Hemodynamics

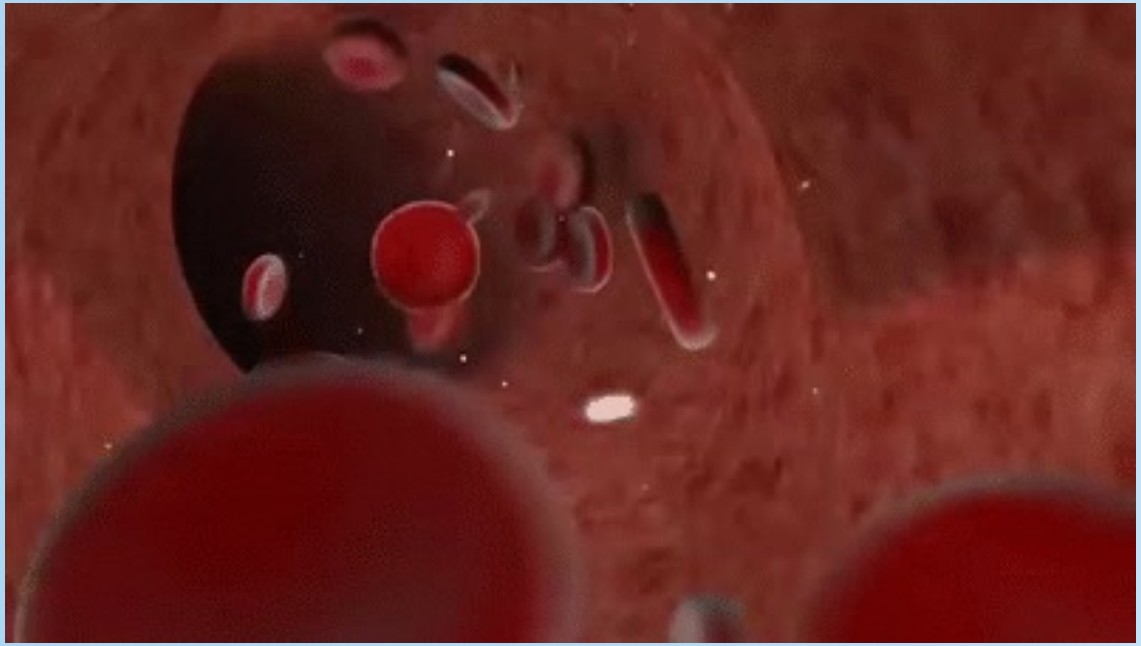
L.D. Lord

Cardiovascular Physiology Seminar

March 2024

Hemodynamics =

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



Is this patient hemodynamically stable?

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Q: What makes blood flow through the circulatory system?

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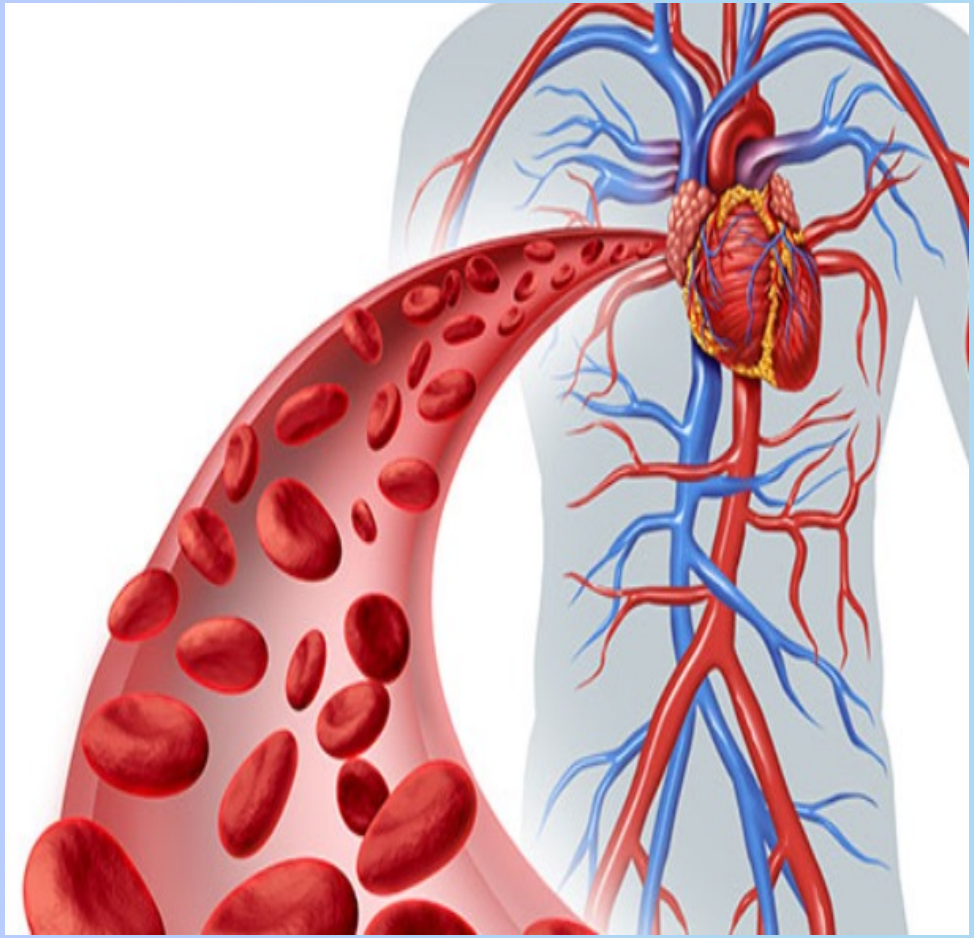

A: PRESSURE GRADIENTS

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It’s not just fluids in the circulatory system that follow pressure gradients….

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Hemodynamics Seminar Outline

1. Pattern of normal blood flow

2. Blood Flow Equation: Flow Rate, Pressure Gradient & Resistance

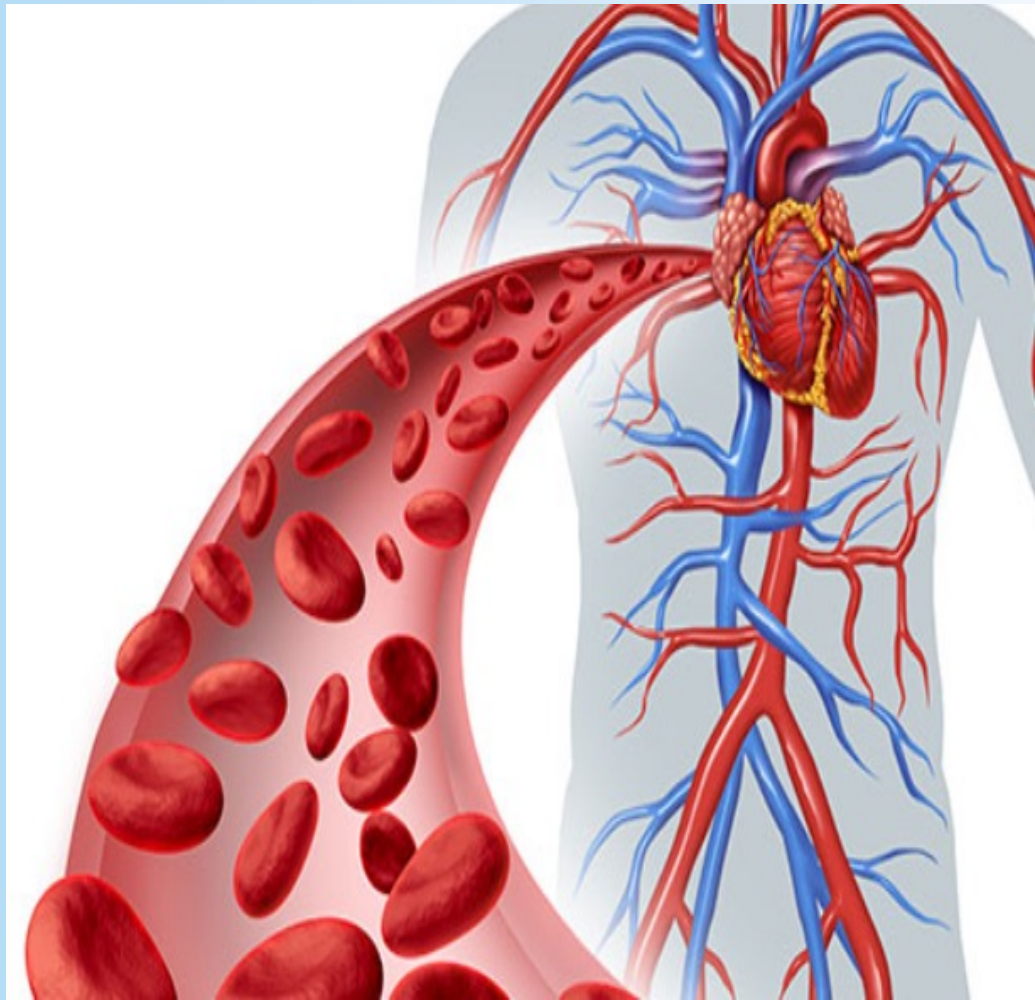
4. Distribution of Blood in Systemic Vasculature

5. Flow Velocity

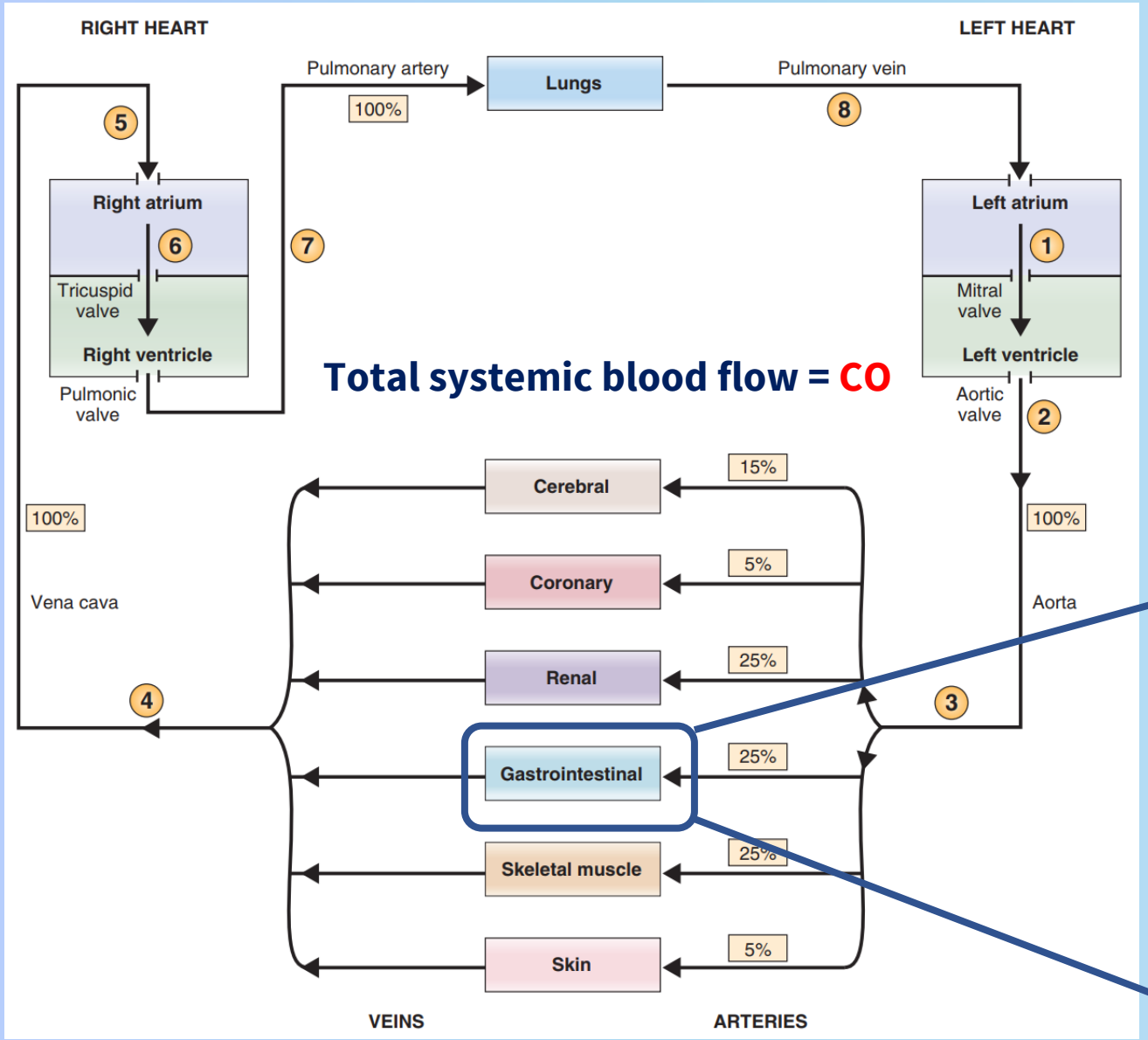
6. Laminar vs Turbulent Flow

7. Systemic vs Pulmonary Circulation

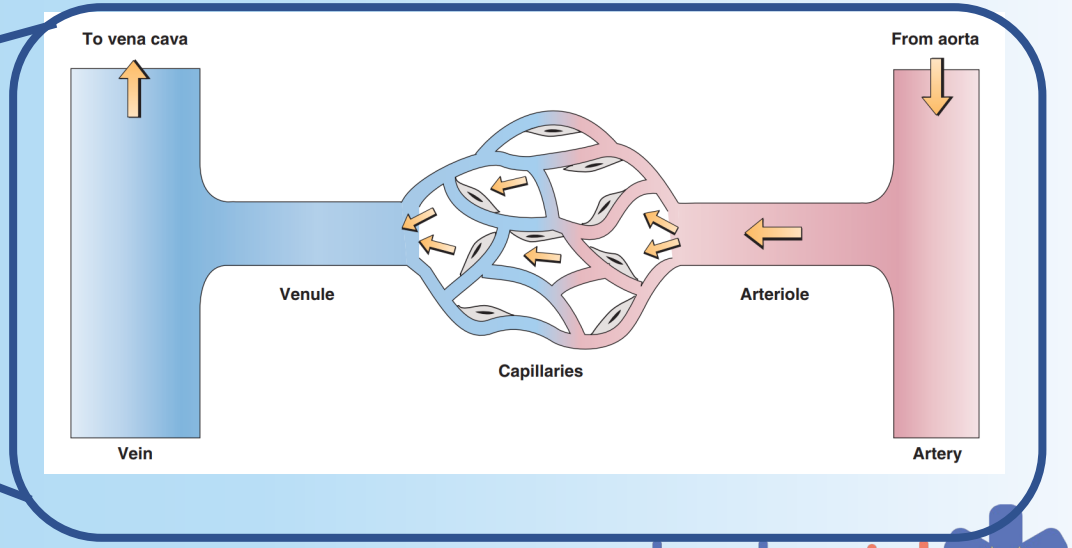
8. Practice questions (Wooclap!)



Pattern of normal blood flow (Systemic



What happens to the blood flow when it leaves the heart?



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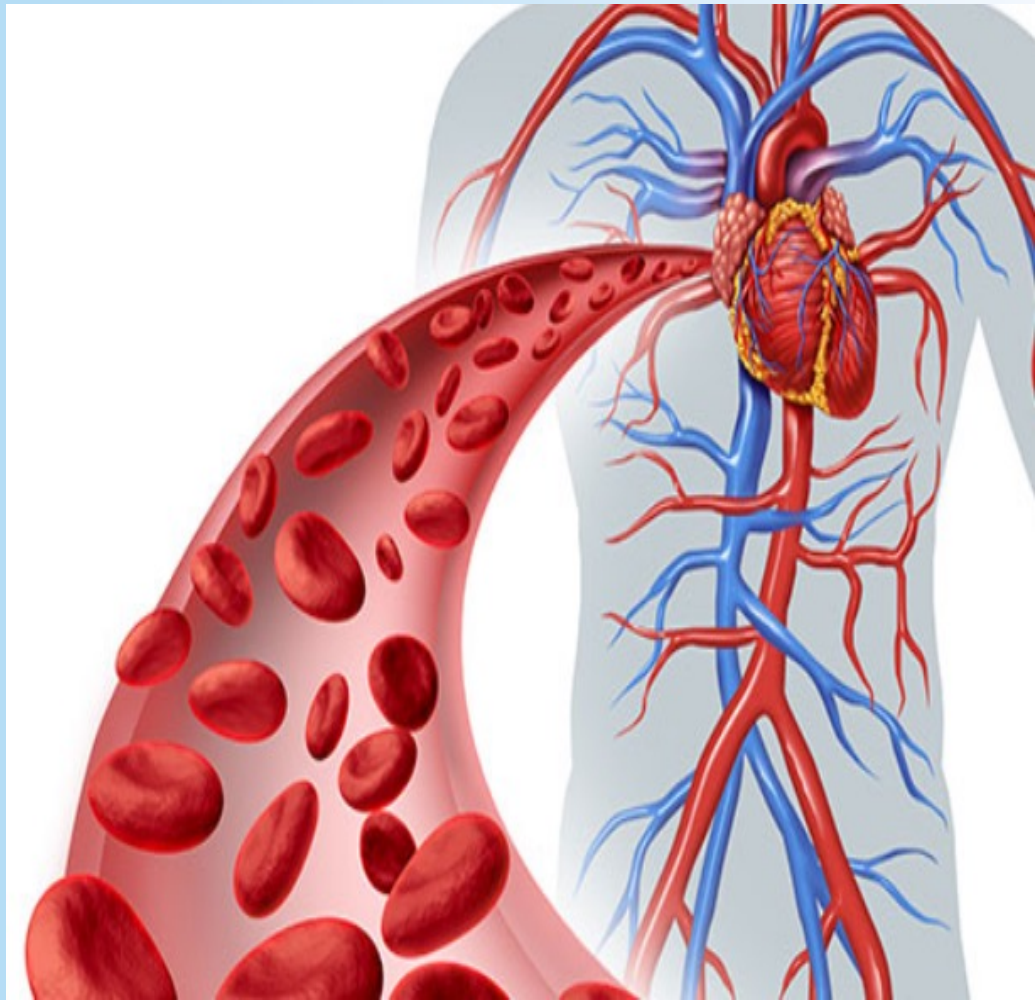
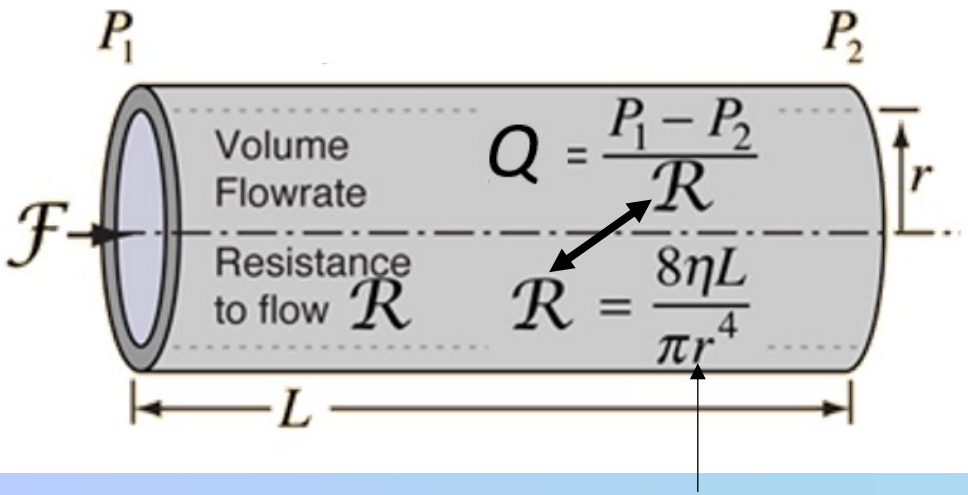


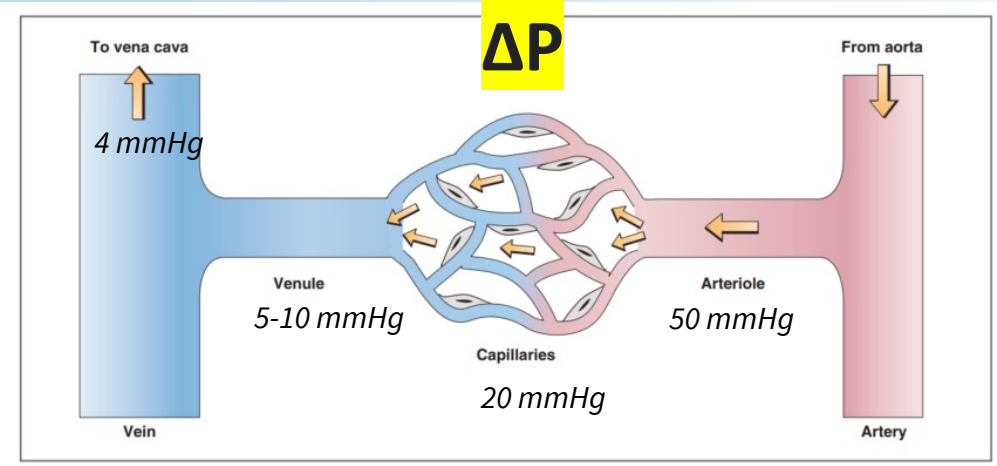
Blood Flow Equation: $Q = \Delta P / R$



most important!

= Flow (mL/min)
= Pressure difference (mm Hg)
= Resistance (mm Hg/mL/min)

R = Resistance
η = Viscosity of blood
l = Length of blood vessel
r^4 = Radius of blood vessel raised to the fourth power



Blood** (or any fluid) **flows from high to low pressure!

*What provides a pressure gradient **ΔP** in the circulatory system?*

The pumping action of the **heart provides *ΔP***

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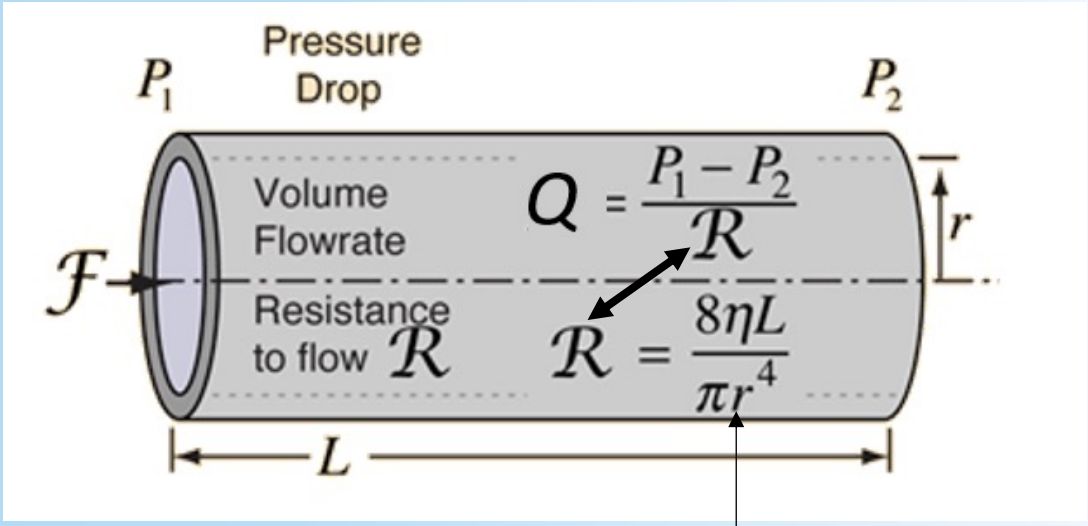
A drug constricts a blood vessel to half of its original radius, what is the effect on resistance in this particular vessel?

a) Increase by a factor of 4
b) No change
c) Increase by a factor of 16
d) Decrease by a factor of 16
e) None of the above



most important!

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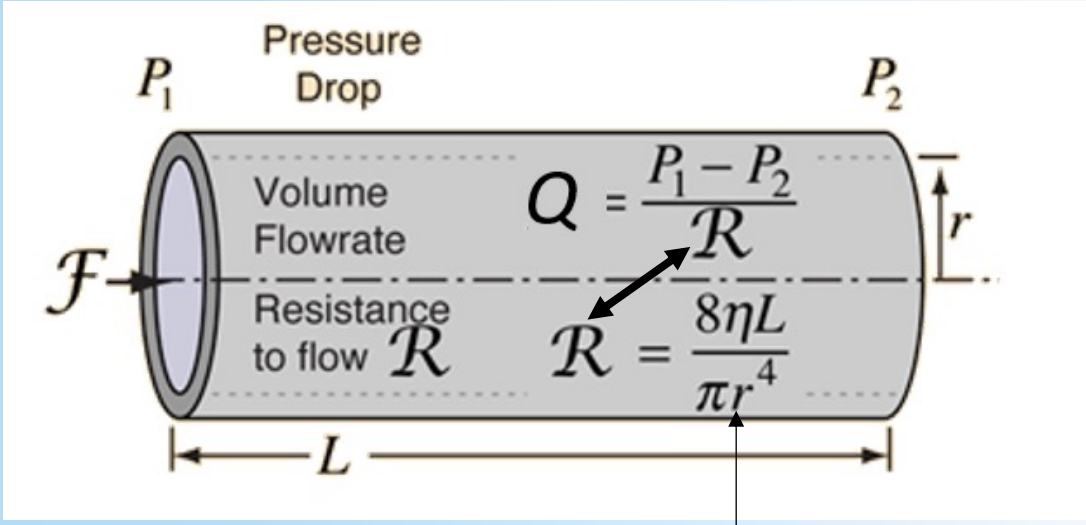
$$R \propto \frac{1}{r^4}$$

$$R \propto \frac{1}{\left(\frac{1}{2}\right)^4} = \frac{1}{\frac{1}{16}} = 16\times$$



most important!

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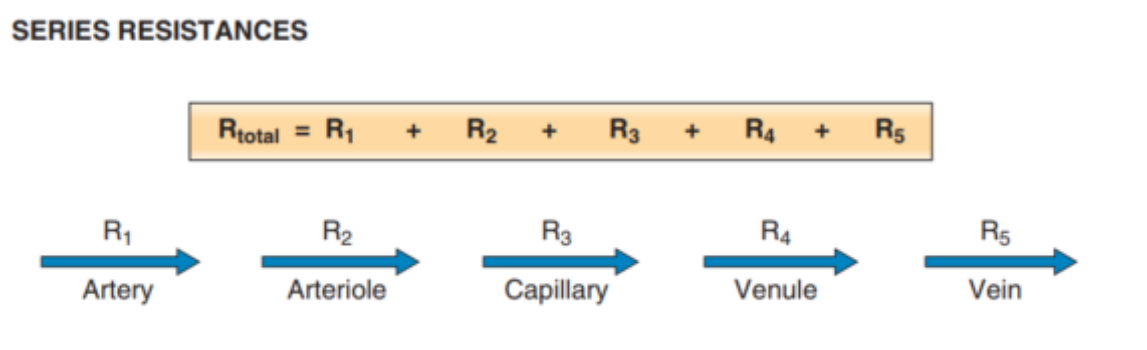
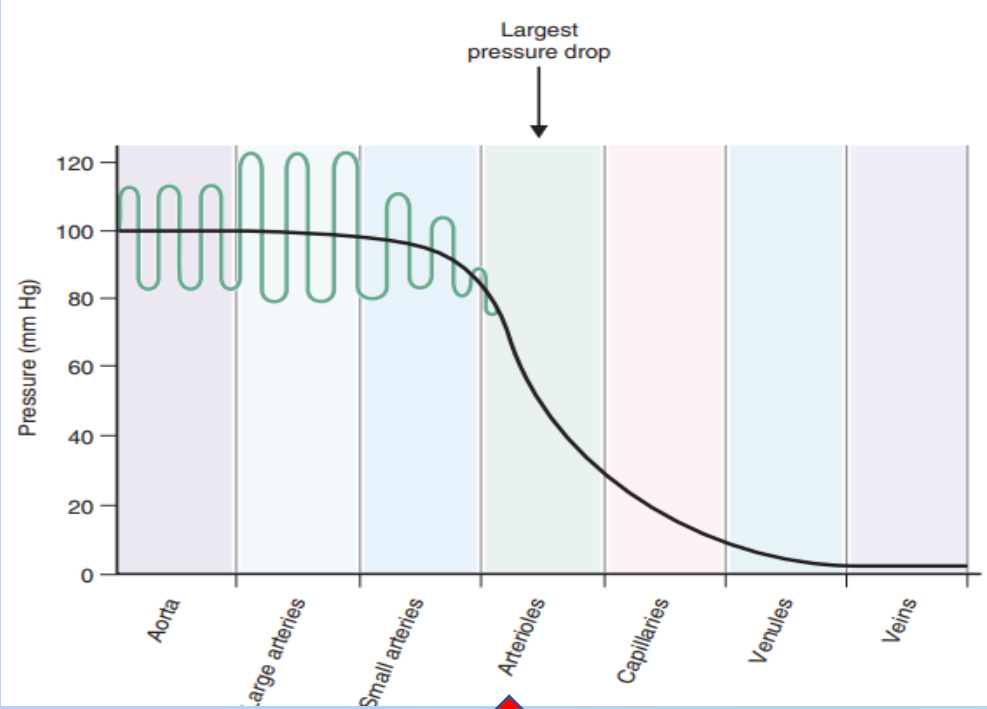
But why does blood pressure eventually drop?





<u>Blood flow through an organ</u> is arranged **in series**

A physiological consequence of this is:

progressive <u>reduction</u> of blood pressure from major artery supplying the organ → major vein draining the organ

- ***The biggest contributors to <u>series resistance</u> are…..***

Arterioles!

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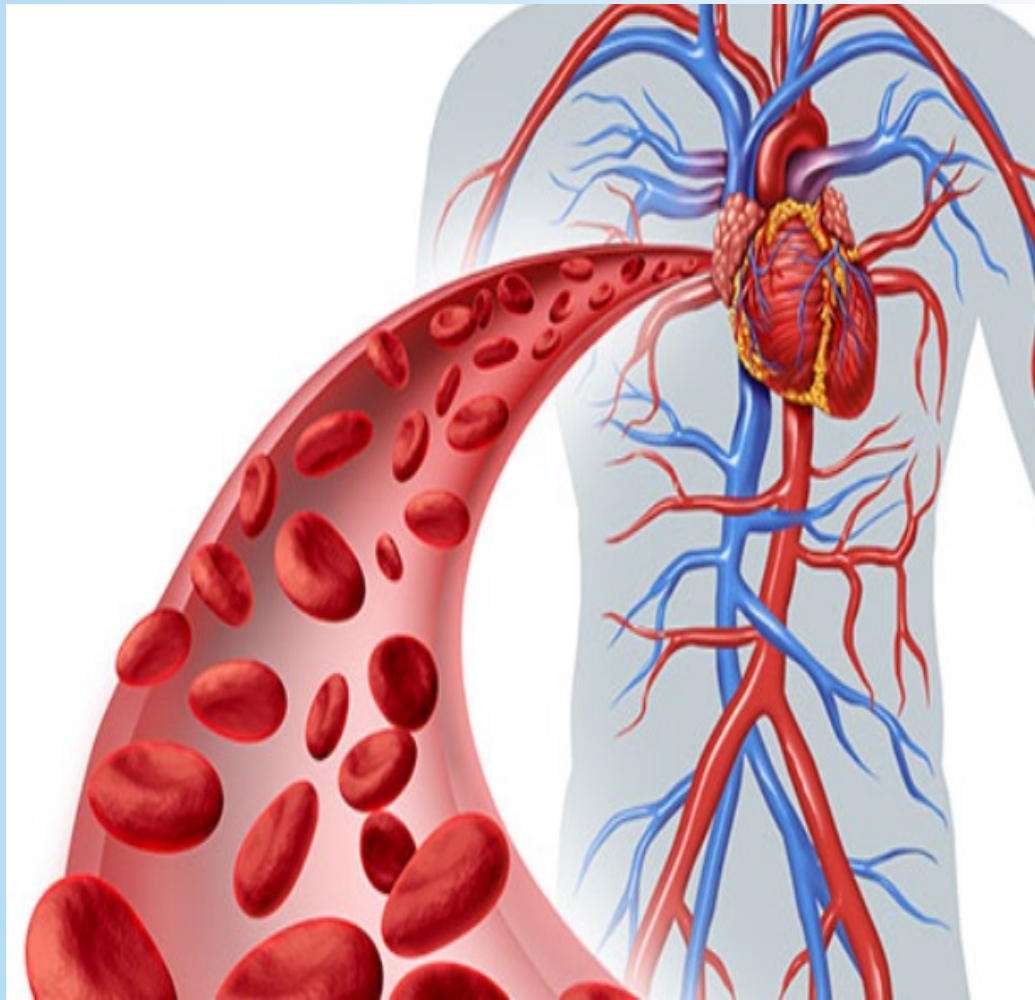
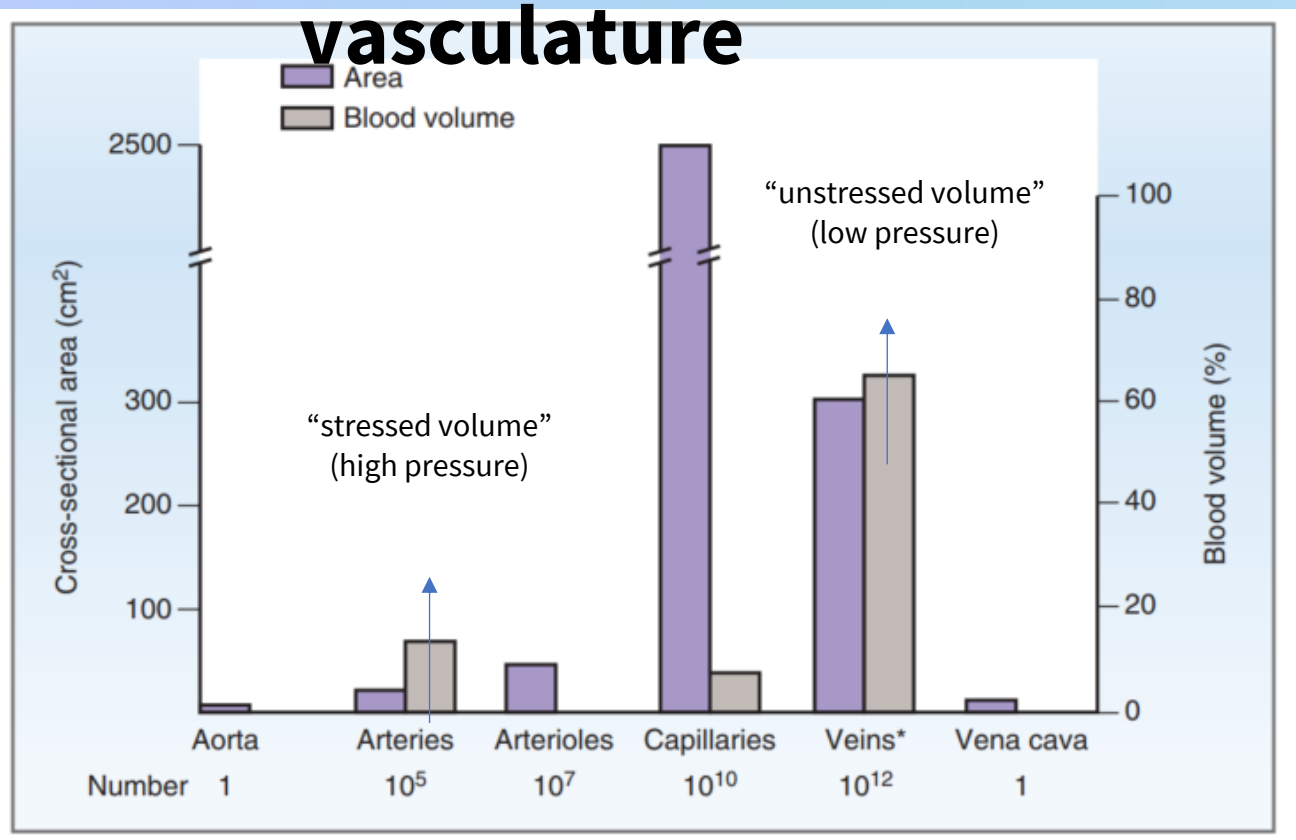


Distribution of blood in the systemic vasculature



Veins *can hold a large volume of blood at* ***low pressure*** *because they have* ***high compliance***

high compliance ***= high ability to expand***

Vessels containing the ***highest % of total blood volume*** *in the cardiovascular system?*

→ ***Veins***

Vessels having the ***largest total cross sectional area*** *in the cardiovascular system*

→ ***Capillaries***

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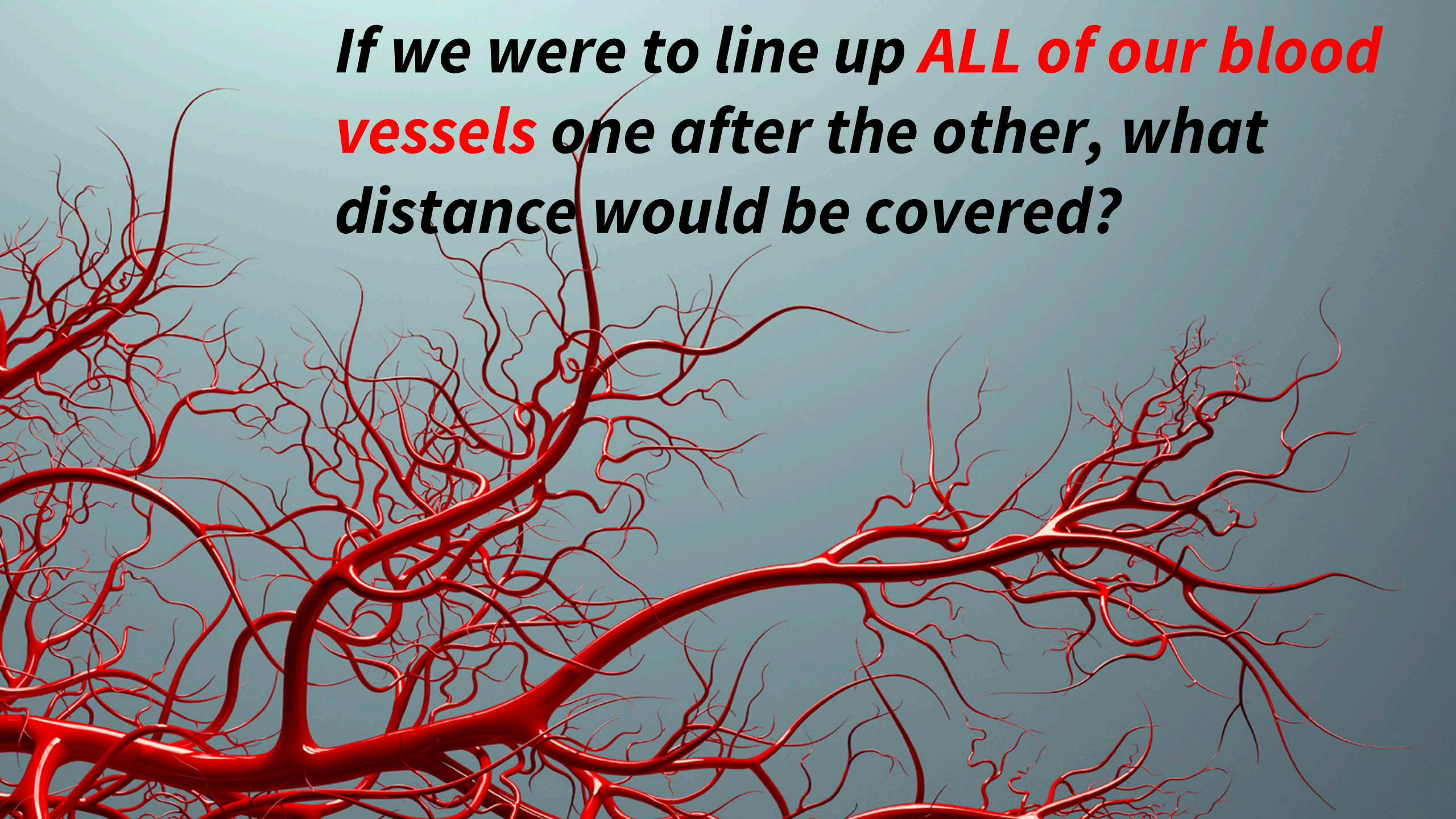
If we were to line up ALL of our blood vessels one after the other, what distance would be covered?

*If we were to line up **ALL of our blood vessels** one after the other, what distance would be covered?*

160,000 km

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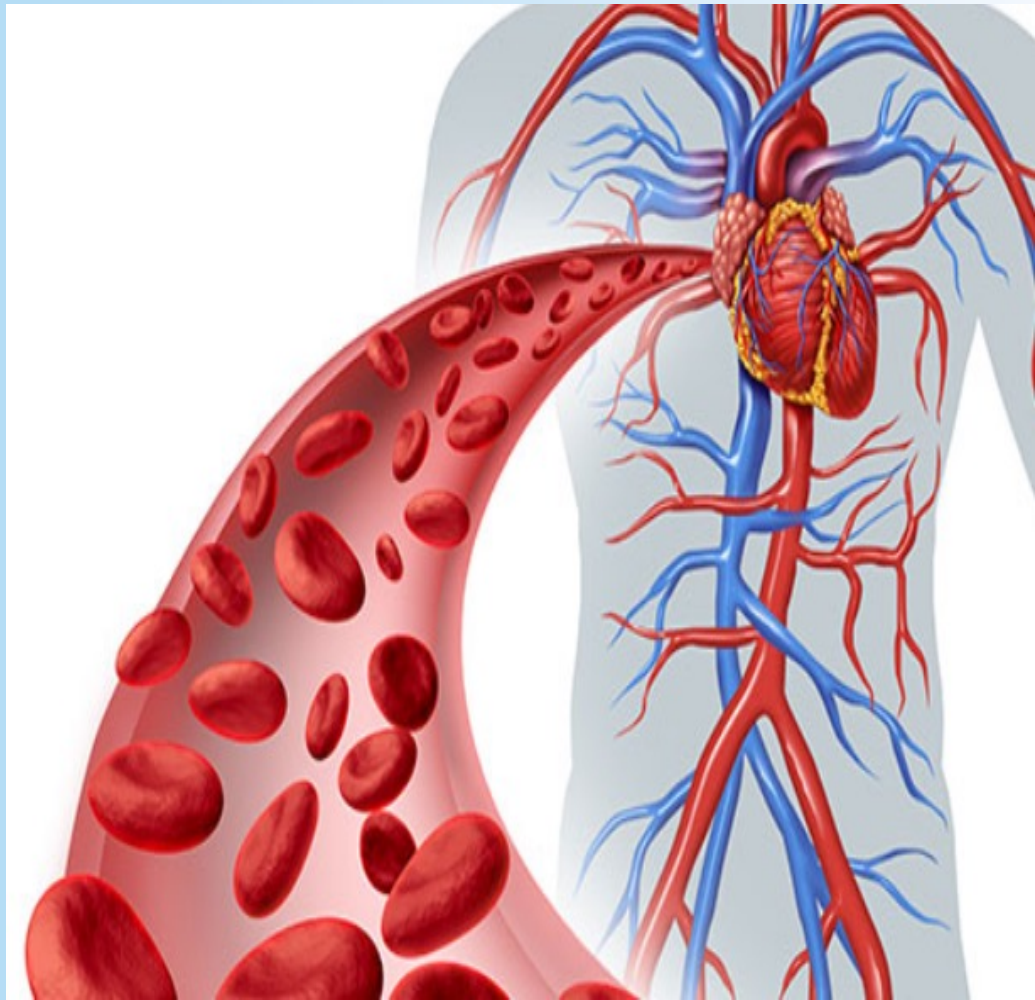

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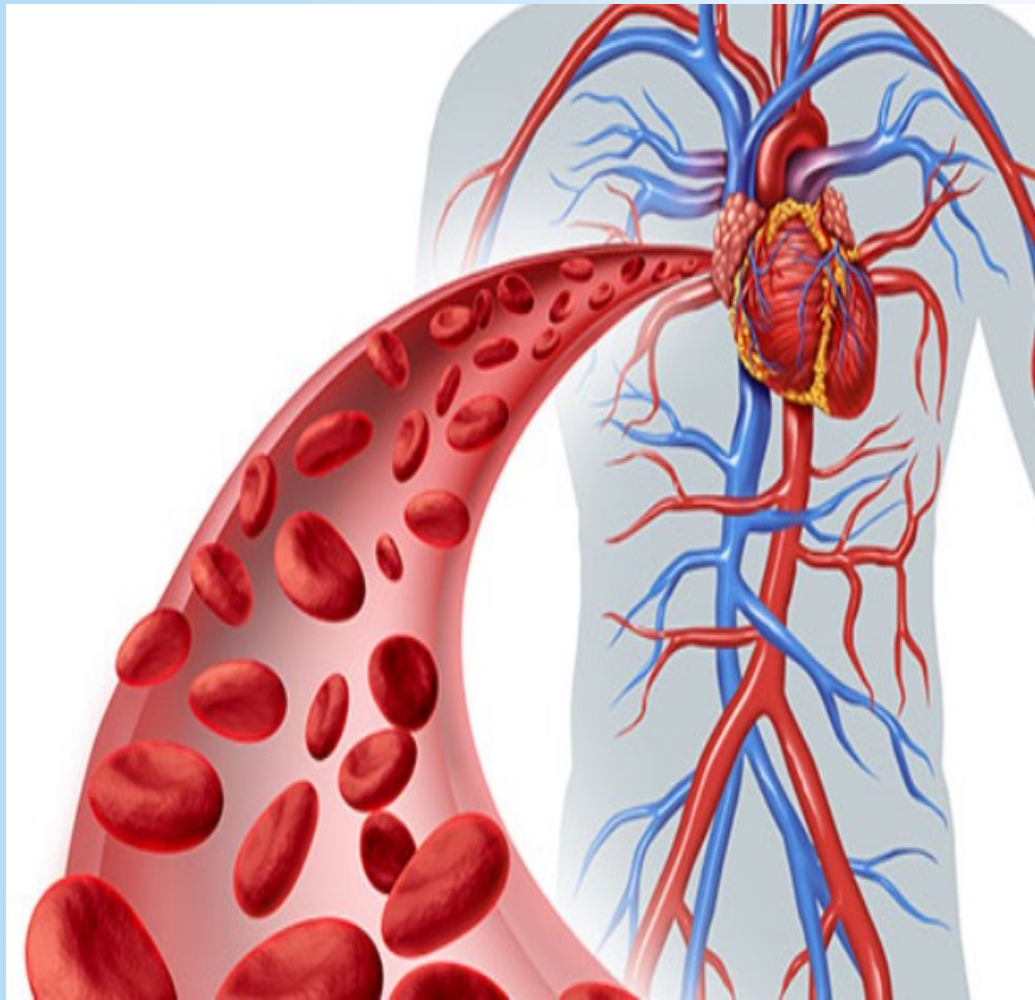
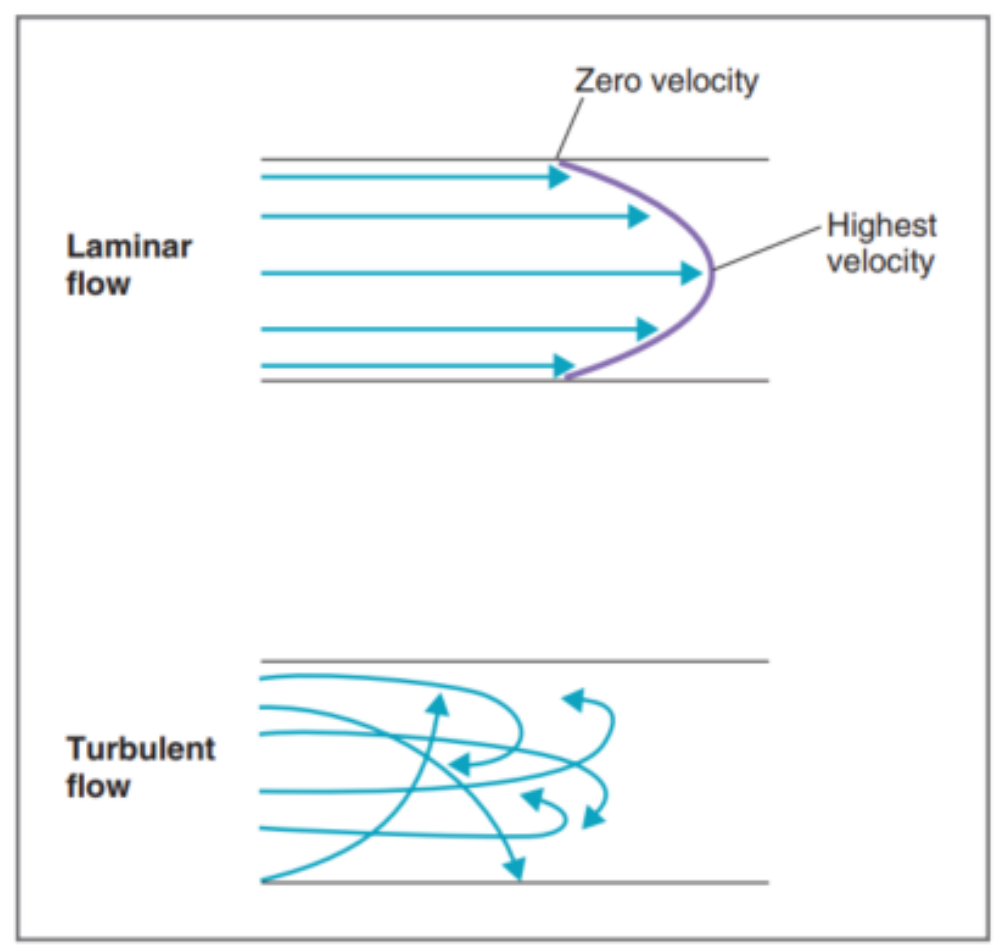


Laminar vs Turbulent Flow



Ideally, **blood flow** should be ***laminar*** (i.e. streamlined)

Laminar flow: **velocity** of blood flow is **highest** at the **center** of a blood vessel and **lowest** near the **vessel wall**

Turbulent blood flow is characterized physiologically by presence of **an audible murmur**

*Nb: some **pathologies** (thrombi, valve disorders, anemia) can cause blood flow to become **turbulent** in the affected vessel*

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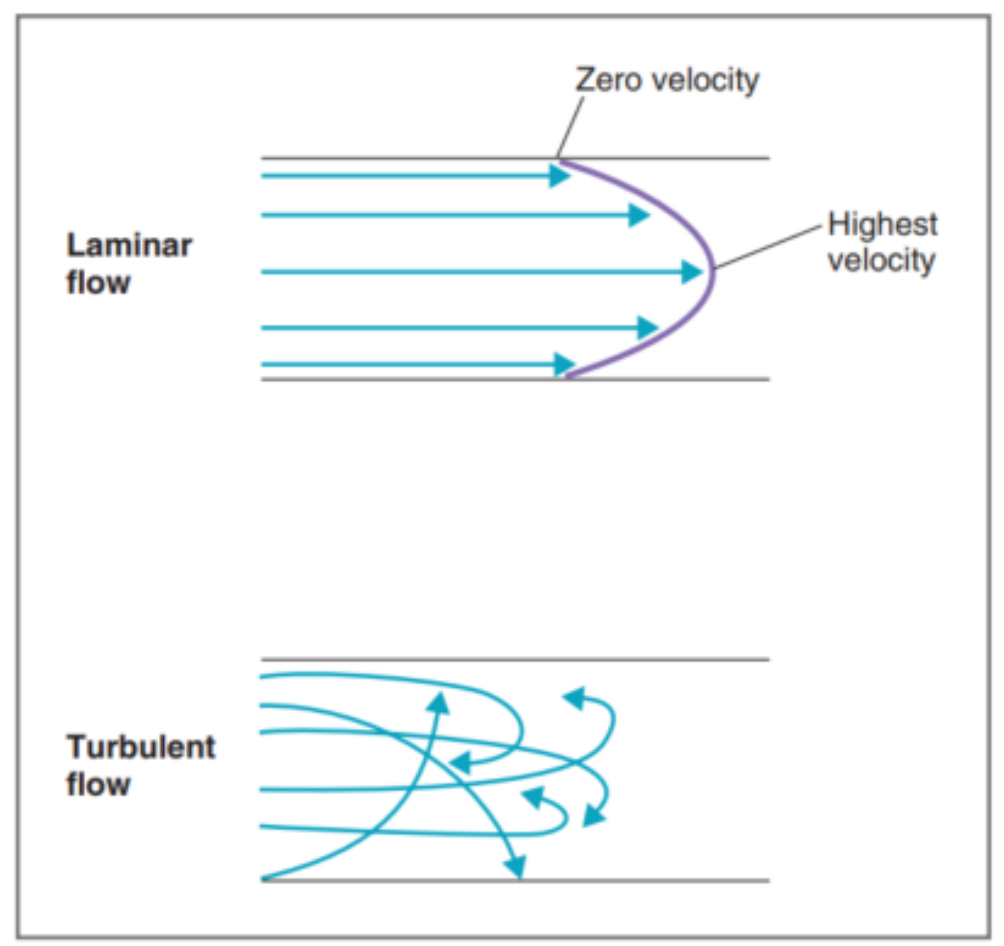
Laminar vs Turbulent Flow



Reynold's number (N_R) is a dimensionless index to predict ***whether blood flow will be laminar or turbulent:***

$$N_R = \frac{\rho d v}{\eta}$$

where

N_R = Reynolds number
ρ = Density of blood
d = Diameter of blood vessel
v = Velocity of blood flow
η = Viscosity of blood

$N_R > 3000$ → always turbulent
$N_R < 2000$ → always laminar

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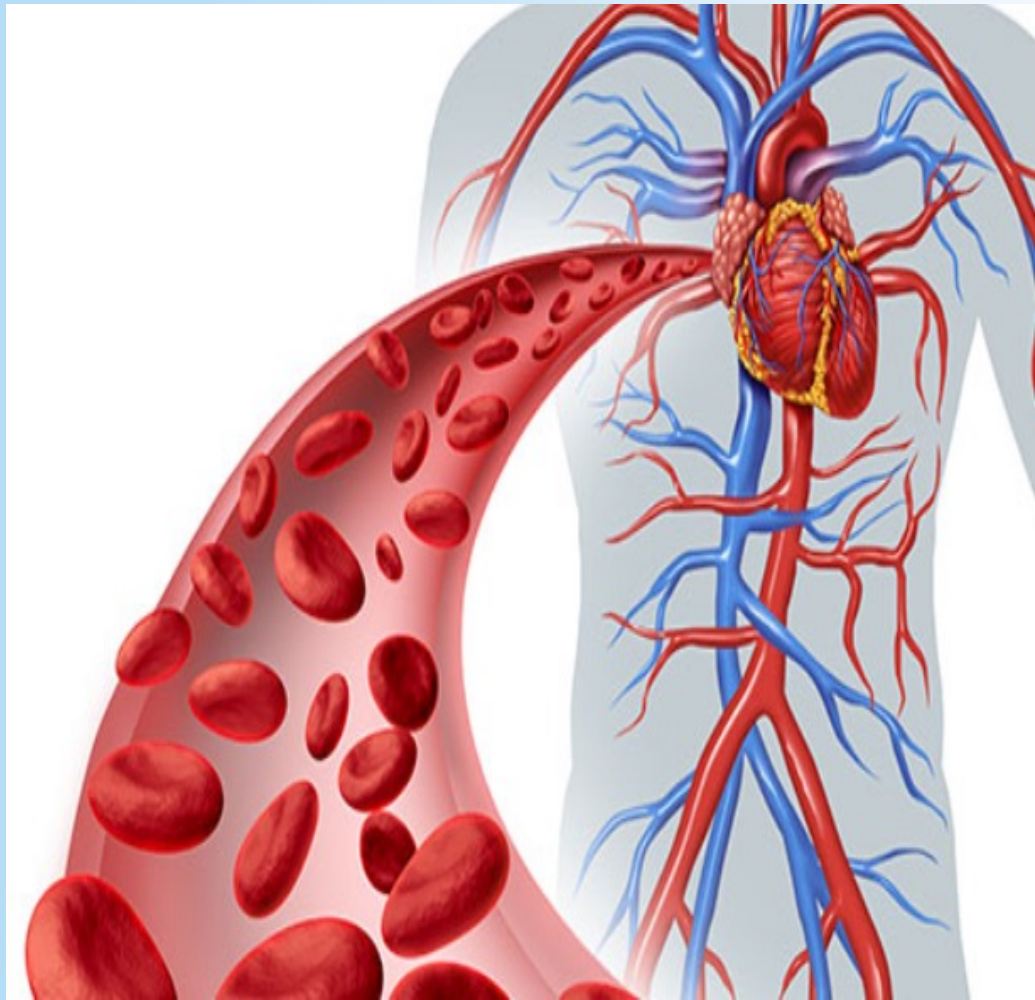
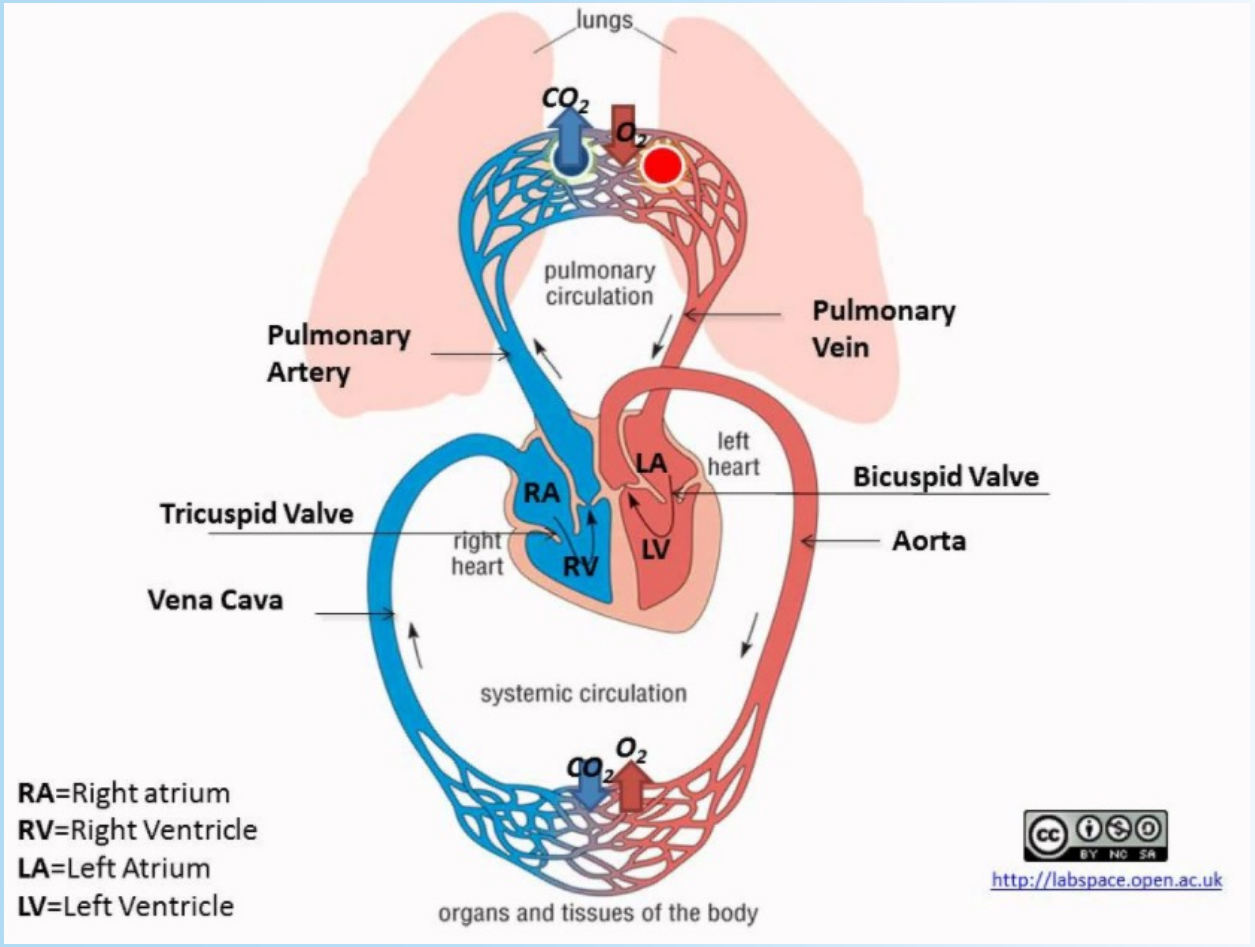


Pulmonary Circulation vs Systemic Circulation

Location	Mean Pressure (mm Hg)
Systemic	
Aorta	100 ⬅
Large arteries	100 (systolic, 120; diastolic, 80)
Arterioles	50
Capillaries	20
Vena cava	4
Right atrium	0–2 ⬅
Pulmonary	
Pulmonary artery	15 (systolic, 25; diastolic, 8) ⬅
Capillaries	10
Pulmonary vein	8
Left atrium*	2–5 ⬅



pulmonary artery *pressure* << ***large systemic arteries*** *pressure*

Pulmonary circulation is coupled <u>in series</u> <u>with</u> the systemic circulation

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Pulmonary Circulation vs Systemic Circulation

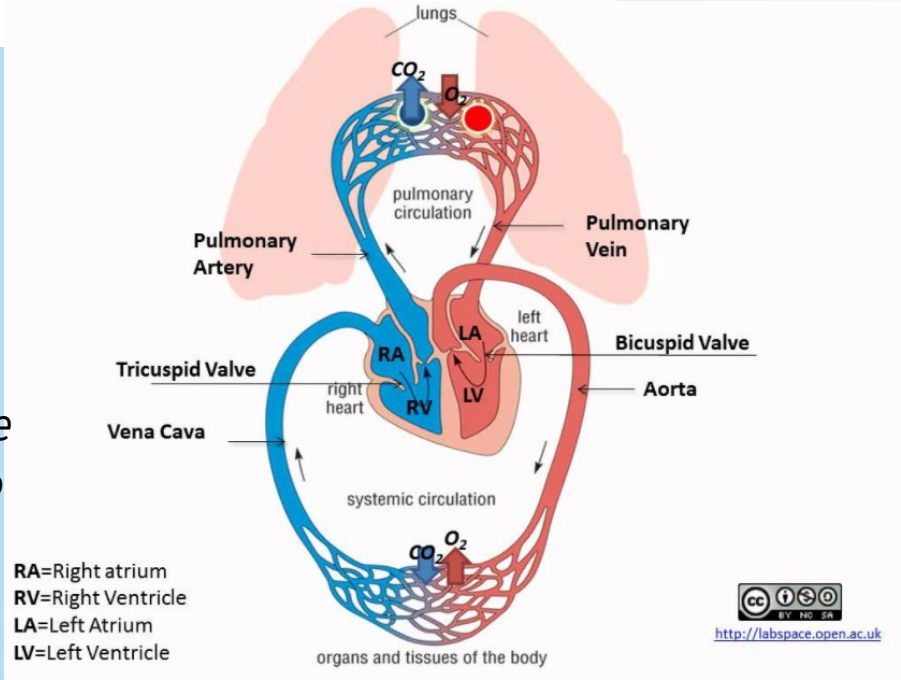
	Pulmonary circulation	Systemic circulation
Pressure	Low	High
Pressure gradient	→ Small[1]	→ Large[2]
Resistance	Low	High
Flow[3]	→ 5 L/min	→ 5 L/min

[1] 10 mmHg
[2] 93 mmHg
[3] 70 kg male

Blood flow rate (Q) is the **same** in the **pulmonary** and **systemic circulations** since the cardiac output (CO) of the left and right heart is equal!

Equal blood flow (Q) *can be achieved in pulmonary & systemic circulations, because while the* ***pressure gradient*** *in pulmonary circulation is* ***lower****, the* ***resistance*** *is also* ***lower****

$$Q = \Delta P / R$$



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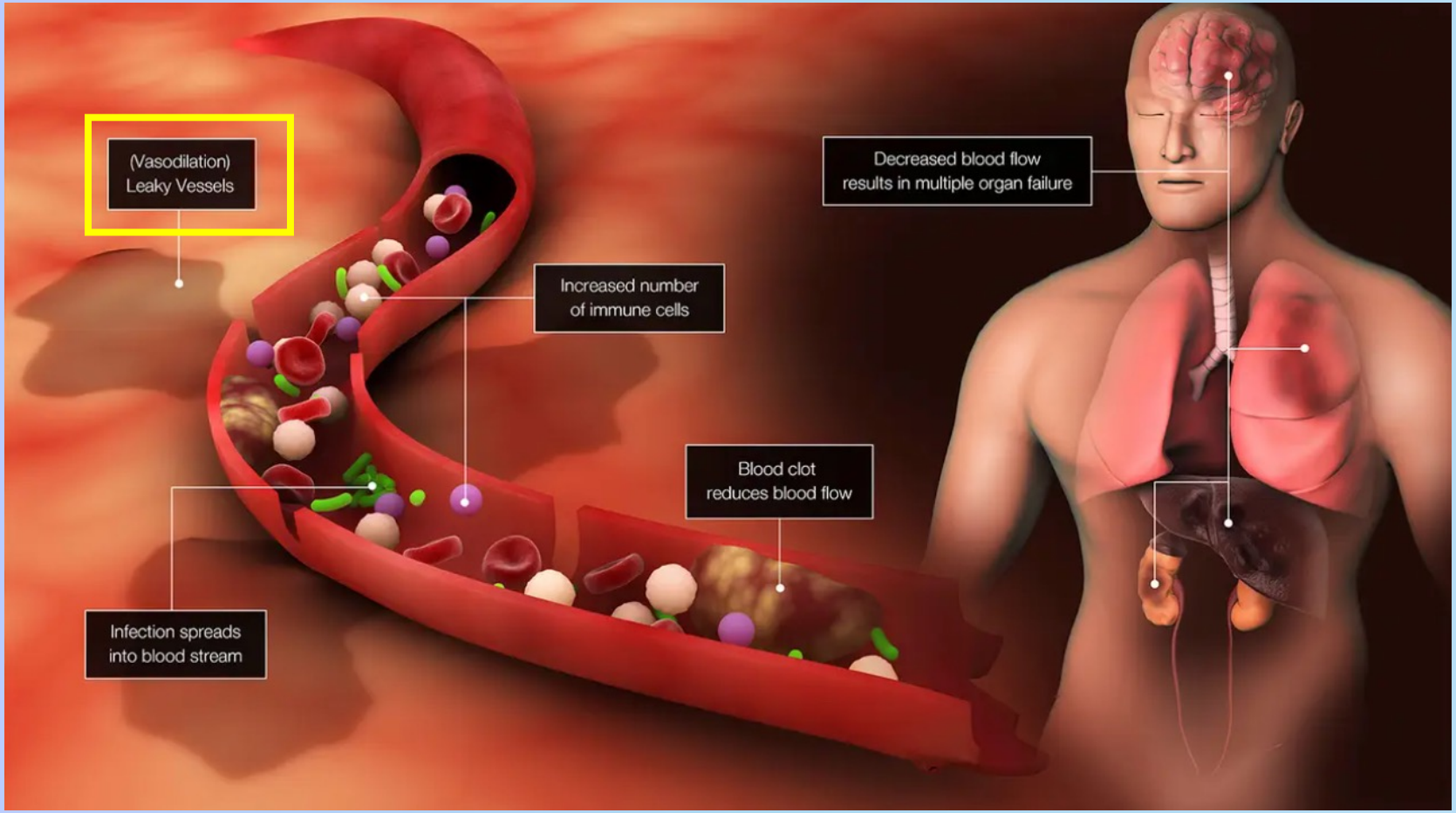
Clinical correlation: Septic shock



Case:
-52M with AIDS
- CAP dx 5 days ago
- temp: 40C
- confusion
- RR: 30
- HR: 130
- BP: 78 / 52

Explain these vitals?
Treatment?

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WEB

1. Connect to **www.wooclap.com/HEMODYNX**
2. You can participate

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