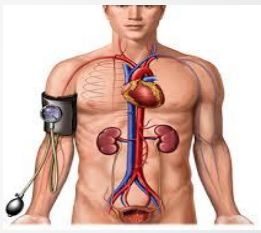
جامعة الملك سعود
King Saud University

Cardiovascular Physiology



Arterial Blood Pressure

Dr. Abeer A. Al-Masri, PhD

A. Professor,

Consultant Cardiovascular Physiologist,

Faculty of Medicine, KSU.

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.

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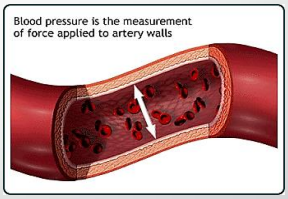
What is meant by Arterial Blood Pressure?

= 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.

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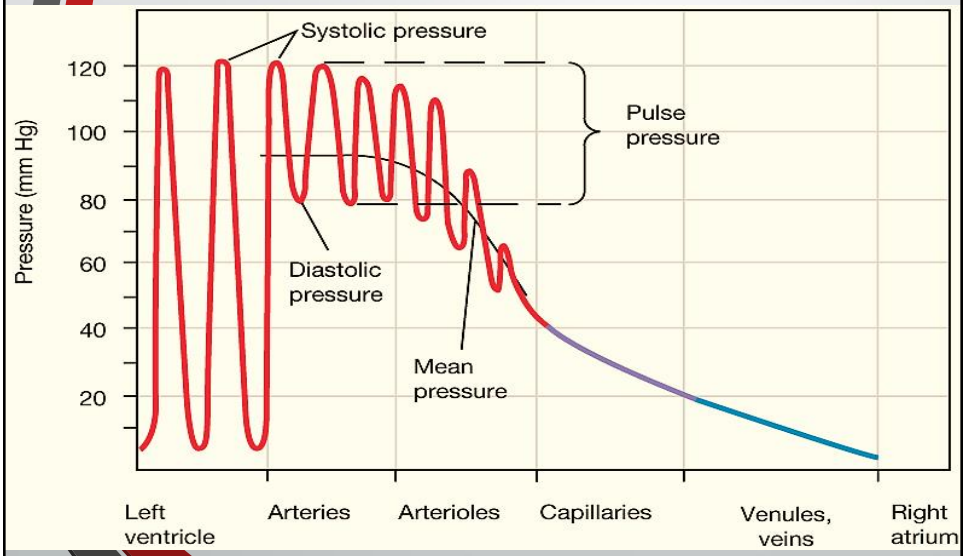
Pressure changes throughout the systemic circulation



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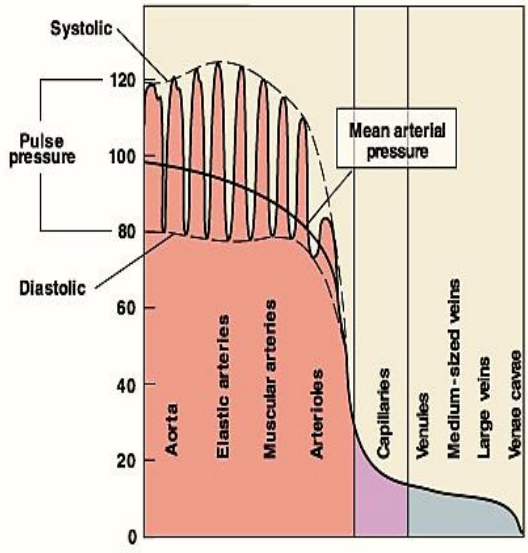
Pressure changes throughout the systemic circulation



- 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.

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

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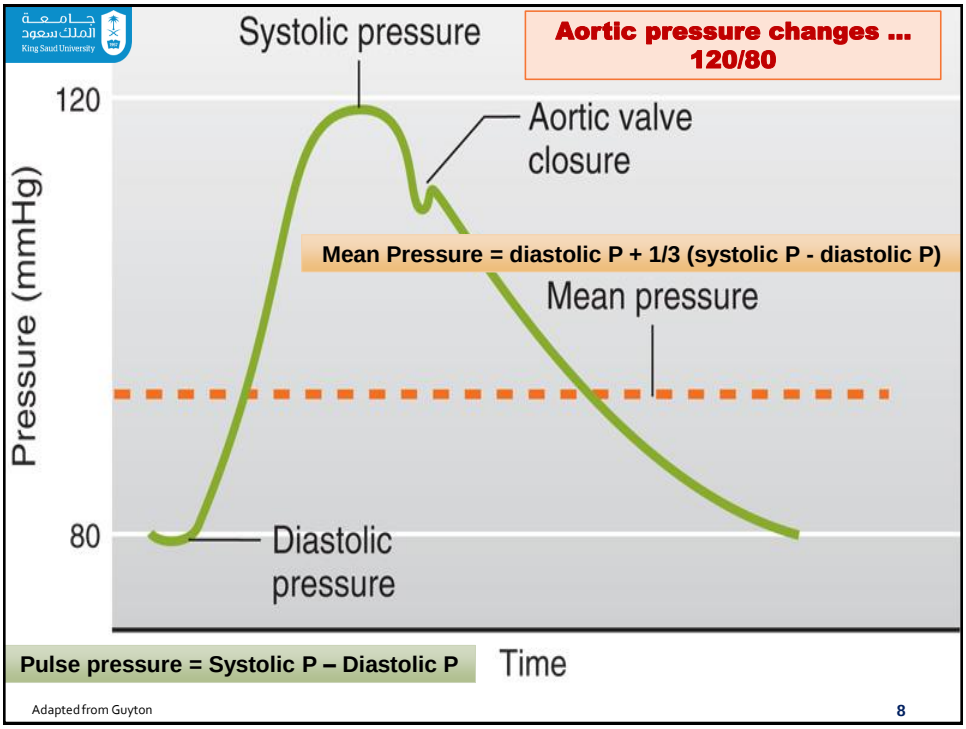

Adapted from Guyton

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Factors Affecting ABP

- **Sex** … M > F … (equal @ menopause)
- **Age** … Elderly > children …(atherosclerosis)
- **Emotions** …↑ … (neural factors)
- **Exercise** …↑ … (↑ venous return)
- **Hormones** …↑ (e.g. Adrenaline, noradrenaline, thyroid H)
- **Gravity** … ↑ Lower limbs > upper limbs
- **Race** … (? dietary factors, or stress)
- **Sleep** … ↓ … (↓ venous return)
- **Pregnancy** …↑ … (↑ metabolism)
- **Temperature** … Heat (vasodilatation); Cold (vasoconstriction)

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Factors Determining ABP

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

Blood Pressure = Cardiac Output X Peripheral Resistance

(MABP)	(CO) Blood Flow	(PR) Peripheral resistance

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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/bt)	≈ 70-75 beats/min (N. 60-100 beats/min)

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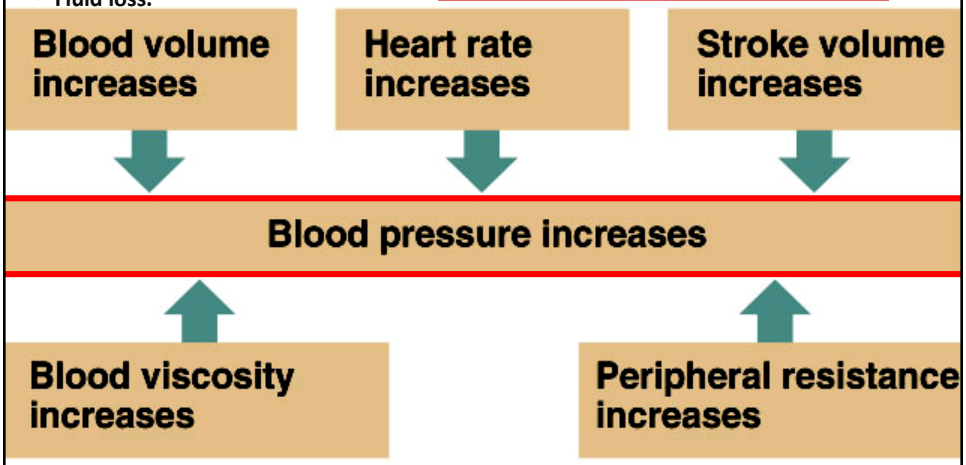
Blood Volume depends on:
- Fluid intake.
- Fluid loss.

CO = SV X HR



Resistance depends on:
- Size & length of blood vessel.
- Thickness (viscosity) of blood.

Adapted from Guyton 12

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.

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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 $R = 8\eta L / \pi r^4$

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Poiseuille's Law

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

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

Difference in Pressure | Viscosity | Length | Radius

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Total Peripheral Resistance

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

Systemic Circulation:

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

$$TPR = \frac{100 - 0\ \text{mmHg}}{83.3\ \text{ml/sec}\ (5\ \text{L/min})}$$

TPR = 1.2 (PRU's)

Pulmonary Circulation:

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

$$\text{Pul. R.} = \frac{15 - 5\ \text{mmHg}}{83.3\ \text{ml/sec}}$$

Pul. R. = 0.12 (PRU's)

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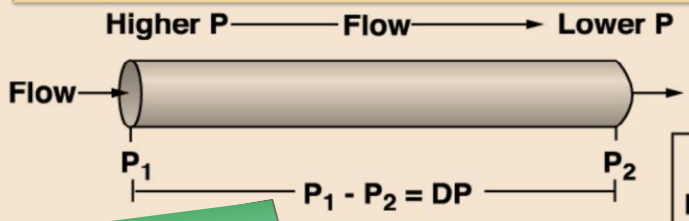
Blood Flow and Pressure

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

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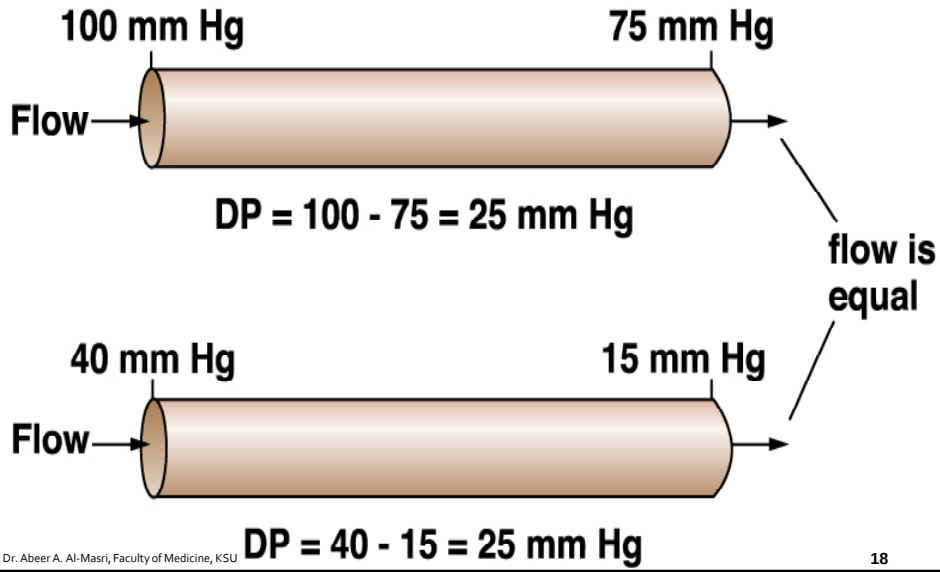
How does the flow differ in these two vessels?



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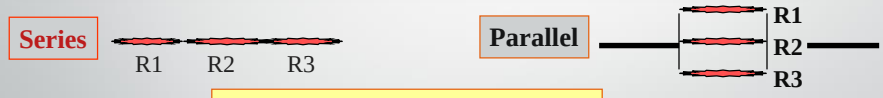
Resistance to Flow in the Cardiovascular System

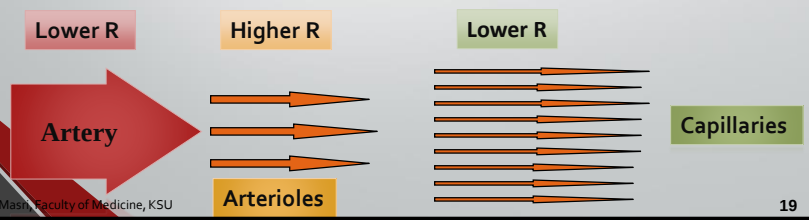
Basic Concepts

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

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



What Really Happens in the CVS?



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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:**

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

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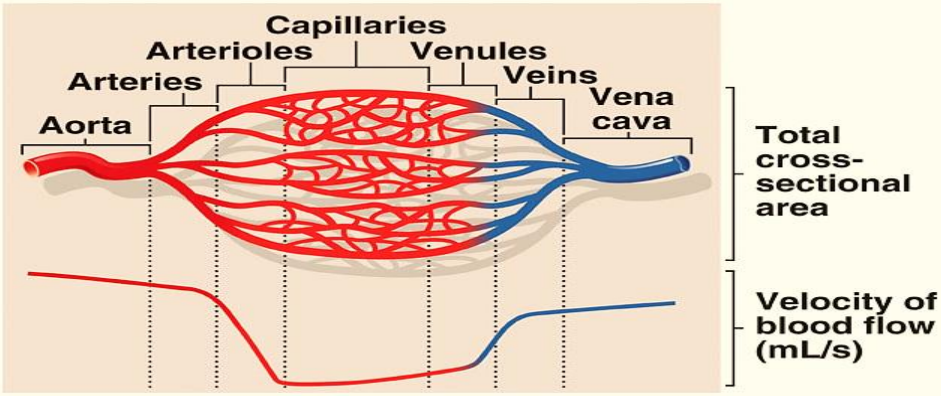
Cross-Sectional Area

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



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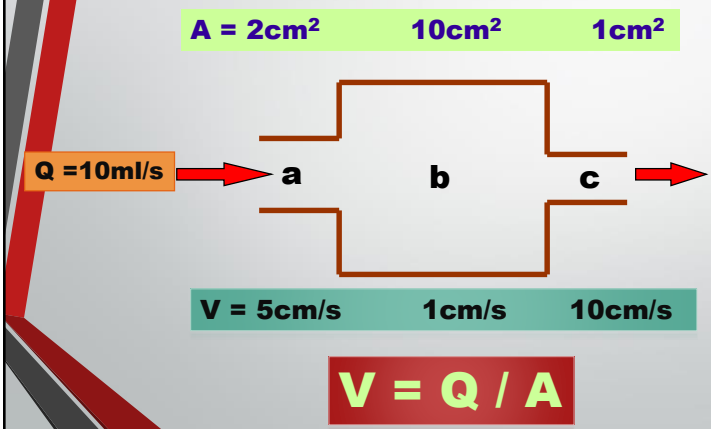
Velocity and Cross Sectional Area



$V = Q / A$

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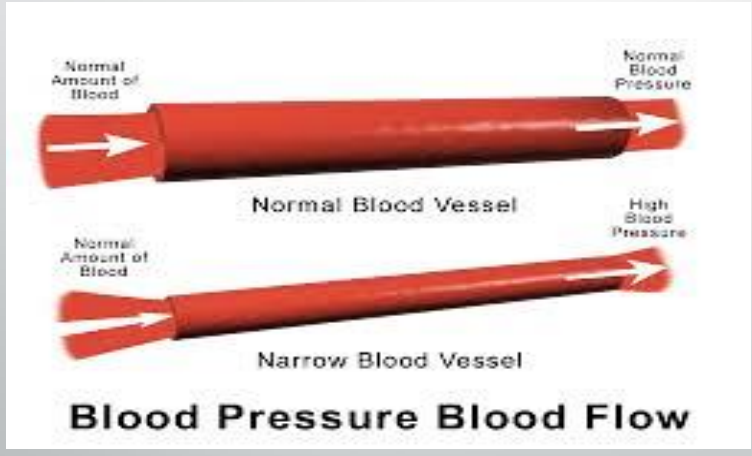
Effect of Radius on Pressure



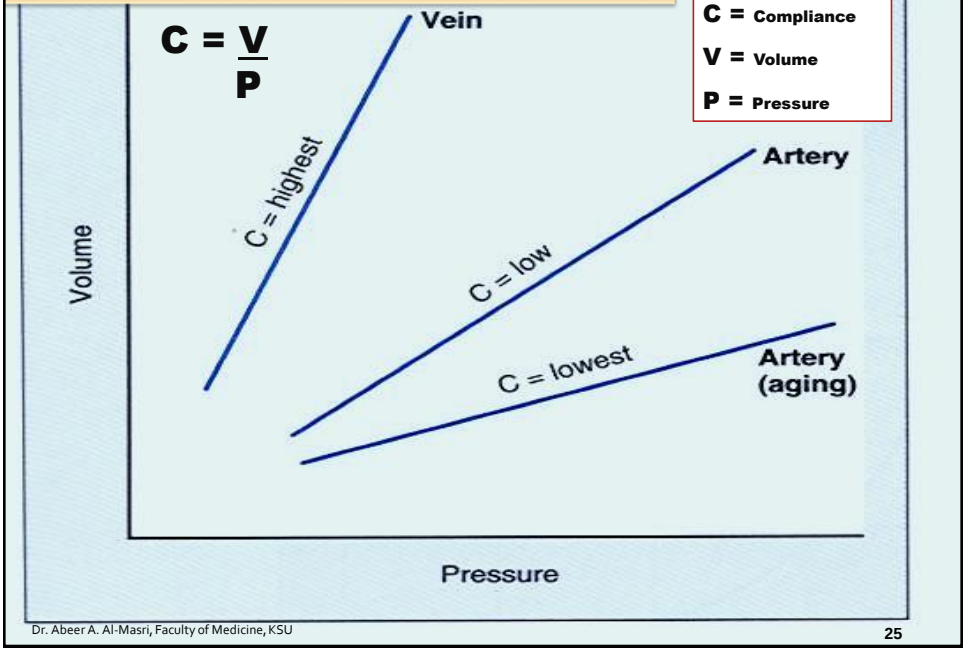
Compliance of Blood Vessels

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

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

- **Vascular compliance**, is the tendency for blood vessel volume to increase as BP increases.

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



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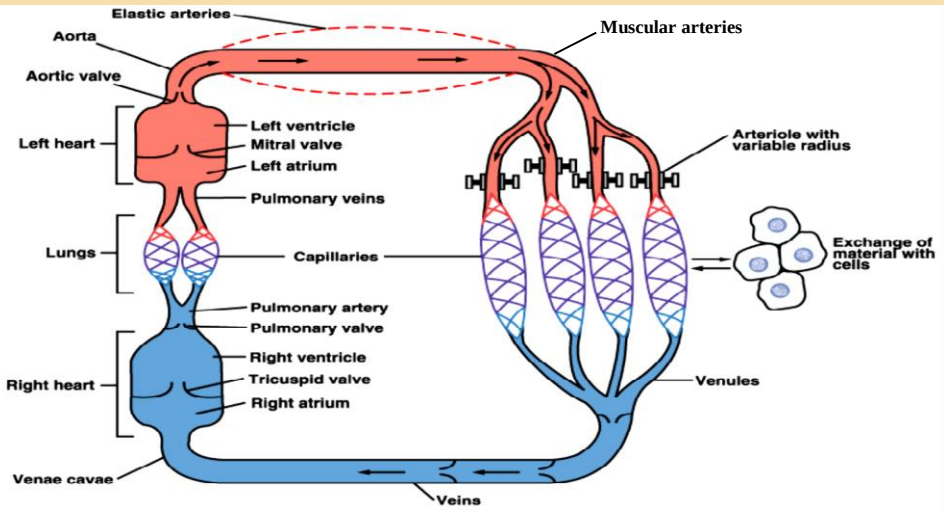
Vascular system possesses different mechanisms for promoting continuous flow of blood to the capillaries:

Elastic recoil | Smooth m. regulation of diameter | Sphincters | Valves



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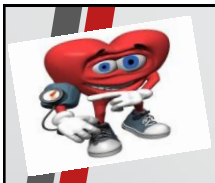
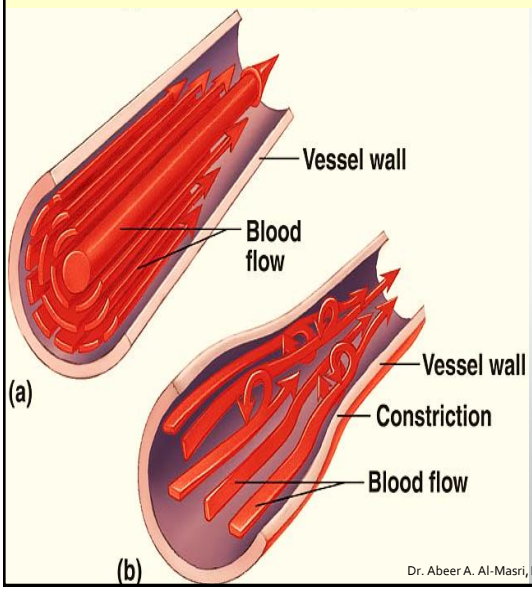


Measurement of Arterial Blood Pressure

- **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

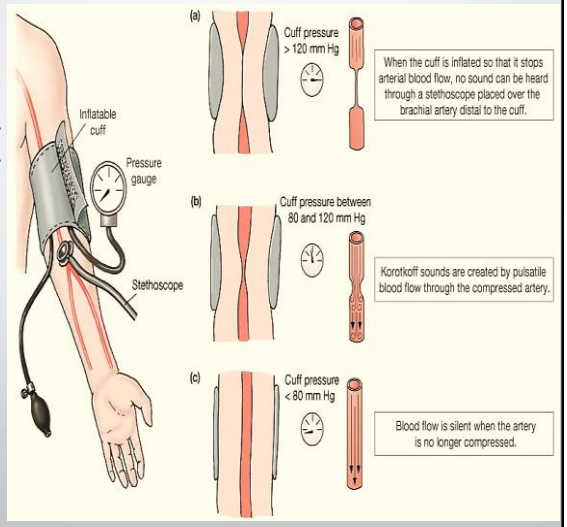


- **Laminar flow**
  - Stream-lined
  - Outermost layer moving slowest & center moving fastest
- **Turbulent flow**
  - Interrupted
  - Fluid passes a constriction, sharp turn, rough surface
  - Rate of flow exceeds critical velocity

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



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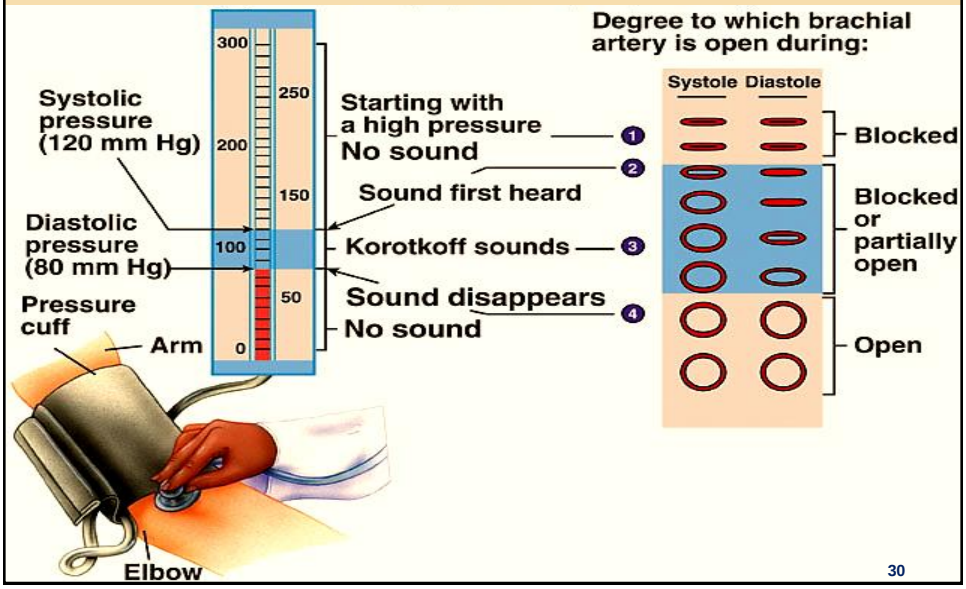
Blood Pressure (BP): Measurements



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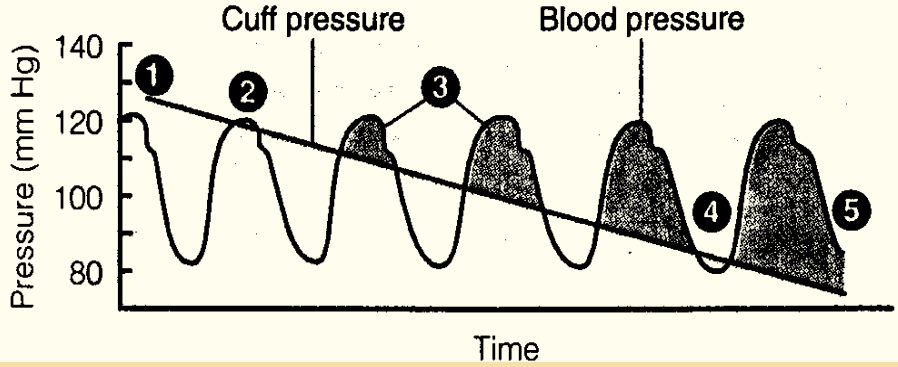
Measuring Blood Pressure Turbulent Flow



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.

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