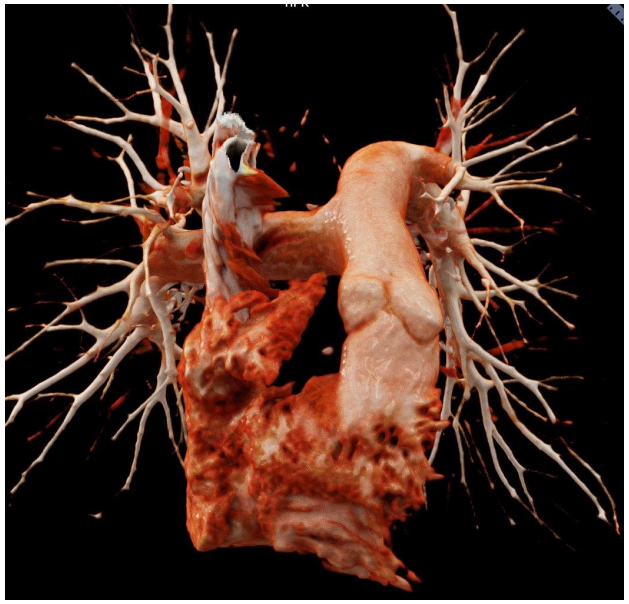
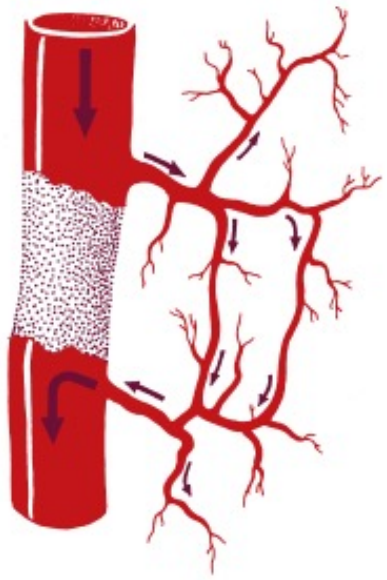
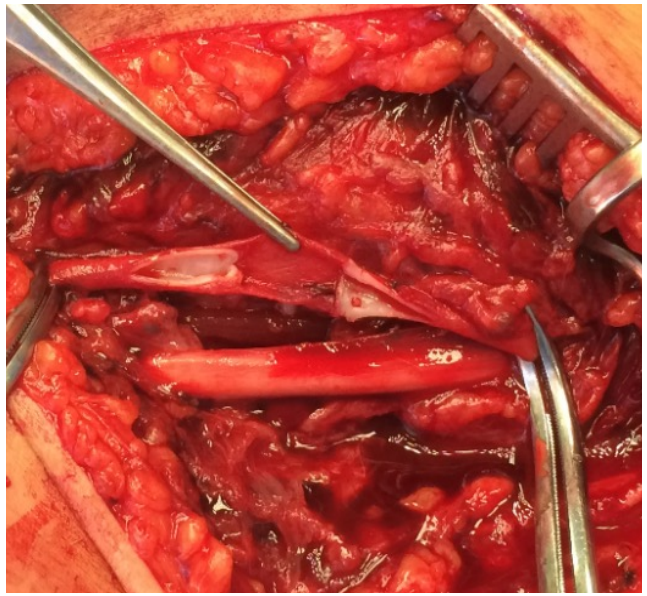
General anatomy – circulation of fluids



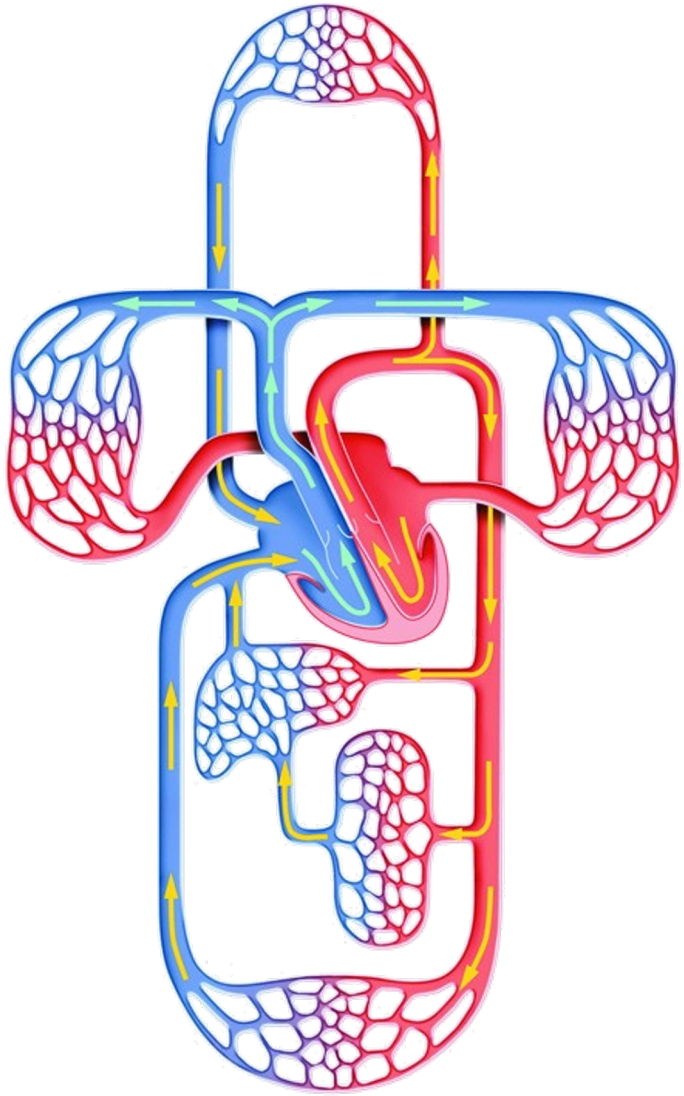




Prof. MUDr. Jiří FERDA, Ph.D.

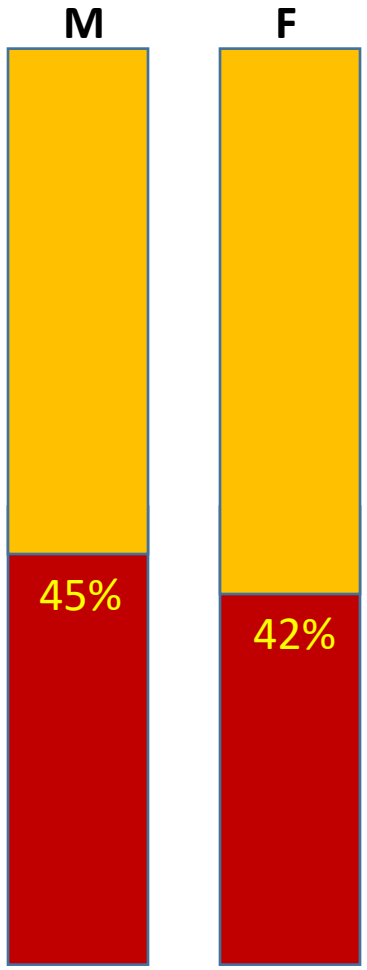
General anatomy – circulation of fluids

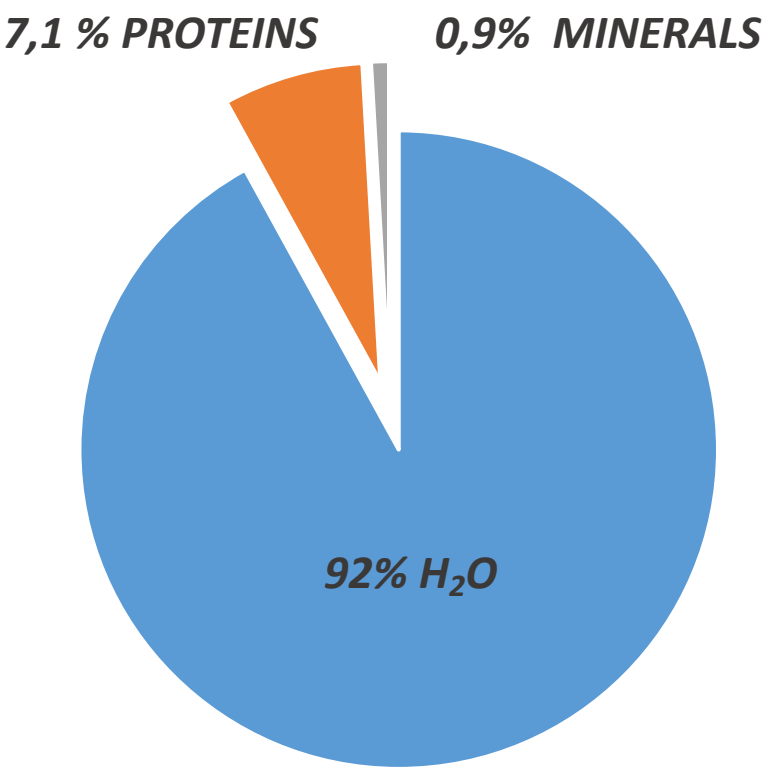
- **CIRCULATION OF THE BODY FLUID**
  - **BLOOD – sanguis**
    - *Ciculates in the closed system*
    - *Blood elements*
    - *Blood plasma*
  - **LYMPHA – lympha**
    - *Taken from intercellular fissures*
    - *Flows through the sysem of the lymphatic vessels*
    - *Ingflow to the blood system at two points*
- **FUNCTION OF THE CIRCULATORY SYSTEM**
  - *Transportation*
  - *Regulation of the body temperature*
  - *Turgor of tissues*



Blood - sanguis

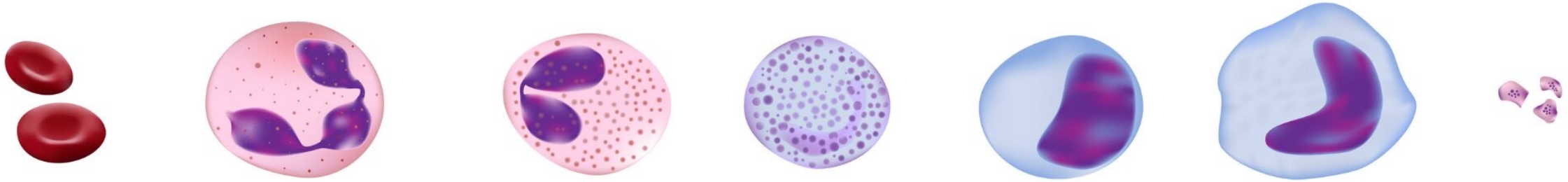
- **blood**
  - *5 titres, 6 % body weight*
- **corpuscula sanguinis**
  - *males* *44-46 %*
  - *females* *41-42 %*
- **plasma sanguinis**
  - ***H_2O*** ***92 %***
  - ***proteins*** ***7,1 %***
    - *albumin* *4,1 %*
    - *globulins* *2,7 %*
    - *fibrinogen* *0,27 %*
  - ***elektrolytes (salts)*** ***0,9 %***
  - ***other*** ***0,0…1 %***
- ***Blood serum – plasma without fibrinogen***





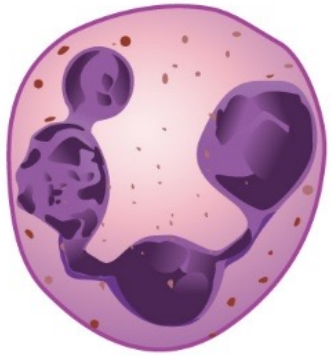
Blood corpuscles

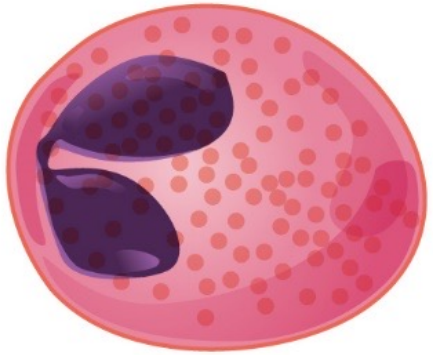
- **erythrocytes** — **4,3 – 5,3 x 10^6 / 1 mm^3**
  - *7,2 x 2,5* µm
- **leukocytes** — **4,0 – 10,0 x 10^3 / 1 mm^3**
  1. *neutrofilic granulocytes* — *60 – 70 %*
  2. *eosinofilic granulocytes* — *3 -5 %*
  3. *basofilic granulocytes* — *0,5 -1 %*
  4. *lymphocytes* — *15 – 40%*
  5. *monocytes* — *5 %*
- **thrombocytes** — **150 - 400 x 10^3 / 1 mm^3**

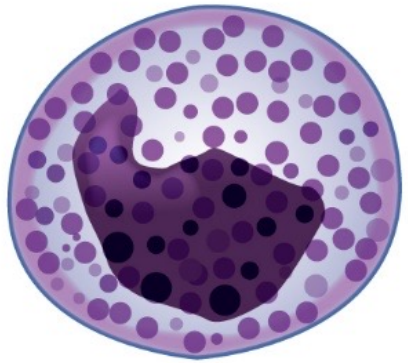


Leucocytes

- **granulocytes**
  - **neutrofilic**
    - *fagocytose, peroxidase*
  - **eosinofilic**
    - *parazitic diseases*
    - *allergic diseases*
  - **basofilic**
    - *histamine, heparin*
    - *Prezenttion of the antigen*
- **monocytes**
  - *Cellular immunity – macrophages - retikuloendothelial system*
- **lymphocytes**
  - **B-lymfocytes – bursa abdominalis – humoral immunity**
  - **T-lymfocytes - CD4 - helpers, CD8 – cytotoxic, γδ-T-lymphocytes**
  - **NK – natural killers**

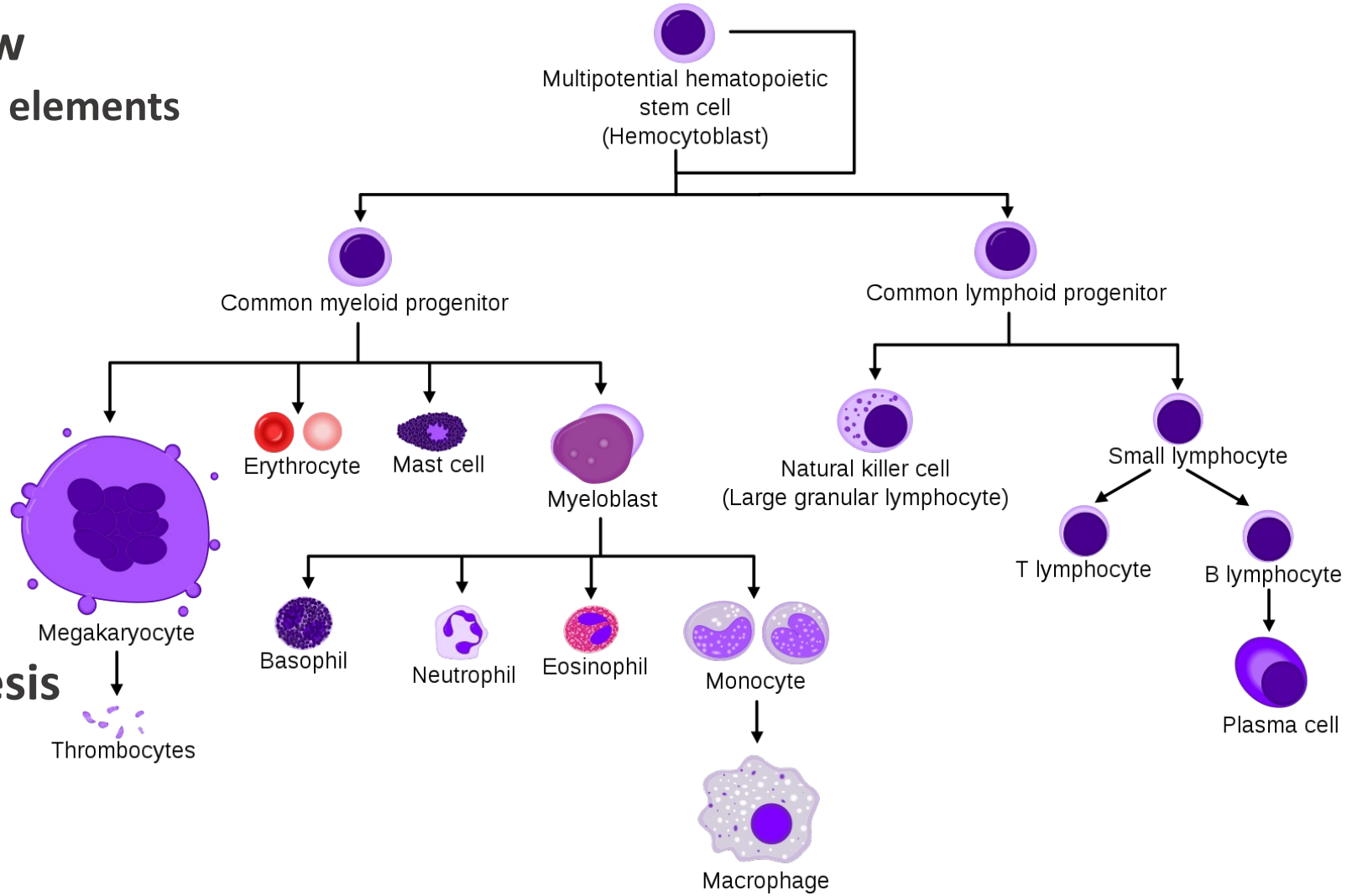






Bone marrow

- Hematopoetic bone marrow
  - Cellular precursors of blood elements
  - megakaryocyes
  - large capillaries - sinusoids
- newborn
- childhood
- adulthood
- Activated hematopoesis
  - Bone marrow
- Extramedullary hematopoesis
  - liver
  - spleen
  - retroperitoneum



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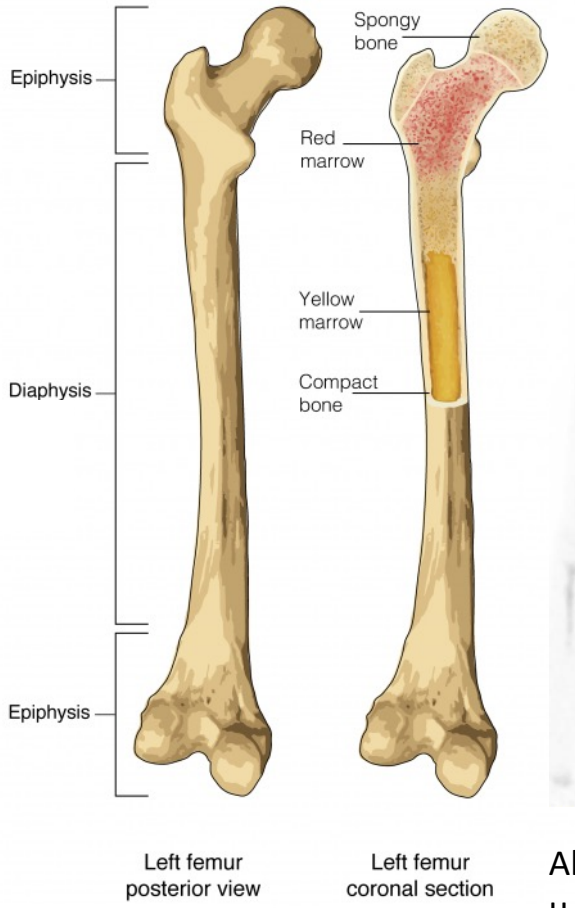
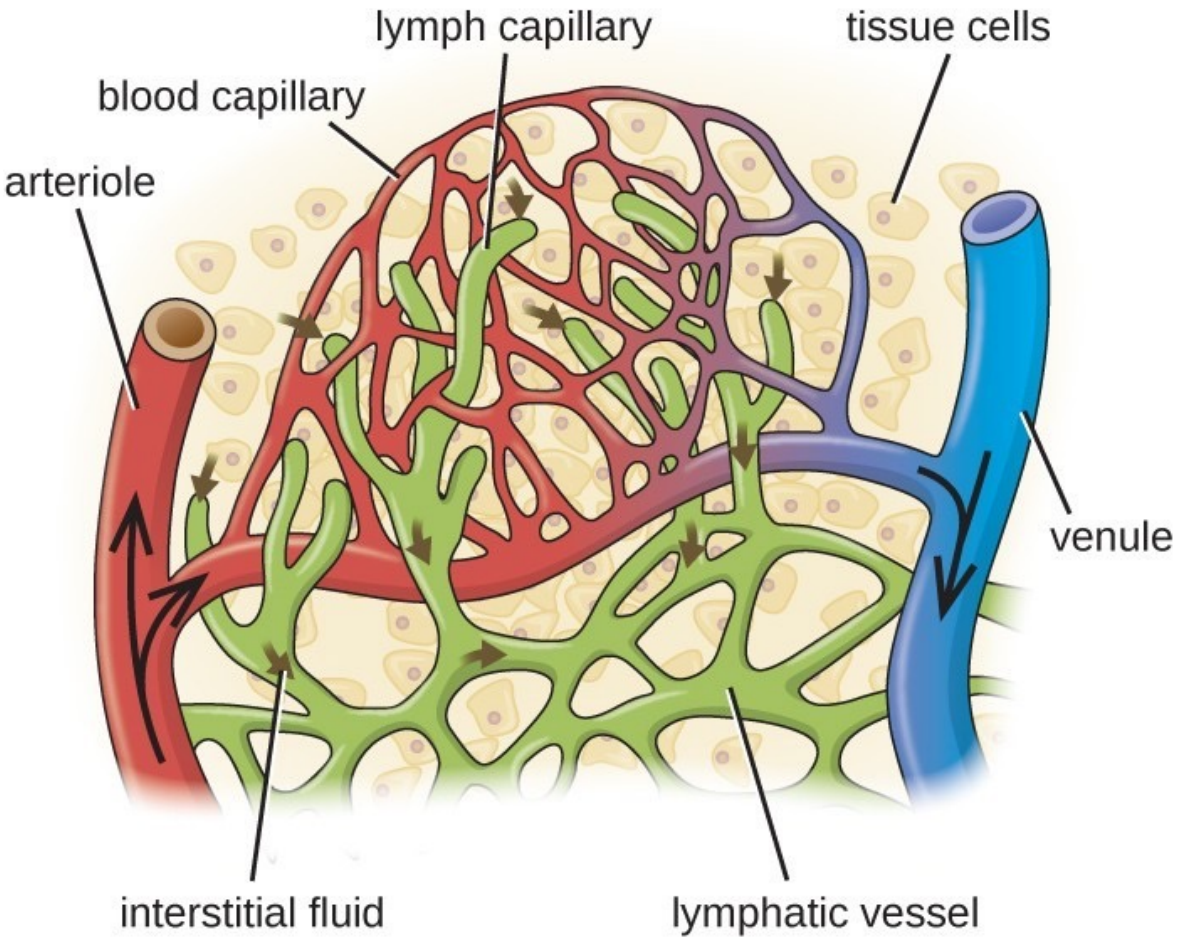
https://open.oregonstate.education/aandp/chapter/6-1-the-functions-of-the-skeletal-system/



Aktivní červená kostní dřeň u adolescenta – ^{18}F-FLT-PET

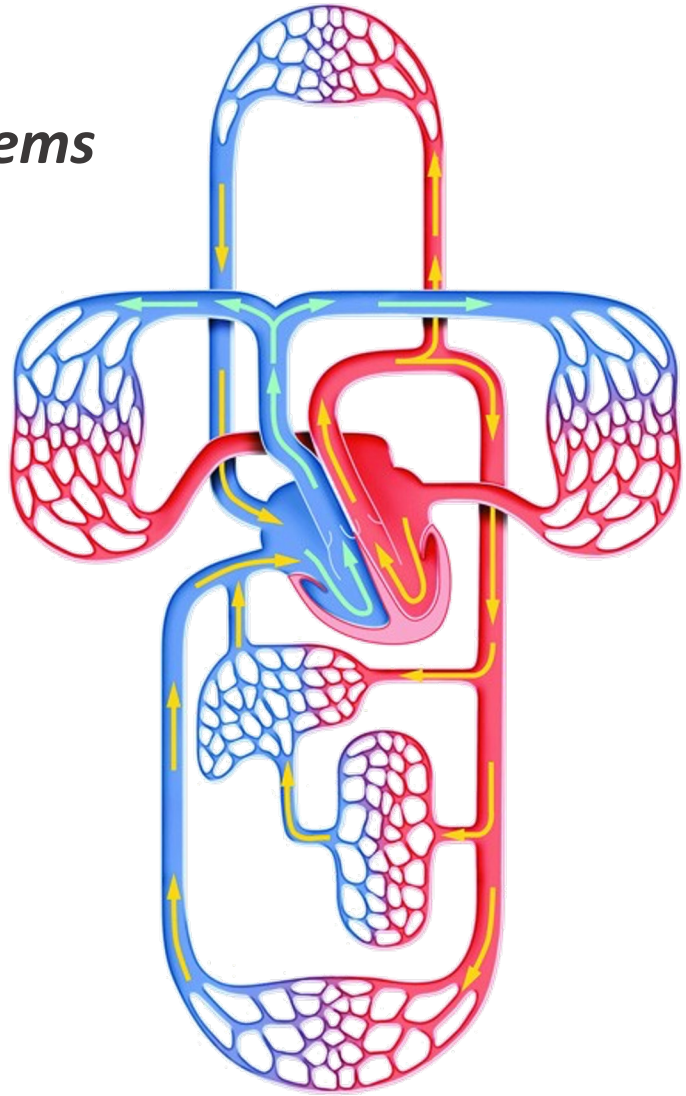
Angiology

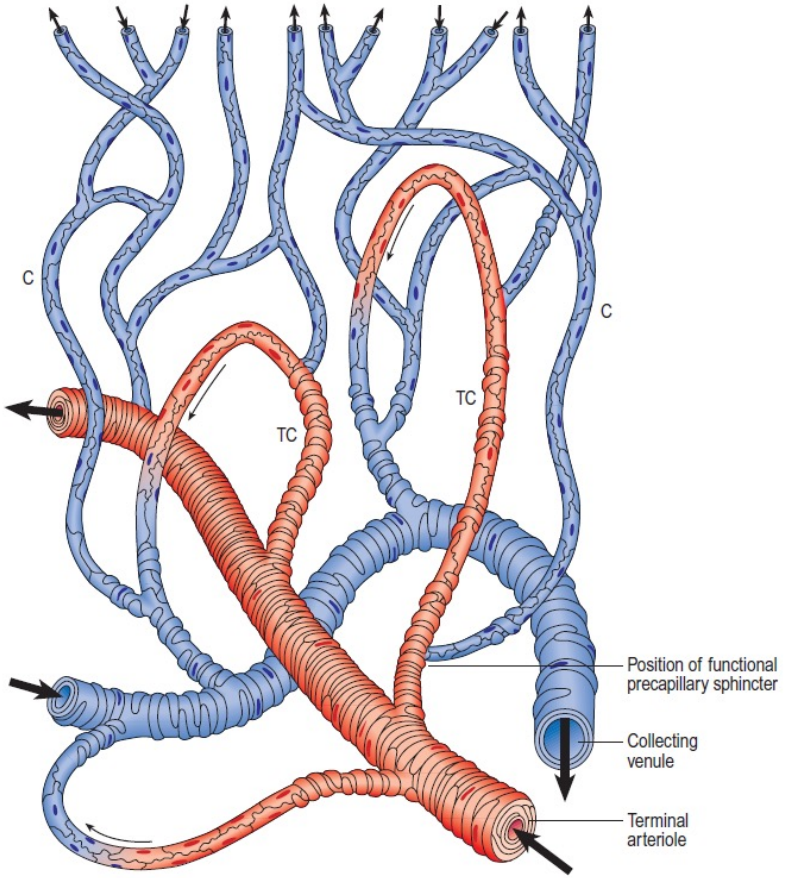
- **Blood system – systema sanguinis**
  - *Blood – sanguis*
  - *Heart – cor*
  - *arteries – arteriae*
  - *Capillaries - capillariae*
  - *Veins – venae*
- **Lymphatic system – systema lymphatica**
  - *Lympha*
  - *Lymphatic vessels – vasa lymphatica*
  - *Lymphatic nodes – nodi lymphatici*
  - *Lymphatic follicles – folliculi lymphatici*
  - *Tonsills - tonsillae*
  - *Spleen – lien (splen)*
  - *Thyme - thymus*



Blood circulation

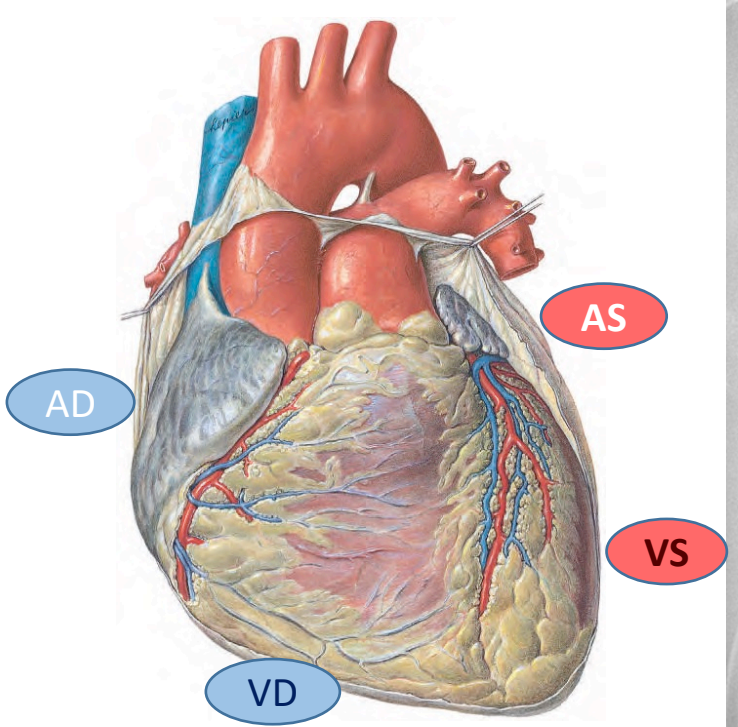
- **Makrocirculation**
- ***Blood supply to organ systems***
- ***Organ blood supply***
  - *Heart*
  - *Arteries*
  - *veins*
- **Mikrocirculation**
- ***Supply of the tissues***
- ***Perfusion***
- ***Tissue functions***
  - *Arterioles*
  - *Capillaries*
  - *Venules*





Heart - cor

- hollow muscular organ localized in mediastinum
- PAIRED MUSCULAR PUMP
- Endocardium
  - valves
- Myocardium
  - Working myocardium
  - Conduction system
- Epicardium
  - Epicardial fatty tissue
  - Cardiac vessels
- Pericardium
  - Pericardial sac
- Blood vessels, lymphatic vessels and nerves



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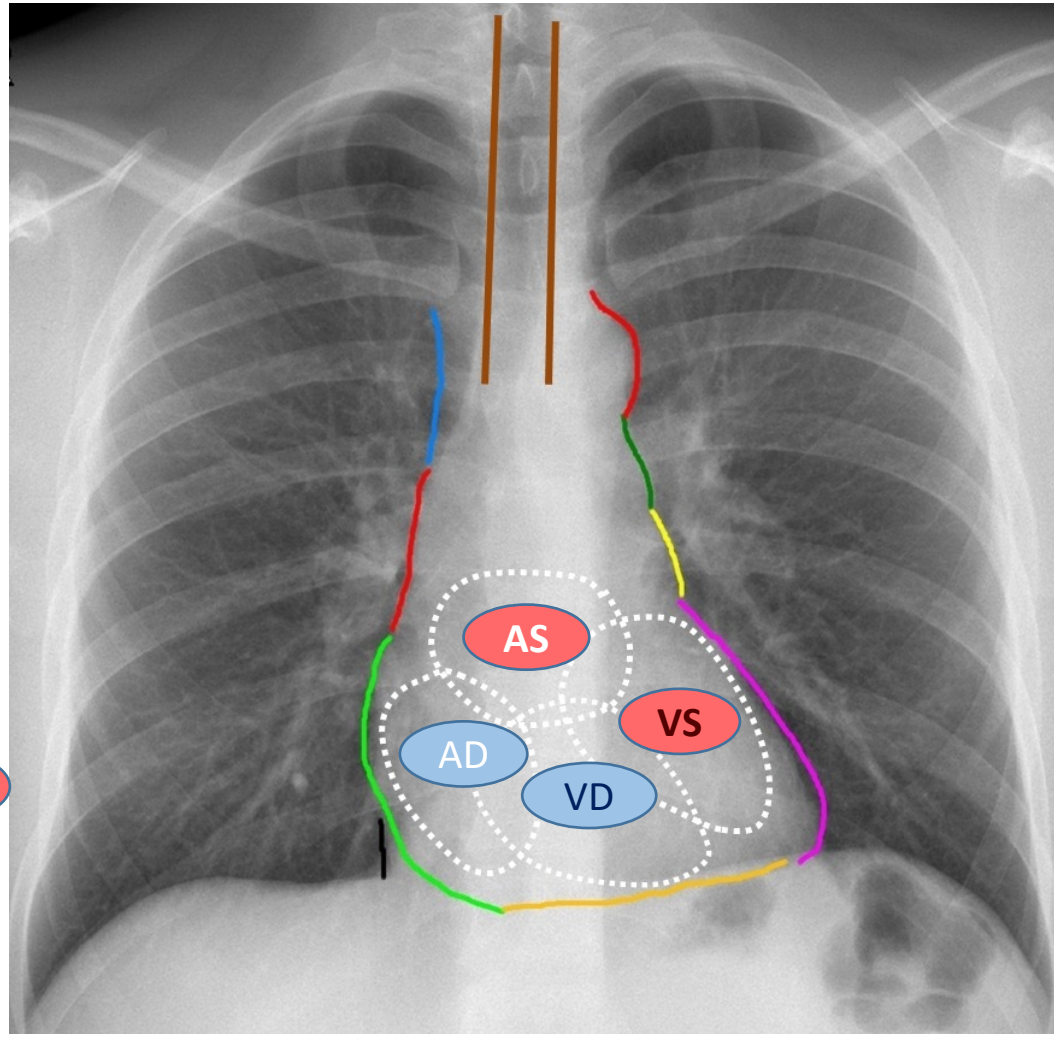
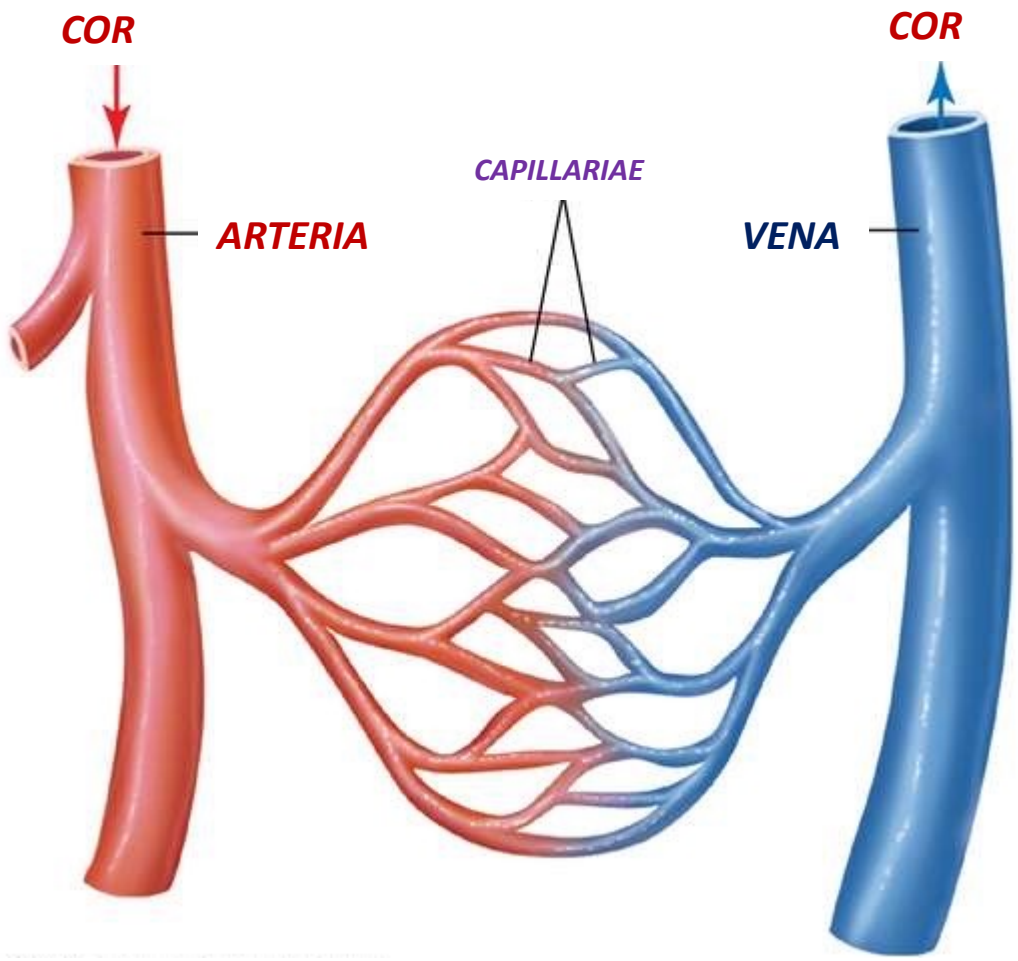
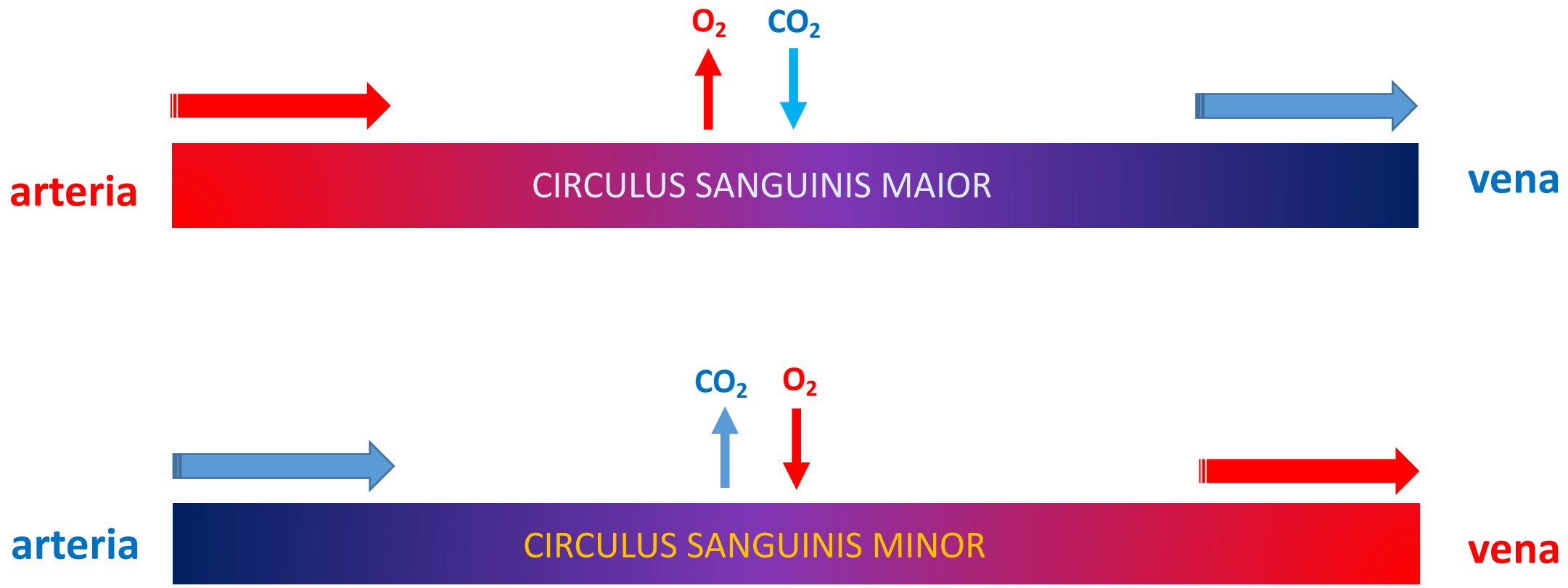


Blood vessels – vasa sanguinis

- **Arteriae – aer-terein – lead the air**
  - **Leading blood from the heart**
  - **High-pressure vessels**
  - Empty in the dead body
    - *Blood pushed out to veins*
  - The wall thicker than venous
  - Less compressible
  - Bright blood - jetting
- **Venae**
  - **Leading blood to the heart**
  - **Low-pressure vessels**
  - Filled in the dead body
  - Wall thinner
  - Easily compressible
  - Dark blood – flowing out



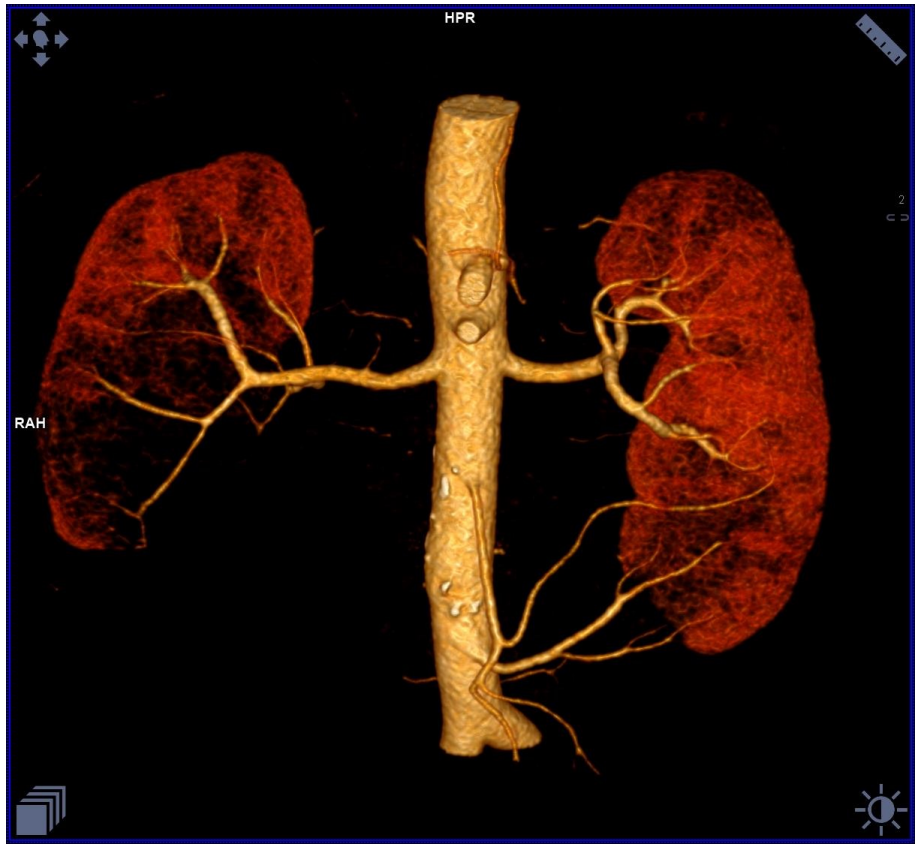
circulation



Organ blood supply

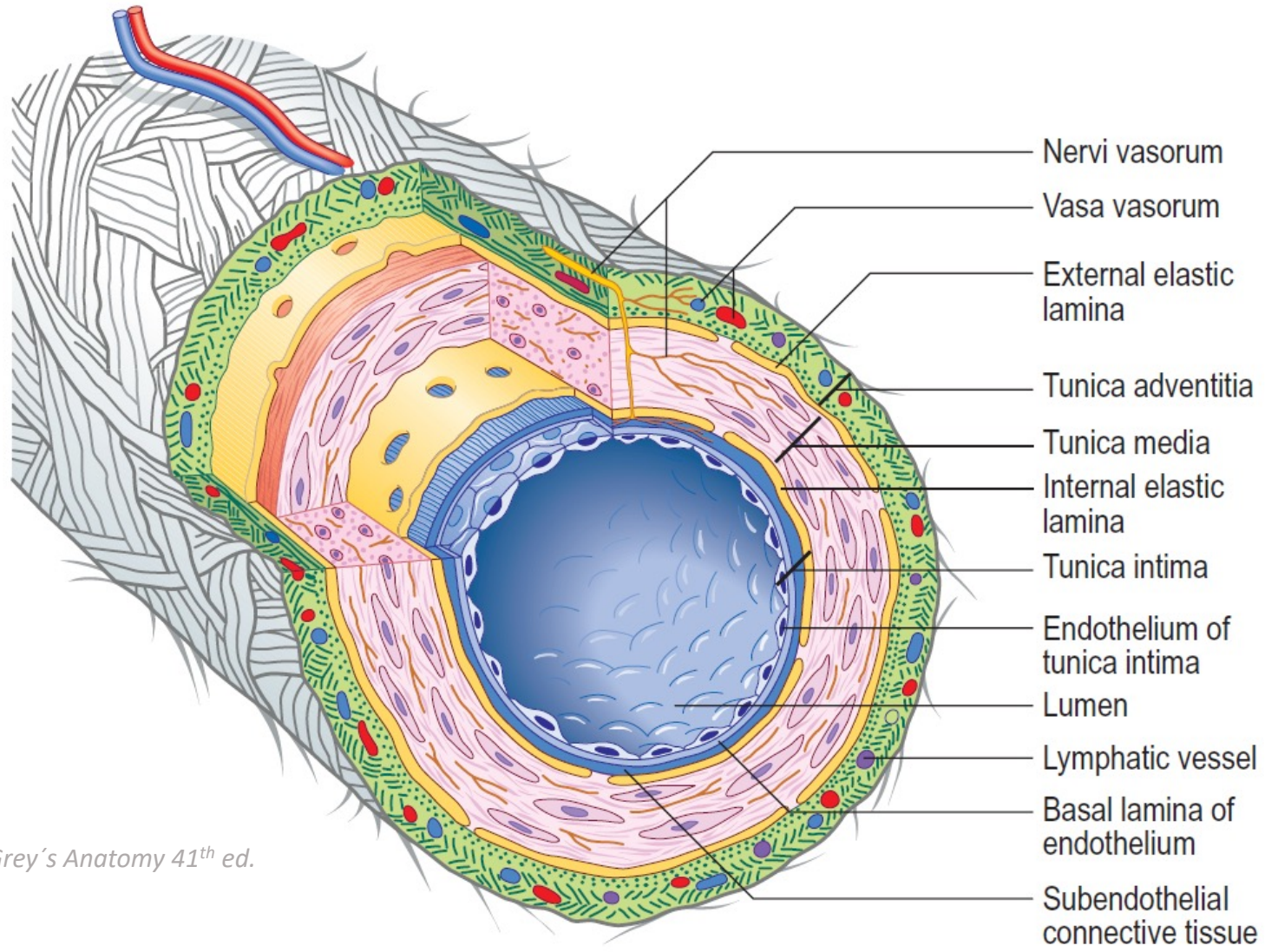
- **Typical and atypical blood supply**
- *Variability*
- *Adaptation*
- *Anomalia*

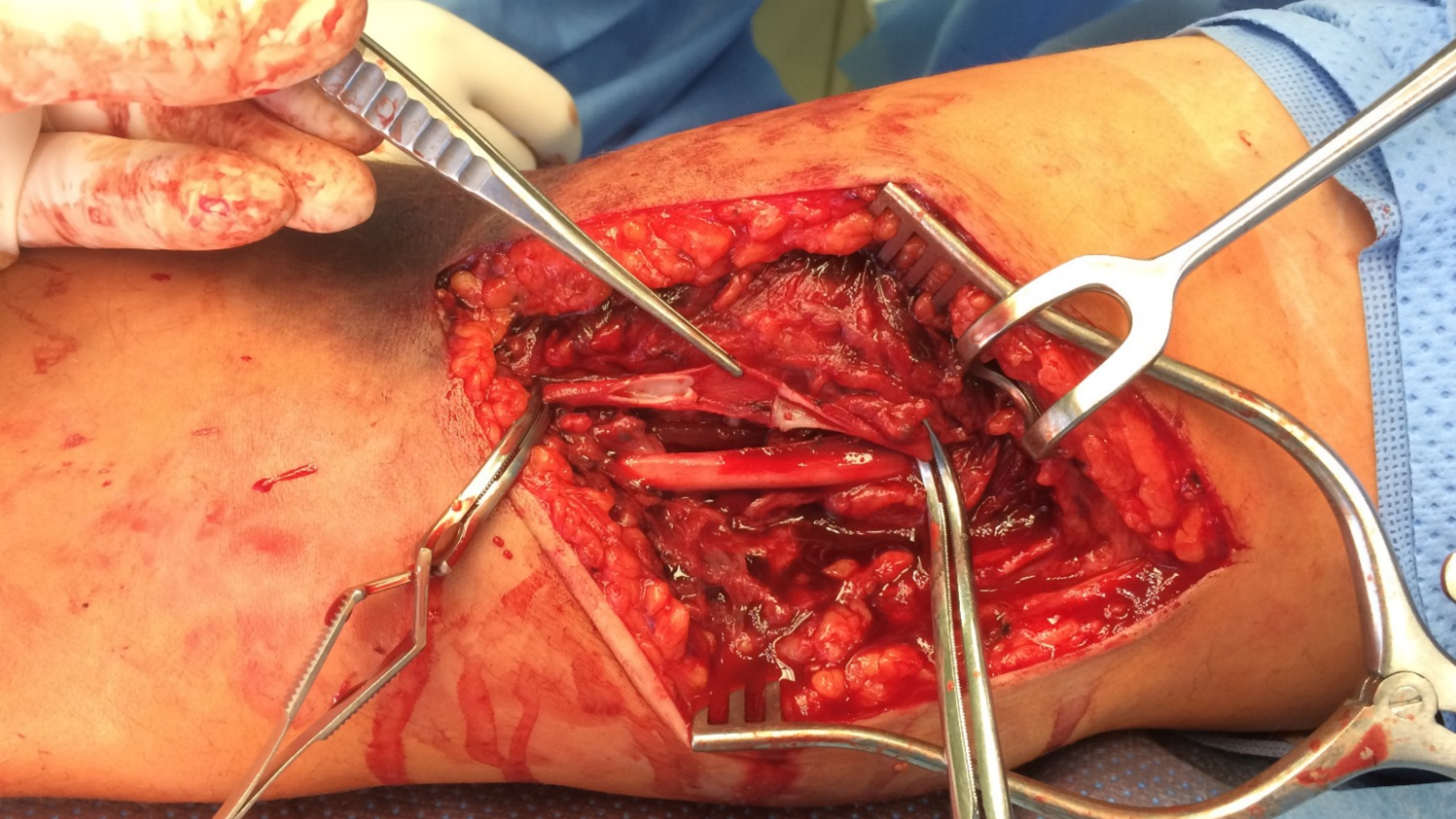
- **Arteries**
- **Veins**
- **Dual supply**
  - **Lungs**
  - **Portal systems**
  - *Hypophysis*
  - *Liver*



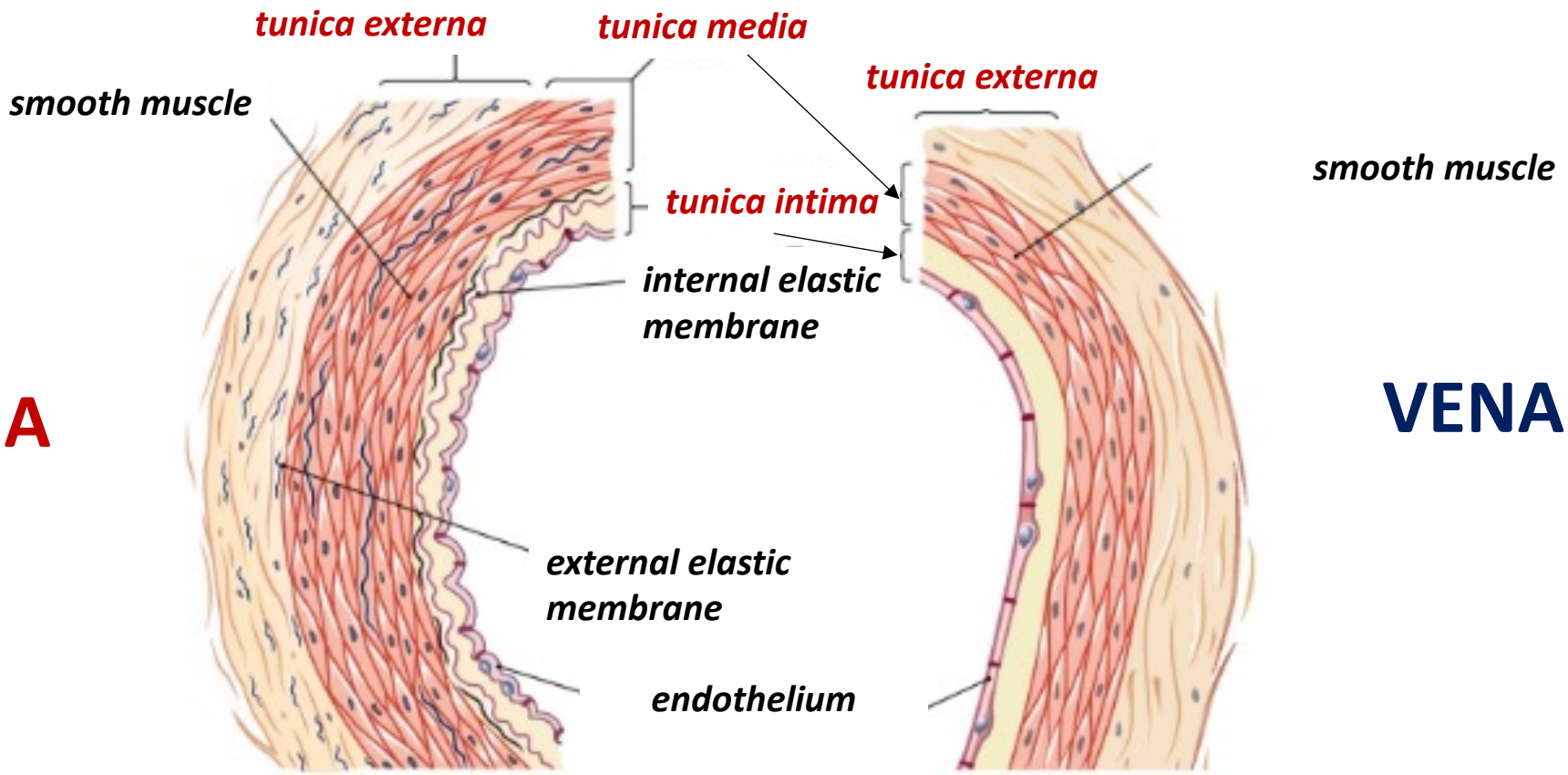
Wall of the blood vessel

- **Mesodermal origin**
- **tunica intima**
  - *endothelium*
  - *basal membrane*
  - *Subendothelial connective tissue*
  - *membrana (lamina) elastica interna*
- **tunica media**
  - *Smooth muscle*
  - *ending nervi vasorum*
  - *membrana (lamina) elastica externa*
- **tunica adventitia**
  - *nervi vasorum*
  - *vasa vasorum*
  - *vasa lymphatica vasorum*





Layers

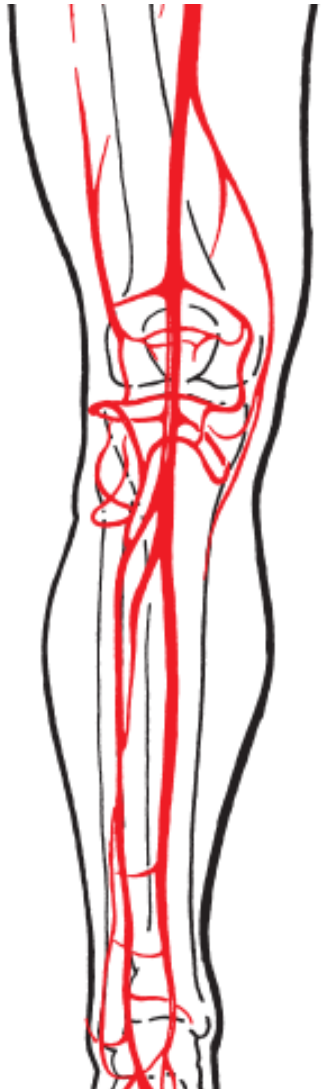


ARTERIA

VENA

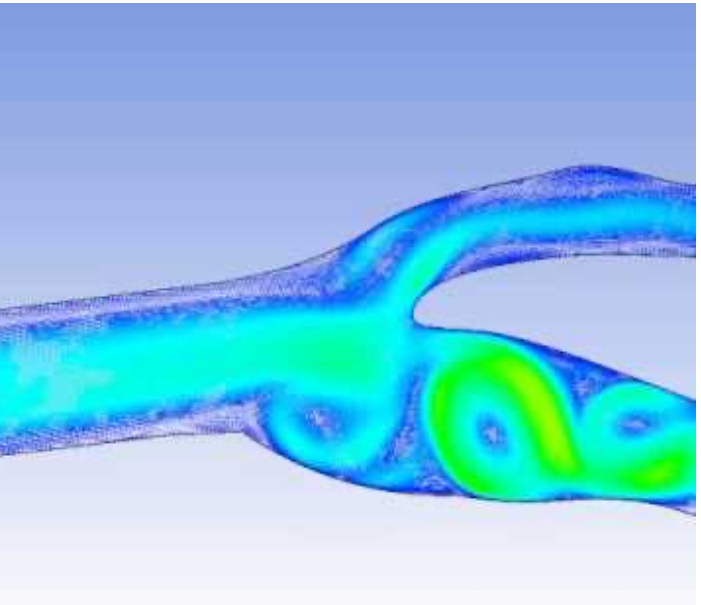
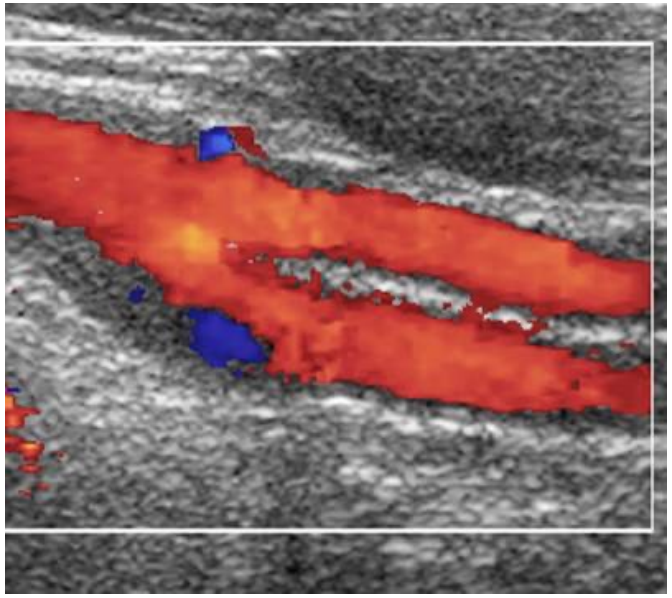
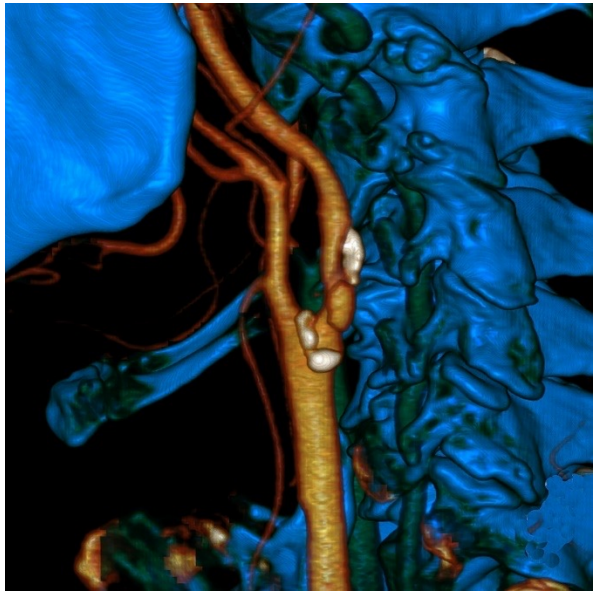
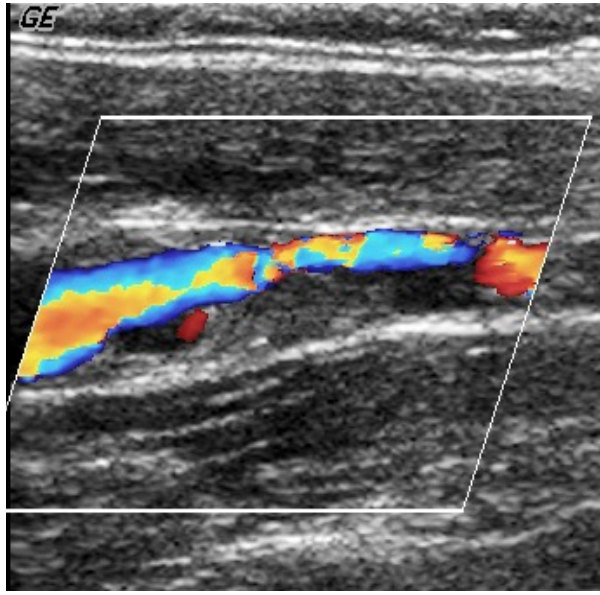
Arteries

- **Truncus pulmonalis and braches**
  - Deoxygenated blood
  - **Arteria pulmonalis dextra et sinistra**
  - *Lobar, segmental and subsegmental branches*
- **Aorta and its branches**
  - Oxygenated blood
  - **30 mm diameter, area 7 cm²**
  - *Subsequent branching to 4 x 10^6 arterioles*
  - *area of arteriole 10 µm*
  - *Total area of diameters of all arterioles 150 cm^2*
  - *Flow velocity decreasing from aorta to capillaries*
  - *Number of capillaries 16 x 10^6*



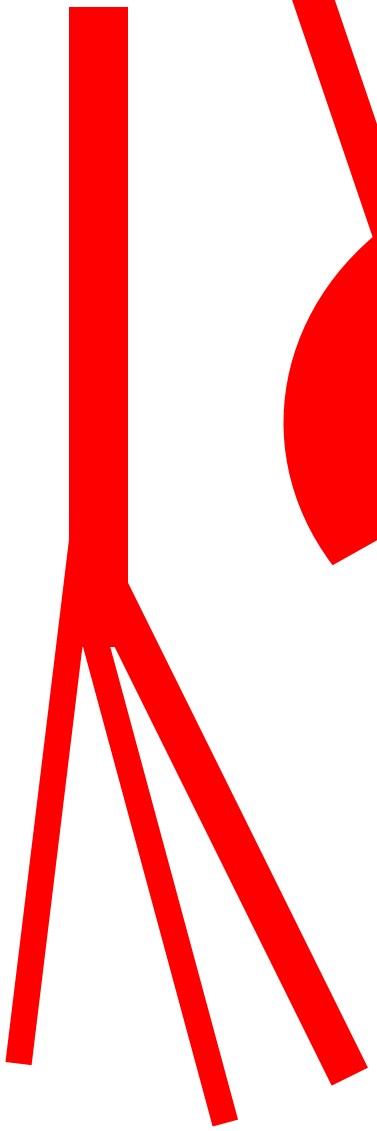
Branching, flow

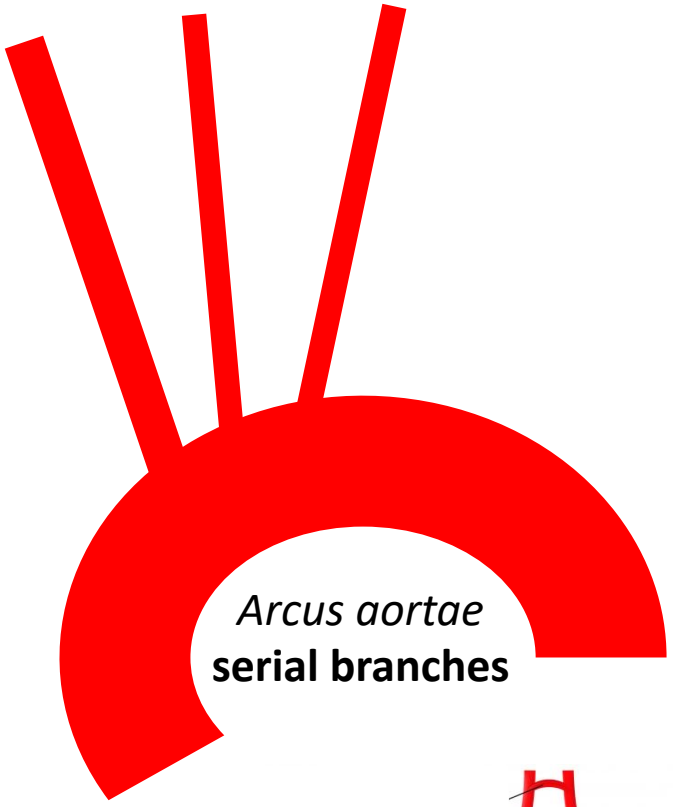
- **Arterial arch, serpentinous, branching –** *laminary, turbulent flow, jetting*
- **Geometrical ways of branching**
  - *Bifurcation*
  - *Trifurcation*
  - *Serial branching*
  - *Arcades*
  - *Anastomoses – circulus arteriosus, palma manus, planta pedis*

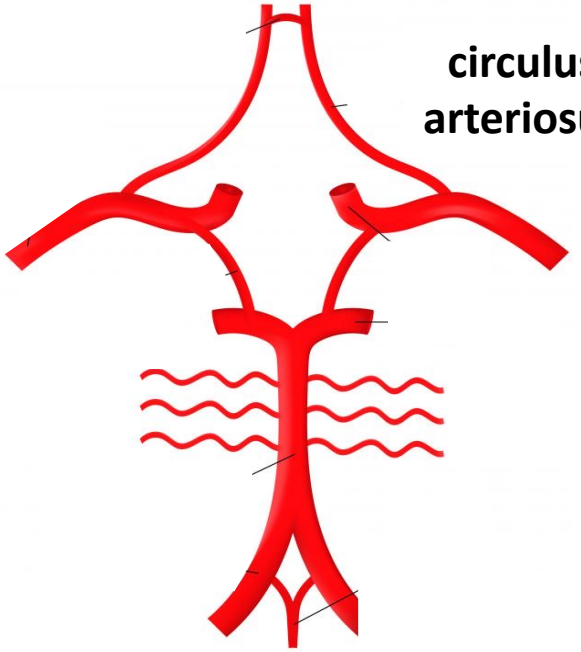
bifurcation
a. carotis communis

trifurcation
a. poplitea



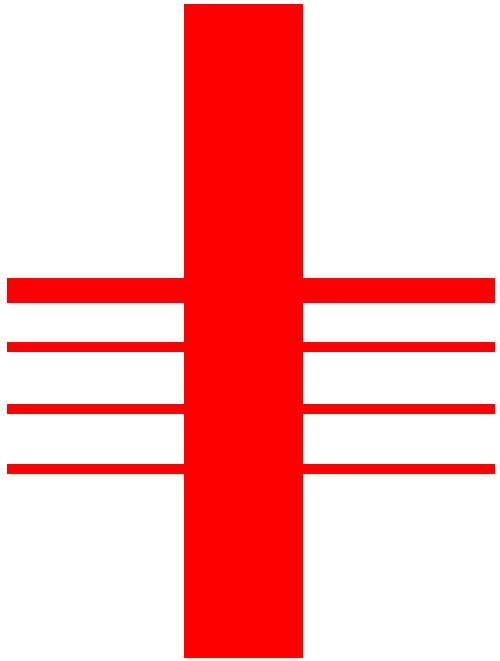


Arcus aortae
serial branches

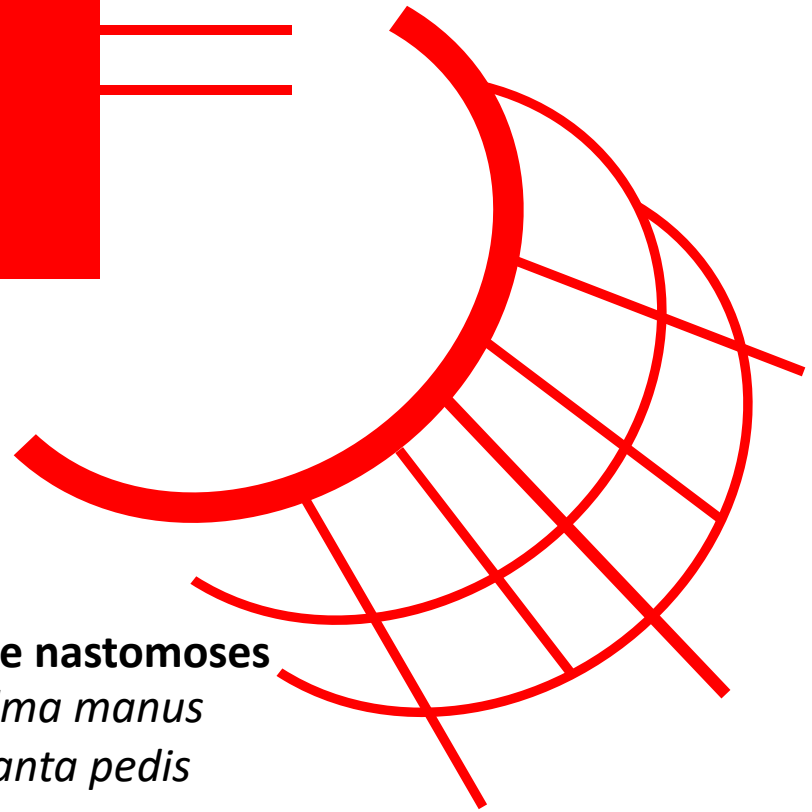


circulus arteriosus

paired branches
Aorta descendes et abdominalis



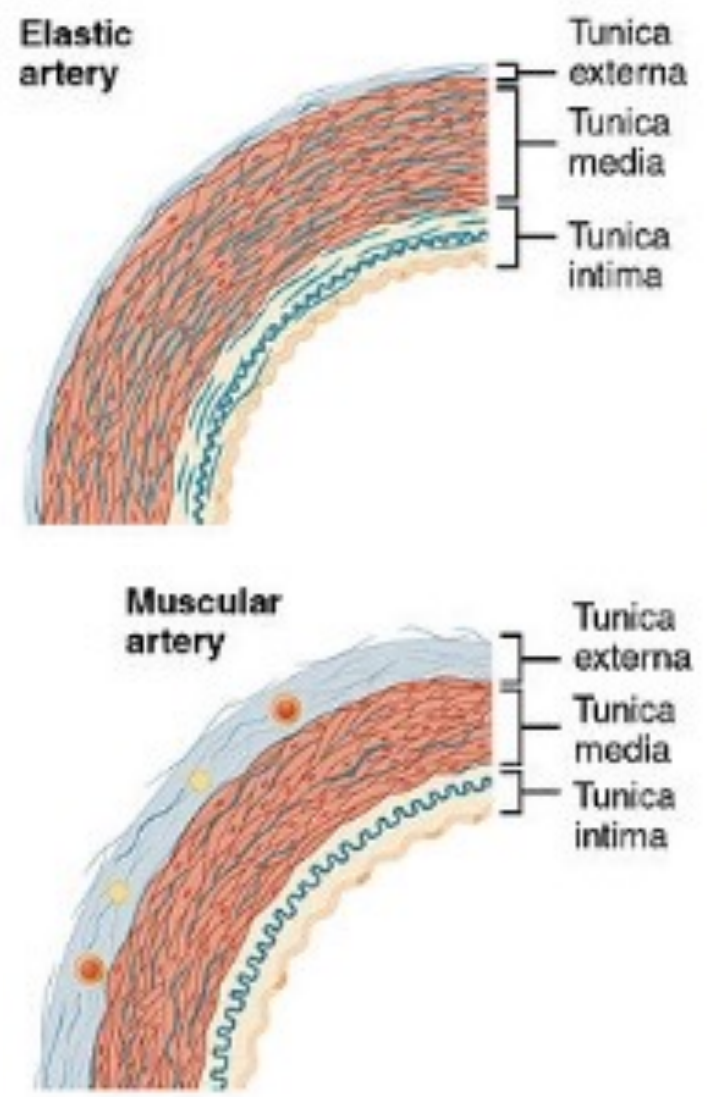
arcades
a. mesenterica superior



arcuate nastomoses
Palma manus
Planta pedis

Arterial wall

- **Increasing ratio of muscular layer**
  - *Large arteries 1/5 -1/15*
    - *Aorta descendens – diameter 17 mm - wall 1,1 mm*
  - *arterioles 1/2*
- **Large arteries of the elastic art**
  - ***Efect of the elasticity***
  - *Increased content of elastic connective tissue*
- **Arteries with the continual diastolic flow**
  - **Aa. carotides internae**
  - **Aa. renales**
- **Arteries of the muscular art**
  - **Flow regulation**
  - **The largest thicknes of the muscular layer**



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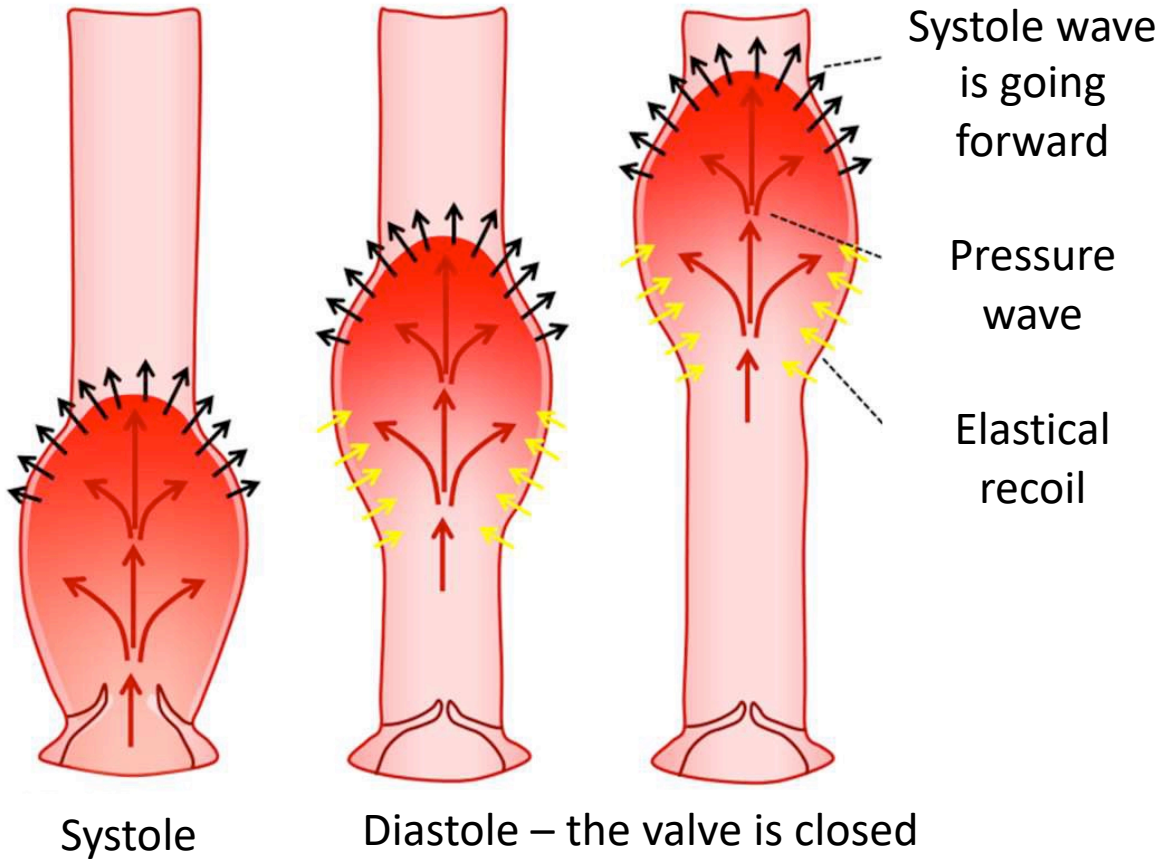
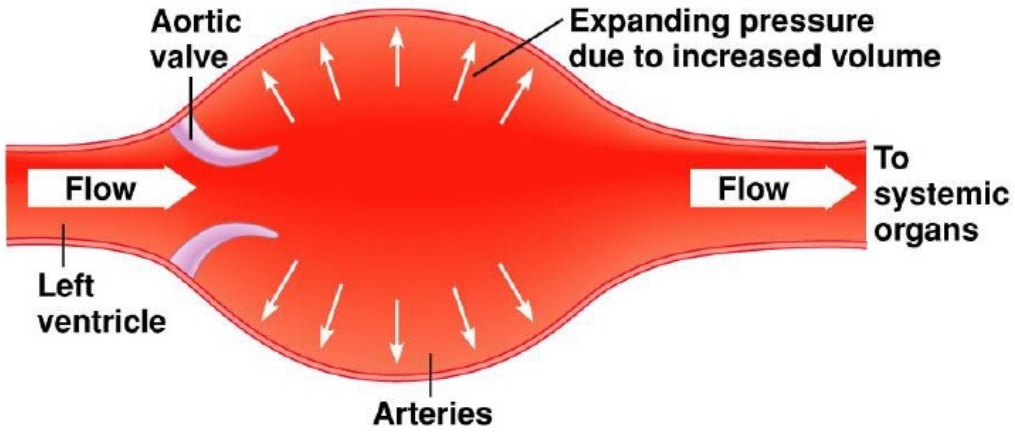
Flow - ellastical effect

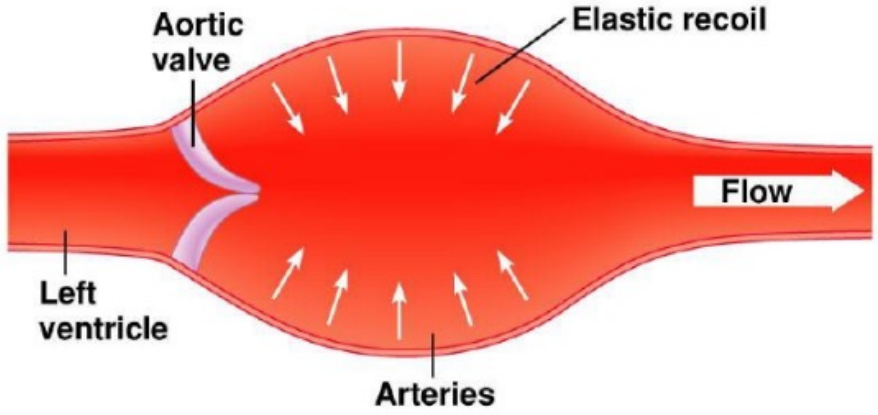
- **Pushing forward of the pulse wave**
  - *Large arteries*
- **Energy accumulation**
  - ***Elastic extension***
  - *Elastic deformation of hte wall*
  - *Energy transformation*
- **Energy release**
  - **Elastical passive contraction (recoil)**
  - **Luminal compression**
  - **Blood is pushed forward**
- **Puls wave**

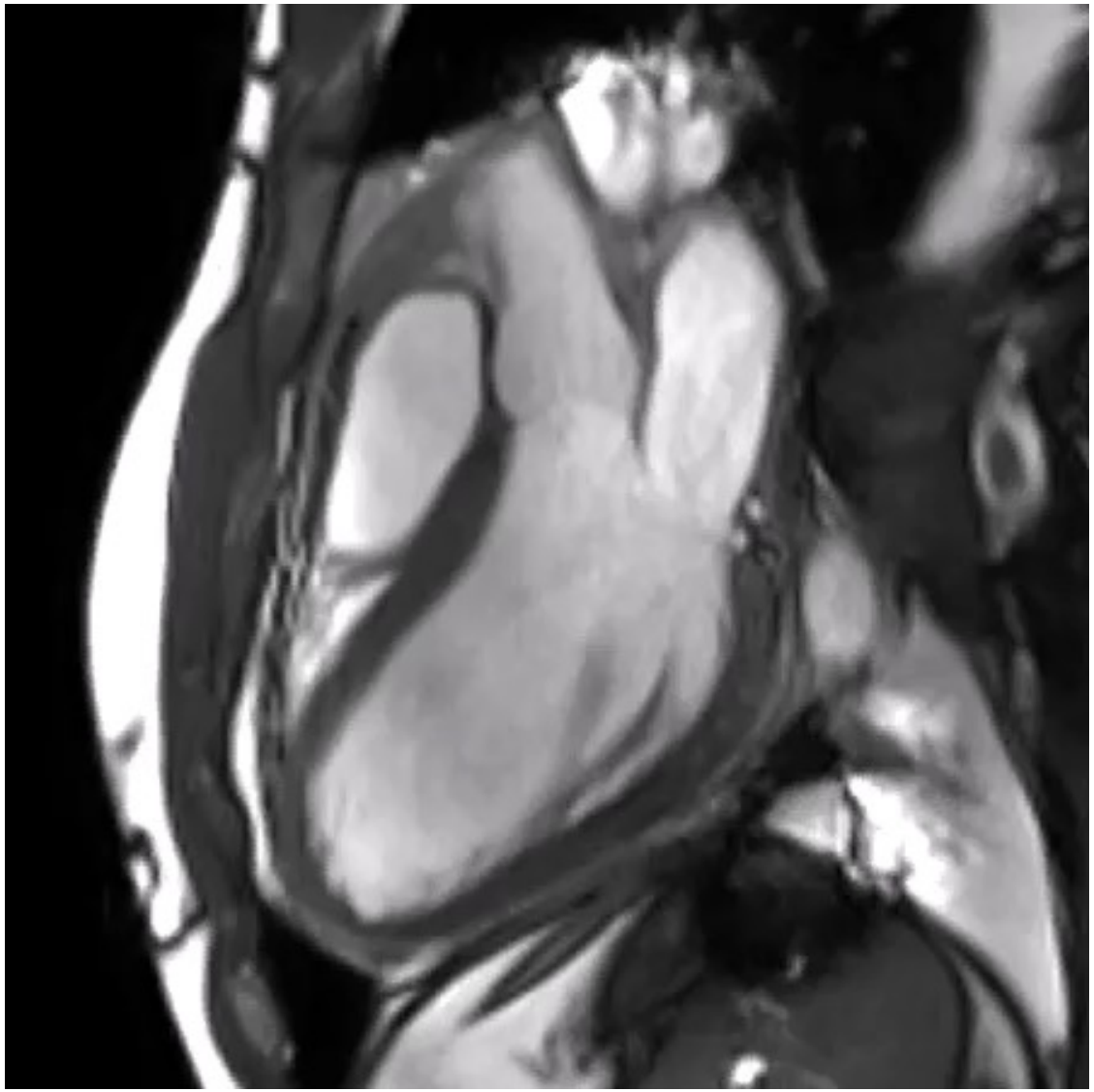


https://is.muni.cz/el/1431/jaro2017/Bi4182c/um/Matematicky_model_funkce_aorty.pdf

Puls wave

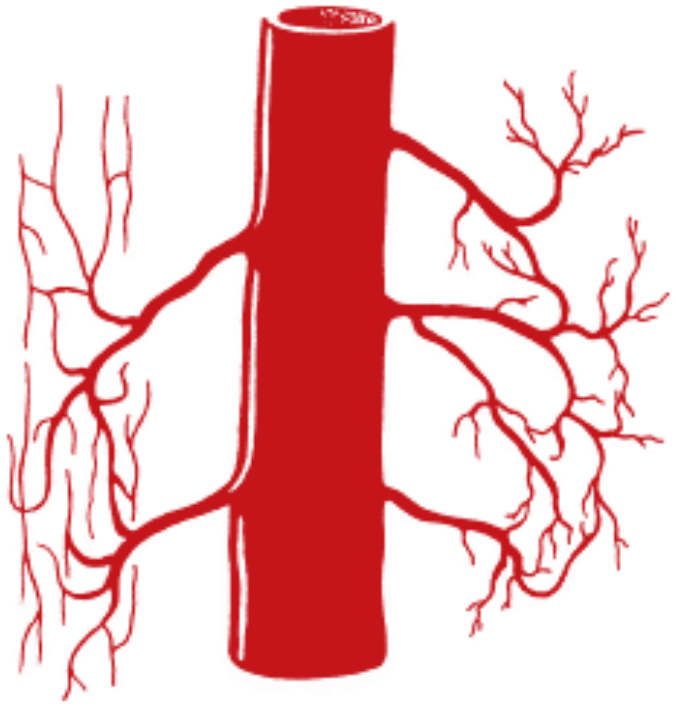






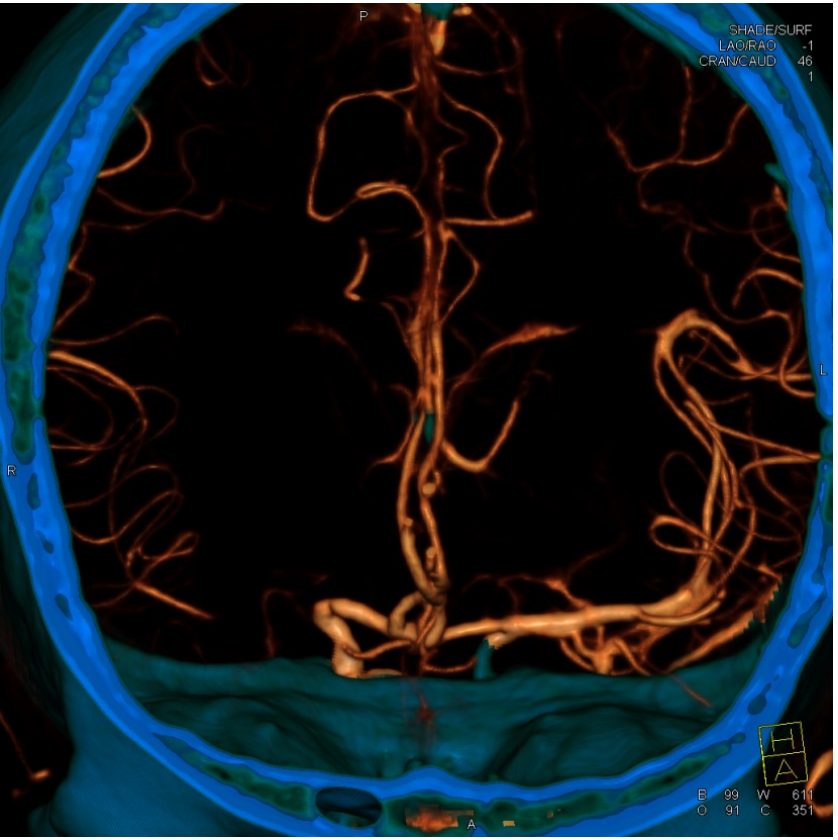
Vascular bed architecture

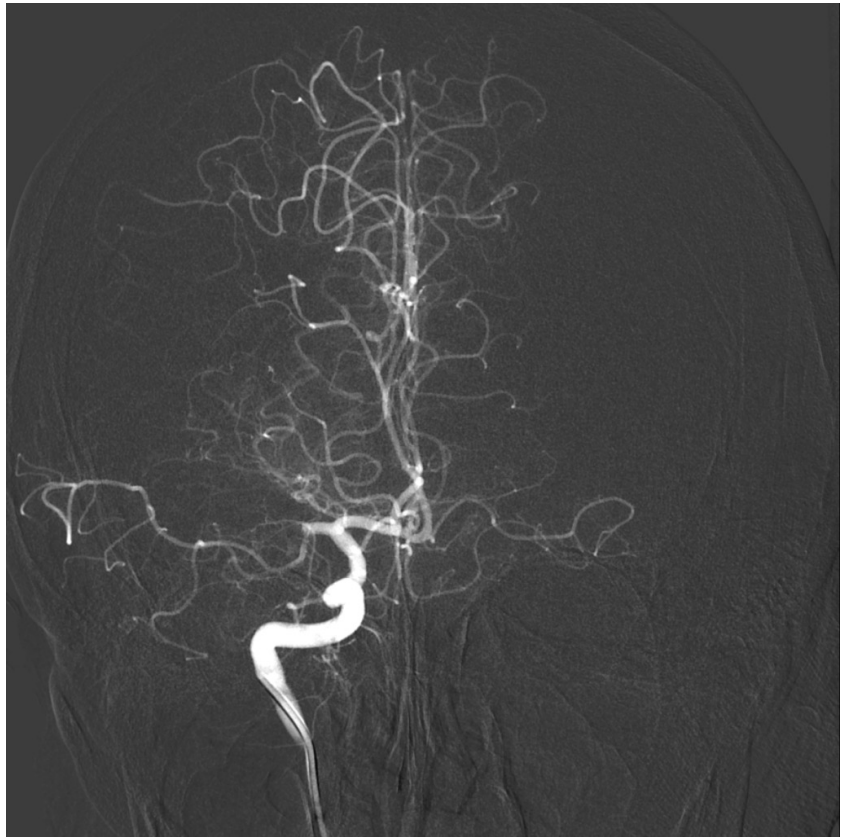
- Terminally ending– aa. renales, aa. pennicilatae
- Peripherally anastomosing – aa. cerebri, aa. coronariae
- Interterritorial anastomoses - aa. membri inferioris et superioris

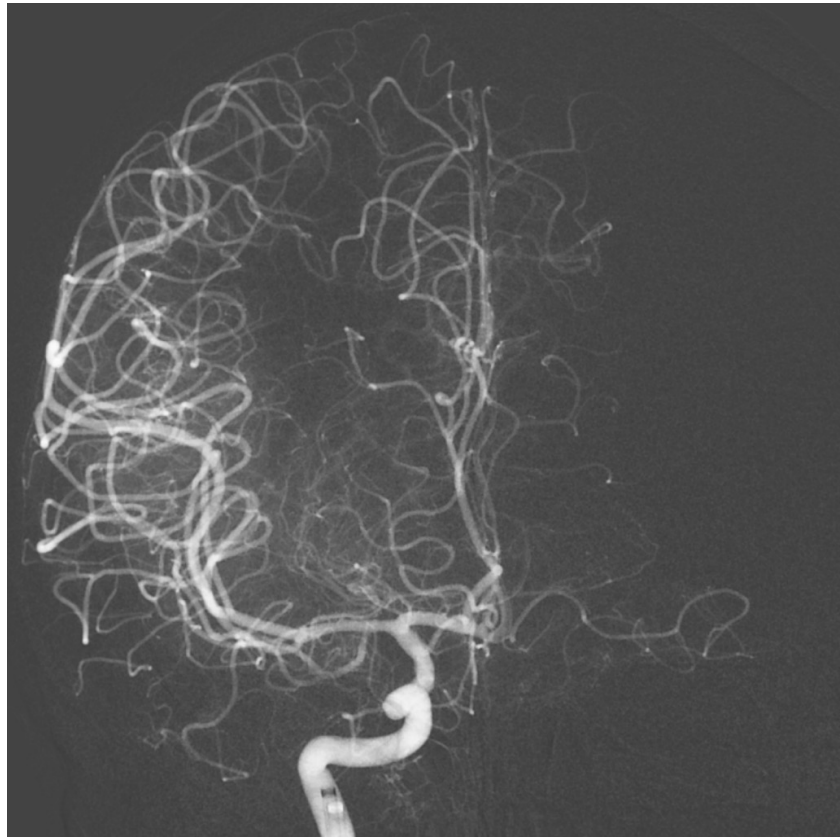


Ending arteries – functional ending arteries

- **existing rare peripheral anastomoses - collaterals**
  - Sudden occlusion - ischemia
  - Peripheral part of bed has tiny anastomoses – slowly developing occlusion - collaterals

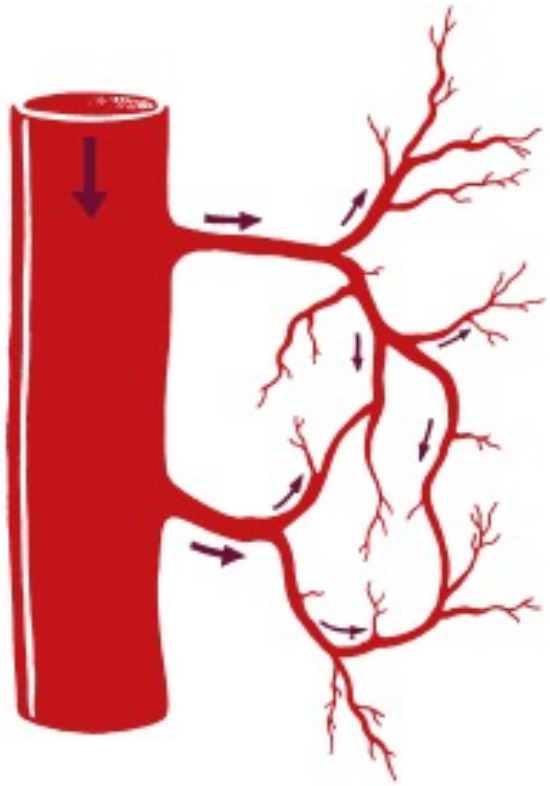


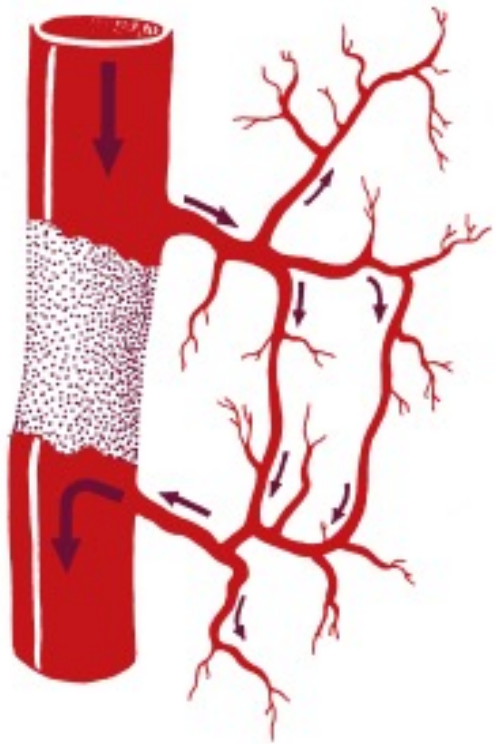


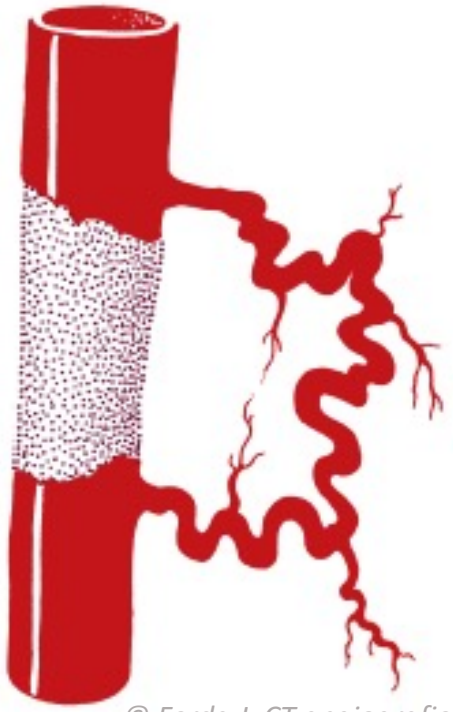


Collateral circulation

- **Preformated junction of vascular beds**
  - Decresed flow in main vessel
  - Dilatation of anastomoses
  - **When main vessel occluded, collaterals leading blood flow to periphery**

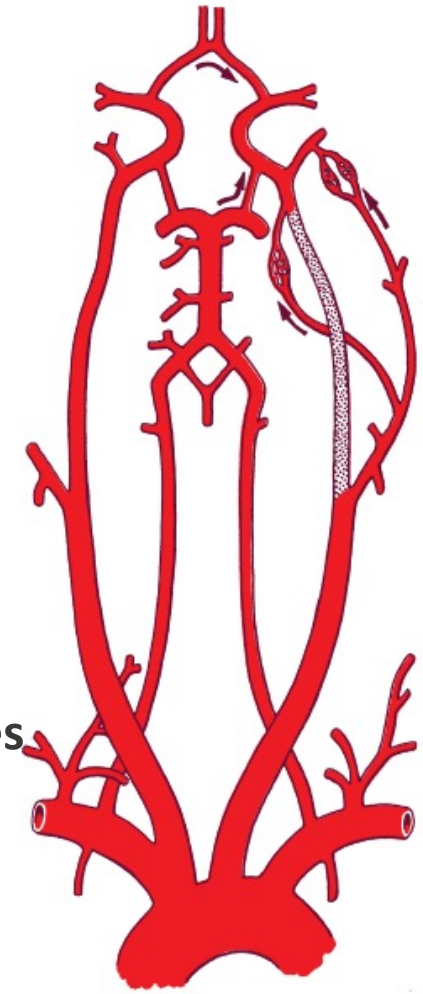


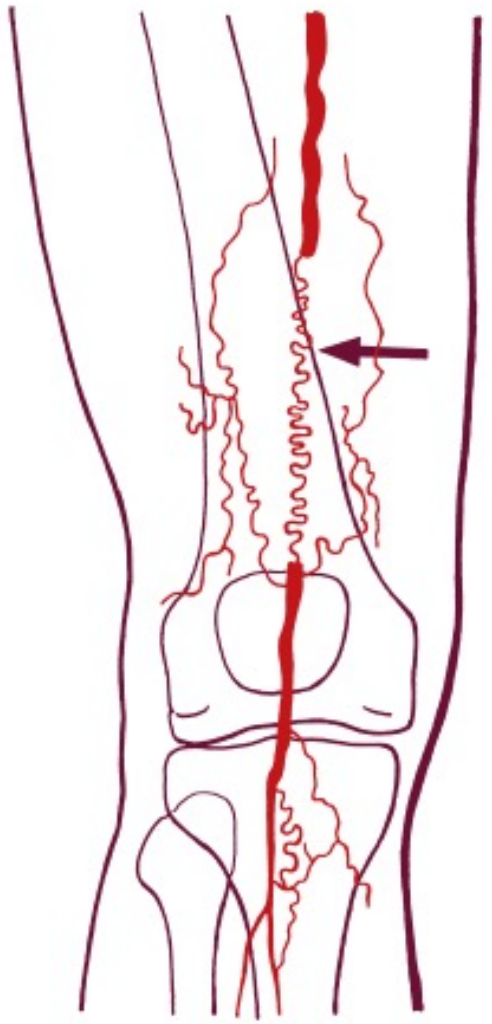


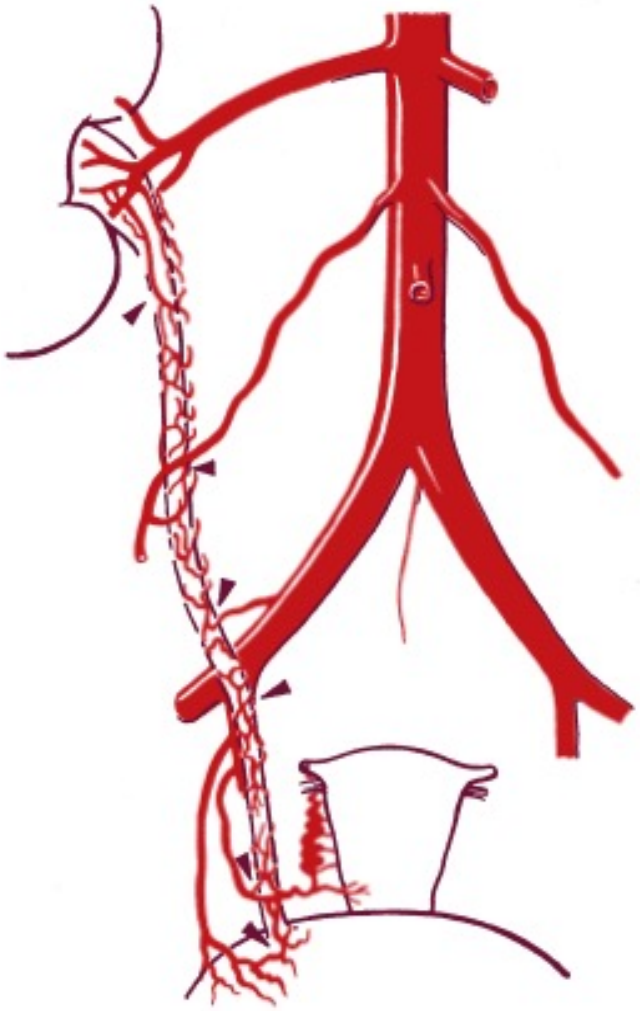


Collateral circulation

- **Natural anastomoses**
  - Brain
  - Reseve circulation
  - *Circulus arteriosus Willisi*
- **homocollaterals**
  - Inside own territory
  - *Lower limb*
    - vasa nervorum
    - a. commitans n. ischiadici
- **heterocollaterals**
  - Inbetween two territories
  - Plexus inside wall
    - ureter
    - bile duct

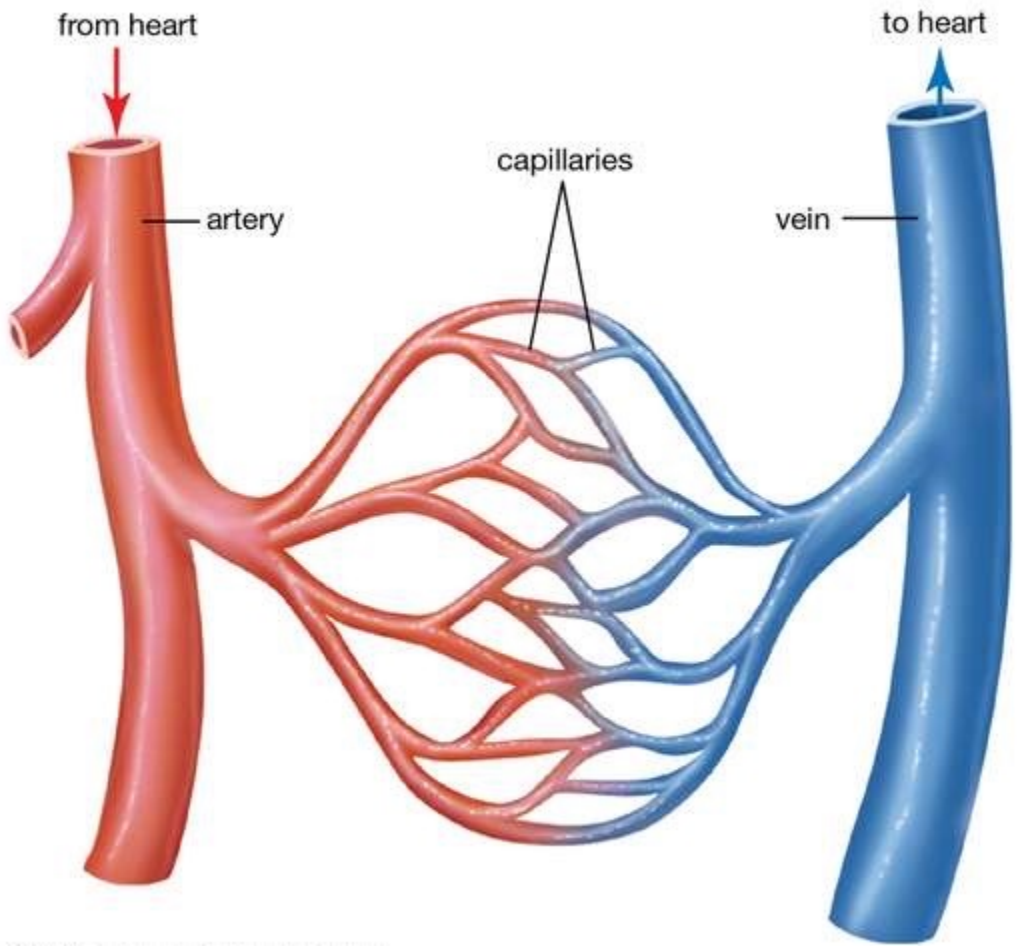






Terminal vascular bed - microcirculation

- **Rete capillare**
  - *Sphincters – flow regulation*
  - *Thoroughfare channel*
- **Arteriovenous anastomose**
- **Sinusoid**
  - ***Large spaces with mixing the blood***
  - ***Liver, bone marrow***
- **Glomus**
  - *Enriched innervation*
  - *Epitheloid cells*
  - *Neurohumoraů regulation*
- *Arteriovenous malformation*
- *Pathological neovascularisation*



Microcirculation

- arterioles
- Terminal arterioles
- Metaarterioles - precapillaries
- capillaries
  - *No muscular layer*
- prevenules – postcapillaries
  - *No muscular layer*
- Collecting venules
- Venules

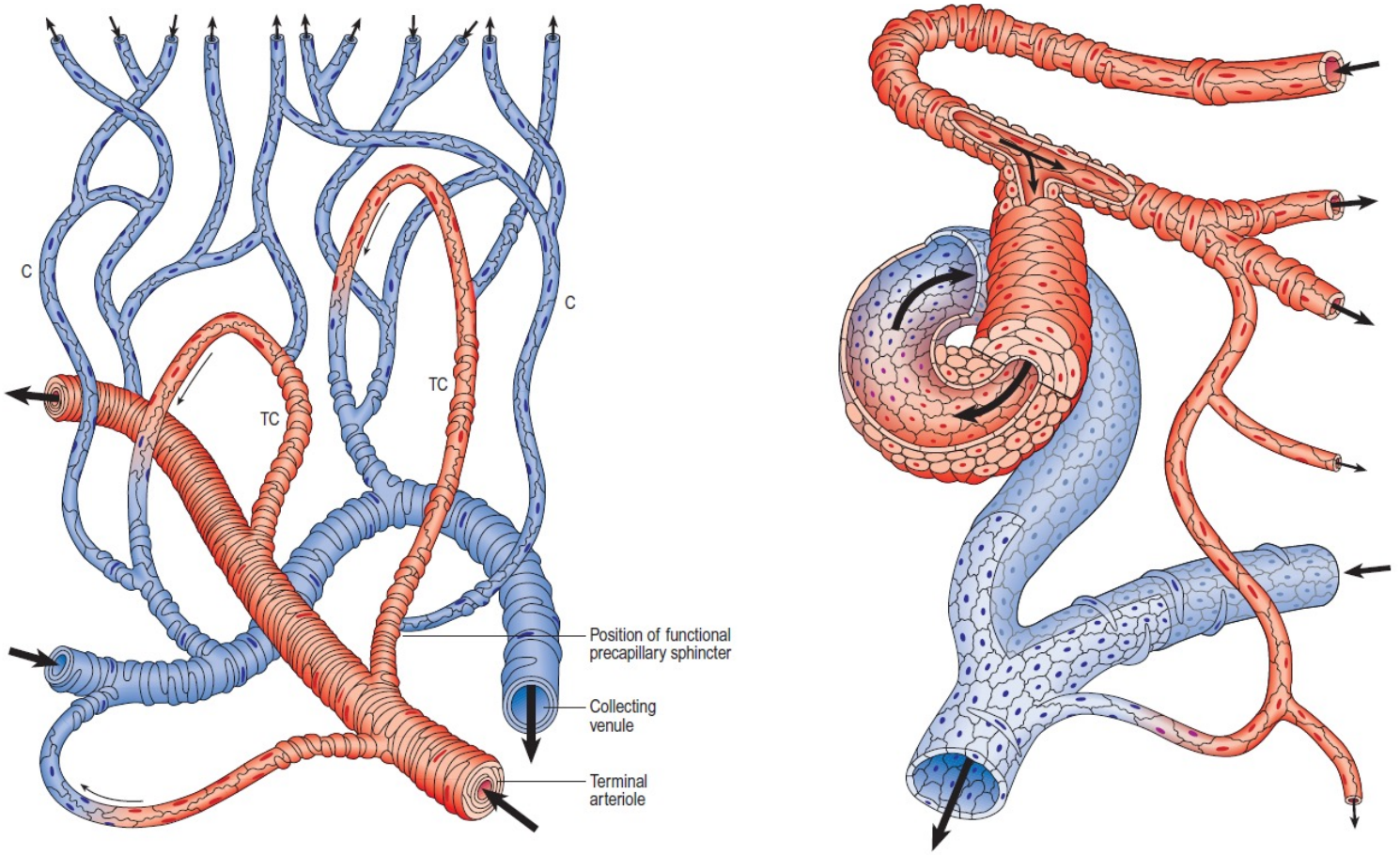
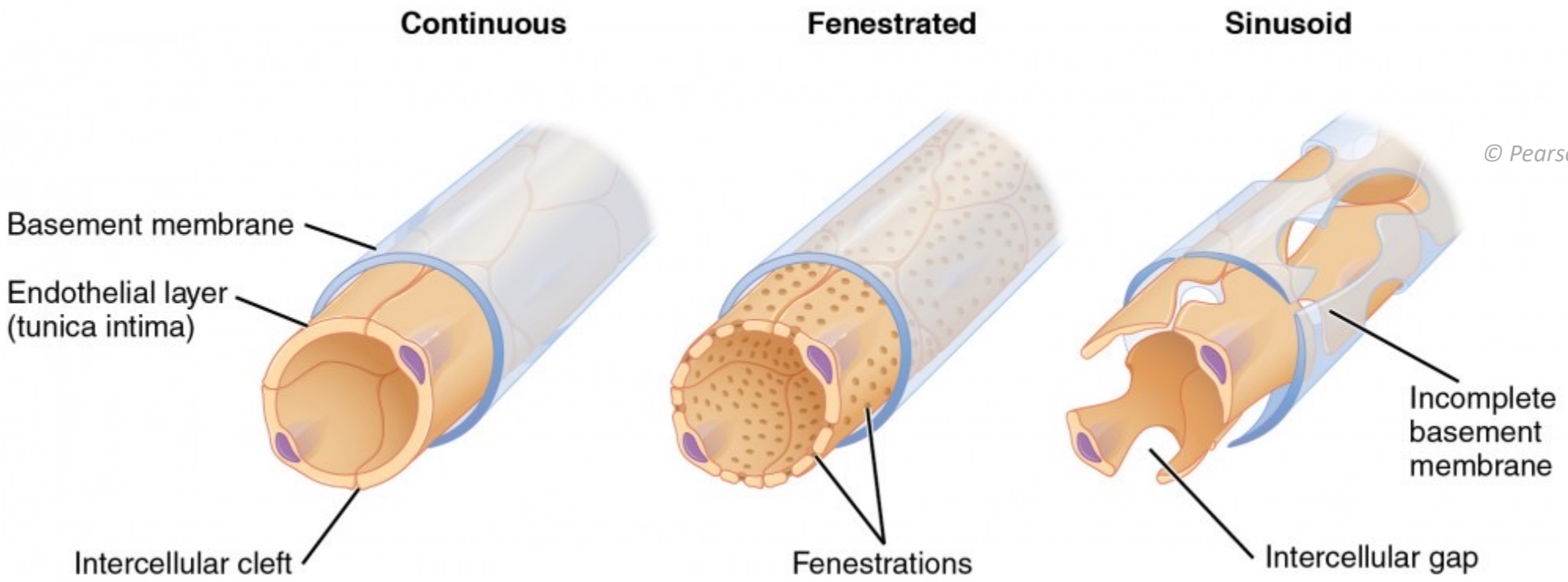


Fig. 6.15 A, A microcirculatory unit, showing a terminal arteriole, thoroughfare channels (TC) formed of metarterioles, capillaries (C) and collecting venule. The distribution of smooth muscle cells and one of the precapillary sites where perfusion of the capillary bed is regulated are also shown. **B**, An arteriovenous anastomosis. Note the thick wall of the anastomotic channel composed of layers of modified smooth muscle cells.

capillaries

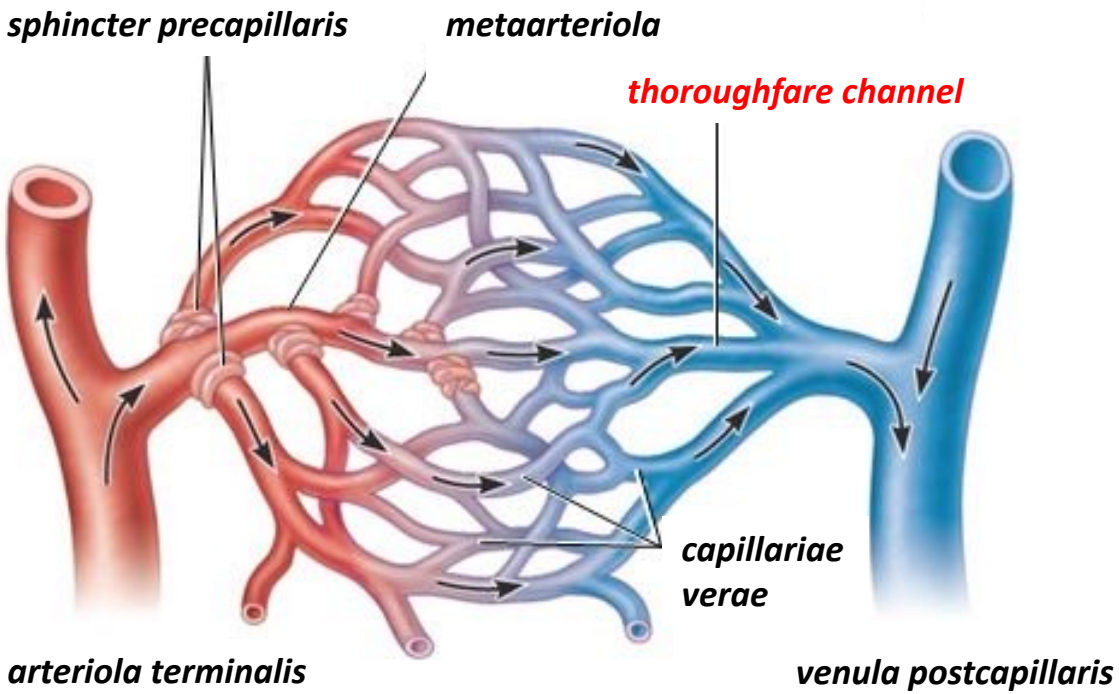
- **metaarterioles - precapillaria**
  - ***thoroughfare channel***
  - *flow capillary*
  - *Arteriovenous bridging*
- **capillaries**
  - *Only one endothel cel around*
  - *5-7 um*
  - *fenestration*
  - *pericytes (Rouget cells)*
  - *sinusoids (12-15 um)*

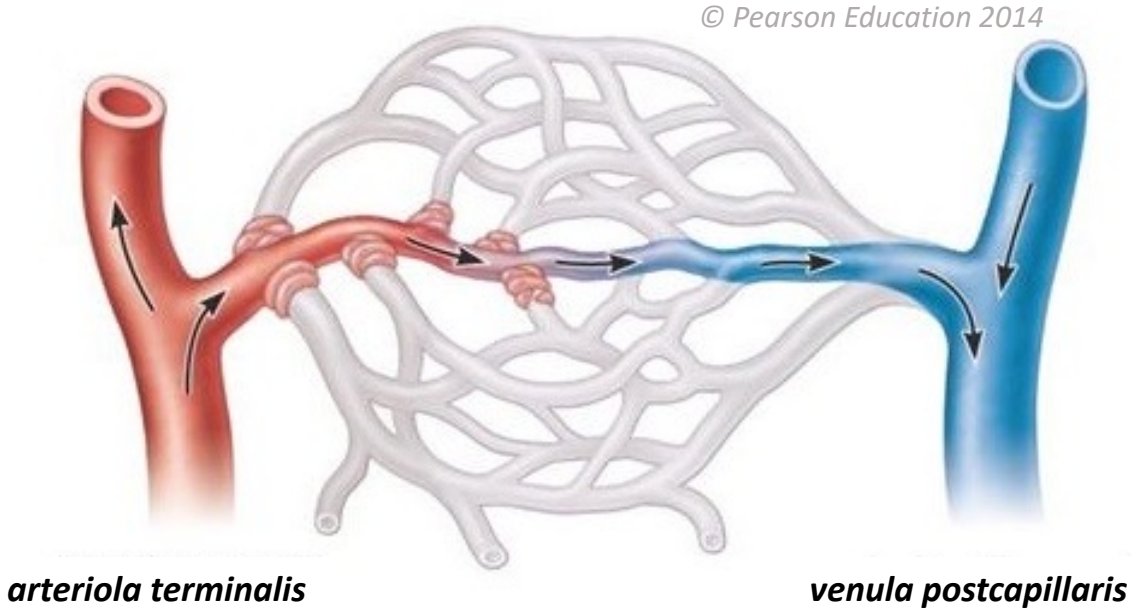
capillaries



muscle **kidney** **liver**

Thoroughfare channel

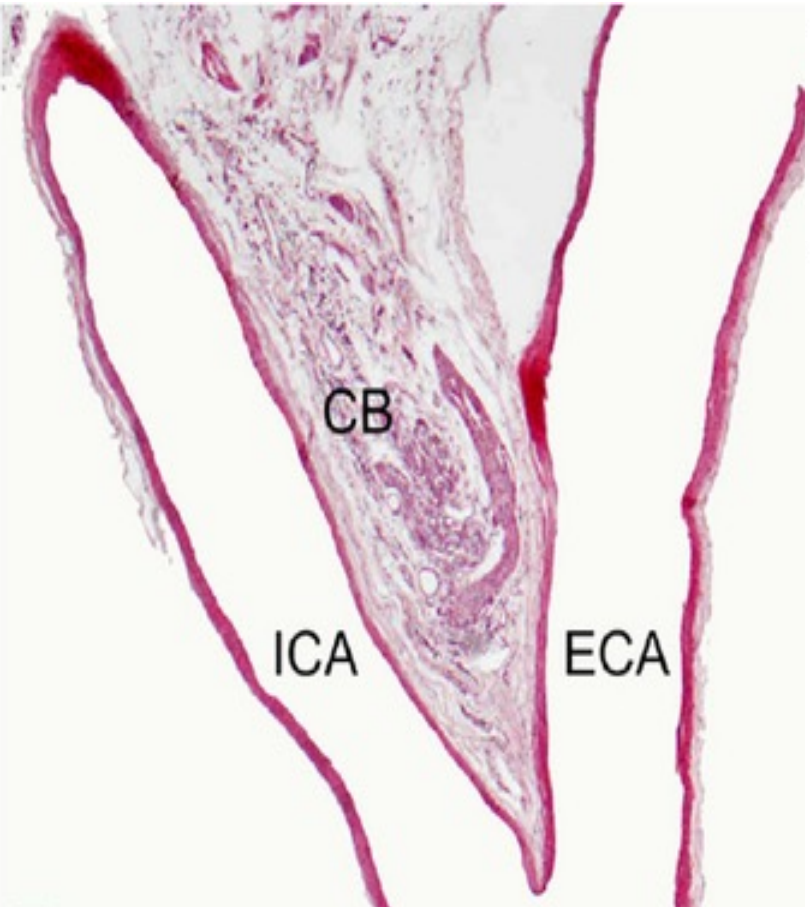




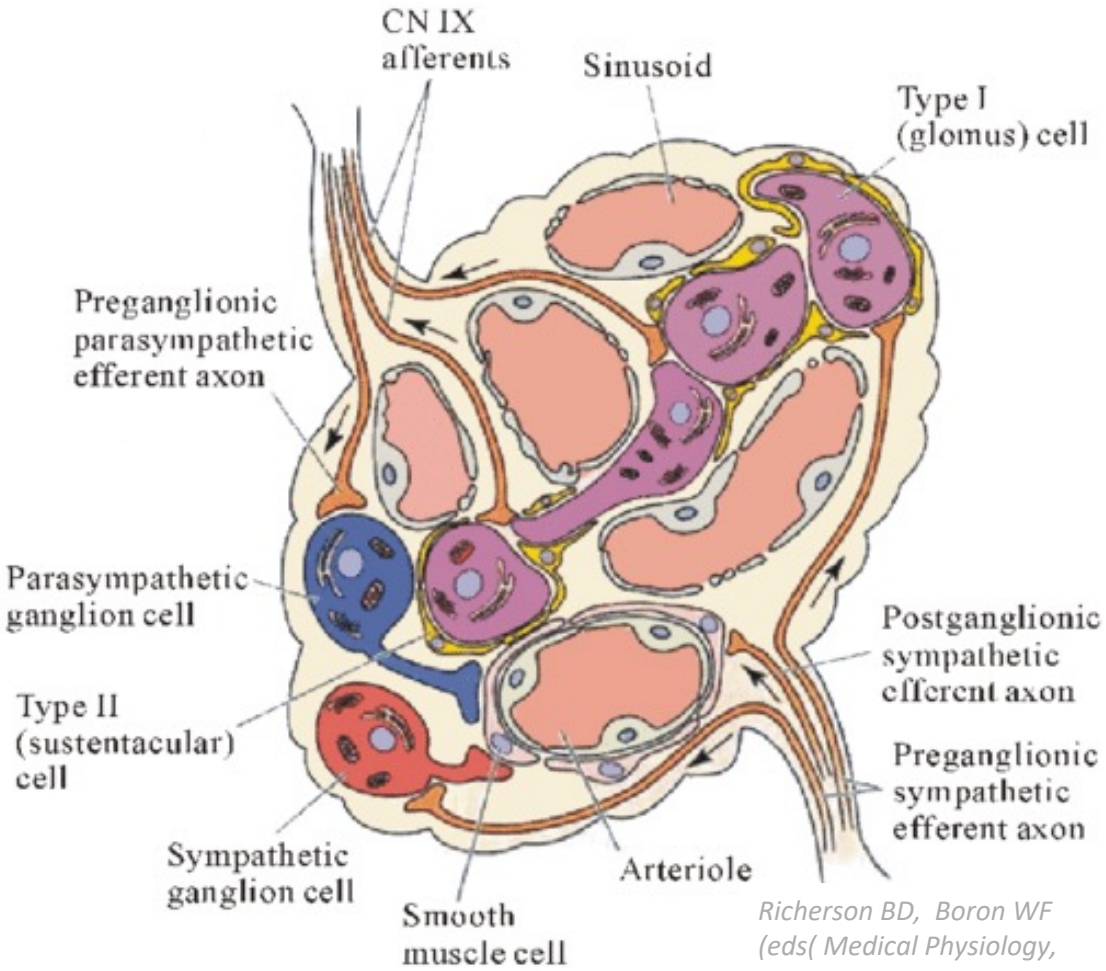
When sphincters relaxed, blood flows through capillaries

When sphincters closed, blood flows through
thoroughfare channel
blood bypassing true capillaries

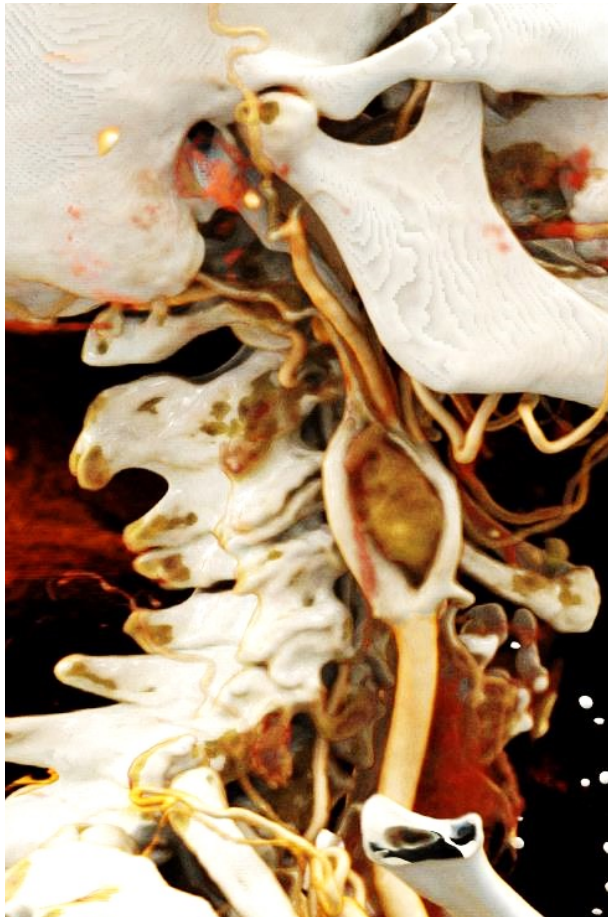
glomus



https://www.researchgate.net/figure/Location-of-the-carotid-bod bifurcation_fig1_259761100



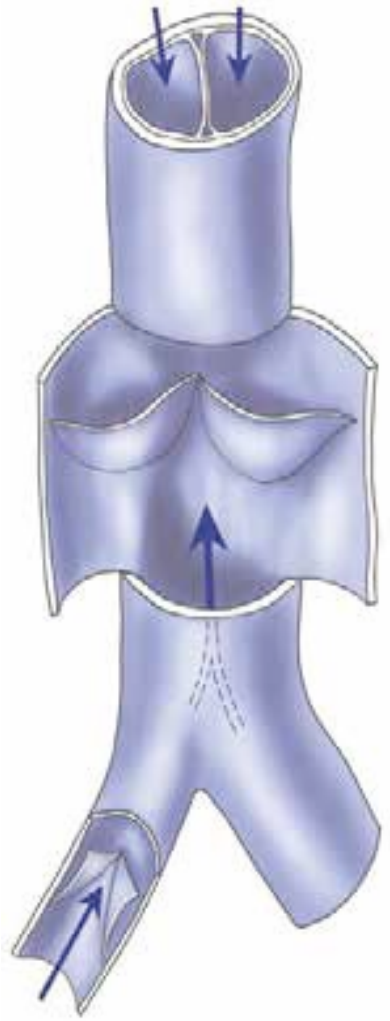
Richerson BD, Boron WF (eds(Medical Physiology, Elsevier, 2016



Veins - venae

- wall
  - Tunica intima
  - Tunica media
  - Tunica adventitia
- valves
  - insufficiency
  - Congenital dispositionx
  - varices
- Venous pressure
  - Lesser than in arteries
  - Near heart - negative
  - Underpreassure – sucking the air
  - Air embolia

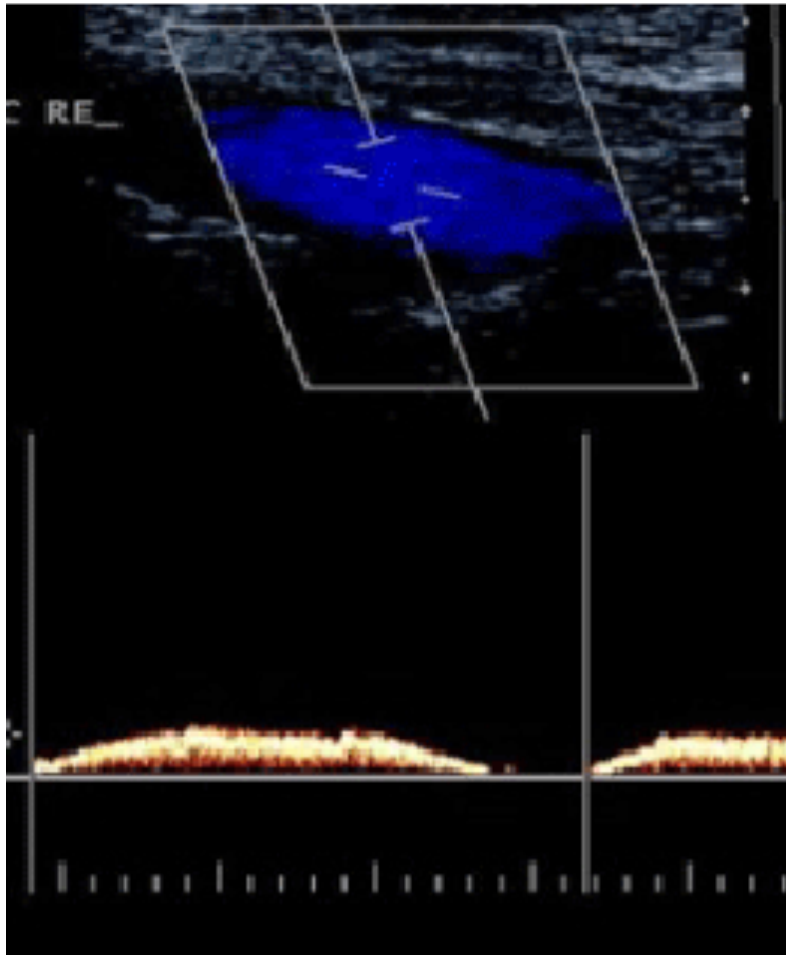
Grim M, Druga R et al.: Základy anatomie 2, Galén, 2016

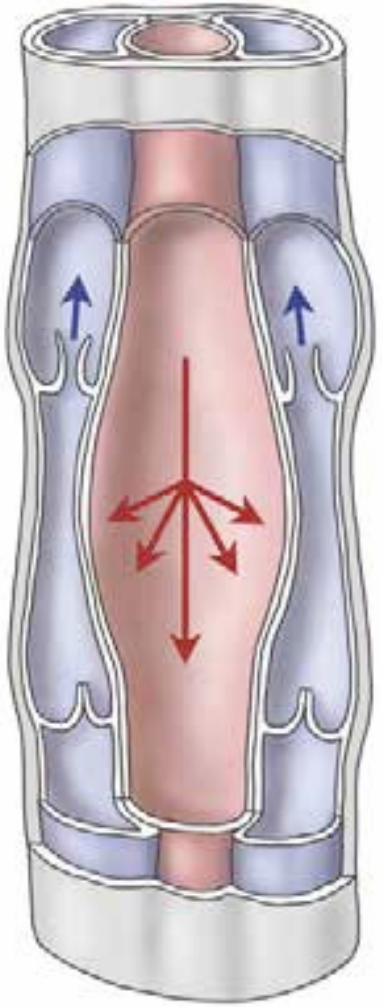


Veins - venae

- **Reverse flow with arteries**
  - *Common space with artery*
  - *Arterial pulse wave effect*
  - *Valvae – blocking hte venous reverse flow*
- **Valsala maneuvre**
  - **Breathing, oscillation of hte pressure**
- **Heart activity**
  - **Underpressure (negative pressure)**
  - **in diastola**

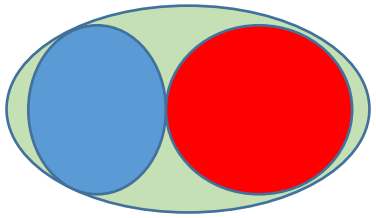
Grim M, Druga R et al.: Základy anatomie 2, Galén, 2016

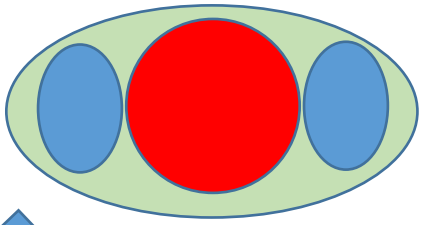


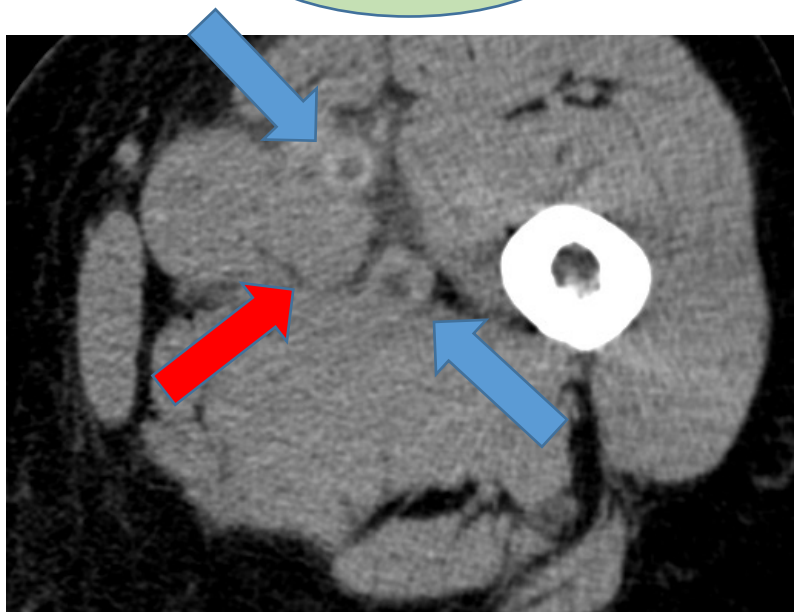


Veins - venae

- **Superficial system**
  - **Variable course in subcutaneous space**
  - **Main stem superficial veins are being constant**
  - *v. saphena magna, v. saphena parva*
  - *v. cephalica, v. basilica*
- **Deep veins are accompanying arteries**
- **Large artery, one vein**
  - *Vasa iliaca*
- **Smaller artery a couple of veins**
  - *Vasa femorales*
  - *Vasa cruris*

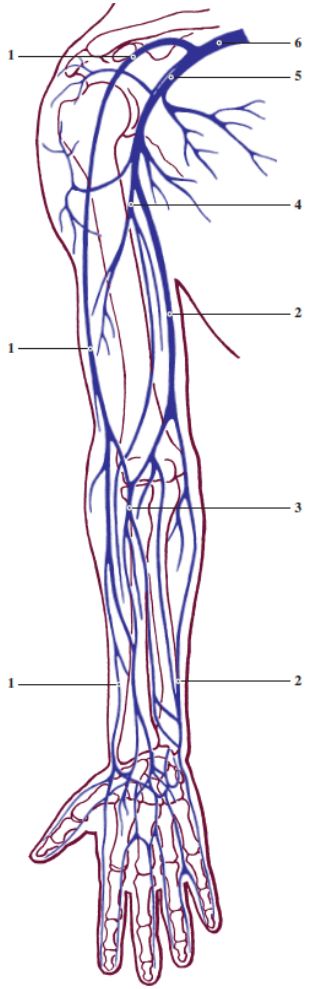




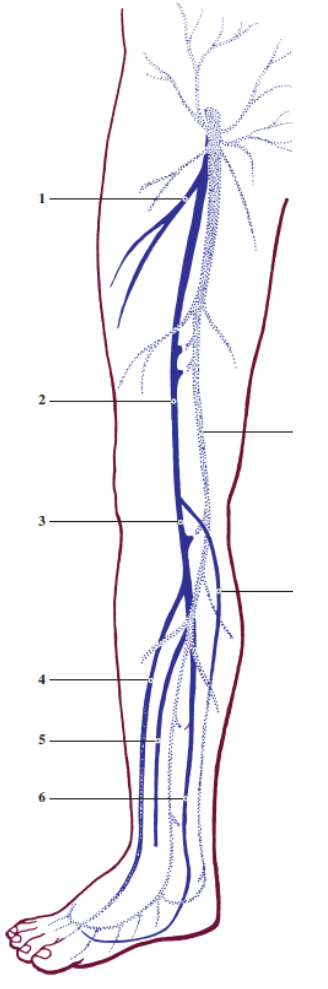


Superficial and deep veins

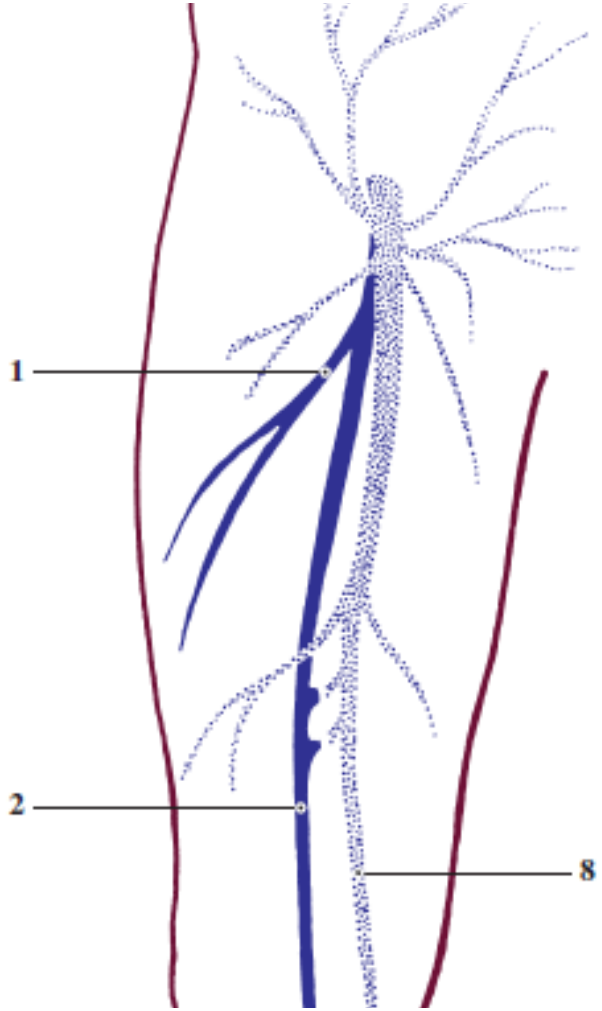
- vv. communicantesseu perforantes
  - perforators
- Connecting superficial and deep veins
  - Direct junctions
  - Indirect junctions – across muscullar vv.
  - *Lower extremity 160*
  - *Plantar and crural cca 110*
- Flow in superficial veins
  - Influence of arterial flow
  - Participation of valvular system
  - Involved by the muscular contractions



Obr. 9.17B. Anatomie žil horní končetiny – schéma. 1 – v. cephalica; 2 – v. basilica; 3 – v. mediana cubiti; 4 – v. brachialis; 5 – v. axillaris; 6 – v. subclavia



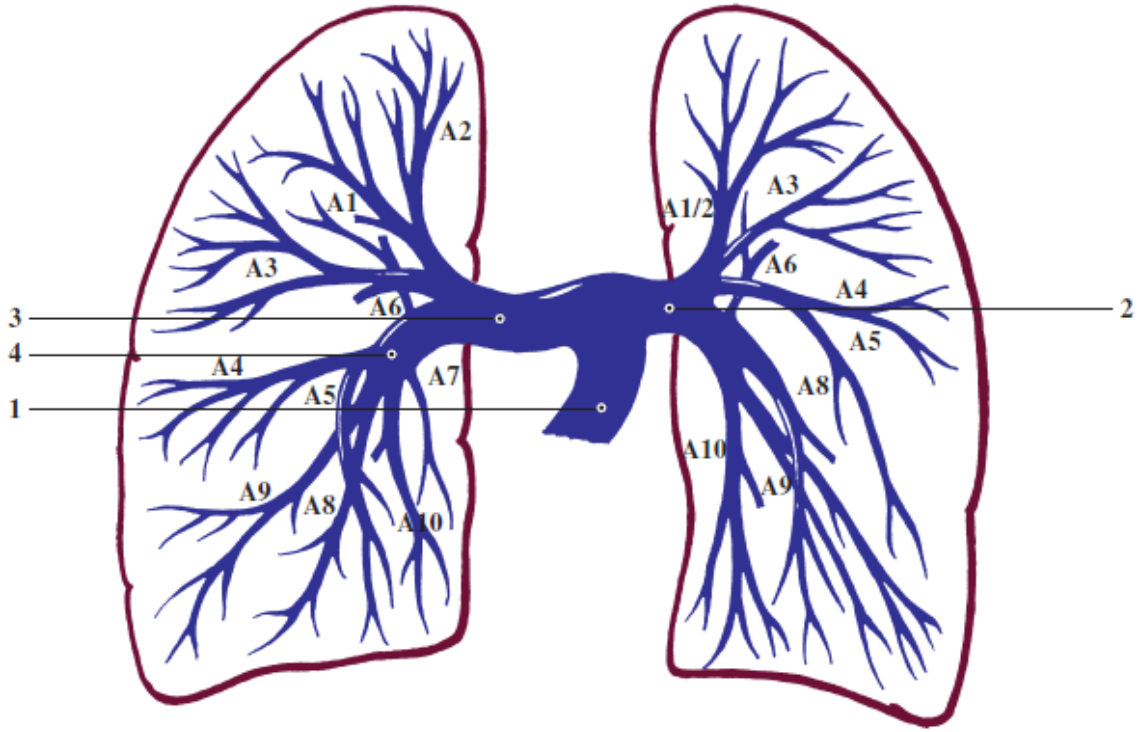
Obr. 9.17C. Anatomie žil dolní končetiny – schéma. 1 – moralis profunda; 2 – v. femoralis superficialis; 3 – v. poplitea; 4 – v. tibialis anterior; 5 – v. fibularis; 6 – v. tibialis posterior; 7 – v. saphena parva; 8 – v. saphena magna



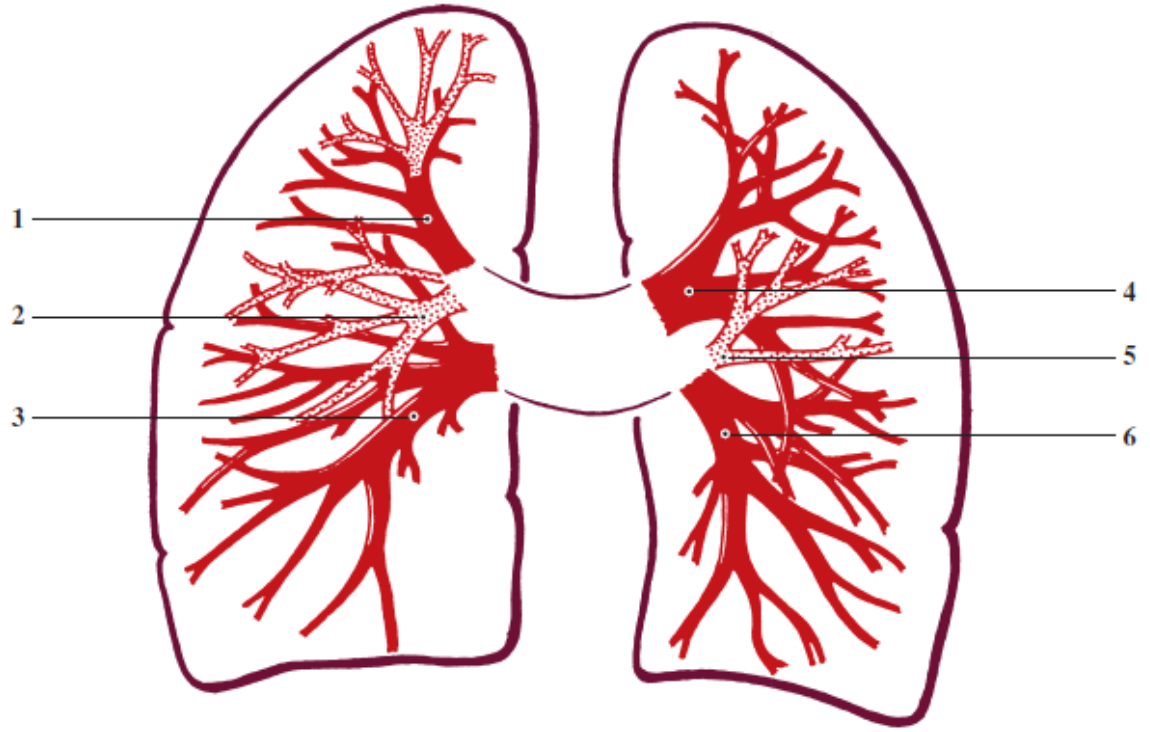
Pulmonary circulation

- **Arteries following segmentary constitution**
- **Pulmonary veins are constituing several stems –** different course than arteries in the central part

In the wall of pulmonary veins there are the elements of the conduction myocardium



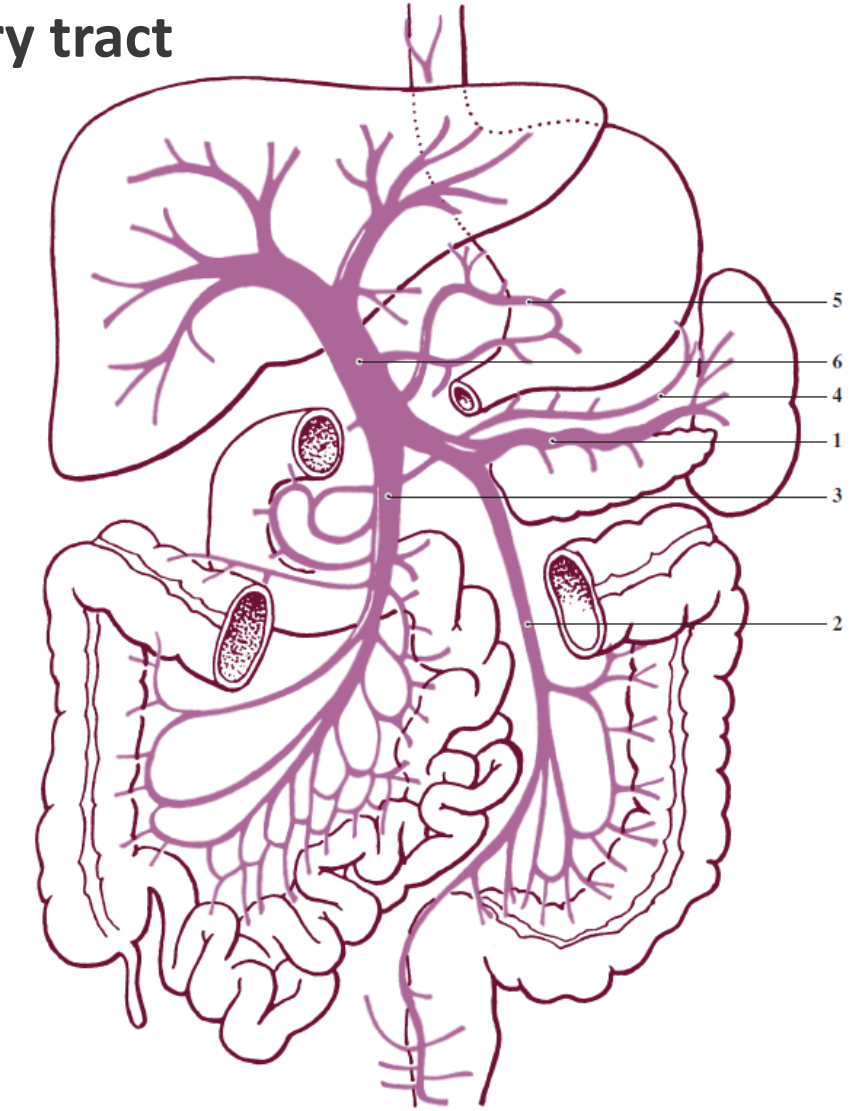
Obr. 4.1. Anatomie plicnice – schéma. 1 – a. pulmonalis – truncus; 2 – r. sinister; 3 – r. dexter; 4 – truncus intermedius; A1 až A10 – segmentární tepny



Obr. 4.2. Anatomie plicních žil – schéma. 1 – v. pulmonalis superior dextra; 2 – v. pulmonalis media dextra; 3 – v. pulmonalis inferior dextra; 4 – v. pulmonalis superior sinistra; 5 – v. pulmonalis media sinistra; 6 – v. pulmonalis inferior sinistra

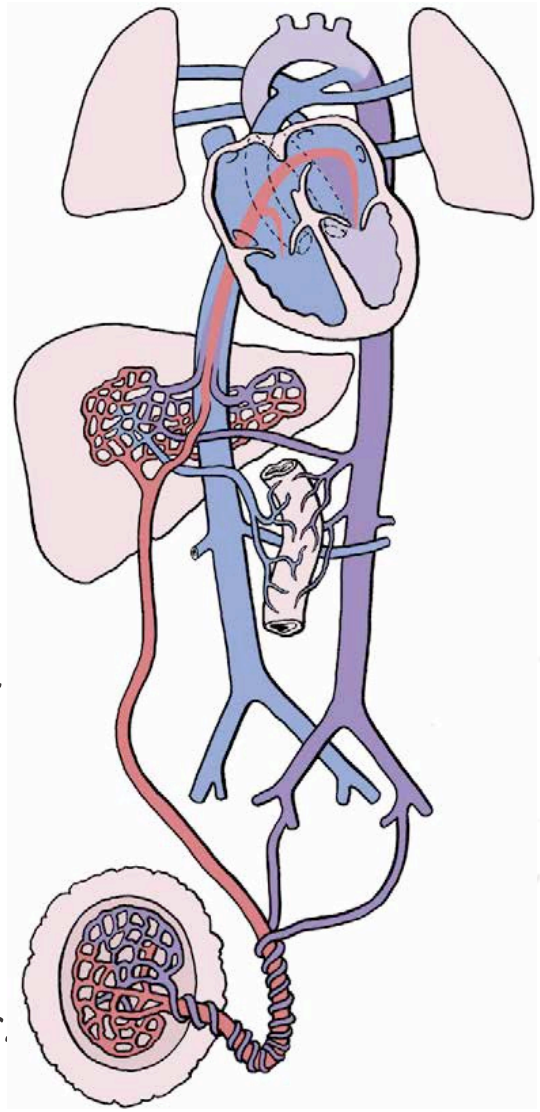
Portal circulation

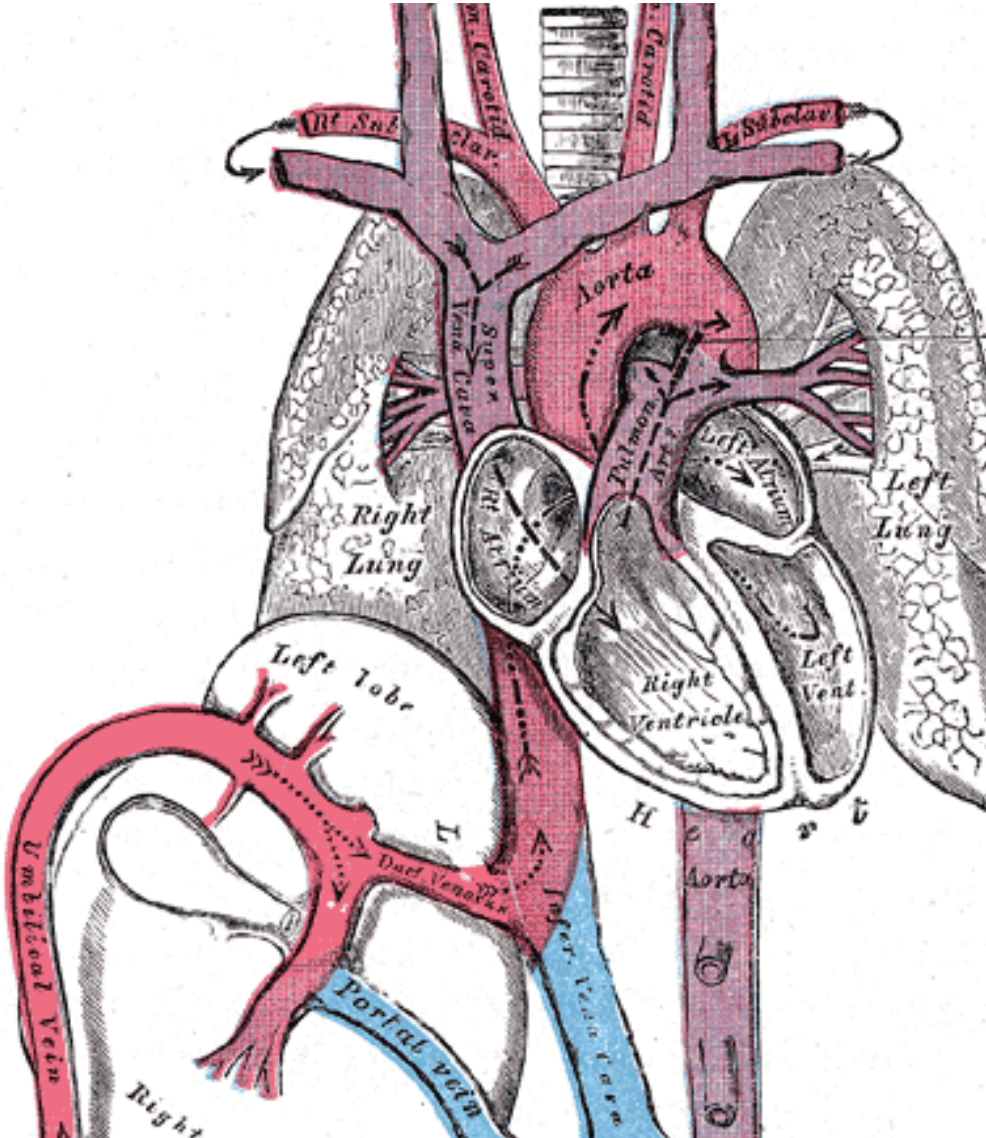
- **Circulation of the blood coming from alimentary tract**
- **V. portae hepatis**
- **V. lienalis**
- **V. mesenterica superior**
- ***V. mesenterica inferior***
- *V. gastroomentalis (seu gastroepiploica)*
- *V. gastrica sinistra (seu coronaria ventriculi)*
- *Vv. gastricae breves*



Fetal circulation

- **Placenta**
- **Umbilical cord - vasa umbilicales**
  - **V. umbilicalis – oxygenated blood**
  - **Aa. umbilicales – mixed blood**
- **Shunts**
  - *Oxygenated blood*
  - *into systemic circulation*
- **ductus venosus Arantii**
  - *from v. umbilicalis to v. cava inferior*
- **foramen ovale**
  - *From right to left atrium*
- **ductus arteriosus**
  - *From pulmonary trunc to aorta desc*





Lymphatic system

- **Lymphatic system – systema lymphatica**
  - *lympha*
  - *vasa lymphatica*
    - *vasa lymphocapillaria*
    - *rete lymphocapillare*
    - *vasa afferentia*
    - *vas efferens*
    - *collectores et trunci lymphatici*
  - *nodi lymphatici*
  - *Folliculi lymphatici*
  - *Tonsillae – circulus Waldayeri*
  - *thymus*
  - *splen, lien*

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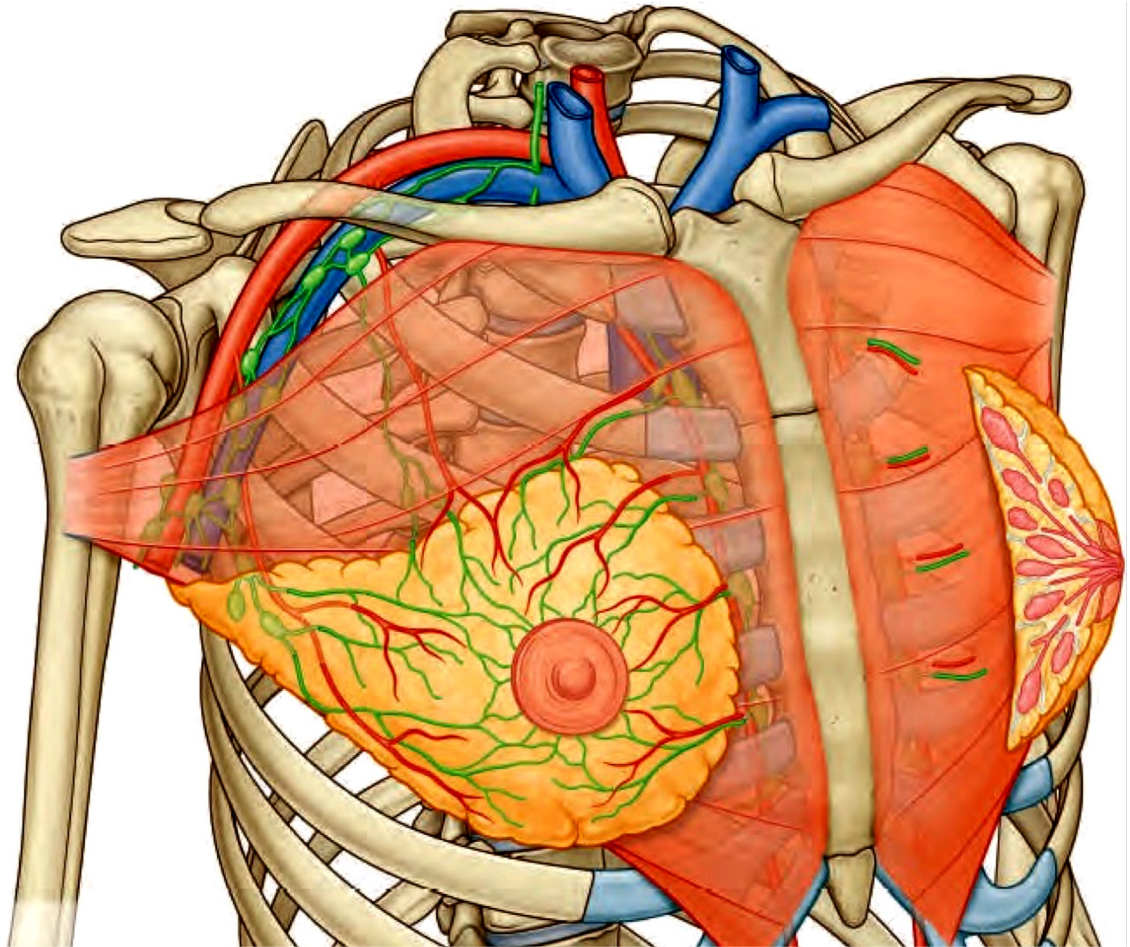
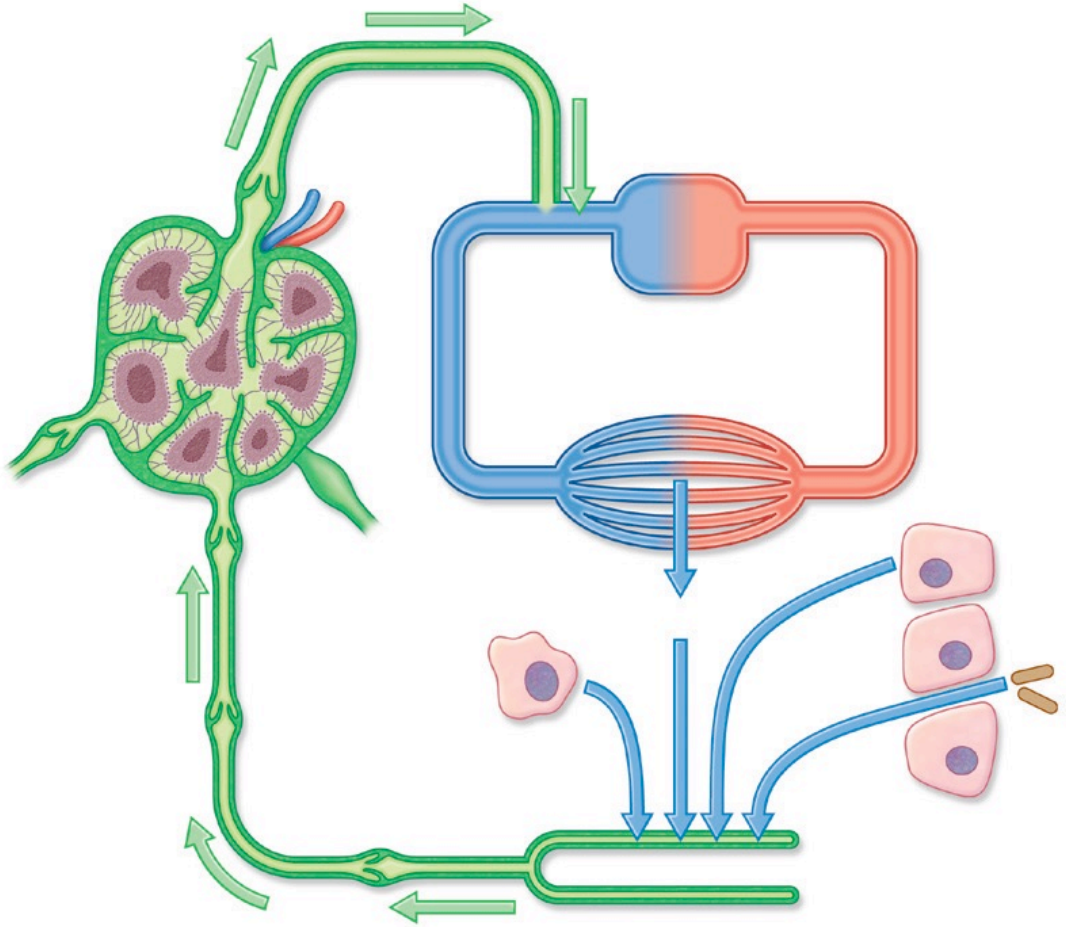


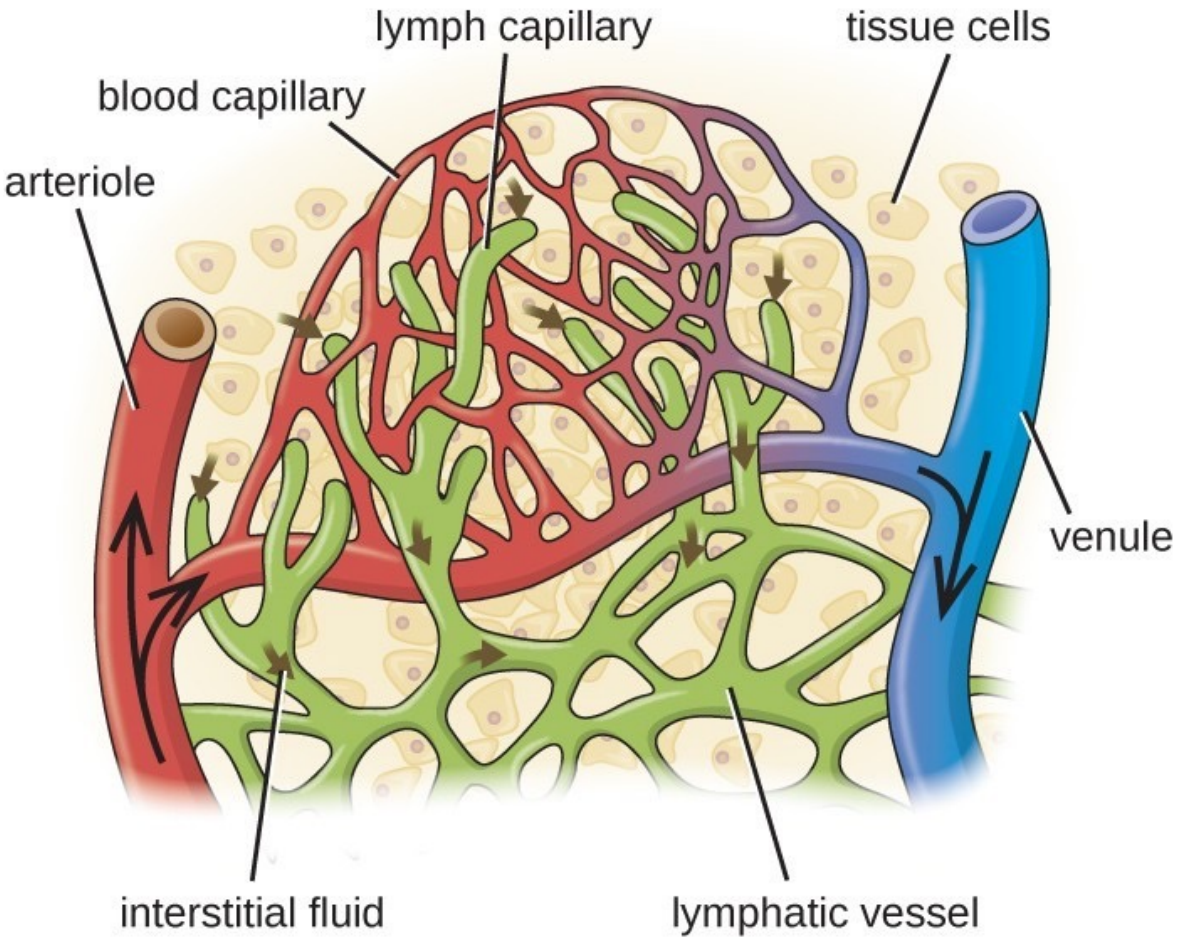
Lymphatic system

- **Lymph**
  - *opalesq*
  - *containing lymphocytes*
- **Chylus**
  - *From GIT*
  - *Emulgated fat*
  - *Milky cloudy*
- **The sense of lymphatic system**
  - *Drainage of the tissue interstitial fluid*
  - *Collection of fatty substances from GIT*
  - *Infection spread*
  - *Tumorous spread (lymphogenic)*
  - *Lymphogenic edema*



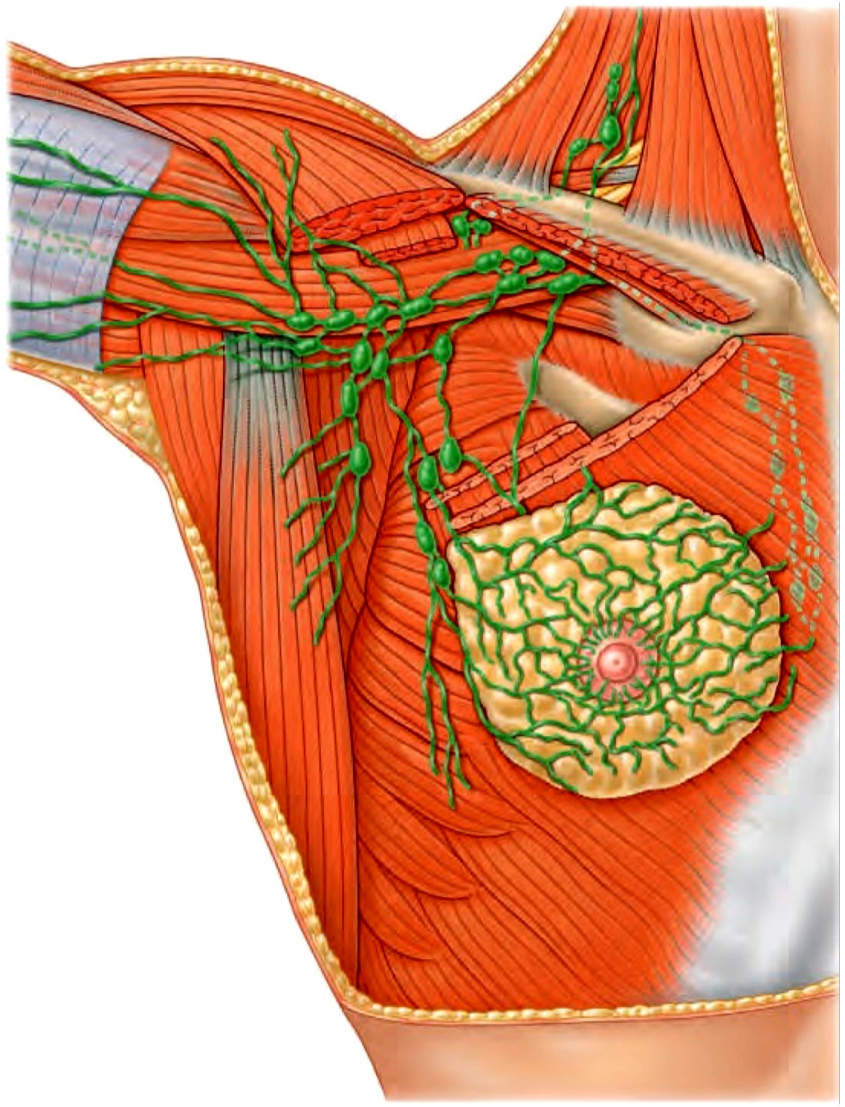
Lymphatic vessels

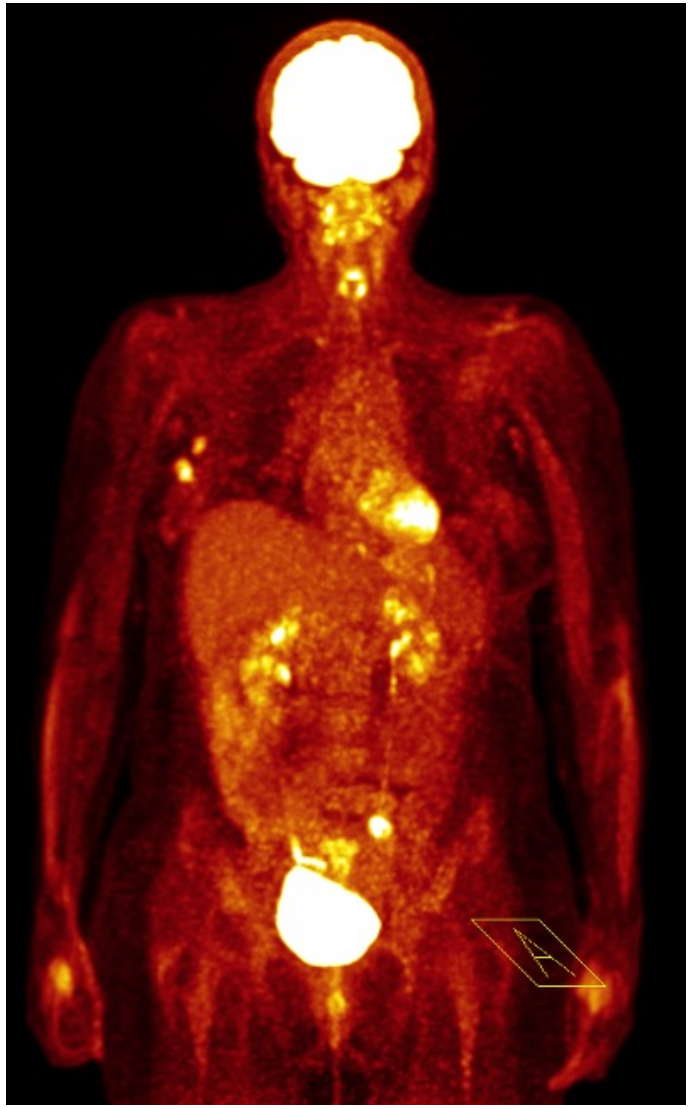
- **Lymphatic capilaries**
  - **Blinfd origin**
  - *Glove-like origines*
  - *Dense rete*
- **Lymphatic vessels**
  - *Constituted from capillaries*
  - *All three parts of wall (intima, media, adventictia)*
  - *Very thin wall*
  - ***valves***
  - *Accompanying vessels*
- **Lymph nodes**
  - *Interposition in between vessels*
  - *Arranged in larger groups*

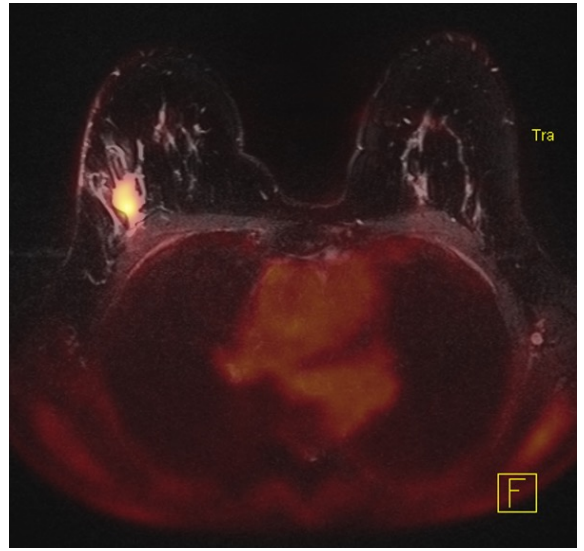


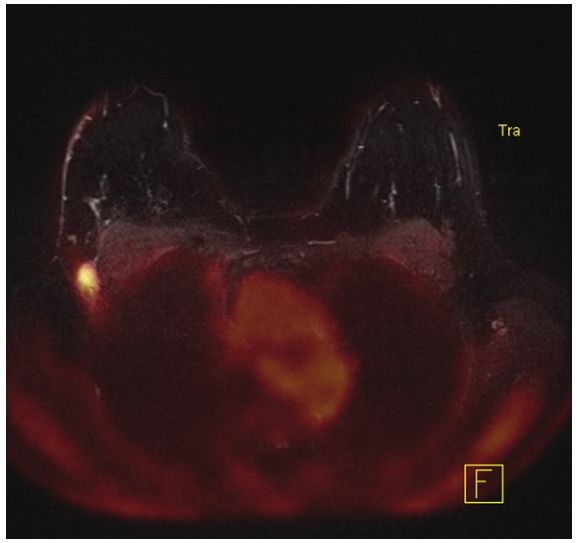
Lymphatic drainage

- capillariae
- vasa
- nodi
- collectores
- trunci

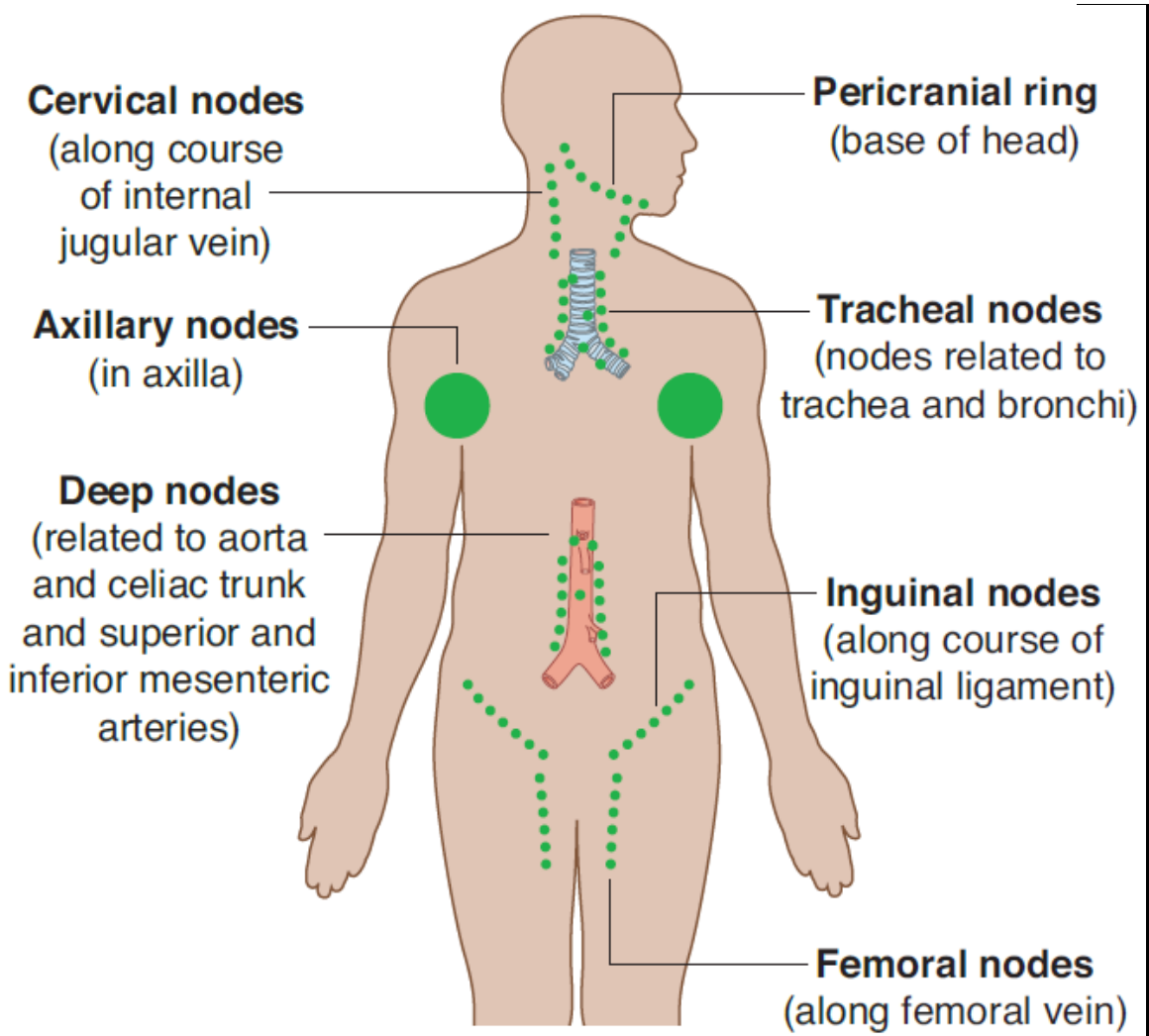


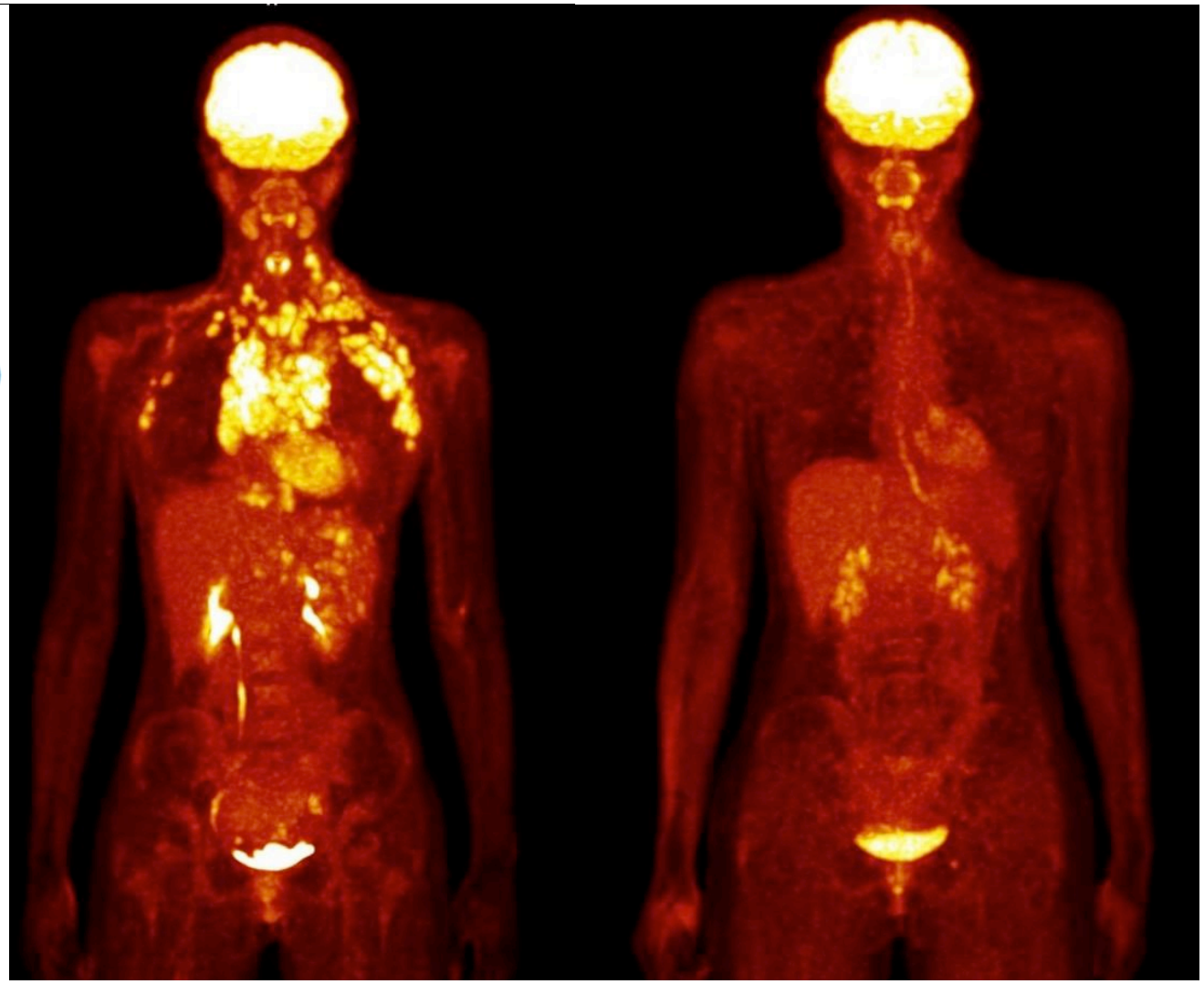






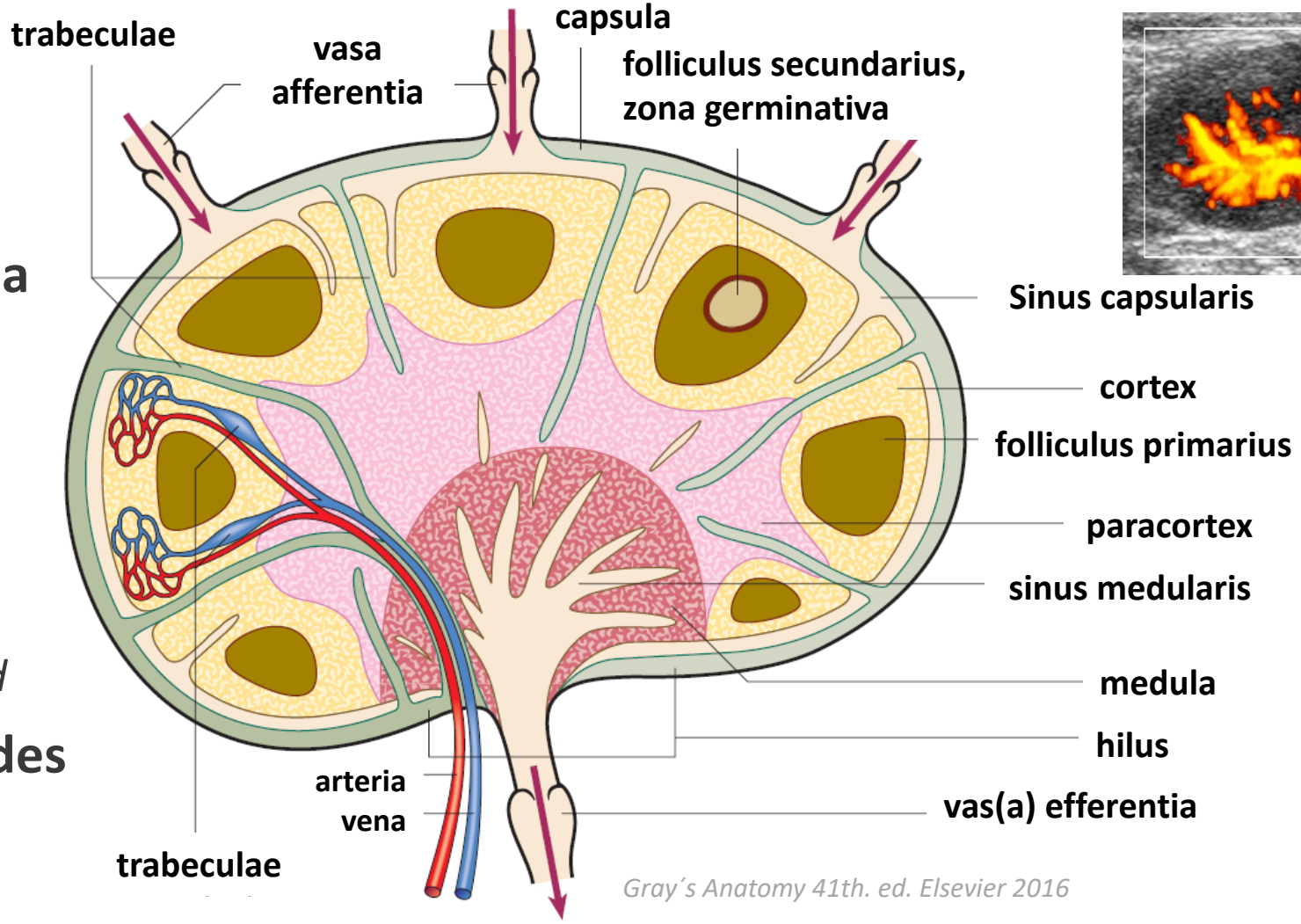
Lymphatic nodes

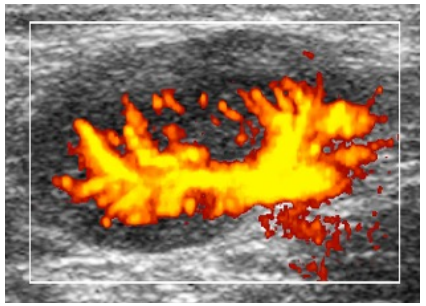




Lymphatic node

- **Bean-like shape**
- **Size different**
  - *Largest - neck and groin*
- **Vasa afferentia et efferentia**
  - *More afferent vessels*
  - *Less efferent vessels*
- **Valves**
  - *insufficiency*
  - *Retrograde flow*
  - *Retrograde tumorous spread*
- **Vascular supply of lyph nodes**
  - *A. et v. into the cortex*
  - *Capilaries inside cortex*





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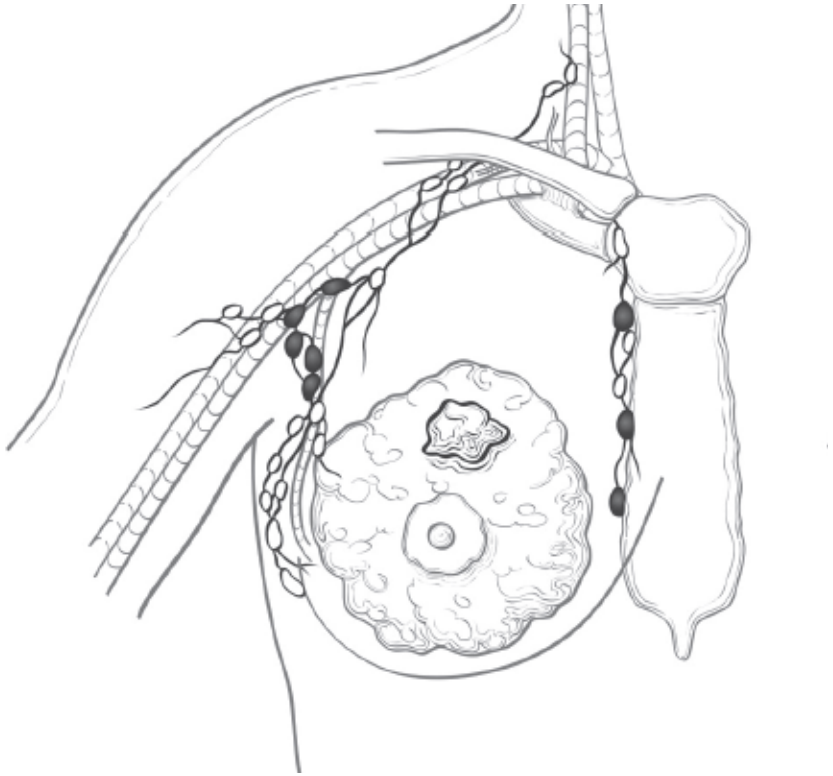
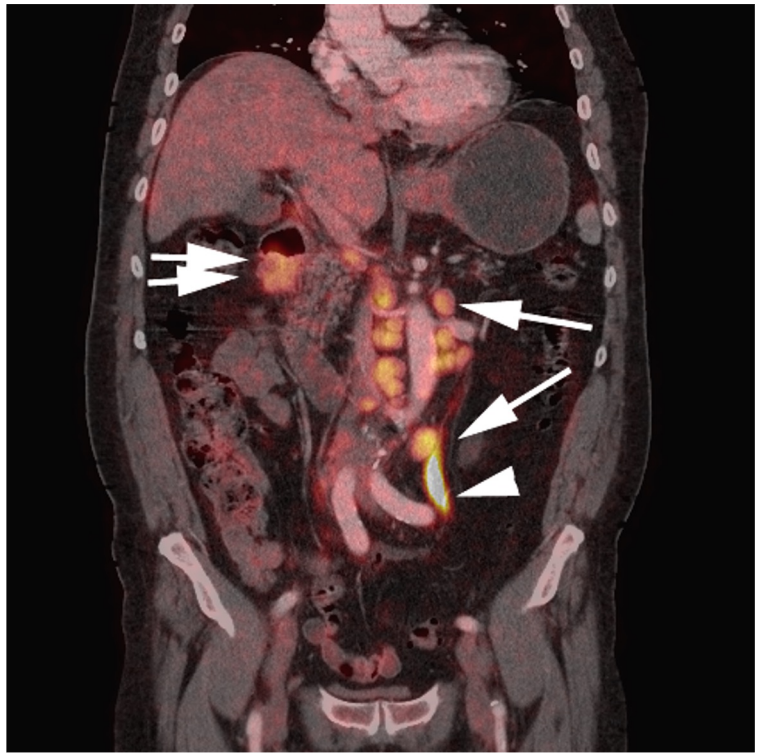
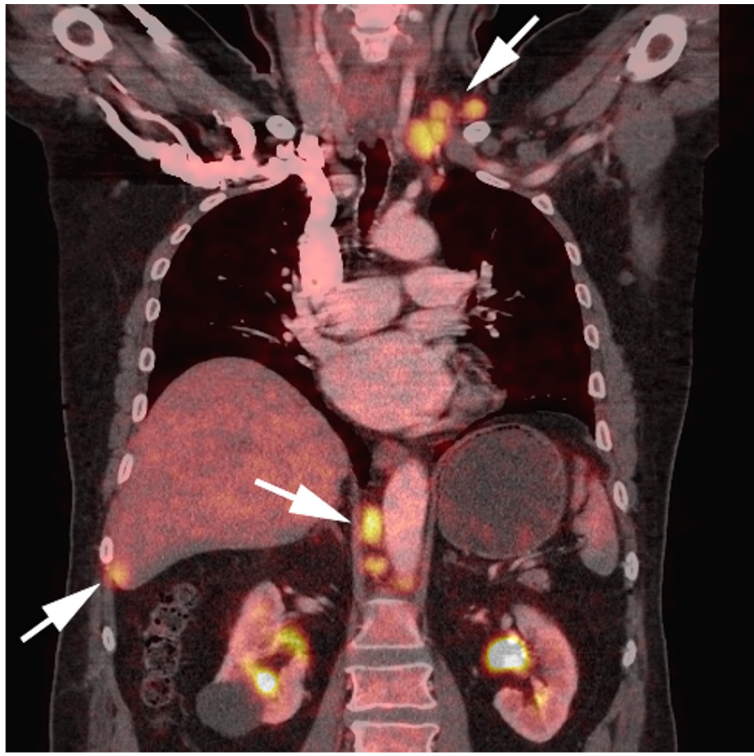
Regional lymph nodes

- Inflow from anatomical region
- Tributary region
- Sentinell lymph node

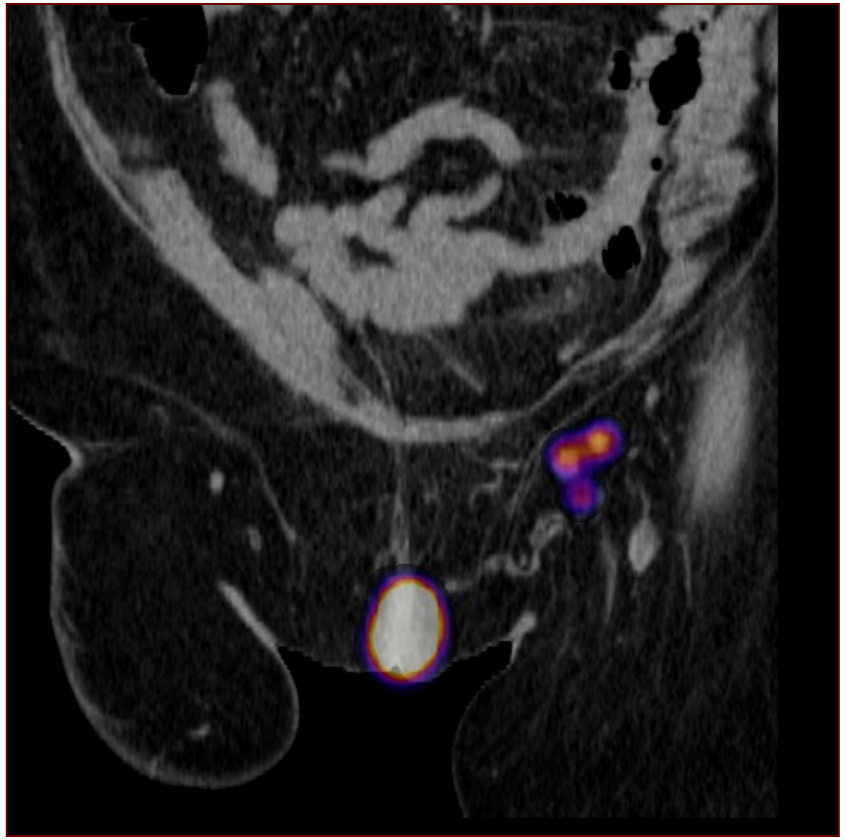


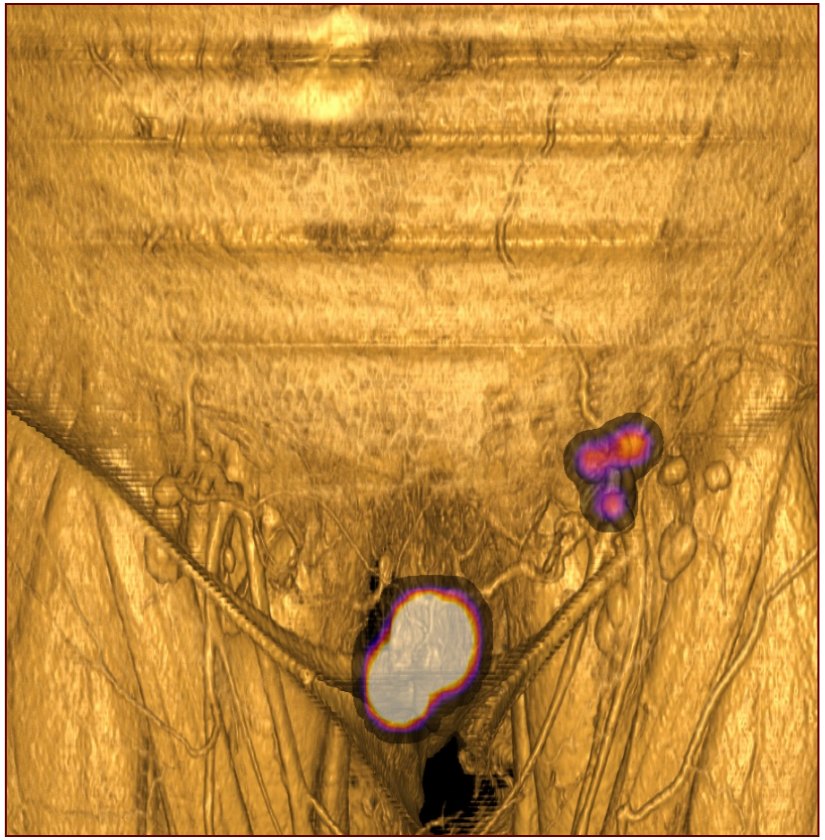




Sentinel lymph node

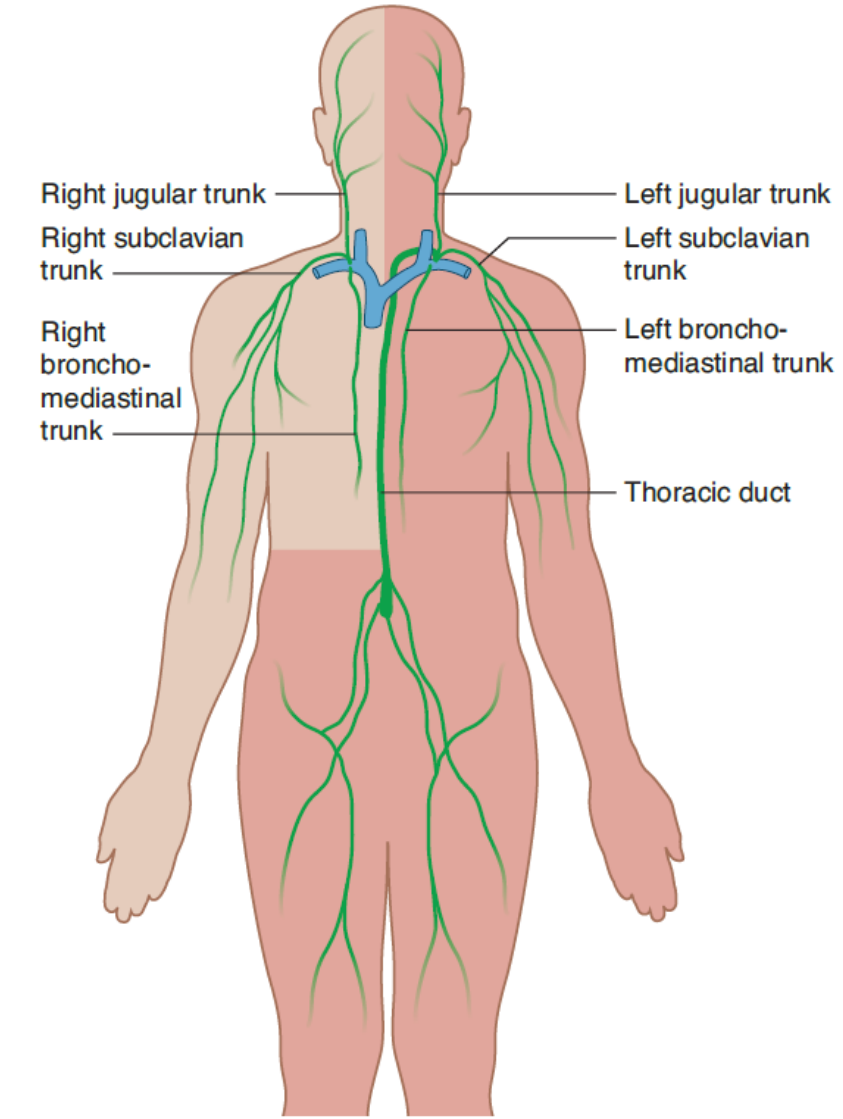
- **First in the way of flow**
  - Detection of the tumorous spread
  - Lymfoscintigraphy – radiolabeled coloids

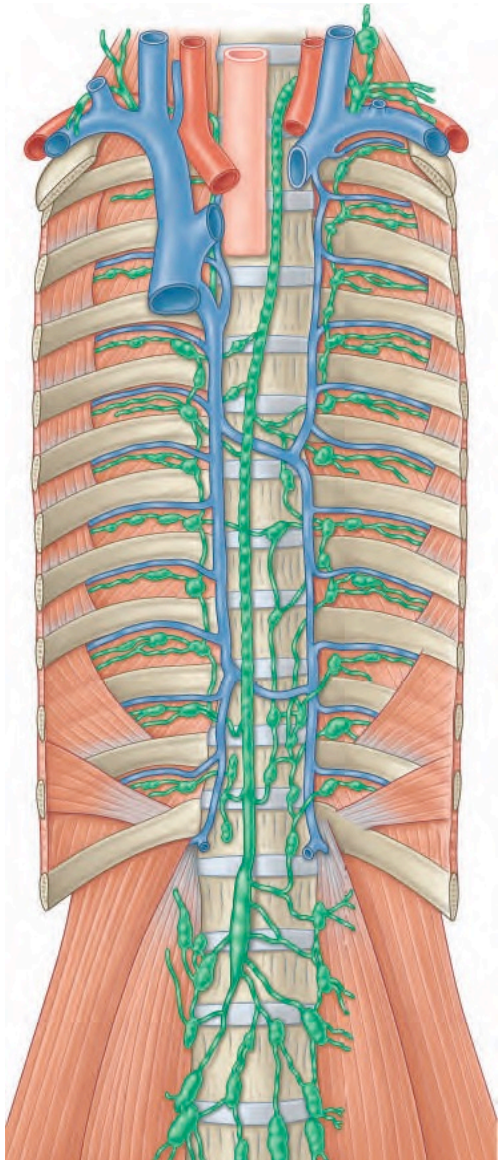




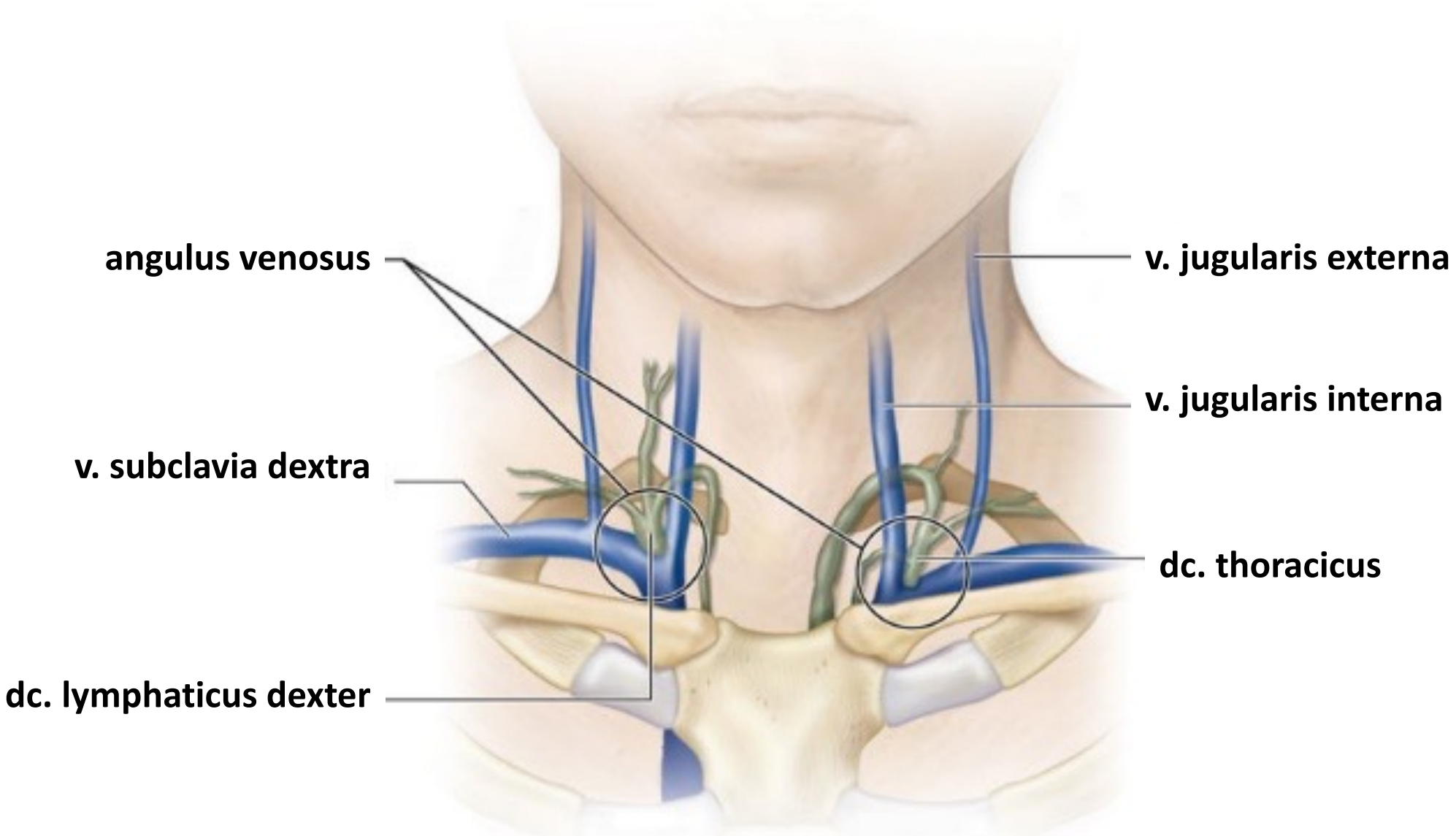
Collectors, trunci, ductus thoracicus

- *Trunci lumbales*
- *Trunci intestinales*
- *Cisterna chyli*
- **Ductus thoracicus (hiathus aorticus)**
- *Tr. brochomediastinalis sinister*
- *Tr. subclavius sinister*
- *Tr. jugularis sinister*
- **Angulus venosus sinister (3/4 body)**
- *Tr. brochomediastinalis sinister*
- *Tr. subclavius sinister*
- *Tr. jugularis sinister*
- *Tr. lymphaticus dexter*
- *Angulus venosus dexter (1/4 body)*

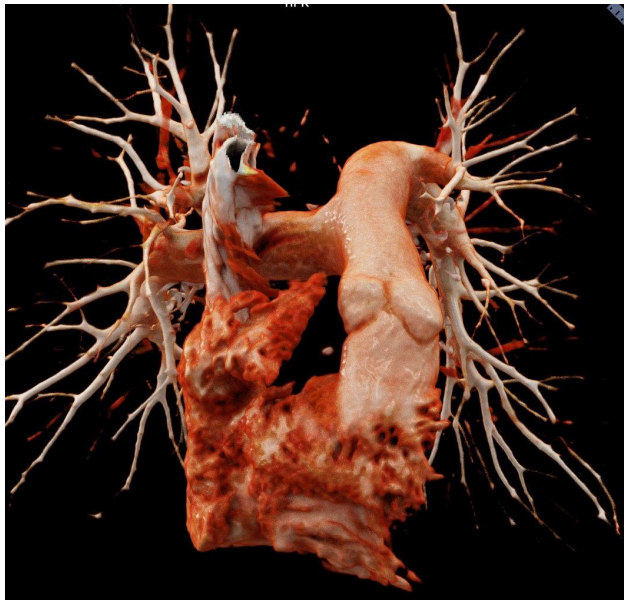


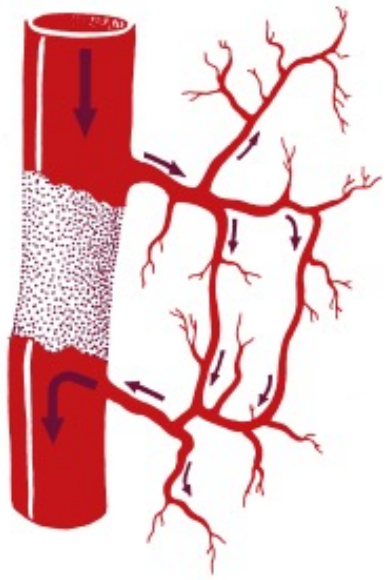


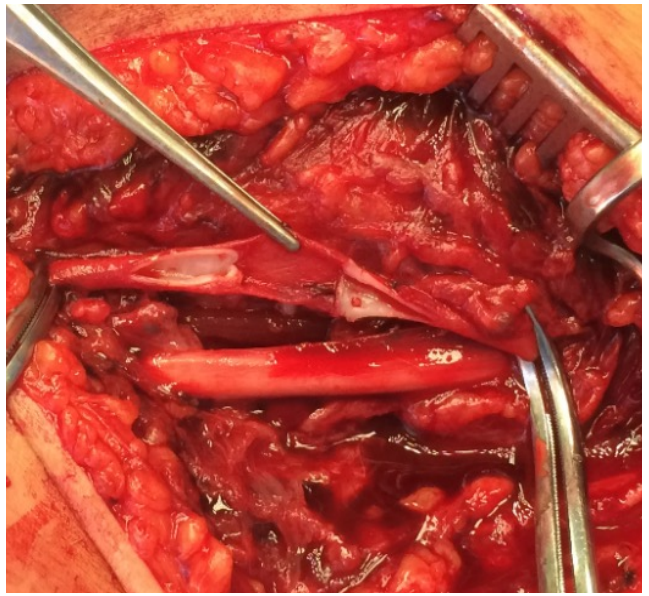
Angulus venosus



Circulation system







Prof. MUDr. Jiří FERDA, Ph.D.