The history of Hemodynamics

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Semester Schedule

Week	Date	Topic
1		History of Hemodynamics, Circulatory System
2		Arterial System
3		Venous System and Microcirculation
4		Microcirculation and Cardiovascular control mechanisms
5		Mechanics of the vessel wall
6		Pressure measurement (invasive and non-invasive)
7		Cardiovascular diseases
8		Basic concepts in fluid mechanics
9		Medical Imaging
10		From medical image to numerical geometry
11		ID simulation for cardiovascular problems
12		3D simulations for cardiovascular problems
13		Usual quantities in the evaluation of numerical hemodynamics
14		Lab

Course work

- Scientific paper review (max two pages)
  - Deadline: **7th week, individual task**
- **Group project** (1-2 person/team)
  - Numerical or experimental work
  - Proposed assignments: next slide
  - Deadline: 14th week
  - Poster in A3 format

Proposed assignments

1. Hemodynamic analysis of the basilar artery treated with a coronary stent
2. Modelling the buckling of the brachial artery during BPM
3. 1D simulation of the flow in the arterial system
4. Numerical simulation of simplified stenosed arteries
5. Wall Shear Stress analysis of a carotid bifurcation with stenosis
6. Flow structure analysis of a carotid bifurcation with stenosis

Contents

- What is Hemodynamics?
- History on basic physiology
- History of blood pressure measurement (BPM)
- Departmental history
- The cardiovascular system

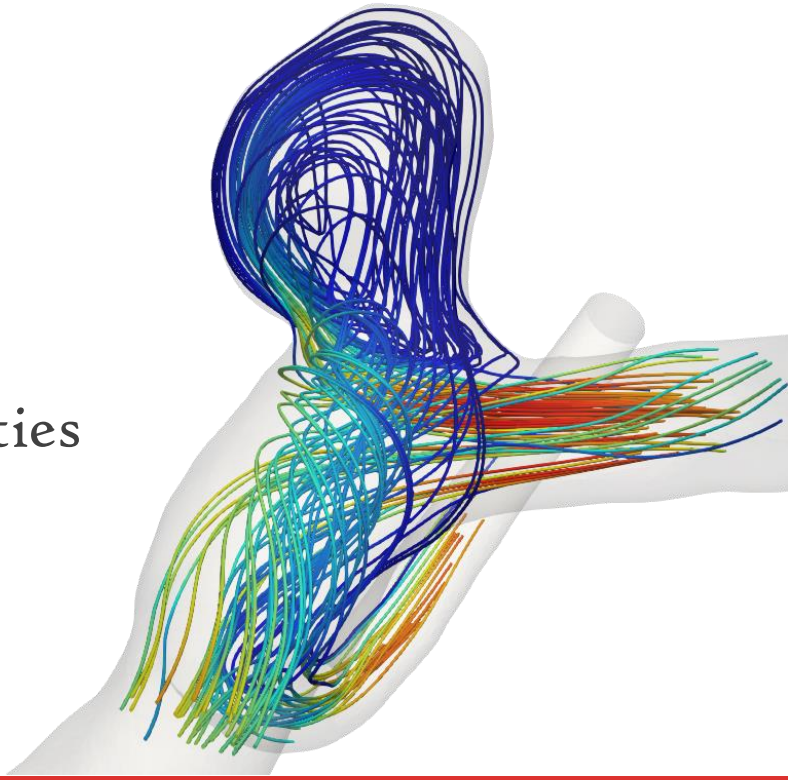
Hemodynamics

- is to study the **biomechanical aspects** of the cardiovascular (circulatory) system.

- explains the **physical laws** that govern the flow of blood in the blood vessels

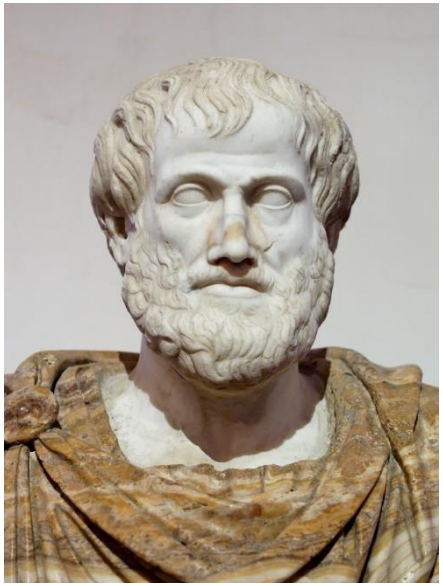
Describe the relations between:

- blood pressure
- blood flow
- vascular geometry, material properties
- rheologic properties of the blood



We "stand on the shoulders of giants"

Aristotle



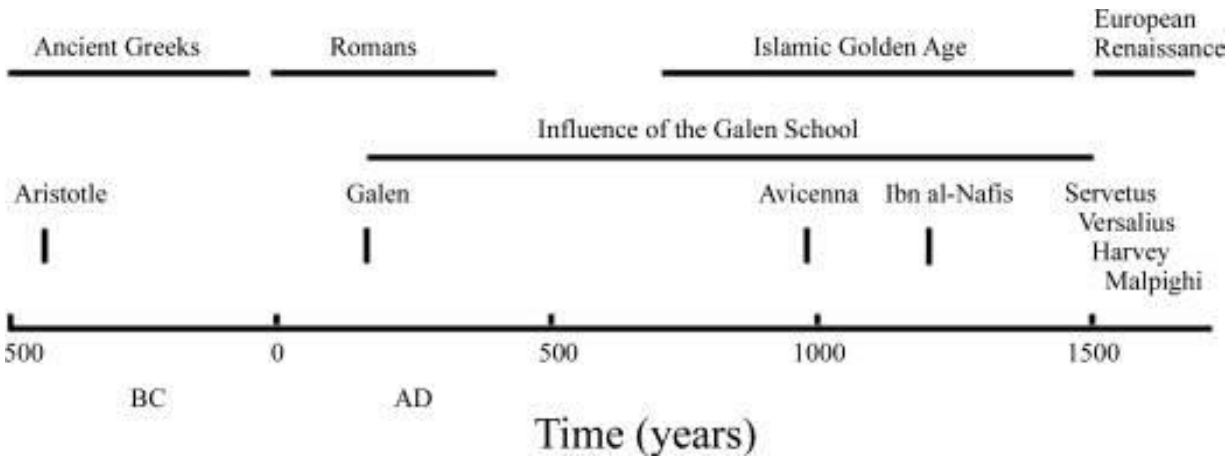
384 – 322 BC

Heart is the center

Praxagoras

~ 340 BC

Arteries and Veins



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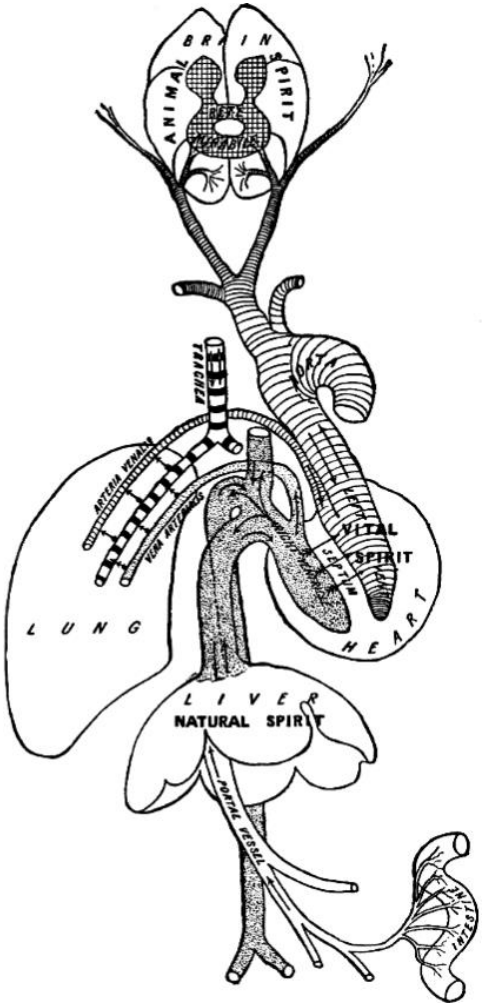
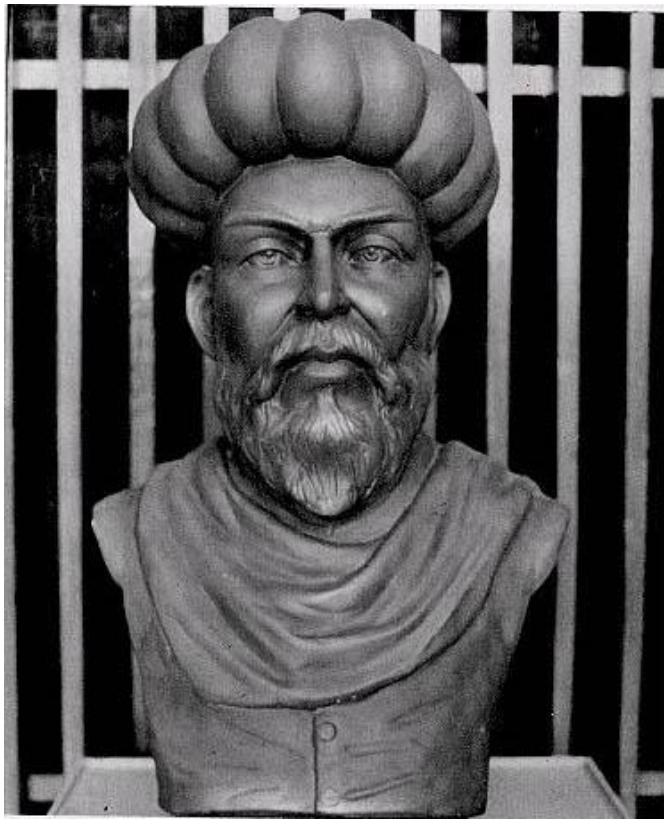


Galen

AD 129 – c. 210

Circulation

Ibn al-Nafis (1213 - 1288)

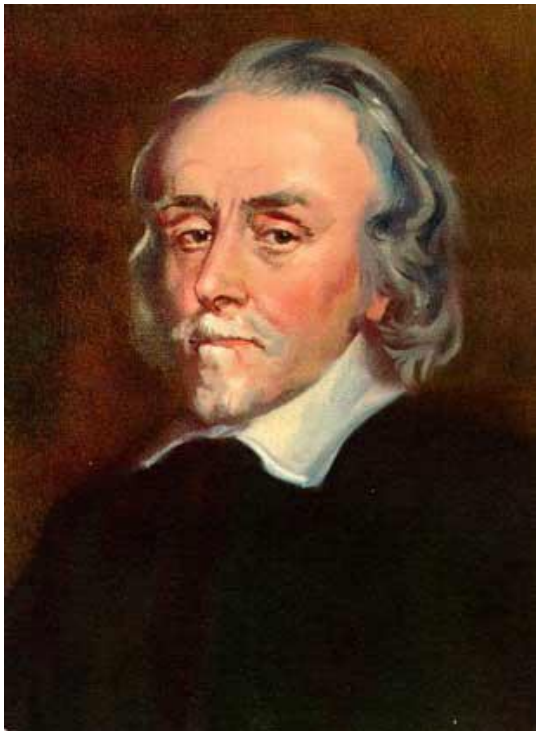


Pulmonary circulation

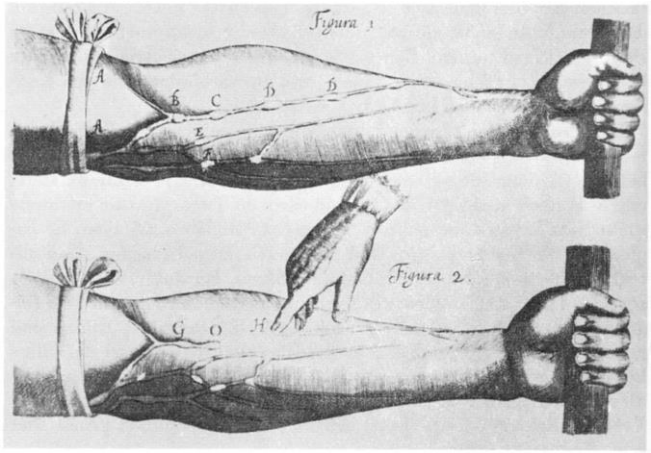
Early insight of the coronary and capillary circulations

Brain is center for thinking and sensation

William Harvey (1578 - 1657)



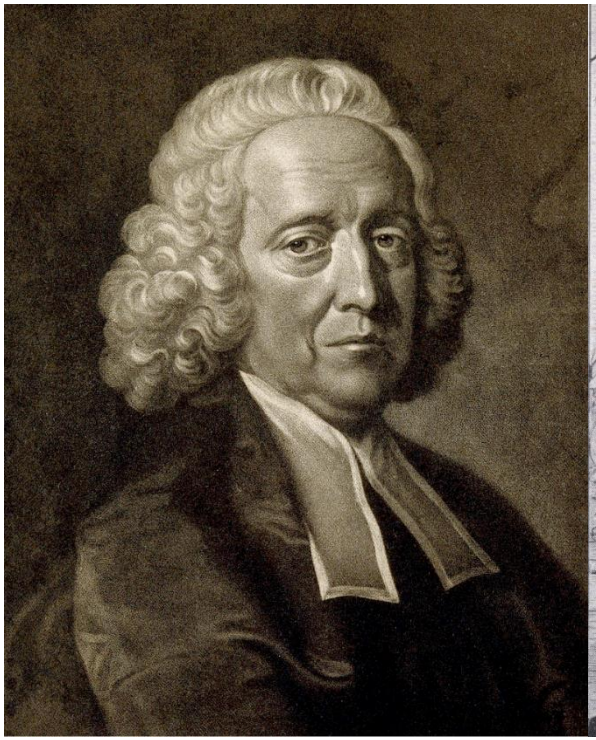
"An anatomical study of the motion of the heart and of the blood of animals."



Blood is pumped from the heart and **recirculated.**

Detailed description of the circulatory system.

Stephen Hales (1677 - 1761)



„Invasive"...
pressure measurement

Resistance due to friction
in small blood vessels

Role of the mitral
and aortic valve

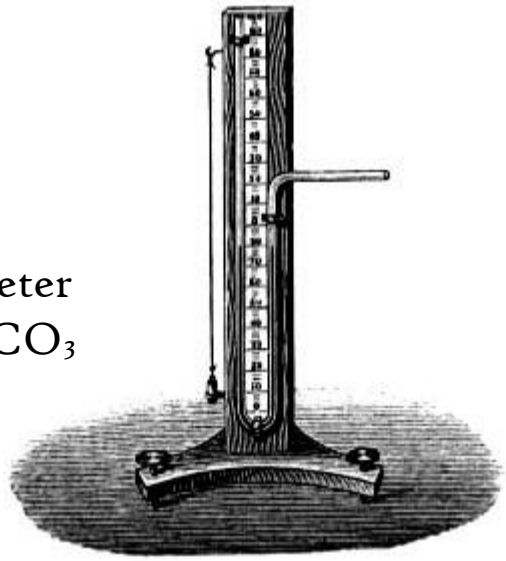
Jean Léonard Marie Poiseuille (1797 – 1869)

Hagen–Poiseuille law

$$\Delta p = \frac{8\mu L Q}{\pi R^4}$$

Invasive blood pressure

mercury filled U manometer connected through $NaHCO_3$ solution.



The born of “modern” blood pressure measurement

Departmental History

Dr. Gábor Halász

- **1D modelling of the arterial system**
  - Optimization for patient specific parameters
  - Backward Calculation
- Experimental validations

Dr. György Paál

- **3D modelling of arterial malformations**
  - Aneurysms
  - Stenosis
- Experiments for treatment devices

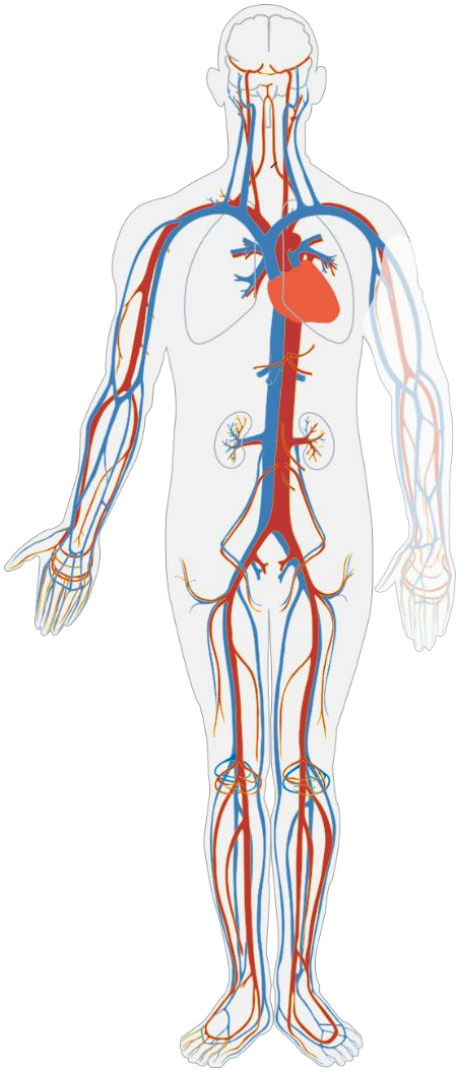
The circulatory system

Aim

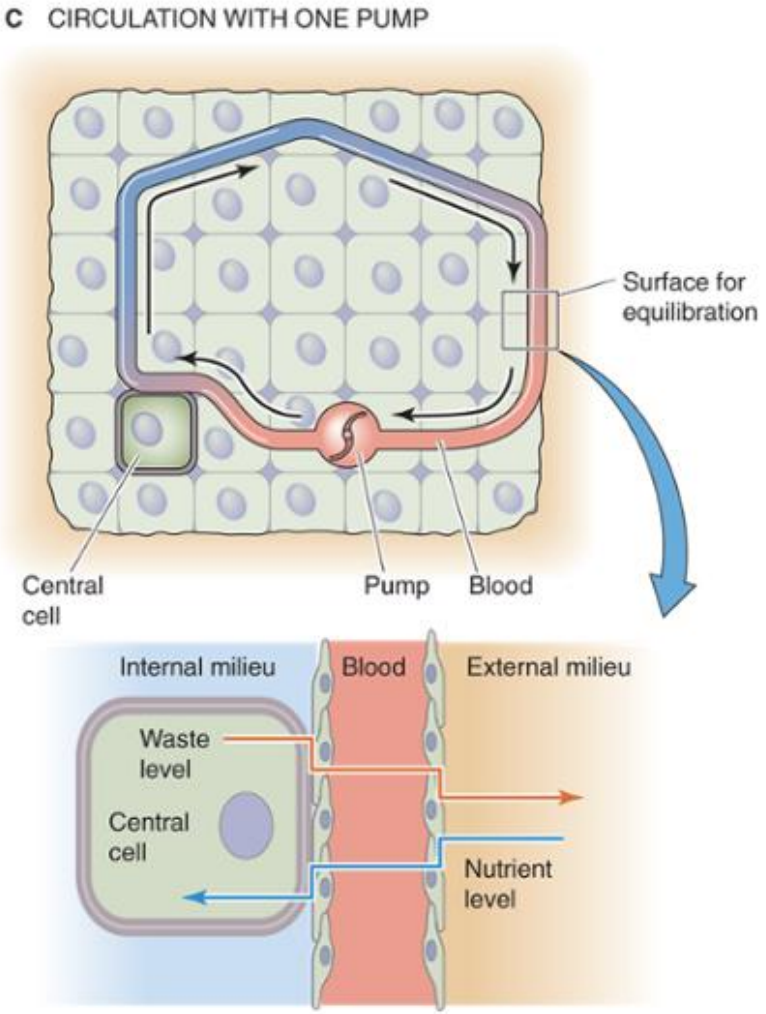
- Transport nutrients to cells
- Transport waste away from cells
- Gas transport (oxygen, co2)
- Help in fighting disease
- Stabilize temperature
- …

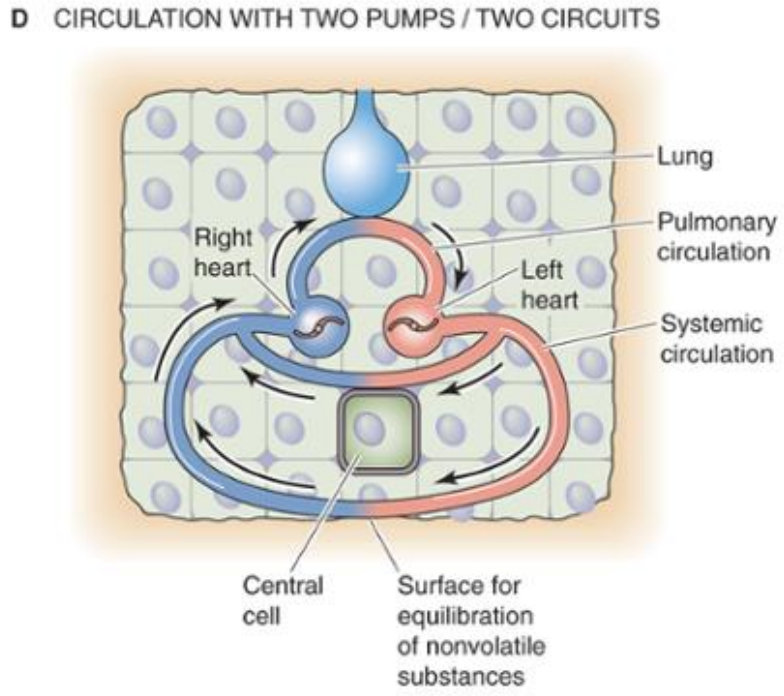
Components

- The heart: two “volumetric” pumps
  - Left and right heart
- Blood: plasma and blood cells
  - Non-Newtonian liquid!
- Blood vessels: tubes (Visco-elastic)
  - Arteries
  - Veins
  - Capillaries
- Lymphatic System

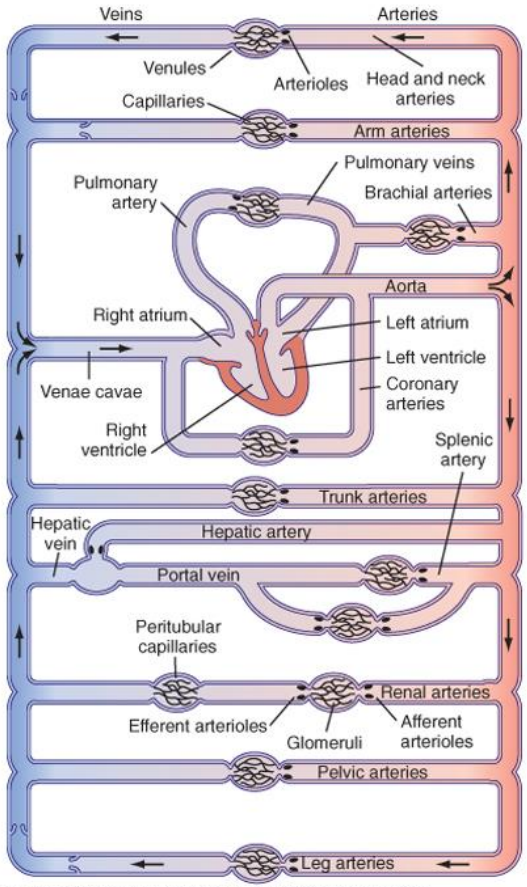


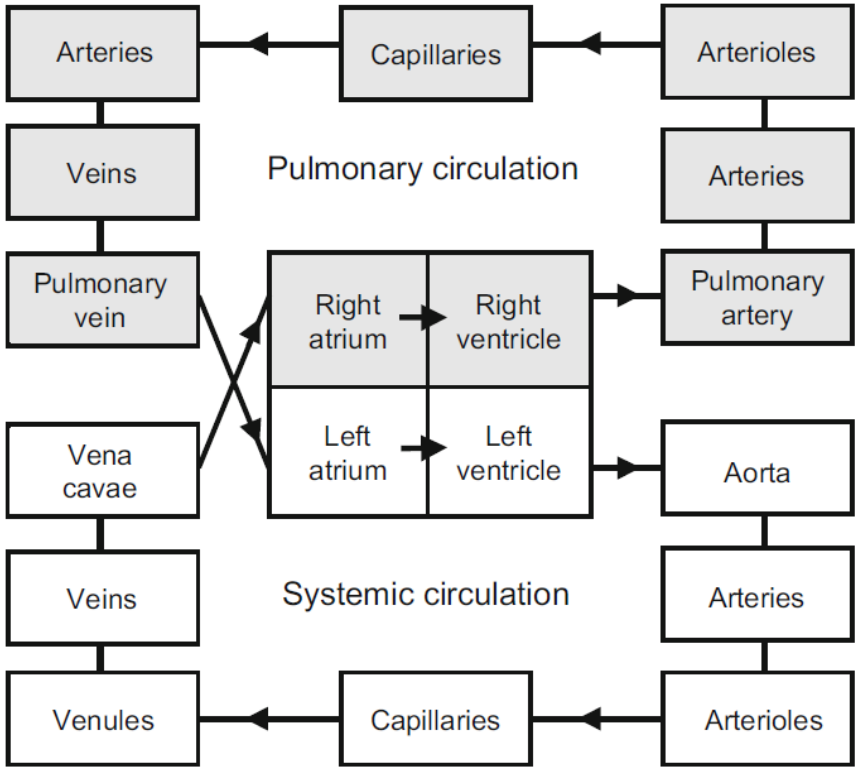
Evolution of the circulatory system





The human circulatory system





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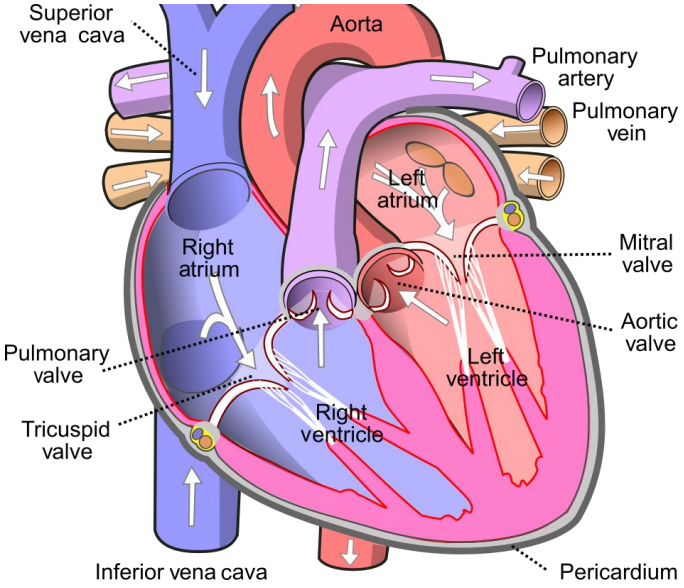
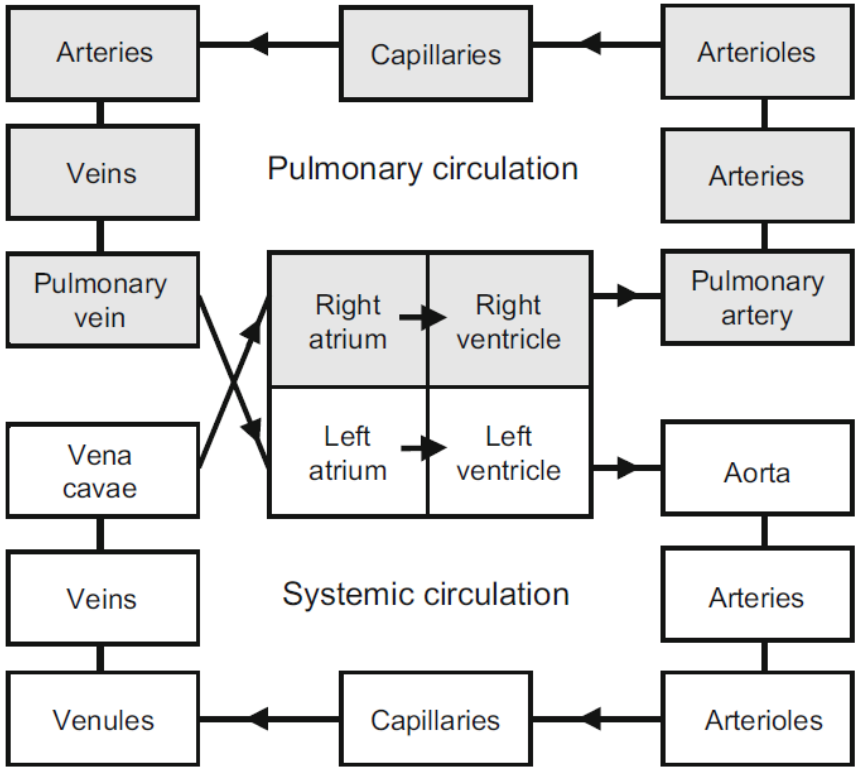
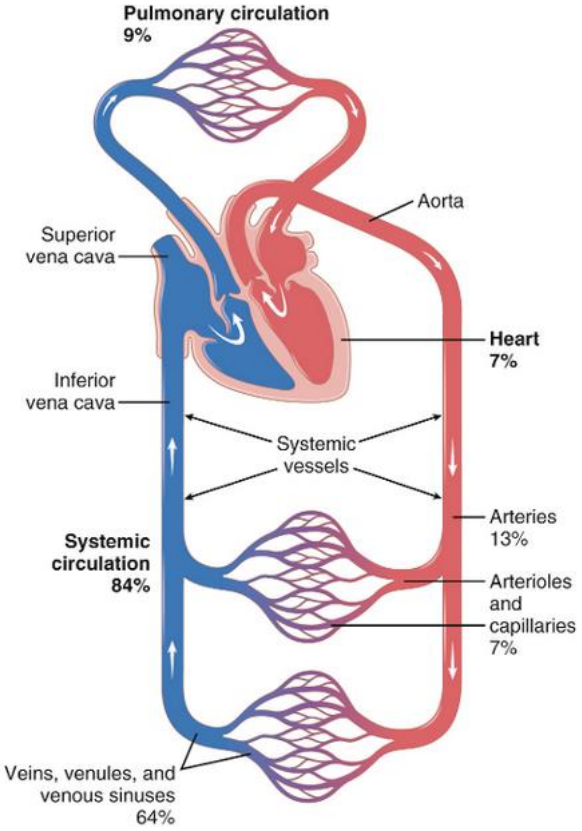
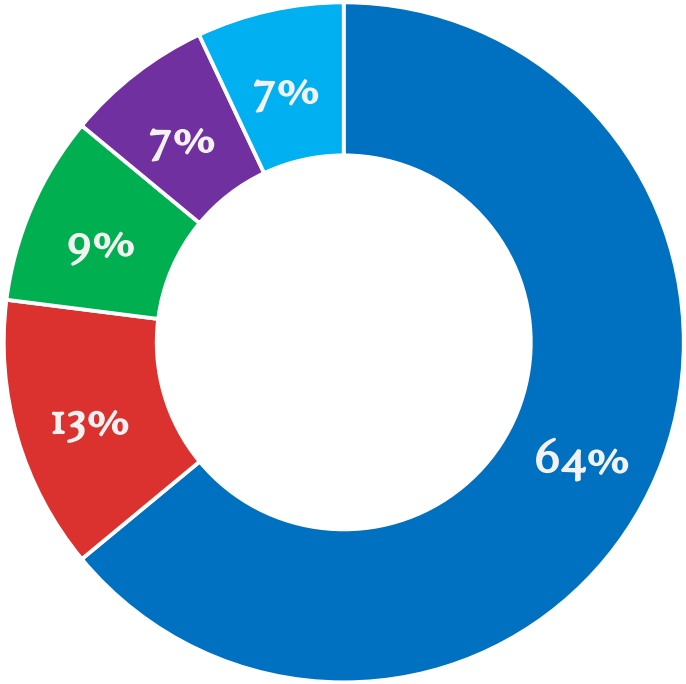


diagram authored by Wapcaplet and Yaddah. https://commons.wikimedia.org/wiki/File:Diagram_of_the_human_heart_(cropped).svg



Distribution of total blood volume





- Veins
- Arteries
- Pulmonary circulation
- Capillaries
- Heart

Distribution of total blood volume

Stroke volume: ~ 70 ml/beat
Normal pulse: 70/min

100800 beats/day
~ 7m3 blood pumped/day

~ 2.5 billion beats in a lifetime
~ 200 000 m3 blood pumped!