GENERAL PHYSIOLOGY
(LECTURE 27)
THE VASCULAR SYSTEM

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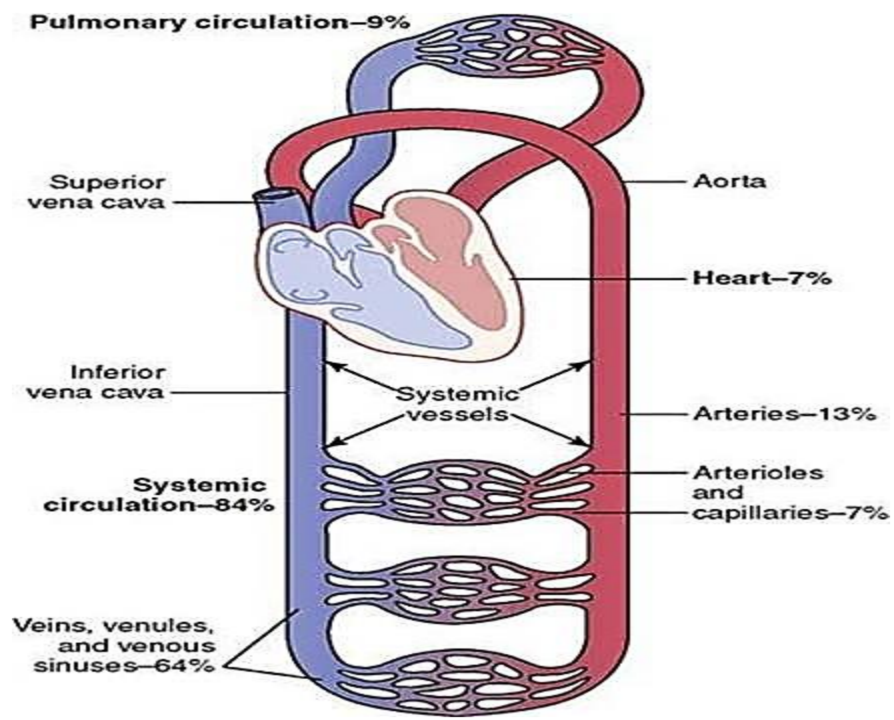
THE VASCULAR SYSTEM

The blood vessels include:

- Elastic vessels: aorta, pulmonary artery and large arteries.
- Low resistance vessels: medium-sized and small arteries.
- High resistance vessels: arterioles.
- Exchange vessels: capillaries.
- Capacitance vessels : veins.

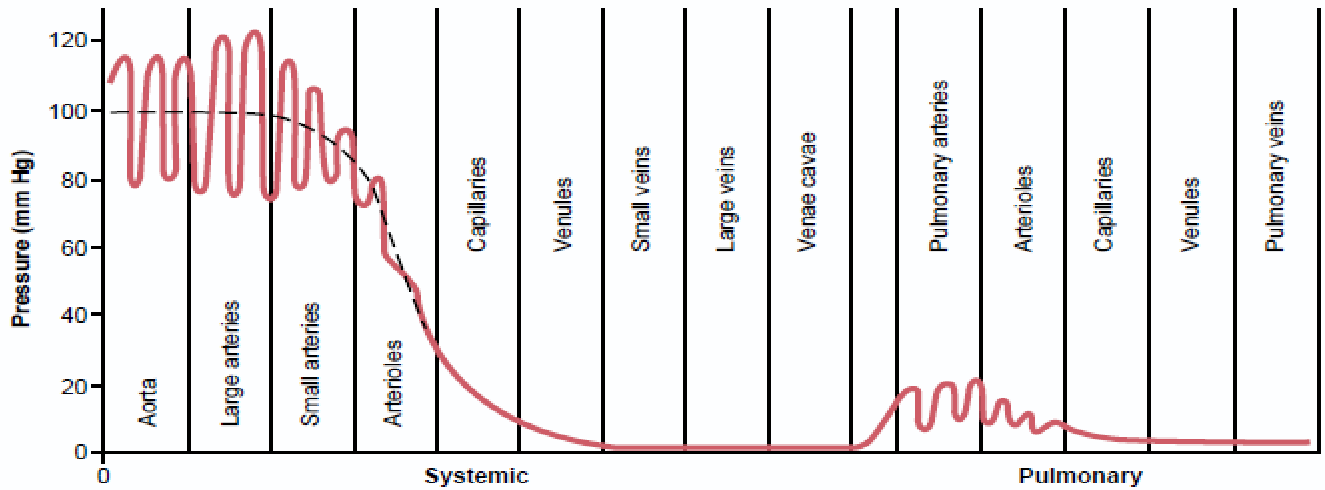
Volumes of blood in different parts of circulation

- Pulmonary circulation: 9%
- Heart: 7%
- 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

- Mean pressure in aorta averages about 90 mmHg.
- Systolic blood pressure: 120 mmHg.
- Diastolic blood pressure: 80 mmHg.
- Right atrium: 0 mmHg.
- The pressure in the systemic capillaries varies from as high as 35 mm Hg near the arteriolar ends to as low as 10 mm Hg near the venous ends.
- 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.



Biophysics of blood flow

The blood flow rate (F):

It is directly proportionate to the pressure gradient (difference between the mean arterial B.P. and the atrial pressure) and inversely proportionate to the peripheral resistance.

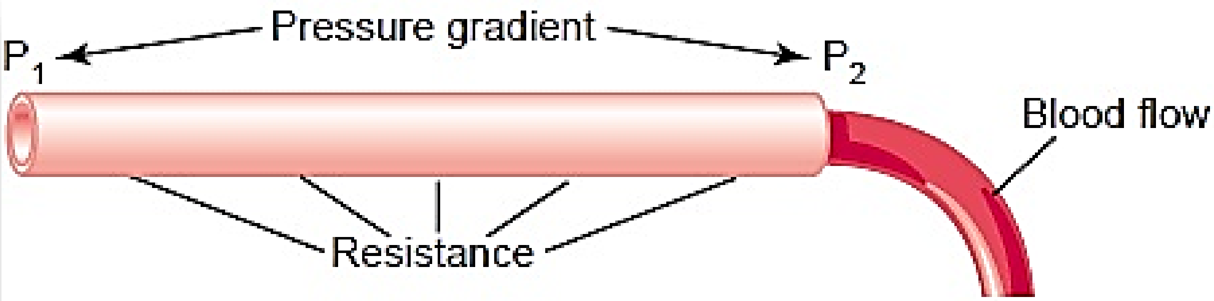


Figure 14–3

Interrelationships among pressure, resistance, and blood flow.

Therefore,

$$F = \frac{\textbf{Pressure gradient}}{\textbf{peripheral resistance}}$$

In the systemic circulation, since (F) = cardiac output (CO), and the pressure gradient= mean systemic arterial B.P. (because the right atrial pressure is almost zero),

$$\text{So, CO} = \frac{\text{mean systemic arterial B.P.}}{\text{peripheral resistance}}$$

And

The mean systemic arterial B.P. = CO X peripheral resistance.

Factors that affect peripheral resistance (R)

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

The main factors that affect R include the following:

1-Diameter of blood vessels (especially the arterioles). R is inversely proportional to the arteriolar diameter. 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). Viscosity is increased by dehydration and polycythemia, and decreased by anemia and hypoproteinemia.

3-length of blood vessels: It is constant in the human organism, so it would not involved in the determinants.

Because the lengths of blood vessels are constant and the changes in viscosity are normally relatively small, these factors only share in producing peripheral resistance but play no role in its regulation. Consequently, **the diameters of blood vessels remains the most important factor that regulates R**.

Determinants of peripheral resistance (R)

R can't be directly measured but can be calculated from F and the pressure gradient as follows:

Since $F = \frac{\text{pressure gradient}}{(R)}$,

Then pressure gradient= (F) X (R)

and

$R = \frac{\text{pressure gradient}}{(F)}$

Accordingly, R can be obtained by dividing the pressure gradient (in mmHg) by the flow (in ml/second) and the result is expressed in R units (one R unit refers to the resistance that allows the flow of 1 ml blood/second at a pressure gradient of 1 mmHg), e.g. in the systemic circulation, if F (the left ventricular CO) is 90 ml/second and the pressure gradient is 90 mmHg, then R= 90/90= 1 R unit.

VELOCITY OF BLOOD FLOW

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

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

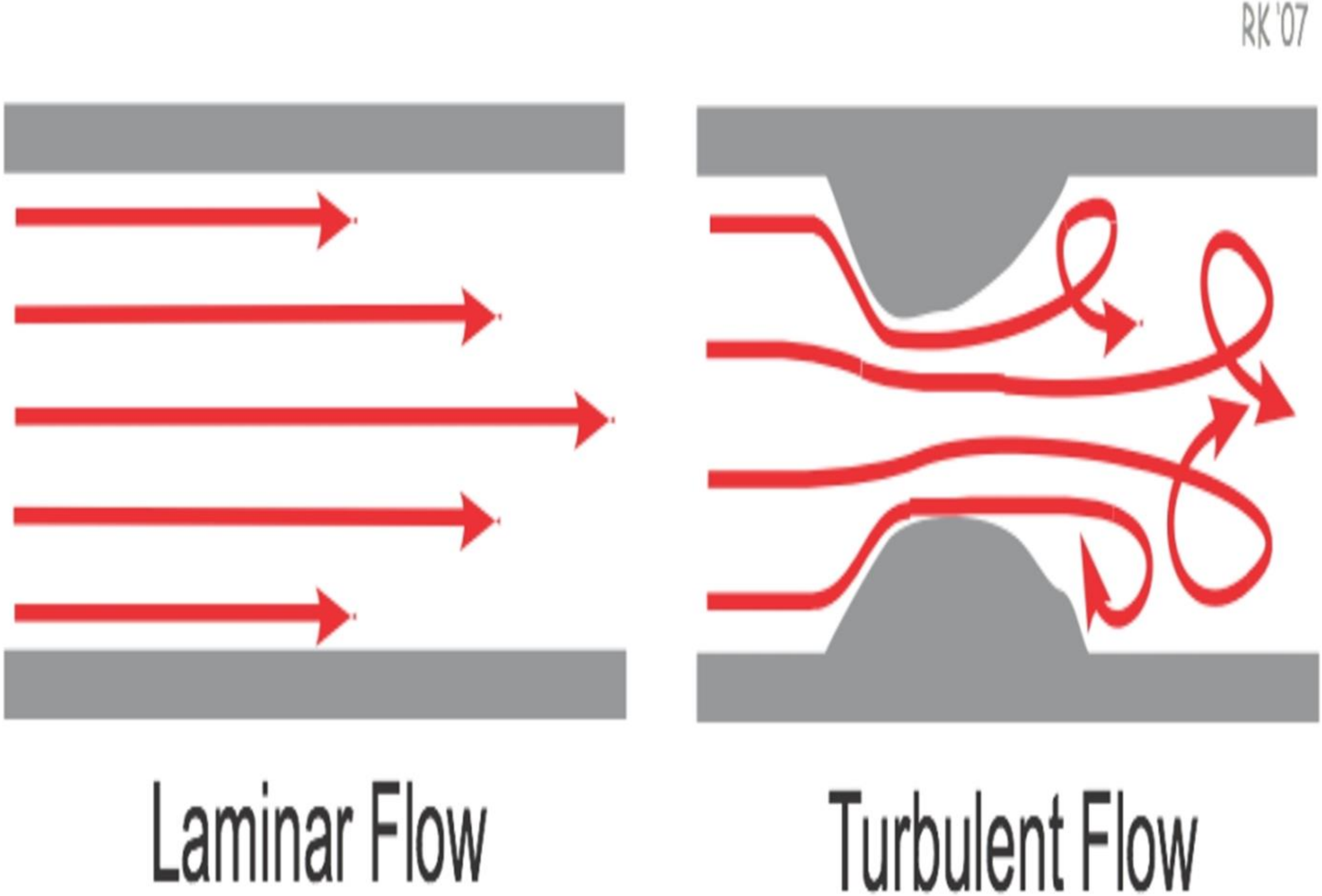
In the aorta : the blood flow rate (COP) is about 90 ml/second and its cross sectional area is 2.5 cm^2 . So, Velocity of blood flow = 90/2.5 = 36 cm/second.

In capillaries: Velocity of blood flow is slow (0.2-0.3 mm/second) as the cross sectional area of capillaries is wide (3000 - 4500 cm^2)

Types of blood flow

(1) Laminar (streamline): **This is the normal smooth flow of blood. It is silent and laminar.**

(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.**


RK '07
Laminar Flow
Turbulent Flow

Cause of laminar (streamline) flow

Wall stress (a type of shear stress):
When a fluid, in this case, blood, flows through a pipe, friction exists between the fluid and the wall of the tube. This friction decreases the velocity of the blood closest to the wall (hence the shorter lines are closer to the tube wall).

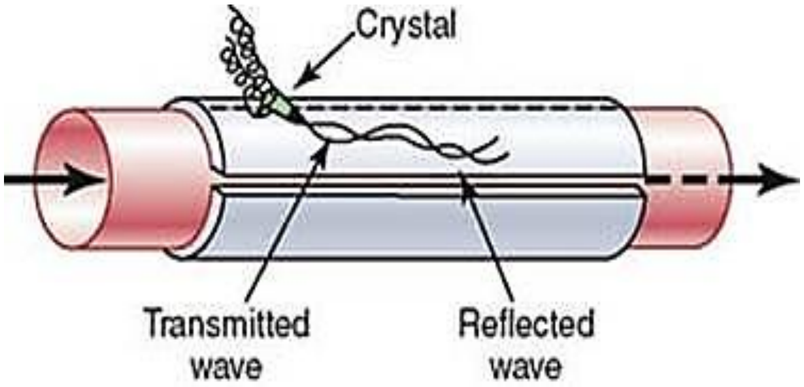
Causes of turbulent flow

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

Measurement of blood flow rate (F)

F can be measured by:

1. Using the electromagnetic and ultrasonic Doppler flowmeter.
2. Applying the Fick's principle.
3. Plethysmography.

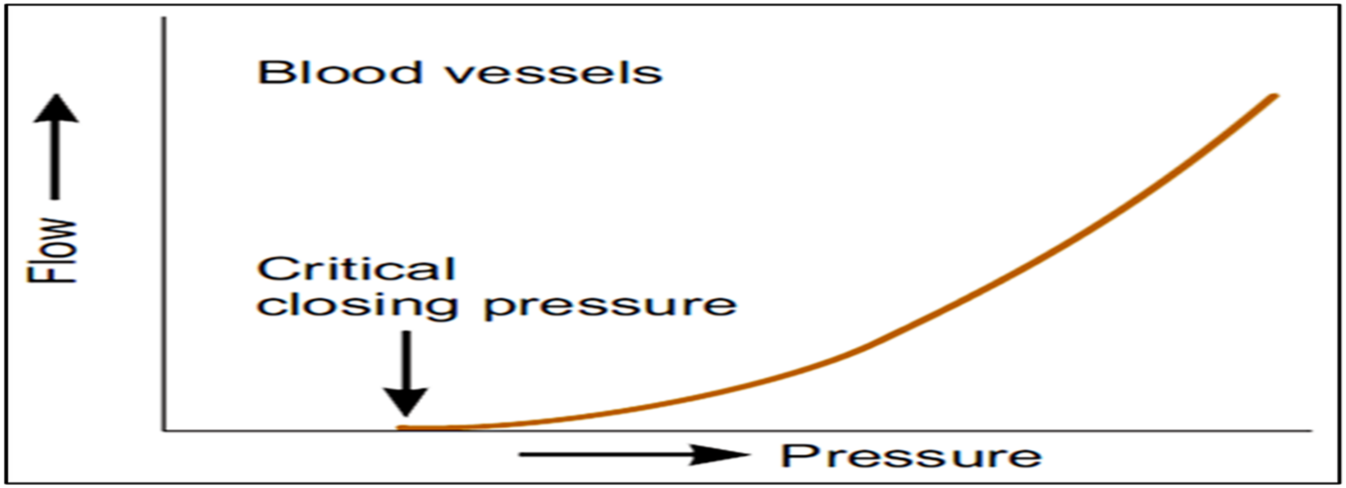


THE CRITICAL CLOSING PRESSURE

When the pressure in a small blood vessel (= intraluminal pressure) is decreased, the blood flow is proportionally decreased till it stops completely.

The intraluminal pressure at which blood flow stops is called the critical closing pressure,

e.g. In severe haemorrhage, blood loss leads to a significant reduction in pressure. This, combined with activity in the sympathetic autonomic nerves supplying smooth muscle, leads to vasoconstriction to the extent that the vessels may collapse. This occurs at the critical closing pressure, closing off blood supply to tissues.

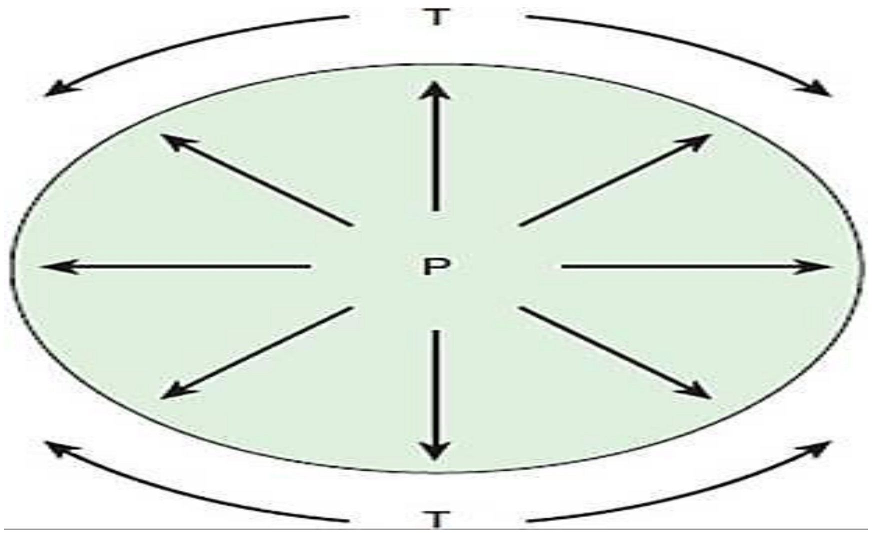


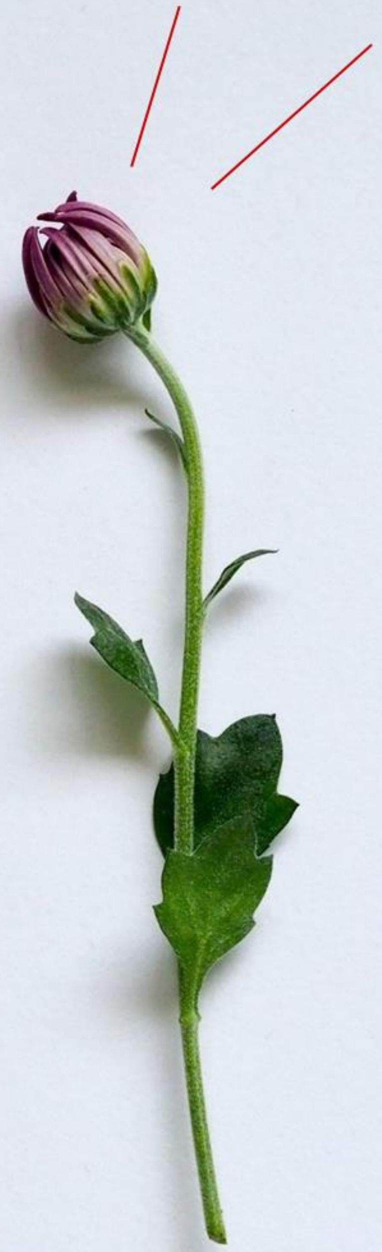
LAW OF LAPLACE

The tension (T) developed in the wall of a hollow organ = distending pressure (P) x radius of the organ (r)

$T = P x r$ and $P = T/r$

It applies to several sites in the body e.g. the urinary bladder, lung alveoli, stomach and blood vessels.





THANK YOU