CVS
PHYSIOLOGY

Modified NO: 12

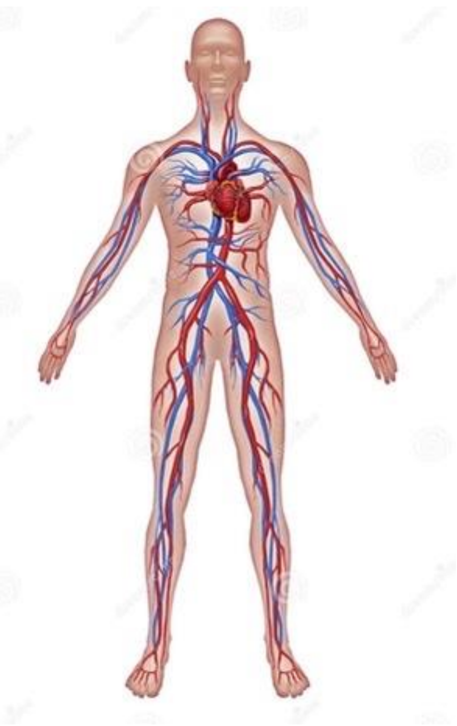
كتابة: ريناس الخريسات
أحمد المطارنة

تدقيق: تم التدقيق

الدكتور: Fatima Ryalat

Cardiovascular Physiology

Fatima Ryalat, MD, PhD
Assistant Professor, Physiology and Biochemistry Department
School of Medicine, University of Jordan



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	Slides
	Doctor
	Additional info
	Important

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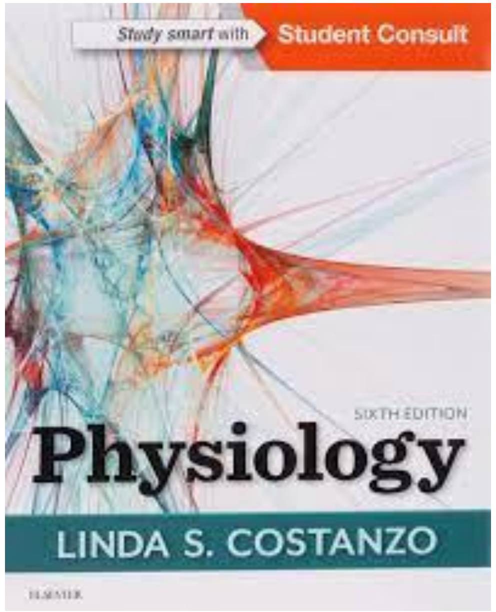
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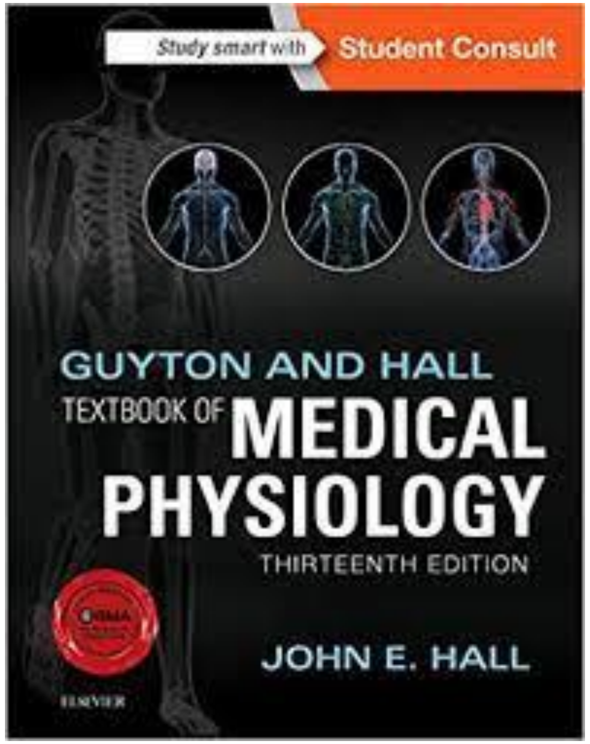
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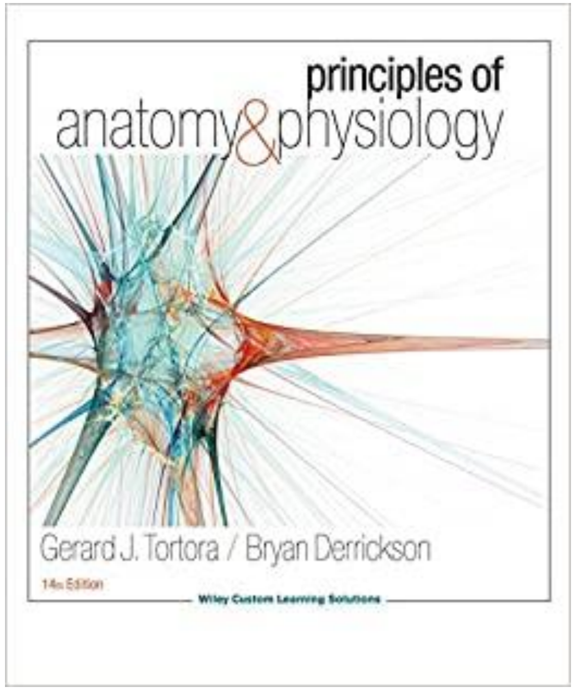
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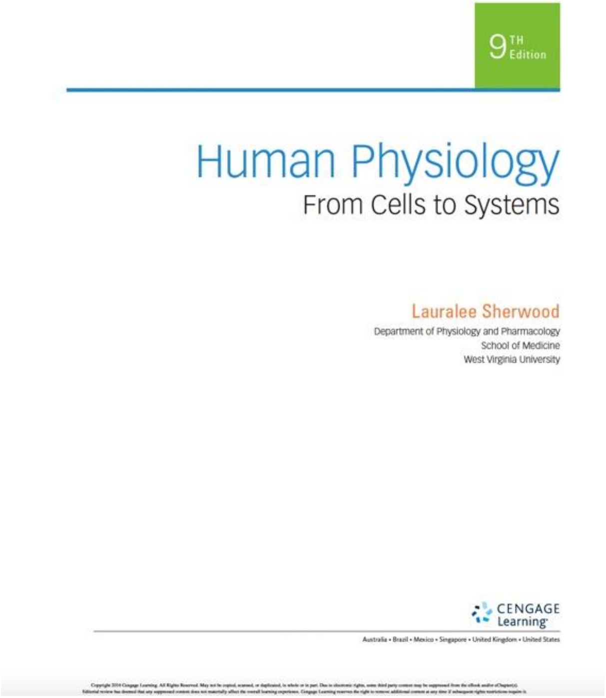
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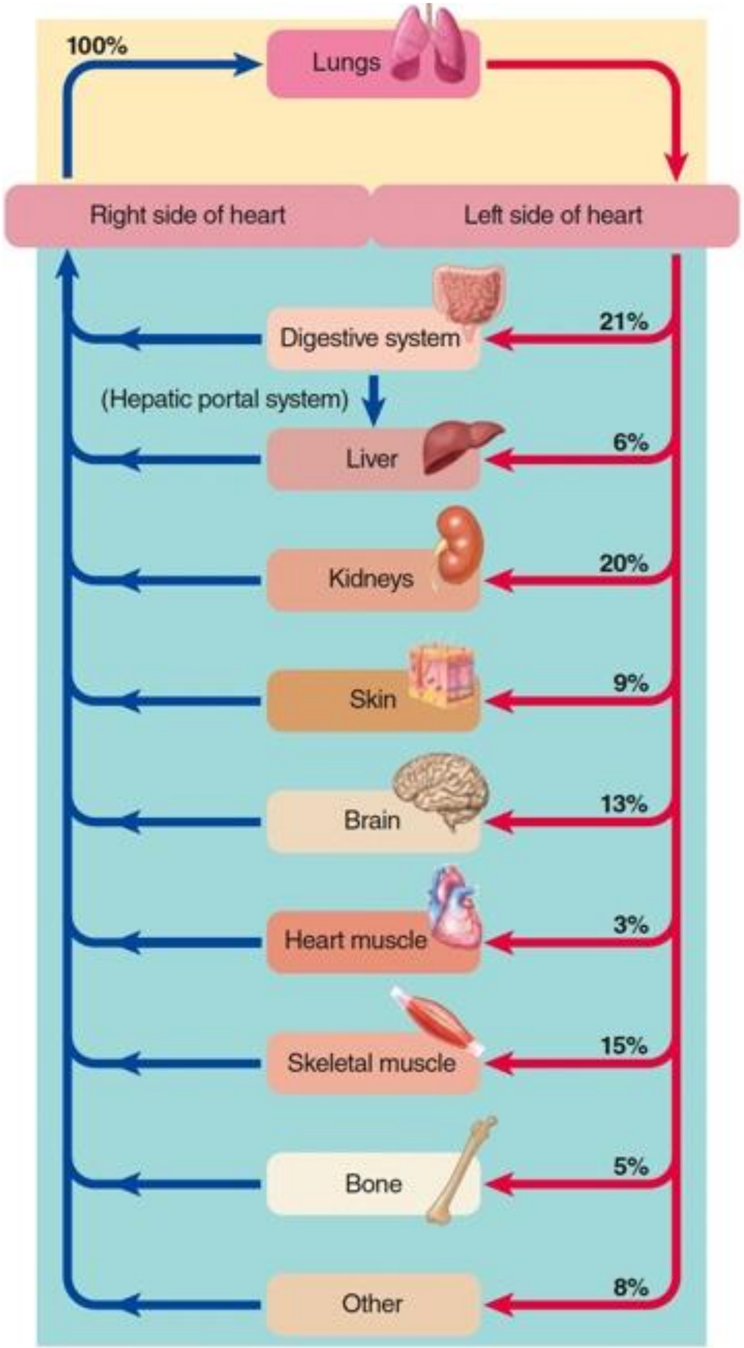
Vascular hemodynamics-1

Hemodynamics

- The principles that govern blood flow in the cardiovascular system.



100%
Lungs
Right side of heart
Left side of heart
Digestive system
21%
(Hepatic portal system)
Liver
6%
Kidneys
20%
Skin
9%
Brain
13%
Heart muscle
3%
Skeletal muscle
15%
Bone
5%
Other
8%

- The blood is pumped by the left ventricle into the systemic circulation is distributed in various proportions to the organs through a parallel arrangement of vessels that branch from the aorta. And from the right side , it goes to the pulmonary circulation. (we are focusing on systemic circulation)
- The blood flow distribution is differed between different organs (different percentage to different organs)
- Parallel arrangement of vessels ensure they all organs receive blood of the same composition (if they don't, organs will have different O2 levels , blood composition distribution) .
- blood flow through each systemic organ can be independently adjusted as needed.

- A question from doctor :

--> Are all organs in the body receive a volume of blood flow that matches their metabolic needs ?
=NO, it's false , there are organs that do other functions to the blood (reconditioning organs) . Blood takes waste products from all tissues, and it send it to the kidneys, so we need a large amount of blood to go there (kidney needs 20% of blood volume not for metabolic rate matching , this amount is for getting rid of the waste products).

- We need to bring nutrients to the blood but from where ? From the GI system , it takes 21% , it's very important for blood reconditioning .
- On the skin , it's 9% for body regulating Temperature .
- **Kidneys, skin, digestive system** :This is a Reconditioning organ, meaning it normally receives much more blood flow than is necessary to meet its basic metabolic needs.
- Other organs will receive blood amount , matching their metabolic rate .

- The brain suffers permanent damage when transiently deprived of blood supply. Therefore, a constant delivery of an adequate blood to the brain is a high priority.
- The brain can't tolerate decreased blood supply for even a seconds .


The parallel arrangement

- The blood pumped by the left side of the heart into the systemic circulation is distributed in various proportions to the systemic organs through a parallel arrangement of vessels that branch from the aorta.
- This arrangement ensures that:
- 1. All organs receive blood of the same composition.
- 2. Blood flow through each systemic organ can be independently adjusted as needed.

Reconditioning organs

- Blood is constantly “reconditioned” so that its composition remains relatively constant despite an ongoing drain of supplies to support metabolic activities and despite continual addition of wastes from the tissues.
- Organs that recondition the blood normally receive much more blood flow than is necessary to meet their basic metabolic needs, so they can adjust the extra blood to achieve homeostasis.

Reconditioning organs

- Blood flow to the other organs is for filling these organs' metabolic needs and can be adjusted according to their level of activity.
- Because reconditioning organs—digestive organs, kidneys, and skin—receive blood flow in excess of their needs, they can withstand temporary reductions in blood flow much better than other organs can that do not have this extra margin of blood supply.

Reconditioning organs

- the brain, which can least tolerate disrupted blood supply, is a high priority in the overall operation of the circulatory system.
- In contrast, the reconditioning organs can tolerate significant reductions in blood flow for quite a long time, and often do.

Flow rate

- The flow rate of blood through a vessel is the volume of blood passing through per unit of time.
- It is directly proportional to the pressure gradient and inversely proportional to vascular resistance.
- $F = \Delta P/R$

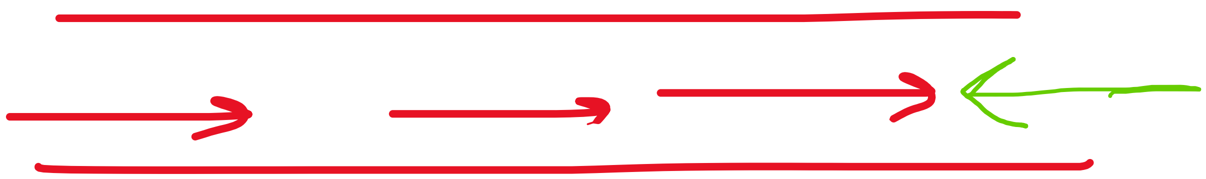
Pressure gradient

- the difference in pressure between the beginning and the end of a vessel.
- Blood flows from an area of higher pressure to an area of lower pressure down a pressure gradient.
- It is generated by contraction of the heart.
- Because of resistance, the pressure drops as blood flows throughout the vessel's length.
- The greater the pressure gradient, the greater the flow rate through the vessel.

Factors affecting the Blood flow

1)Resistance
2) viscosity
3) pressure

P_1 P_2



Direction of blood flow ---->

Resistance , will decrease the blood flow rate , anything that will increase the friction between the blood and the blood vessel wall , will decrease the flow rate .

1 I need to know the blood flow which will reach different organs. I must have force which will come from the heart contraction (left ventricle).

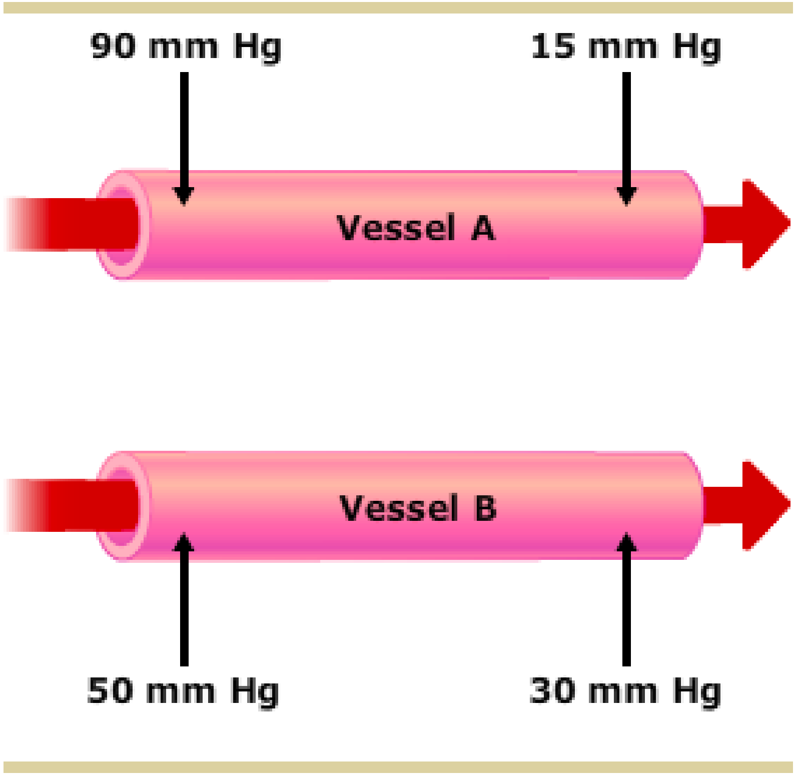
2 The left ventricle is generating a pressure this pressure will be a force that direct the blood to. flow in a specific direction , the flow rate depends on different factors : pressure gradient (different in pressure in order to the blood to flow) .

3 P1 is larger than P2 , P1 must be larger , as this pressure gradient increases the blood flow increase . Proportional relationship . So if p2 is higher than p1 , blood won't flow due to the low pressure in p1 (no force to push blood forward) .

pressure gradient

- The more pressure gradient (difference) , the more blood flow will be , as shown here in this figure .

- Extra image



Resistance

- a measure of opposition to blood flow through the vessel, caused by friction between the moving fluid and the vascular walls.
- As resistance to flow increases, it is more difficult for blood to pass through the vessel, so flow rate decreases.

Total peripheral resistance

- There is a regional resistance and total resistance
- The resistance of the entire systemic vasculature is called the total peripheral resistance (TPR) or the systemic vascular resistance (SVR).
- TPR can be measured with the flow, pressure, and resistance relationship by substituting cardiac output for flow (Q) and the difference in pressure between the aorta and the vena cava for ΔP.

$R = \Delta P / F$ (from the previous flow rate equation)
To measure total resistance:

- we need the difference in pressure between the beginning of the systemic circulation (aorta, highest pressure, name it →P1) to its end (just before right atrium, lowest pressure, name it →P2).
- We also measure the total flow, which is also the cardiac output (the volume that pass the systemic circulation per minute)

$R = (P1 – P2) / F$
Example → $R = (100 – 0) / 5$
$=100/5=20$

- Now let's measure for regional resistance
- The same thing will be applied here as systemic resistance!

Resistance in a single organ

SAMPLE PROBLEM. Renal blood flow is measured by placing a flow meter on a woman's left renal artery. Simultaneously, pressure probes are inserted in her left renal artery and left renal vein to measure pressure. Renal blood flow measured by the flow meter is 500 mL/min. The pressure probes measure renal arterial pressure as 100 mm Hg and renal venous pressure as 10 mm Hg. *What is the vascular resistance of the left kidney in this woman?*

SOLUTION. Blood flow to the left kidney, as measured by the flow meter, is Q. The difference in pressure between the renal artery and renal vein is ΔP. The resistance to flow in the renal vasculature is calculated by rearranging the blood flow equation:

$$Q = \Delta P / R$$

Rearranging and solving for R,

$$\begin{aligned} R &= \Delta P / Q \\ &= (\text{Pressure in renal artery} - \text{Pressure in renal vein}) / \\ &\quad \text{Renal blood flow} \end{aligned}$$

$$\begin{aligned} R &= (100 \text{ mm Hg} - 10 \text{ mm Hg}) / 500 \text{ mL per min} \\ &= 90 \text{ mm Hg} / 500 \text{ mL per min} \\ &= 0.18 \text{ mm Hg/mL per min} \end{aligned}$$

Resistance

- Resistance to blood flow is
- (1) directly proportional to viscosity of the blood, **like in polycythemia vera**
- (2) directly proportional to vessel length,
- (3) inversely proportional to vessel radius, which is by far the most important.
- Poiseuille equation:

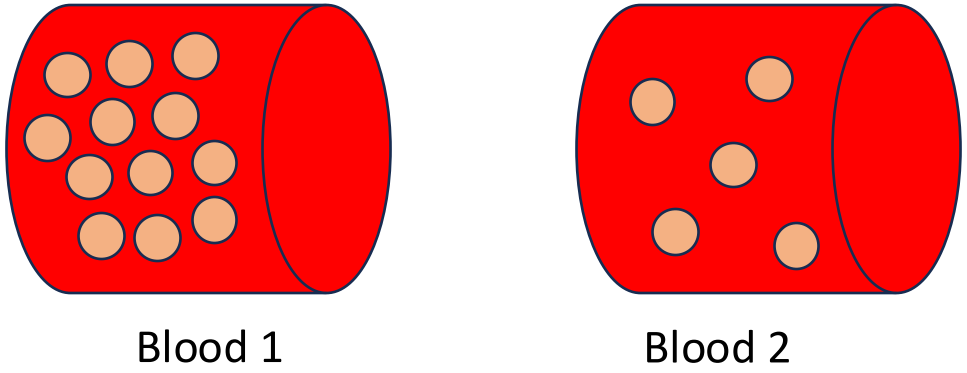
$$R = \frac{8\eta l}{\pi r^4}$$

r is the radius of the vessel
l is length of the vessel
η is viscosity of the blood

Viscosity

- the friction developed between the molecules of a fluid as they slide over each other during flow of the fluid.
- The thicker a liquid is, the greater its viscosity, the greater the resistance to flow.
- Blood viscosity is determined primarily by the number of circulating red blood cells.

Blood viscosity effect on flow rate



- Viscosity is mainly the friction between the particles , as the particles increases the friction increase so more viscosity .

- Blood vessel 1 has higher viscosity than 2 , so when RBCs increase the viscosity will increase , we measure it with the hematocrit , example , polycythemia , the flow rate is lower than normal because of the higher viscosity , inverse relationship.

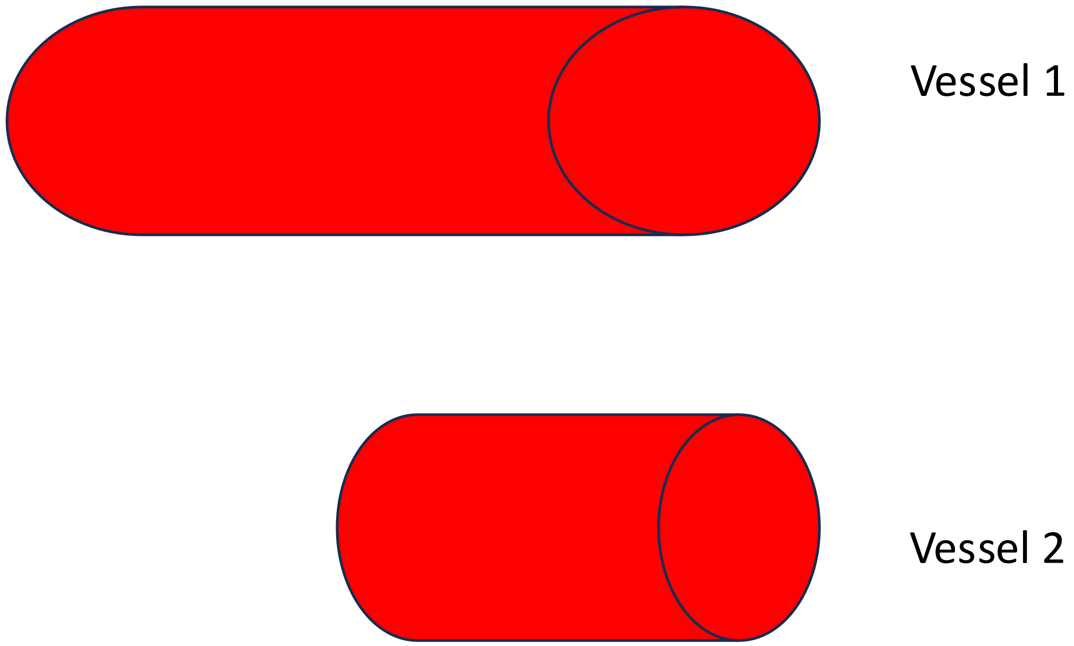
Vessel length and radius

- the longer the vessel, the greater the surface area and the greater the resistance to flow.
- resistance is inversely proportional to the fourth power of the radius.
- the radius of arterioles can be regulated and is the key factor in controlling resistance to blood flow throughout the vascular circuit.

Blood vessel length

- Factors are related to blood vessels and affect the blood flow rate

1-Blood vessel length
2-Blood vessel diameter

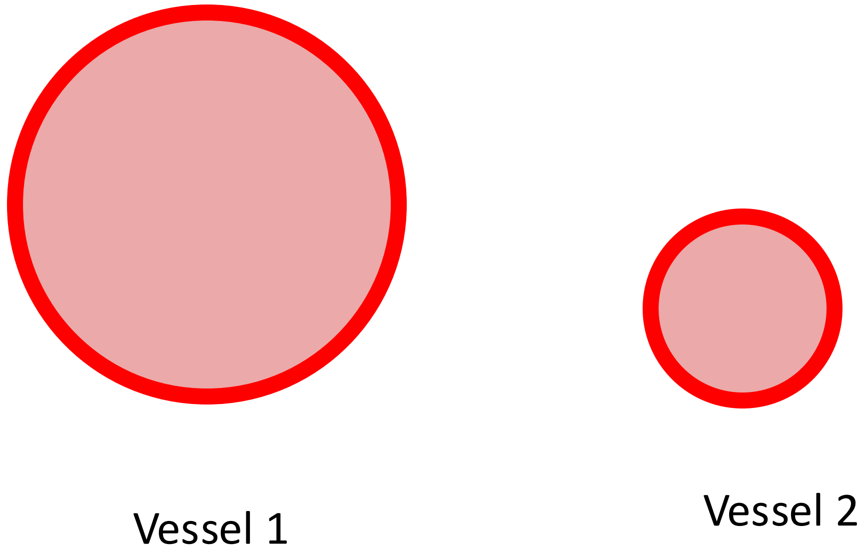


- Blood vessel 1 and blood vessel 2 , similar diameter , different length , the flow rate will be higher at blood vessel 2 and the resistance will be higher at blood vessel 1 , as the length increase the chance of friction between blood vessels and blood increase more resistance , which means less flow rate at vessel 1 .

Blood vessel diameter

- The most important factor effecting the resistance in the blood circulation (radius),it is the factor that can be regulated

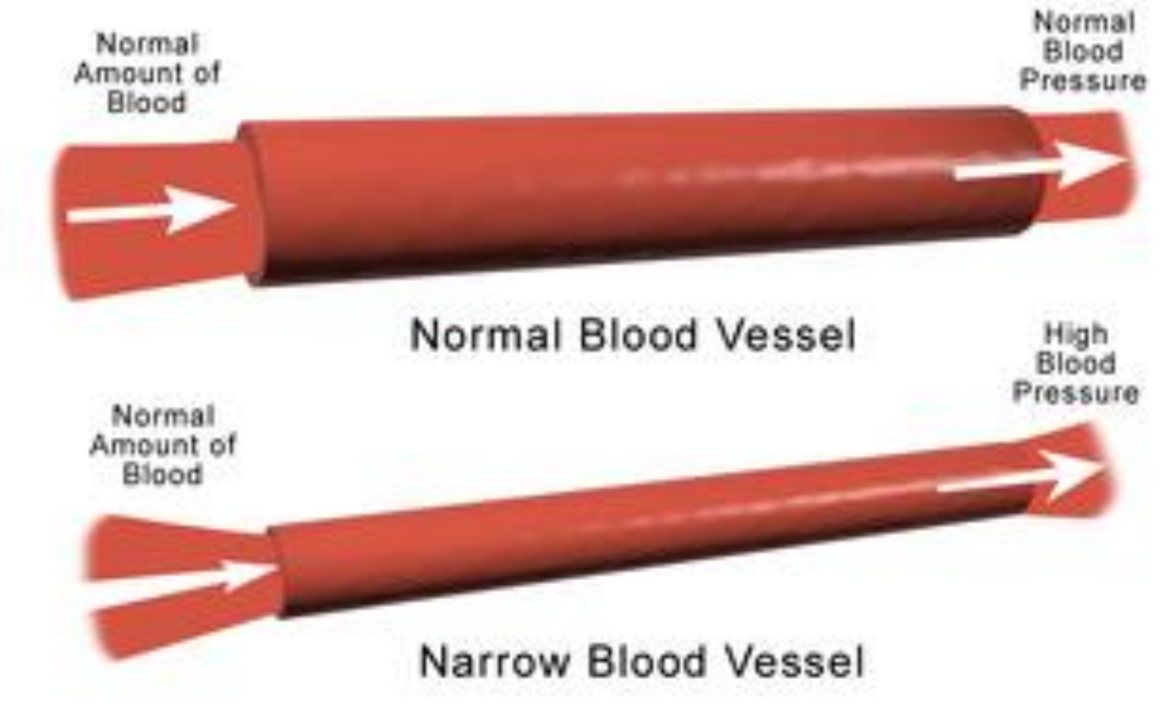
- The diameter , blood vessel one has a higher diameter, blood vessel 2 with smaller diameter has a higher friction rate .
- Rule = The lower the radius the more the resistance , the less the flow rate will be .



Blood vessel diameter

- As shown here , the more resistance , the more blood difficulty flow will be.
- As resistance to flow increases, it is more difficult for blood to pass through the vessel, so if the pressure gradient does not change, the flow rate will decrease. To maintain a uniform flow rate, the pressure gradient will have to increase accordingly if resistance is increased.

- Extra image



Velocity of blood flow

- The velocity of blood flow is the rate of displacement of blood per unit time.
- The blood vessels of the cardiovascular system vary in terms of diameter and cross-sectional area. These differences in diameter and area, in turn, have profound effects on velocity of flow.
- The relationship between velocity, flow, and cross-sectional area (which depends on vessel radius or diameter) is
- $V = Q/A$
- **Q → Flow rate A → cross sectional area**
- **Please pay attention and don't get confused**

Flow rate is volume per unit time, but velocity is distance per unit time "displacement ", so they are not the same.

- **Velocity depend on flow rate (directly proportional) and cross-sectional area (inversely proportional)**

The higher flow rate the higher the volume carried per unit time → higher velocity and displacement.

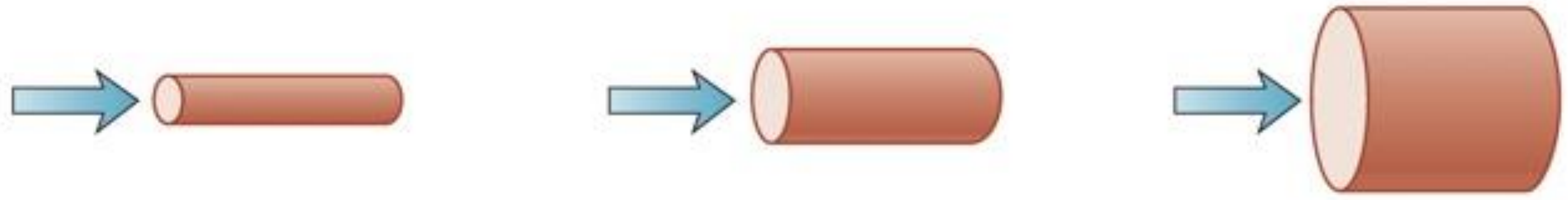
Velocity of blood flow

- Because of the inverse relationship between velocity and total cross-sectional area, the velocity of blood flow will be highest in the aorta and lowest in the capillaries.
- From the standpoint of capillary function (i.e., exchange of nutrients, solutes, and water), the low velocity of blood flow is advantageous, as it maximizes the time for exchange across the capillary walls.

- Here we controlled the flow to see the effect of cross-sectional area to velocity

$$v = Q/A$$

10 mL/s



Area (A)	1 cm^2	10 cm^2	100 cm^2
Flow (Q)	10 mL/s	10 mL/s	10 mL/s
Velocity (v)	**10 cm/s**	**1 cm/s**	**0.1 cm/s**

- A very common mistake !!

  If we only focus on one capillary vs aorta → the result will be that the capillary have faster flow than aorta, since the cross-sectional area is less than aorta. ❌

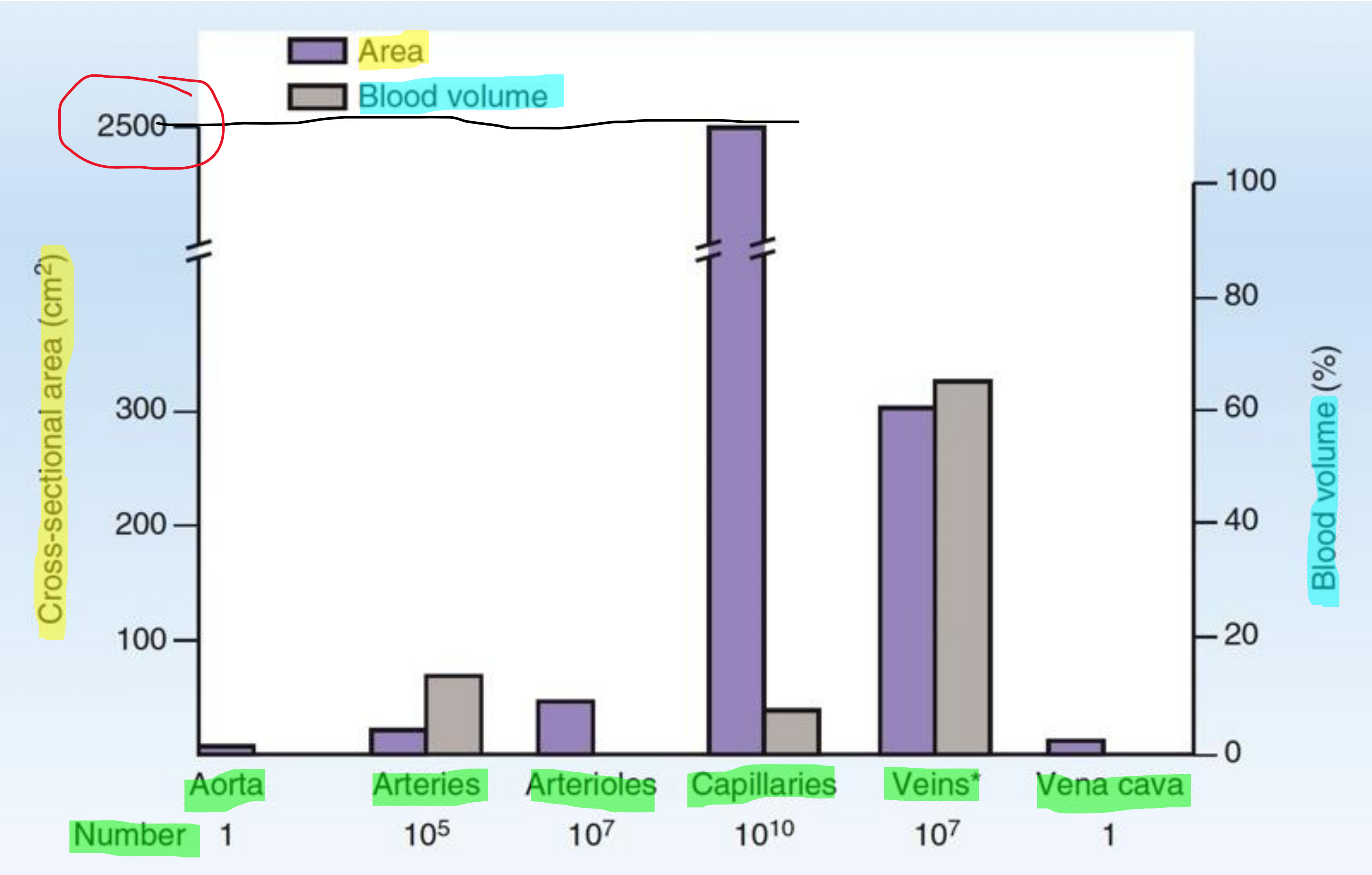
  → Single capillary → lower cross-sectional area than aorta

  → Total capillaries in the body → higher cross-sectional area than aorta
- cross-sectional "total" capillary cross-sectional area around the body exceed the cross-sectional area of the aorta
- Why? The aorta branch into arteries → arteriole → capillaries; this save the cardiac output "the flow rate"
- So, when we calculate the cross-sectional area, we calculate to the whole capillaries at the same time
- So, its final cross-sectional area is larger than aorta → lower velocity
- So, the lowest velocity will be in the capillaries ✔

Which make sense, since we need lower velocity for better exchange of nutrient

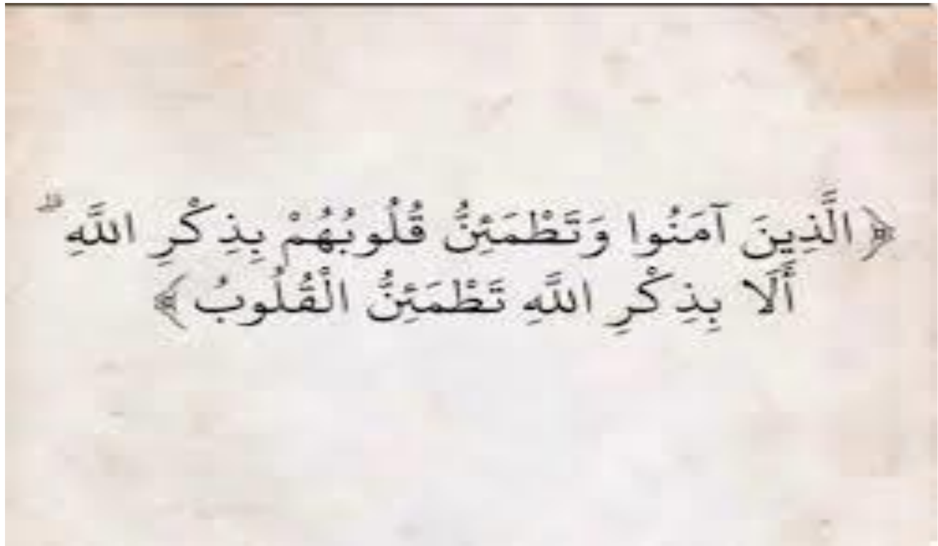
- And the highest velocity is in aorta

Which also make sense so that the blood reach downstream to the tissues and the organs


Area
Blood volume
2500
300
200
100
Cross-sectional area (cm²)
100
80
60
40
20
0
Blood volume (%)
Aorta
Arteries
Arterioles
Capillaries
Veins*
Vena cava
Number
1
10⁵
10⁷
10¹⁰
10⁷
1

Thank you

Additional sources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أَلَا بِذِكْرِ اللَّهِ تَطْمَئِنُّ الْقُلُوبُ﴾

VERSIONS	SLIDE #	BEFORE CORRECTION	AFTER CORRECTION
V1→ V2			
V2→V3			

امسح الرمز و شاركنا بأفكارك لتحسين أدائنا!!