

BIOLOGICAL FRAMEWORKS FOR ENGINEERS

Session #21 [m: Cardiovascular System]

General Objectives:

- ✓ The cardiovascular system utilizes all four tissue types in the process of delivering nutrients and O_2 to cells while removing their waste
- ✓ Feedback control is central to the function of the cardiovascular system
- ✓ Hemodynamics governs the flow of blood to the body and its ability to exchange nutrients, gases, and waste

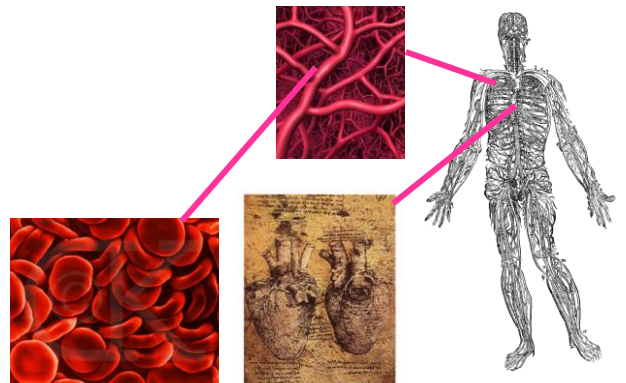
Central Framework:

- ✓ The cardiovascular system is a dynamic flow system with feedback control enabling the body systemically to maintain the viability and metabolic activity of individual tissues and cells

Session Outline:

Basic Physiology of the Cardiovascular System

System Parts



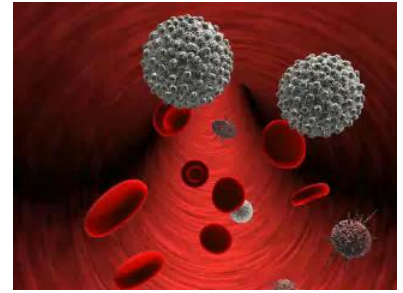
Function

Blood

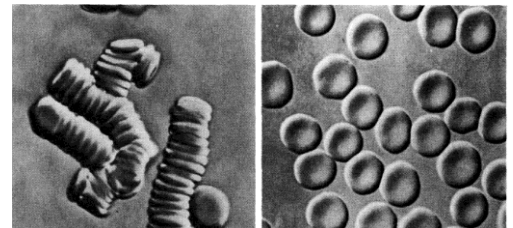
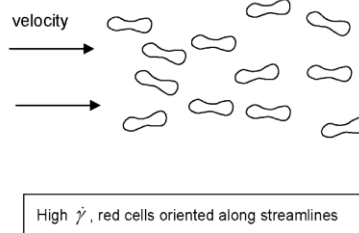
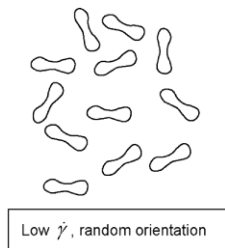
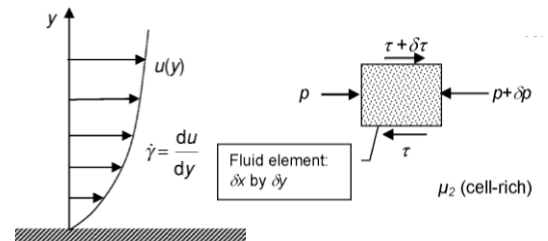
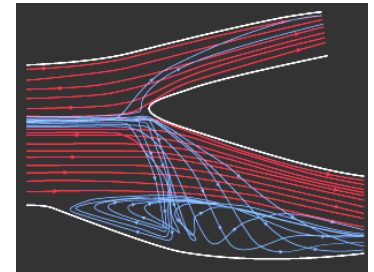
Composition

Plasma

Cells



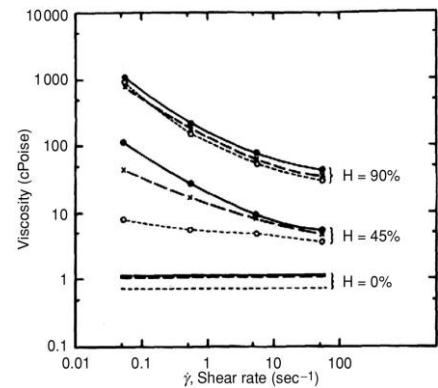
Hemodynamics



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

Viscosity

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.



Basic 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

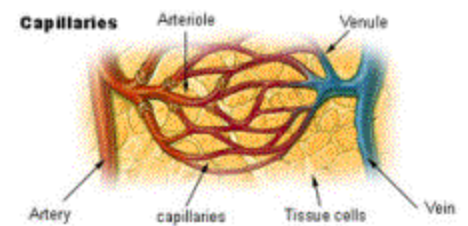
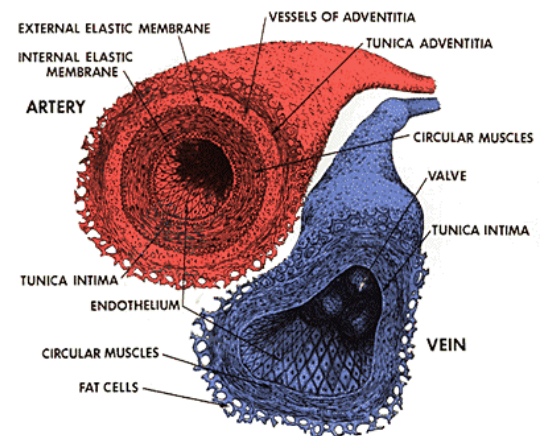
Site of exchange between blood and tissues
Thinnest, most porous walls
40,000 km of capillaries in adult human

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

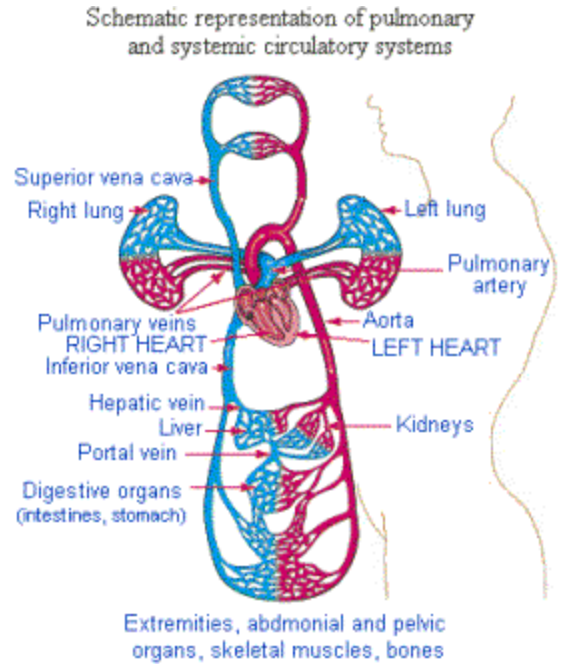


Cardiovasculature

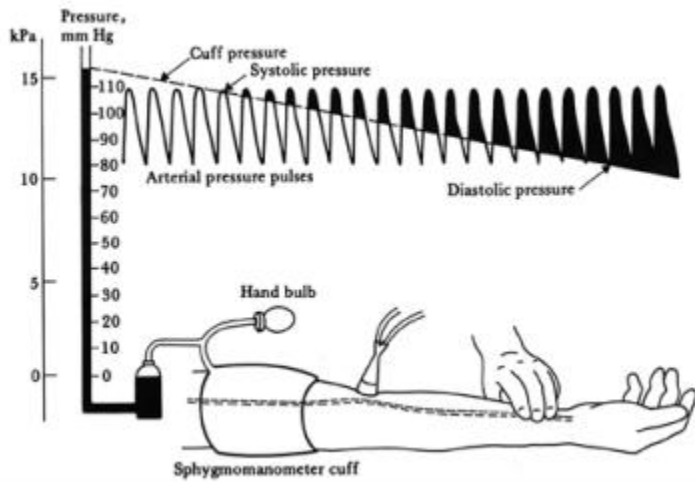
Pulmonary vs. systemic circulations

What are the primary functions of the cardiovascular system?

How are these functions regulated?

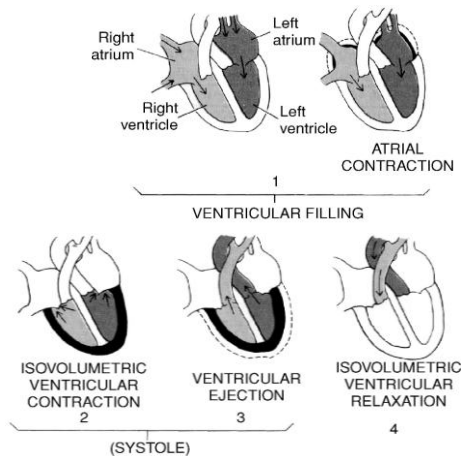
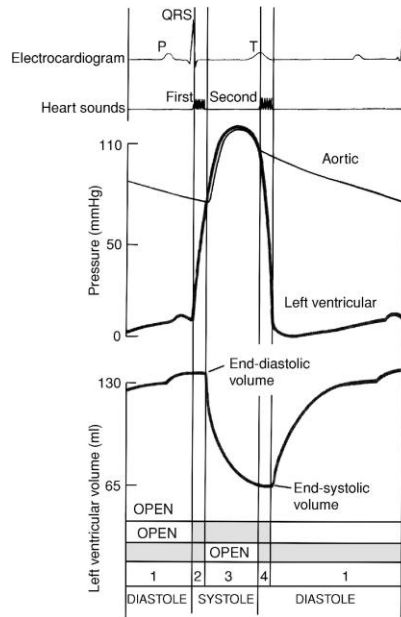


Sphygmomanometer



Cycles

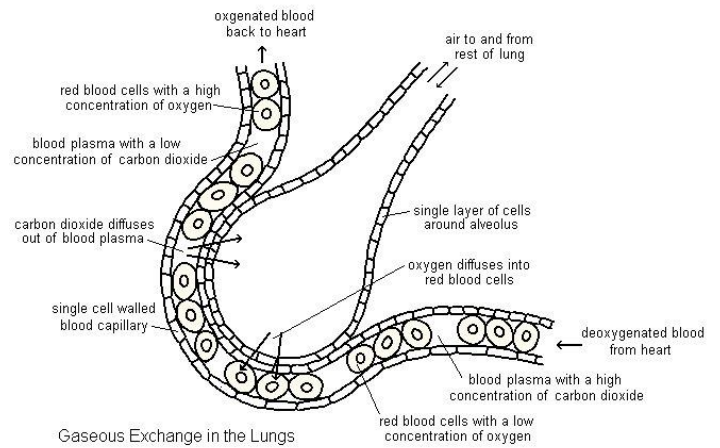
Cardiac Cycle



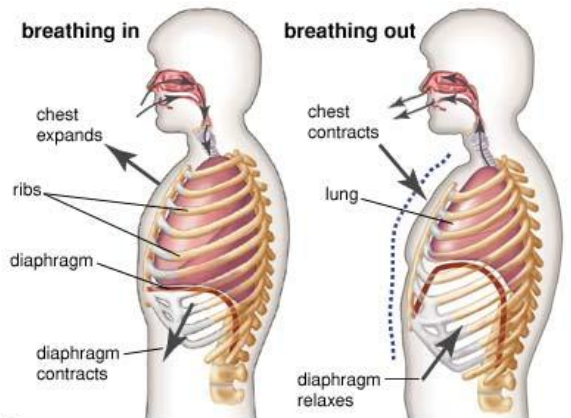
Pulmonary cycle

Airways

Alveoli



Respiration vs. Ventilation

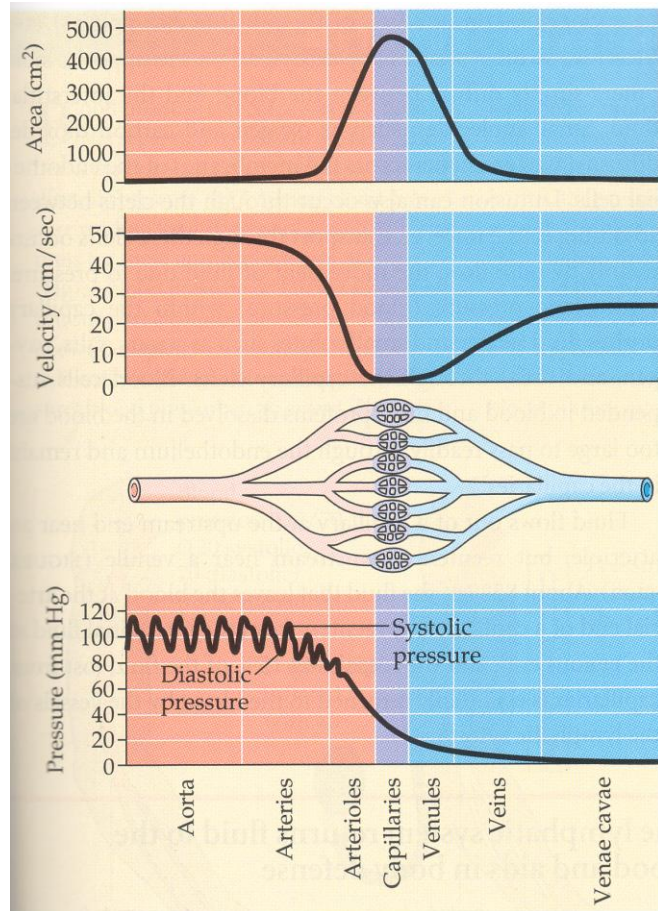


Modeling the System

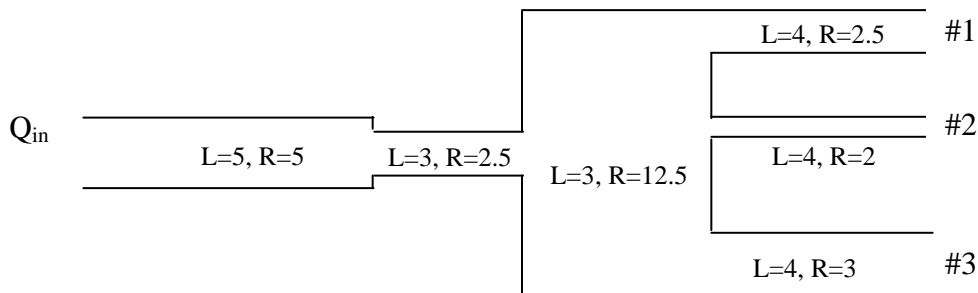
Blood Velocity (Poiseuille's Law)
 $CO = Q = \pi(P_1 - P_2)R^4 / 8\mu L$

Cardiac output = Blood Velocity
 (CO = HR x SV)

Blood pressure = Cardiac Output
 x Peripheral Vascular Resistance
 (BP = CO x PVR)



Modeling Vascular Resistance



What is the flow at point #1?

If output #2 is blocked, what is the flow rate at point #1?