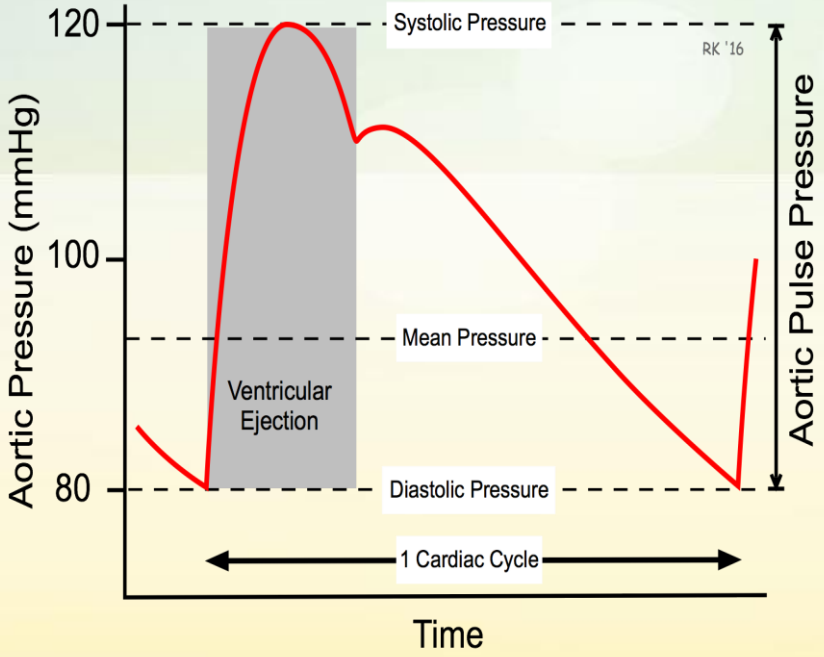
السلام عليكم ورحمة الله وبركاته

Physiology of Cardiovascular System

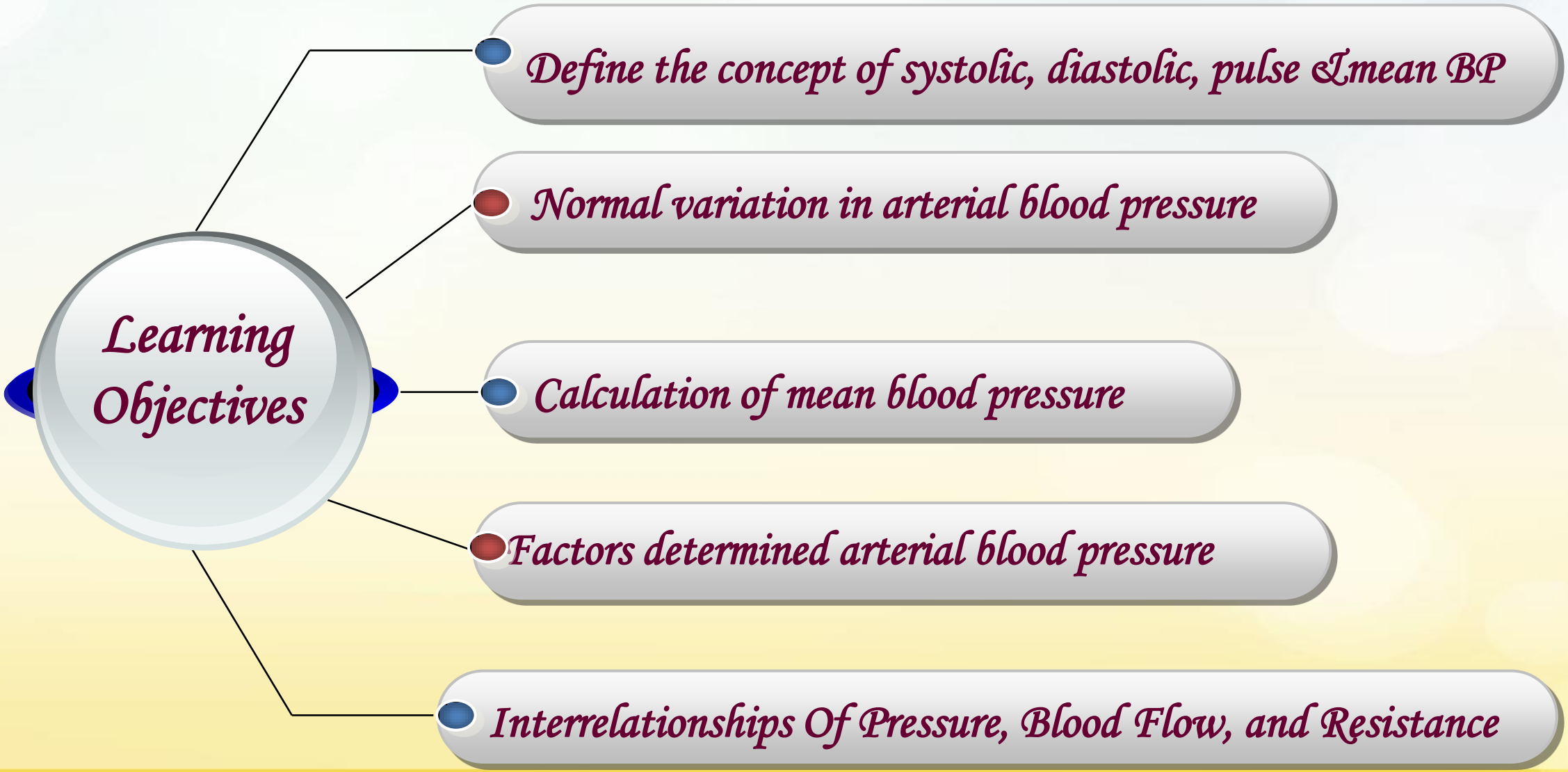


Arterial Blood Pressure & its Measurement

By: Dr. Hayam Gad

Associate Professor of Physiology

College of Medicine, KSU


Learning Objectives
Define the concept of systolic, diastolic, pulse &mean BP
Normal variation in arterial blood pressure
Calculation of mean blood pressure
Factors determined arterial blood pressure
Interrelationships Of Pressure, Blood Flow, and Resistance

What is meant by Arterial Blood Pressure?

- ✓ It is the force exerted by the blood against any unit area of the vessel wall.
- ✓ It is the force that keeps blood circulating continuously even between heart beats.

In normal adult ≈ 120/80 mmHg.

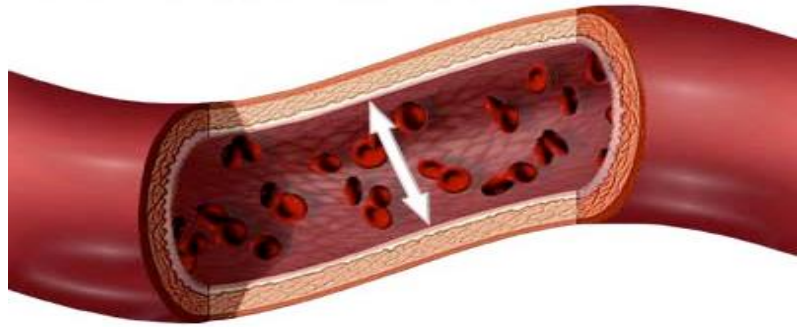
- ✓ Top number (systolic):

  = Pressure at the peak of ventricular contraction

- ✓ Bottom number (Diastolic):

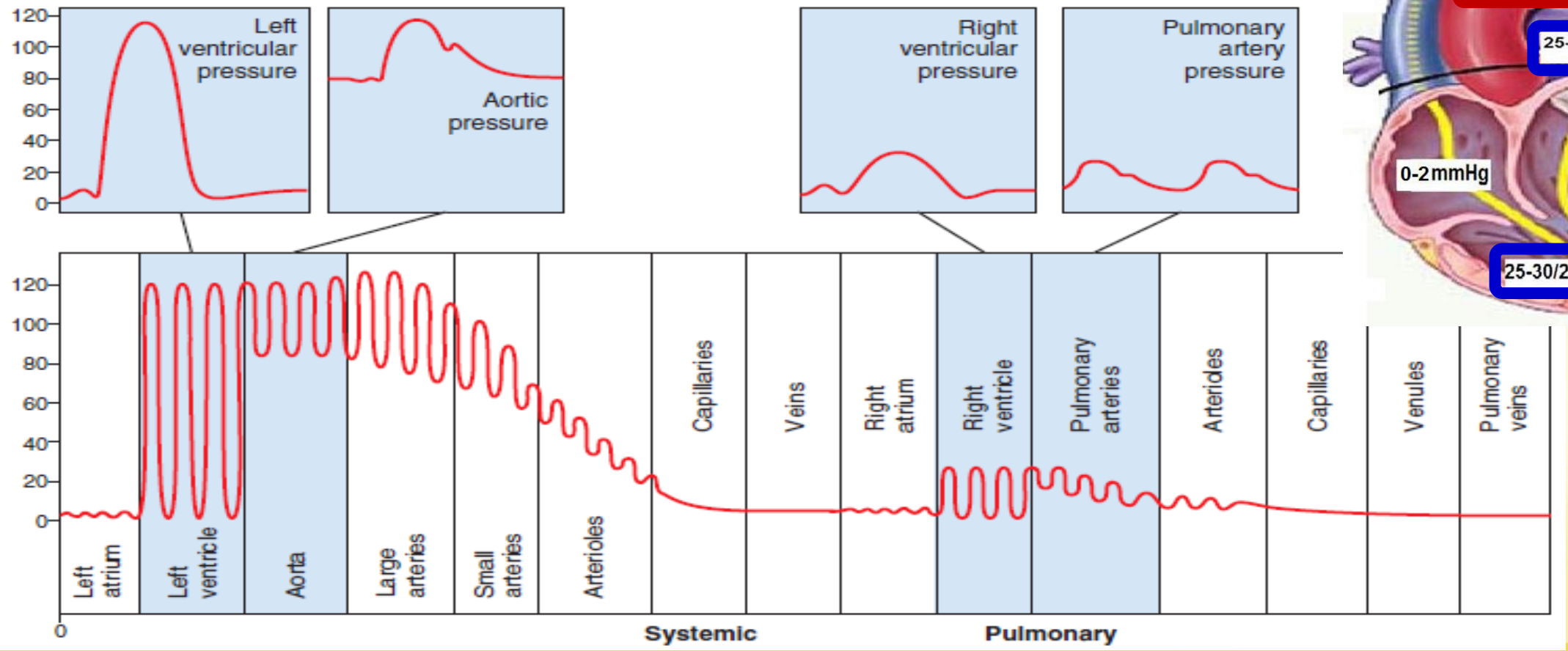
  = Pressure when the ventricles relax

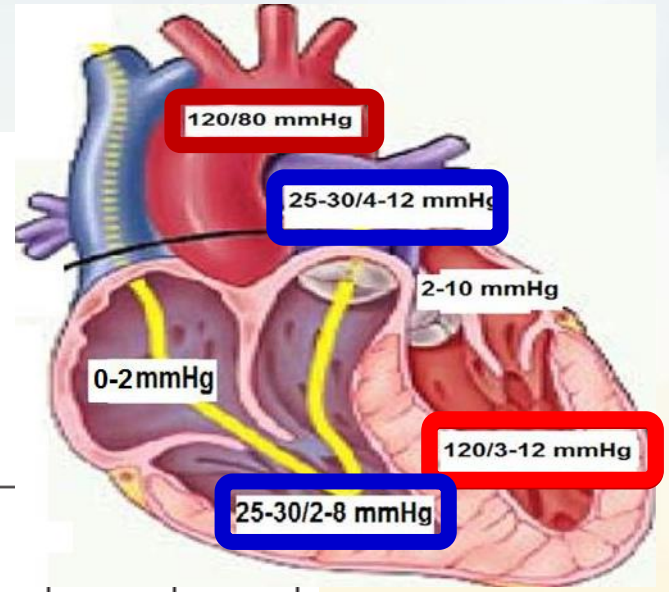
Blood pressure is the measurement of the force applied to artery wall



Normal Blood Pressure in the Different Portions of the Circulatory System (Systemic VS Pulmonary Circulation)

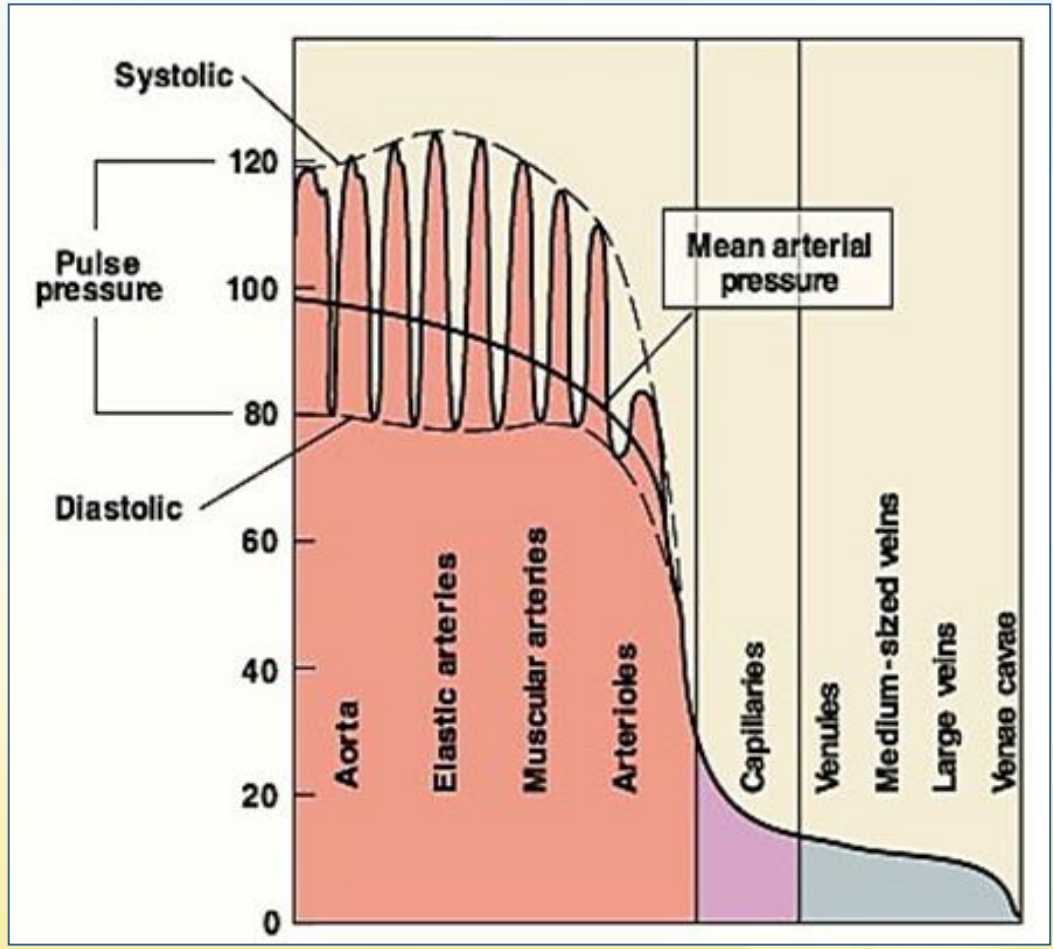
When a person is lying in the horizontal position





Pressure Changes throughout the Systemic Circulation

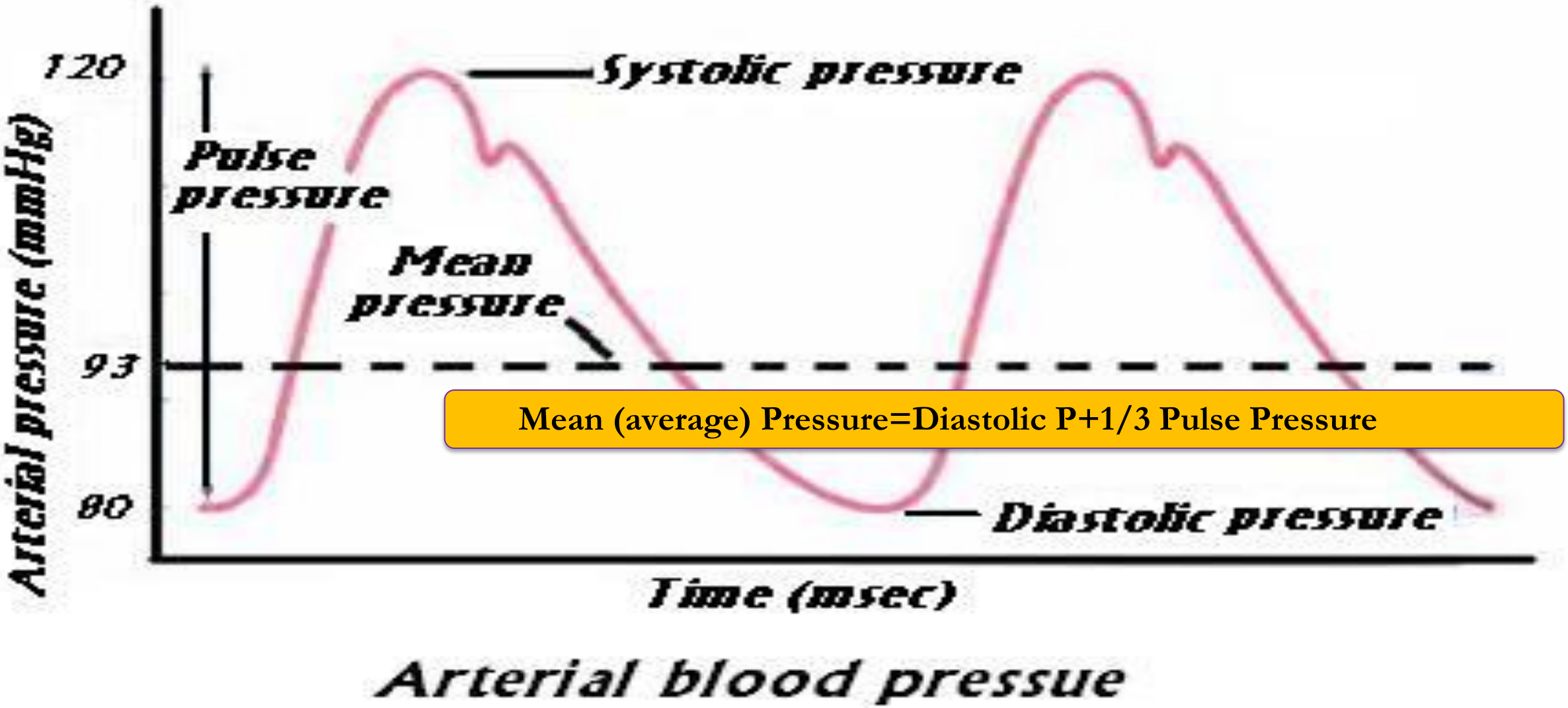
- ✓ Blood flows down a pressure gradient.
- ✓ Highest pressure at the heart.
- ✓ Decrease over distance.
- ✓ Decrease 90% from aorta to vena cava.
- ✓ Greatest drop in the pressure occurs in arterioles.
- ✓ No large fluctuation in the capillaries and veins.
- ✓ Blood pressure averages 120mmHg in aorta and drops to 0-2mmHg in Rt atrium.



Variation in Arterial Blood Pressure

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

Aortic Pressure changes=120/80



Arterial blood pressue

Mean (average) Pressure=Diastolic P+1/3 Pulse Pressure

Pulse Pressure=Systolic P- Diastolic P

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 at menopause).
- ✓ Age: Elderly > Children (due to atherosclerosis, diabetes….etc.).
- ✓ Emotions: ↑ ABP due to hormonal factors.
- ✓ Exercise: ↑ ABP due to ↑ venous return.
- ✓ Hormones: Adrenaline, noradrenalin & thyroid hormones ↑ ABP.
- ✓ Gravity: ABP is > in lower limbs than upper limb.
- ✓ Race: May be due to dietary factors or stress.
- ✓ Sleep: ABP ↓due to ↓venous return.
- ✓ Pregnancy: ABP ↑ due to ↑ metabolism.
- ✓ Temperature : ABP ↓with heat due to vasodilation , and ↑ with cold due to vasoconstriction.

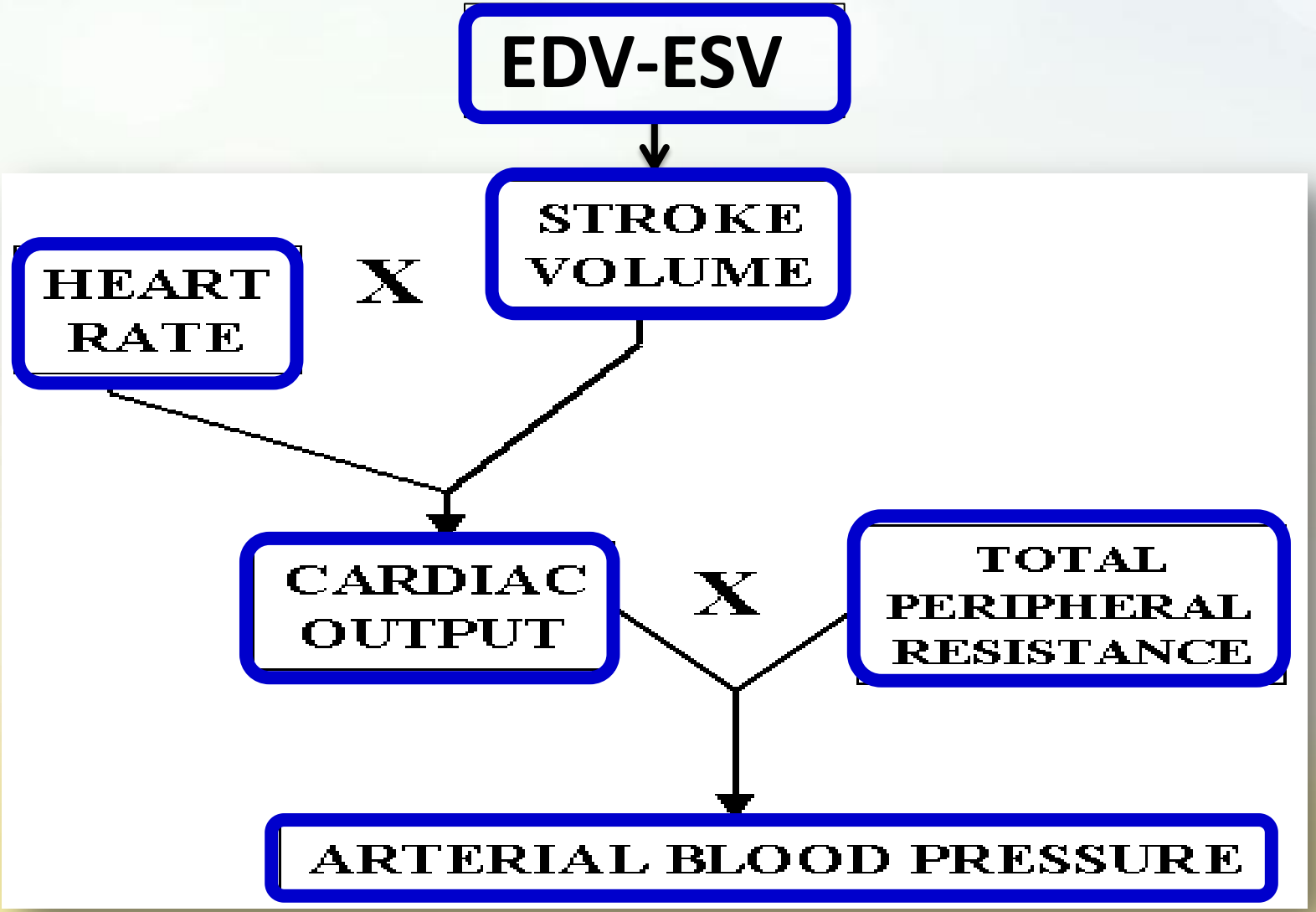
Factors Determining ABP

- Two mail Factors:-
  - Cardiac output (Flow.)
  - Peripheral Resistance.

Arterial blood pressure =Cardiac output X Peripheral resistance

- So, ABP is directly related to cardiac output and peripheral resistance.

Factors Determining ABP



Cardiac Output (CO)

- Cardiac output (CO) is the amount of blood pumped by ventricles per minute.
- Factors determining CO:
  1. Stroke volume (EDV-ESV)
  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
(≈ 5-6 L/min)	(≈ 70-80 ml/beat)	≈ 70-75 beats/min
	=EDV-ESV	(N. 60-100 beats/min)

Blood Flow

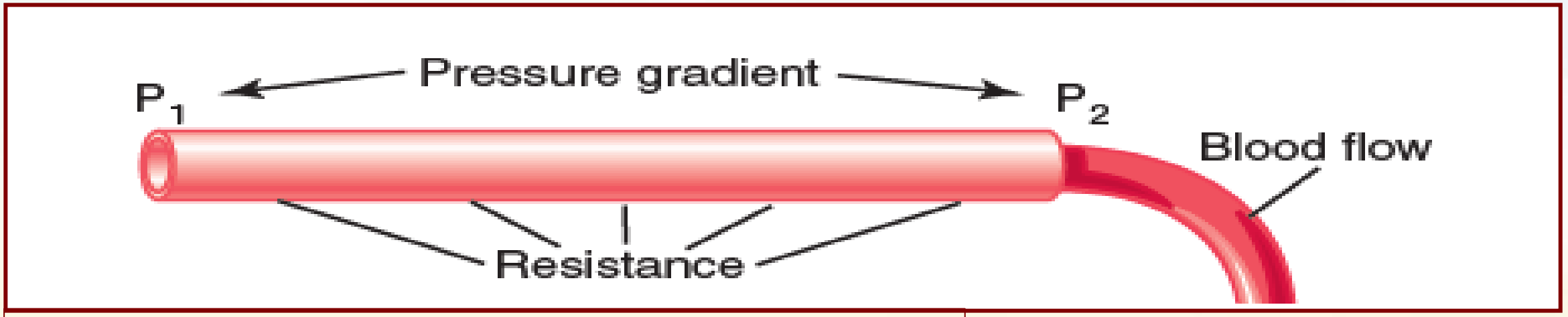
Amount of blood moving through a vessel in a given time period (ml or L/min. or Sec.).

- ✓ Generally, it is equal to Cardiac output (CO.)
- ✓ It is affected by: pressure & resistance.

Ohm's law

$$\text{Blood Flow (F)} = \frac{\text{Pressure differences } (\Delta P)}{\text{Resistance (R)}}$$

Interrelationships Of Pressure, Blood Flow, and Resistance



P1: Pressure at the origin of the vessel
P2: Pressure at the other end of the vessels

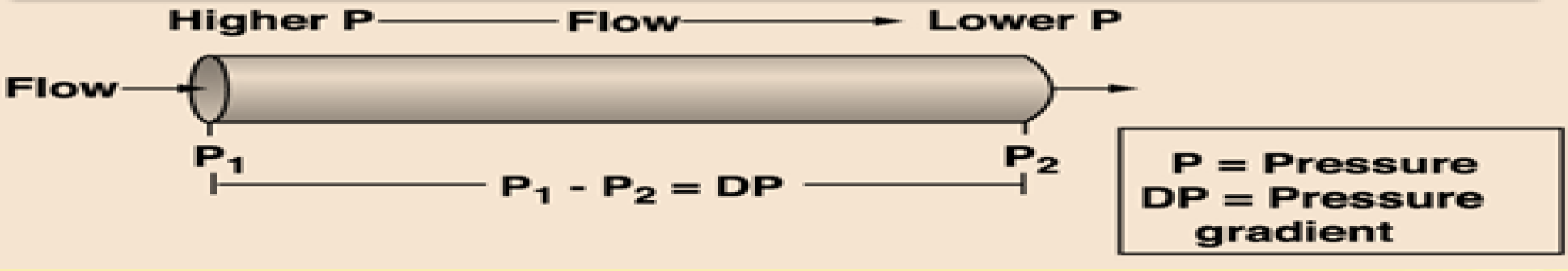
Blood Flow is:-

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

Blood Flow and Pressure

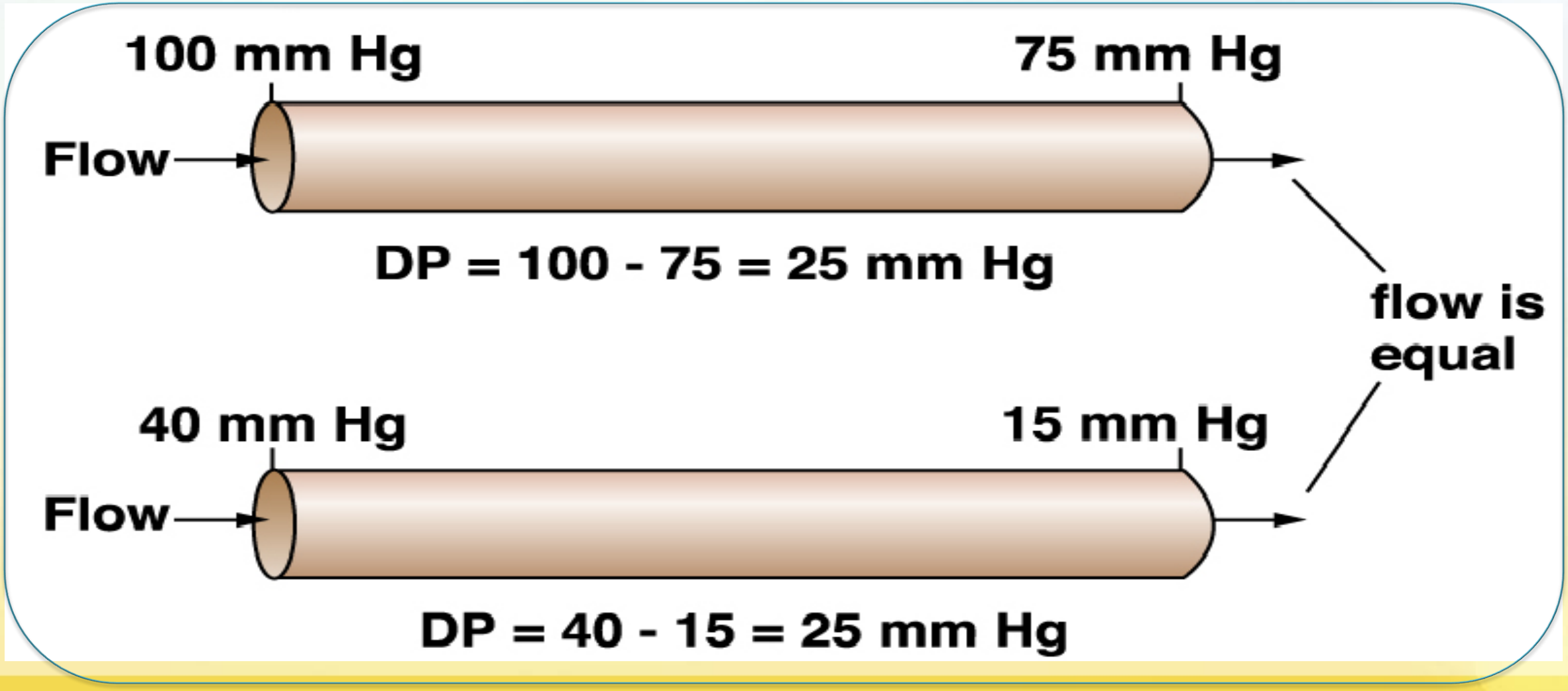
Flow (F) is directly proportional to Pressure (P).

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



Resulting pressure is called the deriving pressure in the vascular system

How does the flow differ in these two vessels?



Resistance (R)

It is the tendency of vascular system to oppose flow.

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

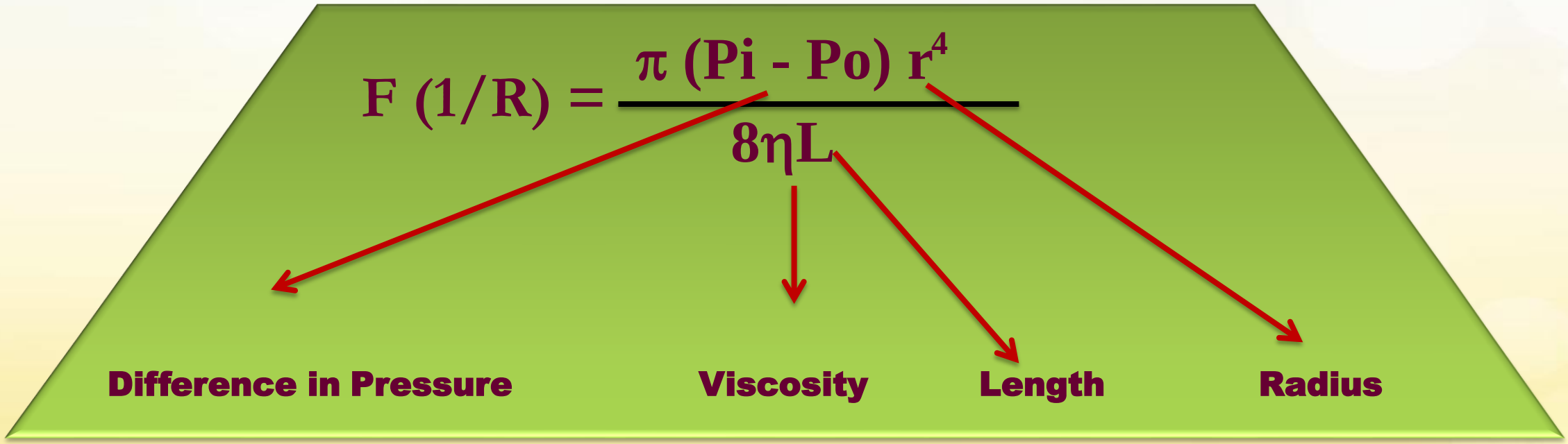
Resistance is influenced by:
Viscosity of the blood (η); Length of the vessel (L), & Radius of the vessel (r).

Poiseuille's Law $\quad \text{Resistance (R)} = 8\,\eta L/\pi r^4$

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

Fluid flow (F) through cylindrical tubes decreases (↓) when resistance increases {i.e when pressure difference (↓), when vessel diameter (↓), or when blood viscosity increases}.



Total Peripheral Resistance (TPR)

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

Systemic Circulation:

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

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

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

Pulmonary Circulation:

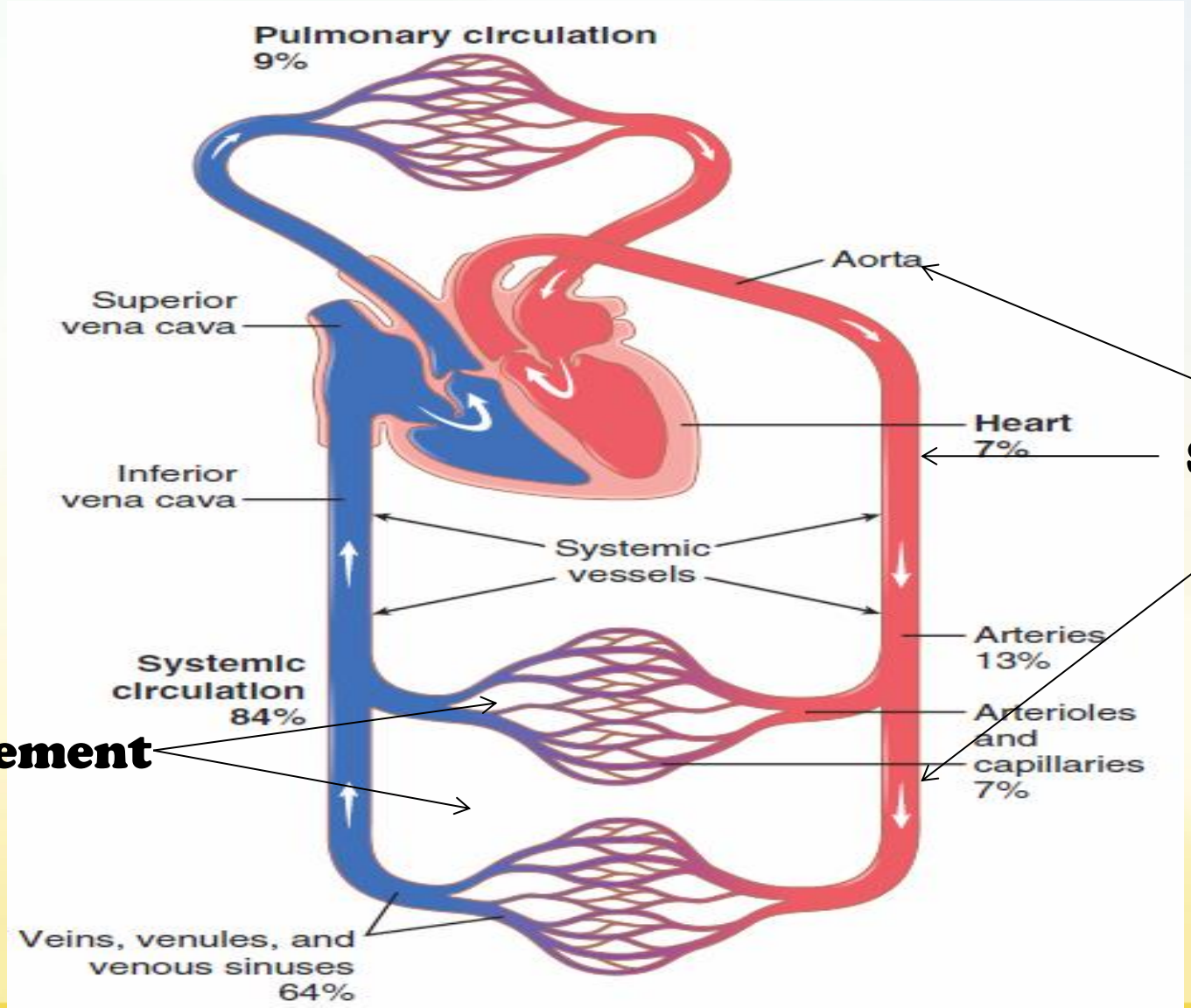
$$\text{Pul. R.} = \frac{\text{Pulmonary Art. P. - LAP}}{\text{Blood Flow}}$$

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

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

PRU's: Peripheral resistance units

Arrangement of Blood Vessels in CVS



Series arrangement

Parallel arrangement

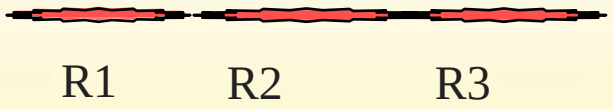
Resistance to Flow in the Cardiovascular System

Basic Concepts

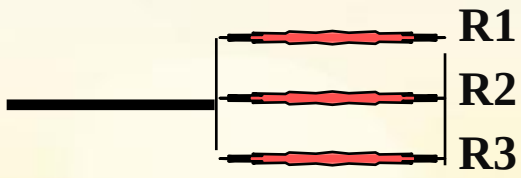
Rt = R1 + R2 + R3 .... Series Resistance

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

Series



Parallel



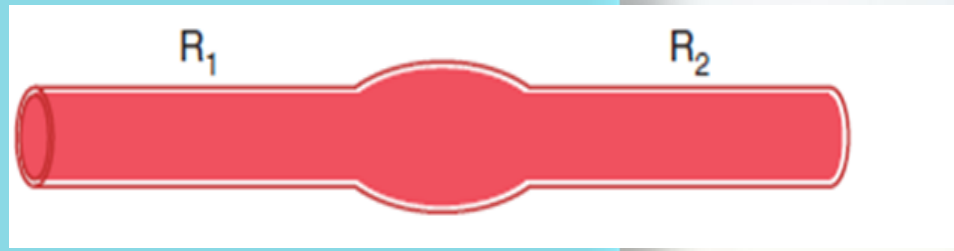
Resistance to Flow in the Cardiovascular System….Cont.

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

❖ **Series arrangement gives:**

$$R_T = R_1 + R_2 + R_3$$

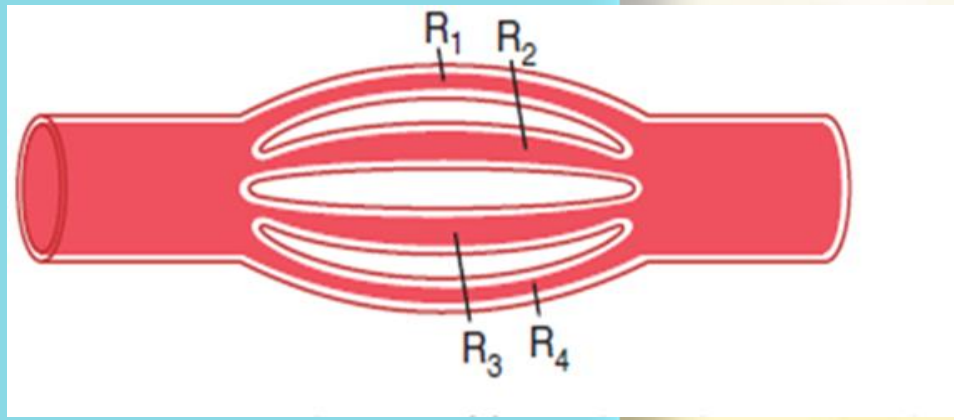
$$R_T = 2+4+6 = 12 \text{ (PRU's)}$$



❖ **Parallel arrangement gives:**

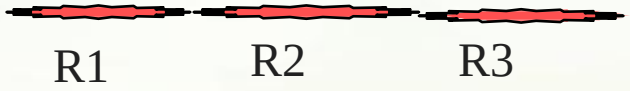
$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

$$= 1.94 \text{ (PRU's)}$$



What Really Happens in the CVS?

Series

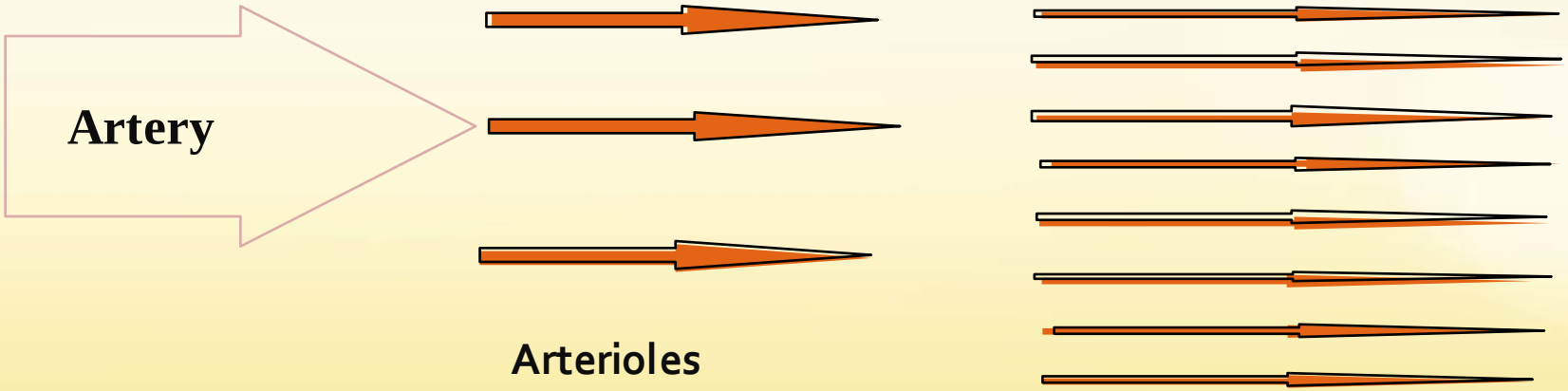


Parallel

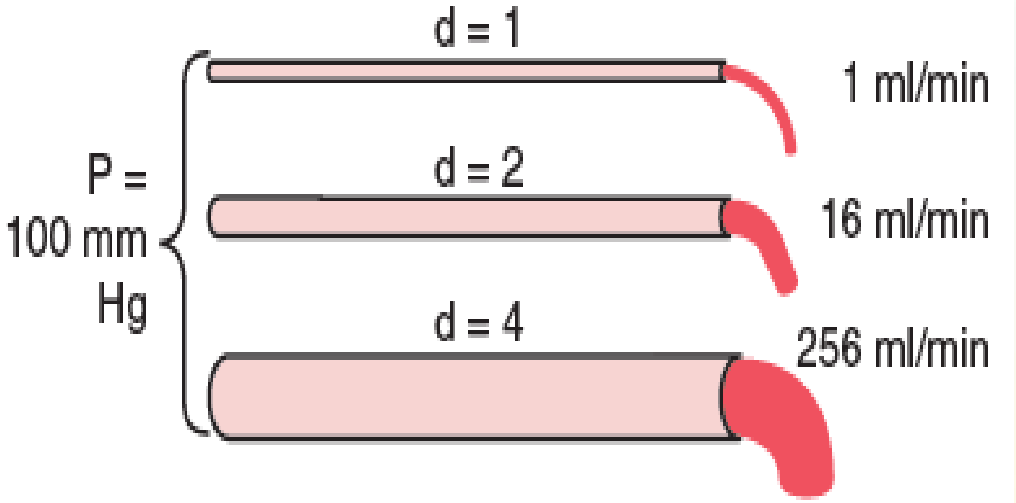
Lower R

Higher R

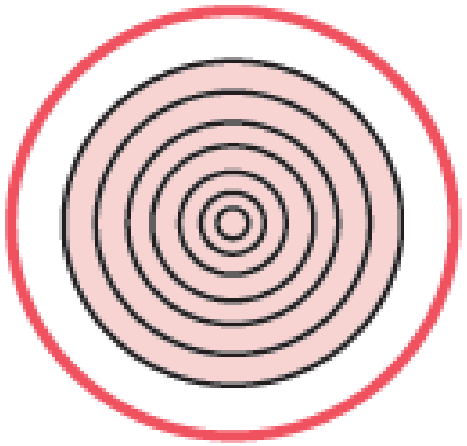
Lower R



The Effect of Radius on Blood Flow



d; Diameter, p; Pressure difference between the two ends of the vessel



Large vessel

Small vessel

Why?

According to Poiseuille's Law, blood flow (↑) when vessel diameter (↑)

Concentering rings of blood flow at different velocities; the farther away from the vessel wall, the faster the flow.

The Effect of Radius on Pressure

Blood Pressure & Blood Flow

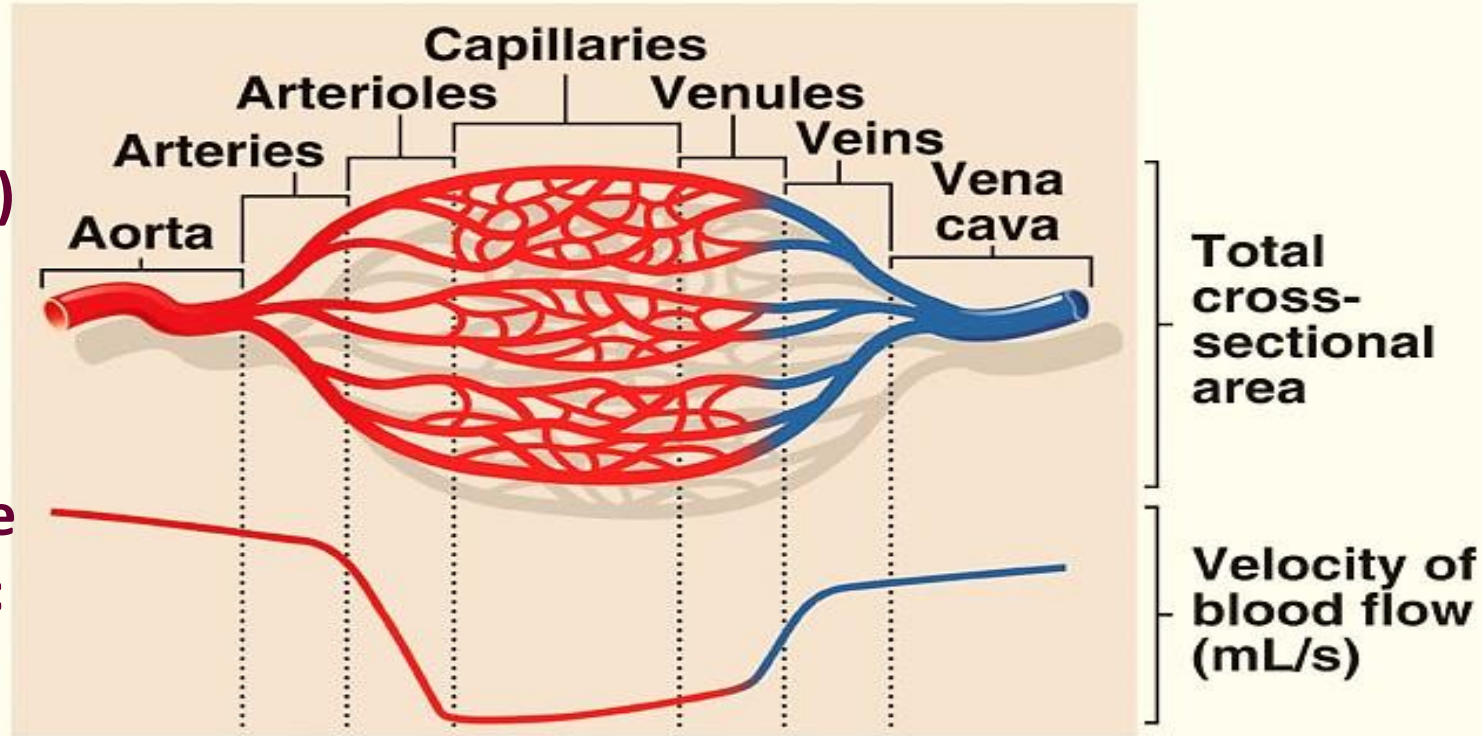
The Effect of Total Cross-Sectional Area on velocity of Blood Flow

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

- ✓ **Because the same blood volume flow (F) must pass through each segment of the circulation each min., the velocity of blood flow (V) is inversely proportional to vascular cross-sectional area (A):**

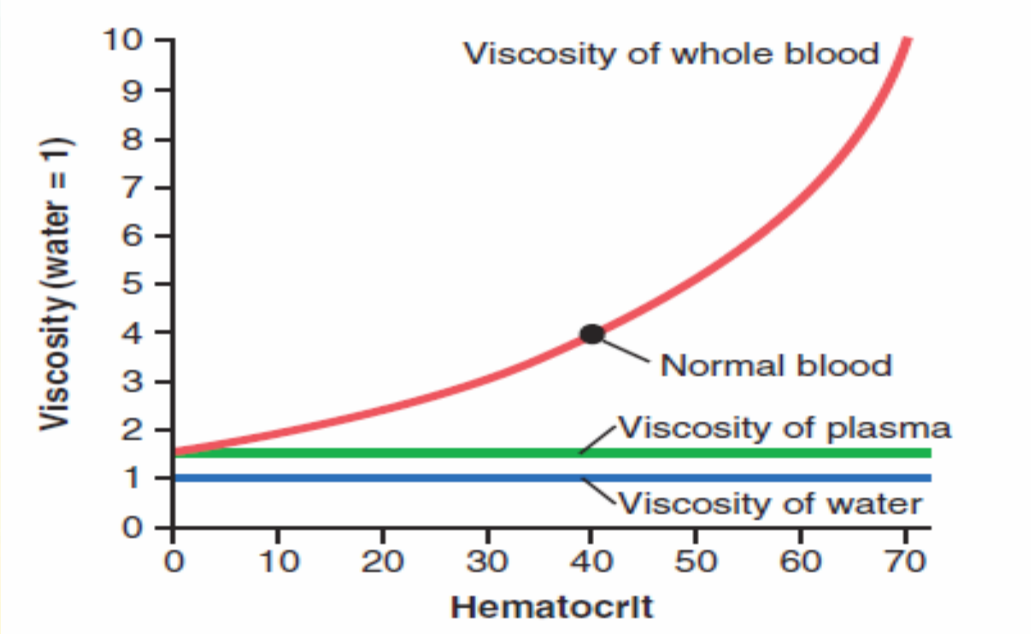
$$V = F/A$$

- ✓ **Thus, under resting conditions, the velocity averages about 33 cm/sec in the aorta but is only about 0.3 mm/sec in the capillaries.**



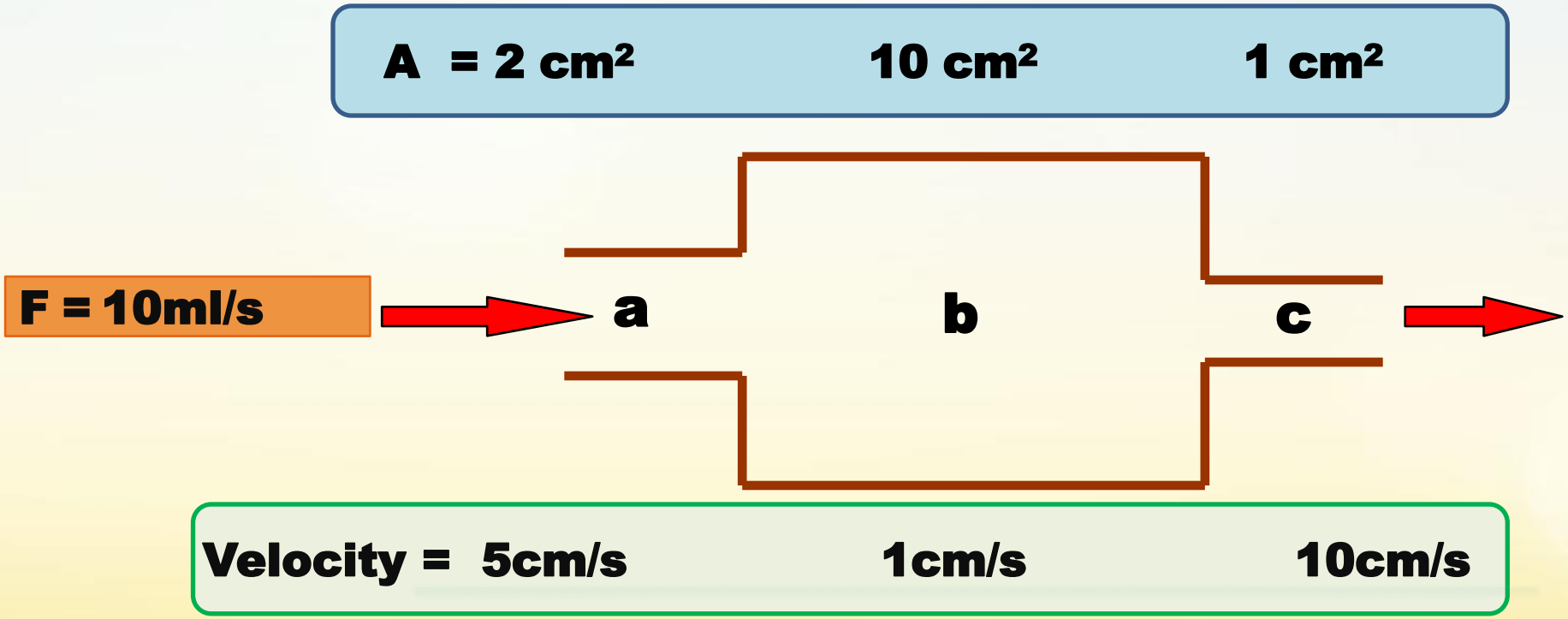
Effect of Blood Viscosity on Vascular Resistance and Blood Flow

- Blood viscosity is mainly due to the large numbers of suspended red cells in the blood, and to less extent due to types & concentration of proteins in the plasma.
- The viscosity of blood increases drastically as the hematocrit increases
- The greater the viscosity, the more the vascular resistance and the lower the flow in a vessel.



Effect of hematocrit on blood viscosity (water viscosity= 1).

Relationships between Velocity (V), Cross Sectional Area (A) and Flow rate (Q)



$$V = F / A$$

Compliance (distensibility) of Blood Vessels

- ✓ Compliance is the volume of blood that the vessel can hold at a given pressure.
- ✓ This capability provides smooth, continuous flow of blood through the very small blood vessels of the tissues.
- ✓ The most distensible blood vessels are the veins (similar in both pulmonary & systemic circulation).
- ✓ Therefore, *the veins provide a reservoir* for storing large quantities of extra blood that can be called into use whenever blood is required elsewhere in the circulation.
- ✓ Vascular distensibility (C) is expressed as the fractional increase in volume (V) for each mmHg rise in pressure (P), in accordance with the following formula:-

$$C = V/P$$

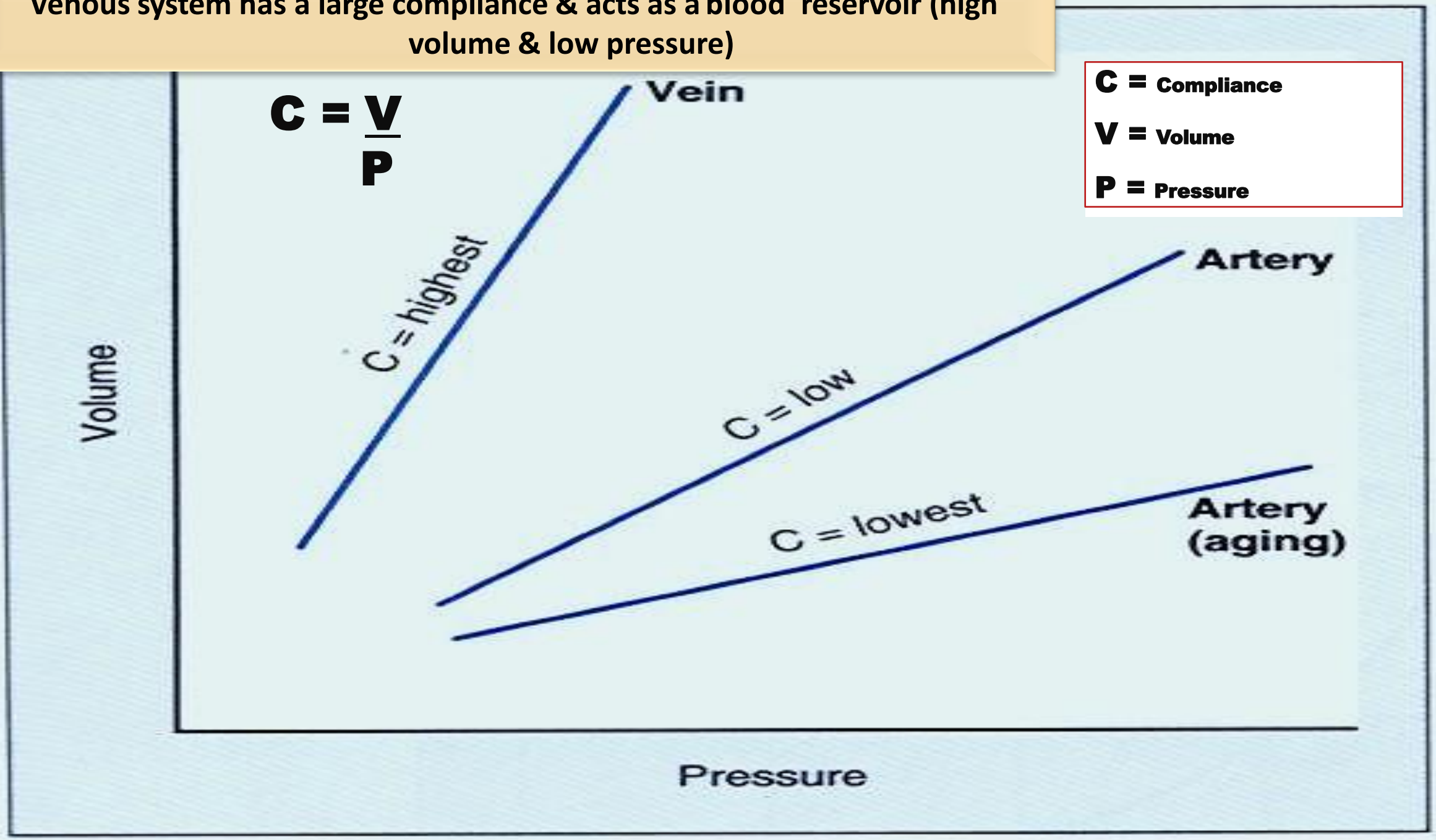
Venous system has a large compliance & acts as a blood reservoir (high volume & low pressure)

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

C = Compliance

V = Volume

P = Pressure



Measurement of Arterial Blood Pressure

Two methods:

- ✓ Direct measurement (using catheter inside the arteries).
- ✓ Indirect measurement (Auscultatory method)

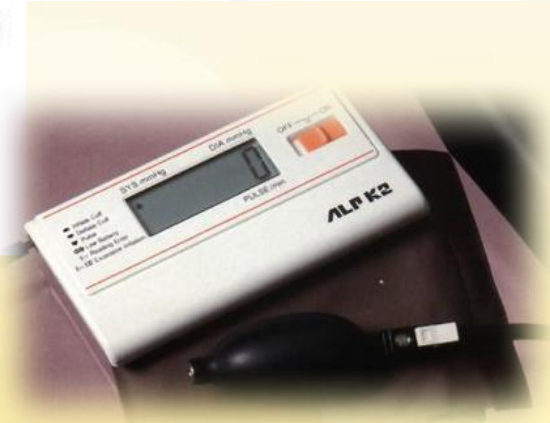
Using the Stethoscope & Sphygmomanometer:

Many types:

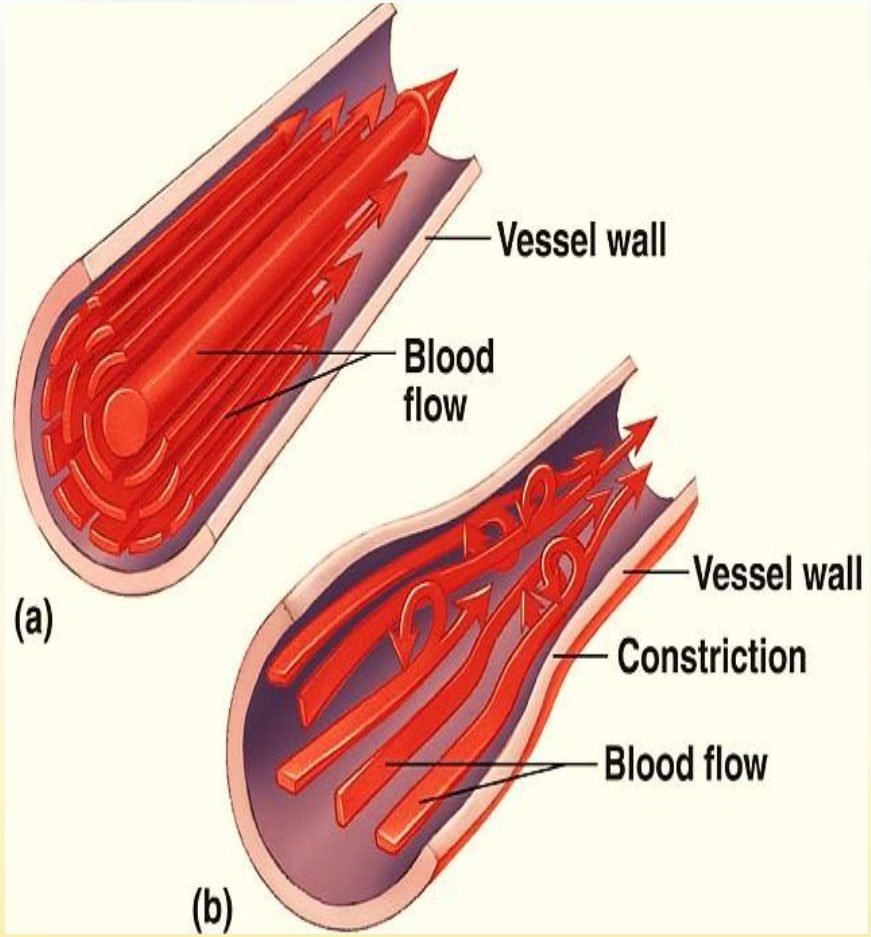
- Mercury sphygmomanometer
- Aneroid equipment
- Automatic equipment

Blood Pressure Cuff Size:

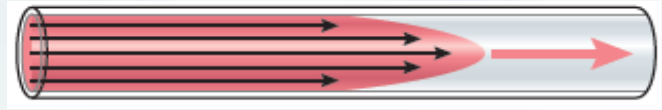
- Small – children & small adults
- Average
- Large – overweight & large adults



Laminar and Turbulent blood Flow



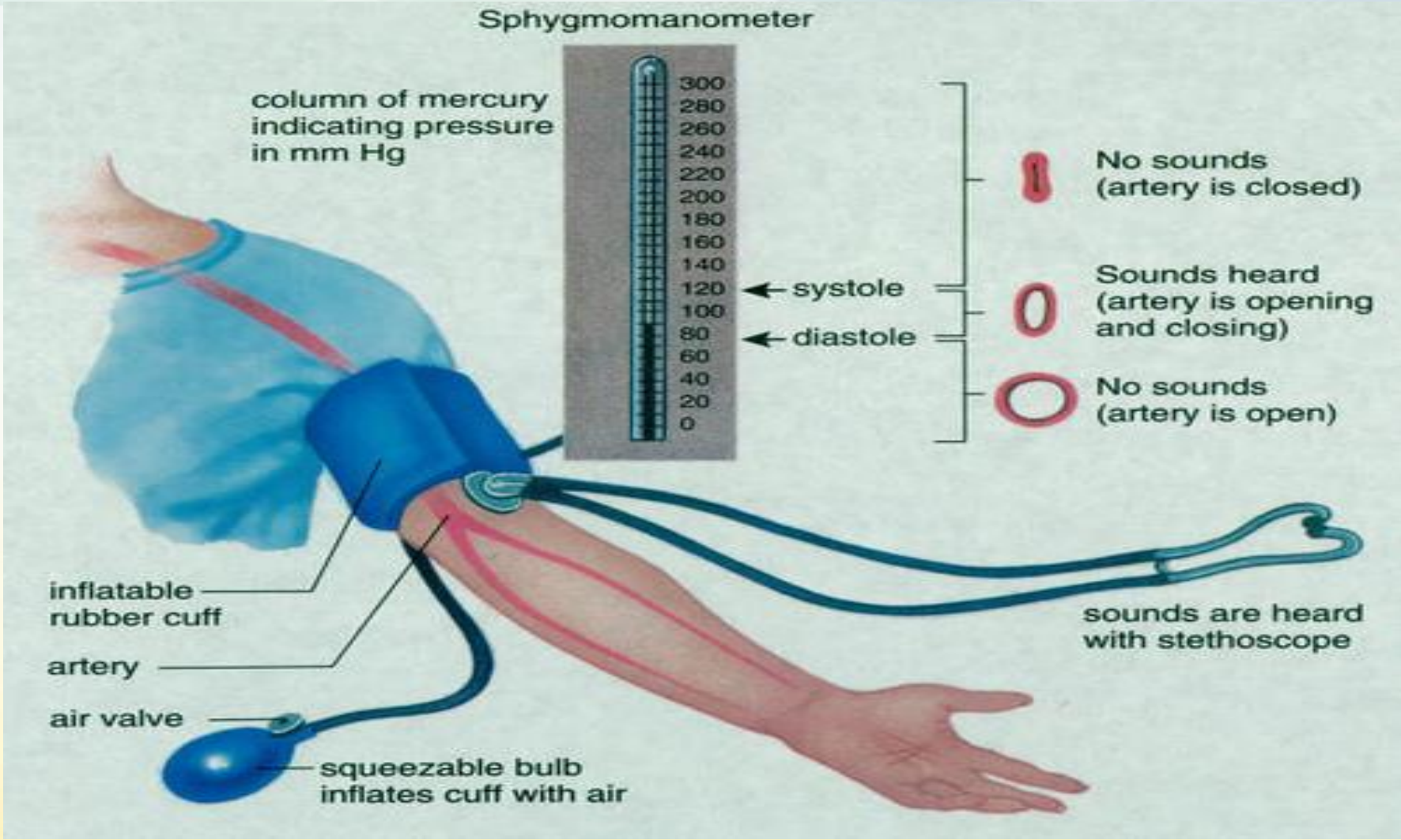
❑ **Laminar flow (a)**



- Streamlined
- Outermost layer moving slowest & center moving fastest

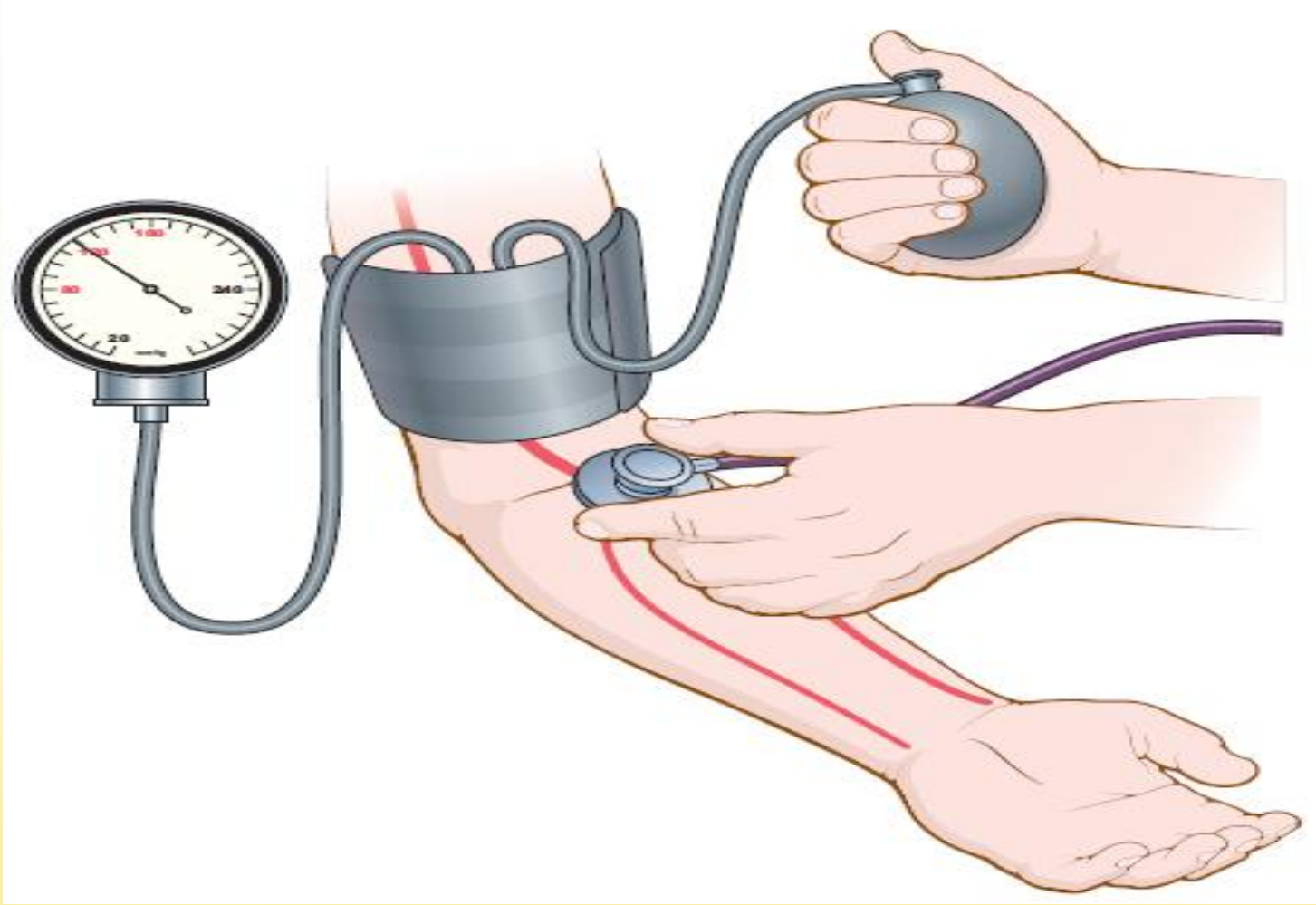
❑ **Turbulent flow (b)**

- Means blood flows crosswise in the vessel and along the vessel, usually forming whorls in the blood, called eddy currents. It occurs when:-
- Blood flow rate becomes too great
- It passes by an obstruction in a vessel
- It makes a sharp turn
- It passes over a rough surface



Auscultatory Method for Measurements of Arterial Blood Pressure

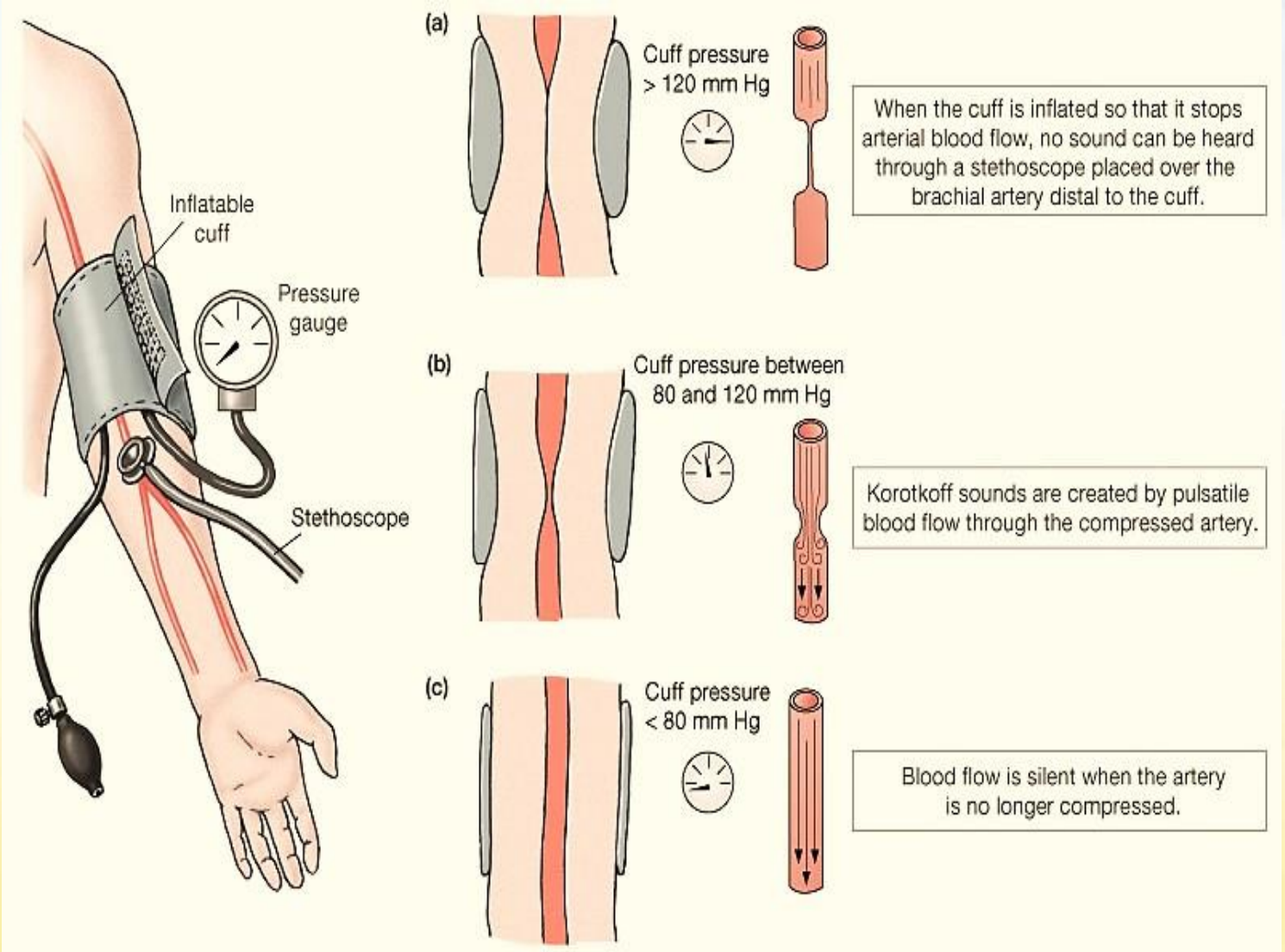
Auscultatory Method for Measurements of Arterial Blood Pressure



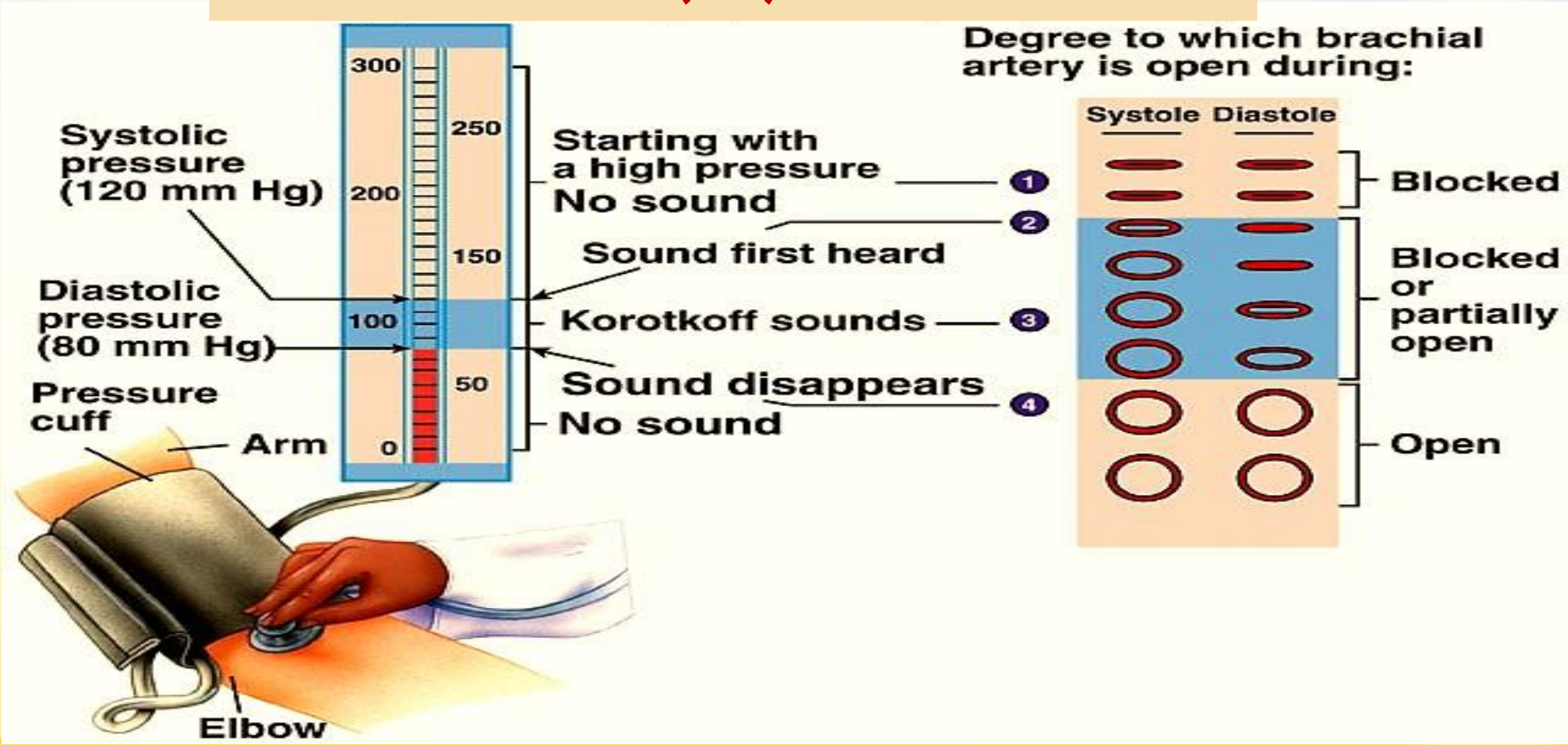
Measurements of Arterial Blood Pressure….Cont.

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

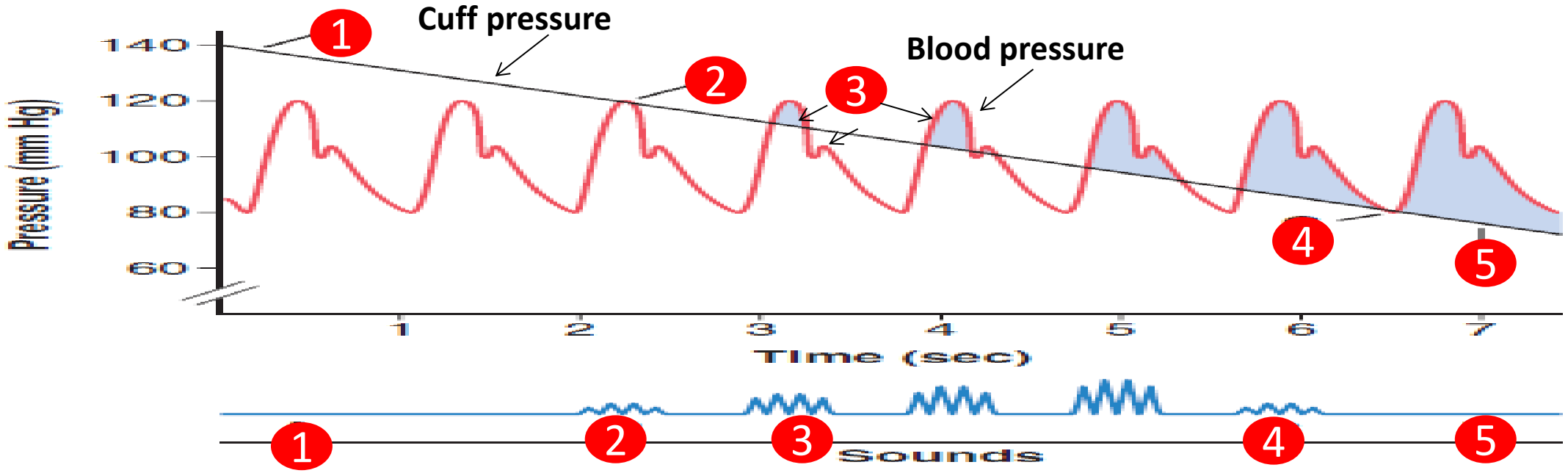
- **Systolic pressure**
  = when 1st sound is heard.
- **Diastolic pressure**
  = when last sound is heard.



Blood Pressure (BP): Measurements

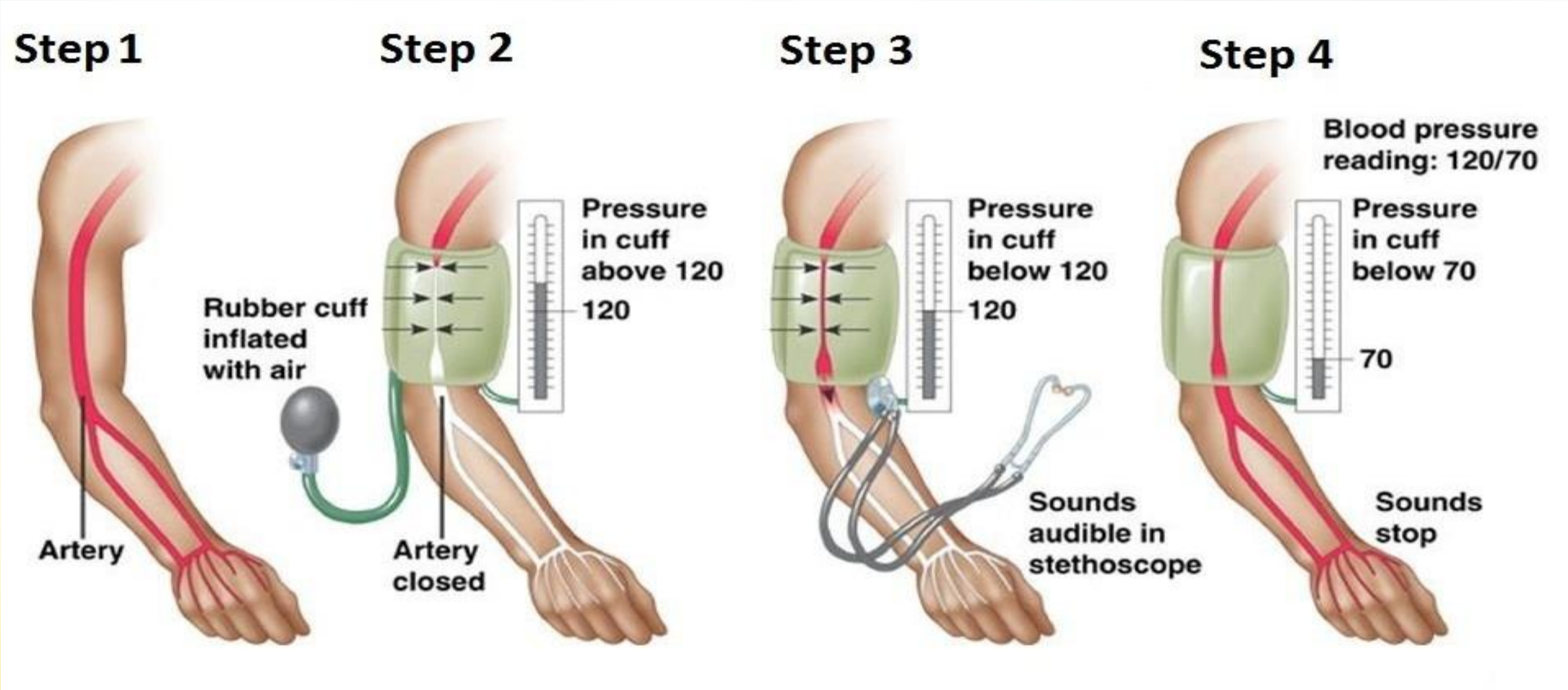


Measuring Blood Pressure
Turbulent Flow



1. Cuff pressure > systolic blood pressure…. No sound
2. The first sound is heard at peak systolic pressure.
3. While cuff pressure is < blood pressure….Sounds heard
4. Cuff pressure is near diastolic pressure…. Sounds become muffled
5. When cuff pressure < diastolic pressure…. Sound disappears

Measurement of Arterial Blood Pressure




THANK YOU!