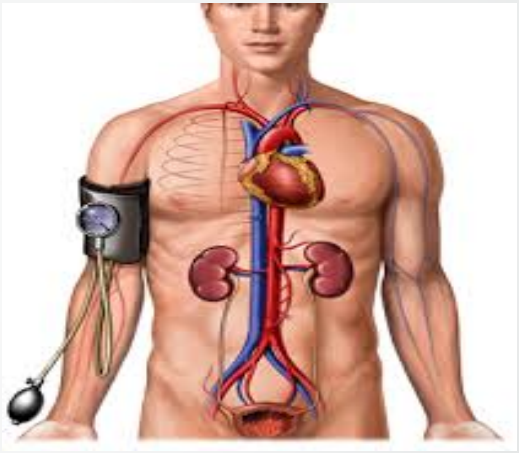
جامعة الملك سعود
King Saud University

Cardiovascular Physiology



Arterial Blood Pressure

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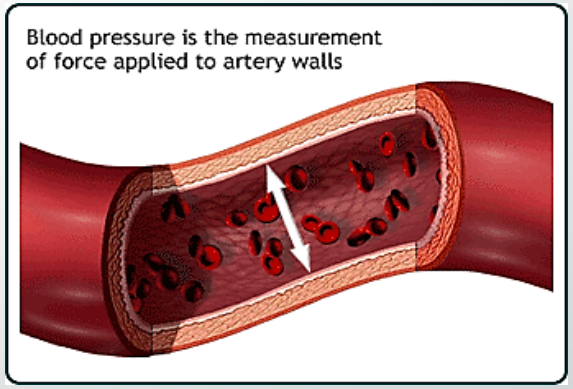
Lecture Outcomes

- Concept of mean blood pressure, systolic, diastolic, & pulse pressure.
- Normal variations in arterial blood pressure.
- Factors determined blood pressure.
- Calculation of mean blood pressure.
- Relationship between CO, BP & total peripheral resistance.

What is meant by Arterial Blood Pressure?

= Lateral pressure created by the heart as it pumps blood, against any unit area of the vessel wall.

In normal adult ≈ 120/80 mmHg



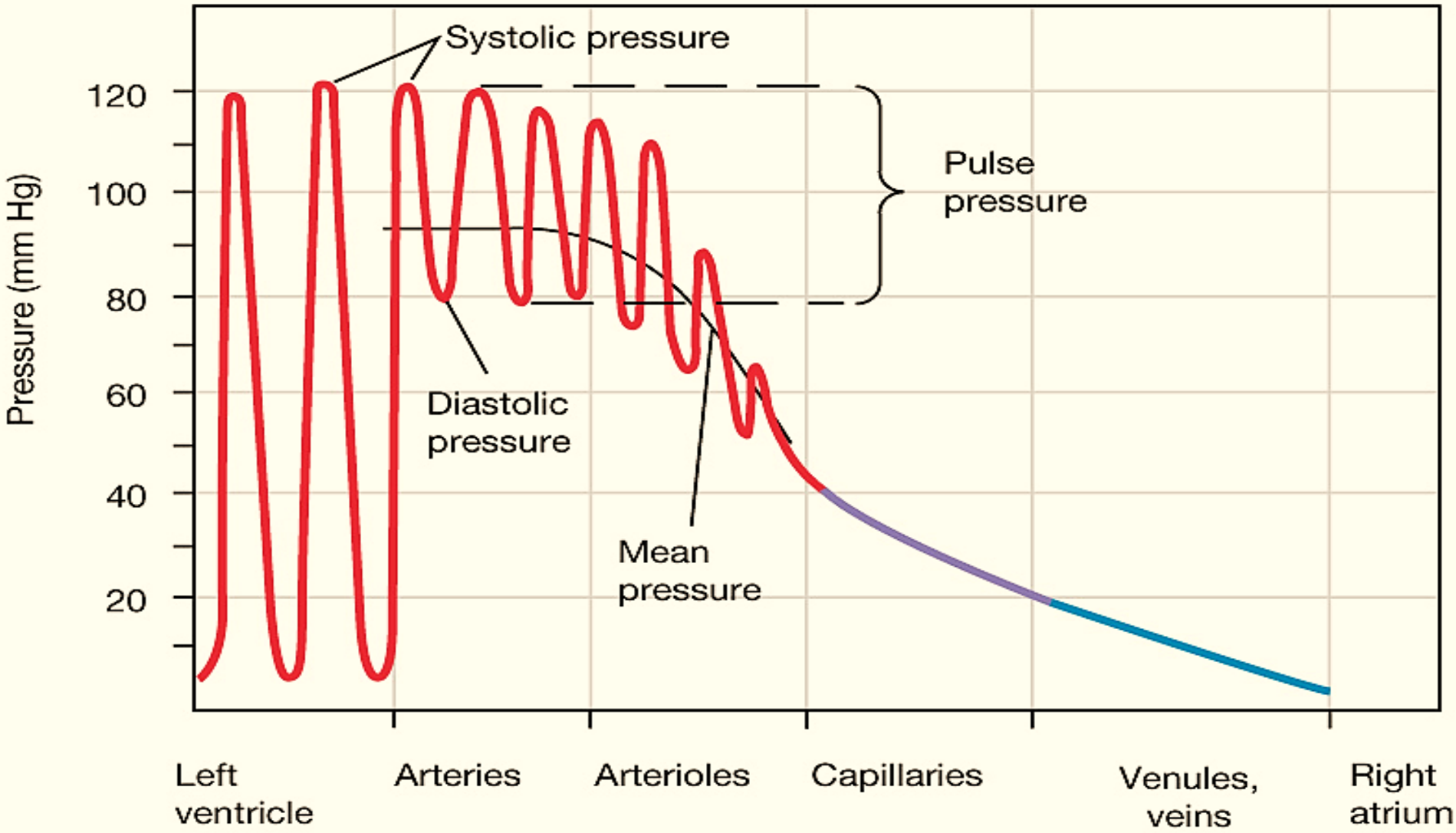
- **Top number (Systolic):**

  = Pressure while the heart is beating.

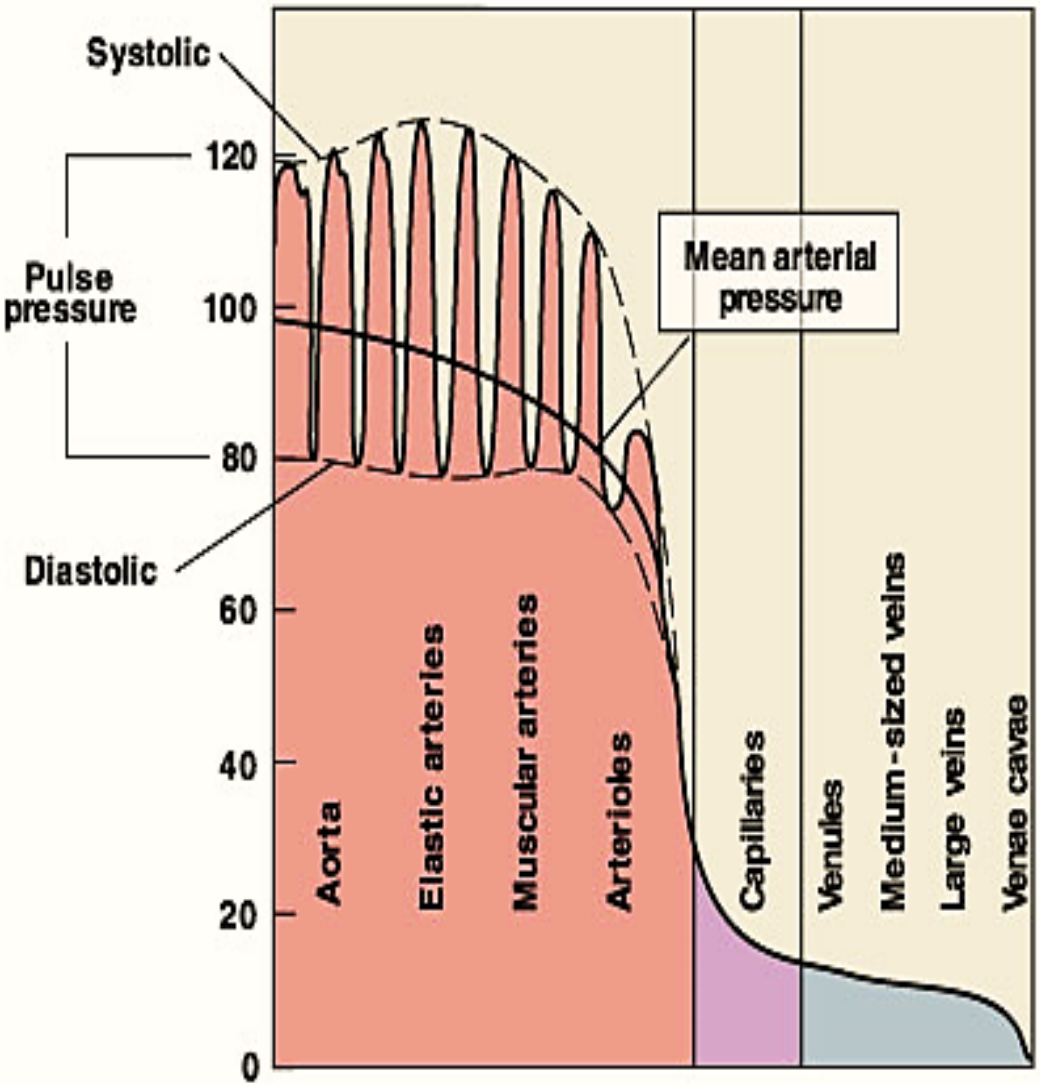
- **Bottom number (Diastolic):**

  = Pressure while the heart is relaxing.

Pressure changes throughout the systemic circulation



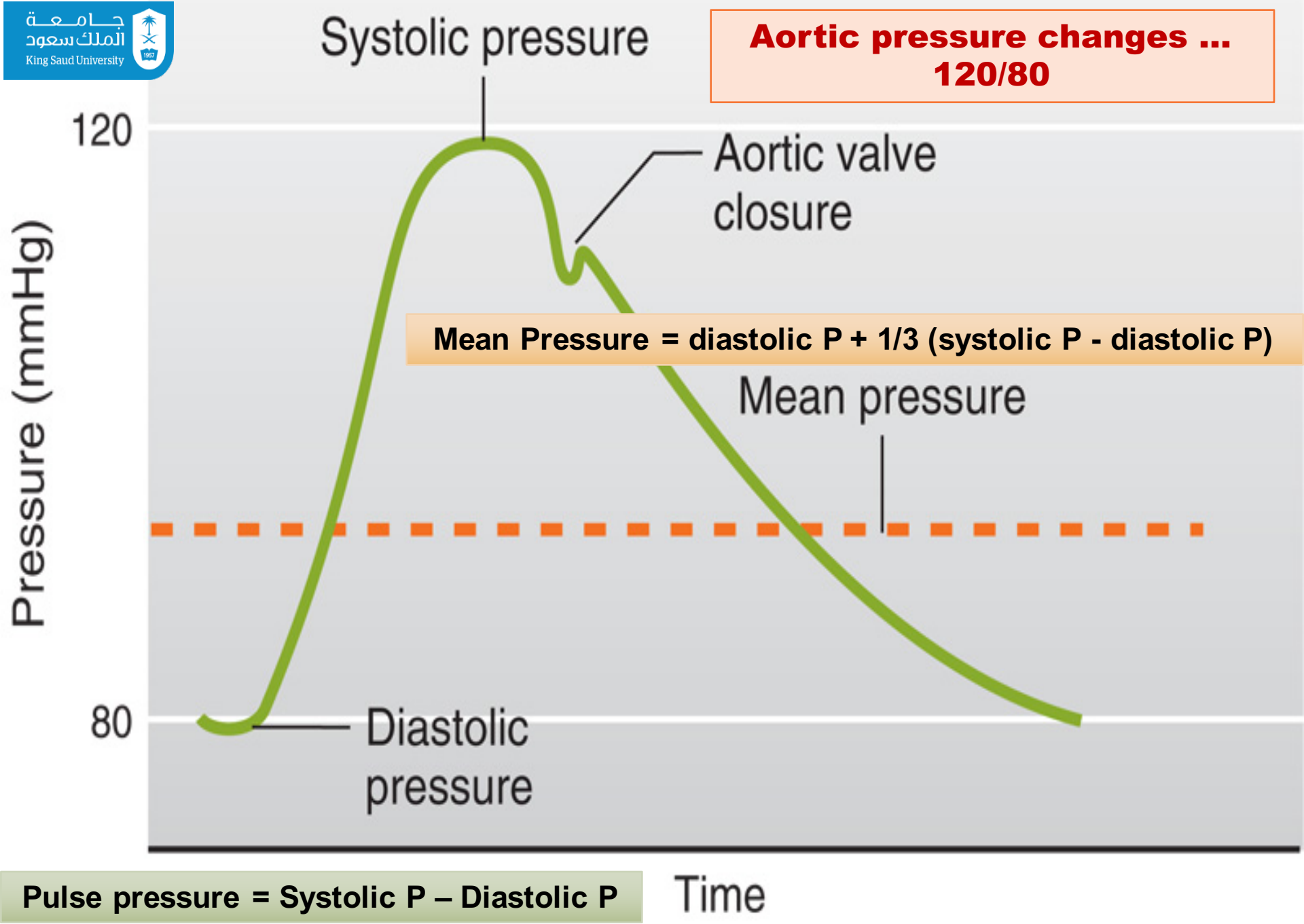
Pressure changes throughout the systemic circulation



- Blood flows down a pressure gradient.
- Highest at the heart.
- ↓ over distance.
- ↓ 90% from aorta to vena cava.
- Greatest drop in pressure occurs in arterioles.
- No large fluctuations in capillaries & veins.
- BP averages 120 mm Hg in aorta & drops to 0-2 mm Hg in RA.

Variations in Arterial Blood Pressure

- **Aortic pressure:**
  - 120 mmHg systolic.
  - 80 mmHg diastolic.
- **Normal arterial pressure:**
  - 110 – 130 mmHg systolic.
  - 70 – 85 mmHg diastolic.



Pulse pressure = Systolic P – Diastolic P

Adapted from Guyton

American Heart Association

Recommended Blood Pressure Levels

Adult BP range 110 – 130 / 70 – 85 mmHg

BP Category	Systolic (mmHg)		Diastolic (mmHg)	Follow-up
Optimal	< 120	&	< 80	Recheck 2 years
Normal	< 130	&	< 85	Recheck 2 years
High Normal (Pre-hypertension)	130-<140	or	85-<90	Recheck 1 year

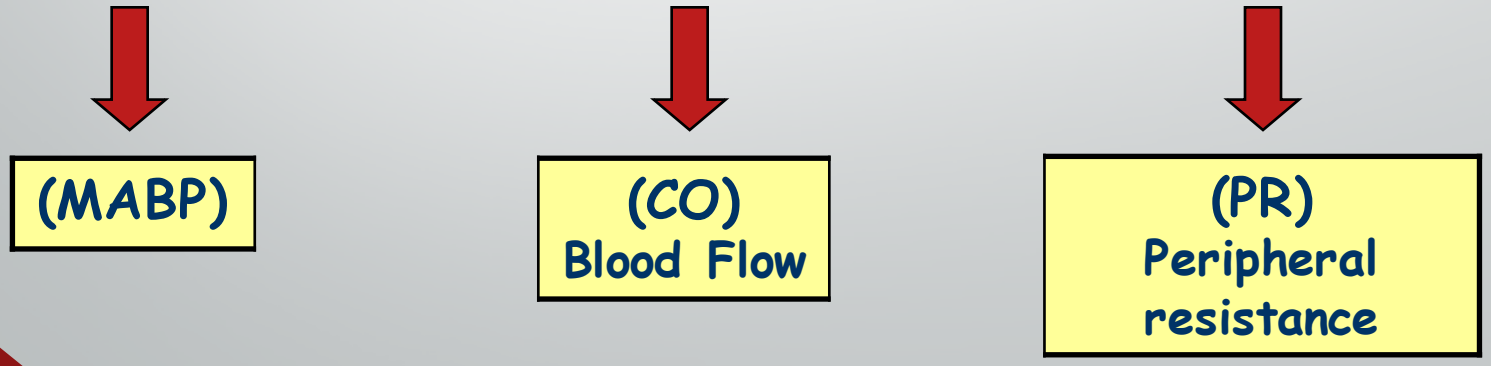
Factors Affecting ABP

- **Sex:** Male > Female … (equal @ menopause)
- **Age:** Elderly > children …(due to atherosclerosis, diabetes, …)
- **Emotions:** BP (↑) due to neural & hormonal factors.
- **Exercise:** (↑) BP due to ↑ venous return.
- **Hormones:** Some hormones like adrenaline, noradrenaline & thyroid H (↑) BP.
- **Gravity:** BP is higher in lower limbs than upper limbs.
- **Race:** (? dietary factors, or stress)
- **Sleep:** BP (↓) due to ↓ venous return.
- **Pregnancy:** BP (↑) due to ↑ in metabolism.
- **Temperature:** BP (↓) with Heat due to vasodilatation, & (↑) with Cold due to vasoconstriction.

Factors Determining ABP

- Cardiac output (Flow.)
- Peripheral Resistance.
- Blood volume.

Blood Pressure = Cardiac Output X Peripheral Resistance



Cardiac Output (CO)

- **Cardiac output (CO) is the amount of blood pumped by ventricles per minute.**
- **Factors determining CO:**
  1. Stroke volume
  2. Heart rate

Cardiac Output = Stroke Volume X Heart Rate

Cardiac Output (CO)	Stroke Volume (SV)	Heart Rate (HR)
= Output of ventricles / minute	= Output of ventricles / beat	= beats/ minute
≈ 5 L/min (av. 5-6 L/min)	70 ml/beat (av. 70-80 ml/beat)	≈ 70-75 beats/min (N. 60-100 beats/min)

Blood Flow

- Amount of blood moving through a vessel in a given time period.
- Generally is equal to Cardiac output (CO.)
- Affected by: pressure & resistance.

$$Q = \frac{\Delta P}{R}$$

- **Directly proportional to** pressure differences.
- **Inversely proportional to** resistance.

Resistance (R)

= tendency of vascular system to oppose flow.

$$\text{Flow} = \frac{1}{R}$$

Influenced by:

Length of the tube (**L**), radius of the tube (**r**), & viscosity of the blood (**η**)

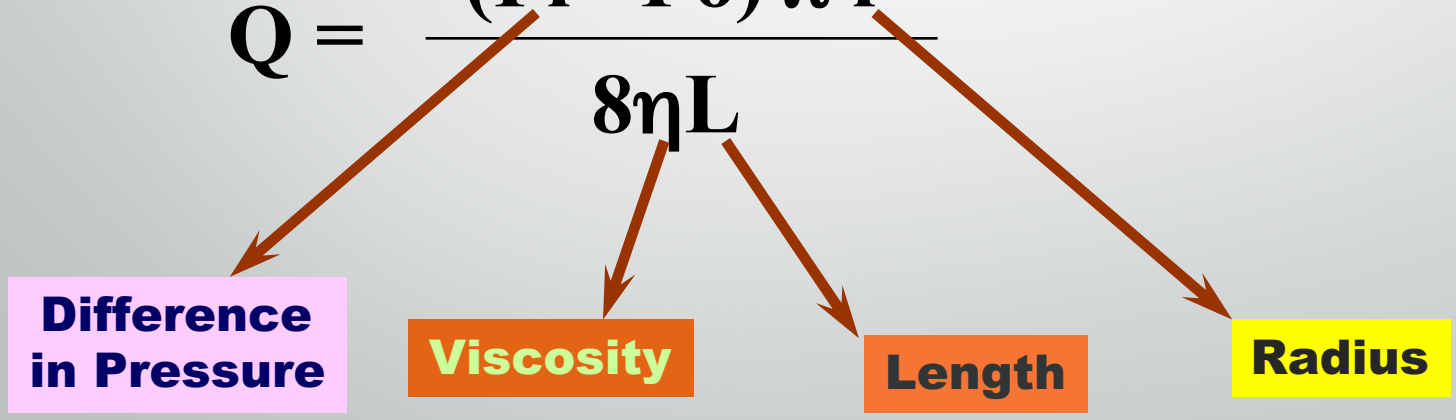
- In a normal human, length of the system is fixed, so blood viscosity & radius of the blood vessels have the largest effects on resistance..

Poiseuille's Law $R = 8\eta L / \pi r^4$

Poiseuille's Law

- Fluid Flow (Q) through Cylindrical Tubes.
- Flow decreases (↓) when resistance increases.
- Flow resistance decreases (↓) when vessel diameter increases.

$$Q = \frac{(Pi - Po)\,\pi\, r^4}{8\eta L}$$



Total Peripheral Resistance (TPR)

$$R = \frac{\Delta P}{Q}$$

Systemic Circulation:

$$TPR = \frac{\text{Aortic Pressure - RAP}}{\text{Flow}}$$

$$TPR = \frac{120 - 2 \text{ mmHg}}{83.3 \text{ ml/sec } (5 \text{ L/min})}$$

$$TPR = 1.2 \text{ (PRU's)}$$

Pulmonary Circulation:

$$\text{Pul. R.} = \frac{\text{Pulmonary Art. P. - LAP}}{\text{Flow}}$$

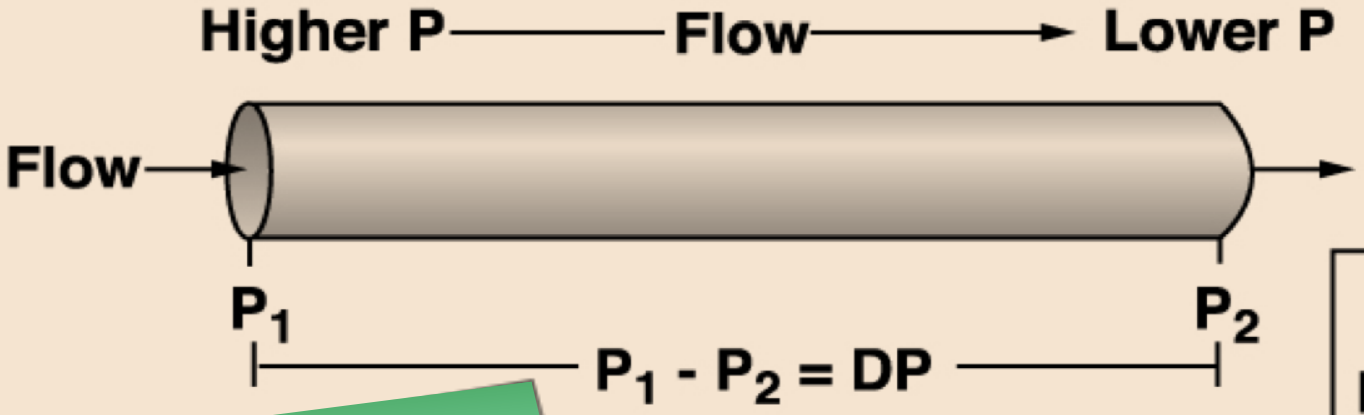
$$\text{Pul. R.} = \frac{15 - 3 \text{ mmHg}}{83.3 \text{ ml/sec } (5 \text{ L/min})}$$

$$\text{Pul. R.} = 0.12 \text{ (PRU's)}$$

Blood Flow and Pressure

P directly proportional to F

- Blood flows down a pressure gradient.
- Absolute value of pressure is not important to flow, but the difference in pressure (DP or gradient) is important to determining flow.

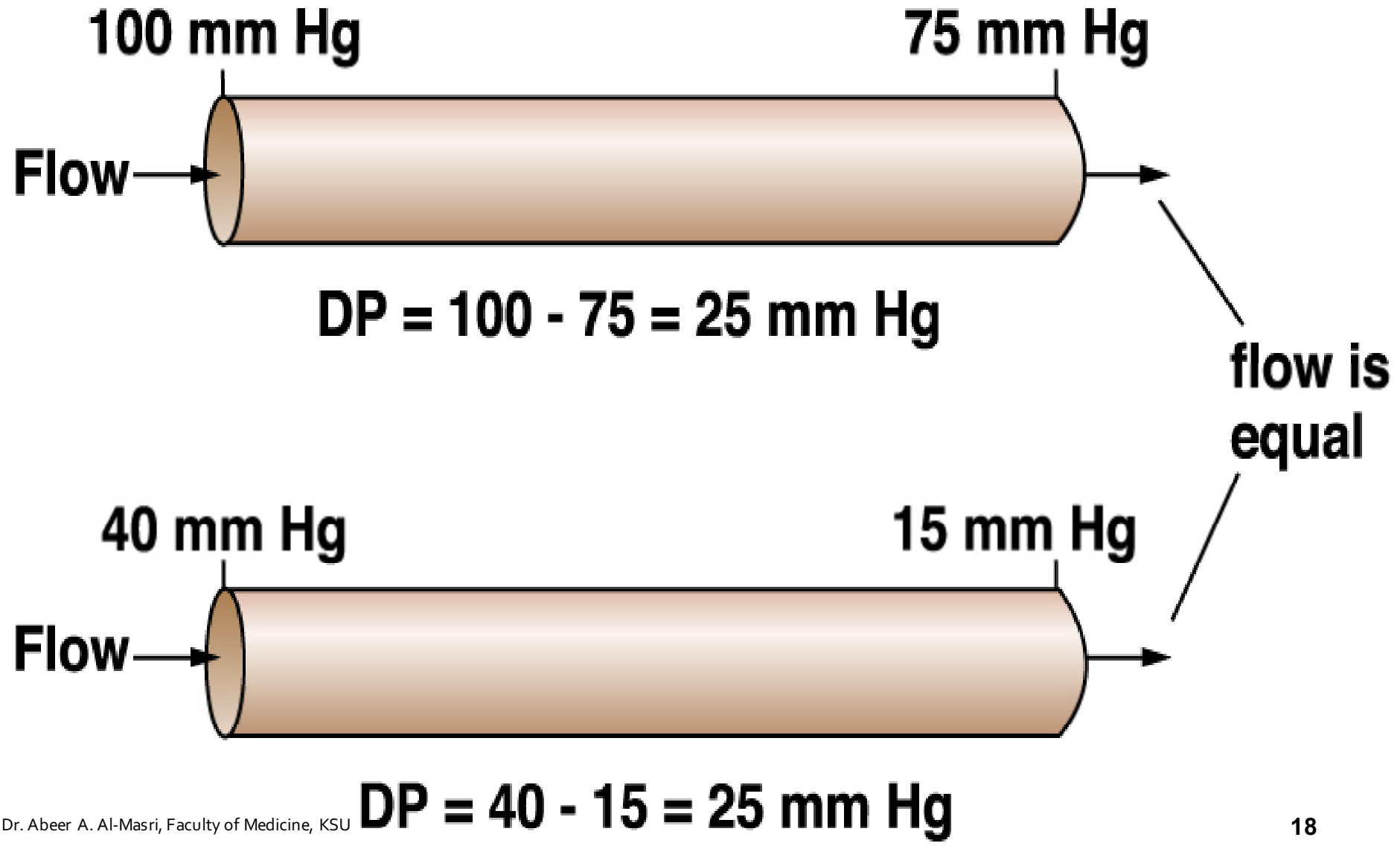


P = Pressure
DP = Pressure gradient

What happens to pressure if we decrease the fluid volume? As in ventricles during systole

Resulting pressure is called the driving pressure in vascular system

How does the flow differ in these two vessels?



Resistance to Flow in the Cardiovascular System

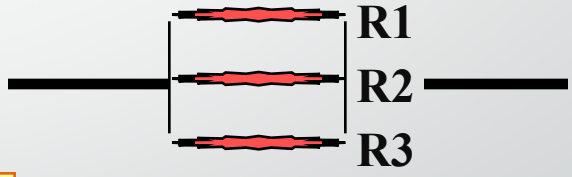
Basic Concepts

Rt = R1 + R2 + R3 .... Series Resistance

1/Rt = 1/R1 + 1/R2 + 1/R3 .... Parallel Resistance

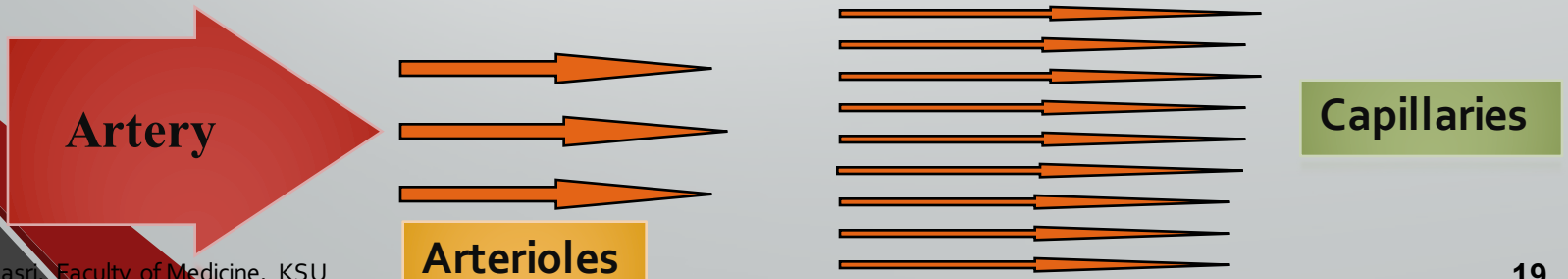
Series

Parallel



What Really Happens in the CVS?

Lower R | Higher R | Lower R



Resistance to Flow in the Cardiovascular System

If: $R_1 = 2$; $R_2 = 4$; $R_3 = 6$ Peripheral Resistance Units (PRU's)

- **Series arrangement gives:**

$$R_T = R_1 + R_2 + R_3$$

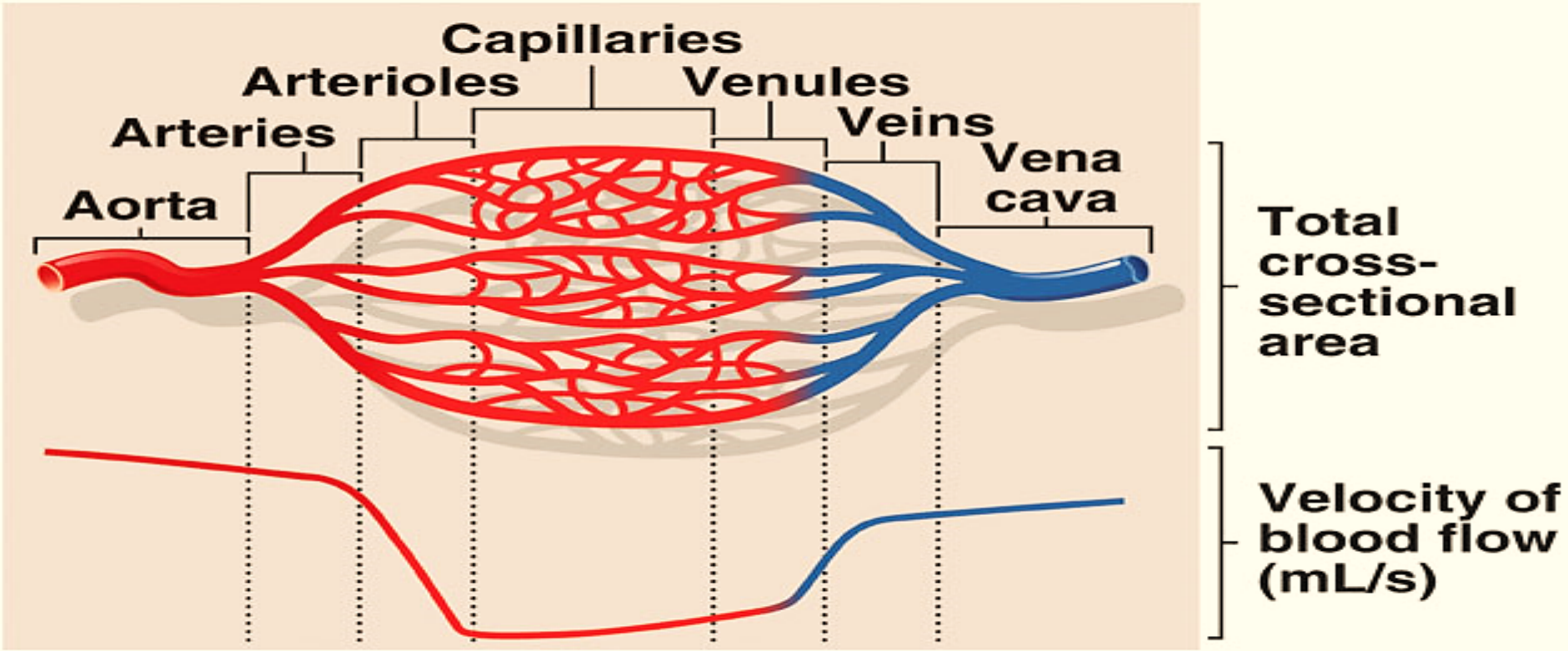
$$R_T = 12 \text{ (PRU's)}$$

- **Parallel arrangement gives:**

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = 1.94 \text{ (PRU's)}$$

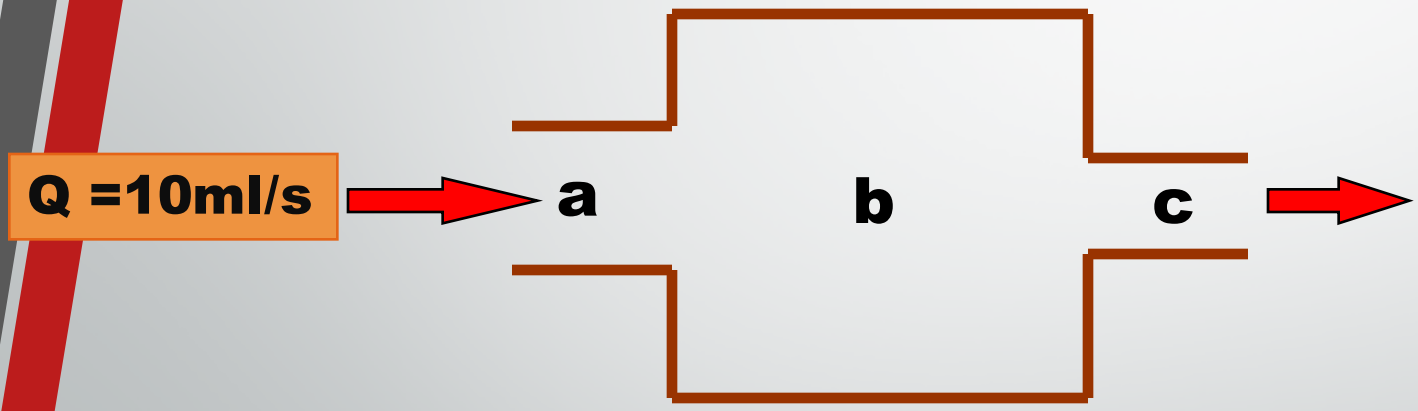
Cross-Sectional Area

As diameter of vessels ↓, the total cross-sectional area ↑ & velocity of blood flow ↓



Velocity and Cross Sectional Area

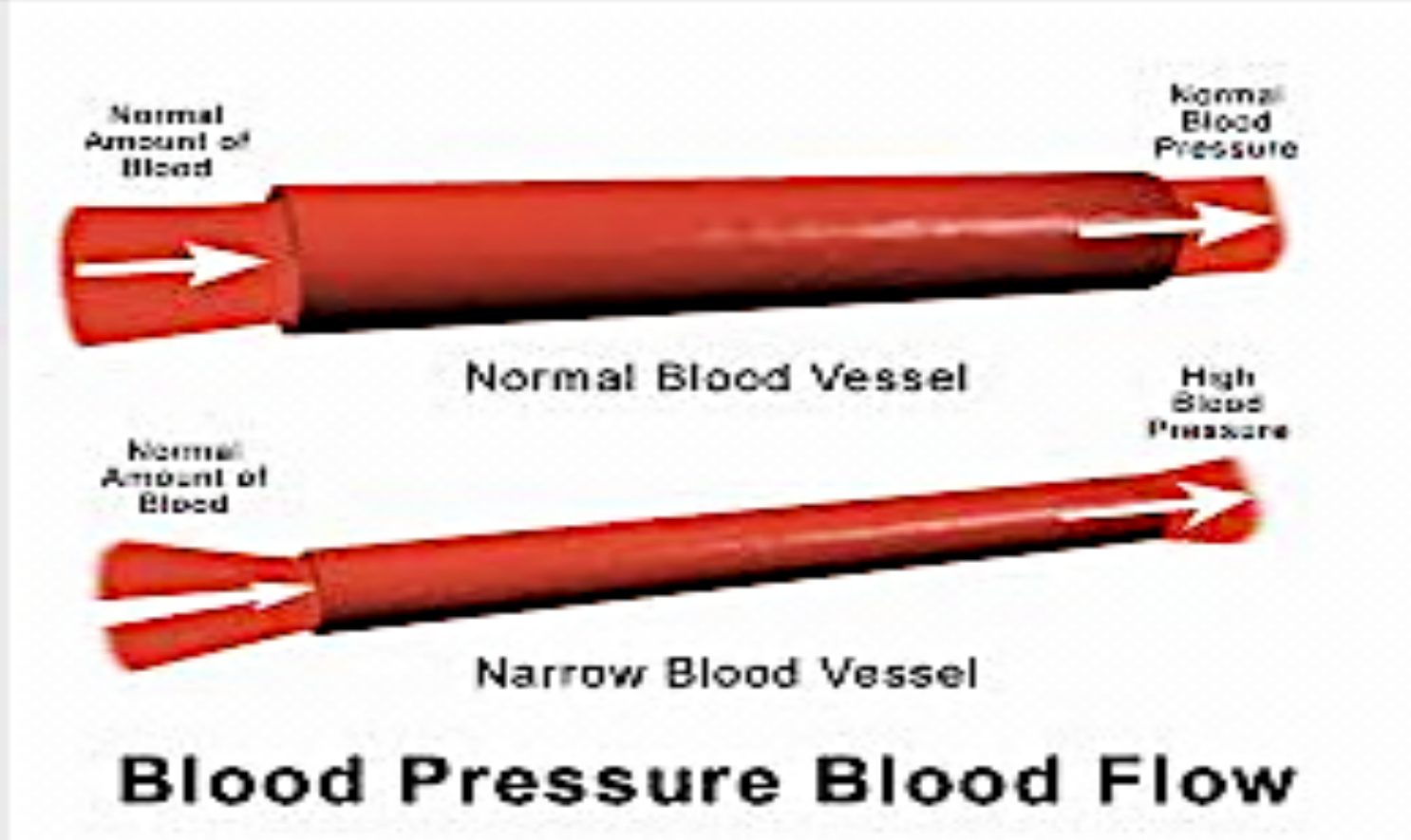
A = 2cm² 10cm² 1cm²



V = 5cm/s 1cm/s 10cm/s

V = Q / A

Effect of Radius on Pressure

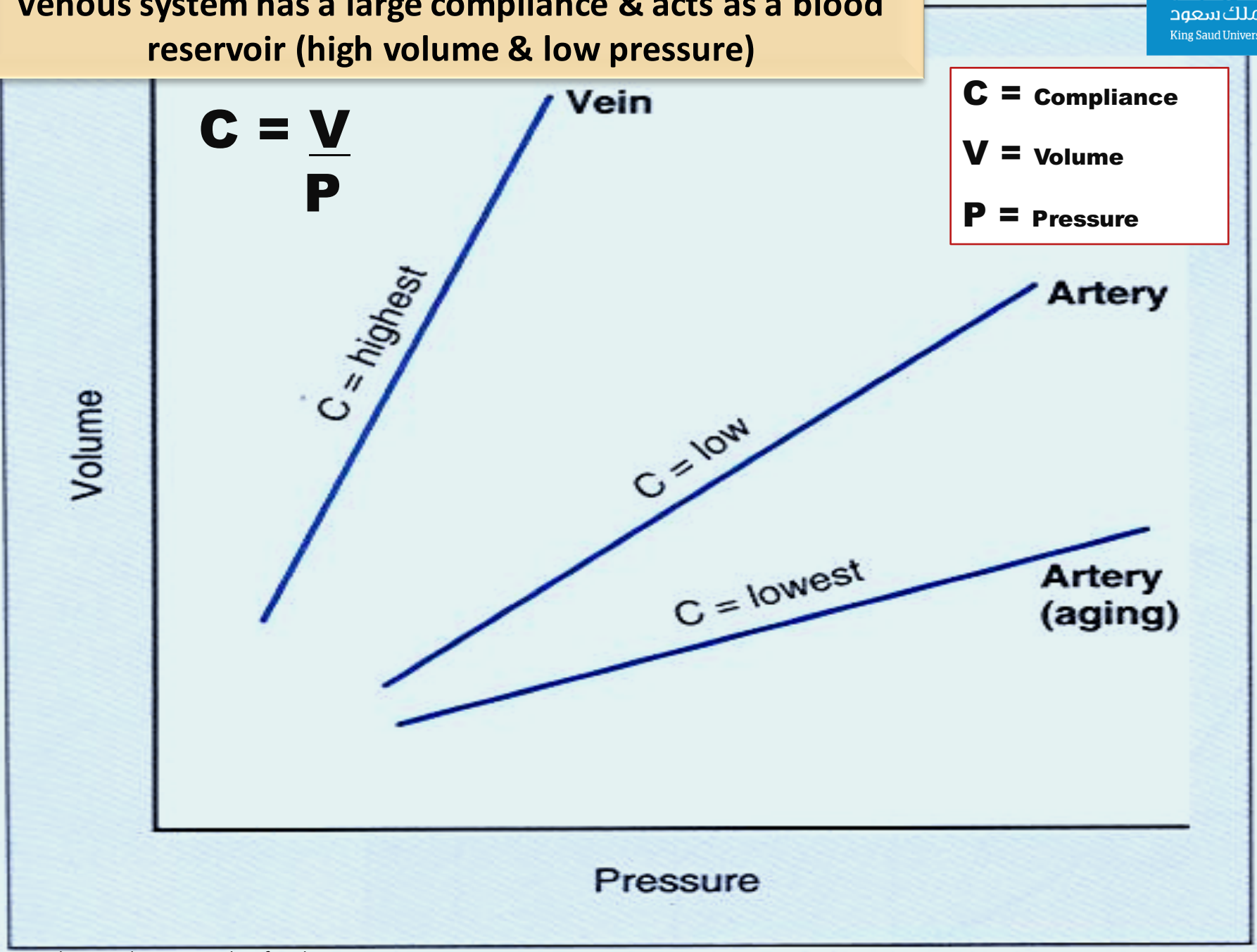


Compliance of Blood Vessels

- **Compliance = distensibility.**
- Compliance is the volume of blood that the vessel can hold at a given pressure.

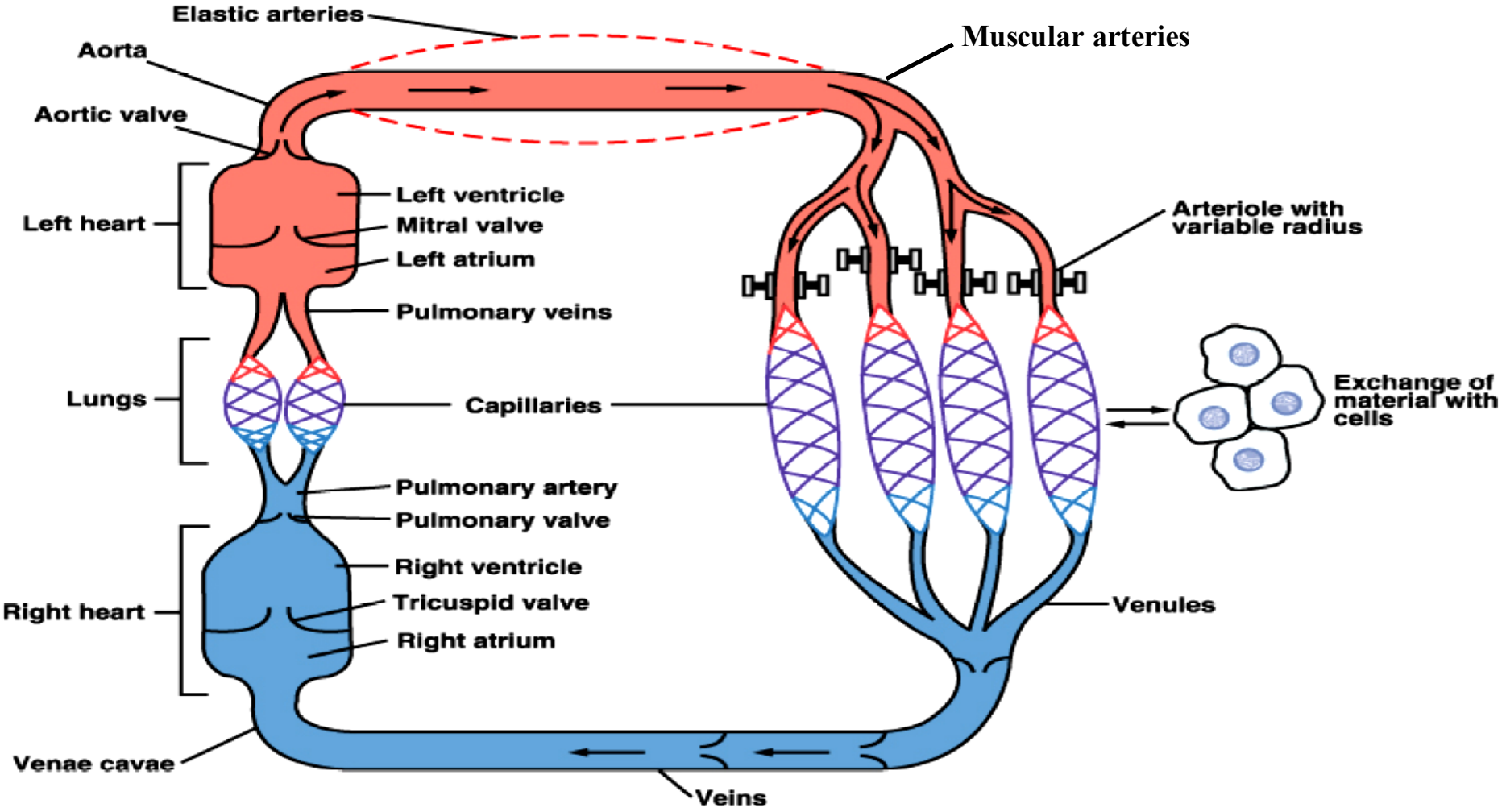
$$C = \frac{V}{P}$$

Venous system has a large compliance & acts as a blood reservoir (high volume & low pressure)



Vascular system possesses different mechanisms for promoting continuous flow of blood to the capillaries:

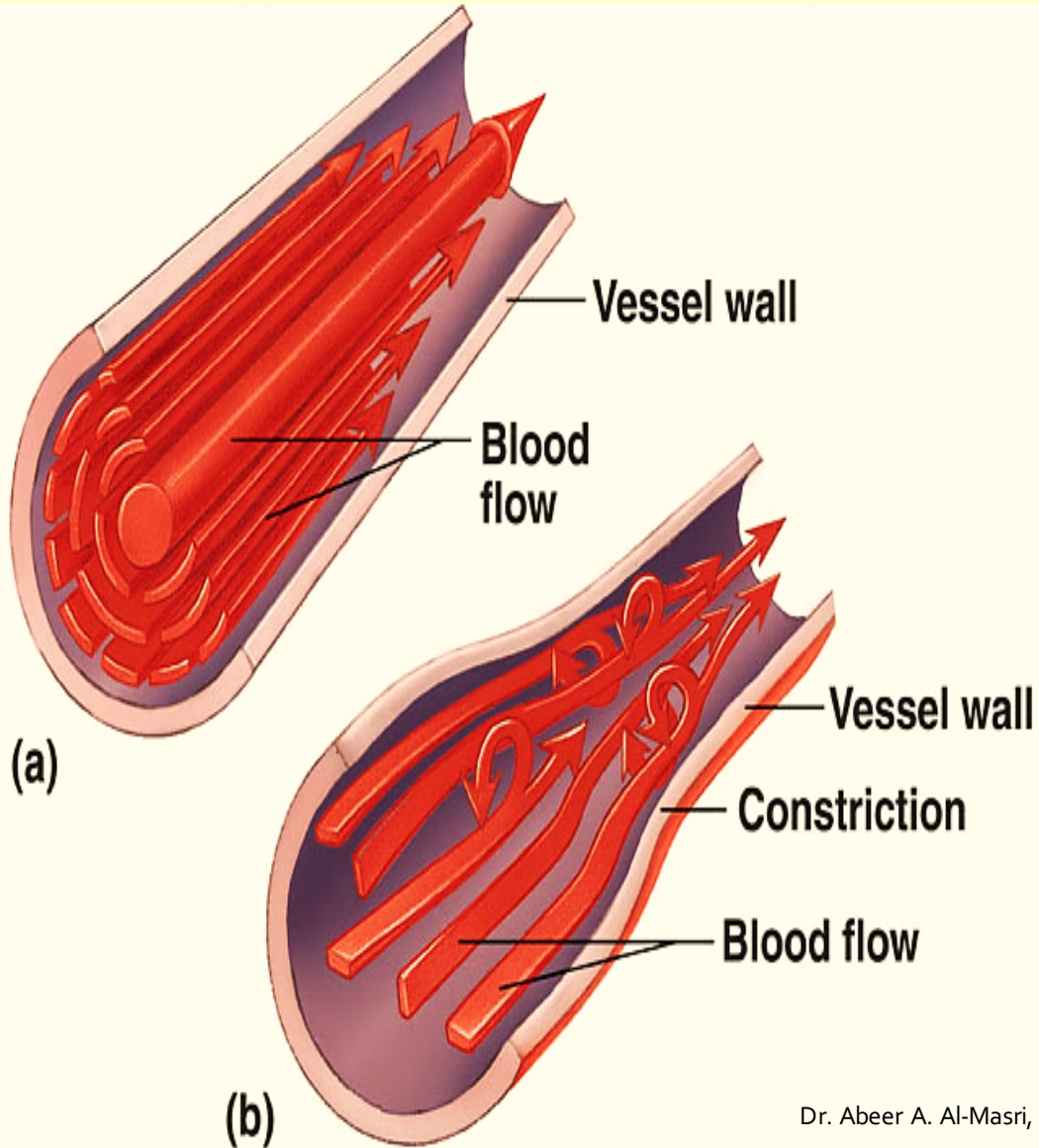
Elastic recoil	Smooth m. regulation of diameter	Sphincters	Valves



Measurement of Arterial Blood Pressure

- **Two methods:** Direct & indirect
- **Sphygmomanometer:**
  - Indirect method, "Estimate of pressure"
  - **Many types:**
    - ✓ Mercury sphygmomanometer
    - ✓ Aneroid equipment
    - ✓ Automatic equipment
  - **Blood Pressure Cuff Size:**
    - ✓ Small – children & small adults
    - ✓ Average
    - ✓ Large – overweight & large adults

Laminar and Turbulent Flow



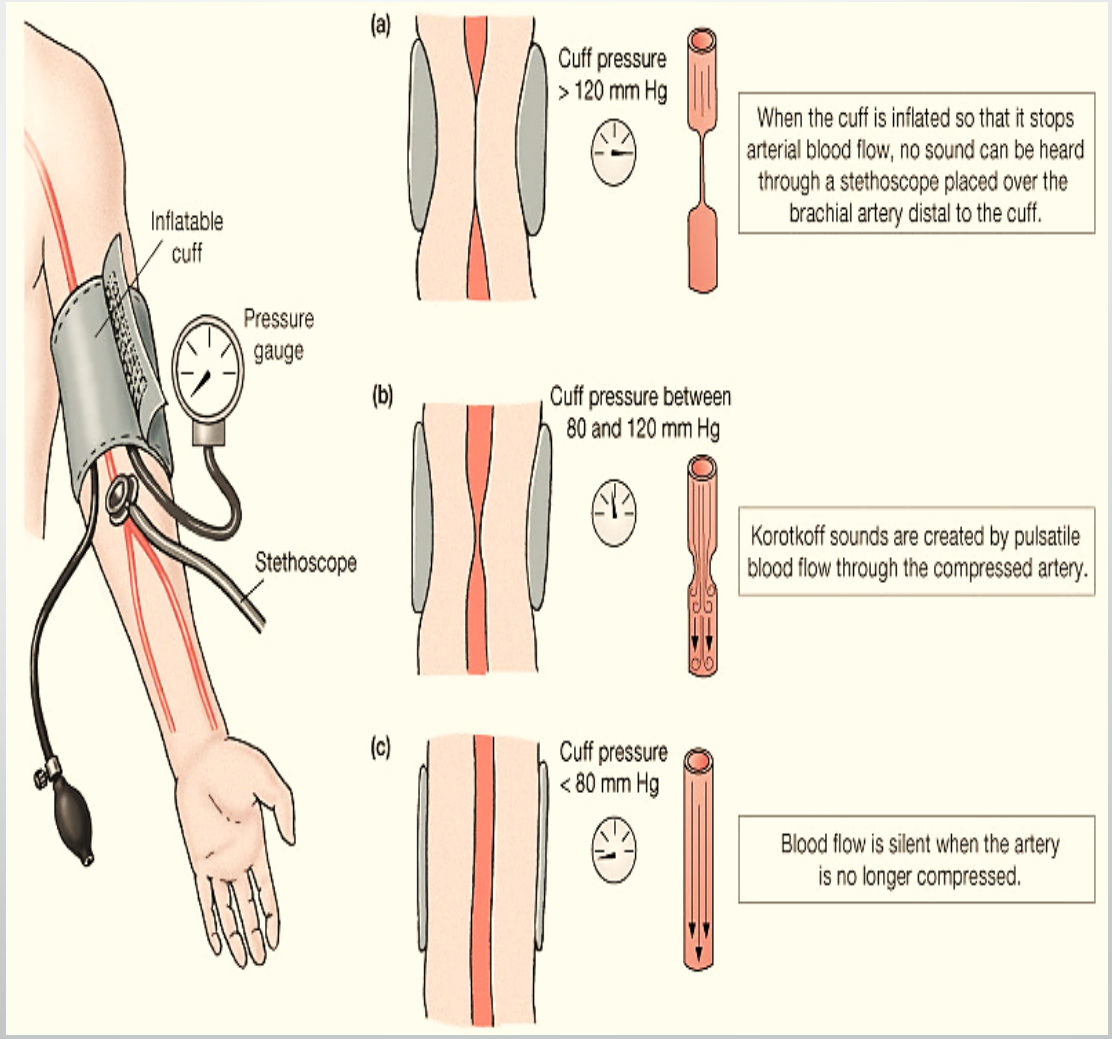
- **Laminar flow**
  - Stream-lined
  - Outermost layer moving slowest & center moving fastest

- **Turbulent flow**
  - Interrupted
  - Fluid passes a constriction, sharp turn, rough surface
  - Rate of flow exceeds critical velocity

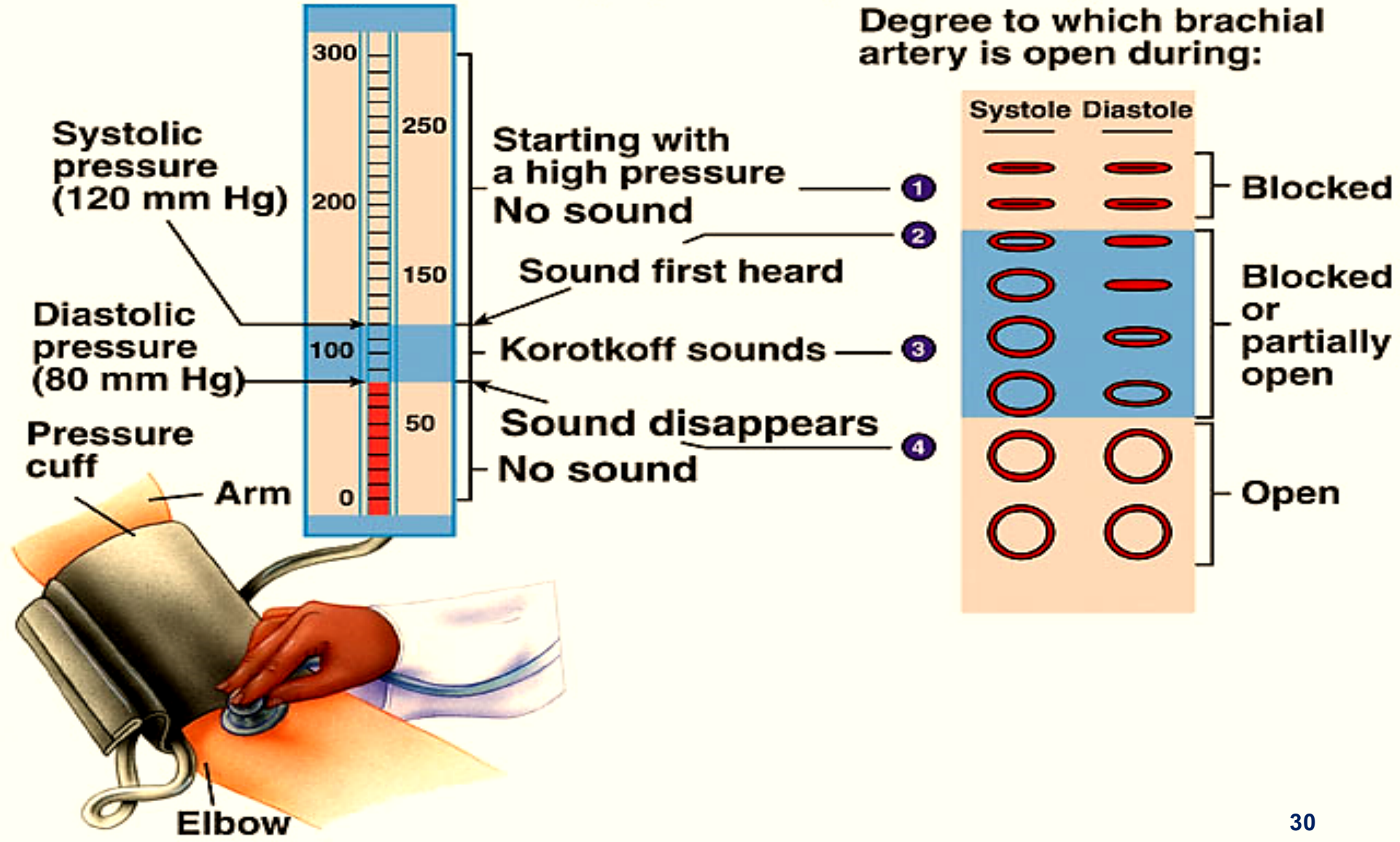
Blood Pressure (BP): Measurements

BP is measured by listening for **Korotkoff sounds** produced by turbulent flow in arteries:

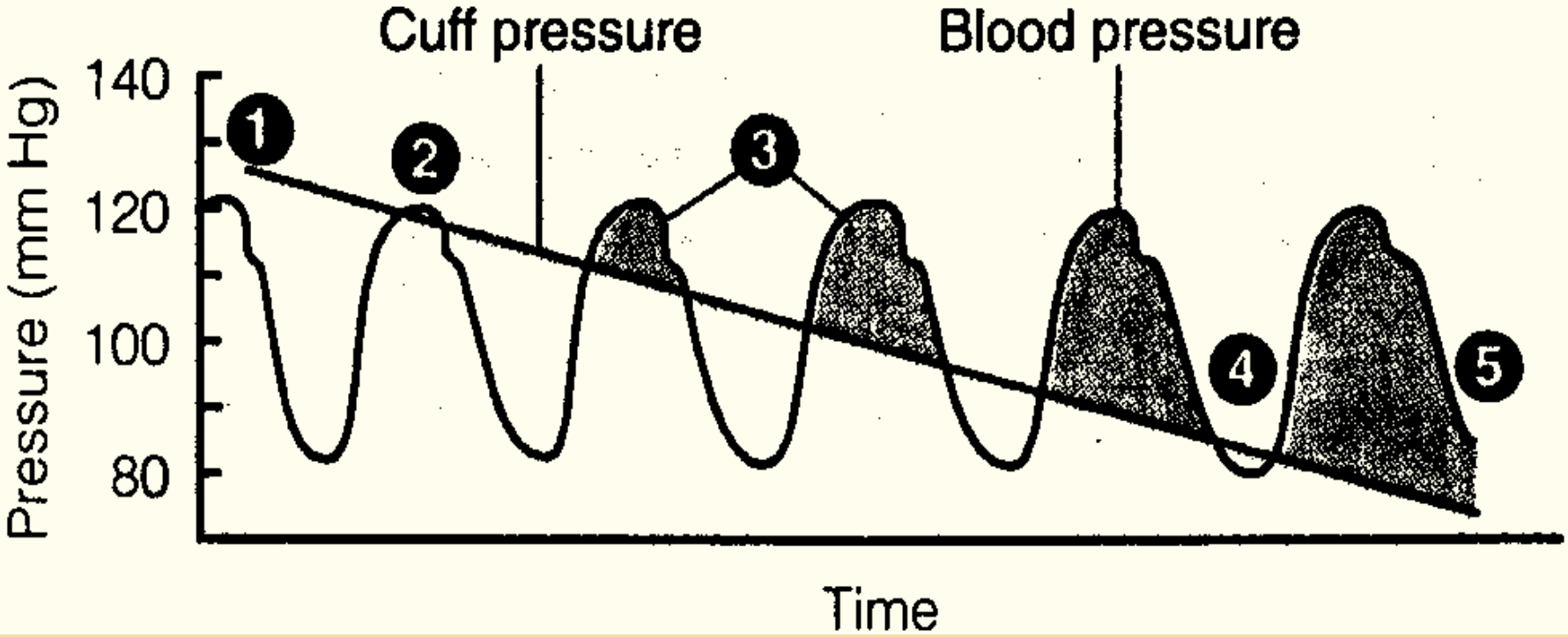
- **Systolic pressure**
  = when 1st sound is heard.
- **Diastolic pressure**
  = when last sound is heard.



Blood Pressure (BP): Measurements



Measuring Blood Pressure
Turbulent Flow



1. Cuff pressure > systolic blood pressure.. No sound
2. The first sound is heard at peak systolic pressure.
3. Sounds are heard while cuff pressure < blood pressure.
4. Sound disappears when cuff pressure < diastolic pressure.


Thank You