
الله
﴿ ٱلَّذِينَ ءَامَنُواْ وَتَطۡمَئِنُّ قُلُوبُهُم بِذِكۡرِ ٱللَّهِۗ
أَلَا بِذِكۡرِ ٱللَّهِ تَطۡمَئِنُّ ٱلۡقُلُوبُ ٢٨ ﴾
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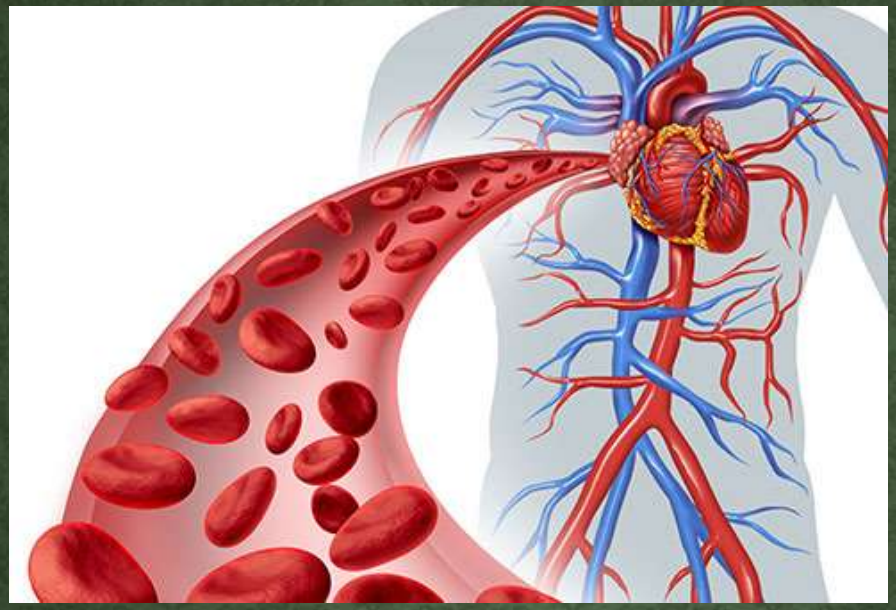
الهدى
ALHUDA


Me trying to get out of bed
every morning, like...

The teacher talking to the 9:00 am Zoom class:



BIOPHYSICS OF PRESSURE, FLOW, AND RESISTANCE - OVERVIEW OF CIRCULATION

Dr Sarah Shahid
FCPS Medicine
Mphil Physiology scholar

LEARNING OBJECTIVES

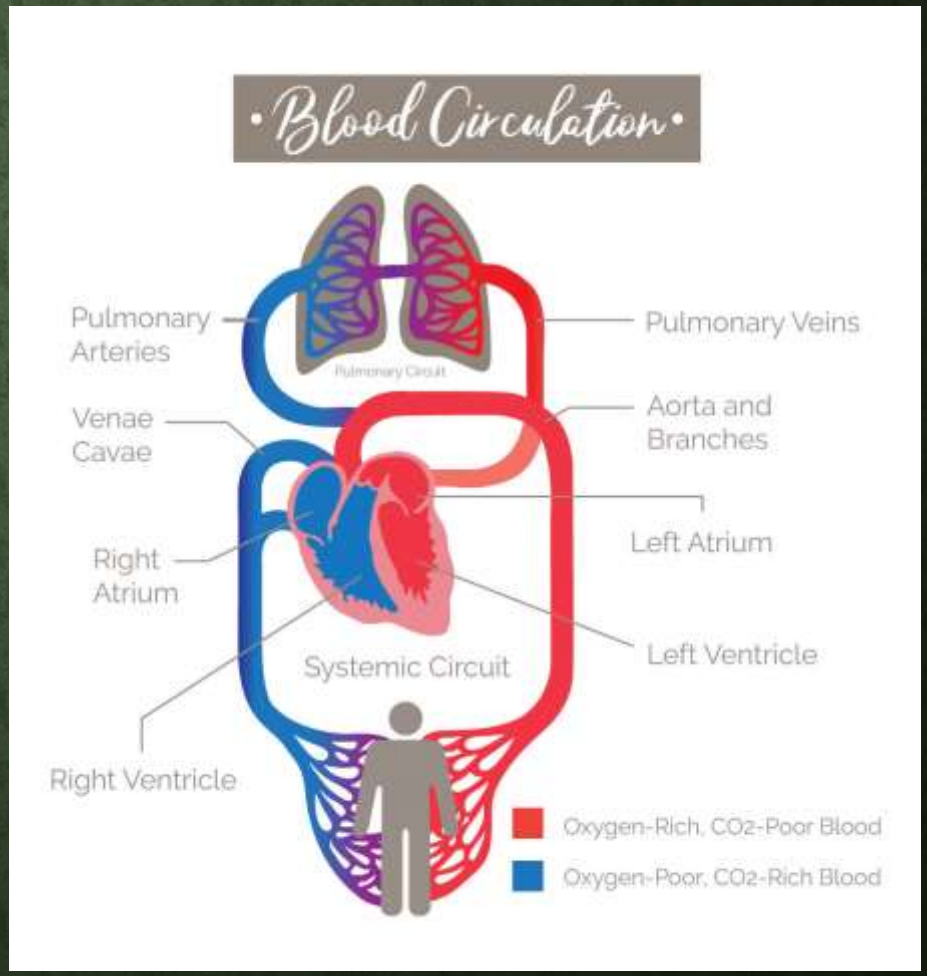
- Describe the interrelationship of pressure, flow and resistance.
- Describe the Ohm's law and Poisiuelle law
- Describe laminar blood flow and causes of its turbulence.


بسم الله الرحمن الرحيم

What does this remind you of…?

The Circulatory system

It is the transport system that circulates blood throughout body in a continuous circuit, to serve the needs of body tissues.



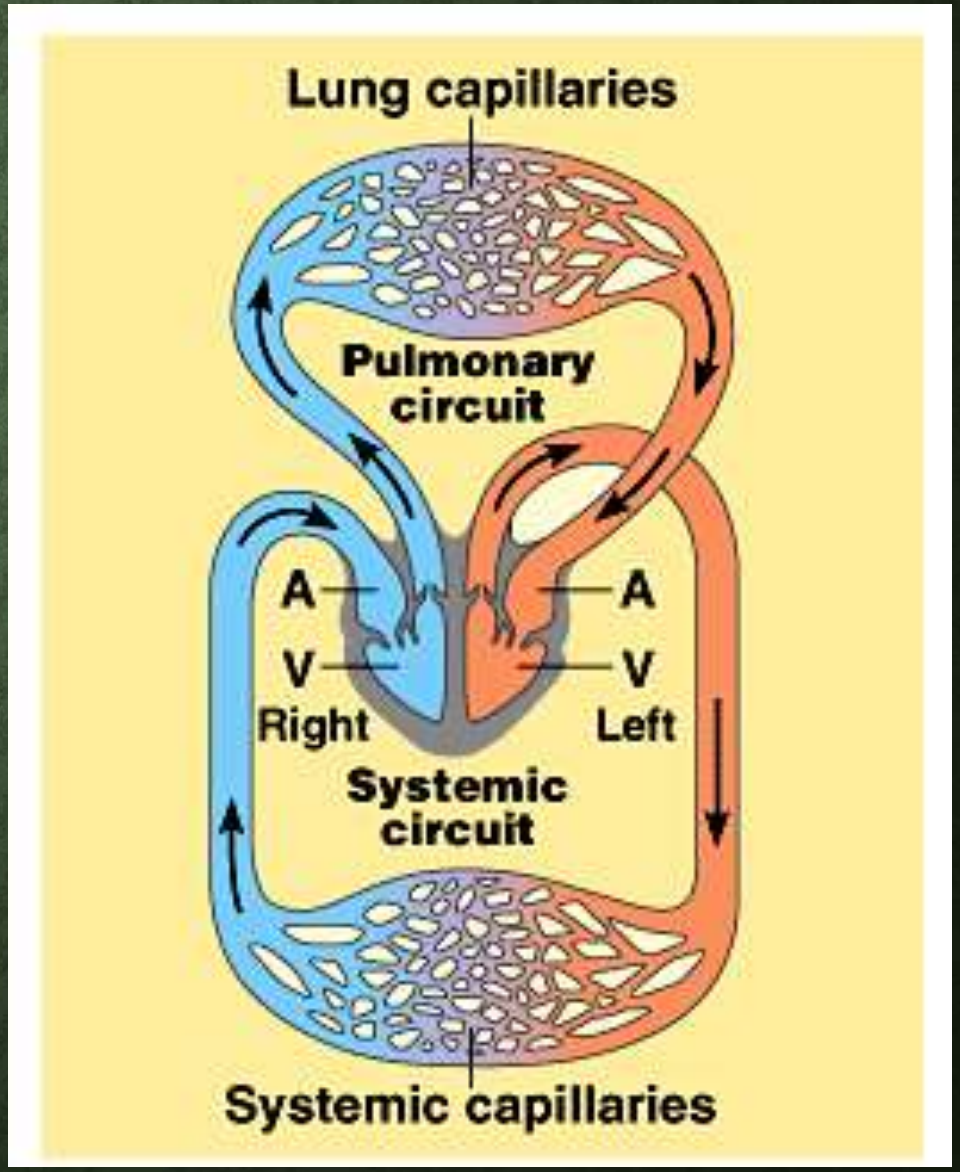
FUNCTIONS

- ✓ It transports O_2 and nutrients to tissue
- ✓ Returns CO_2 to lungs and other Waste materials to kidney.
- ✓ Temperature Regulation.
- ✓ Distributes hormones and other substances that regulate cell function.
- ✓ Maintains proper ionic concentration and homeostasis.

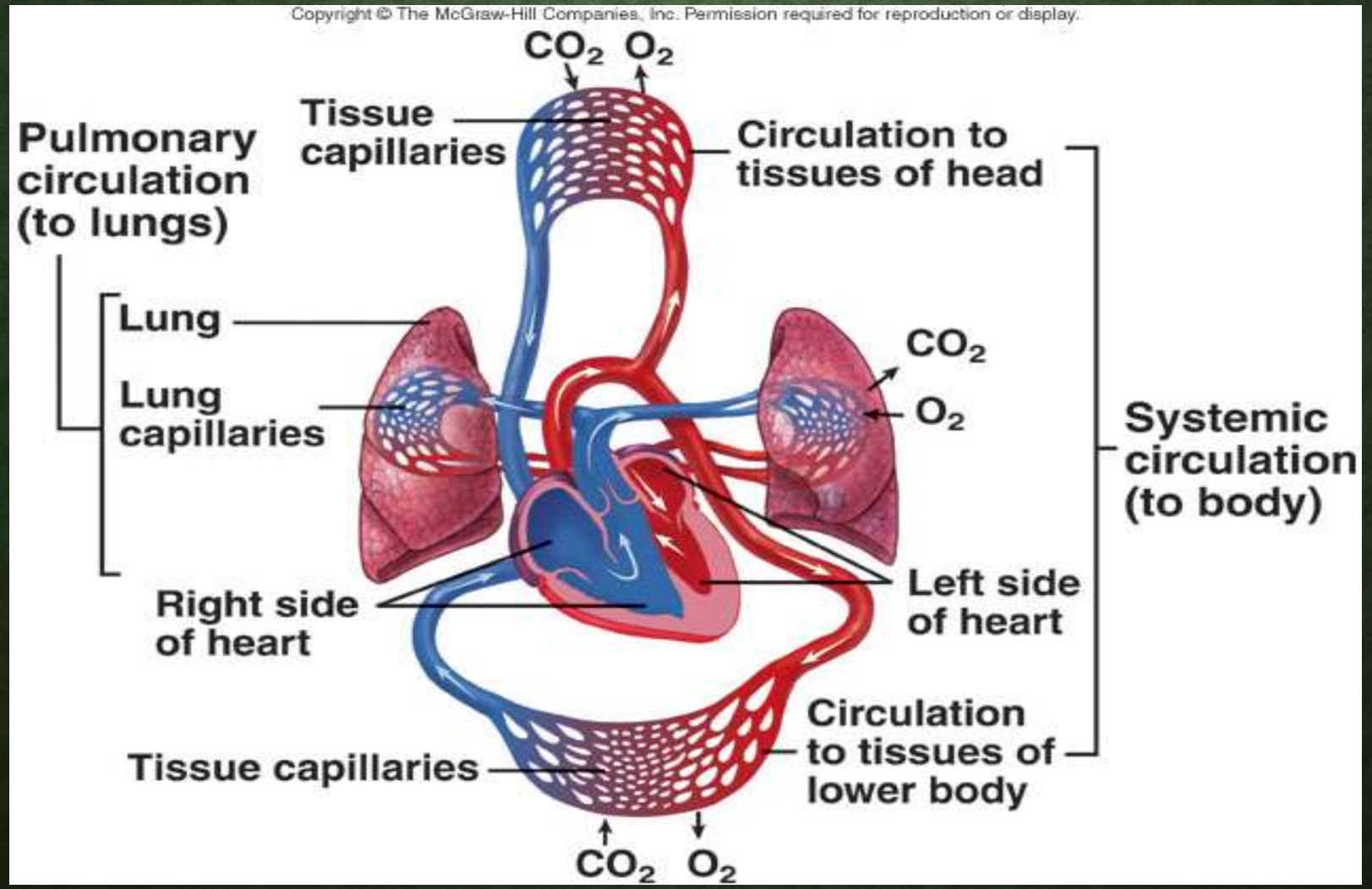
PHYSICAL CHARECTERISTICS OF CIRCULATION

CIRCUITS

- Pulmonary circuit
  - The blood pathway between the right side of the heart, to the lungs, and back to the left side of the heart.
- Systemic circuit
  - The pathway between the left and right sides of the heart.



SYSTEMIC AND PULMONARY CIRCULATION



SUB-DIVISIONS OF CIRCULATION

Systemic Circulation

- Aorta
- Arteries
- Arterioles
- Capillaries
- Venules
- Veins
- Venae Cavae
- Right Atrium

Pulmonary Circulation

- Right Ventricle
- Pulmonary Arteries
- Pulmonary Arterioles
- Pulmonary Capillaries
- Pulmonary Venules
- Pulmonary Veins
- Left Atrium

FUNCTIONAL PARTS OF THE CIRCULATION

- Arteries
- Arterioles
- Capillaries
- Venules
- Veins

FUNCTIONAL PARTS OF THE CIRCULATION

Blood Vessels -A network of tubes

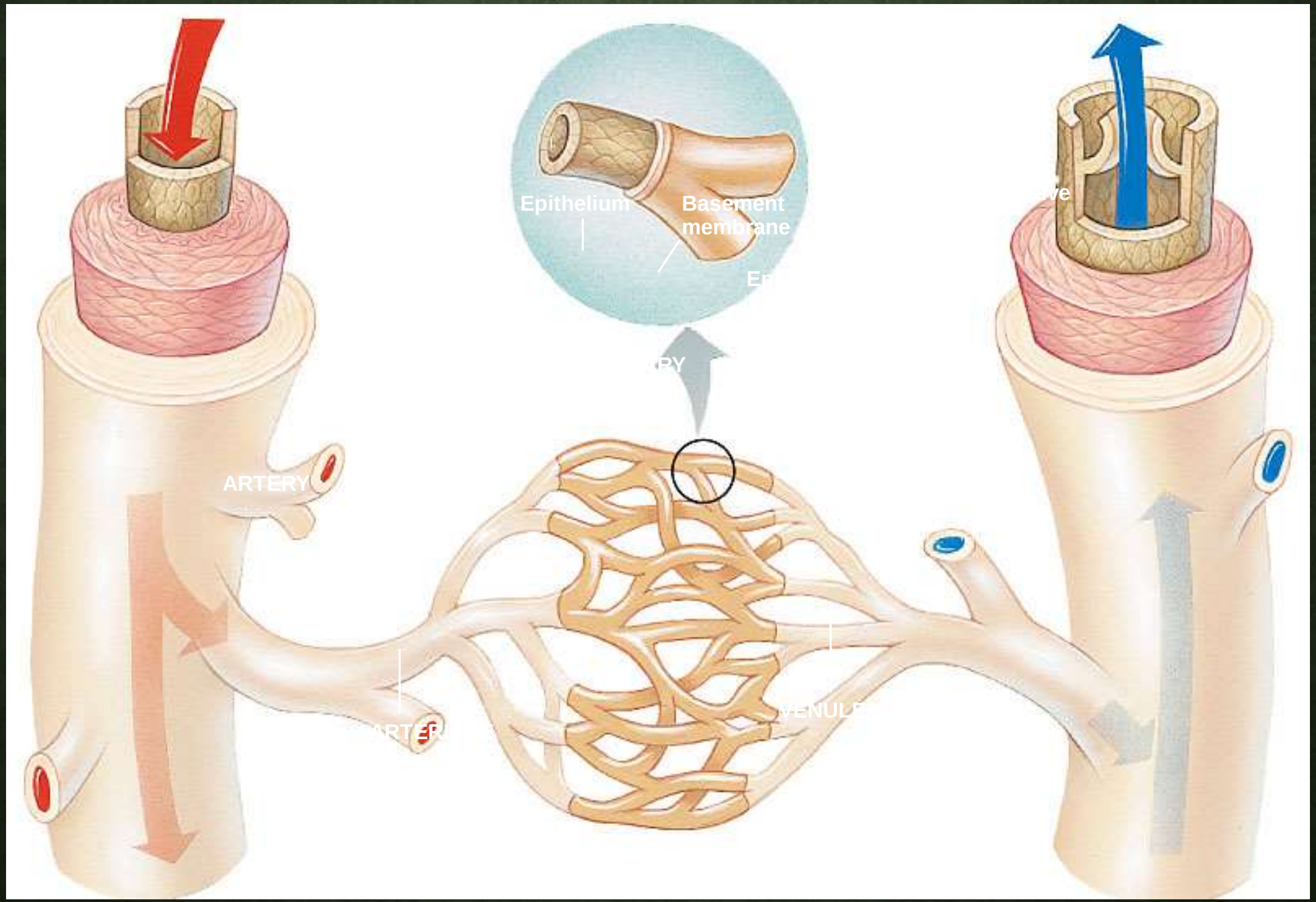
- Arteries→arterioles move away from the heart
  - Elastic Fibers
  - Circular Smooth Muscle

- Capillaries – where gas exchange takes place.
  - One cell thick
  - Serves the Respiratory System

- Veins→Venules moves towards the heart
  - Skeletal Muscles contract to force blood back from legs
  - One way valves
  - When they break - varicose veins form

THE STRUCTURE OF BLOOD VESSELS FITS THEIR FUNCTIONS

- Arteries and veins have smooth muscle and connective tissue
  - Valves in veins prevent the backflow of blood
  - A single layer of epithelial cells forms capillary walls


Epithelium
Basement membrane
ARTERY

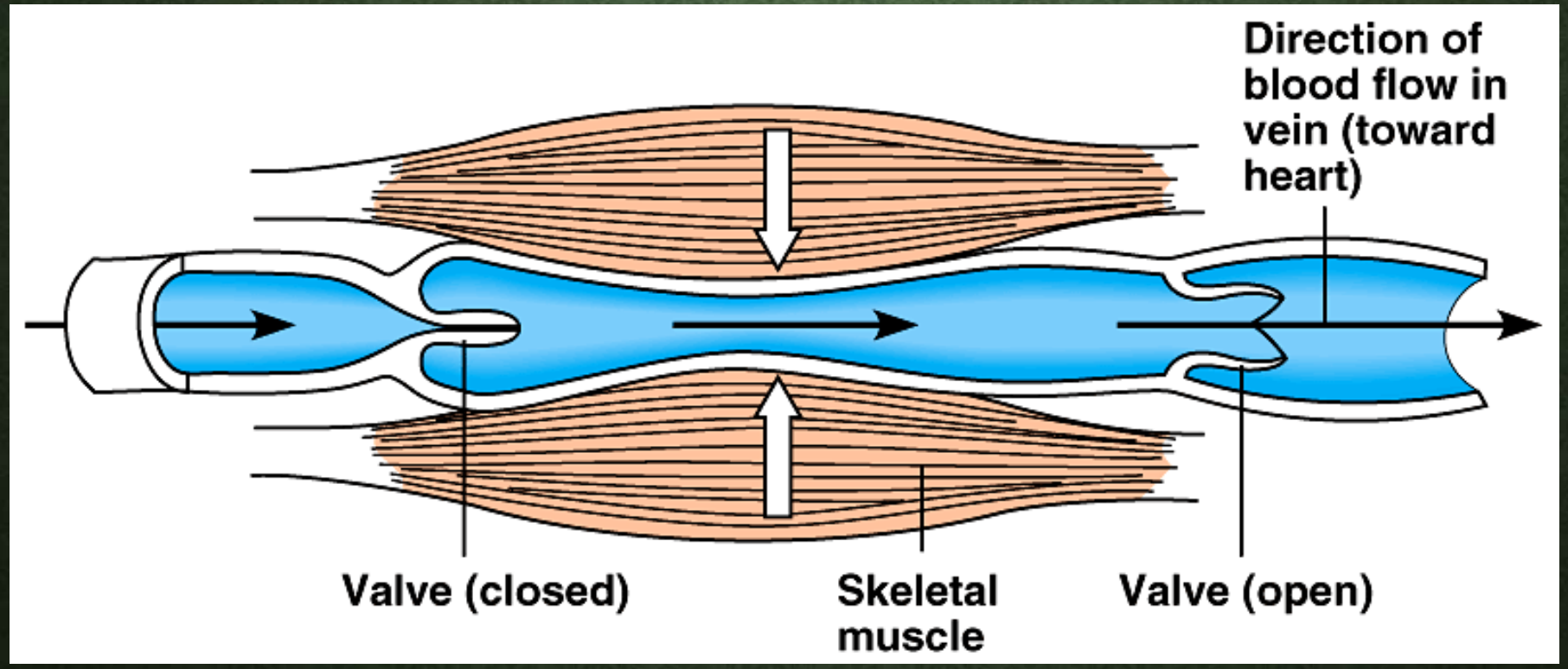
ARTERIES

- Carry blood away from the heart.
- Thick-walled to withstand hydrostatic pressure of the blood during ventricular systole.
- Blood pressure pushes blood through arteries.

VEINS

- Carry blood to the heart.
- Thinner-walled than arteries.
- **Possess one-way valves that prevent backwards flow** of blood.
- Blood flow due to body movements, not from blood pressure.

ONE-WAY VALVES IN VEINS

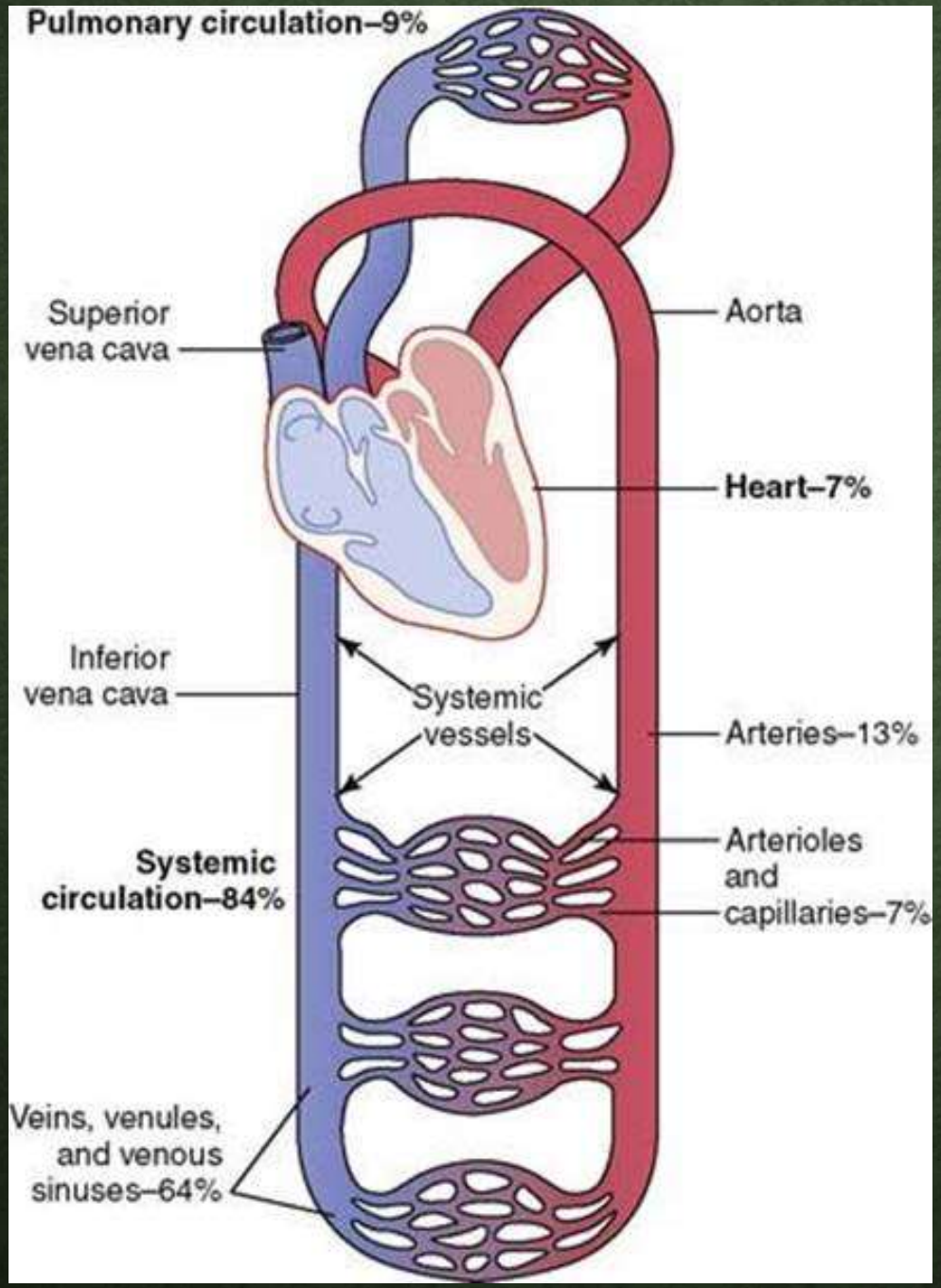


BLOOD FLOW

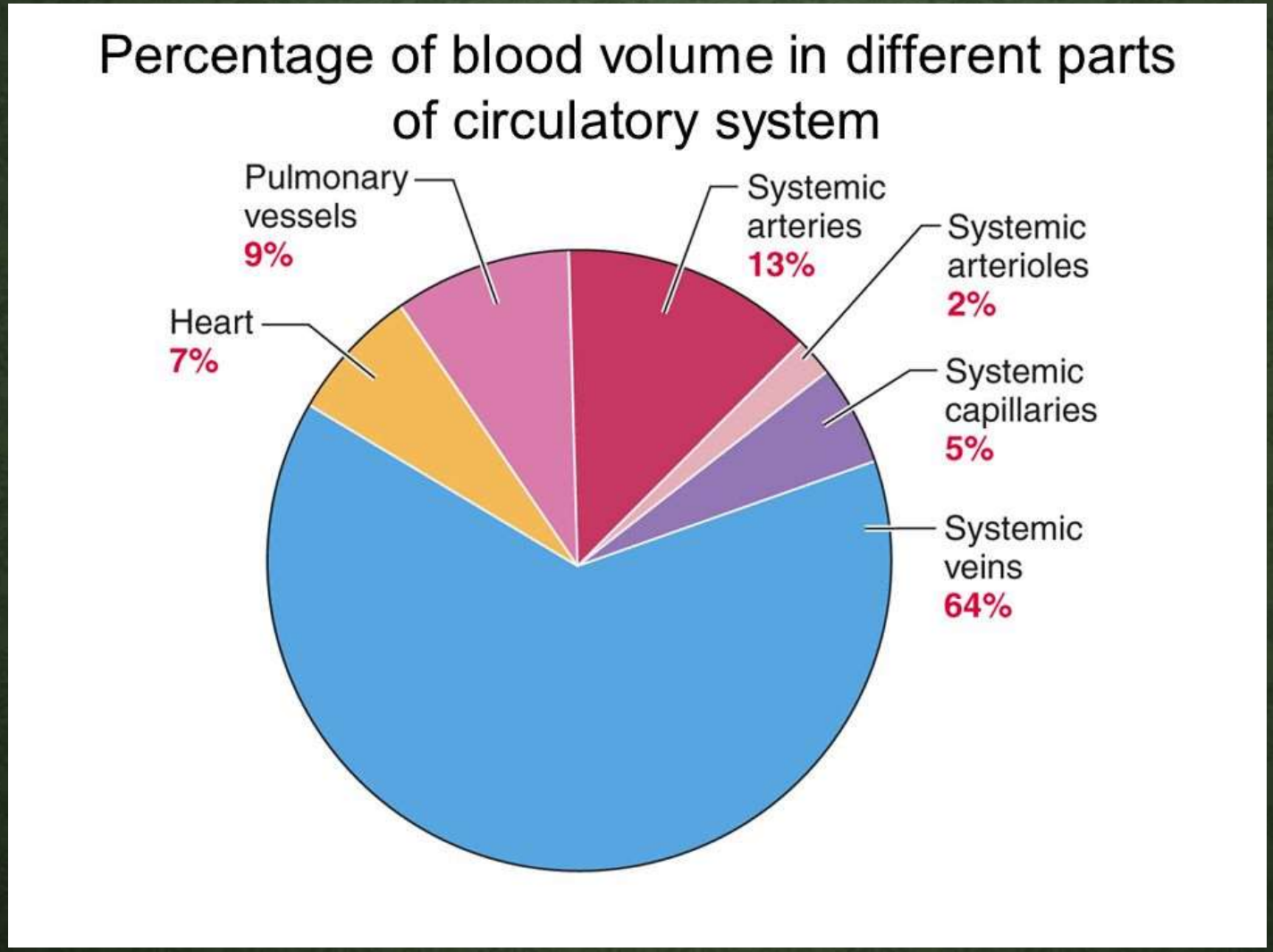
Quantity of blood that passes a given point in circulation in given period of time is called blood flow.

Value = 5 L/min

- Ordinarily blood flow is expressed in milliliters per minute or liters per minute
- The **overall blood flow** in the total circulation of an adult person at rest is about **5000 ml/min** which is called the **cardiac output**



Volumes of Blood in the Different Parts of Circulation



Distribution of blood in different parts of the circulatory system

Vessel	Cross-Sectional Area (cm^2)
Aorta	2.5
Small arteries	20
Arterioles	40
Capillaries	2500
Venules	250
Small veins	80
Venae cavae	8

Blood Pressure in Various Parts of Circulation

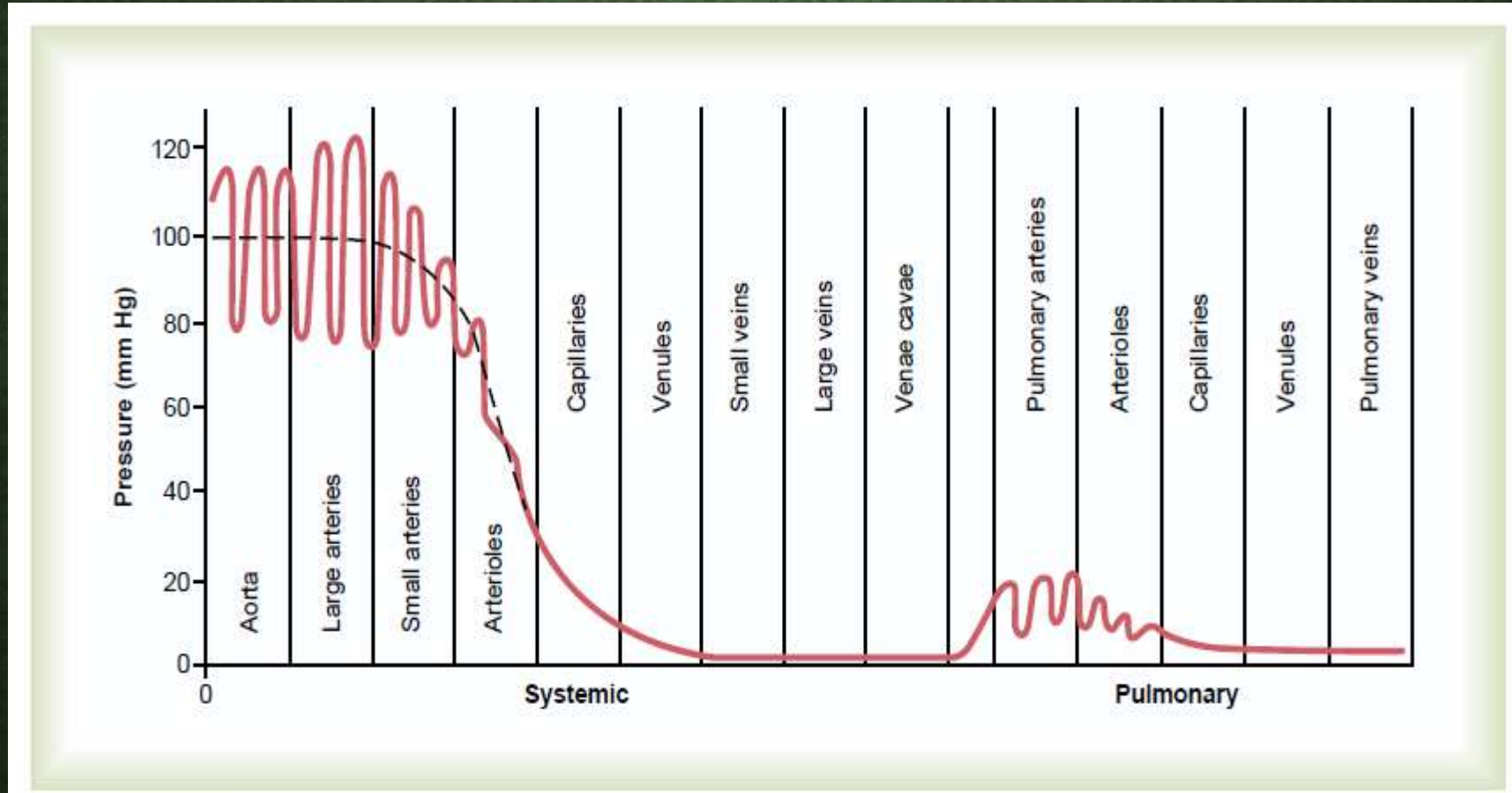


Figure 14–2

Normal blood pressures in the different portions of the circulatory system when a person is lying in the horizontal position.

Interrelationship Among Pressure, Flow, and Resistance

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

Interrelationships Among Pressure, Flow, and Resistance

OHM'S LAW OF BLOOD FLOW:

It states "Blood flow is directly proportional to pressure difference b/w two ends of vessel & inversely proportional to resistance to blood flow through vessel"

Interrelationships Among Pressure, Flow, and Resistance

- It can be expressed in milliliters per second or in any other unit of flow

Interrelationships Among Pressure, Flow, and Resistance

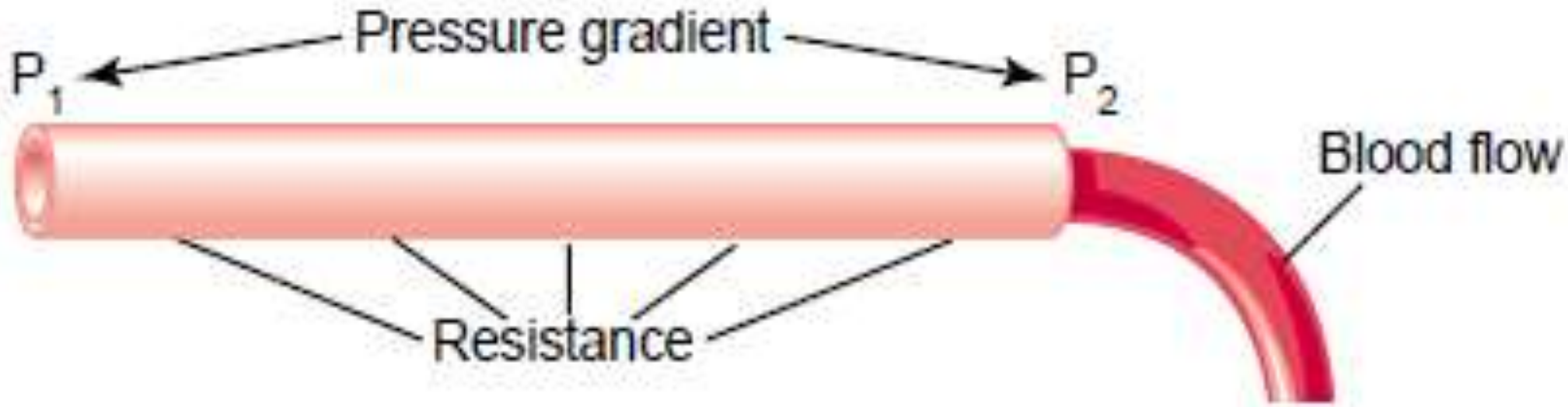


Figure 14–3

Interrelationships among pressure, resistance, and blood flow.

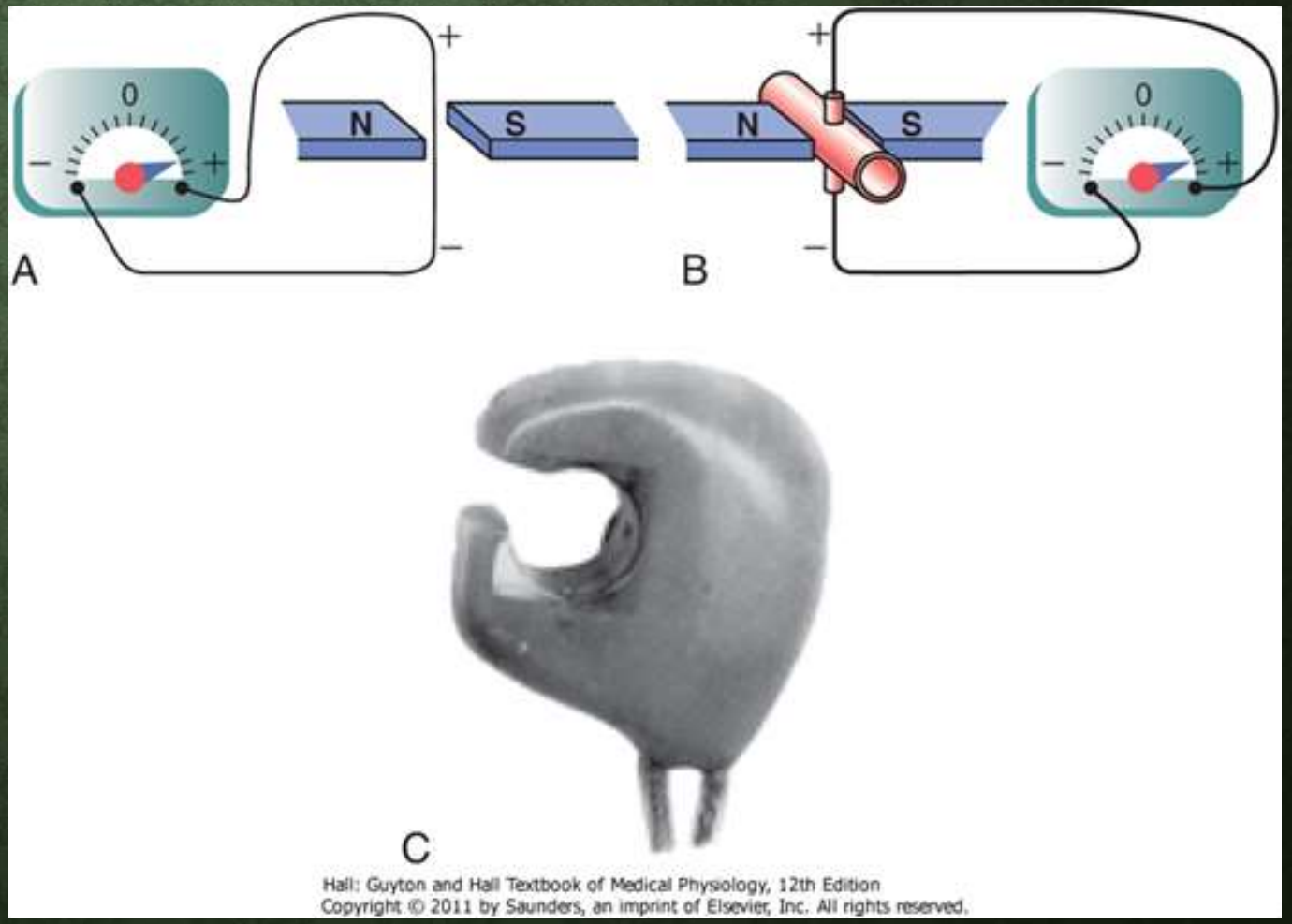
Interrelationships Among Pressure, Flow, and Resistance

$\uparrow \Delta P \rightarrow \uparrow F$

$\downarrow \Delta P \rightarrow \downarrow F$

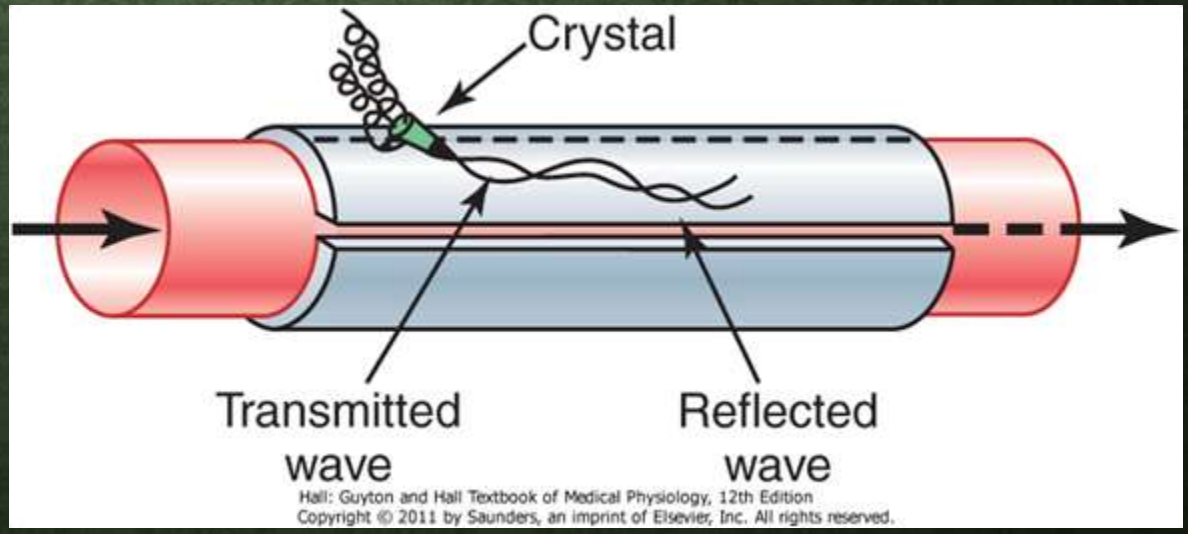
ELECTROMAGNETIC FLOWMETER

Records changes in flow in less than 1/100 of a second, allowing accurate recording of pulsatile changes in flow, as well as steady flow



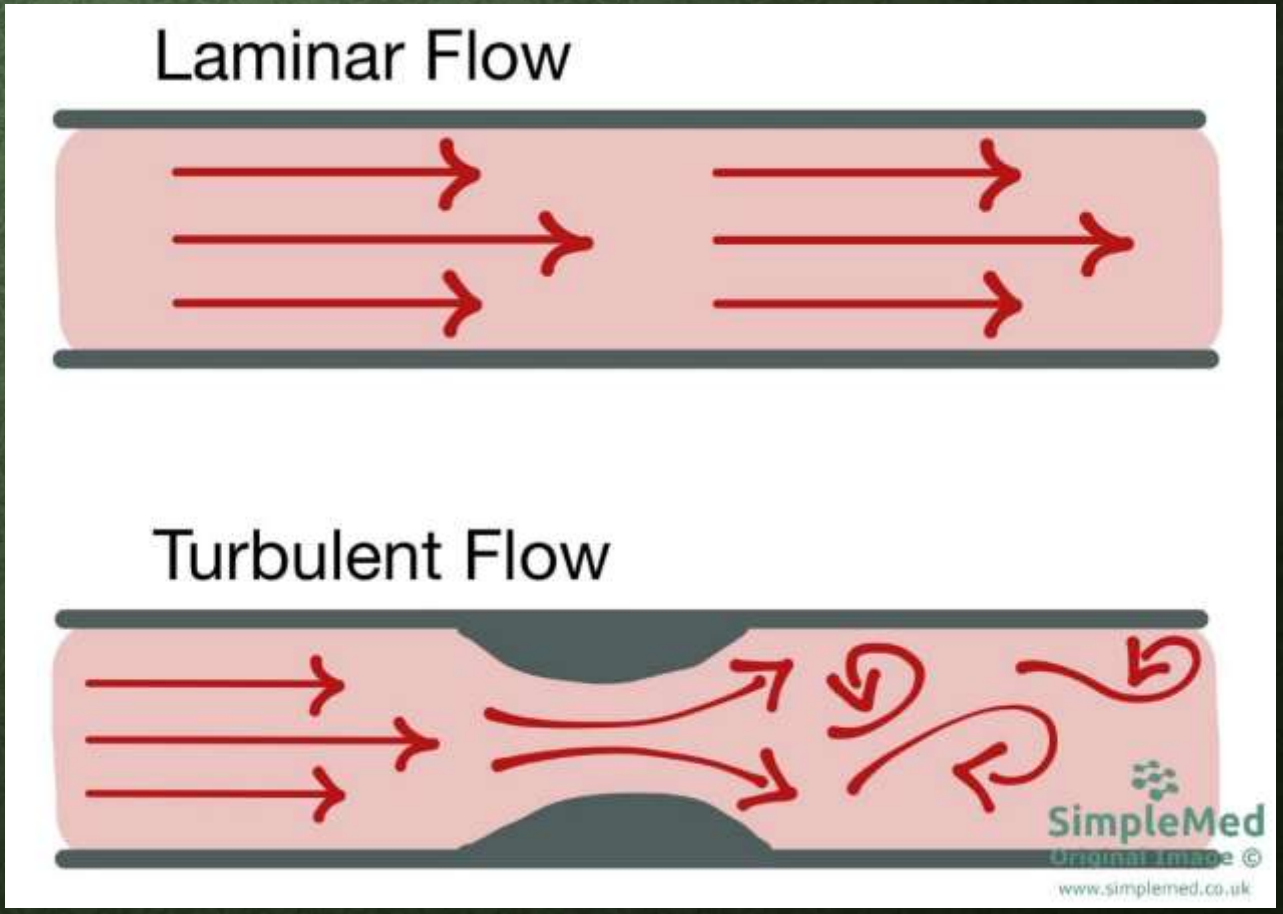
ULTRASONIC DOPPLER FLOWMETER

- minute piezoelectric crystal
- sound is reflected by the red blood cells
- records rapid, pulsatile changes in flow,
- as well as steady flow



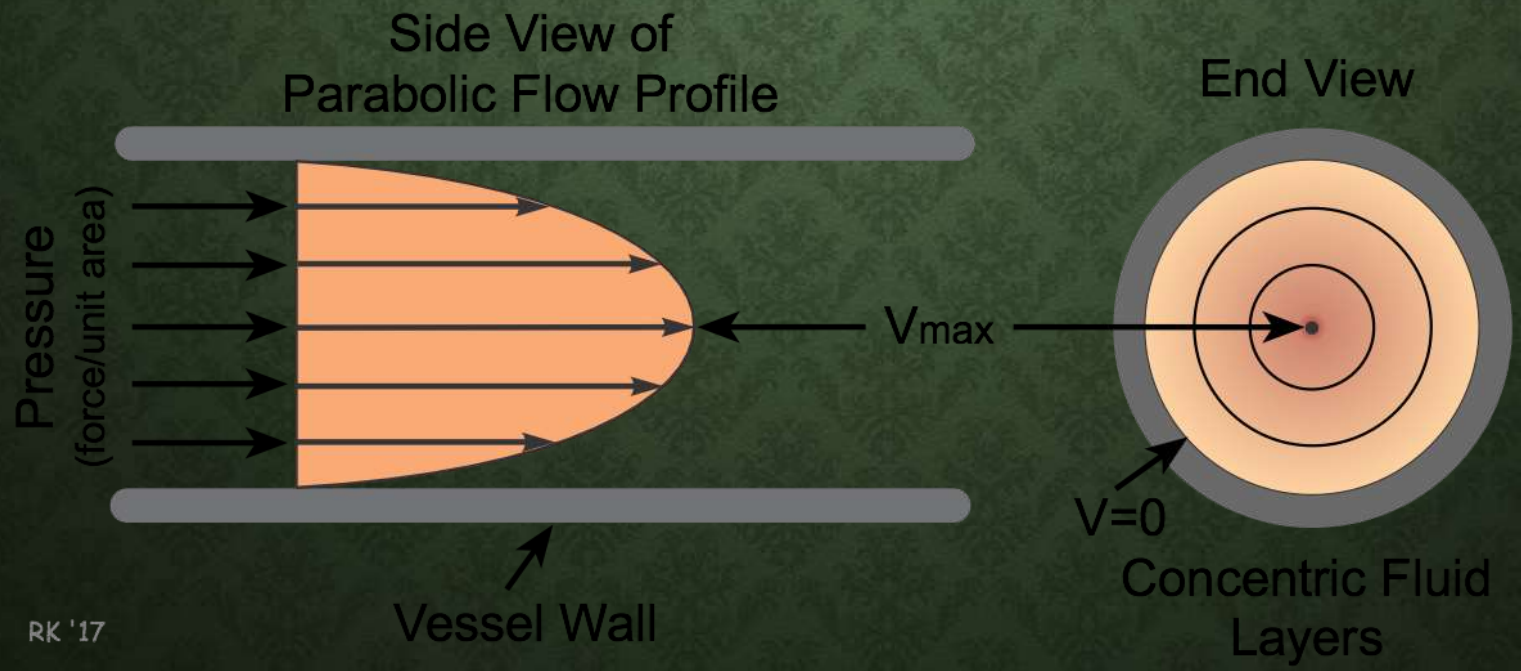
BLOOD FLOW TYPES

- Laminar flow
- Turbulent flow



LAMINAR OR STREAMLINE BLOOD FLOW

- When blood flows at steady rate through long and smooth vessel
- each layer of blood remains at same distance from vessel wall
- the central portion of blood is highest velocity blood (Vmax)

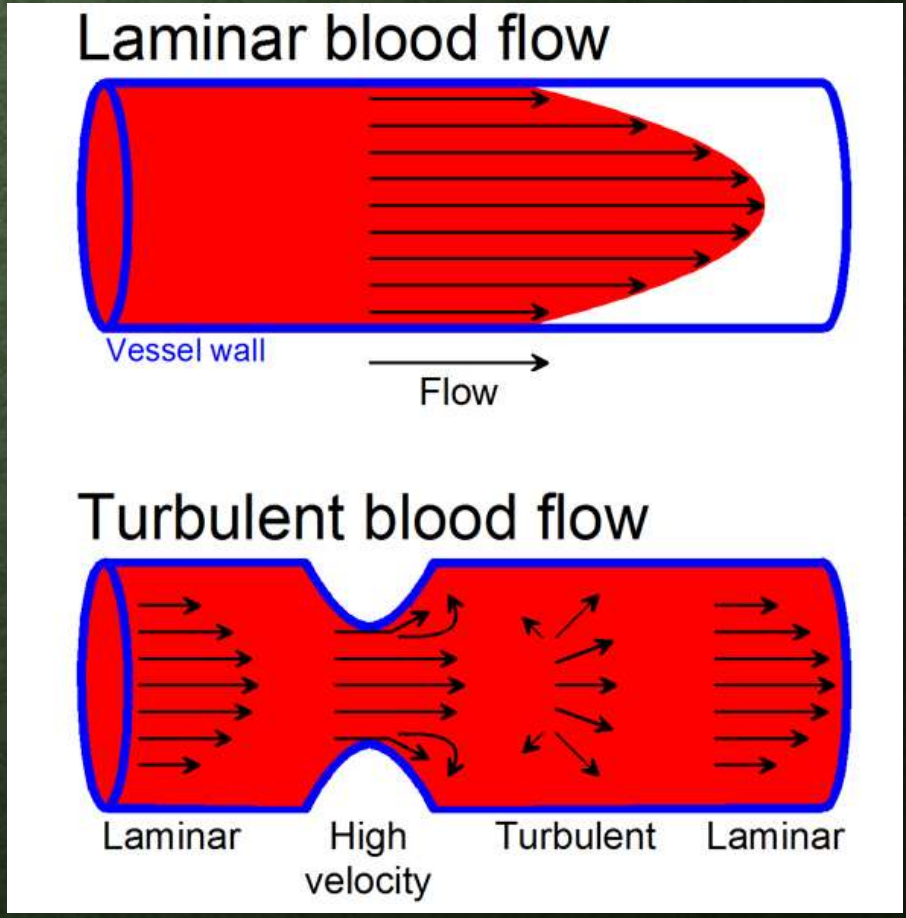


PARABOLIC VELOCITY PROFILE DURING LAMINAR FLOW.

- When the fluids are made to flow, a parabolic interface develops between them,
- the portion of fluid adjacent to the vessel wall has hardly moved, the portion slightly away from the wall has moved a small distance, and the portion in the center of the vessel has moved a long distance.
- the velocity of flow in the center of the vessel is far greater than that toward the outer edges.
- This effect is called the parabolic profile for velocity of blood flow.

TURBULENT BLOOD FLOW

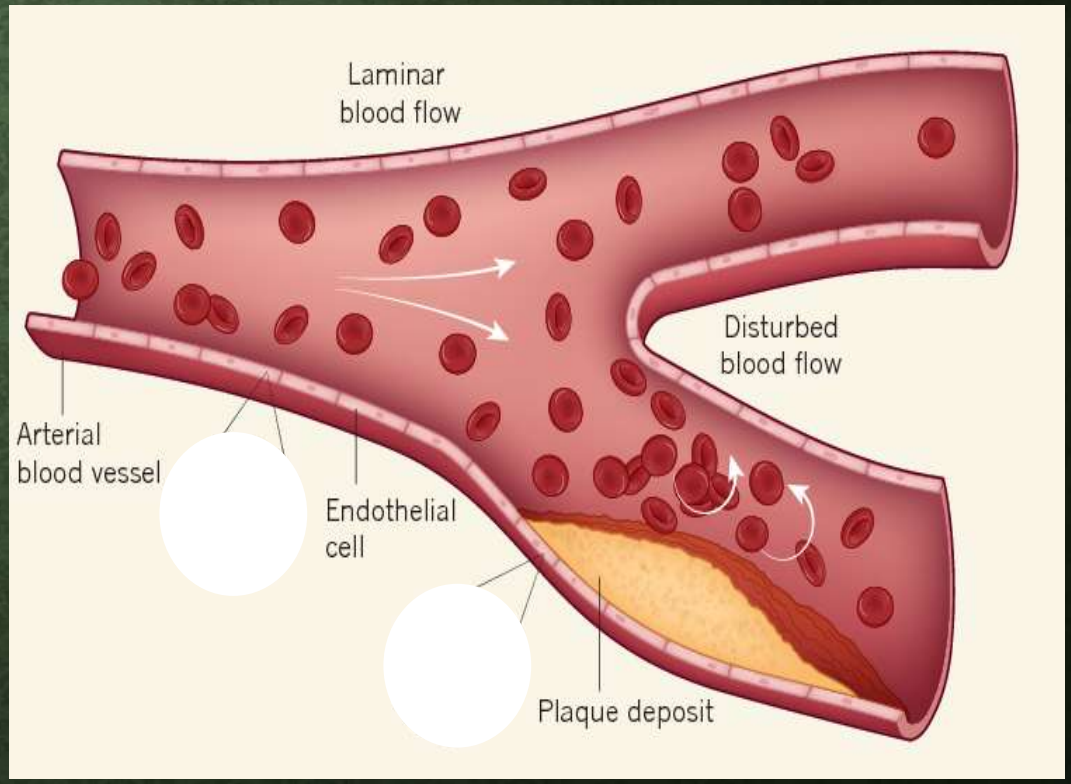
- Disorderly blood flow when it passes through an obstruction, sharp turn or roughened surface
- Turbulent flow means that the blood flows crosswise in the vessel as well as along the vessel
- usually forming whorls in the blood called eddy currents



Whirlpool

TURBULENT BLOOD FLOW CAUSES

- When the rate of blood flow becomes too great
- When it passes by an obstruction in a vessel
- When it makes a sharp turn
- When it passes over a rough surface

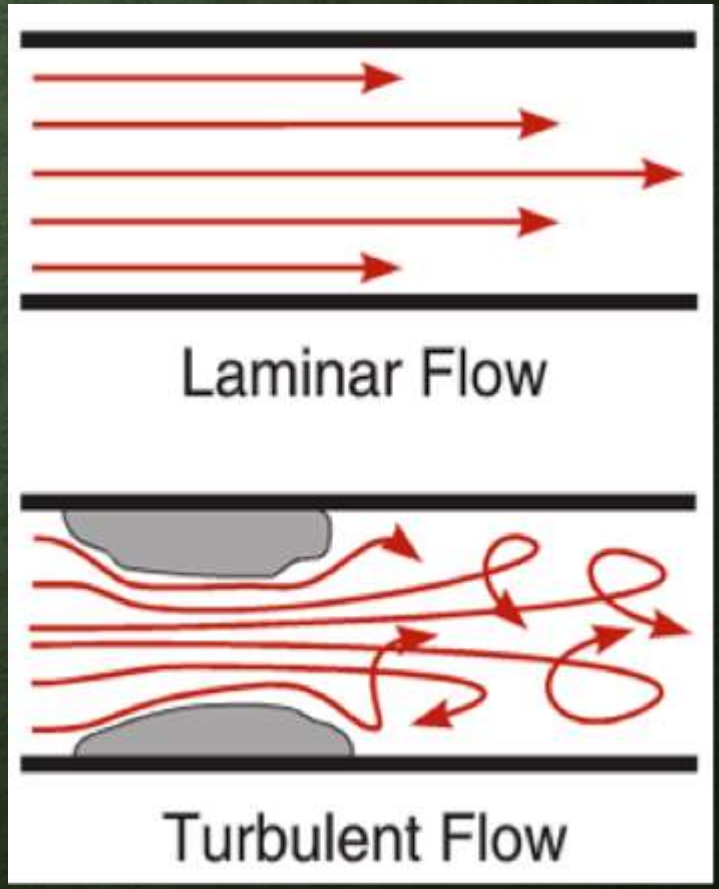


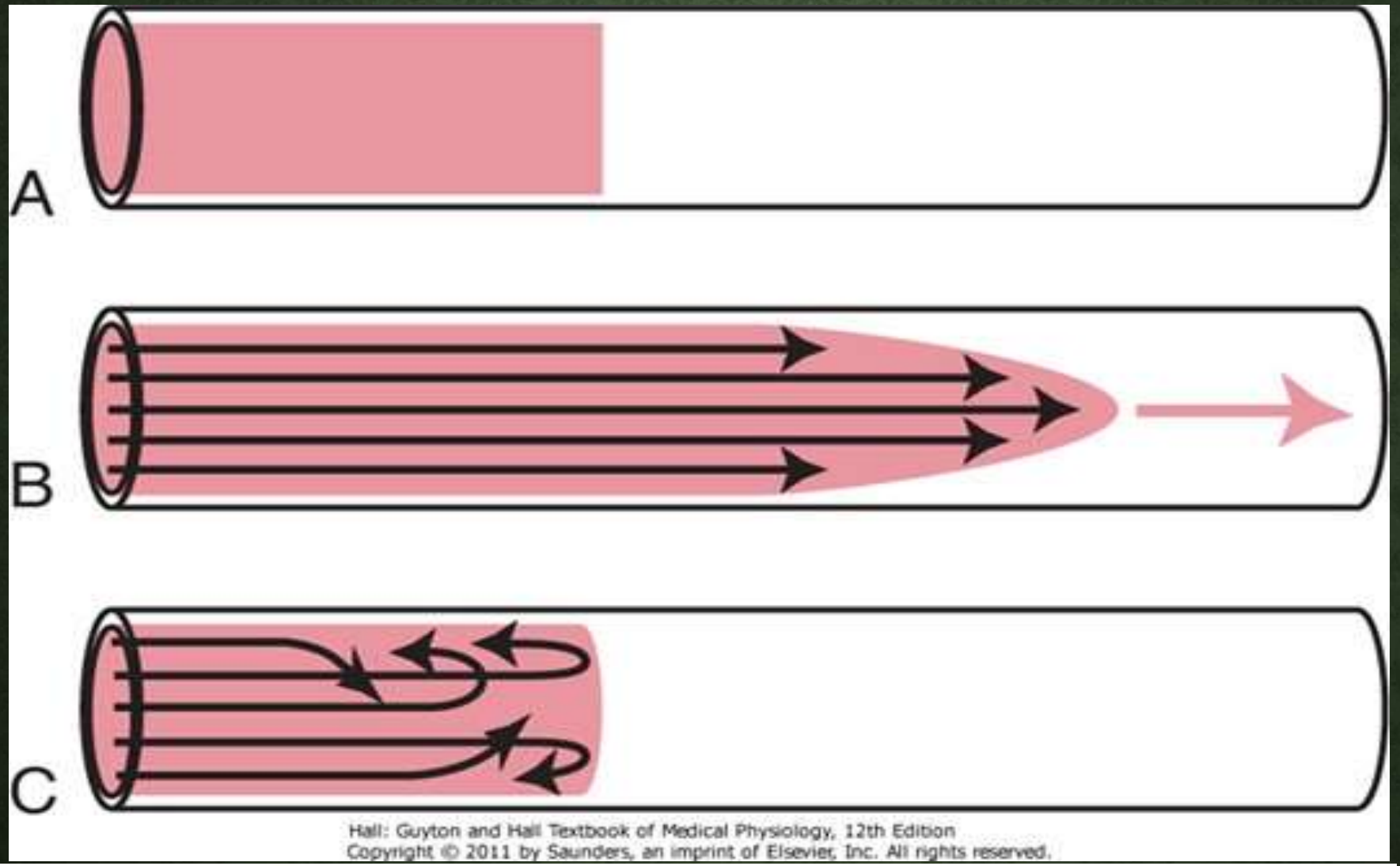
TURBULENT BLOOD FLOW

It produce more resistance than laminar flow.

It can produce murmurs.

A heart murmur is a blowing, whooshing sound heard during a heartbeat. The sound is caused by turbulent (rough) blood flow through the heart valves or near the heart.

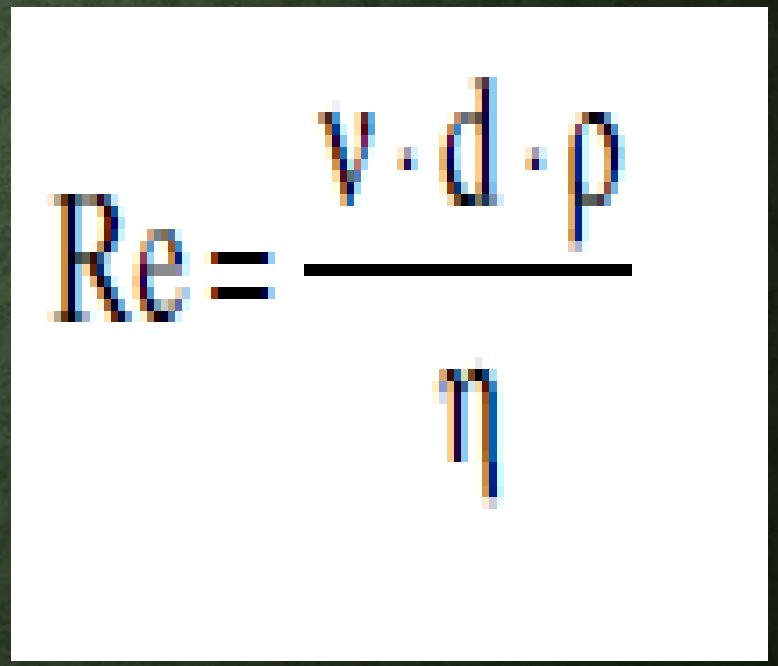




A, Two fluids (one dyed red, and the other clear) before flow begins; *B*, the same fluids 1 second after flow begins; *C*, turbulent flow, with elements of the fluid moving in a disorderly pattern.

REYNOLD'S NUMBER

- Re is **Reynolds' number** and is the measure of the tendency for turbulence to occur



- v is the mean velocity of blood flow (in centimeters/second)
- d is the vessel diameter (in centimeters)
- **ρ (**Rho) is density
- η (Eta) is the viscosity

- **Greater the Reynold's number, greater is the tendency for turbulent flow**

REYNOLD'S NUMBER

➢ **The tendency for turbulent flow increases in direct proportion to:**

- Velocity of blood flow
- Diameter of the blood vessel

➢ **Turbulent blood flow is inversely proportional to:**

- Viscosity of the blood

FACTORS AFFECTING BLOOD FLOW

- Resistance
- Pressure Difference between two ends of vessel.
- Diameter of the vessel
- Hematocrit
- Blood Viscosity

RESISTANCE TO BLOOD FLOW

- **Opposition to blood flow in a vessel is called resistance to blood flow.**
- Its caused by friction between moving fluid and stationary walls
- The volume of blood flow is inversely proportional to resistance
- depends on:
  - Viscosity
  - Vessel length
  - Vessel radius

TOTAL PERIPHERAL RESISTANCE (TPR)

- Resistance of entire **systemic circulation** is called total peripheral resistance
- Vasoconstriction throughout the blood vessels of the body causes an increase in the TPR
- Conversely when the vessels become greatly dilated, the resistance can fall
- In pulmonary circulation, the total resistance is about $1/7^{th}$ that in the systemic circulation

CONDUCTANCE OF BLOOD IN A VESSEL

- Is a measure of the blood flow through vessel for a given pressure difference
- It is the reciprocal of resistance

$$\text{Conductance} = \frac{1}{\text{Resistance}}$$

CONDUCTANCE OF BLOOD IN A VESSEL

small changes in vessel diameter markedly changes its conductance

$$\text{Conductance} \propto \text{Diameter}^4$$

FOURTH POWER LAW OF RADIUS

- Change in radius alters resistance to the fourth power of the change in radius.
- For example, a 2-fold increase in radius decreases resistance by 16-fold (2^4)

$$R \propto \frac{\eta \cdot L}{r^4}$$

FOURTH POWER LAW OF RADIUS

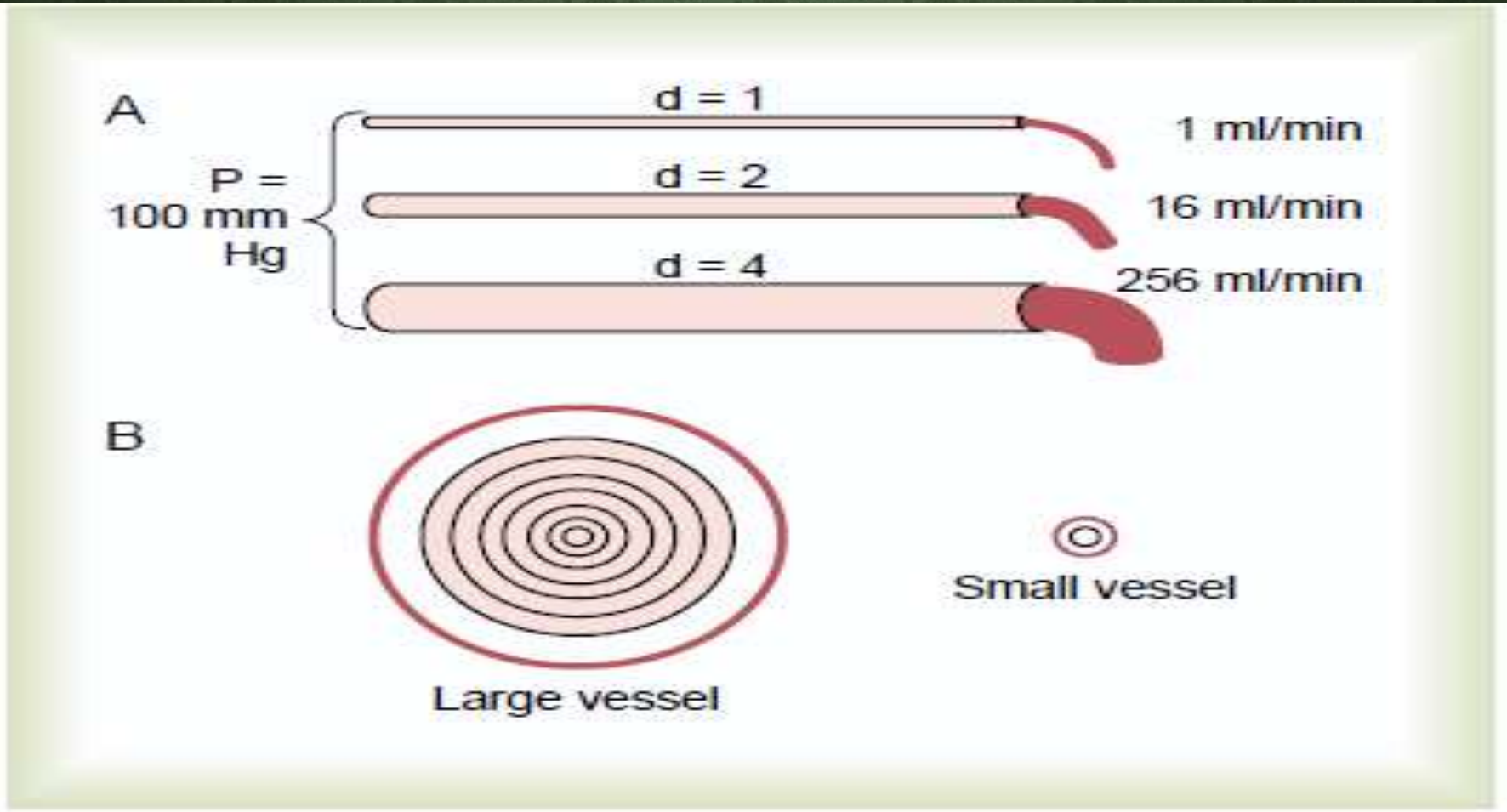
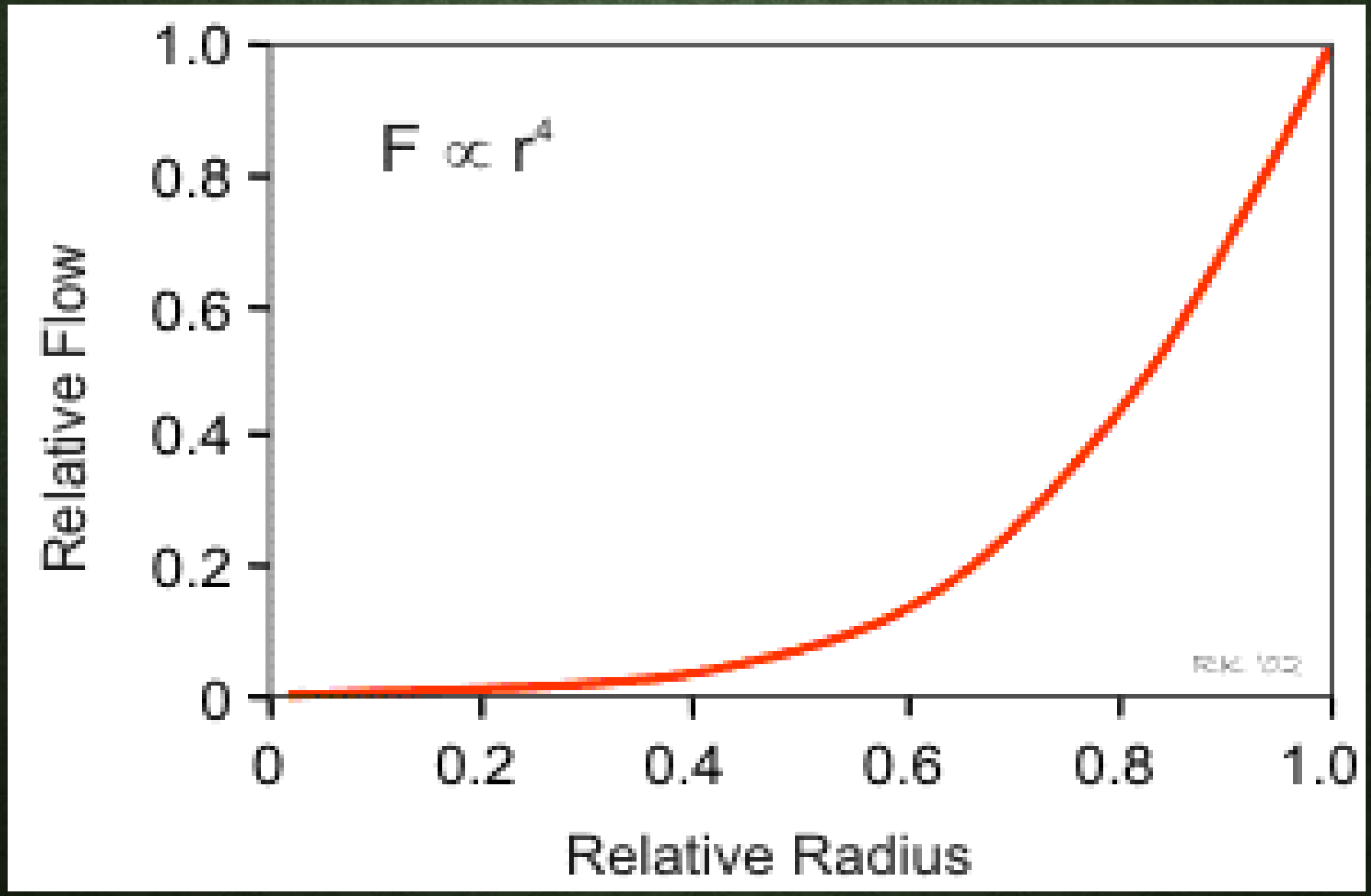


Figure 14–9

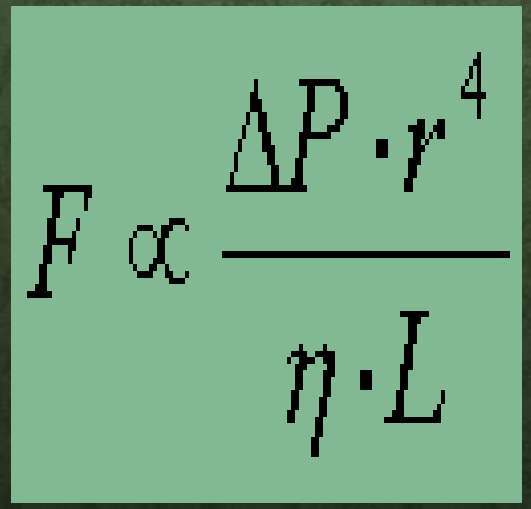
A, Demonstration of the effect of vessel diameter on blood flow. *B*, Concentric rings of blood flowing at different velocities; the farther away from the vessel wall, the faster the flow.

Fourth Power Law of Radius



POISEUILLE'S LAW

- It states "rate of blood flow is directionally proportional to pressure difference & fourth power of radius & inversely proportional to viscosity & length of vessel"



- Ohm's law - Increasing pressure <u>increases</u> blood flow and increasing resistance <u>decreases</u> blood flow $F = \frac{\Delta P}{R}$

- Poiseuille's law - Increasing vessel diameter <u>decreases</u> resistance and increasing viscosity <u>increases</u> resistance

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

Note – increasing pressure cause more than a proportionate increase blood flow because it also distends the vessels.

Resistance to Blood Flow in Series and Parallel Vascular Circuits

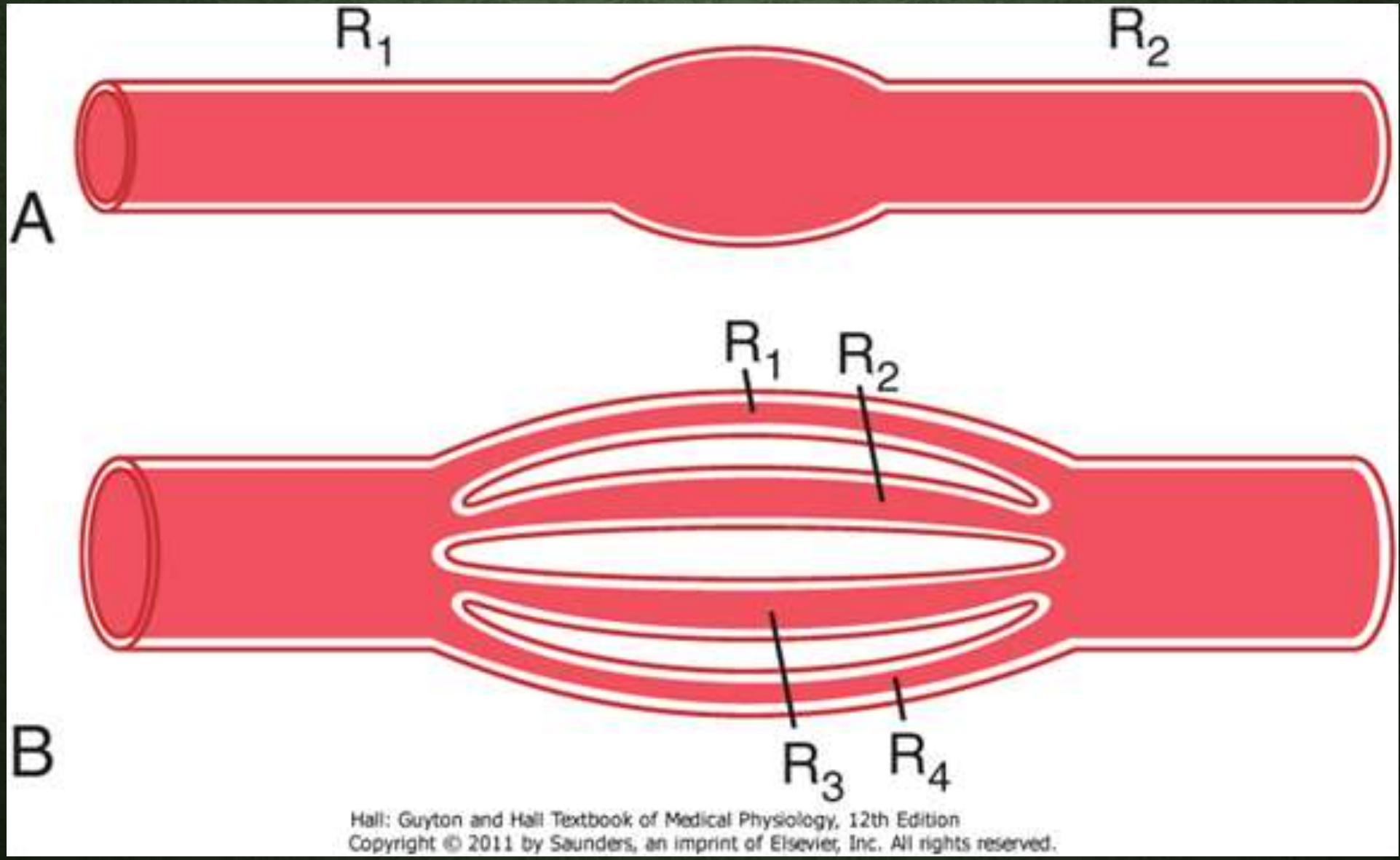
The arteries, arterioles, capillaries, venules, and veins are collectively arranged in series.

When blood vessels are arranged in series, flow through each blood vessel is the same and the total resistance to blood flow (R_{total}) is equal to the sum of the resistances of each vessel:

The total peripheral vascular resistance is therefore equal to the sum of resistances of the arteries, arterioles, capillaries, venules, and veins.

the total vascular resistance is equal to the sum of R_1 and R_2.

$$R_{total} = R_1 + R_2 + R_3 + R_4 \ldots$$

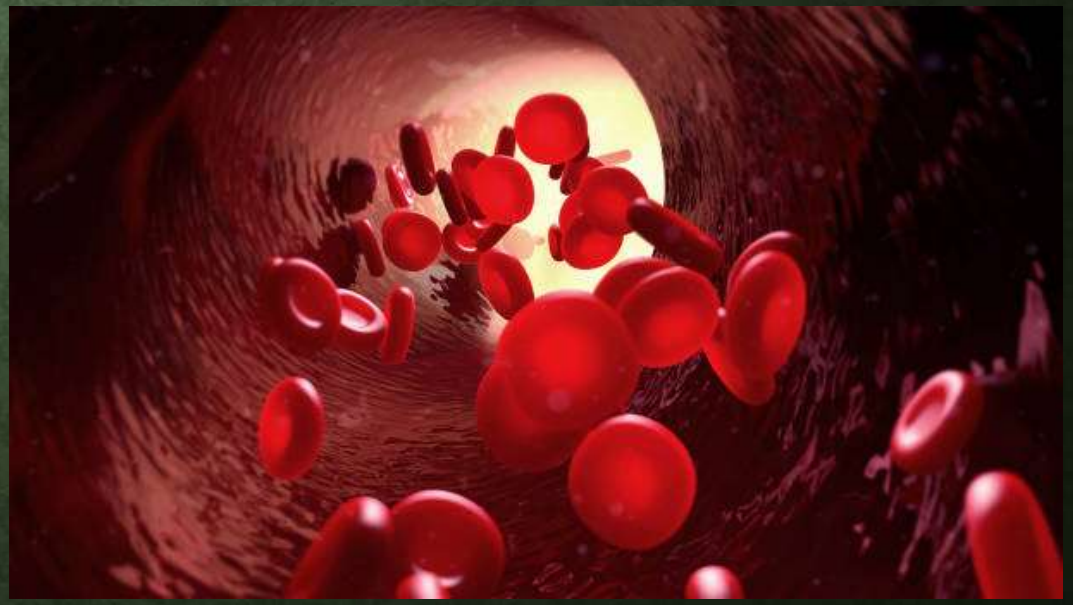


- Blood vessels branch extensively to form parallel circuits that supply blood to the many organs and tissues of the body.
- This parallel arrangement permits each tissue to regulate its own blood flow, to a great extent, independently of flow to other tissues.
- For blood vessels arranged in parallel (Figure 14-9 *B*), the total resistance to blood flow is expressed as:
-

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

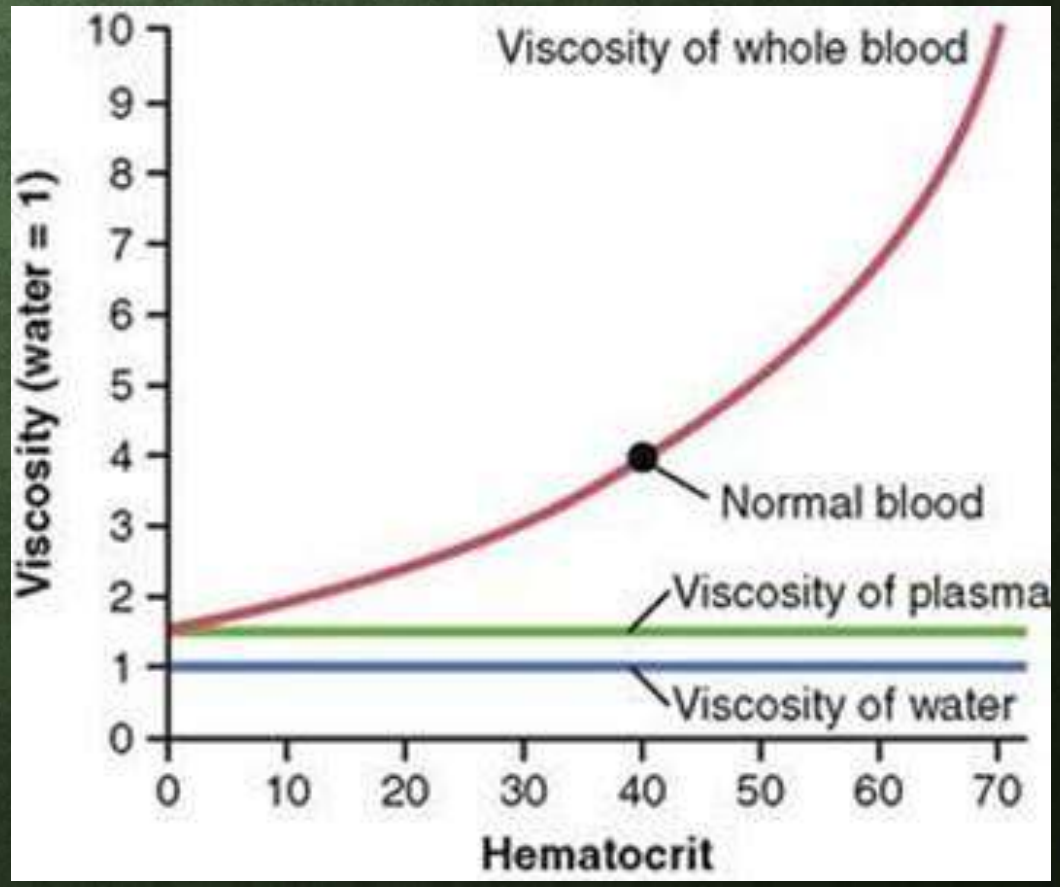
VISCOSITY OF BLOOD

- Viscosity is the friction of blood against the wall of blood vessel.
- The number of RBC (the hematocrit) is the main factor that determines the viscosity
- Another substance are the plasma proteins esp albumin
- The volume of blood flow is inversely proportional to viscosity



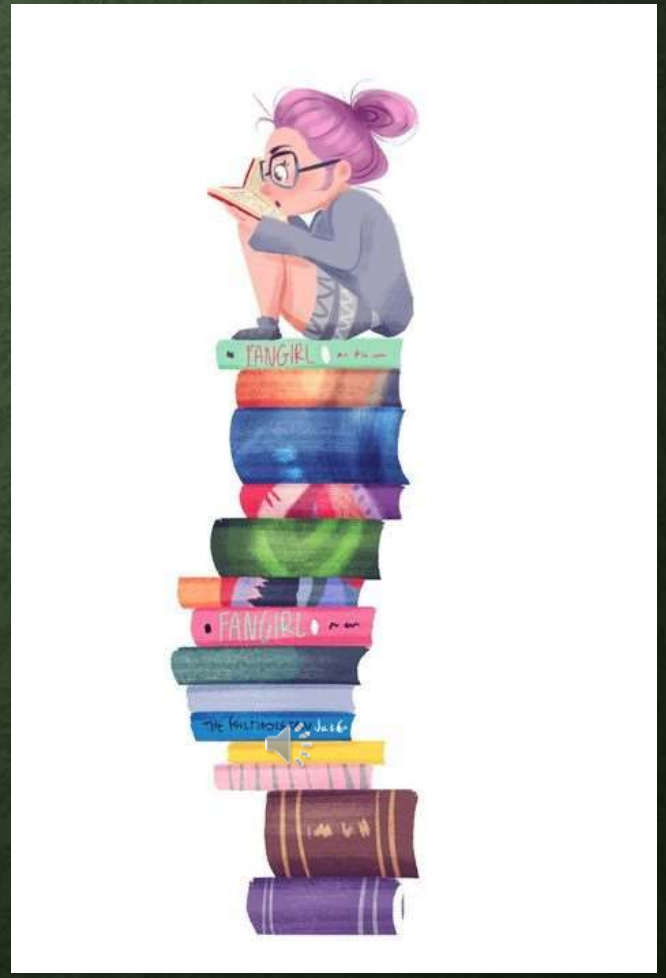
EFFECT OF HEMATOCRIT ON BLOOD VISCOSITY

- The viscosity of blood increases drastically as the hematocrit increases.
- The viscosity of whole blood at normal hematocrit is about 3;
- this means that three times as much pressure is required to force whole blood as to force water through the same blood vessel.



RECOMMENDED BOOKS

- Text book of Medical Physiology- Guyton and Hall
- Principles of human Physiology- Lauralee Sherwood
- Essentials of medical Physiology- K Sembulingum



For questions, comments and feedback
dr_sarah@yahoo.com


That's all Folks!
SUPERB wallpapers

Me before going to an 8am class