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M1 Musculoskeletal Sequence

Medical Histology

Cartilage / Mature Bone

Fall 2008

University of Michigan Medical School

Cartilage

Cartilage is a specialized form of firm and resilient connective tissue that can bear stresses without permanent distortion.

It consists of cells (chondroblasts, chondrocytes) and extracelluar matrix, consisting of fibers and ground substance (hyaluranan, proteoglycans, glycoproteins).

It is an avascular tissue.

It serves as a precursor or model for the embryonic development and subsequent growth of many long bones.
(It is replaced by bone tissue in adult life, except for the surfaces that articulate with other bones.)

Cartilage

There are three types of cartilage:

- Hyaline cartilage (Type II collagen)

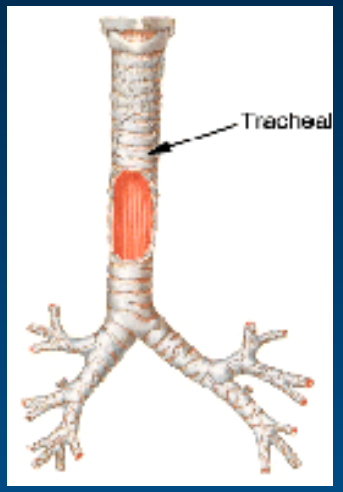
  Articular surfaces, Ephiphyseal plate, Tracheal wall, etc.

- Elastic cartilage (Type II collagen, elastic fibers)

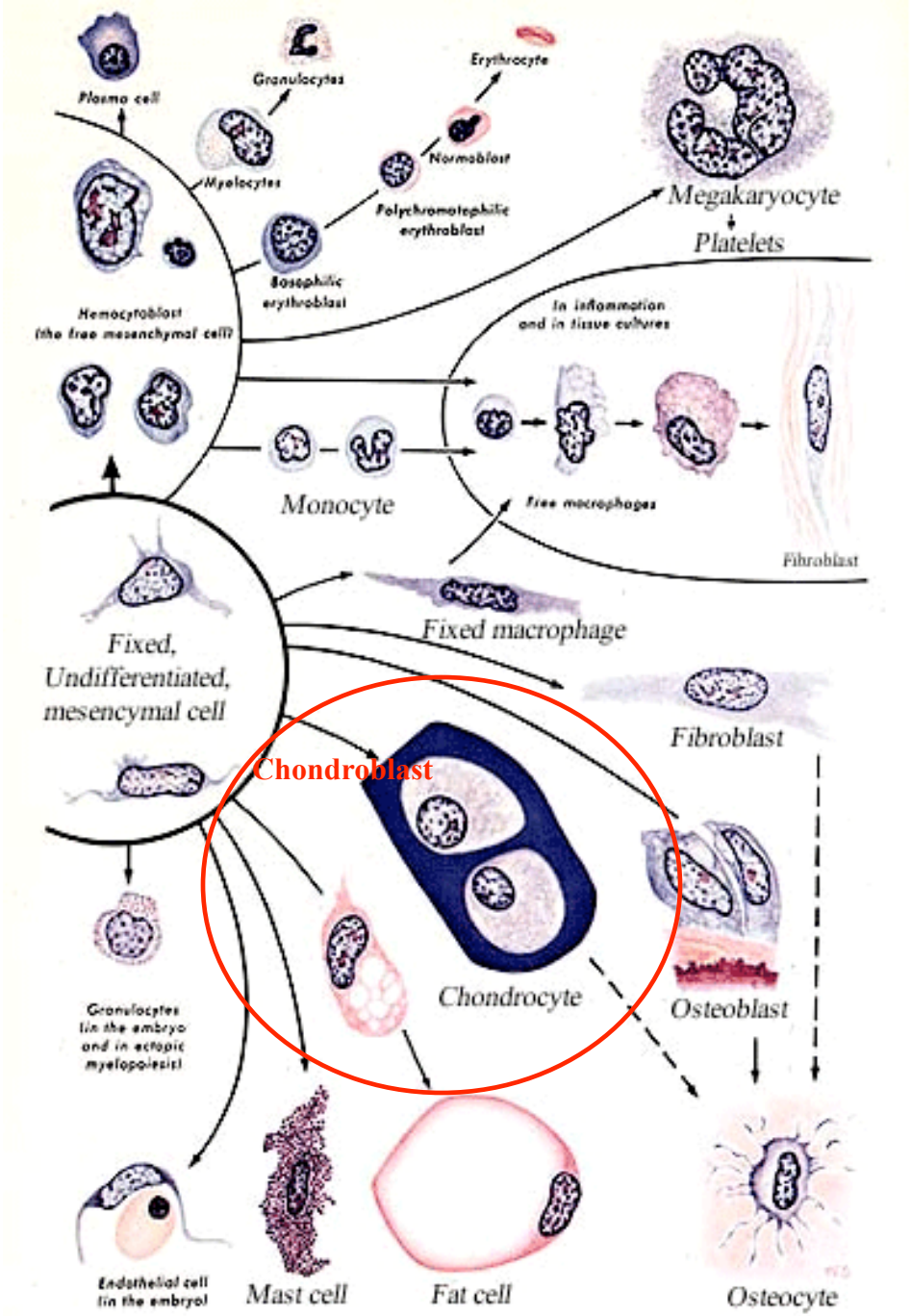
  Pinna of the ear, Epiglottis, Eustachian tube, etc.

- Fibrocartilage (Type II and Type I collagen)

  Intervertebral disks, Pubic symphysis, insertion sites of tendons and ligaments

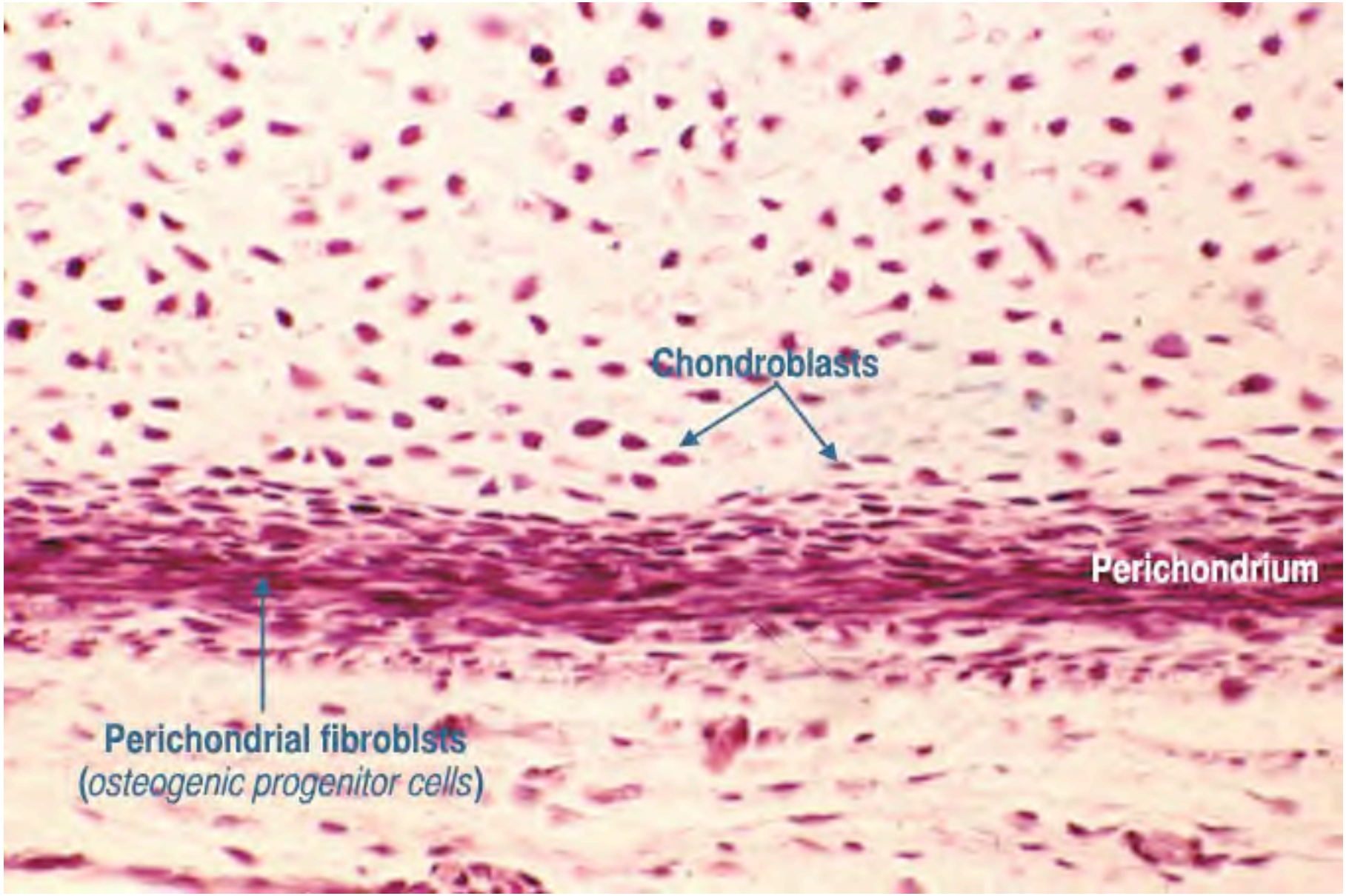


Stem cells

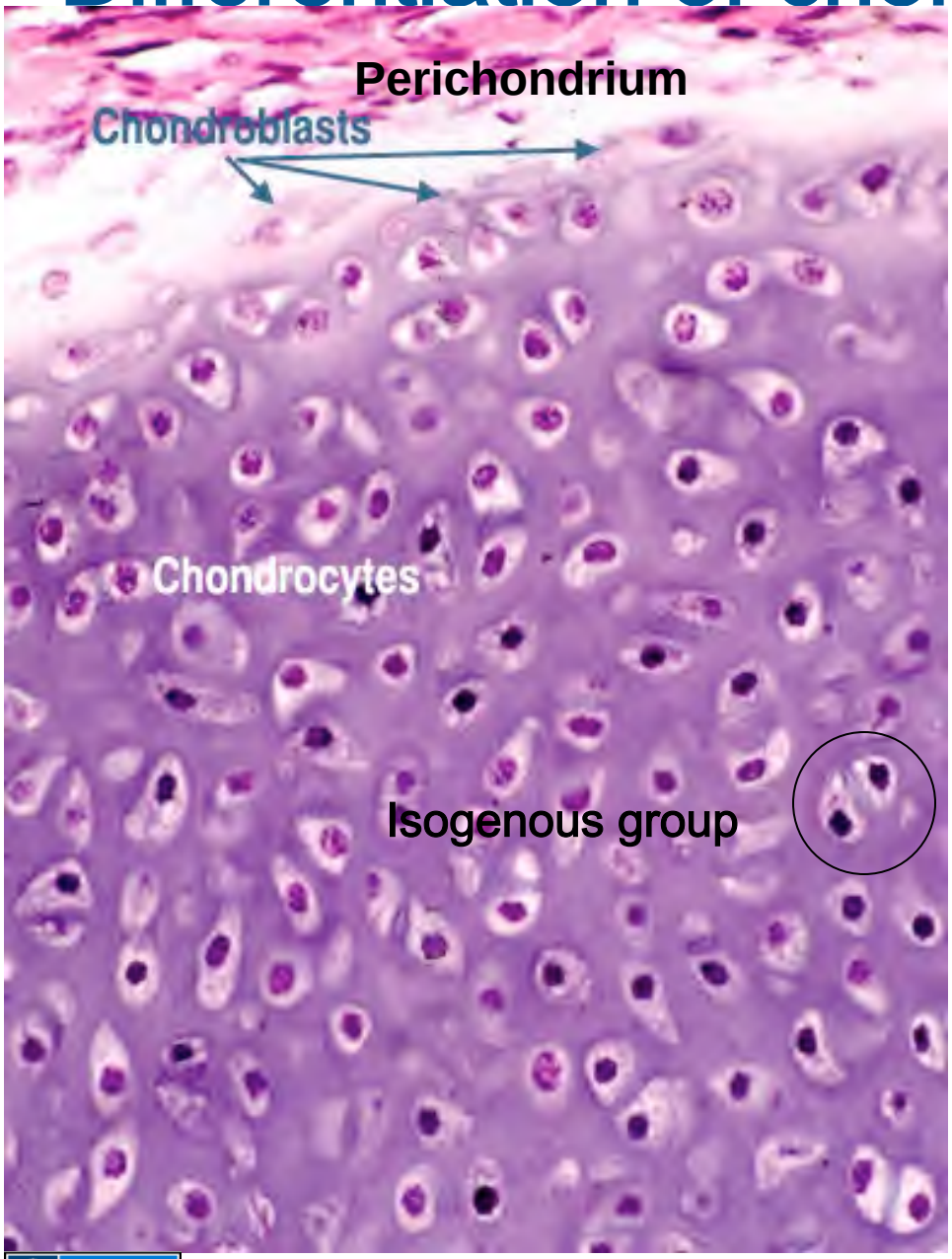


Initiation of Cartilage Formation
(embryonic mesenchymal cells)

Beginning of cartilage Formation



Differentiation of chondrogenic cells



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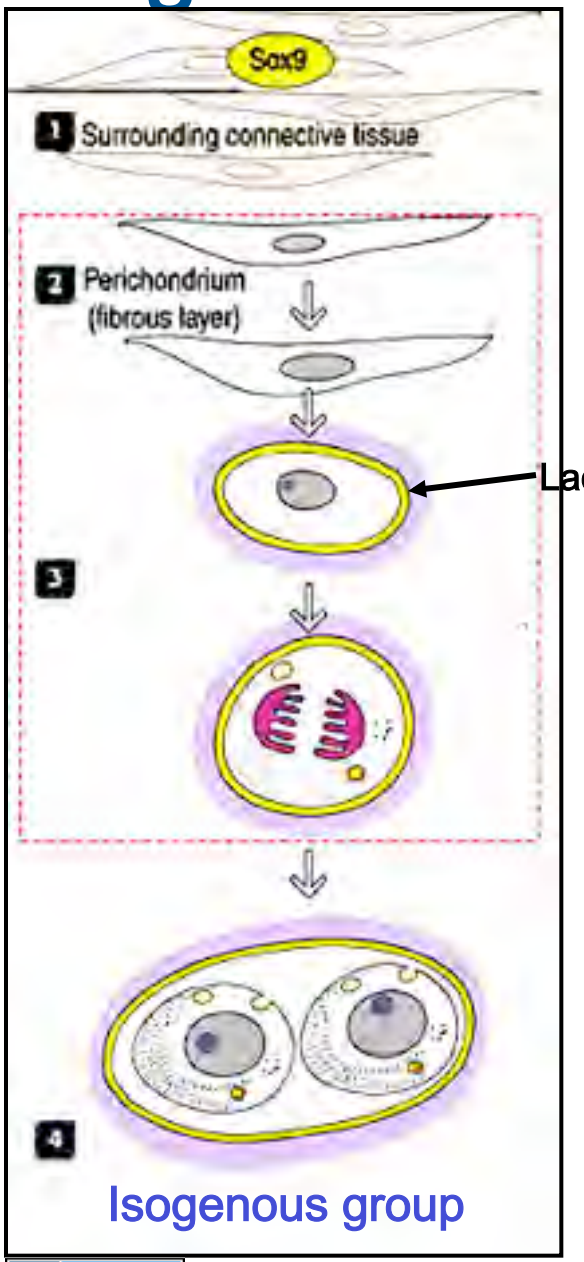
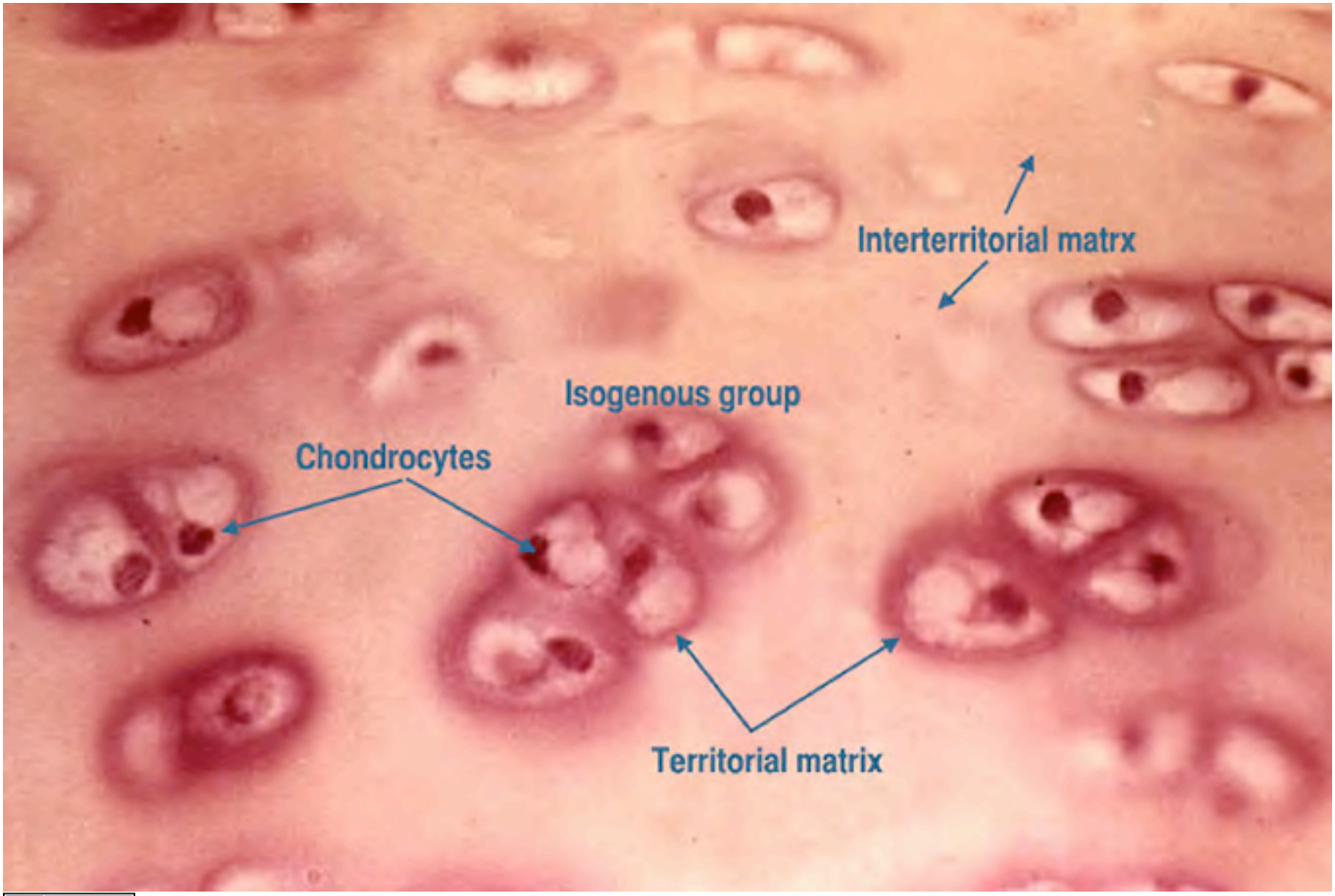
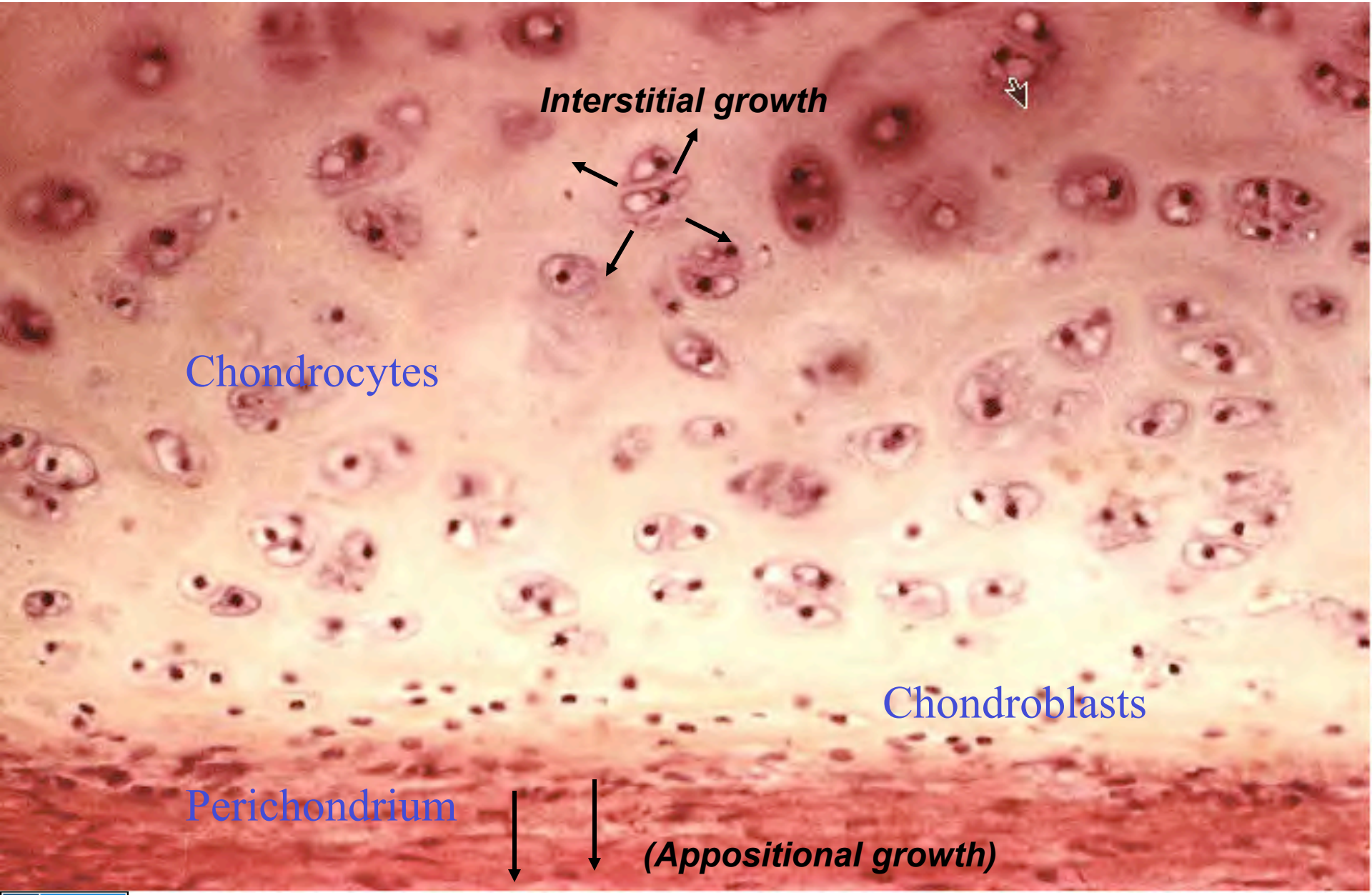


 Kierszenbaum, p. 115

Formed Hyaline Cartilage



Formed Hyaline Cartilage

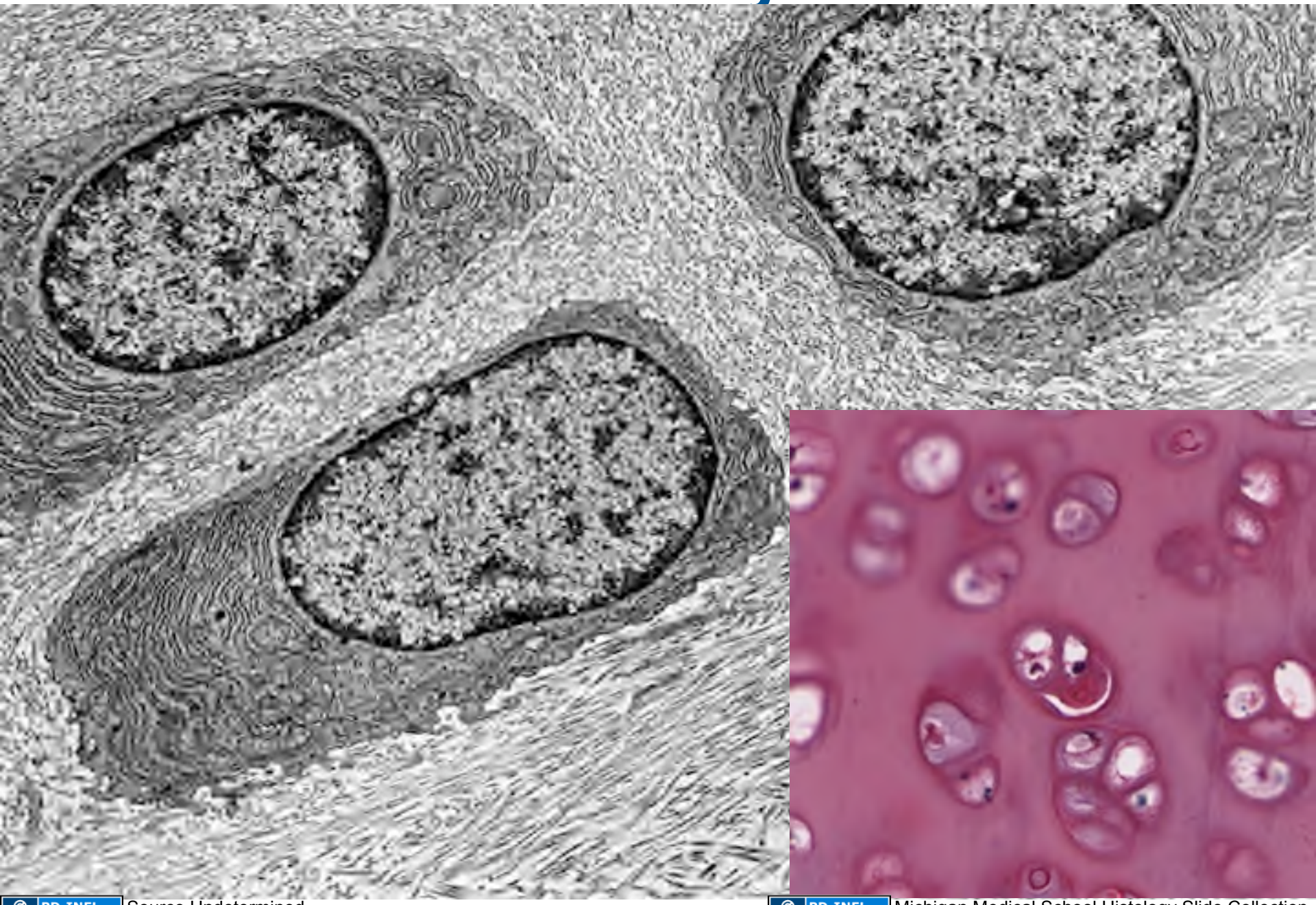


Cartilage growth

Appositional Growth: Deposition of new cartilage on the surface of existing cartilage.

Interstitial Growth: Formation of new cartilage within an existing cartilage.

Chondrocytes

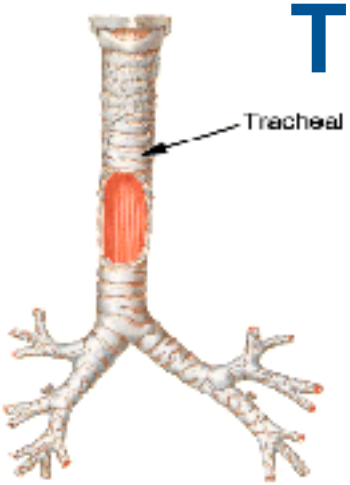


Hyaline cartilage

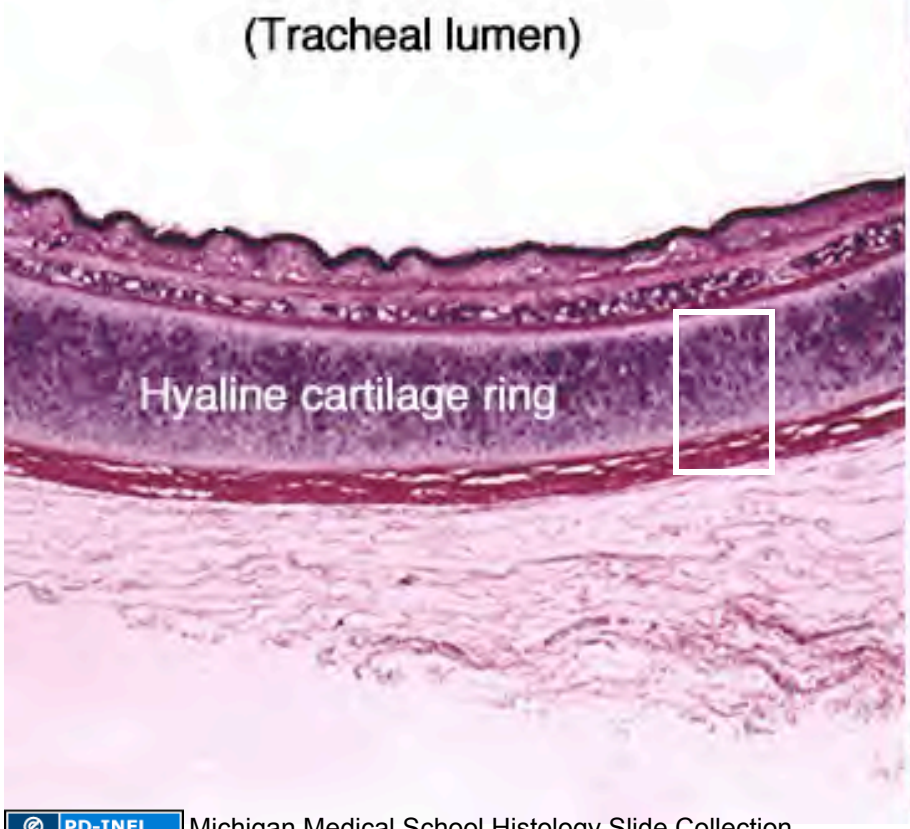
Most common types of cartilage.

Nasal septum, larynx, tracheal rings, sternal ends of ribs, most articular surfaces and forms the template for developing long bones.

Tracheal Hyaline Cartilage



PD-INEL Netter 2nd Ed. Plate 190



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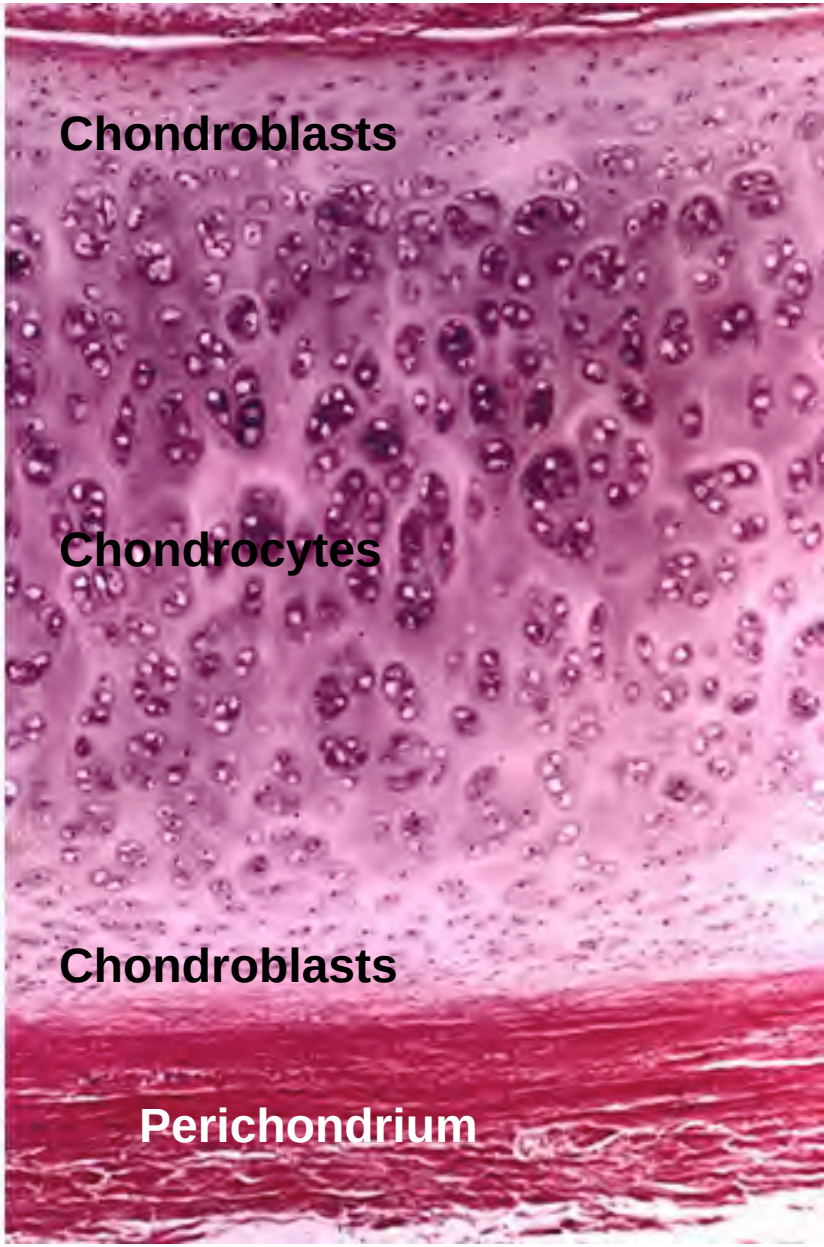
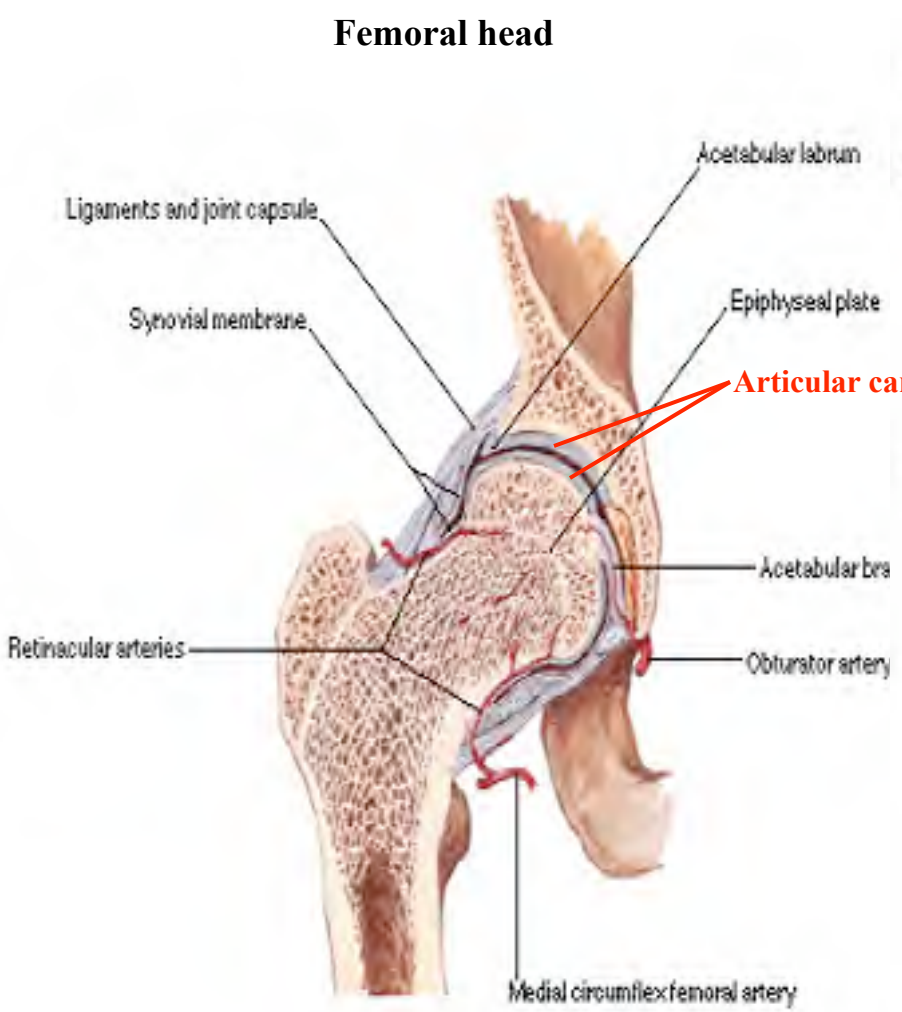


Articular Cartilage

(Specialized form of hyaline cartilage)



Articular (hyaline) Cartilage in Joints

BY-SA Ed Yourdon, flickr

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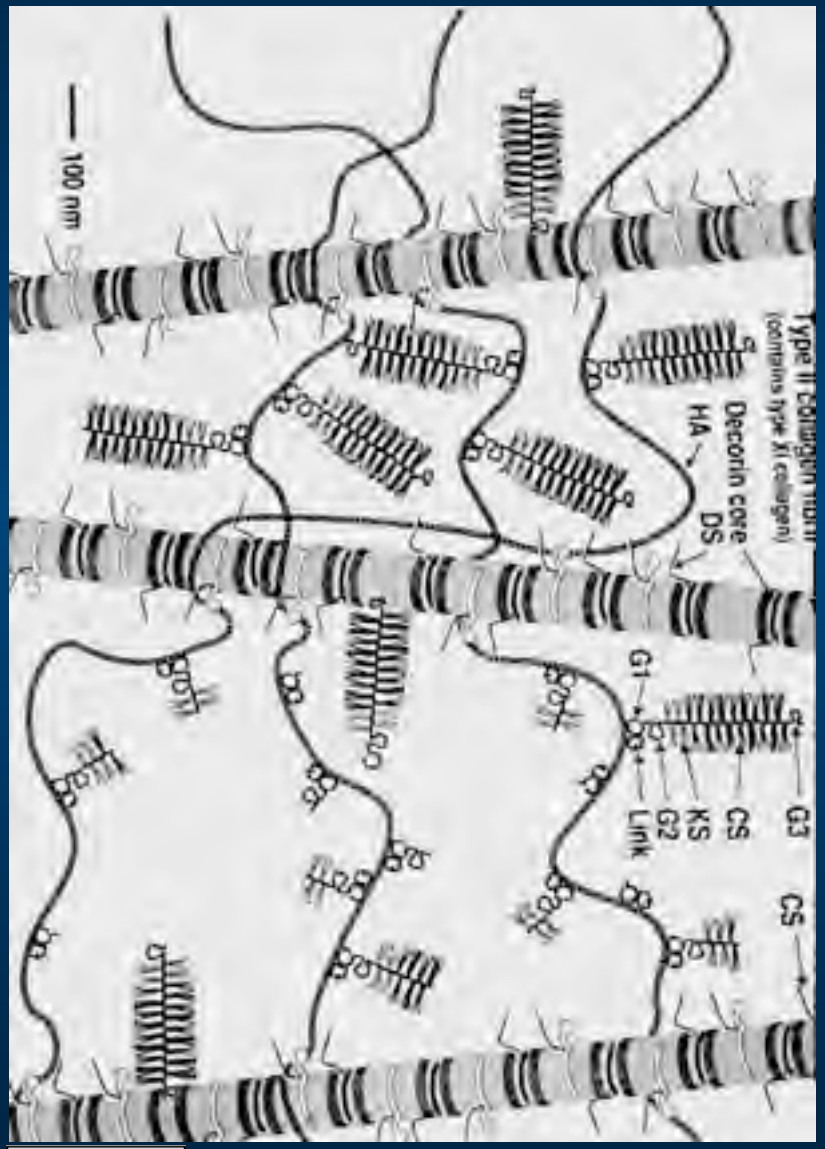
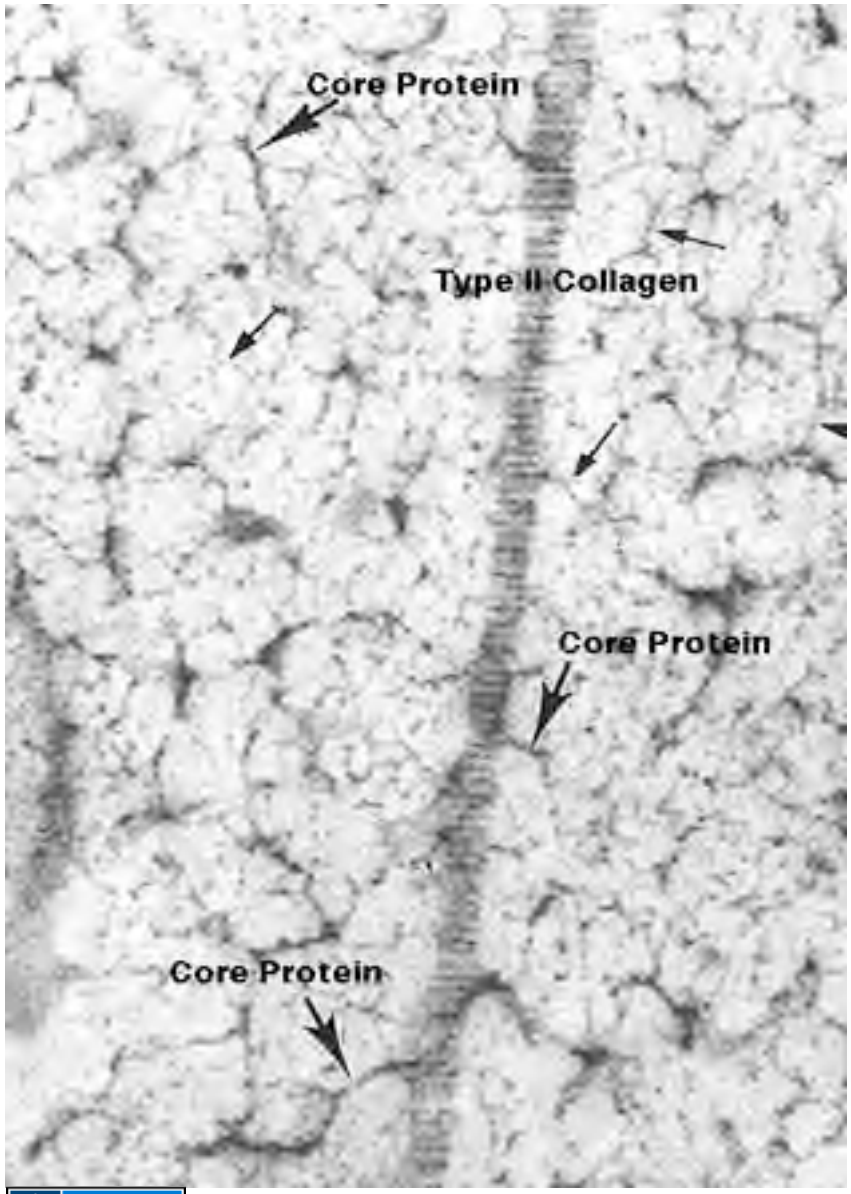
Cartilage Matrix

- Type II collagen
- Hyaluranan (hyaluronic acid) up to $8X10^6$ d
- Proteoglycans ($3.5X10^6$ daltons)
  - Aggrecan
    - Proetin Core
    - Glycosaminoglycans (GAGs)
      - Chondroitin sulfate
      - Keratin sulfate



Hyaline Cartilage Matrix



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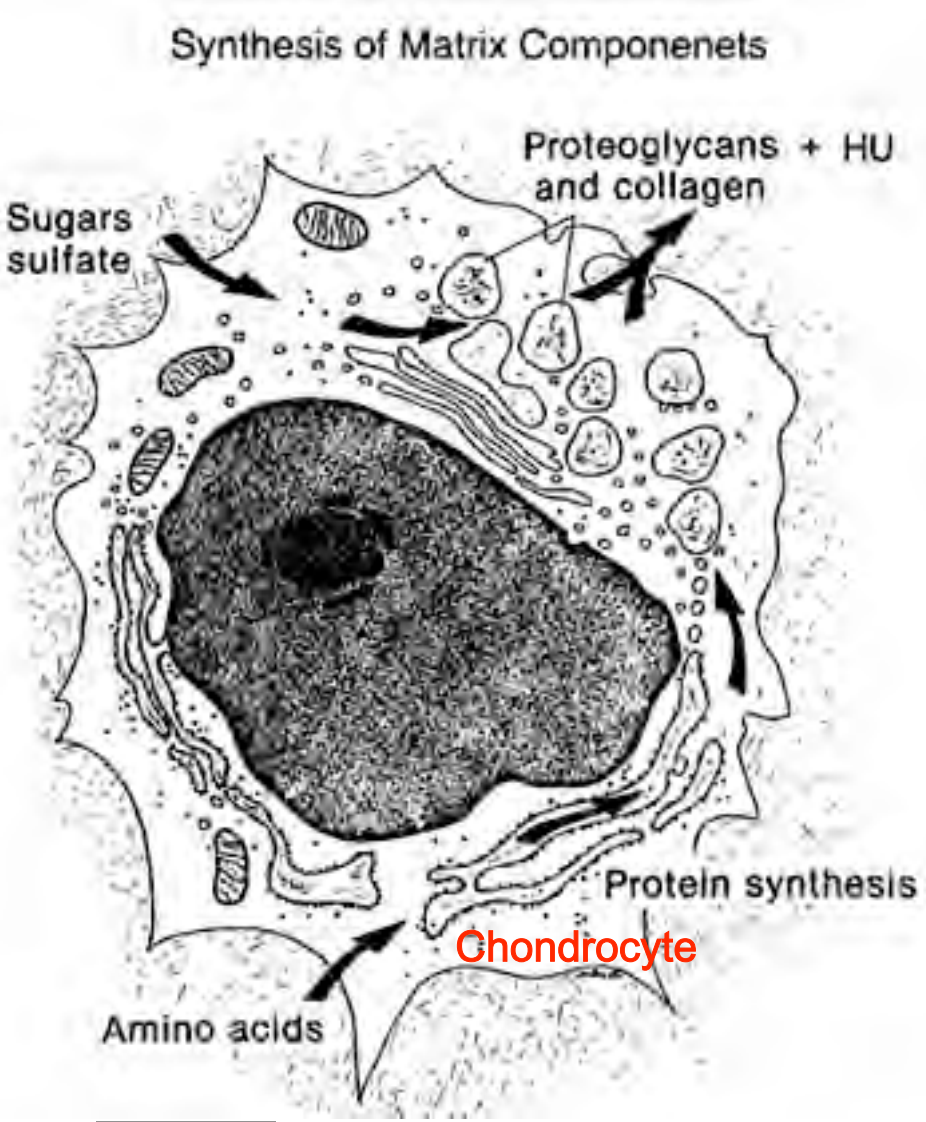
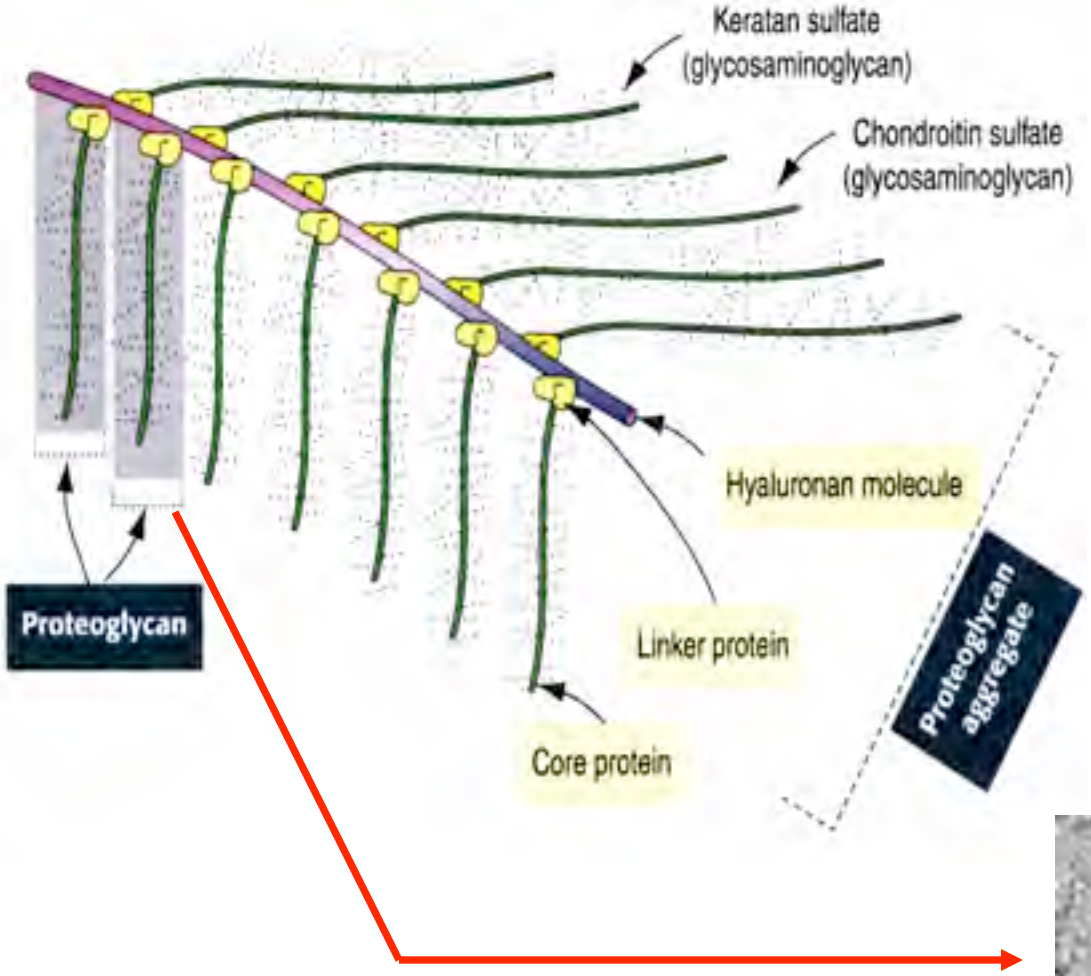


PD-INEL Bloom & Fawcett, 12th ed. p. 189

Proteoglycan Aggregates

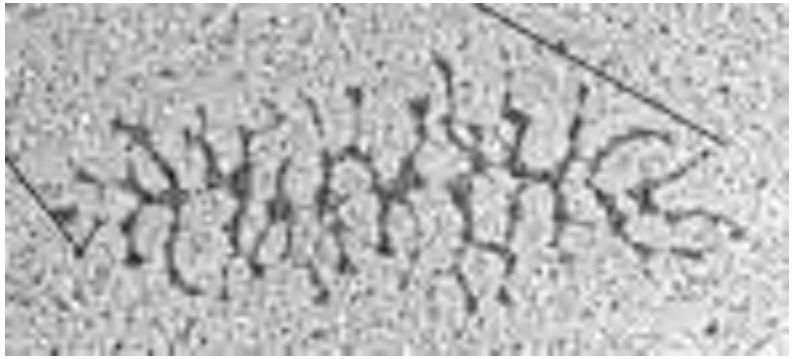


Consist of:

1. **An axial *hyaluronan*(HU) molecule.**
2. ***Core proteins* attached to the HU molecule by a *linker protein.***
3. ***Glycosaminoglycans* attached to a core protein.**

Kierszenbaum, p. 108

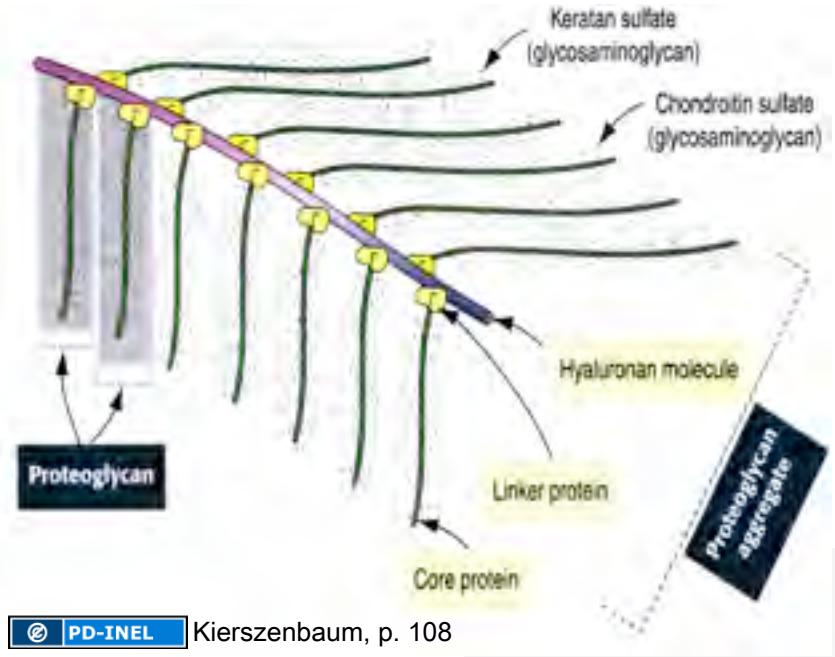
EM view of spread preparation



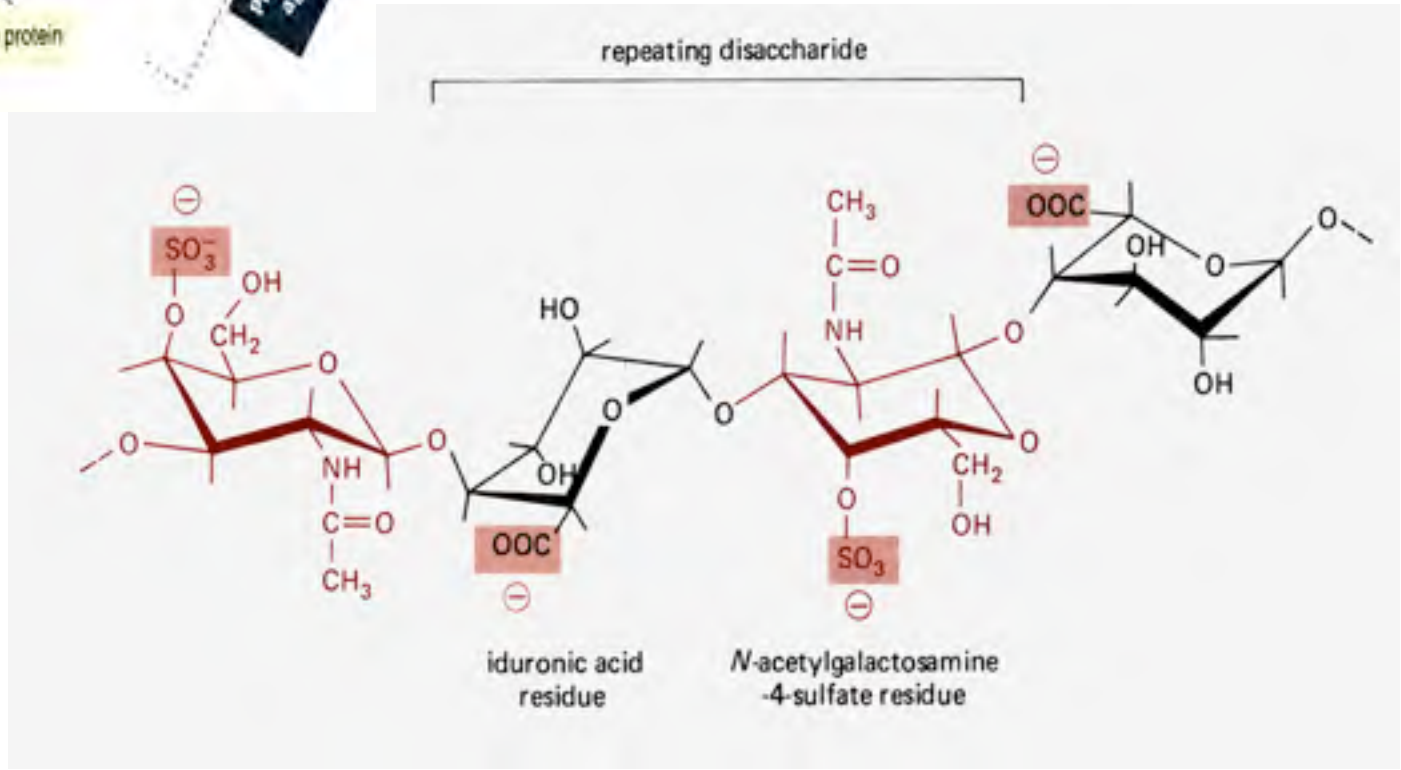
 Kierszenbaum, p. 108

 Source Undetermined

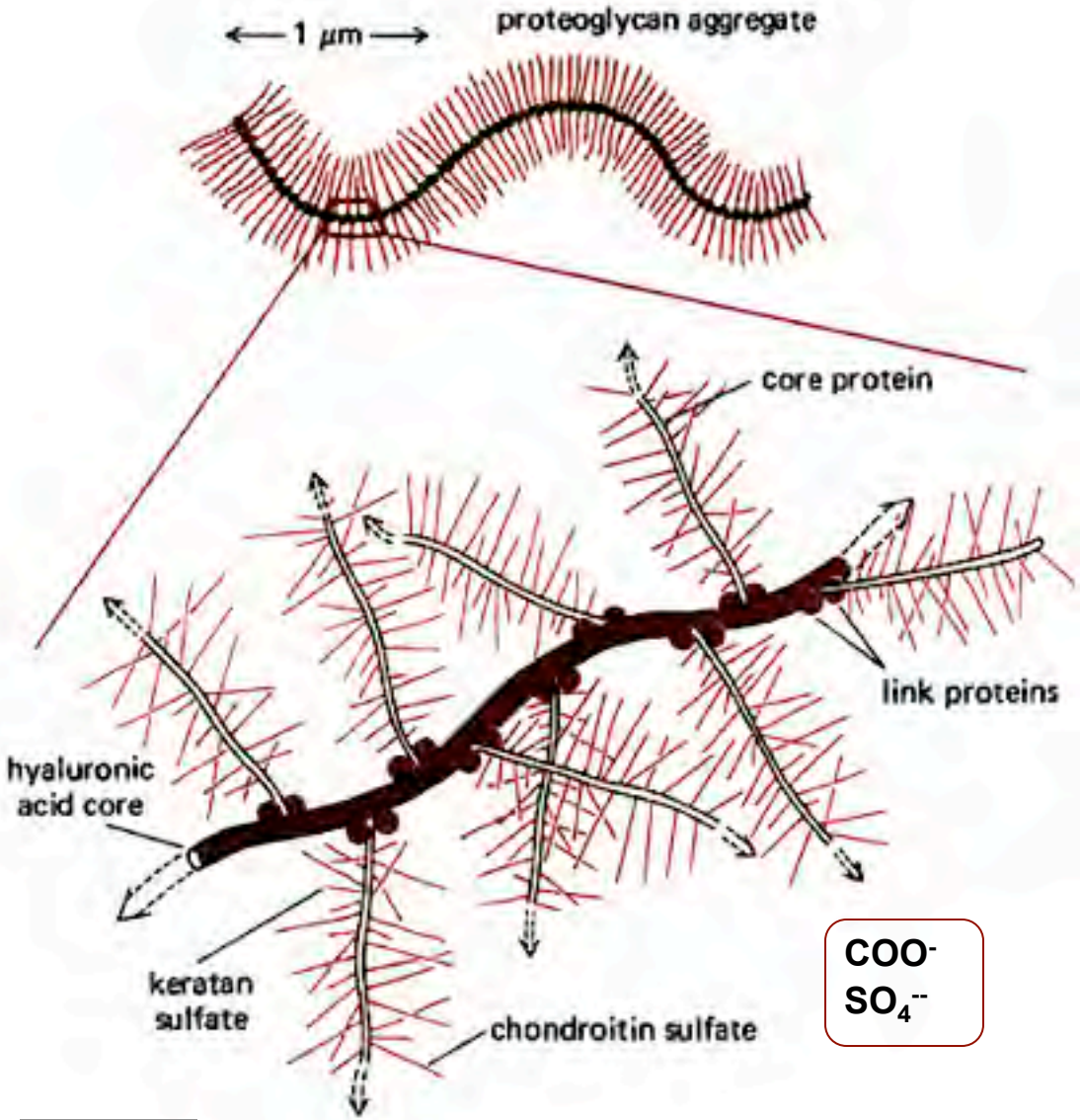
Glycosaminoglycans



PD-INEL Kierszenbaum, p. 108



PD-INEL Albert et al., 2nd ed. p. 804



PD-INEL Albert et al., 2nd ed. p. 807

Extended random coil conformation of a single molecule of hyaluronan

PD-INEL Albert et al., 2nd ed. p. 804

Cartilage Matrix and It's function

The glycosaminoglycans (GAGs) tend to adopt highly extended, so called random coil conformations, which occupy a huge volume relative to their mass and they form gel.

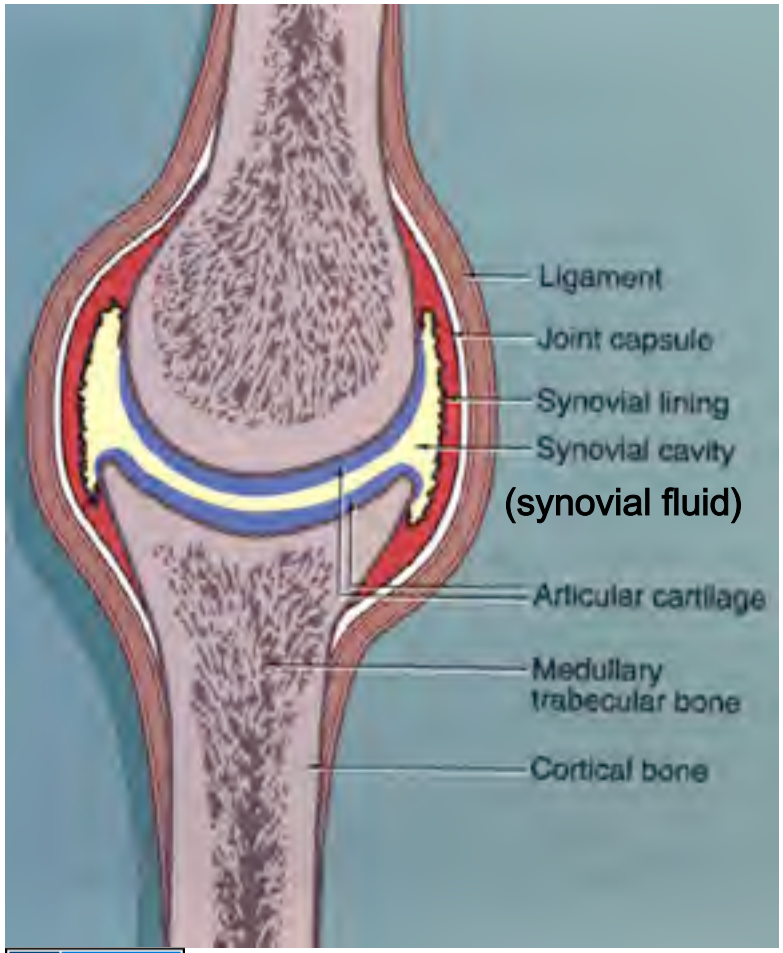
Their high density of negative charges attract cations, such as Na^{++} that are osmotically active causing large amounts of water to be sucked into the matrix.

This creates a swelling pressure or turgor, that enables the matrix to withstand compressive forces (in contrast to collagen fibers which resist stretching forces).

Cartilage matrix resist compression by this mechanism. [Alberts: p804]

Basophilia in hyaline cartilage matrix

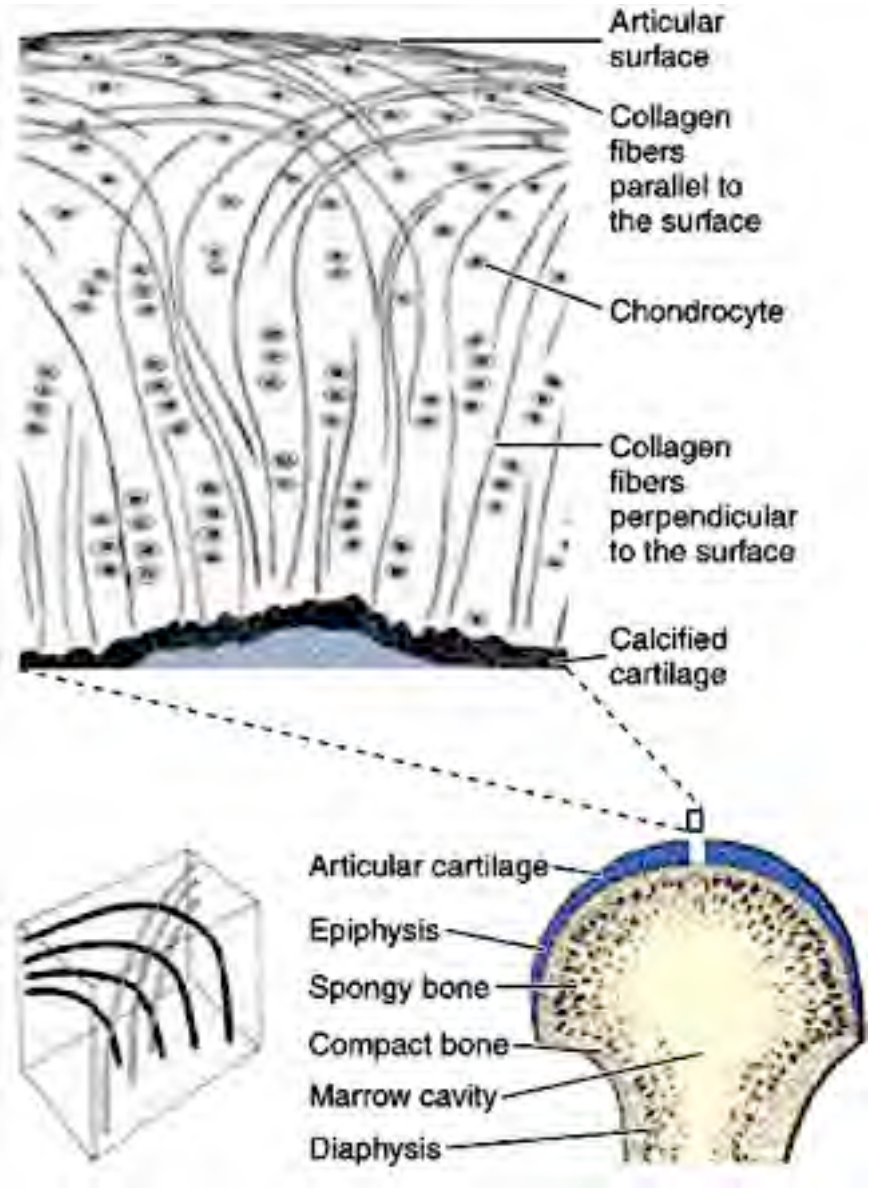
Diarthrosis and Articular Cartilage



PD-INEL Wheater p. 202

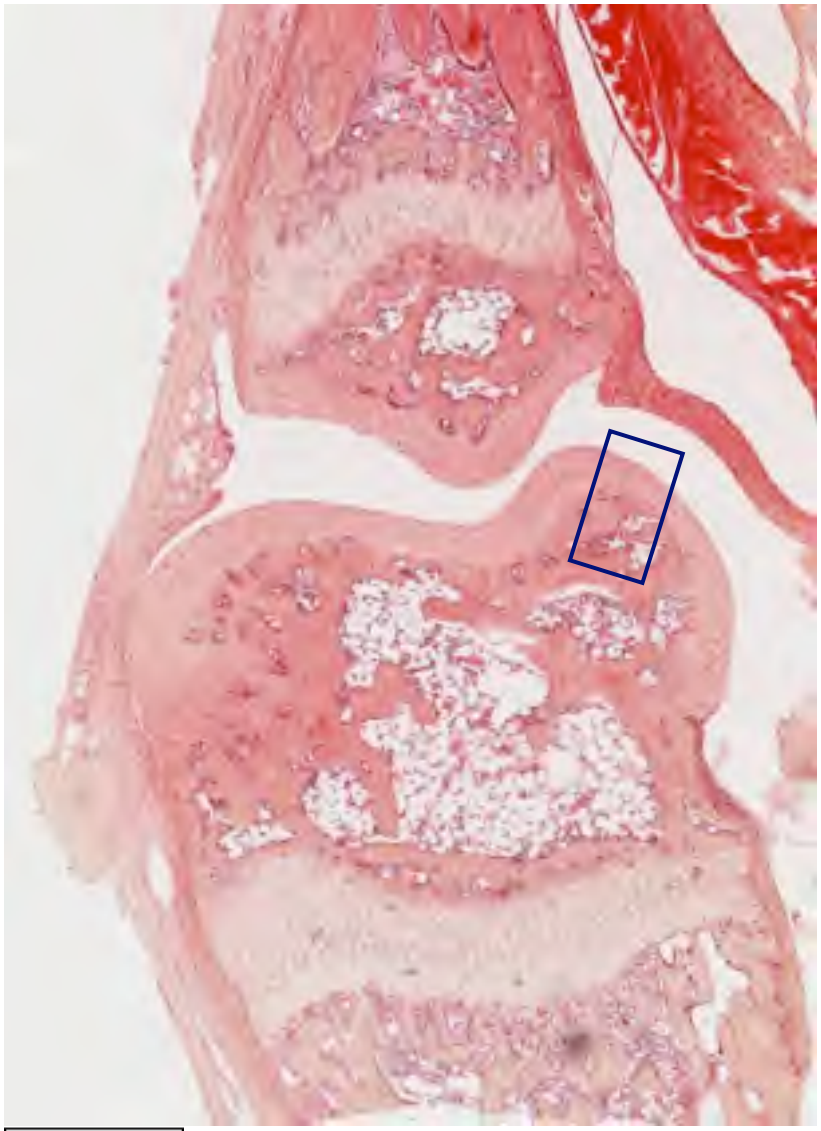
Bathed in synovial fluid.

No perichondrium
Collagen fibers - arranged as gothic arches
Chondrocytes - in vertial rows.



PD-INEL Junqueira, p.157

Articular cartilage



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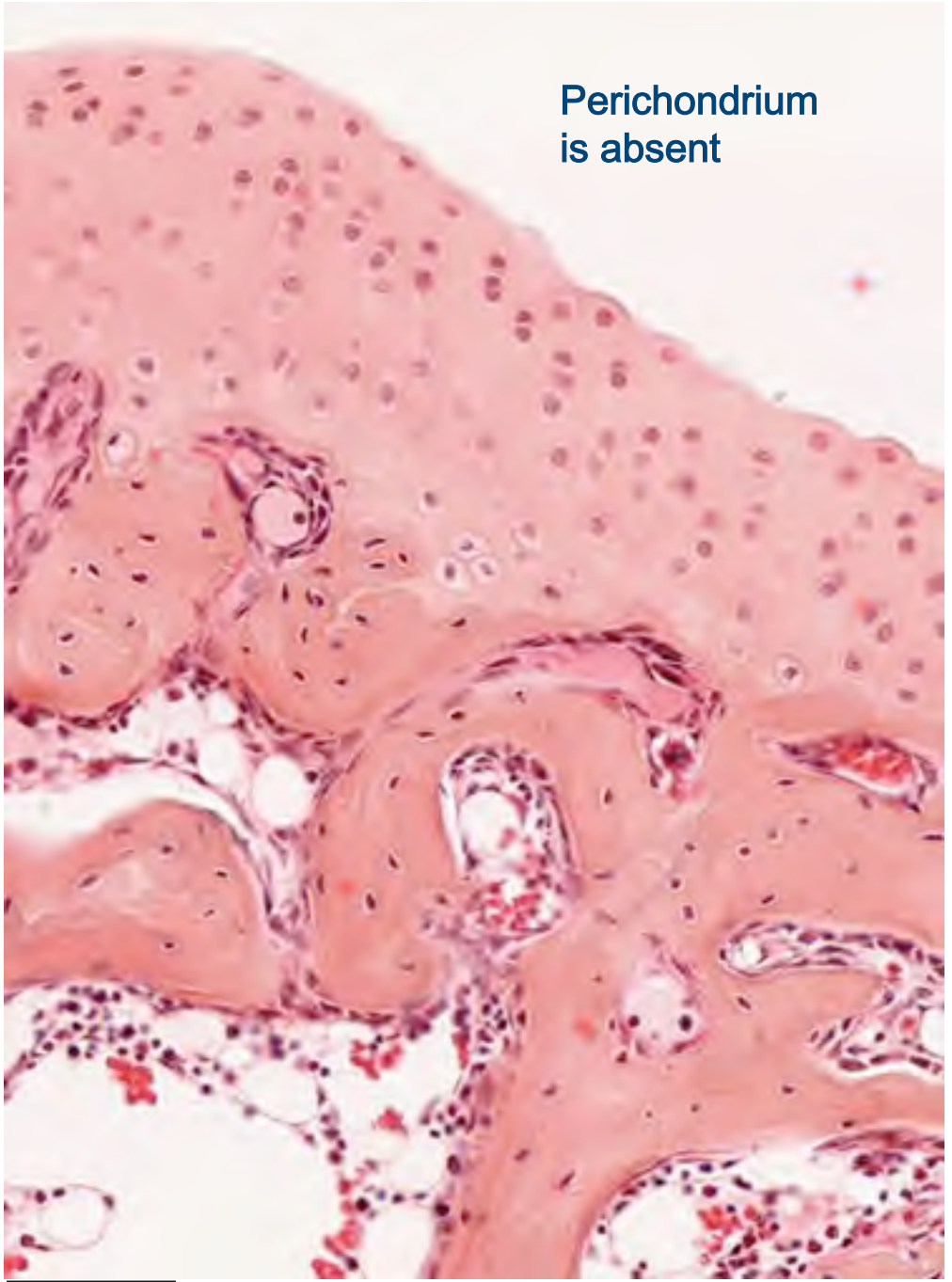

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Cartilage Damage

Cartilage Changes with Aging

Not much changes with collagen.

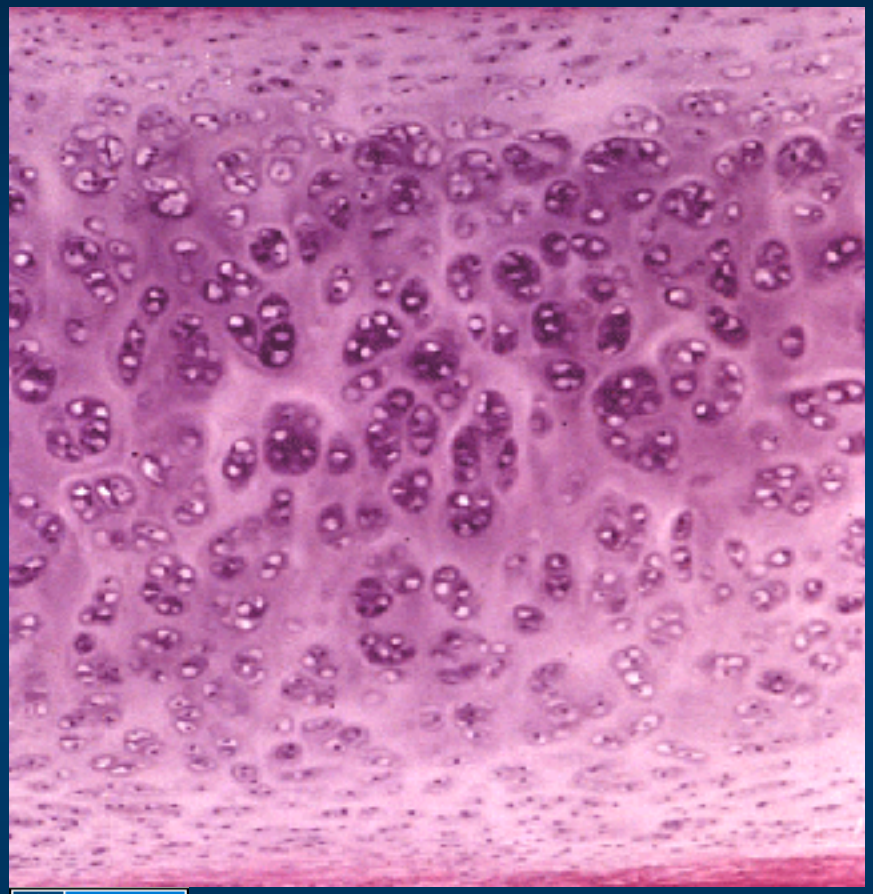
The proteoglycans produced in older individuals are smaller with shorter chondroitin sulfate chains than in younger individuals.

Chondrocytes seem less efficient in renewing the matrix thus reducing proteoglycan contents.

These changes might reduce water contents in the matrix and make the cartilage less able to resist compressive forces.

These changes, in turn, would make matrix more vulnerable to injuries in weight-bearing, and the inflammatory response to injury would cause painful symptoms of arthritis.

Differences in basophilic staining in cartilage matrix



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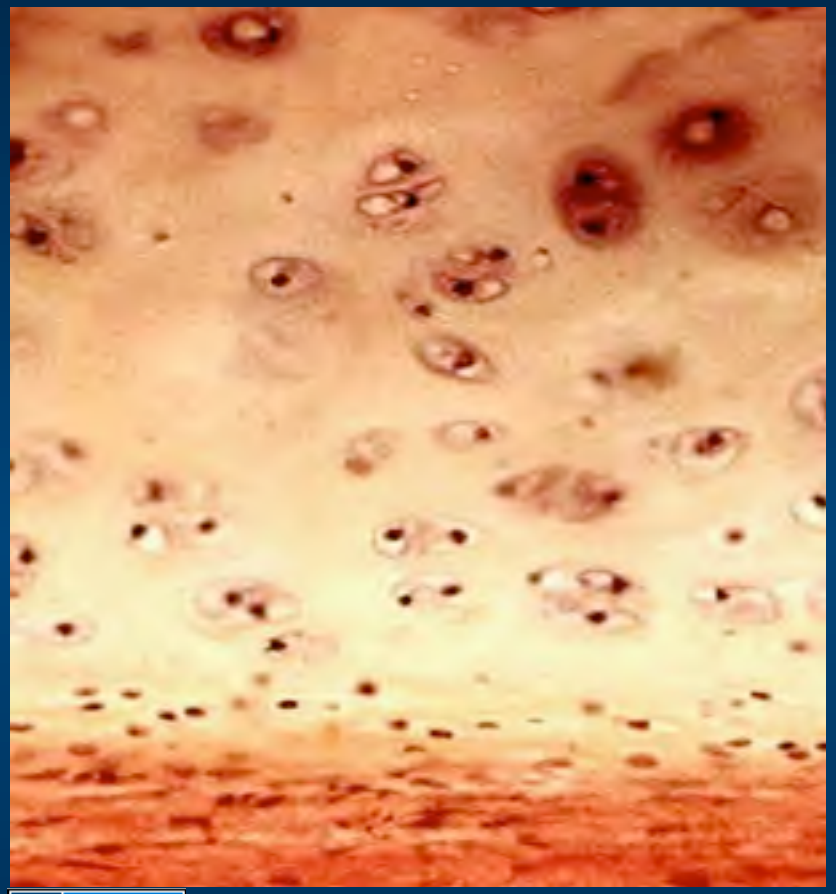


PD-INEL Source Undetermined

The difference in basophilic staining reflects the relative matrix content of glycosaminoglycans (aggrecans).

The decrease in size of proteoglycans or the length of chondroitin sulfate chains will reduce the relative matrix content of glycosaminoglycans This, in turn, will reduce the intensity of basophilic staining in the cartilage matrix.

Elastic cartilage: contains elastic fibers.

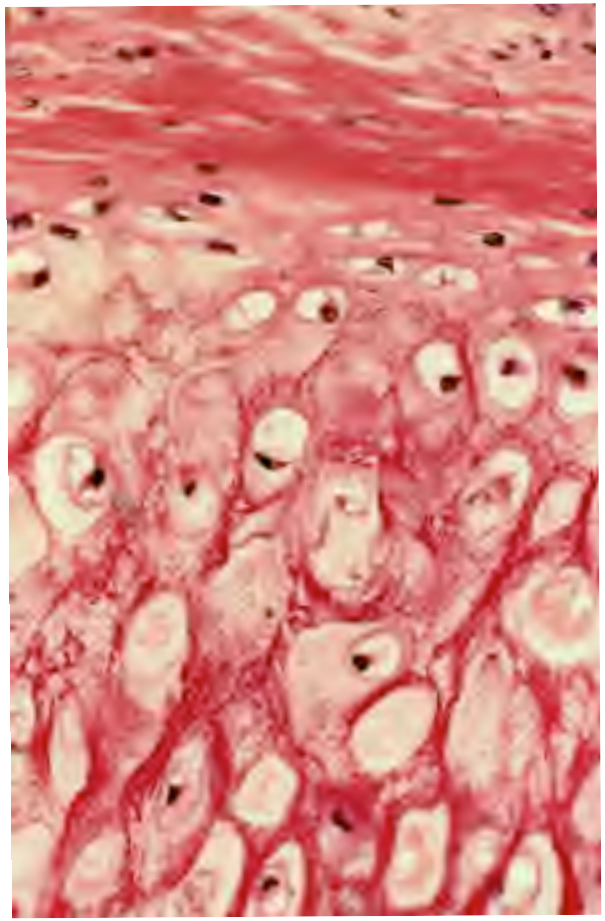
Pinna of the external ear, auditory canal, epiglottis, Eustachian tube.

Fibrocartilage: intermediate between cartilage and dense regular connective tissue.

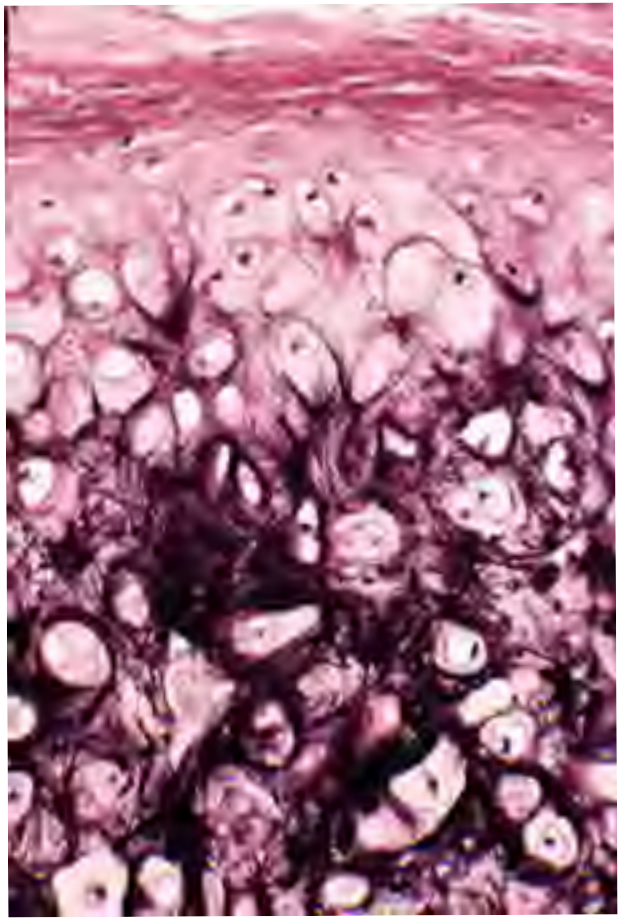
intervertebral discs, pubic symphysis, etc.

Elastic Cartilage

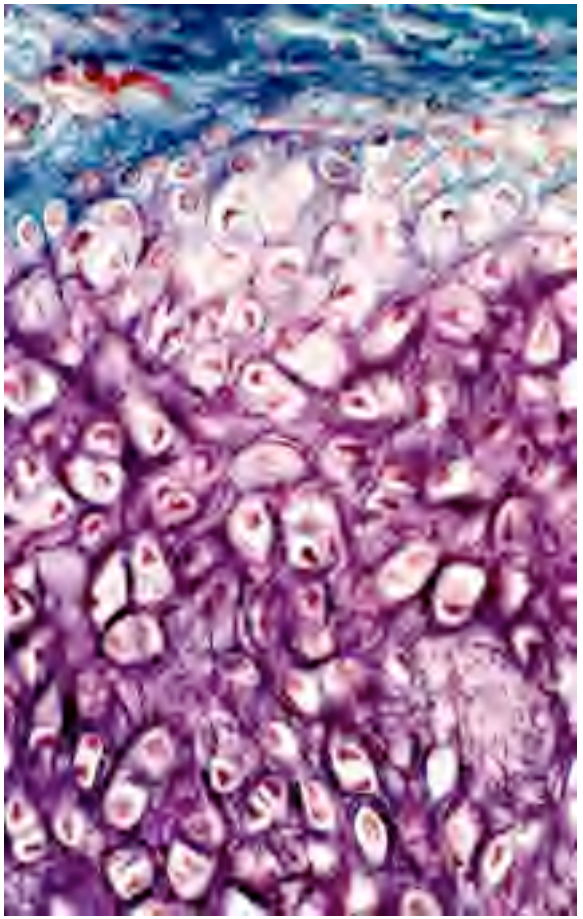
H&E stain



Weigert's stain

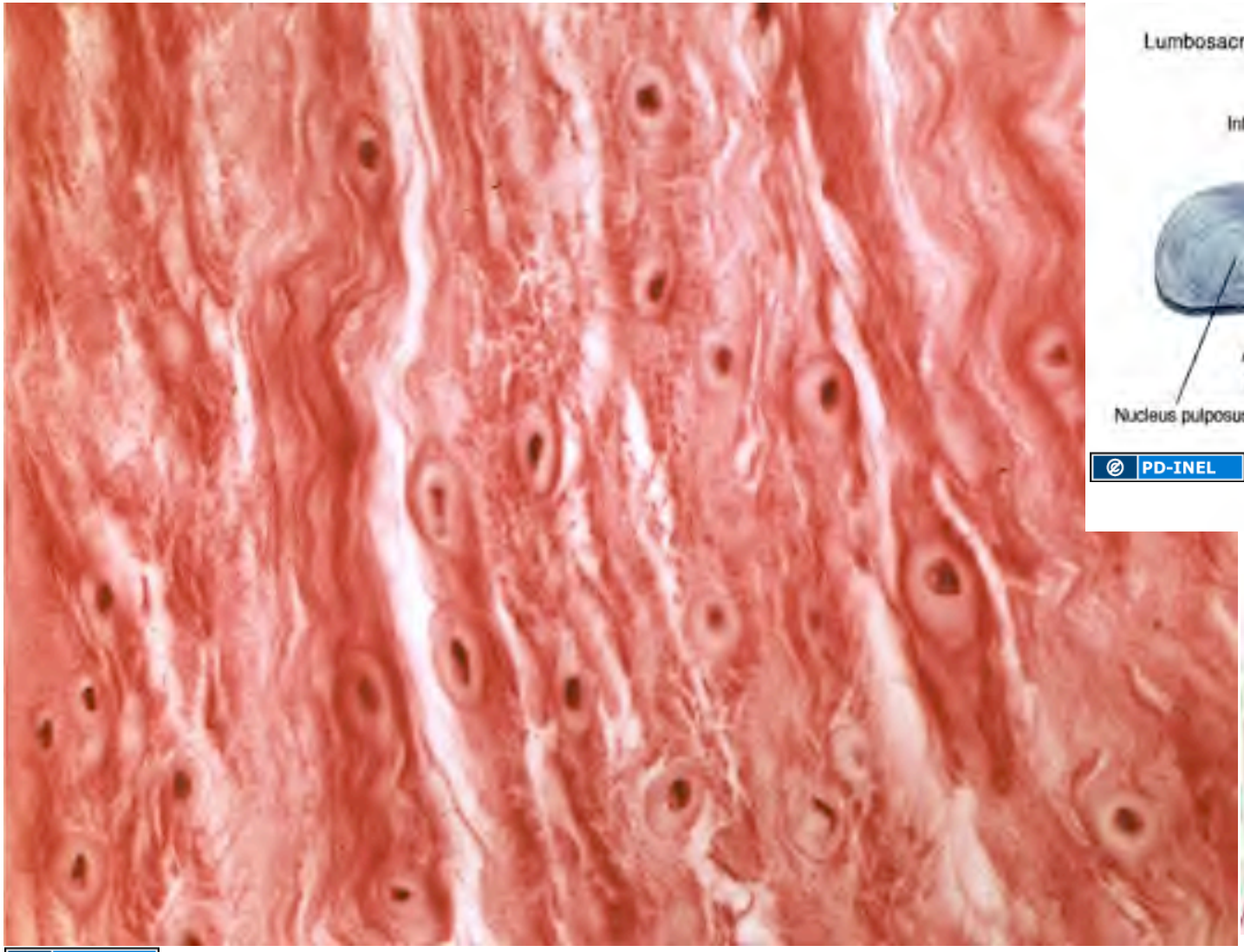


Aldehyde Fuchsin



Fibrocartilage

Type I and II collagen. No identifiable perichondrium



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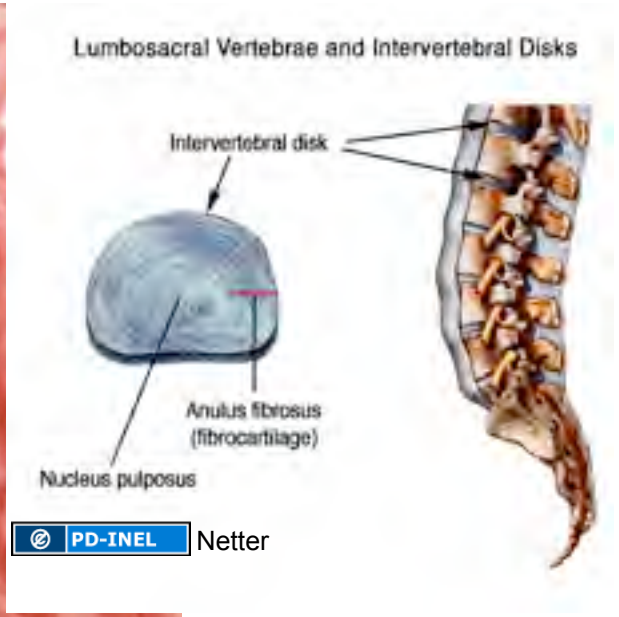
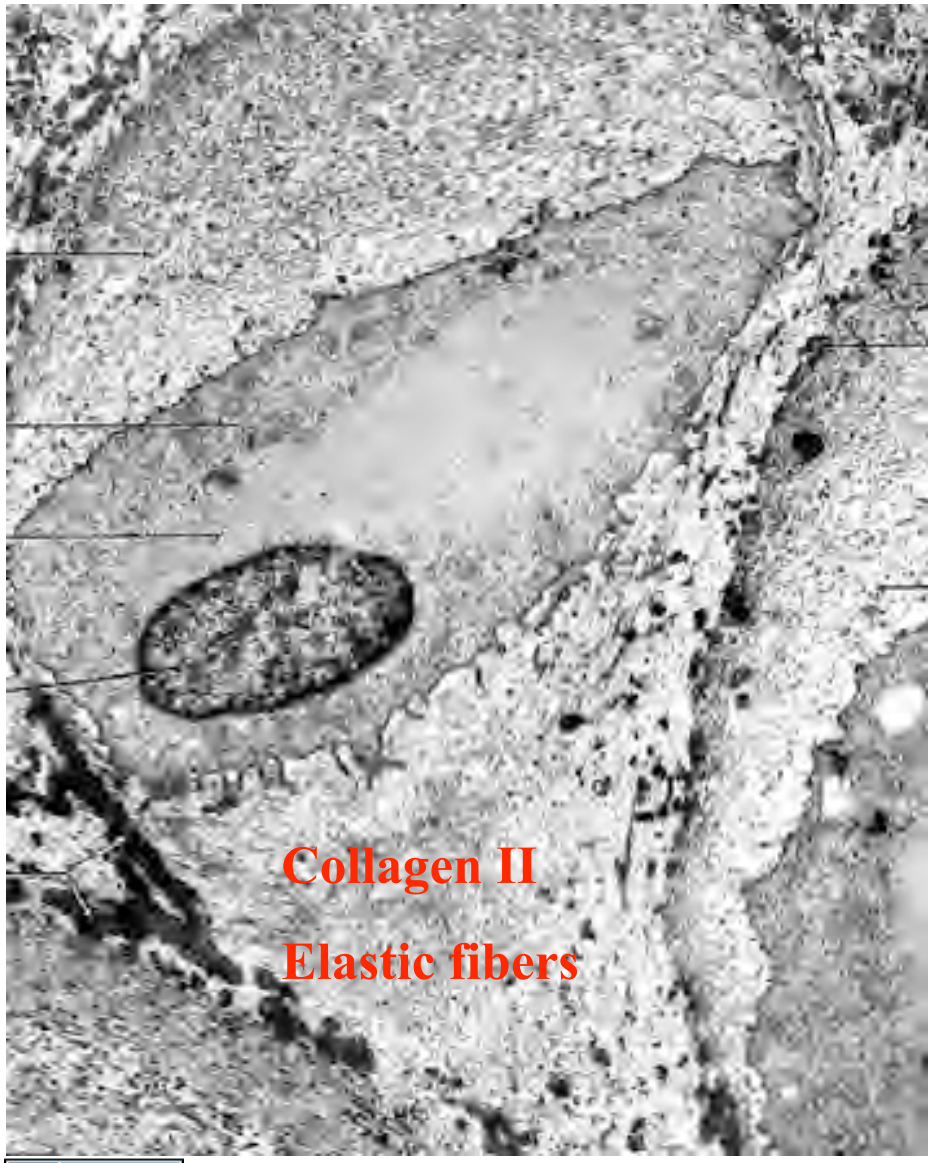


PD-INEL Netter

Elastic Cartilage and Fibrocartilage



PD-INEL Rhodin p.181

PD-INEL Source Undetermined

Bone

Cells: Osteoblasts, Osteocytes, Osteoclasts

Fibers: Type 1 Collagen

Bone Matrix:

- Ground Substance
  - GAGs: Hyaluronan, Chondroitin & Keratan Sulfate
    - Proteoglycans: short core proteins and relatively fewer GAG side chains than in cartilage.
- Hydroxyapatite crystals [$Ca_{10}(PO4)_6(OH)_2$]:
  - Calcium phosphate

Cartilage

Water content: ~70%

Collagen II: ~40% of organic content.

Grows interstitially and by apposition.

Avascular

Bone

Water content: 25%

Collagen I: 90% of organic content.

Other Ground Substance

- Osteonectin: anchor collagen to bone mineral.
- Osteocalcin: Calcium binding protein involved in bone calcification.
- Osteopontin: Binding of osteoblasts and osteoclasts to bone.

Grows only by apposition.

Highly vascular

Bone

Provides support for the soft tissues of the body.

Provides sites for attachment of the muscles and tendons essential for locomotion.

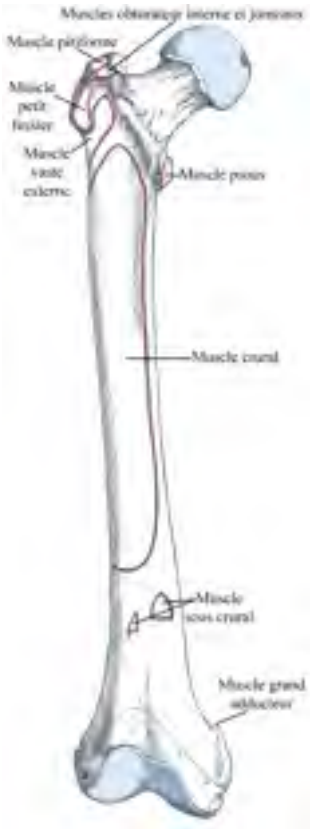
Protects the vital organs of the cranium and various body cavities.

Encloses blood-forming elements in the bone marrow.

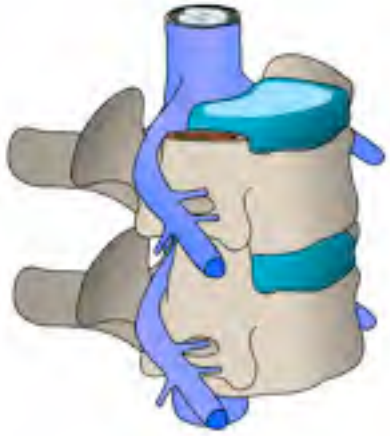
Plays an important role as a mobilizable store of calcium and phosphate.

Types of Bone
(Flat, long, short and irregular bones)

 Palica, wikimedia commons

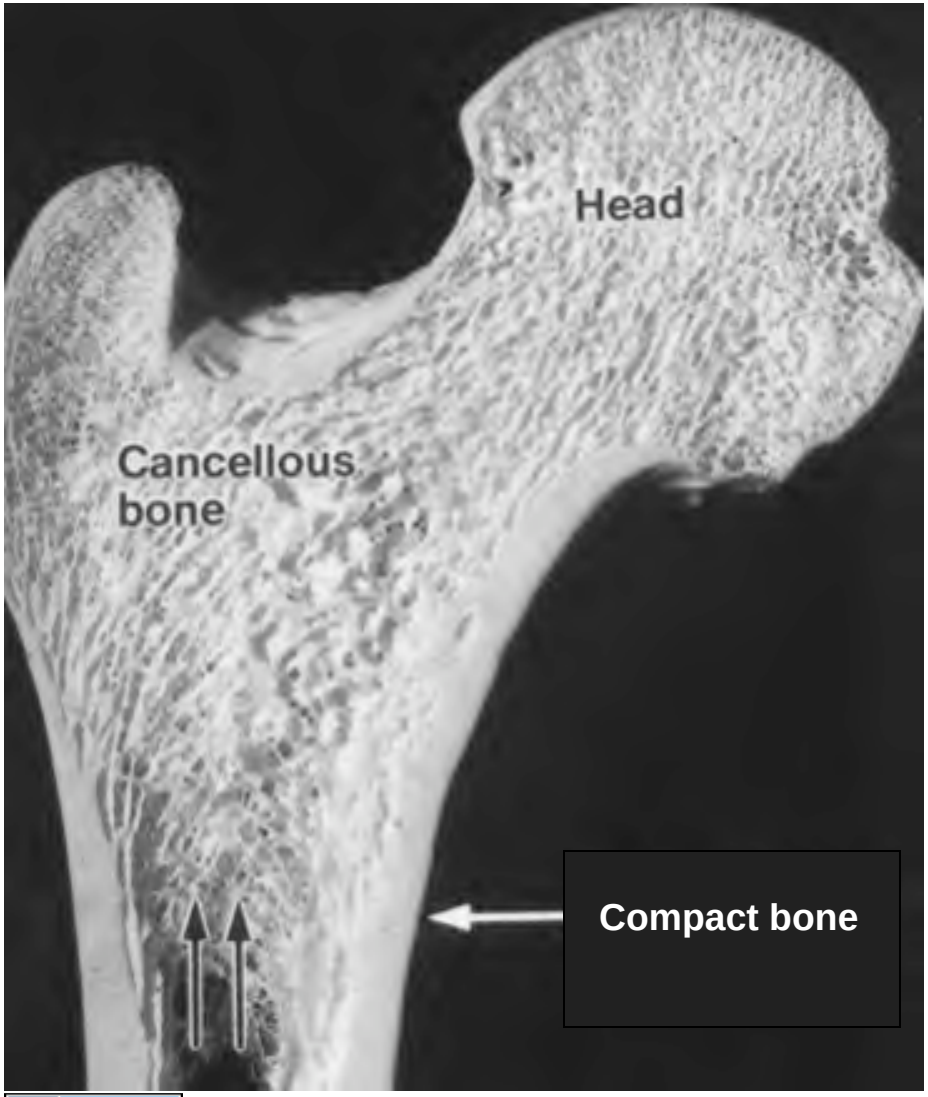


 Berichard, wikimedia commons



 Debivortt, wikimedia commons

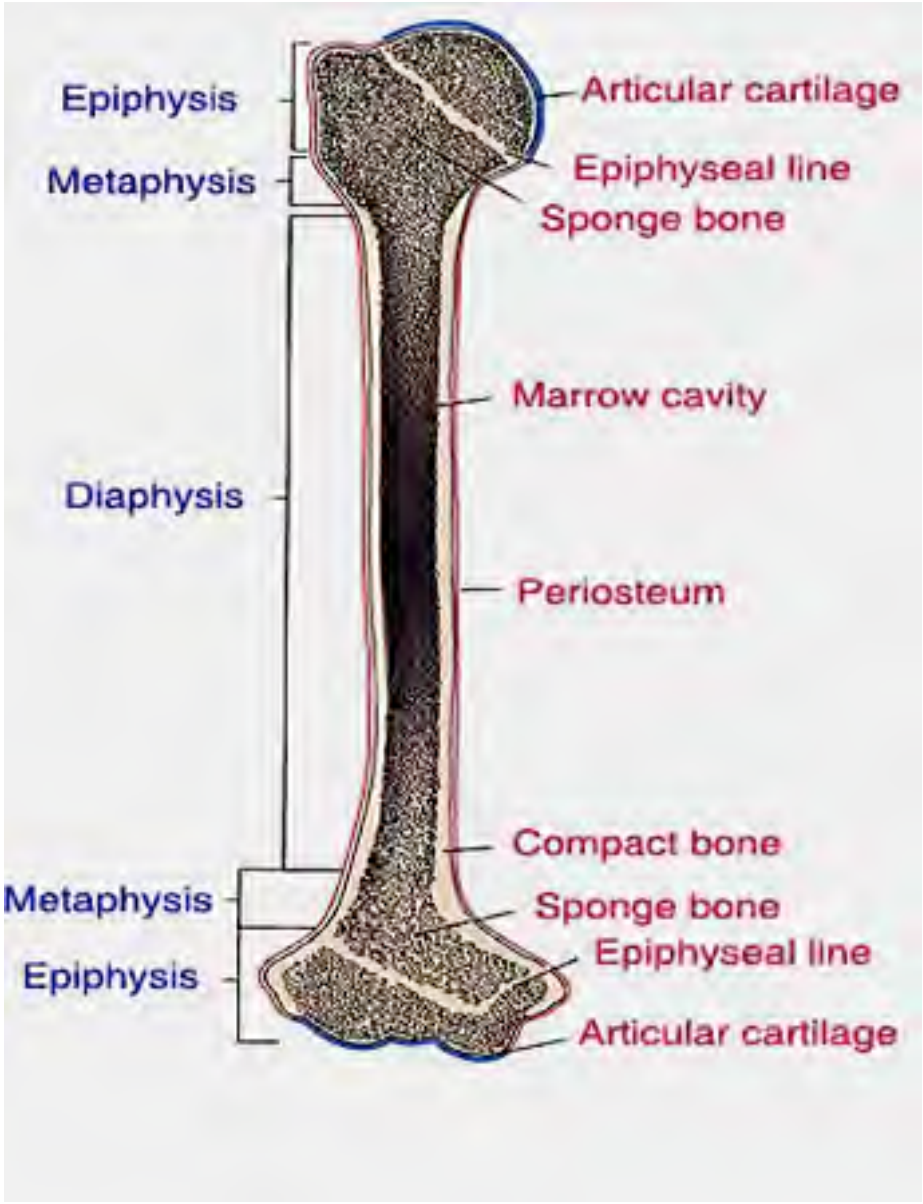
Compact (dense) and Spongy (cancellous) Bone

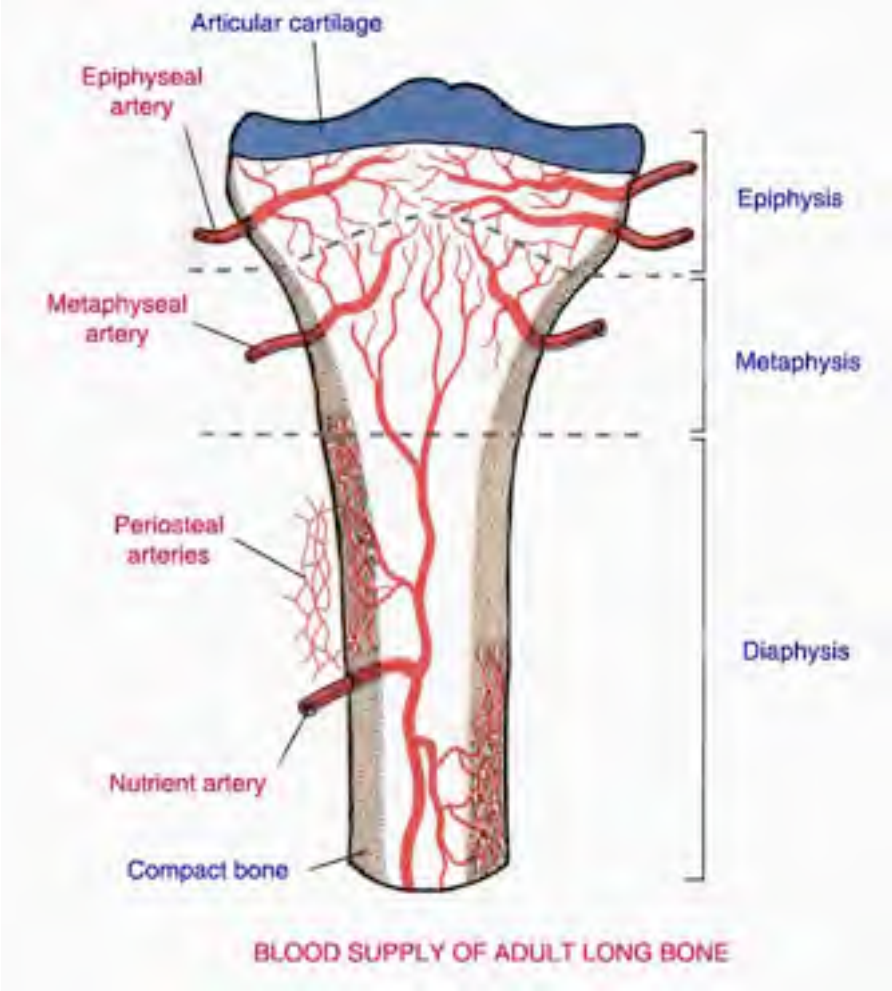


PD-INEL Weiss, 6th ed., p. 218

PD-INEL Ross et al., 4th ed., p. 182

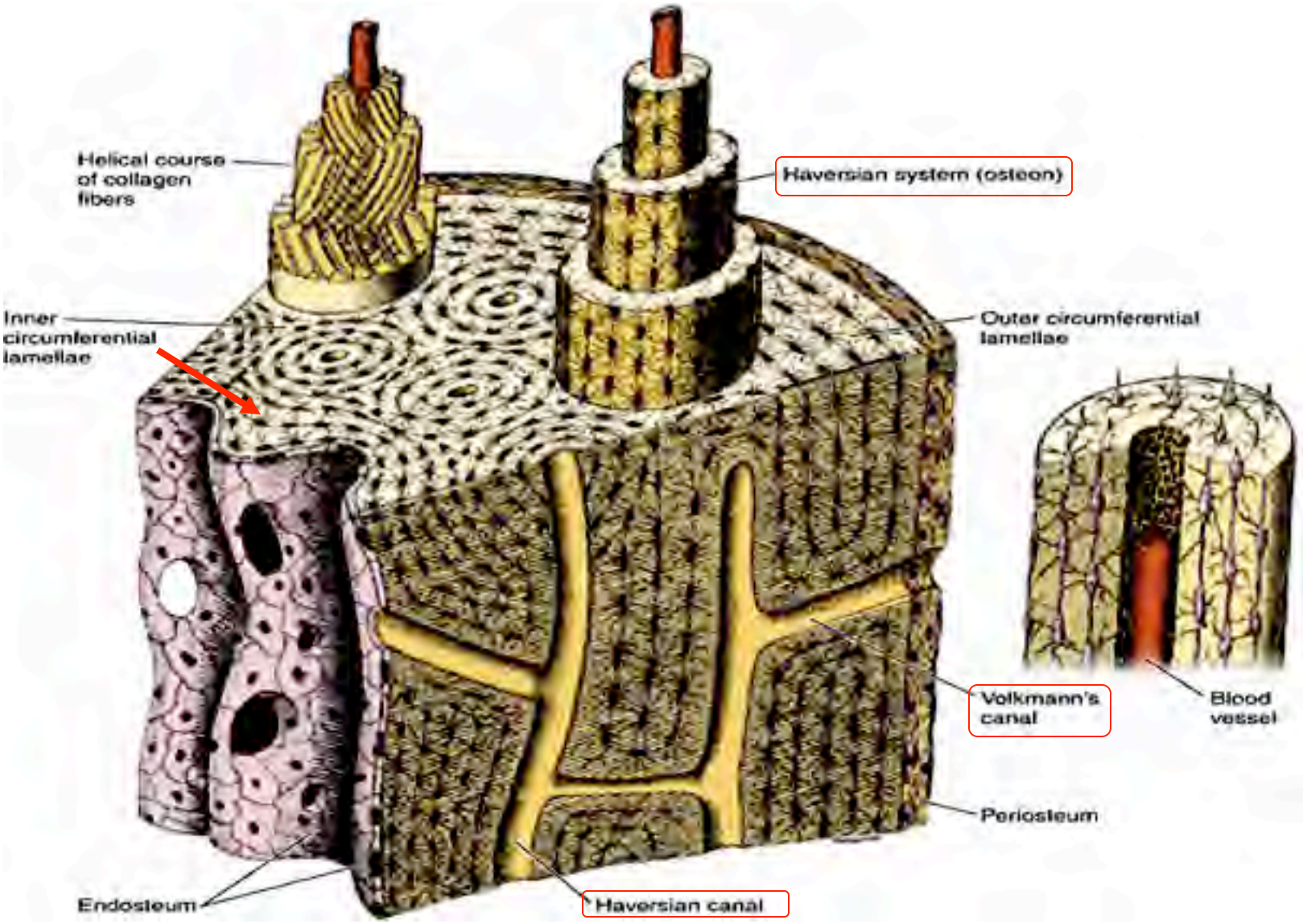
Long Bone





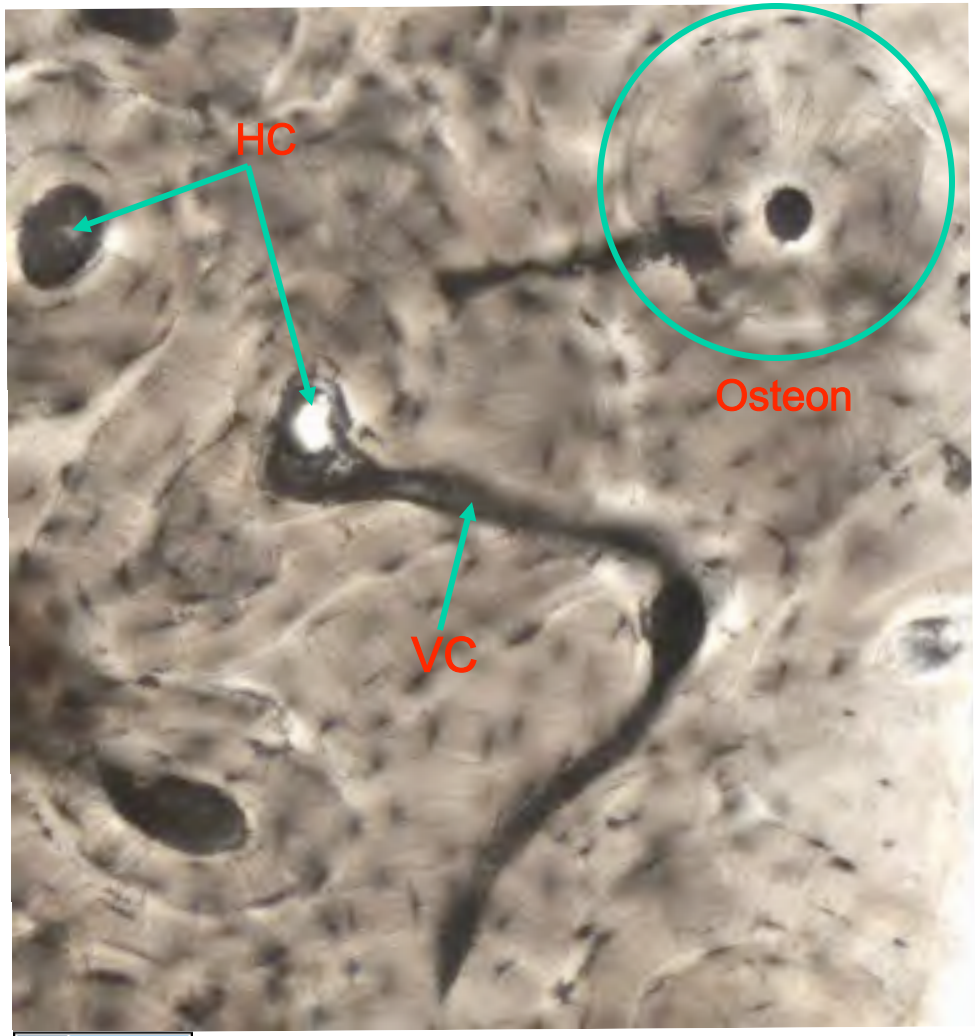
 Ross et al., 4th ed., p. 182 & 185 (Both images)

Wall of a Long Bone



 Junqueera & Carneiro, 10th ed. p. 144

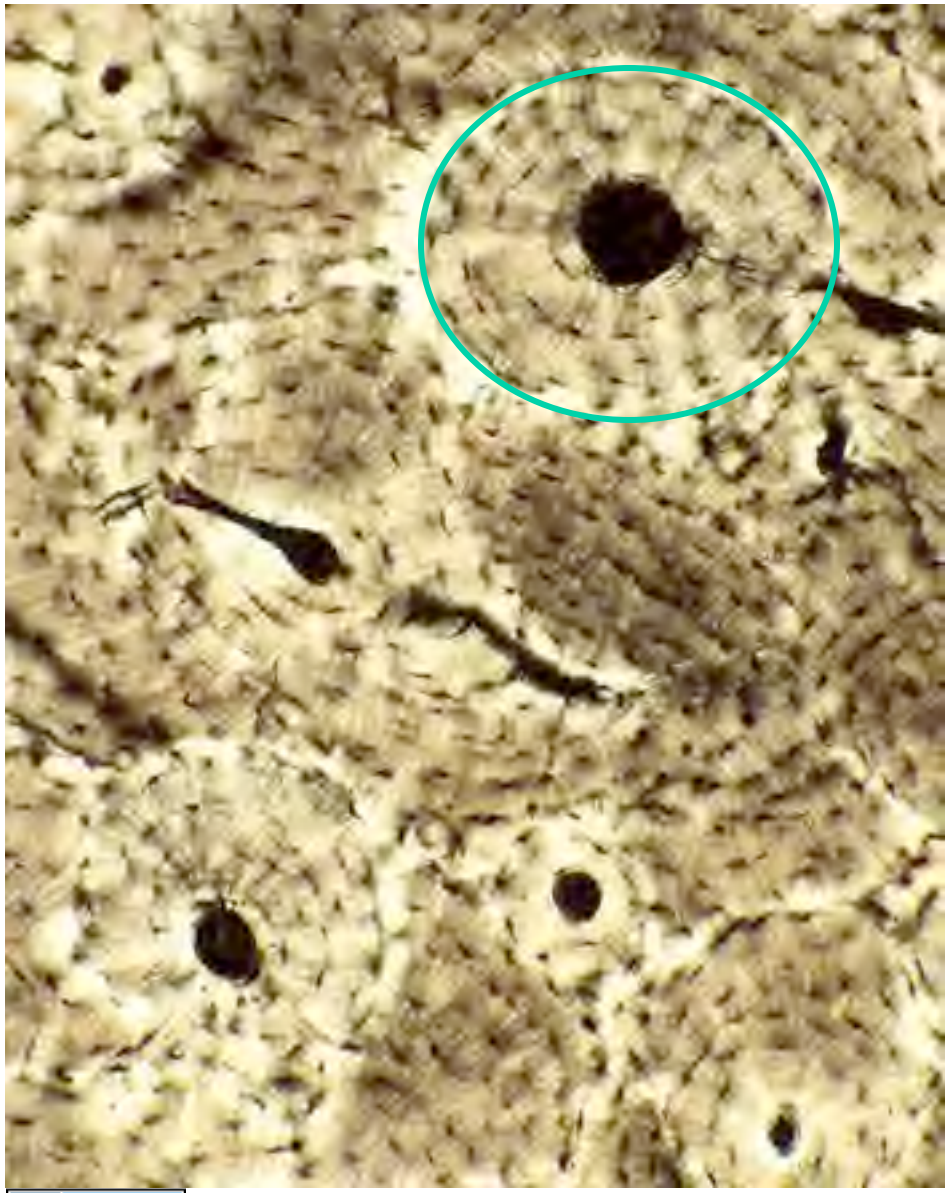
Haversian system (osteon), Haversian canal (HC) and Volkmann's canal (VC)



Transverse section

Longitudinal section

Haversian system (osteon) /Harversian canal



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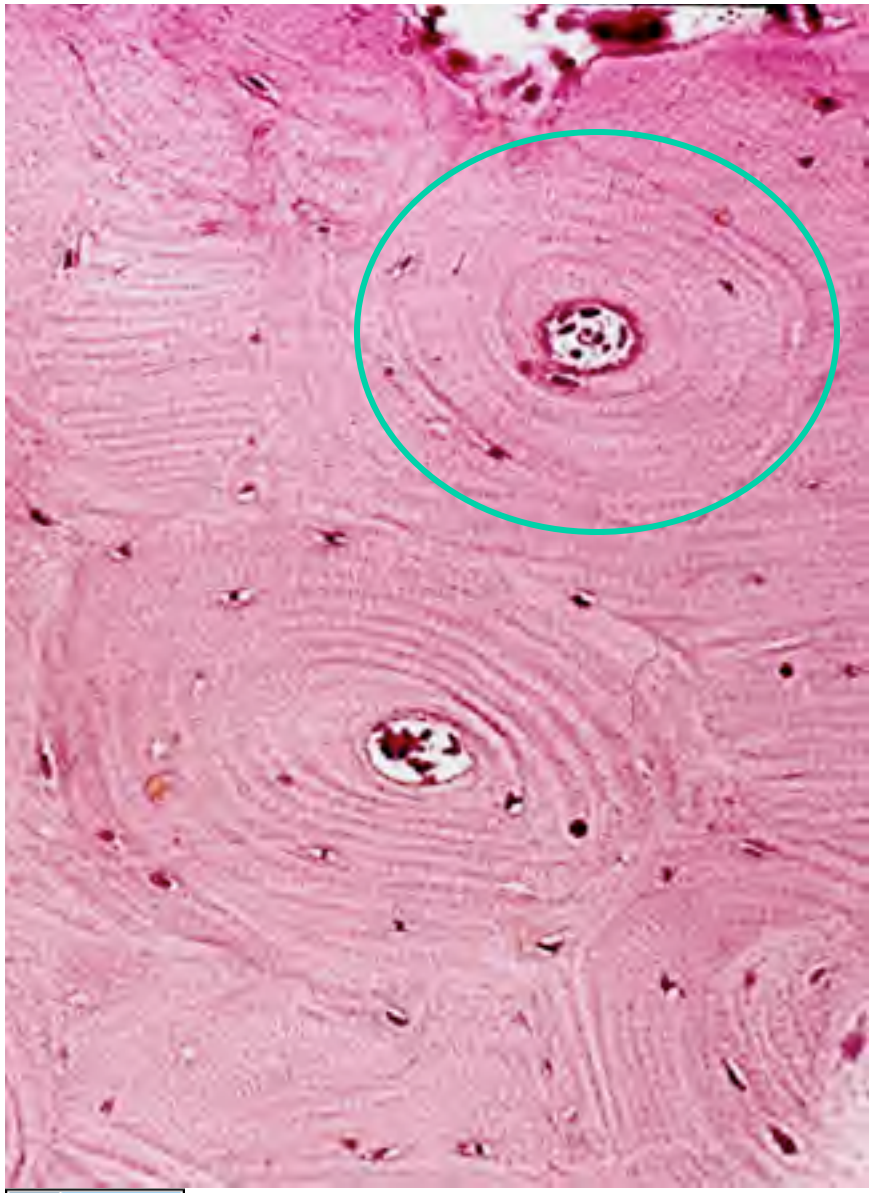

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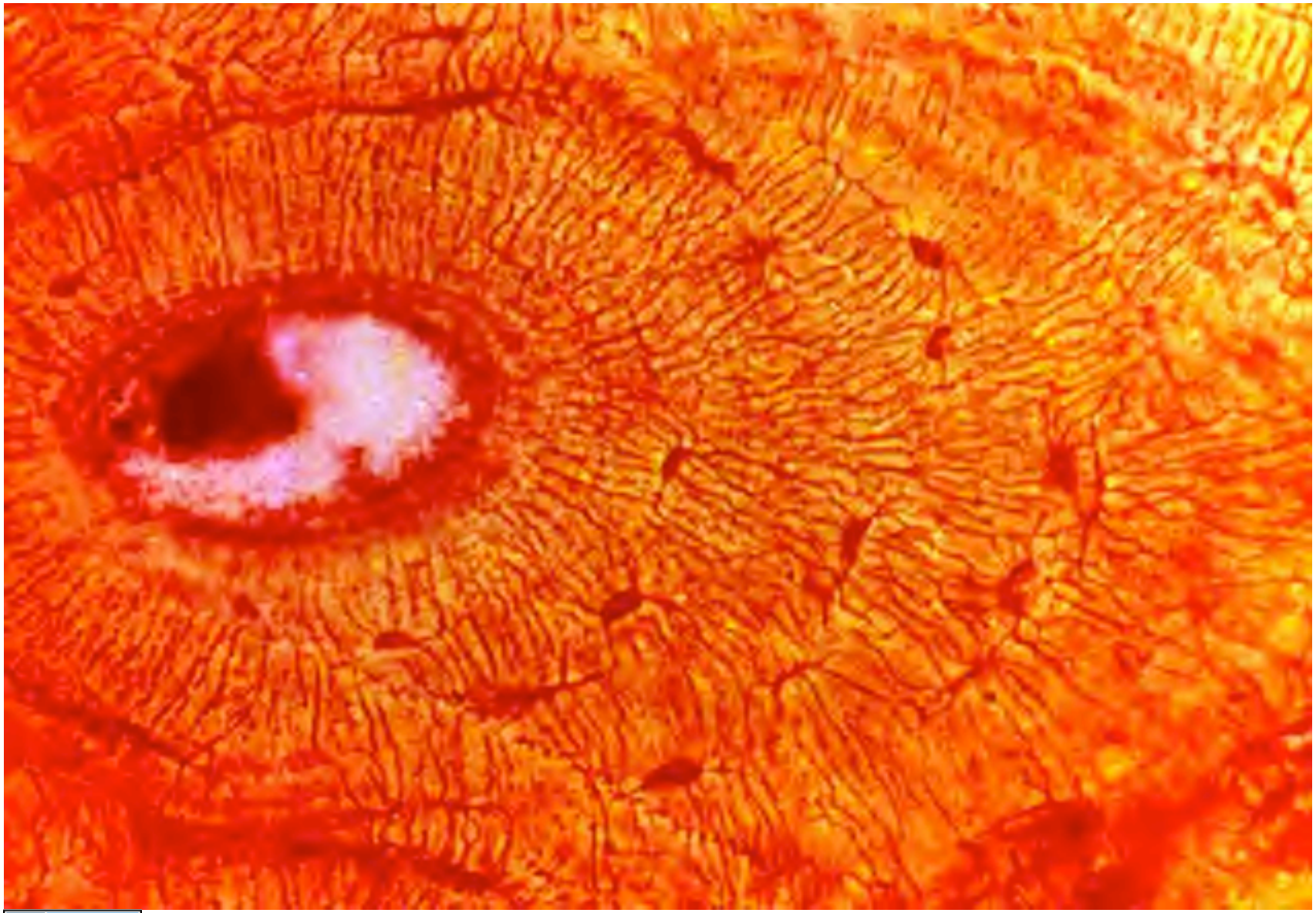
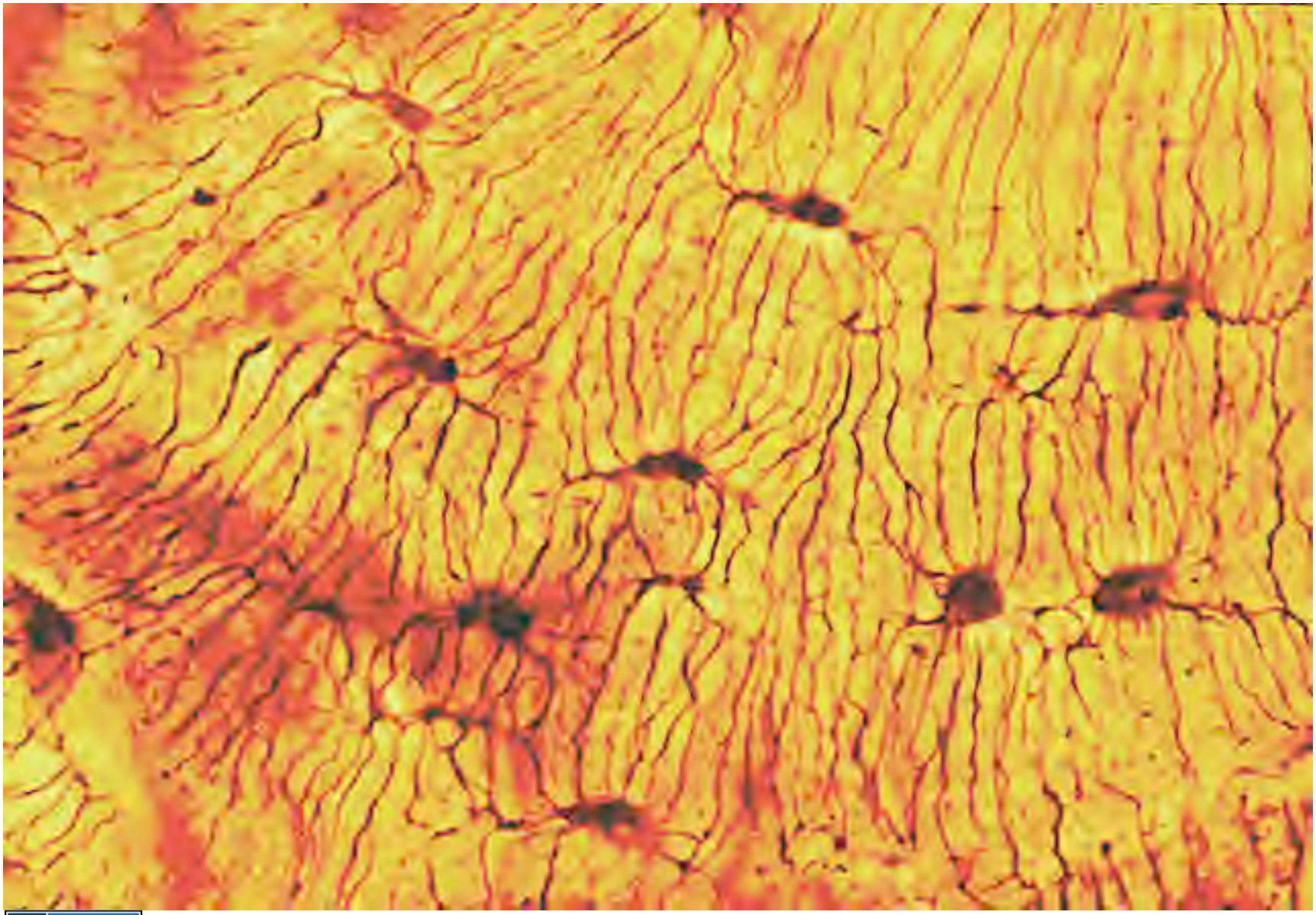
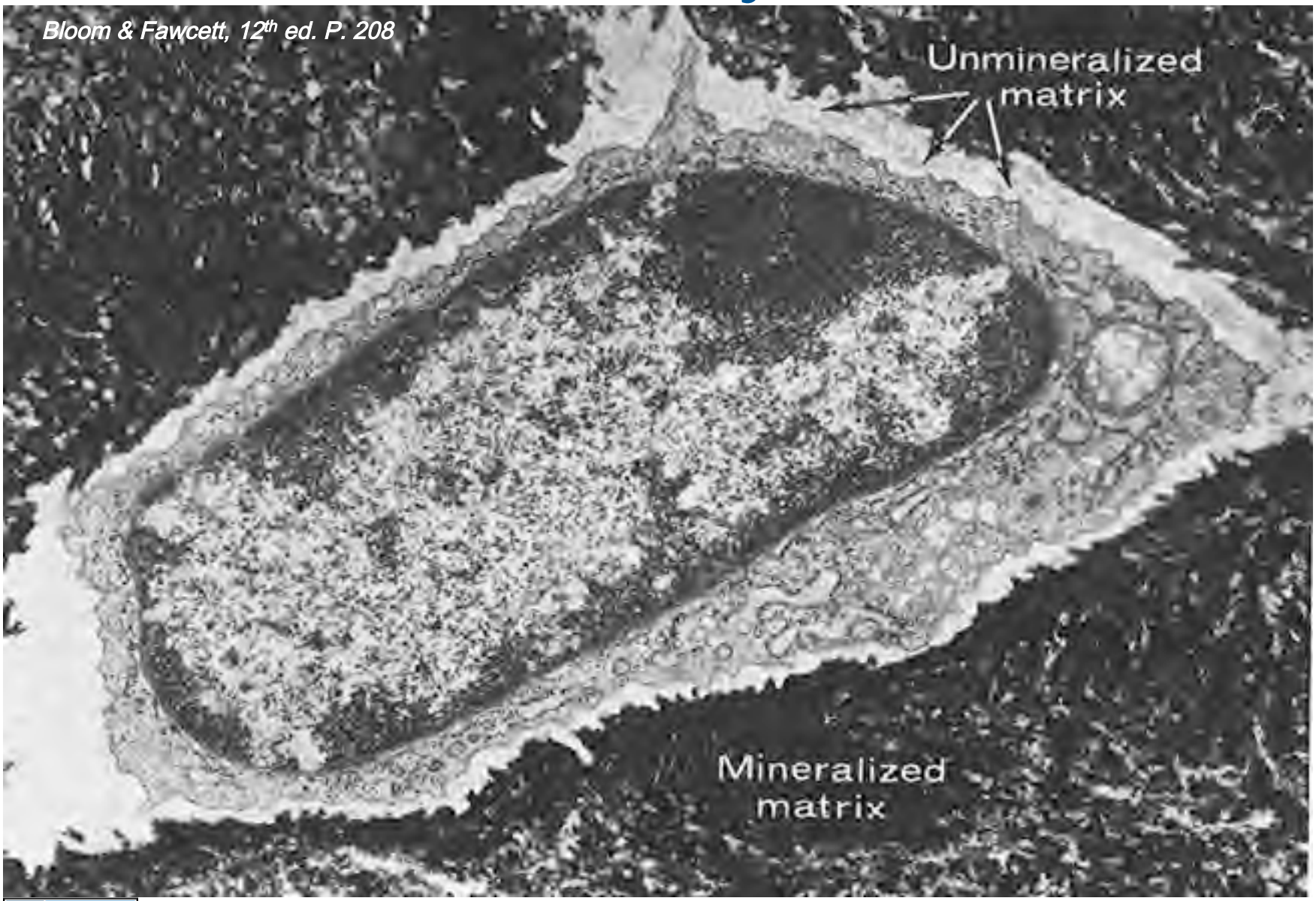
Haversian Canal and Canaliculi



Osteocytes, Lacunae and Canaliculi

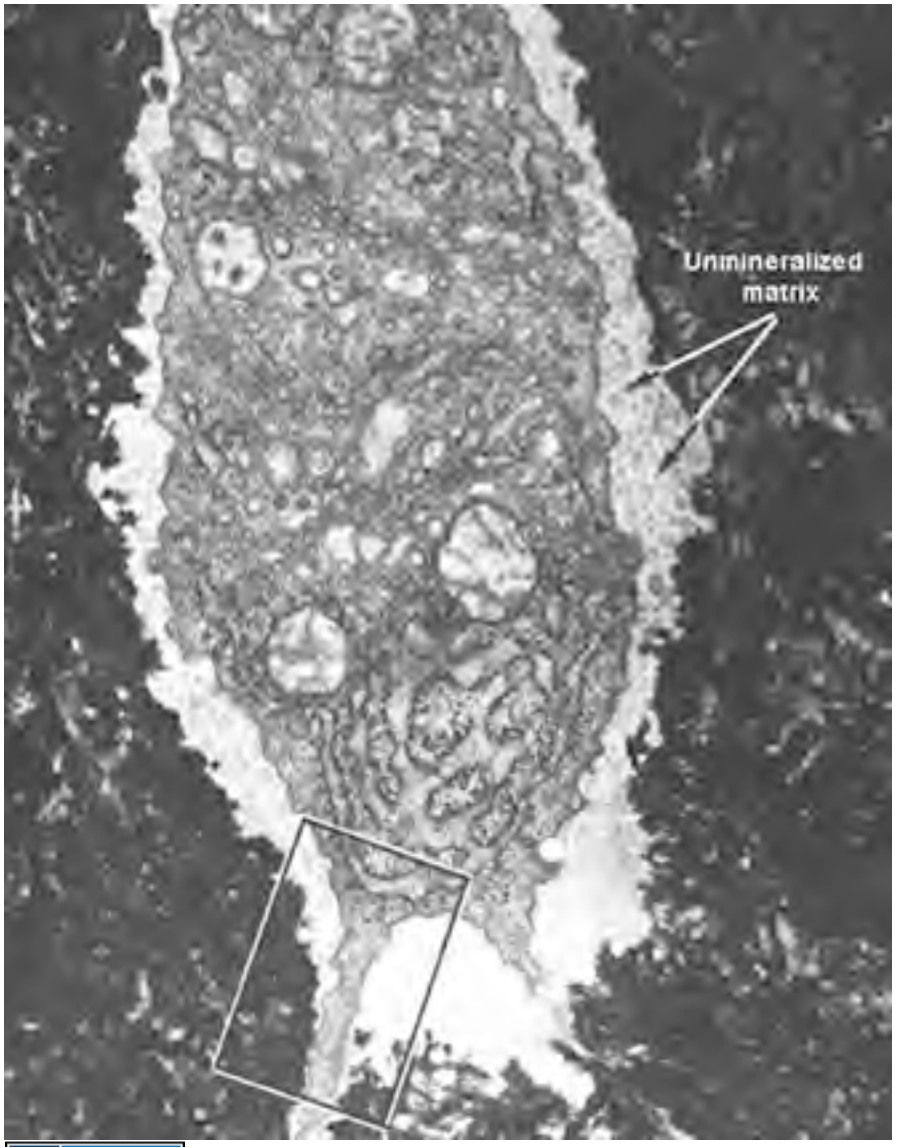


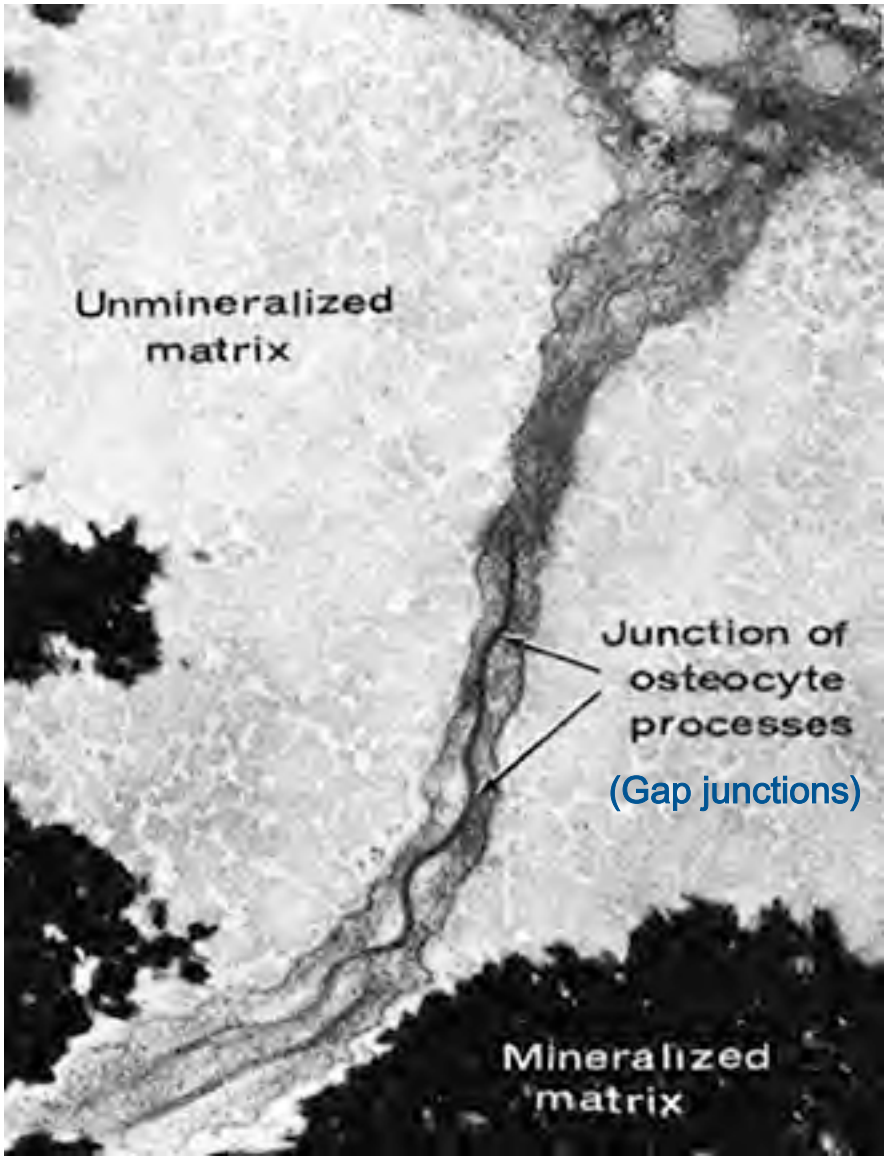
Osteocyte



 Bloom and Fawcett 12th Ed. P. 208

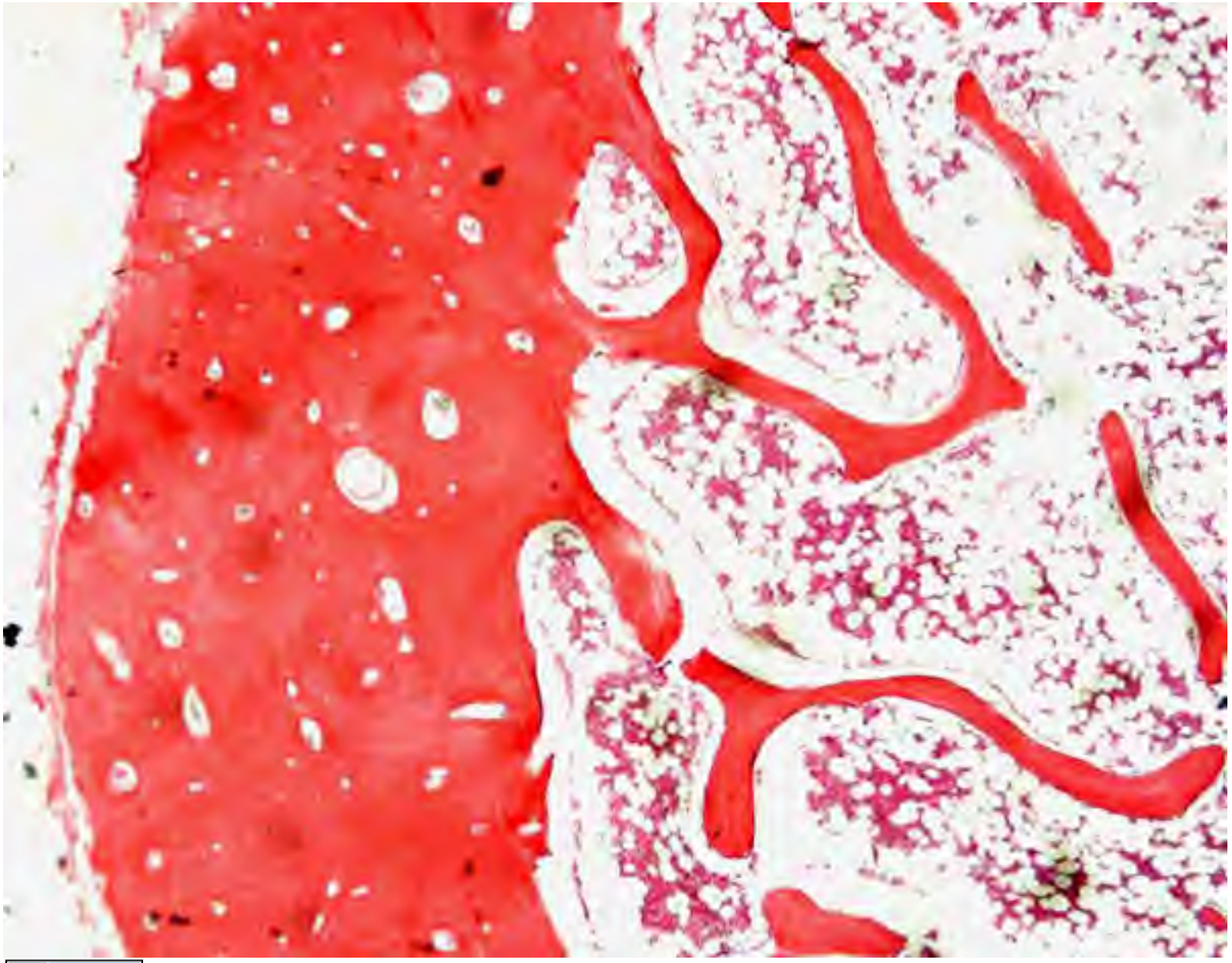
Osteocyte and its Process



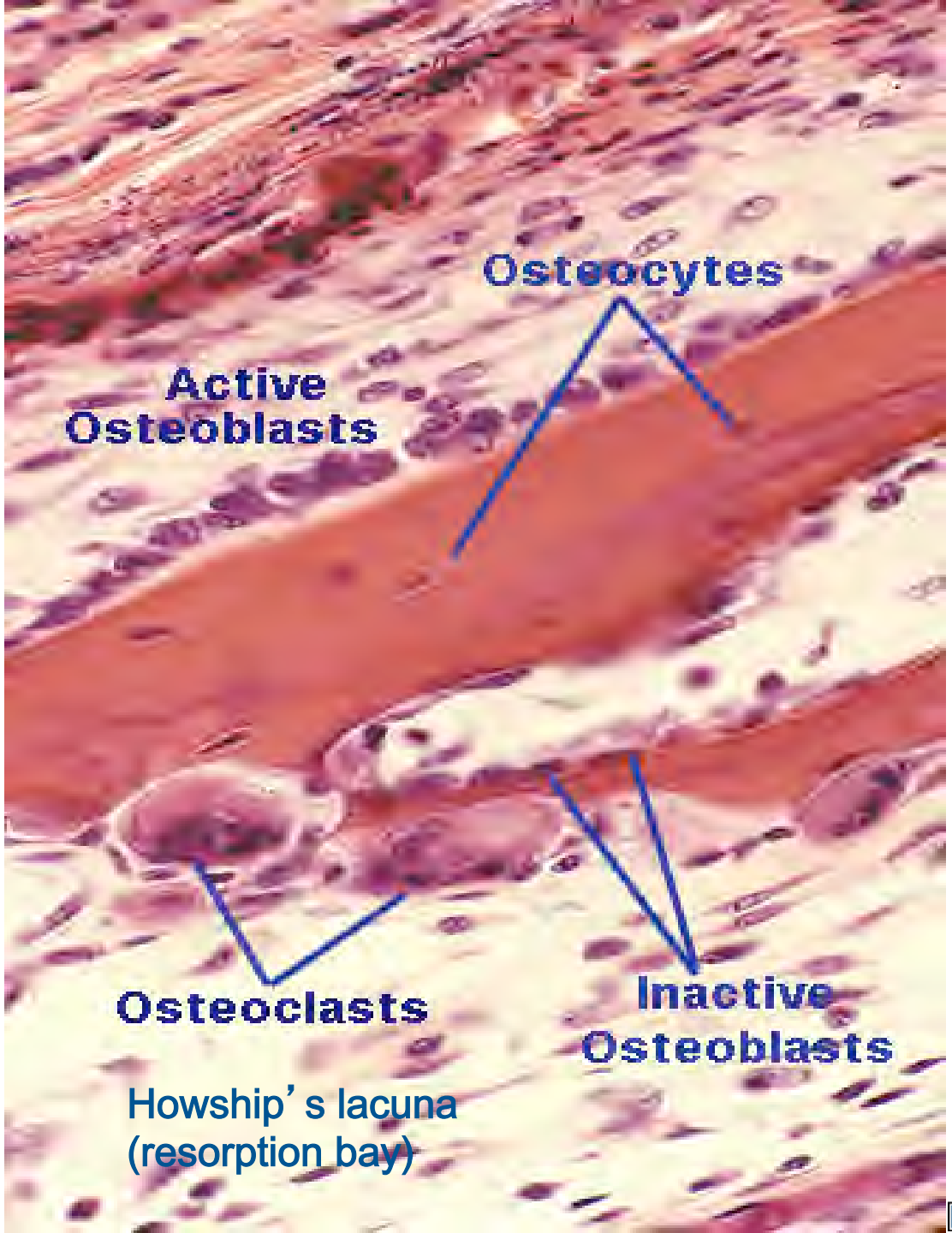


 Bloom & Fawcett, 12th ed. p. 206-7 (Both images)

Compact and Cancellous Bone



Sponge (cancellous) bone



Bone cells

Osteoblasts

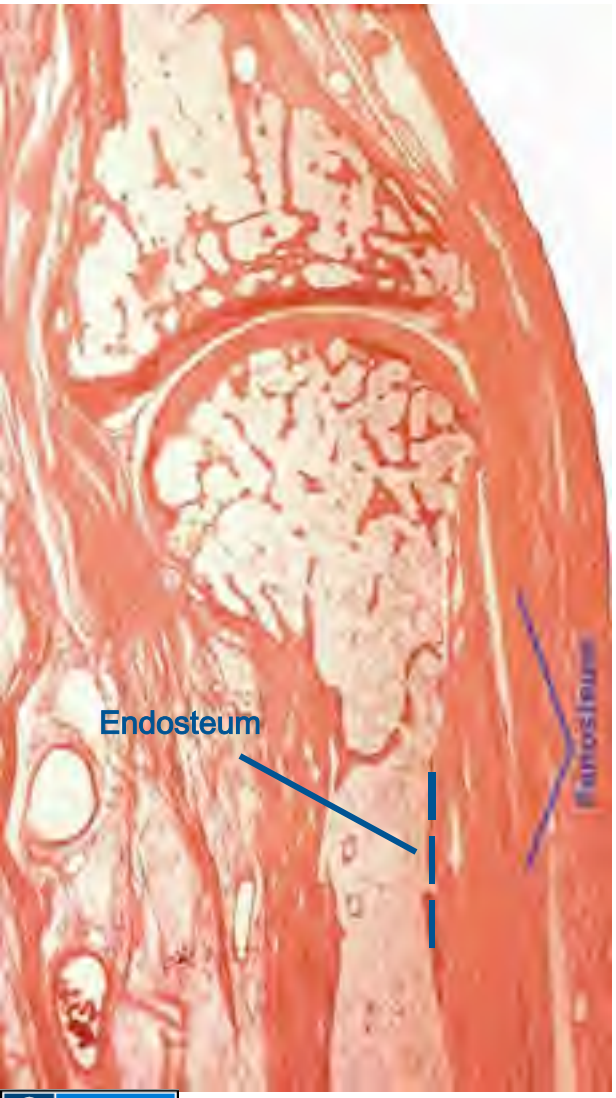
Active

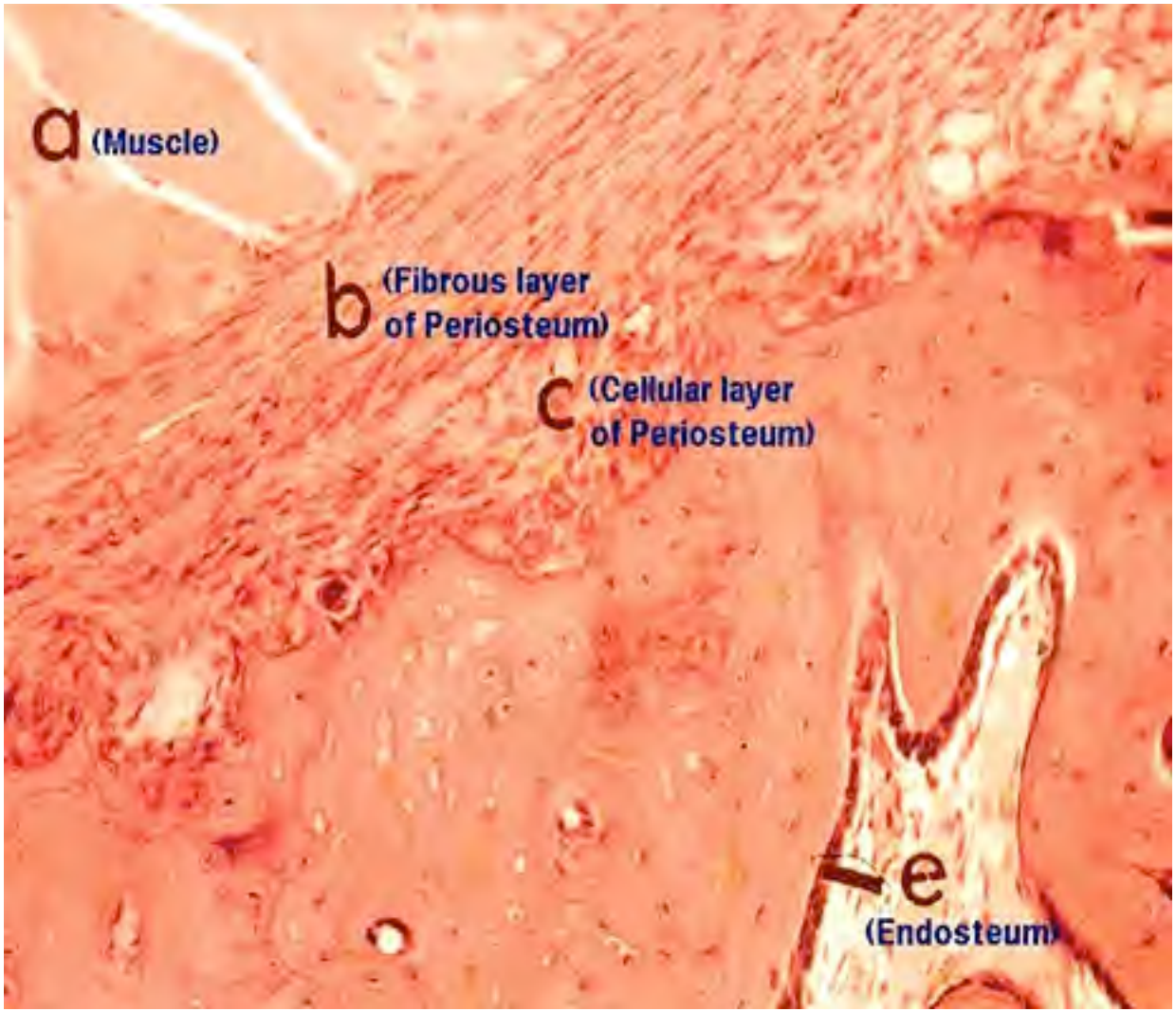
Inactive

Osteocytes

Osteoclasts

Periosteum and Endosteum





Learning Objectives

Cartilage

- Be able to recognize the three major cartilages types in light microscopic sections and know where in the body each type occurs.
- Be able to identify cells and structures in a section of cartilage (e.g. chondroblast, chondrocyte, lacuna, isogenous group, two type of matrix, perichondrium, etc).
- Know the contents of cartilage matrix and understand the molecular basis for resilience of cartilage.
- Be able to describe the process of chondrogenesis and know how cartilage grows.
- Understand what changes occur with aging in the matrix.

Learning Objectives

- Adult Bone
- Be able to recognize compact and cancellous bone in conventional and ground sections and know the structural differences in the two types.
- Be able to identify the component parts of adult bone and know their functions (e.g. periosteum, endosteum, osteon, canaliculus, lacuna, osteocyte, Haversian and Volkmann canal).
- Be able to recognize the cells in adult bone at the light and EM level and know their functions (e.g. active and inactive osteoblasts, osteocytes, osteoclasts).
- Know the major differences in matrix contents of cartilage and bone.

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Slide 13: Source Undetermined; Michigan Medical School Histology Slide Collection
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Slide 20: Kierszenbaum, p. 108; Source Undetermined
Slide 21: Kierszenbaum, p. 108; Albert et al., 2nd ed. p. 804
Slide 22: Albert et al., 2nd ed. p. 807; Albert et al., 2nd ed. p. 804
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Slide 39: Ross et al., 4th ed., p. 182 & 185; Original source, Ross et al., 4th ed., p. 182 & 185
Slide 40: Junqueera & Carneiro, 10th ed. p. 144
Slide 41: Michigan Medical School Histology Slide Collection
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Slide 46: Bloom & Fawcett, 12th ed. p. 206-7
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