

Chapter 1

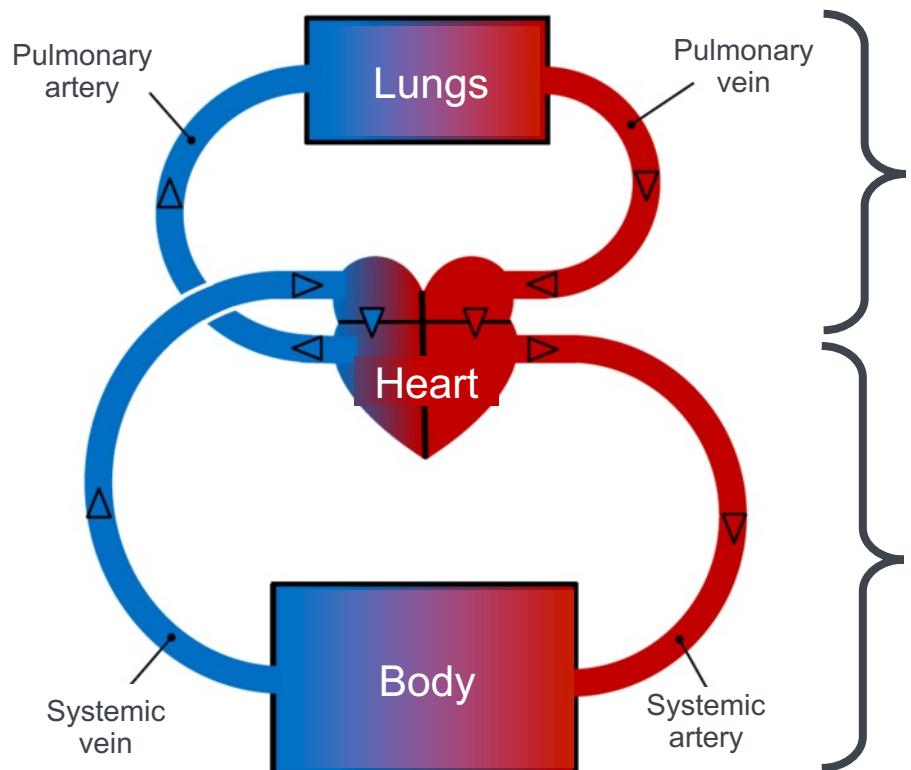
Physiology and basics



1.1 Cardiovascular system und blood vessels



The cardiovascular system (mammals)



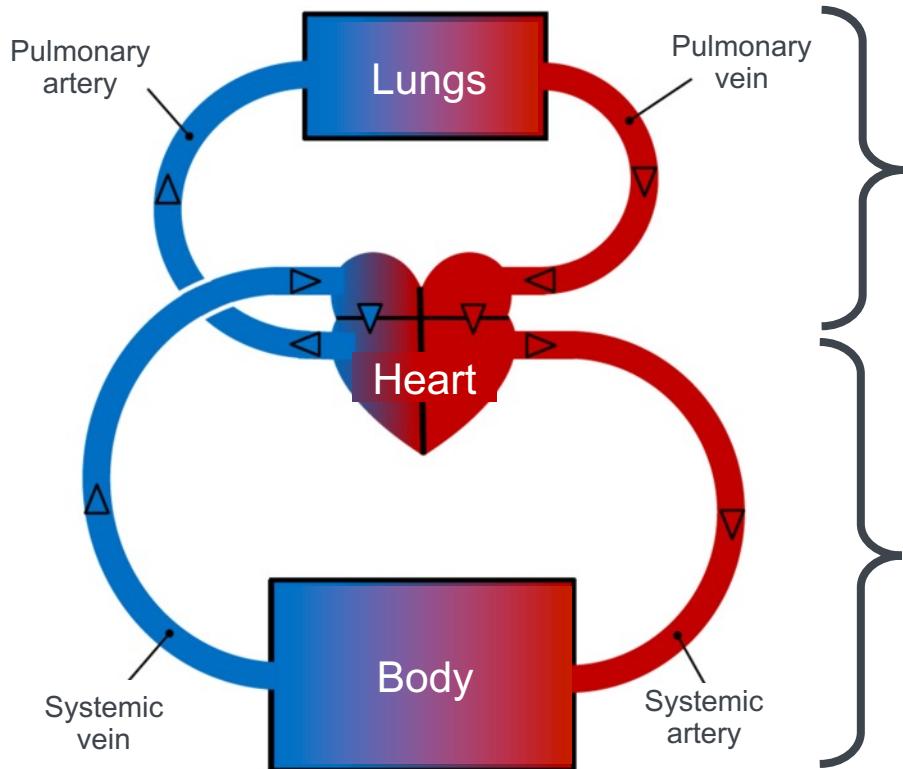
Pulmonary circulation

Systemic circulation



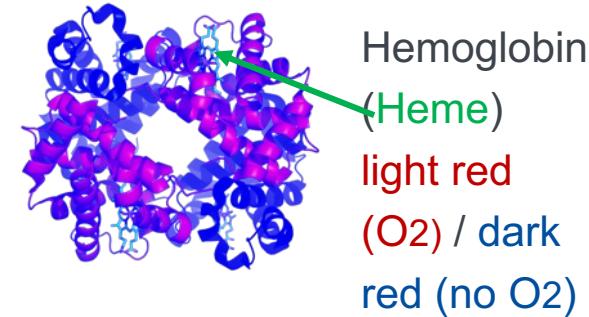
The cardiovascular system (mammals)

deoxygenated blood oxygenated blood

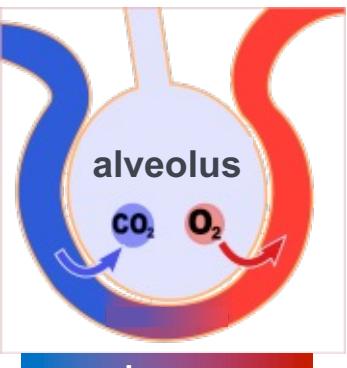


Pulmonary circulation

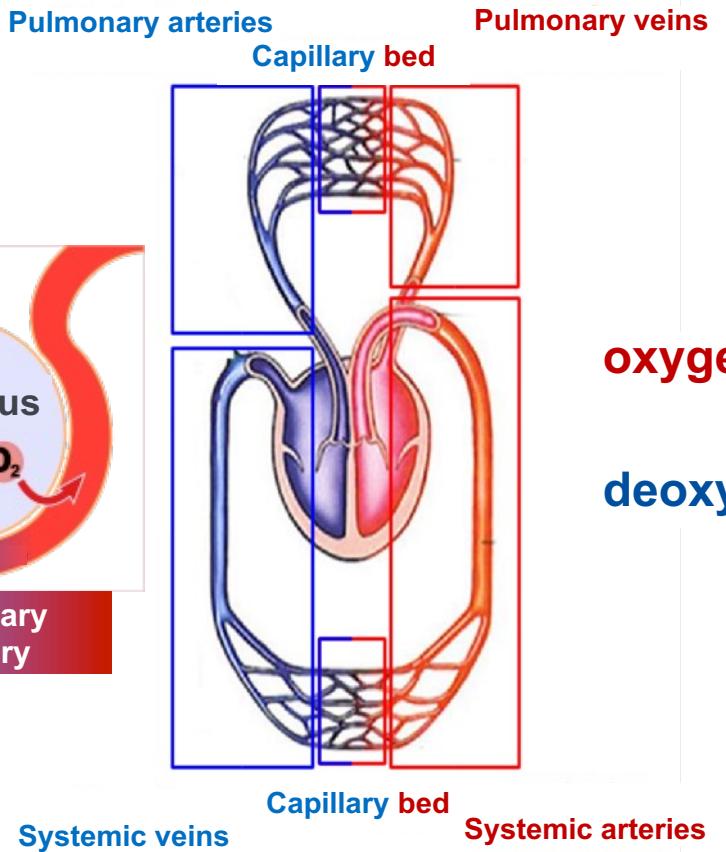
Systemic circulation



The cardiovascular system (human)

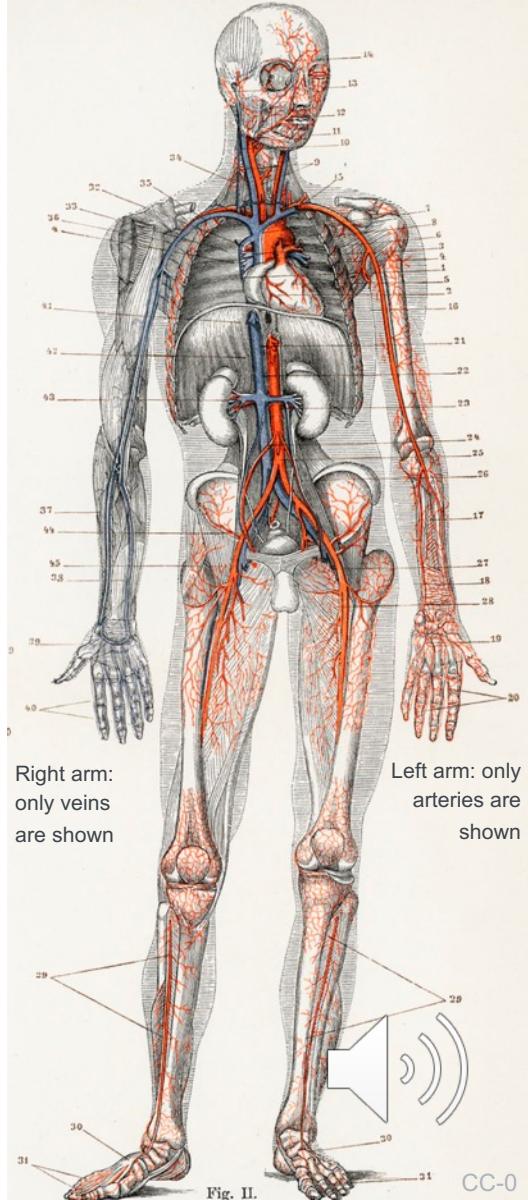


pulmonary capillary

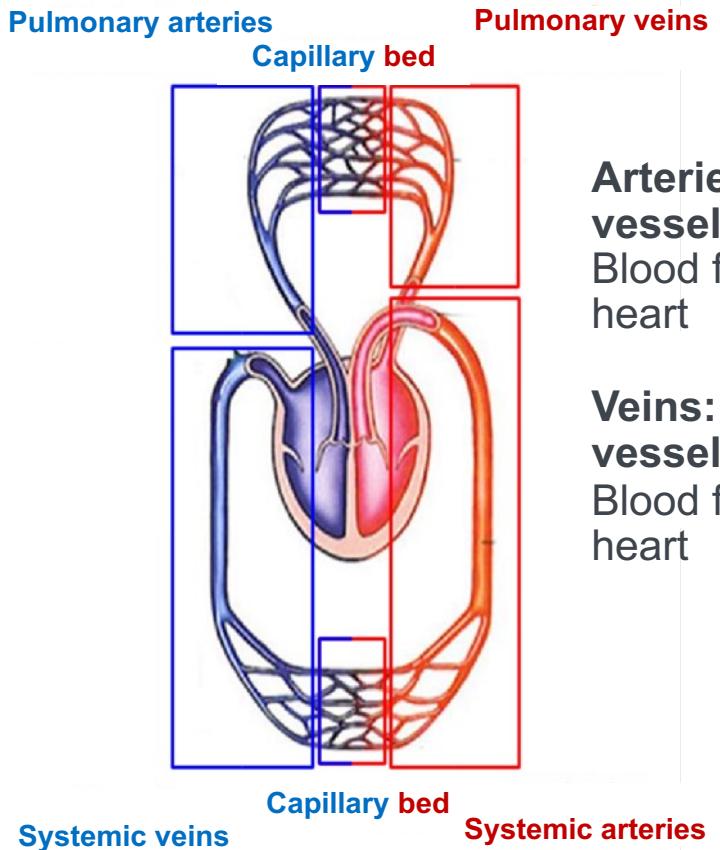


oxygenated blood

deoxygenated blood

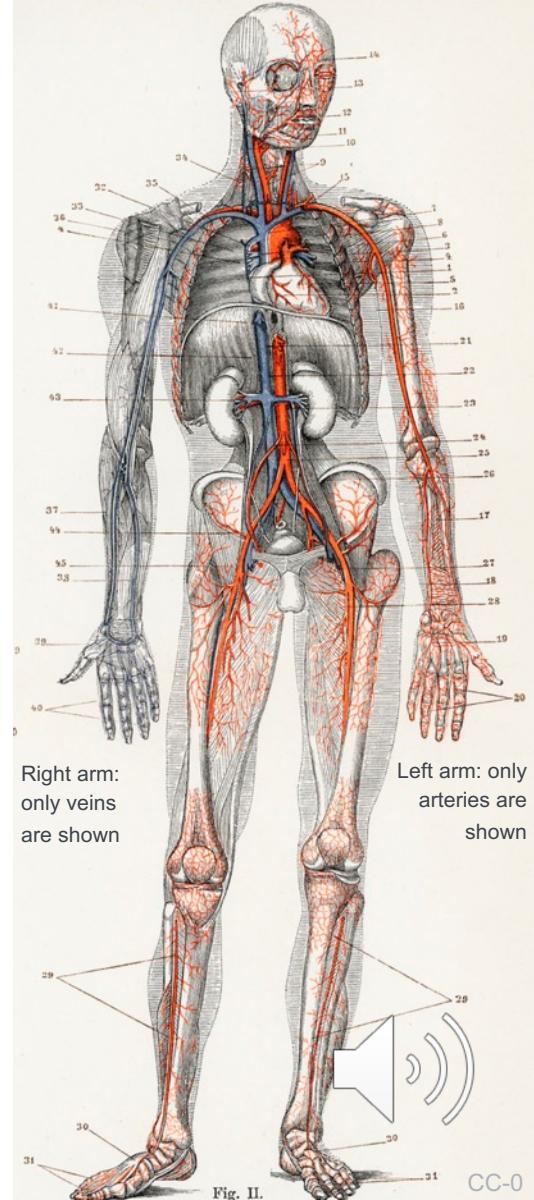


The cardiovascular system (human)

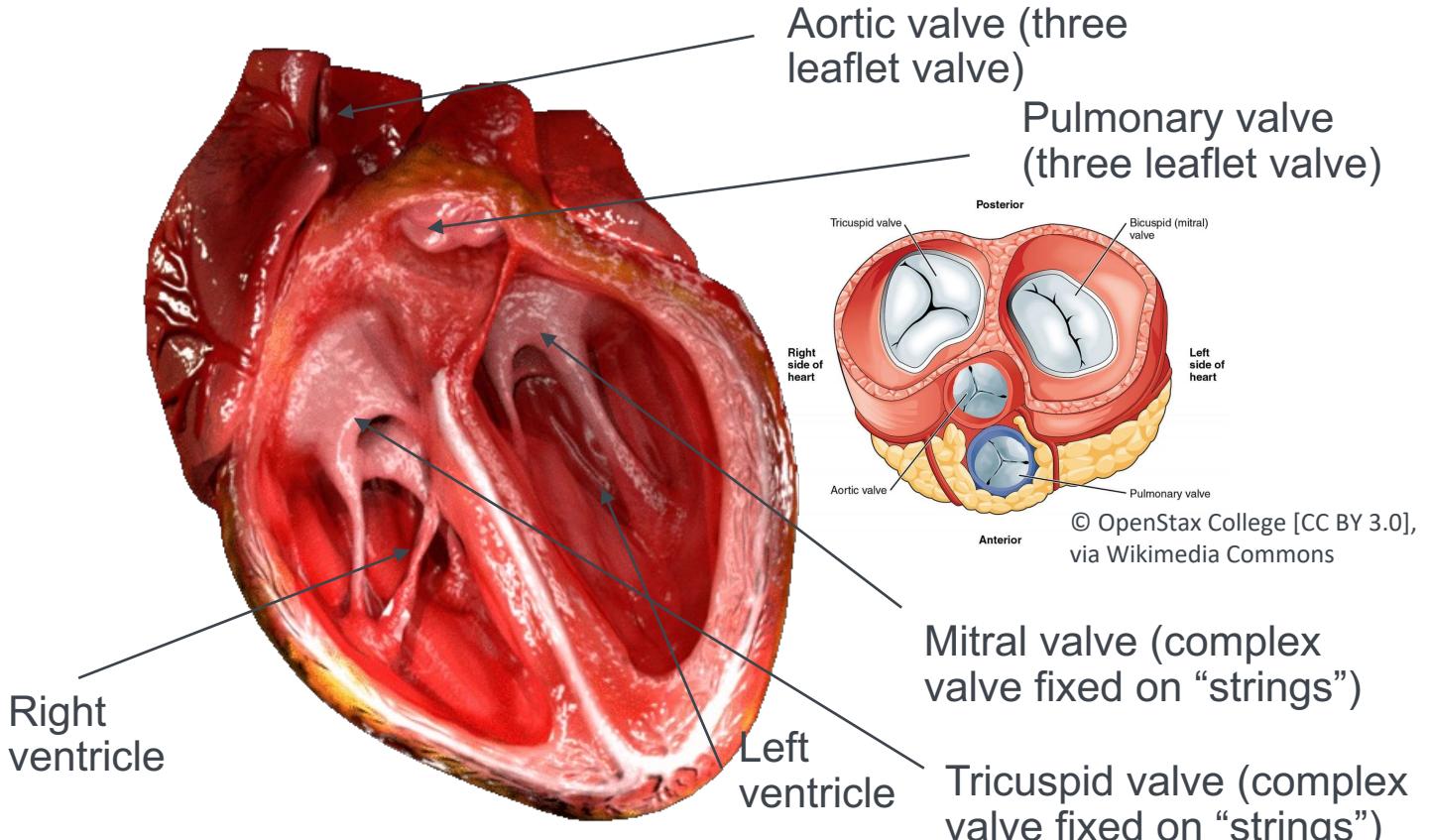


Arteries: High pressure vessels
Blood flows away from the heart

Veins: Low pressure vessels
Blood flows towards the heart

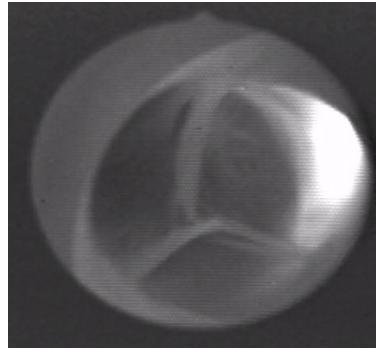


The heart – driver/pump of blood circulation



By DrJanaOfficial - Official Website, Support, License: CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=50477765>
In 3D @ <https://sketchfab.com/3d-models/3d-animated-realistic-human-heart-v20-168b474fba564f688048212e99b4159d>

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Pig aortic valve in the lab
(© Valveguru CC-BY-SA 3.0)

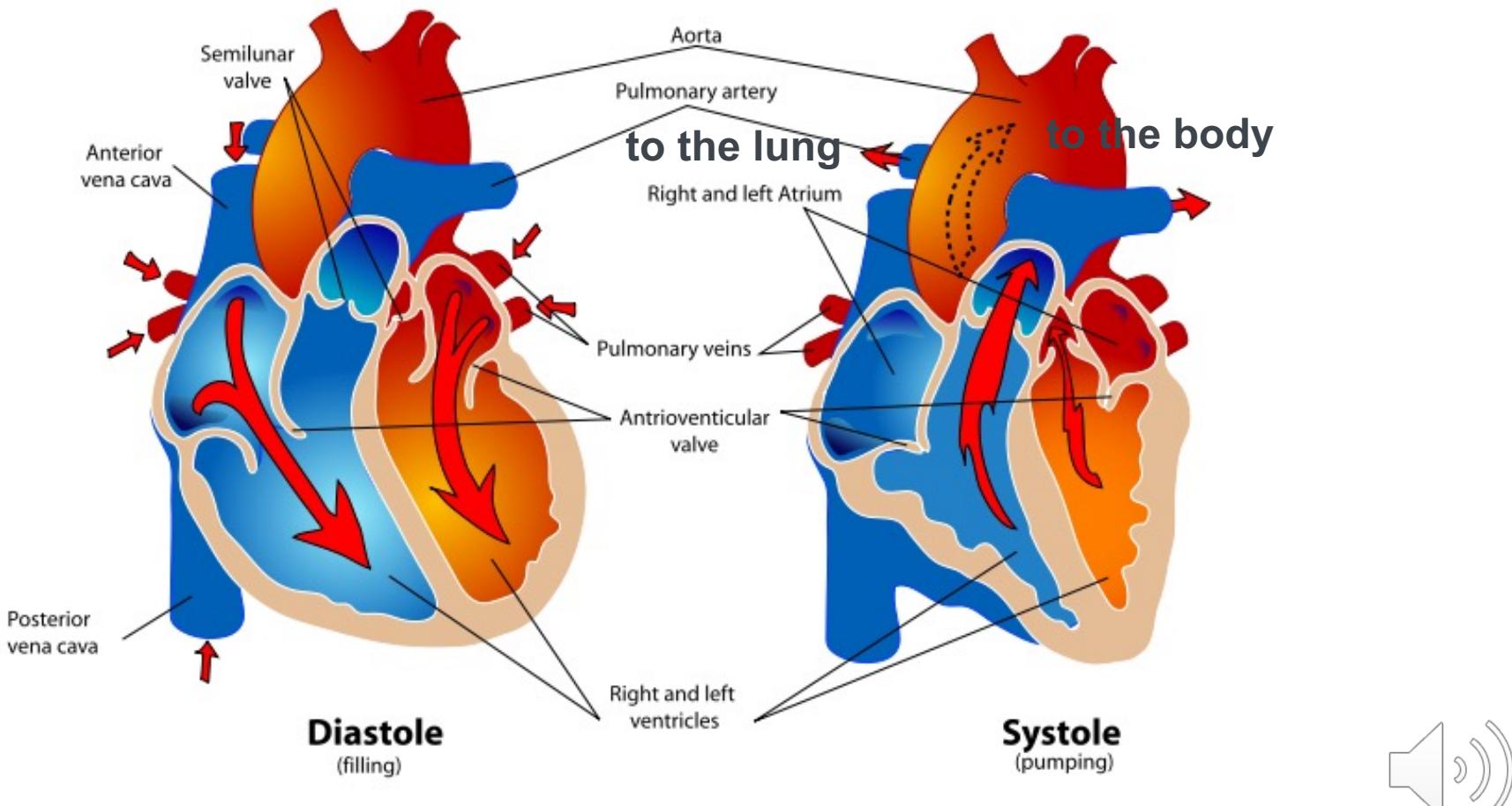


Artificial biological tissue valve
(© Stif Komar CC-BY-SA 3.0)

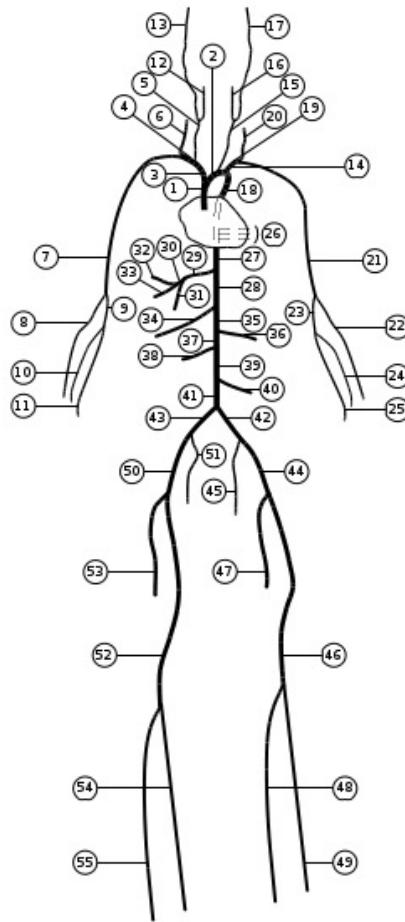


Mechanical valve
(© public domain)

The heart – driver/pump of blood circulation



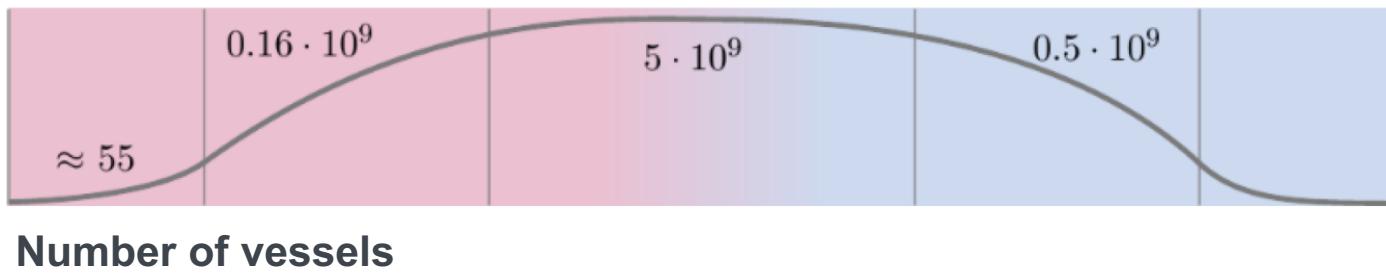
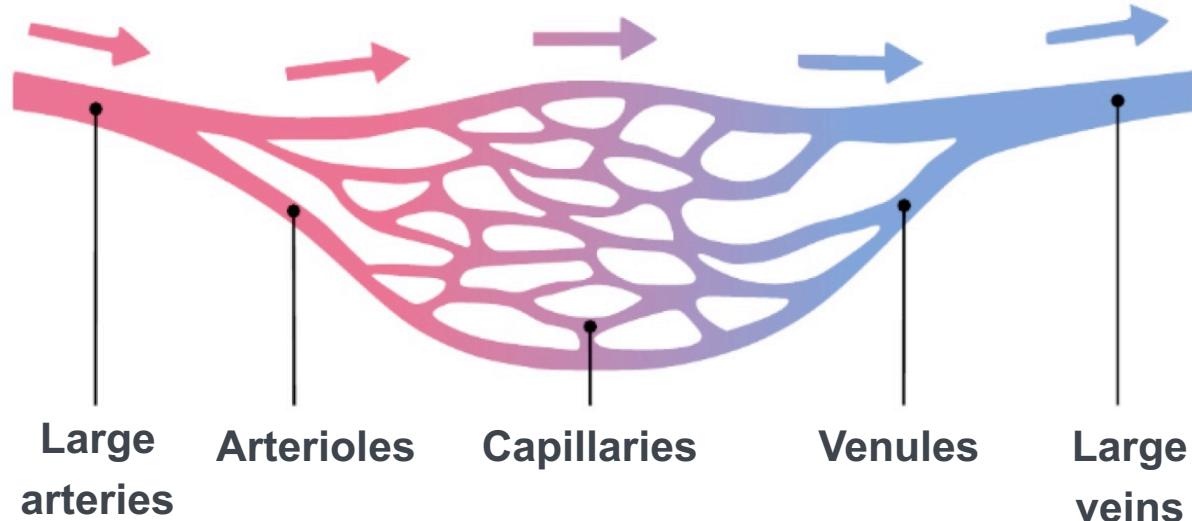
The human vascular system – aorta and large arteries



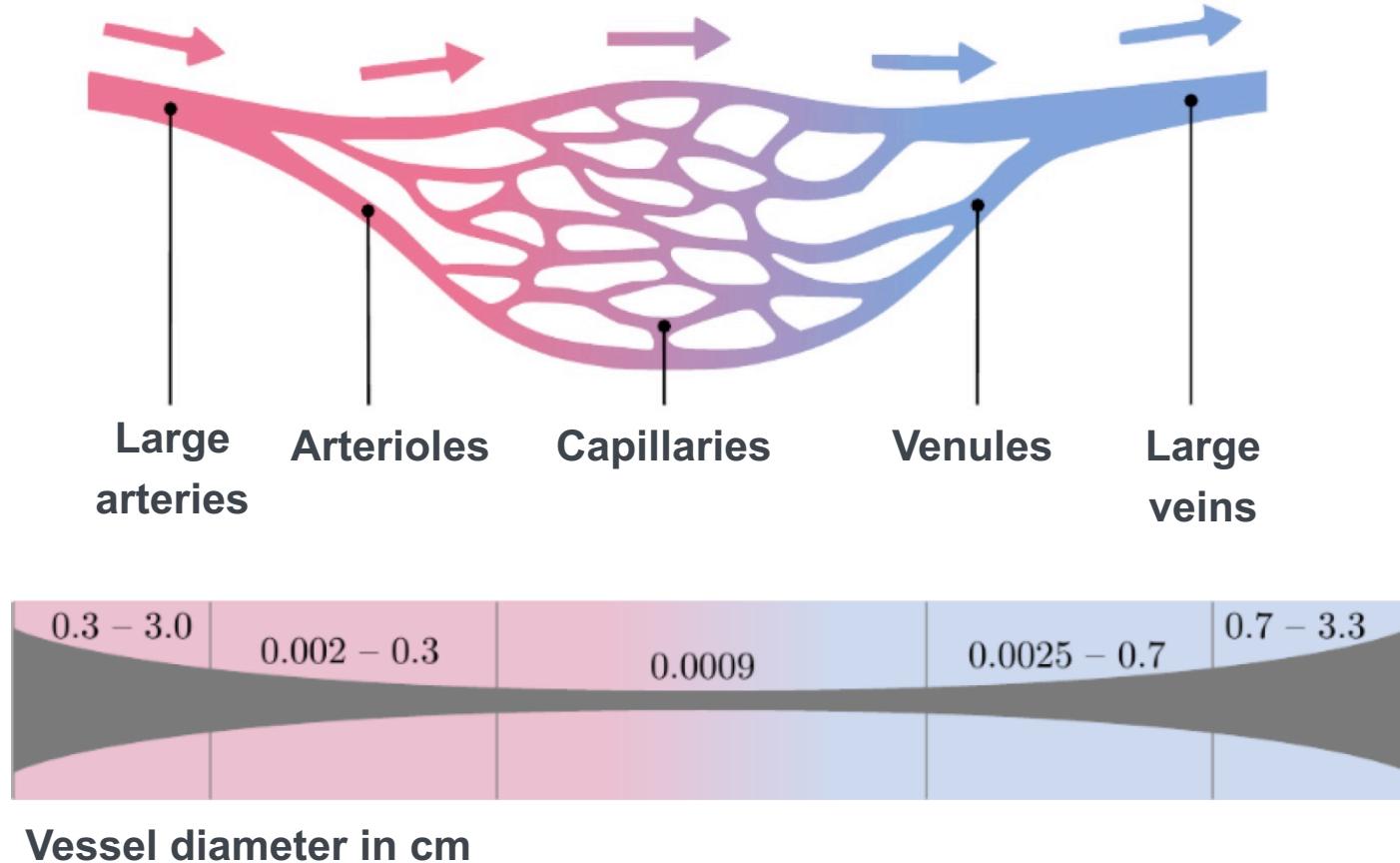
- Duration of systole: 0.15 s
- Duration of diastole: 0.70 s
- Ca. 70 heart beats per minute
- Between 5 and 6 liter of blood are pumped through the vascular system per minute
- Left ventricle is connected to aorta
- The aorta is connected to a system of 55 large arteries



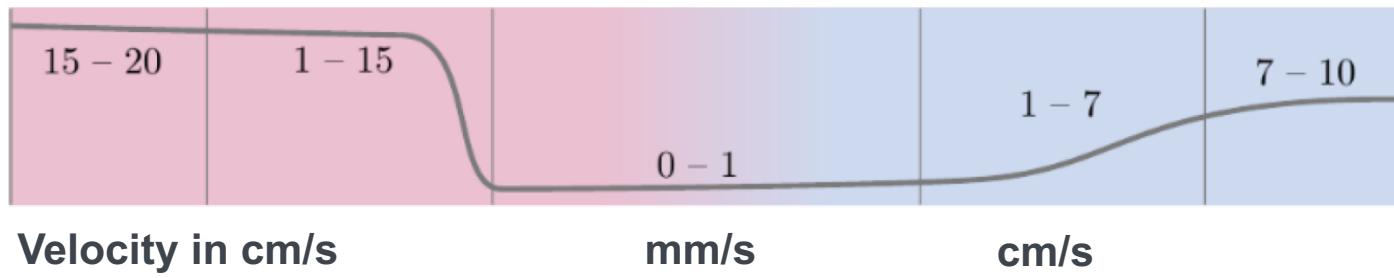
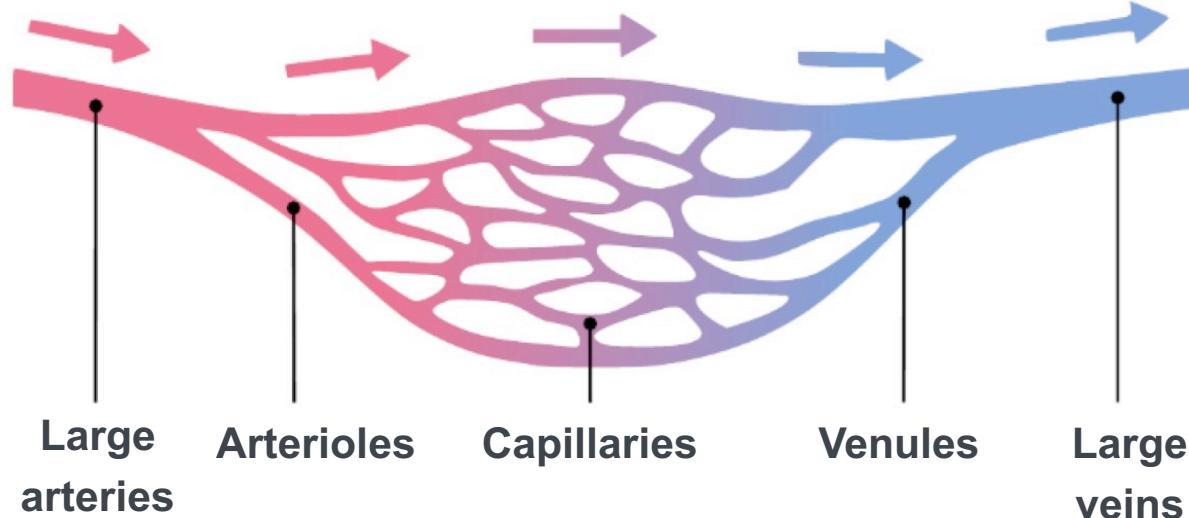
Structure and properties of the vascular system



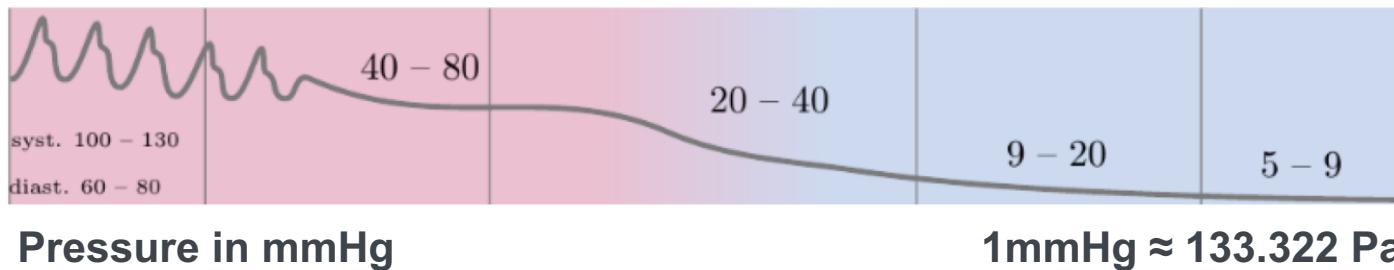
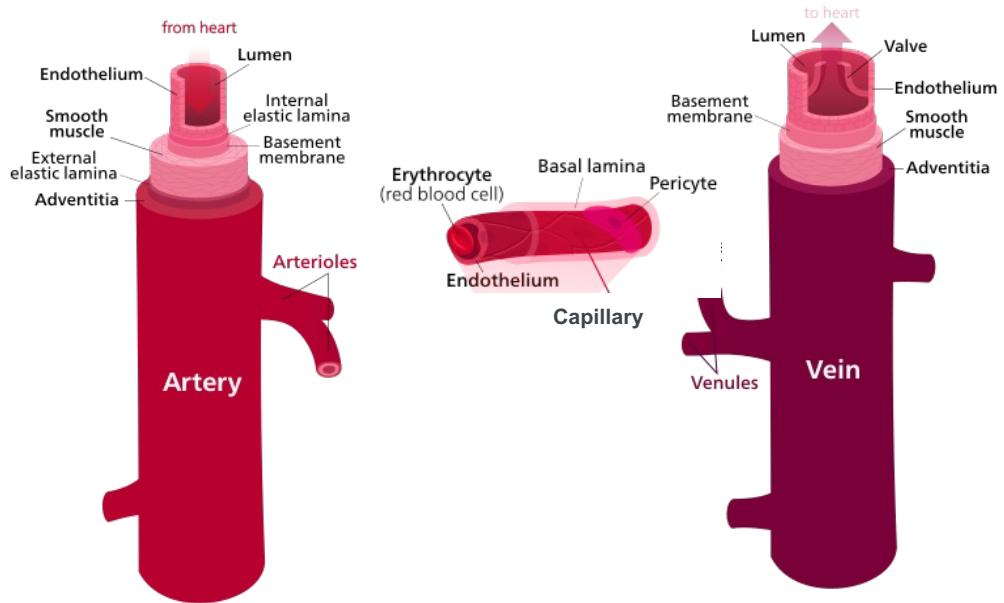
Structure and properties of the vascular system



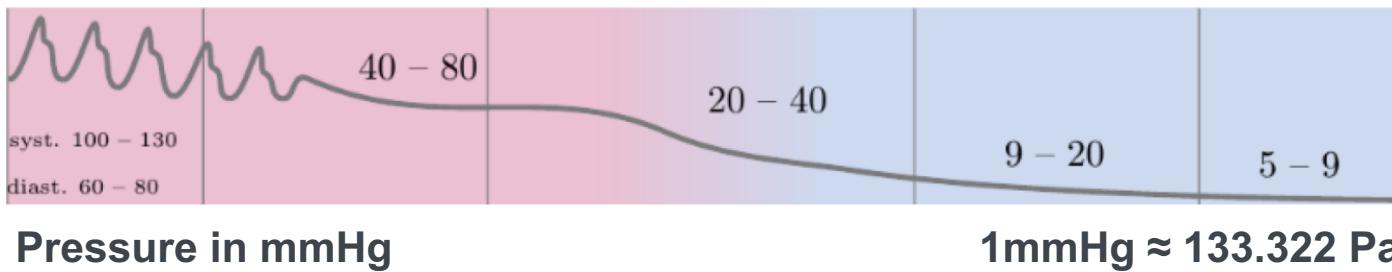
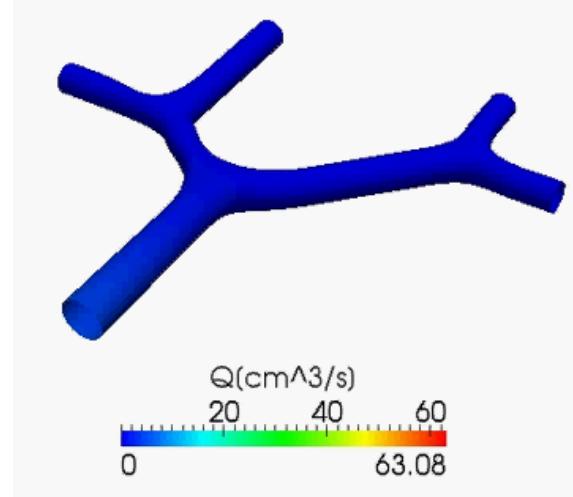
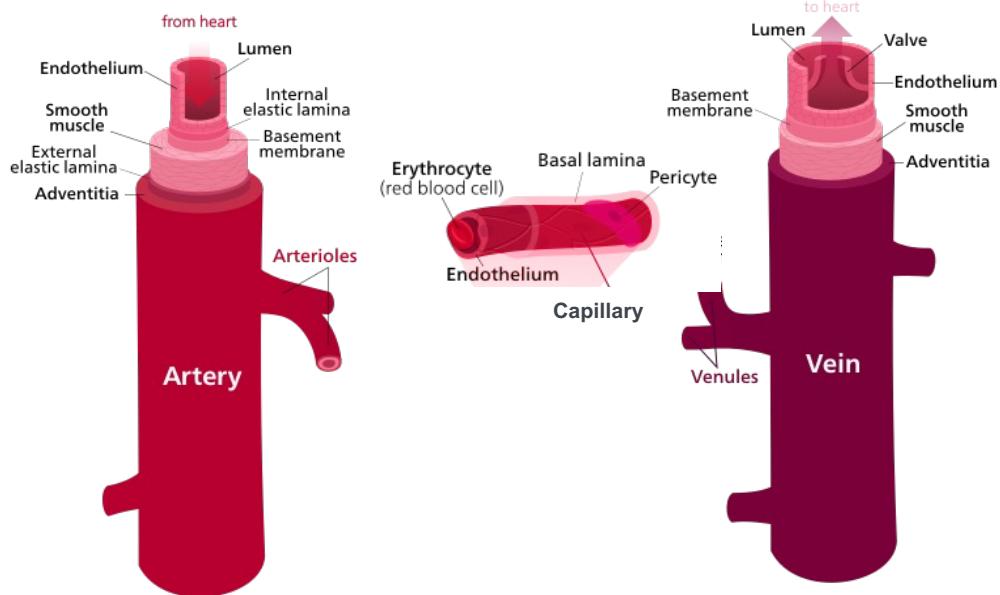
Structure and properties of the vascular system



Structure and properties of the vascular system



Structure and properties of the vascular system

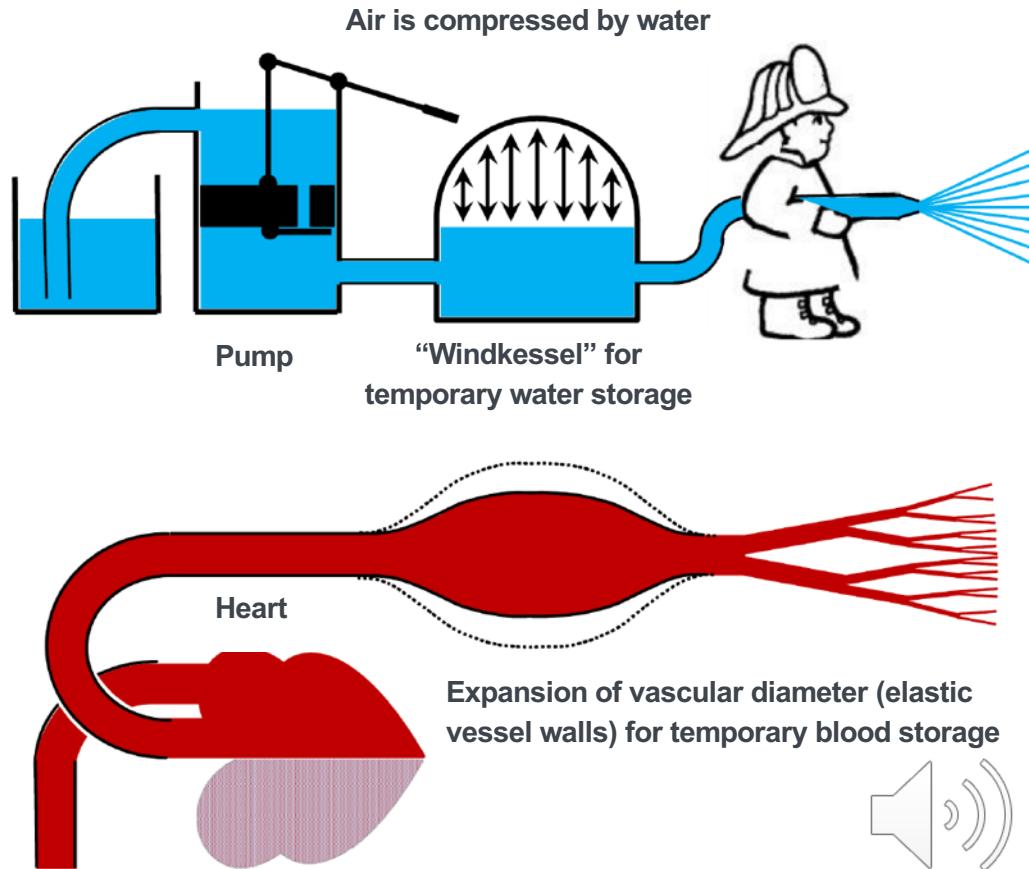


Structure and properties of the vascular system

What effect does the elasticity of the (large) vessels have?

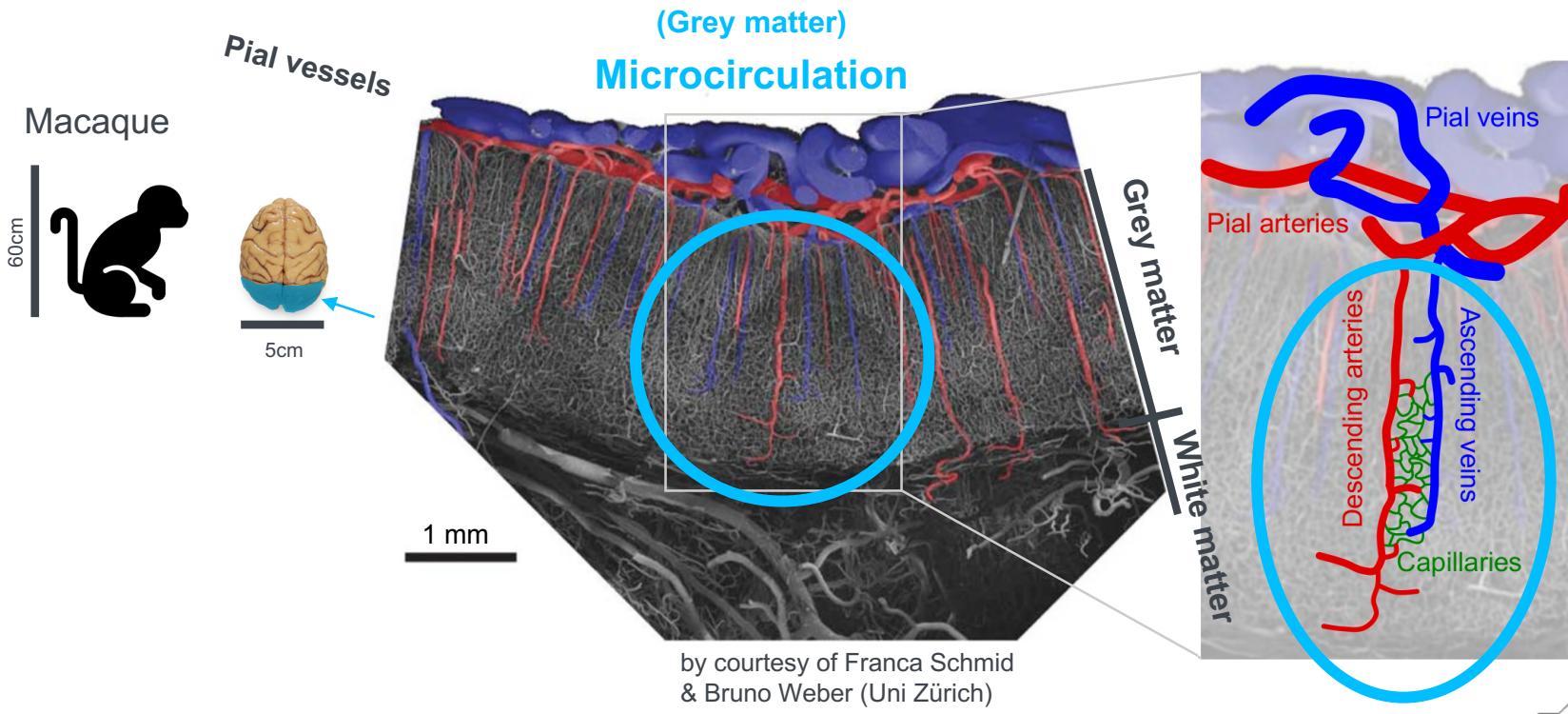
“Windkessel”-effect

The elastic wall of arteries allows them to store blood temporarily during the systole. Contractile forces push blood forward into the smaller vessels. Thus, continuous blood supply of all organs is achieved.



Structure and properties of the vascular system

Microvasculature (example: brain)



For more info read: Schmid et al. (2017) *Vascular density and distribution in neocortex*, *NeuroImage*, doi:10.1016/j.neuroimage.2017.06.046.

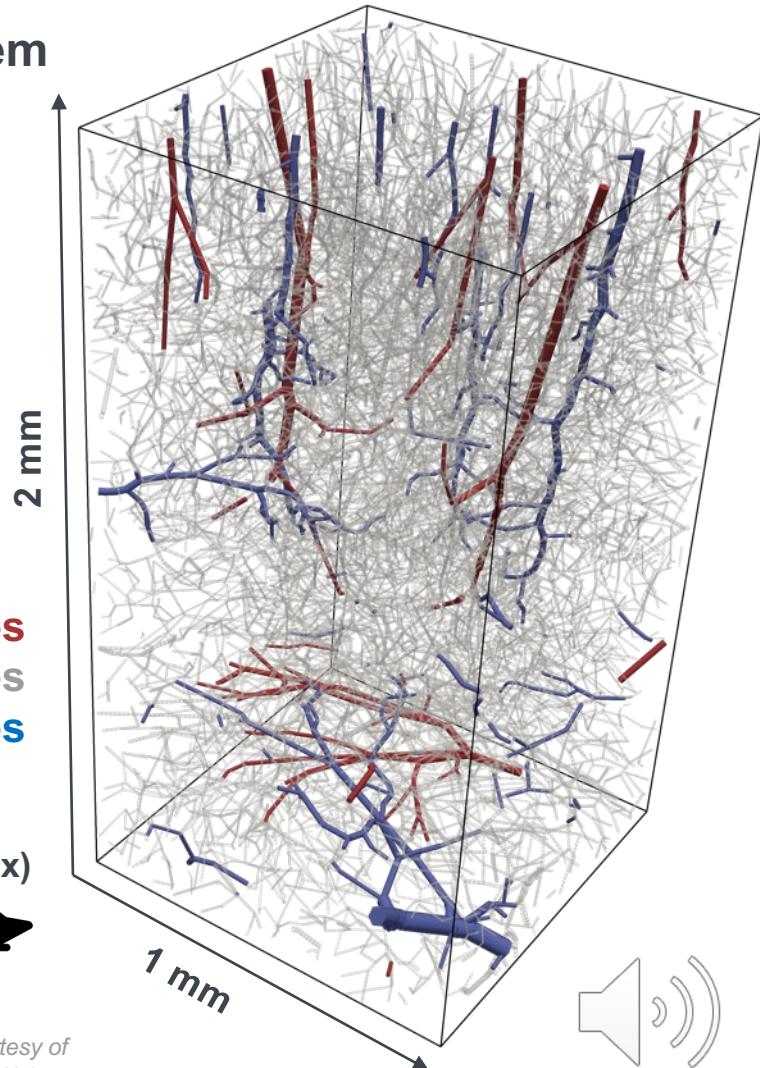
Structure and properties of the vascular system

Microvasculature

- Small diameters (approx. $<50\text{-}500\mu\text{m}$ depending on species and definition)
- Uniform flow through without pulsatile effects due to heartbeat
- Exchange of fluid and substances with tissue (capillaries)
- Dense network ($20\text{-}100\mu\text{m}$ average distance between capillaries)

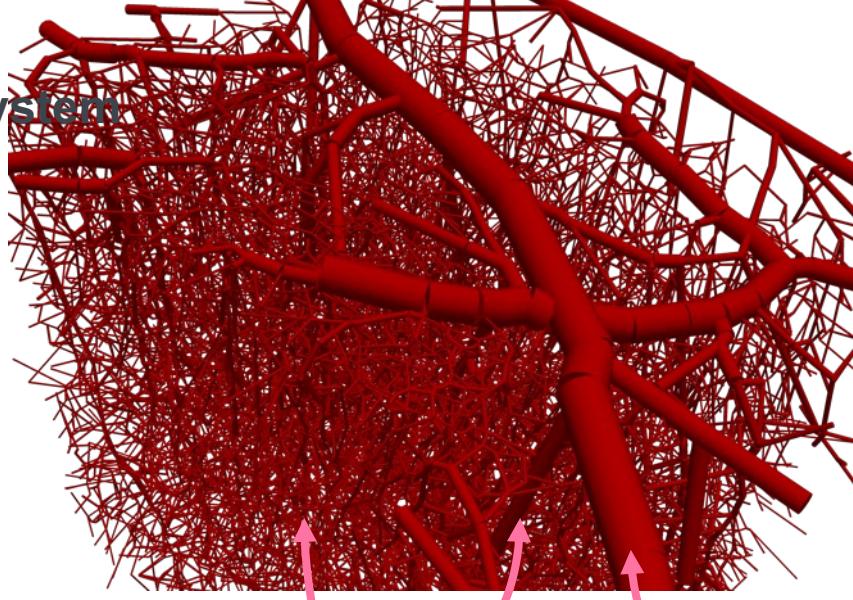
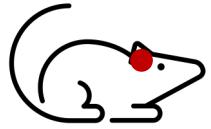
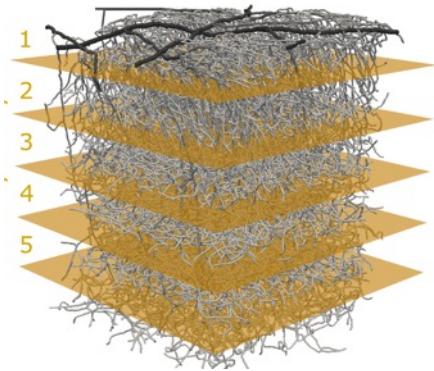
Arterioles
Capillaries
Venoles
Rat brain (cortex)


*Network geometry by courtesy of
Johannes Reichhold, Bruno Weber,
Patrick Jenny ETH Zürich & Uni Zürich*

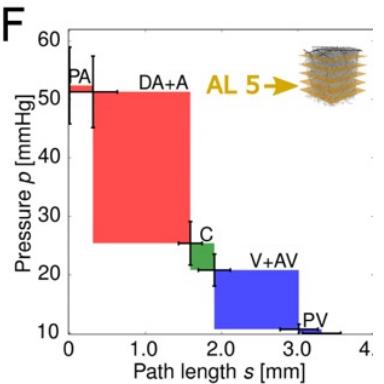
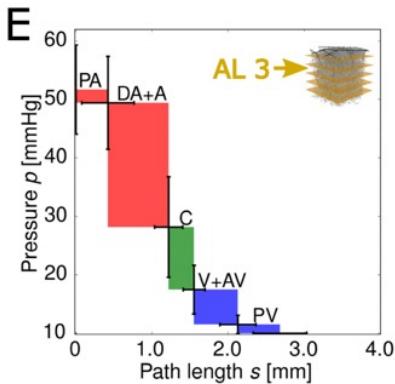
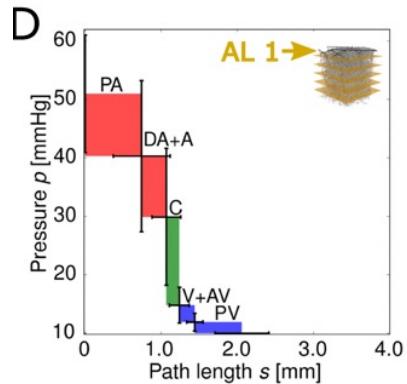


Structure and properties of the vascular system

Microvasculature (example: brain)

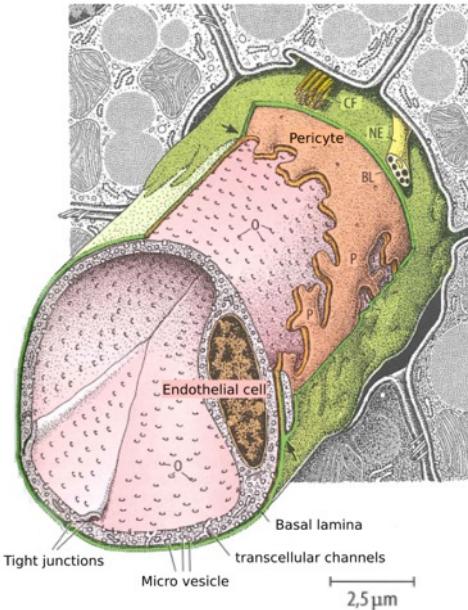


Pressure drops along pathways of different cortical depth

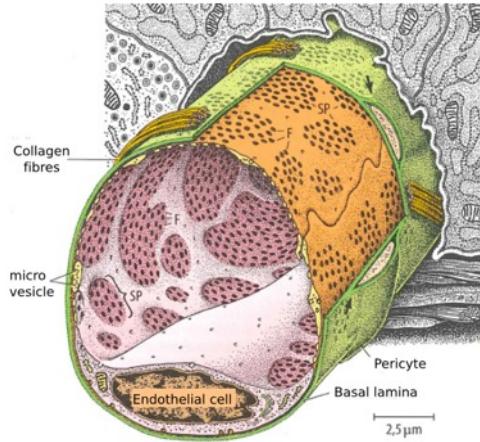


Structure and properties of the vascular system

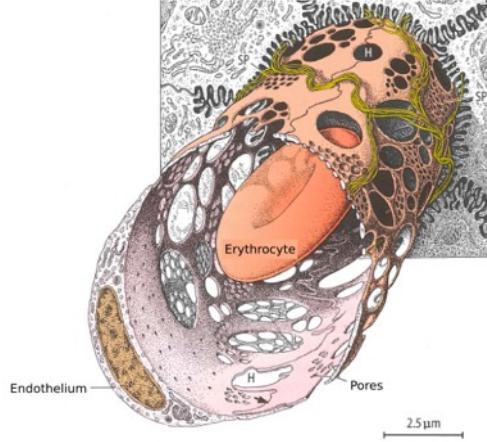
Different types of capillaries



(a) Continuous capillary.
brain, skeletal muscle, skin



(b) Fenestrated capillary.
kidney (glomeruli), pancreas, intestines



(c) Discontinuous capillary.
liver, bone marrow



Extra-vascular tissue

Example: Brain

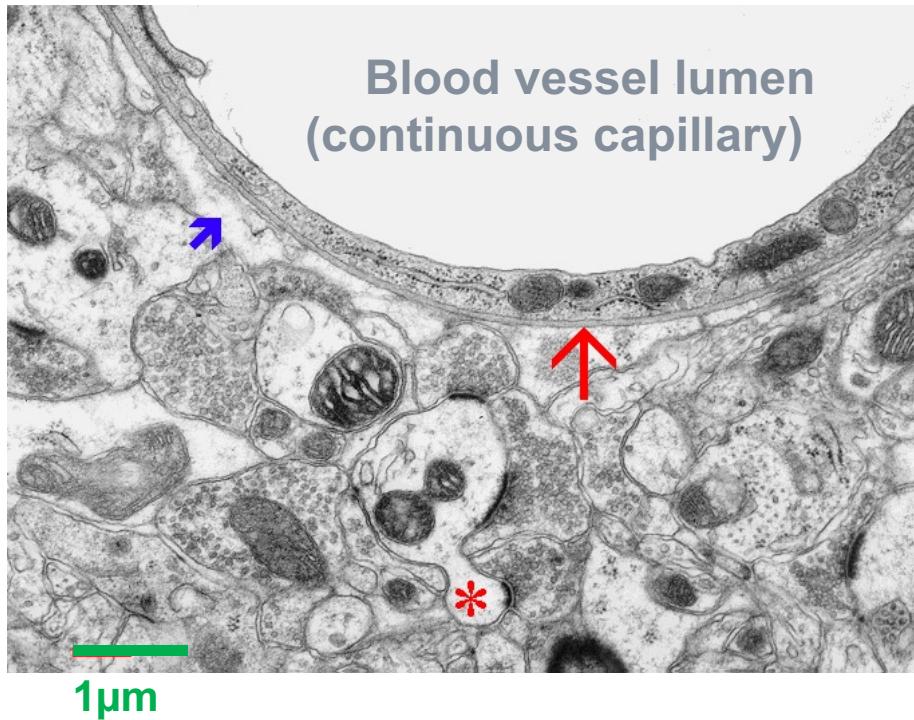
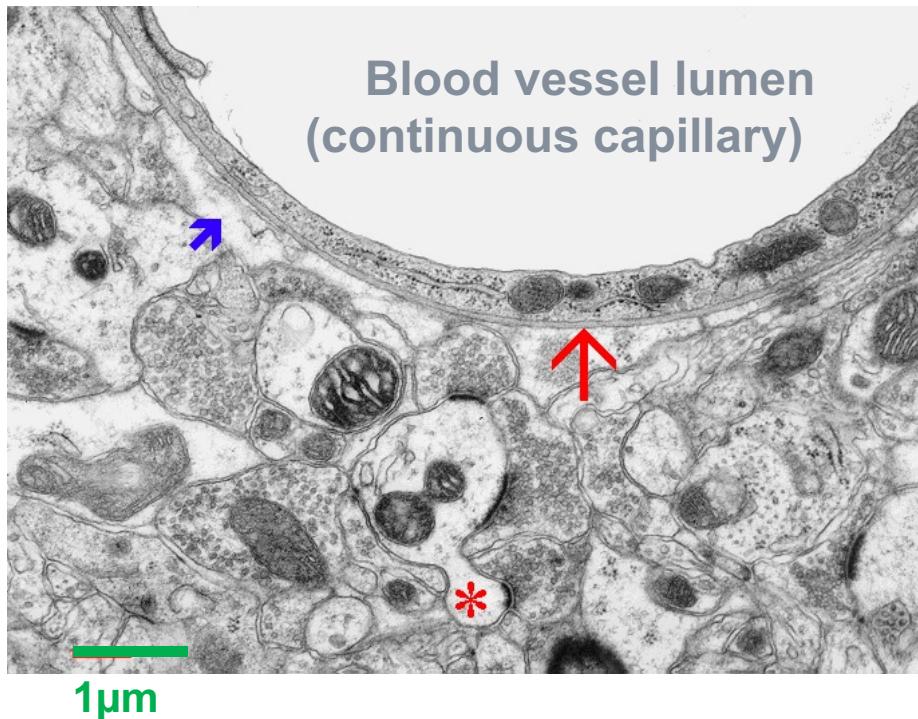


Figure 3.05 from the Atlas of Ultrastructural Neurocytology at SynapseWeb (by Josef Spacek, <https://synapseweb.clm.utexas.edu/atlas>, Kristen M. Harris, PI).



Extra-vascular tissue

Example: Brain



Interstitial / extra-cellular matrix (ECM):
20-100nm wide “tunnels” / “sheets”

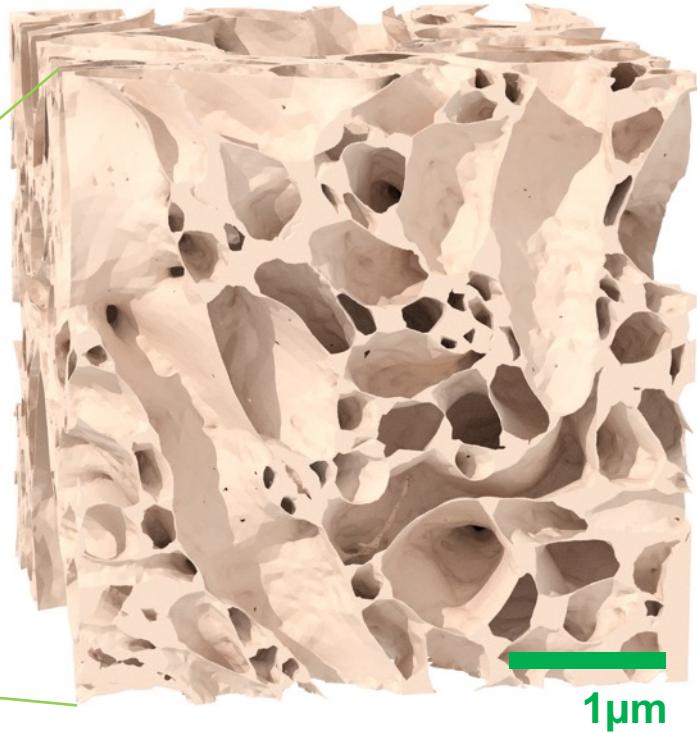
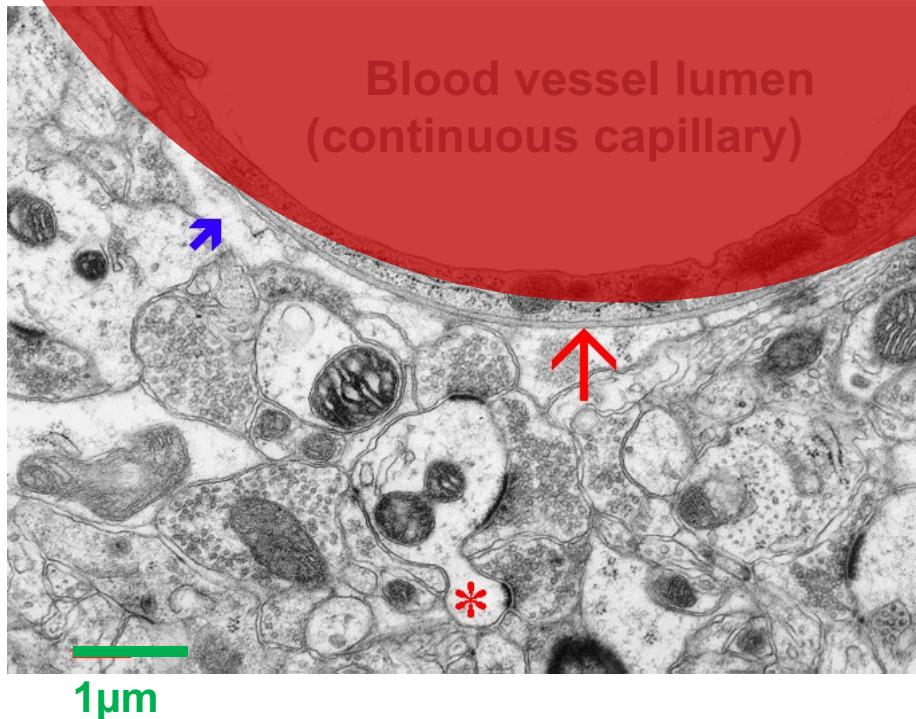


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Hippocampal Neuropil ECM. 3D rendering by T Koch based on data from JP Kinney et al (2012), JCN, <https://doi.org/10.1017/cbo.2012.181>

Extra-vascular tissue

Example: Brain



Interstitial / extra-cellular matrix (ECM):
20-100nm wide “tunnels” / “sheets”



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Extra-vascular tissue
Example: Brain

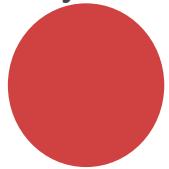
10 μm

capillary

arteriole /
Small artery



• capillary



small artery

100 μm

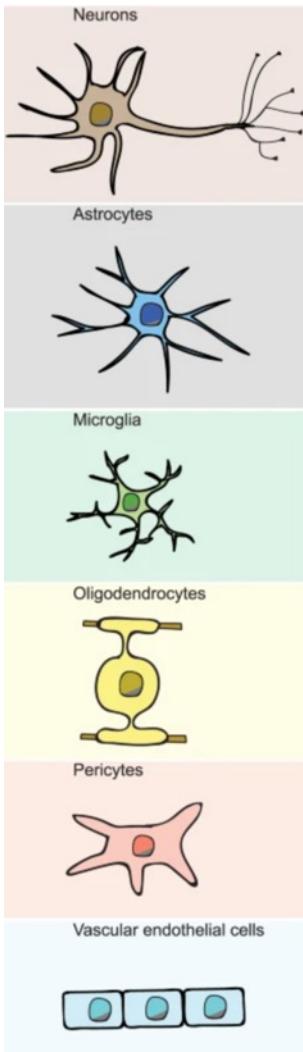
mid-sized /
large artery
(mm)



Extra-vascular tissue

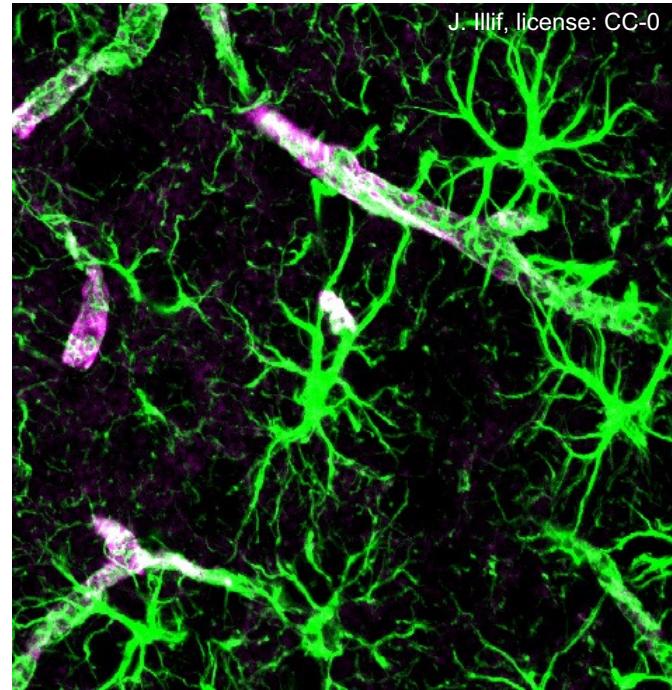
Example: Brain

- Variety of cells in different sizes (approx. 1-20 μm) and shapes
- Small intercellular spaces (100nm)
- *Mathematical modeling:* Extra-vascular tissue is often described in simplified terms as a homogeneous porous medium with averaged properties (properties may differ depending on tissue type) → Cells as solid phase and interstitium (pore space) filled with fluid phase



Modified from Penney et al (2020)
<https://doi.org/10.1038/s41380-019-0468-3>
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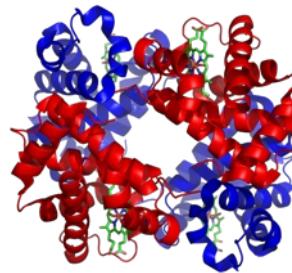
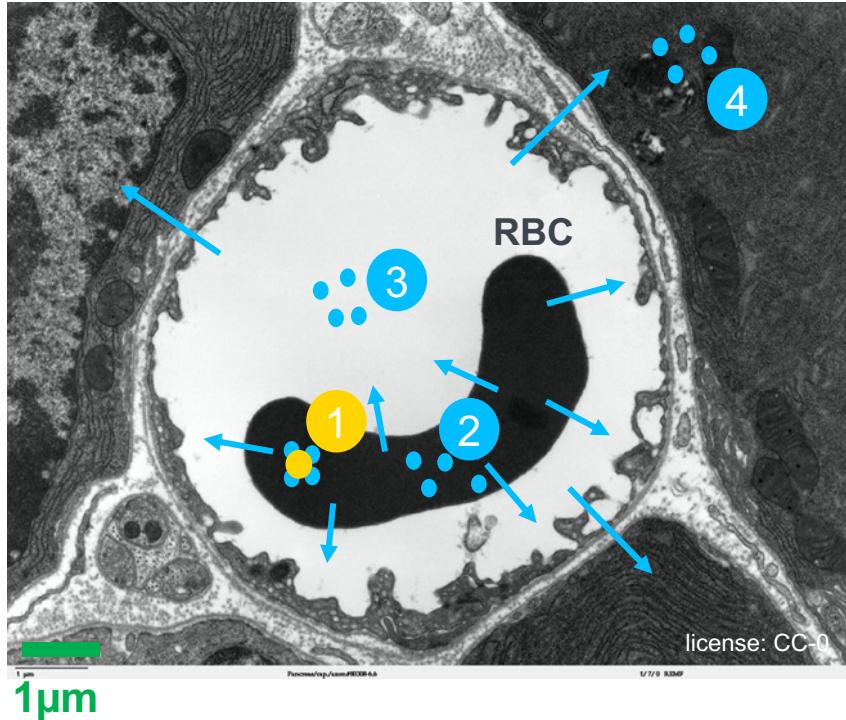
Cell types parenchyma



Glia cells (astrocytes green) and blood vessels

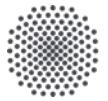
Extra-vascular tissue

Oxygenation of tissues through blood flow



1. Hemoglobin-bound oxygen
(4 heme groups, one O₂-molecule per heme)
2. Free oxygen in erythrocytes (dissolved)
3. Oxygen in vessel lumen (blood plasma)
4. Oxygen in extra-vascular tissue
(oxygen consumption by metabolism)





University of Stuttgart

Institute for Modelling Hydraulic and Environmental Systems

Thank you!



<https://www.iws.uni-stuttgart.de/lh2/>

Timo Koch (Oslo)

e-mail timokoch@ui.no

University of Stuttgart
Pfaffenwaldring 61, 70569 Stuttgart

**Institute for Modelling Hydraulic
and Environmental Systems,**

**Department of Hydromechanics
and Modelling of Hydrosystems**



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