

ME 411 / ME 511

Biological Frameworks for Engineers

Class Organization

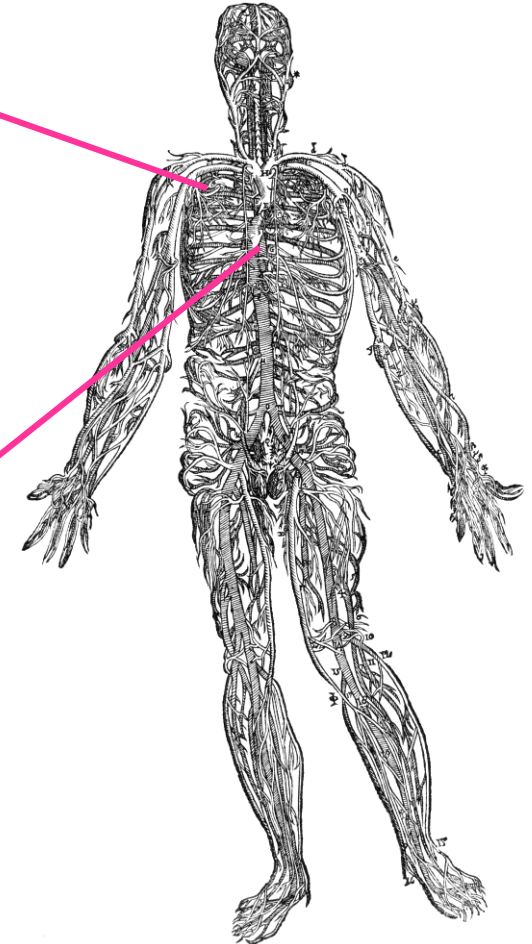
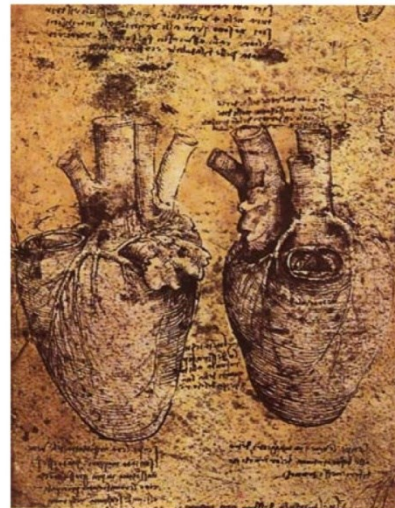
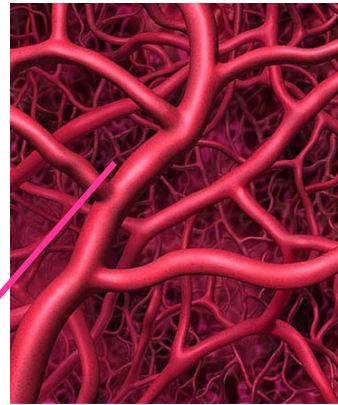
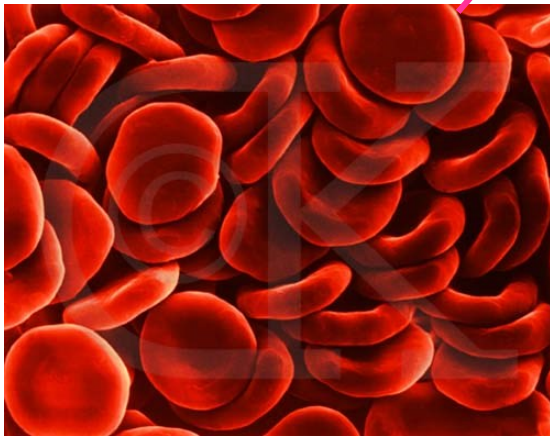
- HW7 due on Wed
- Final Exam
 - Take-home
 - Assigned on Wed 12/4
 - Due on Wed 12/11

ME 411 / ME 511

Vascular System

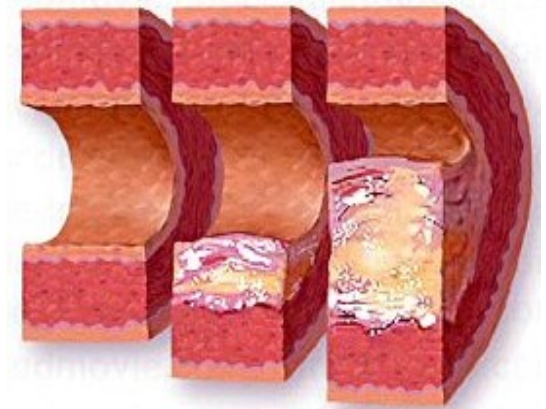
System

- Blood
- Blood vessels
- Heart

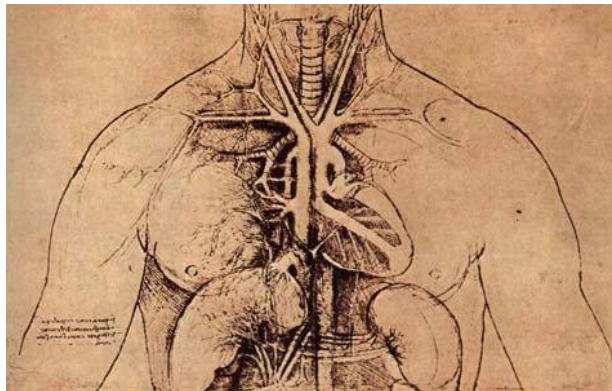


Function

- Transport
- Protective
- Regulatory



Atherosclerosis

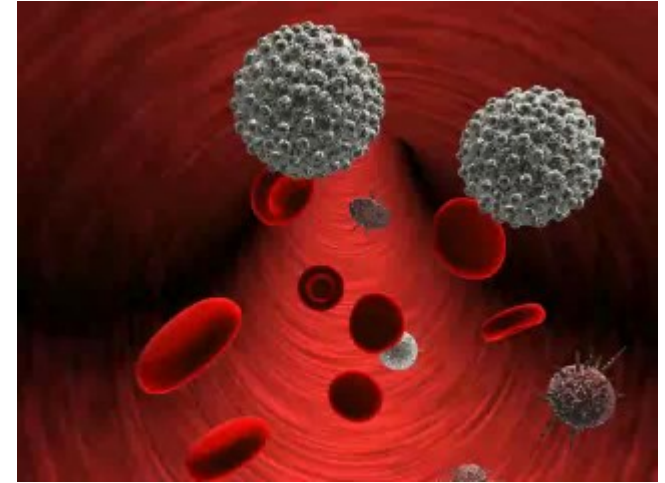


Rusty Pipe? CITY OF
JGTON

Blood Composition

Plasma - 55% (v/v)

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

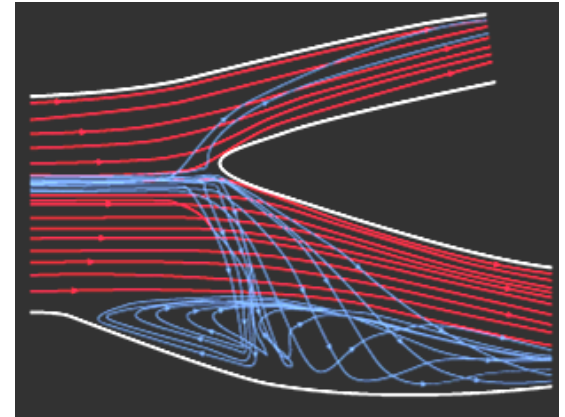


Cells - 45% (v/v)

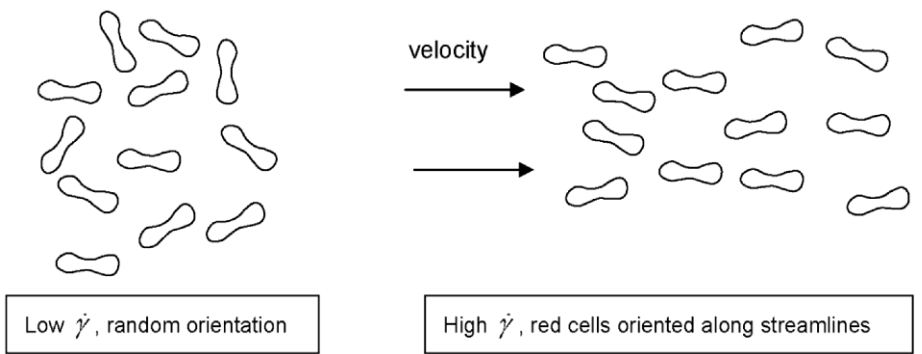
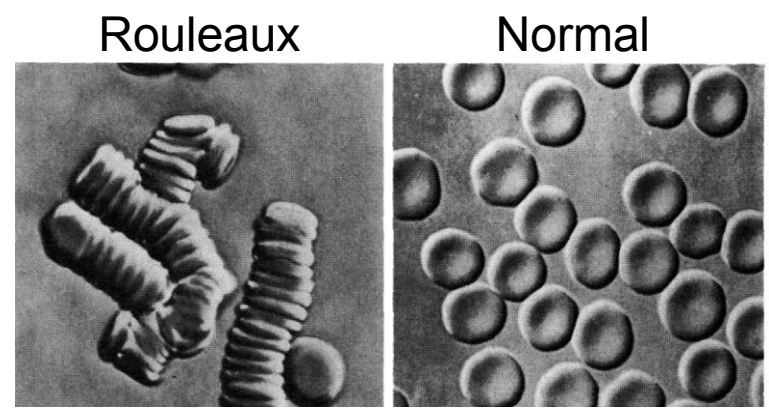
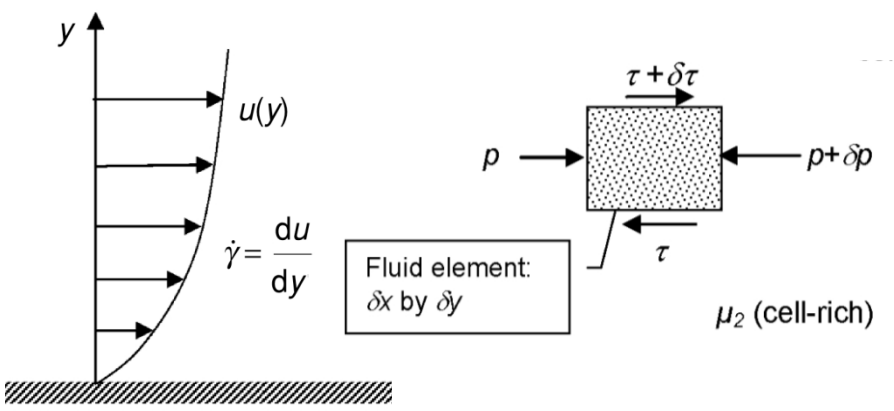
- Erythrocytes (red blood cells - RBC) – about 5 billion/mL. 8 μm disc dia. Marrow produces 2.5 million/sec. Flexible. Anuclear.
- Leukocytes (white blood cells - WBC) – about 4-11 million/mL. 7-22 μm round dia. Uni- or polynuclear
- Thrombocytes (platelets) – about 0.25-0.5 billion/mL. 2-4 μm disc dia.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

Hemodynamics

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

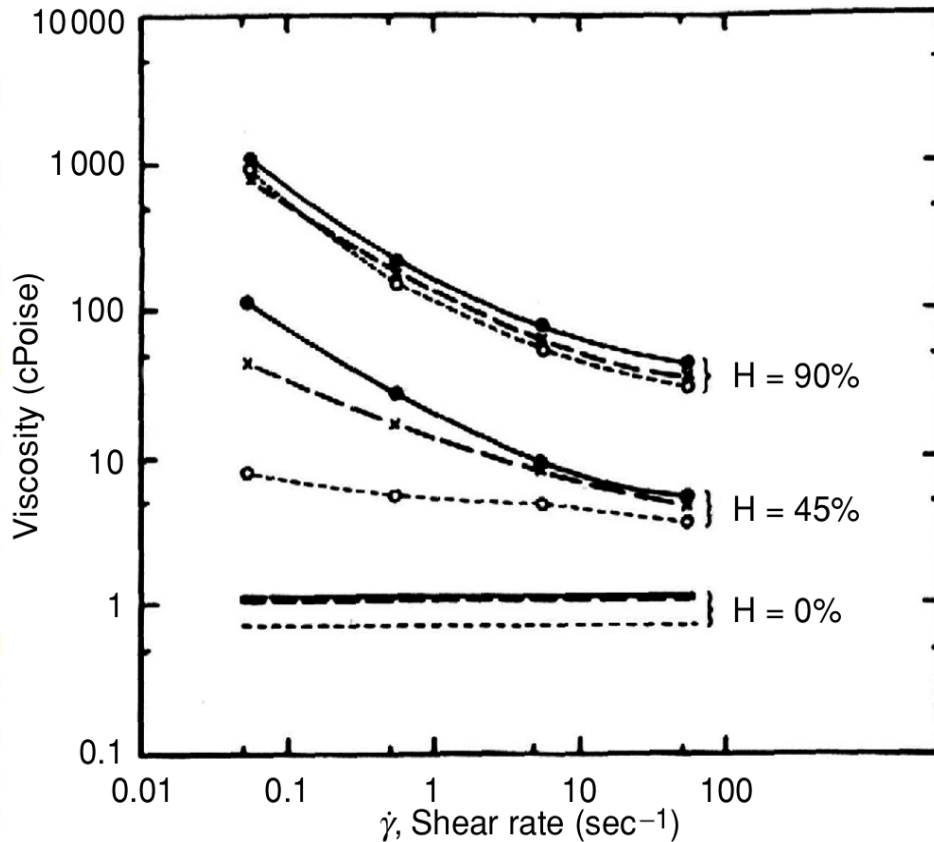


Blood Rheology



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



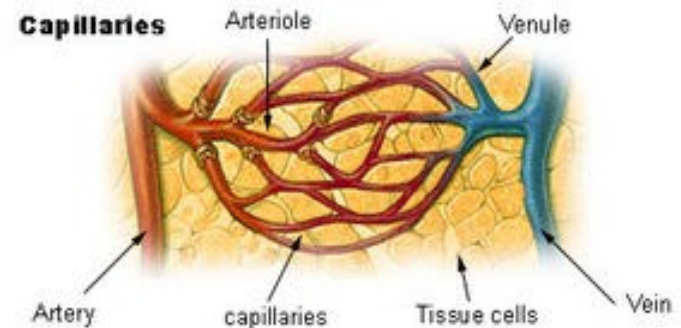
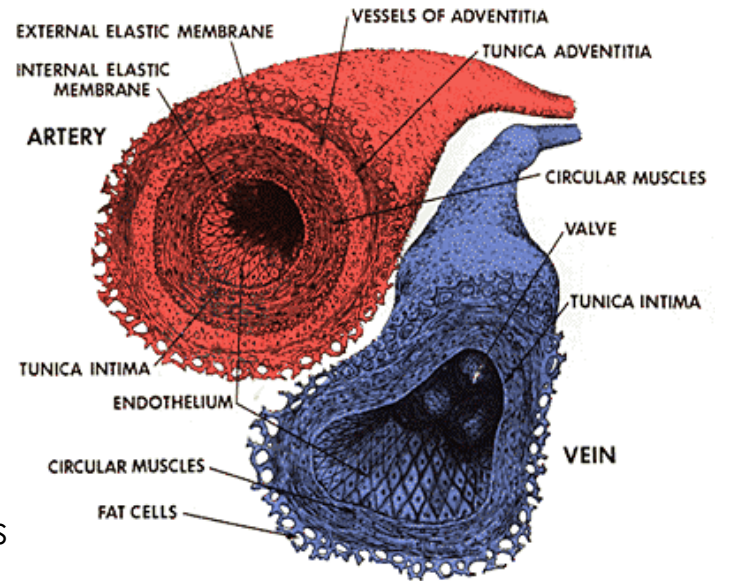
$$\mu_{\text{plasma}} = 1.2 \text{ cP}$$

$$10 \text{ Poise} = \text{Pa}\cdot\text{s}$$

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.

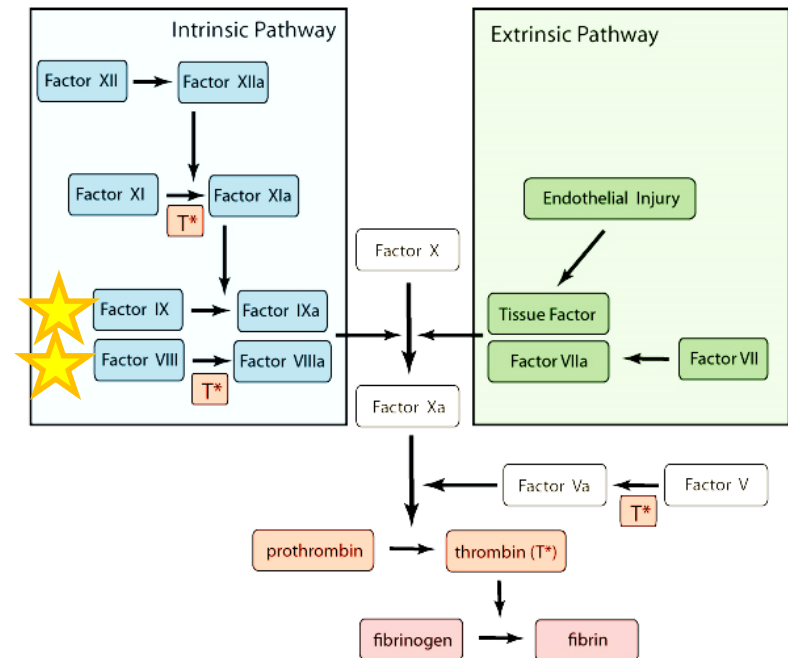
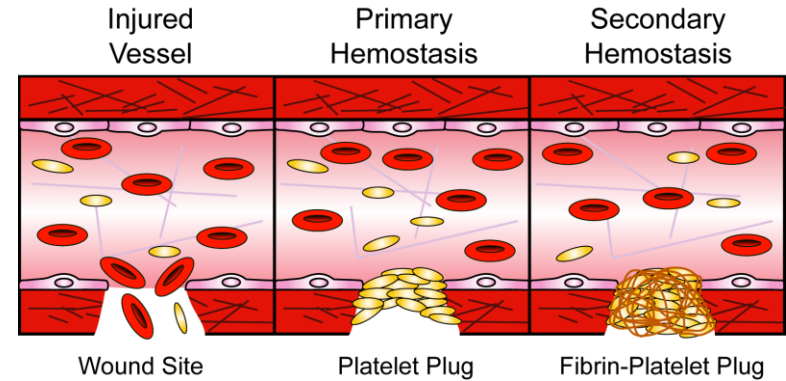
Anatomy - Vasculature

- 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 inflamed or infected tissue
- Veins
 - Larger diameter, Volume reservoir (~2/3)
 - Lowest blood pressure
 - Flap-like valves because blood runs against gravity back to heart



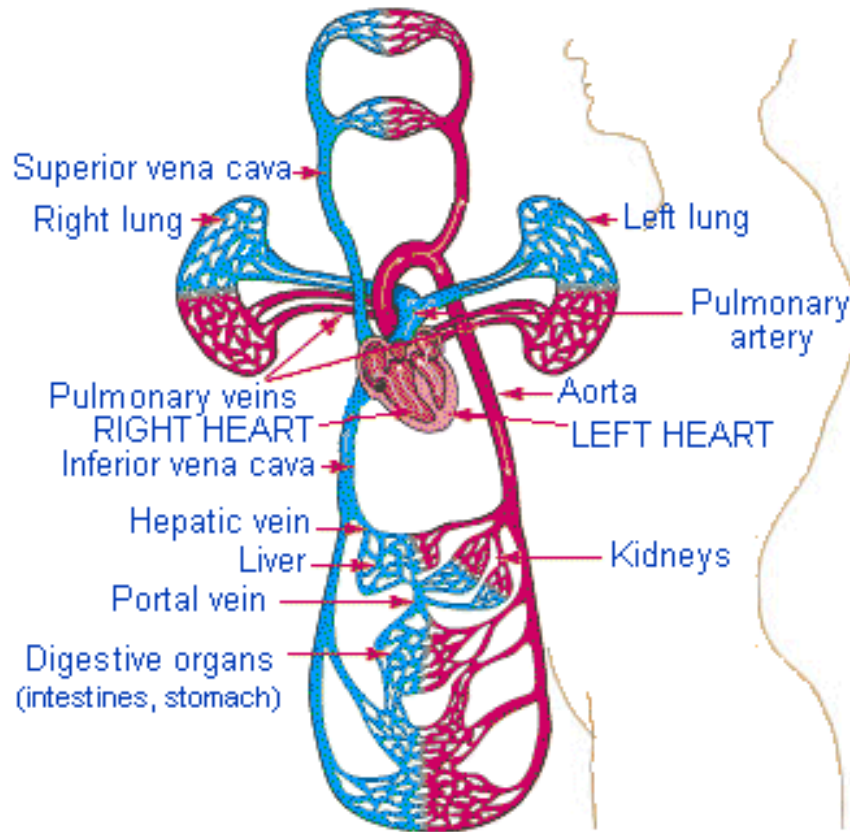
Coagulation

- Hemostasis
- Thrombosis
- Coagulation Cascade

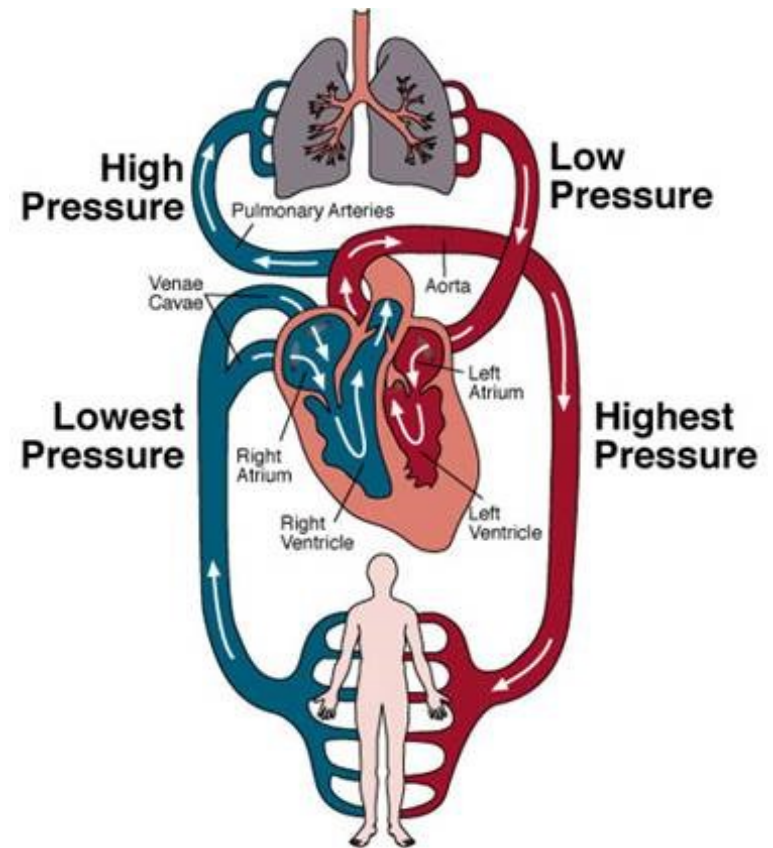


Cardiovascular Anatomy

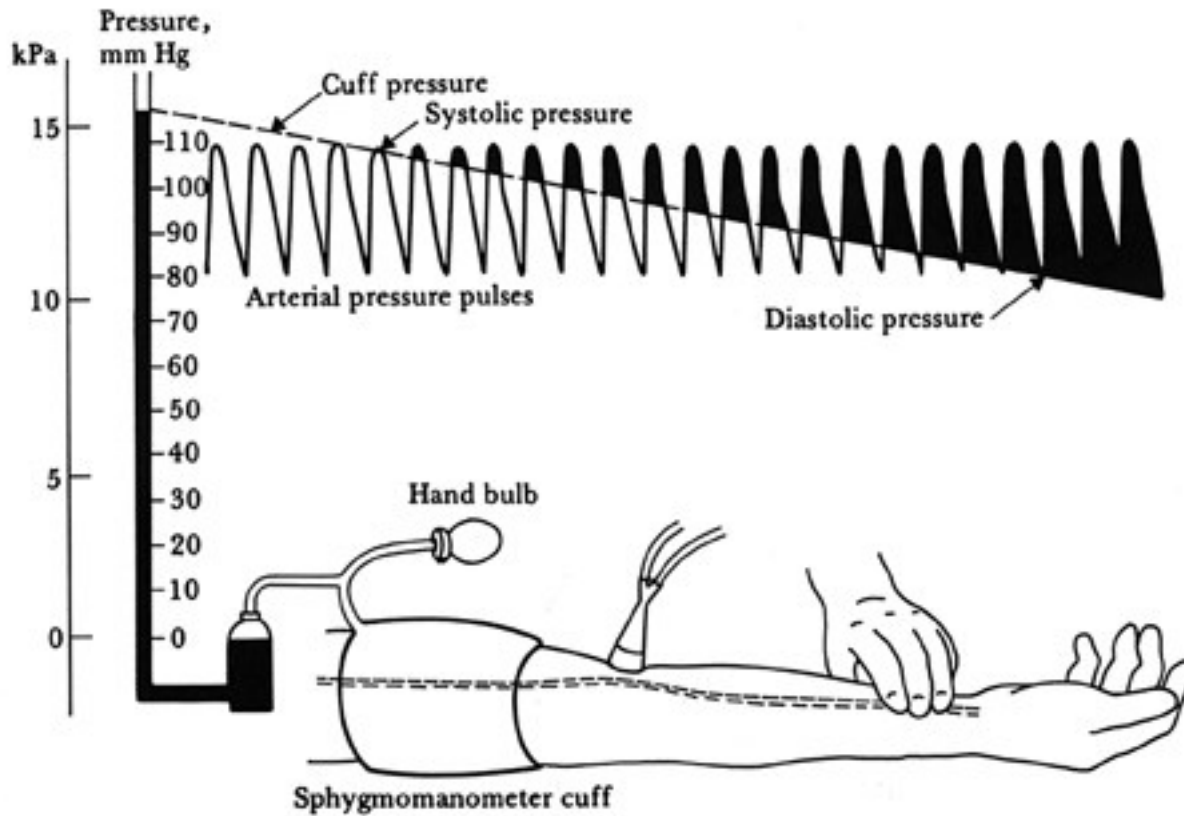
Schematic representation of pulmonary and systemic circulatory systems



Extremities, abdominal and pelvic organs, skeletal muscles, bones



Blood Pressure Measurement

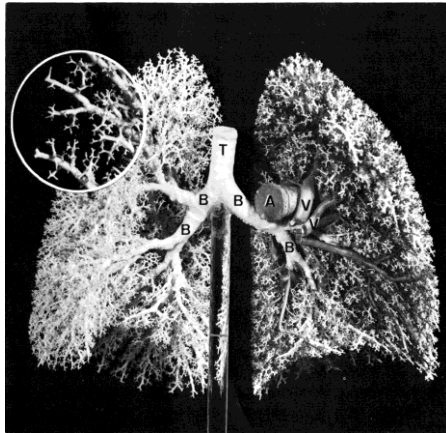


Ventral contraction

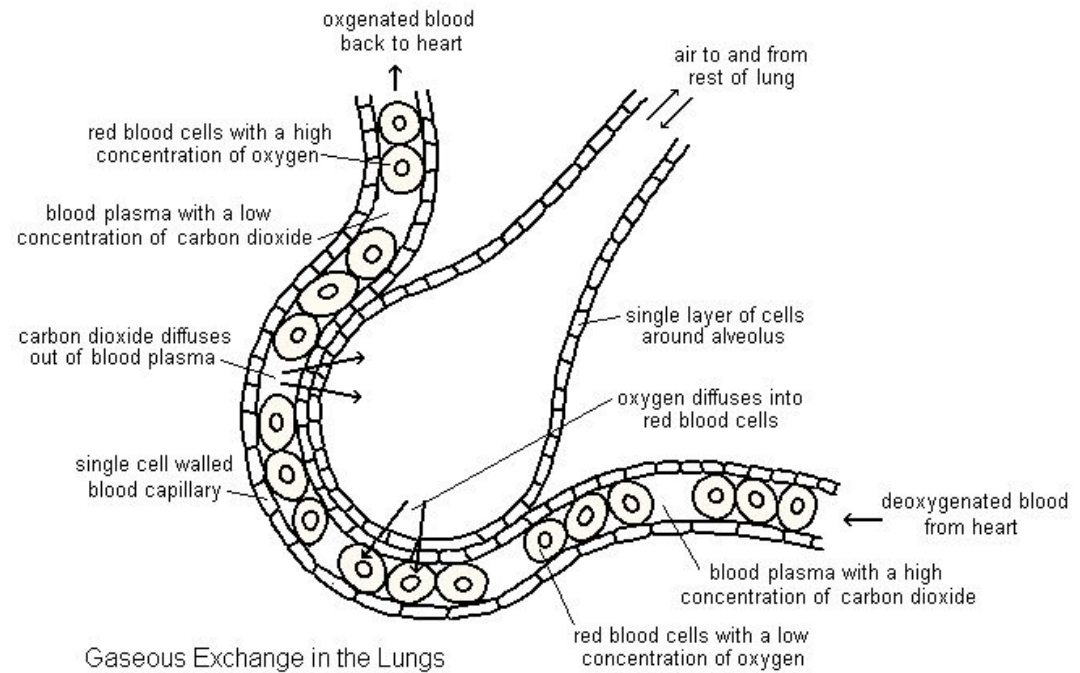
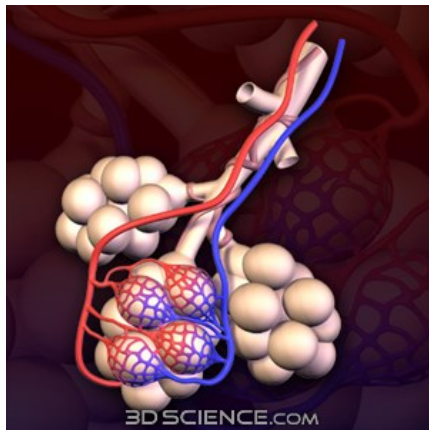
Ventral relaxation

Pulmonary Cycle

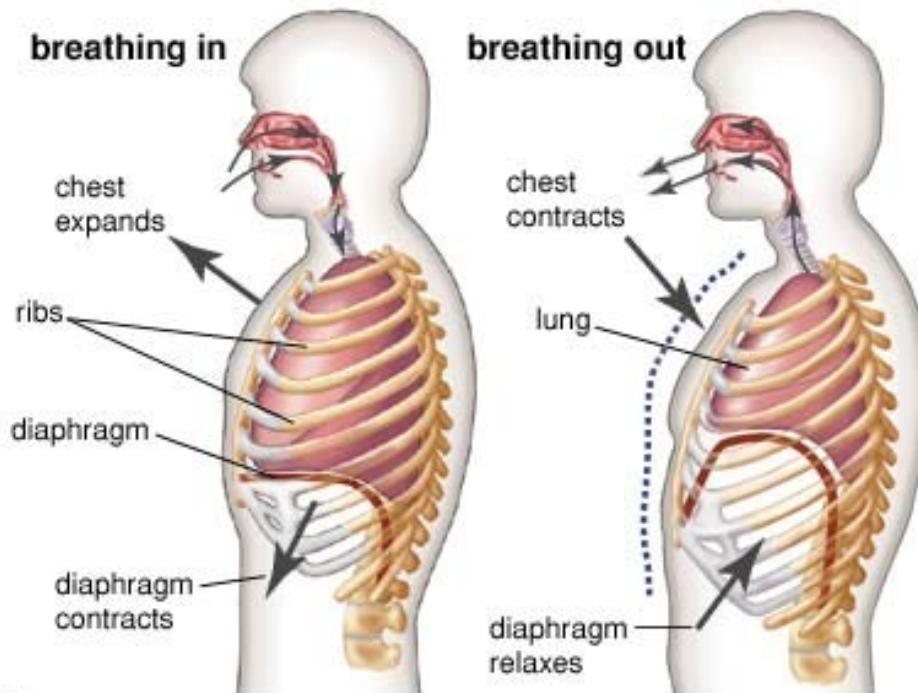
Airways



Alveoli



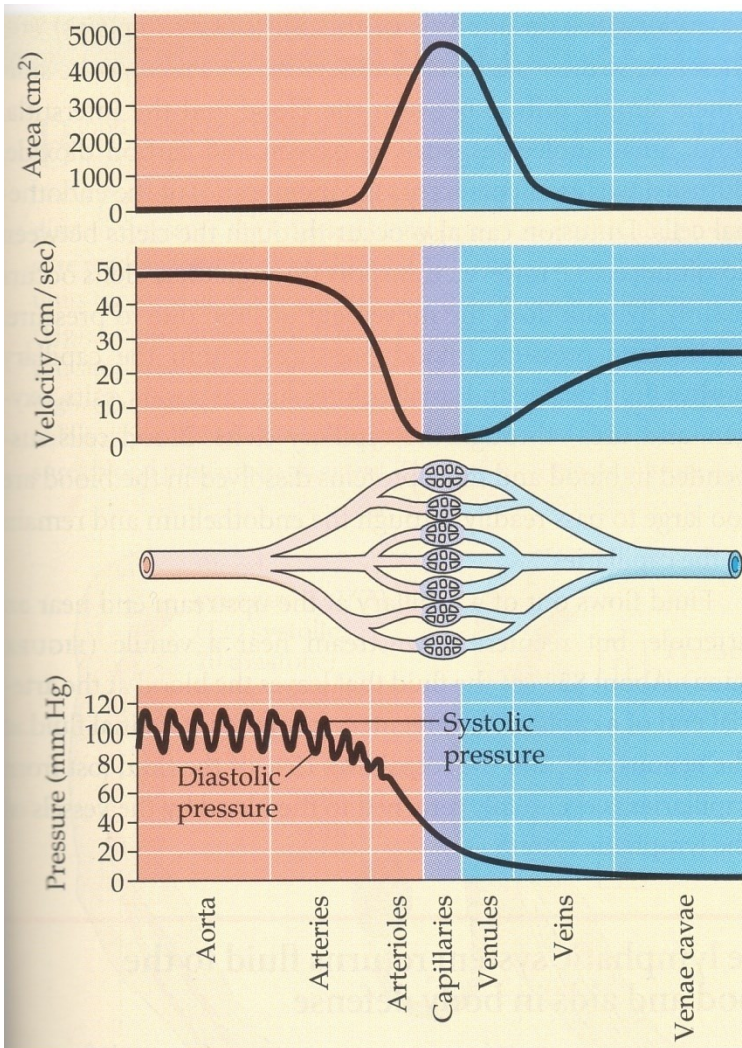
Pulmonary Cycle



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- 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?