Ministry of Higher Education and Scientific Research
Al-Mustaqbal University
College of Medicine

Medical Physics

Physics of the Cardiovascular System

First stage

Lecture 9

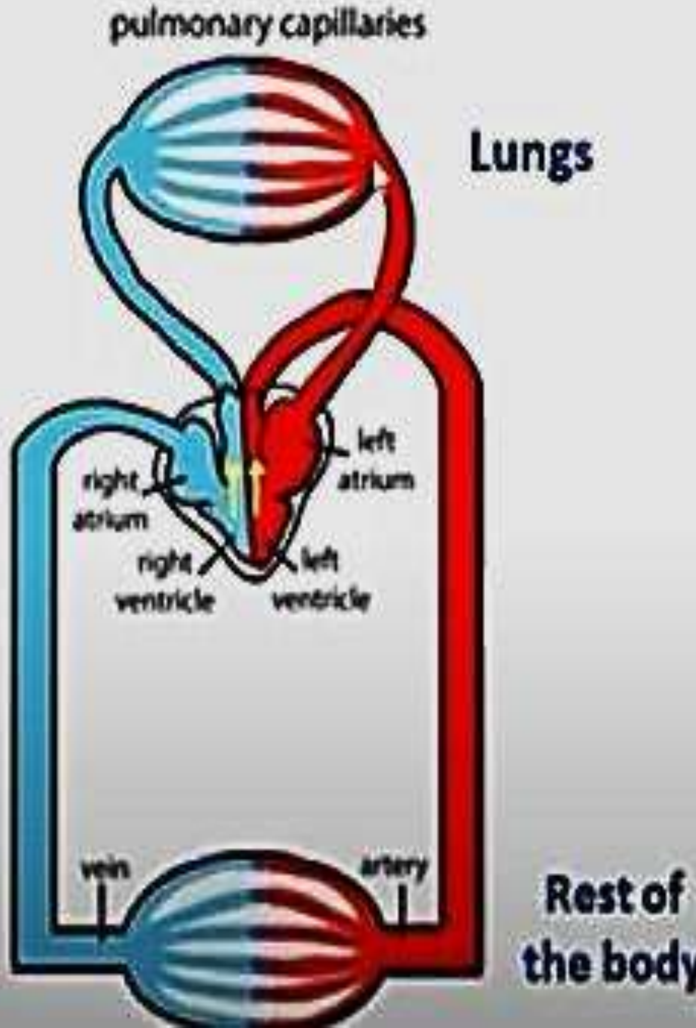
2024-2025

Dr. Mohammed Abdullah Jassim

Cardiovascular System (CVS)

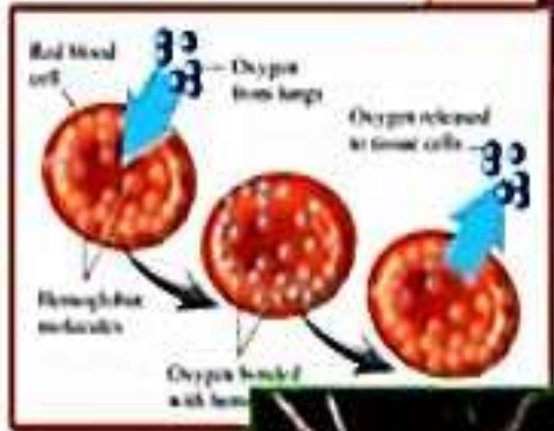
- Since the body has many billions of cells an elaborate transportation system is needed to deliver the fuel and O_2 to the cells and remove the by-products.

- The **blood** performs this important body function.
- The blood, blood vessels, and heart make up the cardiovascular system (CVS).
- The main function of CVS is to maintain blood flow to all parts of the body, to allow it to survive.



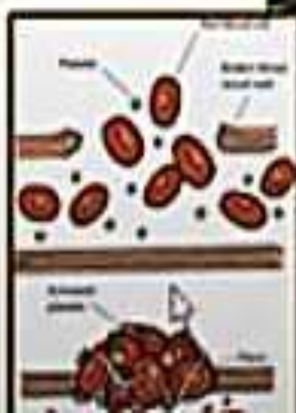
Blood Components

- Plasma ≈ 55-60% of the blood's volume.



- Red blood cell (erythrocytes); determines the fluid characteristic of blood.

- White blood cells (leukocytes); important for the human immune system.



- Platelets (thrombocytes), important for blood clotting.

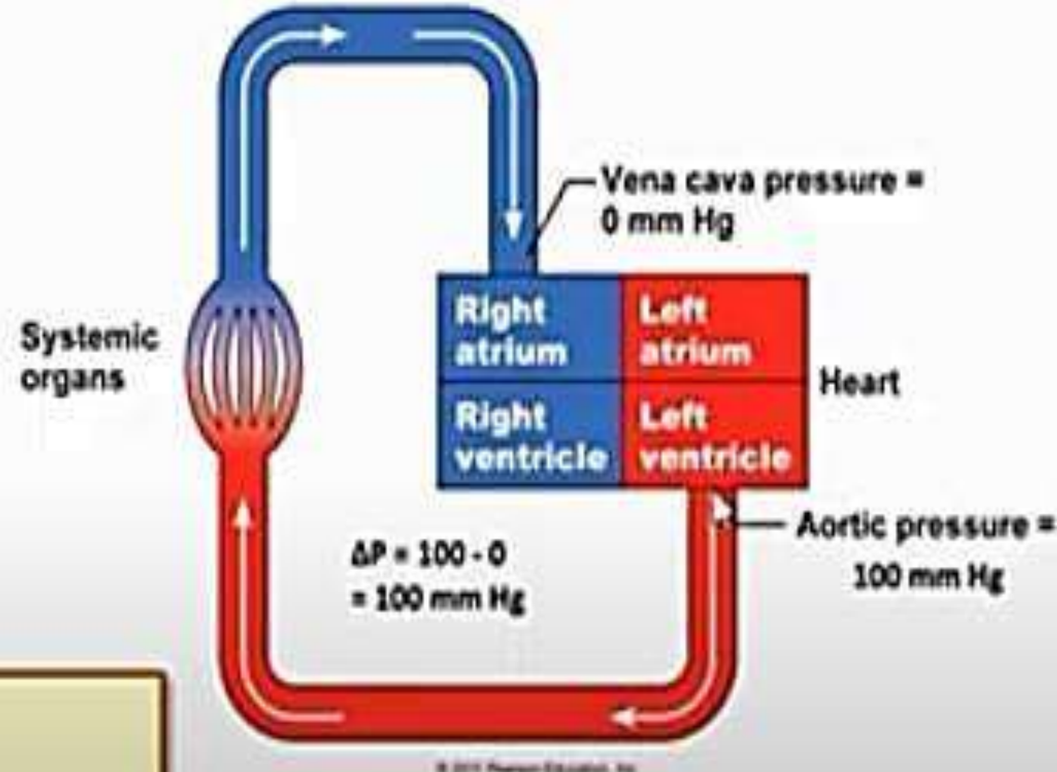
Blood Circulation

- Blood flow through vesicular system depends on ΔP of the two ends of circulatory system.

$$\Delta P = P_{\text{Left ventricule}} - P_{\text{Rigt atrium}}$$

$$= 100 - 0$$

$$= 100\ \text{mmHg}$$



<u>ΔP controls the blood flow</u>

- ΔP increase → High Blood flow speed
- ΔP decrease → Low Blood flow speed

Blood Circulation

- The blood volume is not uniformly divided between the pulmonary and systemic circulation.

Blood mass = 7% body mass (~ 4.5kg)

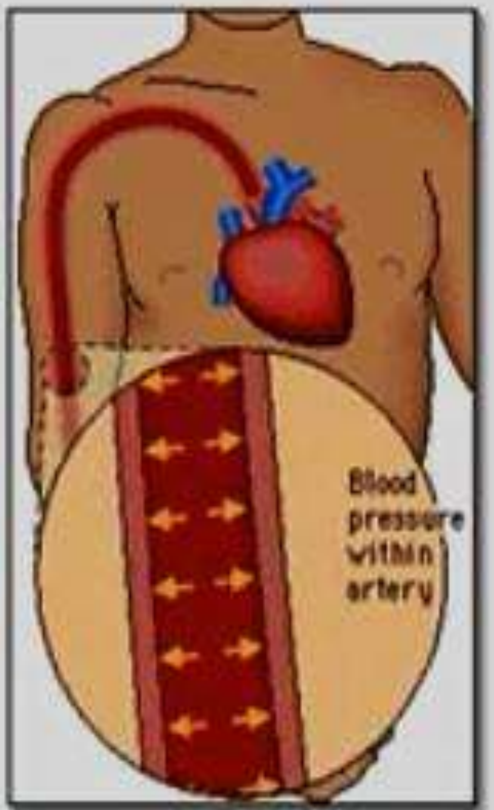
Blood Circulation
100%

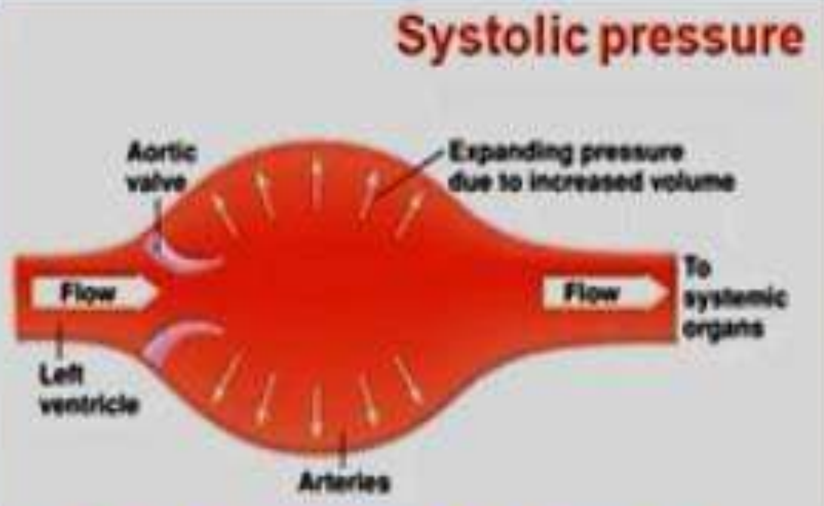
Systemic Circulation
80%

Pulmonary Circulation
20%

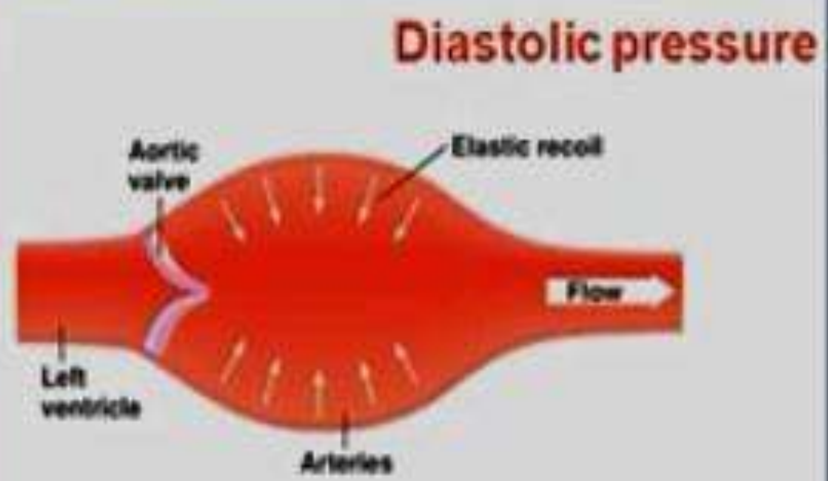
Blood Pressure

- Blood pressure (BP) can be defined as the force per unit area exerted on the wall of a blood vessel by the blood.





P_s = 120 mmHg = 12 cmHg

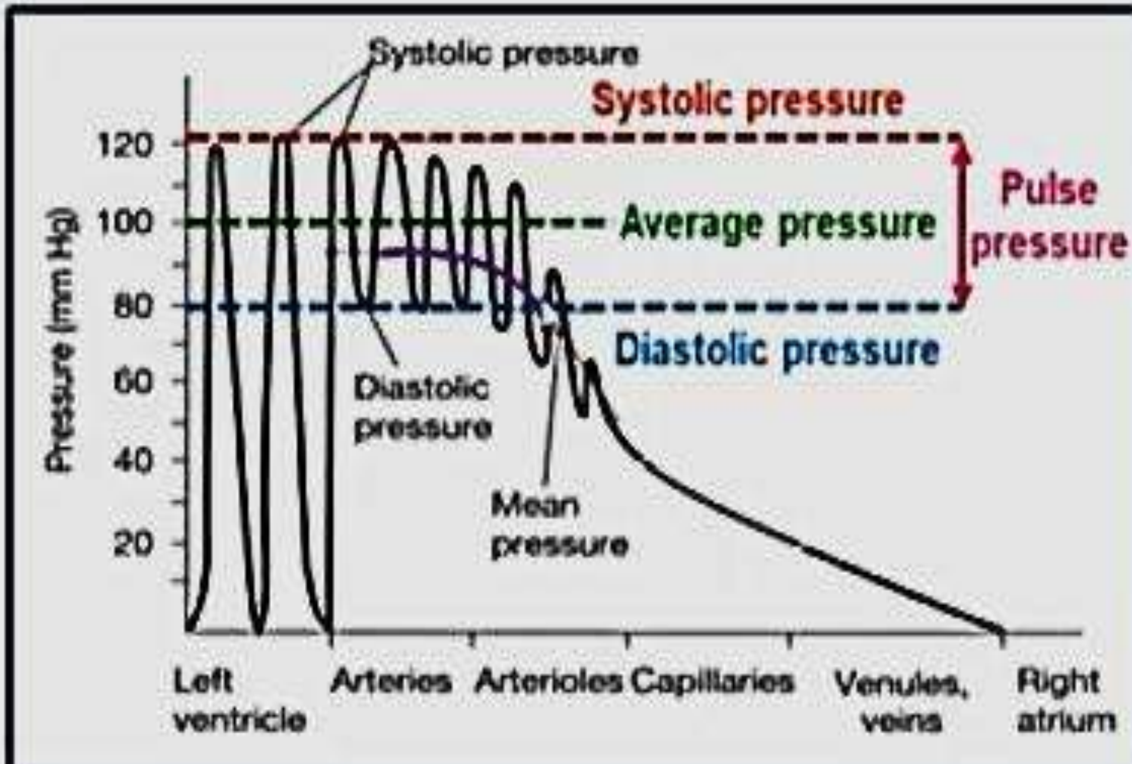


P_d = 80 mmHg = 8 cmHg

Blood Pressure

- The pressure various throughout the circulatory system.

$$BP = \frac{P_s}{P_d} = \frac{120}{80} = \frac{12}{8}$$



Average pressure:

$$P_{ave} = \frac{P_s + P_d}{2}$$

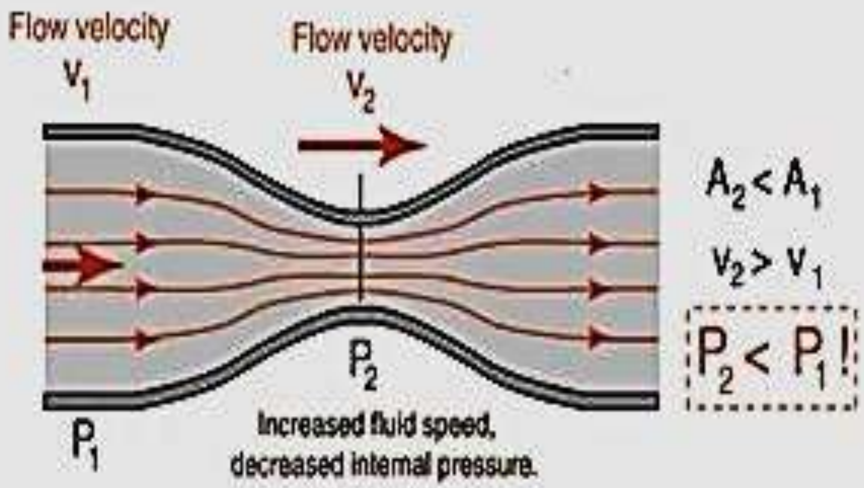
Pulse pressure:

$$P_{pulse} = P_s - P_d$$

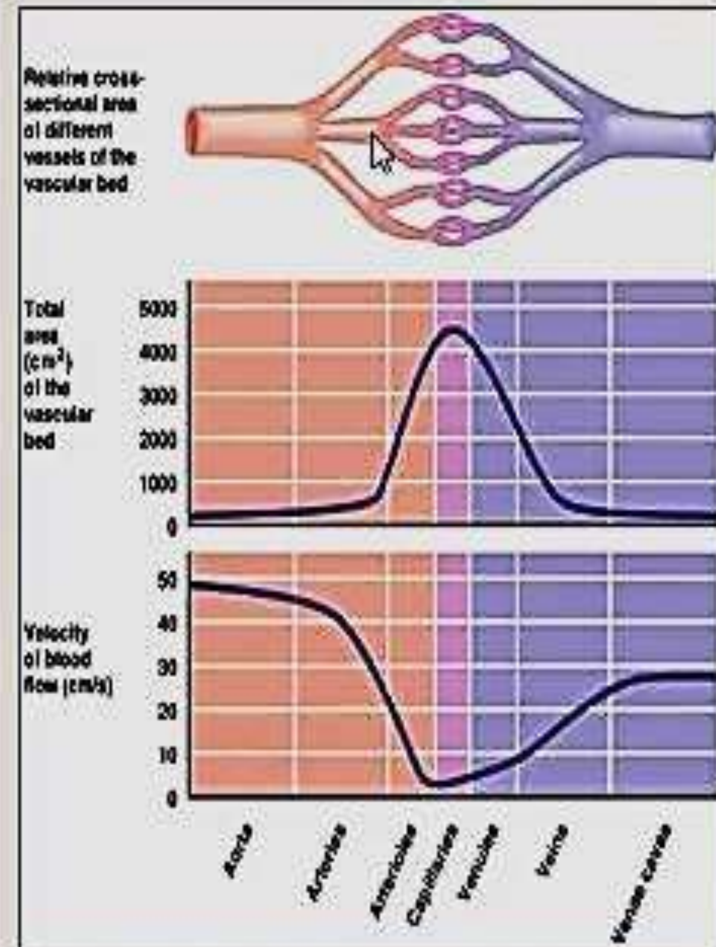
Mean pressure $(\overline{P_m}) = P_d + \frac{1}{3}(P_s - P_d)$

Bernoulli Equation

- It describes the behavior of an inviscous fluid.
- It is called as *Conservation of Continuity*.
- fluid flow in a vessel is constant.



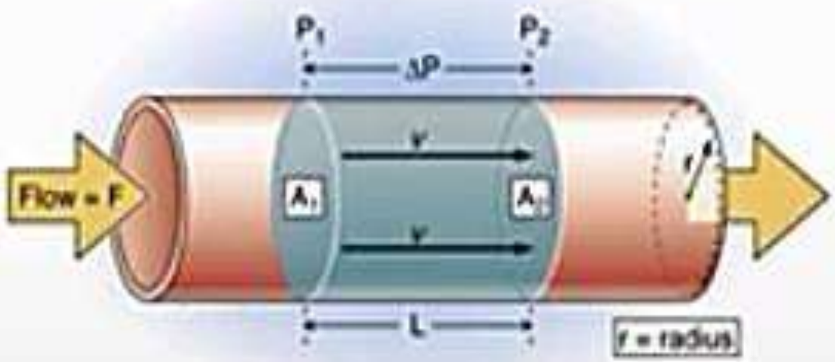
$$\text{Flow}_{in} = \text{Flow}_{out}$$
$$A_1 v_1 = A_2 v_2$$



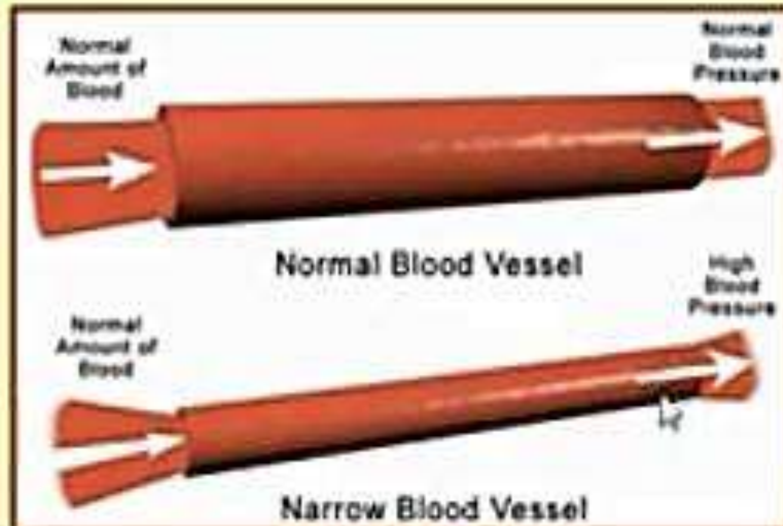
This allows time for diffusion of the gases (O_2 and CO_2) to occur.

Poiseuille's Equation

- Describe the behavior of a viscous fluid.
- The fluid has a viscosity (η) .
- fluid flow is not constant, depending on the viscosity:



$$Q = \frac{\pi r^4 \Delta P}{8\eta L}$$



$$\Delta P \propto \frac{1}{r^4}$$

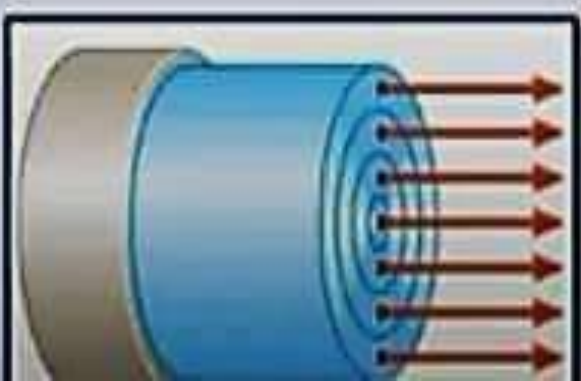
Some drugs for hypertension are designed to lower blood pressure by limiting the contraction of blood vessel walls.

Fluid Flow

There are two types of fluid:

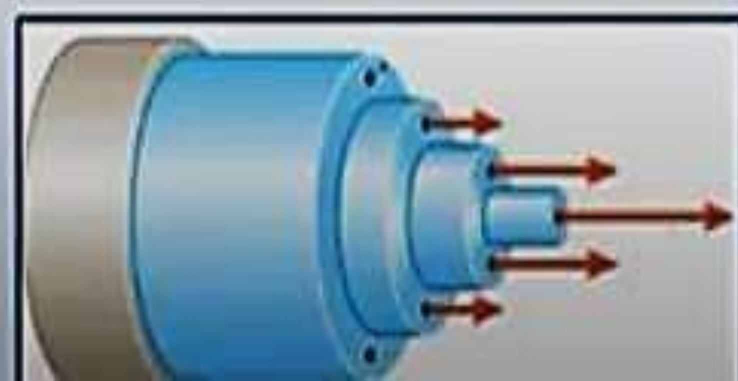
Ideal fluid

- No internal fractional forces.
- All particles flow in parallel layers.
- All particles have equal velocity.
- Mechanical energy is conserved.



Real fluid

- There is internal fractional forces.
- All particles flow with intersect.
- The particles have different velocity.
- Mechanical energy is lost.



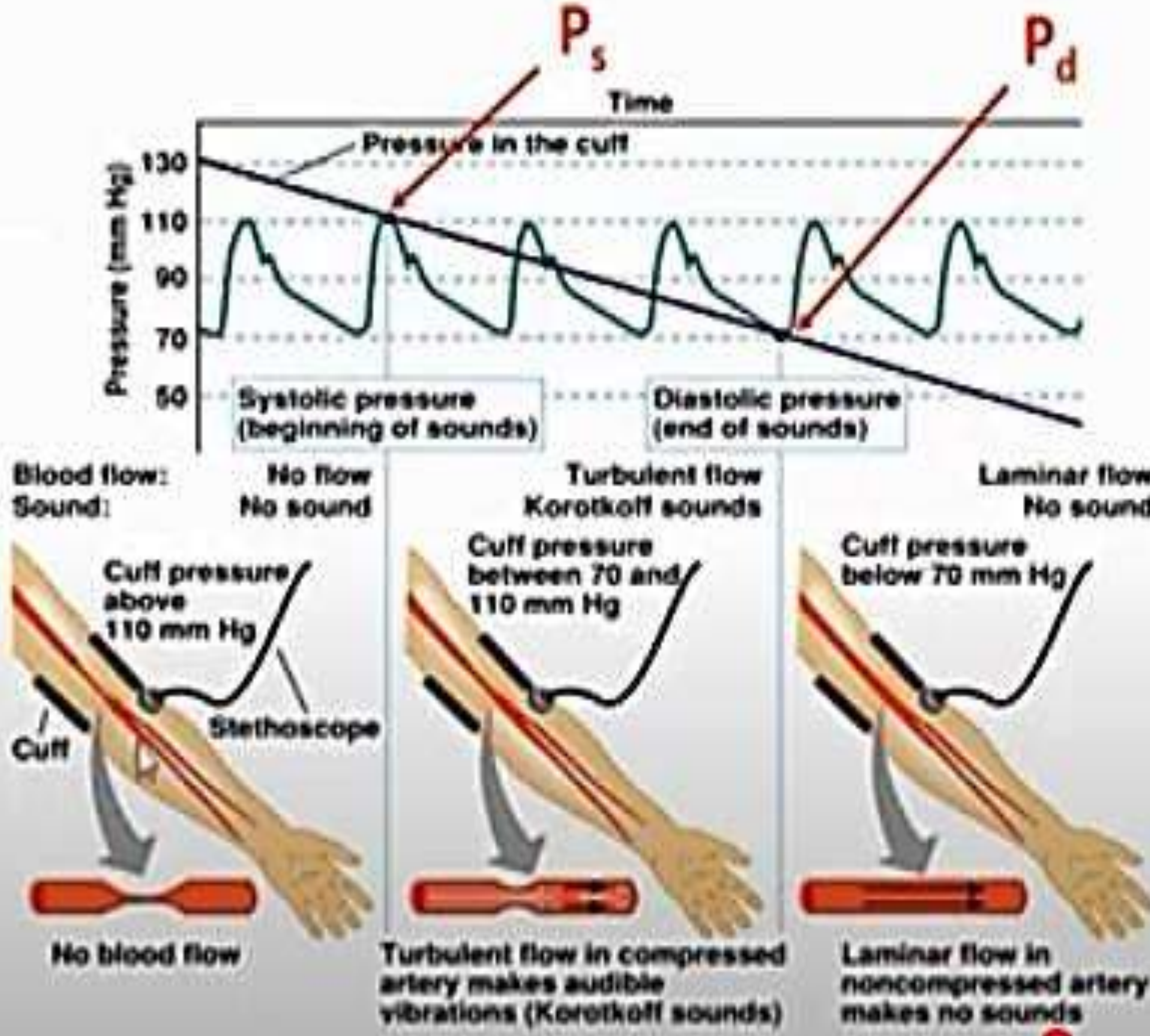
Blood Pressure Measurement

- In measuring the blood pressure, the heart sound can be detected.

- The constriction on the arm produces turbulent flow.

- The 1st sound is P_s.

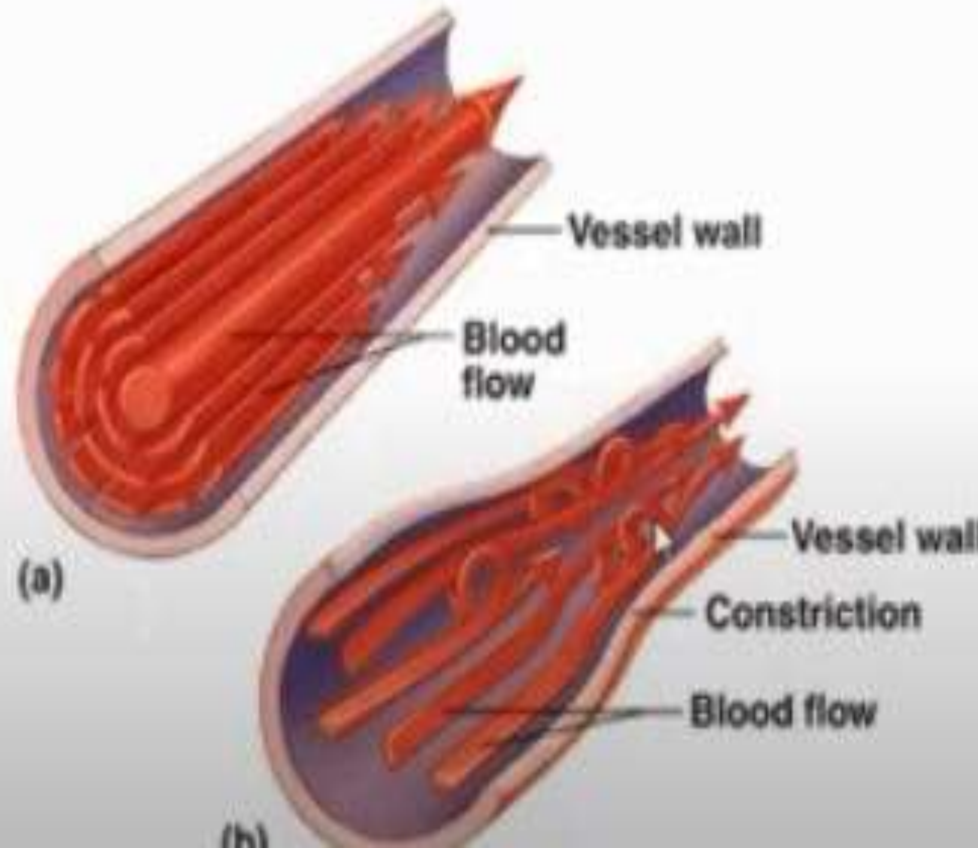
- The last sound is P_d.



Constriction and Flow Rate

The velocity of blood increases by reducing the radius of the tube, it will reach a critical velocity (v_c) when Laminar flow changes into turbulent flow.

$$v_c = \frac{R\eta}{\rho r} = \frac{Q_c}{A}$$

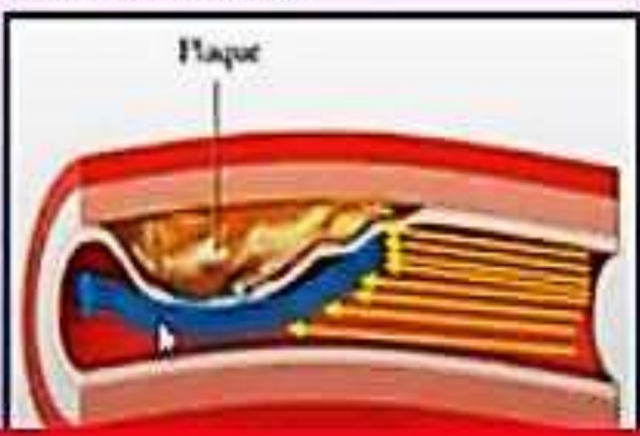


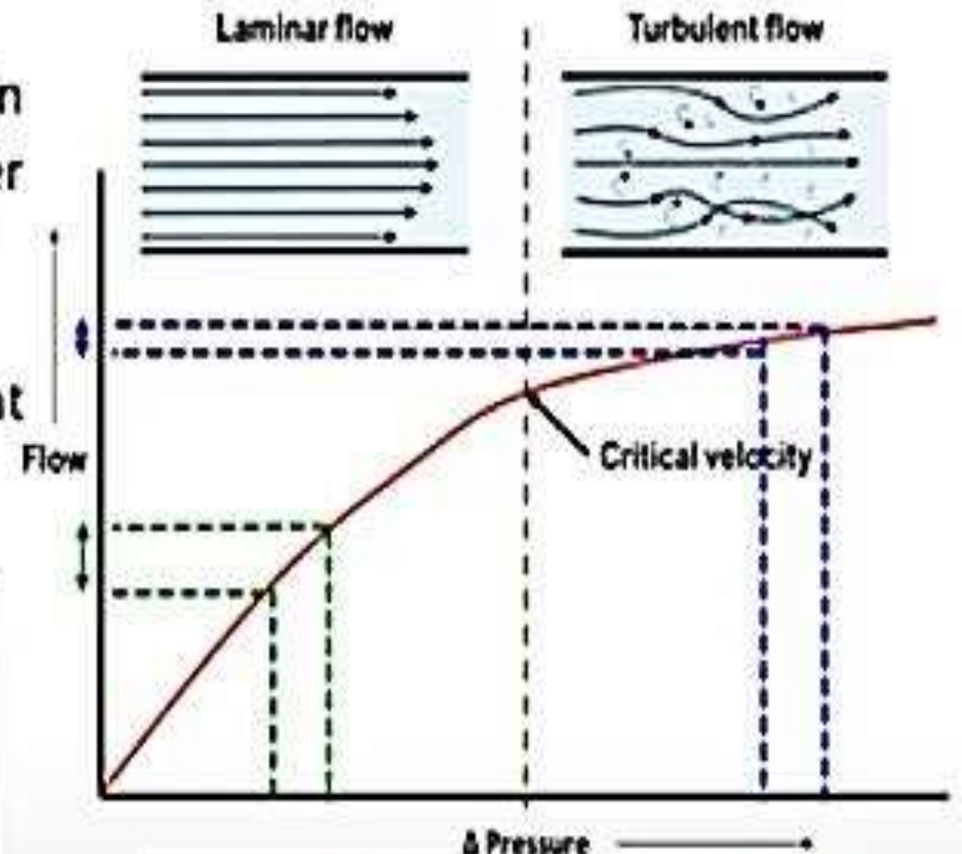
Efficiency of the Flow

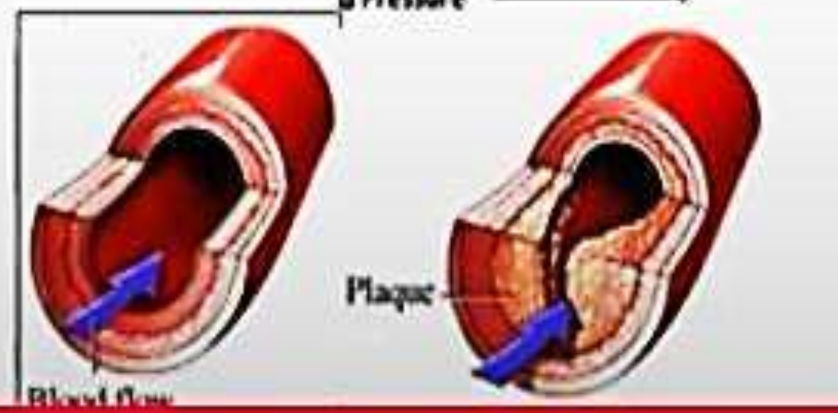
- The flow as a function of pressure in the laminar region is relatively greater than turbulent region.

- The laminar flow is more efficient than turbulent flow.

Obstructed vessel may not be able to deliver which causes chest pain and heart attack.







THANK YOU