Physics Applicable to Circulatory System

Cardiovascular system

- Heart + Blood vessel
- Hemodynamics: study of blood flow

Cardiac output (CO)

- Heart rate (HR): number of heart beats per minute
- Stroke volume (SV): volume of blood pumped out by a ventricle with each beat
- CO = HR x SV

Blood flow (Q)

- Volume of blood flowing through a vessel, an organ, or the entire circulation in a given period
- Equivalent to CO for entire circulation

Blood pressure (BP)

- Force per unit area exerted on the wall of a blood vessel by its contained blood
- Pressure = Force / Area (P = F / A)
- Differences in BP within vascular system provide driving force that keeps blood moving
- BP = Cardiac output x Total peripheral resistance (BP = CO x TPR)
- $Q = \Delta P / R$ (ΔP = difference in pressure across 2 points in the circulation)

Velocity of blood flow (v)

- Distance per unit time in a specific direction
- Velocity = Flow / Cross sectional area
- For incompressible fluids, flow rate at various points is constant (assuming no resistance)

Resistance (R)

- Opposition to Q
- Measure of the amount of friction blood encounters as it passes through vessels
- Factors affecting R: (1) Blood viscosity, (2) Total vessel length, (3) Vessel radius
- **Poiseuille's Law:** $Q = \Delta P \pi r^4 / 8\eta l$
    - Resistance varies inversely with the 4^{th} power of vessel radius
    - Small change in radius → Large change in R

Series & parallel circuits in the circulatory system

- Circulatory system has both series & parallel arrangements of blood vessels.

Laminar & turbulent flow

- Laminar flow: Fluid flows in layers parallel to vessel wall
- Turbulent flow: Irregular movement (some are pathological, e.g. in atherosclerosis)

Cardiovascular dynamics

- Hemodynamics can be visualized by non-invasive methods (e.g. time-resolved 3D MRI)