1ST YEAR MEDICAL STUDENTS
GENERAL PHYSIOLOGY
THE VASCULAR SYSTEM

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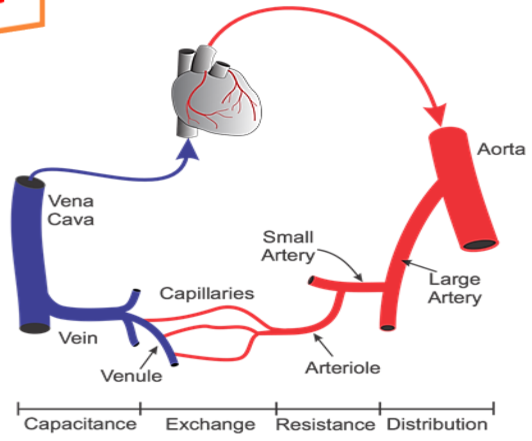
THE VASCULAR SYSTEM

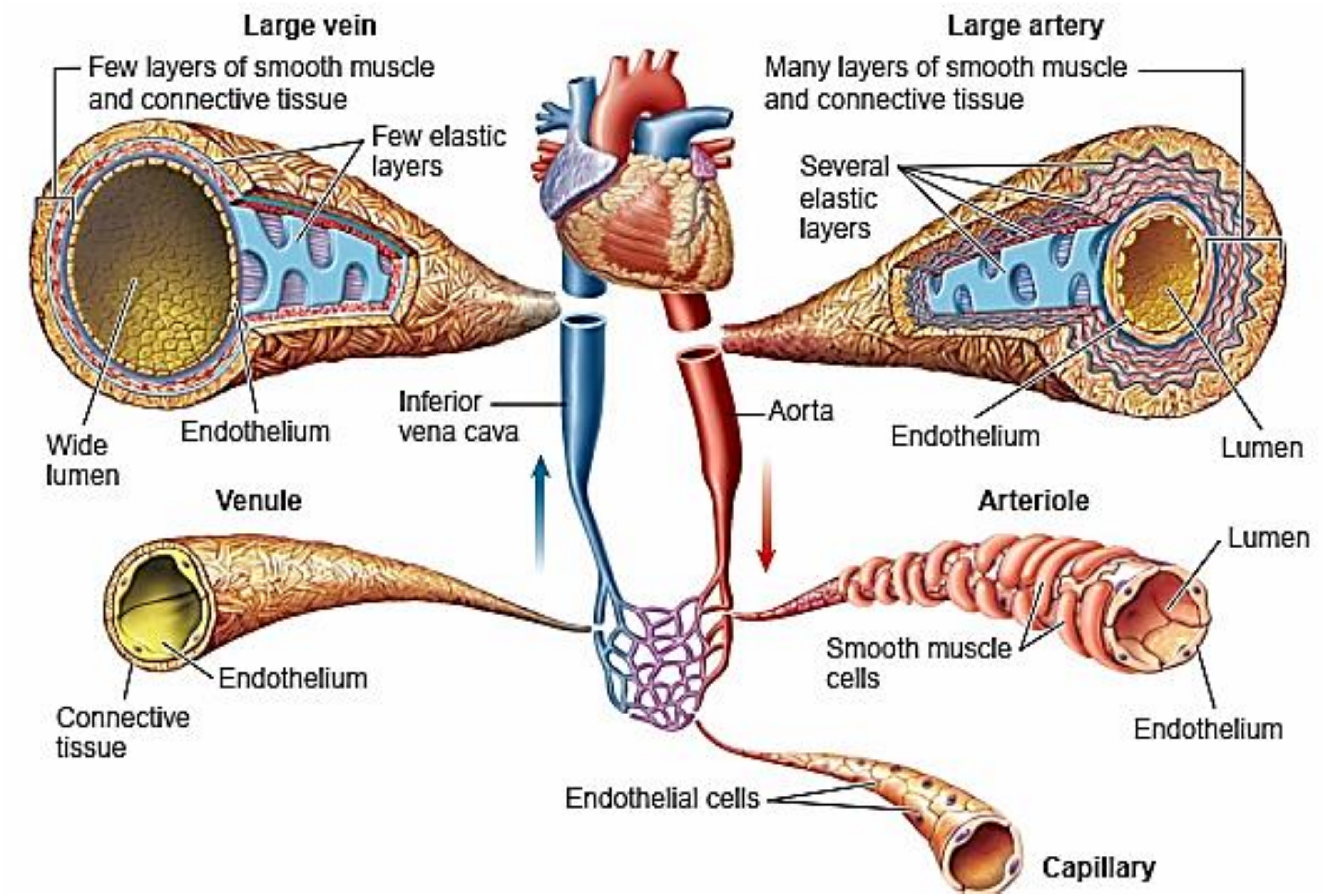


The vascular system

Although the action of the muscular heart provides the overall driving force for blood movement, the vascular system plays an active role in regulating blood pressure and distributing blood flow to the various tissues.

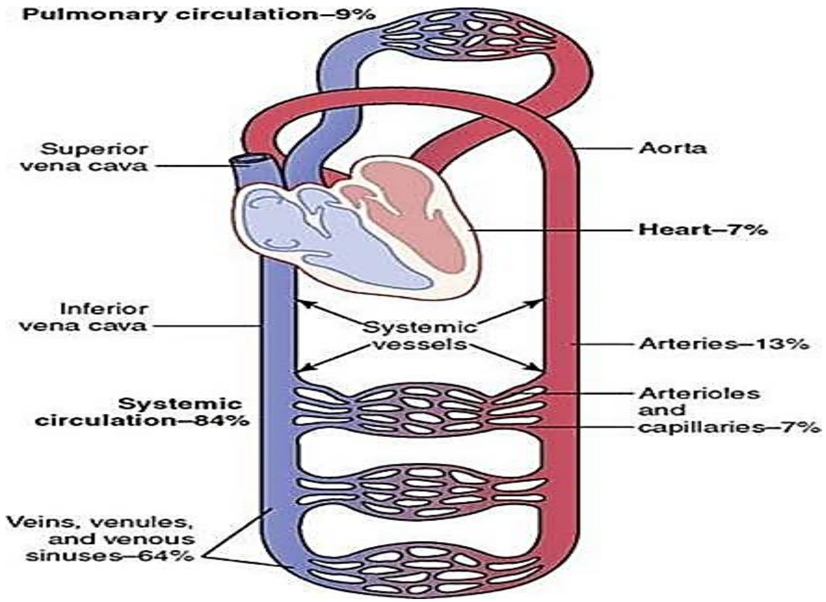
The blood vessels include:

- **Elastic vessels: aorta, pulmonary artery and large arteries.**
- **Resistance vessels: small arteries and arterioles (mainly arterioles).**
- **Exchange vessels: capillaries.**
- **Capacitance vessels (volume reservoir): veins.**


Large vein
Few layers of smooth muscle and connective tissue
Few elastic layers
Wide lumen
Endothelium
Inferior vena cava
Aorta
Large artery
Many layers of smooth muscle and connective tissue
Several elastic layers
Endothelium
Lumen
Venule
Endothelium
Connective tissue
Arteriole
Lumen
Smooth muscle cells
Endothelium
Endothelial cells
Capillary

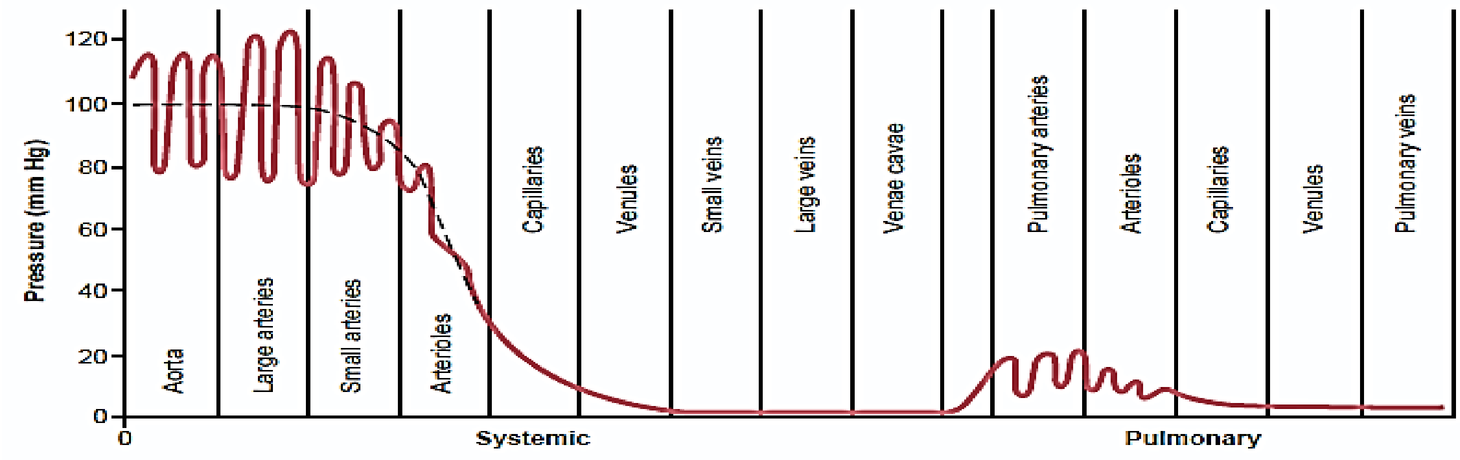
Volumes of blood in different parts of circulation

- Pulmonary circulation: 9%
- Heart: 7%
- Systemic circulation = 84% :
- ✓ Arteries: 13%
- ✓ Arterioles and capillaries: 7%
- ✓ Veins: 64%
- Systemic circulation= arteries + arterioles and capillaries+ veins= 13+7+64= 84%

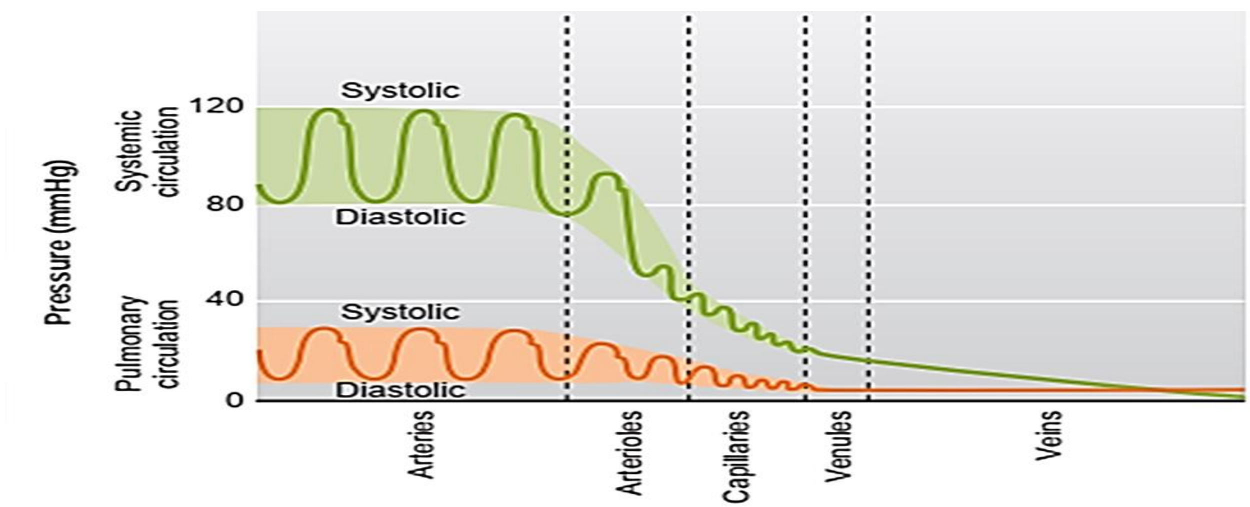


Pressures in various portions of circulation

- **High pressure system:** It is the arterial system (aorta, arteries and arterioles).
- **Low pressure system:** It consists of systemic veins, pulmonary vessels and heart chambers other than left ventricle.
- **Mean pressure in aorta averages about 90 mmHg**.
- Systolic blood pressure: Averages 120 mmHg.
- Diastolic blood pressure: Averages 80 mmHg.
- **Pulmonary artery systolic pressure averages about 25 mm Hg and diastolic pressure 8 mm Hg, with a mean pulmonary arterial pressure of only 16 mm Hg.**
- **The mean pulmonary capillary pressure averages only 7 mm Hg.**



Pressure (mm Hg)
120
100
80
60
40
20
0
0
Aorta
Large arteries
Small arteries
Arterioles
Capillaries
Venules
Small veins
Large veins
Venae cavae
Pulmonary arteries
Arterioles
Capillaries
Venules
Pulmonary veins
Systemic
Pulmonary



Pressure (mmHg)
Systemic circulation
Pulmonary circulation
120
80
40
0
Systolic
Diastolic
Systolic
Diastolic
Arteries
Arterioles
Capillaries
Venules
Veins

Biophysics of blood flow

The blood flow (F) through any organ:

- **It is directly proportionate to the pressure gradient (Δ P).**
- **It is inversely proportionate to resistance (R).**

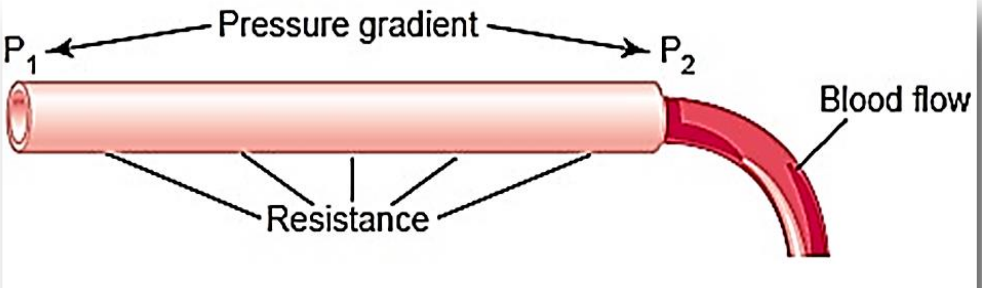


Figure 14–3

Interrelationships among pressure, resistance, and blood flow.

The blood flow (F) is represented by the following equation:

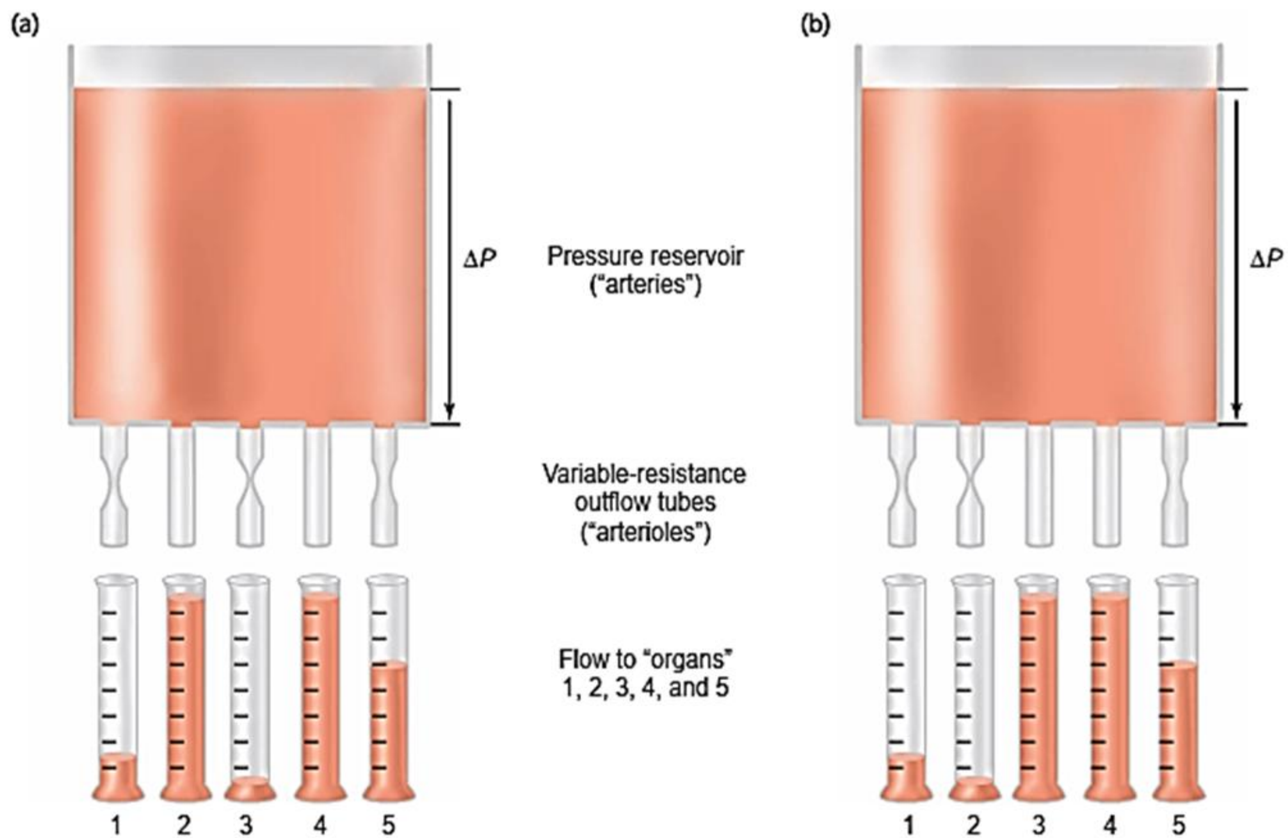
$$F = \frac{\text{Pressure gradient}}{\text{Resistance}} = \frac{\Delta P}{R}$$

F_{organ} = (MAP – Venous pressure)/Resistance $_{organ}$

Venous pressure is normally close to zero, so
F_{organ} = MAP/Resistance $_{organ}$

Mean arterial pressure (MAP):
The average pressure over a complete cardiac cycle of systole and diastole.
MAP is not the simple arithmetic mean of systolic and diastolic pressures.
MAP can be approximated by adding one third of the pulse pressure to the diastolic pressure.
Pulse pressure: It is the difference between systolic and diastolic blood pressure (SP – DP).
MAP = diastolic blood pressure + 1/3 pulse pressure.
Thus,
MAP = 80 + 1/3 (40) = 93 mmHg.

- Because the mean arterial pressure (MAP) is the same throughout the body, **differences in flows between organs** depend entirely on the relative **resistances of their respective arterioles**.
- Arterioles contain smooth muscle, which can either relax and cause the vessel radius to increase (vasodilation), or contract and decrease the vessel radius (vasoconstriction).



In the systemic circulation,

Since (F) = cardiac output (CO)

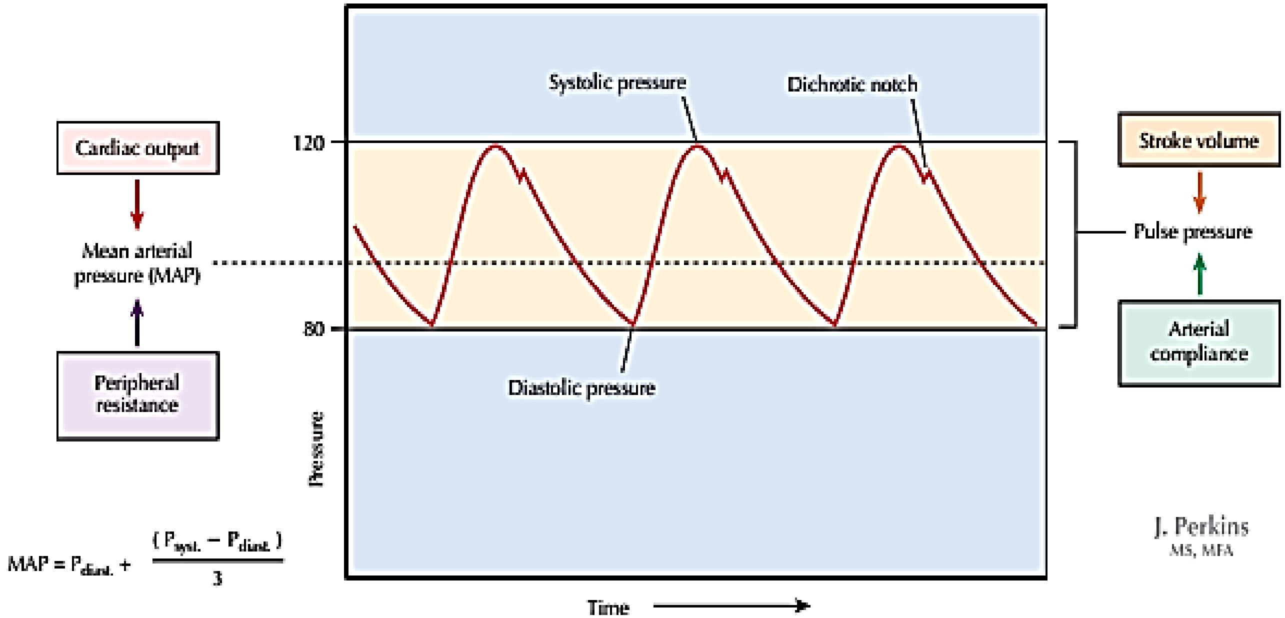
$$\text{So, CO} = \frac{\text{MAP}}{\text{R}}$$

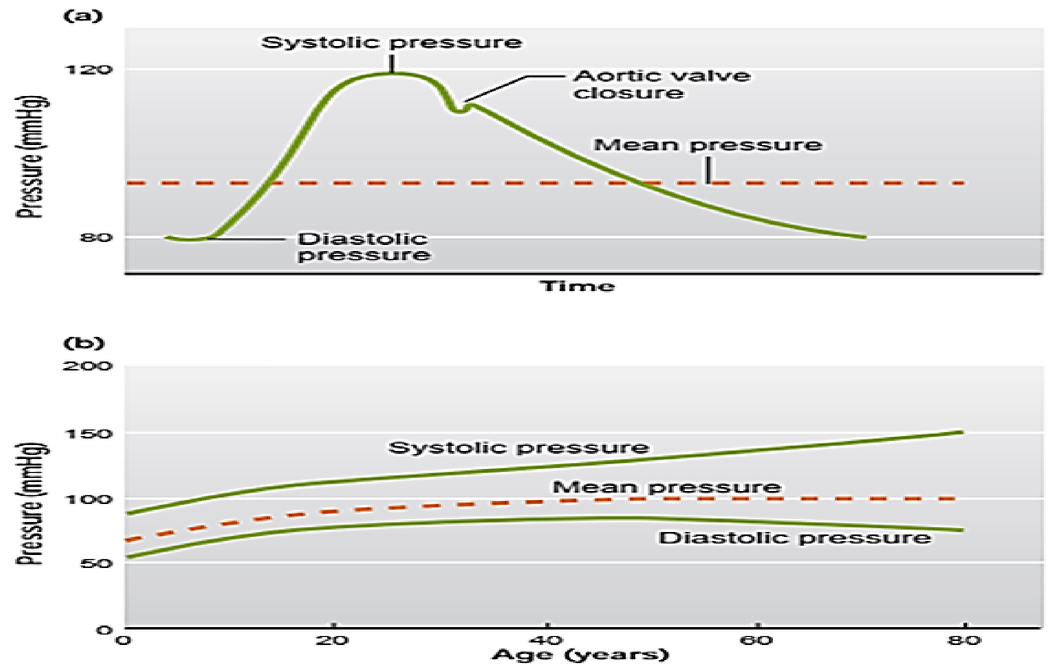
And

The MAP = CO X Peripheral resistance.

Mean arterial pressure (MAP):

It is dependent on CO and peripheral resistance (PR).


Systolic pressure
Dichrotic notch
120
80
Cardiac output
Mean arterial pressure (MAP)
Peripheral resistance
Diastolic pressure
Stroke volume
Pulse pressure
Arterial compliance
Pressure
Time
J. Perkins
MS, MFA
$MAP = P_{diast.} + \frac{(P_{syst.} - P_{diast.})}{3}$


(a)
Systolic pressure
120
Aortic valve closure
Mean pressure
Pressure (mmHg)
80
Diastolic pressure
Time
(b)
200
150
Systolic pressure
Mean pressure
100
Diastolic pressure
50
0
Pressure (mmHg)
0
20
40
60
80
Age (years)

Factors that affect peripheral resistance (PR)

Most of the resistance to blood flow occurs in the arterioles, so it is called peripheral.

The main factors that affect PR include the following:

1-Diameter (radius) of blood vessels (especially the arterioles).

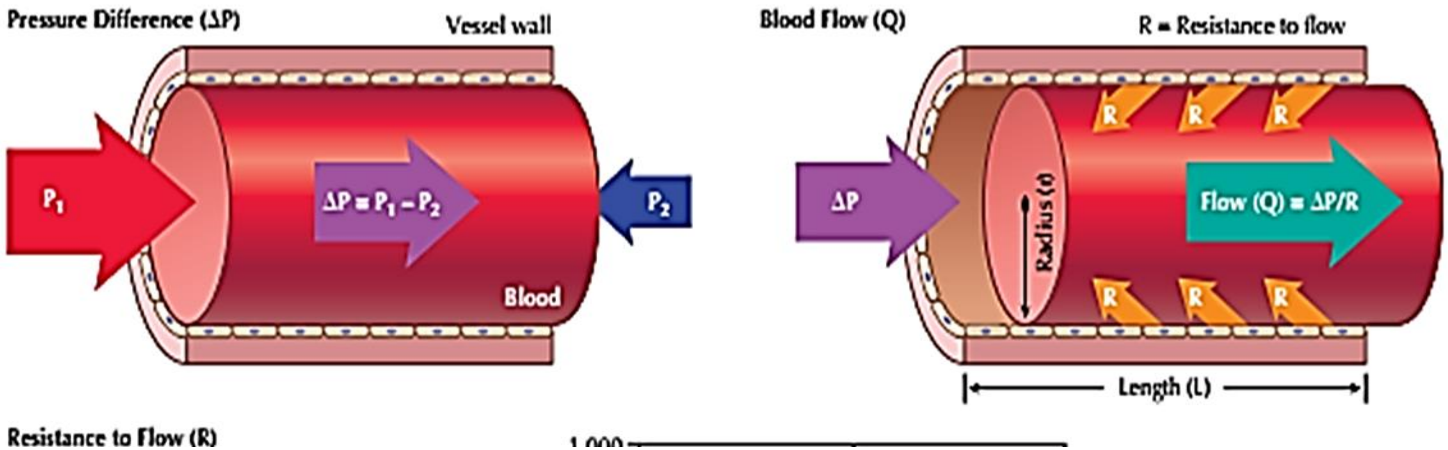
- **PR is inversely proportional to the arteriolar diameter (radius).**
- **Any factor that may cause vasoconstriction or vasodilation will affect the blood pressure by increasing or decreasing it respectively.**

2-Viscosity of blood:

- **It is about 3-4 times more than the viscosity of water.**
- **It is due to plasma proteins, and the blood cells (RBCs).**
- **Under normal circumstances, viscosity of blood is not an issue; however, changes in hematocrit (Hct) are associated with large changes in blood viscosity, as occur in anemia (decreased viscosity) and polycythemia (increased viscosity).**
- **PR is directly proportionate to the viscosity of the fluid.**

3-length of blood vessels:

- ✓ PR is directly proportionate to the length of the vessel.
- ✓ Length of blood vessels is constant in the human organism.
- o Of the factors affecting flow through a tube**, the most important is the radius** of the tube **(diameter of blood vessel)**.
- o Physiological regulation of regional blood flow mainly involves changes in **radius** (vasodilation and vasoconstriction) of the small arteries and **arterioles**.



Measurement of blood flow (F)

F can be measured by:

1. Using the Doppler flowmeter.
2. Applying the Fick's principle.
3. Plethysmography.
4. Special method:

Renal blood flow (RBF) can be determined using the clearance of PAH and Hct.

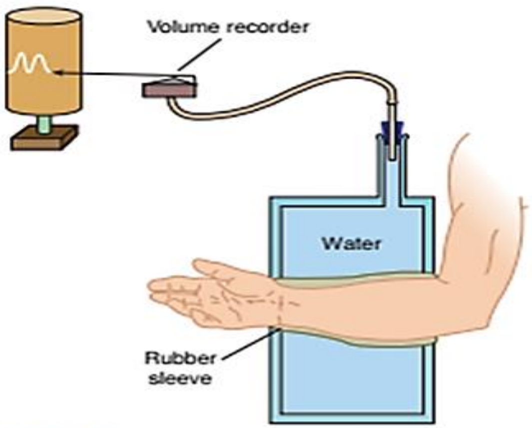
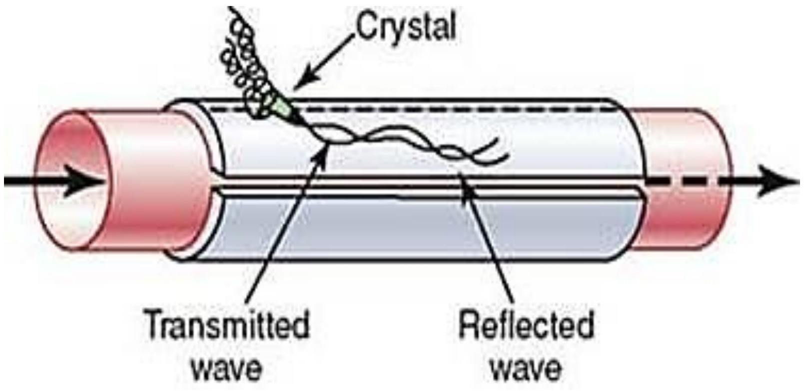


FIGURE 32–20 Plethysmography.



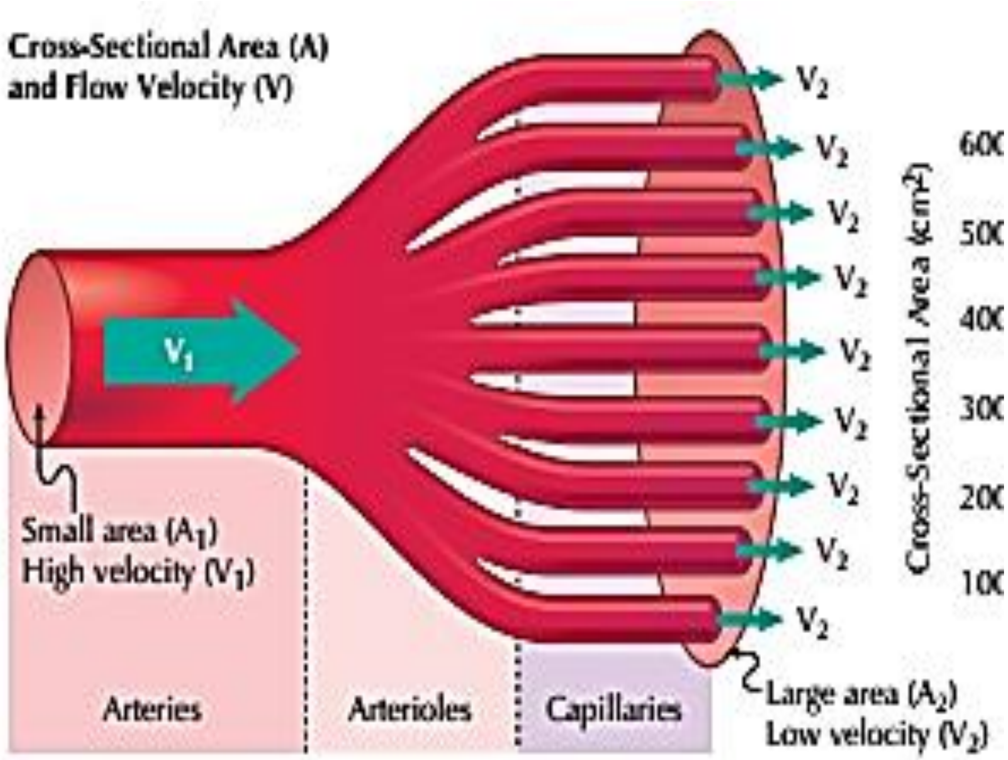
VELOCITY OF BLOOD FLOW

Blood velocity is calculated by dividing the blood flow (ml/second) / cross sectional area (cm^2).

Blood velocity at any point in circulatory system is inversely proportional to the total cross sectional area at that point.

In the aorta : **The blood flow (= CO) is about 90 ml/second and its cross sectional area is a b o u t 2.5 cm^2 . S o , velocity of blood flow = 90/2.5 = 36 cm/second.**

In capillaries: **Velocity of blood flow is slow (0.2-0.3 mm/second) as the cross sectional area of capillaries is wide (3 0 0 0 - 4500 cm^2)**



Cross-Sectional Area (A)
and Flow Velocity (V)
V1
V2
Small area (A1)
High velocity (V1)
Large area (A2)
Low velocity (V2)
Arteries
Arterioles
Capillaries
Cross-Sectional Area (cm2)

Types of blood flow

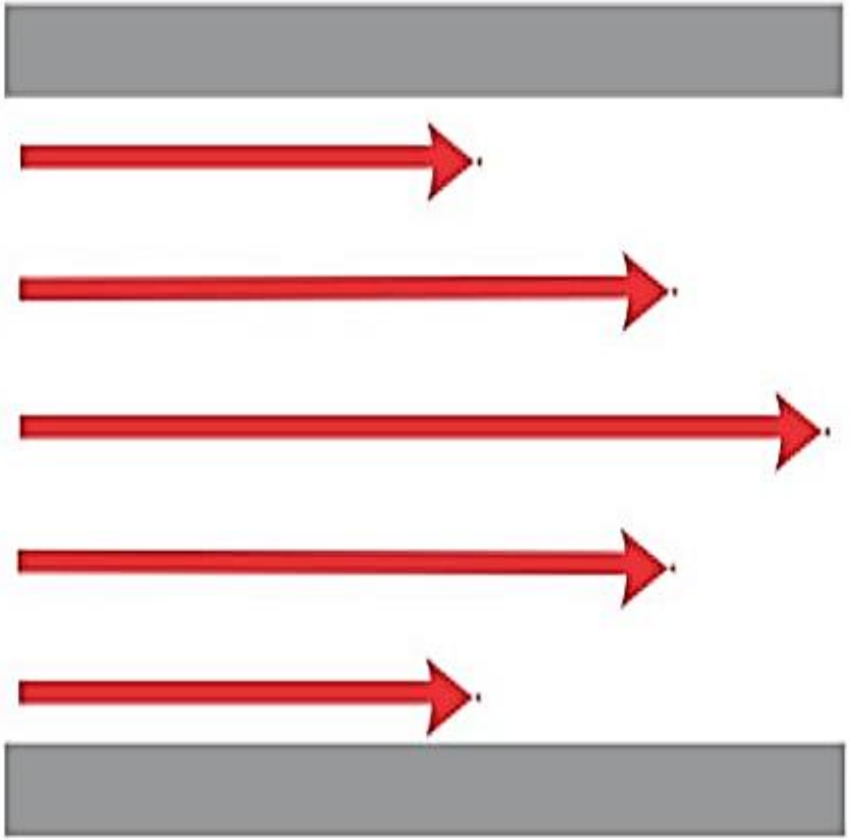
(1) Laminar (streamline):

- **This is the normal smooth flow of blood.**
- **It is silent and laminar.**

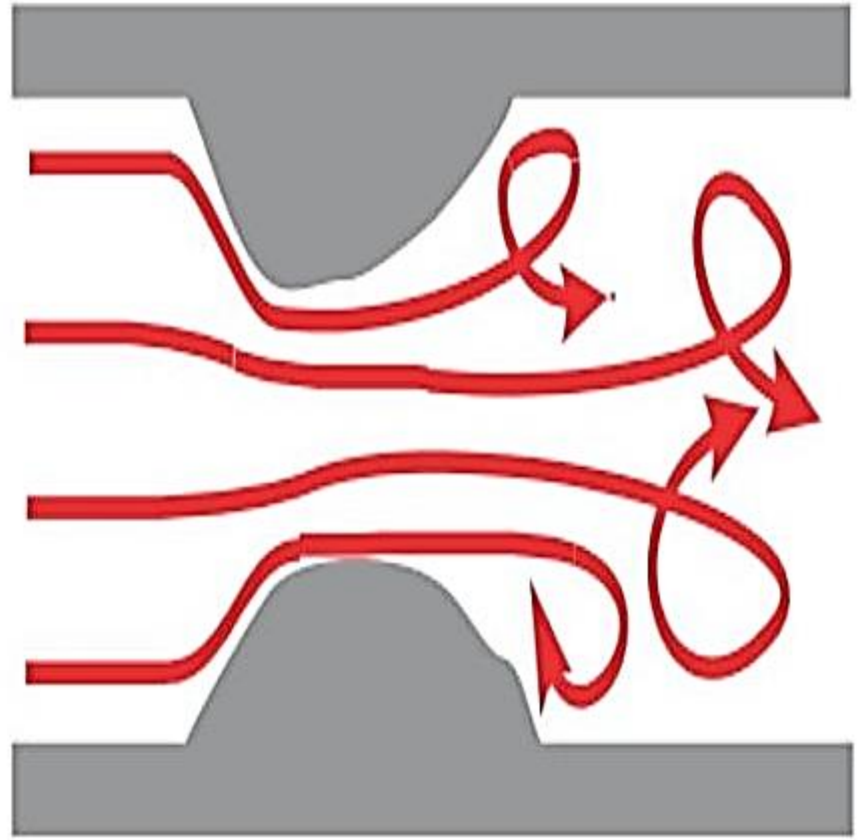
The blood flows in several layers or laminae. The outermost layer of blood in contact with the vessel wall is almost completely static (wall stress; a type of shear stress) while the other layers move by velocities that increase gradually from out inwards till becoming maximal in the central layer of the stream. **Beyond a certain critical velocity, turbulence occurs.**

(2) Turbulent:

- **This is disturbed blood flow in the form of eddies in various directions.**
- **It produces sounds (= bruits or murmurs) which can be heard by stethoscope. It especially occurs when critical velocity exceeded.**



Laminar Flow

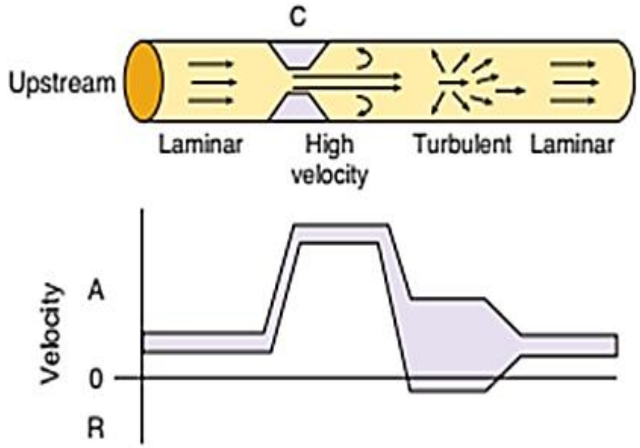


Turbulent Flow

- In addition to blood velocity, blood viscosity as well as diameter of the vessel are also contributing factors in producing turbulence.

- Turbulence occurs pathologically due to increased blood velocity in the following conditions:

✓ Beyond points of constriction in arteries. This produces abnormal sounds (e.g. the bruits heard over arterial areas constricted by atherosclerotic plaques).
✓ In severe anemia (in which blood velocity increases due to reduction of its viscosity). In such cases, turbulence may produce systolic murmurs.



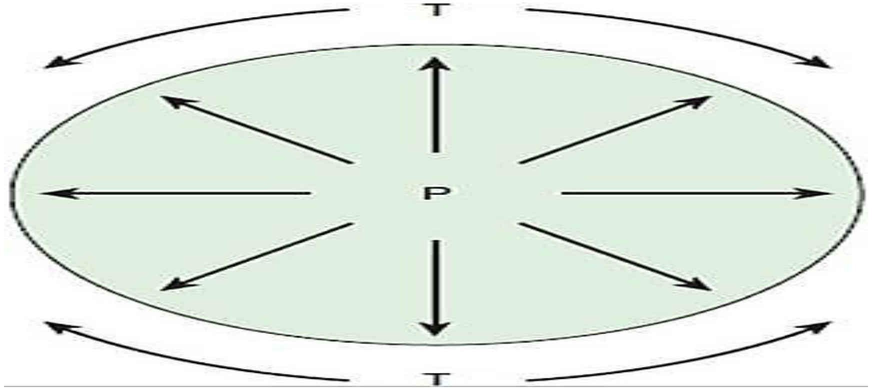
LAW OF LAPLACE

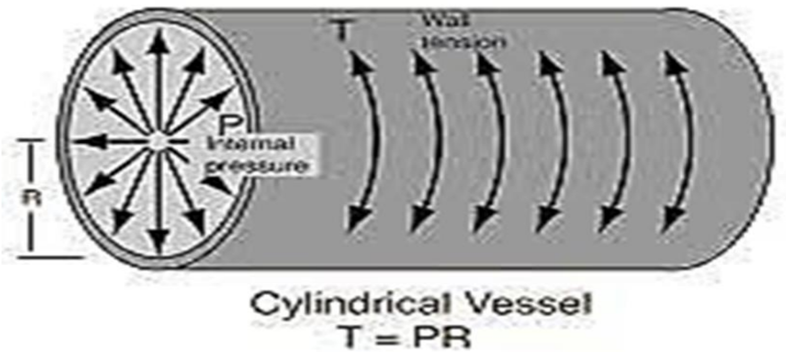
This law states that tension (T) in the wall of a cylinder (as blood vessels) is equal to the product of the transmural pressure (P_t) and the radius (r)

The tension (T) = distending pressure (P_t) x radius (r)

$T = P \times r$

It also applies to hollow viscus e.g. the urinary bladder, lung alveoli and stomach.






thank
you