

Connective tissue

general building plan

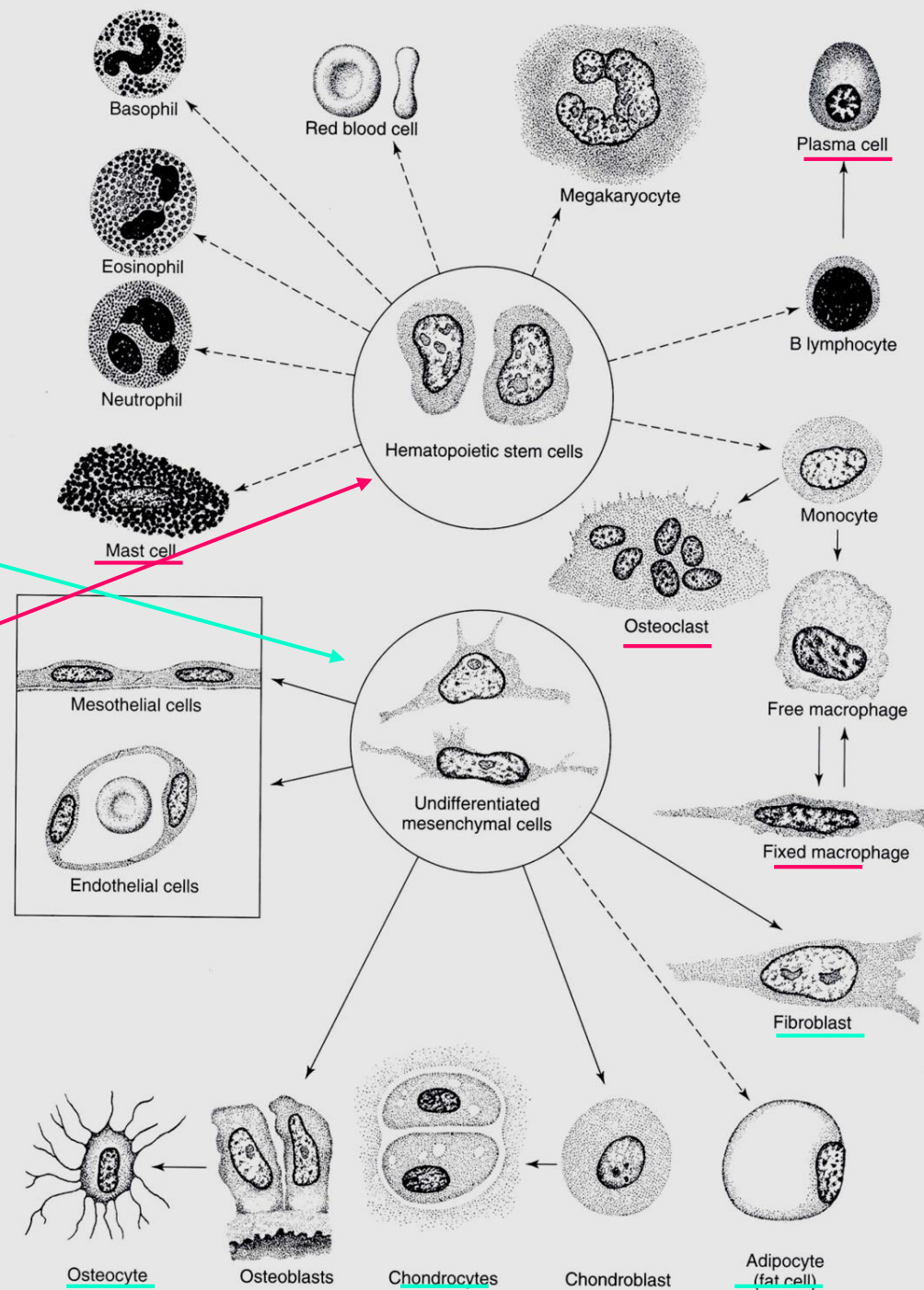
cells embedded in extracellular matrix,
which is produced by the cells
and prevails above them with its
volume

connective tissue proper
cartilage
bone

Cells of the connective tissues

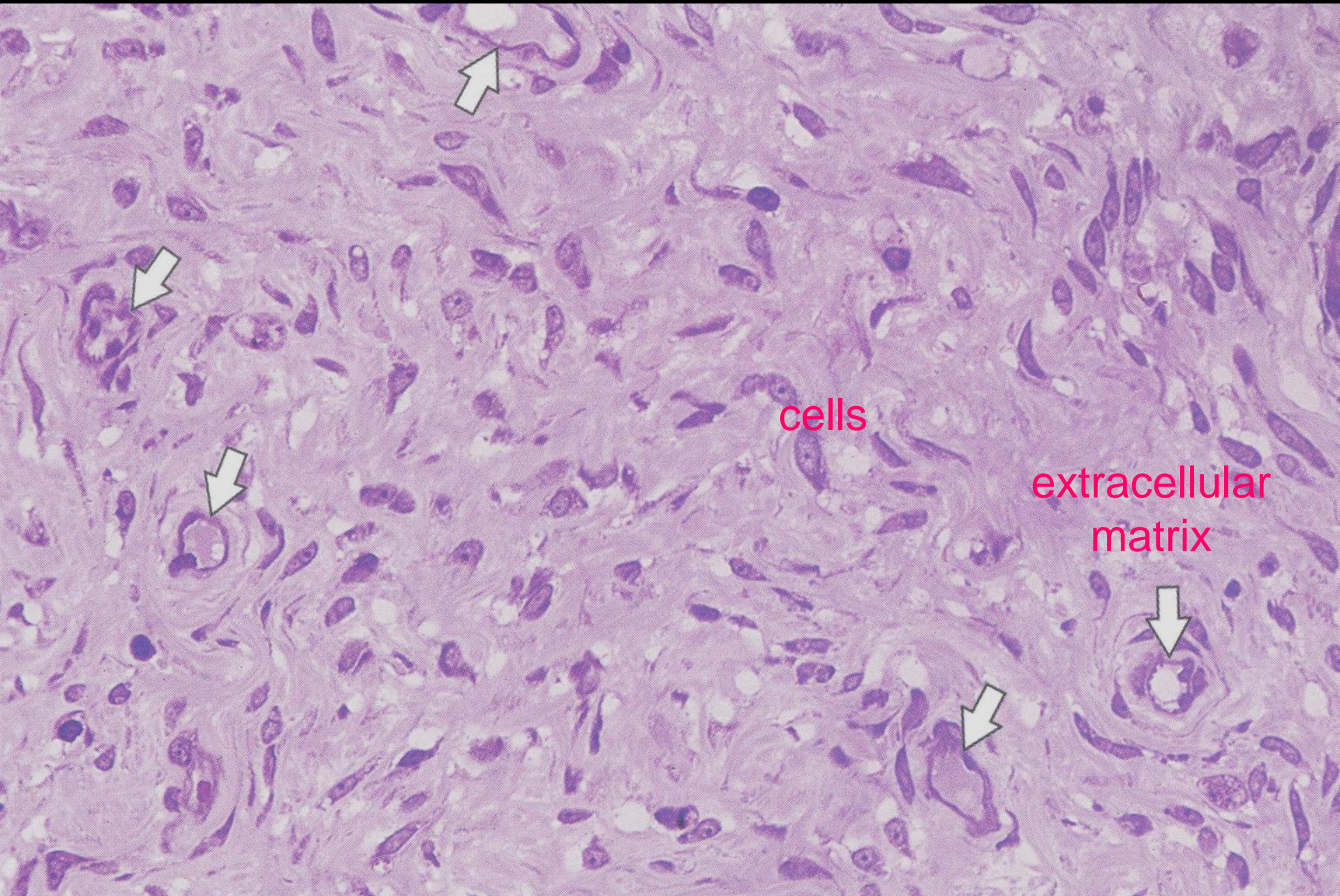
a) resident
– originate in actual tissue; produce intercellular matrix

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)



cells

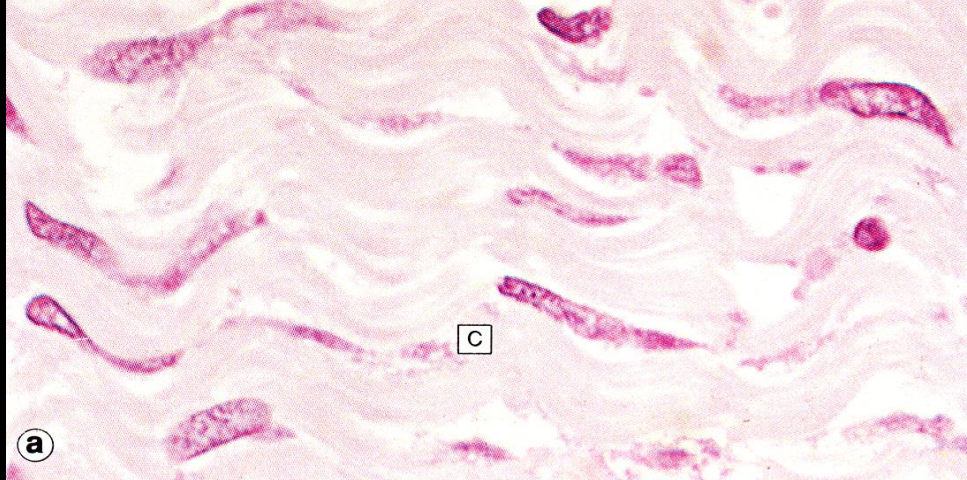
extracellular
matrix

arrows = small vessels

Connective tissue

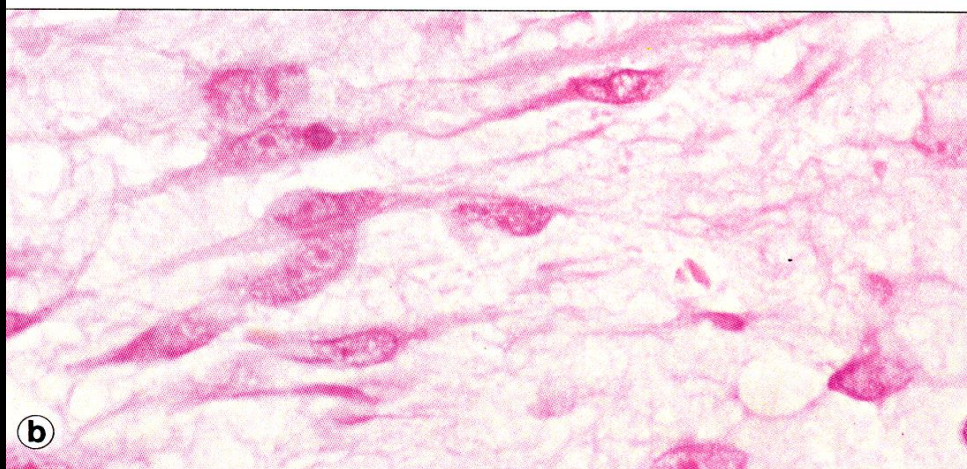
fixed cells

mesenchyme



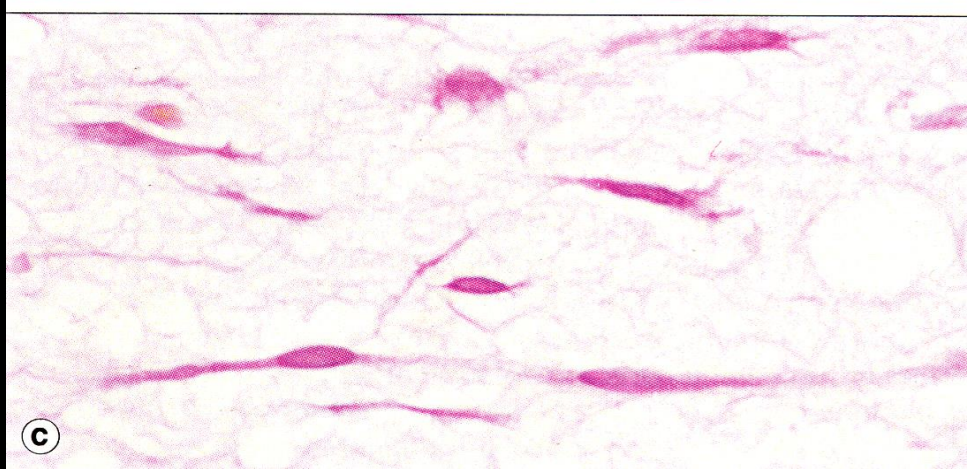
a

fibroblasts



b

fibrocytes



c

collagen fibrils
forming fibers

fibroblast



myofibroblast

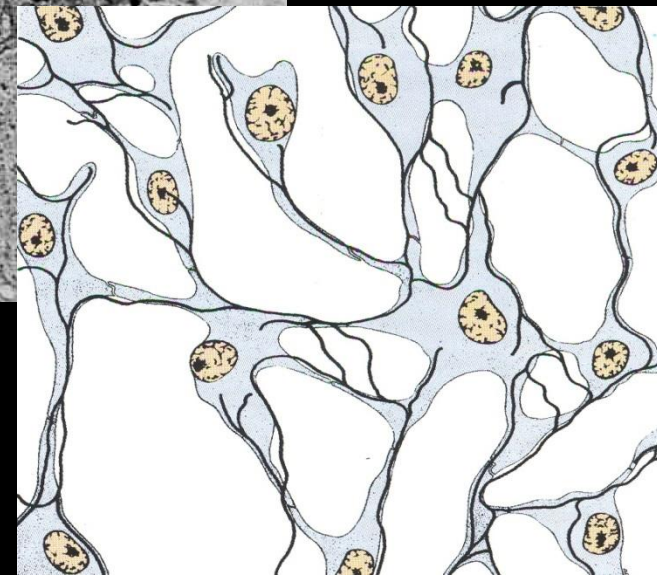
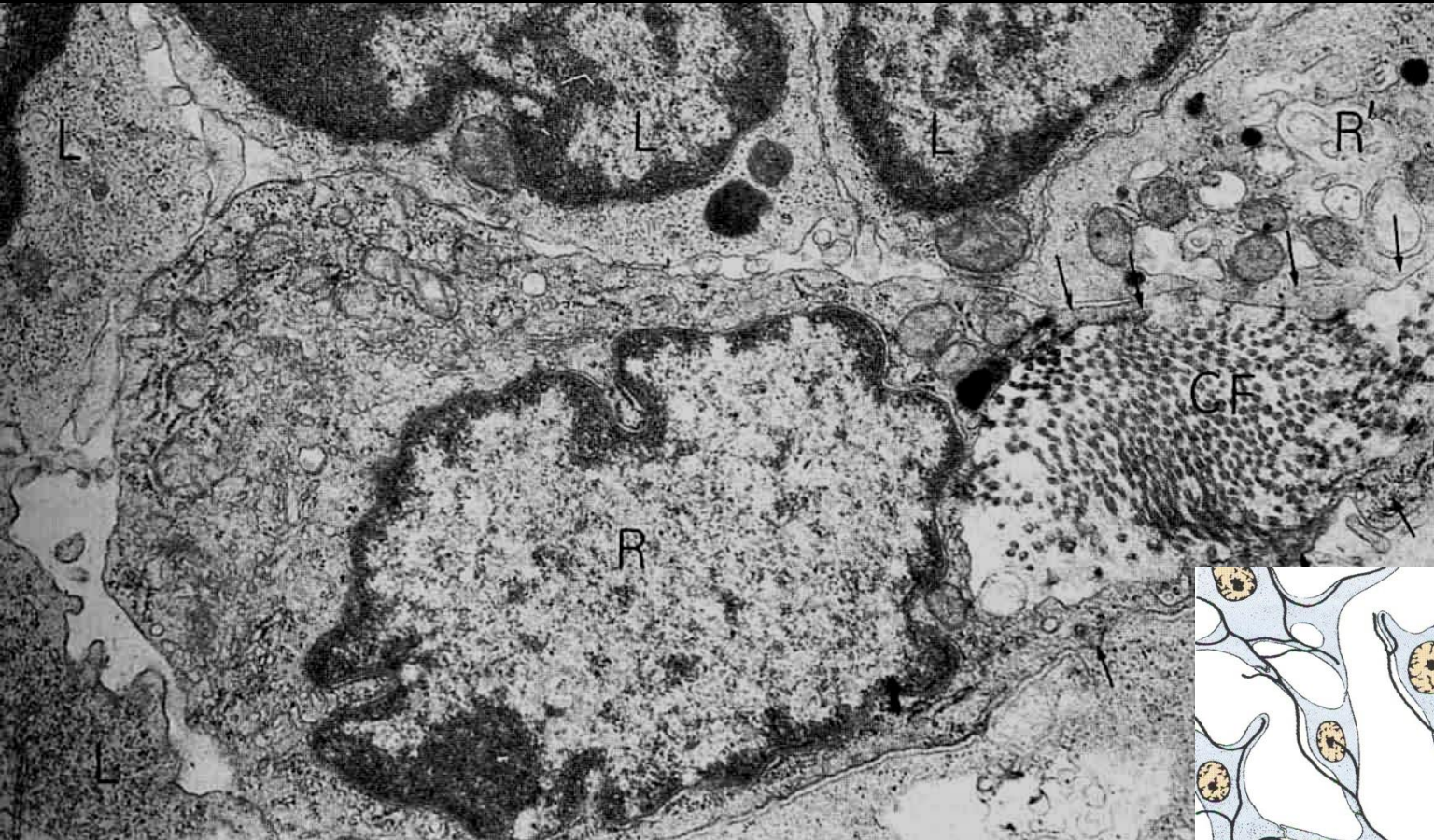


- is not surrounded by external (superficial) lamina
- contains dense bodies

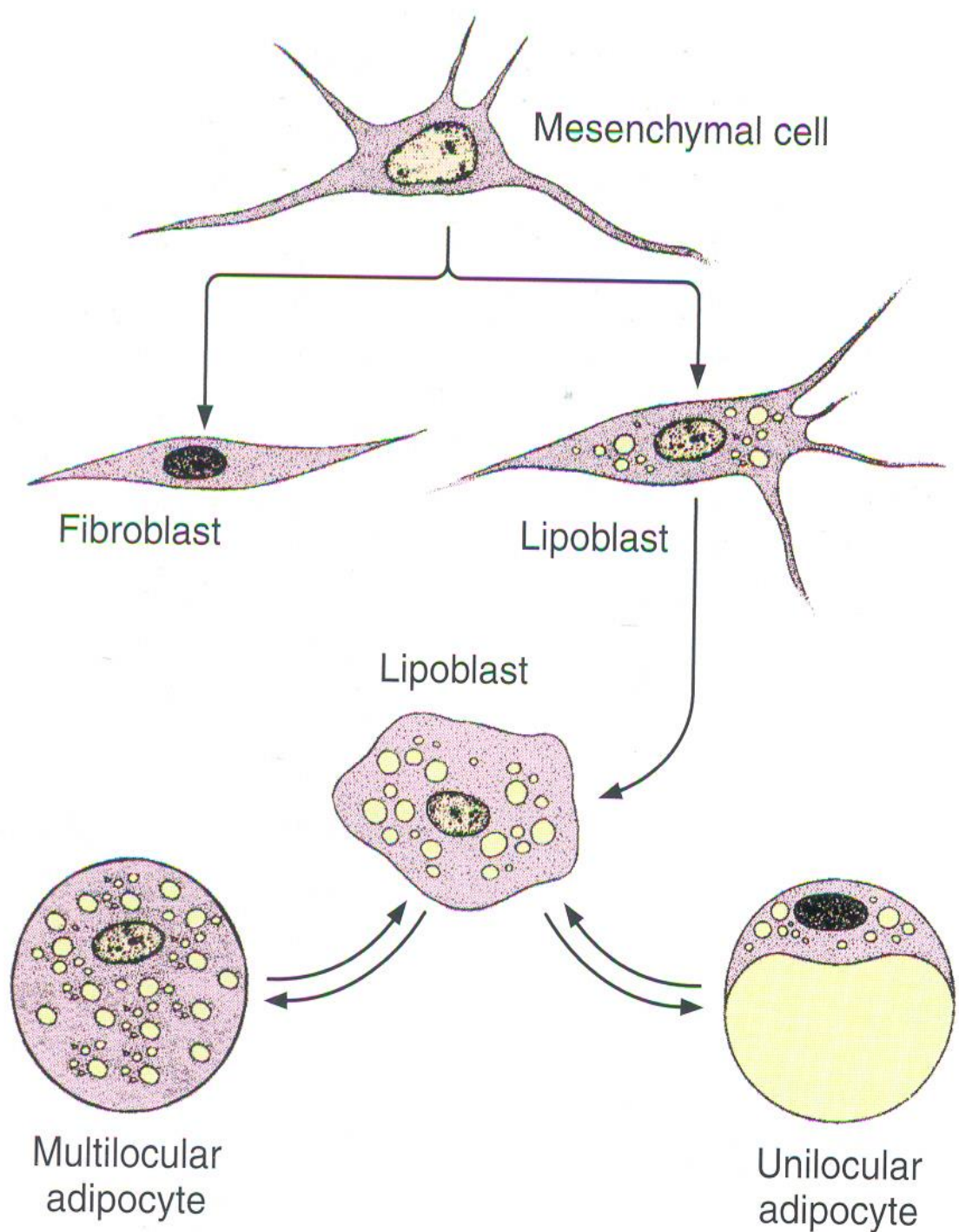
reticular cells (R and R')

L = lymphocytes

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



differentiation of adipocytes



A histological micrograph showing a dense field of unilocular adipocytes. The cells are large and roughly polygonal, with a clear, empty central space representing the lipid droplet. The cell boundaries are defined by thin, pink-stained cell membranes. The nuclei are small, dark, and pushed to the periphery of the cells. The overall appearance is that of a highly organized, uniform tissue structure.

unilocular adipocytes

2 unilocular adipocytes

L = lipid droplets

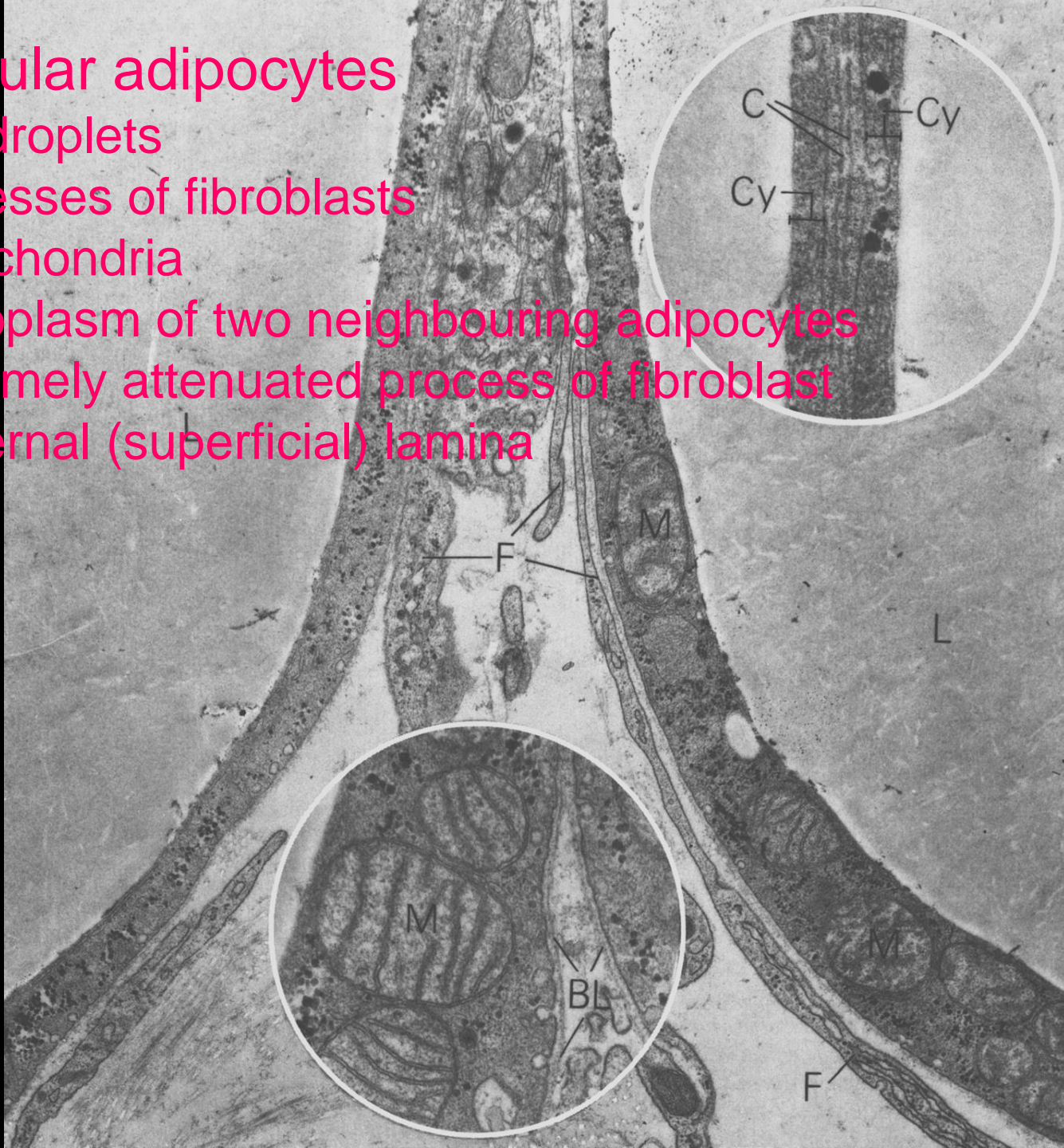
F = processes of fibroblasts

M = mitochondria

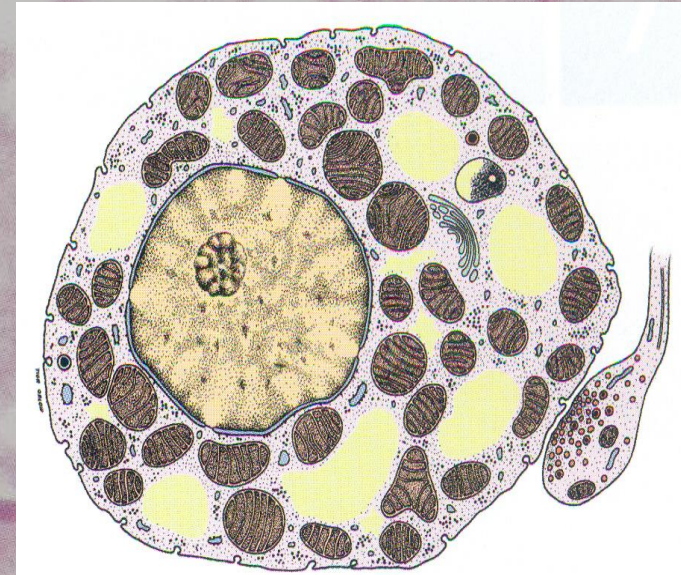
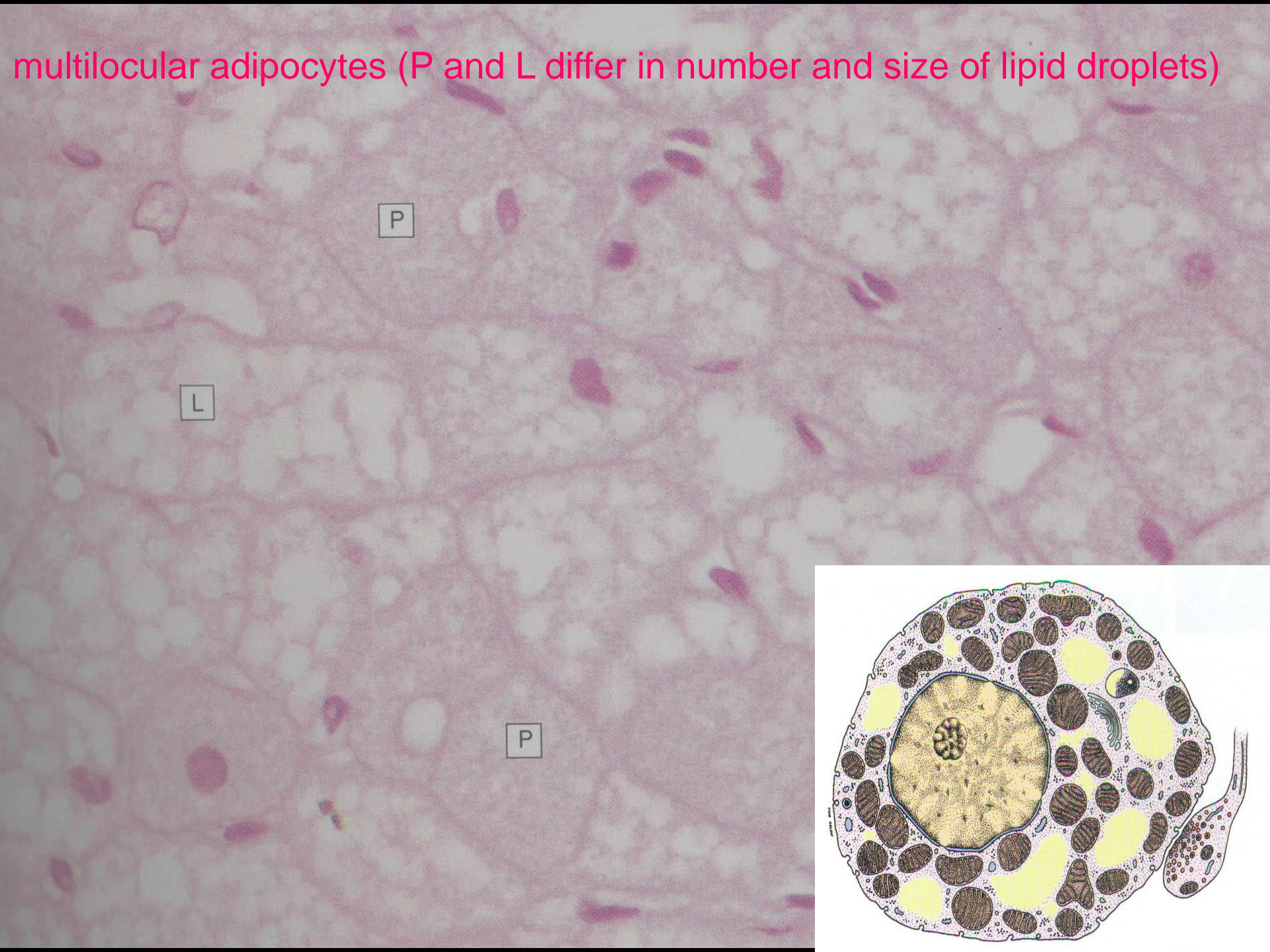
Cy = cytoplasm of two neighbouring adipocytes

C = extremely attenuated process of fibroblast

BL = external (superficial) lamina



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



A light micrograph of cartilage tissue stained with hematoxylin and eosin (H&E). The tissue is composed of numerous small, rounded cells embedded in a pinkish, extracellular matrix. The cells are arranged in a somewhat regular pattern, with some appearing as small, dark spots (chondroblasts) and others as larger, more rounded cells (chondrocytes). The overall appearance is that of a dense, cellular tissue.

chondroblasts

chondrocytes



osteoblasts

osteocytes

Connective tissue

migratory cells

M = macrophages

P = plasma cells

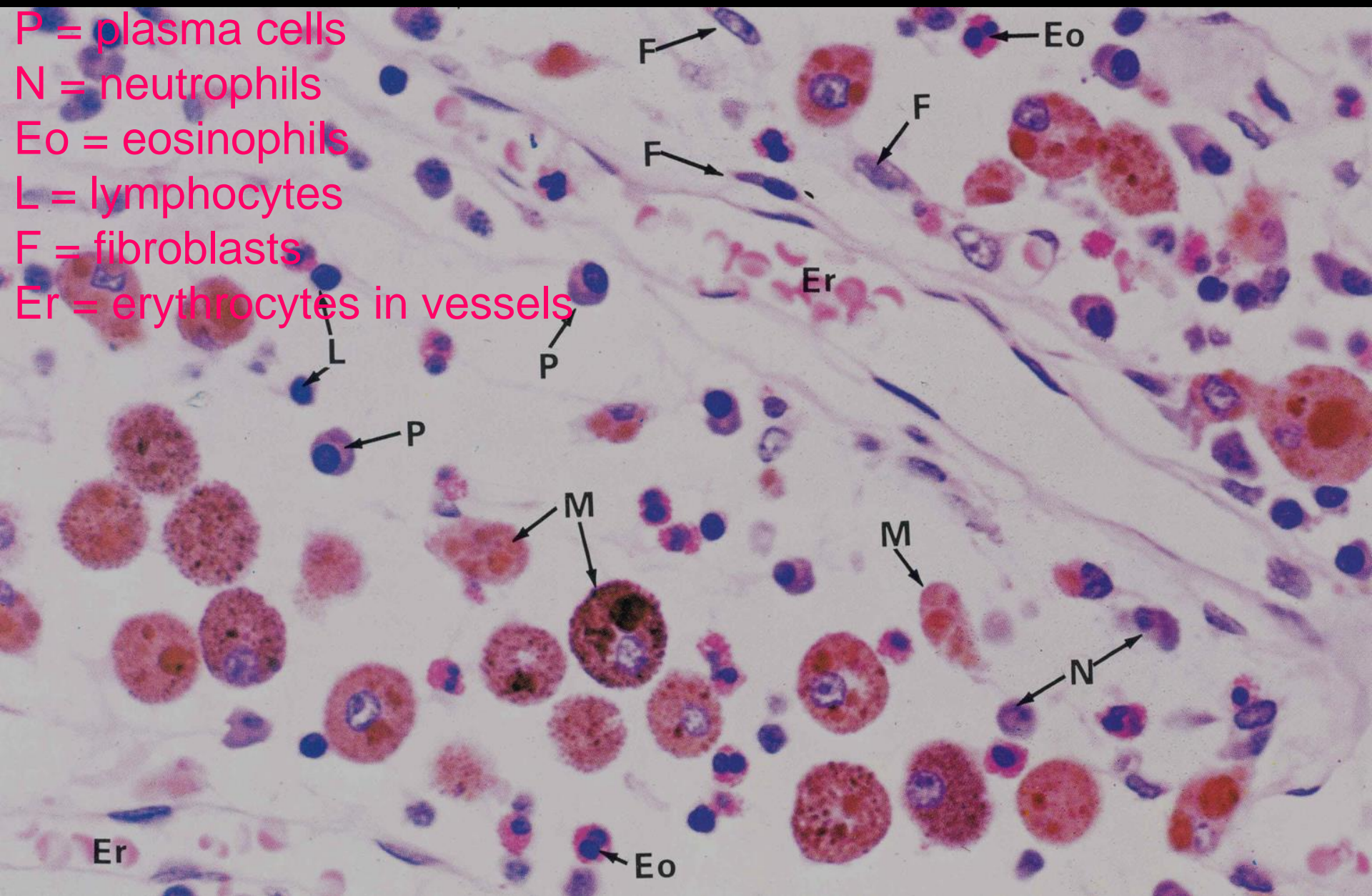
N = neutrophils

Eo = eosinophils

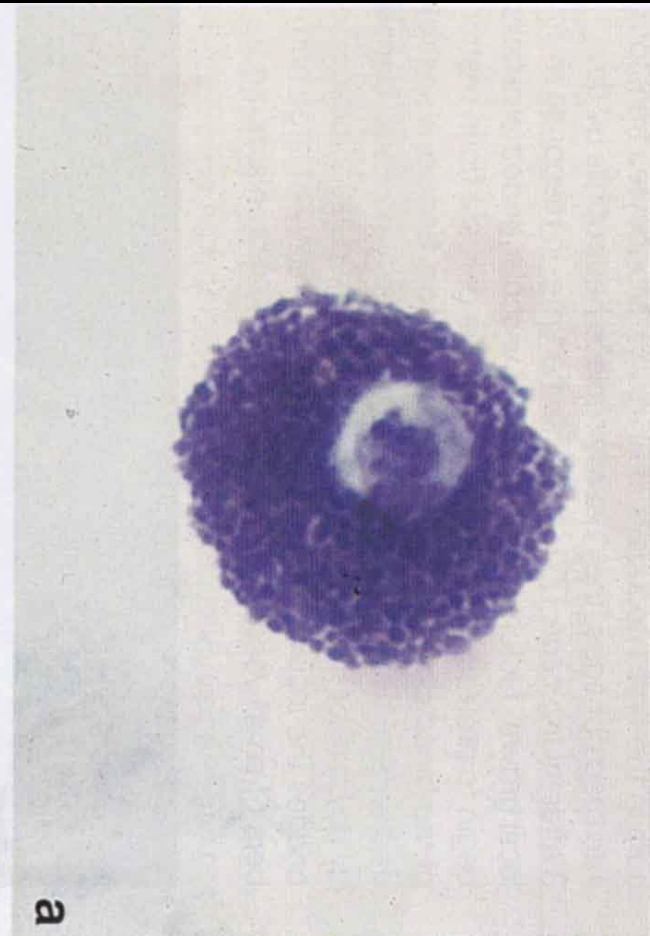
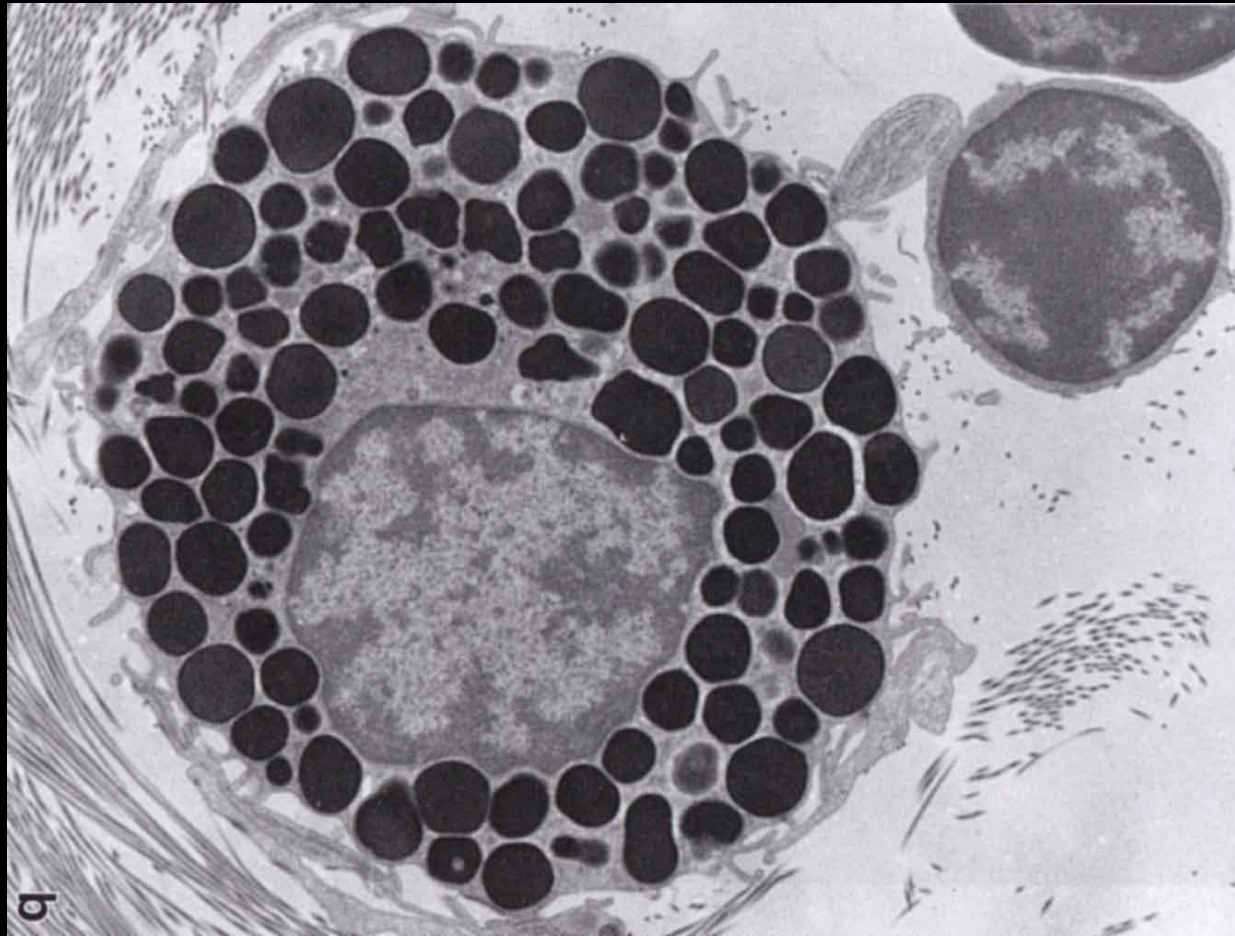
L = lymphocytes

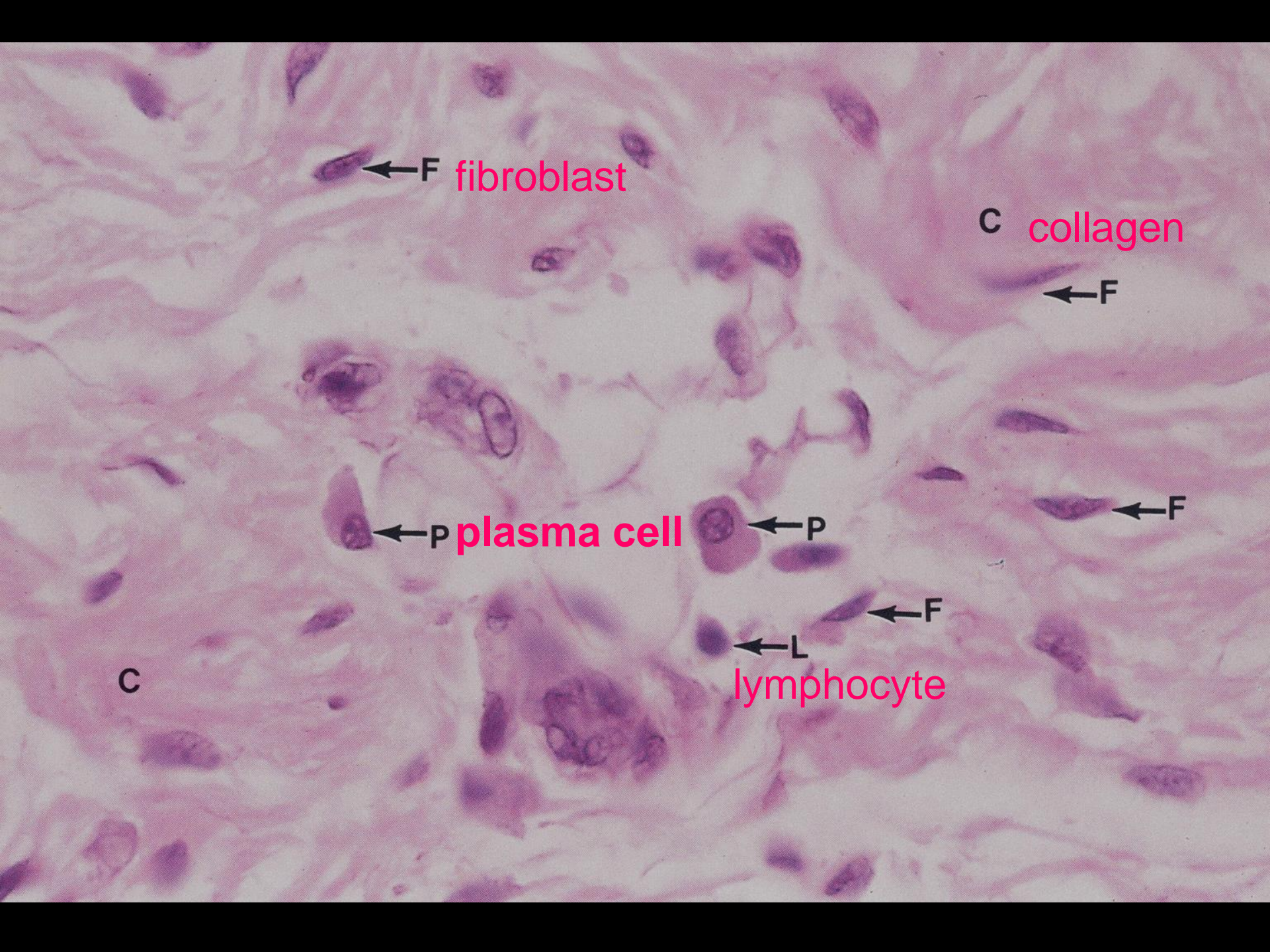
F = fibroblasts

Er = erythrocytes in vessels



mast cells





← F fibroblast

C collagen

← F

← P plasma cell

← P

← F

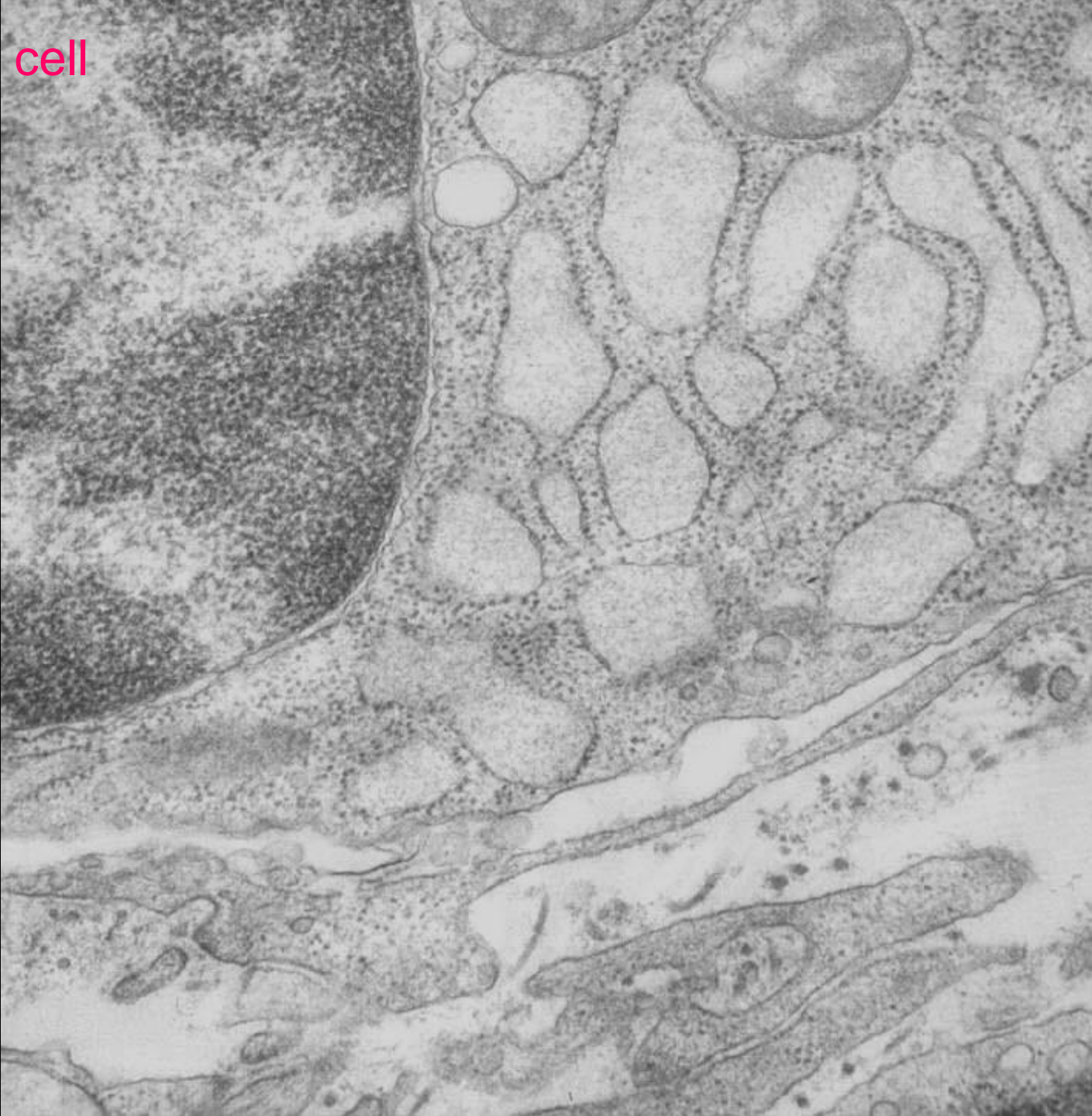
← F

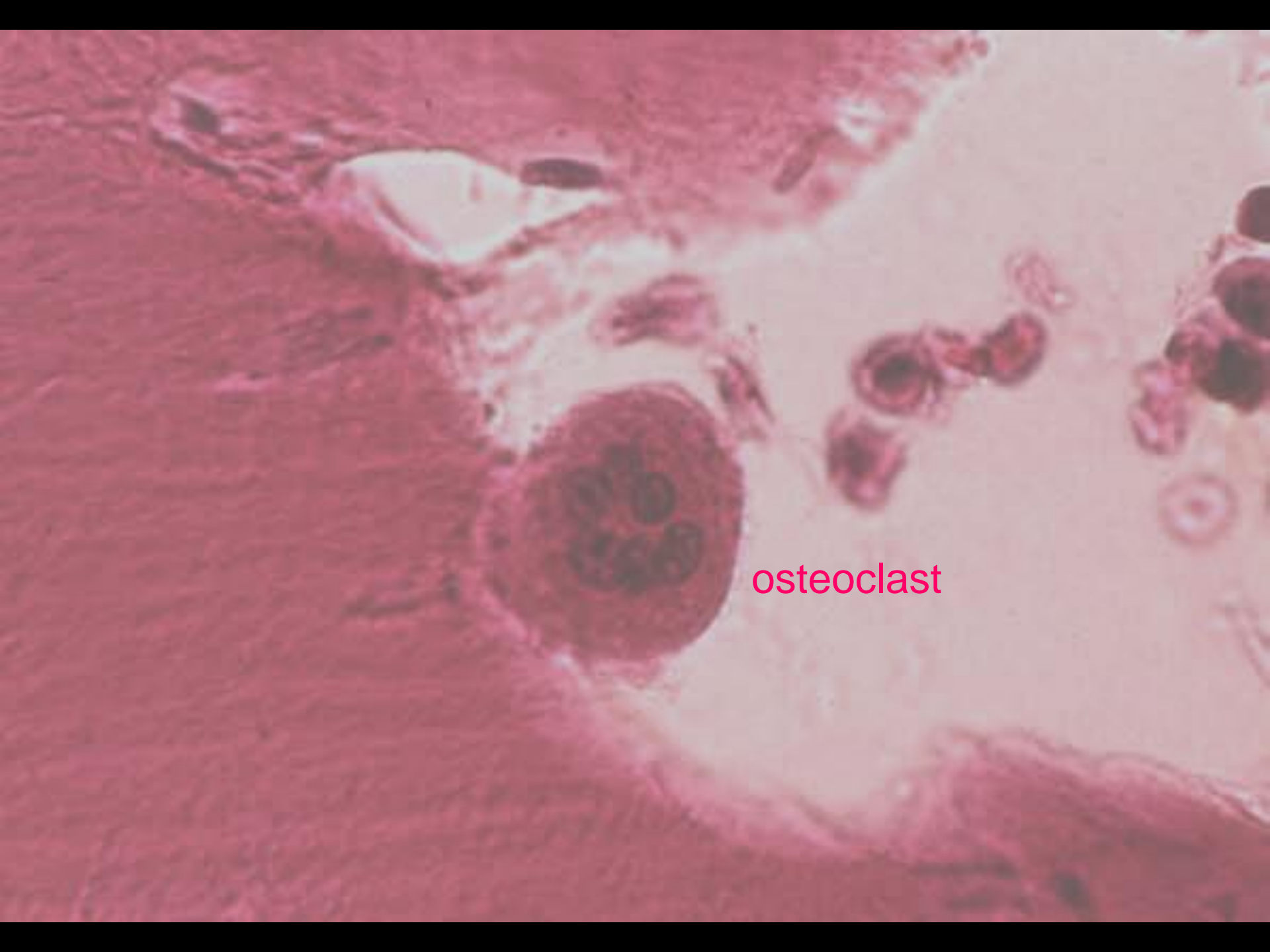
← L

lymphocyte

C

plasma cell



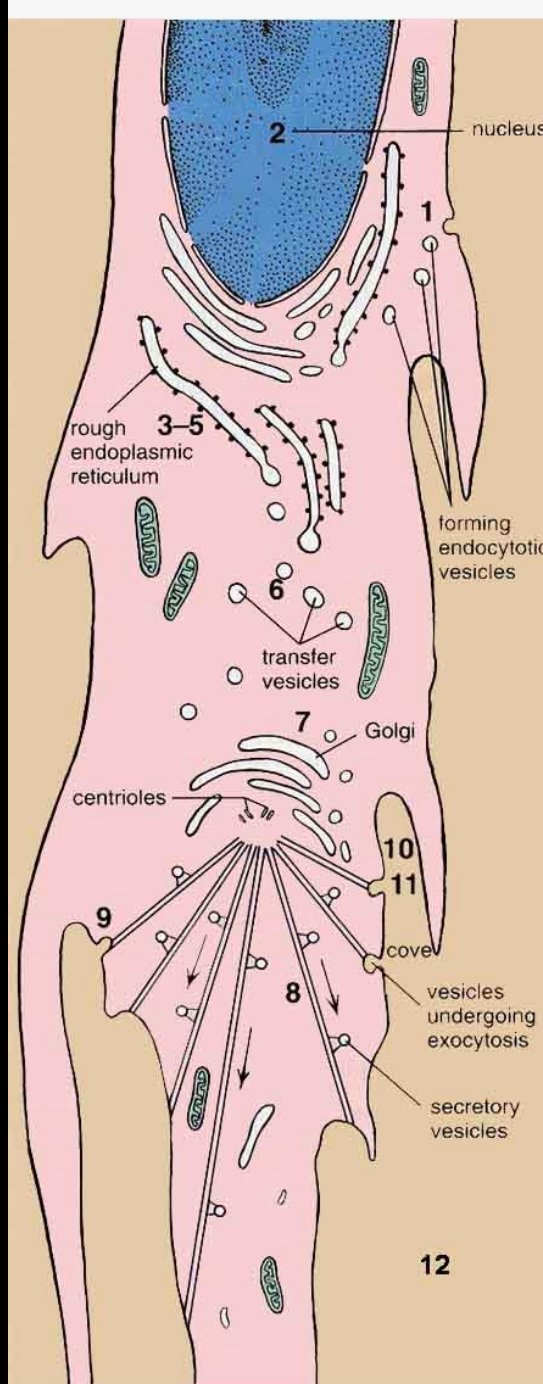


osteoclast

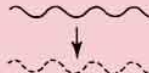
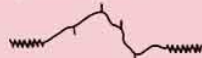
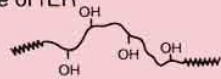
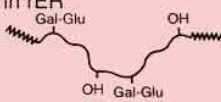

Connective tissue

intercellular matrix

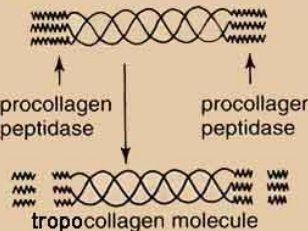
Synthesis and secretion of collagen



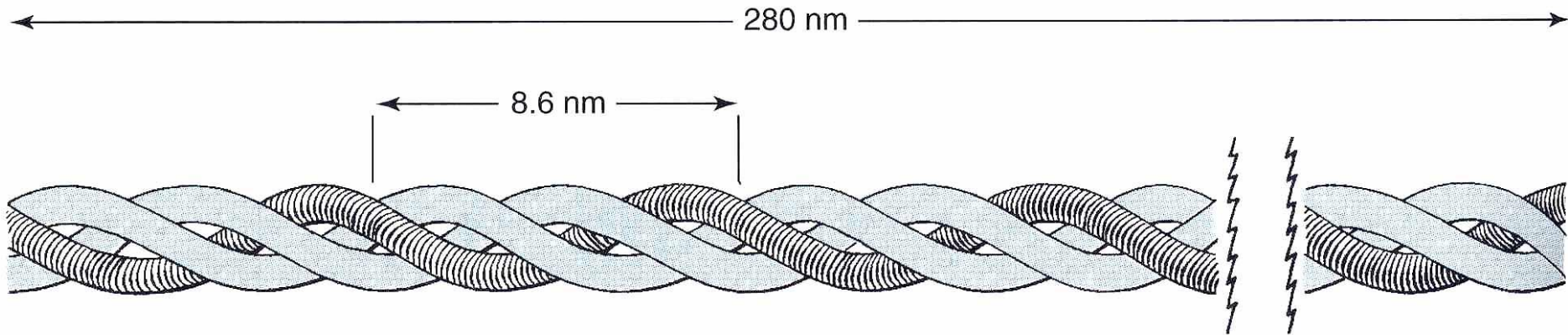
INTRACELLULAR EVENTS

- 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 tropocollagen molecule
 
- 11 Polymerization of tropocollagen molecule into protofibril (in coves initially)
- 12 Parallel aggregation of protofibrils into fibrils

(Tropo)collagen



width 1.5 nm

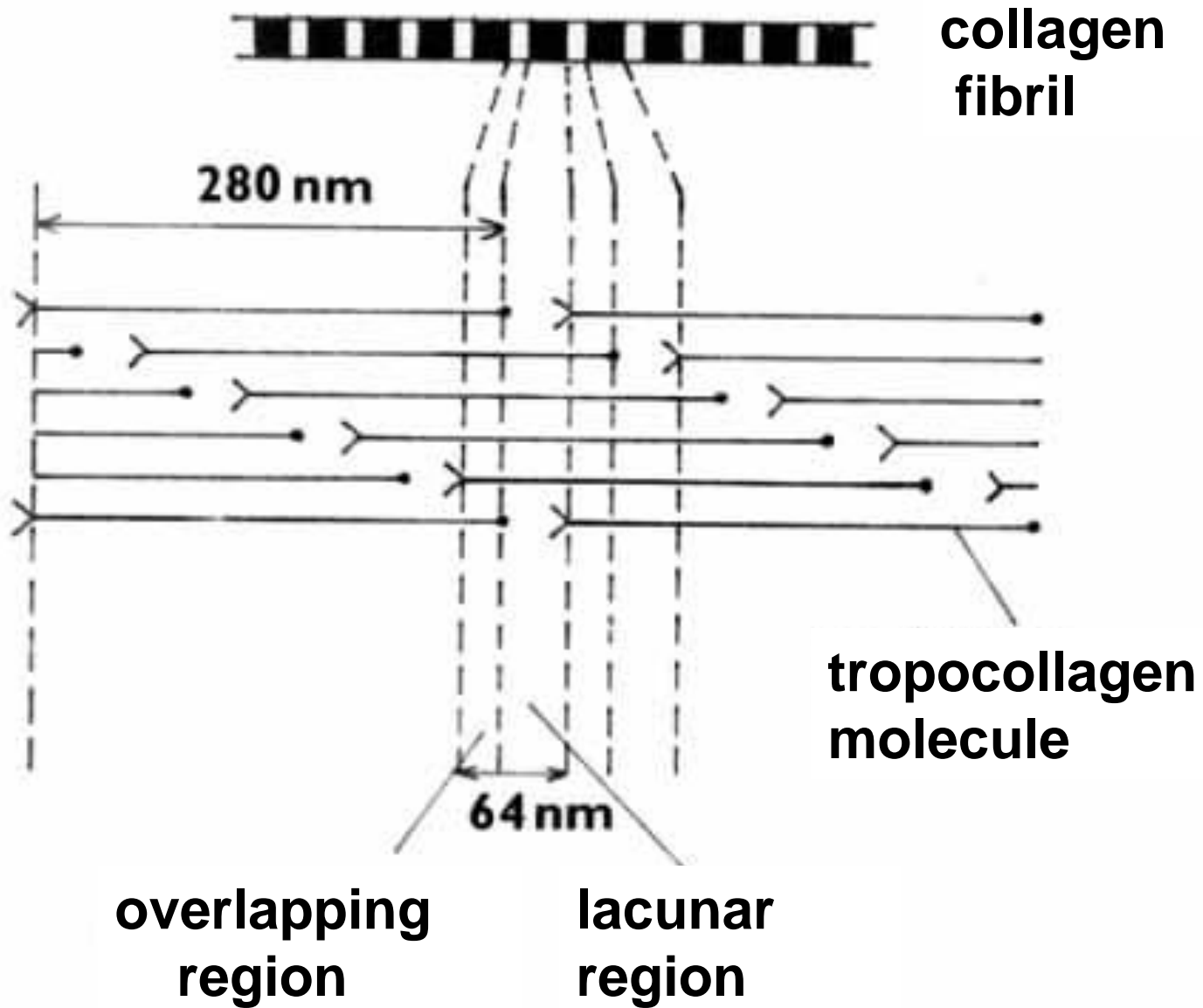
length 280 – 300 nm

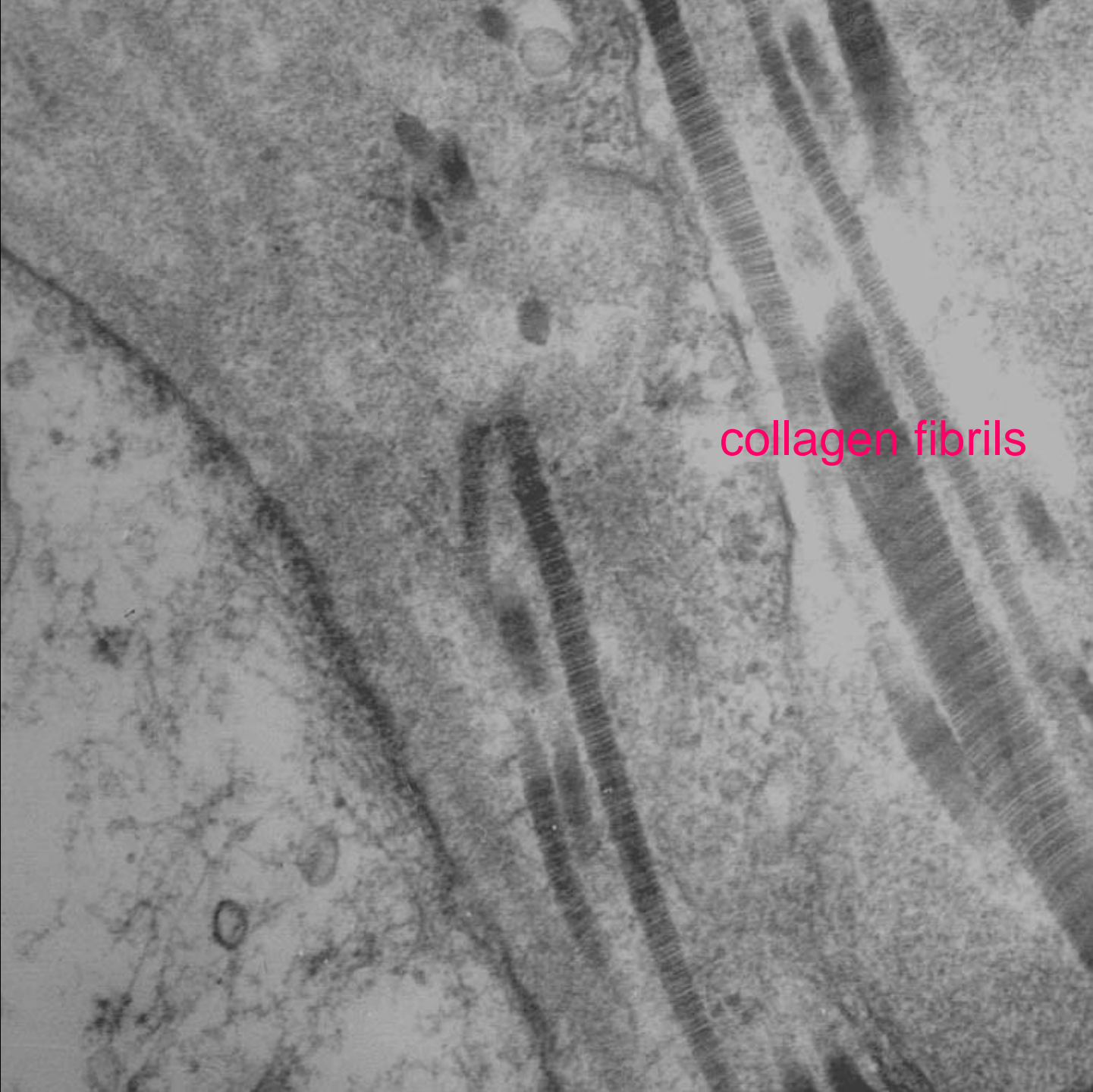
triple helix

heterotrimeric molecules ($2 \alpha_1 + 1 \alpha_2$ or $\alpha_1 + \alpha_2 + \alpha_3$)

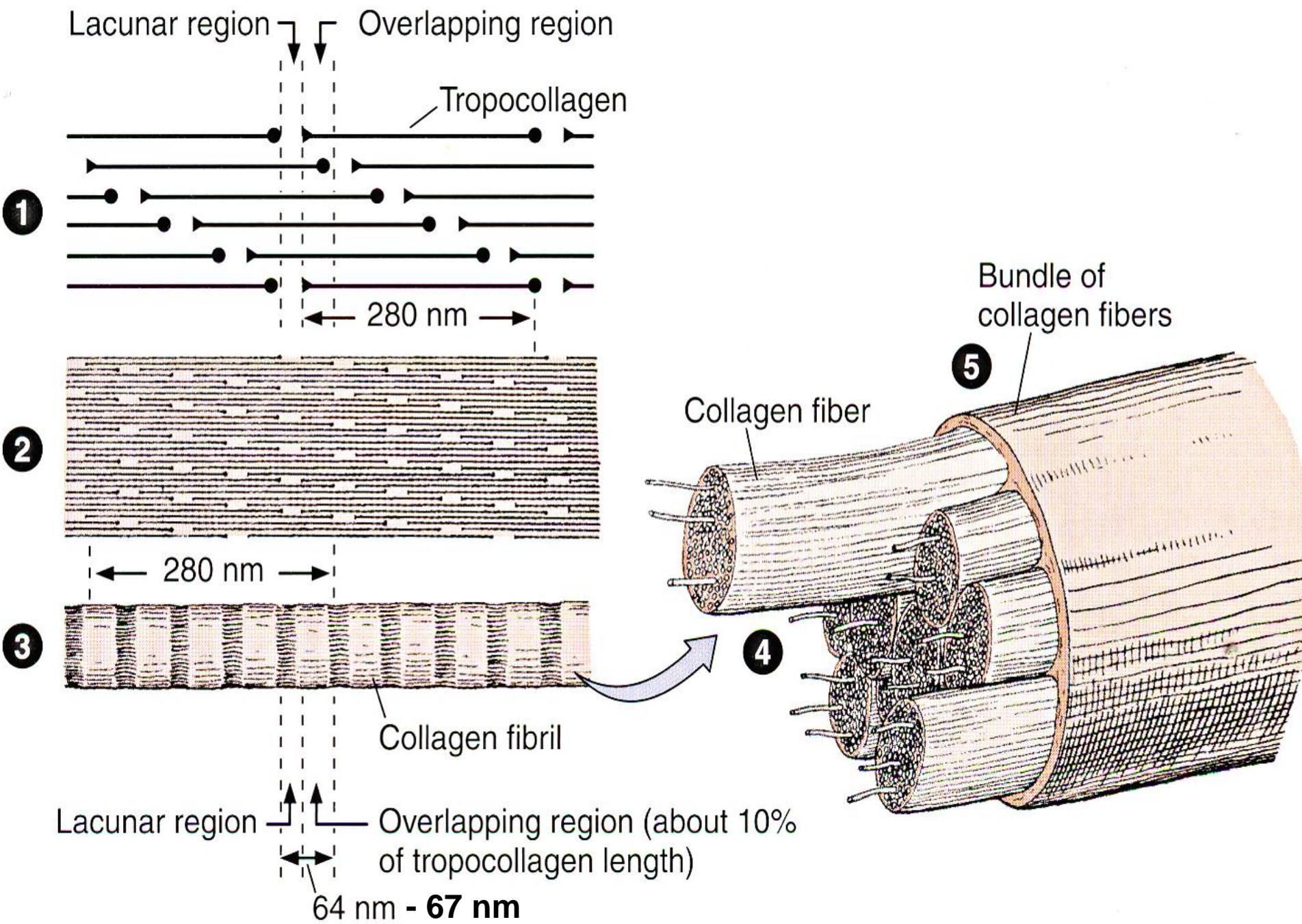
homotrimeric molecules (3 equal α chains)

COLLAGEN FIBRIL STRUCTURE





collagen fibrils



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

Important collagen types

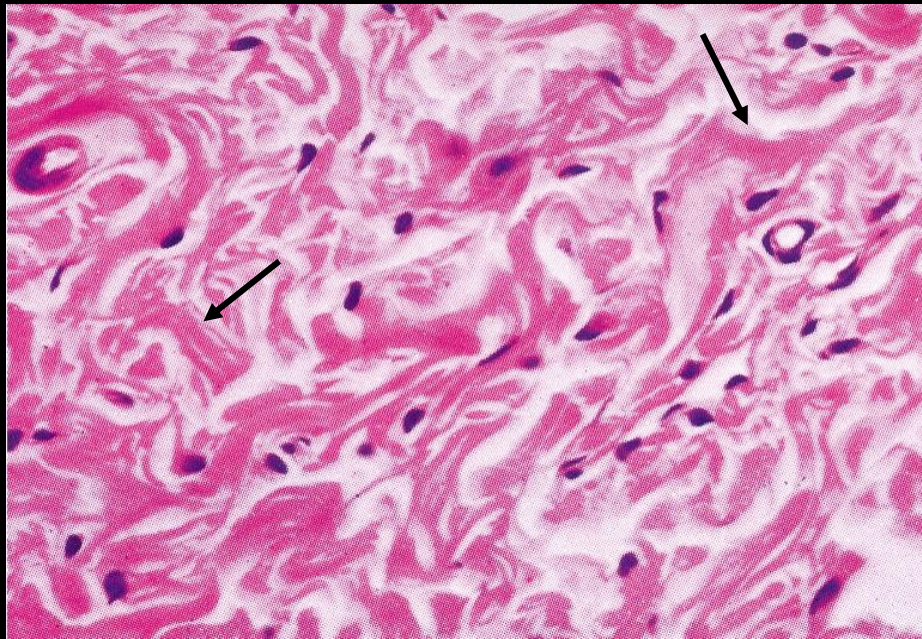
Type	occurrence	fibrils	fibers
I	collagen fibers (connective tissue proper, fibrocartilage, bone)	Ø 75 nm	Ø 2 – 20 µm
II	cartilage	Ø 20 nm	none
III	reticular fibers (connective tissue proper)	Ø 45 nm	Ø 0,1 – 2 µm
IV	basal and superficial laminae	none	none

Collagen
type I

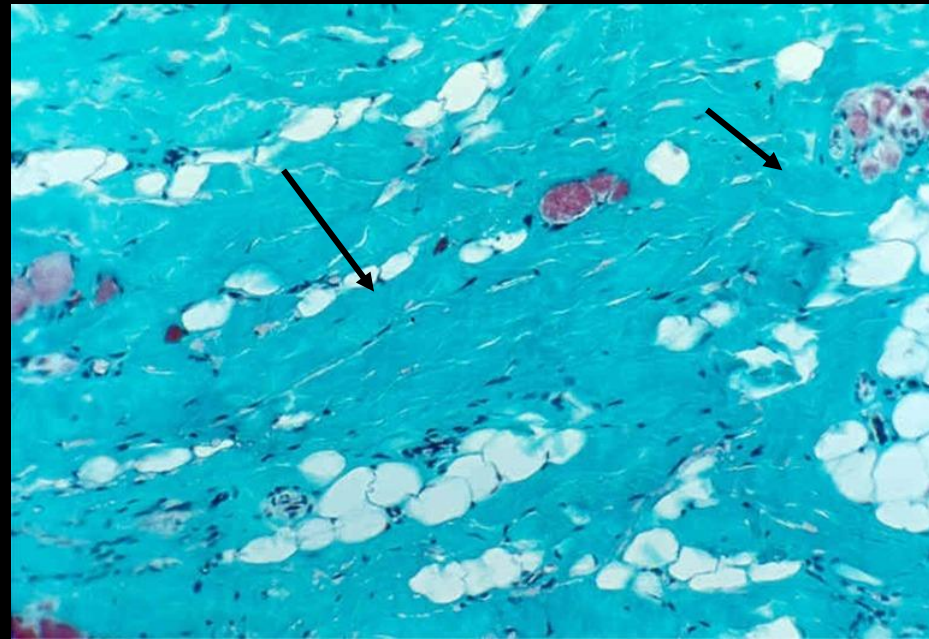


collagen fiber

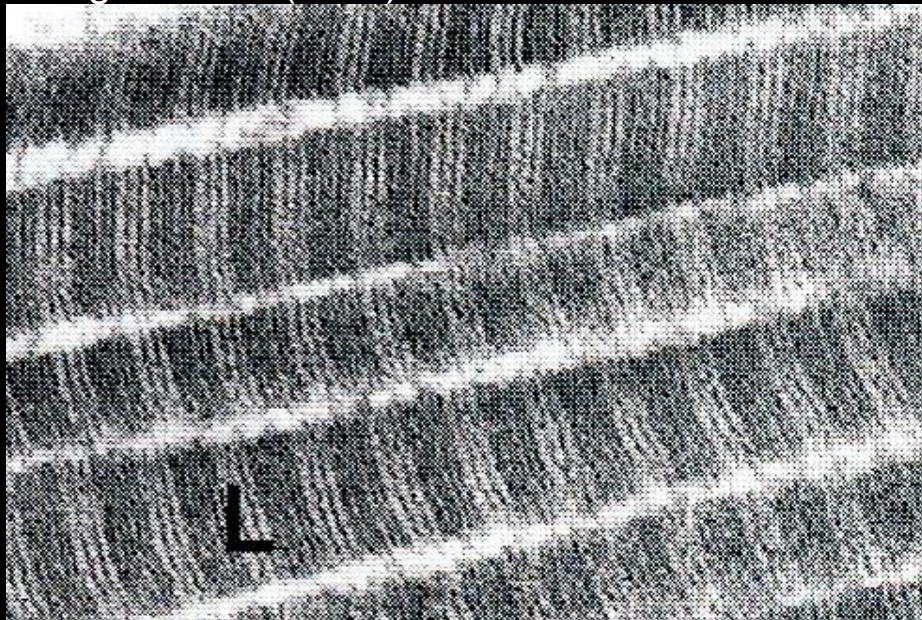
collagen fibers (HE)



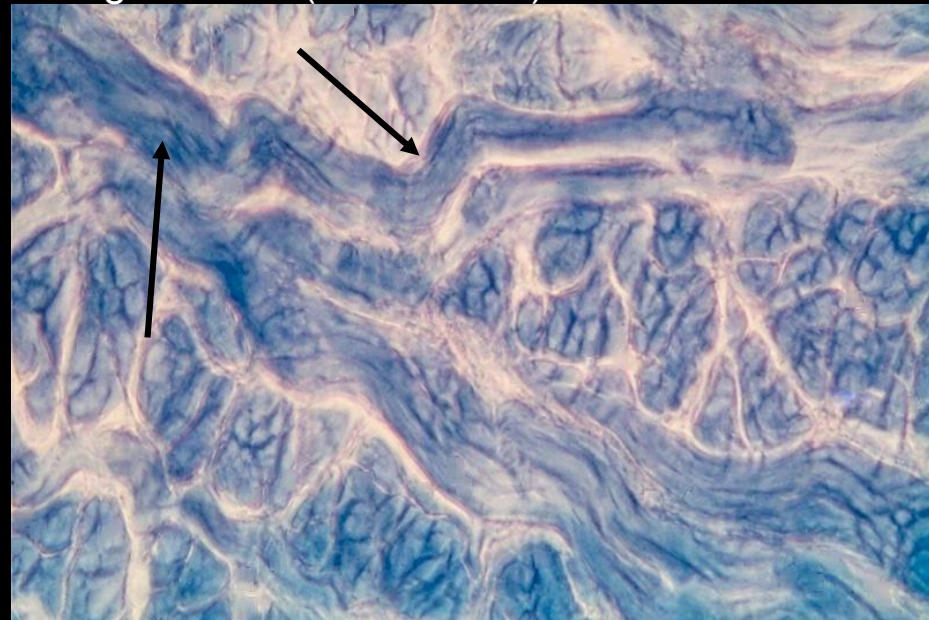
collagen fibers (green trichrom)

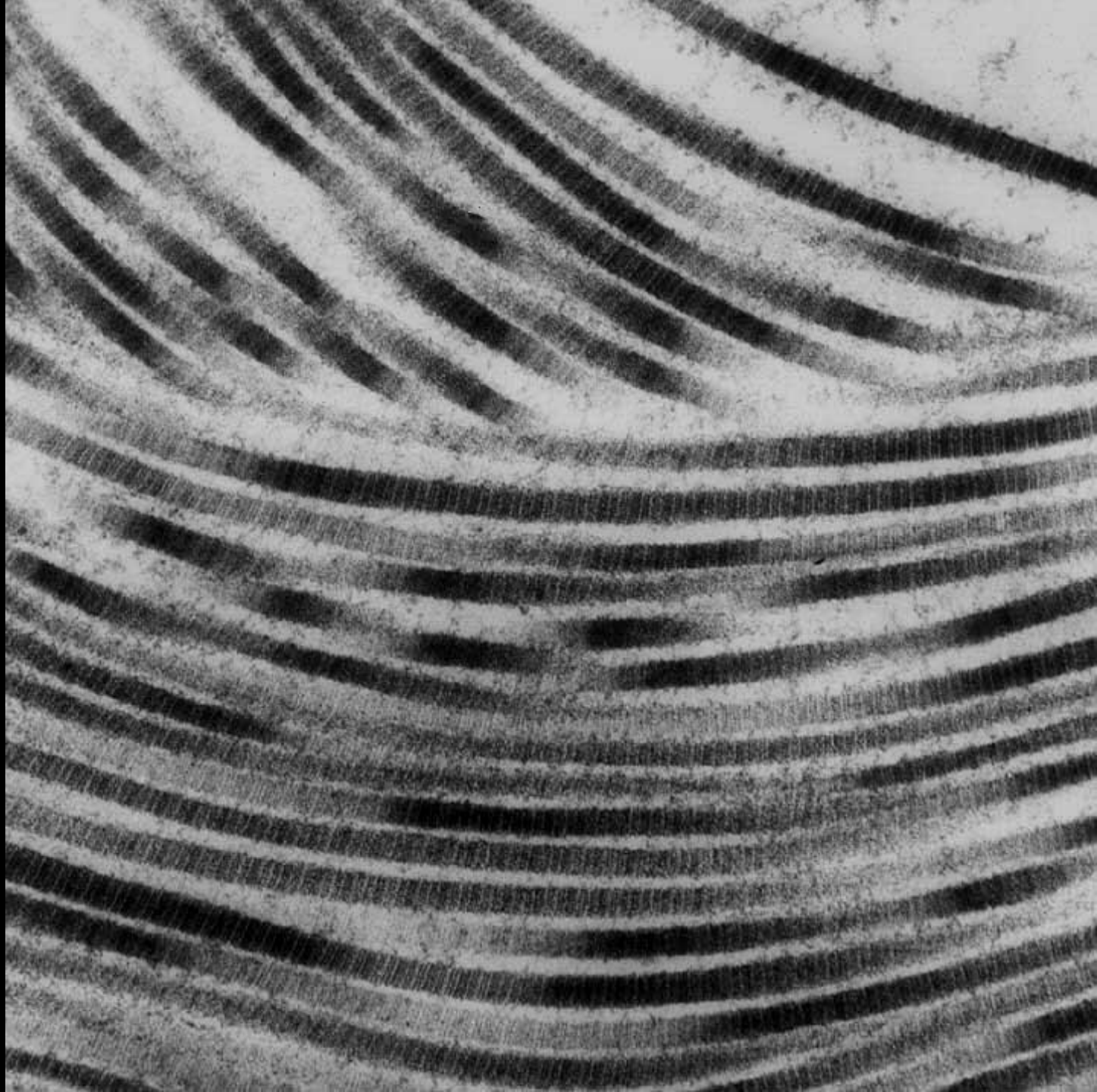


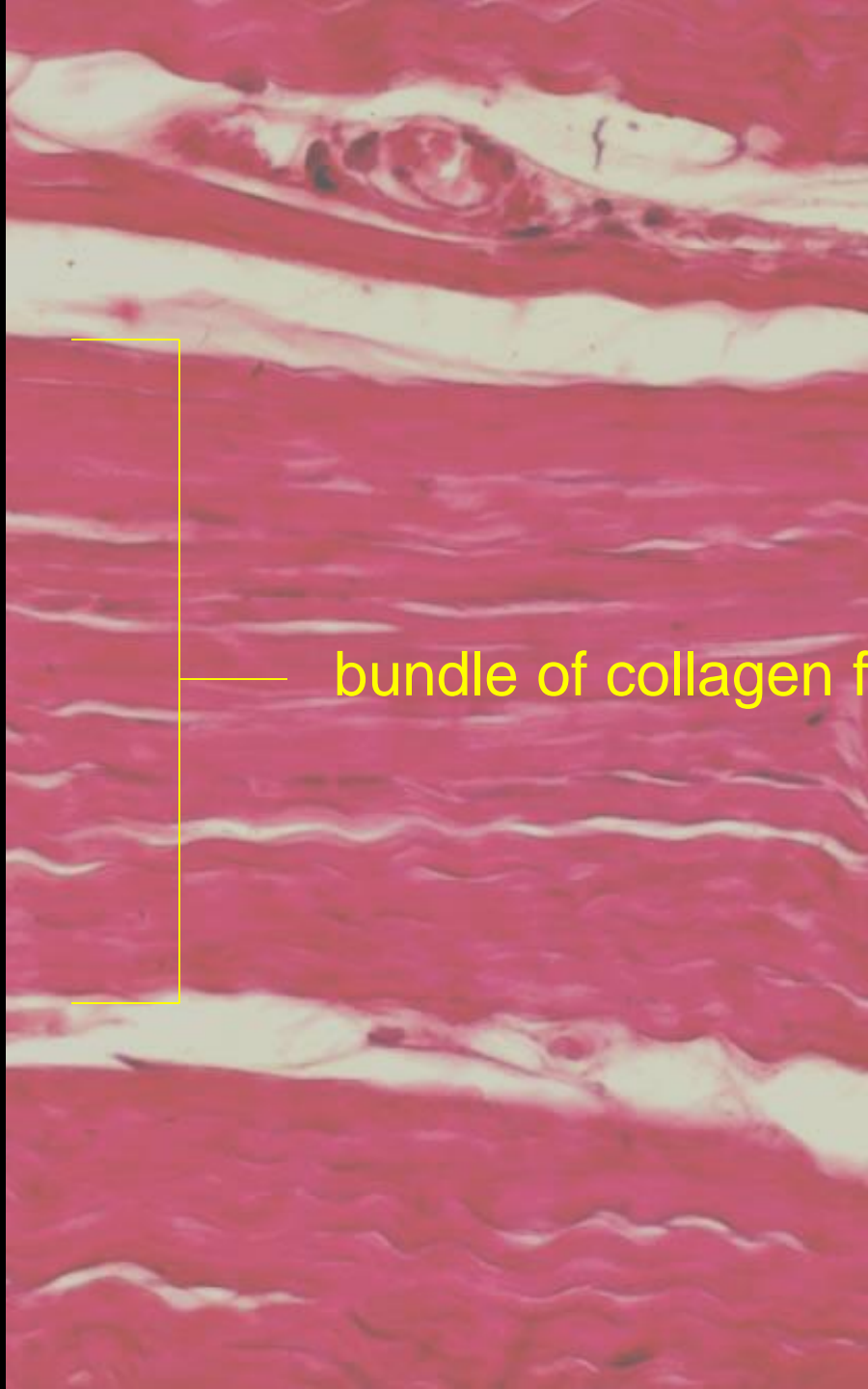
collagen fibrils (TEM)



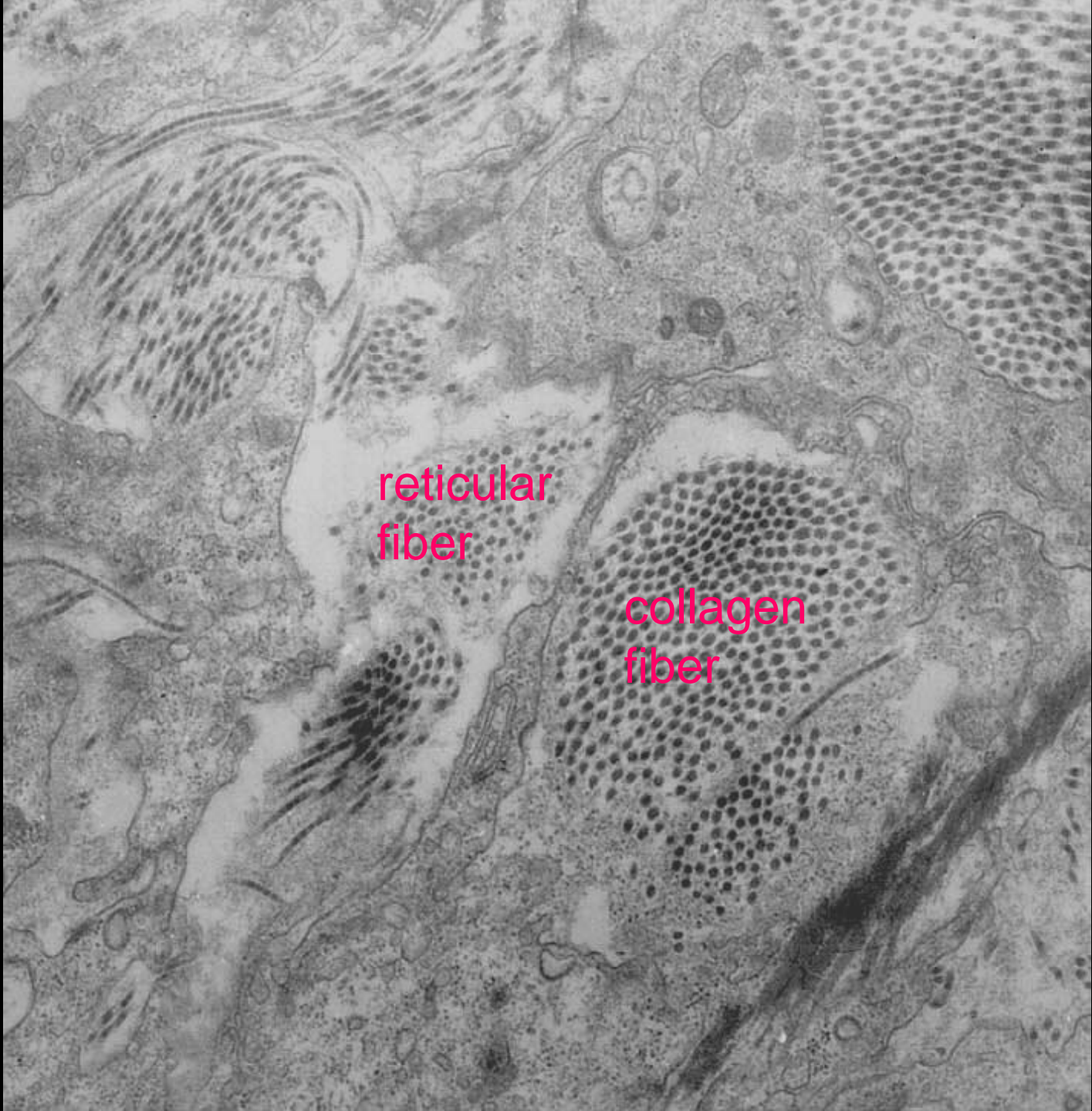
collagen fibers (aniline blue)







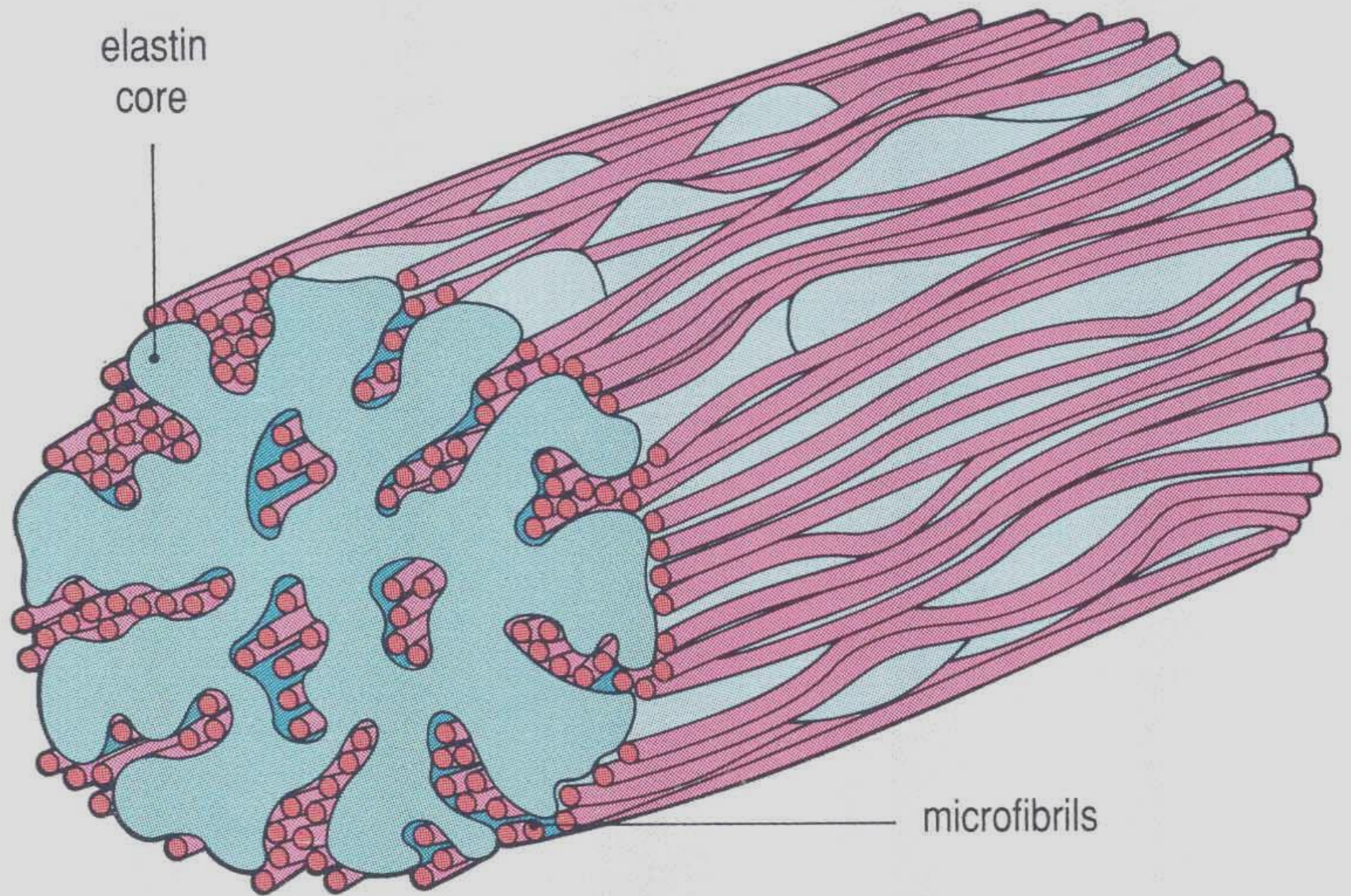
bundle of collagen fibers



reticular
fiber

collagen
fiber

Elastic fiber

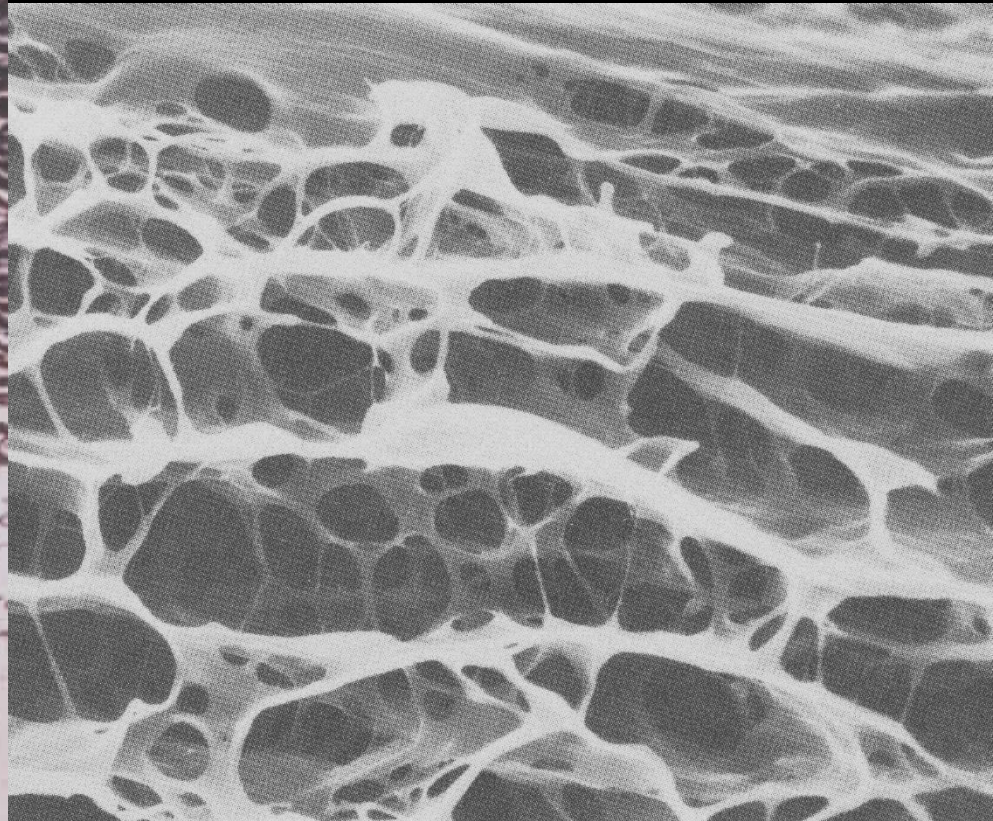
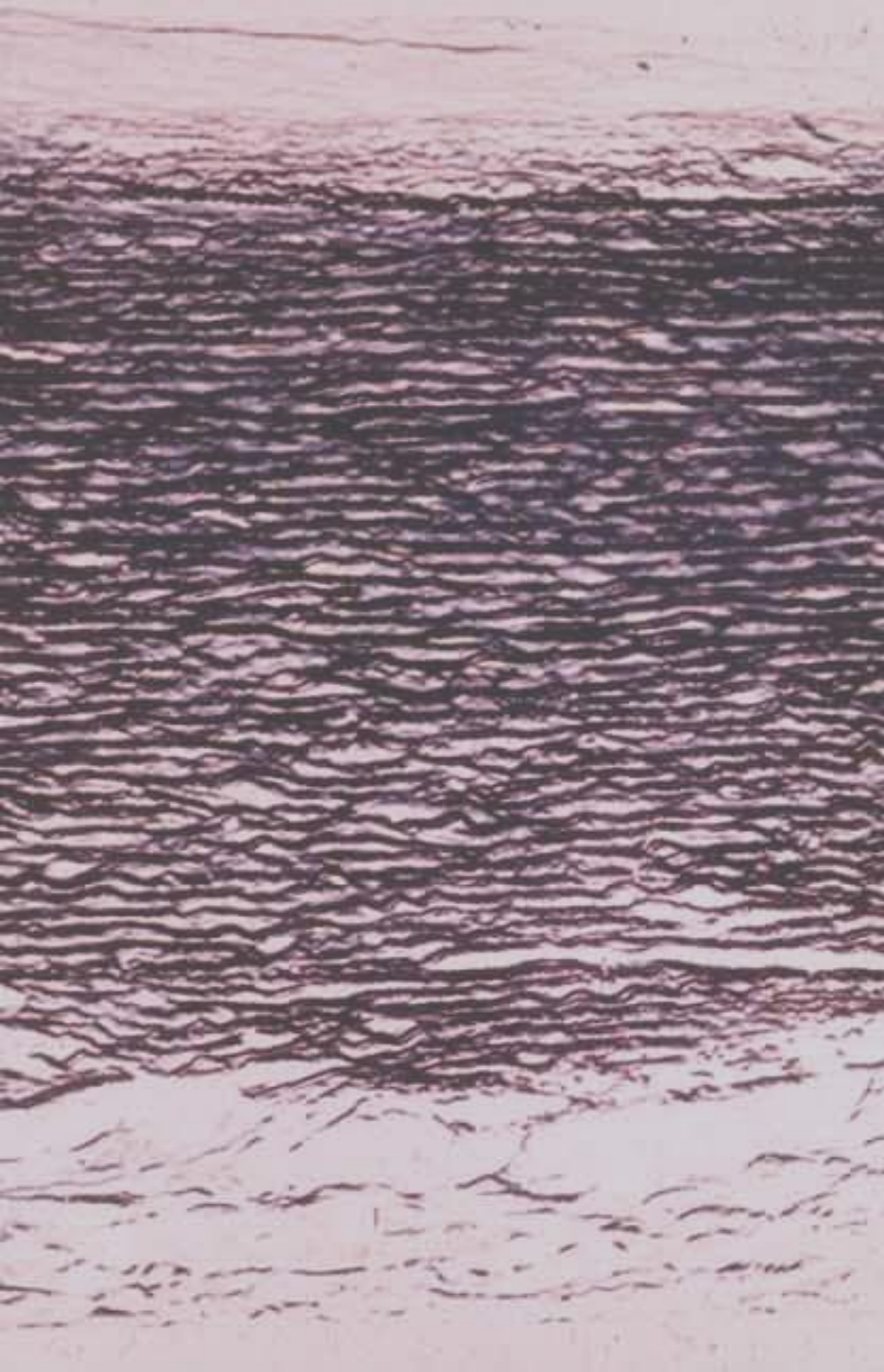


This electron micrograph shows two distinct types of extracellular matrix fibers. The upper portion of the image displays collagen fibers, which appear as parallel, dark, striated bands with a characteristic 64-nanometer periodicity. The lower portion shows elastic fibers, which are much darker, more electron-dense, and have a more irregular, clumped appearance. The labels 'collagen fiber' and 'elastic fiber' are overlaid in red text on the image.

collagen fiber

elastic fiber

membranae fenestratae
in the wall of a large artery

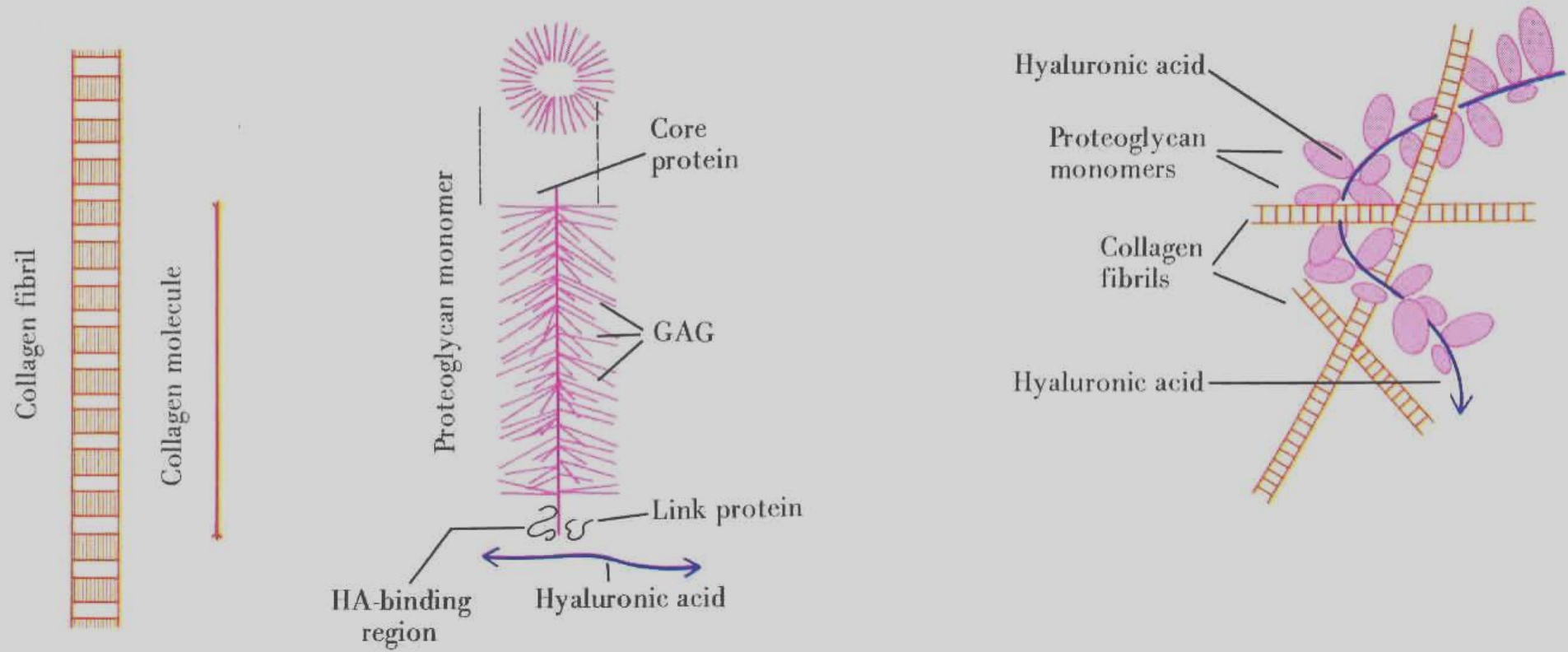


GLYCOSAMINOGLYCANS

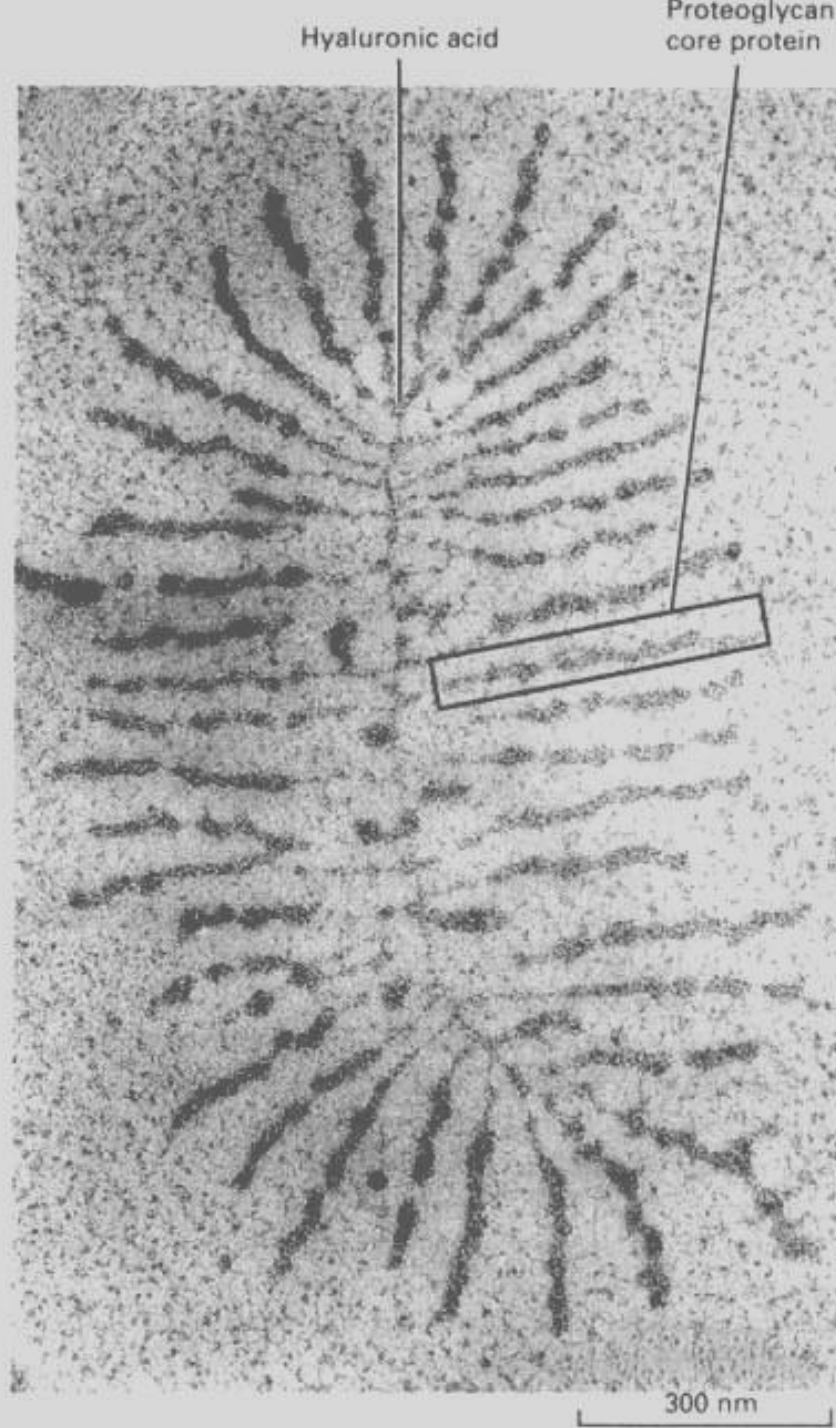
GAG	occurs in	interaction level	collagen type
hyaluronic acid	umbilical cord, synovial fluid, humor vitreus, cartilage	-	-
chondroitin sulphate	cartilage, bone, cornea. skin, aortic media	+++	II
dermatan sulphate	skin, tendon, aortic adventitia	+	I
heparan sulphate	aorta, lung, liver, basal lamina	++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

uronic acid + N-acetylated saccharide

proteoglycans

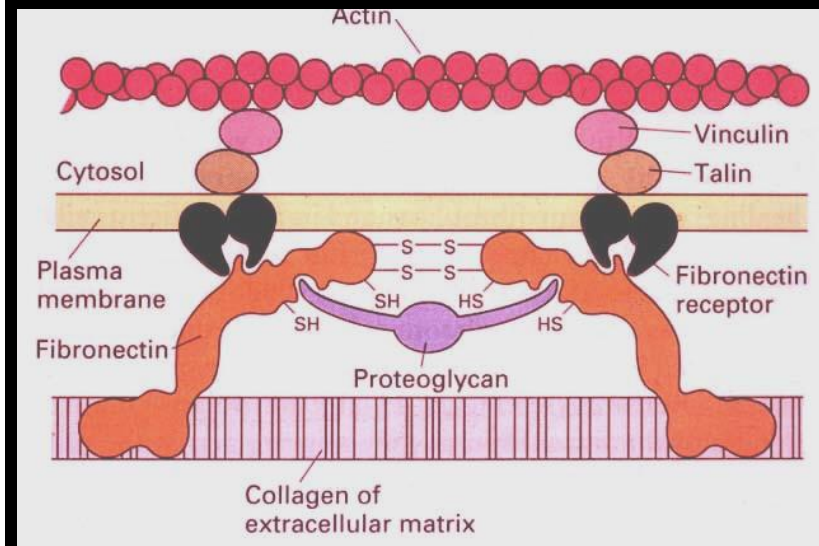
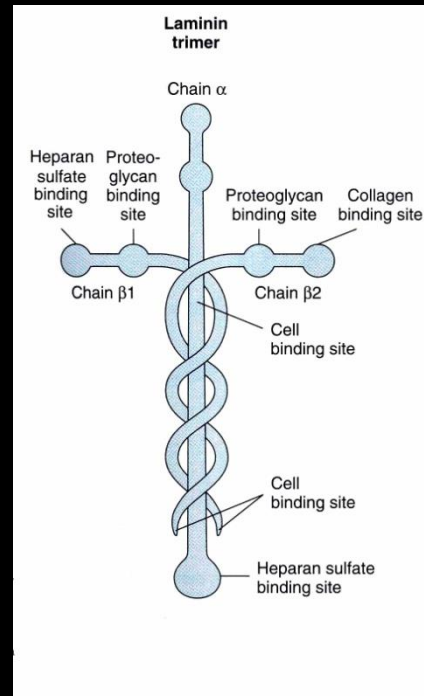
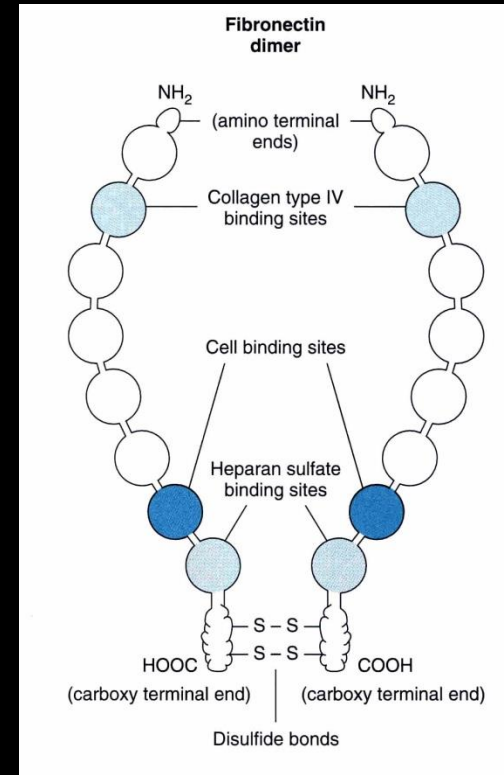


aggrecan



structural glycoproteins

fibronectin
chondronectin
osteonectin
osteopontin
fibrillin
vitronectin
tenascins
laminin



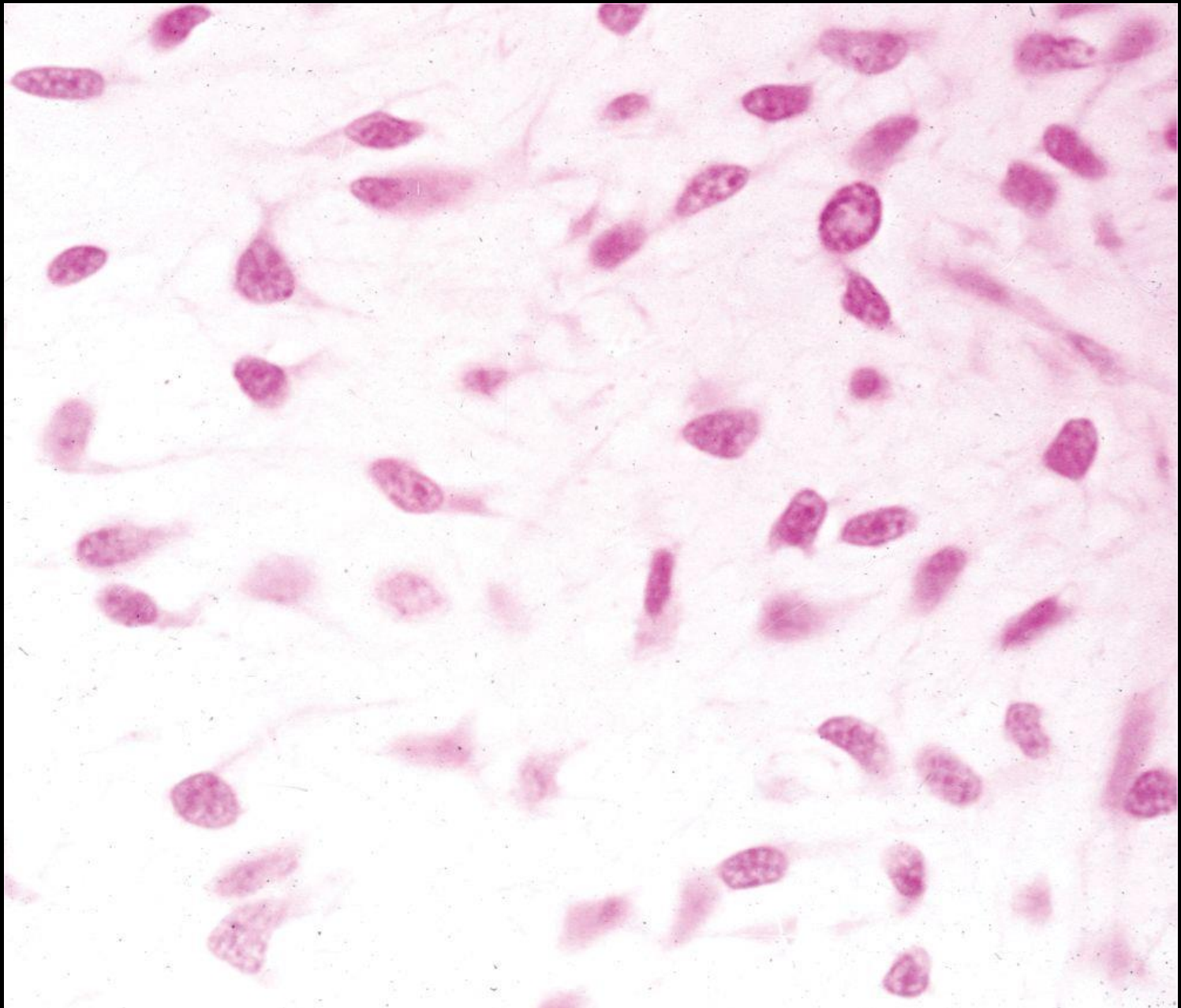
Connective tissue proper and its types

- **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

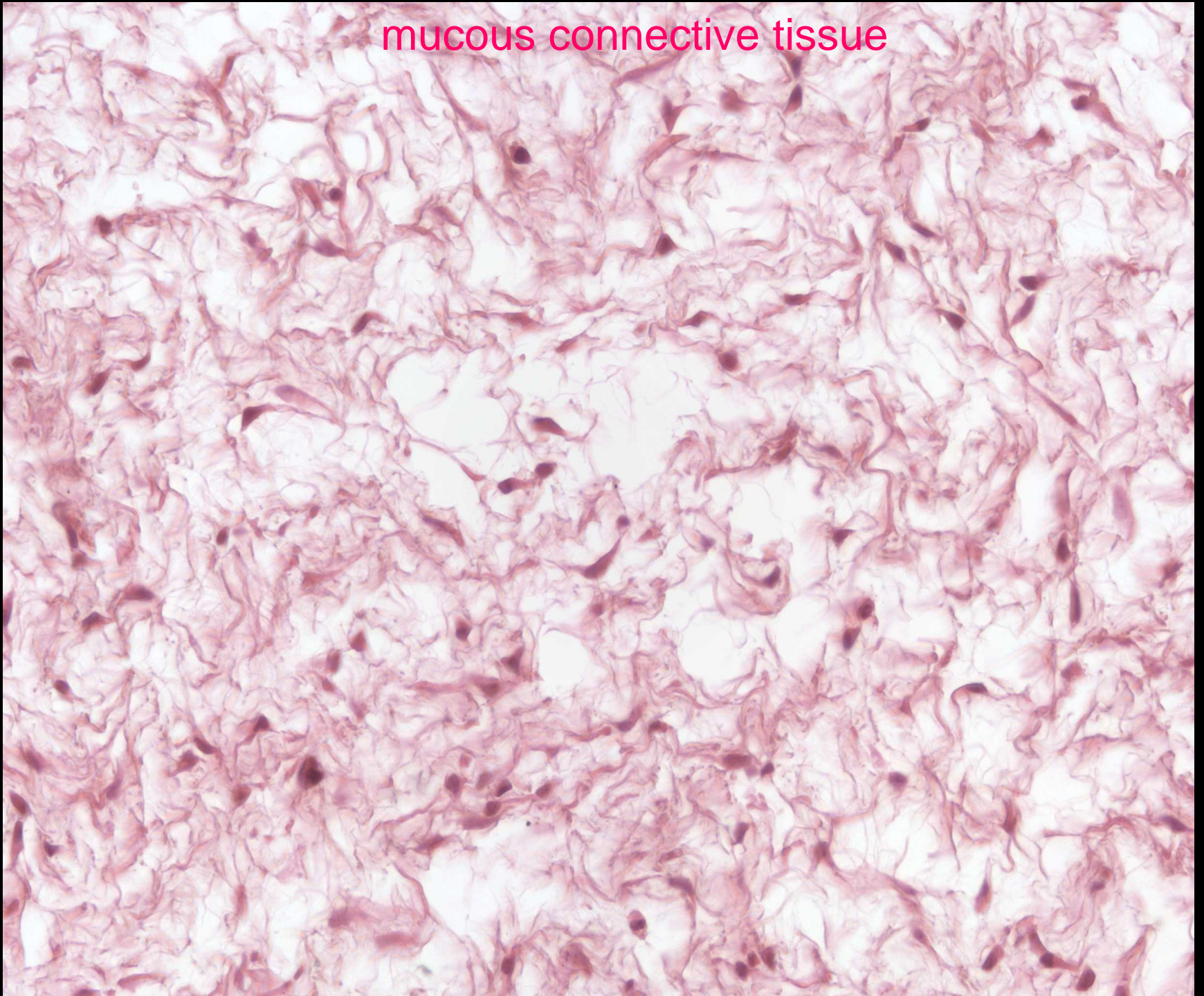
Connective tissue proper types

- **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)

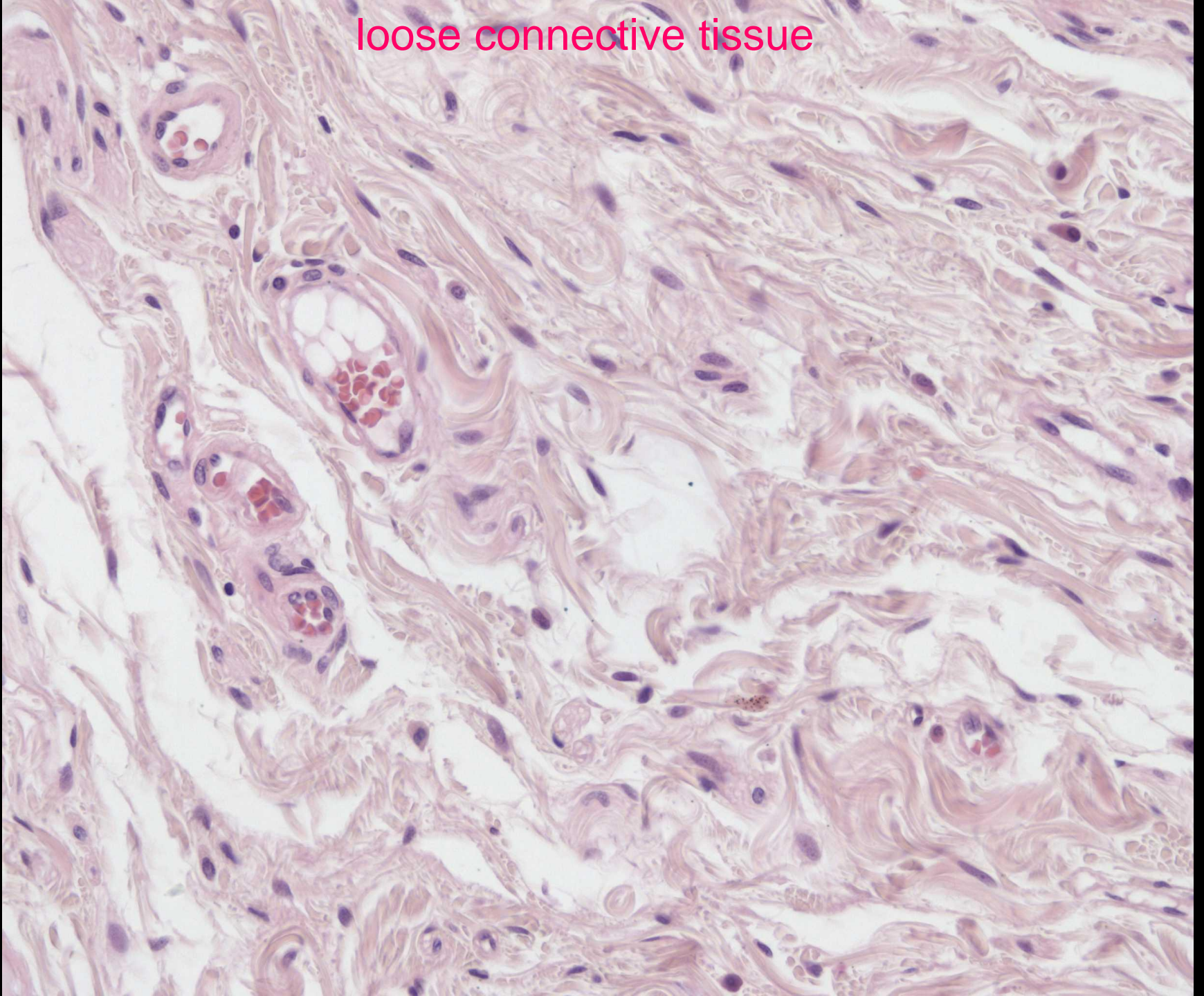
mesenchymal connective tissue



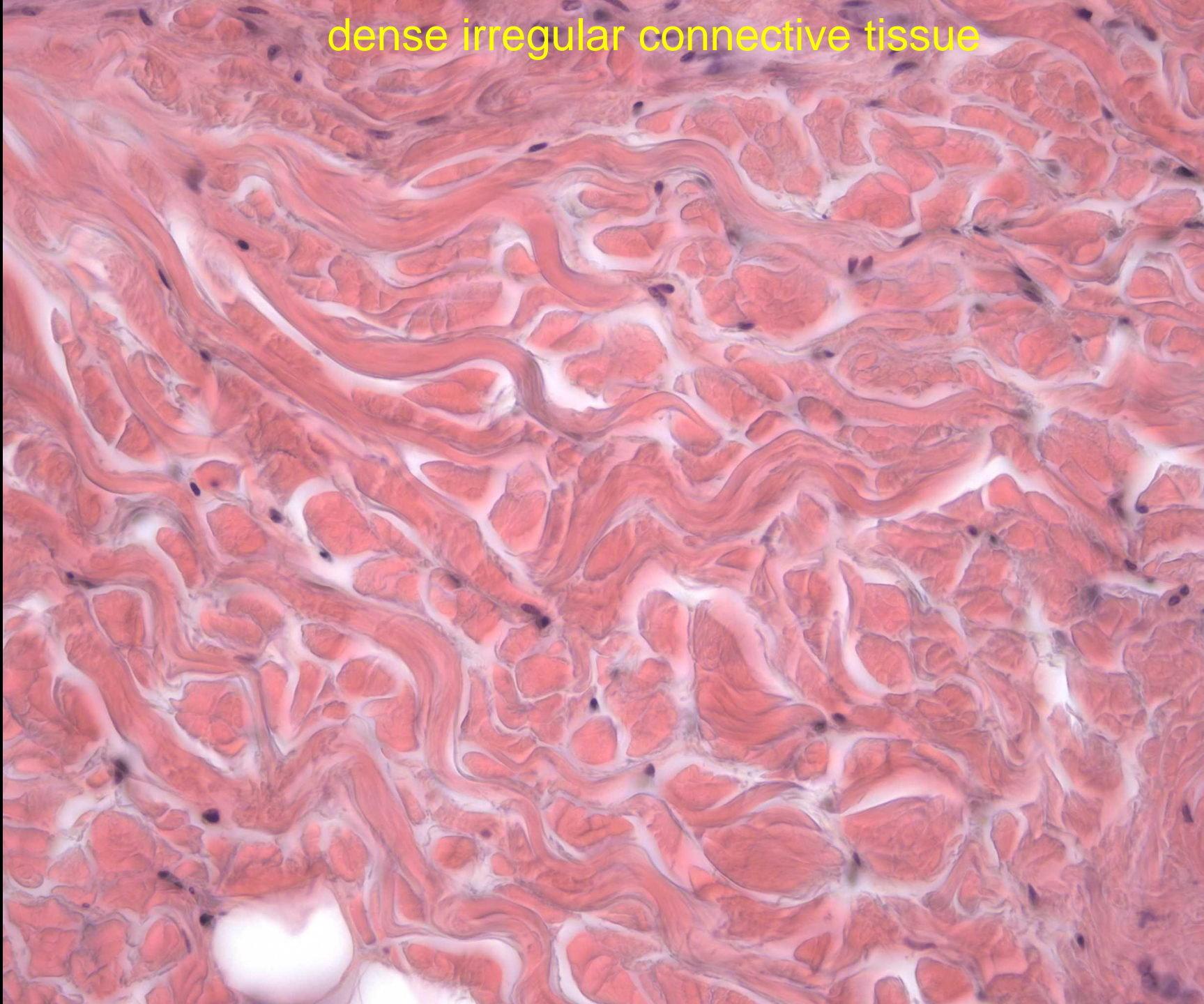
mucous connective tissue



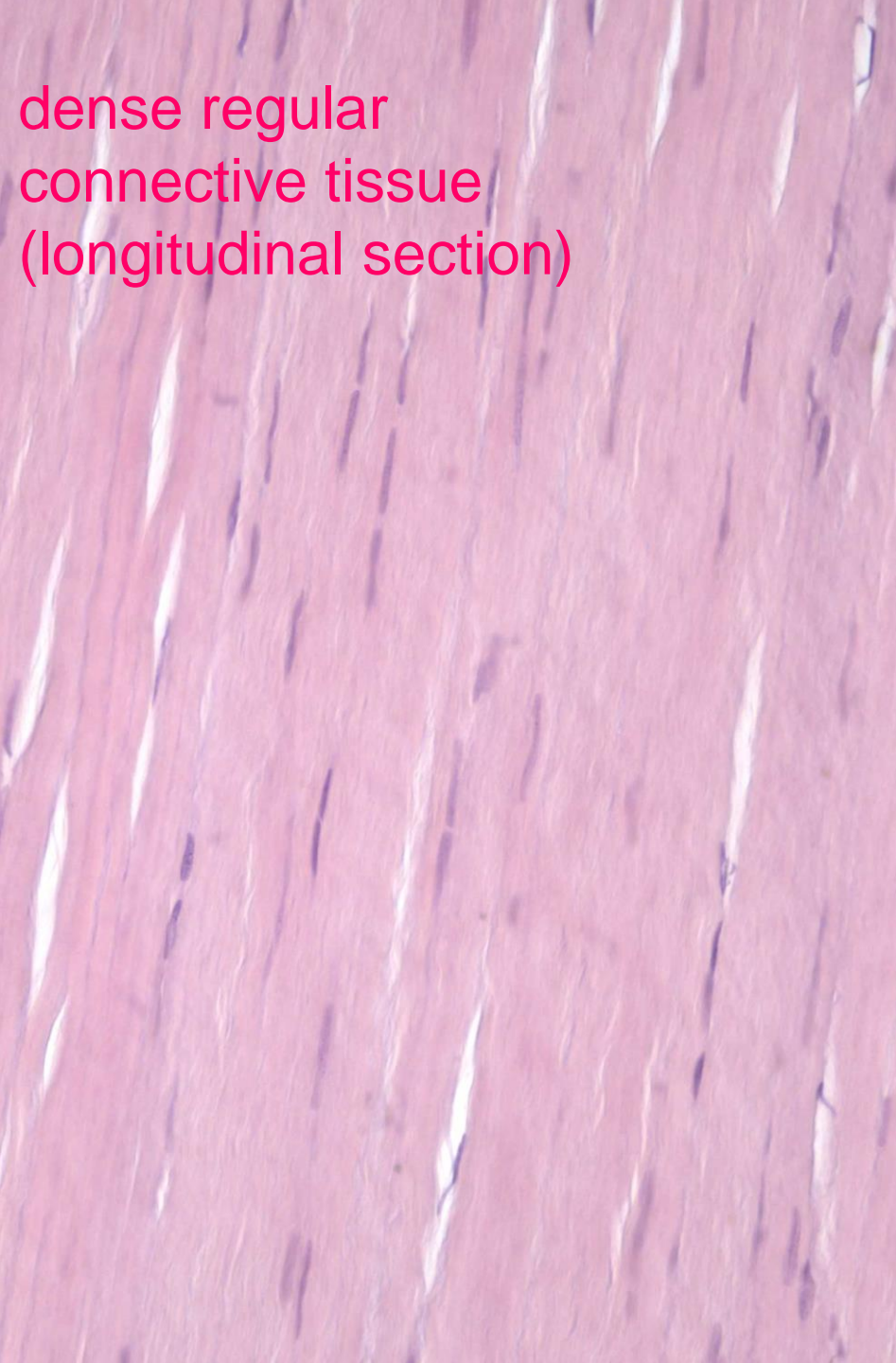
loose connective tissue



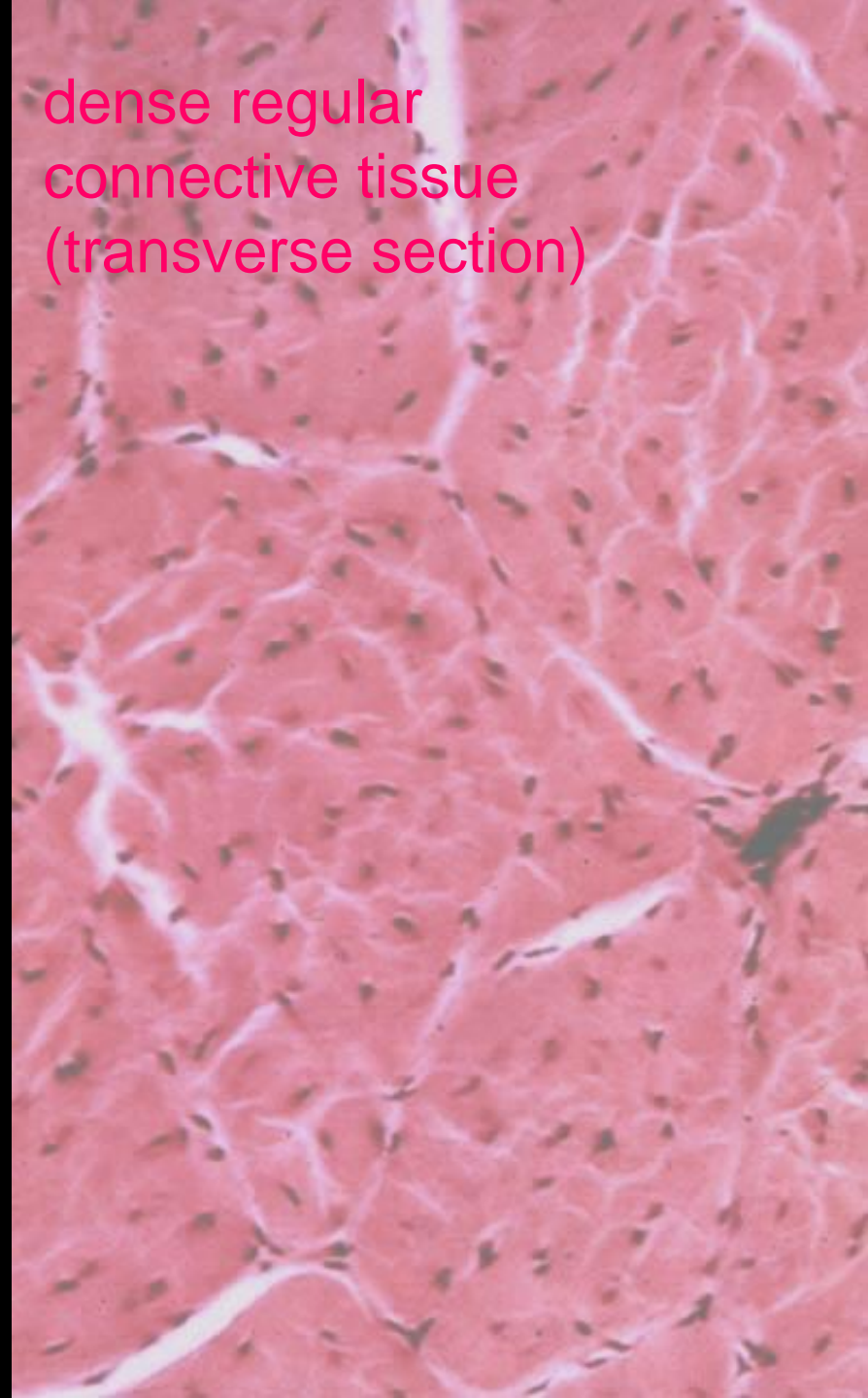
dense irregular connective tissue



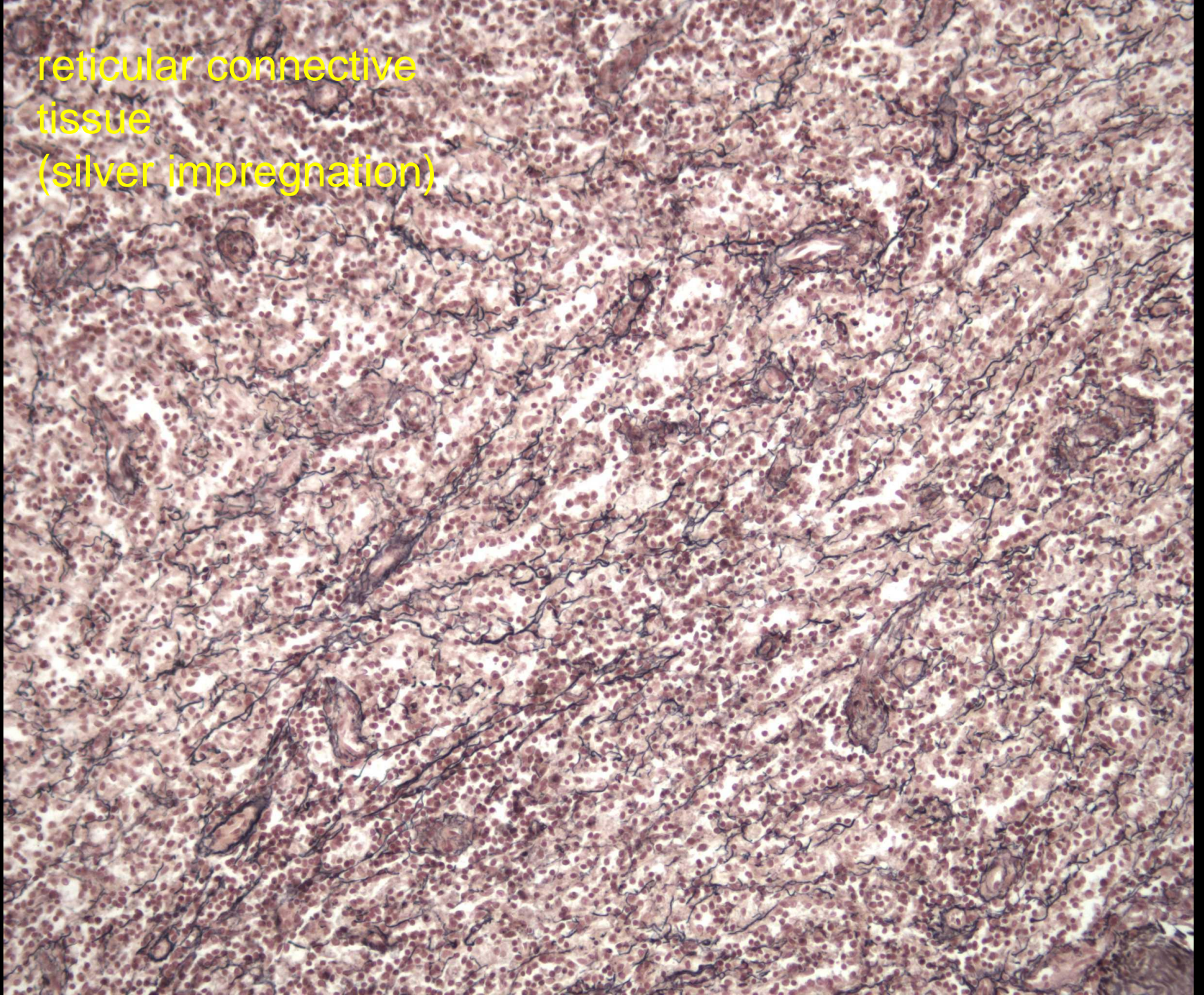
dense regular
connective tissue
(longitudinal section)



dense regular
connective tissue
(transverse section)



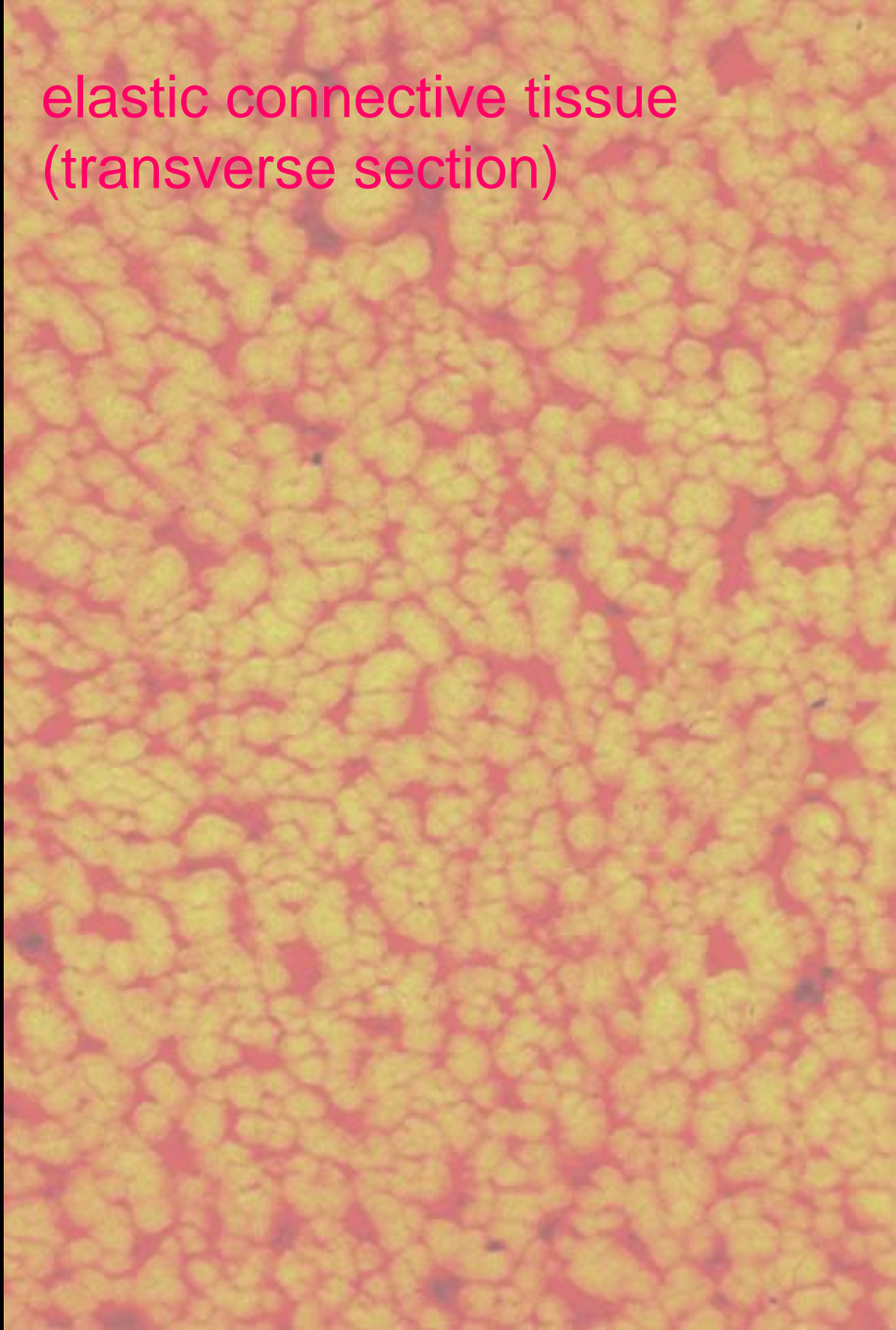
reticular connective
tissue
(silver impregnation)



elastic connective tissue
(longitudinal section)



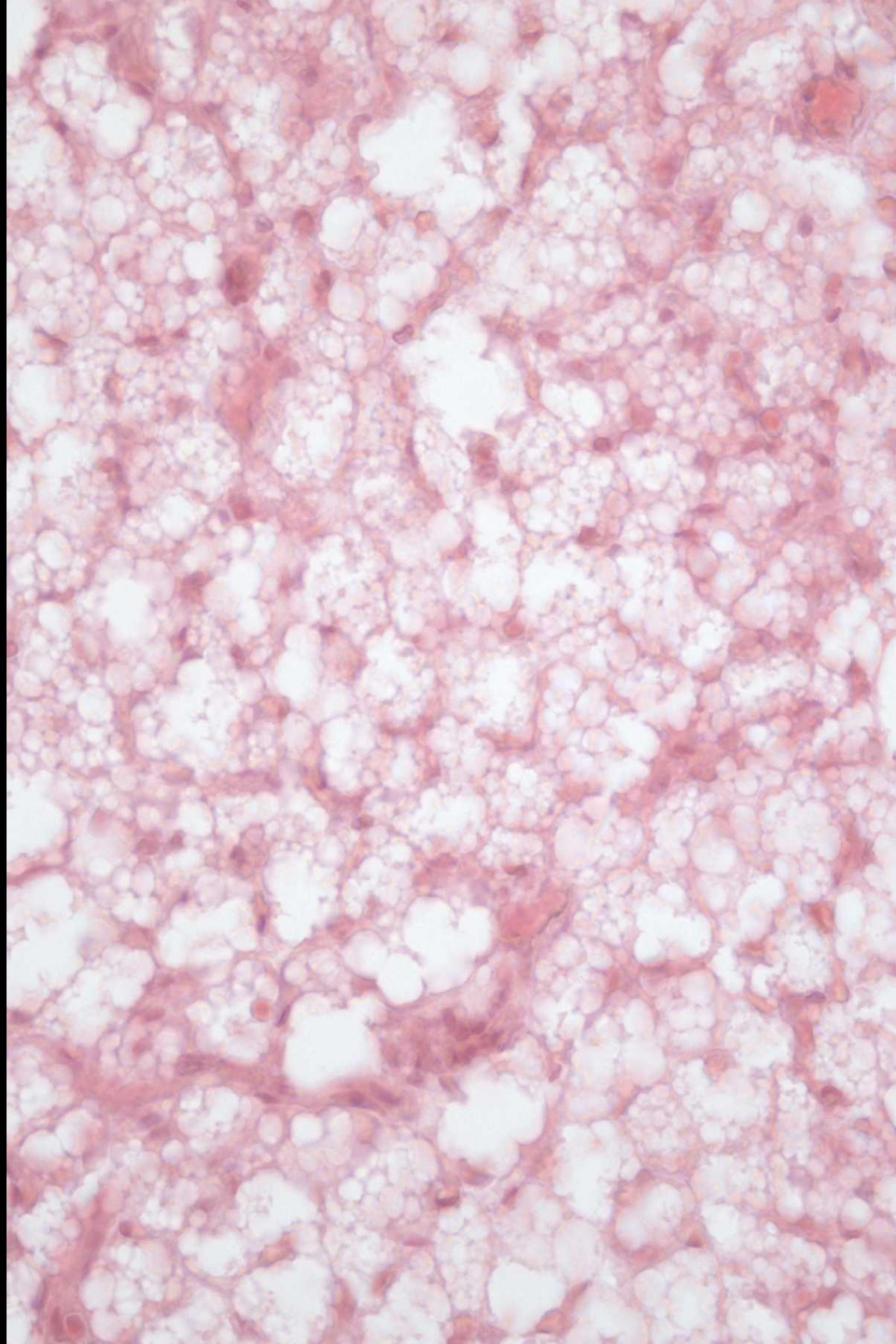
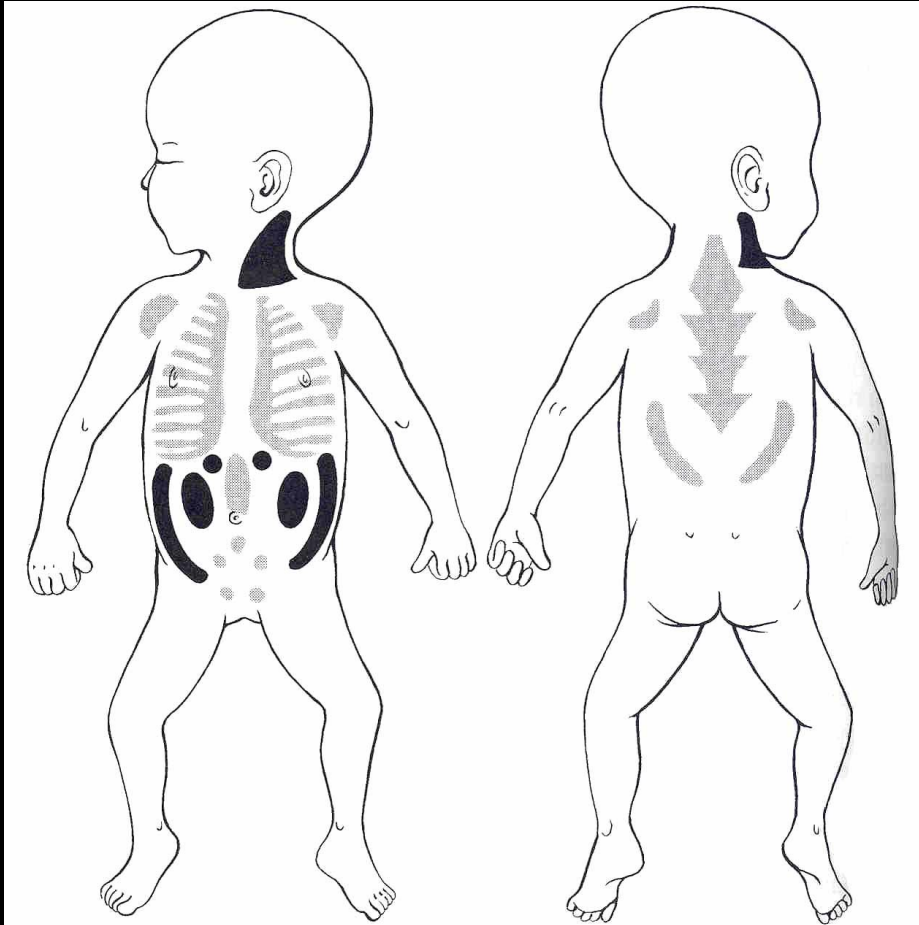
elastic connective tissue
(transverse section)



unilocular adipose tissue

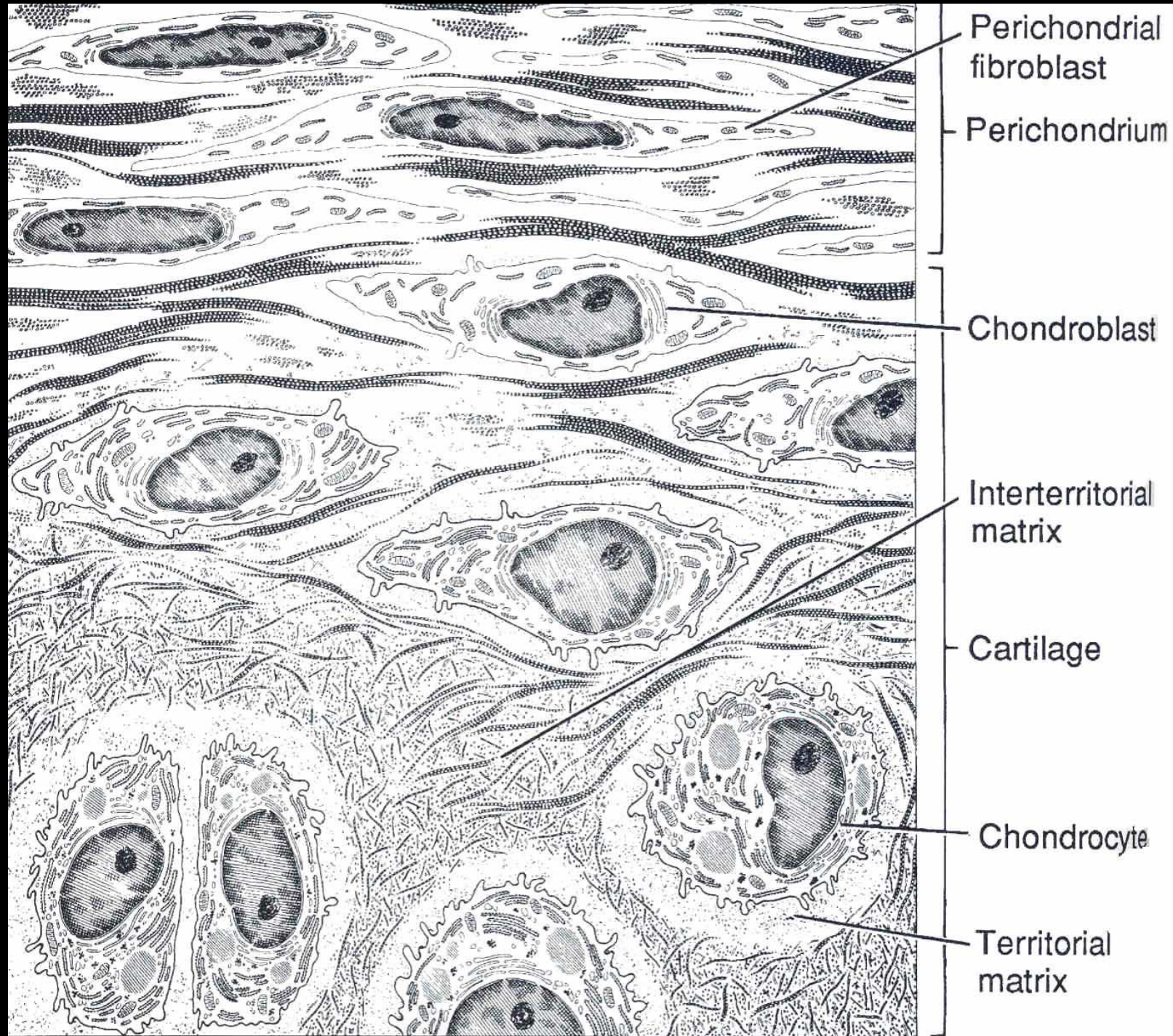


multilocular adipose tissue

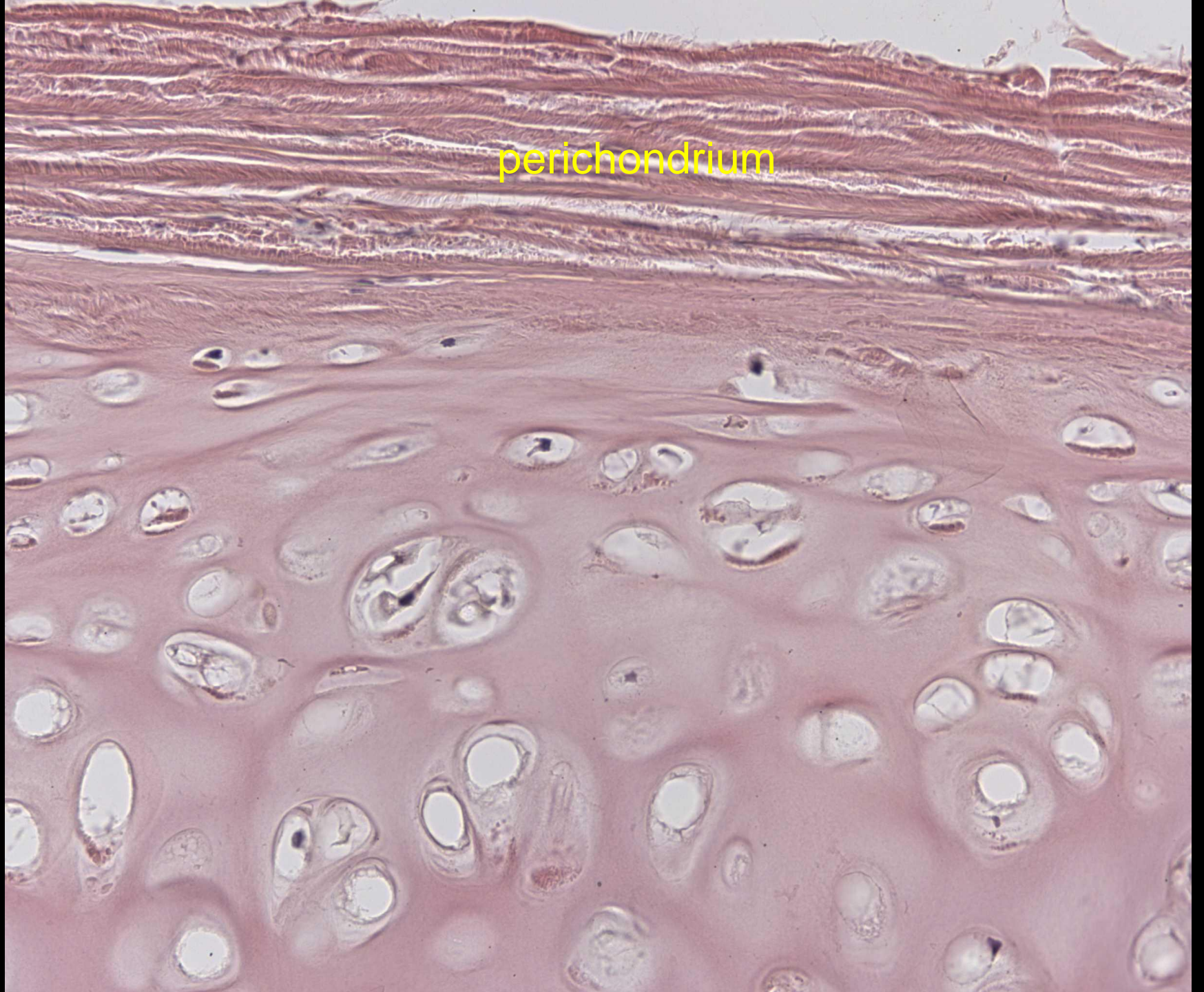


Cartilage - general structure, histogenesis, growth

- **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



perichondrium



A light micrograph of cartilage tissue stained with hematoxylin and eosin (H&E). The tissue is composed of numerous small, rounded cells embedded in a pinkish, extracellular matrix. The cells are arranged in a somewhat regular pattern, with some appearing as small, dark spots (chondroblasts) and others as larger, more rounded cells (chondrocytes). The overall appearance is that of a dense, cellular tissue.

chondroblasts

chondrocytes

isogenous groups



isogenous
group

lipid

rER

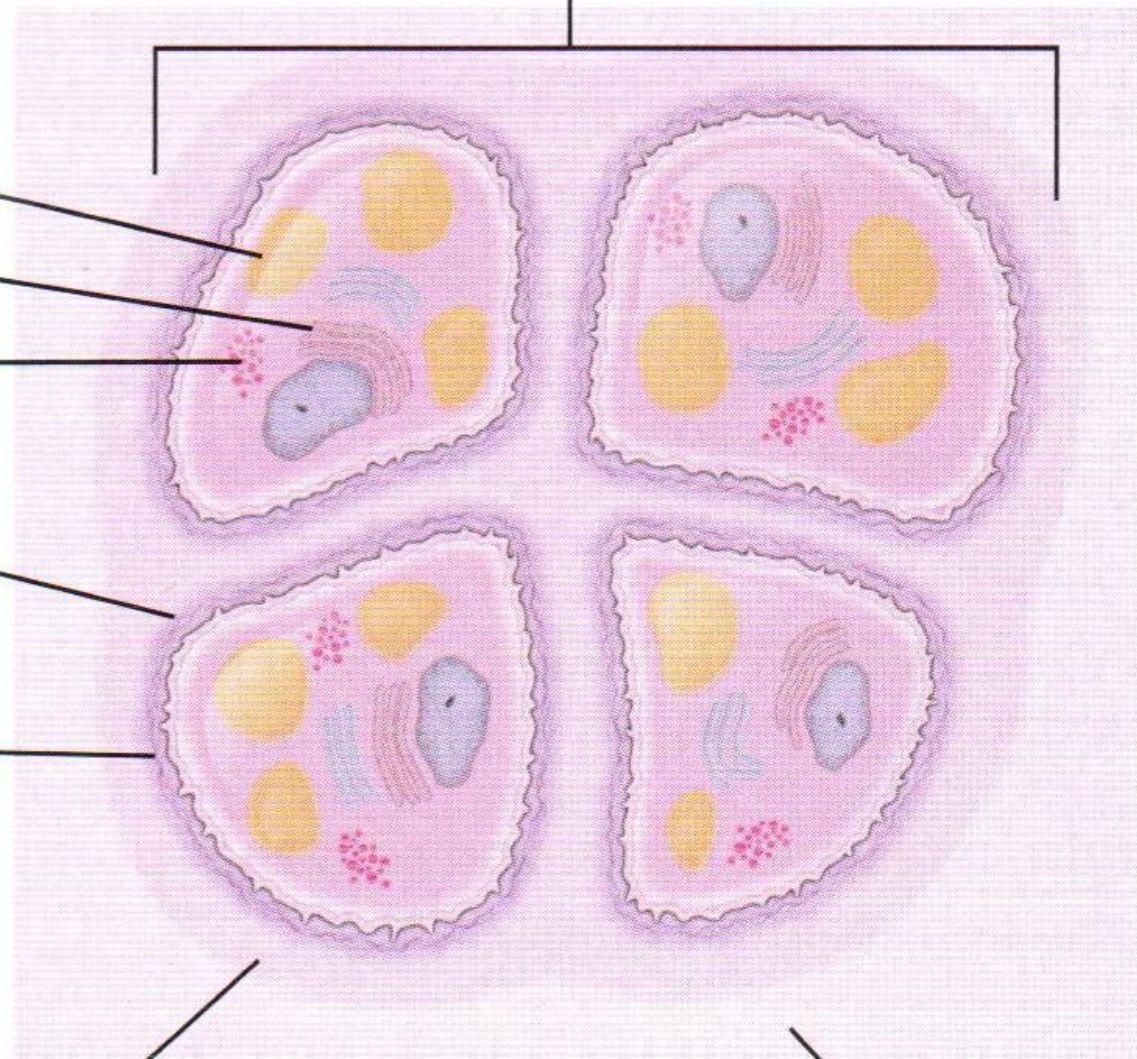
glycogen

capsular
matrix

type VI
collagen
network

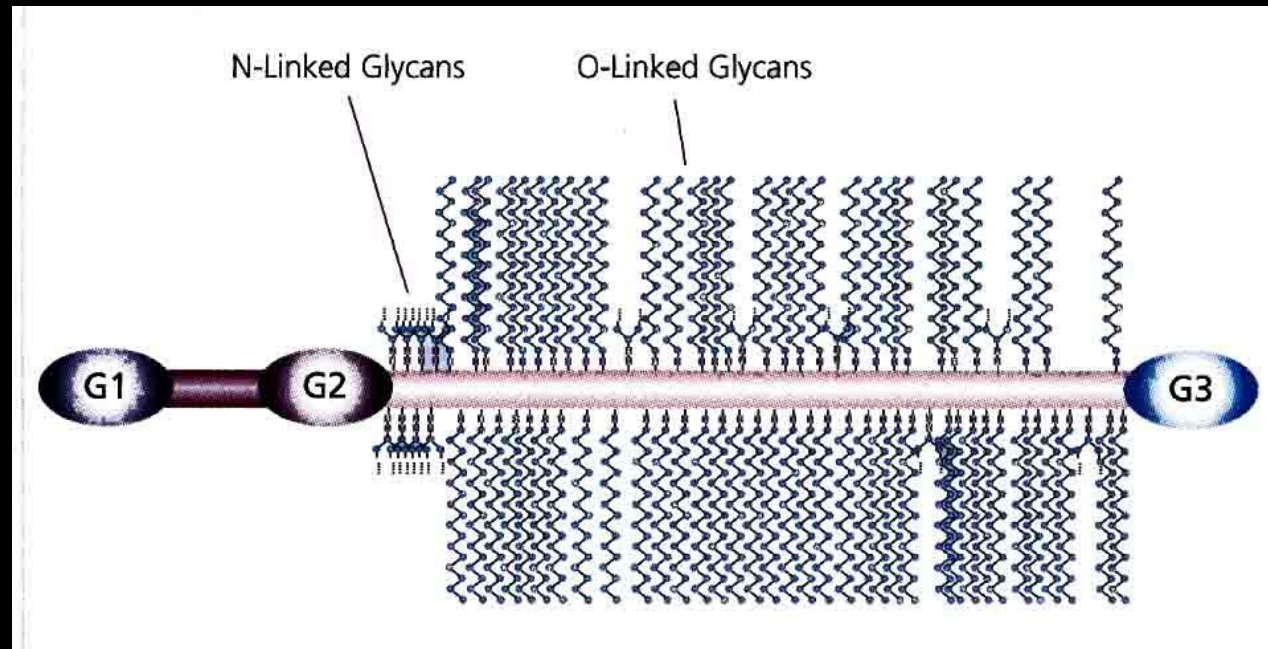
territorial
matrix

interterritorial
matrix

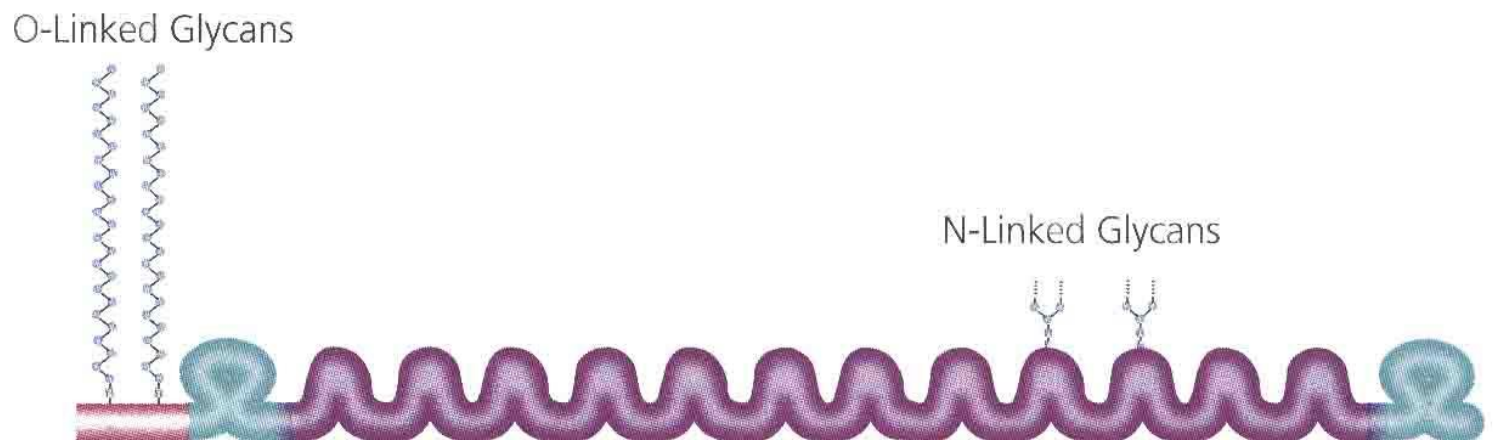


Proteoglycans of cartilage

Aggrecan



Biglycan



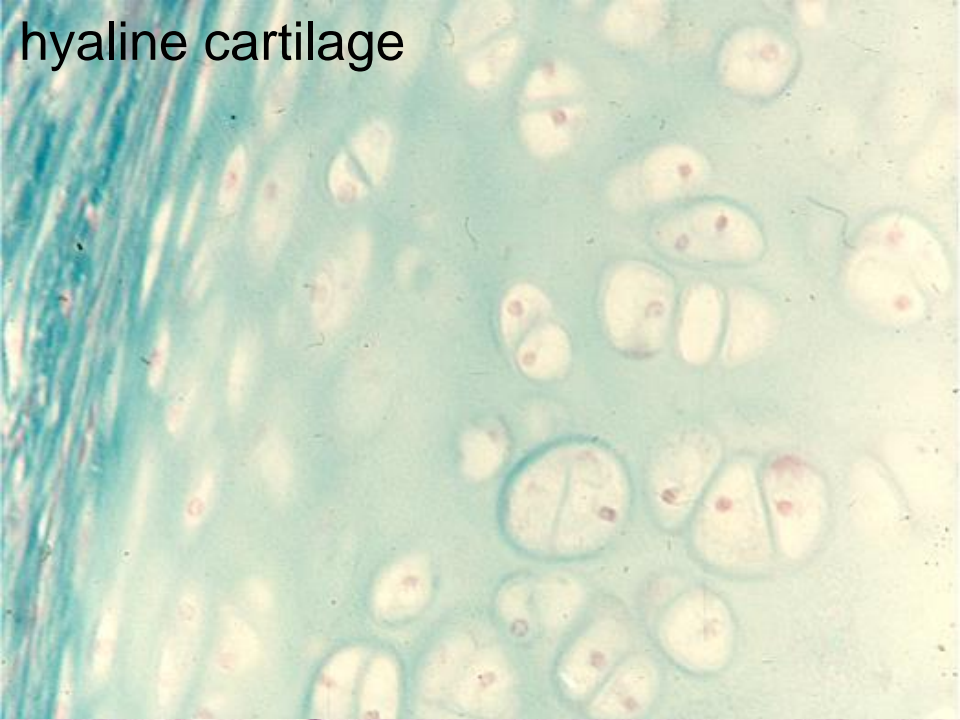
A histological micrograph of bone tissue stained with hematoxylin and eosin (H&E). The image shows several osteons, which are the basic structural units of compact bone. Each osteon is a circular or oval structure with a central canal (Haversian canal) surrounded by concentric layers of bone tissue. The bone tissue is composed of osteons, which are separated by narrow spaces called interstitial lamellae. The overall appearance is that of a highly organized, porous structure. The labels 'apposition' and 'interstitial growth' are placed on the image to highlight specific features. 'apposition' is located in the upper right quadrant, and 'interstitial growth' is located in the lower left quadrant.

apposition

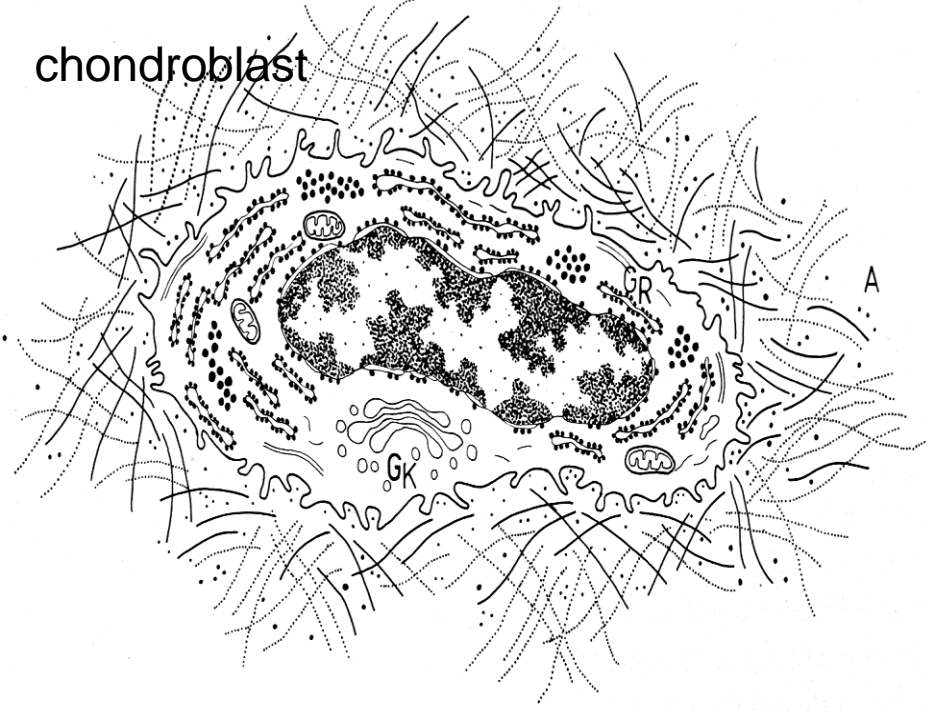
interstitial growth

Types of the cartilage

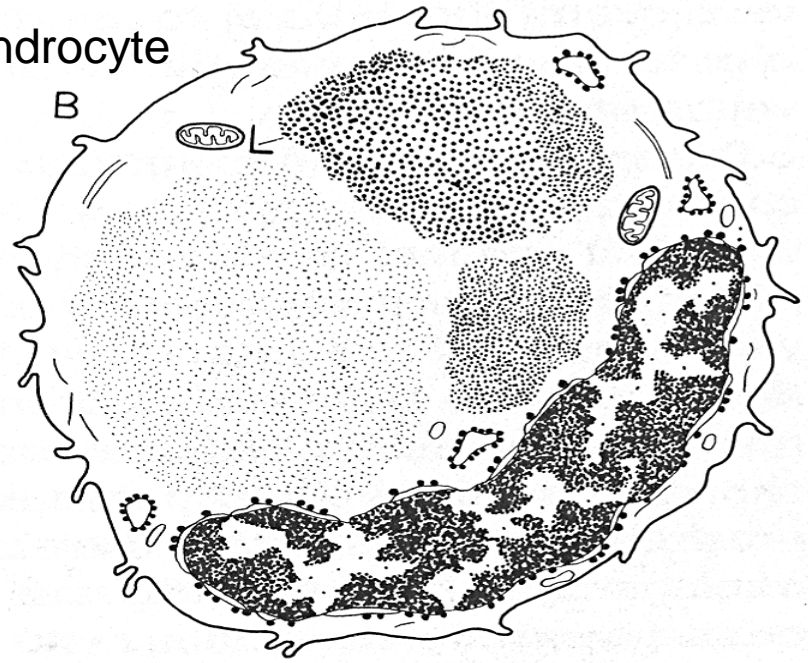
hyaline cartilage



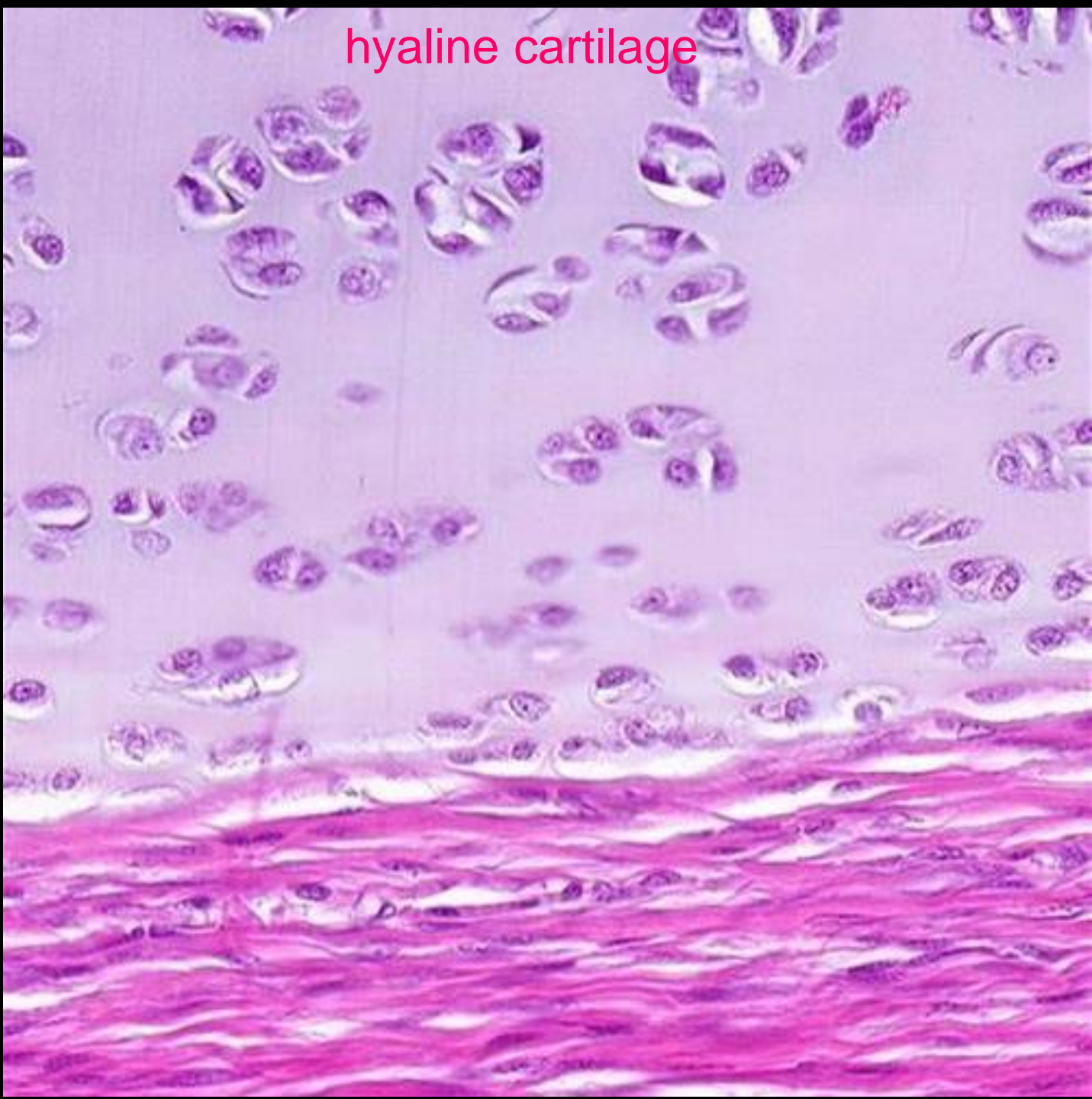
chondroblast



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
 $\text{Ca}_{10}(\text{PO}_4)_6\text{OH}_2$



spongy bone

periosteum (Sharpey's fibres)

compact bone

yellow bone marrow

Osteoclast

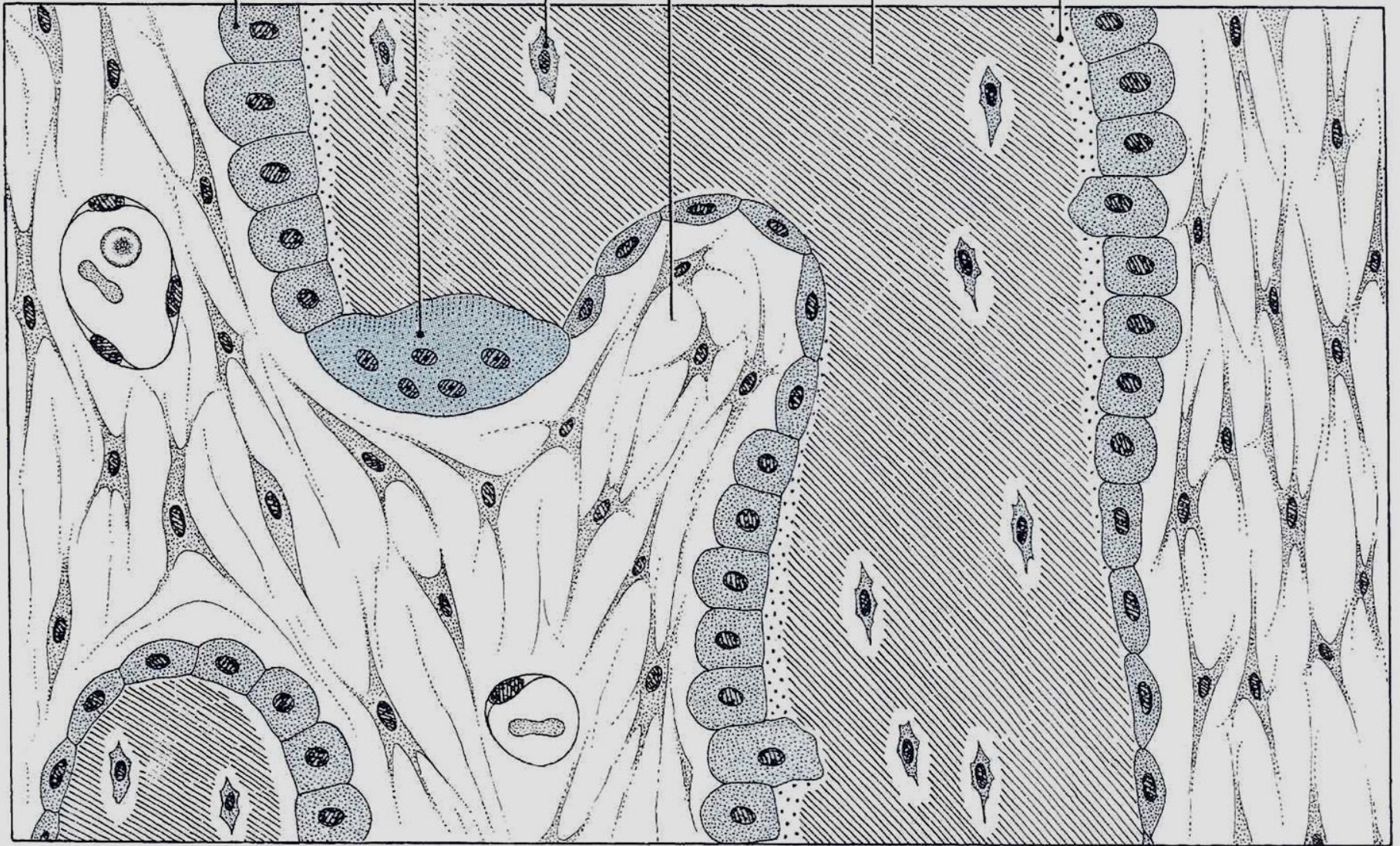
Mesenchyme

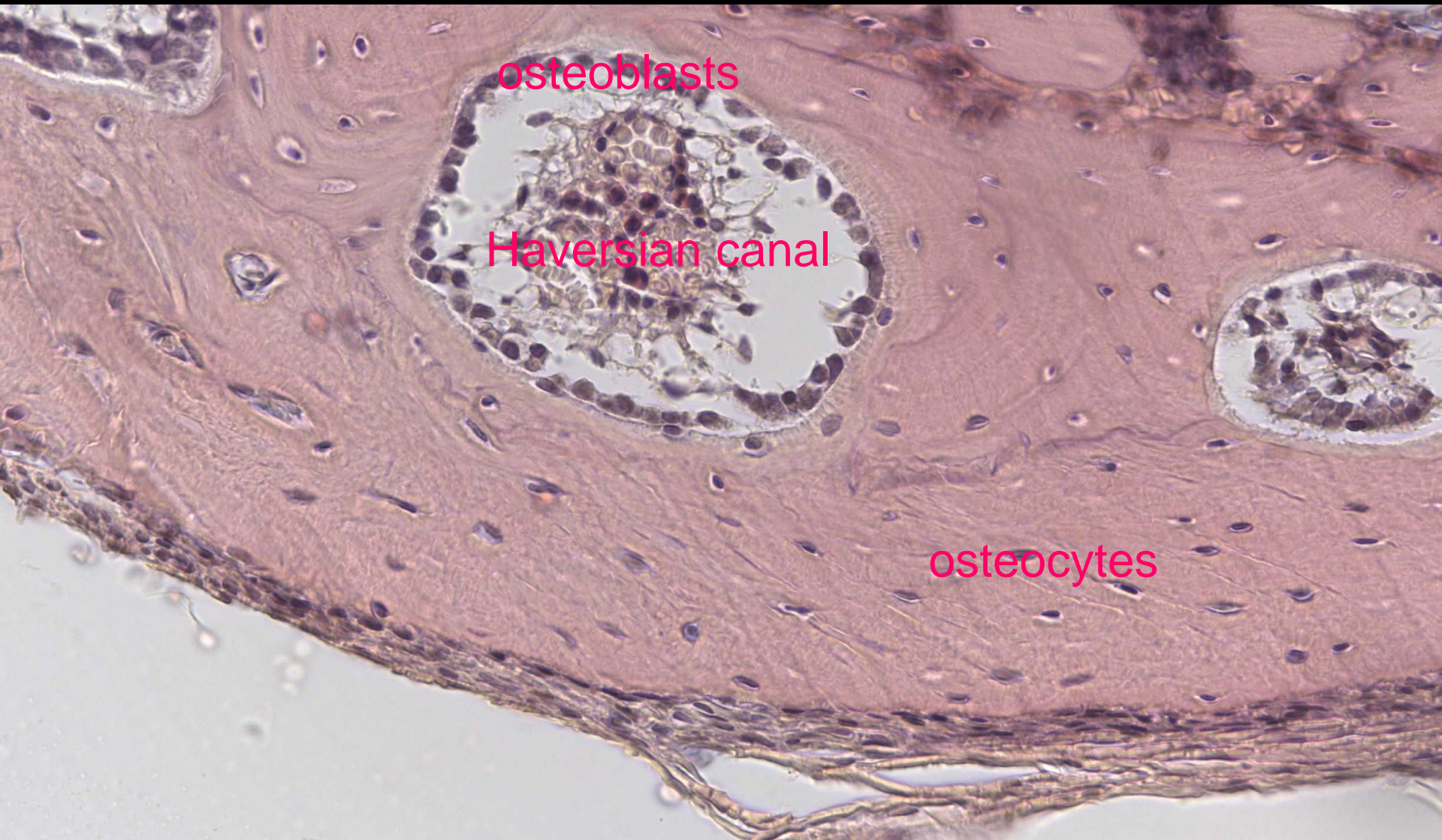
Newly formed matrix (osteoid)

Osteoblast

Osteocyte

Bone matrix





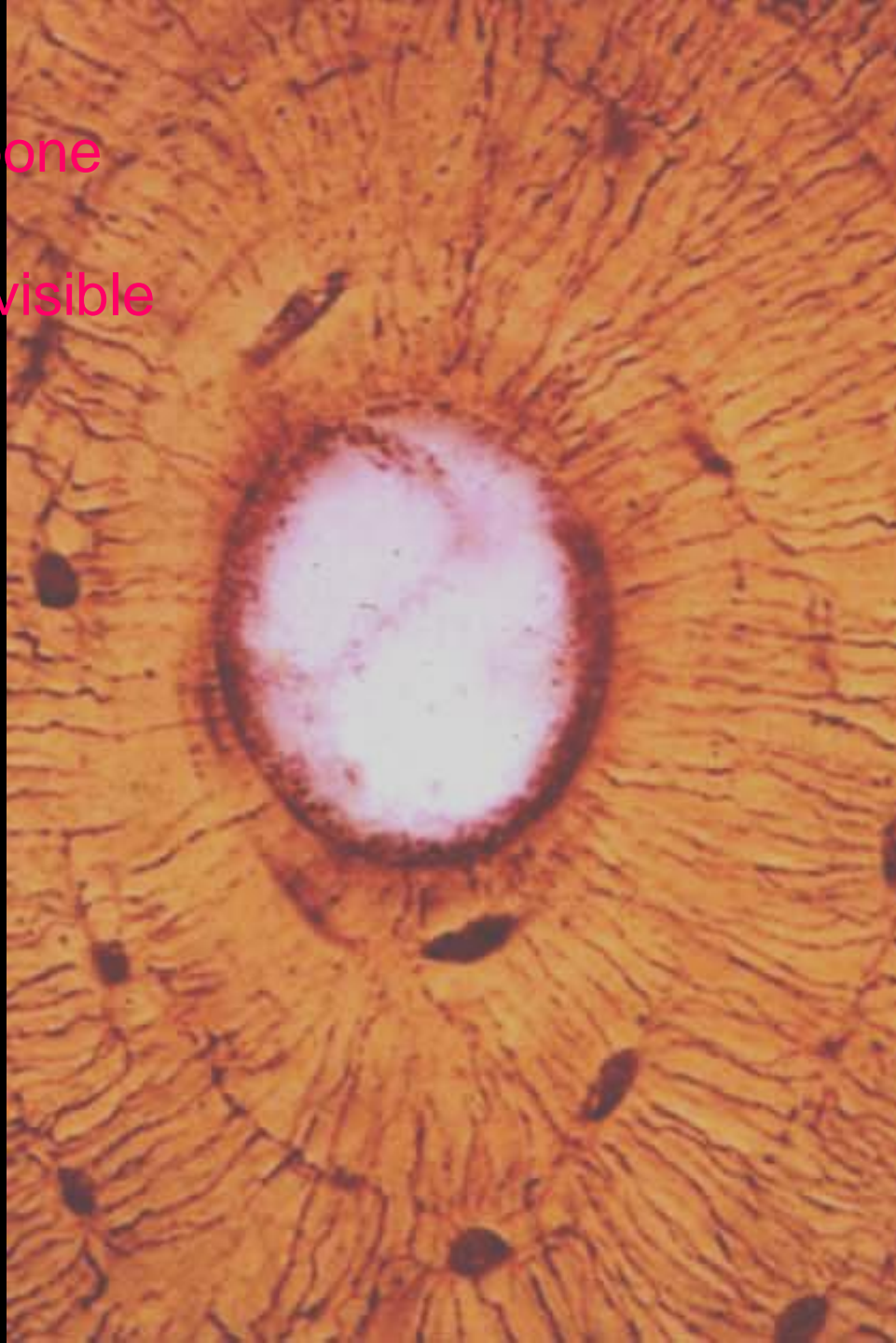
osteoblasts

Haversian canal

osteocytes

grinding cut of bone

bone canaliculi visible



A histological section of compact bone stained with hematoxylin and eosin (H&E). The image shows a dense network of bone tissue with numerous small, dark-stained osteocytes scattered throughout. Two larger, multi-nucleated cells, identified as osteoclasts, are visible in the lower central region. The overall structure is highly organized and shows the characteristic lamellar pattern of compact bone.

compact bone with osteocytes

osteoclasts

Types of bone tissue

Bone tissue types

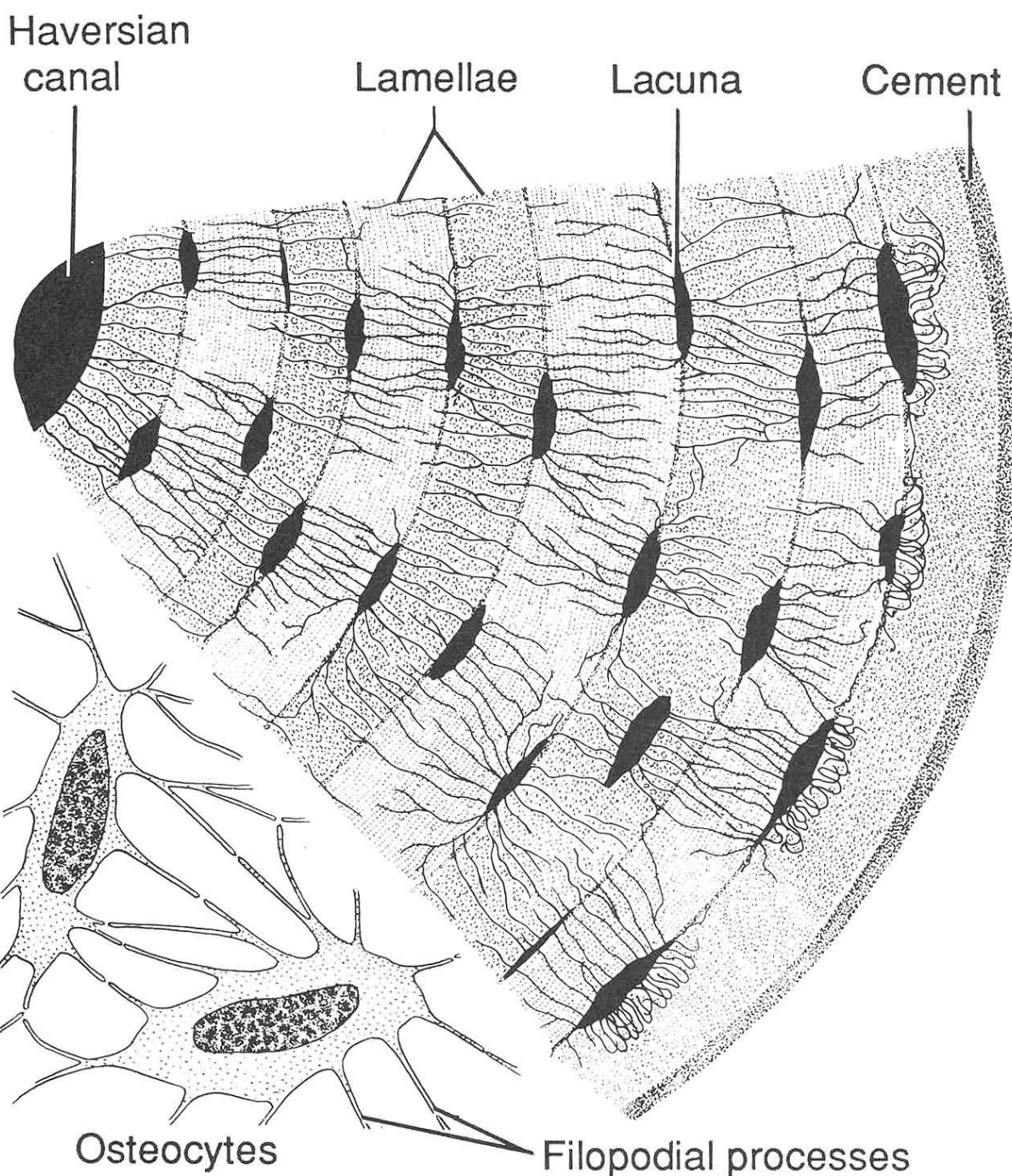
- **woven (primary)** – temporary bone during development and repair, irregular arrangement, low mineralization
- **lamellar (secondary)** – build of lamellae of parallel collagen fibers embedded in mineralized matrix, osteocytes mostly in between lamellae within cementing substance
 - **compact** –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

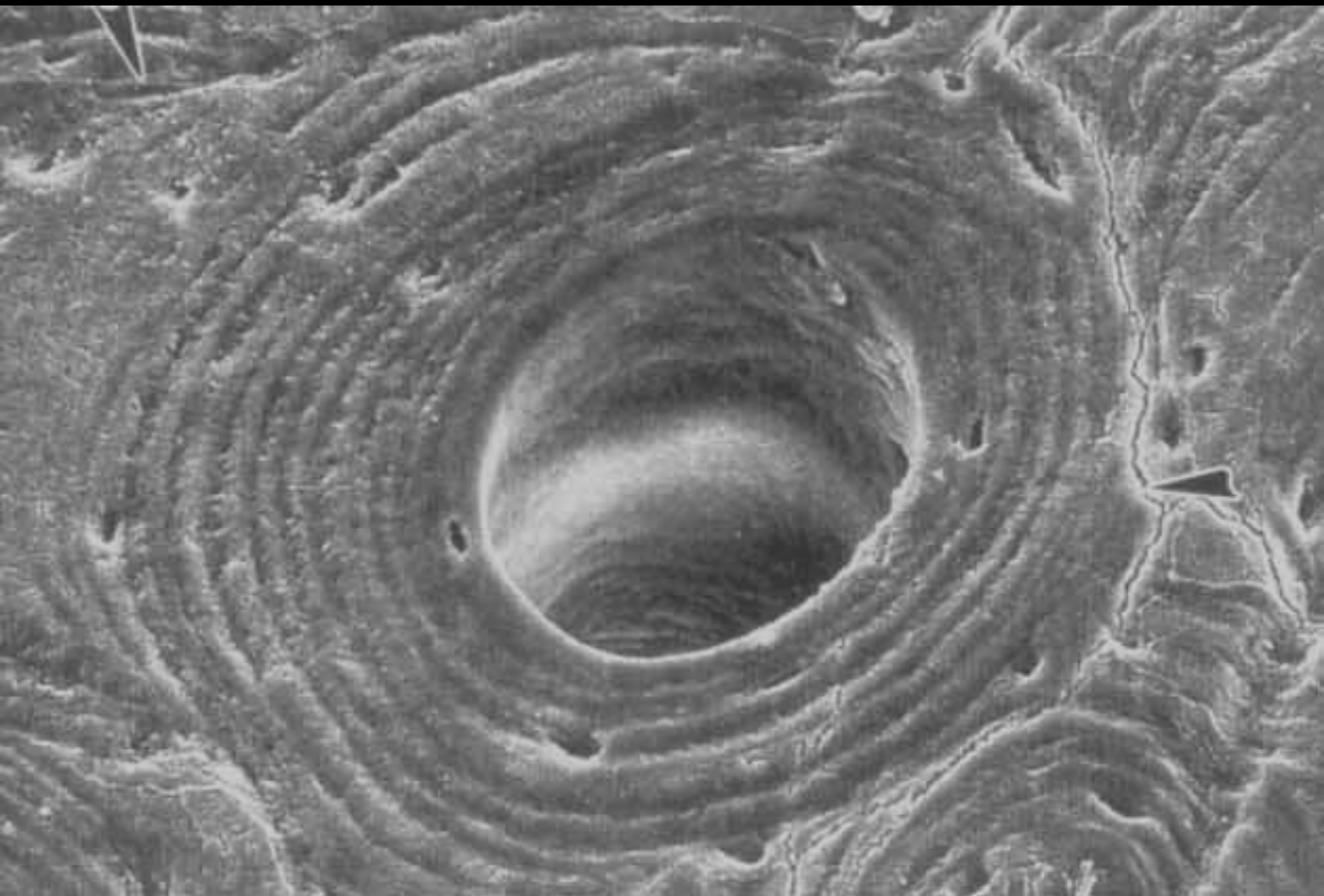


Woven bone (primary)

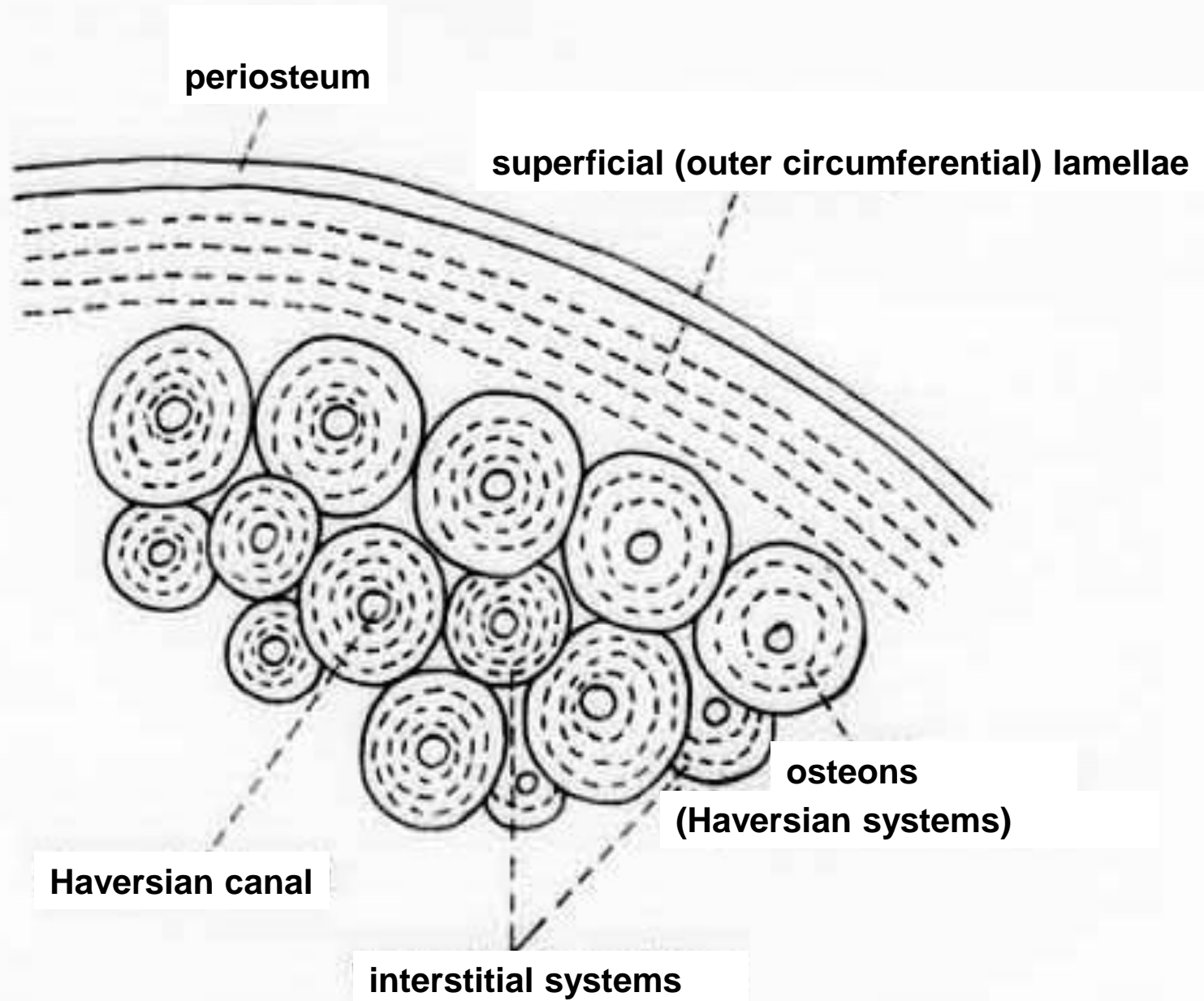
This histological micrograph displays woven bone, a type of primary bone. The image shows several large, irregularly shaped trabeculae stained a deep reddish-brown. These trabeculae are embedded within a lighter, more fibrous matrix. The trabeculae themselves contain numerous small, dark-stained osteons, which are the basic structural units of bone. The overall appearance is that of a disorganized, interlocking network of bone tissue, characteristic of woven bone. The surrounding matrix is composed of a complex arrangement of collagen fibers and other extracellular matrix components, with scattered osteocytes visible as small, dark spots.

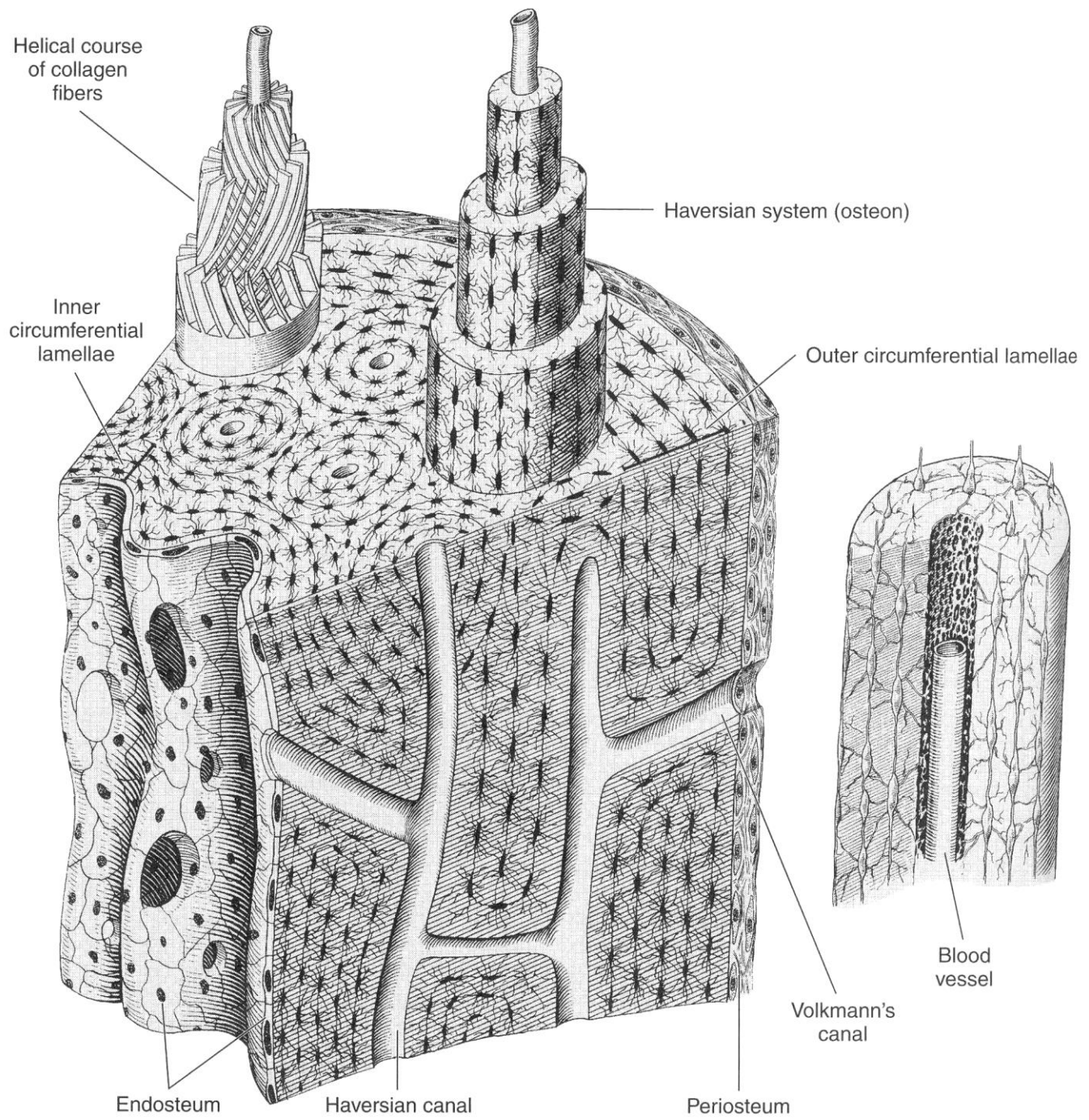
Lamellar bone (secondary)



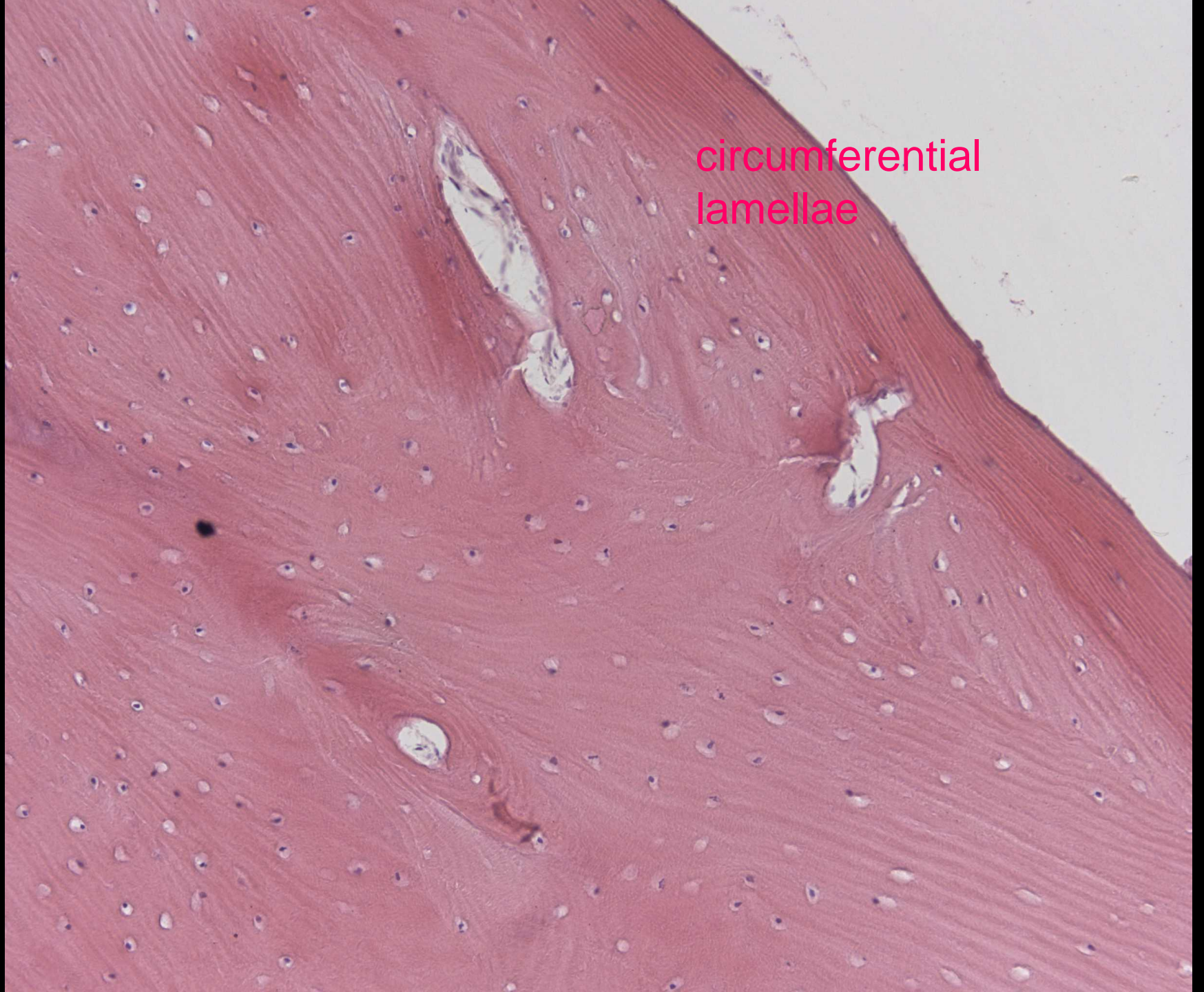


Compact bone





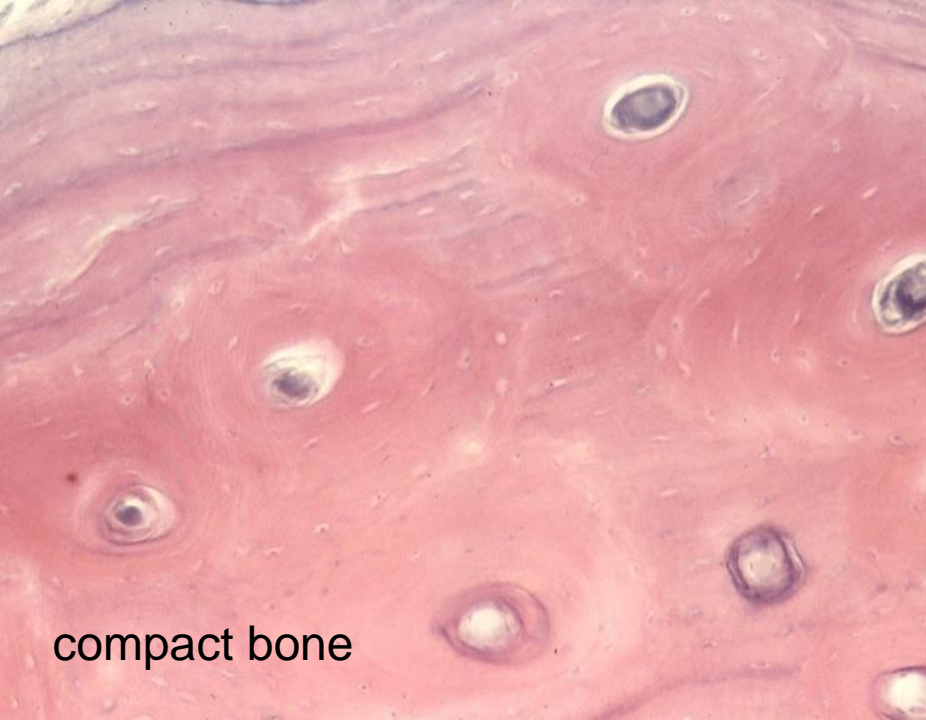
circumferential
lamellae





osteon
(Haversian
system)

This image shows a histological section of compact bone. The tissue is characterized by concentric layers of bone tissue called lamellae, which form circular or oval structures known as osteons. Each osteon contains a central Haversian canal, which is a blood vessel. The osteons are arranged in a regular, repeating pattern. The overall appearance is that of a highly organized, layered structure. The text 'osteon (Haversian system)' is overlaid in red on the image, pointing to one of the circular structures.



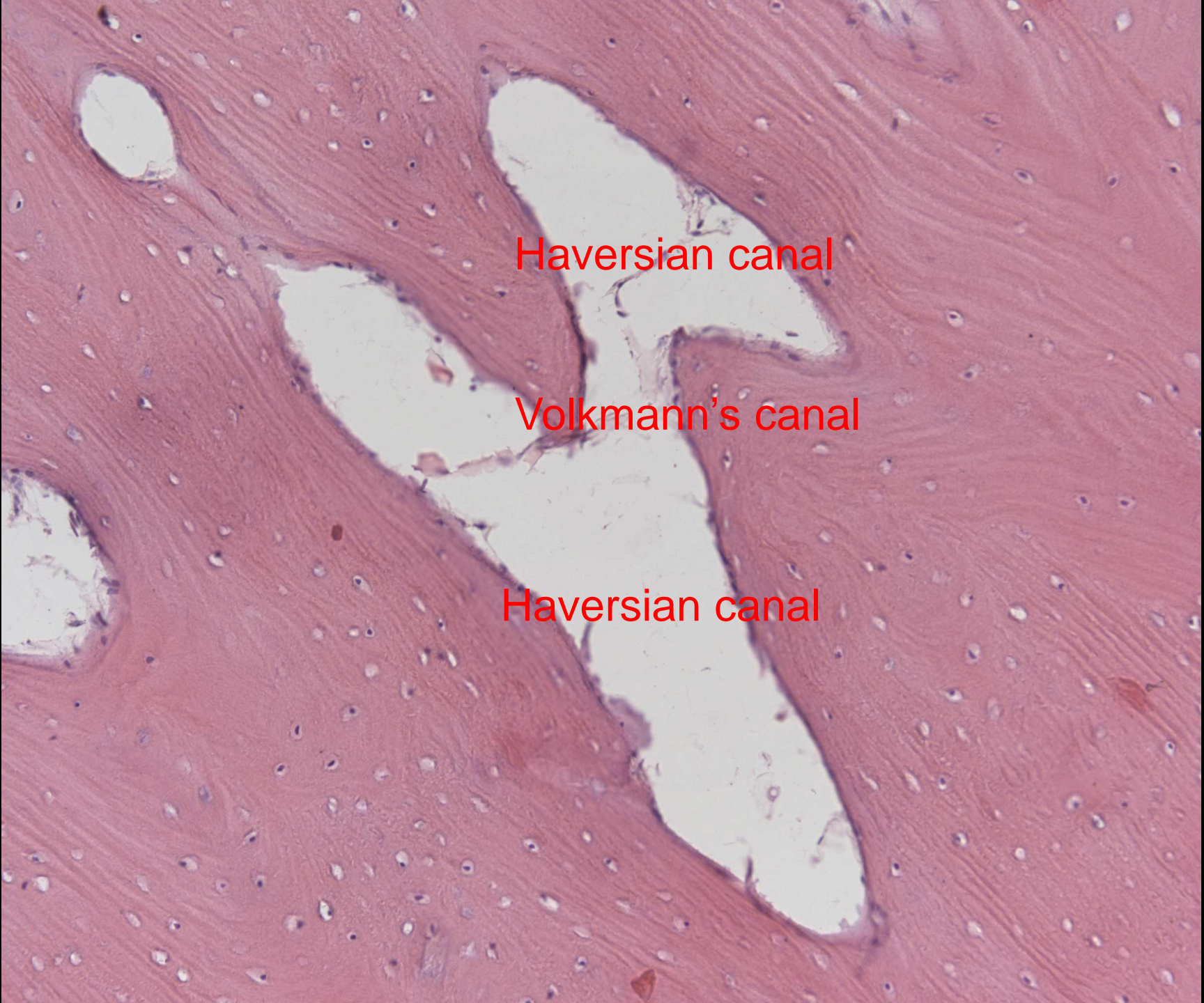
compact bone



osteon, Haversian system



Haversian canal



Haversian canal

Volkmann's canal

Haversian canal

**Spongy
(cancellous)
bone**

