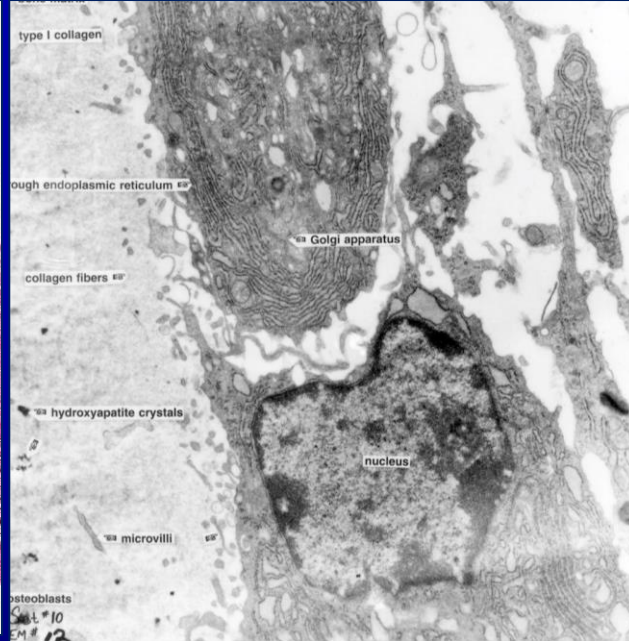
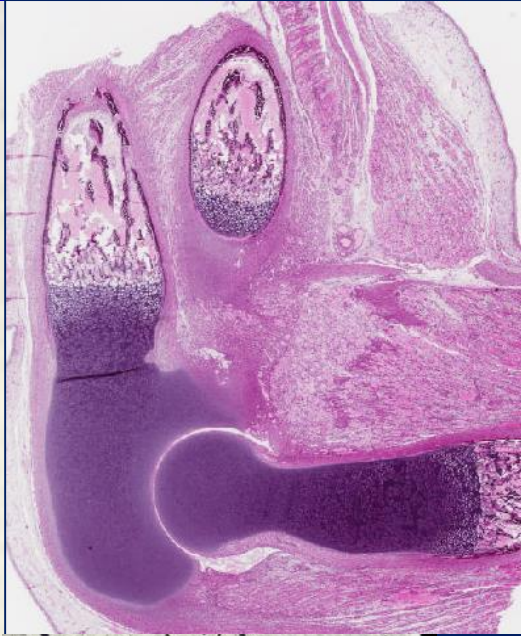
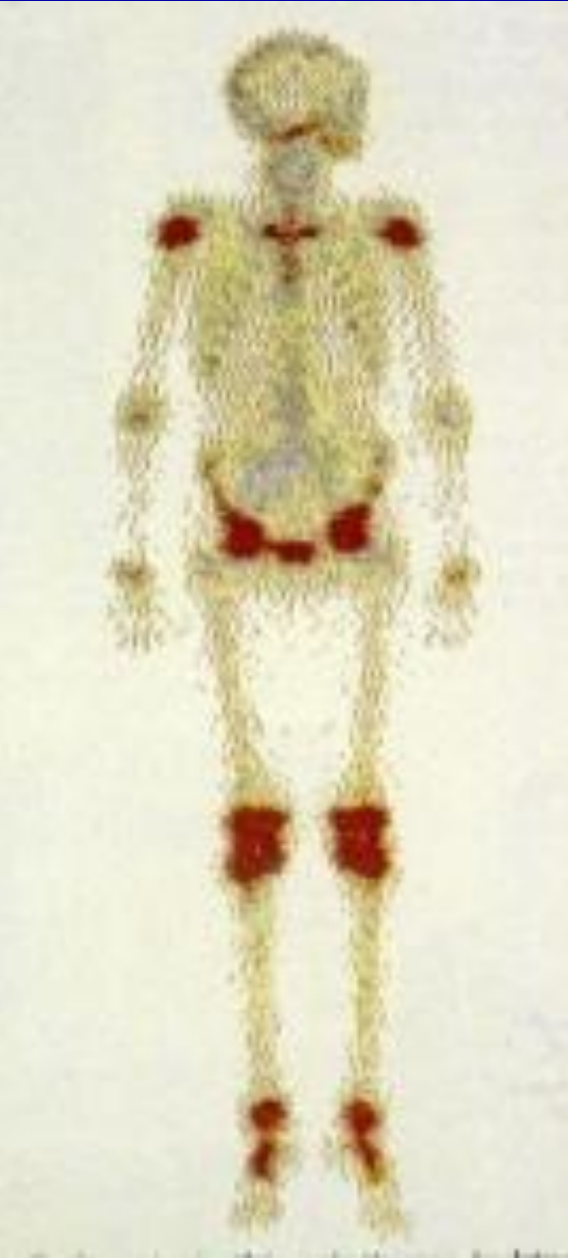
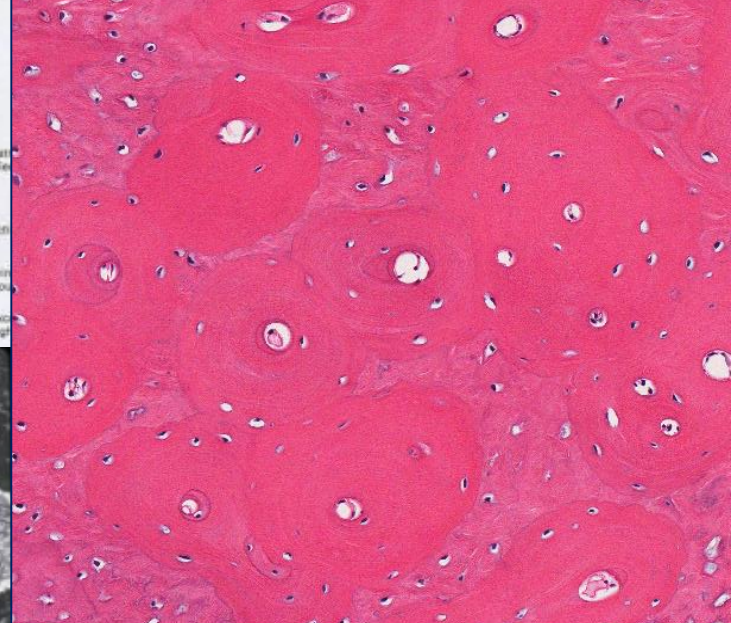
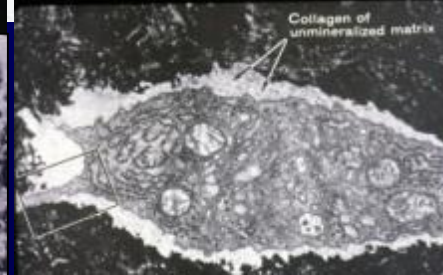
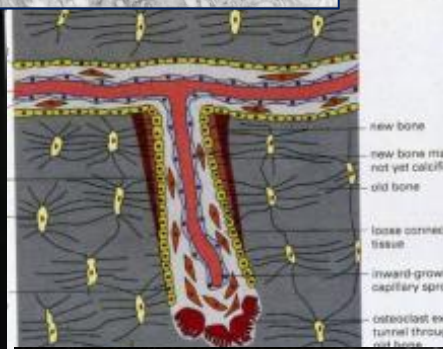
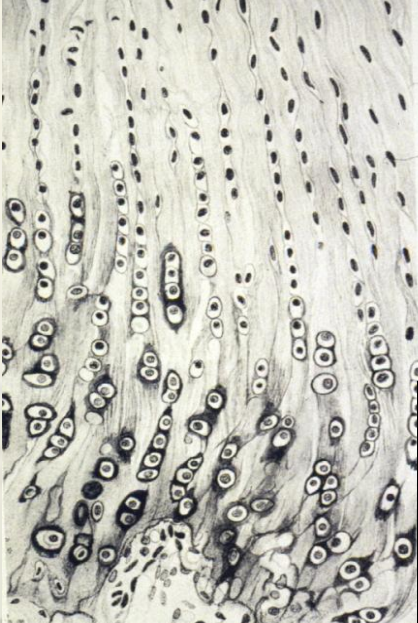


Skeletal Connective Tissue



Undergraduate – Graduate
Histology Lecture Series

Larry Johnson, Professor
Veterinary Integrative Biosciences
Texas A&M University
College Station, TX 77843



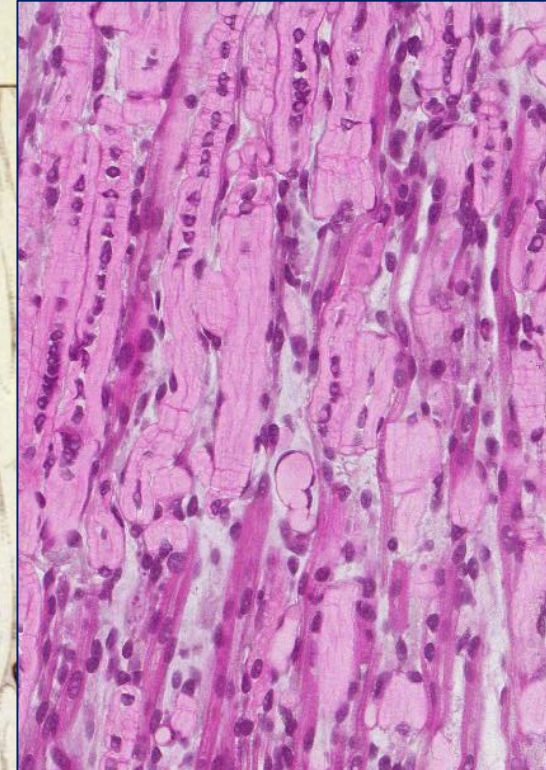
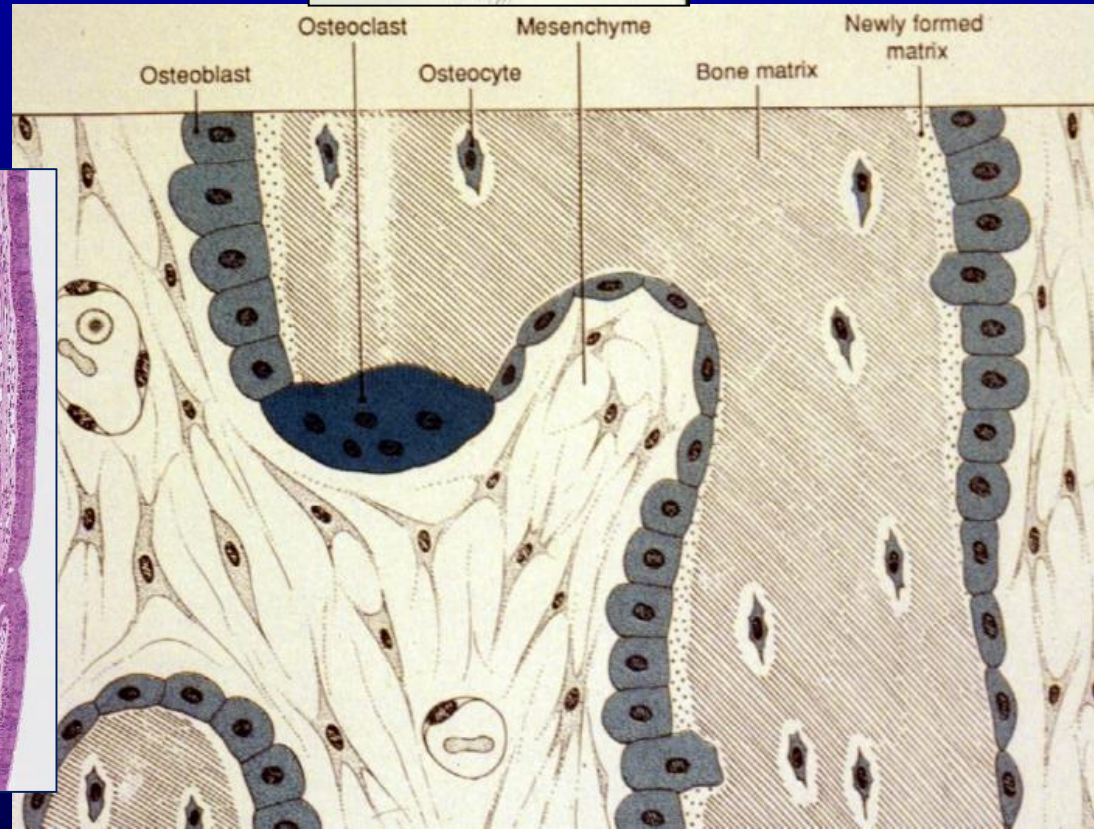
Objectives: cartilage and bone

General organization

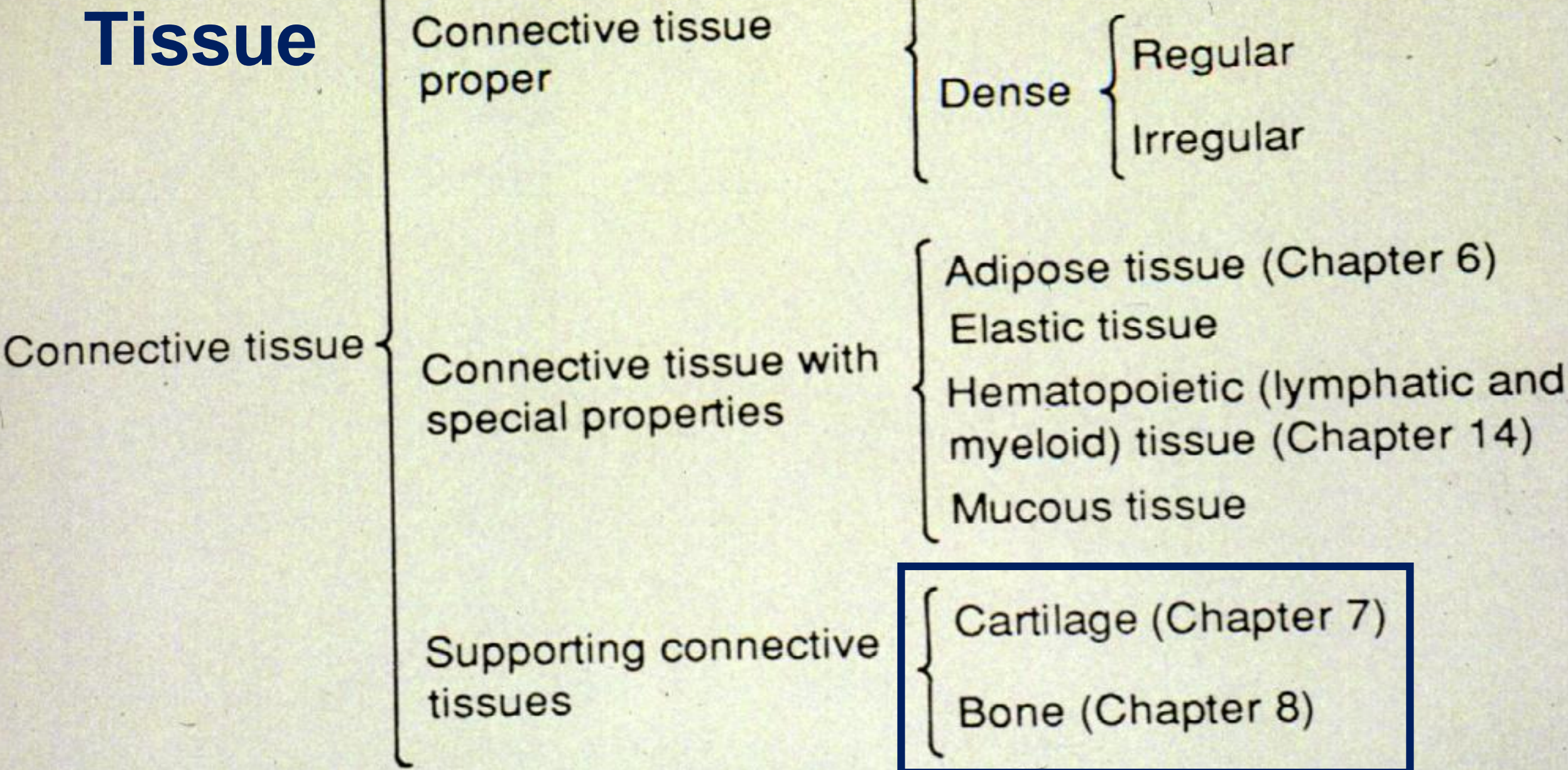
Mechanism of growth

Mineral and organic constituents

Characteristics of cells



Connective Tissue



Connective tissue proper

- Loose (areolar)
- Dense
 - Regular
 - Irregular

Connective tissue

Connective tissue with special properties

- Adipose tissue (Chapter 6)
- Elastic tissue
- Hematopoietic (lymphatic and myeloid) tissue (Chapter 14)
- Mucous tissue

Supporting connective tissues

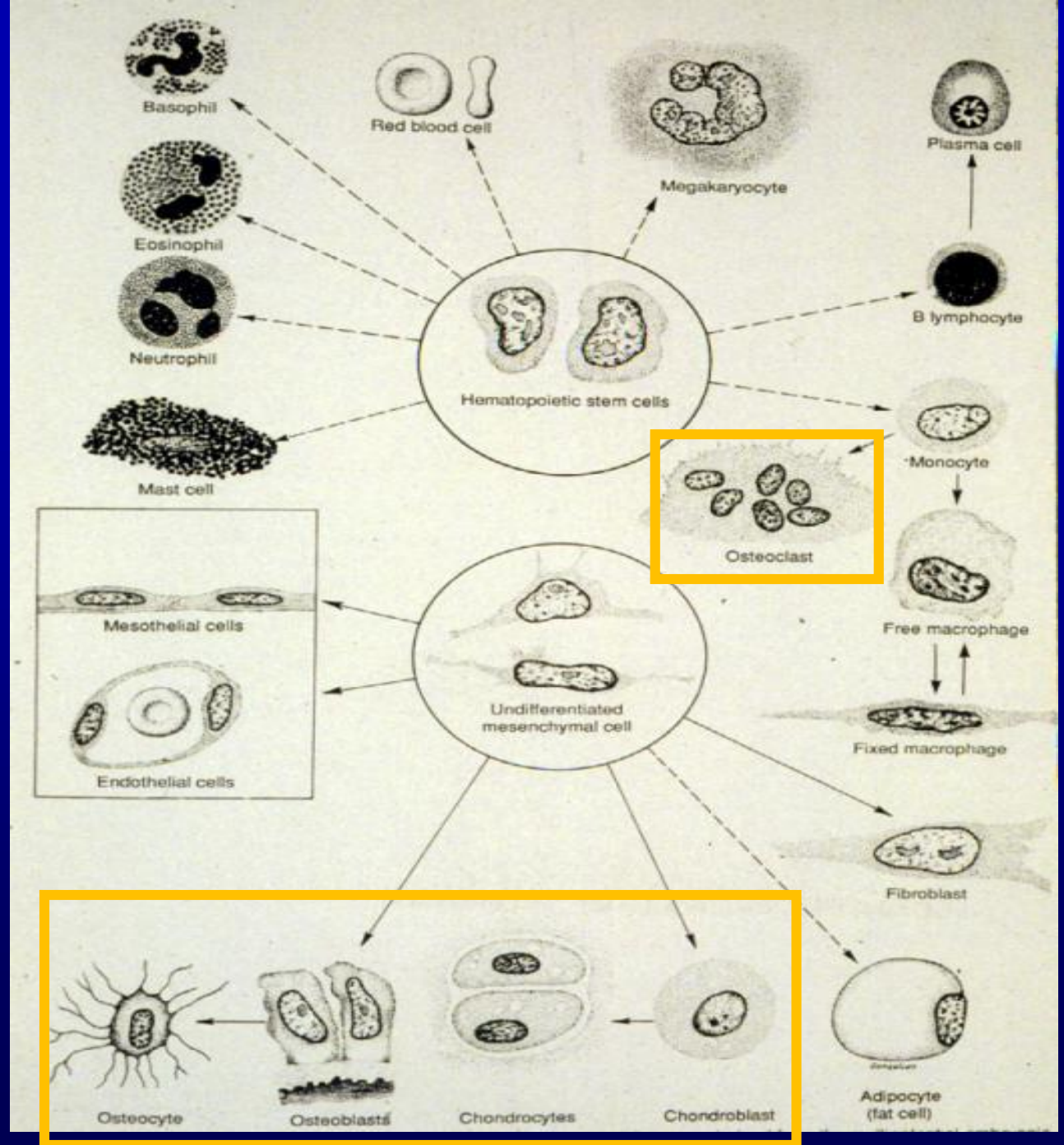
- Cartilage (Chapter 7)
- Bone (Chapter 8)

Cells of CT

Fibroblasts
Mesenchymal cells and RBC
Adipose cells
Macrophage
Plasma cells
Mast cells and WBC

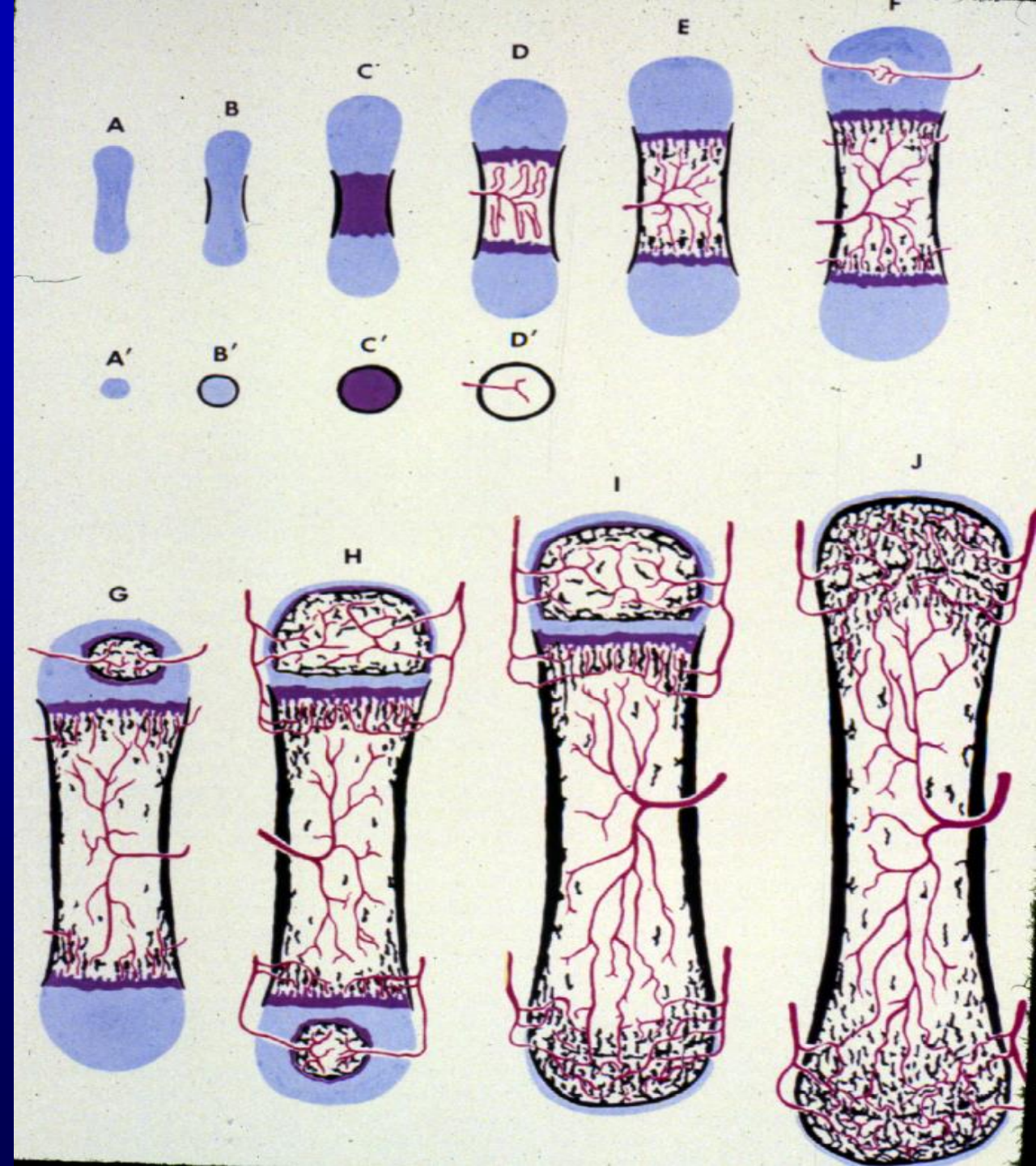
Chondroblasts
Chondrocytes

Osteoblasts
Osteocytes
Osteoclasts



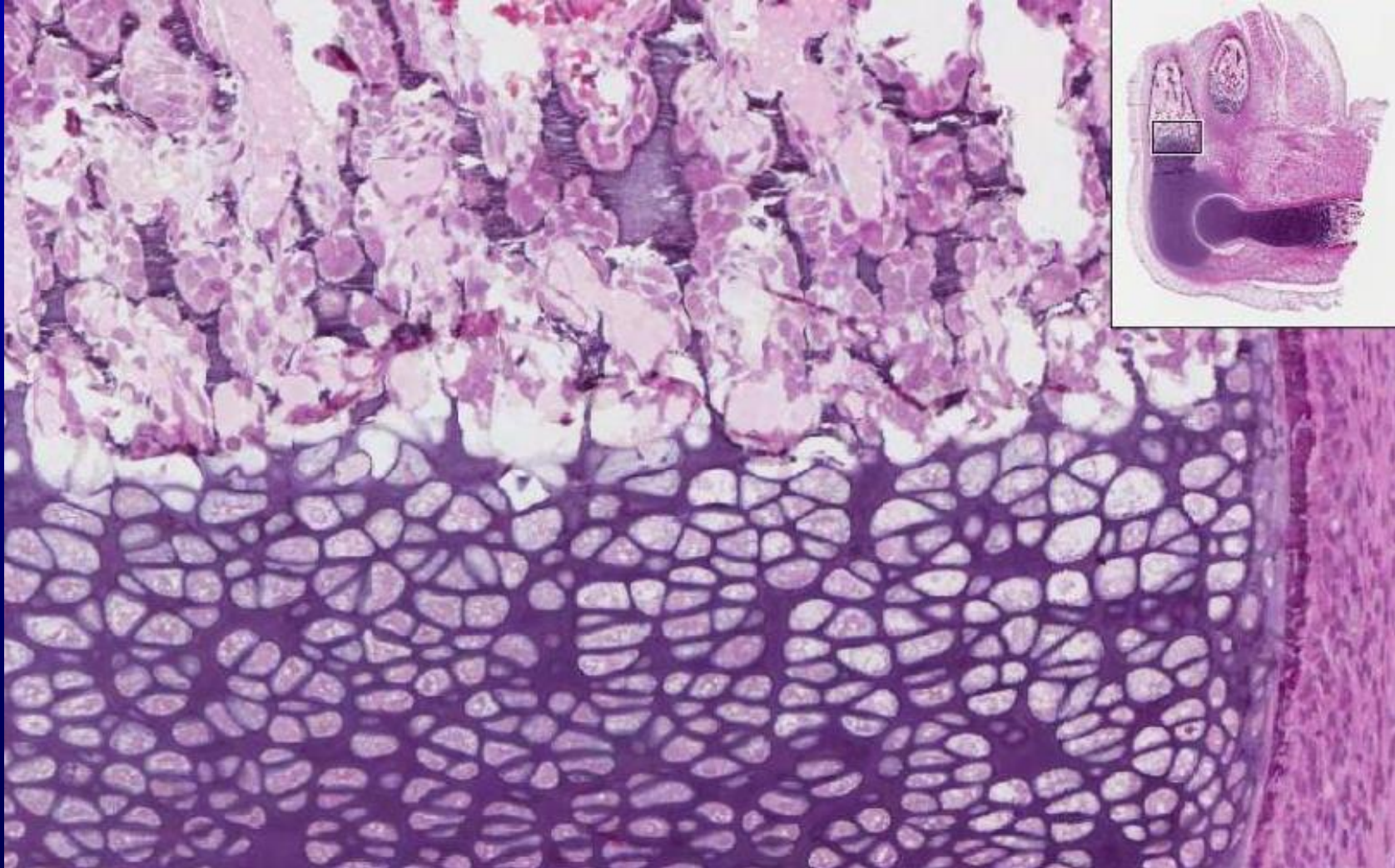
Functions of Cartilage

Evolutionary -
embryonic model
for bones



Functions of Cartilage

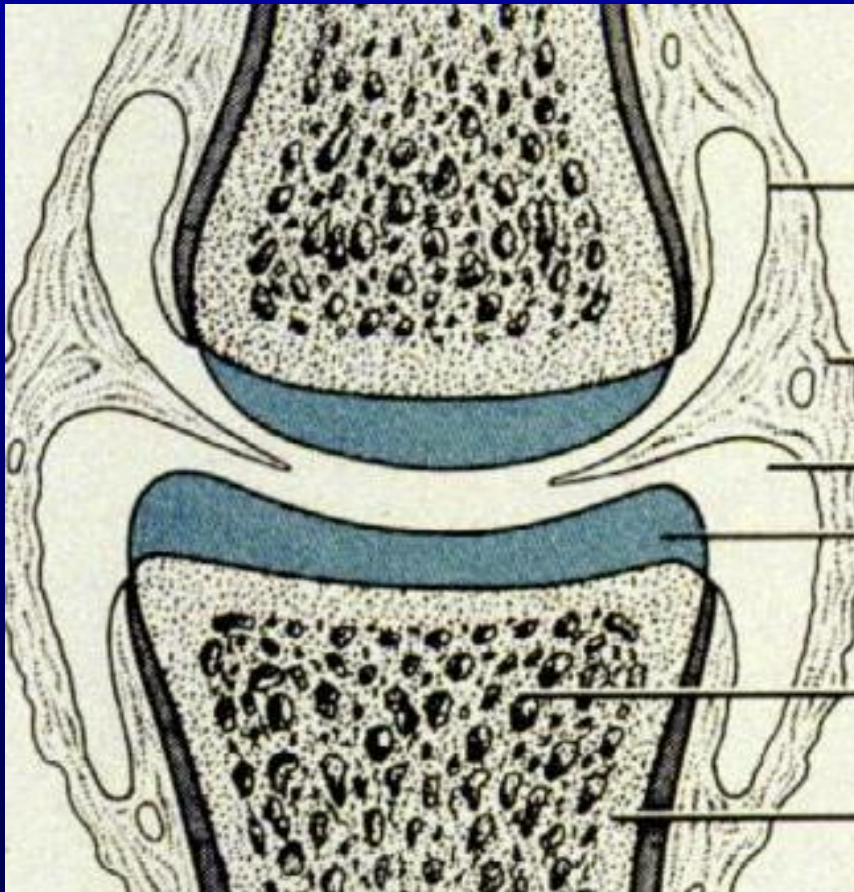
Flexible support - return to original shape (ears, nose, and respiratory)



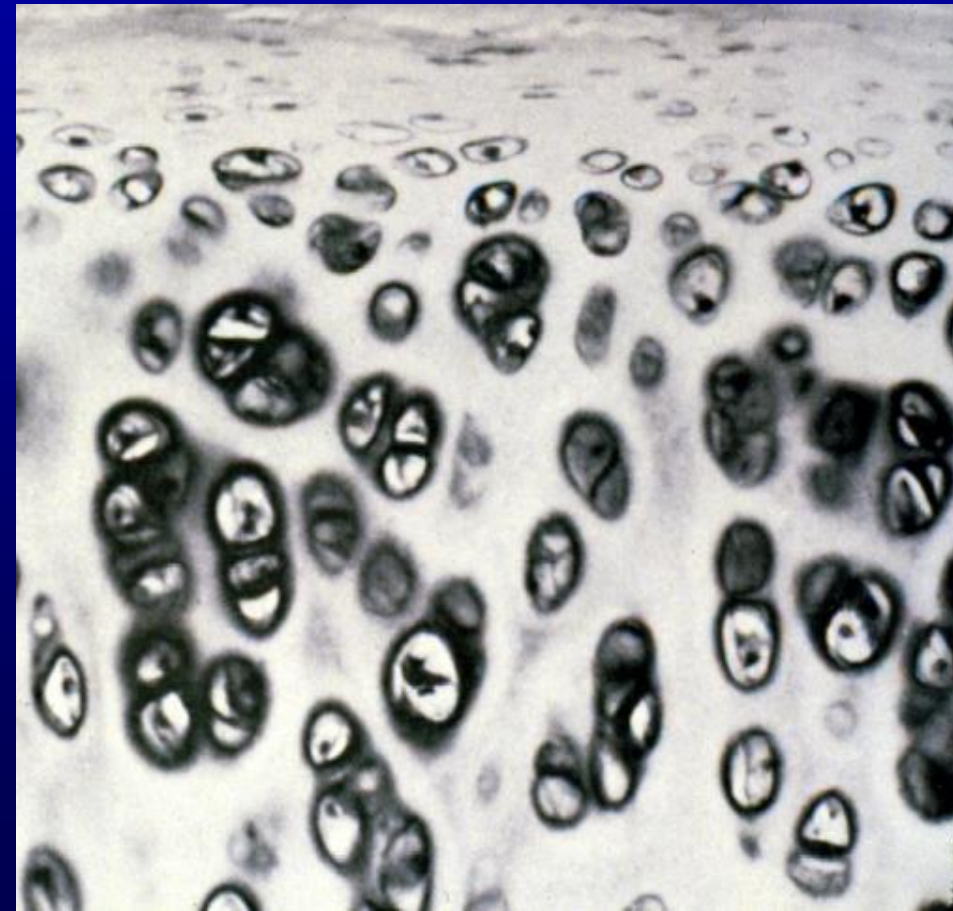
Functions of Cartilage

Slides across each other easily while bearing weight
(joints, articular surfaces of bones)

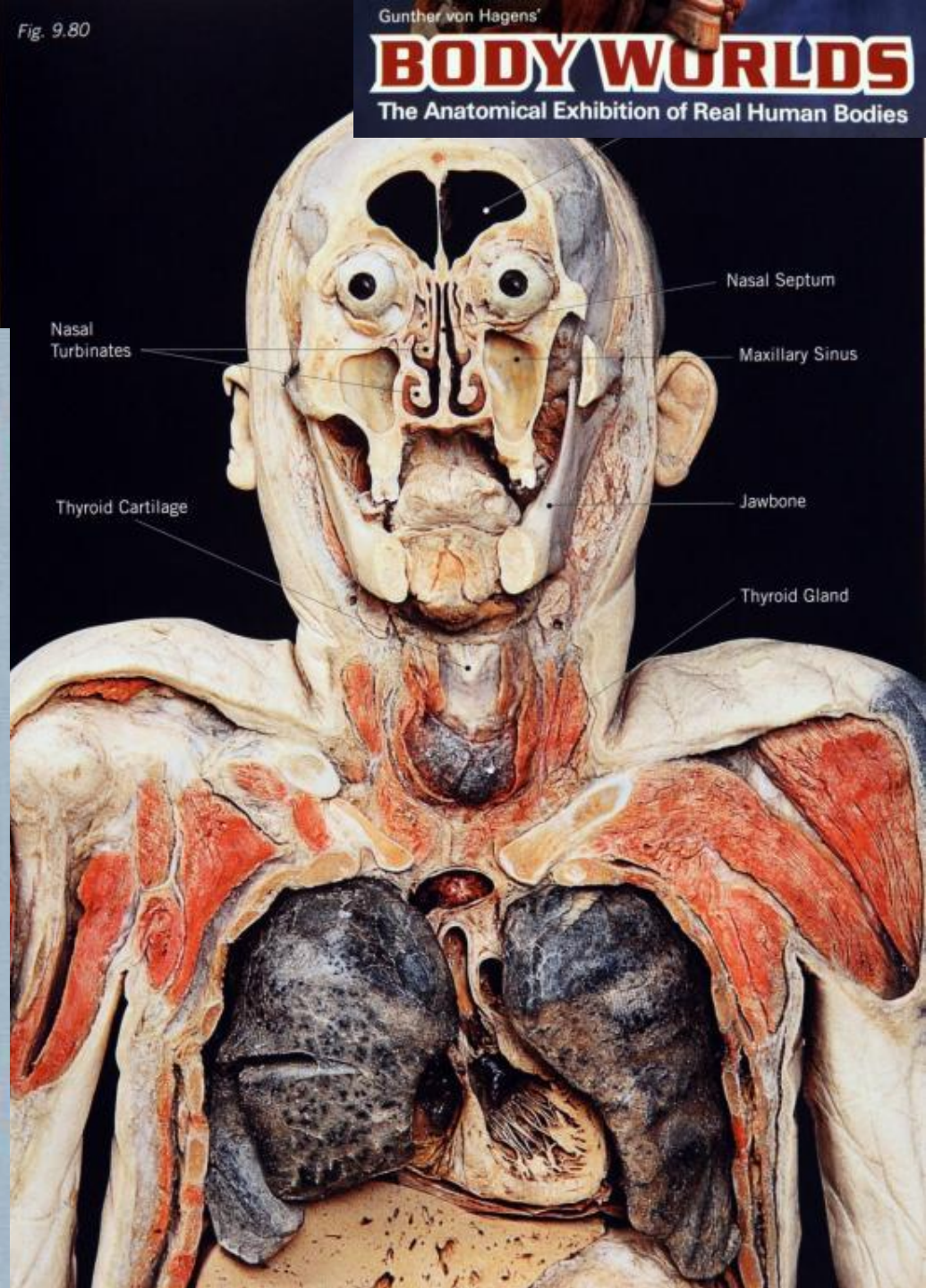
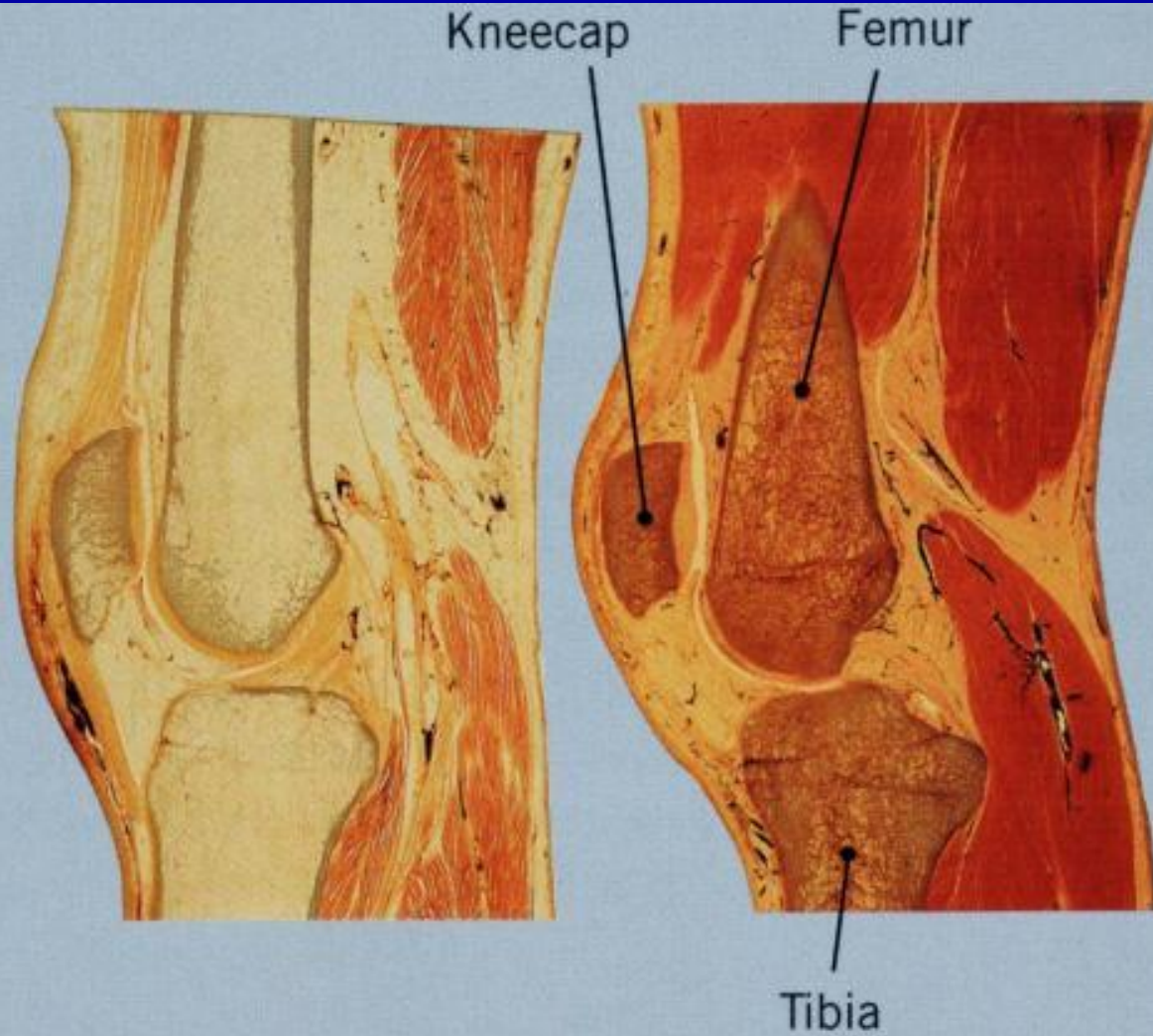
Cushion - cartilage has limited compressibility (joints)



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



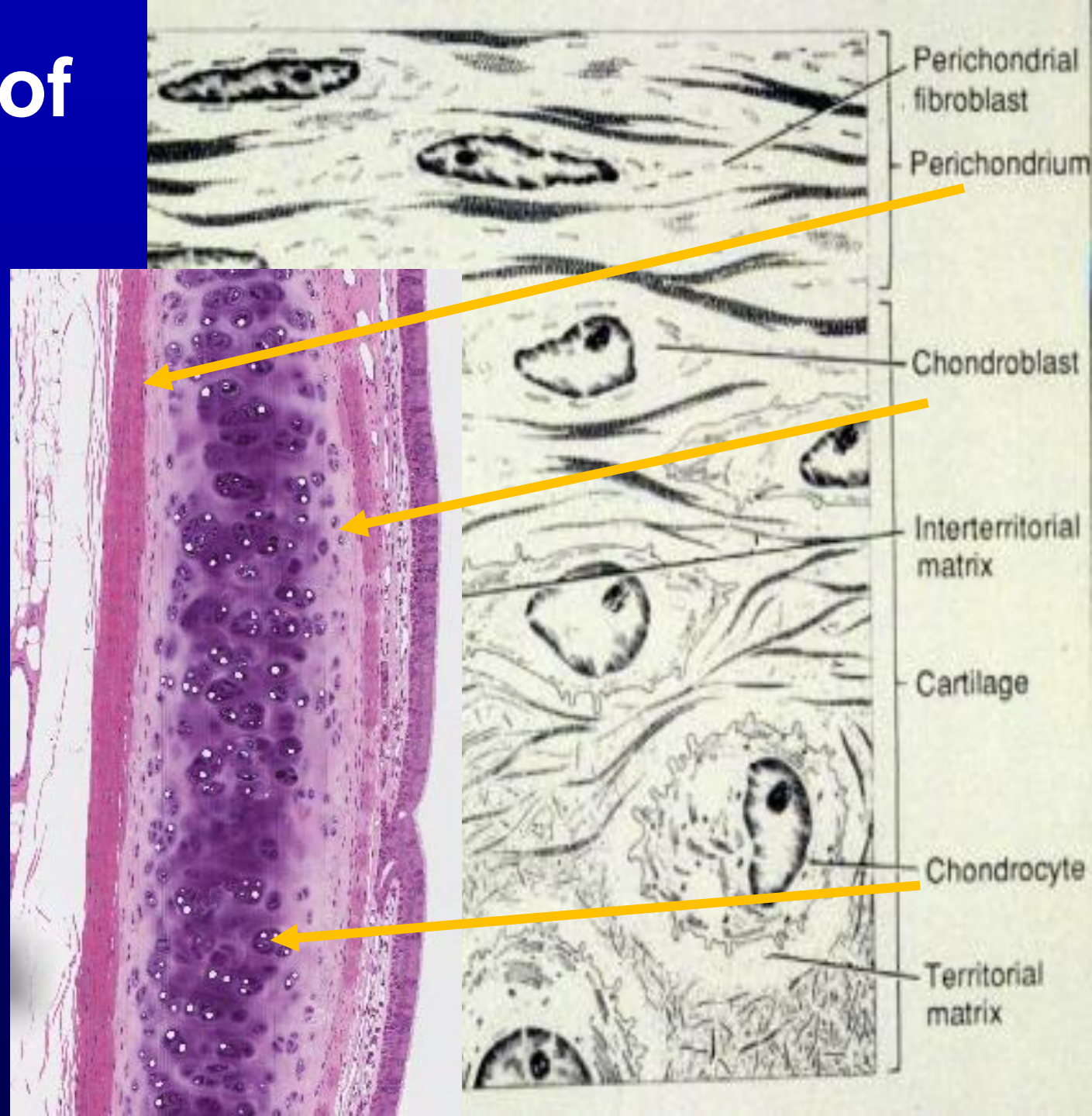
Functions of Cartilage



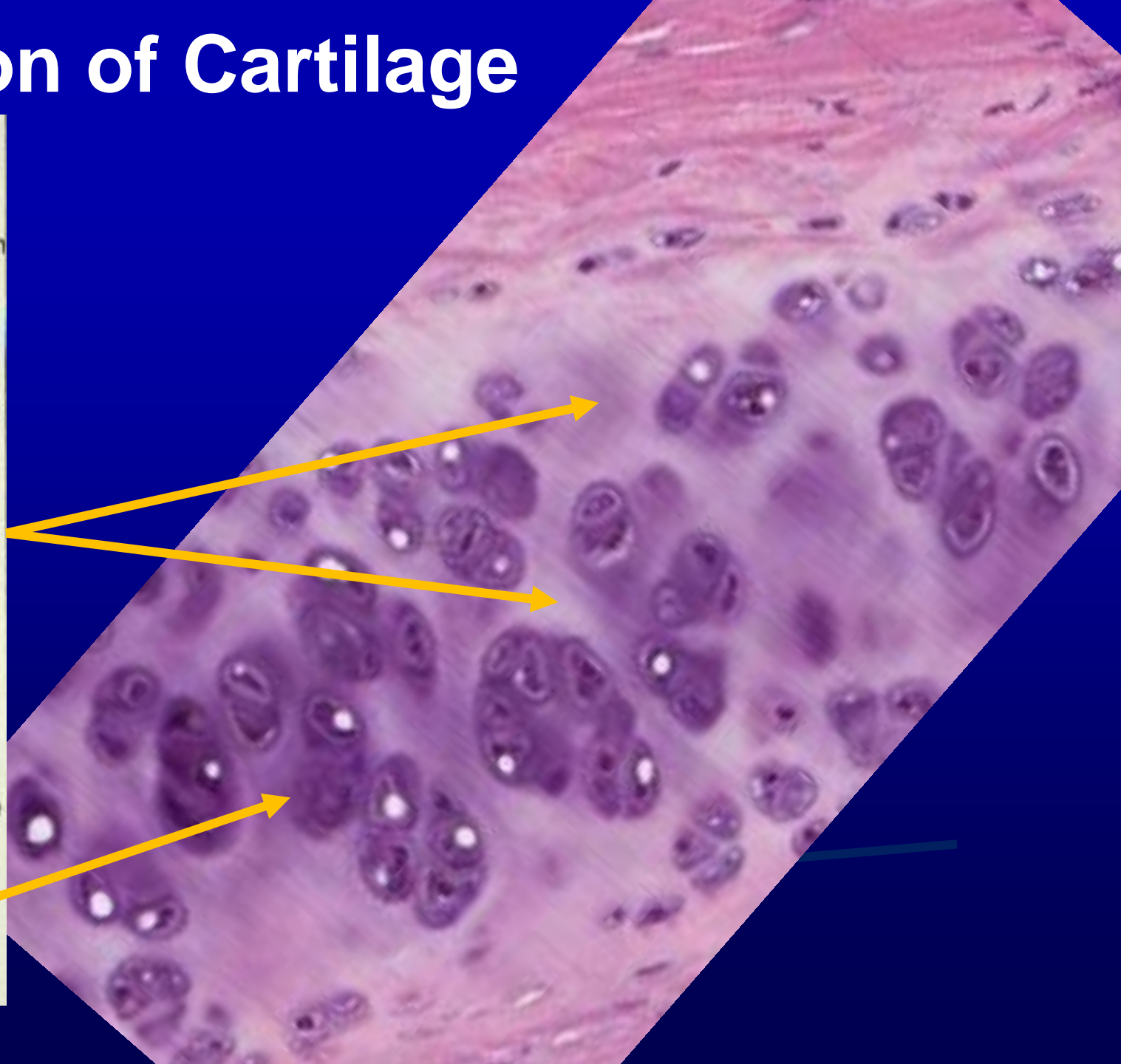
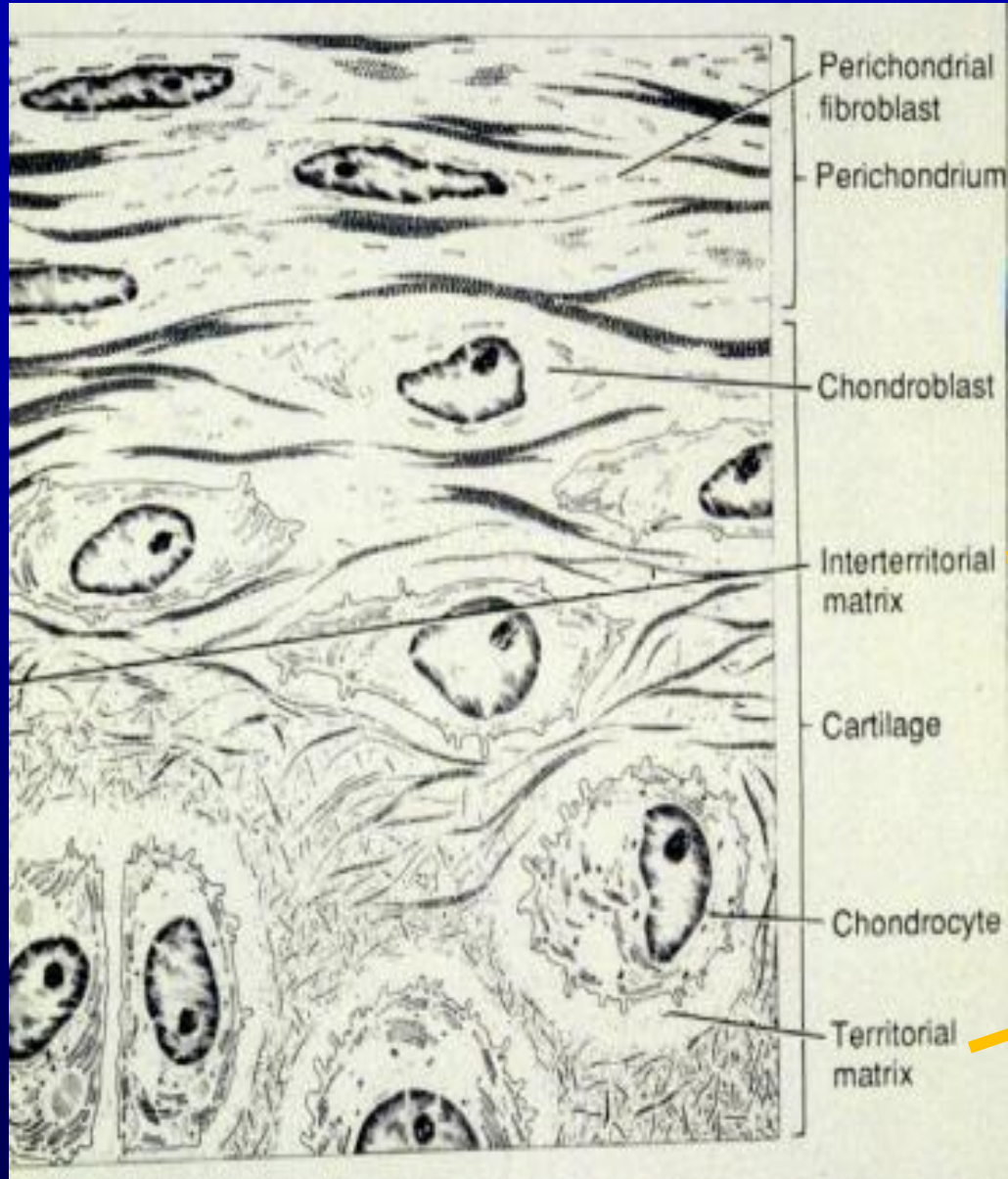
General Organization of Cartilage

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



General Organization of Cartilage

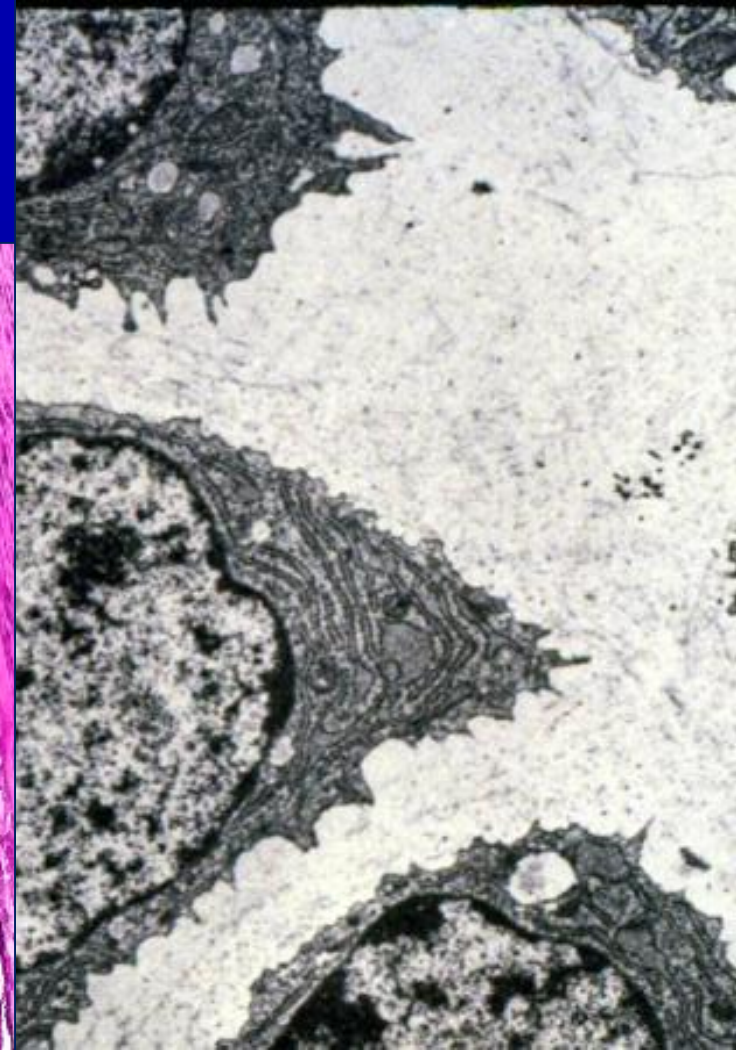
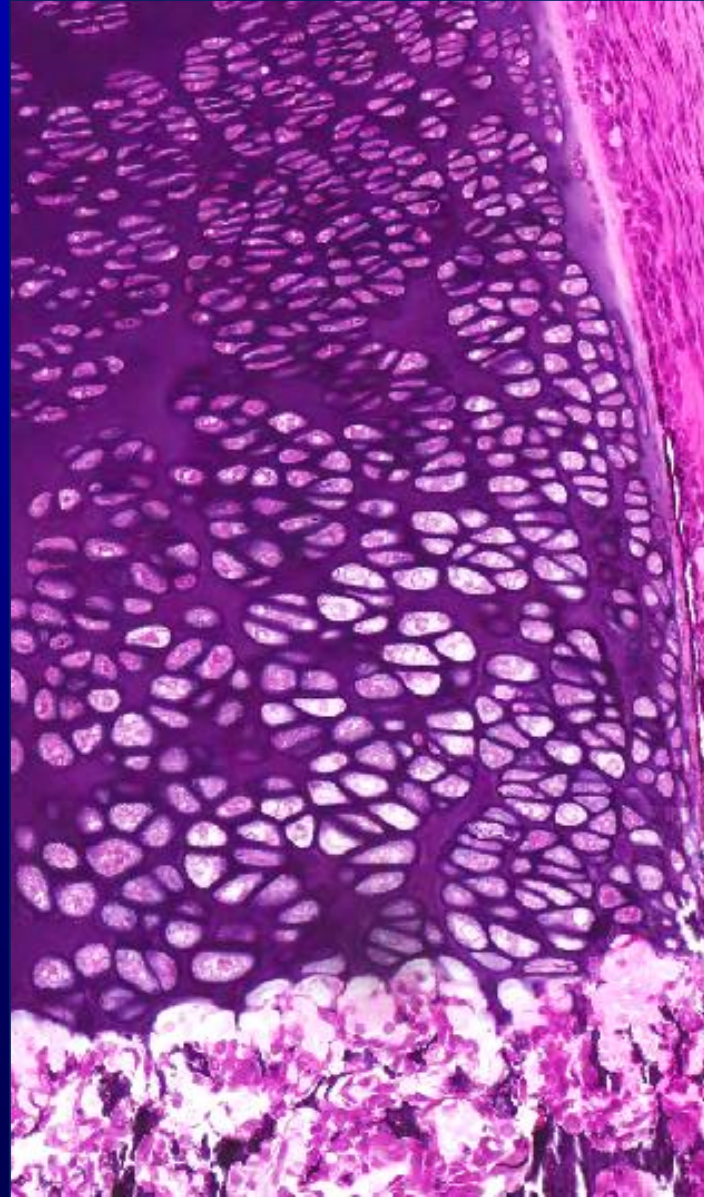
Matrix

Type II collagen (lack of obvious periodicity)

Sulfated proteoglycans (chondroitin sulfate and keratin sulfate) - stain basophilic

Capable of holding water / diffusion of nutrients

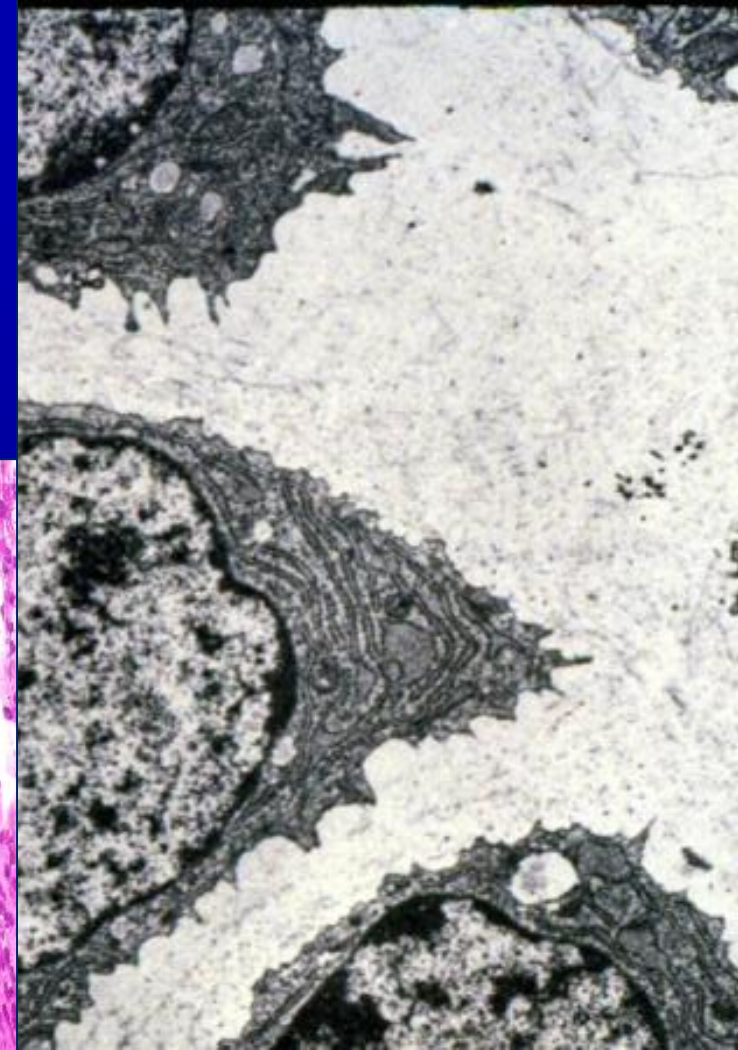
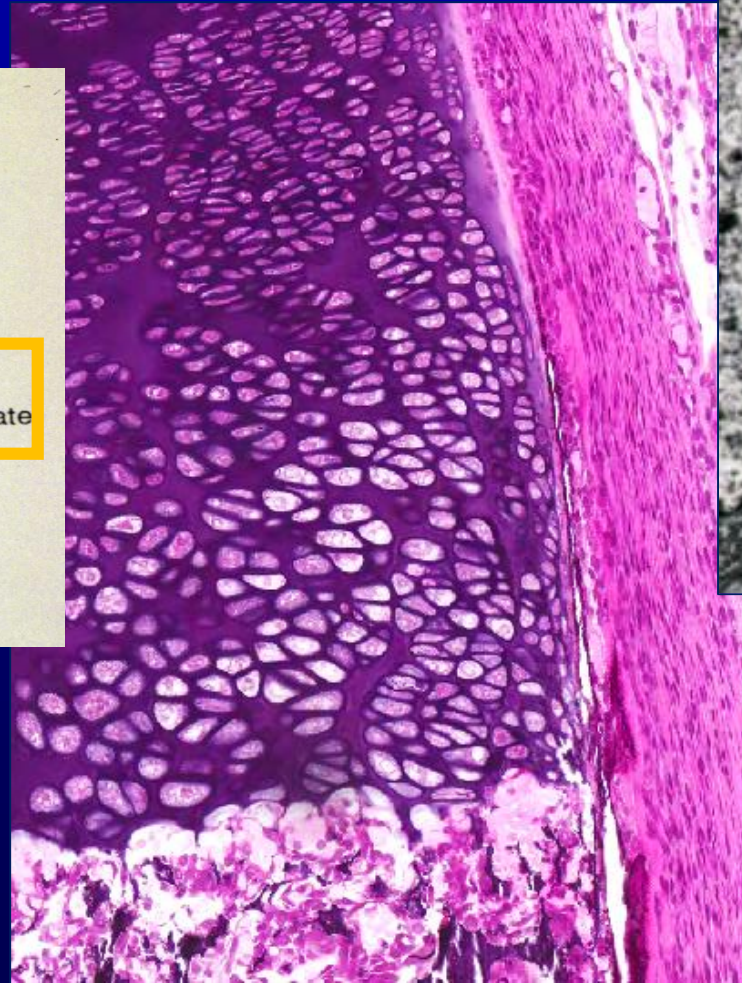
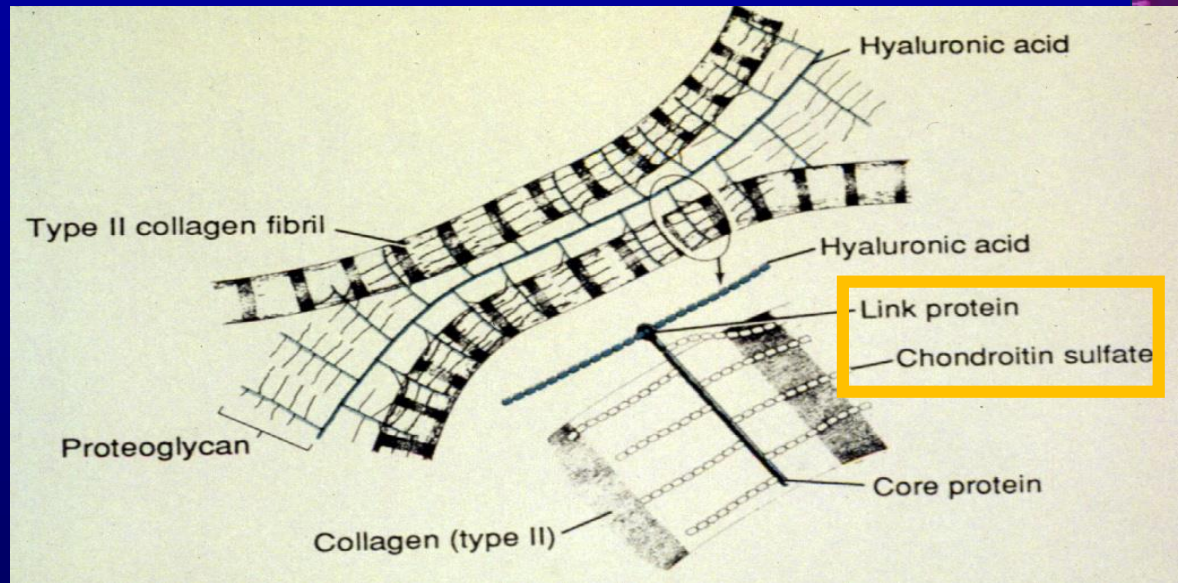
Avascular - gets nutrient/waste exchange from perichondrium



General Organization of Cartilage

Matrix

Type II collagen (lack of obvious periodicity)

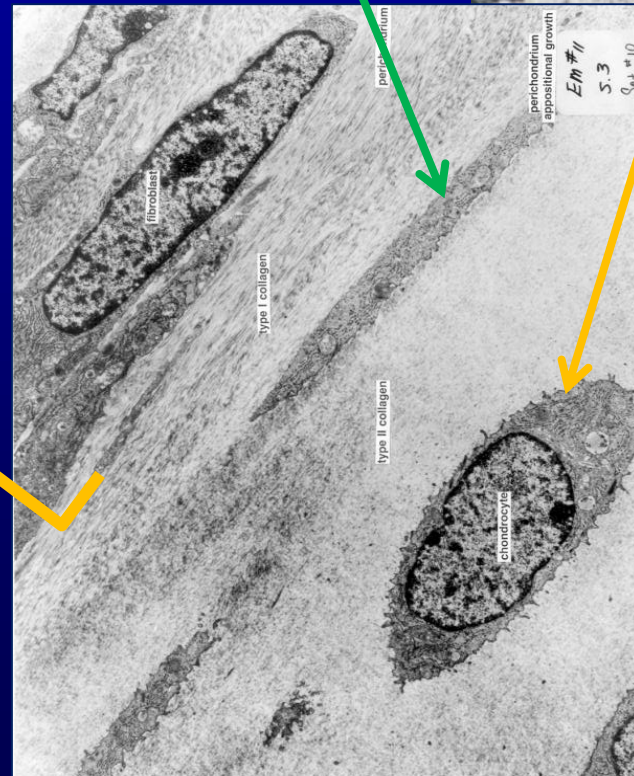
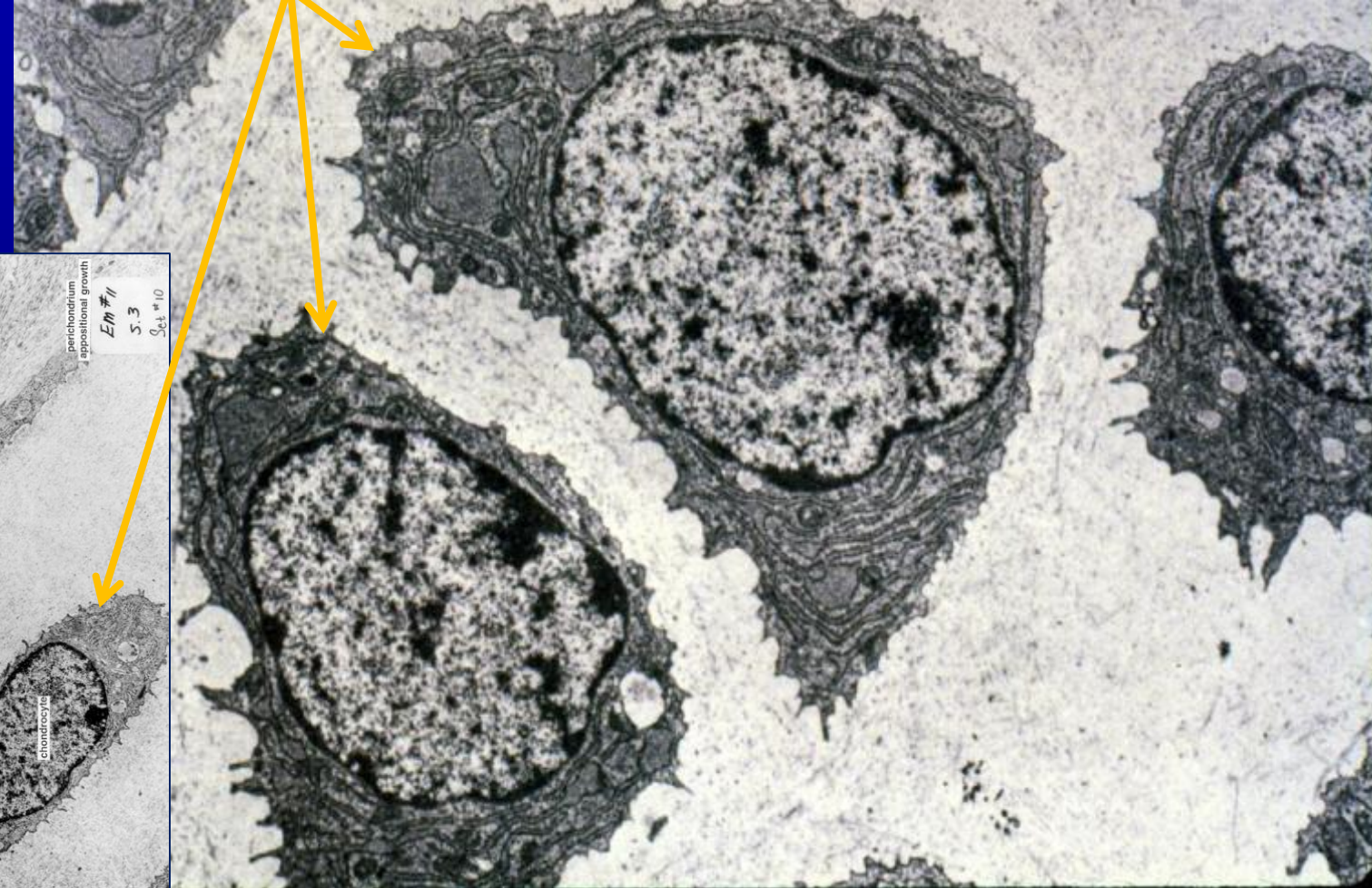
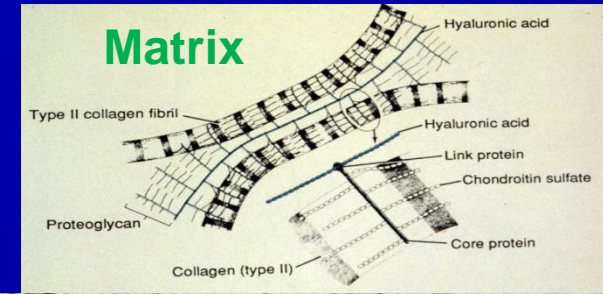


Matrix = fibers and ground substances

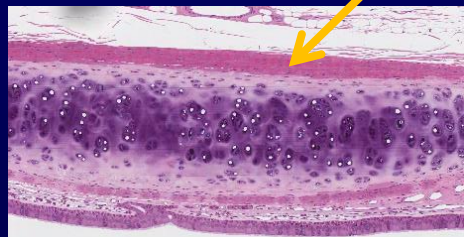
General Organization of Cartilage

Chondroblasts become **chondrocytes**

when they become trapped in lacunae (space) surrounded by matrix they secreted.

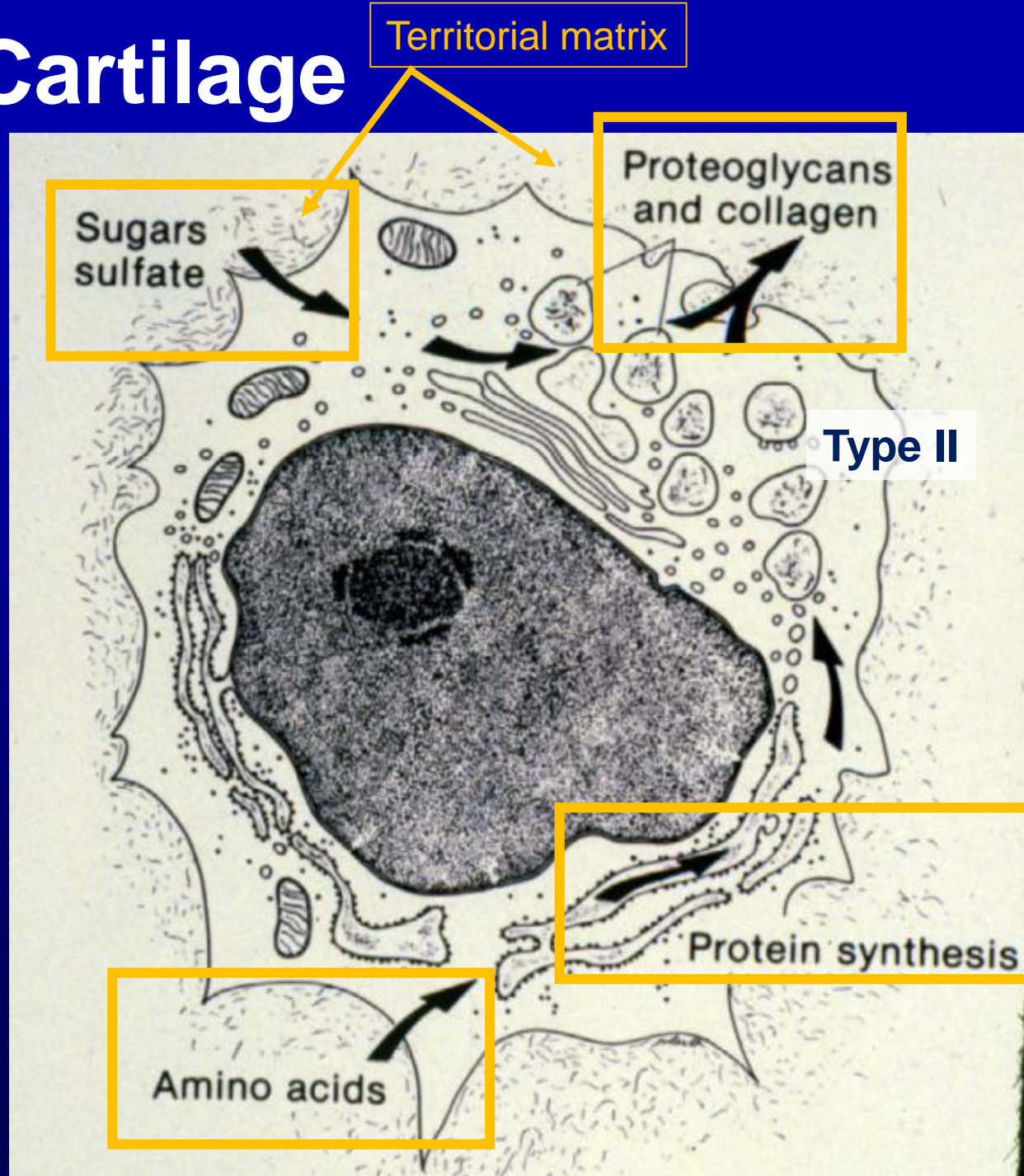
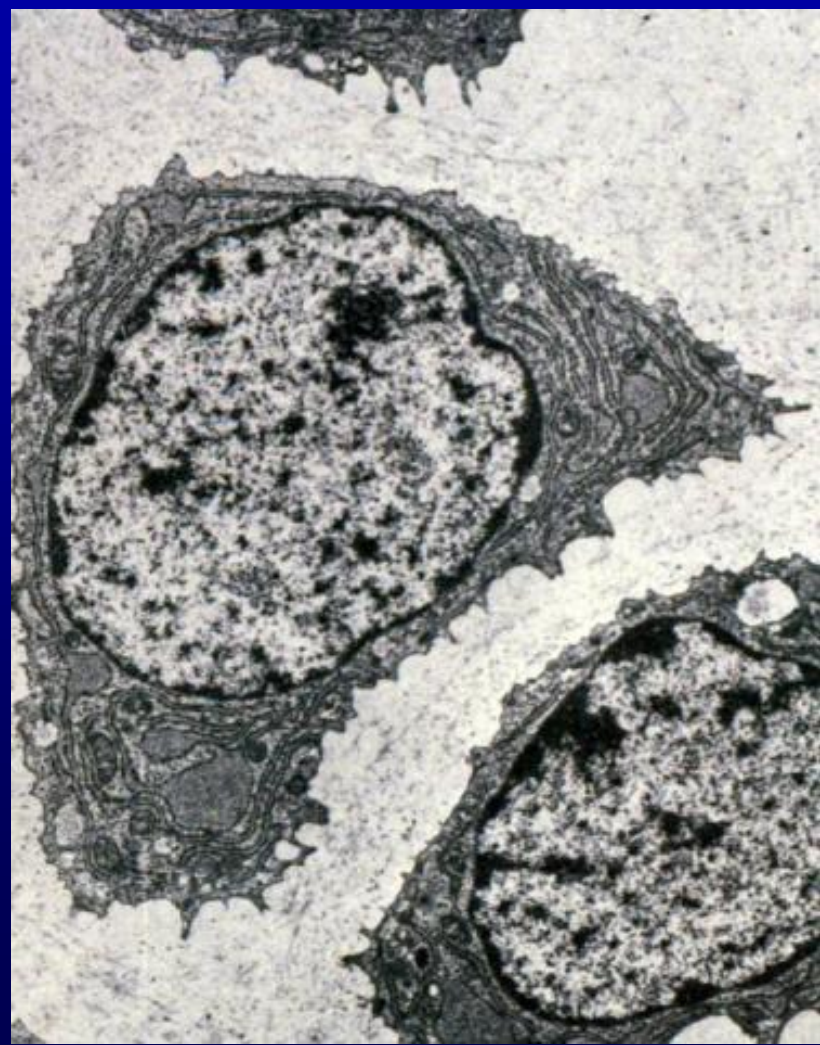


Perichondrium



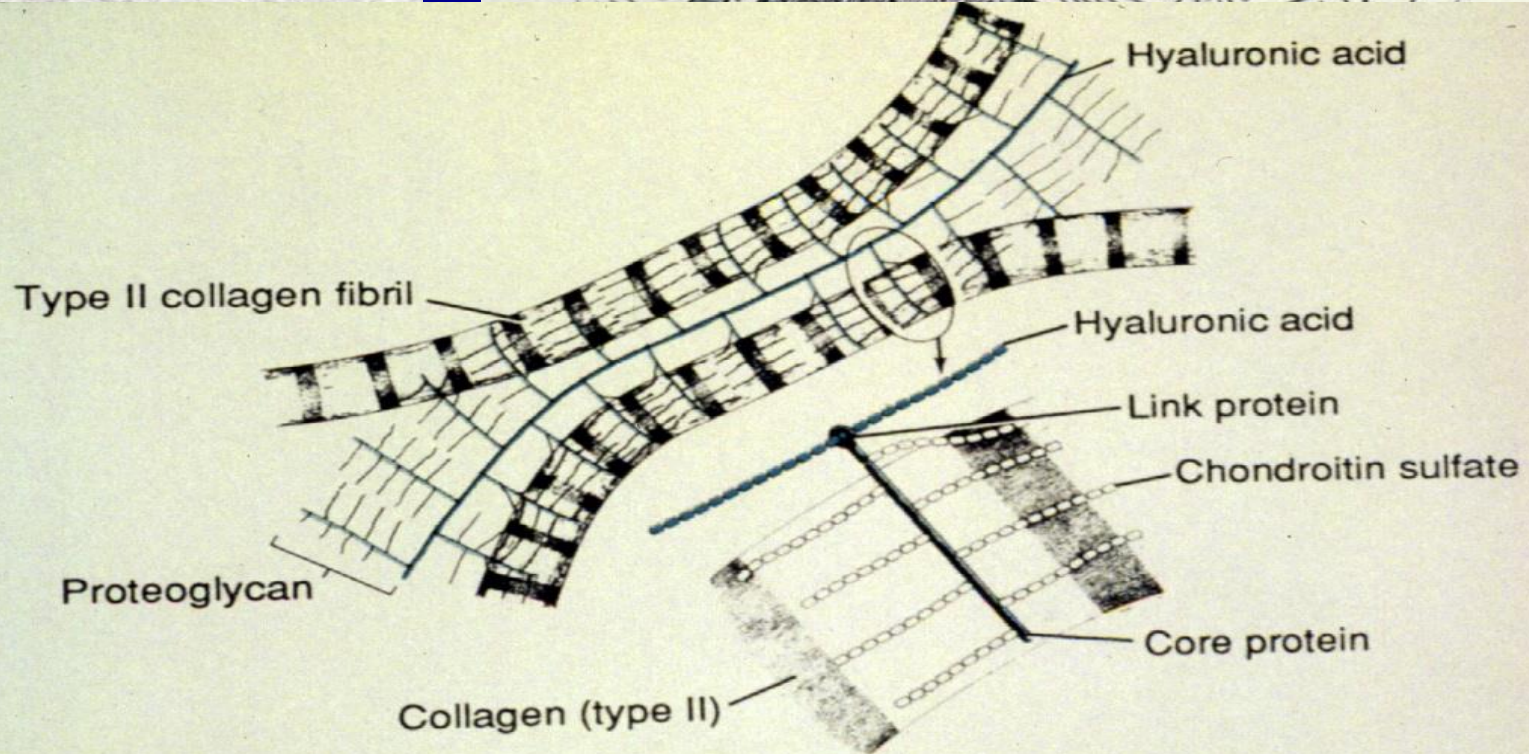
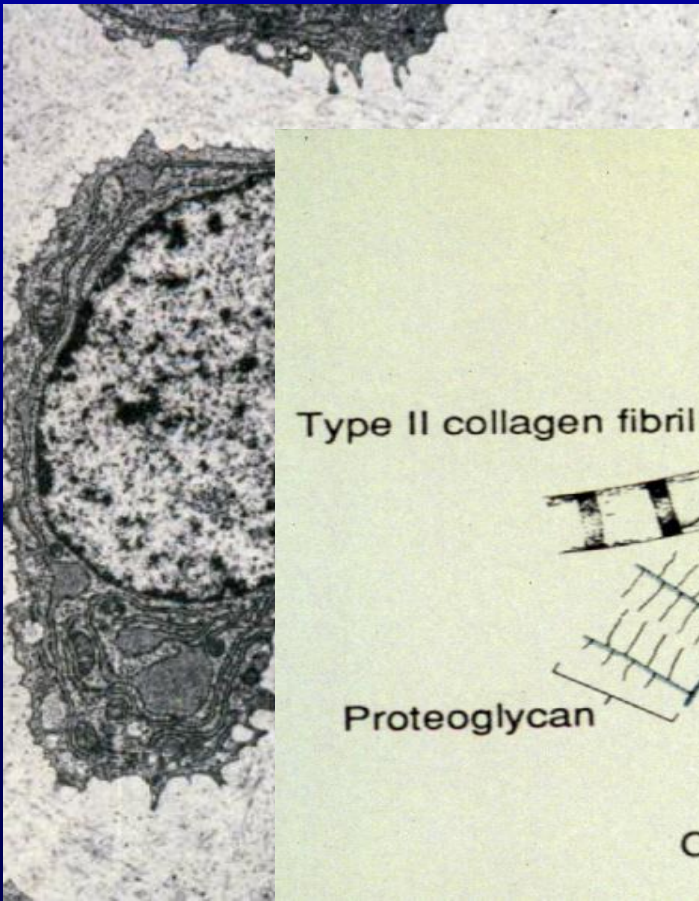
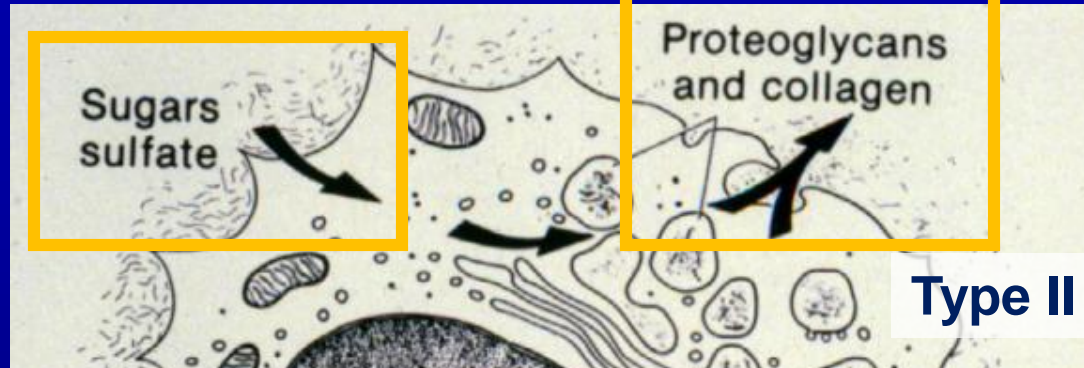
General Organization of Cartilage

Chondrocytes /
Chondroblasts



General Organization of Cartilage

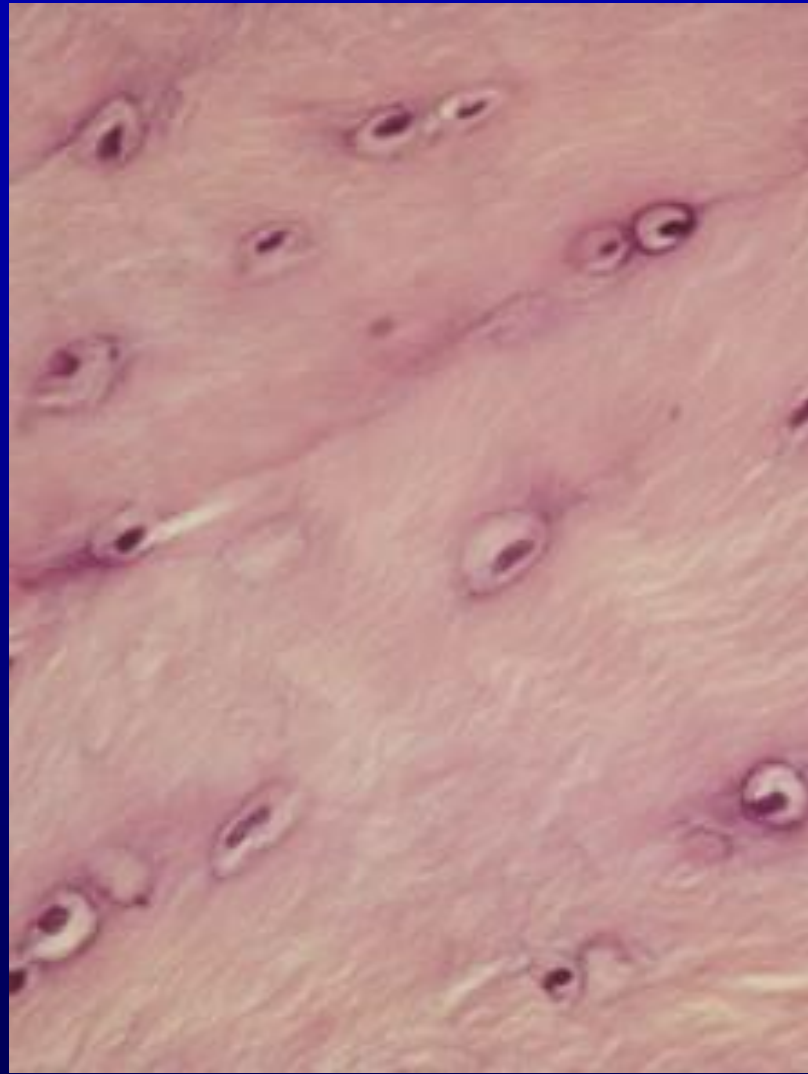
Chondrocytes /
Chondroblasts



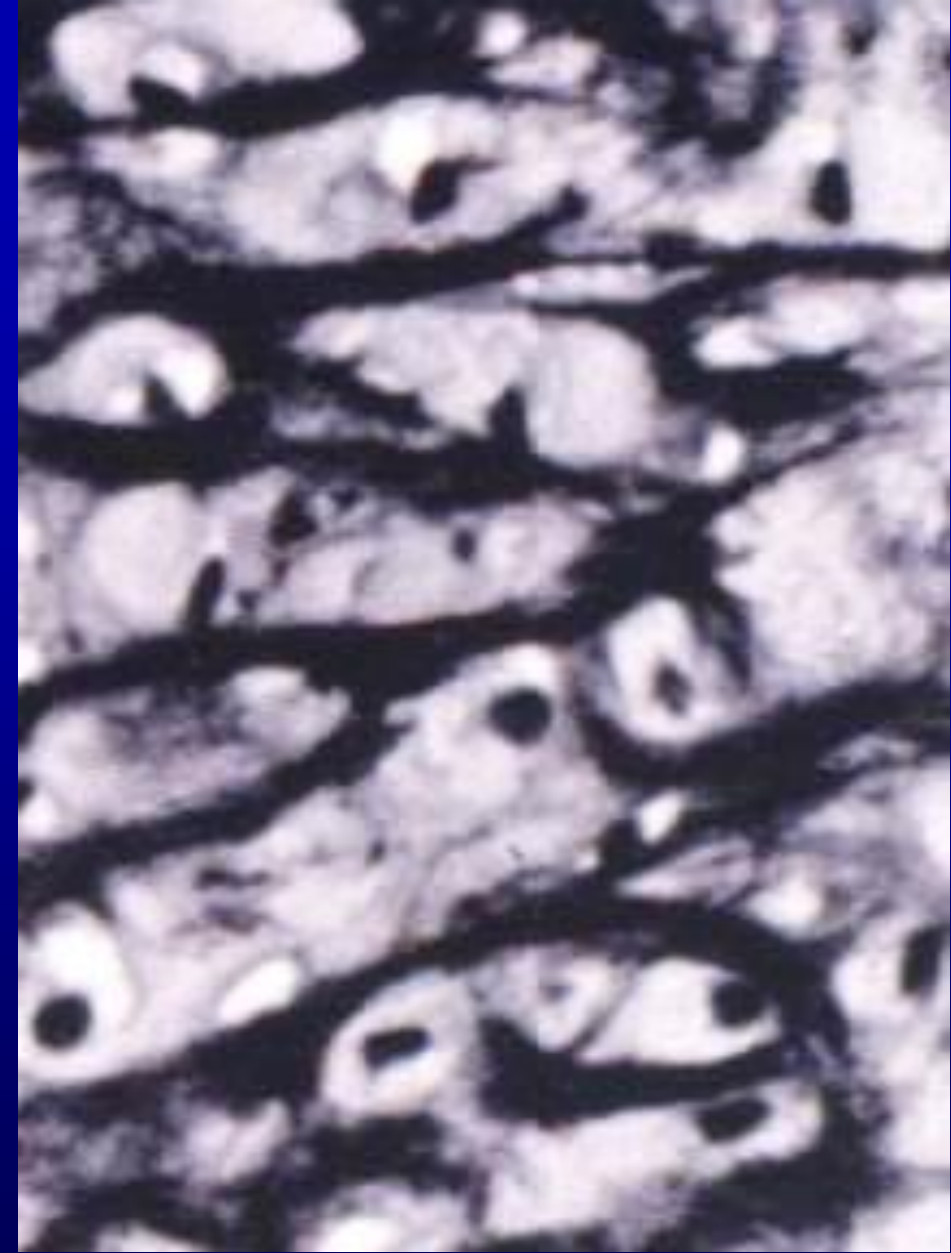
Types of Cartilage



Hyaline cartilage



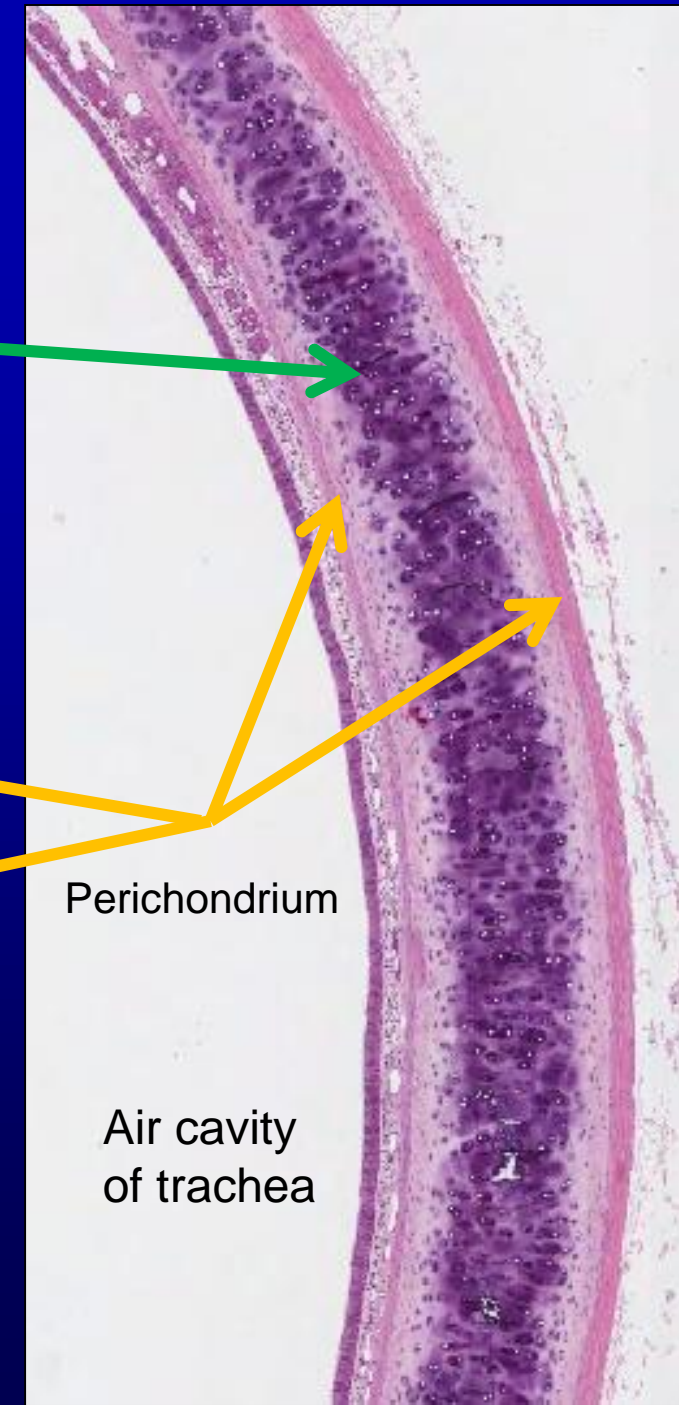
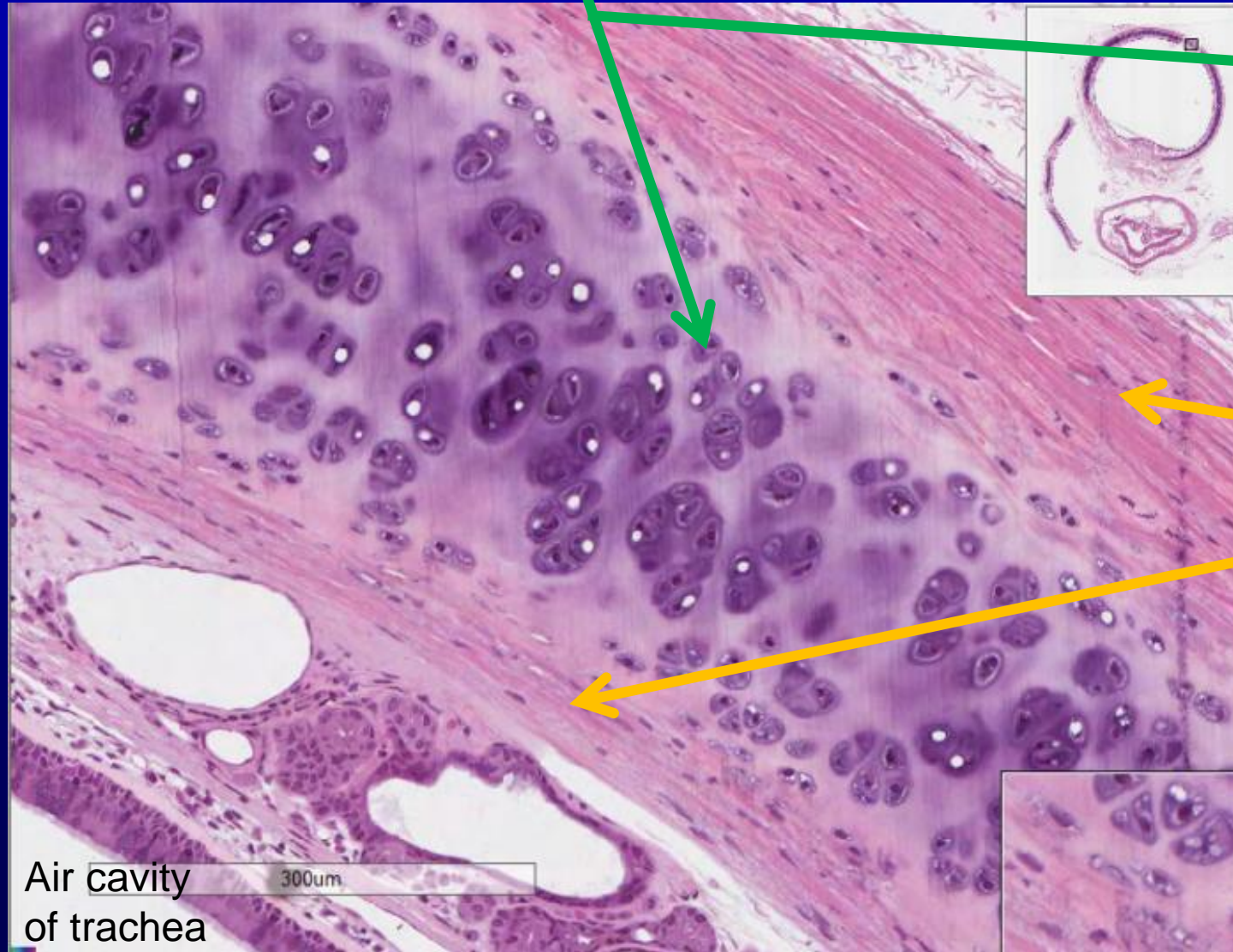
Fibrocartilage



Elastic cartilage

Slide 133: Trachea, monkey

– Hyaline cartilage for structural support



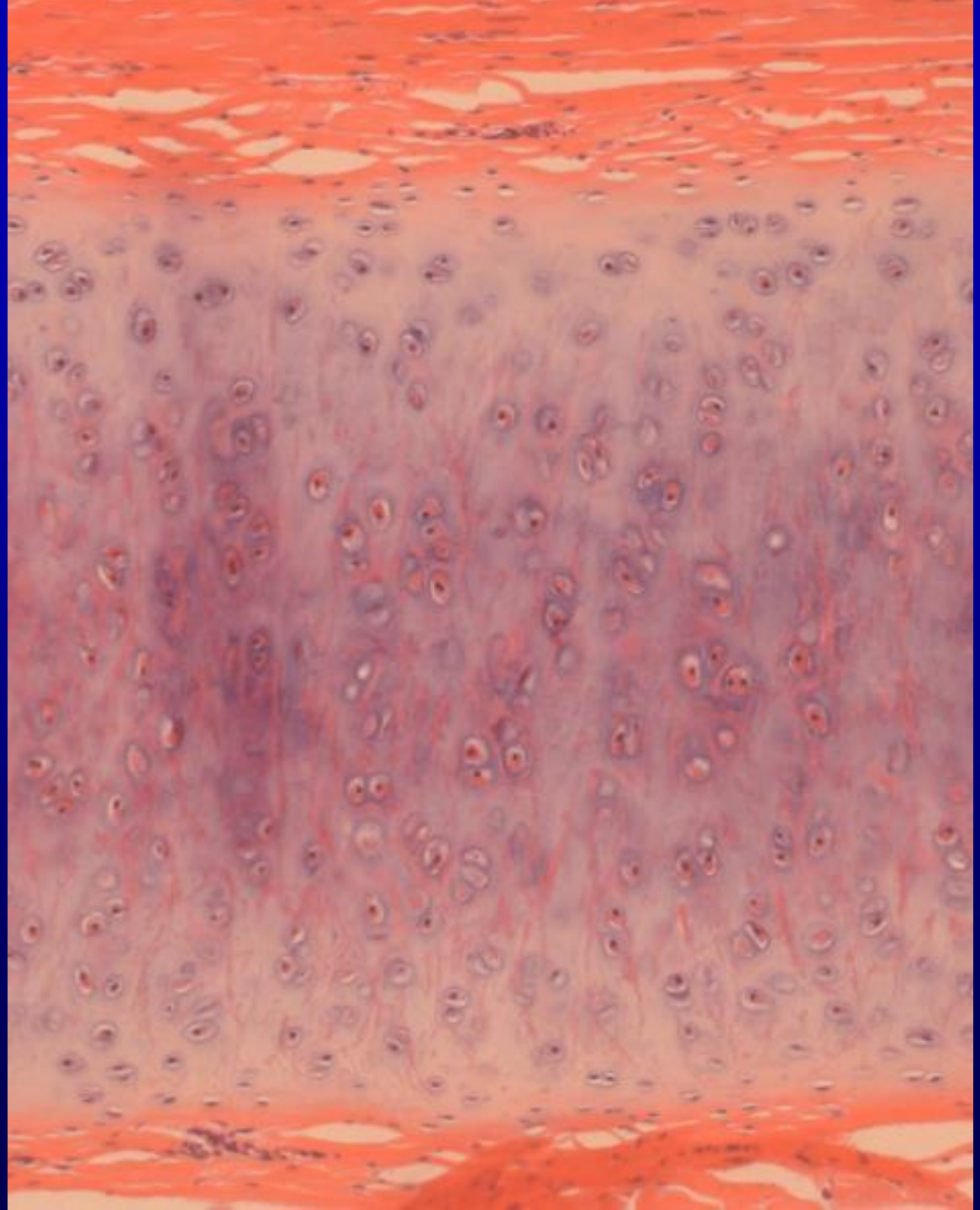
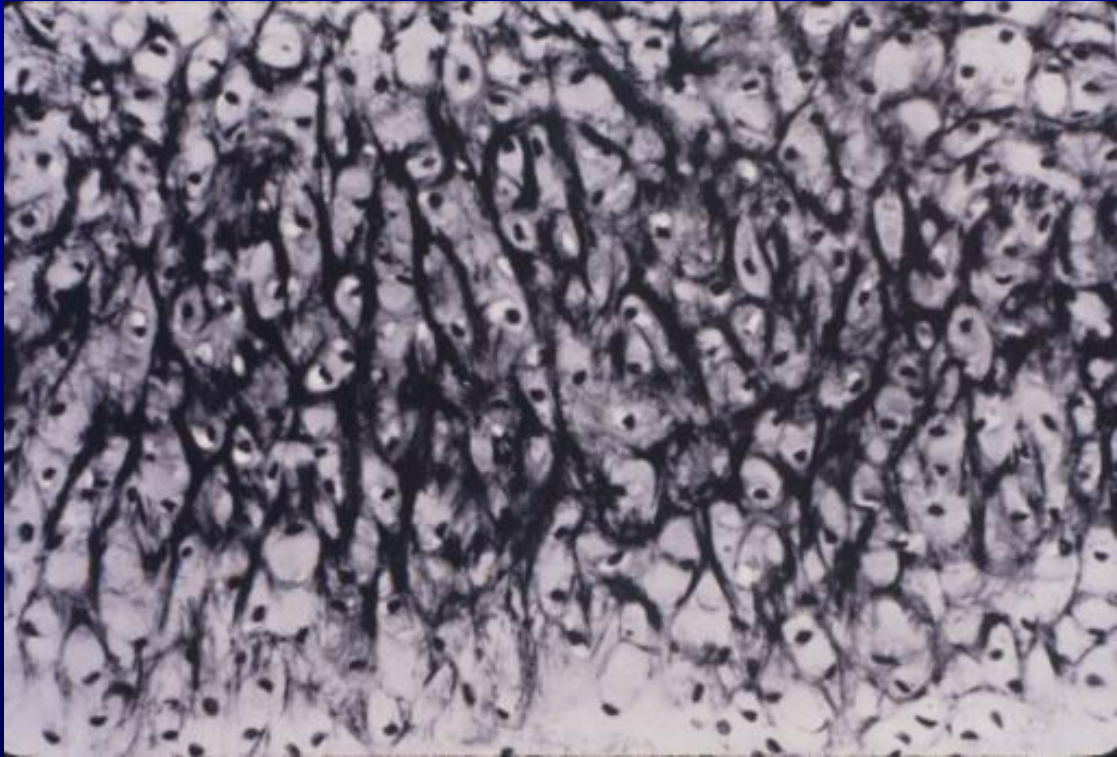
Perichondrium

Air cavity
of trachea

Elastic Cartilage

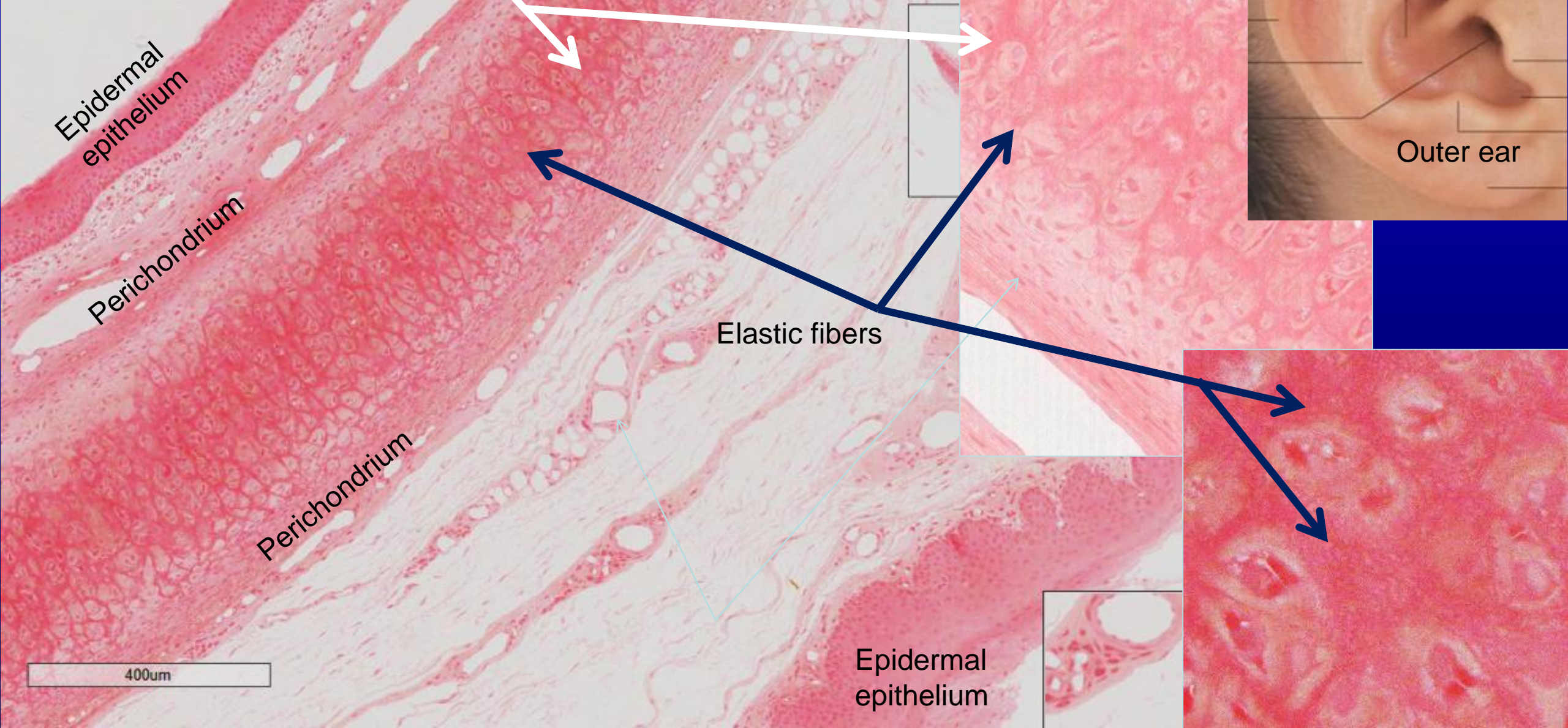
Same as hyaline

Except it has an abundant network of fine elastic fibers, found in pinna of ear, auditory canals, Eustachian tubes, and epiglottis where flexibility and reshaping are needed

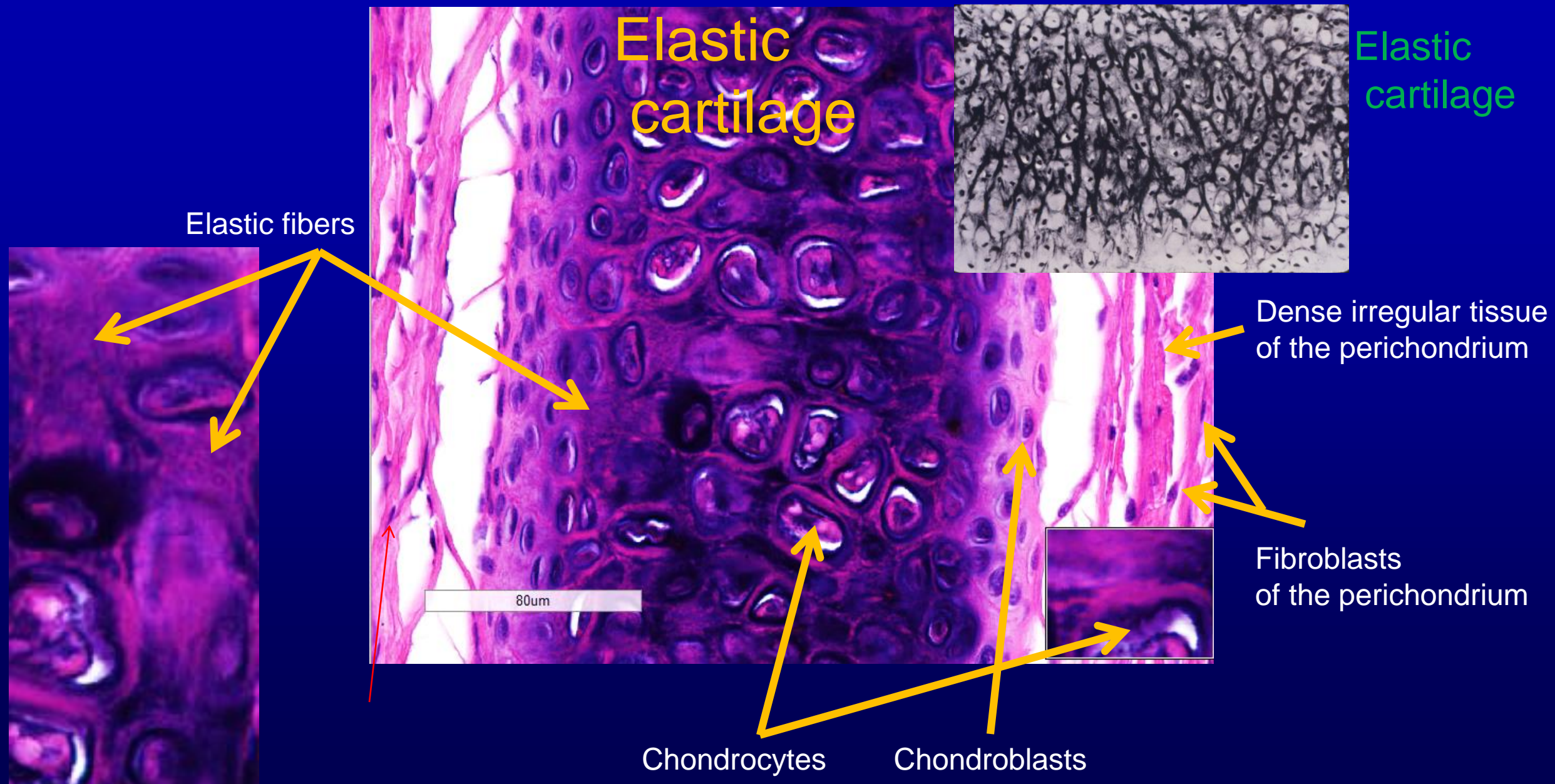


Slide 19762: Outer ear

– Elastic cartilage – return to original shape



DEMO SLIDE BOX 223 (F-H-48-1) – Pinna of ear, cat



FIBROCARILAGE

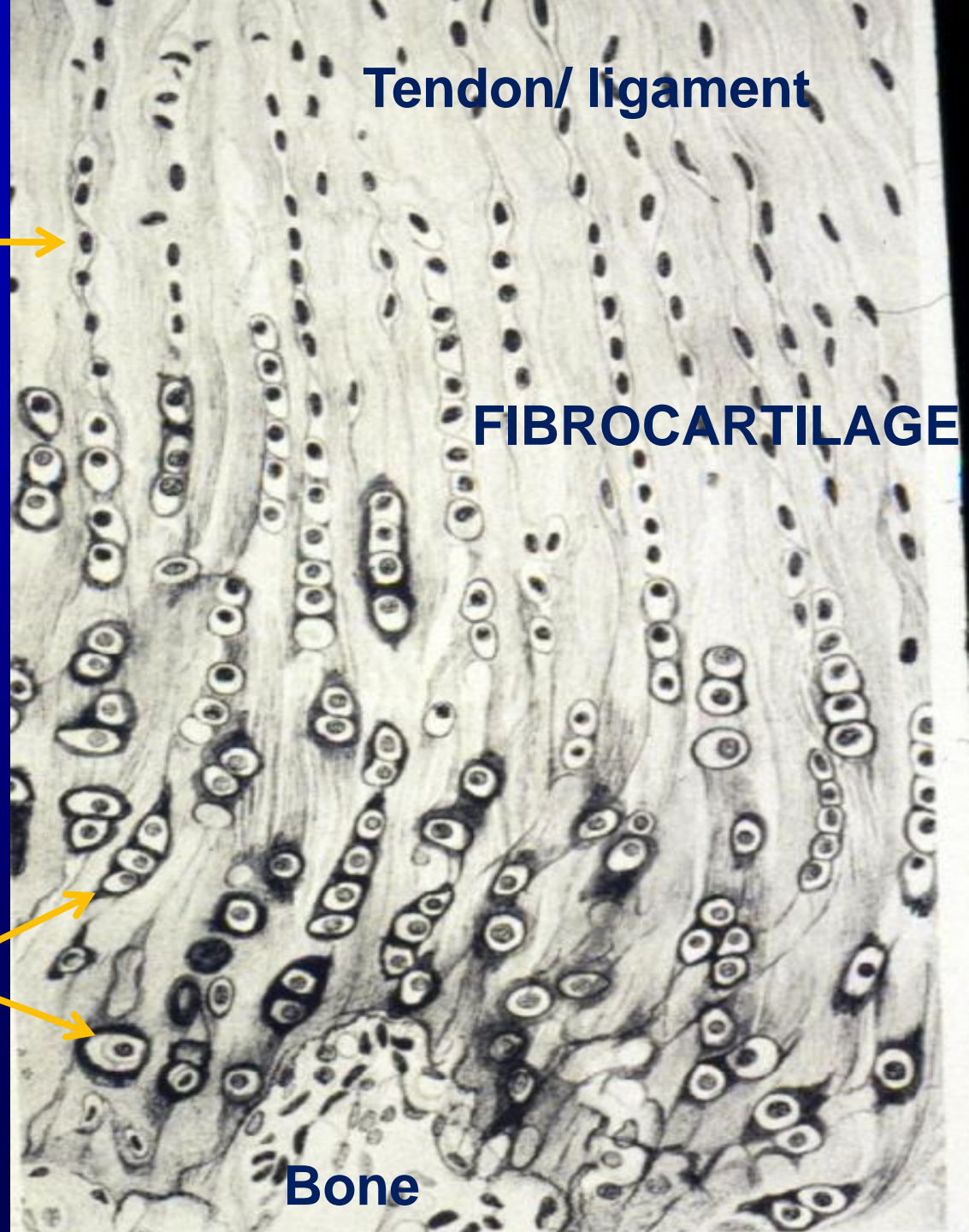
Fibroblasts in
Tendon/ligament

INTERMEDIATE BETWEEN
DENSE REGULAR
CONNECTIVE TISSUE
AND HYALINE
CARTILAGE

Attaches tendon/ligament
to bone

NO PERICHONDRIUM

Chondrocytes in
fibrocartilage



Tendon/ ligament

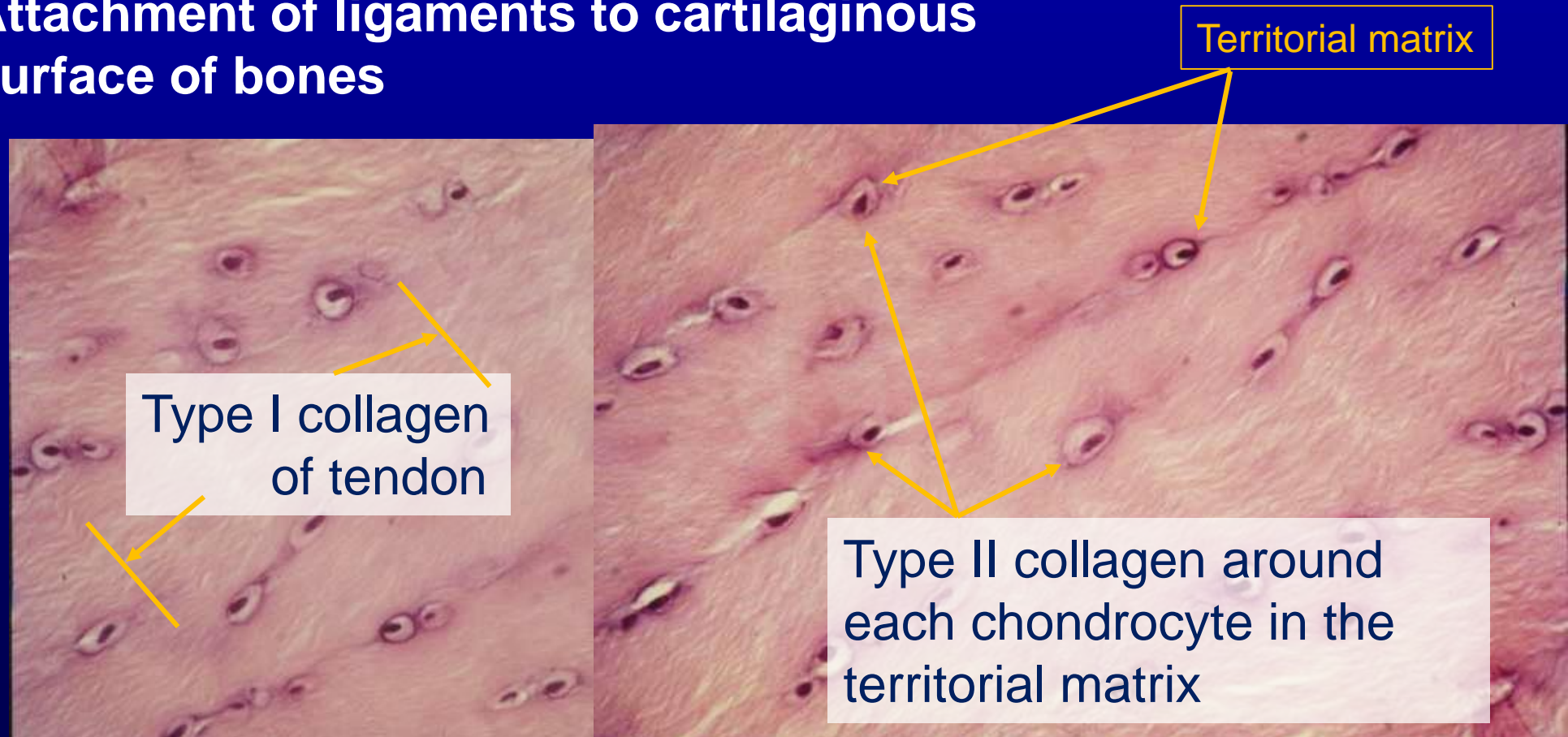
FIBROCARILAGE

Bone

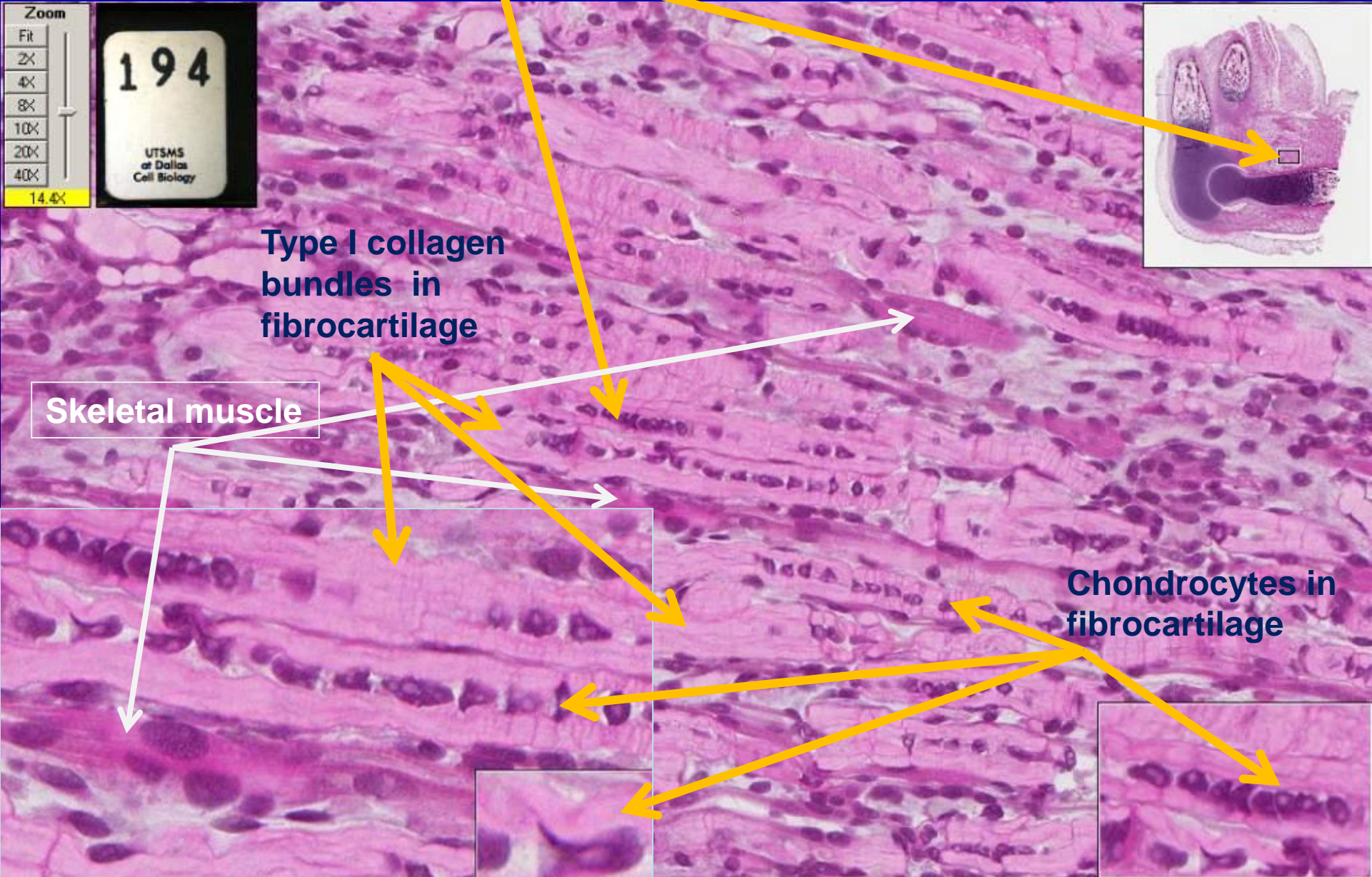
Fibrocartilage = chondrocytes inside a tendon or ligament on the surface of bone at the site of the attachment

Found in :

- Intervertebral discs
- Attachment of ligaments to cartilaginous surface of bones



Developing fibrocartilage of Fetal elbow



Zoom
Fit
2X
4X
8X
10X
20X
40X
14.4X

194
UTSMS
at Dallas
Cell Biology

Type I collagen
bundles in
fibrocartilage

Muscle
striations

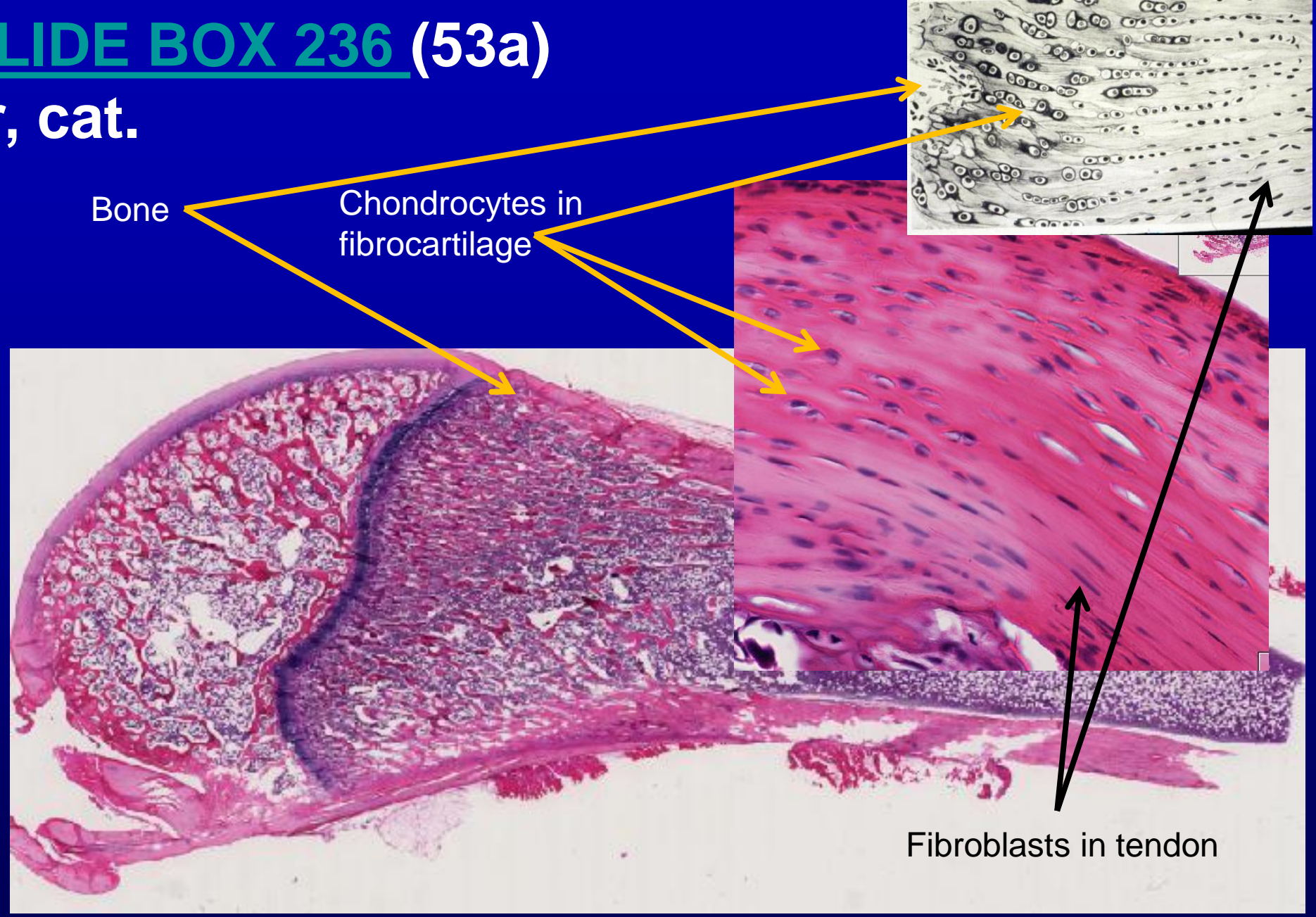
Skeletal muscle

Chondrocytes in
fibrocartilage



DEMO SLIDE BOX 236 (53a)

– Femur, cat.



Bone

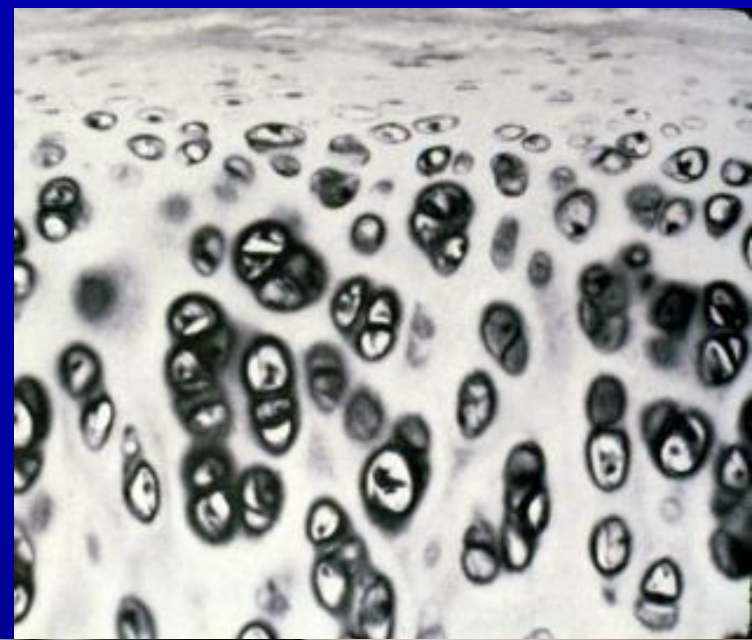
Chondrocytes in fibrocartilage

Fibroblasts in tendon

Fibrocartilage is found connecting other structures. Here, the fibrocartilage is joining tendon to bone.

Hyaline Cartilage

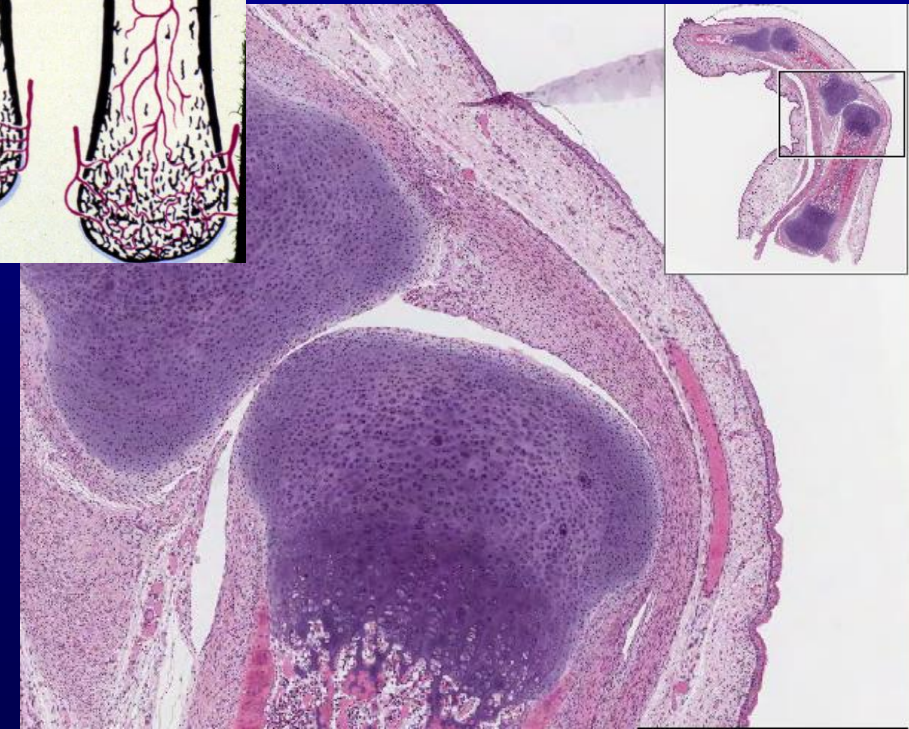
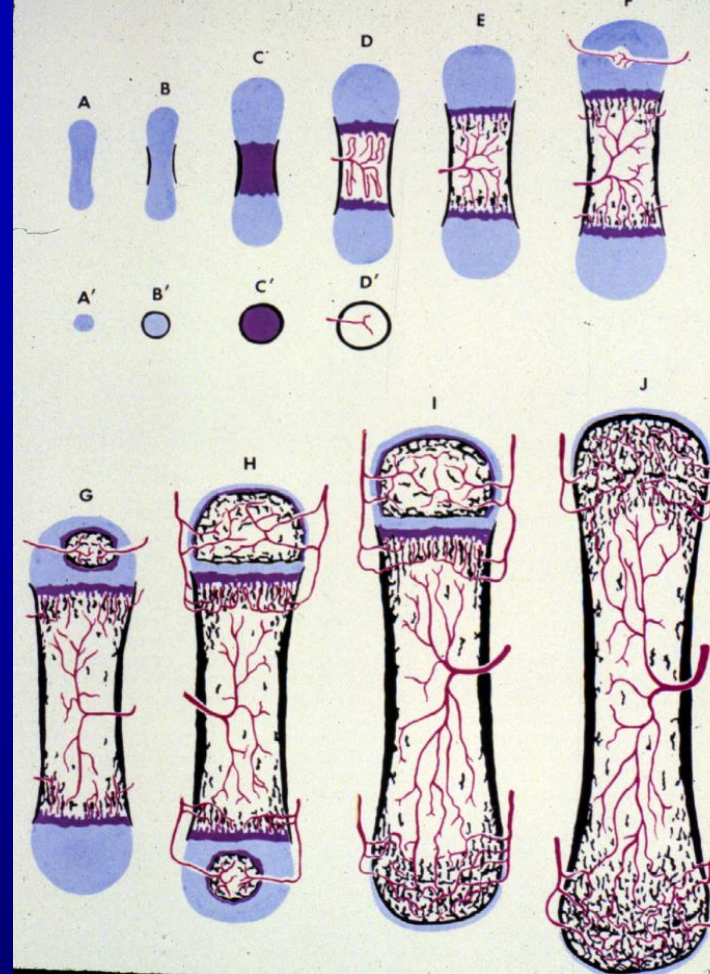
Glassy (bluish-white and translucent due to negative charge of sulfur in the gags)



Hyaline Cartilage

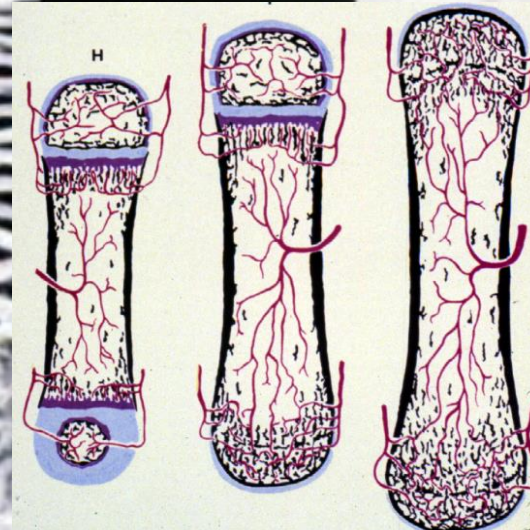
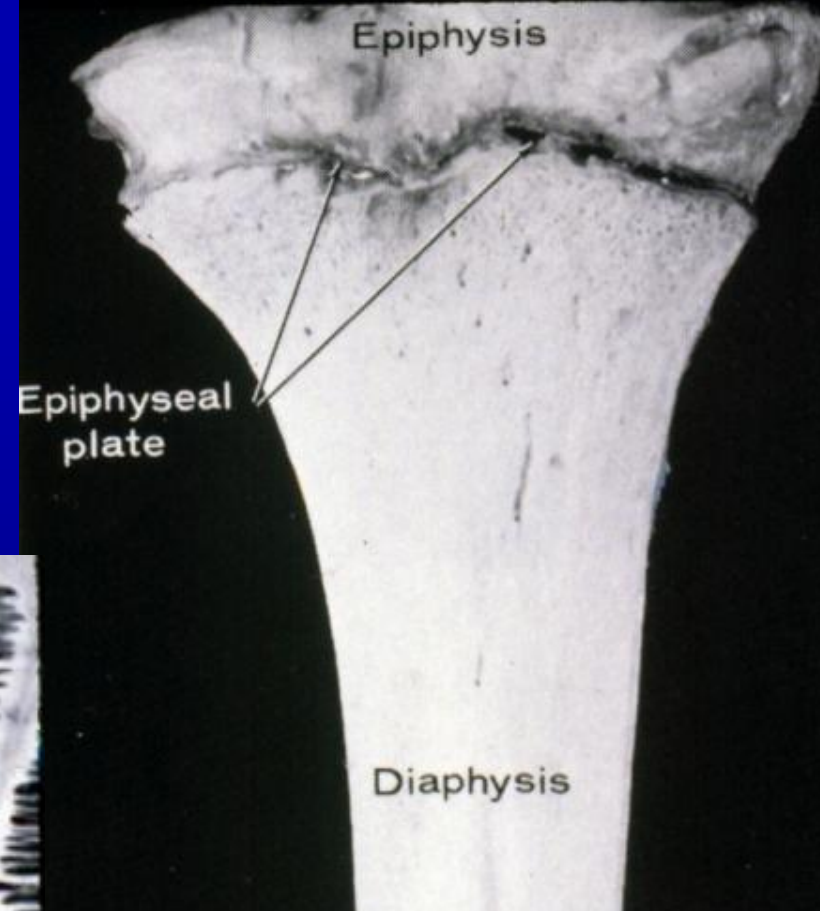
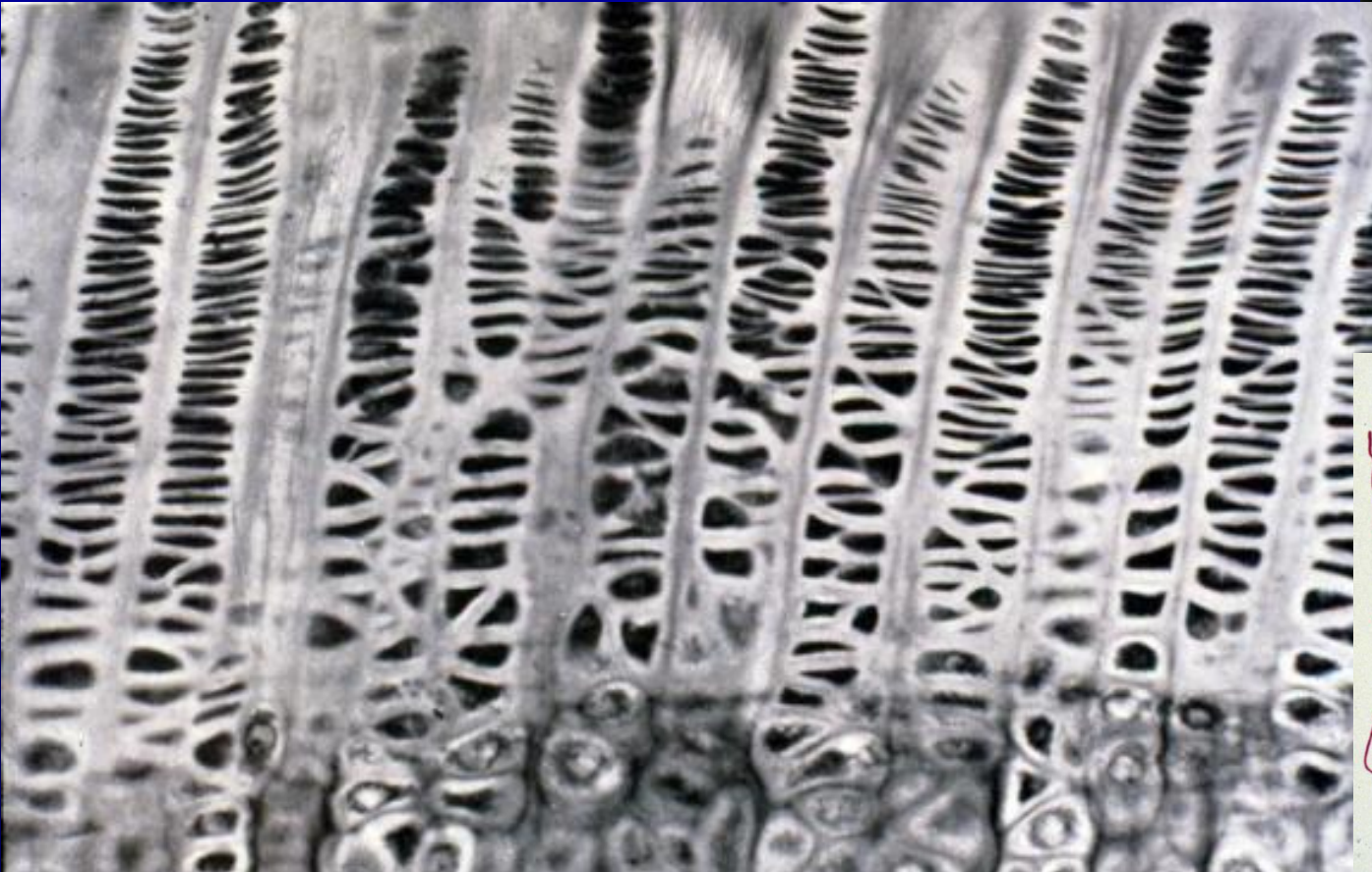
Glassy (bluish-white and translucent due to negative charge of sulfur in the gags)

Temporary skeleton in embryo and ends of bones in adults



Hyaline Cartilage

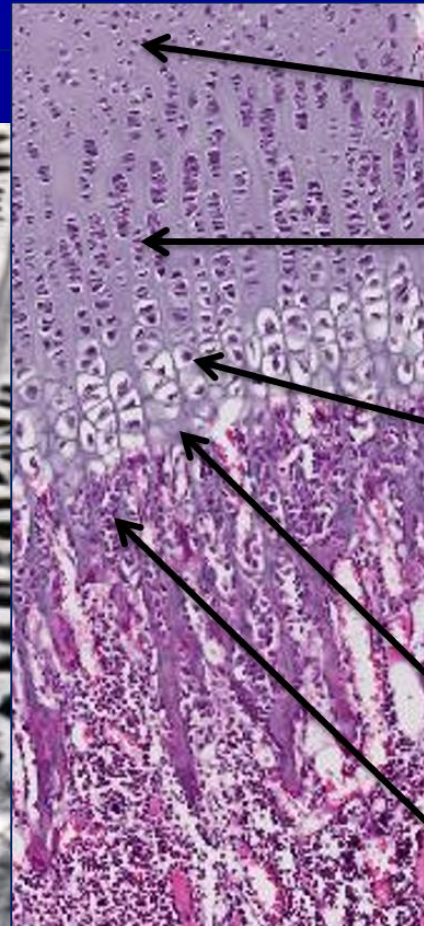
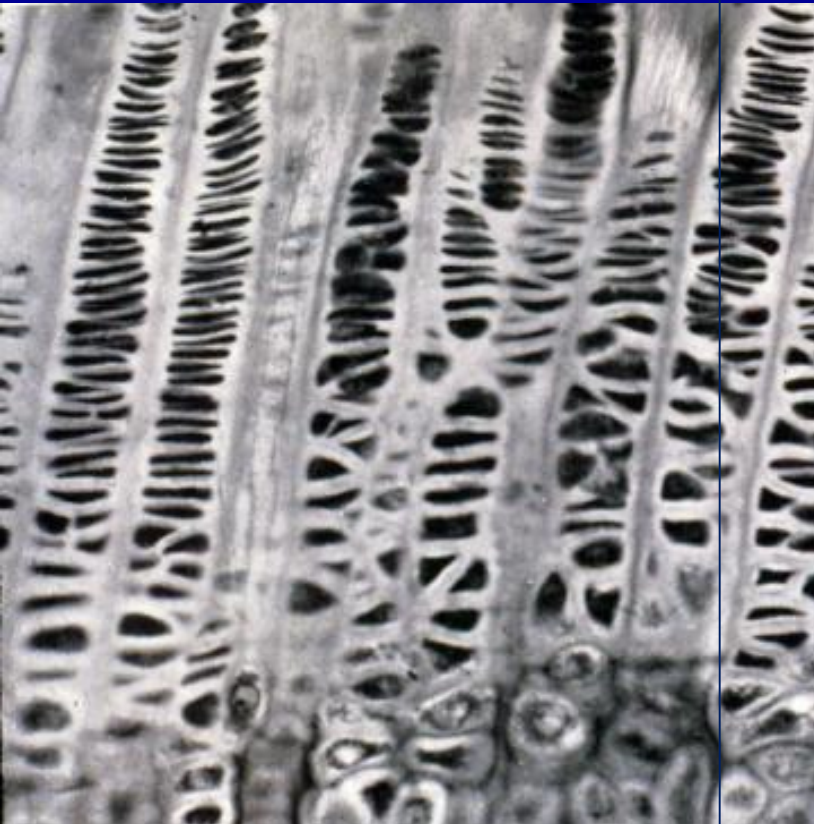
Epiphyseal plate, responsible for longitudinal growth of long bones



Nutrient canal

HYALINE CARTILAGE

EPIPHYSEAL PLATE,
RESPONSIBLE FOR
LONGITUDINAL GROWTH OF
LONG BONES



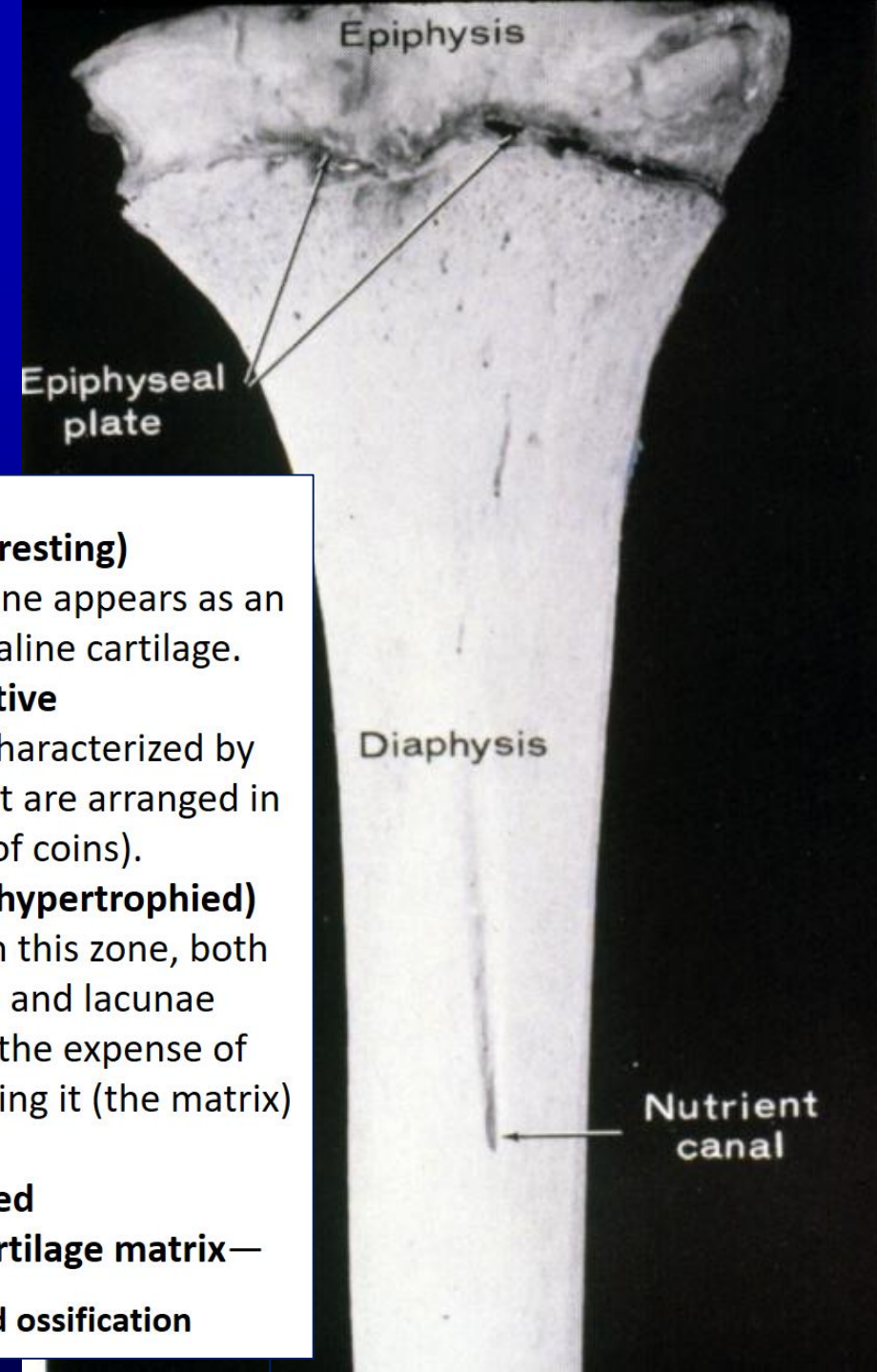
Zone of reserve (resting) cartilage—this zone appears as an area of typical hyaline cartilage.

Zone of proliferative chondrocytes—characterized by chondrocytes that are arranged in rows (like stacks of coins).

Zone of mature (hypertrophied) chondrocytes—in this zone, both the chondrocytes and lacunae have enlarged at the expense of the matrix, reducing it (the matrix) to thin strands.

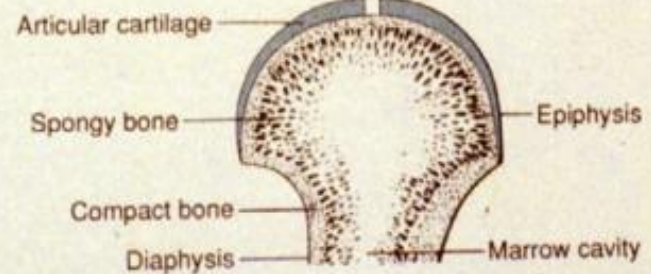
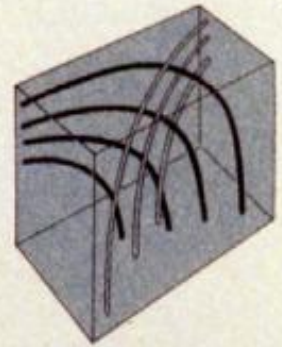
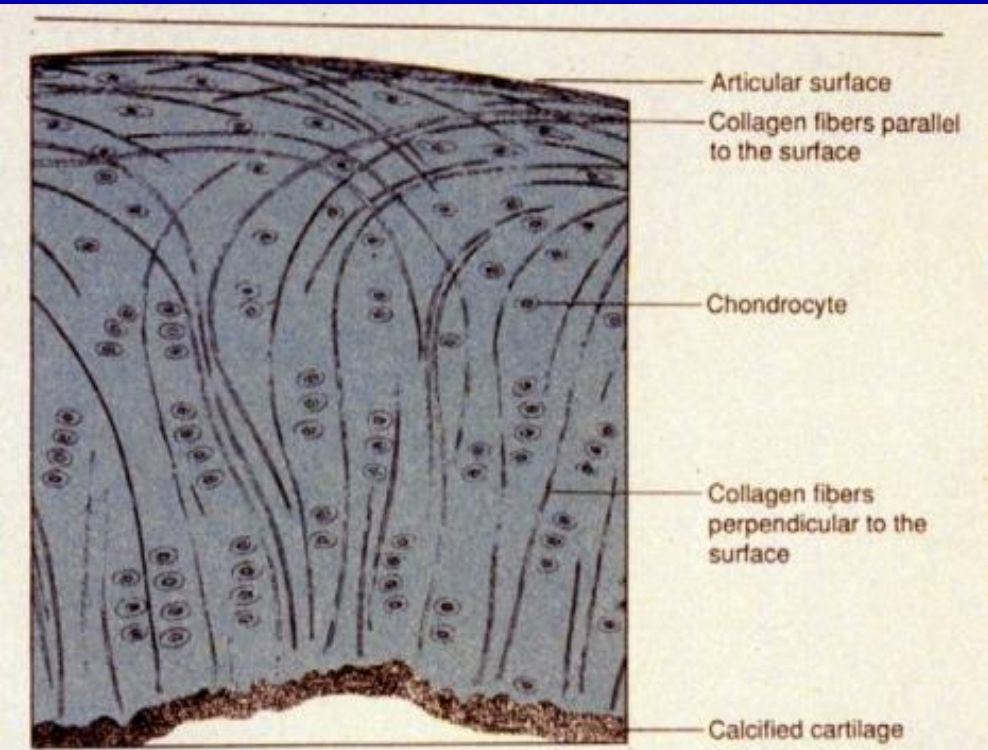
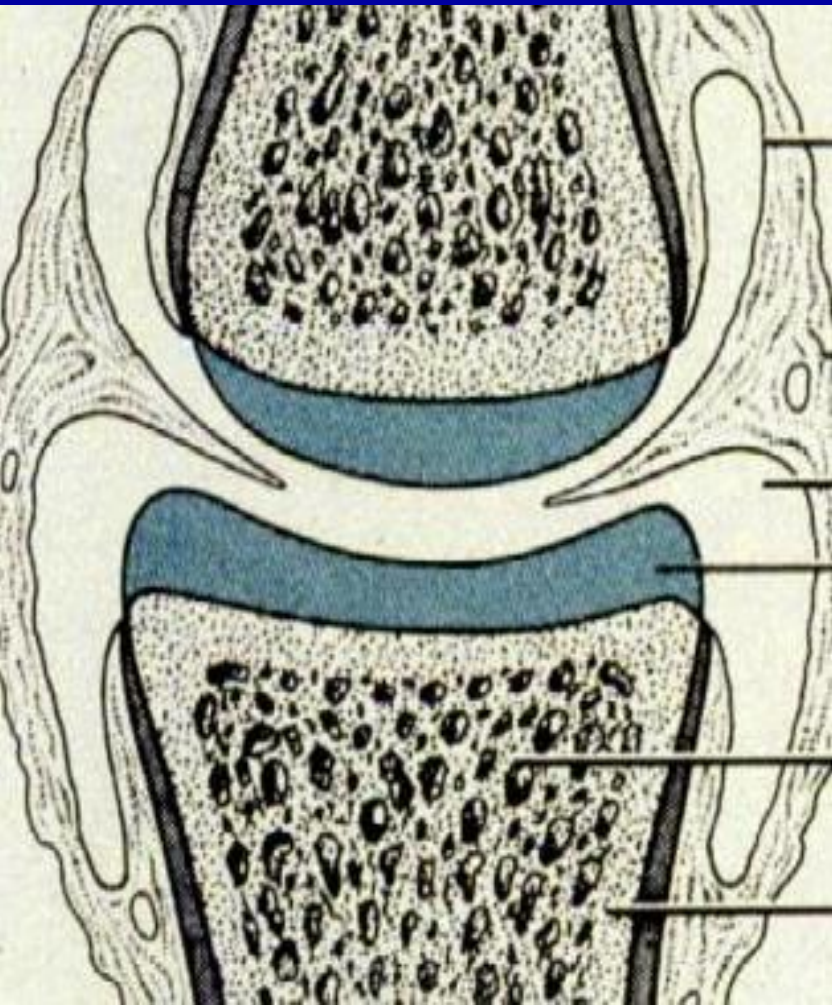
Zone of calcified chondrocytes/cartilage matrix—

Zone of erosion and ossification



Hyaline Cartilage

Found at articular surfaces of movable bones



Hyaline Cartilage

Found at articular surfaces of movable bones

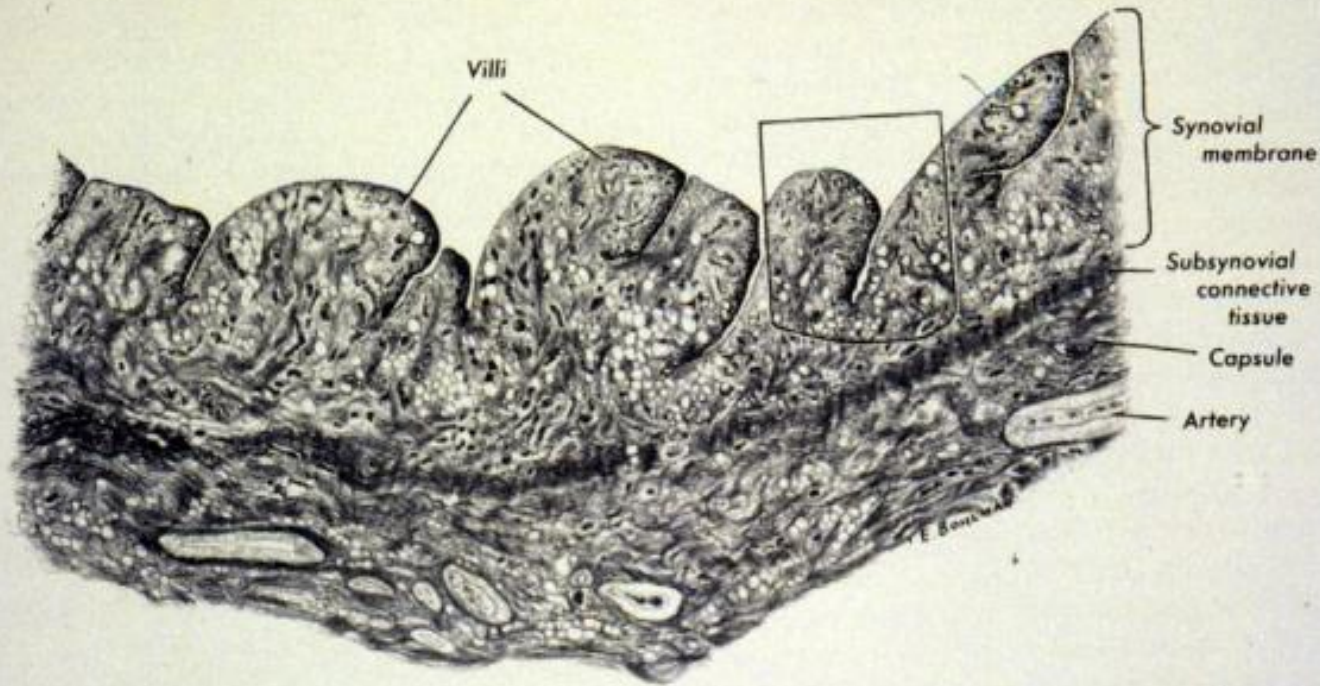


Figure 8-37. Section through capsule of the knee joint of a young man, showing the villi and connective tissue components. The area outlined is shown at higher magnification in Figure 8-38. (From a preparation of H. Hatcher)

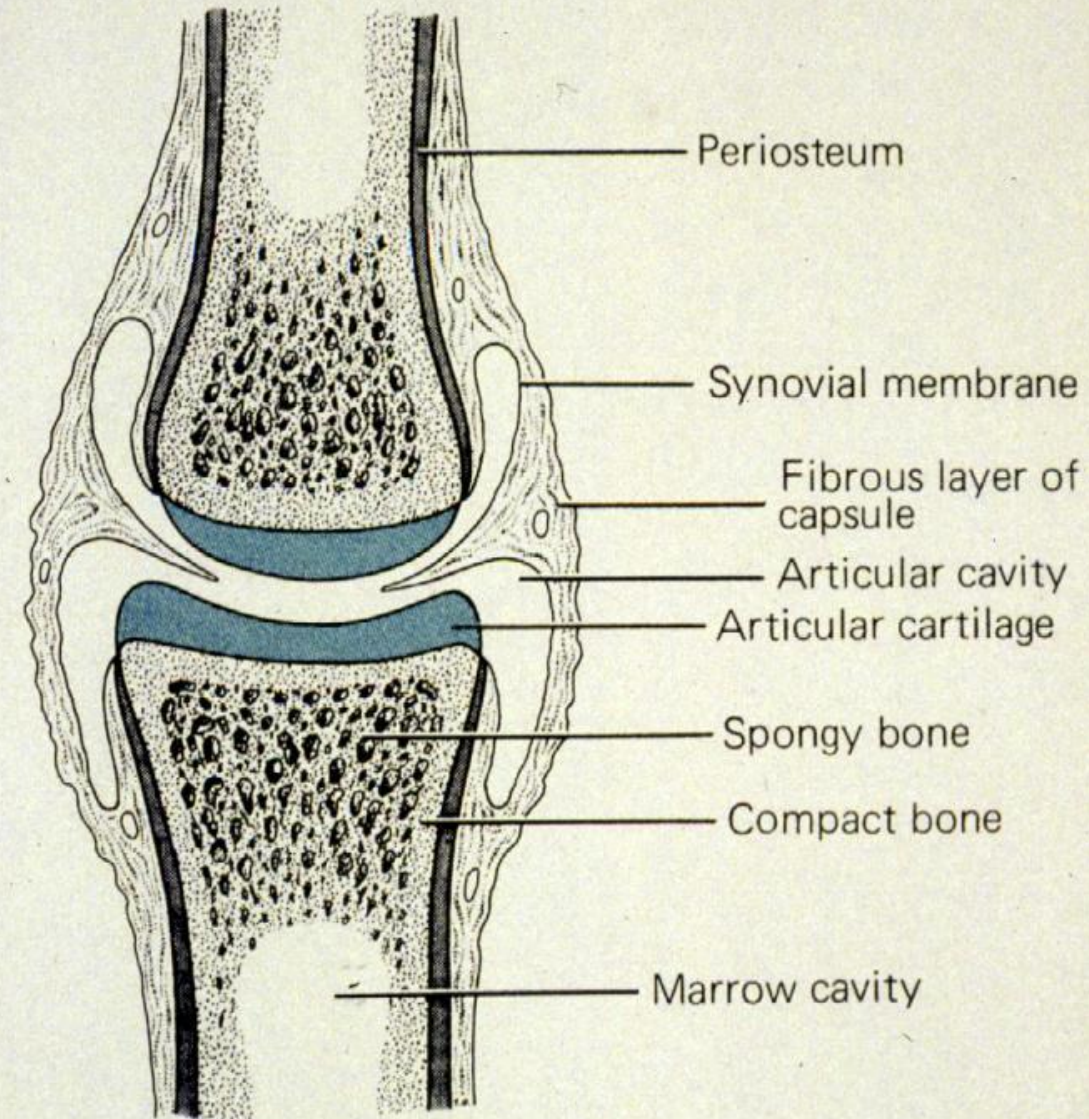
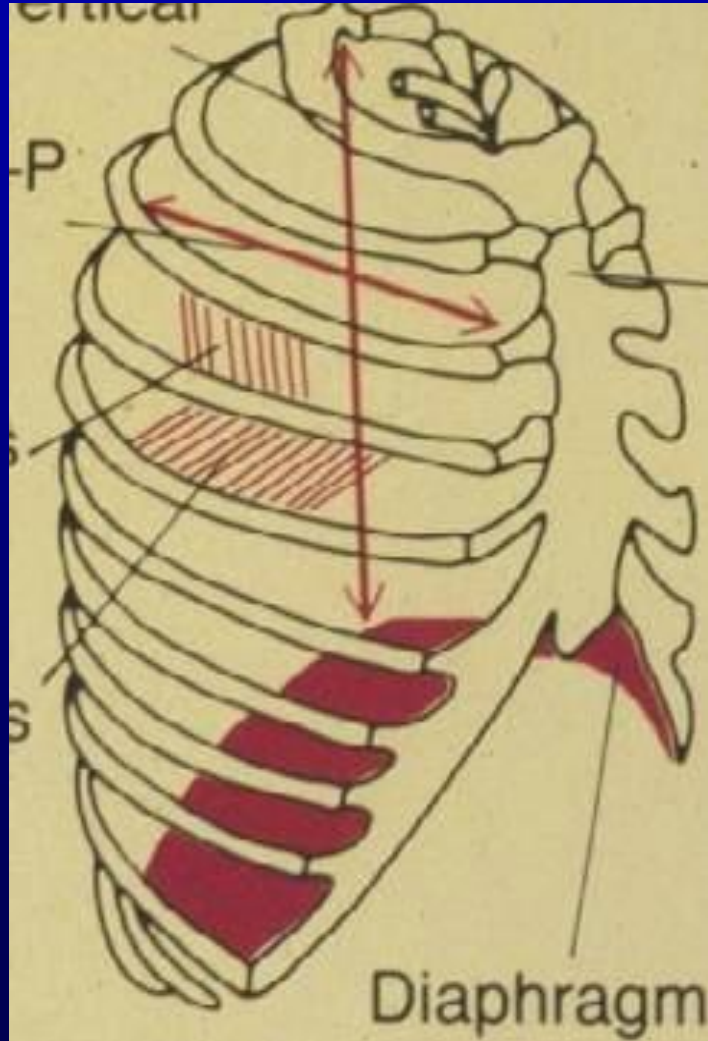


Figure 8-22. Schematic drawing of a diarthrosis. The capsule is formed by 2 parts: the external **fibrous layer** and the **synovial layer** (synovial membrane) that lines the articular cavity except for the cartilaginous areas.

Hyaline Cartilage

Attaches sternum to ribs

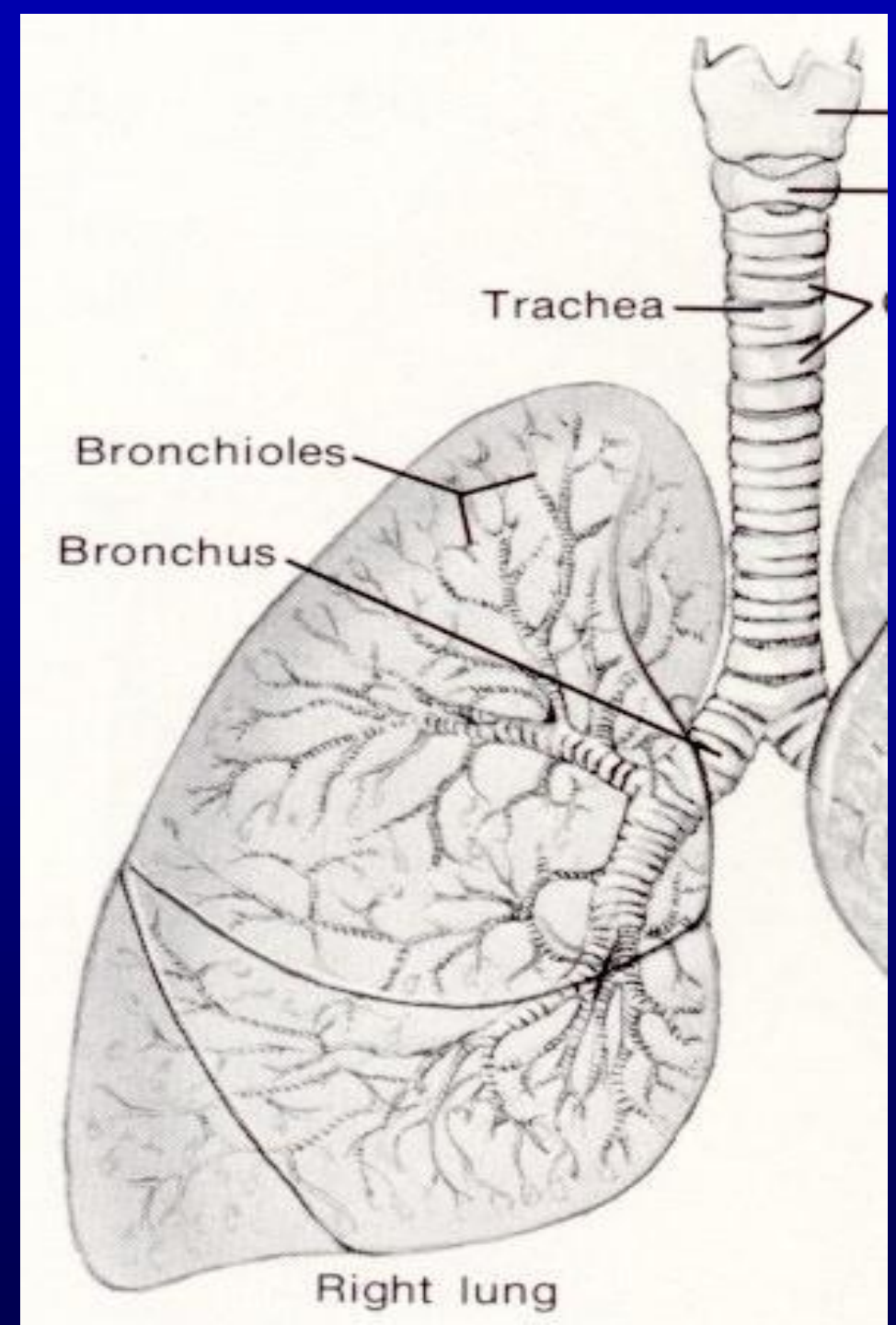
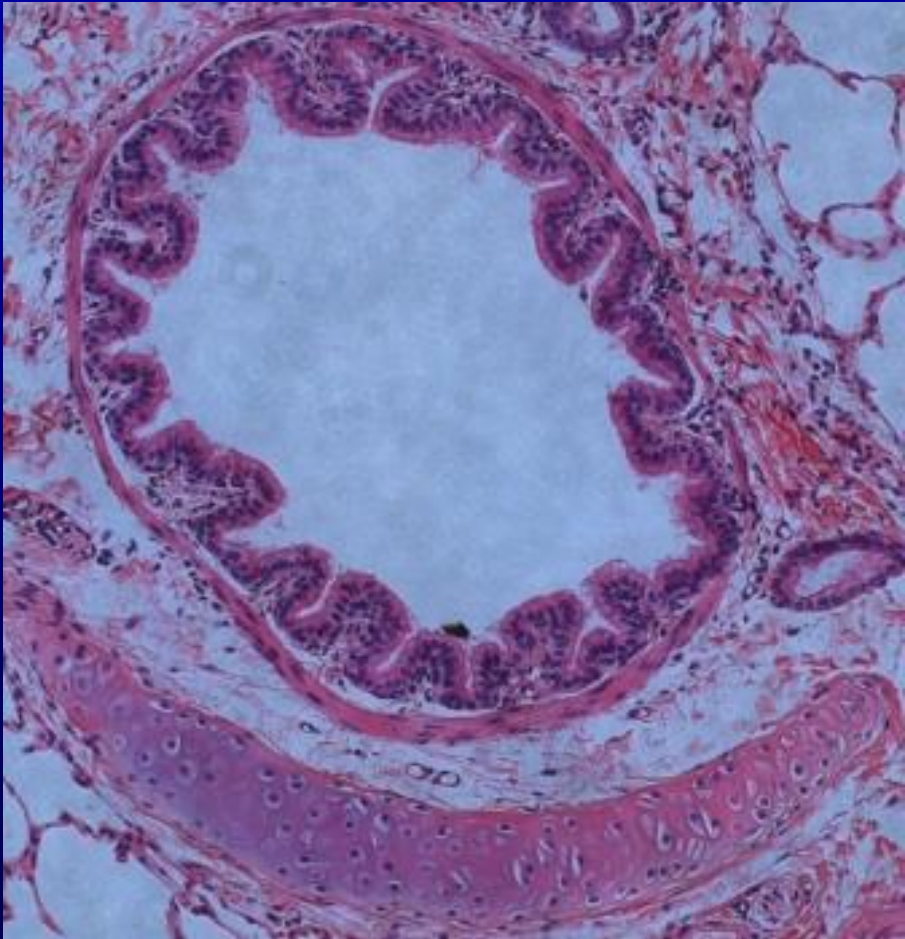


Gunther von Hagens
BODY WORLDS
The Anatomical Exhibition of Real Human Bodies



Hyaline Cartilage

In walls of respiratory passages
to hold them open air cavity under low
vacuum conditions.



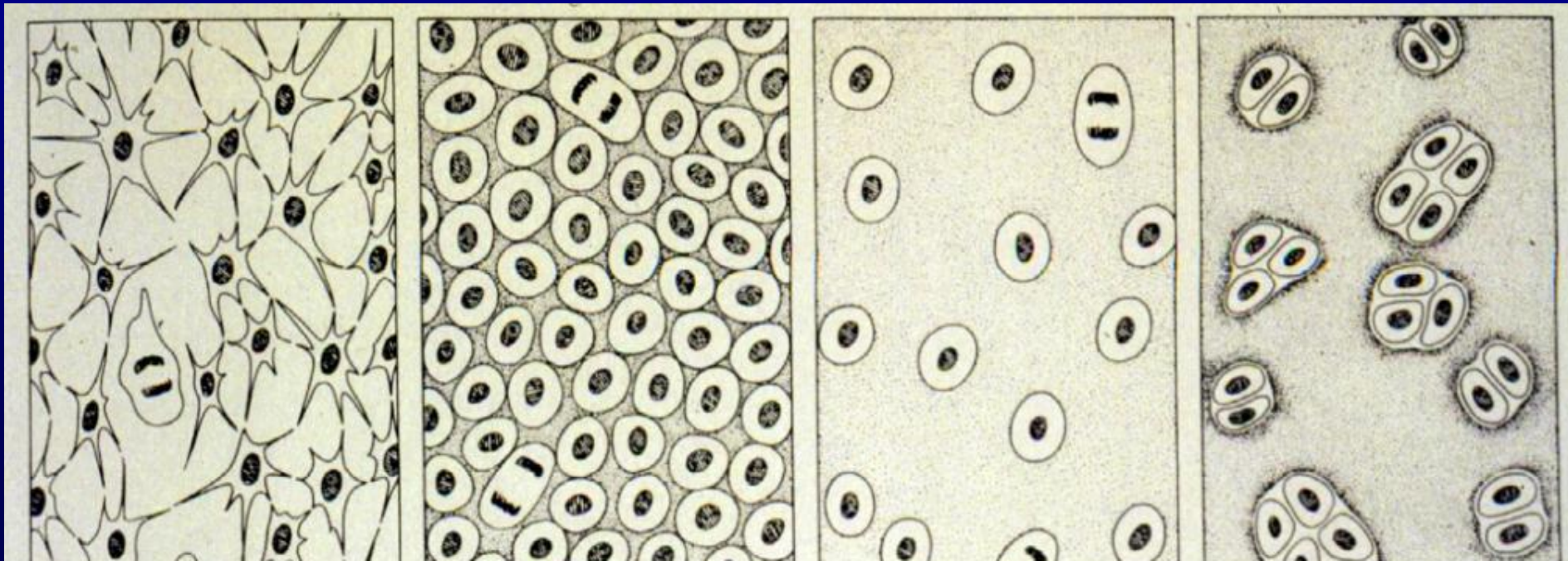
Histogenesis of Cartilage

Centers of chondrification – from mesenchymal cells

Growth

Interstitial - from within by division of preexisting chondrocytes

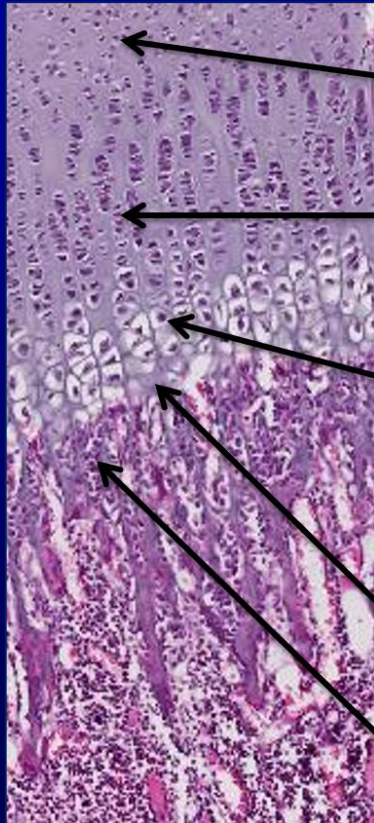
- Isogenous group - 8 cells from one



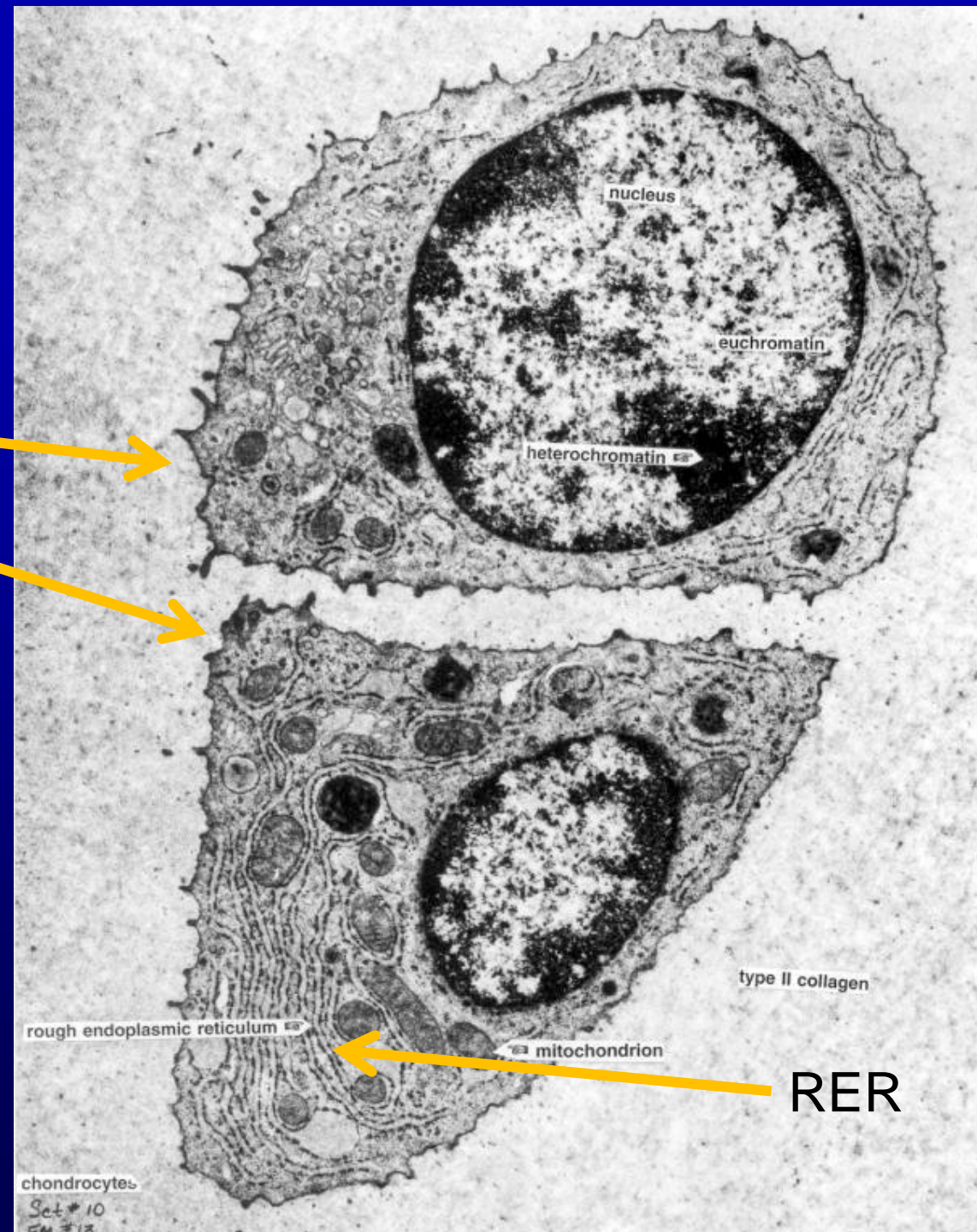
EM 13: Chondrocytes

Interstitial growth =
mitotic division within the cartilage,
chondrocytes

Growth plate



- Zone of reserve (resting) cartilage**—this zone appears as an area of typical hyaline cartilage.
- Zone of proliferative chondrocytes**—characterized by chondrocytes that are arranged in rows (like stacks of coins).
- Zone of mature (hypertrophied) chondrocytes**—in this zone, both the chondrocytes and lacunae have enlarged at the expense of the matrix, reducing it (the matrix) to thin strands.
- Zone of calcified chondrocytes/cartilage matrix**—
- Zone of erosion and ossification**

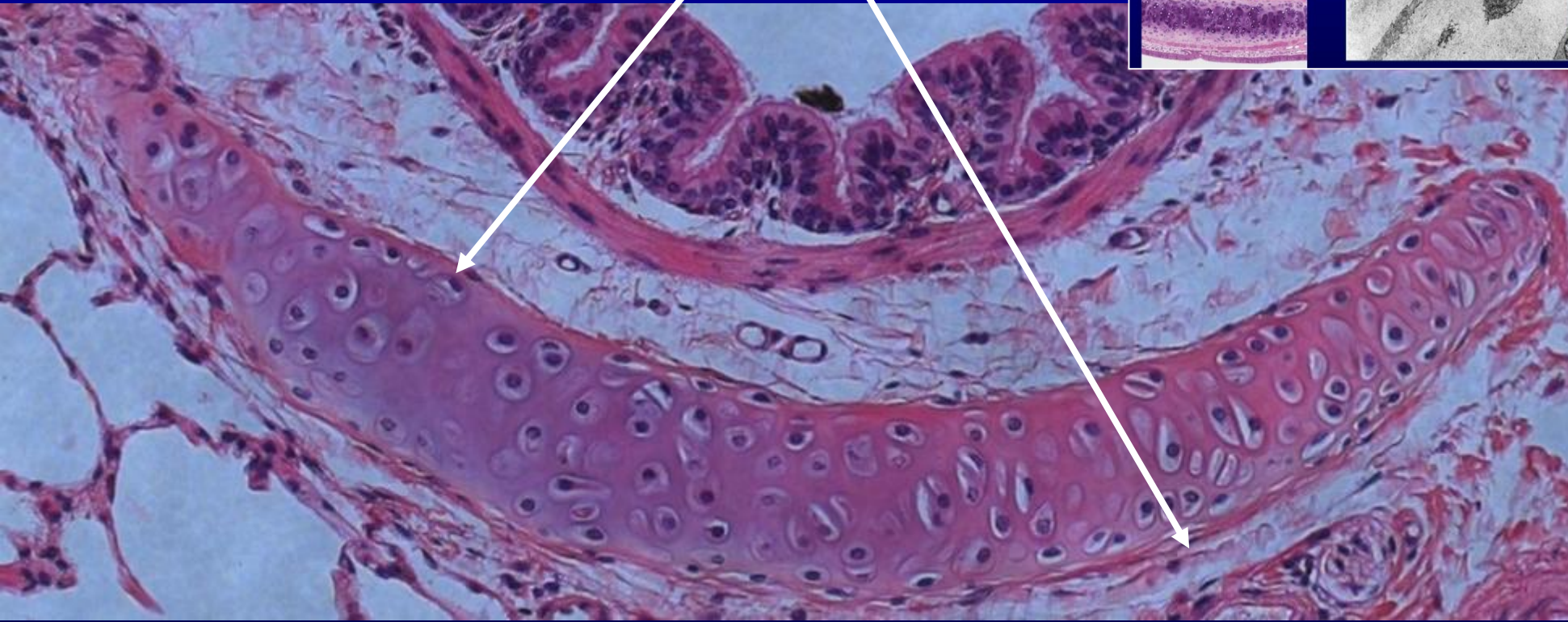


RER

Histogenesis of Cartilage

Growth

Appositional - occurs at surfaces from perichondrium by cell differentiation

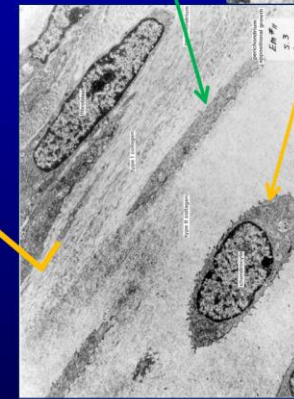
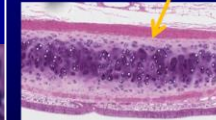


General Organization of Cartilage

Chondroblasts become chondrocytes

when they become trapped in lacunae (space) surrounded by matrix they secreted.

Perichondrium



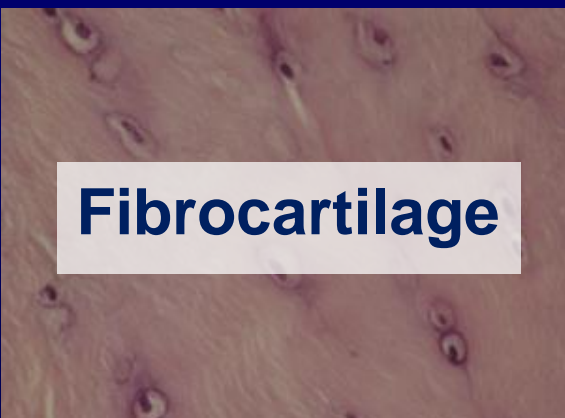
Summary of Cartilage



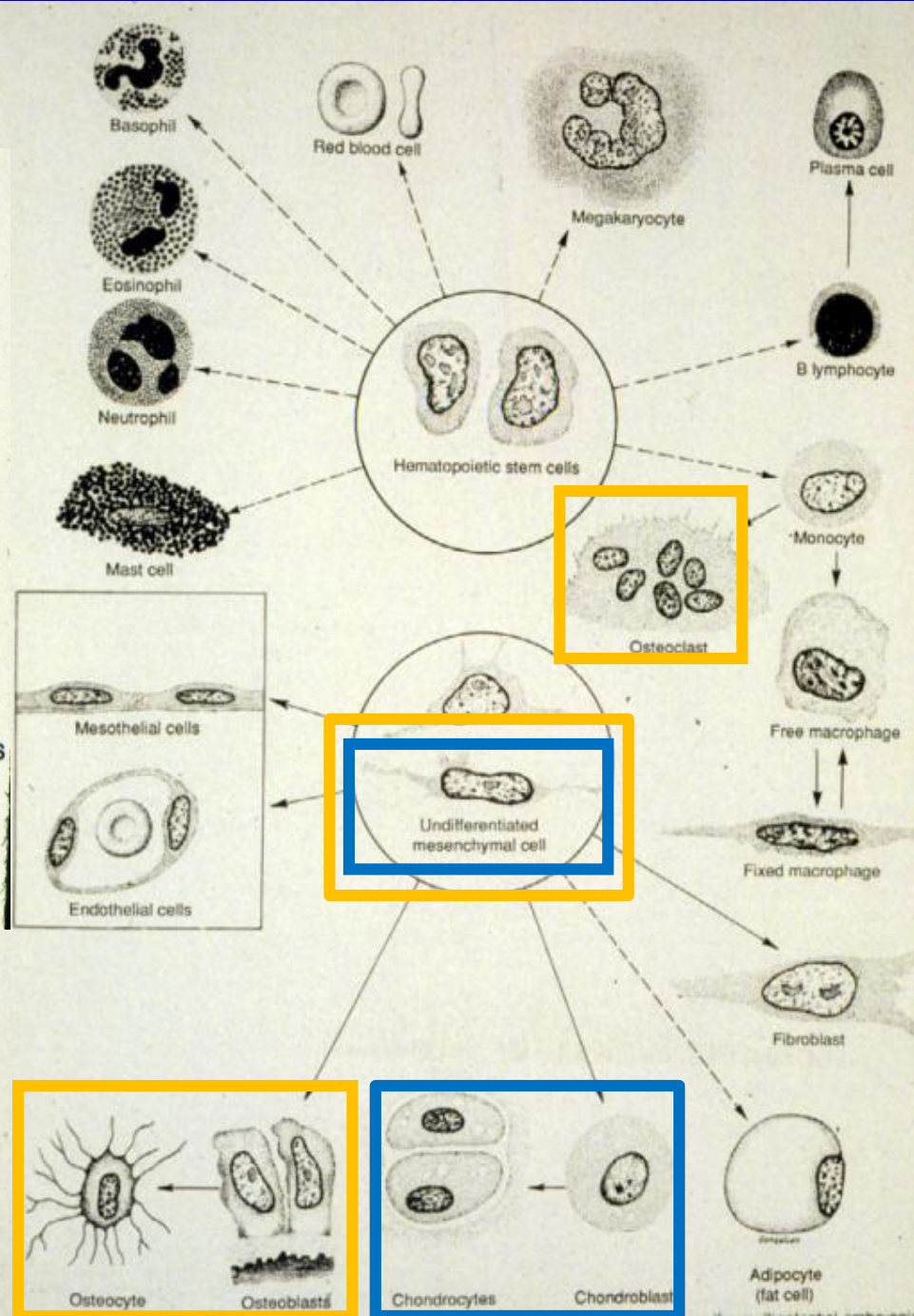
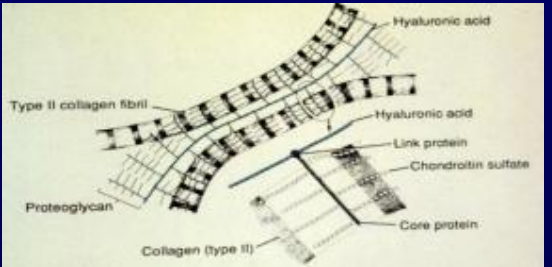
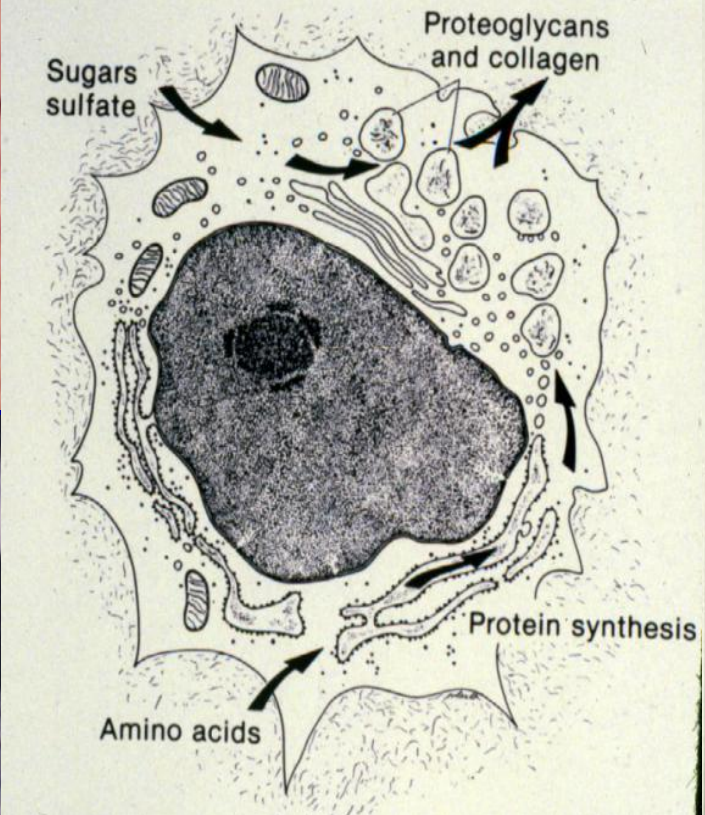
Hyaline



Elastic

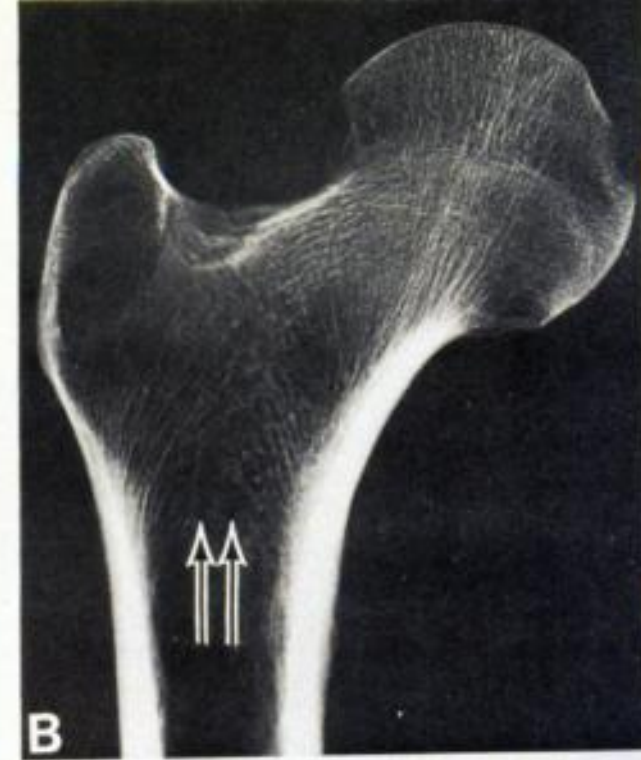
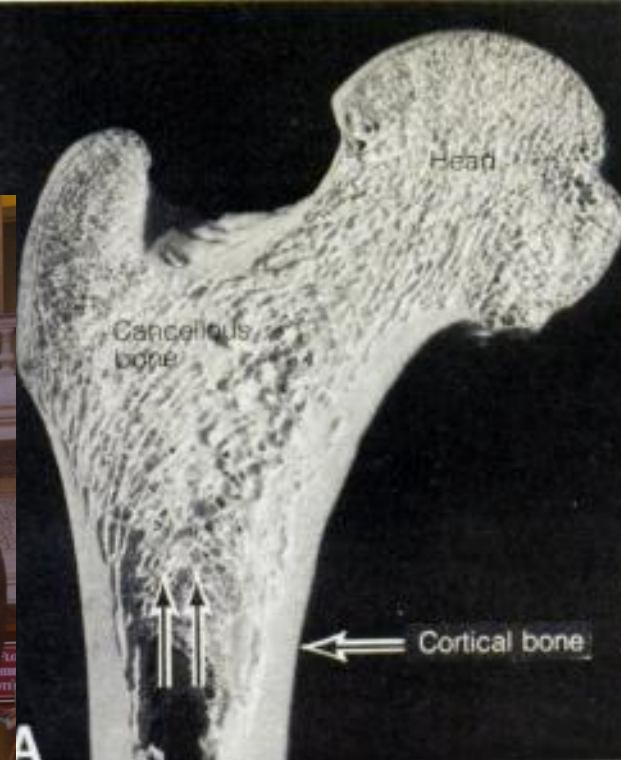


Fibrocartilage

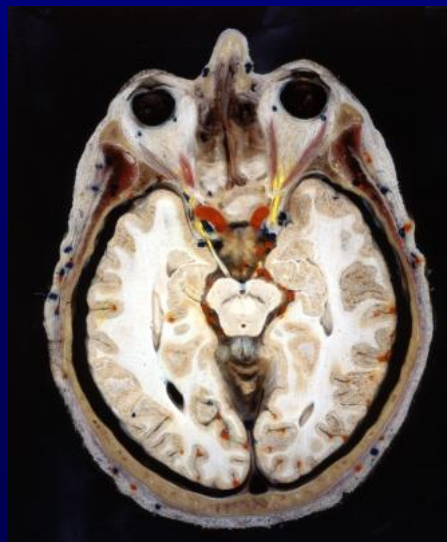


Functions of Bone

Skeletal support land animals

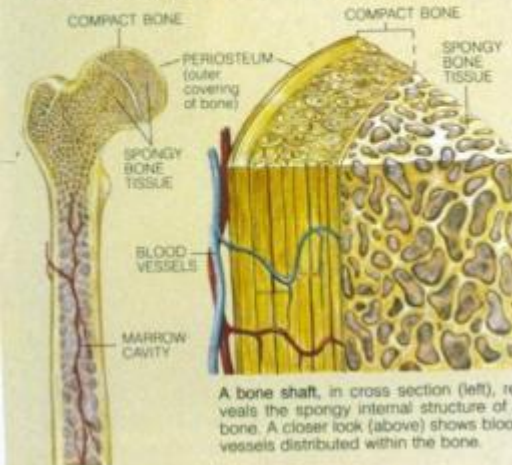


Protective enclosure
Skull to protect brain and long bone to protect hematopoietic cells



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.

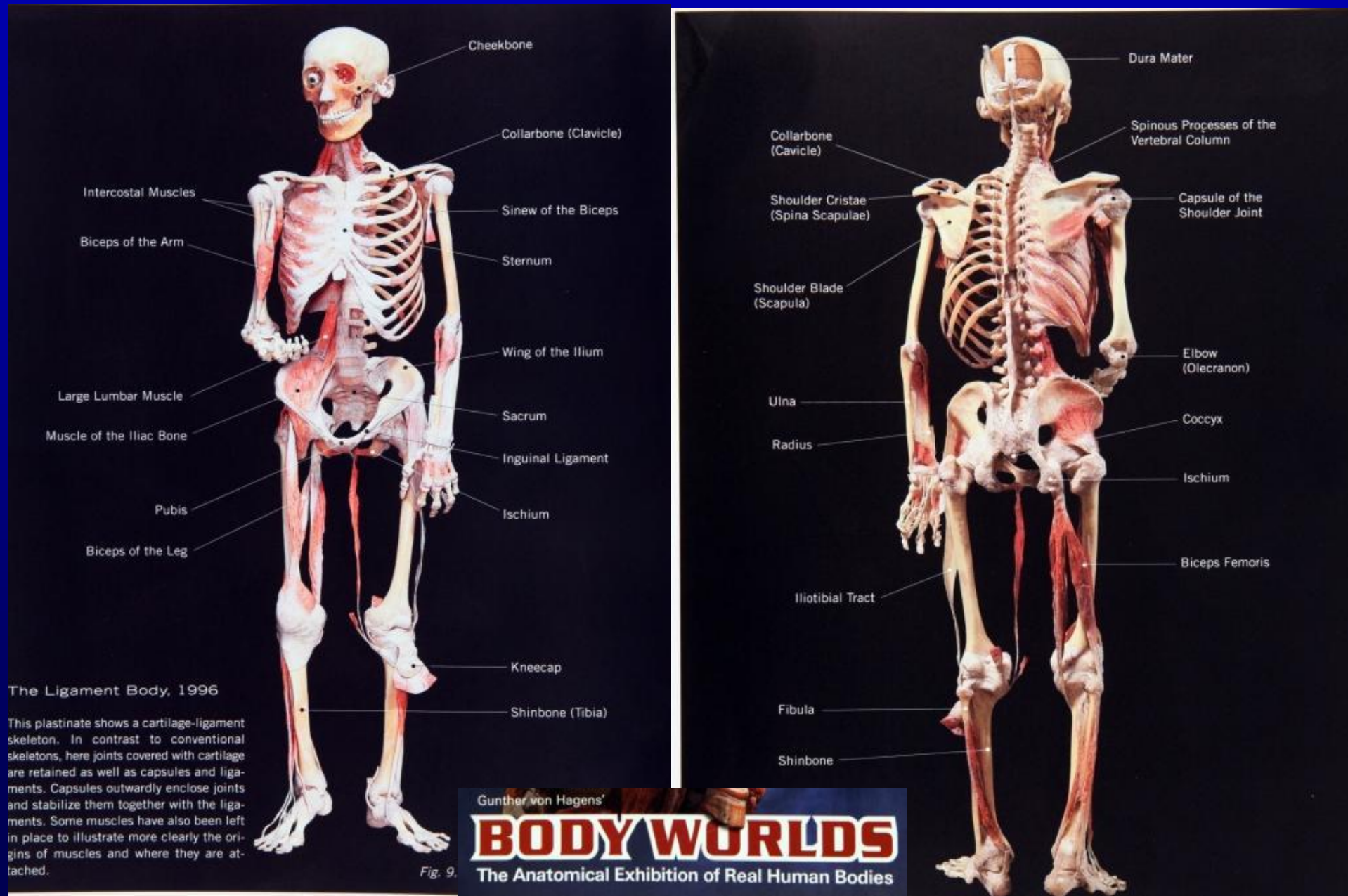


A bone shaft, in cross section (left), reveals the spongy internal structure of a bone. A closer look (above) shows blood vessels distributed within the bone.



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

Functions of Bone



Functions of Bone

Calcium regulation

Parathyroid 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.

Hematopoiesis

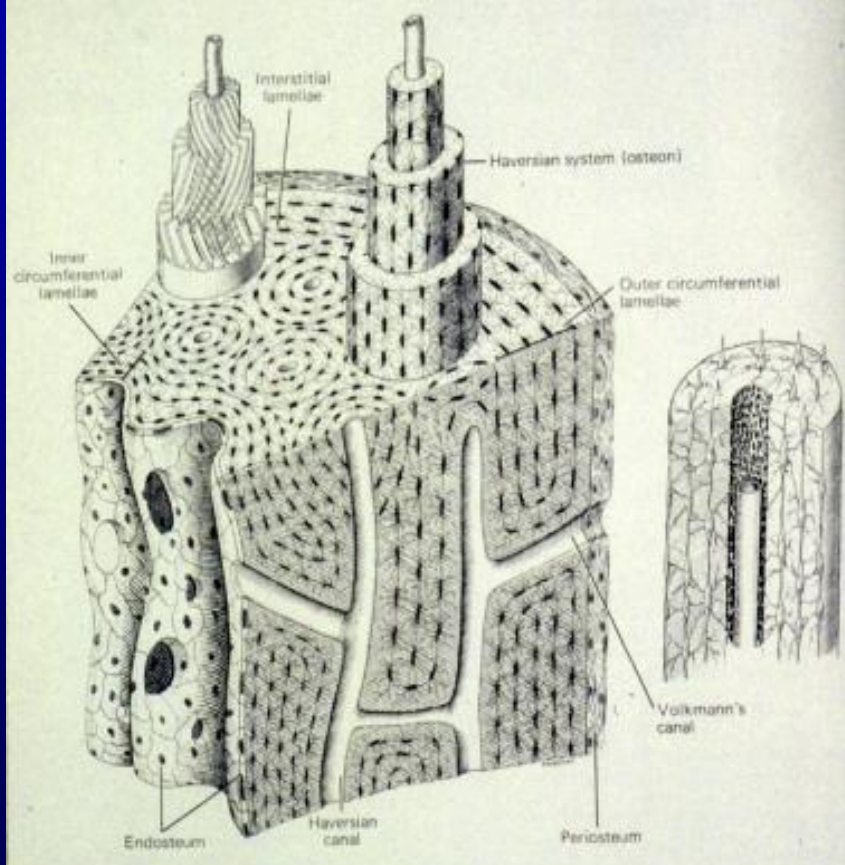
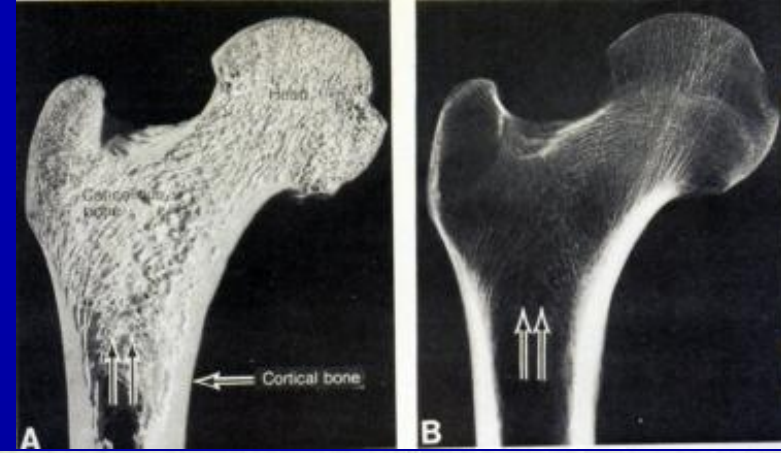
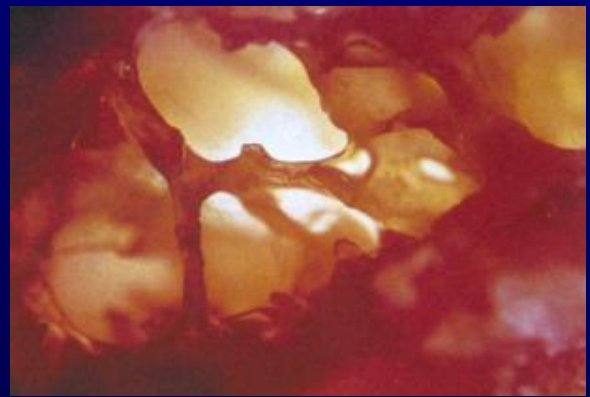
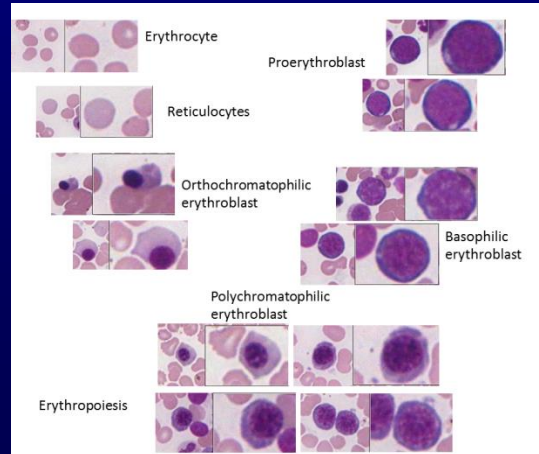


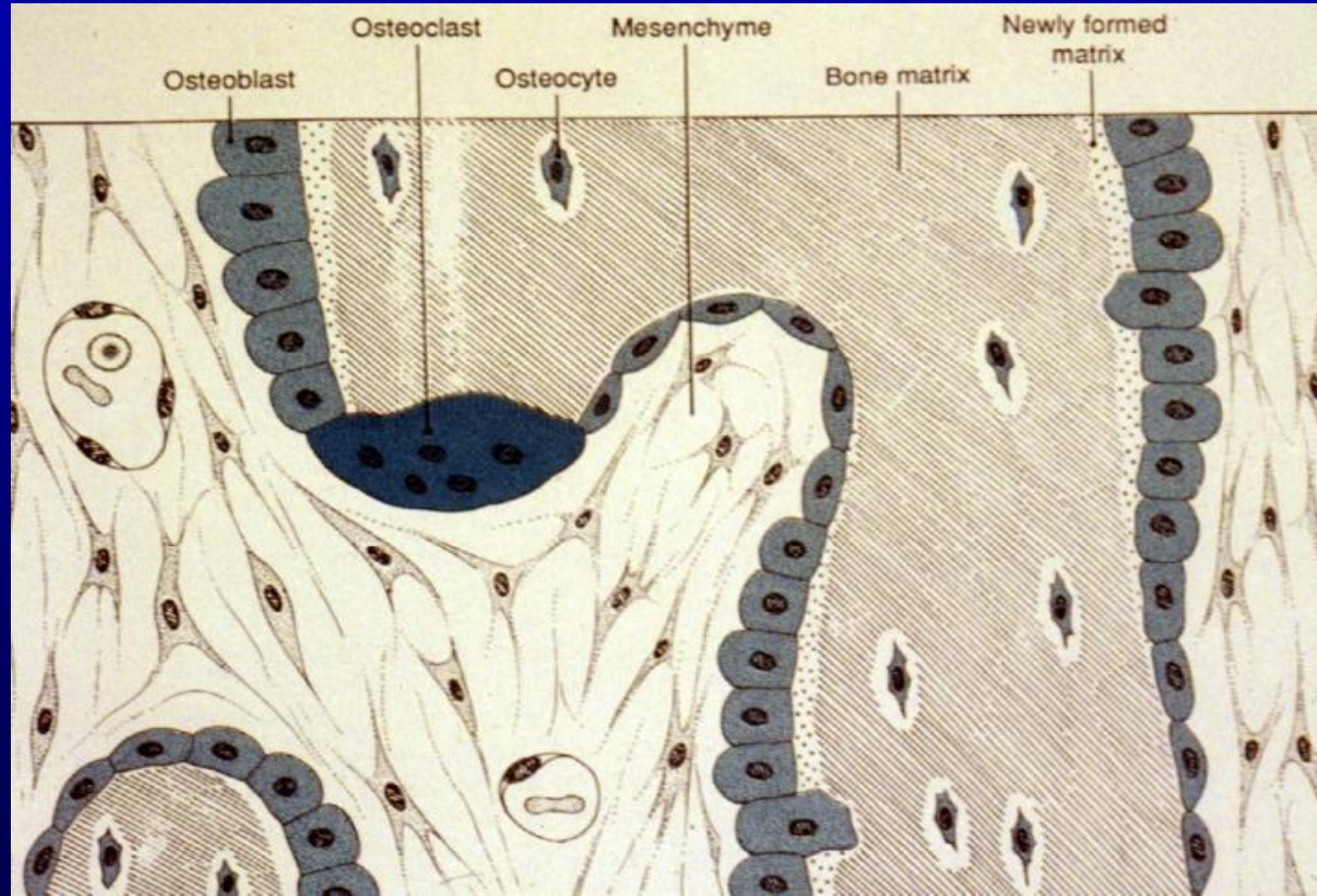
Figure 5-6. Schematic drawing of the wall of a long bone diaphysis. Observe the 4 types of lamellar bone: haversian system, outer and inner circumferential lamellae, and interstitial lamellae. The protruding haversian system on the left shows the orientation of collagen fibers in each lamella. At the right is a haversian system showing lamellae, a central blood capillary, and many osteocytes with their processes.

Cells of Bone

Osteoblasts - secrete osteoid - bone

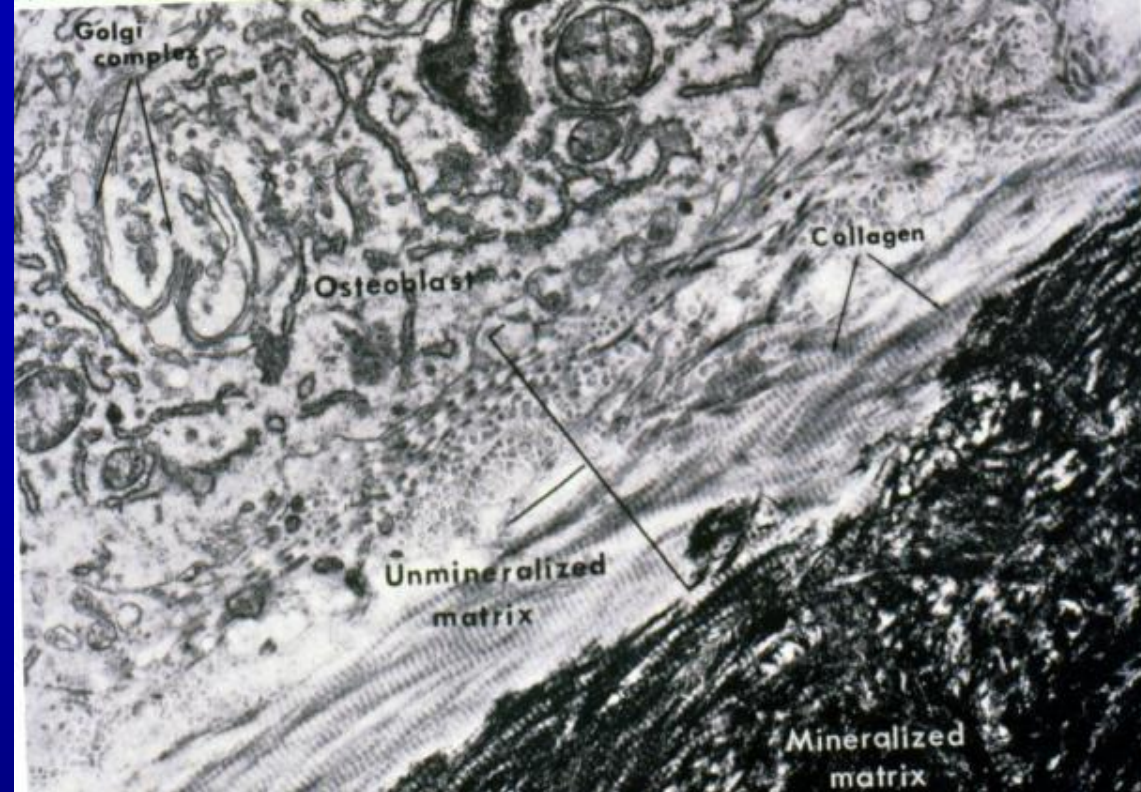
– Expand bone by appositional growth

**Osteocyte =
osteoblast
trapped in
matrix of
bone**



Cells of Bone

Osteoblasts



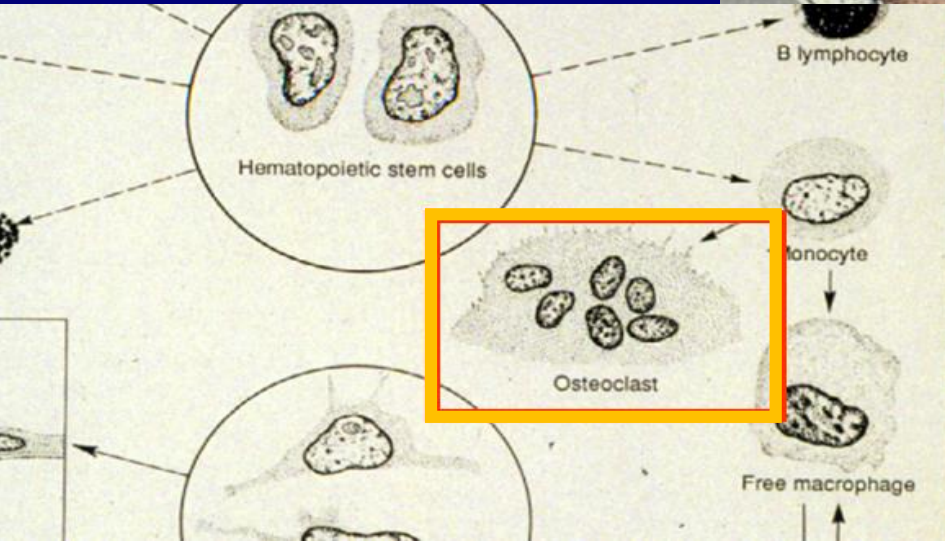
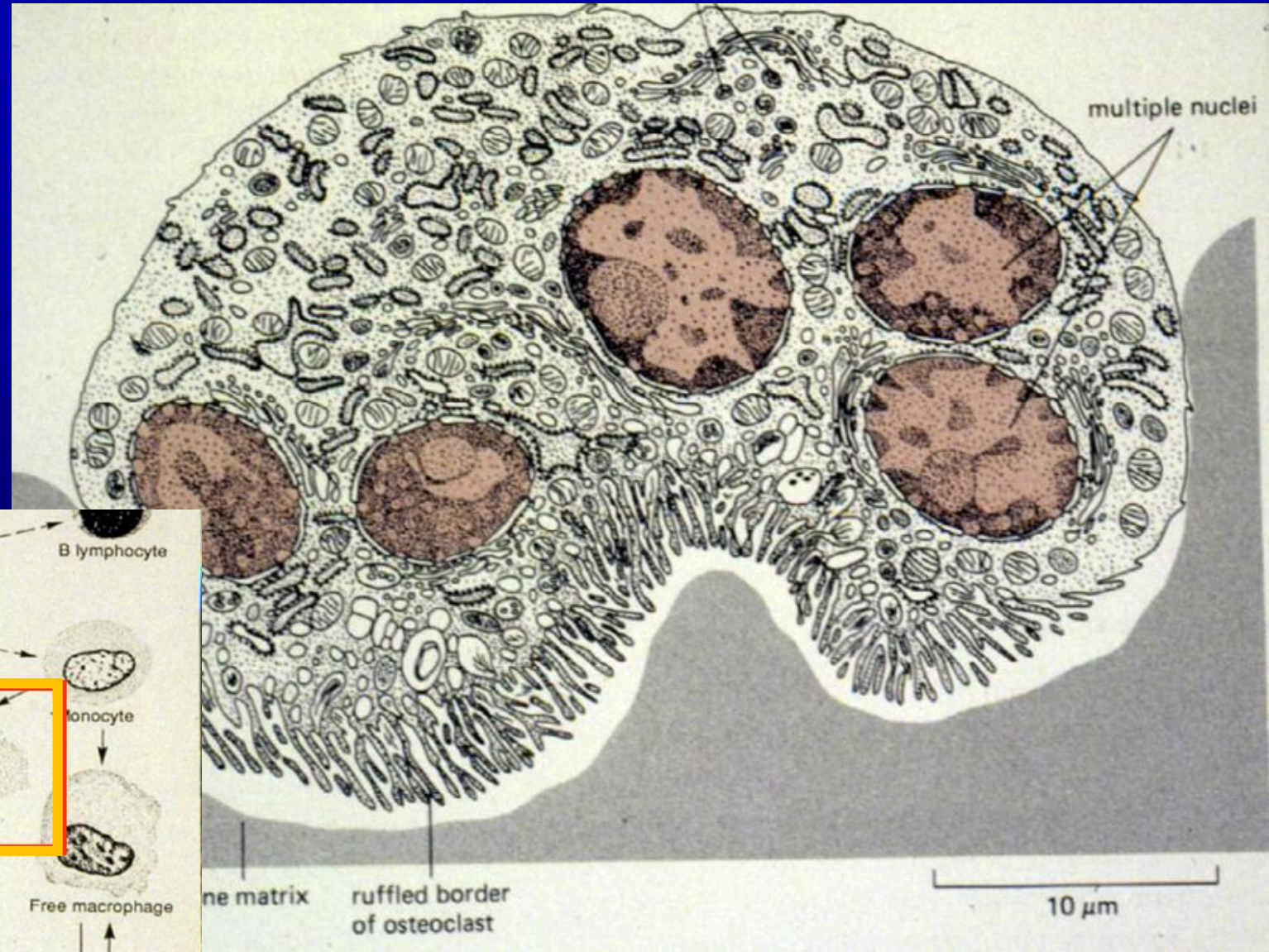
Osteocytes – osteoblasts trapped in matrix of bone



Cells of Bone

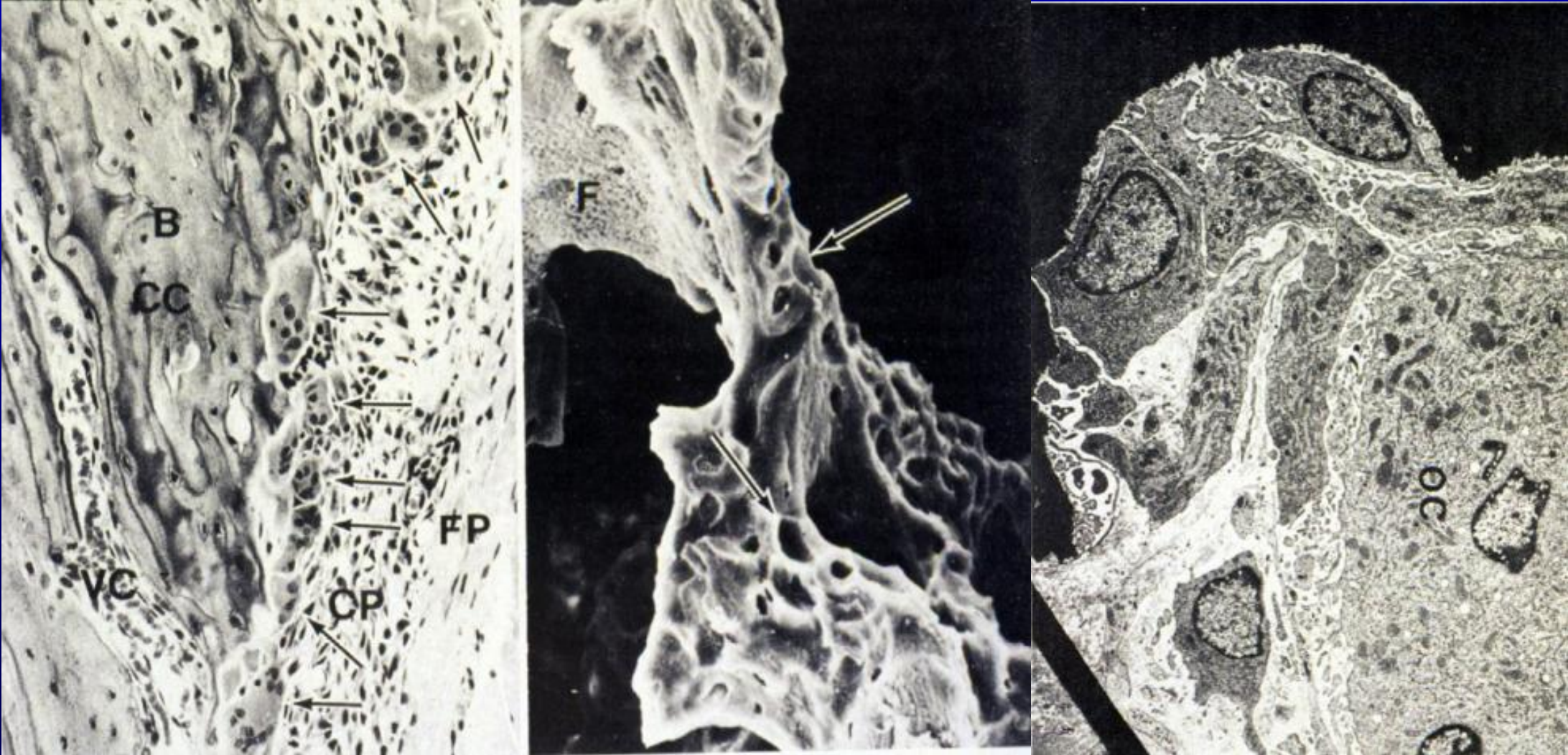
Osteoclasts - multinucleated phagocytic

Cells
from
monocytes



Cells of Bone

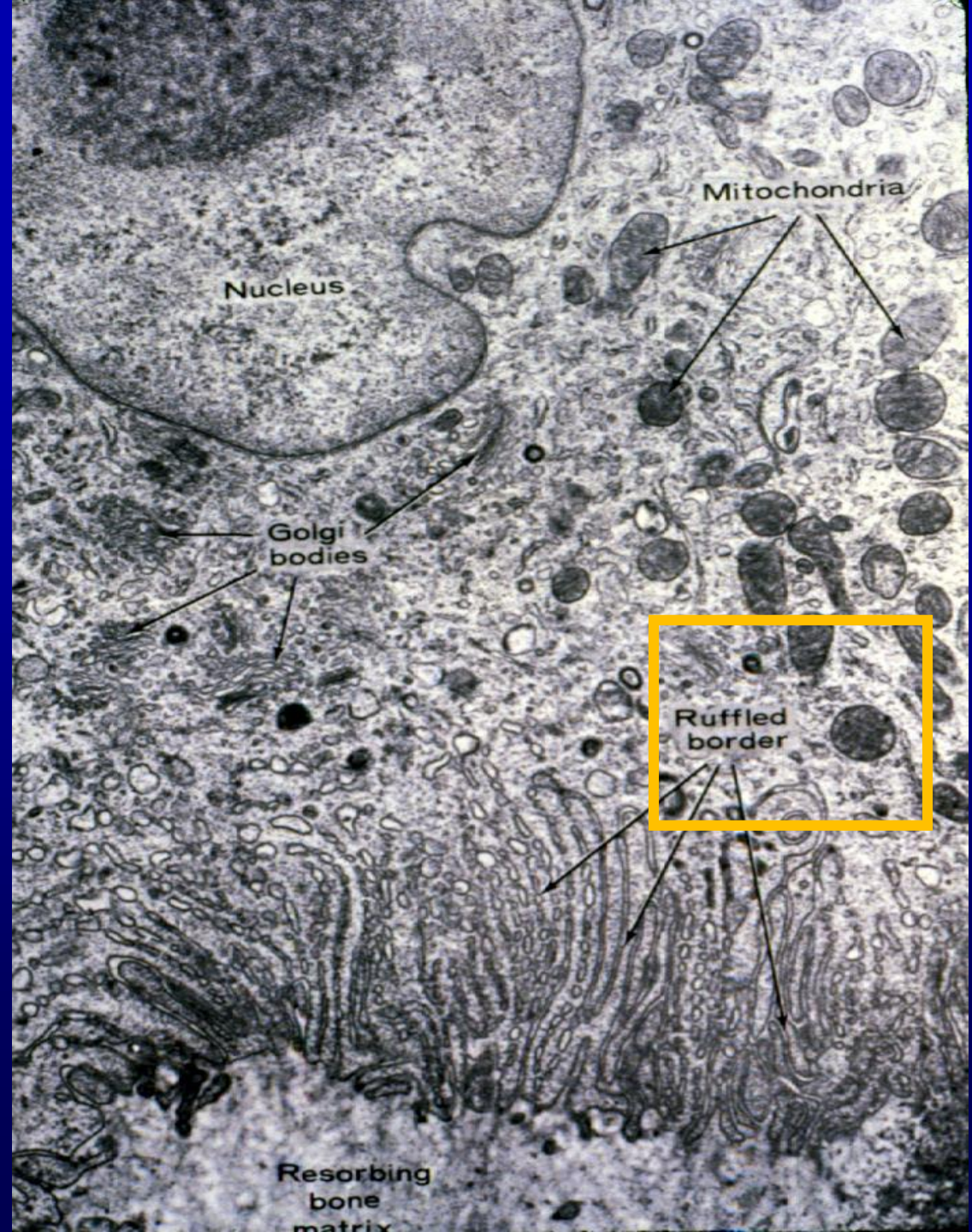
Osteoclasts - multinucleated phagocytic cells



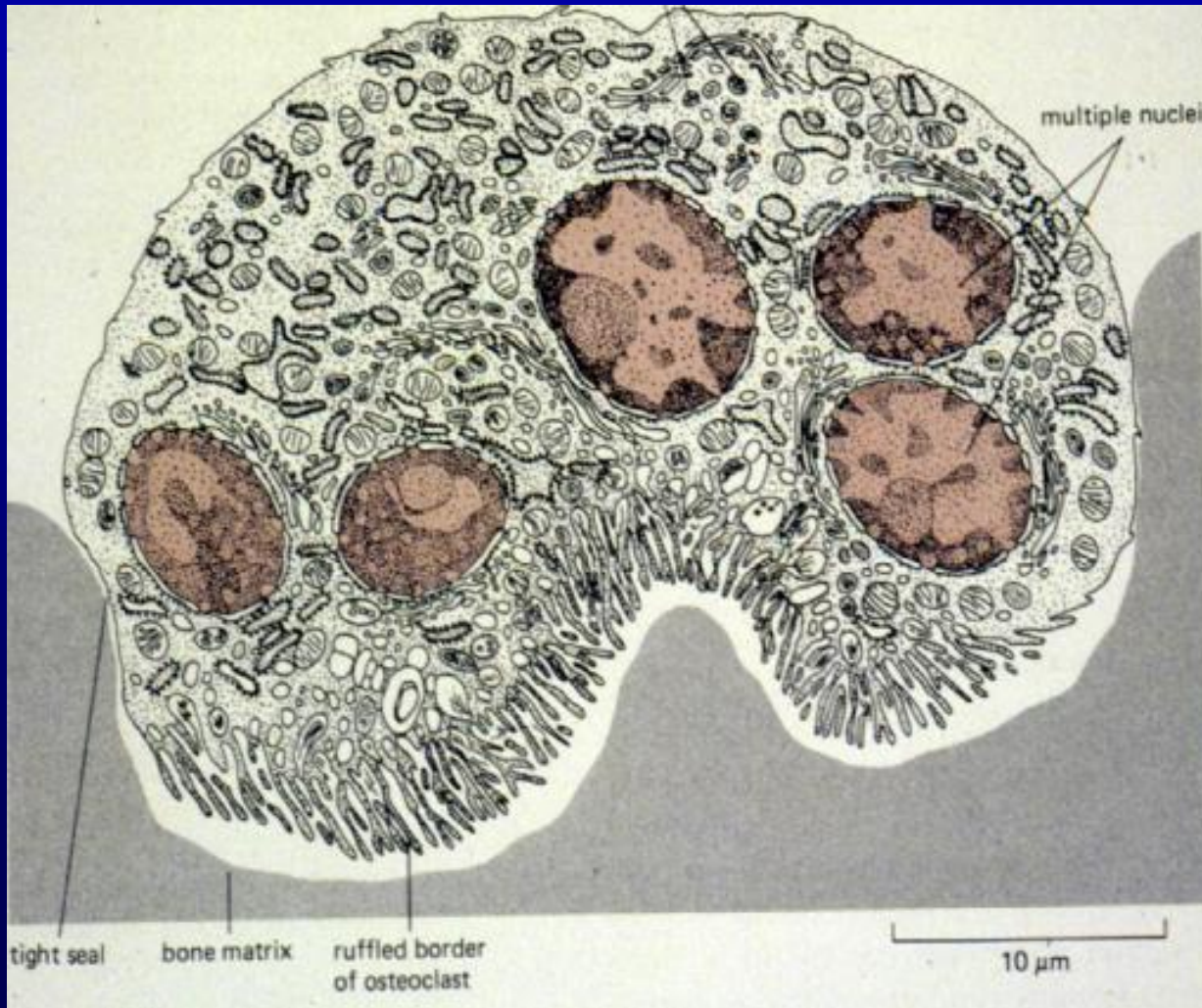
Cells of Bone

Osteoclasts

Digest bone in **microenvironment** where it secretes citrate and lysosomes to lower pH to solubilize calcium phosphate and digest the type I collagen of bone



Cells of Bone



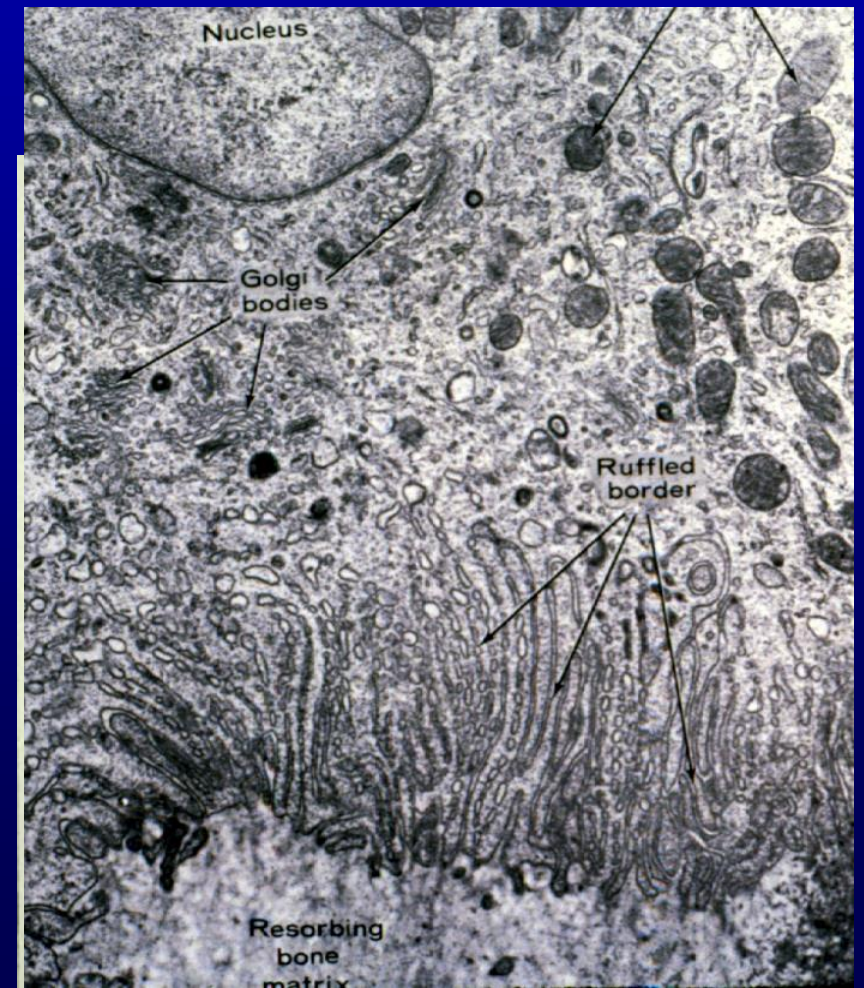
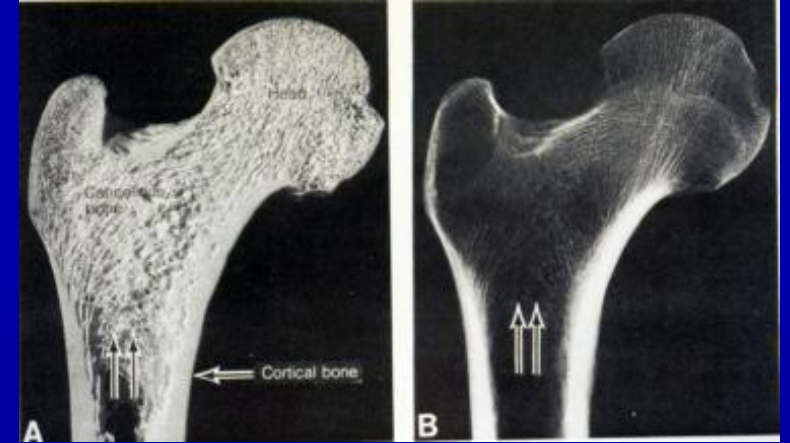
Functions of Bone

Calcium regulation

Parathyroid hormone (stimulates osteoclast production)

Calcitonin (removes osteoclast's ruffled border which prevents resorption)

Remember that these hormones are involved in tight regulation of free Ca^{++} as 1/4 of free Ca^{++} in blood is exchanged each minute.



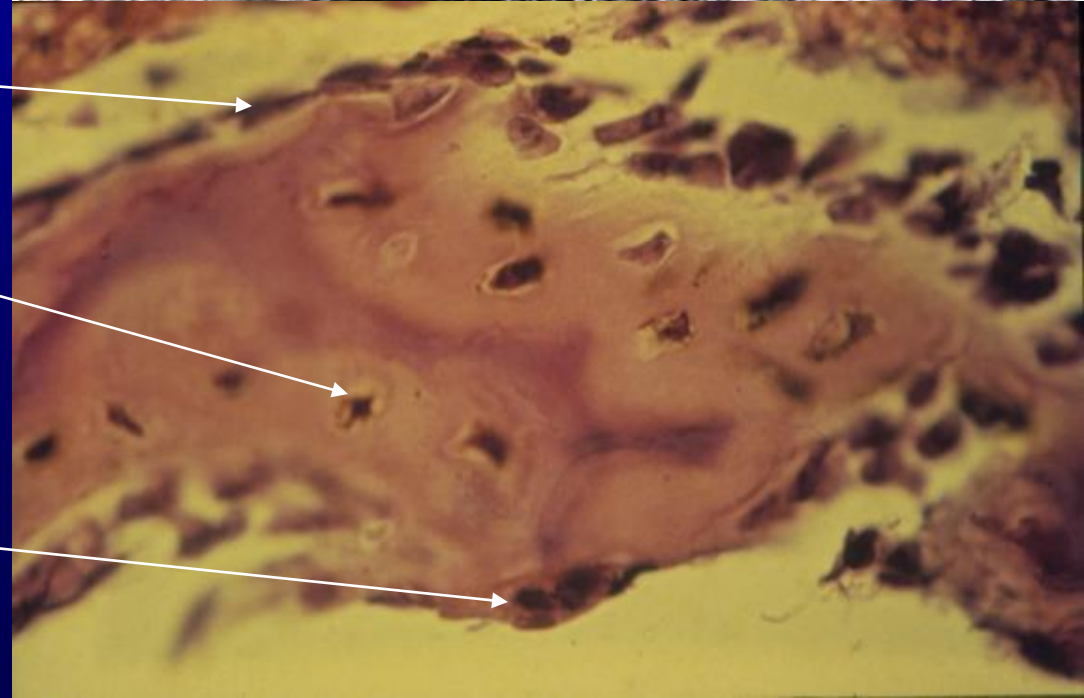
Cells Of Bone



Osteoblast

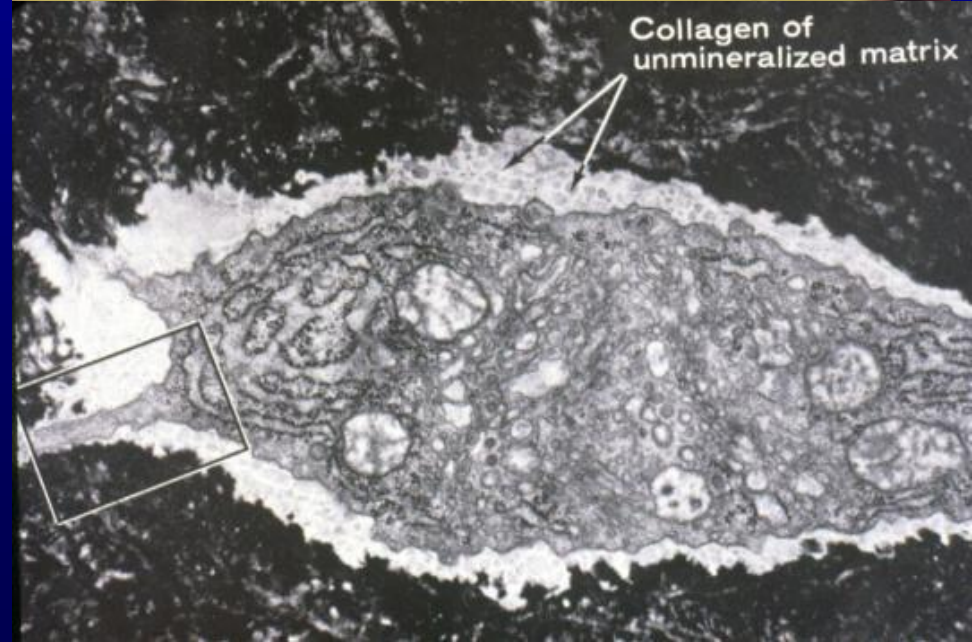
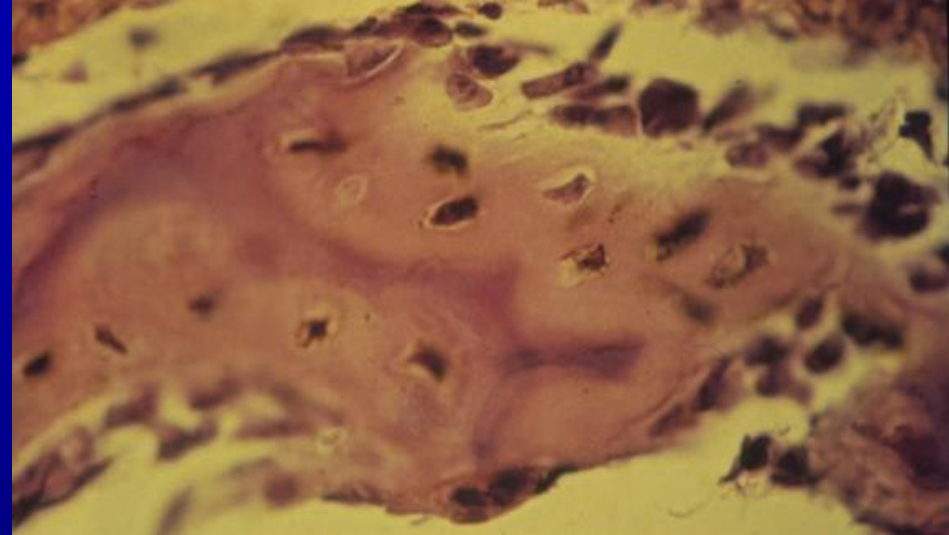
Osteocyte

Osteoclast



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**)



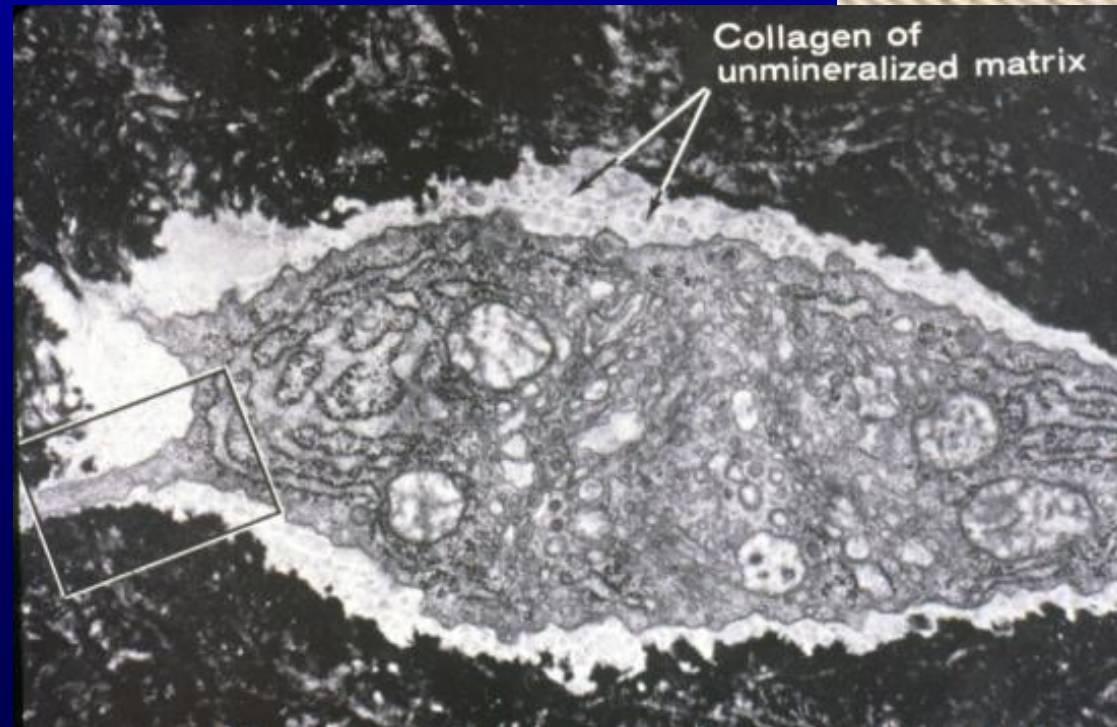
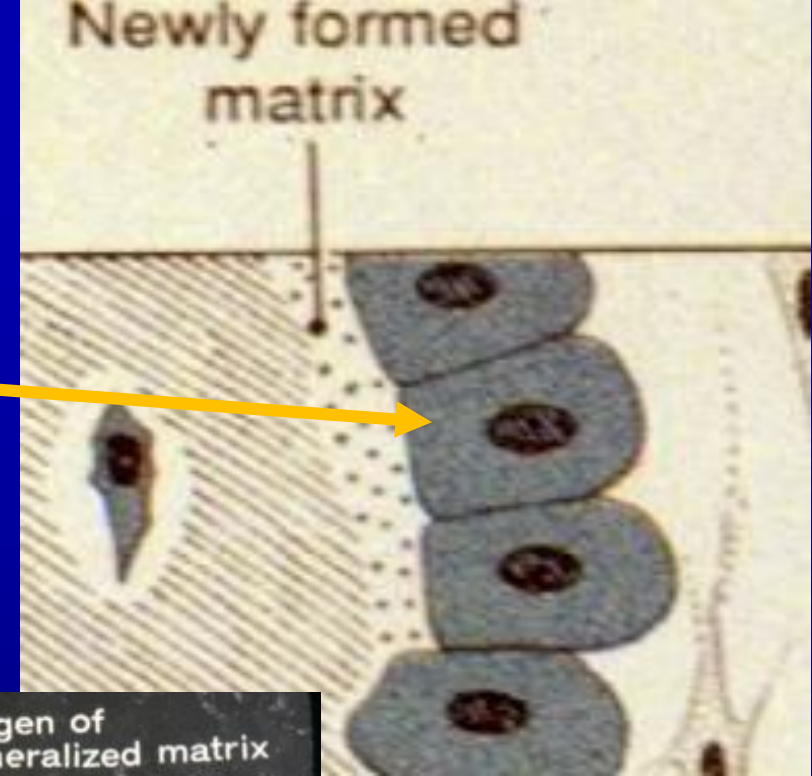
<http://www.youtube.com/watch?v=Rwya1Q2Rgho>

<http://www.youtube.com/watch?v=Uy5qGzGd7hl>

Extracellular Matrix of Bone

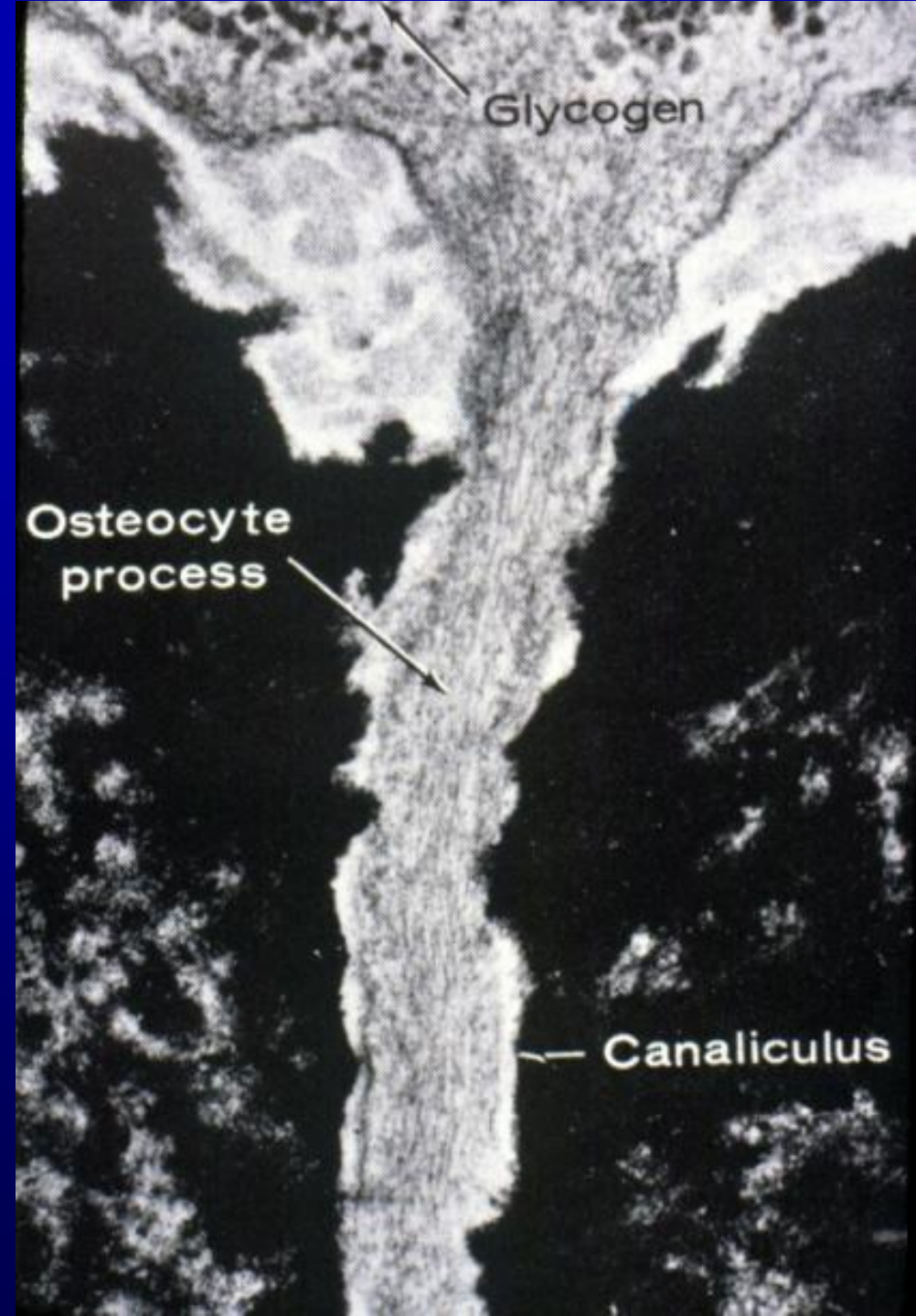
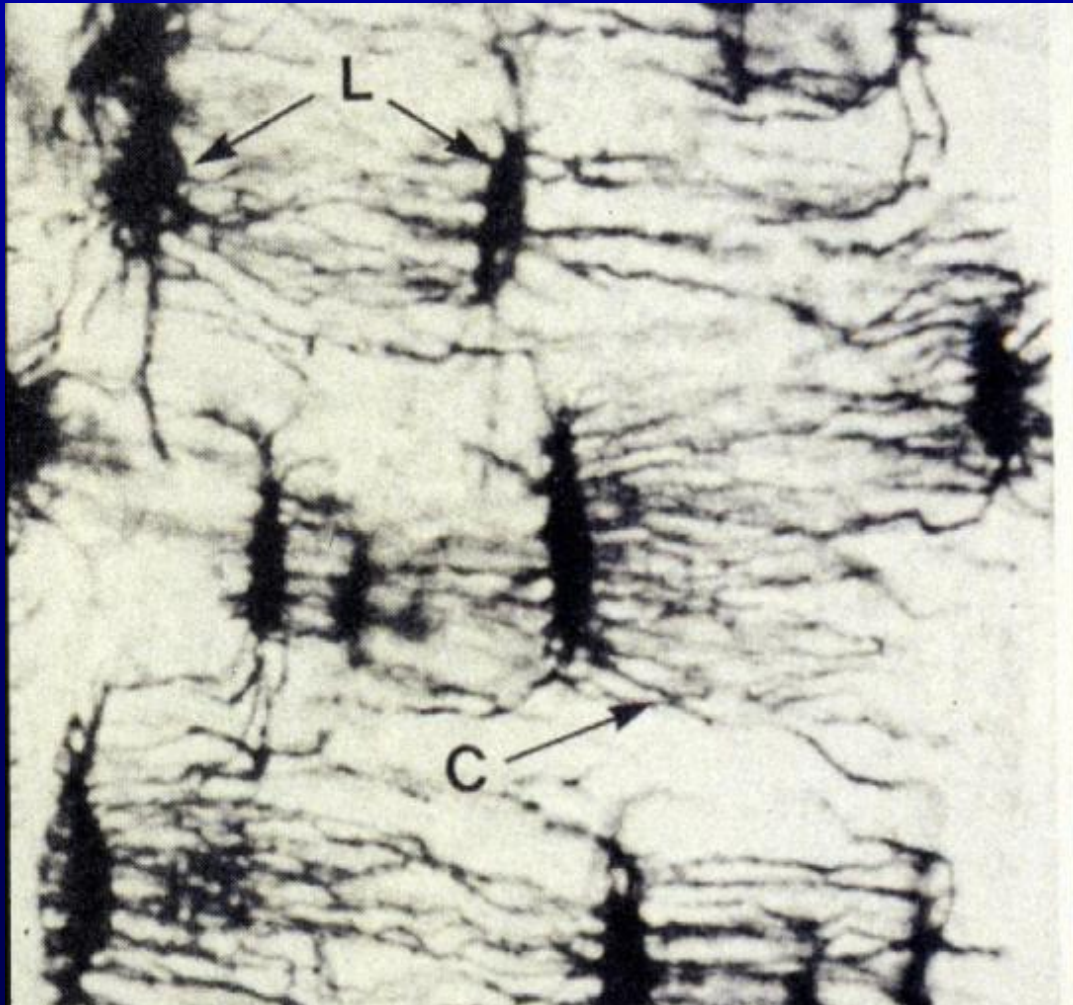
Secreted by **polarized** osteoblasts

Calcification - adds firmness, but prevents diffusion through matrix material



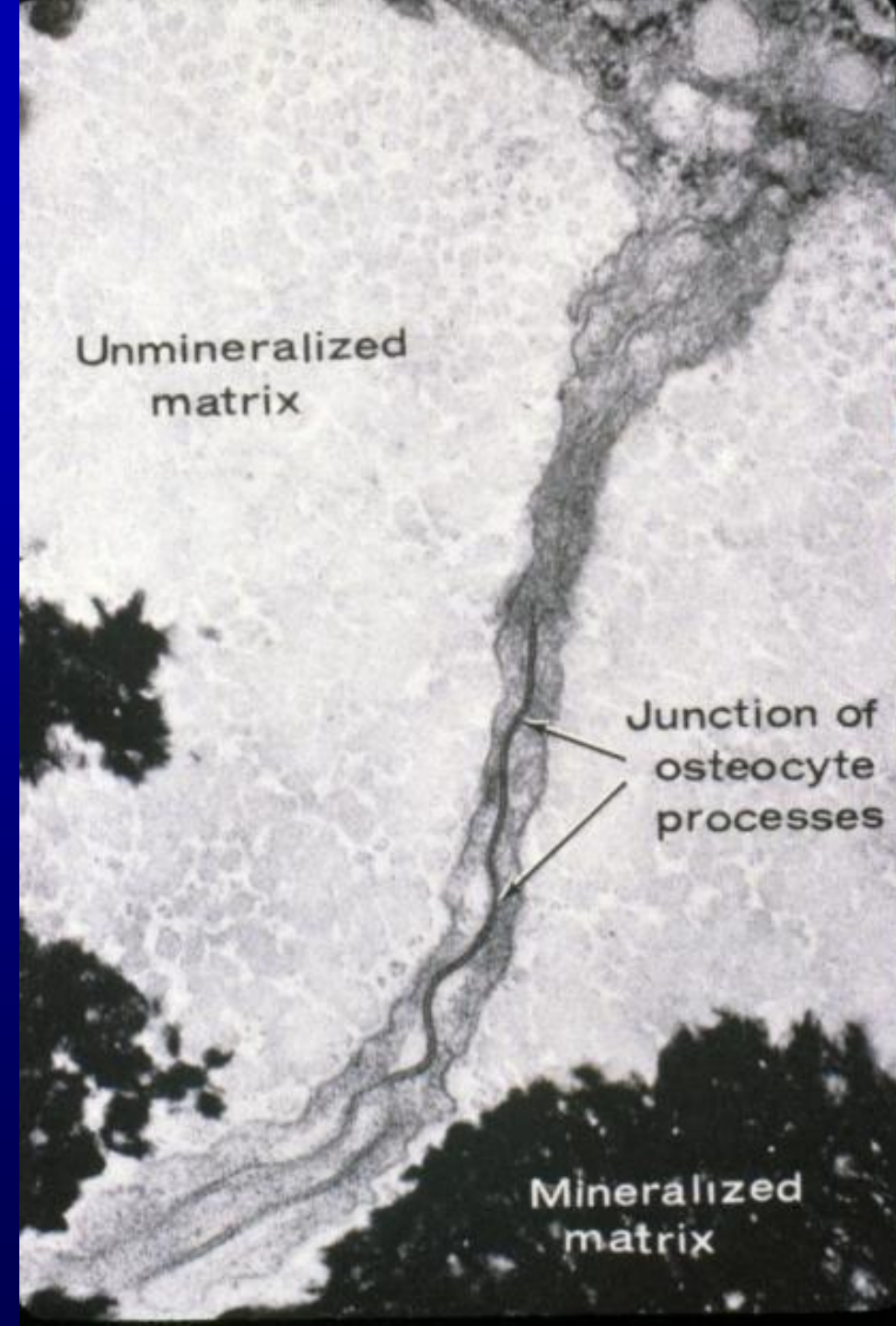
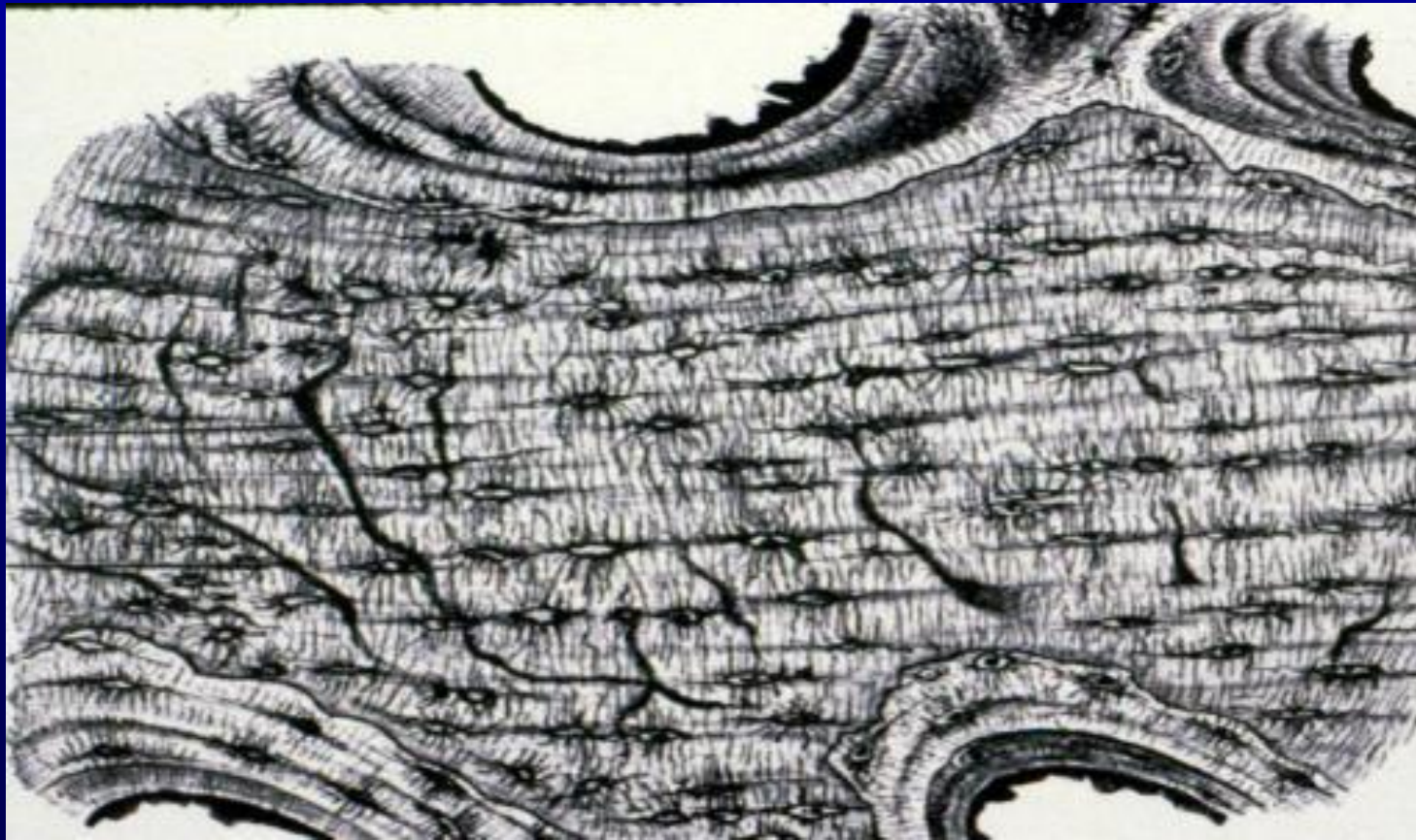
Extracellular Matrix of Bone

Forms **lacunae** and **canaliculi** -

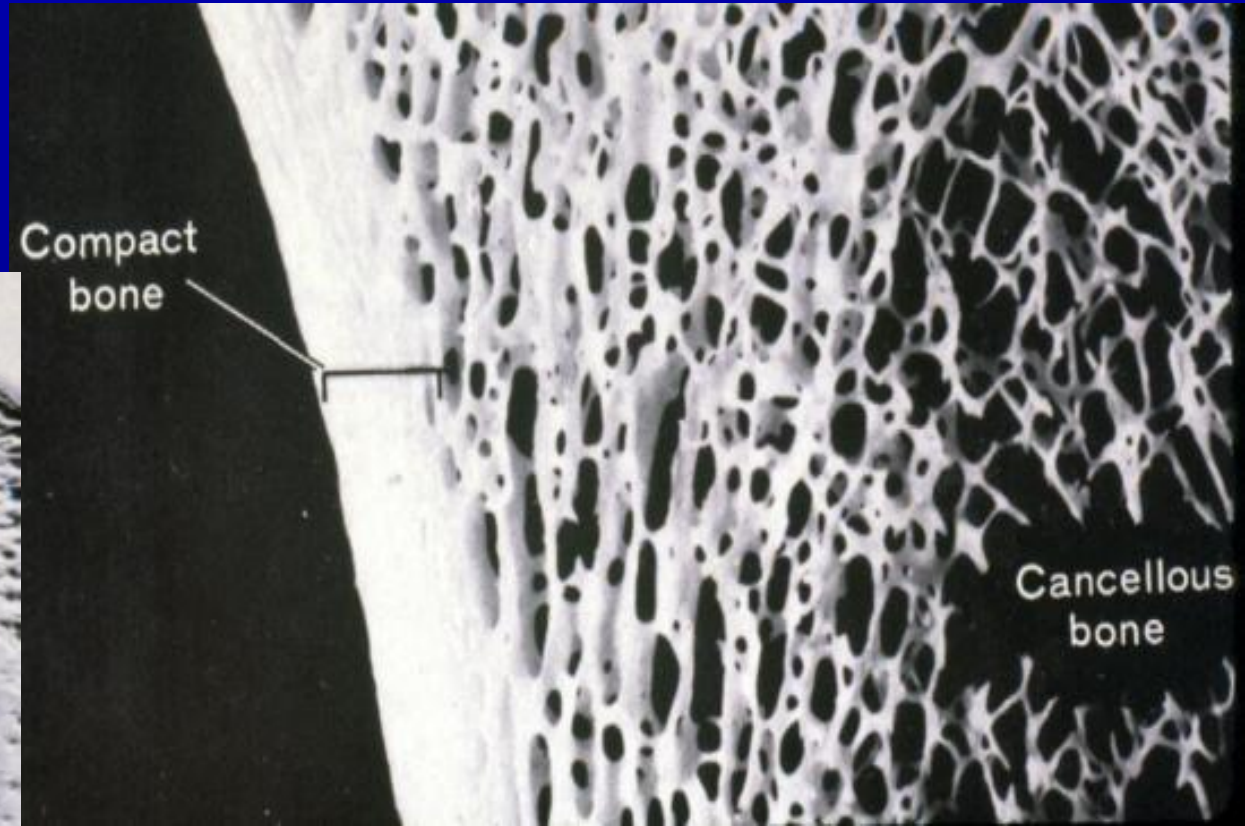
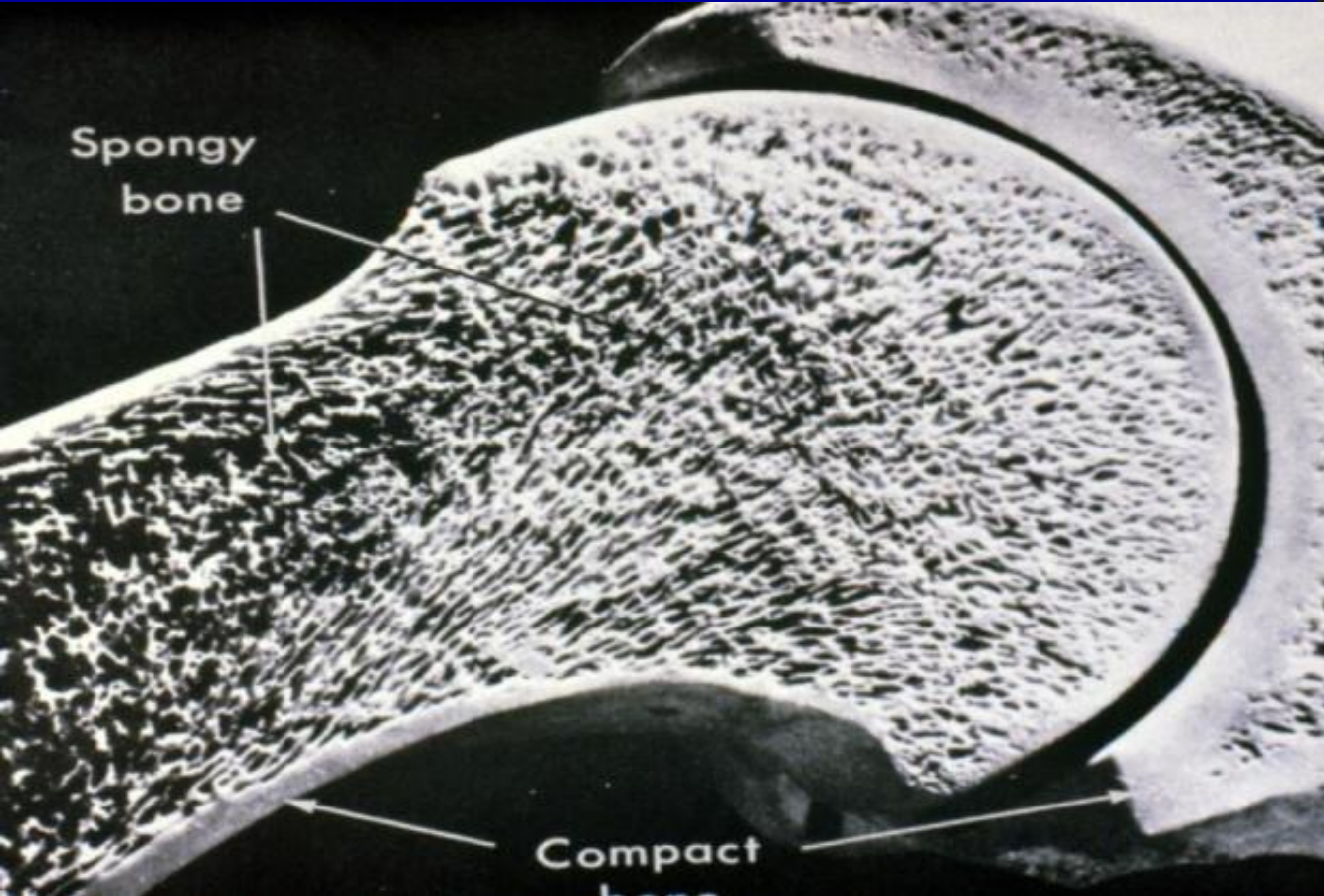


Extracellular Matrix of Bone

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



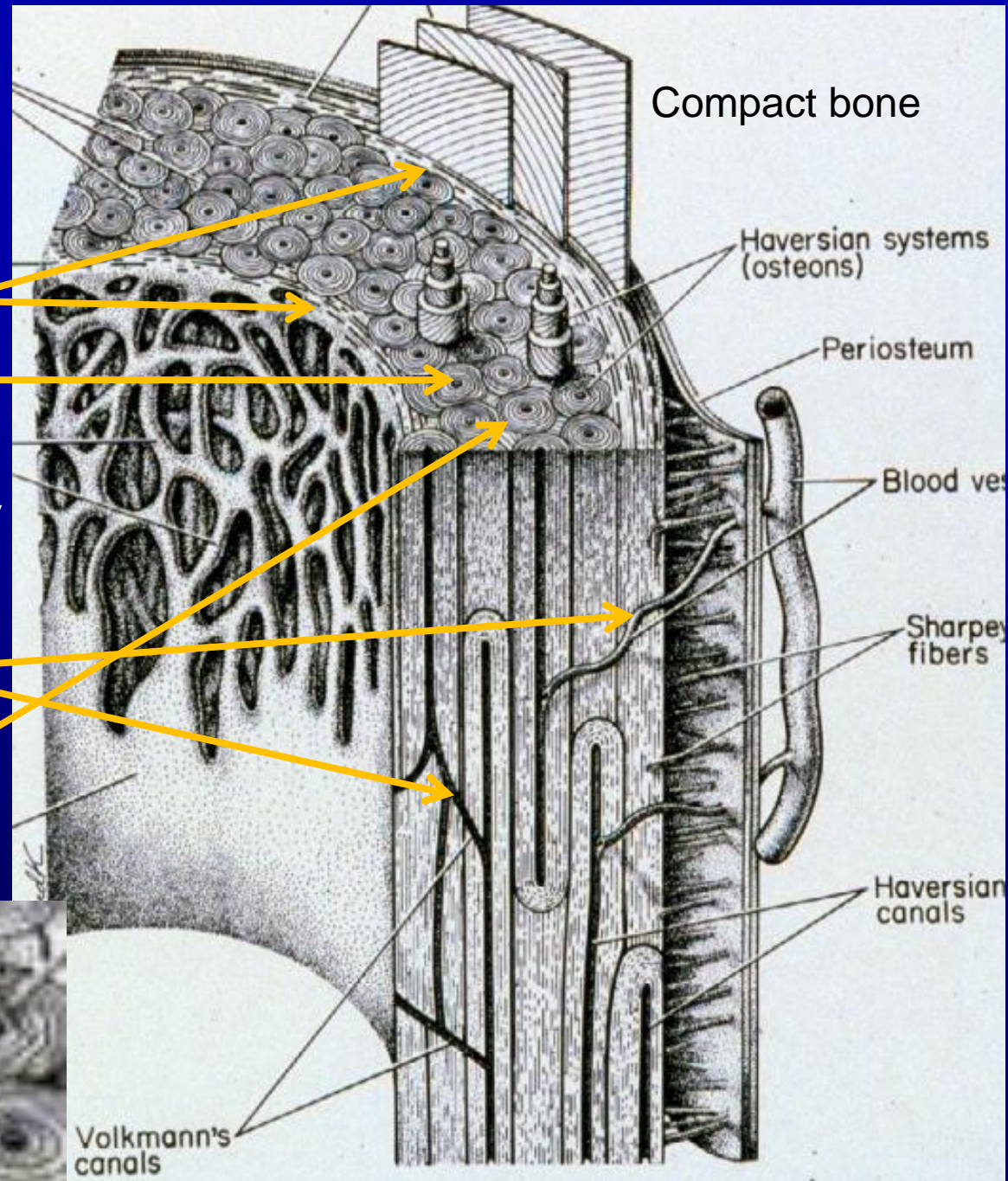
Bone diagram

- circumferential lamellae
- Haversian canal

- Volkmann's canal
- Haversian system

Concentric lamellae

Haversian canal



Compact bone - shaft and outer surface of long bones

Periosteum

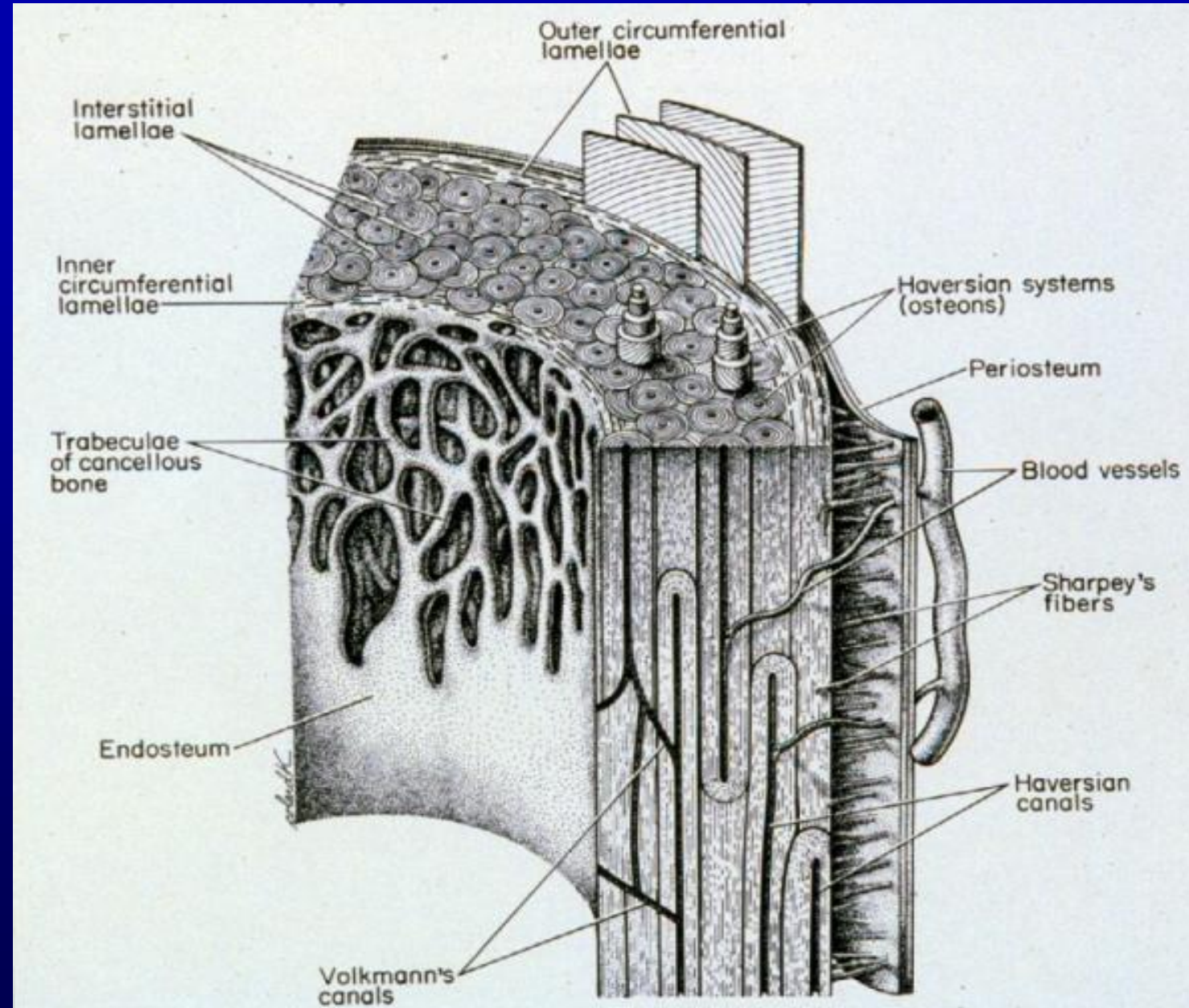
fibroblasts cover

circumferential lamellae

– Appositional growth

(Note: bone has

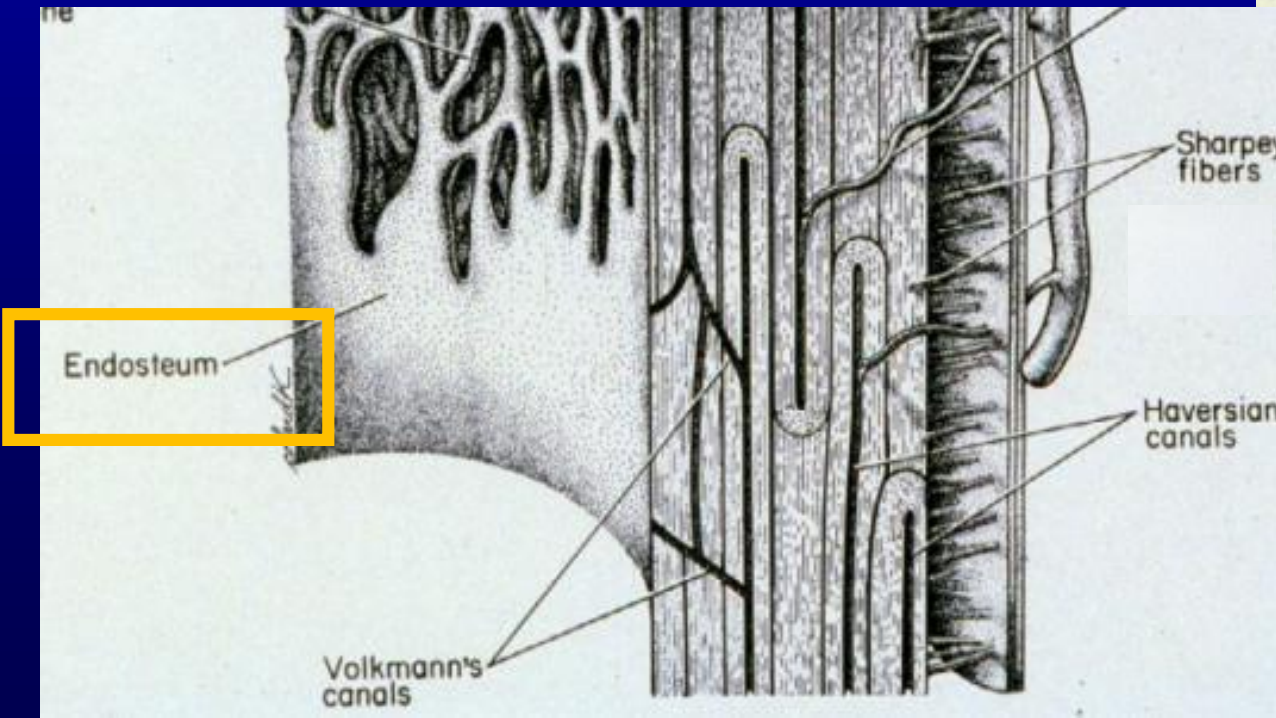
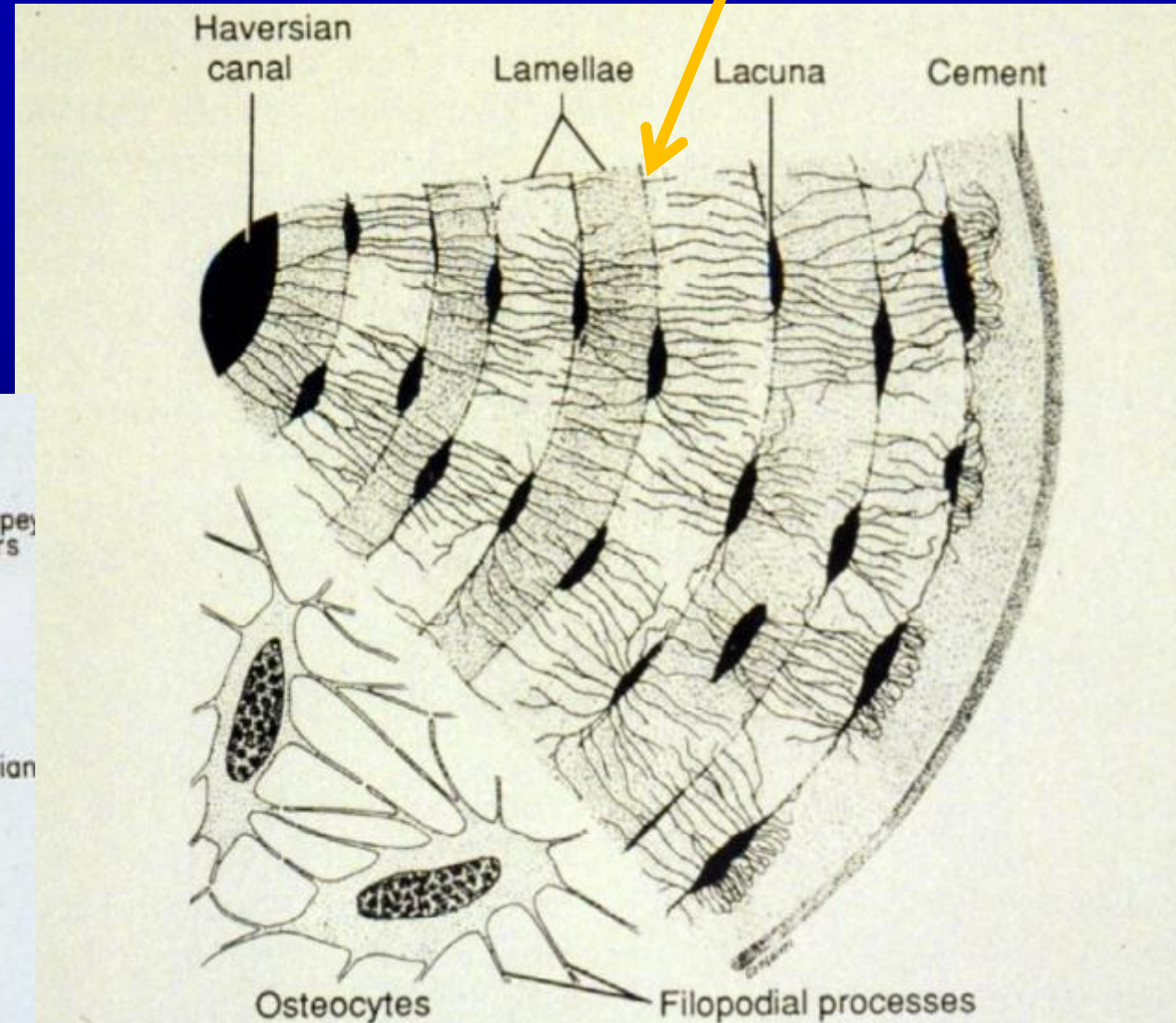
no interstitial growth
as does cartilage)



Compact Bone - Shaft and Outer Surface of Long Bones

Endosteum - inside compact bone, surfaces of spongy bone, inside Haversian systems

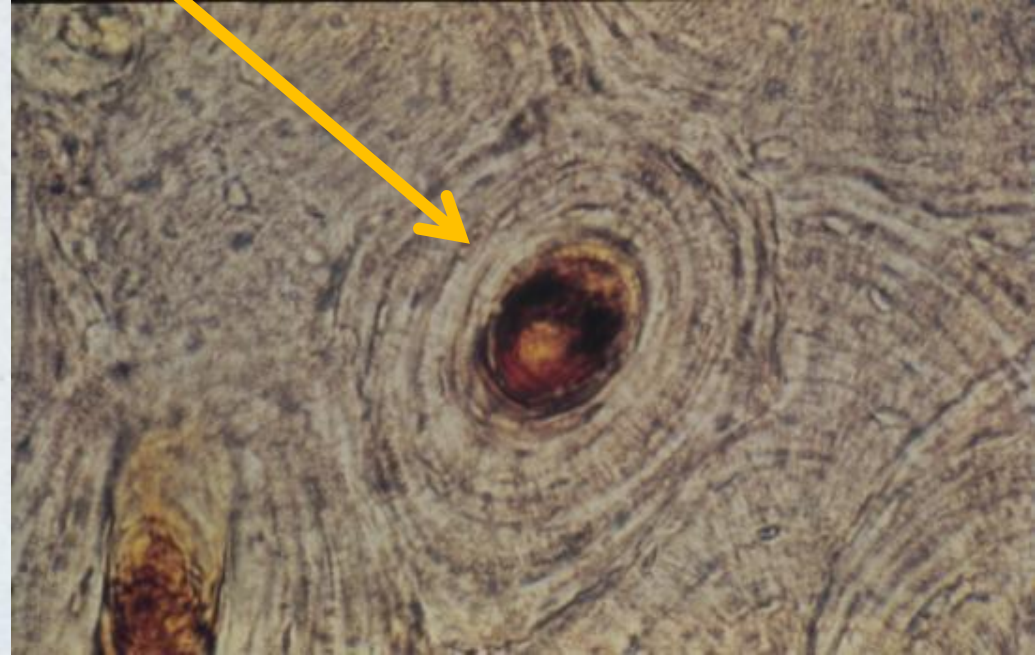
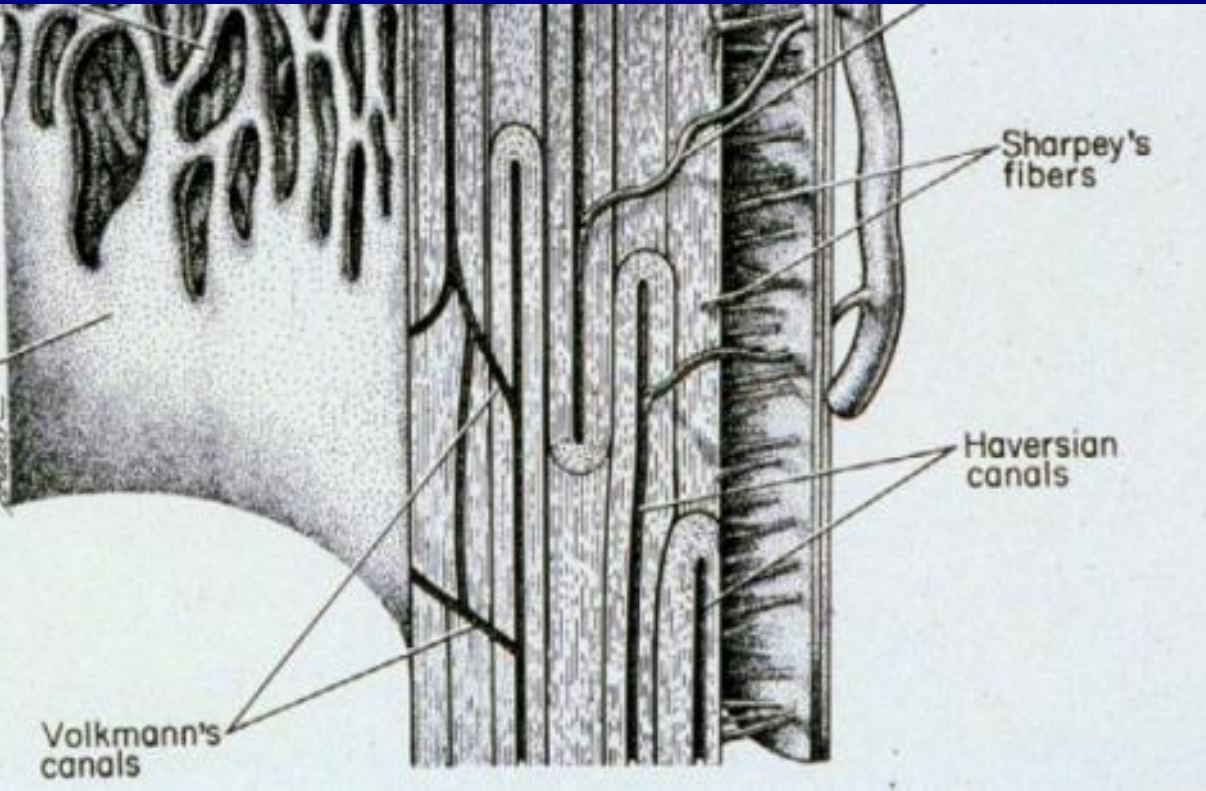
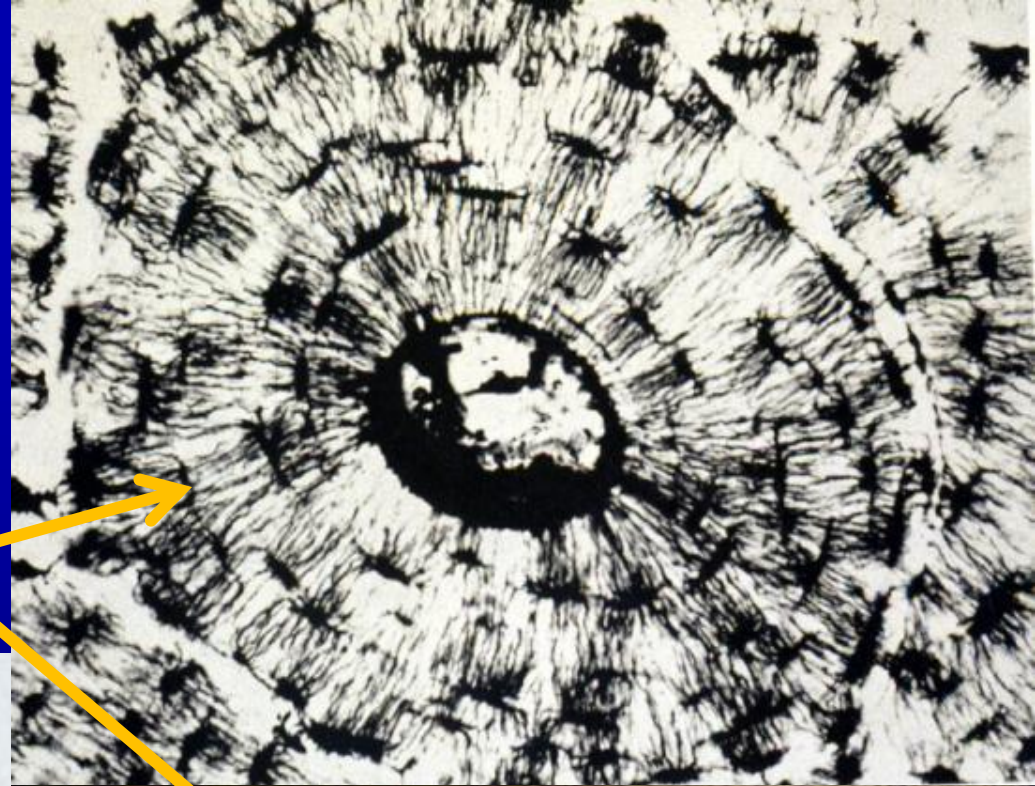
Concentric lamellae



Compact Bone

Haversian systems -
lamellae of bone around
Haversian canal linked
by Volkmann's canal

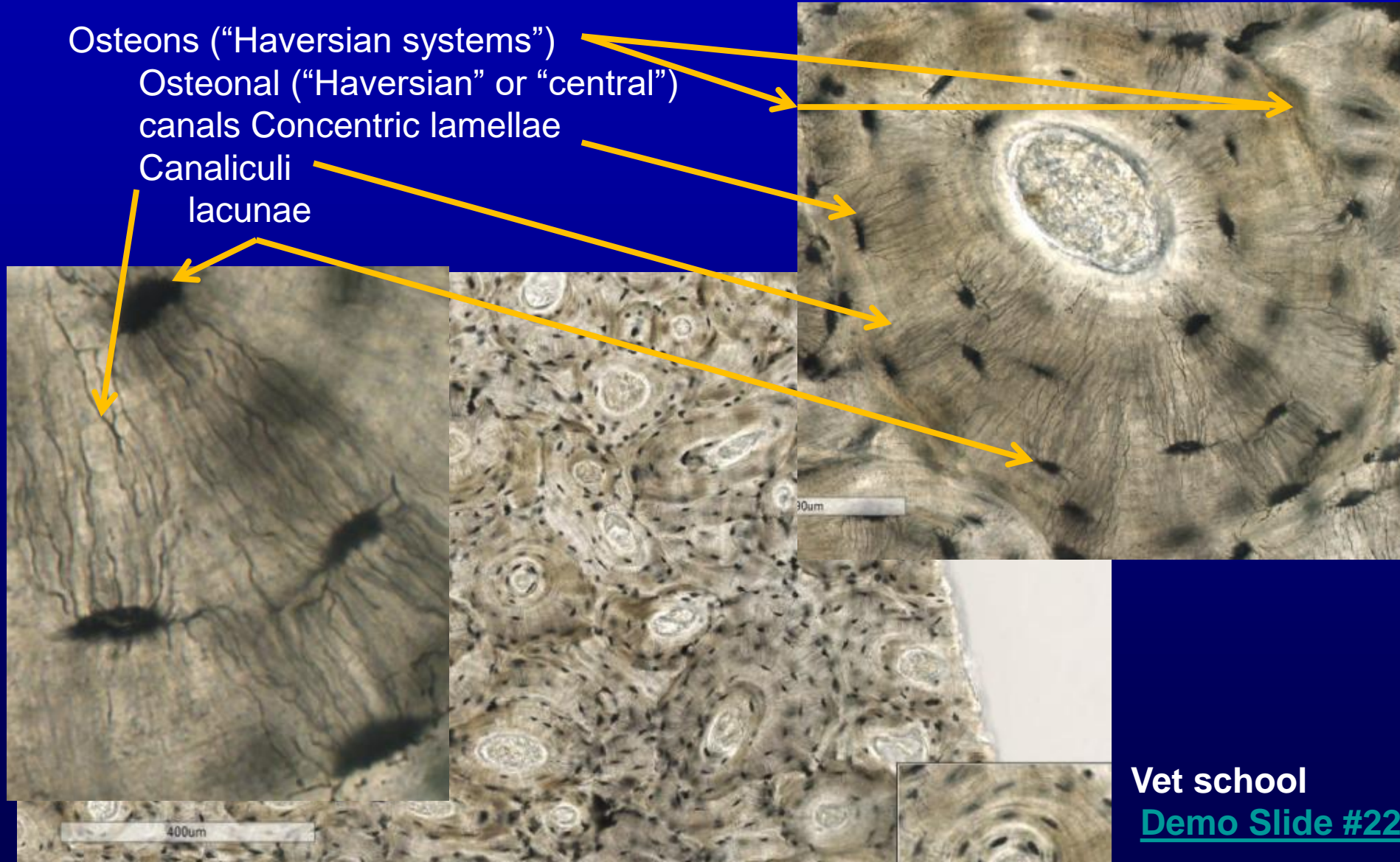
Concentric
lamellae



Haversian system = osteon

Bone matrix = osteoid

Osteons ("Haversian systems")
Osteonal ("Haversian" or "central")
canals
Concentric lamellae
Canaliculi
lacunae

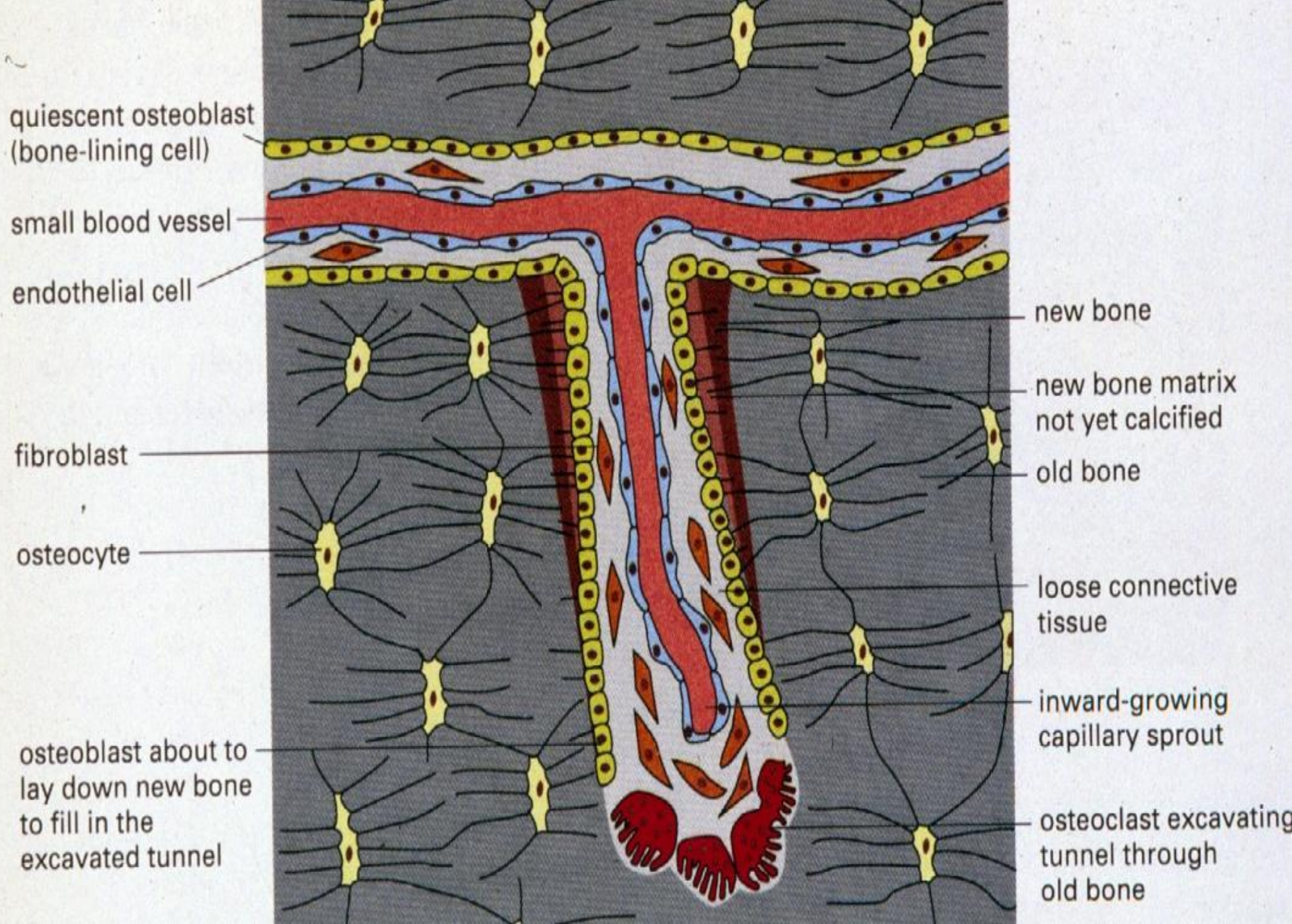


- <http://www.youtube.com/watch?v=c5zcGv8MvMc&NR=1>

<https://www.youtube.com/watch?v=d9owEvYdouk>

Compact Bone

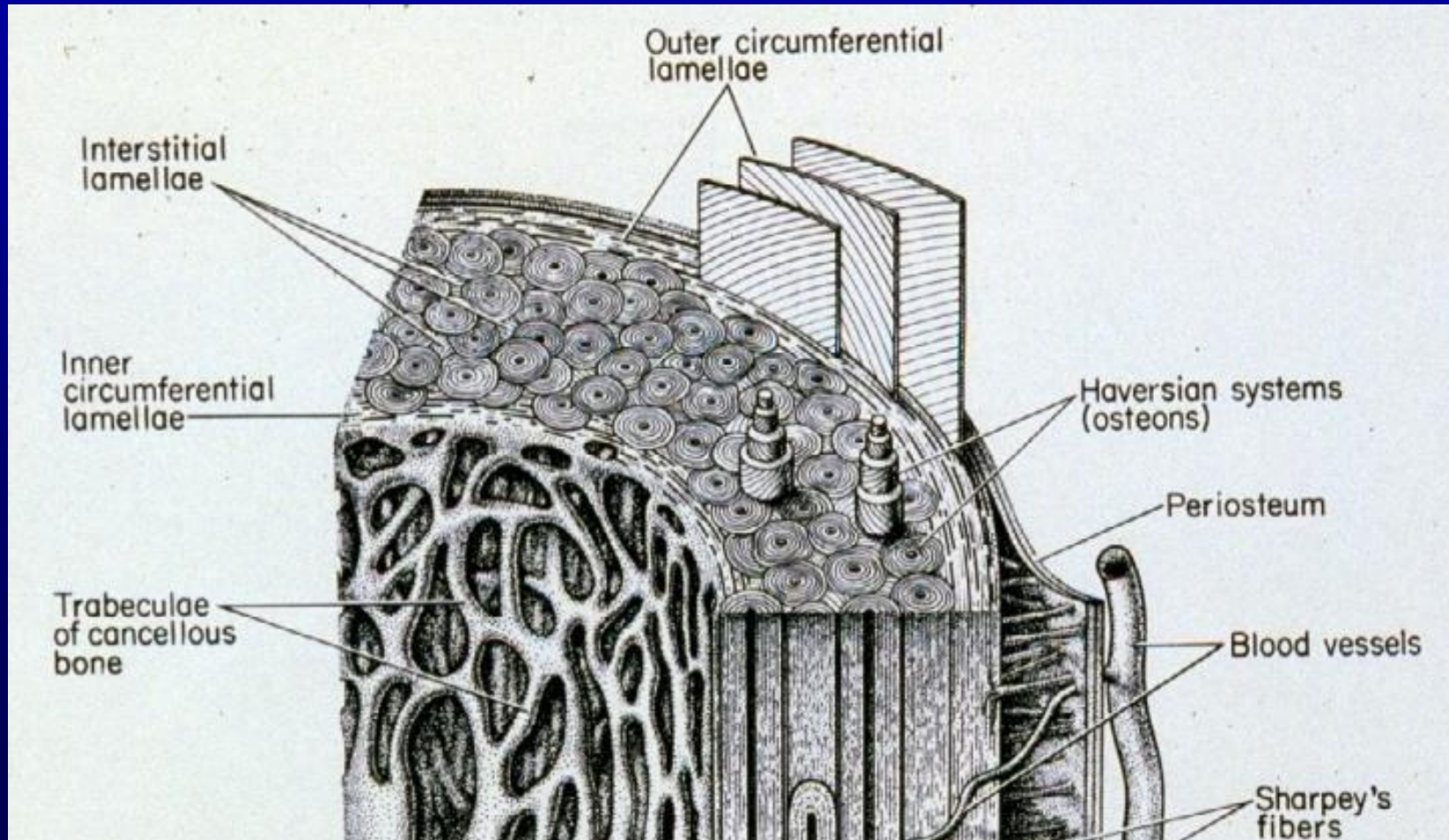
Remodeling –
osteoclasts
digest bone,
osteoblasts
from
endosteum
replaces it



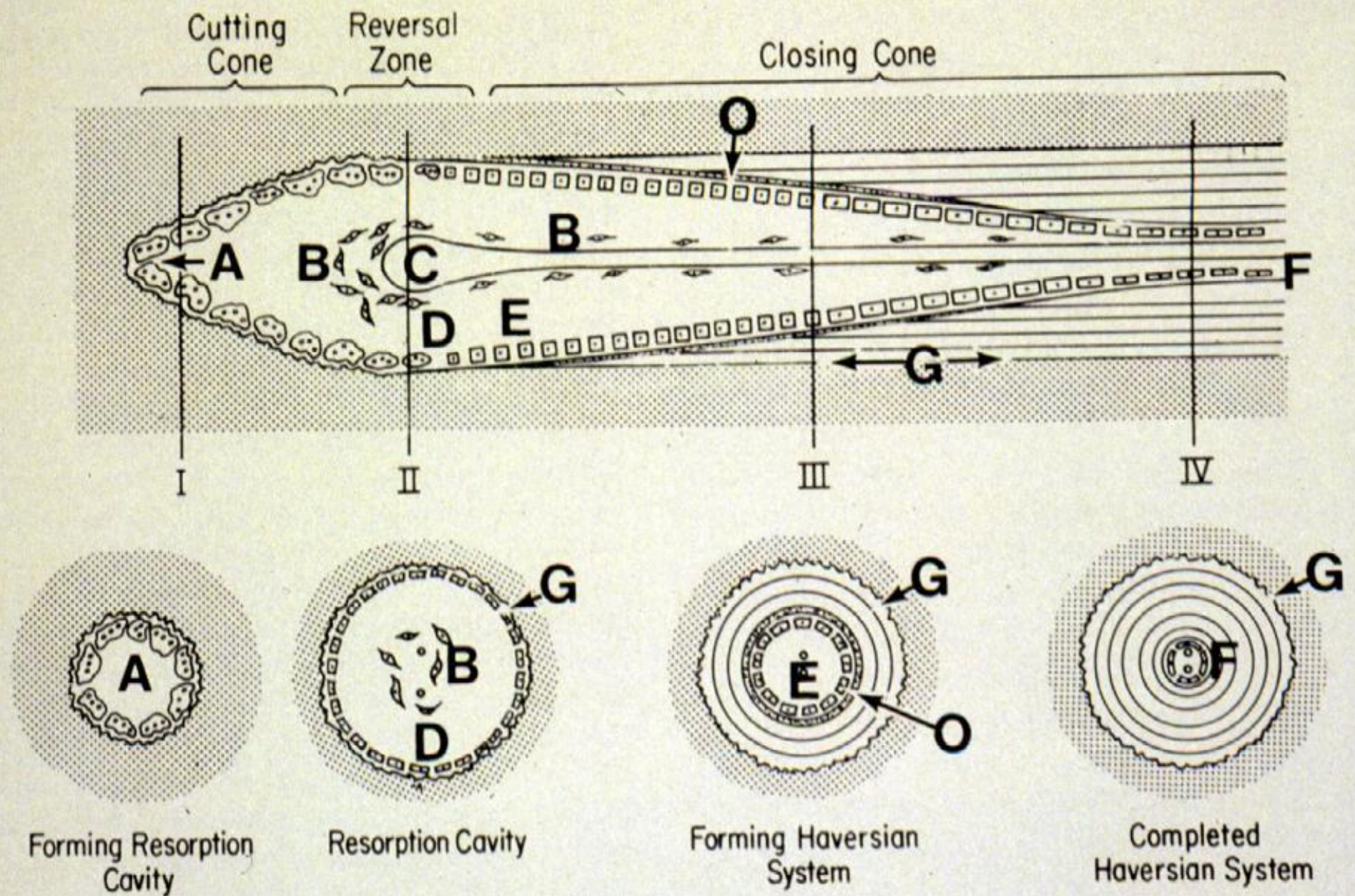
Compact Bone

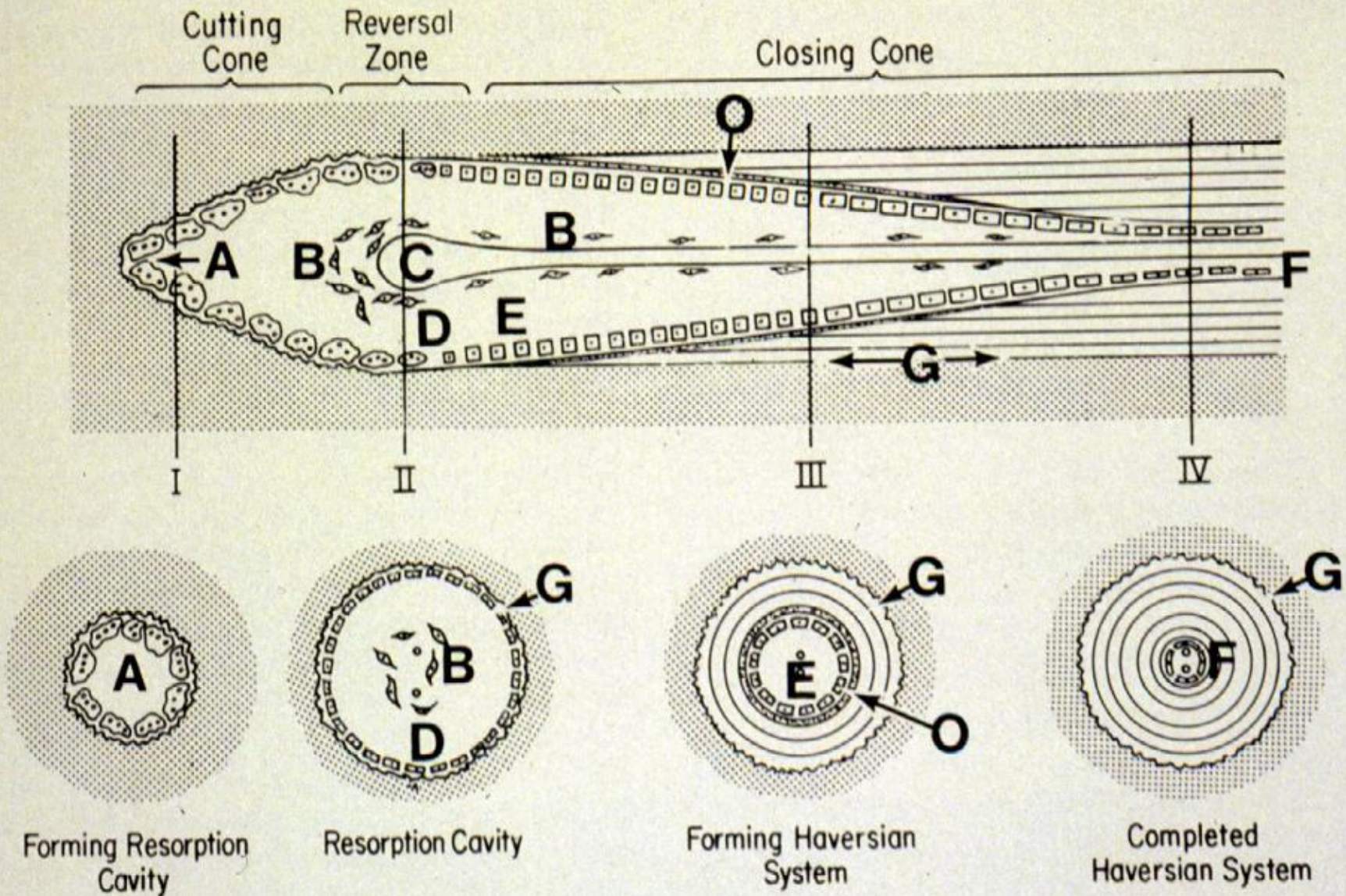
Remodeling - osteoclasts, osteoblasts from endosteum

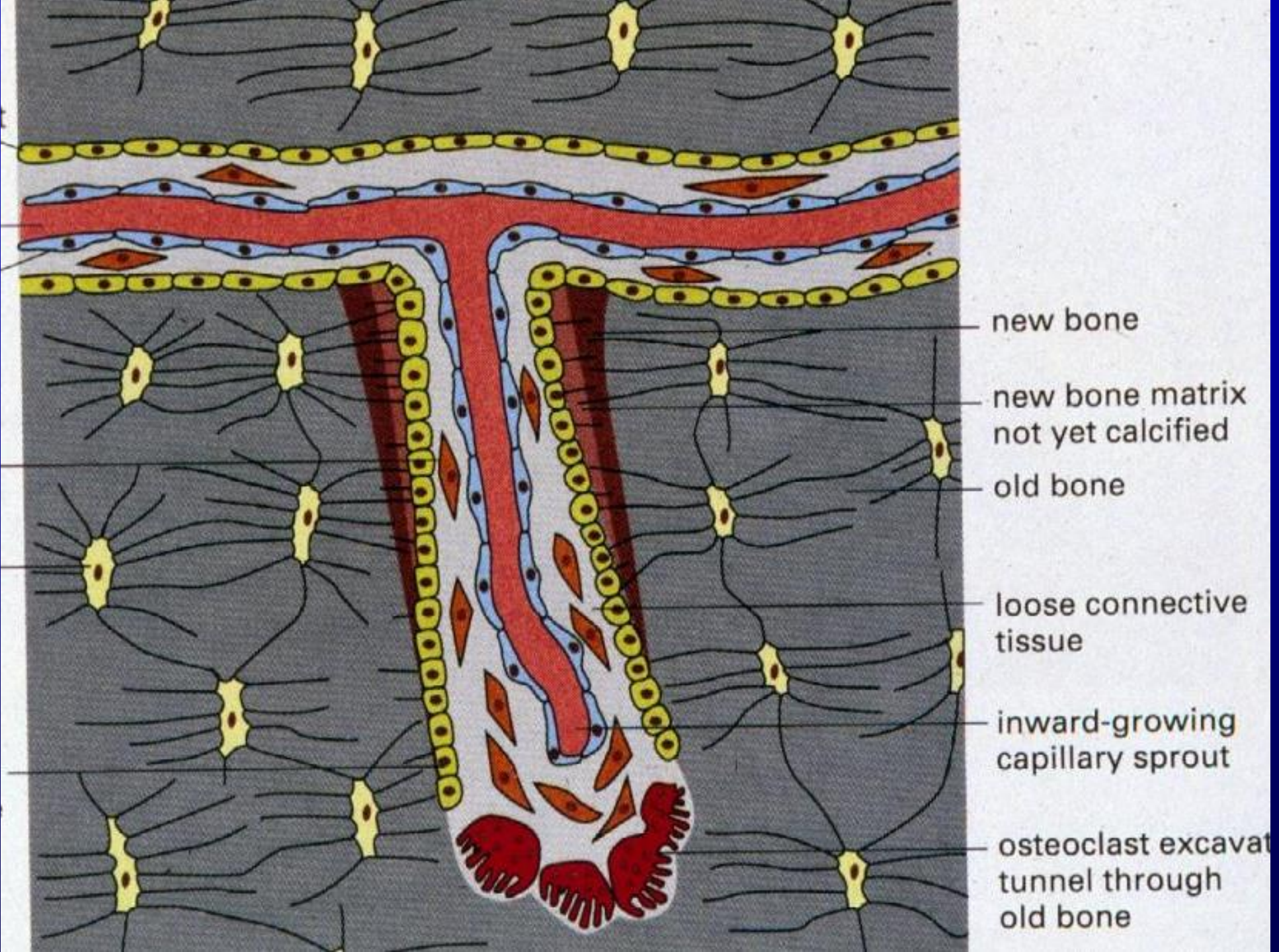
Interstitial lamellae - between latest



Compact Bone Remodeling







new bone

new bone matrix
not yet calcified

old bone

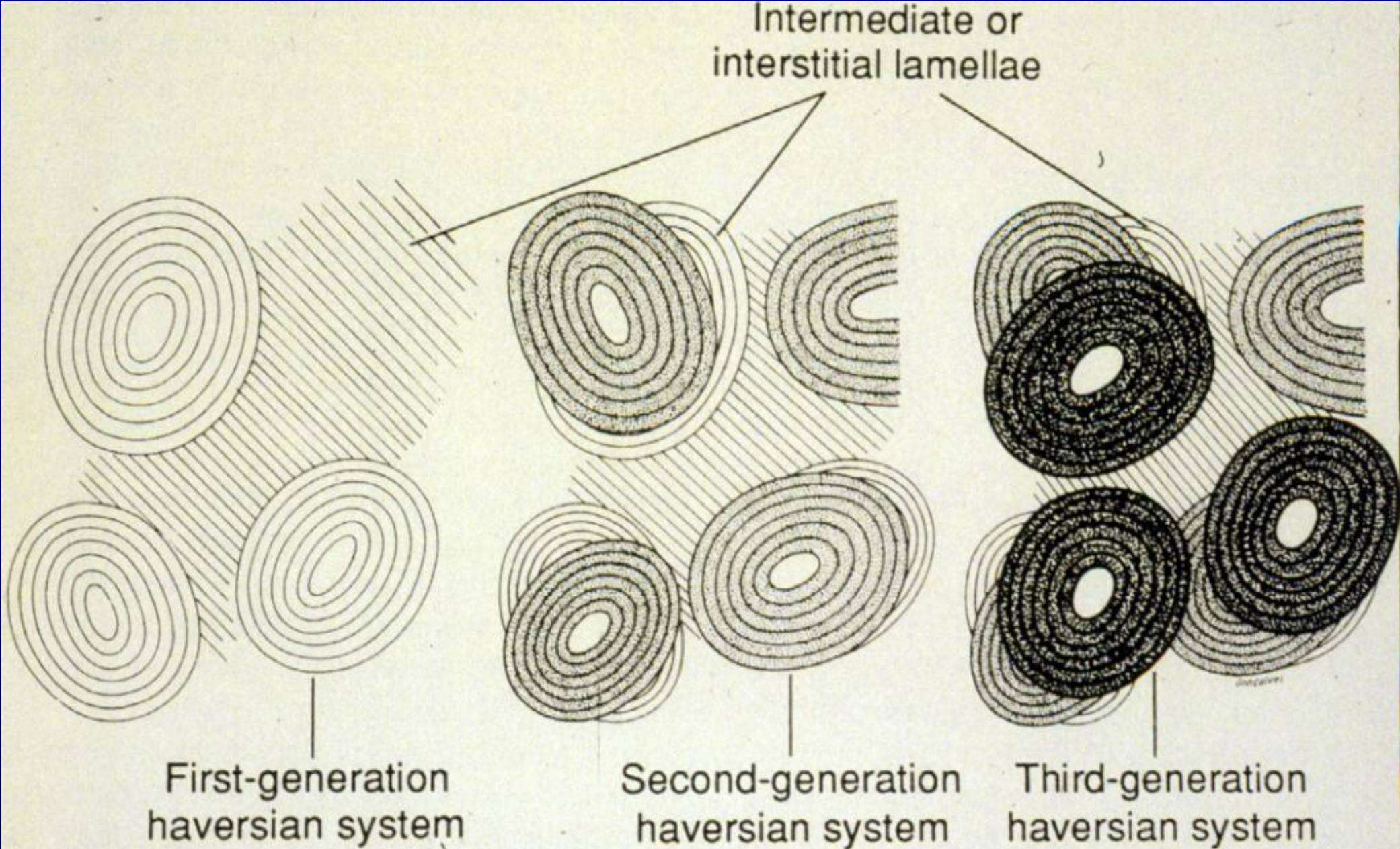
loose connective
tissue

inward-growing
capillary sprout

osteoclast excavat
tunnel through
old bone

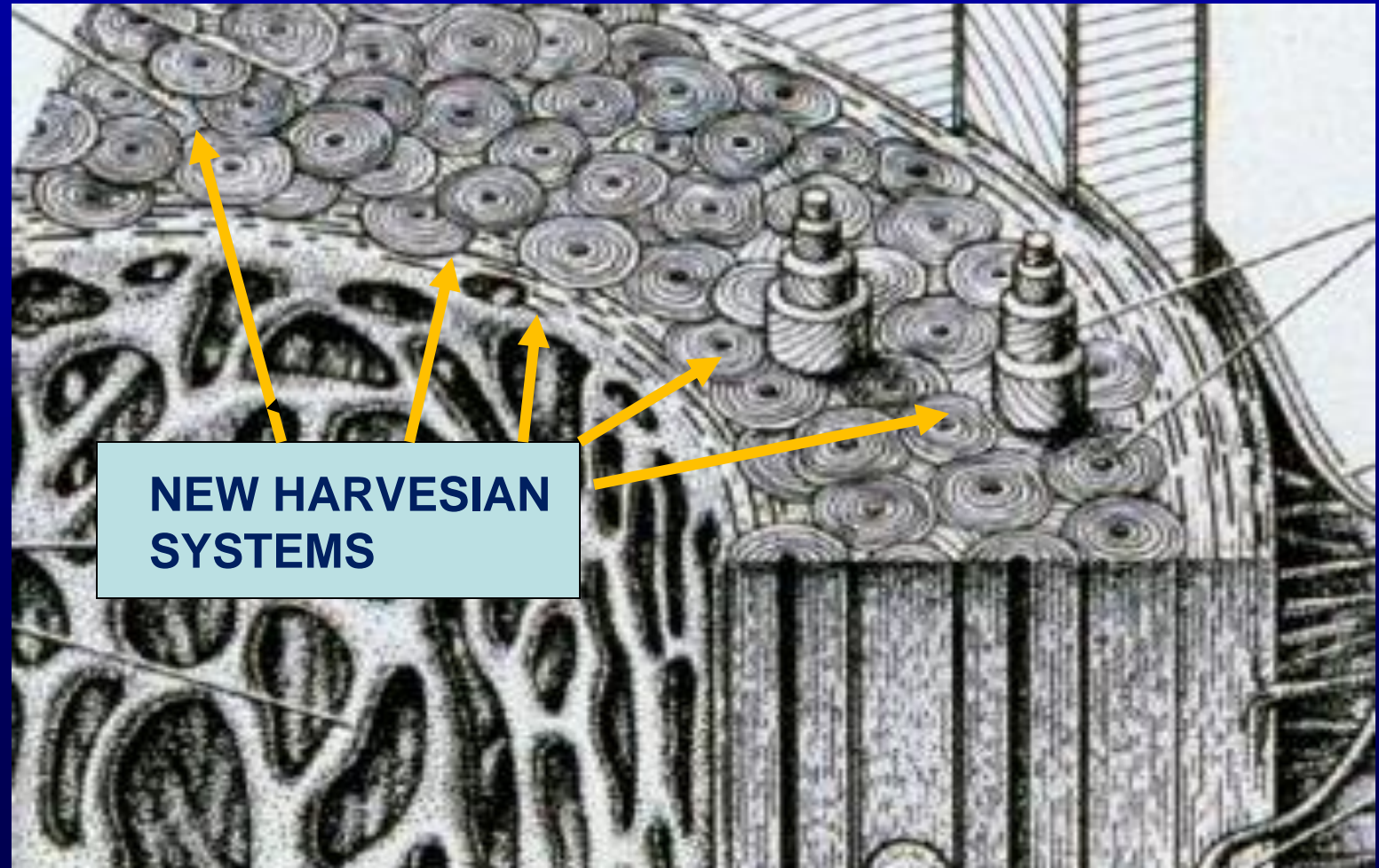
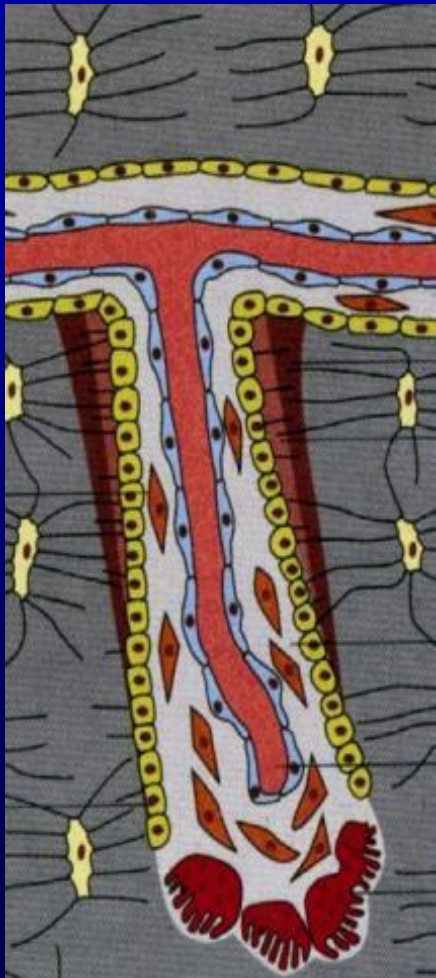
Compact Bone

Remodeling

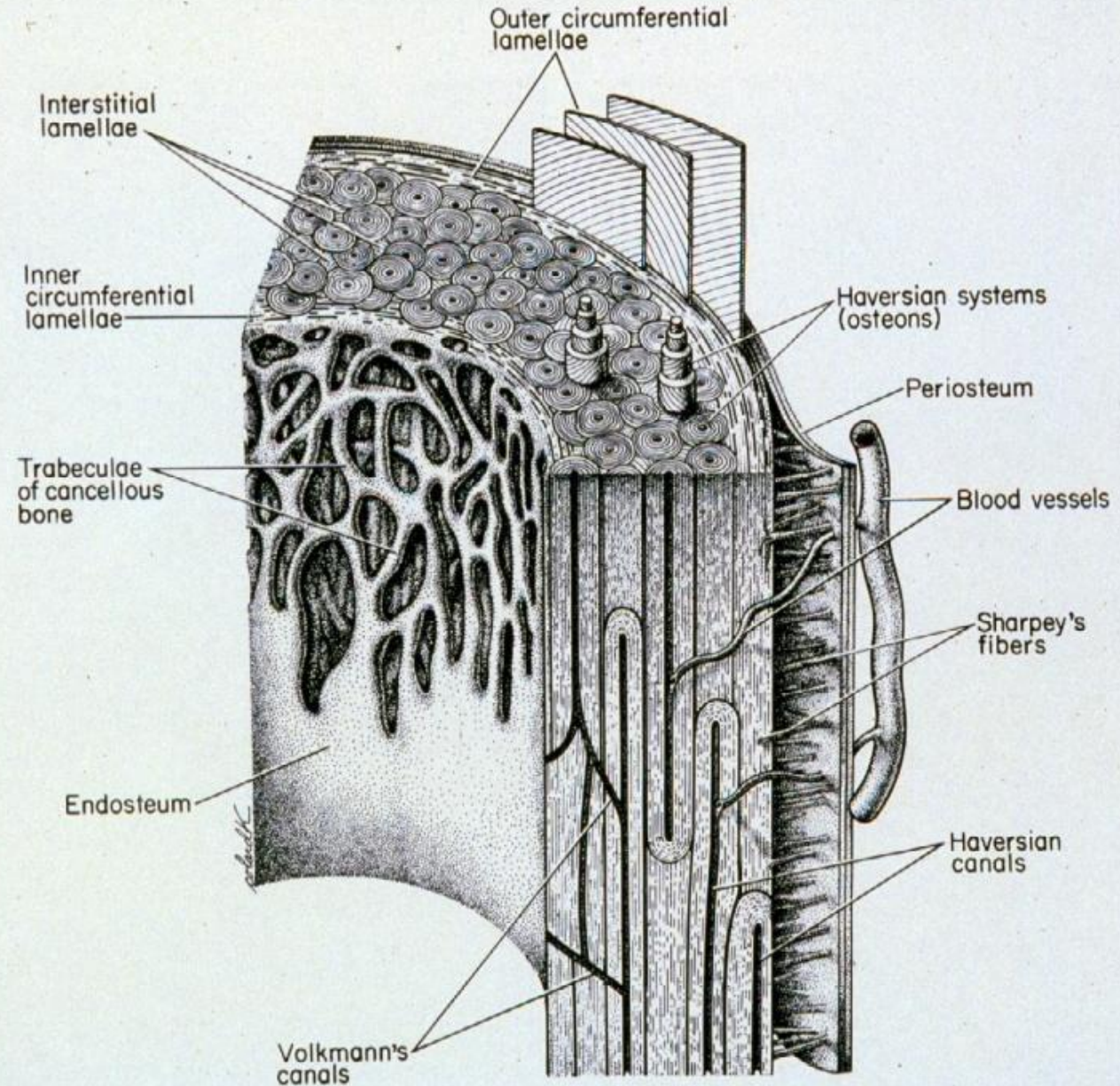
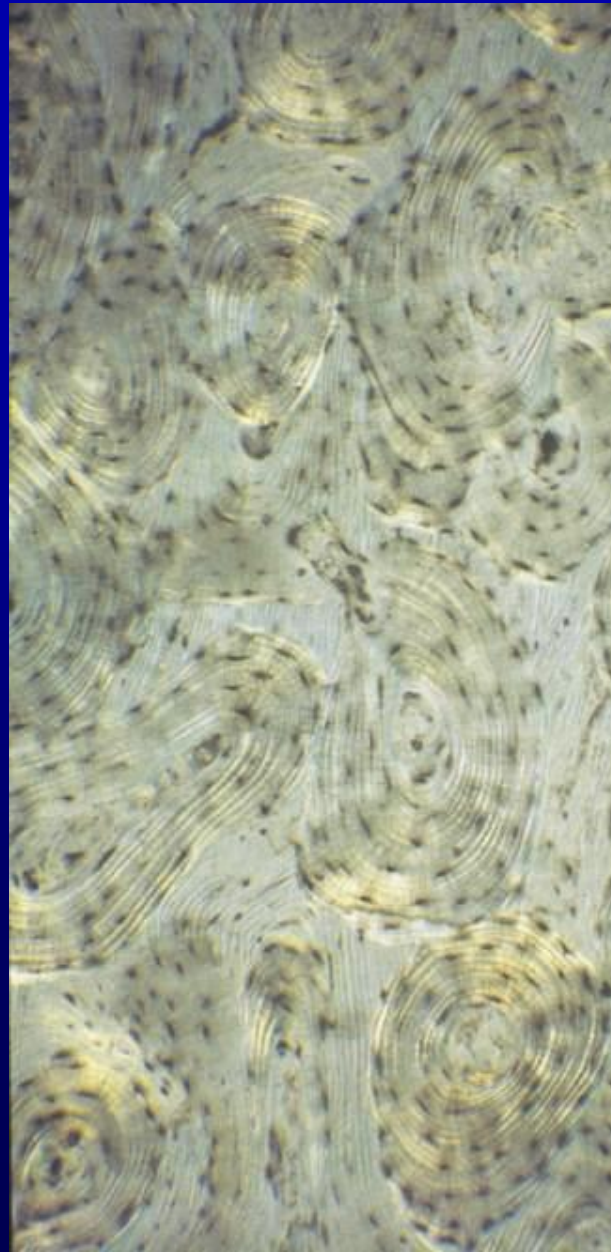


Compact Bone - Remodeling

A **Piezoelectrocic field**, caused by compression of minerals (Ca^{++} crystals and others), directs osteoclasts down the length of long bone as they excavate a tunnel. osteoblasts lay down new bone to fill the excavated tunnel and create a new Haversian system down the length of compact bone.



Compact Bone, Remodeling

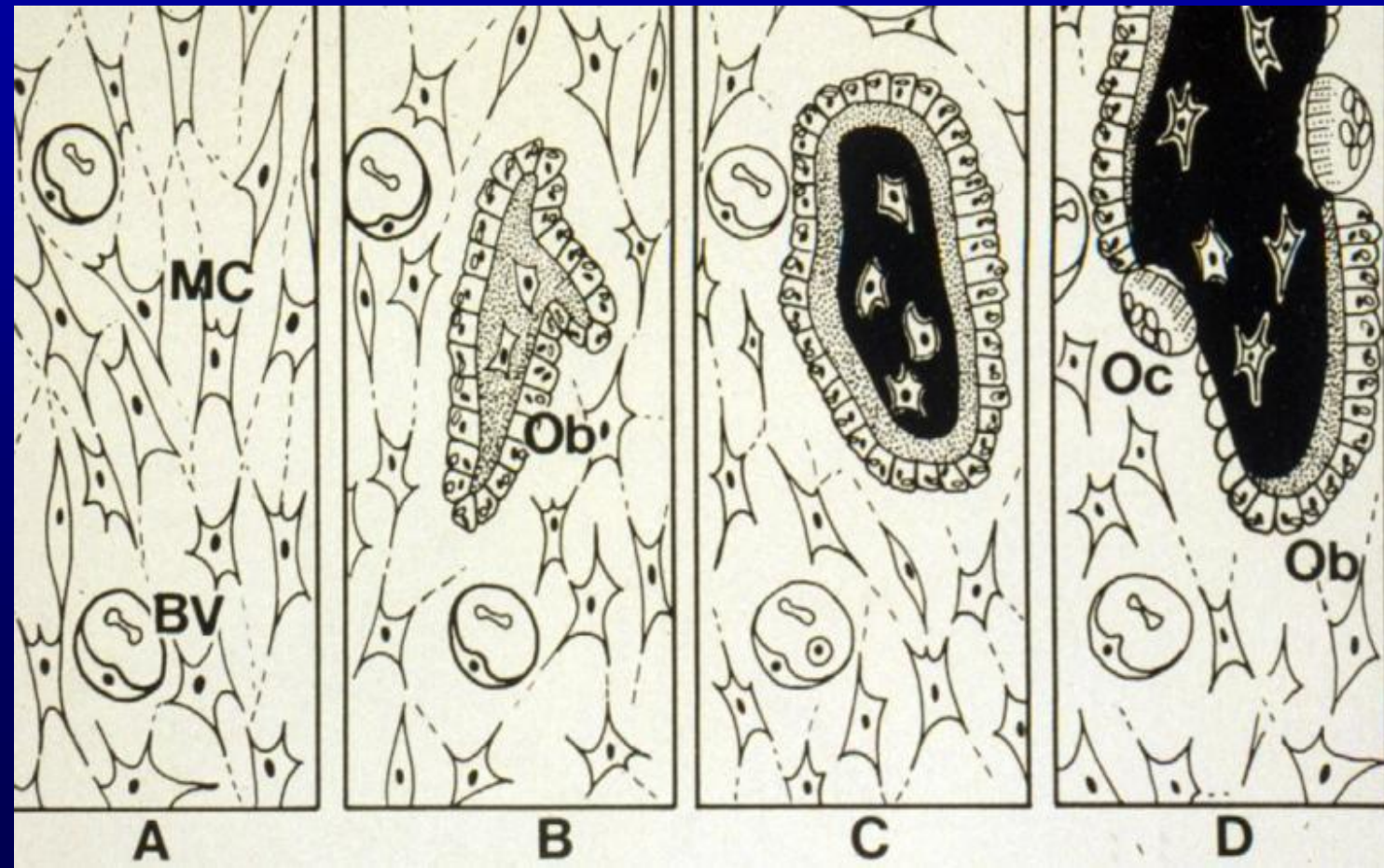


Histogenesis of Bone

<https://www.youtube.com/watch?v=p-3PuLXp9Wg>

Intramembranous ossification

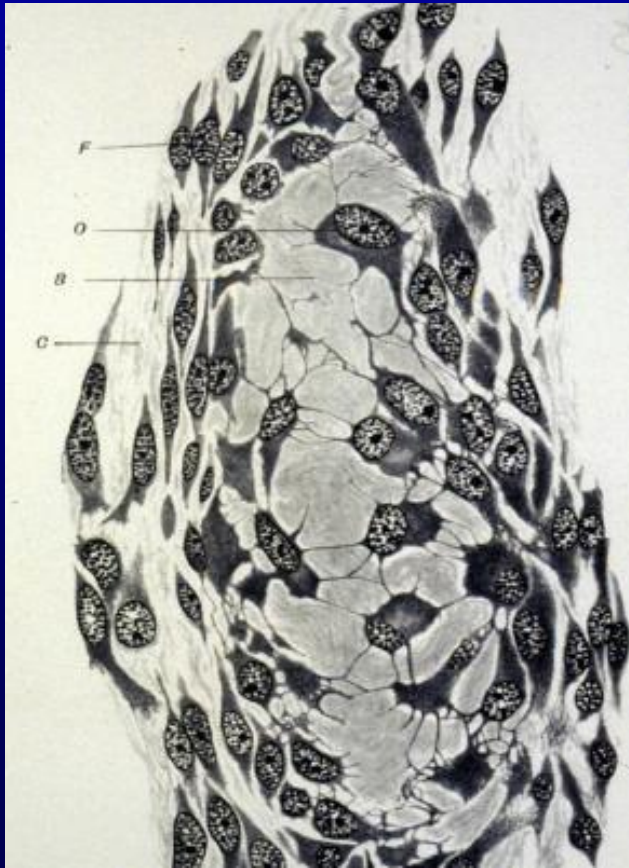
Direct mineralization of matrix secreted by osteoblast **without** a cartilage model



Histogenesis of Bone

Intramembranous ossification

Flat bones
of skull

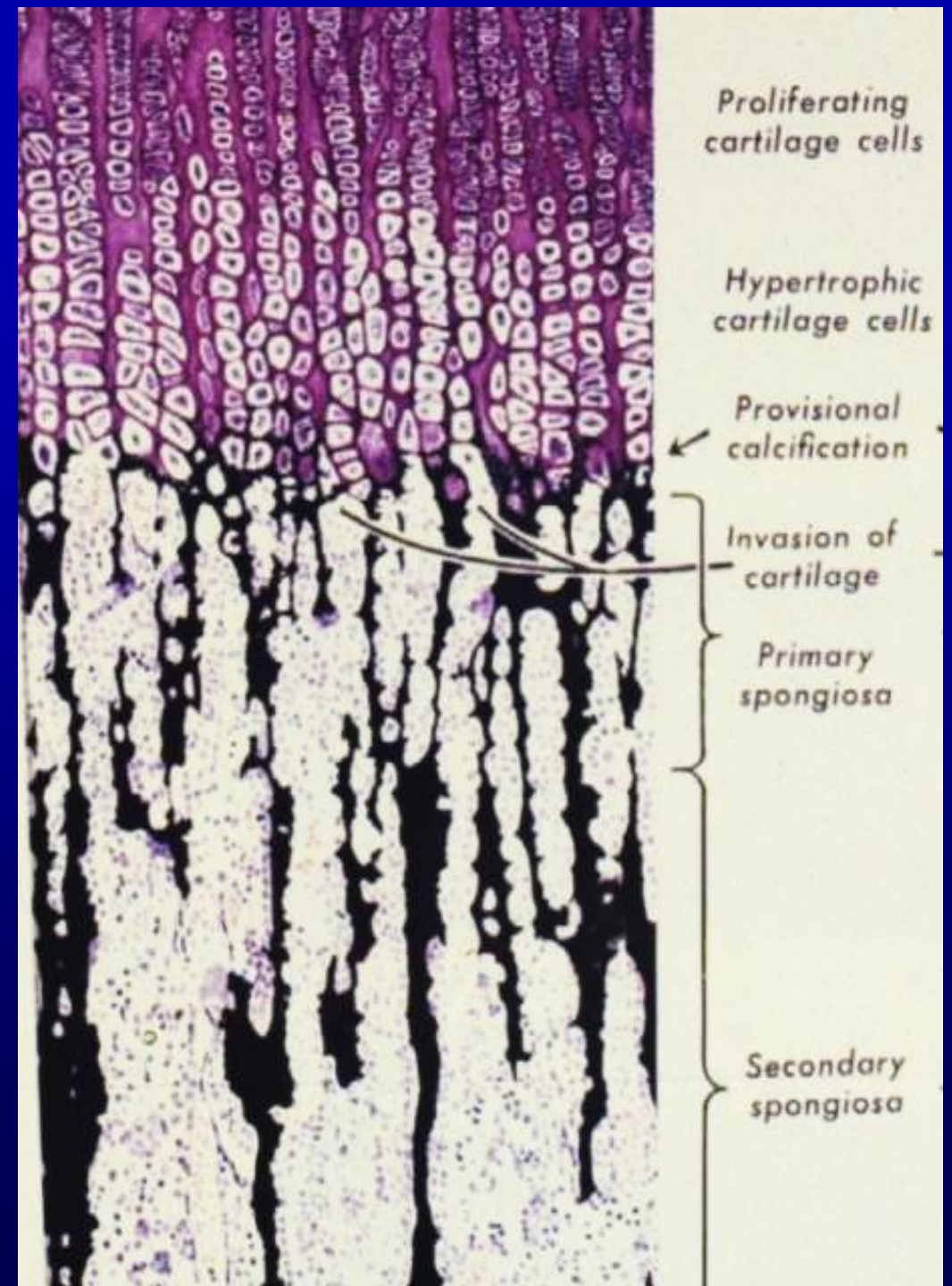
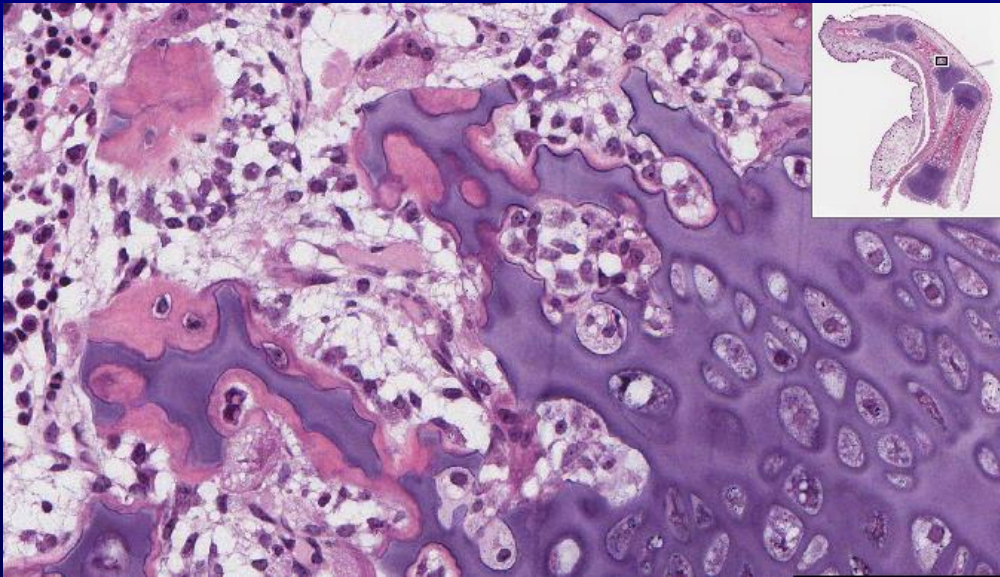


Histogenesis of Bone

Endochondral ossification

Deposition of bone matrix on a preexisting cartilage matrix

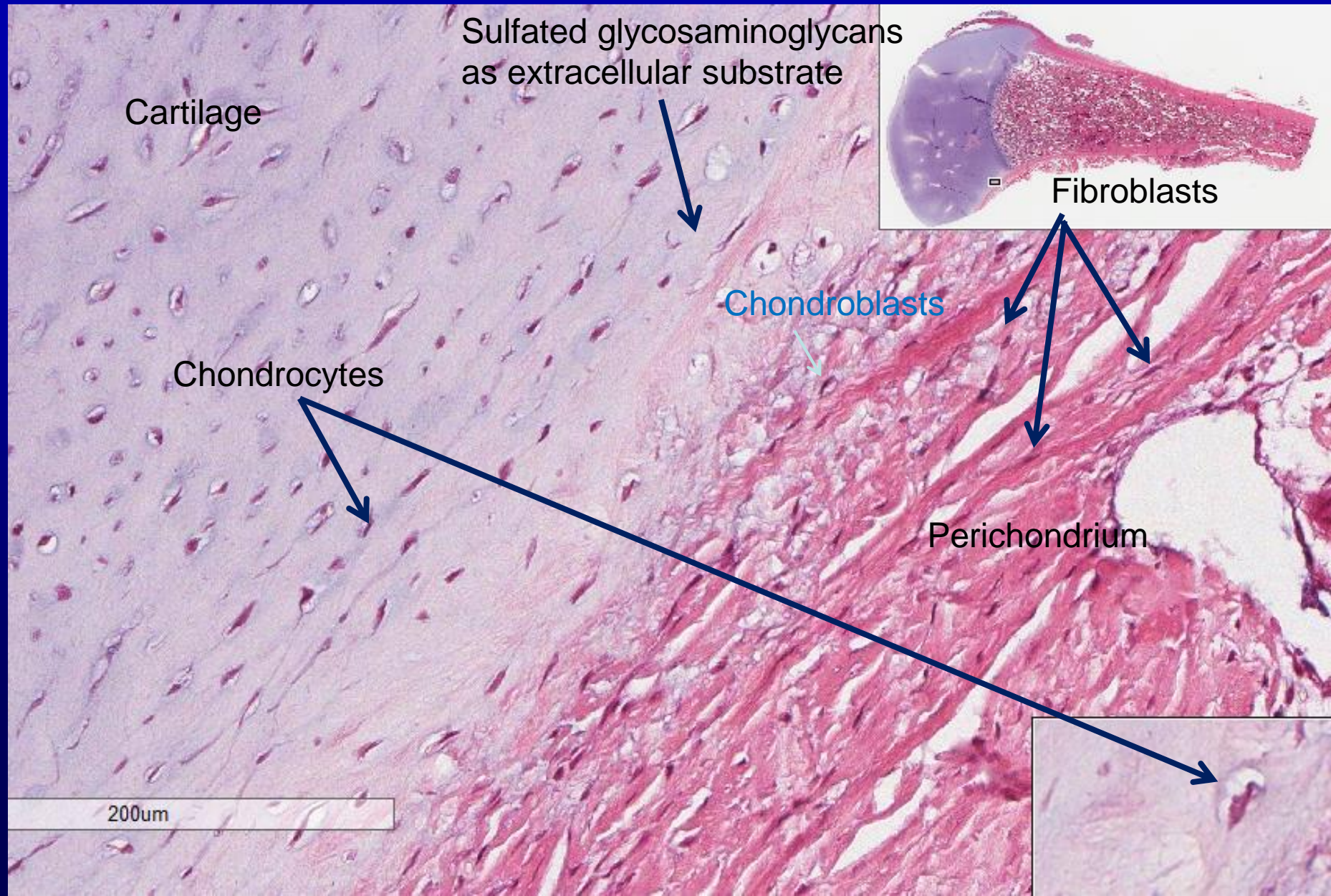
Characteristic of long bone formation



Tibia, fetal

Endochondral ossification

421



Endochondral (spongy/ cancellous) Bone Formation

Cartilage model

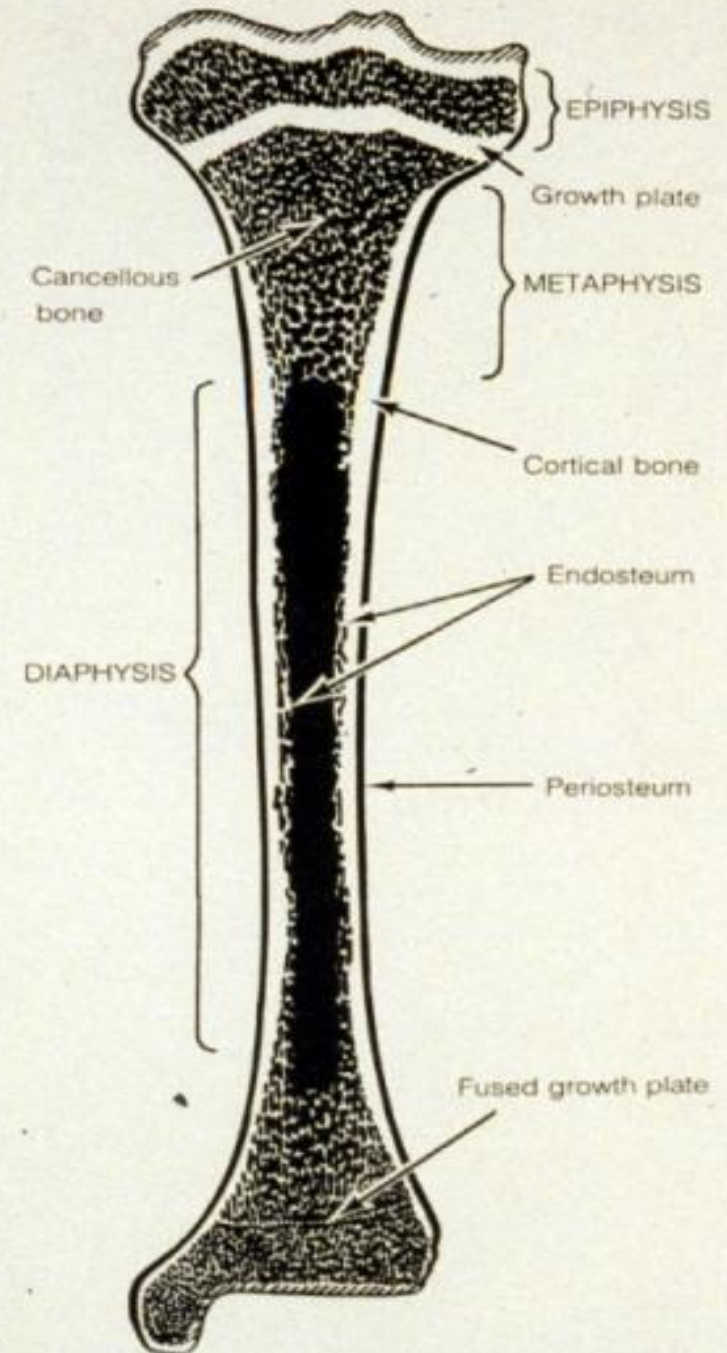
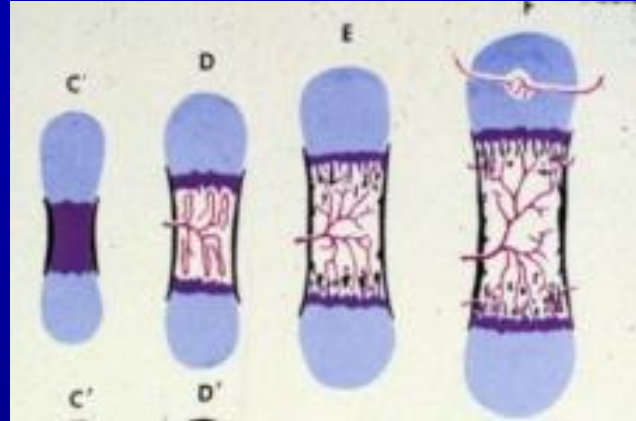
Centers of ossification

Primary center of ossification

- Diaphysis

Second center of ossification

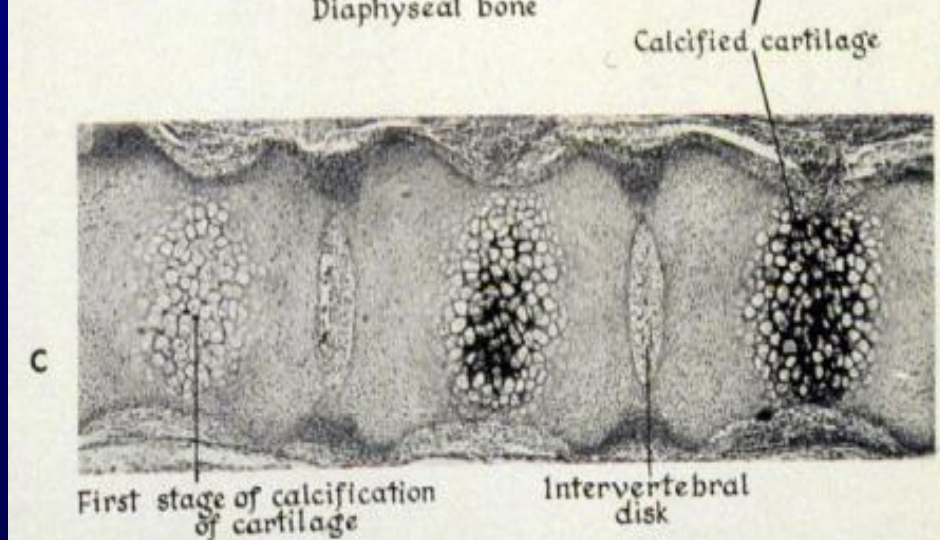
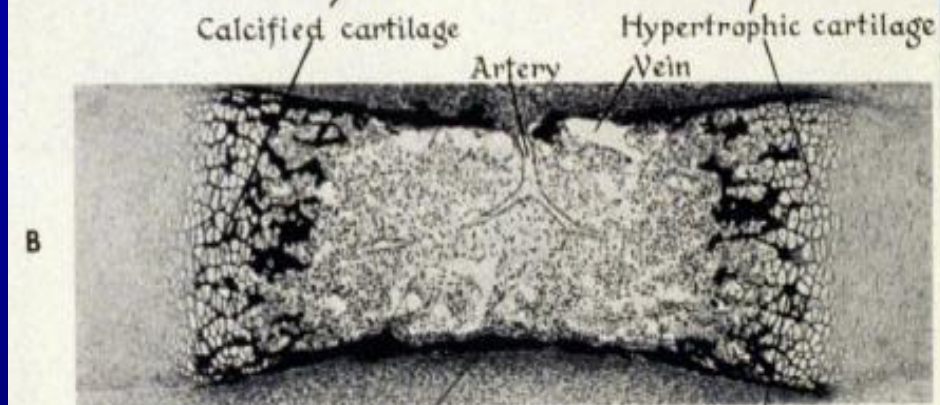
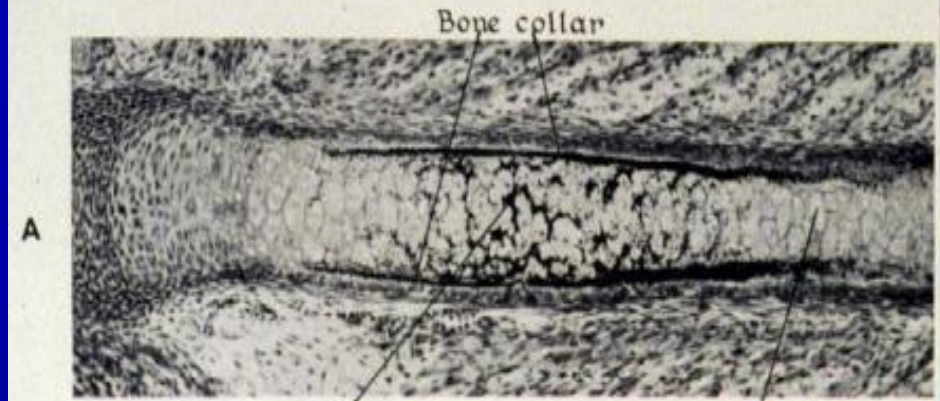
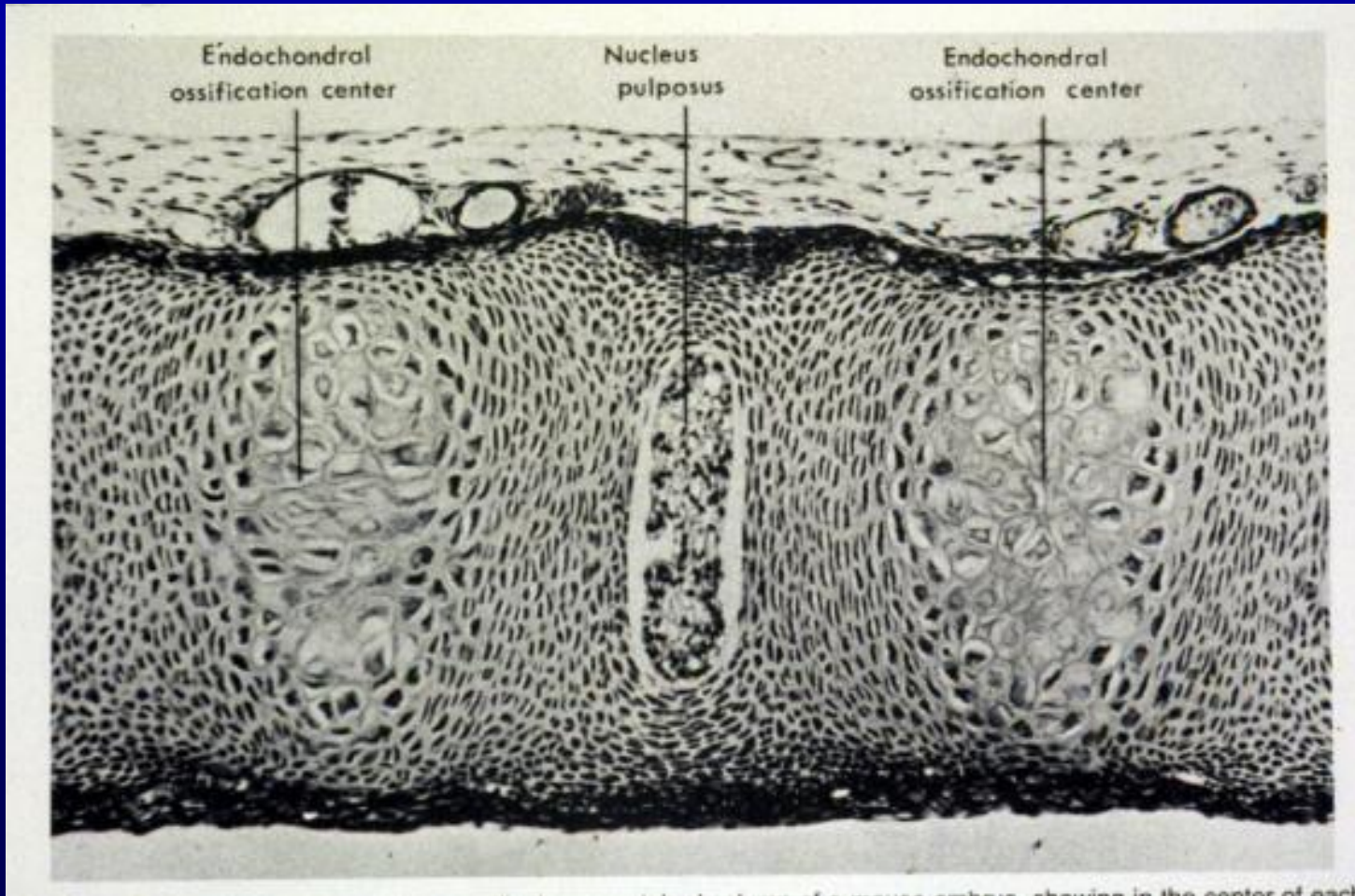
- Center of each epiphysis



Endochondral Bone Formation

Cartilage model

Centers of ossification



Endochondral Bone Growth

In width - extension of compact bone by appositional growth

In length - epiphyseal plate

Cartilage growth

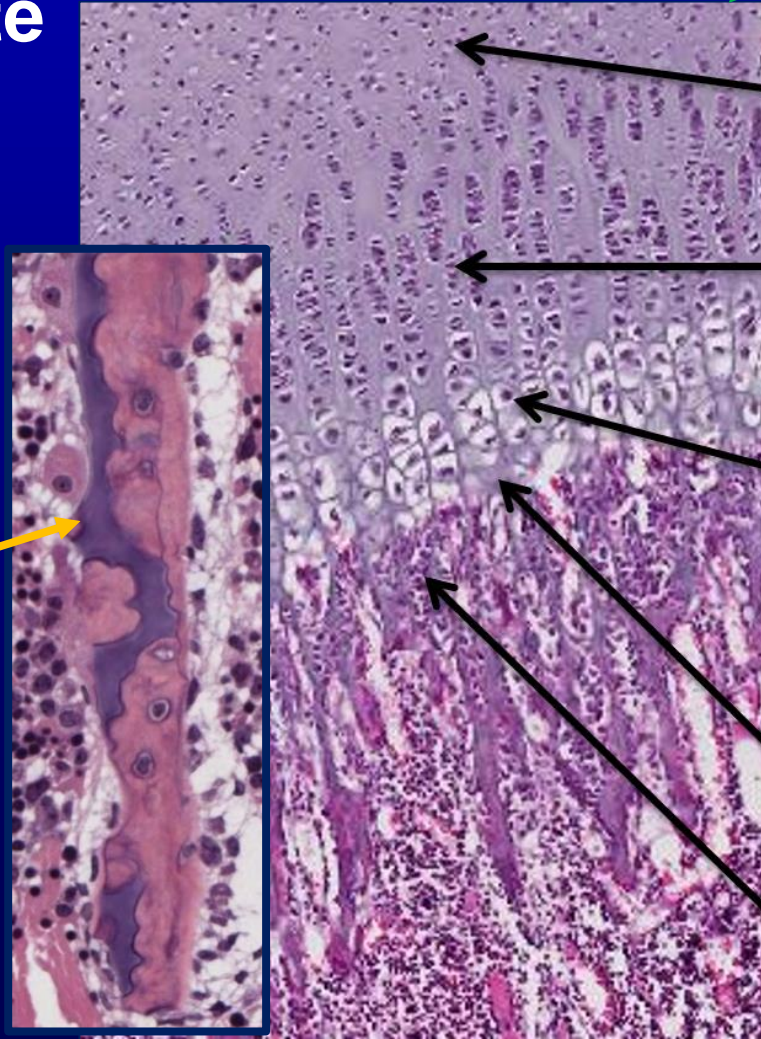
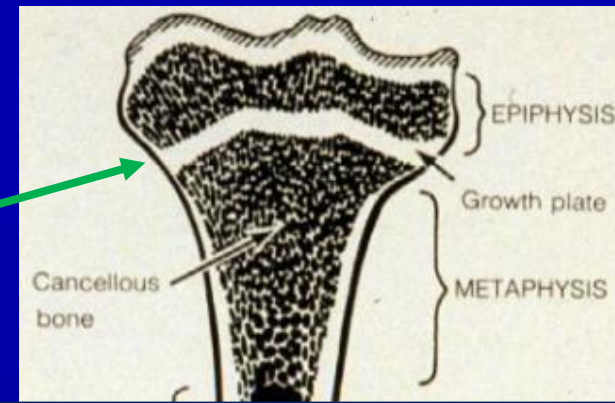
Calcification of cartilage

Spongiosa

Primary spongiosa – cartilage core

Secondary spongiosa – osteoid core

Growth plate



Zone of reserve (resting) cartilage—this zone appears as an area of typical hyaline cartilage.

Zone of proliferative chondrocytes—characterized by chondrocytes that are arranged in rows (like stacks of coins).

Zone of mature (hypertrophied) chondrocytes—in this zone, both the chondrocytes and lacunae have enlarged at the expense of the matrix, reducing it (the matrix) to thin strands.

Zone of calcified chondrocytes/cartilage matrix—

Zone of erosion and ossification

Endochondral Bone Growth

In length - epiphyseal plate

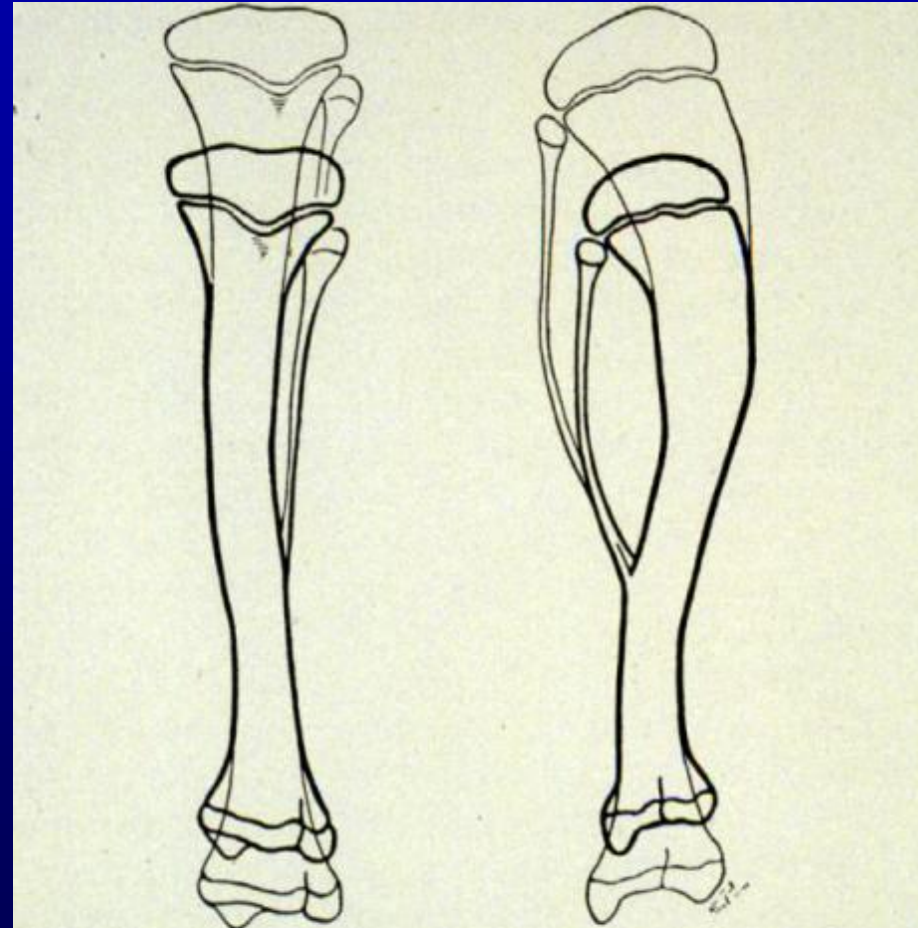
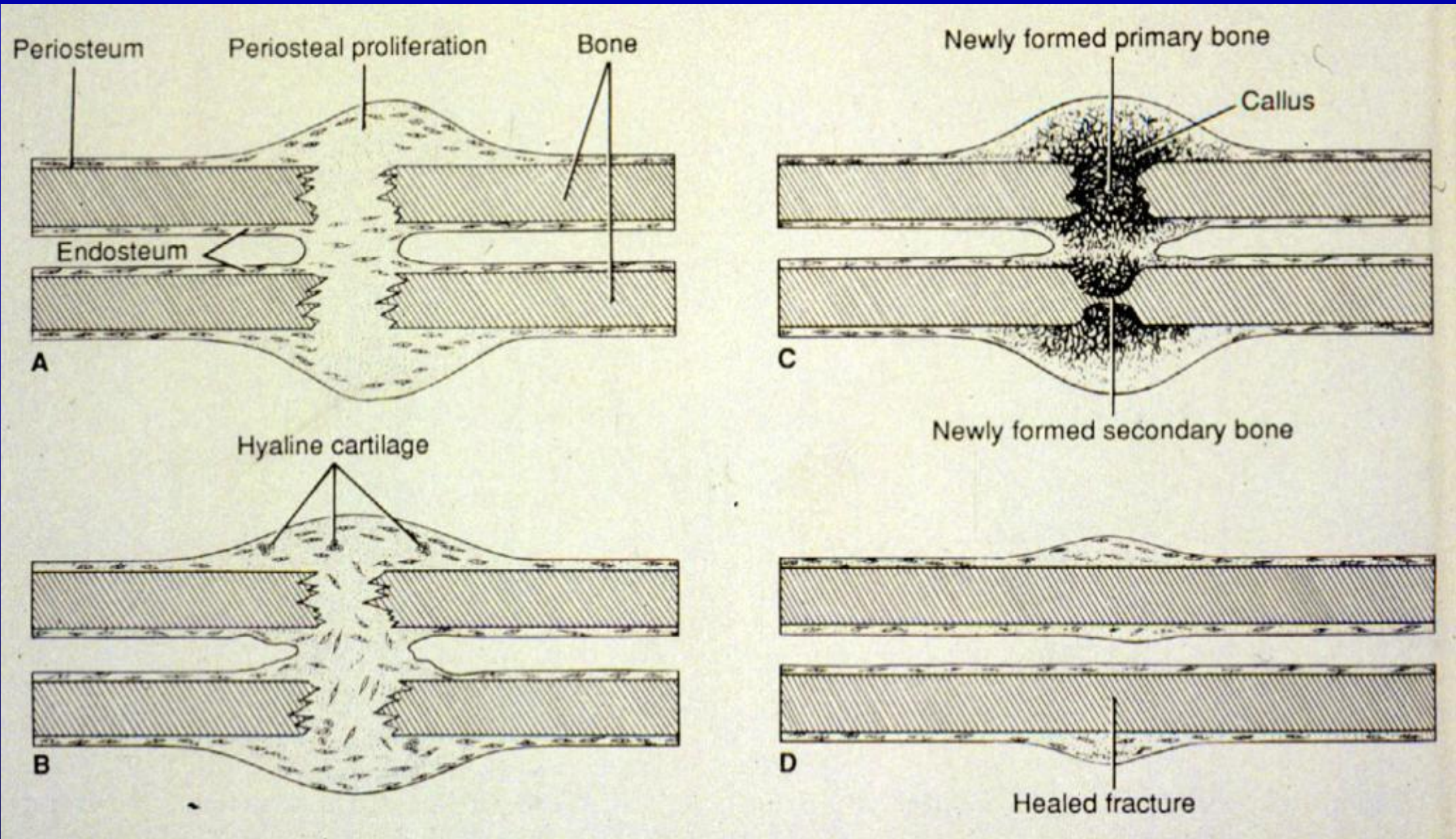


Figure 8-30. Diagram to illustrate remodeling during growth of tibia and fibula of rat, viewed from anterior aspect and in profile. (After Wolbach.)

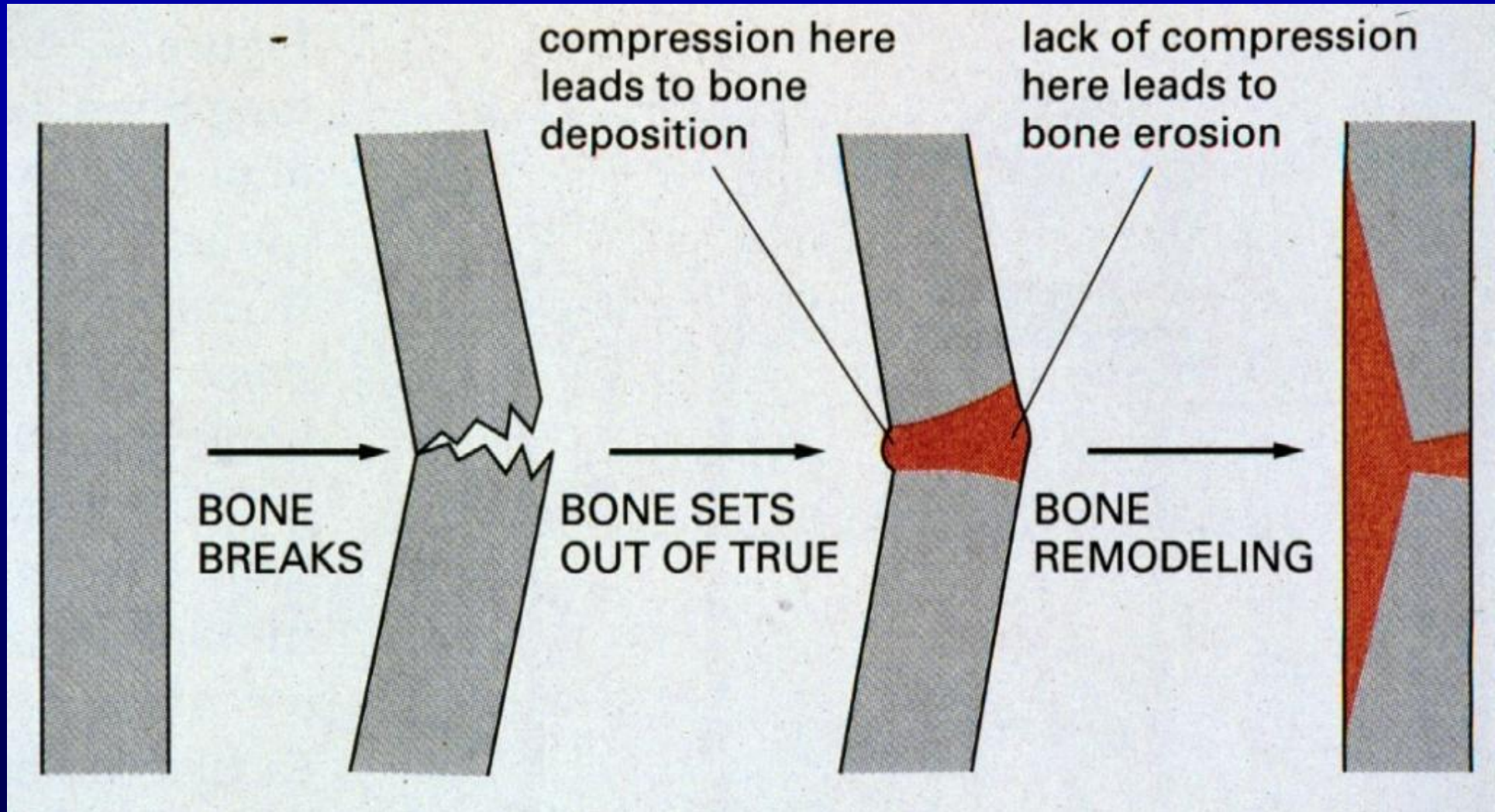


Red spots in this scintigram (a kind of scanning photo) mark growing areas at the ends of normal child's bones. Before puberty, growth depends mainly on somatotropin; later, mainly on sex hormones.

Bone Repair



Bone Repair



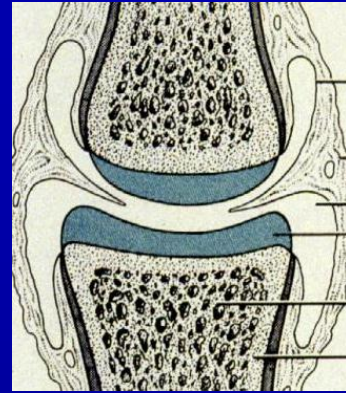
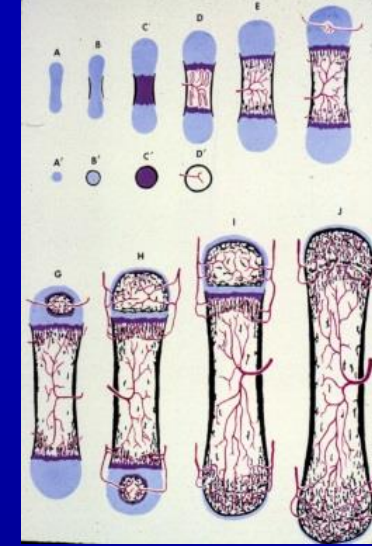
- <http://www.youtube.com/watch?v=qVougiCEgH8&feature=related>

Functions of Cartilage and Bone

Cartilage

Evolutionary - embryonic model for bones
Slides across each other easily while bearing weight (joints, articular surfaces of bones)

Cushion - cartilage has limited compressibility (joints)

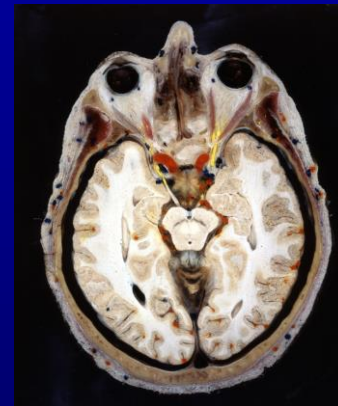
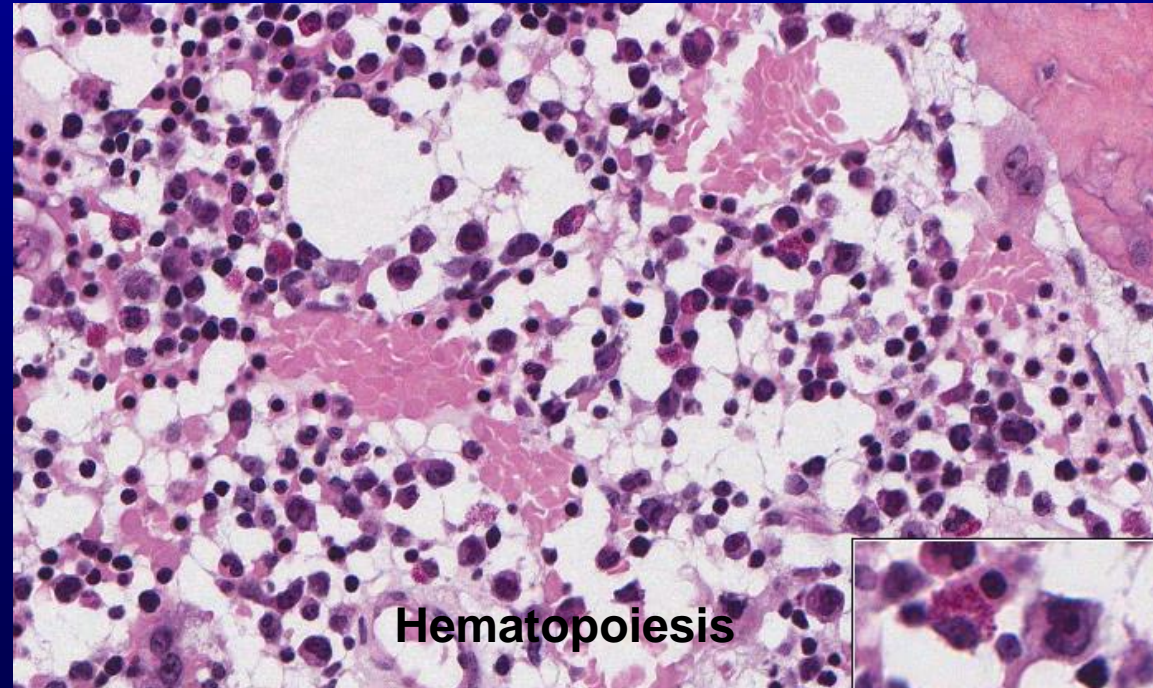


Bone

Skeletal support land animals
Protective enclosure (vital organs)

Skull to protect brain and
long bone to protect hematopoietic cells

Hematopoiesis



In final summary

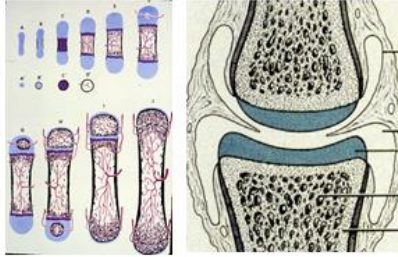
Functions of Cartilage and Bone

Cartilage

Evolutionary - embryonic model for bones

Slides across each other easily while bearing weight (joints, articular surfaces of bones)

Cushion - cartilage has limited compressibility (joints)



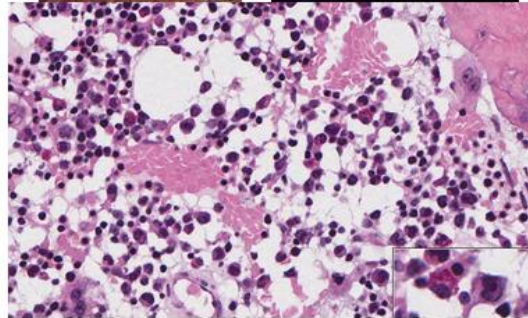
Bone

Skeletal support land animals

Protective enclosure (vital organs)

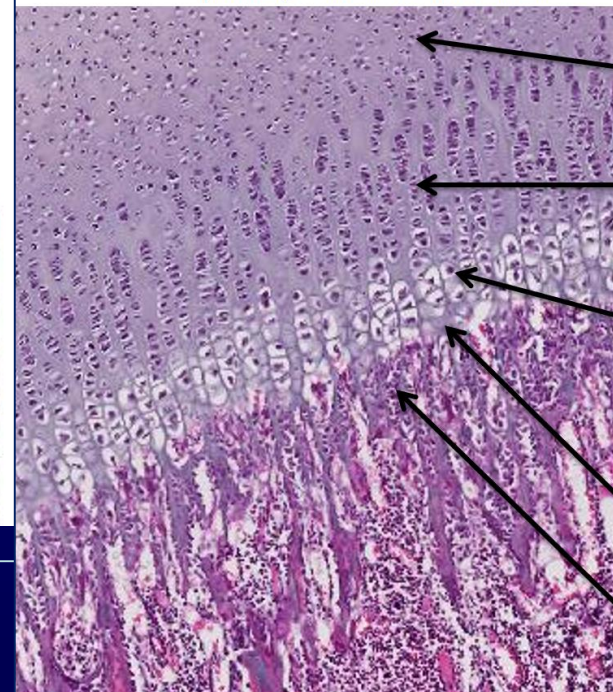
Skull to protect brain and long bone to protect hemopoietic cells

Hemopoiesis

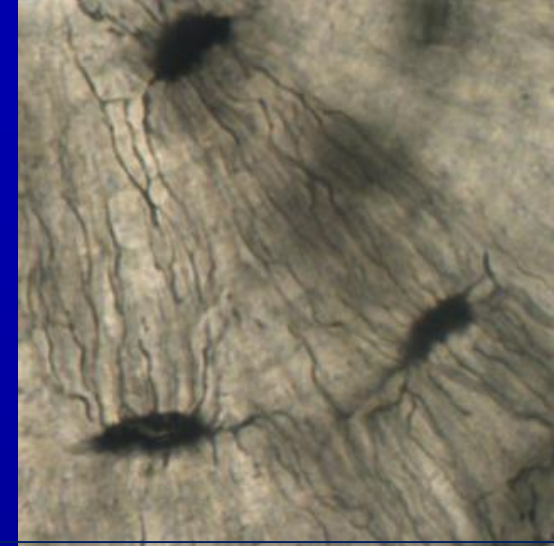


DEMO SLIDE BOX 159 (1089) –Developing bones and synovial joint, kitten.

primary center of ossification



- Zone of reserve (resting) cartilage**—this zone appears as an area of typical hyaline cartilage.
- Zone of proliferative chondrocytes**—characterized by chondrocytes that are arranged in rows (like stacks of coins).
- Zone of mature (hypertrophied) chondrocytes**—in this zone, both the chondrocytes and lacunae have enlarged at the expense of the matrix, reducing it (the matrix) to thin strands.
- Zone of calcified chondrocytes/cartilage matrix**—
- Zone of erosion and ossification**



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

- Bruce Alberts, et al. 1983. Molecular Biology of the Cell. Garland Publishing, Inc., New York, NY.
- Bruce Alberts, et al. 1994. Molecular Biology of the Cell. Garland Publishing, Inc., New York, NY.
- William J. Banks, 1981. Applied Veterinary Histology. Williams and Wilkins, Los Angeles, CA.
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