Biological Frameworks for Engineers

ME 411 / ME 511

# Biological Frameworks for Engineers

UNIVERSITY OF WASHINGTON

# Class Organization

- HW7 due on Fri
- Final Exam
  - Take-home
  - Assigned on Wed 12/3
  - Due on Wed 12/10

Biological Frameworks for Engineers

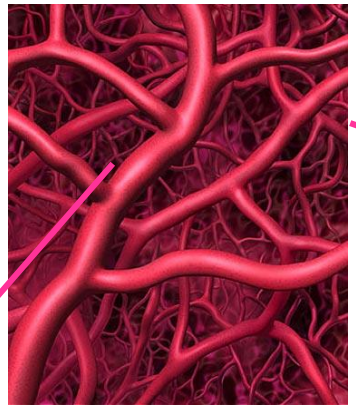
ME 411 / ME 511

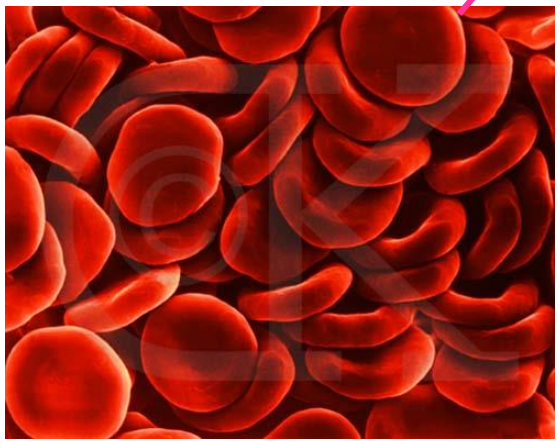
# Vascular System

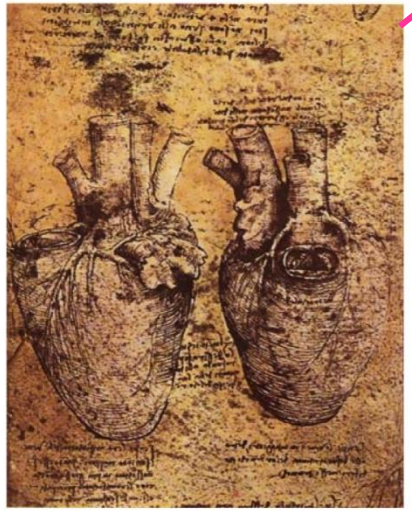
UNIVERSITY OF WASHINGTON

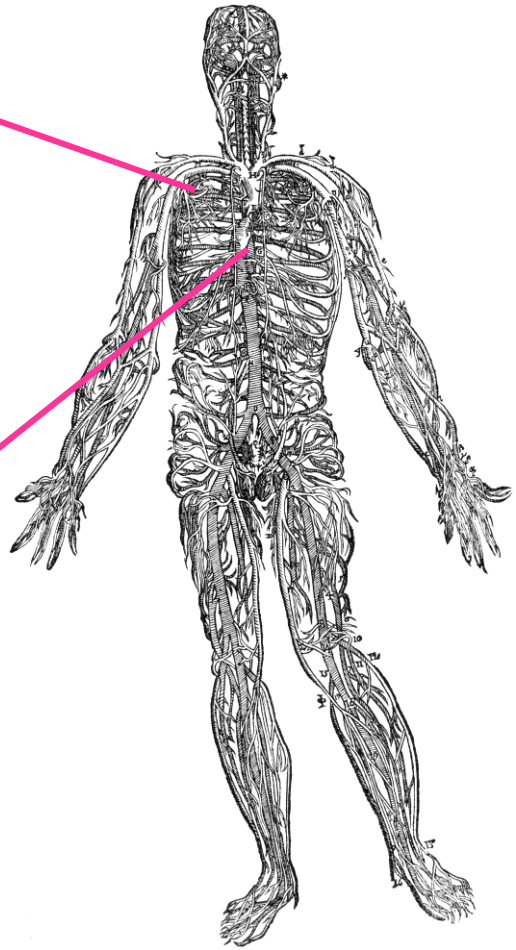
# System

- Blood
- Blood vessels
- Heart



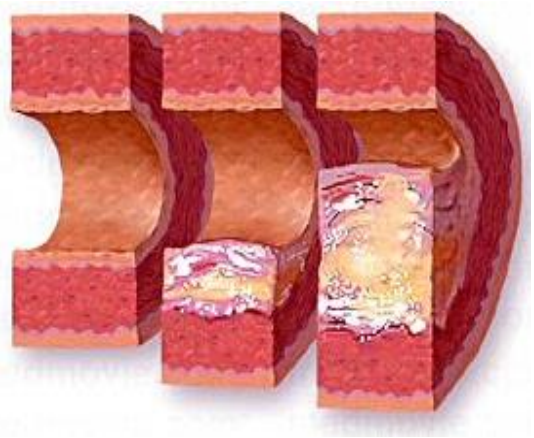




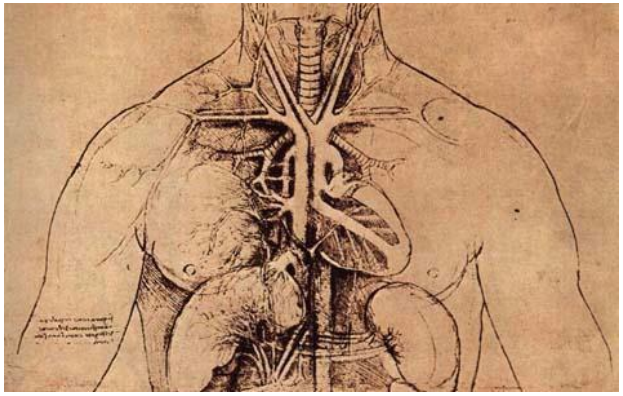


# Function

- Transport
- Protective
- Regulatory

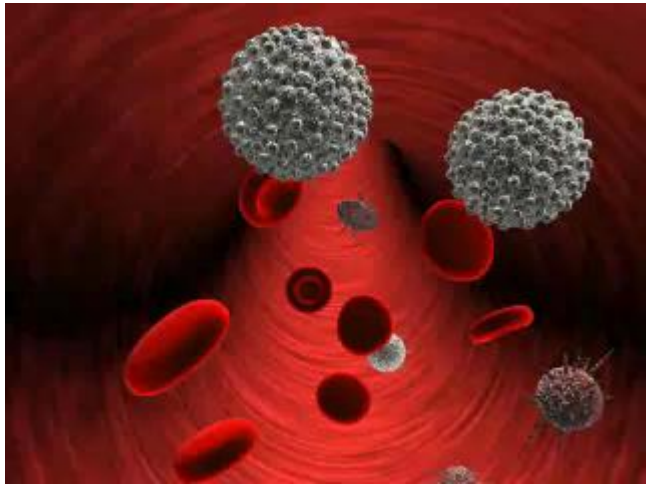


Atherosclerosis



Rusty Pipe?

# Blood Composition



## Plasma - 55% (v/v)

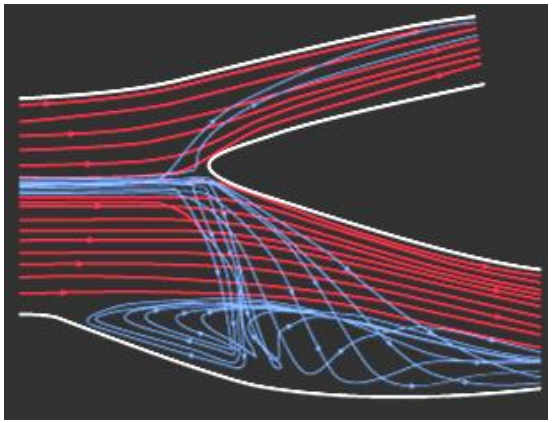
- water - 91-92%
- proteins - 7-8% (albumin, antibodies, fibrinogen)

## Cells - 45% (v/v)

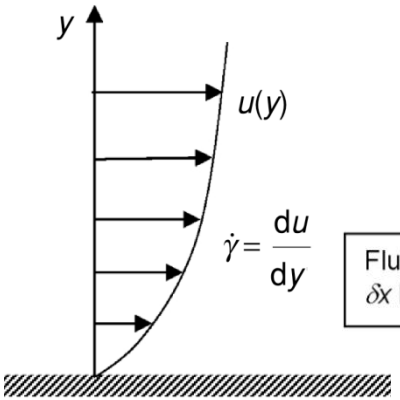
- Erythrocytes (red blood cells - RBC) – about 5 billion/mL. 8 μm disc dia. Marrow produces 2.5 million/sec. Flexible. Anuclear.
- Leukocytes (white blood cells - WBC) – about 4-11 million/mL. 7-22 μm round dia. Uni- or polynuclear
- Thrombocytes (platelets) – about 0.25-0.5 billion/mL. 2-4 μm disc dia.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

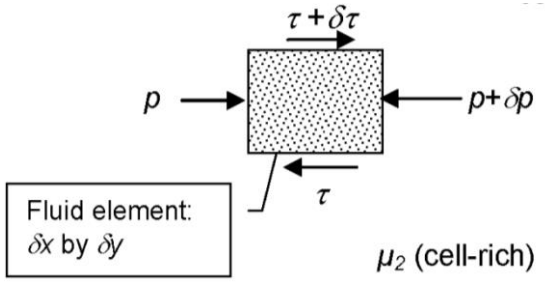
# Hemodynamics

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

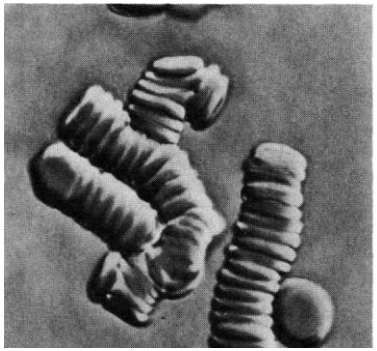


# Blood Rheology

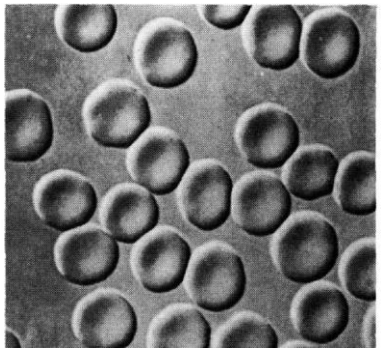


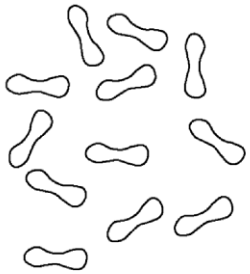




Rouleaux

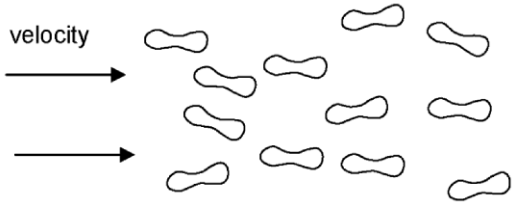


Normal





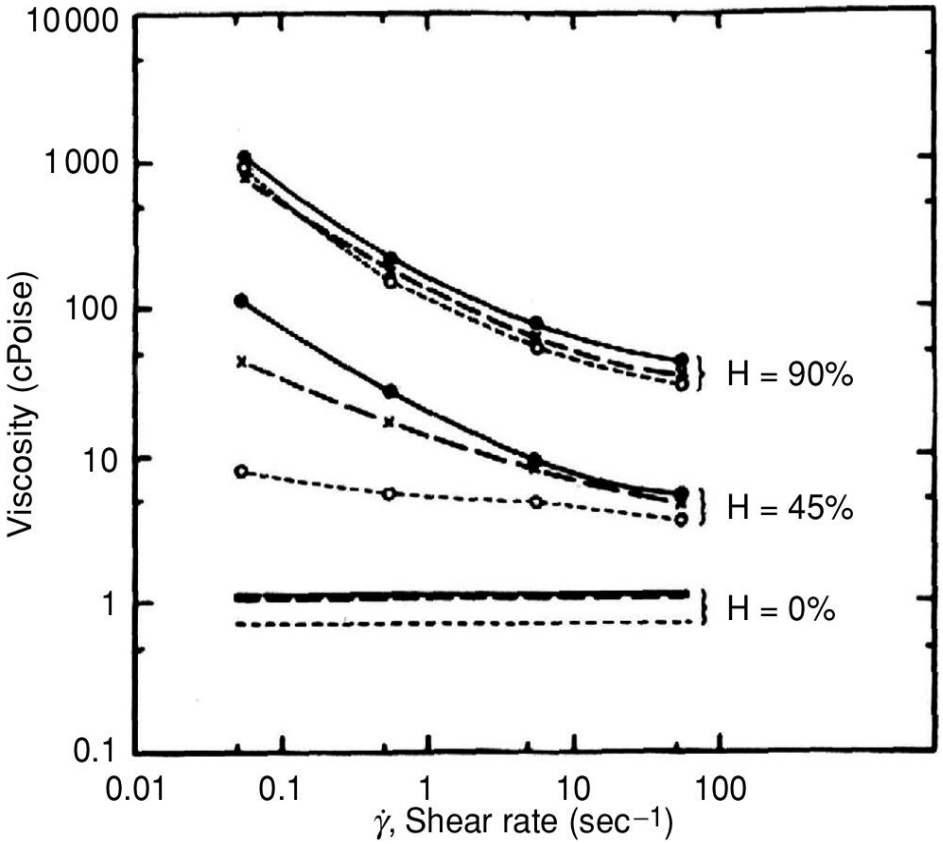
Low $\dot{\gamma}$, random orientation




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

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

# Blood Viscosity



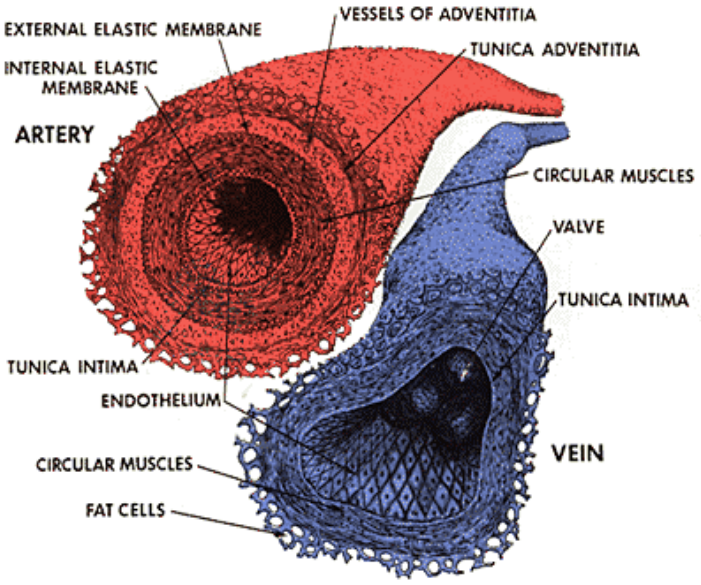

$\mu_{plasma}$ = 1.2 cP

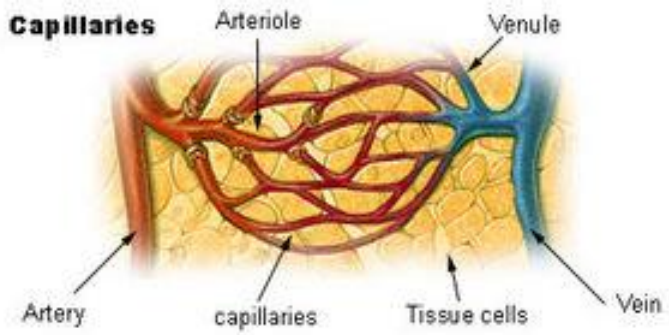
10 Poise = Pa*s

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

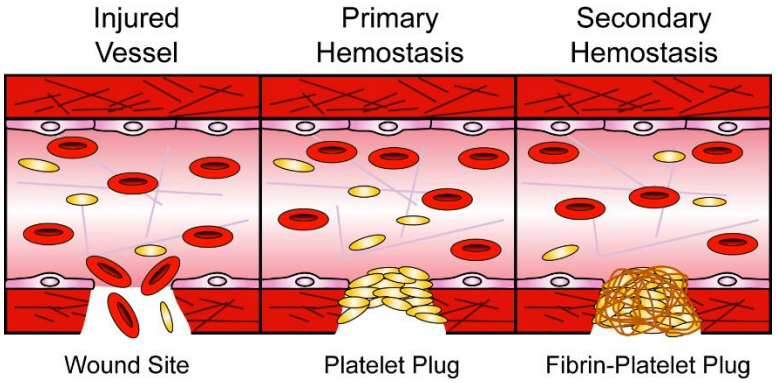
- Arteries
  - Thick walled, pressure reservoir
  - Collagen, elastin and smooth muscle cladding
- Arterioles
  - Determines most of the resistance of the system (smooth muscle)
  - Major role in determining rate of flow to different tissues
- Capillaries
  - Site of exchange between blood and tissues
  - 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

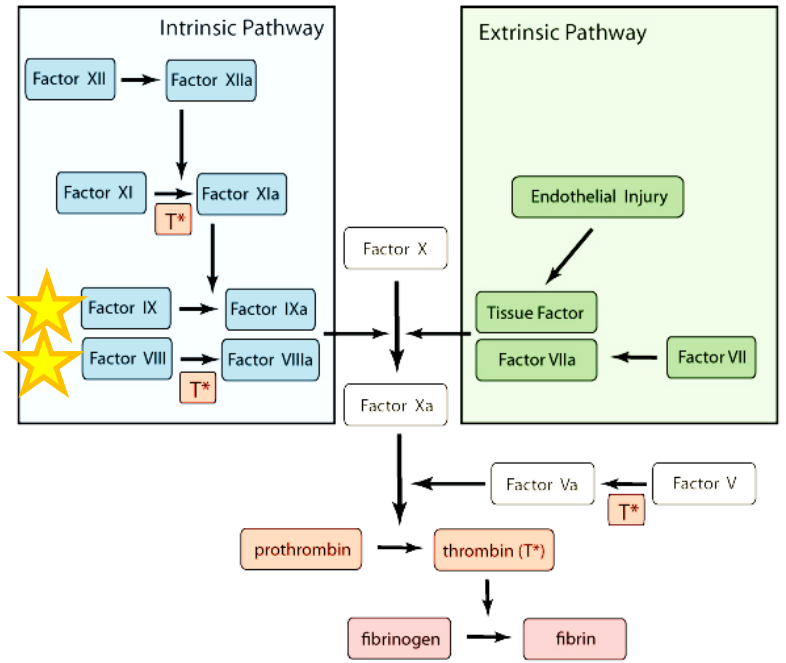


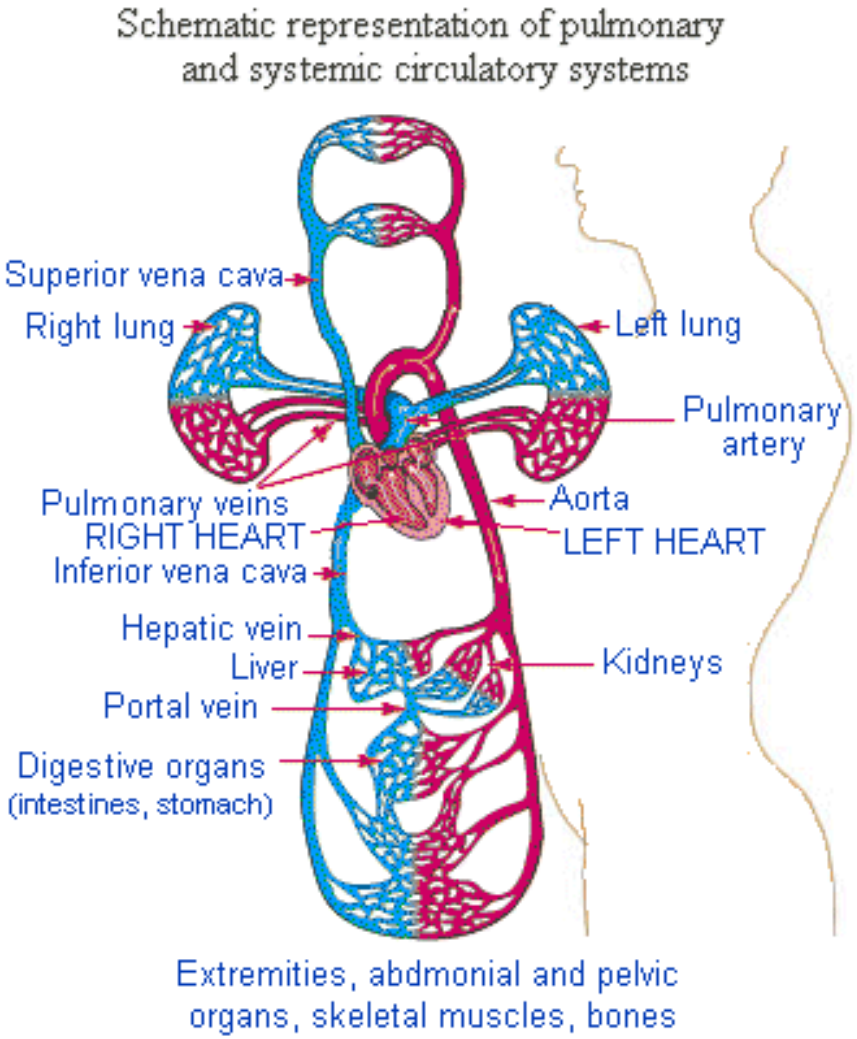
# Coagulation

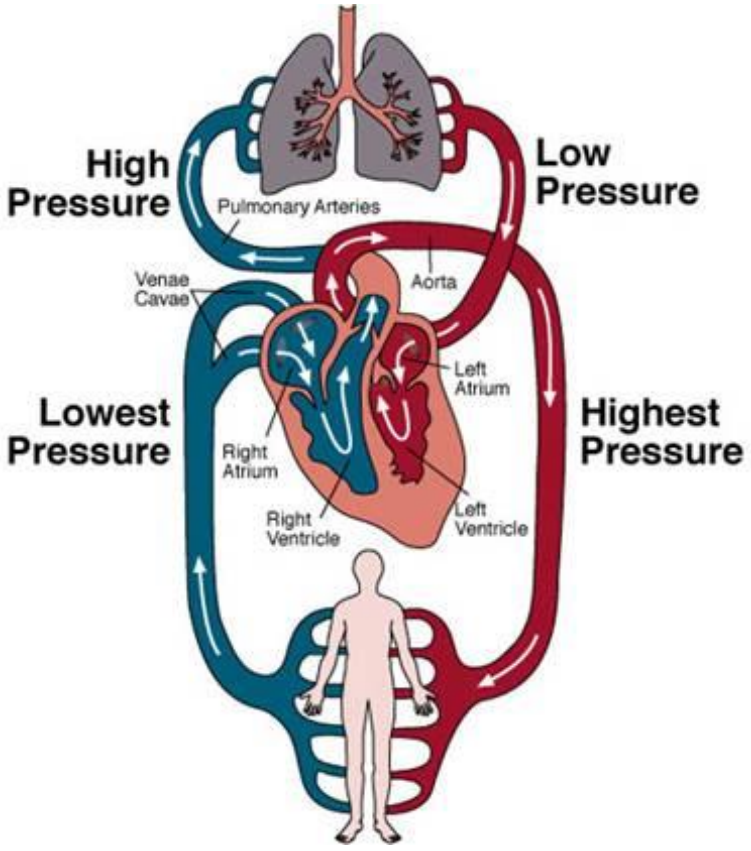
- Hemostasis
- Thrombosis
- Coagulation Cascade



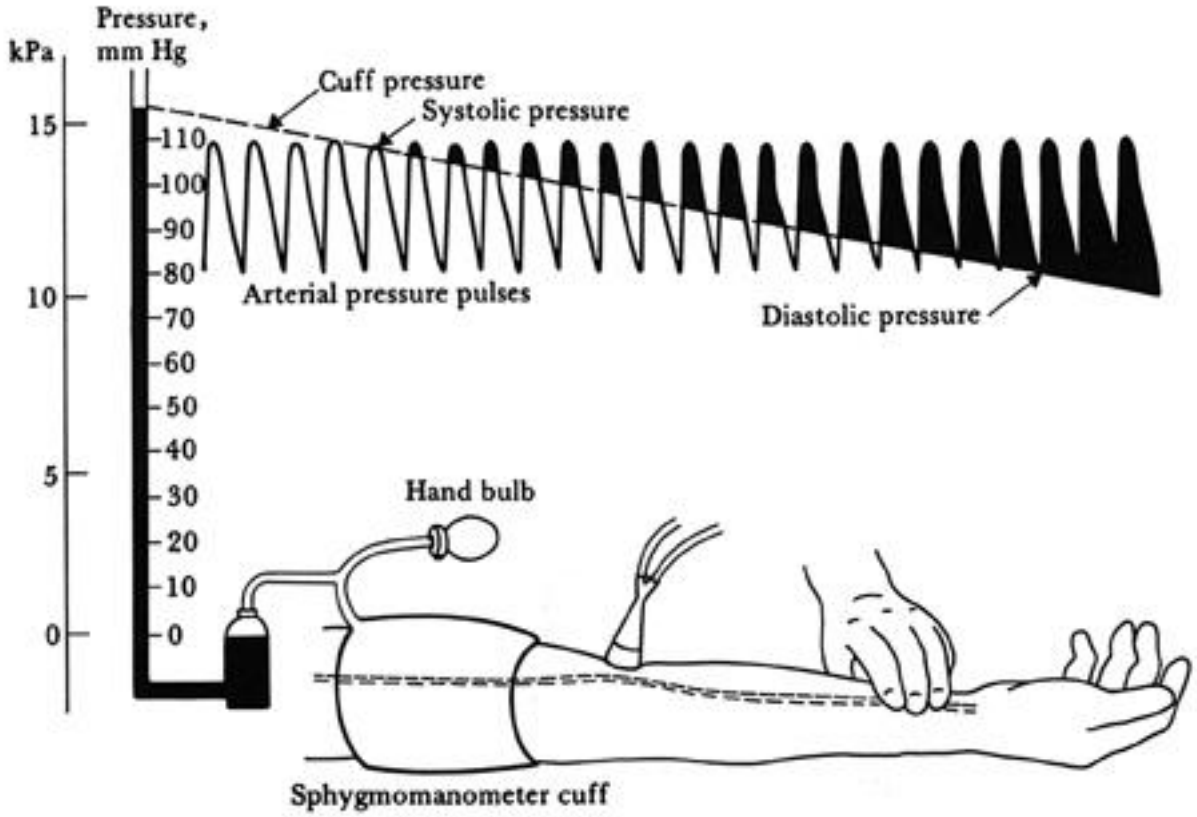



# Cardiovascular Anatomy



# Blood Pressure Measurement

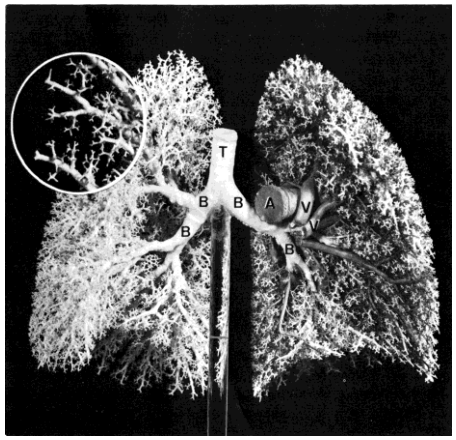



Ventral contraction

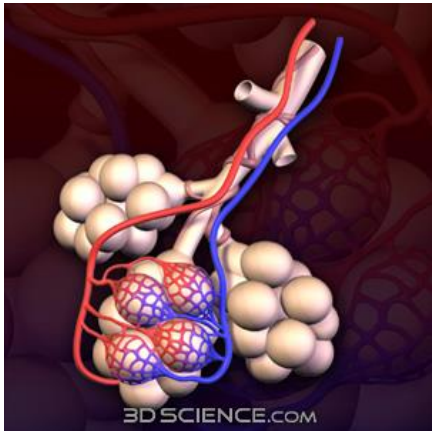
Ventral relaxation

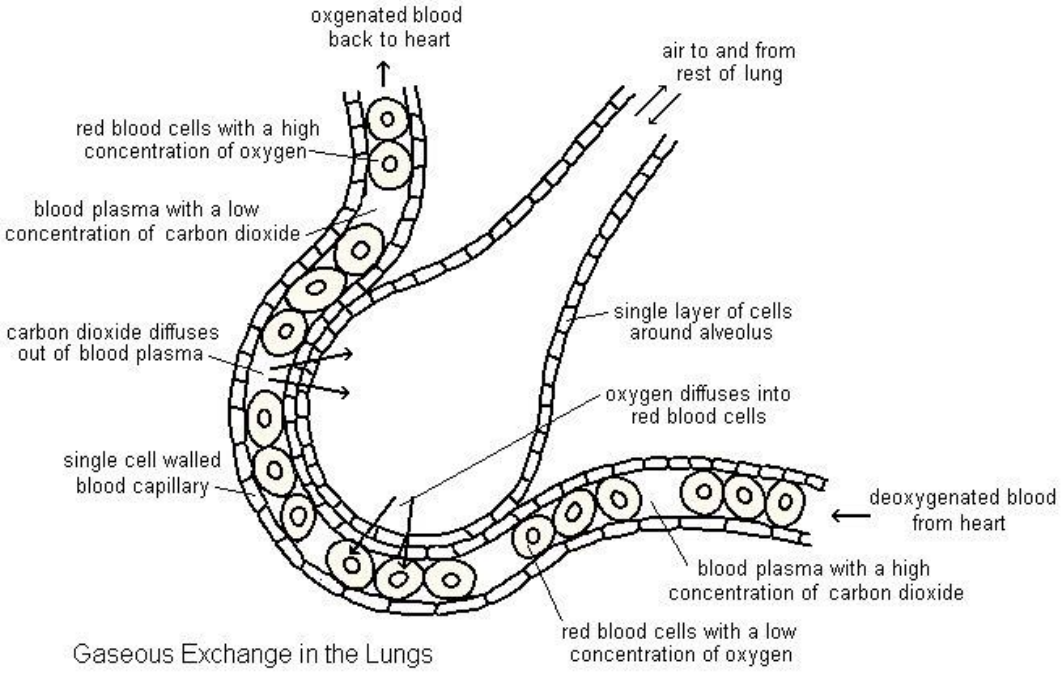
# Pulmonary Cycle

Airways

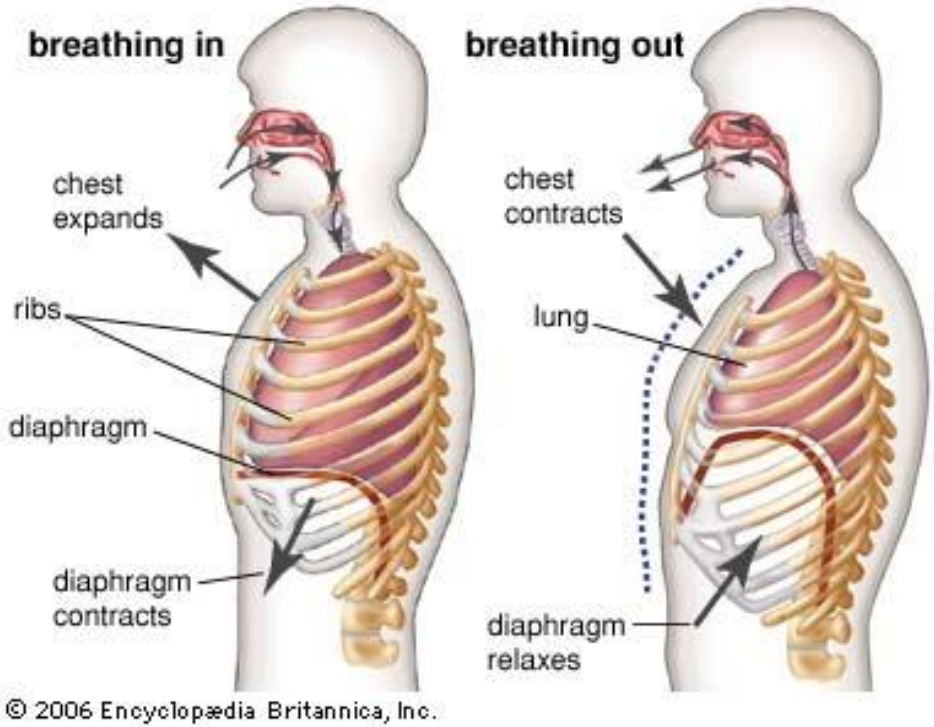



Alveoli



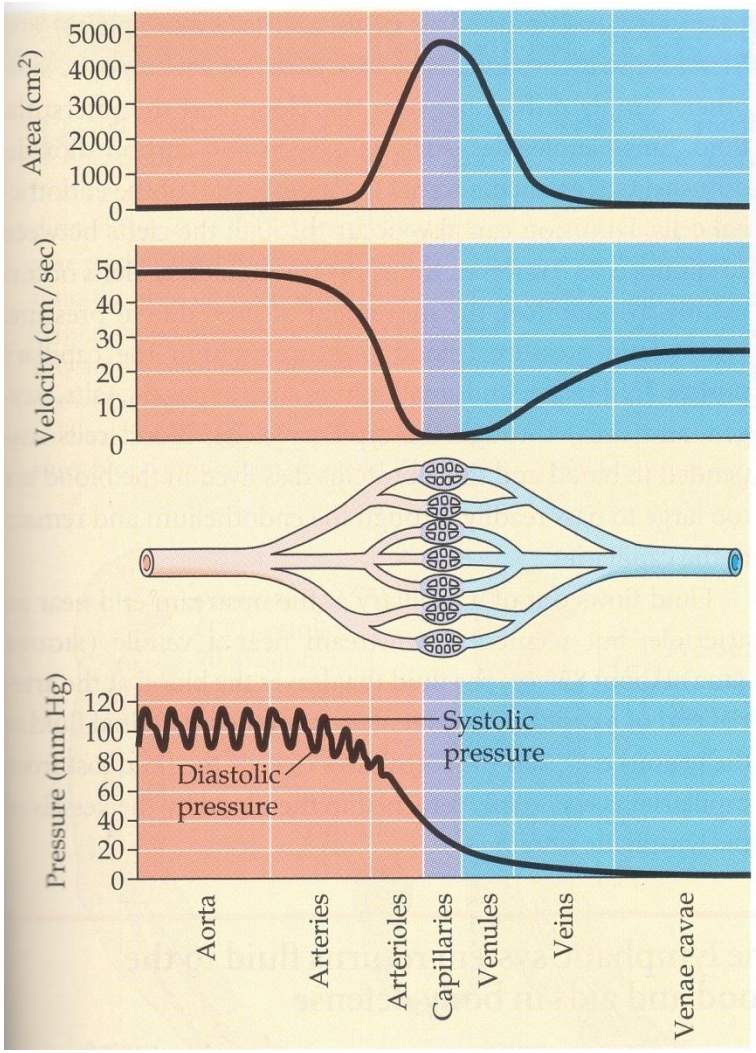
# Pulmonary Cycle




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 Vascular 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.



# Questions?