

A 3D illustration of a blood vessel cross-section. The vessel walls are shown in a reddish-brown color. Inside the vessel, there is a dense population of red blood cells (erythrocytes) and a few white blood cells (leukocytes). The red blood cells are depicted as biconcave discs, while the white blood cells are larger and more spherical. The overall scene is set against a dark red background, suggesting the interior of a blood vessel.

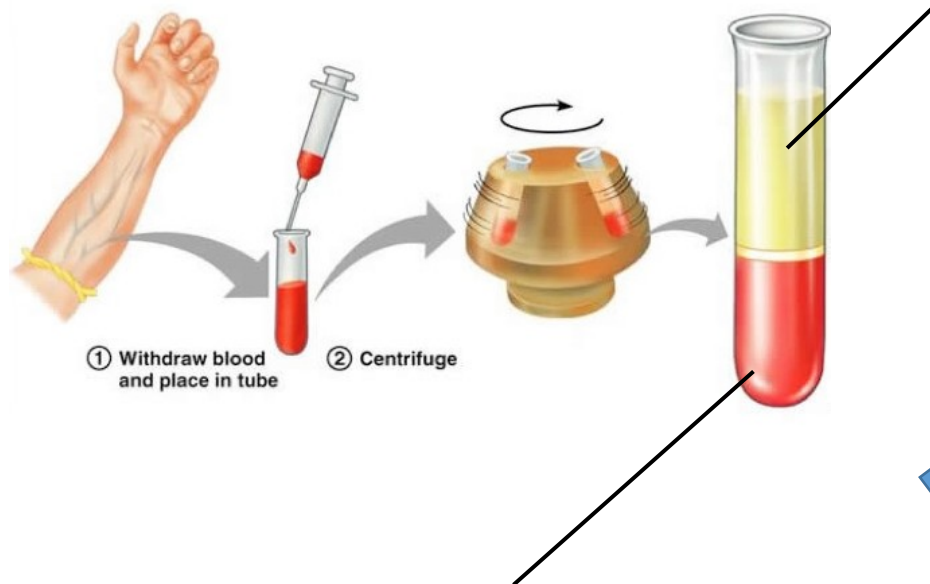
KREV A KRVETVORBA

Petr Vaňhara

Ústav histologie a embryologie LF MU

Krev je tělní tekutina

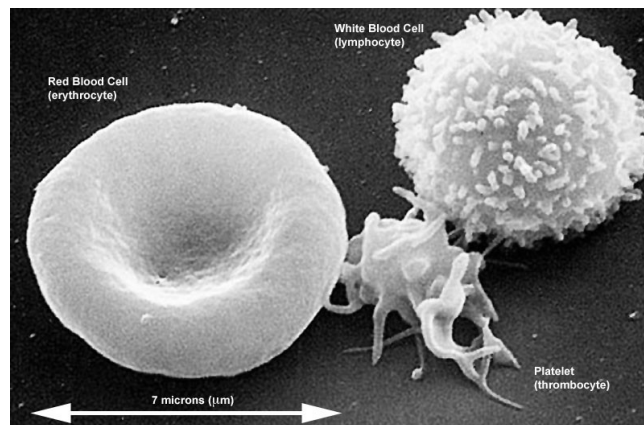
- transportní médium (O₂, CO₂, metabolity, hormony, živiny...)
- homeostáza vnitřního prostředí těla (termoregulace, acidobazická rovnováha, onkotický tlak)
- integrita kardiovaskulárního systému (srážecí kaskáda)
- imunitní reakce



plazma

- ionty, proteiny, nízkomolekulární organické látky
- tekutá ECM

Krev lze považovat za trofickou pojivovou tkáň



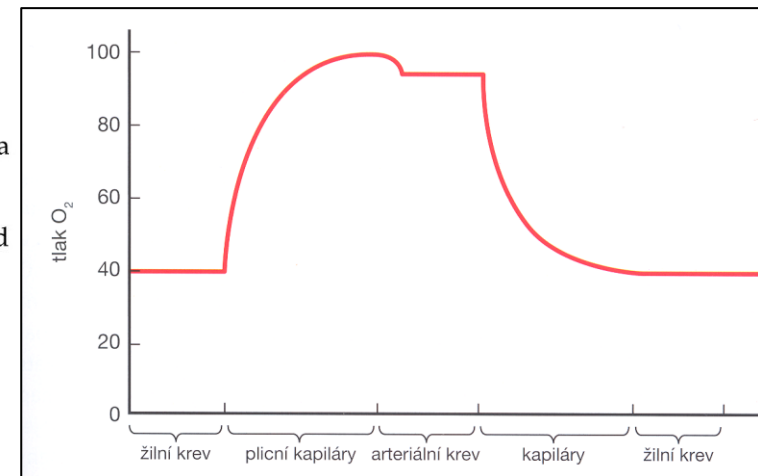
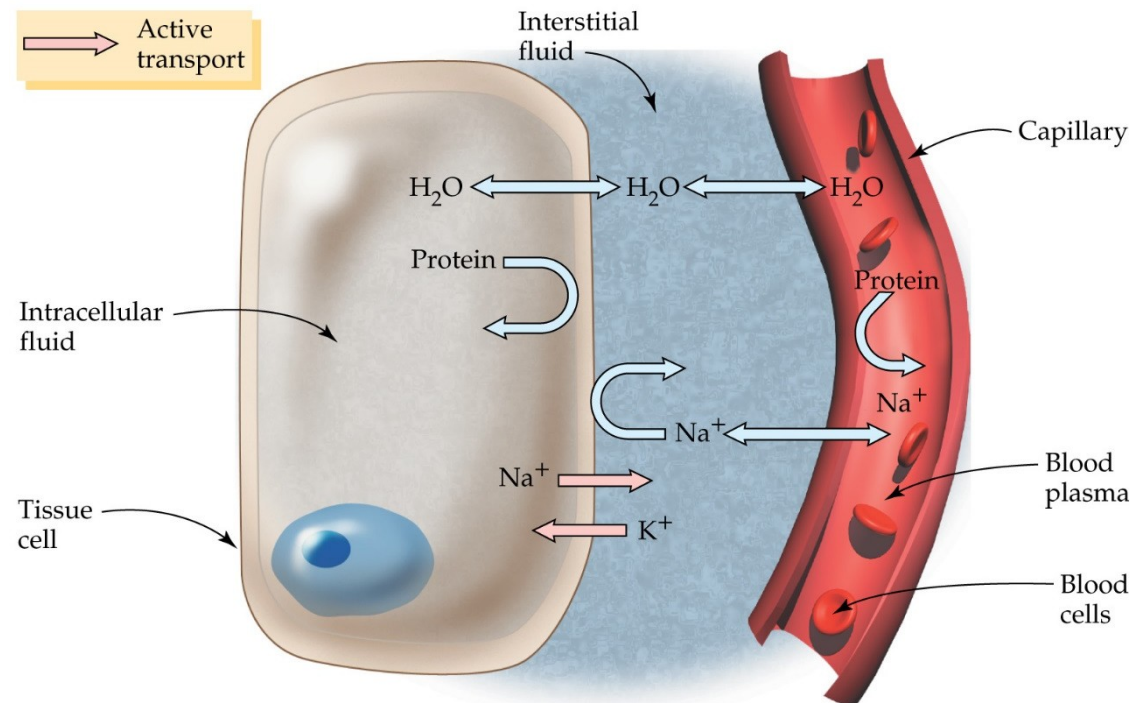
formované krevní elementy – krvinky

- erythrocyty
- leukocyty
- trombocyty

KREVŇÍ PLAZMA A TKÁŇOVÝ MOK

plazma

- 2,8-3,5 l
- pH 7.4 (\pm 0.05)
- ~ 92% voda
- ~ 1% **ionty** (Na^+ , K^+ , Ca^{2+} , Mg^{2+} , Cl^- , HCO_3^-), **nízkomolekulární organické látky** (glukóza, aminokyseliny, cholesterol, lipidy, odpadní produkty), **dýchací plyny**
- ~ 7% **proteiny** (albuminy, globuliny, fibrinogen)



IONTY A MALÉ MOLEKULY KREVŇÍ PLAZMY (~1%)

- ~ 1% **ionty** (Na, K⁺, Ca⁺, Mg⁺, Cl⁻, HCO₃⁻), **nízkomolekulární organické látky** (glukóza, aminokyseliny, cholesterol, lipidy, odpadní produkty), **dýchací plyny**

	Sodík	136–148 mmol/l	Osmotický tlak, objem, pH
	Draslík	3,7–5,0 mmol/l	Membránový potenciál buněk (nervové, svalové)
Kationty	Vápník	2,15–2,61 mmol/l	Permeabilita membrán, srážení krve, nervosvalový přenos
	Hořčík	0,66–0,94 mmol/l	Kofaktor enzymů, nervové přenosy
	Železo ♂	12–27 μmol/l	Kofaktor enzymů, součást hemu v hemoglobinu
	Železo ♀	10–24 μmol/l	
	Měď	12–22 μmol/l	Kofaktor enzymů
	Chloridy	95–110 mmol/l	Osmotický tlak, objem, pH
Anionty	Hydrogenuhličitaný [HCO ₃] ⁻	22–26 mmol/l	Transport CO ₂ , pufr - pH
	P _i	0,6–1,4 mmol/l	Pufr - pH
	Jód	276–630 μmol/l	Hormony štítné žlázy

IONTY A MALÉ MOLEKULY KREVŇÍ PLAZMY (~1%)

- ~ 1% **ionty** (Na, K⁺, Ca⁺, Mg⁺, Cl⁻, HCO₃⁻), **nízkomolekulární organické látky** (glukóza, aminokyseliny, cholesterol, lipidy, odpadní produkty), **dýchací plyny**

Glukóza	3,3–6,1 mmol/l
Aminokyseliny	2,3–3,9 mmol/l
Močovina	3,0–7,6 mmol/l
Lipidy	4–9 g/l
Triacylglyceroly	0,5–1,8 mmol/l
Fosfolipidy	1,8–2,5 g/l
Kreatinin	55–110 μmol/l
Cholesterol (celkový)	3,5–5,2 mmol/l
Bilirubin	3,3–18,0 μmol/l
Laktát	0,55–2,22 mmol/l

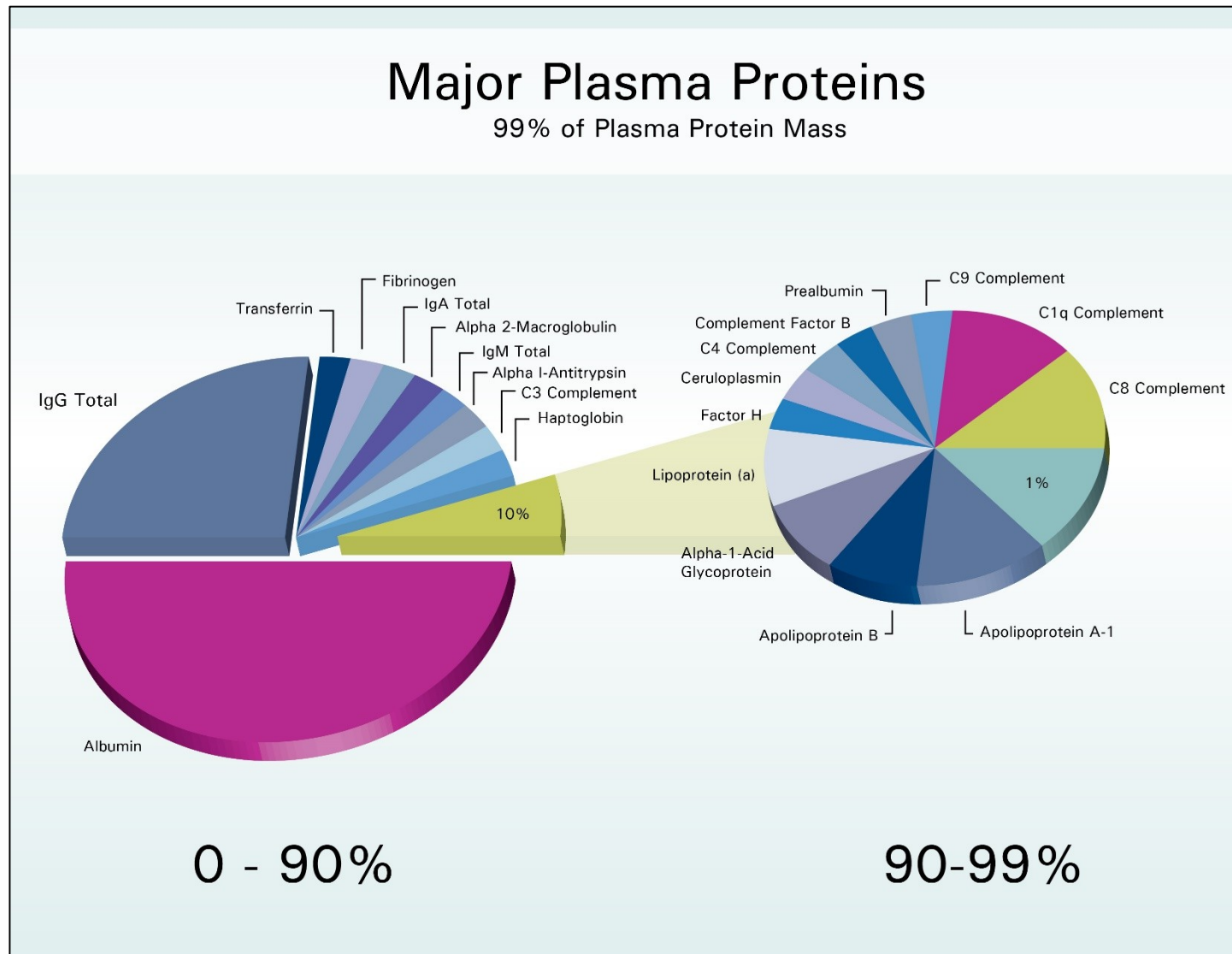


SLOŽENÍ KREVŇÍ PLAZMY JE VELMI STÁLÉ

- je regulované v úzkém rozmezí → zásadní pro klinickou medicínu

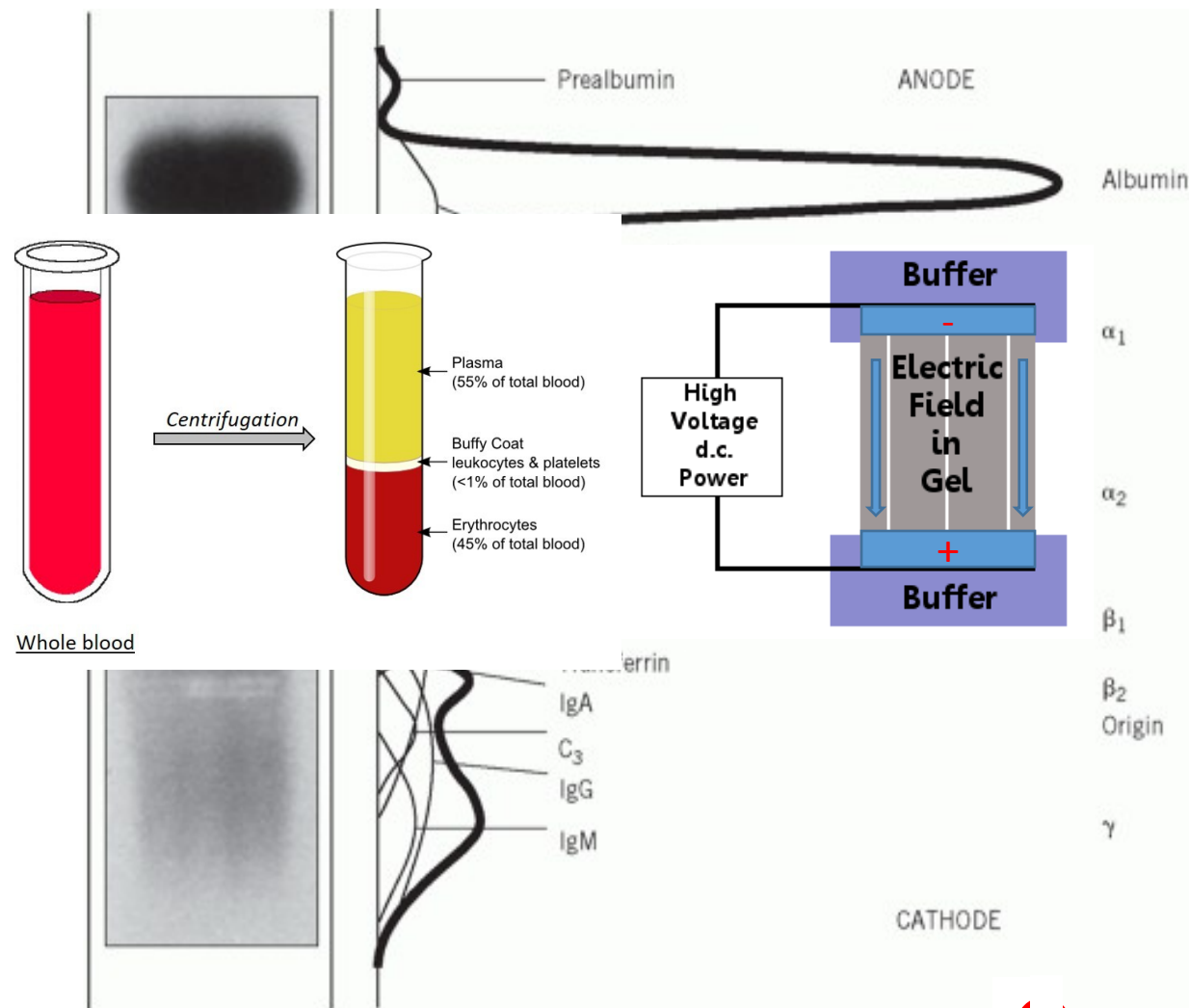
PROTEINY KREVŇÍ PLAZMY (7%)

- osmotický tlak krve
- transport
- koagulace
- imunitní odpověď
- regulační proteiny



PROTEINY KREVŇÍ PLAZMY (7%)

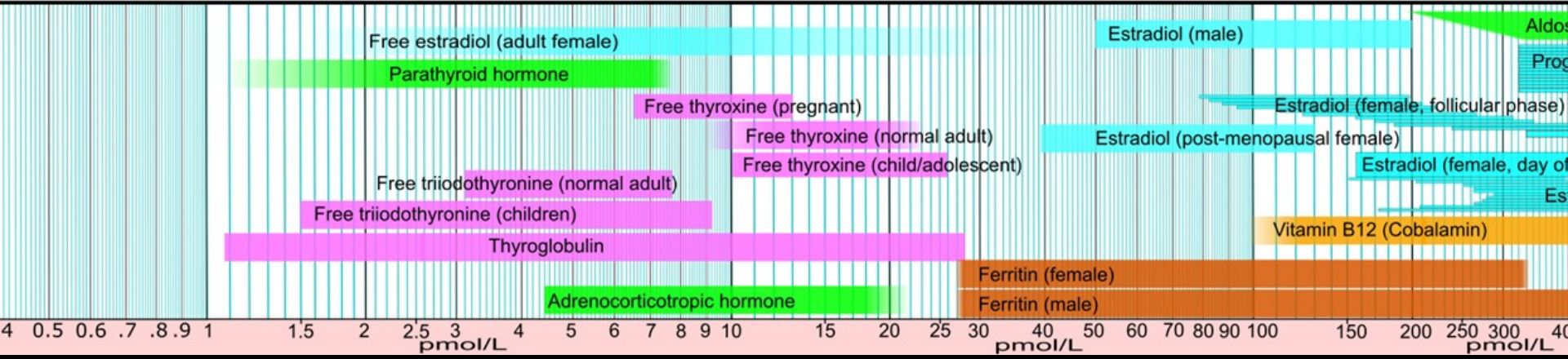
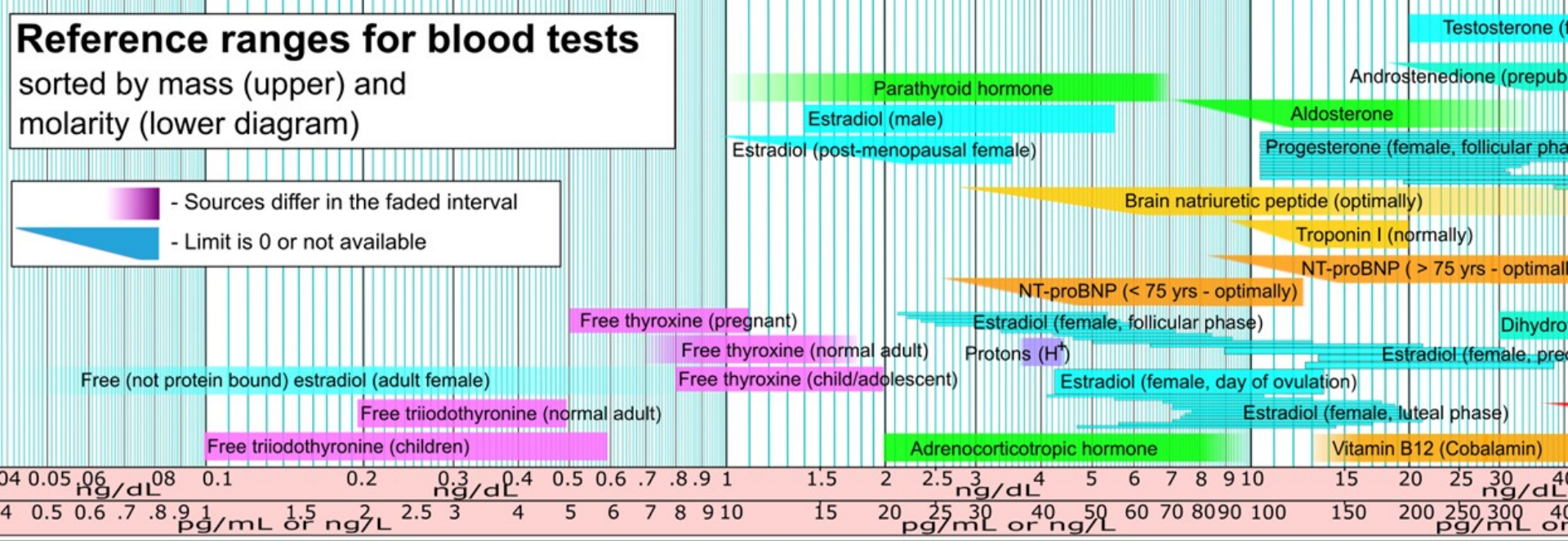
- **prealbumin**
 - transport
- **albumin**
 - 68kDa
 - transport
 - osmotický tlak
- **α1 oblast**
 - α1 lipoprotein (HDL)
 - α1 kyselý glykoprotein
 - α1 antitrypsin (α1 fetoprotein)
- **α2 oblast**
 - α2 makroglobulin
 - haptoglobin
- **β1 oblast**
 - transferrin
 - hemopexin
- β lipoprotein (LDL)
- C4 (komplement)
- **β2 oblast**
 - CRP
 - fibrinogen
 - β2 mikroglobulin
 - C3 (komplement)
- **γ oblast**
 - IgA, IgG, IgM



Reference ranges for blood tests

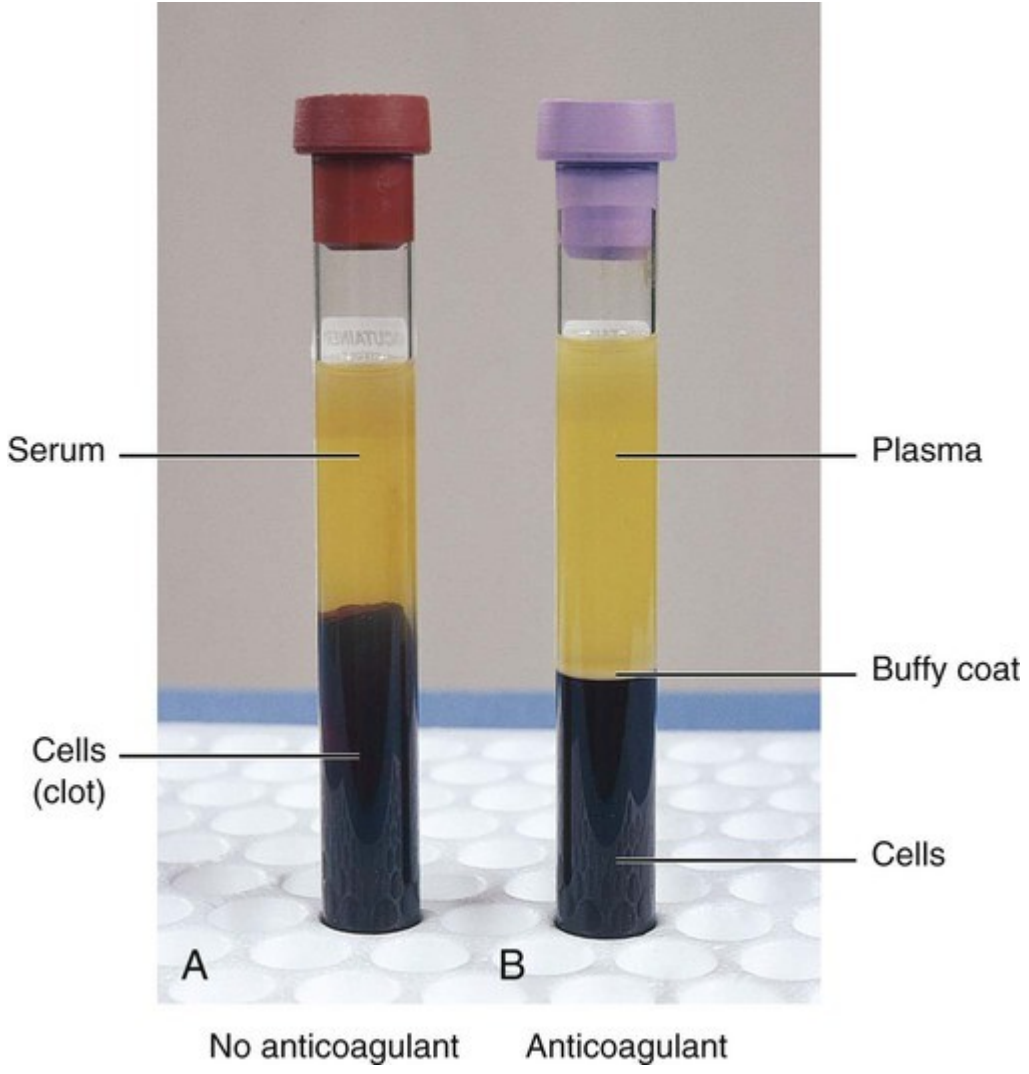
sorted by mass (upper) and molarity (lower diagram)

- Sources differ in the faded interval
- Limit is 0 or not available

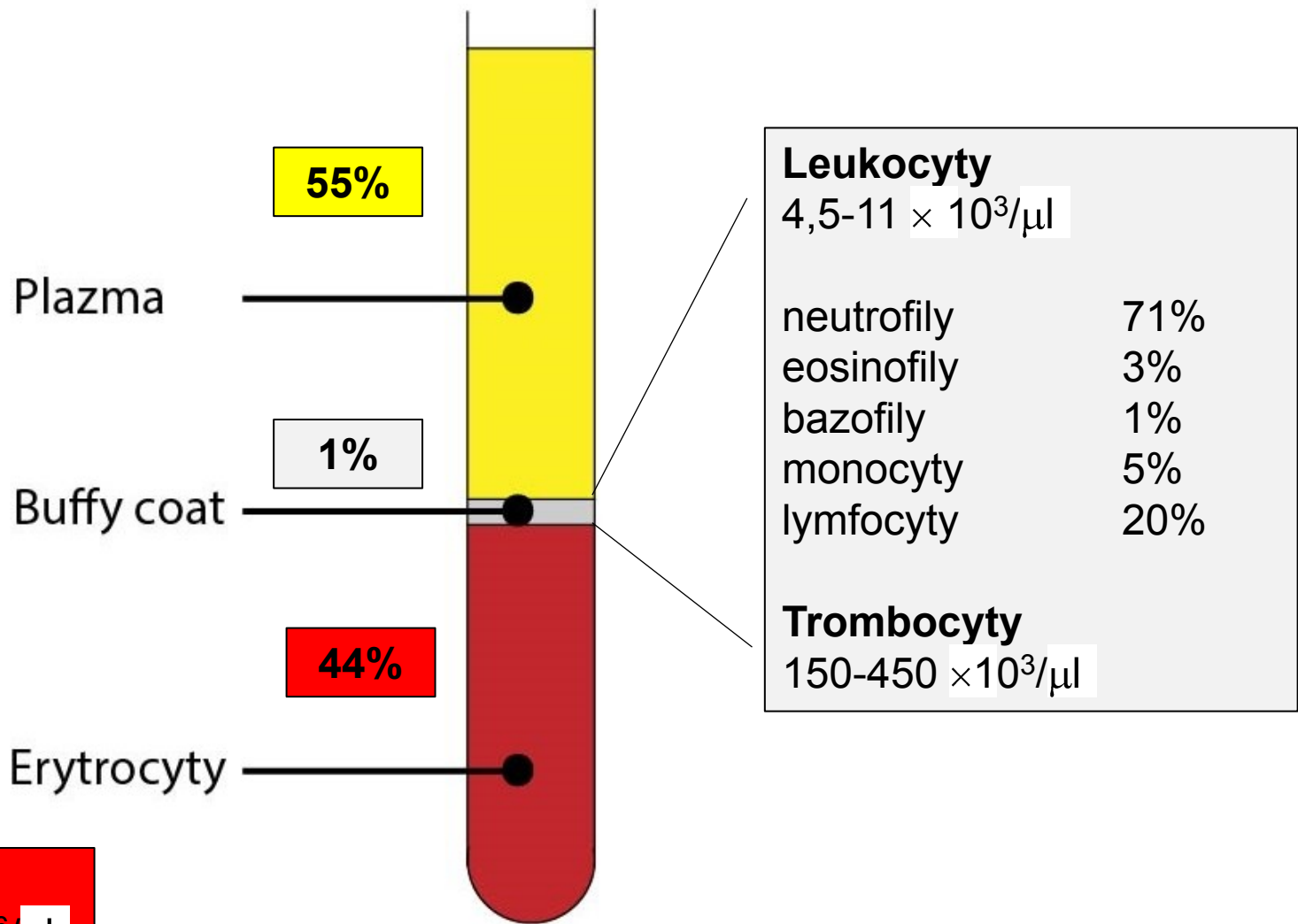


KREVŇÍ PLAZMA A SÉRUM

- sérum ≠ plazma



FORMOVANÉ KREVŇÍ ELEMENTY



Erythrocyty

$4,2-6,2 \times 10^6/\mu\text{l}$

HEMATOKRIT

Podíl objemu erytrocytů a objemu plné krve

Erytrocyty
 $4,2-6,2 \times 10^6/\mu\text{l}$

$47 \pm 5\%$

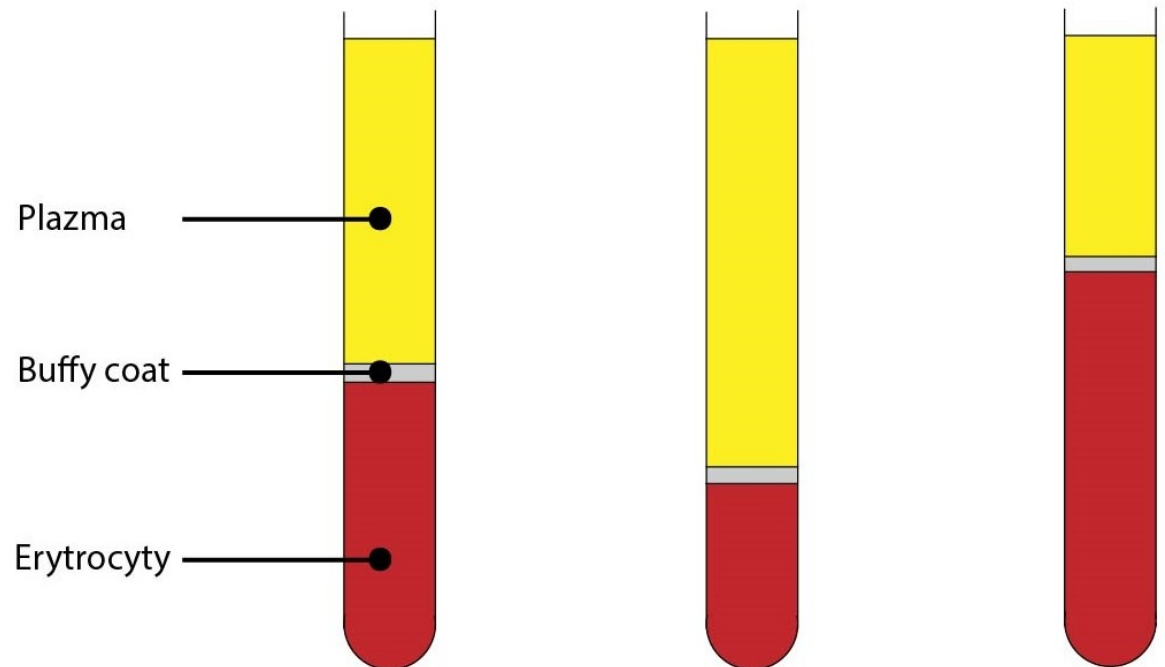
$42 \pm 4\%$

HEMATOKRIT

Norma

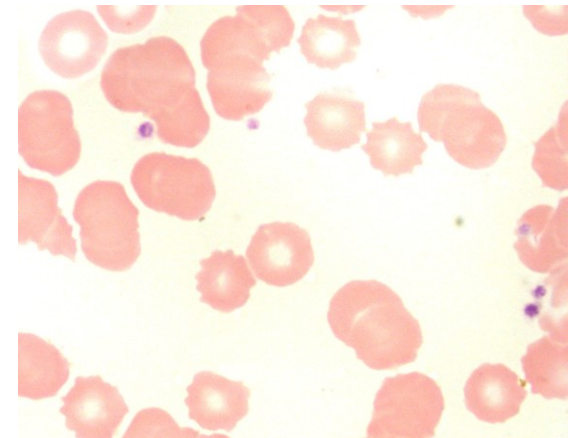
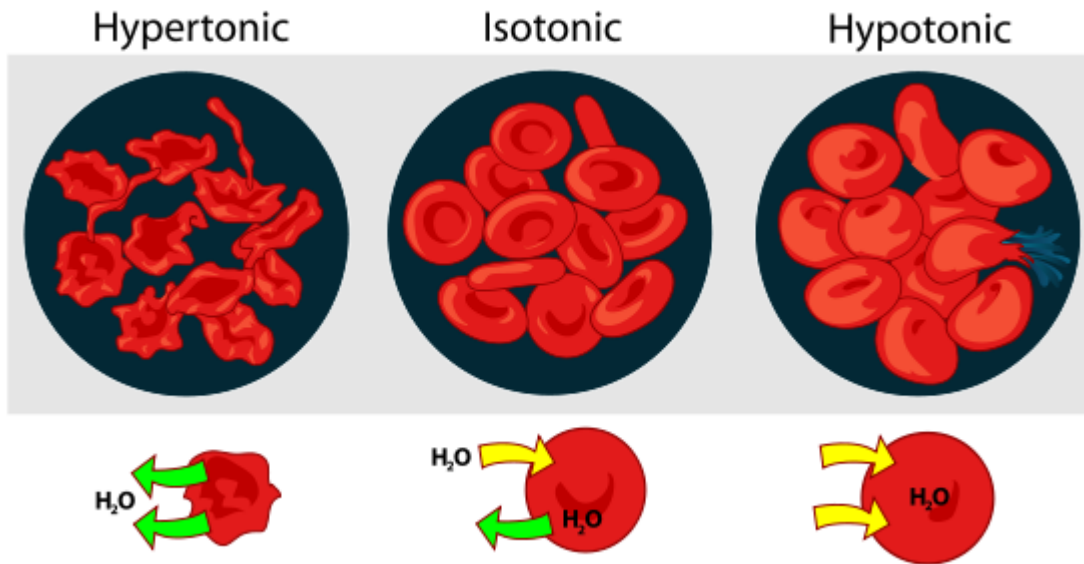
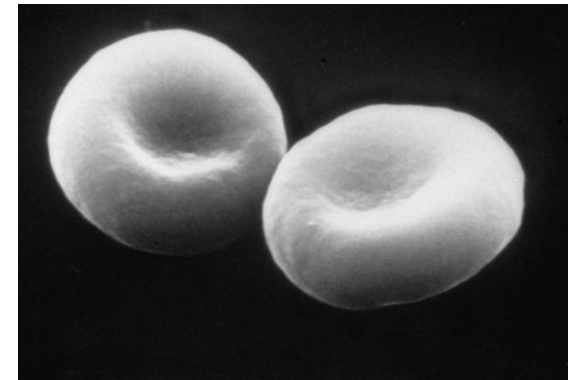
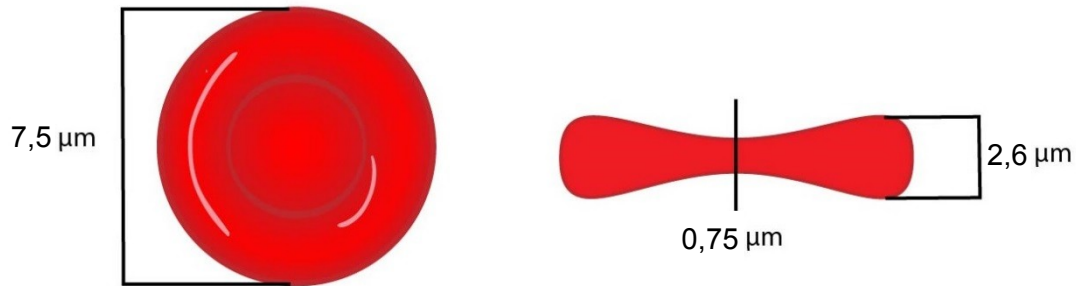
Anémie

Polycytémie



ERYTROCYTY

Velikost je závislá na osmotickém tlaku prostředí

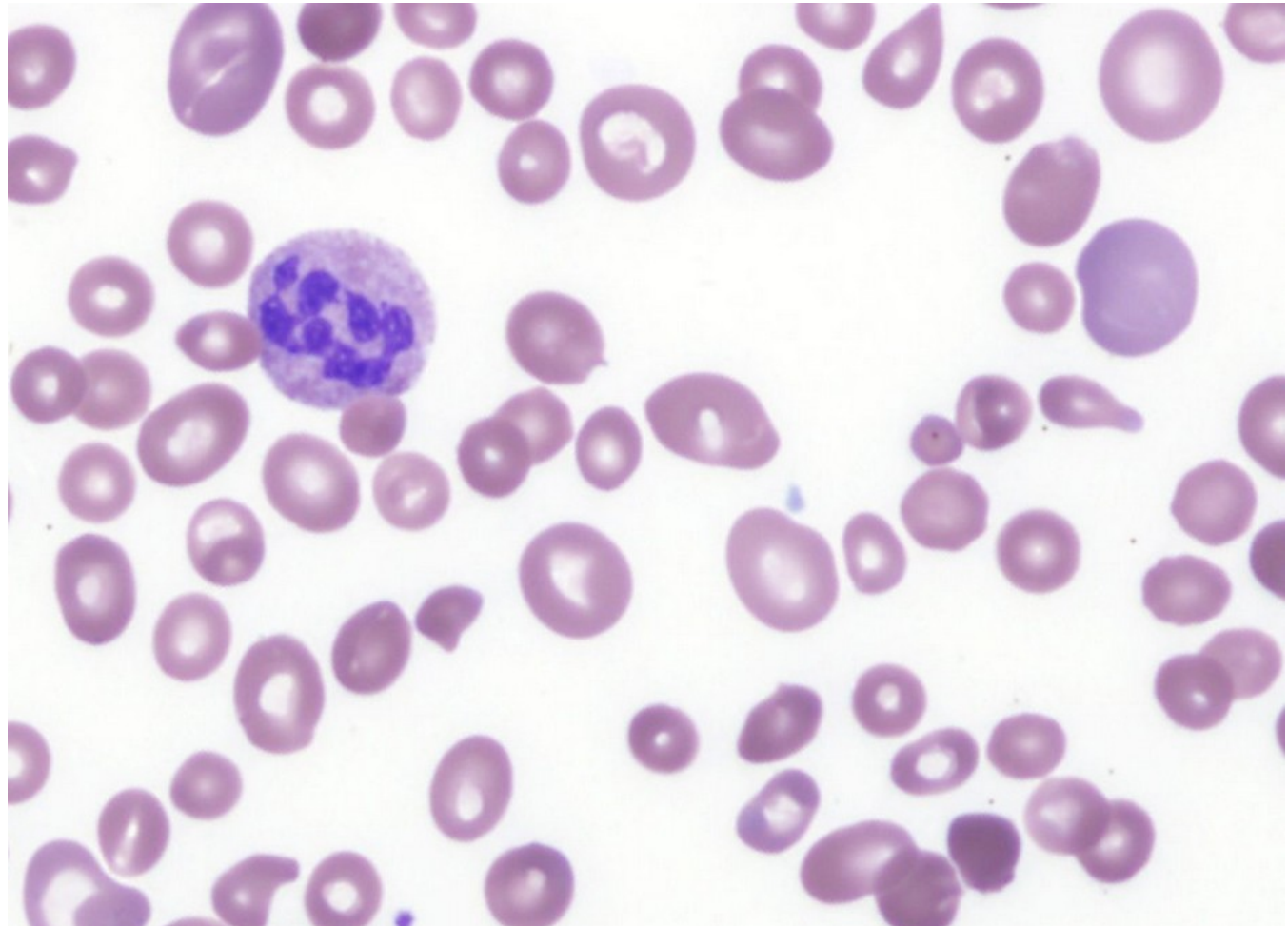


ERYTROCYTY

Odchylky od běžné velikosti

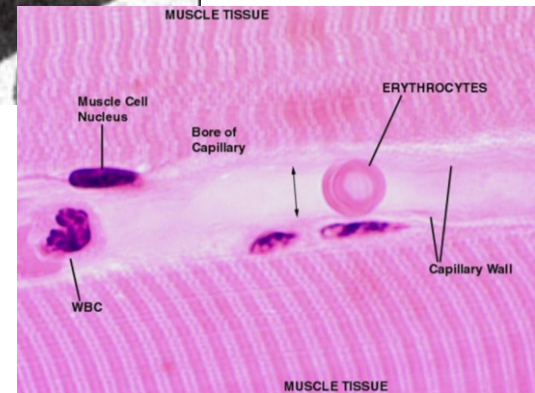
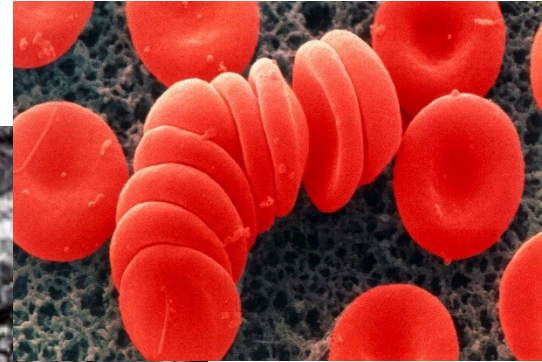
- **anisocytóza**

- makrocyty ($>9 \mu\text{m}$)
- mikrocyty ($<6 \mu\text{m}$)



ERYTHROCYTY

Tvar erythrocytu umožňuje značnou flexibilitu



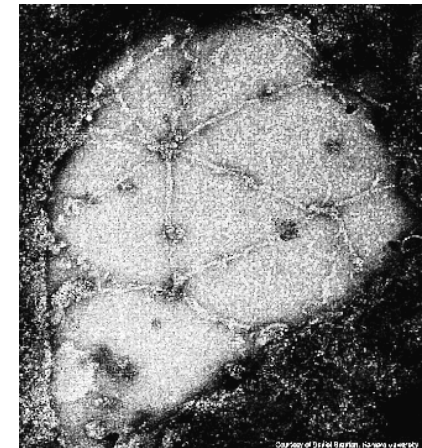
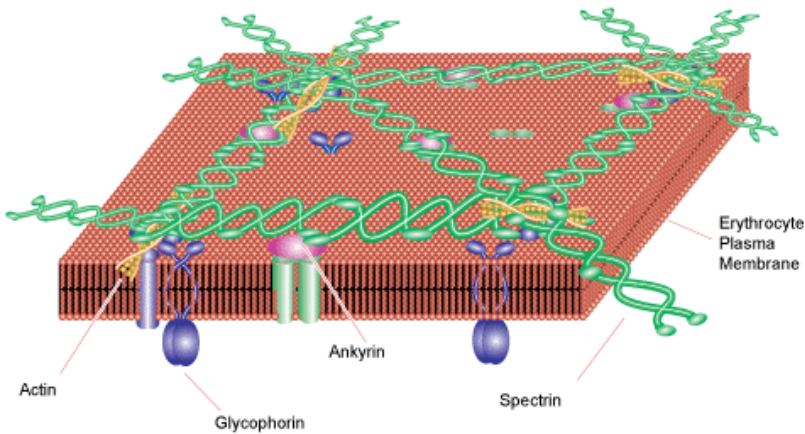
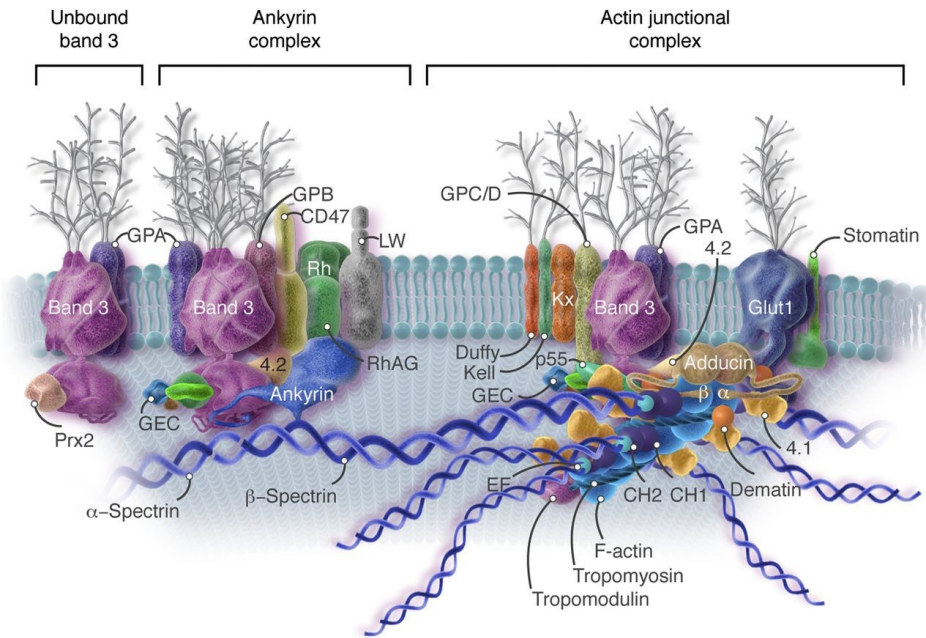
ERYTHROCYTY

Tvar erythrocytů

- **integrální proteiny**
 - band 3, glykoprotein A (iontové transportéry)
- **spektrin**
- **ankyryn**

- **aktin a s aktinem asociované proteiny**
 - tropomodulin, tropomyosin

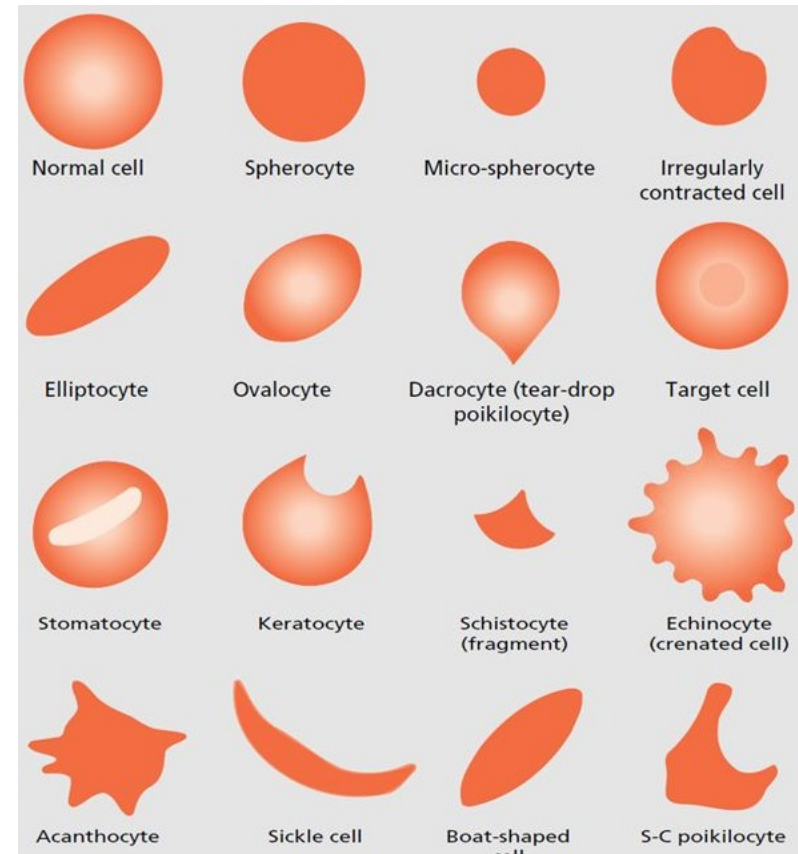
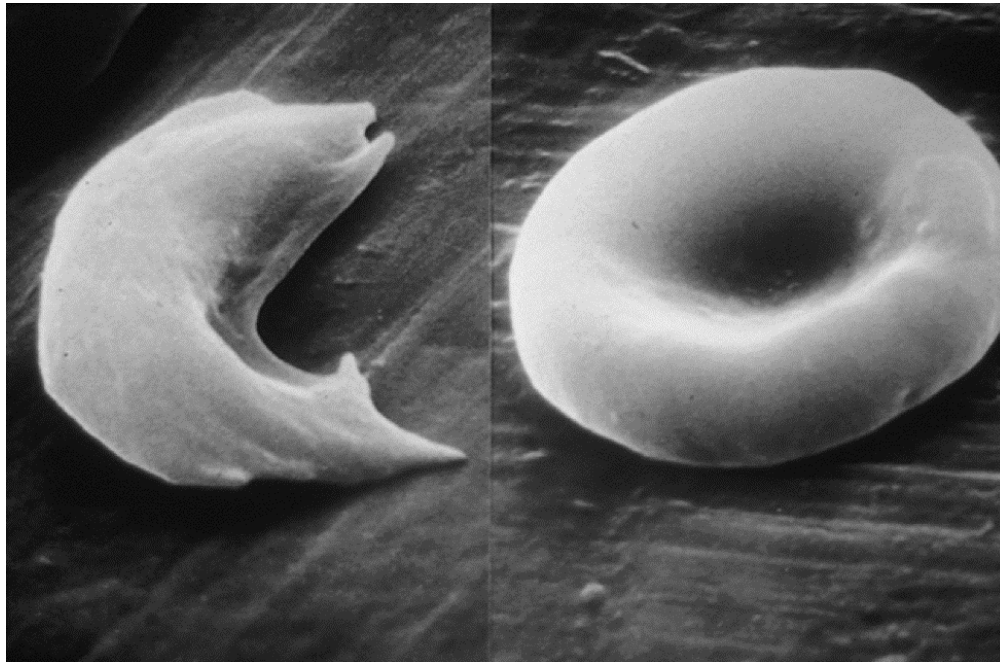
- **hemoglobin**



ERYTROCYTY

Odchylky od běžného bikonkávního tvaru

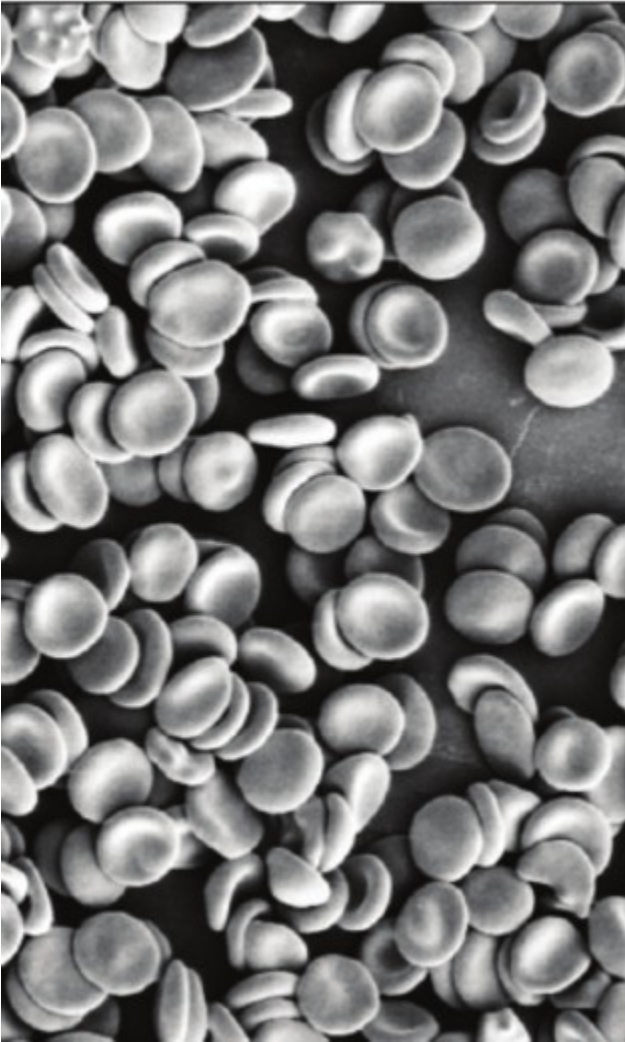
- **poikilocytóza**
 - **akantocyty** (nepravidelné trnovité výběžky membrány)
 - **kodocyty** („pneumatika“)
 - **echinocyty** (trnovité výběžky na celém povrchu)
 - **eliptocyty** (eliptický tvar)
 - **sferocyty** (kulovitý tvar)
 - **stomatocyty** (chybějící části membrány nebo jiné nepravidelnosti)
 - **drepanocyty** (srpkovitý tvar)
 - **dakrocyty** (kapkovitý tvar)



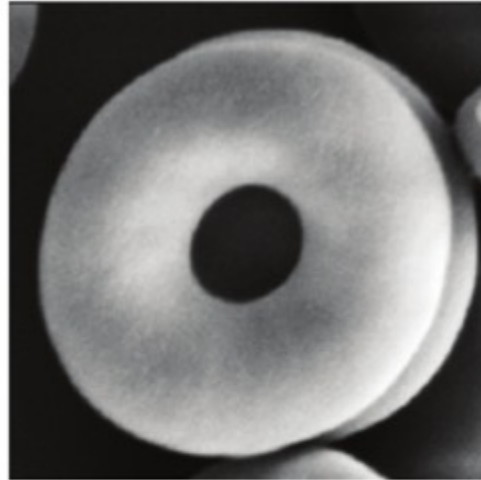
ERYTROCITY

Odchyly od běžného bikonkávního tvaru

Normální

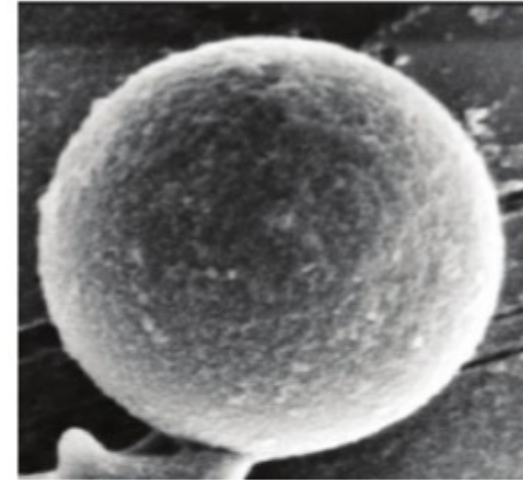


Kodocyt

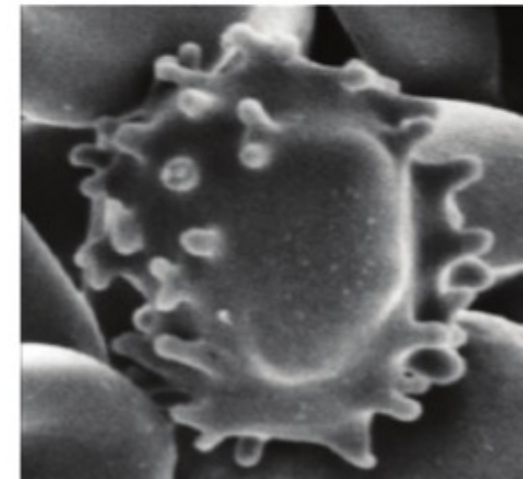
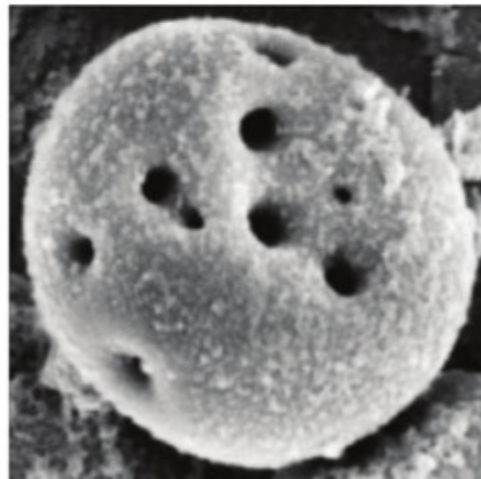


(b)

Sferocyt



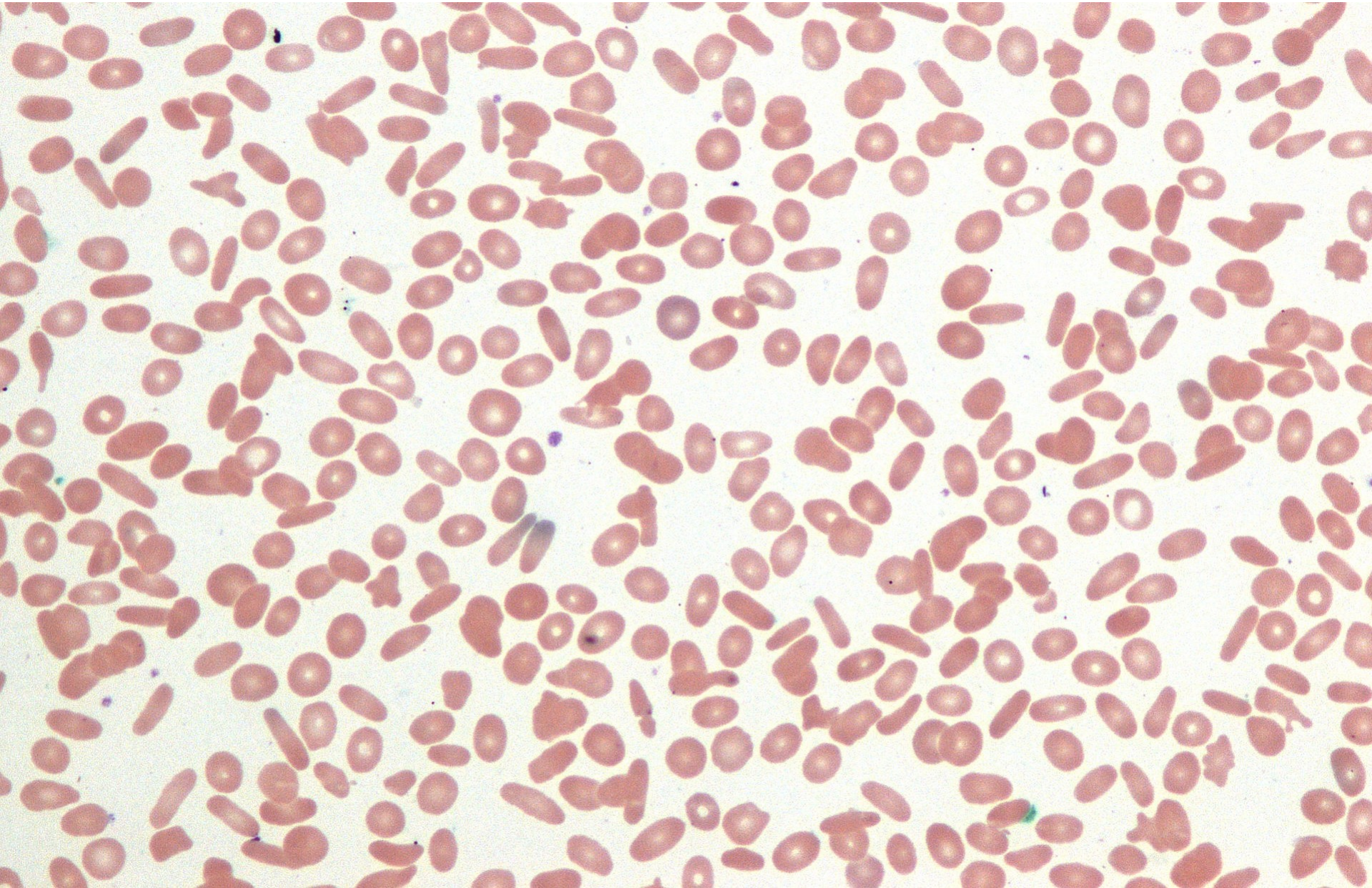
(d)



Echinocyt

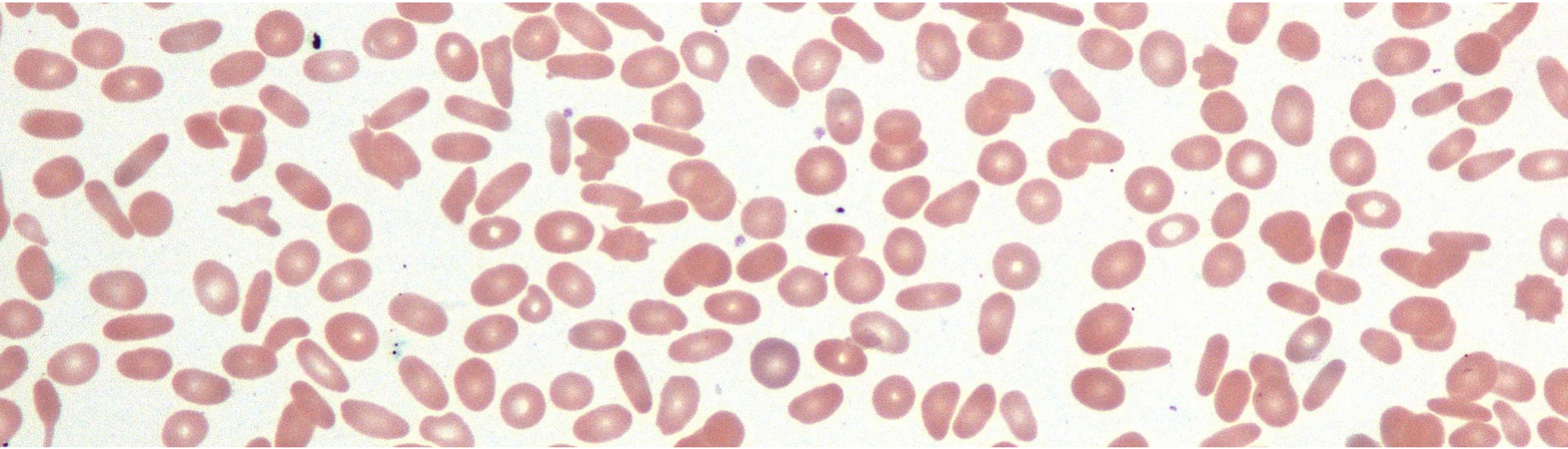
ERYTHROCYTY

Hereditární eliptocytóza

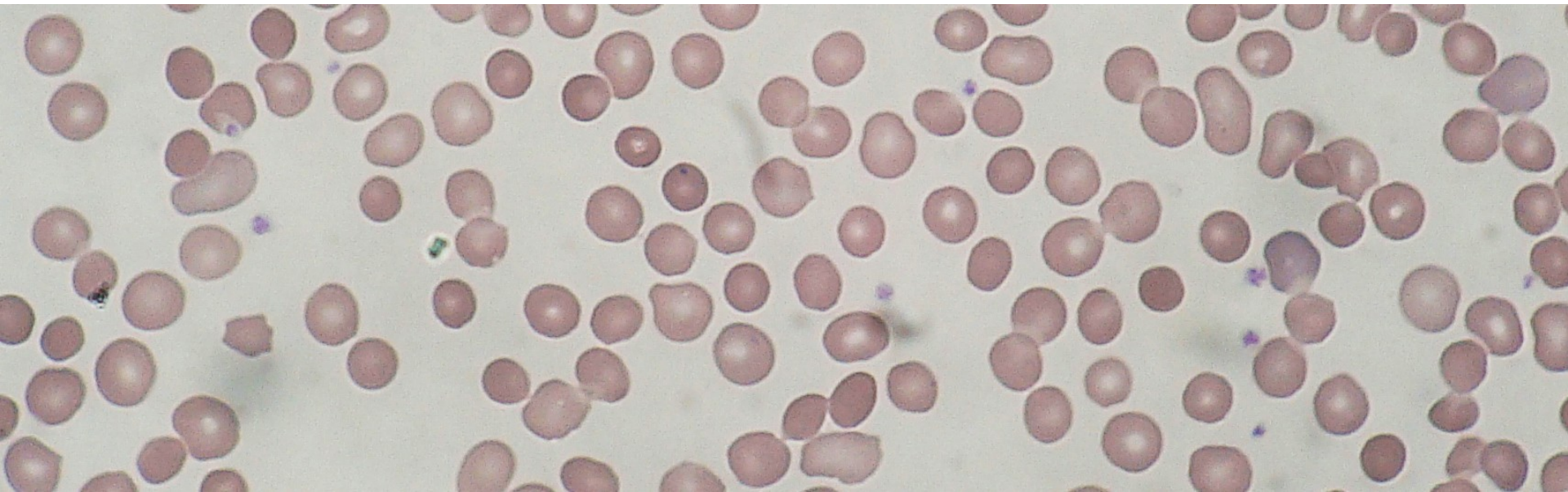


ERYTROCYTY

Hereditární eliptocytóza



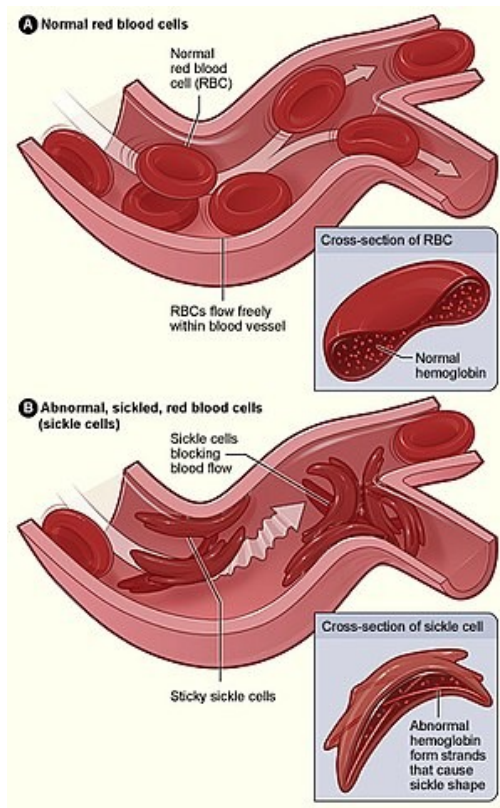
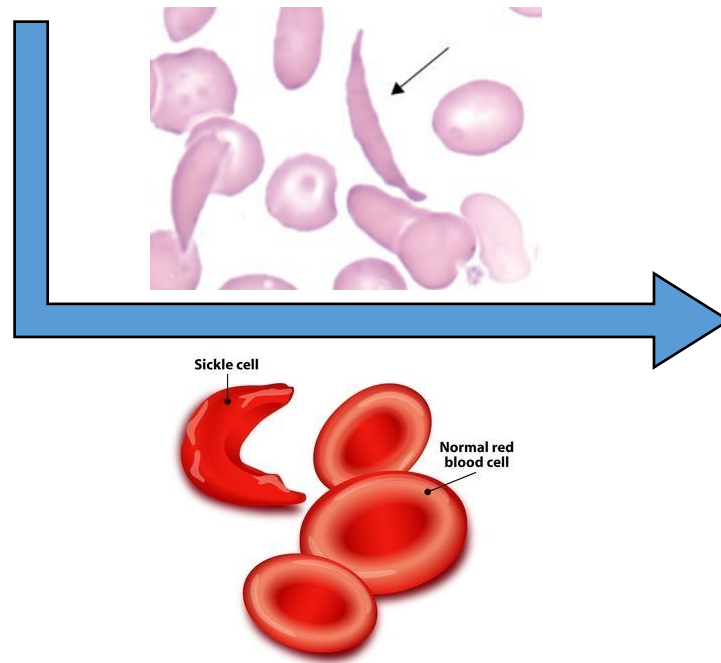
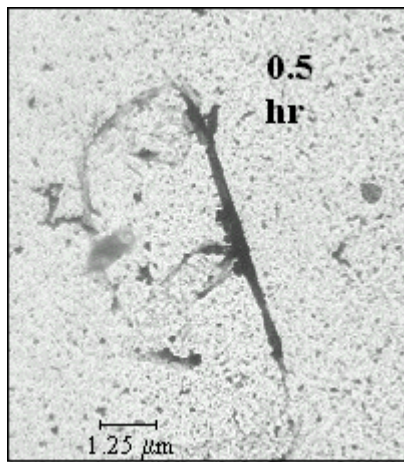
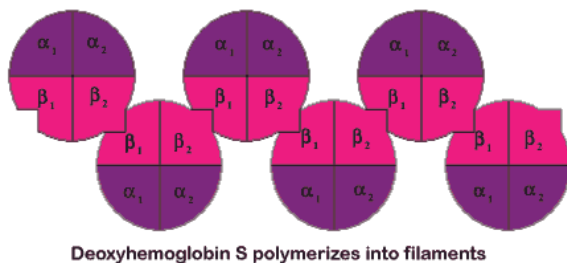
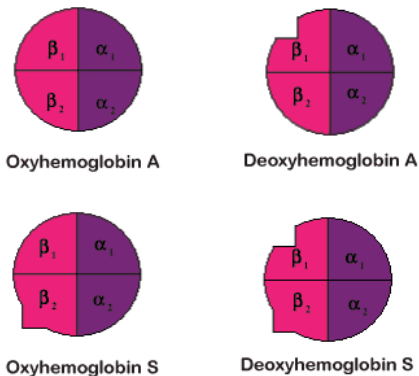
Hereditární sférocytóza



ERYTROCYTY

Srpkovitá anemie

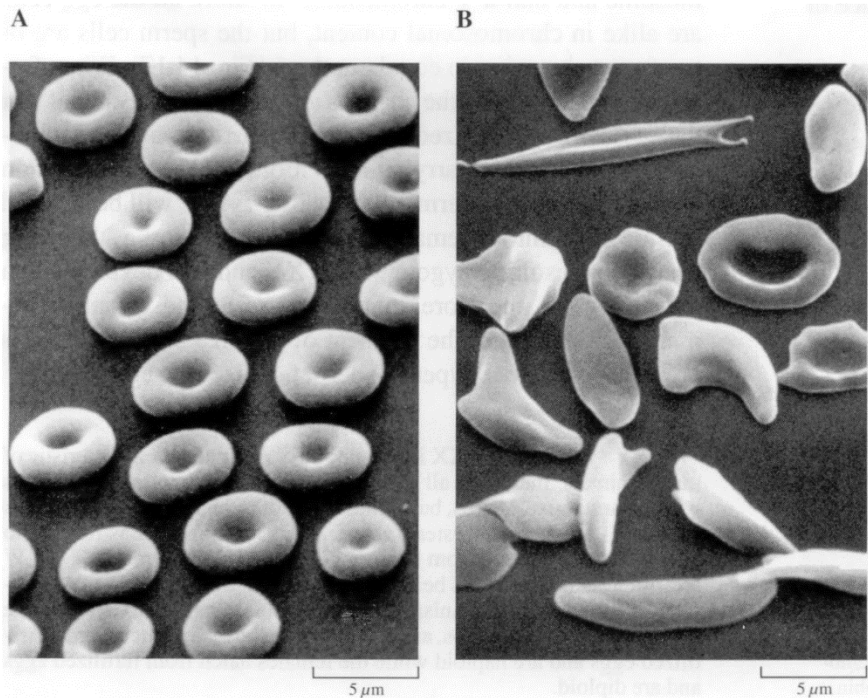
- Abnormální hemoglobin (hemoglobin S)



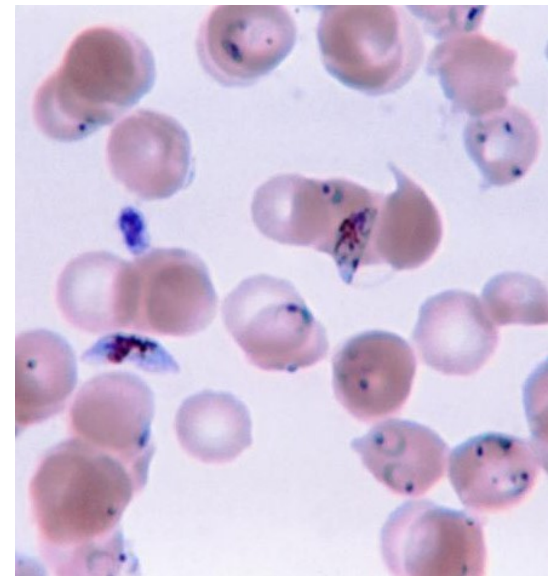
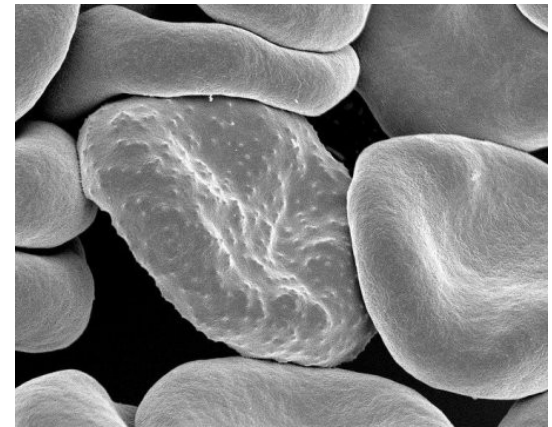
ERYTROCITY

Srpkovitá anemie

- Patologický genotyp (heterozygot HbS/HbA) může být i prospěšný



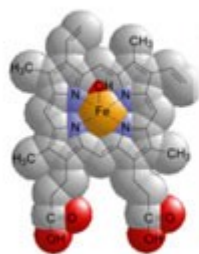
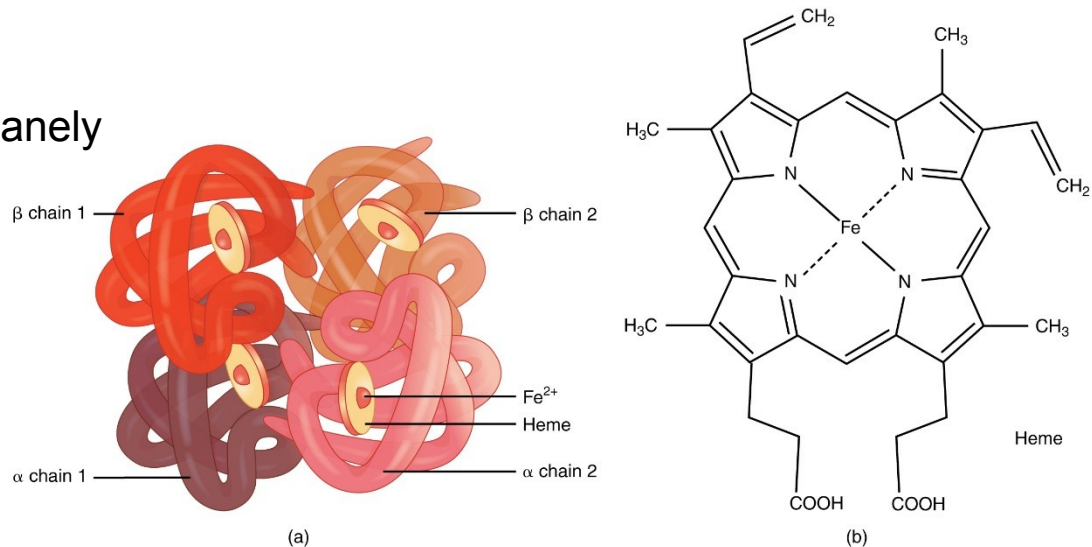
Malárie



ERYTROCITY

Ultrastruktura

- Erytrocyty neobsahují jádro ani organely
- Anaerobní glykolýza
- Hemoglobin



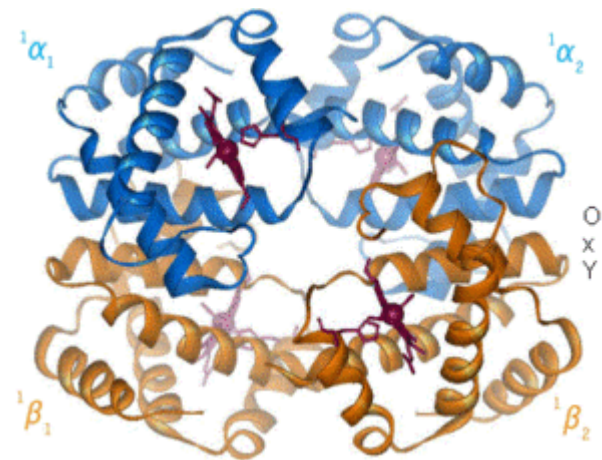
Heme



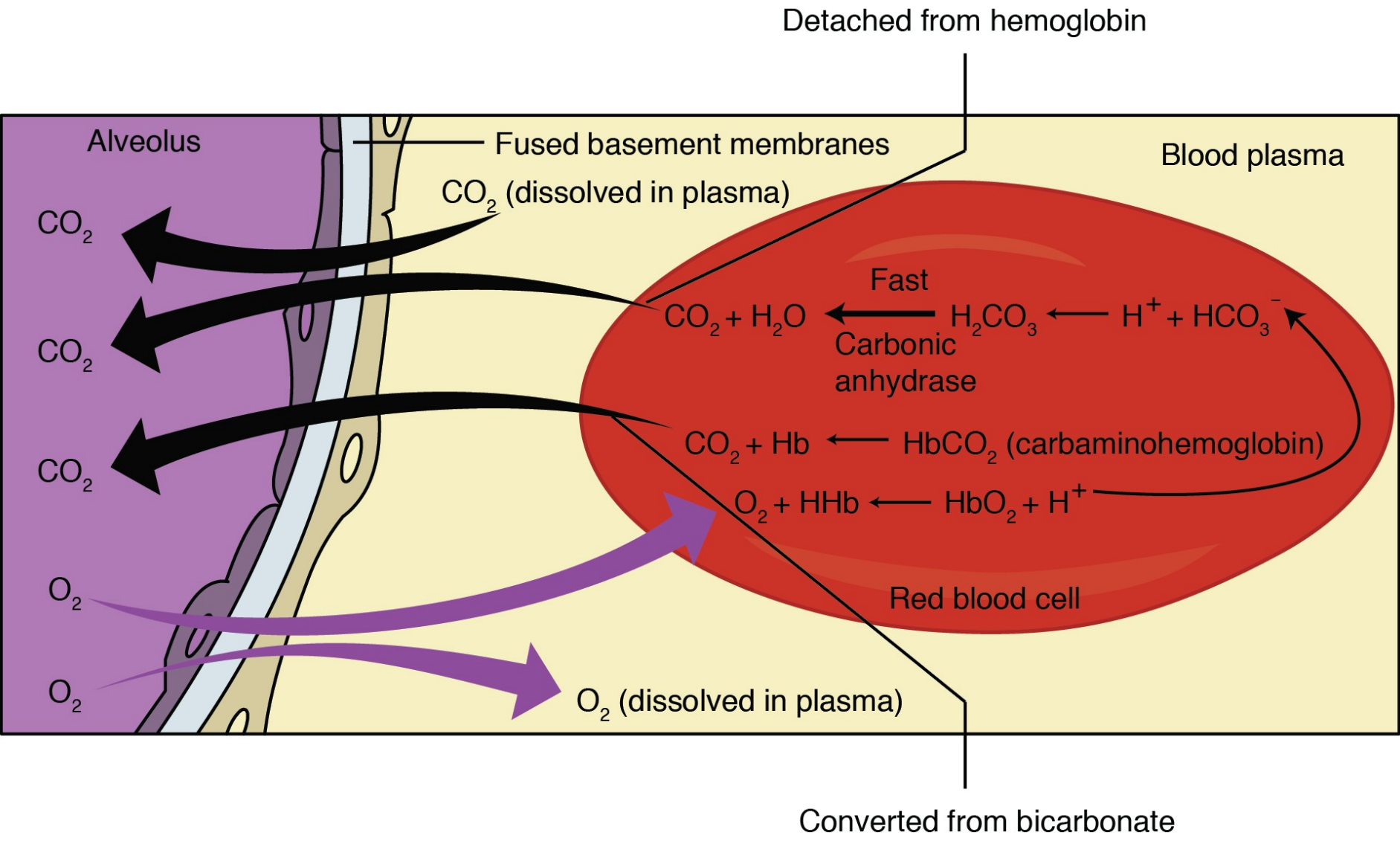
Hemoglobin



Erythrocyte

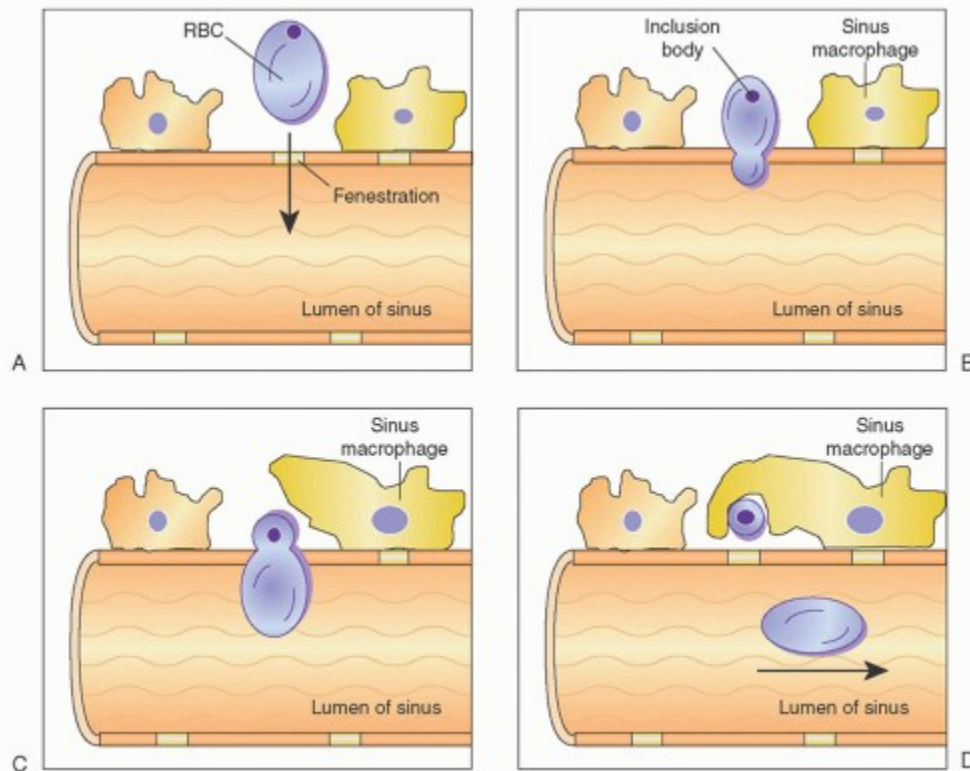
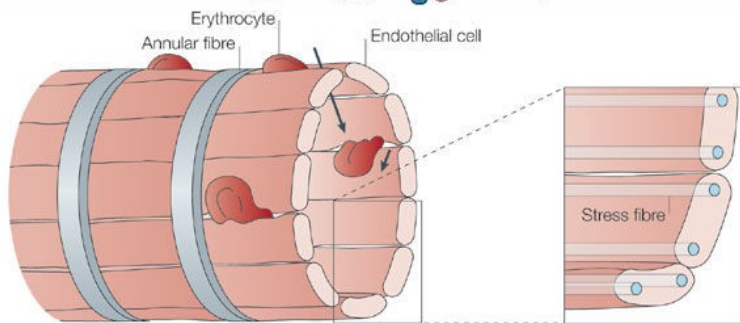
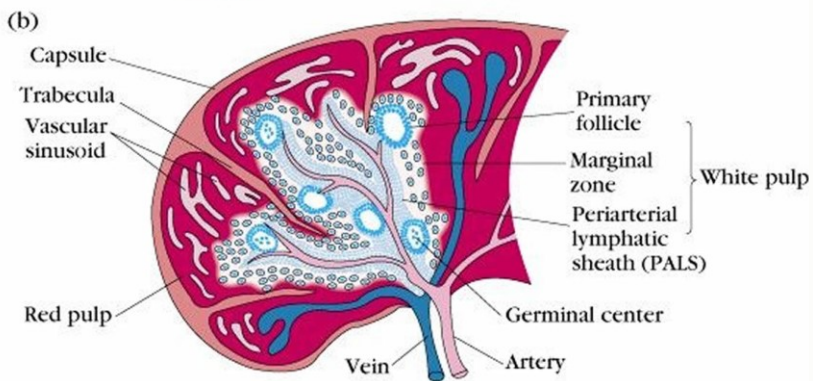
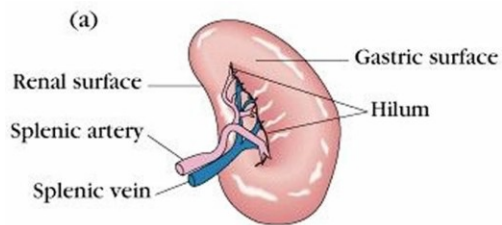
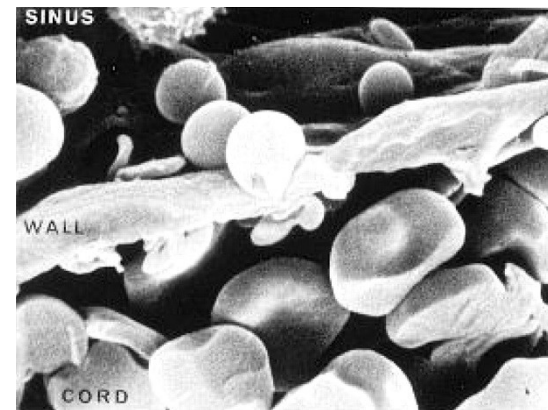


ERYTHROCYTY



ERYTHROCYTY

- Životnost 120 dní
- Konstantní poškození
- Opravy jsou nemožné
- Odstranění starých a poškozených erytrocytů ve slezině



LEUKOCYTY

- imunitní odpověď
- morfologická klasifikace – **přítomnost cytoplazmatických granul** (neodpovídá schématu hematopoeze)

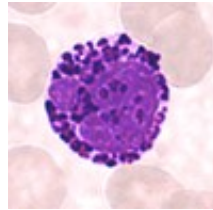
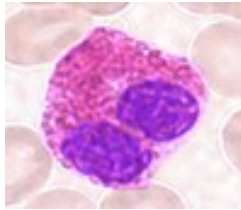
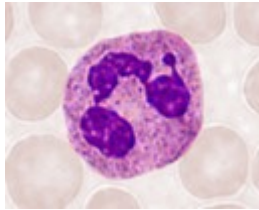
Granulocyty

Agranulocyty

Neutrofily

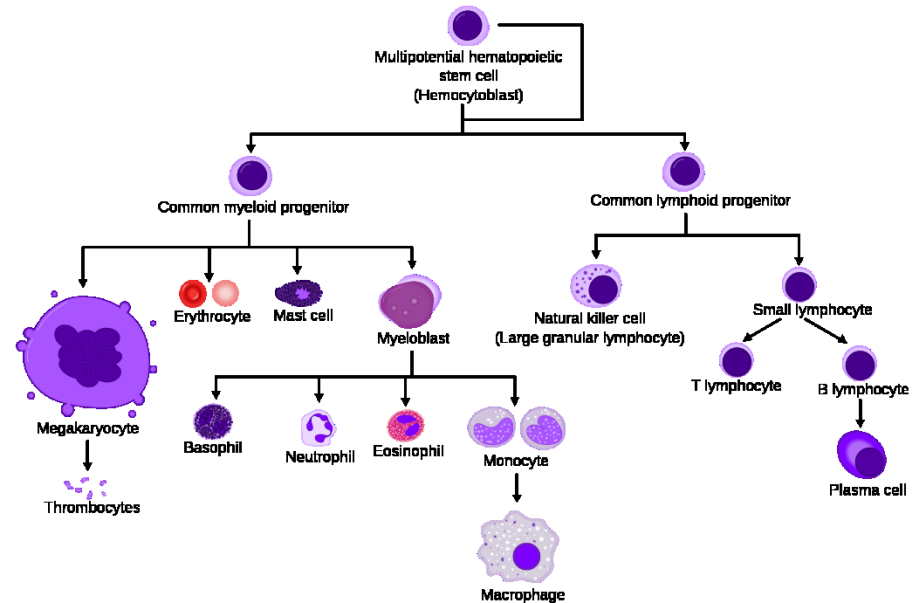
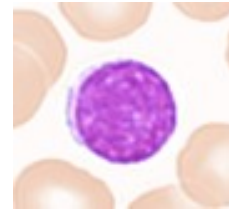
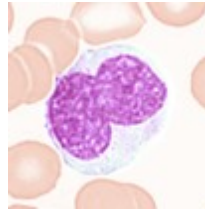
Eosinofily

Basofily



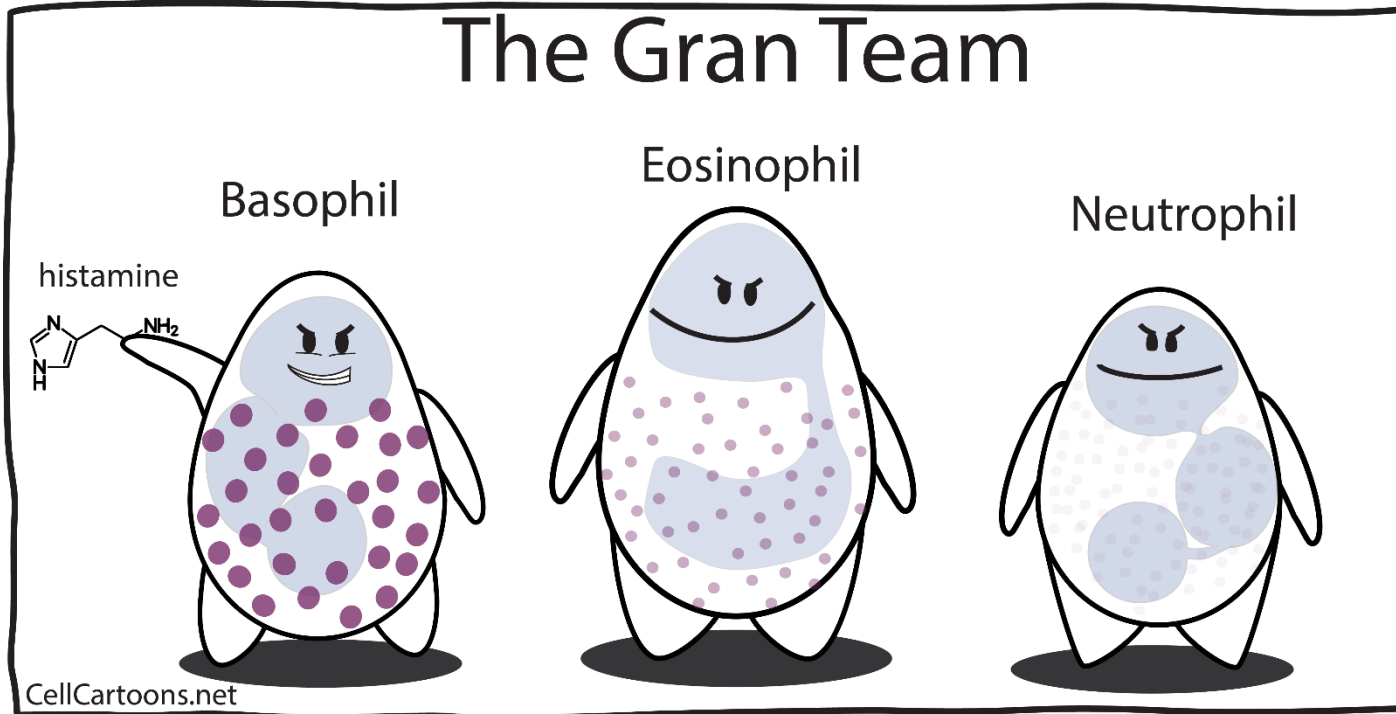
Monocyty

Lymfocyty



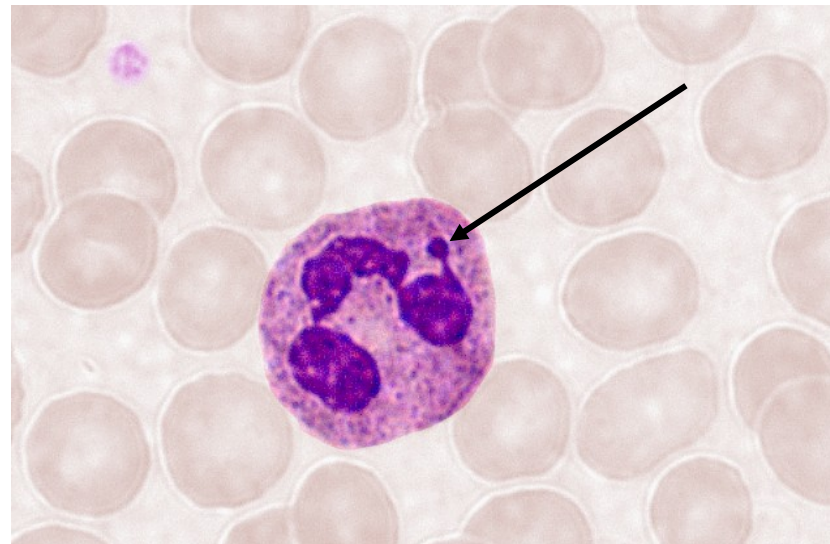
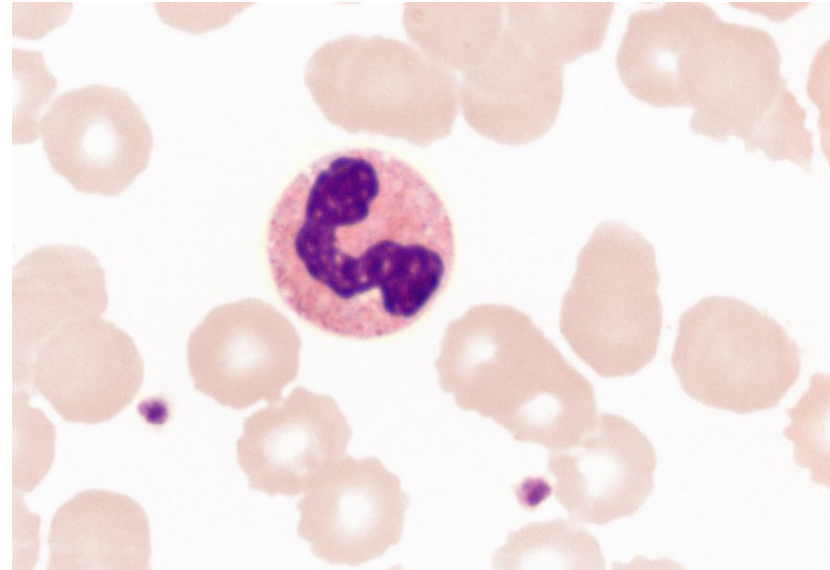
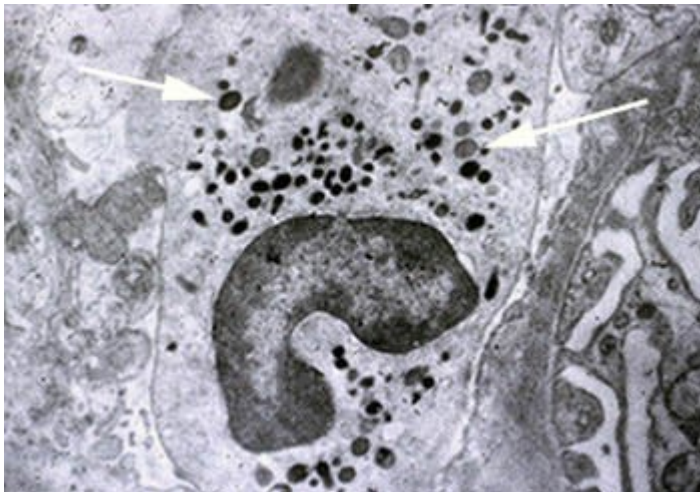
GRANULOCYTY

- Lizosomy (primární, azurofilní, nespecifická granula)
- Specifická (sekundární) granula
- Polymorfní jádro
- Terminálně diferencované
- Krátká životnost
- Redukované ER, GA i počet mitochondrií (anaerobní glykolýza)
- Apoptóza

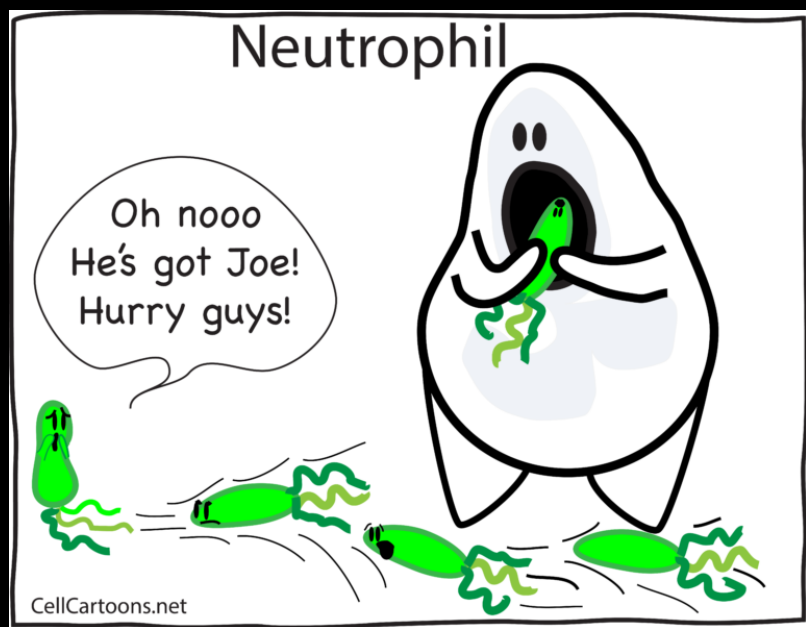
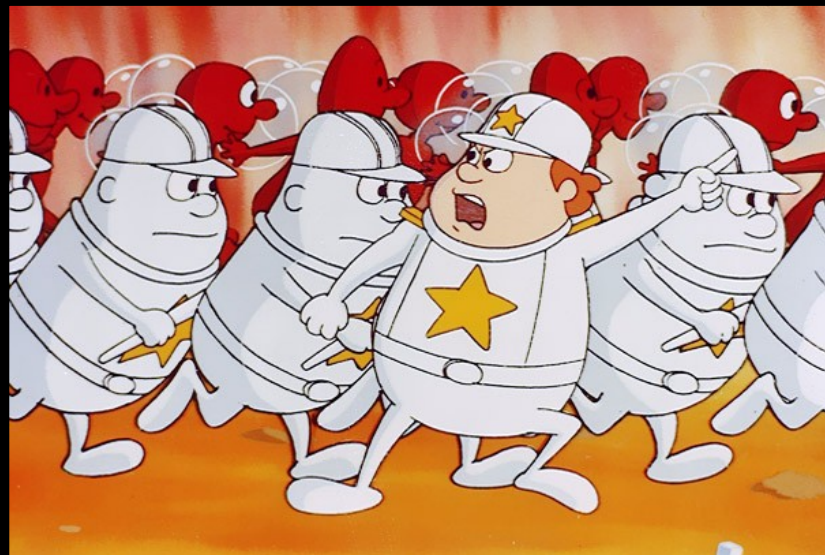


NEUTROFILNÍ GRANULOCYTY

- **Neutrofilny**
 - 50-70% cirkulujících leukocytů
 - $\varnothing > 12 \mu\text{m}$
 - Segmentované jádro
 - Barrovo tělísko u žen
 - **Azurofilní (primární) granula**
 - myeloperoxidáza, lysozym, proteázy, defensiny
 - **Neutrofilní (sekundární) granula**
 - kolagenáza, baktericidní enzymy
 - Chemotaxe dalších leukocytů
 - Mikrofágy
- **Neutrofilní tyčka**
- **Neutrofilní segment**

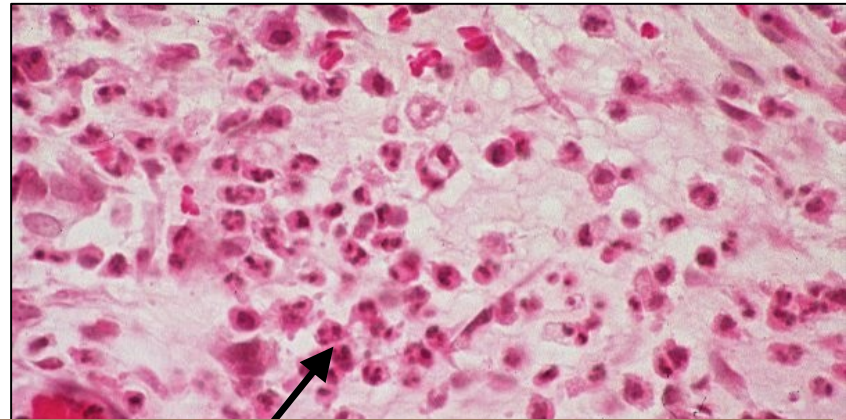
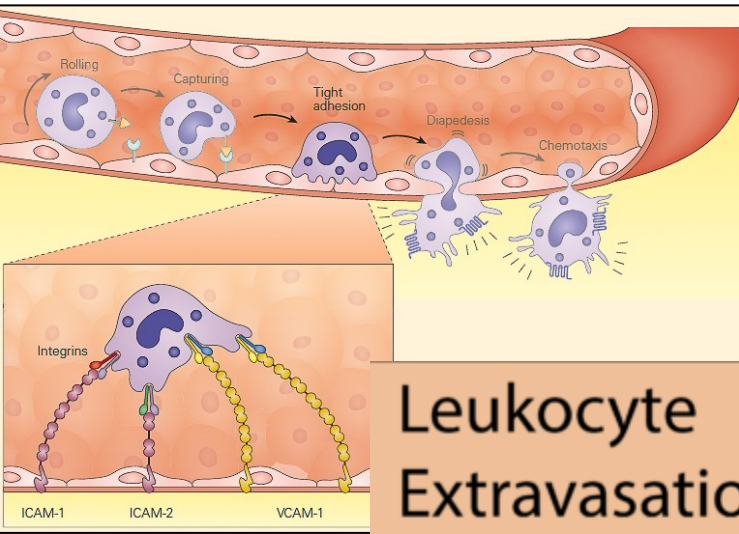


NEUTROFILNÍ GRANULOCYTY

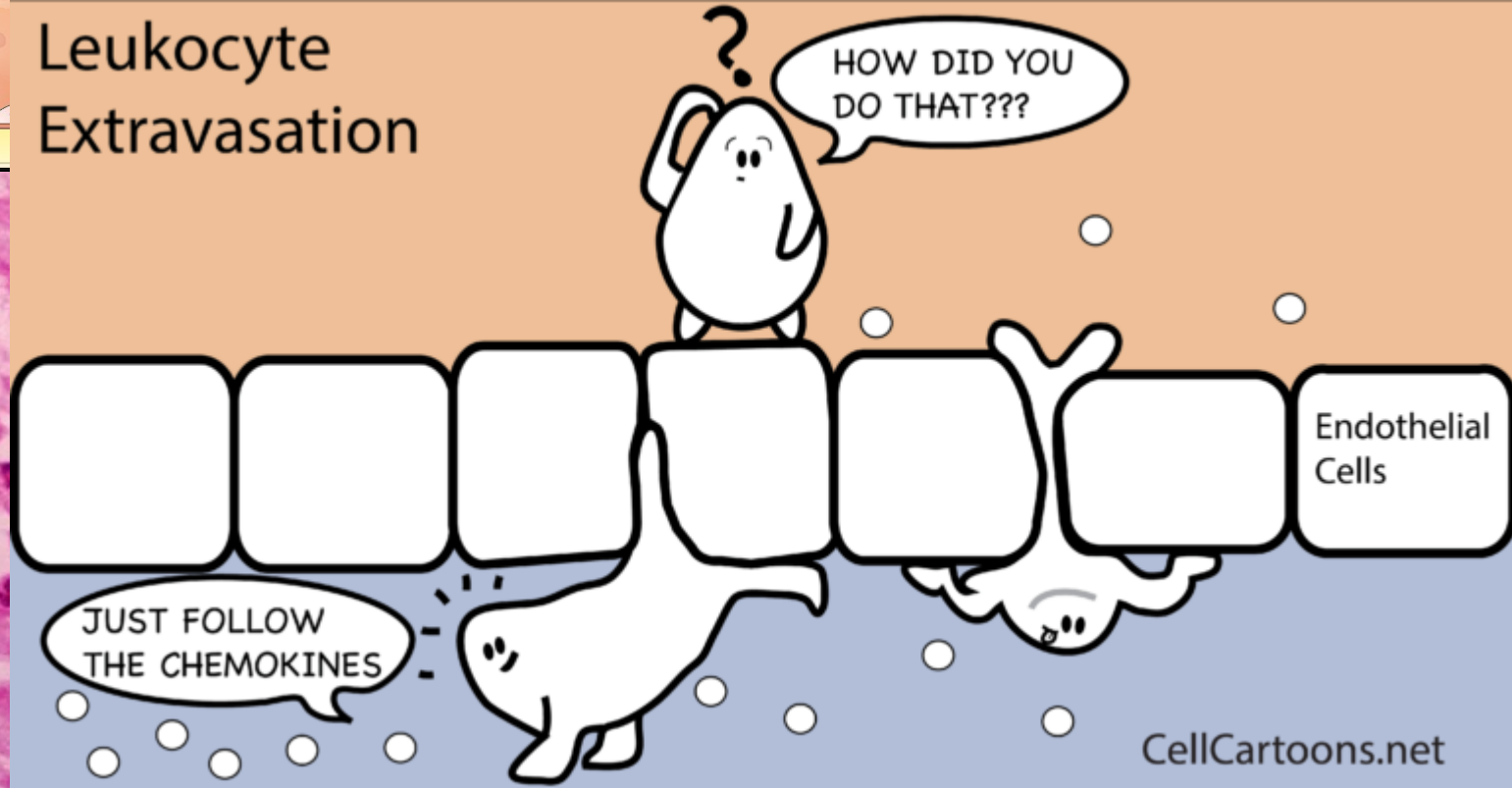


GRANULOCYTY

- Extravazace (diapedeza)

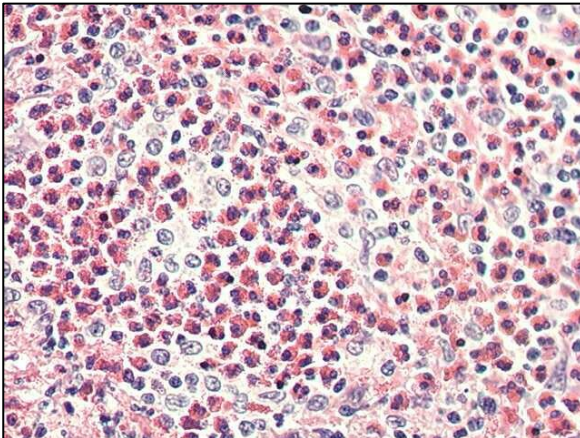
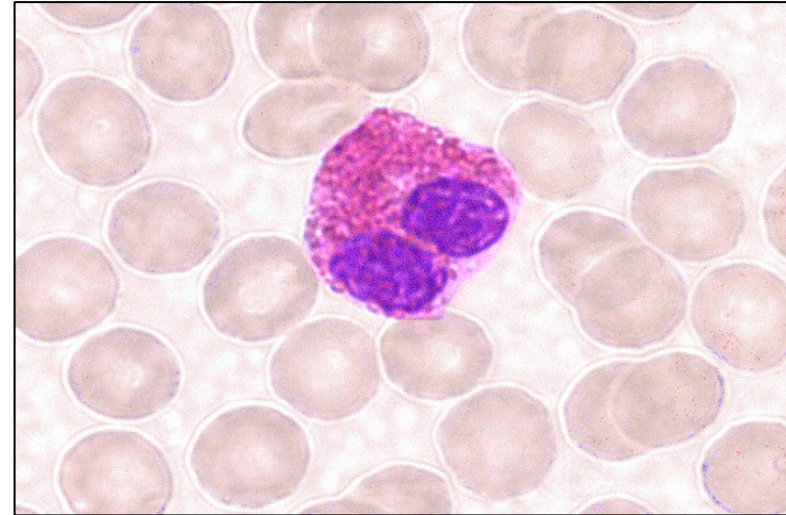


Leukocyte
Extravasation



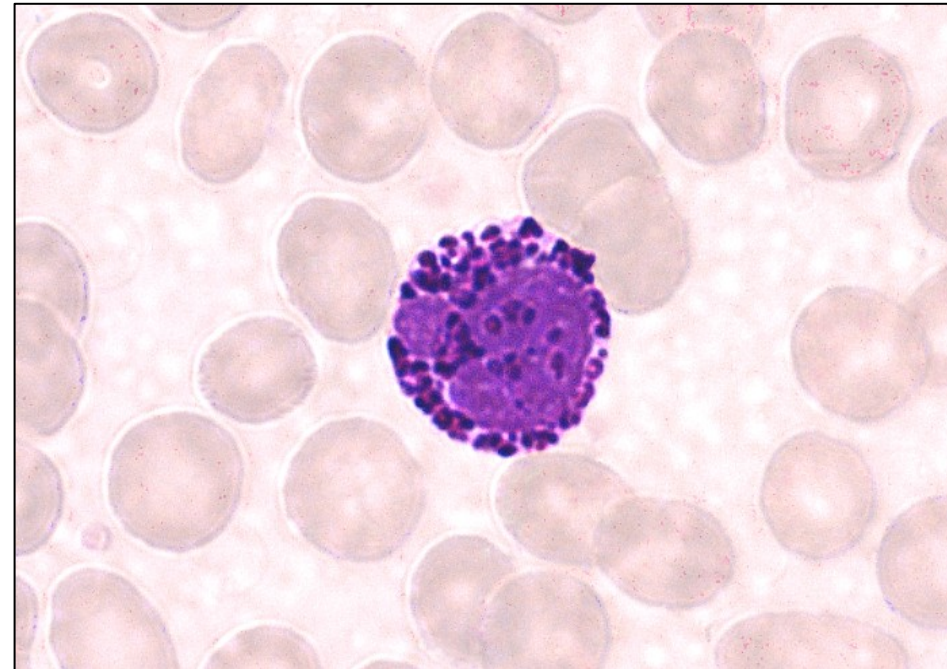
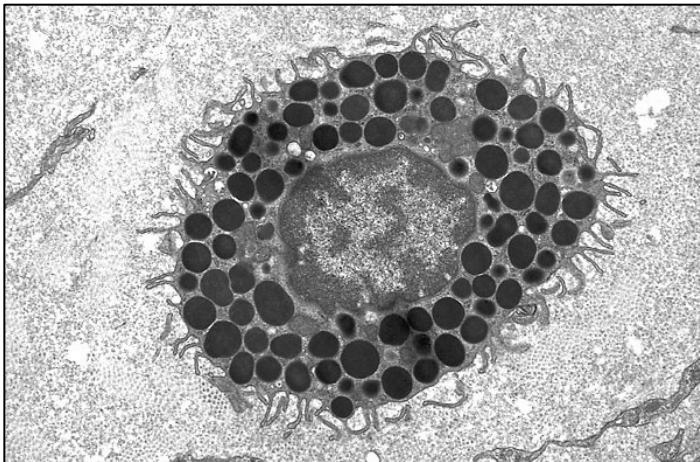
EOZINOFILNÍ GRANULOCYTY

- **Eozinofily**
 - 1-4% cirkulujících leukocytů
 - \varnothing 12-15 μm
 - Nepravidelné, typicky dvousegmentové jádro
 - **Azurofilní (primární) granula**
 - myeloperoxidáza, lysozym, proteázy, defensiny
 - **Eozinofilní (sekundární) granula**
 - jasně červená (eosinofilní)
 - hlavní bazický protein
 - peroxidáza
 - cytokiny, chemokiny
- Chemotaxe dalších leukocytů
- Fagocytóza komplexů antigen-protilátka
- Parazitární infekce, alergické reakce
- Chronický zánět



BAZOFILNÍ GRANULOCYTY

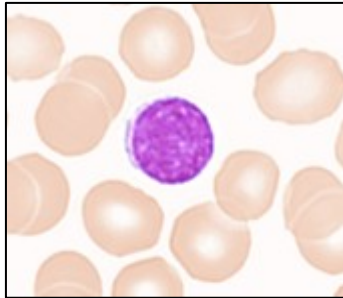
- **Bazofily**
 - <1% cirkulujících leukocytů
 - \varnothing 12 μm
 - Nepravidelné, dvousegmentové jádro, maskované granuly
- **Azurofilní (primární) granula**
 - myeloperoxidáza, lysozym, proteázy, defensiny
- **Bazofilní (sekundární) granula**
 - 0.5 μm
 - velká tmavá (basofilní)
 - heparin, histamin - vazodilatace
 - fosfolipáza A
- Analoga žírných buněk
- Receptory pro IgE
- Alergie, anafylaxe, zánět



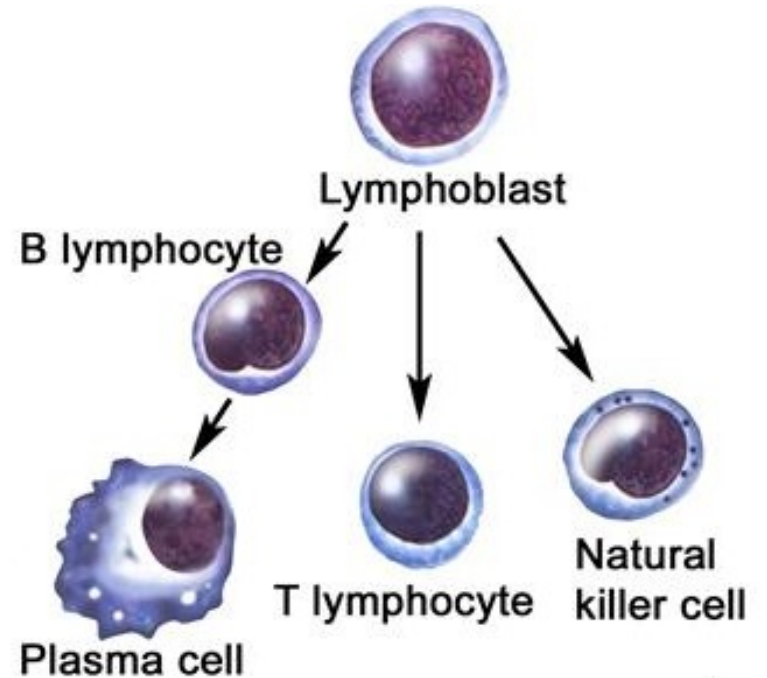
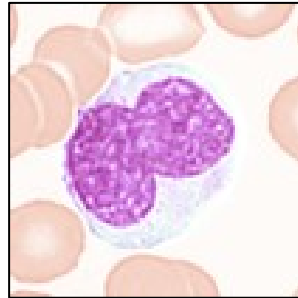
AGRANULOCYTY

- Pouze lyzosomy (azurofilní, nespecifická granula)
- Specifická granula chybí
- Nesegmentované jádro

Lymfocyty



Monocyty

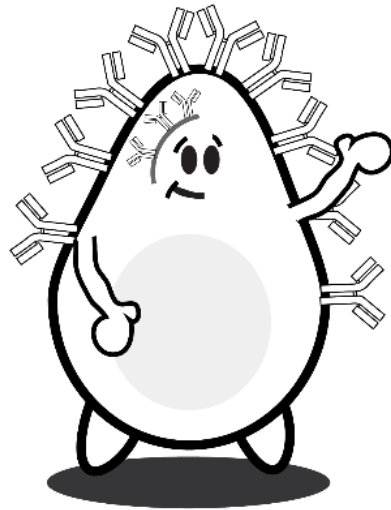


Lymphocytes

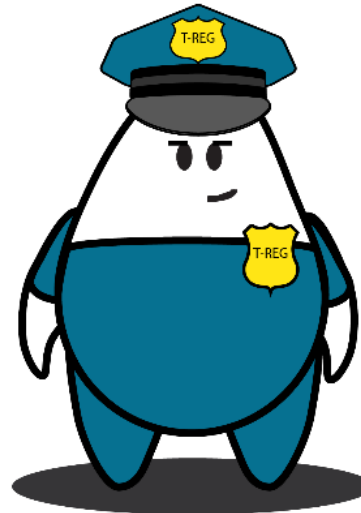
CD8 T Cell



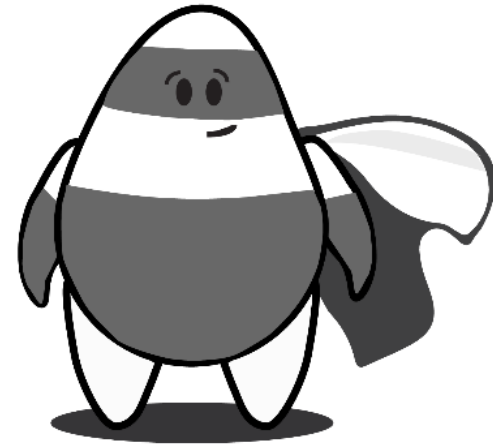
B Cell



Regulatory
T Cell

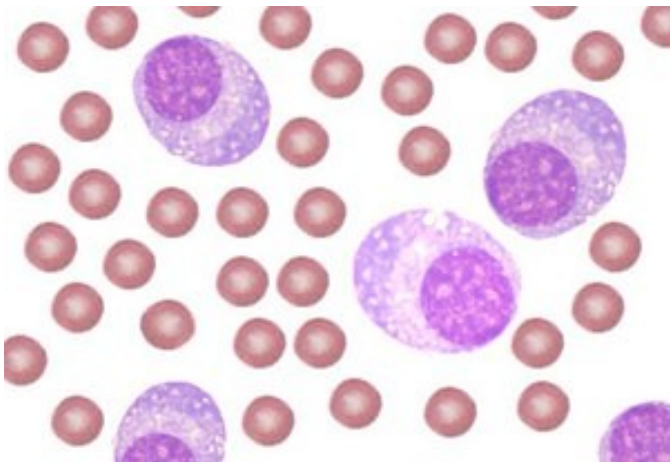
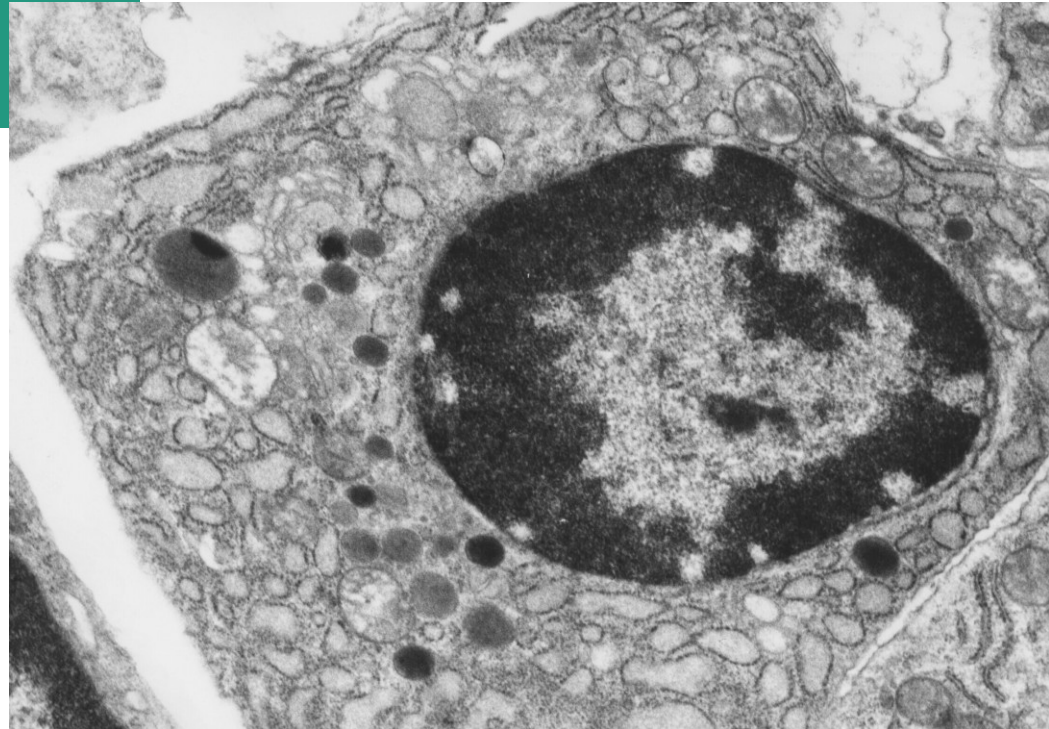
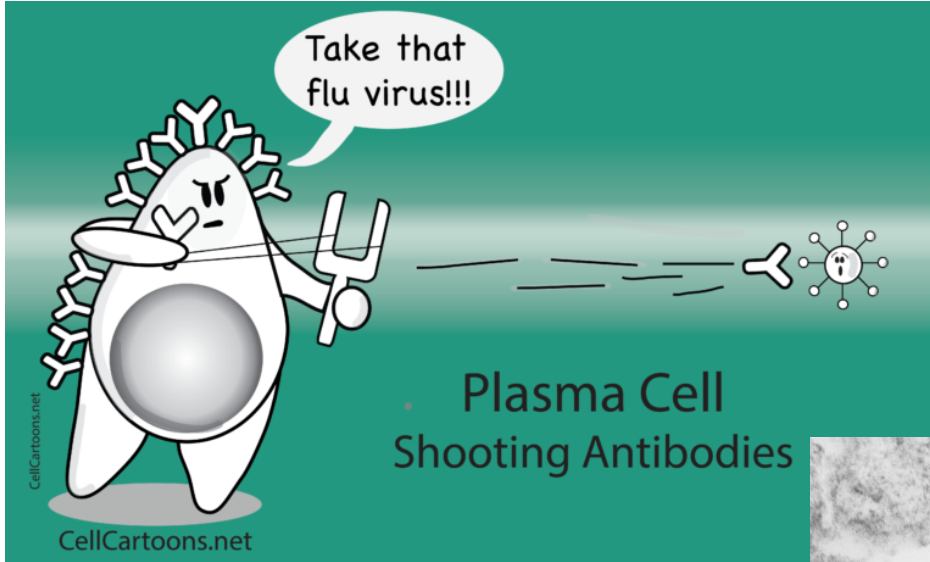


CD4 T Cell



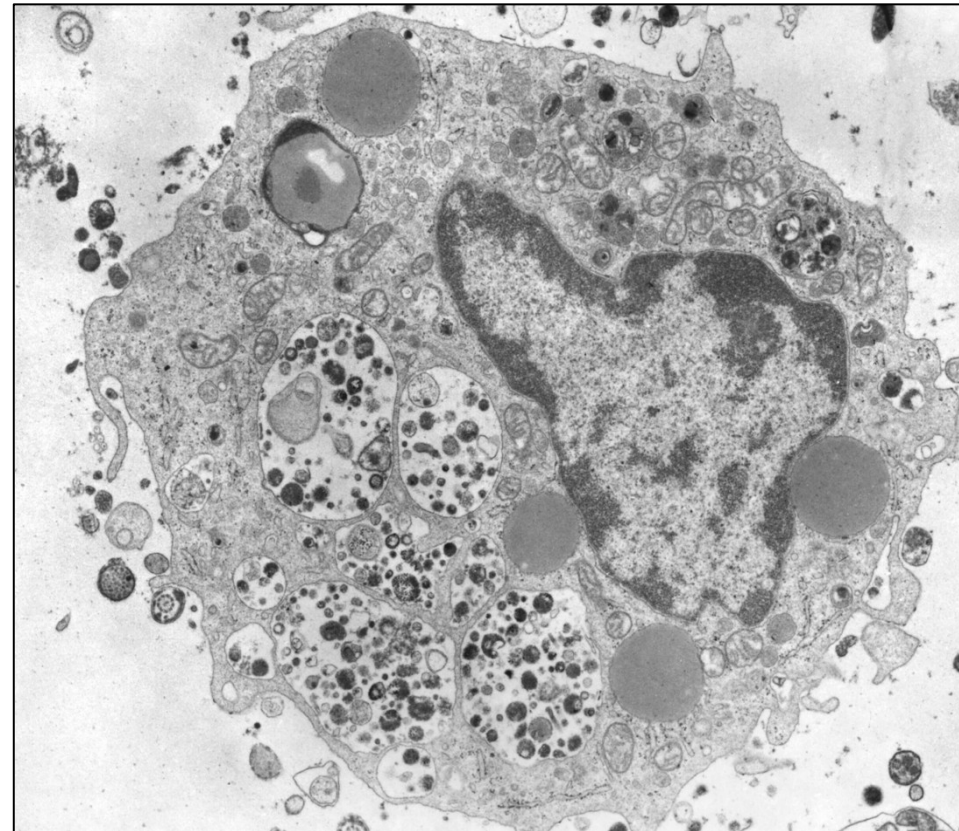
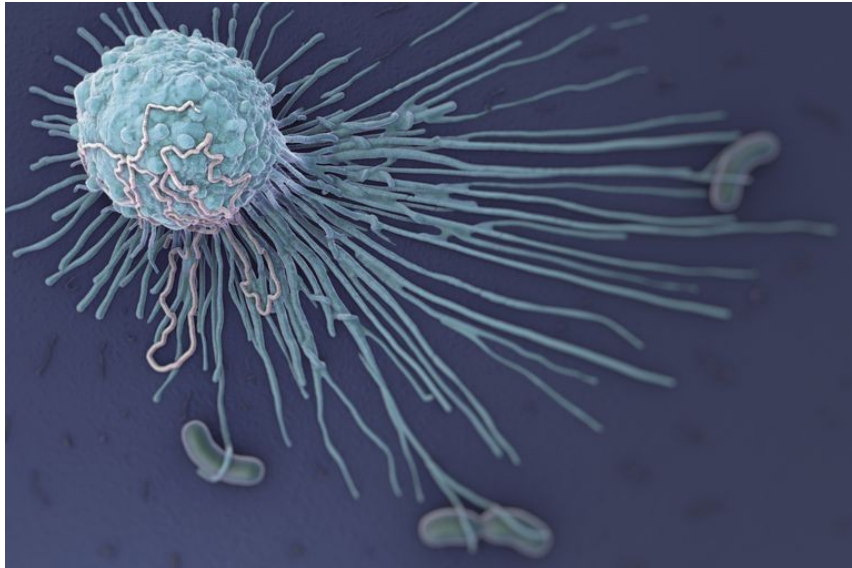
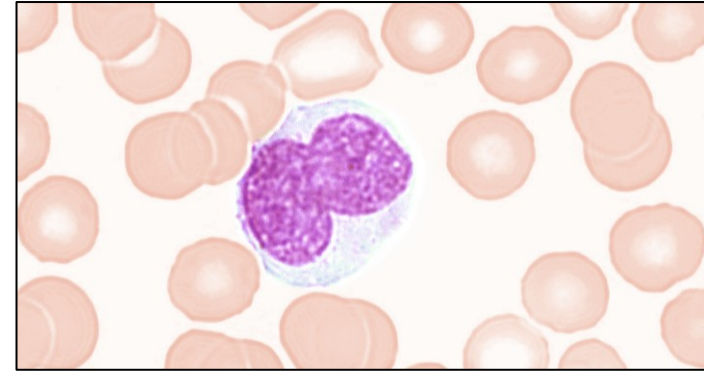
LYMFOCYTY

- Plazmatické buňky



MONOCYTY

- \varnothing 12-15 μm
- Cirkulující prekurzory makrofágů, osteoklastů, mikroglíí, Kupferových buněk a dendritických buněk
- Mononukleární fagocytární systém
- Velké oválné (fazolovité) jádro s méně kondenzovaným chromatinem a 2-3 jadérky
- Bazofilní cytoplazma
- Azurofilní granula



TROMBOCYTY

- Bezjaderné buněčné fragmenty
- \varnothing 2-3 μm , tvar disku
- hyalomera, granulomera
- $150-400 \times 10^3/\mu\text{l}$
- srážení krve, oprava poškození cévní stěny

α -granula
300-500 nm

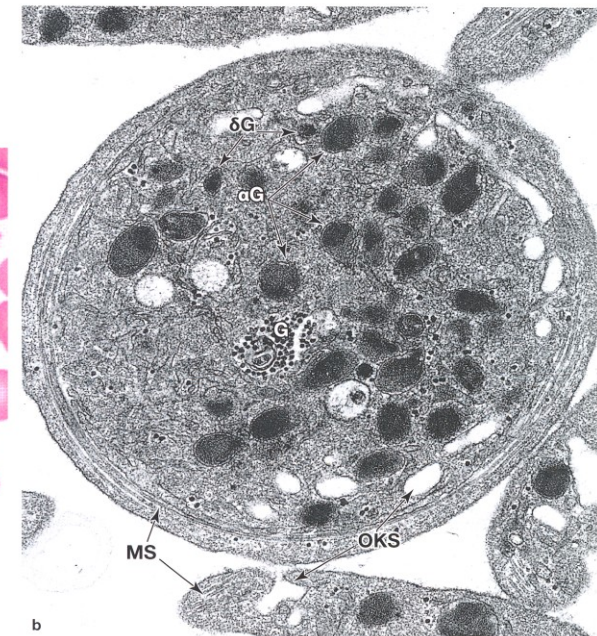
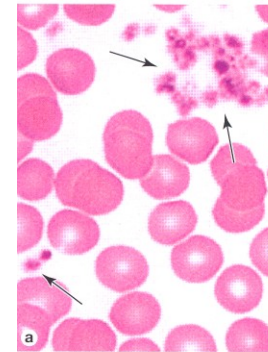
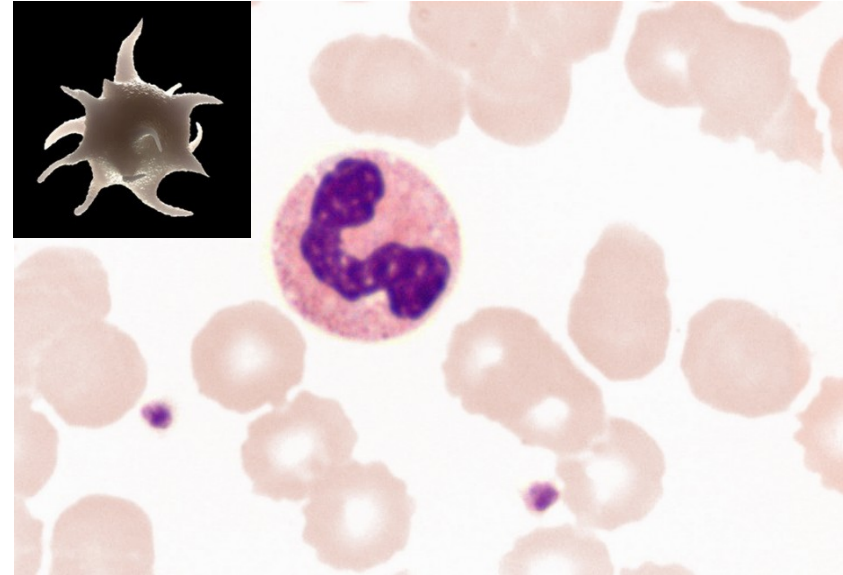
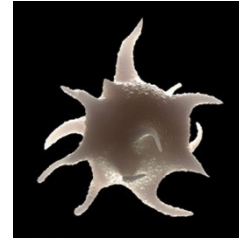
fibrinogen, PDGF

δ -granula
250-300 nm

serotonin, Ca^{++}
pyrophosfát
ADP, ATP

λ -granula
175-200 nm

lyzosomální enzymy



TROMBOCYTY

1. Primární agregace destiček

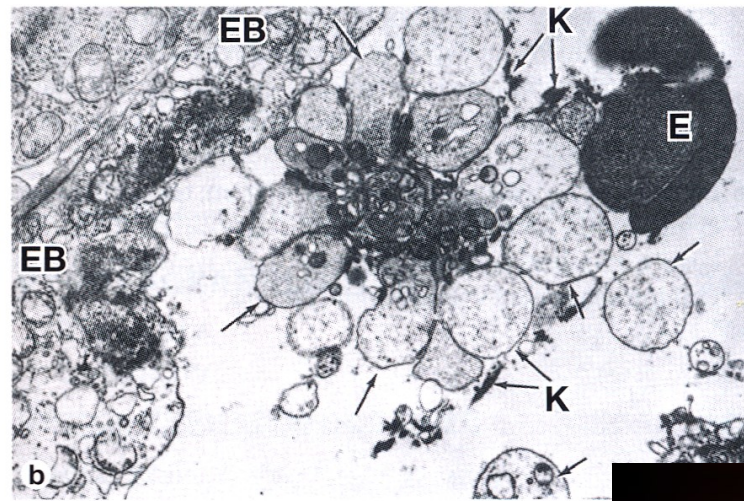
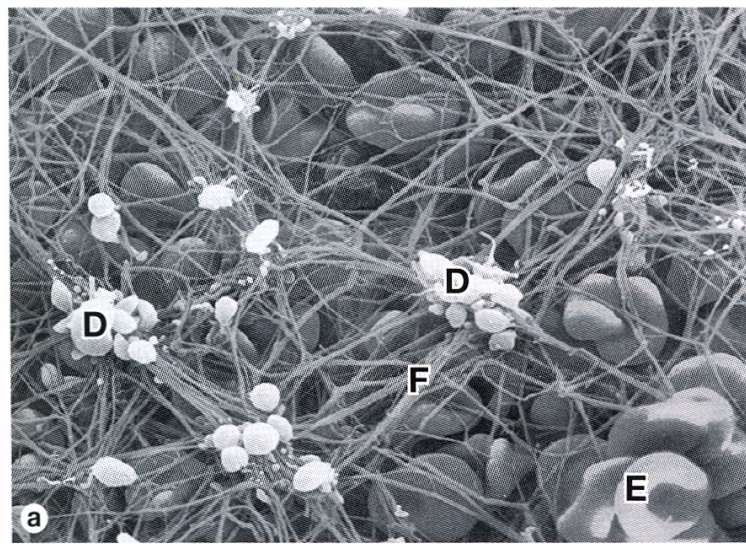
- narušení endotelu, obnažení kolagenních vláken
- destičková zátka

2. Sekundární agregace destiček

- srážecí faktory, ADP z agregovaných trombocytů – další trombocyty – *bílý trombus*

3. Koagulace – srážení krve

- tvorba fibrinové sítě zachycující erytrocyty – *červený trombus*



4. Retrakce trombu

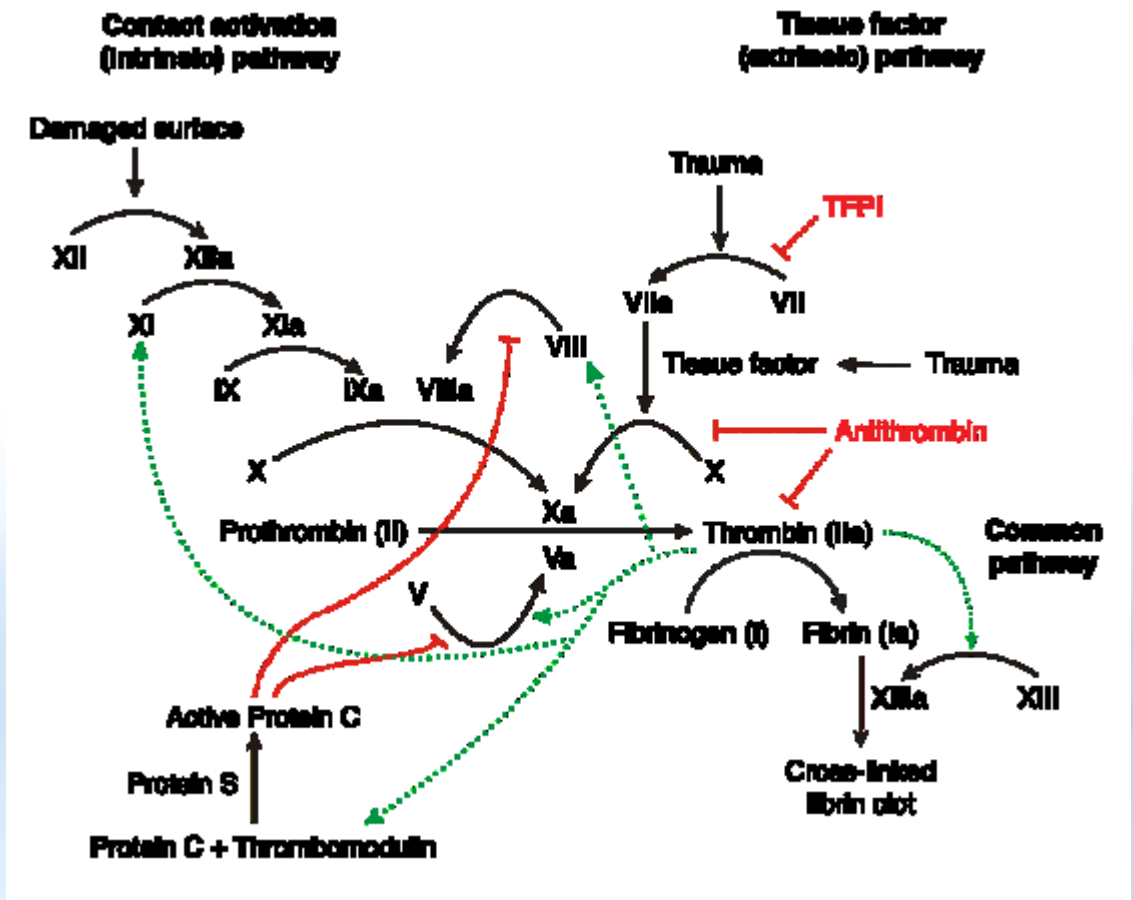
- kontrakce sraženiny (destičkový aktin a myosin)

5. Trombolýza

- rozpuštění sraženiny (plazmin) a hojení tkáně



TROMBOCYTY



DIFERENCIÁLNÍ BÍLÝ OBRAZ KREVNI

Norma

Neutrofily	tyčky	4 %
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	segmenty	67 %
--	-----------------	-------------

1:17

posun doleva

zvýšený počet tyček

posun doprava

zvýšený počet segmentů

Eozinofily		3 %
-------------------	--	------------

Bazofily		1 %
-----------------	--	------------

Lymfocyty		20 %
------------------	--	-------------

Monocyty		5 %
-----------------	--	------------

$\Sigma = 100 \%$

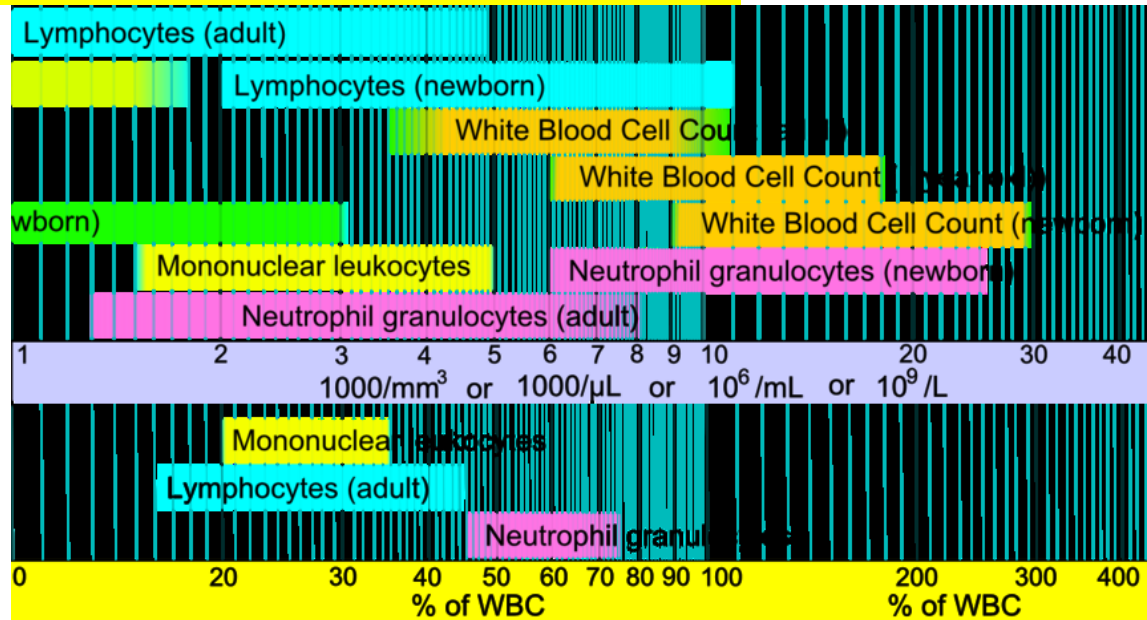
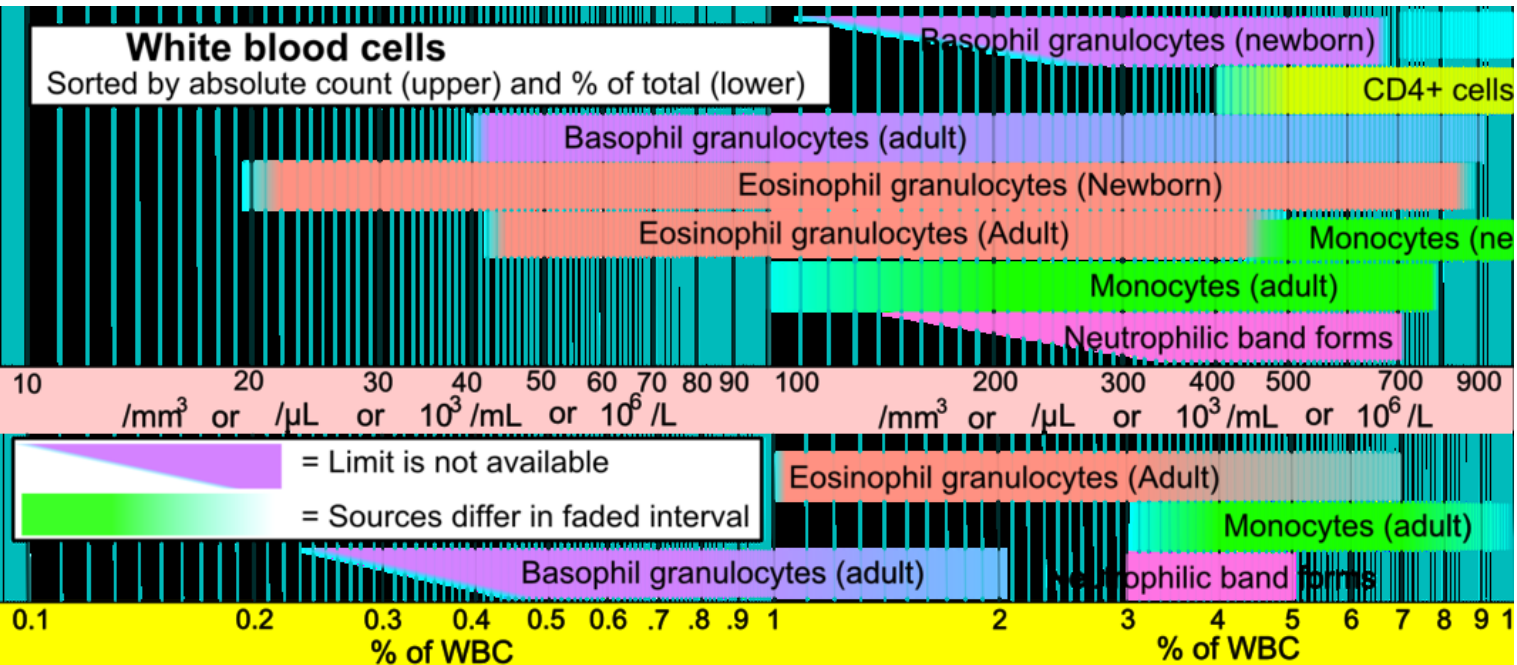
Odchyly od normy

	↑	↓
Neutrofily	neutrofilní granulocytóza	neutrofilní granulocytopenie
Eozinofily	eozinofilní granulocytóza	eozinofilní granulocytopenie
Bazofily	bazofilní granulocytóza	bazofilní granulocytopenie
Lymfocyty	lymfocytóza	lymfocytopenie
Monocyty	monocytóza	monocytopenie

Příklad populační variability

Neutrofily	tyčky	0-5 %
	segmenty	35-85 %
Eozinofily		0-4 %
Bazofily		0-1 %
Lymfocyty		20-50 %
Monocyty		2-6 %

DIFERENCIÁLNÍ BÍLÝ OBRAZ KREVNI



DIFERENCIÁLNÍ BÍLÝ OBRAZ KREVNI

Závislost na věku

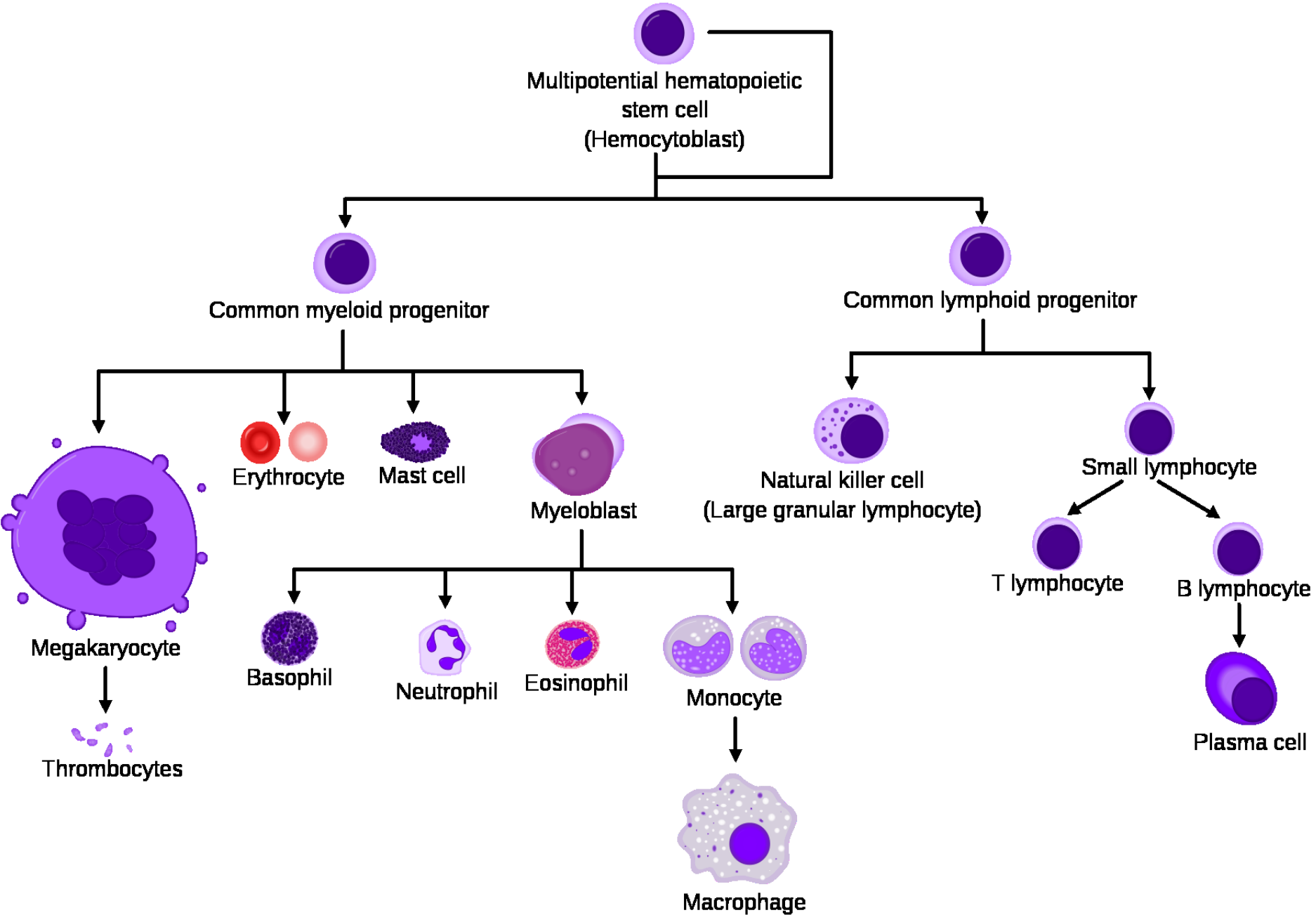
Age	Leukocytes ($\times 10^3$)	Neutrophils (%)	Lymphocytes (%)	Monocytes (%)	Eosinophils (%)
Birth	18	61	31	6	2
1 week	12.2	45	41	9	4
1 mo	10.8	35	56	7	3
6 mo	11.9	32	61	5	3
1 yr	11.4	31	61	5	3
4 yr	9.1	42	50	5	3
10 yr	8.1	54	38	4	2
16 yr	7.8	57	35	4	3

WBC, White blood cell.

LEUKOCYTY – SHRNU TÍ

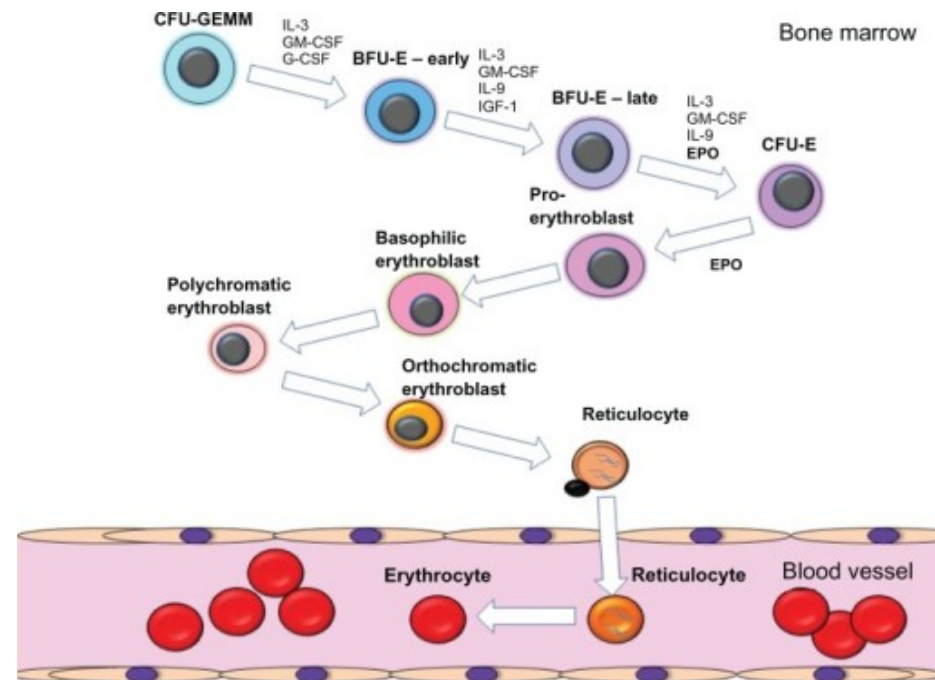
Leukocyt	Jádro	Granula	%	Životnost	Funkce
<u>Granulocyty</u>					
Neutrofily	3-5 segmentů	azurofilní + neutrofilní (světle růžová)	71	1-4 dny	mikrofág (bakterie)
Eozinofily	2 segmenty (laloky)	azurofilní + eozinofilní (jasně červená)	3	1-2 týdny	parazitické infekce (helminti), modulace lokální imunitní reakce
Bazofily	2 segmenty nebo tvar „S“	azurofilní + bazofilní (modrofialová)	1	měsíce	modulace lokální imunitní reakce, uvolnění histaminu
<u>Agranulocyty</u>					
Lymfocyty	kulaté	nejsou	20	hodiny – roky	adaptivní imunita, mnoho funkcí
Monocyty	ledvinovité	jen azurofilní	5	hodiny – roky	prekurzory buněk monocyto-makrofágového systému

HEMATOPOEZE

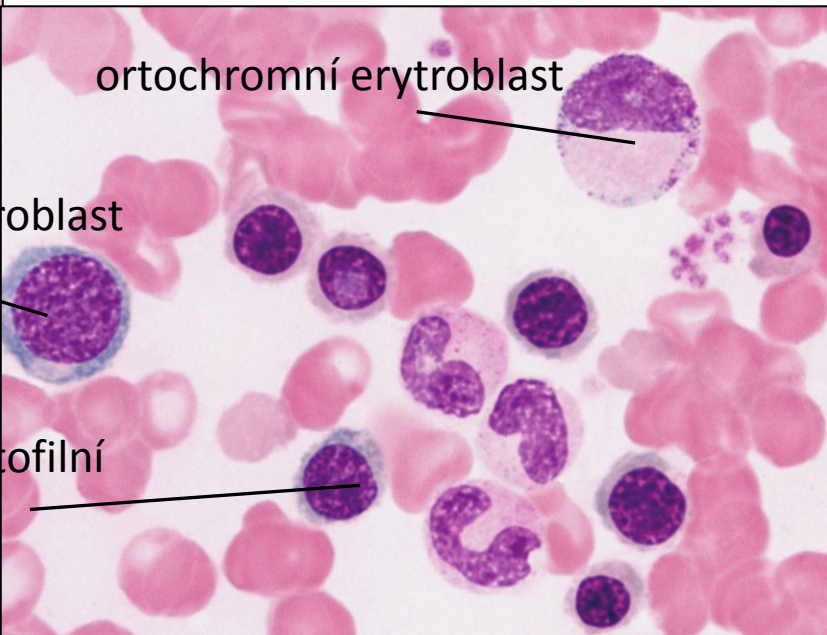
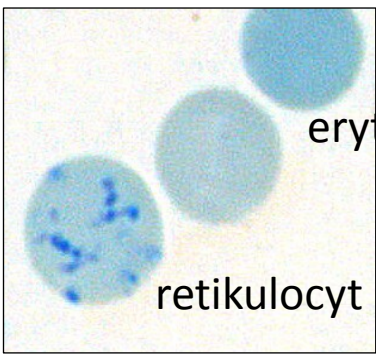
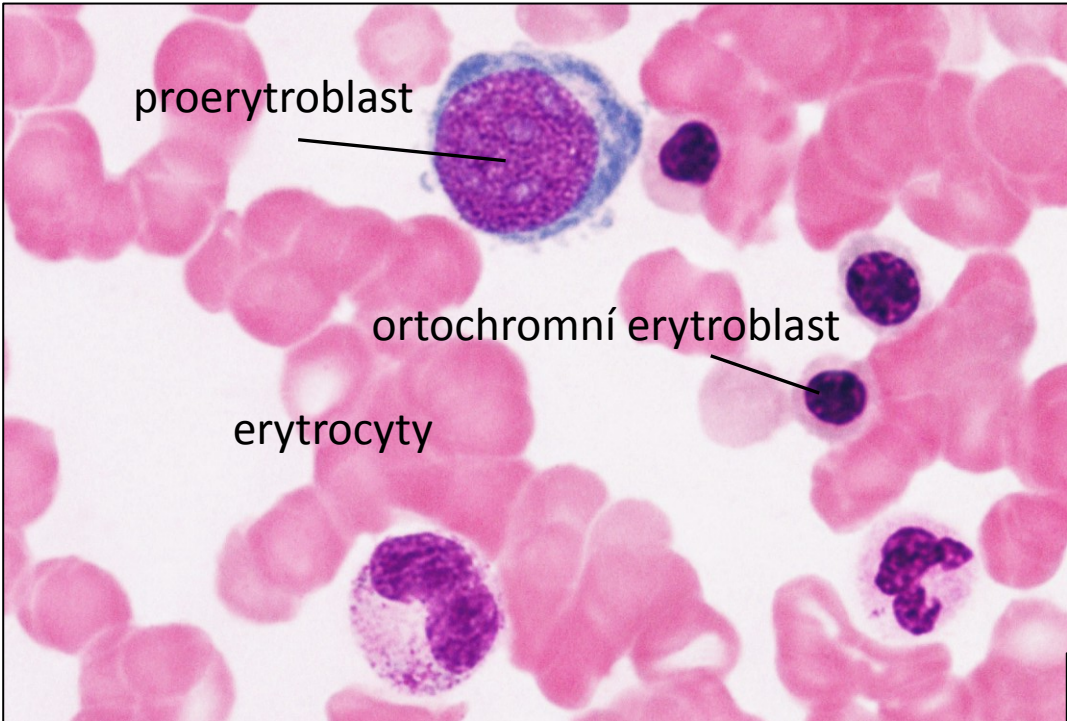


ERYTROPOEZE

- 2×10^{11} nových erytrocytů denně
- **proerytroblast** (~14-19 μm)
 - mitoticky aktivní
 - dominantní, kulaté jádro s 1-2 jádérky
 - mírně bazofilní cytoplazma
- **bazofilní erytroblast** (~13-16 μm)
 - mitoticky aktivní
 - heterochromní jádro s nezřetelnými jádérky
 - bazofilní cytoplazma
- **polychromatofilní erytroblast** (~13-16 μm)
 - mitoticky aktivní
 - **produkce hemoglobinu**
 - šedomodrá cytoplazma – bazofilní (polyribosomy a acidofilní aspekt (hemoglobin)
 - heterochromní jádro (šachovnice)
- **ortochromatofilní erytroblast** (~8-10 μm)
 - mitoticky neaktivní
 - malé, kompaktní, excentrické, pyknotické jádro → extruze
 - mírně acidofilní cytoplazma s bazofilními reziduy
- **reticulocyt** (polychromatofilní erytrocyt, ~ 7-8 μm)
 - **nemá jádro, stále sférická buňka**
 - acidofilní cytoplazma
 - *substantia reticulofilamentosa* – speciální barvení (brilliant cresyl blue)
- **erytrocyt** (~7-8 μm)
 - **bezjaderný, bikonkávní disk**
 - acidofilní cytoplazma

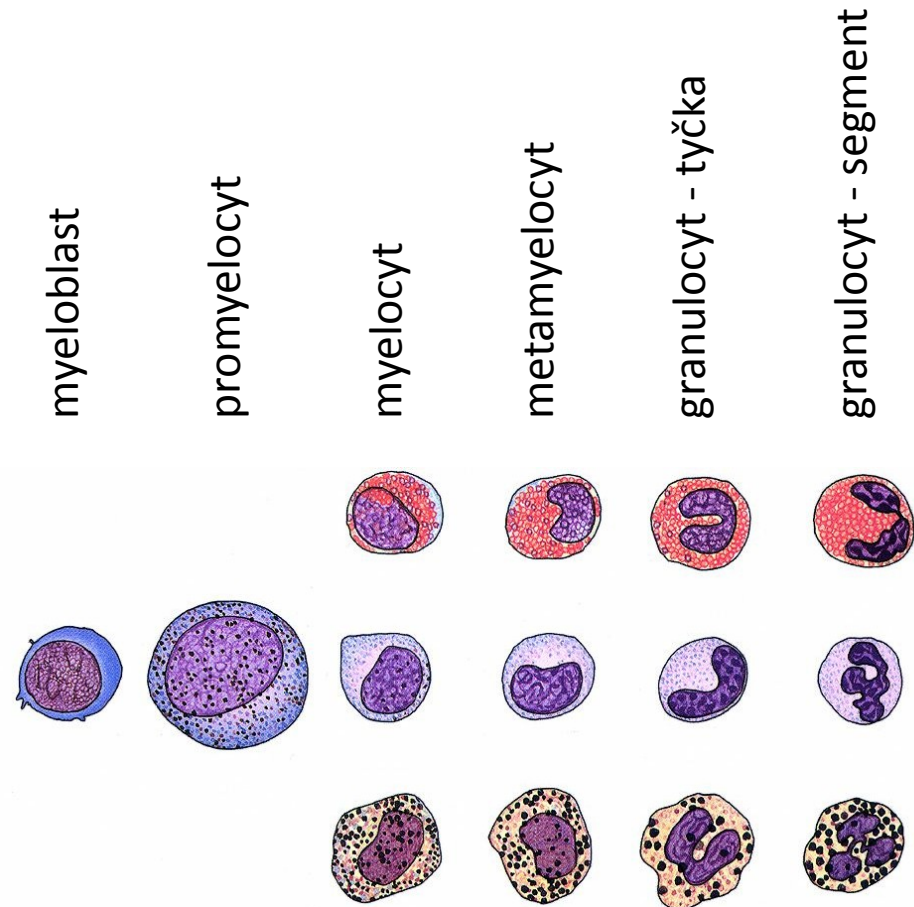


ERYTROPOEZE



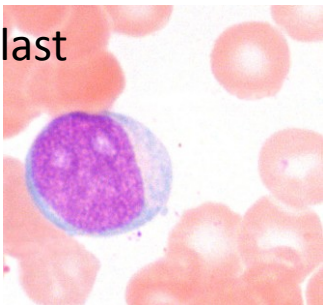
GRANULOPOEZE

- **myeloblast** (~15 μm)
 - mitoticky aktivní
 - kulaté nebo oválné jádro, bohatý euchromatin
 - 2-6 jadérek
 - slabě bazofilní cytoplazma bez granul
- **promyelocyt** (~15-24 μm)
 - mitoticky aktivní
 - kulaté nebo oválné jádro, částečně kondenzovaný chromatin
 - slabě bazofilní cytoplazma s azurofilními granuly
- **neutrofilní, eozinofilní a bazofilní myelocyt** (~10-16 μm)
 - mitoticky aktivní
 - kulaté nebo oválné jádro, částečně kondenzovaný chromatin
 - zvyšující se počet specifických granul v cytoplazmě
- **neutrofilní, eozinofilní a bazofilní metamyelocyt** (~10-12 μm)
 - mitoticky neaktivní
 - podkovovité jádro s kondenzovaným chromatinem
- **neutrofilní, eozinofilní a bazofilní granulocyt** (~10-12 μm)
 - segmentace jádra
 - azurofilní i specifická granula

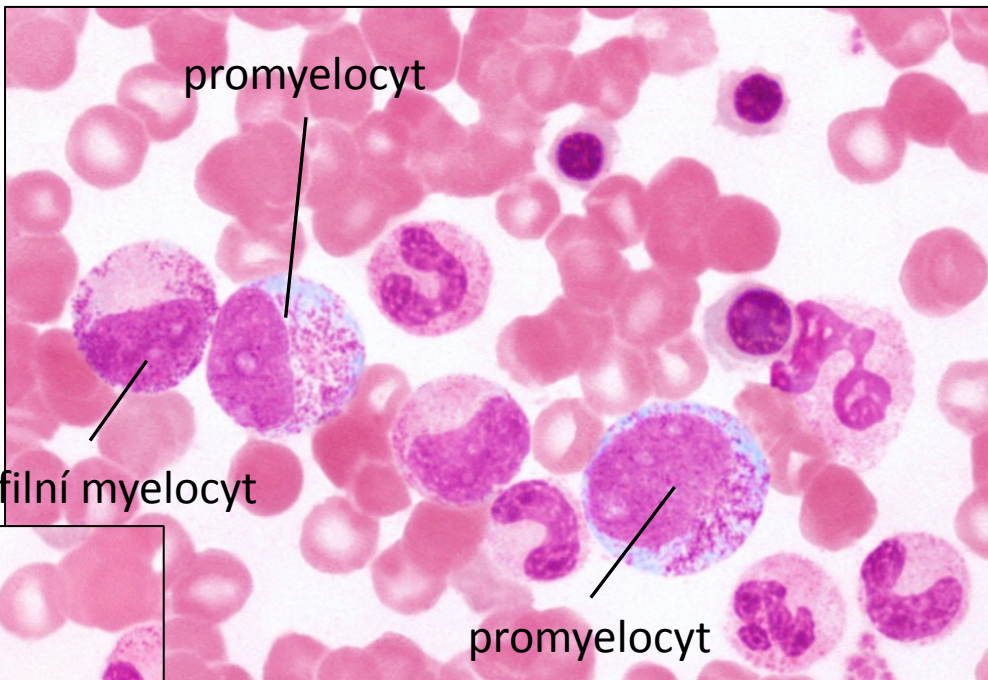


GRANULOPOEZE

myeloblast



promyelocyt



neutrofilní myelocyt

promyelocyt

polychromatofilní erythroblast

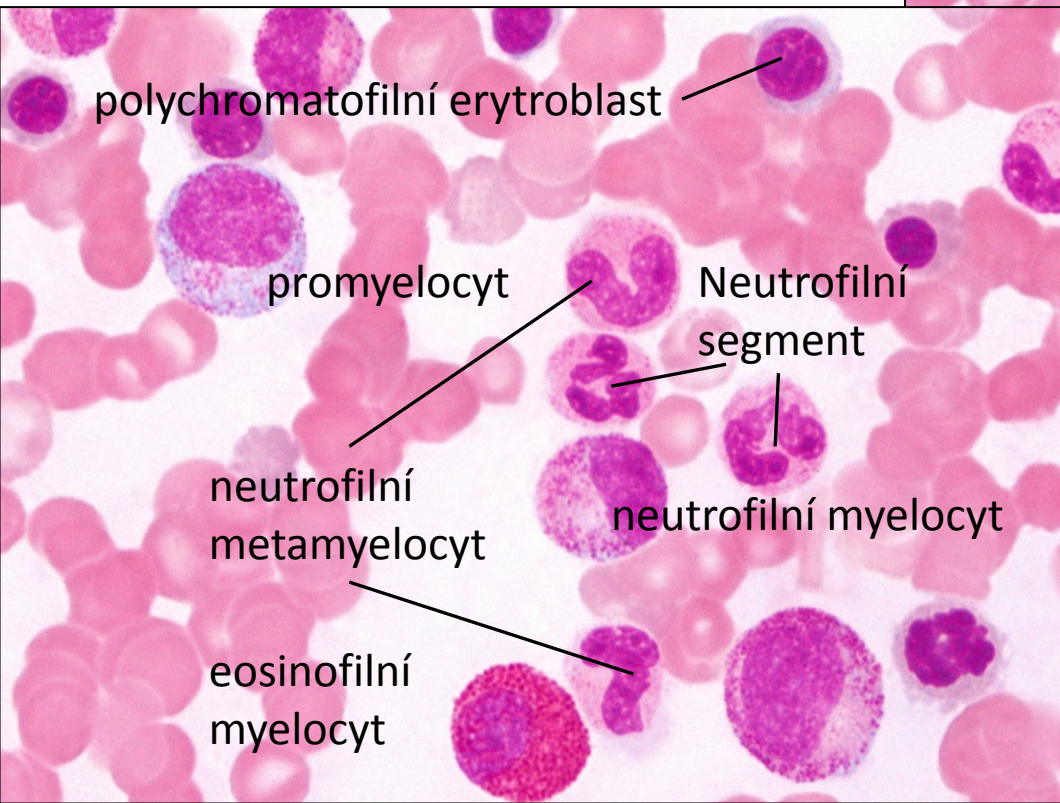
promyelocyt

Neutrofilní segment

neutrofilní metamyelocyt

neutrofilní myelocyt

eosinofilní myelocyt

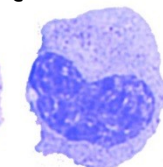
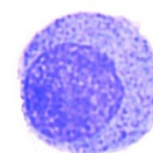
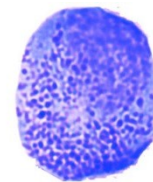
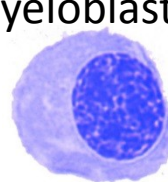


promyelocyt

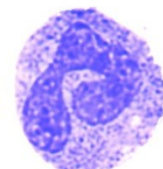
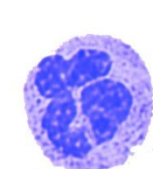
metamyelocyt

myeloblast

myelocyt

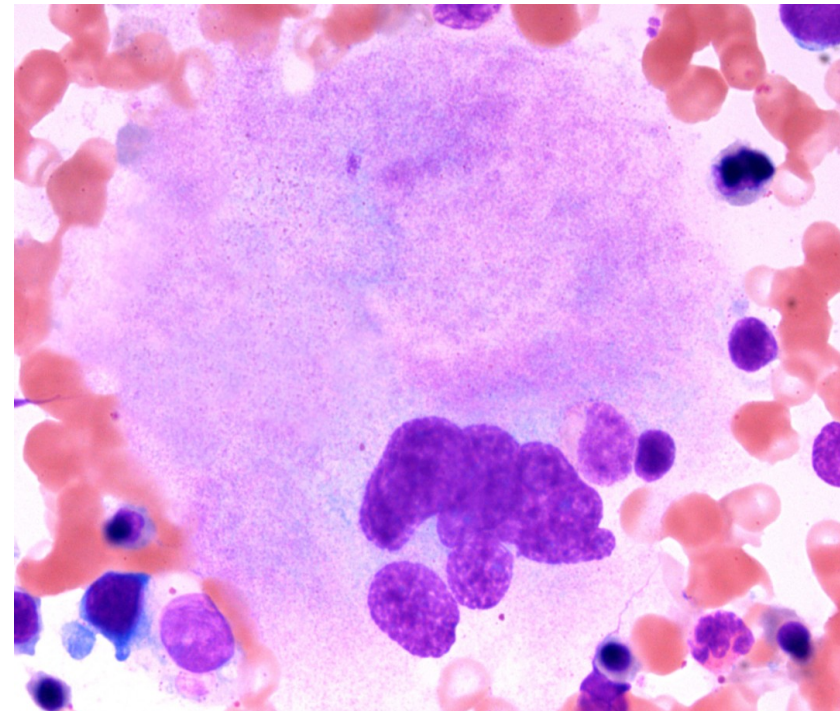
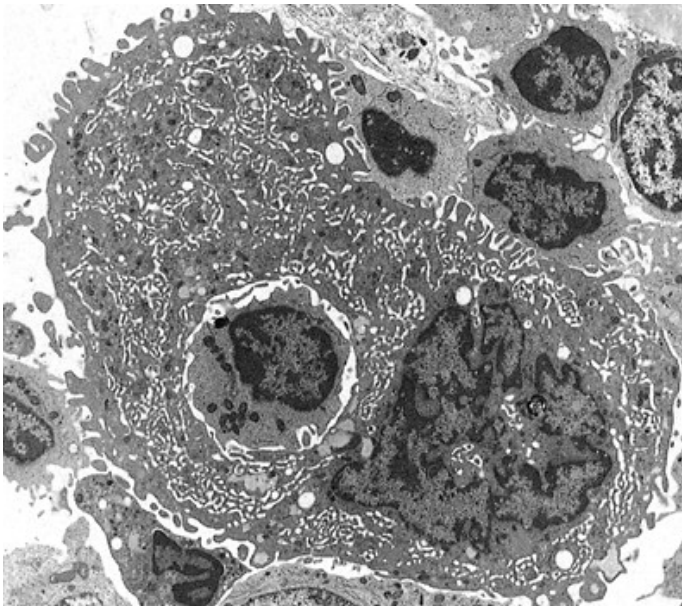
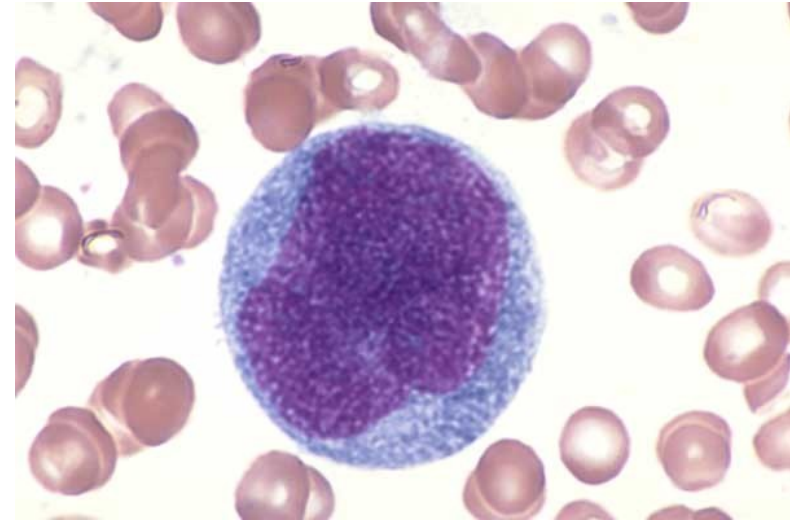


granulocyt



TROMBOPOEZE

- **megakaryoblast** (až 30 μm)
 - velké, oválné jádro s nápadnými jadérky
 - bazofilní cytoplazma
 - série endomitóz
- **promegakaryocyt** (až 100 μm)
 - velká buňka s polyploidním jádrem (8n-64n)
- **megakaryocyt** (80-150 μm)
 - polyploidní jádro s laloky (8n-64n)
 - azurofilní a destičková granula
 - vícečetné centrioly, vyvinuté ER a Golgiho aparát
 - četné membránové invaginace – demarkační kanály (linie)



MONOCYTOPOÉZA A LYMFOPOÉZA

MONOCYTOPOÉZA

- **monoblast** (~16 μm)
 - mitoticky aktivní
 - kulaté nebo ledvinovité jádro s jadérky
 - mírně bazofilní cytoplazma
- **promonocyt** (~16-20 μm)
 - mitoticky aktivní (1-2)
 - velké jádro se zářezem, nepatrná jadérka
 - bazofilní cytoplazma
 - azurofilní granula
- **monocyt**
 - krátce v cirkulaci, poté opouští krevní oběh a diferencuje v tkáňové makrofágy

LYMPHOPOÉZA

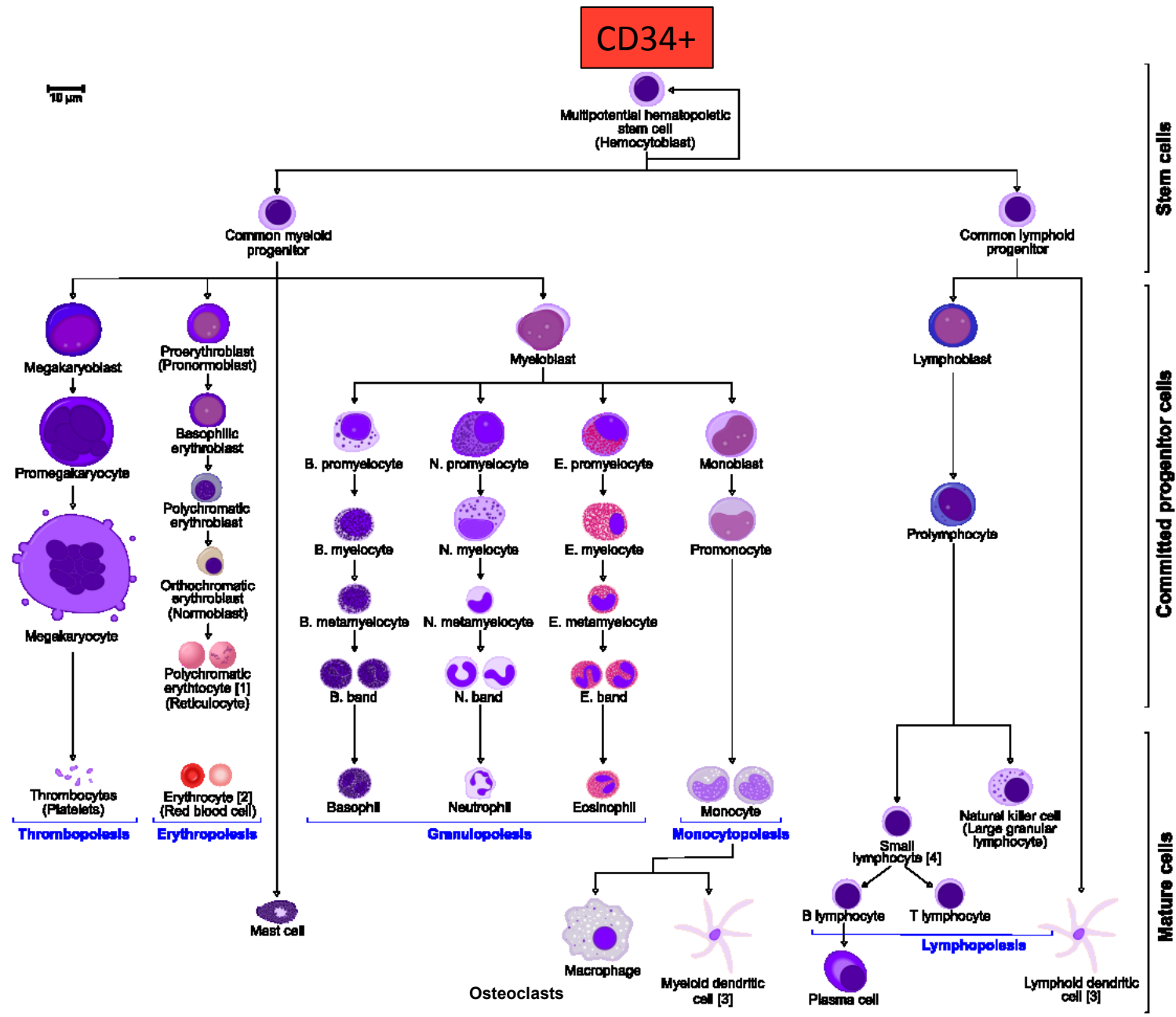
- **lymfoblast** (~18-20 μm)
 - kulaté-oválné jádro s jadérky
 - mírně bazofilní cytoplazma bez azurofilních granul
- **prolymfocyt** (~12-15 μm)
 - maturace do lymfocytů
- **lymfocyt**
 - další maturace a diferenciaci mimo kostní dřeň

PŘEHLED ADULTNÍ KRVETVORBY

Bone marrow

Blood

Tissue



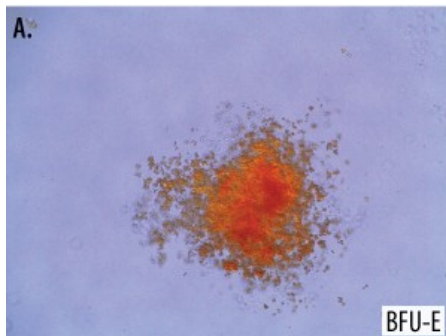
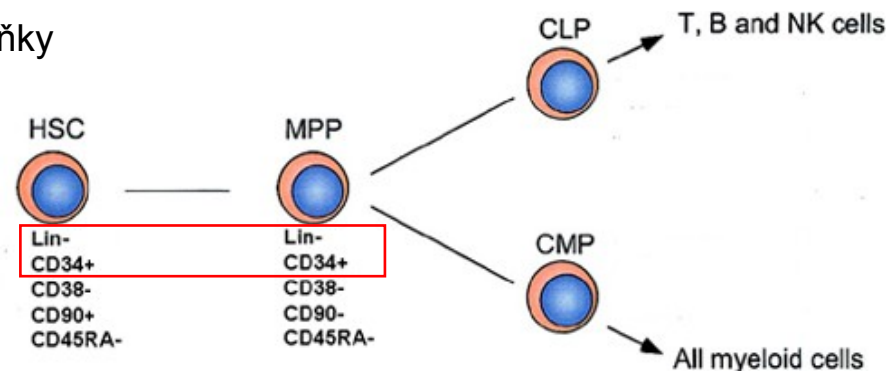
HEMATOPETICKÁ KMENOVÁ BUŇKA A PROGENITORY

- **Hematopetická kmenová buňka**

- Klidová, pomalý buněčný cyklus
- Transmembránový fosfoglykoprotein CD34⁺ - adheze v niche
- Neexprimuje povrchové markery determinovaných linií (je Lin⁻)
- Transplantace

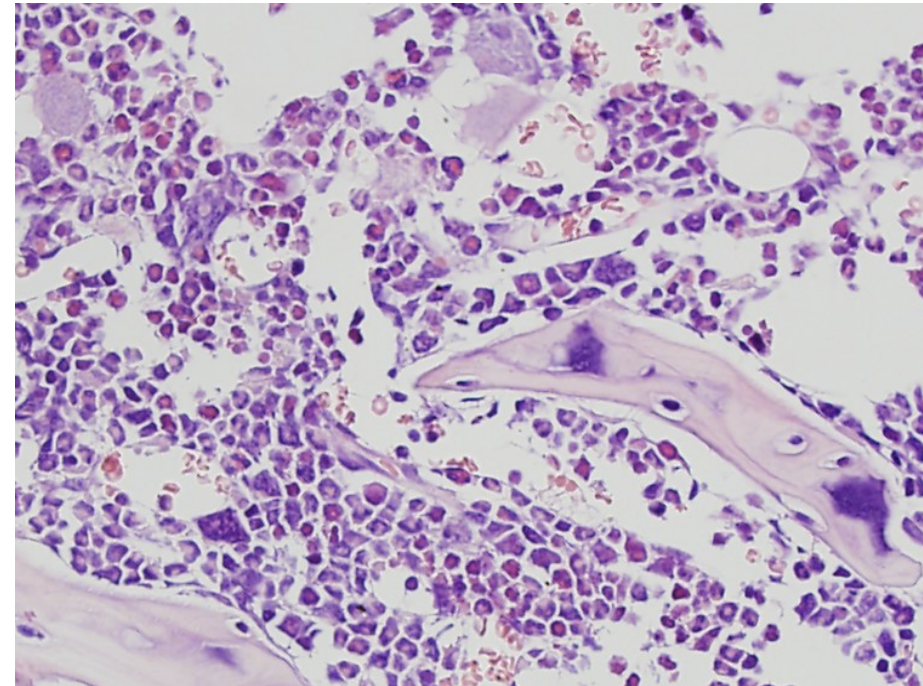
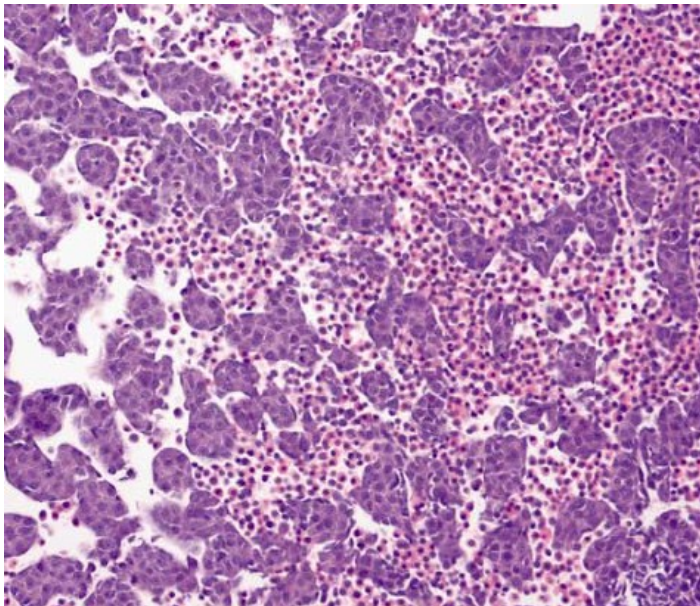
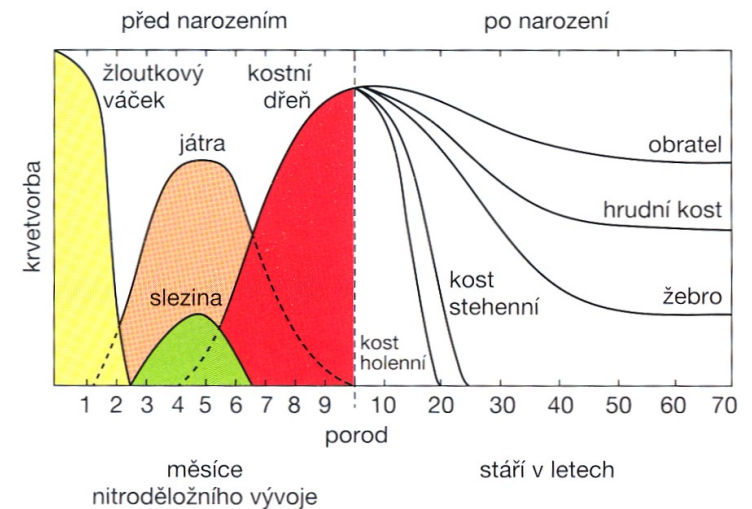
- **Colony/Burst – Forming Unit – CFU/BFU**

- Progenitory jednotlivých linií – unipotentní kmenové buňky
- Tvoří kolonie in vitro



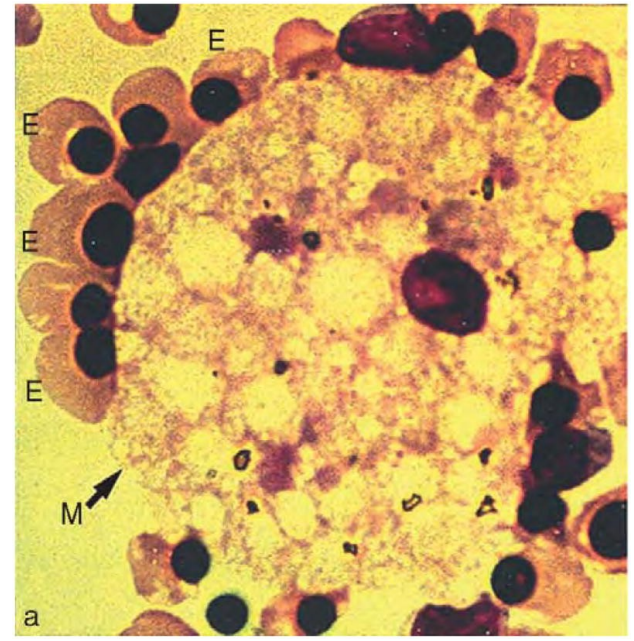
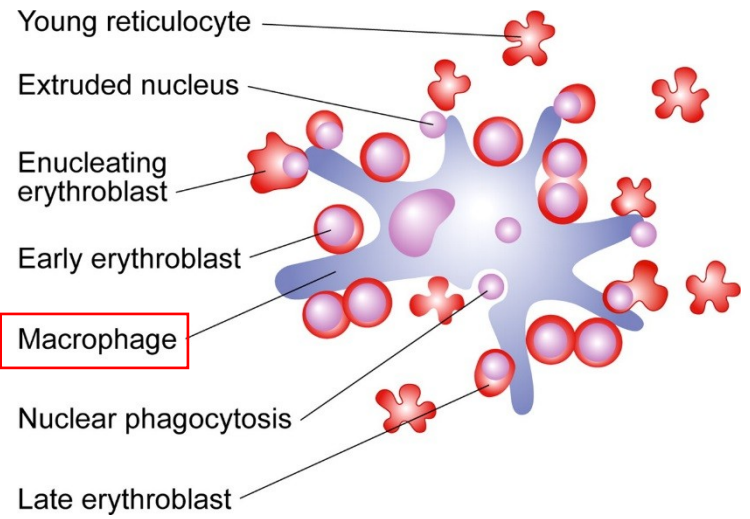
EMBRYONÁLNÍ KRVETVORBA

- **extraembryonální mezoblastická perioda (16-20. den – 8. týden)**
 - žlutkový váček
 - klasický model – hemangioblasty (bipotentní buňky)
 - velké jaderné erytroidní buňky
- **aorta-gonad-mesonephros (28. den – 4. týden)**
 - para-aortické clustery v mezodermu splanchnopleury
 - zdroj embryonálních krvetvorných kmenových buněk
- **hepatolienální perioda (1. měsíc – krátce po porodu)**
 - kolonizace fetálních jater a sleziny
- **medulární perioda (4-6. měsíc – celý život)**
 - kostní dřeň

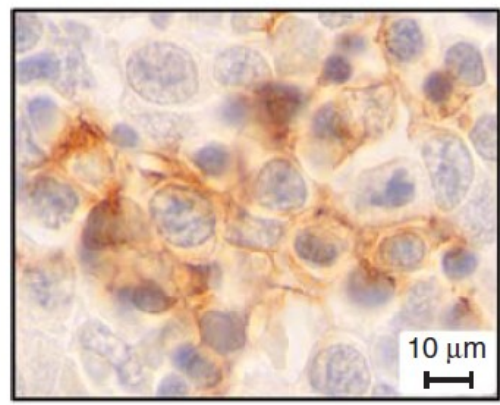


HEMATOPOETICKÉ OSTRŮVKY

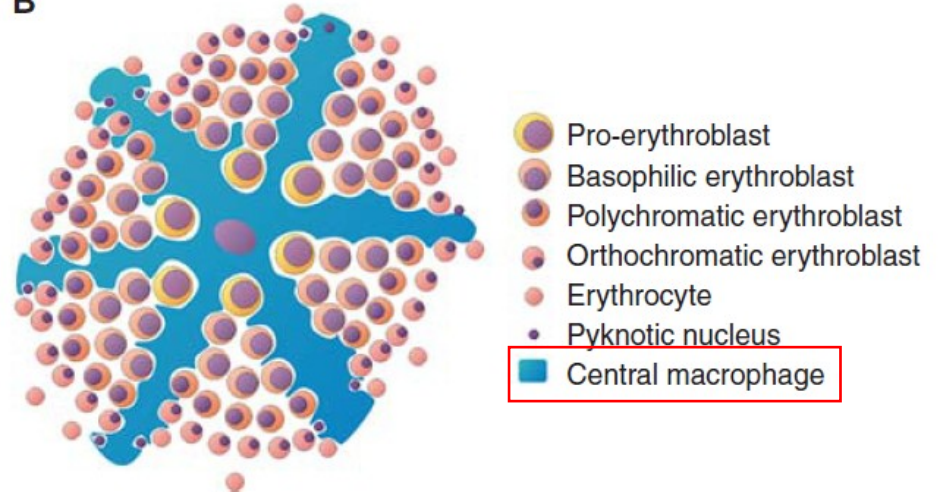
- Hepatolienální a medulární krvetvorba
- Erytroblastické ostrůvky



A

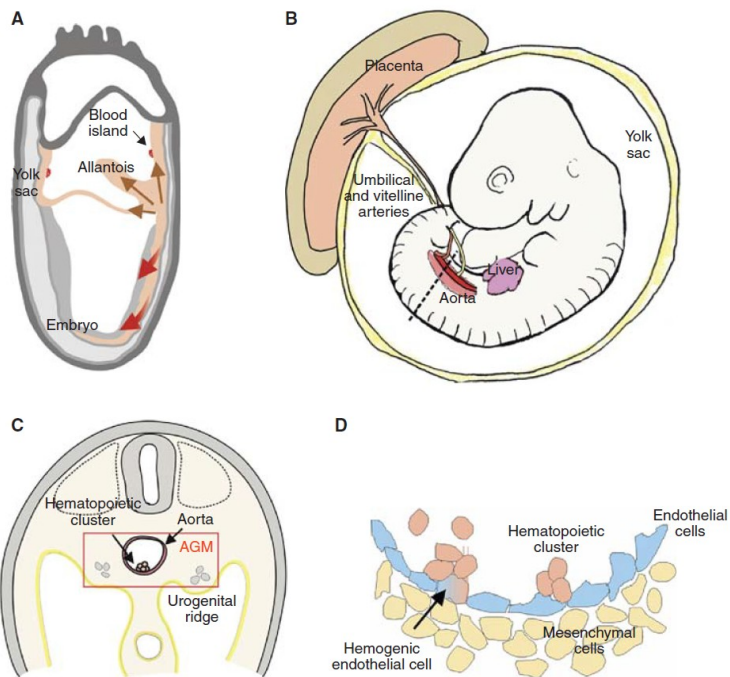
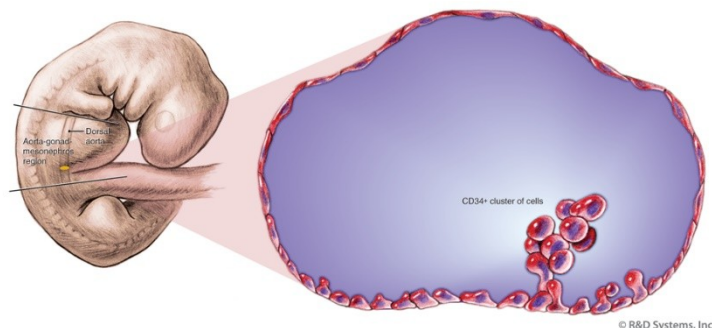


B

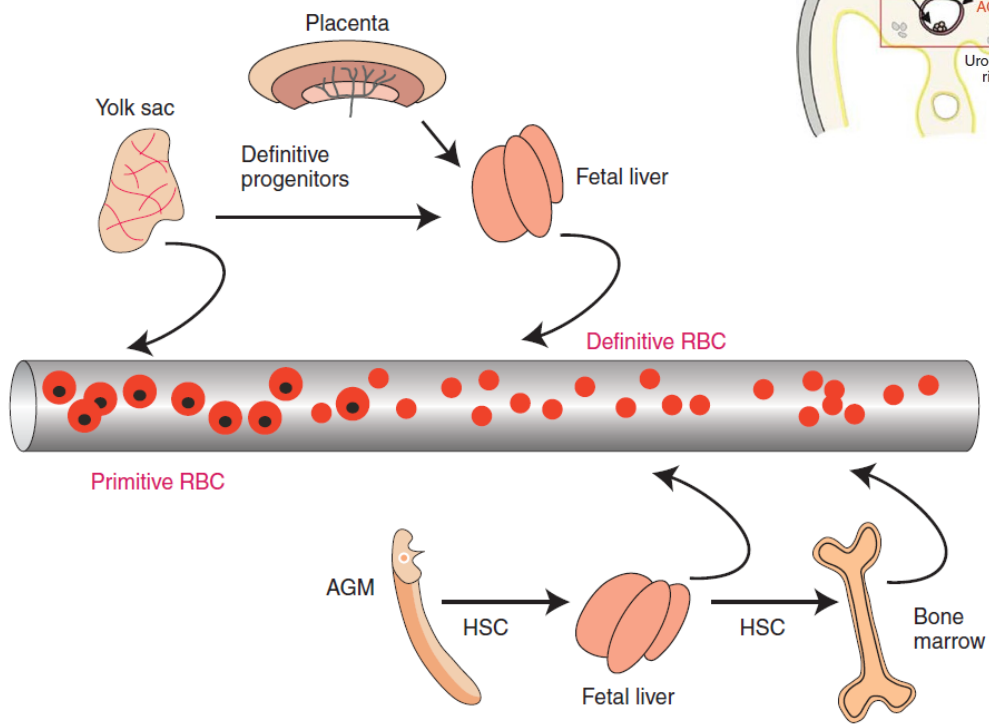


INTRAEMBRYONÁLNÍ KRVETVORBA

- **Aorta-gonad-mesonephros (28. den – 4. týden)**
- para-aortické clustery v mezodermu splachnopleury
- zdroj embryonálních krvetvorných kmenových buněk



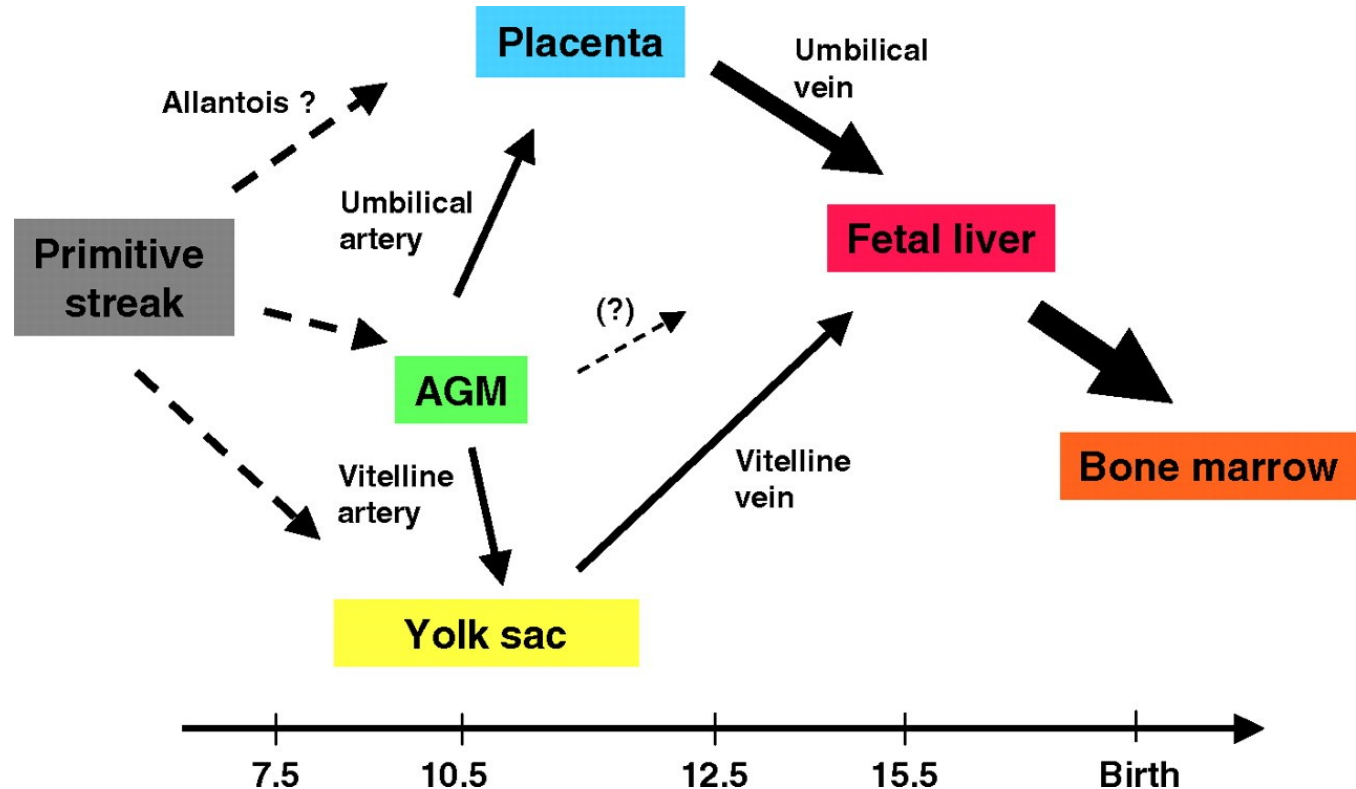
- **Placenta**



KRVETVORBA - SHRNUTÍ

Embryonální

- žloutkový váček
- AGM
- játra a slezina
- kostní dřeň



Adultní

- kostní dřeň
- červená/žlutá
- extramedulární hematopoéza výjimečně (patologicky)

Kardiovaskulární systém

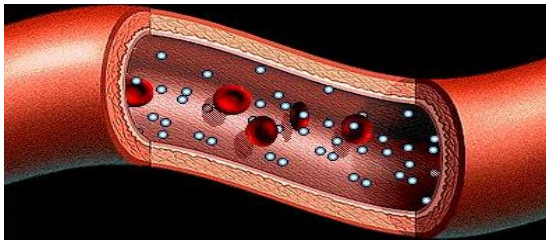
- Celkový koncept
- Cévy
- Artérie - Tepny
- Mikrocirkulace
- Vény - Žíly
- Lymfatické cévy
- Srdce
- Převodní systém srdce

Kardiovaskulární systém

= součást cirkulačního systému

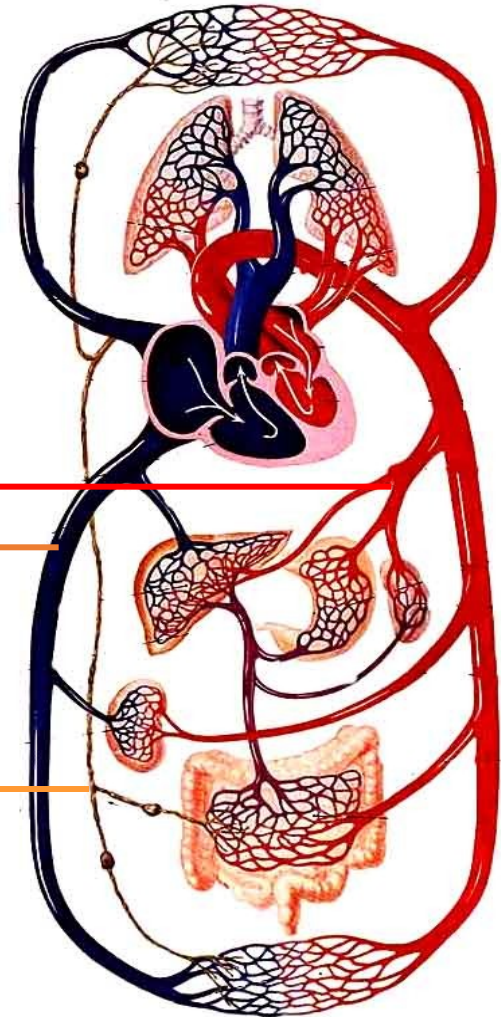
Cirkulační s. = Uzavřený systém trubic

(carries fluids (blood, lymph) in tubes)



Blood cardiovascular

Lymphatic vascular system

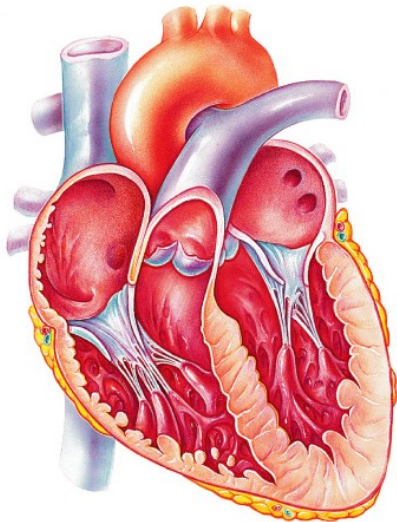


Kardiovaskulární systém – obecná stavba

Srdce

PUMPA

- moves blood with all its elements through the body



Krevní cévy

TRUBICE

- distribute the blood to the cells throughout

Three major types

Arterie - Tepny

- deliver blood from the heart to the capillaries

Kapiláry

- intimate with body cells – place of exchange between blood

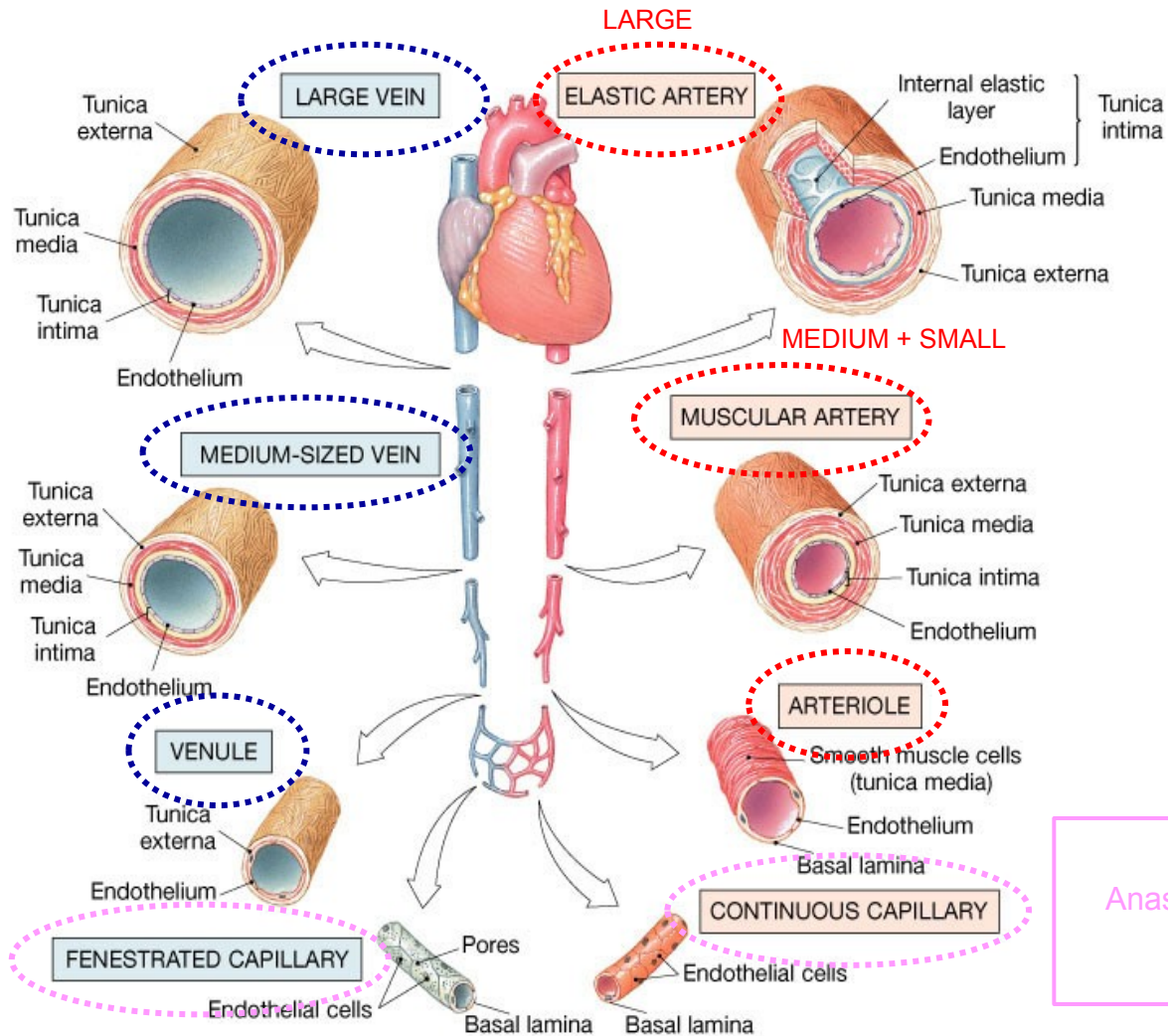
Krevní cévy – několik různých podob

Žíly
 ALWAYS return the blood to the heart
 (contain about 2/3 body's blood at any given time)

Arterie
 ALWAYS carry blood from the heart to the periphery

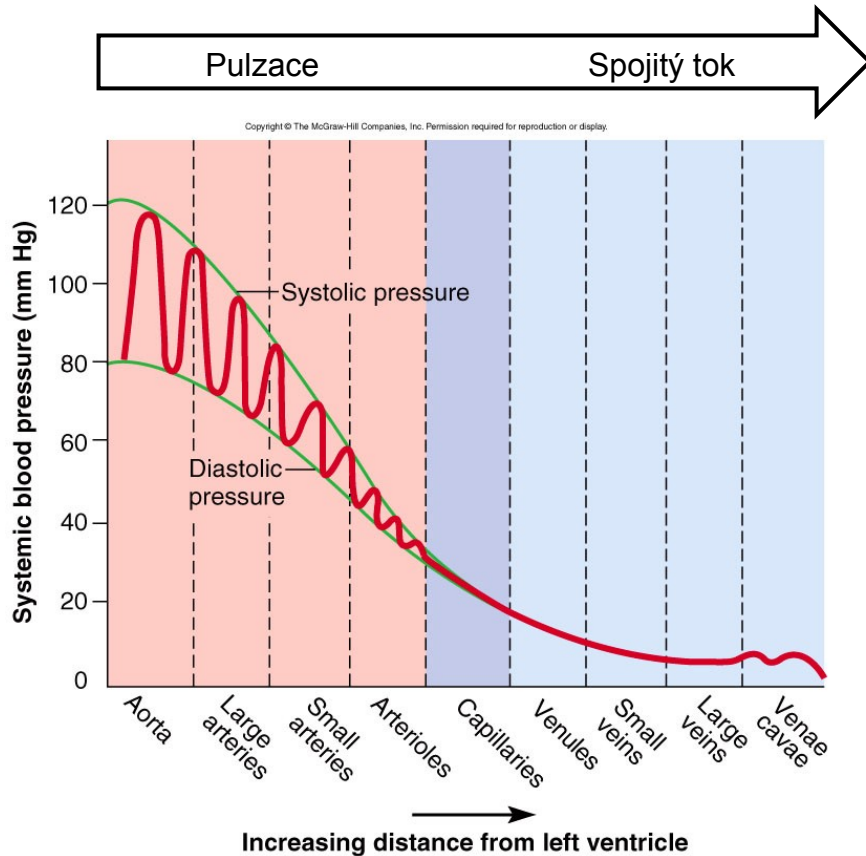
↑
 Macrovasculature – diameter > 0.1 mm
 ↓

↑
 Microvasculature – < 0.1 mm
 ↓



Capillaries
 Anastomosing tubules among arteries and veins
 = microvascular bed

Krevní cévy – tok krve



Due to specific morphologies of the vessels

For example

V diastole:

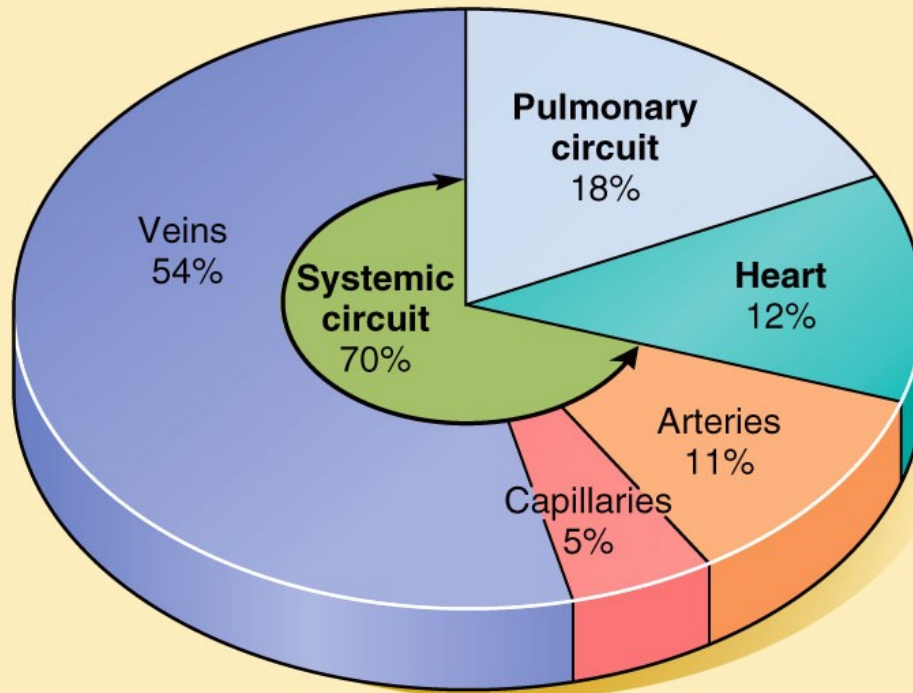
- the semilunar valves are closed
- no blood enters the arteries
- the blood moves forward due to the action of arteries

Vessel type	Diameter (mm)	Blood velocity (mm/sec)
Aorta	25	1 200 (systolic)
Arterioles	0.02-0.05	15
Capillaries	0.005-0.009	0.4
Venules	0.02	5
Inferior vena cava	30	80

...odráží se v nejednotné distribuci krve v cévách

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Distribution of Blood



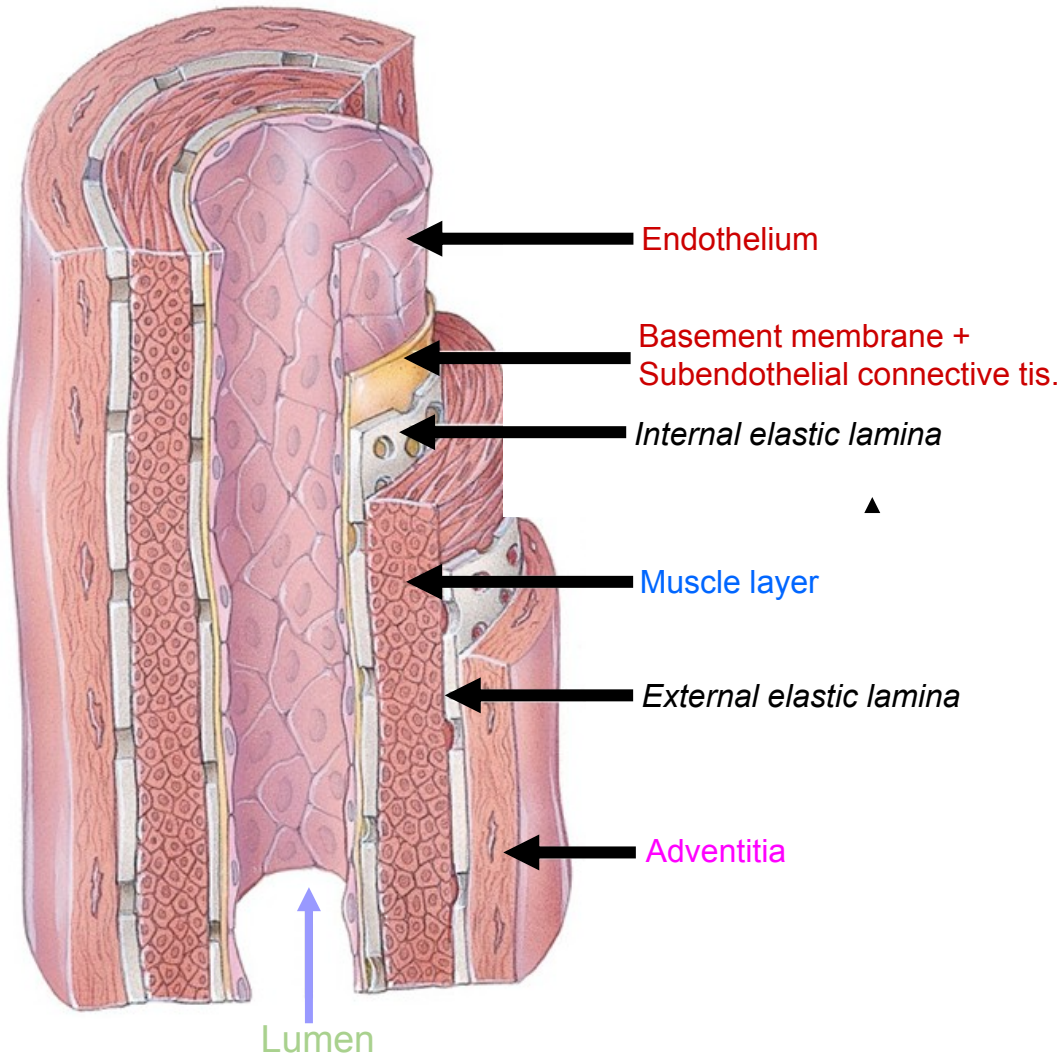
65 – 70% in veins

- Reservoir
- Lumens are larger than in corresponding arteries

Capillaries

~ 100 thousand km (estimate)
&
only 5% of blood volume
&
largest surface area (~ 600 m²)
&
most of the cells are no farther than 50 μ m from a capillary.

Krevní cévy – jednotný stavební plán (trojvrstevnost)



Tunica intima

Endothelial cells:

- polygonal, squamous, elongated
- covered by negatively charged glycocalyx (0.5 μm)
- provide repellent surface for cell elements
- glycocalyx - binding site for various regulators
- regulate permeability
- secrete regulators (e.g. interleukins,

Tunica media

- mainly smooth muscle (circularly arranged in layers)
- collagen and elastic fibers (lamellae), reticular fibers
- proteoglycans
- strengthen the vessels
- provide vasomotion

Tunica externa

- connective tissue (collagen 1 + elastin)
- home for vasa vasorum and nerve fibers
- continuous with stroma of the surrounding tissues

Arterie

Several categories according to their: **size + structure + function**

Velké arterie **elastického** typu

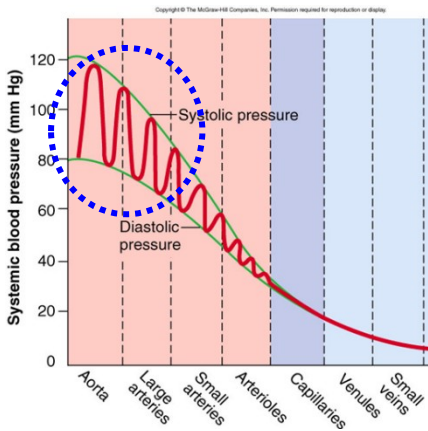
(*aorta, common carotid, subclavian a., common iliac a., pulmonary trunk*)

Arterie **svalového** typu ($D > 1 \text{ mm}$)

(*brachial, ulnar, femoral, renal, ...*)

Malé arterie ($D = 0.1 - 1 \text{ mm}$)

Arterioly ($D < 0.1 \text{ mm}$)

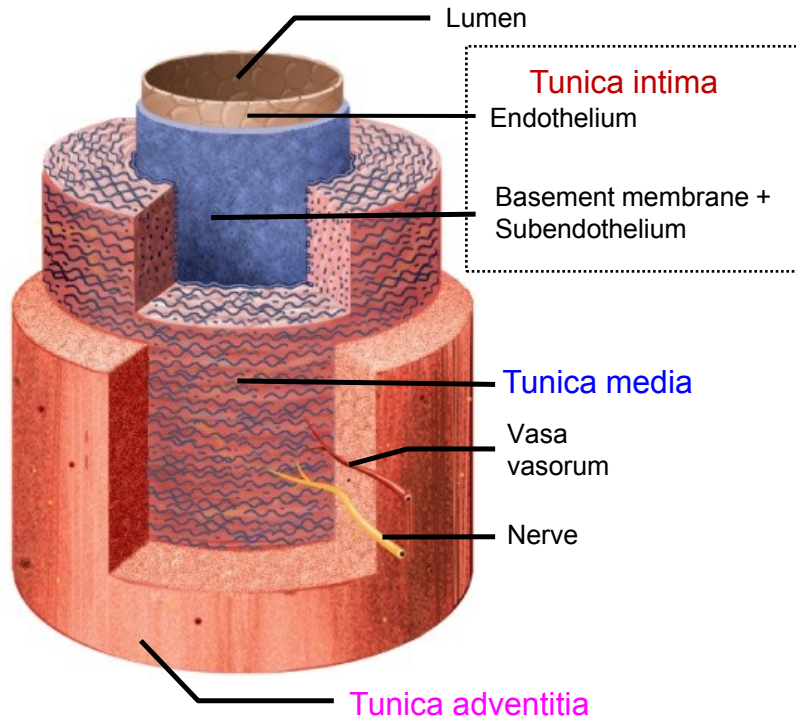


Arterie elastického typu

- their major function is to transport blood away from the heart
- they absorb and store the contractile energy of the left ventricle and transform the pulsatile flow of blood in smooth out
- during ventricular contraction (systole), the elastic laminae of conducting arteries are stretched and reduce the pressure change
- during ventricular relaxation (diastole) ventricular pressure drops to a low level but the elastic rebound of conducting arteries helps to maintain arterial pressure
- as a consequence, arterial pressure and blood flow decrease and become less variable as the distance from the heart increases

Arterie elastického typu

Relatively thin wall as compared to their wide lumen (1/10 of the vessel diameter).



Endothelium

- elongated cells - along the long axis

Subendothelial layer

- loose connective tissue
- contains many fine longitudinal elastic fibres - these gradually merge into the elastic components of t. media
- some smooth muscle cells near the boundary with t. media - longitudinally arranged
- place of atherosclerotic changes

Internal elastic lamina

- not clearly demarcated

- elastic fibers arranged circularly as discontinuous fenestrated membranes about $2.5 \mu\text{m}$ thick - about 50 lamellae
- smooth muscle cells - circularly oriented, interspersed between elastic membranes

- relatively thin
- loose connective tissue
- some elastic fibers – longitudinally arranged, next to the t. media
- vasa vasorum and lymphatics (some into t. media)
- nerves

0.15 mm

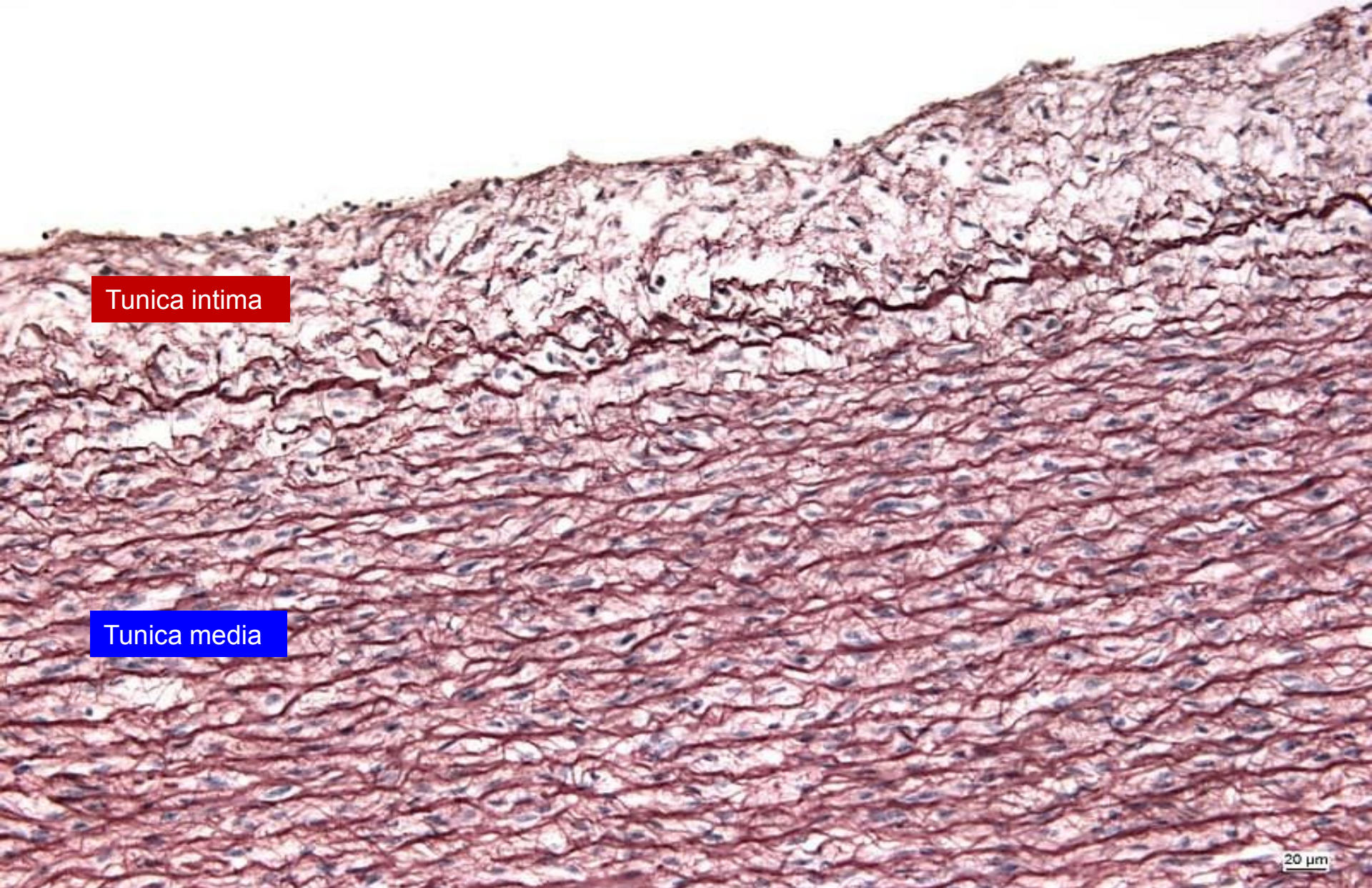
2 mm



Arterie elastického typu

Tunica intima

Tunica media

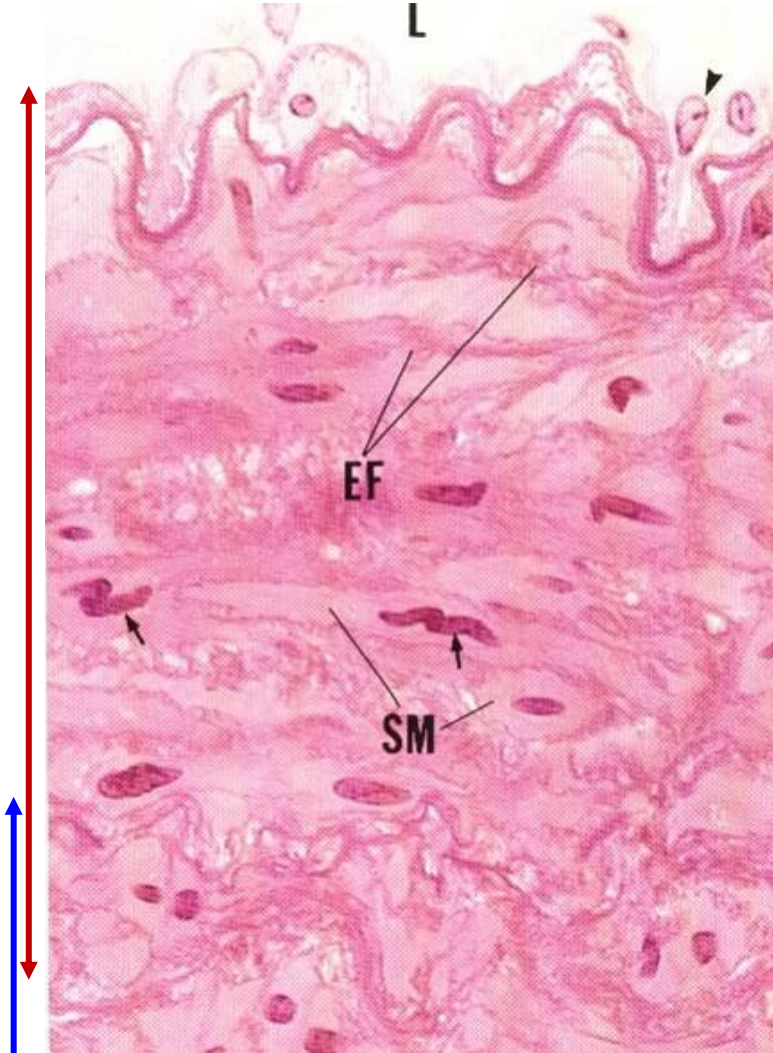


Arterie elastického typu

Opice
H & E
x540

Tunica intima

Tunica media

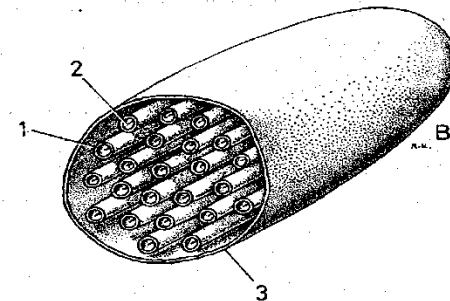
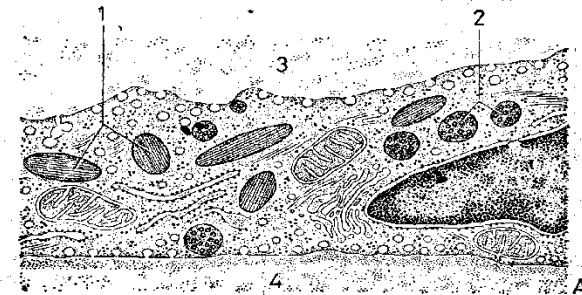


přechod

Arterie - Endotel

Weibel-Paladeho tělíska

- organelles that are unique to endothelial cells
- contain von Willebrand factor (activates coagulation factor VIII) + P-selectin



Arterie – Aterosklerotické změny

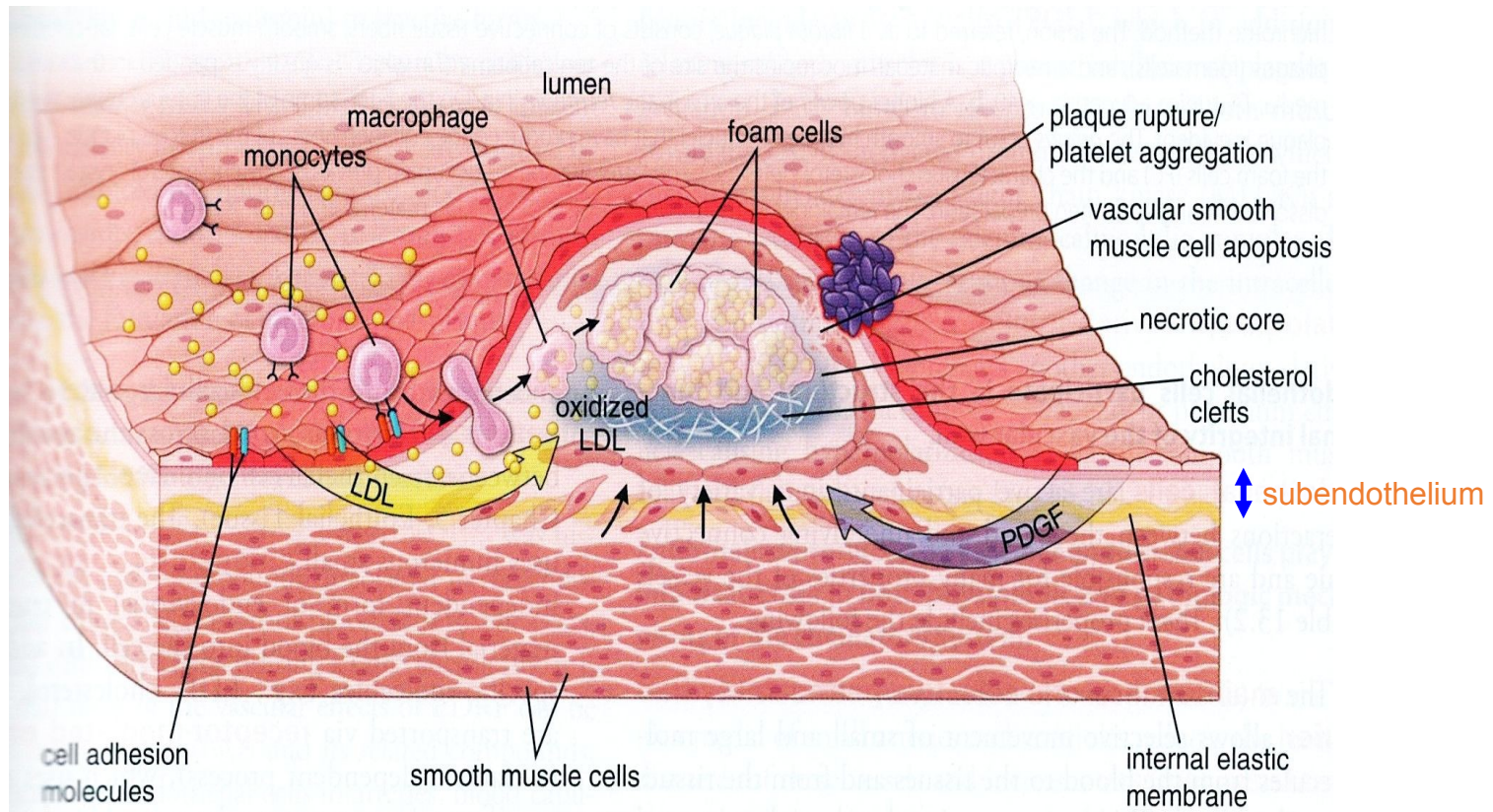
Endothelial injury
(upon predisposing factors)

Production of ROS

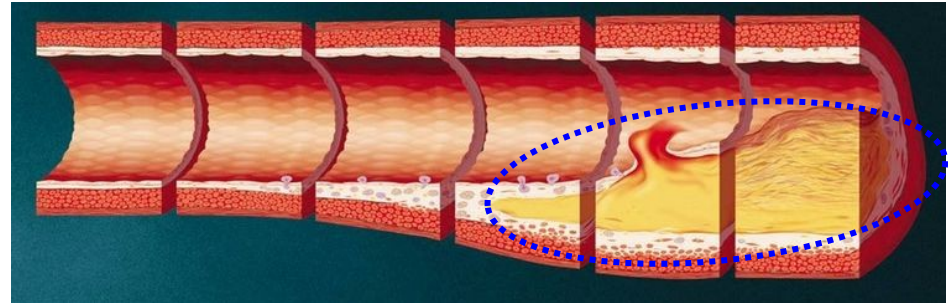
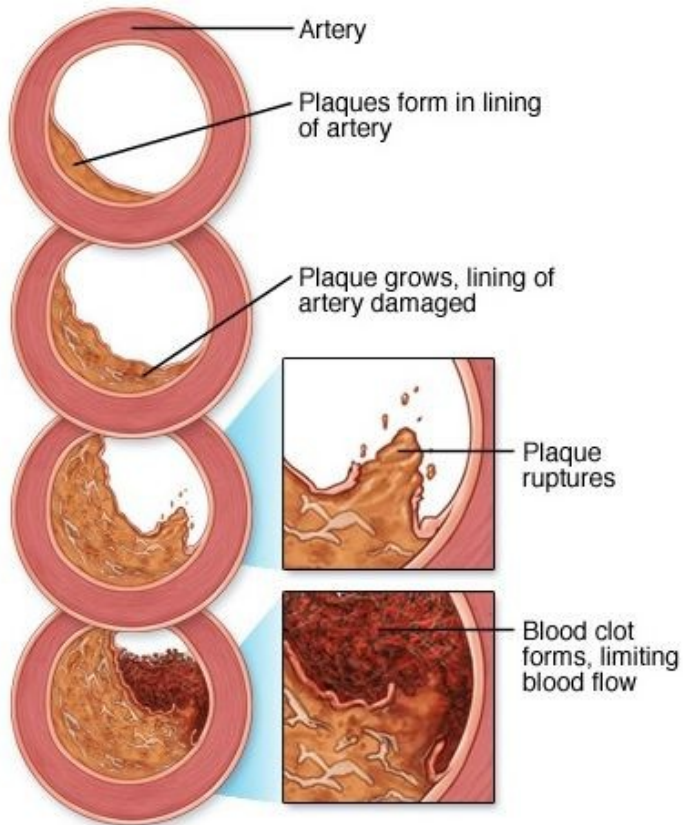
Oxidizing of LDL

Entry of monocytes
(conversion to foam cells)

Plaque formation
(necrosis + lipid accumulation)



Arterie – Aterosklerotické změny



Ateromatózní plát



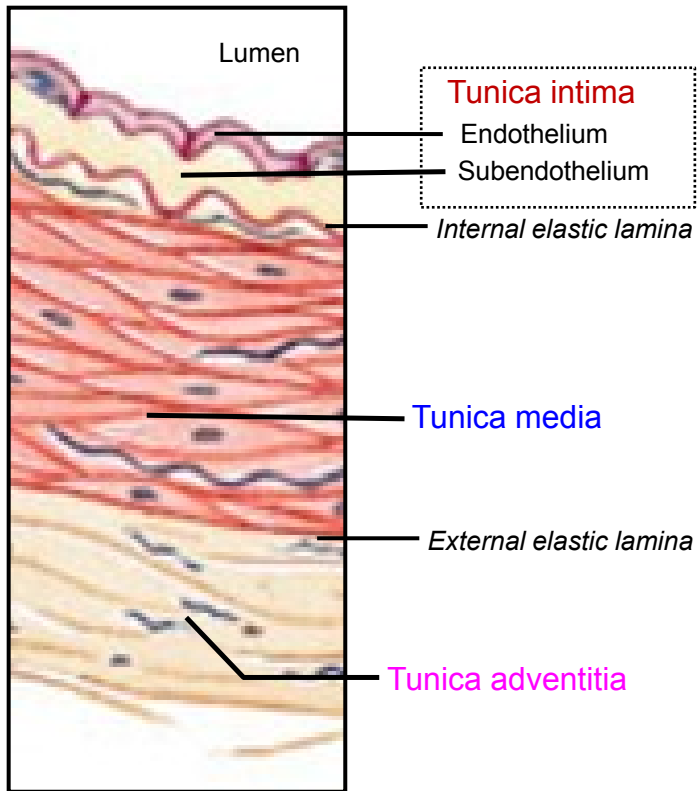
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Ucpání arterie

Arterie svalového typu = „distribuční“ arterie

- distribute blood to specific destinations/organs
- size varies from centimeter down to just visibility by unaided eye
- they regulate the perfusion of different parts of the body under physiological conditions

Arterie svalového typu



Muscular artery

Endothelium

- elongated cells along the long axis
- well developed adhesion, tight, and gap junctions
- Glycocalyx

Subendothelial layer

- thickness increases with age
- loose connective tissue
- many fine longitudinal elastic fibres
- some smooth muscle cells

Internal elastic lamina

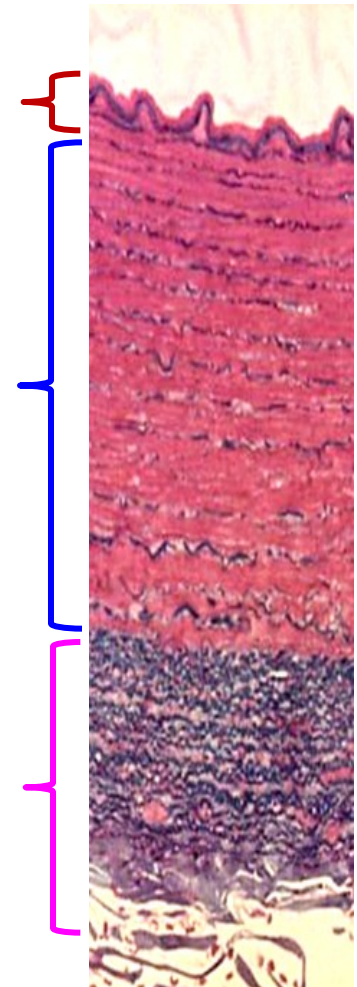
- well developed

- very thick
- concentrically arranged smooth muscle cells
- up to 50 layers of smc
- ECM with elastic, collagen and reticular fibers
- GAP junctions between smc (coordination)

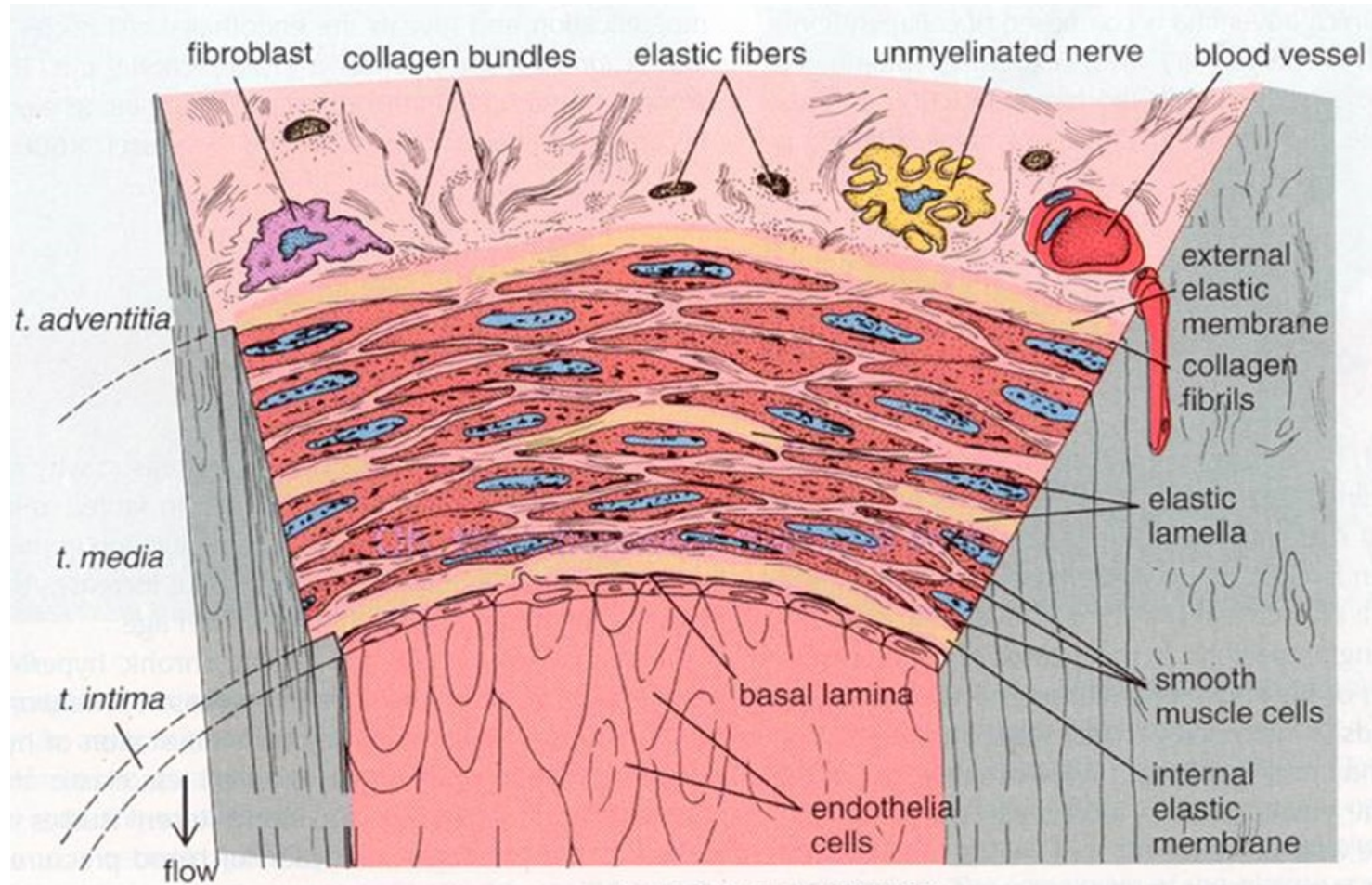
External elastic lamina

- well demarkated only in large caliber arteries

- relatively thick (~ 1/2 of the tunica media)
- collagen and elastic fibers
- some fibroblasts and adipocytes
- vasa vasorum and lymphatics (some into t. media)
- nerves – efferent – maximal in small caliber arteries

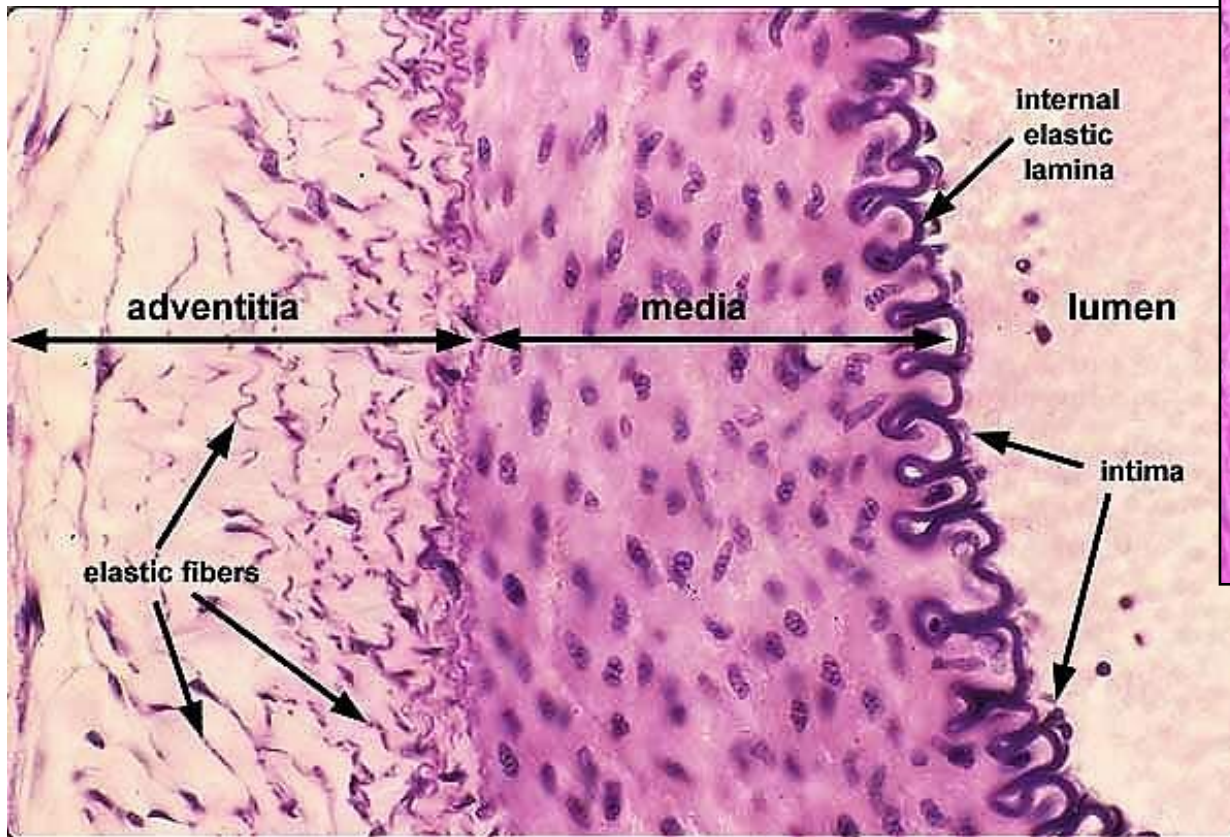


Arterie svalového typu

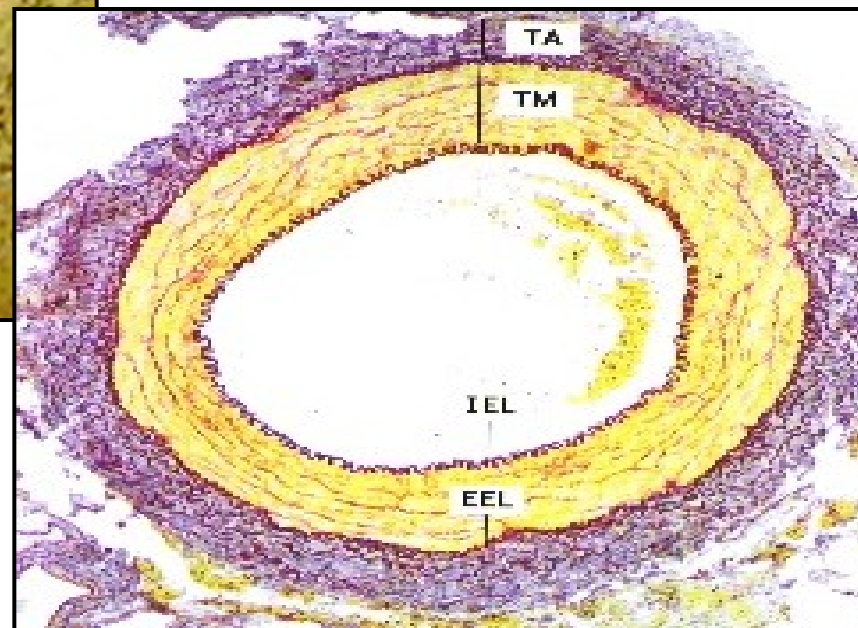
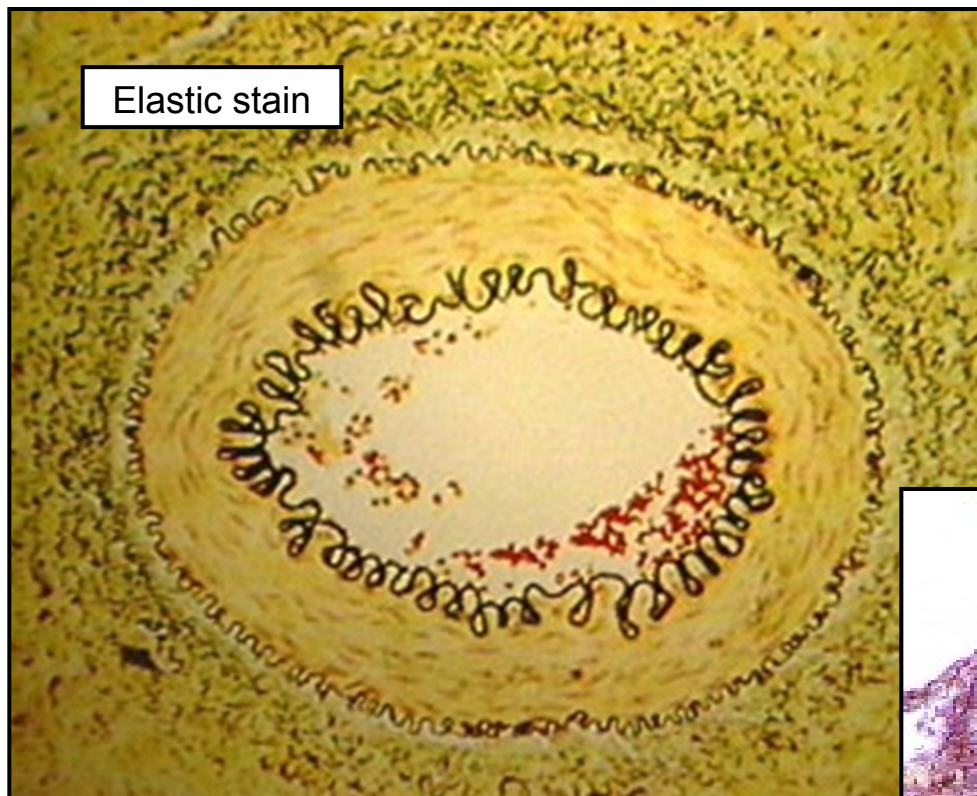


Arterie svalového typu

Undulation - Artefact
(due to postmortem contraction of smooth muscle cells)

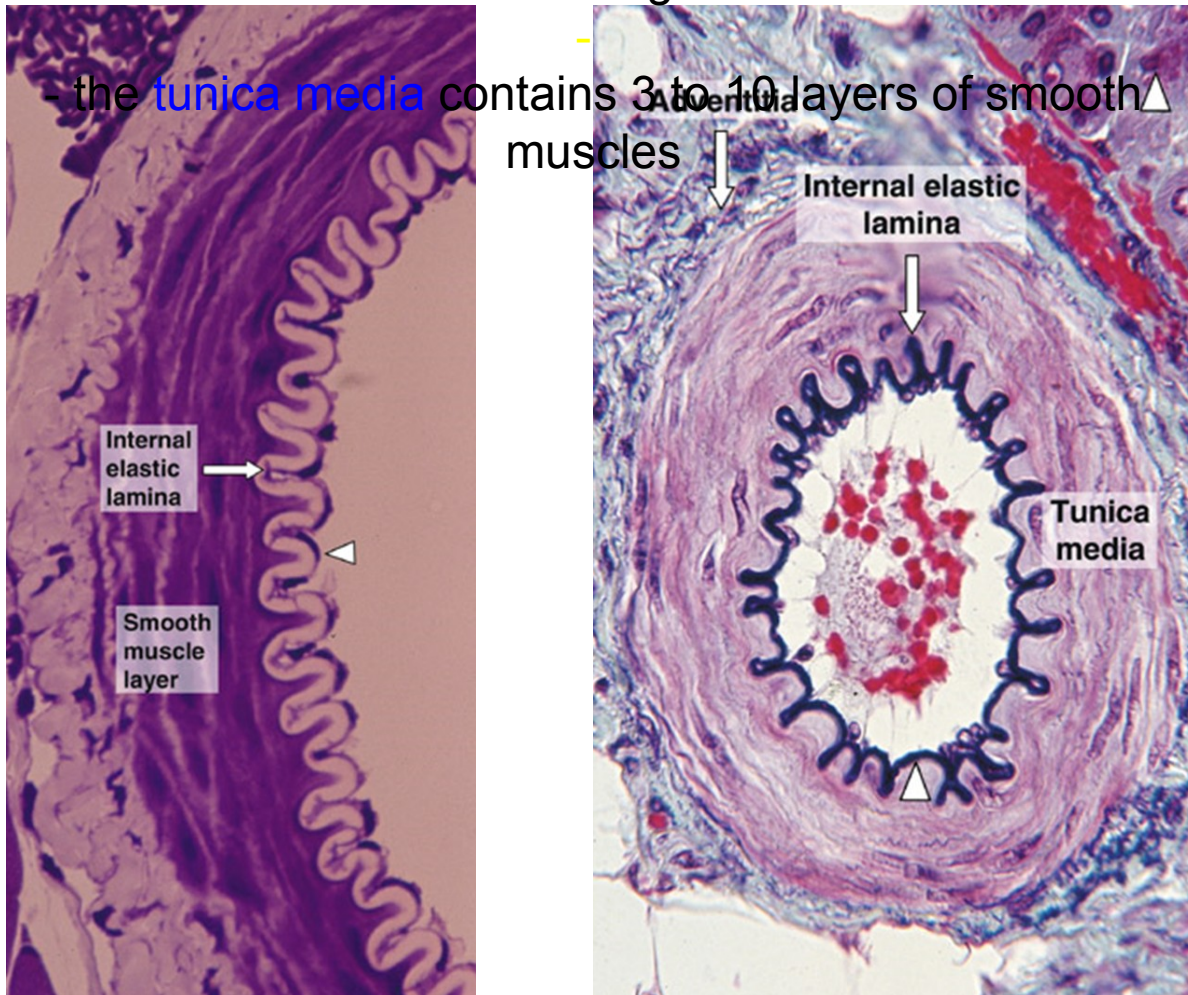


Arterie svalového typu

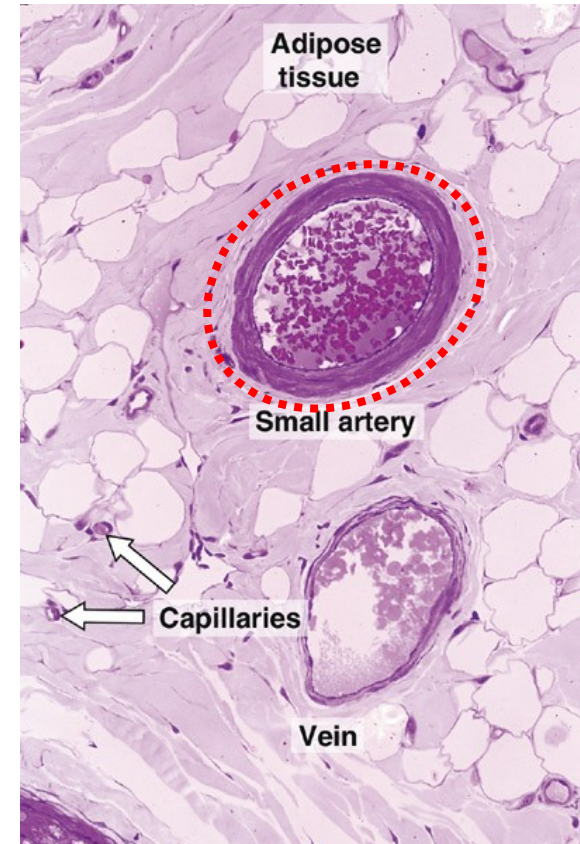
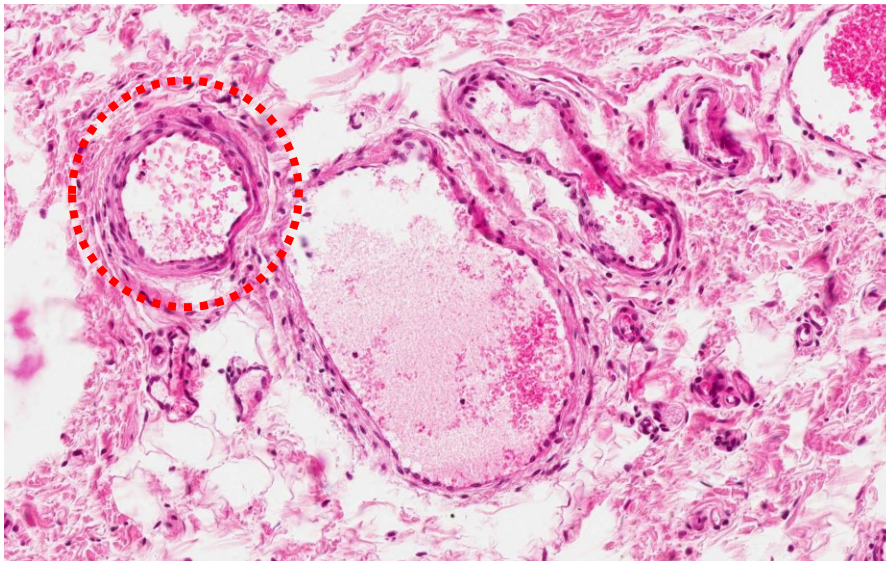
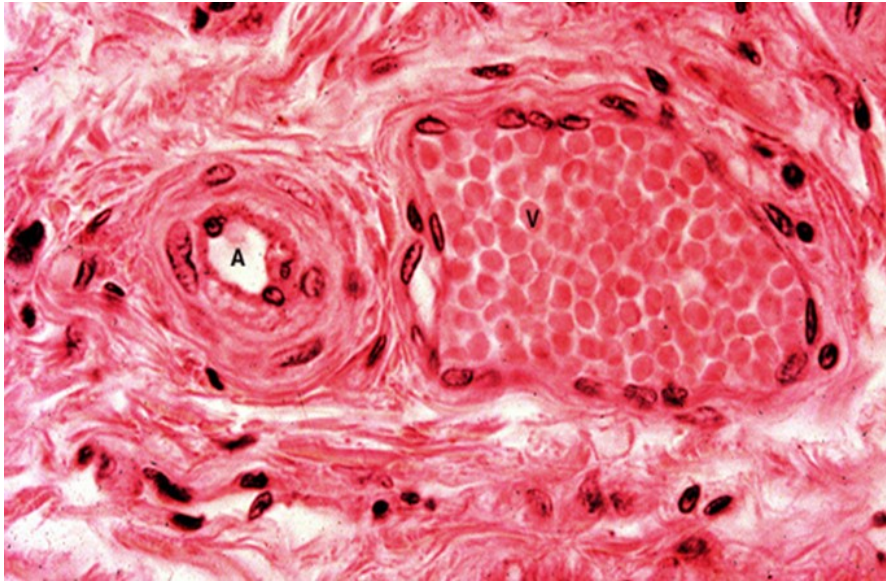


Arterie svalového typu - malý kalibr

- peripheral resistance vessel (along with arterioles)
- internal elastic lamina is clear x external elastic lamina is not distinguished



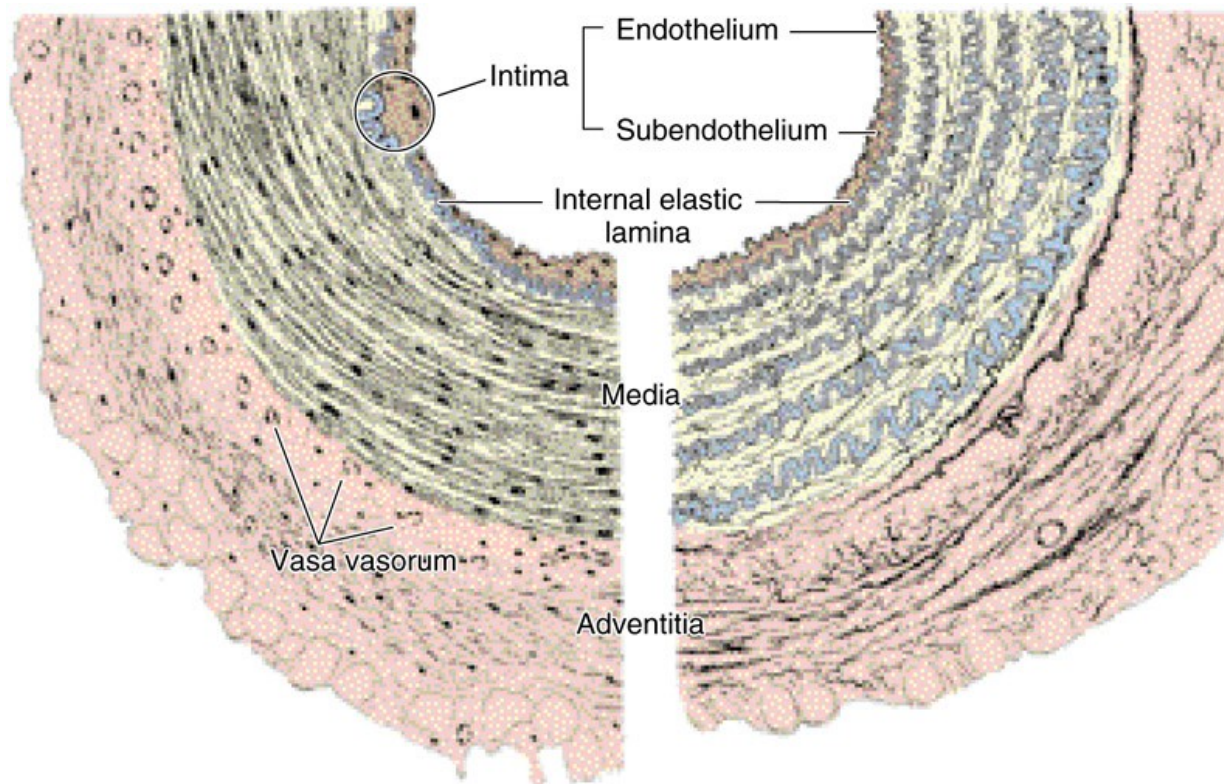
Arterie svalového typu - malý kalibr



Arterie svalového typu x Arterie elastického typu

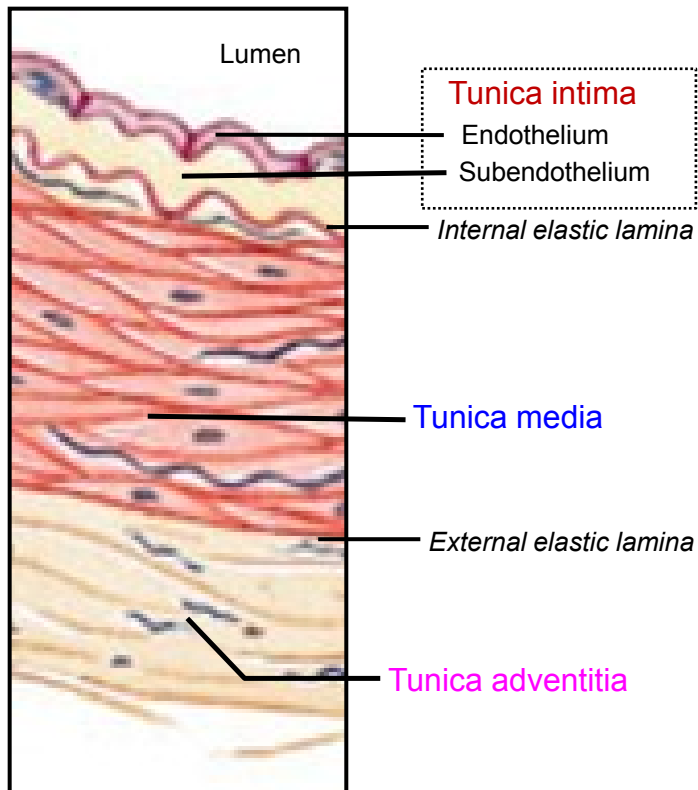
Smooth muscle cells predominate in their media

Elastic elements predominate in their walls



Arterioly

- peripheral resistance vessel (along with small-sized arteries)
- part of the microcirculation (terminal circulation)
- internal diameter < 0.1 mm
- they regulate the flow of blood through capillary bed



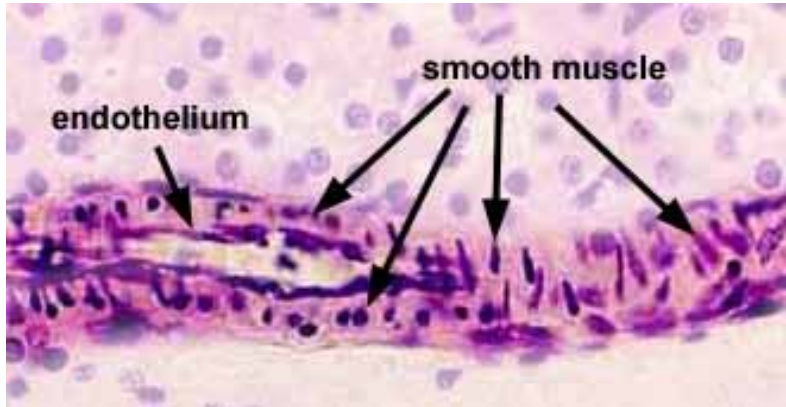
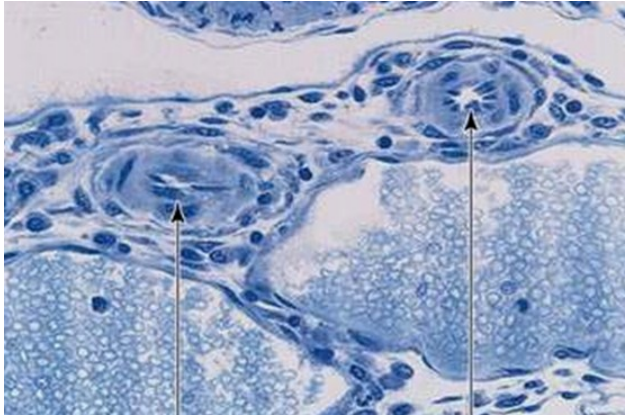
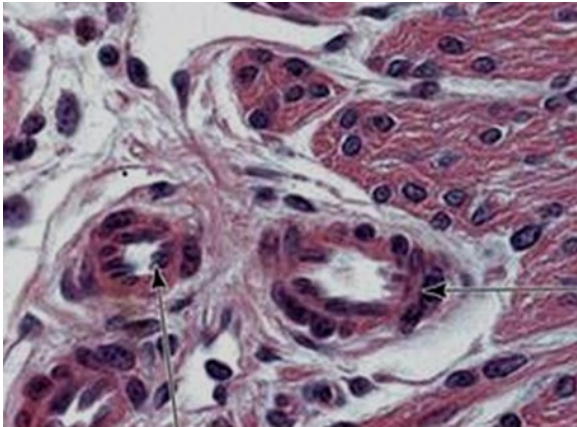
Muscular artery

- Endothelium
 - elongated cells along the long axis
- Subendothelial layer
 - non-developed
- Internal elastic lamina*
 - non-developed

- thin (still the major part of the wall)
- 1 to 2 layers of smooth muscle cells
- External elastic lamina*
 - non-developed

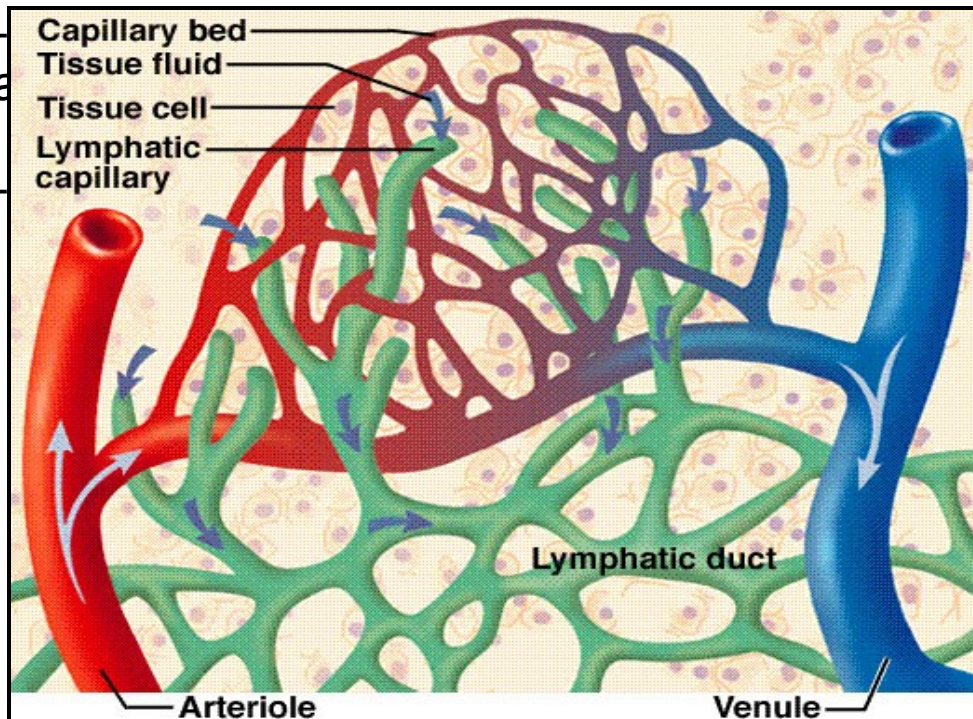
- reduced to only sheath of collagen fibers
- NO vasa vasorum

Arterioly



Kapiláry

- are the site where materials carried in the blood are unloaded and other materials are loaded into the blood
- are the **thinnest, simplest, largest, longest, and most widely distributed** functional unit of the blood vascular system
- are inserted between arterial and venous limbs of the circulation



The total length of all the capillaries of the human body =

about 100 000 km

The total cross-sectional area of capillaries =

about 800 x
greater than of the aorta

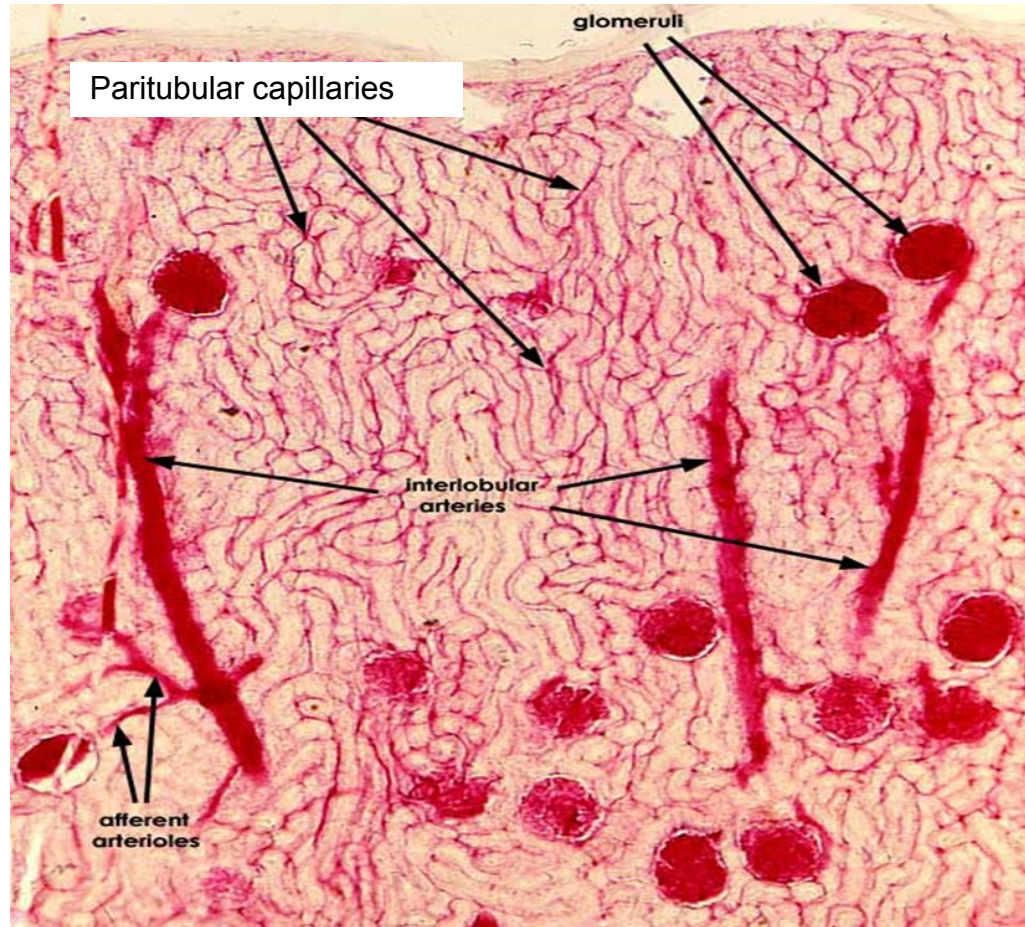
Maximal distance of tissue cell from the capillary =

about 50 μm

The length of the capillaries usually varies between

about 0.25 and 1 mm

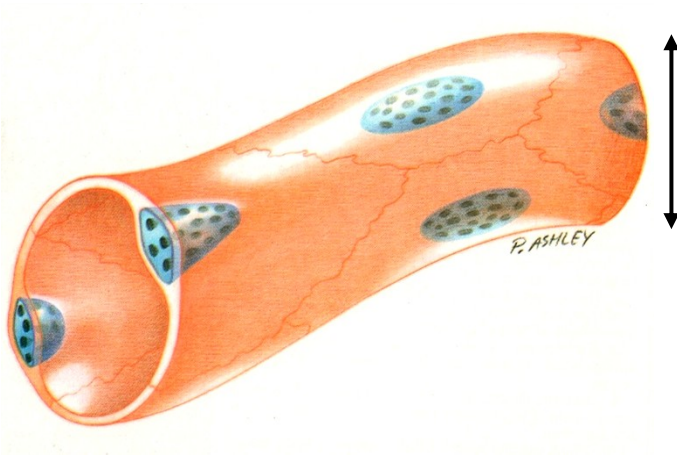
Kapiláry



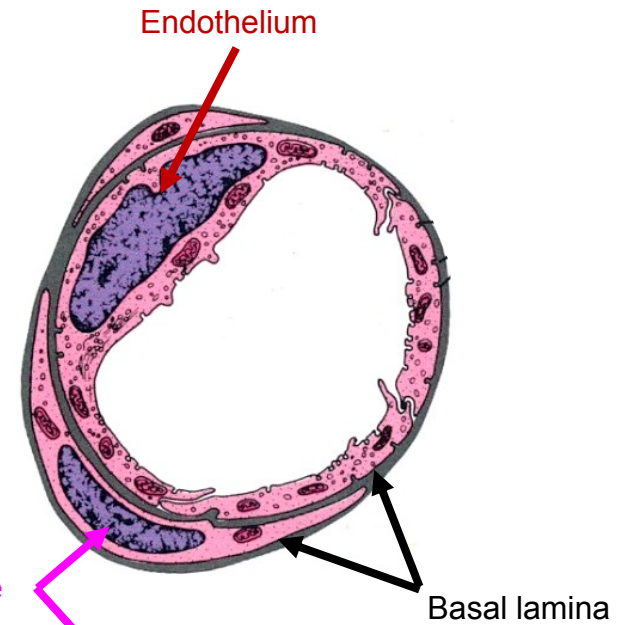
Extensive vasculature of renal cortex (perfused by red dye)

Velmi řídké v: šlachy, vazy
Zcela chybí v: chrupavka, epidermis, cornea

Kapiláry



average diameter about 8 μm



Capillary wall

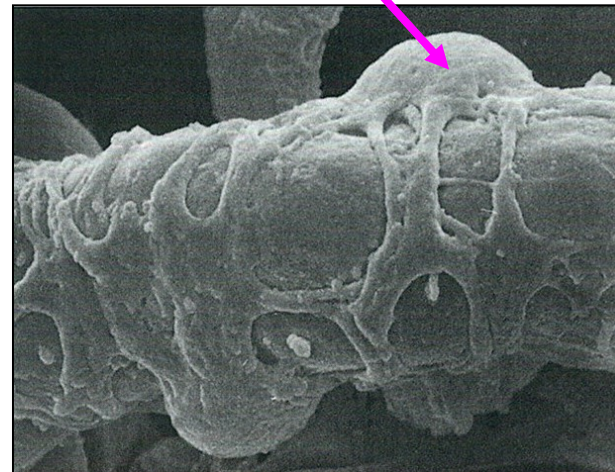
Endothelium

- single layer, squamous
- serrated (wavy) cell borders
- zonulae occludentes + desmosomes + GAP junctions

Basal lamina

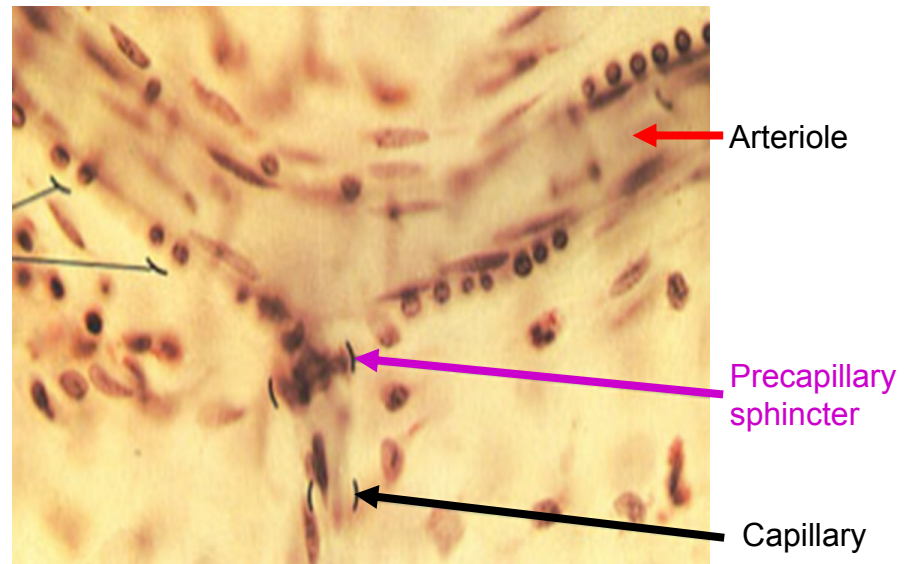
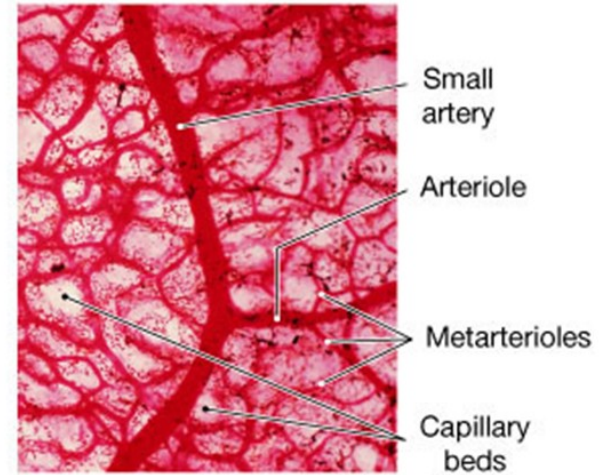
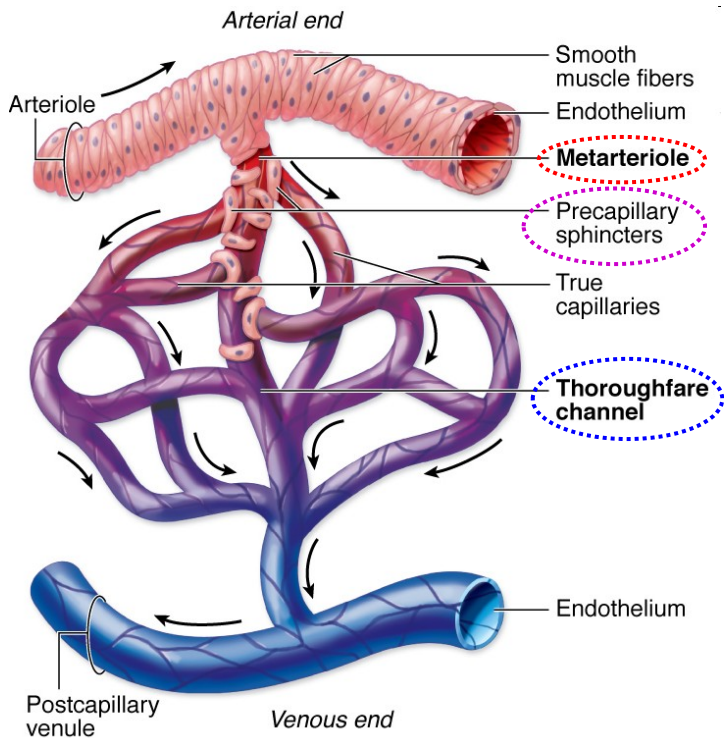
„Envelope“

- pericytes (+ reticular fibers and macrophages)



Kapiláry

Only about 25 - 50 % of capillary volume is actively moving (containing) blood under normal conditions.



Rabbit mesentery (H+E; 600x)

Kapiláry – Regulace průtoku krve

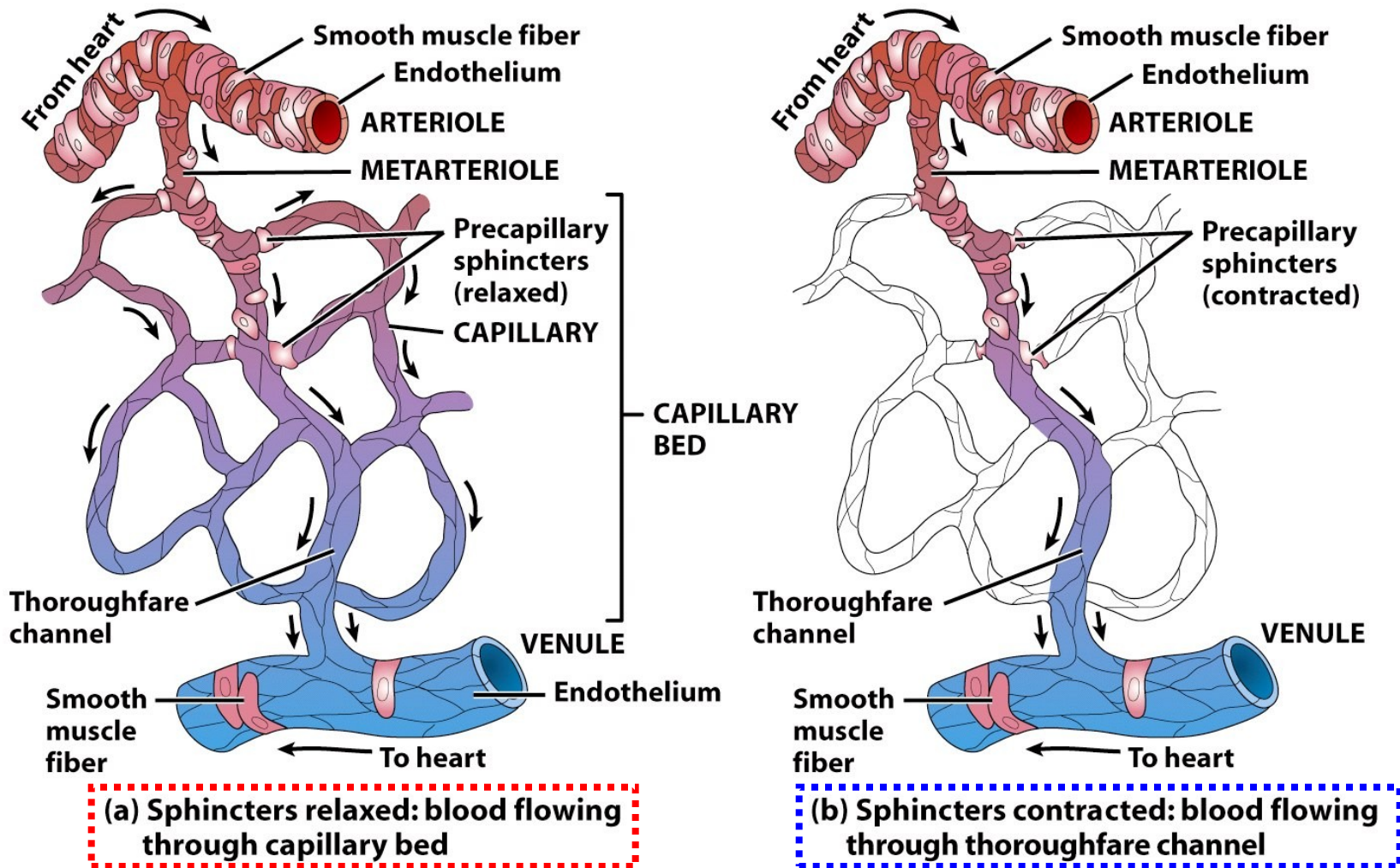
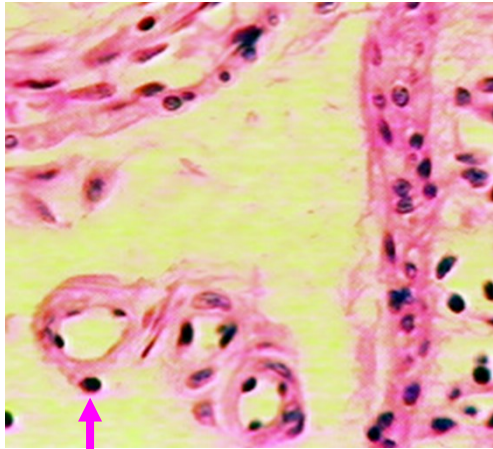
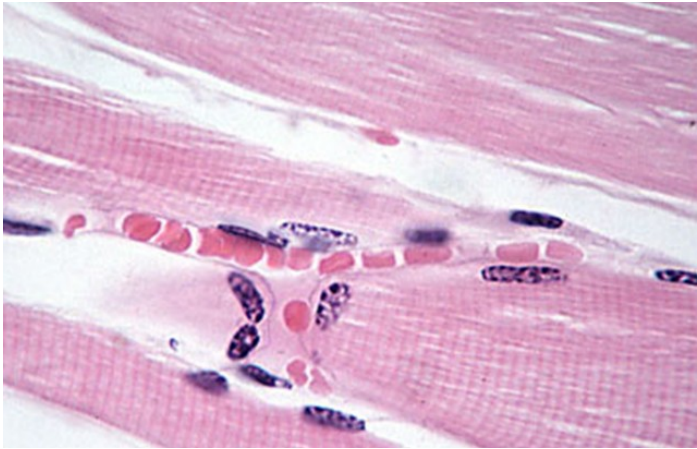


Figure 21-3 Principles of Anatomy and Physiology, 11/e
© 2006 John Wiley & Sons

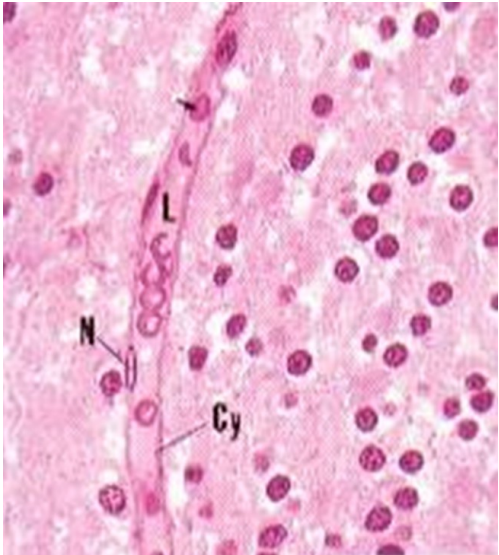
Kapiláry



Pericyte



Striated muscle

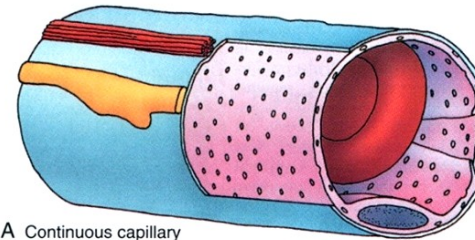


Cerebellum (monkey)

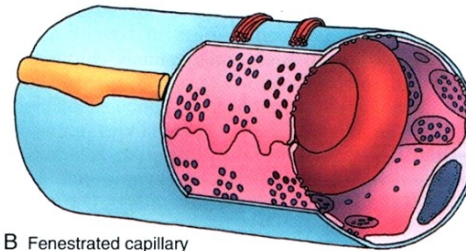
Kapiláry

According to the integrity of the endothelium and basement membrane – by TEM:

- Kapiláry se souvislou výstelkou
- Fenestrované kapiláry
- Sinusoidy



A Continuous capillary

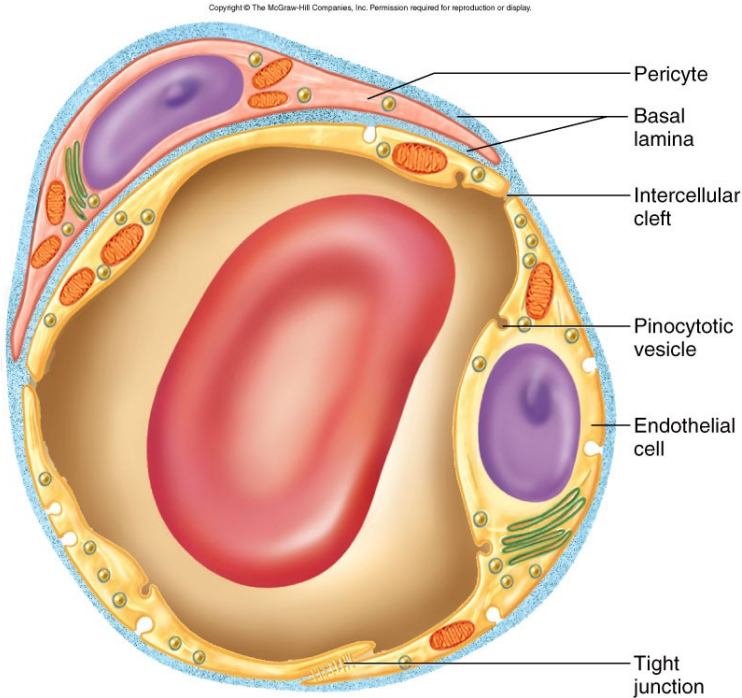
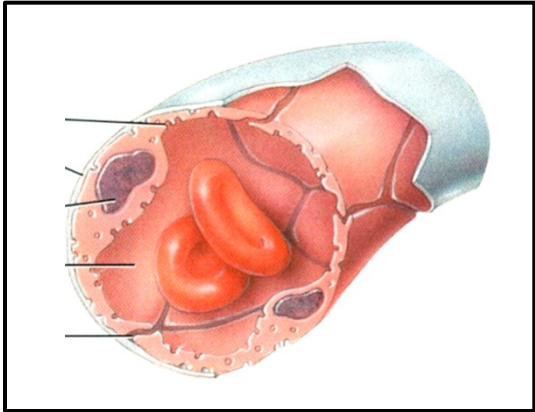


B Fenestrated capillary



C Sinusoidal (discontinuous) capillary

Kapiláry se souvislou výstelkou



Typické znaky

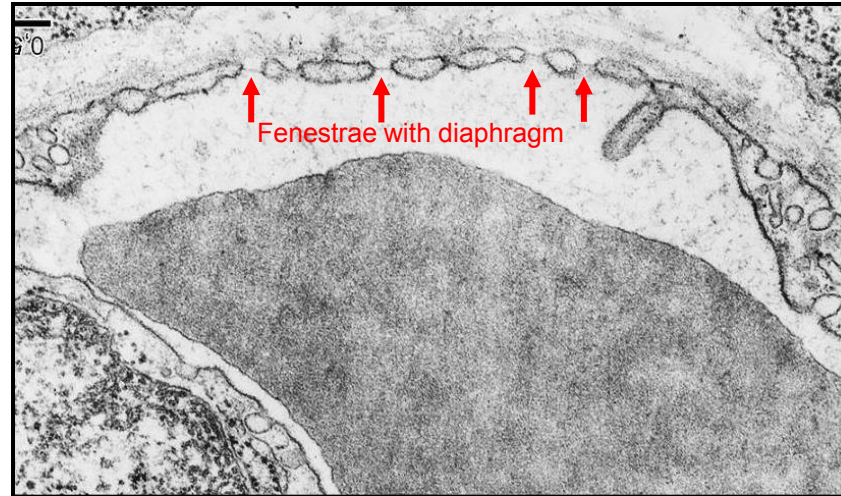
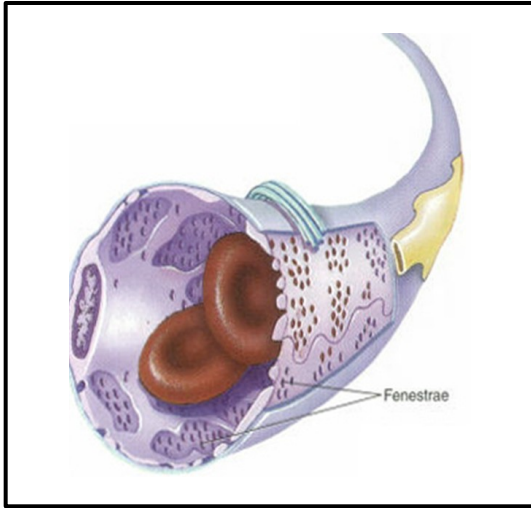
- non-interrupted lining
- no defects in the wall

Lokalizace

- most common type
- muscle, connective tissue, nerve tissue (blood-brain barrier), exocrine glands



Fenestrované kapiláry

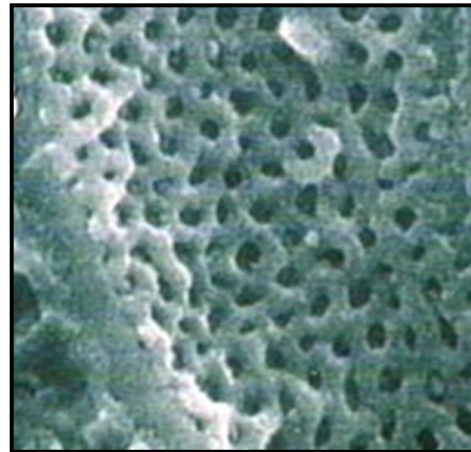


Typické znaky

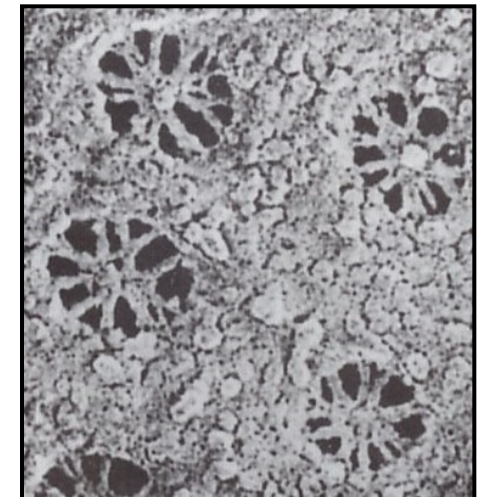
- endothelial cells perforated
(diameter ~60-80 nm; diaphragm 4-6 nm)
- continuous basal lamina

Lokalizace

- in tissues where rapid interchange of substances occurs between the tissue and the blood
- intestinal mucosa, some endocrine glands, pancreas



Fenestrated capillary - kidney



Diaphragm

Sinusoidy

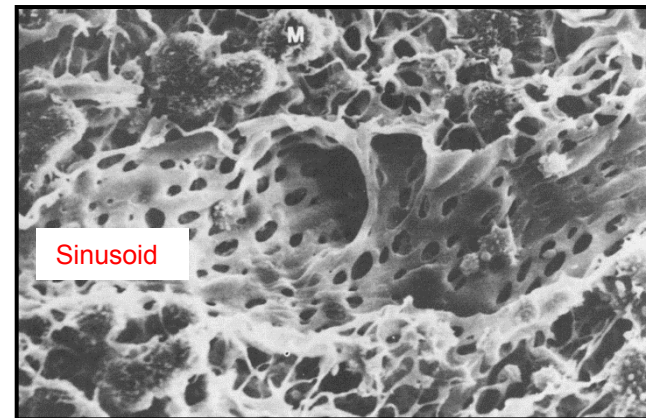
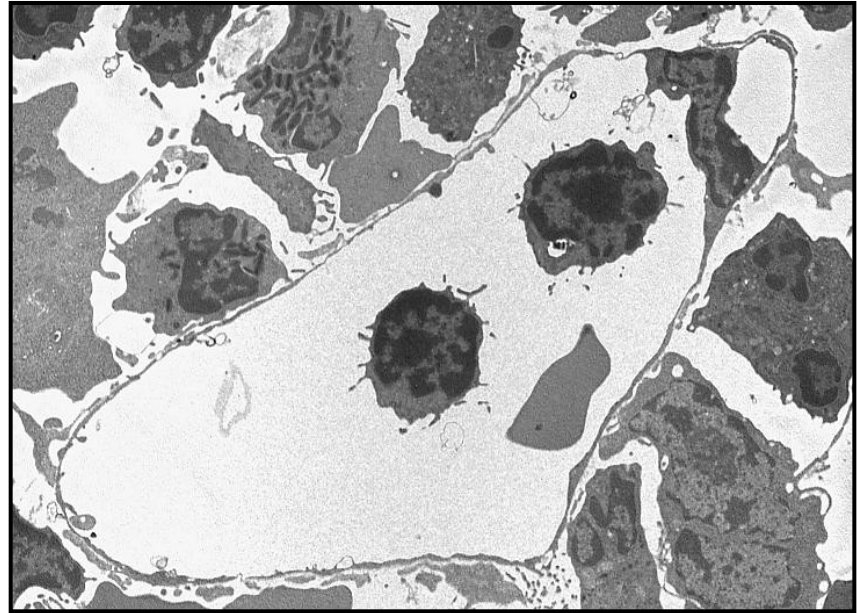


Typické znaky

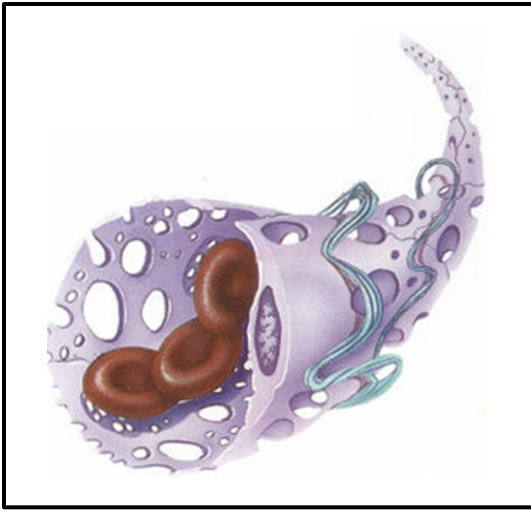
- enlarged diameter (up to 40 μm)
- endothelial cells with large pores without diaphragm
- large clefts between

Lokalizace

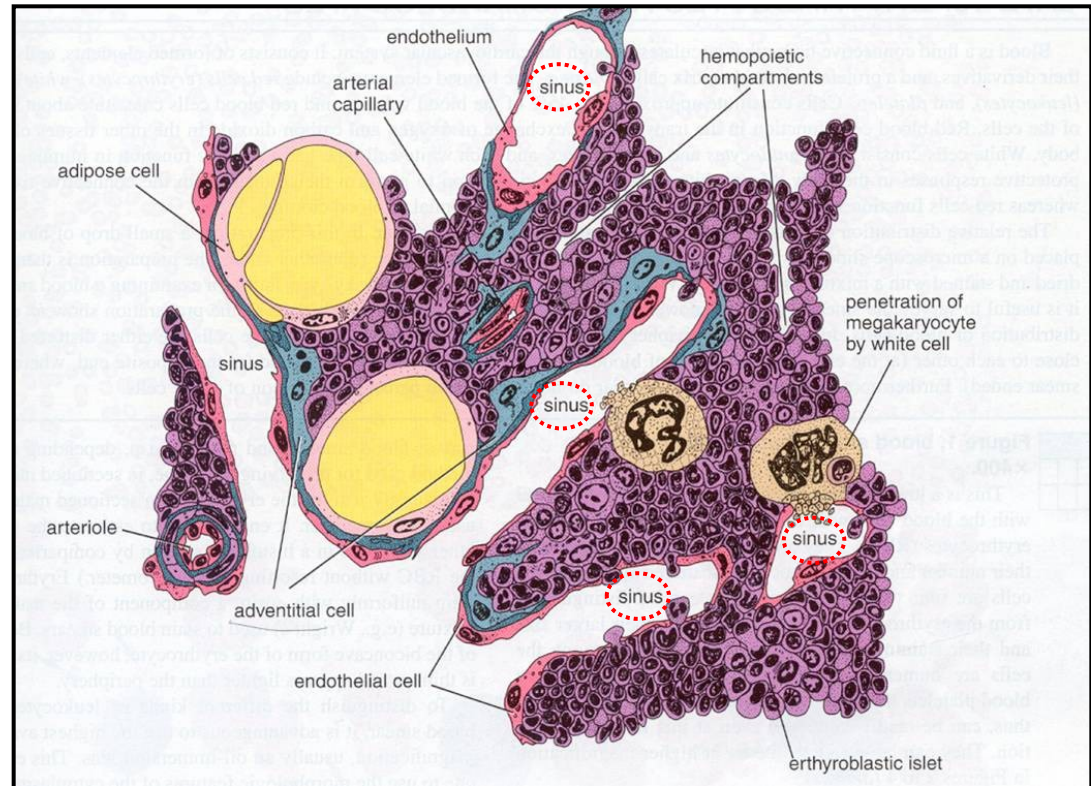
- liver (pores 100 nm)
 - hematopoietic regions (bone marrow)
- (macrophages instead)



Sinusoidy



Kostní dřeň



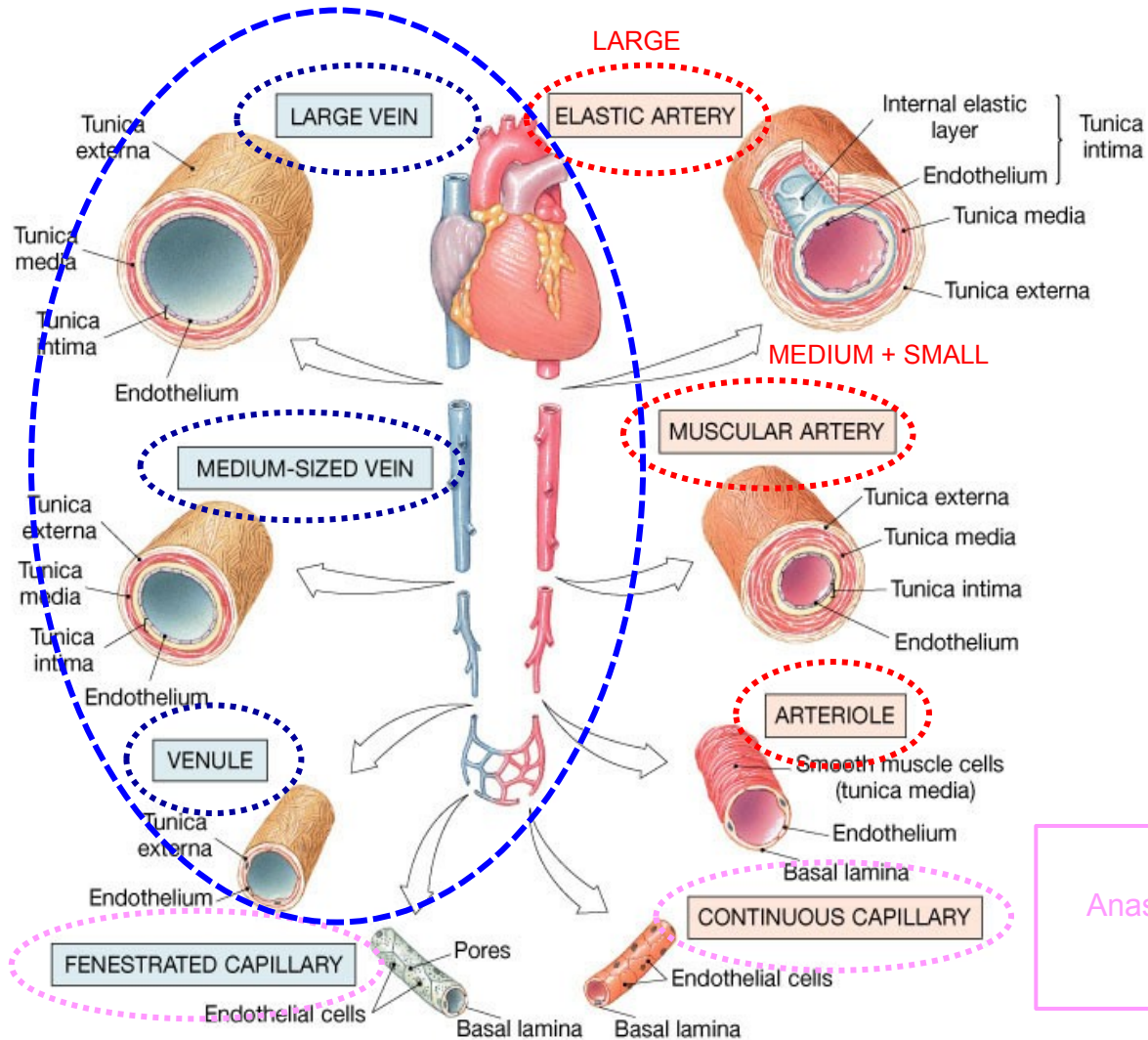
Krevní cévy – několik různých podob

Žíly
 ALWAYS return the blood to the heart
 (contain about 2/3 body's blood at any given time)

Arterie
 ALWAYS carry blood from the heart to the periphery

Macrovasculature – diameter > 0.1 mm

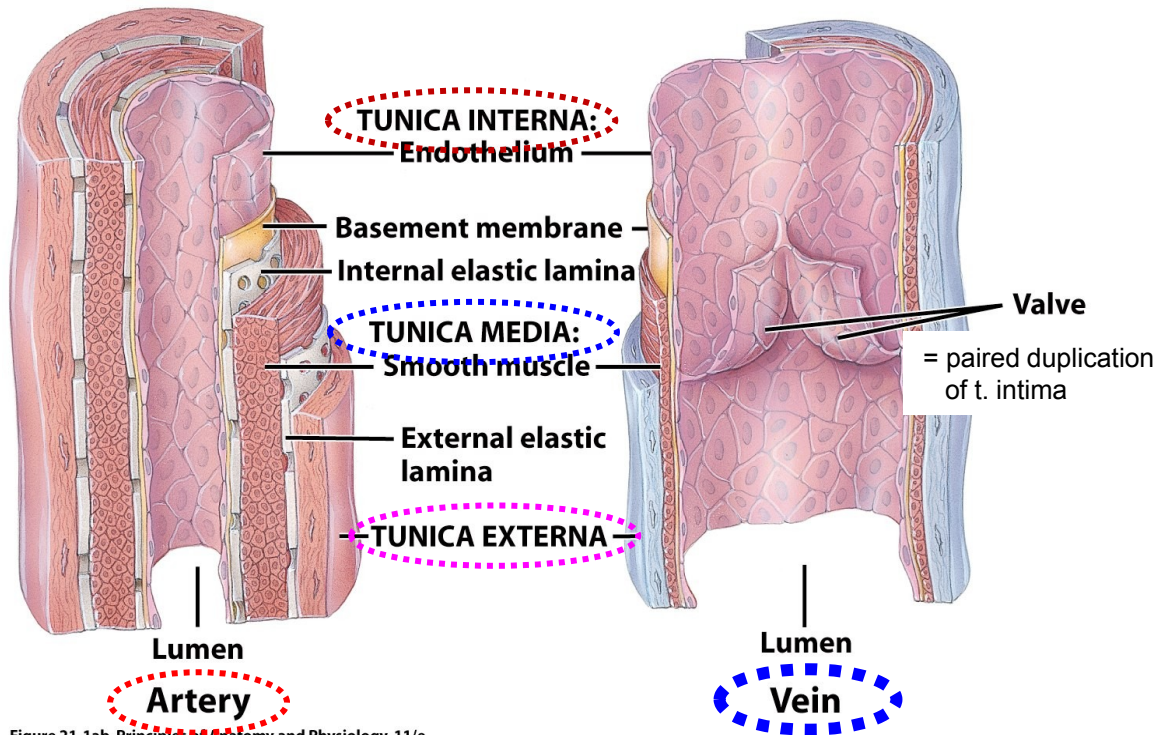
Microvasculature – < 0.1 mm



Capillaries
 Anastomosing tubules among arteries and veins
 = microvascular bed

Žíly

- they function as blood reservoir - greater capacity for blood containment than arteries due to thinner wall
- lower blood pressure (10 mm Hg with little fluctuation)
- valves aid skeletal muscles in upward blood flow (typically in lower limbs – veins with diameter > 2 mm)



General features

- Endothelium
 - very thin
- Subendothelial layer
 - very thin
- Internal elastic lamina
 - missing or only very thin

- relatively thin (except for lower limbs)
- Little bundles of smooth muscle cells
- collagen fibers – considerable amount
- External elastic lamina
 - non-developed

- well developed – thickest layer
- often with longitudinally arranged bundles of smooth muscle cells
- robust vasa vasorum (often penetrate deep to t. media)

Three layered bulding plan

Figure 21-1ab Principles of Anatomy and Physiology, 11/e
© 2006 John Wiley & Sons

Žíly – kategorie podle průměru

Postcapillary venules

- endothelial cells + some pericytes
- receive blood from capillaries
- more porous than capillaries
- larger diameter than capillaries (15-20 μm)

Collecting & Muscular venules

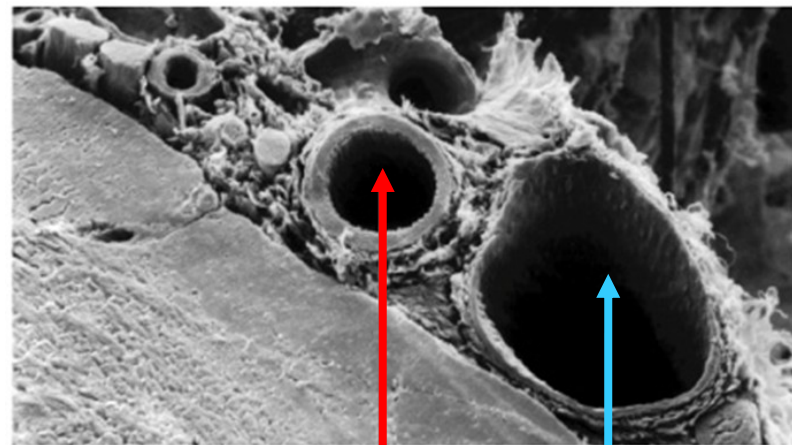
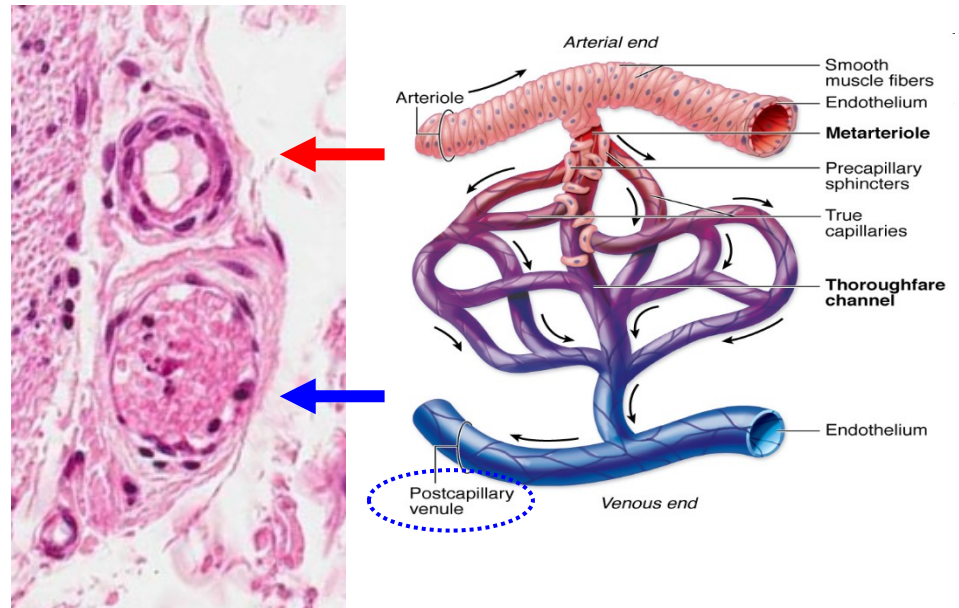
- increasing number of contractile cells
- tunica media is defined in muscular venules

Small- & Medium-sized veins

- most have individual names
- run parallel with corresponding arteries
- many have valves

Large veins

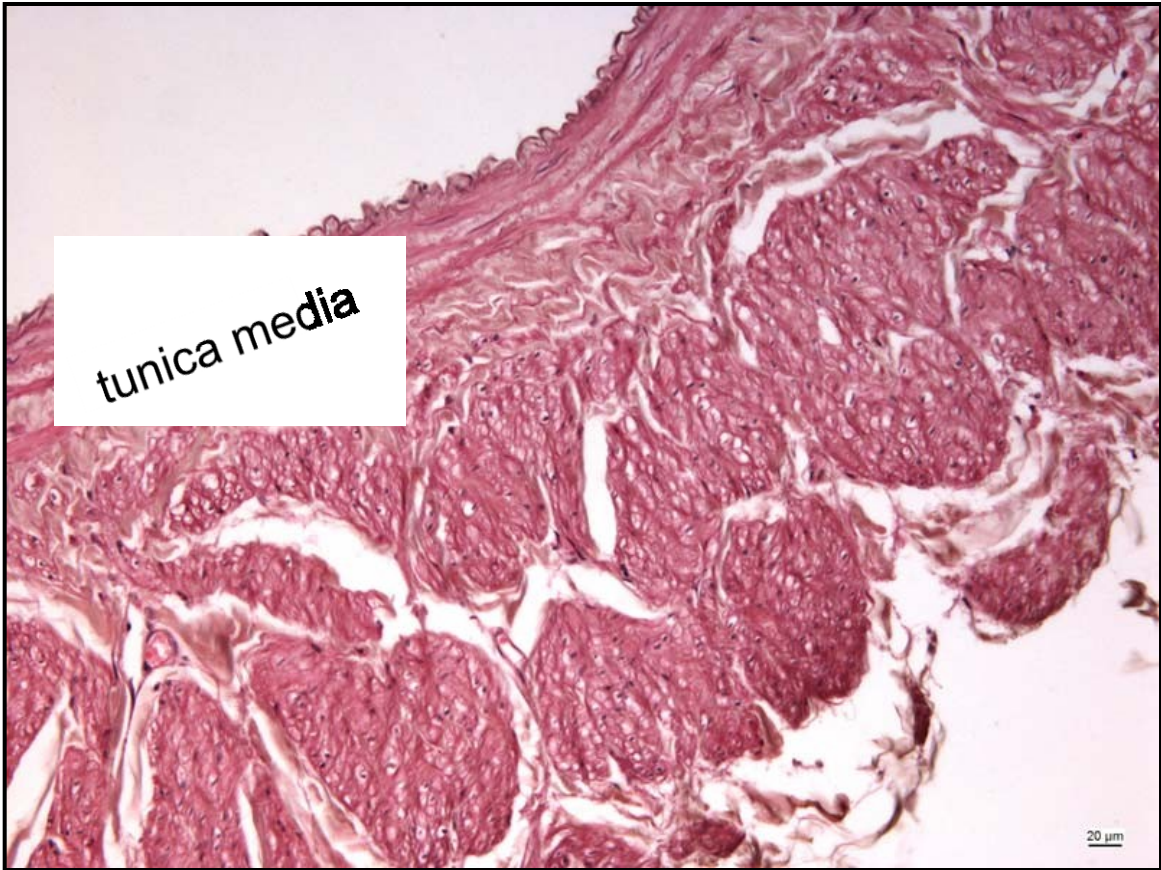
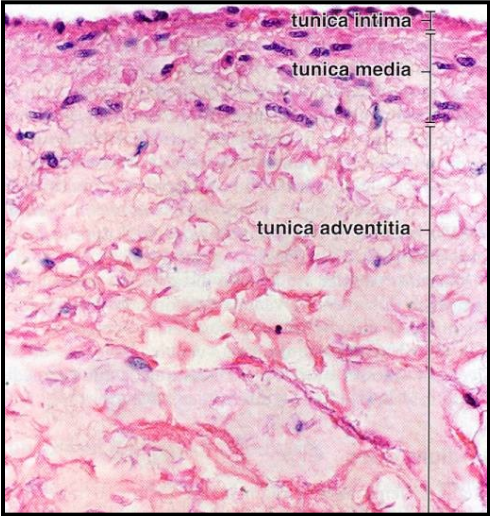
- close to the heart
- (*v. cavae, pulmonary veins, internal jugular veins*)
- paired with elastic arteries
- diameter > 10 mm
- with valves
- t. media is thin (muscle cells+connective tissue)
- thick t. externa (with longitudinal bundles of SMC; myocardial sleeves)



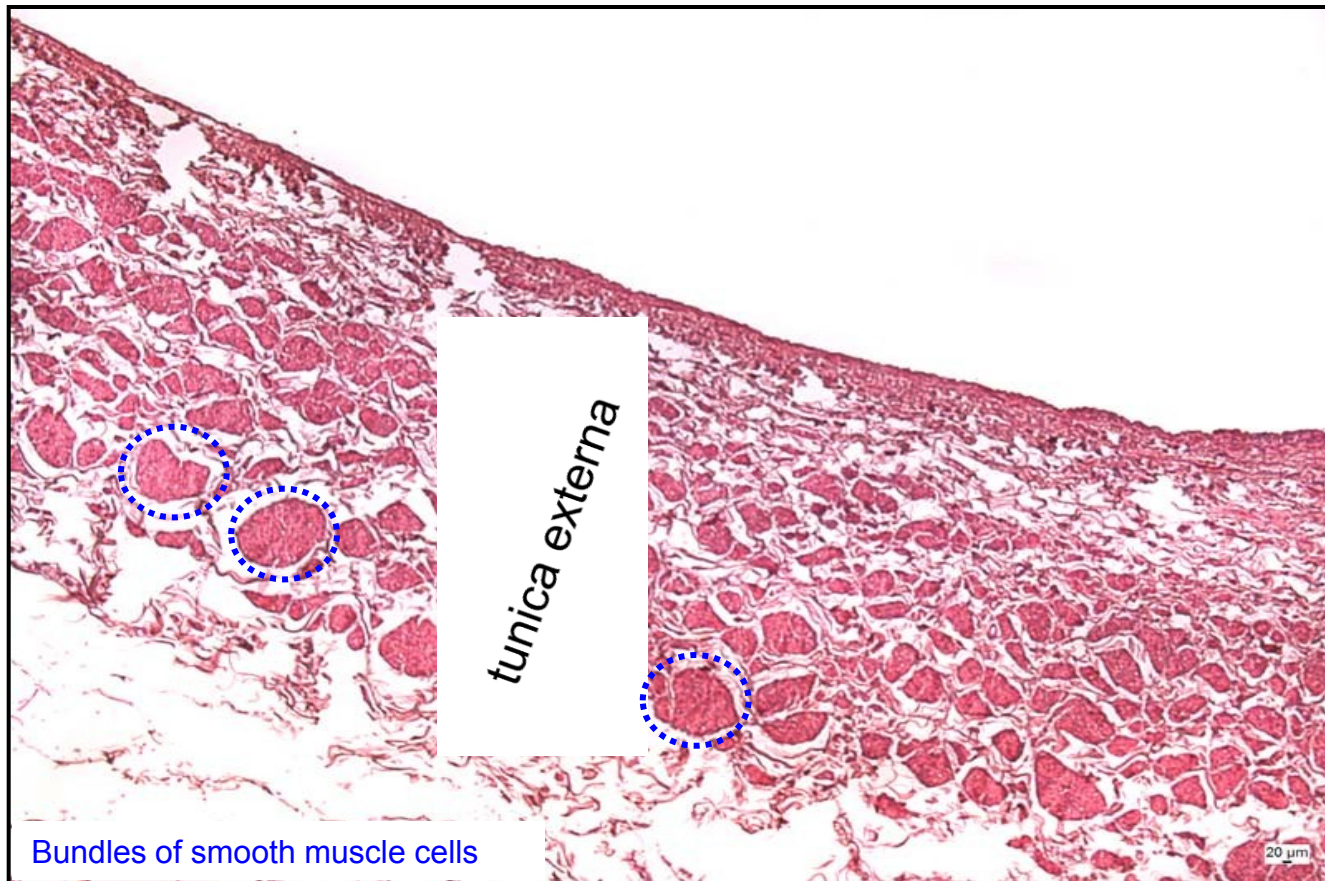
Artery

Vein

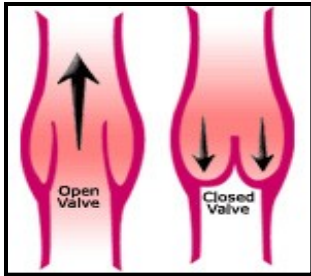
Žíly – střední kalibr



Žíly – velký kalibr



Vena cava

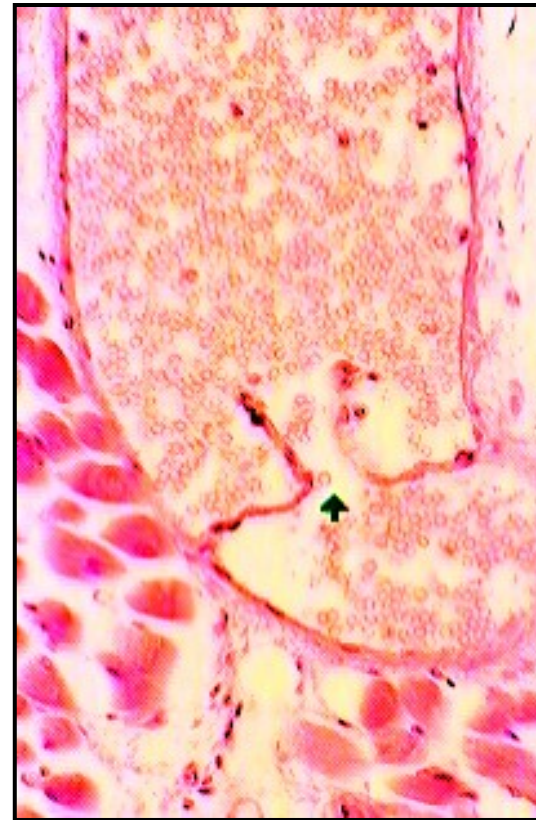


Žíly - Chlopně

- bag-like protrusion of tunica intima, which prevent the blood flow from running to opposite direction
- only in the veins that has low position or far away from heart



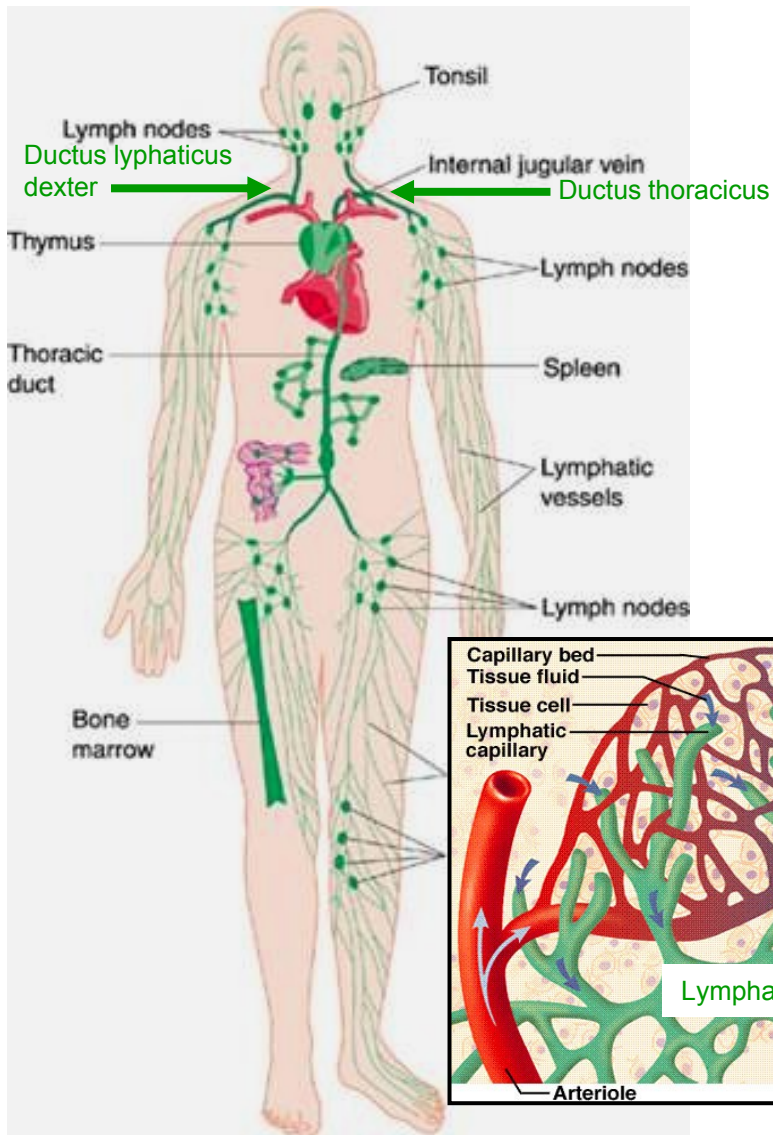
Appearance of internal surface



Histological view

Lymfatické cévy

- return fluid from tissues to the circulatory system
- depend on skeletal muscles to move fluid

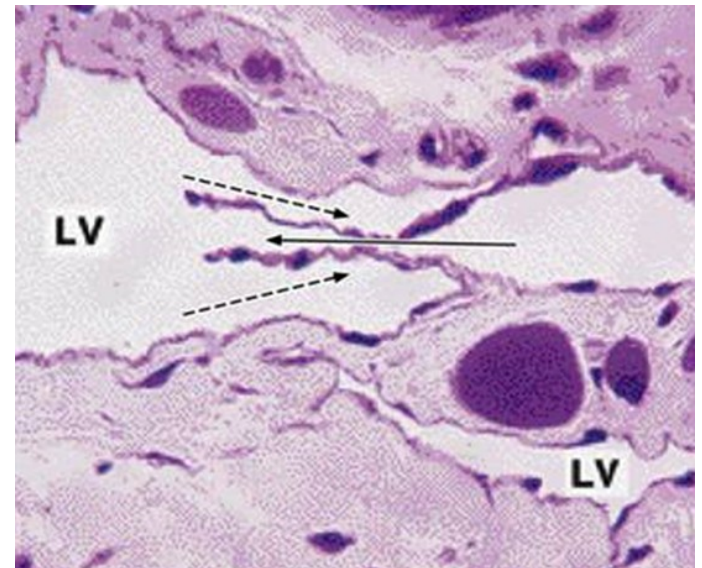
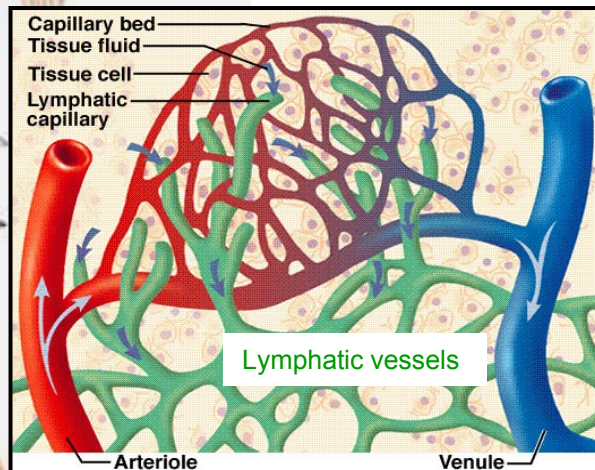


Lymfatické kapiláry

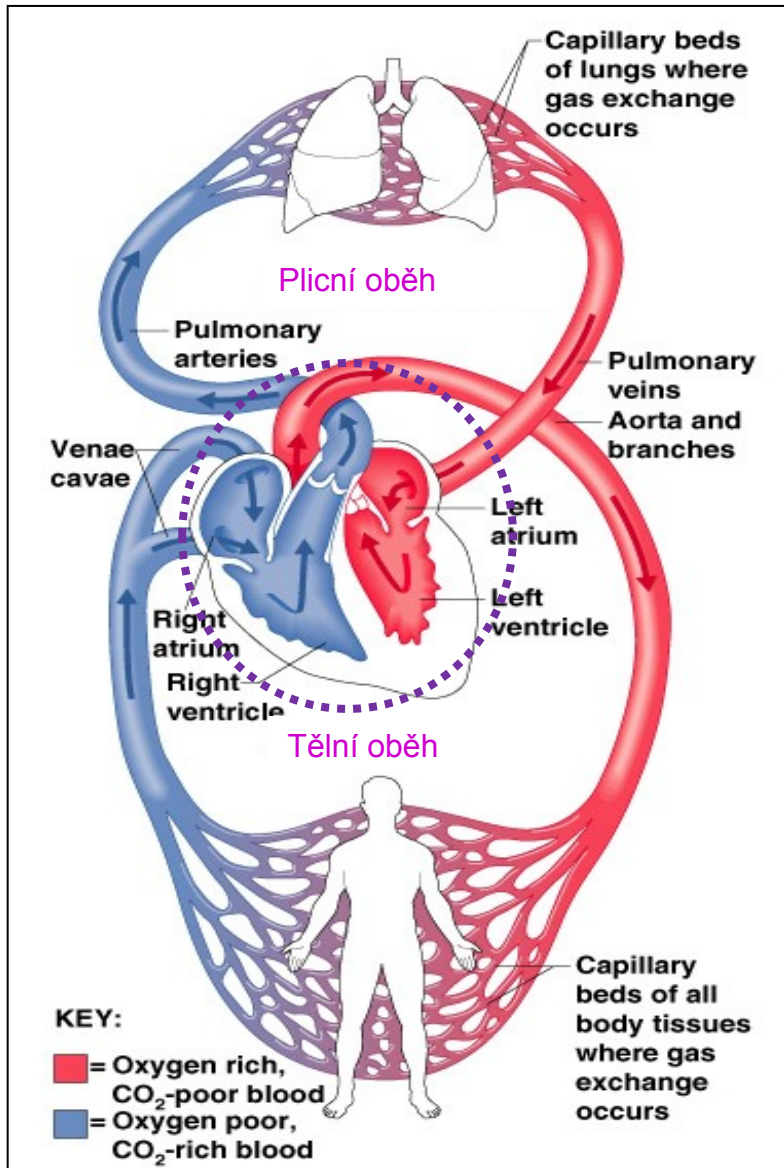
- blunt ended
- very simple structure
- endothelial cells + fine reticular fibres of circular orientation
- the basal lamina is not developed

Lymfatické cévy a kmeny (ductus)

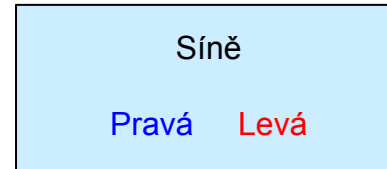
- thin walled tubes
- resemble veins in their structure (intima+media+adventitia)
- have valves



Srdce - Anatomie



- a hollow organ that contracts rhythmically
- it functions as a pump
- it is composed of two sets of chambers:



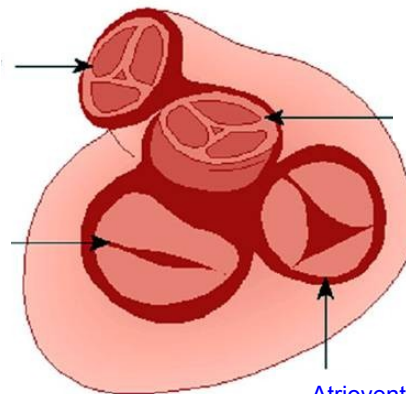
- it is equipped by four valves (blood can travel in only one direction)

Plicní poloměšičitá

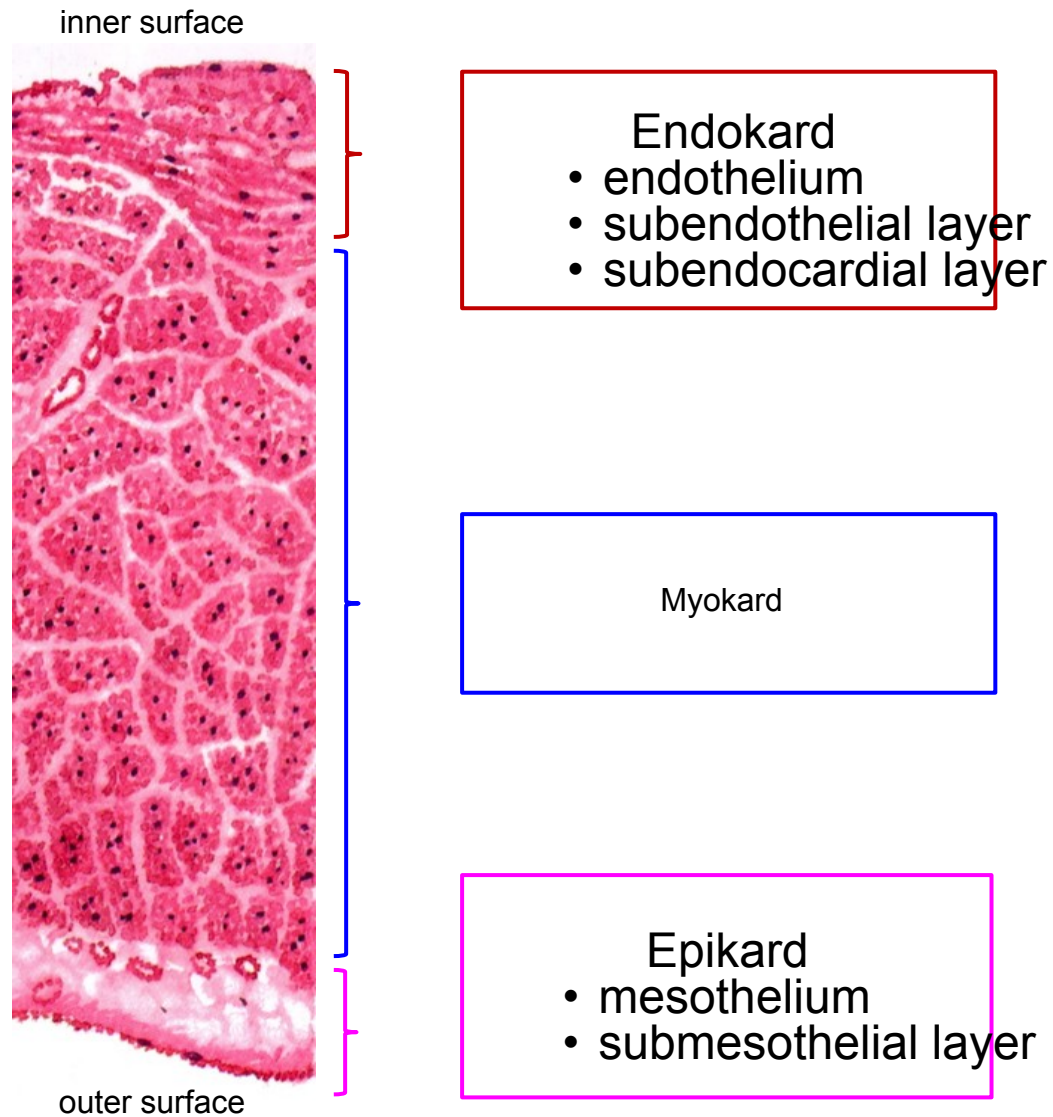
Aortální poloměšičitá

Atrioventrikulární dvojčípá (levostranná)

Atrioventrikulární trojčípá (pravostranná)

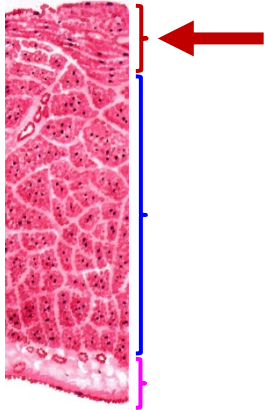


Srdce – stavba stěny



inner surface

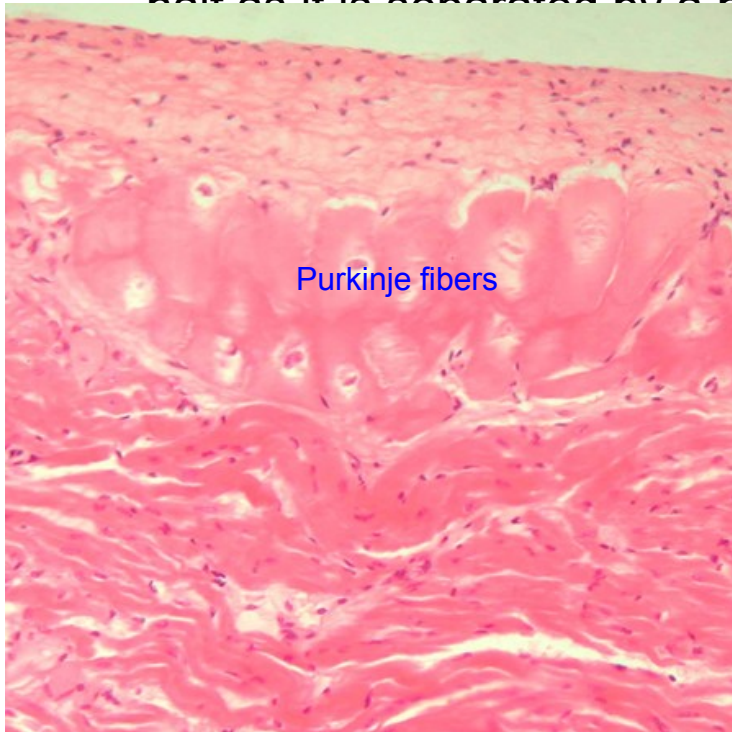
Srdce - Endokard



- is continuous with the tunica intima of the large vessels entering and leaving the heart

- the endocardium of the left half of the heart is not continuous with the one on the right

half as it is separated by a heart septum



Endothelium
with continuous basal membrane

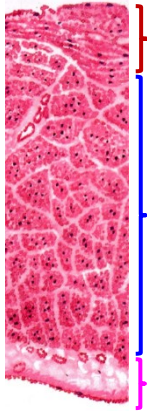
Subendothelial layer

- connective tissue
- collagen, elastics, solitary smc, small blood vessels, nerves

Subendocardial layer

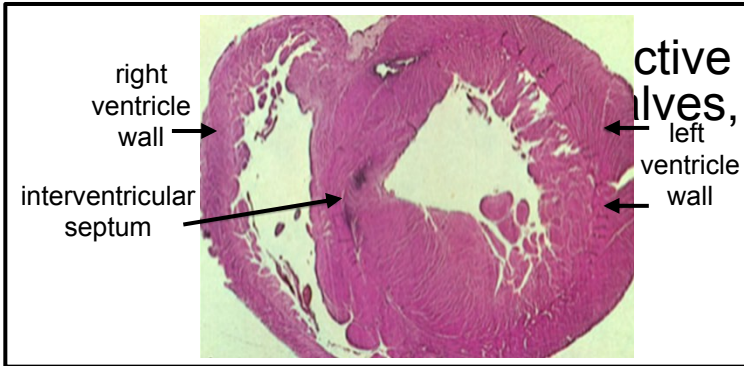
- loose connective tissue
- continuous with endomysium of the myocardium
- nerve fibers, vessels, [impuls-conducting system](#)

inner surface

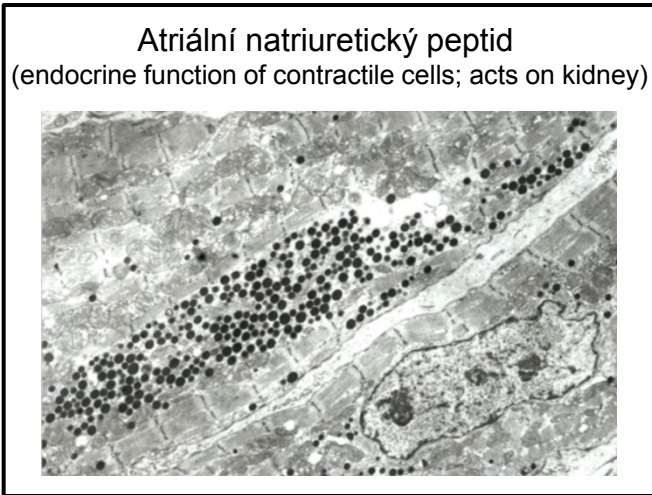
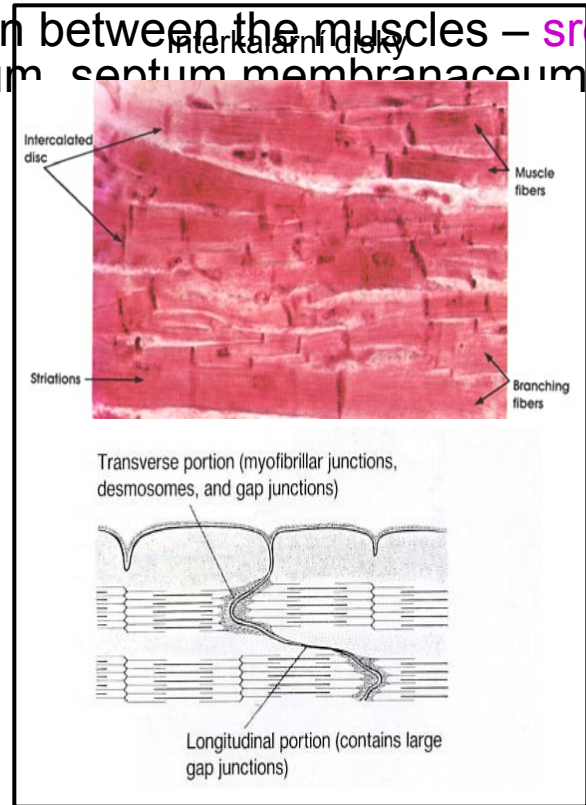


Srdce - Myokard

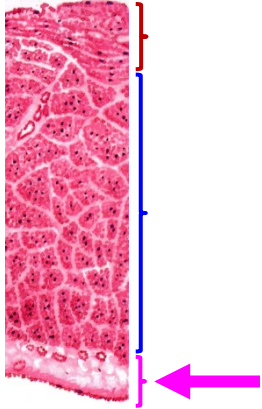
- its thickness varies in different parts (thickest – left ventricle; thin in right ventricle)
- has rich blood supply (many capillaries)
- has no regenerative capacity
- muscle fibers are arranged circularly around chambers



contractile tissue in between the muscles – **srdeční skelet** (intercalated discs, trigonum septum membranaceum)



inner surface



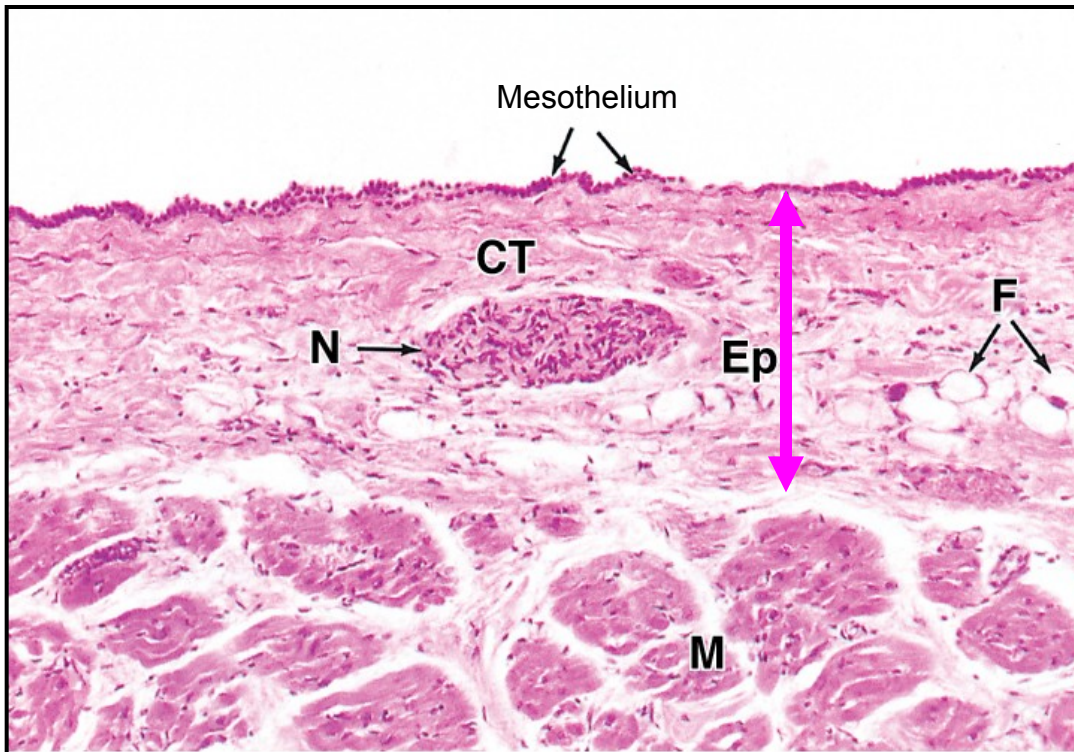
Srdce - Epikard

- represents visceral layer of the **perikard**

Perikard

Fibroserous sac enveloping heart

- **mesothelium with basal lamina** (faces epicardium)
- **fibrous layer** (dense connective t. with vessels and nerves)



Mesothelium

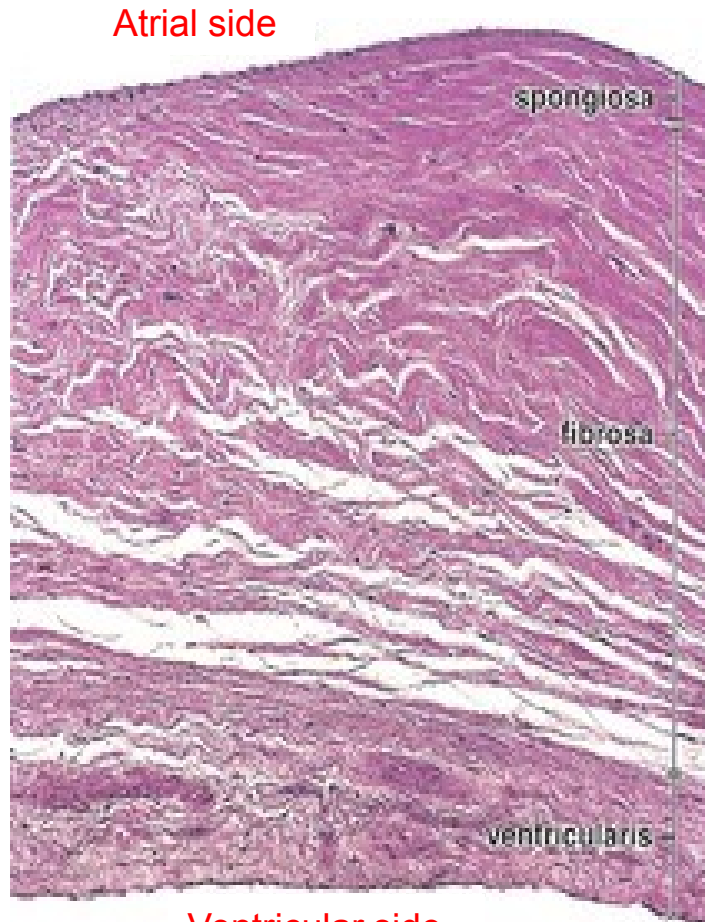
- simple squamous epithelium
- basal lamina
- secretes pericardial fluid

Submesothelial layer

- loose connective tissue
- elastic fibers
- nerves
- blood and lymphatic vessels
- home of coronary vessels
- adipocytes (high in obese individuals)

Srdce - Chlopně

- composed of connective tissue layers covered by **endothelium on each side**



Spongiosa

- loose collagen

Fibrosa

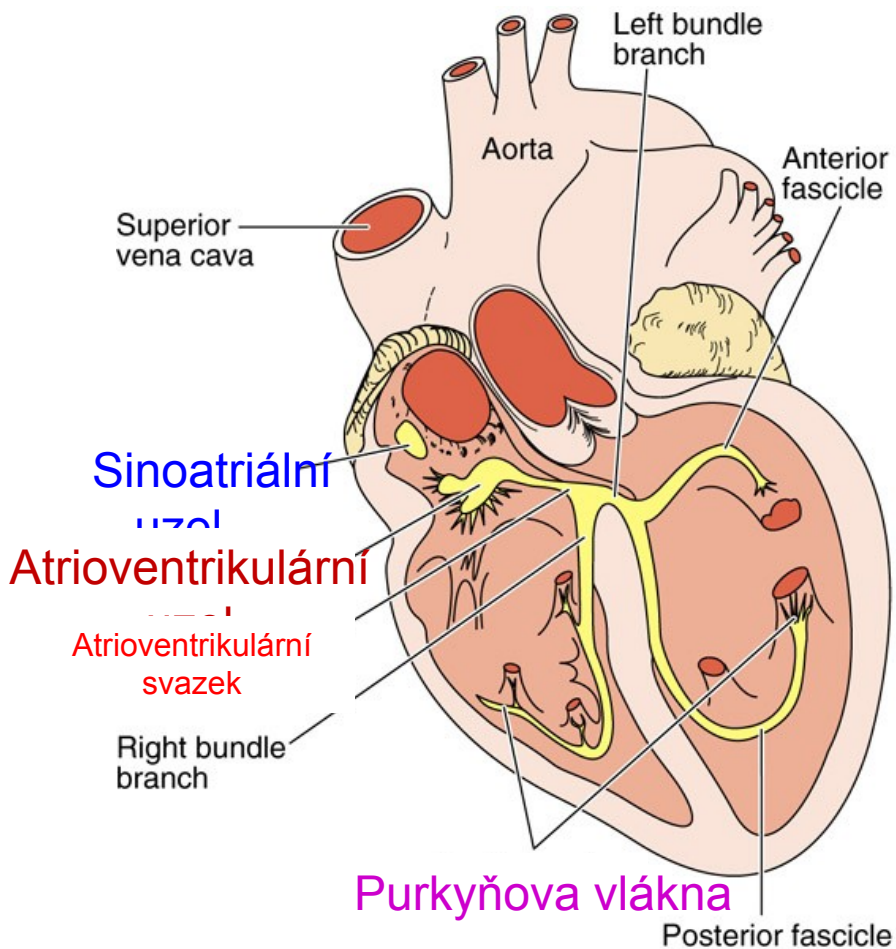
- dense core of connective tissue

Ventricularis

- dense connective tissue with many elastic and collagen fibers

Srdce – Převodní systém

- specially modified cardiac muscle cells (non-contracting, less myofibrils, abundant GA junctions)
- generate and conduct impulses of heart contraction to various parts of myocardium
- assure proper succession of beat of atria and ventricles



Sinoatriální uzel (Keith-Flackův)

- it lies on the medial wall of the right atrium near the entrance of the superior vena cava
- **PRIMÁRNÍ PACEMAKER**

Atrioventrikulární uzel (Ascoff-Tawarův)

- it runs on the right side of the interatrial septum
- **SEKUNDÁRNÍ PACEMAKER**

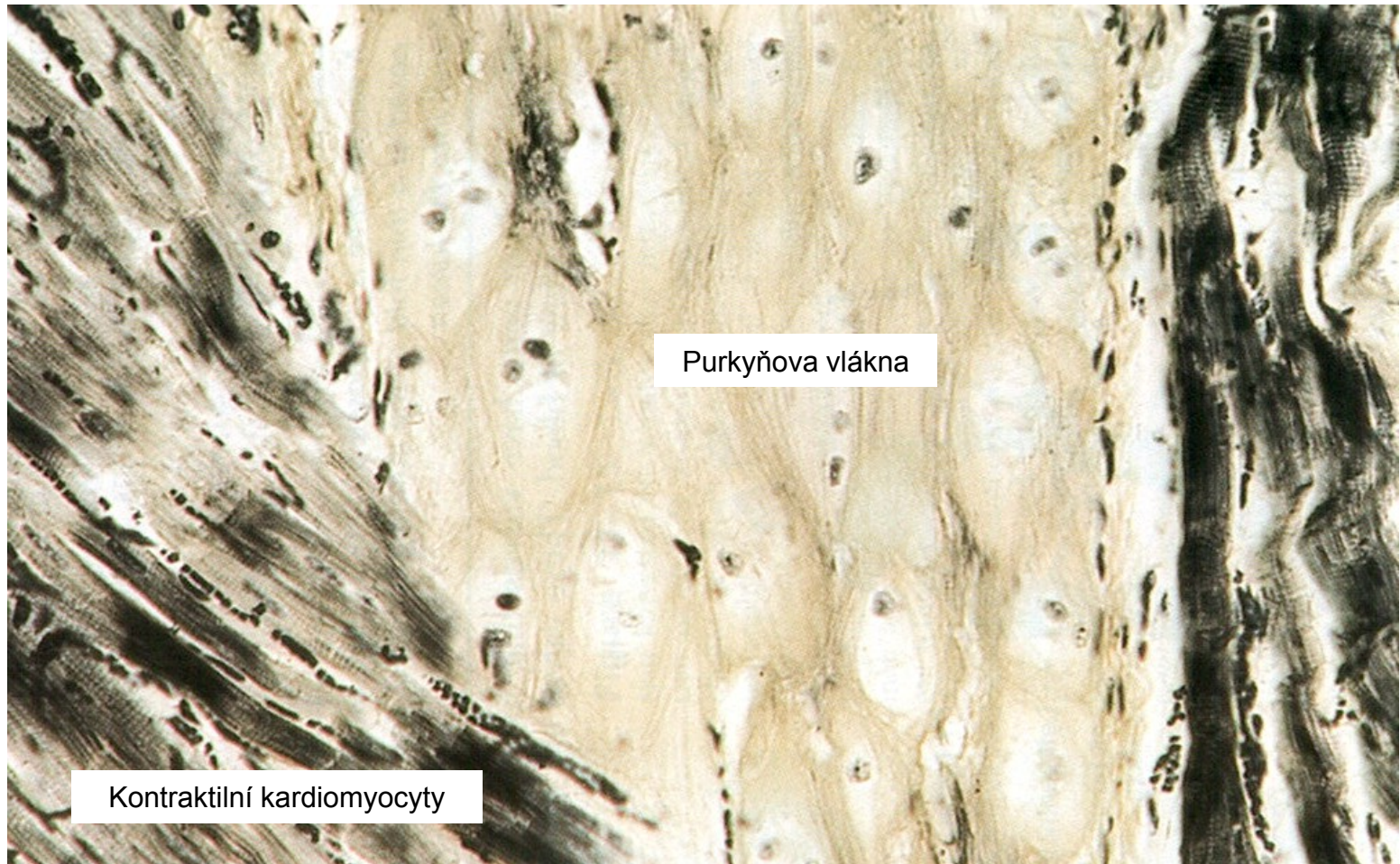
Atrioventrikulární svazek (Hisův)

- it divides into 2 branches (for the left and right ventricles)

Purkyňova vlákna

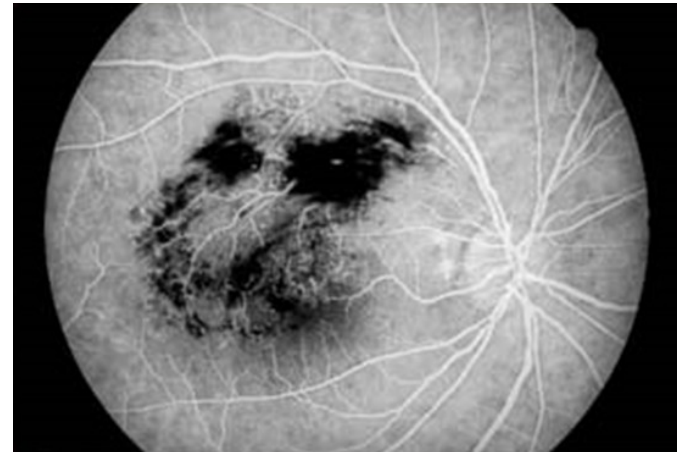
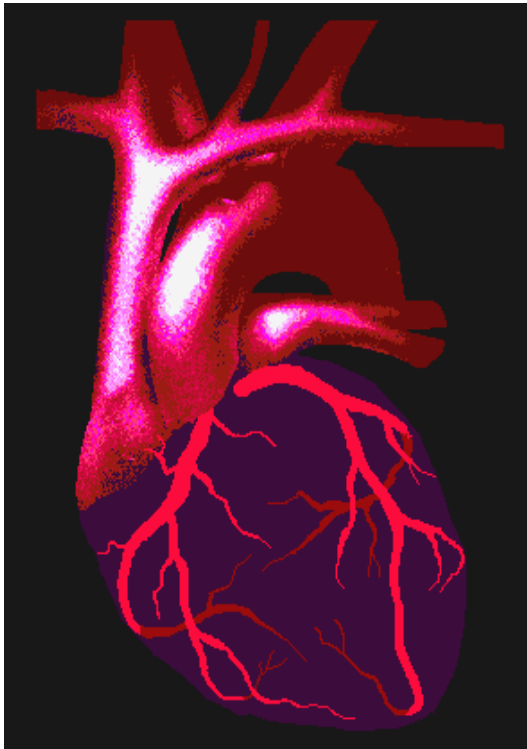
- terminal ramifications of the AV bundle

Srdce – Převodní systém



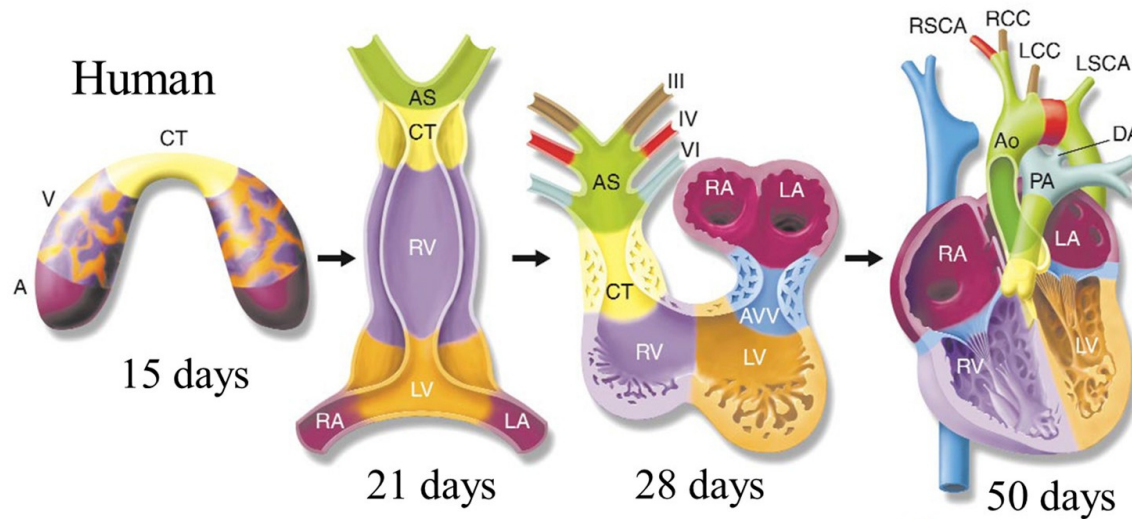
Srdce – Koronární cévy

- blood in the heart chambers does not nourish the myocardium
- the heart has its own nourishing circulatory system: Coronary **arteries** & **veins**
- 5-7% of blood flows through the coronary arteries
- blood empties into the right atrium via the coronary sinus

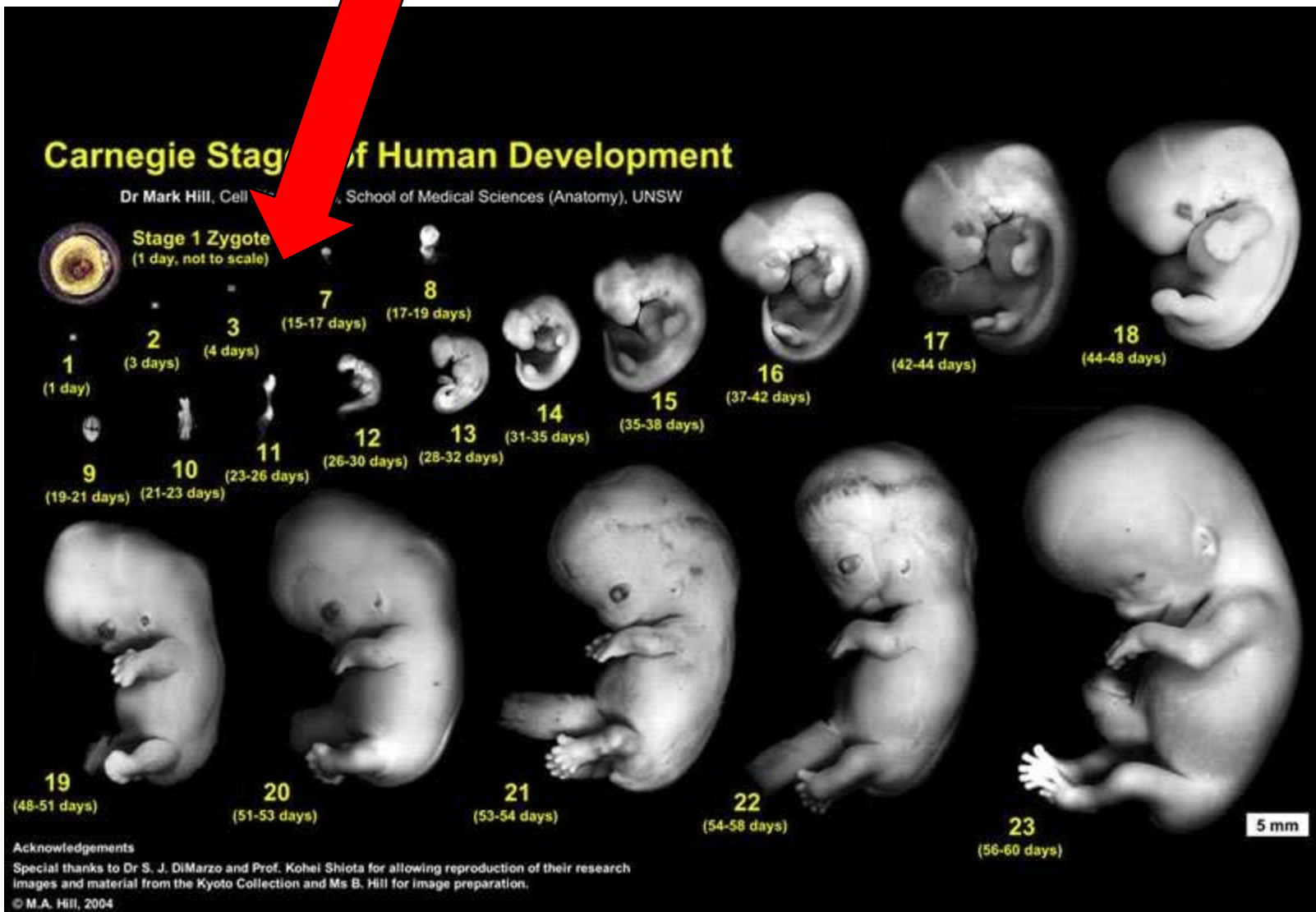


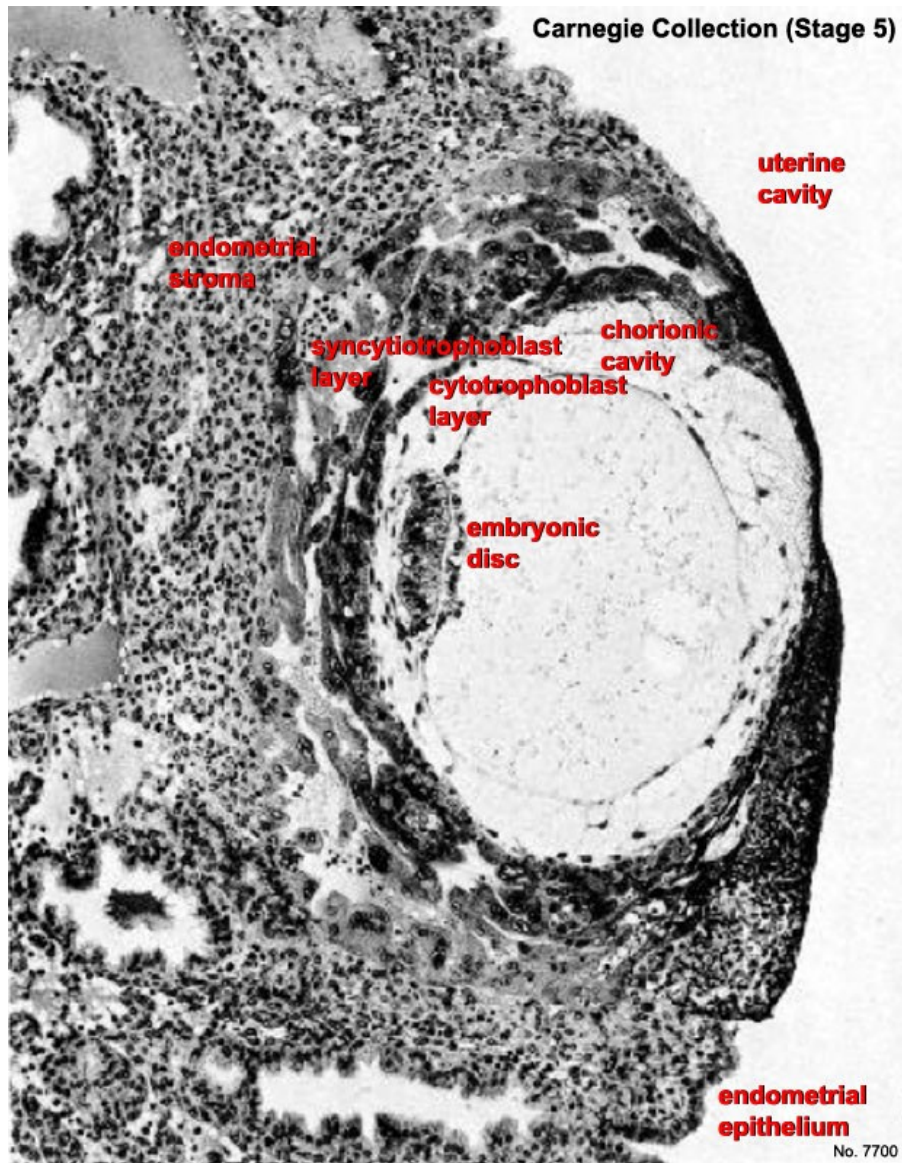
Dye injected into heart
X-ray to examine blockages

VÝVOJ KARDIOVASKULÁRNÍHO SYSTÉMU

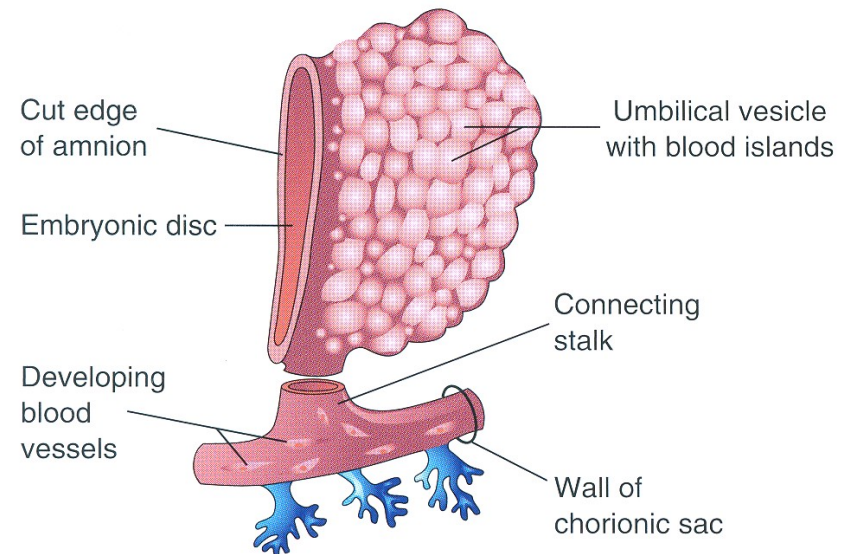


Petr Vaňhara, PhD
Ústav histologie a embryologie
LF MU



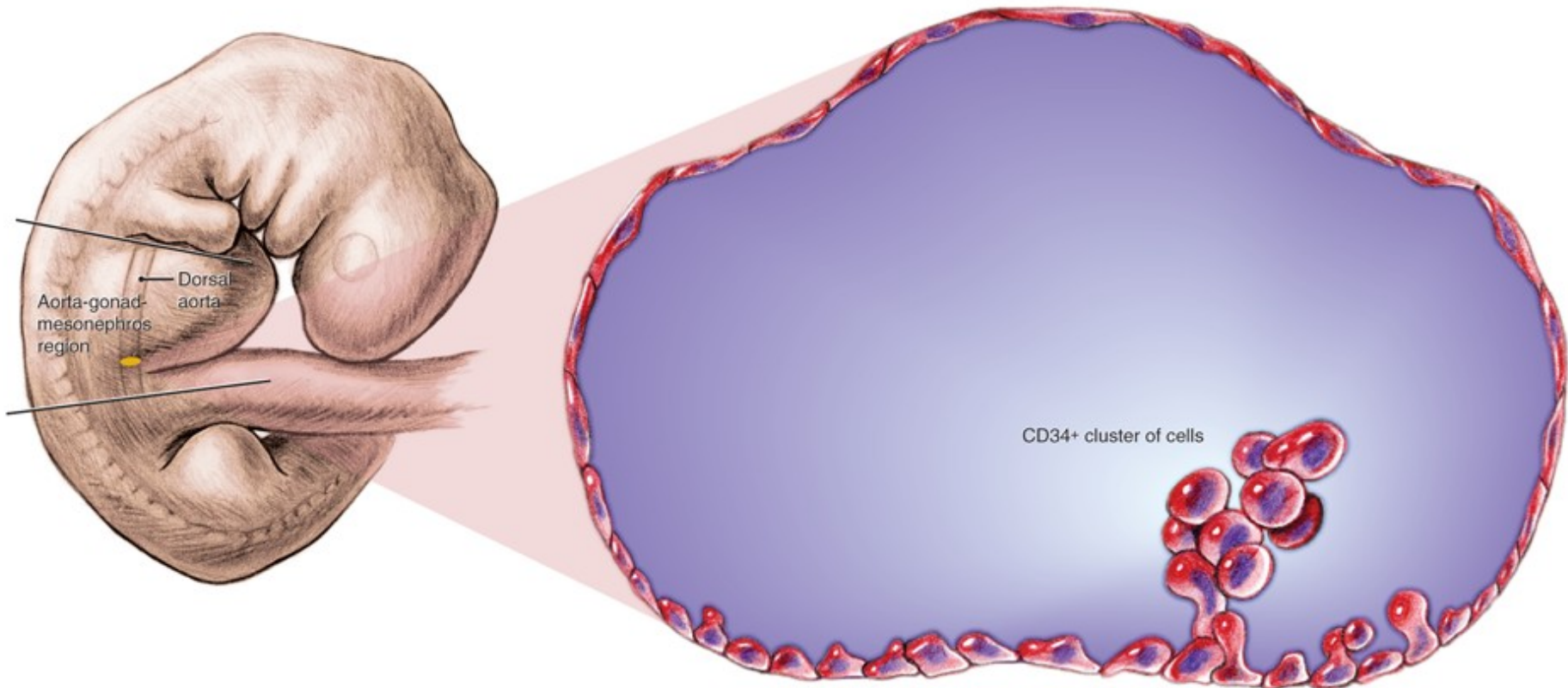
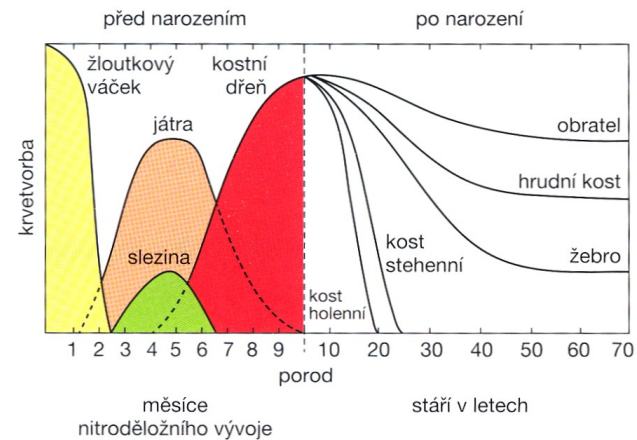


- rychlý růst embrya
- difúze limitovaná
- první vaskularizace **extra-embryonálně** – žloutkový vak, chorion zárodečný stvol
- bipotentní (hem)angioblasty
- krevní ostrůvky
- vasculogeneze a angiogeneze, hematopoeze

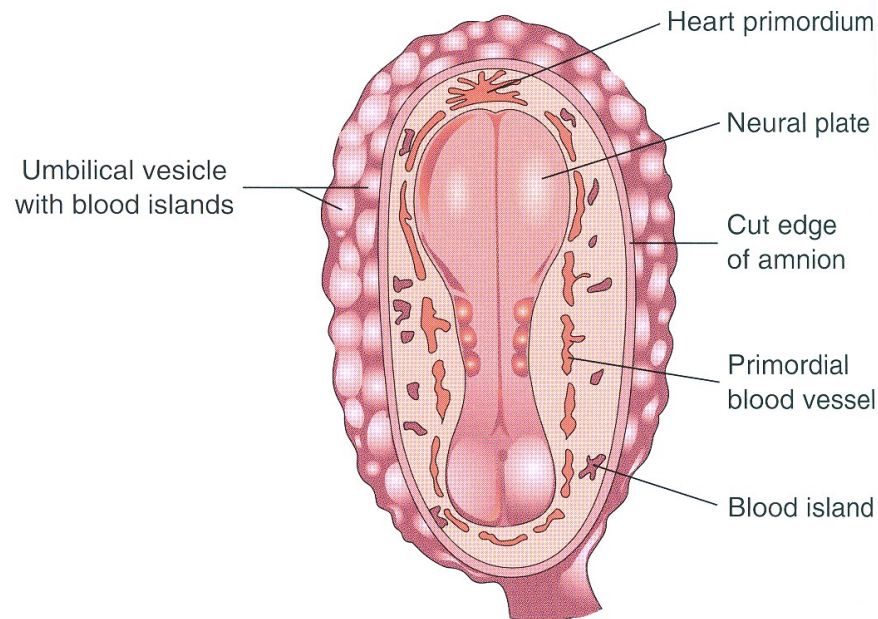


EMBRYONÁLNÍ KRVETVORBA

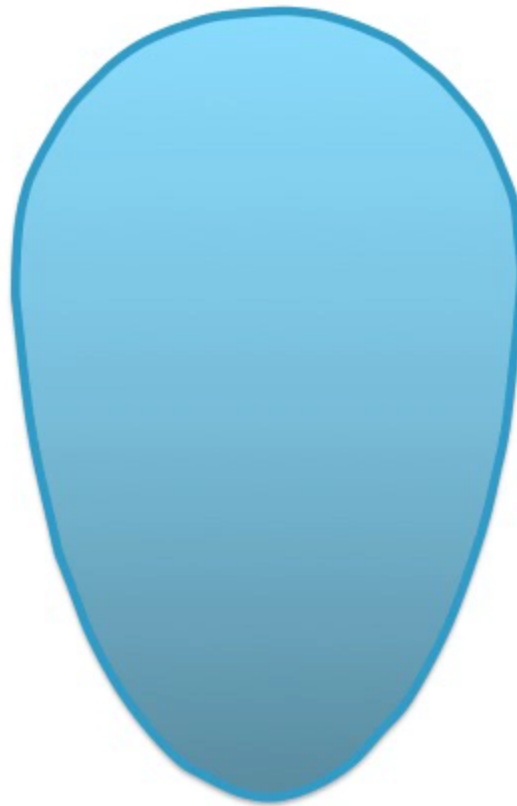
- **extraembryonální mezoblastická perioda (16-20. den – 8. týden)**
 - žlutkový váček
 - klasický model – hemangioblasty (bipotentní buňky)
 - velké jaderné erytroidní buňky
- **aorta-gonad-mesonephros (28. den – 4. týden)**
 - para-aortické clustery v mezodermu splanchnopleury
 - zdroj embryonálních krvetvorných kmenových buněk



- **embryonální vaskulogeneze** cca 2 dny po založení extraembryonální vaskularizace
- primordiální krevní cévy
- srdeční primordium v kardiogenní oblasti
- embryonální hematopoeze z para-aortálních klastrů v AGM



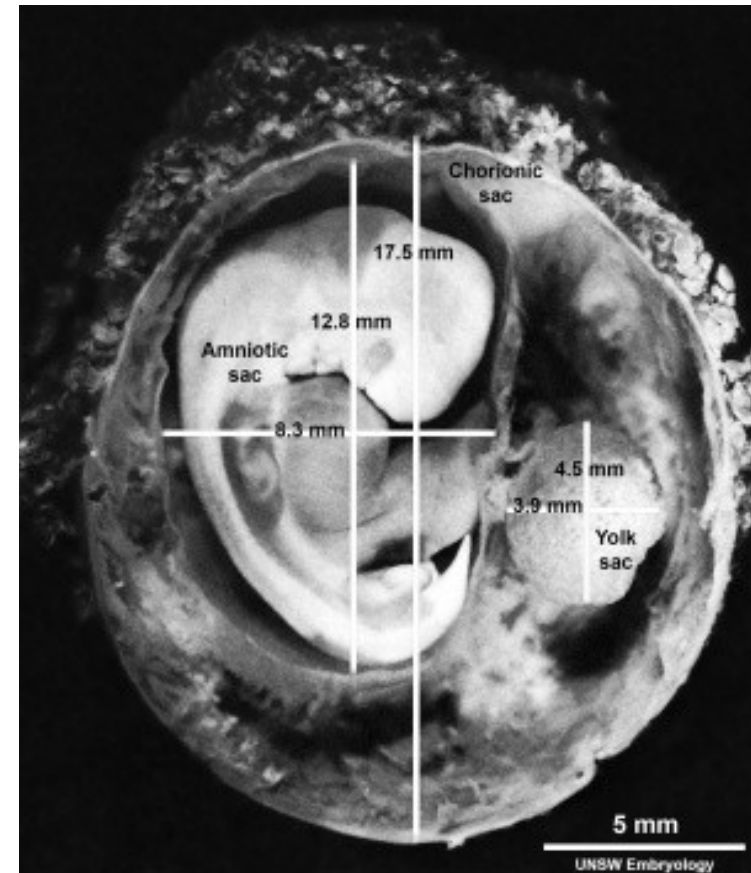
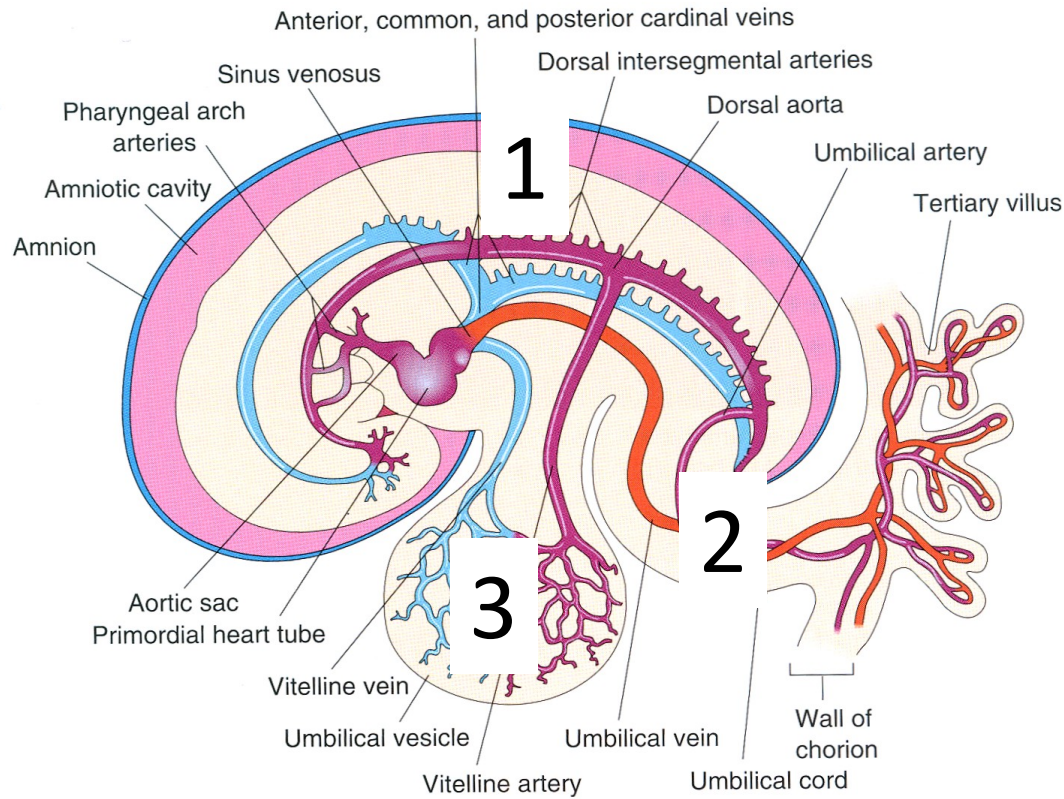
3. týden



Epiblast
18 days, dorsal surface

VÝVOJ KARDIOVASKULÁRNÍHO SYSTÉMU

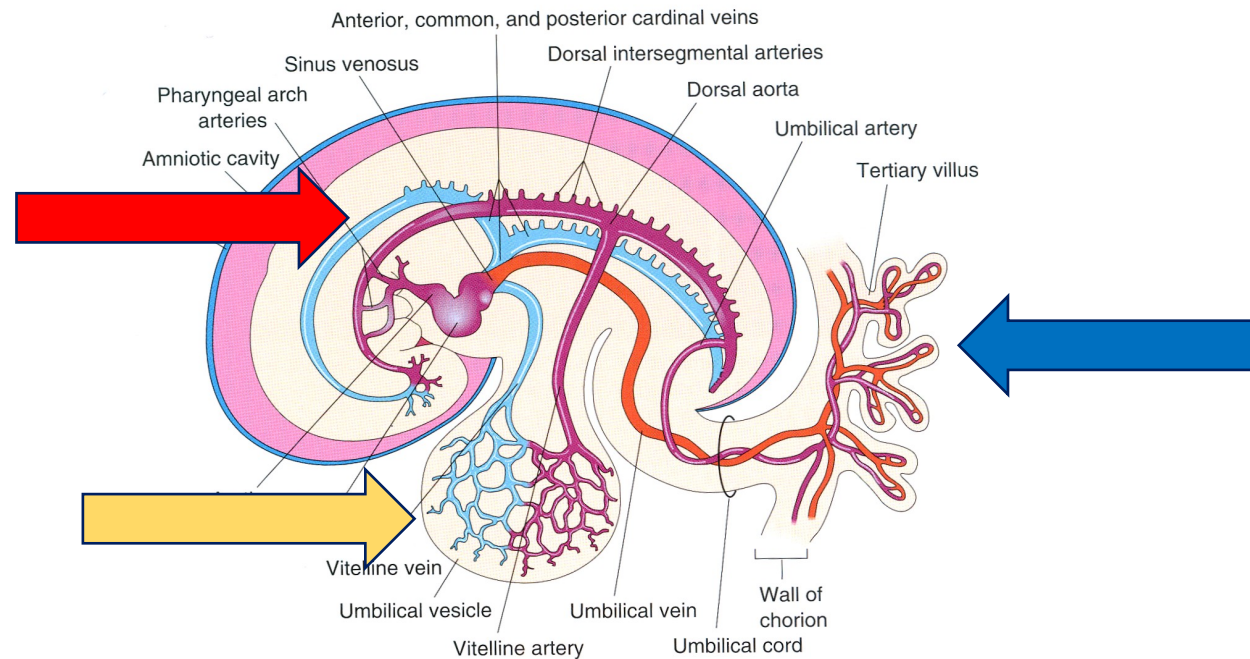
4. týden



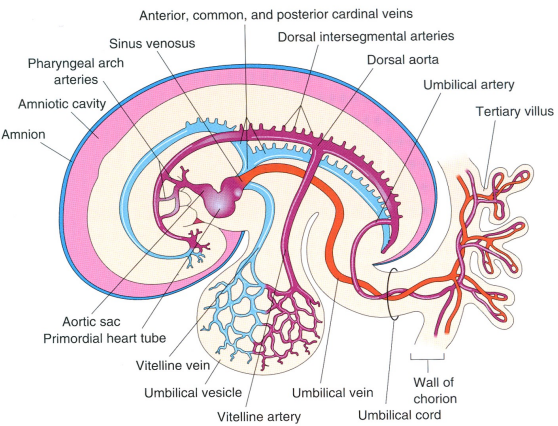
VÝVOJ KARDIOVASKULÁRNÍHO SYSTÉMU

4. týden

- embryonální oběh:** srdeční trubice → *truncus arteriosus* → aortální oblouky → dvě dorsální aorty → splývají v jednu aortu dorsalis → kapiláry → párové kardinální vény (do kterých ústí pre- a postkardinální vény) → *ductus Cuvieri* → *sinus venosus*
- vitelinní oběh:** dorsální aorty → *aa. omphalomesentericae* → splývají v jednu *a. omphalomesenterica* → *vv. omphalomesentericae* + *vv. umbilicales* → párový *truncus vitelloumbilicalis* → *sinus venosus*
- umbilikální oběh:** dorsální aorty → *aa. umbilicales* → chorion → *vv. umbilicales* + *vv. omphalomesentericae* → párový *truncus vitelloumbilicalis* → *sinus venosus*

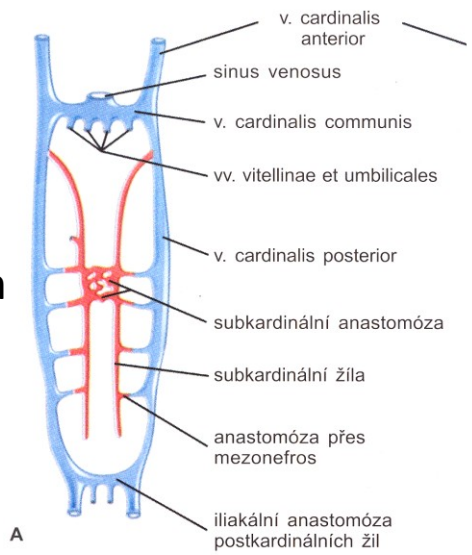


VÝVOJ KARDIOVASKULÁRNÍHO SYSTÉMU



4. týden

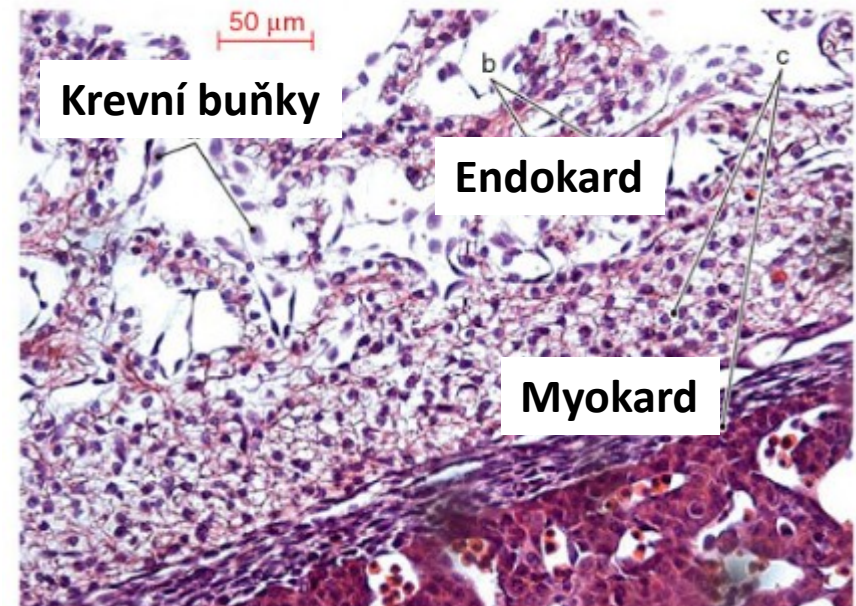
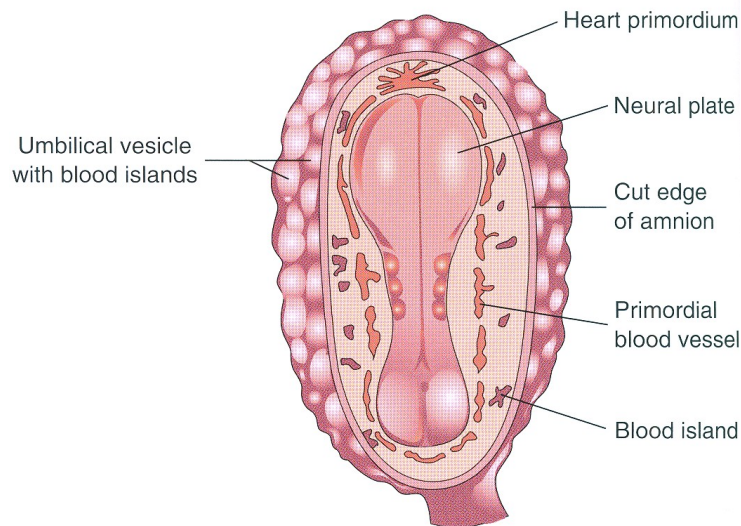
6. týden



 kardinální, umbilikální a vitelinní vény	 subkardinalní vény	 suprakardinalní vény	 hepatický segment	v. – vena w. – vény
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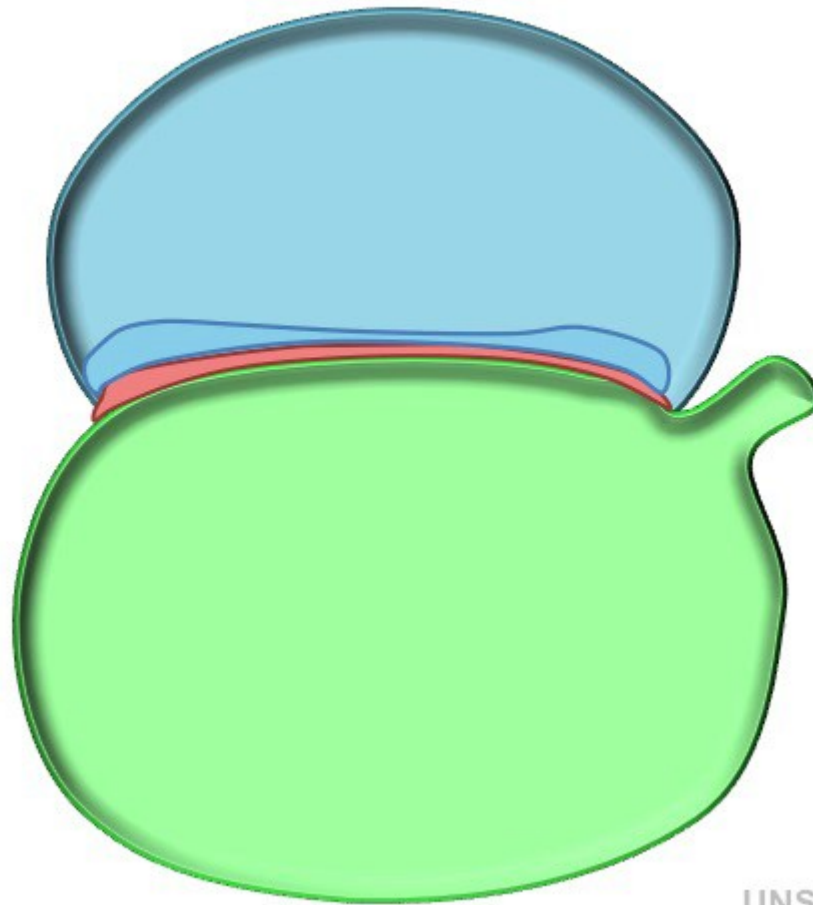
Vývoj primitivního srdce

- párové **endoteliální trubice** (cor tubulare duplex) z embryonální splanchnopleury v kardiogenní oblasti
- flexe → mediálně fúzí: **jednoduché trubicovité srdce** (cor tubulare simplex)
- viscerální mezoderm: **myoepikardový plášť: myokard a epikard**
- **srdeční rosol** (cardiac jelly) → subendokardové vazivo
- srdeční kontrakce 21-22. den (5.týden podle LMP)
- uzavřená cirkulace ~ 4.týden (gestační)



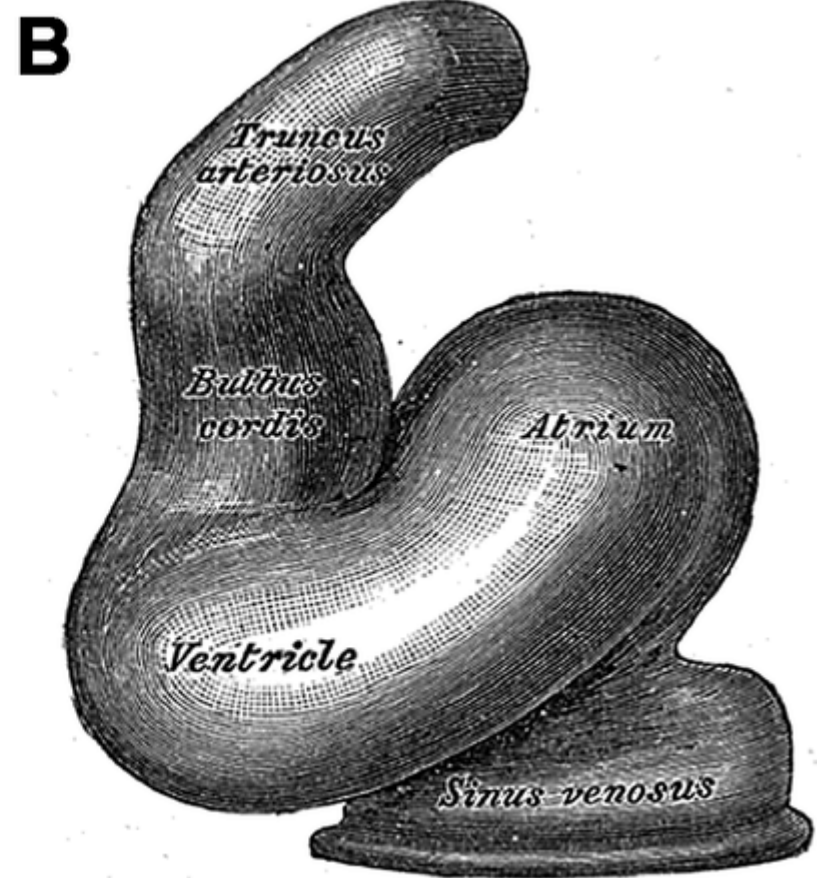
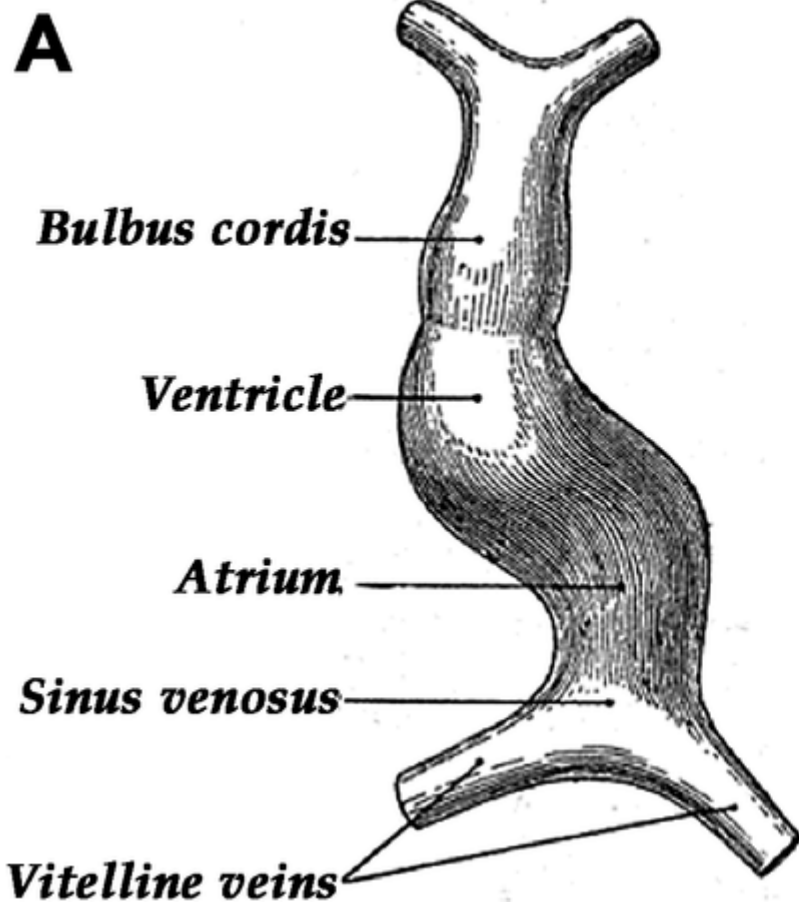
3-4. týden

Folding and Fusion of the Heart Tubes



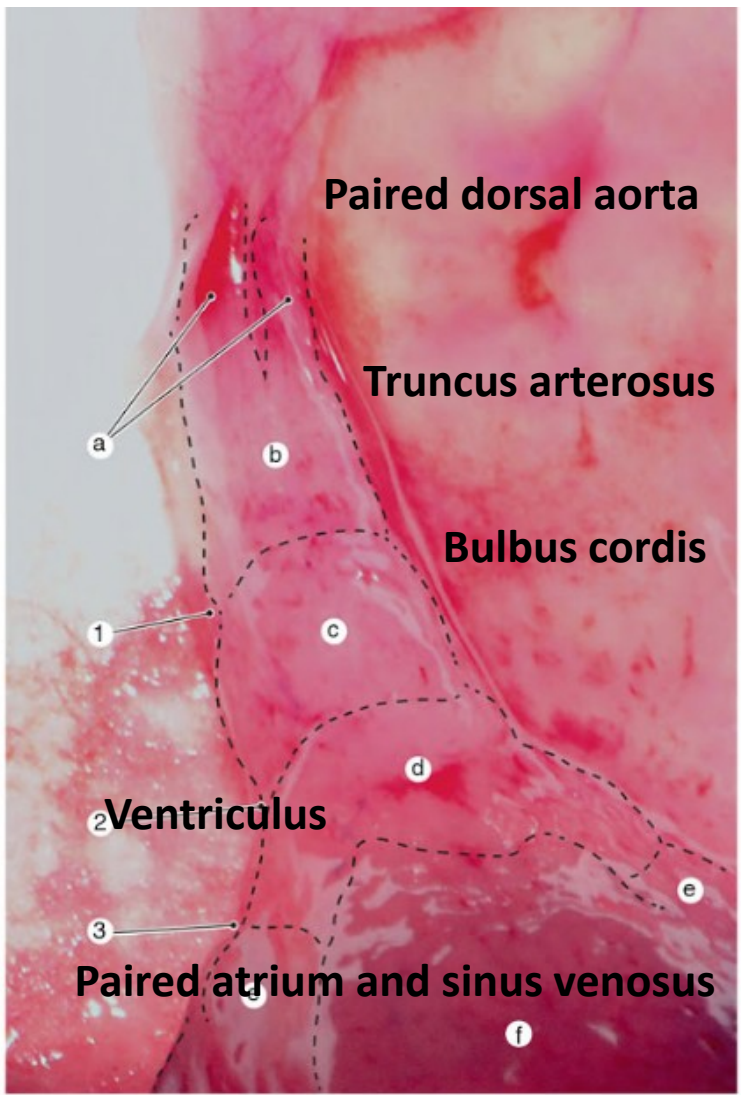
4. týden

- jednoduché tubulární srdce (cor tubulare simplex a cor tubulare sigmoideum)
- **sinus venosus → atrium → ventriculus → bulbus cordis → truncus arteriosus**

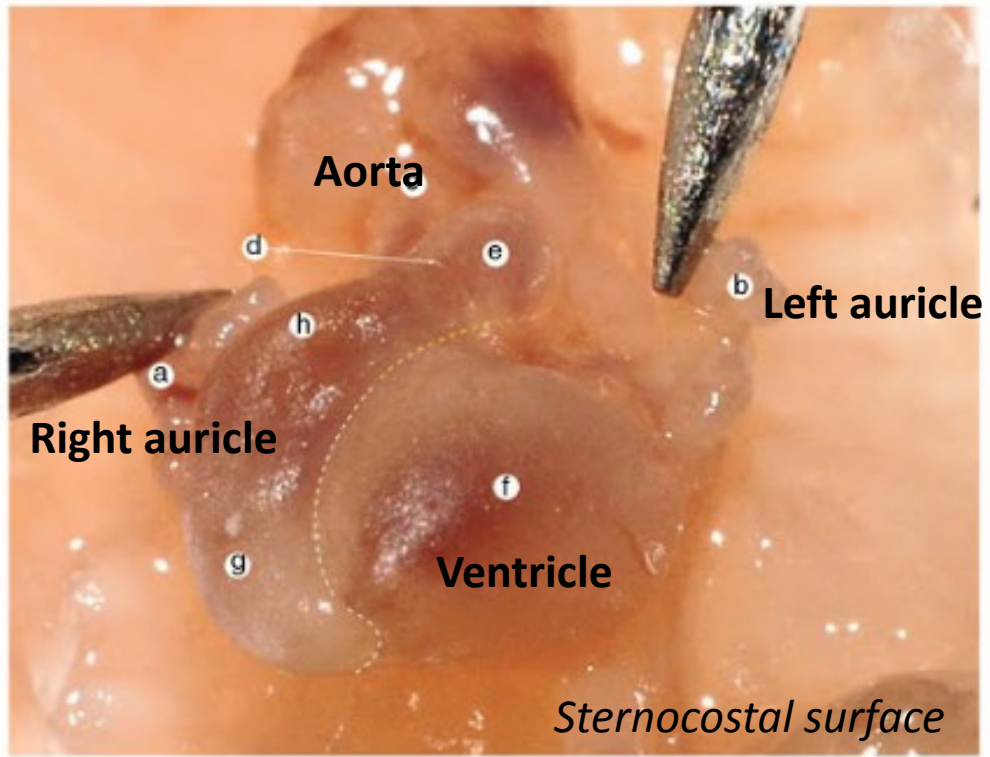


4. týden

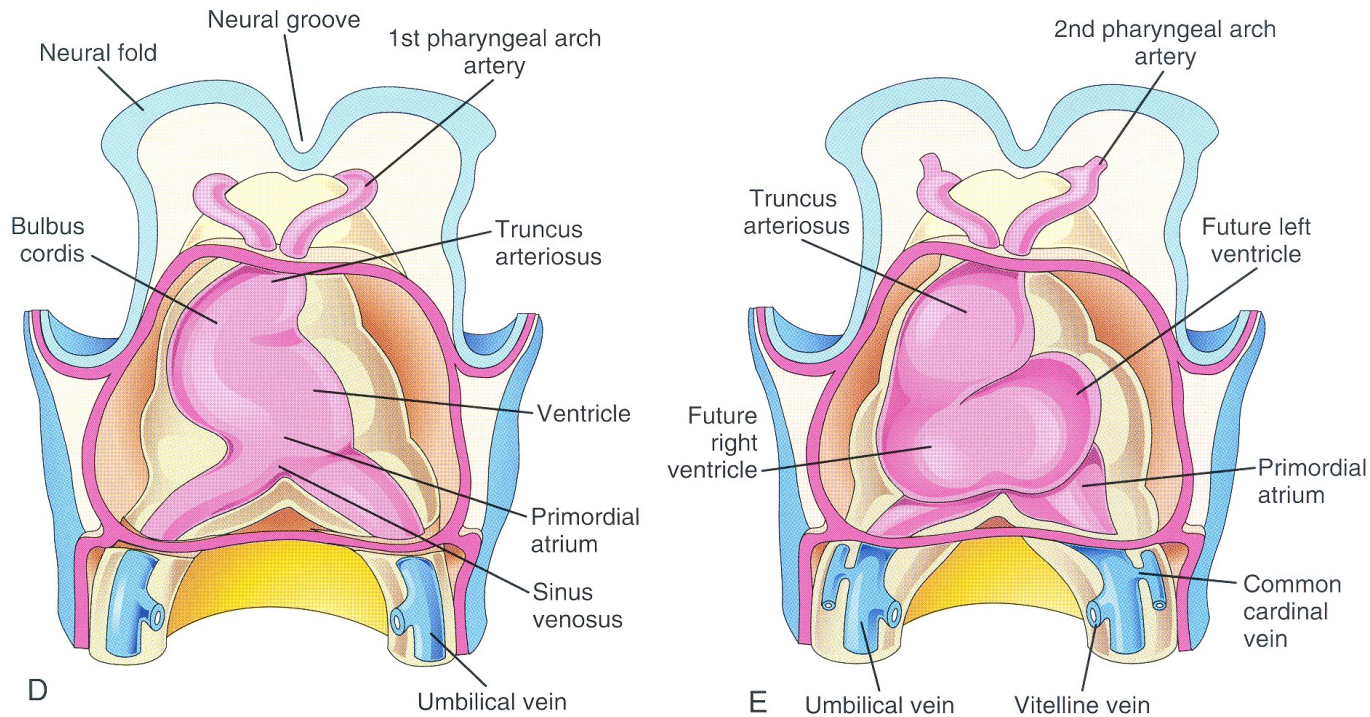
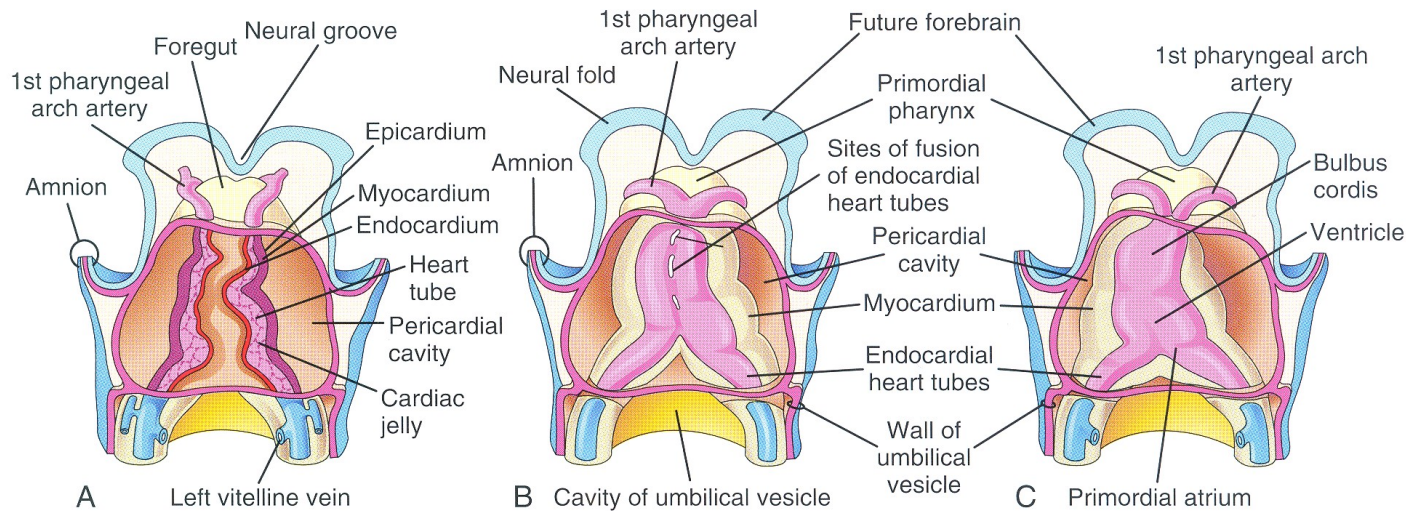
Cor tubulare simplex



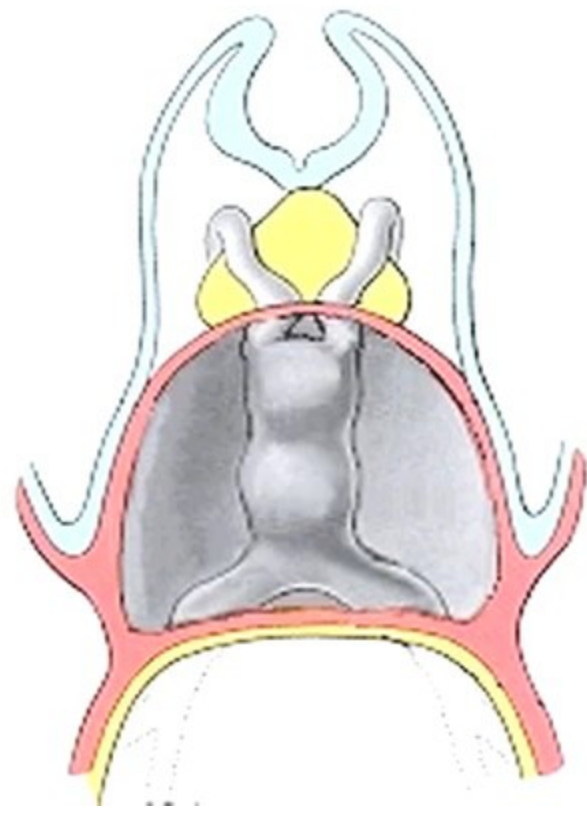
Cor tubulare sigmoideum



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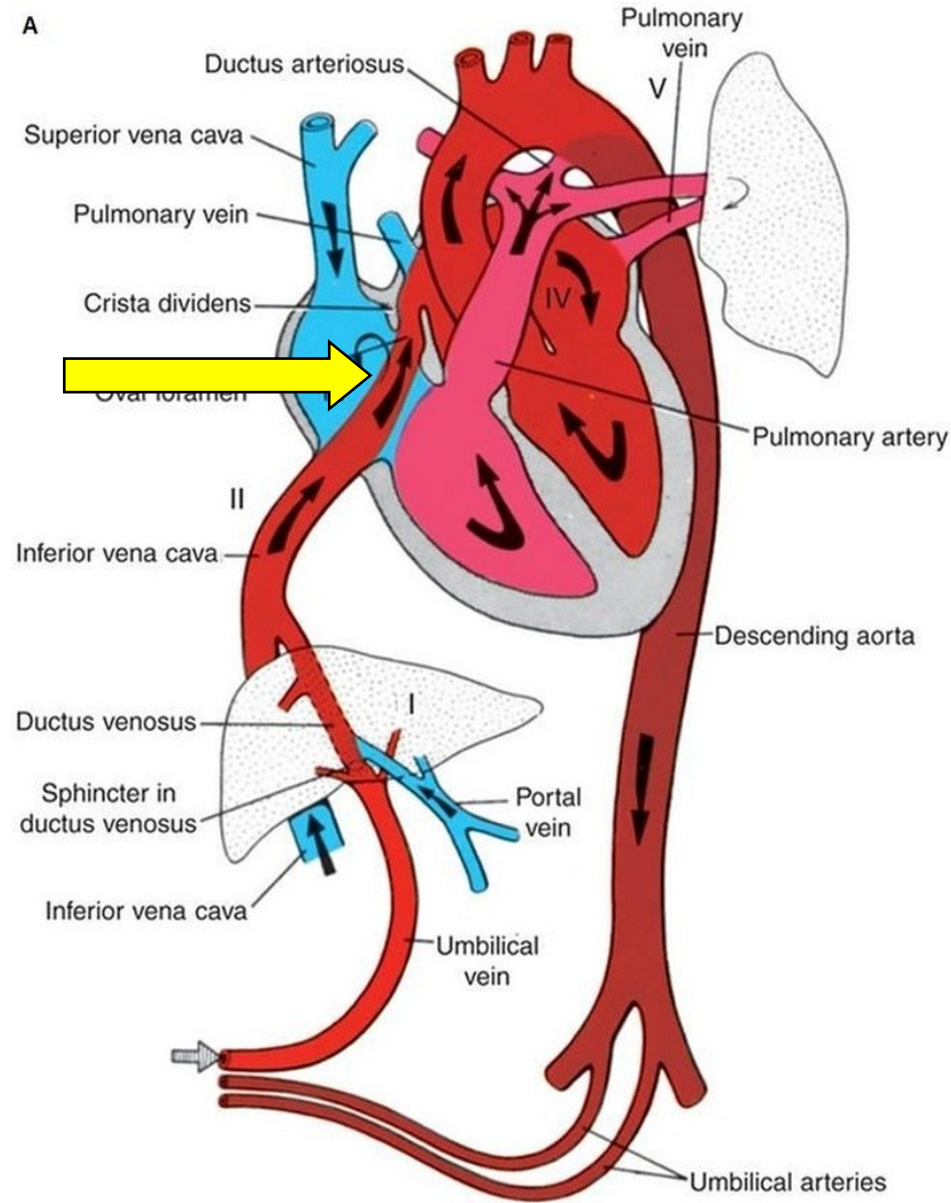


4. týden



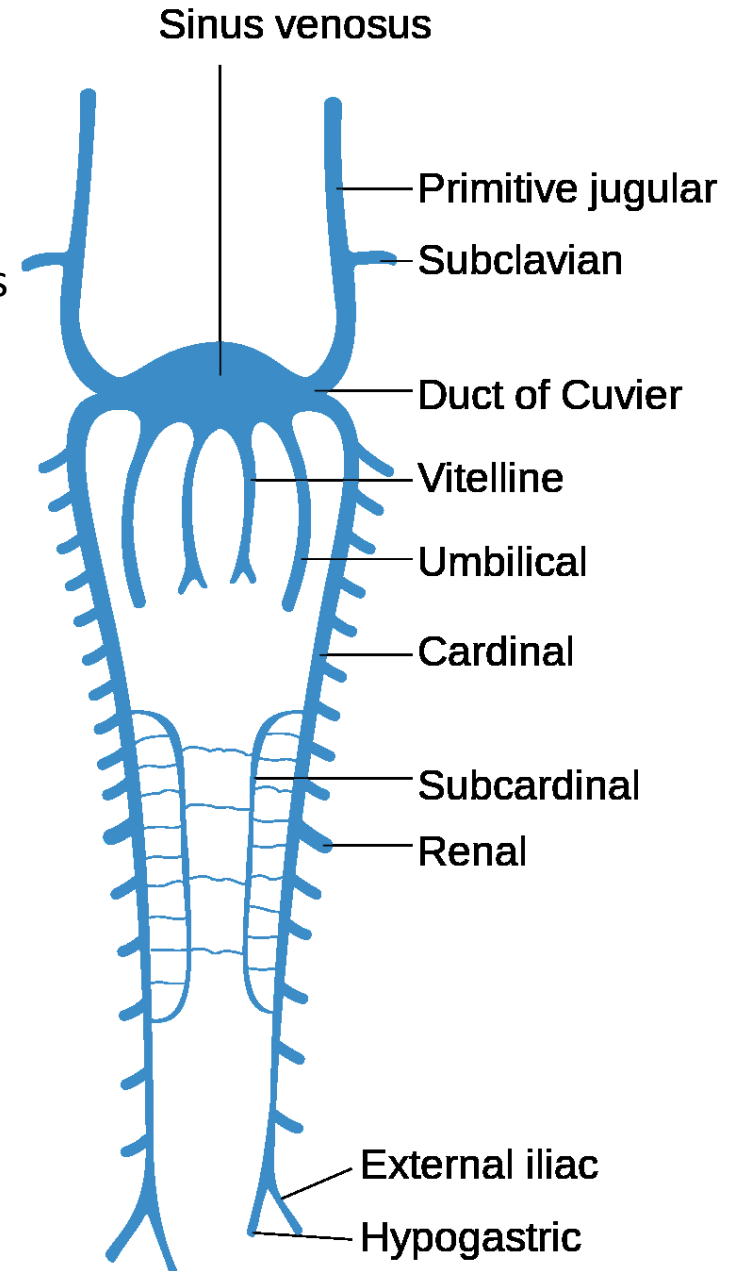
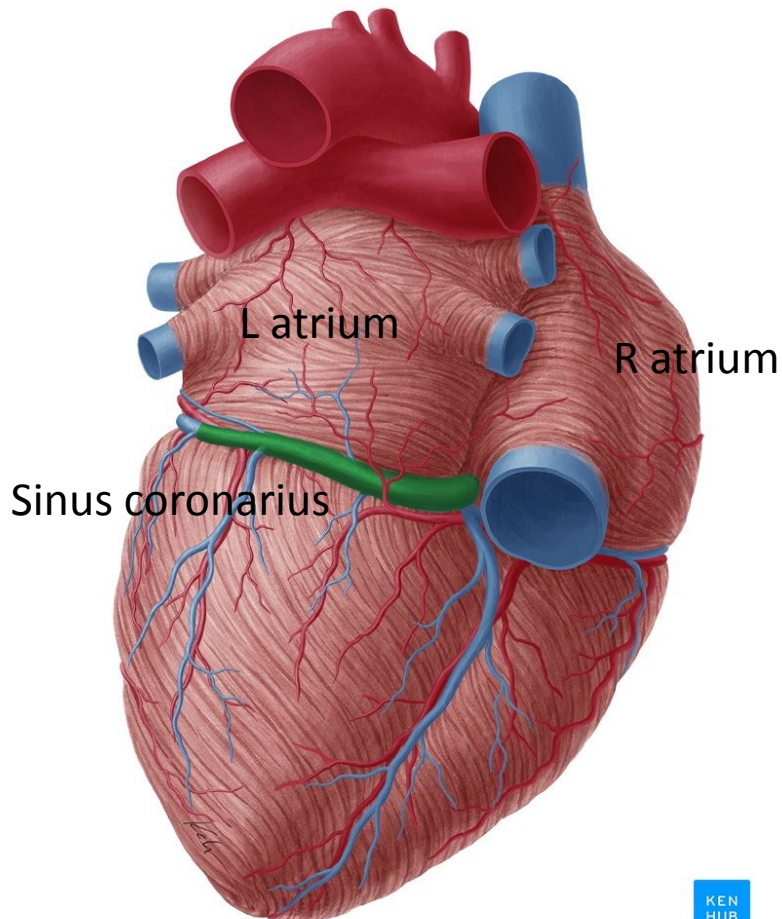
Rozdělení společného atria (atrium communis)

- septum primum z dorso-kraniální stěny směrem k endokardovým polštářům (endocardial cushions)
- neúplné uzavření → **foramen (ostium) primum**
- apoptóza → **foramen secundum**
- **septum secundum** → **foramen ovale**
- valvula foraminis ovalis z septum primum
- foramen ovale: kritická embryonální spojka
- foramen ovale patens

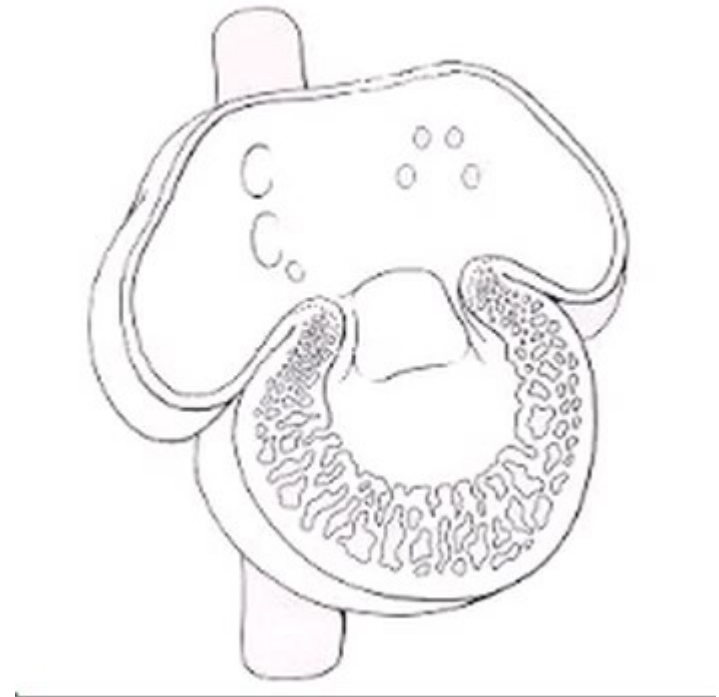
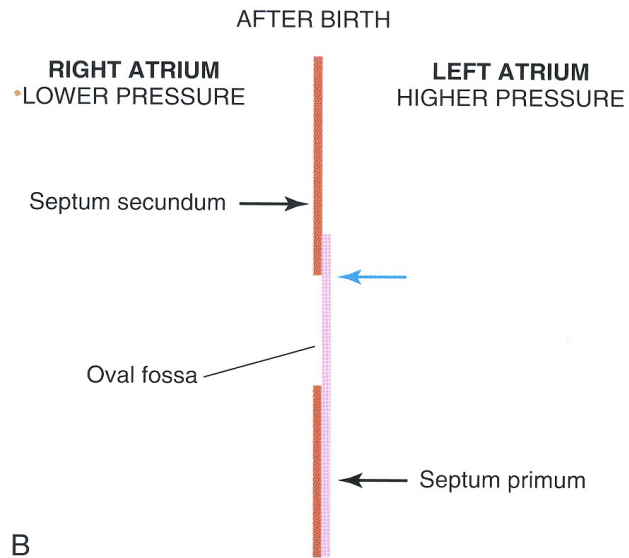
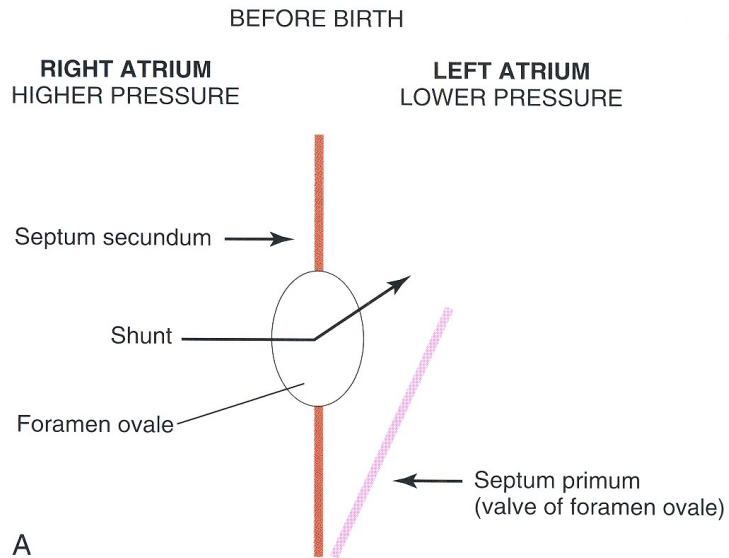


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- sinus venosus během atriální septace:
 - posun ústí sinus venosus doprava → pravé atrium
 - levá část sinus venosus se odděluje → sinus coronarius

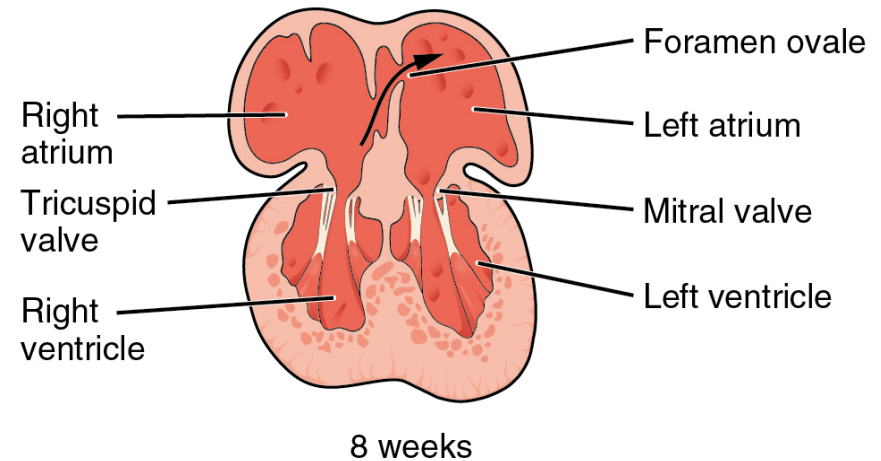
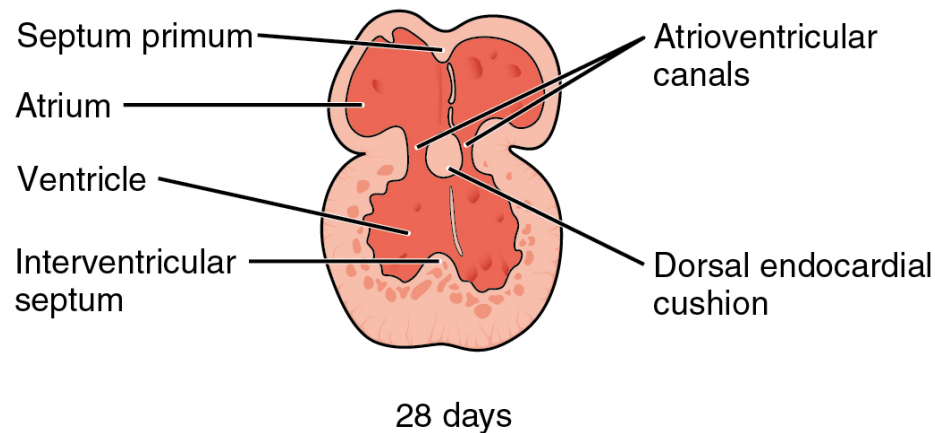


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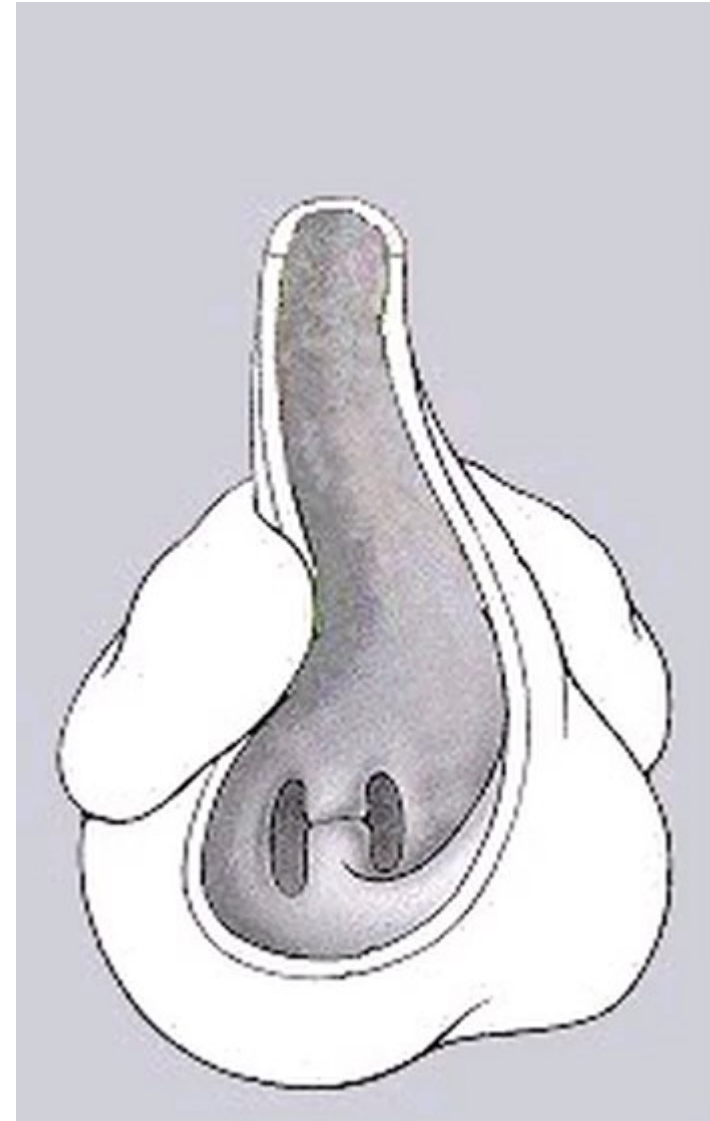
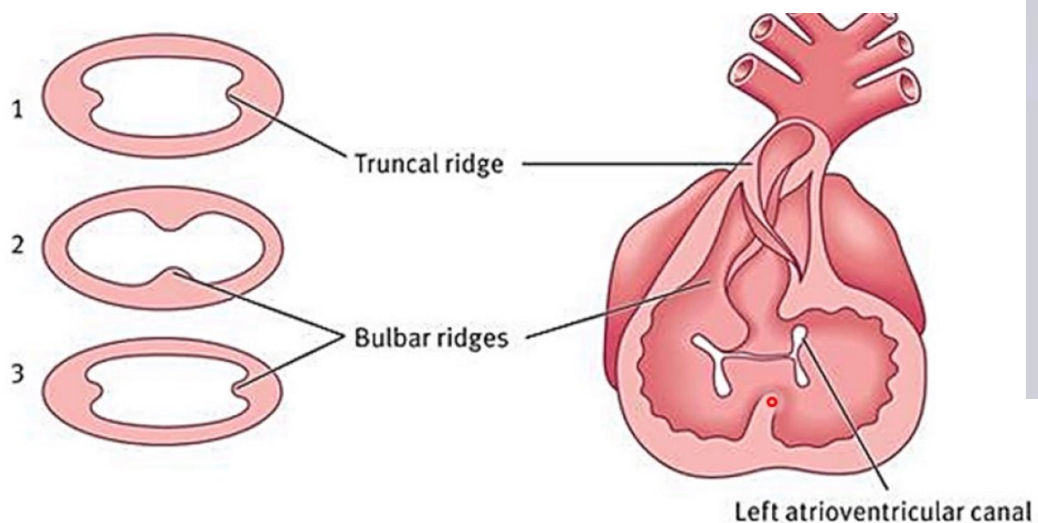
Rozdělení společné komory (ventriculus communis)

- septum interventriculorum primitivum – dočasné
- septum interventriculare na konci 4. týdne – kraniálně, sagitálně směrem k foramen atrioventriculare
- foramen interventriculare – uzavírá se během tvorby aorto-pulmonálního septa
- pars membranacea septi interventricularis



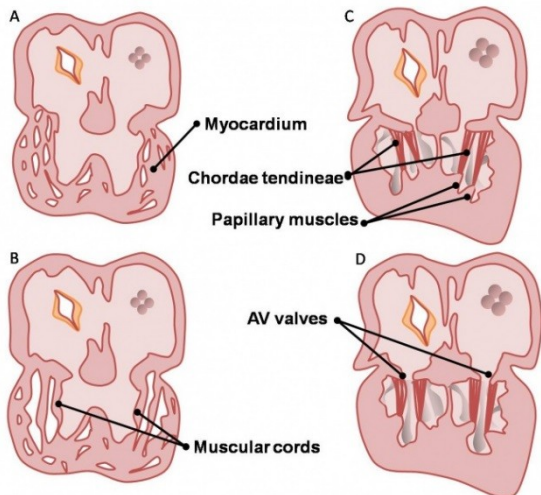
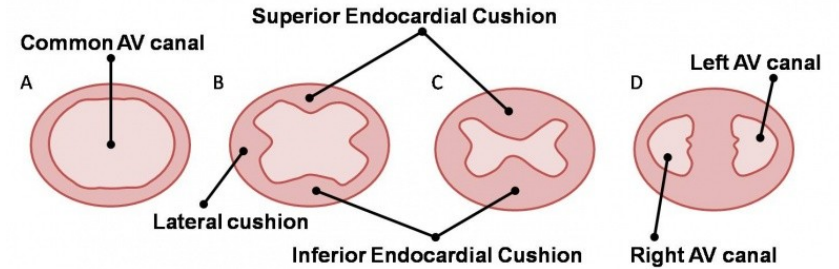
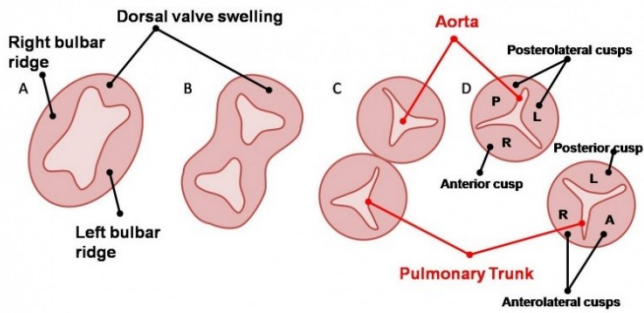
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- Rozdělení **bulbus cordis** a **truncus arteriosus**
- 5. týden – bulbární a trunkální valy
- vazivo původem z neurální lišty
- 180° otočení – spirálovité aorto-pulmonární septum
- plicní kmen a aorta se otáčejí kolem sebe
- bulbus cordis je součástí definitivních komor:
pravá komora: conus arteriosus (infundibulum) → plicní kmen
levá komora: vestibulum aortae

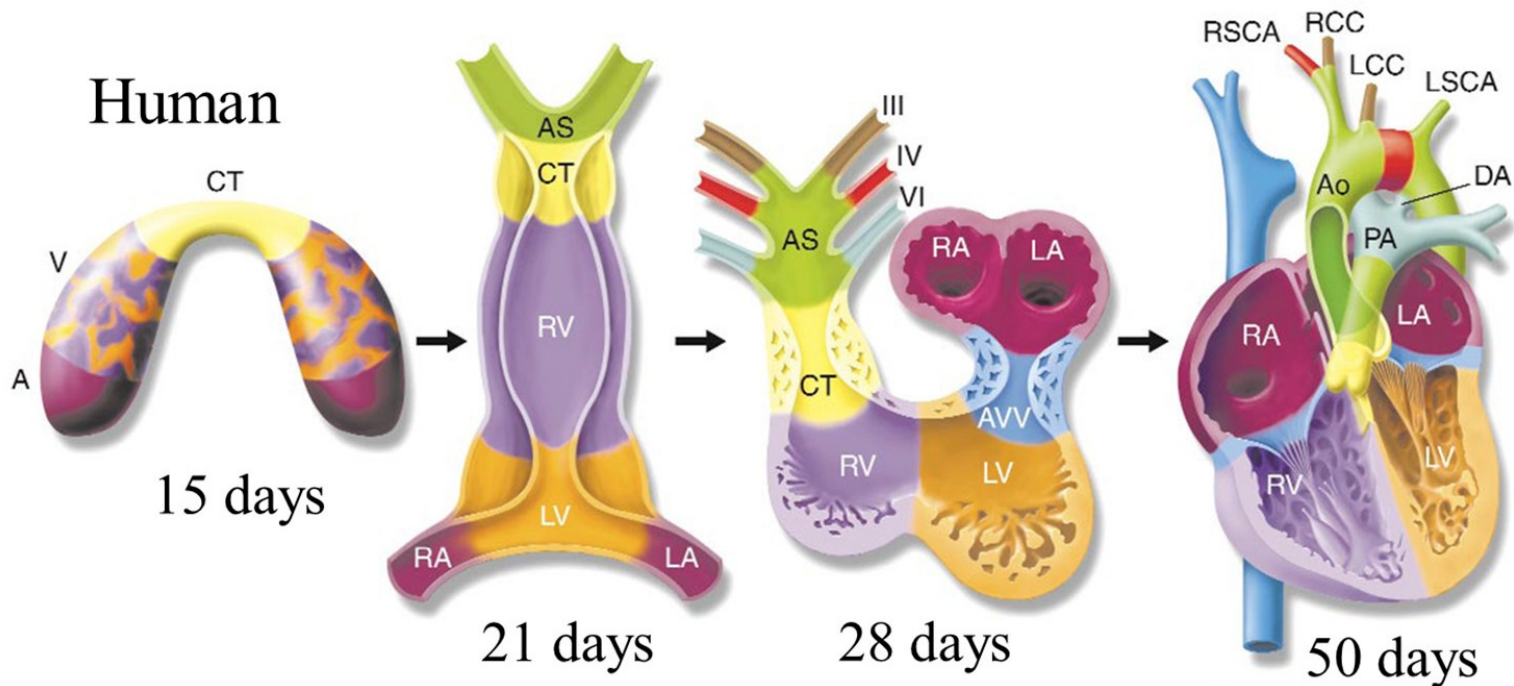
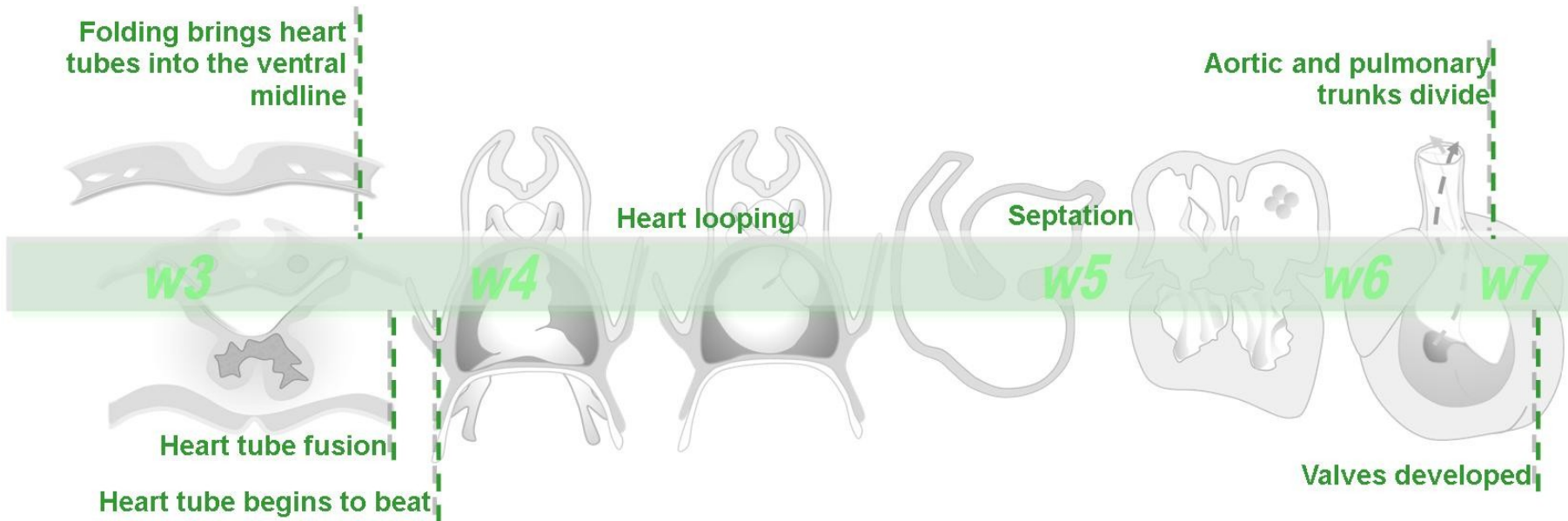


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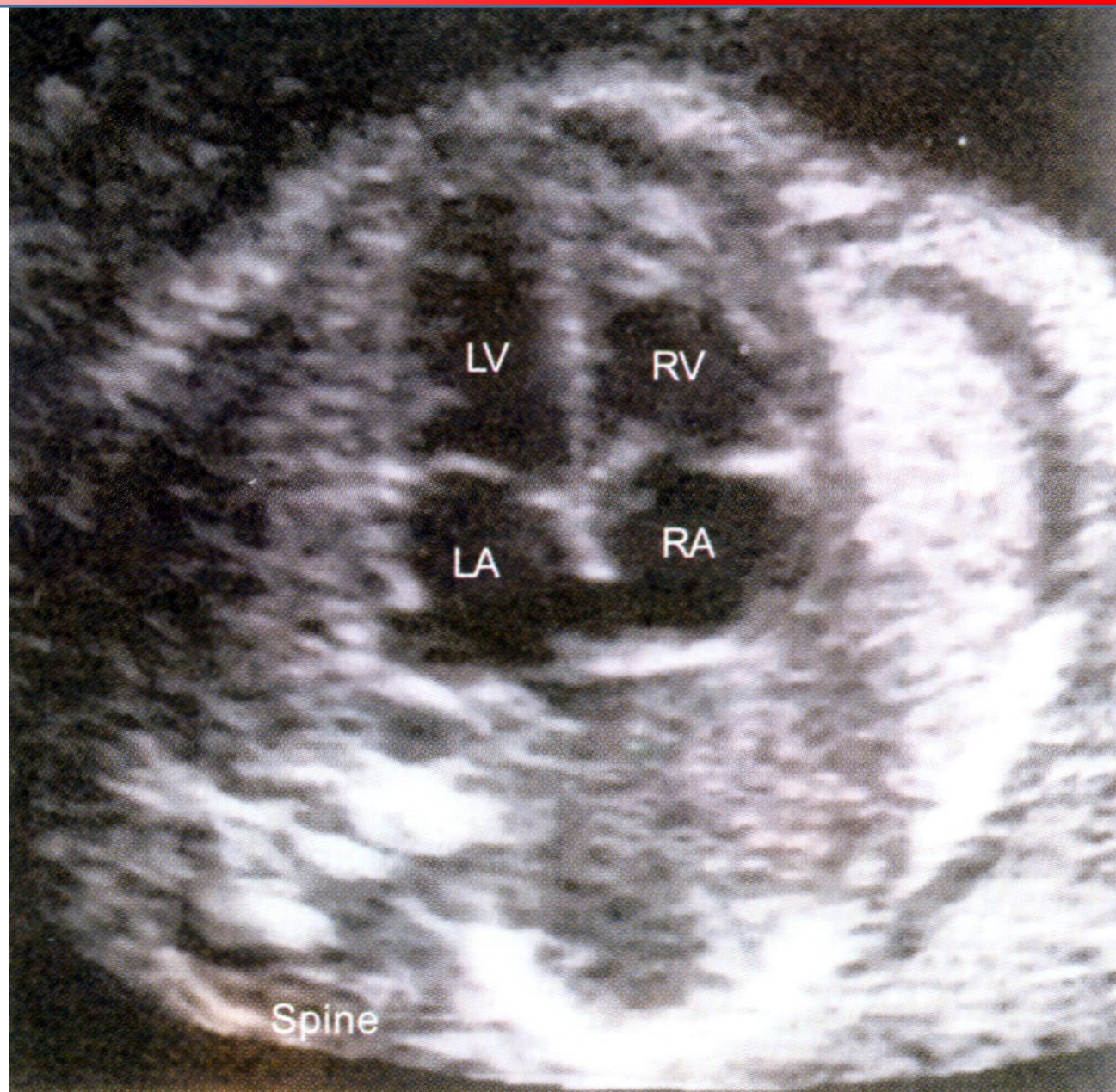
- Vývoj srdečních chlopní
- **semilunární chlopně** během septace truncus arteriosus z endokardových polštářů atrioapulmonárního septa
- **atrioventrikulární chlopně** z endokardových polštářů a myokardu ve foramen atrioventriculare commune



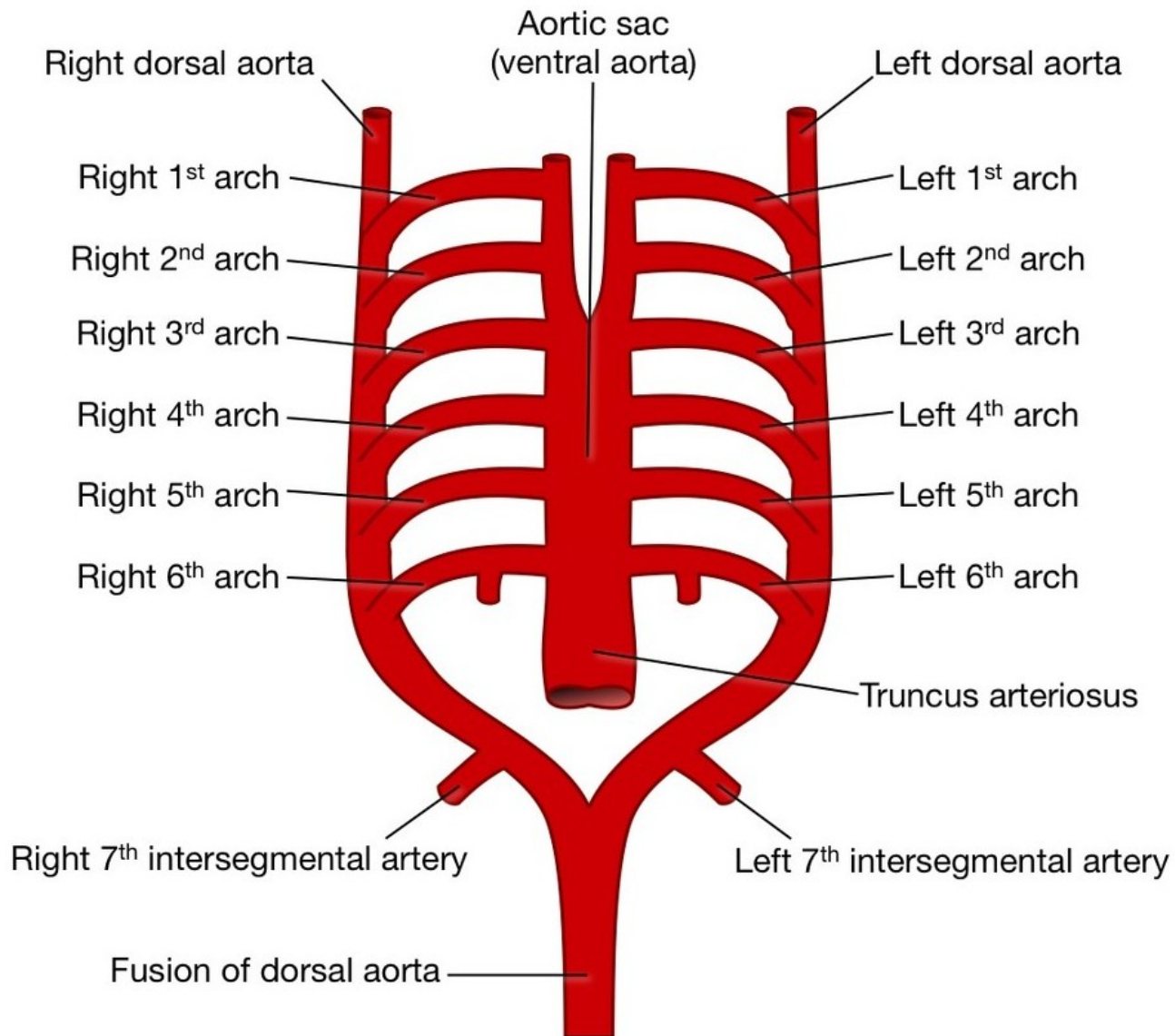
VÝVOJ KARDIOVASKULÁRNÍHO SYSTÉMU



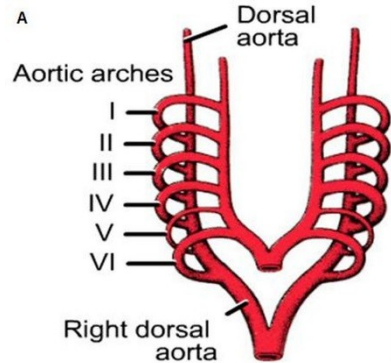
20. týden



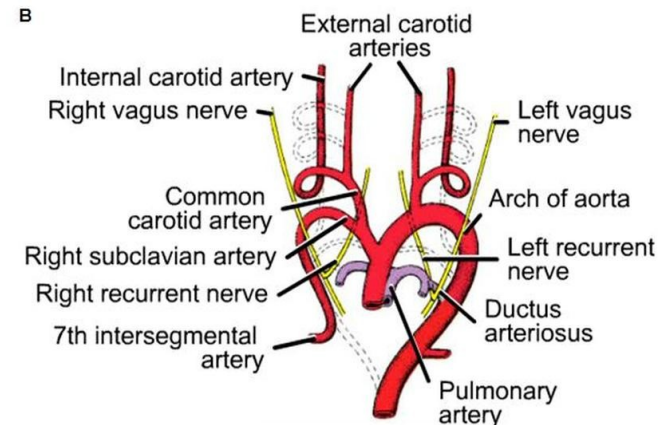
Aortální oblouky



Aortální oblouky

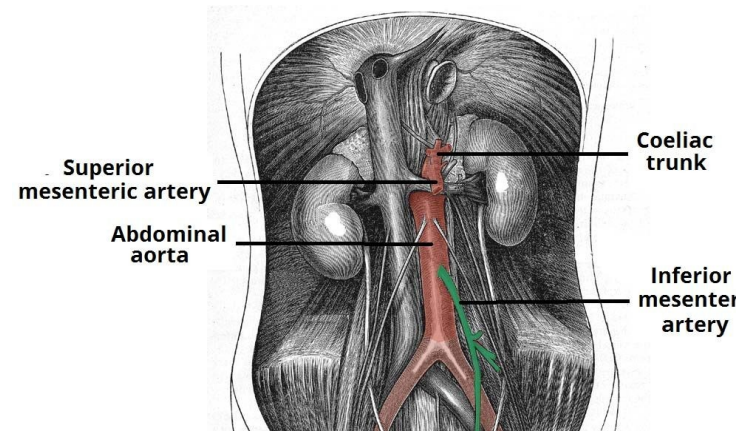
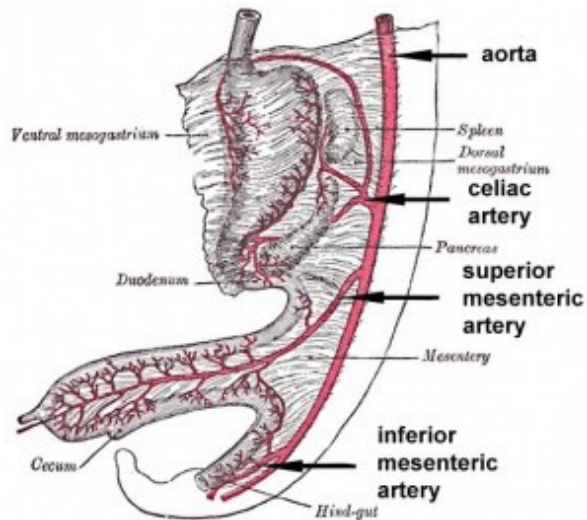
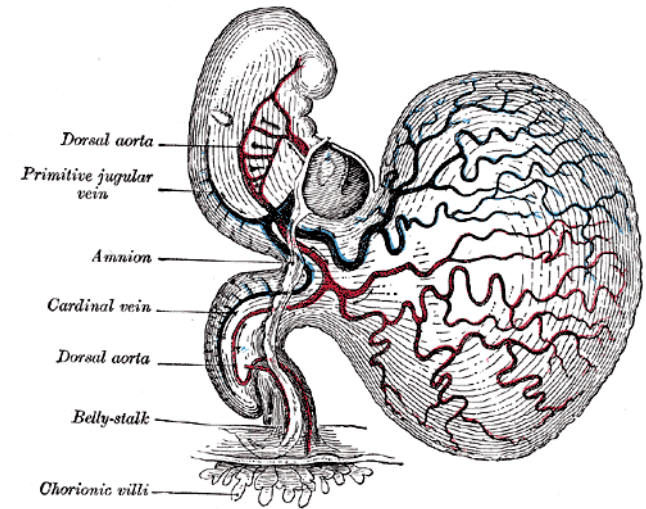


- 1 zaniká, z části **a. maxillaris**
- 2 zaniká, z části **a. stapedia** a **a. hyoidea**
- 3 **a. carotis communis, a. carotis interna**
- 4 pravý dává vznik proximální části **a. subclavia dextra** (distální část pochází z dorsální aorty a ze 7. intersegmentální arterie); z levého vzniká **arcus aortae**
- 5 -
- 6 vpravo z proximální části vzniká **a. pulmonalis dextra**, distální část zaniká; vlevo z proximální části vzniká **a. pulmonalis sinistra**, z distální části vzniká **ductus arteriosus**.



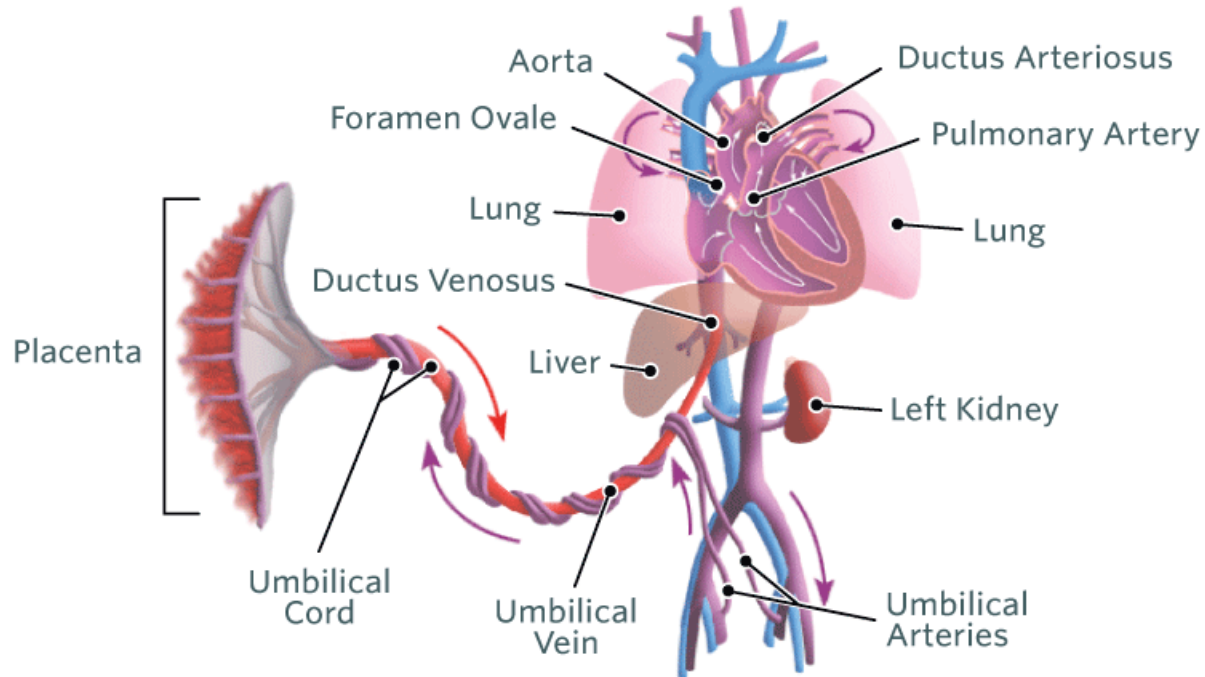
Žlutkové tepny

- aa. vitellinae (aa. omphalomesentericae)
- ventrální větve dorsálních aort
- redukce během vývoje na tři hlavní cévy:
 - 1 **truncus coeliacus**
 - 2 **a. mesenterica superior**
 - 3 **a. mesenterica inferior**



Pupečníkové tepny

- aa. umbilicales
- ventrální větve dorsálních aort, později napojeny na aa. iliacae communes.
- po narození: proximální části a. umbilicales tvoří aa. iliacae internae a aa. vesicales superiores.
distální části obliterují.



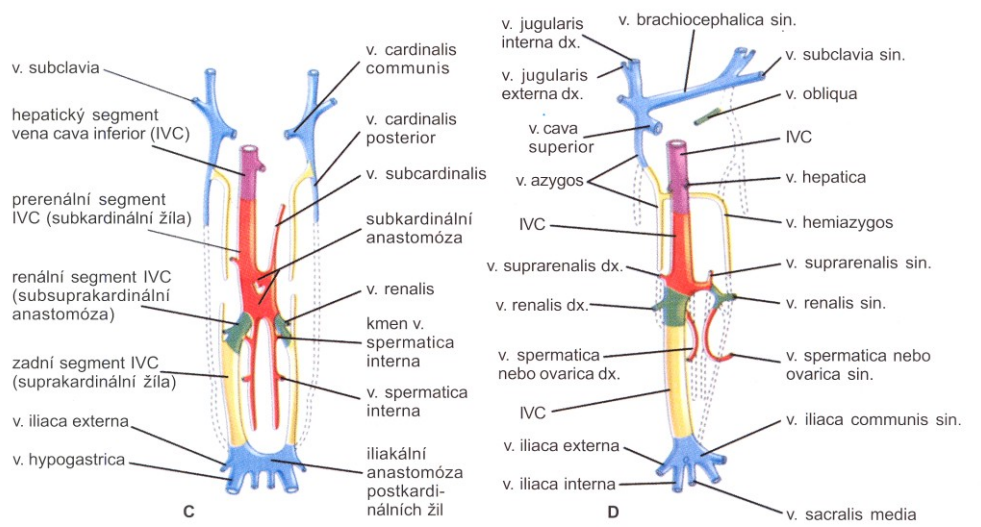
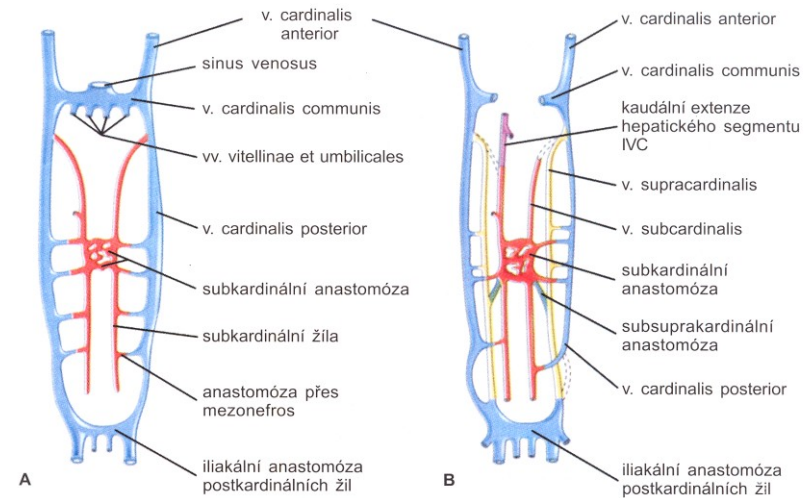
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Kardinální vény a vývoj vena cava inferior

- čtyři základní segmenty
- 1 hepatický segment (proximální část v. omphalomesenterica = v. hepatica)
- 2 prerenální segment (pravá v. subcardinalis)
- 3 renální segment (anastomóza mezi v. subcardinalis a v. supracardinalis)
- 4 postrenální segment (pravá v. supracardinalis)



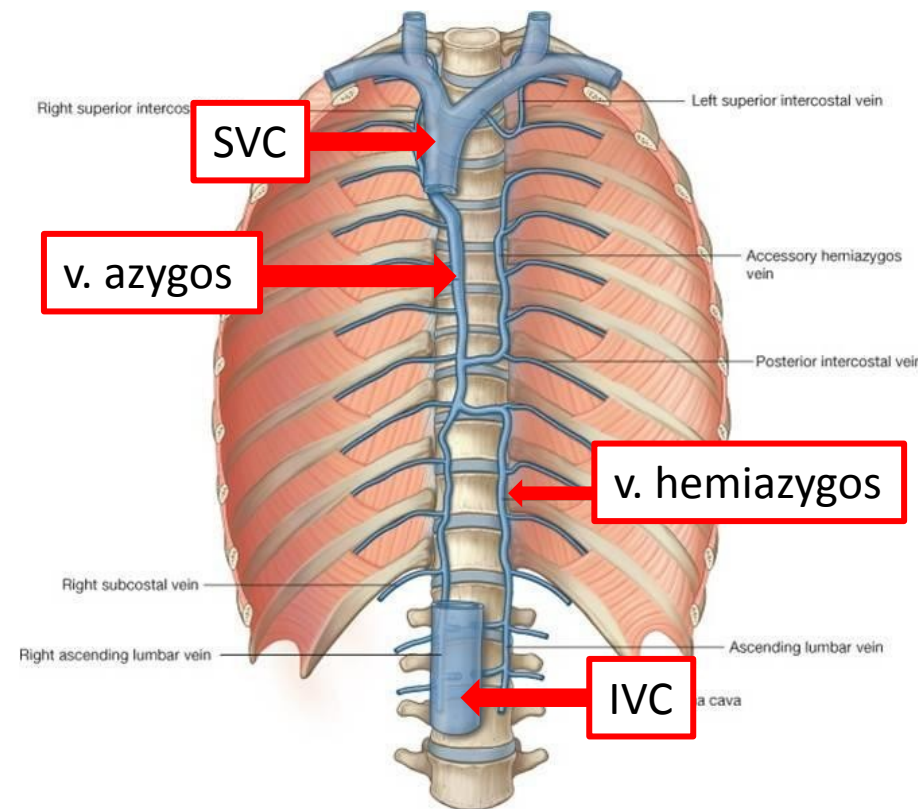
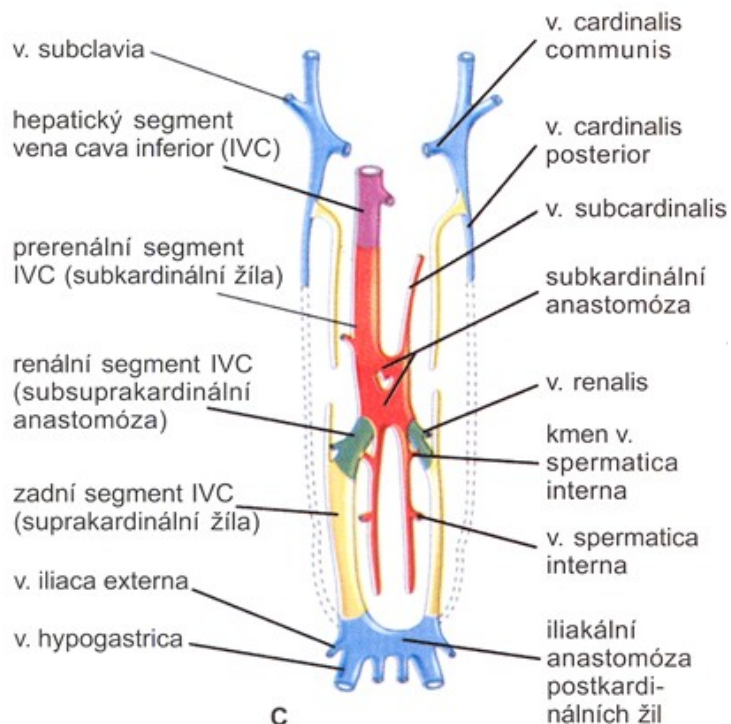
Vena cava superior: pravá v. cardinalis communis a v. cardinalis anterior



■ kardinální, umbilikální a vitelinní vény	■ subkardinální vény	■ suprakardinální vény	■ hepatický segment	v. - vena w. - vena
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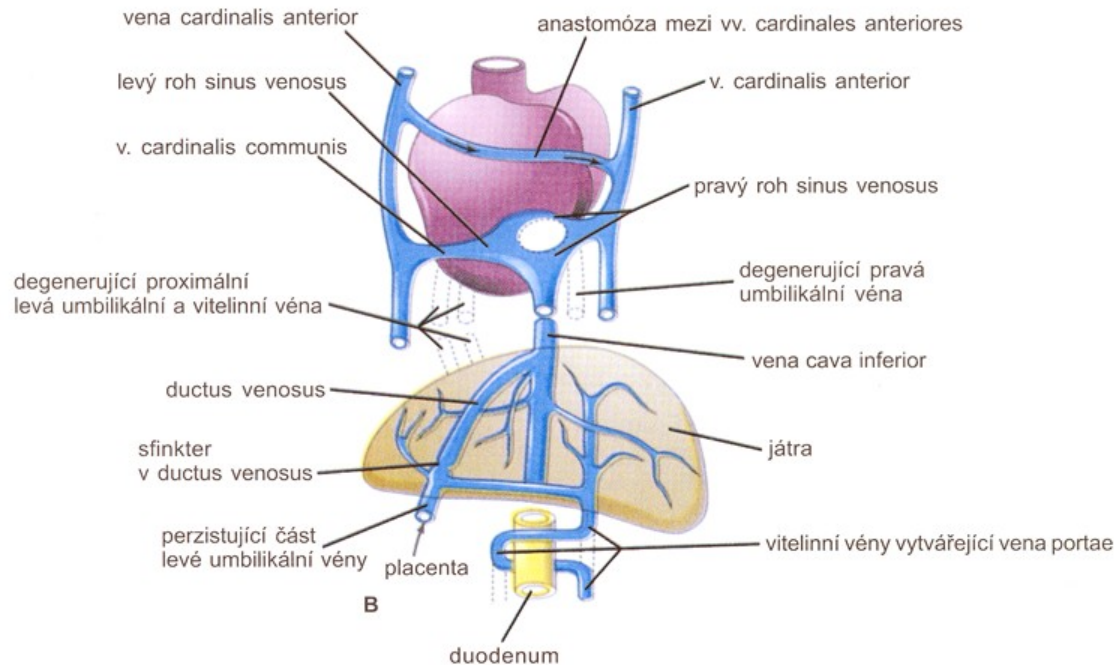
Anomálie velkých dutých žil

- **Dvojitá SVC:** levá přední kardinální žíla perzistuje → levá SVC
- **Levá SVC:** pravá v. cardinalis anterior a v. cardinalis communis degenerují, zůstávají levostranné vény
- **Absence hepatického segmentu IVC:** krev odchází cestou v. azygos a hemiazygos do pravého atria.
- **Dvojitá IVC:** perzistence základů obou IVC v důsledku absence anastomóz mezi kaudálními vénami



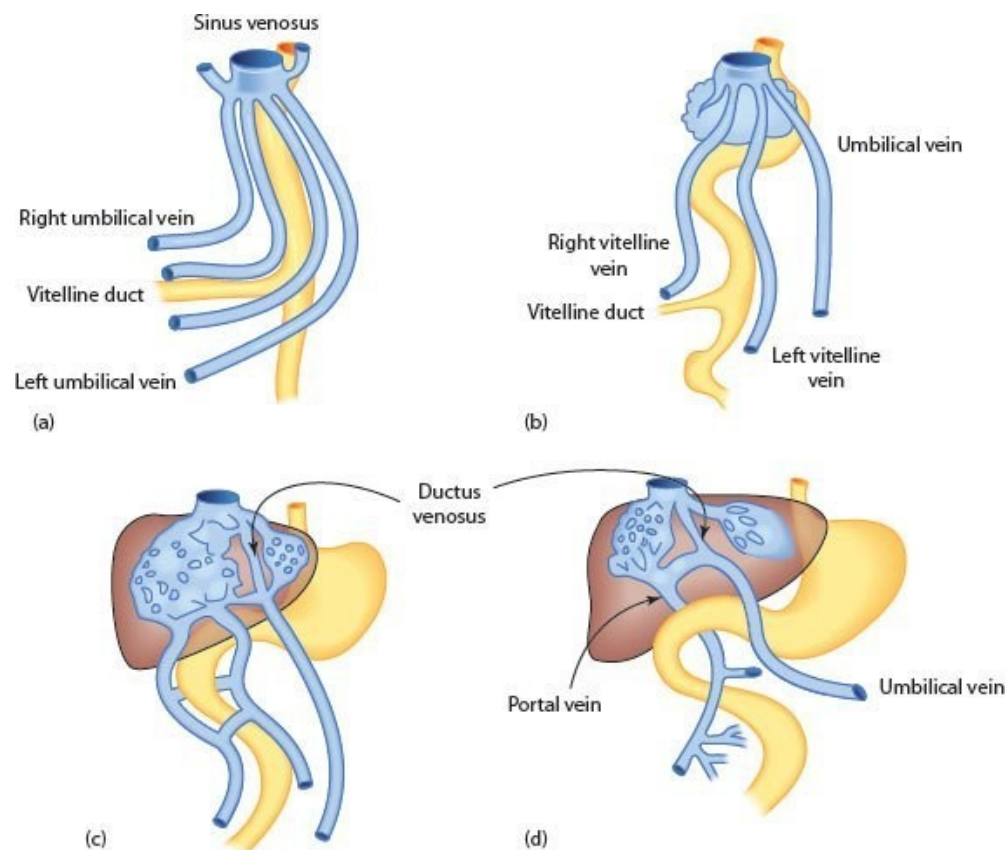
Žloutkové vény

- párové vv. omphalomesentericae, vedou krev ze žloutkového vaku
- septum transversum
- ústí do sinus venosus (spolu s pupečnickovými vénami jako trunci vitelloumbilicales)
- růst jater – rozdělení vv. omphalomesentericae na proximální oddíl (žloutkový vak-játra) a distální část (játra-srdce)
- proximální úsek levé v. omphalomesenterica mizí
- proximální úsek pravé v. omphalomesenterica posthepatický segment IVC
- distální úseky vytvoří dvě anastomózy a následně v. portae



Pupečníkové vény

- párové (na začátku) vv. umbilicales, vedou krev z choriových klků
- v důsledku růstu jater zanikají proximální úseky obou vén
- distální část pravé umbilikální vény mizí
- distální část levé umbilikální vény tvoří ductus venosus



gestation

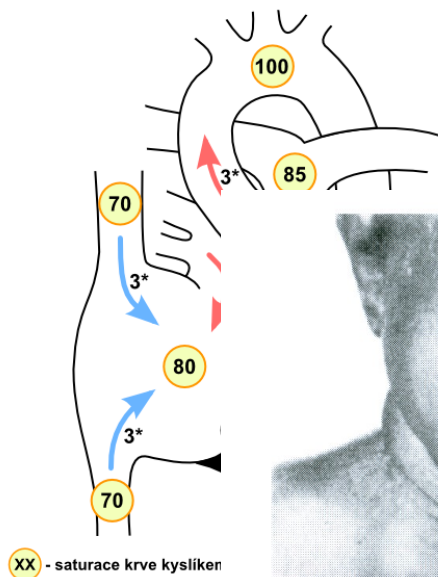
Intrauterin

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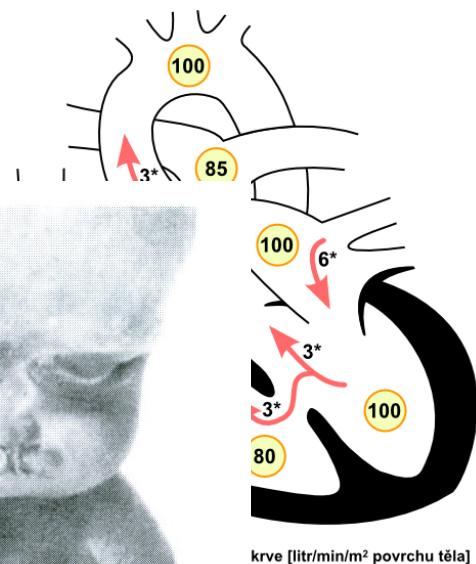
Teratologie

- Acardia
- Ectopia cordis
- Dextrokardie
- Atriální septální defekty
- Ventrikulární septální defekty
- Stenóza truncus pulmonalis
- Fallotova tetralogie (pentalogie)
- Koarktace aorty
- Ductus arteriosus apertus

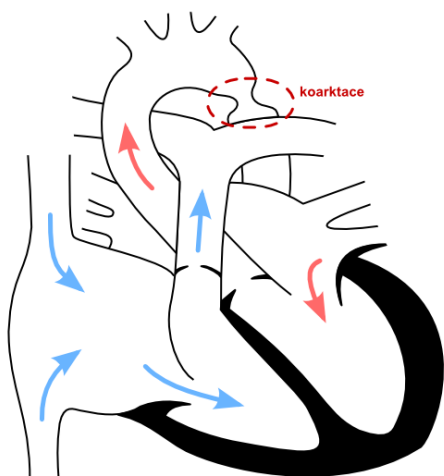
Defekt síňového septa



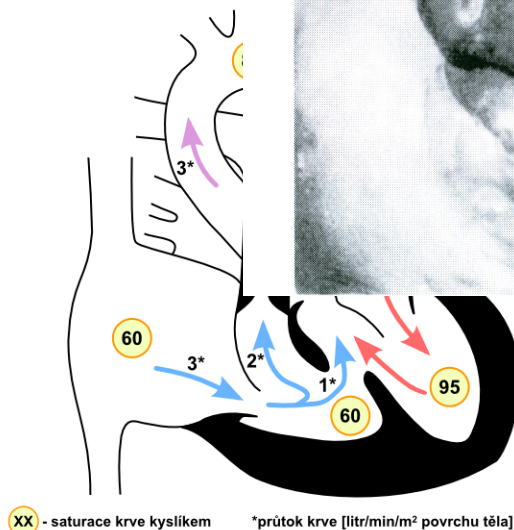
Defekt komorového septa



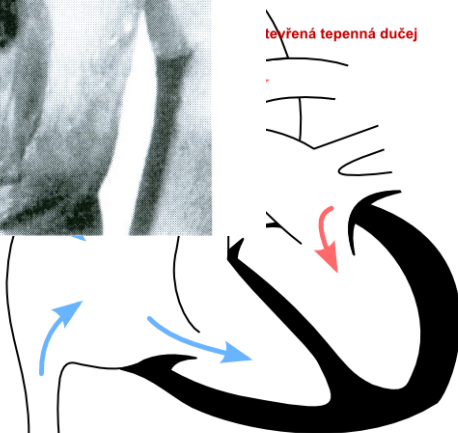
Koarktace aorty

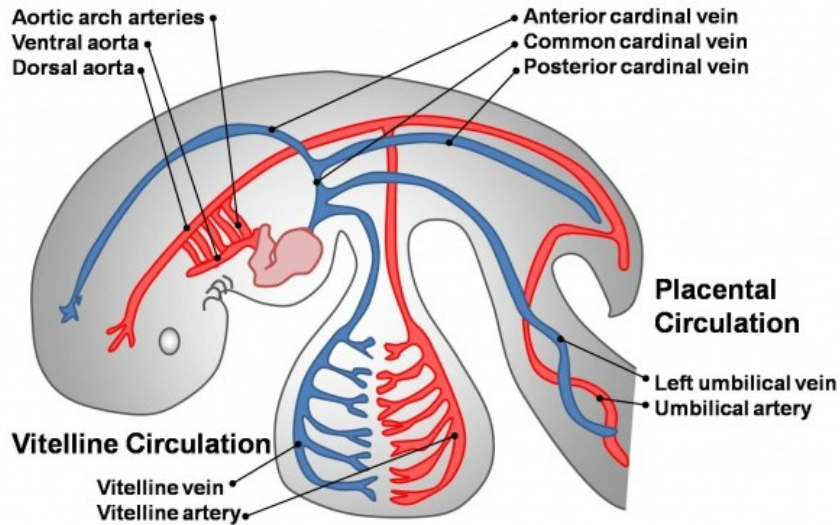


Fallotova tetralogie



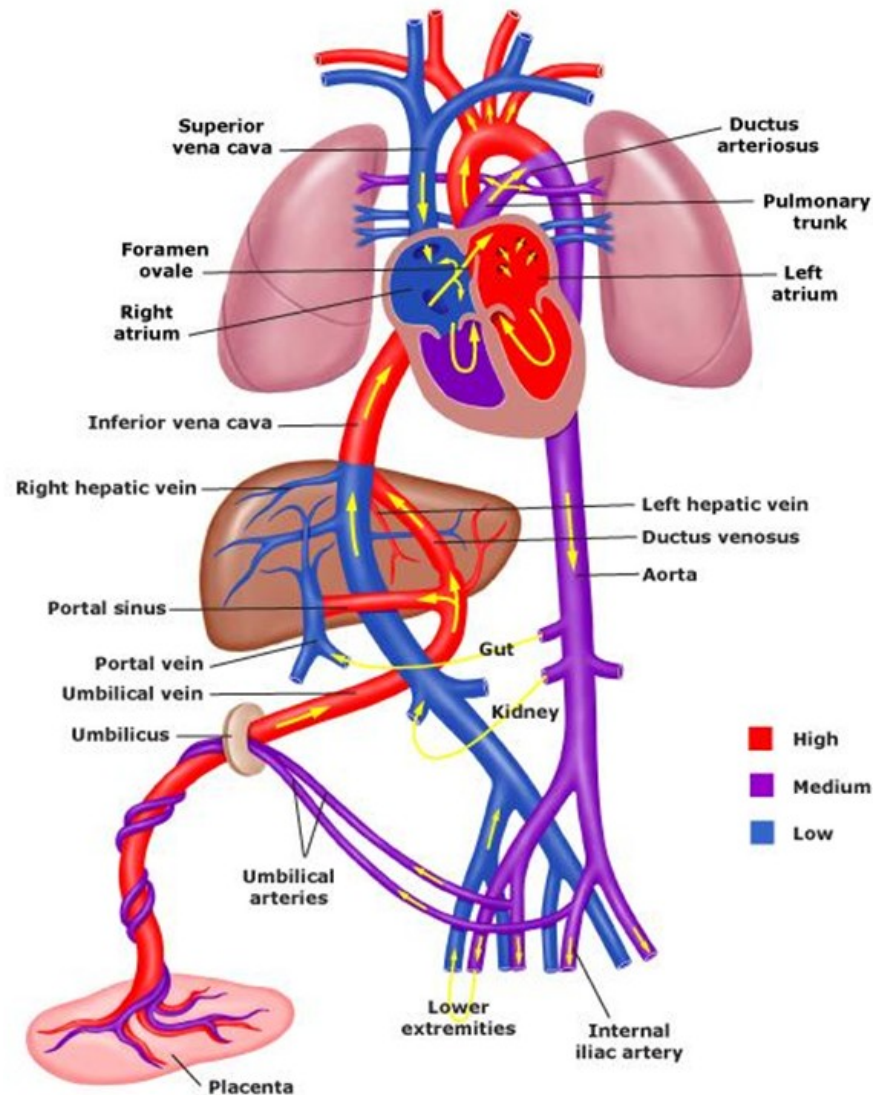
teplá tepenná dučej



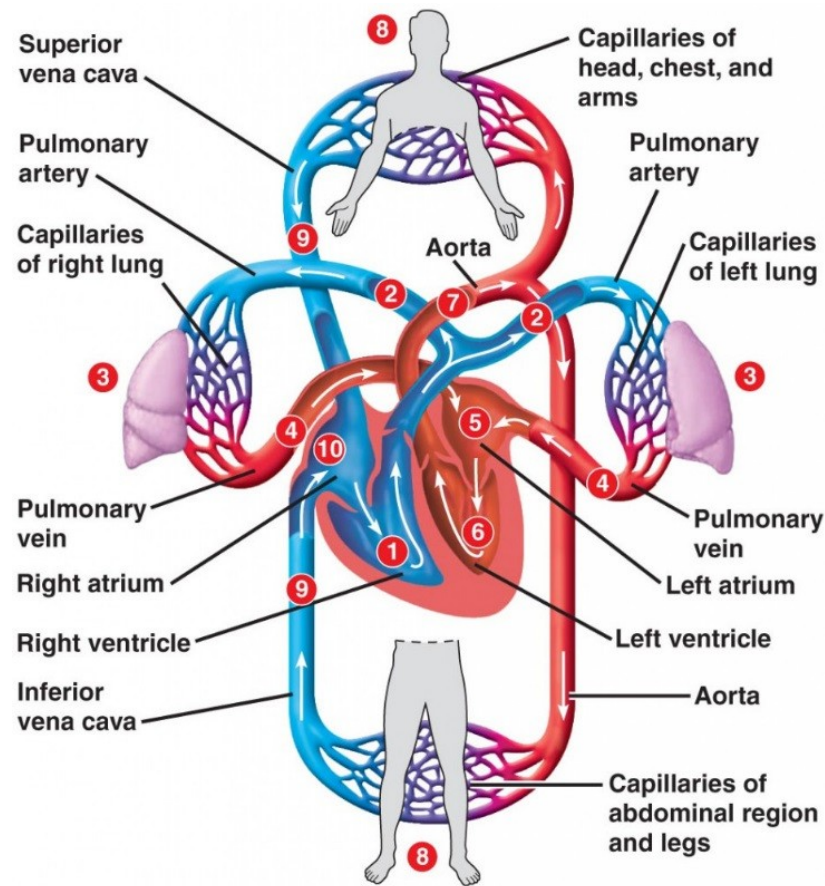
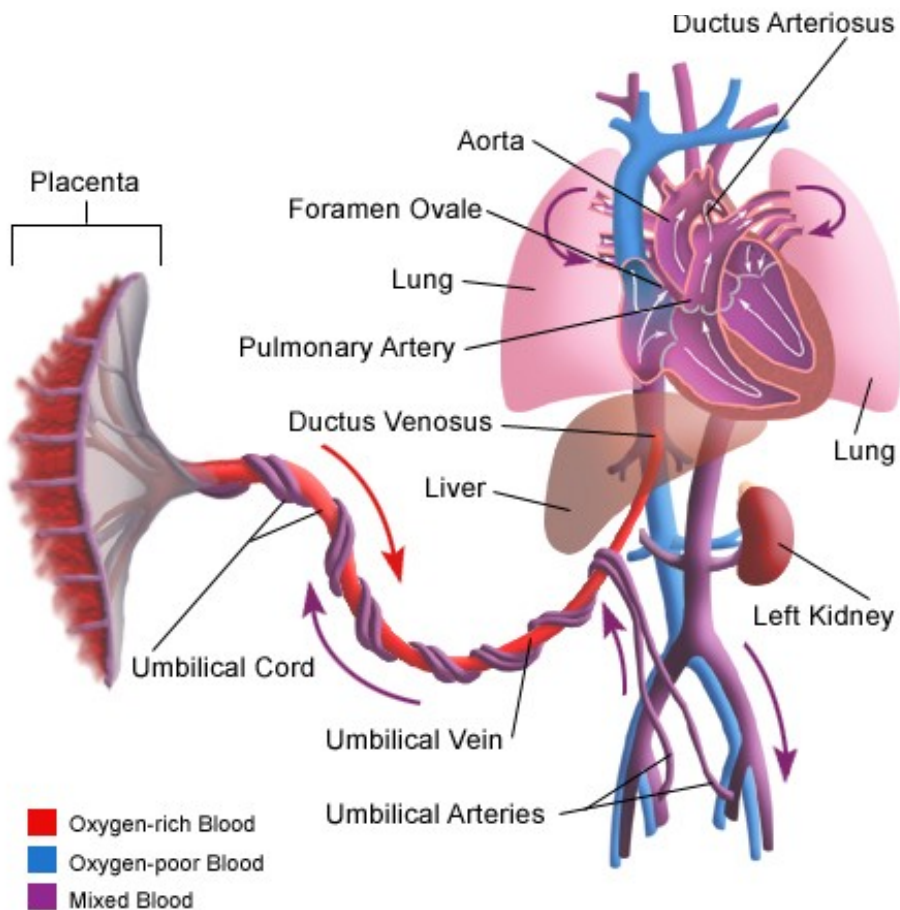


Embryonální oběh

Fetální oběh



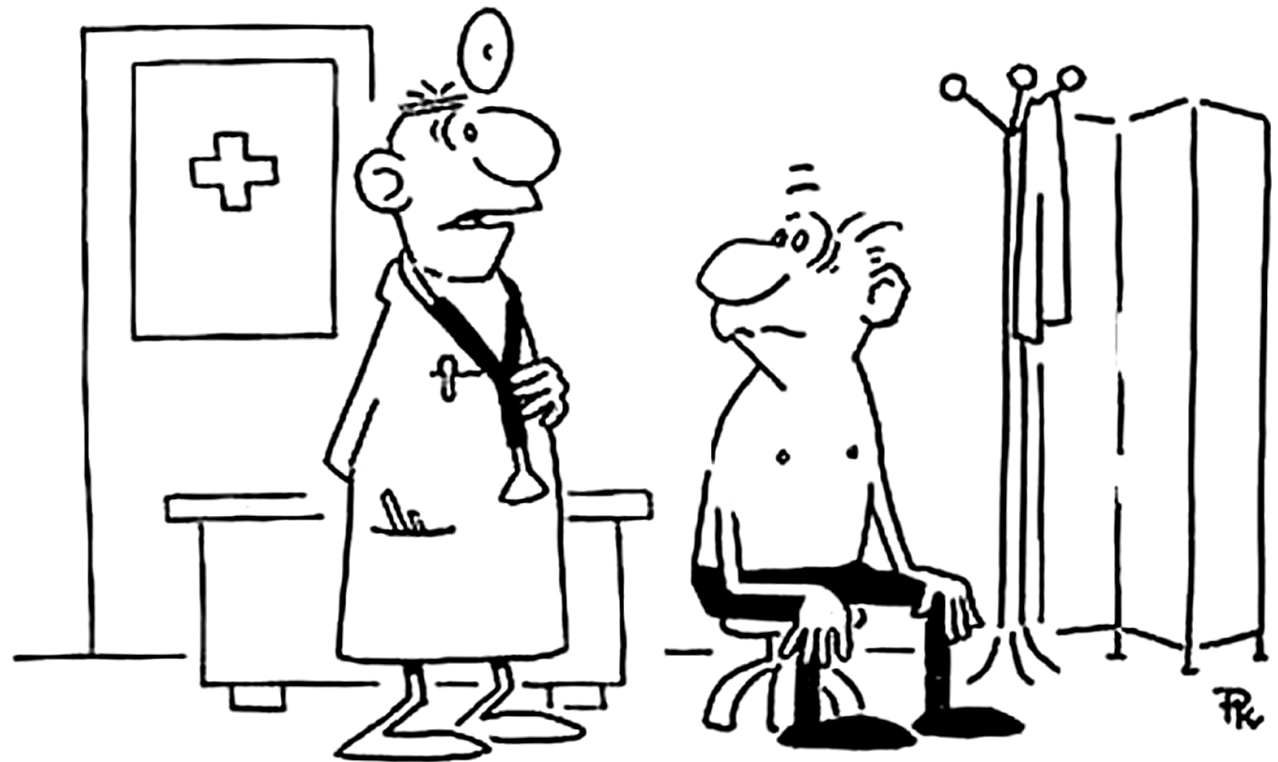
Fetální oběh



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Postnatální oběh

Děkuji za pozornost



"No, já bych začal tou dobrou zprávou. Bude se o vás psát v lékařských sbornících."