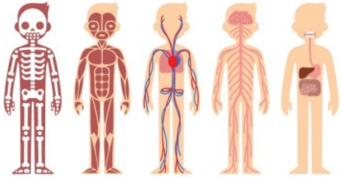
Physiology



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Vascular Physiology

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Functional Morphology of arteries:

Circulation divided into pulmonary circulation and systemic (or peripheral) circulation.

A. 84% of the blood found in systemic circulation including:

❶ 64% of body blood found in veins

❷ 13 % is in the systemic arterial sy

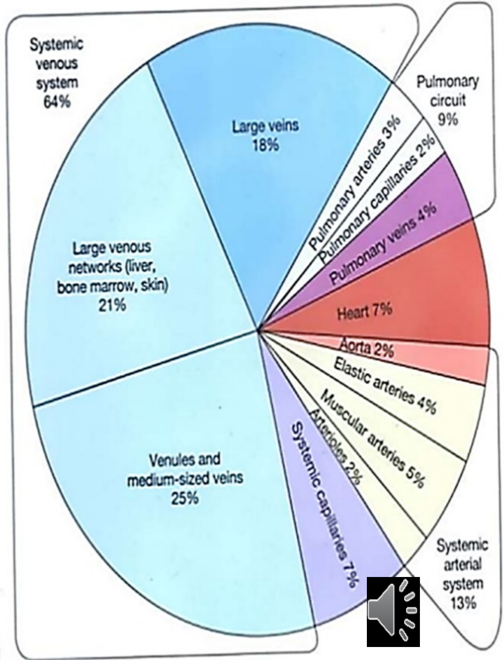
❸ 7 % is in the systemic capillaries

B. 7 % is in the heart

C. 9% is in the pulmonary vessels

Blood found in arterial system and Le ventricles (High pressure system)

Blood found in systemic veins, pulmo circulation, heart(Low pressure syste chambers other than Left ventricle



1. Arteries (distribution vessels): includes

a. large elastic arteries (windkessel vessels)

b. medium muscular arteries (distribution vessels)

2. Arterioles (resistance vessels)

Arterioles are the smallest branches of the arteries.
Arterioles are under high pressure.
Arterioles blood volume called the stressed volume.
Arteriolar act as control conduits through which blood released into the capillaries.

Arterioles have a high smooth muscle wall that extensively innervated by autonomic nerve fibers (the grates effect on autonomic is when there is highest concentration of smooth muscle).

Alpha 1 Adrenergic receptors are found on the arterioles of the

❶skin,

❷ splanchnic (Splanchnic organs - including the stomach, small intestine, large intestine, pancreas, spleen, liver, and may also include the kidney.)

❸renal circulations.

Beta 2 Adrenergic receptors found on arterioles of skeletal muscle.

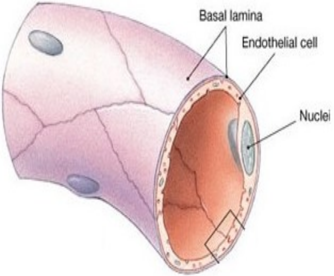
Sheet Note 1

>> stressed volume : pressure against the walls of the vessels : هو حجم الدم اذي يوسع جدار الوعاء الدموي اكثر

>> arterioles are considered as resistance vessels because they have the largest amount of smooth muscles .

Arterioles precise diameter of the lumen at any given moment determined by
①neural (sympathetic) and
②chemical (norepinephrine)
The vasoconstriction and vasodilation in the arterioles are the primary mechanisms for of both
①resistance and
②regulation of blood pressure.
Therefore,
Arterioles are the site of highest resistance in the cardiovascular system (resistance vessels).
Arterioles are critical in slowing down (or resisting) blood flow to the capillary
Arterioles muscle fibers are normally slightly contracted, causing arterioles to maintain a consistent (muscle tone) in this case referred to as vascular tone

<u>3. Capillaries (exchange vessels)</u>



Capillaries have the largest total cross-sectional and surface area.
Capillaries wall is only 1 cell thick and is simple squamous epithel surrounded by basal lamina.
Capillaries are thin walled.
Capillaries are the site of exchange of nutrients, water, and gases.
Capillaries have no muscle, or elastic valve.
Capillaries total thickness wall is only about 0.5 micrometer
Capillaries internal diameter is 4 to 9 micrometers, barely large enough for red blood cells and other blood cells to squeeze
Capillaries have a typical length of only 0.3 to 1 millimeter, so the blood remains in the capillaries for only 1 to 3 seconds, which is surprising because all diffusion of nutrient food substances and electrolytes that occurs through the capillary walls must be performed in this short time

Sheet Note 2

>> we classified arterioles as resistance vessels, **because given their small lumen, they dramatically slow the flow of blood from arteries**. In fact, arterioles are the site of greatest resistance in the entire vascular network.

>> The surface area for the arteriole itself is very small compered to other vessels , but we look at the surface area for all the arterioles in the body and we find it the largest surface area compered to other vessels in the body , and that’s explains why the exchange process occurs mostly in the arterioles (cause it has the largest surface area so makes the diffusion faster and easier).

Functional morphology of capillaries:

The arterioles divided into smaller muscle-walled vessels (meta-arterioles), and these in turn feed into capillaries. Each metarteriole arises from a terminal arteriole and branches to supply blood to a **capillary bed** that may consist of 10–100 capillaries.

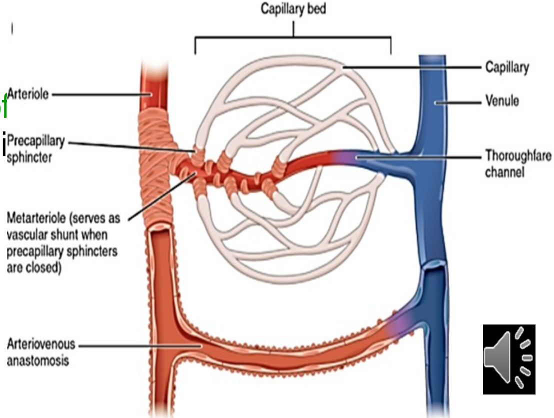
A **meta-arteriole**

- slightly larger than the typical capillary (10-20 μm)
- has structural characteristics of both an arteriole and a capillary.
- the smooth muscle of the tunica media of the metarteriole

①is not continuous

②have individual smooth muscle cells placed a short distance apart

③when constricted reduces or shuts of blood flow through their respective capi beds.



>> **meta-arteriole :** **هي حلقة الوصل بين الارتيريول والكابيلاري**

>> smooth muscles in meta-arteriole are **not** continuous , instead they are separated to conroll the blood flow between the arterioles & capillaries so when they are constricted they reduces or shut off blood flow through their respective capillary (كي ينتقل الدم علـى دفعـات ولـيس مرة واحدة)

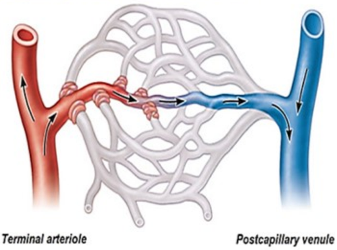
The **precapillary sphincters**, circular smooth muscle cells that surround the capillary at its origin with the metarteriole, tightly regulate the flow of blood from a metarteriole to the capillaries it supplies. Their function is critical: If all of the capillary beds in the body were to open simultaneously, they would collectively hold every drop of blood in the body and there would be none in the arteries, arterioles, venules, veins, or the heart itself. Normally, the precapillary sphincters are closed. When the surrounding tissues need oxygen and have excess waste products, the precapillary sphincters open, allowing blood to flow through and exchange to occur before closing once more. If all of the precapillary sphincters in a capillary bed are closed, blood will flow from the metarteriole directly into a **thoroughfare channel** and then into the venous circulation, bypassing the capillary bed entirely. This creates what is known as a **vascular shunt**. In addition, an **arteriovenous anastomosis** may bypass the capillary bed and lead directly to the venous system.

Blood dose not flow continuously through the capillaries. Instead, it flows intermittently, turning on and off every few seconds, this is called (vaso-motion).

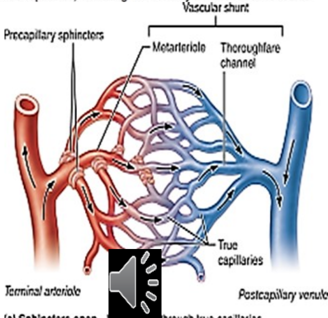
Vasomotion: intermittent contraction and relaxation of pre-capillary and met-arteriole smooth muscle (5-10 time/min) which is regulated both locally (metabolically) and by sympathetic control. .

Vasomotion regulated by chemical signals that are triggered in response to changes in internal conditions, such as oxygen, carbon dioxide, hydrogen ion, and lactic acid levels.

Capillary Beds – "Vascular Shunt"



(b) Sphincters closed (sympathetic stimulation)—blood flows *straight through* Metarteriole Thoroughfare Channel and *bypasses* the true capillaries, "shunting" blood away from this area of tissue.



(a) Sphincters open— ... through true capillaries.

Sheet Note 4

>> if the blood flow from the artery to the vein directly through capillary we call it (**arteriovenous shunt)** which is an abnormal motion of blood.

Capillaries and post-capillaries venules have (Pericytes) outside the endothelial cells.

These cells have long processes that warp around the vessels.

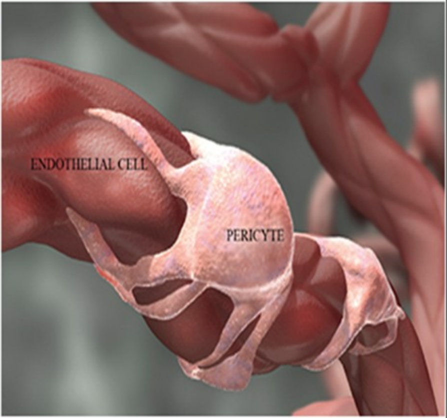
They have the following functions:

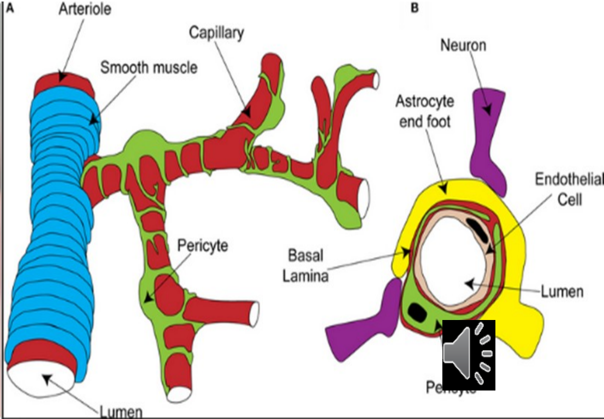
❶ They are contractile

❷ Release a wide variety of vasoactive substances (vasoconstriction & vaso-dilation)

❸ Synthesize and release constituents of the basement membrane and extra-cellular matrix

❹ Regulate the flow through the junction between endothelial cells.





Sheet Note 5

Pericytes : are cells that surround the capillaries , they have the ability of contraction

Types of capillaries:

There are three main types of capillaries:

A. Continuous capillary:

By “continuous,” this definition describes:

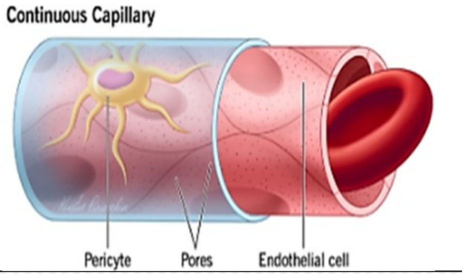
- endothelial cells that have a lining that is uninterrupted with
- tight junctions between endothelial cells.

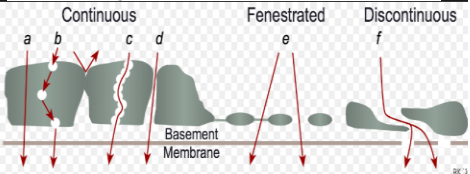
Continuous capillary is the most common type of capillary and found in almost all vascularized tissues.

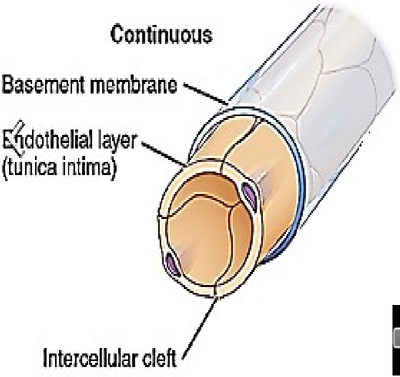
Continuous capillaries only allow smaller molecules to pass (like gases, water, glucose, ions, and some hormones) through their intercellular clefts (small gaps in between their endothelial cells). Lipid-soluble molecules can passively diffuse through the endothelial cell membranes along concentration gradients.

Tight junction capillaries can be further subdivided into:

1. Those with numerous transport vesicles, which found primarily in skeletal muscle, fingers, gonads, and skin
2. Those with few vesicles, which primarily found in the CNS (are a constituent of the blood Brain Barrier).







Sheet Note 6

>> **continuous** type of capillaries have continuous endothelial structure and continuous basement membrane .

B. Fenestrated

Fenestrated capillary (derived from fenestra Latin for "window") have

1. Endothelium:

a. pores in the endothelial cells (60-80 nm in diameter) ➡ allow small molecules and limited amounts of protein to diffuse

b. tight junctions in the endothelial lining

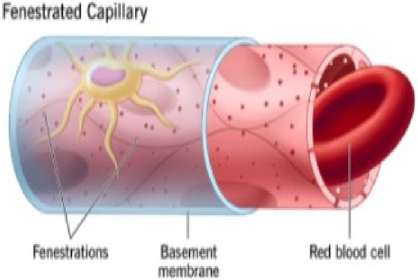
2. continuous basal laminae.

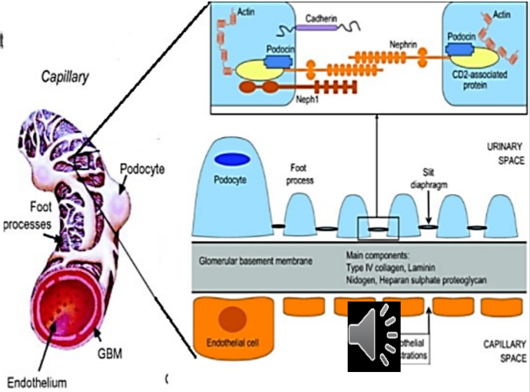
The number of fenestrations and their degree of permeability vary, however, according to their location.

Fenestrated capillaries are common in the small intestine, glomeruli of the kidney, choroid plexus of the brain and many endocrine structures, including the hypothalamus, pituitary, pineal, and thyroid glands. The types of fenestrations are:

❶With diaphragm which is radially oriented fibers

❷With no diaphragm (as in the renal glomerulus), instead have podocytes foot processes or pedicles, which have slit pores with a function analogous to the diaphragm of the capillaries.



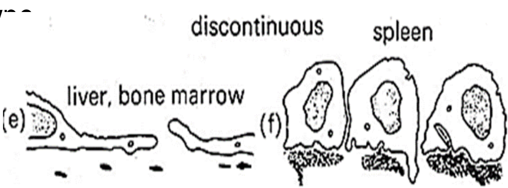


Sheet Note 7

>> Fenestrated : مثقب \اي يحتوي على ثقوب

<u>C. Sinusoidal (also known as a discontinuous capillary):</u>

Sinusoidal capillary is the least common ty



① Endothelium are flattened,

③ incomplete basement membranes

④ extensive intercellular gaps.

⑤ intercellular clefts and fenestrations (a pore capillary); that have larger openings (30-40 μm in diameter) increasing the permeability of the capillary

Sinusoid blood vessels are primarily located in the

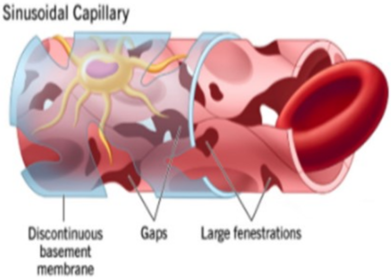
① bone marrow allow RBC and WBC (7.5 μm - 25 μm diameter)

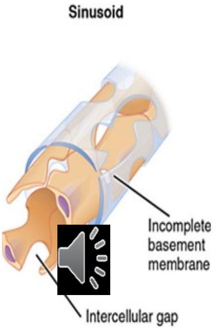
② liver allows various serum proteins to pass, aided by a discontinuous basal lamina.

③lymph nodes

④adrenal glands

⑤spleen



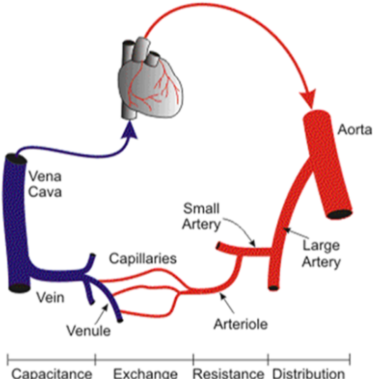


4. Venules

Venule is an extremely small vein, generally 8–100 micrometers in diameter.
Post-capillary venules join multiple capillaries exiting from a capillary bed
Capillaries and post-capillaries venules have (Peri-cytes) outside the endothelial cells.

5. Veins (capacitance vessels)

- Progressively merge to form larger veins. The largest vein, the vena cava, returns blood to the heart.
- are thin-walled and easily distended. Because they contain little elastic tissue and smooth muscles, but considerable vasoconstriction produced by activity in the nor-adrenergic nerve
- are under low pressure.
- contain the highest proportion of the blood in the cardiovascular system (the unstressed volume).
- have $\acute{\alpha}_1$-adrenergic receptors.
- equipped with valves



Sheet Note 8

>> veins have less amount of smooth muscles than arteries so its affected by sympathetic stimulation less than parasympathetic stimulation .

Biophysical consideration:

Hemodynamics branch of physiology dealing with forces involved in the circulation of the blood.

Blood rheology study of flow properties of blood and its elements of plasma and cells

<u>Blood flow & velocity</u>

Blood flow refers to the movement of blood through the vessels from heart ►arteries ►arterioles ►capillaries ► Venules ►veins ►heart

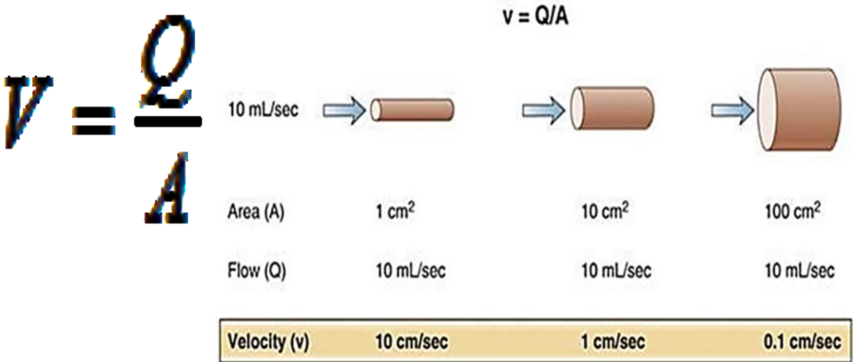
Blood flow means the quantity of blood that passes a given point in the circulation in a given period (mm^3/sec or litter/min or litters/sec).

Blood flow (mm^3/sec) = velocity (mm/sec) X cross-section area (mm^2)

The overall blood flow in the total circulation of an adult person at rest is about 5000 ml/min. This called the **cardiac output** because it is the amount of blood pumped into the aorta by the heart each minute.

Blood flow velocity is the speed, which blood moves along the circulation in any particular segment and expressed in unit of distance per time.

V= Q / A Where V: Velocity of blood flow (cm/sec). Q: Flow (mL/sec). A: Cross-sectional area



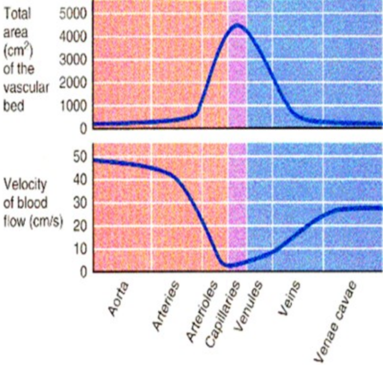
The velocity of blood is inversely relation to cr[redacted] sectional area

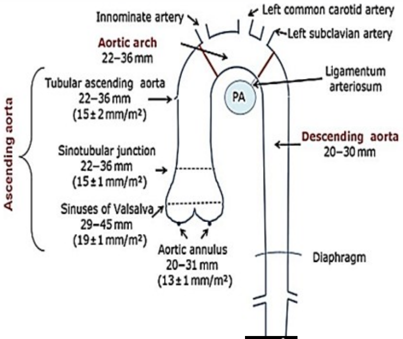
The highest velocity is seen in aorta with a sm[redacted] cross-sectional area= 2.5 cm average velocity of 40-50 cm/s)

The lowest velocity is seen in capillaries (8 to 10 microns in diameter, just large enough for red blood cells to pass through them in single file and a very slow flow (0.03 cm/s) (taken in consideration that the sum of all of the capillaries (large cross-sectional area = 4500 cm^2).

The lower velocity of blood in the capillaries optimizes conditions for exchange of substances across the capillary wall.

The cross-sectional areas of the veins are much larger than the arteries, averaging about four times those of the corresponding arteries. This difference explains the large blood storage capacity of the venous system in comparison with the arterial system.





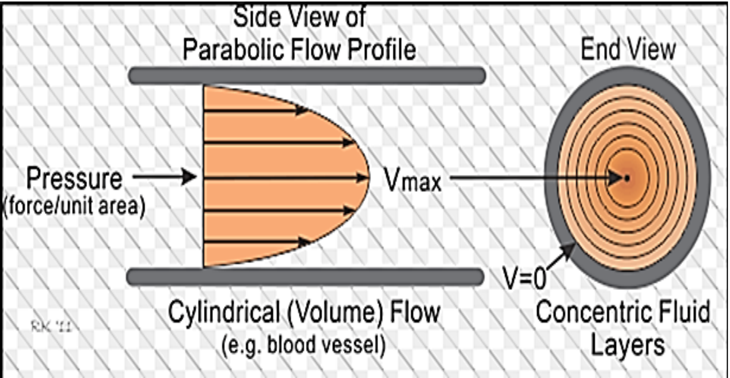
Types of flow:

Laminar (Streamline) flow

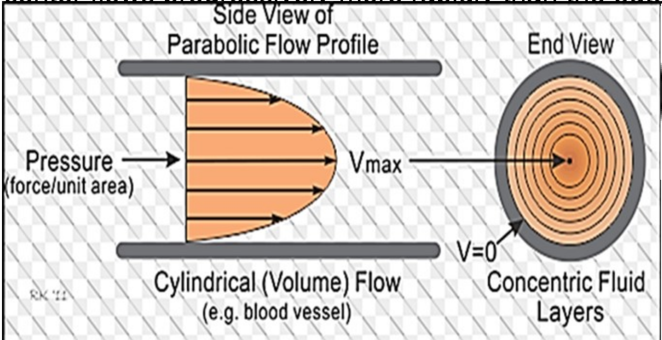
Laminar flow (or viscous flow) describes the movement of fluid through a tube in concentric layers that slip past each other.

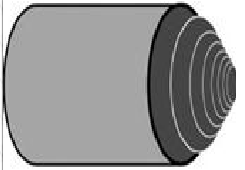
Laminar flow characterized by concentric layers of blood moving in parallel down the length of a blood vessel.

Laminar flow is the most efficient pattern of flow velocities, in that the fluid exerts the least resistance to flow in this configuration.



When laminar flow occurs, the velocity of flow in the center of the vessel is far greater than that toward the outer edges.
The highest parabolic laminar flow velocity (V_{max}) found in the center of the vessel.
The lowest parabolic laminar flow velocity (V=0) found along the vessel wall.
The cause of the parabolic profile is the following:
The fluid molecules touching the wall move slowly because of adherence to the vessel wall. The next layer of molecules slips over these, the third layer over the second, the fourth layer over the third, and so forth. Therefore, the fluid in the middle of the vessel can move rapidly because many layers of slipping molecules exist between the middle of the vessel and the vessel wall; thus, each layer toward the center flows progressively more rapidly than the outer layers.





Turbulent flow has crosscurrents تيارات متقاطعة and eddies دوامات, and the fastest velocities are not necessarily in the middle of the stream.

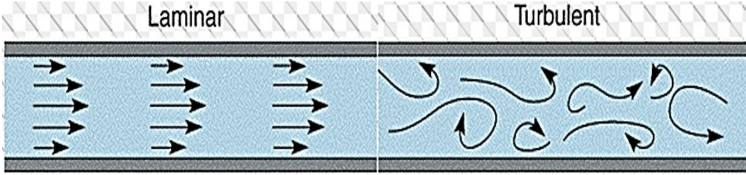
Several factors contribute to the tendency for turbulence:

❶high flow velocity,

❷large tube diameter,

❸high fluid density,

❹low viscosity



1. All of these factors can be combine to calculate **Reynolds number** (NR), which quantifies the tendency for turbulence:

$$N_R = v d \rho / \eta$$

Where **v** is the mean velocity, **d** is th **rho)**, is the fluid density, and **η (eta)** is the fluid viscos

Turbulent flow occurs when N_R exceeds a critical value.

When Reynolds' number rises above approximately 2000, turbulence will usually occur even in a straight, smooth vessel.

Conditions are appropriate for turb

(1) High velocity of blood flow,

(2) Pulsatile nature of the flow,

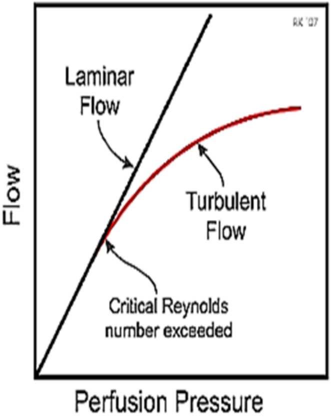
(3) Sudden change in vessel diam

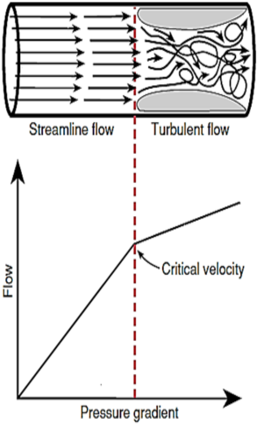
(rapid narrowing of blood vessel)

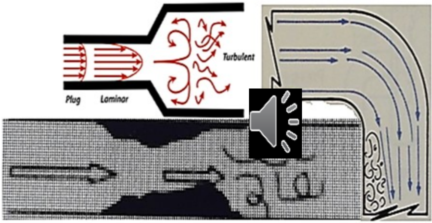
(4) Large vessel diameter.

(5) Sharp turns in the circulation

(6) Rough surface in the circulatio







Turbulent flow means that blood flow in a laminar and crosswise (بشكل موازي و متعامد مع الجدار) forming whorls in the blood, called eddy currents.
When eddy currents are present, the blood flows with much greater resistance than when the flow is streamlined, because eddies add tremendously to the overall friction of flow in the vessel.

Eddy current occurs in

A. Normal condition: As in,

①the beginning of aorta and pulmonary artery

Eddy currents generated because blood is forced through an orifice into a broad vessel, surrounding the valve and cusps of the valve and keep the cusps in the stream and not against the chamber wall.

the Reynold number can rise to several thousands due to high velocity during ejection phase

②bifurcation of artery (as common carotid artery bifurcation)

the Reynolds' number rises above 200 to 400, turbulent flow will occur at some branches of vessels but will die out along the smooth portions of the vessels

Reynolds number less than or equal to 2000 indicates laminar flow

Reynolds number more than or equal to 2000 turbulence will usually occur even in straight smooth vessel.

Reynolds' number is almost never high enough, in small vessels, to cause turbulence

Reynolds number is without units

B. Abnormal conditions:

❶Murmurs

Murmur in the heart is an abnormal, extra sound during the heartbeat cycle

Murmur generated by turbulent flow of blood in the heart where Eddy currents generated because blood is forced through an orifice into a broad chamber, surrounding the valve and cusps of the valve and keep the cusps in the stream and not against the chamber wall

Murmur generated due to

a. pathological changes in the cardiac valves either

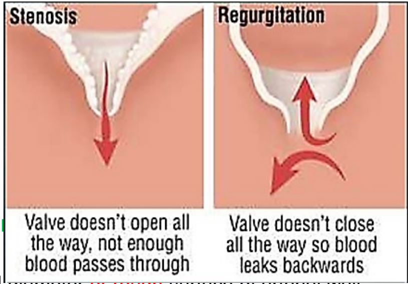
①dilation (regurgitation)

②narrowing (stenosis)

b. septal defect

that raise flow velocity often induce turbulent flow.

Murmur important in diagnosing cardiac valvular lesions.



❷ Bruits (or vascular murmur)

Bruits is the abnormal sound generated by turbulent flow of blood in an a

Bruits occurs in

①vessels stenosis, occurs in atherosclerosis due to narrowing of arterial diameter or rough surface of arterial wall.

②arterio-venous shunts.

Bruits occurs due high blood flow velocity.

(7) High fluid density

(8) Low viscosity.

Viscosity

Isaac Newton described viscosity in 1713 as internal friction to flow in a fluid or lack of slipperiness.

Viscosity reflects to the thickness of fluid.

Viscosity is a property of fluids that indicates resistance to flow.

Viscosity can be measure in vitro by viscometer

Unit of viscosity Poise (after Poiseuille).

A fluid of 1 Poise viscosity has a force of 1 dyne/cm^2 of contact between layers when flowing with a velocity gradient of 1 cm/sec.

The poise (P) is the unit of dynamic viscosity in the gram –centimeter-second

Th

$$1\,\mathrm{P} = 0.100\,\mathrm{kg}\cdot\mathrm{m}^{-1}\cdot\mathrm{s}^{-1} = 1\,\mathrm{g}\cdot\mathrm{cm}^{-1}\cdot\mathrm{s}^{-1}.$$

second (Pa s).

$$1\,\mathrm{Pa}\cdot\mathrm{s} = 1\,\mathrm{kg}\cdot\mathrm{m}^{-1}\cdot\mathrm{s}^{-1} = 10\,\mathrm{P}.$$

Relative viscosity:

Relative viscosity is a more often used term.

Relative viscosity refers to the viscosity of fluid relative to viscosity of water at body temperature (37°C)

Viscosity of water at 21 °C is 0.01 poise or 1centipoise.

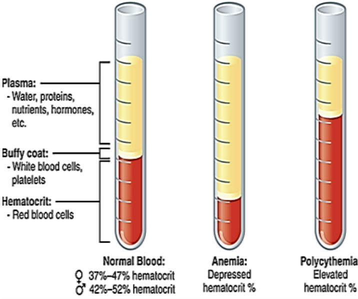
Viscosity of water at body temperature (37 °C) is 0.695 centipoise

Plasma has a viscosity of 1.2 centipoise at 37°C

Plasma has a relative viscosity of 1.7.

Blood has a viscosity of 2.8-3.8 centipoise at 37°C

Blood (plasma plus cells) has a relative viscosity of about 4-5.



Several factors affecting viscosity including:

(1) Blood composition changes:

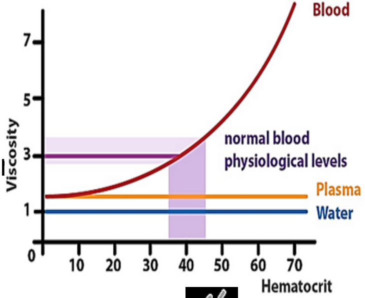
①RBC mass: increase the number of RBC, Hematocrit (or Packed cell volume), and hemoglobin all will increase viscosity.

Examples:

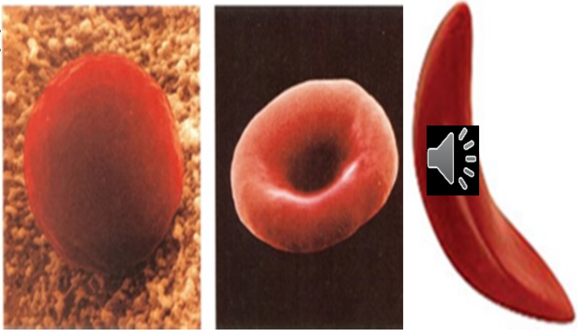
a. anemia decrease viscosity

b. polycythemia increases viscosity

Those factors considered as most important factors that increase viscosity



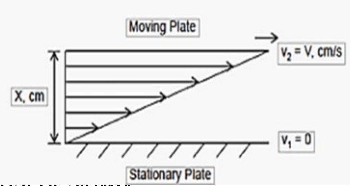
The most important factor of these is the RBC because each RBC exerts frictional drag against adjacent cells and against the wall of the blood vessel.
When the hematocrit rises to 60 or 70%, which it often does in polycythemia, the blood viscosity can become as great as 8-10 times that of water, and its flow through blood vessels is greatly retarded
②Plasma protein: increase plasma protein will increase viscosity.
Changes in Plasma protein (such as hyper-gamma-globulin-emia) has less effect on viscosity than RBC changes.
③Resistance of cell to deformation: viscosity increase in hereditary spherocytosis and sickle cell
④If **clotting** mechanisms are stimulated in the blood, platelet aggregation and interactions with plasma proteins occur. This leads to entrapment of red cells and clot formation, which dramatically increase blood viscosity.
All these factors will explain the higher viscosity of blood than water.
(2) Temperature:
↓ body temperature ►↑ blood viscosity
Blood viscosity increase 2% for each one° C
decrease in temperature.
When the hand kept in ice water regional bl
viscosity show a threefold increase.



(3)Shear rate or blood flow velocity gradient.

Viscosity of the blood decrease as the shear rate or velocity gradient increase and vice versa.

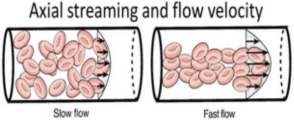
Shear rate is the rate of change of velocity at which one layer of fluid passes over an adjacent layer. As an example, consider that a fluid placed between two parallel plates that are 1.0 cm apart, the upper plate moving at a velocity of 1.0 cm/sec and the lower plate fixed.



Newtonian fluids such as Water, air, alcohol, glyce ... sma their viscosity remains the same whether they are flowing f...

Non- Newtonian fluids such as Whole blood its viscosity changes with its velocity.

A. At high blood flow velocity (or high shear rate) such as (exercise, during systole) blood viscosity decrease.



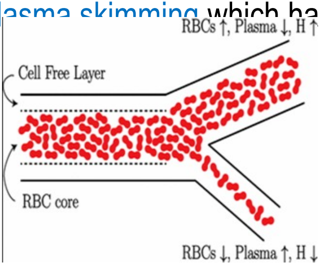
في السرعة العالية تتجمع الكريات في الوسط
مما يقلل المقاومة واللزوجة
في السرعة الواطئة لا تتجمع الكريات في الوسط
مما يزيد المقاومة واللزوجة

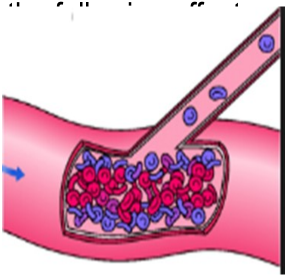
This is because red cells te... f th... and move with their long axis parallel to the ... ra... cell free zone of plasma at periphery, an arra... eaming.

Axial streaming ► reduces the viscosity ► reduces resistance to flow.

The RBC tend to accumulate along the axis of the blood vessel has consequence that result in decrease of hematocrit as blood approaching the micro-vessel. The phase separation due to axial migration affects the cellular content of blood flowing into the side branches of blood vessels. A branch originating from a vessel of higher order fed mainly by the marginal stream (which contains plasma) of the higher order vessel so receives blood with a lower hematocrit.

This is called plasma skimming which has





Larger branches with higher flow rates receive relatively more RBC and therefore have higher hematocrit blood

Smaller breaches with low flow rates receive relatively less RBC and therefore have lower hematocrit blood .

This explains why the hematocrit of capillary blood is about 25% less than the whole– body hematocrit.

Sheet Note 9

لينك ل فيديو بسيط وتوضيحي لبعض مما سبق

https://youtu.be/sWfCKdjxLc0

اعتذر عن عدم كتابتي لتفاصيل معينة في الشرح لعدم قدرتي على توصيل المعلومة وشرحها

انصح بالرجوع للريكورد لان الدكتور شارح المحاضرة كتيير منيح