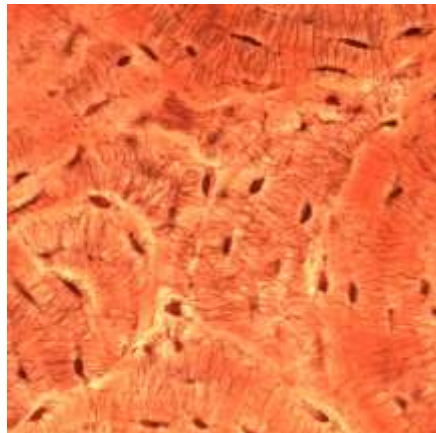
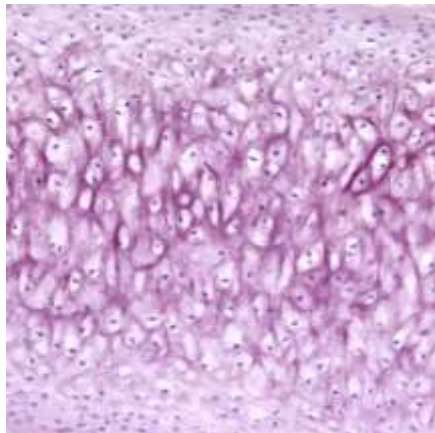
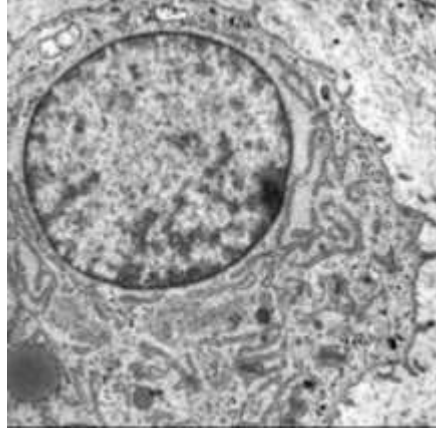
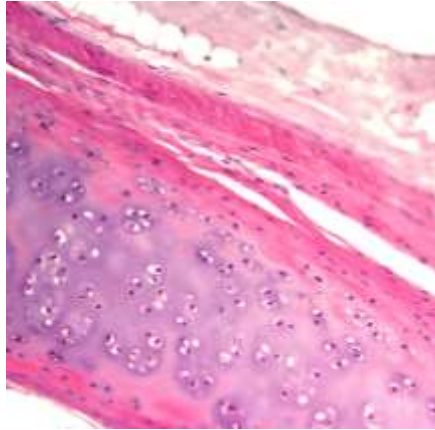


6. CARTILAGE AND BONE



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A histological micrograph of cartilage tissue. The image shows a dense population of chondrocytes, which are small, rounded cells with dark nuclei, embedded within a light pink, amorphous extracellular matrix. The tissue is stained with hematoxylin and eosin (H&E). In the upper portion of the image, there is a layer of more organized tissue, possibly representing the perichondrium or a layer of connective tissue. A scale bar in the bottom right corner indicates 20 micrometers.

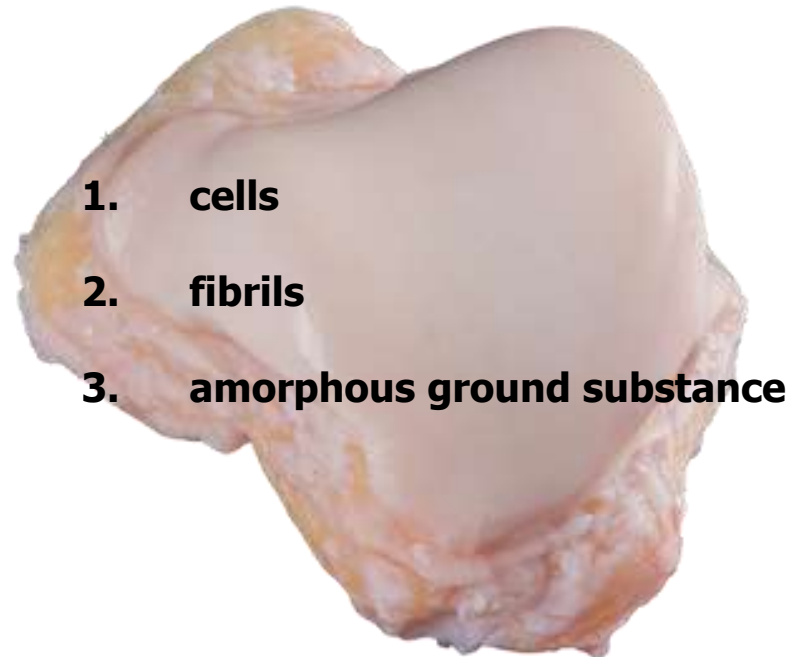
■ CARTILAGE

20 μ m

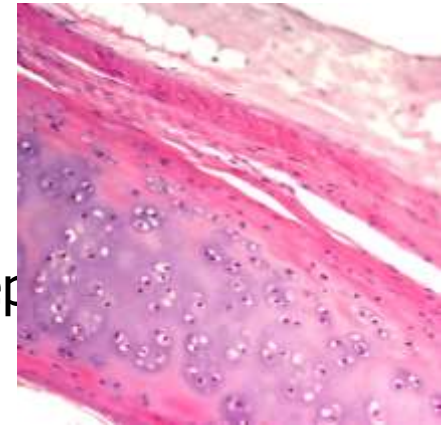
■ Cartilage

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



■ Composition and structure



- Perichondrium – connective tissue around cartilage (except

Nutrition
Growth

- Extracellular matrix – water, proteoglycans and collagen fibrils

Solid consistence
Pressure elasticity

- Cells of cartilage - chondroblasts, chondrocytes

Growth
ECM production

■ Distribution

cartilage in adults

Hyaline

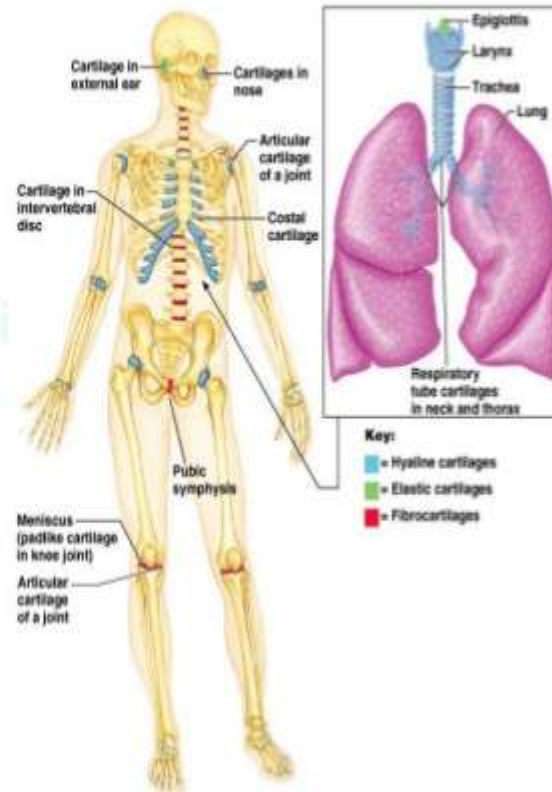
- Nose
- Joint surfaces
- Costal
- Larynx - voice box
- rings of trachea & bronch

Elastic

- External ear
- Epiglottis
- Eustachian tube

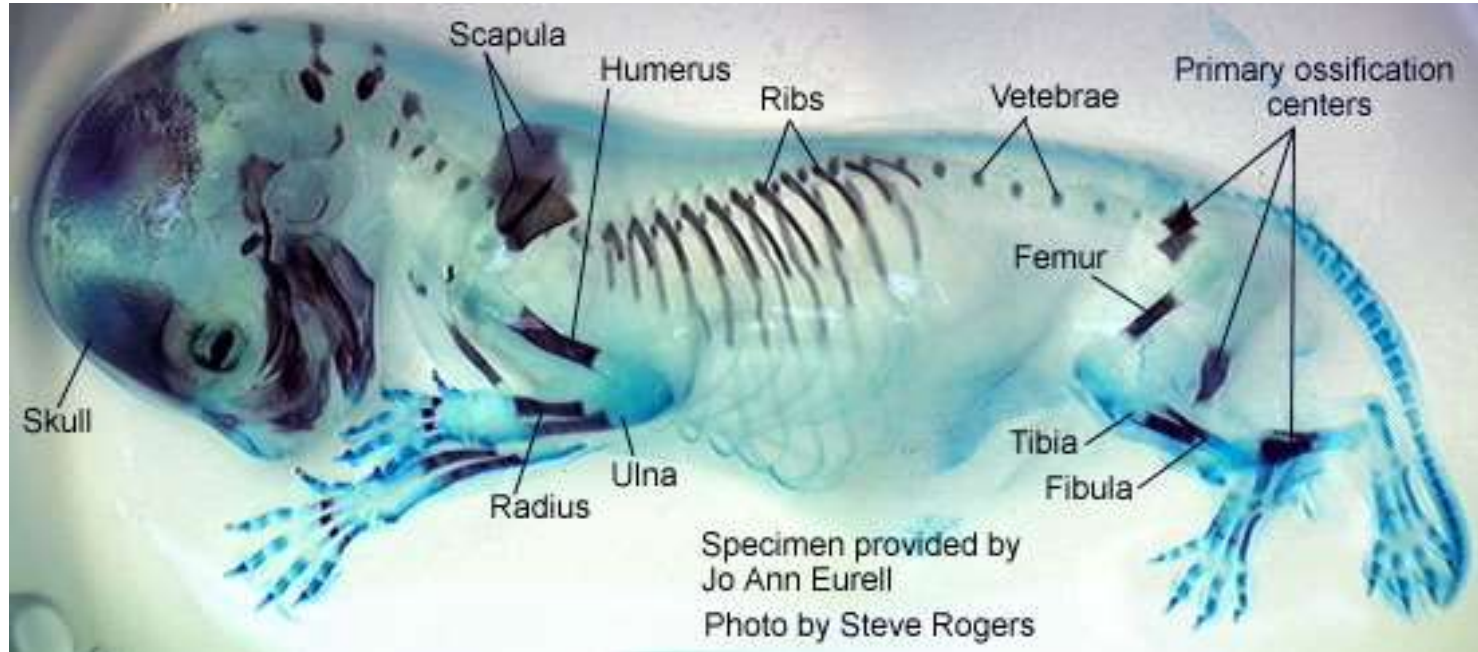
Fibrous

- IVDs
- Pubic symphysis
- meniscus in knee joint



■ Distribution

Hyaline



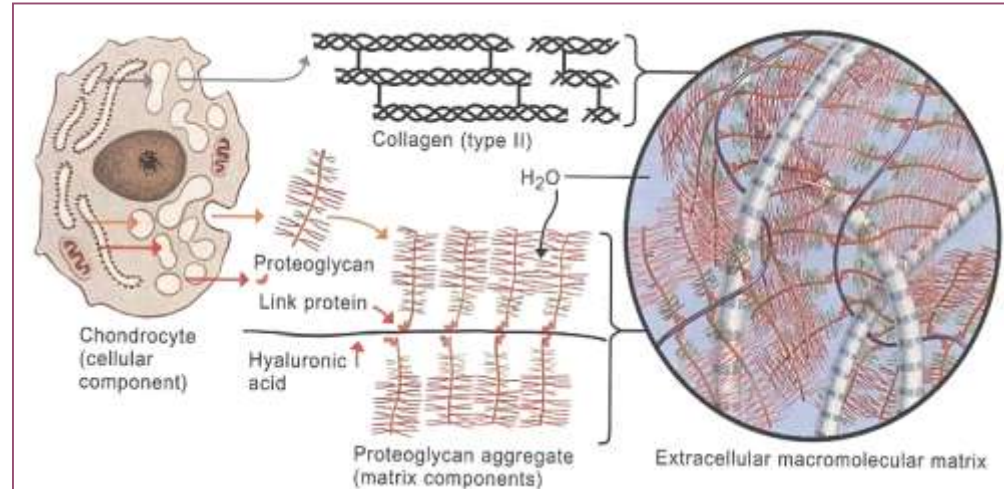
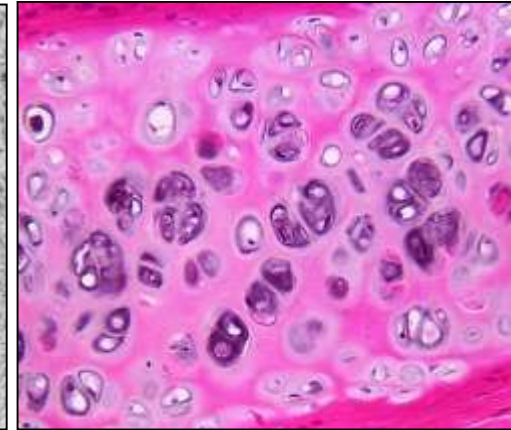
Alcian Blue&Alizarin Red

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

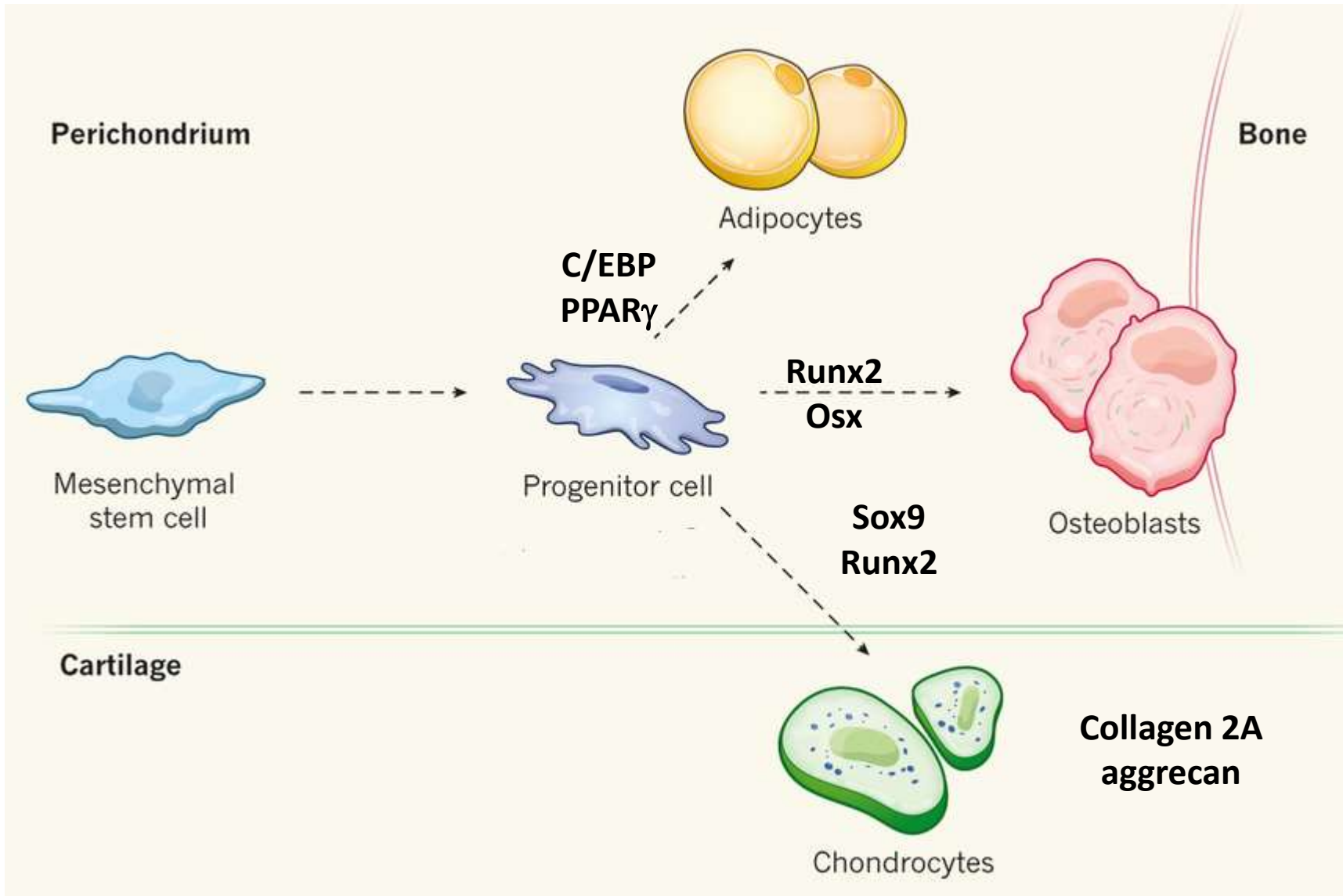
■ Cells of cartilage

■ Chondroblasts and chondrocytes

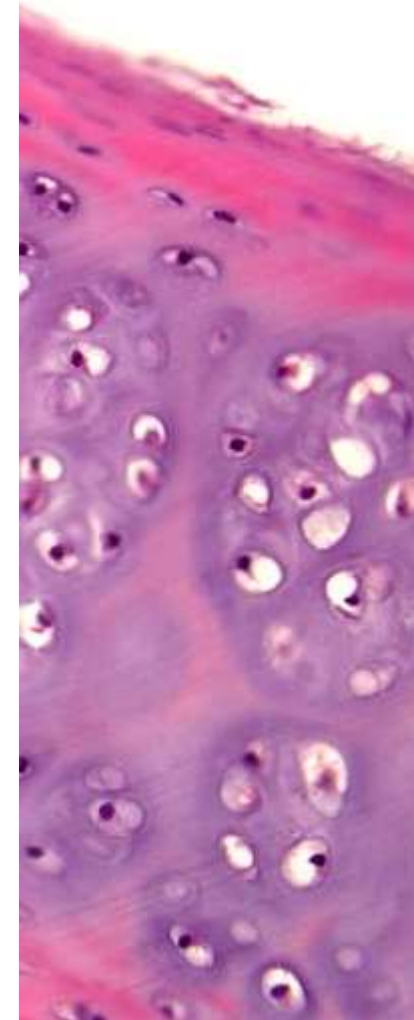
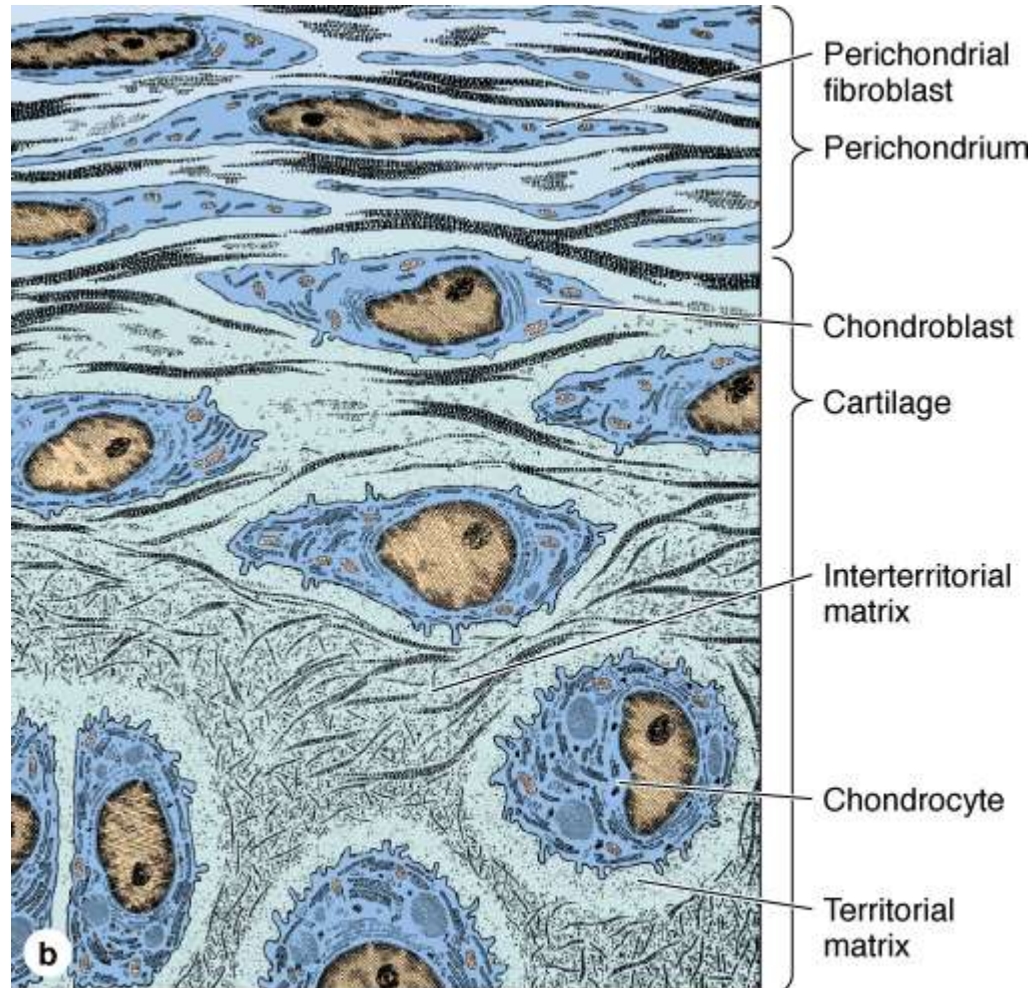
- mesenchymal origin
- typical ultrastructure of proteosynthetically active cells
- production of extracellular matrix
- interstitial proliferation
- isogenetic groups, lacunae



■ Origin of chondrocytes



■ Origin of chondrocytes

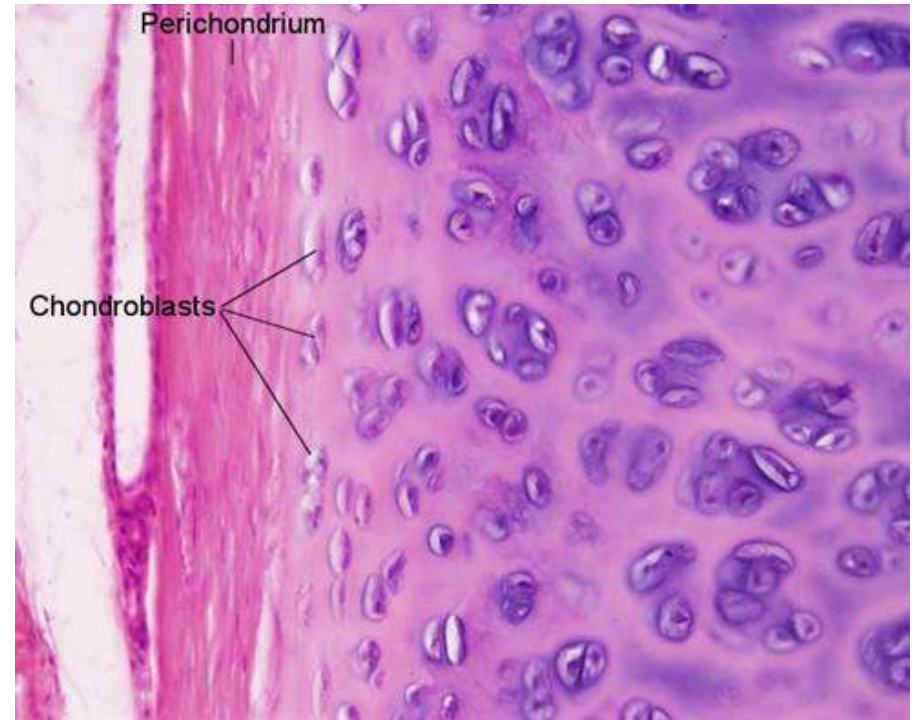


Source: Mescher AL: *Junqueira's Basic Histology: Text and Atlas, 12th Edition*: <http://www.accessmedicine.com>

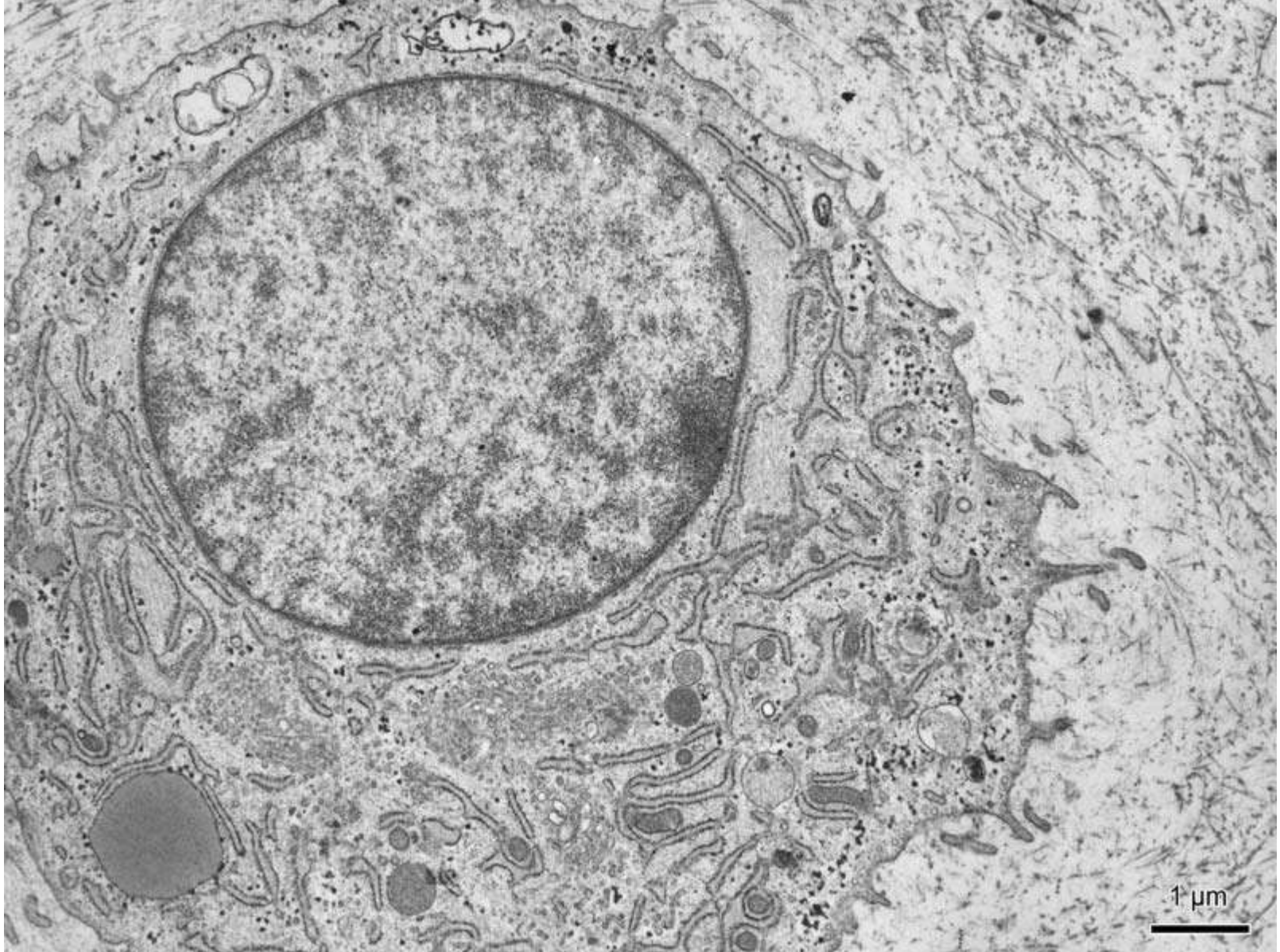
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■ Ultrastructure of chondrocytes

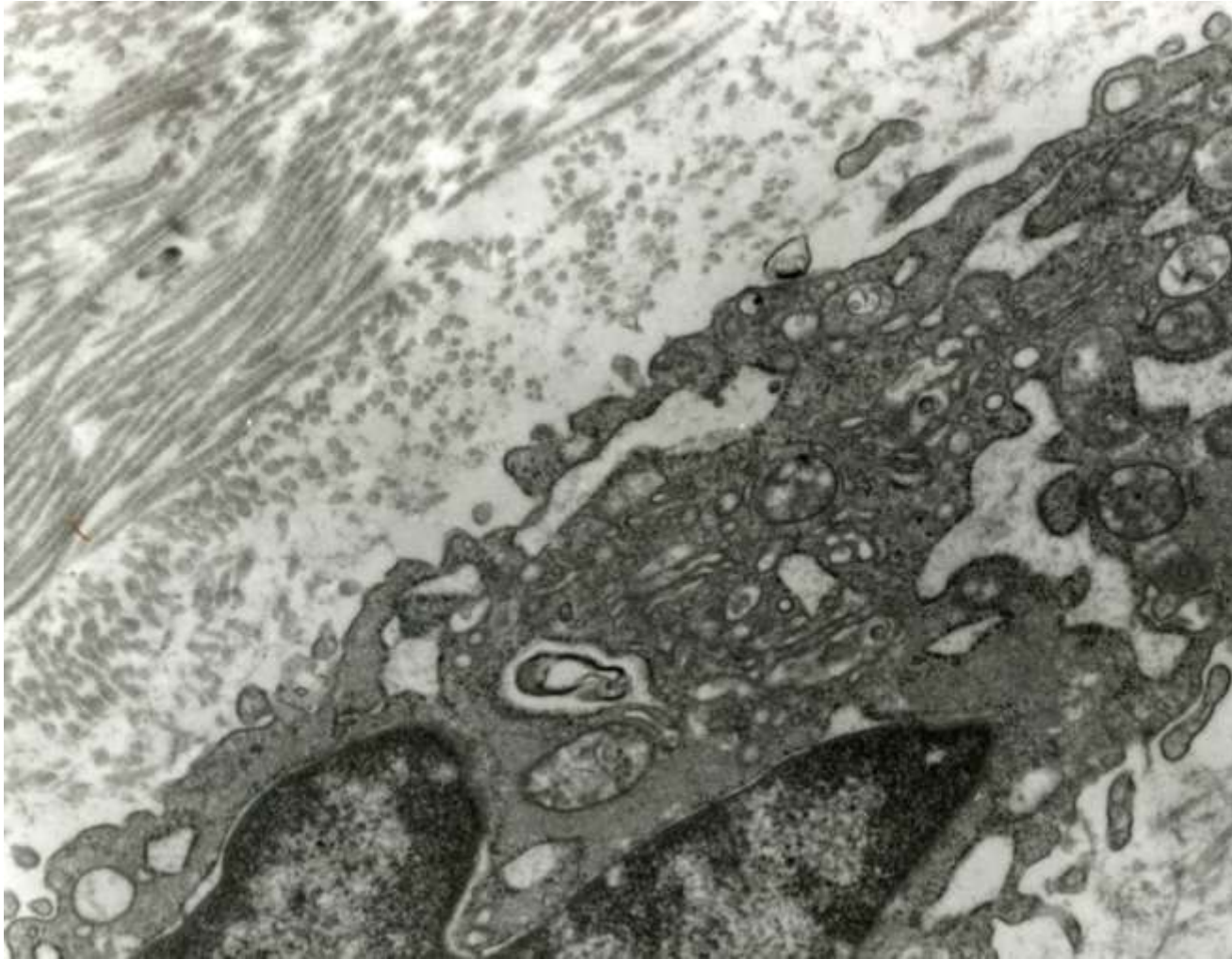
- oval → round cells
- rich in organelles, especially rER and GA
- glycogen granules (anaerobic metabolism)
- occasionally lipid droplets



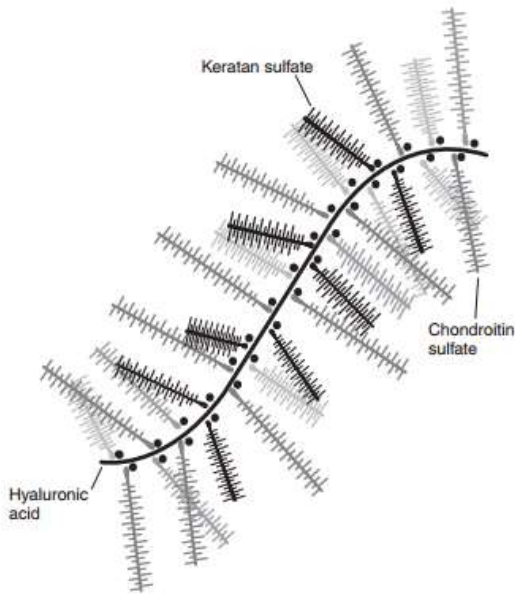
- Ultrastructure of chondrocytes



- Ultrastructure of chondrocytes



■ Extracelulární matrix



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

biomechanical properties

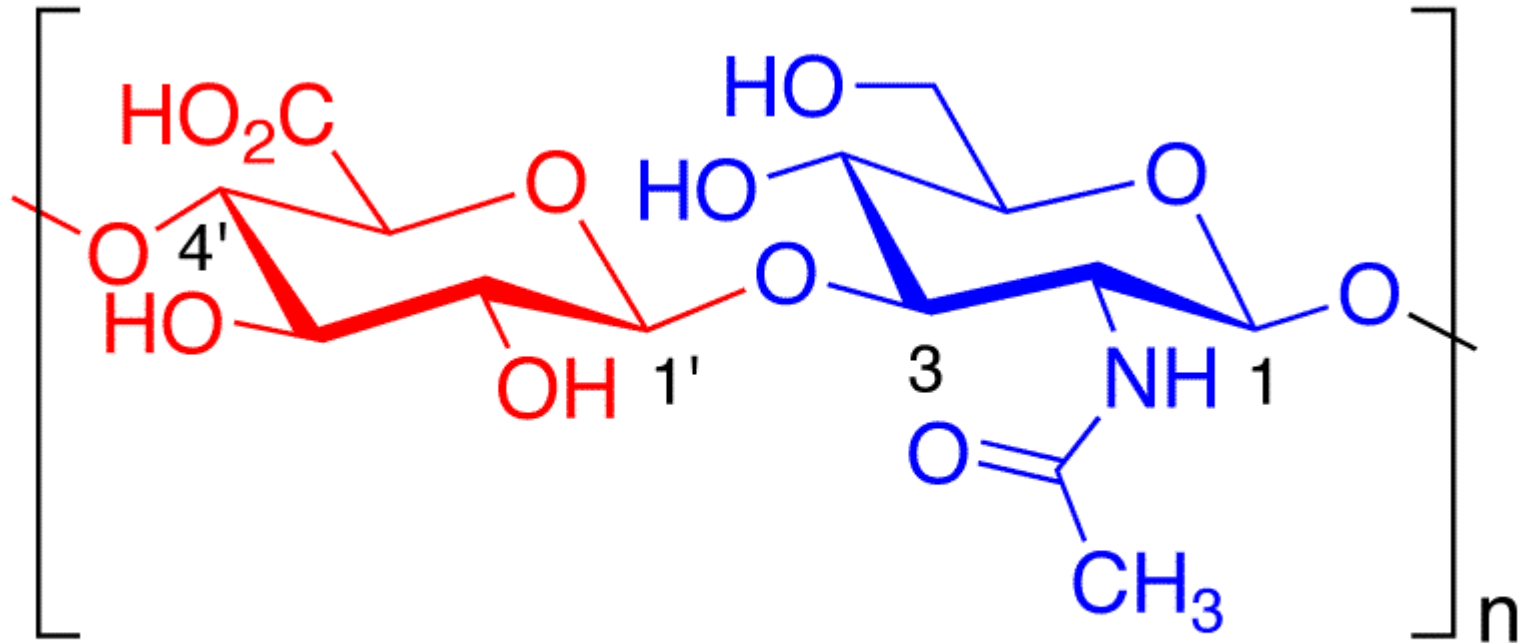
Glycosaminoglycans

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

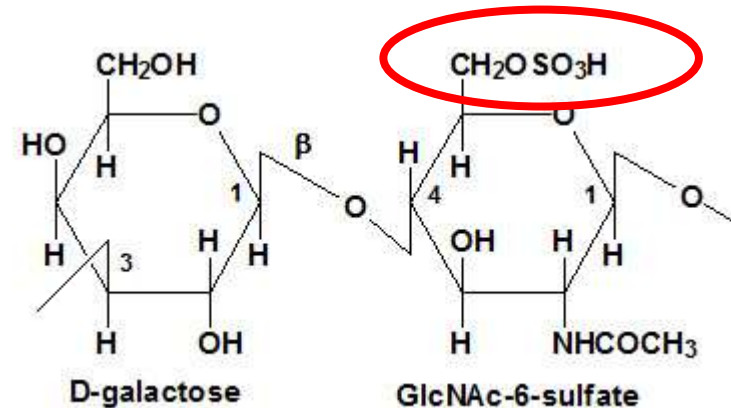
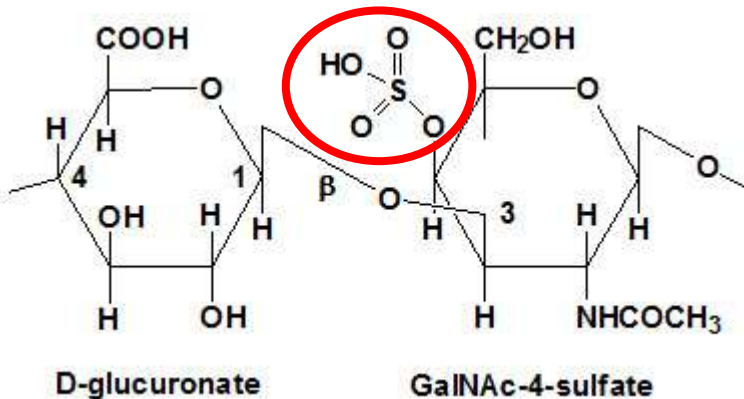
Skin, ligaments, adventitia of aorta

Heparansulphate

Aorta, lungs, liver, basal membranes

Keratansulphate

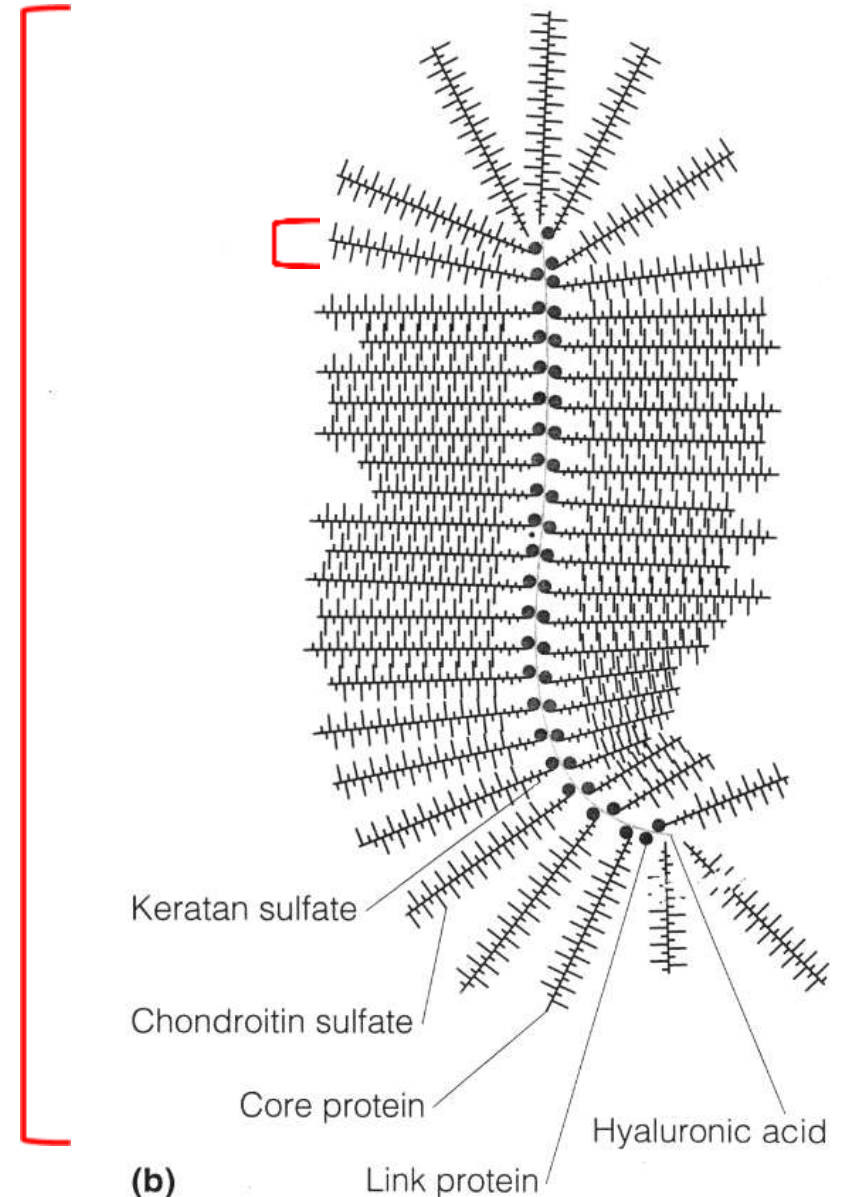
Iris, cartilage, nucleus pulposus, anulus fibrosus



Proteoglycans

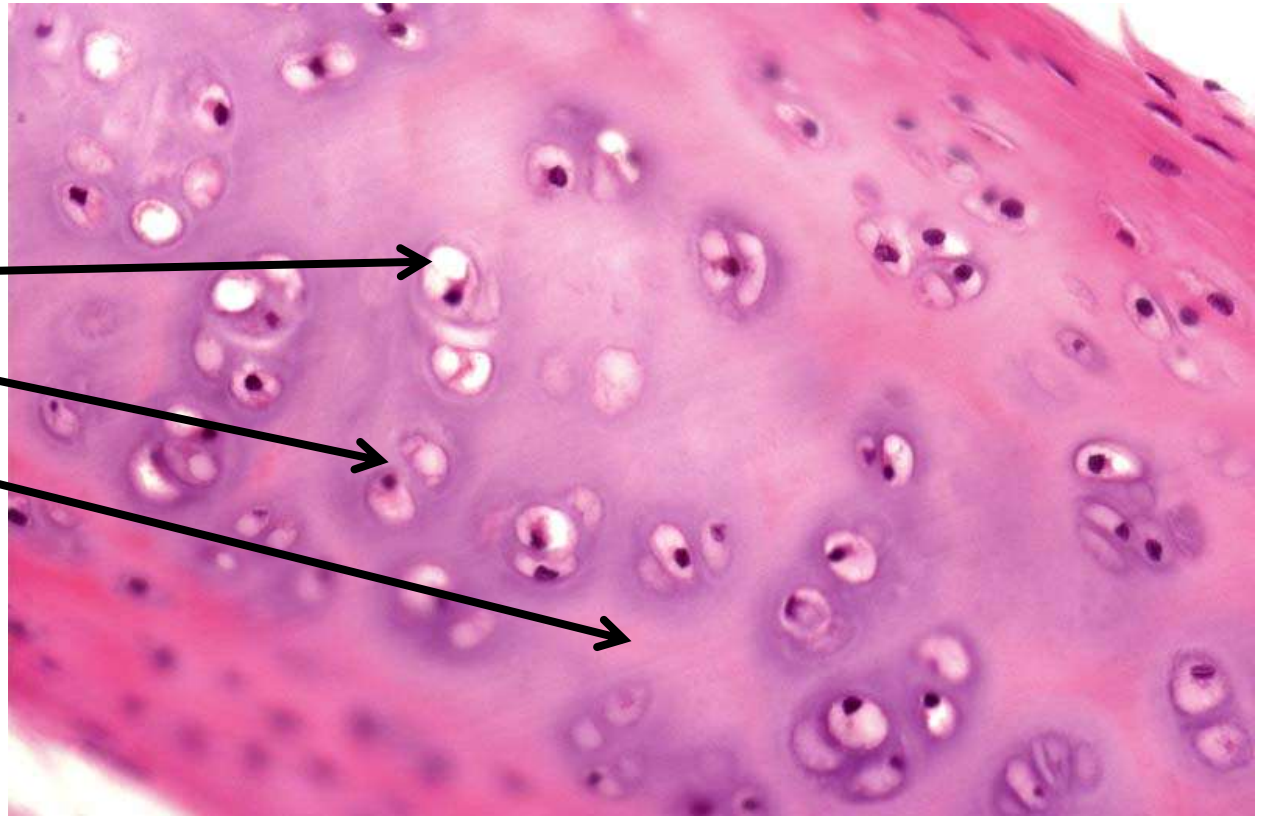
- protein + dominant linear saccharide component
- proteoglycan aggregates
- water-binding, volume dependent of hydration
- **aggrecan (cartilage)**
- syndekan
- fibroglykan

Figure 9.25b Proteoglycan structure in bovine cartilage



■ Architecture of extracellular matrix

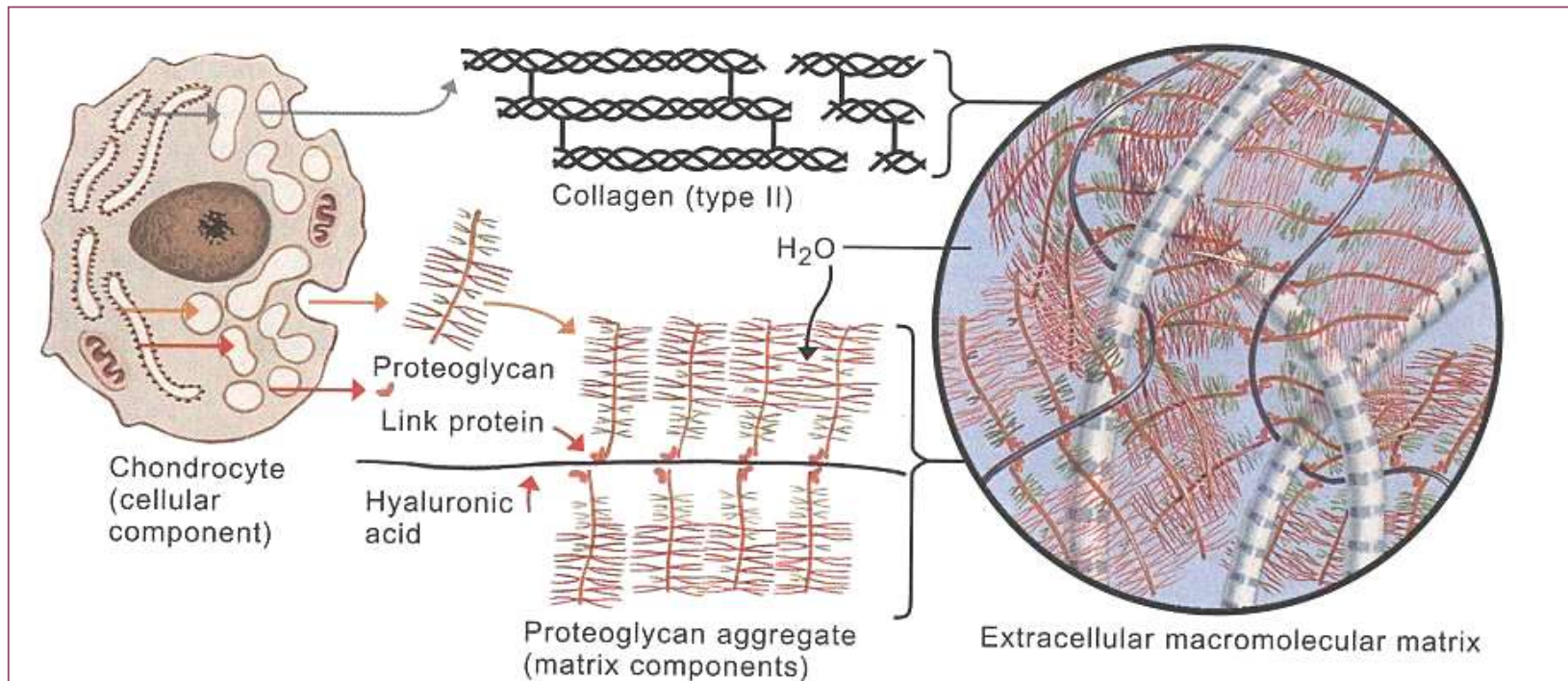
- pericellular
- territorial
- interterritorial



transduction of biochemical and biomechanical signals

■ Extracellular matrix

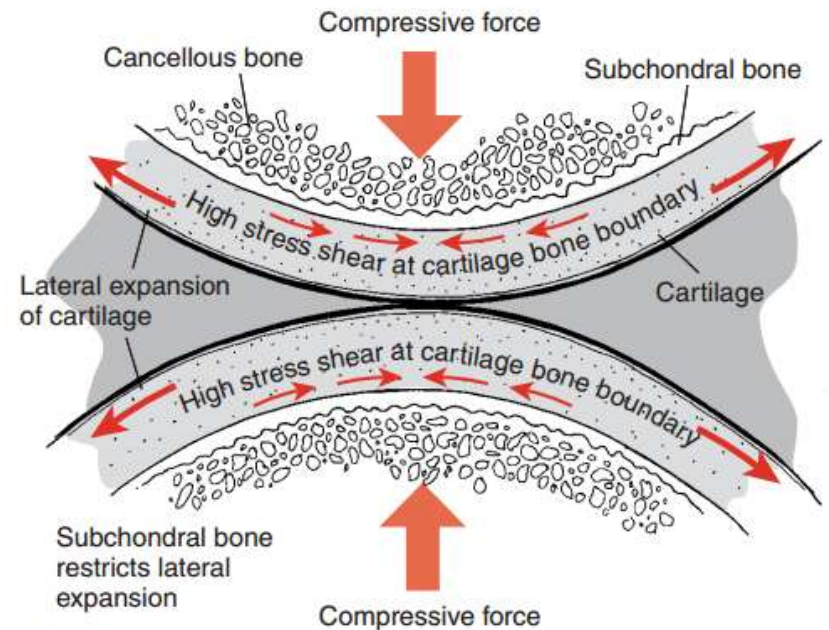
- **collagen fibrils**
 - col II + col IX/XI
 - thin fibrils (15-20 nm → no striation) do not form fibers
 - interconnected with perichondrium
- **proteoglycans and glycosaminoglycans**
 - aggrecan hyaluronan-based aggregates
- **water**
 - 80%



■ Architecture of extracellular matrix

- **pressure elasticity**

- proteoglycans – polyanionic (COO^- , $\text{SO}_4^{\text{II}-}$)
- 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 starts 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

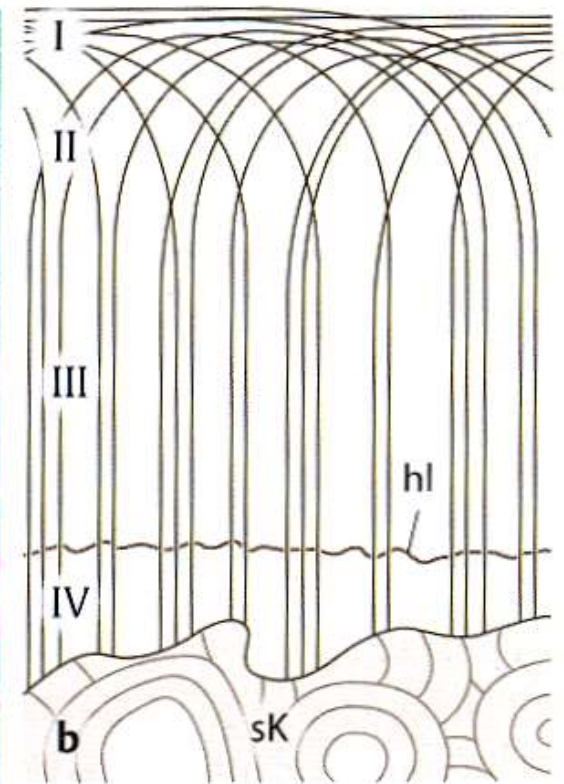
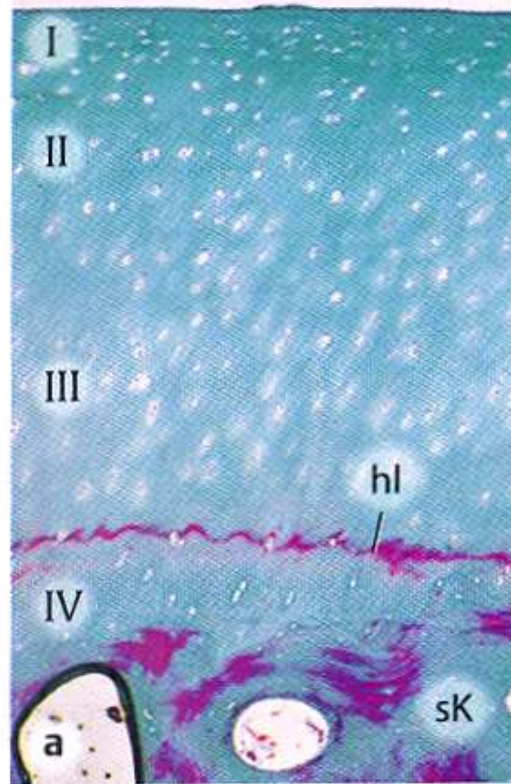
II. transitional zone

III. radial (deep) zone

tide mark

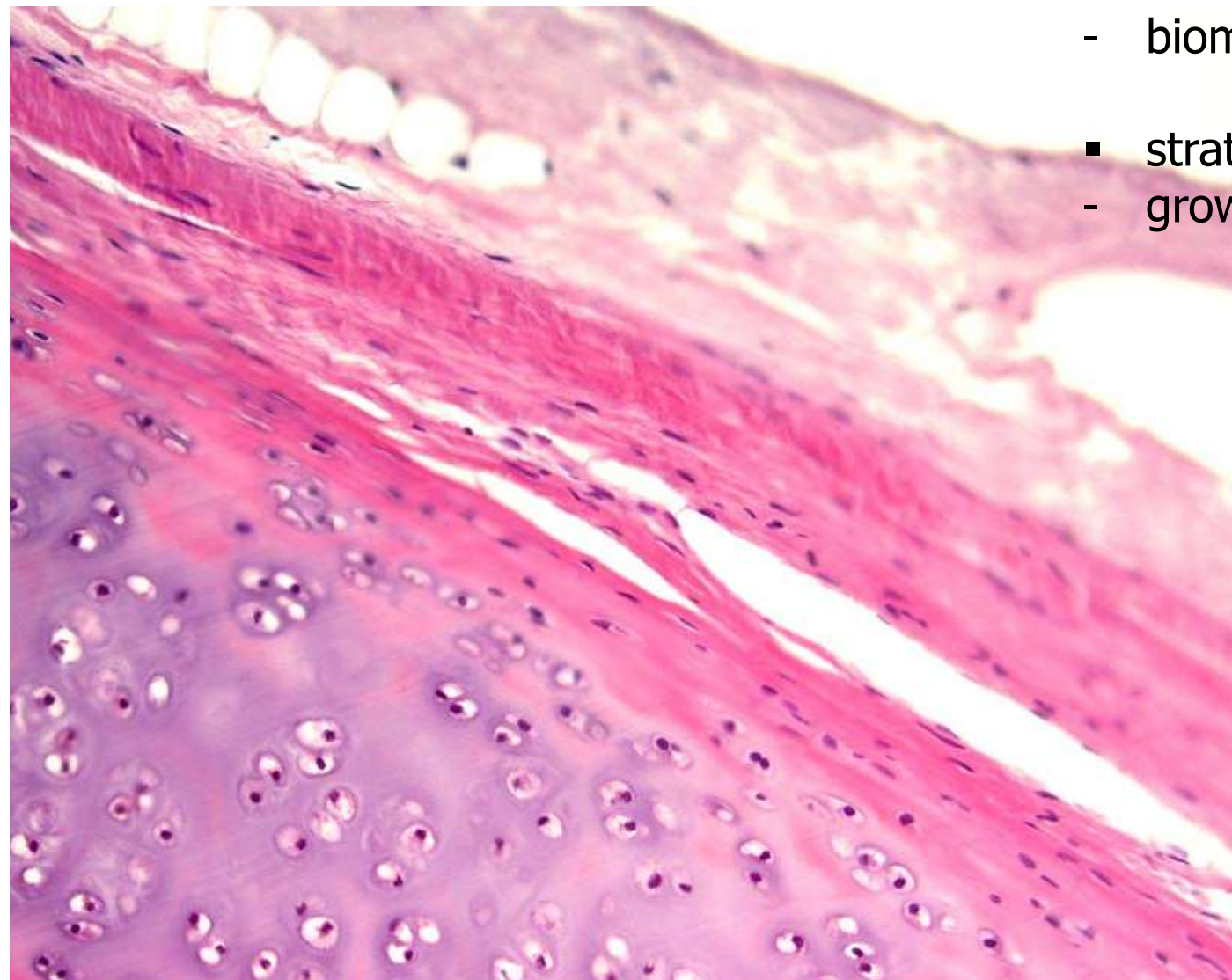
I. mineralized cartilage zone

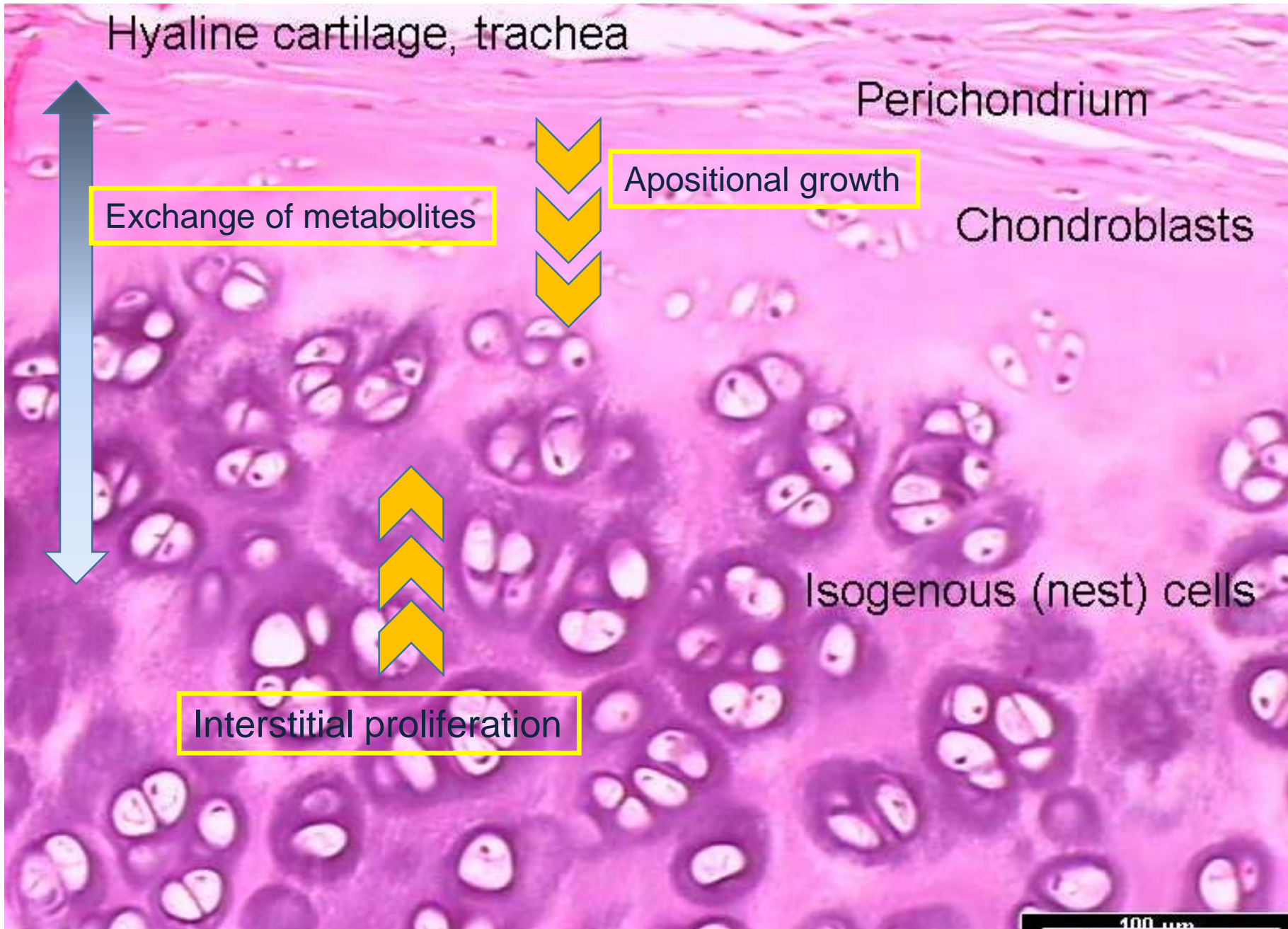
subchondral bone



■ Perichondrium

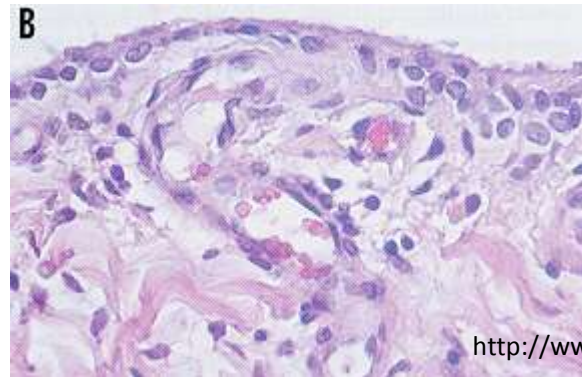
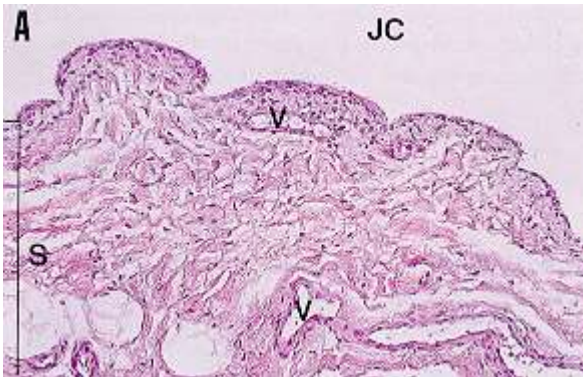
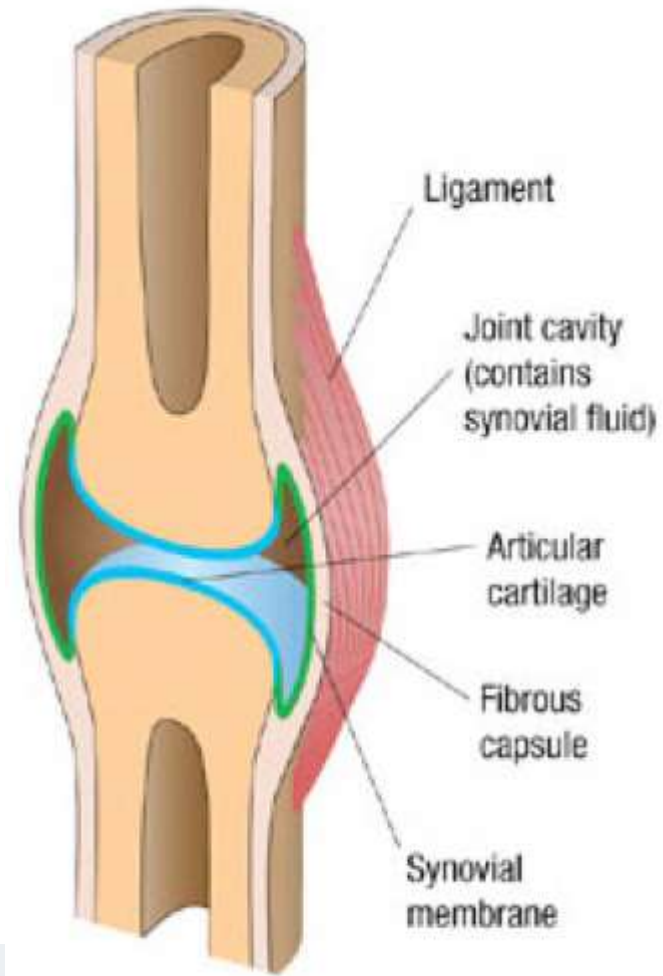
- stratum fibrosum
 - biomechanics
- stratum chondrogenicum
 - growth





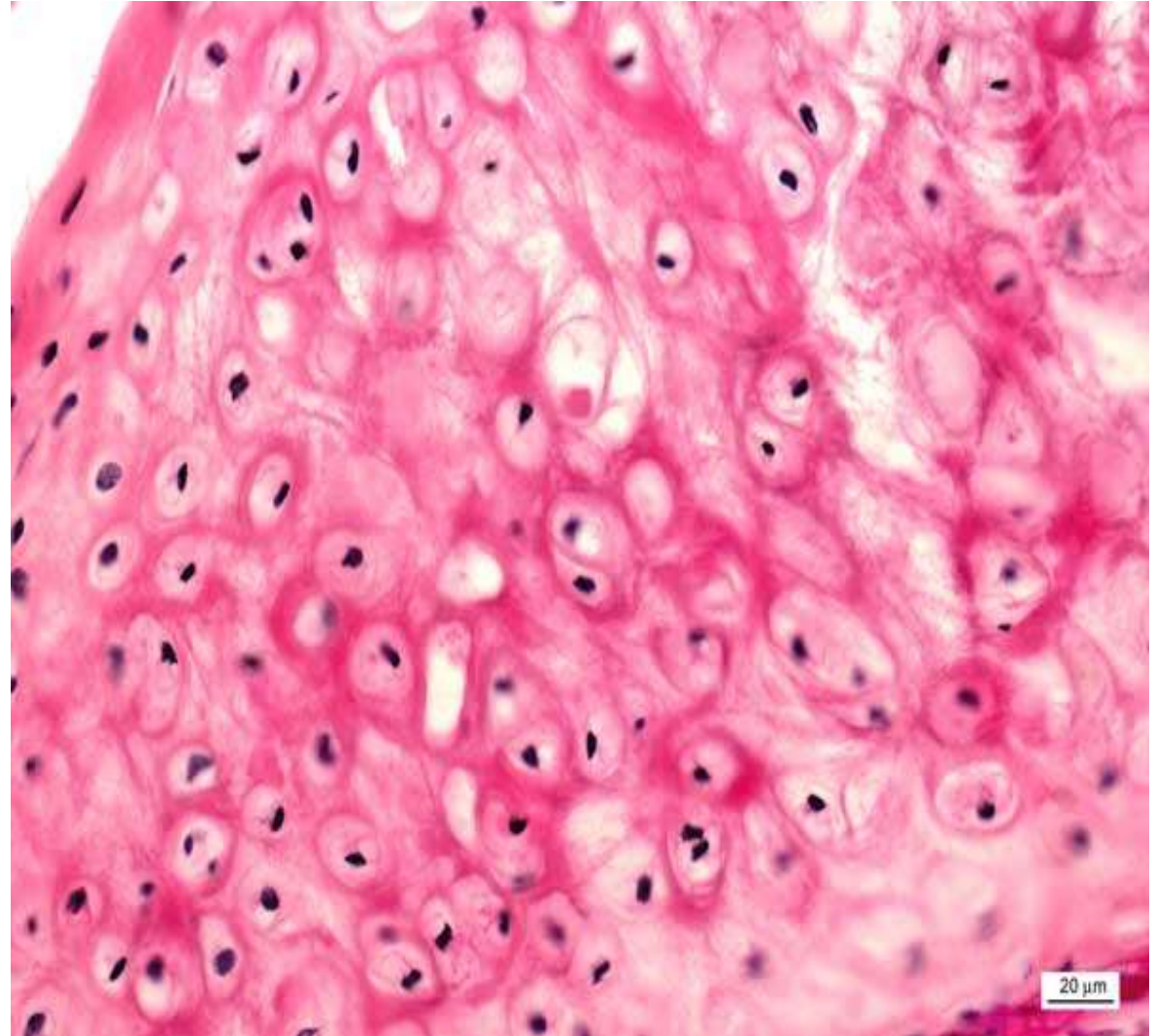
■ Synovium

- *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*



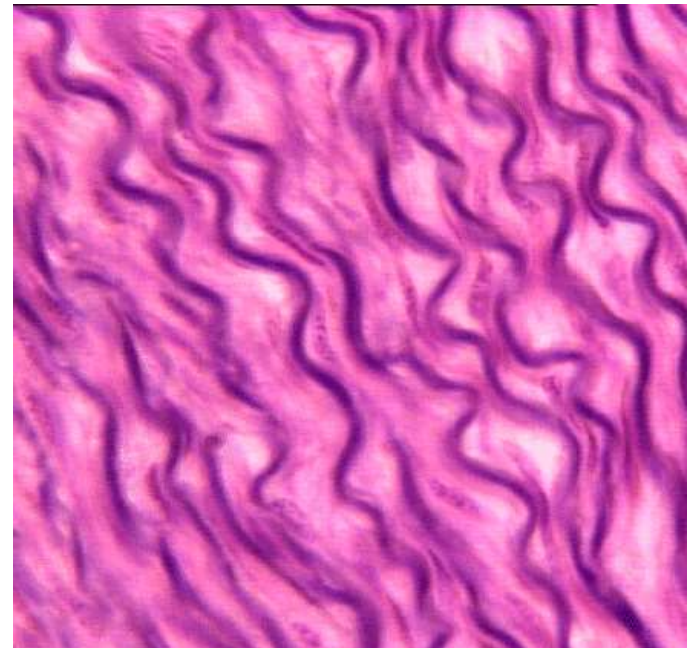
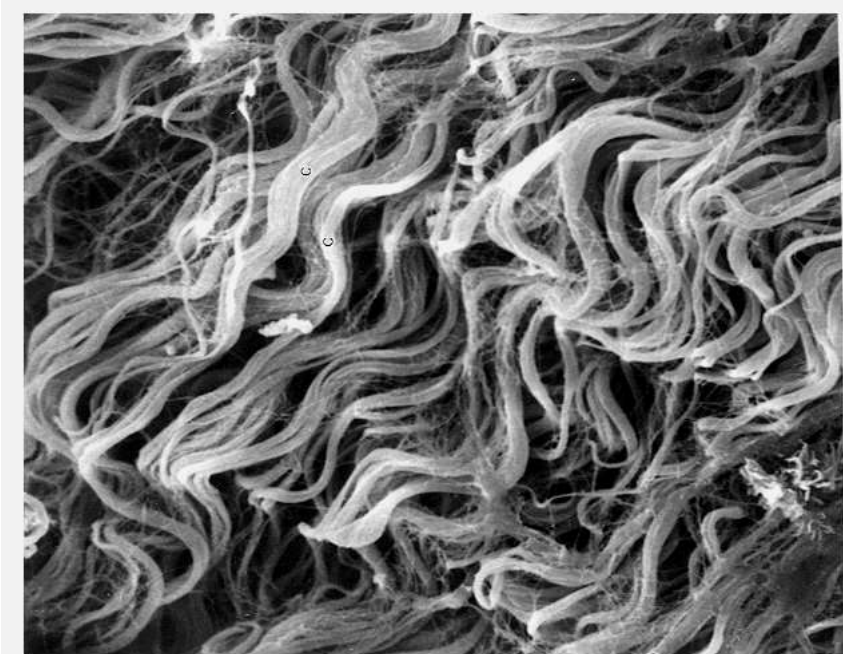
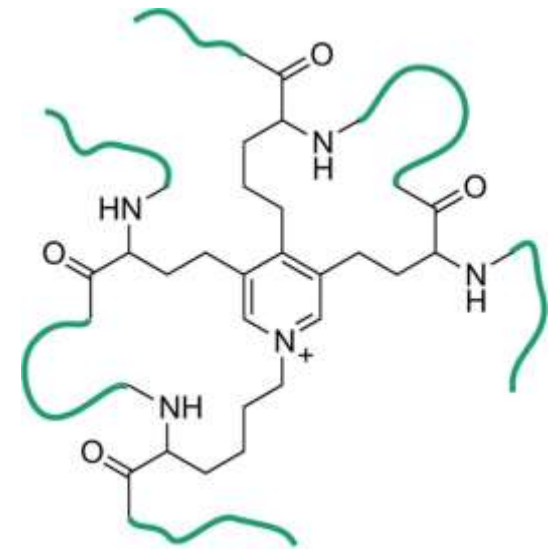
■ Elastic cartilage

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

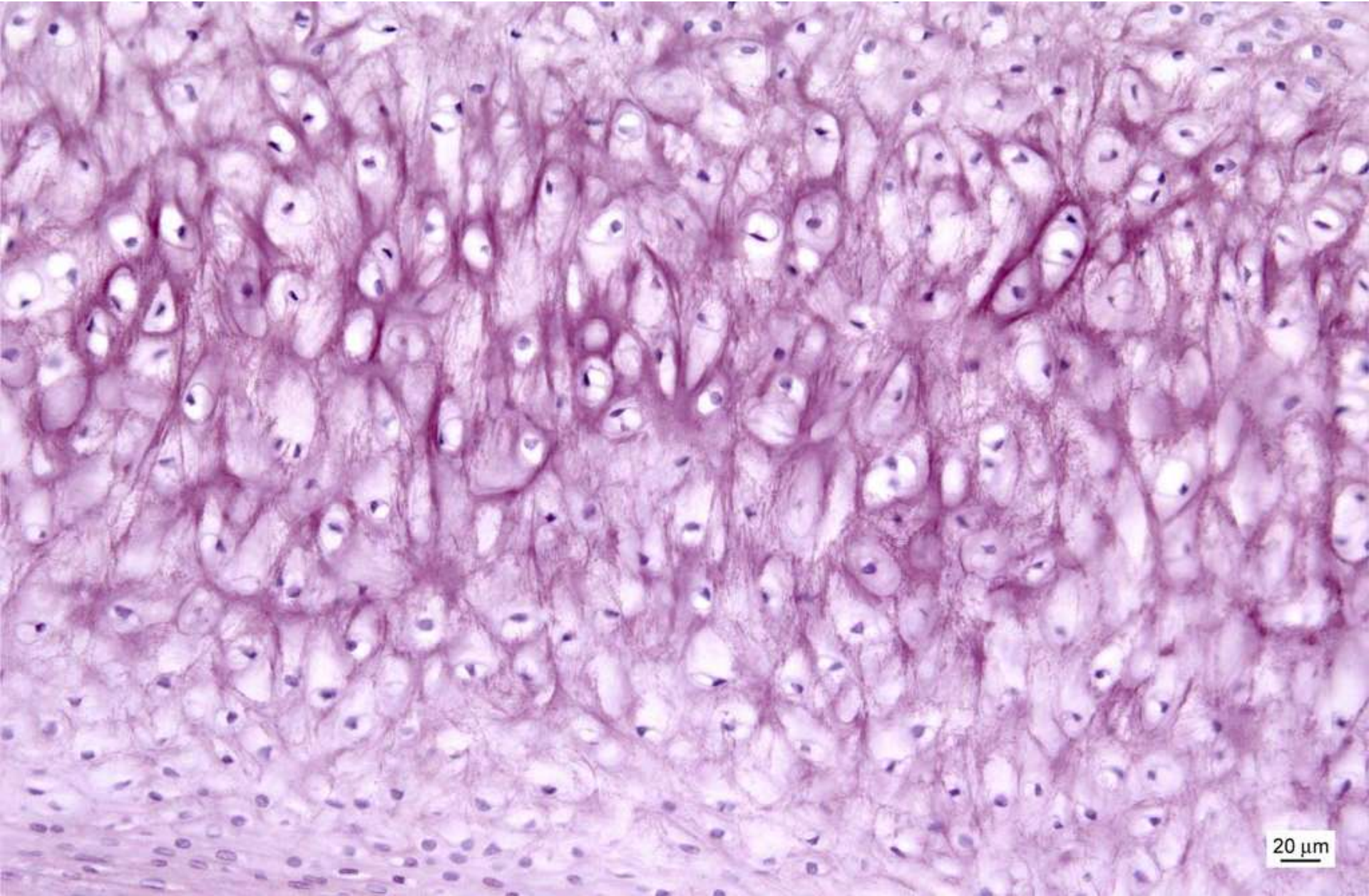


■ Elastic fibers

- 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

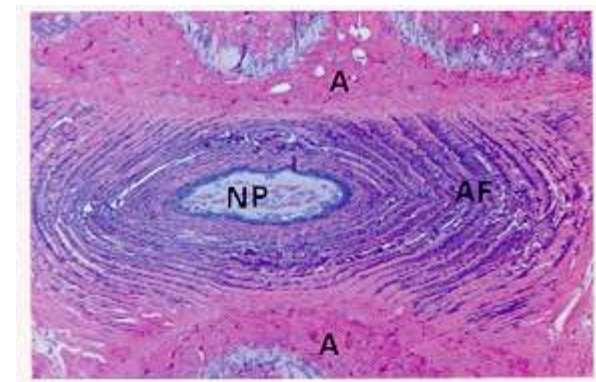
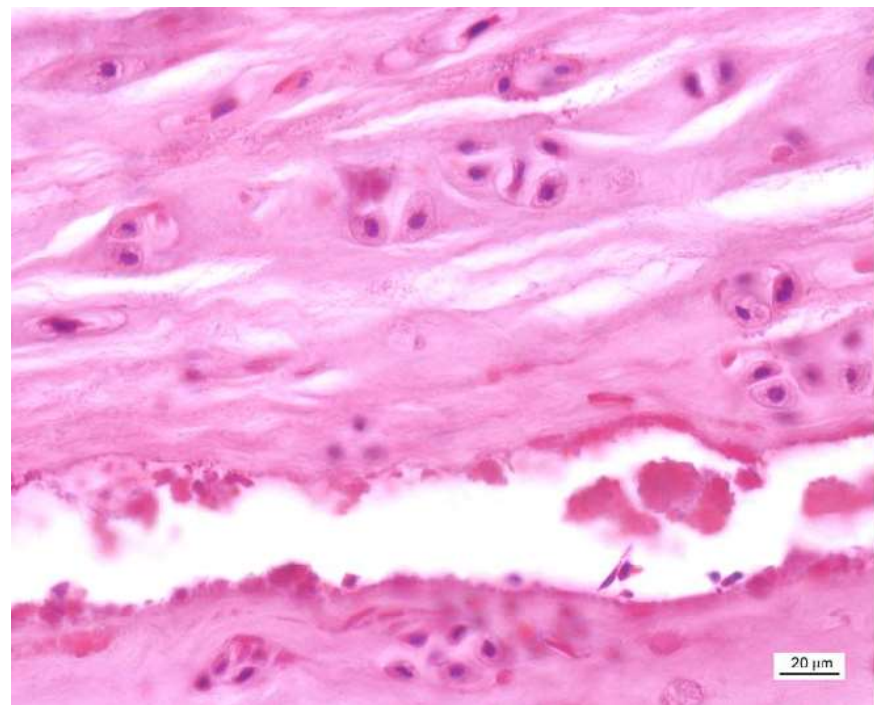
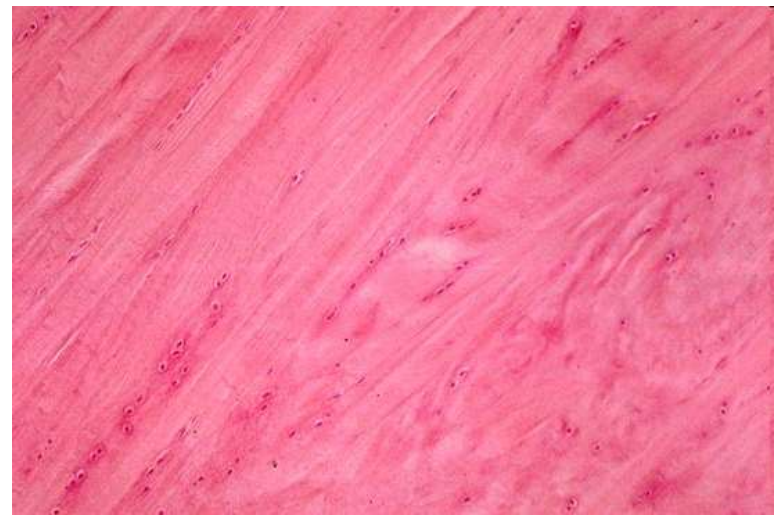


- Elastic cartilage

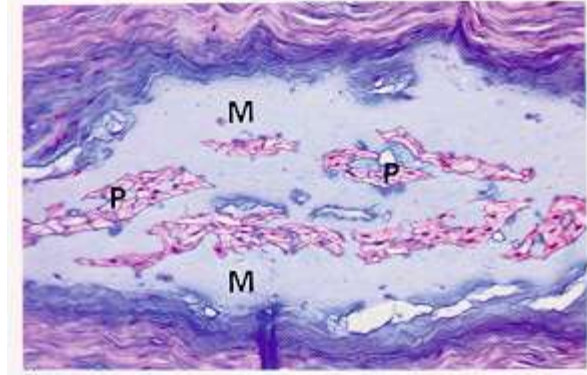


■ Fibrocartilage

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



(a)



(b)

■ Clinical correlations

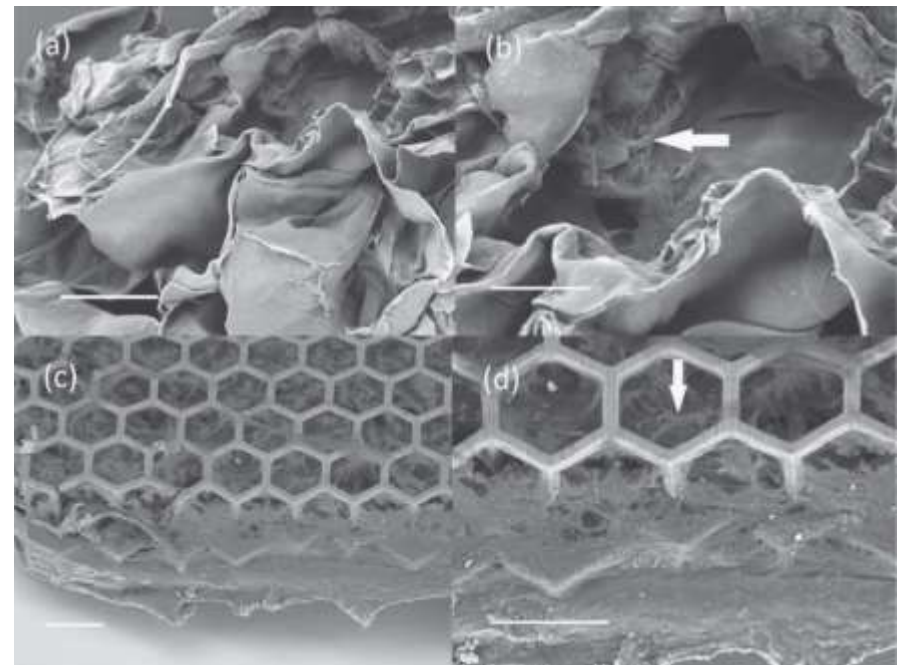
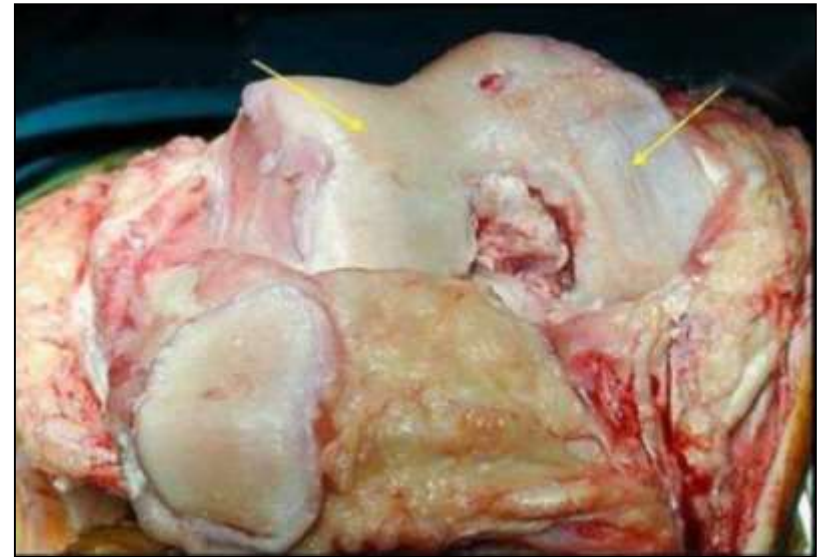
Cartilage – no innervation, no vascularization – no spontaneous regeneration

No migration of chondrocytes to site of damage

Initiation of other degenerative events leading to cartilage erosion (arthritis)

Therapy:

- joint mobility
- restoration of biochemical and biophysical parameters of cartilage
- prevention of further damage
- removal of damaged tissue, autologous transplantation, MSCs on biocompatible scaffolds



A histological micrograph of bone tissue stained with hematoxylin and eosin (H&E). The image displays several osteons, which are the basic structural units of bone. Each osteon consists of concentric layers of bone tissue (lamellae) surrounding a central canal. Small, dark-stained cells (osteocytes) are visible within the lamellae, connected by a network of fine canals (canaliculi). The overall structure is highly organized and shows a clear radial pattern.

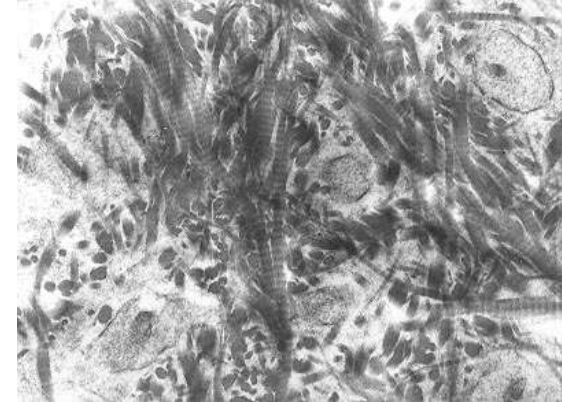
■ BONE

20 μ m

■ Histological classification of bone tissue

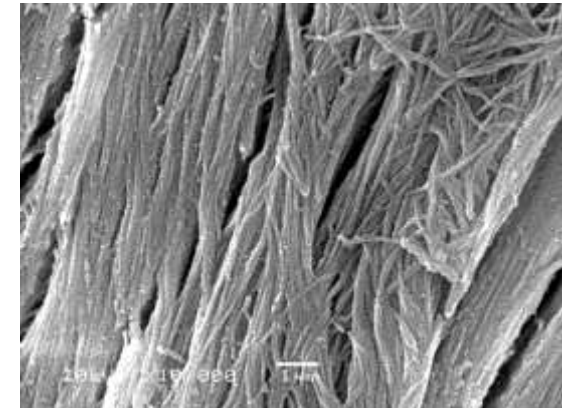
- **Primary (woven, fibrous)**

- 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 (3-7 μ m) around a canal with capillaries = Haversian system (osteon)

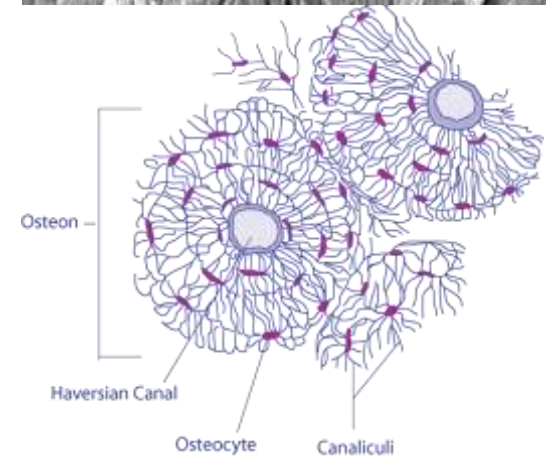


- **Spongy (trabecular)**

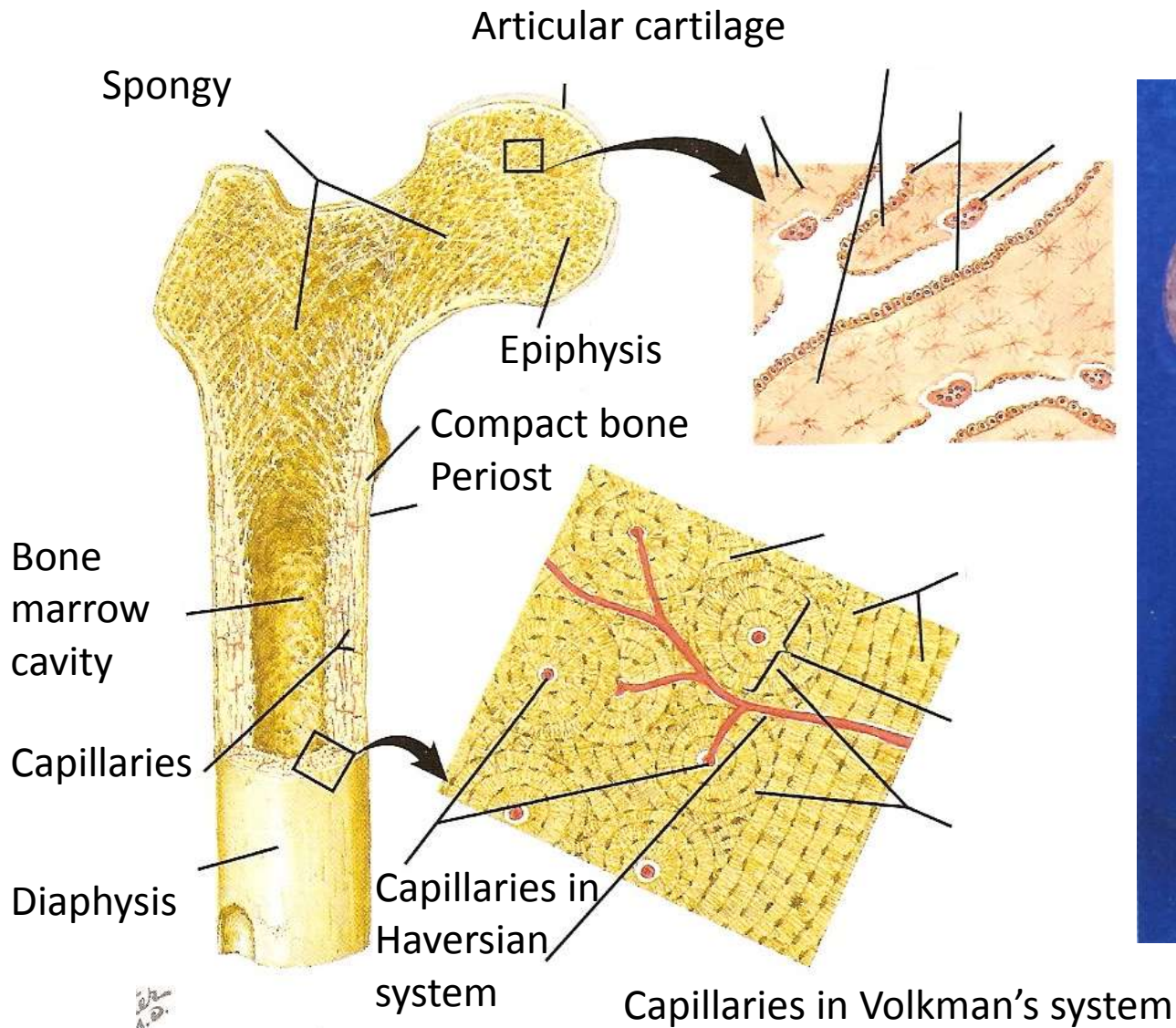
- Trabeculae, similar to compact
- Epiphyses of long bones, short bones, middle layer of flat bones of the skull (*diploe*)

- **Compact**

- Outer and inner coat lamellae typical Haversian systems
- Volkmann's canals
- Interstitial canals

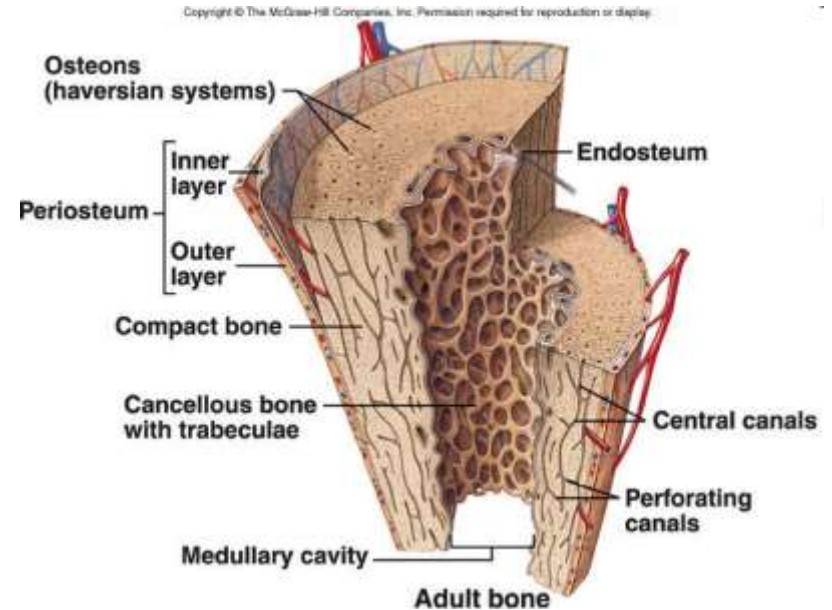


■ Bone



■ Surface of compact bone

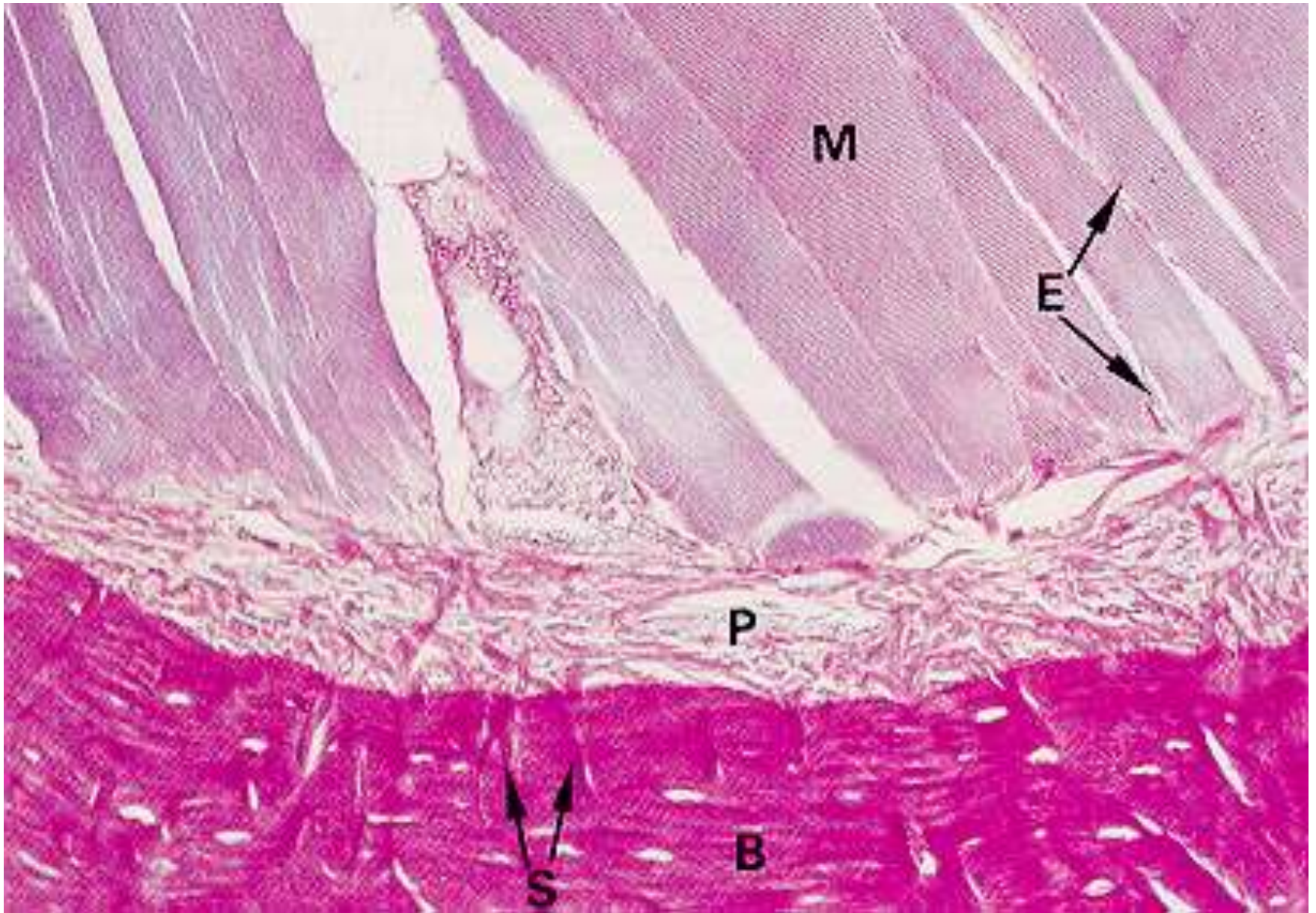
- Outer surface
 - Synovial joint – hyaline cartilage
 - **periosteum (periost)** – membrane – dense CT, inner layer (osteoblasts) and outer layer (fibrous CT)
 - Inactive bone - fibrous CT in periost dominant
 - Collagen fibers – parallel to the bone surface
 - Sharpey's fibers fix periost to the bone



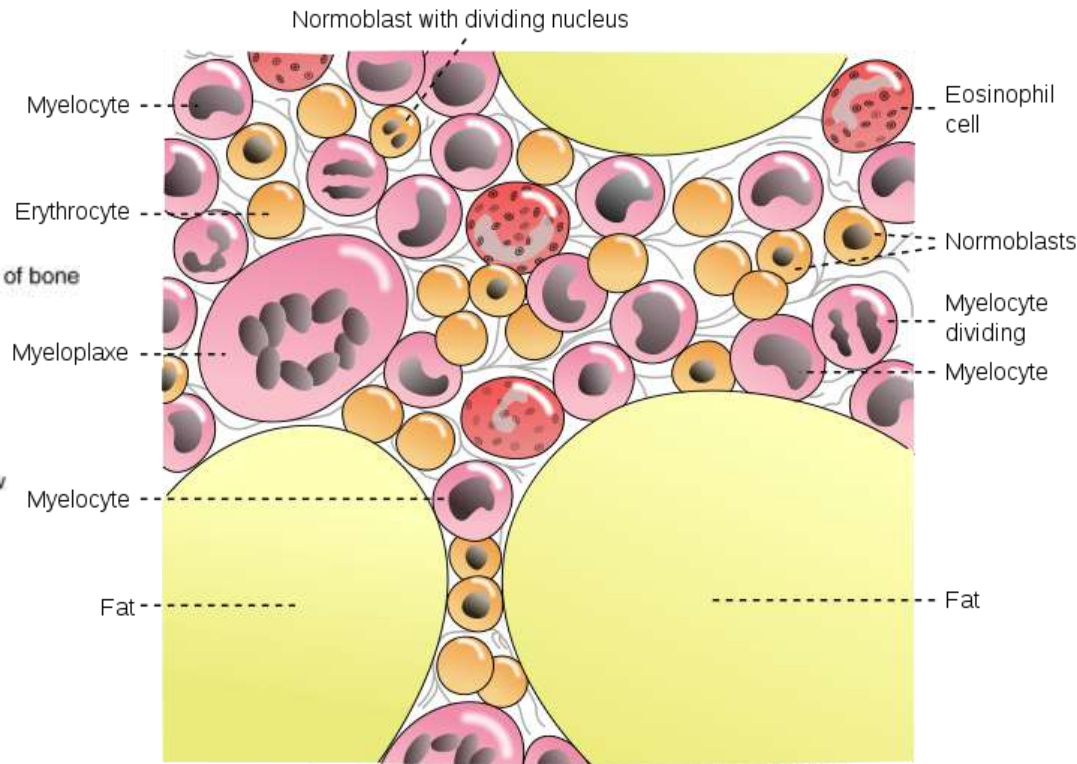
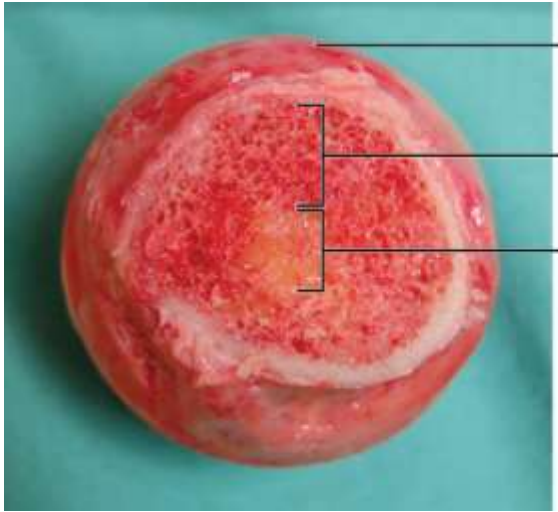
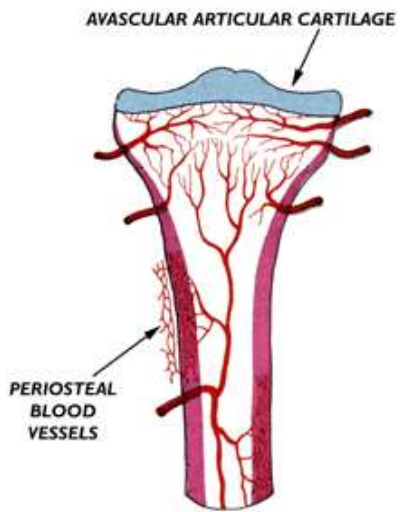
■ Surface of compact bone



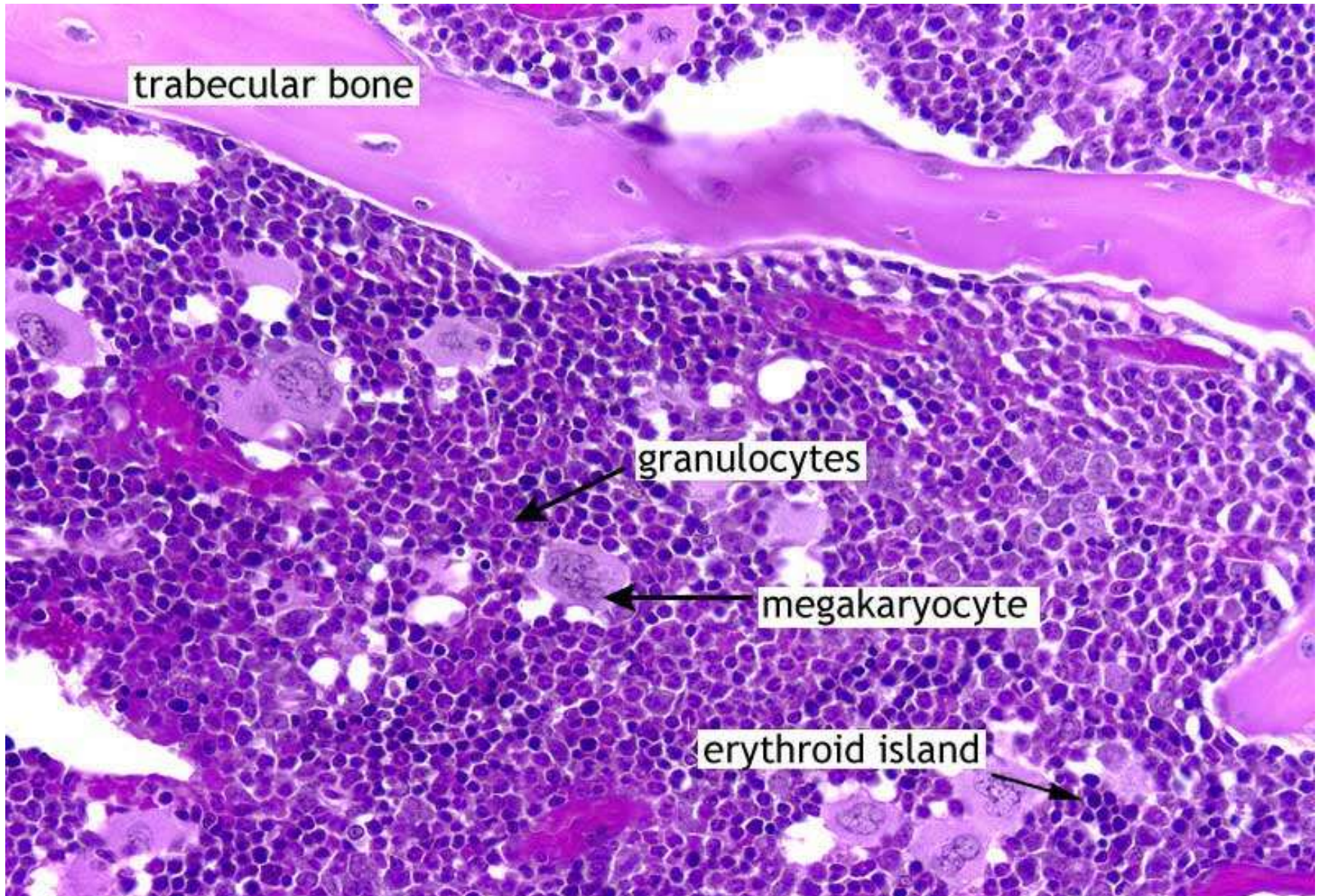
- Surface of compact bone



- **Inner surface** – cavities lining
- 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

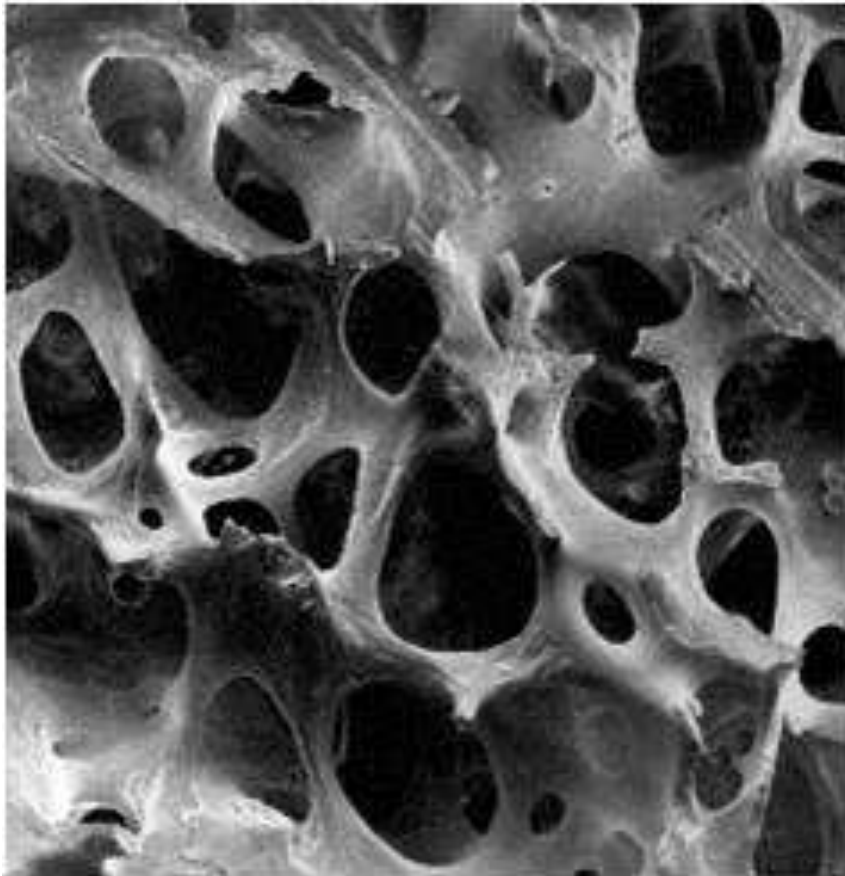


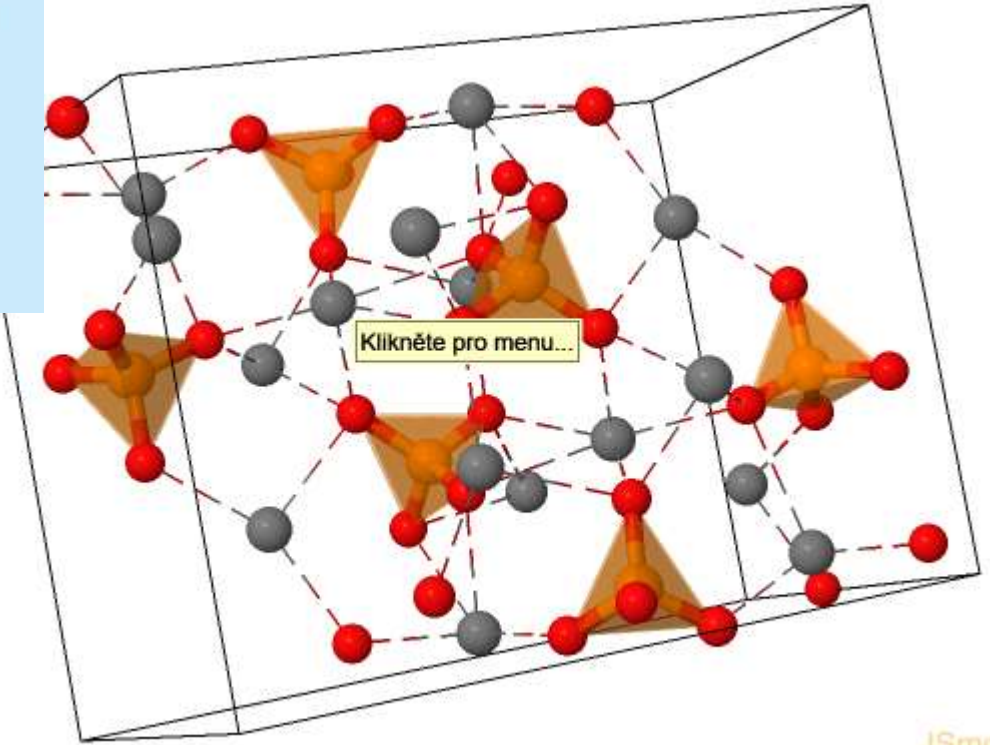
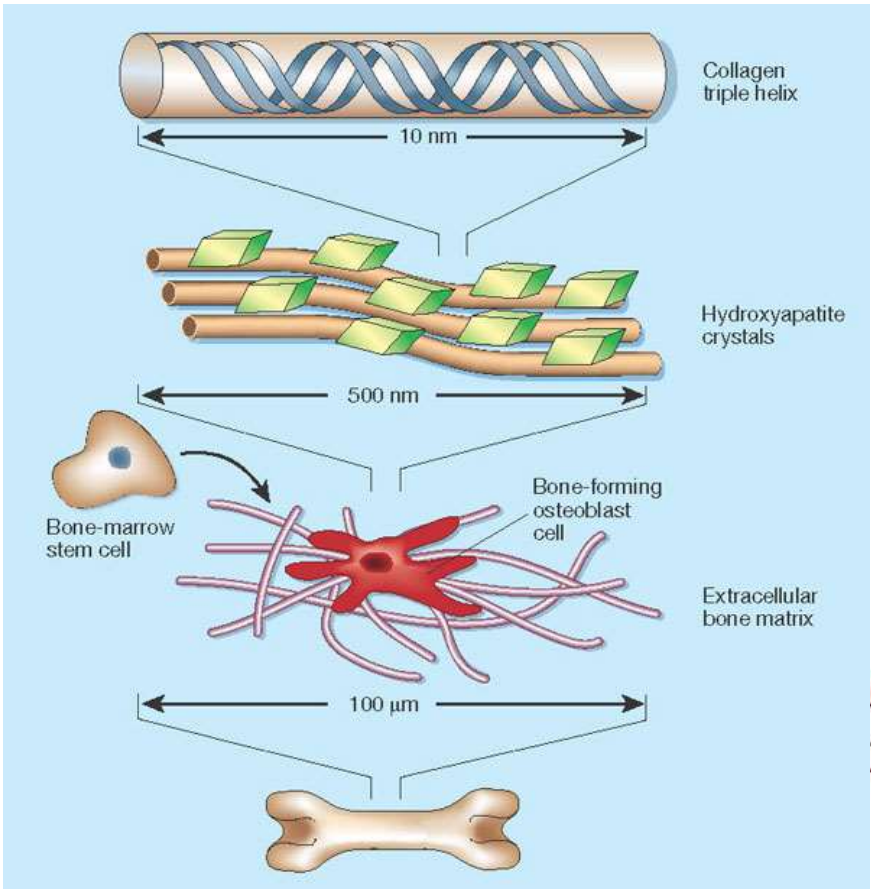
- Endosteal surface of compact bone



■ Bone matrix

- 60% mineral compound, 24% organic compound 12% H₂O, 4% fat
- crystals – calcium phosphate, hydroxyapatite

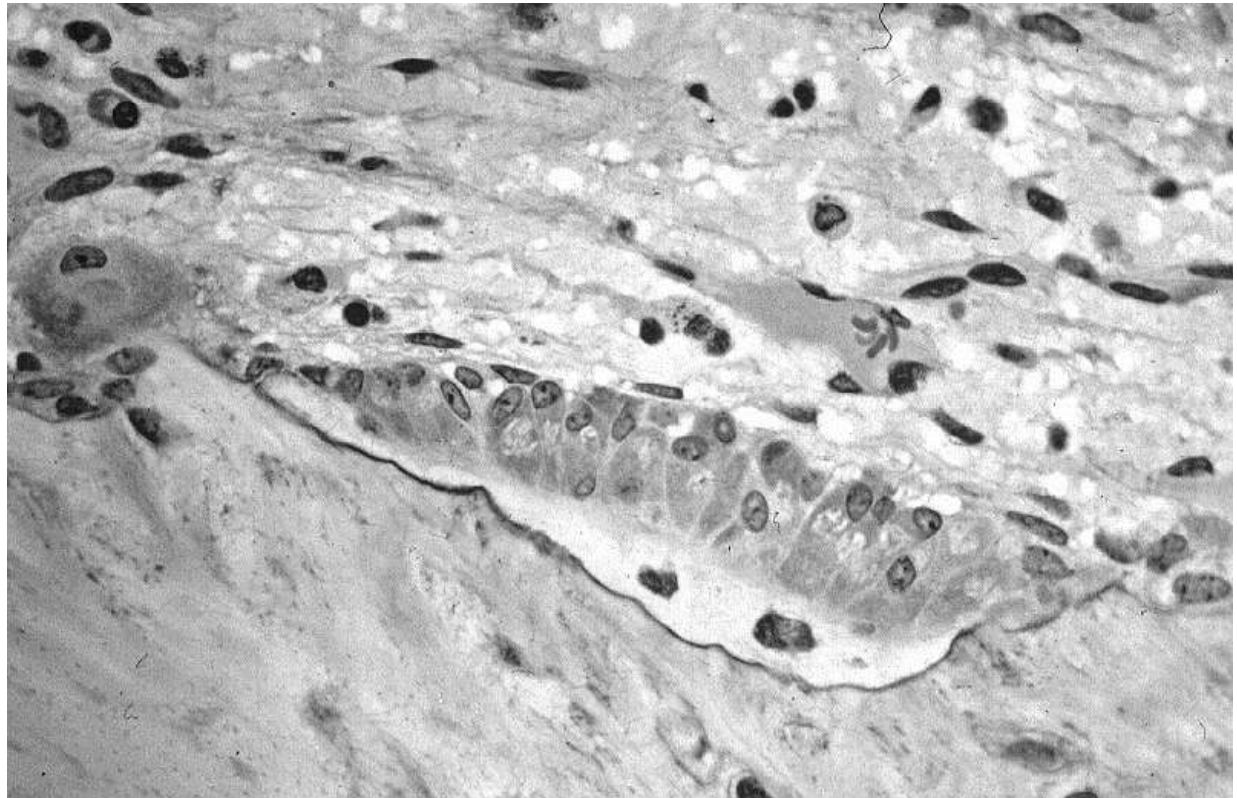




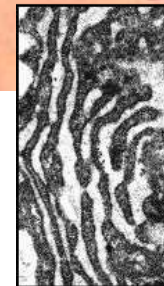
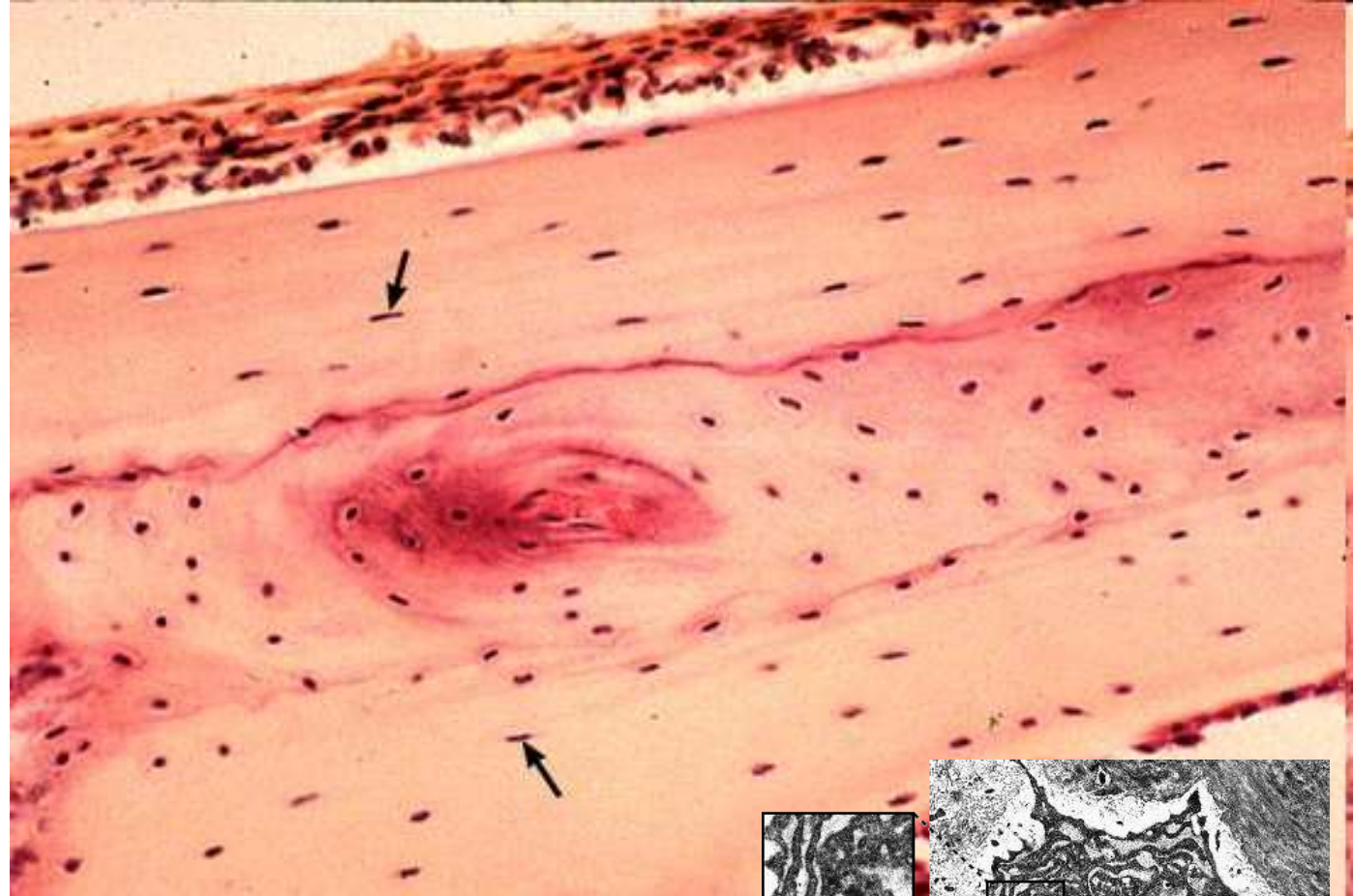
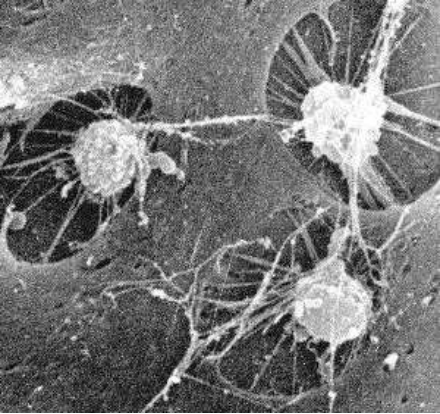
■ Cells of the bone - osteoblasts

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

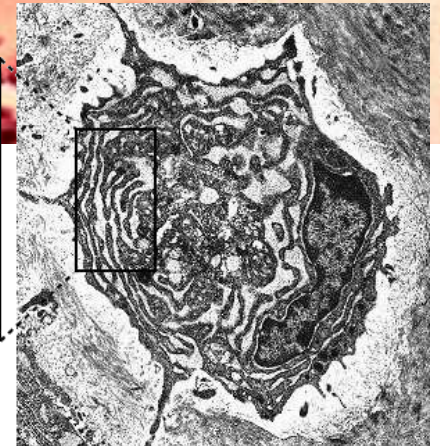
- **osteocytes** embedded in matrix
- *canaliculi ossium*



Cells of the bone - osteocytes

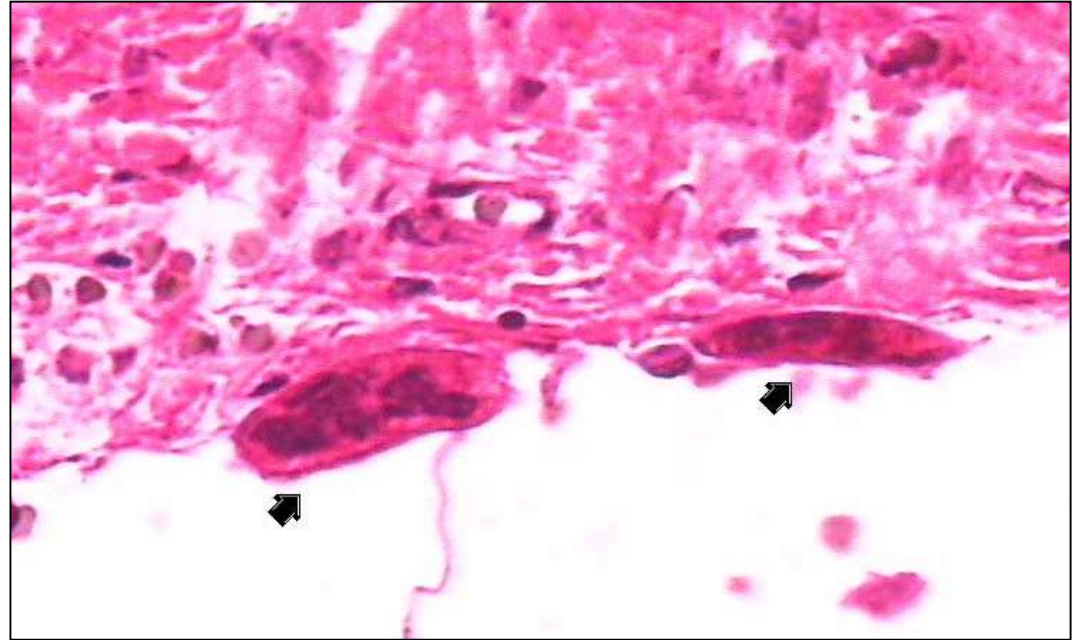
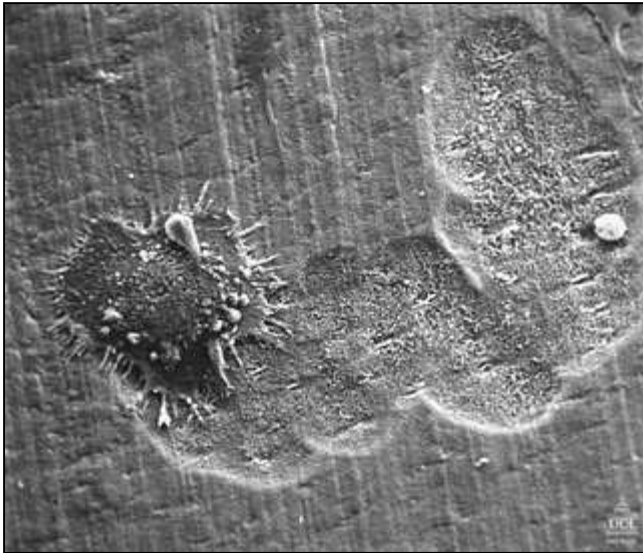


RER
-rough
endoplasmic
reticulum



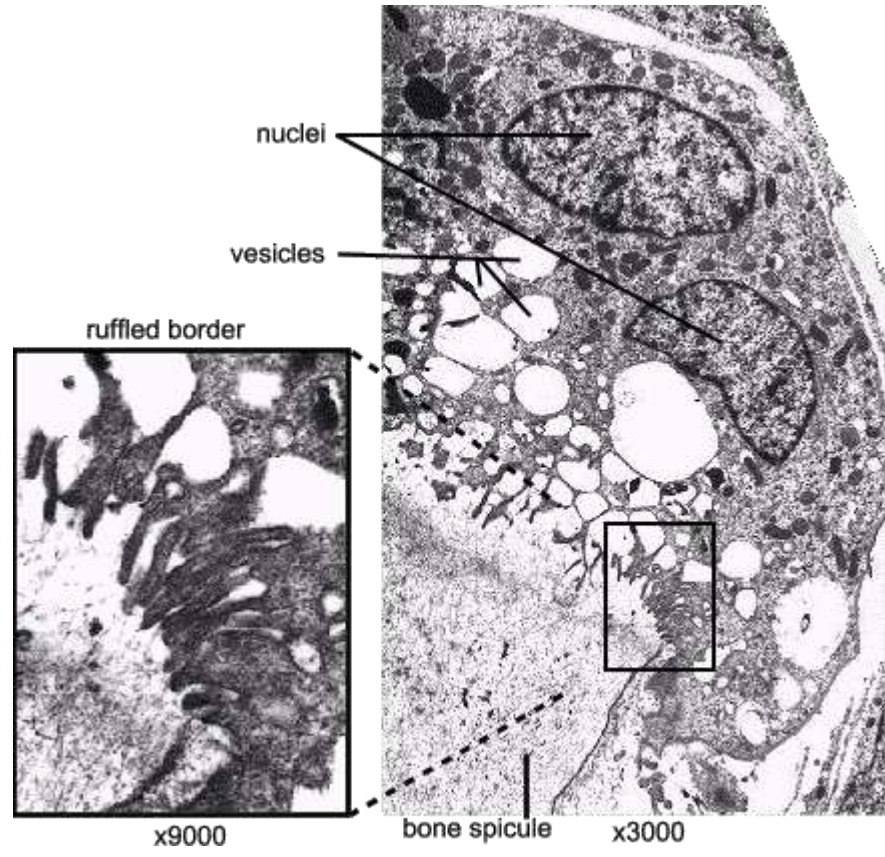
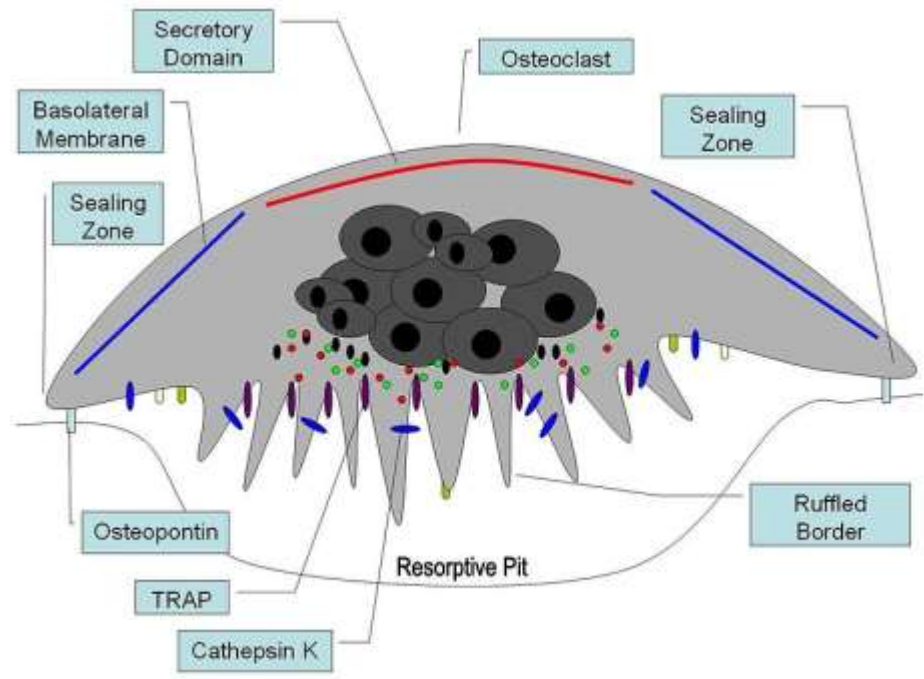
■ Cells of the bone - osteoclasts

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



Cells of the bone - osteoclasts

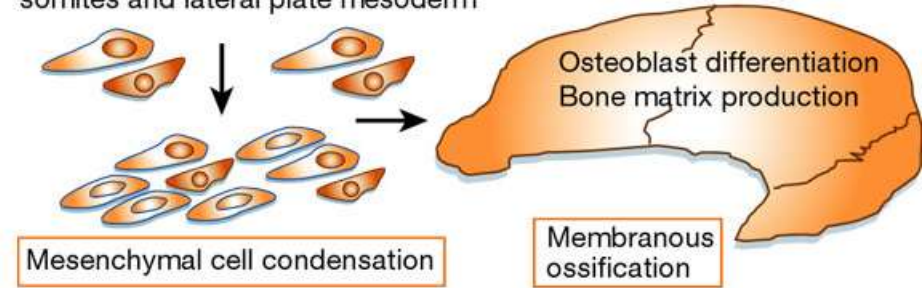
- complex architecture
- enzymes degrading organic matrix
- HCl



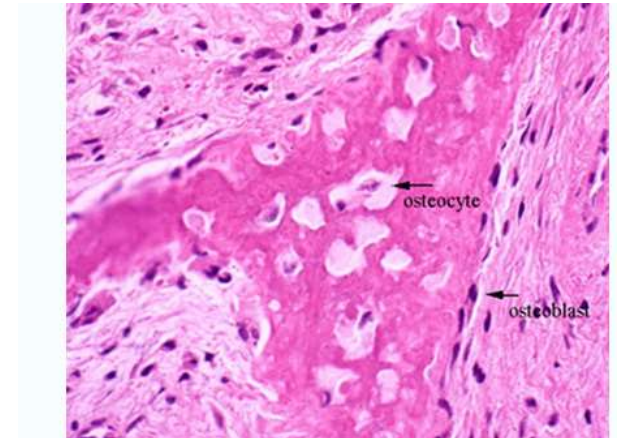
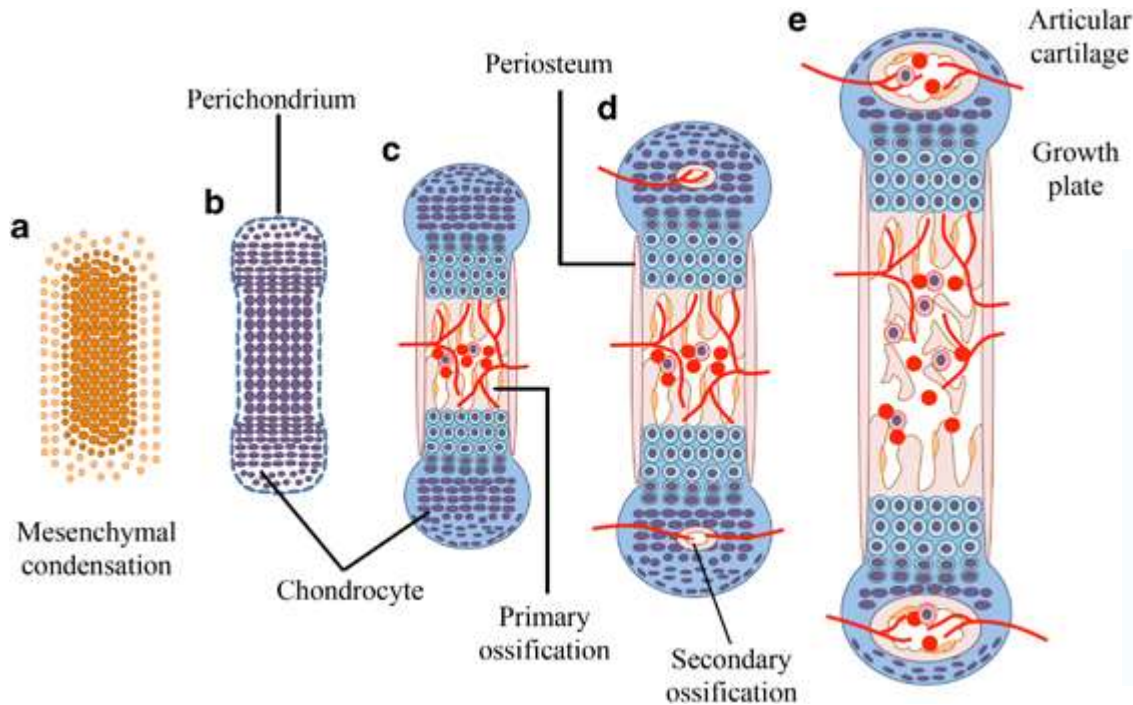
■ Ossification

Intramembraneous

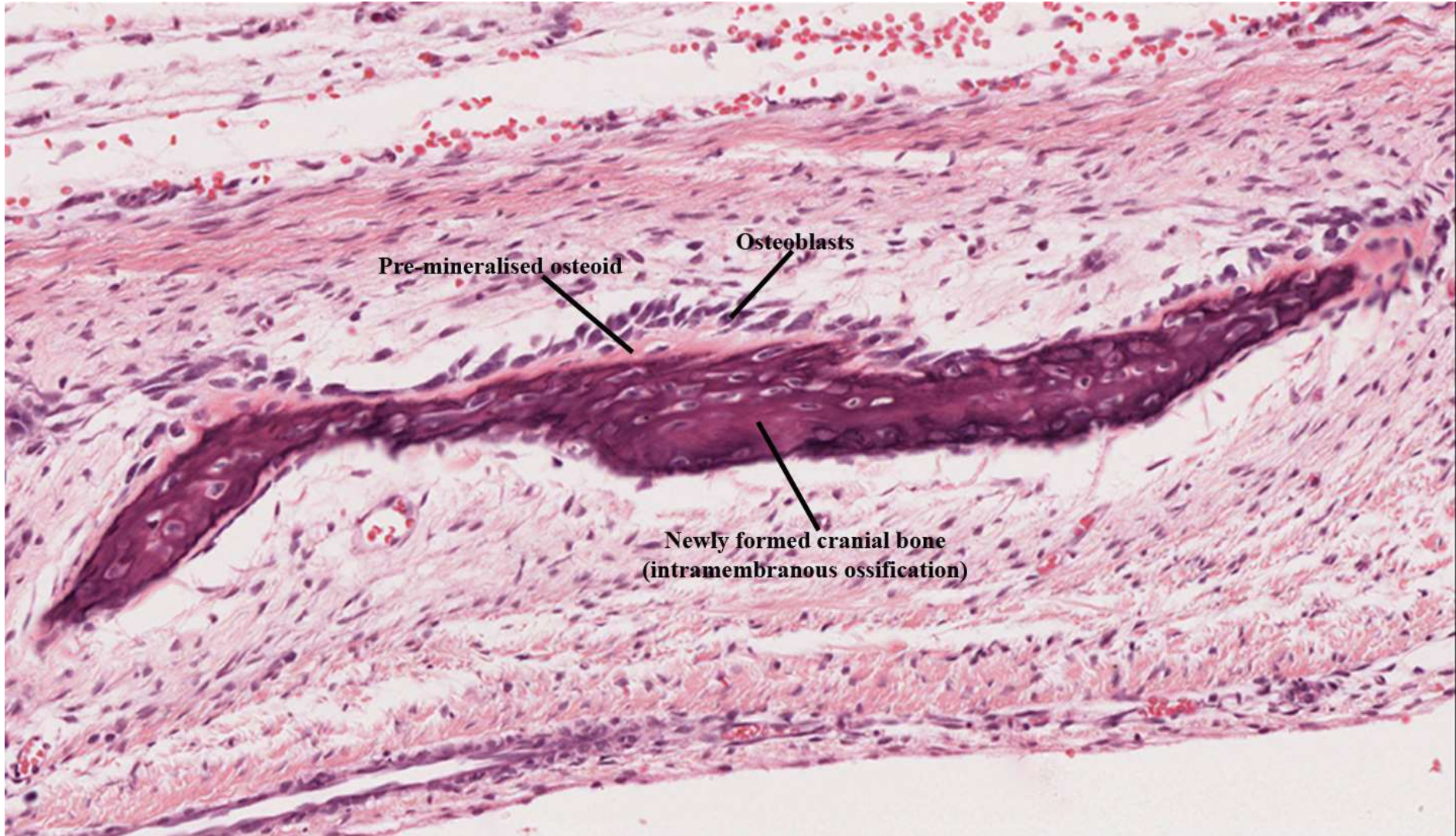
Cells from cranial neural crest, somites and lateral plate mesoderm



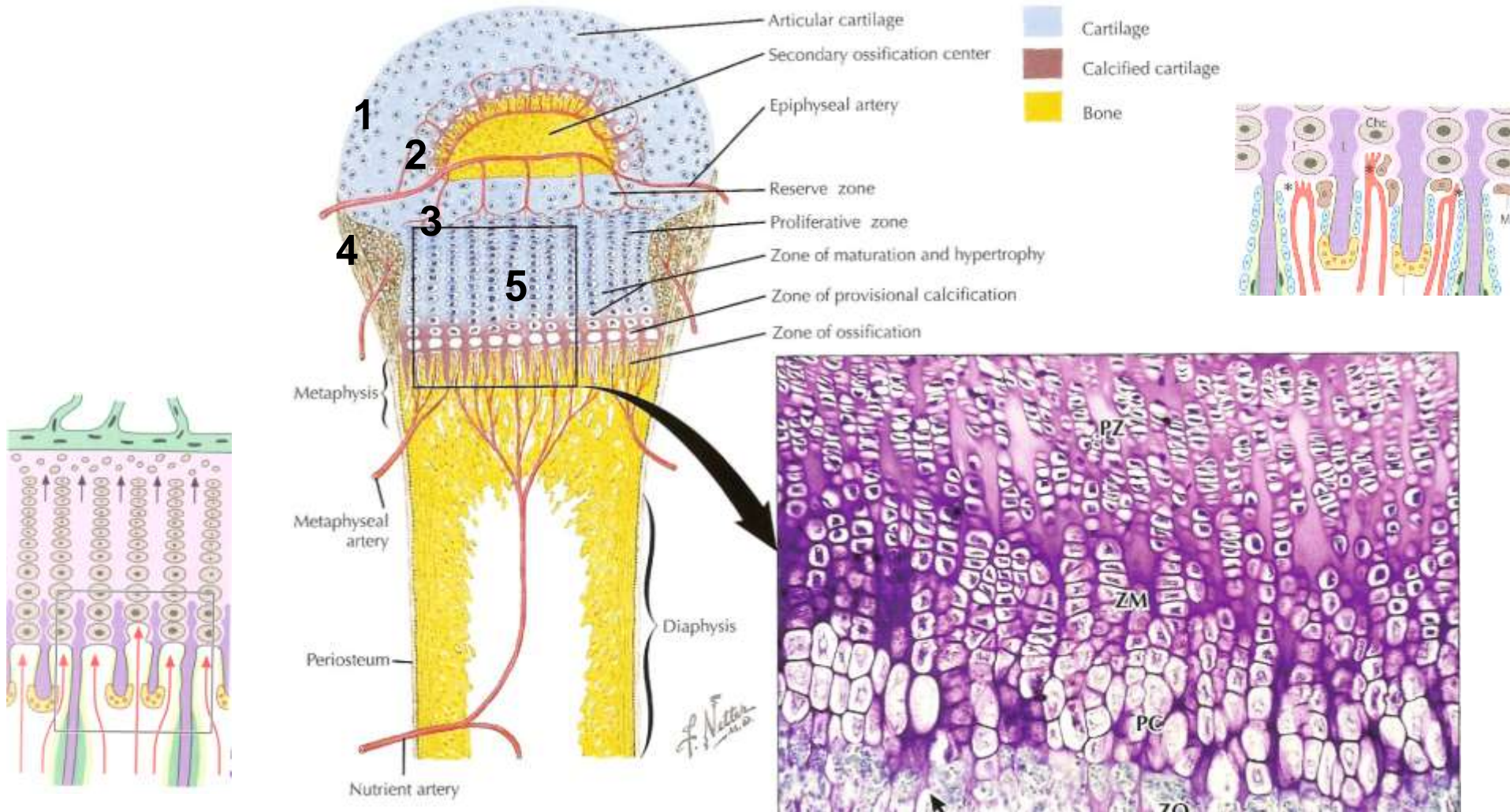
Endochondral



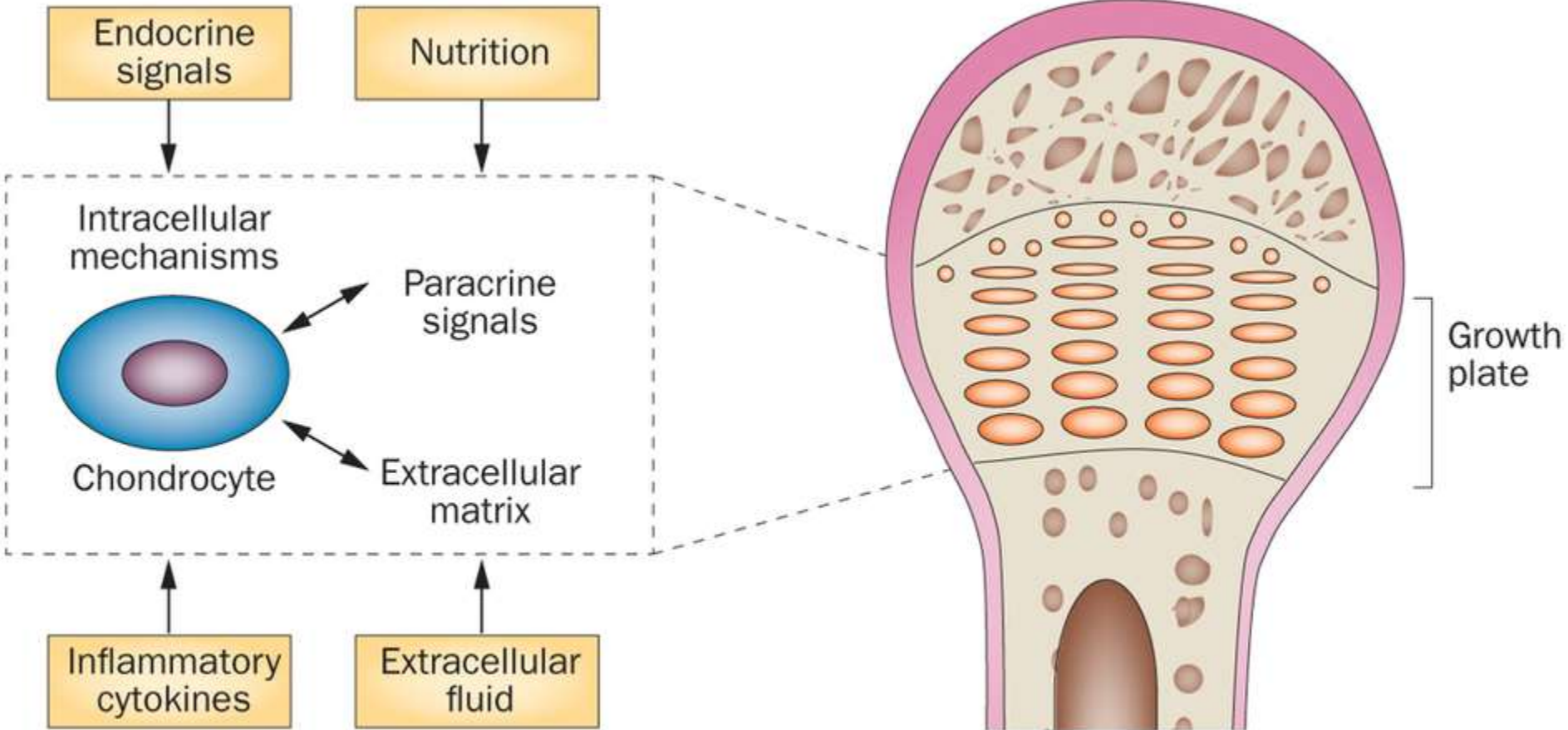
■ Intramembraneous ossification



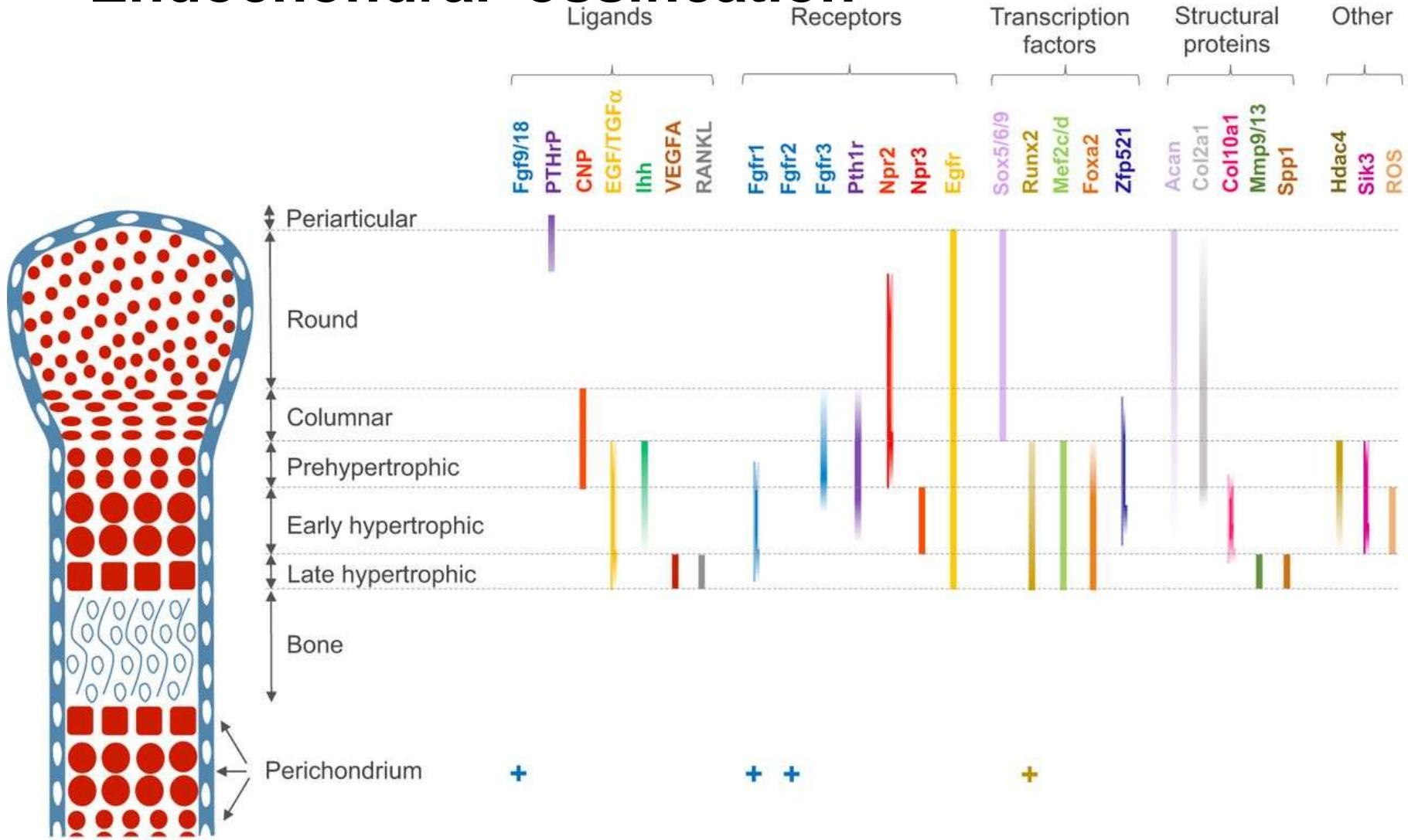
■ Endochondral ossification



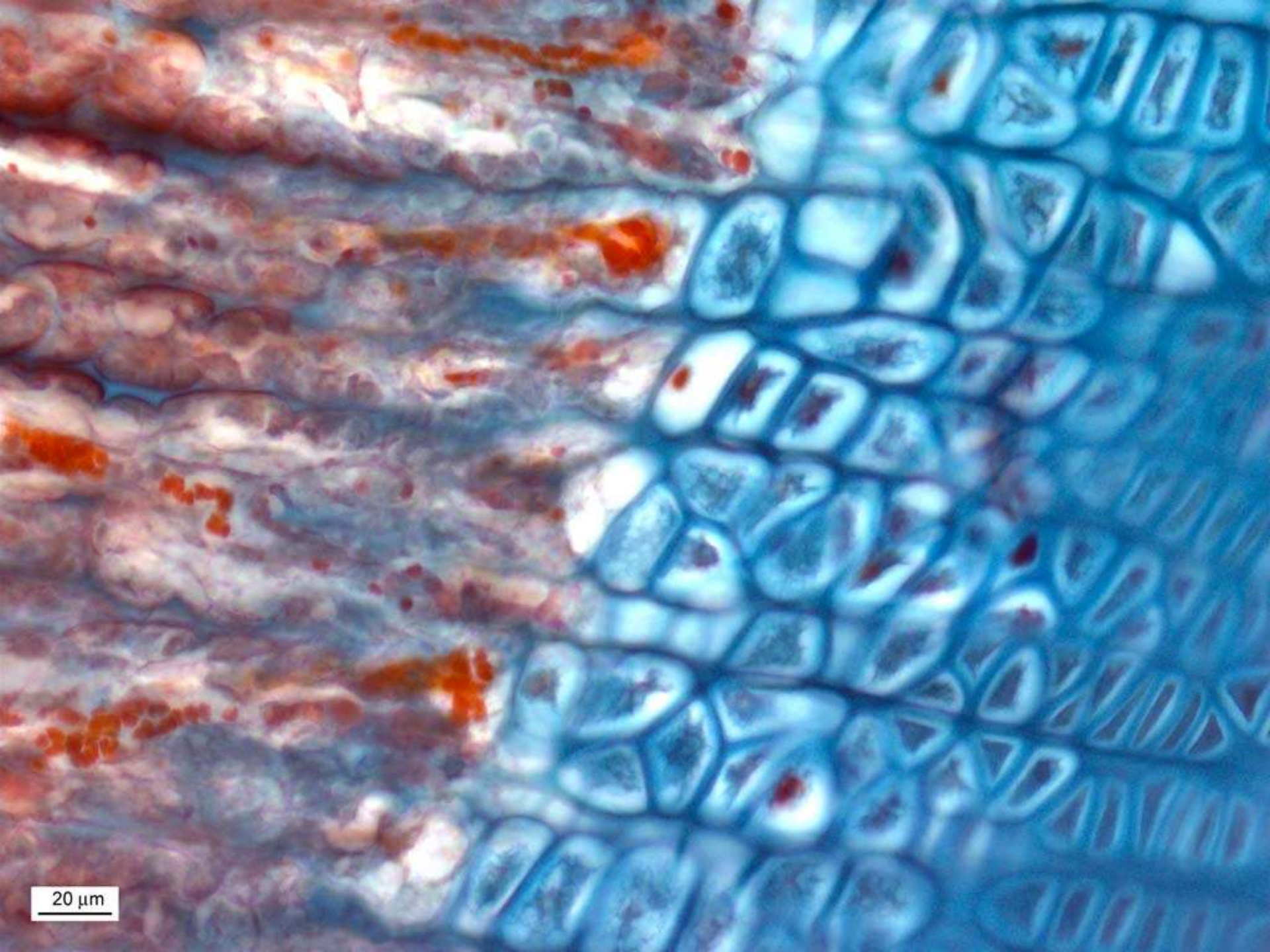
■ Endochondral ossification



Endochondral ossification

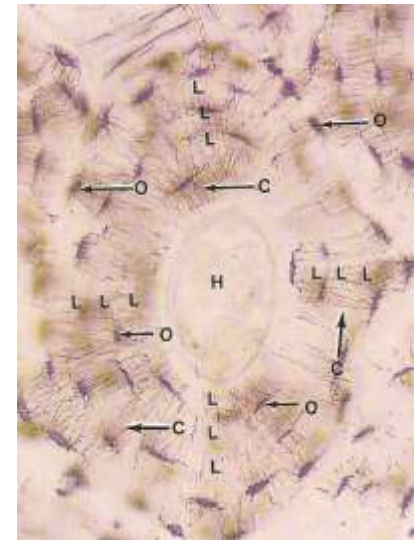
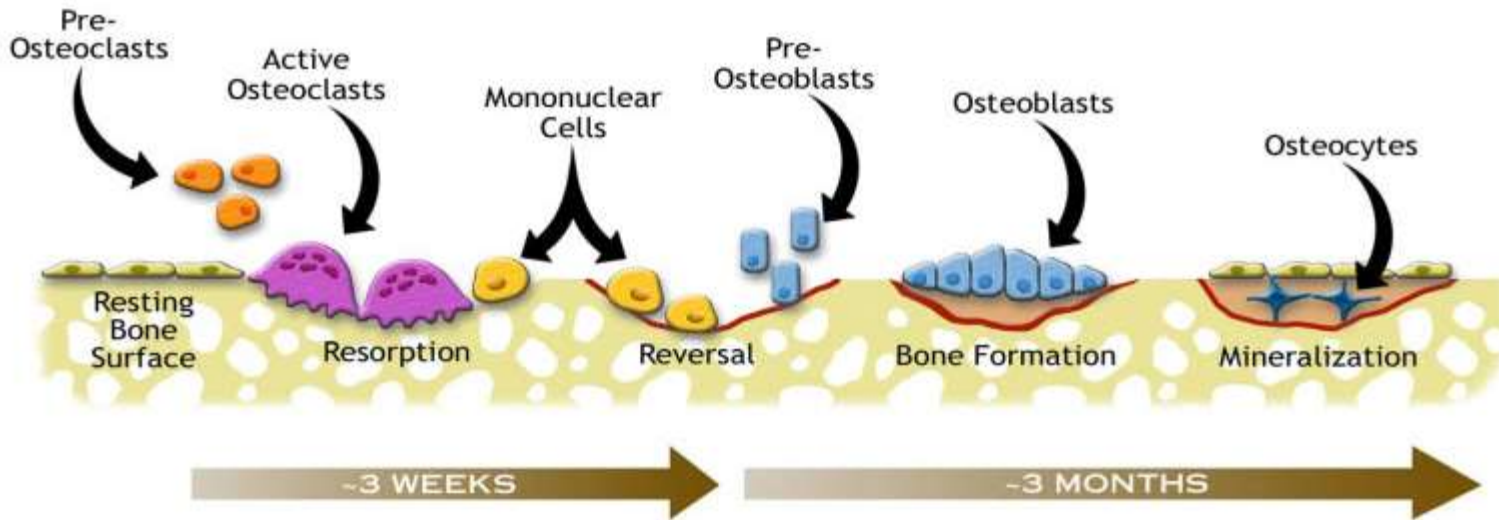






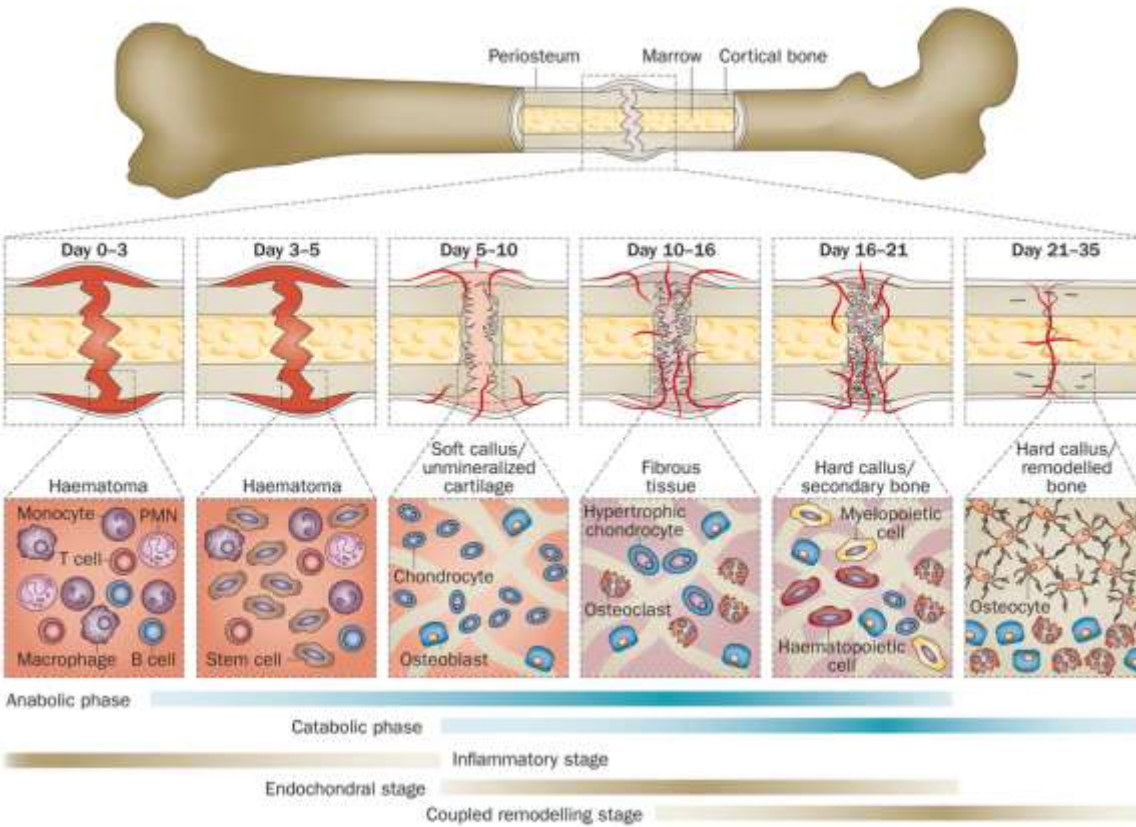
20 μm

■ Bone remodelling



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

■ Clinical correlations - fracture healing



Reactive Phase

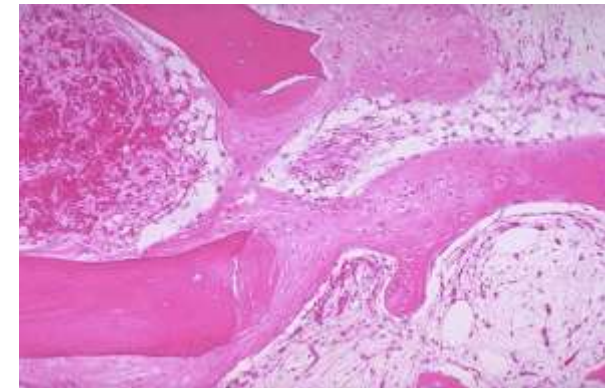
- fracture and inflammatory phase
- granulation tissue formation

Reparative Phase

- cartilage *callus* formation
- lamellar bone deposition

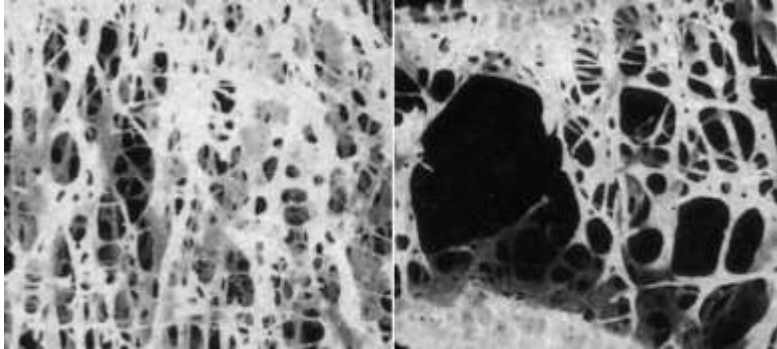
Remodeling Phase

- remodeling to original bone shape



▪ Clinical correlations – disbalance in osteosynthesis and osteoresorption

• OSTEOPOROSIS



• REVMATOID ARTHRITIS

• OSTEOPETROSIS

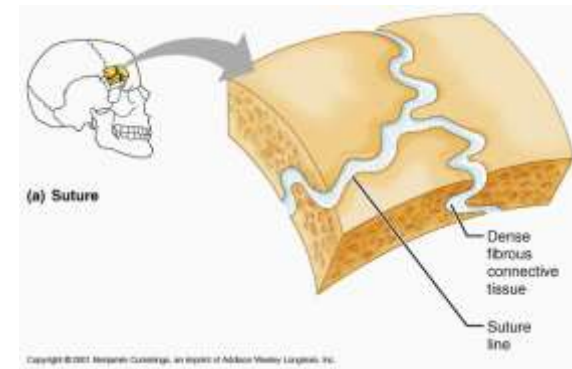


■ Skeletal joints

Synarthrosis

- joint by intercalated tissue (cartilage, bone or c.t.)

- **Synostoses** – joint by bone tissue – os coxae, os sacrum
- **Synchondrosis** – joint by hyaline cartilage – development of synostosis
- **Symphysis** – joint by fibrocartilage – os pubis, intervertebral discs
- **Syndesmosis** – dense collagen regular c.t. – sutures of skull, gomphosis

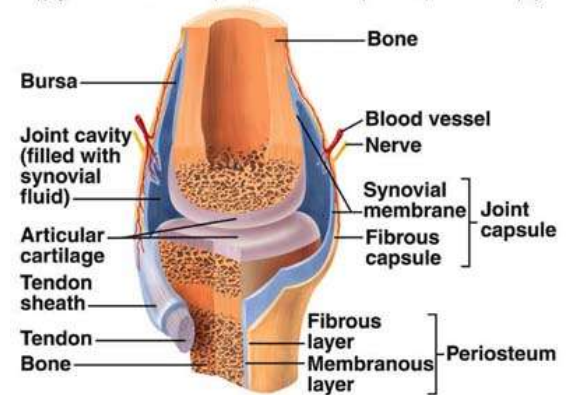


Diarthrosis

- synovial joint

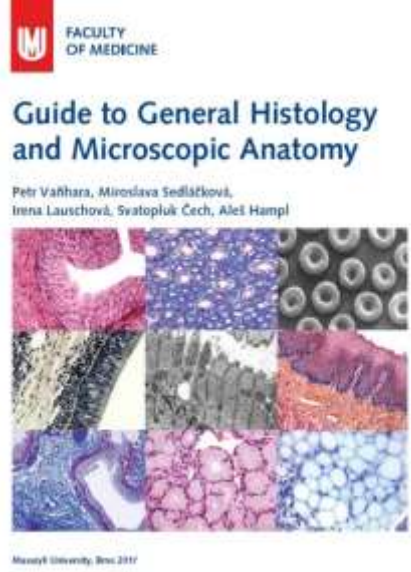
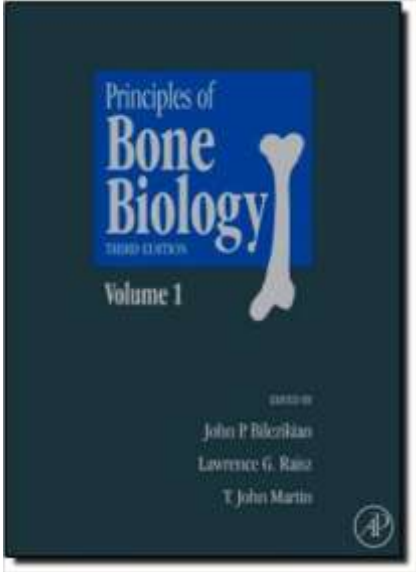
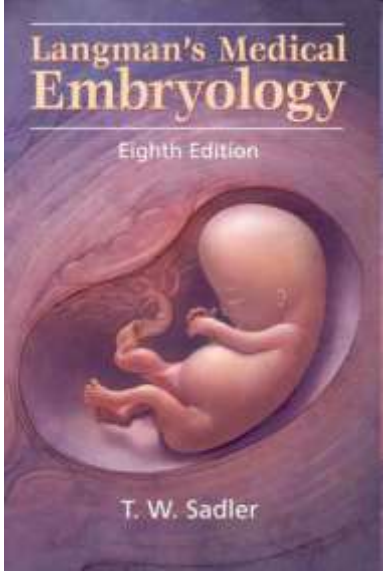
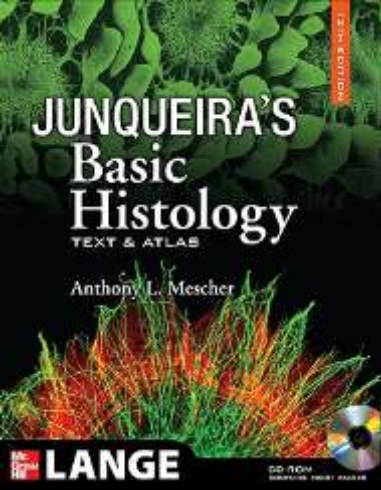
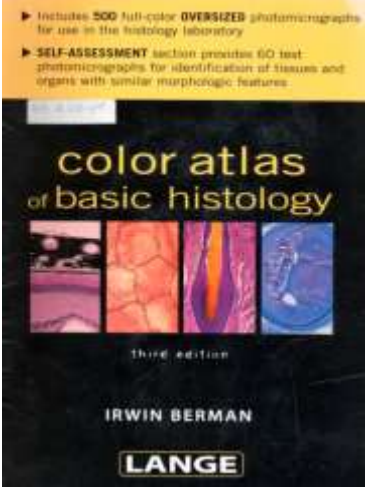
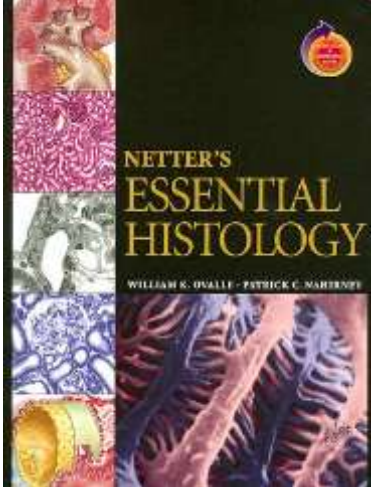
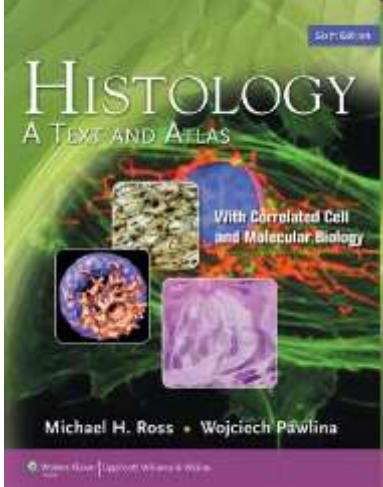
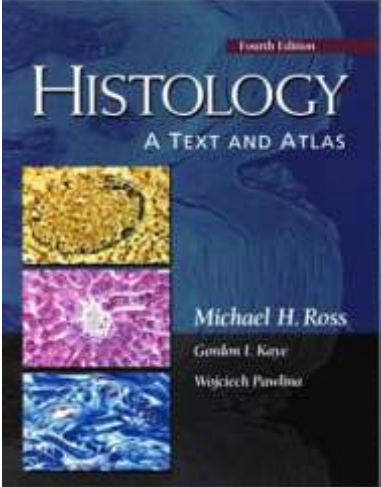
- hyaline cartilage without perichondrium
- cartilage calcification in site of attachment to the bone
- joint capsule
 - *Stratum fibrosum*
 - *Stratum synoviale*

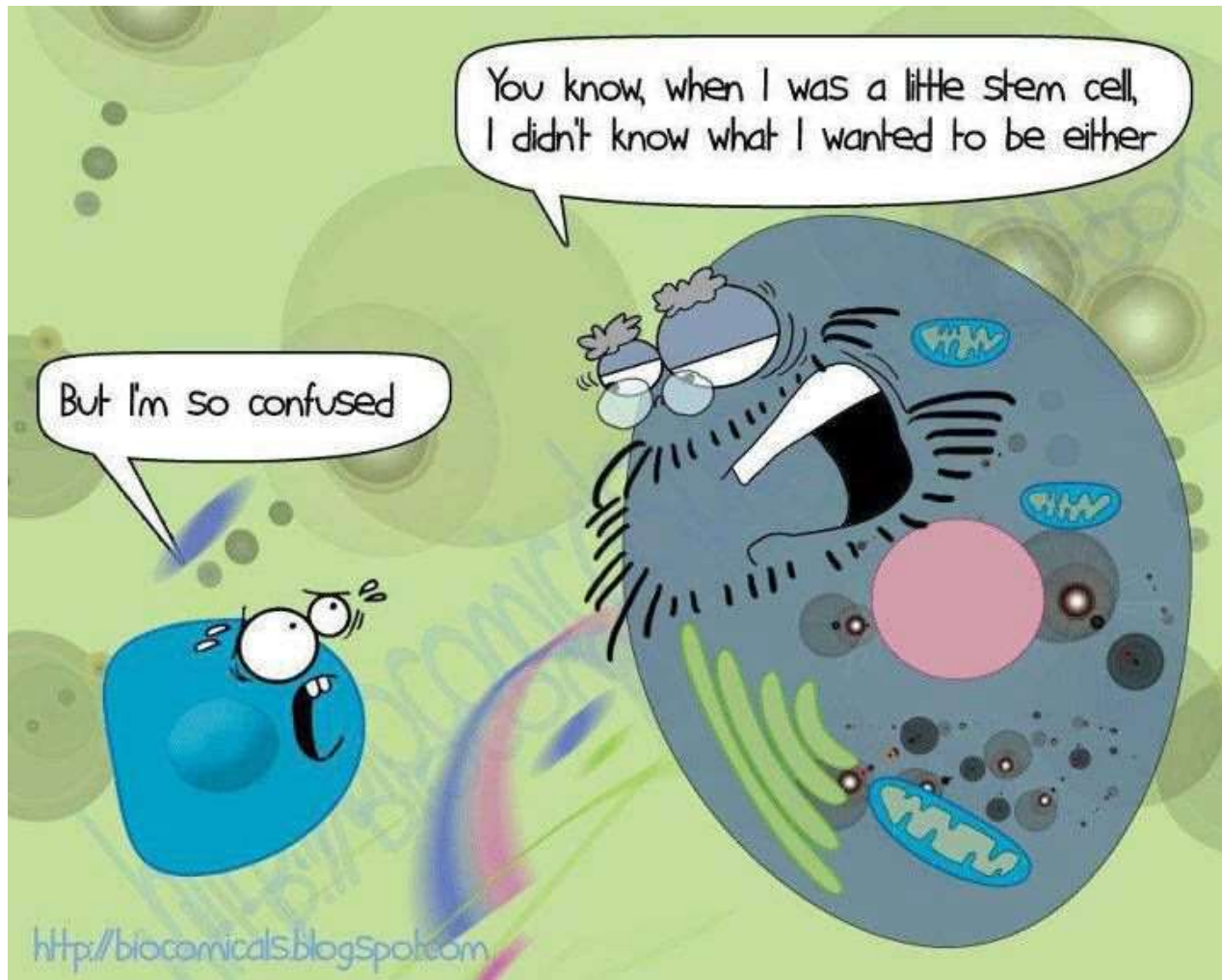
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- Meniscus – fibrocartilage, avascular, without innervation
- tendons – dense collagen regular c.t., elastic fibers
- bursae – like joint capsule

Further study





Thank you for attention