Haemodynamics

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Haemodynamics

- The function of the circulation is to serve the needs of the body tissues to transport nutrients, waste products hormones, and to maintain homeostasis.
- The heart and blood vessels are controlled to provide the necessary **blood flow**.
- The term hemodynamics refers to the **principles that govern blood flow in the cardiovascular system.**
- These basic principles of physics are the same as those applied to **the movement of fluids in general**.
- **Haeodynamics** is the study of the relationships between pressure, resistance and the flow of blood in the cardiovascular system.

Functional parts of the circulation

- **Arteries**: transport blood under high pressure and high velocity to the tissues → they have Thick ,strong, **elastic** vascular wall, blood in arteries " stressed volume".
- **Arterioles**: have strong muscular walls that dilate or constrict in response to neurohormonal stimuli. They are the main control on peripheral resistance **(resistance vessels**) and consequently on blood pressure and blood flow to tissues.

Functional parts of the circulation

- **Capillaries**: **(exchange vessels).** Their walls are thin and have numerous pores and have the largest total surface area.
- ⇨ **Venules**: The venules collect blood from the capillaries and gradually coalesce into progressively larger veins.
- ⇨ **Veins**: Thin walled vessels that have the highest ***capacitance (or compliance)*** in the CV system **(capacitance vessels**). Veins serve as a **controllable reservoir** of extra blood.

Capacitance (Compliance)

- **Compliance** is change in **volume** per unit change in **pressure**.

$$\mathbf{C = \Delta V / \Delta P}$$

(C = capacitance (ml/ mm Hg), V = volume (ml) & P = pressure in mm Hg).

- Capacitance describes distensibility of a blood vessel.
- It is inversely related to elastance.
- Veins are more compliant than arteries *i.e. a large amount of blood can be added to the vein without a large rise in venous pressure* so; more blood is stored in veins than in arteries.

Capacitance (Compliance)

- With aging, vessels stiffen and become less compliant.
- When extra blood is administered by transfusion, less than 1% is distributed in the arterial system and more than 99% in the systemic veins, pulmonary circulation (**the low-pressure system).**
- The large blood storage capacity of the venous system can be explained by:

1. Large cross-sectional area (4 times those of the corresponding arteries).
2. Less elasticity.

Volumes of Blood in the Different Parts of the Circulation

1. **<u>84 % in the systemic circulation</u>**

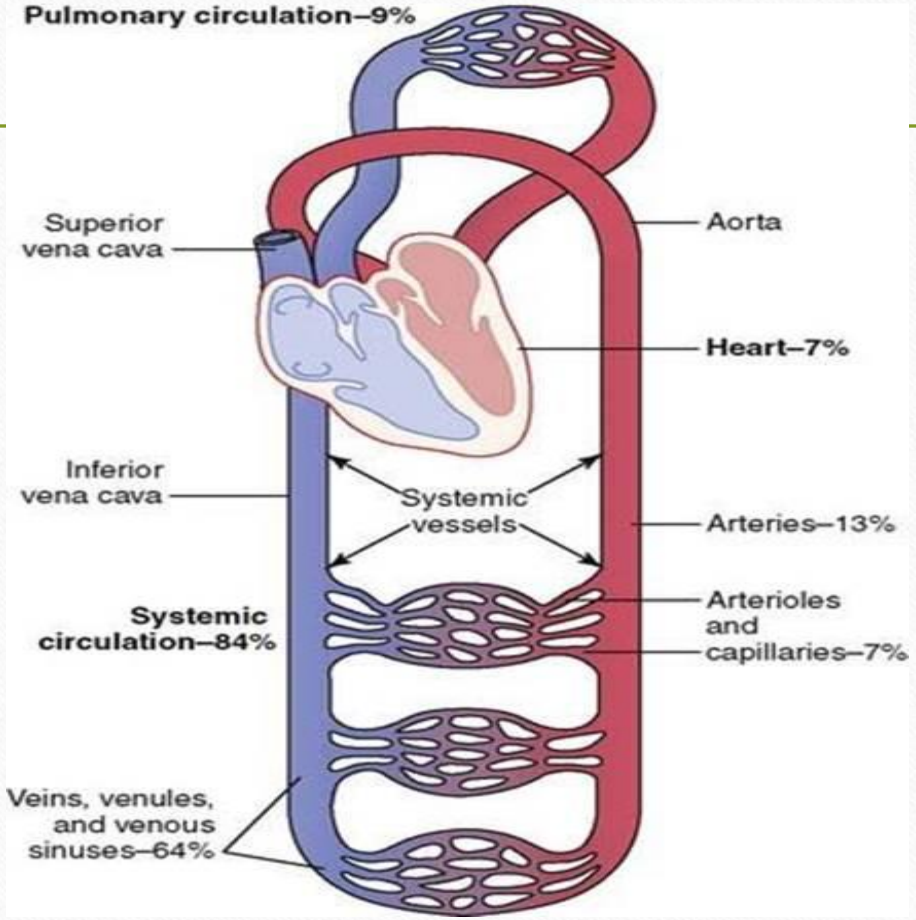
64 % is in the veins

13 % is in the arteries

7 % is in the arterioles and capillaries.

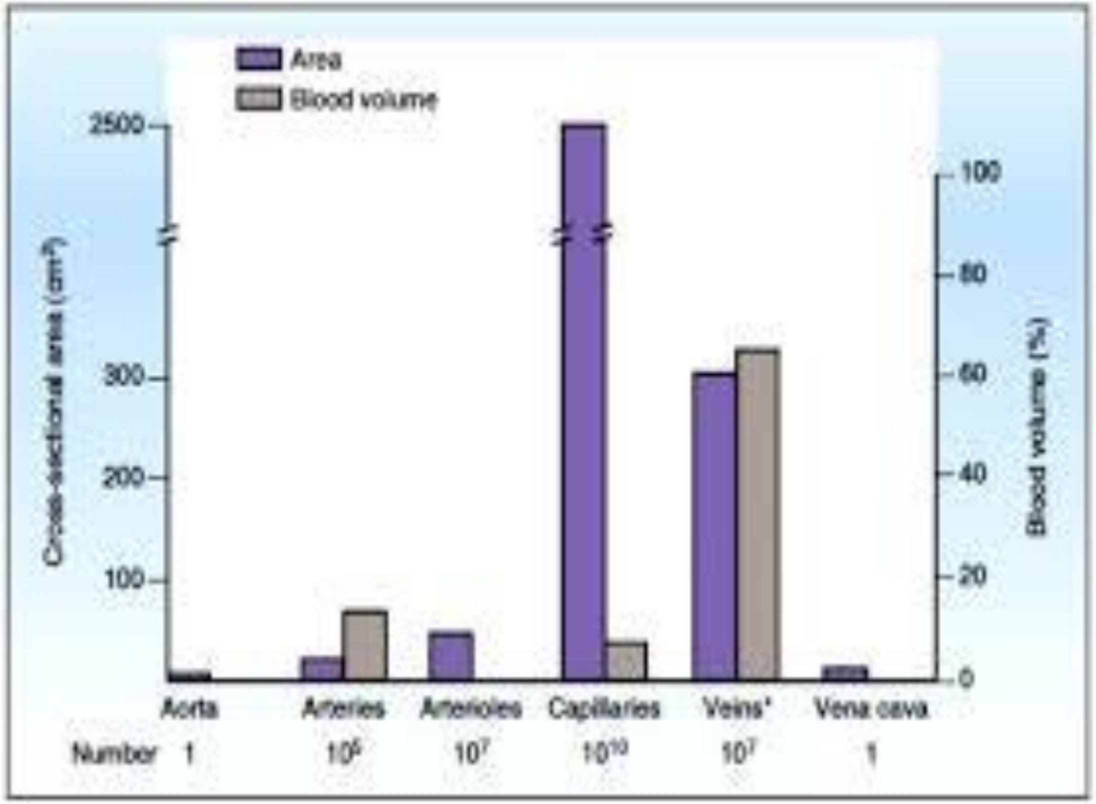
2. **<u>16 % is in the heart and lungs.</u>**

The heart contains 7 % of the blood, and the pulmonary vessels 9 %.



Cross-Sectional
Areas and Velocities of Blood Flow

- all the *systemic vessels* of each type were put side by side, their approximate total cross-sectional areas would be as follows:
- **Aorta 2.5**
- **Small arteries 20**
- **Arterioles 40**
- **Capillaries 2500**
- **Venules 250**
- **Small veins 80**
- **Venae cavae 8**



Velocity of Blood Flow

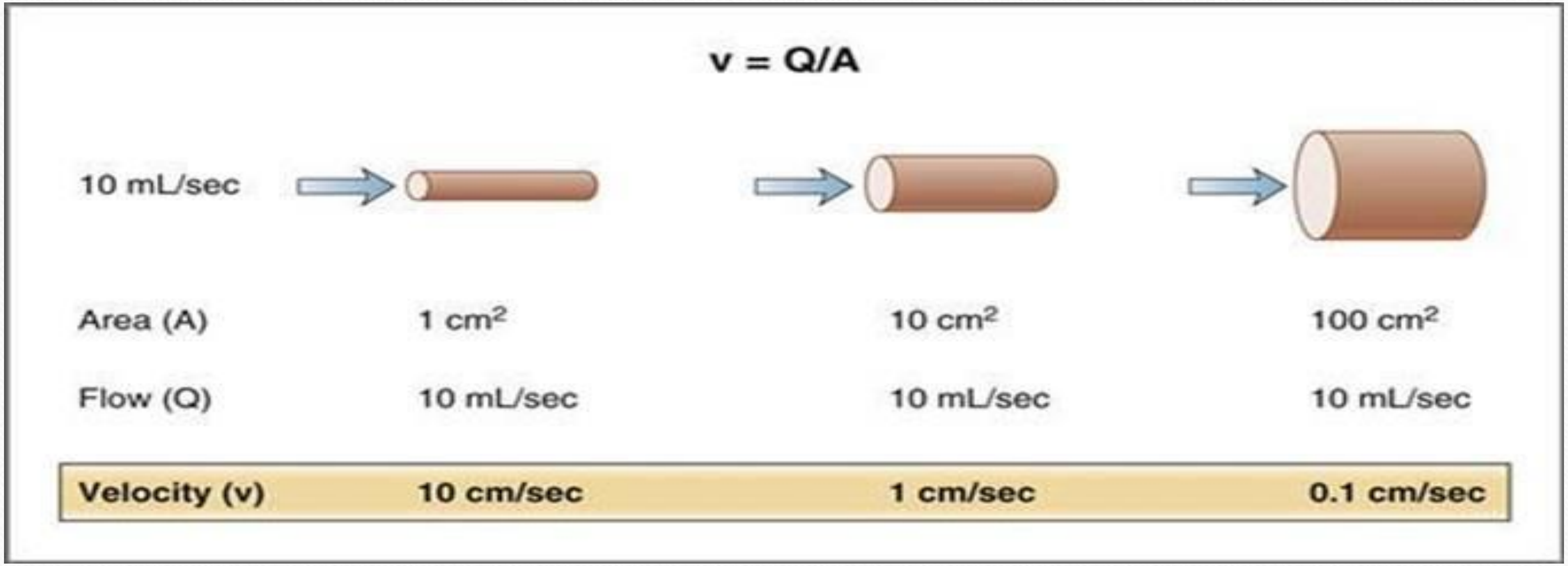
- V= F/ A

V = velocity, F (Q) = flow, A= cross sectional area.

Velocity of Blood Flow

- Velocity is directly proportional to blood flow and inversely proportional to area.
- Blood flow velocity in the aorta (33 cm/sec) is greater than in the capillaries (0.3 mm/sec) .
- Blood velocity in veins is less than that in arteries due to the greater cross sectional area in veins.

Effect of the diameter of the blood vessel on the velocity of blood flow



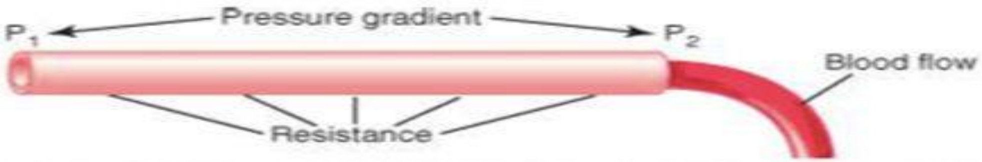
Relationships Between Blood Flow, Pressure and Resistance

- **BLOOD FLOW:** the quantity of blood that passes a given point in the circulation in a given period of time.
- **Blood flow through a blood vessel is determined by two factors:**

1) ***Pressure gradient*** between the two ends of the vessel.

2) **The *resistance to blood flow through the vessel***: It occurs as a result of friction between the flowing blood and the endothelium along the inside of the vessel.

Ohm's Law Applied to Blood Flow



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

F = blood flow

ΔP = pressure difference (P_1-P_2)

R = resistance

Ohm's law

$$\mathbf{F\ (Q) = \Delta P\ /\ R}$$

F or Q = flow, ΔP =(P1 – P2) = the pressure difference between the two ends of the vessel, R = resistance

$$\mathbf{\Delta P = F \times R}$$

$$\mathbf{R = \Delta P\ /\ F}$$

Ohm's law

- Resistance (R) is directly proportional with the pressure gradient (ΔP) and inversely proportional with the blood flow (Q).
- **Pressure gradient** drives flow from high pressure (e.g. aorta) to low pressure (e.g. vena cava).

Measurement of Resistance

- calculated from measurements of blood flow and pressure difference.

$$\mathbf{F\ (Q) = MABP - CVP/\ TPR}$$

MABP = mean arterial blood pressure

CVP = central venous pressure

TPR = total peripheral resistance

Measurement of Resistance

1. The rate of blood flow **(Q)** through the entire circulatory system is approximately **=** 100 ml/sec.
2. The pressure difference (ΔP) from the systemic arteries to the systemic veins is about 100 mm Hg (MABP = 100 & CVP = 0).
3. The *total peripheral resistance* is about 100/100, or 1 PRU.

Total Pulmonary Vascular Resistance:

- Blood flow in pulmonary circulation = blood flow in systemic circulation.
- Both Pressure gradient and resistance in pulmonary circulation are less than that in systemic circulation by 6-7 times.
- MABP in pulmonary circulation = 14 mmHg.
- TPR = 0.14 so Q = 14 / 0.14 = 100 ml/sec as systemic circulation.

Peripheral resistance and arterial blood pressure

- Peripheral resistance is one of the factors that affect the arterial blood pressure.
- ABP is directly proportional with peripheral resistance (PR).
- ↑PR → ↑ ABP (mainly diastolic BP)
- Hence (Q or F = ΔP /R)
- The blood flow (Q or F) is equal to the cardiac output (COP)
- ΔP = (ABP – central venous pressure which equal zero) so ΔP = ABP
- So, **COP = ABP / PR** or **ABP = COP x PR**

POISEUILLE-HAGEN FORMULA

$$Q = \frac{\Delta P \pi r^4}{8 \eta l}$$

- **Q or F = blood flow**
- **ΔP = pressure difference between the vessel end.**
- **r = radius of the blood vessels**
- **η = viscosity of the blood**
- **ι = length of the blood vessel**

POISEUILLE-HAGEN FORMULA
Factors affecting resistance

$$R = \frac{8\eta l}{\pi r^4}$$

1-Diameter (twice the radius) of the blood vessels

- Resistance is inversely proportional to the fourth power of the radius, so increasing the radius by 2 times decreases the resistance and increases the blood flow 16 times ($2^4 = 16$).
- ***Fourth power law:*** 4 fold increase in blood vessel diameter → 256 fold increase in blood flow
- Strong sympathetic stimulation, some hormones such as *norepinephrine*, *angiotensin II*, *vasopressin*, or *endothelin* and drugs that can cause **vasoconstriction →** increase in R.

Vasodilation → Decrease in R.

Resistance in Series Vascular Circuits

- The arteries, arterioles, capillaries, venules, and veins are arranged in series.
- When blood flow through each blood vessel is the same, the total resistance to blood flow (Rtotal) is equal to the sum of the resistances of each vessel:
- **R total = R1 + R2 + R3 + R4 …**

Resistance in Parallel Vascular Circuits

- Blood vessels branch extensively to form parallel circuits that supply all body organs.
- This parallel arrangement permits each tissue to regulate its own blood flow independently of flow to other tissues.
- Parallel blood vessels make it easier for blood to flow through the circuit because each parallel vessel provides another pathway for blood flow.

Resistance in Parallel Vascular Circuits

- For blood vessels arranged in parallel, the total resistance to blood flow is expressed as:

$$\frac{1}{Rtotal} = \frac{1}{R1} + \frac{1}{R2} + \ldots + \frac{1}{Rn}$$

- adding more blood vessels to a circuit reduces the total vascular resistance. Many parallel blood vessels, however, make it easier for blood to flow through the circuit because each parallel vessel provides another pathway for blood flow.

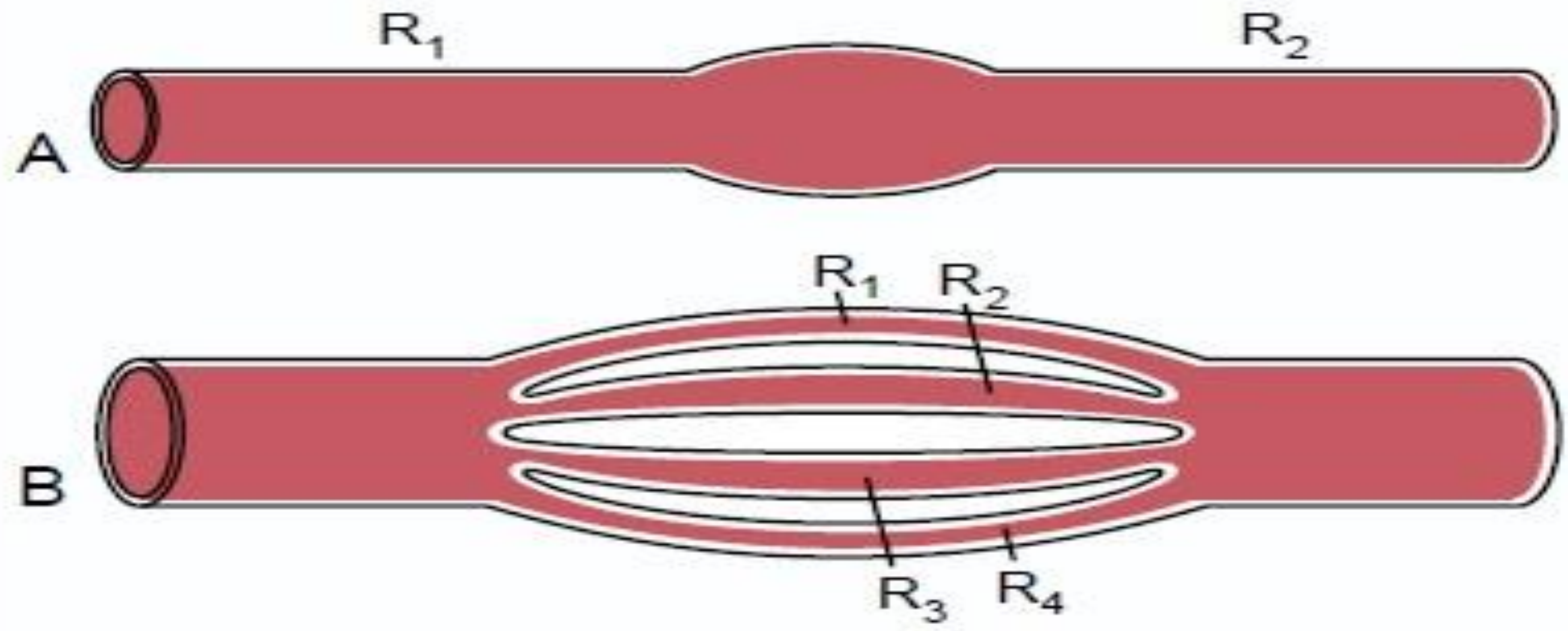


Figure 14–10

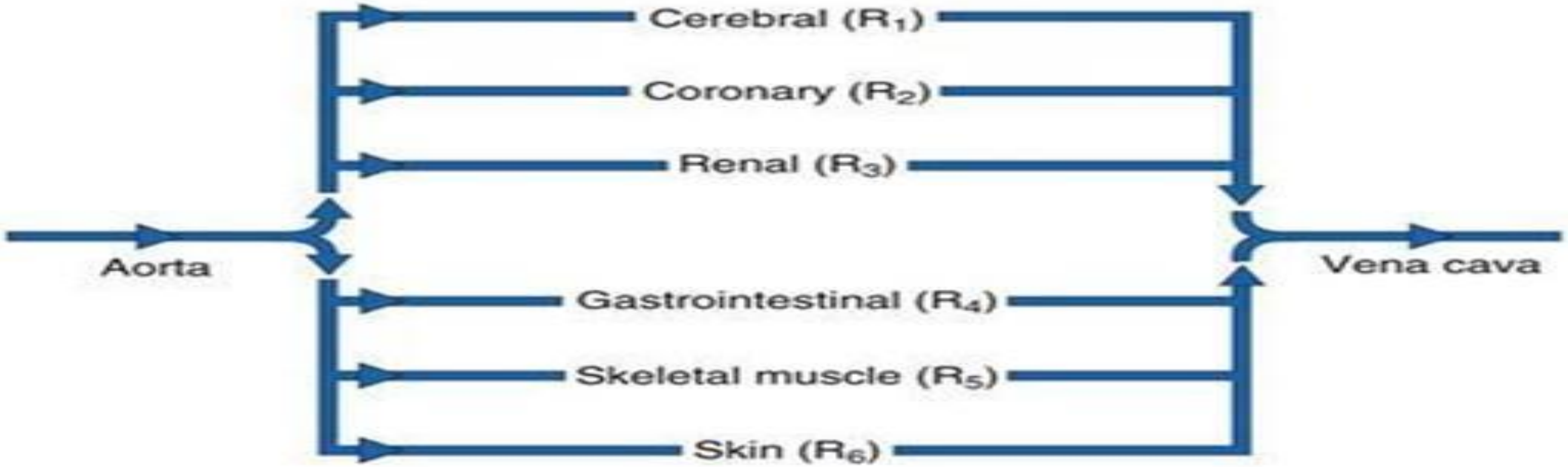
Vascular resistances: *A*, in series and *B*, in parallel.

SERIES RESISTANCES

$$R_{total} = R_1 + R_2 + R_3 + R_4 + R_5$$

PARALLEL RESISTANCES

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6}$$



2- Effect of Blood Viscosity on Vascular Resistance

- The greater the viscosity, the greater the resistance and the lower the flow in a vessel.
- *Blood viscosity is about 3-5 times as great as the viscosity of water* which means that 3-5 times as much pressure is required to force whole blood as to force water through the same blood vessel.
- **Viscosity is mainly due to:** -Large numbers of RBCs (the main factor). -Plasma protein.
- Viscosity ↑ in **polycythemia** & in hyperproteinemia.
- Viscosity ↓ in **anemia** & in **hypoproteinaemia**.

3- Length of blood vessel

- It is of little value in regulation of ABP as the length of vessels is constant in the same person.
- Increase ***length of vessels*** increases the ***resistance*** and consequently raises the ***ABP.***
- This explains the higher blood pressure in adults than children and the higher blood pressure in big animals e.g. elephant than small animals e.g. rats.
- Giraffe BP is the highest of all animals, reaching about 300/200

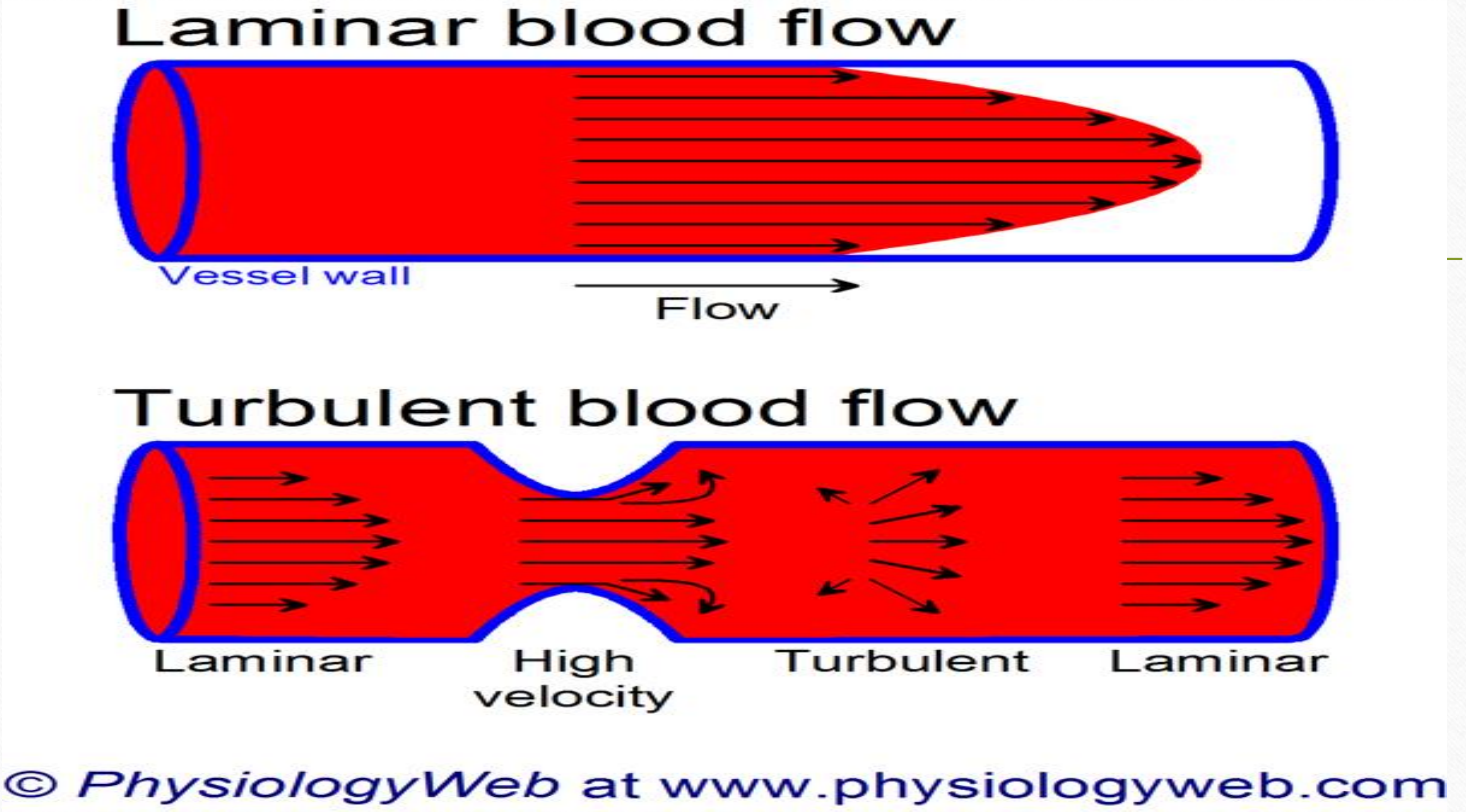
Laminar Flow

- When blood flows at a steady rate through a long smooth blood vessel, it flows in streamlines, with each layer of blood remaining at the same distance from the vessel wall.

- Laminar flow is streamlined ,The thin layer of blood in contact with the wall of the vessel does not move. The next layer has a low velocity, the next a higher velocity, and so forth, velocity being greatest in the center of the stream.

Turbulent Flow of Blood

- *turbulent flow*, which is blood flowing in all directions in the vessel and continually mixing in the vessel.
- When the rate of blood flow becomes too great, when it passes by an obstruction in a vessel, when it makes a sharp turn, or when it passes over a rough surface, the flow may then become *turbulent*,
- Turbulent flow means that the blood flows crosswise in the vessel and along the vessel, usually forming whorls in the blood, called *eddy currents*.
- These eddy currents are similar to the whirlpools that can be seen in a rapidly flowing river at a point of obstruction.


Laminar blood flow
Vessel wall
Flow
Turbulent blood flow
Laminar
High velocity
Turbulent
Laminar
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