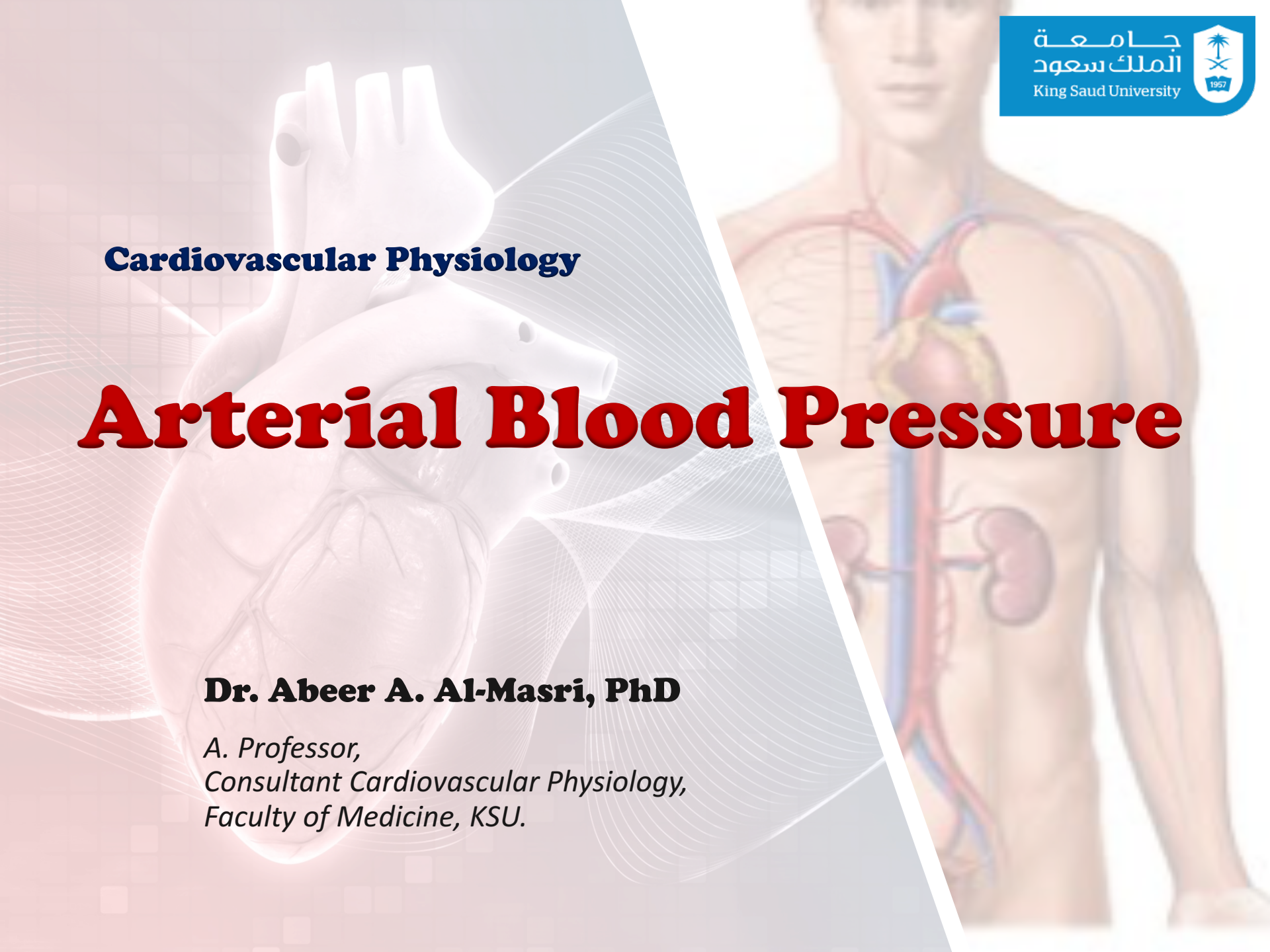

Cardiovascular Physiology

Arterial Blood Pressure

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جامعة الملك سعود
King Saud University

Lecture Outcomes

- Concepts of blood pressure.
- Normal levels of Arterial Blood Pressure.
- Calculating Pulse & Mean Arterial Pressures.
- Factors affecting & determining blood pressure.
- Relationships between blood pressure, Cardiac Output, & Total Peripheral Resistance.

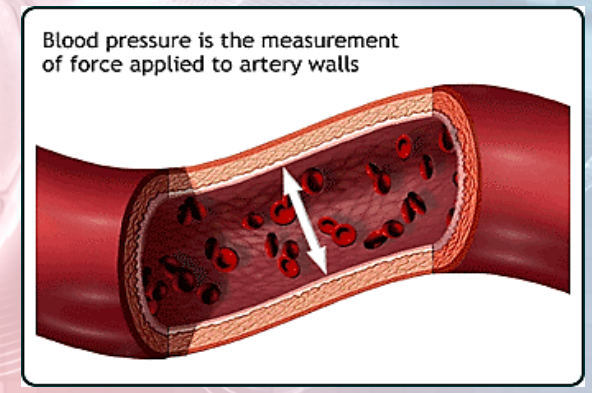
Types of Blood Pressure

Depending on the nature of the blood vessels

- Arterial Blood Pressure.
- Venous Blood Pressure.
- Capillary Blood Pressure.

Definition of Arterial Blood Pressure

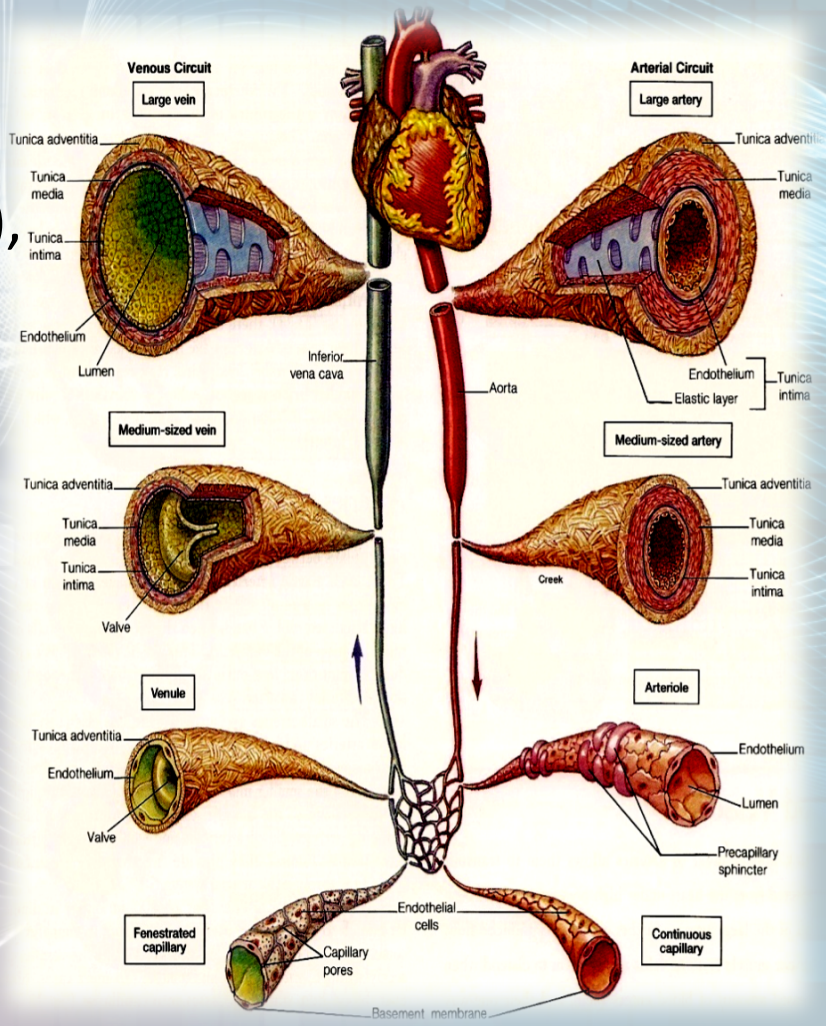
= It is the lateral pressure force applied on the arterial wall exerted by the blood flow.



- **BP is one of the most important vital signs.**
- **It is important to keep normal levels of blood pressure for proper blood flow to the body's organs & tissues.**
- **Measured in (mmHg), & sometimes in (cmH_2O).**
  (1mmHg = 1.36 cmH_2O)

Pressure Changes Throughout Systemic Circulation

- **Blood flows down a pressure gradient.**
- Highest at the heart (driving Pressure), & decreases over distance.
- Decreases 90% from aorta to vena cava.
- **Greatest drop** in pressure occurs in **arterioles** which regulate blood flow through tissues.
- No large fluctuations in capillaries & veins.
- BP averages 100 mm Hg in aorta & drops to 2 mm Hg in Right Atrium.



Normal Levels of Arterial Blood Pressure

In normal adult ≈ 120/80 mmHg

- **Top number (Systolic Pressure):**
  = Arterial Pressure recorded during maximum contraction of the heart.
- **Bottom number (Diastolic):**
  = Arterial Pressure recorded during maximum relaxation of the heart.

Both numbers are important to determine the state of the heart health.

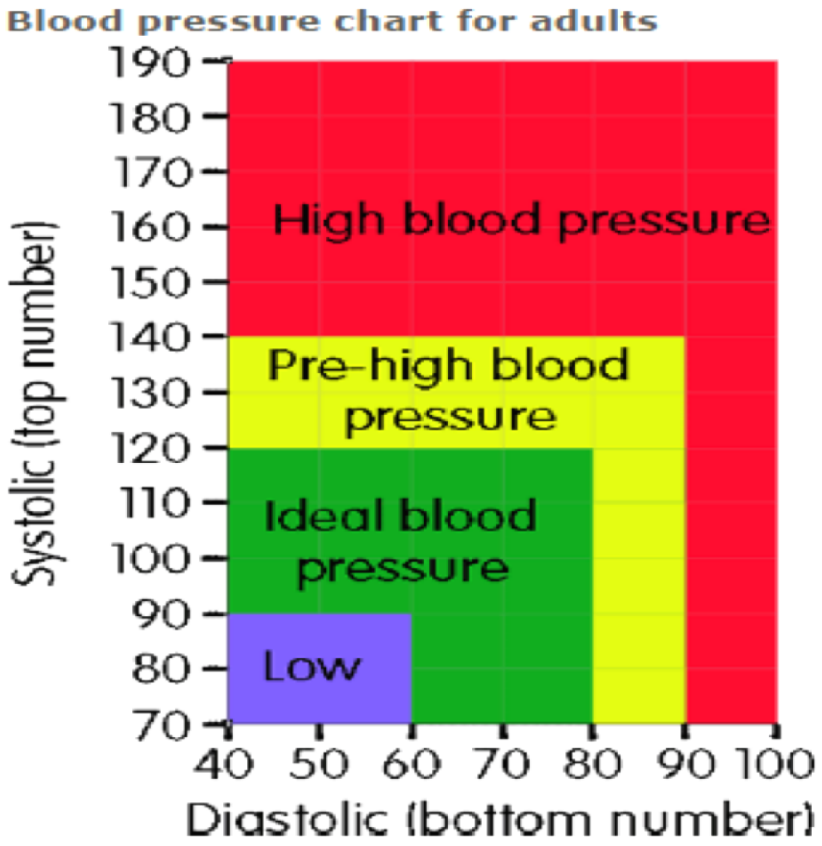
Range & Variations in Arterial Blood Pressure Levels

Arterial pressure is Pulsatile.

- **Aortic Pressure:**
  - 120 mmHg systolic.
  - 80 mmHg diastolic.
- **Normal Arterial Pressure:**
  - 90 – 120 mmHg systolic.
  - 60 – 80 mmHg diastolic.

Greater numbers than the ideal range indicate that the heart is working too hard to pump blood to the rest of the body.

Blood Pressure Chart



Using this blood pressure chart: To work out what your blood pressure readings mean, just find your top number (systolic) on the left side of the blood pressure chart and read across, and your bottom number (diastolic) on the bottom of the blood pressure chart. Where the two meet is your blood pressure.

National Heart, Lung, and Blood Institute

JNC 7 Blood Pressure Classification In Adults Aged ≥ 18 Years			
Category	**Systolic**		**Diastolic**
Normal	<120	and	<80
Prehypertension	120-139	or	80-89
Hypertension, Stage 1	140-159	or	90-99
Hypertension, Stage 2	≥160	or	≥100

National Heart, Lung, and Blood Institute. *JNC 7 Express. The Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation and Treatment of High Blood Pressure. 2003.*

Adult BP range: 90 – 120 / 60 – 80 mmHg

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American Heart Association

Blood Pressure Categories under new guidelines.

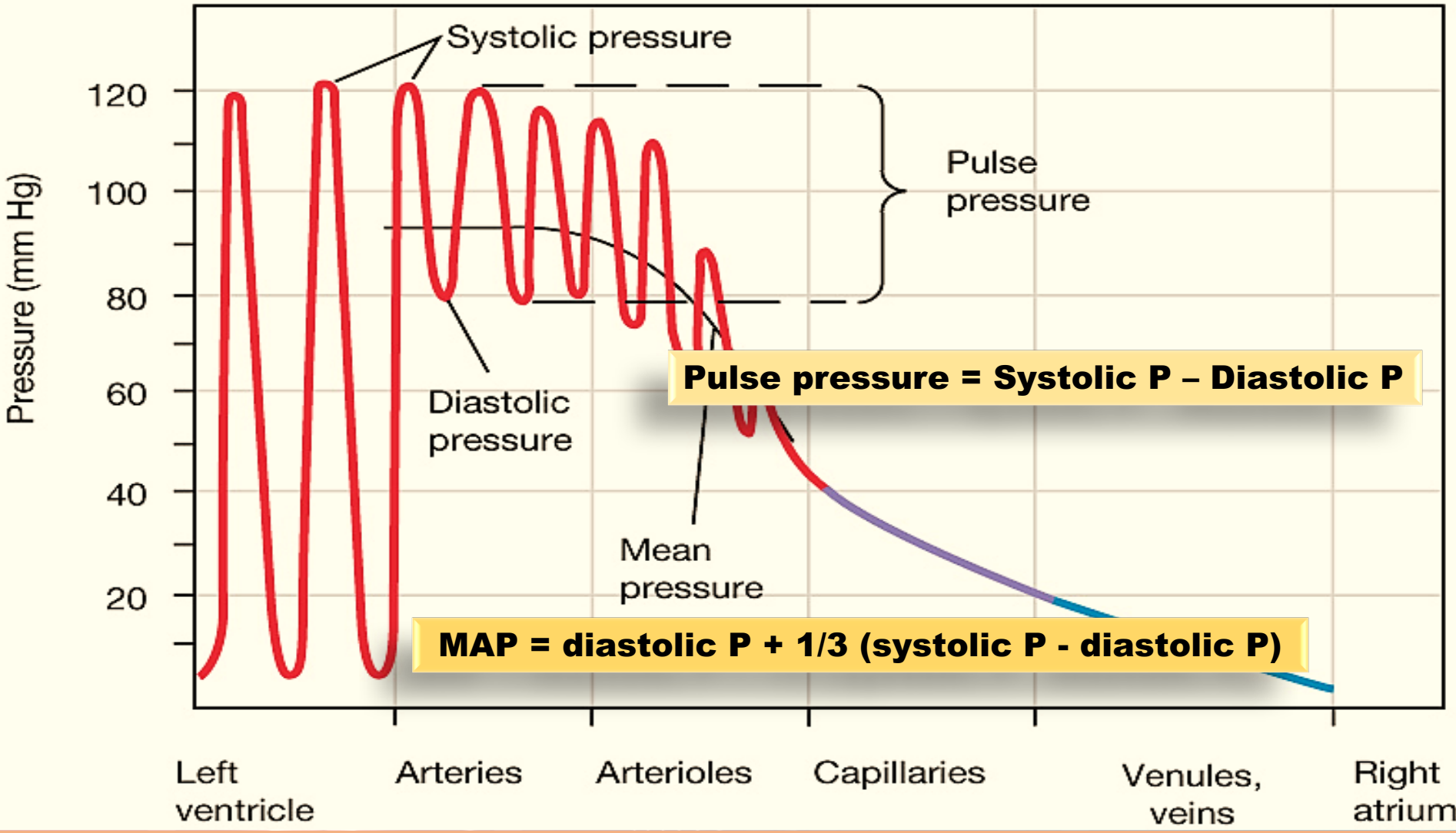
Nov 2017

Blood Pressure Categories

American Heart Association | American Stroke Association

BLOOD PRESSURE CATEGORY	SYSTOLIC mm Hg (upper number)		DIASTOLIC mm Hg (lower number)
NORMAL	LESS THAN 120	and	LESS THAN 80
ELEVATED	120 – 129	and	LESS THAN 80
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 1	130 – 139	or	80 – 89
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 2	140 OR HIGHER	or	90 OR HIGHER
HYPERTENSIVE CRISIS (consult your doctor immediately)	HIGHER THAN 180	and/or	HIGHER THAN 120

Pulse and Mean Arterial Pressures



Arterial pressure is pulsatile, so a single value is used to represent the overall driving pressure. This is called the Mean Arterial Pressure.

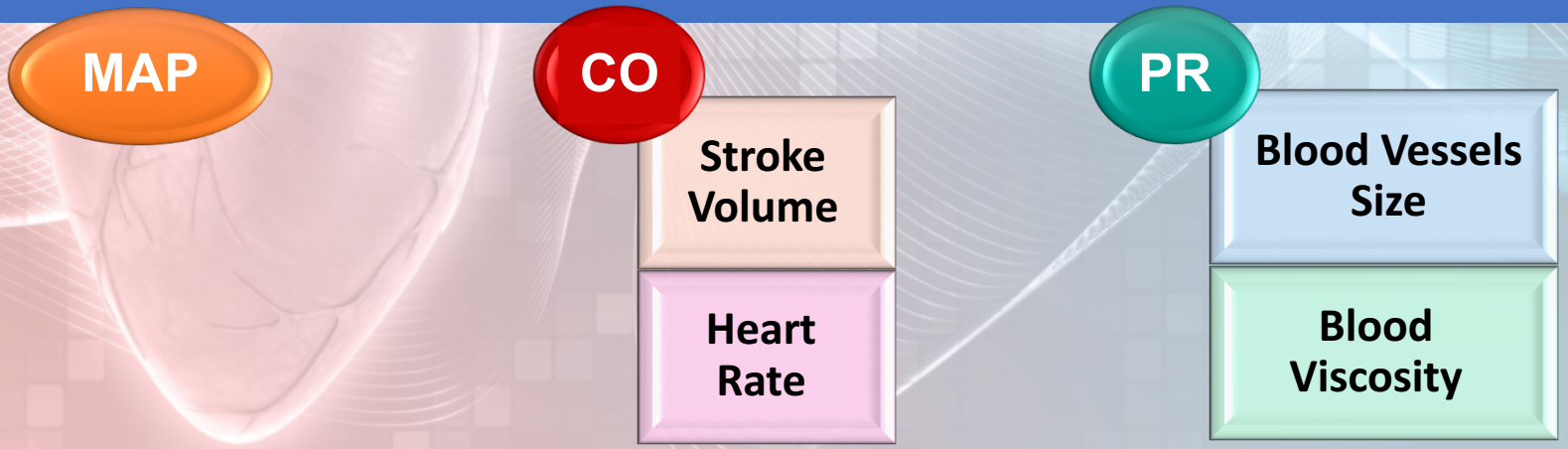
Factors Affecting Arterial Blood Pressure

- **Sex:** Male > Female … (equal @ menopause)
- **Age:** BP rises with age, elderly > children …(due to atherosclerosis, diabetes, …
- **Body mass index:** BP rises with body size.
- **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 Arterial Blood Pressure

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

Blood Pressure = Cardiac Output X Peripheral Resistance



CO = SV X HR

Heart Rate (↑)

Stroke Volume (↑)

CO

Resistance depends on:

- Size & length of blood vessel.
- Thickness (viscosity) of blood.

Peripheral Resistance (↑)

PR

Blood Pressure Increases **MAP**

Blood Volume (↑)

Blood Volume depends on:

- Fluid intake &
- Fluid loss

Blood Flow: Affecting factors

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

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

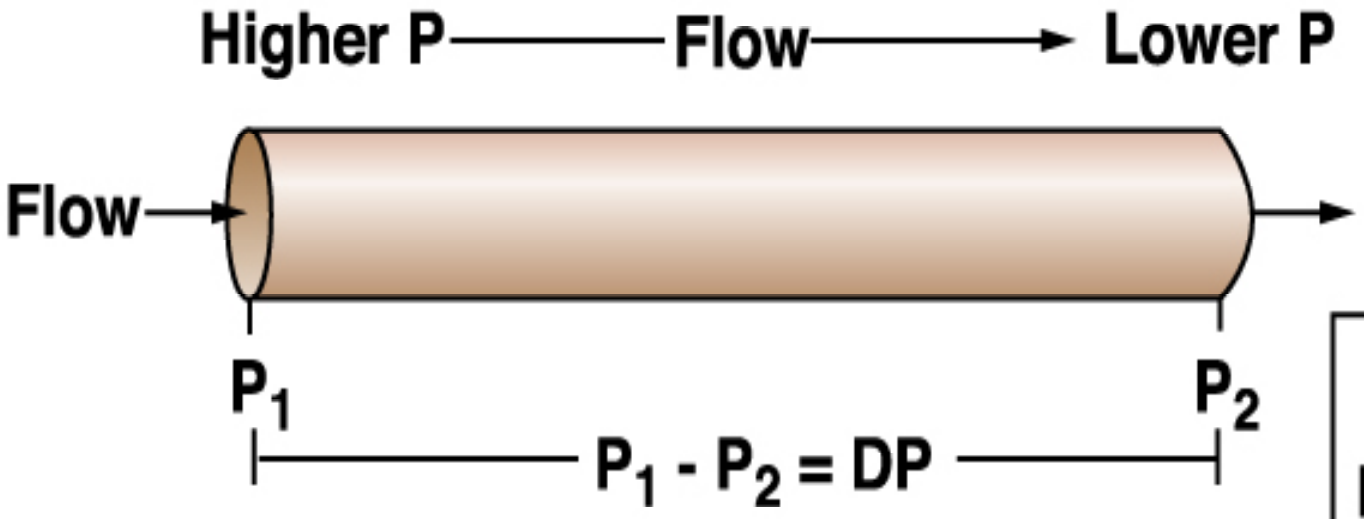
- **Directly** proportional to **pressure differences**.
- **Inversely** proportional to **resistance**.

Blood Flow and Pressure

Pressure difference is directly proportional to the Flow

Resulting pressure is called the driving pressure in vascular system

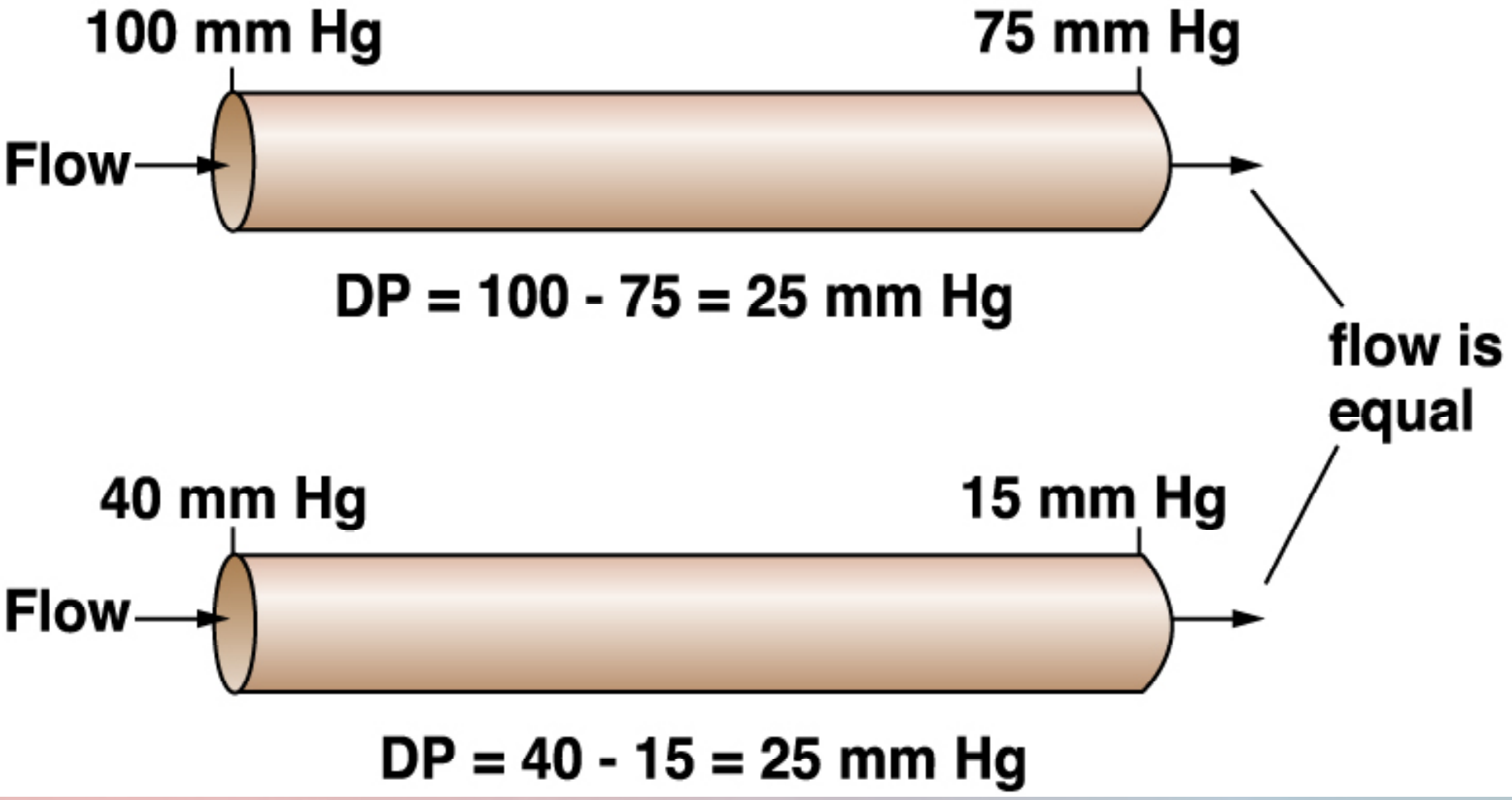
- Blood flows down a pressure gradient.
- Absolute value of pressure is not important to flow, but the difference in pressure (DP or gradient) is important to determining flow.



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

P = Pressure
DP = Pressure gradient

How does the flow differ in these two vessels?



Resistance (R) and Flow:

Affecting Factors

Resistance = tendency of vascular system to oppose flow.

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

Resistance is influenced by:

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

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

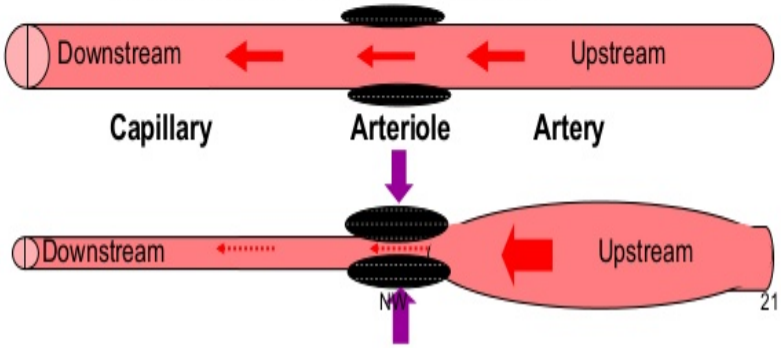
Poiseuille's Law $R = 8\eta L / \pi r^4$

Effect of Radius (r) on flow & Pressure

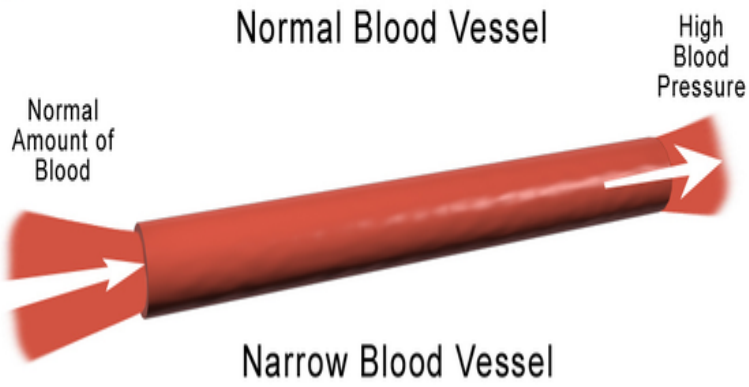
Directly proportional to flow.

Vascular tone - effects

- Increased tone in a segment of blood vessel
- e.g. **increased arteriolar tone**
- → decreased radius of arteriole
- → greatly increased resistance to blood flow
- → greatly decreased blood flow across the arteriole
- → the effects on blood volume
  - Increased upstream (in the artery)
  - Decreased downstream(in the capillaries)



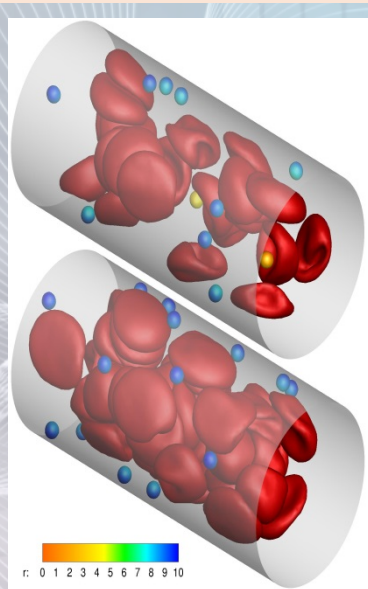
Inversely proportional to pressure.



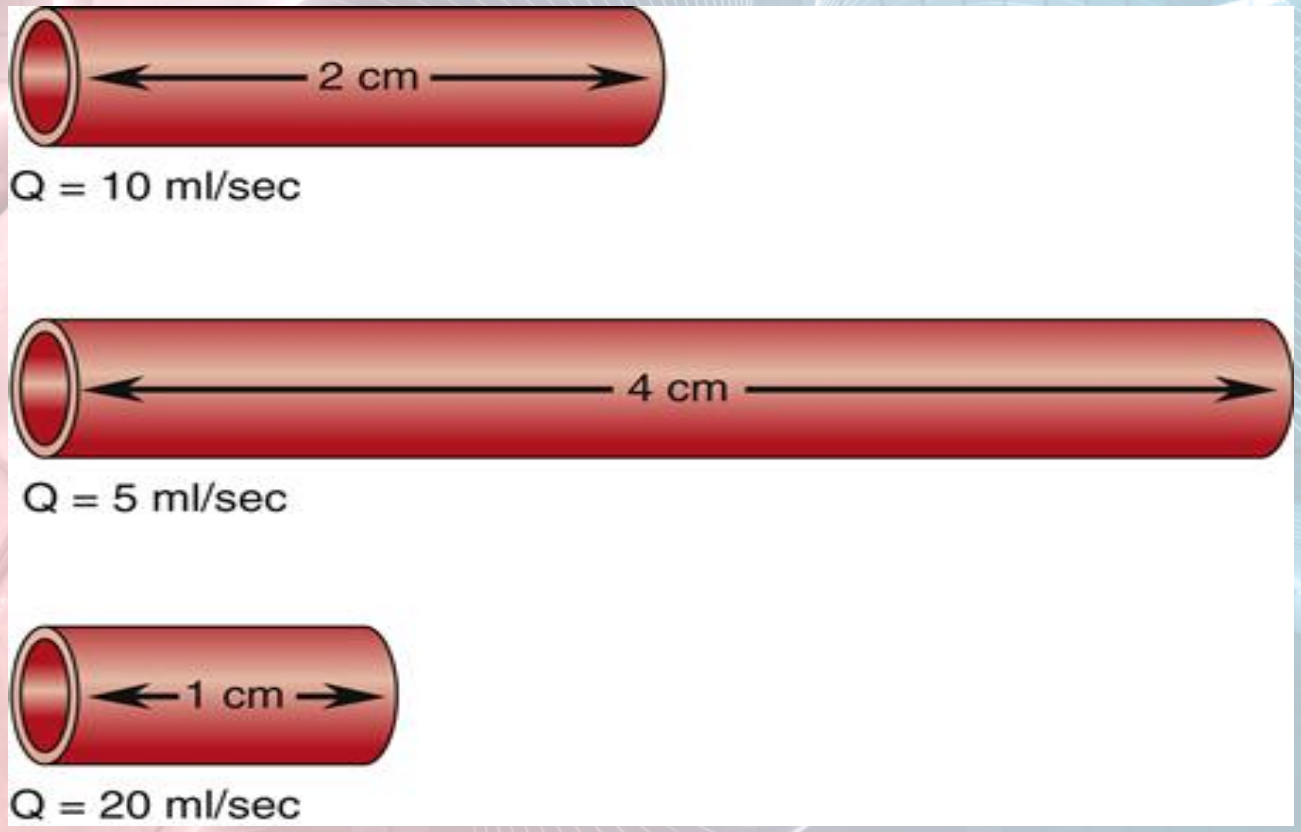
Blood Pressure Blood Flow

Effect of Viscosity (η) on flow

- Blood viscosity is the thickness & stickiness of the blood.
- It is an important factor that determines the resistance of blood to flow.
- Human blood is five times more viscous than distilled water.
- Viscosity of the whole blood is mainly due to cells, & that of plasma is due to plasma proteins.
- **Viscosity is inversely proportional to the flow.**



Effect of Length (L) on Flow



Length is inversely proportional to the flow.

N.B. In a normal human, length of the vascular system is fixed.

Flow and Poiseuille's Law

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

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

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

Difference in Pressure

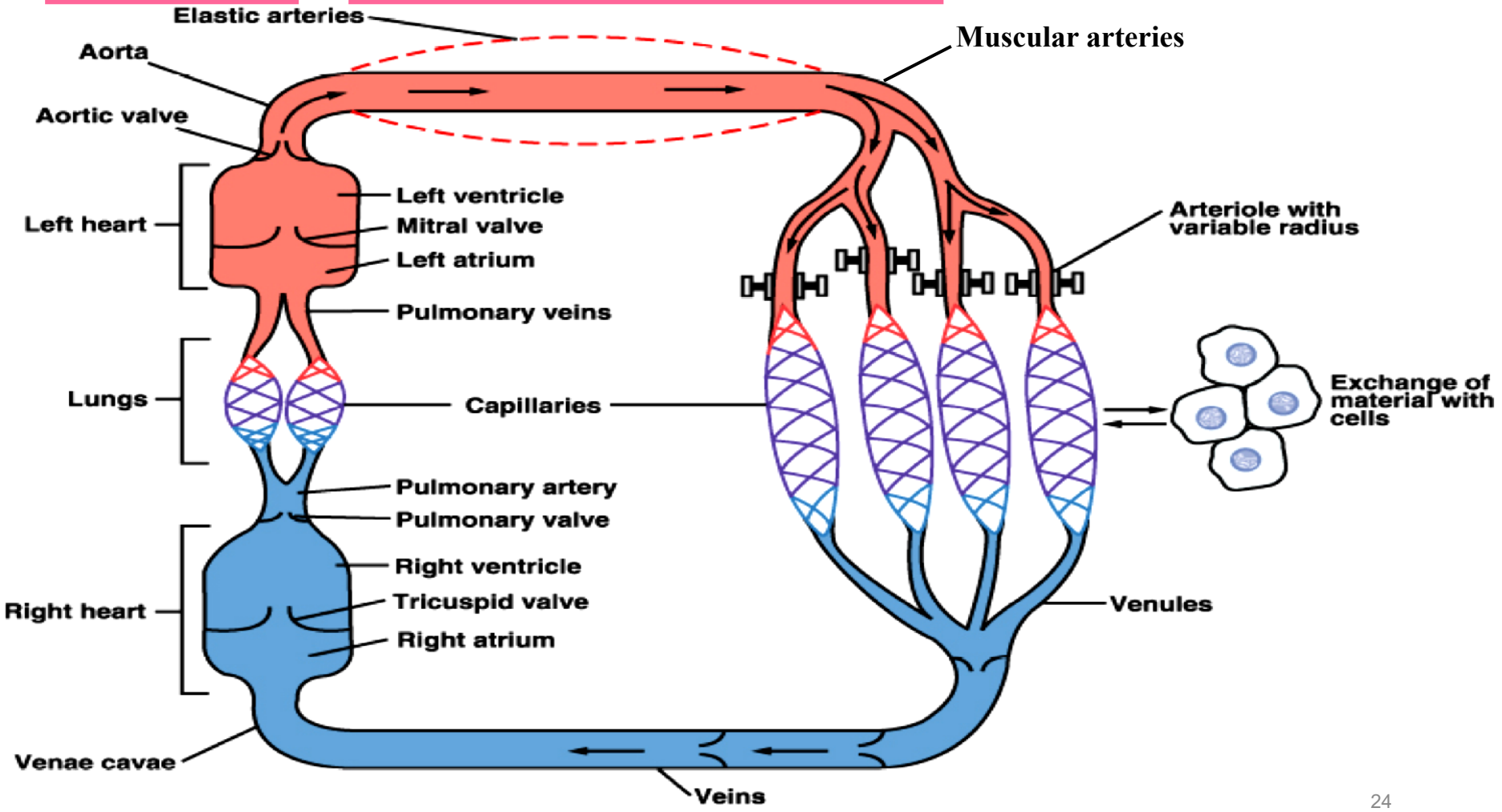
Viscosity

Length

Radius

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

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



Total Peripheral Resistance (TPR):

Affecting Factors

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

Systemic Circulation

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

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

TPR = 1.2 (PRU's)

Pulmonary Circulation

$$PulR = \frac{\text{Pulmonary Pressure - LAP}}{\text{Flow}}$$

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

PulR = 0.12 (PRU's)

TPR= Total Peripheral Resistance; Pul R= Pulmonary Resistance; RAP= Right Atrial Pressure; LAP= Left Atrial Pressure; PRU= Peripheral Resistance Units.

Resistance to Flow in the Cardiovascular System

Basic Concepts

Series Resistance

$R_{Total} = R1 + R2 + R3$

More Resistance

Parallel Resistance

$1/R_{Total} = 1/R1 + 1/R2 + 1/R3$

Less Resistance

Series

Parallel

Arterioles

Higher R

Capillaries

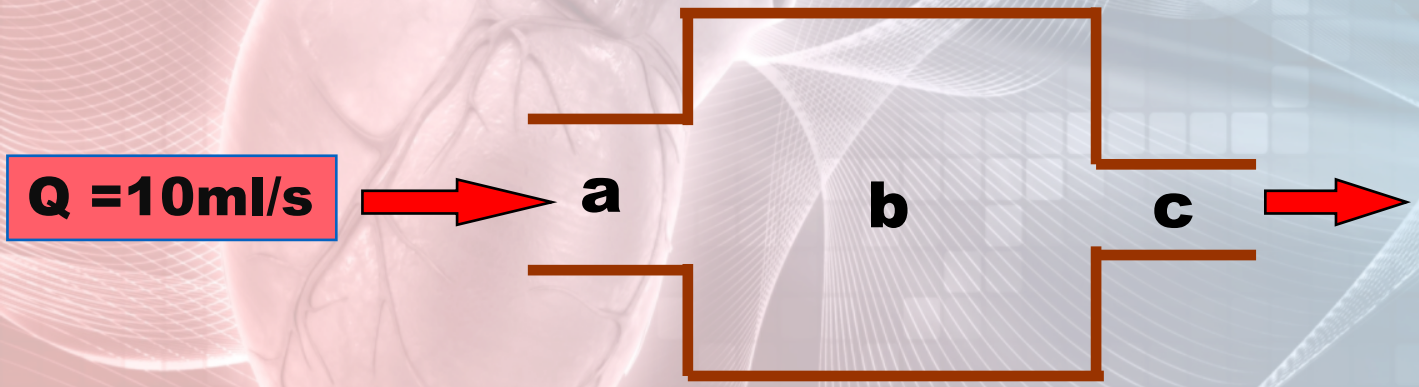
Lower R

R= Resistance; R_{Total}= Total Resistance.

Velocity: Affecting Factors

$$V = Q / A$$

$A = 2cm^2$	$10cm^2$	$1cm^2$

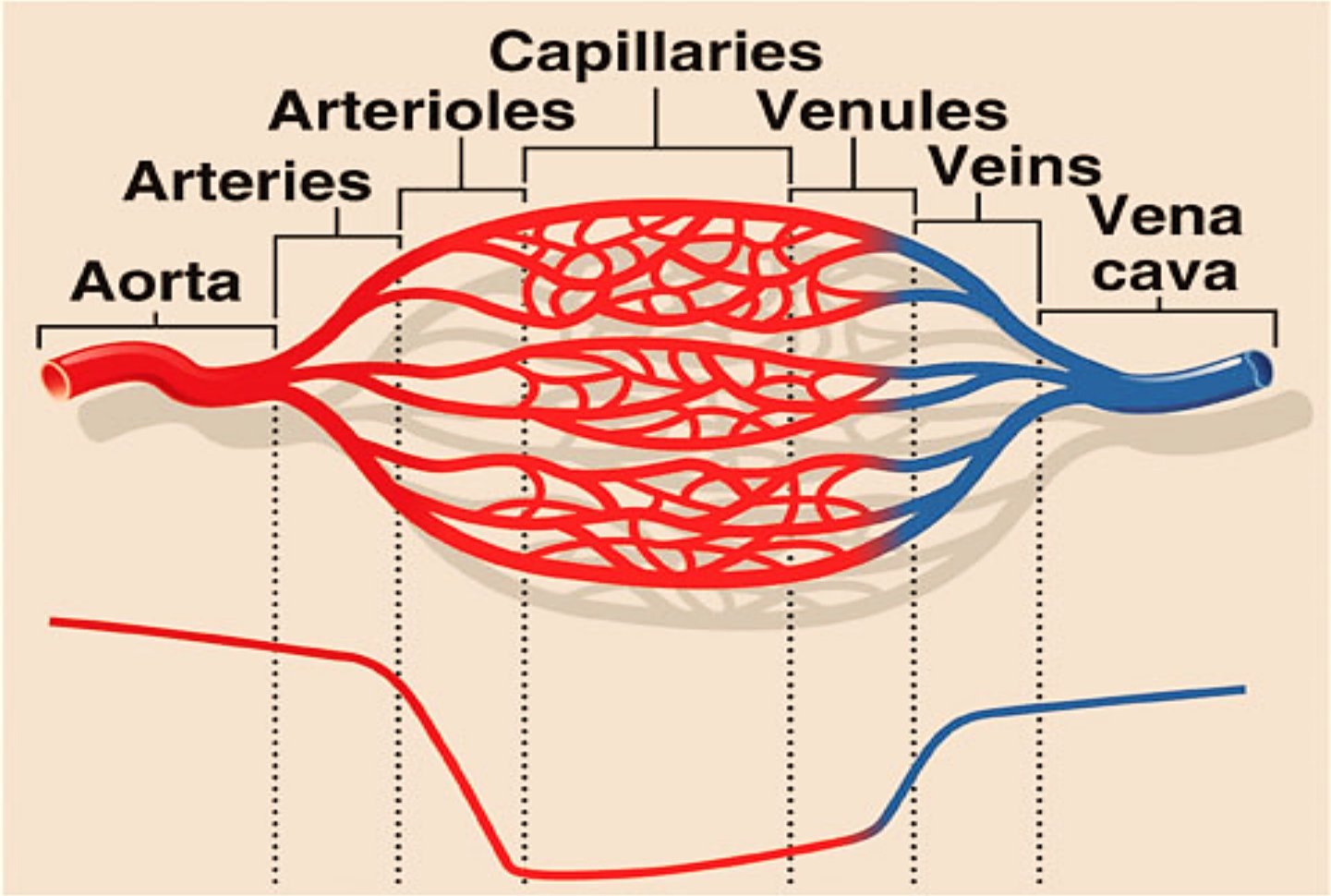


V = 5cm/s	1cm/s	10cm/s

V= Velocity; Q= Flow; A= Cross Sectional Area.

Cross-Sectional Area

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



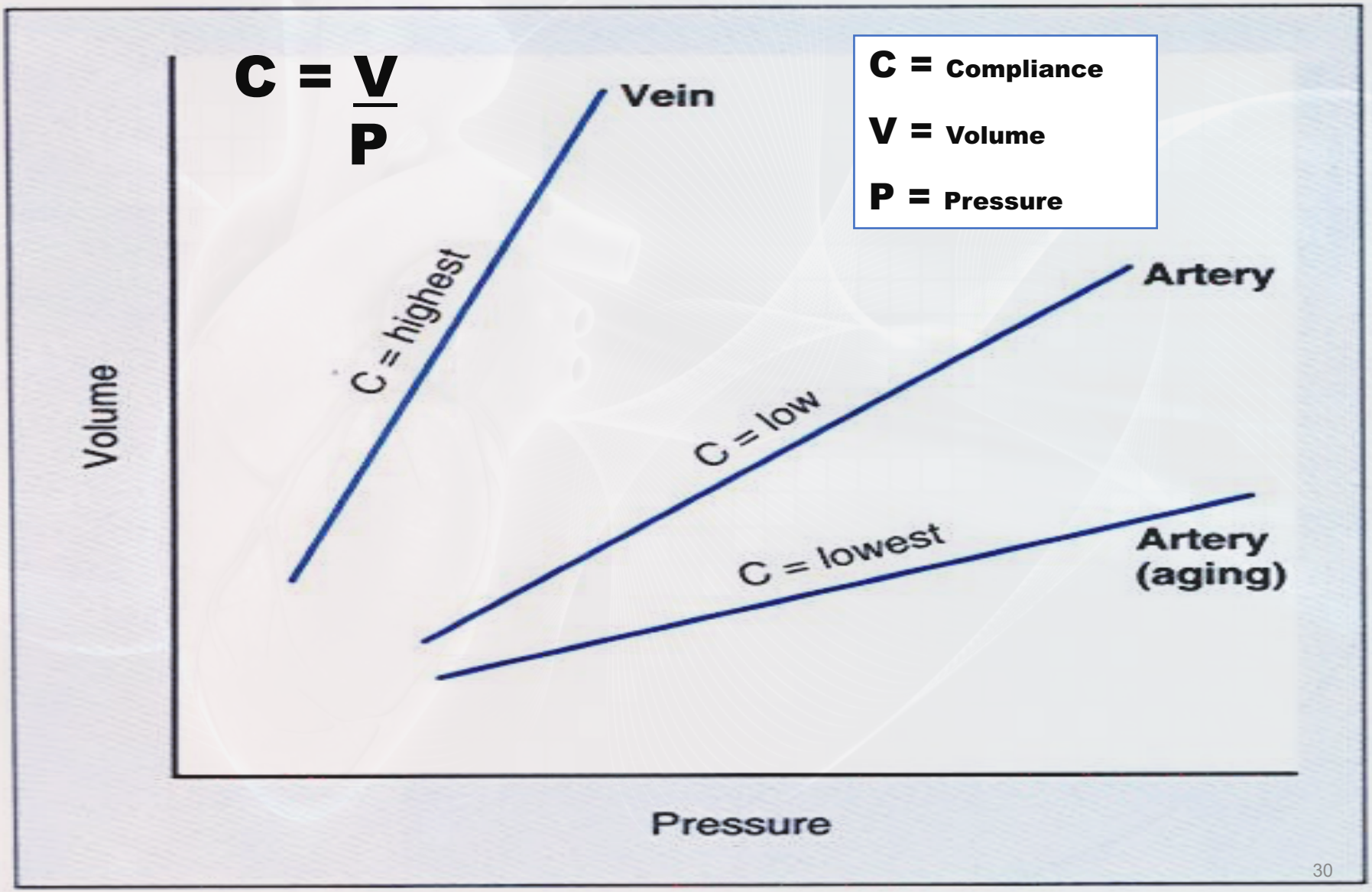
Compliance of Blood Vessels:
Affecting Factors

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

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

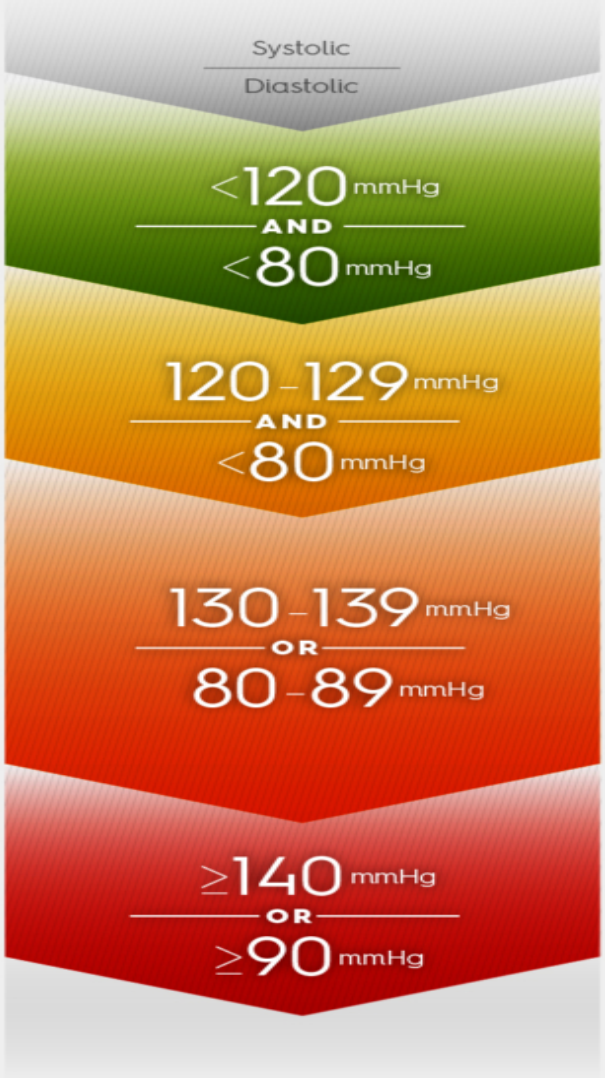
- Venous system has a large compliance & acts as a blood reservoir (high volume & low pressure).

- **Venous system has the highest compliance, while the arterial system has a low compliance.**



KNOW YOUR BLOOD PRESSURE
—AND WHAT TO DO ABOUT IT

By AMERICAN HEART ASSOCIATION NEWS



The newest guidelines for hypertension:

NORMAL BLOOD PRESSURE
*Recommendations: Healthy lifestyle choices and yearly checks.

ELEVATED BLOOD PRESSURE
*Recommendations: Healthy lifestyle changes, reassessed in 3-6 months.

HIGH BLOOD PRESSURE / STAGE 1
*Recommendations: 10-year heart disease and stroke risk assessment. If less than 10% risk, lifestyle changes, reassessed in 3-6 months. If higher, lifestyle changes and medication with monthly follow-ups until BP controlled.

HIGH BLOOD PRESSURE / STAGE 2
*Recommendations: Lifestyle changes and 2 different classes of medicine, with monthly follow-ups until BP is controlled.

**Individual recommendations need to come from your doctor.*
Source: American Heart Association's journal Hypertension
Published Nov. 13, 2017

https://www.youtube.com/watch?v=qWti317qb_w

Thank You