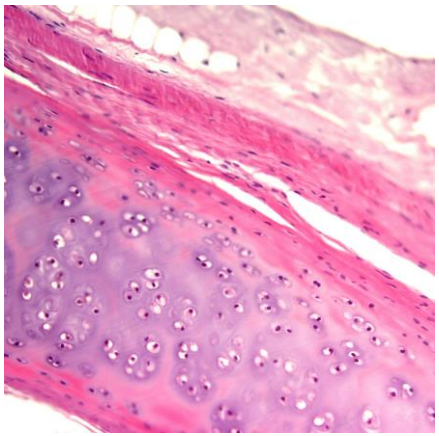
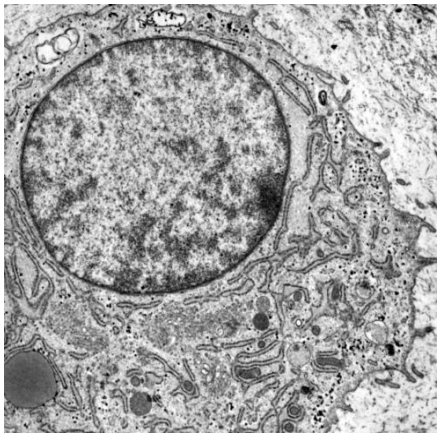
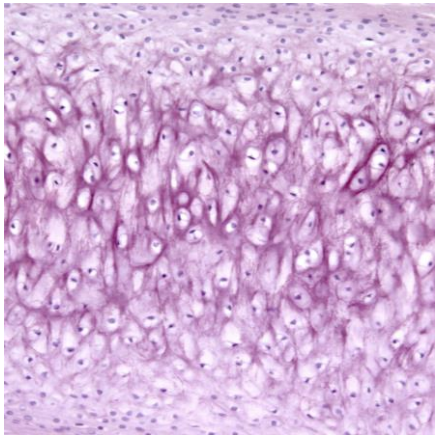
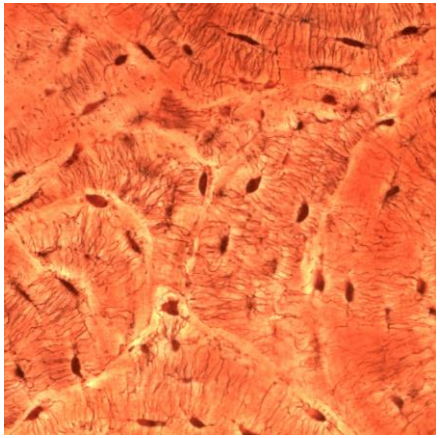
MUNI MED Ústav histologie a embryologie

CARTILAGE AND BONE

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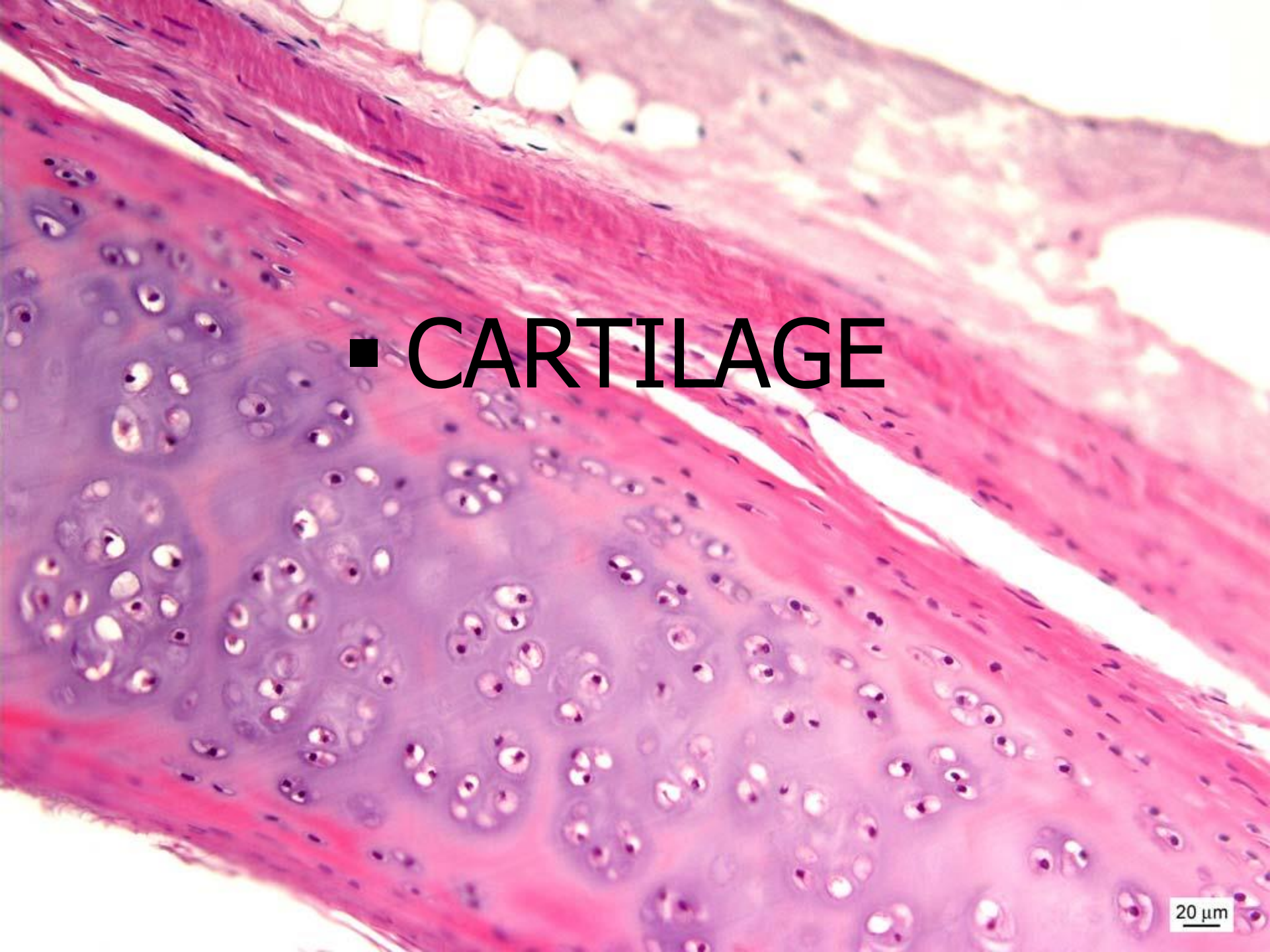

CARTILAGE
20 µm

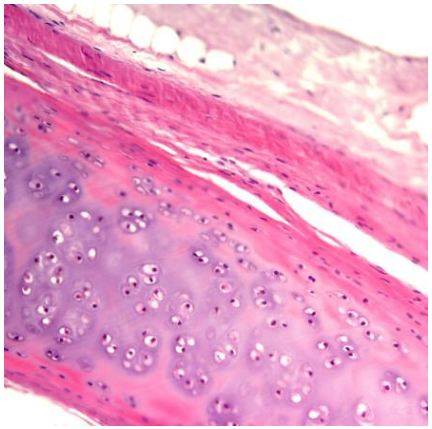
Cartilage

General features:

- **specialized connective tissue** with continuous ECM
- flexible, mechanically resistant
- avascular, non-innervated
- support of soft tissues - trachea, larynx
- skeletal support - costal cartilages
- diarthrosis - joints
- bone growth

1. **cells**
2. **fibrils**
3. **amorphous ground substance**

Composition and structure



- Perichondrium – connective tissue around cartilage (except joints)

  Nutrition
  Growth

- Extracellular matrix – water, proteoglycans and collagen II fibrils

  Solid consistence
  Pressure elasticity

- Cells of cartilage - chondroblasts, chondrocytes

  Growth
  ECM production

Distribution

cartilage in adults

Hyaline

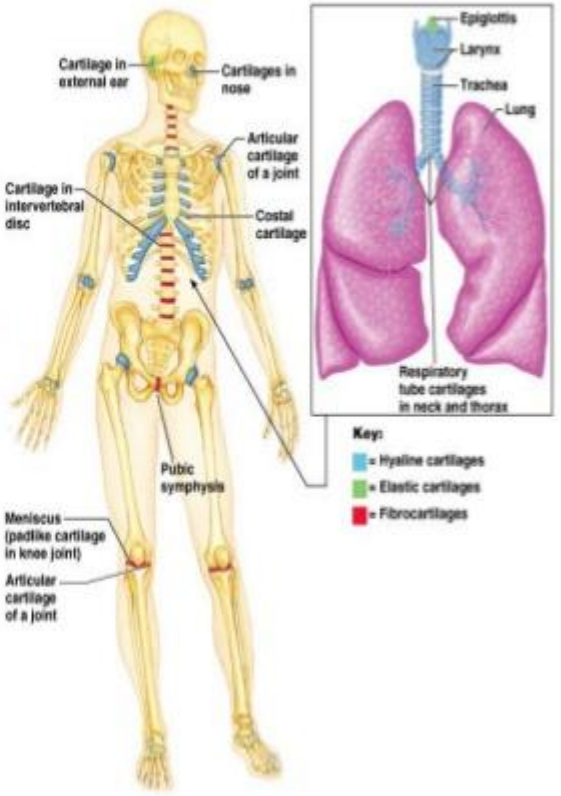
- Nose
- Joint surfaces
- Costal
- Larynx - voice box
- rings of trachea & bronch

Elastic

- External ear
- Epiglottis
- Eustachian tube

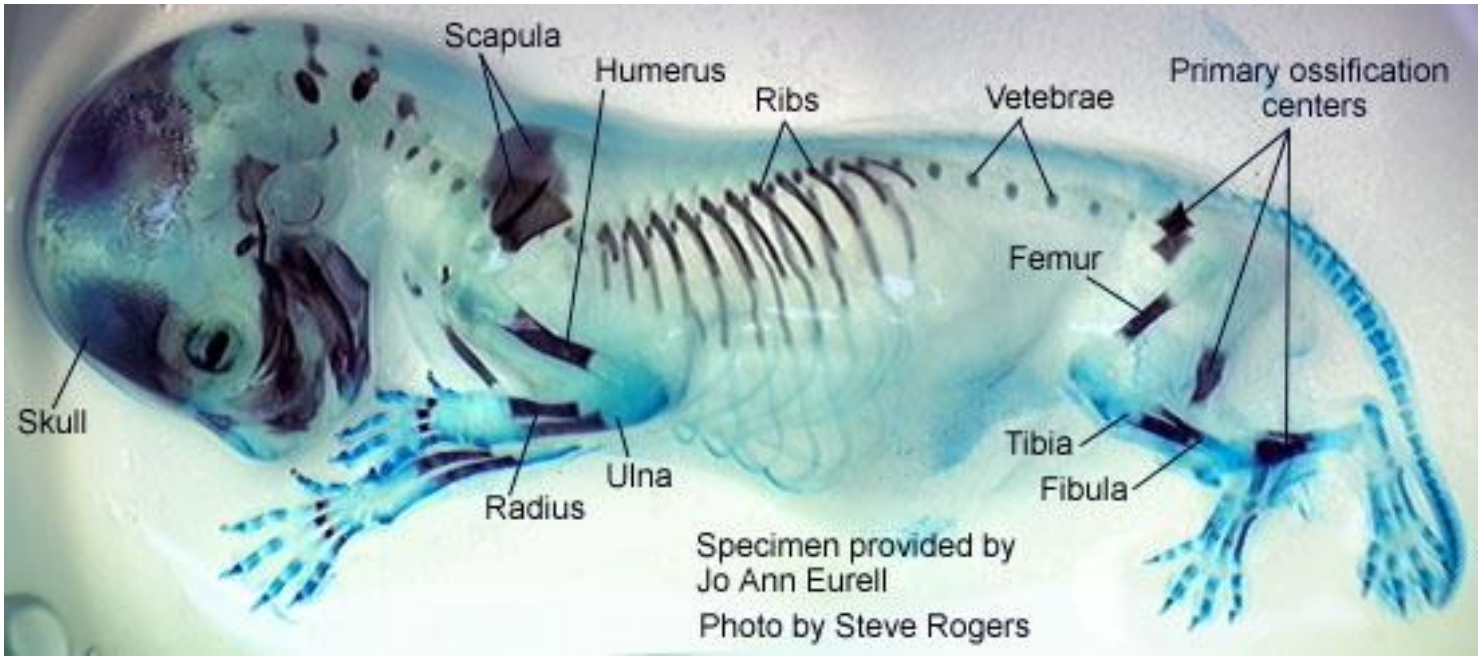
Fibrous

- IVDs
- Pubic symphysis
- meniscus in knee joint



Distribution

Hyaline



Alcian Blue&Alizarin Red

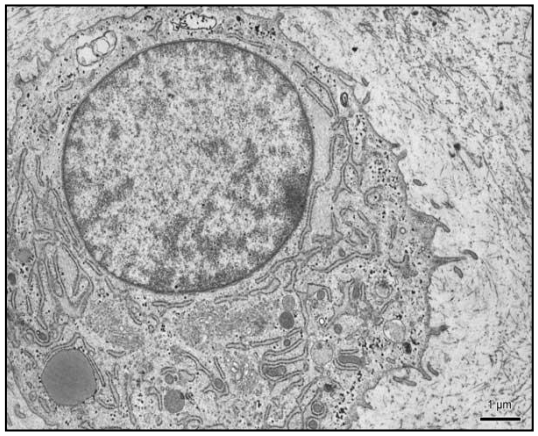
- most abundant
- temporary embryonal/fetal skeleton
- epiphyseal growth plate
- articulation (joints) respiratory passages

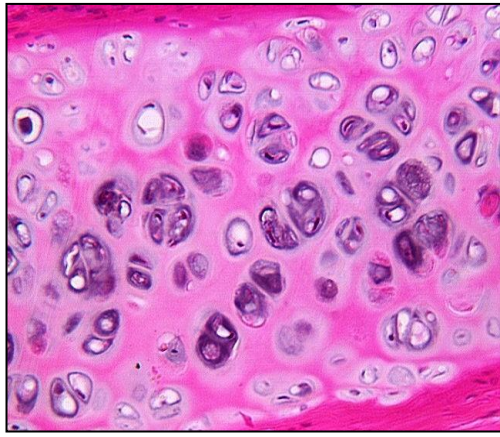
http://chickscope.beckman.uiuc.edu/explore/embryology/day14/dev2.html

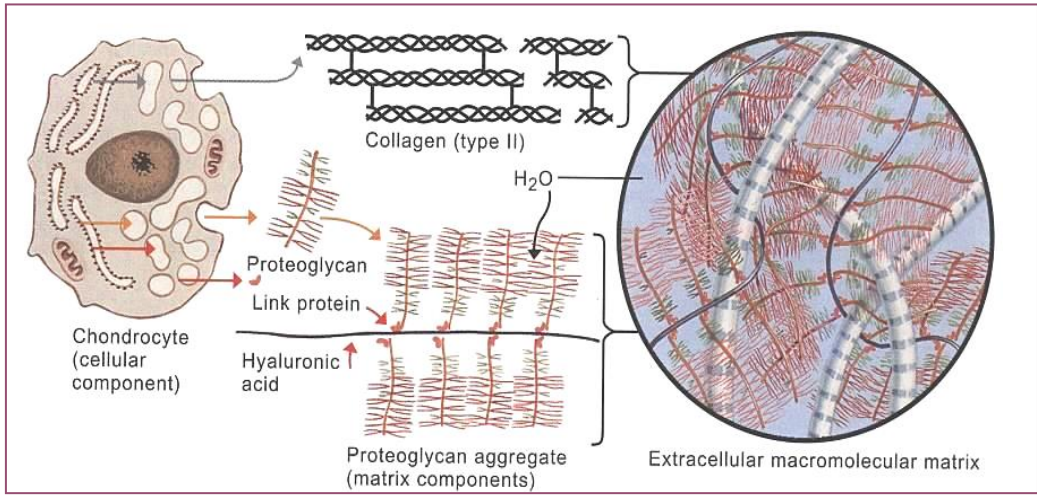
Cells of cartilage

- **Chondroblasts and chondrocytes**

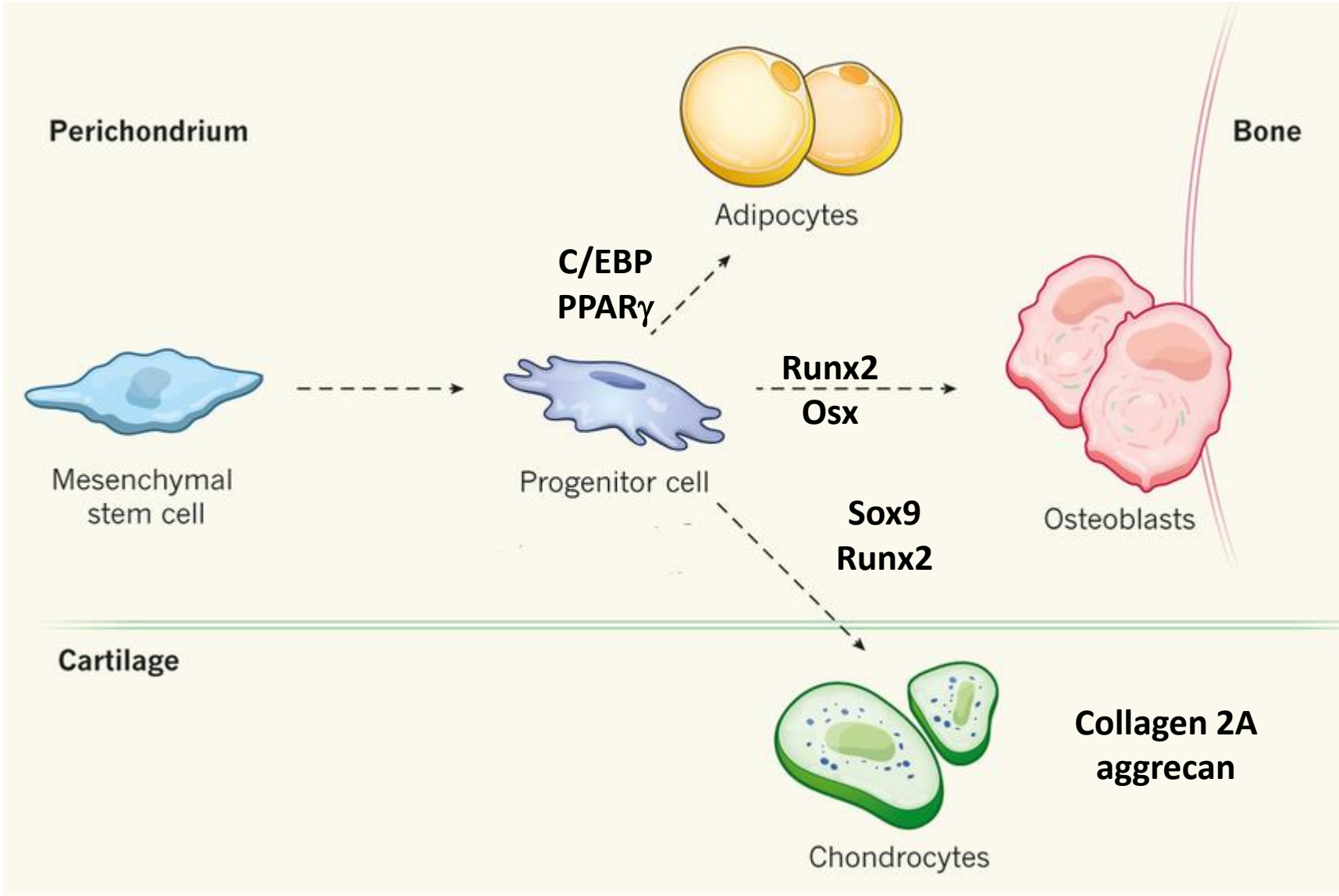
- mesenchymal origin
- typical ultrastructure of proteosynthetically active cells
- production of extracellular matrix
- interstitial proliferation
- isogenetic groups, lacunae



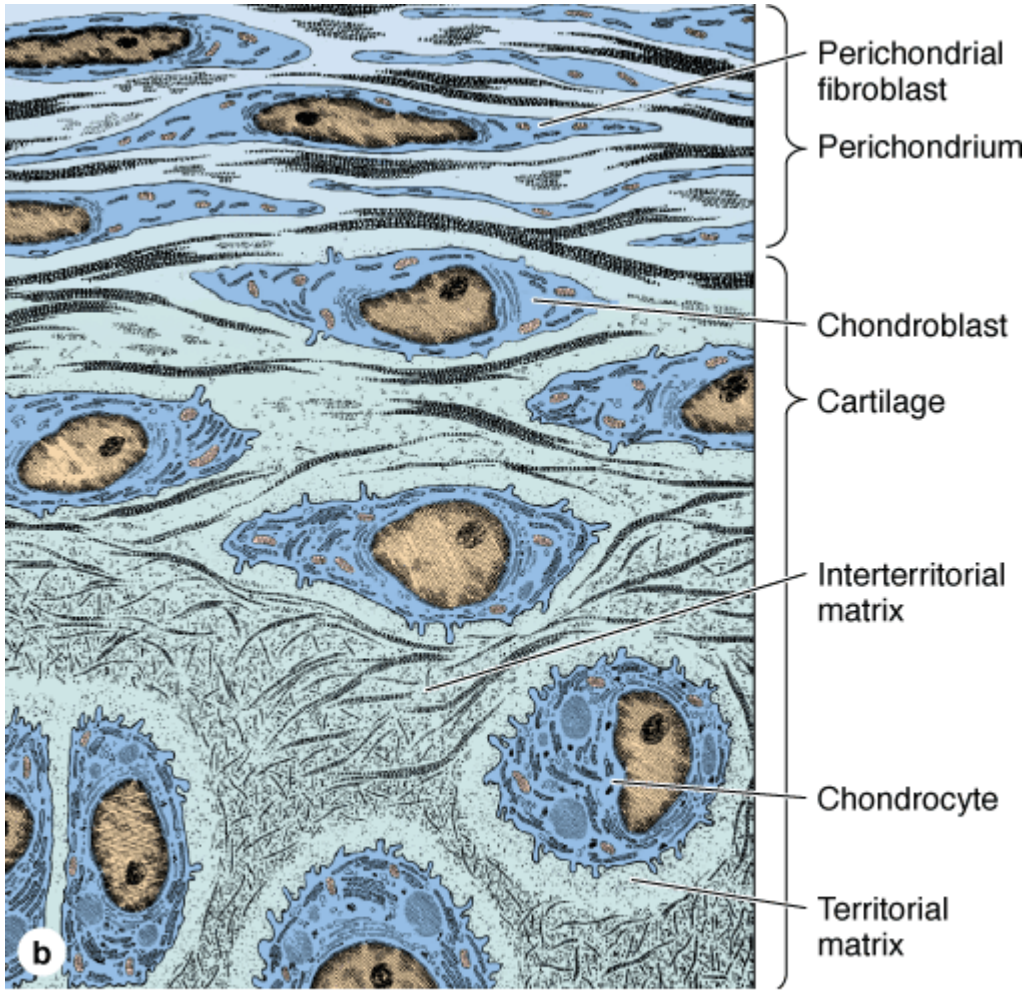


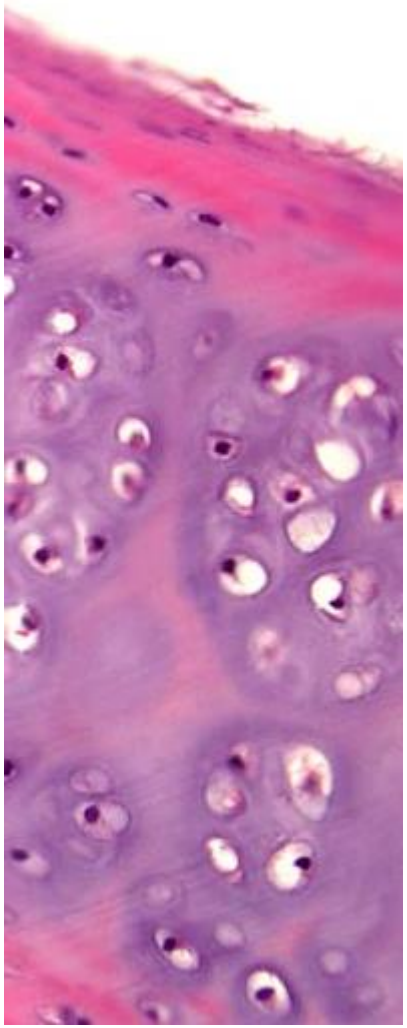


Origin of chondrocytes



- Origin of chondrocytes

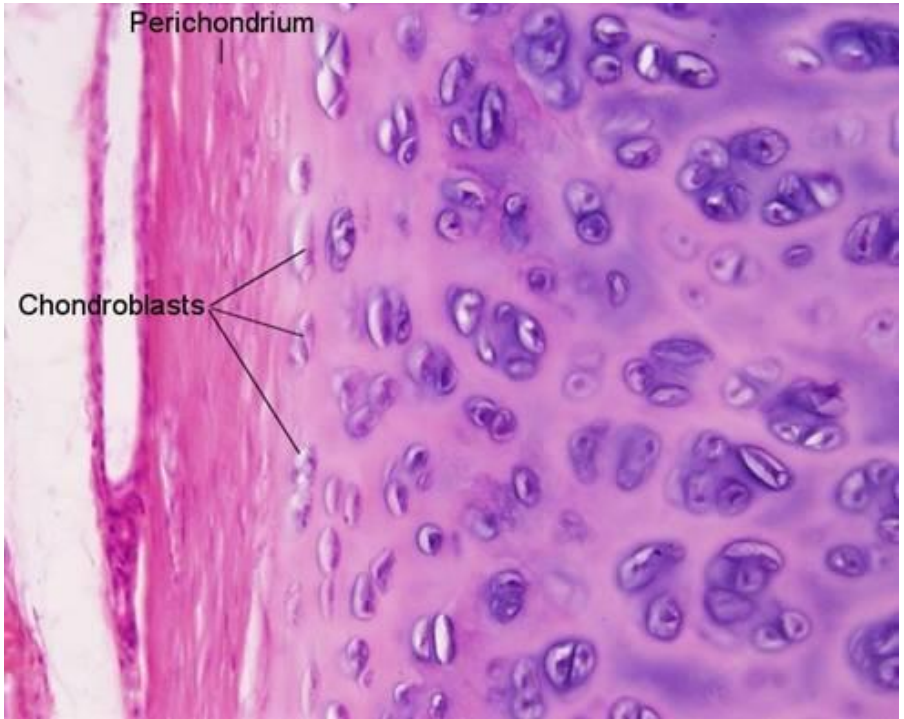




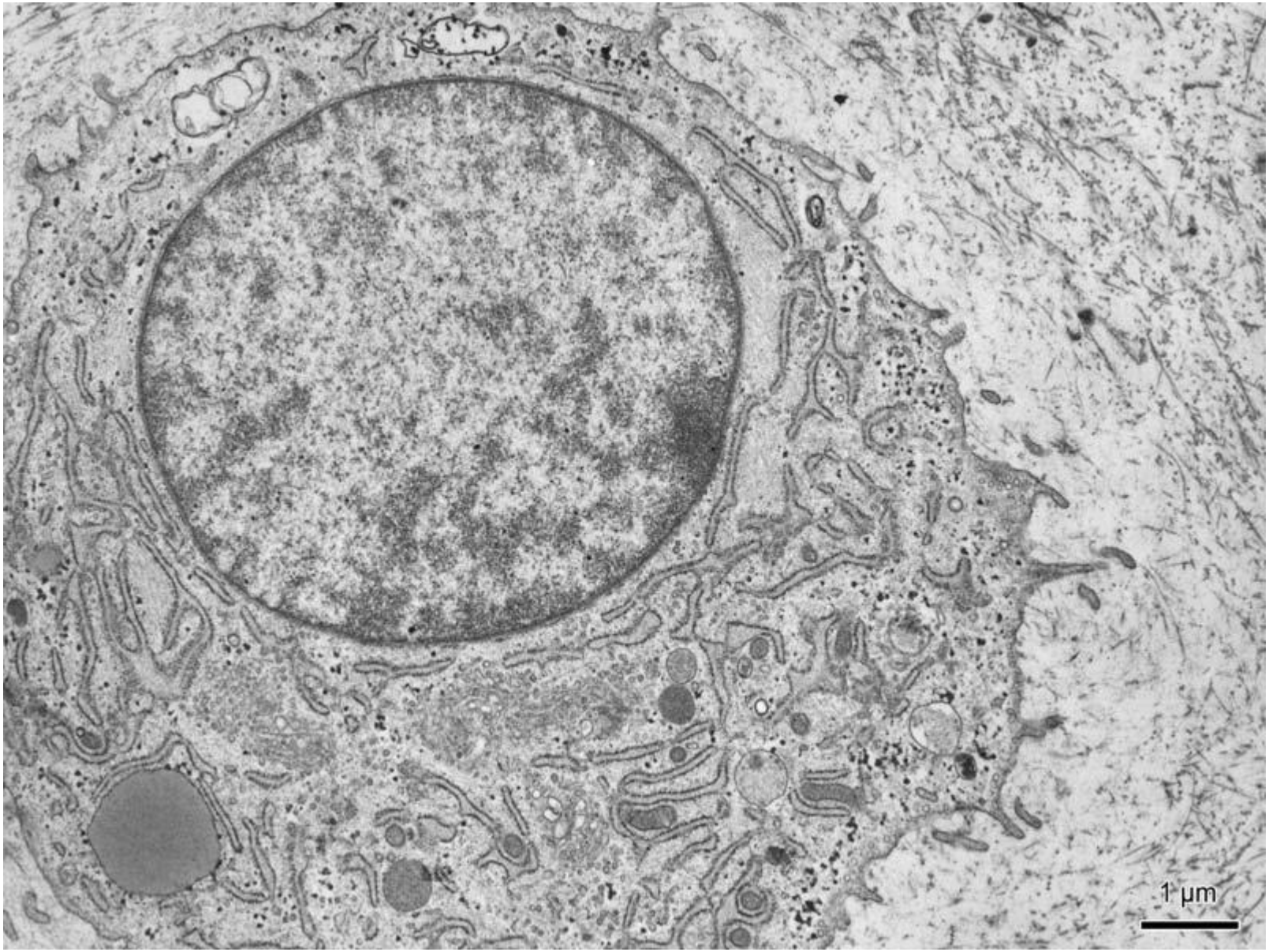
Source: Mescher AL: *Junqueira's Basic Histology: Text and Atlas, 12th Edition:* http://www.accessmedicine.com

Ultrastructure of chondrocytes

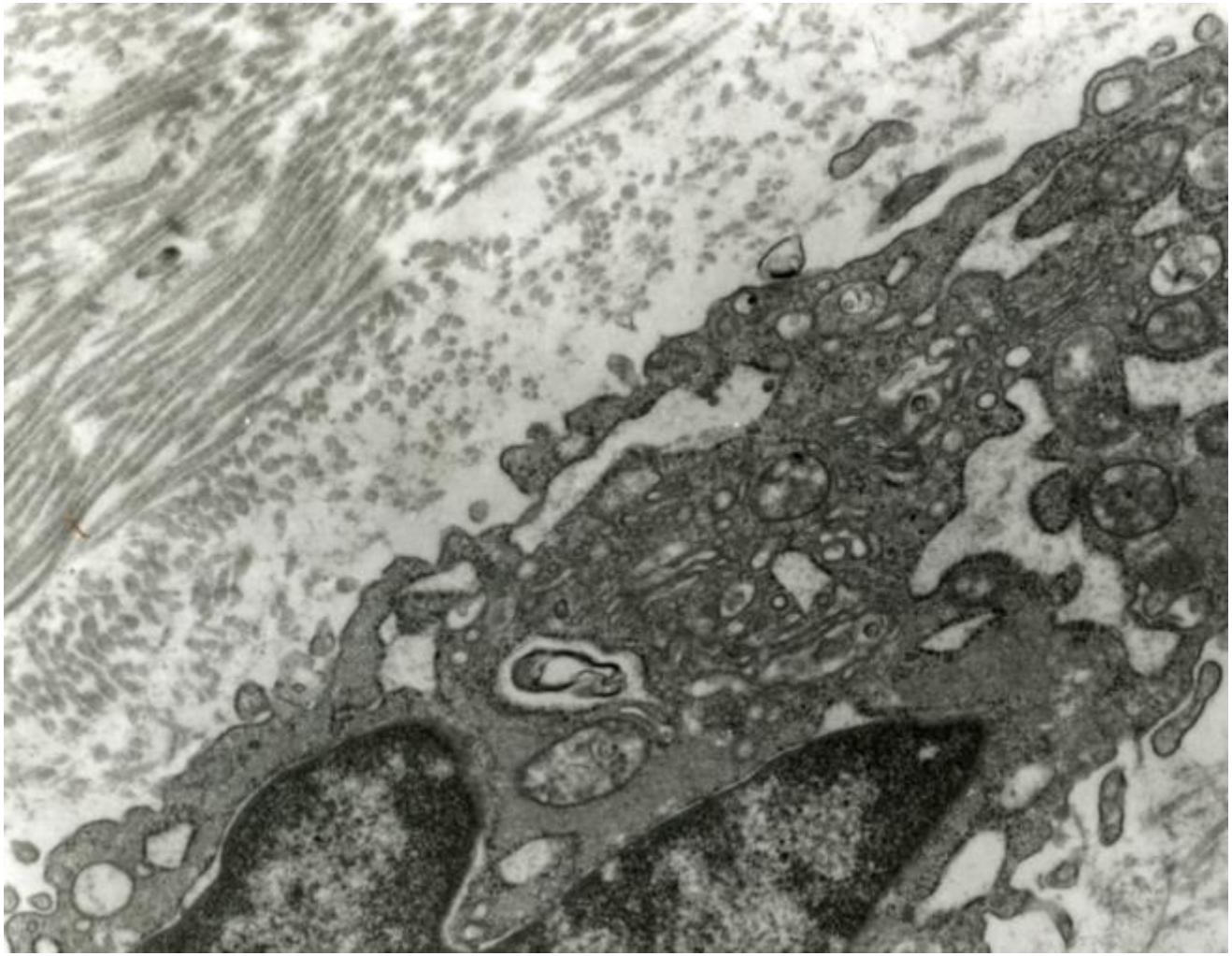
- oval → round cells
- rich in organelles, especially rER and GA
- glycogen granules (anaerobic metabolism)
- occasionally lipid droplets



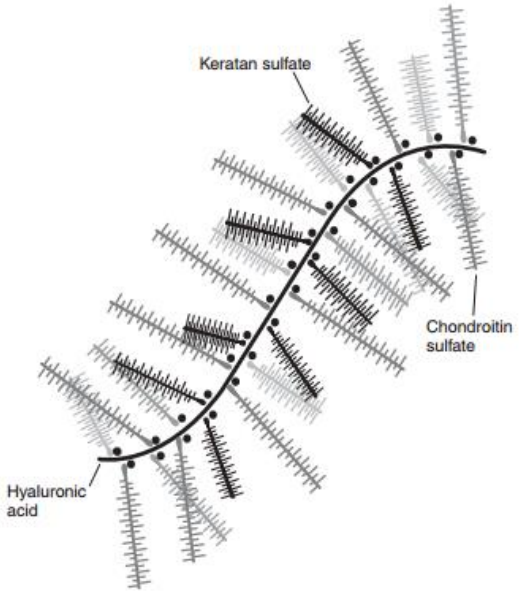
- Ultrastructure of chondrocytes



- Ultrastructure of chondrocytes



- Extracellular matrix



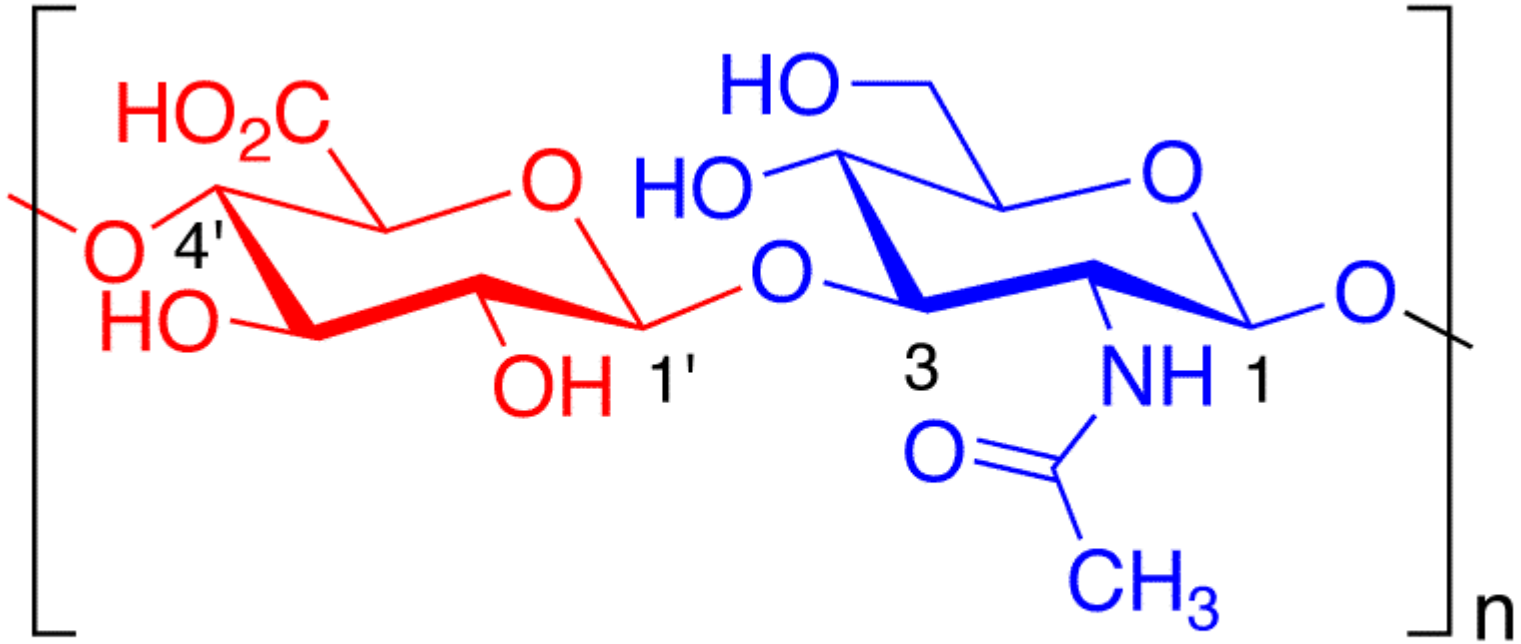
1. glycosaminoglycans
2. proteoglycans
3. fibers
4. water

biomechanical properties

Glycosaminoglycans

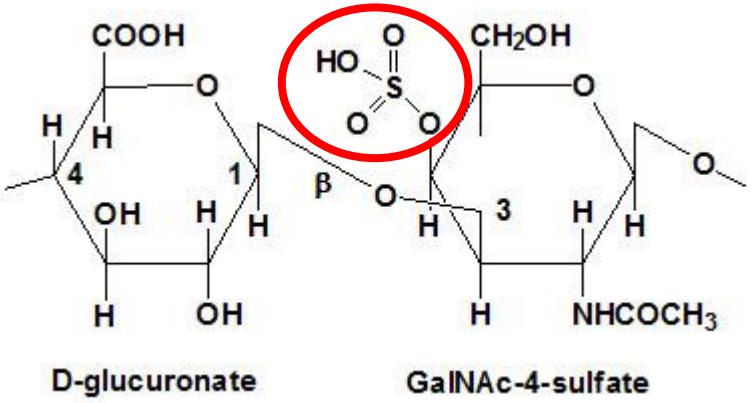
linear unbranched polysaccharides containing a repeating disaccharide unit:
1. N-acetylgalactosamine (GalNAc) or *N*-acetylglucosamine (GlcNAc)
2. uronic acid (glucuronate (GlcA)) or iduronate.

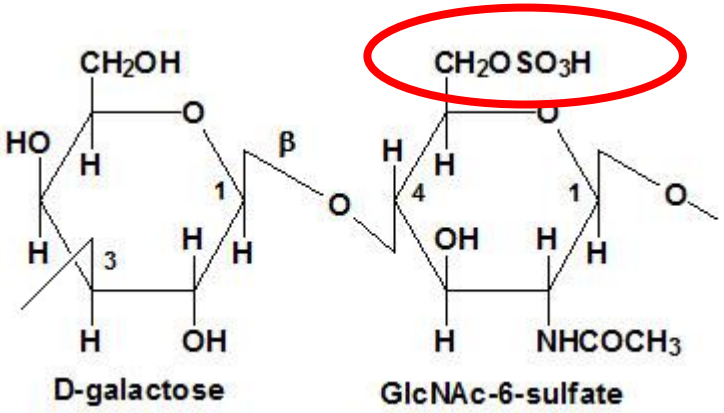
hyaluronic acid



Glucuronic Acid *N-Acetyl-D-glucosamine*

Glycosaminoglycan	Localization
Hyaluronic acid	Umbilical cord, synovial fluid, fluid of corpus vitreum, cartilage
Chondroitinsulphate	Cartilage, bone, cornea, skin, notochord, aorta
Dermatansulphate	Skin, ligaments, adventitia of aorta
Heparansulphate	Aorta, lungs, liver, basal membranes
Keratansulphate	Iris, cartilage, nucleus pulposus, anulus fibrosus





Proteoglycans

— protein + dominant linear saccharide component

— proteoglycan aggregates

— water-binding, volume dependent of hydratation

— **aggrecan (cartilage)**
— syndekan
— fibroglykan

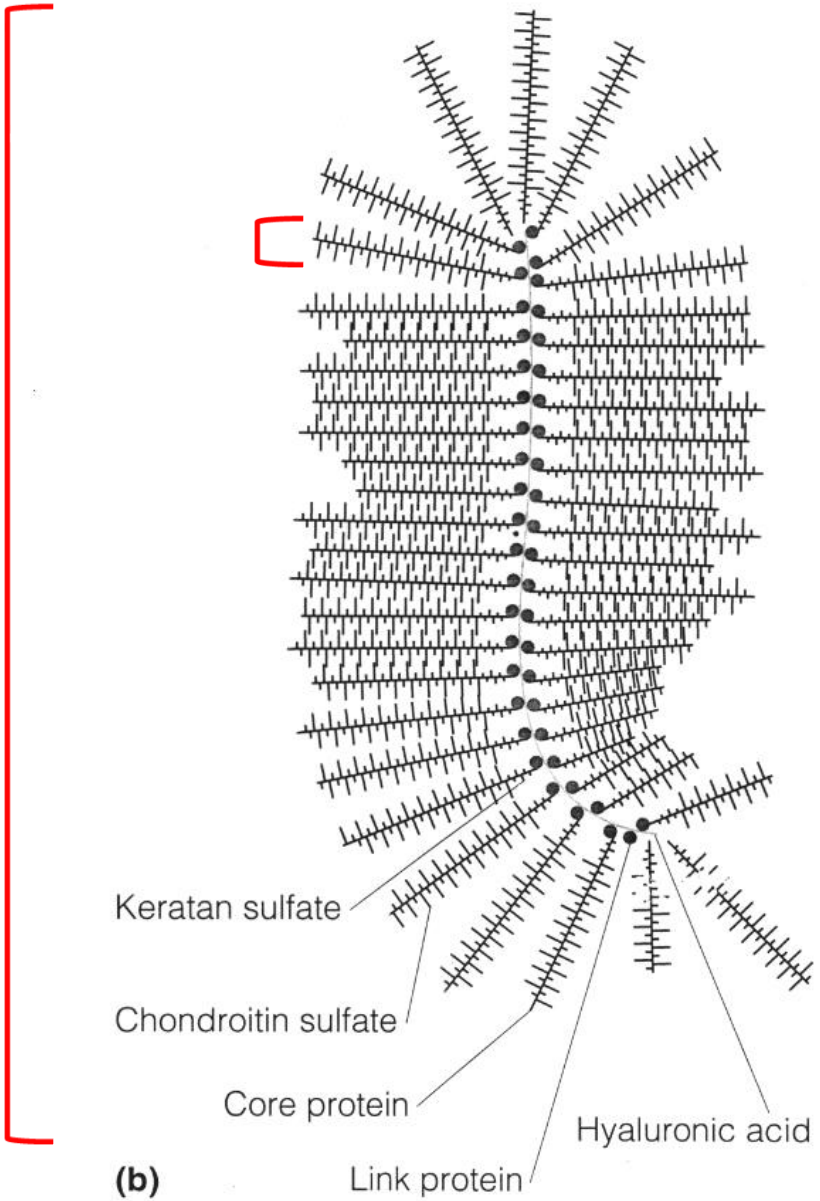
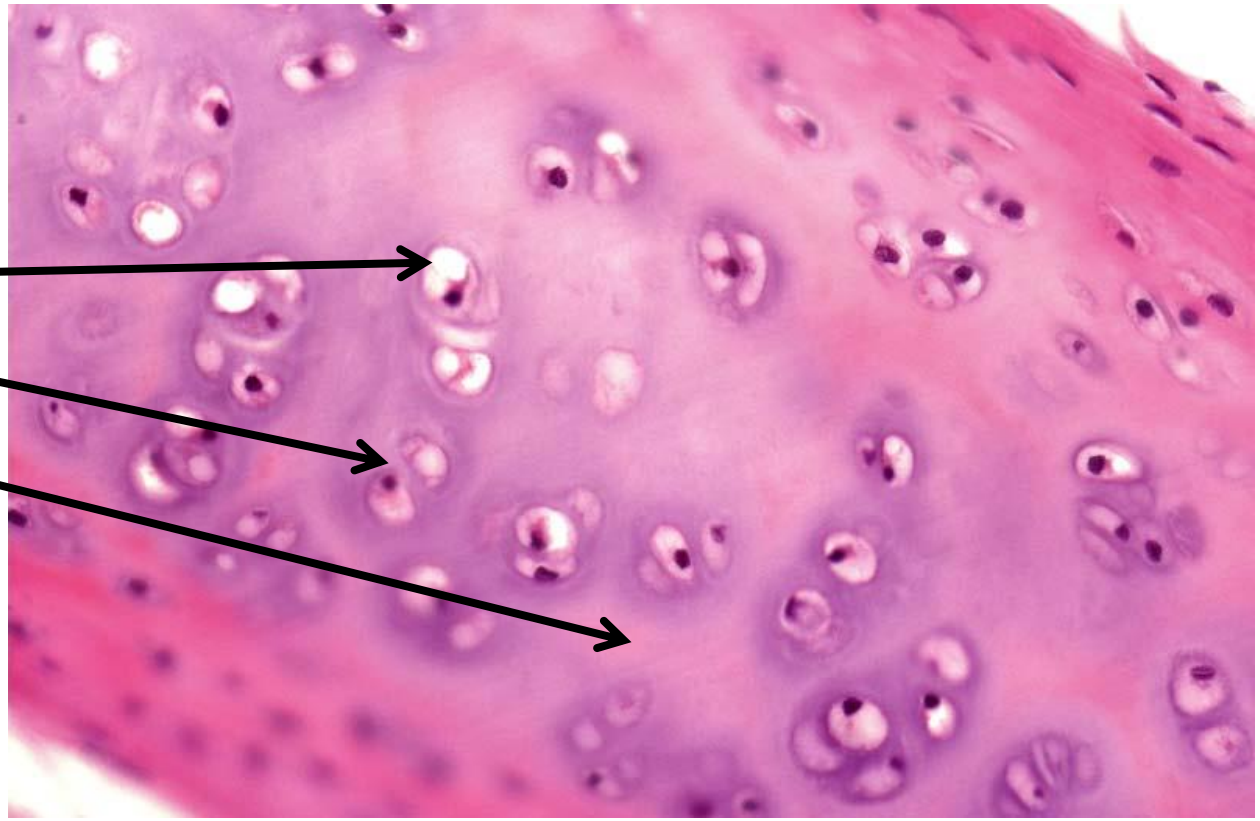


Figure 9.25b Proteoglycan structure in bovine cartilage

From Mathews and van Holde: *Biochemistry 2/e.* © The Benjamin/Cummings Publishing Co., Inc.

Architecture of extracellular matrix

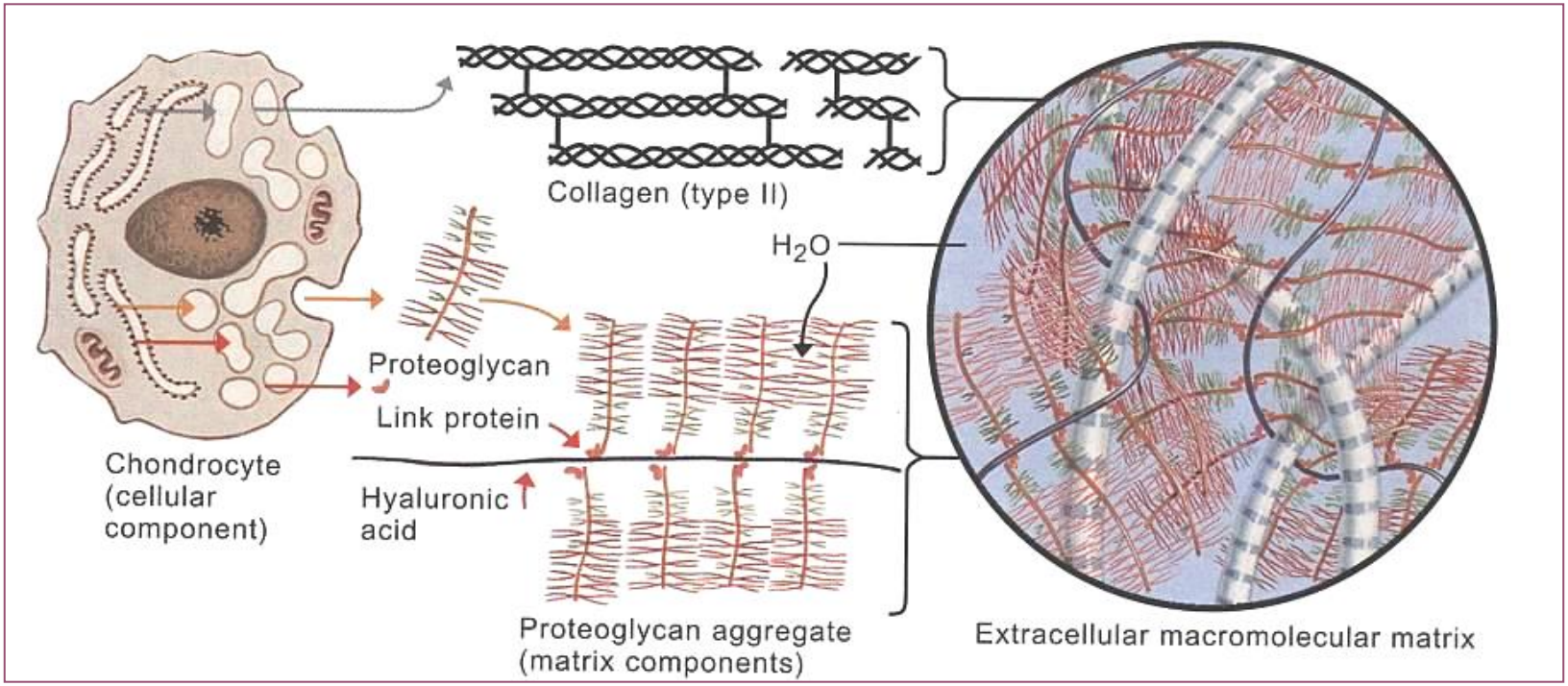
- pericellular
- territorial
- interterritorial



transduction of biochemical and biomechanical signals

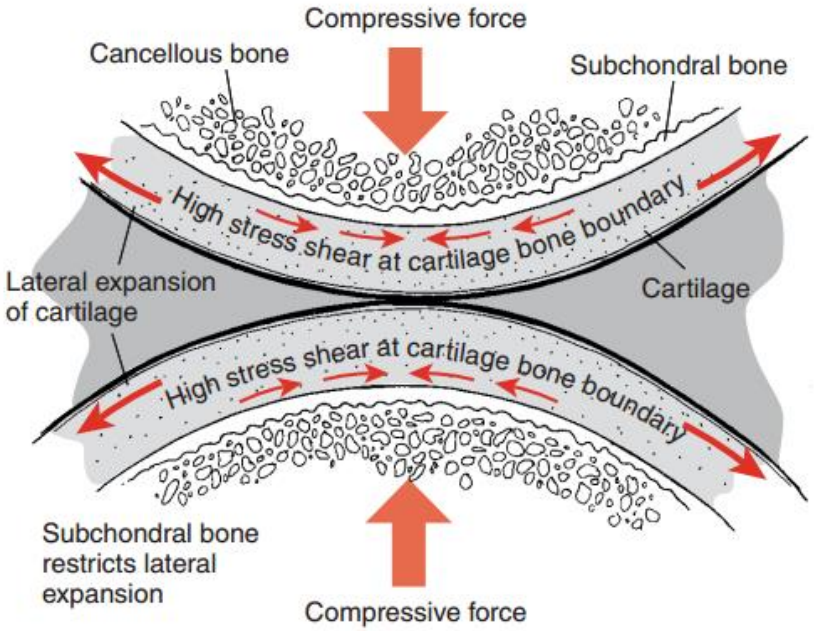
Extracellular matrix

- **collagen fibrils**
- col II + col IX/XI
- thin fibrils (15-20 nm → no striation) do not form fibers
- interconnected with perichondrium
- **proteoglycans and glycosaminoglycans**
- aggrecan hyaluronan-based aggregates
- water
- 80%



Architecture of extracellular matrix

- **pressure elasticity**
- proteoglycans – polyanionic (COO^-, SO_4^{II-})
- expansion prevented by collagen fibrils
- repulsion forces



- **biphasic model of cartilage** conditioned by ECM composition
- proteoglycans, collagen, cells, and lipids constitute the solid phase of the mixture
- interstitial fluid that is free to move through the matrix fluid phase)
- under impact loads, fluid flows through the framework, until the cartilage start to behave as a single-phase, incompressible, elastic solid - the fluid does not flow
- after load release, fluid returns
- nutritive aspect

Architecture of extracellular matrix

- **synovial cartilage**

I. tangential (superficial) zone

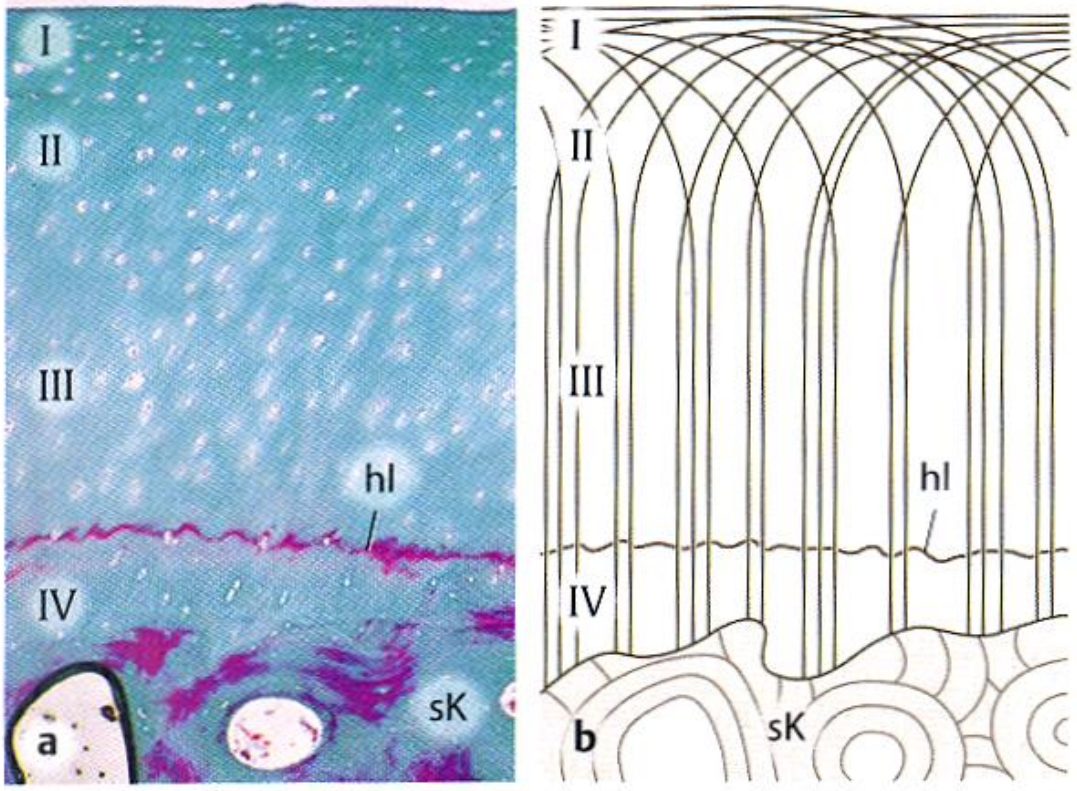
II. transitional zone

III. radial (deep) zone

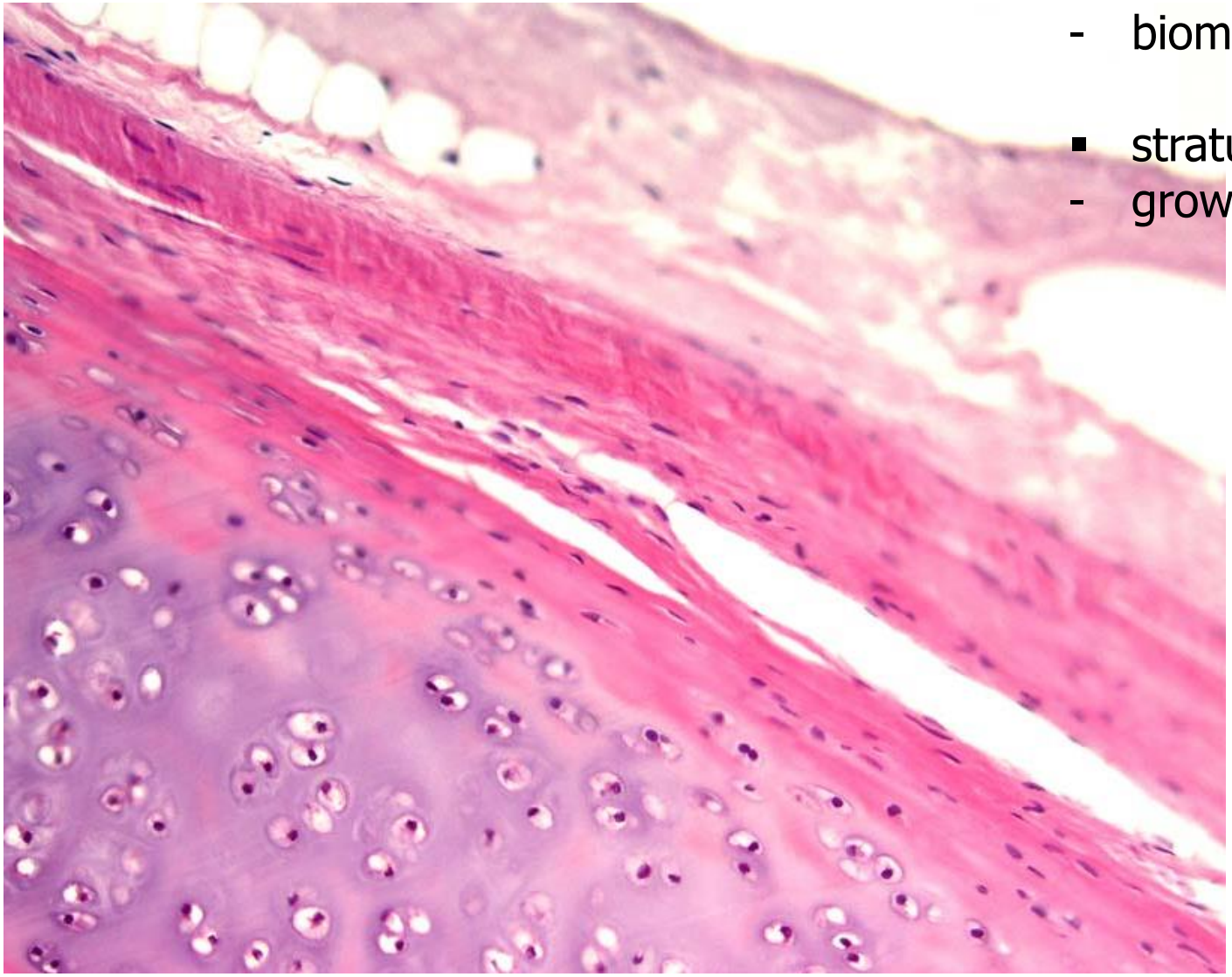
tide mark

I. mineralized cartilage zone

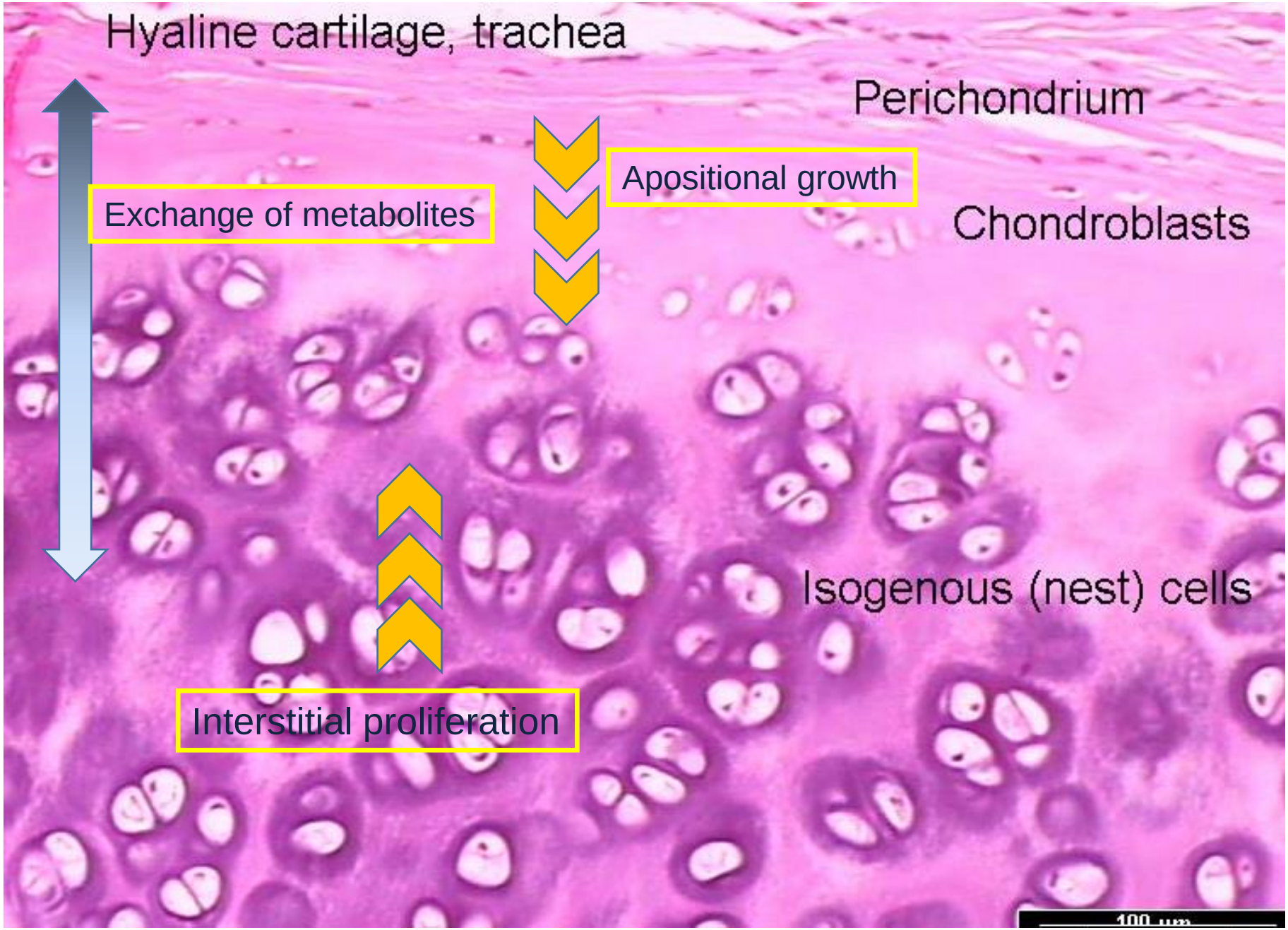
subchondral bone



Perichondrium

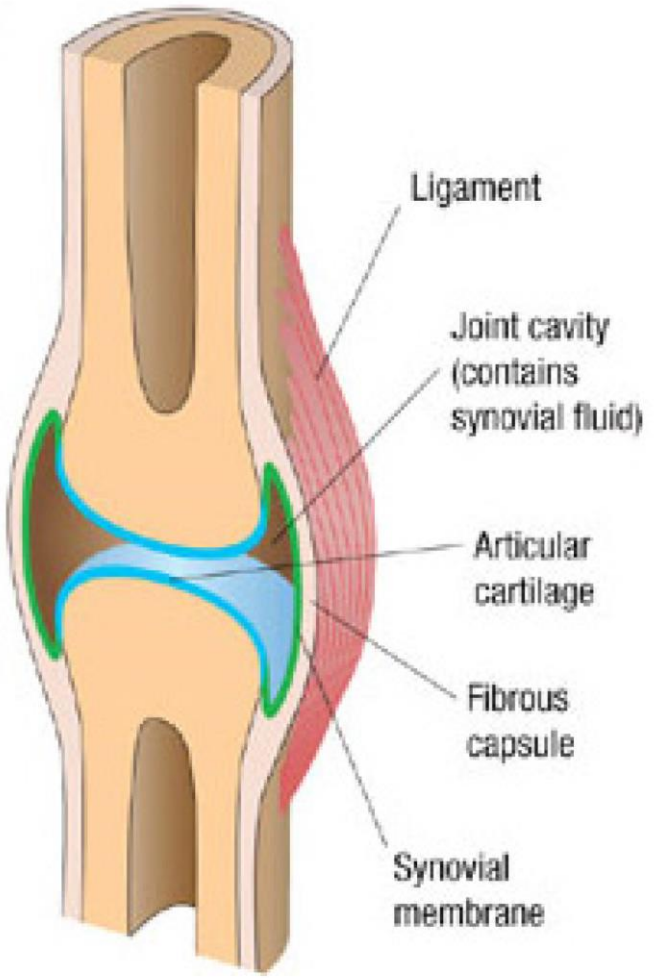


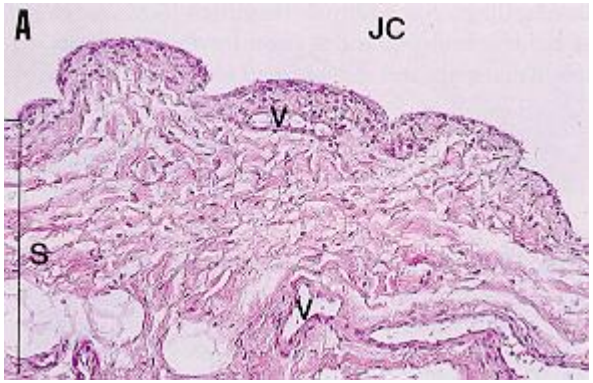
- stratum fibrosum
  - biomechanics
- stratum chondrogenicum
  - growth

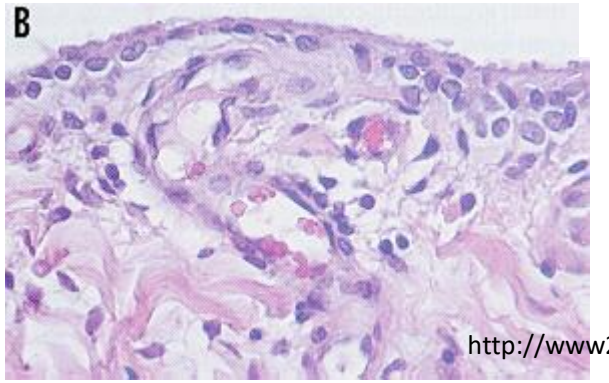

Hyaline cartilage, trachea
Perichondrium
Apositional growth
Exchange of metabolites
Chondroblasts
Isogenous (nest) cells
Interstitial proliferation
100 µm

Synovium

- *membrana fibrosa*
- dense collagen c.t.
- *membrana synovialis*
- intima, subintima
- folds extending to the joint cavity
- numerous blood and lymphatic vessels, nerves
- discontinuous cell layers (synovialocytes)
- basal membrane and intercellular junctions absent - **not an epithelium** but mesenchymal (c.t.) origin
- synovial fluid rich in hyaluronans
- *bursae synoviales, vaginae tendineum*







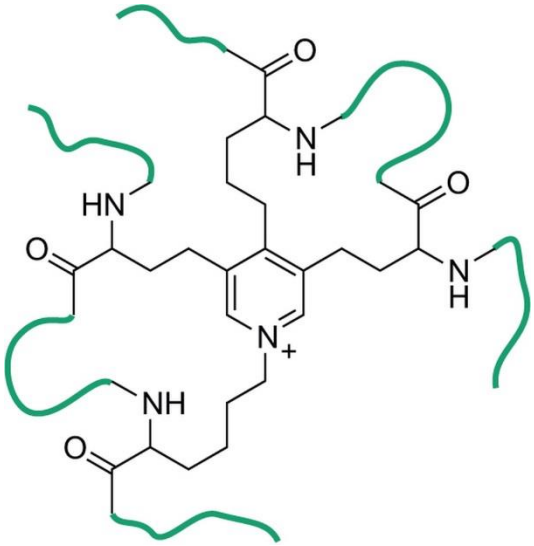
http://www2.indstate.edu/thcme/mmmoga/histology/slide35.html

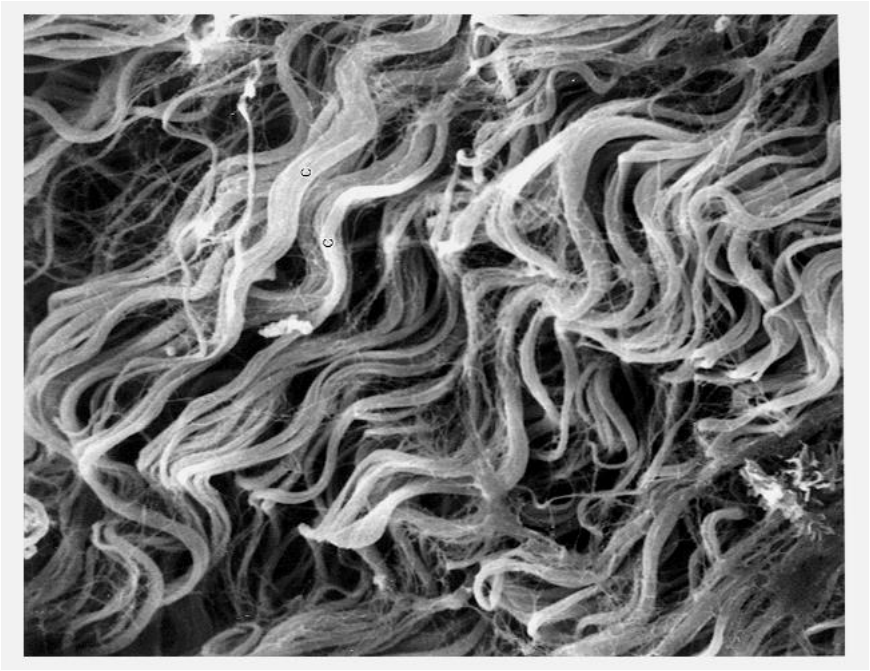
Elastic cartilage

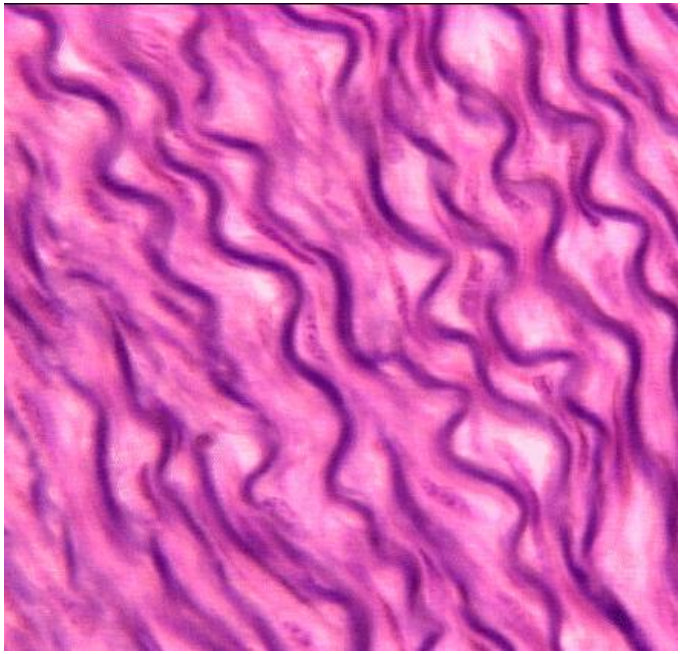
- acidophilic elastic fibers in matrix
- no isogenetic groups
- auricula, meatus, larynx, epiglottis

Elastic fibers

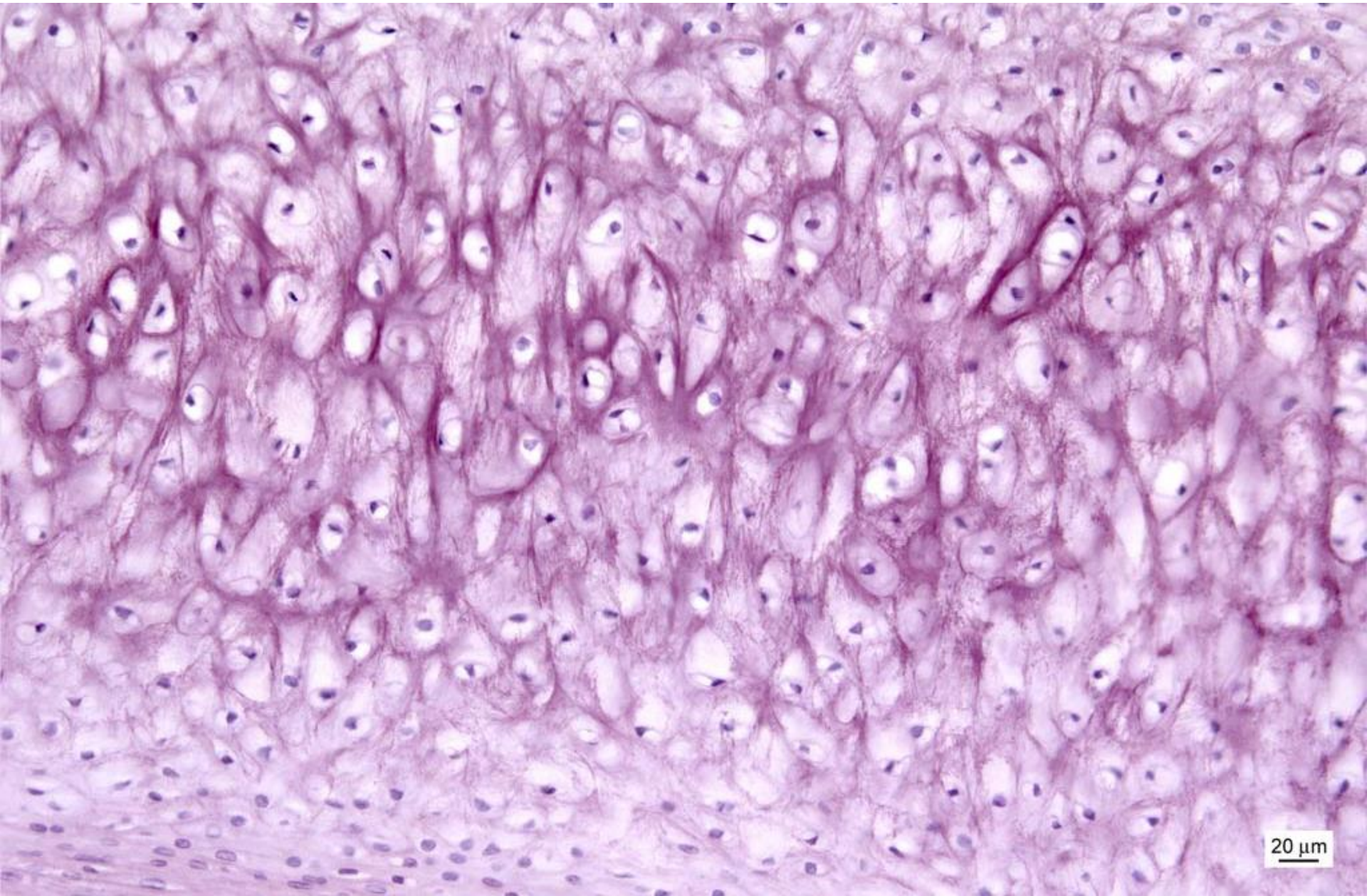
- less abundant than collagen
- polymer – tropoelastin
- minimal tensile resistance, loss of elasticity if overstretched
- reduction of hysteresis = allow return back to original state after mechanic change





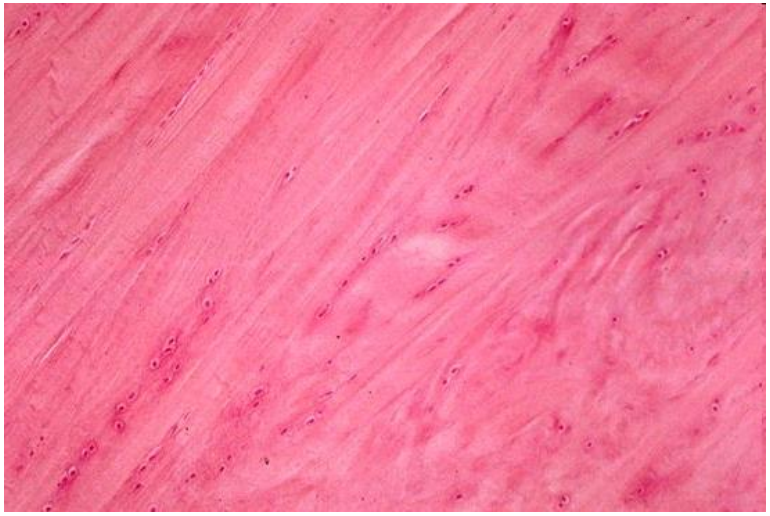


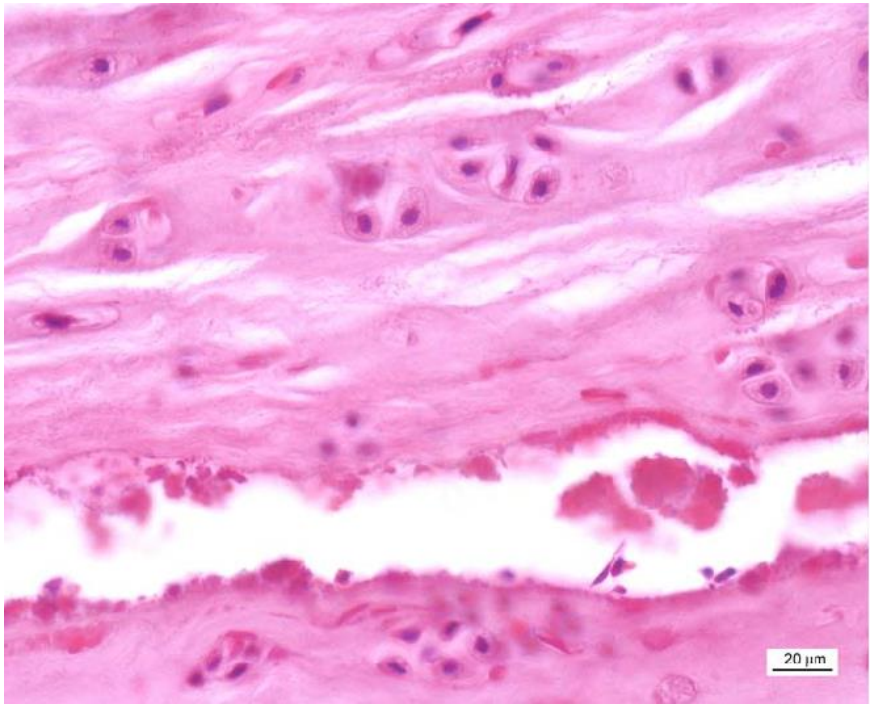
- Elastic cartilage

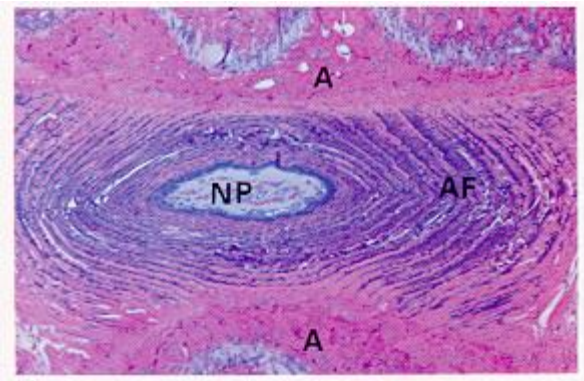


Fibrocartilage

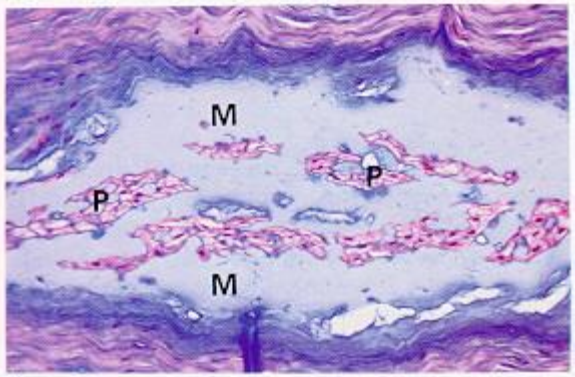
- fibrous compound dominant – collagen I and II – mechanical durability
- minimum of amorphous matrix- fibers visible
- intervertebral discs, symphysis pubis, articular discs, meniscus







(a)

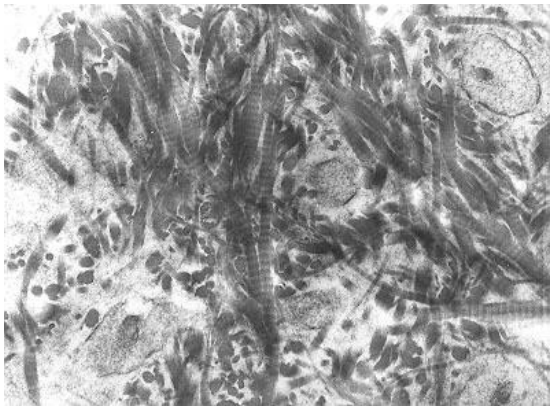


(b)

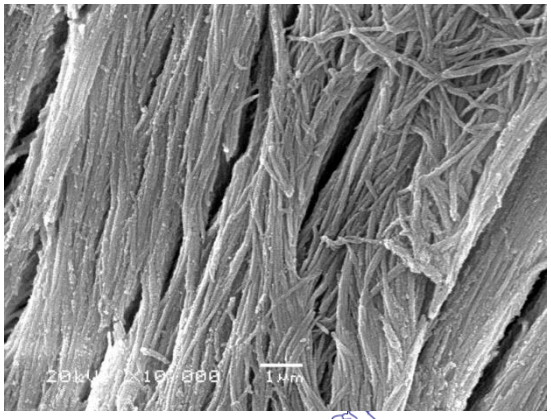

BONE
20 µm

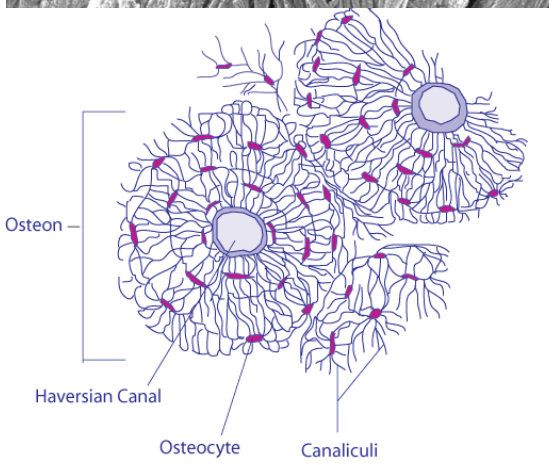
Histological classification of bone tissue

- **Primary (woven, fibrous)**
- Temporary, growth and regeneration of bones, collagen fibrils woven
- Replaced by secondary bone
- Remains only in some parts of body - sutures of skull, *tuberositas ossium*, tooth cement

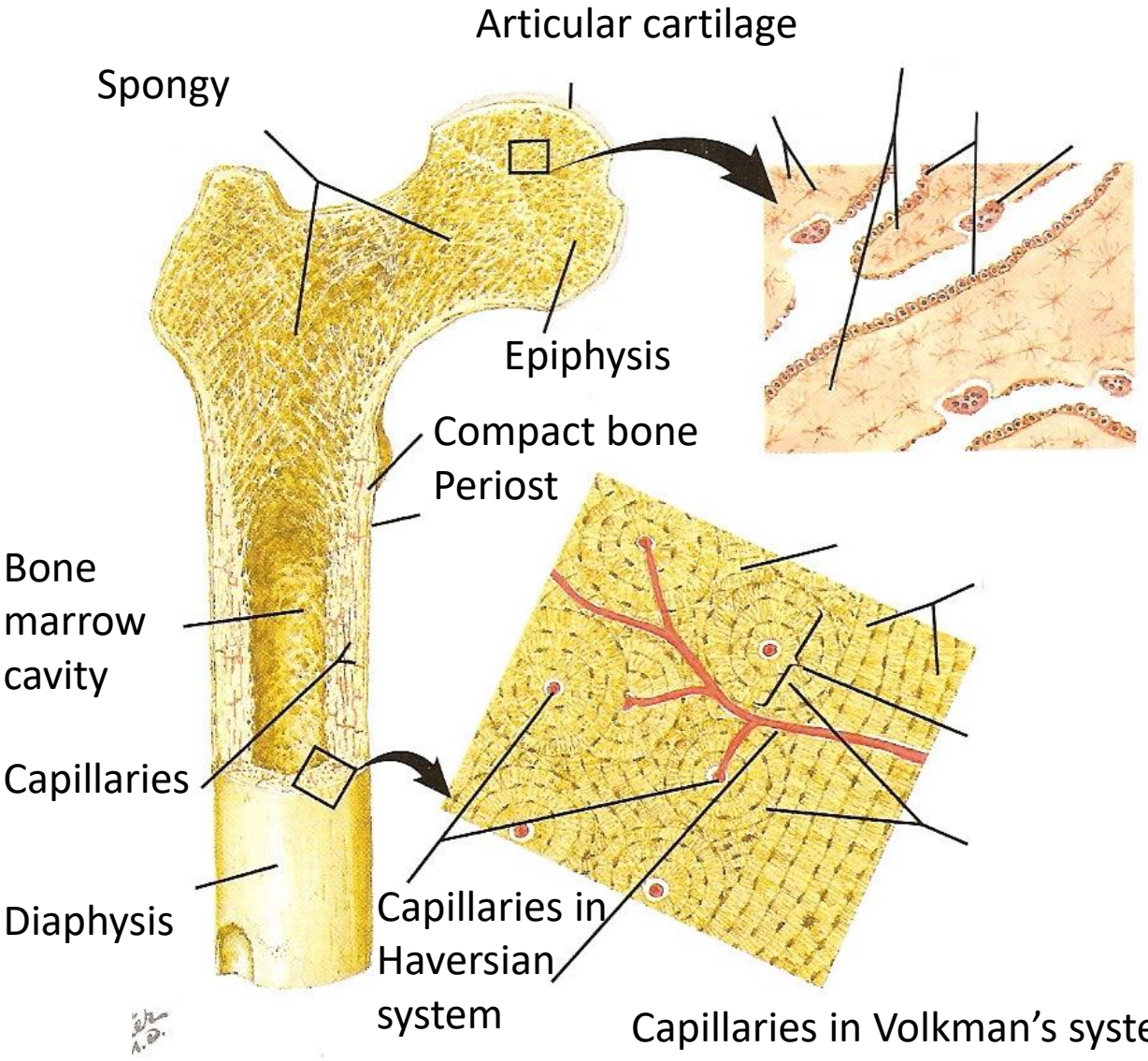


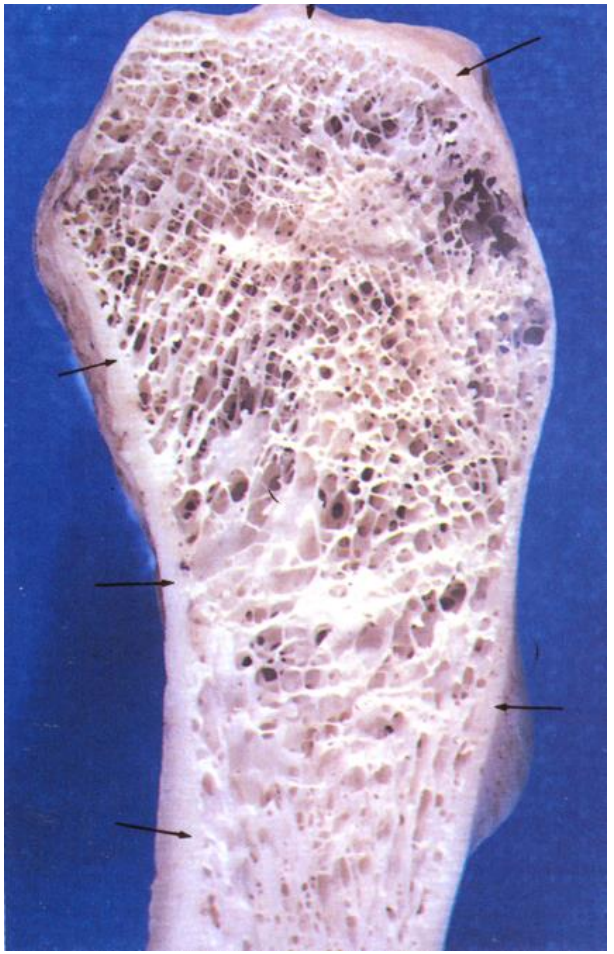
- **Secondary (lamellar)**
- Lamellae – collagen fibers in concentric layers (3-7μm) around a canal with capillaries = Haversian system (osteon)
- **Spongy (trabecular)**
  - Trabeculae, similar to compact
  - Epiphyses of long bones, short bones, middle layer of flat bones of the skull (*diploe*)
- **Compact**
  - Outer and inner coat lamellae typical Haversian systems
  - Volkmann's canals
  - Interstitial canals





- Bone

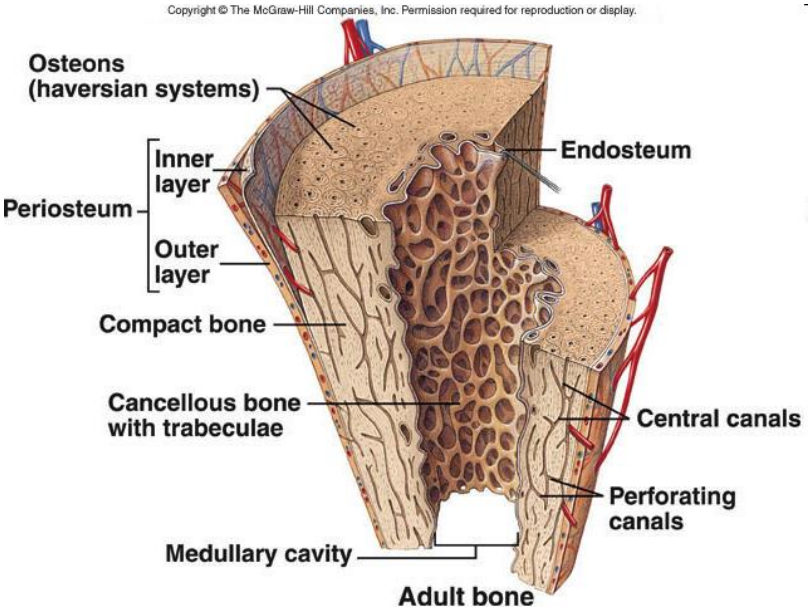




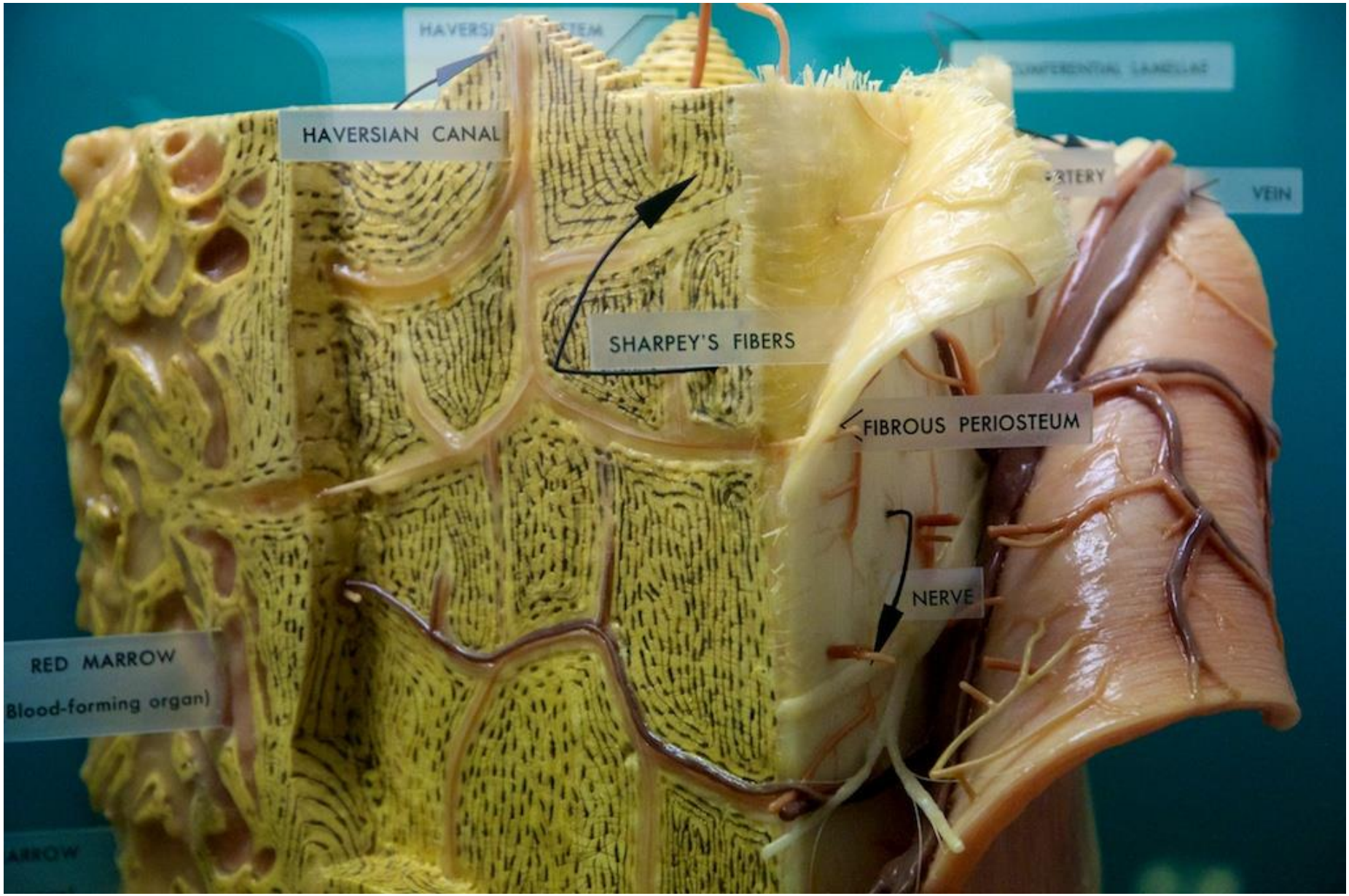
Capillaries in Volkman's system

Surface of compact bone

- Outer surface
- Synovial joint – hyaline cartilage
- **periosteum (periost)** – membrane – dense CT, inner layer (osteoblasts) and outer layer (fibrous CT)
- Inactive bone - fibrous CT in periost dominant
- Collagen fibers – parallel to the bone surface
- Sharpey's fibers fix periost to the bone

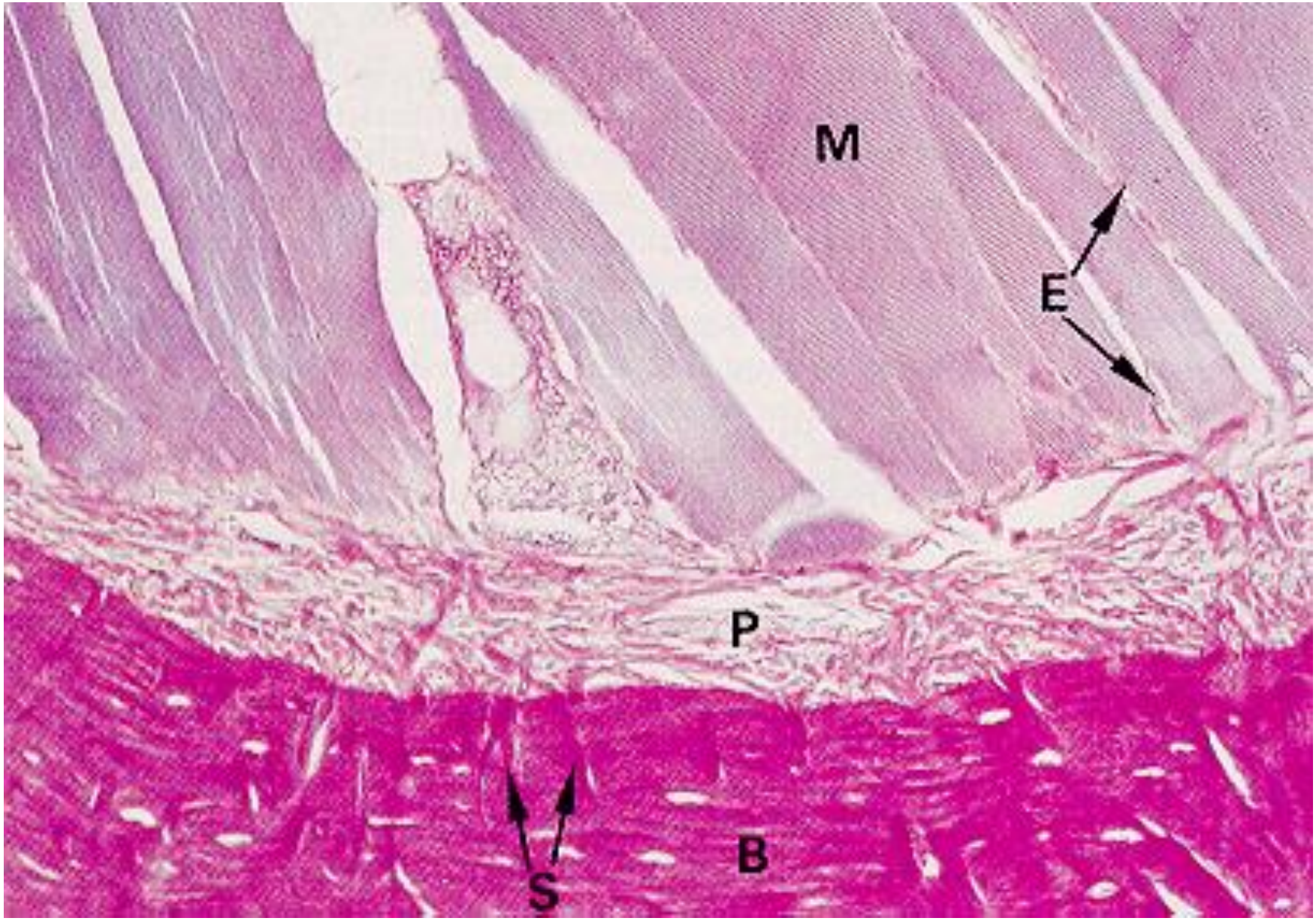


- Surface of compact bone

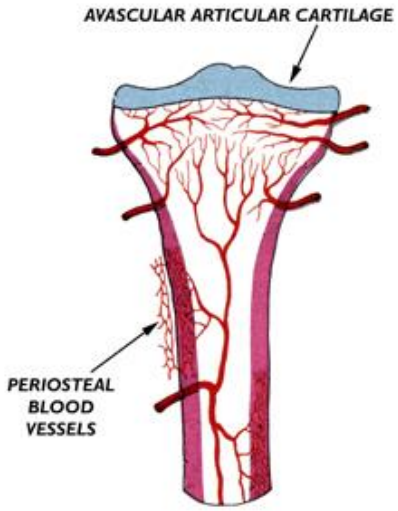


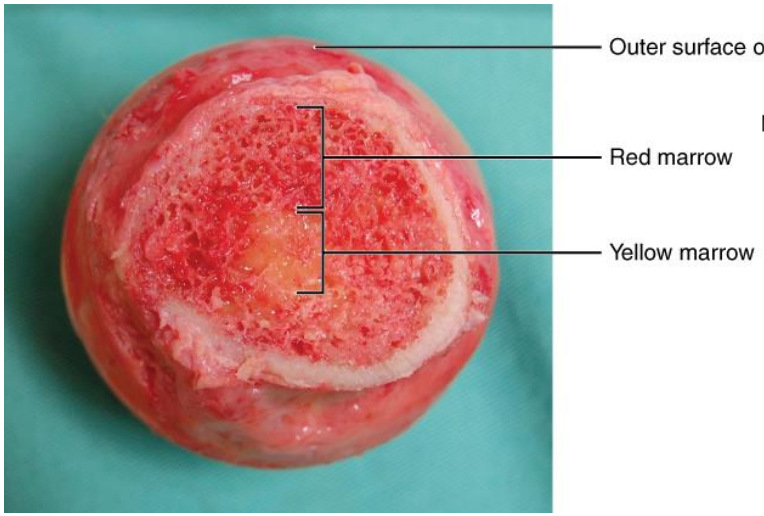
National Museum of Natural History NY, USA

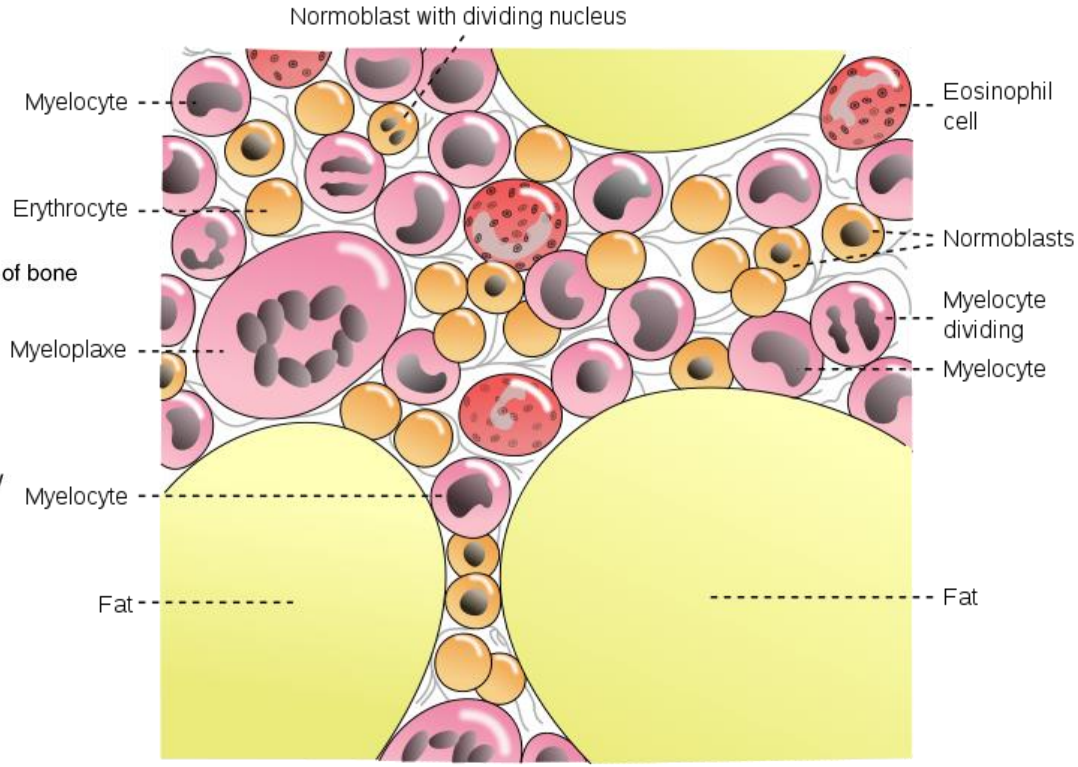
- Surface of compact bone



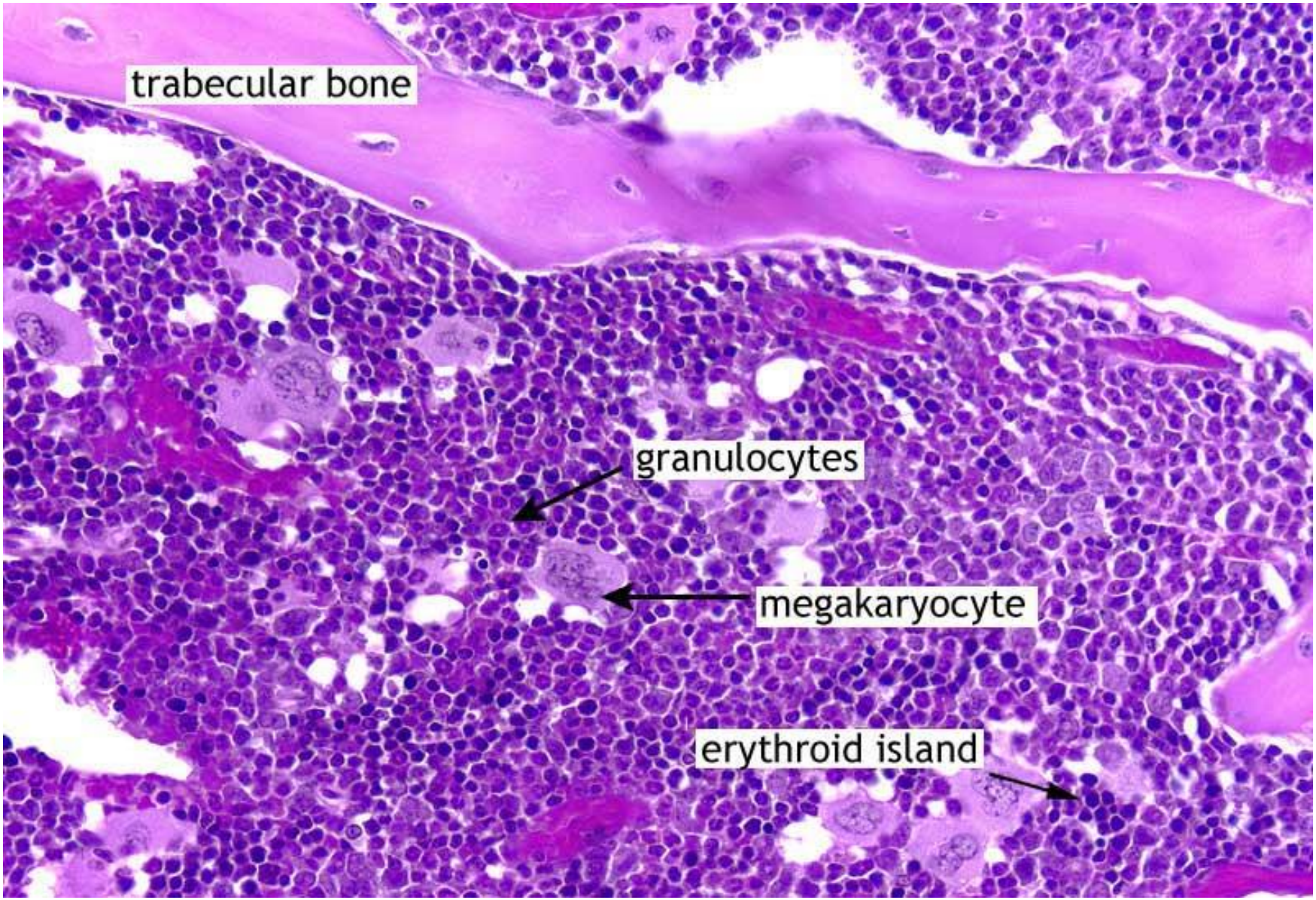
- **Inner surface**
- lining of medullar cavity
- endosteum (endost) – single cell lining – bone remodeling
- red bone marrow – hematopoiesis
- yellow and gray bone marrow – adipocytes or CT
- rich vascularization
- hematopoietic niche





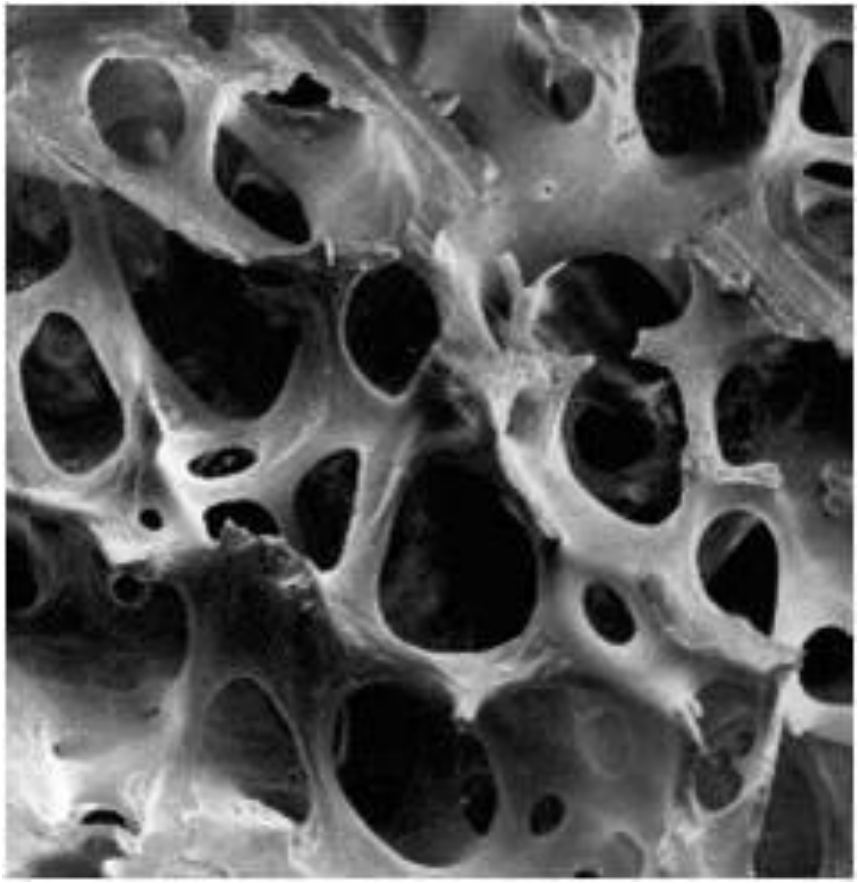


- Endosteal urface of compact bone



- Bone matrix

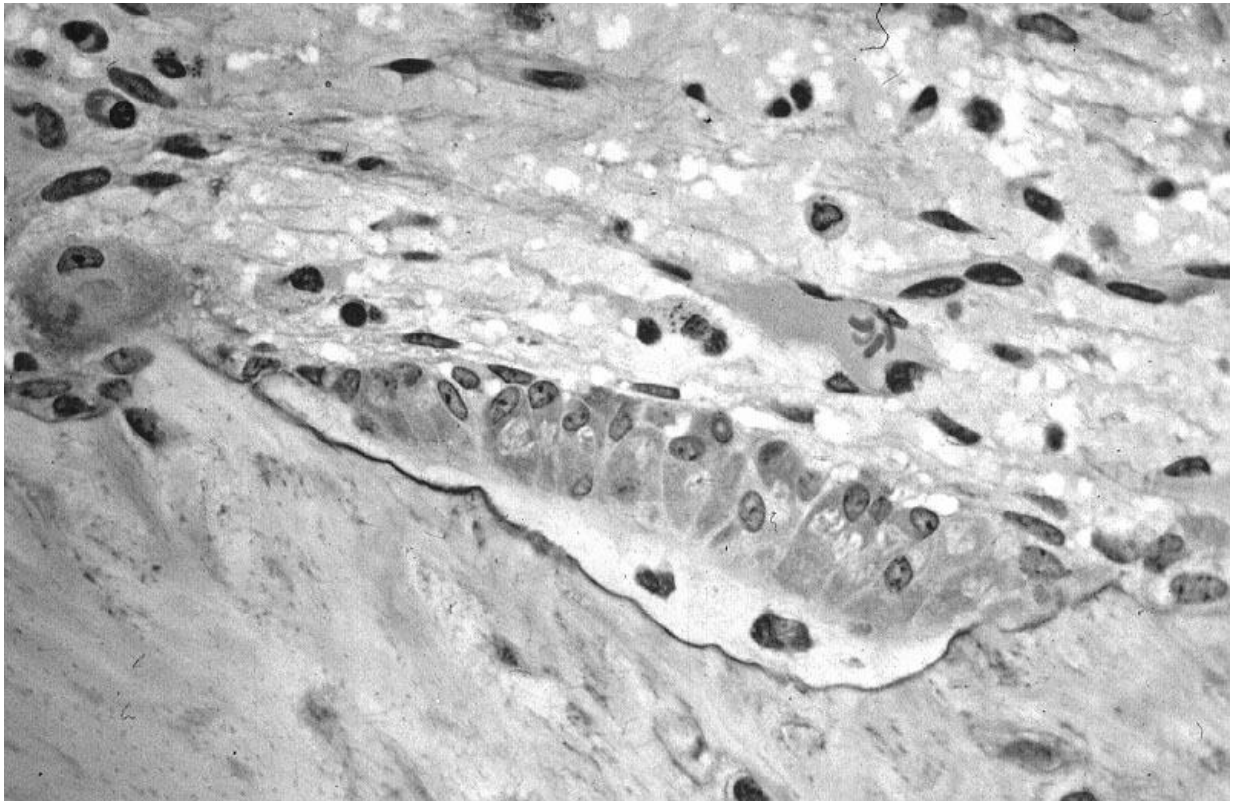
- 60% mineral compound, 24% organic compound 12% H_20, 4% fat
- crystals – calcium phosphate, hydroxyapatite



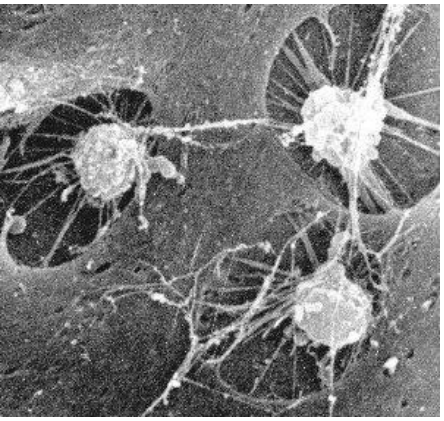
Cells of the bone - osteoblasts

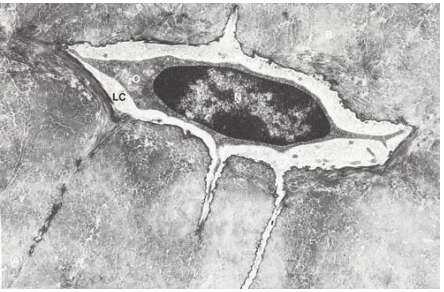
- lining bone surface
- produce ECM – collagen (I) and noncollagenous proteoglycans, glycoproteins
- basophilic cytoplasm, rER, well developer Golgi Apparatus
- euchromatin nucleus

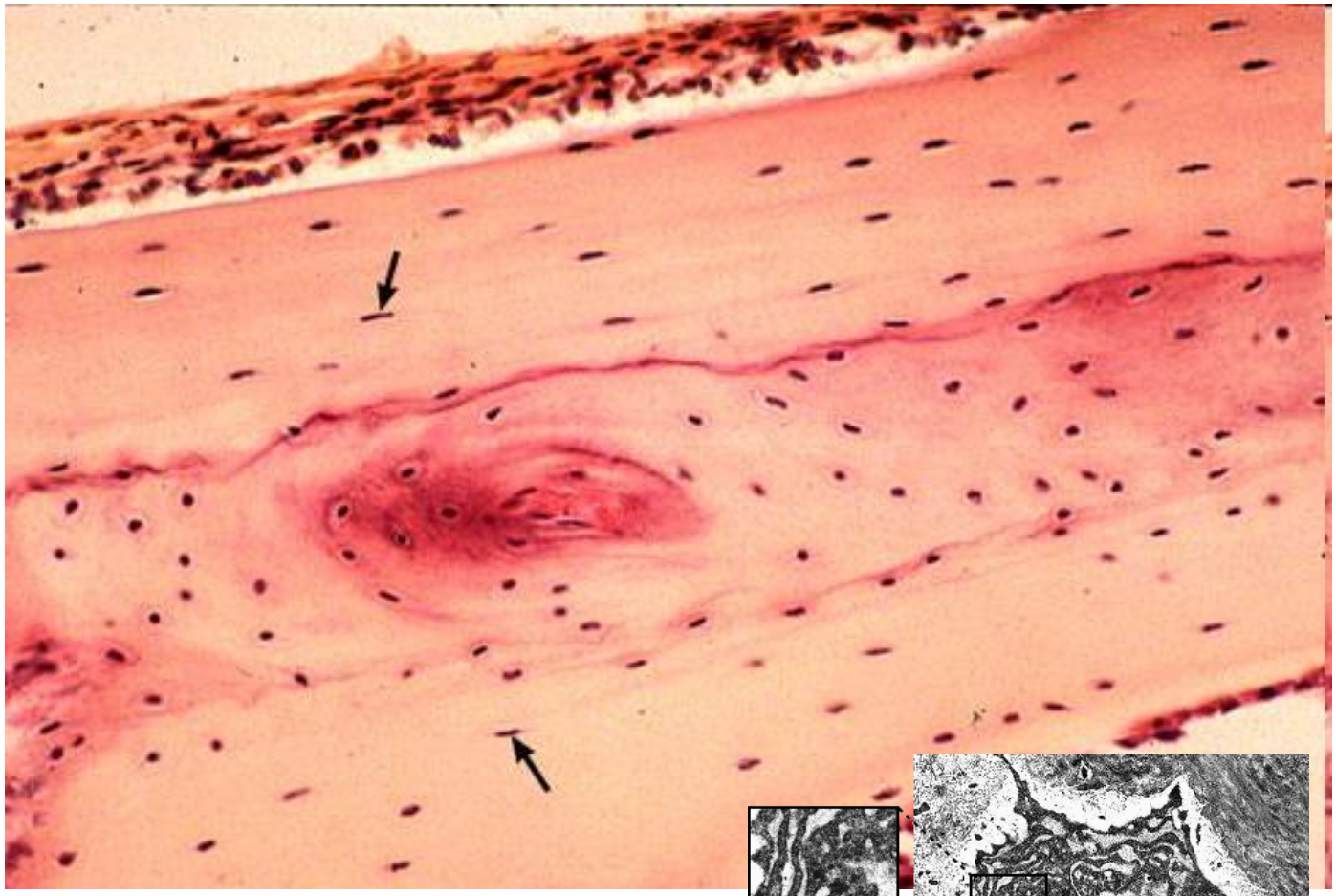
- **osteocytes** embedded in matrix
- *canalliculi ossium*



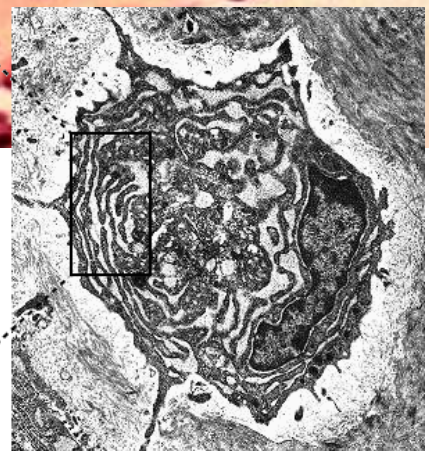
Cells of the bone - osteocytes





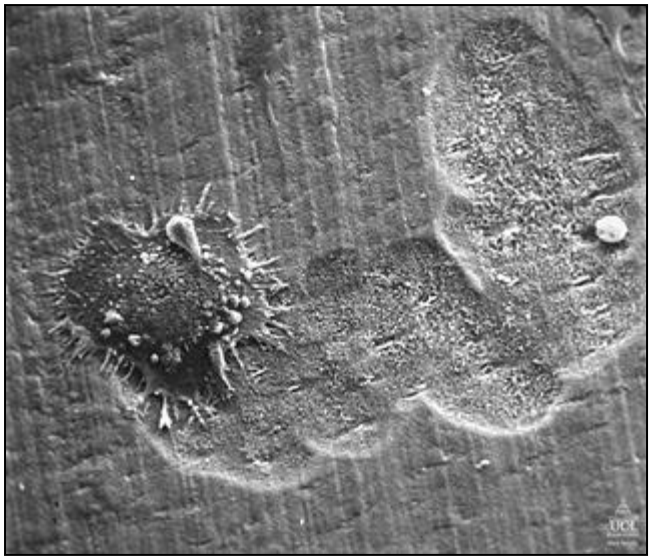


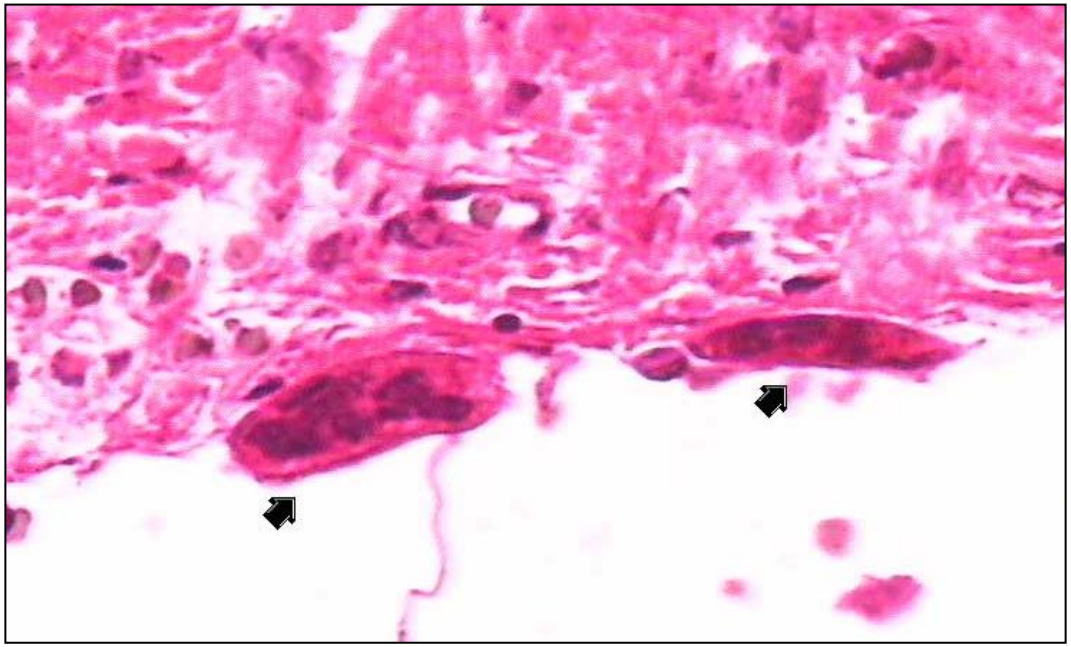
RER
-rough
endoplasmic
reticulum



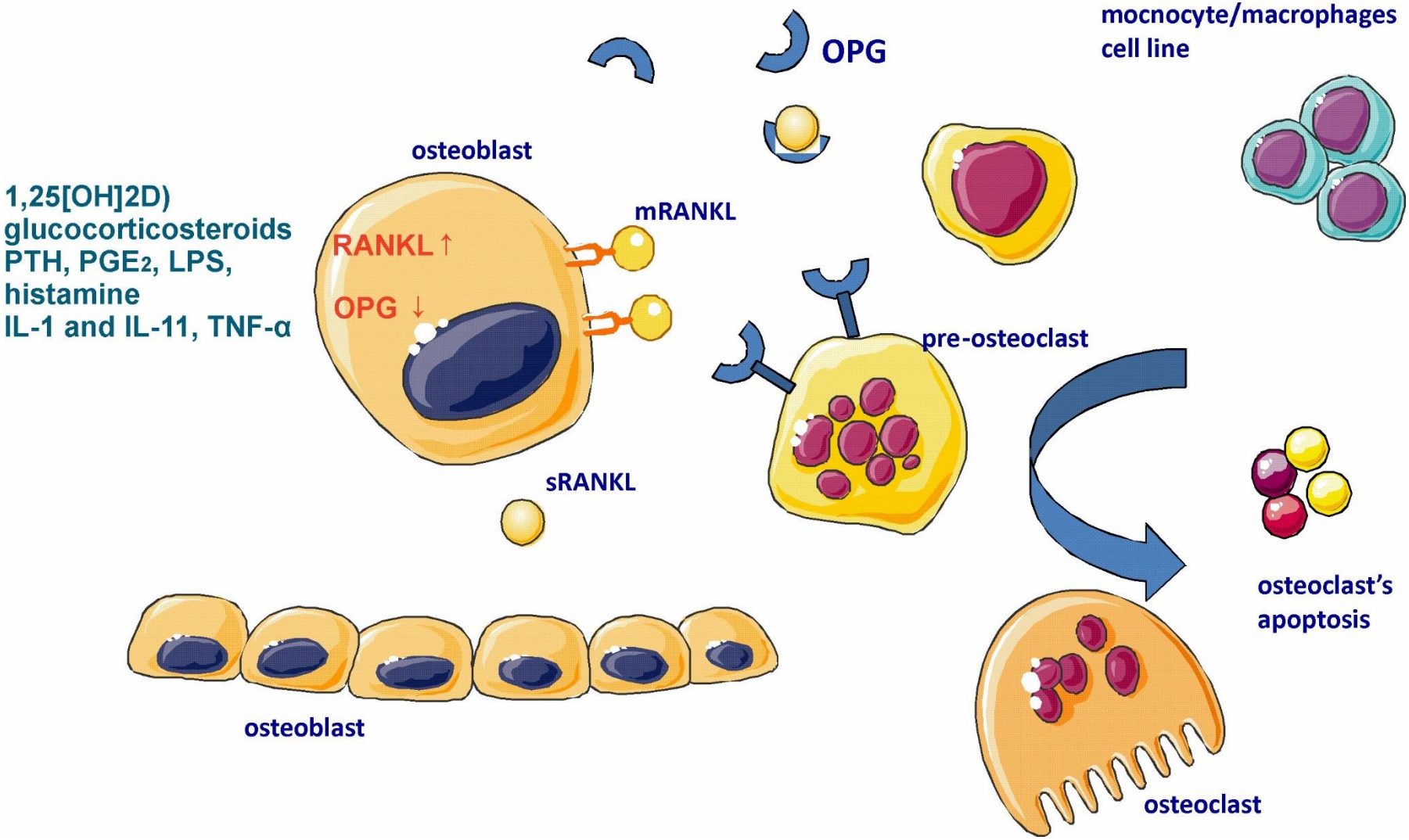
Cells of the bone - osteoclasts

- multinuclear, formed by fusion of mononuclear macrophages
- bone matrix resorption



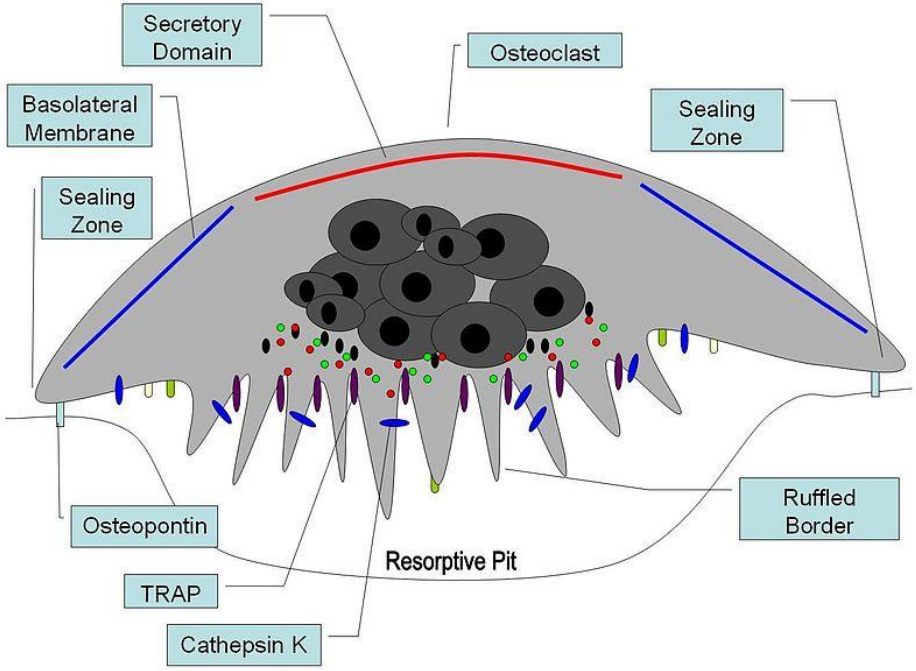


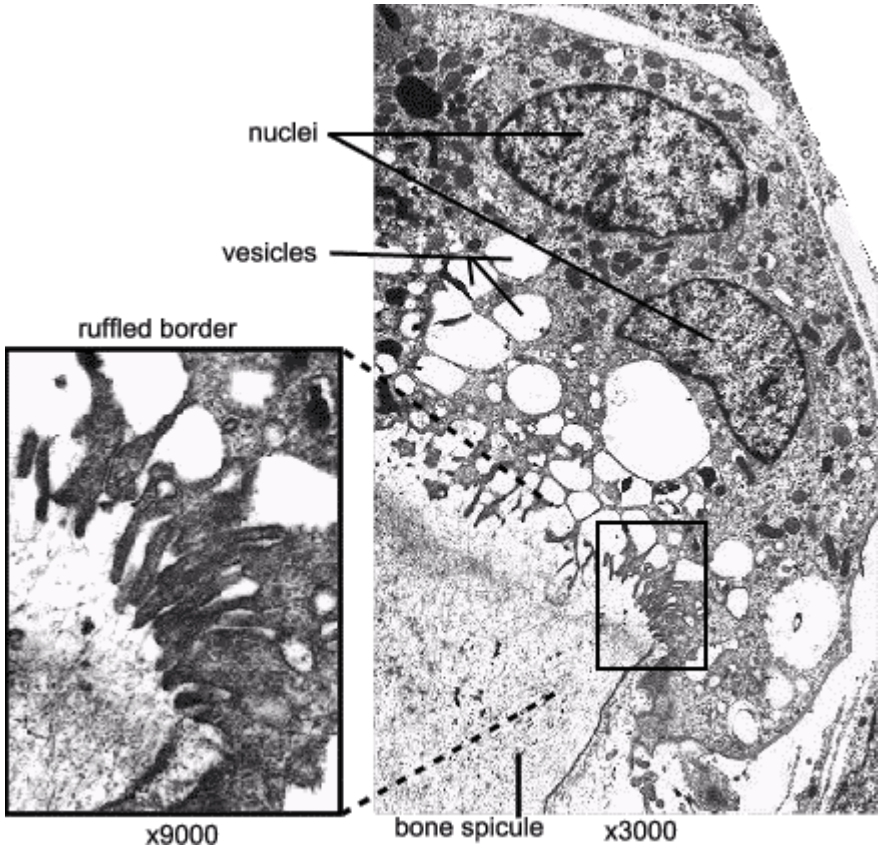
Cells of the bone - osteoclasts



Cells of the bone - osteoclasts

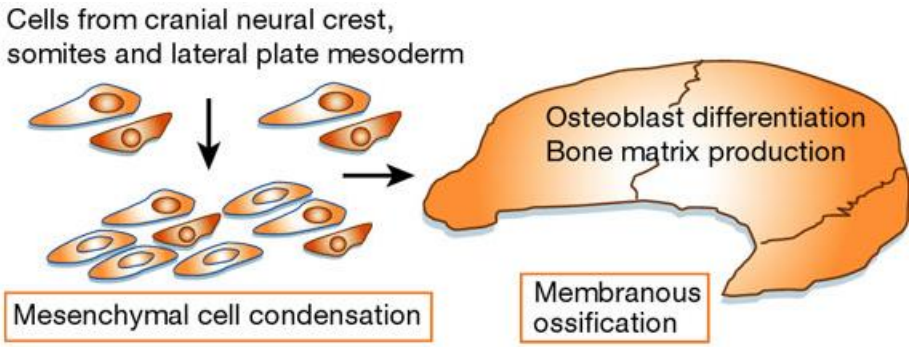
- complex architecture
- enzymes degrading organic matrix
- HCl



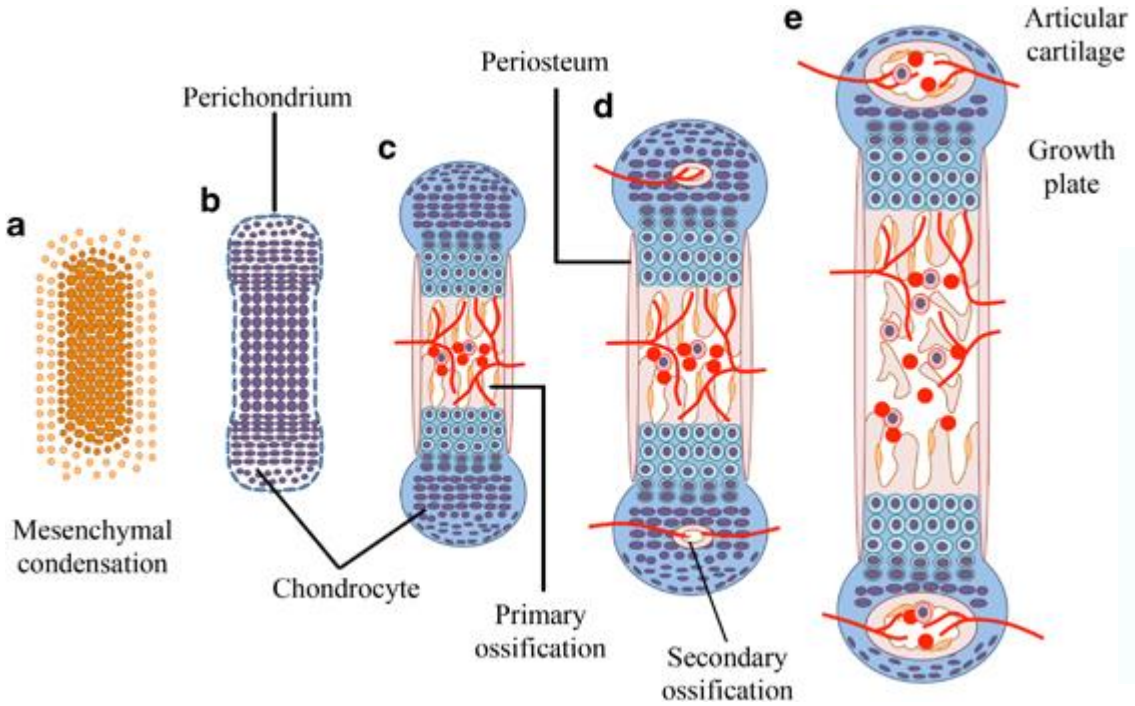


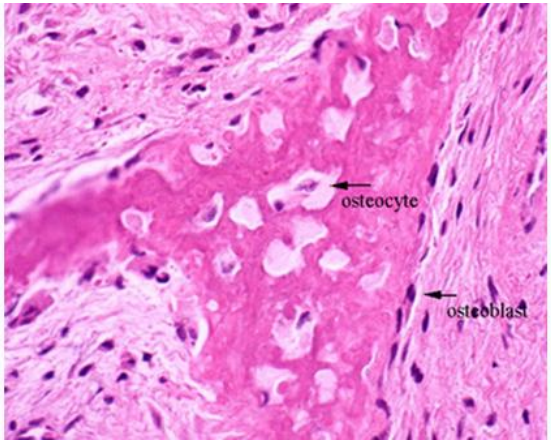
Ossification

Intramembraneous

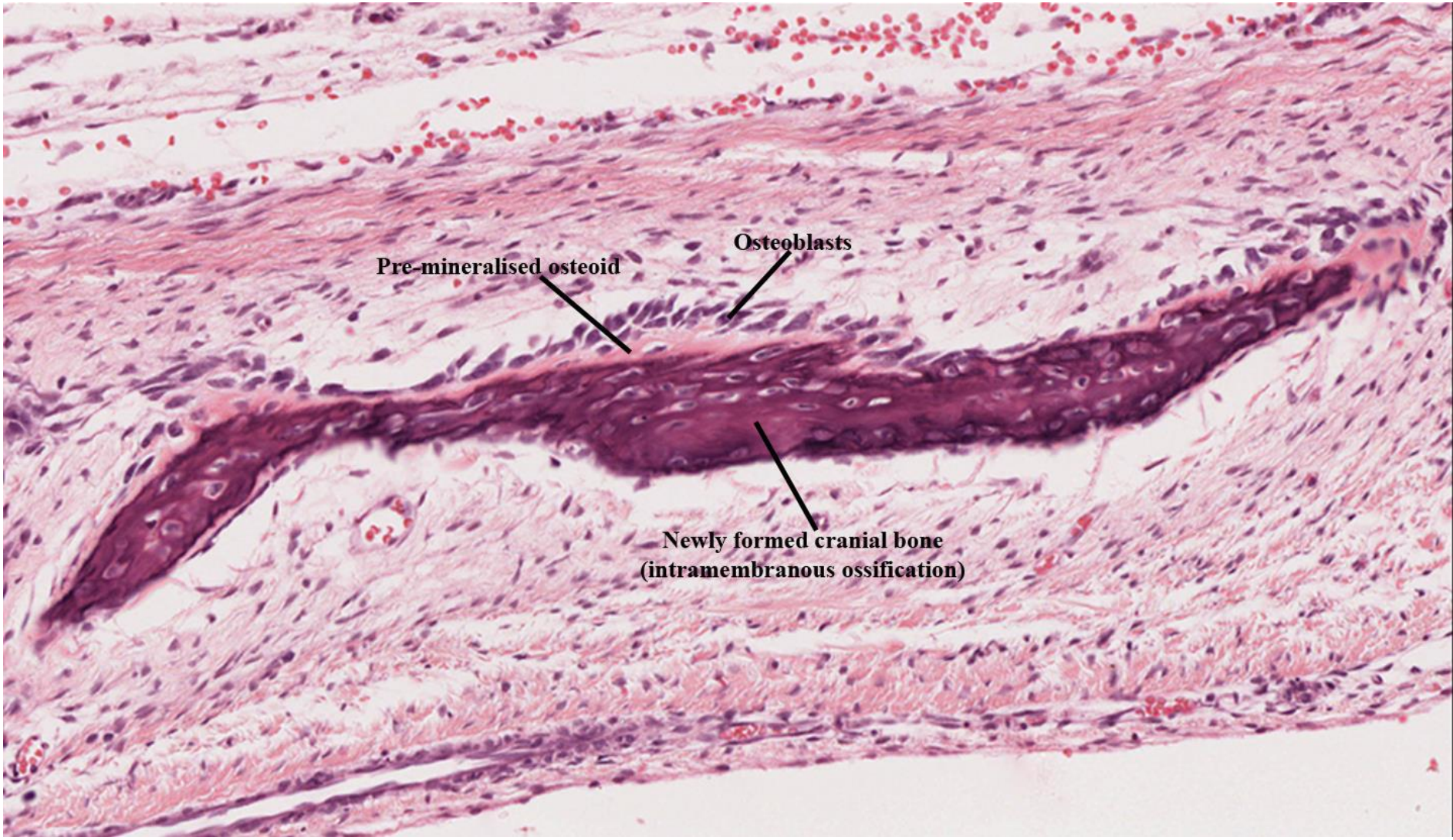


Endochondral

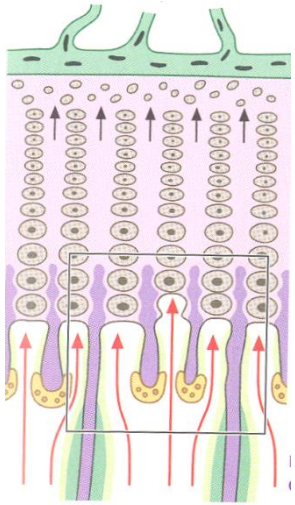


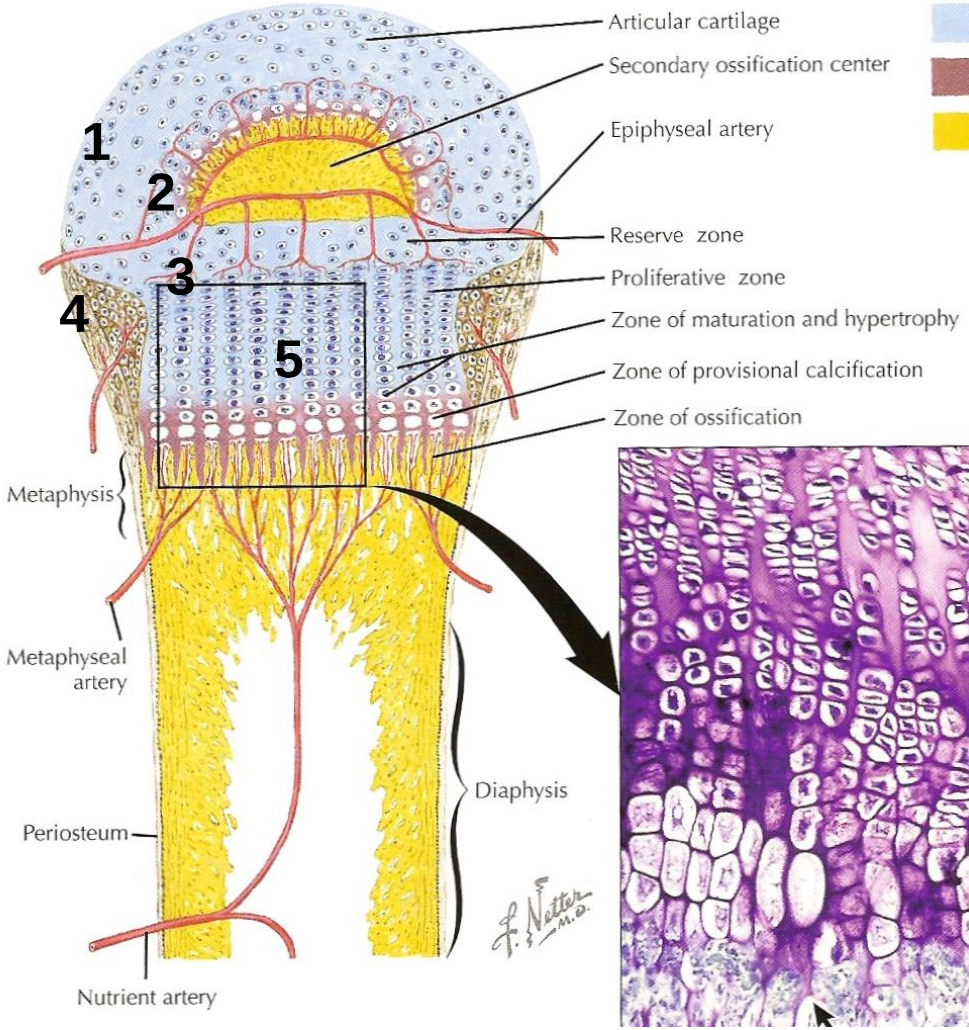


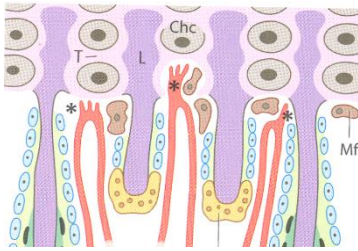
Intramembraneous ossification

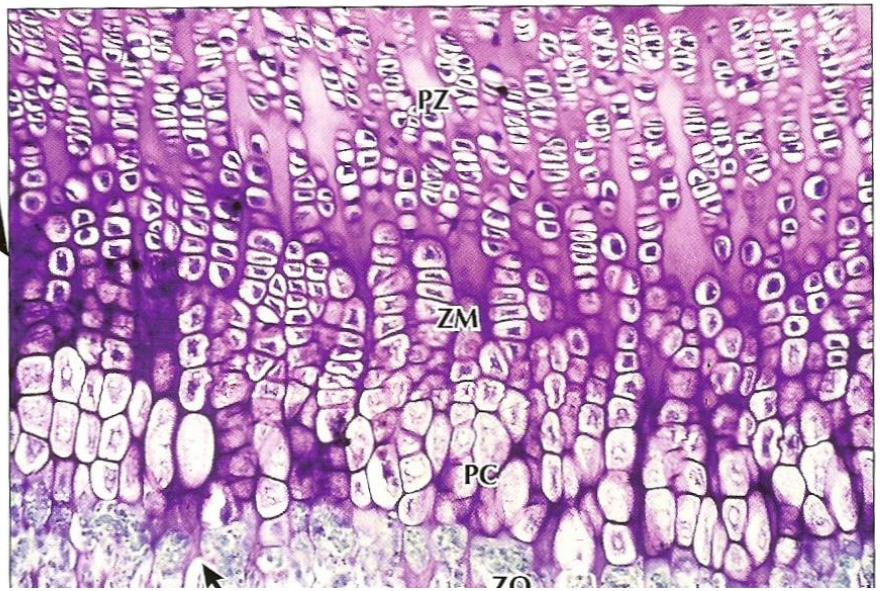


Endochondral ossification

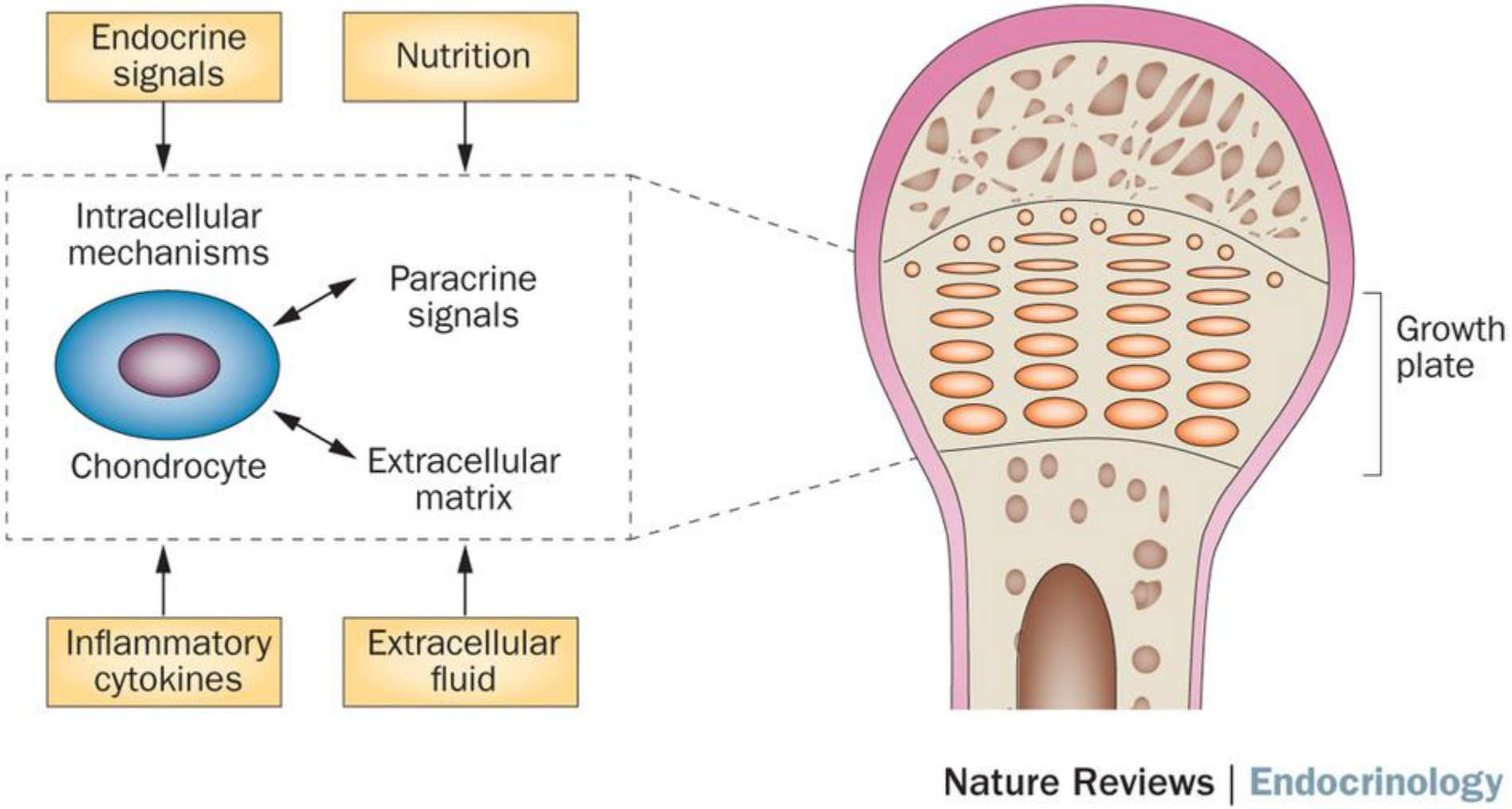




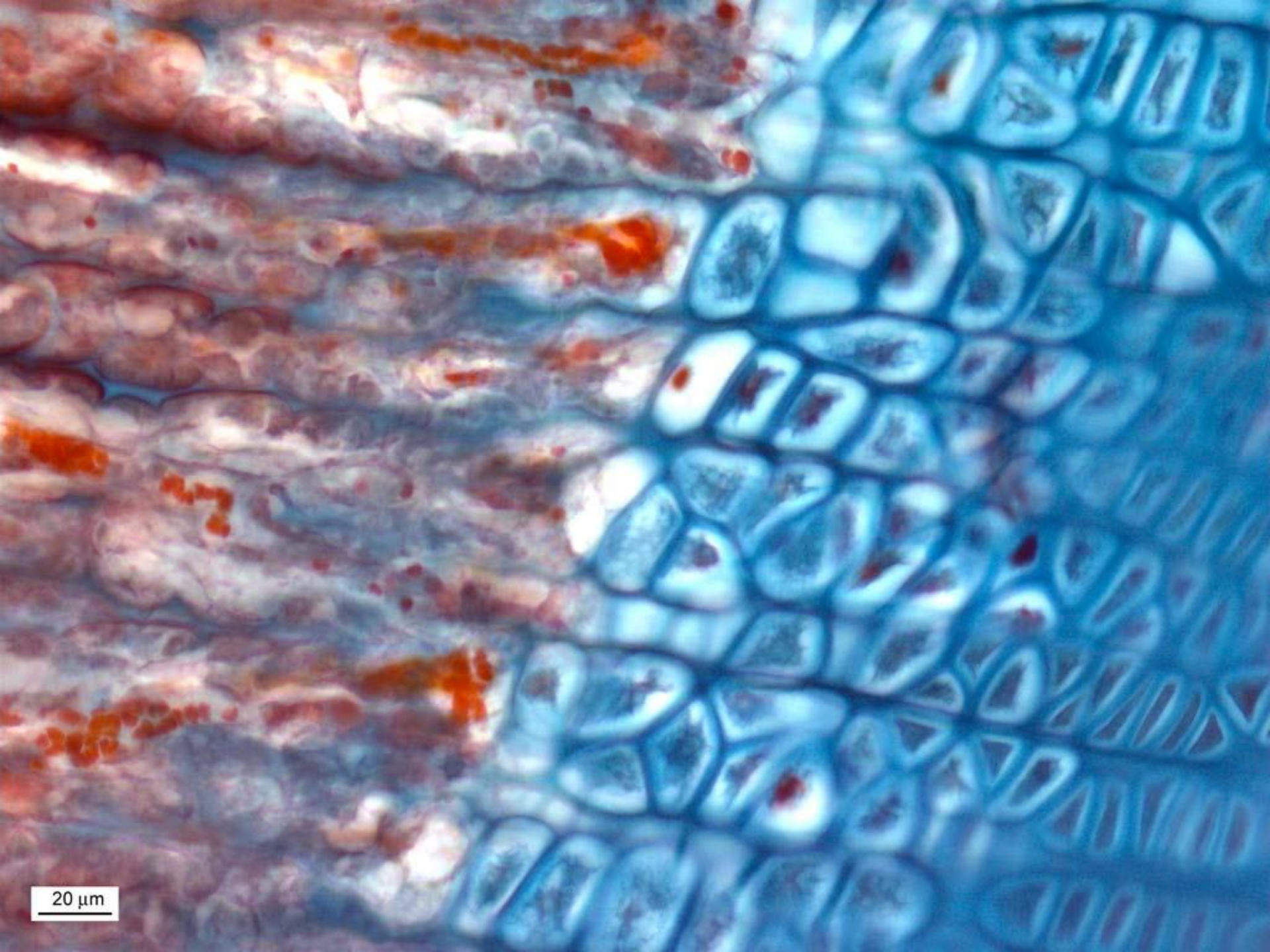




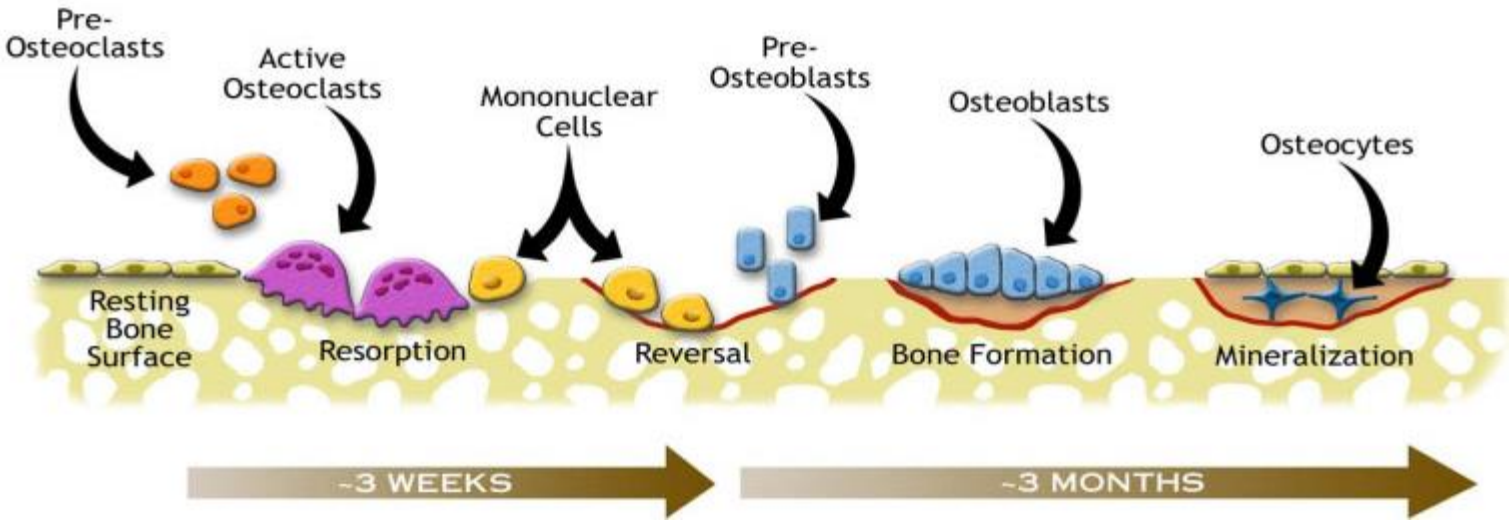
- **Endochondral ossification**

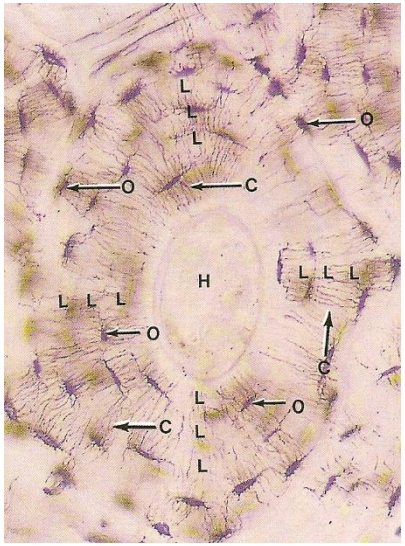



1
2
3
4
5

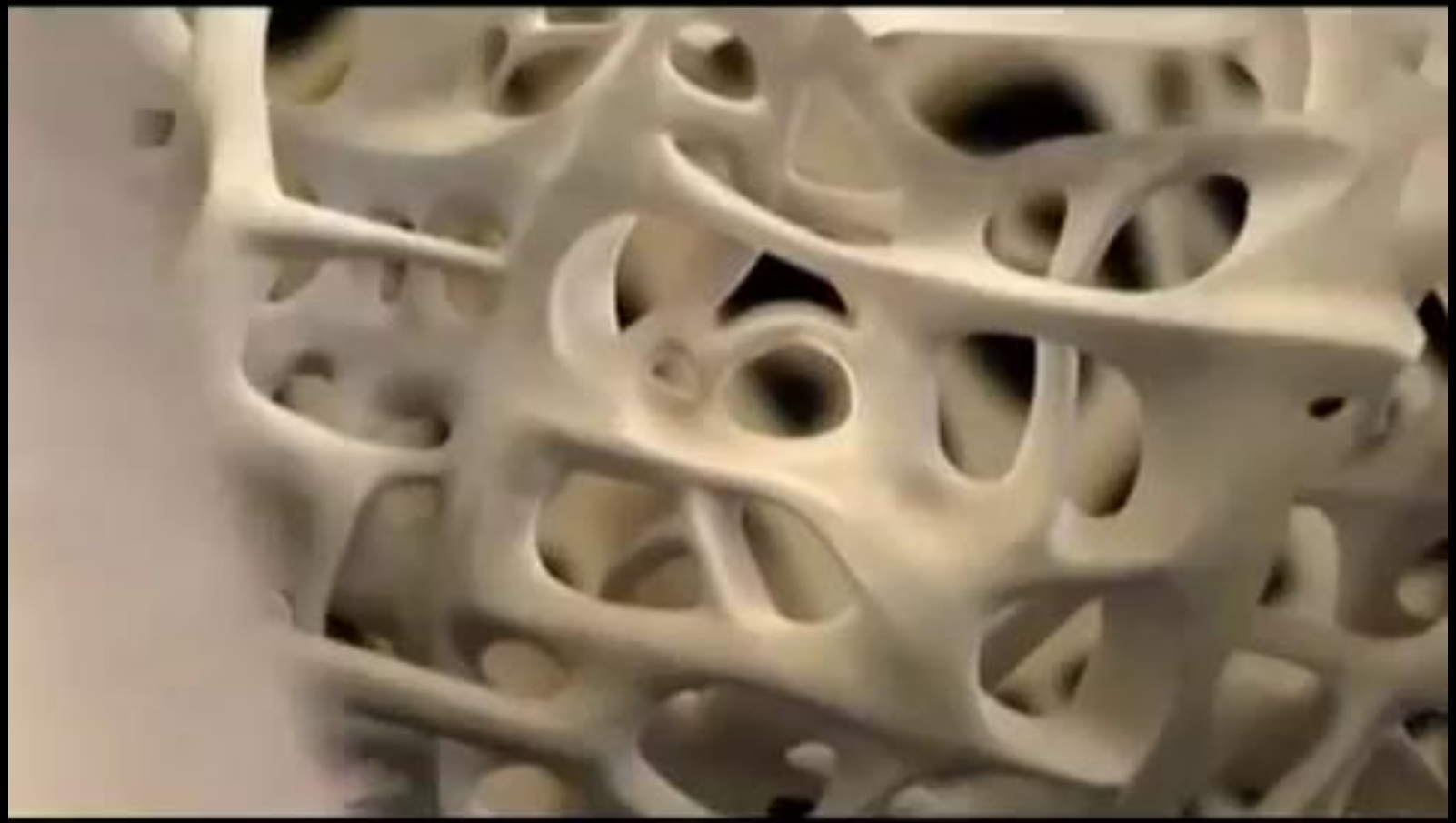

20 µm

Bone remodelling

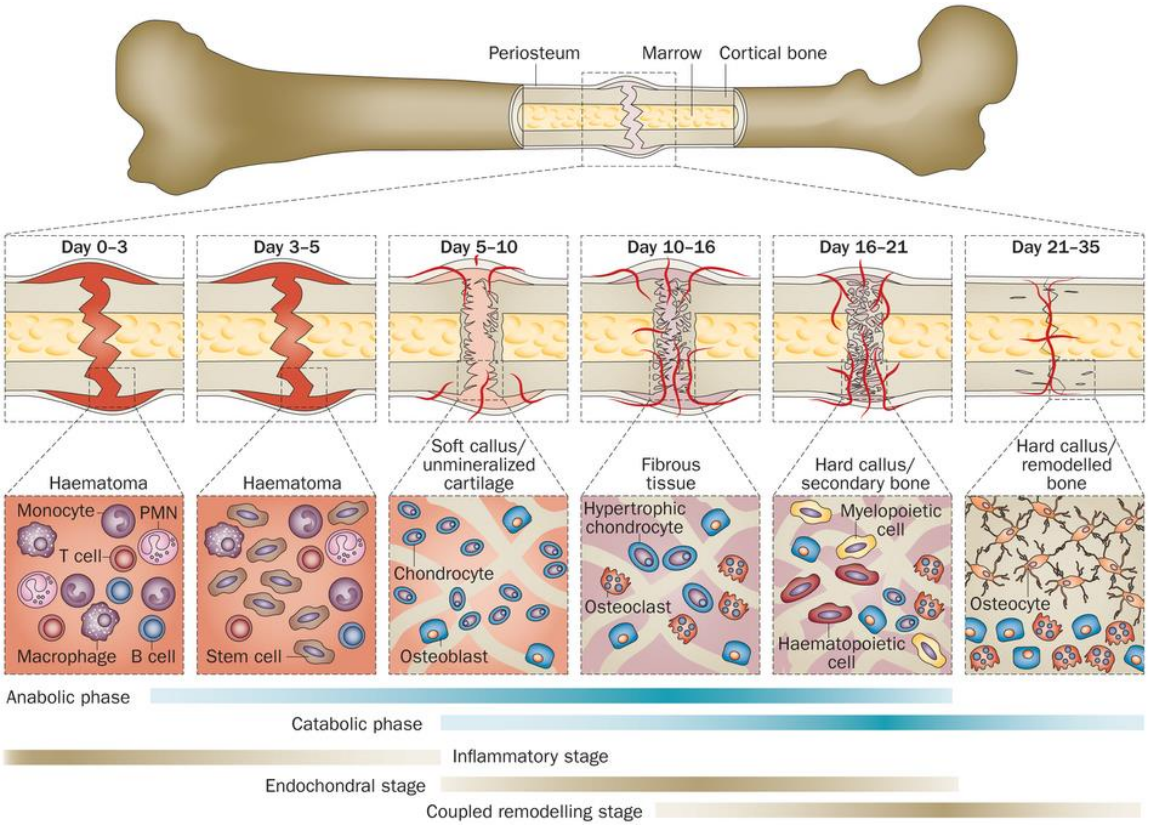




http://ns.umich.edu/Releases/2005/Feb05/img/bone.jpg



Clinical correlations - fracture healing



Reactive Phase

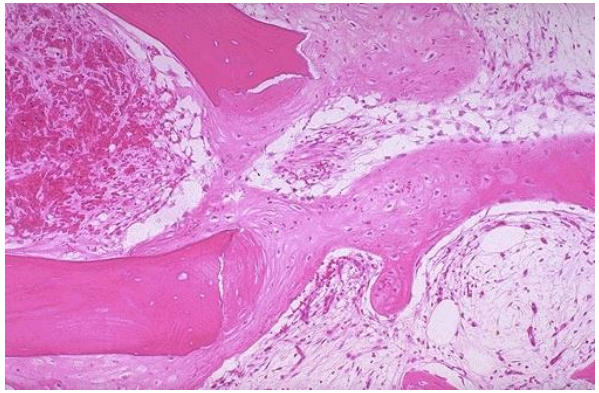
- fracture and inflammatory phase
- granulation tissue formation

Reparative Phase

- cartilage *callus* formation
- lamellar bone deposition

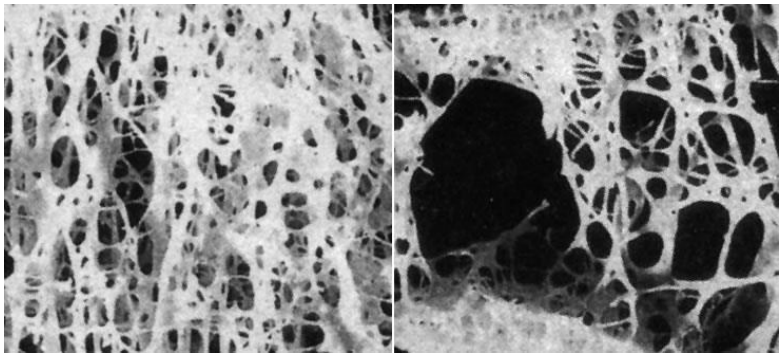
Remodeling Phase

- remodeling to original bone shape



Clinical correlations – disbalance in osteosynthesis and osteoresorption

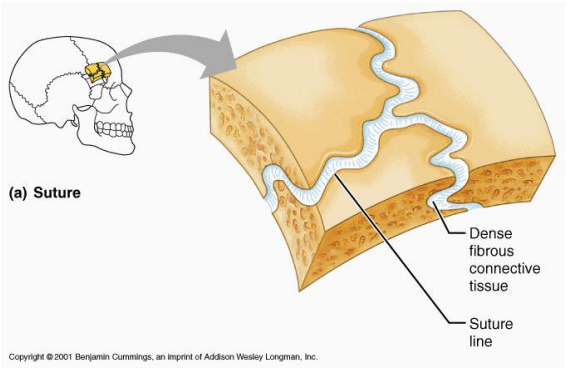
- **OSTEOPOROSIS**



- **OSTEOPETROSIS**

- **REVMATOID** ARTHRITIS

Skeletal joints

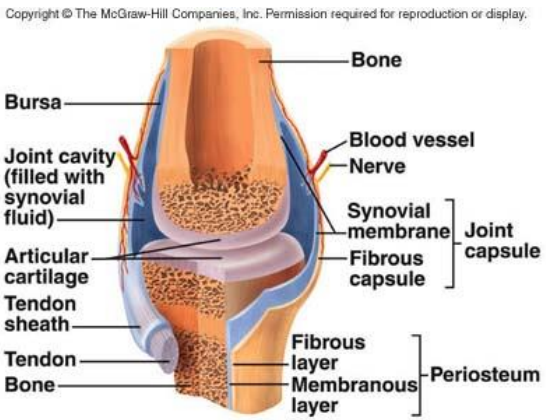


Synarthrosis

- joint by intercalated tissue (catilage, bone or c.t.)
  - **Synostoses** – joint by bone tissue – os coxae, os sacrum
  - **Synchondrosis** – joint by hyaline cartialge – development of synostosis
  - **Symphysis** – joint by fibrocartilage– os pubis, intervertebral discs
  - **Syndesmosis** – dense collage regular c.t. – sutures of skull, gomphosis

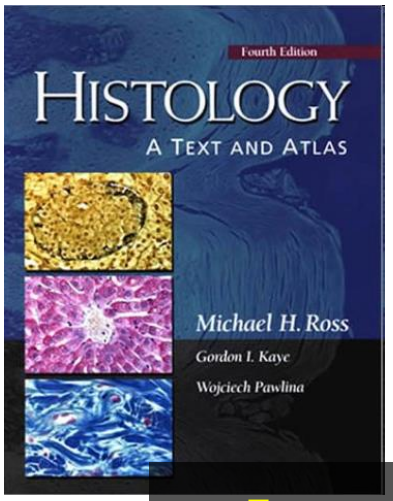
Diarthrosis

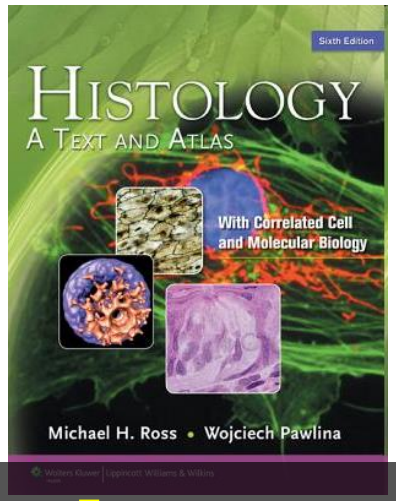
- synovial joint
  - hyaline cartilage without perichondrium
  - cartialge calcification in site of attachment to the bone
  - joint capsule
    - *Stratum fibrosum*
    - *Stratum synoviale*

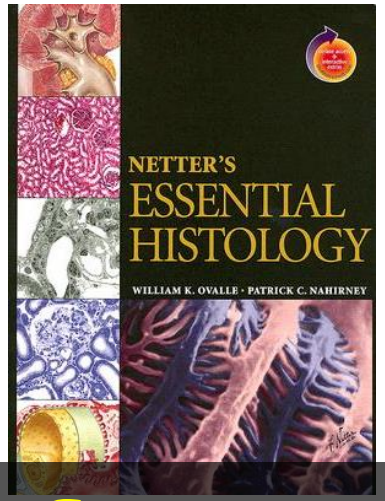


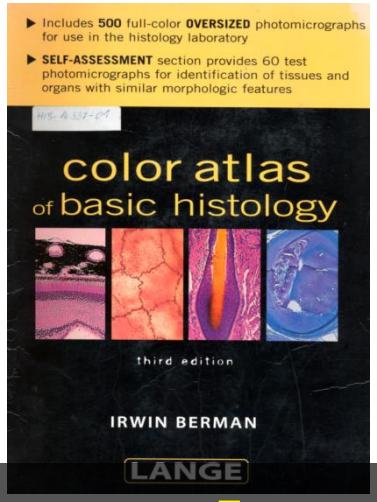
  - Meniscus – fibrocartialge, avascular, without inervation
  - tendons – dense collagen regular c.t., elastic fibers
  - bursae – like joint capsule

Further study

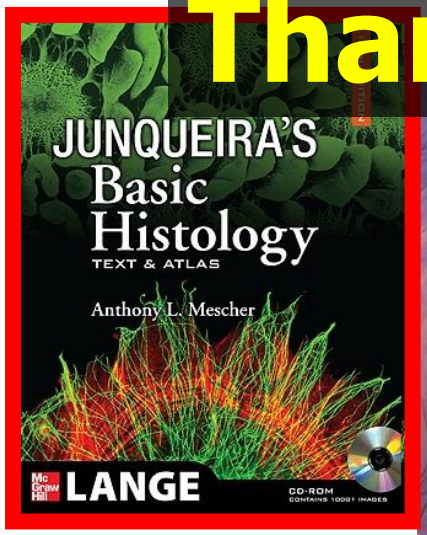


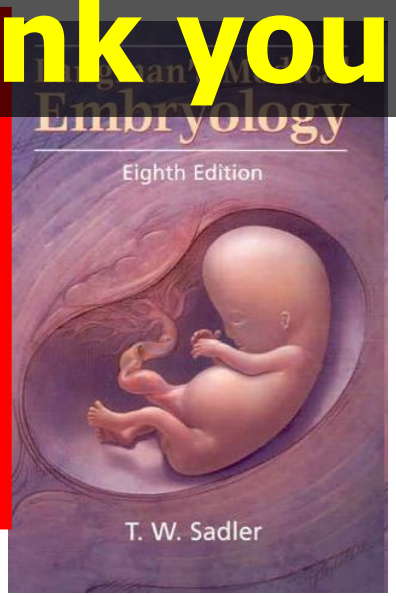


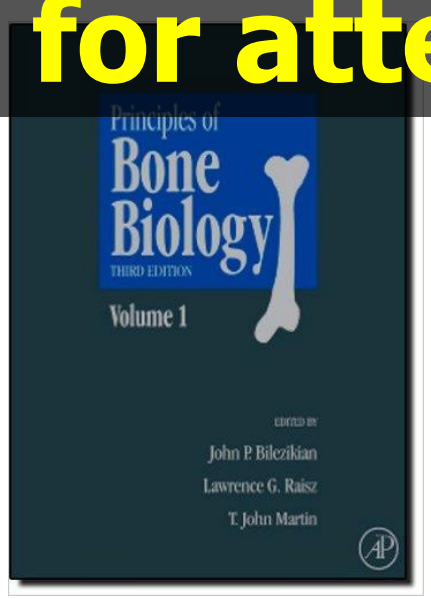


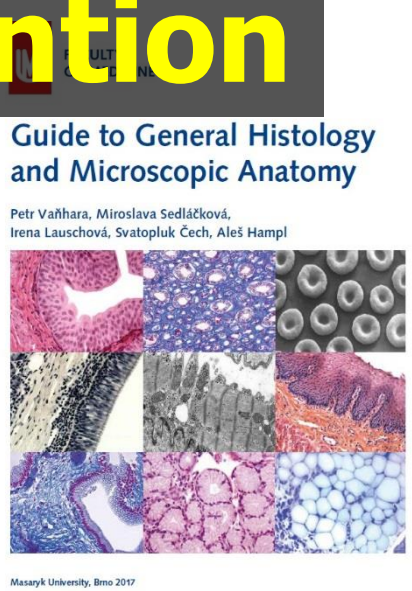


Thank you for attention









http://www.histology.med.muni.cz/