Biological Frameworks for Engineers

ME 411 / ME 511

Biological Frameworks for Engineers

UNIVERSITY OF WASHINGTON

Class Organization

- HW7 assigned
- Exam 2 will be assigned on Wed
- Tiny Workhorse presentations

Who?	What?	When?
Corey & Cory	Mysoin II	Nov 28
Nathan & John	Kinesin	Nov 28
Babak & Alexi	Prestin	Nov 28
Hanna & Lei	F0F1-ATPase	Nov 30
Nikita & Wes	Rotaxane	Nov 30
Michael & Shane	Dynein	Nov 30

Biological Frameworks for Engineers

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Cardiovascular System

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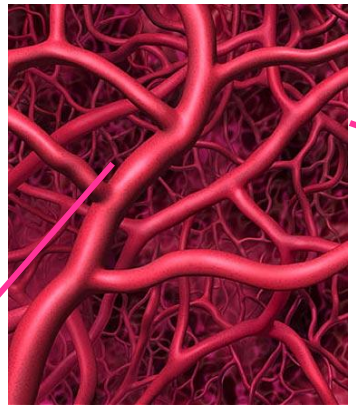
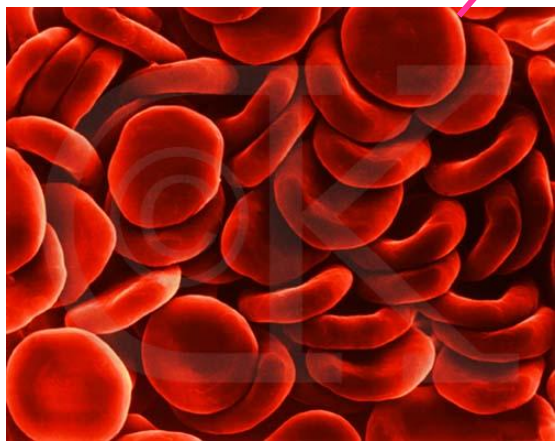
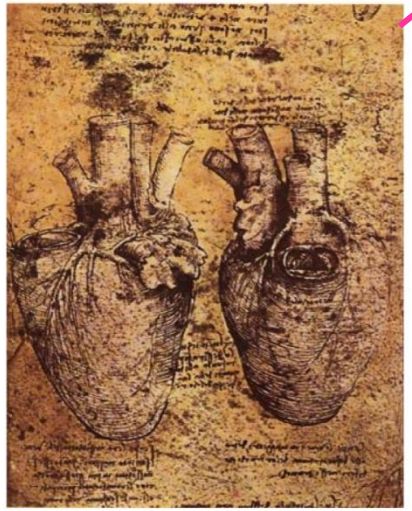
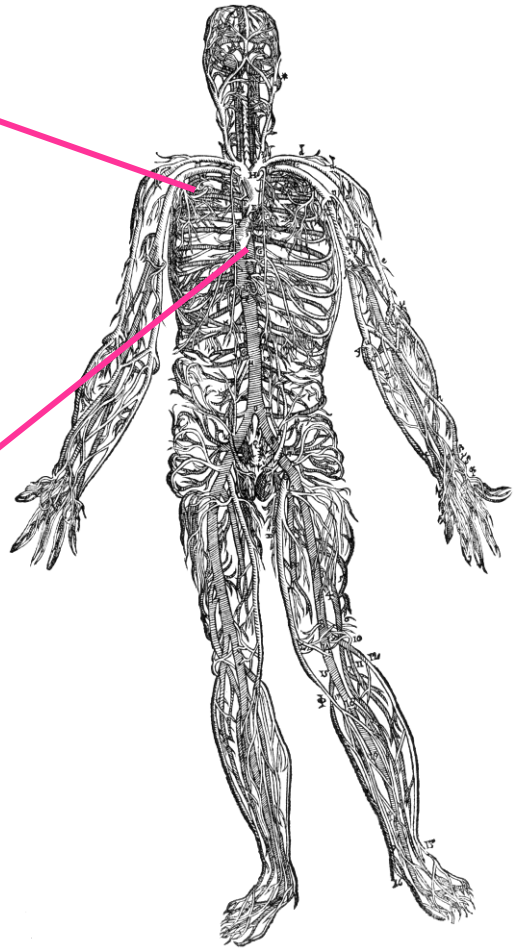
System

- Blood
- Blood vessels
- Heart



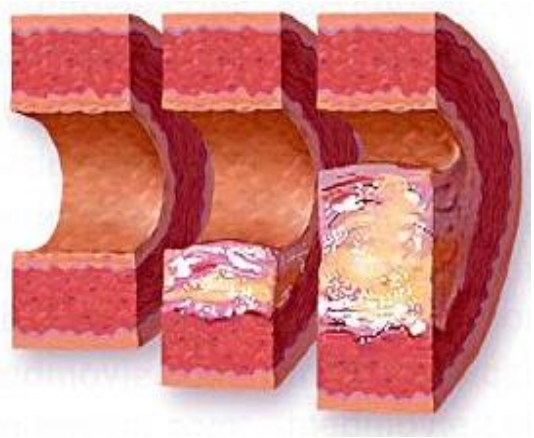




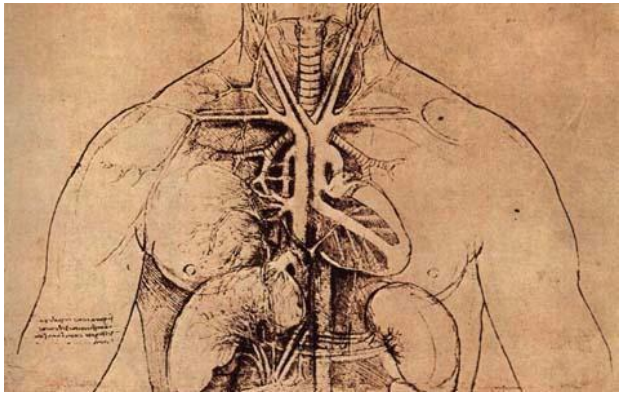


Function

- Transport
- Protective
- Regulatory



Atherosclerosis

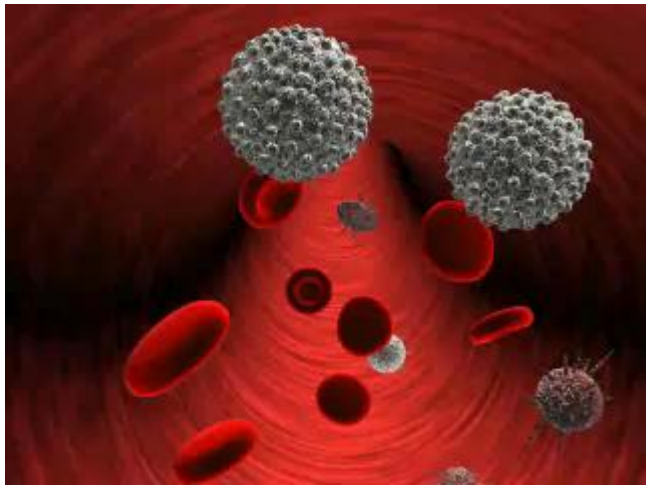


Rusty Pipe?

Blood Composition

Plasma - 55% (v/v)

- water - 91-92%
- proteins - 7-8% (albumin, antibodies, fibrinogen)

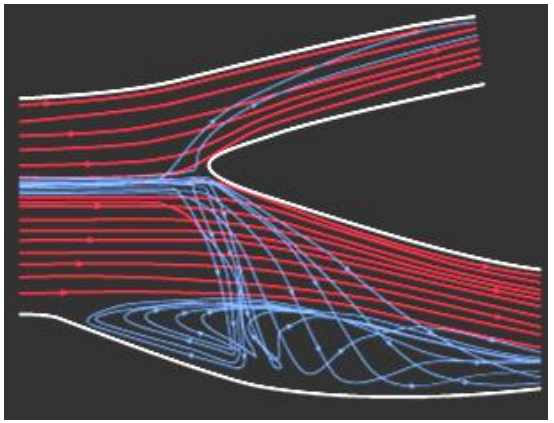


Cells - 45% (v/v)

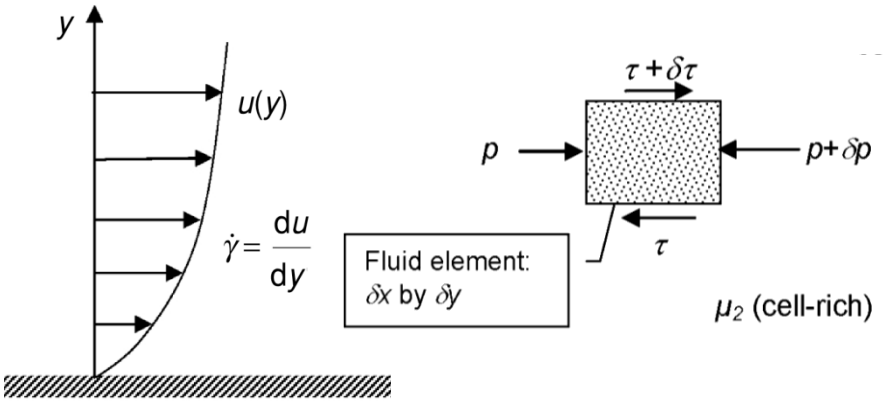
- Erythrocytes (red blood cells - RBC) – about 5 billion/mL. 8 μm disc dia. Marrow produces 2.5 million/sec. Flexible. Anuclear.
- Leukocytes (white blood cells - WBC) – about 4-11 million/mL. 7-22 μm round dia. Uni- or polynuclear
- Thrombocytes (platelets) – about 0.25-0.5 billion/mL. 2-4 μm disc dia. Anuclear.

Hemodynamics

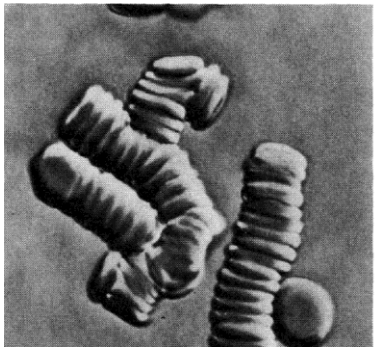
- Viscous
- Non-Newtonian
- Pseudo-plastic
- Laminar and Turbulent
- Spatially and Temporally Changing



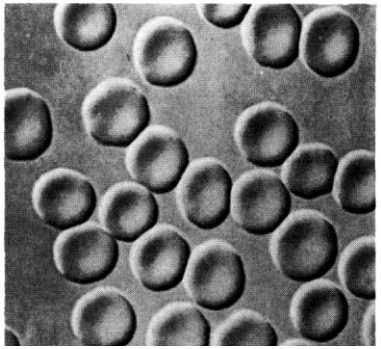
Blood Rheology

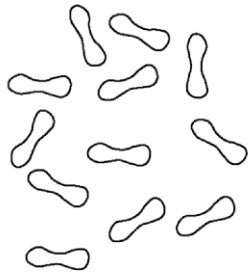


Rouleaux

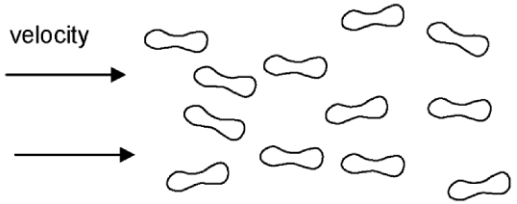


Normal





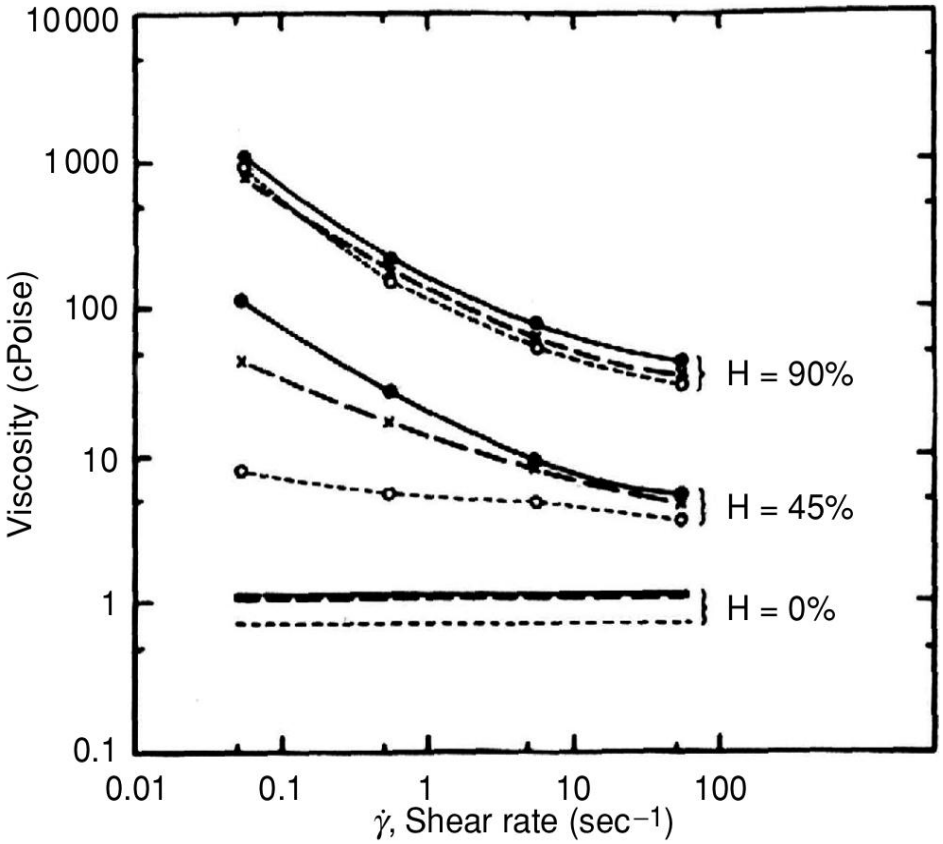
Low $\dot{\gamma}$, random orientation



High $\dot{\gamma}$, red cells oriented along streamlines

Characteristic	Low shear rate	High shear rate
Rouleaux behavior	Rouleaux formation enhanced; effective viscosity μ_{eff} is increased	Rouleaux break up; effective viscosity μ_{eff} is decreased
Individual red cell orientation	Red cells are randomly oriented; μ_{eff} is increased	Red cells are aligned with streamlines; μ_{eff} is decreased

Blood Viscosity



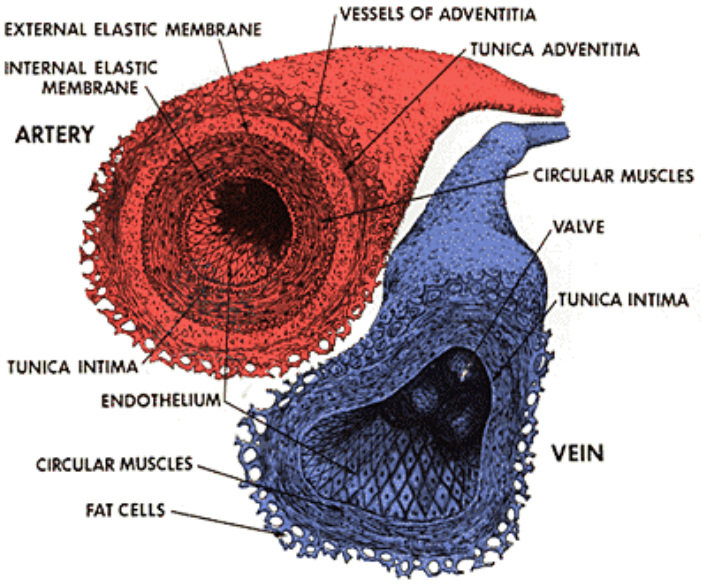
μ_{plasma} = 1.2 cP

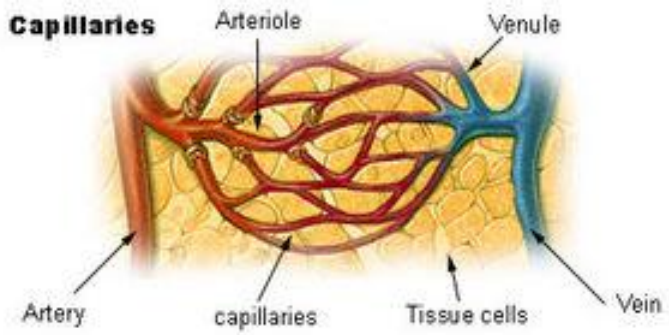
10 Poise = Pa*s

Plot of effective viscosity versus shear rate for blood of differing hematocrits (H). Note the Newtonian behavior of the fluid at zero hematocrit, and the logarithmic vertical scale. •, whole blood; ×, defibrinated blood (i.e., blood from which the clotting protein fibrinogen has been removed); ○, washed cells in Ringer's solution. The points are determined from a fifth-order polynomial curve fit to experimental data. From Chien *et al.* J App Physiol, **21** (1966), 81-87.

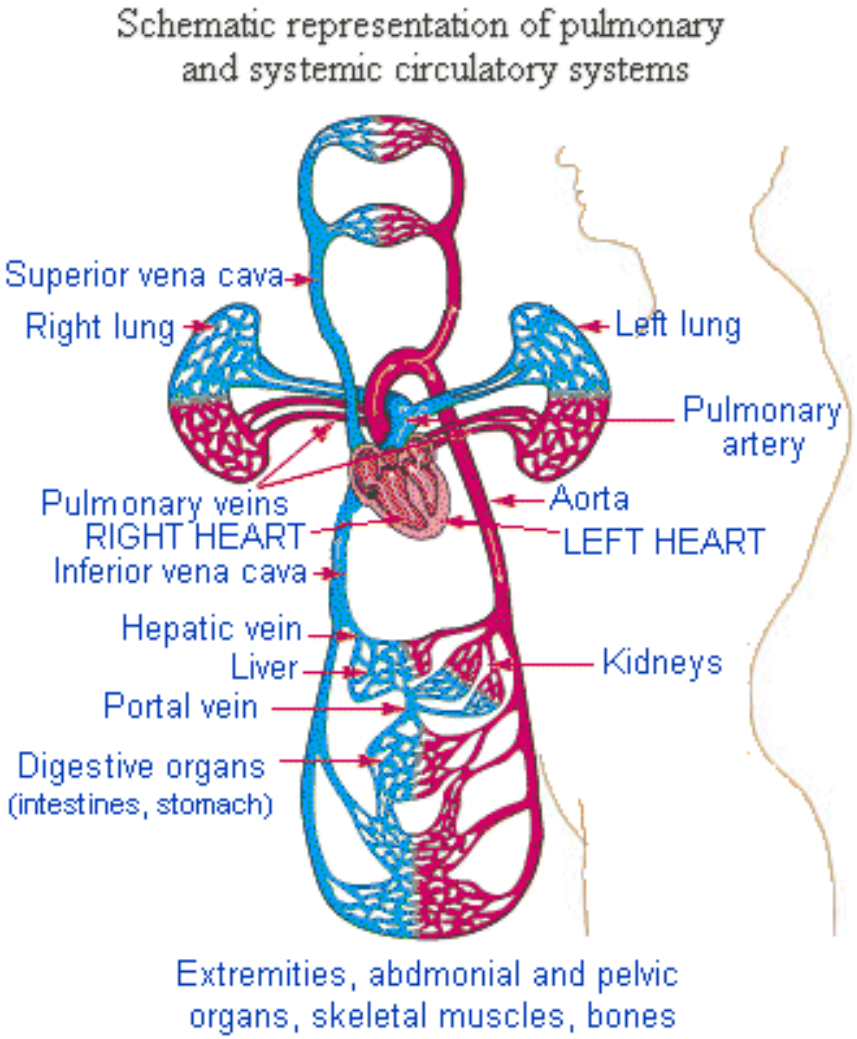
Anatomy - Vasculature

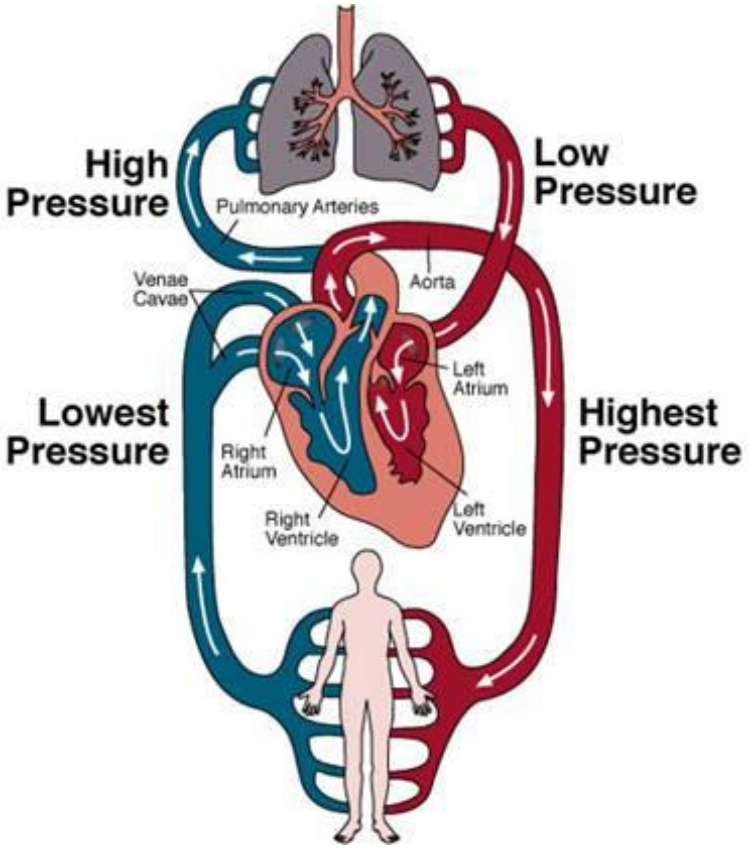
- Arteries
  - Thick walled, pressure reservoir
  - Collagen, elastin and smooth muscle cladding
- Arterioles
  - Determines most of the resistance of the system (smooth muscle)
  - Major role in determining rate of flow to different tissues
- Capillaries
  - Site of exchange between blood and tissues
  - Thinnest, most porous walls
  - 40,000 km of capillaries in adult human
- Venules
  - Small vessel carries deoxygenated blood
  - Formed by joining of several capillaries
  - Porous sites where WBCs emigrate to inflammed or infected tissue
- Veins
  - Larger diameter, Volume reservoir (~2/3)
  - Lowest blood pressure
  - Flap-like valves because blood runs against gravity back to heart



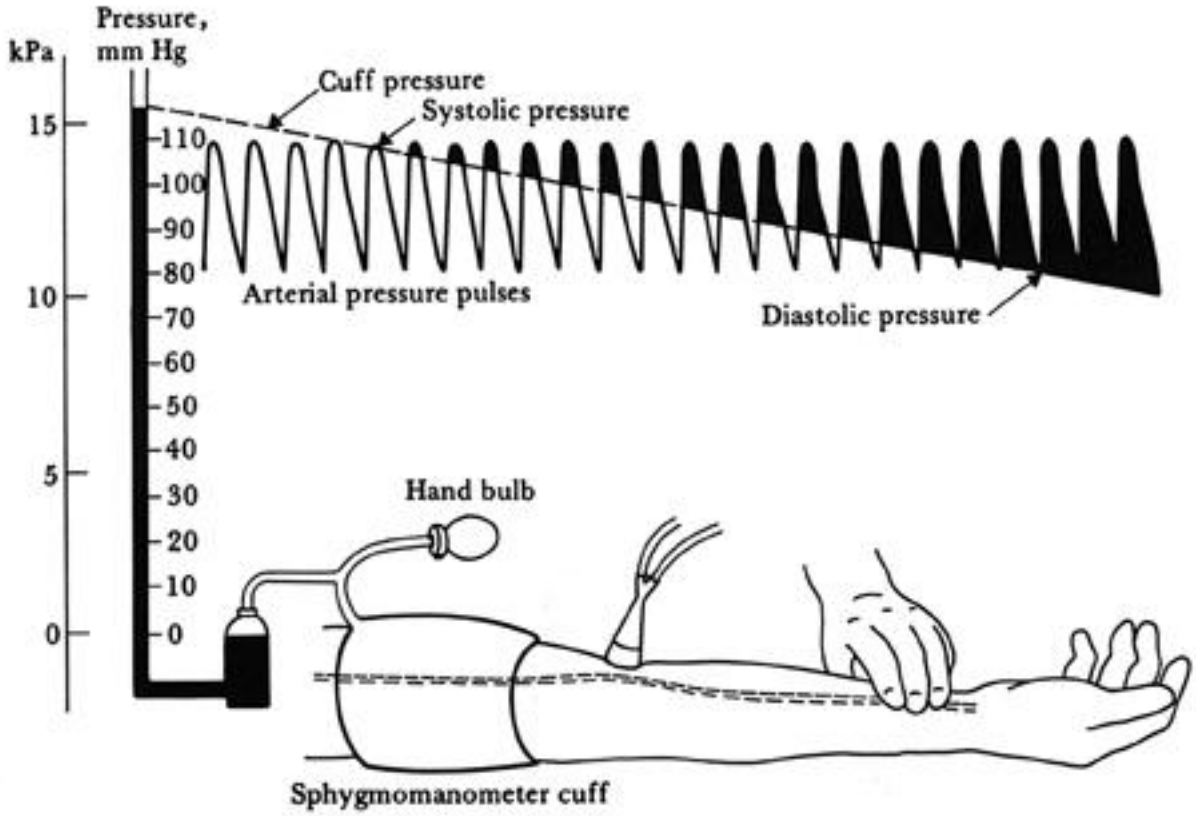


Cardiovascular Anatomy





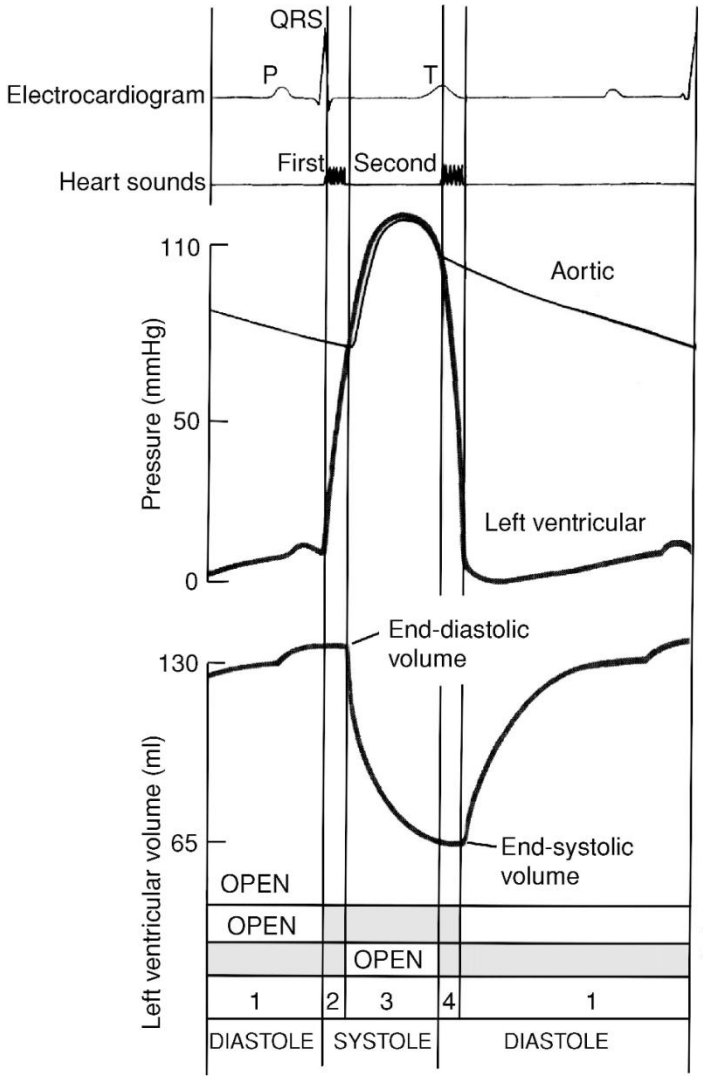
Blood Pressure Measurement



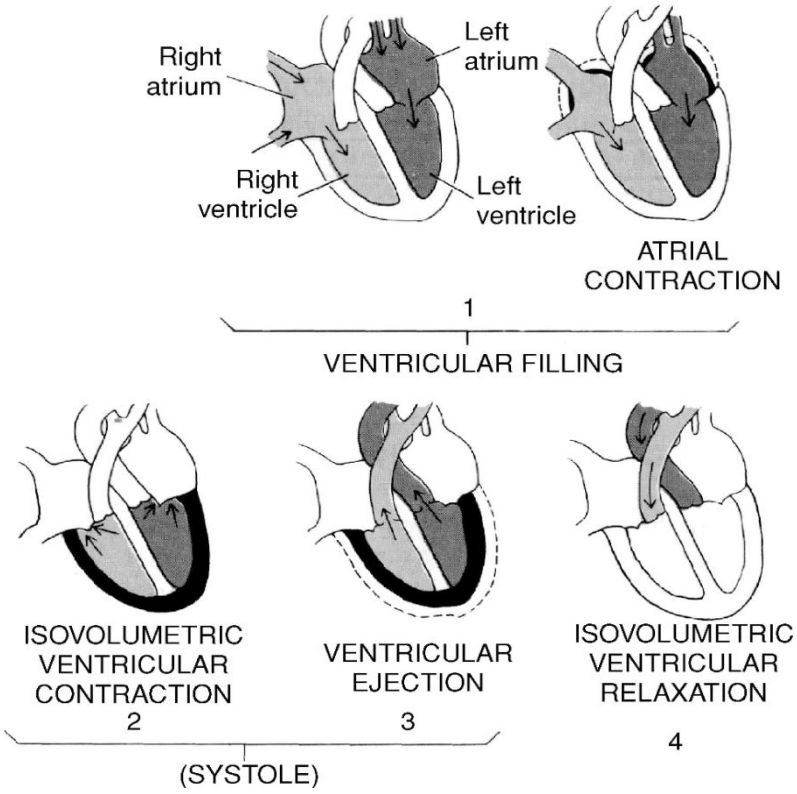
Ventral contraction

Ventral relaxation

Cardiac Cycle

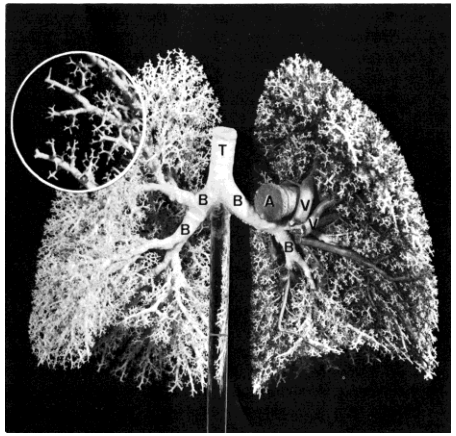


AV VALVES
Aortic and pulmonary valves

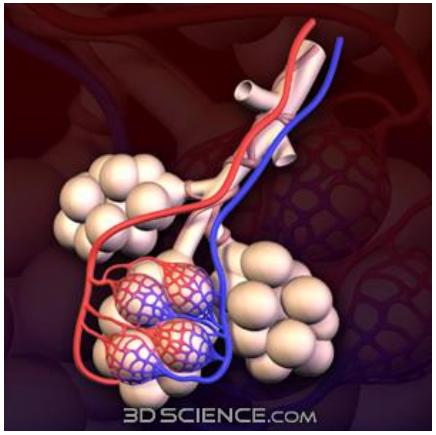


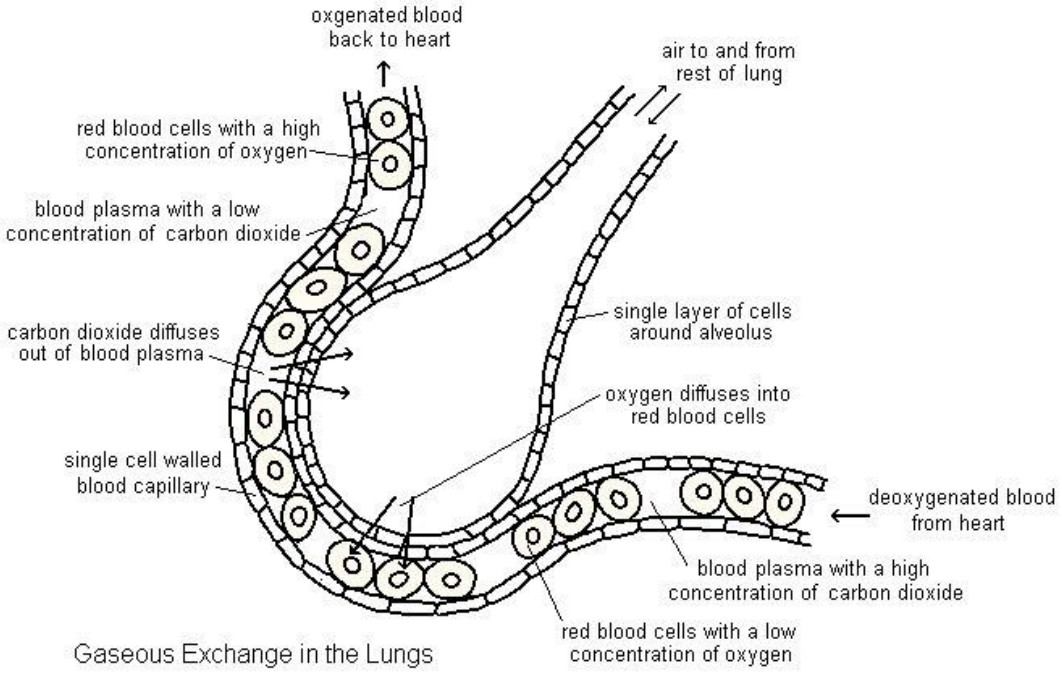
Pulmonary Cycle

Airways

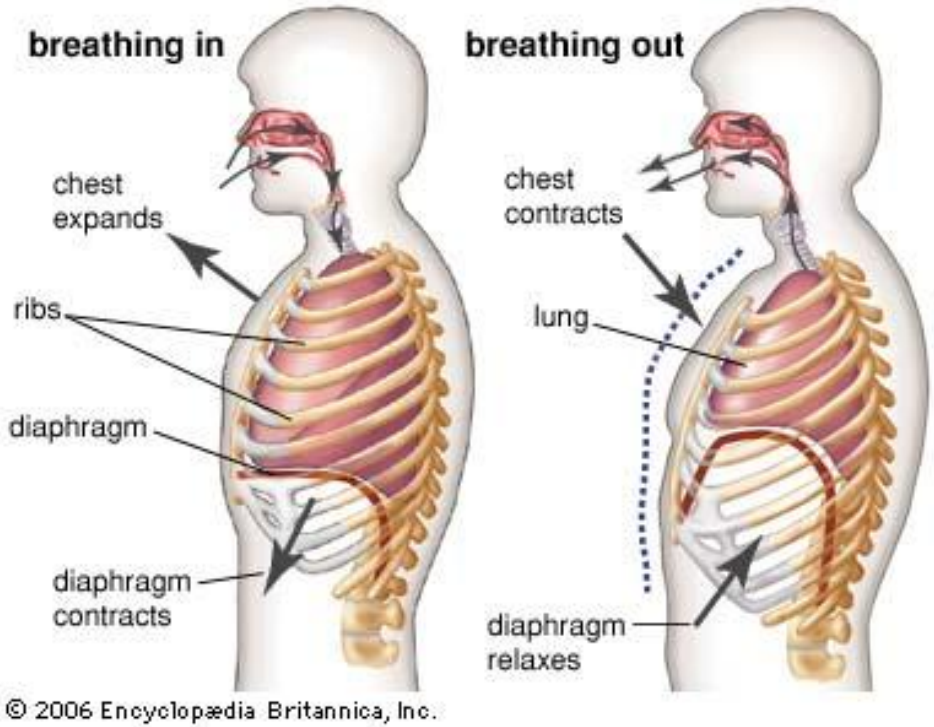


Alveoli





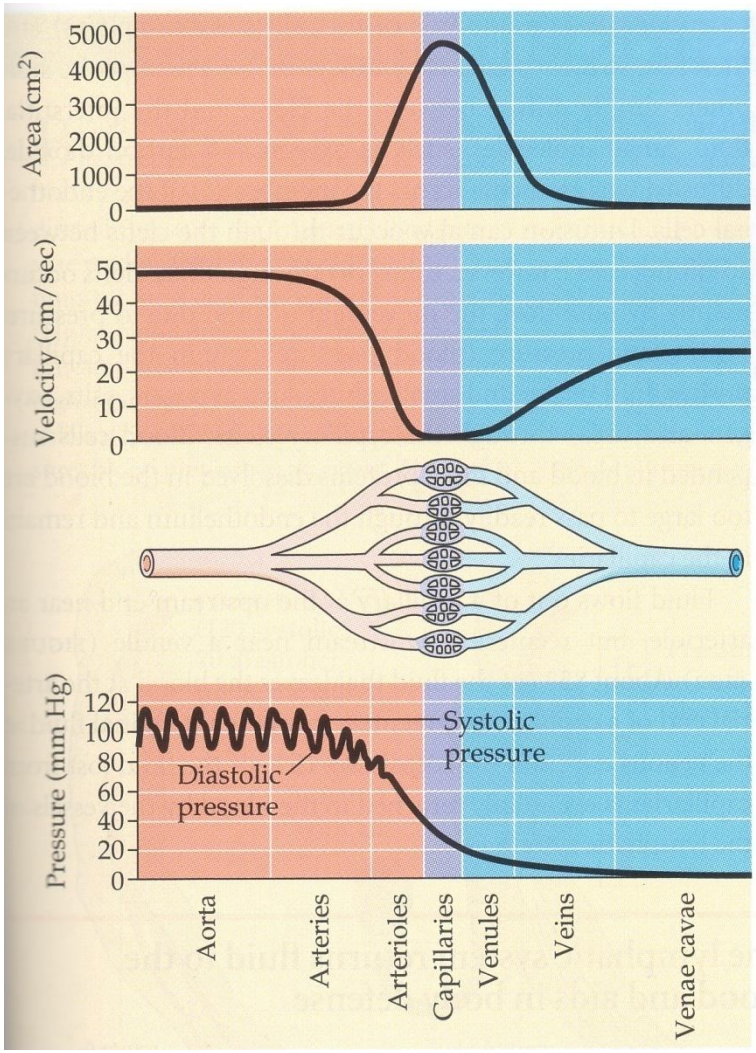
Pulmonary Cycle



Closely regulated, involuntary reflex

- Nerve endings in aorta and carotid arteries sense gas composition (O_2, CO_2)
- Medulla cross-references with brain tissue levels
- O_2 drop or CO_2 rise triggers respiratory muscles (diaphragm and intercostals) and increased heart rate

Pressure and Velocity in the Cardiovascular Network



Large area for capillary network
Small area for large vessels

Flow rate is constant but velocity is different in network

Pressure is the driving force from the heart. P is proportional to Q and R.

Questions?