Connective tissue

general building plan

cells embedded in extracellular matrix, which is produced by the cells and prevails above them with its volume

connective tissue proper

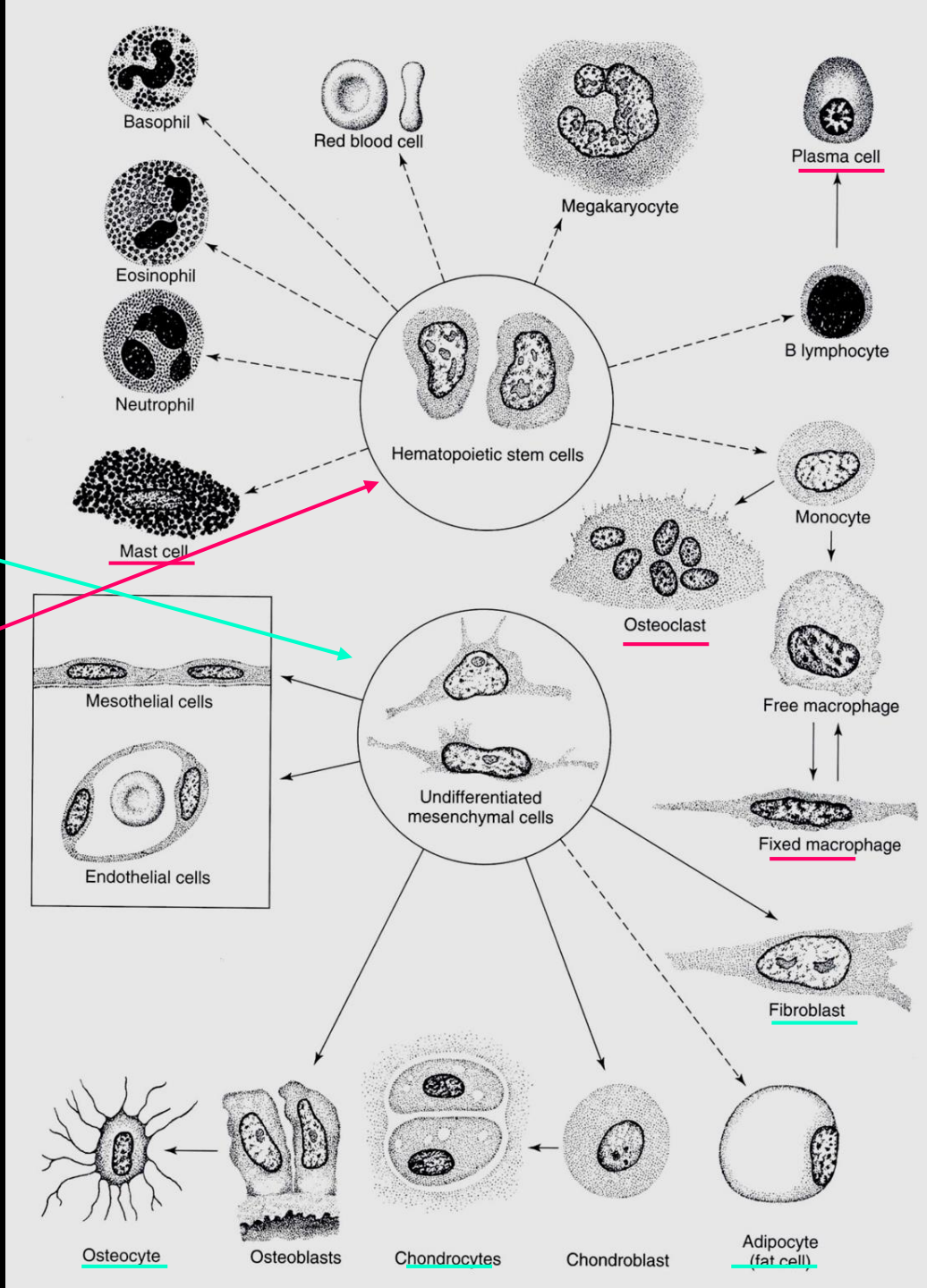
cartilage

bone

Cells of the connective tissues

a) resident
– originate in actual tissue; produce intercellular matrix

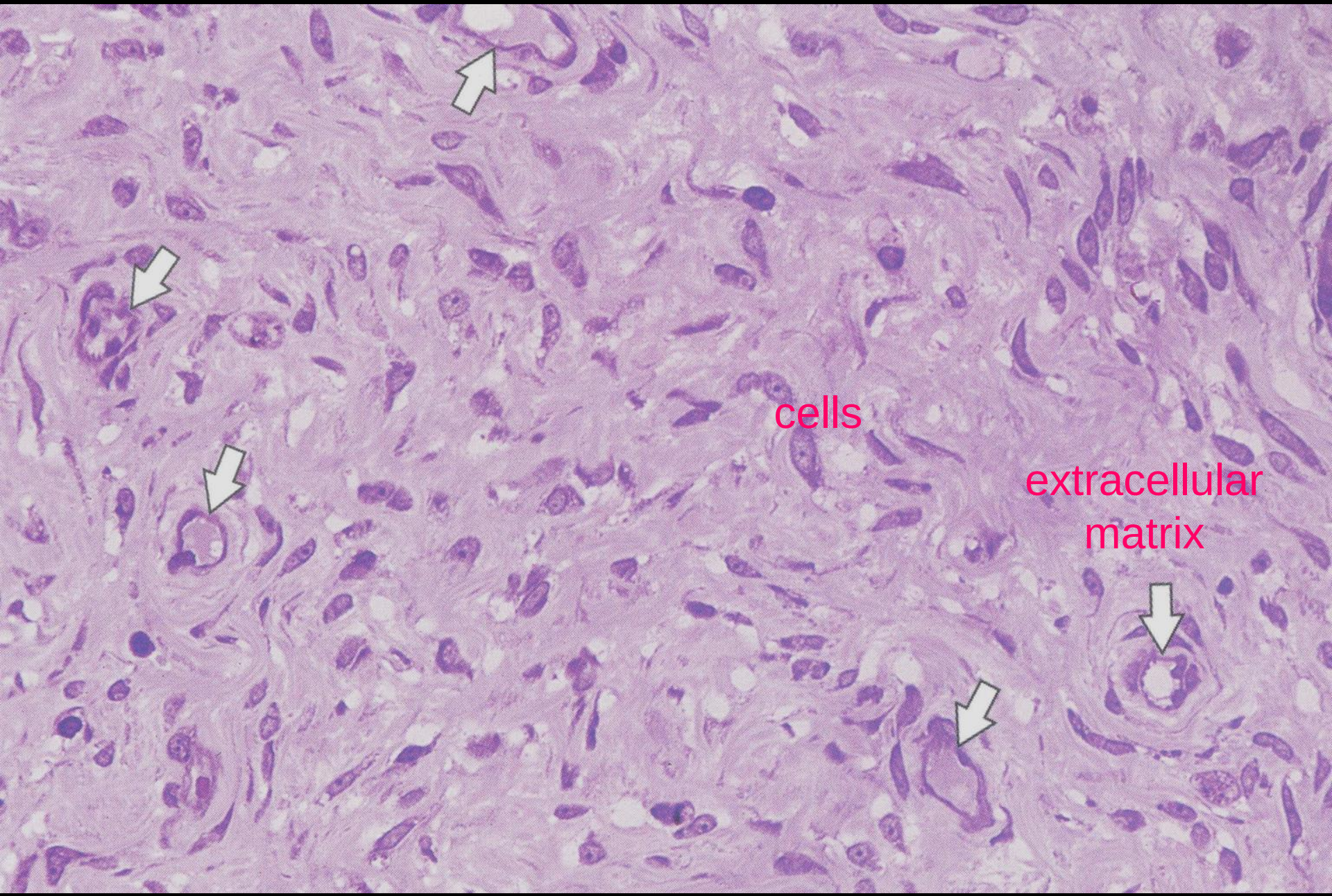
b) migratory (wandering)
– originate in bone marrow; in the connective tissue, they spend a part of their lifespan only



Intercellular or extracellular matrix (ECM) of the connective tissue (CT)

- fibrillar component
  - collagen (various types; only some form fibers)
  - elastin a fibrilin (elastic fibers)

- amorphous component (ground substance)
  - glycosaminoglycans (GAG, linear polysaccharides)
  - proteoglycans (GAGs linked to a protein core)
  - structural glycoproteins (proteins with linked saccharide chains)



arrows = small vessels

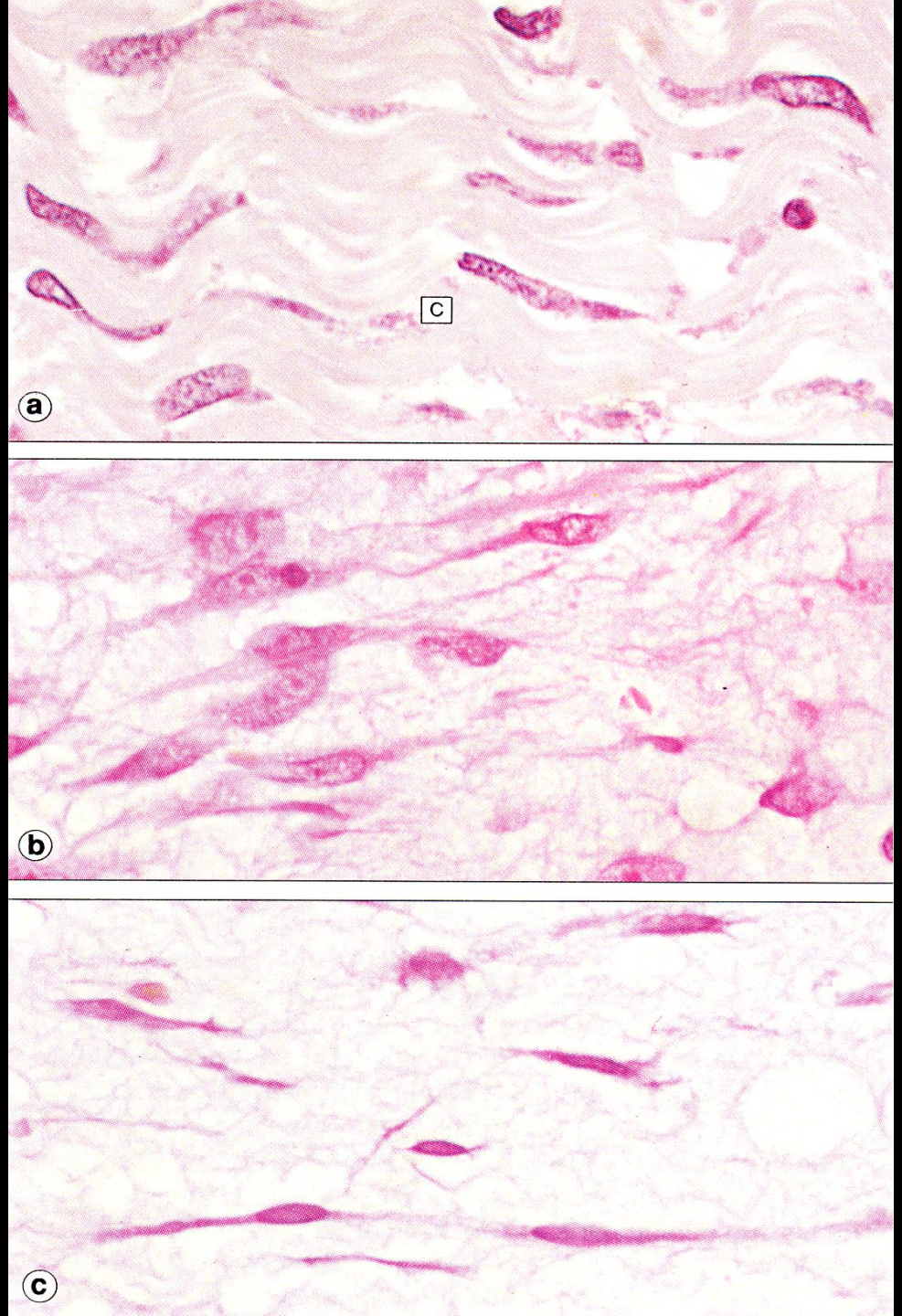
Connective tissue

fixed cells

mesenchyme

fibroblasts

fibrocytes




collagen fibrils
forming fibers
fibroblast

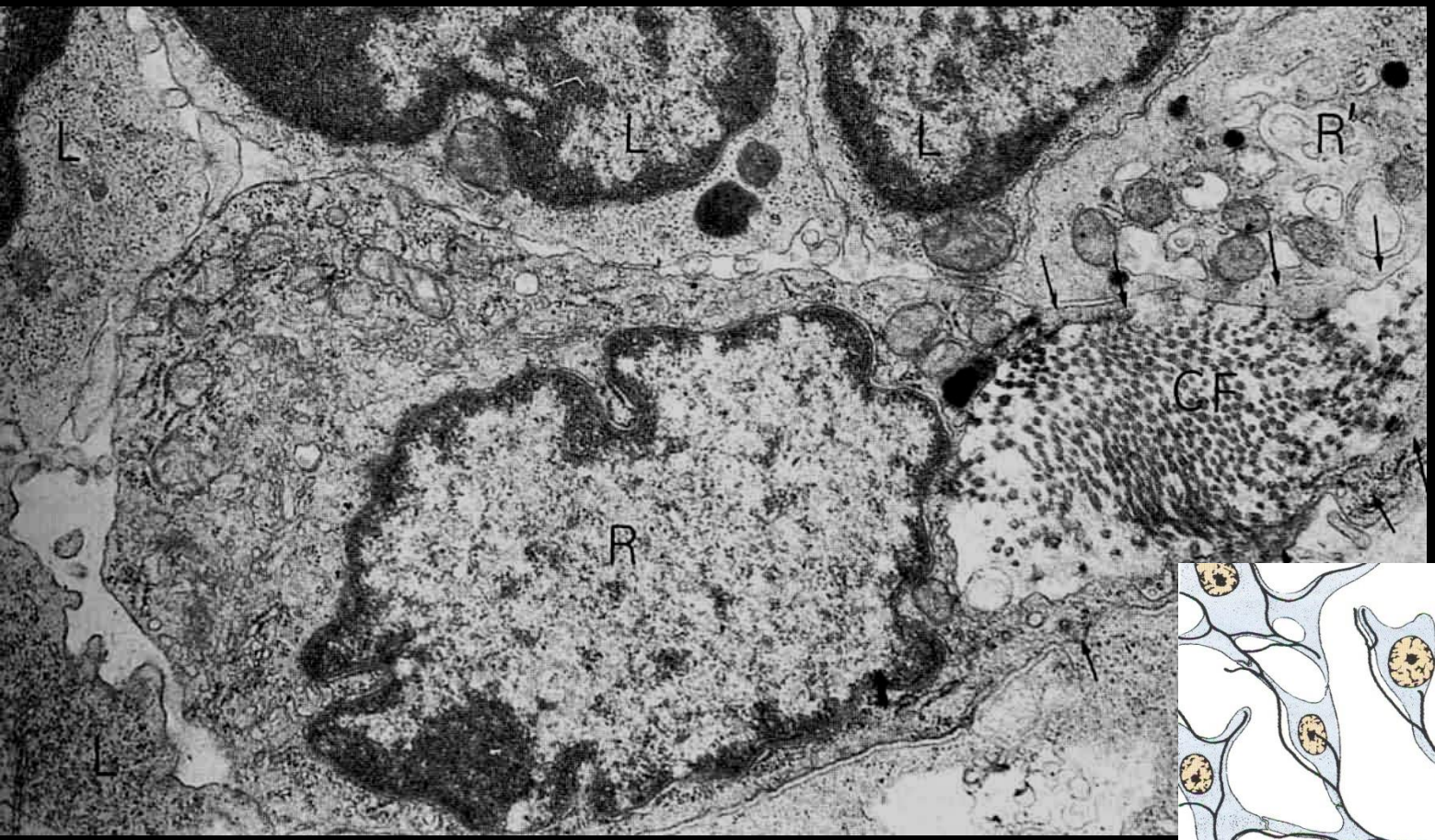
myofibroblast

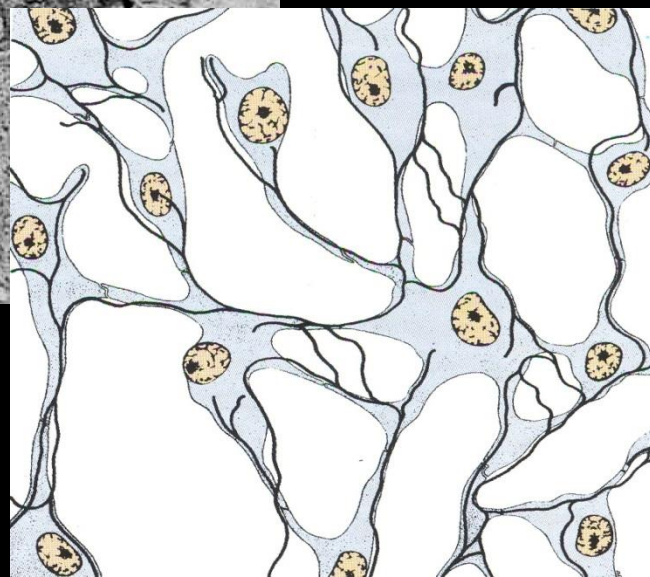
- is not surrounded by external (superficial) lamina
- contains dense bodies

reticular cells (R and R')

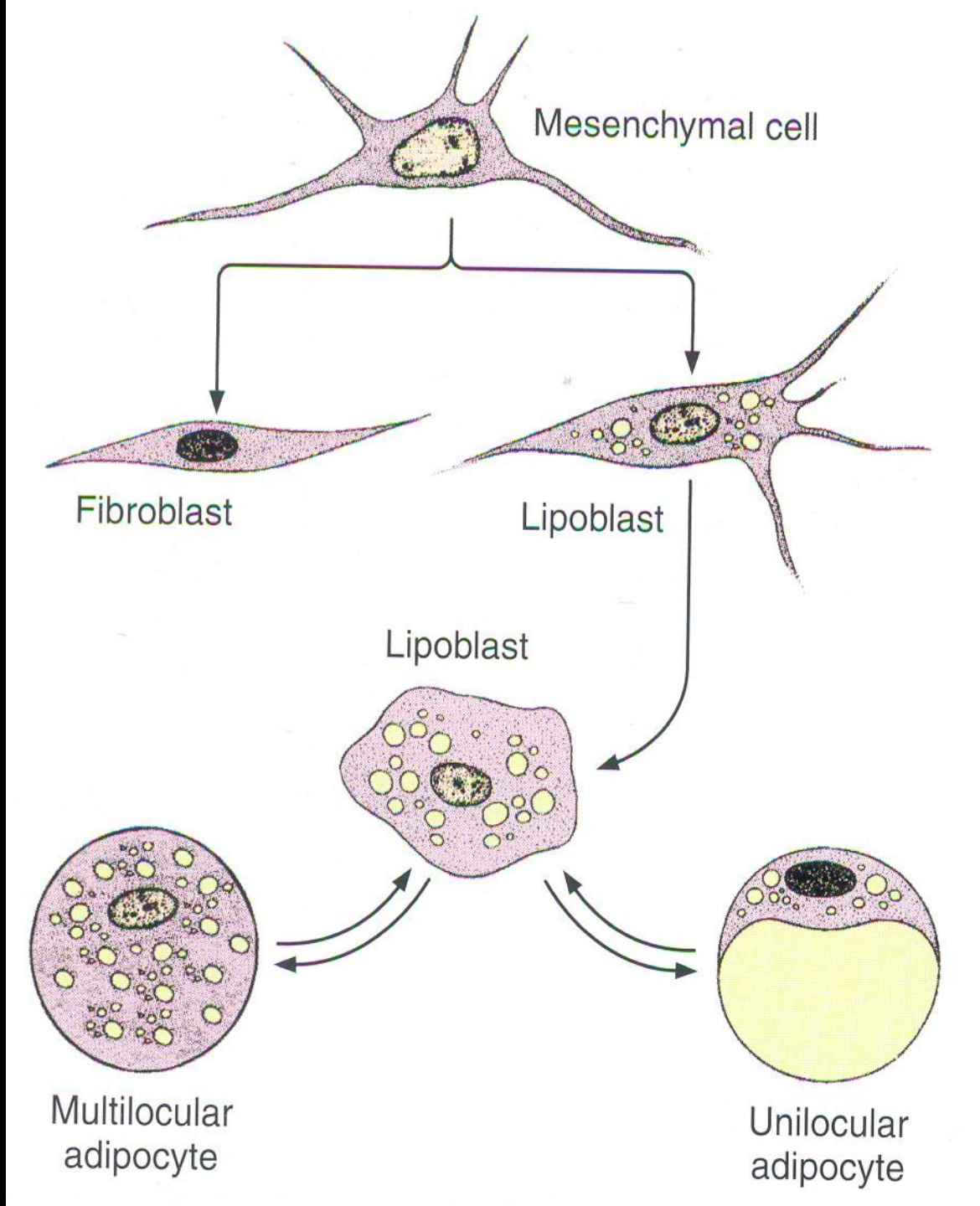
L = lymphocytes

CF = reticular fiber surrounded by reticular cell processes (arrows)





differentiation of adipocytes




unilocular adipocytes

2 unilocular adipocytes

L = lipid droplets

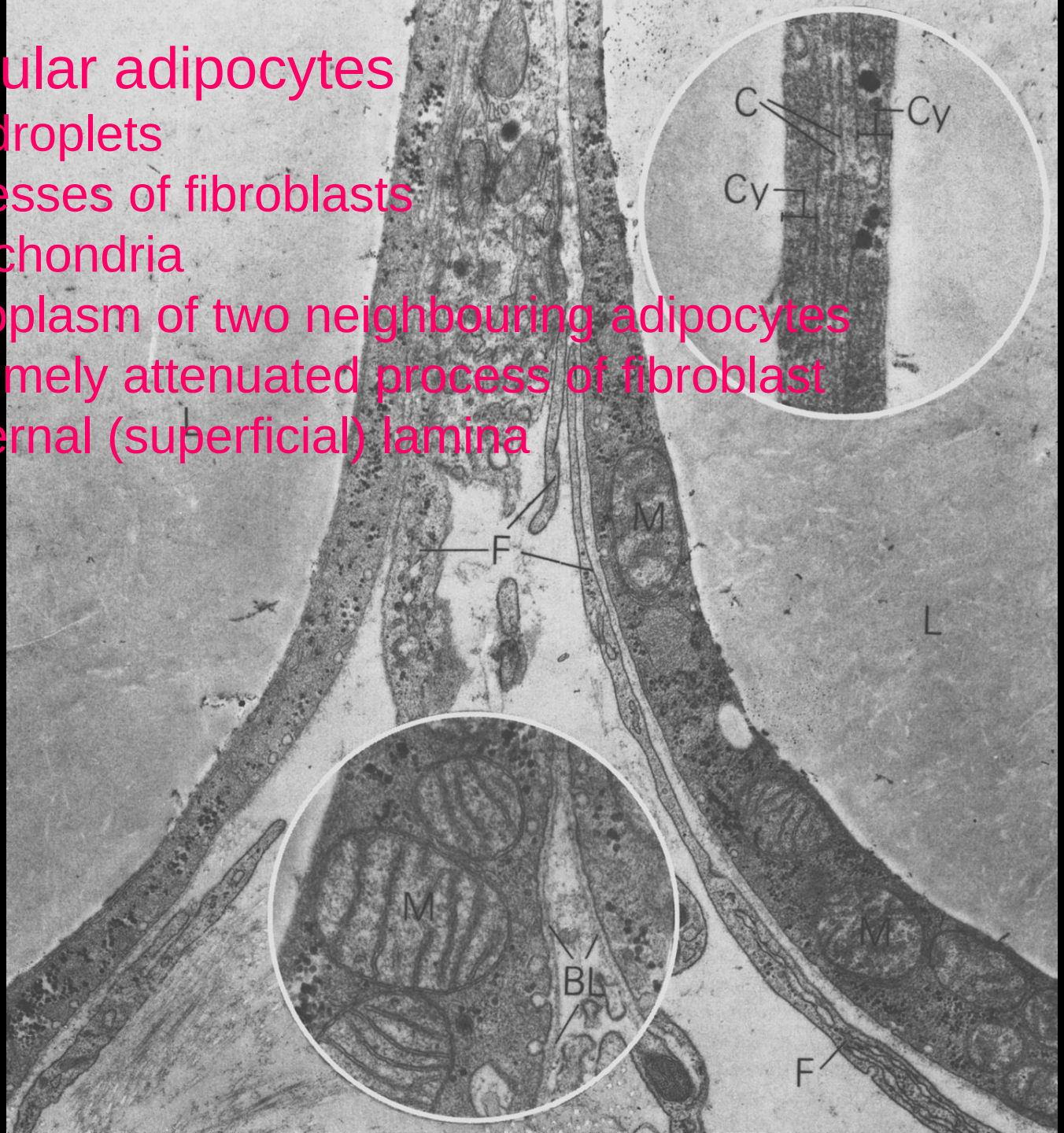
F = processes of fibroblasts

M = mitochondria

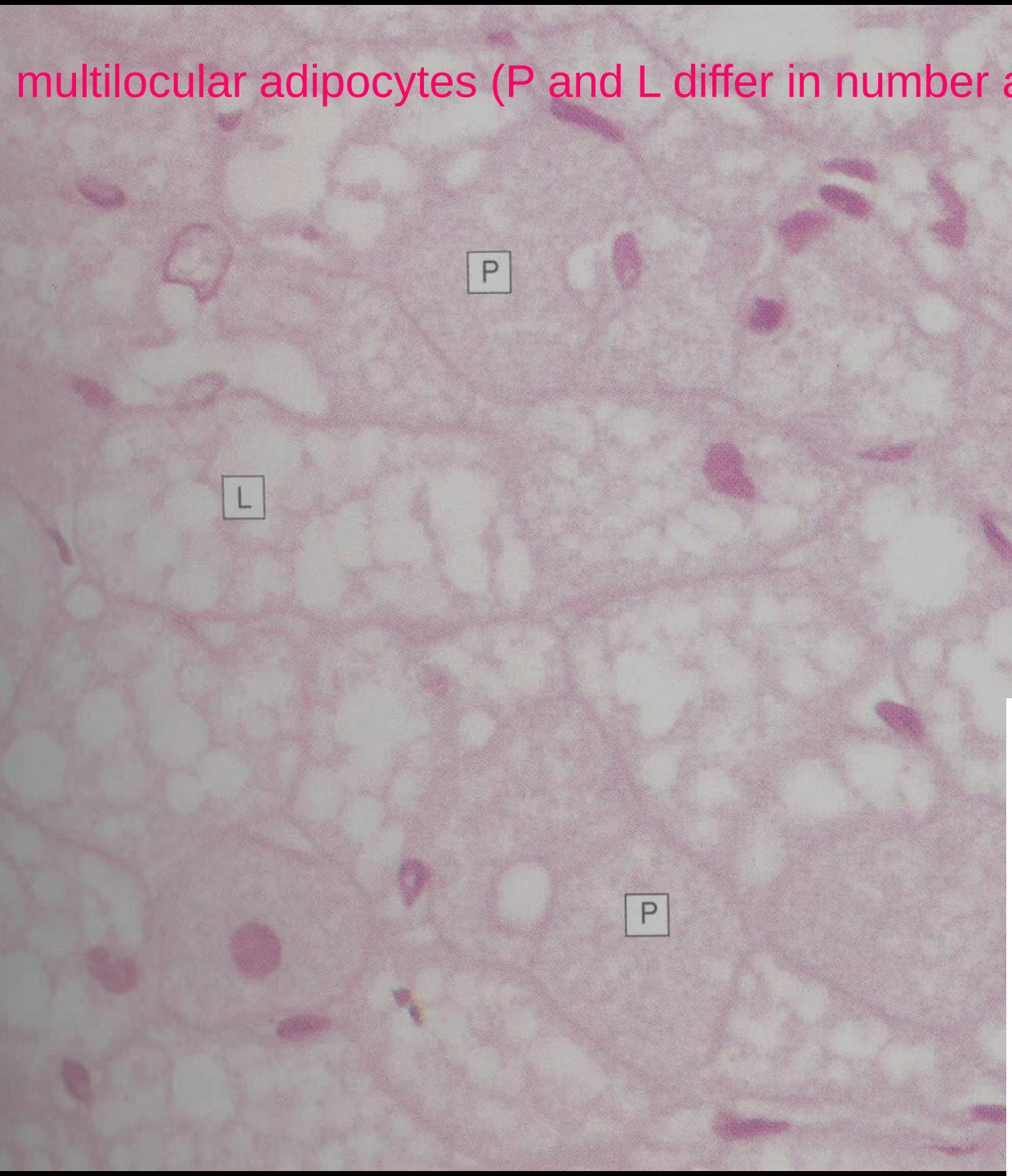
Cy = cytoplasm of two neighbouring adipocytes

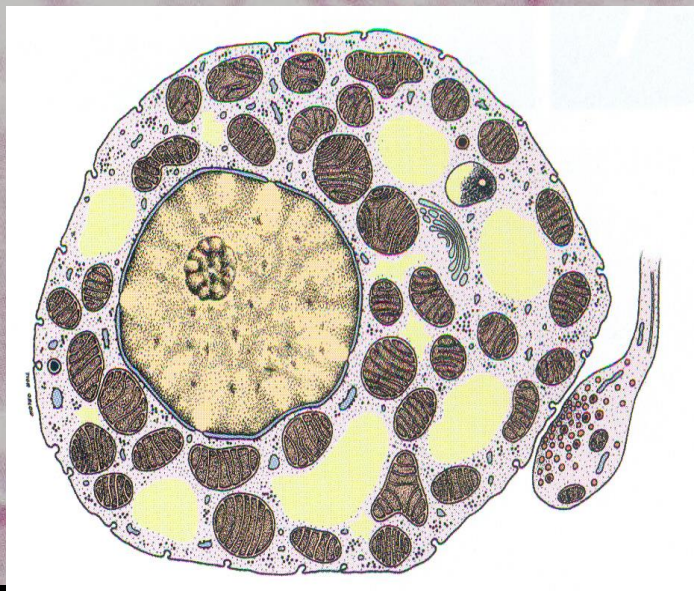
C = extremely attenuated process of fibroblast

BL = external (superficial) lamina



multilocular adipocytes (P and L differ in number and size of lipid droplets)





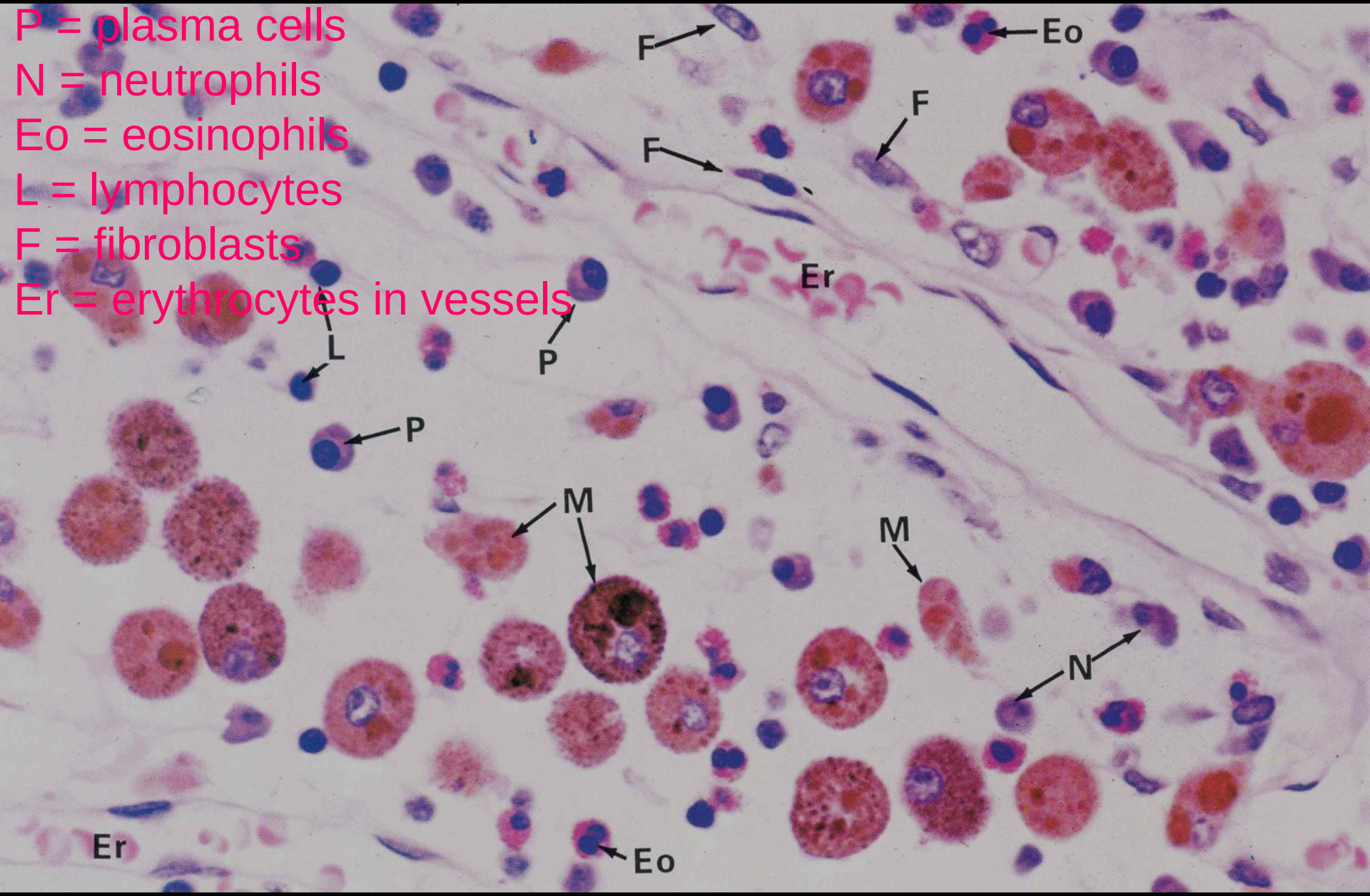

chondroblasts
chondrocytes


osteoblasts
osteocytes

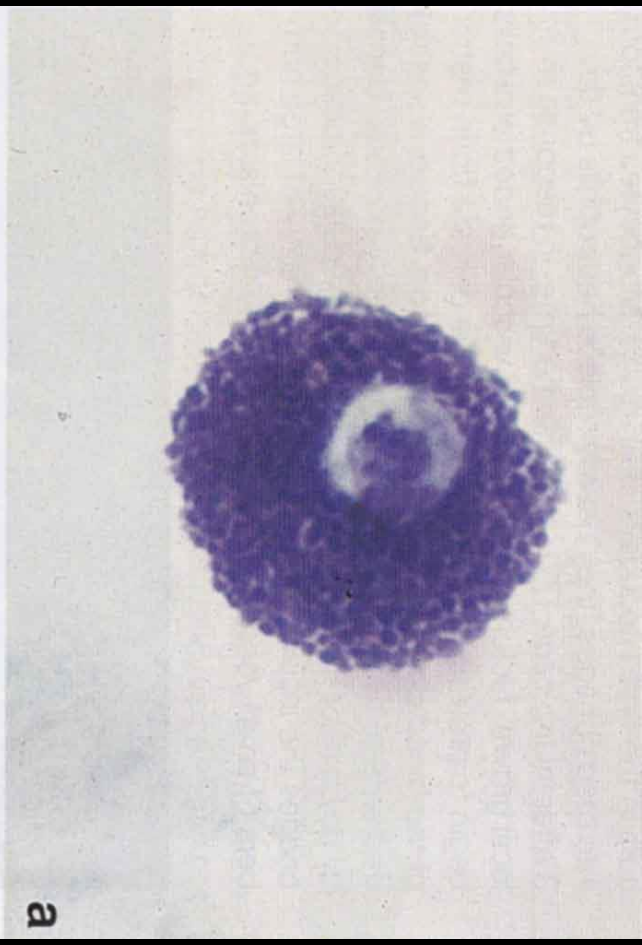
Connective tissue

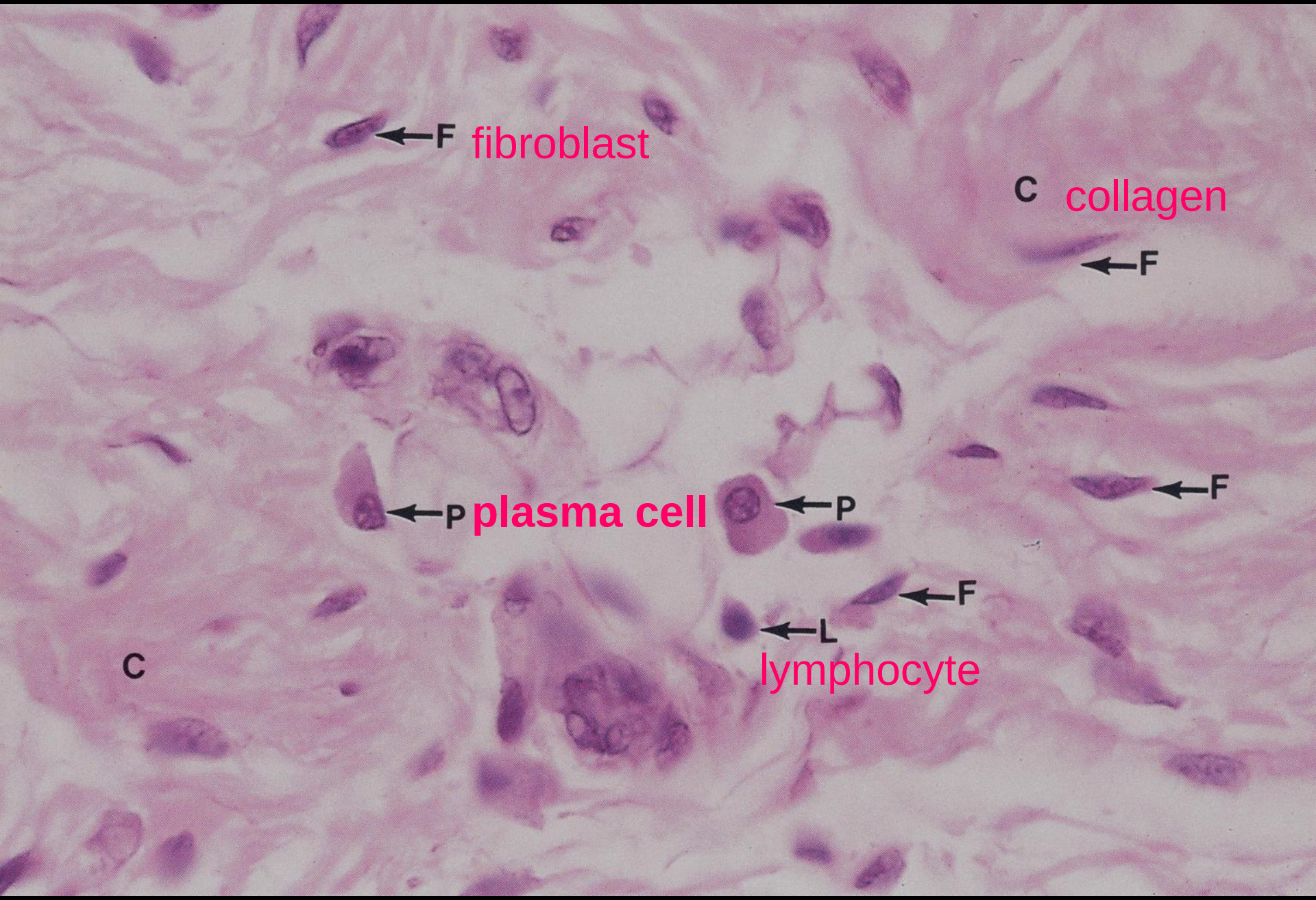
migratory cells

M = macrophages
P = plasma cells
N = neutrophils
Eo = eosinophils
L = lymphocytes
F = fibroblasts
Er = erythrocytes in vessels

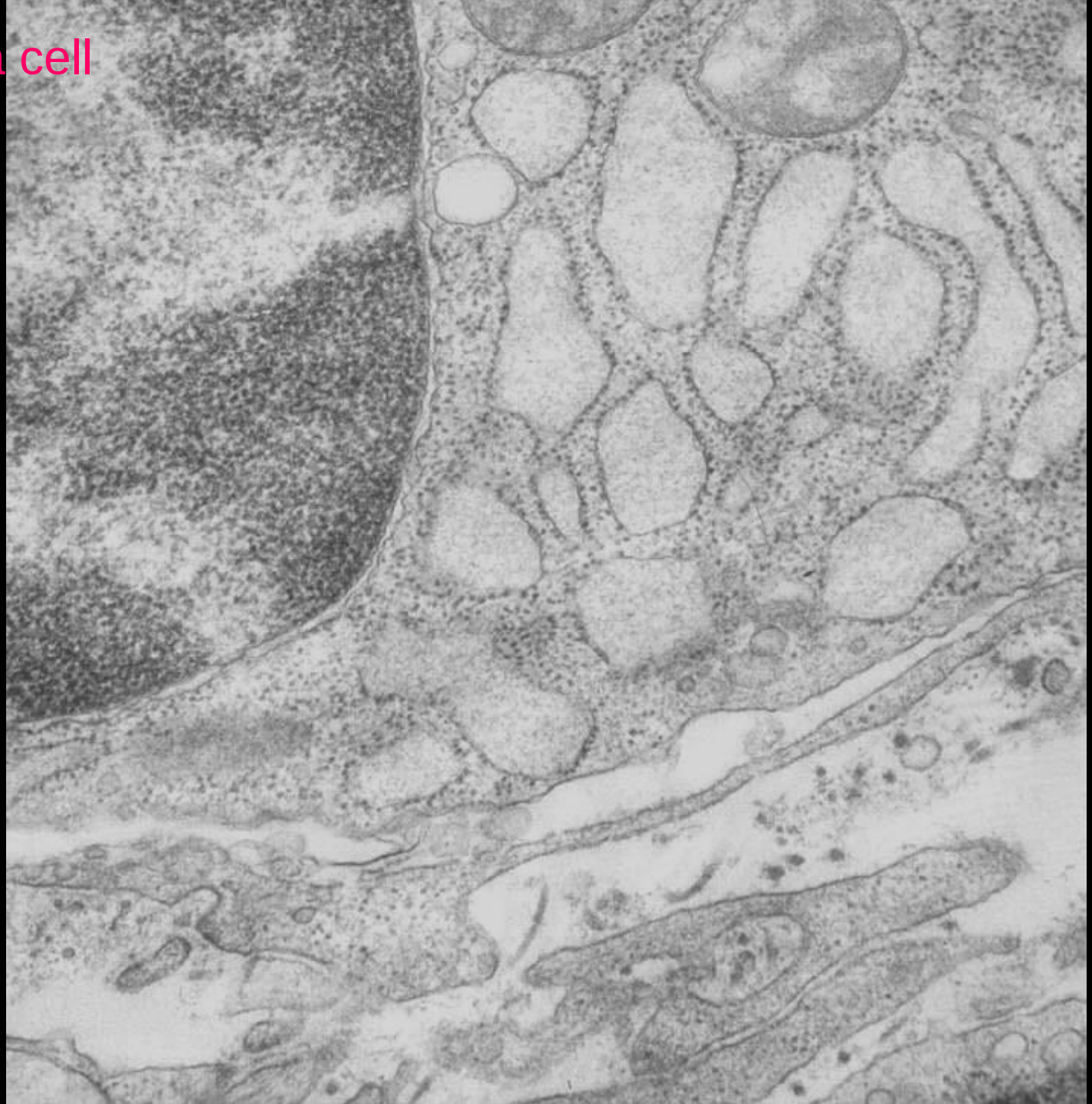


mast cells




F
fibroblast
C
collagen
F
P
plasma cell
P
F
F
L
lymphocyte
C

plasma cell

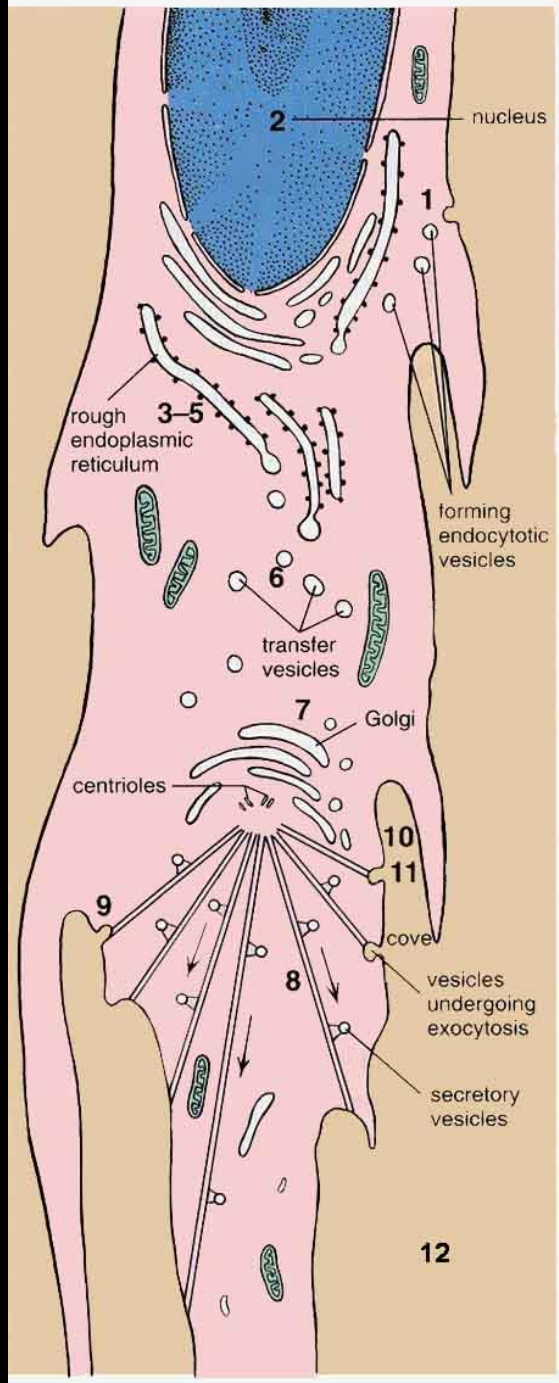



osteoclast

Connective tissue

intercellular matrix

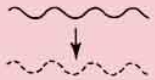
Synthesis and secretion of collagen



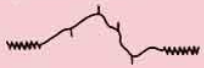
INTRACELLULAR EVENTS

1 Uptake of amino acids (proline, lysine, etc.) by endocytosis

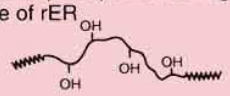
2 Formation of mRNA



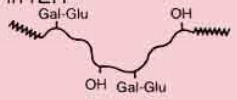
3 Synthesis of α chains with registration peptides by ribosomes



4 Hydroxylation of proline and lysine residues (vitamin C required) and cleavage of signal sequence of rER



5 Glycosylation of specific hydroxylysyl residues in rER



6 Formation of procollagen triple helix molecules in rER and movement into transfer vesicle

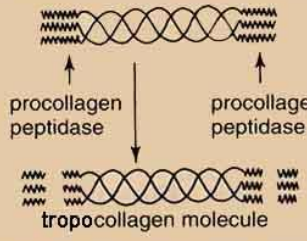
7 Packaging of procollagen by Golgi into secretory vesicles

8 Movement of vesicles to plasma membrane, assisted by microfilaments and microtubules

9 Exocytosis of procollagen

EXTRACELLULAR EVENTS

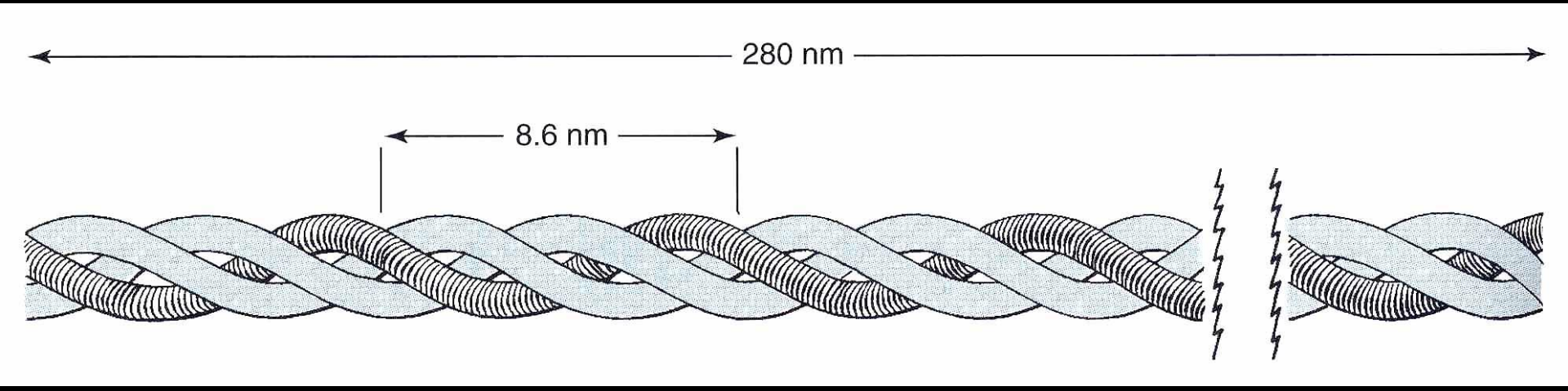
10 Cleavage of registered, nonhelical ends of procollagen to form **tropo**collagen molecule



11 Polymerization of **tropo**collagen molecule into **proto**fibril (in coves initially)

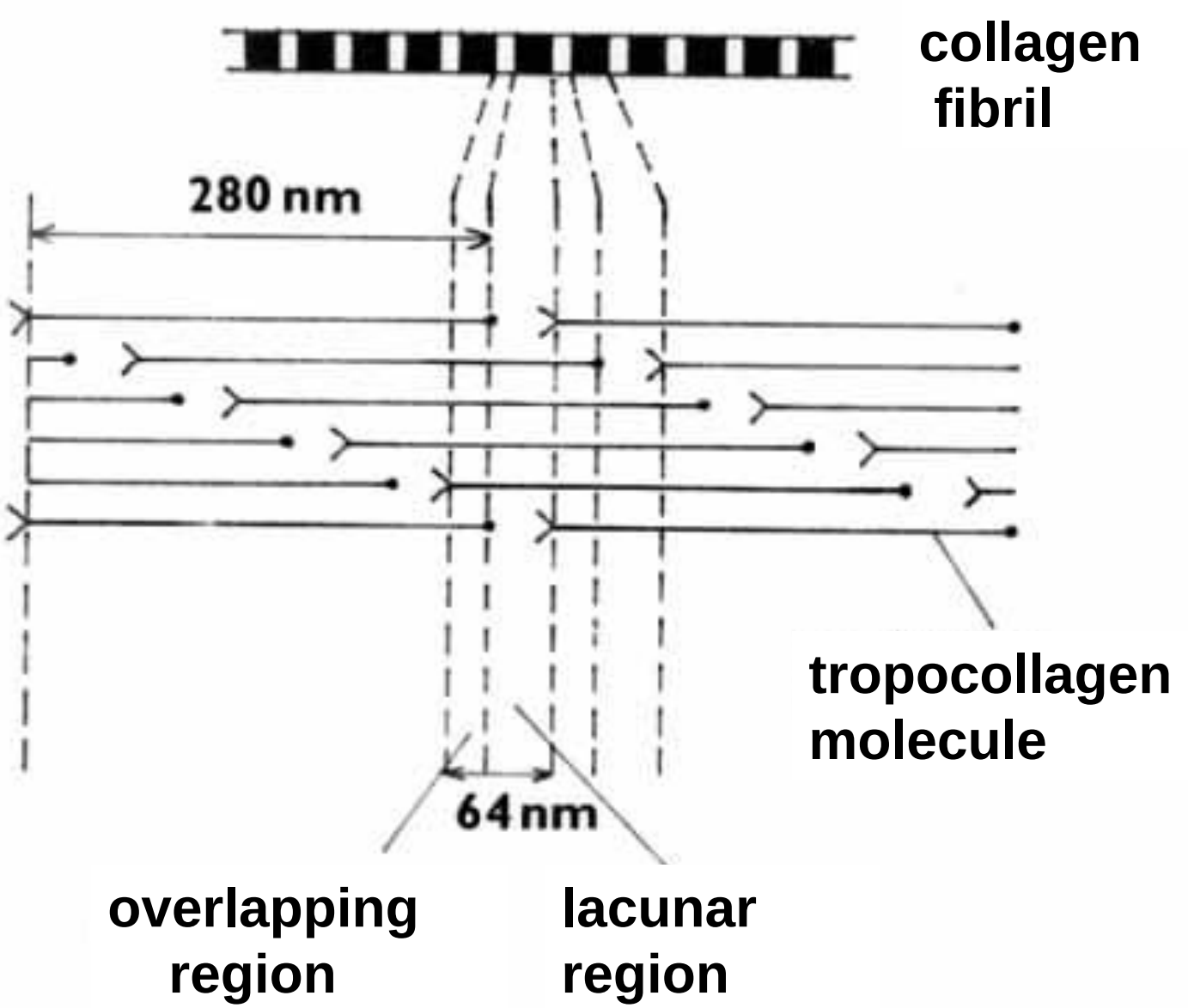
12 Parallel aggregation of protofibrils into fibrils

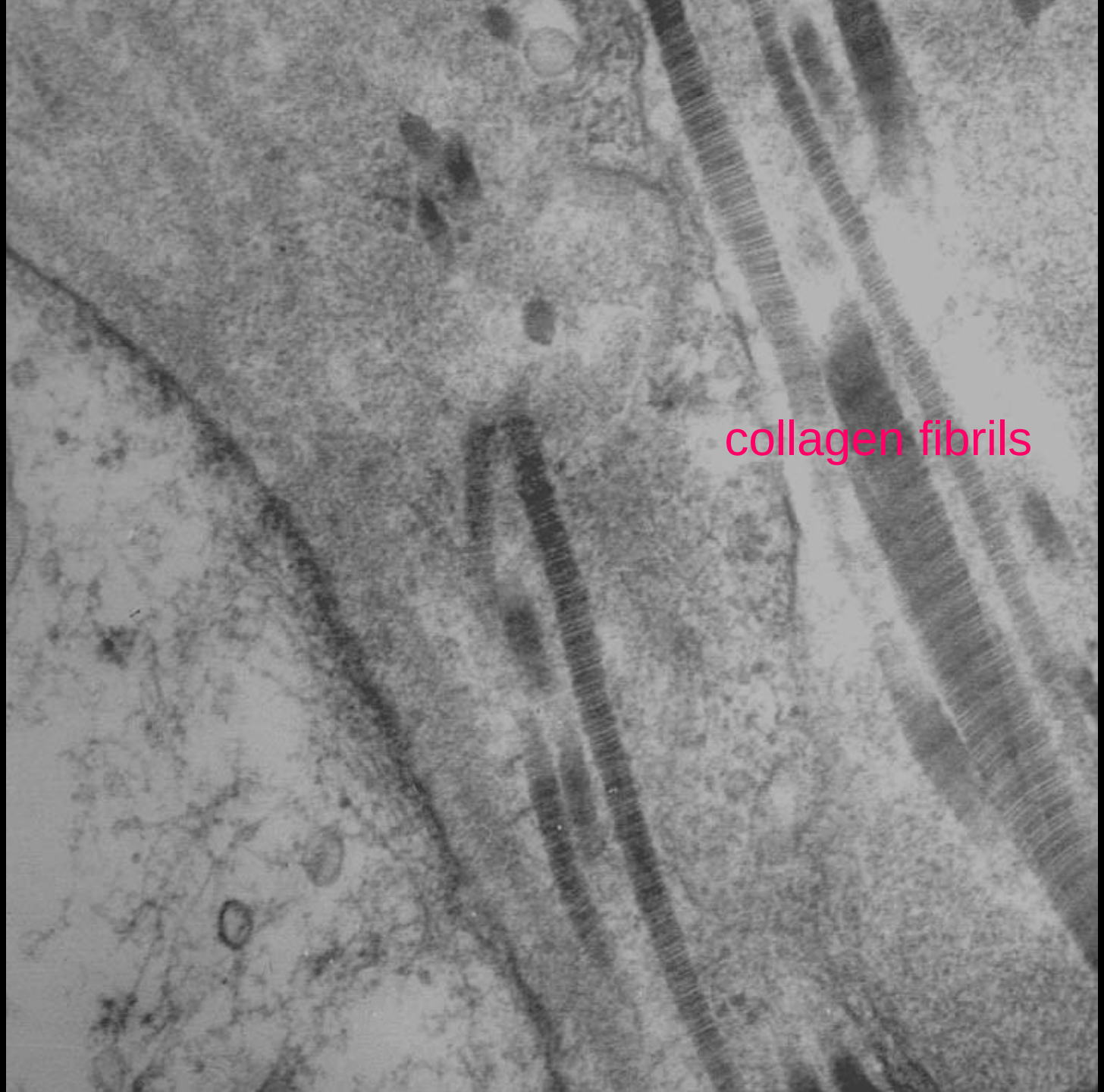
(Tropo)collagen

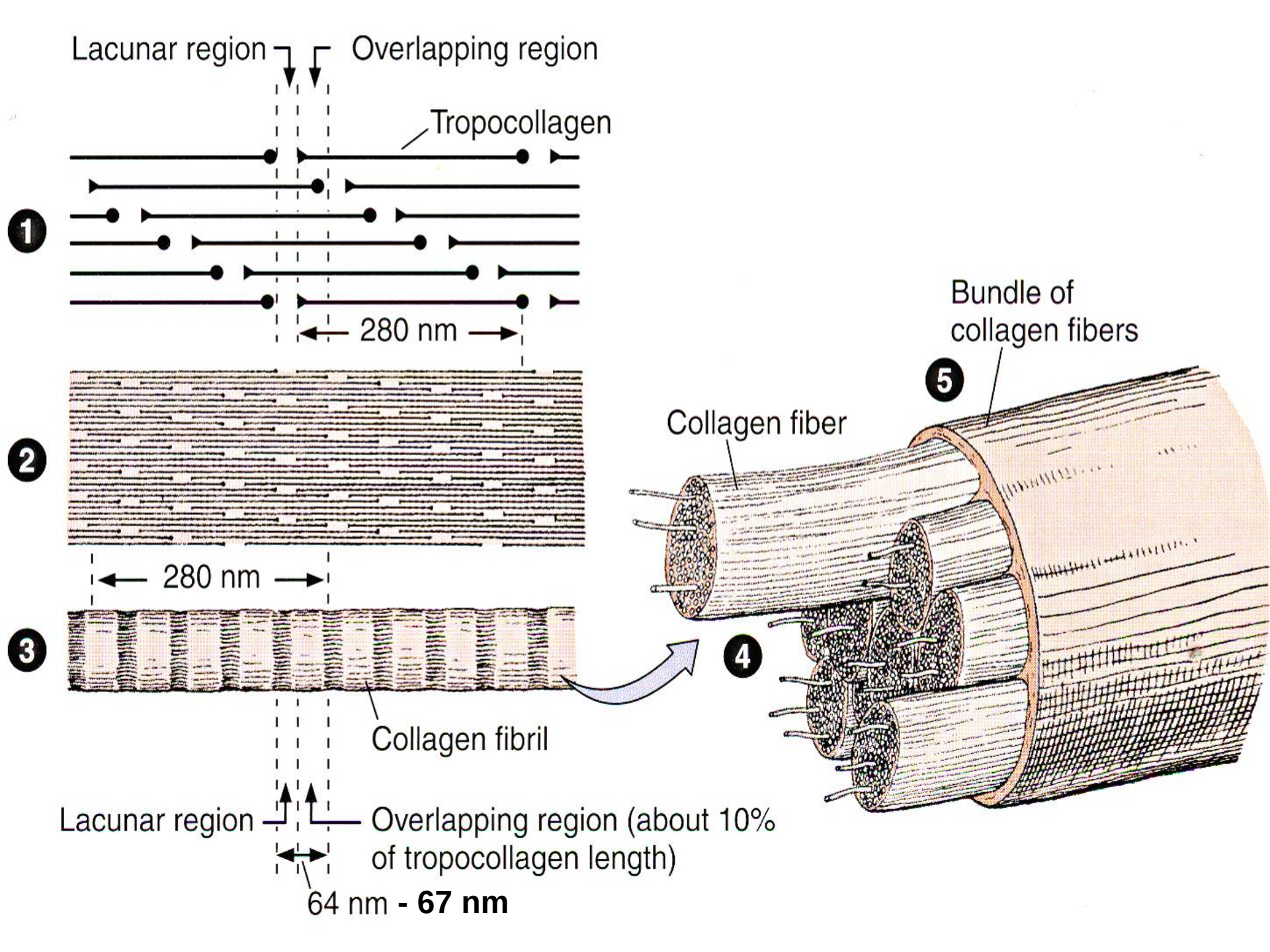


width 1.5 nm
length 280 – 300 nm
triple helix
heterotrimeric molecules (2 α_1 + 1 α_2 or α_1 + α_2 + α_3)
homotrimeric molecules (3 equal α chains)

COLLAGEN FIBRIL STRUCTURE




collagen fibrils


Lacunar region
Overlapping region
Tropocollagen
1
280 nm
2
280 nm
3
Collagen fibril
Lacunar region
Overlapping region (about 10% of tropocollagen length)
64 nm - 67 nm
4
Collagen fiber
5
Bundle of collagen fibers

COLLAGEN

1. fibrillar collagens

- a) types I, II, III, V (collagen type V forms cofibrils with type I and III collagens)
- b) types IX, XII, XIV (form fibrils associated with type I collagen)
- c) type VI (external lamina of muscle tissue, cartilage)
- d) type VII (forms anchoring fibrils)

2. non-fibrillar collagens

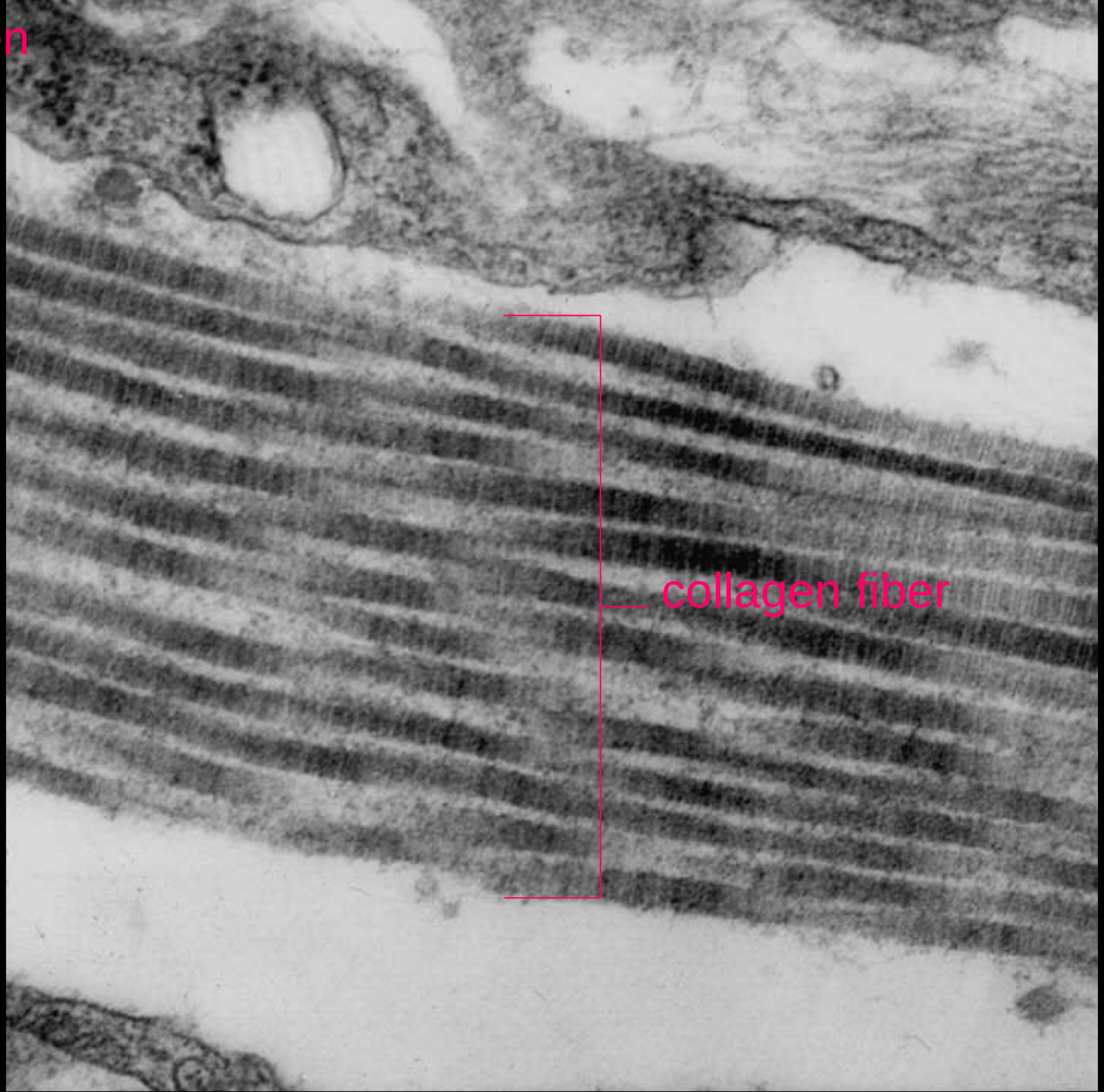
- a) type IV (forms mesh-like structure)


COLLAGEN
COLLAGEN EVERYWHERE
imgflip.com

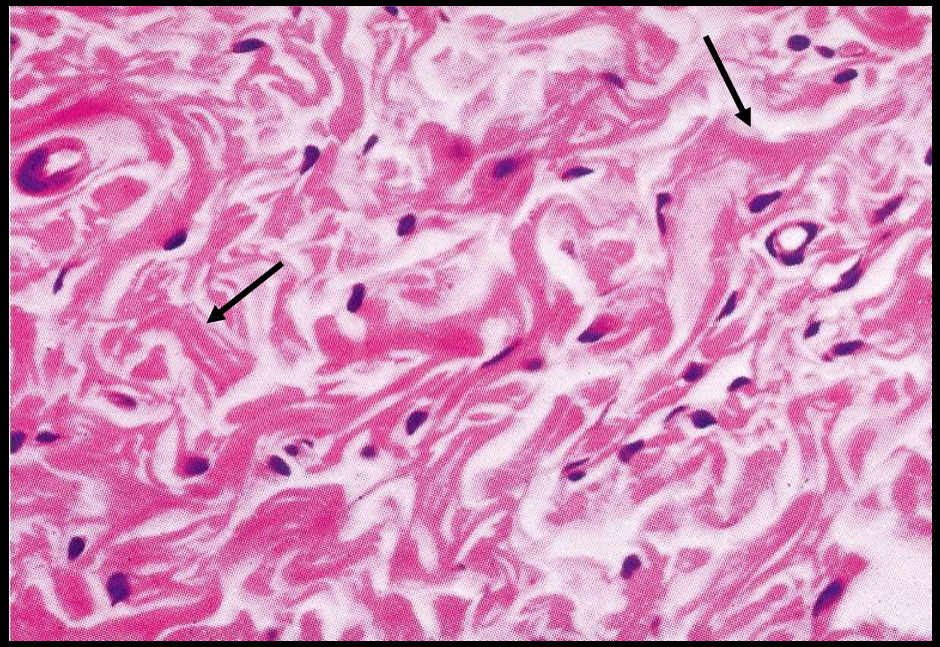
Important collagen types

Type	occurrence	fibrils	fibers
I	collagen fibers (connective tissue proper, fibrocartilage, bone)	Ø 75 nm	Ø 2 – 20 µm
II	cartilage	Ø 20 nm	none
III	reticular fibers (connective tissue proper)	Ø 45 nm	Ø 0,1 – 2 µm
IV	basal and superficial laminae	none	none

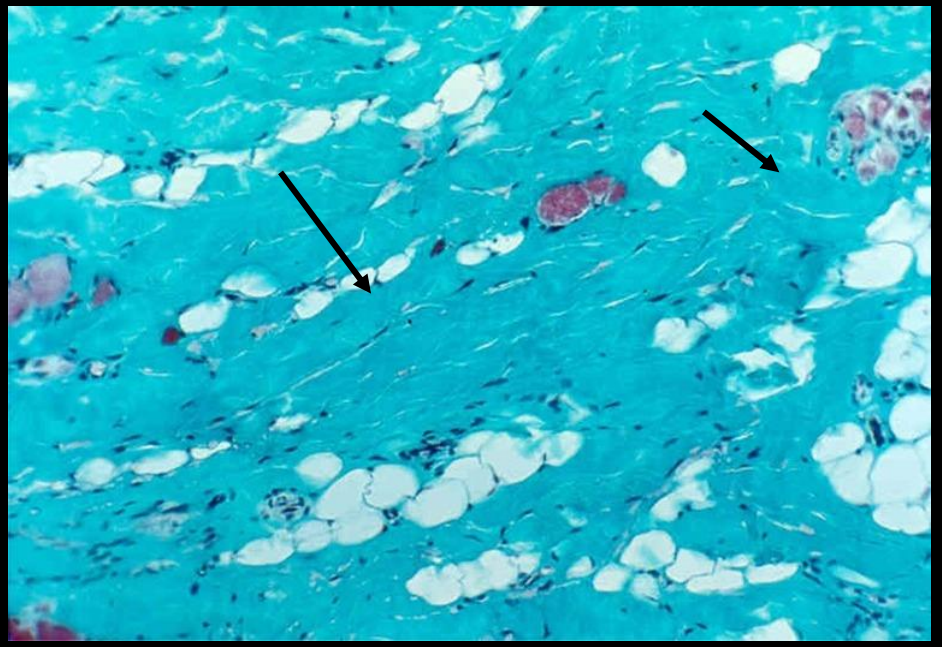
Collagen type I



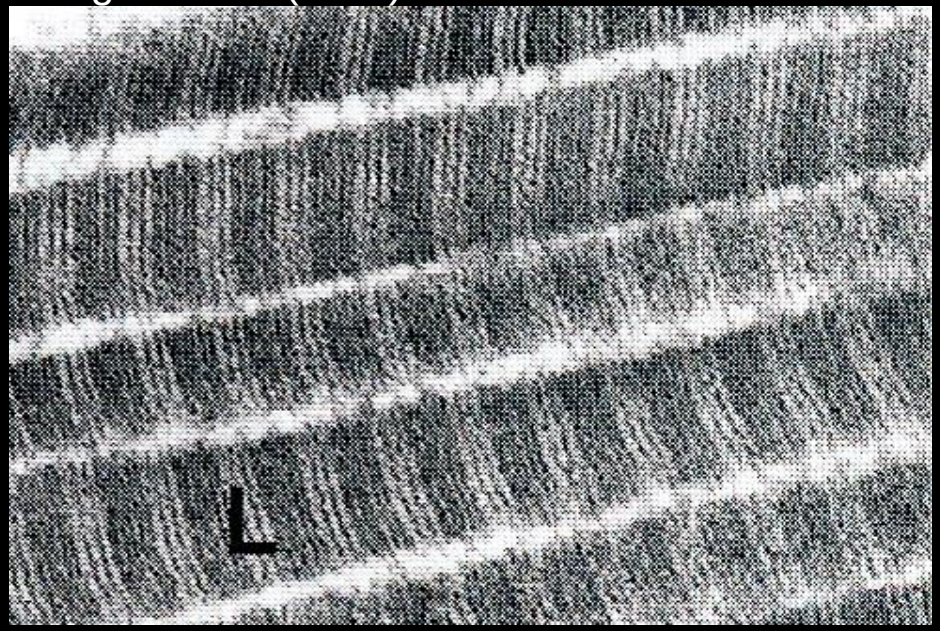
collagen fibers (HE)



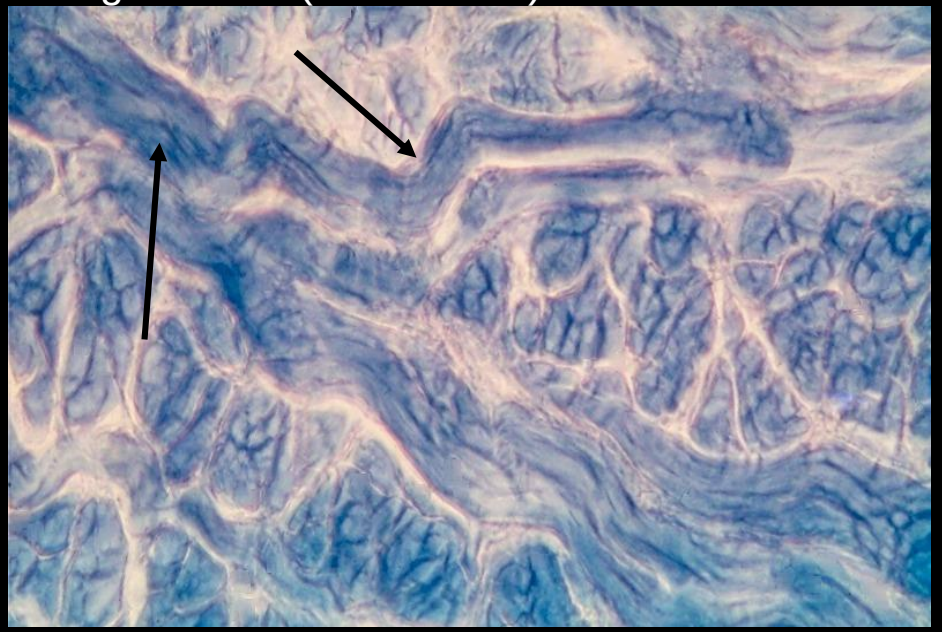
collagen fibers (green trichrom)

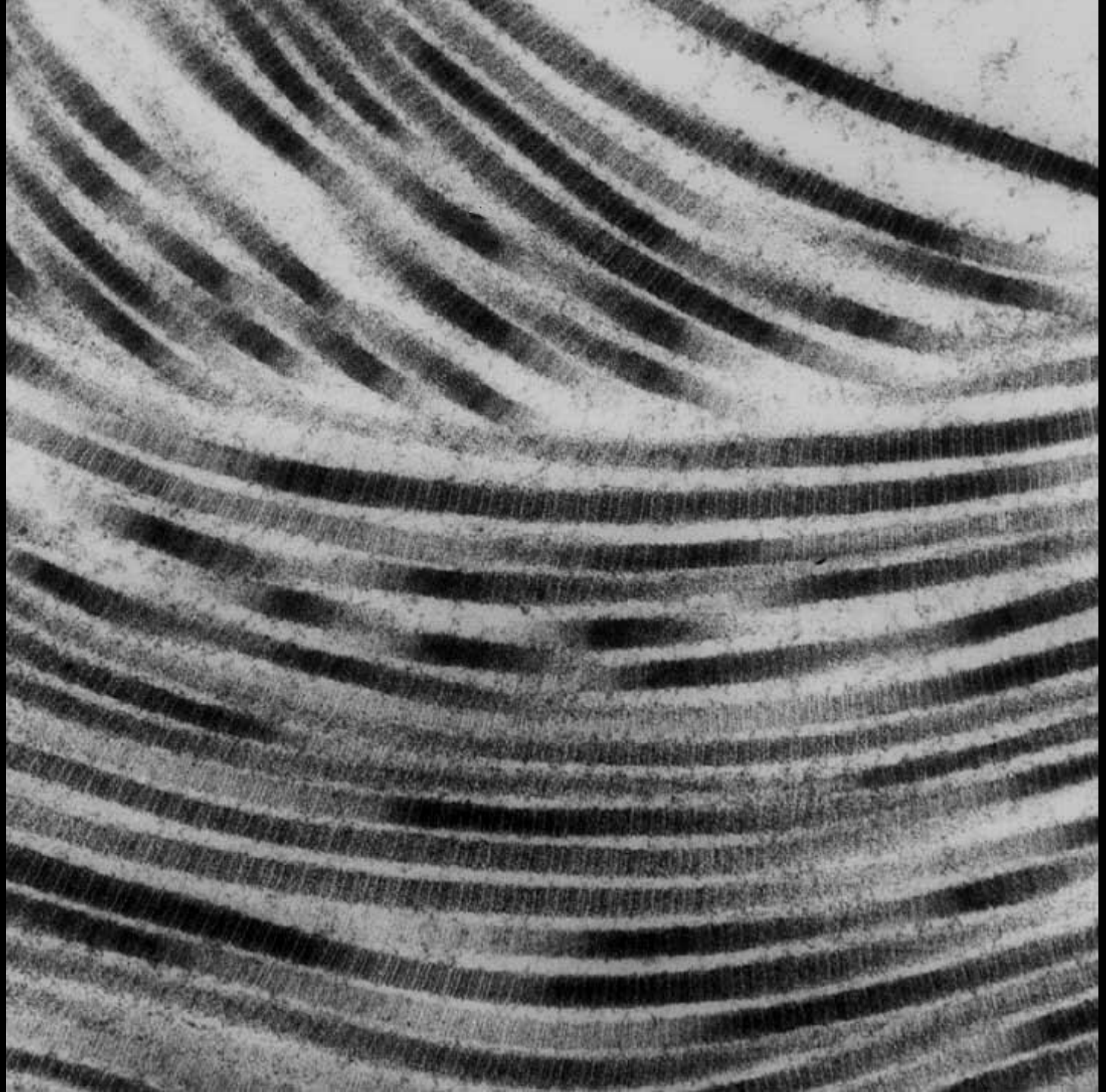


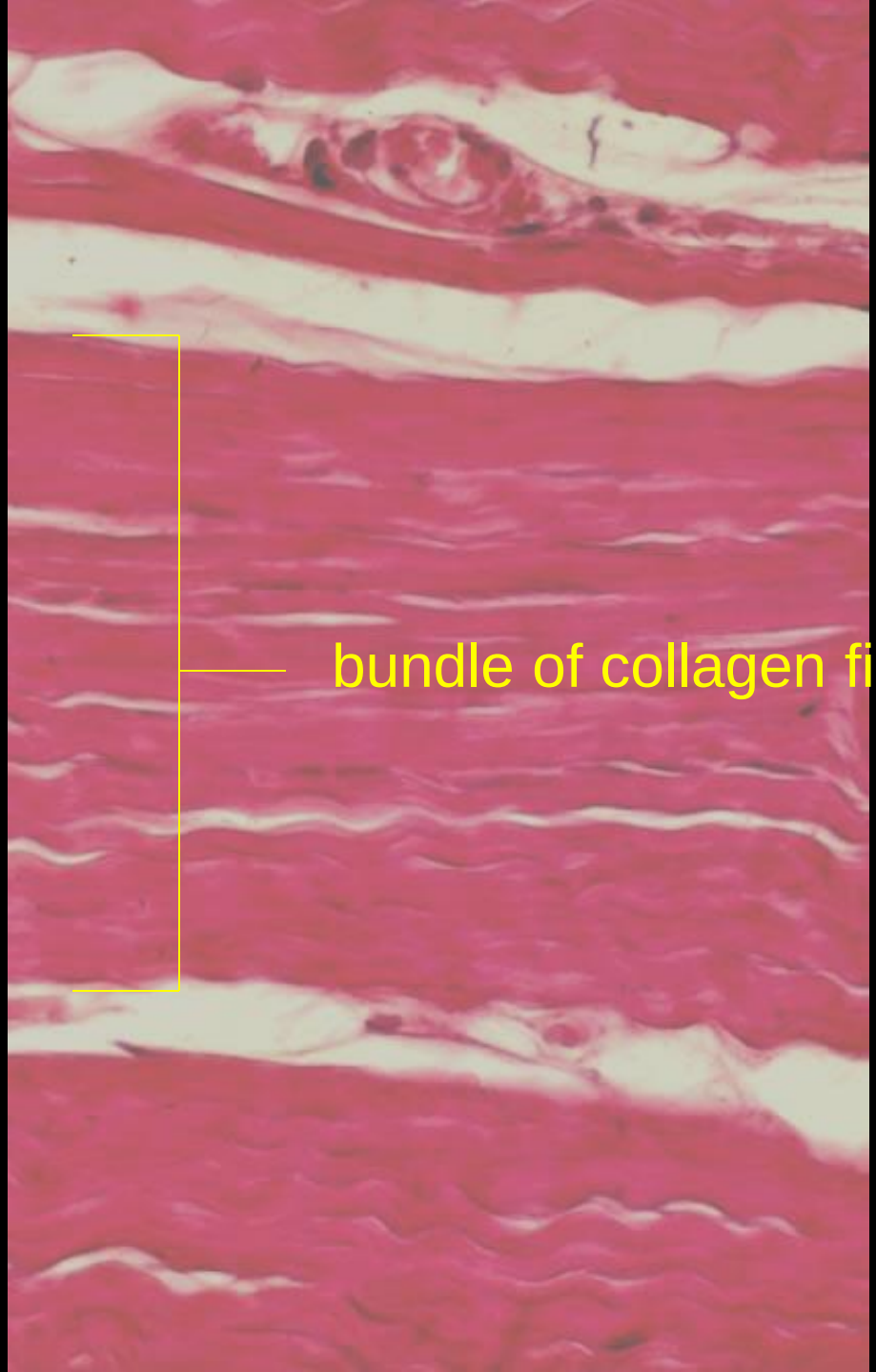
collagen fibrils (TEM)



collagen fibers (aniline blue)

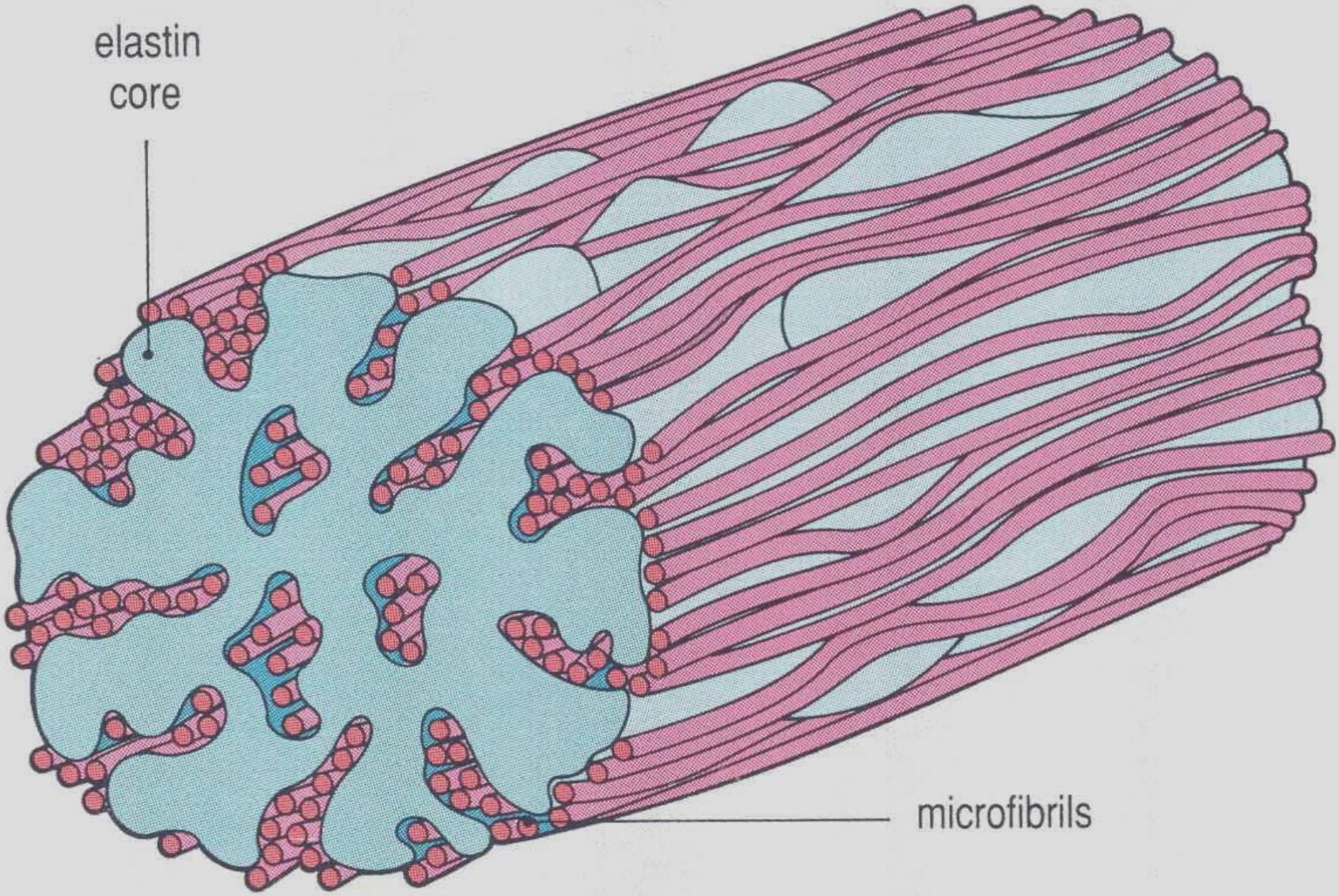


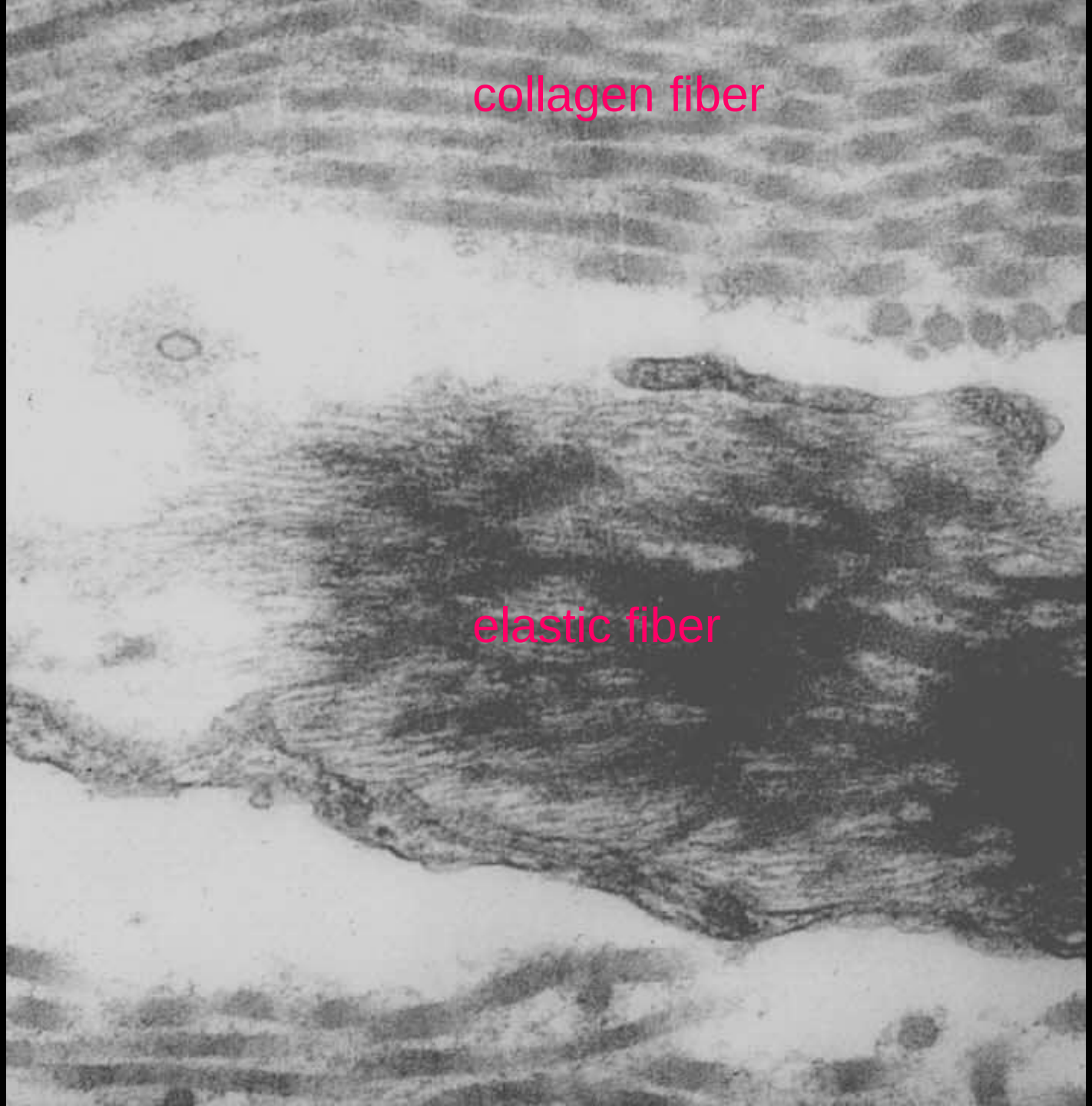



bundle of collagen fibers

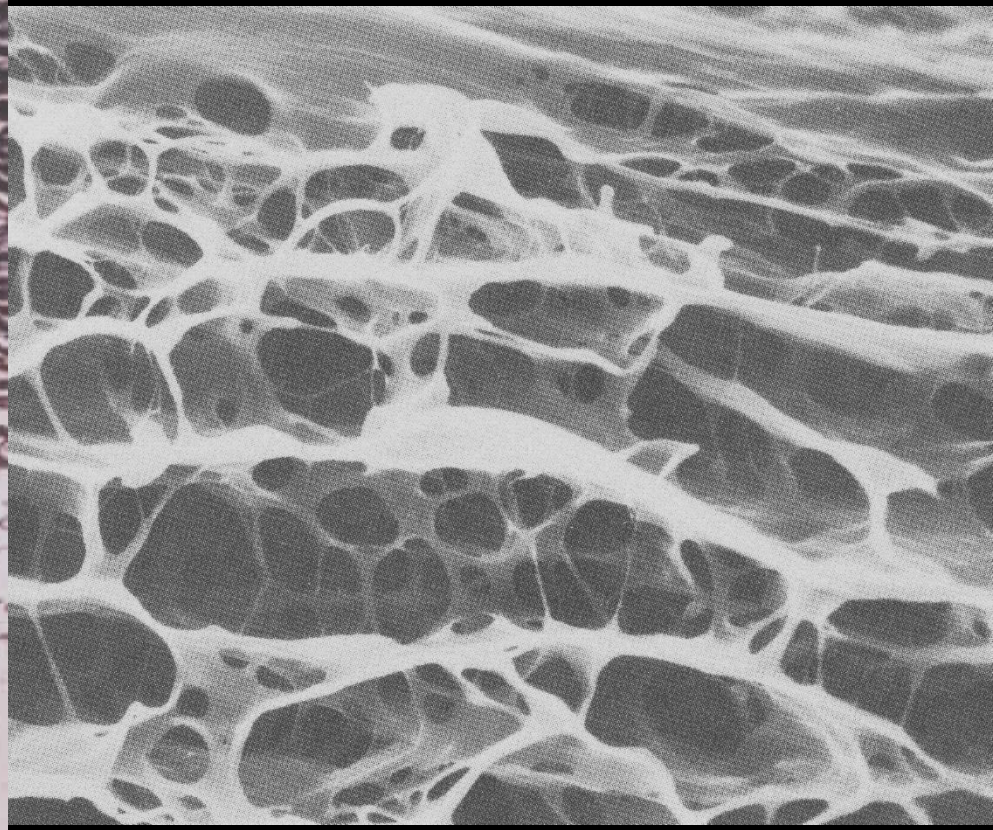

reticular
fiber
collagen
fiber

Elastic fiber




collagen fiber
elastic fiber

membranae fenestratae
in the wall of a large artery

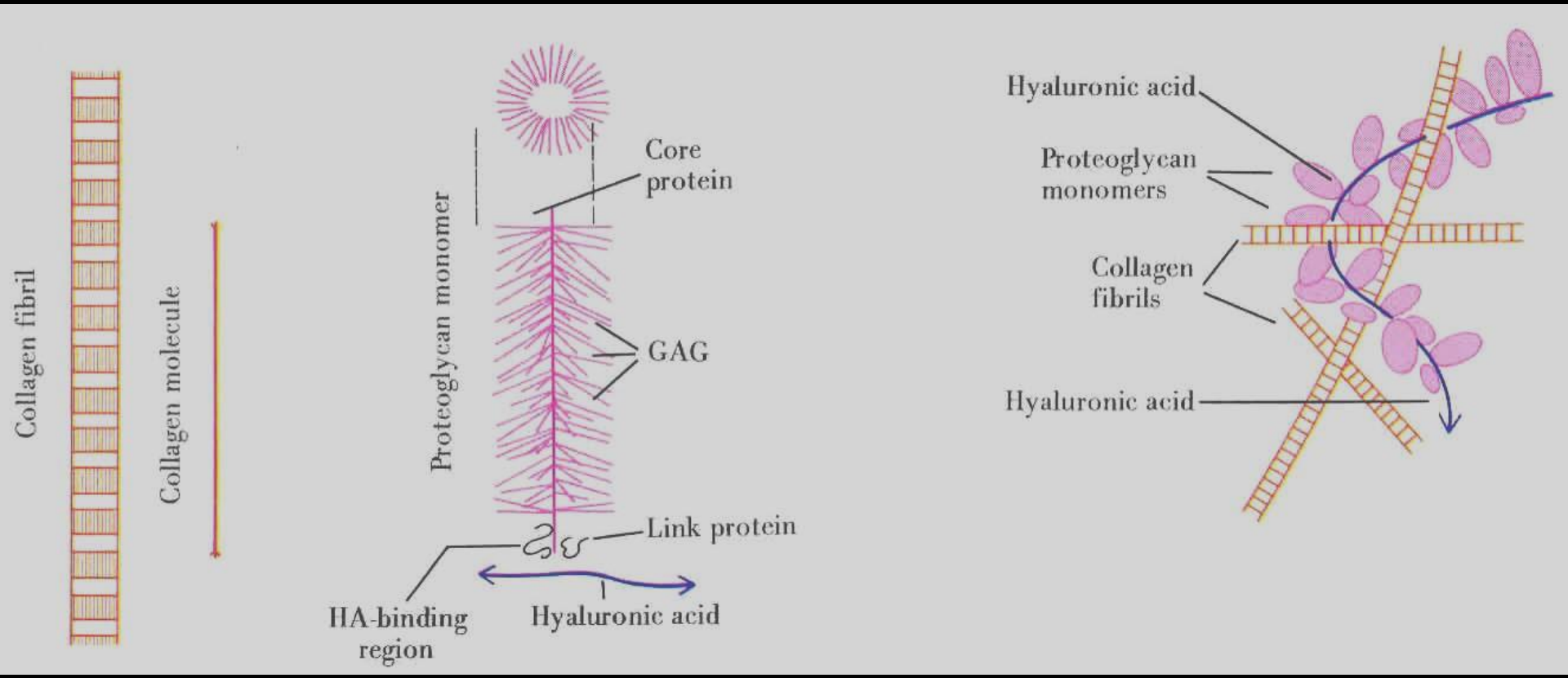


GLYCOSAMINOGLYCANS

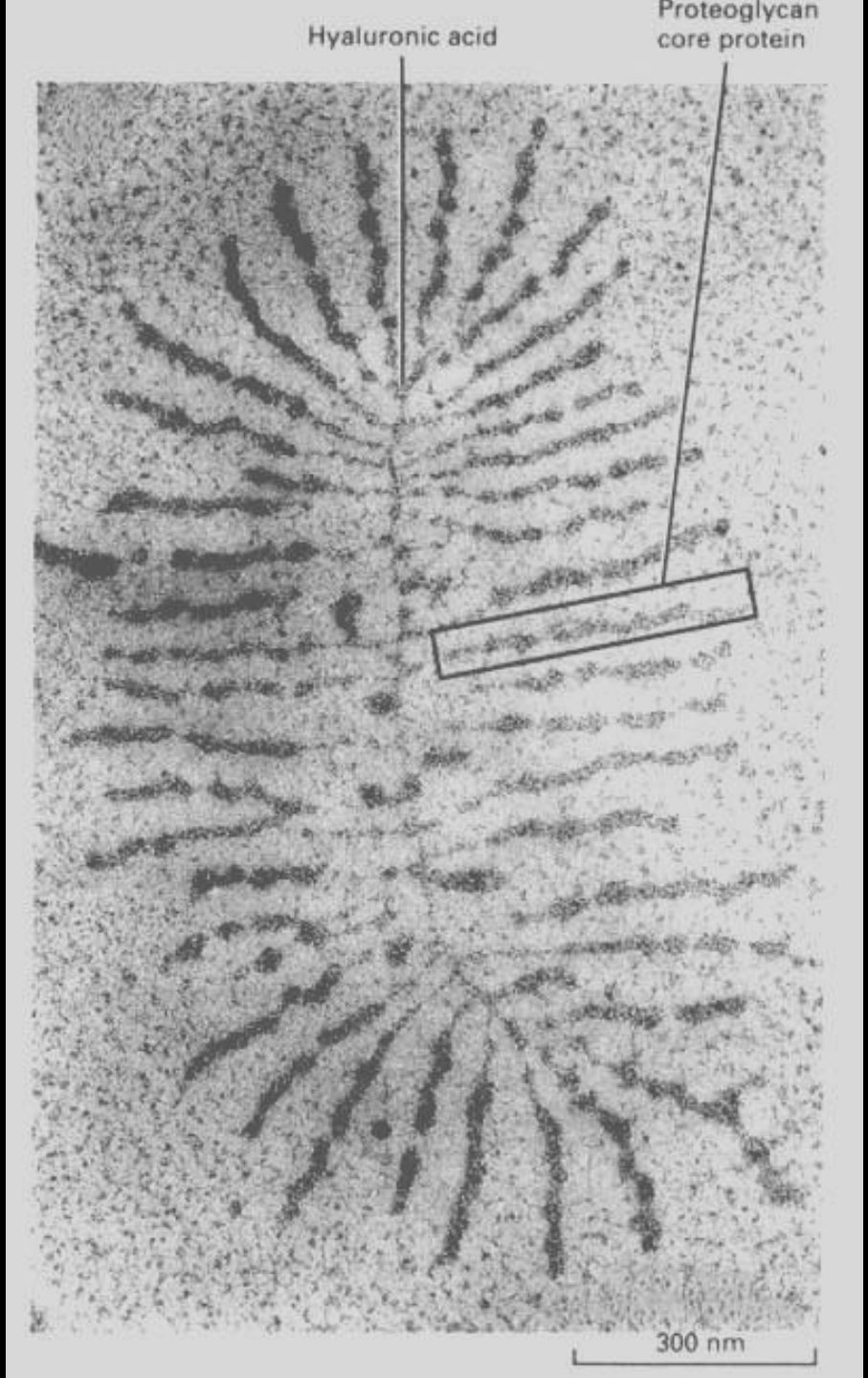
GAG	occurs in	interaction level	collagen type
hyaluronic acid	umbilical cord, synovial fluid, humor vitreus, cartilage	-	-
chondroitin sulphate	cartilage, bone, cornea. skin, aortic media	+++	II
dermatan sulphate	skin, tendon, aortic adventitia	+	I
heparan sulphate	aorta, lung, liver, basal lamina	++	III, IV
keratan sulphate	cornea, cartilage, nucleus pulposus, annulus fibrosus	-	-

uronic acid + N-acetylated saccharide

proteoglycans

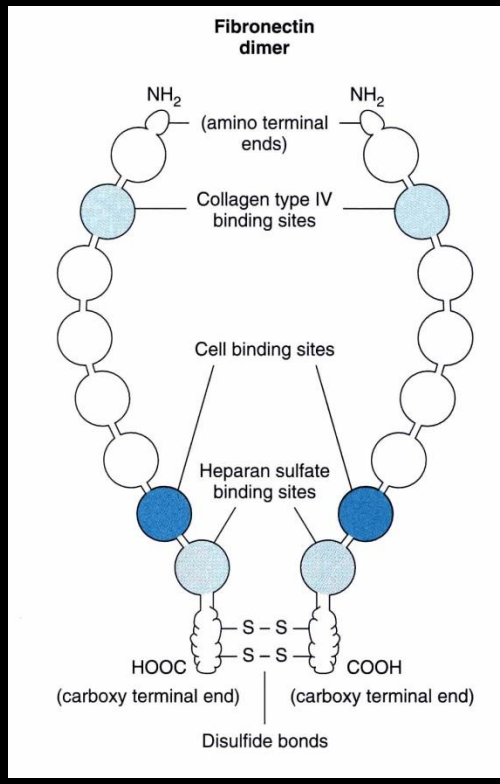


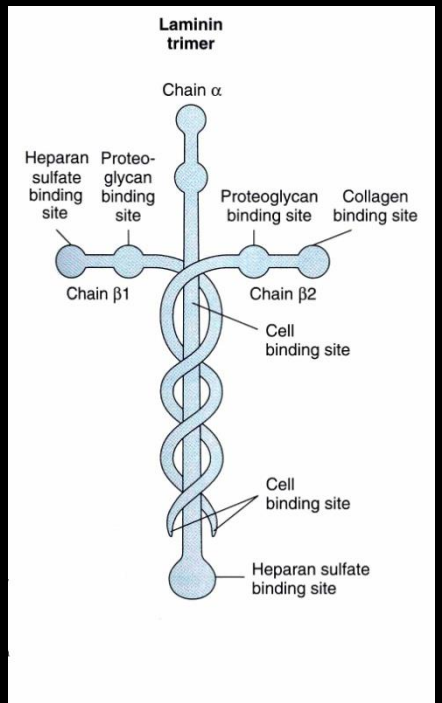
aggrecan

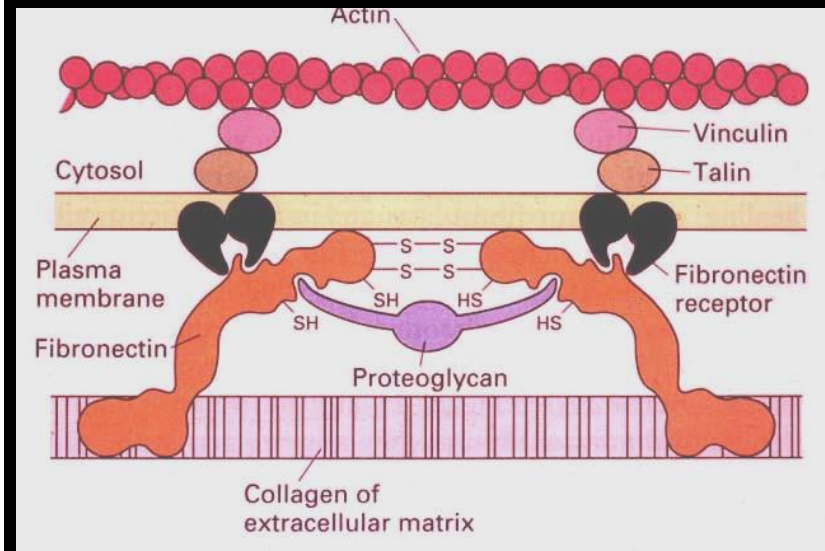


structural glycoproteins

fibronectin
chondronectin
osteonectin
osteopontin
fibrillin
vitronectin
tenascins
laminin







Connective tissue proper and its types

- **resident cells**
  fibroblasts, fibrocytes, myofibroblasts, reticular cells, adipocytes

- **migratory cells**
  macrophages, mast cells, plasma cells, leukocytes

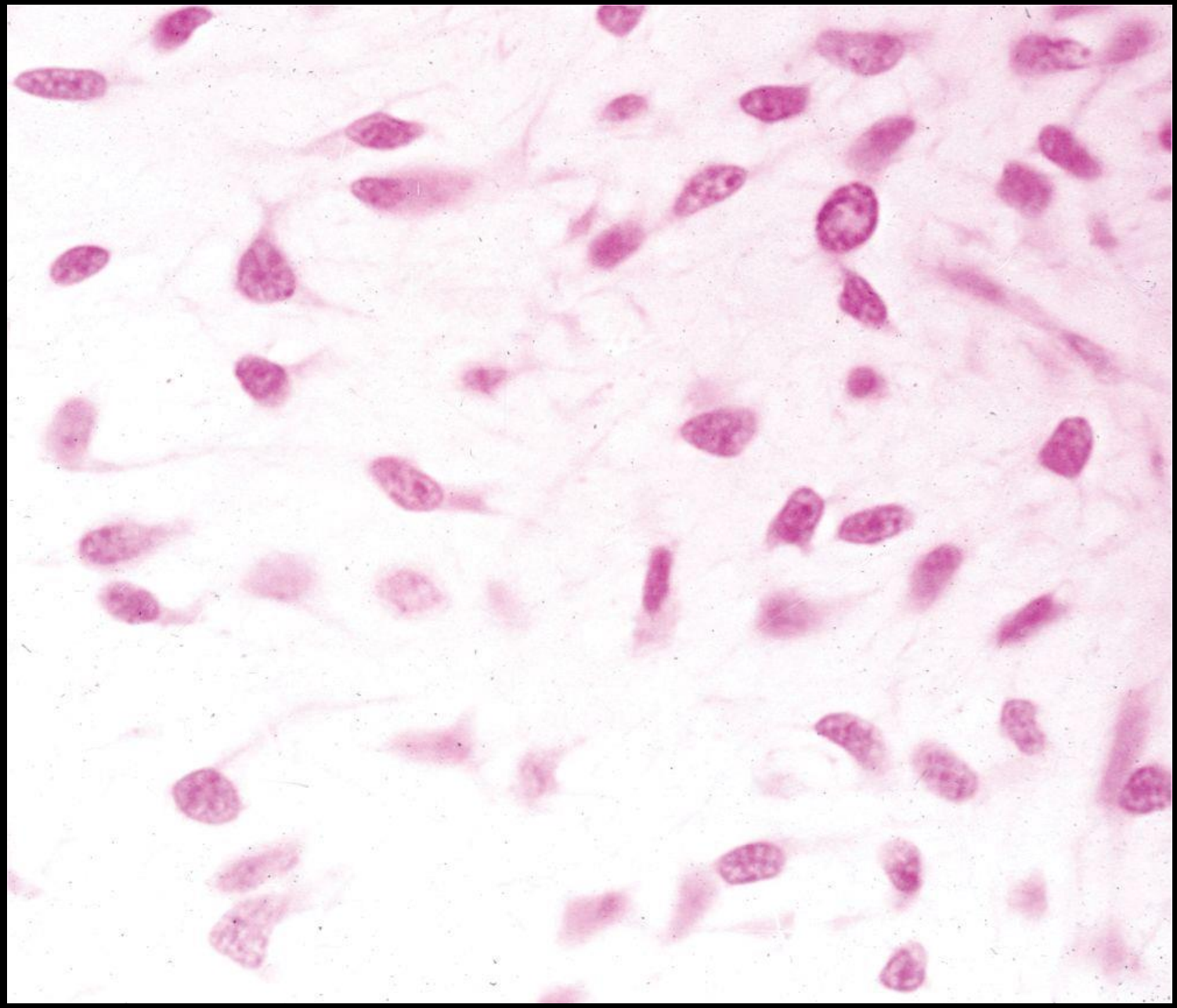
- **fibrillar component of ECM**
  fibers of all 3 types

- **amorphous component of ECM**
  gelatinous; hyaluronic acid, dermatansulfate, fibronectin

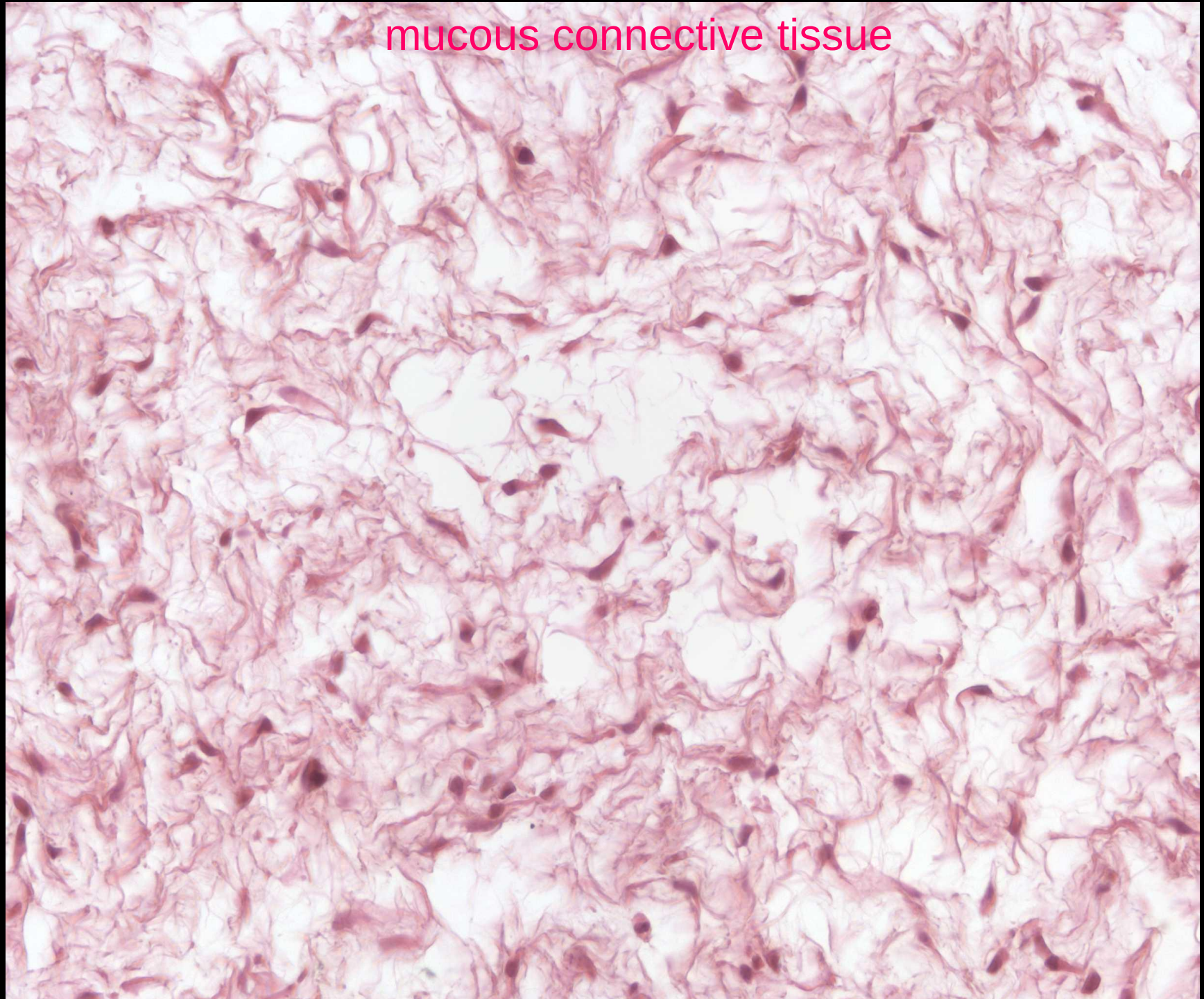
Connective tissue proper types

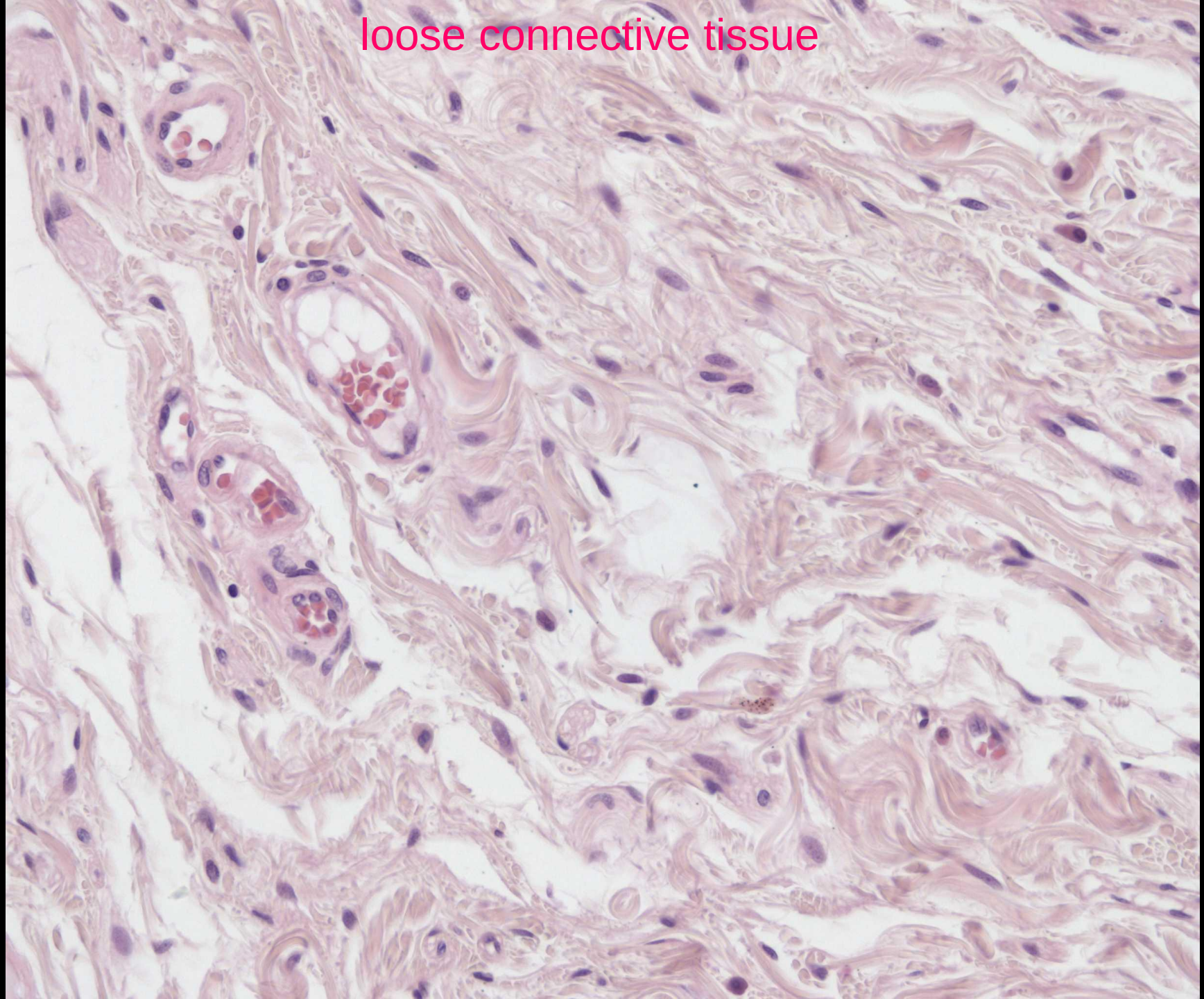
- mesenchyme – embryonic tissue; mesenchymal cells, rare ECM
- mucous CT – umbilical cord (Wharton's jelly), dental pulp; fibroblasts, hyaluronic acid, reticular fibers
- collagen CT – most common, all components
  - loose – thin fibers, more cells (fibroblasts, many migratory cells)
  - dense – regular (tendons, ligaments) and irregular (organ capsules, dermis); thick fibers (collagen), less cells (fibrocytes)
- reticular CT – lymphoid organs, bone marrow; reticular cells, reticular fibers
- elastic CT – yellow ligaments of the vertebral column; fibrocytes, elastic fibers
- adipose CT – white (univacuolar adipocytes) and brown (multivacuolar adipocytes), rare ECM (reticular fibers)

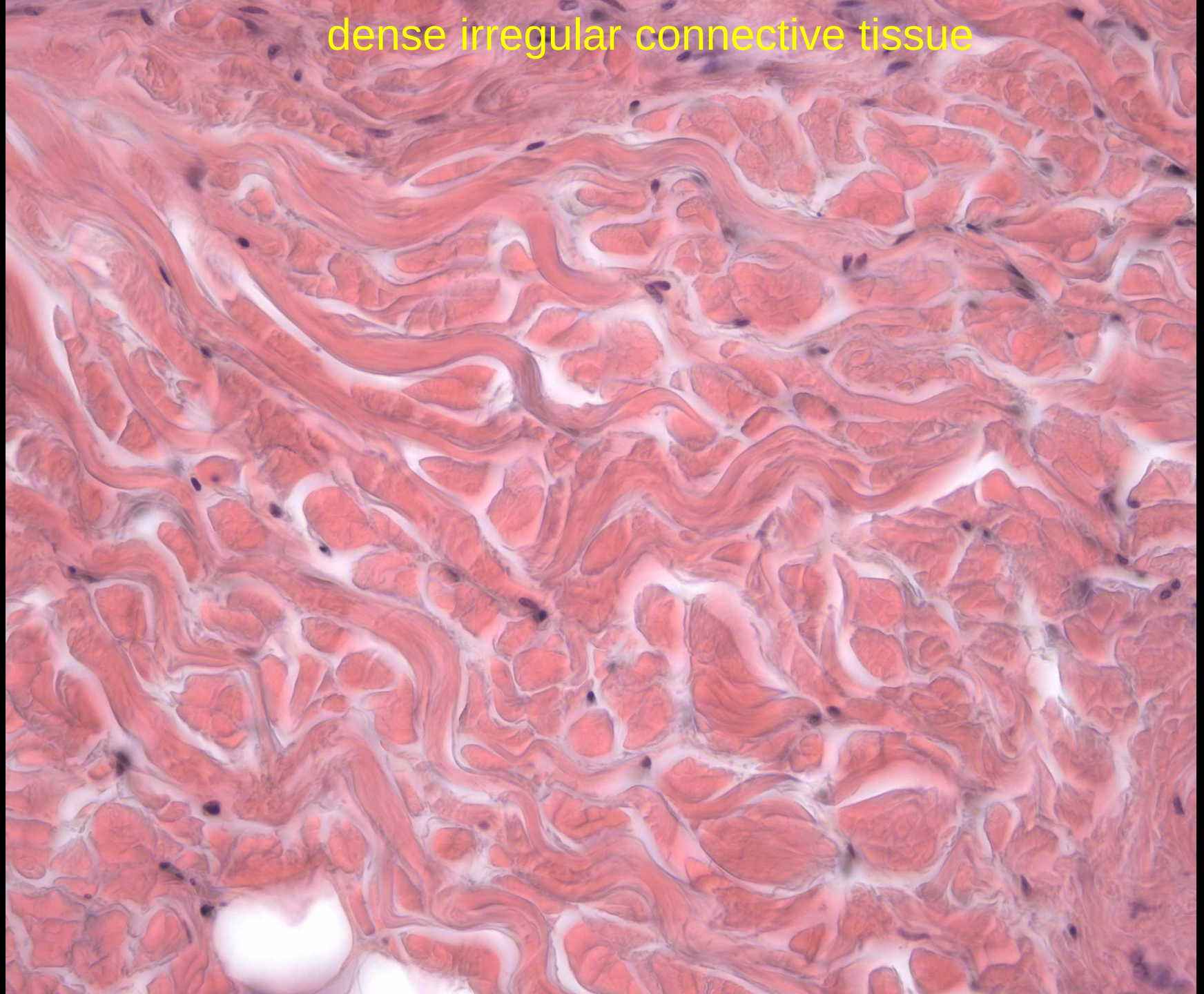
mesenchymal connective tissue

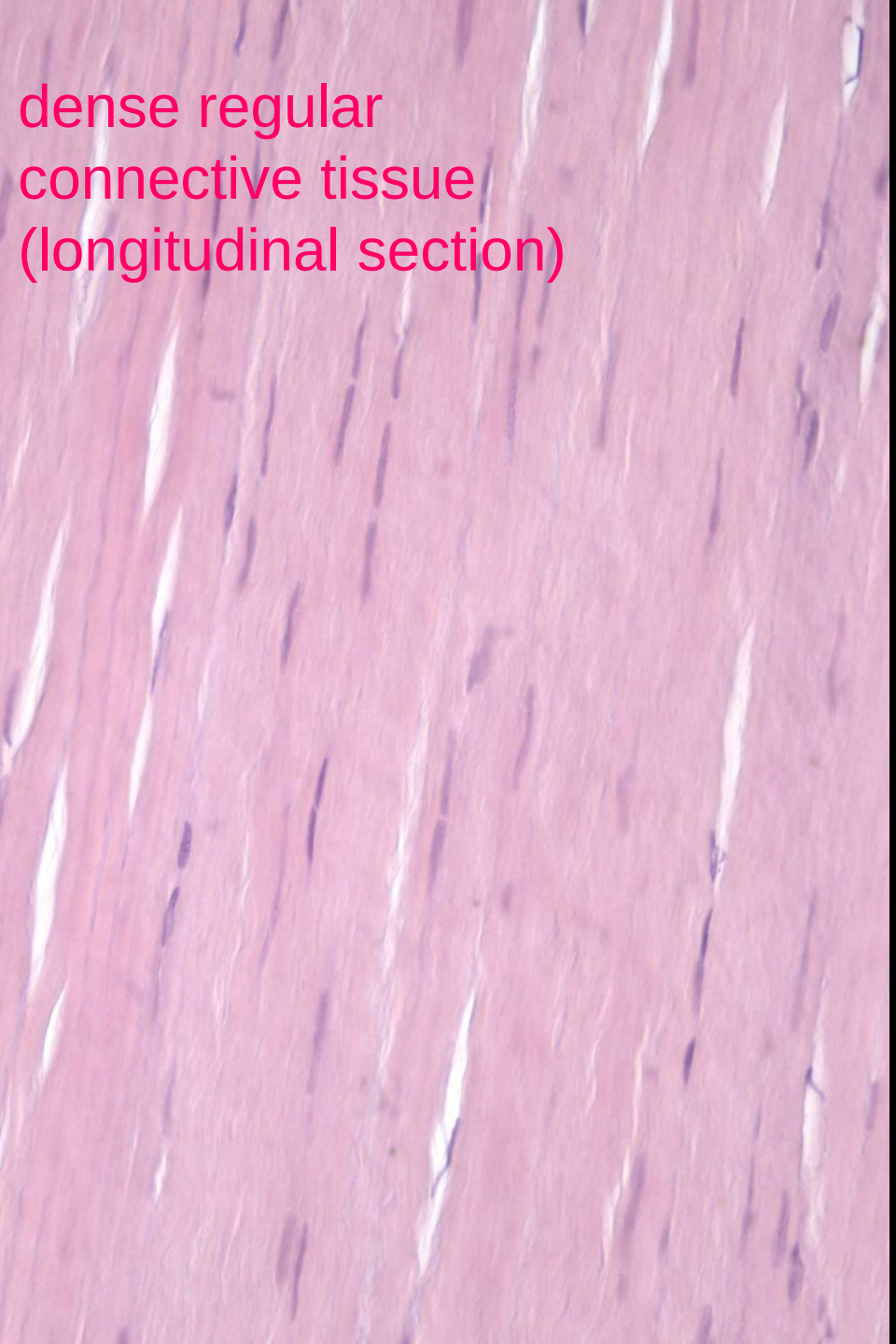


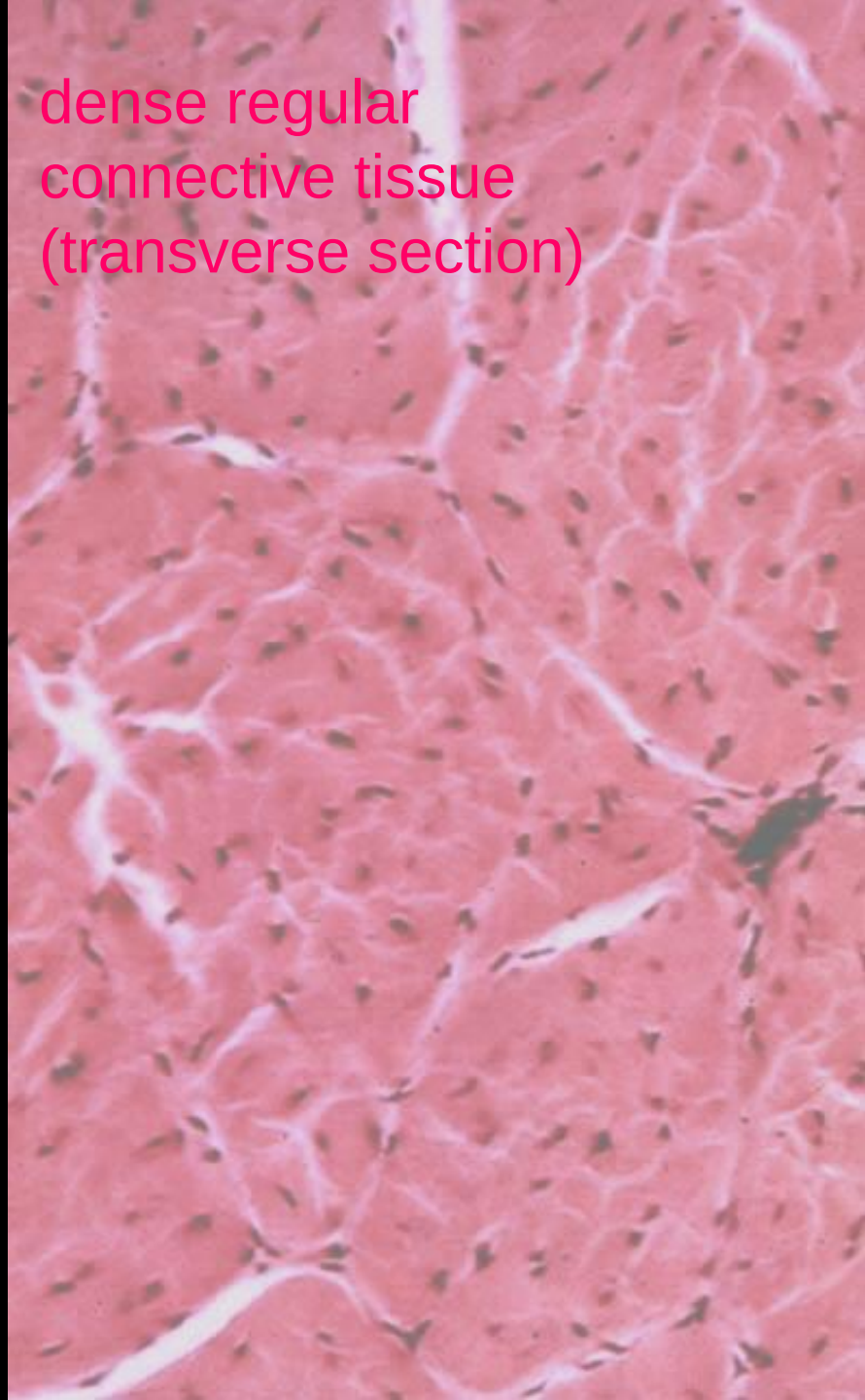
mucous connective tissue

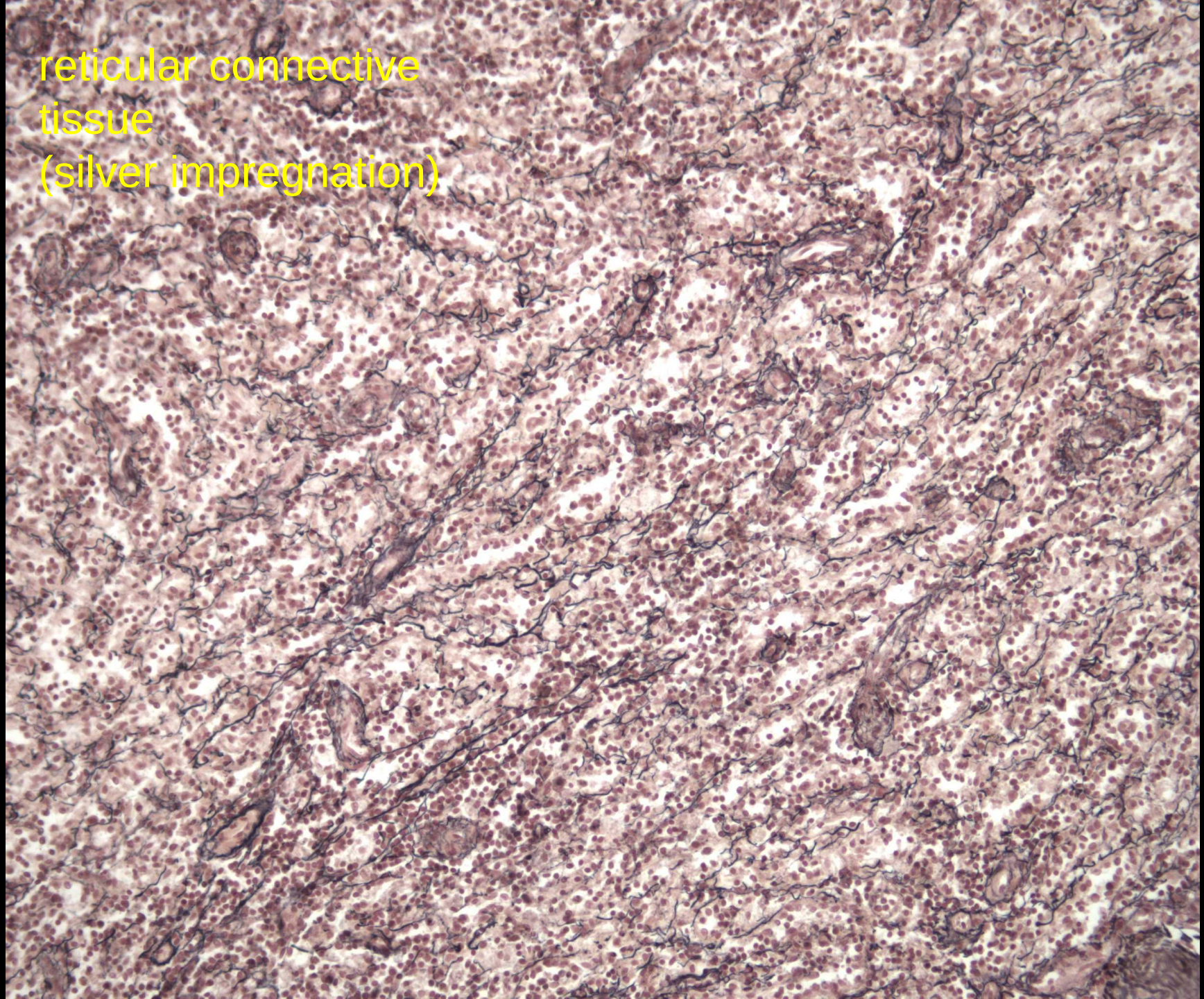



loose connective tissue

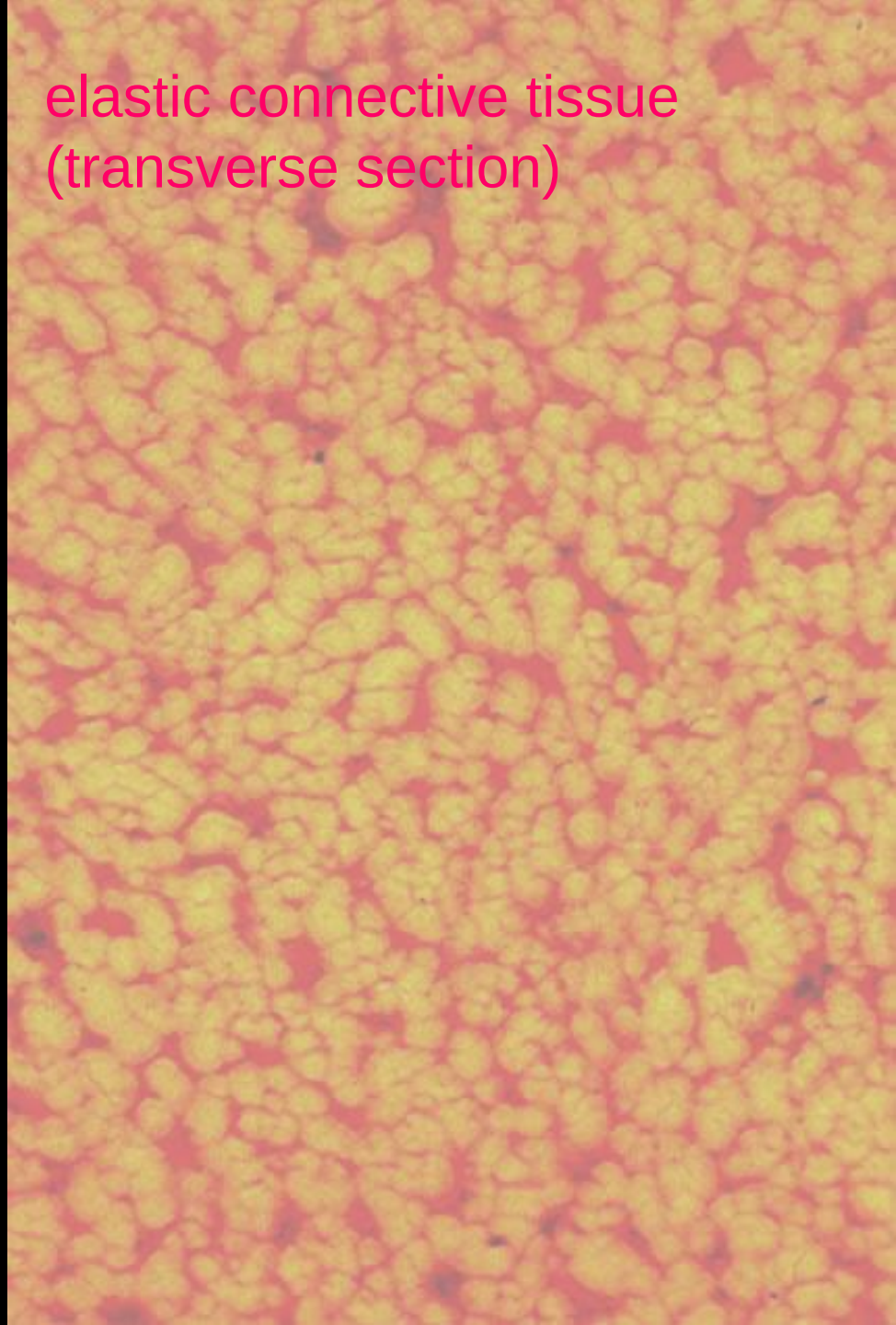

dense irregular connective tissue

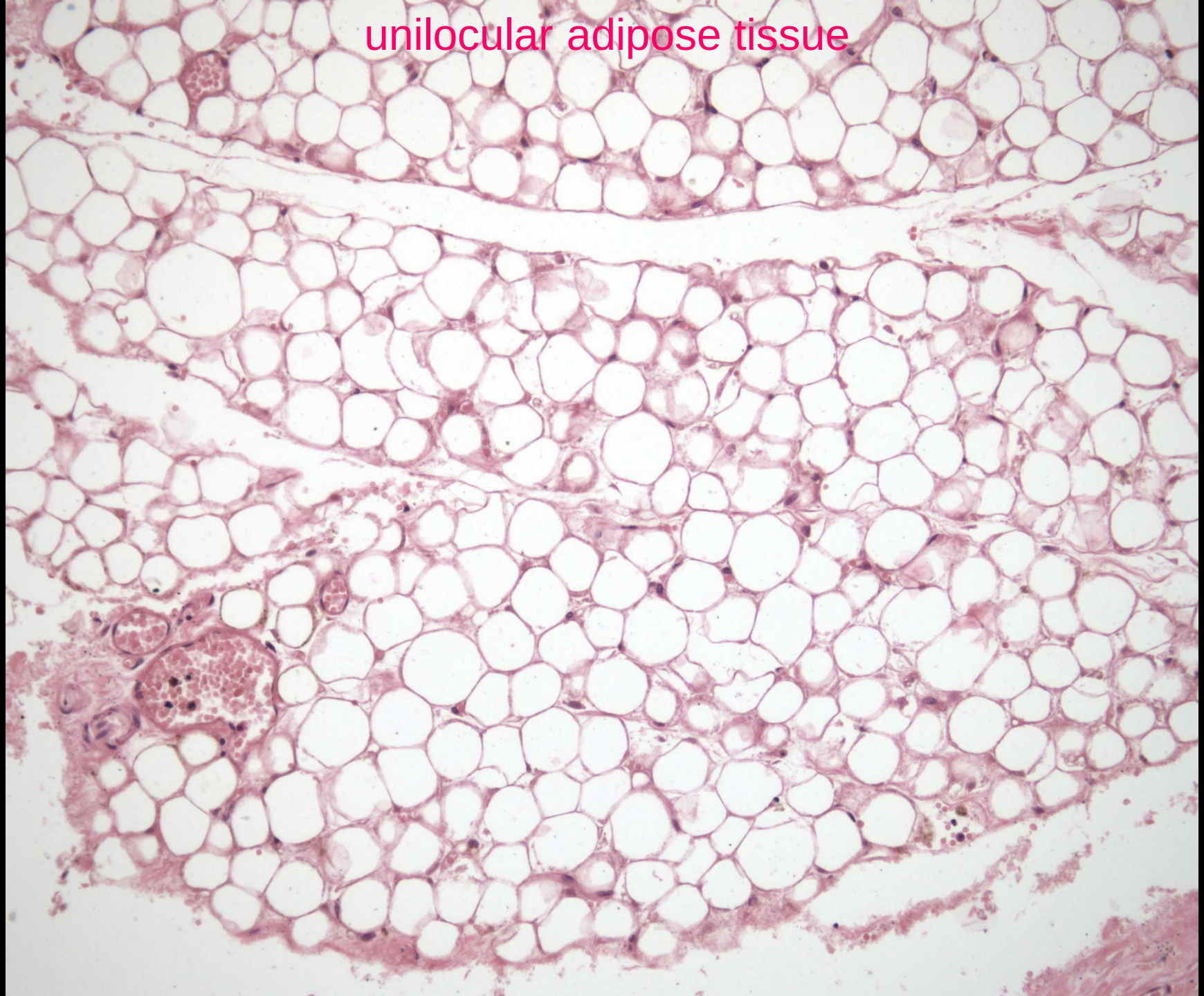

dense regular
connective tissue
(longitudinal section)


dense regular
connective tissue
(transverse section)

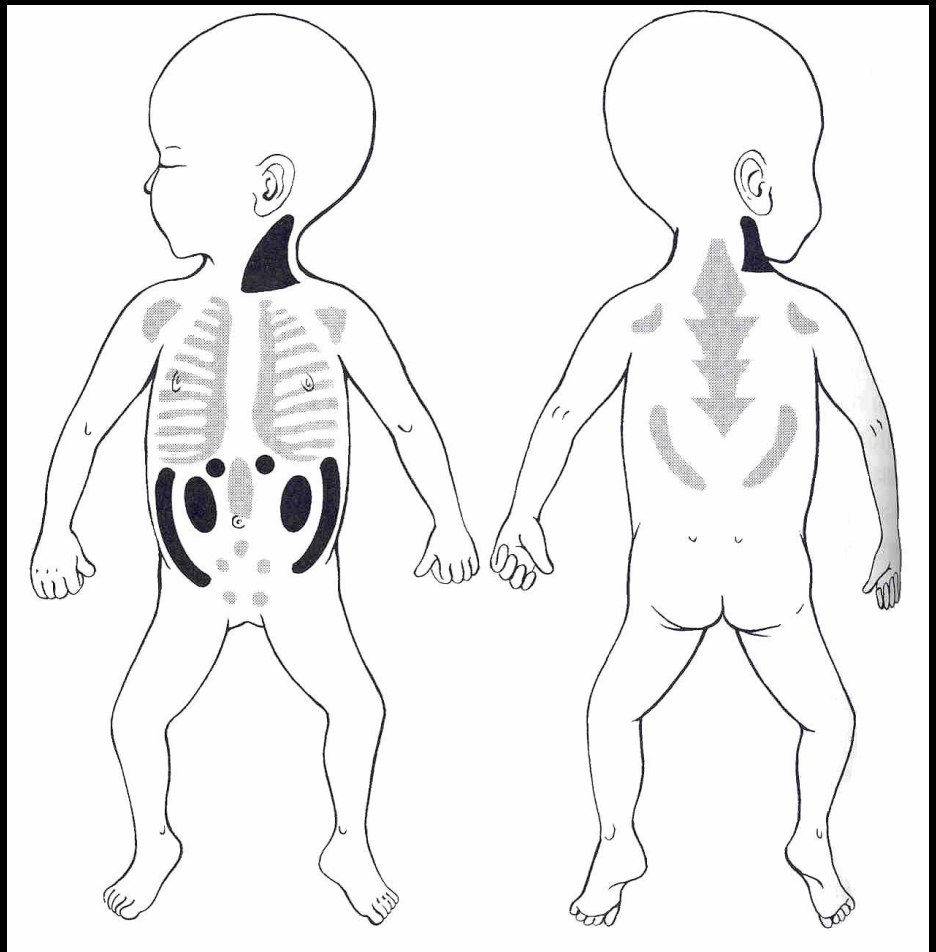

reticular connective
tissue
(silver impregnation)

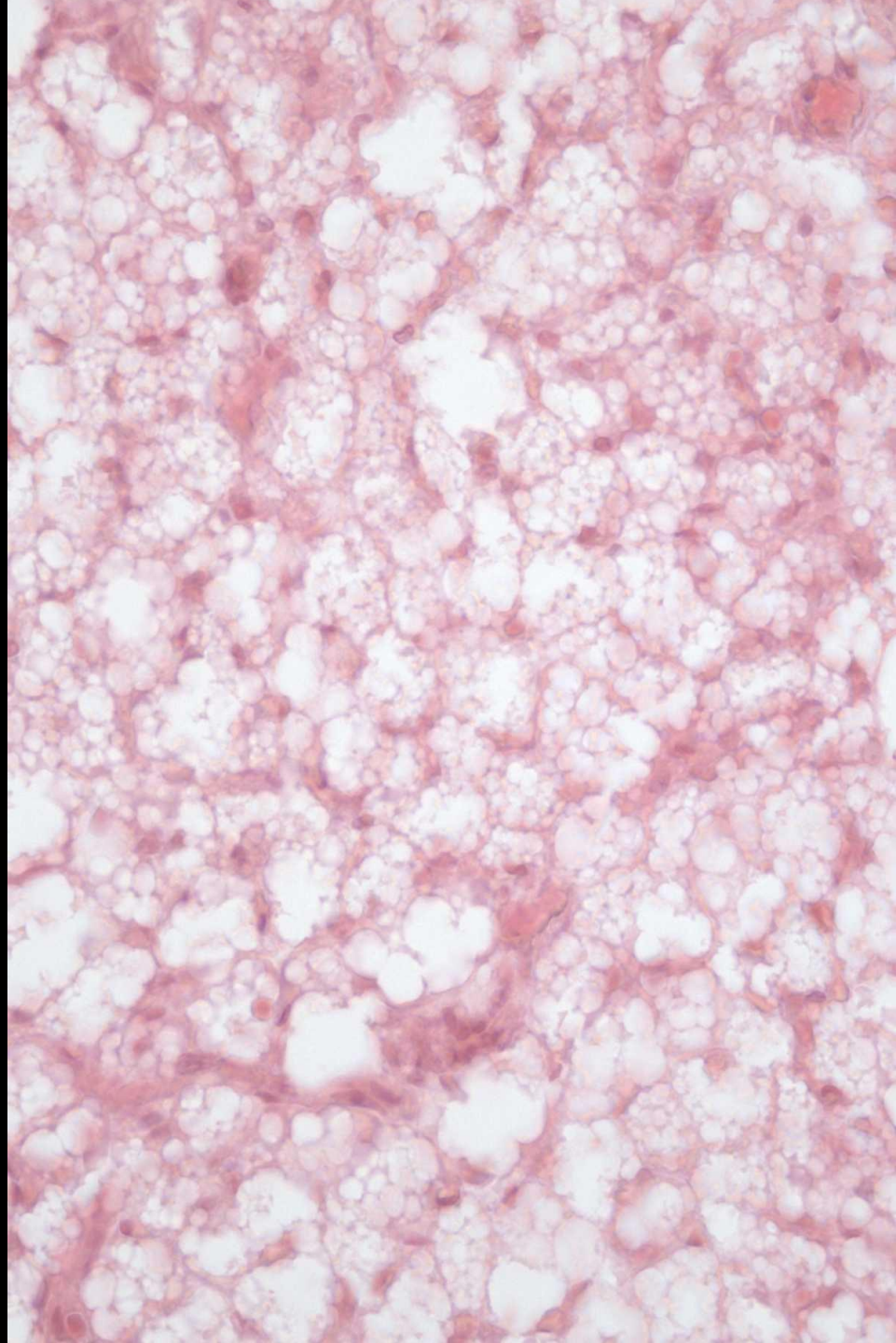

elastic connective tissue
(longitudinal section)


elastic connective tissue
(transverse section)


unilocular adipose tissue

mutilocular adipose tissue





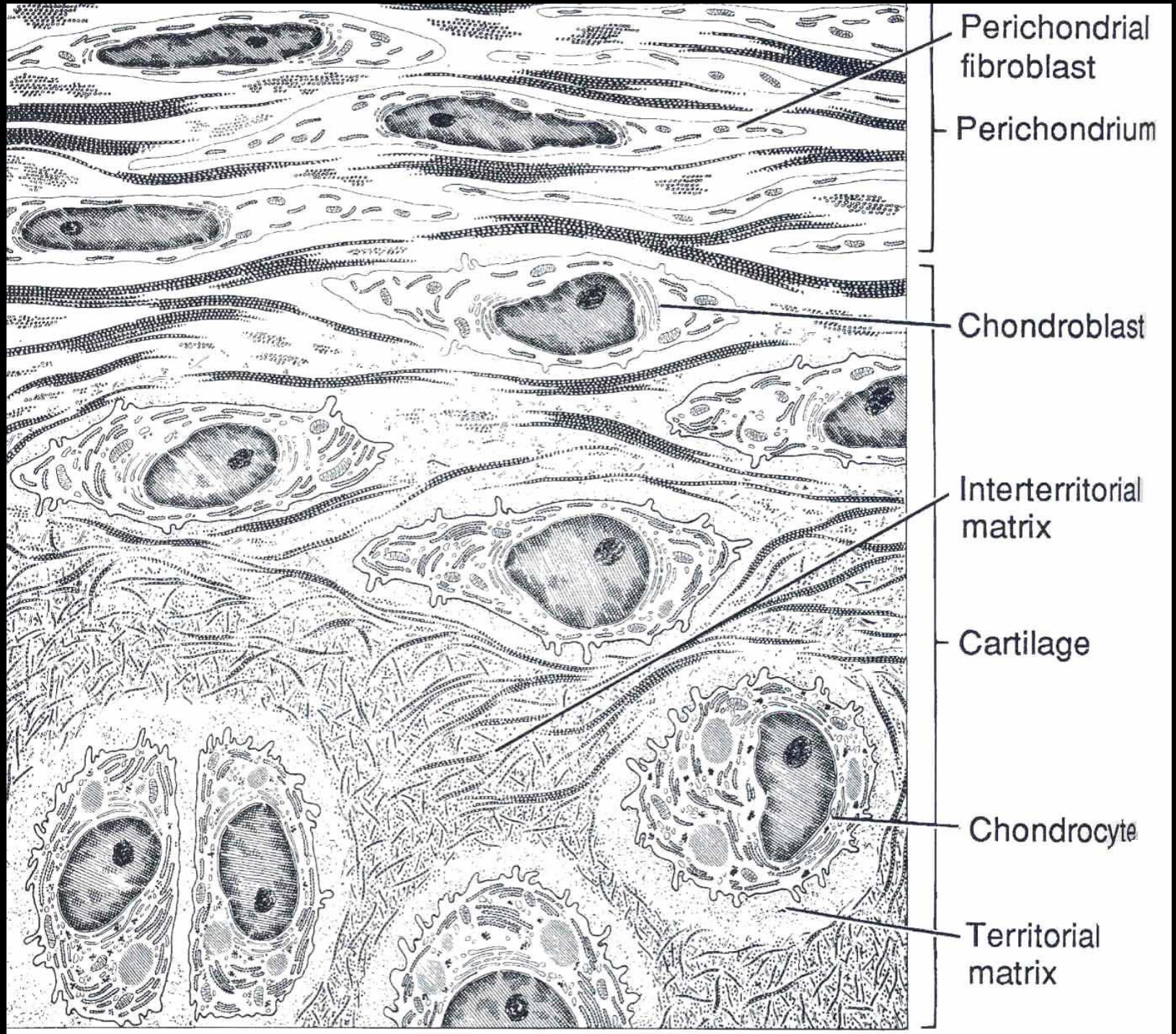
Cartilage - general structure, histogenesis, growth

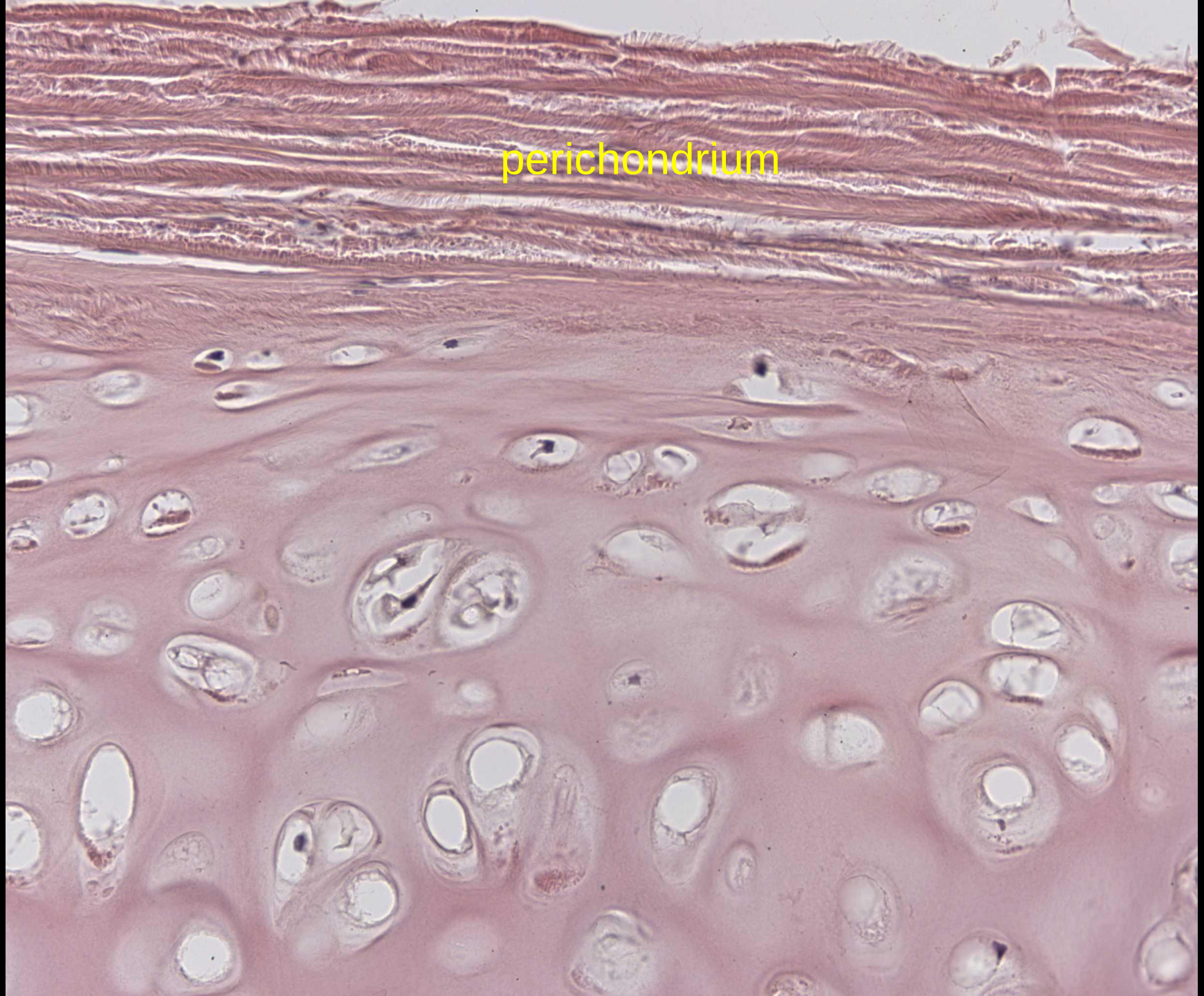
- **resident cells**
  chondroblasts, chondrocytes

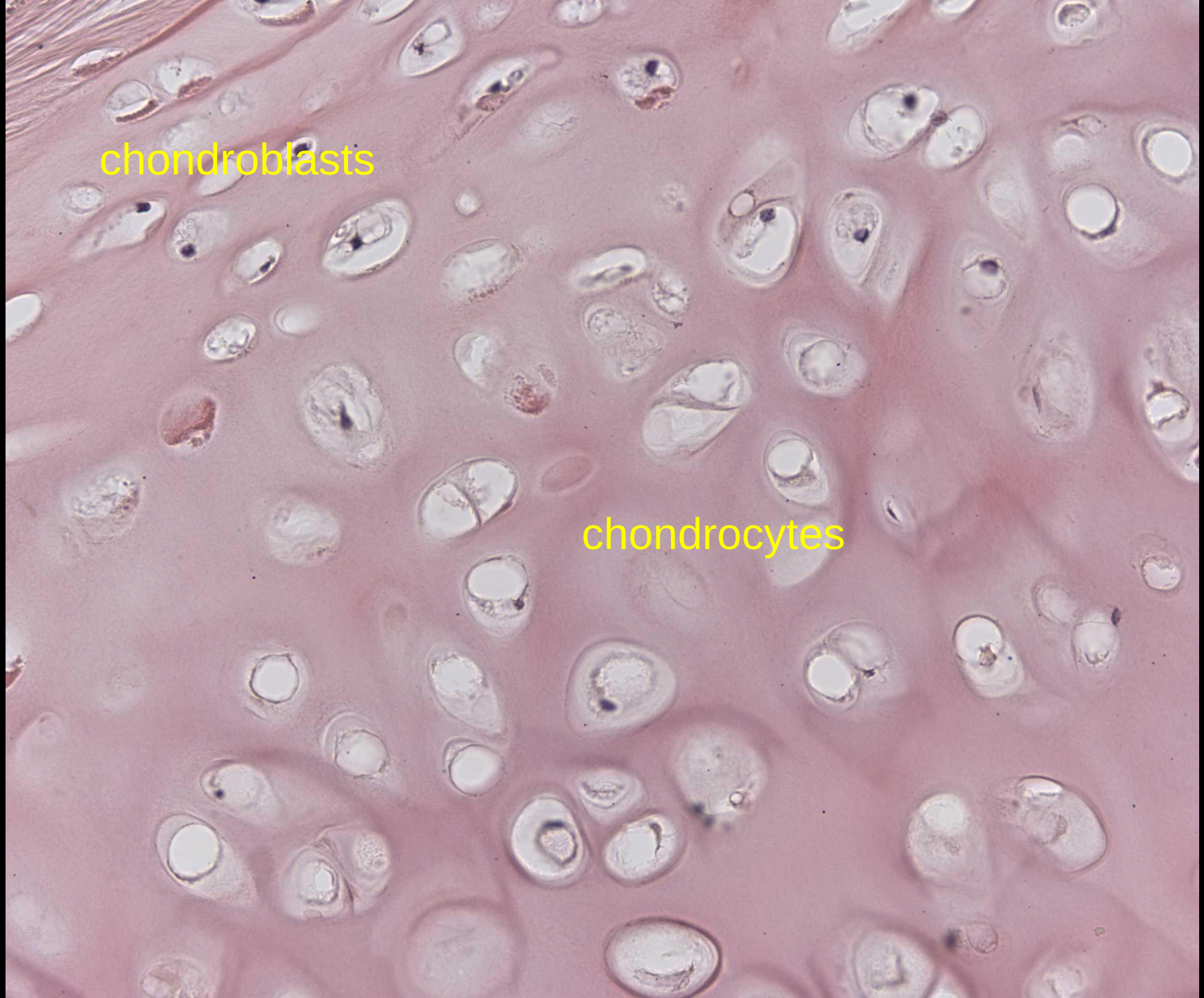
- **migratory cells**
  chondroclasts

- **fibrillar component of ECM**
  always collagen type II
  elastic cartilage + elastic fibers
  fibrocartilage + collagen fibers

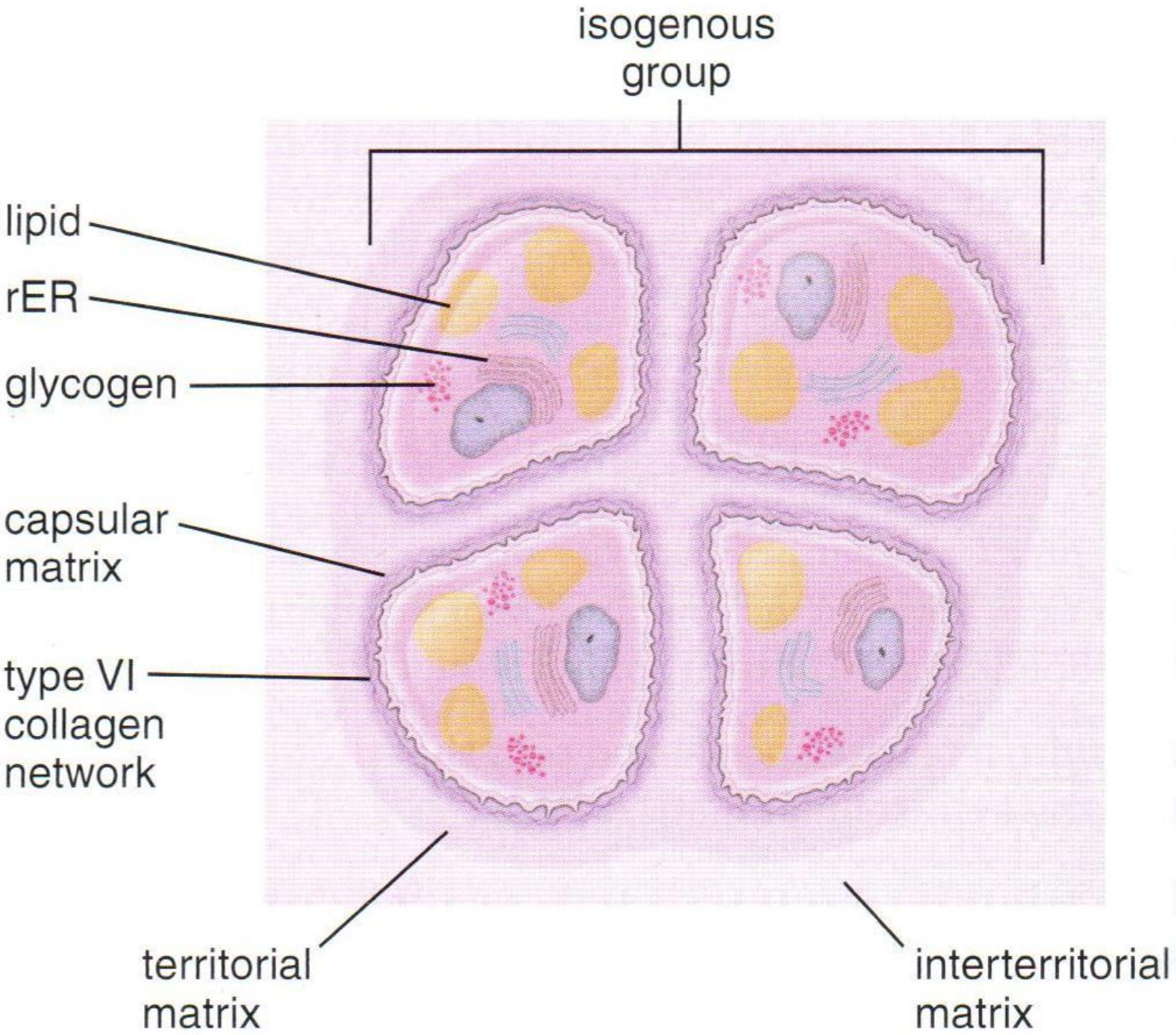
- **amorphous component of ECM**
  firm and floppy
  aggregates of hyaluronic acid and proteoglycans containing chondroitinsulfate and keratansulfate; chondronectin


Perichondrial fibroblast
Perichondrium
Chondroblast
Interterritorial matrix
Cartilage
Chondrocyte
Territorial matrix


perichondrium

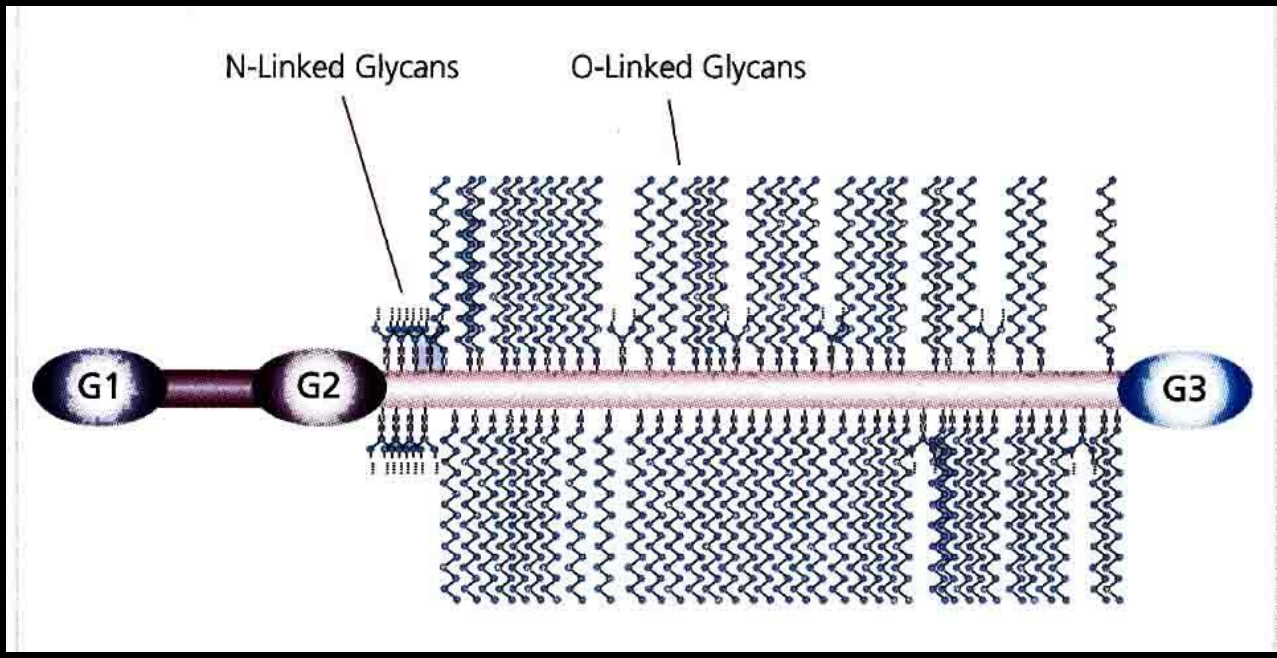

chondroblasts
chondrocytes


isogenous groups

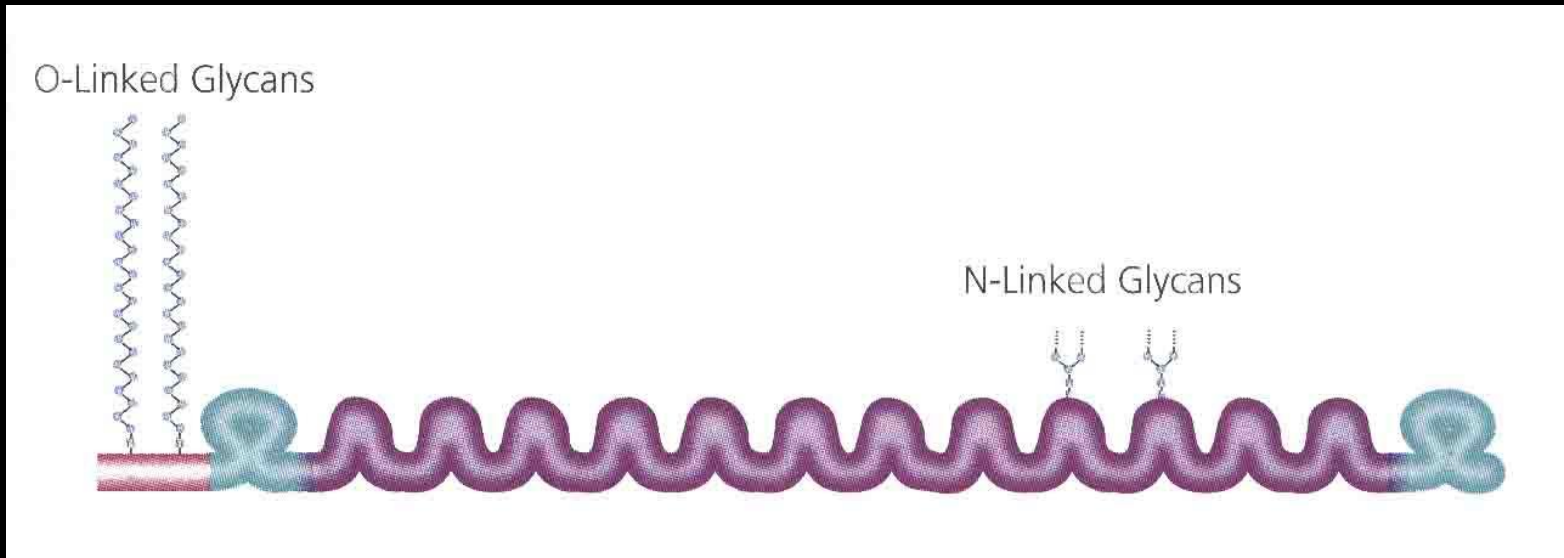

isogenous group
lipid
rER
glycogen
capsular matrix
type VI collagen network
territorial matrix
interterritorial matrix

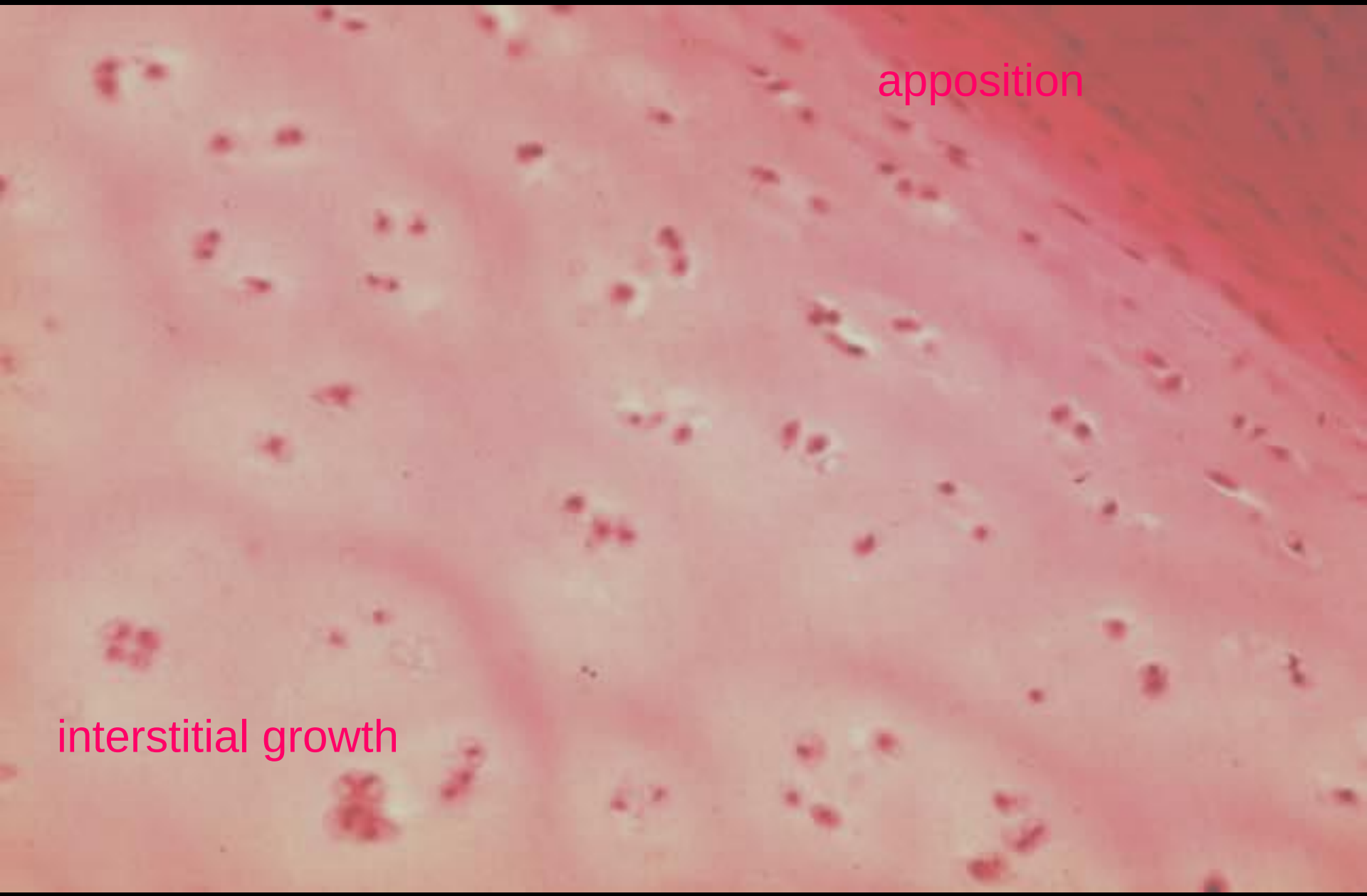
Proteoglycans of cartilage

Aggrecan



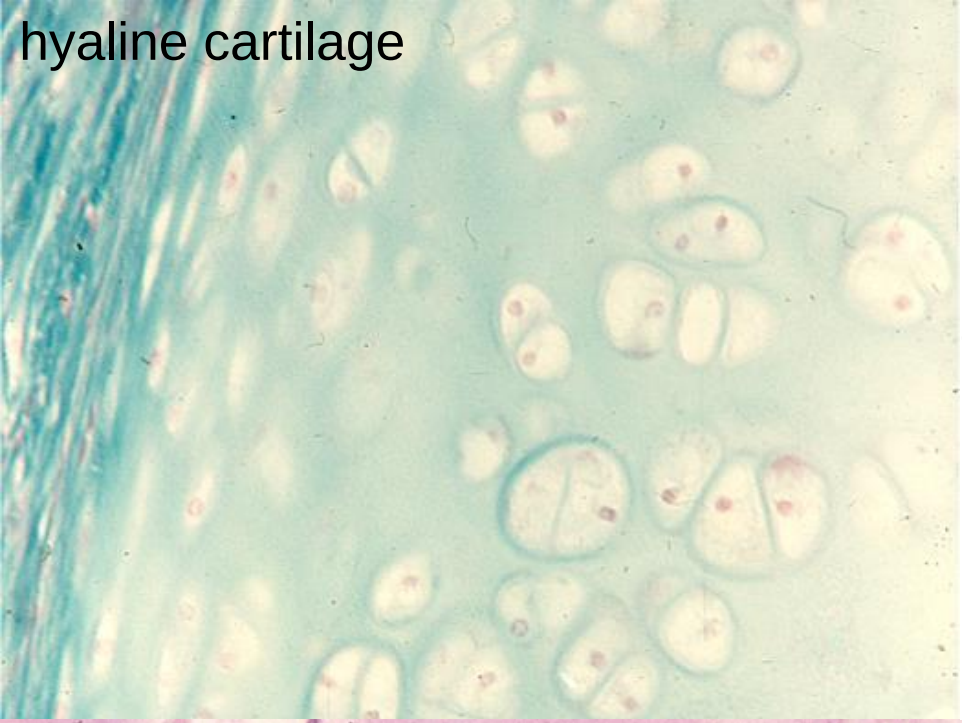
Biglycan



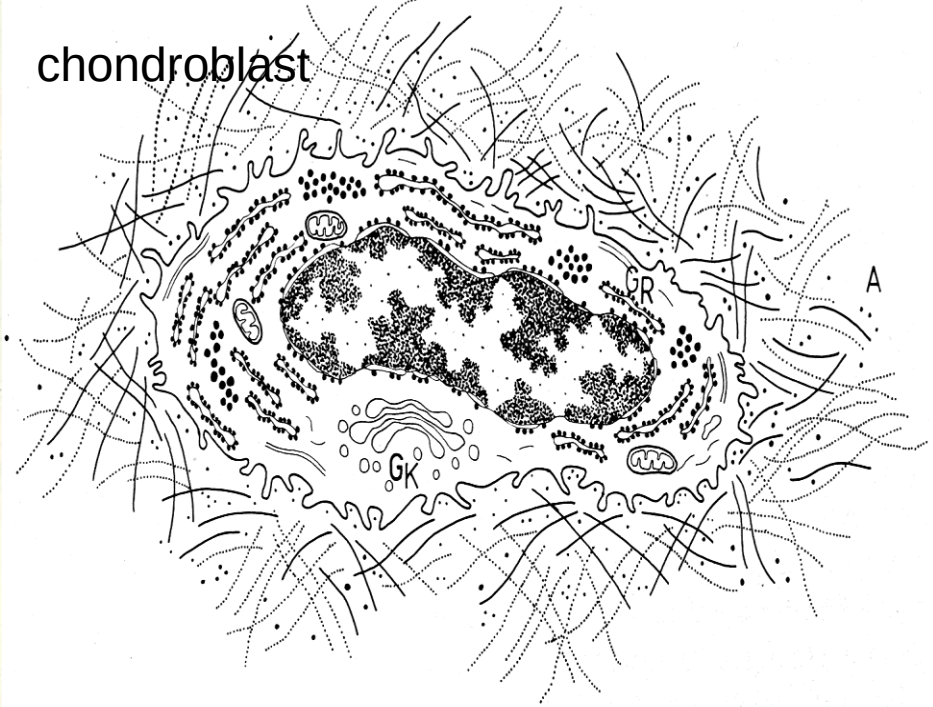

apposition
interstitial growth

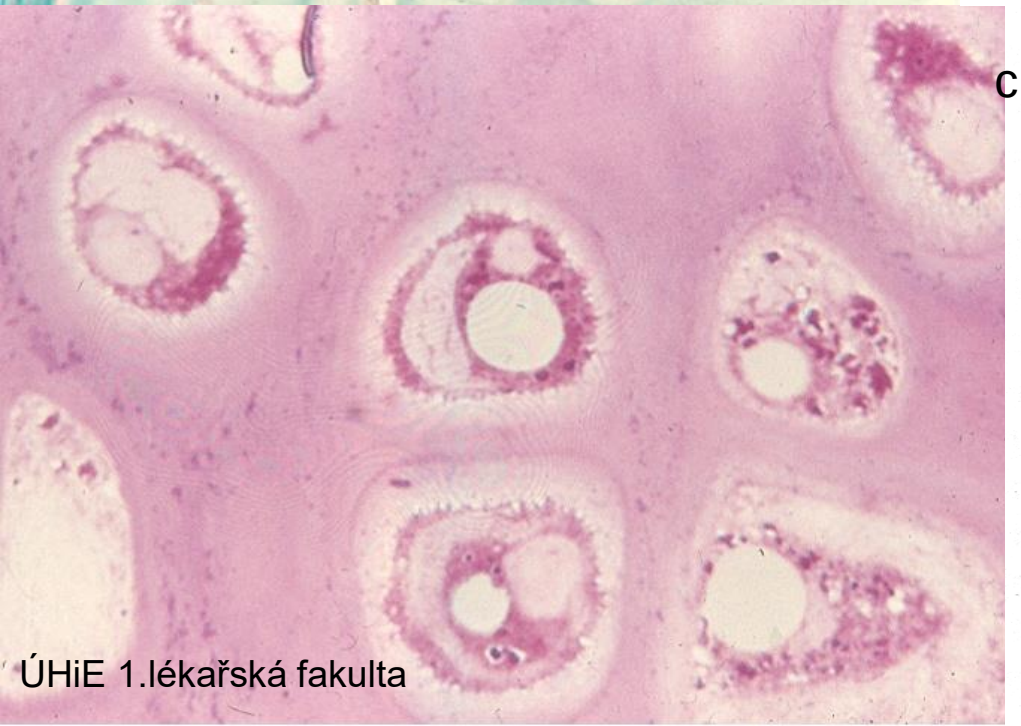
Types of the cartilage

hyaline cartilage

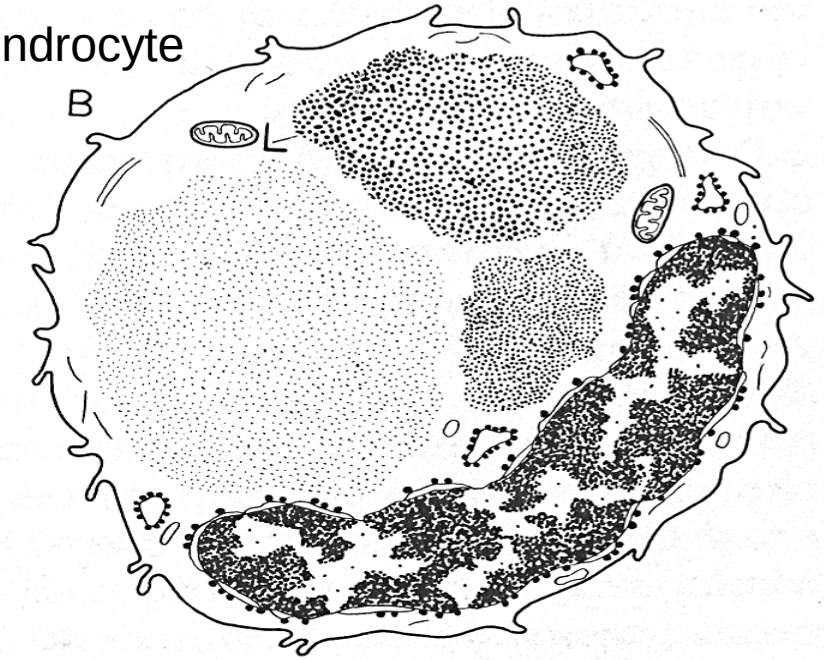


chondroblast





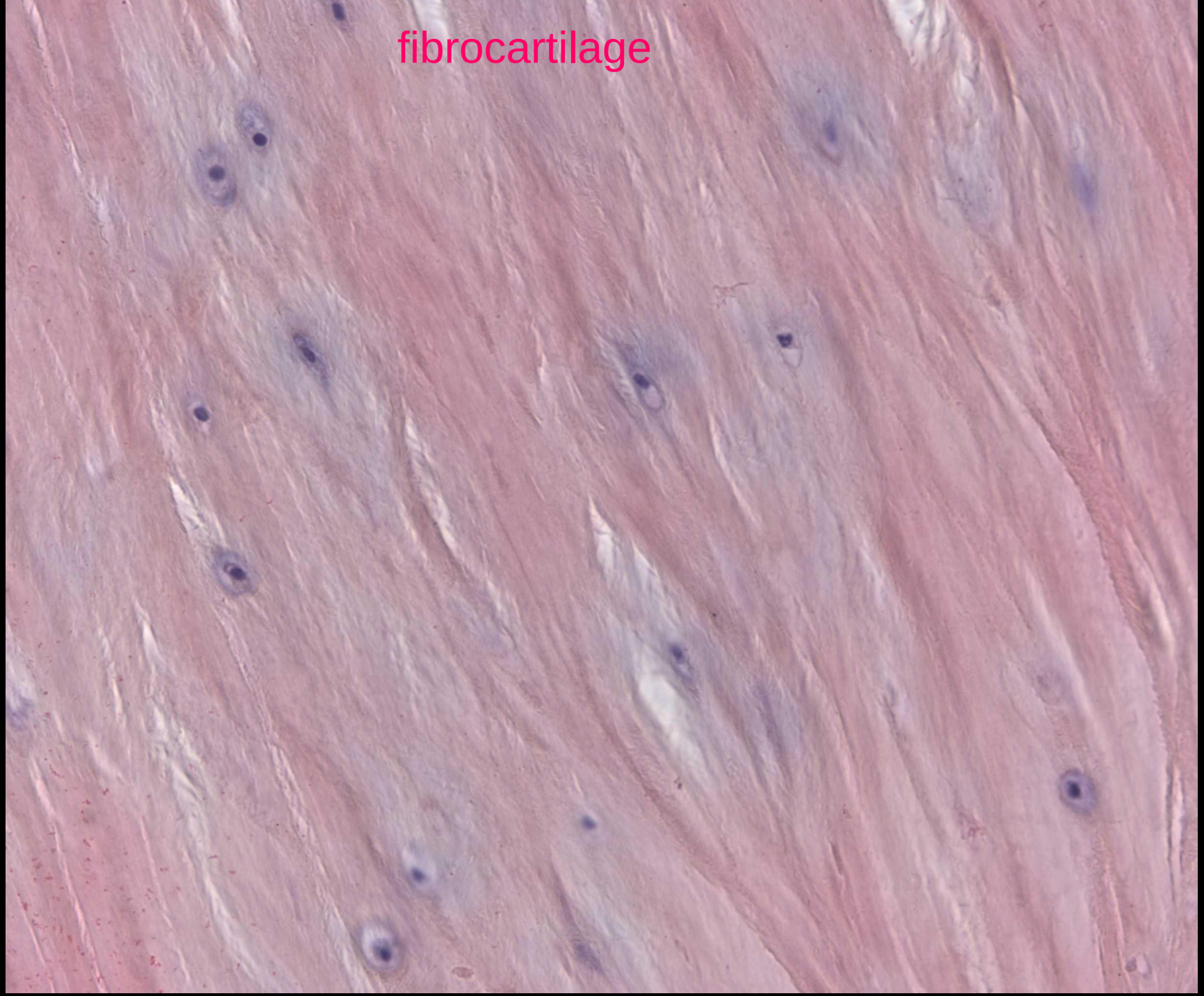
chondrocyte




hyaline cartilage


elastic cartilage


fibrocartilage


fibrocartilage

Bone - general structure

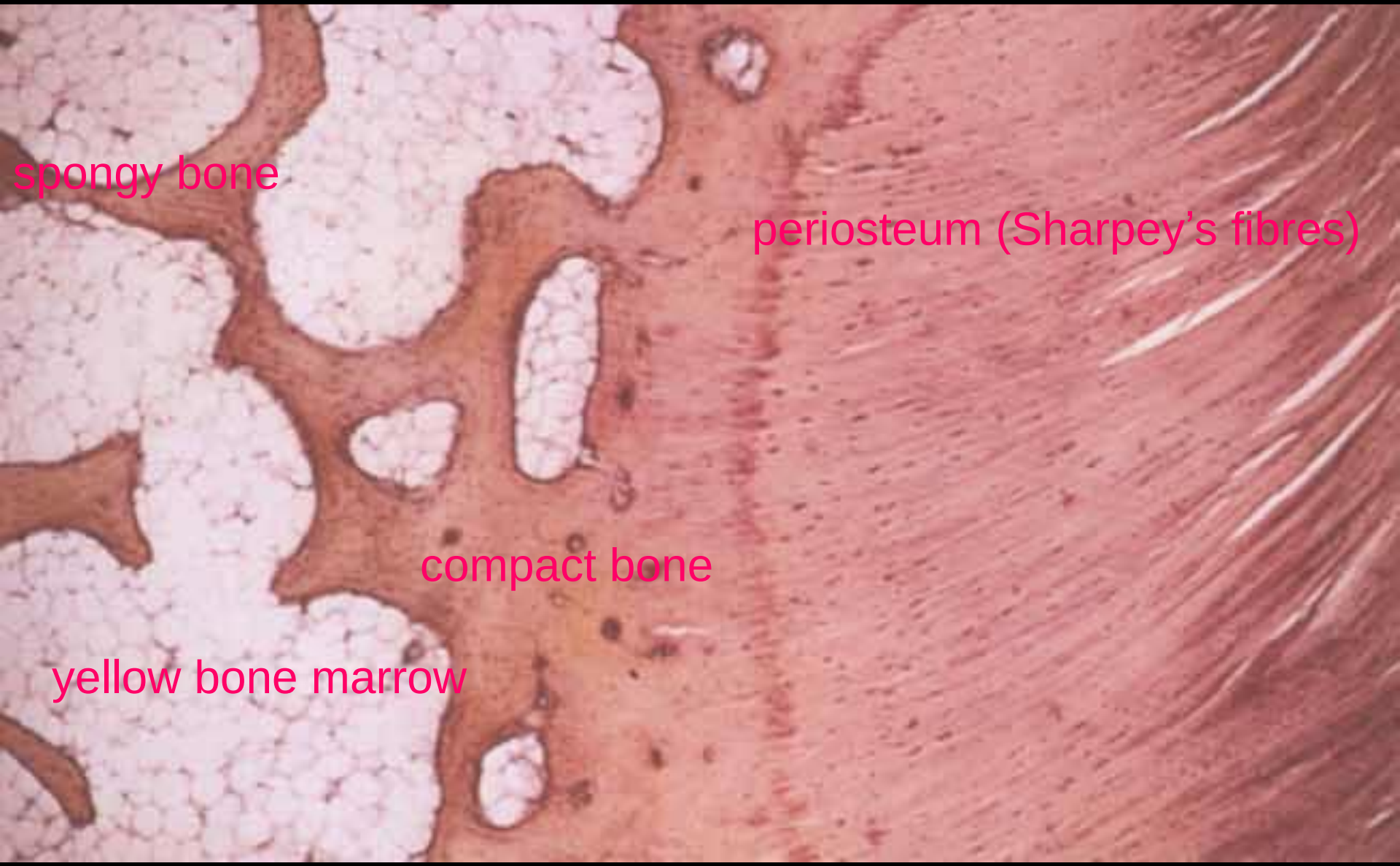
- **resident cells**
  osteoblasts, osteocytes

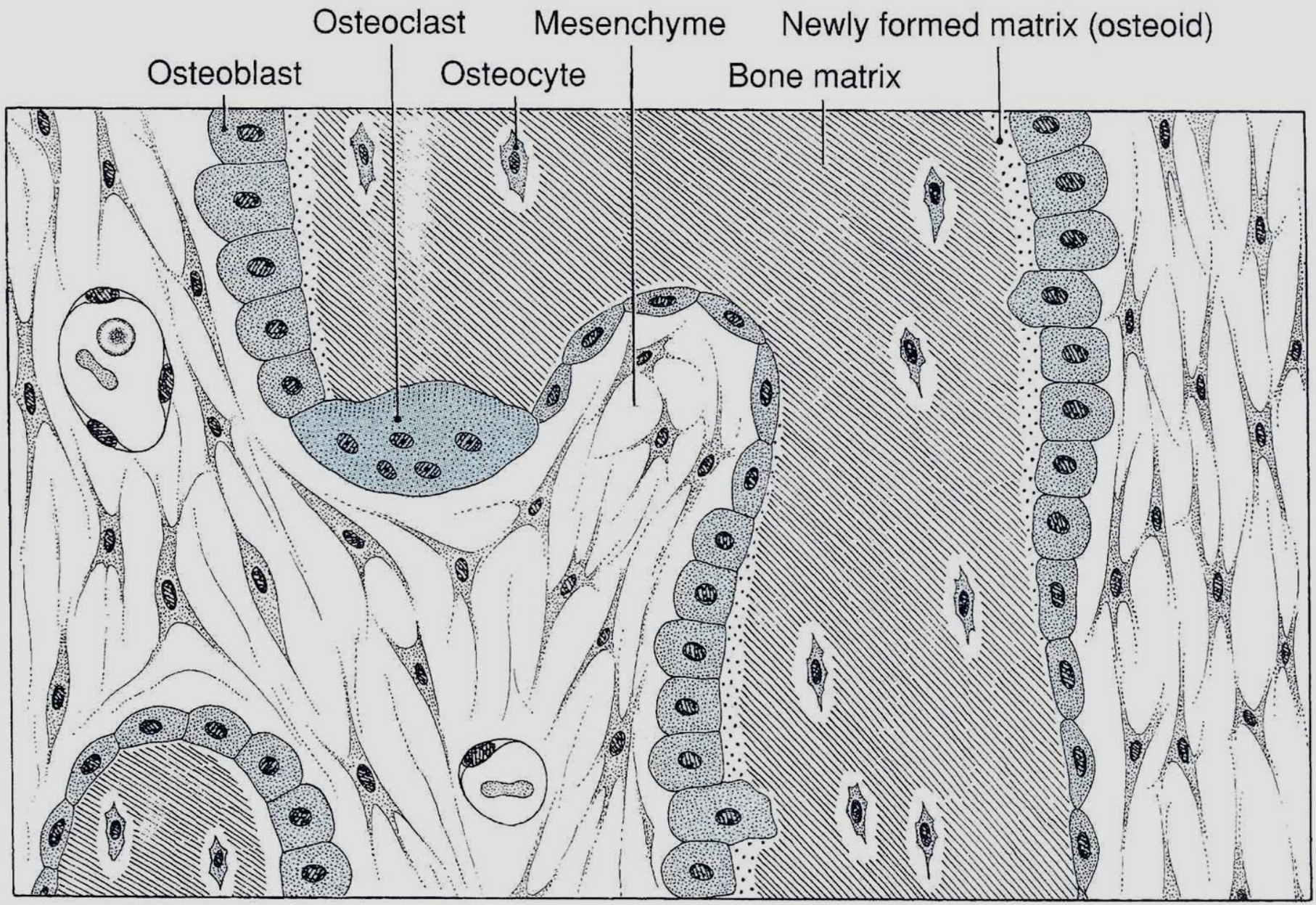
- **migratory cells**
  osteoclasts

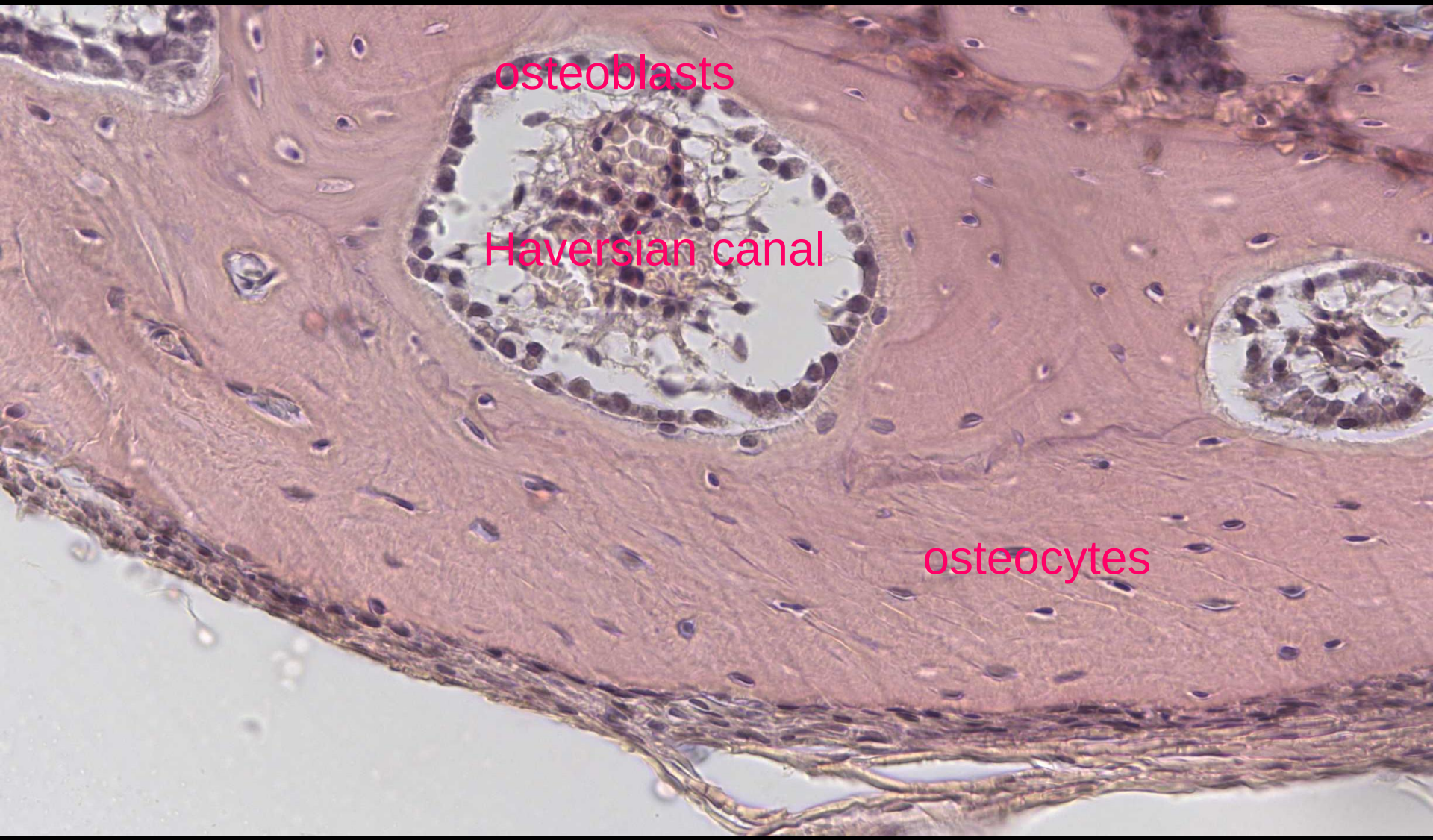
- **fibrillar component of ECM**
  collagen fibers

- **amorphous component of ECM**
  hard and firm; proteoglycans containing chondroitinsulfate and keratansulfate; osteonectin; Ca-binding glycoproteins (sialoprotein, osteocalcin)

- **mineralization of ECM with hydroxyapatite crystals** $Ca_{10}(PO_4)_6OH_2$

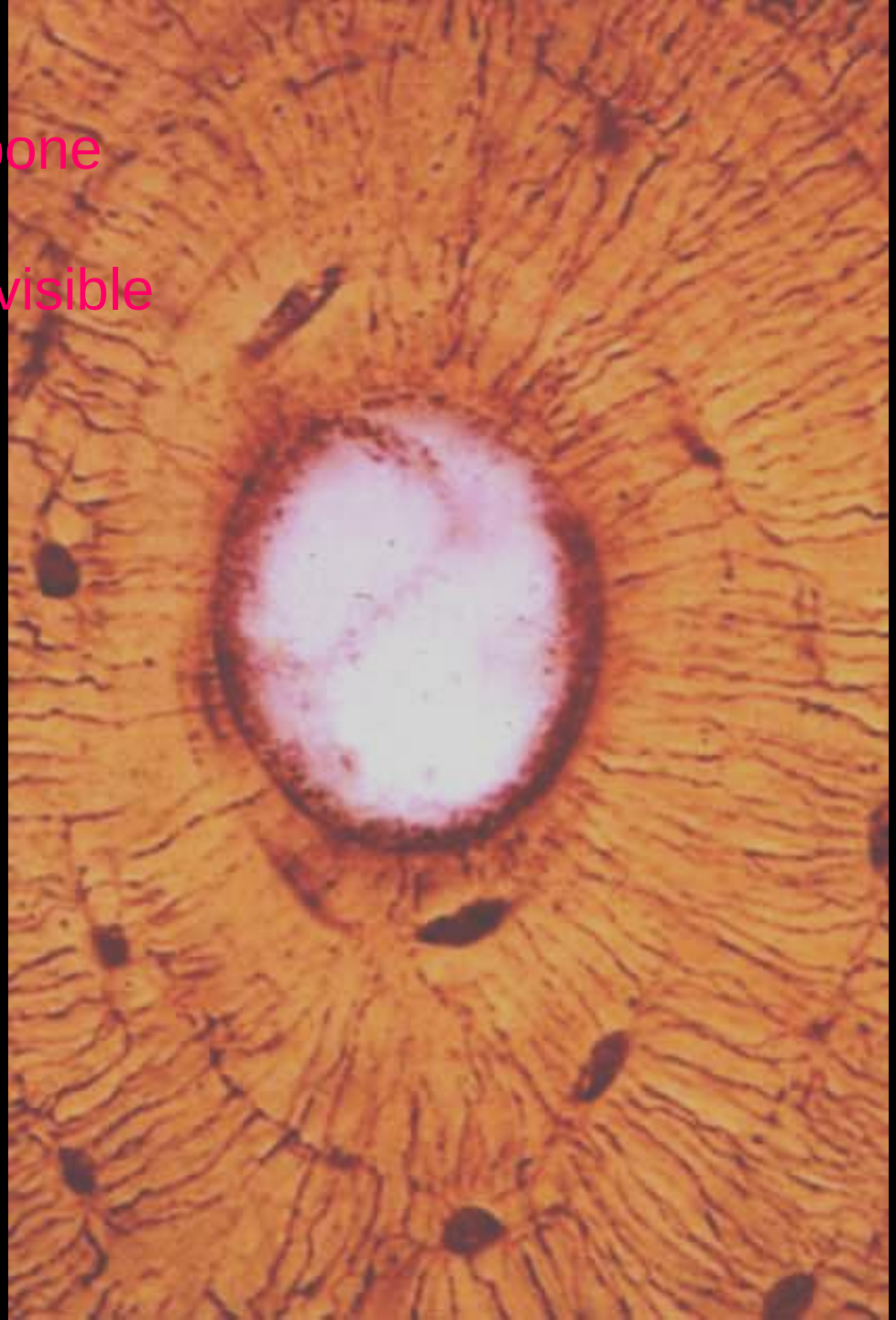

spongy bone
periosteum (Sharpey’s fibres)
compact bone
yellow bone marrow

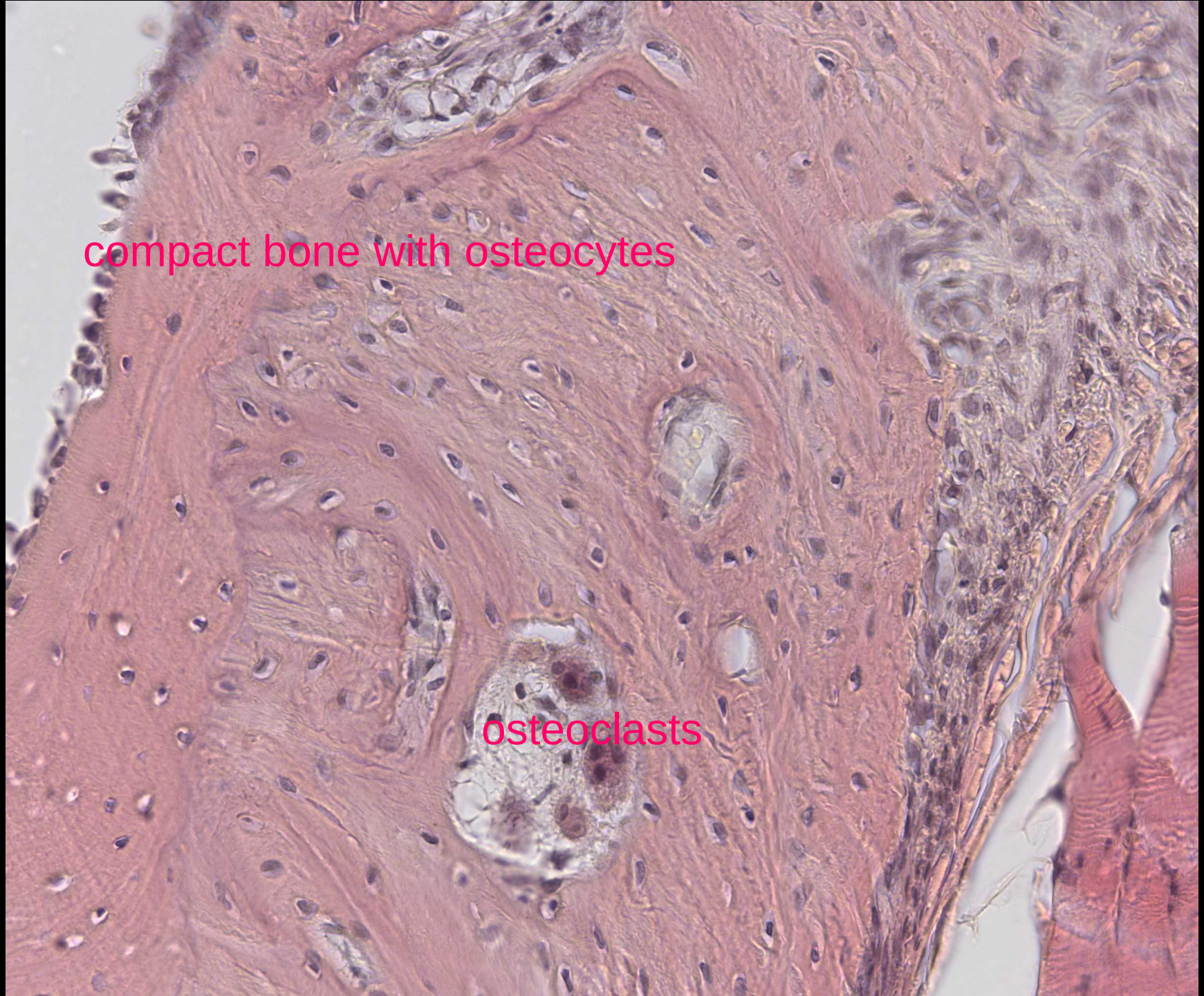

Osteoclast
Mesenchyme
Newly formed matrix (osteoid)
Osteoblast
Osteocyte
Bone matrix


osteoblasts
Haversian canal
osteocytes

grinding cut of bone

bone canaliculi visible

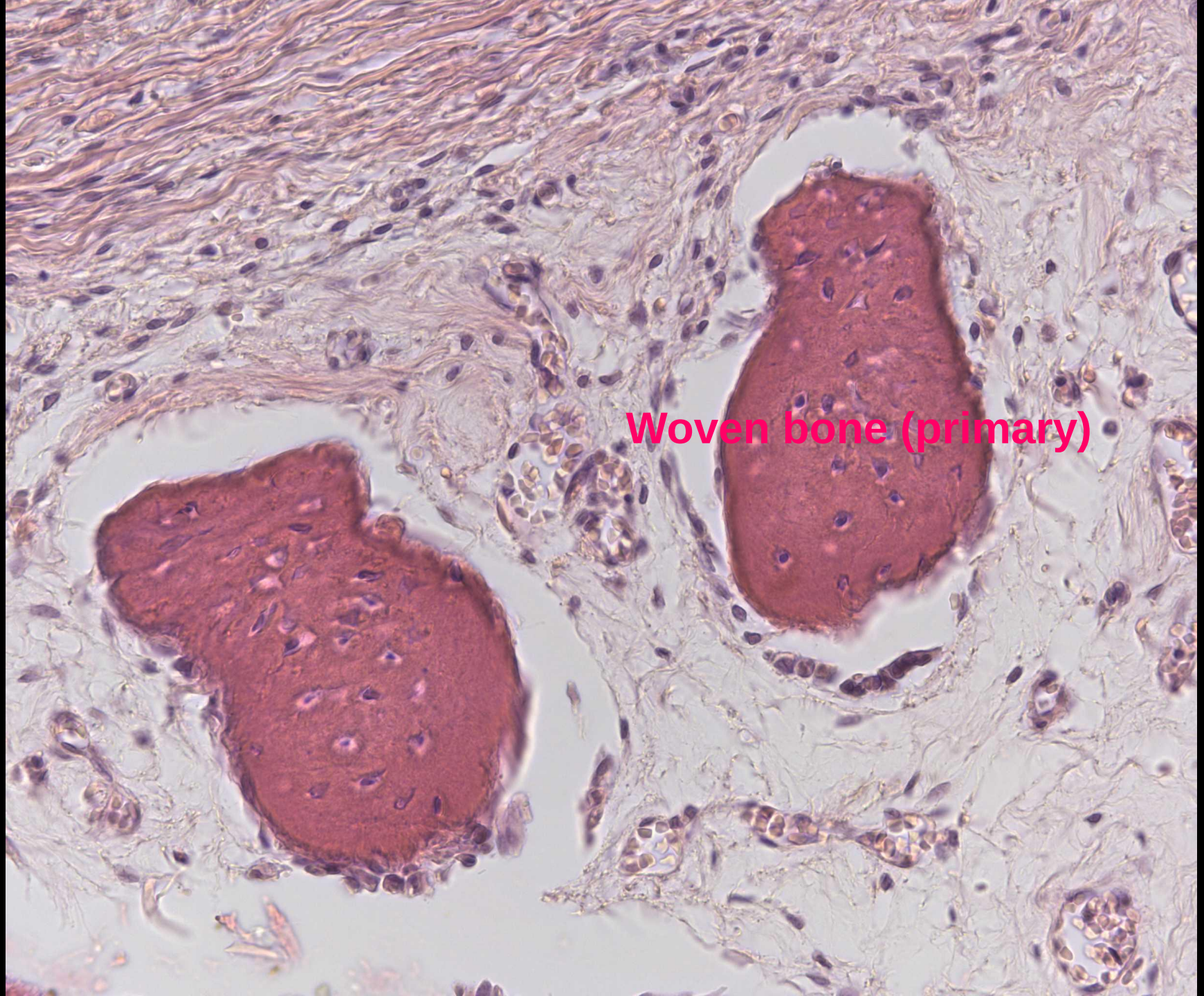



compact bone with osteocytes
osteoclasts

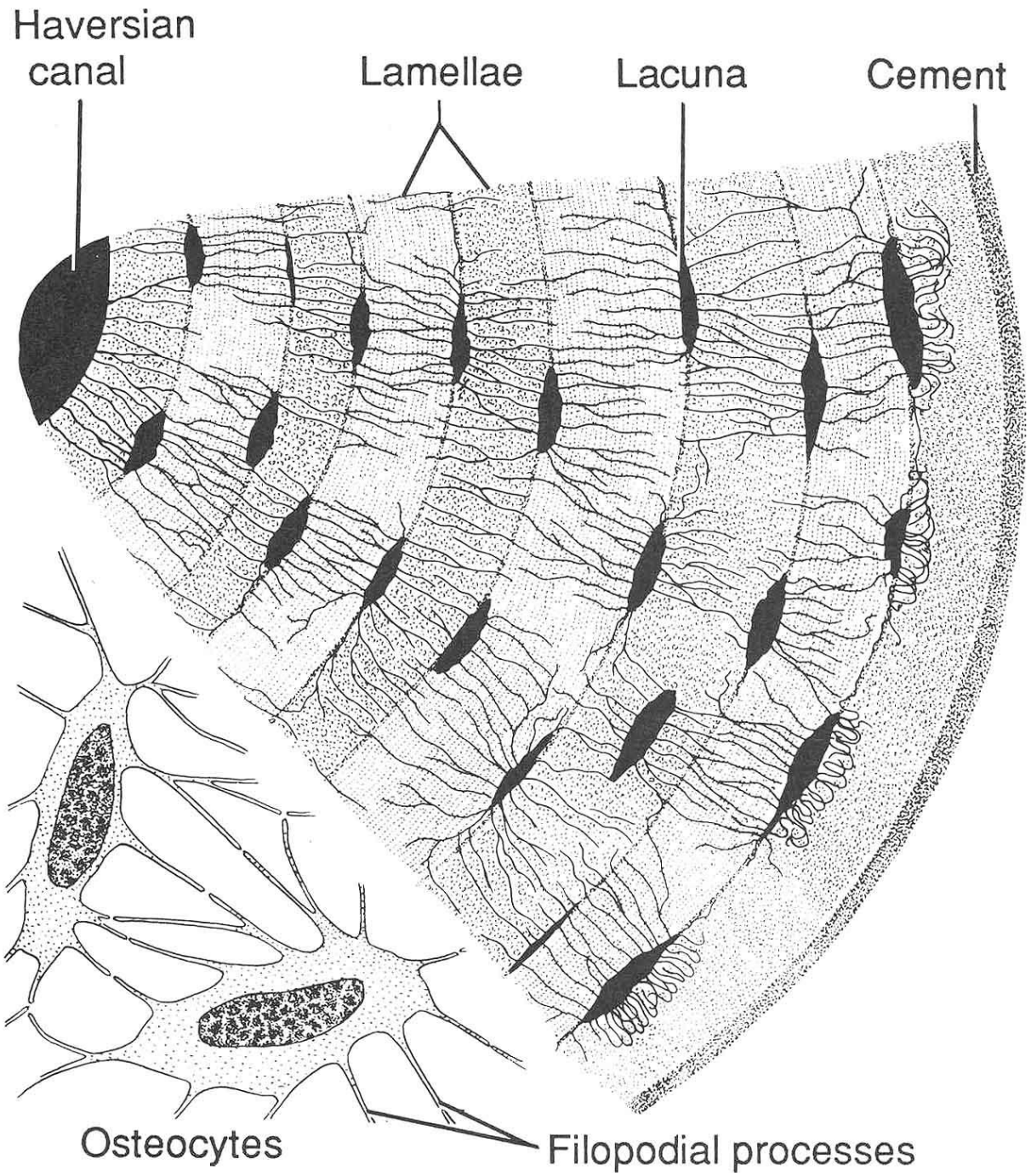
Types of bone tissue

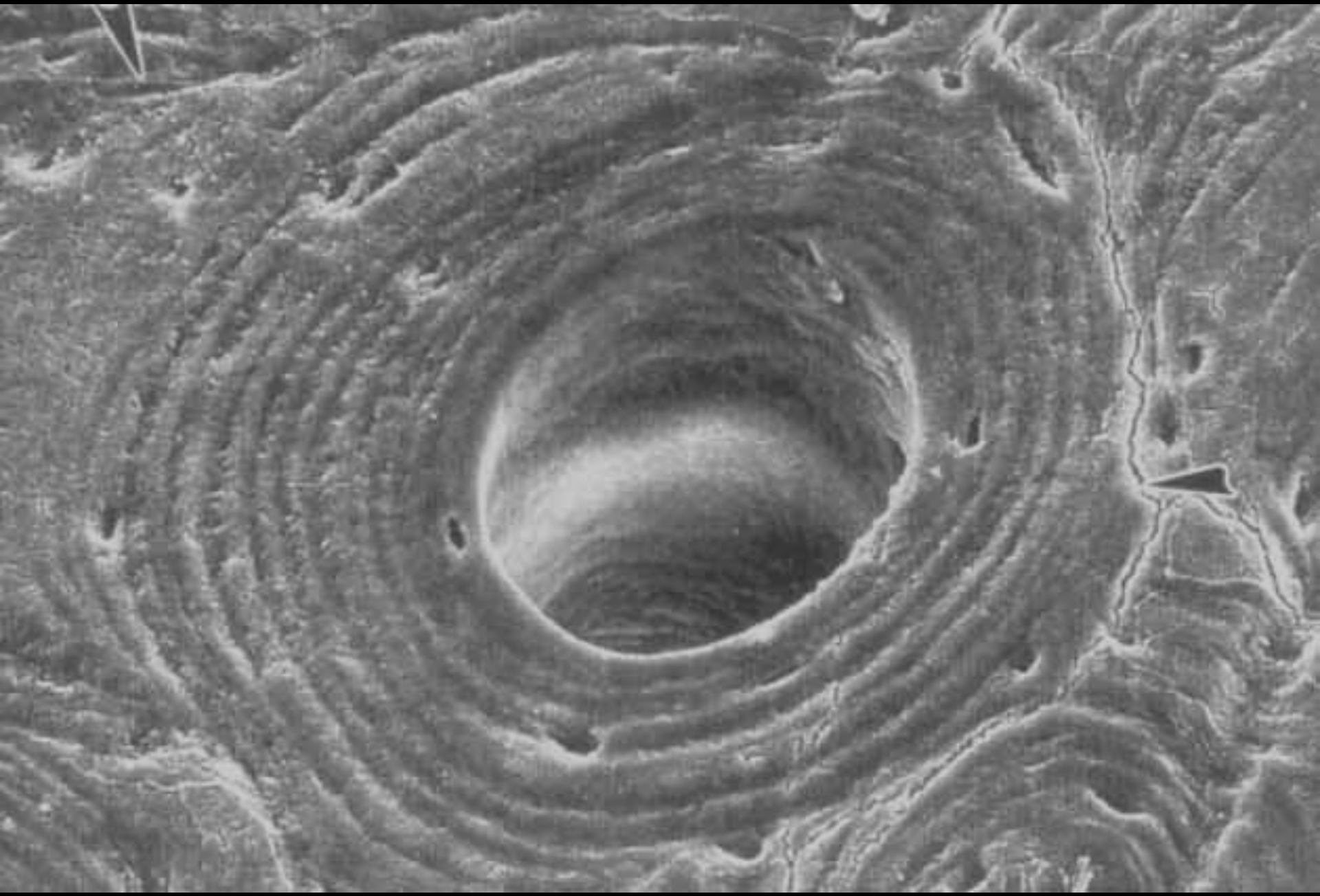
Bone tissue types

- woven (primary) – temporary bone during development and repair, irregular arrangement, low mineralization
- lamellar (secondary) – build of lamellae of parallel collagen fibers embedded in mineralized matrix, osteocytes mostly in between lamellae within cementing substance
  - compact – complete and interstitial osteons (Haversian systems), circumferential lamellae
  - spongy (cancellous) – anastomozing bony trabeculs build of parallel lamellae or osteons

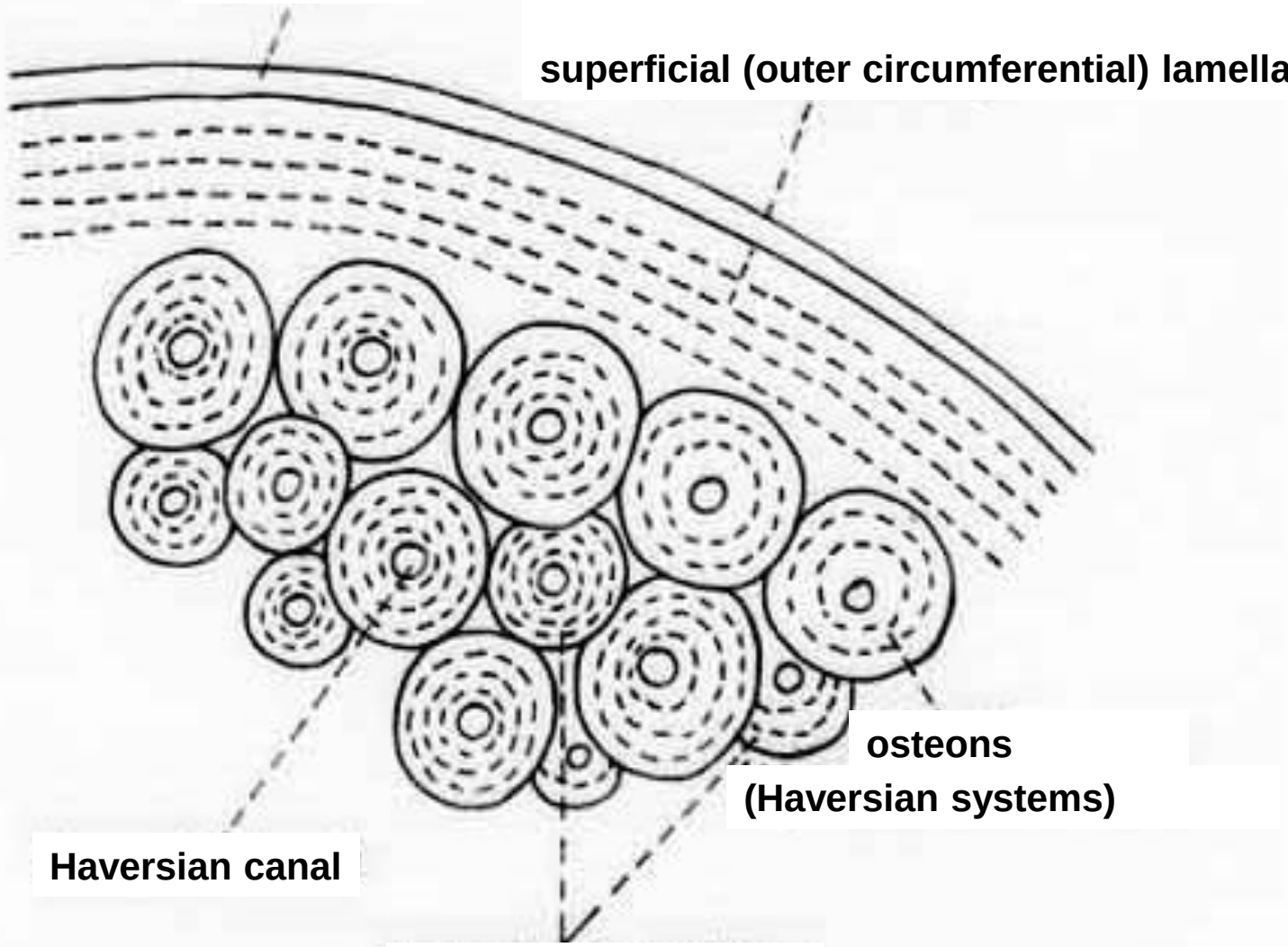

Woven bone (primary)

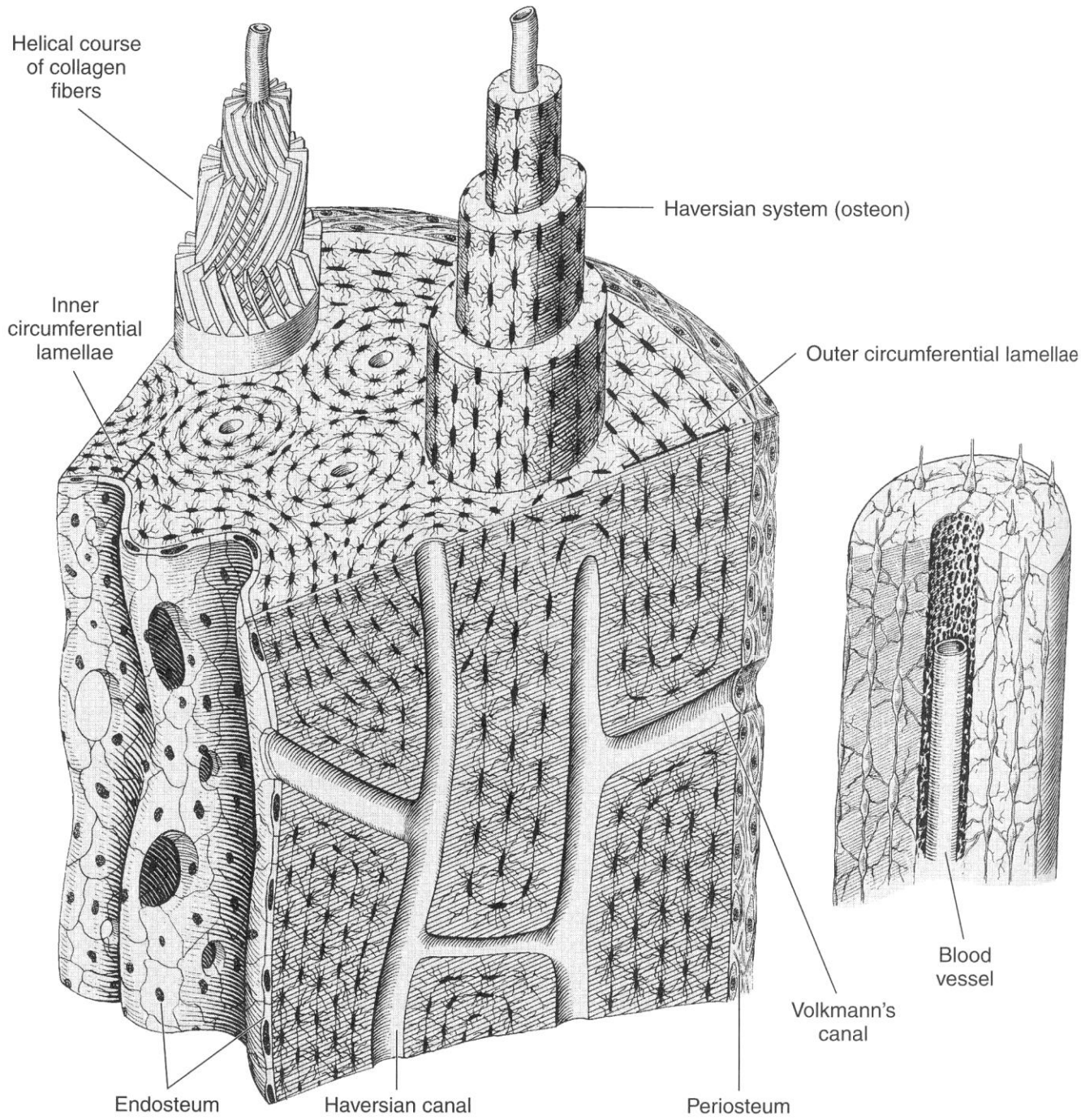
Lamellar bone (secondary)

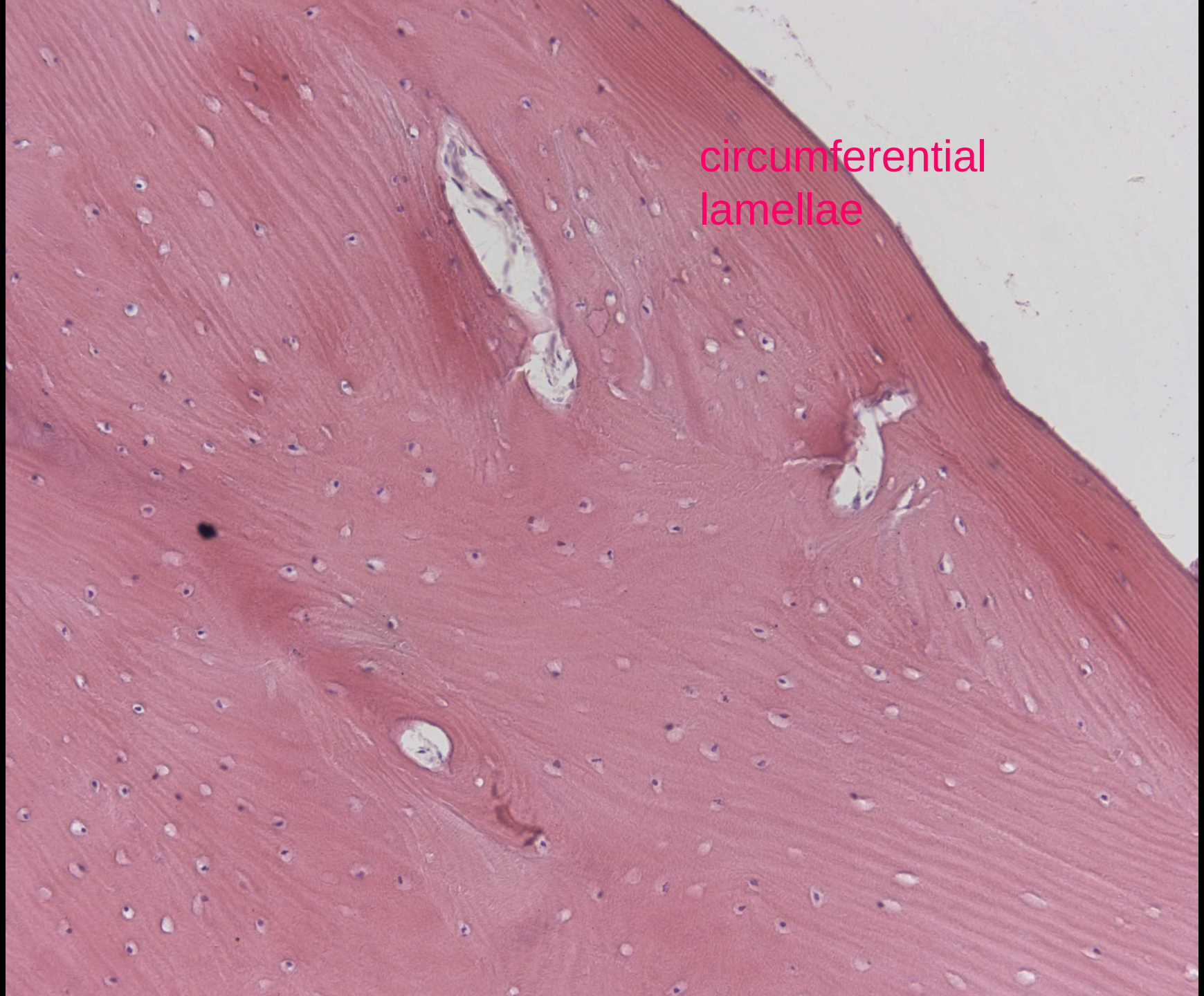




Compact bone




Helical course of collagen fibers
Haversian system (osteon)
Inner circumferential lamellae
Outer circumferential lamellae
Blood vessel
Volkmann's canal
Endosteum
Haversian canal
Periosteum

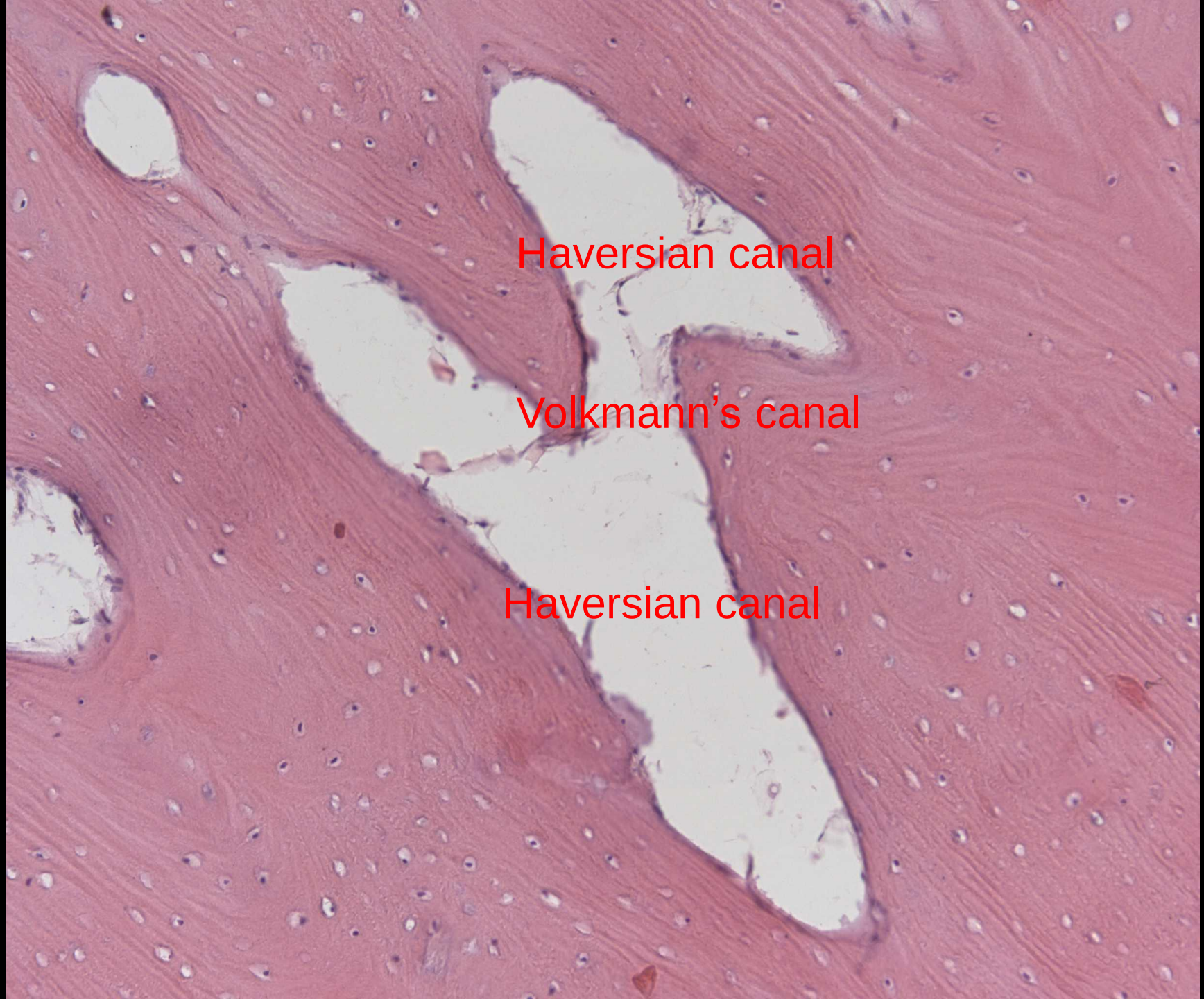

circumferential
lamellae


osteon
(Haversian
system)


compact bone


osteon, Haversian system


Haversian canal


Haversian canal
Volkmann’s canal
Haversian canal

Spongy (cancellous) bone