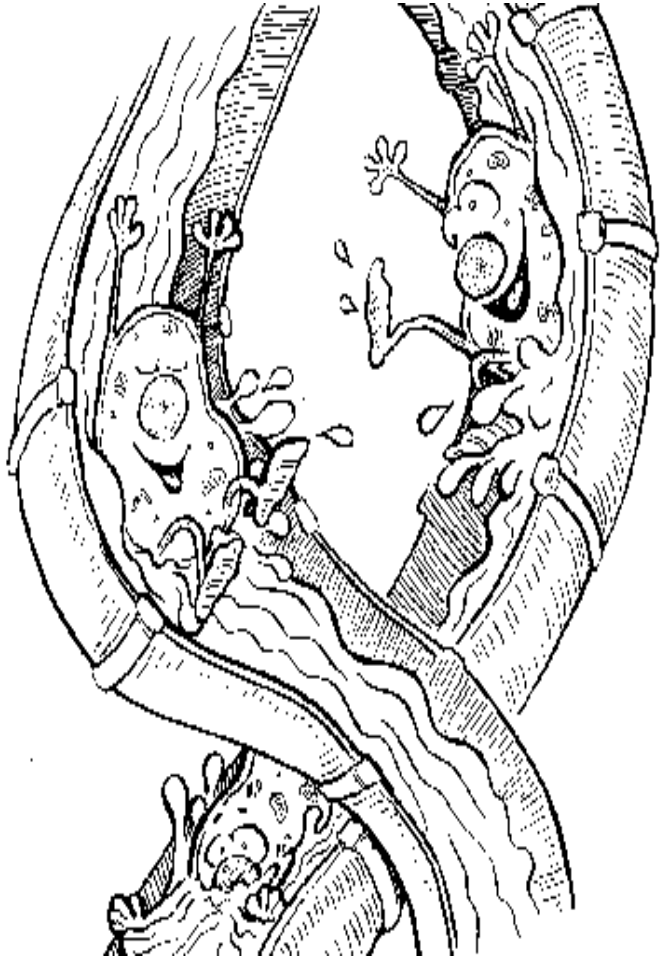
Blood

Warning

- please, do not manipulate the microscope,
- they are prepared for your study of blood smears after presentation,
- you will get instructions, how to study blood smears.



Blood

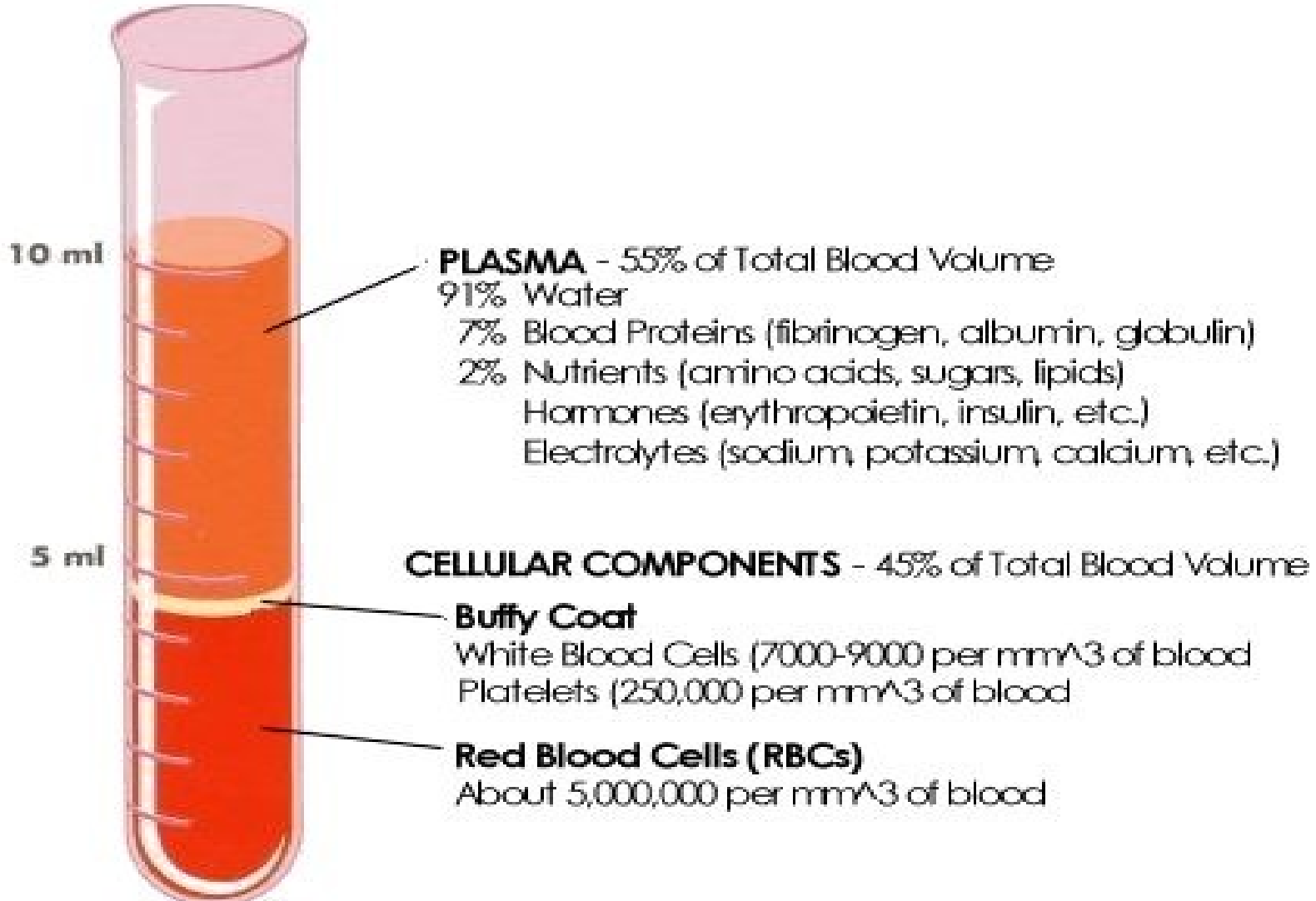
Plasma & Blood cells

Composition of plasma

- Water – 90 %
- Proteins – 7 % (albumins, globulins, fibrinogen)
- Other components – 3 % (blood gasses, nutrients, hormones, enzymes, vitamins, electrolytes)

Hematocrit:

the volume of blood cells per unit volume of blood



Blood

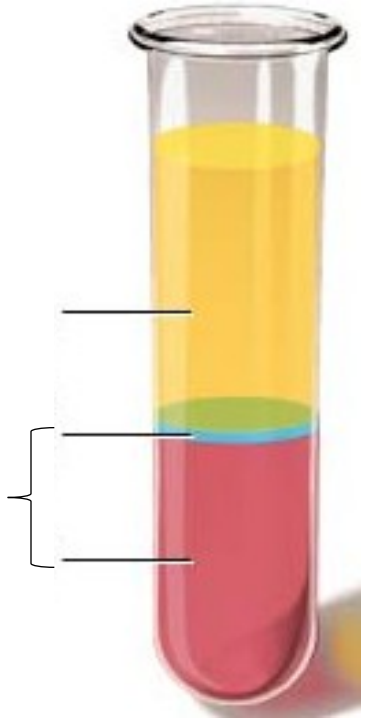
55 % plasma
- 90 % H_2O
- 7 % plasma proteins
- 3 % -AMAs, saccharids, lipids
  - -hormones
  - -electrolytes

45 % blood corpuscles

Hematocrit

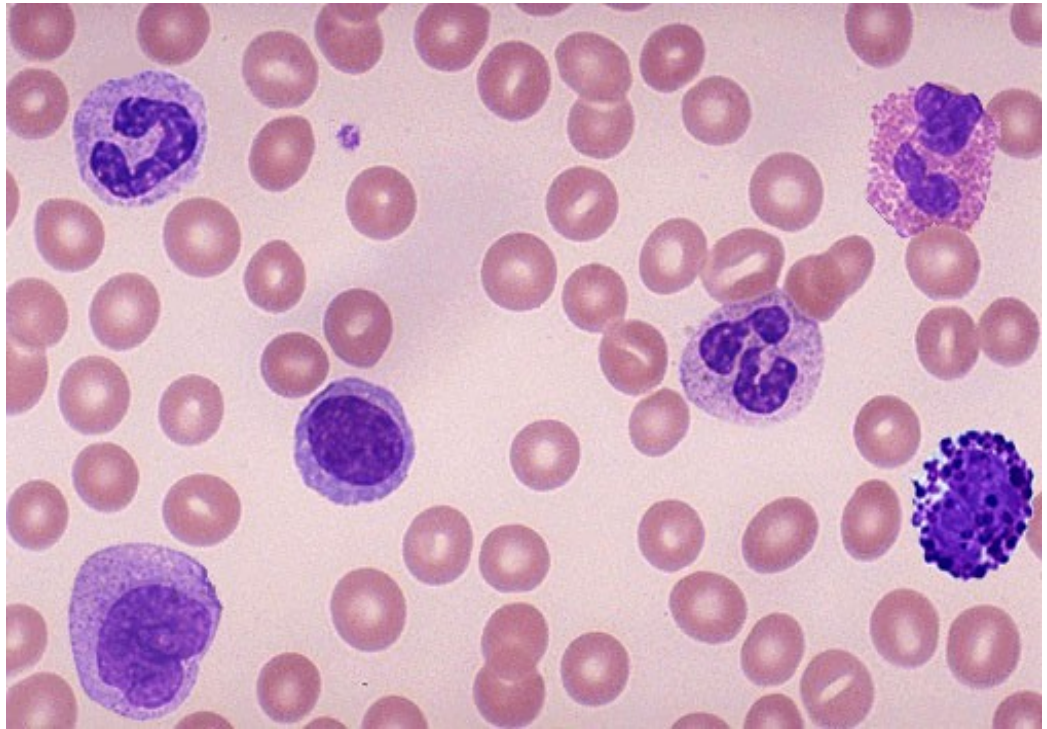
♂ 42 – 52 %

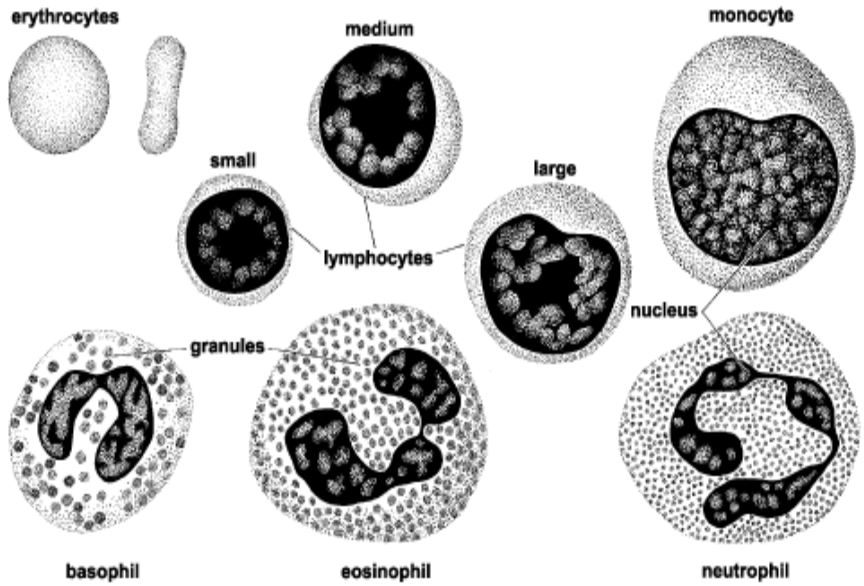
♀ 37 – 47 %



Blood cells (formed elements)

- Red blood cells – **erythrocytes**
- White blood cells – **leukocytes**
- Platelets – **thrombocytes**



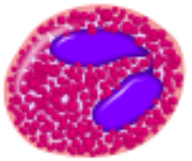
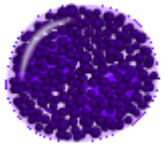


BLOOD CORPUSCLES

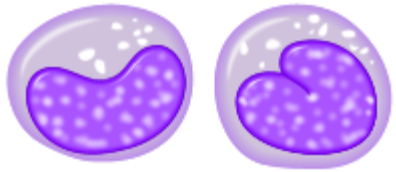
ERYTHROCYTES  7,2 - 7,6 μm

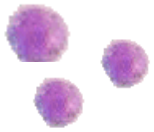
LEUKOCYTES

GRANULOCYTES (polymorphonuclears)

- neutrophilic  0 - 12 μm
- eosinophilic  - 14 μm
- basophilic  8 - 10 μm

AGRANULOCYTES (mononuclears)

- lymphocytes  6 - 8 / 10 -12 μm
- monocytes  0 μm

THROMBOCYTES  2 – 4 μm

REMEMBER forever!

- Erythrocytes: 4 – 6 millions/ 1 μl **of blood**
- Leukocytes: 5,000 – 9,000 / 1 μl
- Thrombocytes: 150,000 – 250,000/ 1 μl

NEVER FORGET !

ERYTHROCYTES

- 4 – 6 million/µl
- Shape: biconcave disc,

  dumble-shaped *(cross section)*
- Size: 7.4 µm in diameter
  (= normocyte)
- Structure: plasmalemma, cytoplasm
  + hemoglobin 33 %
  absence**!** of the nucleus and cell organelles
- Lifespan: 120 days

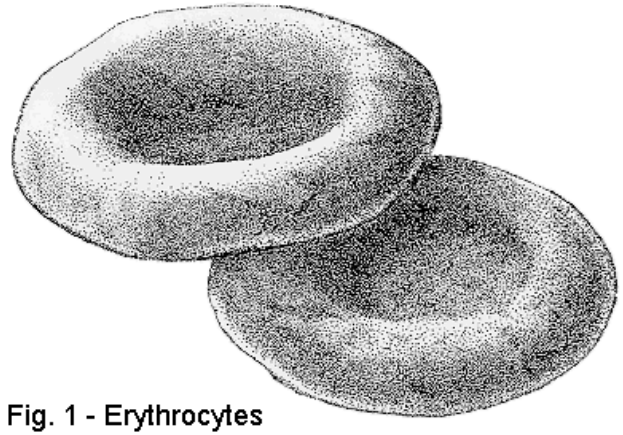
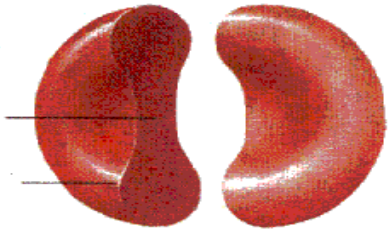
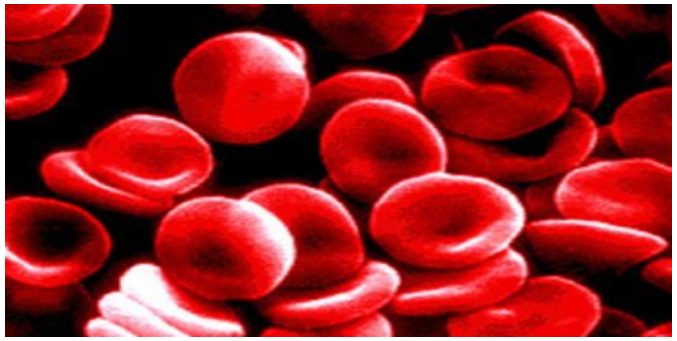
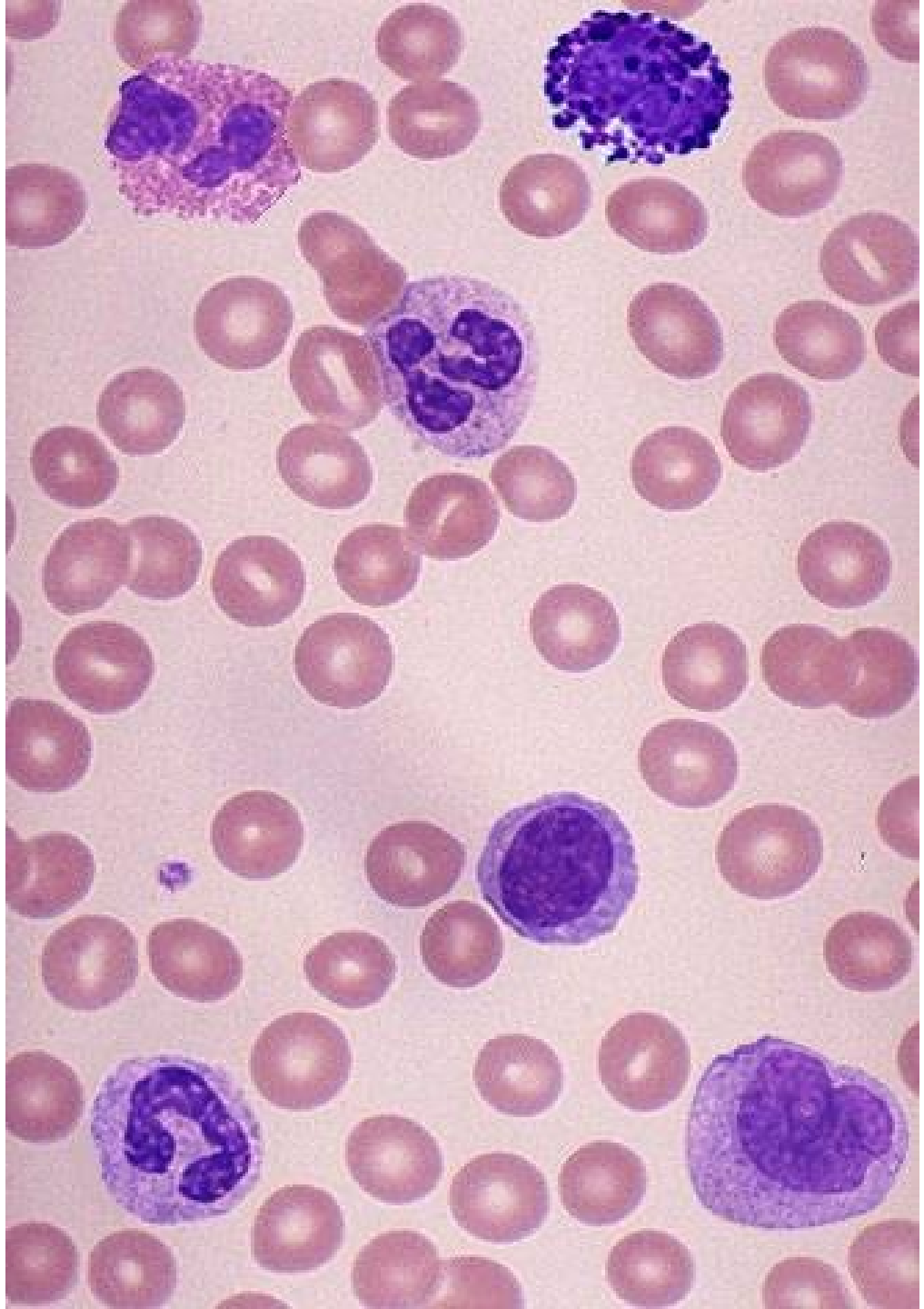
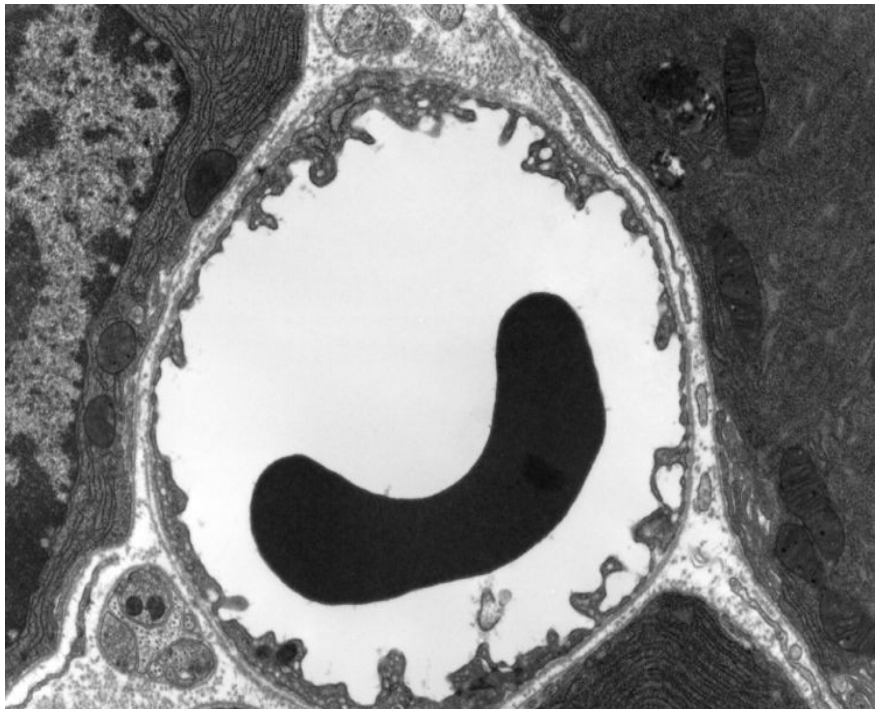


Fig. 1 - Erythrocytes



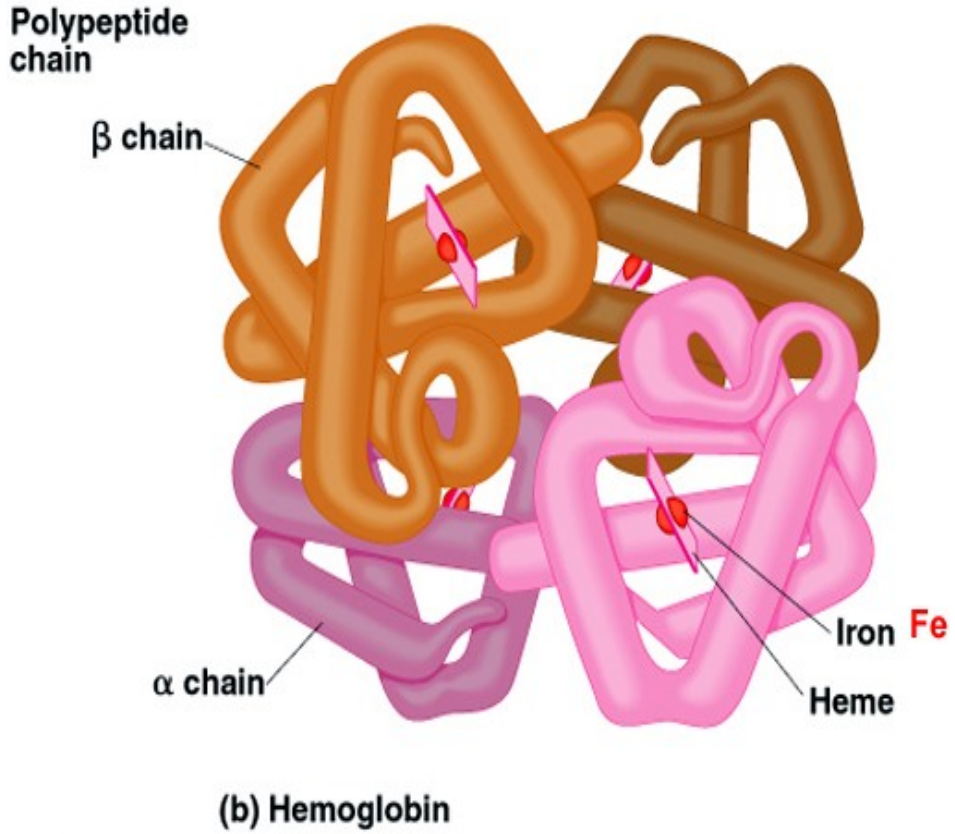






Hemoglobin

- a conjugated protein: 4 polypeptide chains + heme groups = protoporphyrin ring with ferrous iron (Fe^{2+})
- Hb F (fetal)
- Hb A (adult)
- normochromatic ery: 32±2 picogramms (*hyper-, hypo-*)

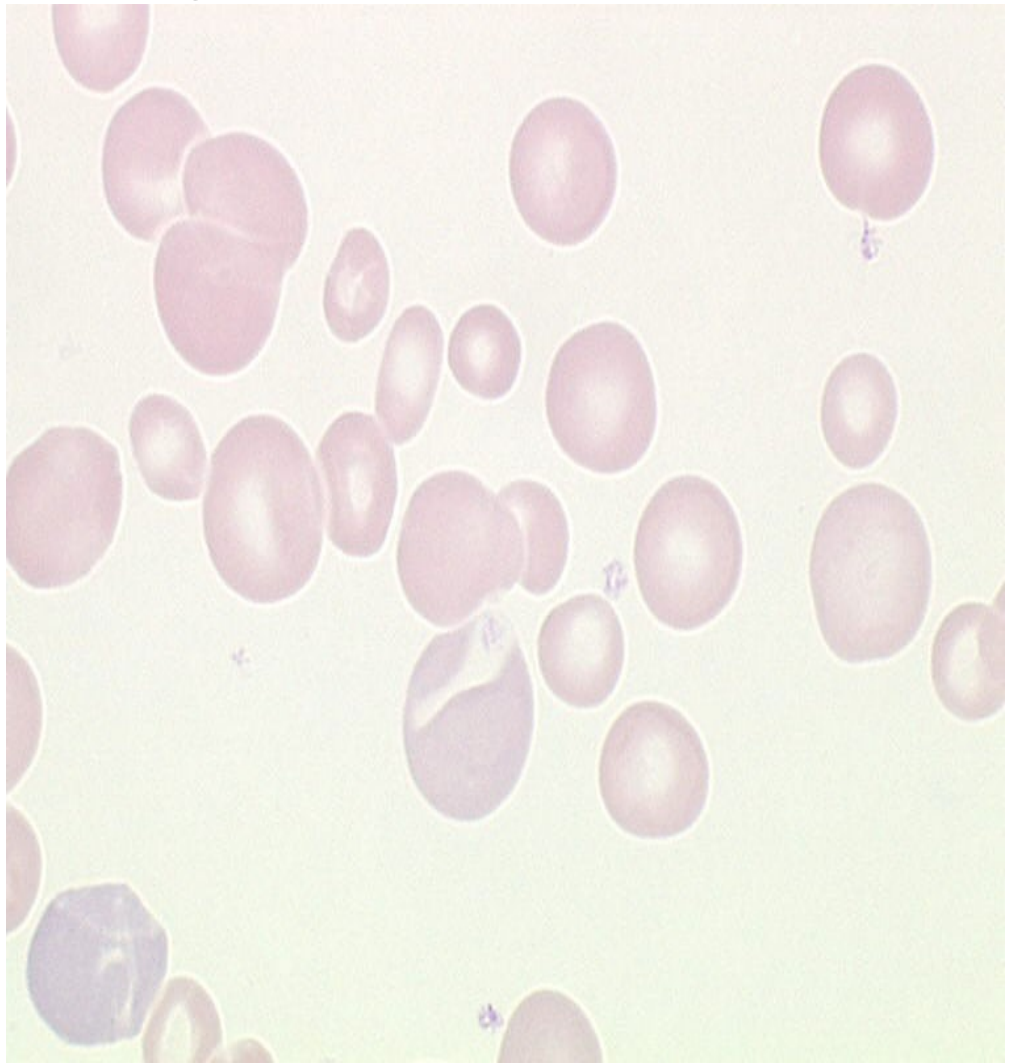


<Important terms>

- **Polyglobulia** – *an increased number of ery*
- **Anemia** – *a decreased number of ery*

- **Poikilocytosis** – *an occurrence of different shaped ery (spherocytes, elliptocytes, drepanocytes = sickle cells, etc.)*
- **Anisocytosis** – *an occurrence of different sized ery (microcytes, macrocytes)*

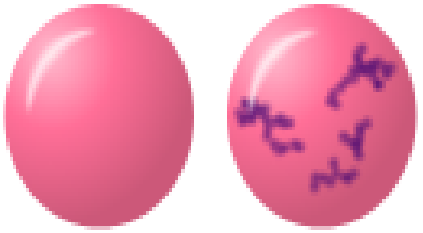
Anisocytosis



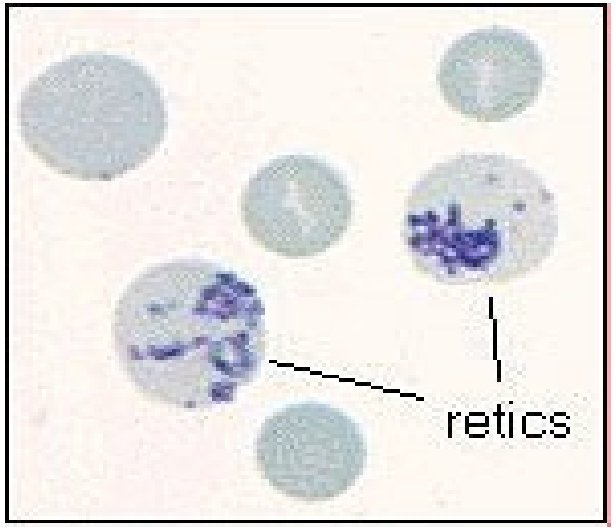
- Microcytes
  ∅ < 6.5 μm
- Normocytes

  ∅ ± 7.4 μm
- Macrocytes ∅
  > 8 μm

Reticulocytes

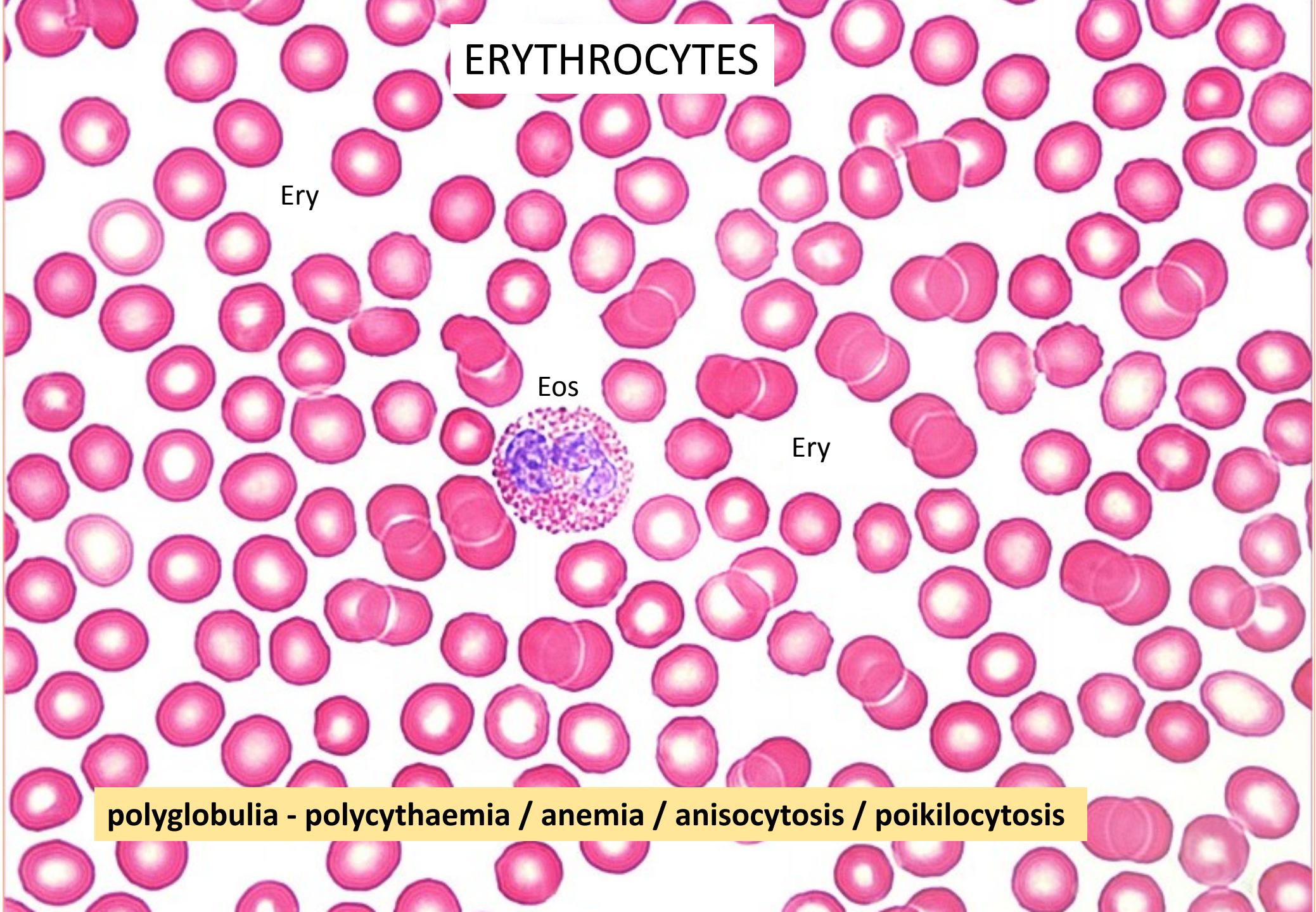


- Immature ery are released from the bone marrow into the peripheral blood (0.5 – 1.5 %)
- They contain the rests of organelles – ribosomes, mitochondria – substantia reticulofilamentosa (*brilantcresyl blue staining is used for detection*)
- maturation into ery – during 24 hours

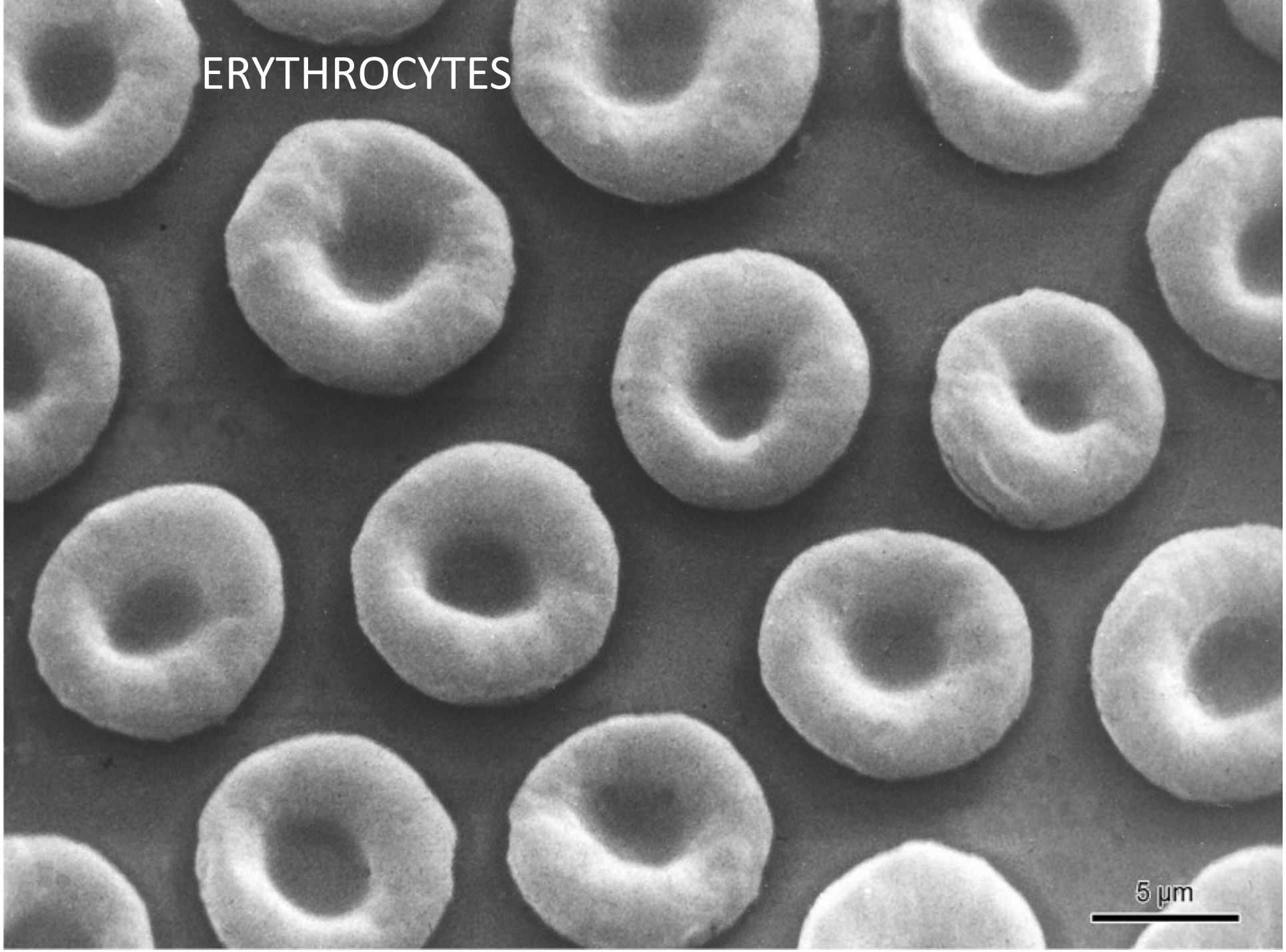


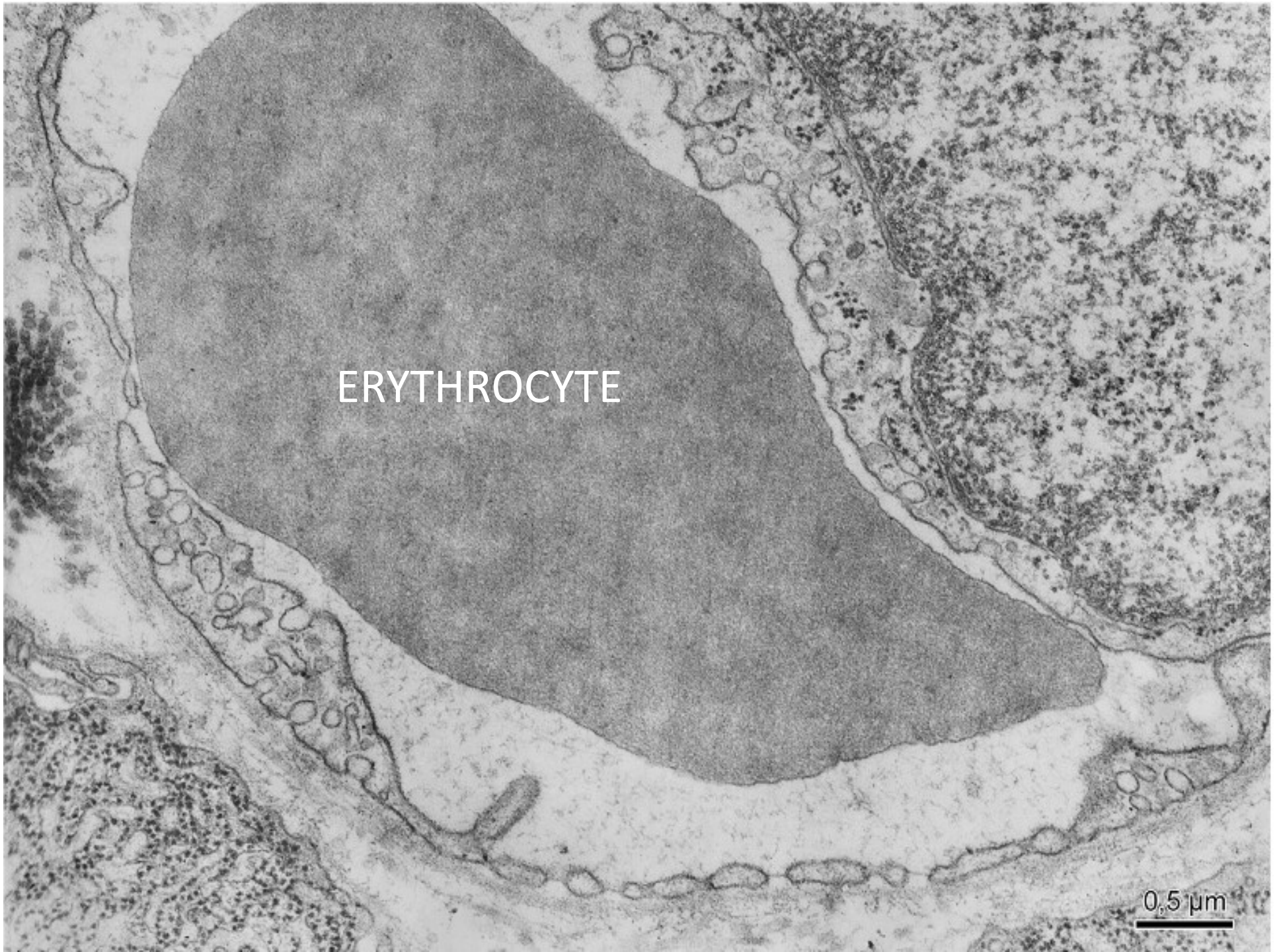
Functions of ery

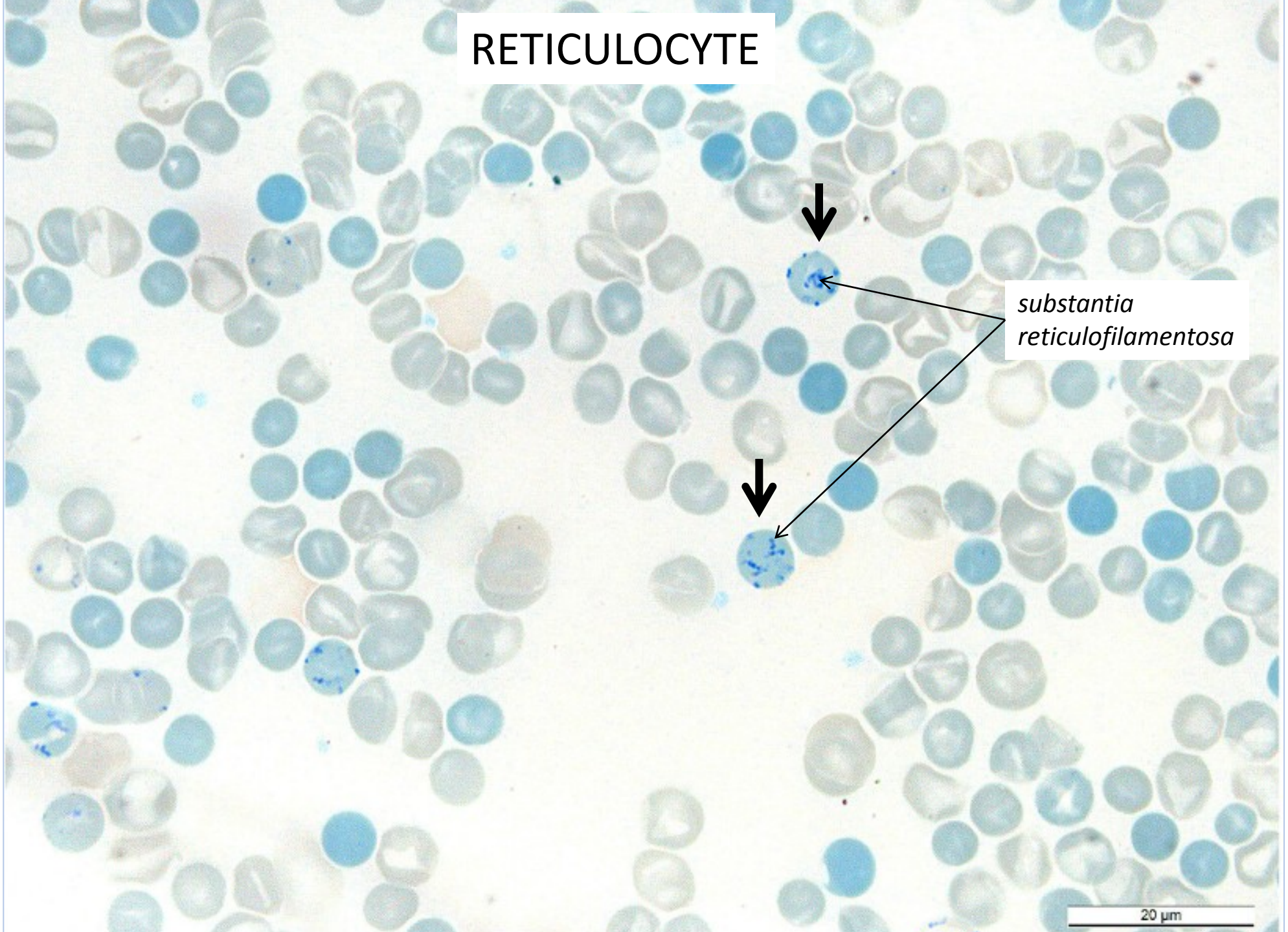
- transport of oxygen from the lungs
- transport of carbon dioxide from the tissues



polyglobulia - polycythaemia / anemia / anisocytosis / poikilocytosis


ERYTHROCYTES
5 µm


ERYTHROCYTE
0,5 µm

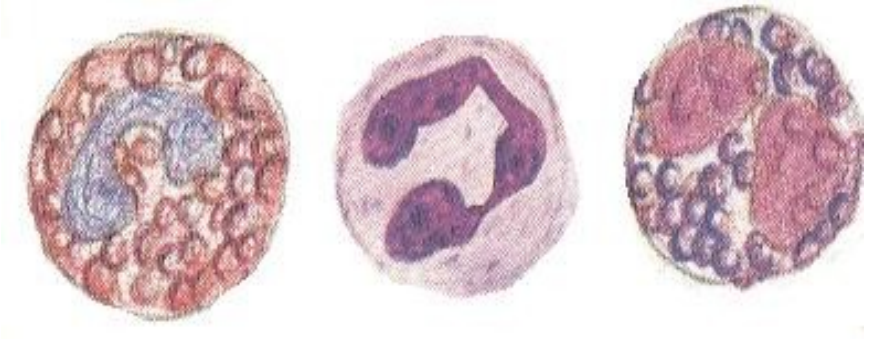

RETICULOCYTE
substantia
reticulofilamentosa
20 µm

LEUKOCYTES

- Granulocytes:
  - neutrophils
  - eosinophils
  - basophils

General characteristic

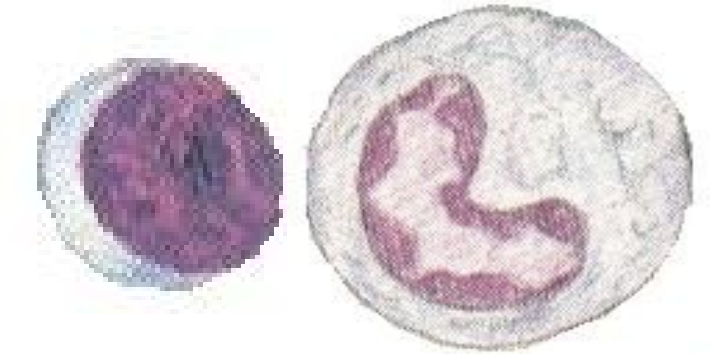
Polymorphonuclears with acidophilic cytoplasm and Specific + azurophilic granules



- Agranulocytes
  - lymphocytes
  - monocytes

General characteristic

Mononuclears with basophilic cytoplasm and azurophilic granules



Granulocytes

- General charcteristic:

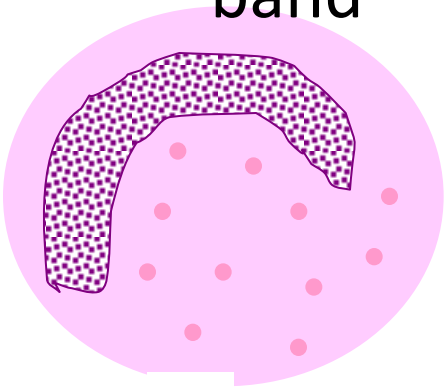
- polymorphonuclears – different shape of nuclei

band segmented with chromatin bridges

- acidophilic cytoplasm – bright-pink
- specific granules – with special enzymes
- azurophilic granules – with lysosomal enzymes
- all granulocytes are able to migrate from the vessels and by diapedesis invade a site of inflamation

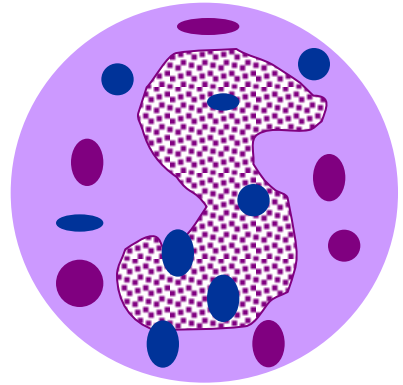
Granulocytes
neutrophils – eosinophils - basophils

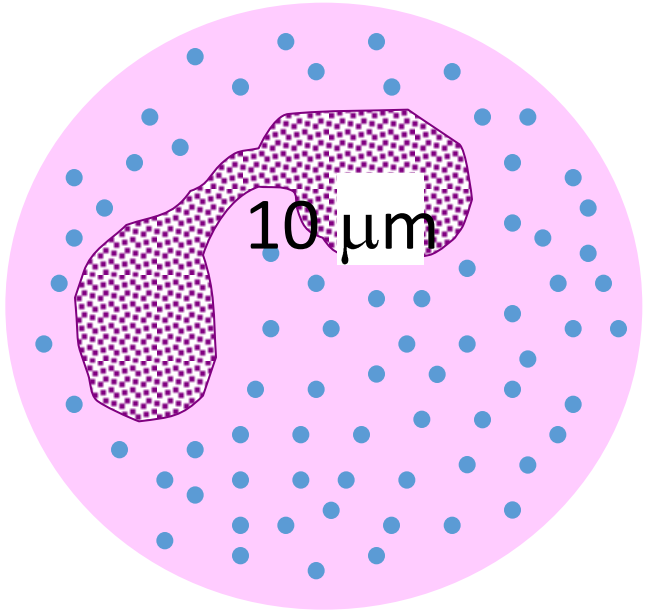
band

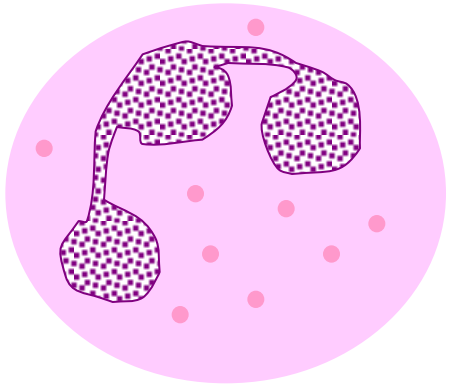


10-12 μm

12-14 μm



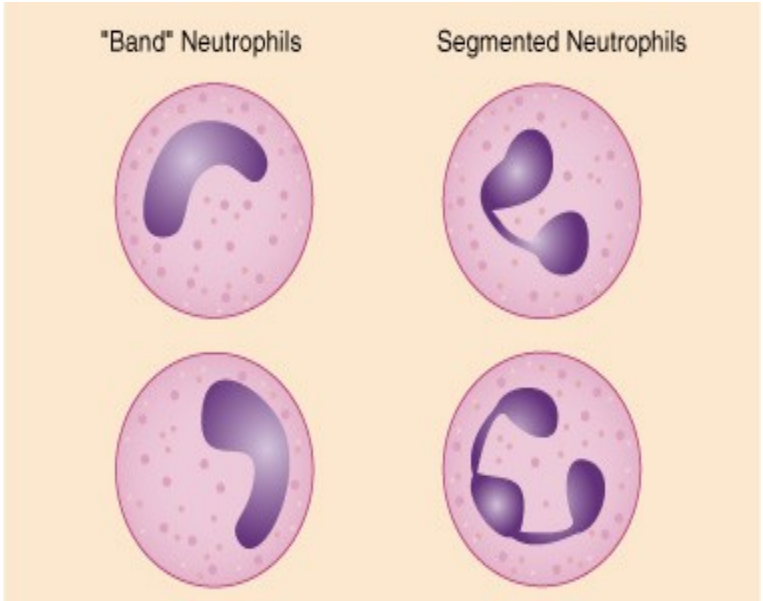


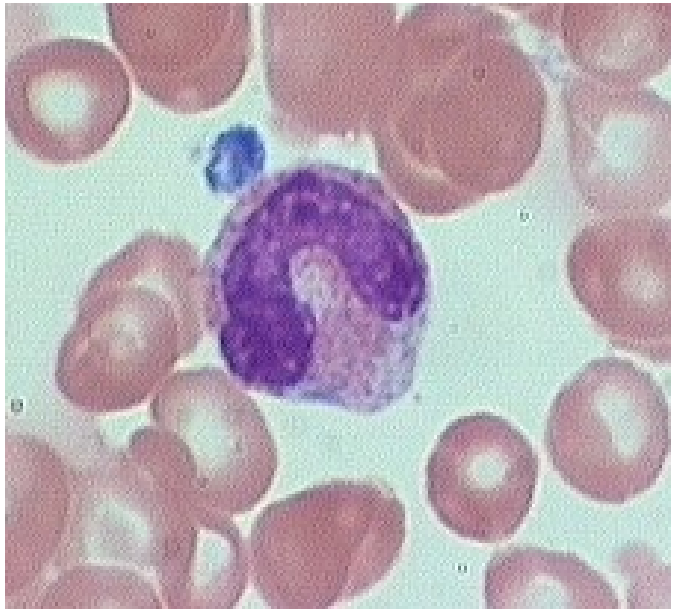


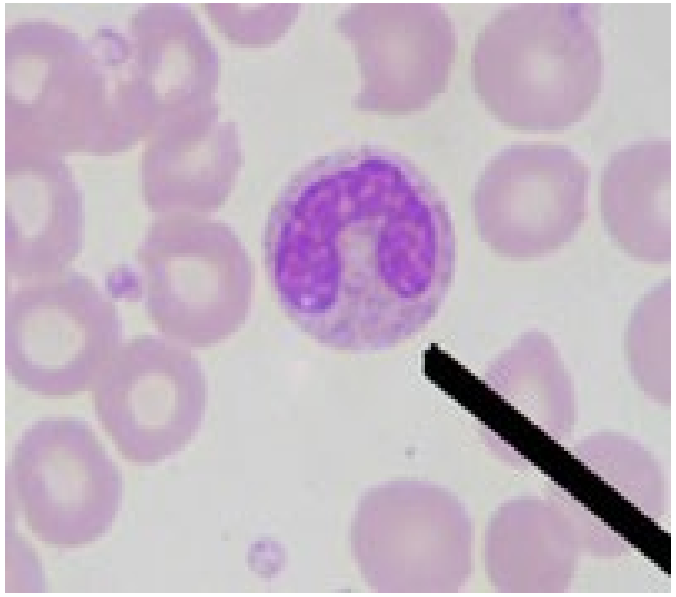
segment

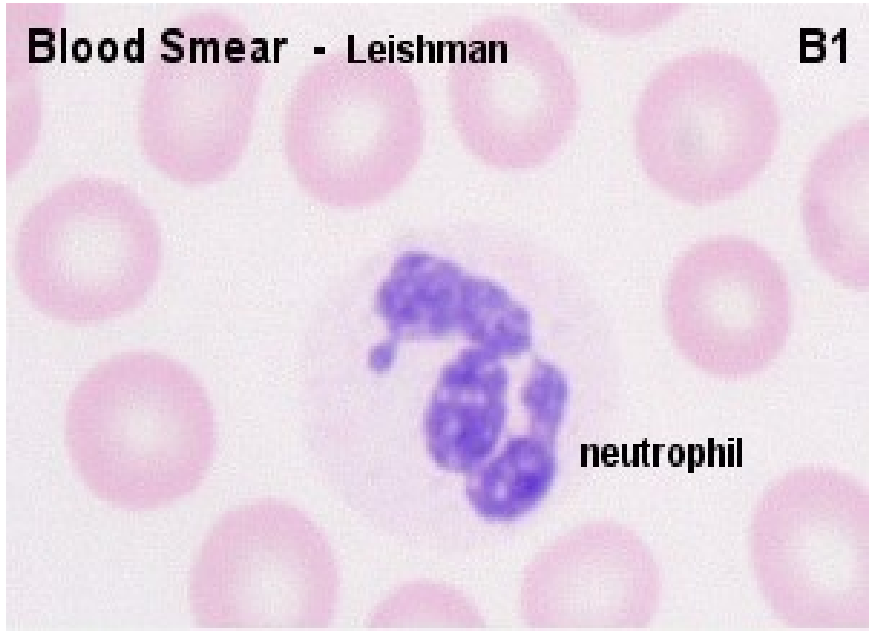
Neutrophil granulocytes (neutrophils)

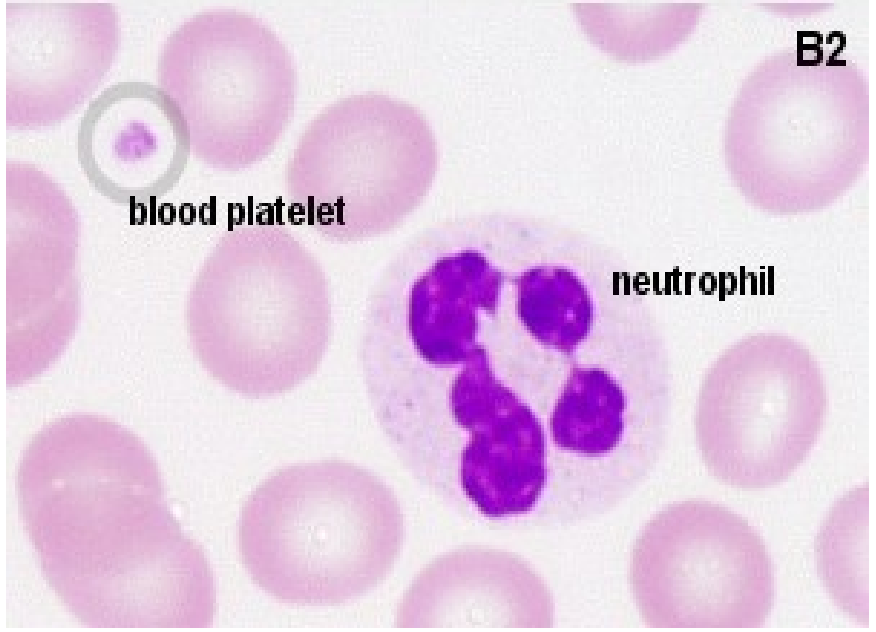
- 71 % of all white blood cells (DWCC)
- ∅ 10 – 12 μm
- Cytoplasm: bright pink (eosinophilic = acidophilic)
- Specific granules: neutrophilic (∅ 0.3 μm) (alcaline phosphatase, kolagenase, lysozyme, …)
- Nucleus:
  shaped (4 %)
  segmented (67 %)
  5 segments)

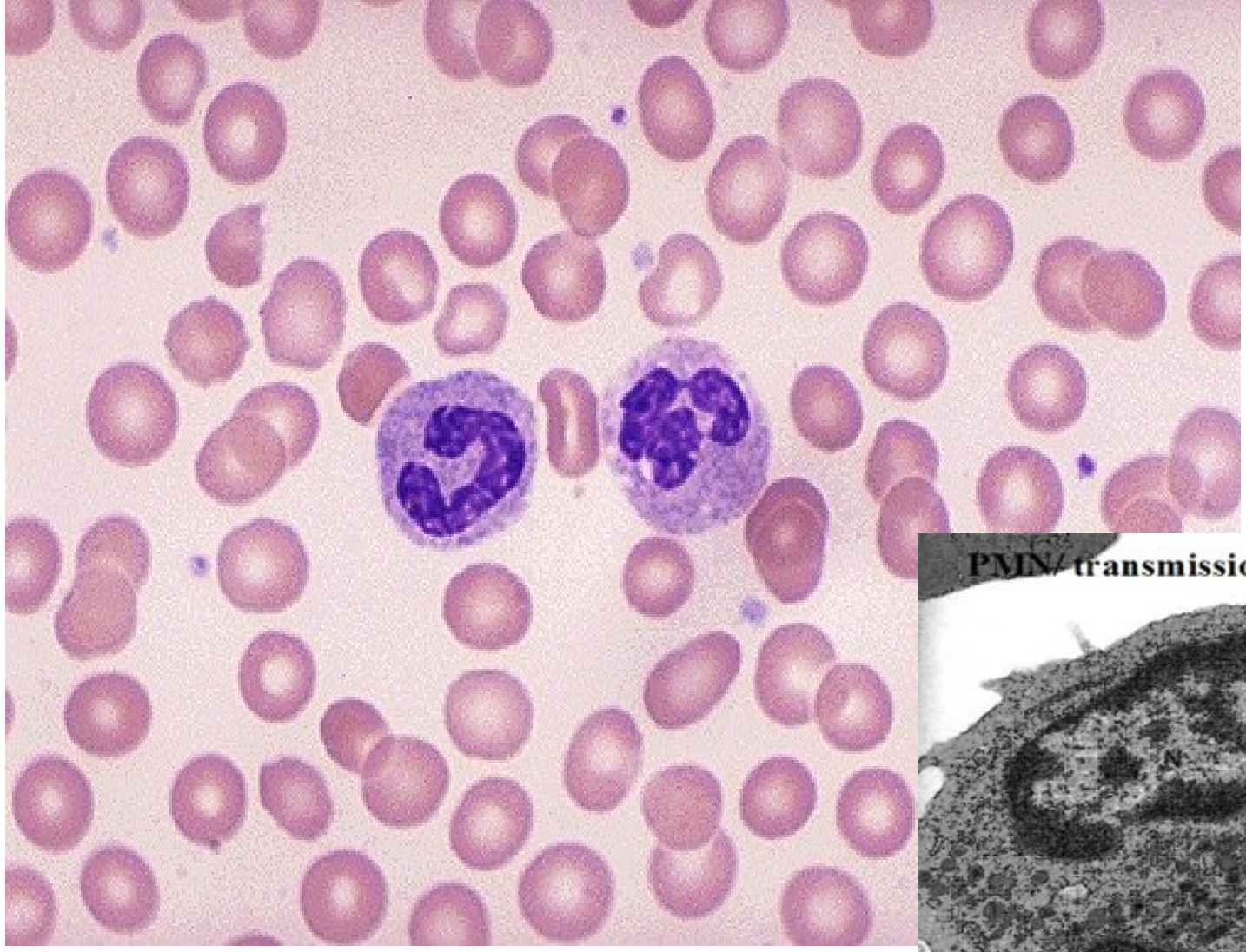


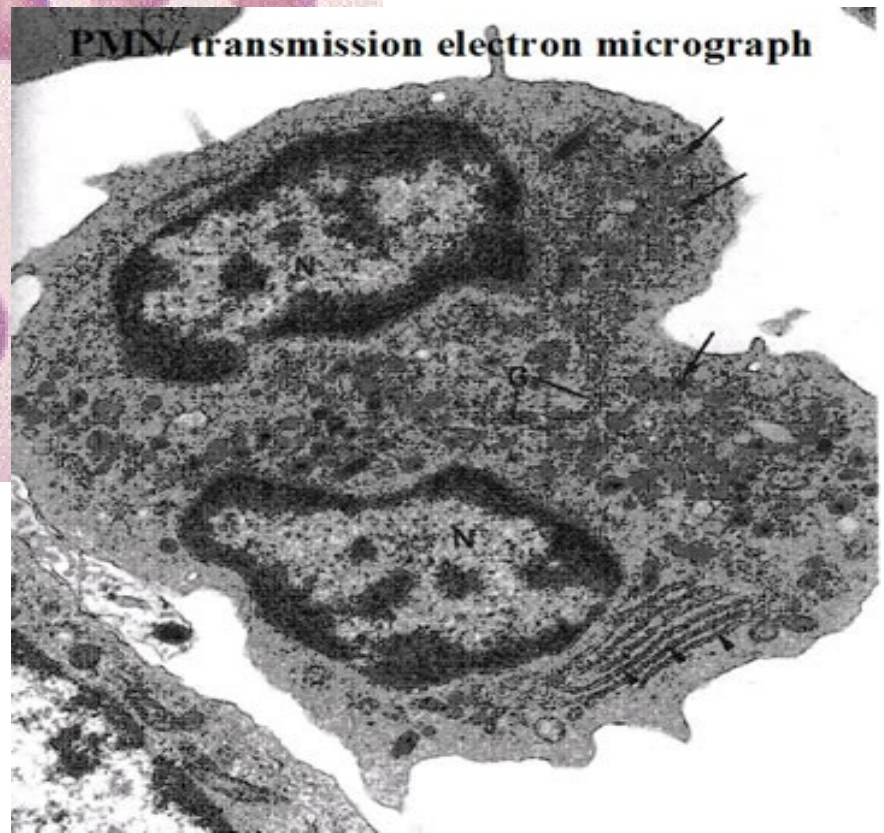





Blood Smear - Leishman
B1
neutrophil


B2
blood platelet
neutrophil




PMN/ transmission electron micrograph
N
G
N

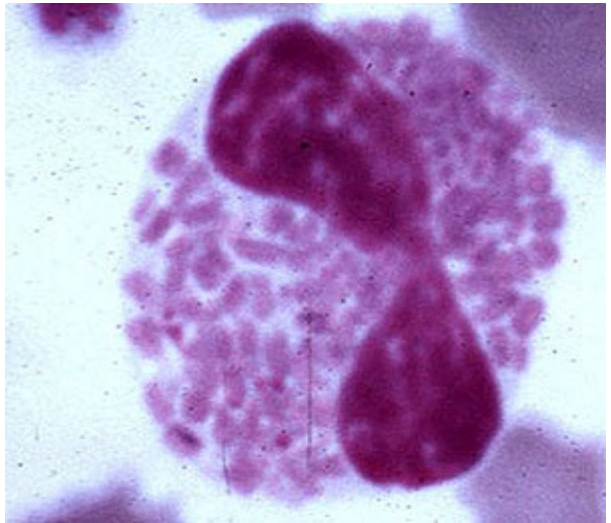
Functions of Neutrophils

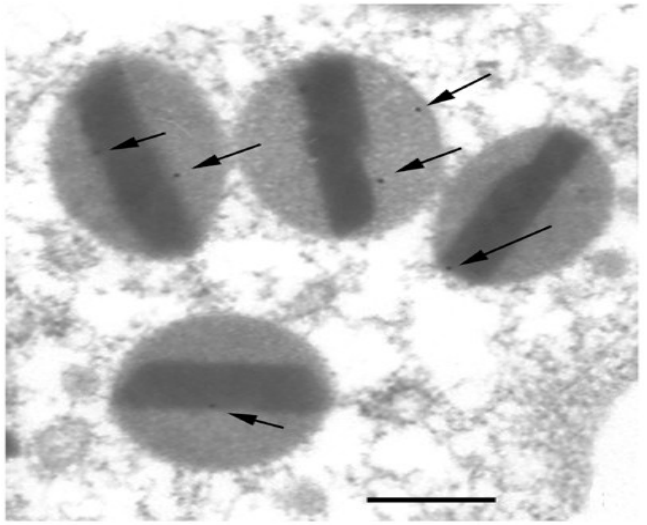
- a central role in inflammatory processes – Neu invade, by diapedesis from the vessels, sites of infection in response to factors (e.g. cytokines) released by cells which reside at an infection site.
- cell membrane receptors allow Neu to recognise foreign bodies (bacteria, tissue debris), which they begin to phagocytose and destroy.

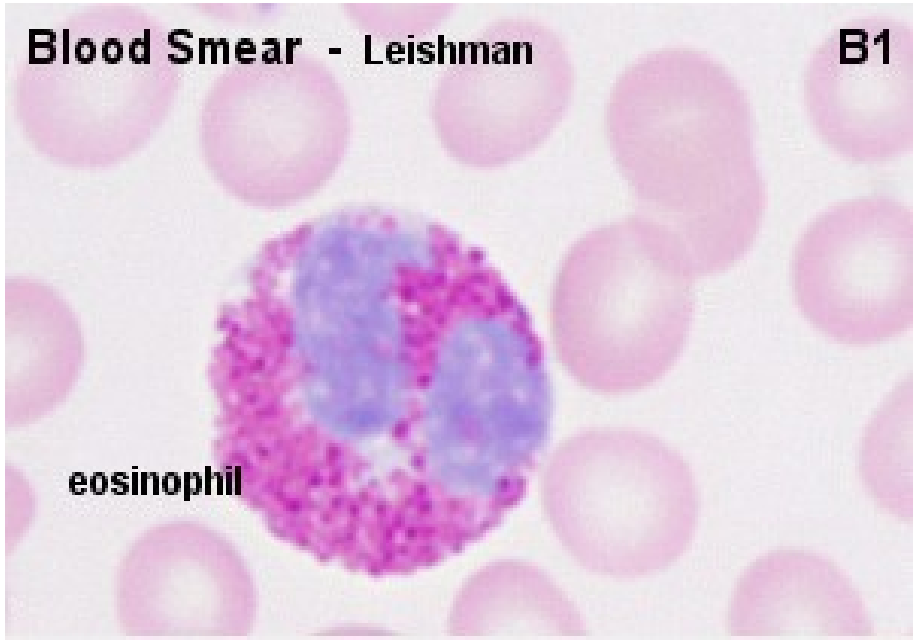
The Neu die once their supply of granules has been exhausted. Their lifespan is only about one week. Dead neutrophils and tissue debris are the major components of pus.

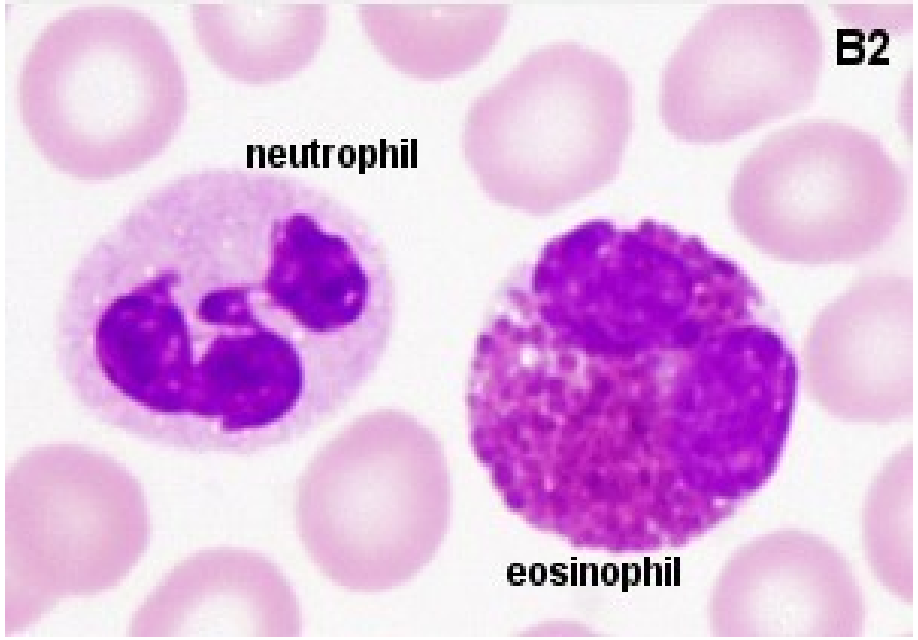
Eosinophil granulocytes (eosinophils)

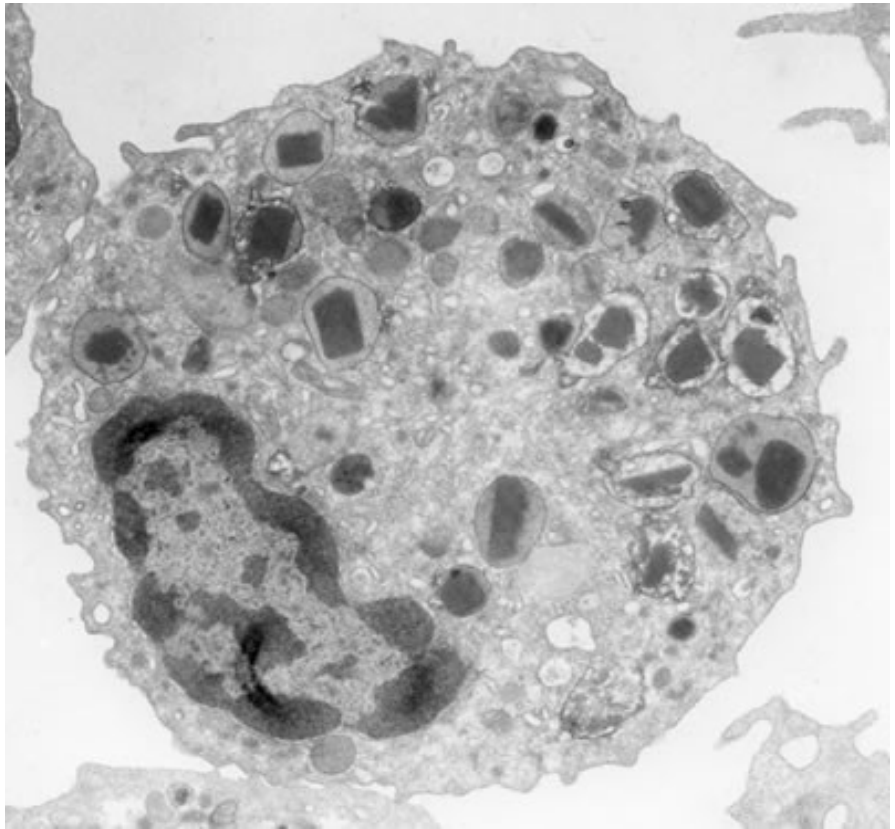
- 1– 4 % of all white blood cells (DWCC)
- ∅ 12 – 14 μm
- Cytoplasm: bright pink (eosinophilic = acidophilic)
- Specific granules: eosinophilic (∅ 0.5 – 1 μm)
  (enzymes: acid phosphatase, peroxidase,histaminase, arylsufatase …)
- Nucleus: dumb-belt, segments)






Blood Smear - Leishman
B1
eosinophil


B2
neutrophil
eosinophil

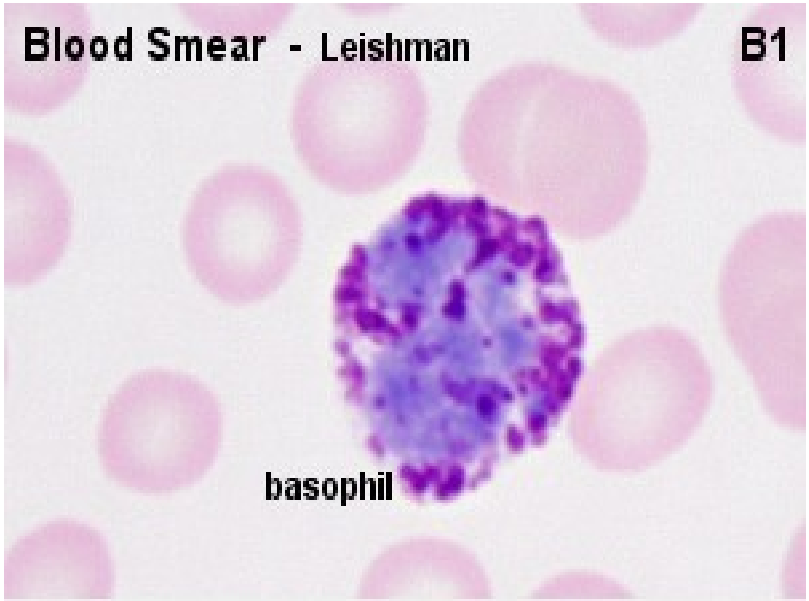


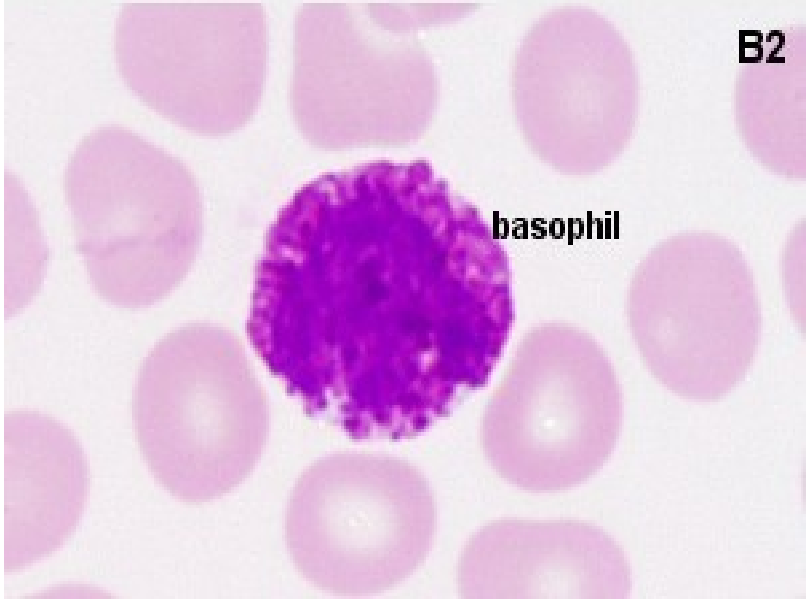
Functions of Eosinophils

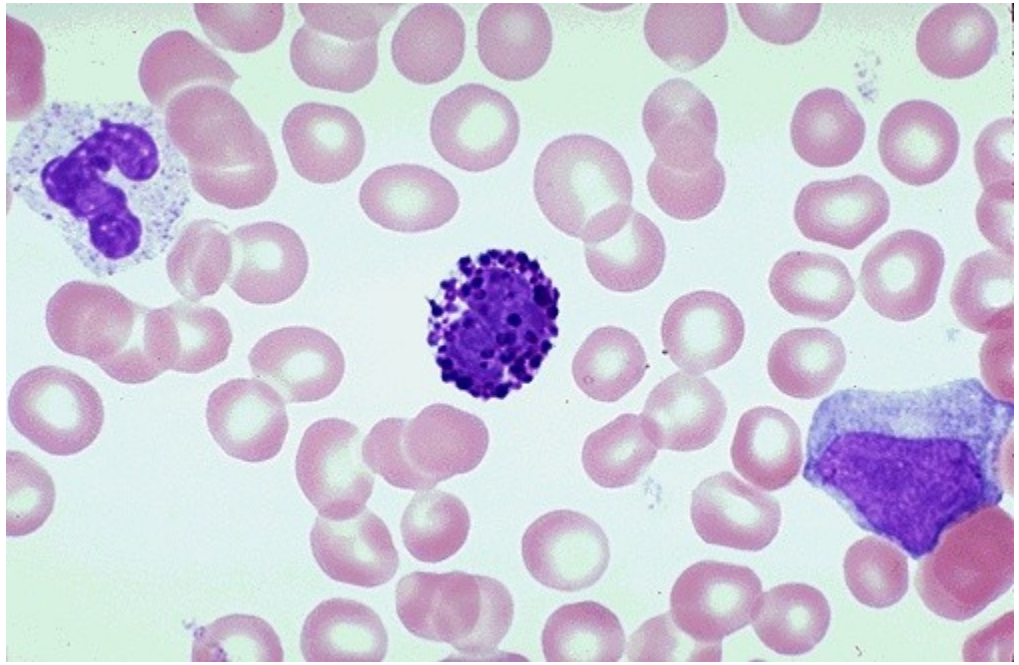
- phagocytosis of antibody-antigen complexes and prevention of the immune system from "overreacting„
- eos are involved in the response of the body against parasitic infections, which are accompanied by an increase in the number of eosinophils.

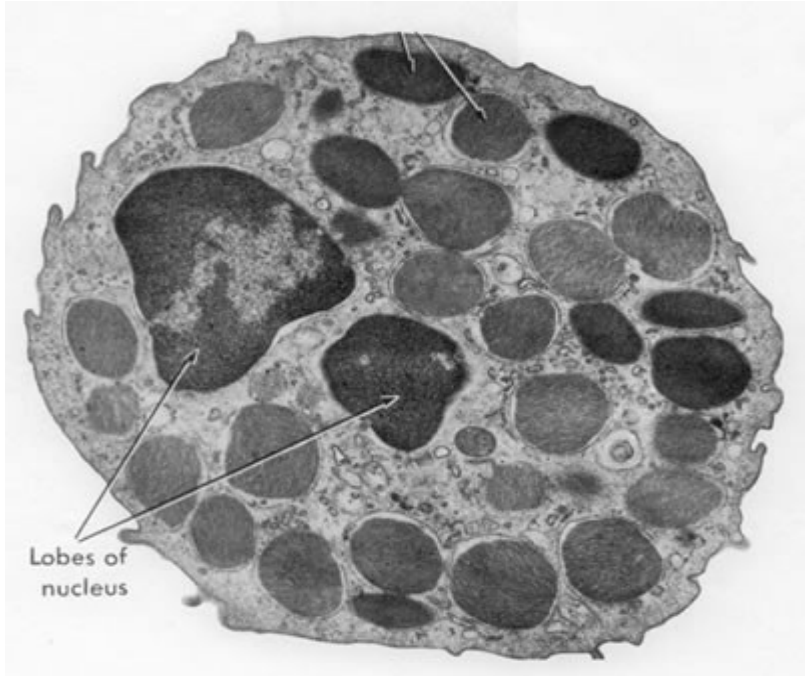
Basophil granulocytes (basophils)

- up to 1 % of all white blood cells (DWCC)
- ∅ up to 10 μm
- Cytoplasm: bright violet-pink (lightly basophilic)
- Specific granules: (∅ 2 μm) (heparin, histamin, …)
- Nucleus: „shape of dick S“


Blood Smear - Leishman
B1
basophil


B2
basophil




Lobes of
nucleus

Functions of Basophils

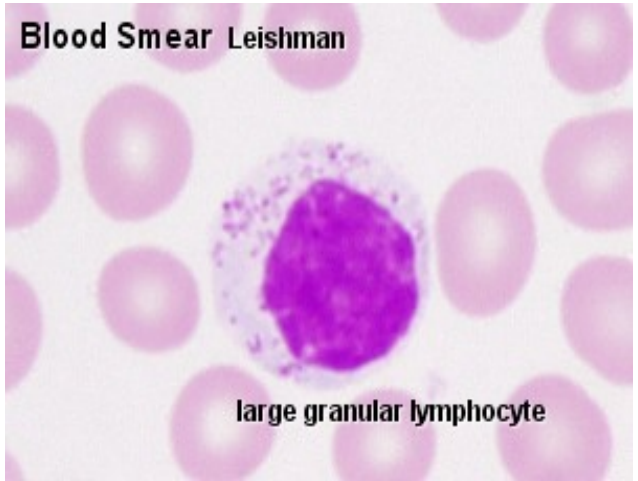
- heparin and histamine are vasoactive substances. They dilate the blood vessels, make vessel walls more permeable and prevent blood coagulation. They facilitate the access of heparinocyte in a site of infection.
- antibodies produced by plasma cells (activated B-lymphocytes) bind to the receptors on the plasma membrane of basophils. If these antibodies come into contact with antigens, they induce the release of the contents of the basophil granules.

Agranulocytes

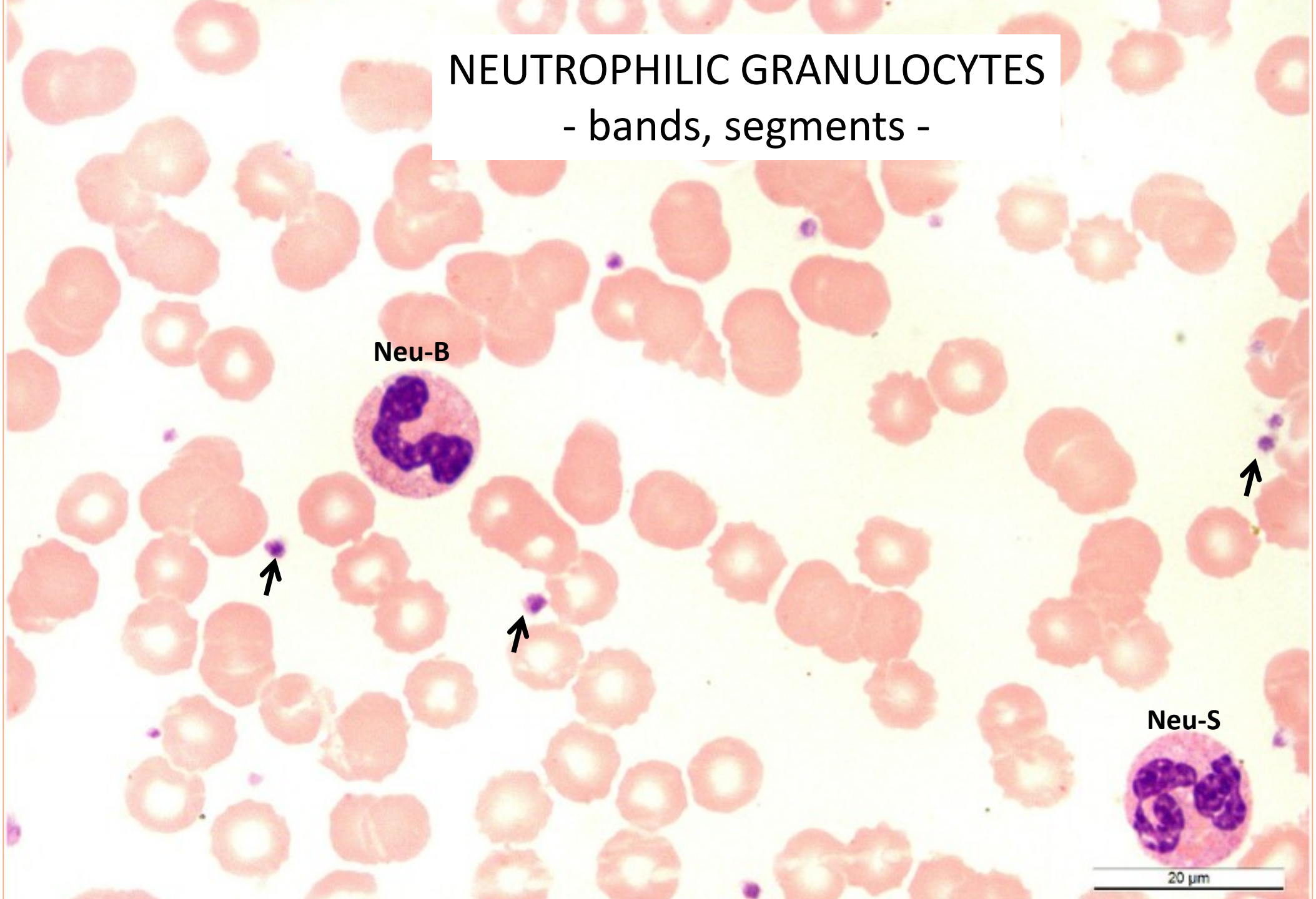
- General charcteristic:

- mononuclears – shape of nuclei is spherical, oval or bean-shaped

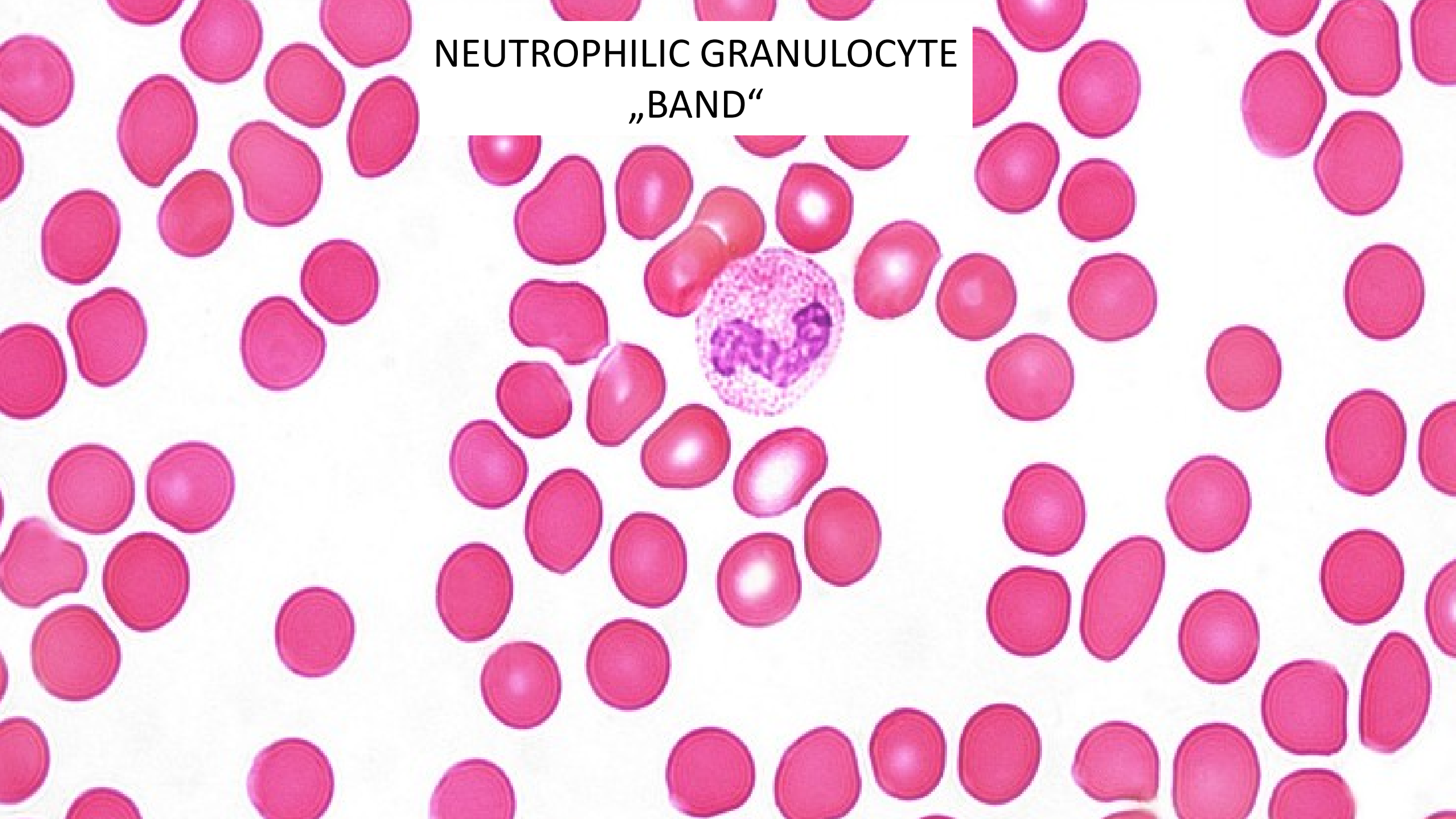
- basophilic cytoplasm – blue
- NO specific granules
- azurophilic ~~granules~~ lysosomal enzymes



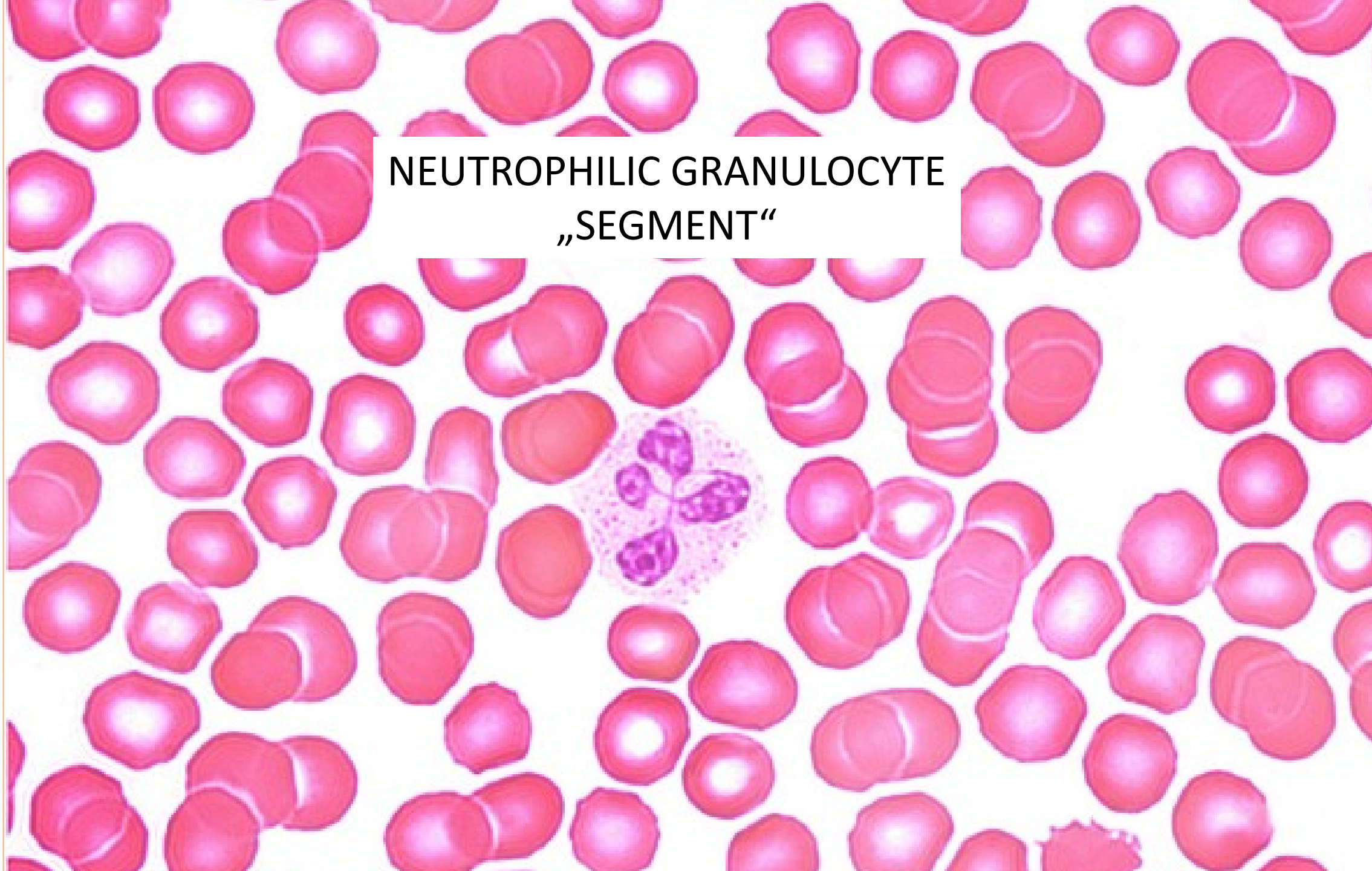
NEUTROPHILIC GRANULOCYTES
- bands, segments -



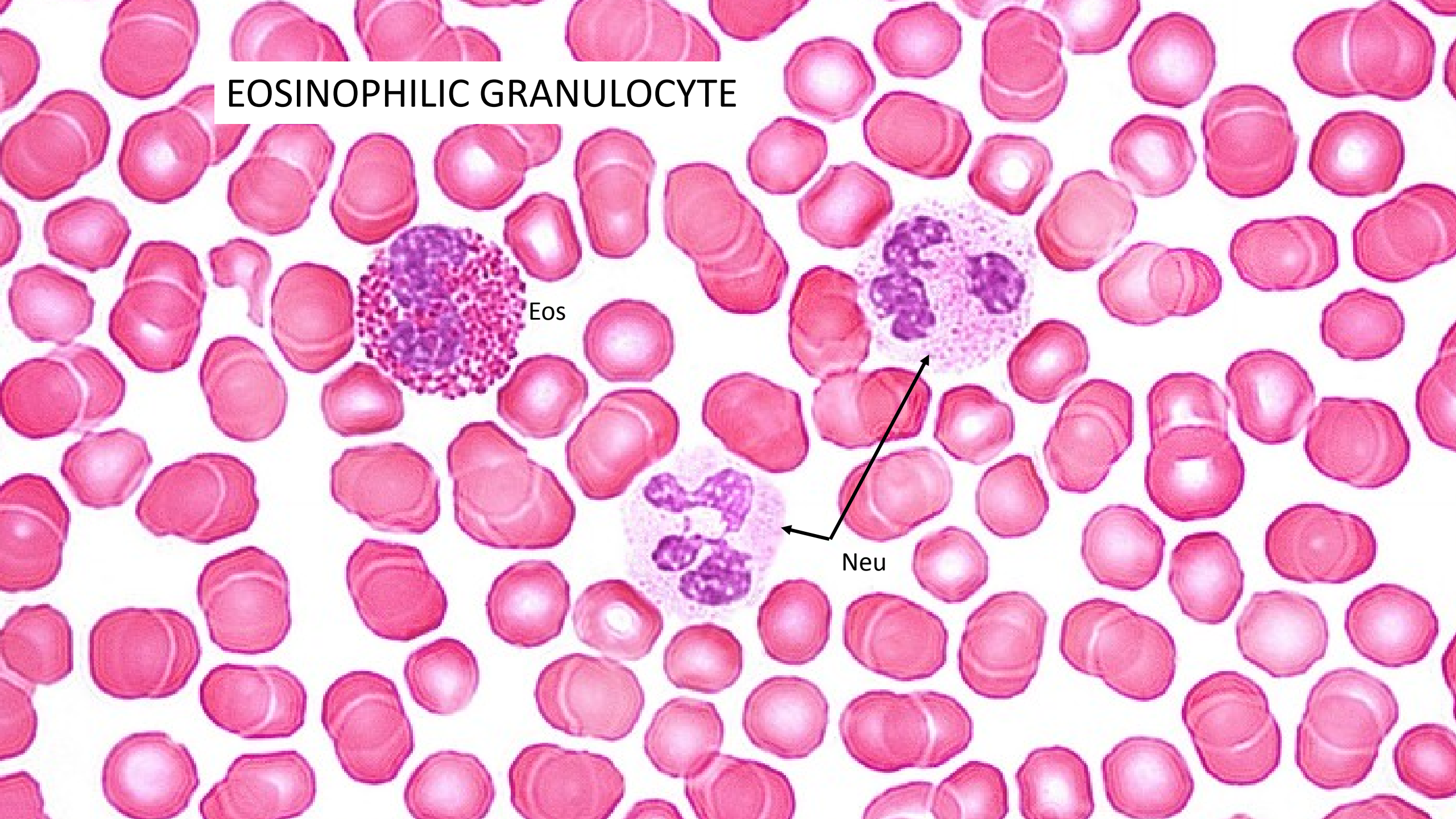
NEUTROPHILIC GRANULOCYTE
„BAND“



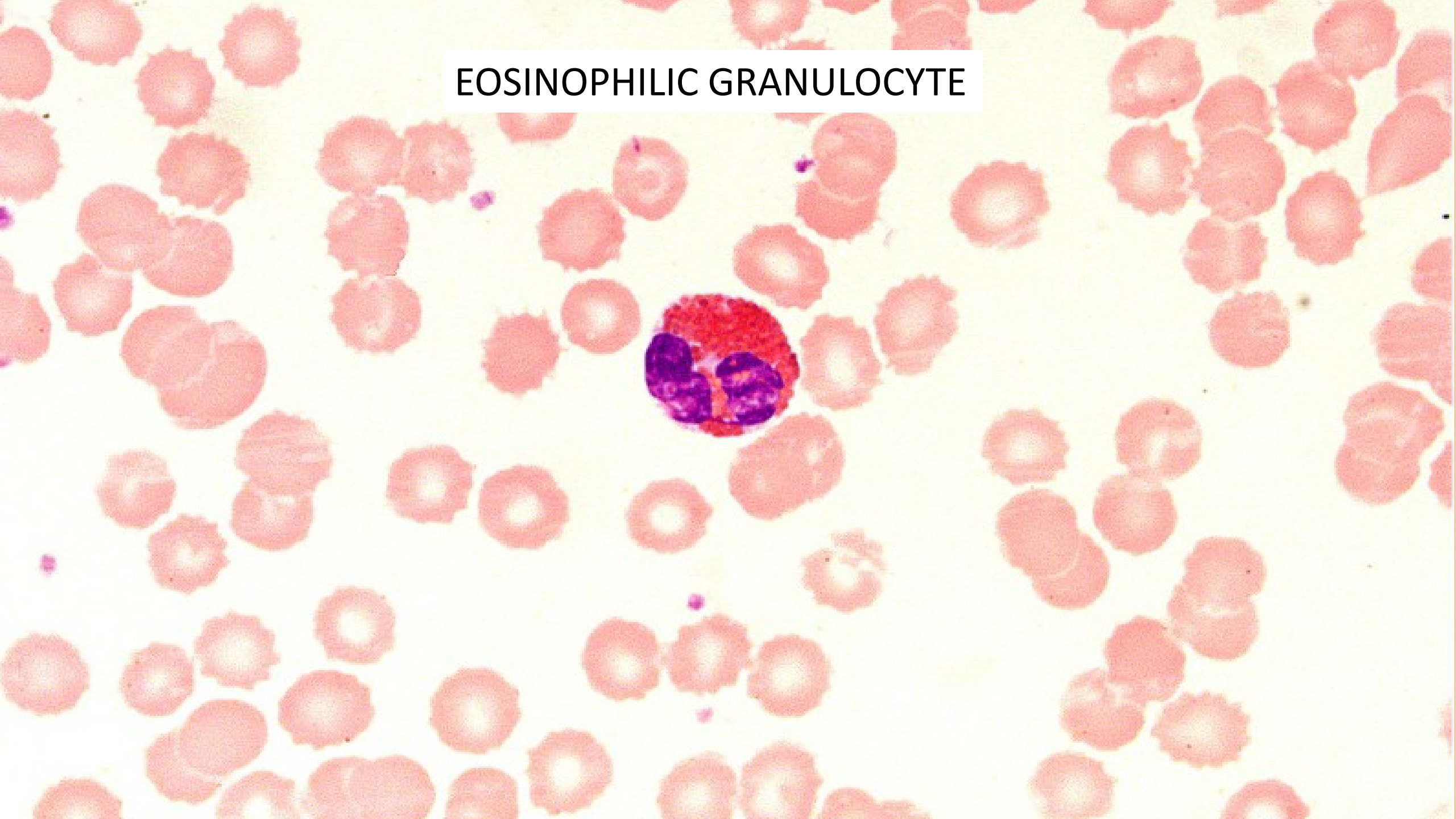
NEUTROPHILIC GRANULOCYTE
„SEGMENT“



EOSINOPHILIC GRANULOCYTE



EOSINOPHILIC GRANULOCYTE



EOSINOPHILIC GRANULOCYTE

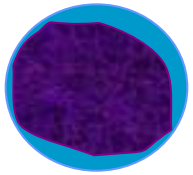
BASOPHILIC GRANULOCYTE

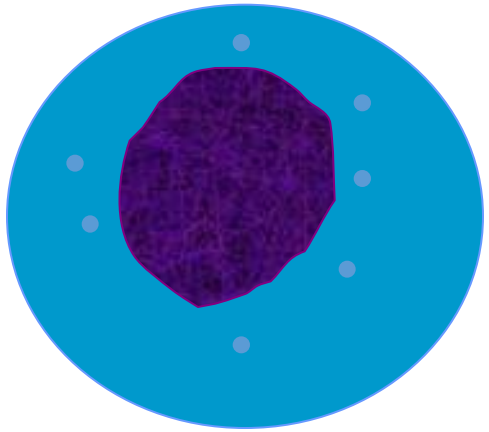
LYMPHOCYTES

- Classification:
  - according to origin – T-Ly (*thymus*), B-Ly (bone marrow ≅ bursa of Fabricius in birds)
  - according to the size – small (∅ 8 μm), medium (∅ 10-12 μm), large (∅ 16-18 μm),
  - according to the function – natural killer cells, helper cells, memmory cells, supressor cells,
  - according to life-span

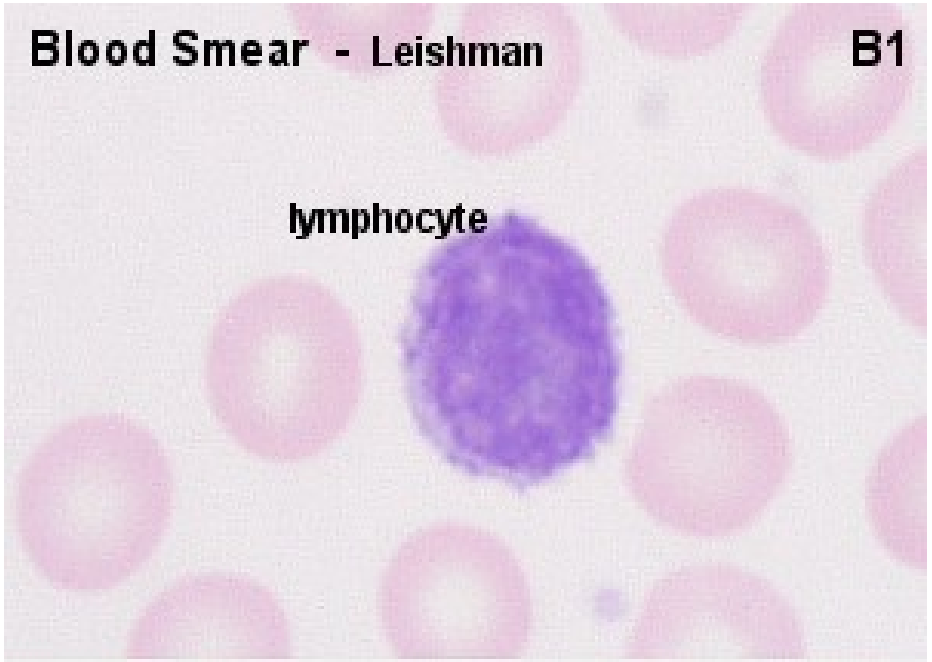
Lymphocytes - structure

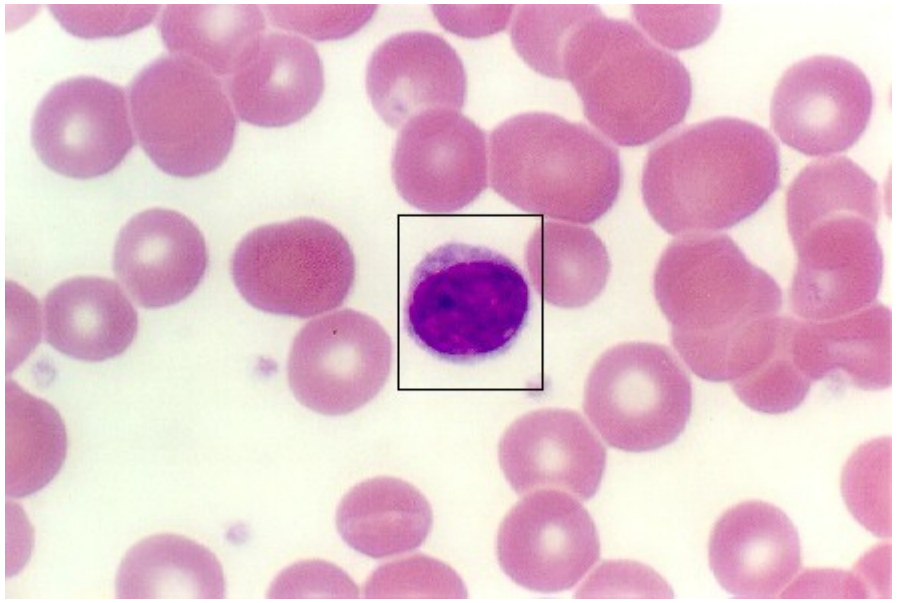
- 20 % of all white blood cells (DWCC)

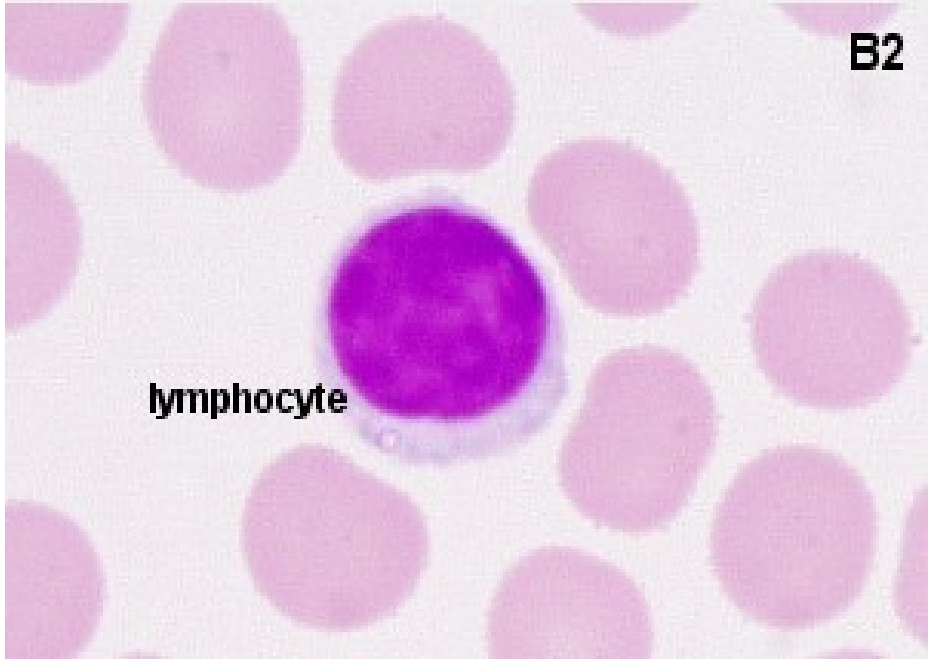


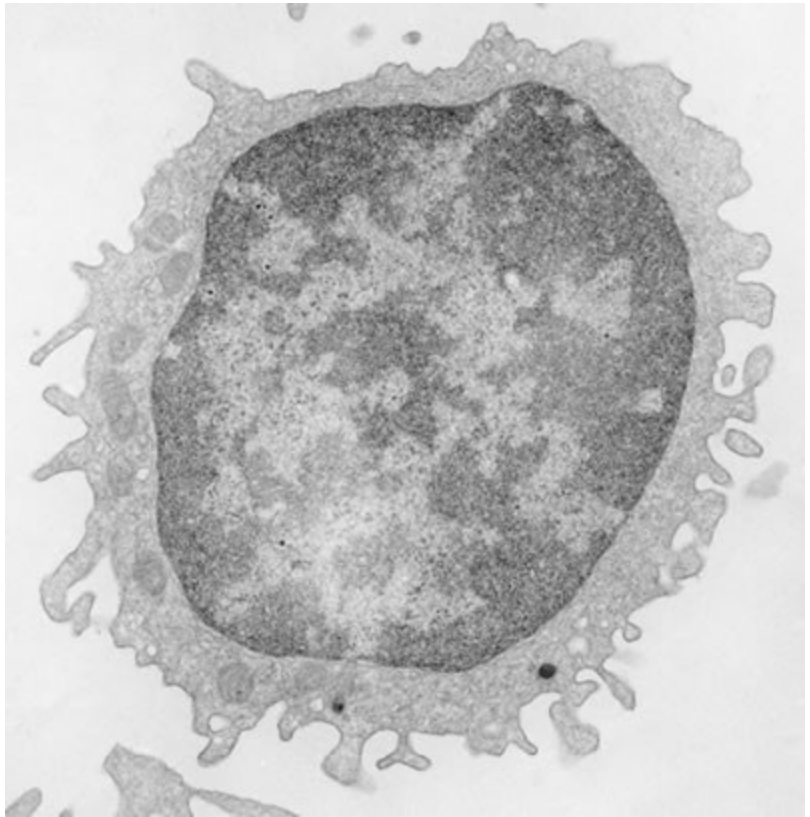


- small, medium-sized, large Ly
- cytoplasm – dark blue, contains non-specific azurophilic granules with lysosomal enzymes (hydrolases) and numerous ribosomes
- nucleus – round, hyperchromatic – coarse grains of heterochromatin (*dark violet colour*)


Blood Smear - Leishman
B1
lymphocyte

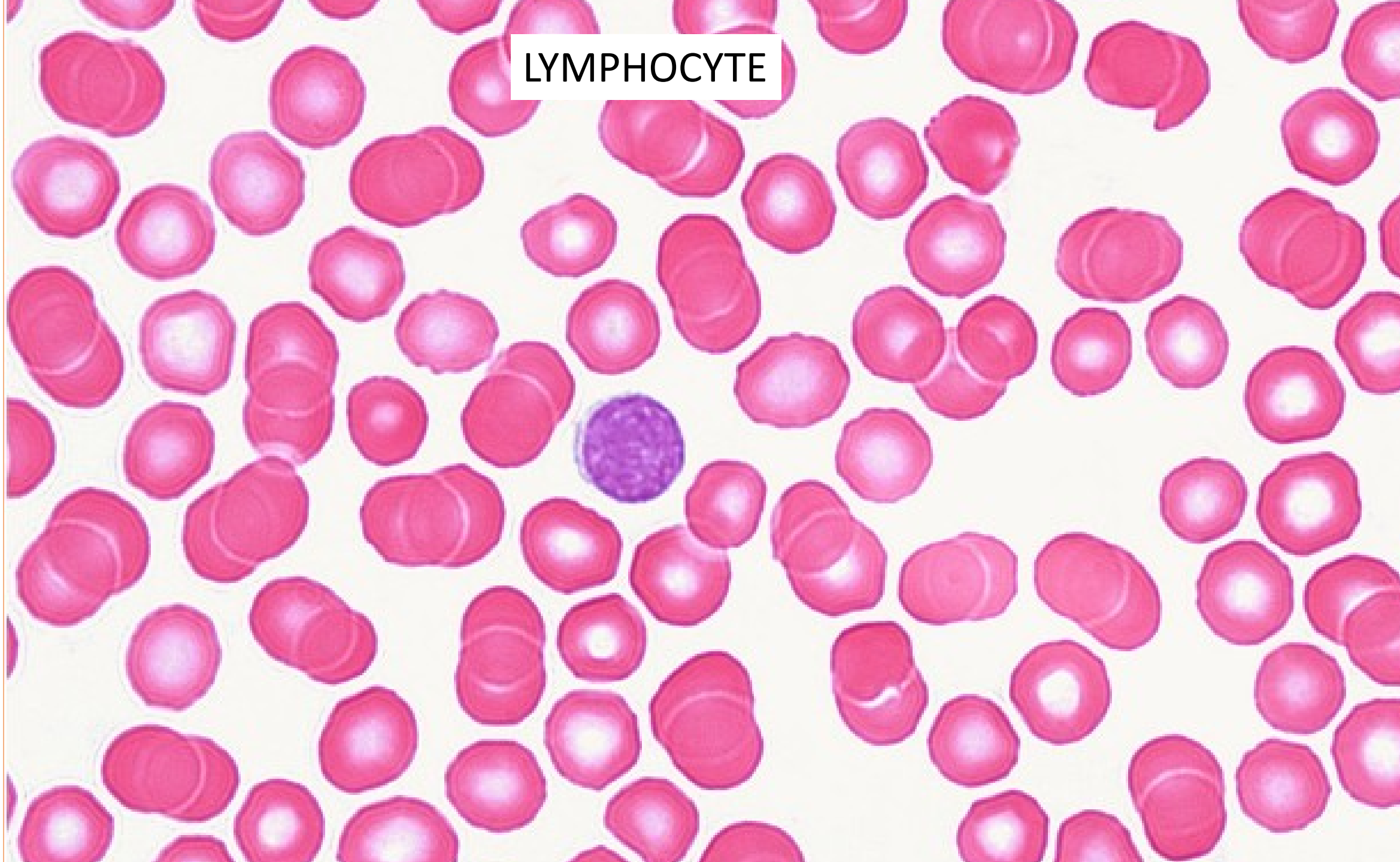



B2
lymphocyte



Functions of Lymphocytes

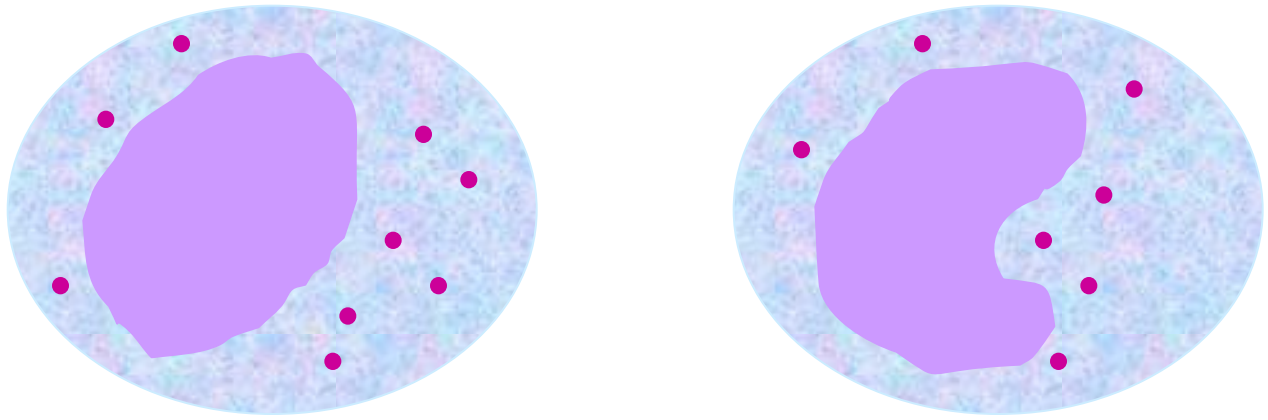
- B-lymphocytes differentiate into antibody producing plasma cells and so they represent "humoral immunity"
- T-lymphocytes represent the "cellular immunity" and may attack foreign cells, cancer cells and cells infected by e.g. a virus

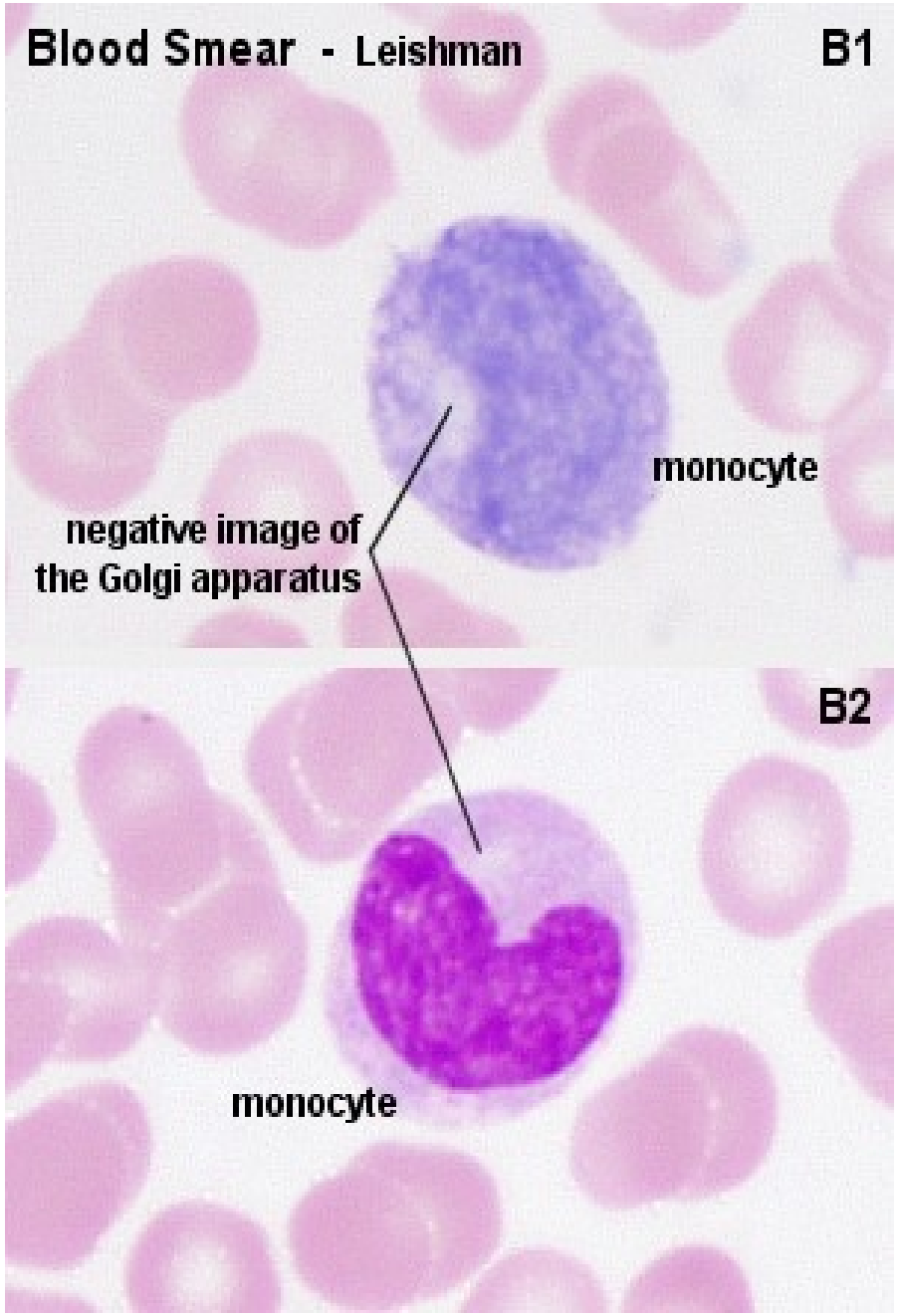

LYMPHOCYTE

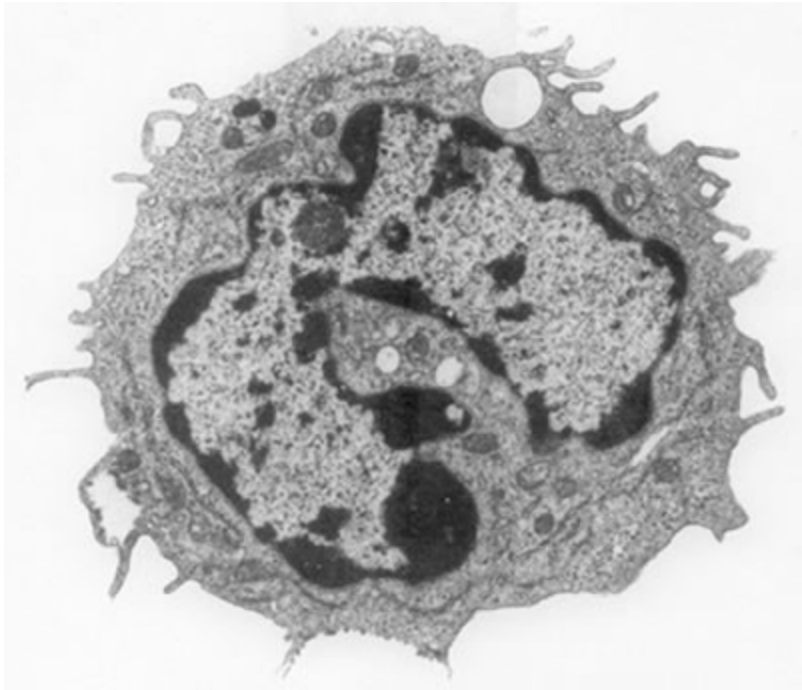

LYMPHOCYTE
0,5 µm

MONOCYTES

- 5 % (DWC), ∅ 15 – 20 μm
- cytoplasm – voluminous, bright blue, contains non-specific azurophilic granules with lysosomal enzymes (hydrolases) and numerous ribosomes
- nucleus – oval to bean-shaped, finely dispersed chromatin




Blood Smear - Leishman
B1
monocyte
negative image of
the Golgi apparatus
B2
monocyte

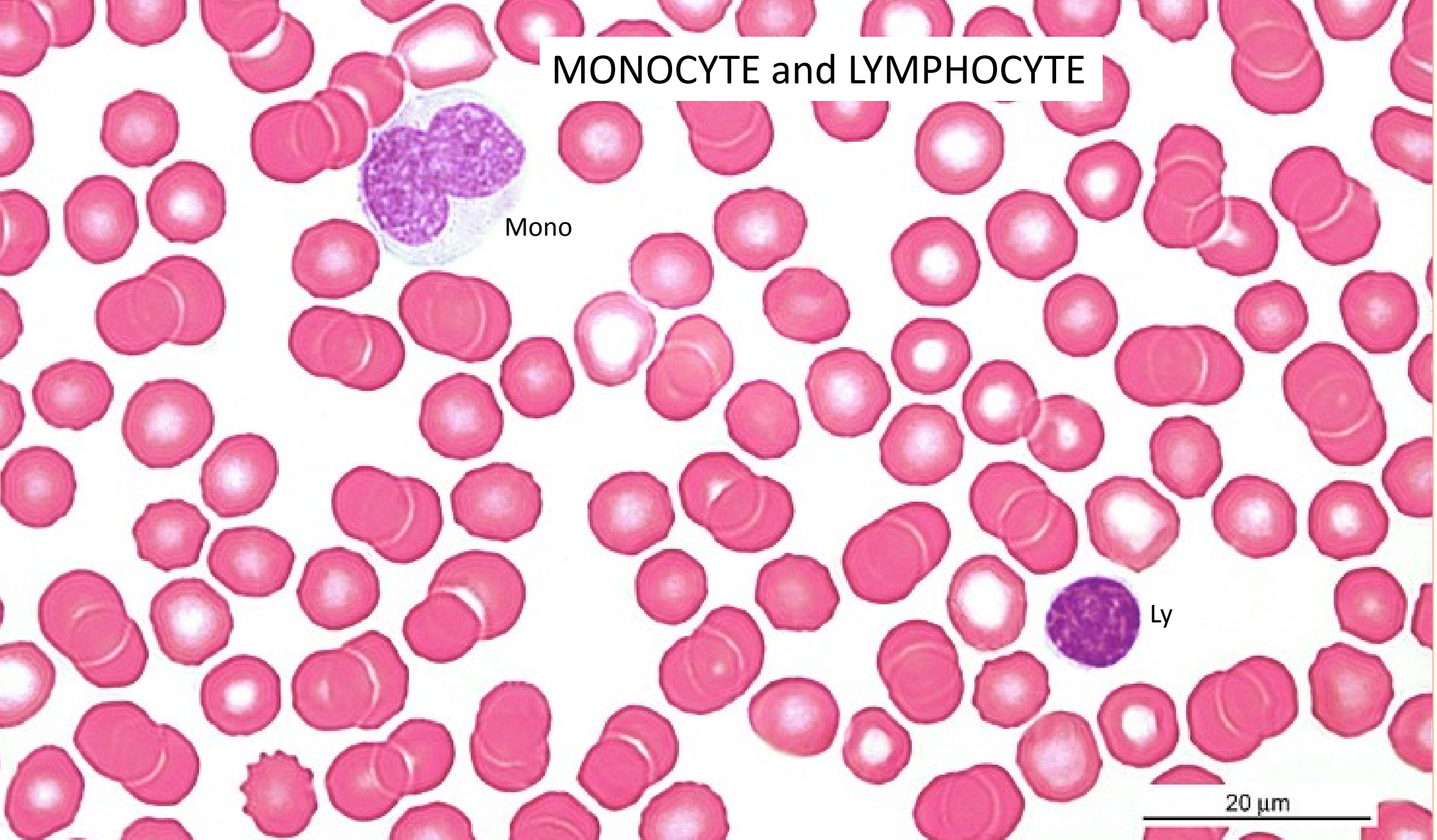


Functions of Monocytes

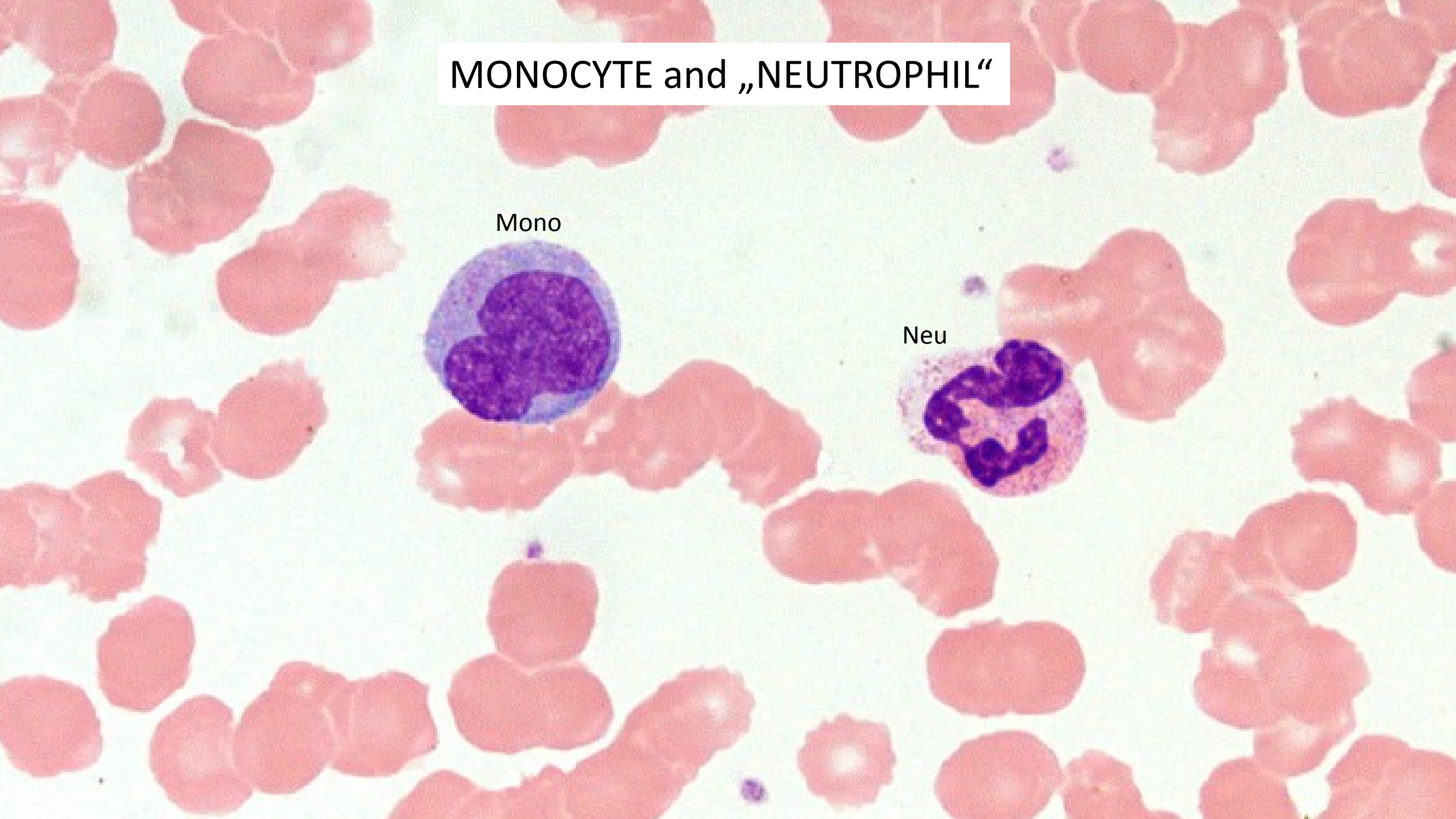
- *monocytes enter the connective tissue they differentiate into macrophages*. At sites of infection macrophages are the dominant cell type after the death of the invading neutrophils.
- macrophages phagocyte microorganisms, tissue debris and the dead neutrophils.

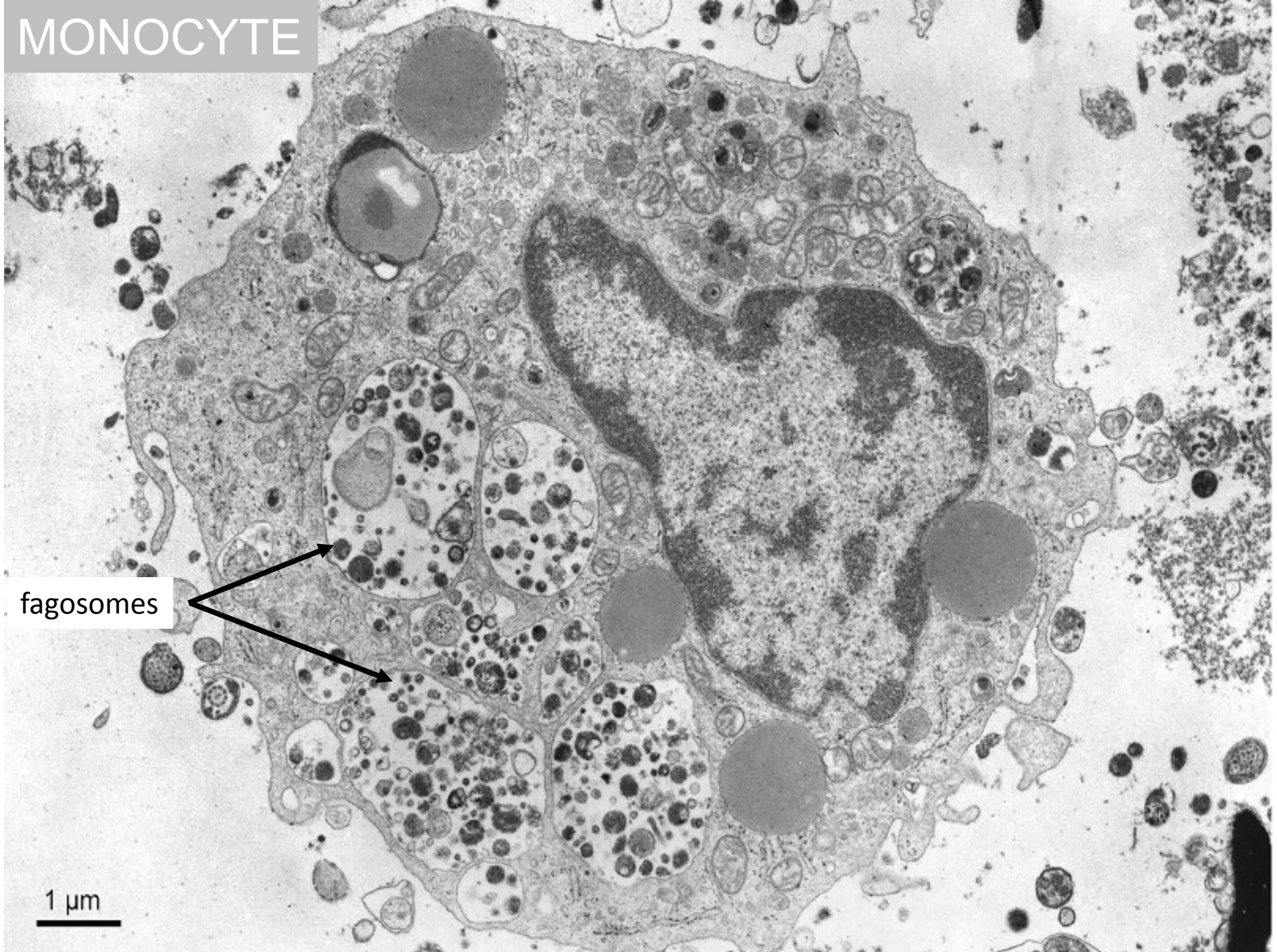
- *mono also give rise to osteoclasts, which are able to distroy bone. They are of importance in bone remodelling.*

MONOCYTE and LYMPHOCYTE



MONOCYTE and „NEUTROPHIL“




MONOCYTE
fagosomes
1 µm

THROMBOCYTES (blood platelets)

- 150,000 – 300,000 / 1 μl of blood
- thrombocytosis X thrombocytopenia
- - are not cells, but cytoplasmic fragments of large cell (megakaryocyte) in bone marrow
- shape: spindle-shaped discoid plate
- size: 2 – 4 μm
- cytoplasm – basophilic (bright violet-blue), contains microtubules and α,δ and λ granules:

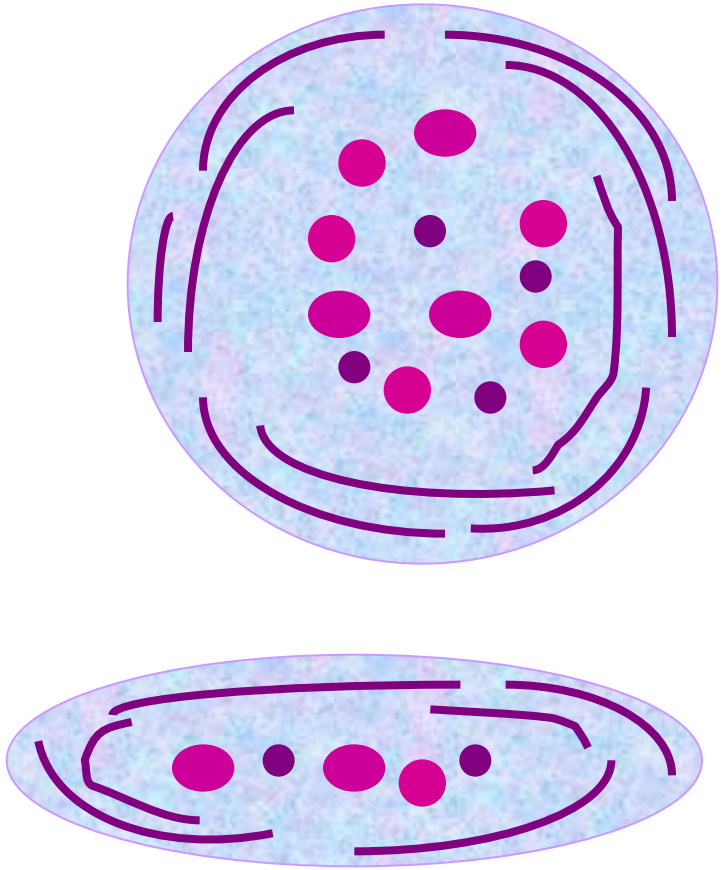
  alpha granules – fibrinogen, …

  delta granules – serotonin, Ca ions, ATP and ADP,…

  lambda granules – are small lysosomes

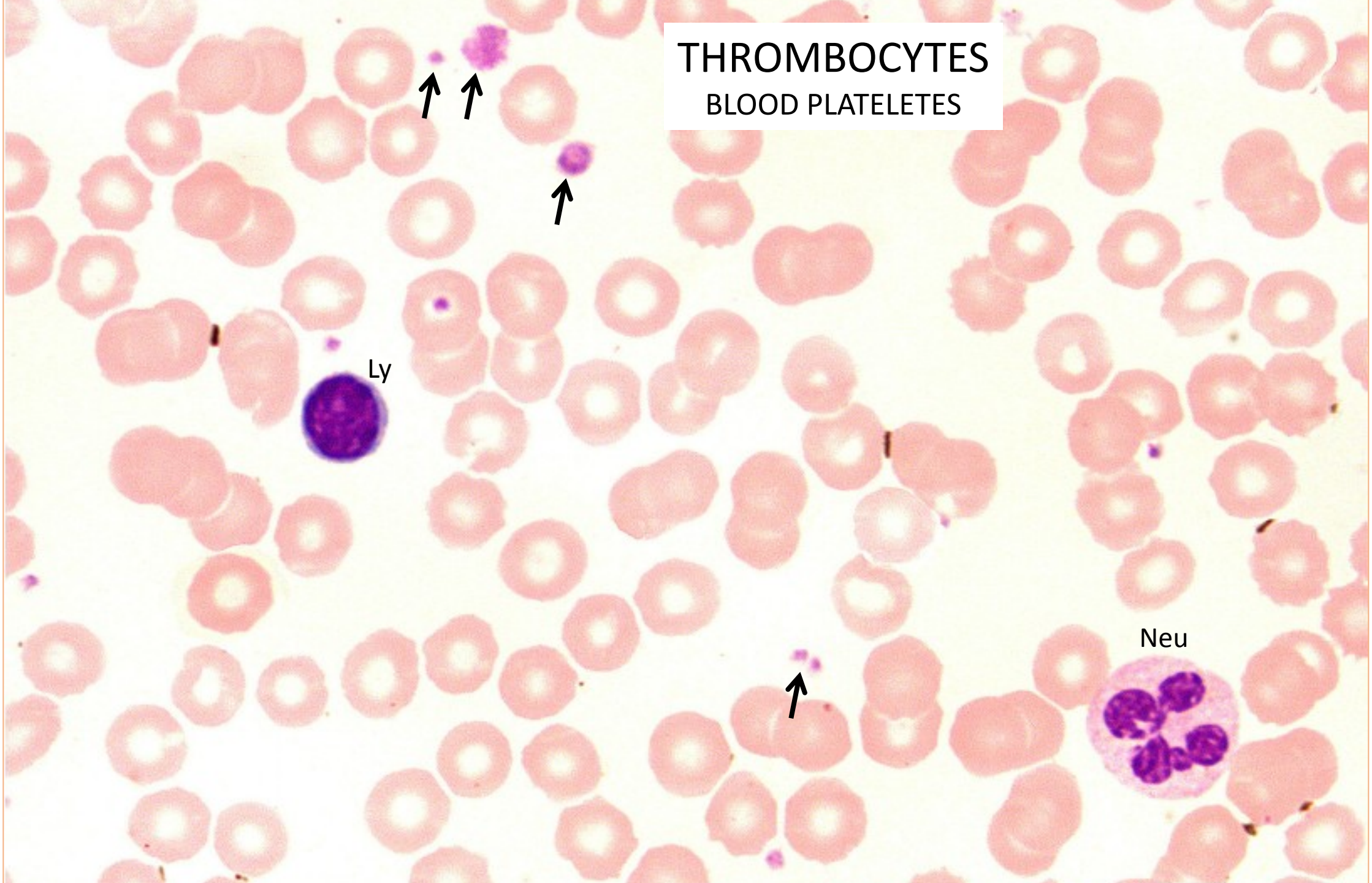
Platelet structure

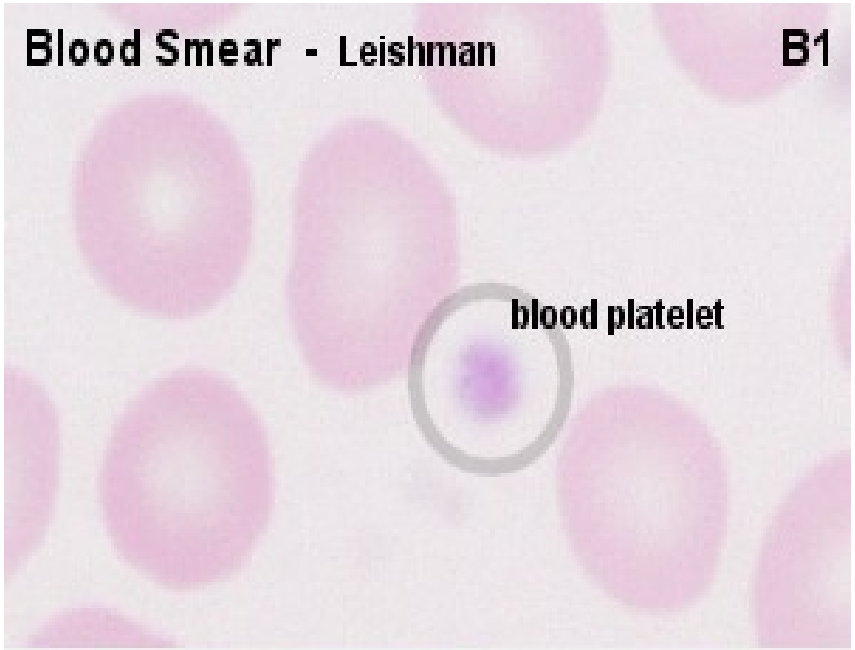
- Hyaloplasm contains microtubules (on the periphery of platelet)
- Granuloplasm contains granules

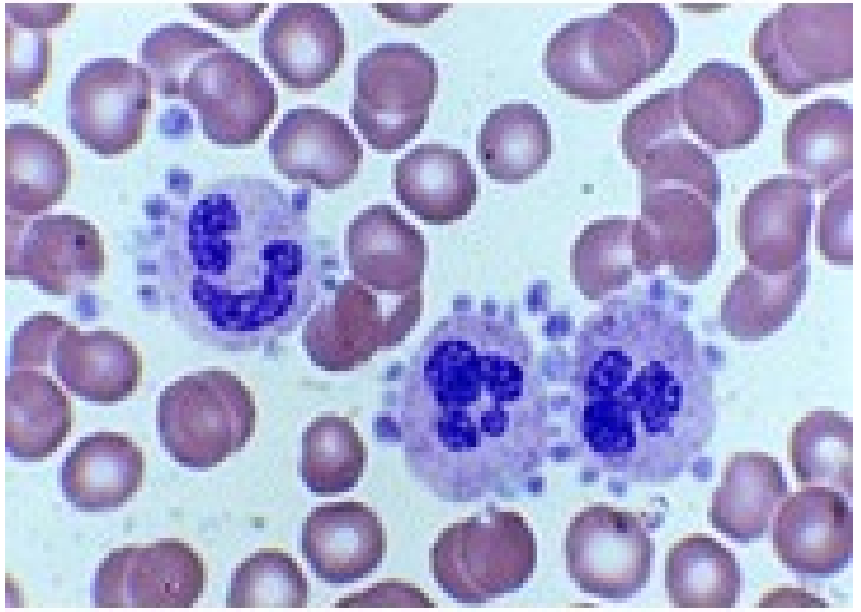


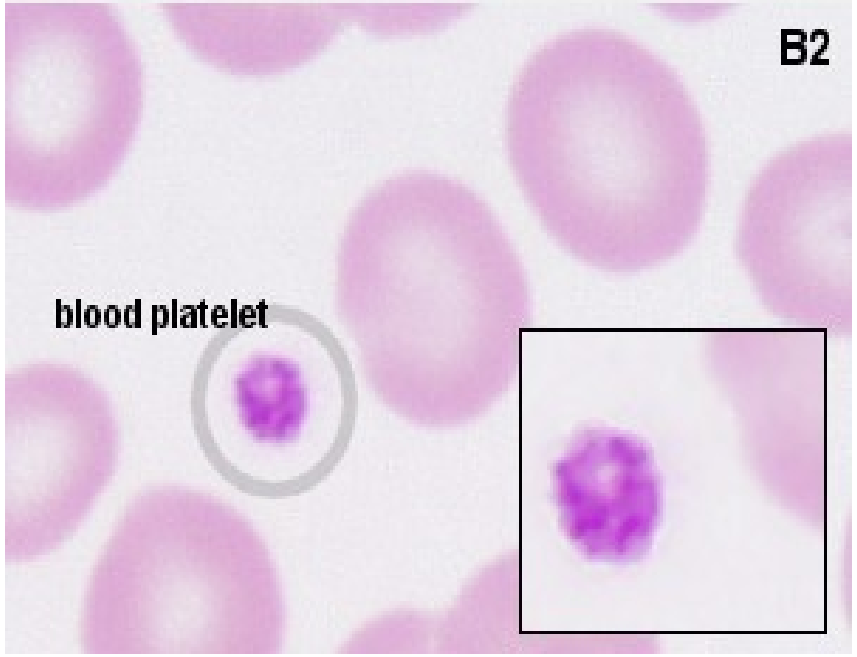
Functions of thrombocytes

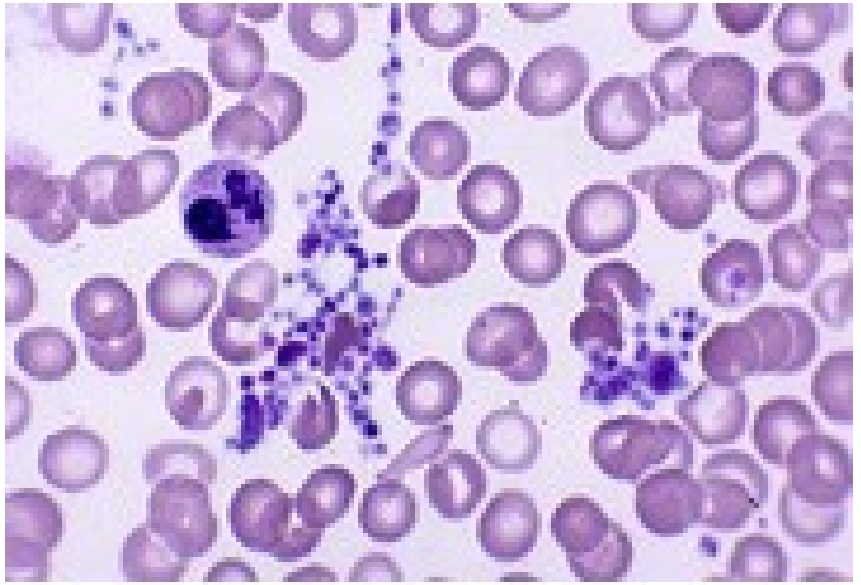
- Platelets assist in ***haemostasis***, *the arrest of bleeding*.
- Serotonin is a vasoconstrictor. Its release from thrombocytes, adhering to the walls of a damaged vessels, is sufficient to close even small arteries. Platelets, which come into contact with collagenous fibers in the walls of the vessel, swell, become "sticky" and activate other platelets to undergo the same transformation. This cascade of events results in the formation of a *platelet plug (or platelet thrombus)*. Finally, activating substances are released from the damaged vessel walls and from the platelets. These substances mediate the conversion of the plasma protein *prothrombin* into *thrombin*. *Thrombin catalyzes the conversion of fibrinogen into fibrin*, which polymerizes into fibrils and forms a fibrous net in the arising blood clot. Platelets captured in the fibrin net contract leading to *clot retraction*, which further assists in haemostasis.


THROMBOCYTES
BLOOD PLATELETES
Ly
Neu

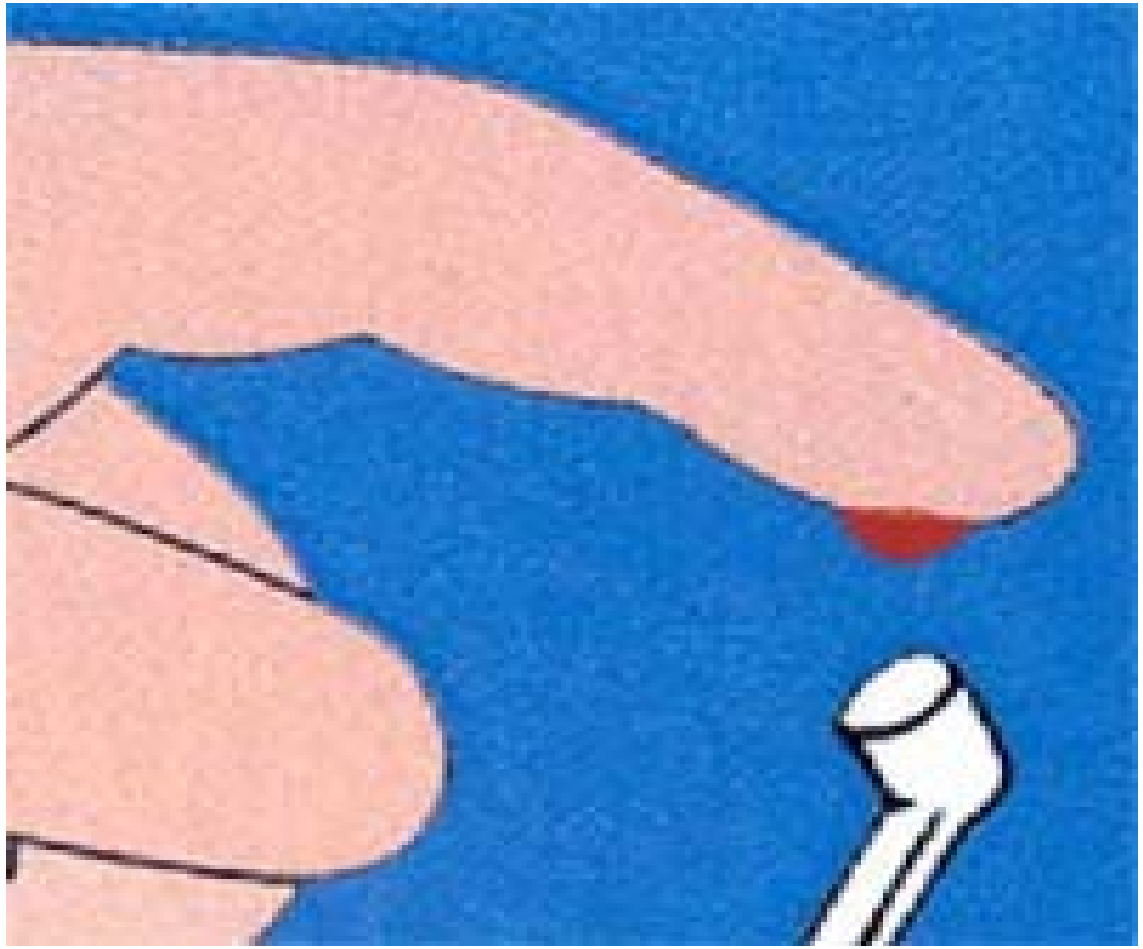

Blood Smear - Leishman
B1
blood platelet




B2
blood platelet

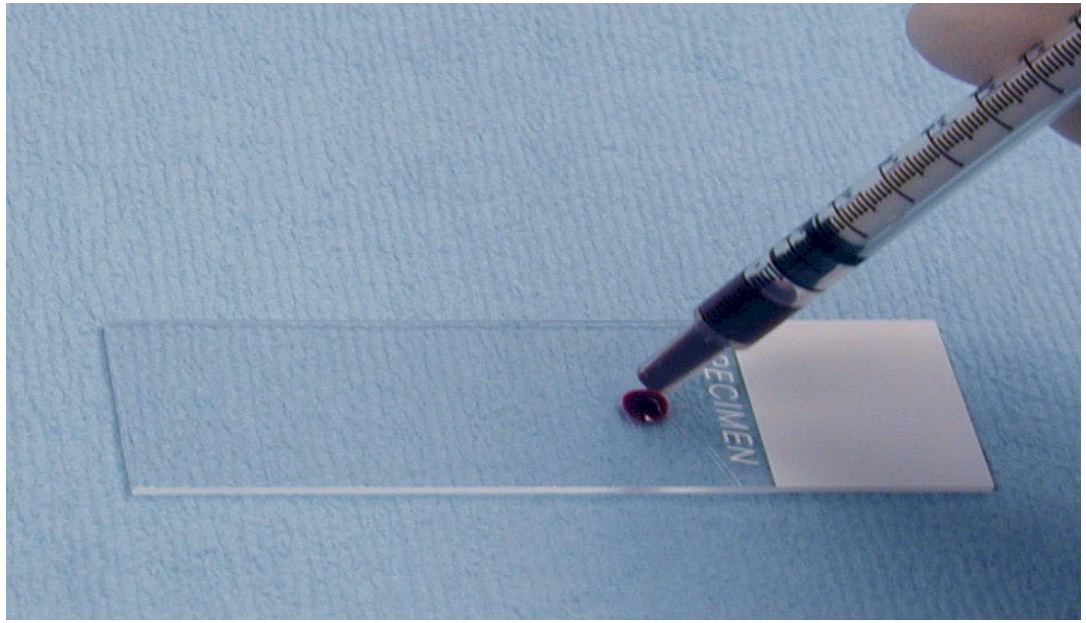


How to prepare blood smear?



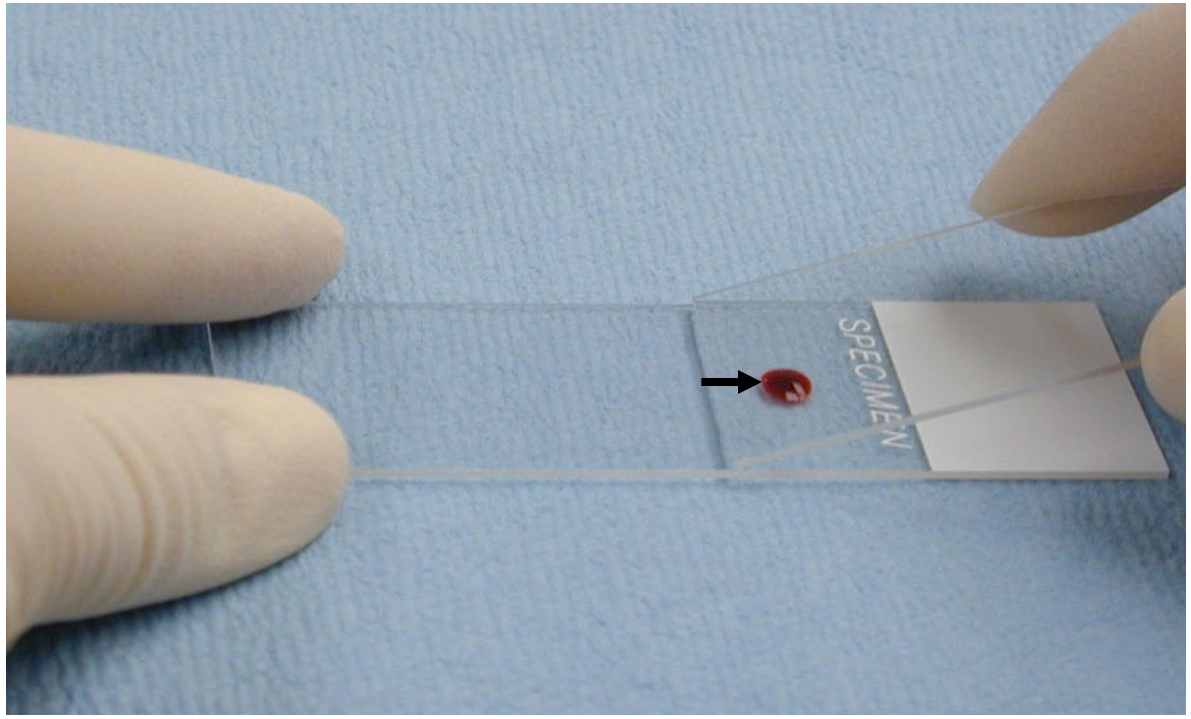
How to prepare blood smear - I

- Smears of peripheral blood must be made immediately.
- Step 1. Place drop of blood about 1cm from the frosted end of a clean slide.



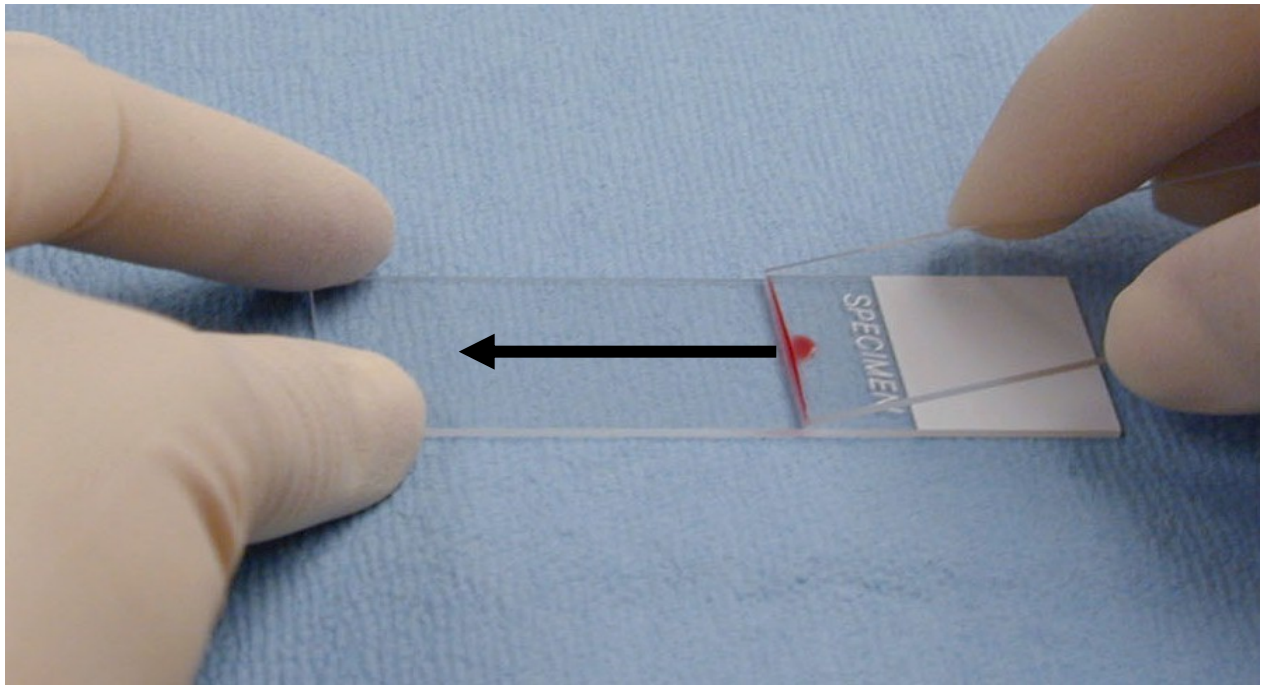
How to prepare blood smear - II

- Step 2. hold the end of a second slide (“spreader”) against the surface of the first slide at an angle of 30-45 degrees.



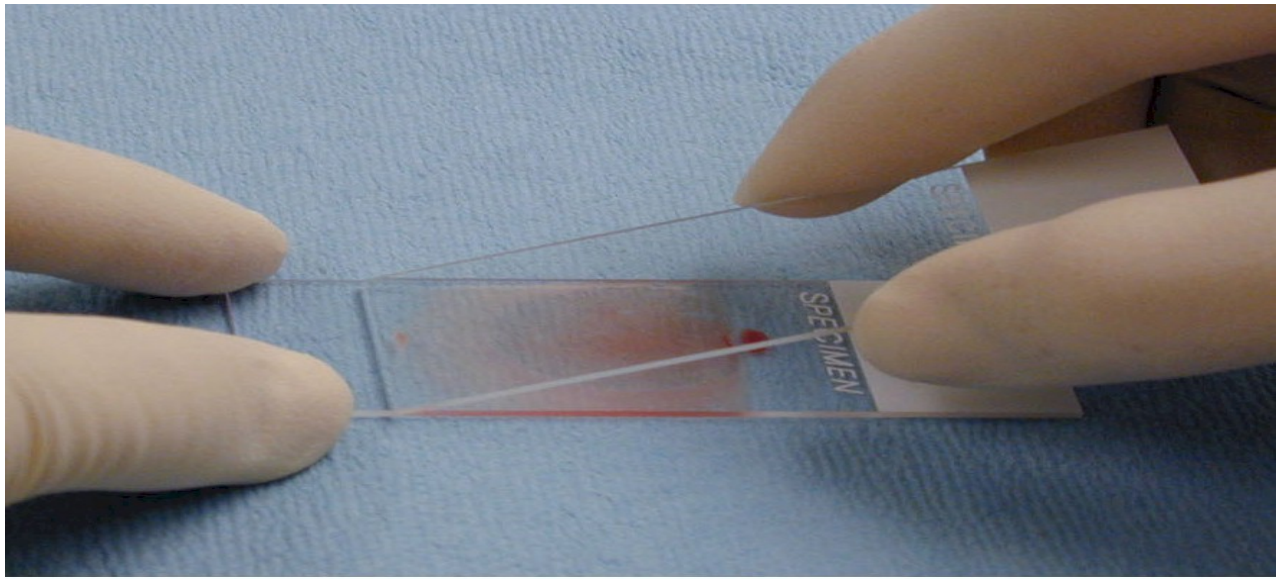
How to prepare blood smear - III

- Step 3. draw it back to contact the drop of blood. Allow the blood to spread and fill the angle between the two slides.



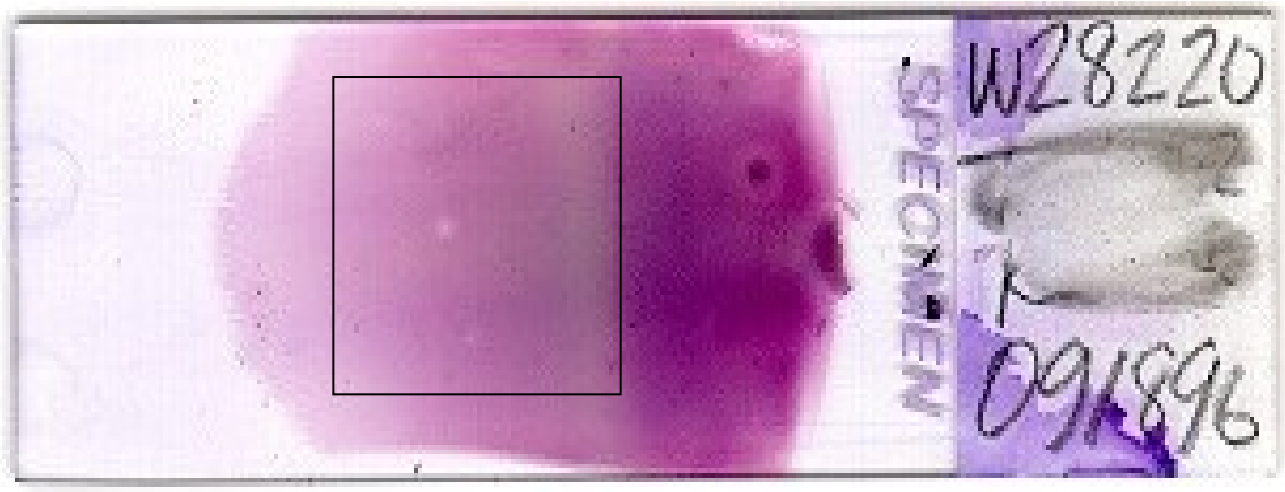
How to prepare blood smear - IV

- Step 4. Push the “spreader” slide at a moderate speed forward until all of the blood has been spread into a moderately thin film.



How to prepare blood smear - V

- prepared smear for fixation (methyl alcohol, 3-5 minutes) and staining (special panoptic method according to Pappenheim can be used)



Light microscope manipulation

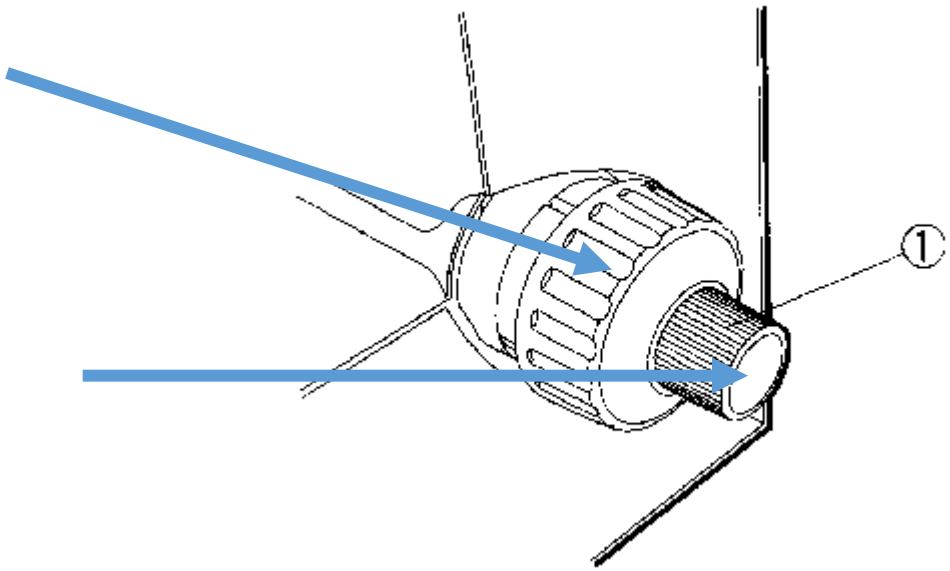
DO NOT USE TODAY

- Course adjustment knob

ONLY

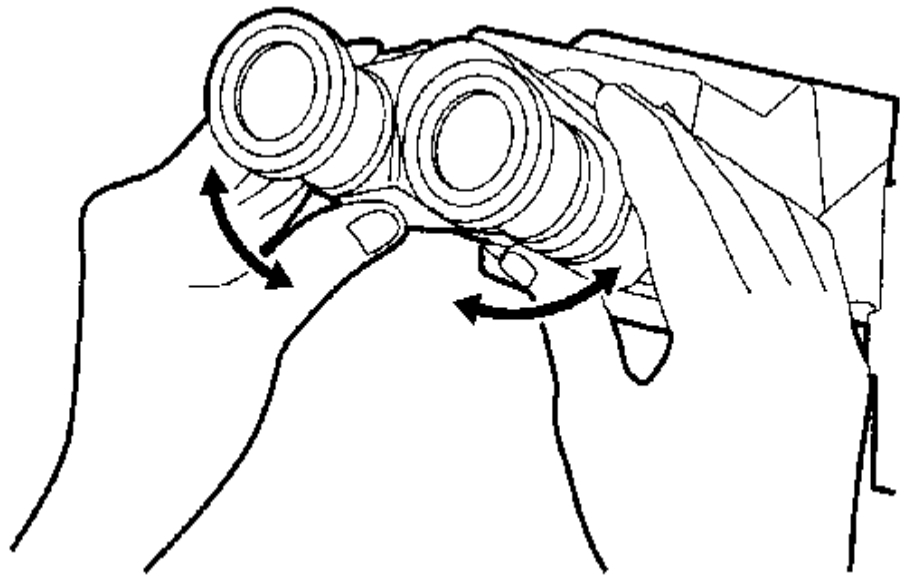
- Fine adjustment knob

YOU CAN USE TODAY



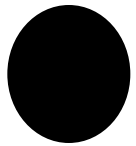
Light microscope manipulation

- focuse a picture in LM and look at it with both eyes
- regulate a distance between the eyepices so, you can see one focused circular field



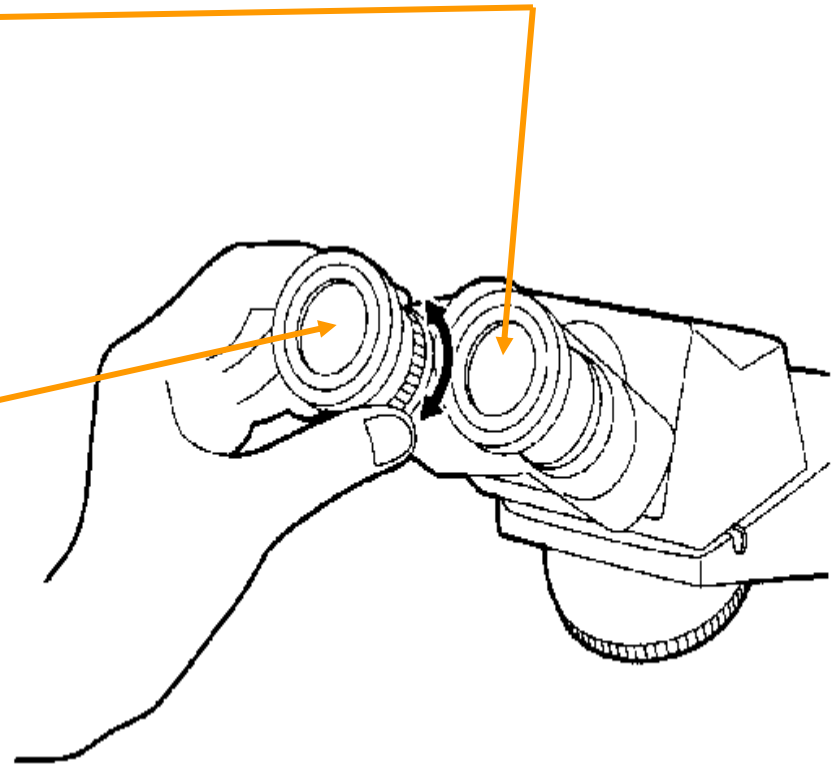
bad

correct

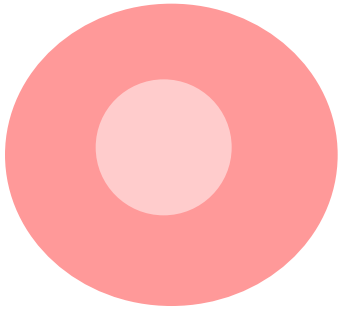


Light microscope manipulation

- Look at the slide only through the right eyepiece and focuse some point in the picture.
- Without refocusing, look at the left eyepiece.
- In doing so, screw the ring below the left eyepiece to focuse the same point.
- So, the dioptric correction is set up.



Now, you can start to study blood smear in your LM ☺

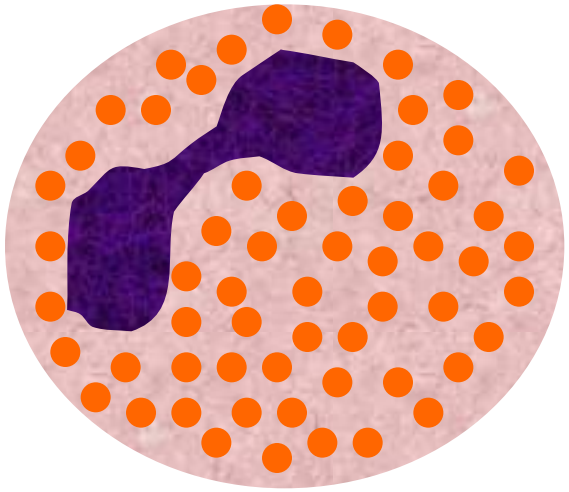


Ery 7.4 μm

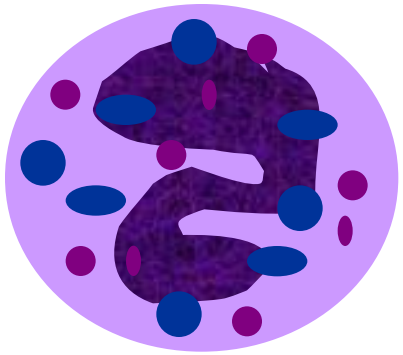
Neu – band

10 – 12 μm

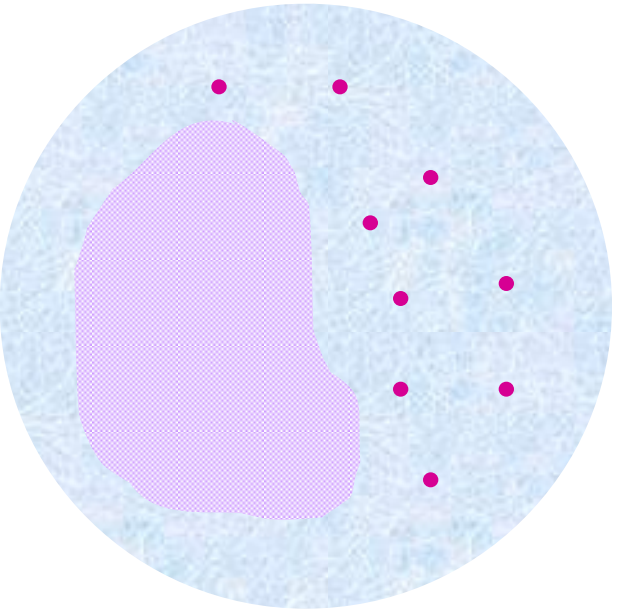
Neu – segment



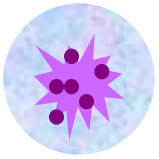
Eos 12-14 μm



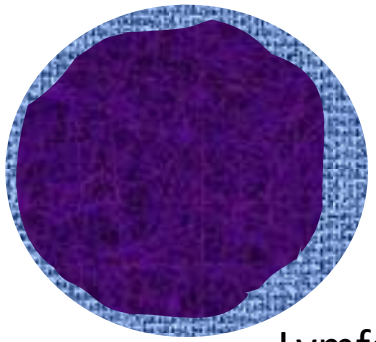
Baso 10 μm



Mono 15 – 20 μm



Platelet 2 – 4 μm



Lymfo 8 μm

How to study blood smear in LM?

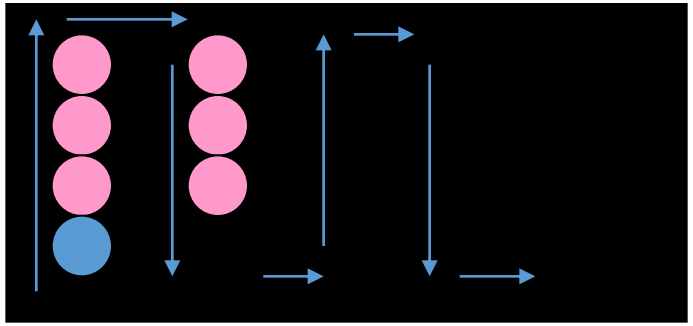
- Lens of immersion objective /magnifying 100x/ is immersed into drop of immersion oil and blood smear is prepared for study.

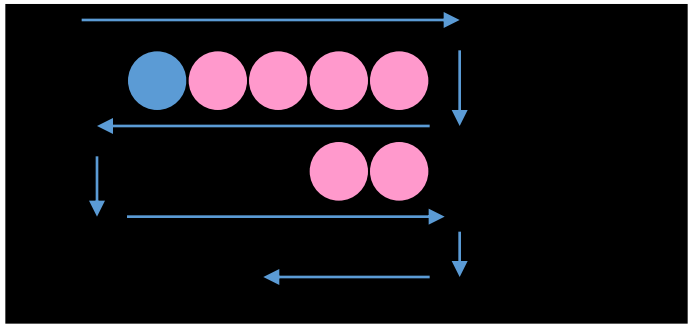
- Swich on the microscope and check the picture in the microscope.

- If the image is not sharp, focus it using **microscrew!** If it is not possible, contact your teacher.

How to count leukocytes in blood smear?

- blood smear have to be systematicaly viewed (for fear to count some cells several-times)





How to count leukocytes in blood smear?

- differential white cell count (DWCC) is an important hematologic sreening which helps to diagnose
- leukocytes percentage is the result of this investigation
- 100 white cells must be count and registered in the table prepared for all types of leukocytes (Neu-bands, Neu-segments, Eos, Baso, Ly, Mono)
- arithmetic sum of each type of leukocytes represents their percentage (%)

Table

	1	2
Neu bands	/	
Neu segments	~~///~~ //	///
Eos		/
Baso		
Ly	//	////
Mono		//
	10 cells	10 cells

→

9	10	results	norm
//			4 %
~~///~~ /	///		67 %
/	//		3 %
	/		1 %
/	~~///~~		20 %
			5 %
10 cells	10 cells	100%	100 %

Differential white cell count (DWCC

- Total number of leukocytes: normal values

Neutrophils - bands	4 %
- segments	67 %
Eosinophils	3 %
Basophils	1 %
Lymphocytes	20 %
Monocytes	5 %
	Σ = 100 %

Anomalies of DWCC

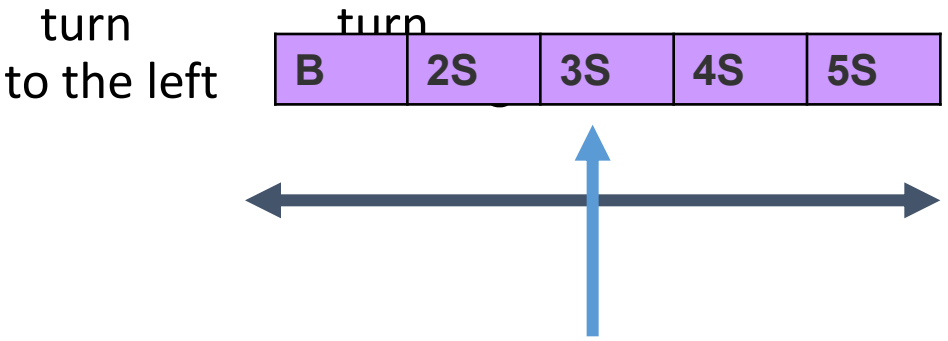
	↑ Increased number	↓ Decreased number
Neutrophils*	neutrophil granulocytosis	neutrophil granulocytopenia
Eosinophils	eosinophil granulocytosis	eosinophil granulocytopenia
Basophils	basoophil granulocytosis	basoophil granulocytopenia
Lymphocytes	lymphocytosis	lymphocytopenia
Monocytes	monocytosis	monocytopenia

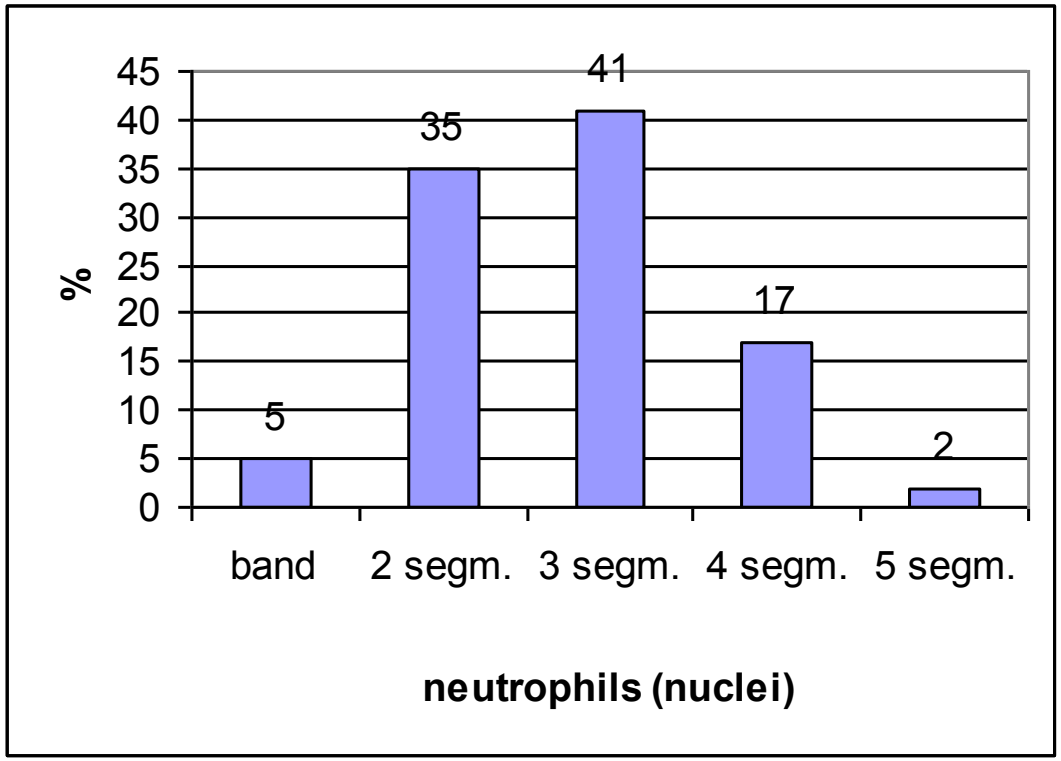
* sum total of bands and segments has to be compared with norm;

normal value is 71 % (4 % bans + 67 % segments)

Normal ratio of neutrophil bands and segments

- (B : S) is 4 % : 68 % = 1 : 17
- **Turn to the left** – bands are increased
- **Turn to the right** – segments are increased in peripheral blood





BLOOD

Slide

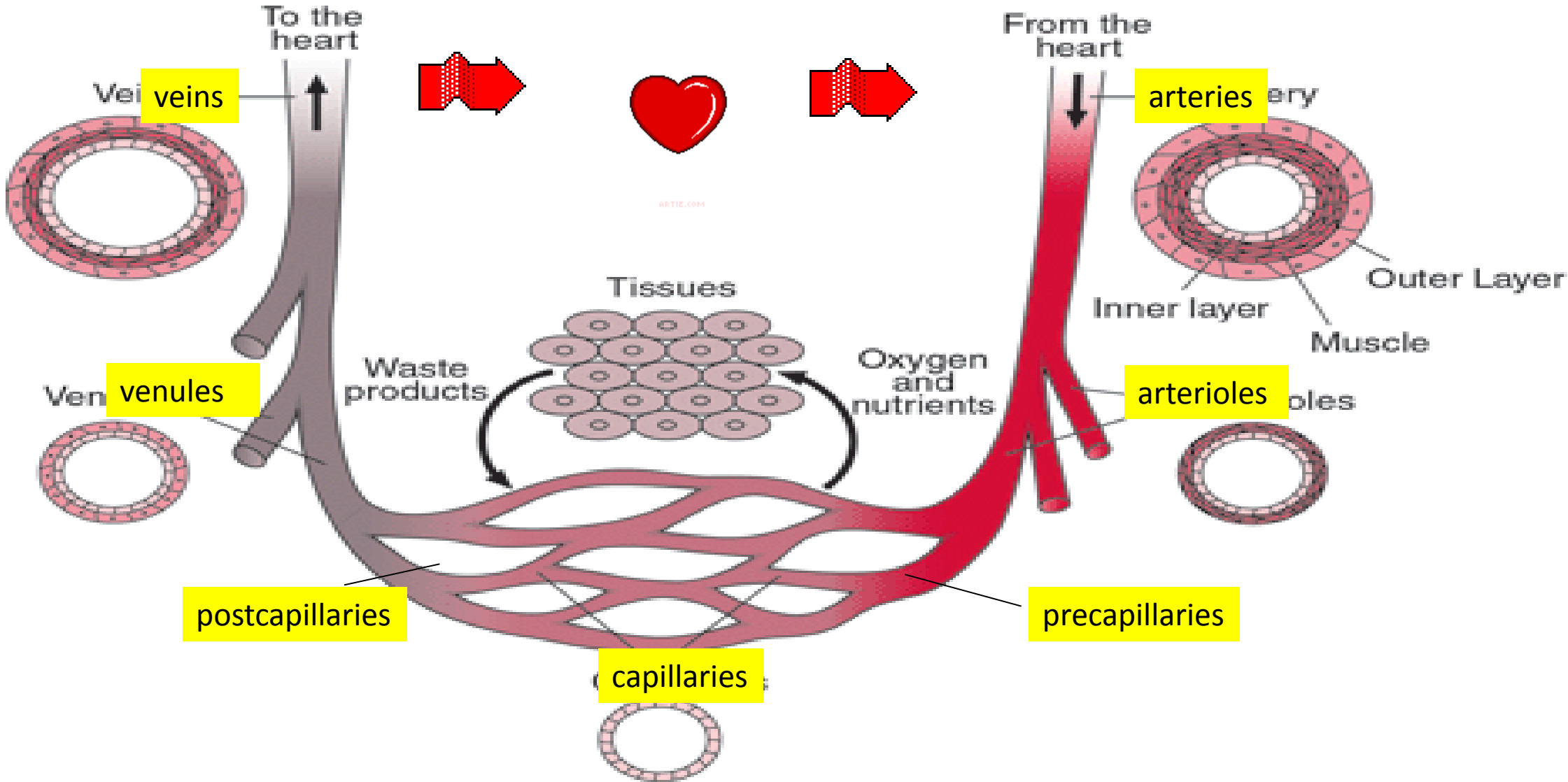
Peripheral blood smear, panoptic staining (method of Pappenheim), immersion oil, magnif. 1000x

Blood vessels
are categorized by function :

- Arteries conduct blood away from the heart and have proportionately more smooth muscle and elastic tissue than veins of comparable size.
  - Arteries are commonly sub-categorized into elastic arteries (*the largest one*), muscular arteries (*middle-sized*), and arterioles.
- Veins return blood to the heart.

The composition of the wall varies among arteries and veins.

Bloodstream organization



Structure of blood vessel wall

- **tunica interna (intima)**

  endothelium + subendothelial connective tissue

membrana elastica interna

- **tunica media**

  smooth muscle tissue – circularly oriented

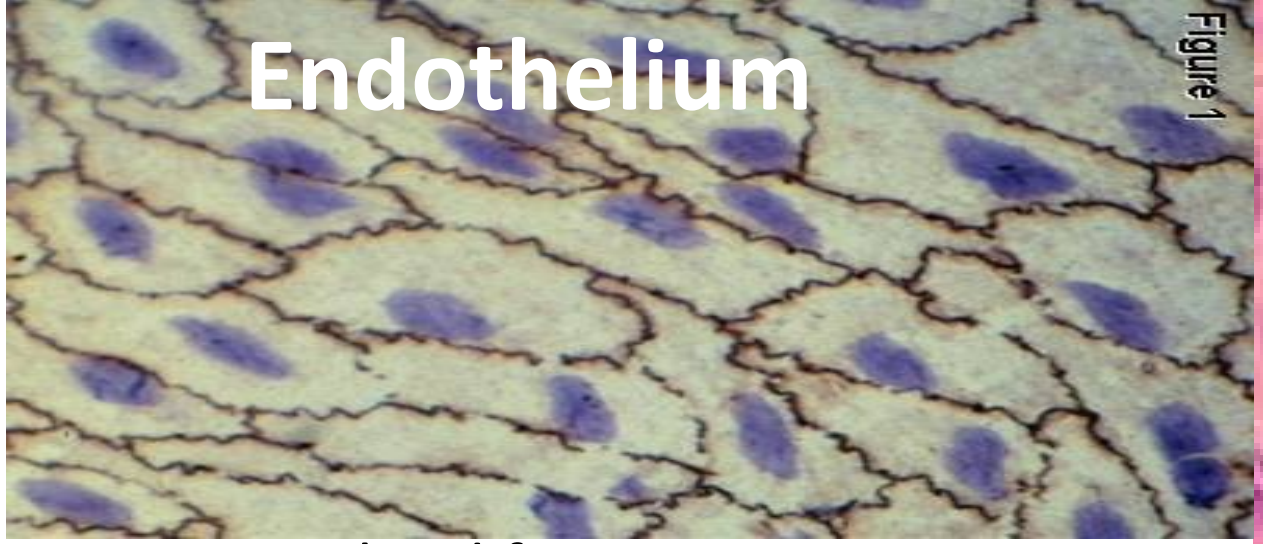
membrana elastica externa

- **tunica externa (adventitia)**

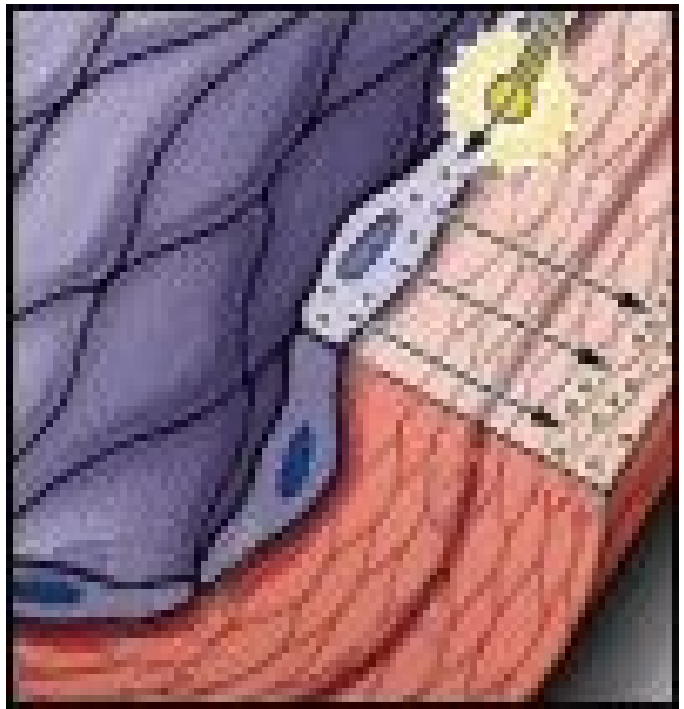
  loose connective tissue + nerves + vasa vasorum

  (+ longitudinal smooth muscle – only in veins)

Endothelium



- is a specialized form of mesenchyme-derived epithelium
- simple squamous epithelium – 1 layer of flattened cells forms a thin, waterproof and antithrombogenic lining of all blood vessels, heart and lymphatic vessels



Function of endothelium

- the control of blood pressure by vasoconstriction and vasodilation,
- blood clotting,
- formation of new blood vessels (angiogenesis),
- control of the passage of materials and the transit of white blood cells into and out of the blood,
- in some organs, there are highly differentiated endothelial cells to perform specialized 'filtering' functions (renal glomerulus in kidney, blood-brain barrier, placental barrier).

ERY

lumen

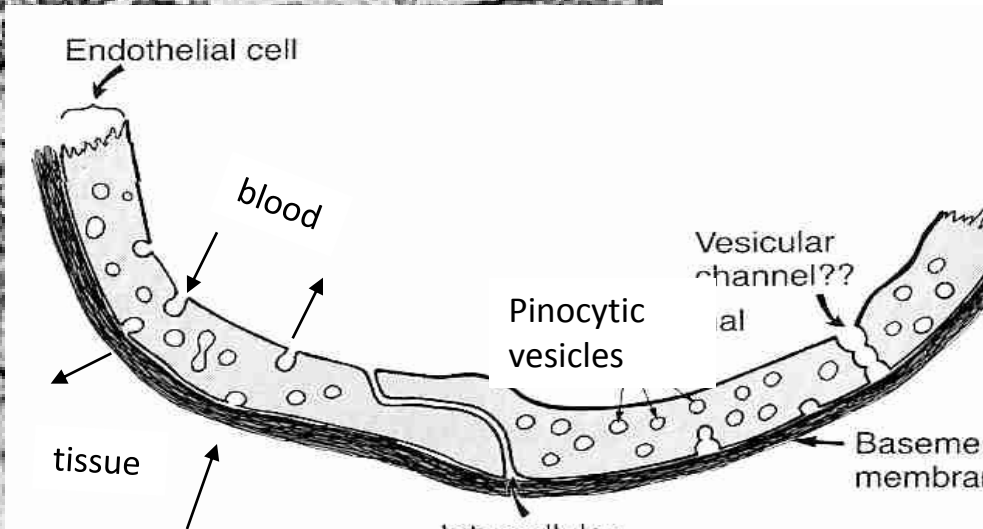
Pinocytic vesicles

Zonula occludens

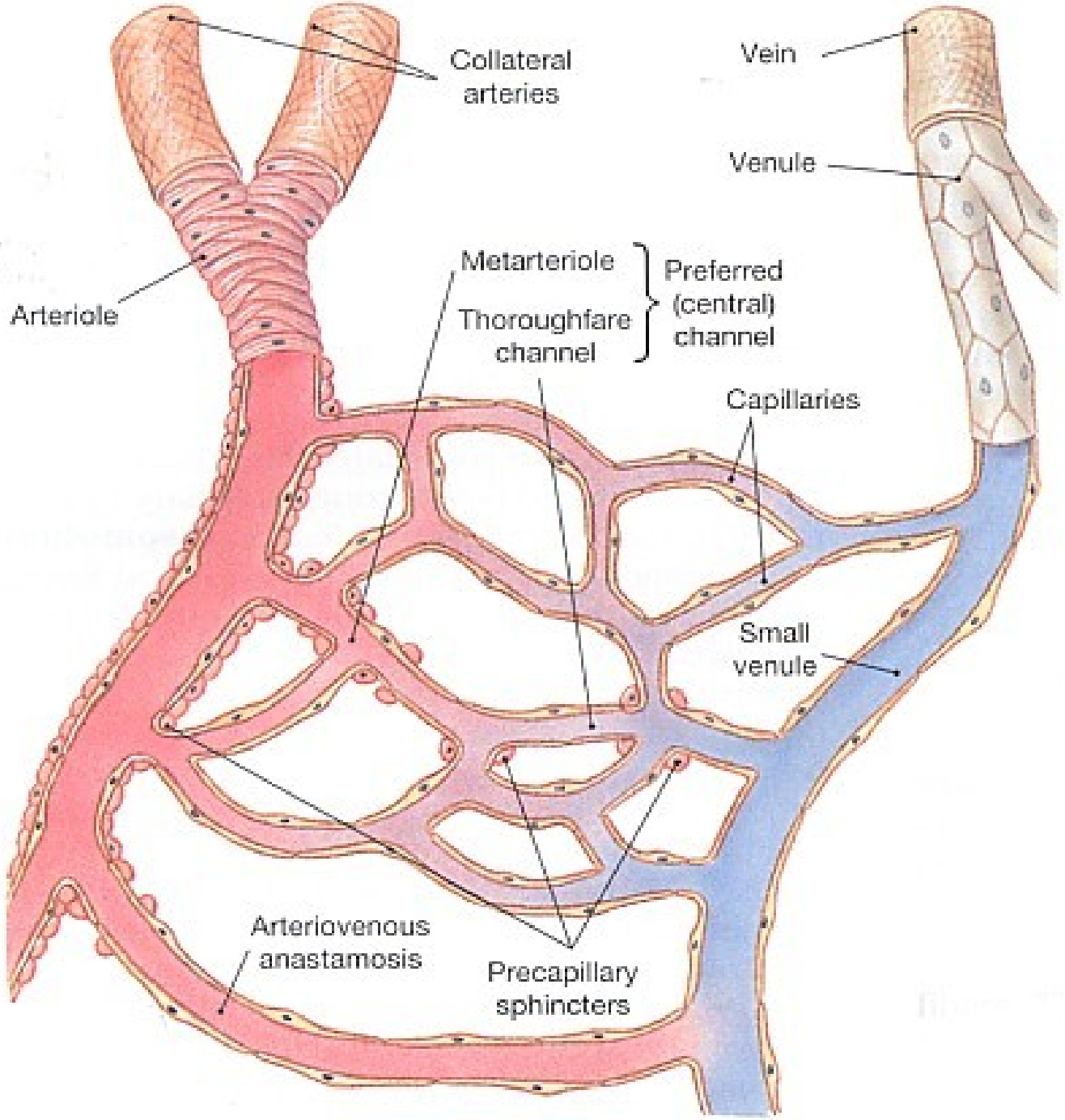
2

1

Endothelial cells (1,2)

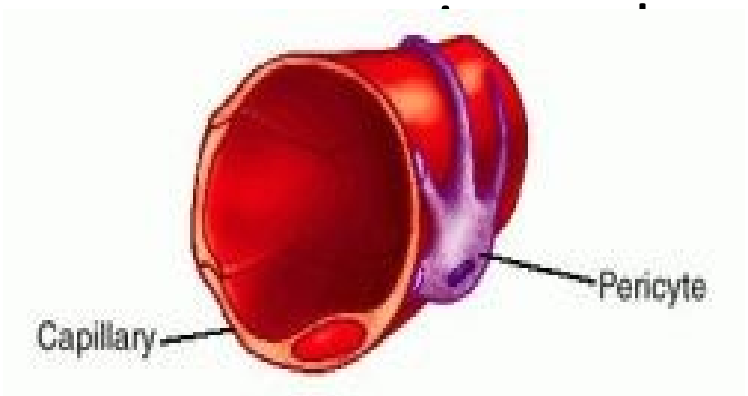


Blood capillaries



Blood capillaries

- diameter from about 8 µm (to 30-40 µm)
- lumen is lined by 1-2 endothelial cell
- reticular fibers surround the capillaries
- capillary bed between veins
- pericytes

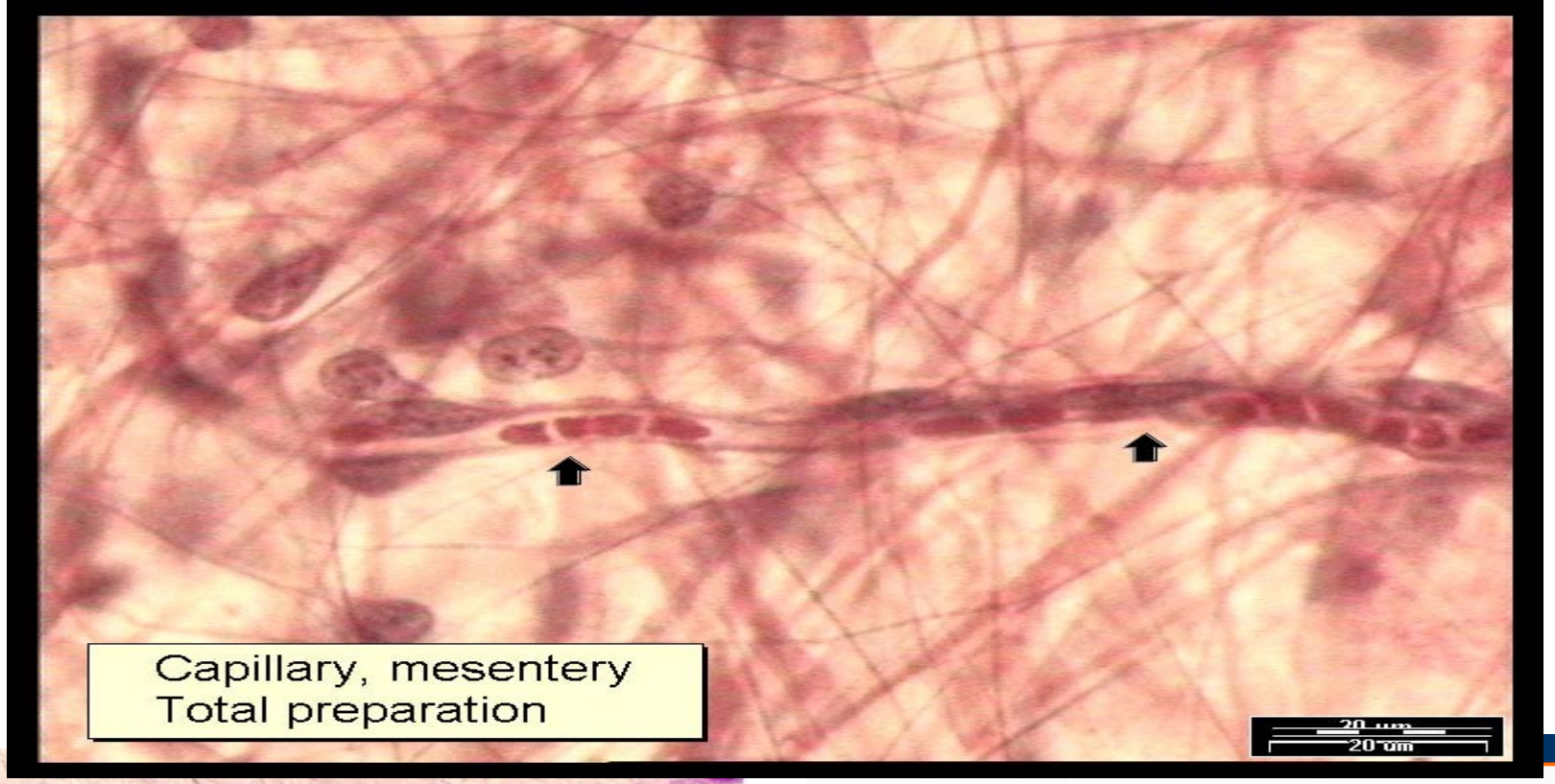


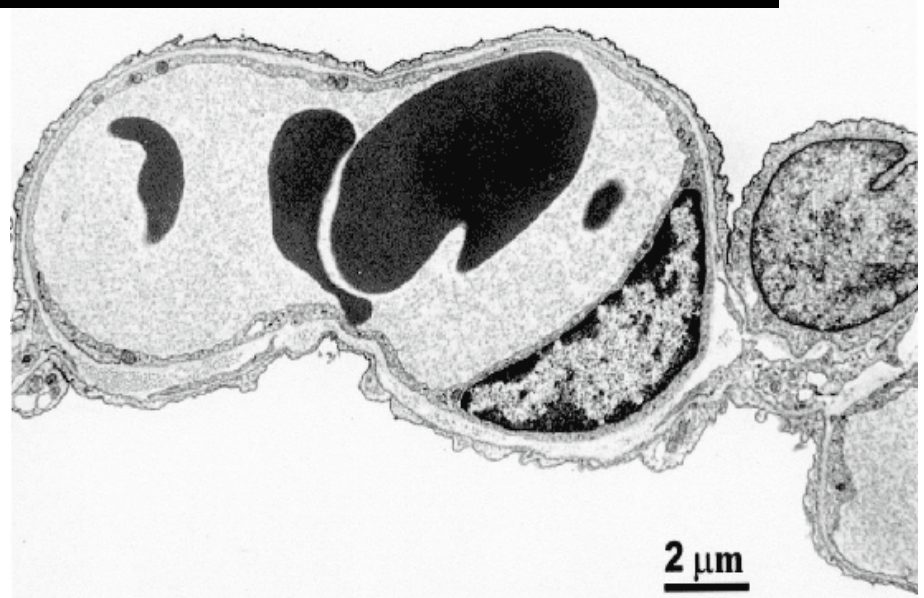
3 types of capillaries

continuous

fenestrated

sinusoids

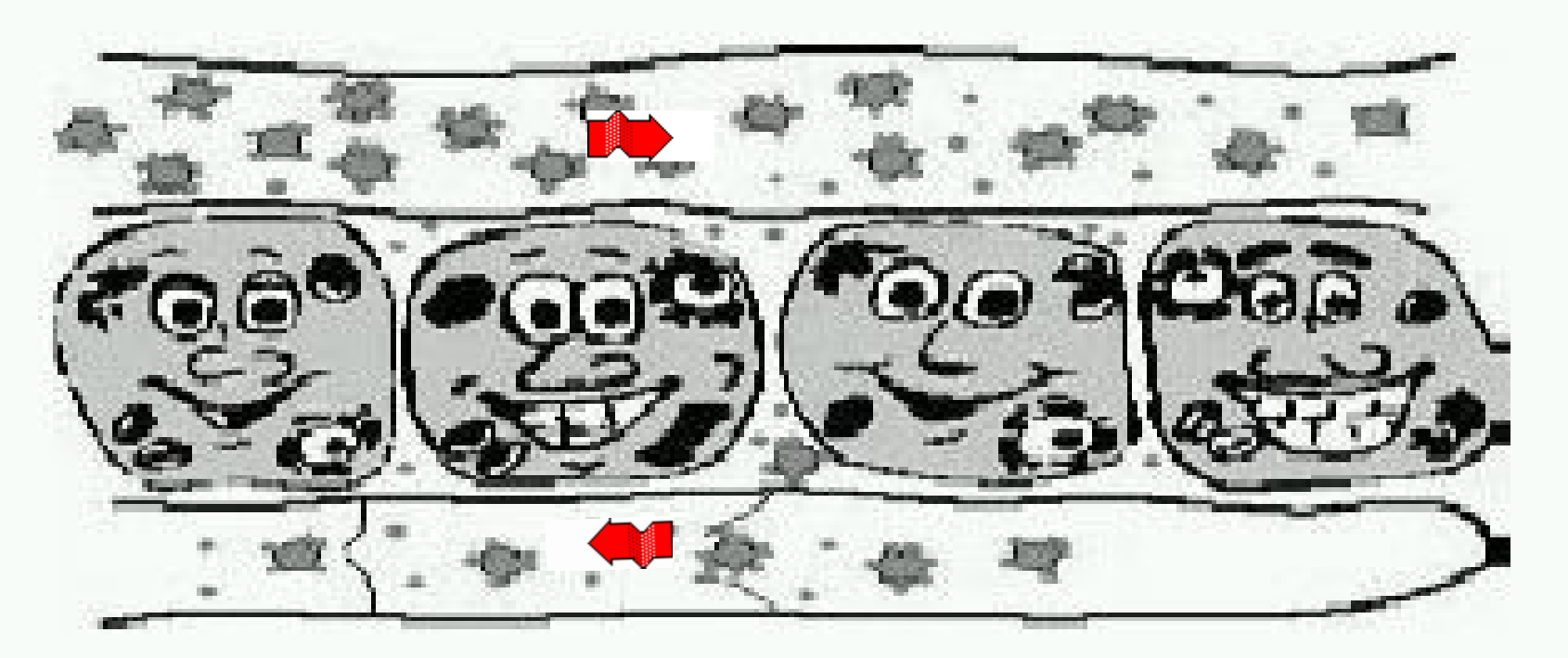




Source: Exerc Sport Sci Rev © 2004 American College of Sports Medicine

Function of capillaries (1)

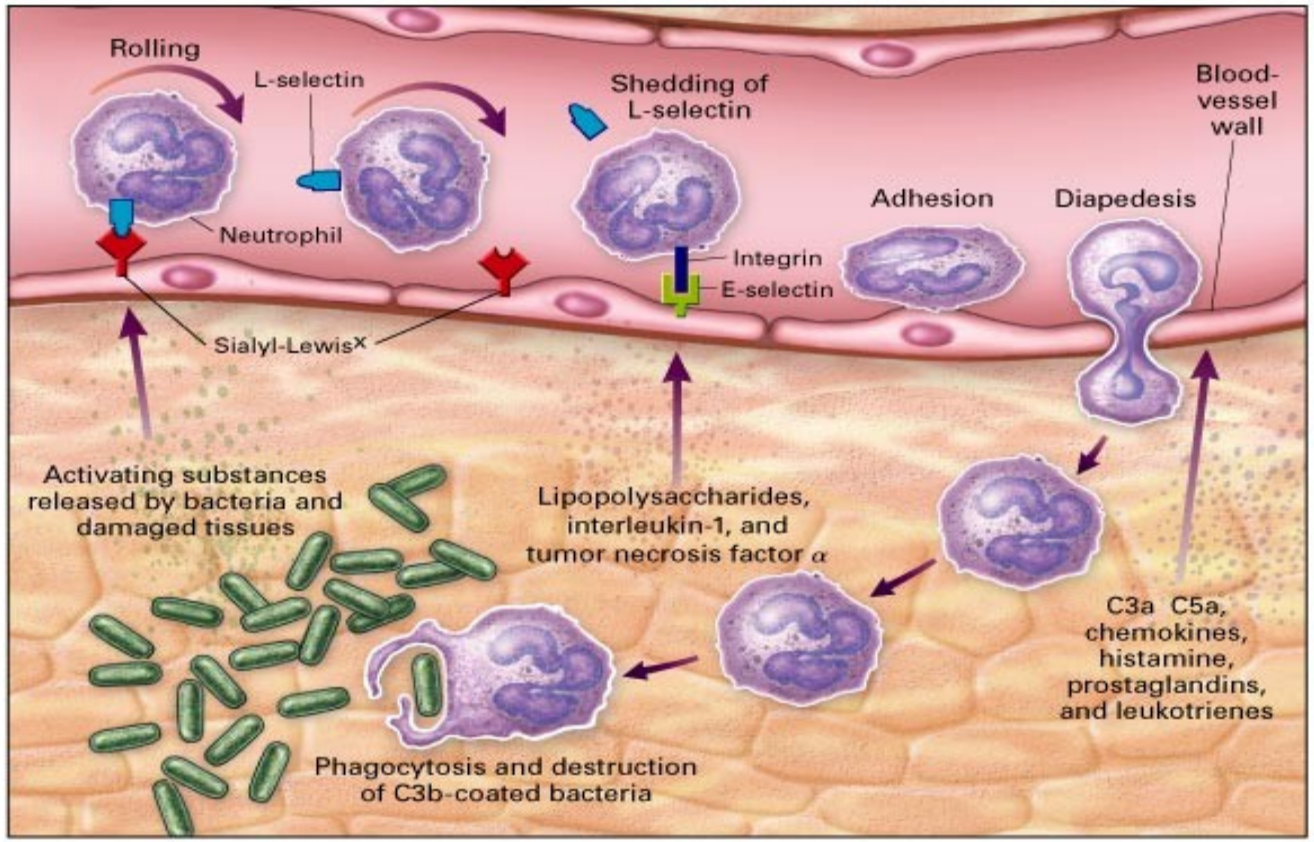
- respiratory gasses, nutrients and waste products change between blood and tissues



The illustration shows the healthy state of the cells in well vascularized tissue ☺

Function of capillaries (2)

- allow the blood cells to pass throughout their wall into the connective tissue (by diapedesis)



Neutrophils

↳ microphages

Eosinophils

Basophils

↳ mast cells

Lymphocytes

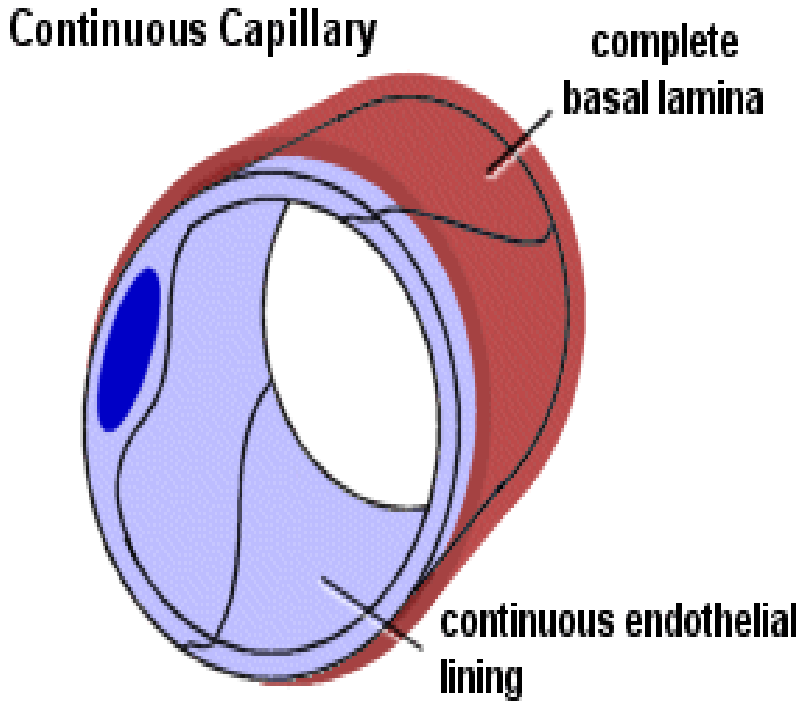
↳ plasma cells

Monocytes

↳ macrophages

Continuous capillaries

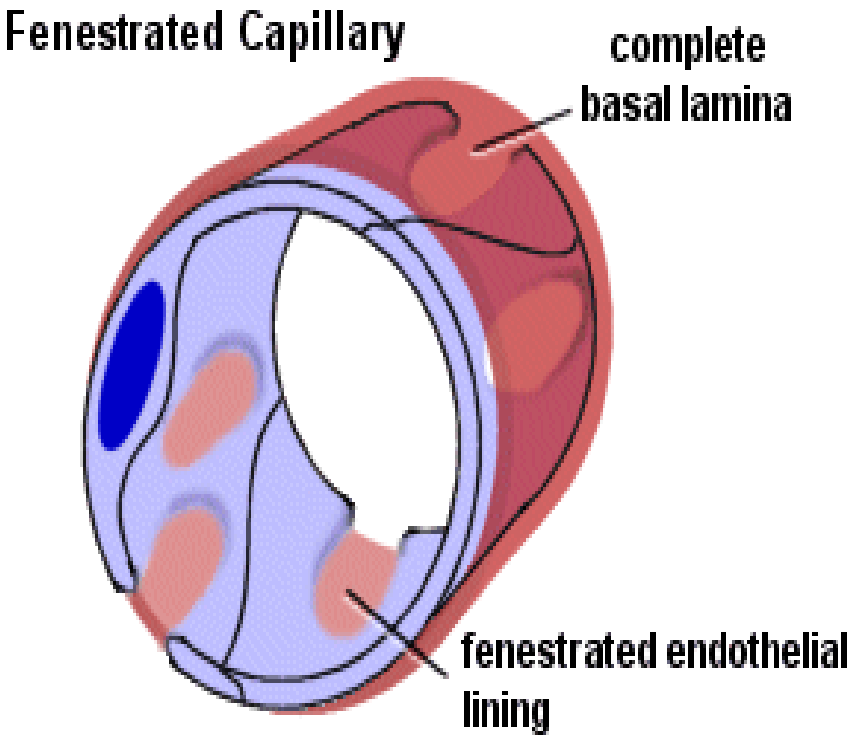
- The smallest: cca 8 μm
- The wall: -
  endothelium – 1-2 cells
  (zonulae occludentes and nexuses)
  - lamina basalis -
  pericytes -
  reticular fibers
- only allow small molecules, water and ions to diffuse



Example of occurrence:
muscle tisue, brain

Fenestrated capillaries

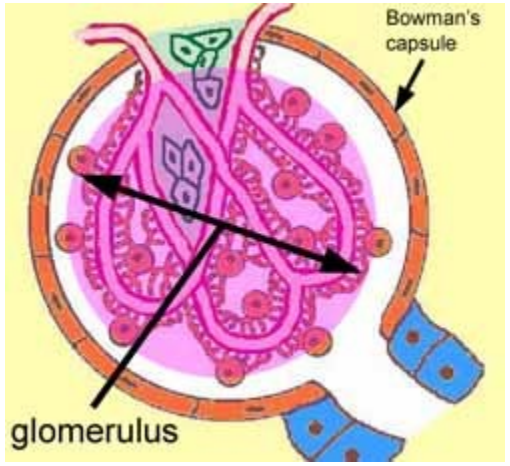
- Endothelial cells with fenestra („windows“) 70 nm ∅, diaphragm (thinner than plasma membrane) boards fenestrum
- continuous basal lamina
- in the organs with quic and intensive metabolism and substances change
- allow small molecules and limited amounts of protein to diffuse

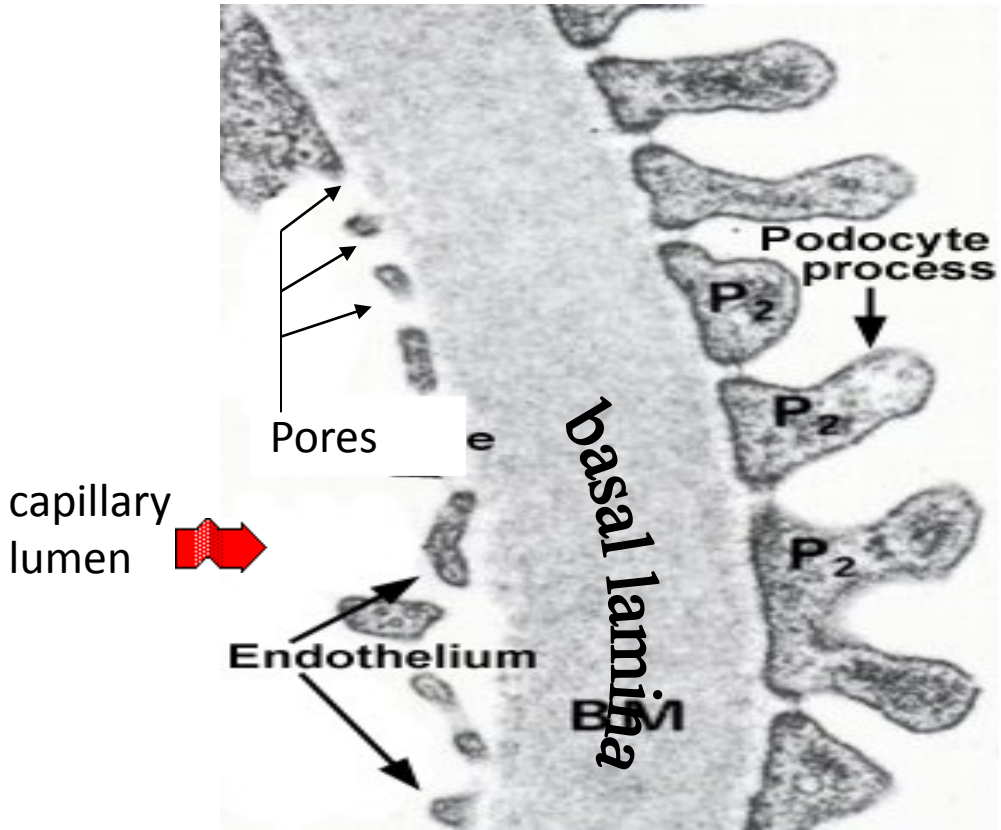


Exampl of occurrence:
intestinal villi, endocrine glands

Capillaries with pores

- special type of fenestrated capillaries
- not fenestra with diaphragm, but opened pores are in endothelium
- in glomeruli of renal corpuscles

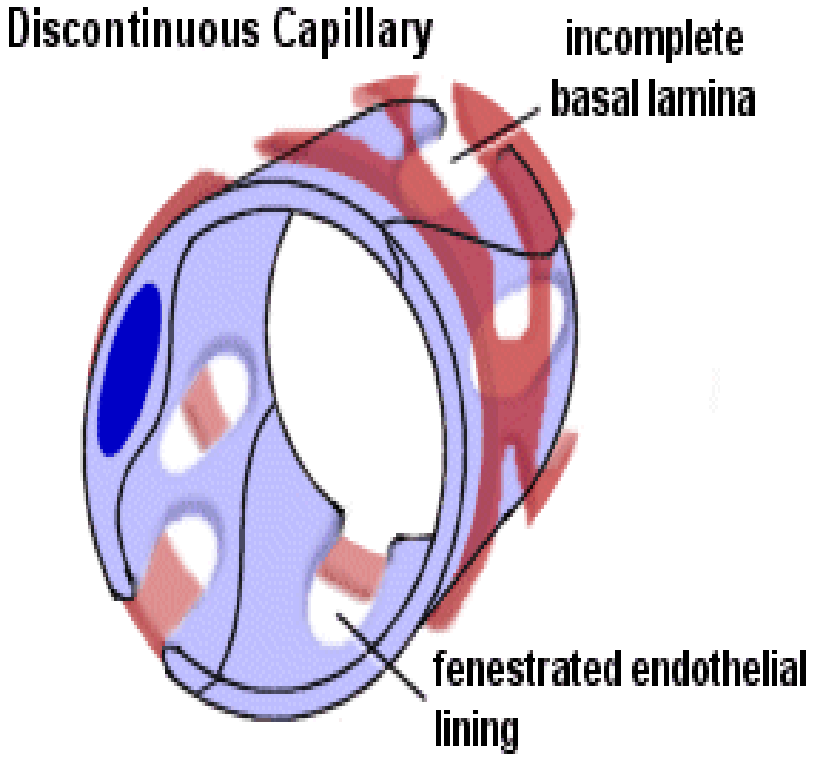




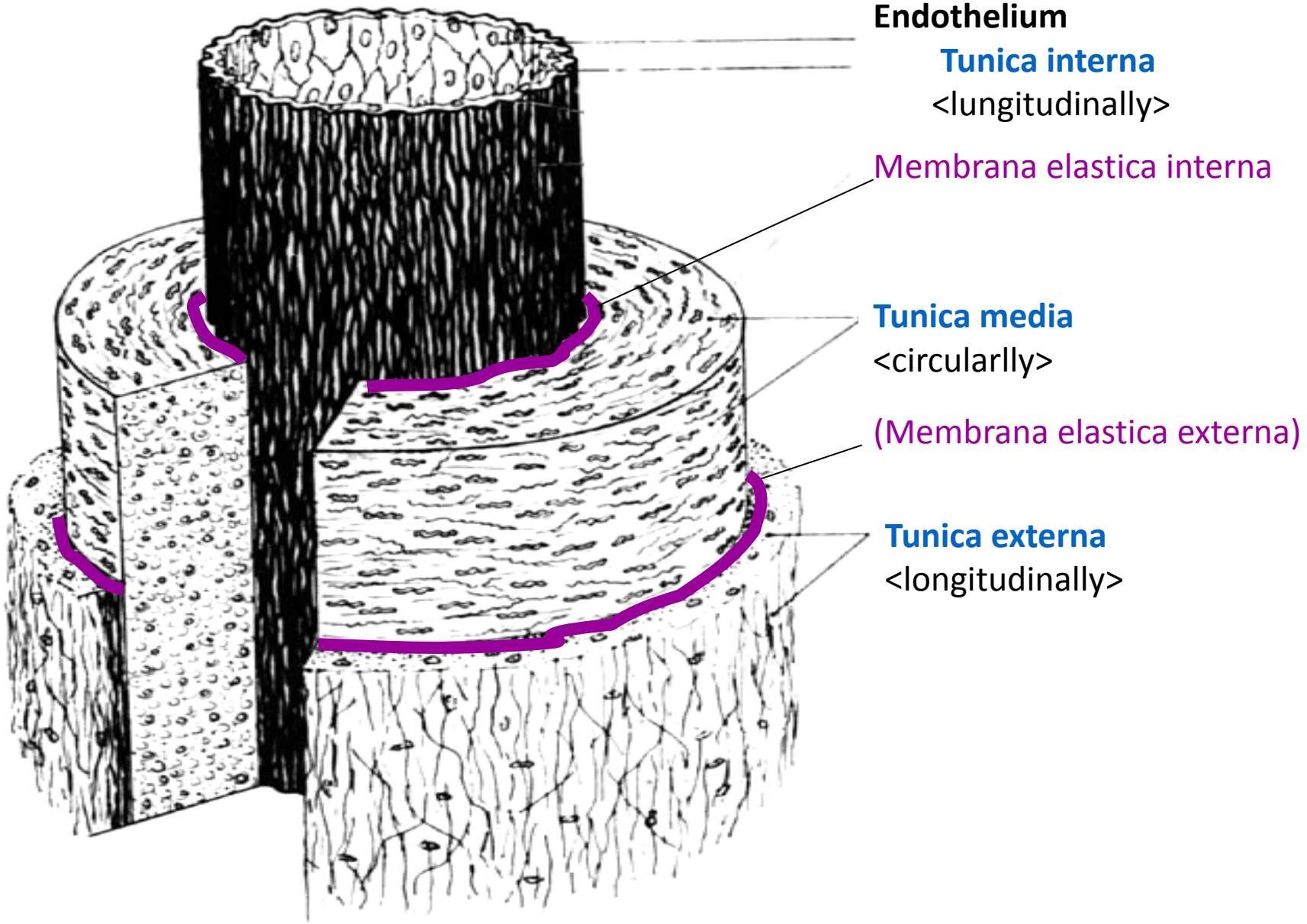
Sinusoidal capillaries (**sinusoids**)

- ∅ from 8 to 40 μm

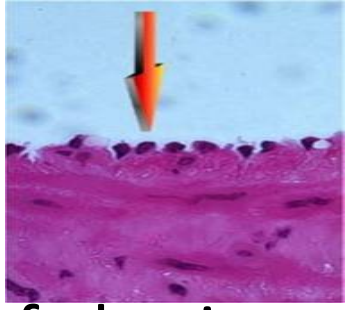
- endothelium – fenestra, pores and intercellular clefts; some cells are able to phagocyte
- incomplete basal lamina
- reticular fibers
- allow erytrhocytes and serum proteins to enter.



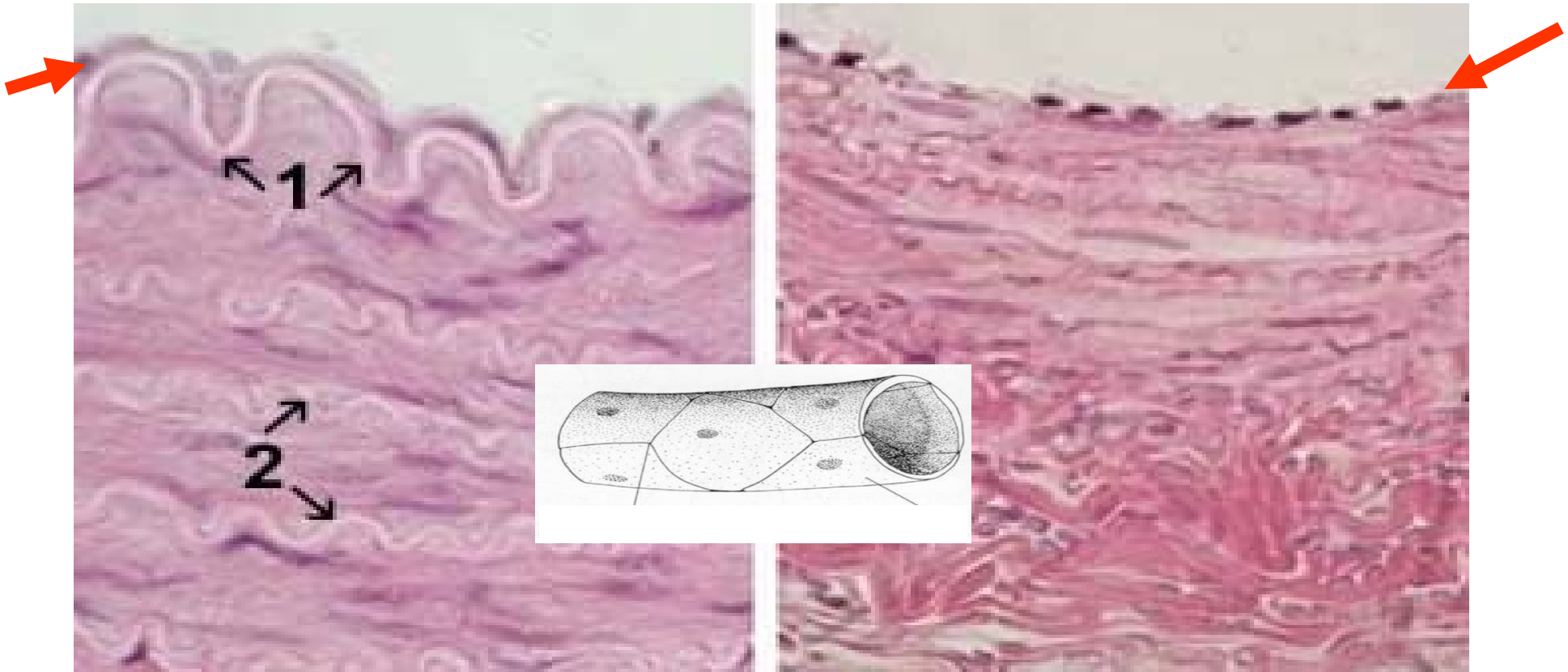
Example of occurrence:
liver, spleen, bone marrow


Endothelium
Tunica interna
<lungitudinally>
Membrana elastica interna
Tunica media
<circularlly>
(Membrana elastica externa)
Tunica externa
<longitudinally>

Tunica interna (*intima*) TI



- **endothelium**
- **subendothelial connective tissue** – thin layer of elastic + collagen fibers *(longitudinally oriented)*



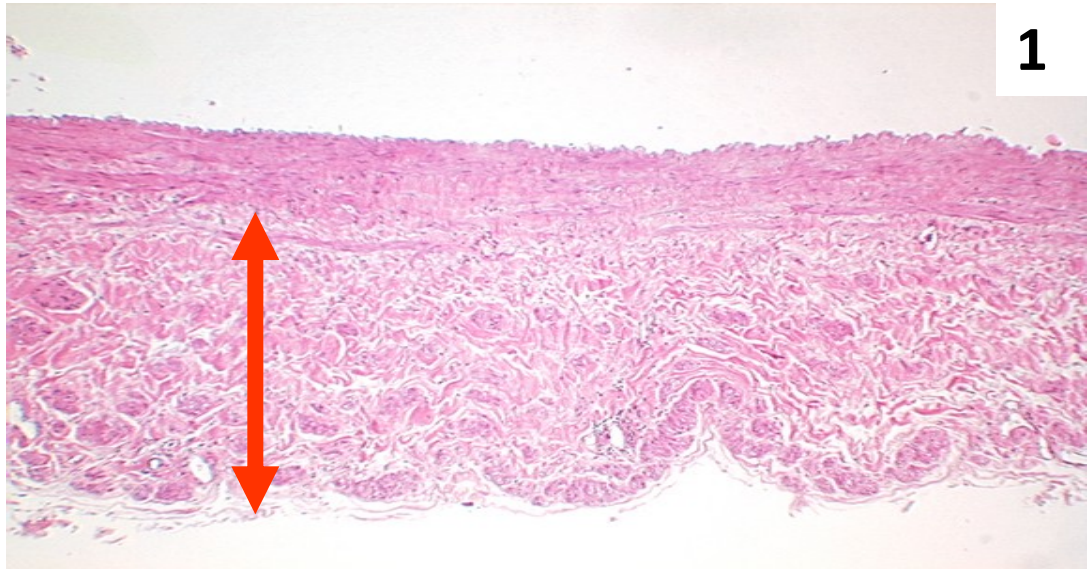
Tunica media TM

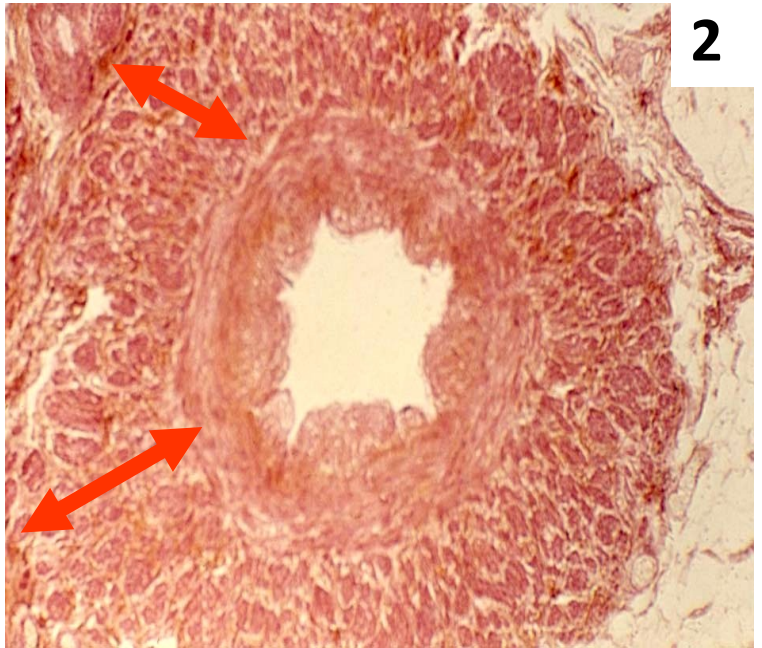
- consists of smooth muscle cells and elastic membranes in varying proportions *(circularly oriented)*
- is thicker in arteries than in veins

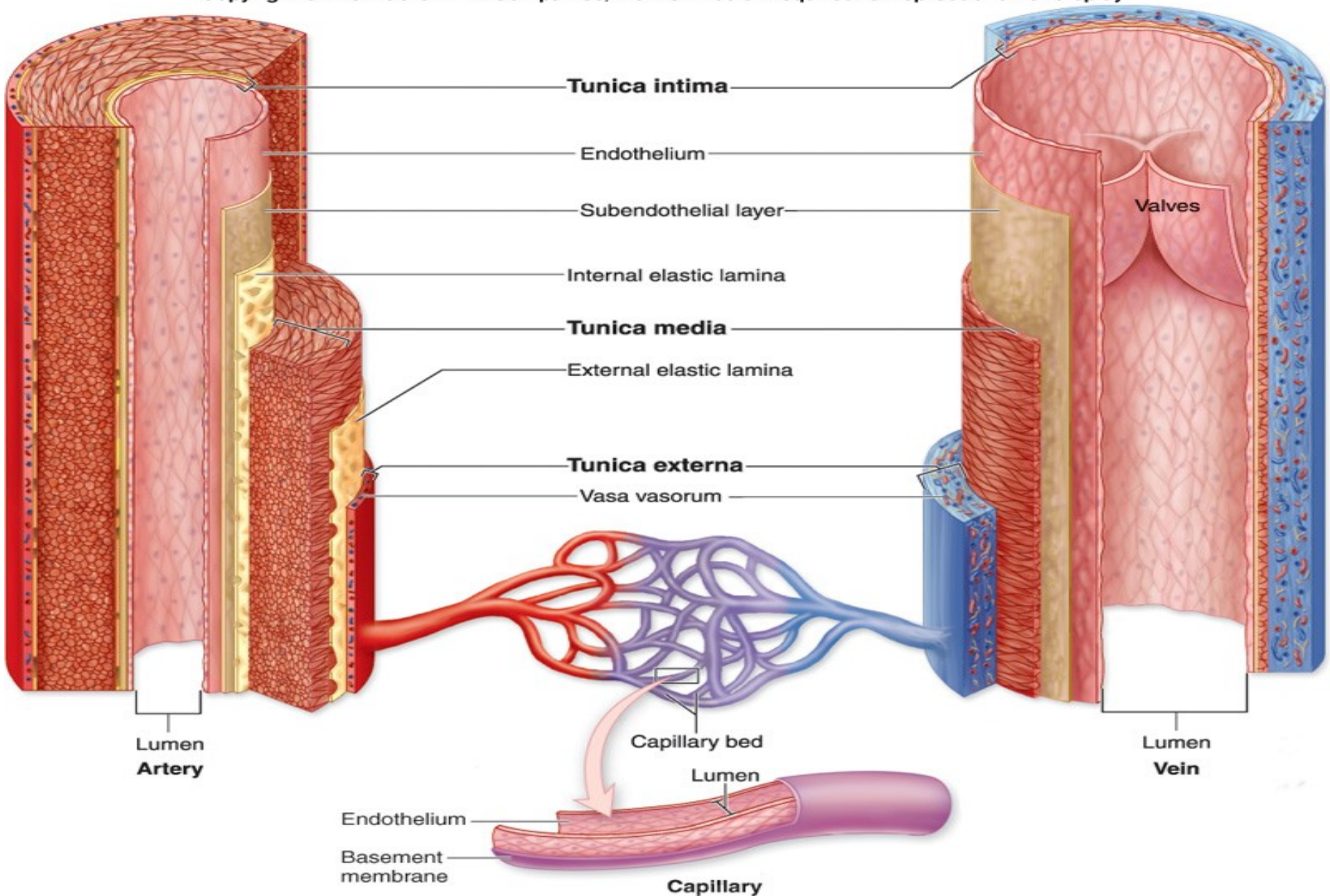
Compare aw – vw:

Tunica externa (*adventitia*) TA

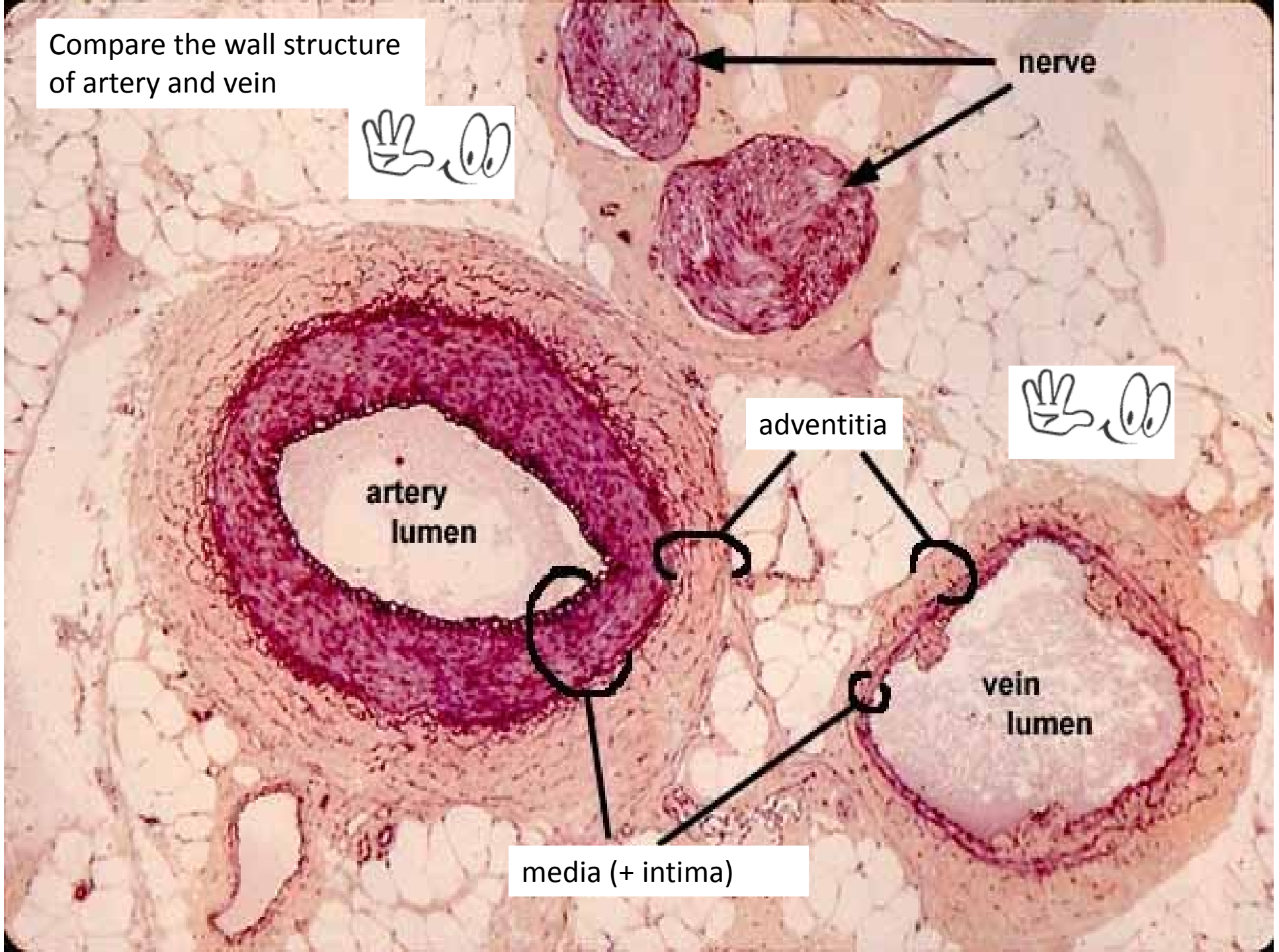
- fibrous connective tissue + smooth muscle cells in veins *(logitudinally)*
- is thicker in vein; is the thickest layer in large veins [1] and veins of low limbs [2]
- contains vessels and nerves (vasa et nervi vasorum) in large vessels







Compare the wall structure of artery and vein



Arterial part of bloodstream

According to diameter, morphological differences and ratio of elastic fibers and smooth muscle cells:

- Arterioles ∅ < 0.5 mm
- Muscular arteries (small and middle-sized)

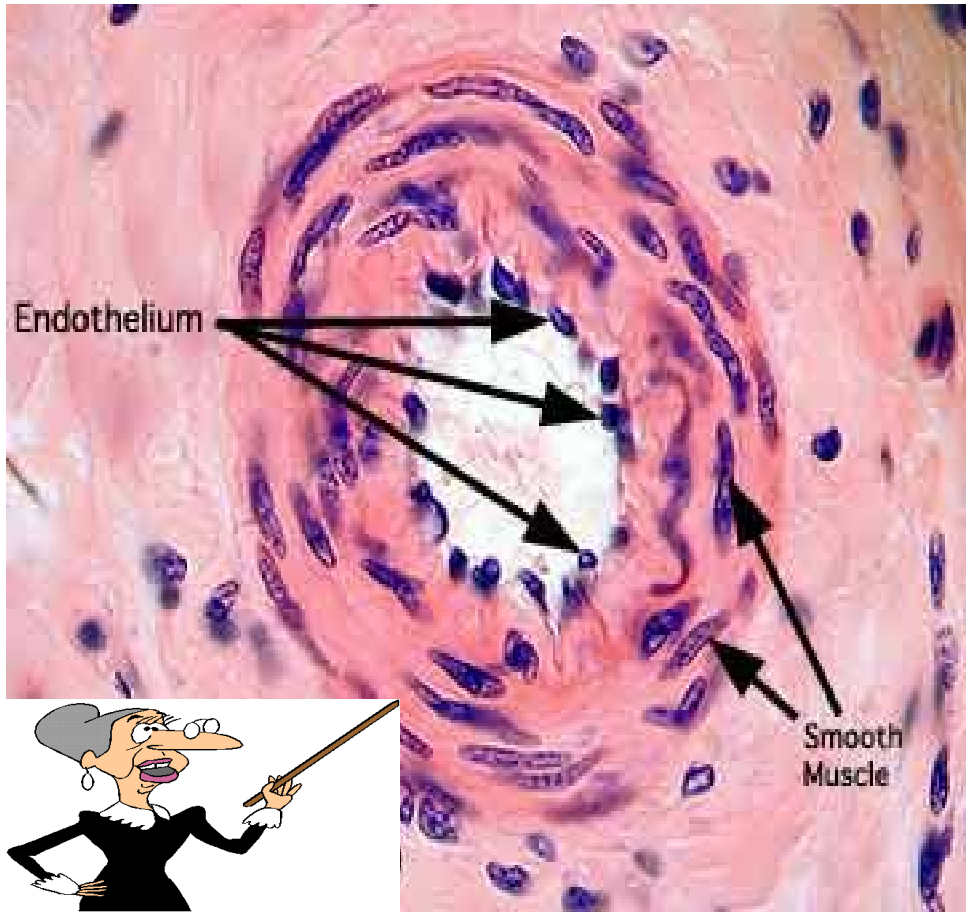
  ∅ 0.5 – 1 mm
- Elastic arteries (large: aorta and arteries growing from aorta)

Arteriole

- ∅ < 0.5 mm

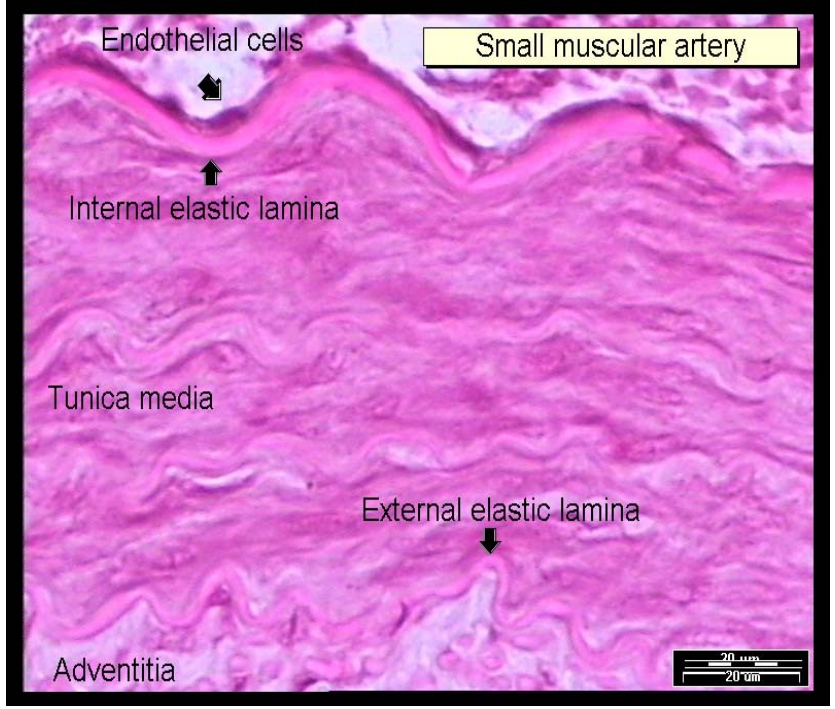
The wall

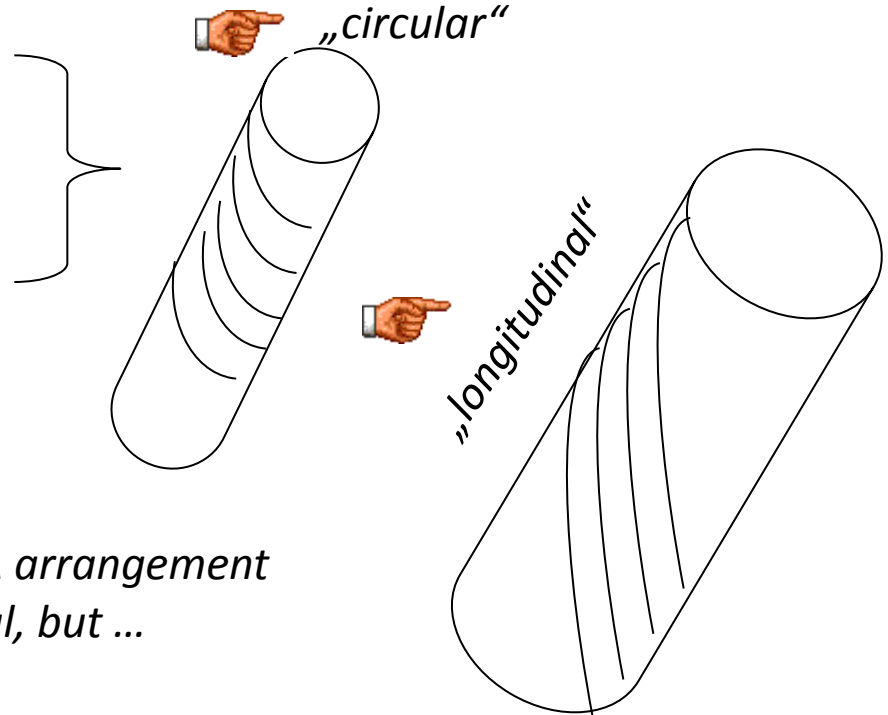
- TI: endothelium + subendothelium
- *membrana elastica int.*
- TM: smooth muscle cells (cca circular 5 layers)
- TA: fibrocytes, reticular (+collagen) fibers



Muscular artery

- TI: endothelium + subendothelium (with smooth muscle cells (longit.)
- *membrana elastica int.*
- TM: up to 40 layers of smooth muscle cells, elastic and collagen fibers
- *membrana elastica ext.*
- TA: loose connective tissue

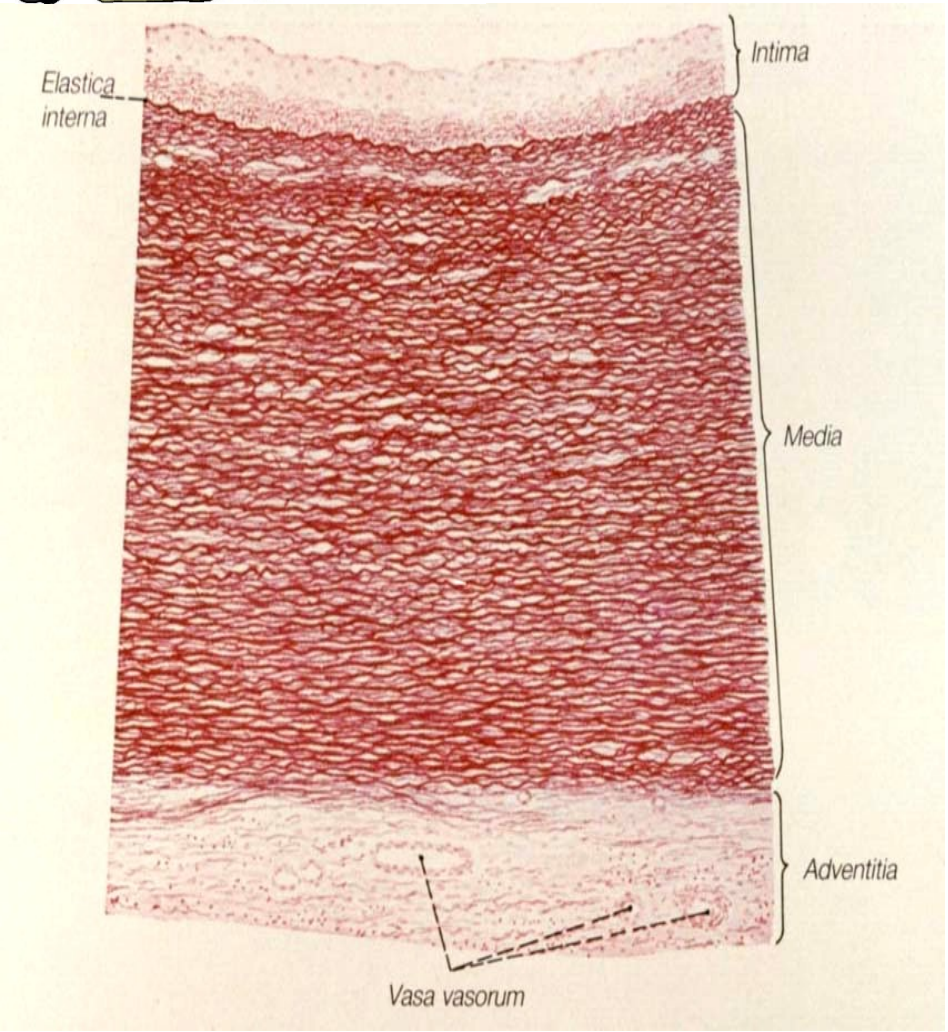




TM+TA arrangement is spiral, but …

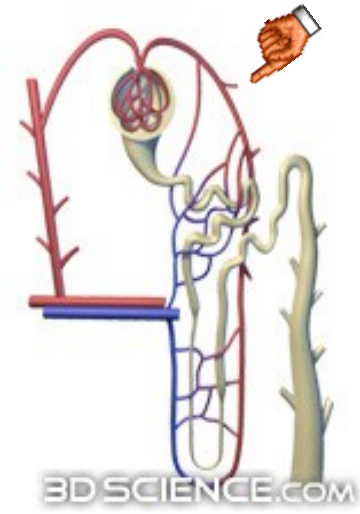
Elastic artery

- TI: endothelium + subendothelium (100 μm wide layer of connective t.)
- TM: up to 40-60 layers of fenestrated elastic membranes, small amount of smooth muscle cells and reticular fibers
- TA: loose connective tissue (+ vasa et nervi vasorum)

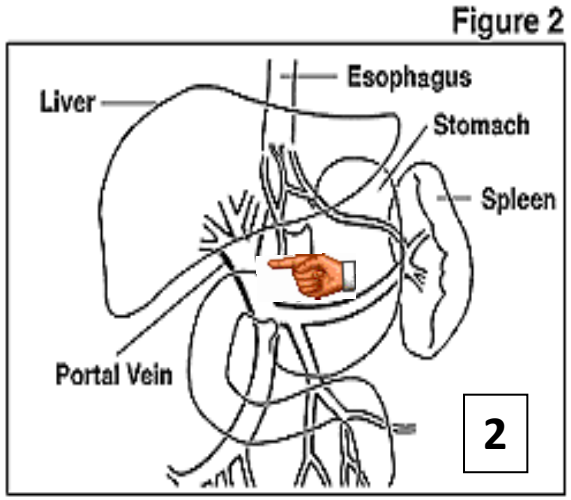


Portal circulation:
arterial or venous

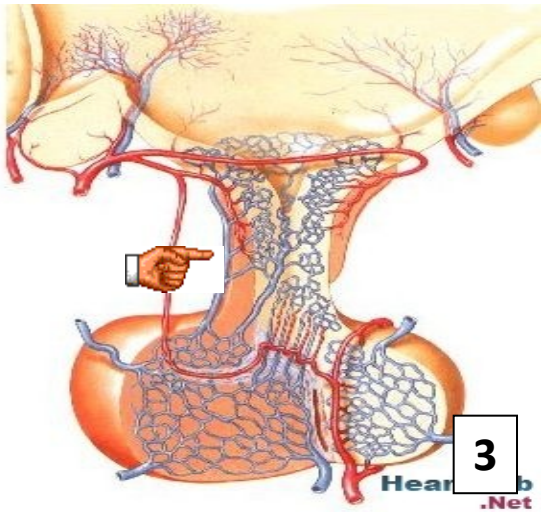
- two capillary systems side-by-side



1



2



3

capillaries → vessel → capillaries WHERE?

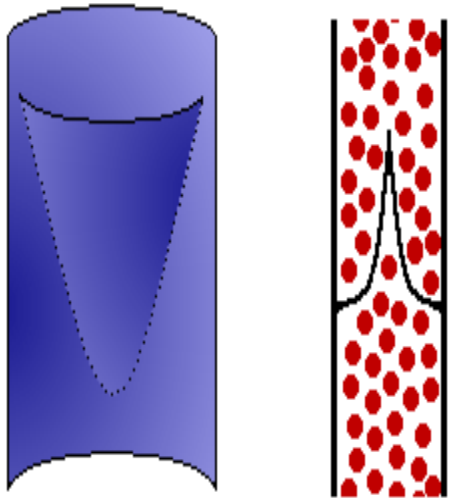
1: glomerulus eferent arteriole renal tubules capillaries in KIDNEY
2: GIT organs vena portae hepatic sinusoids in LIVER
3: hypothalamus hypophyseal vein adenohypophysis in HYPOPHYSIS

Venous part of bloodstream

- Venules ∅ 0.2 – 1 mm
- Small and medium sized veins ∅ 1 – 9 mm
- Large veins (v. cava inf. et. sup. - the largest vein)

- **Valves**
  like duplication of endothelium
  elastic c.t.
  reccurence

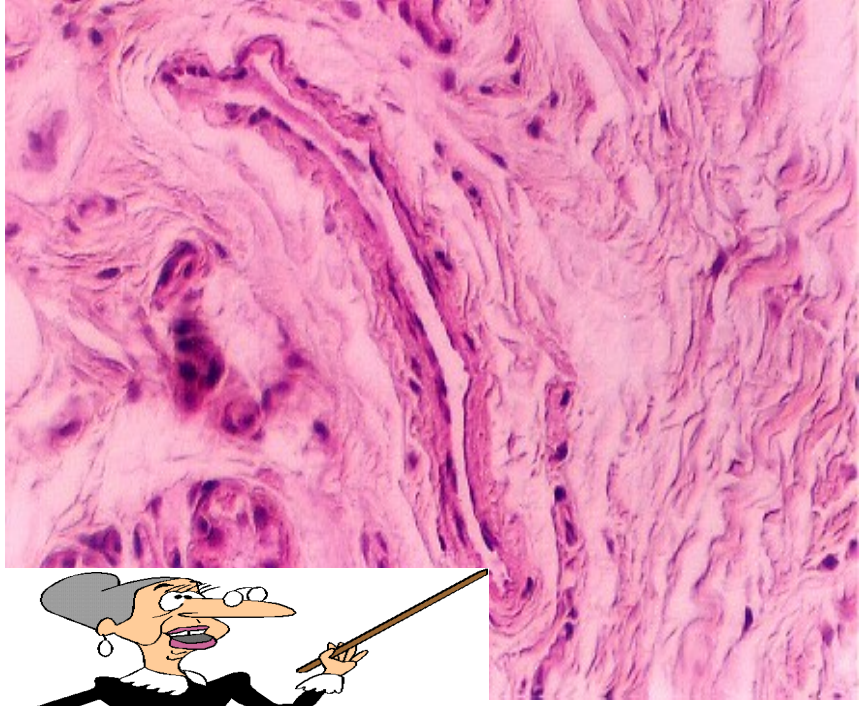
- pro

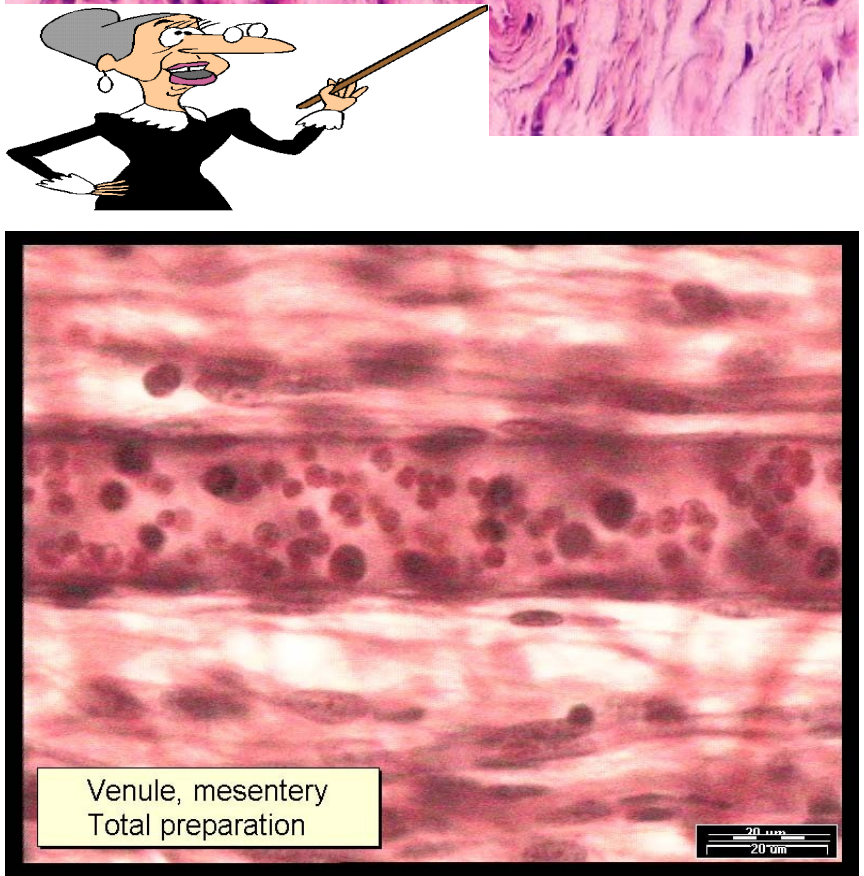


pocket valve

Venule

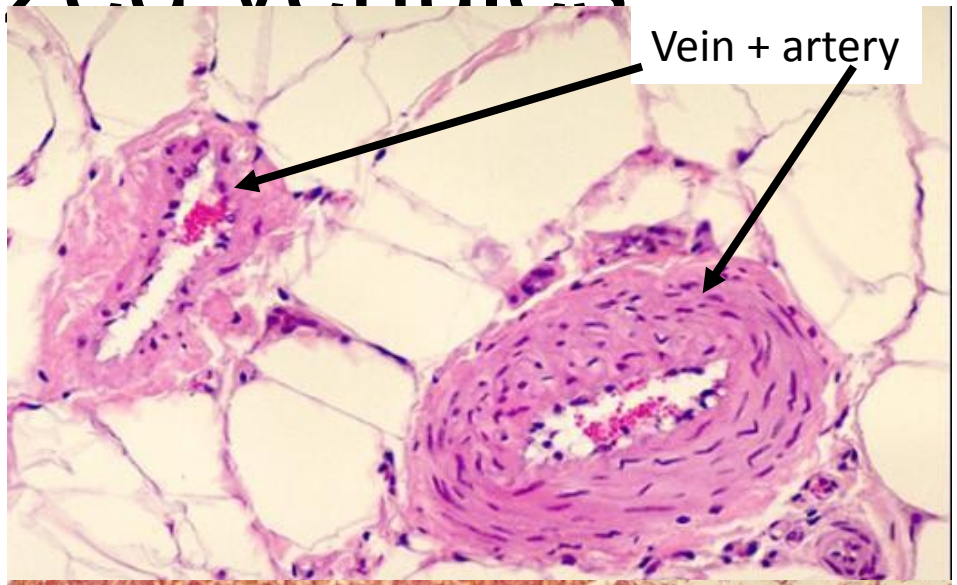
- ∅ < 0.2 - 1 mm
- **The wall**
- TI: endothelium only
- TM: smooth muscle cells (cca circular 1-3 layers)
- TA: thick layer of loose connective tissue

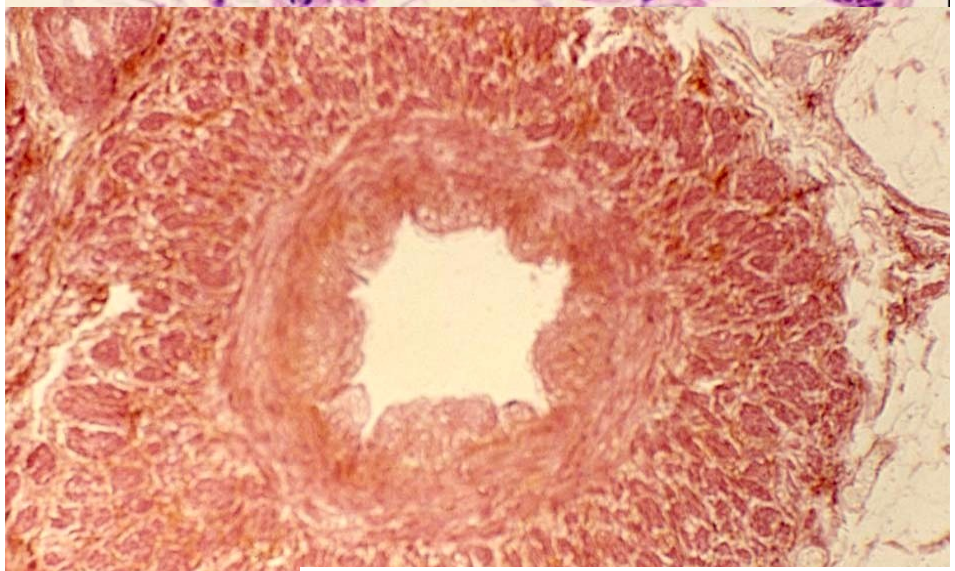




Small and medium-sized venules

- ∅ 1 – 9 mm
- TI: endothelium + irregular layer of subendothelium + valves
- TM: irregular, thin layer of smooth muscle cells, elastic and collagen fibers
- TA: thick layer of loose connective tissue with smooth muscle cells

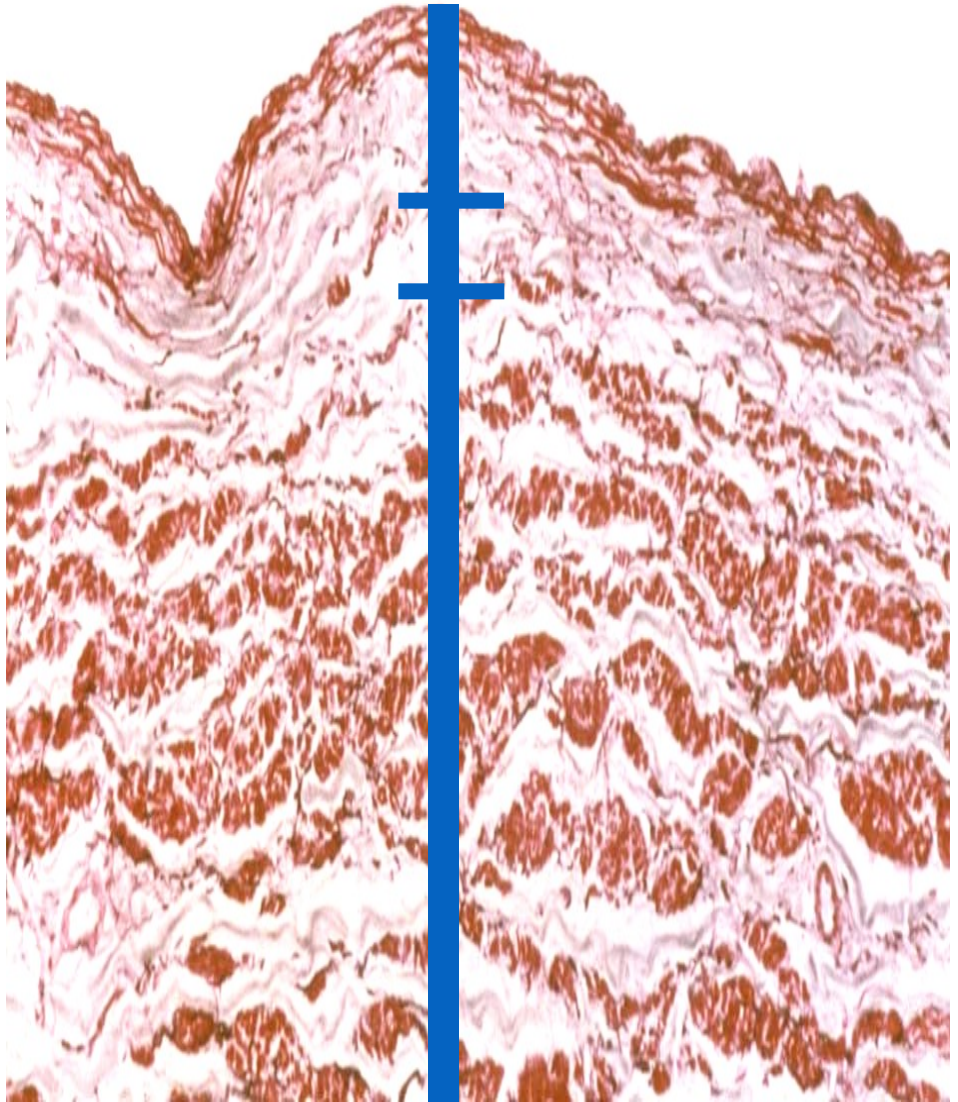




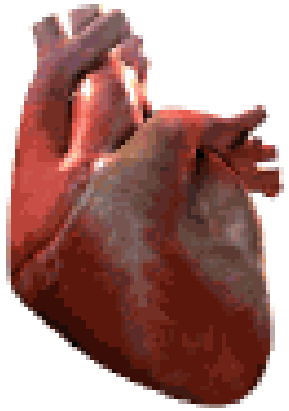
Vein from lower part of body

Large veins

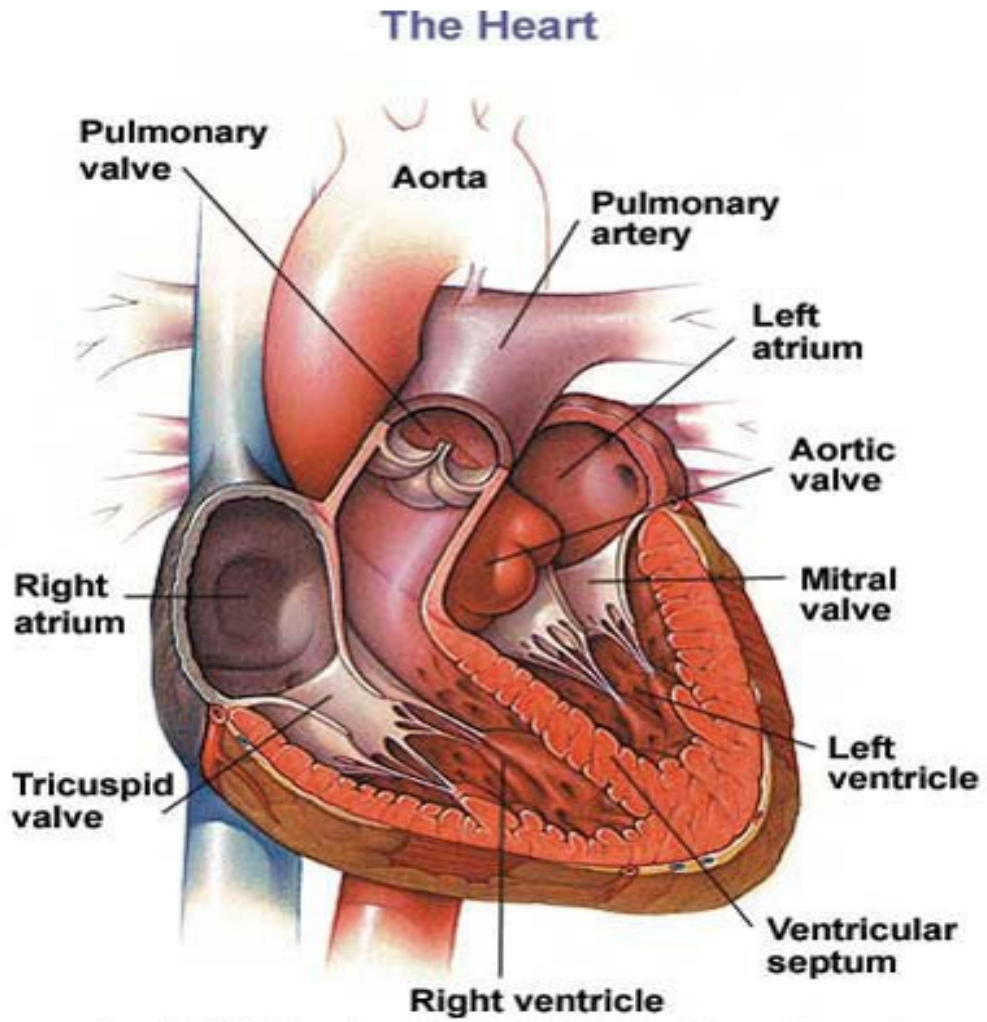
- TI: endothelium + subendothelium (+smooth muscle cells)
- TM: thin layer of connective tissue + reduced amount of smooth muscle cells
- TA: longitudinal bundles of smooth muscle cells in loose connective tissue (vasa et nervi vasorum)



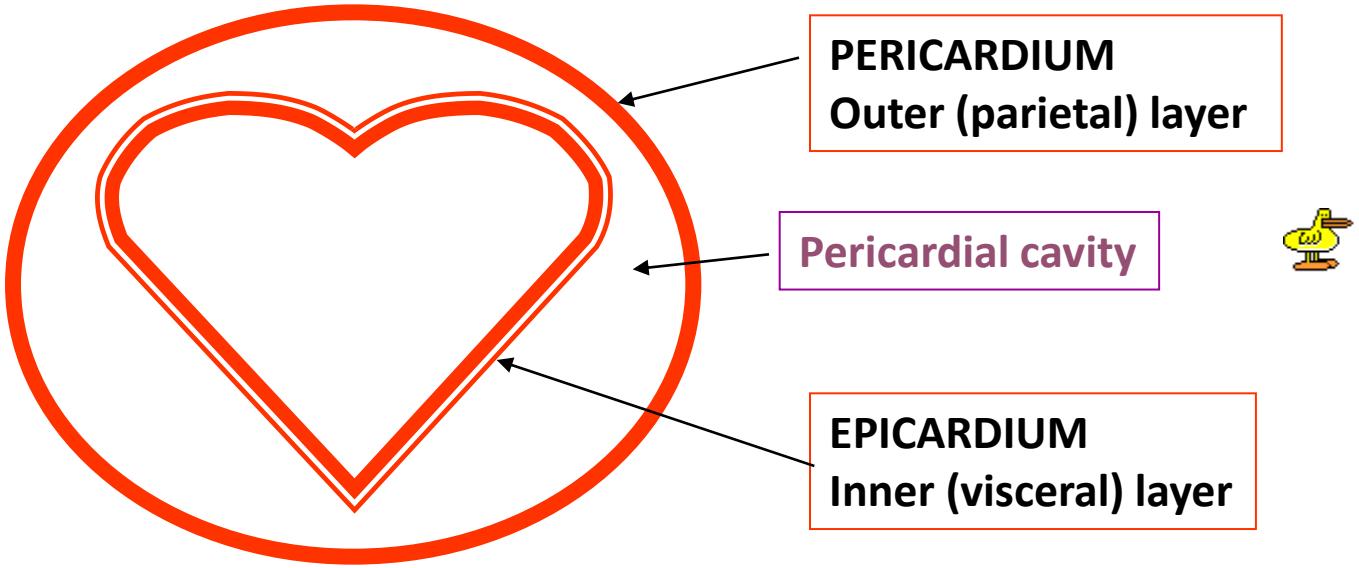
The heart is the hardest working muscle in the human body.



- Hollow muscular organ – blood pump
- Rythmic contraction
- Involuntary muscle



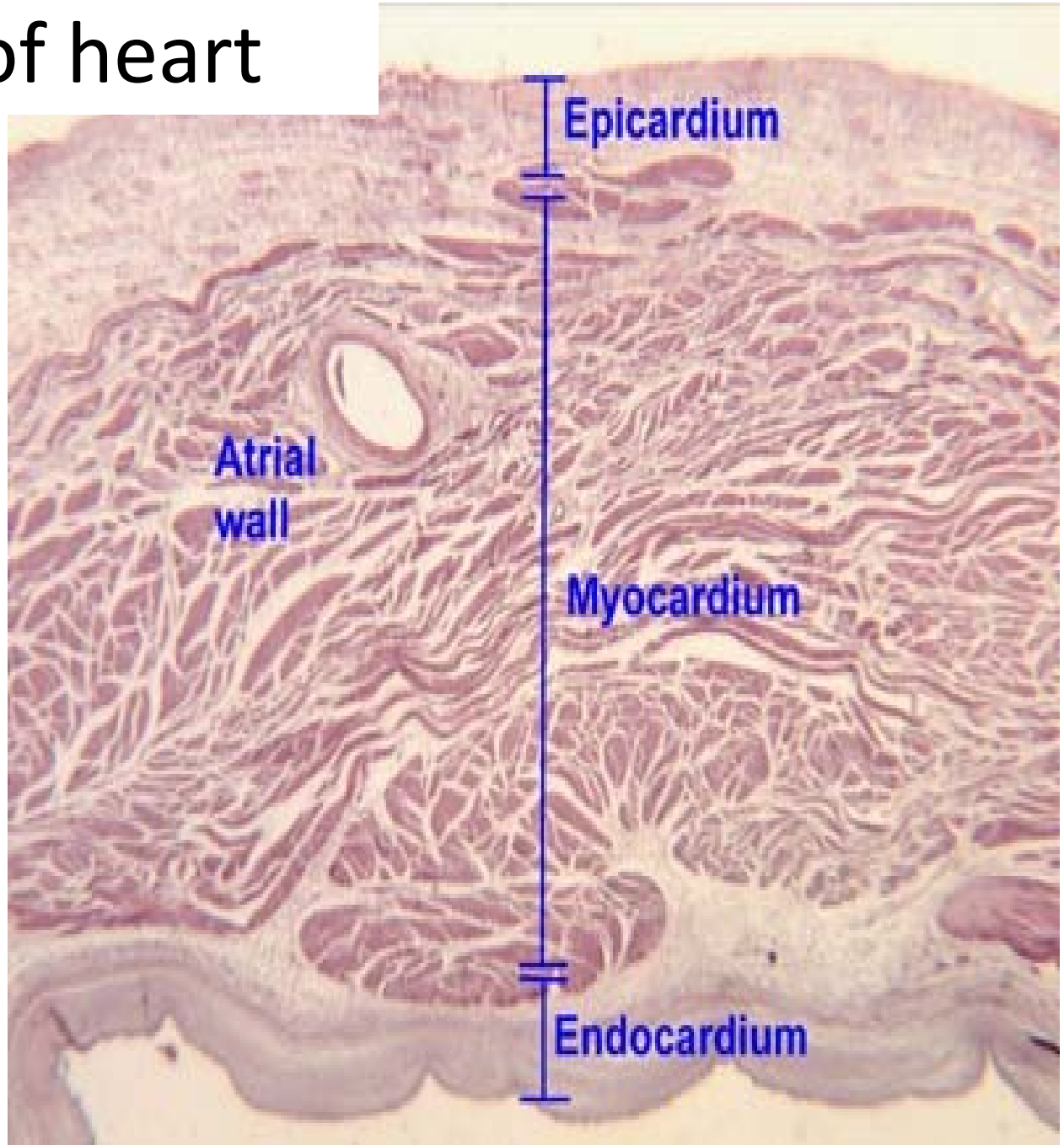
Pericardial sac:
pericardium + epicardium

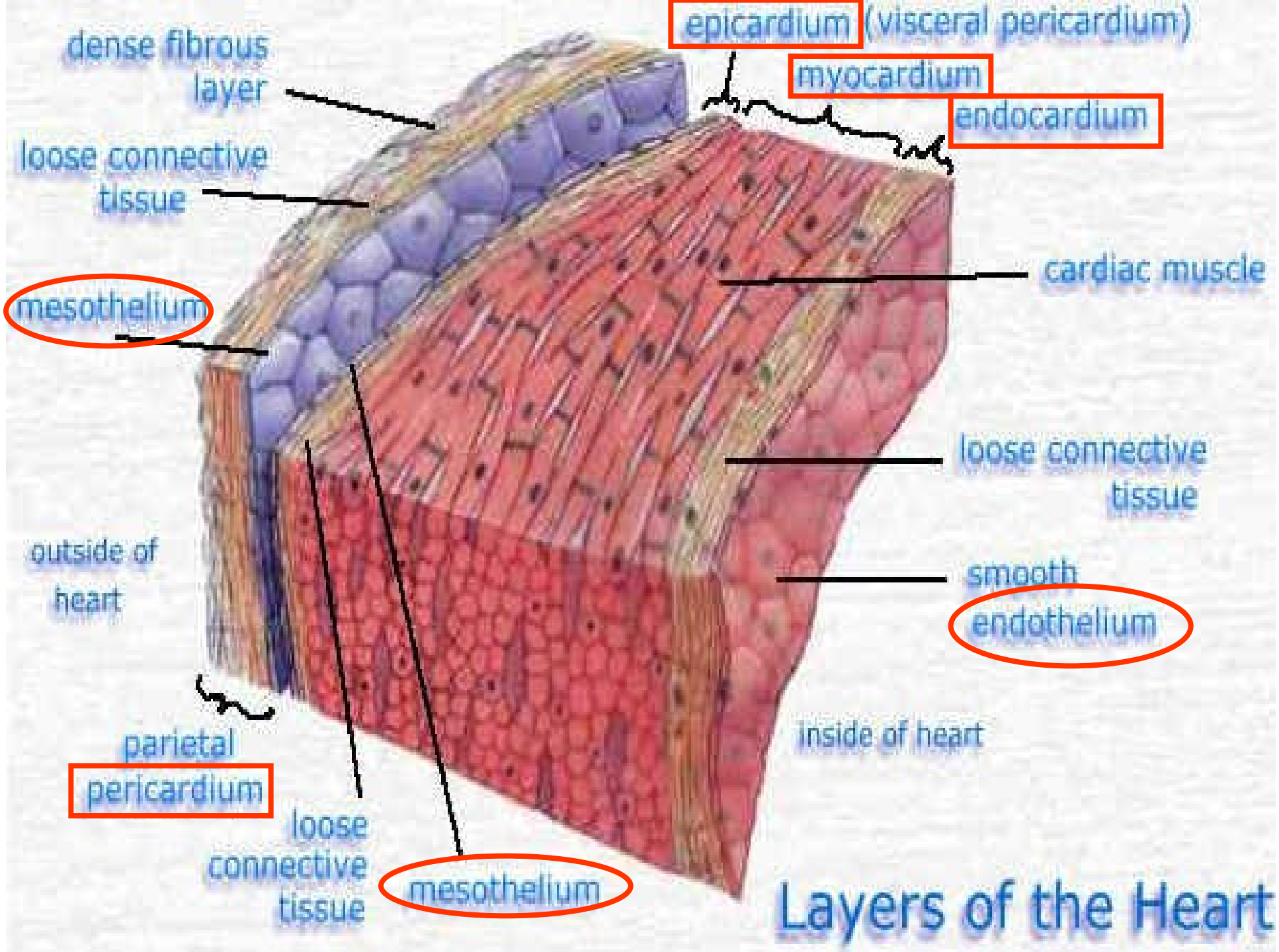


Pericardial cavity - contains 15 – 50 ml of serous fluid serves as lubricans;
- is lined with mesothelium

The wall of heart

- Epicardium
- Myocardium
- Endocardium




epicardium (visceral pericardium)
myocardium
endocardium
dense fibrous layer
loose connective tissue
mesothelium
cardiac muscle
loose connective tissue
smooth endothelium
outside of heart
inside of heart
parietal pericardium
loose connective tissue
mesothelium
Layers of the Heart

Endocardium

(homologous to intima of blood vessels)

Consists of:

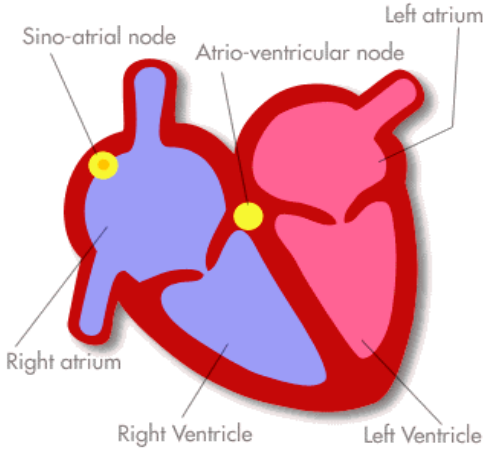
- **Endothelium**
- **Subendothelium** – thin connective tissue layer
- **Elastic-muscular layer** – dense c.t. (elastic fibers, smooth m. cells)
- **Subendocardium** – c.t. + vessels, nerves and distal part of conducting system (ventricular bundles and Purkinje fibers)

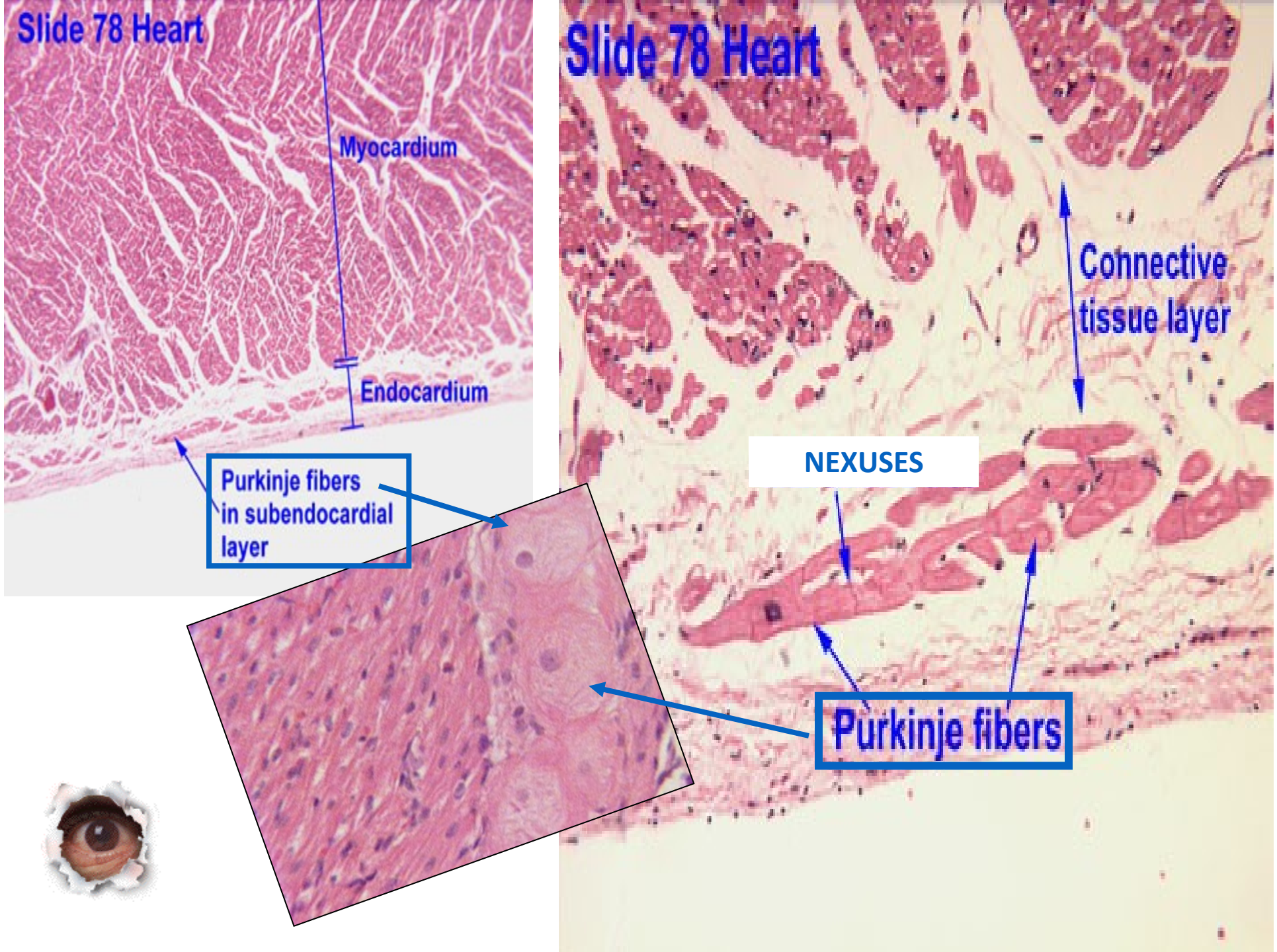
Attention!

Purkinje fibers ≠ **Purkinje cells**

Heart Structure

Conducting System

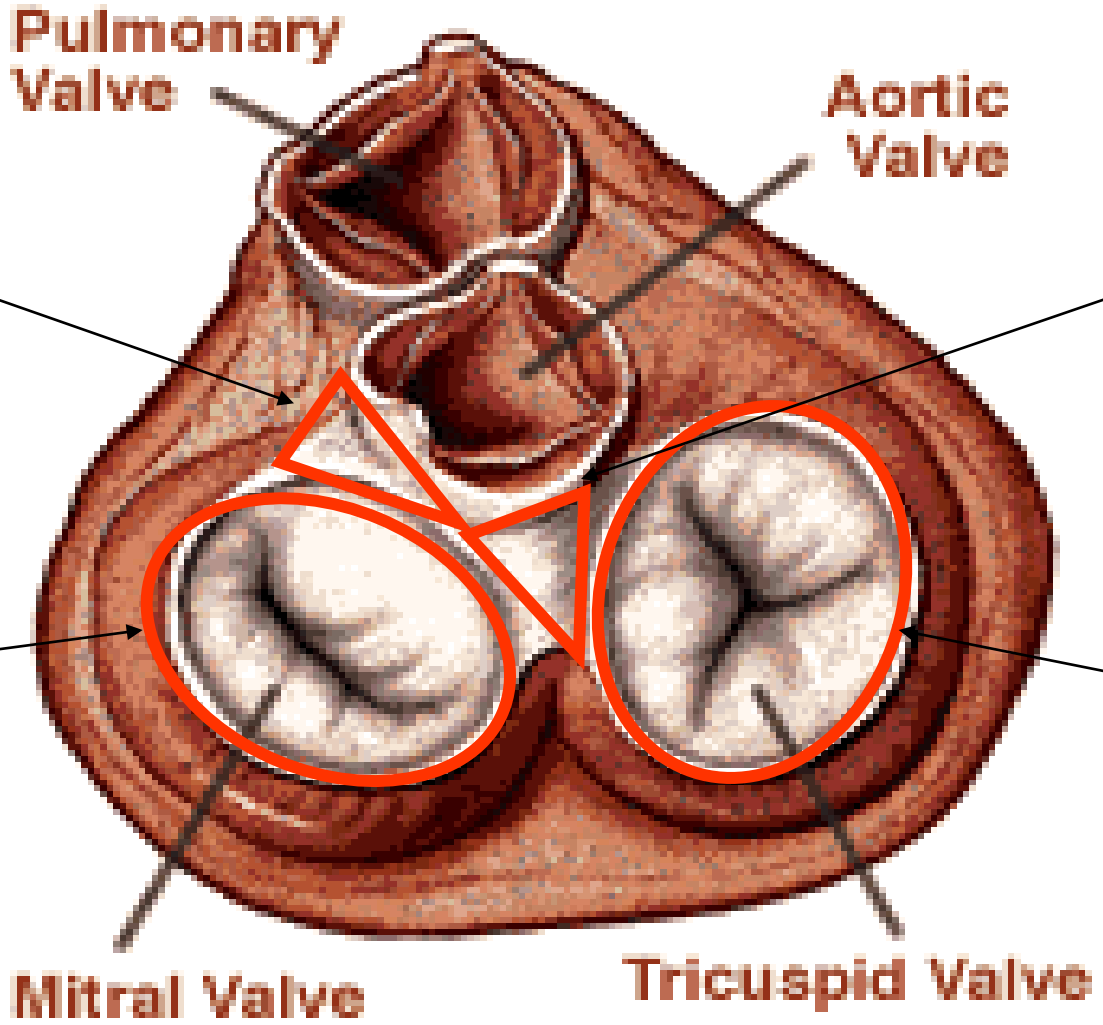



Slide 78 Heart
Myocardium
Endocardium
Purkinje fibers in subendocardial layer
Slide 78 Heart
Connective tissue layer
NEXUSES
Purkinje fibers

Myocardium

- cardiomyocytes „working“
  „conducting“
- cells in right ventricle – **natriuretic factor** (when intravascular volume increases, this factor is released and causes natriuresis and diuresis in kidney)
- **atrial myocardium is thinner than ventricular**
- **„left heart“ myocardium is thinner than „right heart“**
- **cords of cardiomyocytes are ended on heart skeleton**
- **damage of myocardium - infarction**
- **low regeneration of myocardium – by scar (decreases function of heart muscle)**

Heart skeleton



Trigonum fibrosum sin.

Trigonum fibrosum dx.

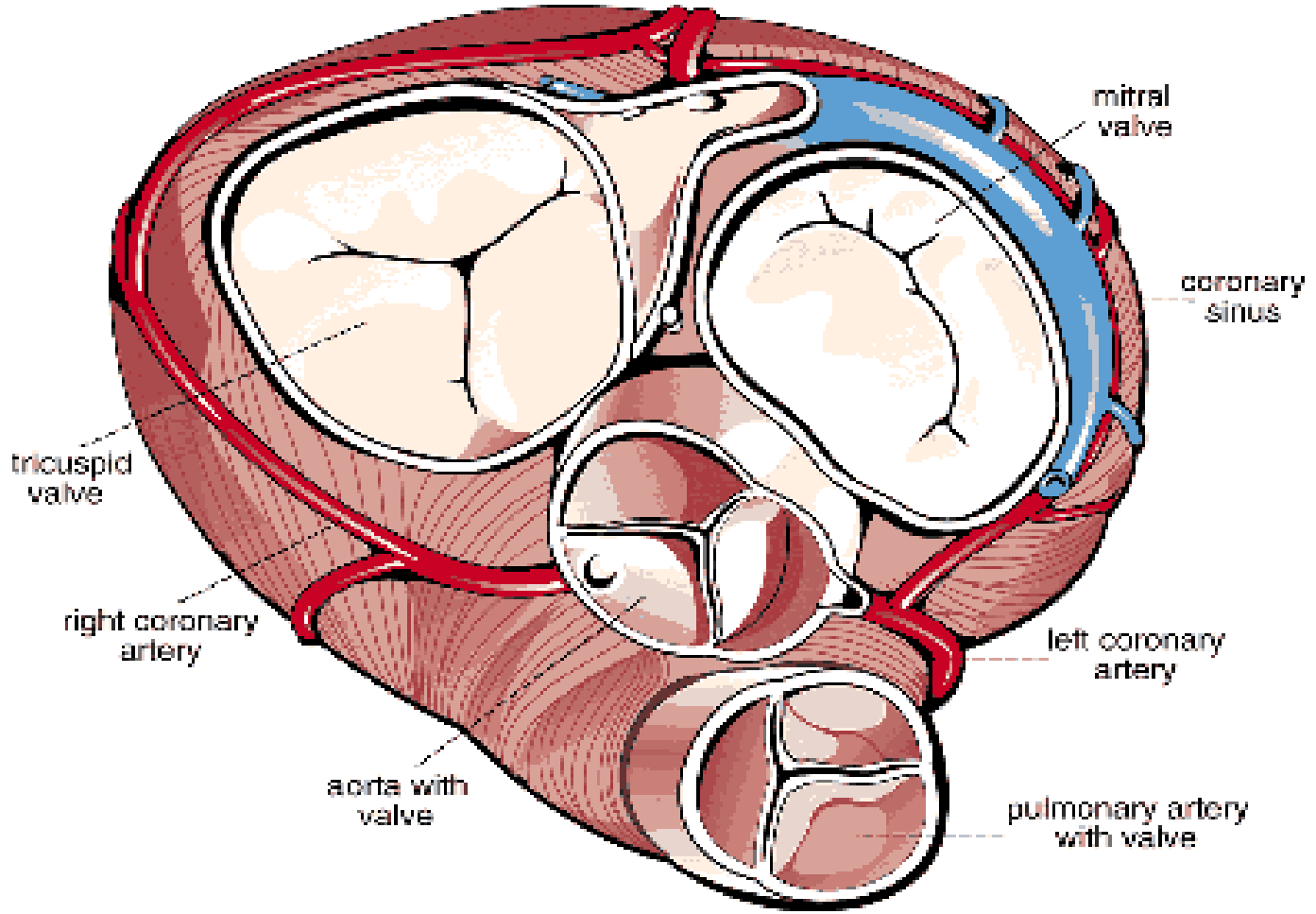
Anulus fibrosus sin.

Anulus fibrosus dx.

Pars membranacea interventricularis

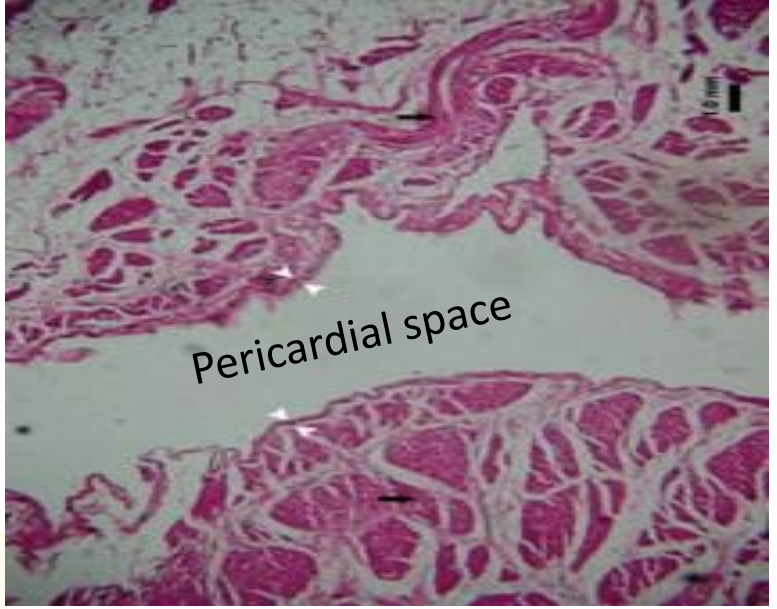
Endocardial valves

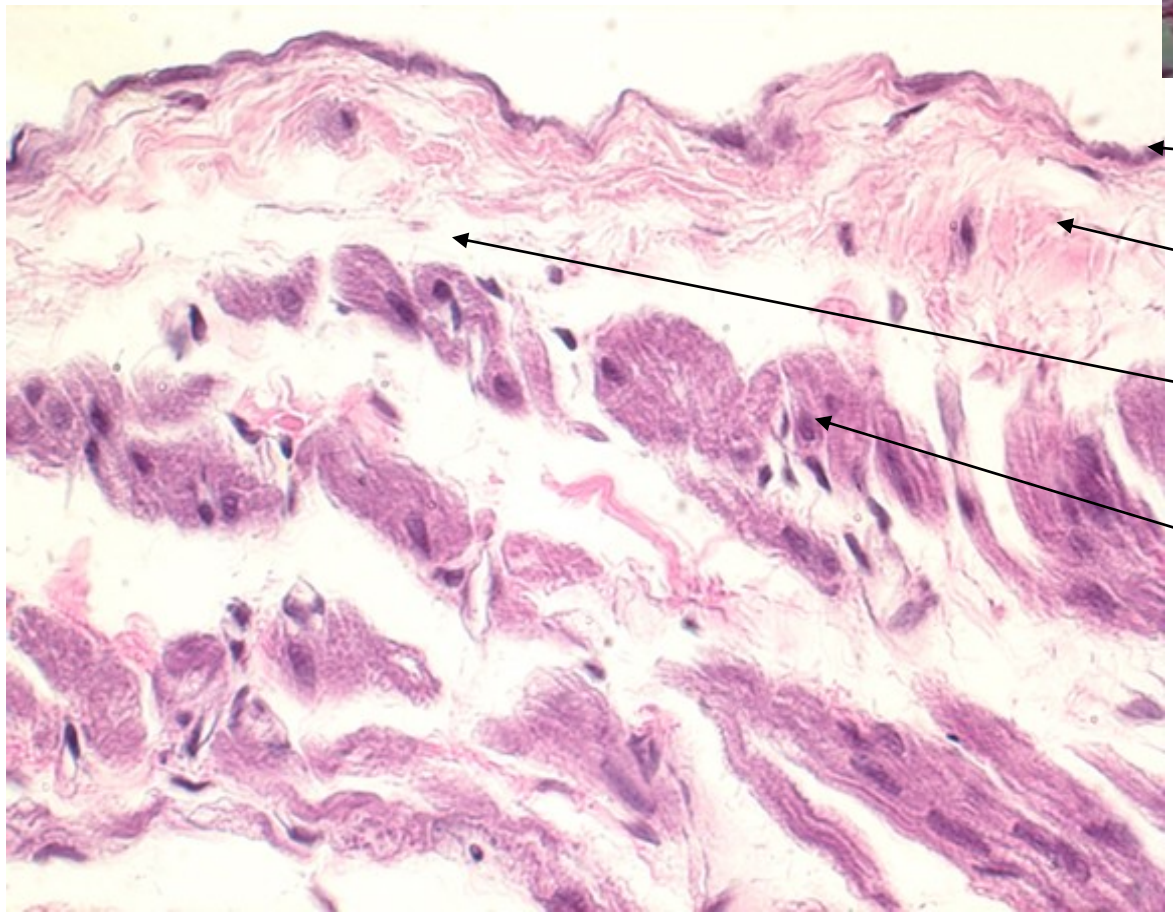
Plates of dense connective tissue (continuous with heart skeleton) covered with endocardium.



Epicardium

Mesothelium lines pericardial space
and so it covers outer surface of epicardium
and inner surface of pericardiu



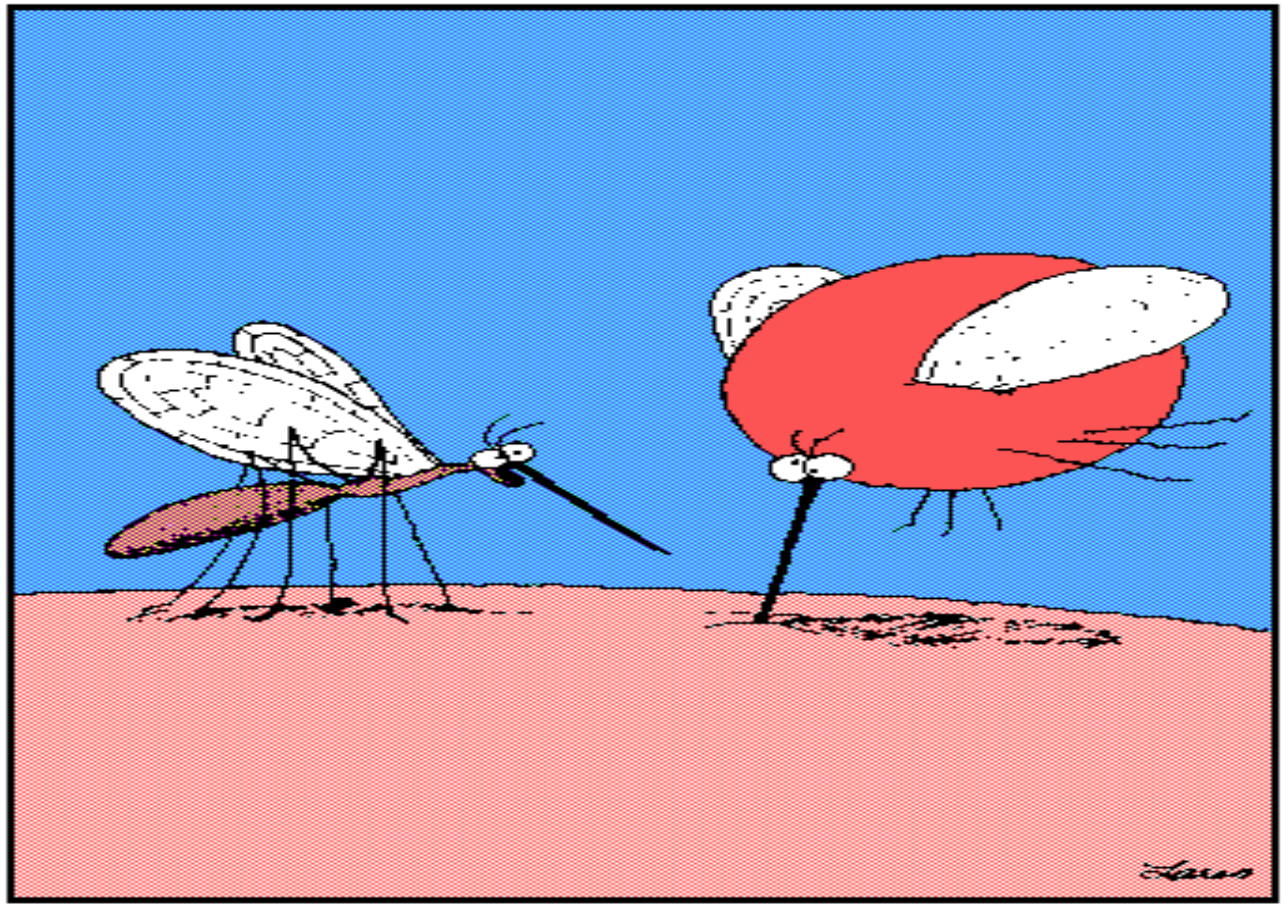


mesothelium

connective tissue

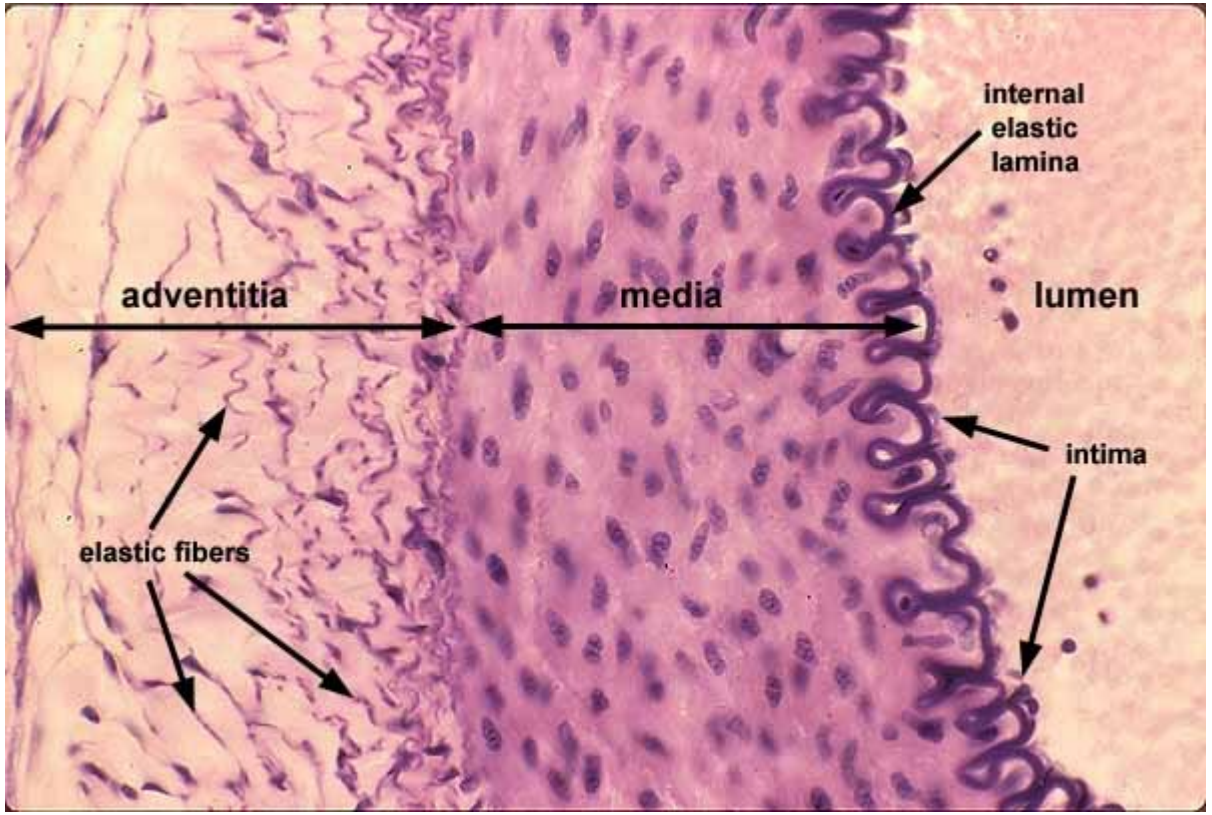
subepicardial c.t.

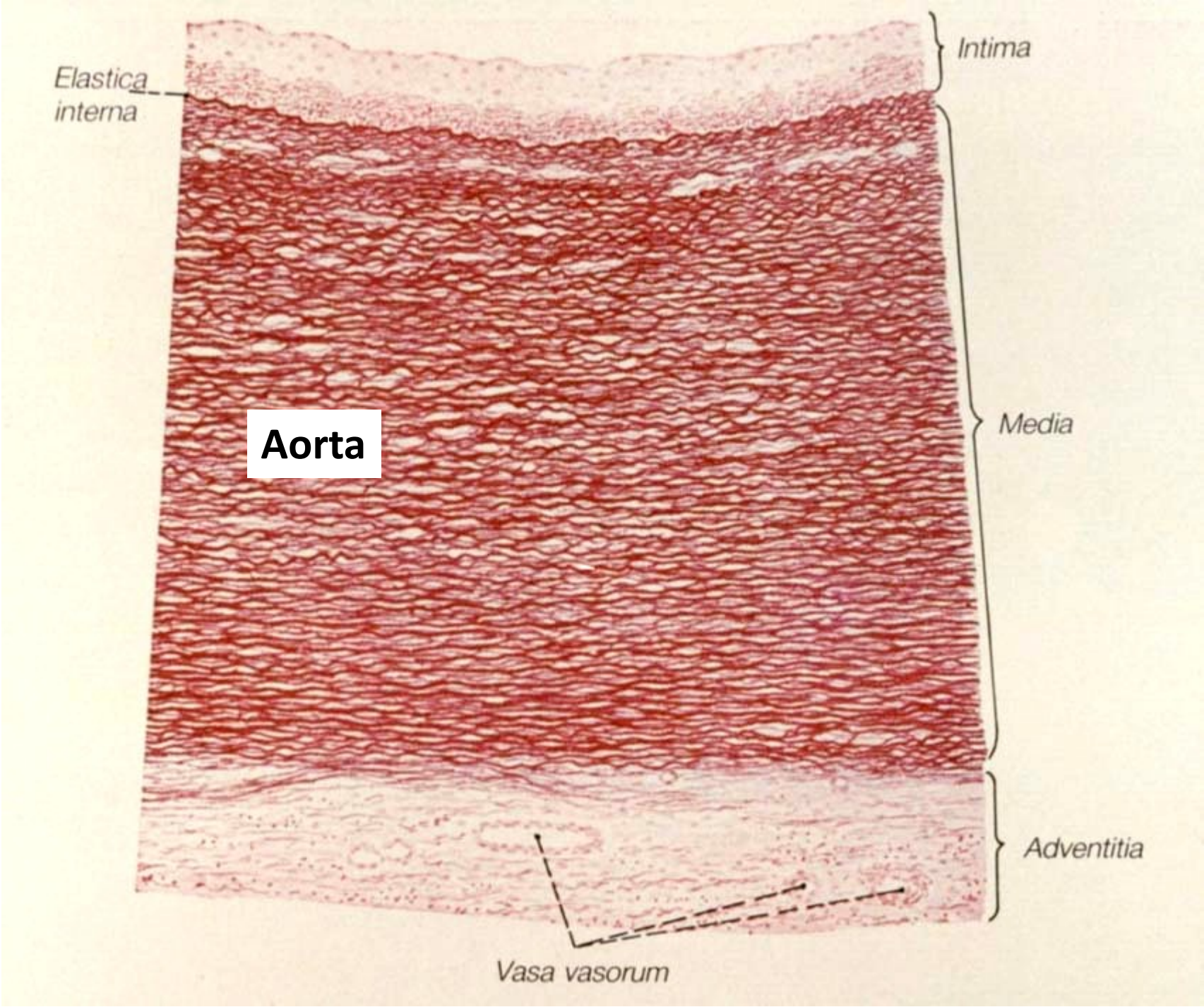
myocardium



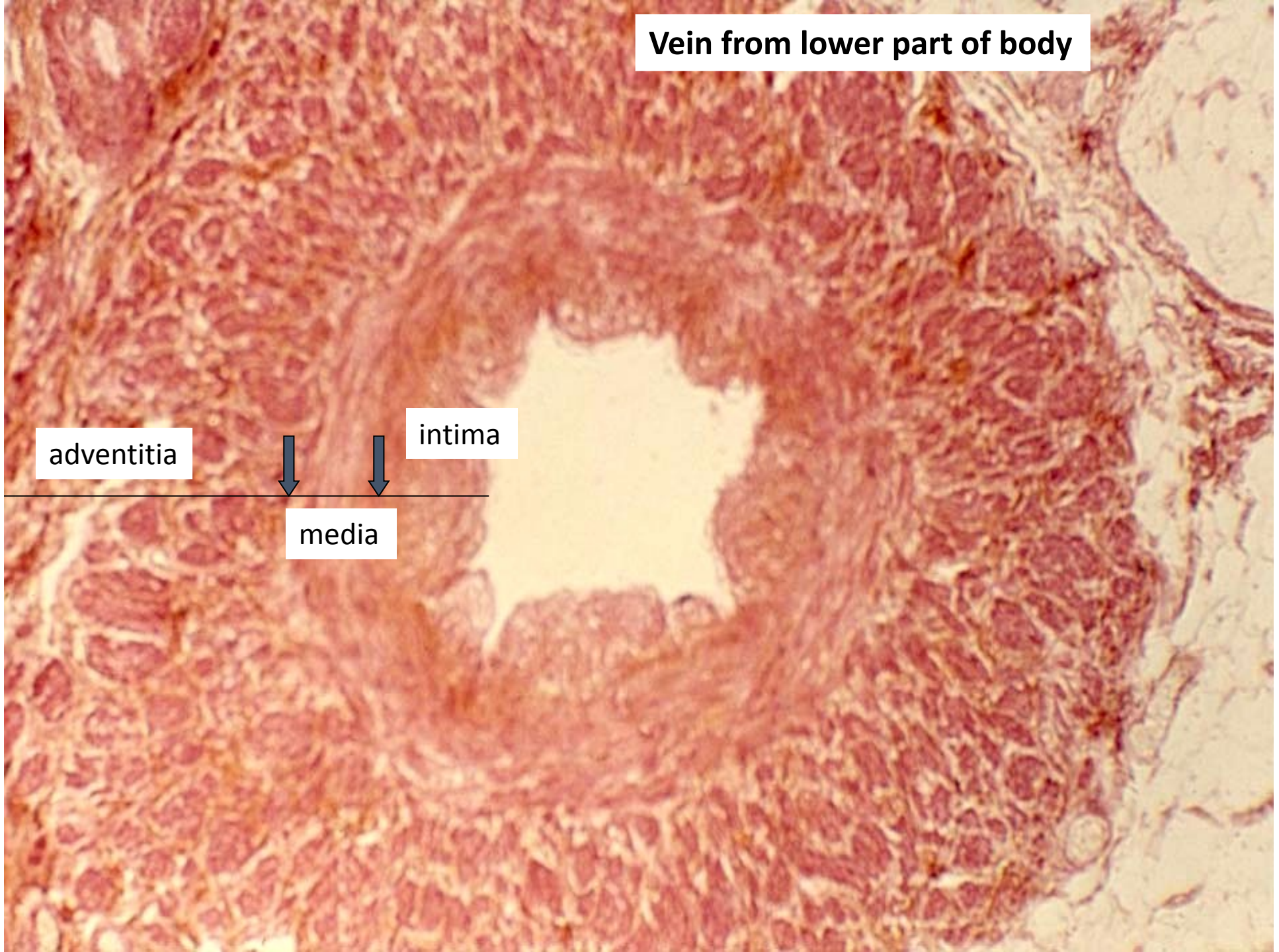
hearty thanks for your attention

Muscular artery

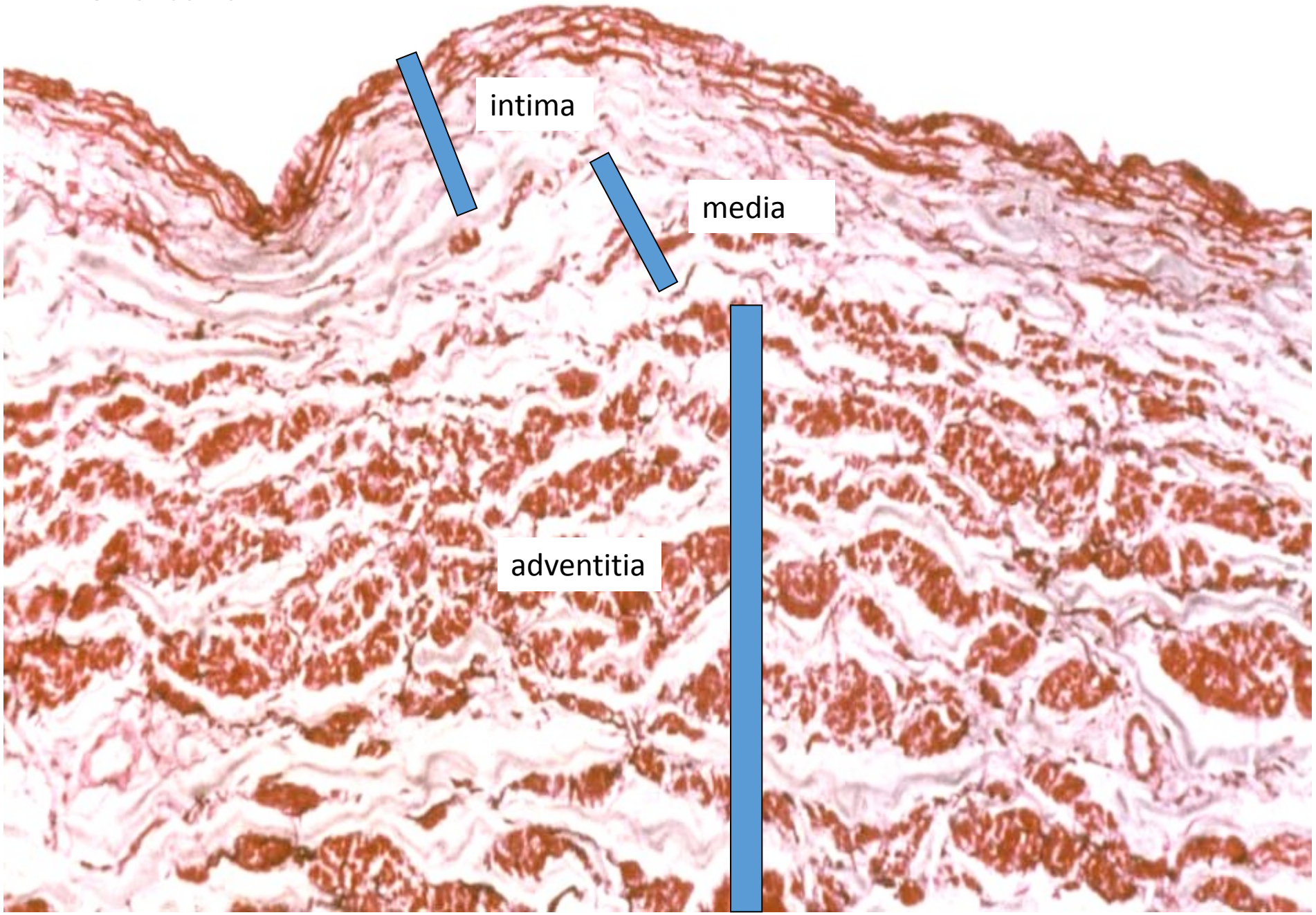


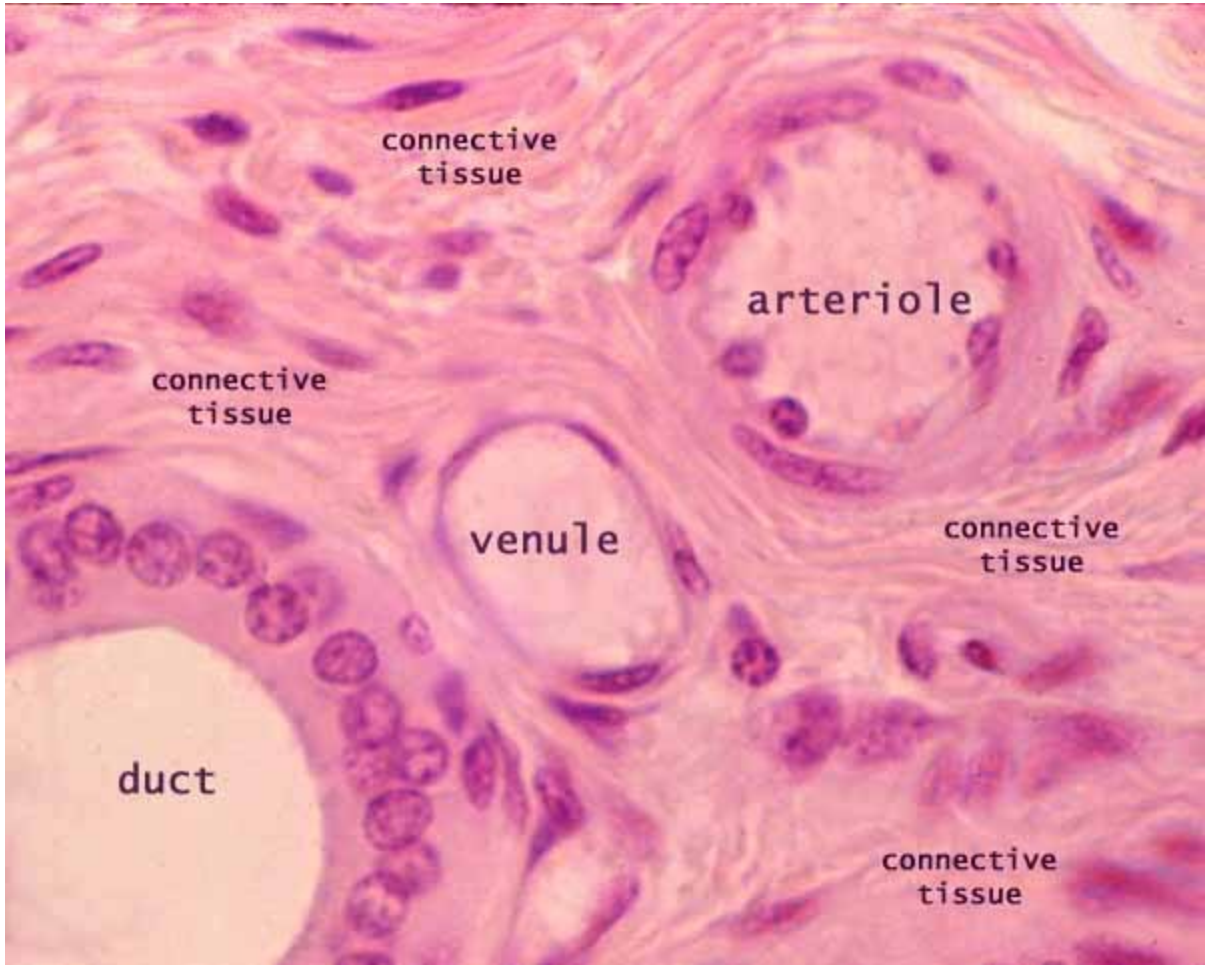


Aorta


Vein from lower part of body
adventitia
intima
media

Vena cava




connective tissue
arteriole
connective tissue
venule
connective tissue
duct
connective tissue

Lymphatic vessells

- **Lymphatic vessels** (often just called *lymphatics*) are channels which drain excess fluid ("lymph") from tissues.
- In most peripheral tissues, some plasma seeps out of capillaries. A portion of this is taken back up in venules while the rest drains into terminal lymphatic channels, also called lymphatic capillaries. A shift in the balance between fluid entering and leaving tissues (e.g., increased vascular permeability due to inflammation) can result in accumulation of tissue fluid, or *edema*.
- All lymphatic vessels eventually lead "downstream" to the thoracic duct, which empties into the vena cava (a point where blood pressure is quite low; higher pressure would impede drainage).
- **Lymphatic vessels** resemble blood vessels with exceptionally delicate walls (and, of course, without red blood cells). Smaller lymphatic vessels consist of little more endothelium.