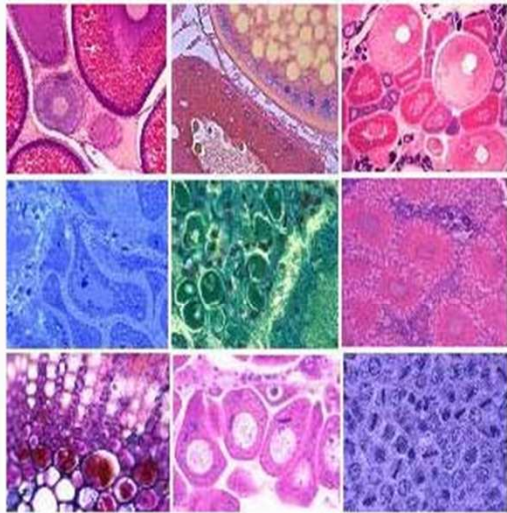


Histology 1 – epithelial and connective tissues



1. Tissues. Classification

2. Epithelial tissue – types:

- ✓ covering epithelia – types
- ✓ glandular epithelia – types

3. Connective tissue – terminology and classification

- ✓ connective tissue proper
- ✓ connective tissue
with special properties
- ✓ supporting connective tissues –
cartilage and bone
- ✓ blood

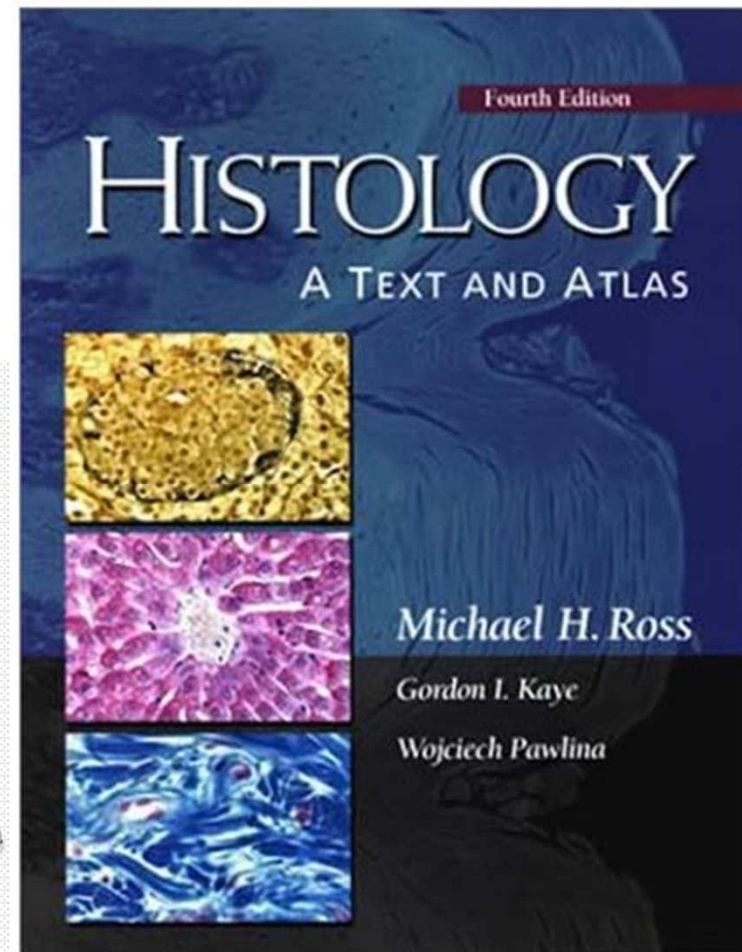
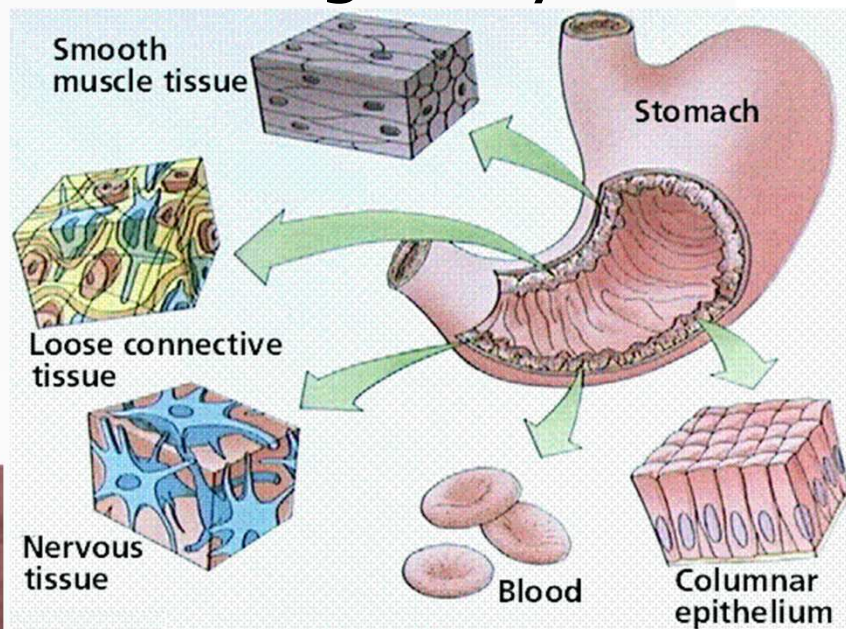


Tissues – concept

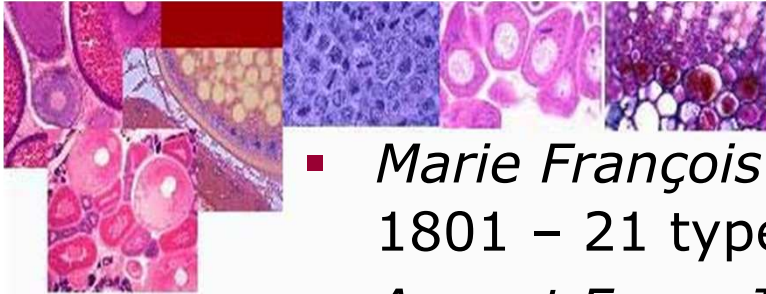
■ Histology:

(Gr. *ιστός*, *histos*, tissue + *logos*, study)

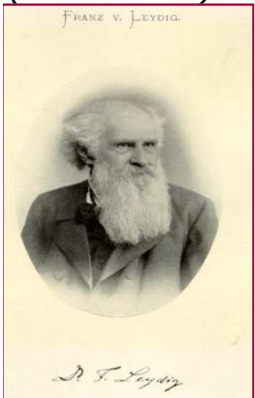
- ✓ general histology
- ✓ special histology = microscopic anatomy of the organ systems



Tissues – classification



Marie Xavier Bichat
(1771-1802)



Franz von Leydig
(1821-1908)



- *Marie François Xavier Bichat, 1797; Fr. tissu = tissue*
1801 – 21 types of tissue
- *August Franz Josef Karl Mayer, histology;*
1819 – 8 types of tissue
- *Franz von Leydig, 1857*
– 4 basic types:
 - ✓ **Epithelial tissue**
 - ✓ **Connective tissue**
 - ✓ **Muscle tissue**
 - ✓ **Nervous tissue**

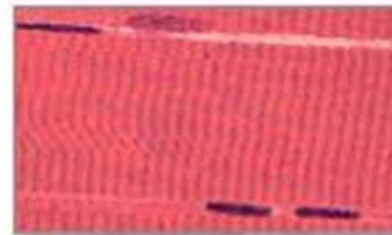
Four types of tissue



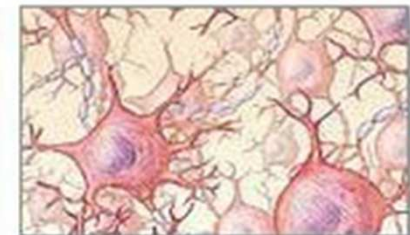
Connective tissue



Epithelial tissue



Muscle tissue



Nervous tissue

Table 4–1. Main Characteristics of the Four Basic Types of Tissues.

Tissue	Cells	Extracellular Matrix	Main Functions
Nervous	Intertwining elongated processes	None	Transmission of nervous impulses
Epithelial	Aggregated polyhedral cells	Very small amount	Lining of surface or body cavities, glandular secretion
Muscle	Elongated contractile cells	Moderate amount	Movement
Connective	Several types of fixed and wandering cells	Abundant amount	Support and protection

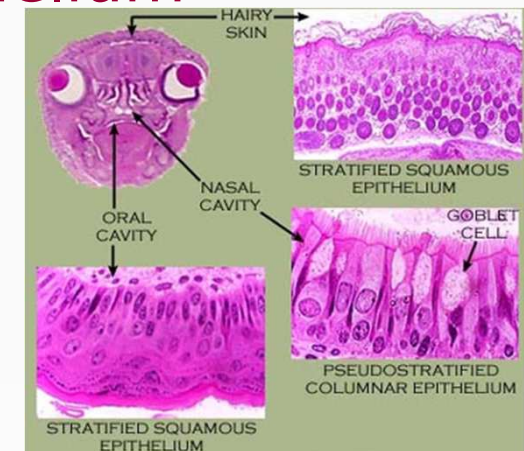
Epithelial tissue

Textus epithelialis:

- Gr. *ἐπί*, *epi*, upon + *θηλή*, *thēlē*, nipple
- Origin – from all three germ layers of the embryo
- The tissue that:
 - ✓ covers surfaces in the body – **epidermis**
 - ✓ lines cavities of hollow organs – **epithelium**

- digestive system
- respiratory system
- urinary system
- reproductive (genital) system
- cardiovascular system

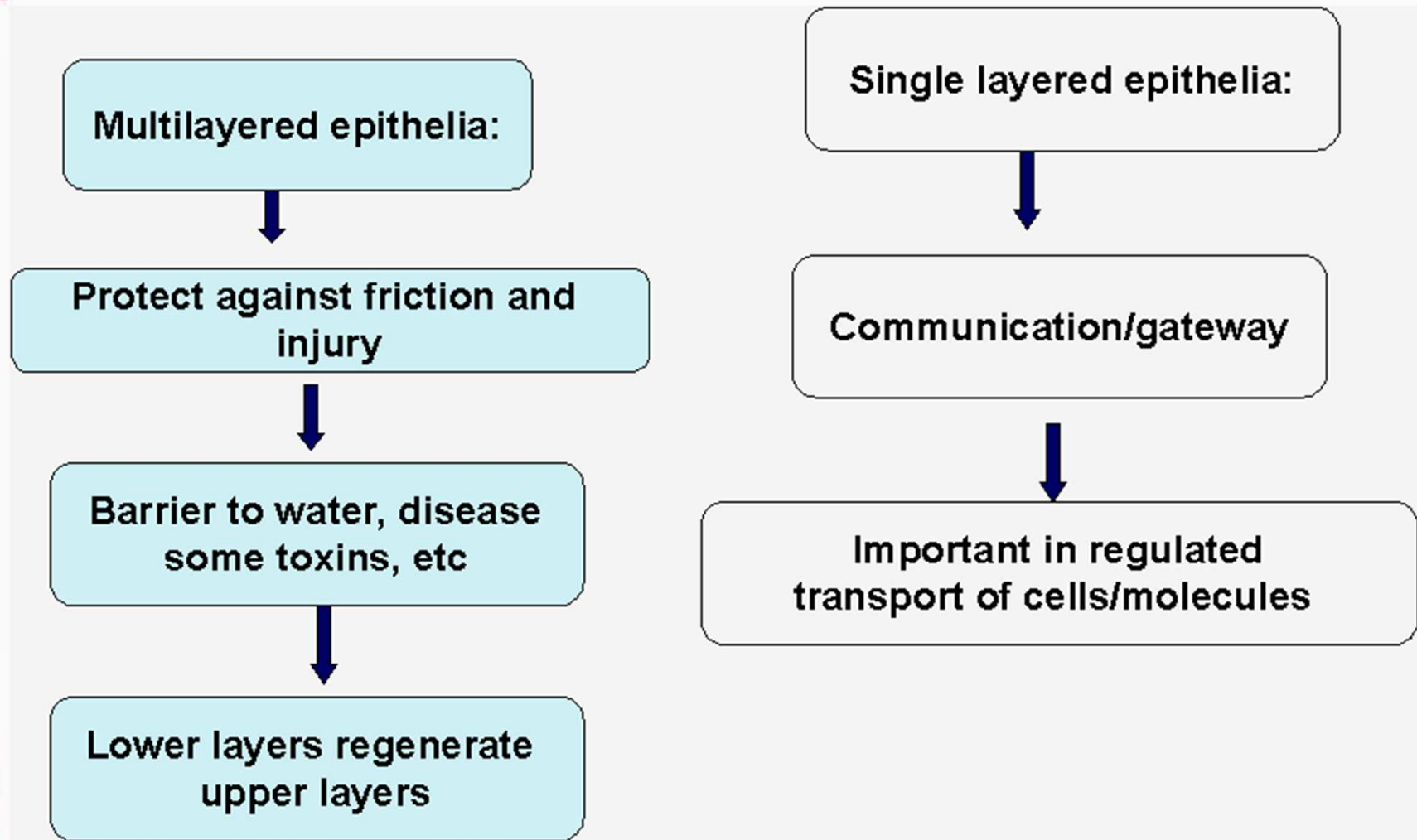
- Many glands are also formed from epithelial tissue (sweat and sebaceous glands, pancreas, liver) – **parenchyma**



Epithelial tissue – functions

▪ Main functions:

✓ protection (barrier), transport and secretion

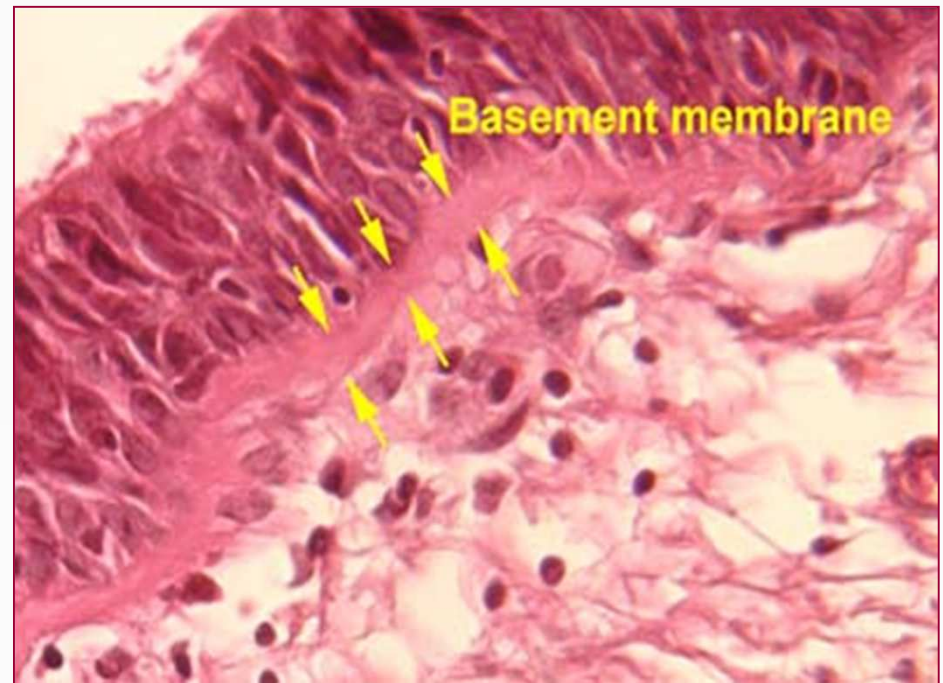
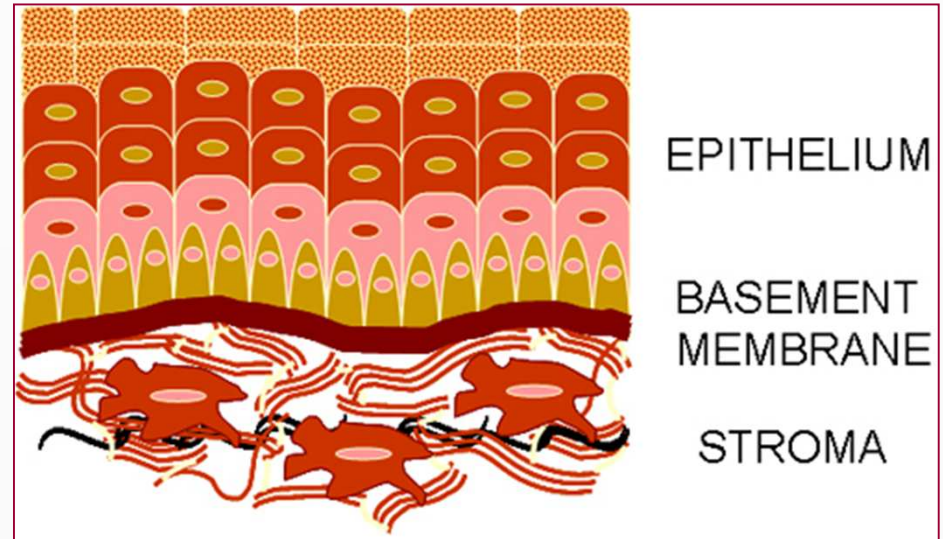


Epithelial tissue – characteristics

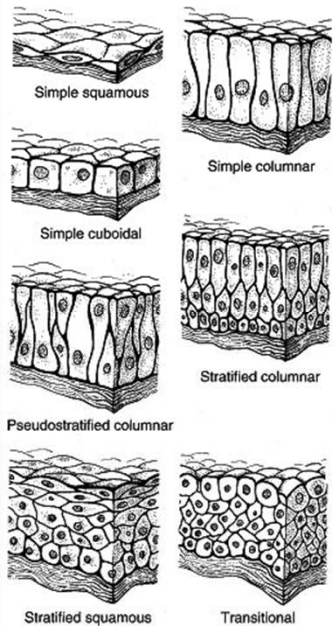
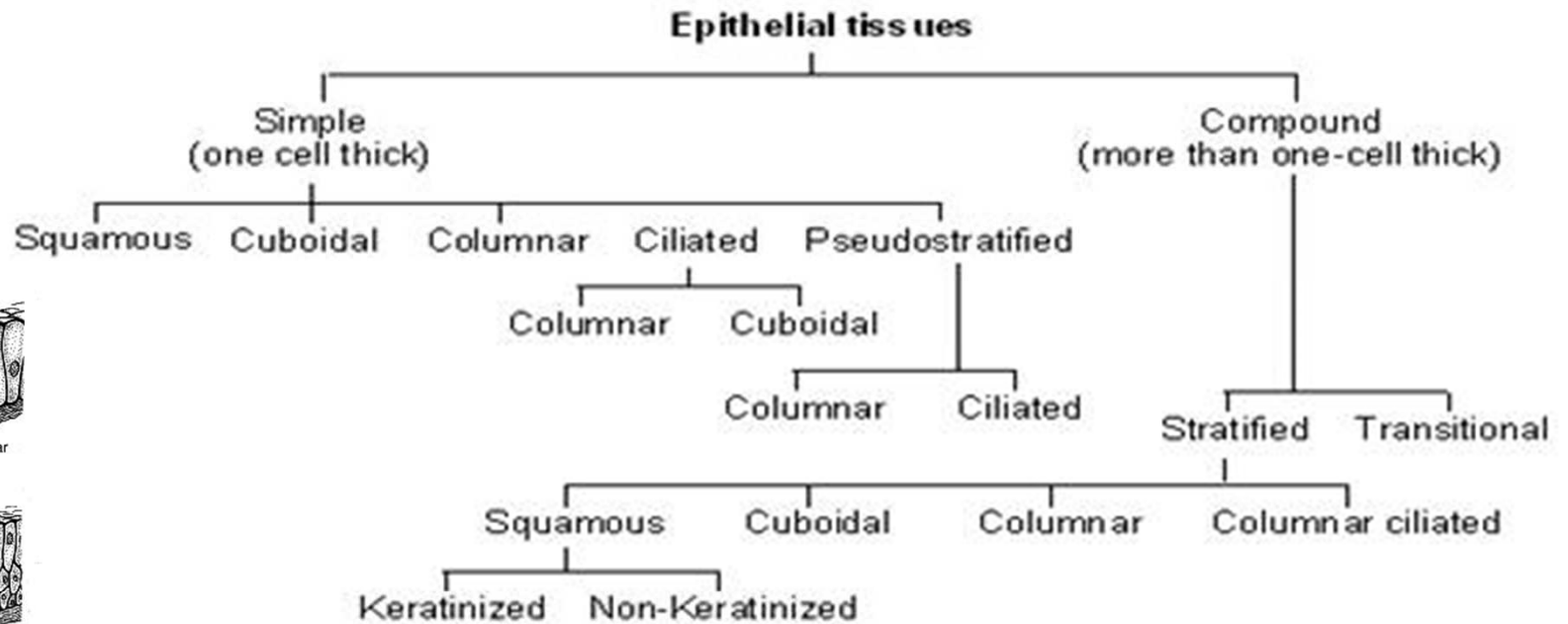


Common features:

- ✓ epithelial cells rest on a basement membrane
- ✓ morphological and functional cell polarity – basal and free apical poles
- ✓ avascular tissue – lacks blood vessels
- ✓ rich innervation
- ✓ limited intercellular space
- ✓ high regenerative capacity

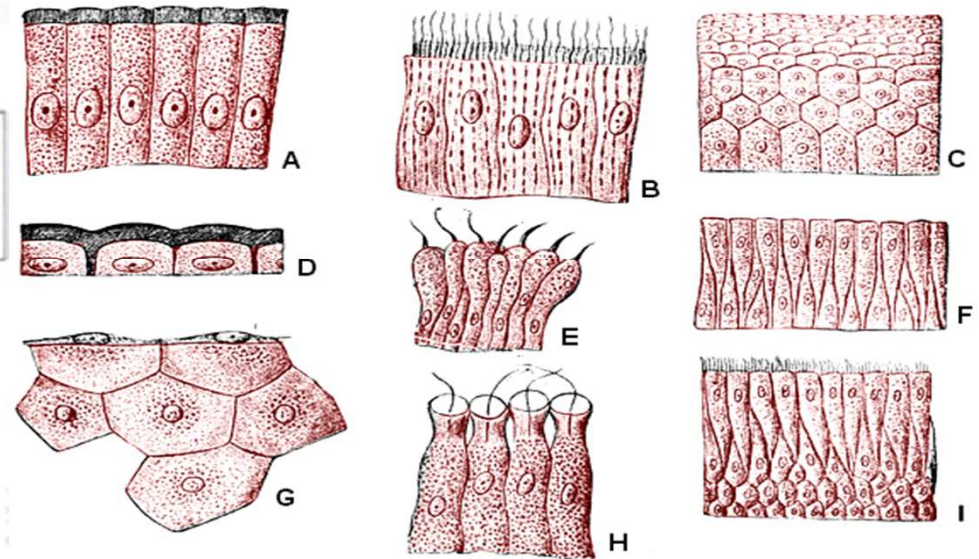


Epithelial tissue – classification

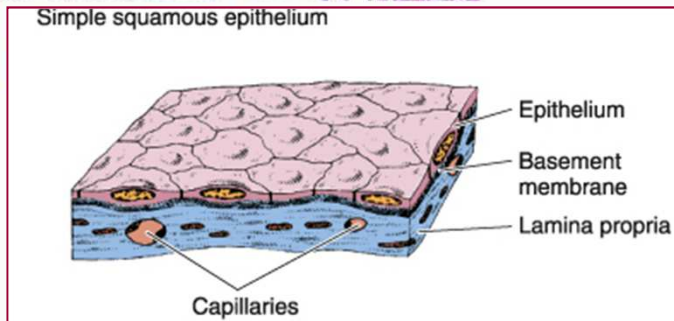
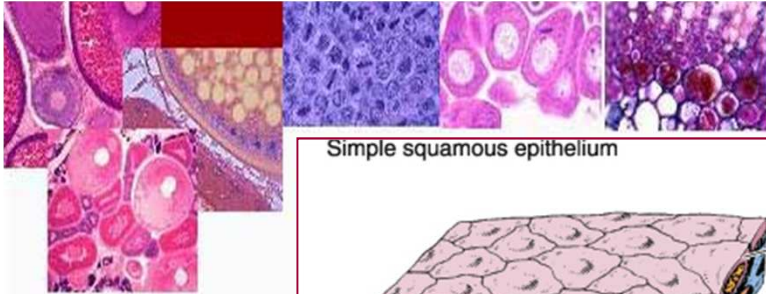


Classification of Epithelial Tissues

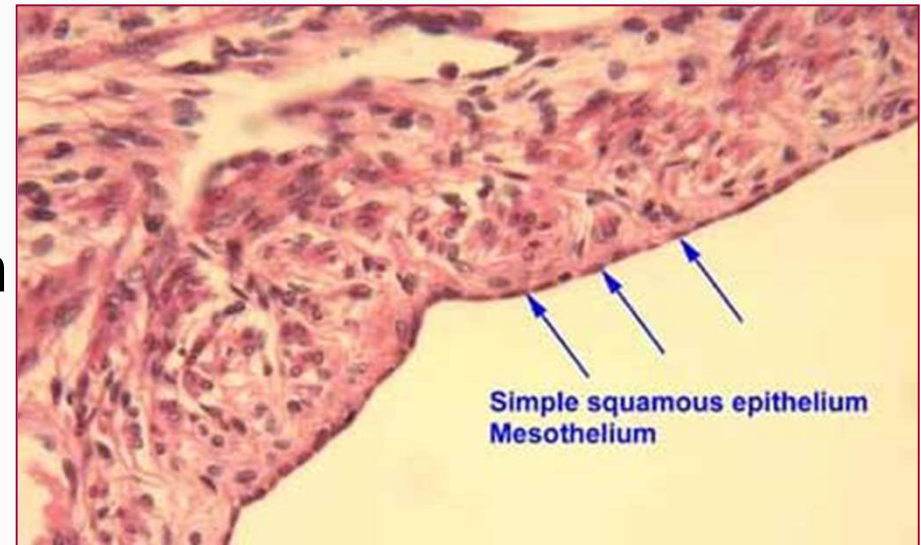
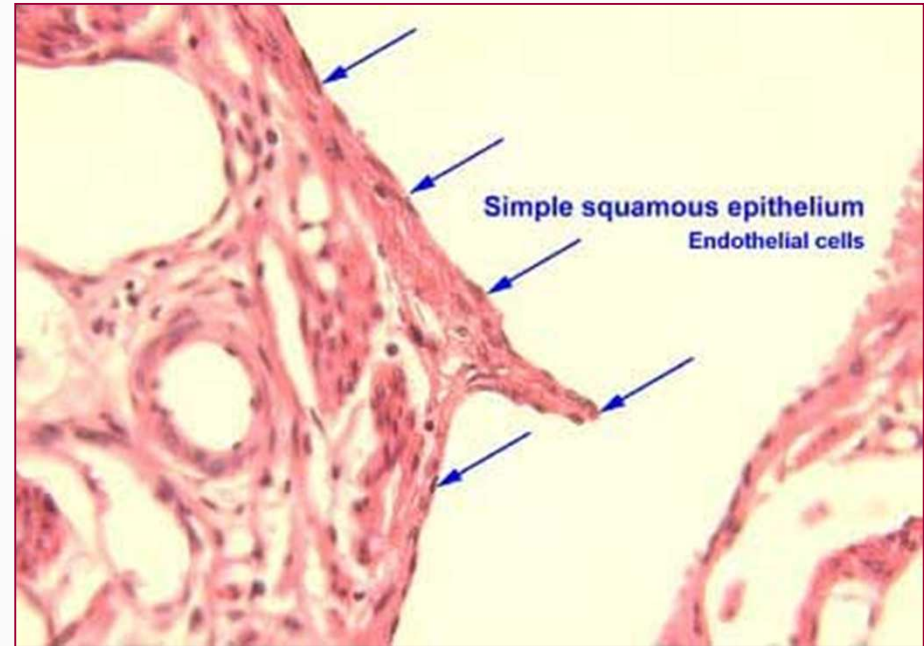
Shapes	Simple	Stratified
Squamous	Simple squamous	Stratified squamous
Cuboidal	Simple cuboidal	
Columnar	Simple columnar	



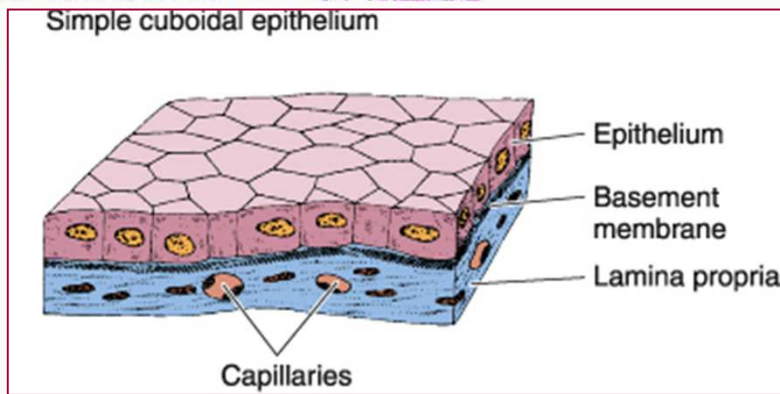
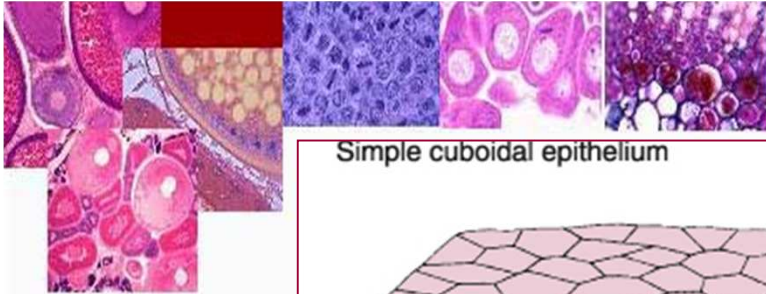
Simple squamous epithelium



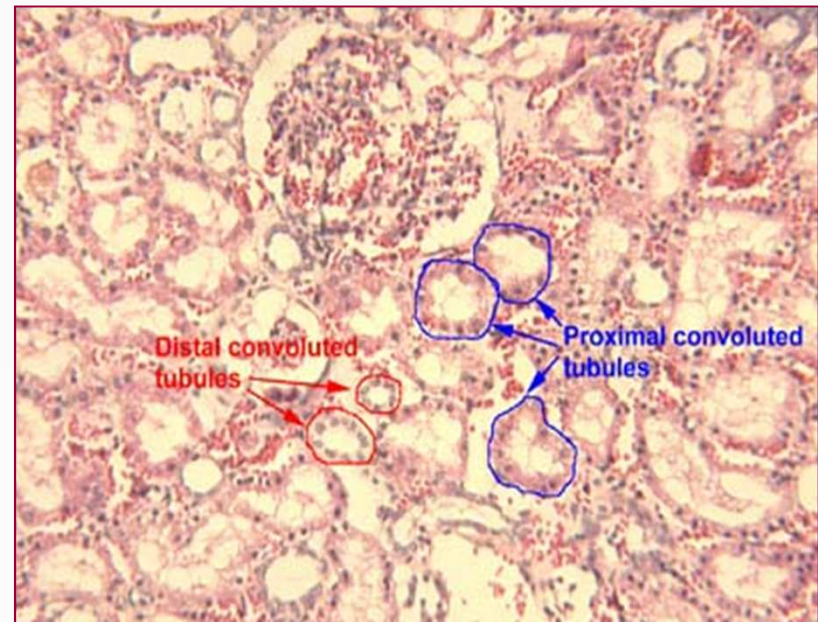
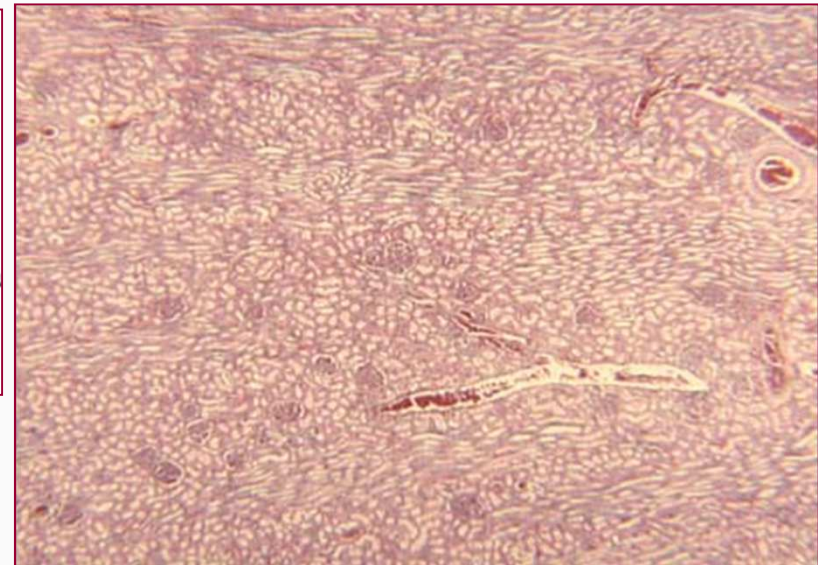
- Epithelium that lines blood and lymph vessels (**endothelium, vasothelium**)
 - ✓ squamous in shape cells
 - ✓ a prominent, protruding nucleus
 - ✓ covering and metabolic functions
- Epithelium that lines certain body cavities, such as the pleural and peritoneal cavities (**mesothelium**)



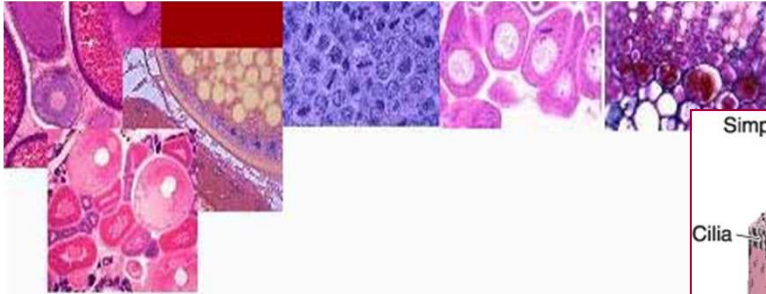
Simple cuboidal epithelium



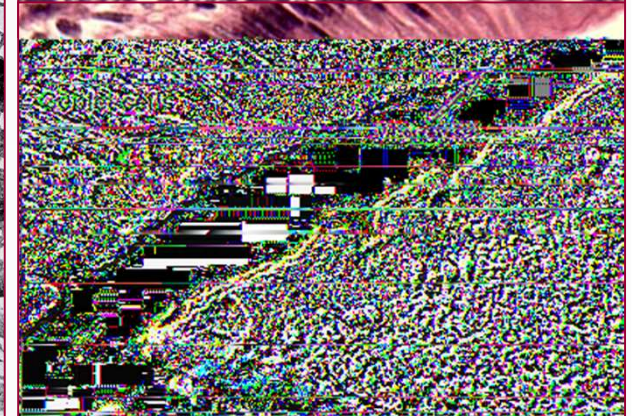
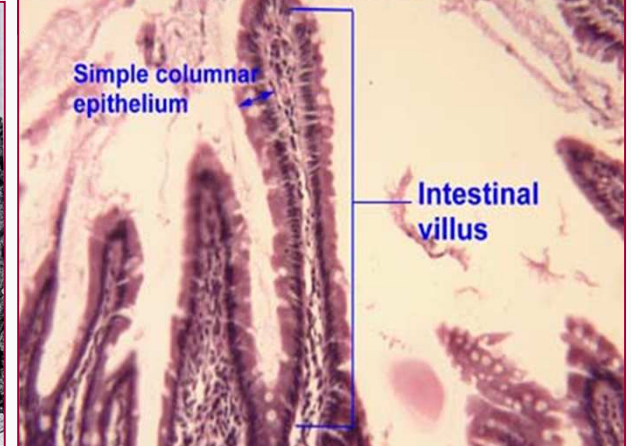
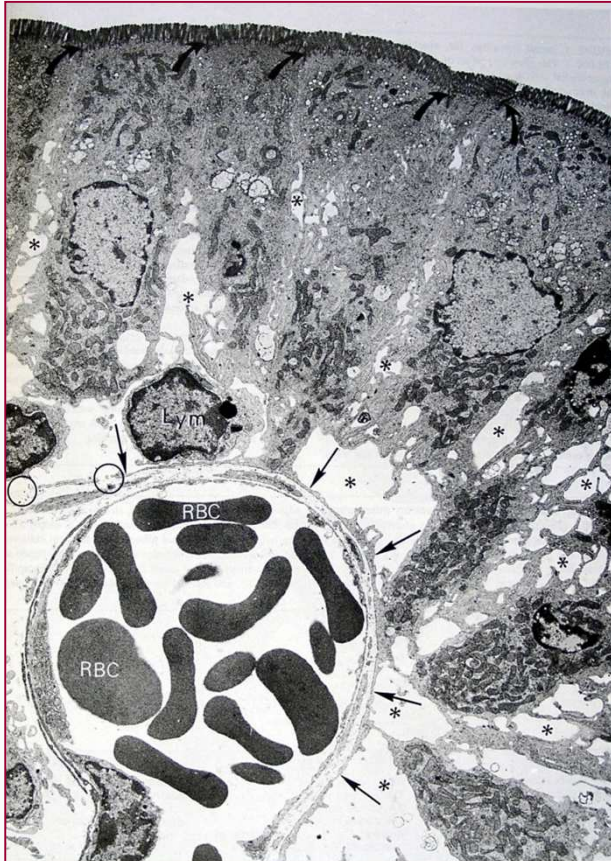
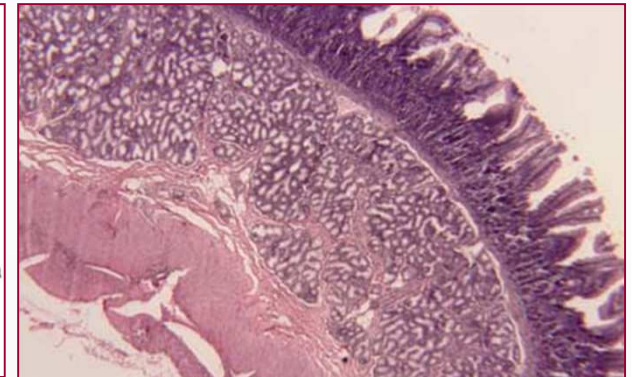
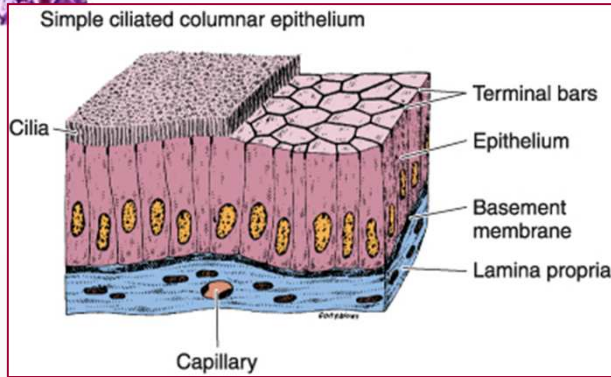
- covering:
 - ✓ ducts of the exocrine glands
 - ✓ ovary
- absorption:
 - ✓ walls of renal tubules
- secretion:
 - ✓ thyroid gland (follicles)



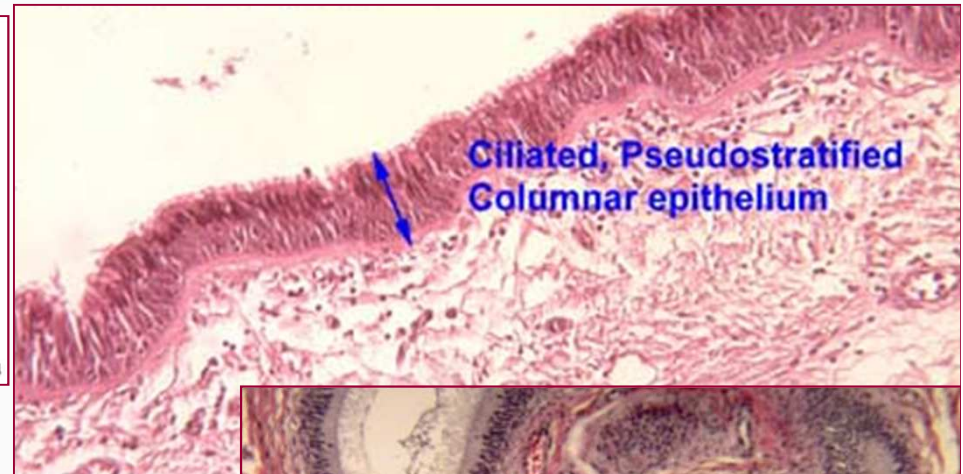
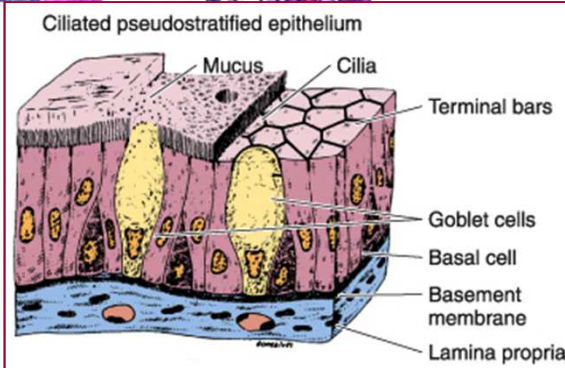
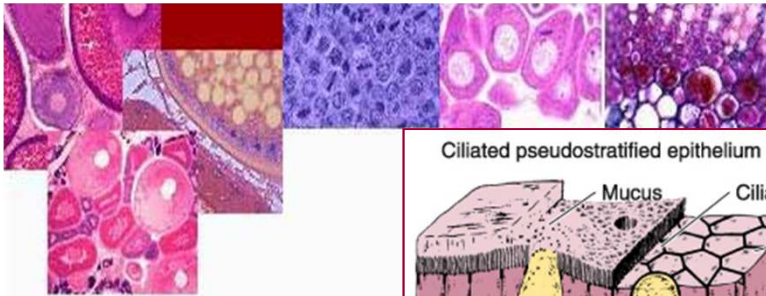
Simple columnar epithelium



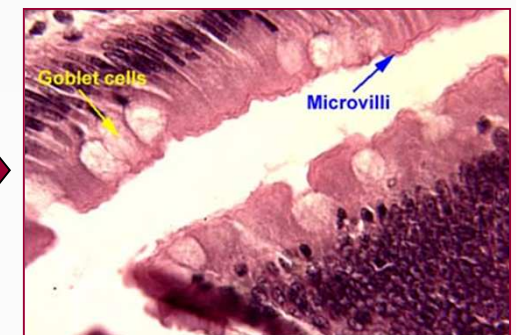
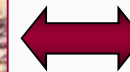
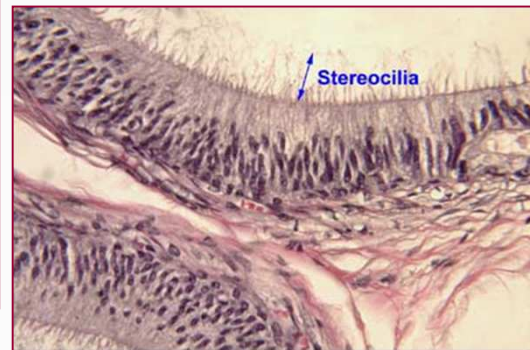
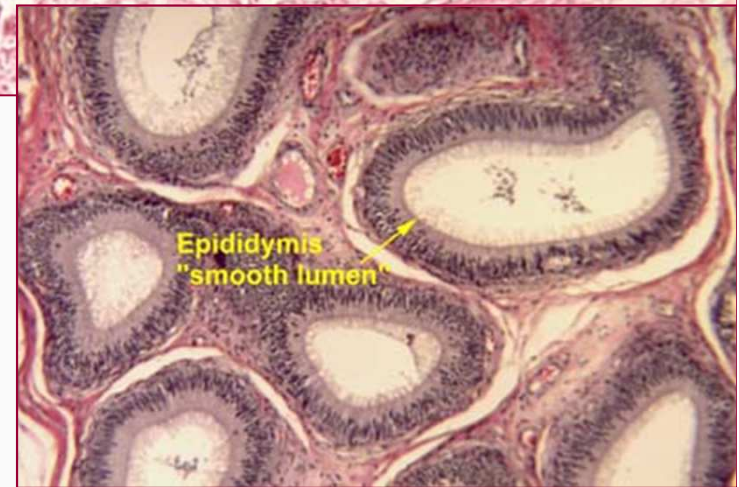
- covering:
 - ✓ ducts of the exocrine glands
- absorption:
 - ✓ intestinal villi
- secretion:
 - ✓ stomach
 - ✓ large intestine
 - ✓ uterus
- ciliated:
 - ✓ Fallopian tubes
 - ✓ distal bronchi



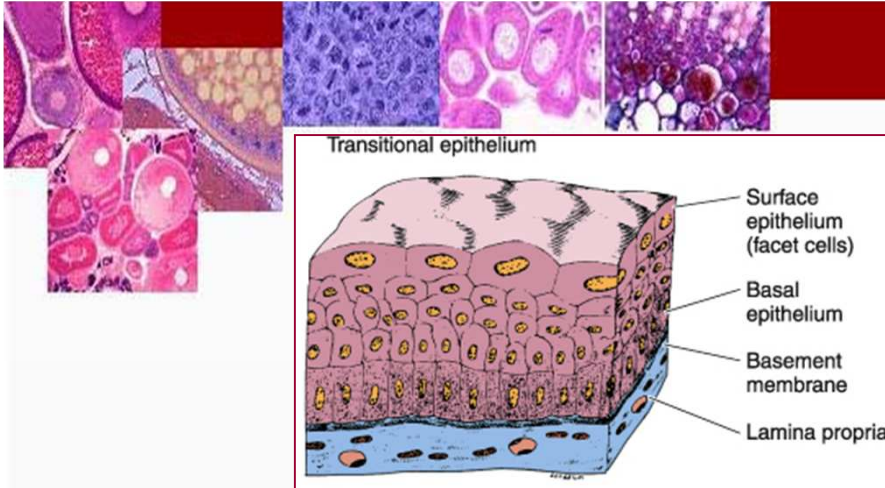
Pseudostratified columnar epithelium



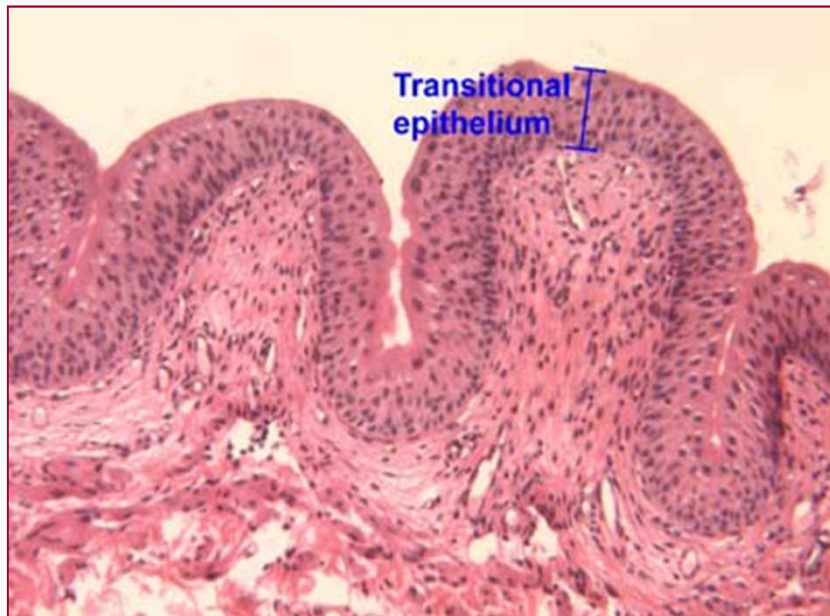
- covering:
 - ✓ large ducts of the exocrine glands
- ciliated:
 - ✓ upper respiratory tract
 - ✓ epididymis



Transitional epithelium



- Uroepithelium (urothelium):
 - ✓ lining of renal calyces
 - ✓ urinary tract – ureters&bladder

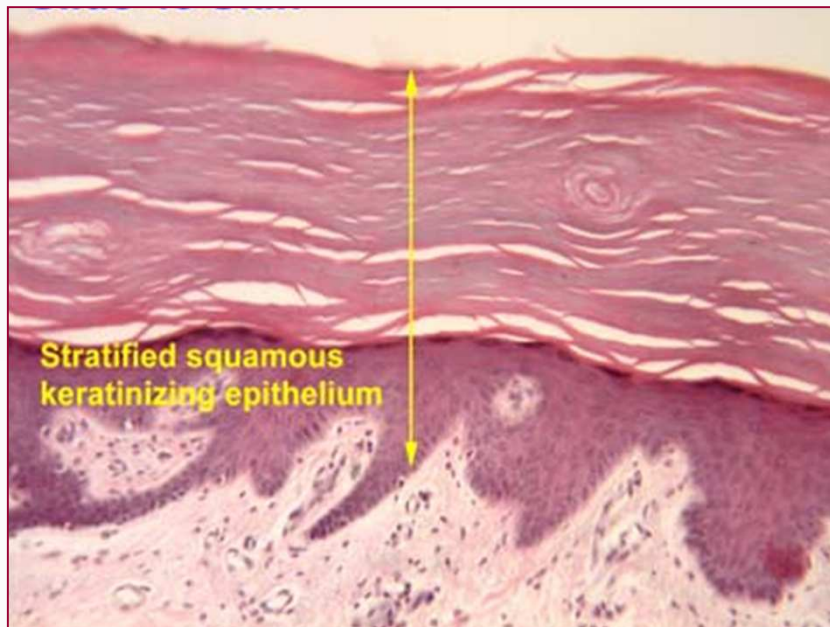
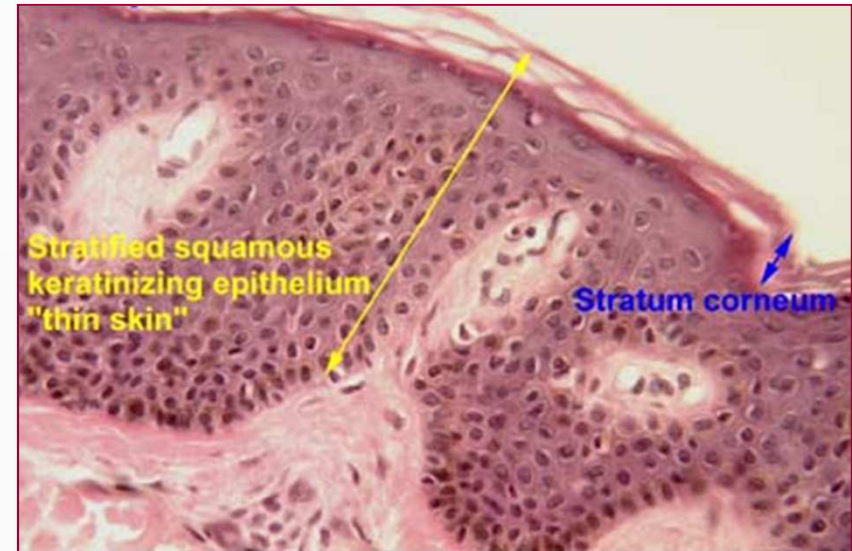


- The form of the cells changes according to the degree of distention of the organ:
 - ✓ five or six cells in thickness
 - ✓ small basal cells
 - ✓ larger pear-shaped cells in the middle layers
 - ✓ superficial cells are rounded and frequently binucleate

Stratified squamous keratinizing



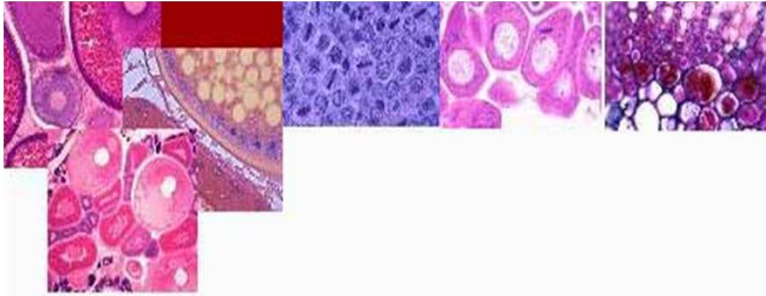
- Skin (epidermis):
 - covers dry surfaces
 - most superficial cells involute and are transformed into dead scales of protein (keratin) without discernible nuclei
 - 5 layers of keratinocytes:



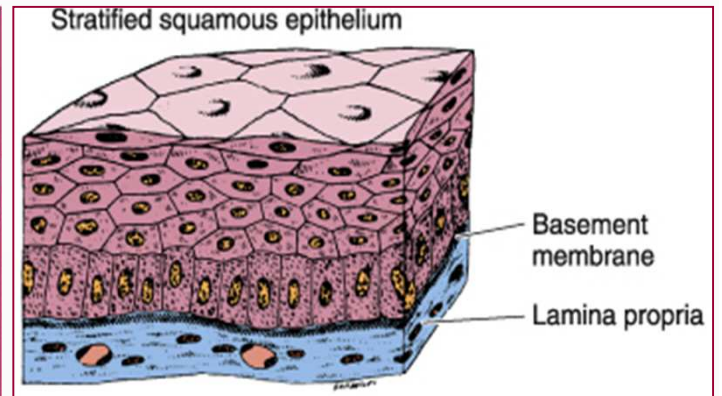
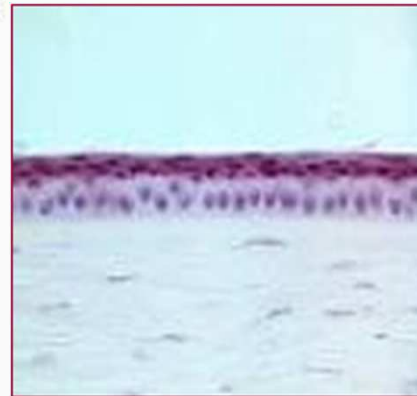
- ✓ *stratum basale*
- ✓ *stratum spinosum*
- ✓ *stratum granulosum*
- ✓ *stratum lucidum*
- ✓ *stratum corneum* – keratin



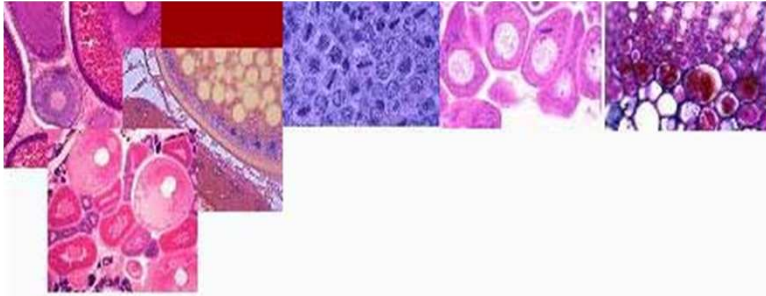
Stratified squamous nonkeratinizing



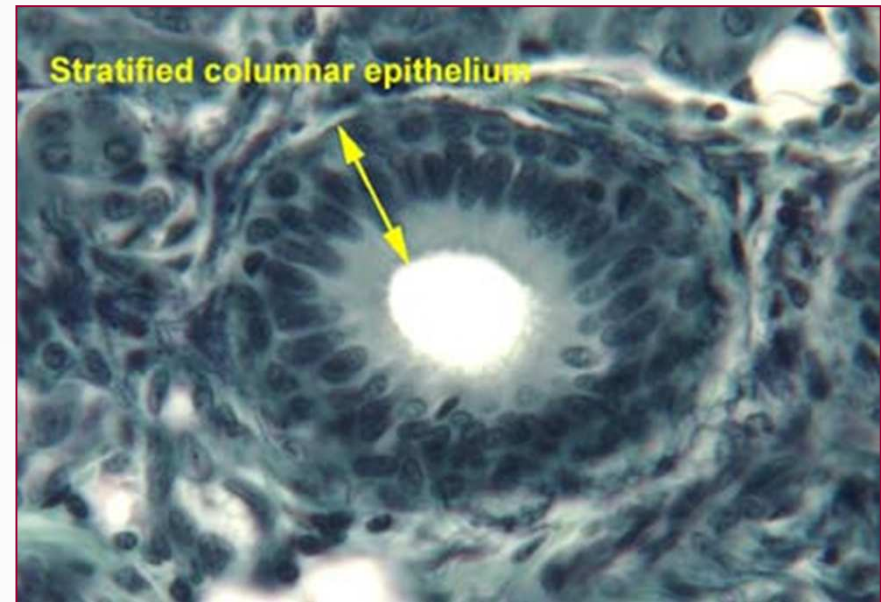
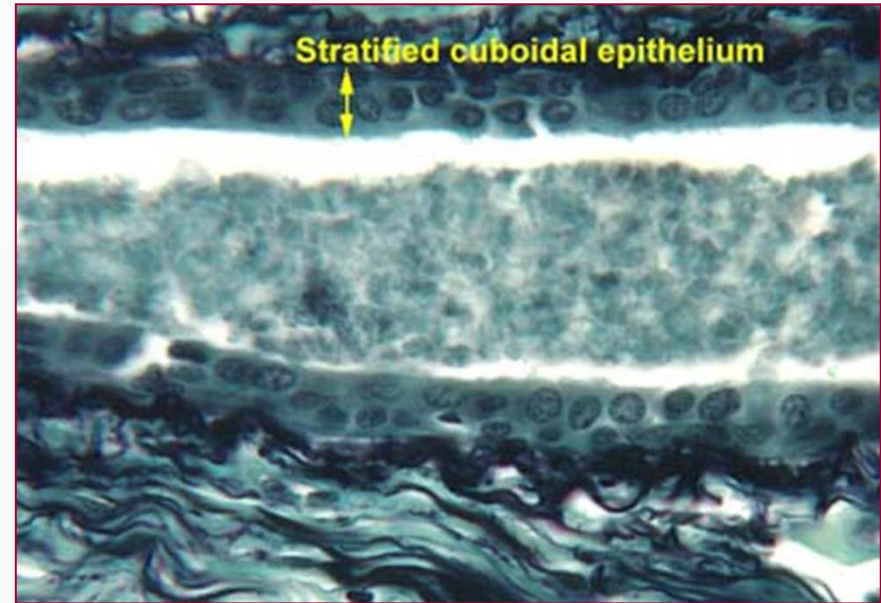
- Mucous epithelium – covers wet surfaces:
 - ✓ oral cavity
 - ✓ oropharynx
 - ✓ esophagus
 - ✓ anal canal
 - ✓ vagina
- Metaplasia
- Corneal epithelium



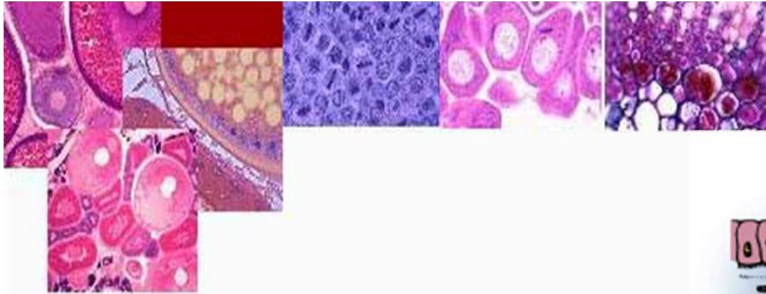
Stratified cuboidal/columnar epithelium



- Bilayered cuboidal epithelium:
 - ✓ ducts of the sweat glands
- Stratified columnar epithelium:
 - ✓ rare – only in small areas
 - ✓ large ducts of salivary glands
 - ✓ part of the urethra
 - ✓ ocular conjunctiva



Types of glandular epithelia



■ Exocrine glands

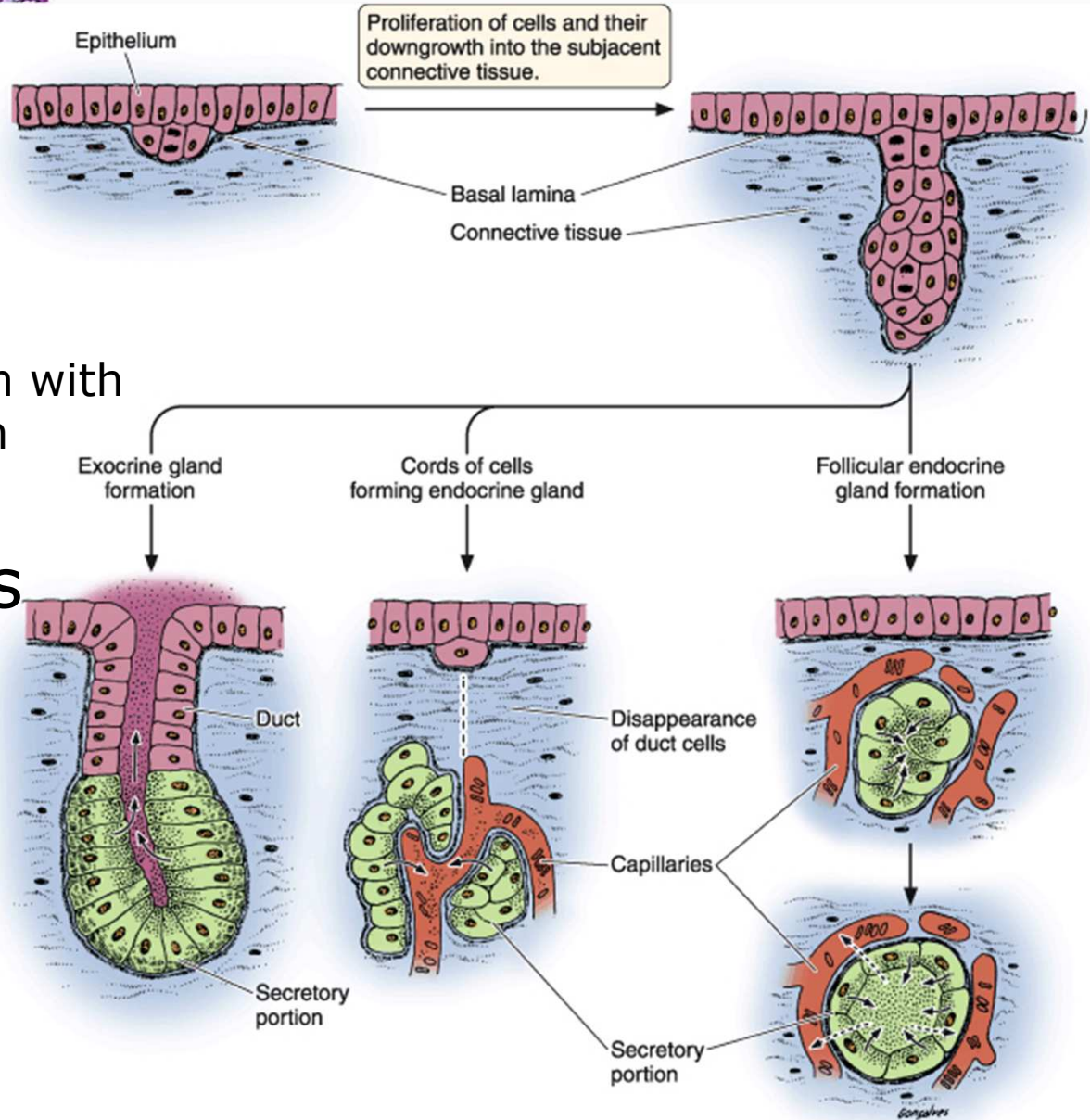
(Gr. *exo*, outside, + *krinein*, to separate):

- ✓ retain their connection with the surface epithelium
- ✓ tubular ducts

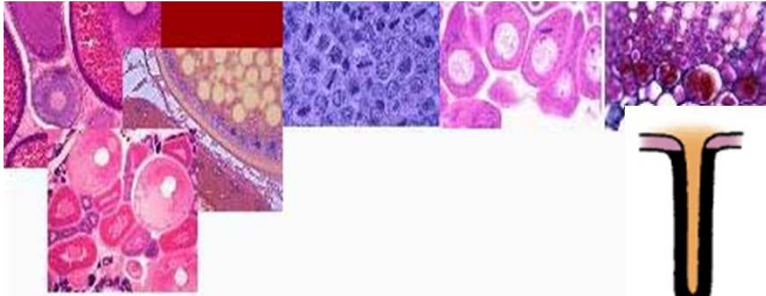
■ Endocrine glands

(Gr. *endon*, within, + *krinein*)

- ✓ connection with the surface is lost during development
- ✓ ductless



Principal types of exocrine glands



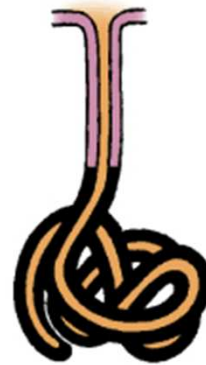
- Many ways of classifying:
 - ✓ structure
 - ✓ product secreted
 - ✓ method of secretion

- Structural types:

- ✓ simple (unbranched)
 - tubular
 - acinar
- ✓ compound (branched)
 - tubular
 - acinar (alveolar)
 - tubuloalveolar



Simple tubular



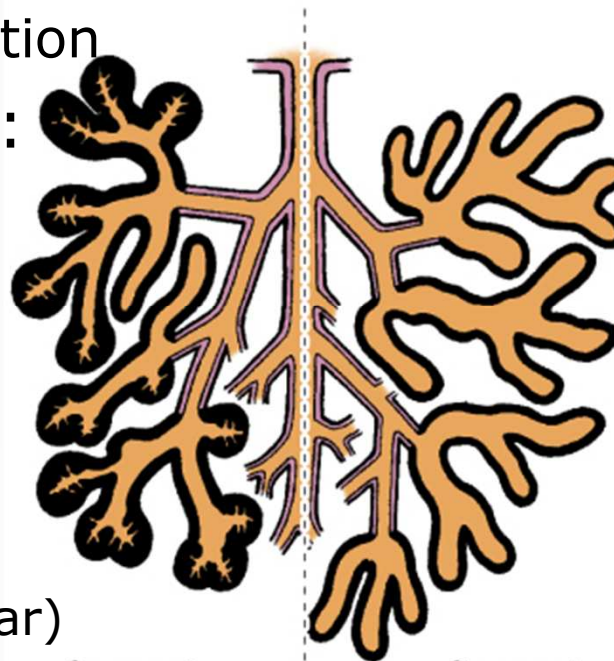
Simple coiled tubular



Simple branched tubular



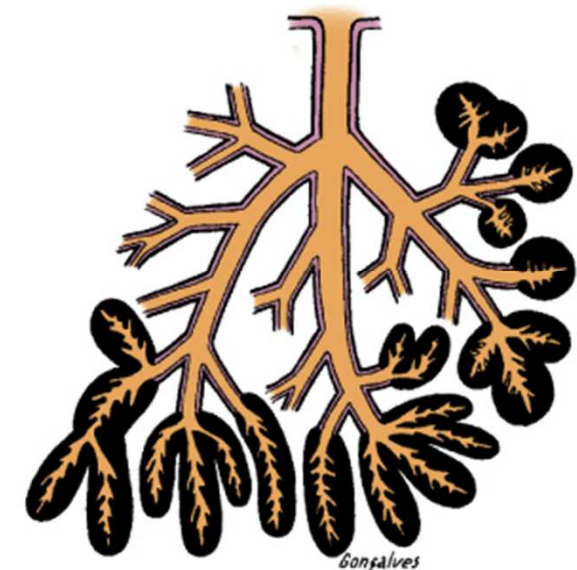
Simple branched acinar



Compound tubuloalveolar



Compound tubular

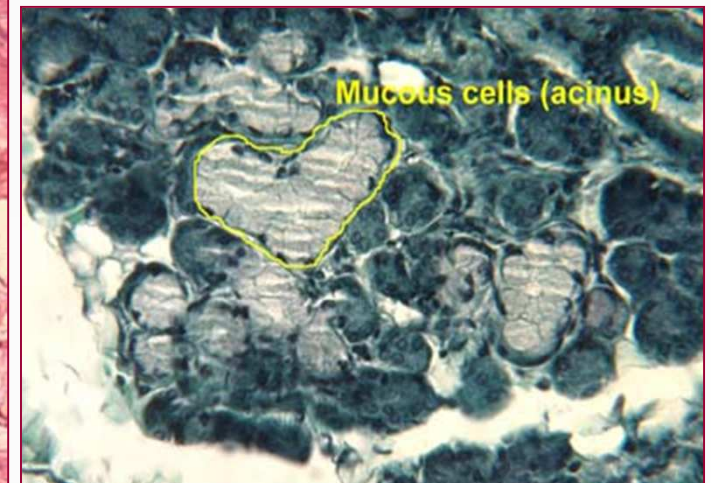
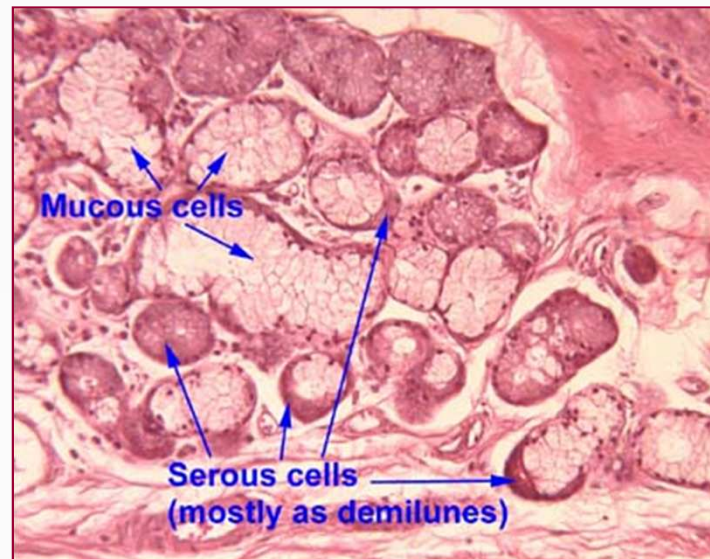
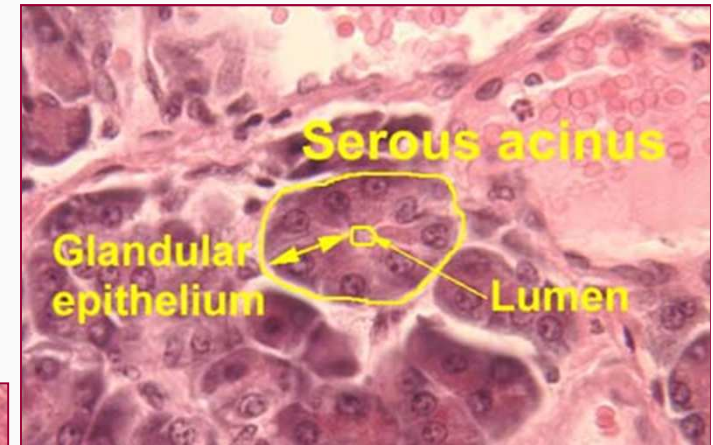
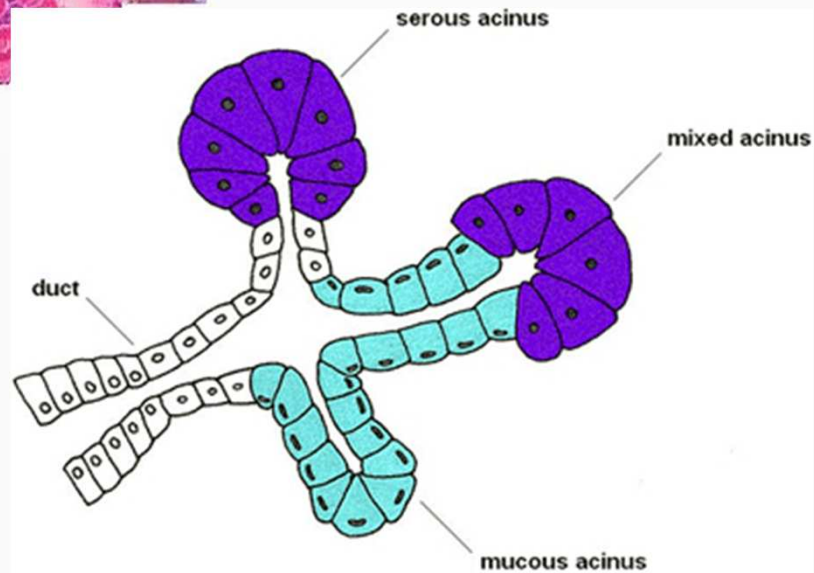


Compound acinar

Exocrine glands – types

- Exocrine glands – product secreted:

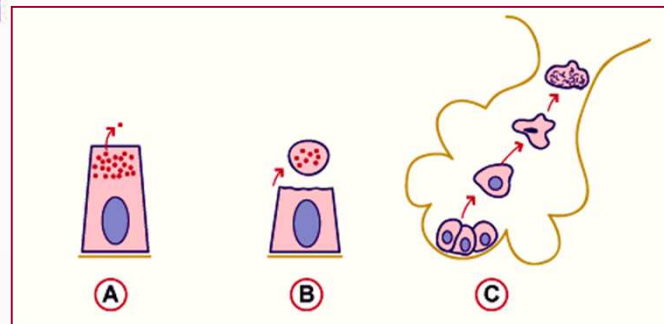
- ✓ serous (*glandula serosa*)
- ✓ mucous (*glandula mucosa*)
- ✓ mixed (*glandula seromucosa*)



Types of glandular exocrine secretions



▪ Exocrine glands
- method of secretion:



✓ **merocrine (eccrine)** glands – exocytosis:

Gr. *meros*, part + *krinein*, to separate

- most of the exocrine glands (eg, the pancreas)
- some endocrine glands

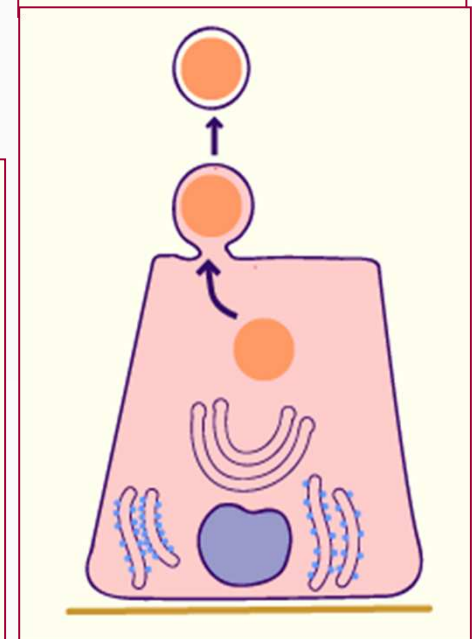
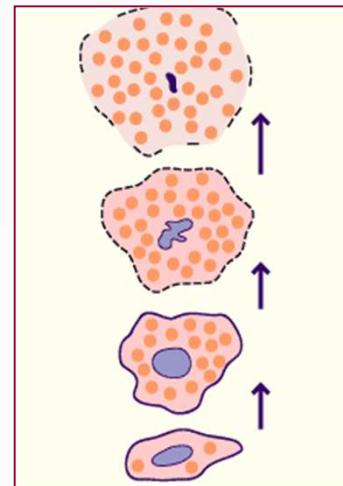
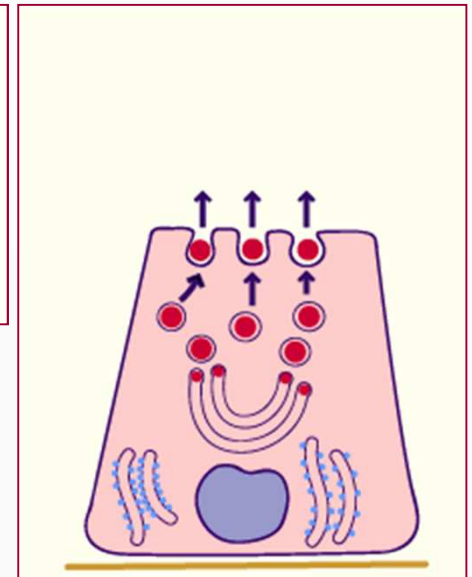
✓ **apocrine** glands: Gr. *apo*, away from + *krinein*

- aromatic glands
- large sweat glands
- mammary glands

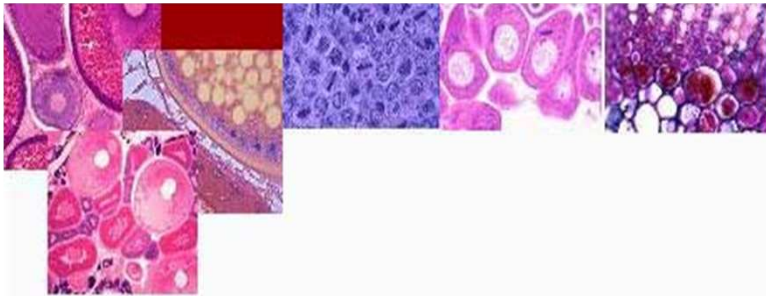
✓ **holocrine** glands:

Gr. *holos*, whole + *krinein*

- sebaceous glands in the skin
- tarsal (Meibomian) glands

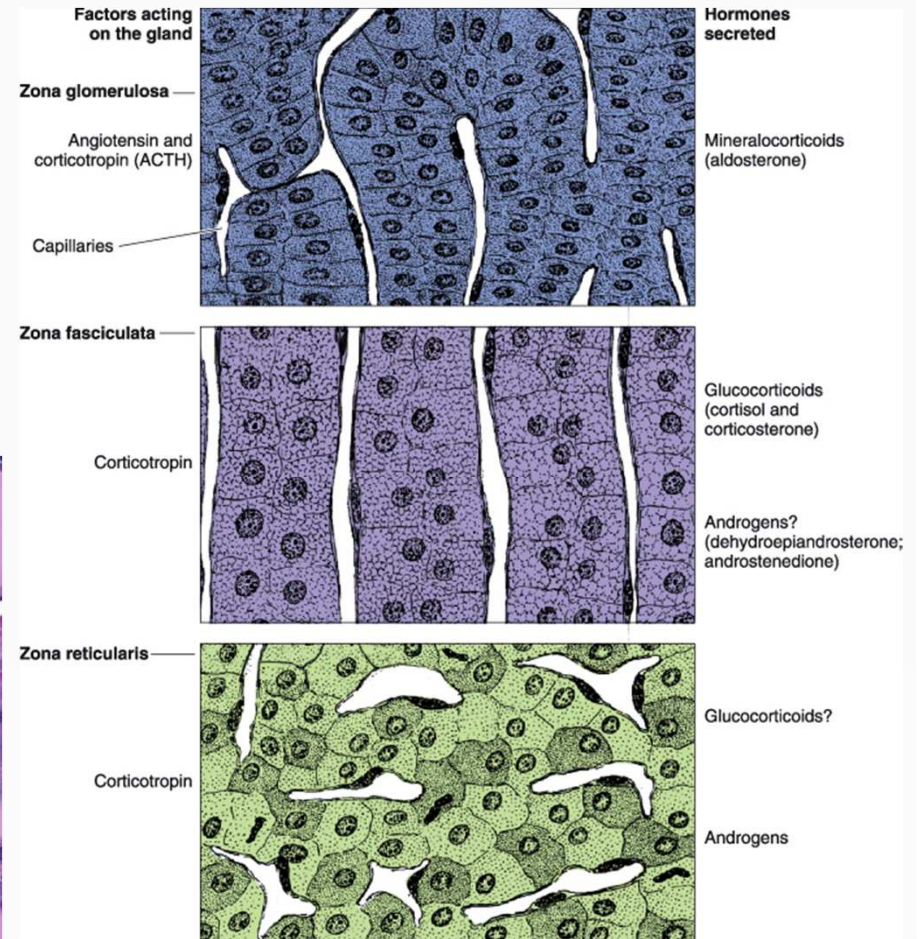
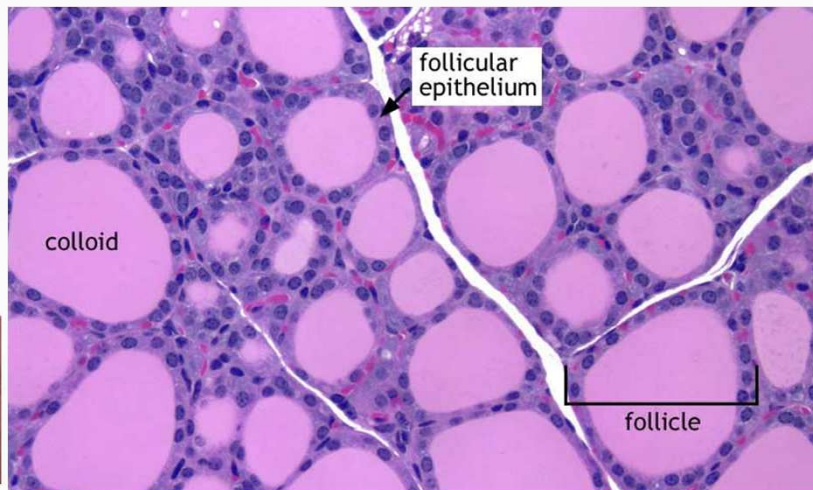


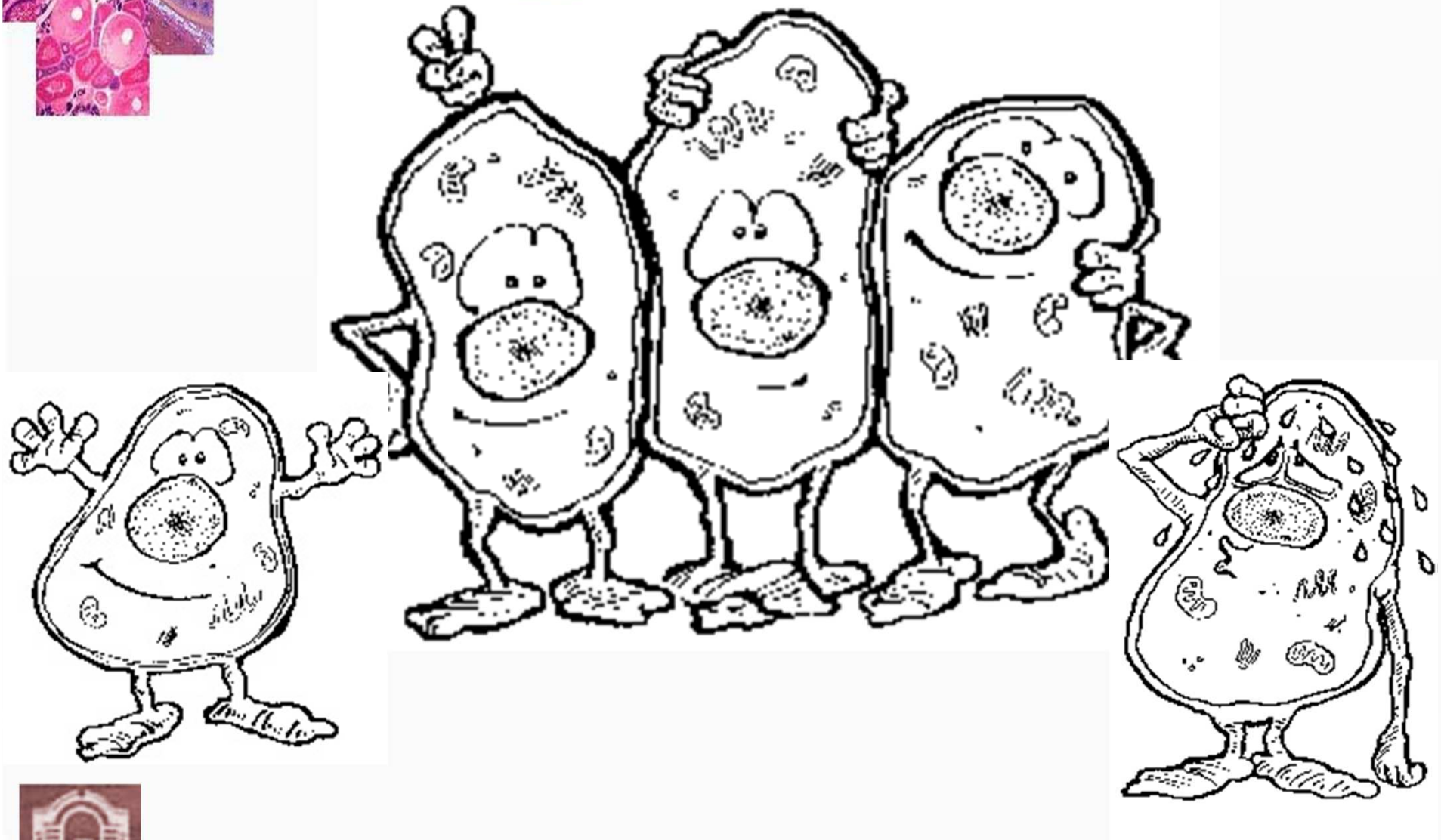
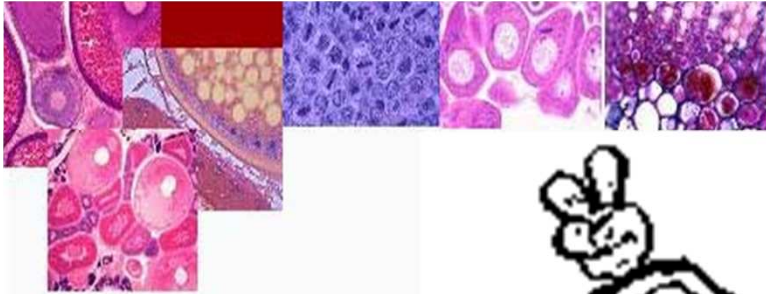
Endocrine glands



- Endocrine glands – types:
 - ✓ endocrine cells may form anastomosing cords
 - anterior lobe of the pituitary
 - parathyroid gland
 - adrenal gland
 - ✓ endocrine cells may arrange as vesicles or follicles
 - thyroid gland

- Endocrine glands:
 - ✓ secrete their products, hormones, directly into the blood
 - ✓ ductless





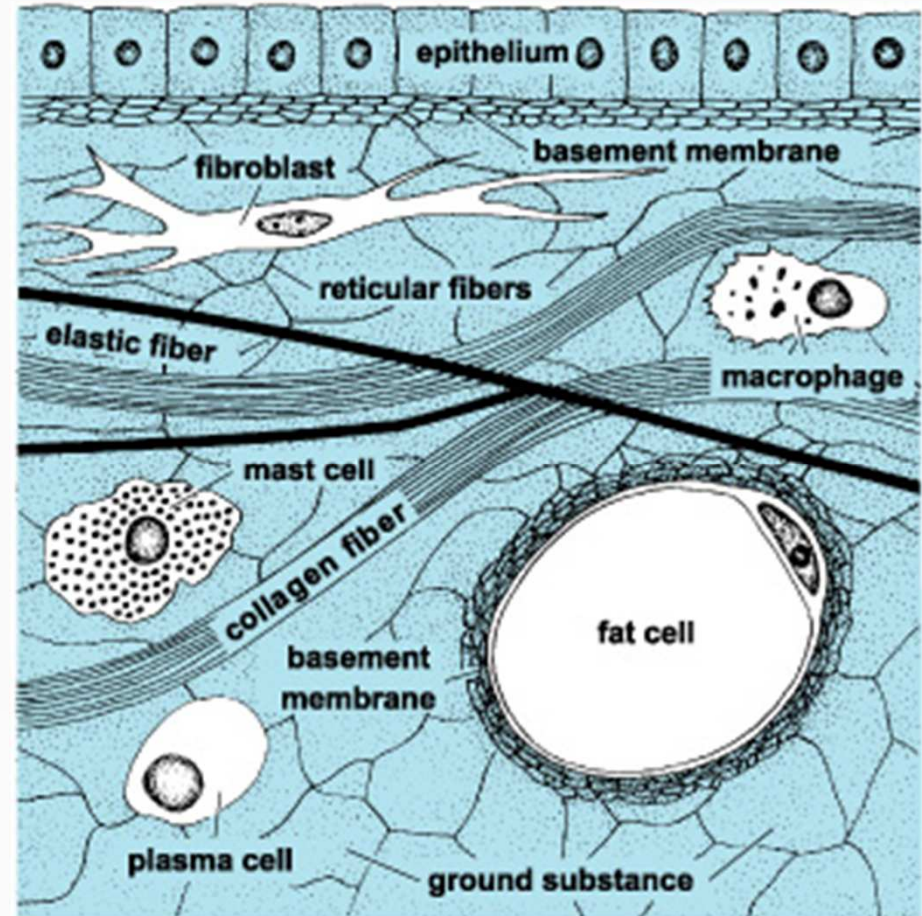
Terminology and peculiarities

- *Textus connectivus*:
 - ✓ cells of mesenchymal origin
 - ✓ extracellular matrix

- **connective tissue features:**

- ✓ interior location – never found at the surface
- ✓ cellular polymorphism
- ✓ abundant amounts of extracellular matrix – determines the species diversity
- ✓ absence of cell polarity
- ✓ high adaptive and regenerative capabilities
- ✓ metaplastic abilities
- ✓ specialized structures:

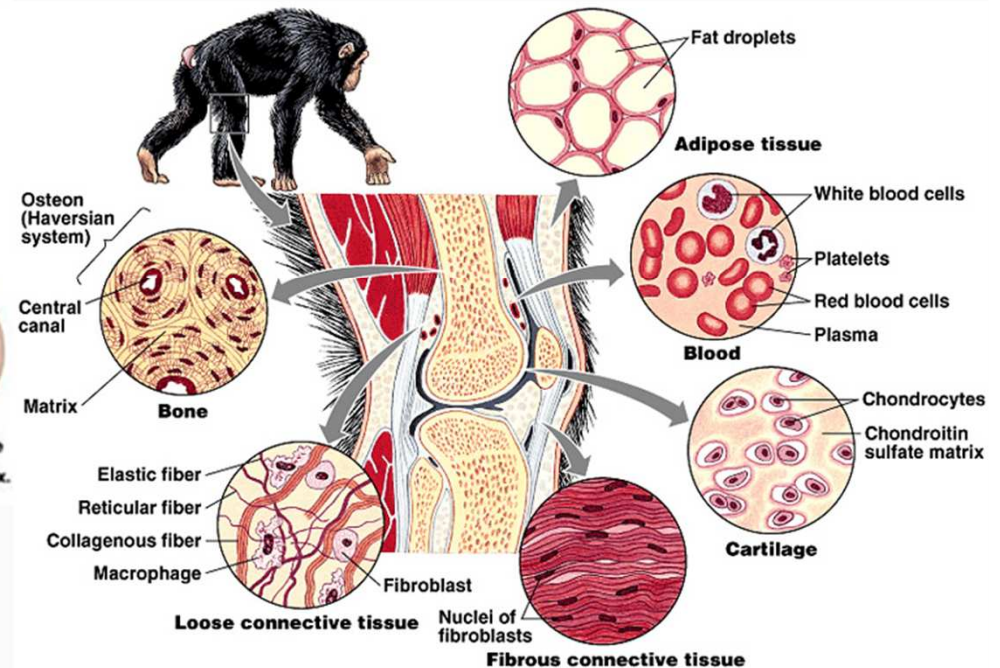
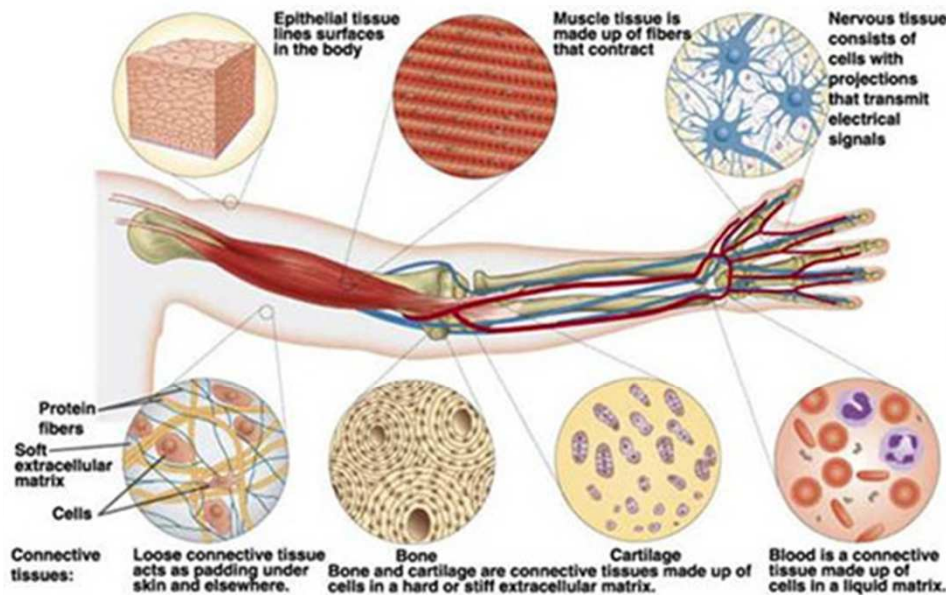
- intracellular
- extracellular



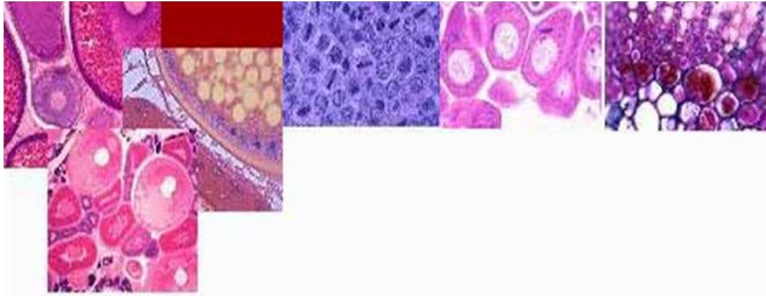
NB: most abundant of the basic tissues – 1/2 of the human body mass

Functions of connective tissue

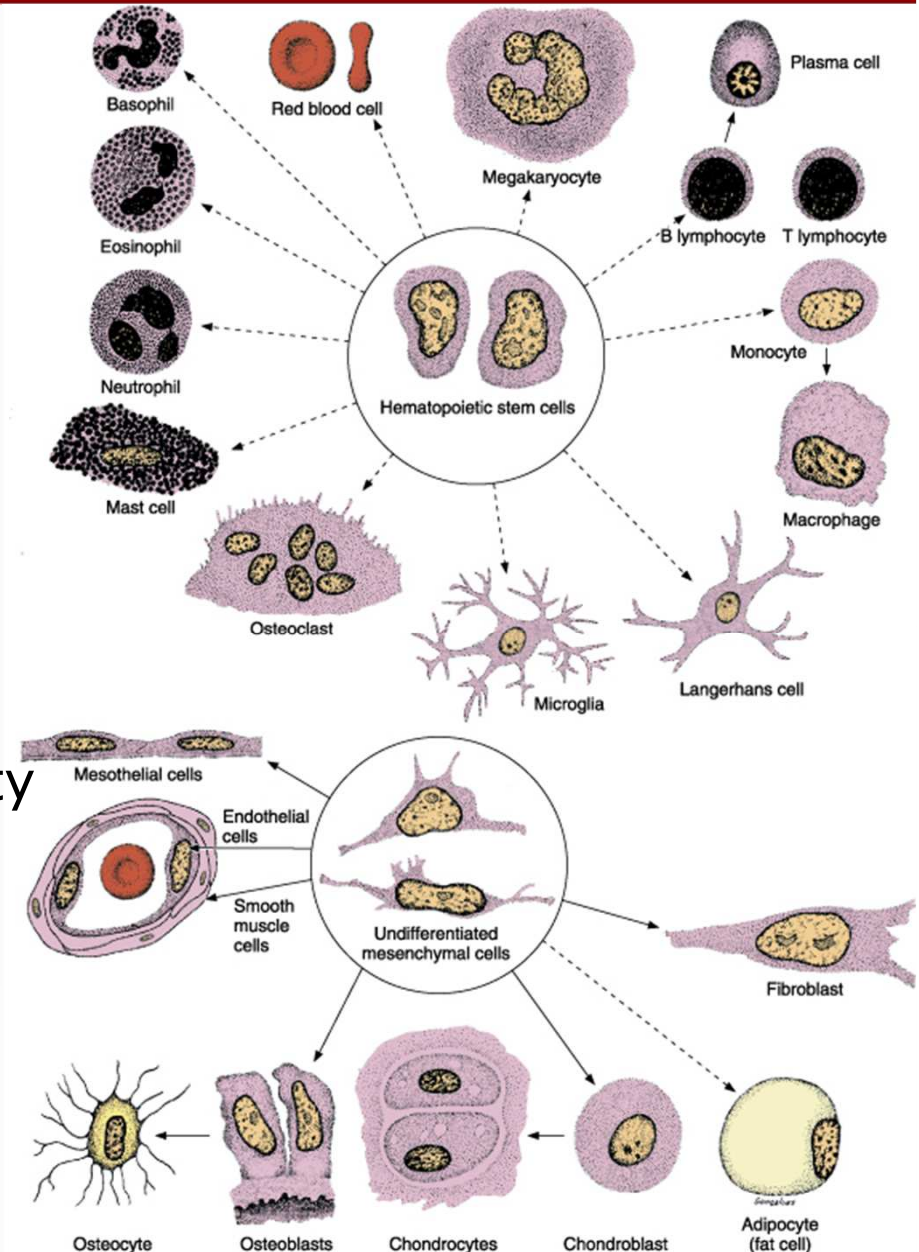
- ✓ binding together other tissues in the formation of organs – capsules
- ✓ structural support (mechanical role) – bones, ligaments and tendons
- ✓ nutritive role (homeostasis) – blood
- ✓ defensive functions (barrier and immunologic – antibodies)



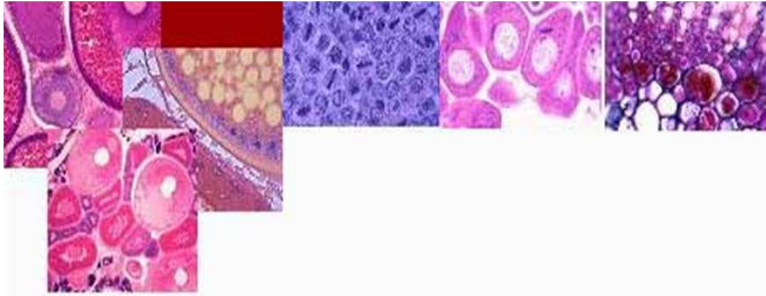
Cells of the connective tissue



- ✓ productive and nutritive:
 - synthesize and secrete the extracellular matrix
 - regenerative and repair abilities
- ✓ defense cells:
 - motile and circulatory activity
- ✓ pigment cells:
 - presence of specialized structures

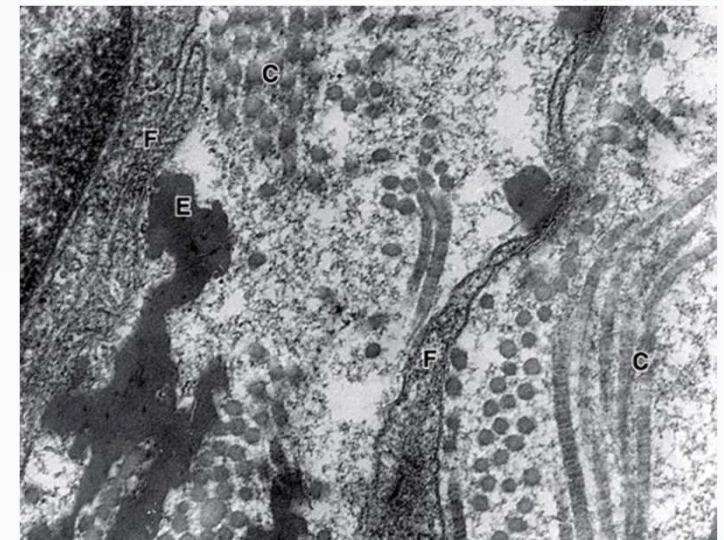
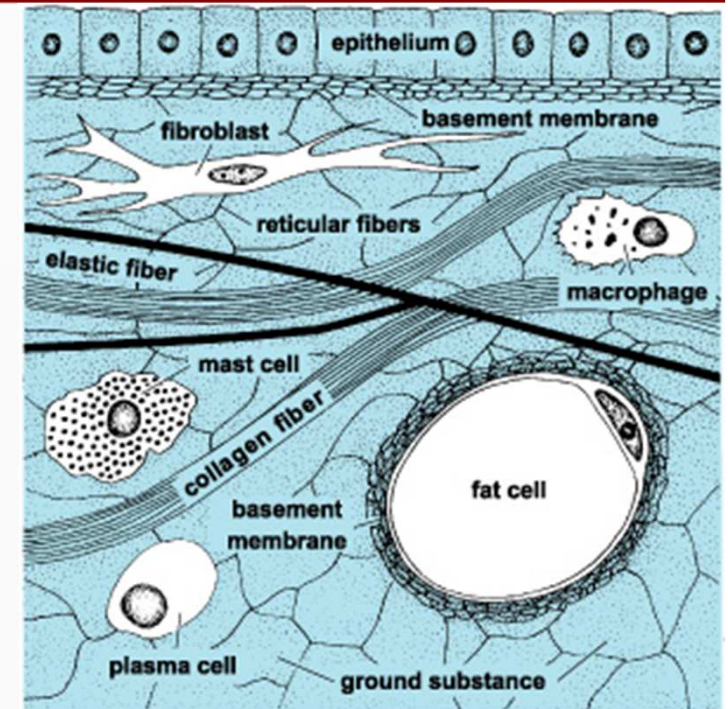


Extracellular matrix

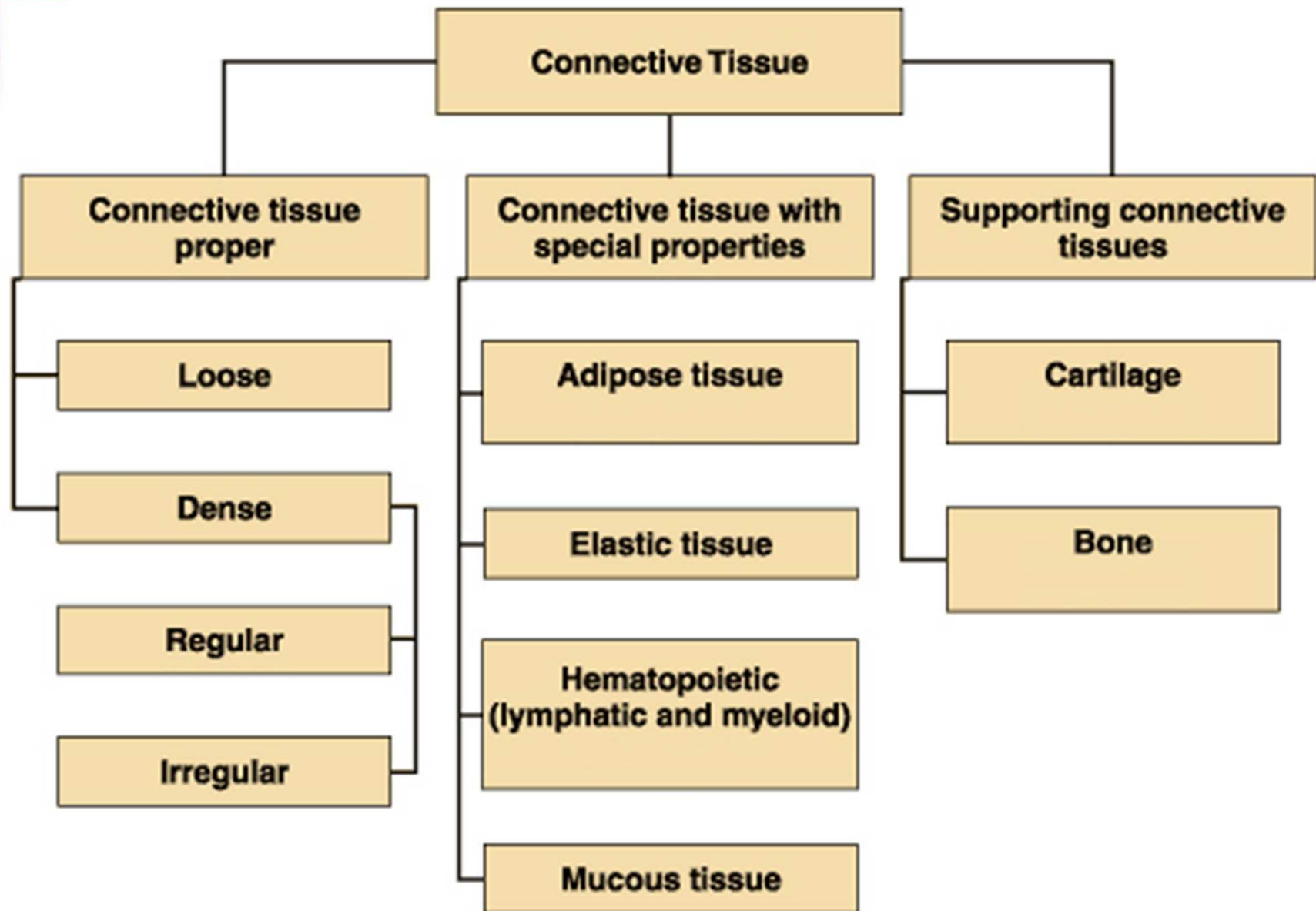


■ Extracellular matrix:

- ✓ amorphous substance (ground substance, tissue fluid)
- ✓ connective tissue fibers – protein fibers – types:
 - collagen fibers
 - elastic fibers
 - reticular fibers



Classification of connective tissue

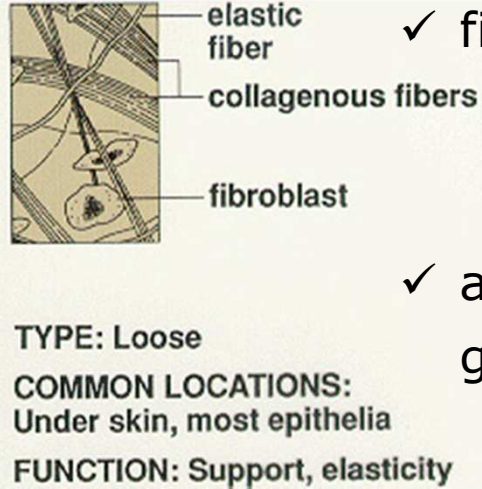


Loose (areolar) connective tissue

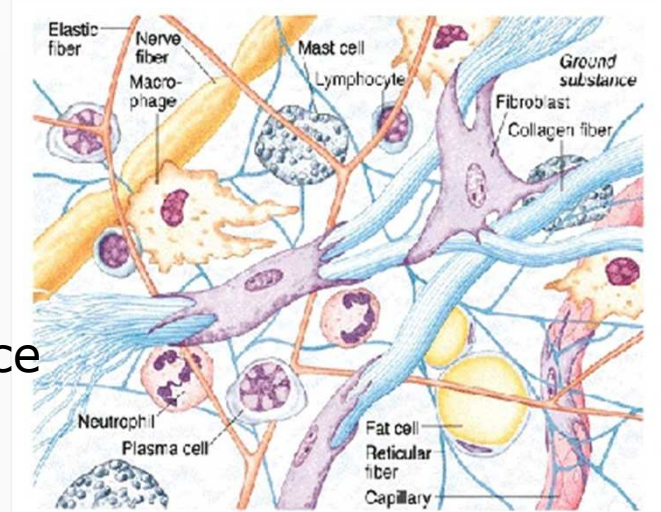


■ *textus connectivus fibrosus laxus*:

- ✓ most widespread type of connective tissue
- ✓ cells and extracellular matrix:

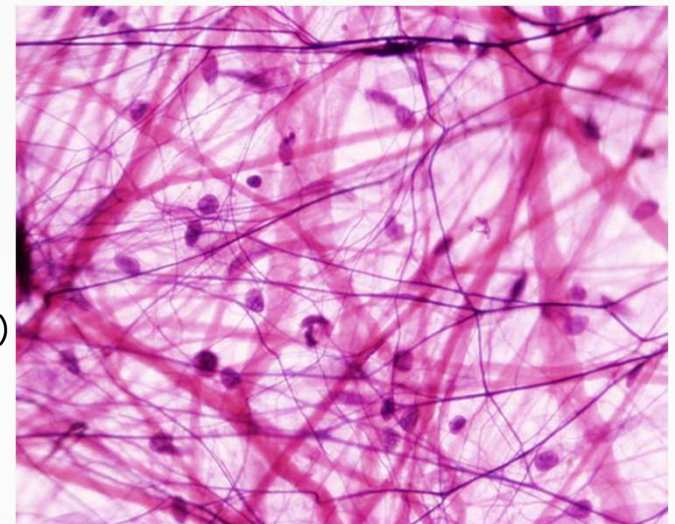


- ✓ fibers:
 - collagen
 - elastic
 - reticular
- ✓ amorphous ground substance



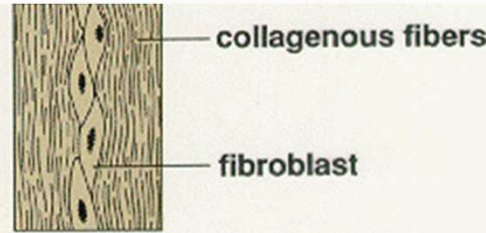
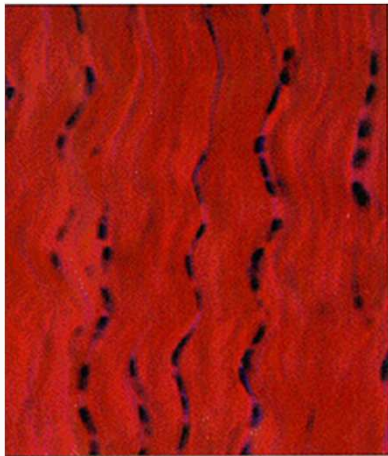
■ Cells – productive, nutritive and defense:

- ✓ proper (fixed):
 - fibroblasts and fibrocytes
- ✓ free:
 - macrophages (histiocytes) – phagocytosis
 - plasma cells – immature and mature (Russell bodies)
 - mast cells
 - leukocytes – granular and agranular
 - melanocytes

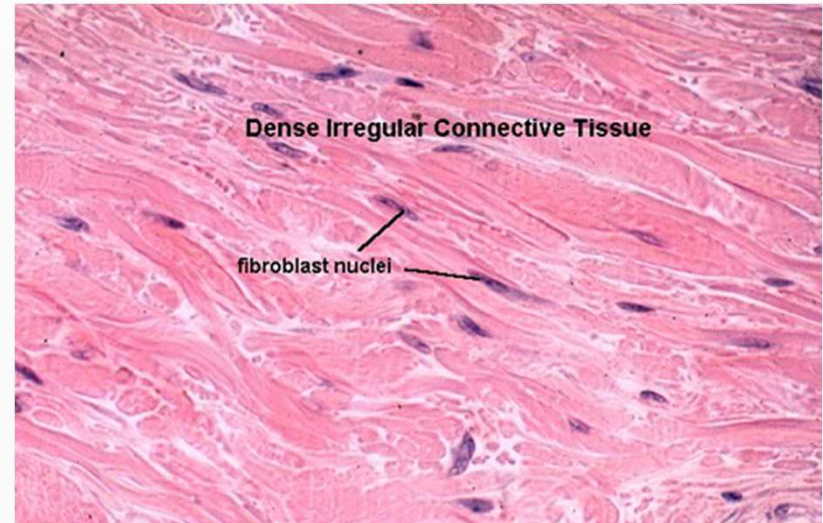


Compact dense connective tissue

- *textus connectivus fibrosus compactus*:
 - ✓ widely distributed – resistant to stress
 - ✓ cells and extracellular matrix – **collagen** fibers



TYPE: Dense, regular
 COMMON LOCATIONS:
 Tendons, skin, kidney capsule
 FUNCTION: Support, elasticity



- Cells – relatively few:
 - ✓ fibroblasts and fibrocytes
- Types:
 - ✓ dense irregular connective tissue:
 - sclera
 - reticular layer of the dermis
 - capsules of the organs
 - ✓ dense regular connective tissue:

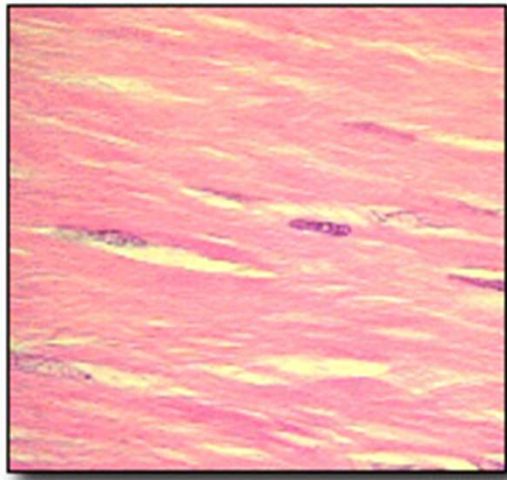


- tendons
- ligaments
- parallel, closely packed bundles of collagen
- fibrocytes ⇨ alar cells

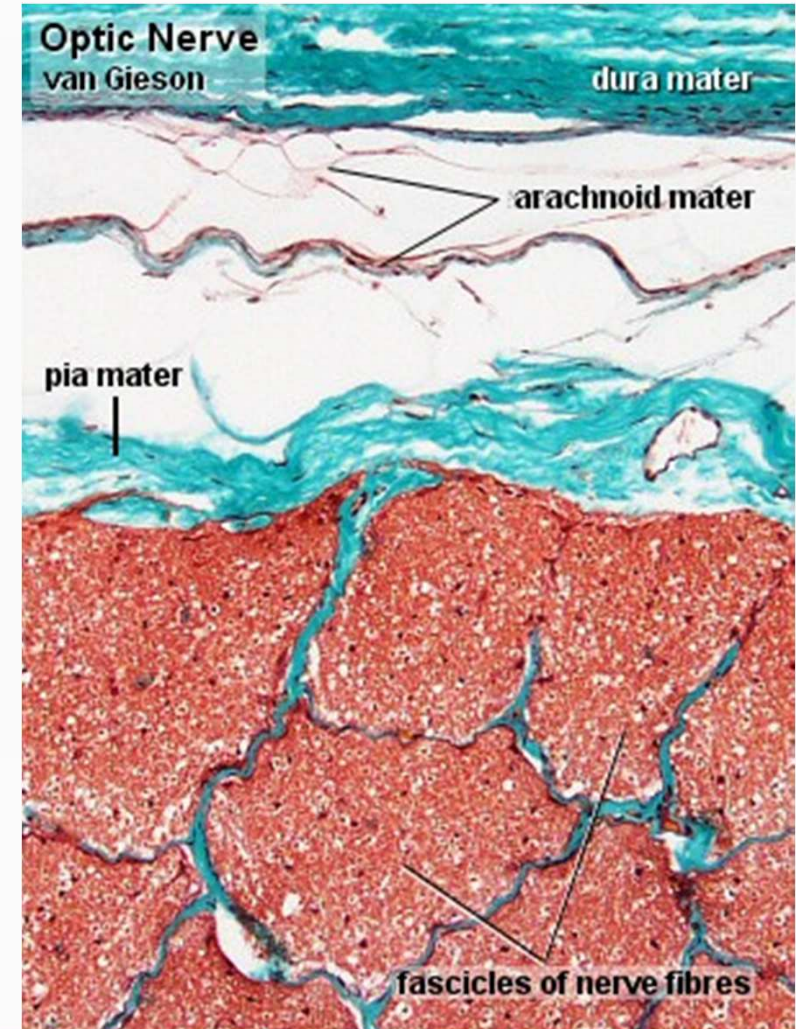


Lamellar dense connective tissue

- *textus connectivus fibrosus lamellaris*:
 - ✓ widespread distribution – aponeuroses and fascia of the muscles, dura mater



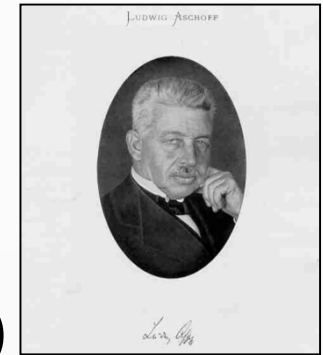
- Cells – relatively few:
 - ✓ fibroblasts and fibrocytes
- Intercellular matrix:
 - ✓ numerous collagen fibers
 - ✓ lesser elastic fibers:
 - layers
 - lamellae



Mononuclear phagocyte system



- ✓ Reticuloendothelial System (RES)
 - *Ludwig Aschoff*, 1924
- ✓ Reticulohistiocyte System (RHS)
- ✓ Mononuclear Phagocyte System (MPS)
 - *Van Furth*, 1969



1866-1942

Table 5-2. Distribution and Main Functions of the Cells of the Mononuclear Phagocyte System.

Cell Type	Location	Main Function
Monocyte	Blood	Precursor of macrophages
Macrophage	Connective tissue, lymphoid organs, lungs, bone marrow	Production of cytokines, chemotactic factors, and several other molecules that participate in inflammation (defense), antigen processing and presentation
Kupffer cell	Liver	Same as macrophages
Microglia cell	Nerve tissue of the central nervous system	Same as macrophages
Langerhans cell	Skin	Antigen processing and presentation
Dendritic cell	Lymph nodes	Antigen processing and presentation
Osteoclast	Bone (fusion of several macrophages)	Digestion of bone
Multinuclear giant cell	Connective tissue (fusion of several macrophages)	Segregation and digestion of foreign bodies



Elastic tissue

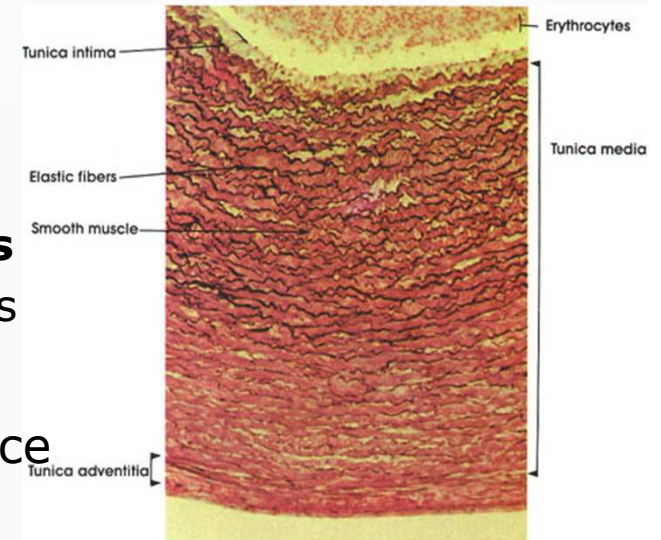
- *textus connectivus elasticus*:

- ✓ vocal folds, *ligg. flava et lig. suspensorium penis*
- ✓ cells and extracellular matrix:

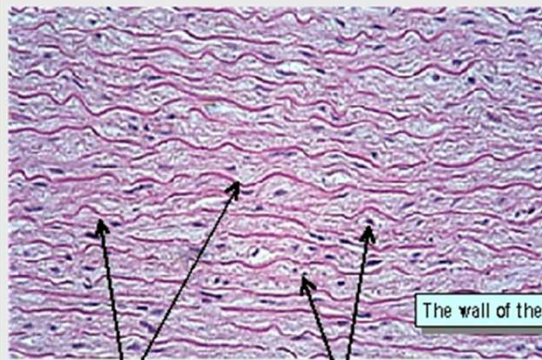
- ✓ protein fibers:

- thin collagen
- thick, parallel **elastic fibers**
- reticular fibers

- ✓ amorphous ground substance



Elastic Connective Tissue



Found in the stroma of the lungs and in the walls of the large arteries.

elastic fibers

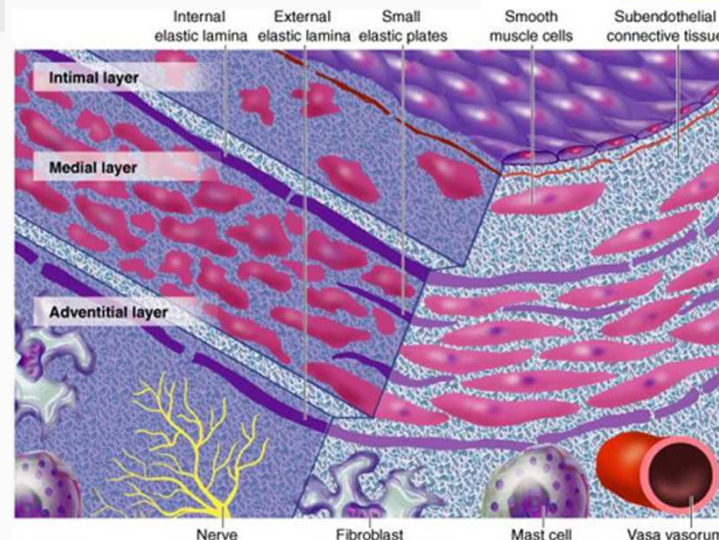
fibroblasts

- Cells:

- ✓ flattened fibroblasts and fibrocytes

- Properties:

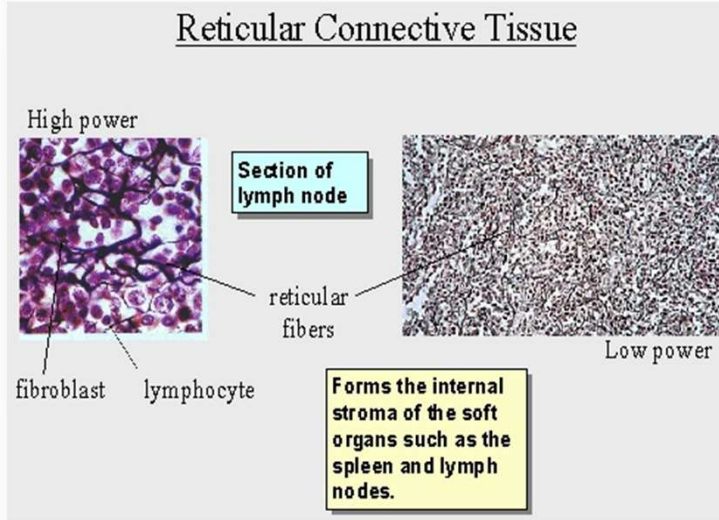
- ✓ typical yellow color
- ✓ great elasticity



Reticular tissue

- *textus connectivus reticularis*:

- ✓ architectural framework of the myeloid (bone marrow) and lymphoid (lymph nodes, spleen) hematopoietic organs

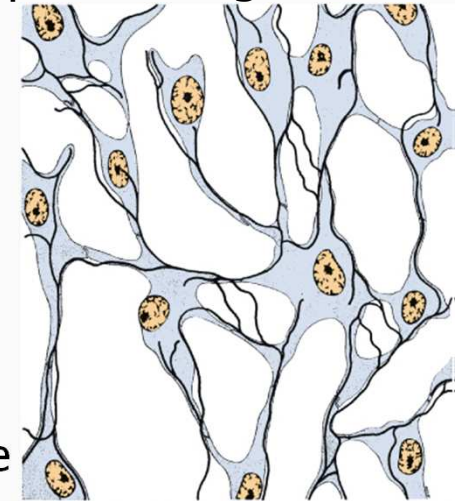


- Extracellular matrix:

- ✓ protein fibers:

- **reticular fibers** (type III collagen) – 100-150 nm in diameter
- PAS-positive and argyrophilic

- ✓ amorphous ground substance



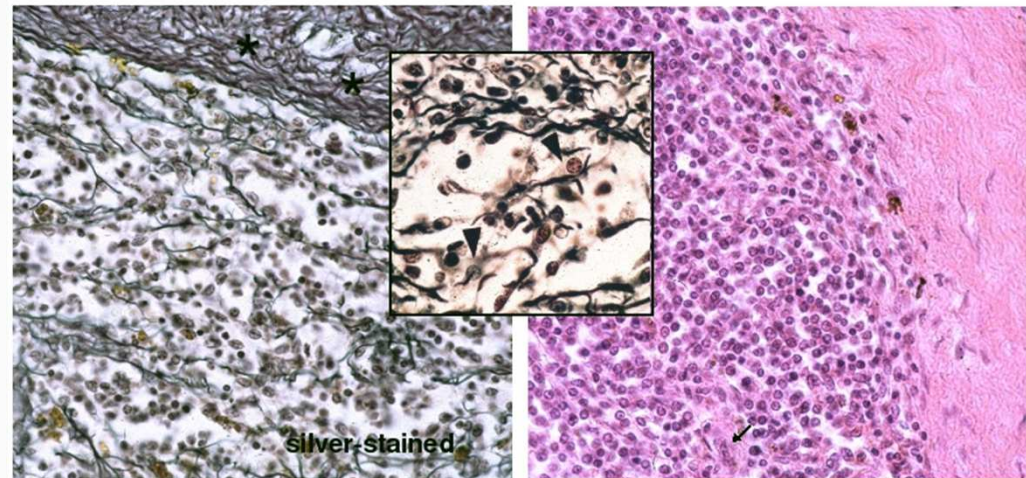
Reticular connective tissue, a delicate support

- Cells:

- ✓ specialized fibroblasts (**reticular cells**)
- ✓ cells of the mononuclear phagocyte system

- Properties and functions:

- ✓ branched reticular fibers form a delicate structural network
- ✓ precursor for fibroblasts
- ✓ phagocytic properties



Embryonic connective tissues



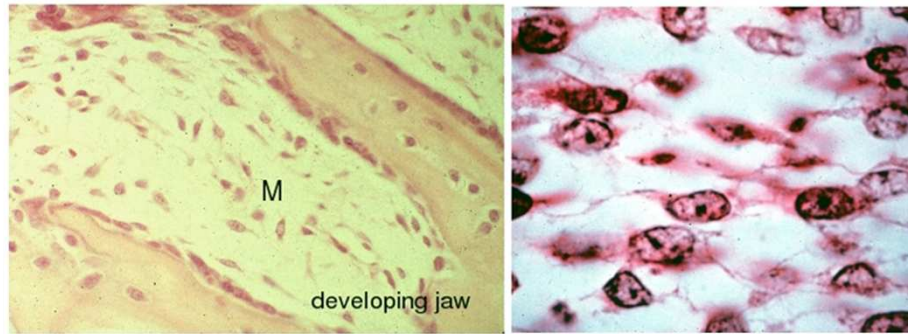
■ mesenchymal connective tissue (mesenchyme):

- ✓ between and within the developing tissues and organs
- ✓ in adult humans, only found in the dental pulp

Embryonic mesenchyme: Cells, cell processes and space

- ✓ derived from all three germ layers
- ✓ prominent ground substance matrix
- ✓ loose network of collagen or reticular fibers
- ✓ mesenchymal cells - stem cell properties capable of developing into connective tissue, bone, cartilage, the lymphatic and the circulatory system

Mucous connective tissue, umbilical cord (Wharton's jelly)



■ mucous connective tissue:

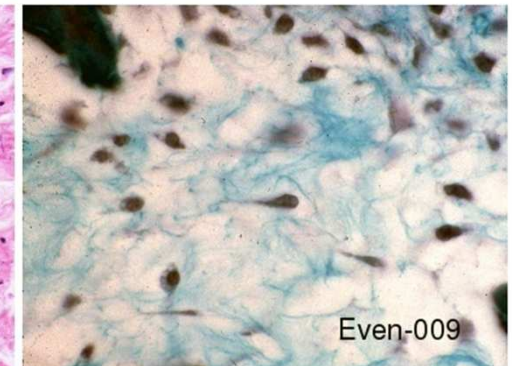
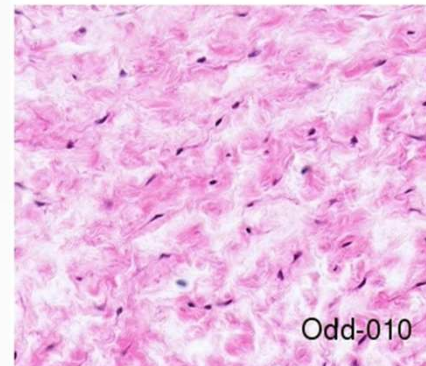
- ✓ found during fetal development
- ✓ umbilical cord (Wharton's jelly), pulp of young teeth
- ✓ structural very similar to mesenchyme
- ✓ lower capability to differentiate

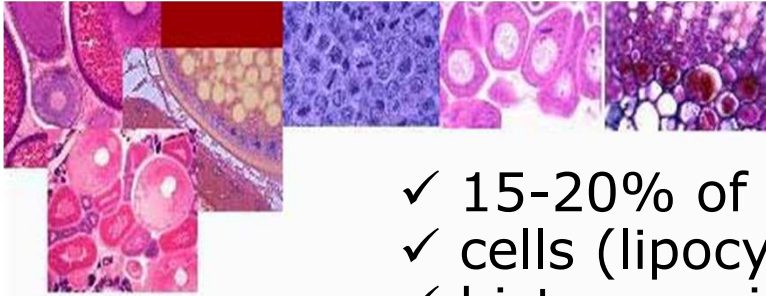
✓ less plastic

✓ cells: mainly fibroblasts

✓ collagen fibers and a few elastic or reticular fibers

✓ abundance of amorphous ground substance (primarily hyaluronic acid)





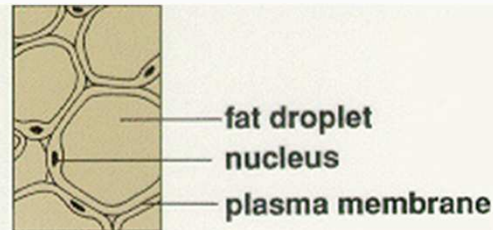
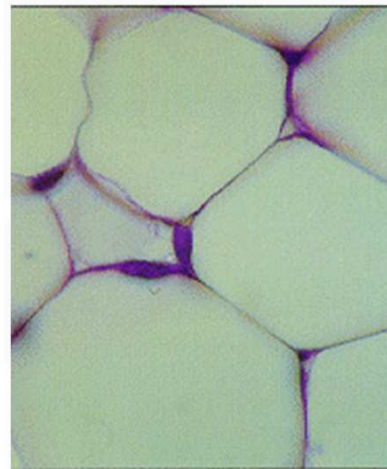
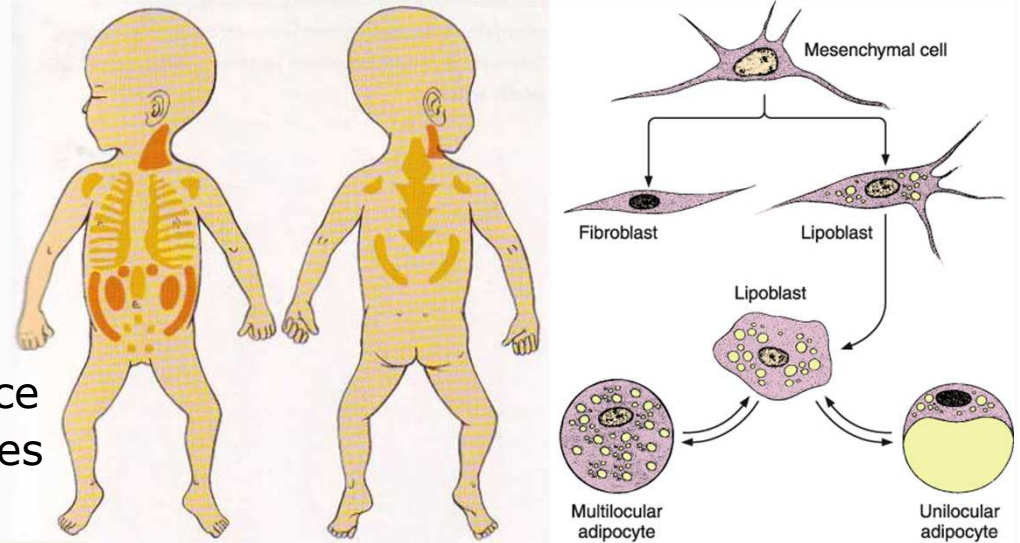
Adipose tissue

▪ *textus adiposus* (Lat. *adeps*, fat):

- ✓ 15-20% of body weight in men; 20-25% in women
- ✓ cells (lipocytes, adipocytes) and extracellular matrix
- ✓ histogenesis – from mesenchymally derived lipoblasts

▪ **Functions:**

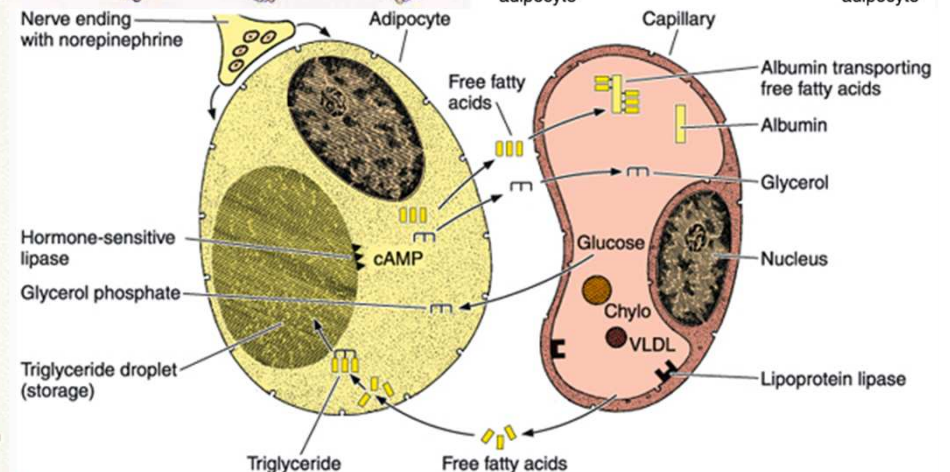
- ✓ largest repository of energy
- ✓ helps to shape the surface of the body
- ✓ acts as shock absorbers
- ✓ contributes to the thermal insulation of the body
- ✓ helps to keep some organs in place
- ✓ secretes various types of molecules
- ✓ has a rich blood supply



TYPE: Adipose

COMMON LOCATIONS: Under skin, around kidneys, heart

FUNCTION: Energy reserve, insulation, padding



Unilocular adipose tissue

- common (white) adipose tissue:

- ✓ its color varies from white to dark yellow (carotenoids dissolved in fat)
- ✓ found throughout the human body except for the eyelids, penis and scrotum

- Location:

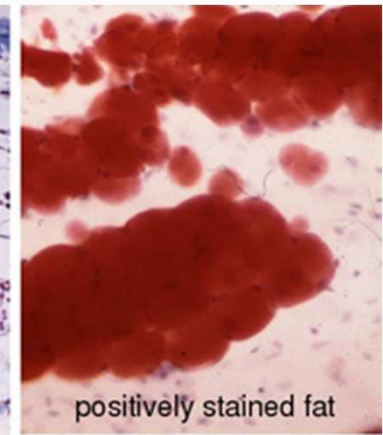
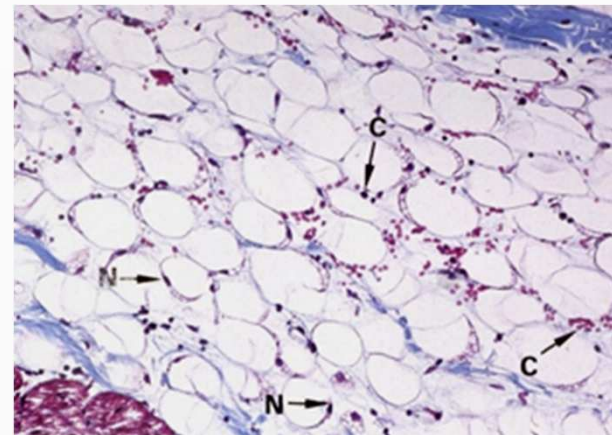
- ✓ hypodermis (*panniculus adiposus*)
- ✓ omentum, mesentery
- ✓ retroperitoneal space, around kidneys
- ✓ breast

- Structure:

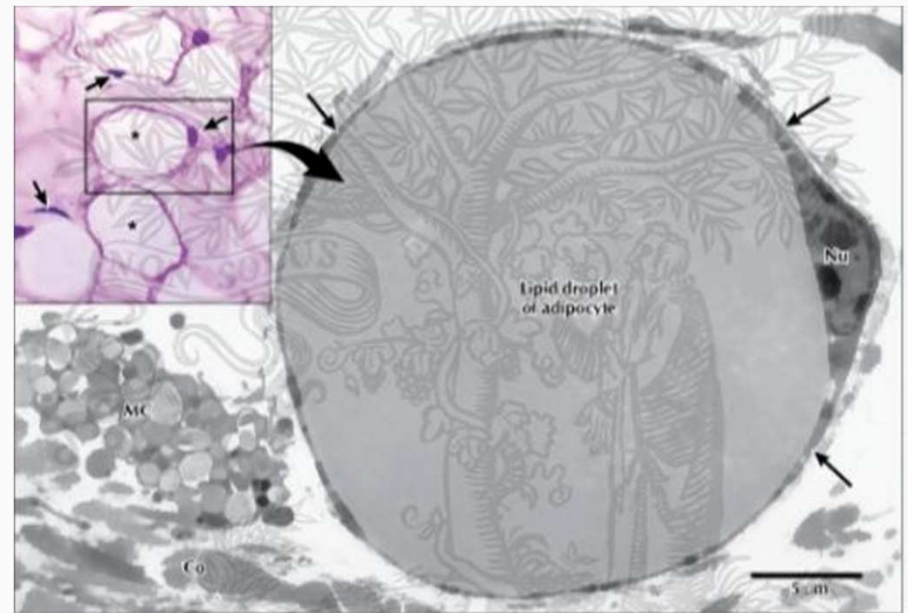
- ✓ subdivided into incomplete lobules
- ✓ unilocular adipose cells:
 - spherical or polyhedral cells
 - large (50-150 μm) cells
 - one large central droplet of fat
 - eccentric and flattened nuclei
 - a thin ring of cytoplasm - **signet ring cells**
- reticular fibers form a fine interwoven network
- a rich vascular bed and network of nerves

- Functions:

- ✓ mechanical cushion of vital organs
- ✓ thermoregulatory role, heat insulation
- ✓ a large depot of energy and water for the organism
- ✓ a secretory organ - leptin



positively stained fat



Multilocular adipose tissue

▪ brown adipose tissue:

- ✓ its color is due to both the large number of blood capillaries and the numerous mitochondria (containing colored cytochromes)

▪ Location – a more limited distribution:

- ✓ in hibernating animals – hibernating gland
- ✓ in rodents and small mammals – around the shoulder girdle
- ✓ in human embryo and newborn – 2-5% of the body weight:
 - on the back, along the upper half of the spine and toward the shoulders

▪ Structure:

✓ multilocular adipose cells:

- polygonal cells
- smaller (10 folds = up to 60 μm) cells
- a large number of lipid droplets
- a spherical and central nucleus
- numerous brown mitochondria with abundant long cristae

✓ subdivided into lobules

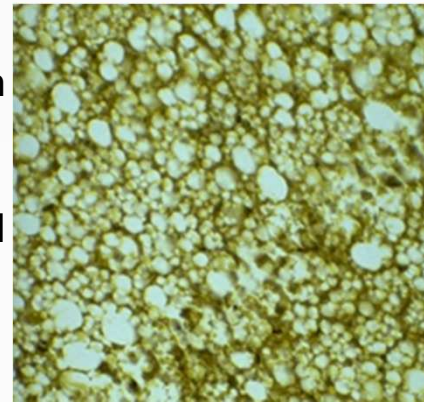
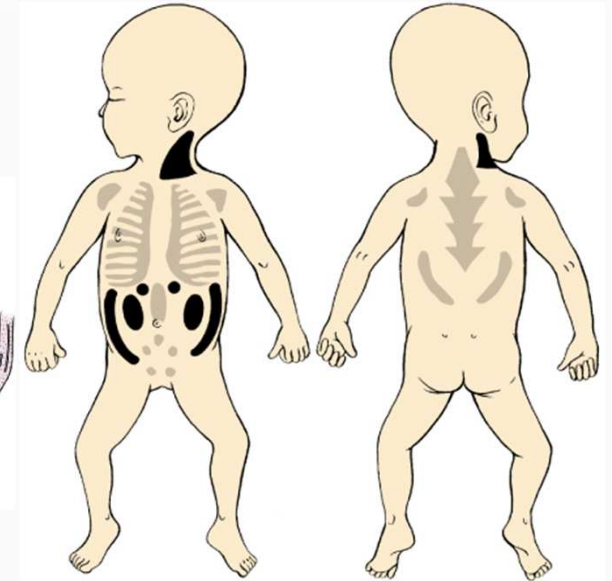
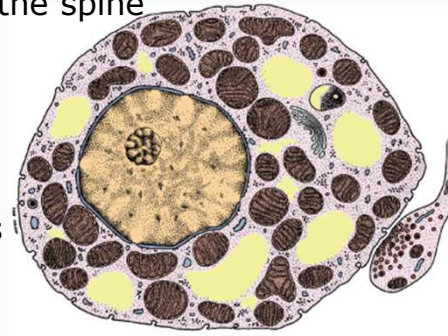
✓ richly vascularized tissue

✓ cells receive direct sympathetic innervation

▪ Functions:

✓ important mainly in the first months of postnatal life, greatly reduced in adulthood

- ✓ thermoregulation
- ✓ source of heat and lipid
- ✓ resembles an endocrine gland

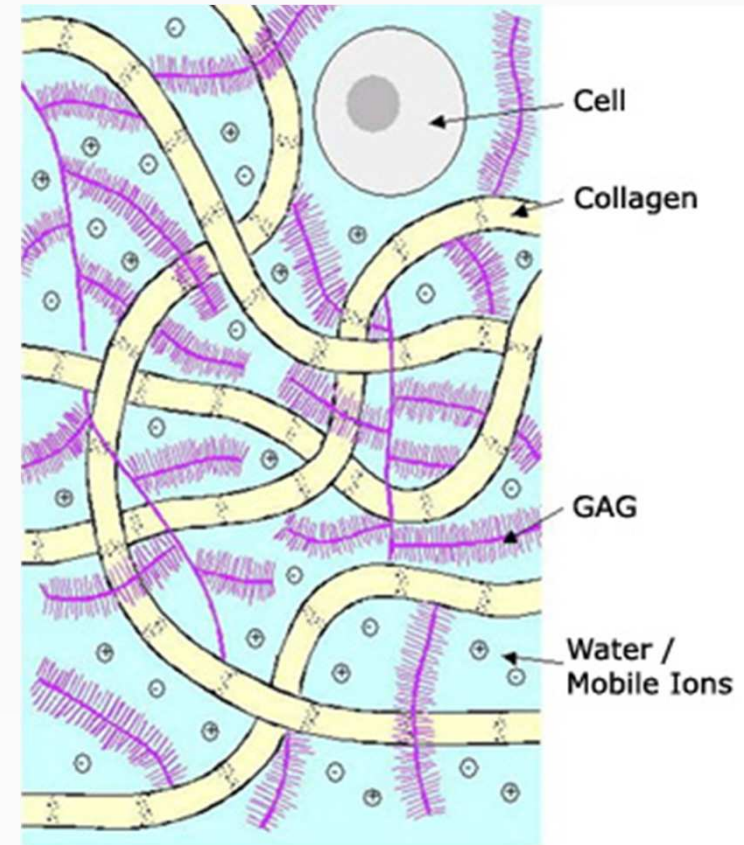


Cartilage tissue

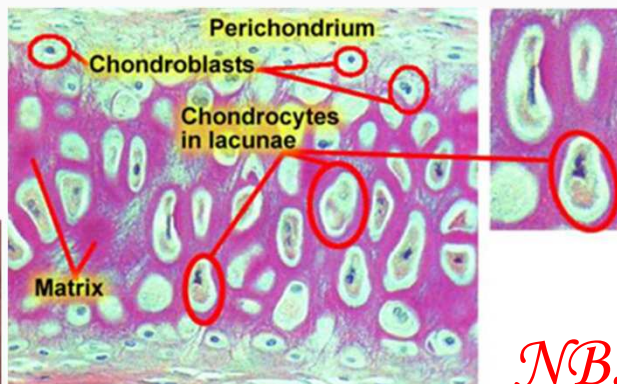
- *textus cartilagineus*: Gr. *chondros*, cartilage
 - ✓ cells – chondroblasts and chondrocytes
 - ✓ extracellular matrix – 95%

- **peculiarities:**

- ✓ specialized cells
- ✓ an extensive extracellular matrix with a firm consistency
- ✓ avascular tissue – lack of proper blood supply
- ✓ has no lymphatic vessels
- ✓ devoid of nerves
- ✓ low regeneration capacity

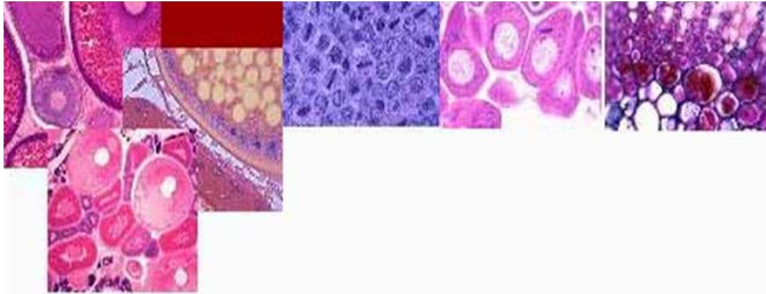


Cartilage

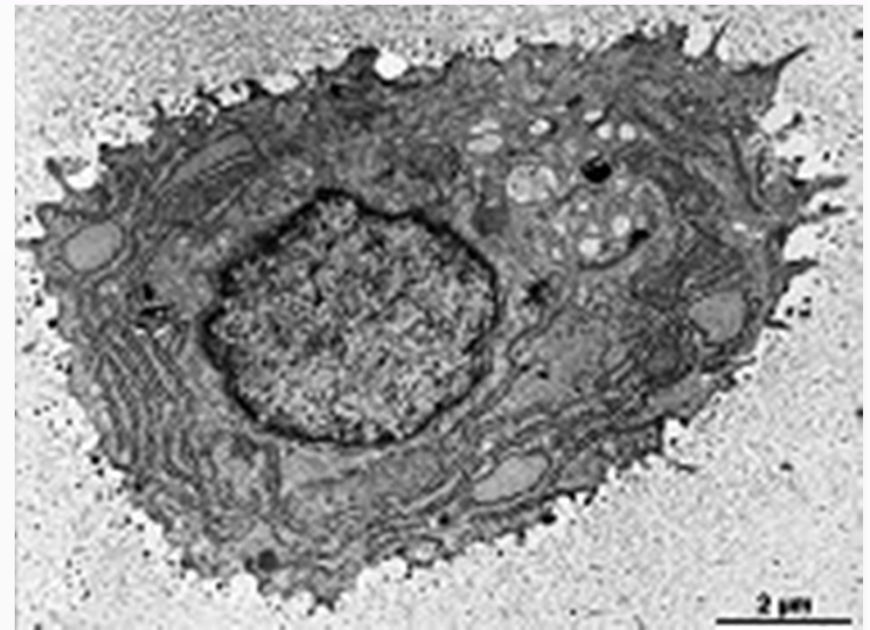


NB: main function – to support soft tissues

Cartilage cells



- ✓ Chondroblasts – origin:
 - undifferentiated mesenchymal cells
 - chondrogenic cells
- ✓ Chondrocytes – 10-30 μm :
 - synthesize and secrete fibers (collagen and elastic) and ground substance
 - their synthesis is accelerated by growth hormone, thyroxine and testosterone, and by vitamin A, C and D
 - located in matrix cavities, lacunae, appearing in **isogenous groups** (Gr. *isos*, equal + *genos*, family)
 - low metabolic activity
 - their mitotic and synthetic activity decline with age



Cartilage matrix



- extracellular matrix:
 - ✓ highly hydrated – 60-70% water
 - ✓ amorphous substance:

- glycosaminoglycans

- hyaluronic acid
- chondroitin sulfates
- keratan sulfate

- proteoglycans

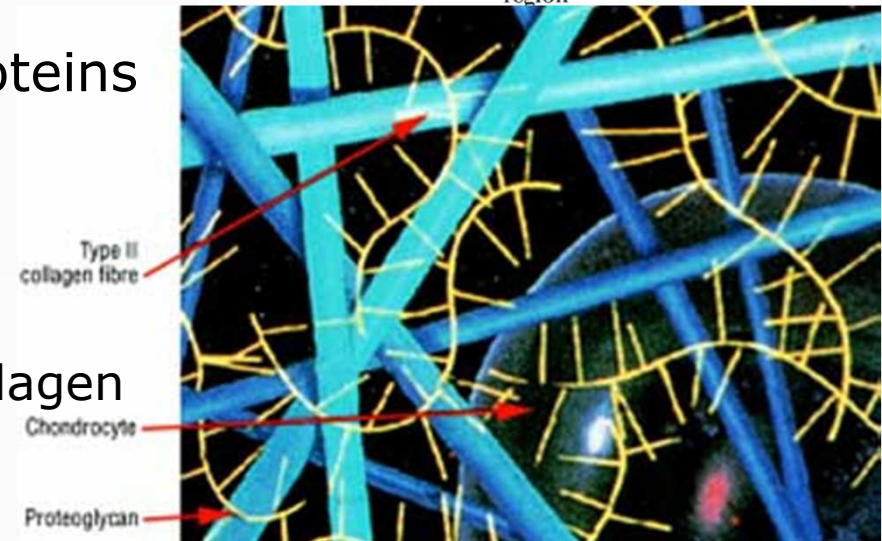
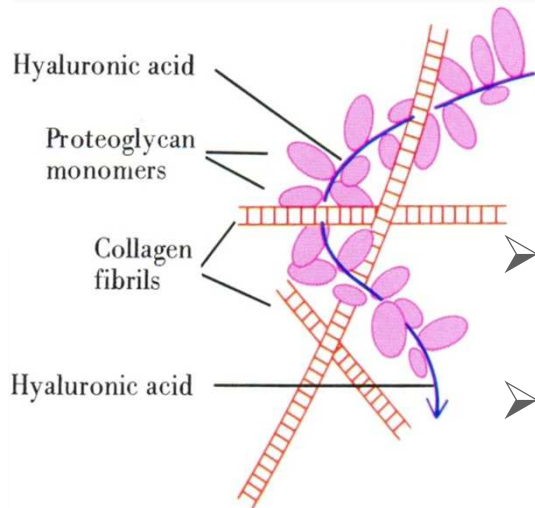
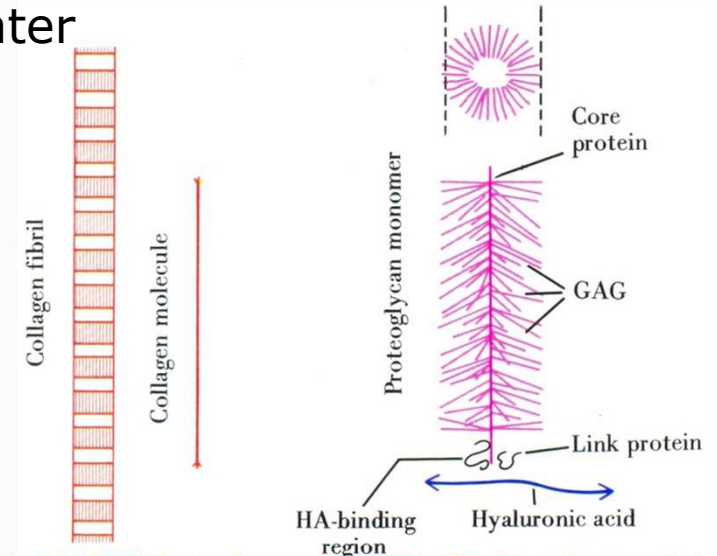
- aggrecan

- structural glycoproteins

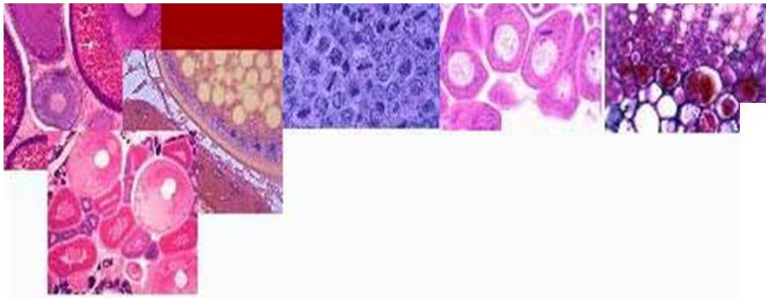
- chondronectin

- ✓ protein fibers:

- collagen – 20 nm
 - type I and II collagen
- elastic fibers



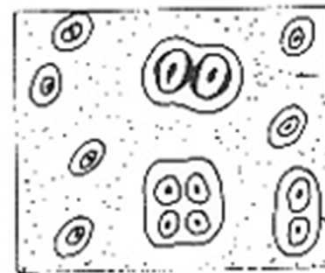
Types of cartilage



✓ hyaline cartilage

✓ fibrous cartilage

✓ elastic cartilage



Hyaline Cartilage

ground substance



Fibrous Cartilage

ground substance
with non-elastic
collagen fibres

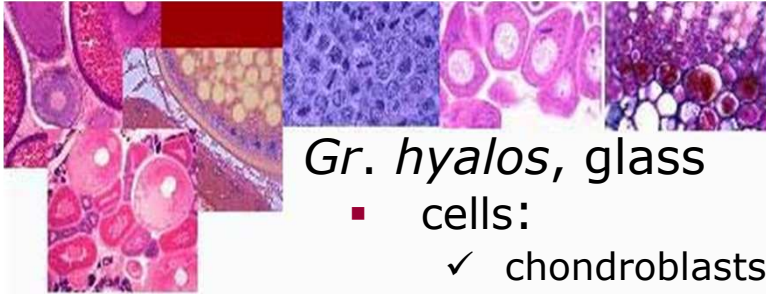


Elastic Cartilage

ground substance with
yellow elastic fibres

Cartilage cells

Hyaline cartilage



Gr. hyalos, glass

- cells:

- ✓ chondroblasts
- ✓ chondrocytes
 - embedded in the lacunae of matrix
 - isogenous groups - 2-8 chondrocytes

matrix – 40% of the dry weight:

- ✓ collagen fibers – collagen type II
- ✓ proteoglycan aggregates (4 μm), contain 70-80% water
- ✓ territorial (capsular) matrix – 50 μm
 - basophilic, metachromasia
 - PAS-positive
 - + isogenous groups = chondron
 - pericellular capsule – 1-3 μm
- ✓ interterritorial matrix

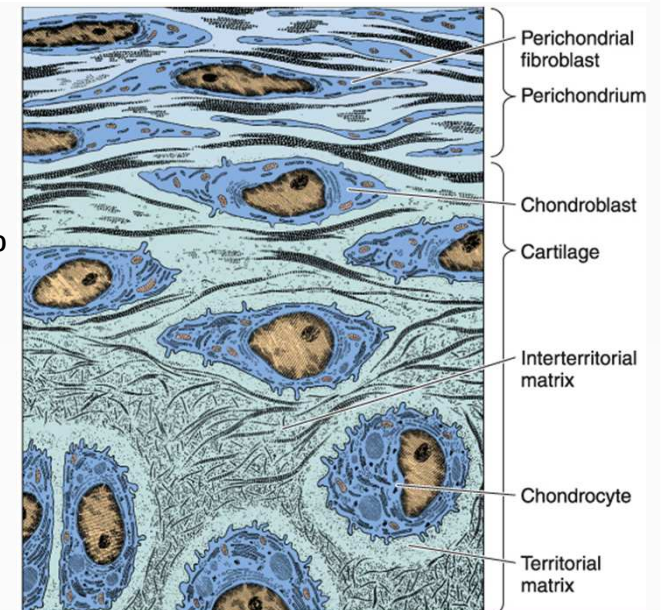
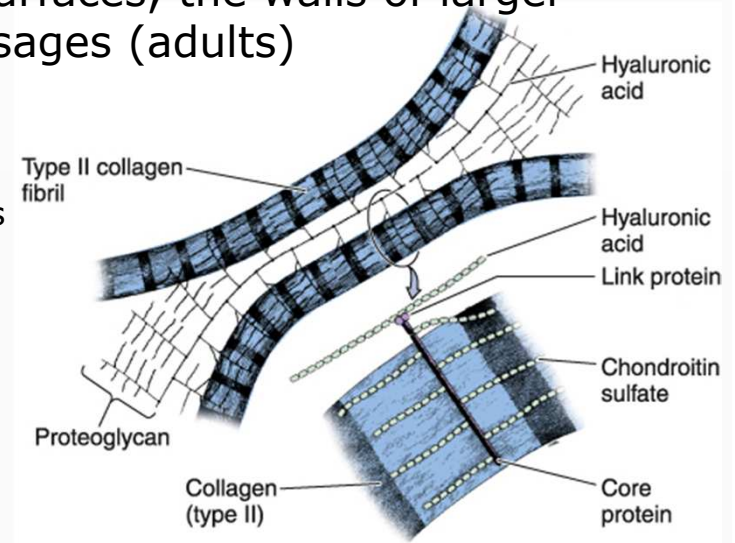
- articular cartilage (2-5 mm) – 4 zones:

- ✓ superficial (tangential zone) – up to 10%
- ✓ middle (transitional) layer
- ✓ deep (radial) layer – largest part
- ✓ calcified layer – partly mineralized

- perichondrium – two layers:

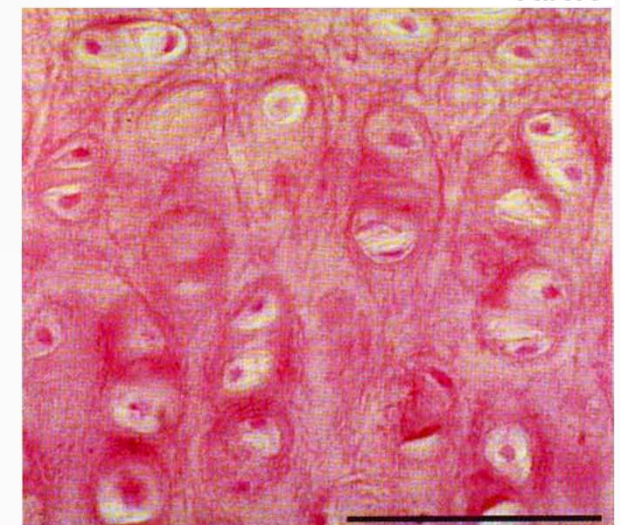
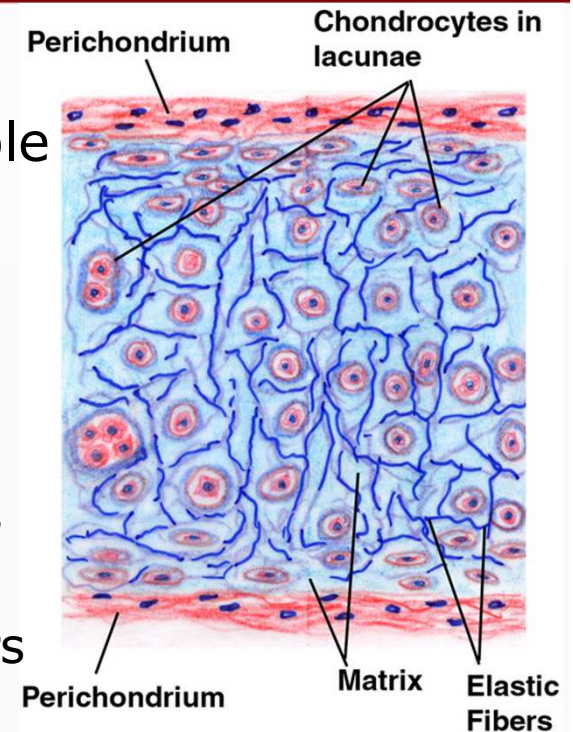
- ✓ *stratum fibrosum* – collagen I fibers
- ✓ *stratum cellulare* – chondrogenic cells
- ✓ nourishes and regenerates the cartilage

✓ wide distributed – temporary skeleton (embryo), ribs, articular surfaces, the walls of larger respiratory passages (adults)

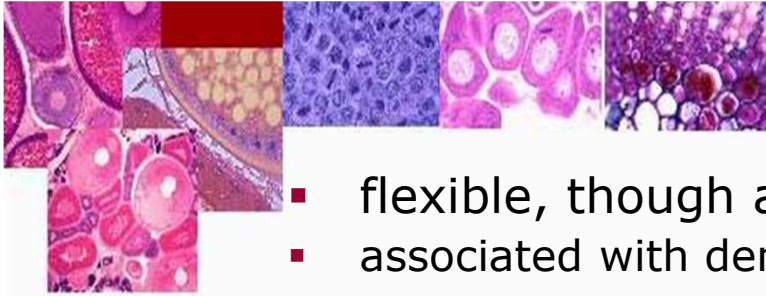


Elastic cartilage

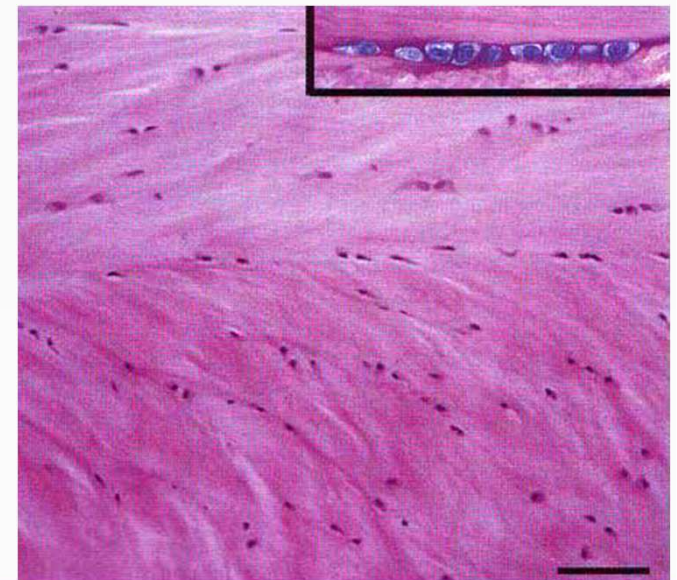
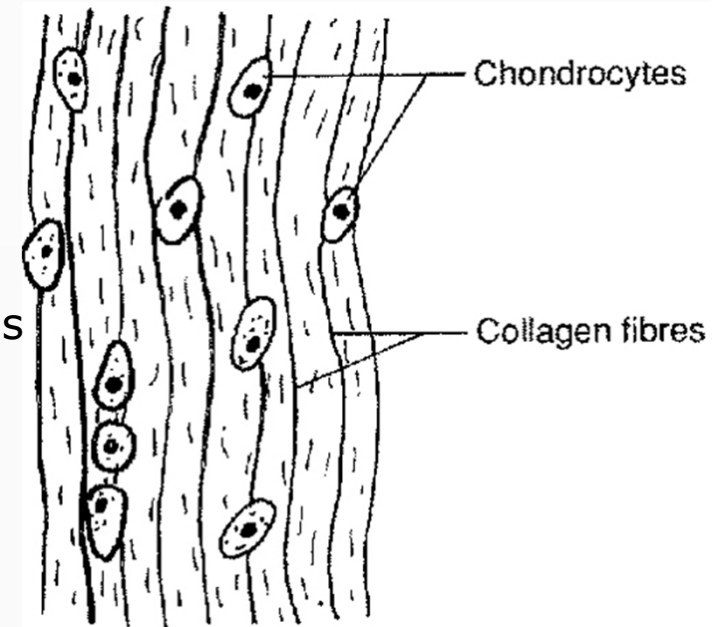
- yellowish color (elastin)
- not normally calcified, less susceptible to degenerative processes
- cells:
 - ✓ chondroblasts
 - ✓ chondrocytes
 - lacunae
 - isogenous groups – 1-2 chondrocytes
- matrix:
 - ✓ abundant network of fine elastic fibers
 - ✓ collagen type II fibrils
 - ✓ proteoglycans
- perichondrium:
 - ✓ appositional growth
- distribution:
 - ✓ auricle and external auditory canal
 - ✓ auditory (Eustachian) tube
 - ✓ cartilages in the larynx (epiglottis)



Fibrocartilage



- flexible, tough and elastic
- associated with dense connective tissue
- cells:
 - ✓ chondroblasts – in columns
 - ✓ chondrocytes – arranged in long rows
 - singly
 - small isogenous groups (2 cells)
- matrix – acidophilic:
 - ✓ parallel collagen fibrils – type I collagen
 - ✓ less abundant basophilic amorphous matrix – sulfated glycosaminoglycans
 - ✓ no identifiable perichondrium
- distribution:
 - ✓ synchondroses
 - ✓ in intervertebral disks
 - ✓ symphysis pubis, articular menisci
 - ✓ some articular surfaces
 - ✓ in attachments of certain ligaments to the cartilaginous surface of bones



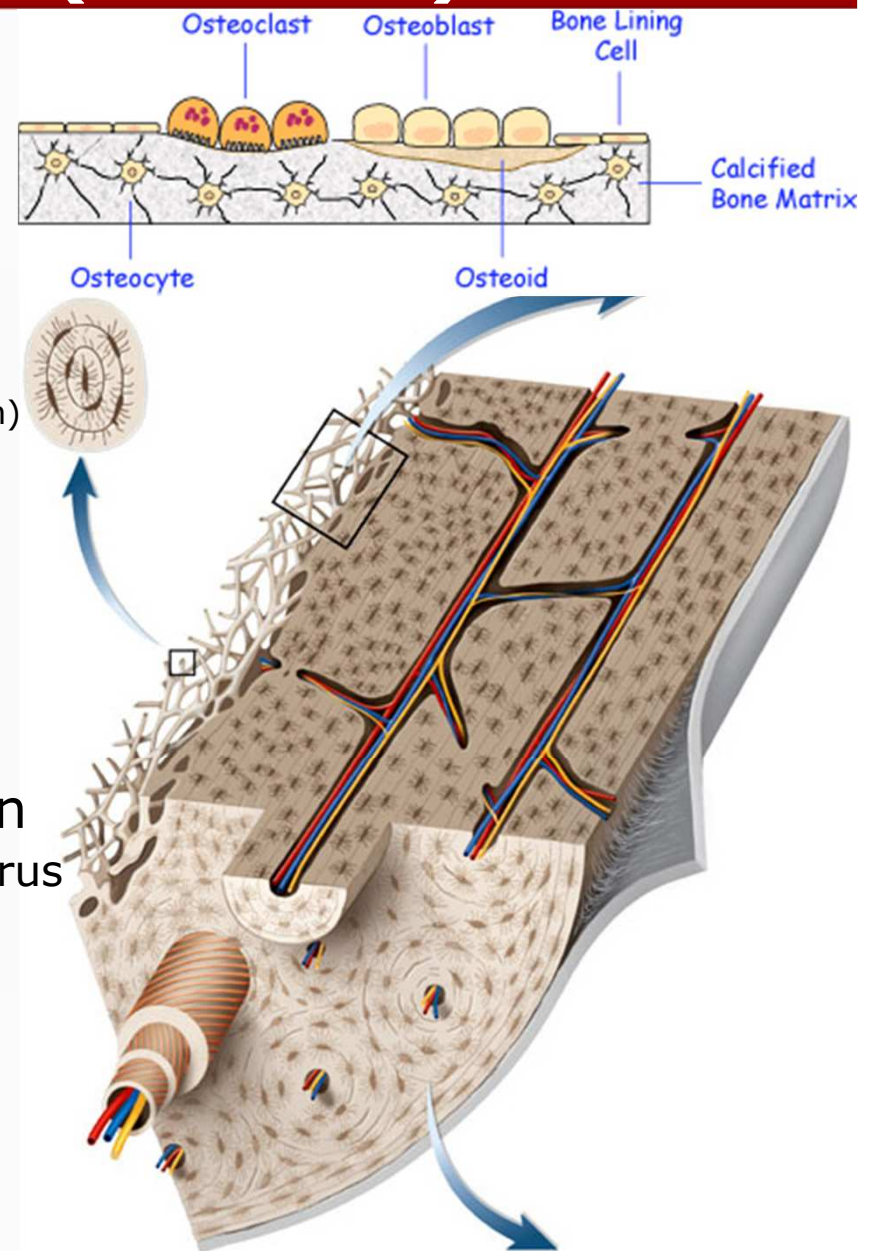
Bone (osseous) tissue

Gr. *osteon*, bone
textus osseus:

- ✓ cells:
 - osteoblasts (Gr. *blastos*, germ)
 - osteocytes (Gr. *kytos*, cell)
 - osteoclasts (Gr. *klastos*, broken)
- ✓ intercellular calcified material (bone matrix)

peculiarities:

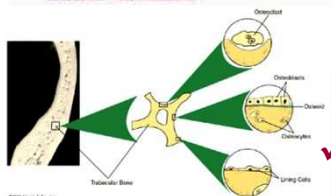
- ✓ one of the hardest tissues of the human body
- ✓ richly vascularized
- ✓ main constituent of adult skeleton
- ✓ reservoir of calcium (99%), phosphorus
- ✓ main function – defense:
 - protection of vital organs in the cranial and thoracic cavities
 - support of freshly structures
- ✓ forms a system of levers – to enhance body movements
- ✓ good regeneration capacity



Bone cells



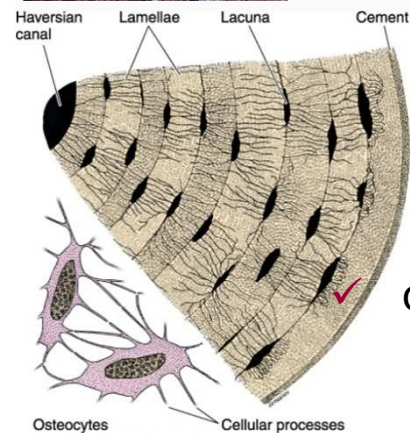
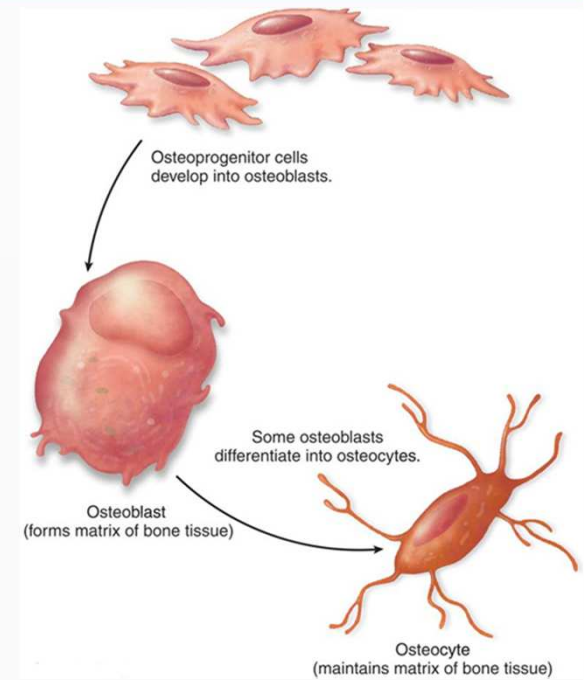
- ✓ osteoprogenitor (osteogenic) cells
 - in periosteum, endosteum and bone canals
 - derived from mesenchymal stem cells
 - develop into osteoblasts or chondroblasts in avascular zones, respectively



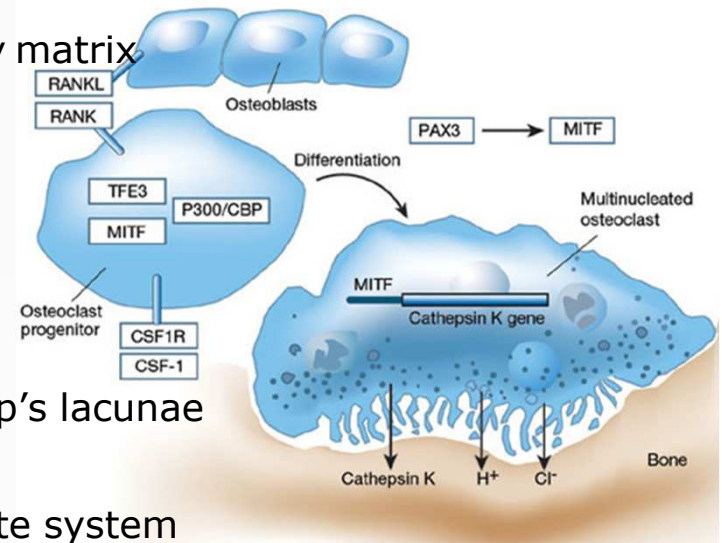
- ✓ osteoblasts (20-30 μm) – basophilic
 - type I collagen
 - proteoglycans and glycoproteins
 - located at the surfaces of bone tissue



- ✓ osteocytes – 10-30 μm :
 - cell bodies lie in the lacunae, cytoplasmic processes in the bone matrix canaliculi
 - involved in the maintenance of the bony matrix
 - synthetic activity completed
 - derive from osteoblasts, do not divide



- osteoclasts – 100-150 μm :
 - multinucleated – 5-50 (100) nuclei
 - acidophilic cytoplasm
 - lie within enzymatically etched Howship's lacunae
 - remove bone tissue (bone resorption)
 - members of the mononuclear phagocyte system



Intercellular material

■ bone matrix:

✓ organic matter (35% of the dry weight)

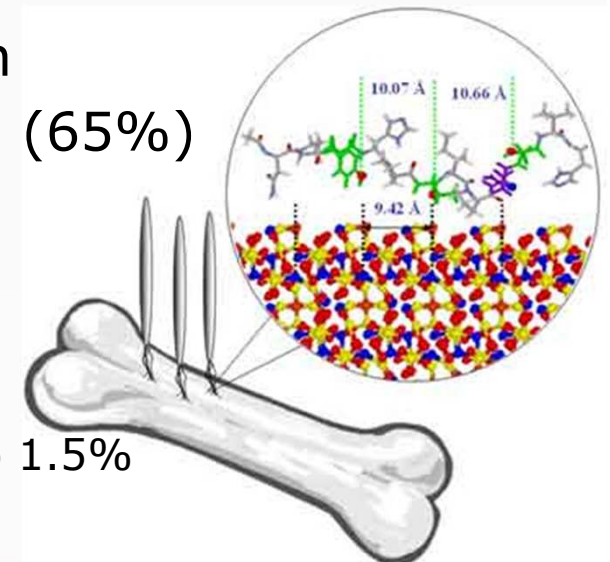
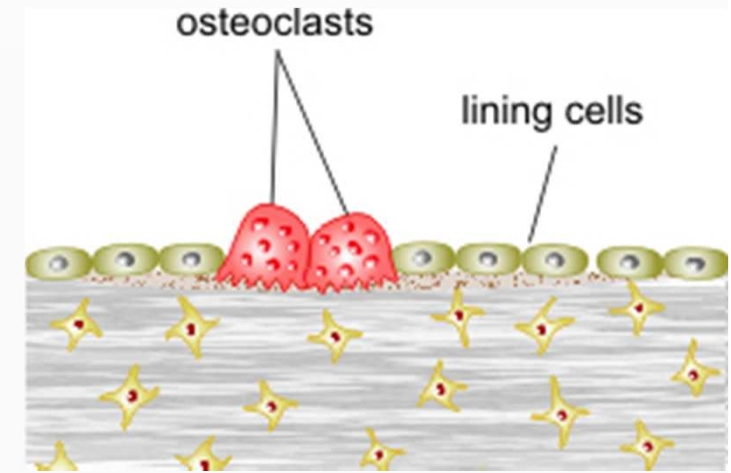
- elasticity:

- type I collagen – 90%
- glycosaminoglycans
 - hyaluronic acid
 - chondroitin sulfates
 - keratan sulfate
- proteoglycans
- specific glycoproteins – osteocalcin and osteospondin

✓ inorganic (mineral) matter (65%)

- rigidity:

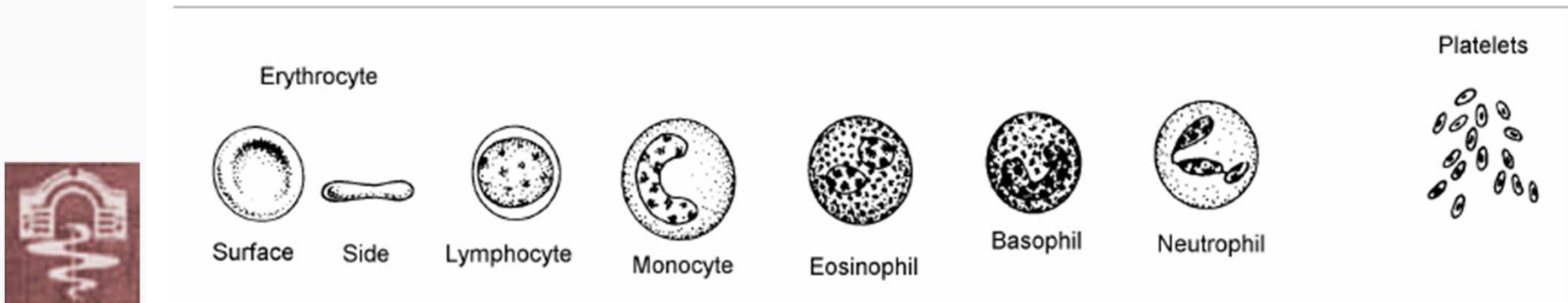
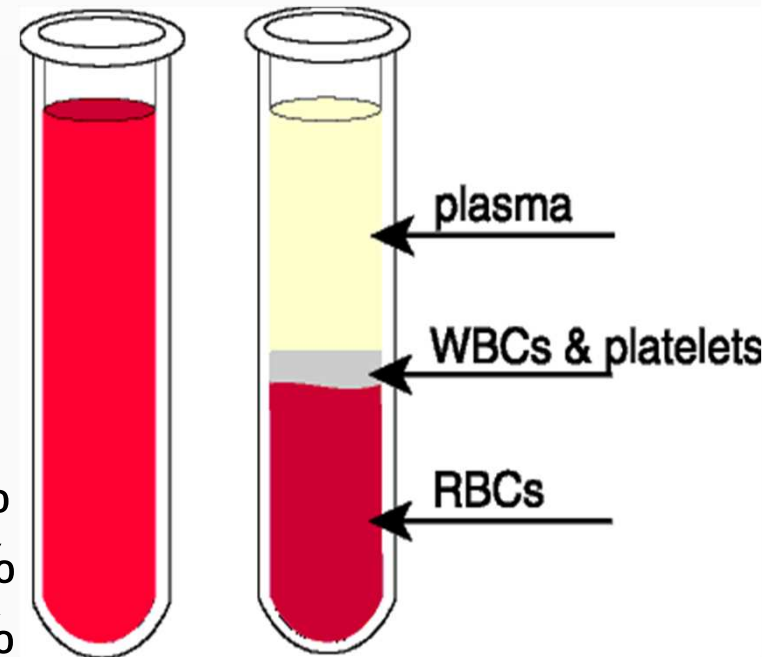
- hydroxyapatite crystals
- calcium phosphate – 85%
- calcium carbonate – 6-10%
- magnesium phosphate – up to 1.5%
- calcium fluoride – traces



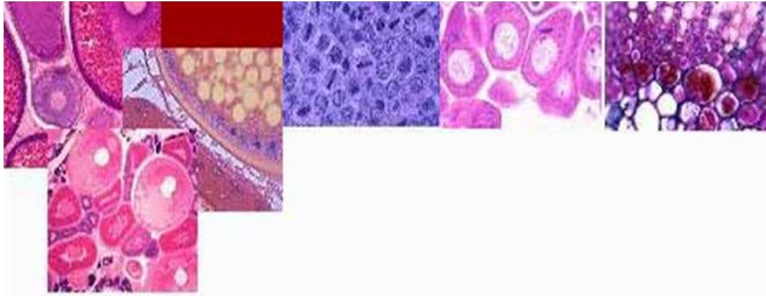
Blood as a tissue

■ Blood tissue – A. Hadjiolov, 1930

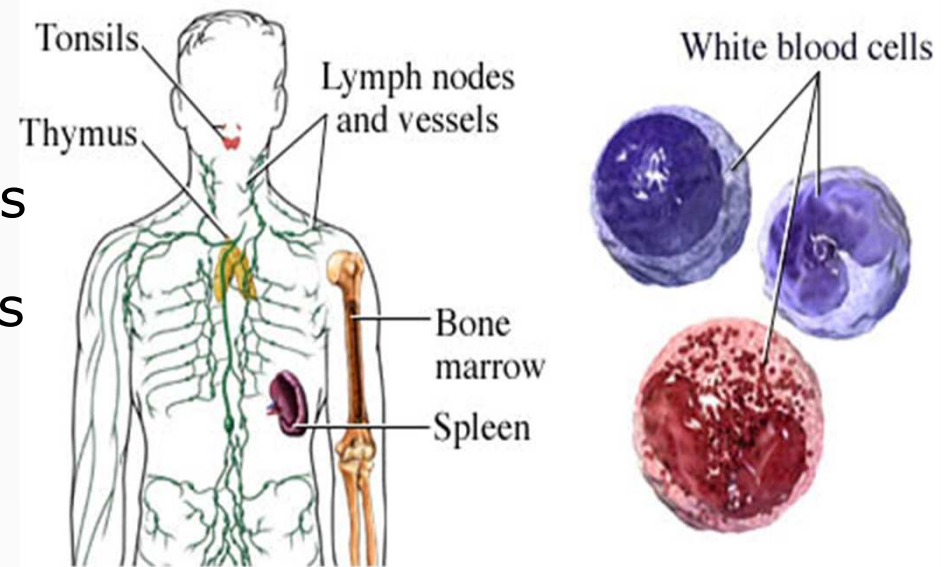
- ✓ specialized (trophic-defensive) fluid form of connective tissue
- ✓ liquid intercellular substance: plasma
- ✓ formed elements of blood (blood cells):
 - erythrocytes (red blood cells) – 96%
 - leukocytes (white blood cells) – 3%
 - thrombocytes (blood platelets) – 1%



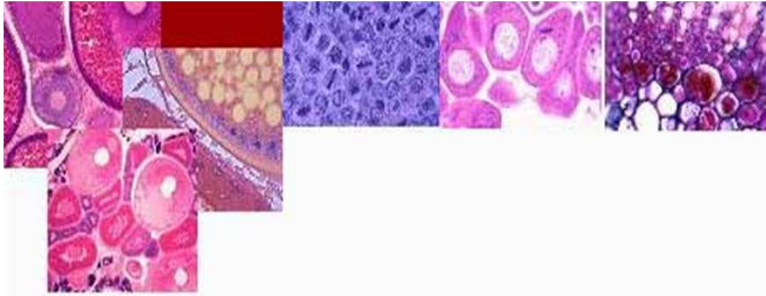
Functions of the blood



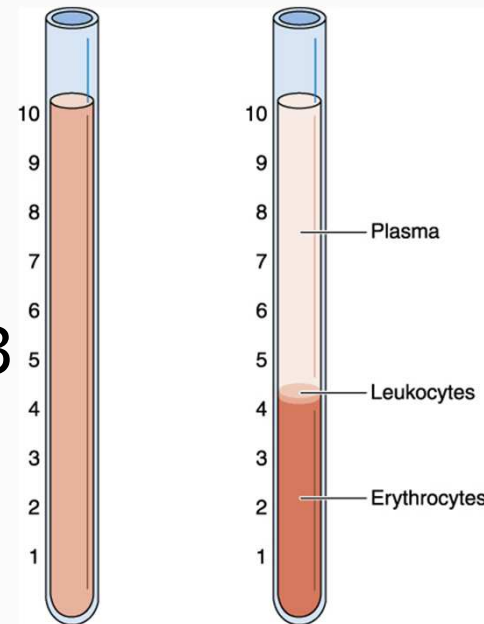
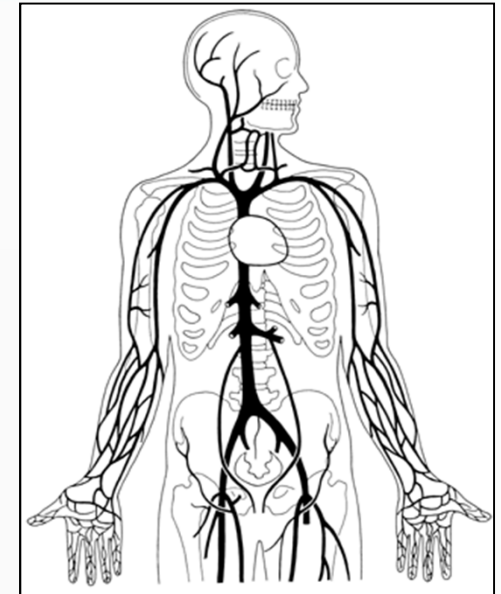
- ✓ transport – nutrients, gases (O_2 , CO_2), hormones, waste products of metabolism
- ✓ removes toxins from the body
- ✓ maintains body temperature
- ✓ buffer – pH control, homeostasis
- ✓ defense – leukocytes, antibodies
- ✓ blood clotting – prevention of hemorrhage



Composition of blood



- ✓ amount: 4-6 liters in a man, ~7-8% of its body weight
 - arteries - 1 liter
 - veins - 3 liters
 - heart
 - blood depots
- ✓ plasma: 55%
- ✓ blood cells: 45%
- ✓ hematocrit: 0.32-0.53
 - 0.40-0.50 in men
 - 0.35-0.45 in women



Formed elements of blood

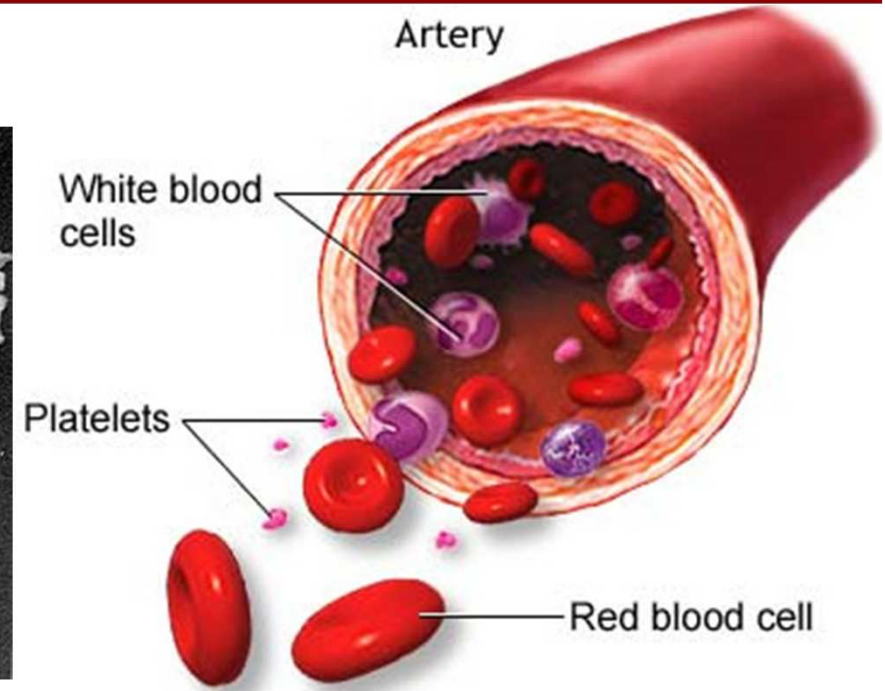
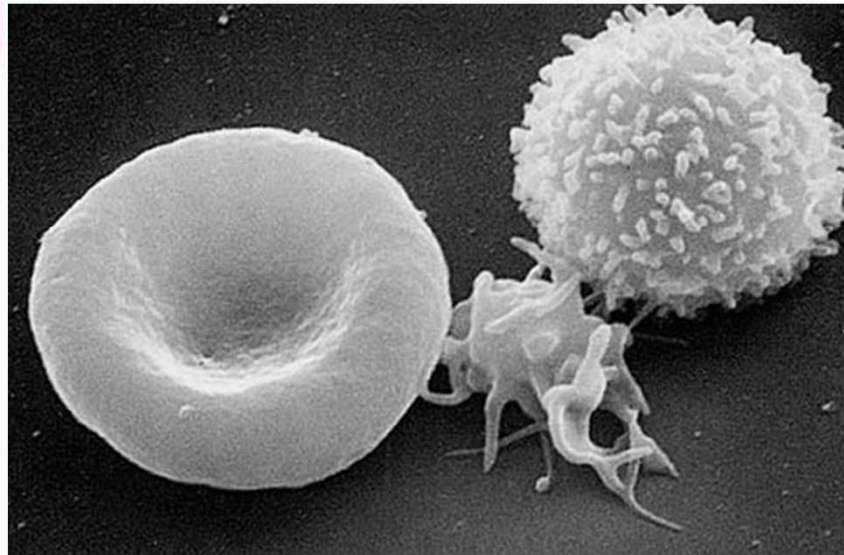
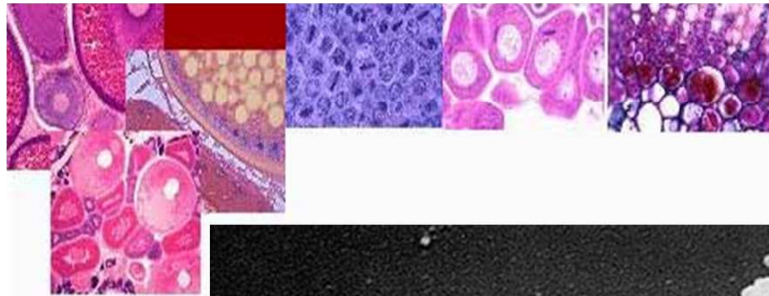
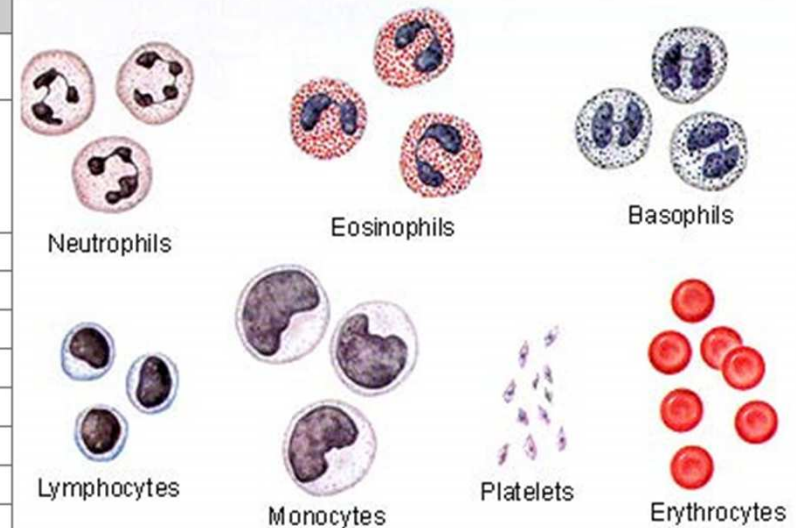


Table 12-3. Number and Percentage of Blood Corpuscles (Blood Count).

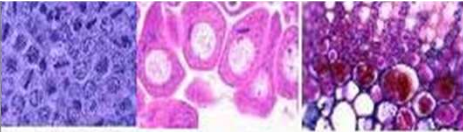
Corpuscle Type	Approximate Number per μL^a	Approximate Percentage
Erythrocyte	Female: $3.9-5.5 \times 10^6/\mu\text{L}$	
	Male: $4.1-6 \times 10^6/\mu\text{L}$	
Reticulocyte		1% of the erythrocyte count
Leukocyte	6000-10,000	
Neutrophil	5000	60-70%
Eosinophil	150	2-4%
Basophil	30	0.5%
Lymphocyte	2400	28%
Monocyte	350	5%
Platelet	300,000	



Erythrocytes



Jan Swammerdam
(1637-1680)



✓ Red Blood Cells (RBCs)
Gr. *erythros*, red

✓ total number: 25×10^{12} /blood
~ 4-6 million/mm³
♂ - $4.1-6.0 \times 10^{12}/l$
♀ - $3.9-5.5 \times 10^{12}/l$

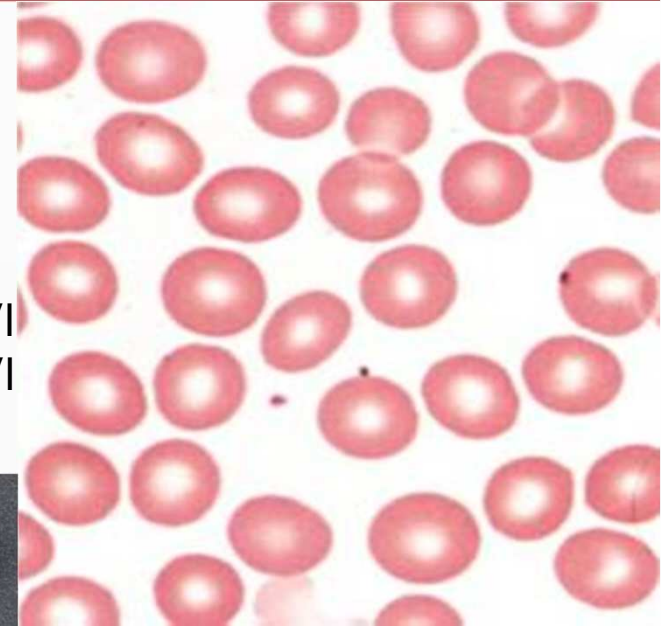
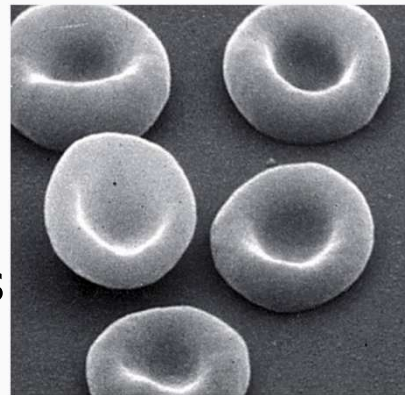
- ↑ erythrocytosis (polycythemia)
- ↓ anemia

✓ size: $7.5 \pm 0.5 \mu\text{m}$

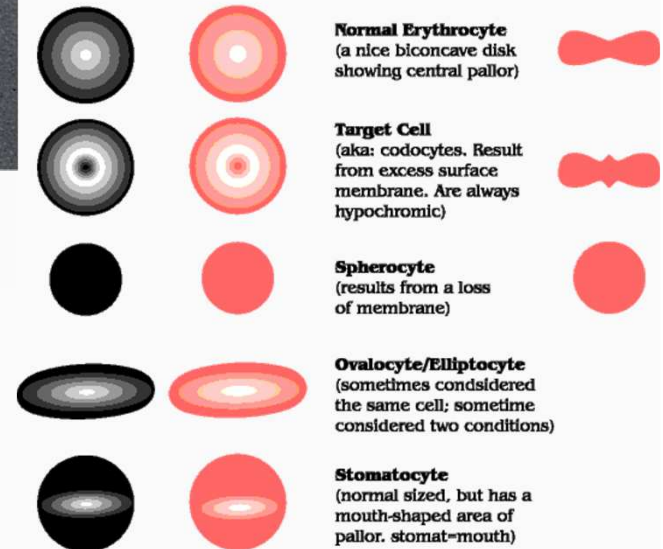
- > 9 μm : macrocytes
- > 12 μm : megalocytes
- < 6 μm : microcytes
- anisocytosis, Gr. *aniso*, uneven

✓ diameter: 0.8 μm in the center
2.6 μm at the rim

- ✓ shape: flexible biconcave disks – spectrin
- ✓ total surface: 140 μm^2 (3500 m^2)



Shape Variation Polkilocytosis



Leukocytes



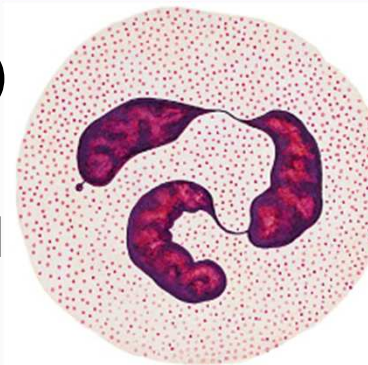
✓ White Blood Cells (WBCs)
Gr. λευκό, *leukos*, white

✓ total number: **4-10x10⁹/l** blood

- ↑ leukocytosis
- ↓ leukopenia (Gr. λευκό, white + πενία, deficiency)

✓ two groups and five types leukocytes:

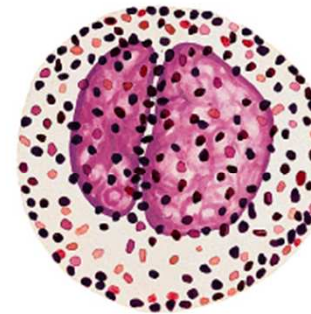
- granulocytes
(polymorphonuclear leukocytes)
 - neutrophilic granulocytes
 - eosinophilic granulocytes
 - basophilic granulocytes
- agranulocytes
(mononuclear leukocytes)
 - lymphocytes
 - monocytes



Neutrophilic granulocyte



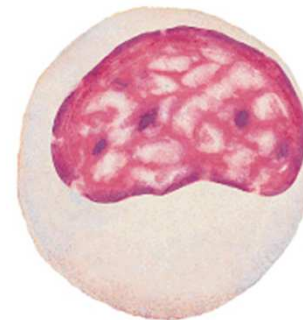
Eosinophilic granulocyte



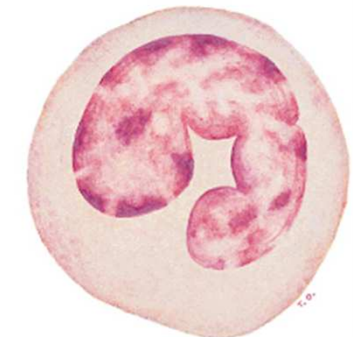
Basophilic granulocyte



Lymphocyte

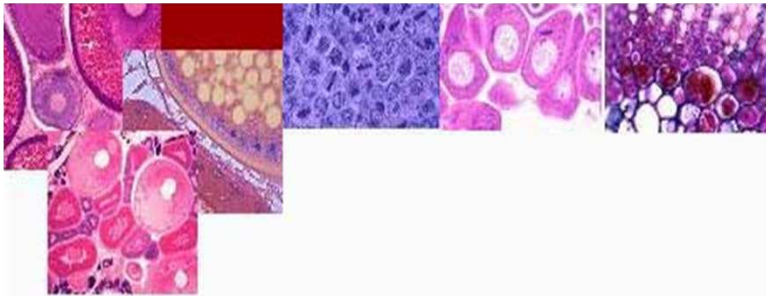


Monocyte



Monocyte

Percentage of leukocytes



- differential count (frequency) of blood leukocytes:

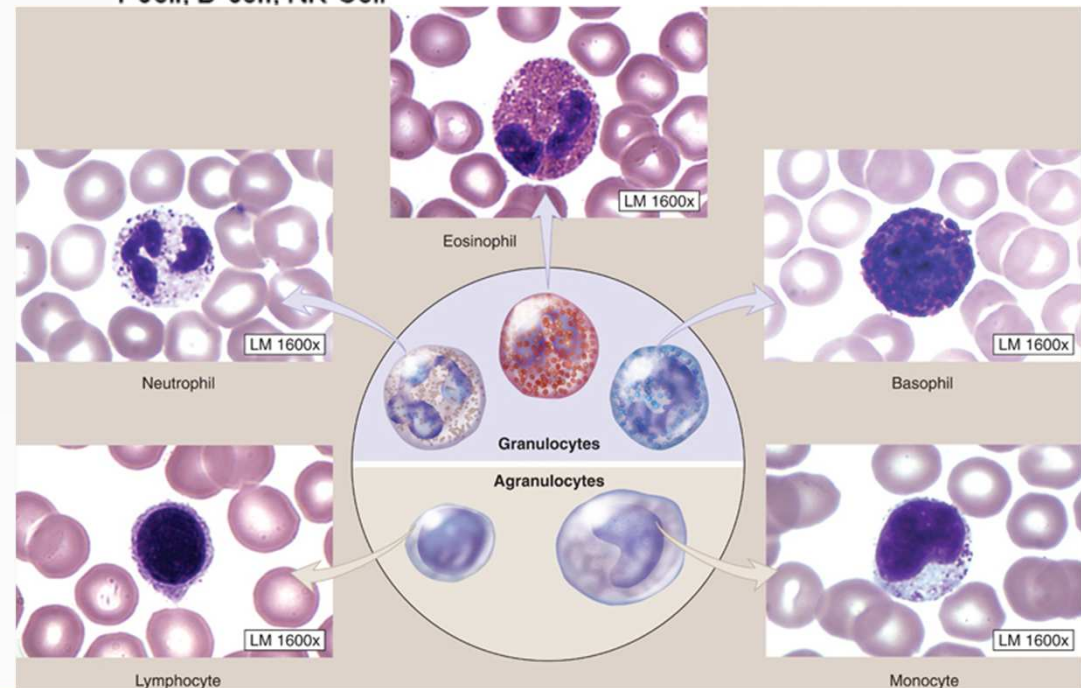
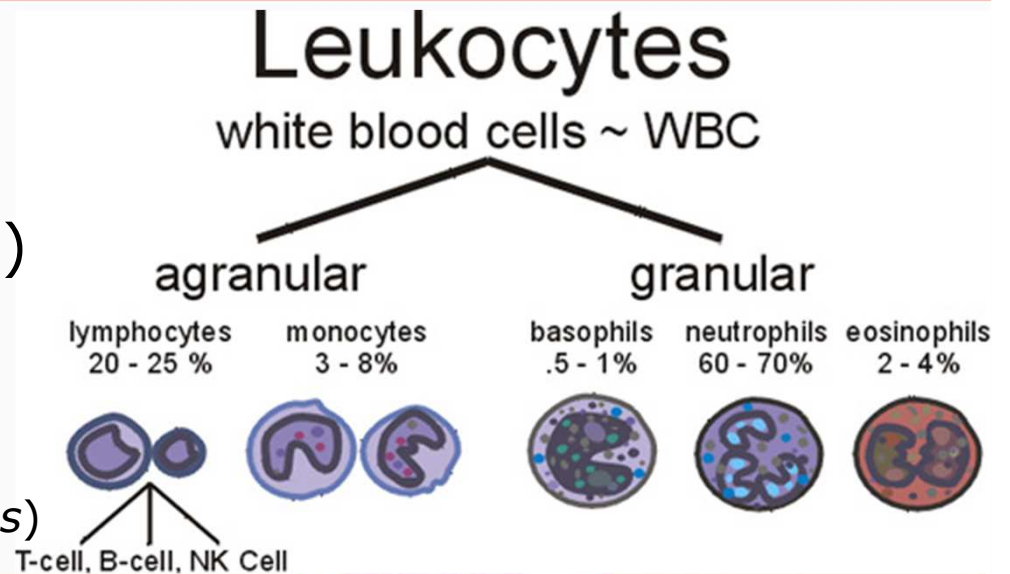
- ✓ granular leukocytes (granulocytes):

(Lat. *granulum*, granule + Gr. *kytos*)

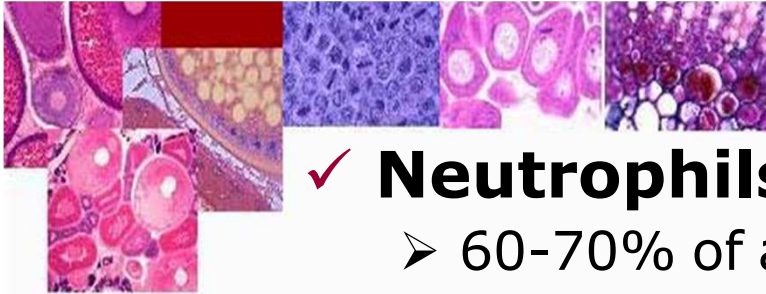
- neutrophils 60 - 70%
 - eosinophils 2 - 4%
 - basophils 0.5 - 1%
 - band cells 2 - 3% (immature neutrophils)

- agranular leukocytes (agranulocytes):

- lymphocytes 20 - 30%
 - monocytes 3 - 8%

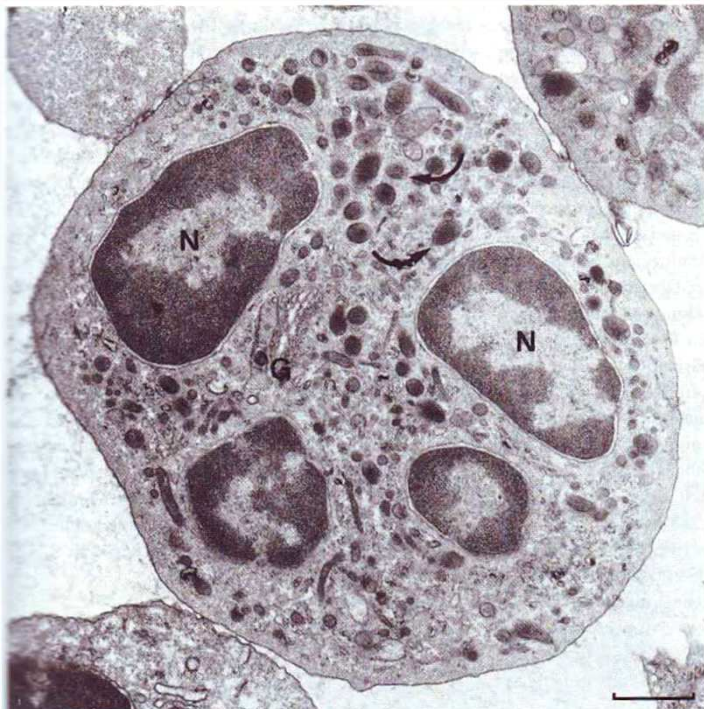
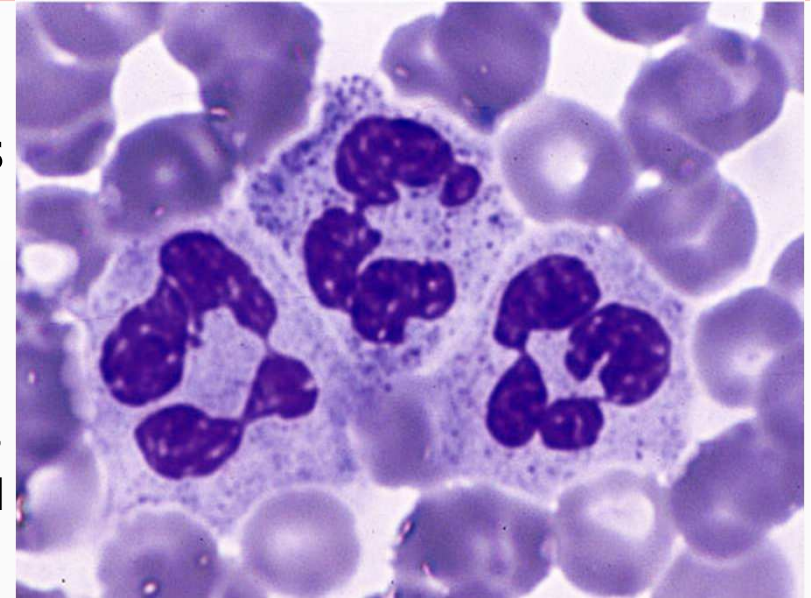


Polymorphonuclear leukocytes



✓ Neutrophils:

- 60-70% of all leukocytes
- size (in diameter):
 - 10-12 μm
- segmented nucleus
 - ⇒ 2-5 (usually 3) lobes
 - > 5 lobes ⇒ hypersegmented



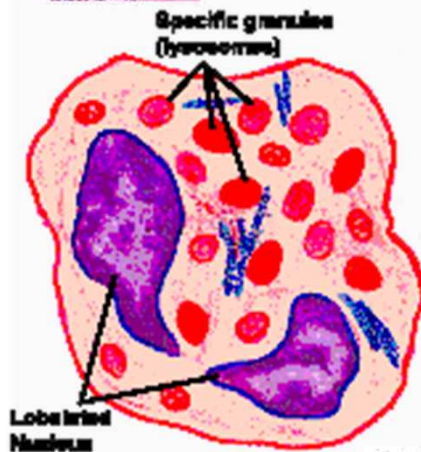
✓ Granules: total number 50-200

- specific (B-granules): 80%
 - ⇒ small-sized – 0.1-0.2 μm
 - ⇒ lysozyme, lactoferrin, collagenase, several nonenzymatic antibacterial basic proteins, alkaline phosphatase
- azurophilic (A-granules): 15%
 - ⇒ lysosomes – 0.4-0.5 μm
 - ⇒ acid hydrolases, peroxidase etc.

Eosinophilic granulocytes

✓ Eosinophils:

- 2-4% of leukocytes
- size (in diameter):
 - 12-17 μm
- bilobed nucleus



✓ specific granules:

about 200/cell, 0.5-1.5 μm /0.3-1 μm

- LM: acidophilic (eosinophilic)
 - ⇒ acid phosphatase, arylsulfatase, peroxidase, histaminase, protein cations (MBP, ECP, EPO, EDN)
- EM: ultrastructure
 - ⇒ unit membrane, crystalline core (major basic protein), parallel to the long axis of the granule

✓ azurophilic granules:

⇒ lysosomal enzymes



Basophilic granulocytes



✓ Basophils:

- less than 1% of leukocytes
- size (in diameter):
 - ⇒ 10-12 μm
- large nucleus
 - ⇒ irregular lobes
 - ⇒ U- or S-shaped

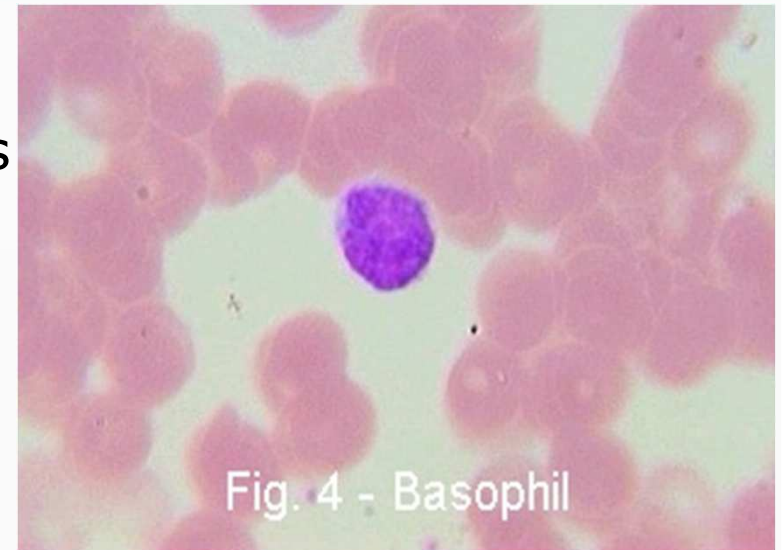
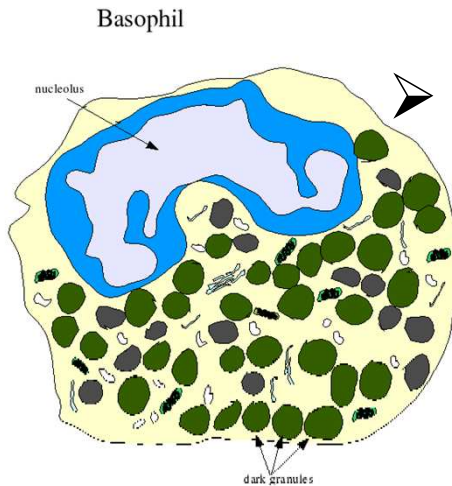


Fig. 4 - Basophil



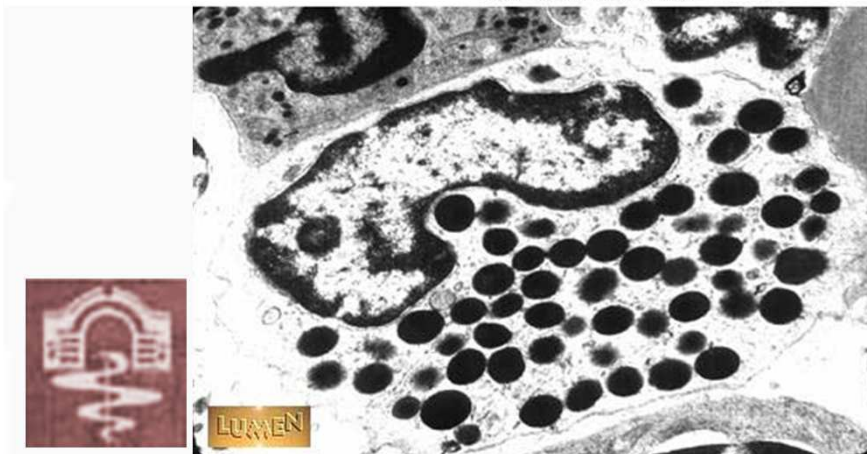
Lab Part 5: Slide 59

✓ specific granules: 0.5 μm

- metachromasia – similar to mast cells
 - ⇒ histamine, (serotonin), heparin, prostaglandins
- ultrastructure
 - ⇒ dense-cored granules

✓ azurophilic granules:

- ⇒ lysosomes ⇒ hydrolytic enzymes



Agranulocytes



✓ Lymphocytes:

- size (in diameter):
 - small – 6-8 μm
 - medium – 8-12 μm
 - large – 12-18 μm
 - nucleus:
 - large, hyperchromatic
eccentrically located
 - cytoplasm:
 - ⇒ scanty, thin rim
around the nucleus
 - ⇒ basophilic with many
free polyribosomes
- ⇒ **B-lymphocytes**
- ⇒ **T-lymphocytes**
- ⇒ **NK cells (NKC)**

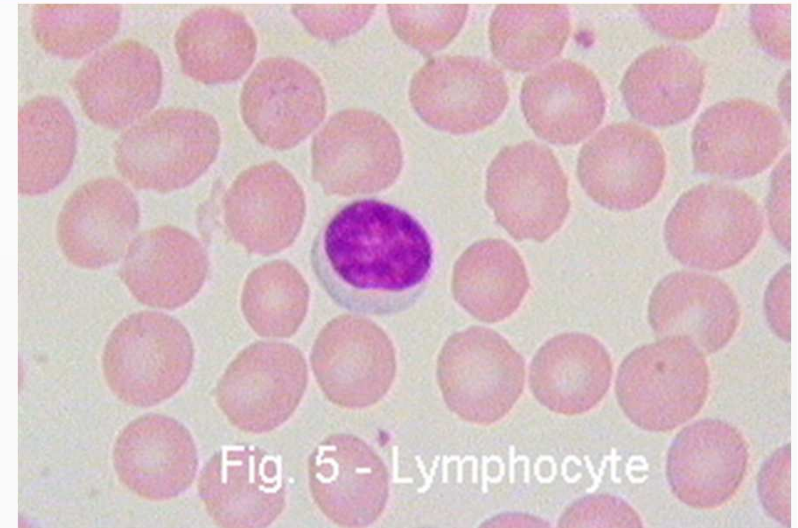
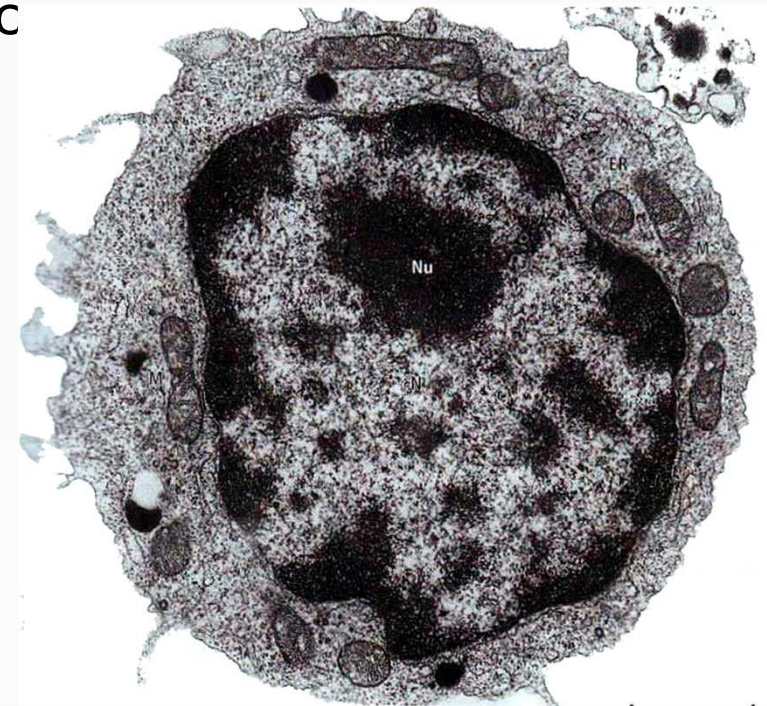
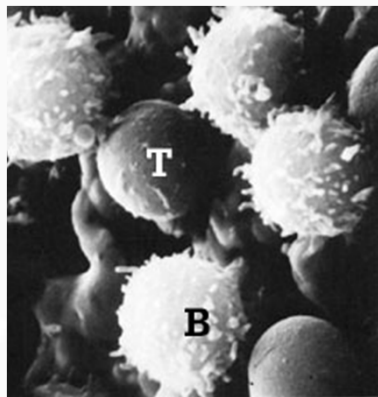
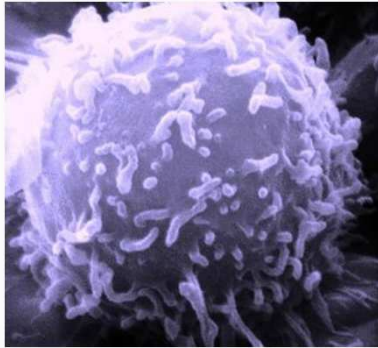


Fig. 5 - Lymphocyte

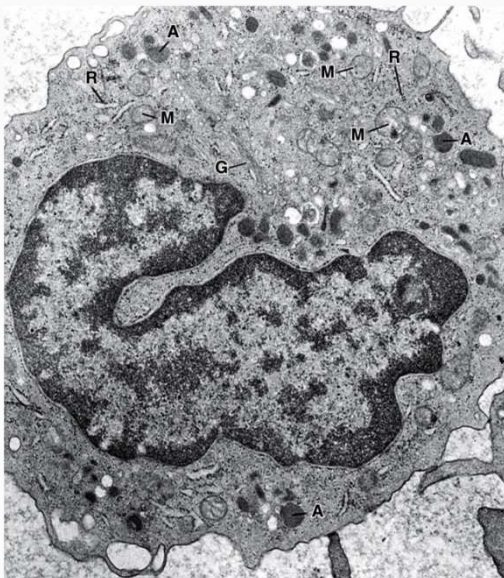
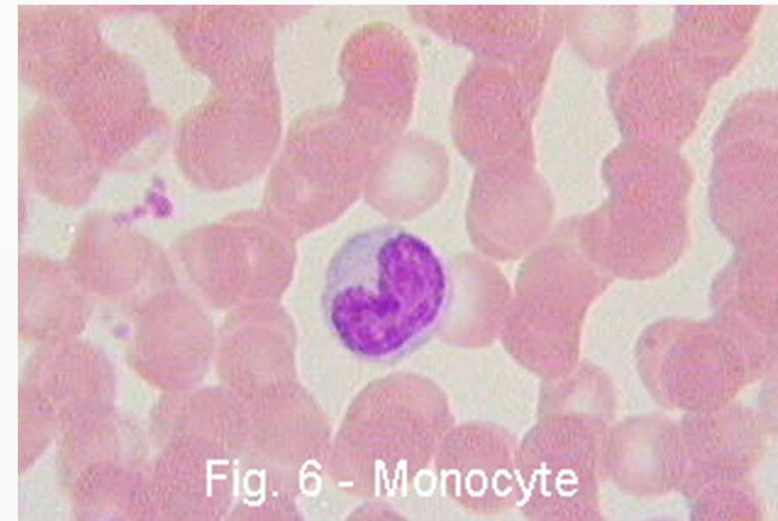


Agranulocytes



✓ Monocytes:

- size (in diameter):
 - 13-20 μm
- nucleus:
 - ⇒ eccentrically placed, oval, horseshoe- or kidney-shaped with 1-2 nucleoli
- pinocytotic vesicles and many microvilli
- cytoplasm – basophilic (bluish-gray color)

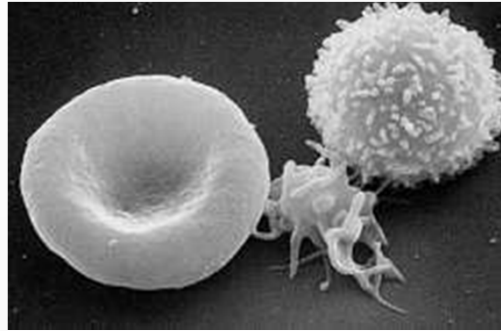
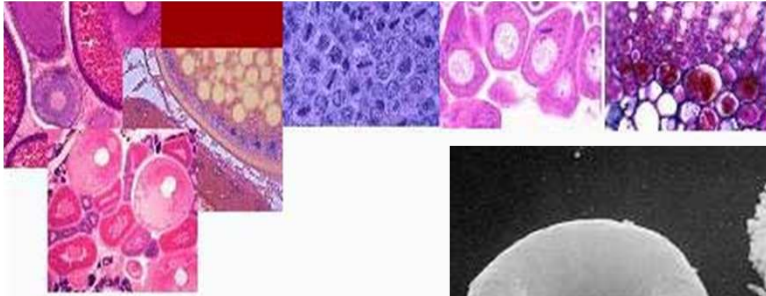


✓ Granules:

- very fine azurophilic (lysosomes)
 - ⇒ peroxidase-positive (acid phosphatase)
 - ⇒ peroxidase-negative (nonspecific esterase)

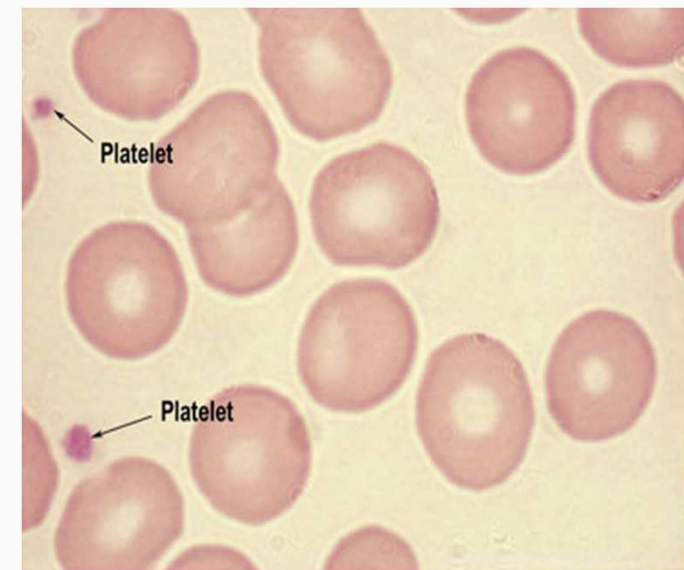
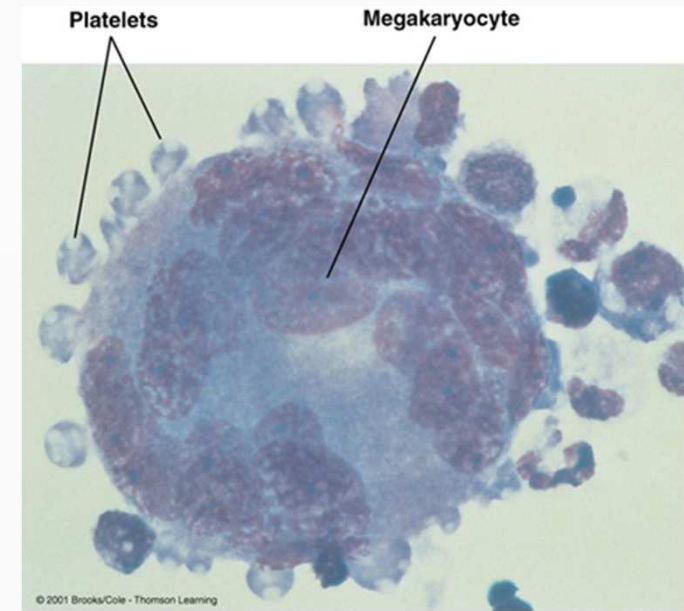


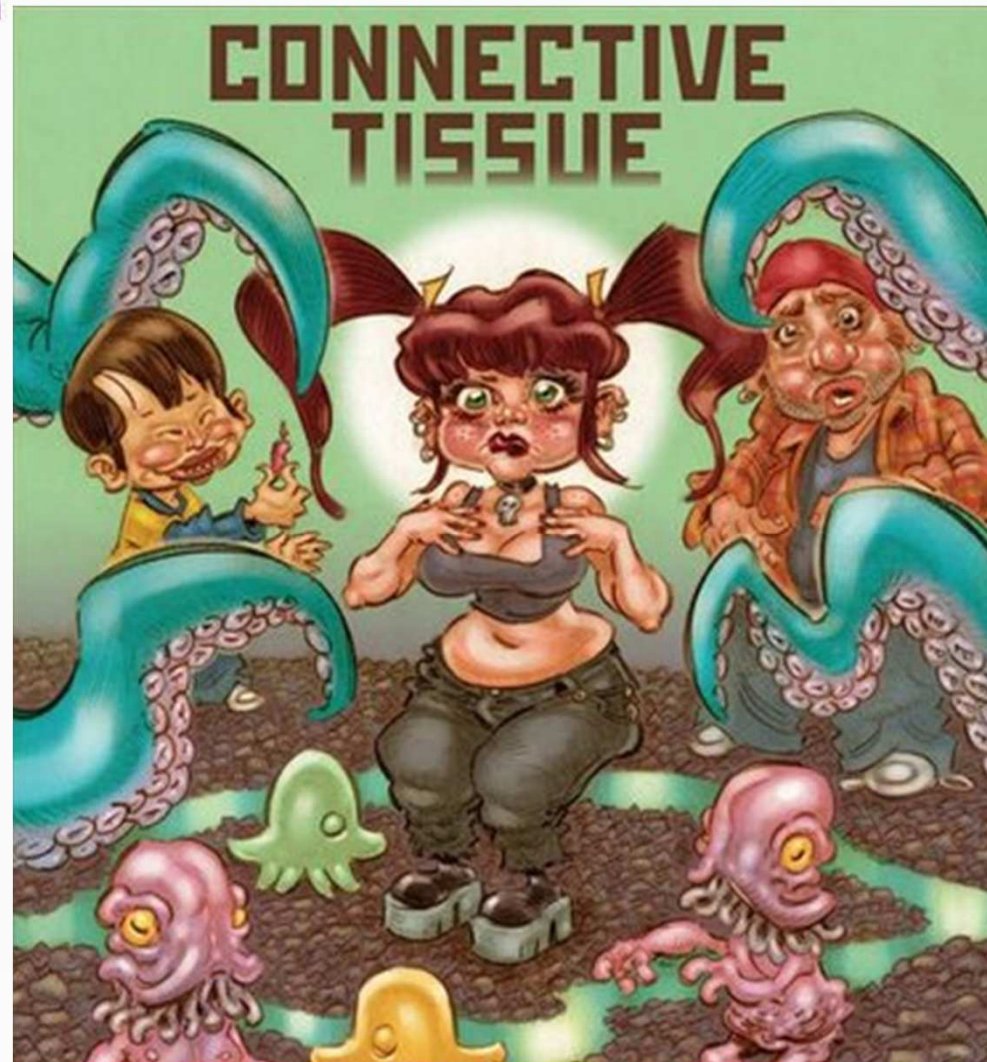
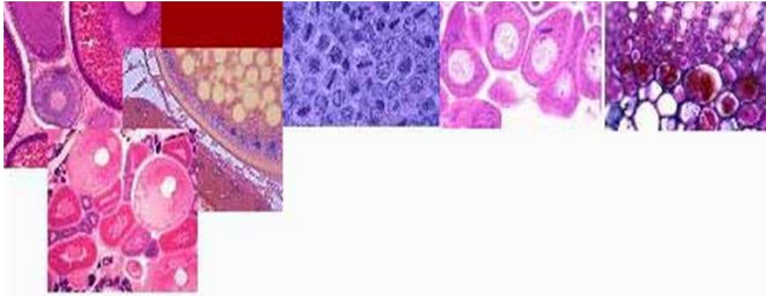
Platelets



✓ fragmentations from giant polyploid megakaryocytes:

- number: $20-40 \times 10^9/l$
- ellipsoid or discoid in shape
- size: $1.5-5 \mu m$
- central zone – **granulomere** (chromomere) containing purple granules
- peripheral light-blue-stained transparent zone – **hyalomere** (microtubules and actin filaments)





Thank you ...