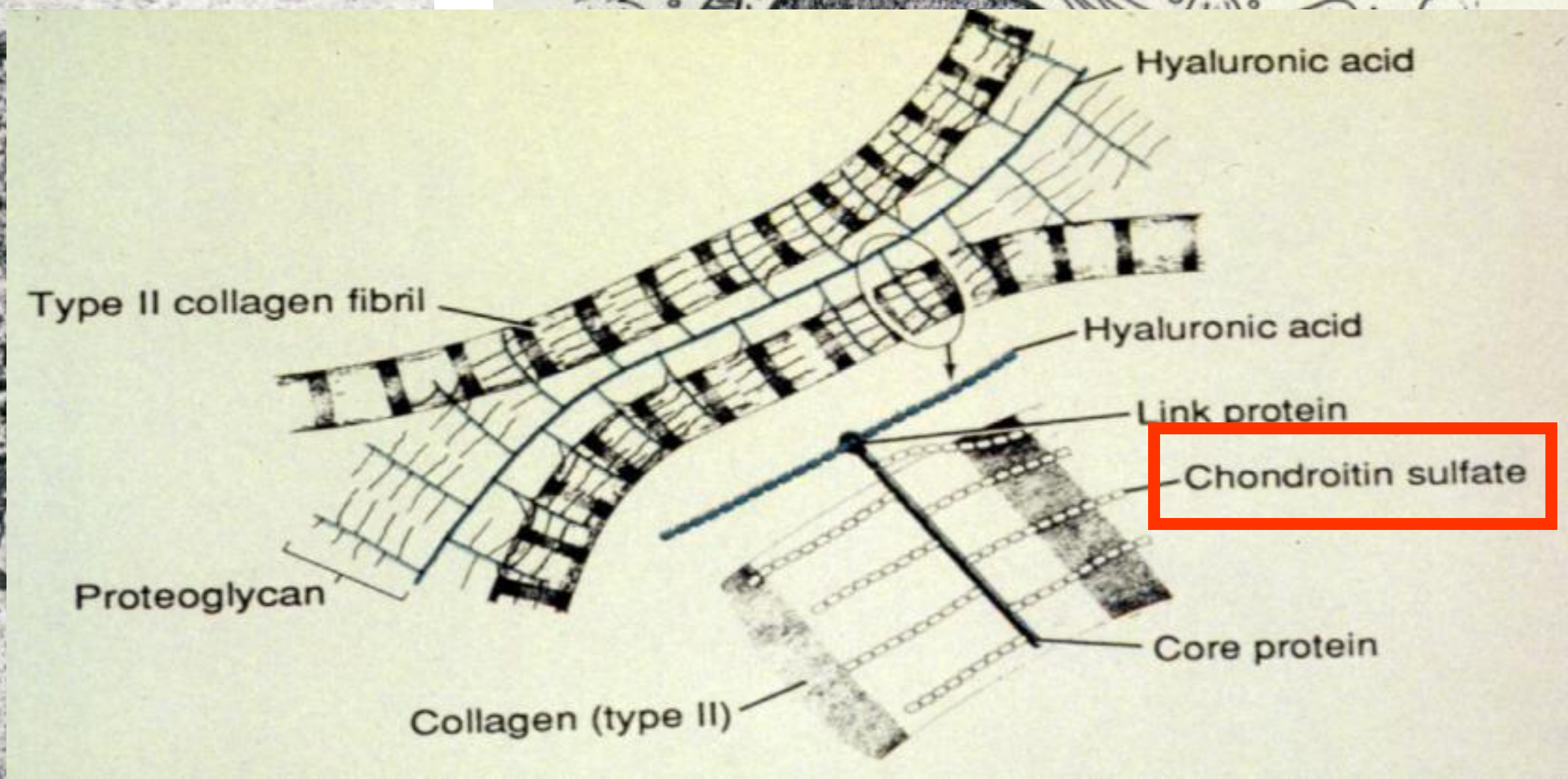
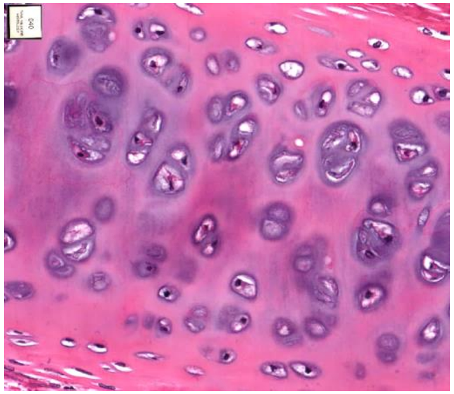






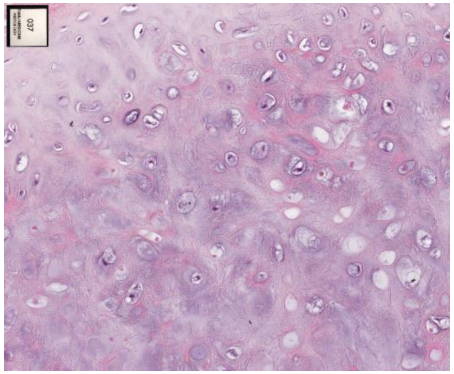
Cartilage

040



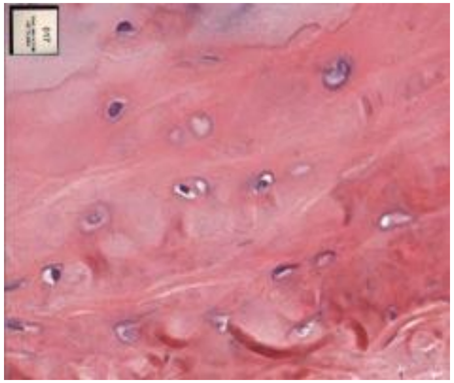
- **Hyaline cartilage**
  - Glassy matrix (GAGs, proteoglycans, collagen II) devoid of blood vessels, surrounded by fibrous sheath **perichondrium**

037



- **Elastic cartilage**
  - Similar to hyaline except chondrocytes become trapped in their secretions (enmeshed within the matrix, **lacunae**), has elasticity thus maintains its shape

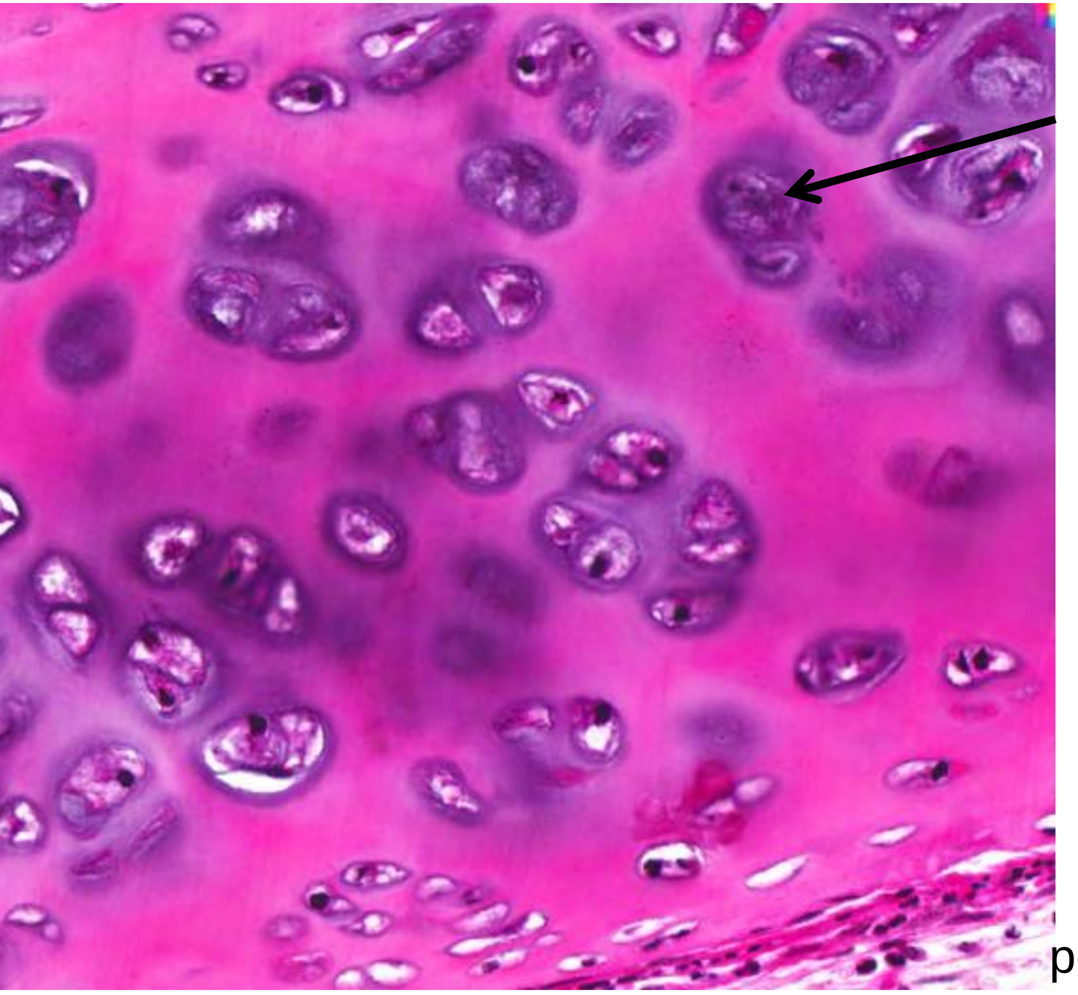
017



- **Fibrocartilage**
  - Course collagen I fibers form dense bundles to withstand physical stresses, strengthen hyaline cartilage

Developing Cartilage

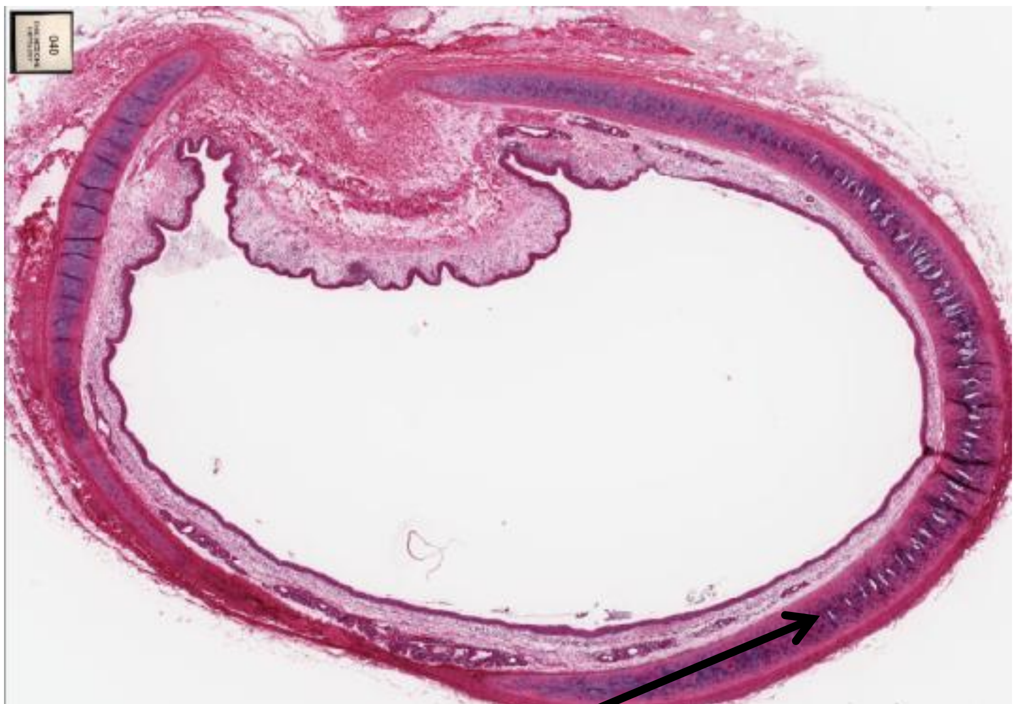
040

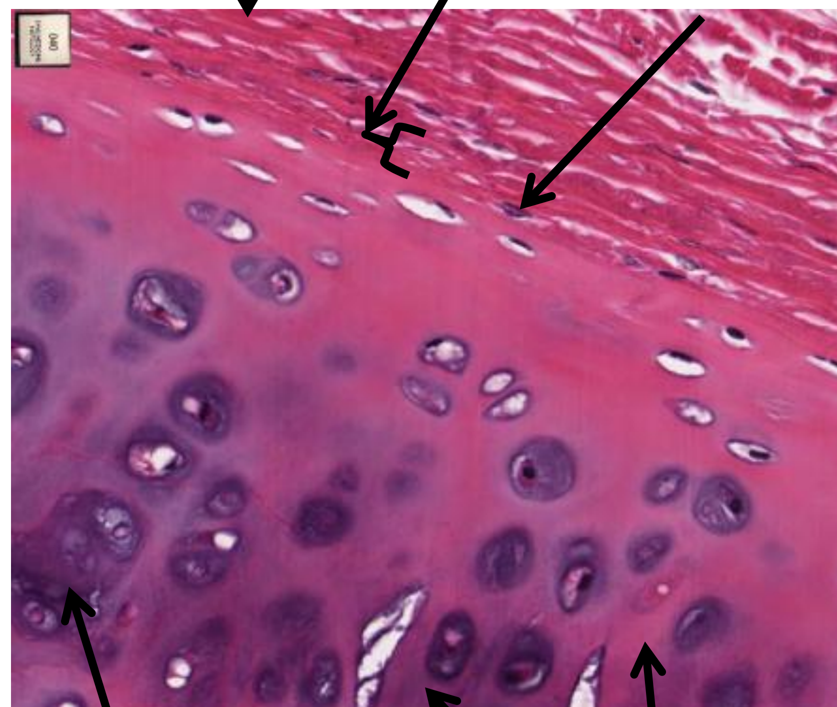


Cartilage grows by both interstitial growth (mitotic division of preexisting chondroblasts) and by appositional growth (differentiation of new chondroblasts from the perichondrium).

perichondrium

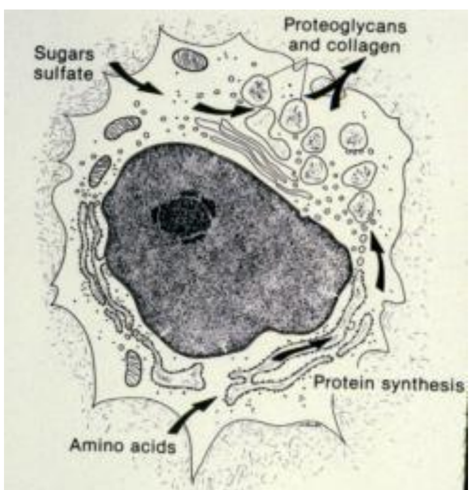
Slide 40: Trachea

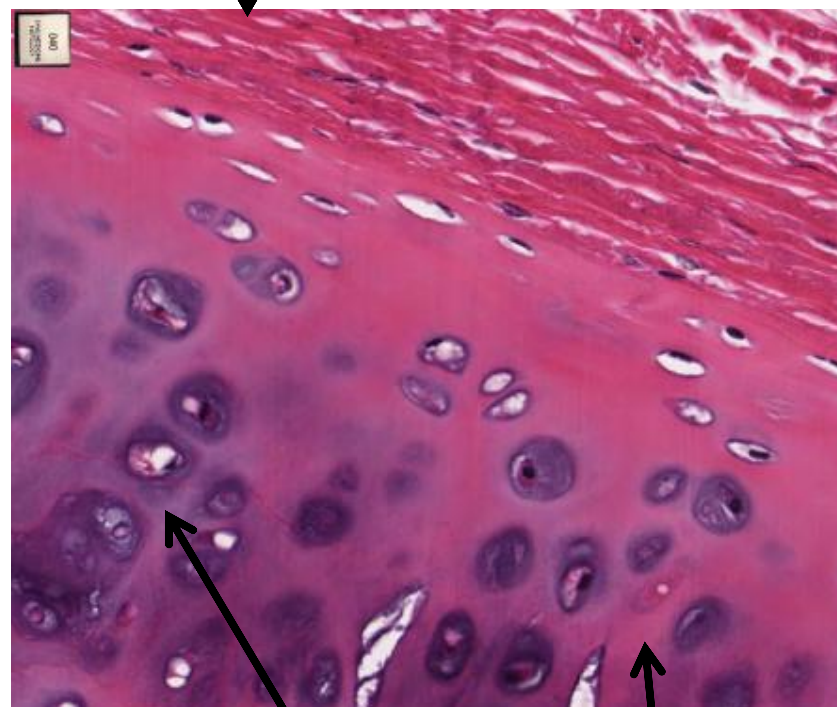




Slide 40: Trachea

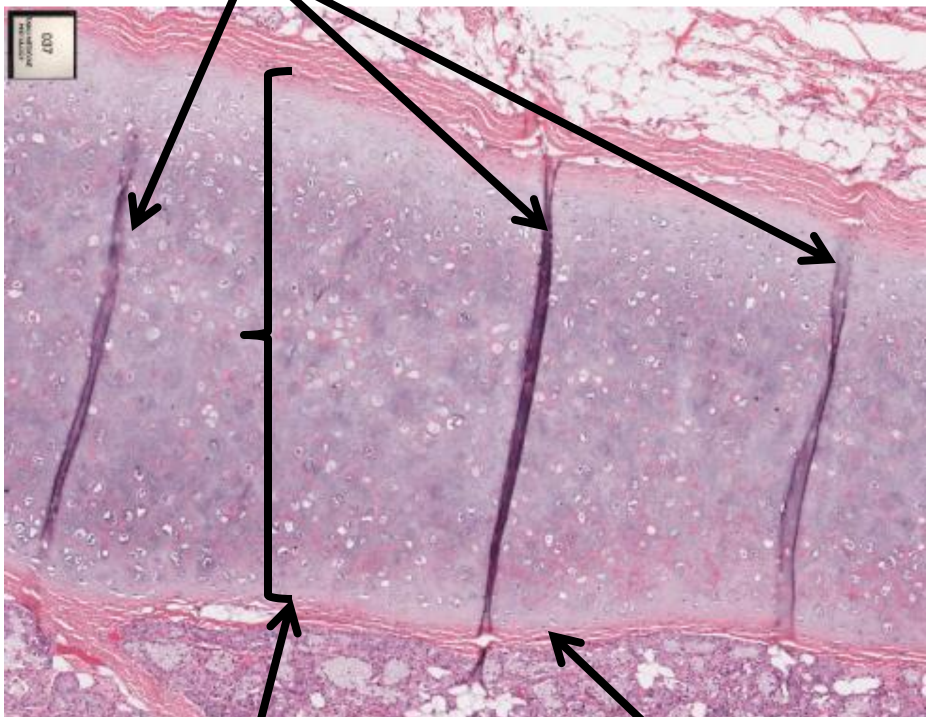
Staining variations within the matrix reflect local differences in its molecular composition. Immediately surrounding each chondrocyte, the ECM is relatively rich in GAGs causing these areas of territorial matrix to stain differently from the intervening areas of interterritorial matrix.





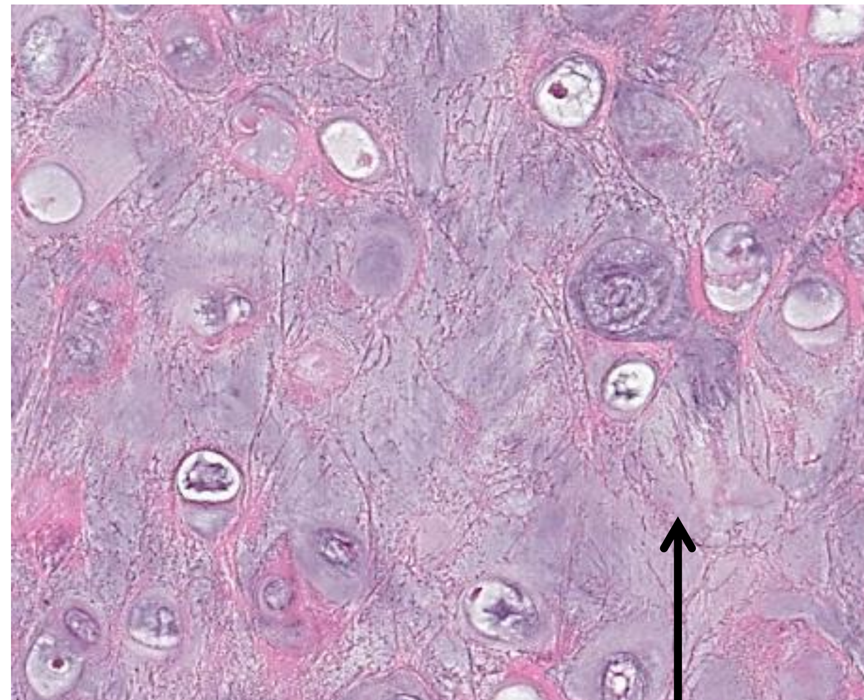
Slide 37: Epiglottis

Fold artifact



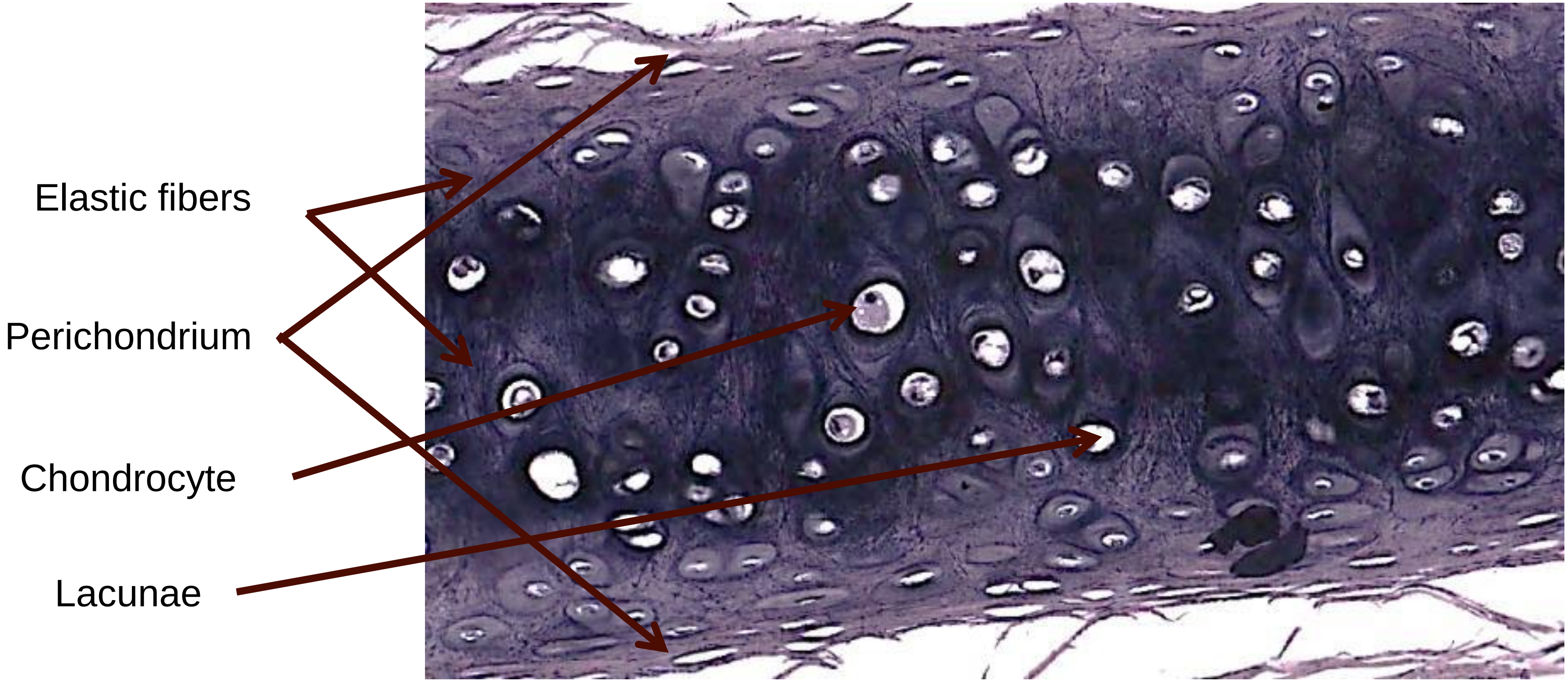
Elastic cartilage

Perichondrium



Elastic cartilage has obvious elastic fibers in an otherwise heterogenous matrix with more individual cells and fewer isogenous groups.

Slide 16: External auditory tube (Verhoff's stain for elastin)



FIBROCARTILAGE

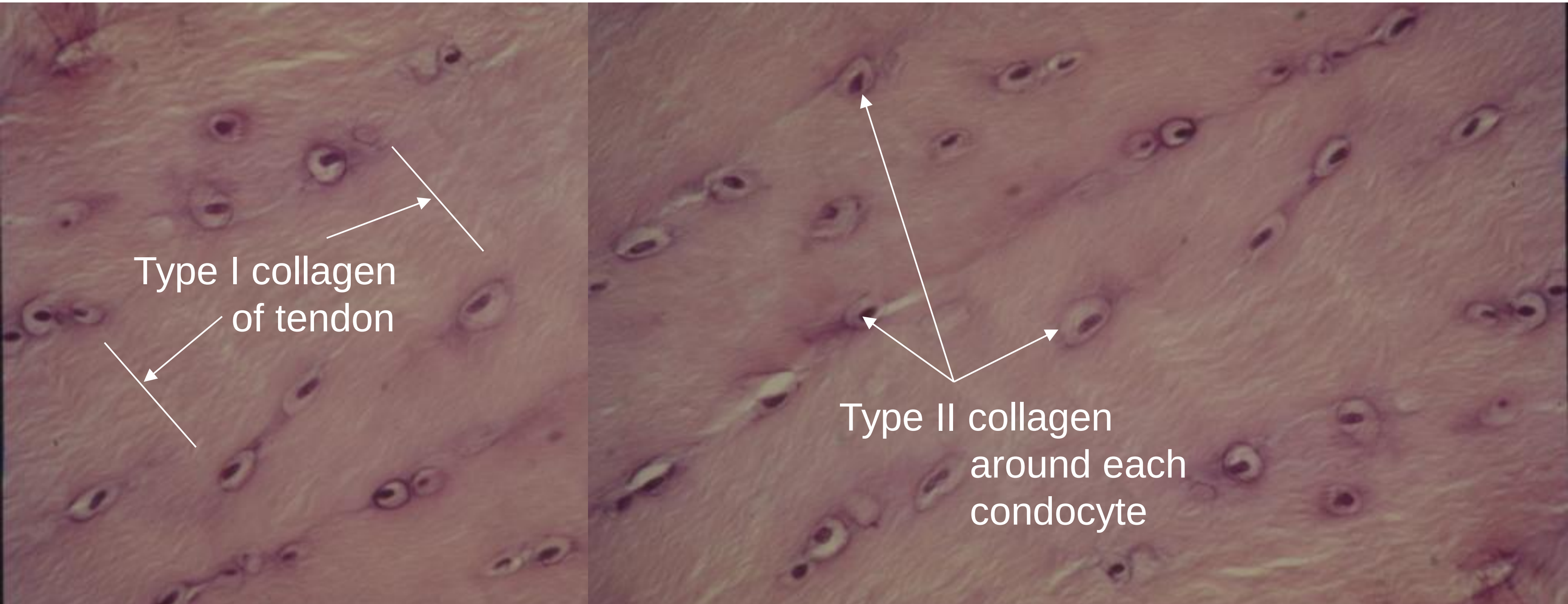
INTERMEDIATE BETWEEN DENSE REGULAR CONNECTIVE TISSUE AND HYALINE CARTILAGE

NO PERICHONDRIUM

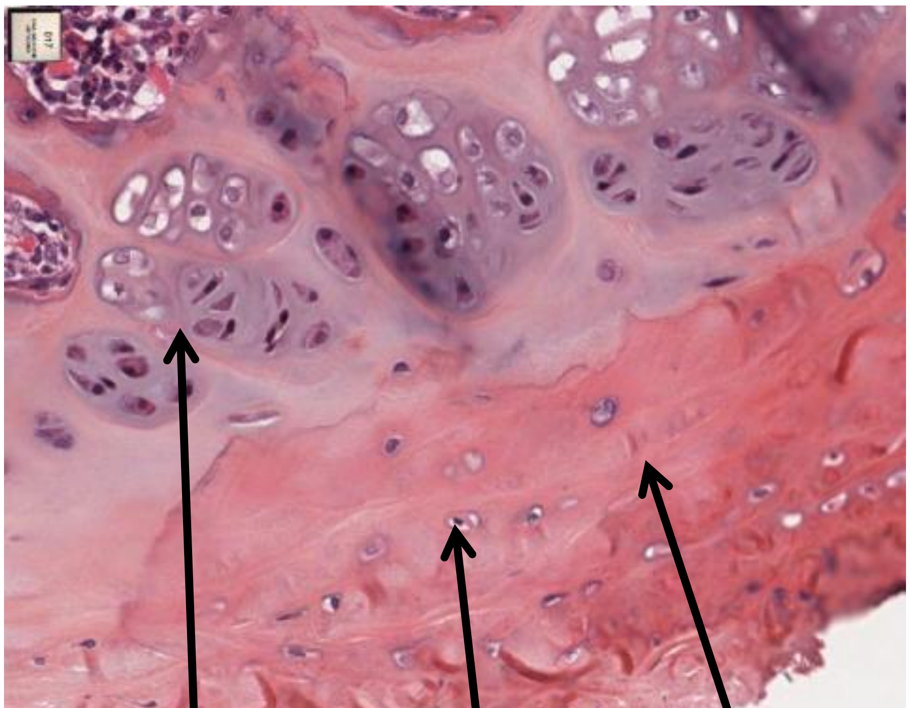
FIBROCARTILAGE

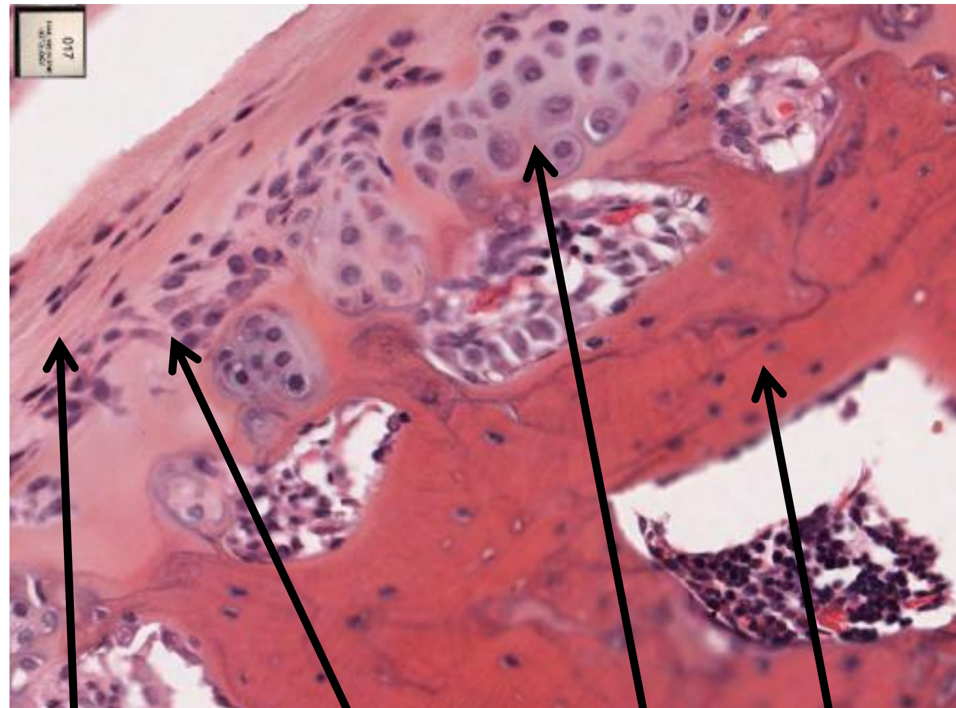
FOUND IN :

- INTERVERTEBRAL DISCS
- ATTACHMENT OF LIGAMENTS TO CARTILAGINEOUS SURFACE OF BONES



Slide 17: Vertebra





Hyaline cartilage

Chondrocyte in lacunae

Fibrocartilage

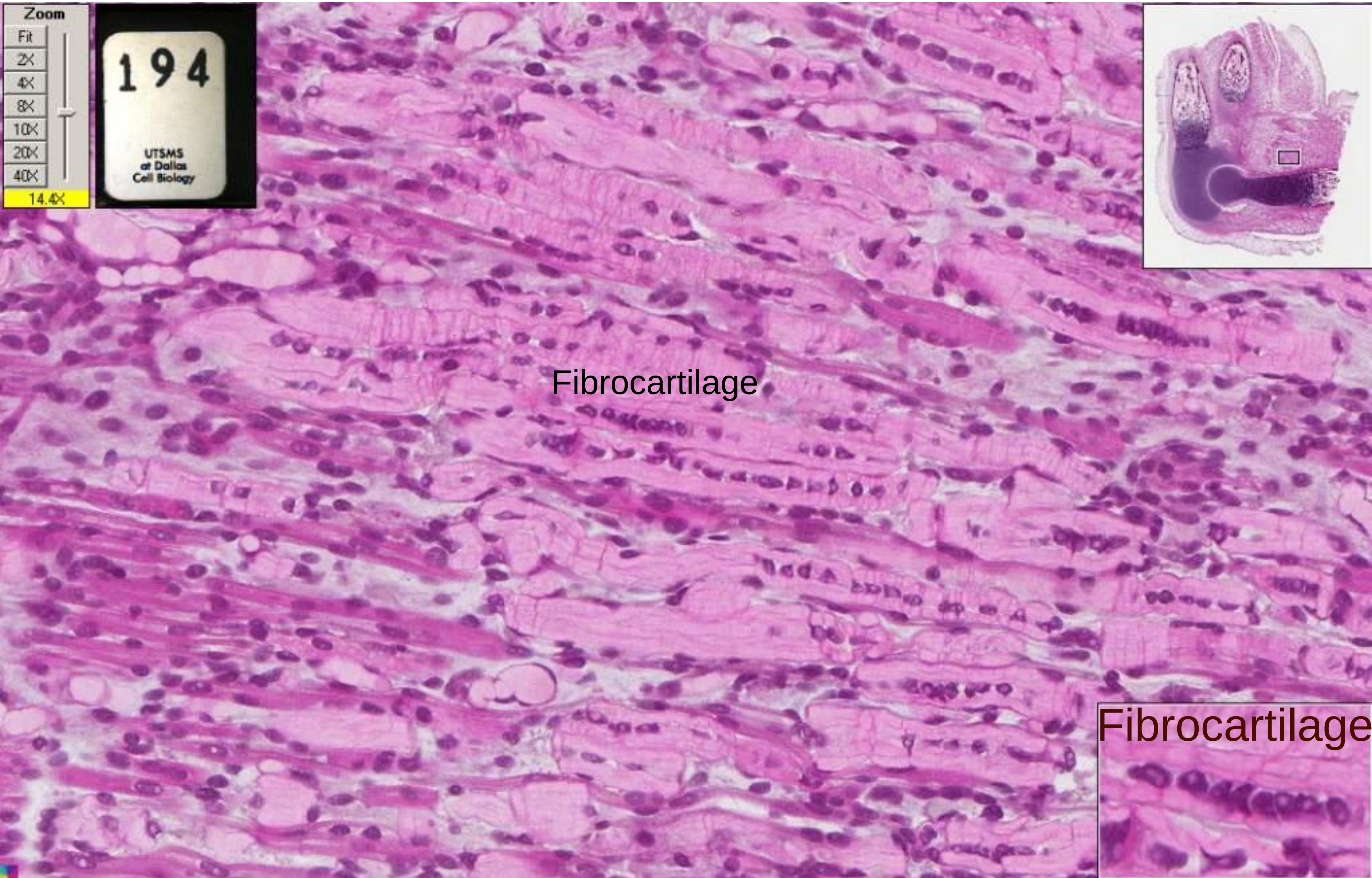
Dense connective tissue

Fibrocartilage

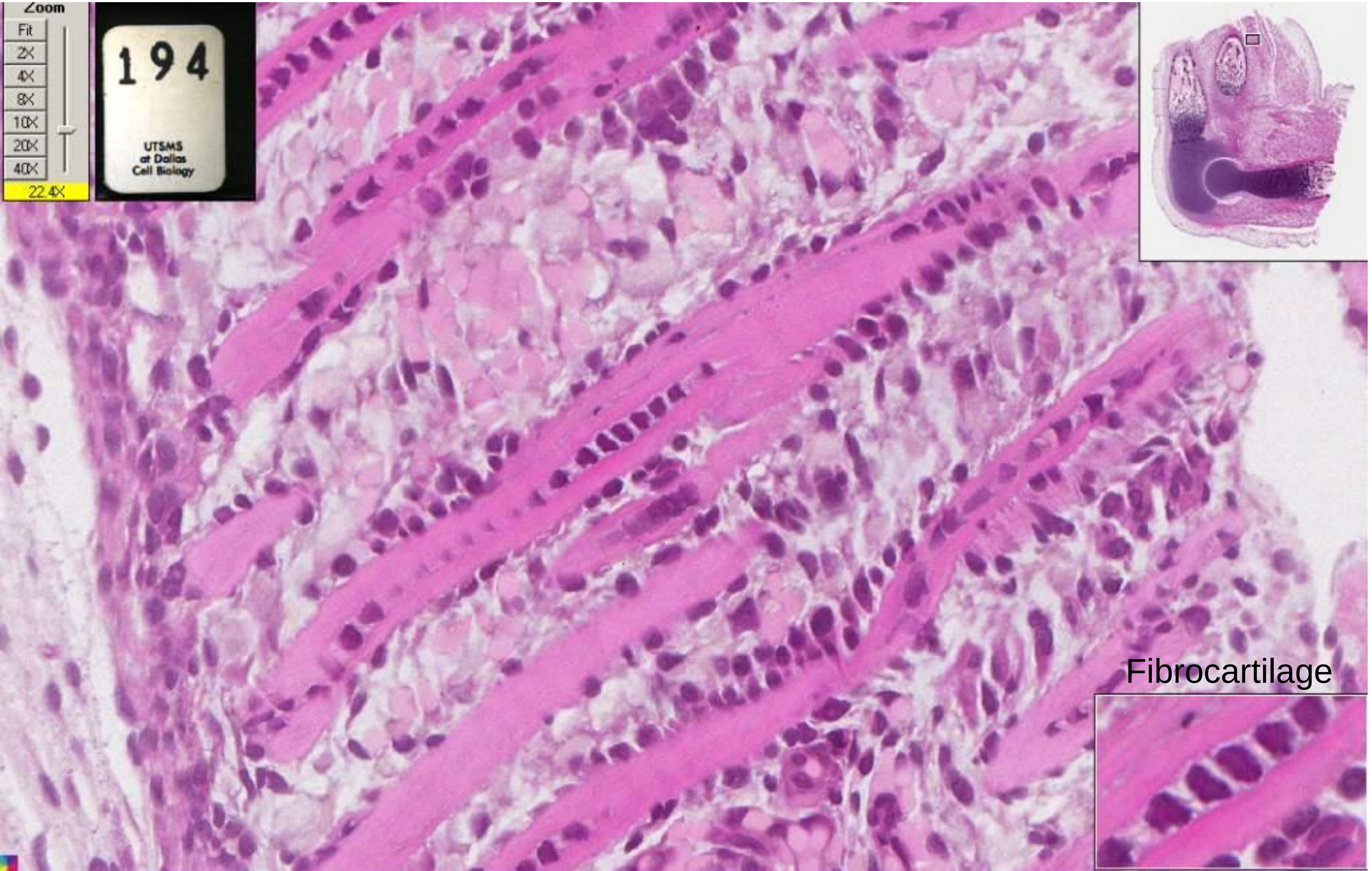
Hyaline cartilage

Bone

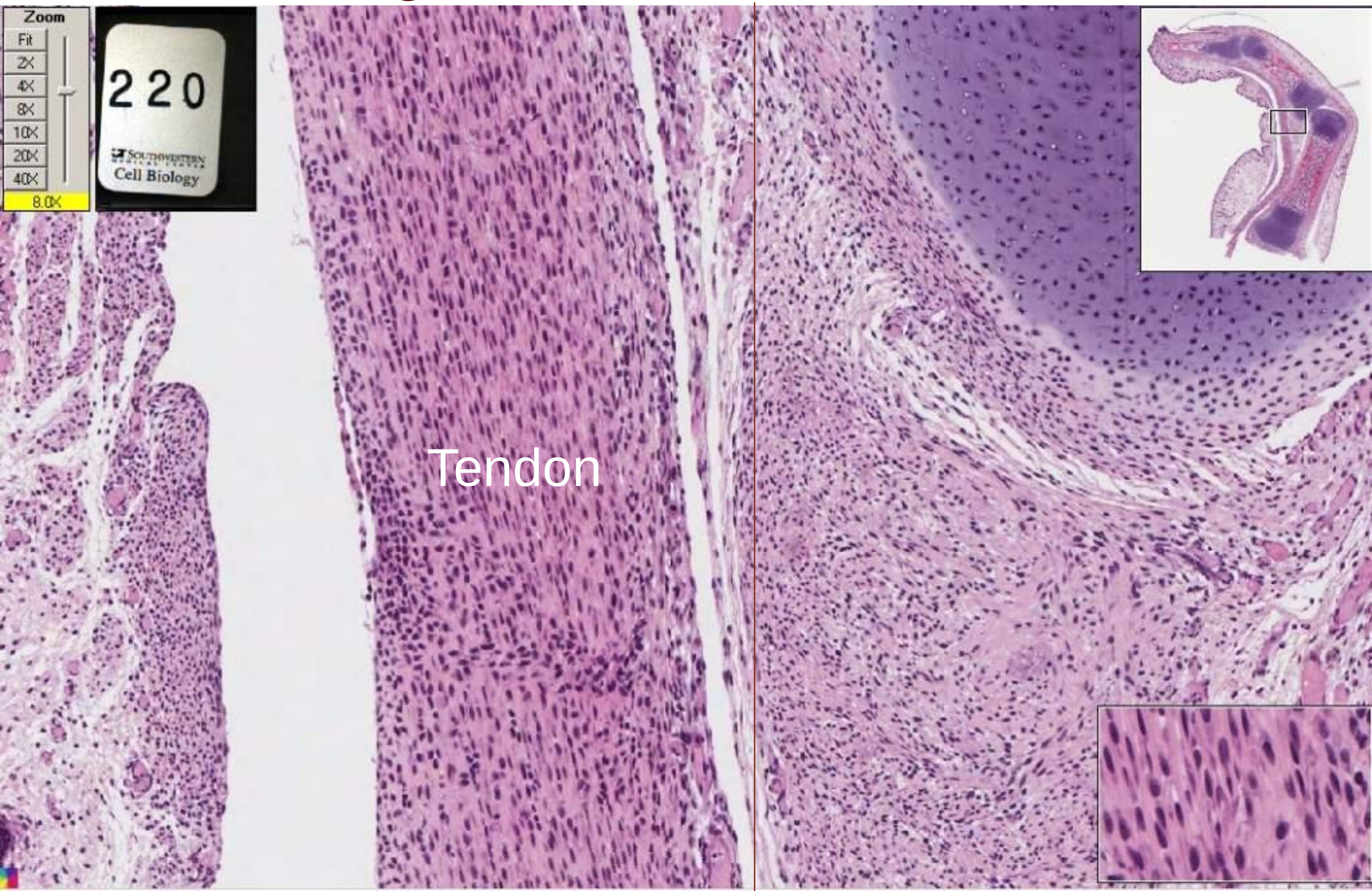
Fibrocartilage of Fetal elbow



Fibrocartilage of Fetal elbow



Fetal finger – fibroblasts in tendon



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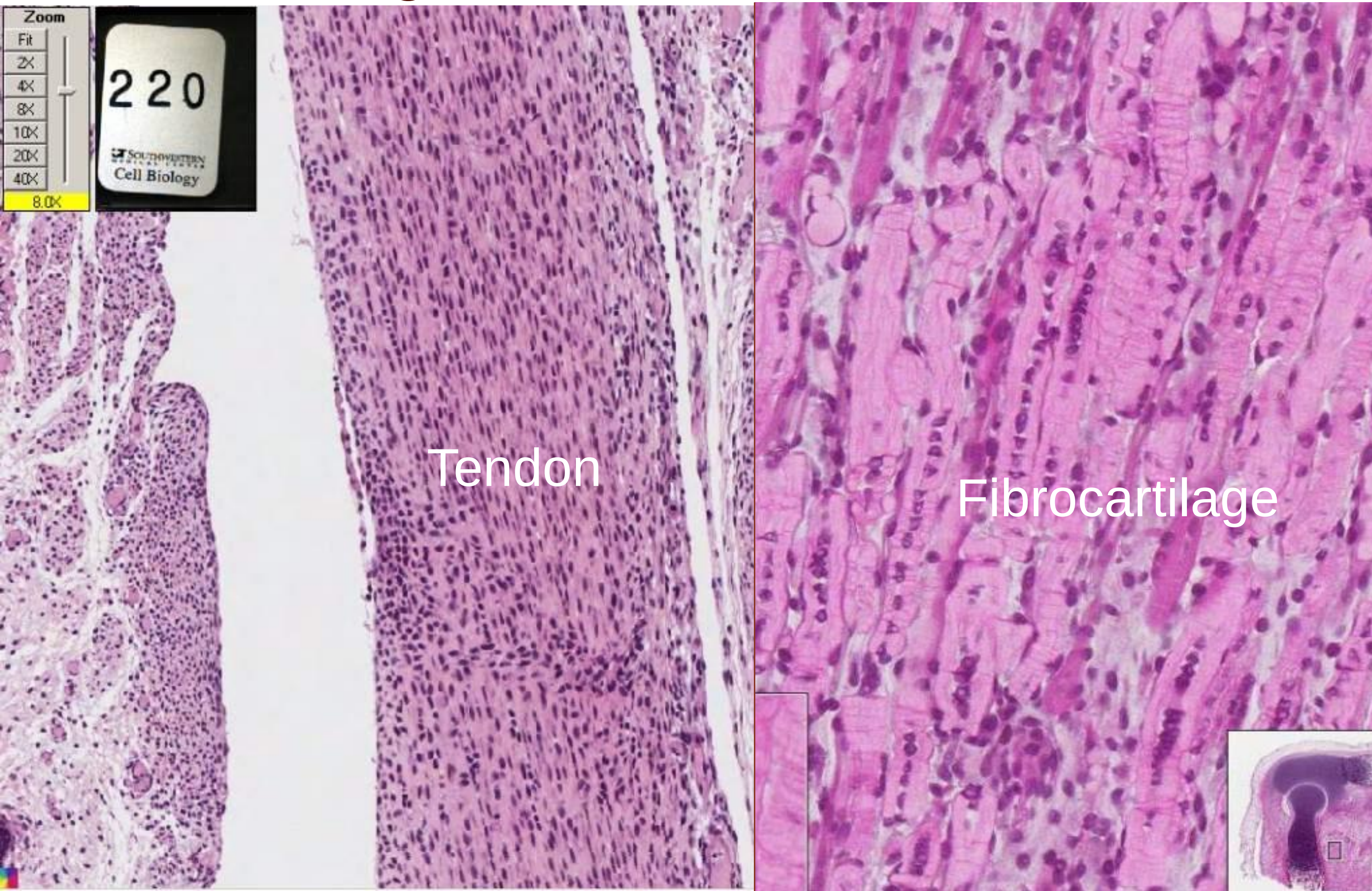
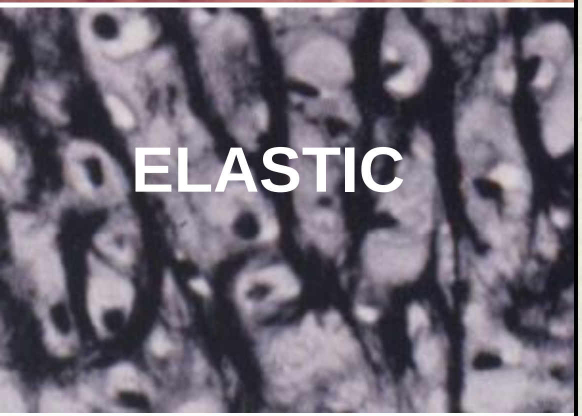
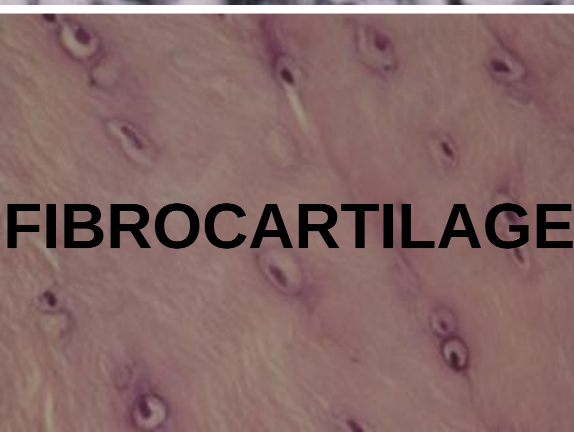
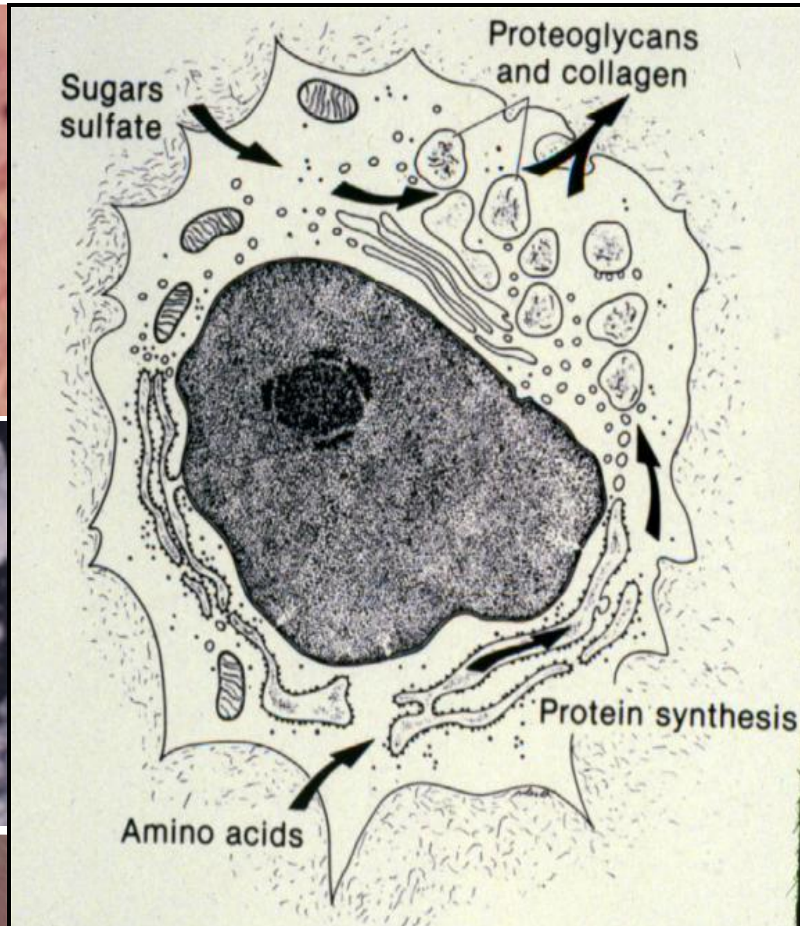
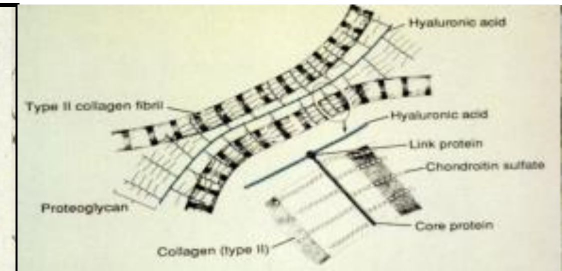


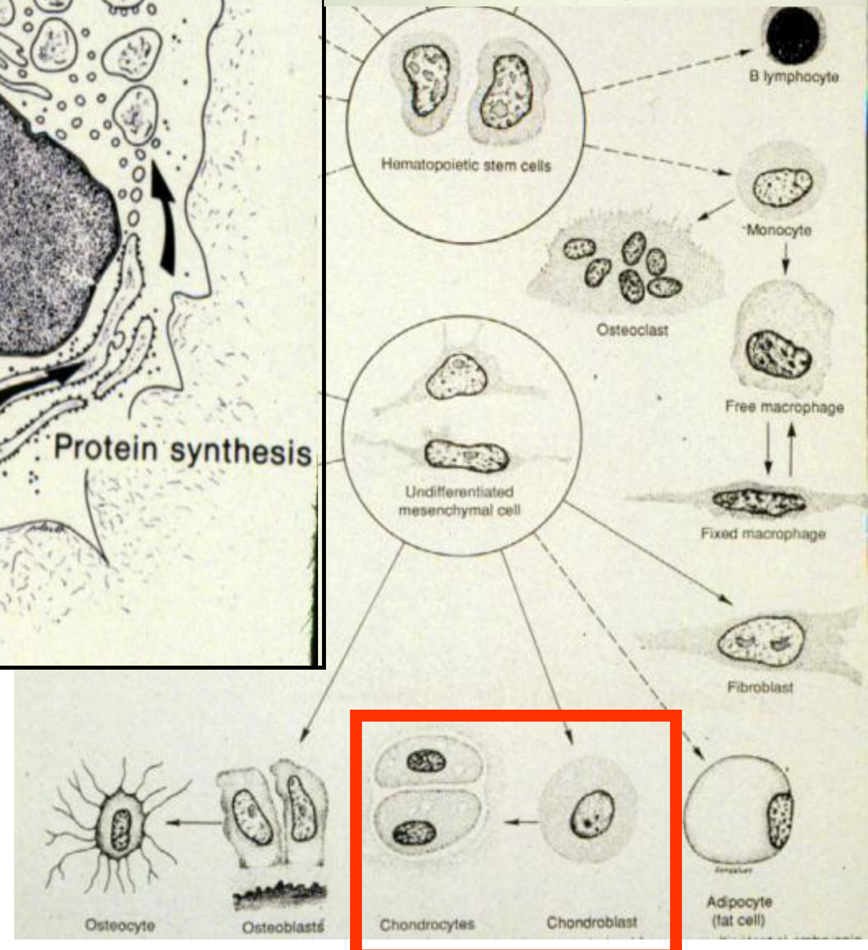
SUMMARY OF CARTILAGE











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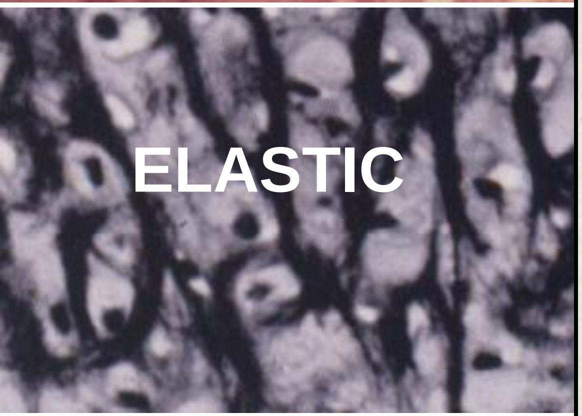
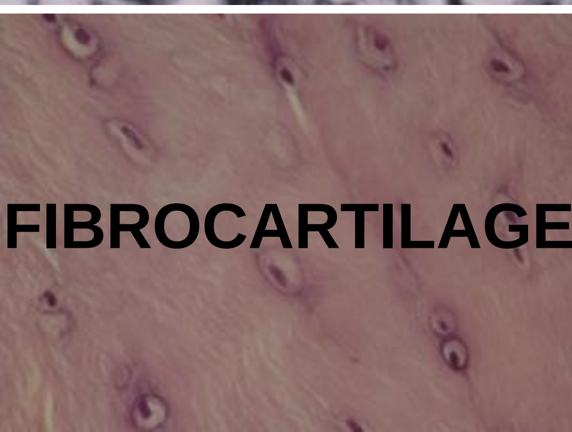
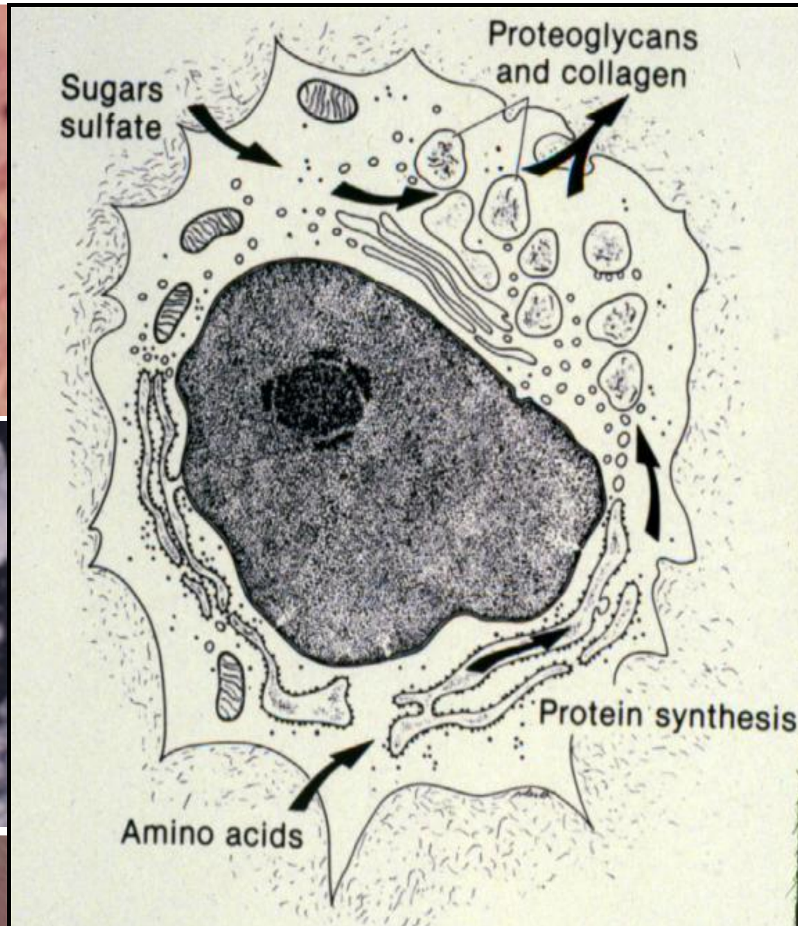
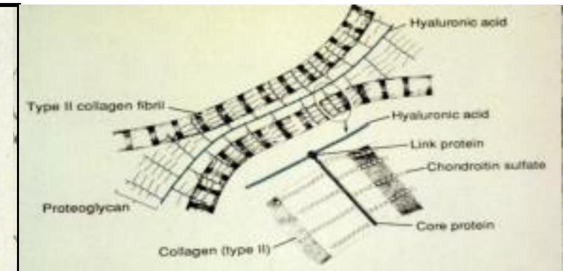
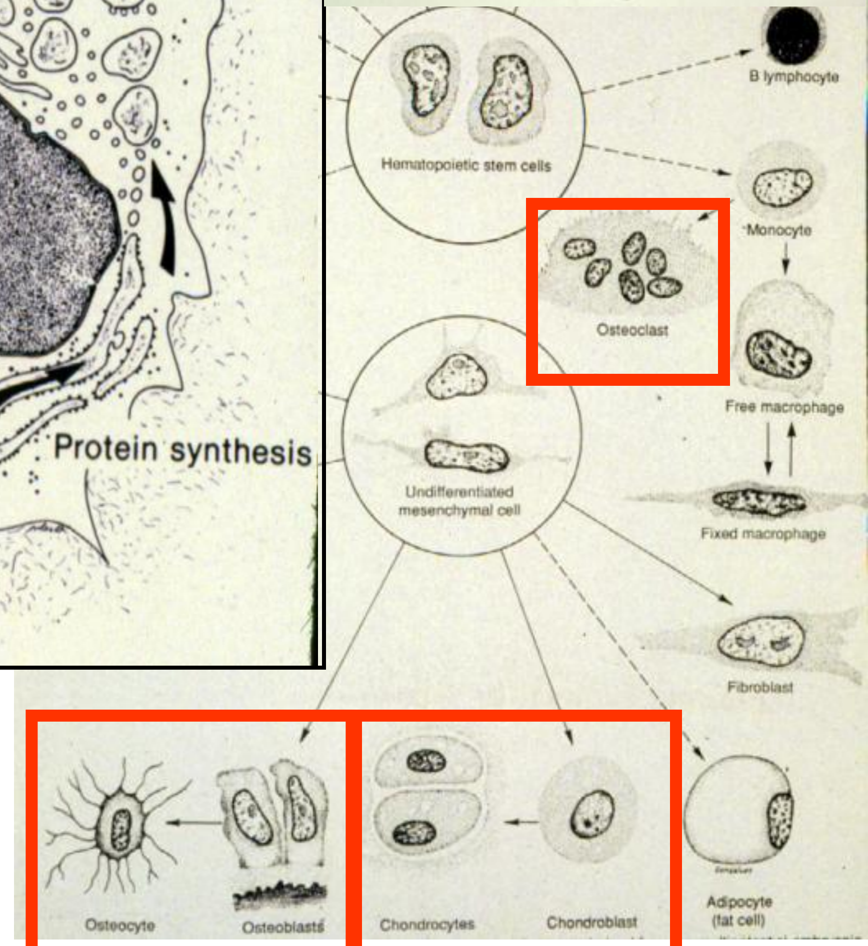




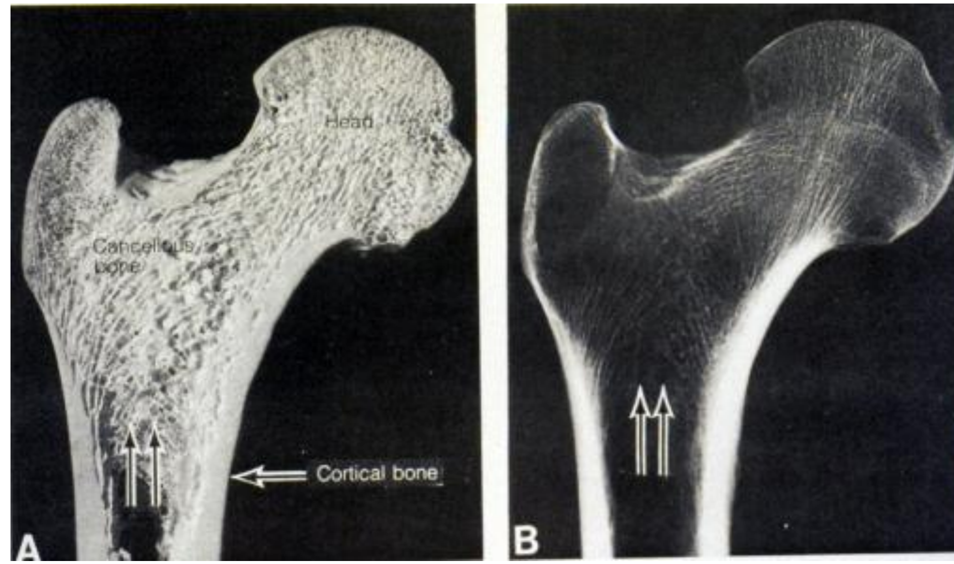






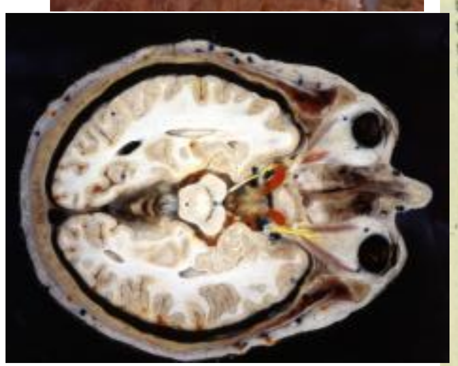
FUNCTIONS OF BONE

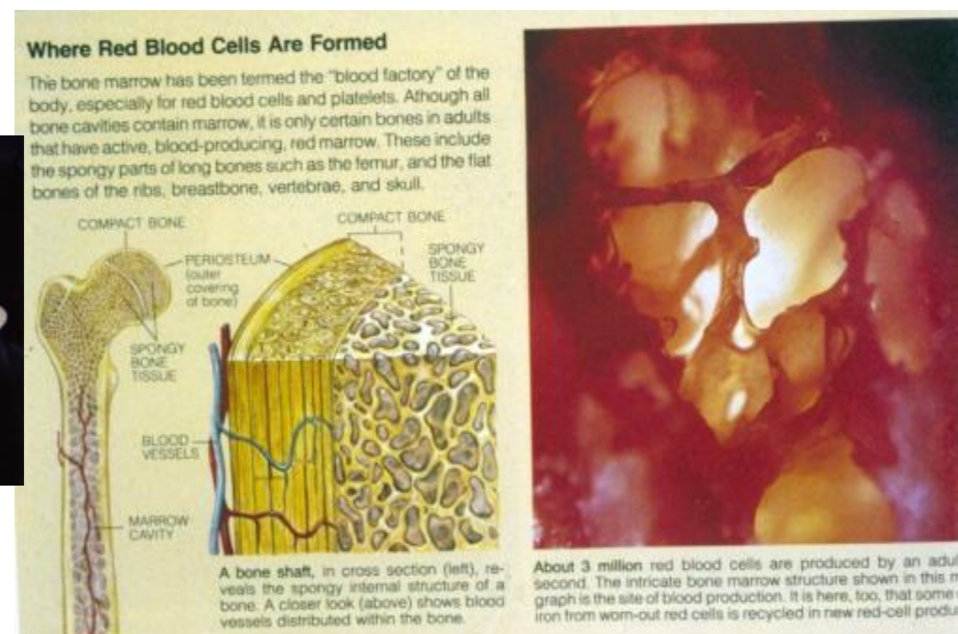
SKELETAL SUPPORT
LAND ANIMALS



PROTECTIVE ENCLOSURE

- SKULL TO PROTECT BRAIN
- LONG BONE TO PROTECT HEMOPOIETIC CELLS





Where Red Blood Cells Are Formed

The bone marrow has been termed the "blood factory" of the body, especially for red blood cells and platelets. Although all bone cavities contain marrow, it is only certain bones in adults that have active, blood-producing, red marrow. These include the spongy parts of long bones such as the femur, and the flat bones of the ribs, breastbone, vertebrae, and skull.

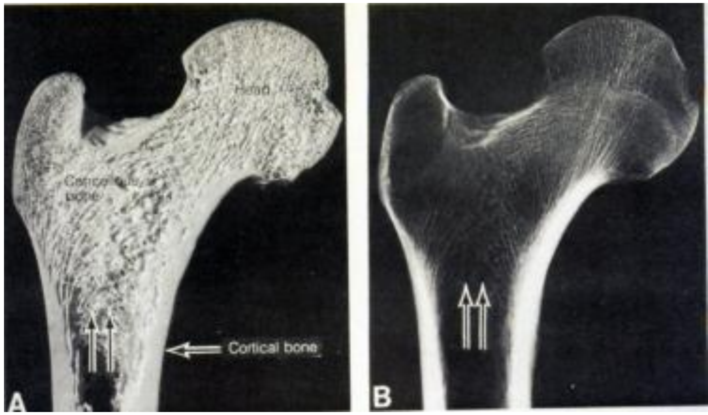
A bone shaft, in cross section (left), reveals the spongy internal structure of a bone. A closer look (above) shows blood vessels distributed within the bone.

About 3 million red blood cells are produced by an adult second. The intricate bone marrow structure shown in this mic graph is the site of blood production. It is here, too, that some of iron from worn-out red cells is recycled in new red-cell product

FUNCTIONS OF BONE

CALCIUM REGULATION

Parathroid hormone (BONE RESORPTION)



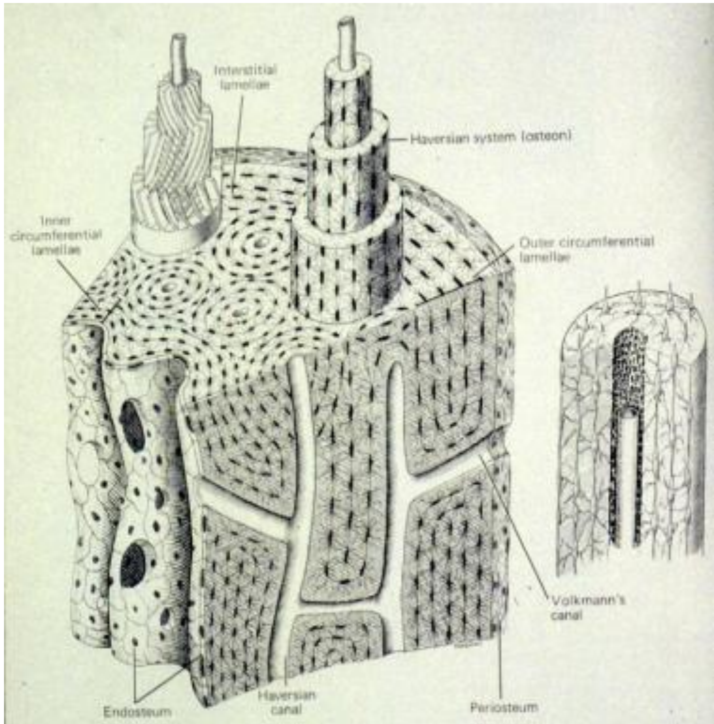


Figure 8–6. Schematic drawing of the wall of a long bone diaphysis. Observe the 4 types of lamellar bone: haversian system, outer and inner circumferential lamellae, and interstitial lamellae. The protruding haversian system on the left shows the orientation of collagen fibers in each lamella. At the right is a haversian system showing lamellae, a centra blood capillary, and many osteocytes with their processes.

FUNCTIONS OF BONE

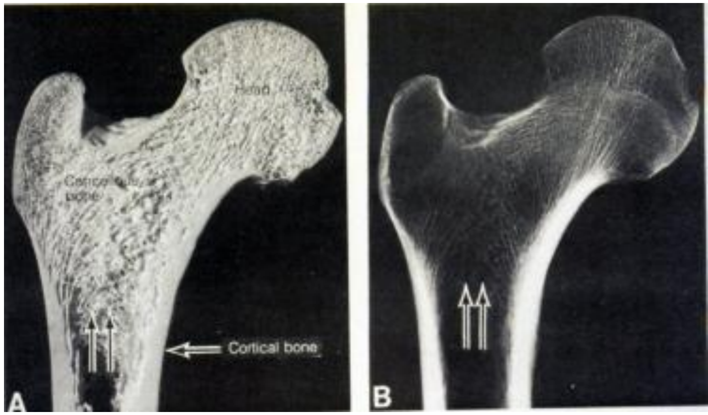
CALCIUM REGULATION

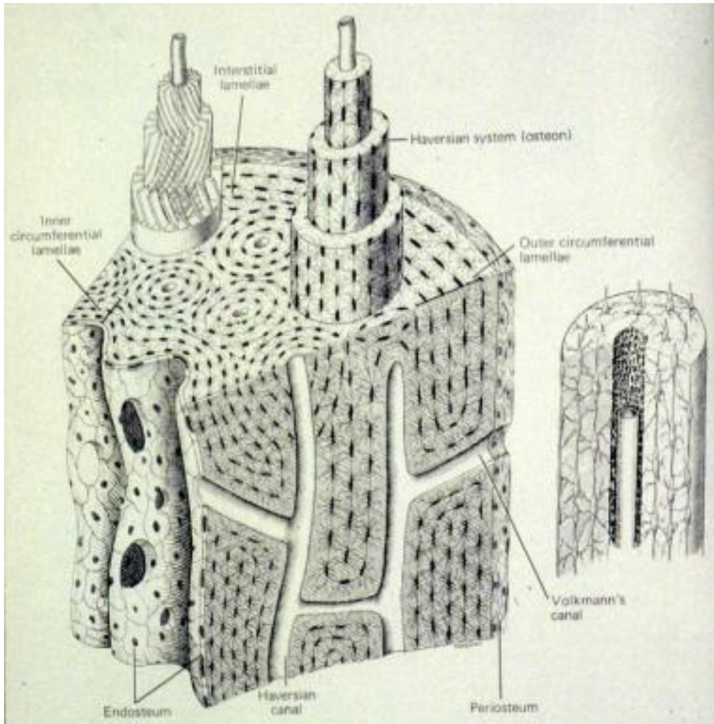
Parathroid hormone (BONE RESORPTION)

Calcitonin (PREVENTS RESORPTION)

These HORMONES are INVOLVED IN TIGHT REGULATION as

1/4 OF FREE CA^{++} IN BLOOD IS EXCHANGED EACH MINUTE.





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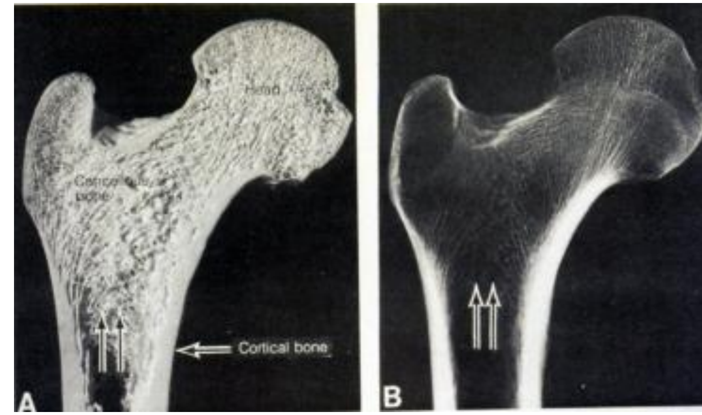
FUNCTIONS OF BONE



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These HORMONES are INVOLVED IN TIGHT REGULATION as

1/4 OF FREE CA^{++} IN BLOOD IS EXCHANGED EACH MINUTE.

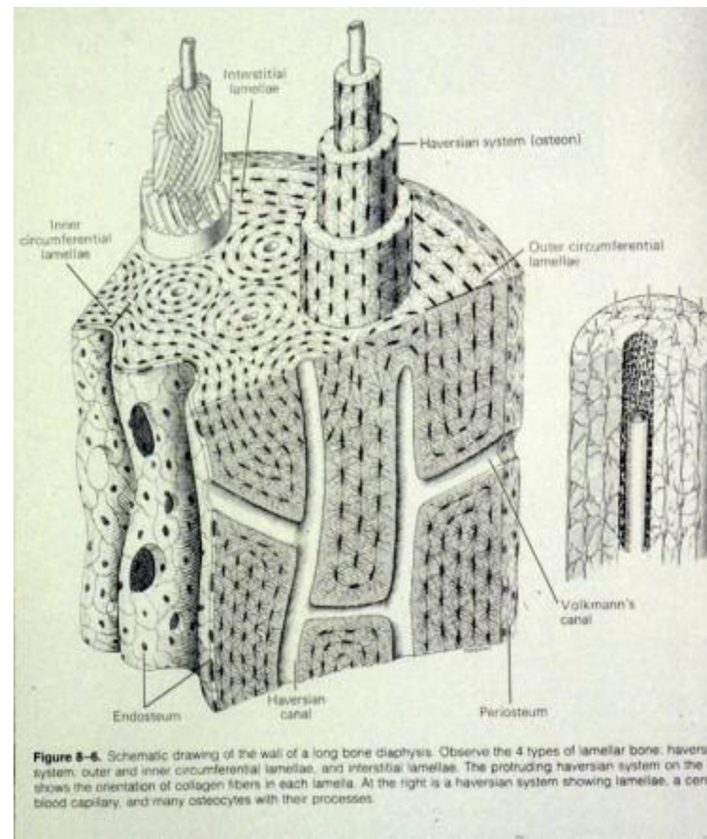
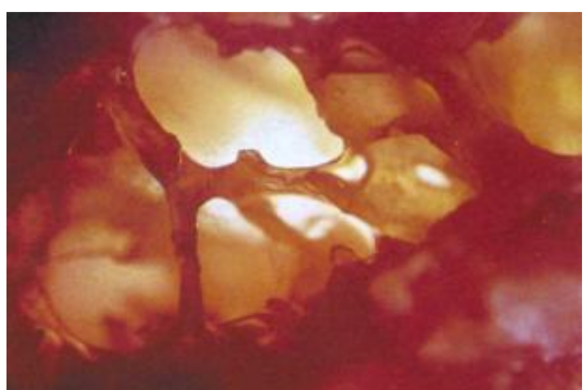


Figure 8–6. Schematic drawing of the wall of a long bone diaphysis. Observe the 4 types of lamellar bone: haversian system, outer and inner circumferential lamellae, and interstitial lamellae. The protruding haversian system on the left shows the orientation of collagen fibers in each lamella. At the right is a haversian system showing lamellae, a central blood capillary, and many osteocytes with their processes.

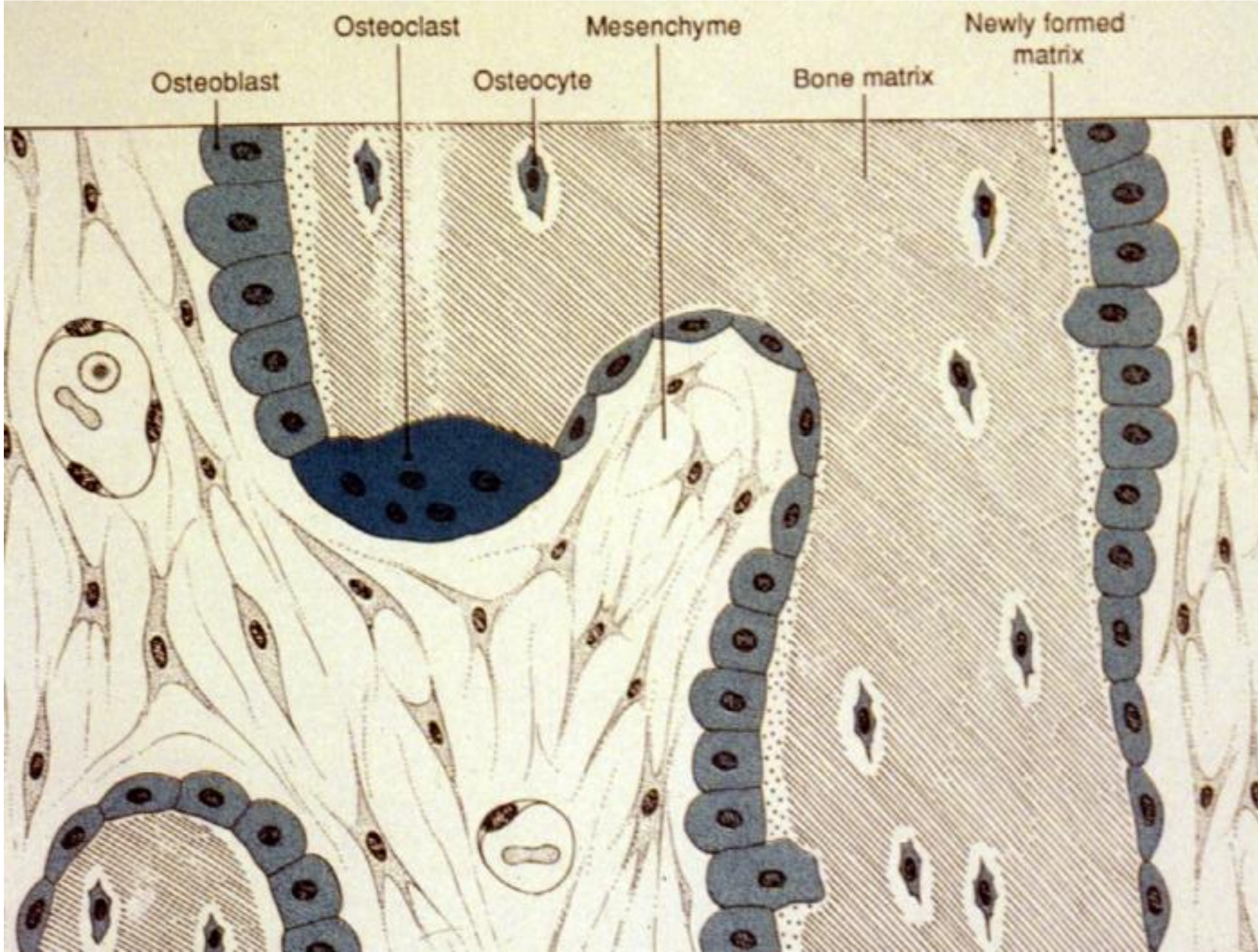
HEMOPOIESIS



CELLS OF BONE

OSTEOBLASTS - SECRETE OSTEOID - BONE

- EXPAND BONE BY APPOSITIONAL GROWTH

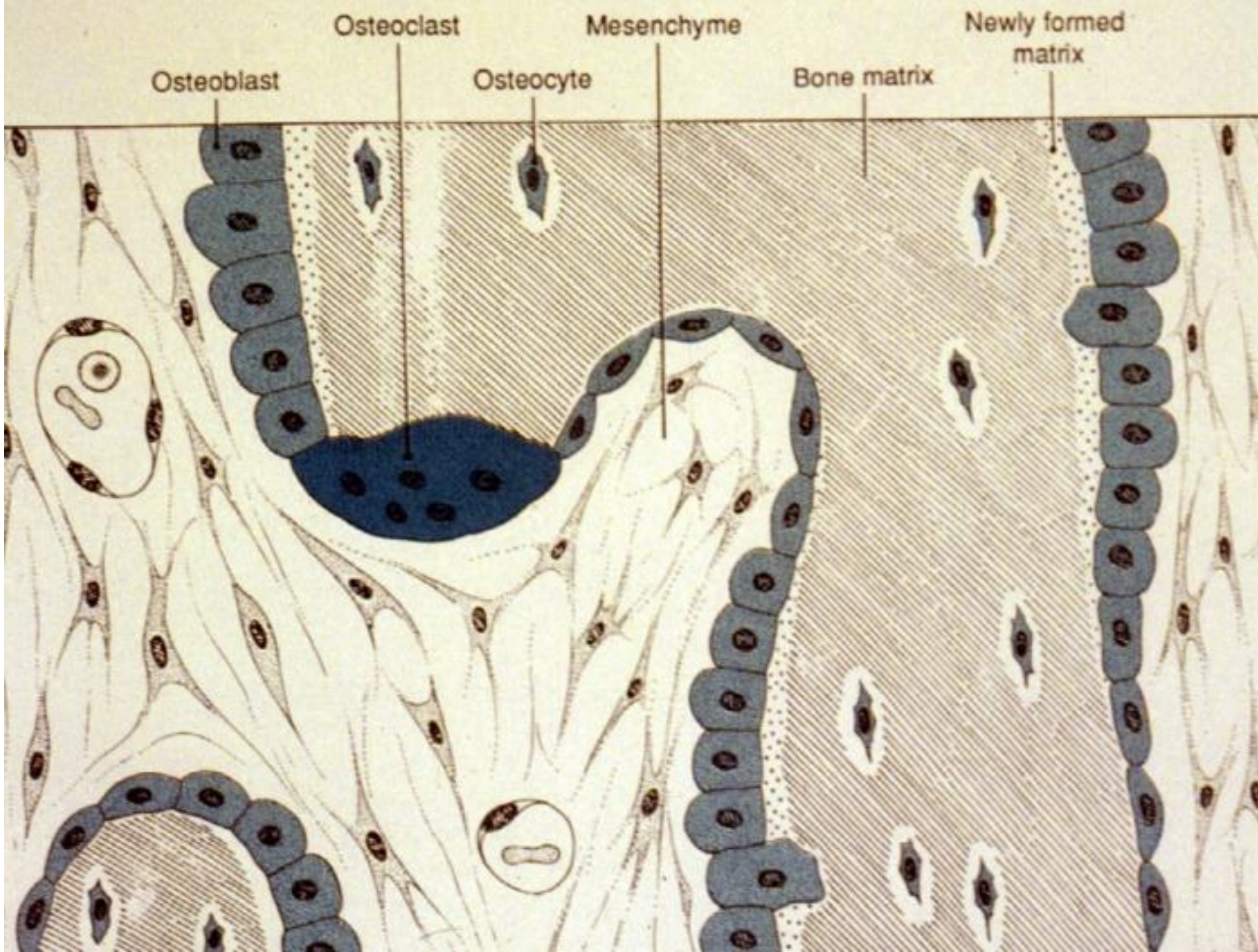


CELLS OF BONE

OSTEOBLASTS - SECRETE OSTEOID - BONE

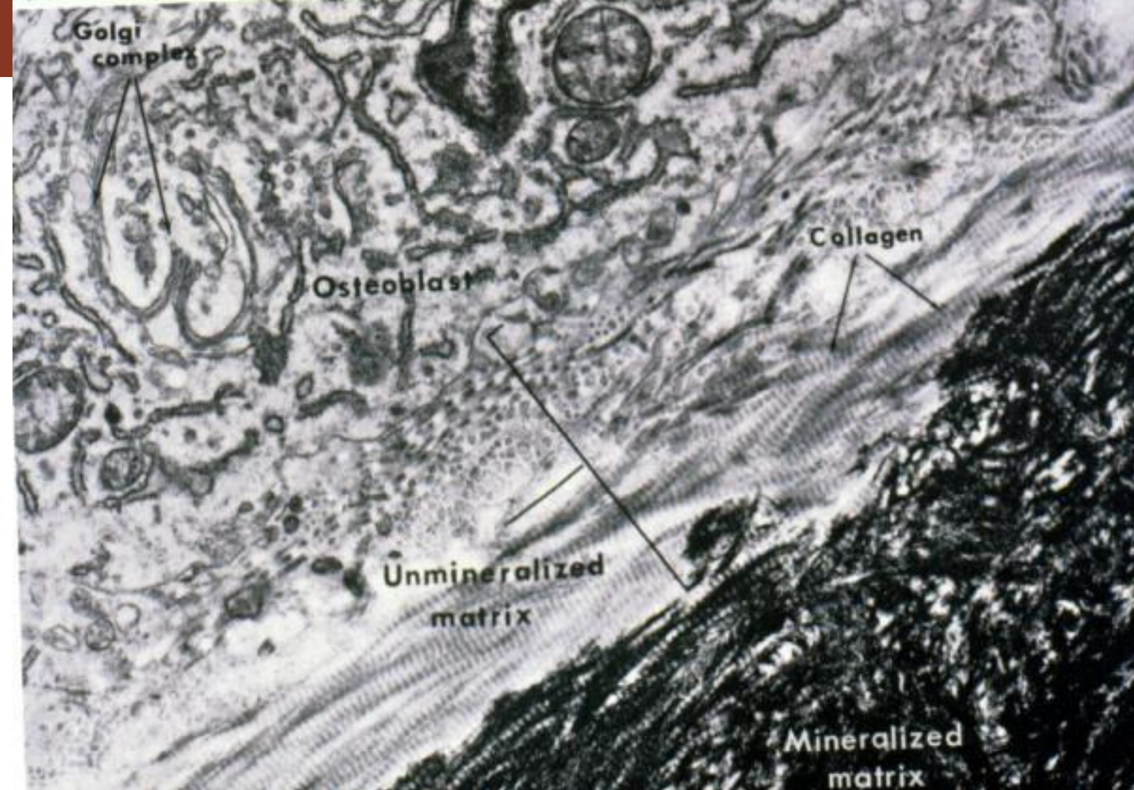
- EXPAND BONE BY APPOSITIONAL GROWTH

OSTEOCYTE = OSTEOBLAST TRAPPED IN MATRIX OF BONE

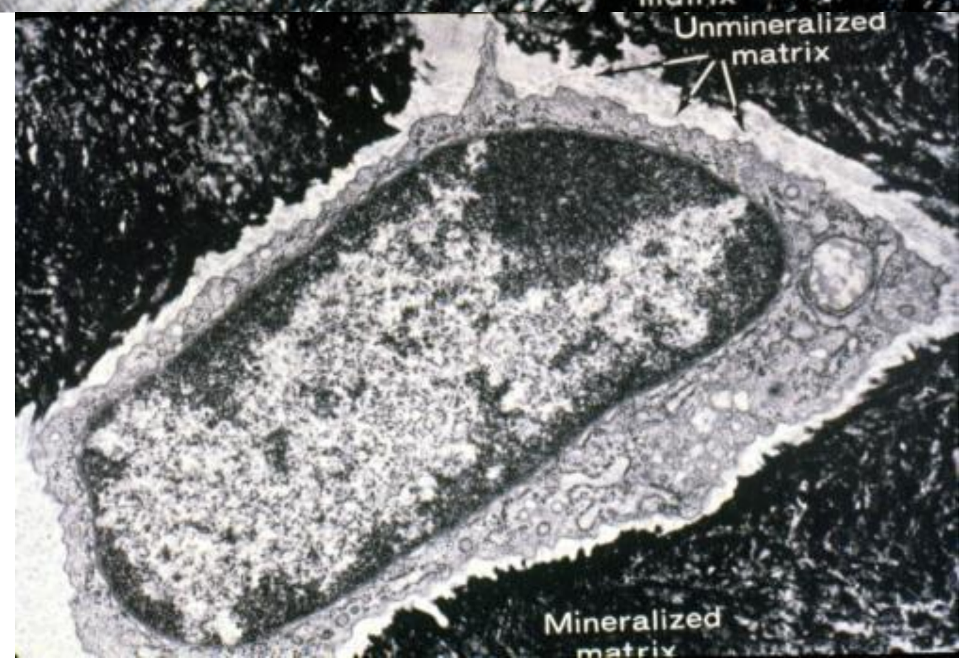


CELLS OF BONE

OSTEOBLASTS

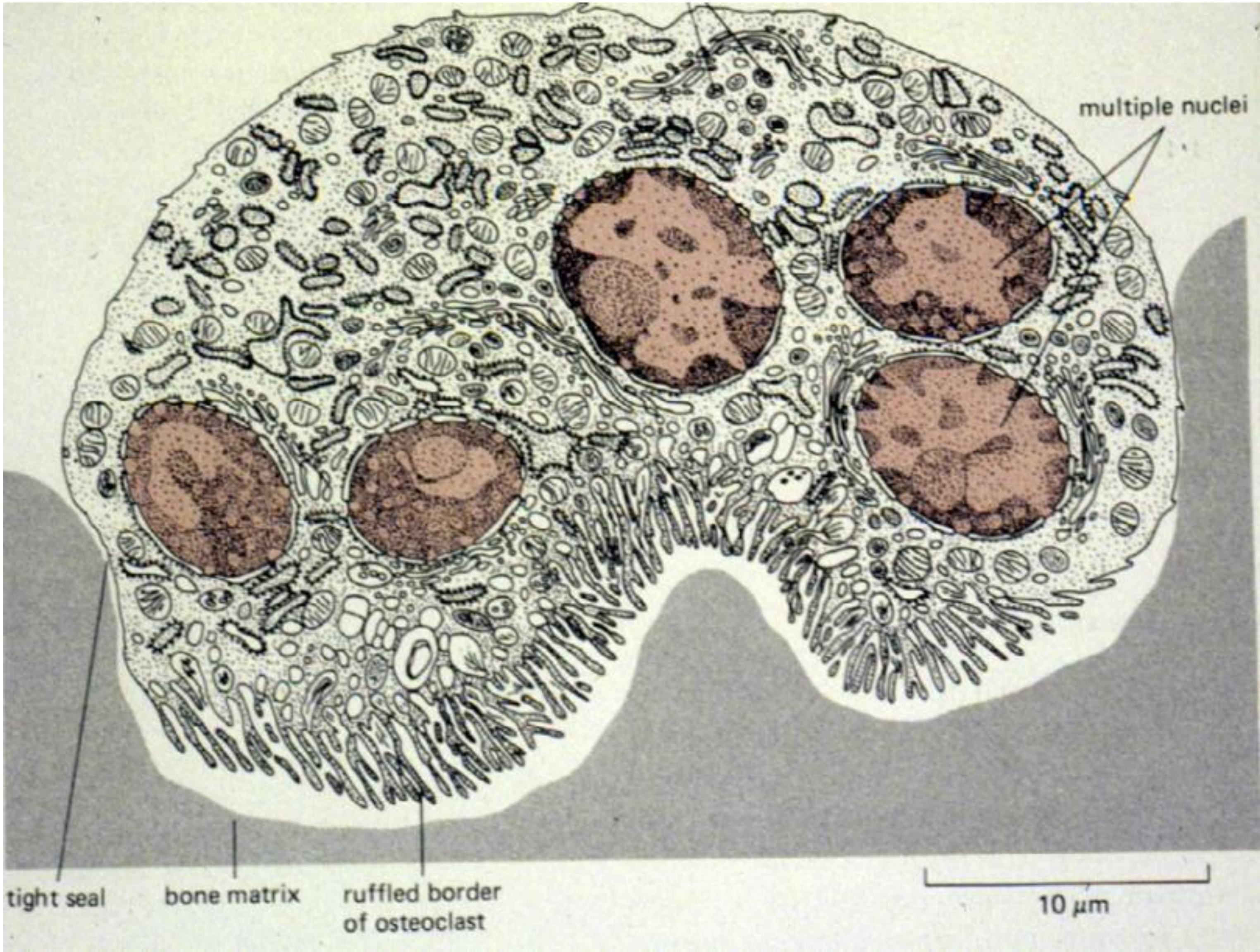


OSTEOCYTES – OSTEOBLASTS TRAPPED IN MATRIX OF BONE



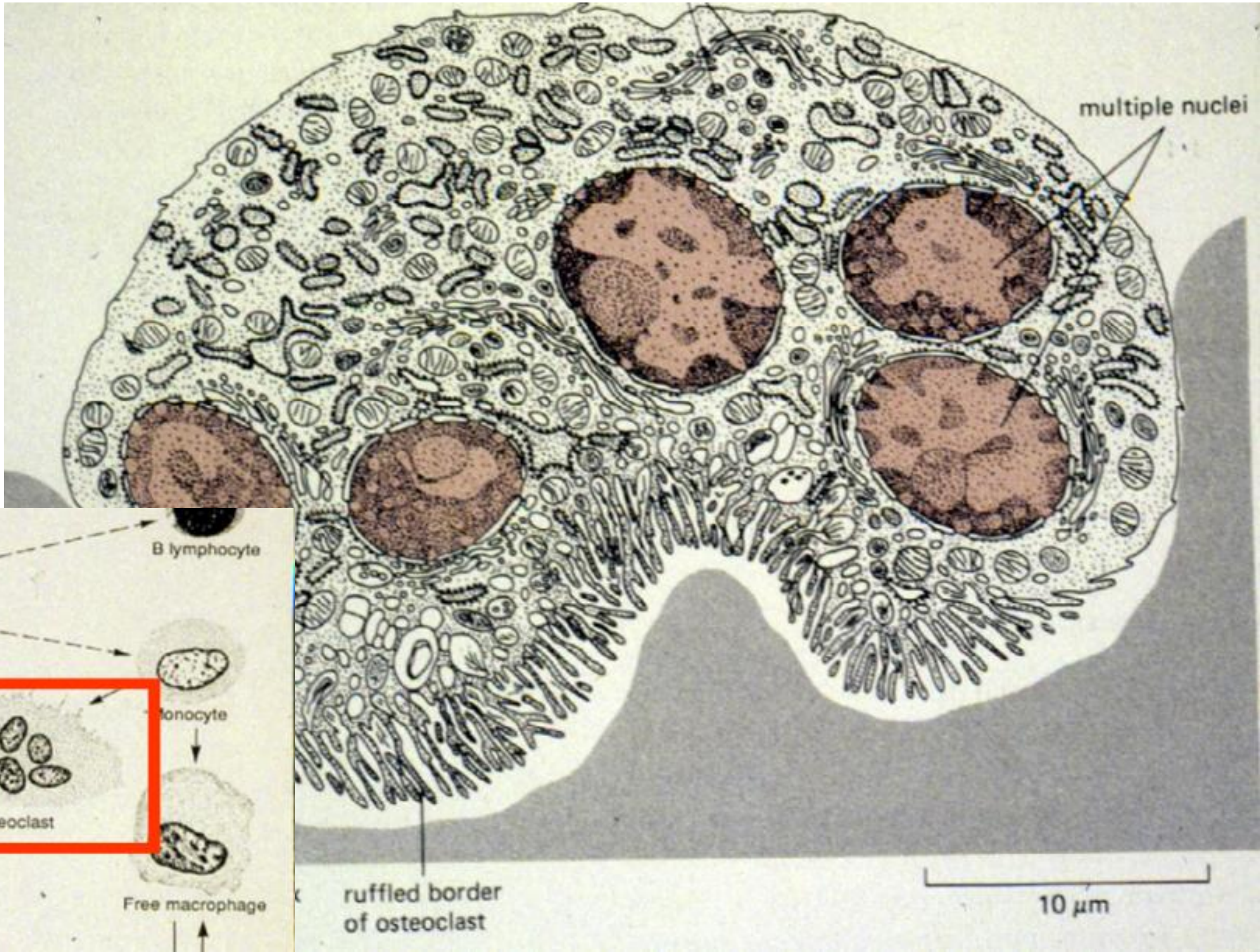
CELLS OF BONE

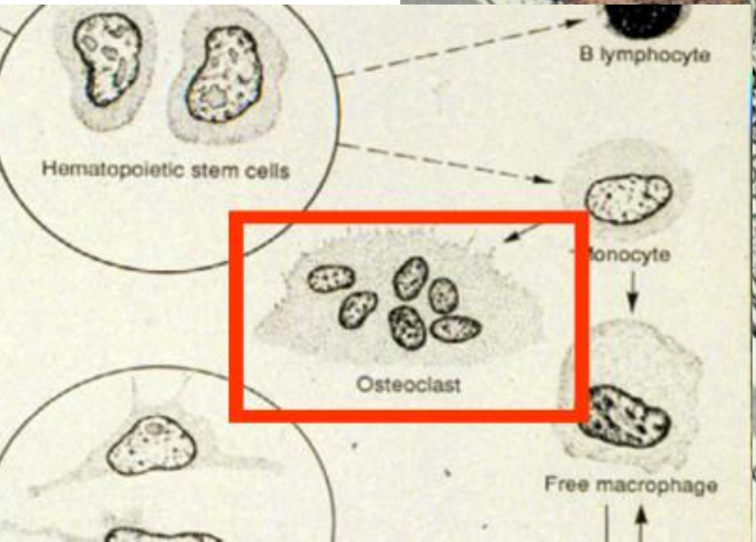
OSTEOCLASTS - MULTINUCLEATED PHAGOCYTIC CELLS FROM MONO-CYTES



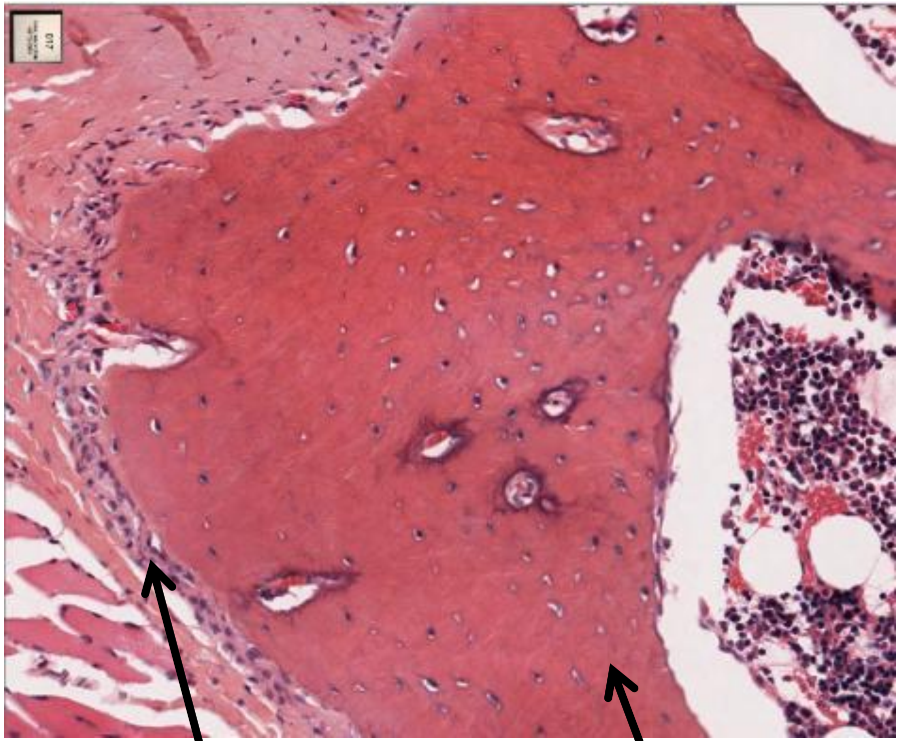
CELLS OF BONE

OSTEOCLASTS - MULTINUCLEATED PHAGOCYTIC CELLS FROM MONO-CYTES



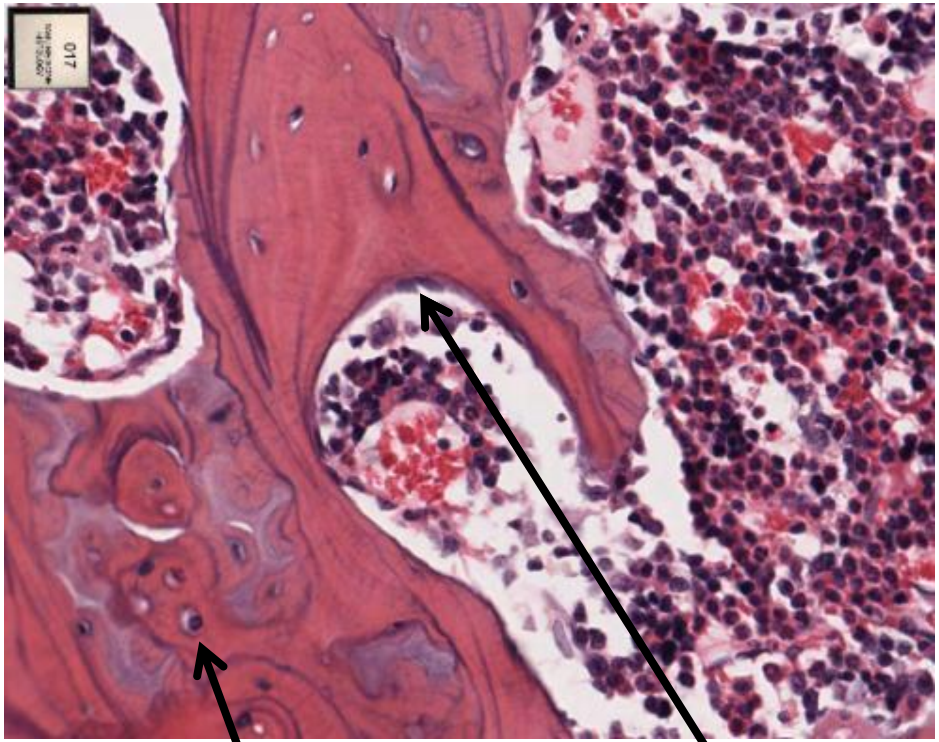


Slide 17: Vertebra



Fibrous periosteum containing fibroblasts

Cancellous bone



Osteocyte in lacunae

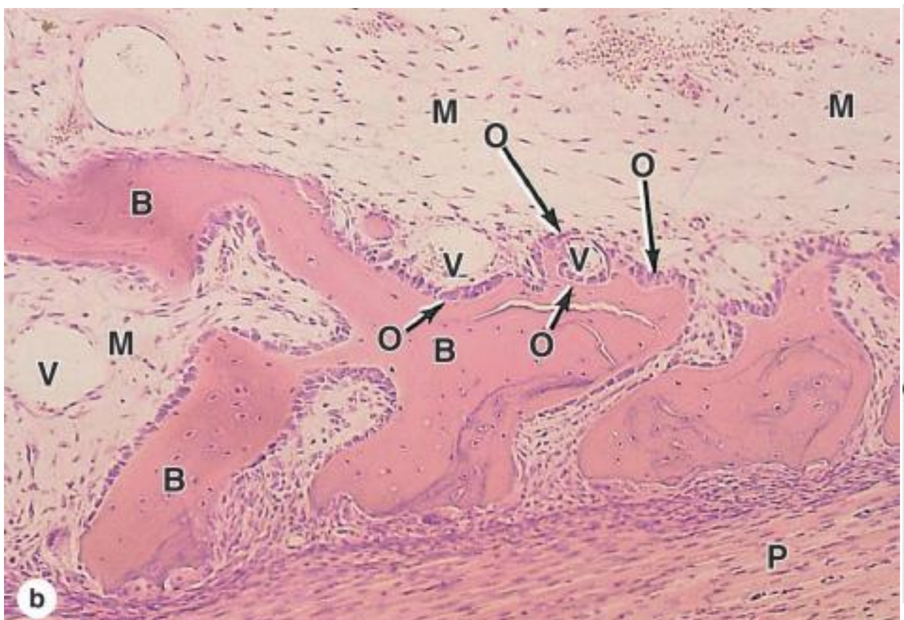
Osteoblasts lining bony trabeculae

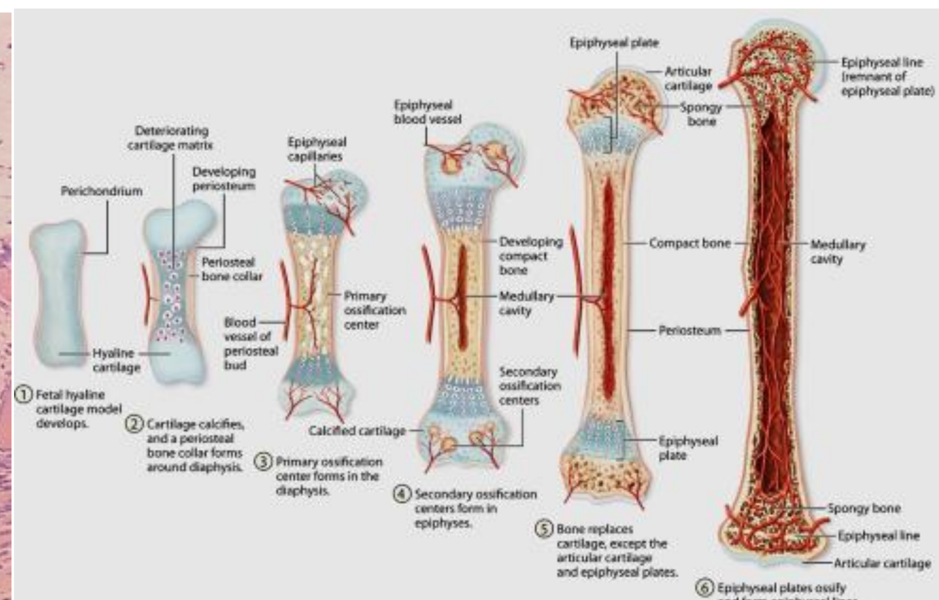
Developing Bone

Methods of bone development

- **Intramembranous**: formation within fibrous/collagenous membranes formation fibroblast like precursor cells

- **Endochondrial ossification**: formation within cartilage model with distinct zones of development, formation by replacing cartilage cells and matrix

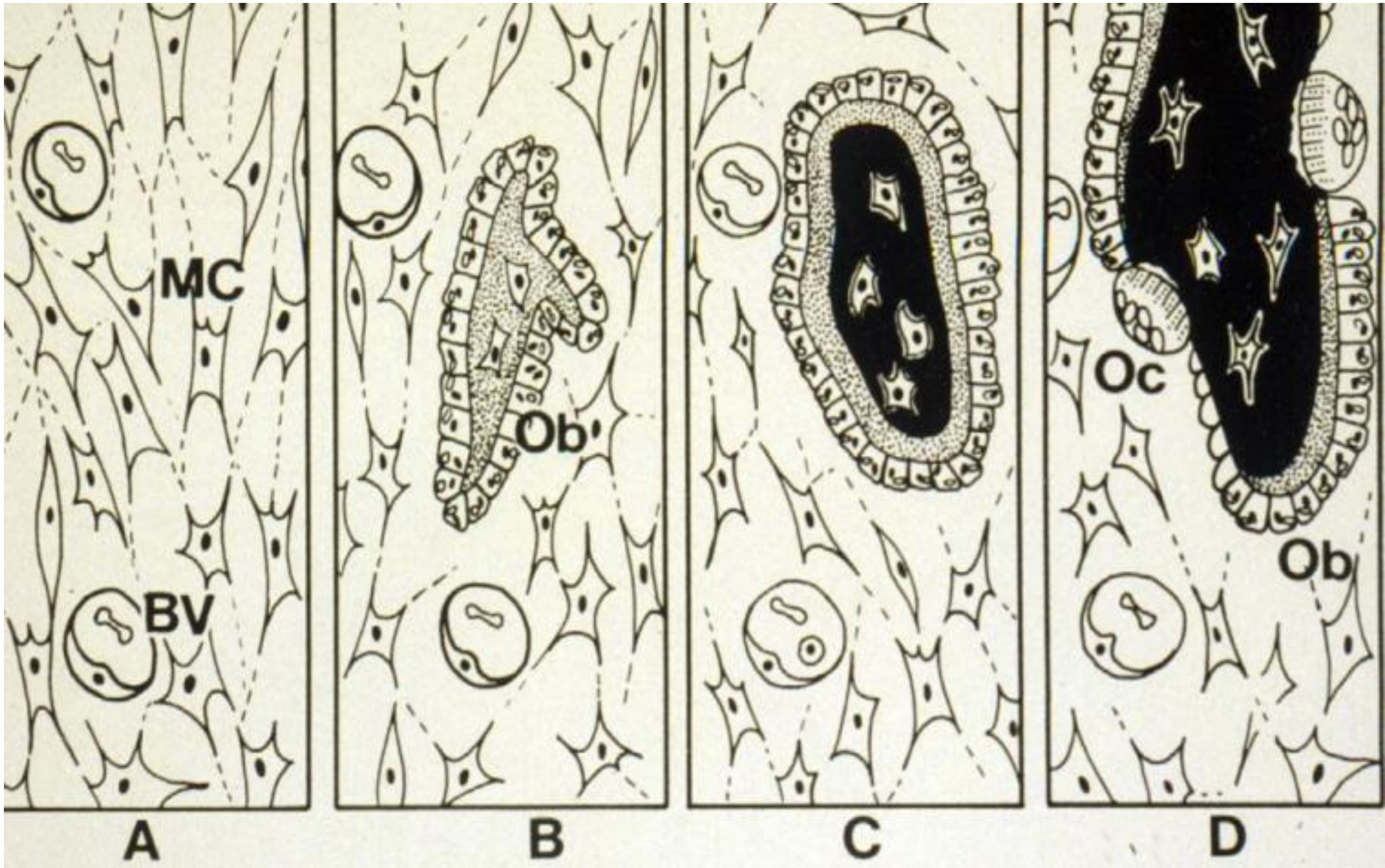




HISTOGENESIS OF BONE

INTRAMEMBRANOUS OSSIFICATION

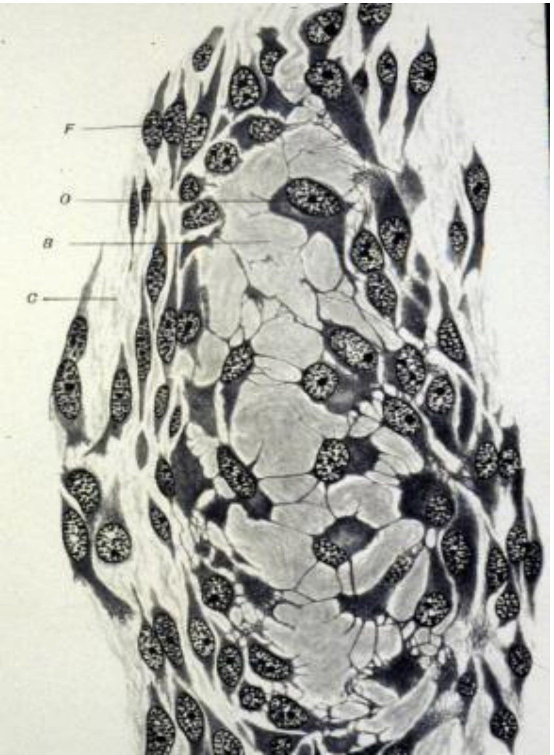
DIRECT MINERALIZATION OF MATRIX SECRETED BY OSTEOBLAST WITHOUT A CARTILAGE MODEL



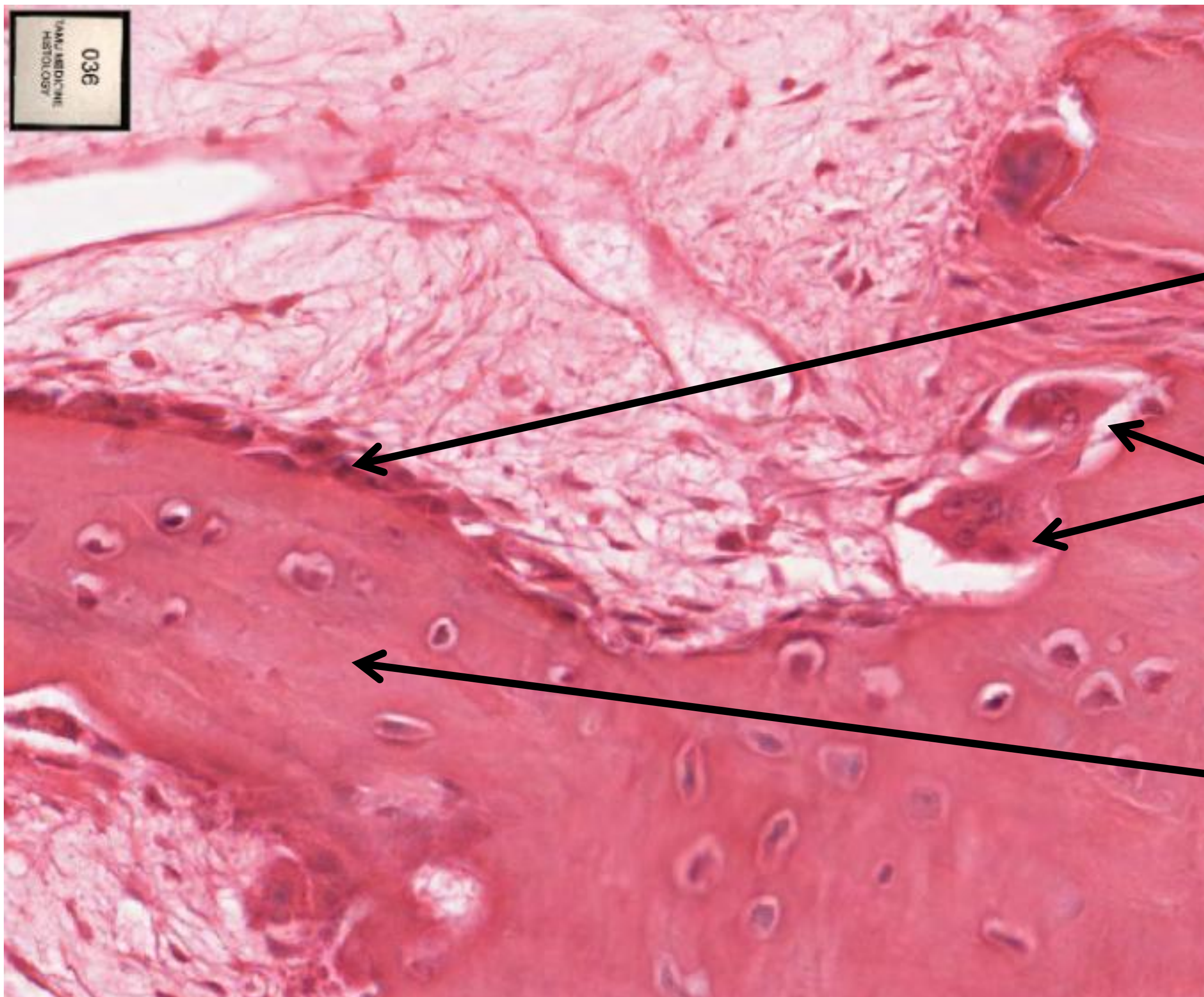
HISTOGENESIS OF BONE

INTRAMEMBRANOUS OSSIFICATION

FLAT BONES
OF SKULL



Slide 36: Nasal septum (intramembranous osteogenesis)



Osteoblasts

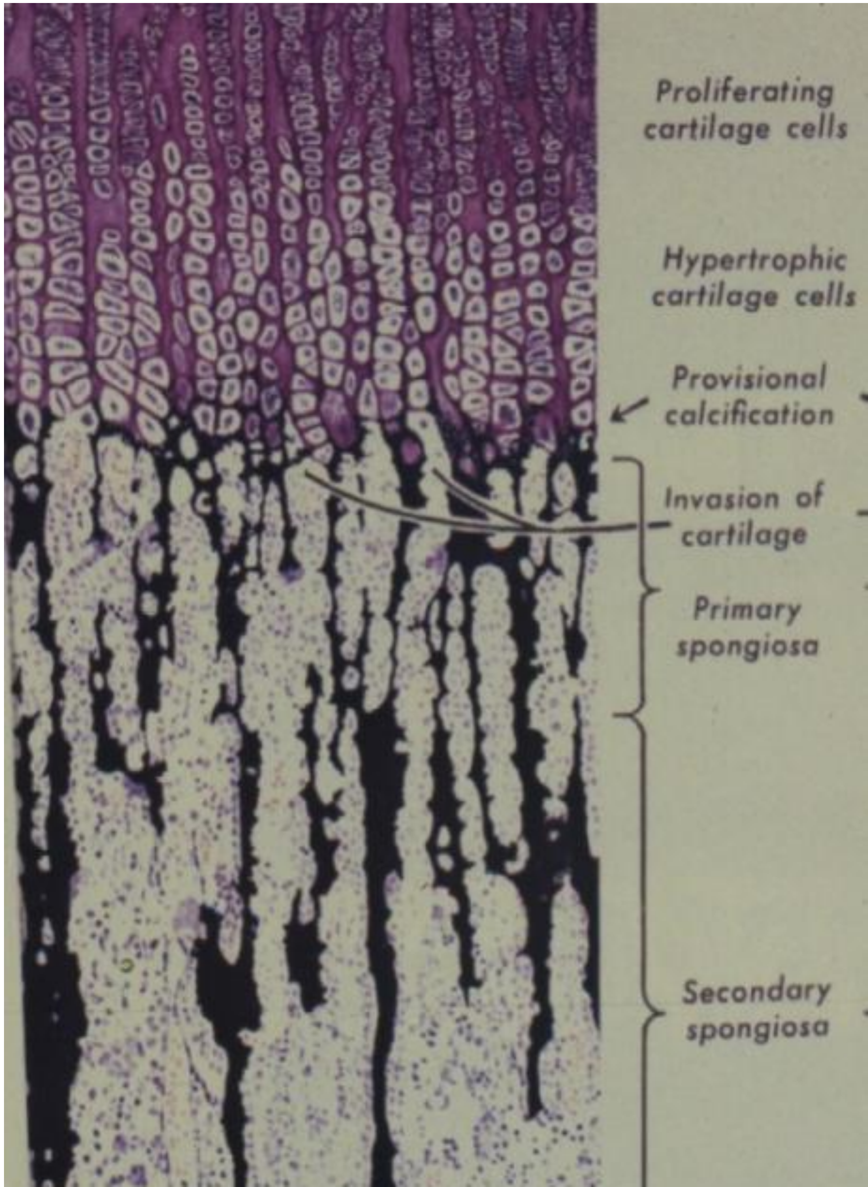
Osteoclasts in Howship's lacunae

Bone spicule

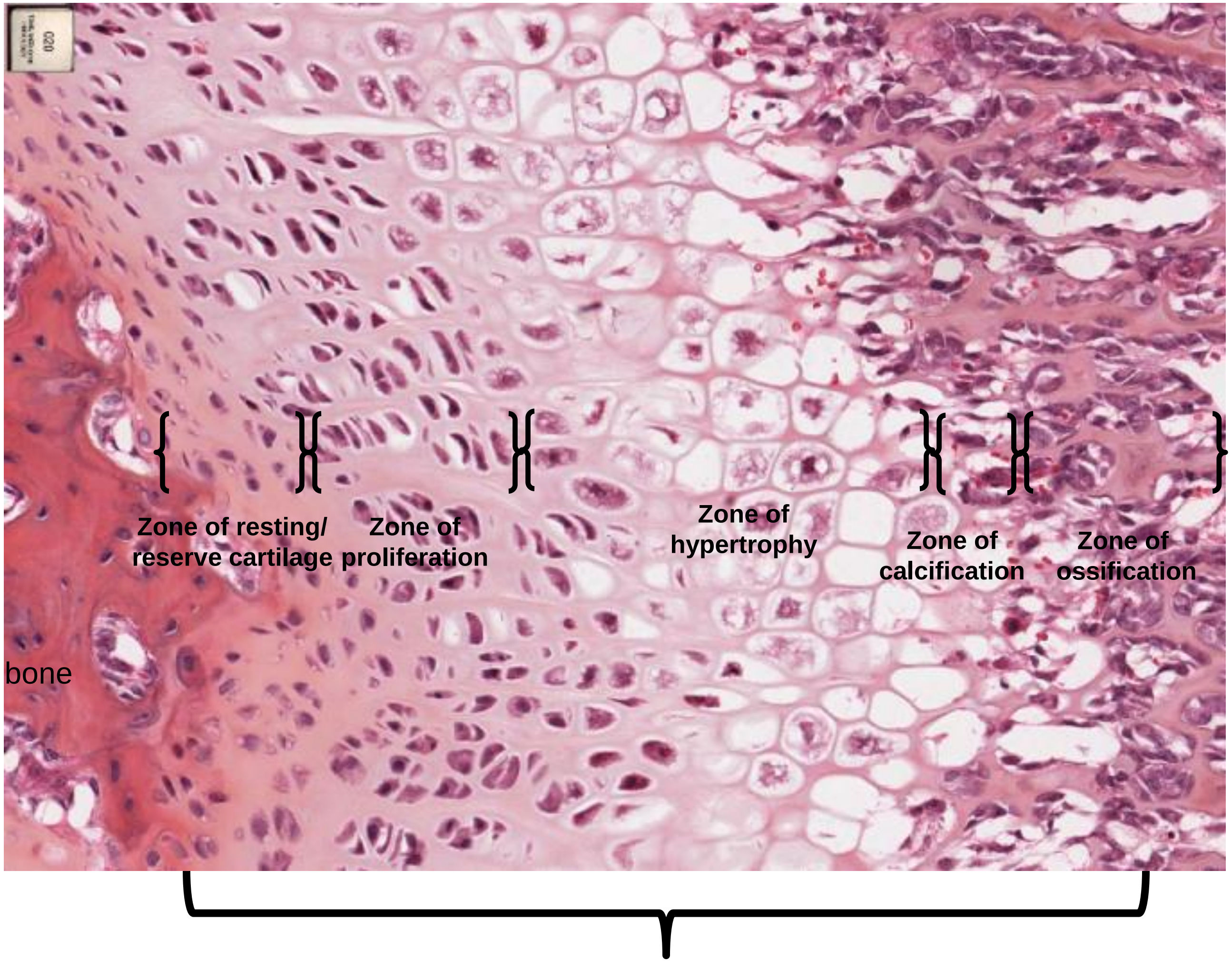
HISTOGENESIS OF BONE

ENDOCHONDRAL OSSIFICATION

- DEPOSITION OF BONE MATRIX ON A PREEXISTING CARTILAGE MATRIX
- CHARACTERISTIC OF LONG BONE FORMATION

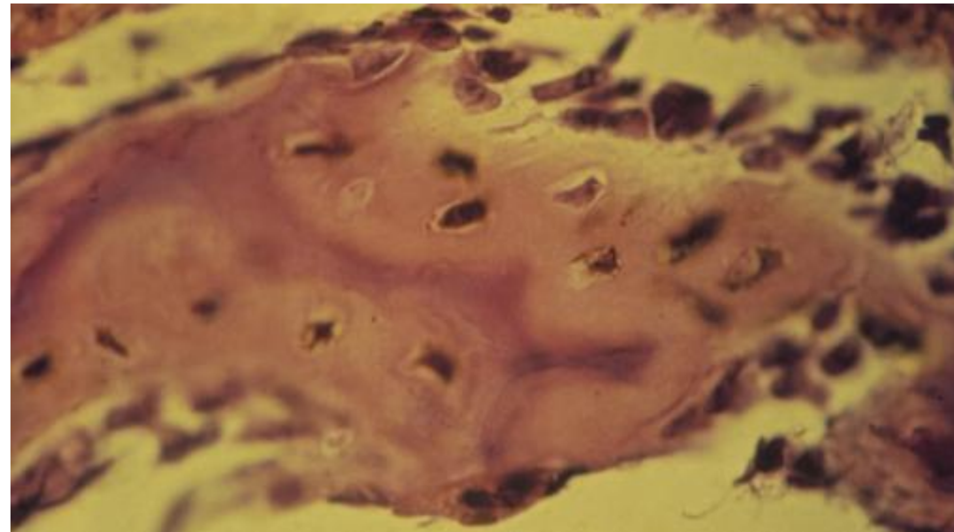


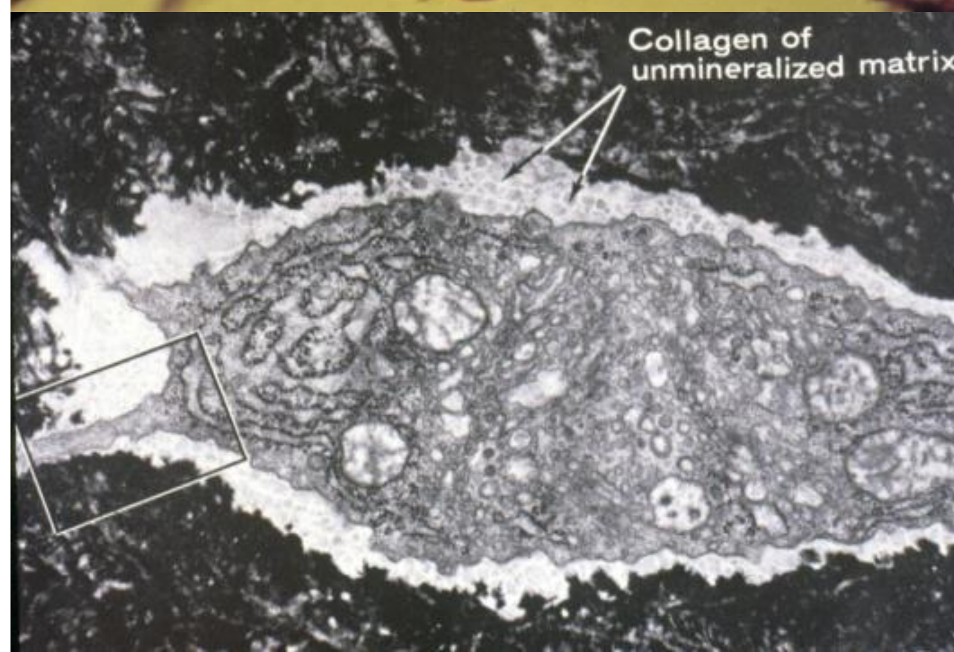
Slide 20: Long bone (longitudinal section; epiephysial plate)



EXTRACELLULAR MATRIX OF BONE

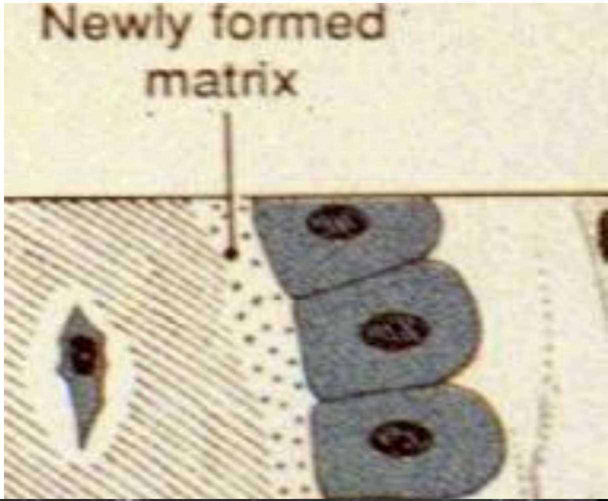
OSTEOID - MIXTURE OF TYPE I COLLAGEN AND COMPLEX MATRIX MATERIAL TO INCREASE THE AFFINITY AND SERVE AS NUCLEATION SITES FOR PARTICIPATION OF CALCIUM PHOSPHATE (HYDROXYAPATITE)



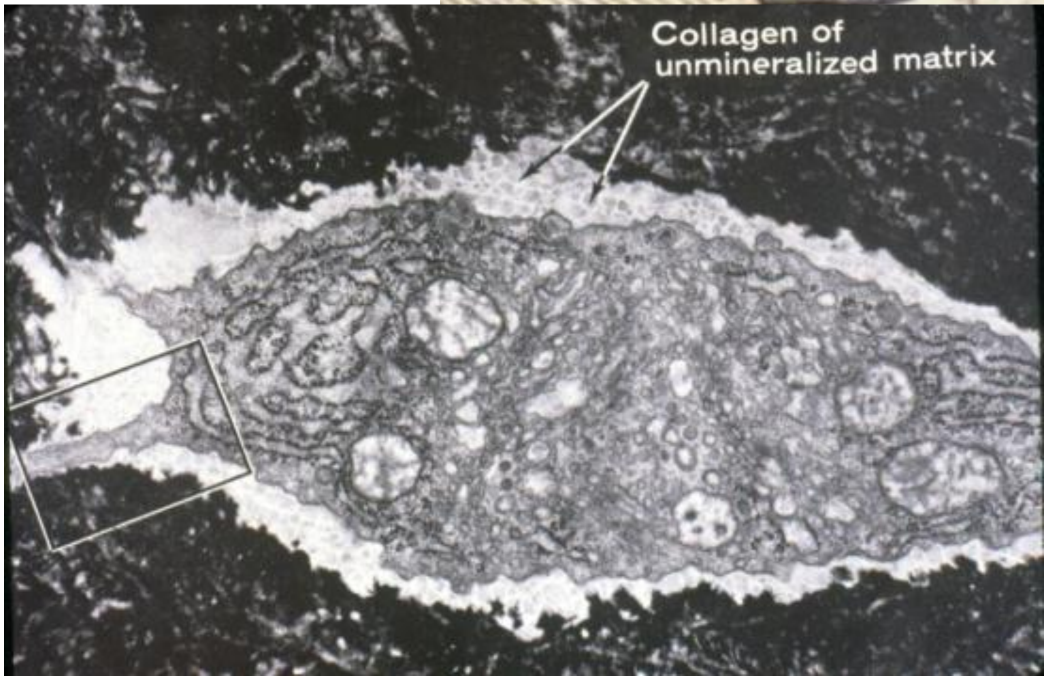


EXTRACELLULAR MATRIX OF BONE

SECRETED by **POLARIZED** OSTEOBLASTs

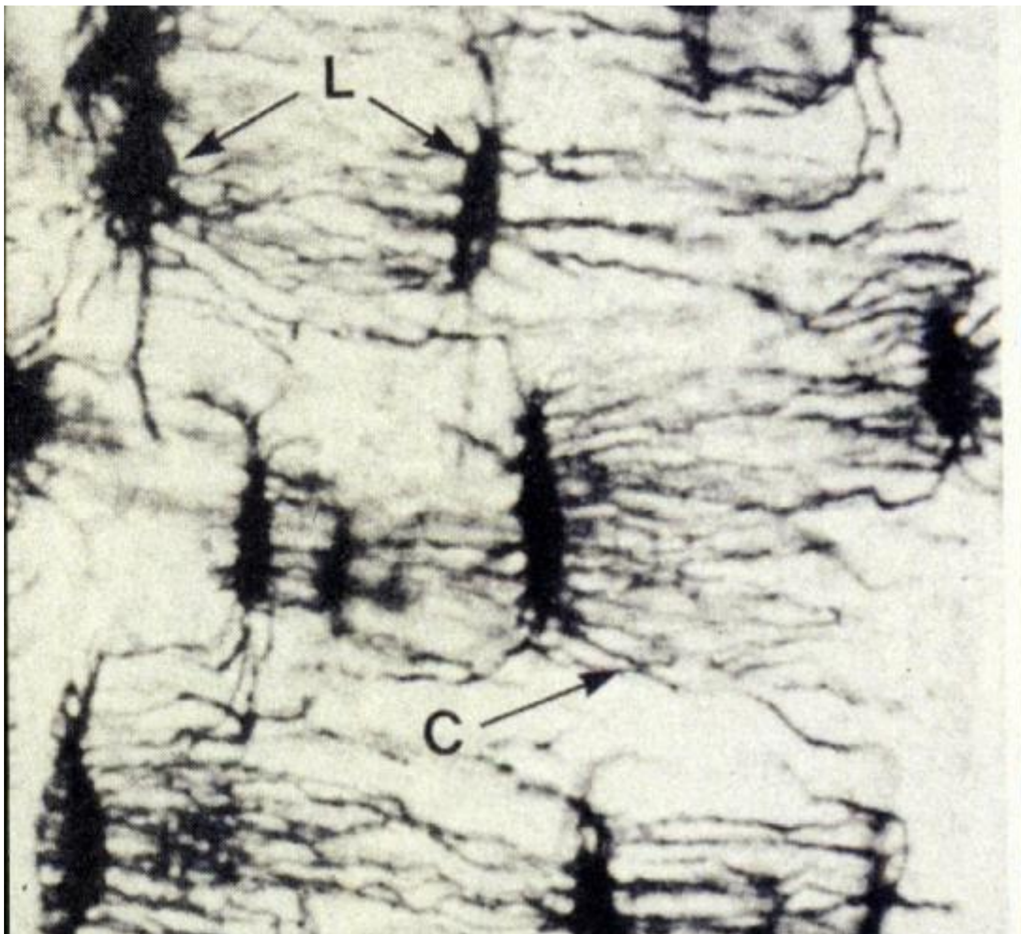


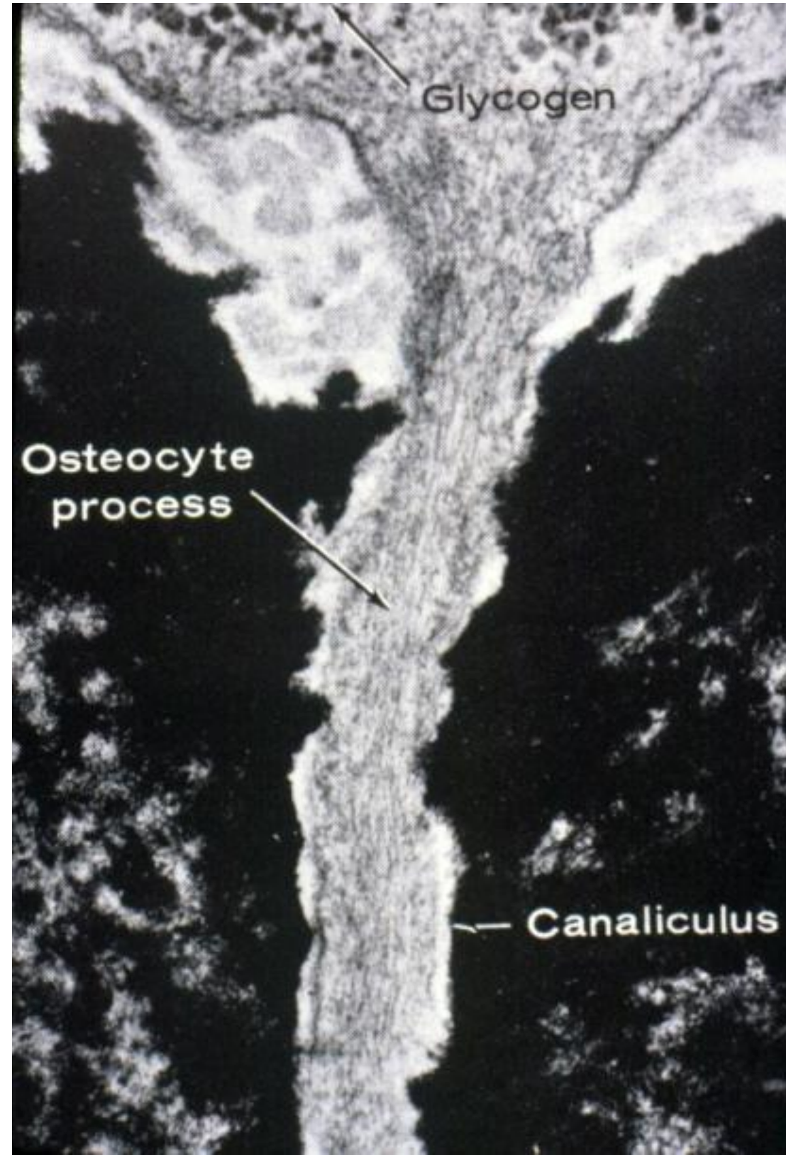
CALCIFICATION - ADDS FIRMNESS, BUT PREVENTS DIFFUSION THROUGH MATRIX MATERIAL



EXTRACELLULAR MATRIX OF BONE

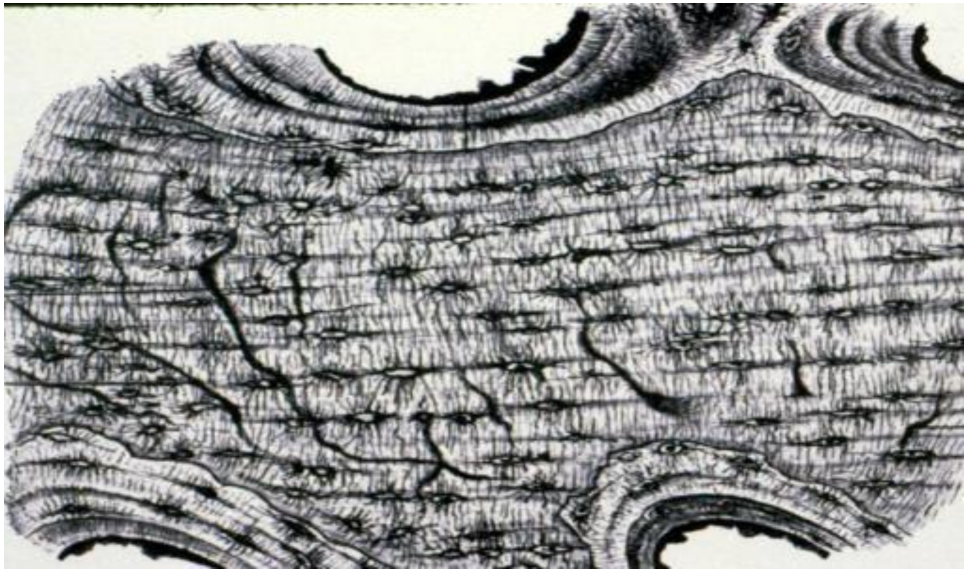
FORMS LACUNAE AND CANALICULI -

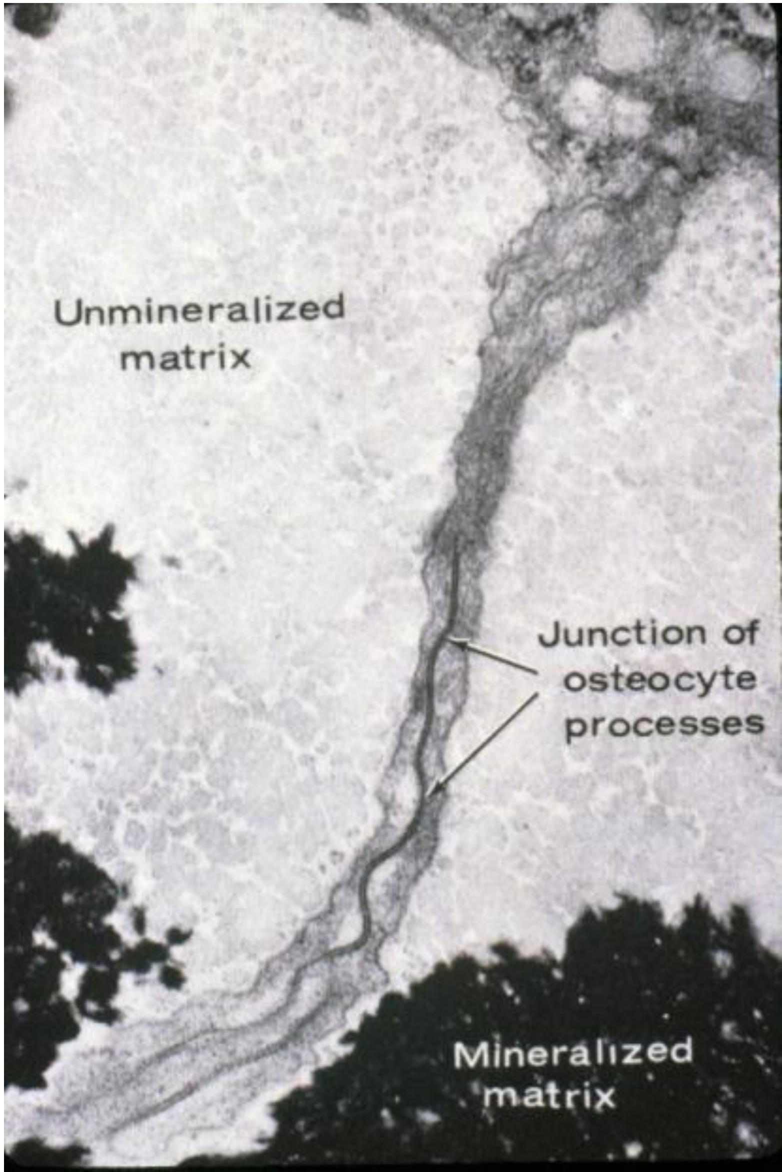




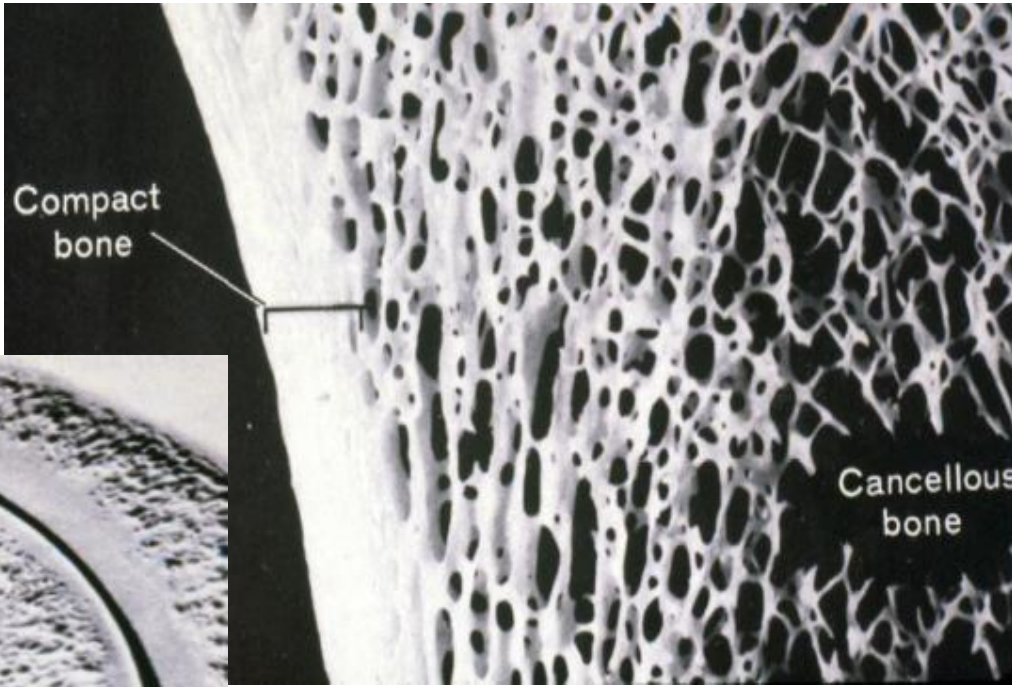
EXTRACELLULAR MATRIX OF BONE

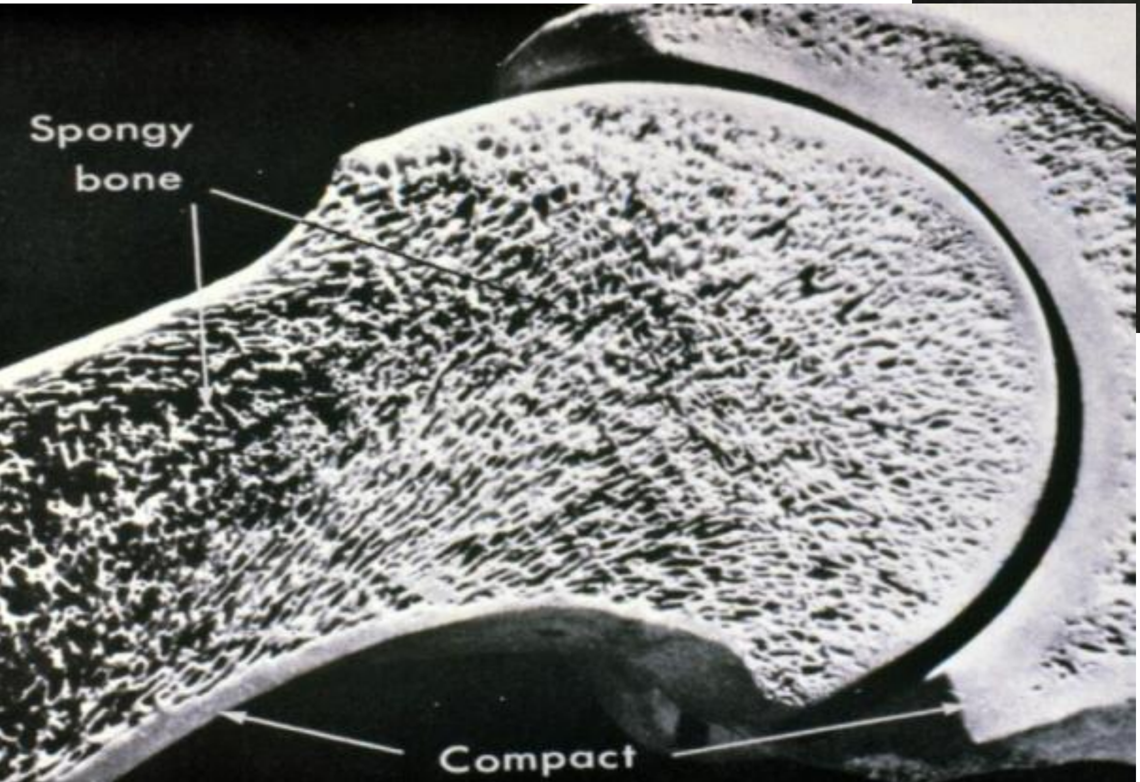
FORMS LACUNAE AND CANALICULI - CAUSES THE NEED FOR NUTRIENTS TO PAST THROUGH THE MANY GAP JUNCTIONS BETWEEN OSTEOCYTES VIA CANALICULI





COMPACT BONE - SHAFT AND OUTER SURFACE OF LONG BONES





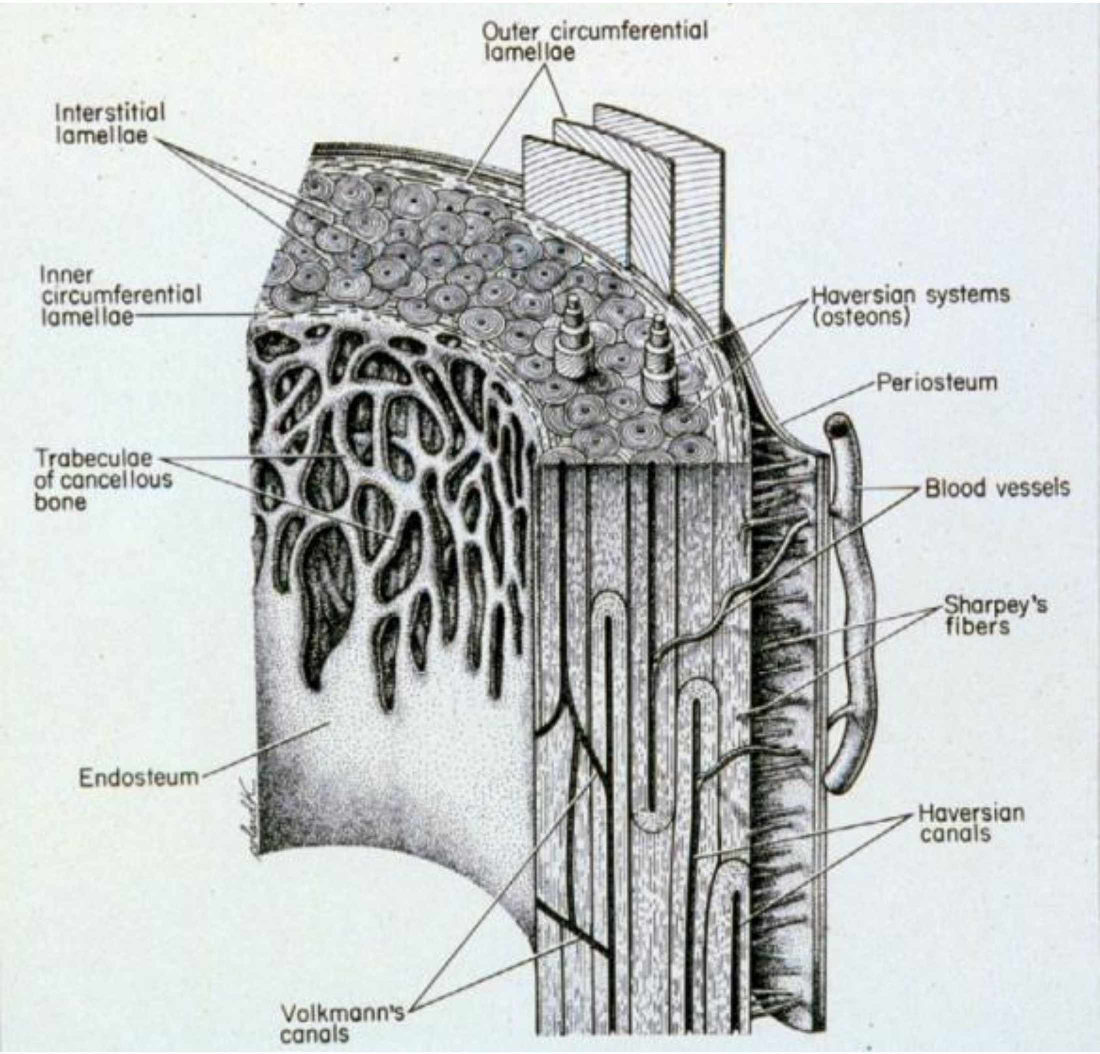
COMPACT BONE-SHAFT AND OUTER SURFACE OF LONG BONES

PERIOSTEUM

FIBROBLAST create

CIRCUMFERENTIAL LAMELLAE

- **APPOSITIONAL GROWTH**



COMPACT BONE-SHAFT AND OUTER SURFACE OF LONG BONES

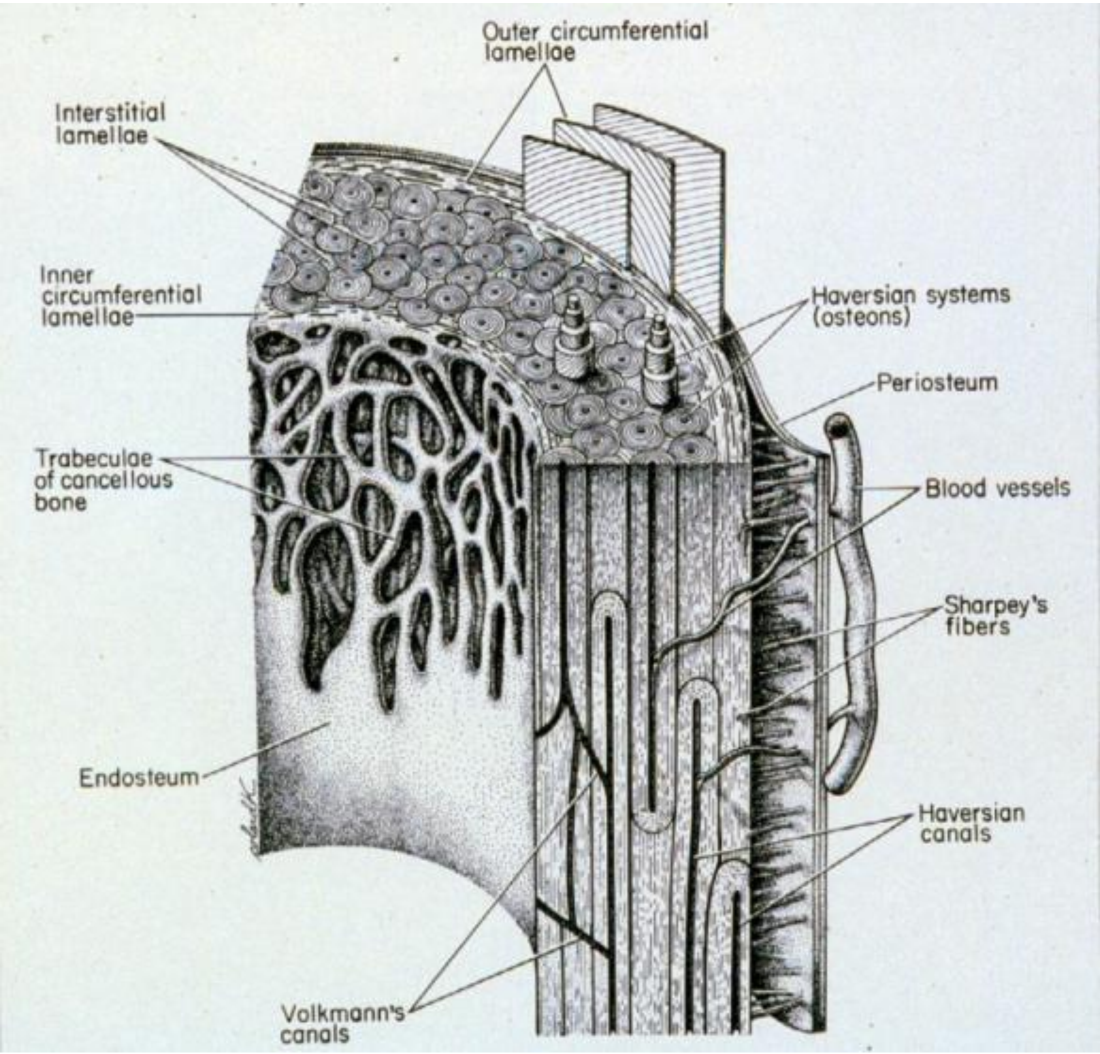
PERIOSTEUM

FIBROBLAST create

CIRCUMFERENTIAL LAMELLAE

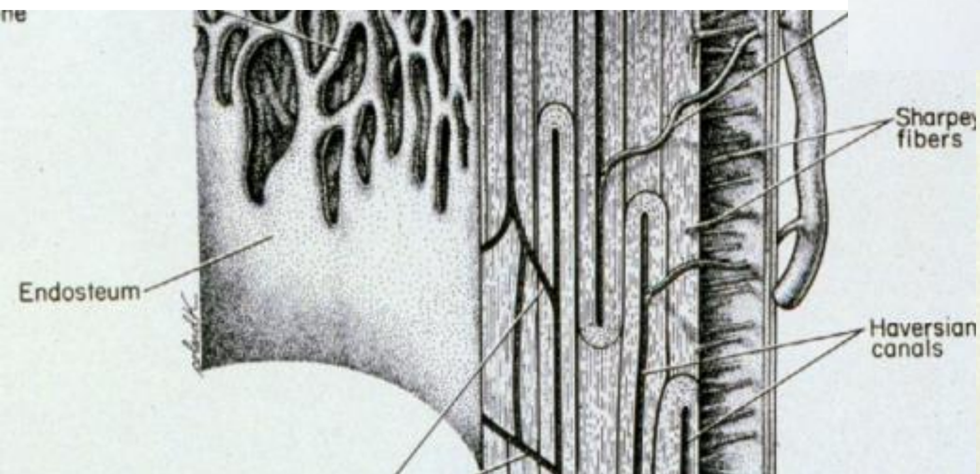
- **APPOSITIONAL GROWTH**

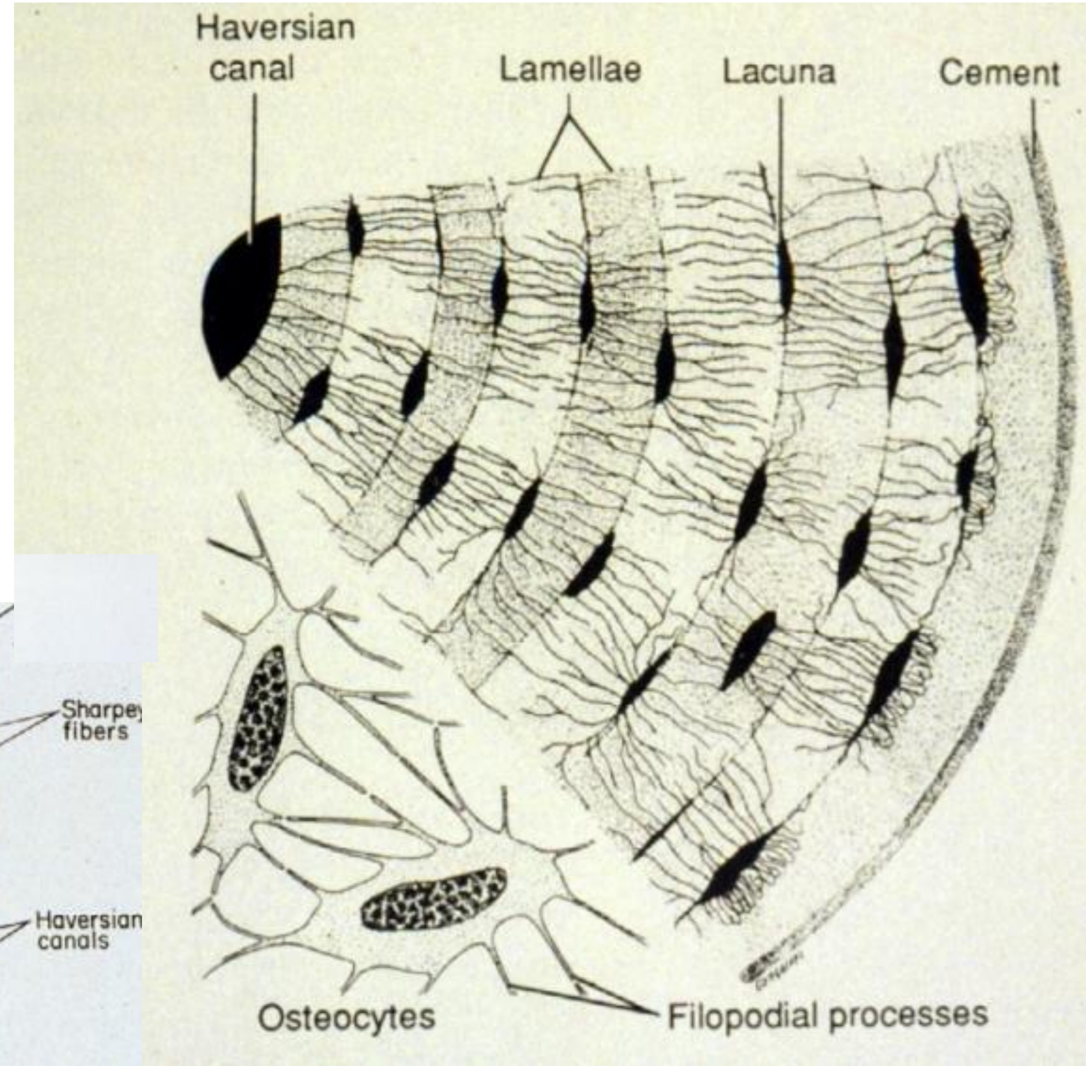
(NOTE: BONE HAS NO INTERSITIAL GROWTH AS DOES CARTILAGE)



COMPACT BONE-SHAFT AND OUTER SURFACE OF LONG BONES

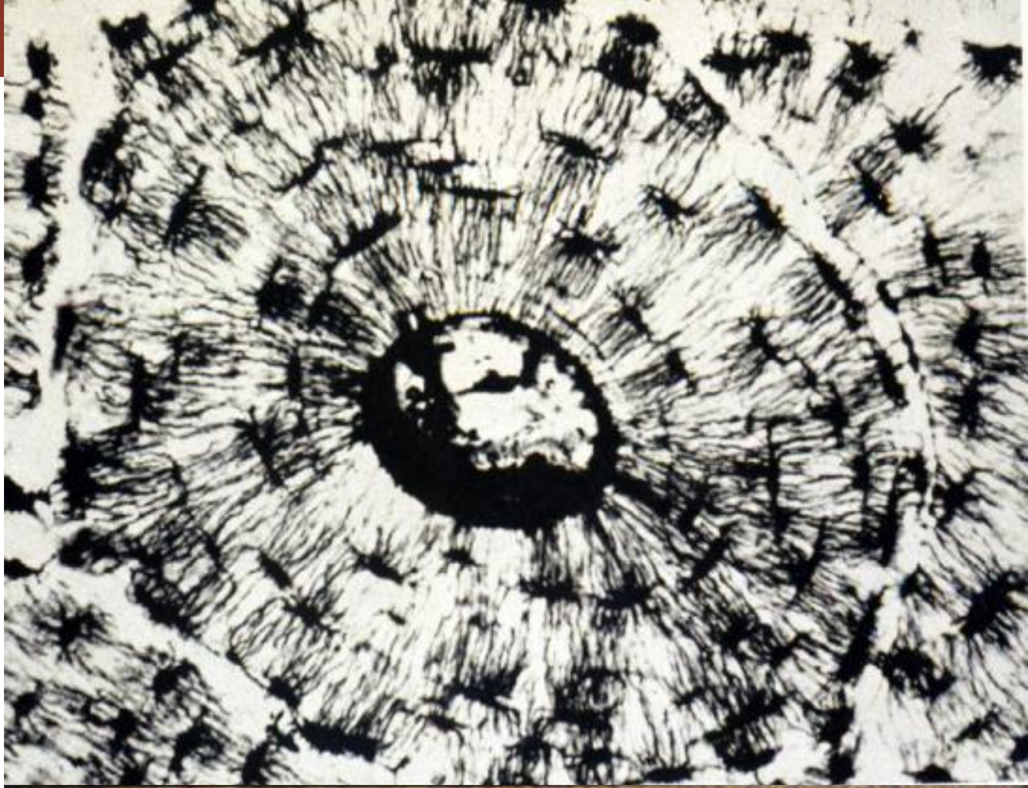
ENDOSTEUM - INSIDE COMPACT BONE, SURFACES OF SPONGY BONE, INSIDE HAVERSIAN SYSTEMS

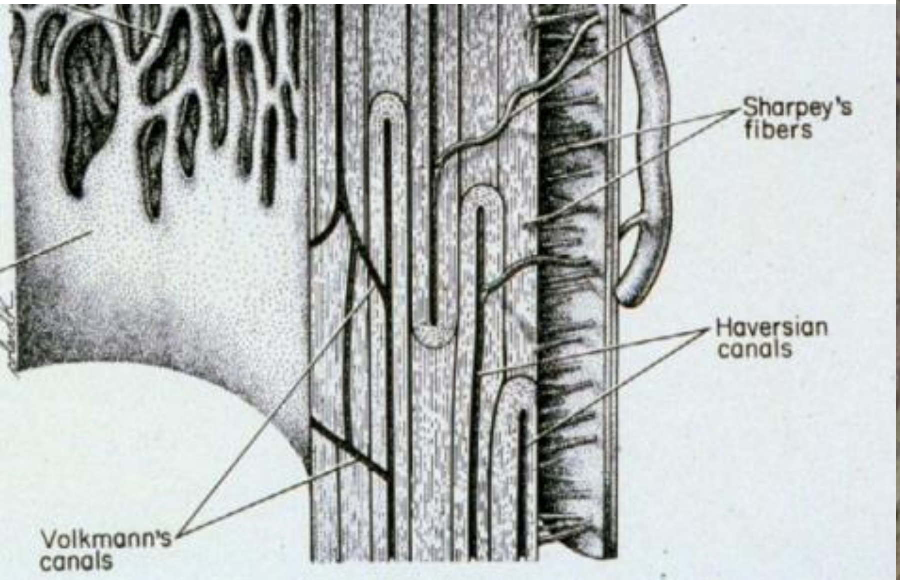


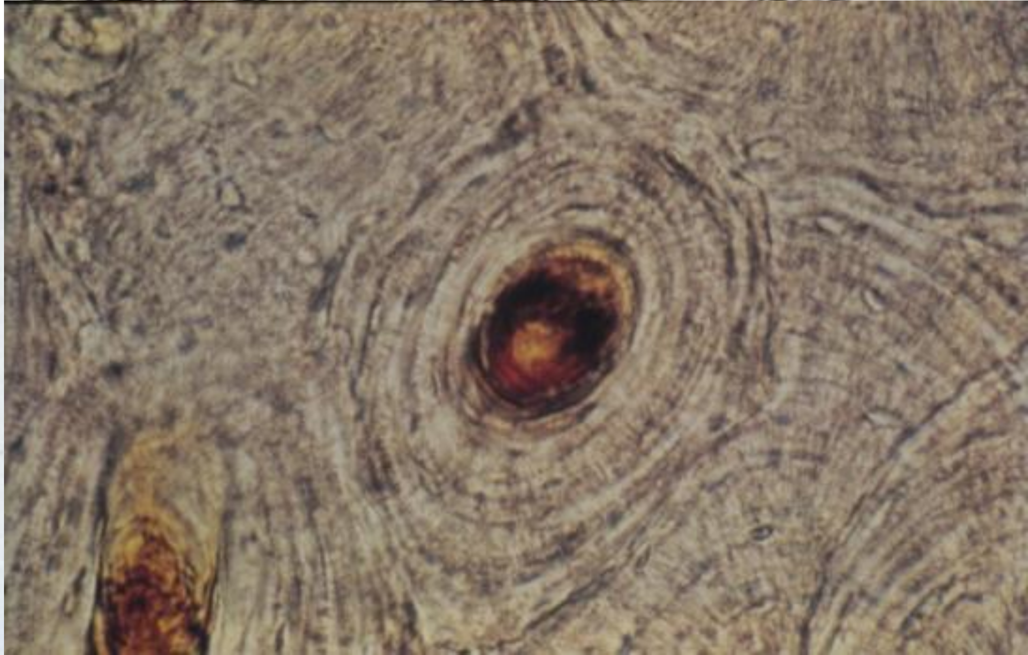


COMPACT BONE

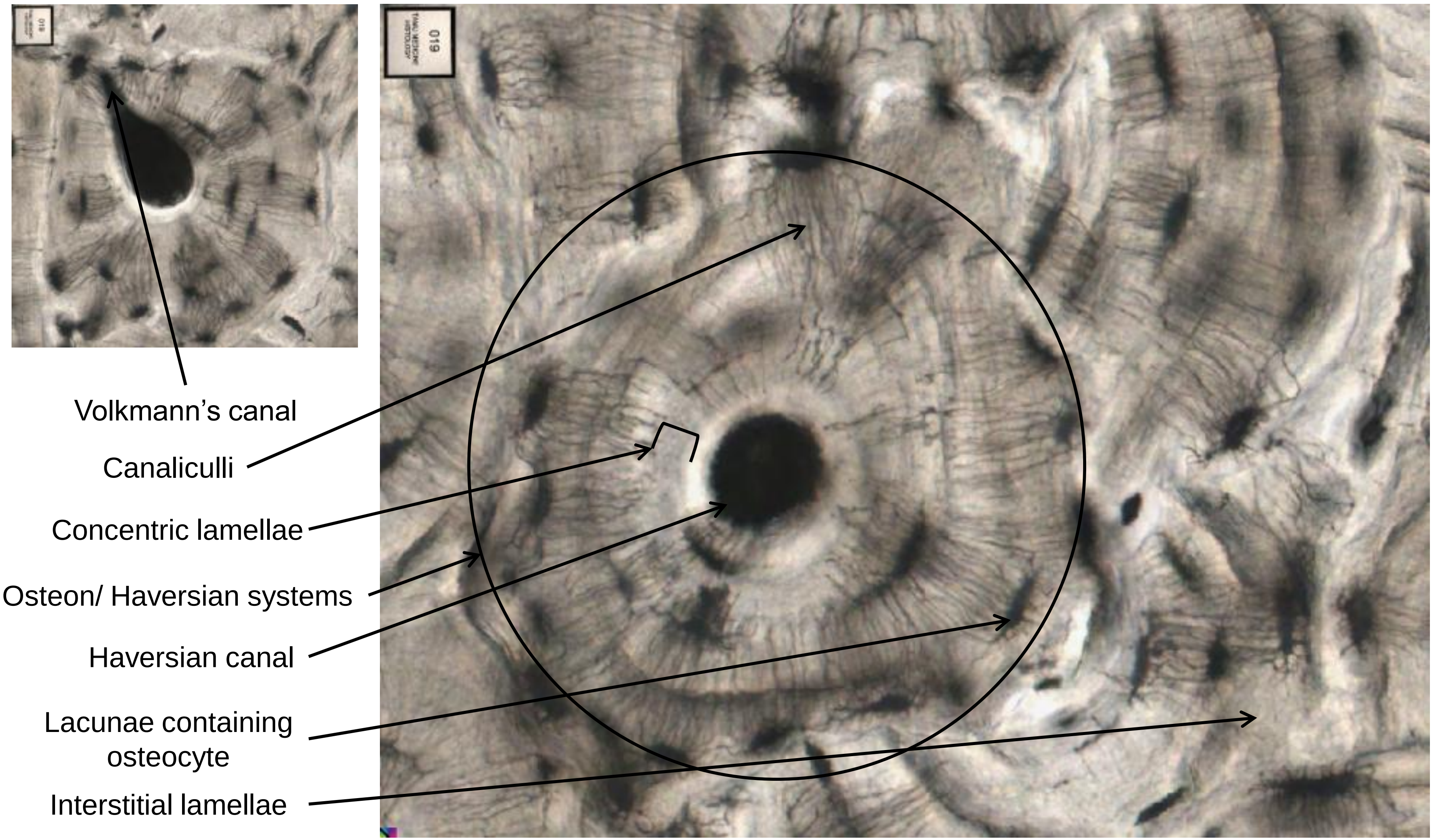
HAVERSIAN SYSTEMS - LAMELLAE OF BONE AROUND HAVERSIAN CANAL LINKED BY VOLKMANN'S CANAL





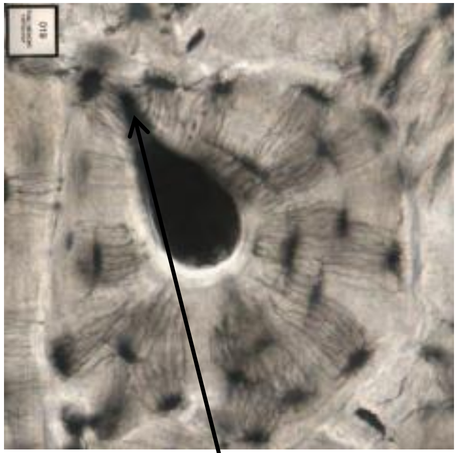


Slide 19: Compact bone (ground cross section)

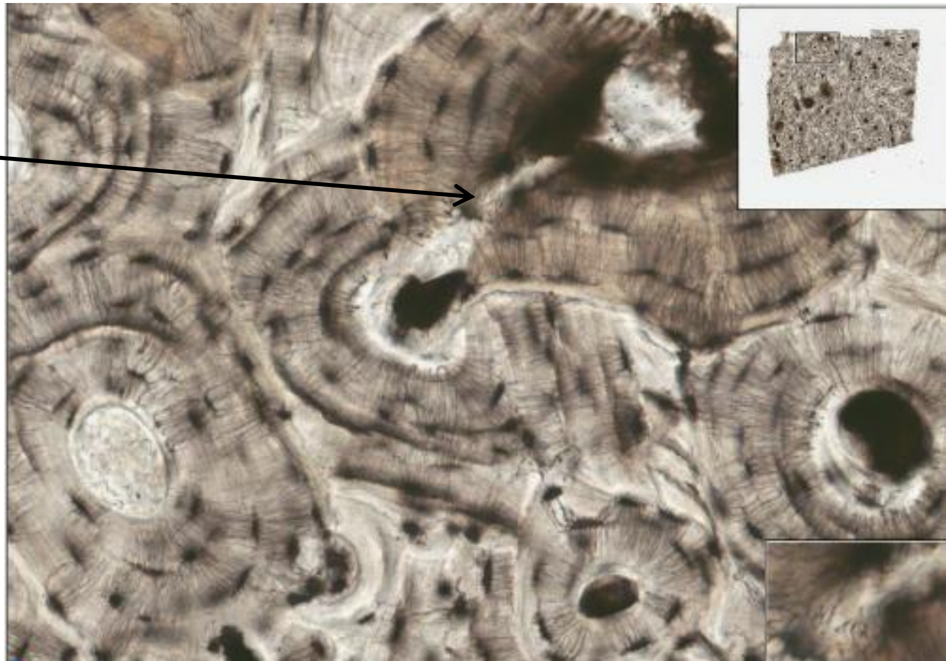


Slide 19: Compact bone (ground cross section)

Connecting adjacent osteons, perforating (Volkmann's) canals provide communication for osteons and another source of microvasculature for the central canals of osteons (nutrients, blood, etc.).



Volkmann's canal



Clinical Correlation

An elderly patient is diagnosed with osteoporosis.

Describe the cells involved that produce this imbalance in bone production and resorption.

Which of these cell types would be more active and which would be less active?

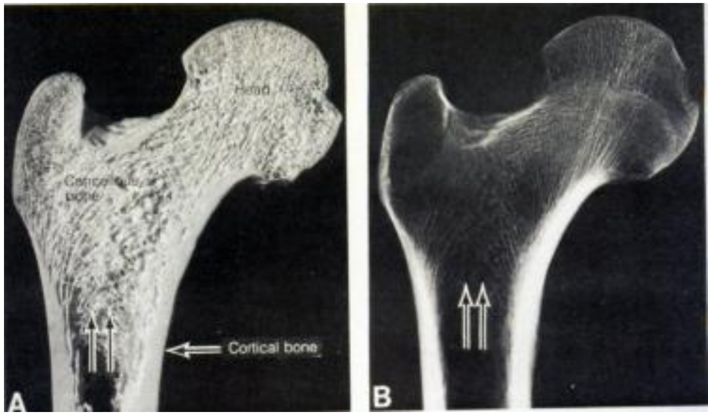
What is the difference between osteoporosis and osteomalacia?
p143&151

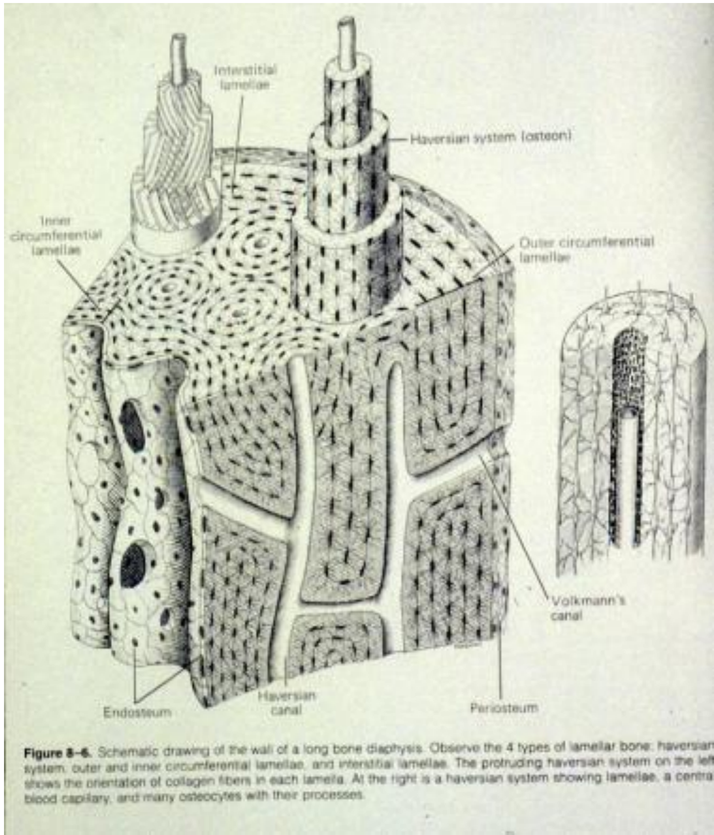
Image adapted from www.webmd.com

FUNCTIONS OF BONE

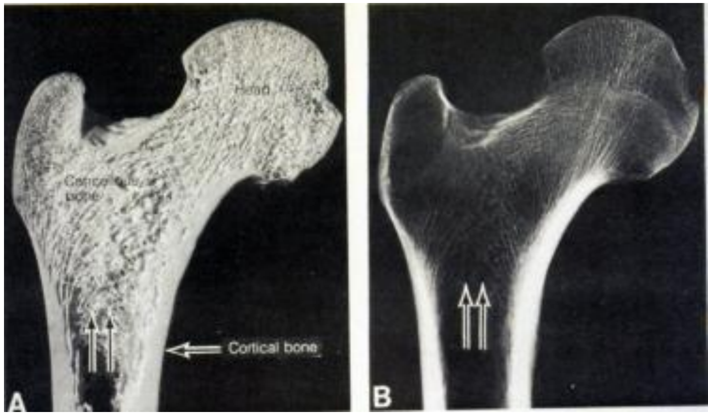
CALCIUM REGULATION

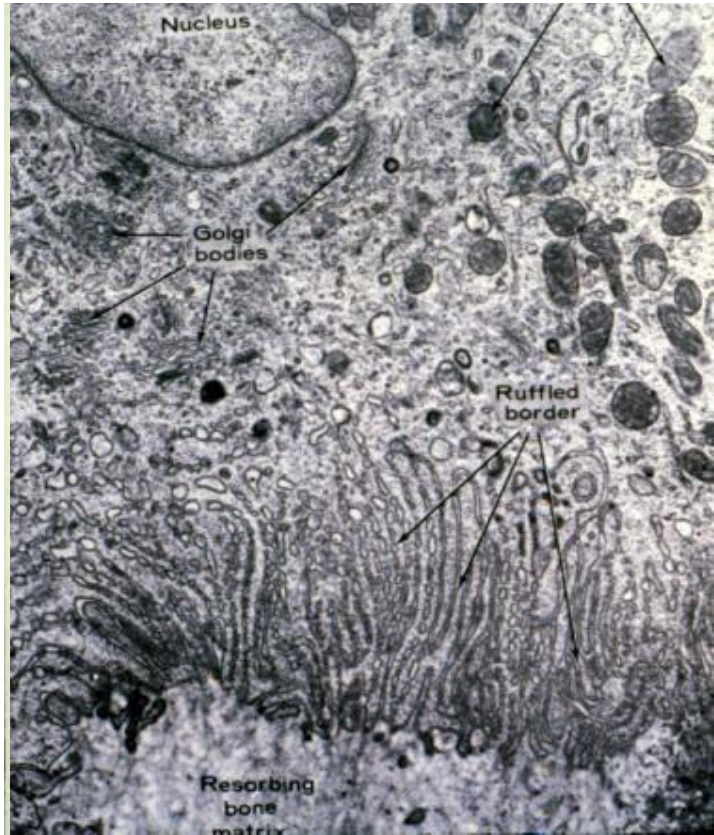
Parathroid hormone (stimulates osteoclast production)





FUNCTIONS OF BONE





CALCIUM REGULATION

Parathroid hormone (stimulates osteoclast production)

Calcitonin (removes osteoclast's ruffled boarder which PREVENTS RESORPTION

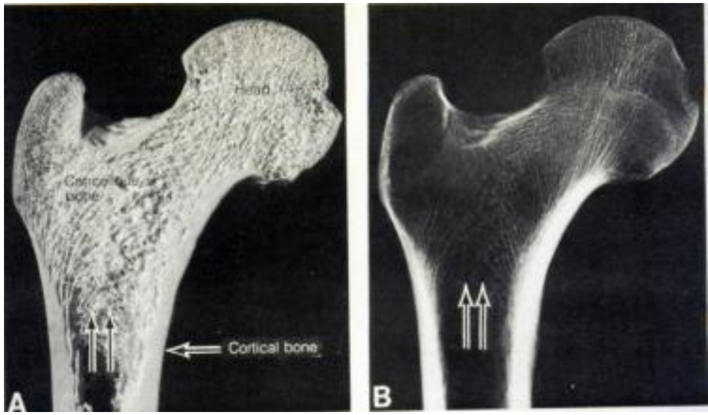
FUNCTIONS OF BONE

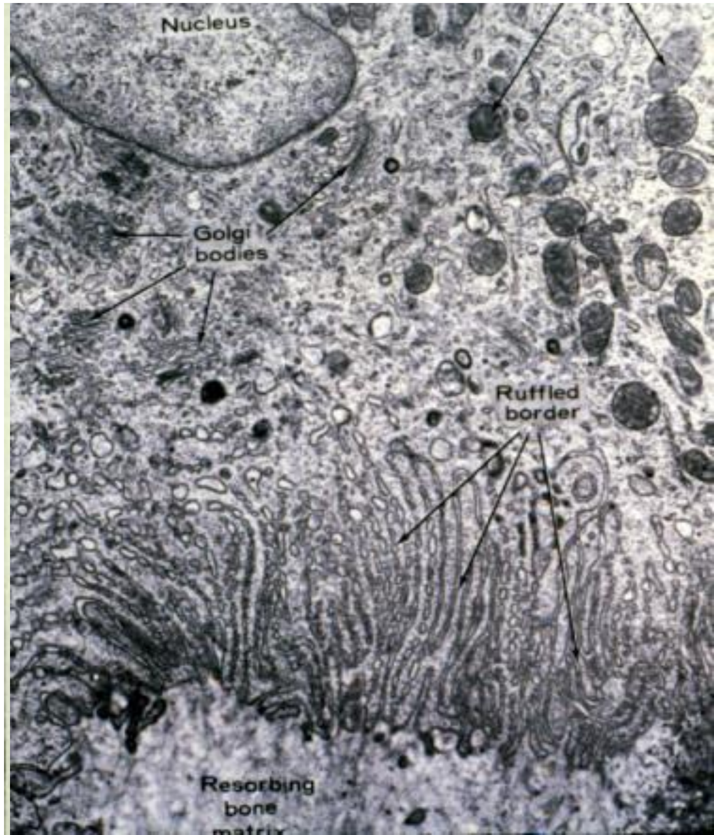
CALCIUM REGULATION

Parathroid hormone (stimulates osteoclast production)

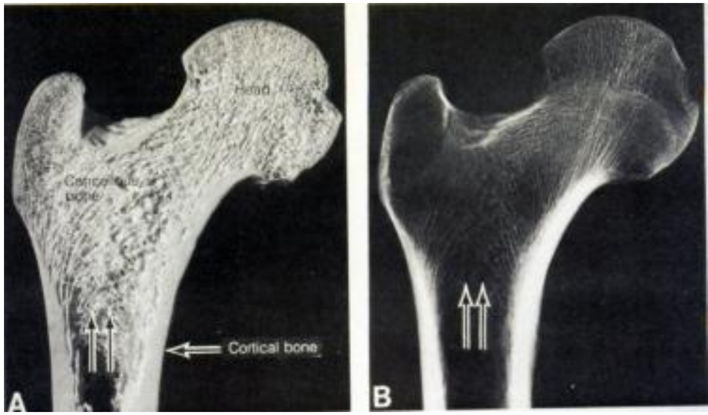
Calcitonin (removes osteoclast’s ruffled boarder which PREVENTS RESORPTION

Osteoporosis is an imbalance in skeletal turnover so that bone resorption exceeds bone formation. This leads to calcium loss for bones and reduced bone mineral density.





FUNCTIONS OF BONE



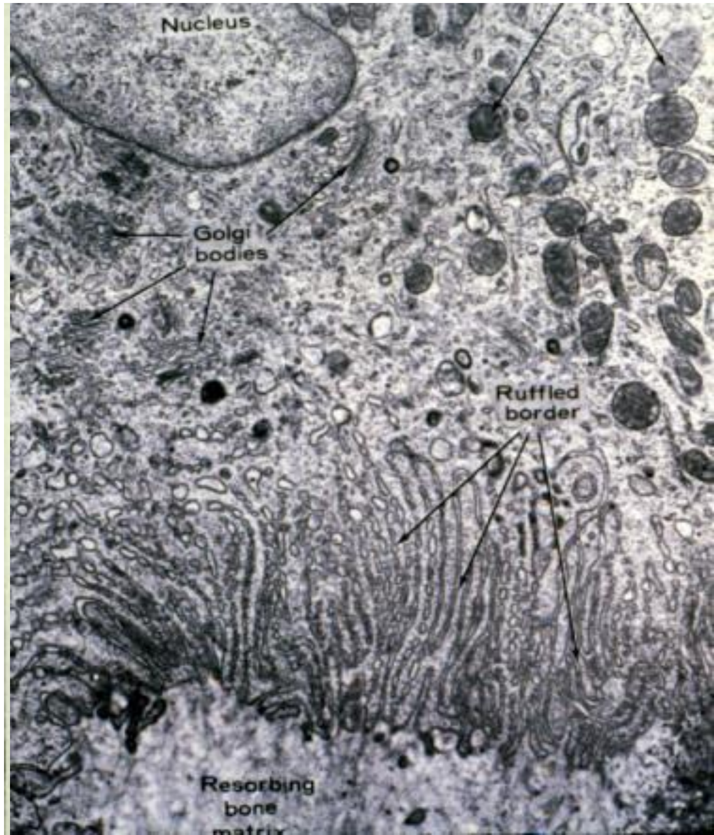
CALCIUM REGULATION

Parathroid hormone (stimulates osteoclast production)

Calcitonin (removes osteoclast's ruffled boarder which PREVENTS RESORPTION

Osteoporosis is an imbalance in skeletal turnover so that bone resorption exceeds bone formation. This leads to calcium loss for bones and reduced bone mineral density.

Osteomalacia is characterized by deficient calcification of recently formed bone and partial decalcification of already calcified matrix.



Many illustrations in these VIBS Histology YouTube videos were modified from the following books and sources: Many thanks to original sources!

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- Douglas P. Dohrman and TAMHSC Faculty 2012 Structure and Function of Human Organ Systems, Histology Laboratory Manual - Slide selections were largely based on this manual for first year medical students at TAMHSC