Vascular Physiology

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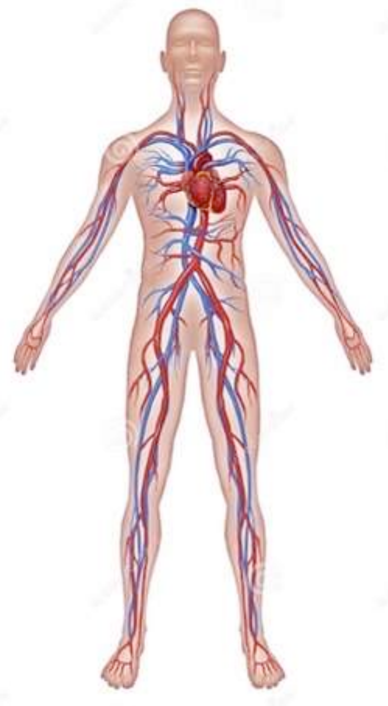
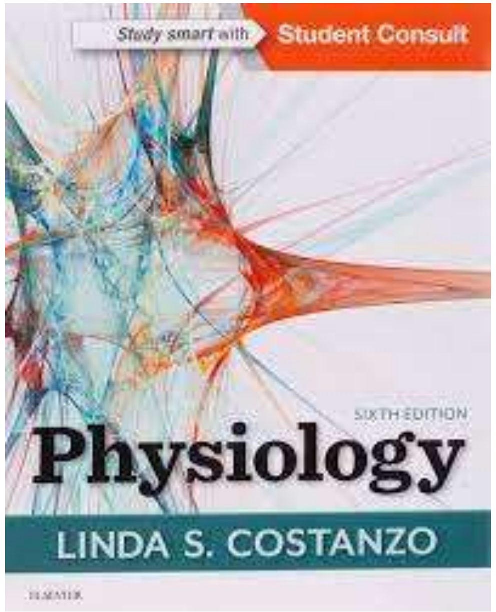


References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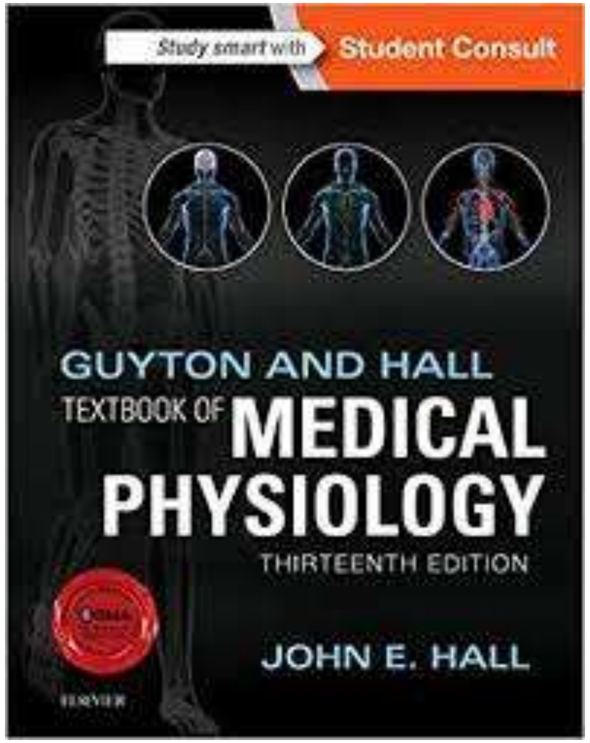
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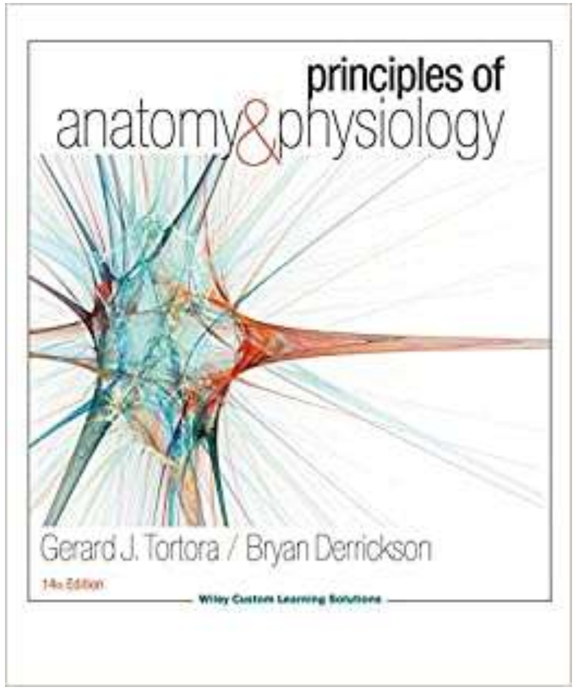
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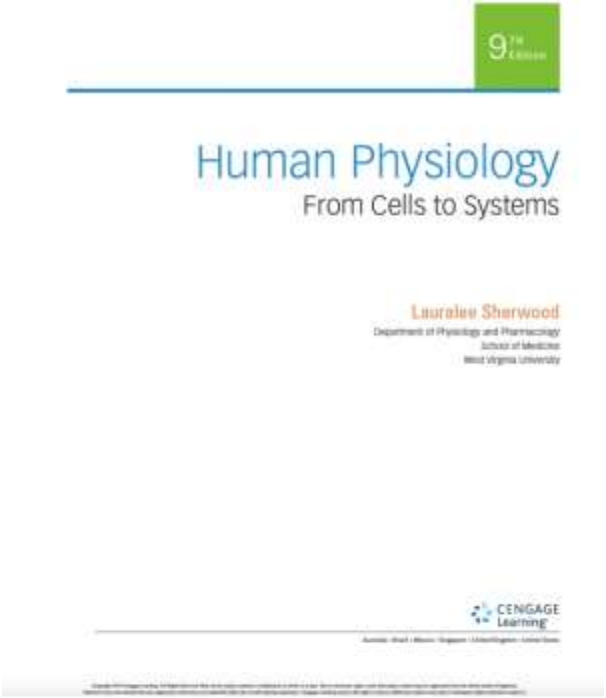
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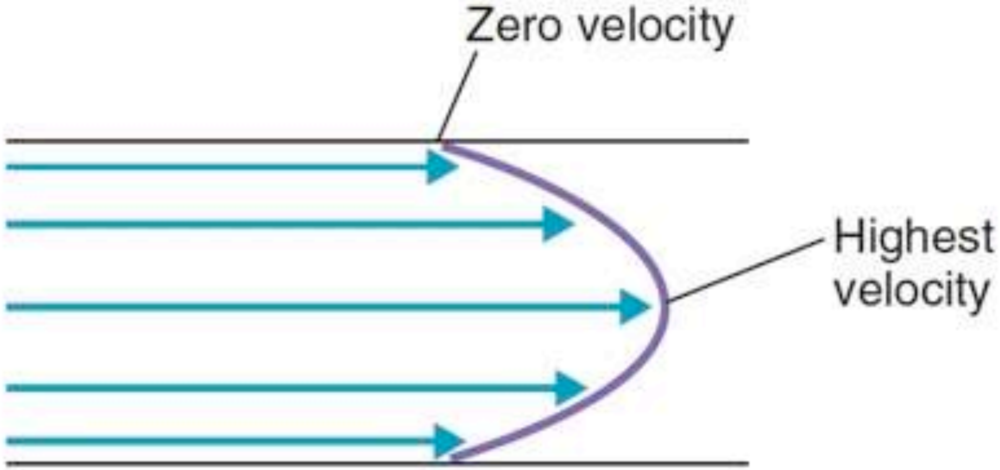
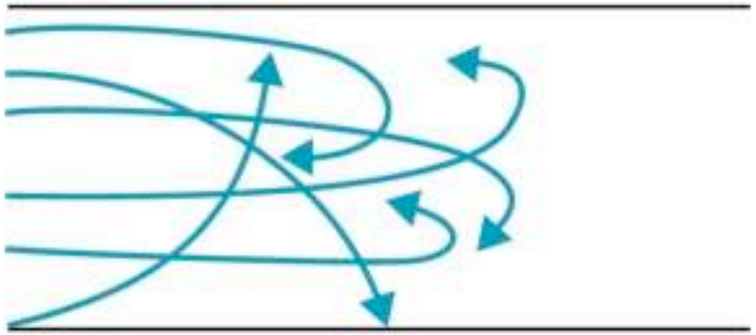
Vascular hemodynamics-2

Laminar flow



Turbulent flow



Reynolds number

- Rn : Inertia / Friction

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

↑N_R = ↑tendancy to be turbulent (dominance of inertia over viscosity)

where

N_R = Reynolds number

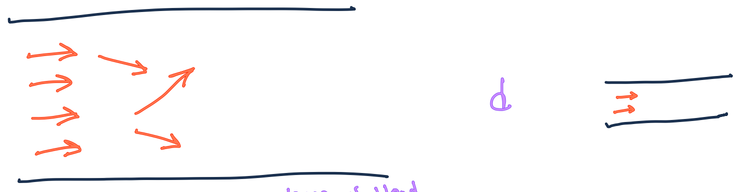
ρ = Density of blood least imp factor? rarely changes or rarely has clinical applications

d = Diameter of blood vessel

v = Velocity of blood flow

η = Viscosity of blood frictional forces between cells within the blood

Reynolds number



in large diameter, there are more layers of blood
↑chance to be turbulent

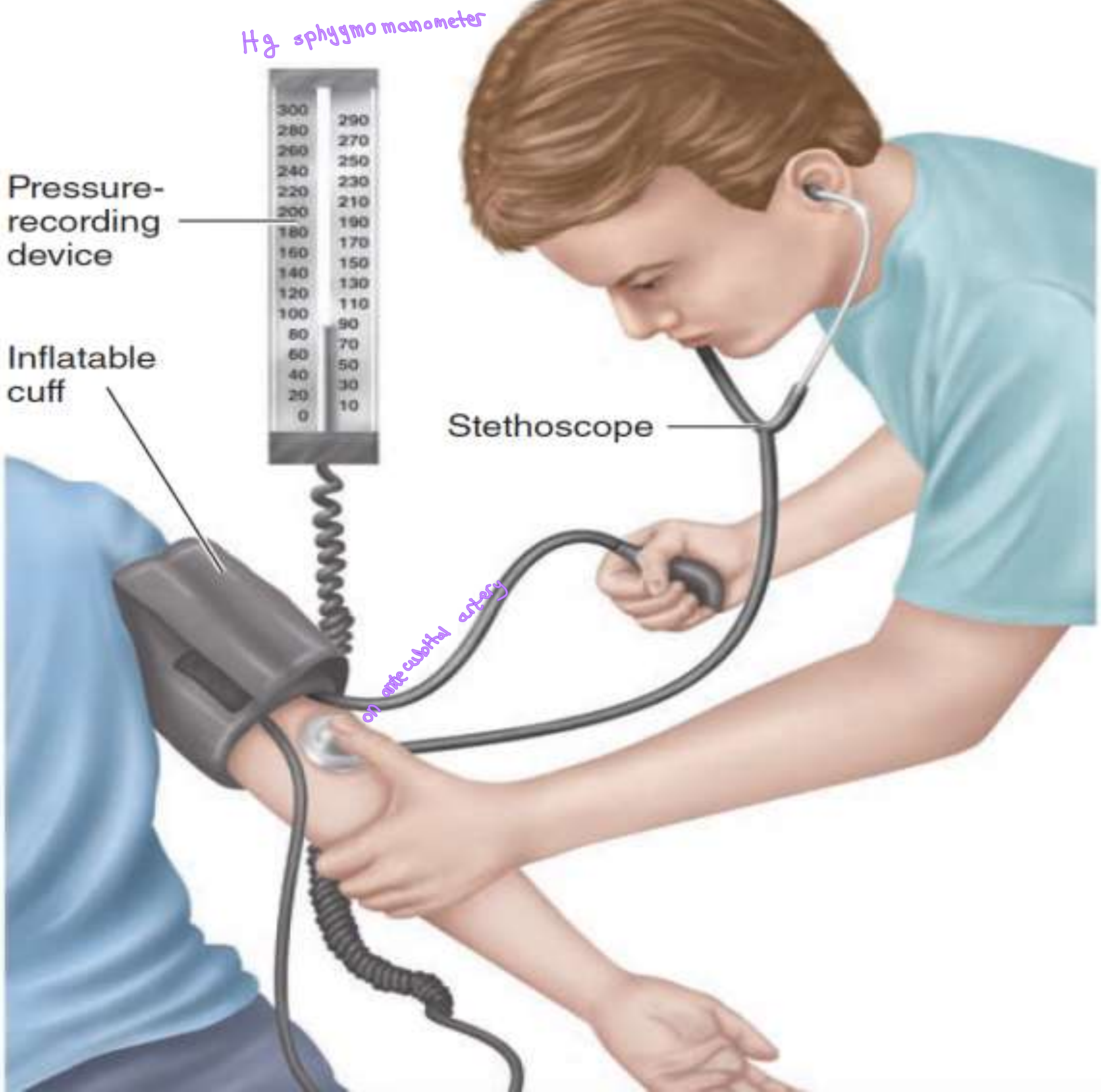
↑(like a highway) → ↑chance for turbulence

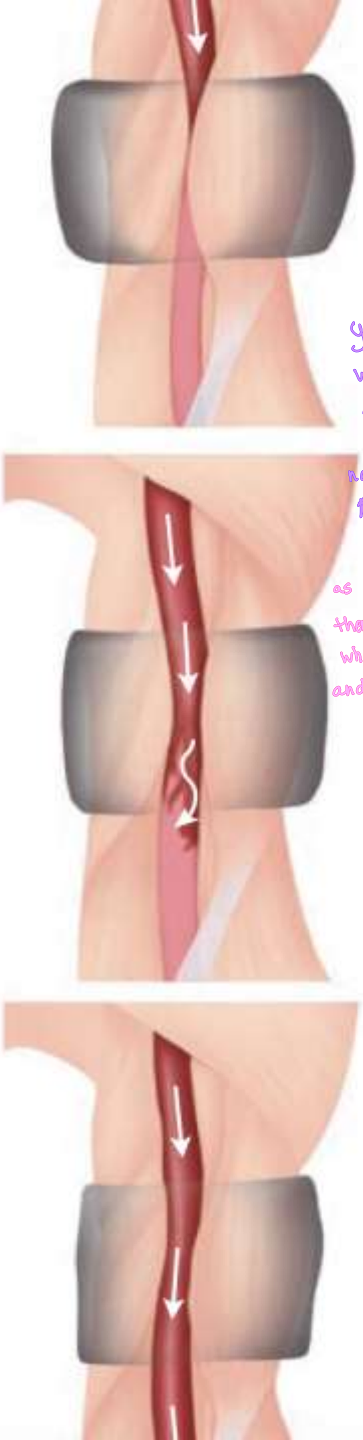
slowly ↓

viscosity: ⁒ particles (★RBCs)
inversly propotional

↑viscosity: ↑particles = ↑frictional forces
no much room for them to cause turbulence
so flow will be mainly laminar

the chances of the particles to move in different directions is higher turbulent flow is audible, this is where we hear murmurs and all the sounds in CVS that we can hear with stethoscope + the basis for the auscultatory method of measuring BP





you start to hear the sound when you deflat, because ↑diameter, but some of the blood flow will go down but through a narrow diameter → ↑reynold # → ↑turbulence tendancy (you can hear 1st sound here "systolic")

as you continue to deflat this cuff there will be no more sounds especially when they are widely open again (laminar) and this represents diastolic BP

Sherwood textbook

Normally Reynold # is 200-400 : laminar except at some branching areas or high flow velocity areas such as the aorta
>2K ~ turbulent blood flow in most of the vessels

Reynolds number clinical implications

- Anemia ↓viscosity ↓reynolds #
- Polycythemia
- Pregnancy
- Thrombus
- Shock
- Stenosis
- Hyperthyroidism

Velocity of blood flow

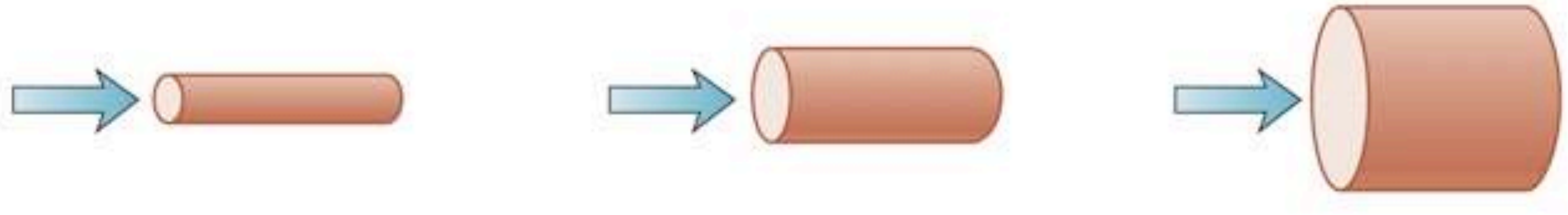
→ flow rate

- $V = F/A$

↳ cross sectional area of the vessel

$$v = Q/A$$

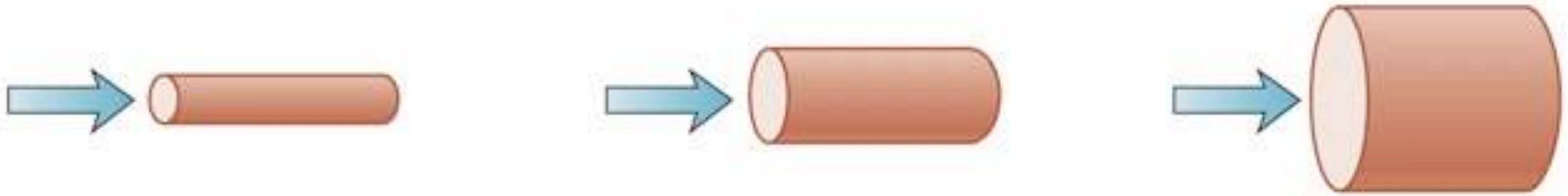
10 mL/s



Area (A)	1 cm^2	10 cm^2	100 cm^2
Flow (Q) constant	10 mL/s	10 mL/s	10 mL/s

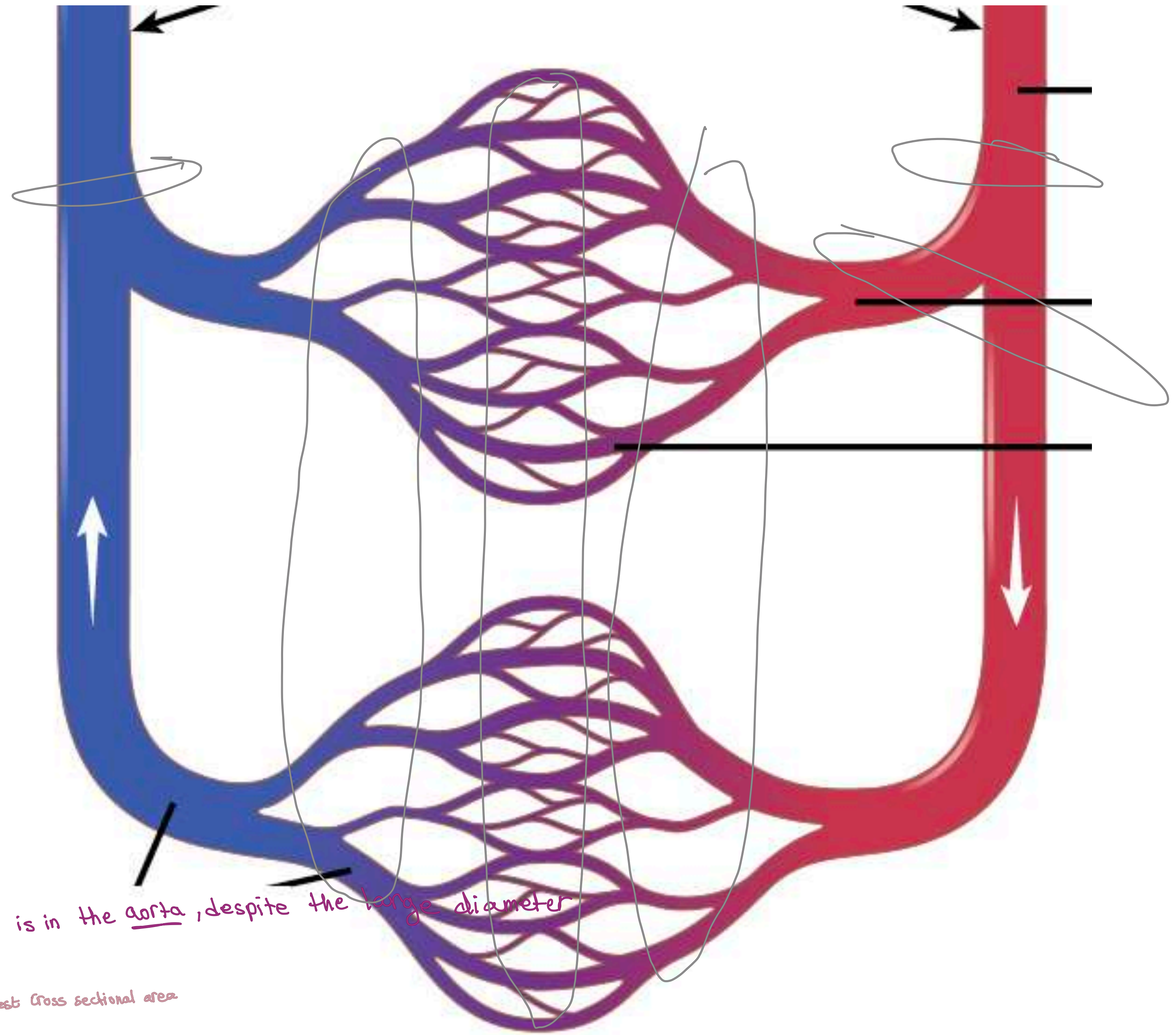
$v = Q/A$

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**

↑cross sectional area (diameter) ~ ↓velocity of blood flow
inverse relation

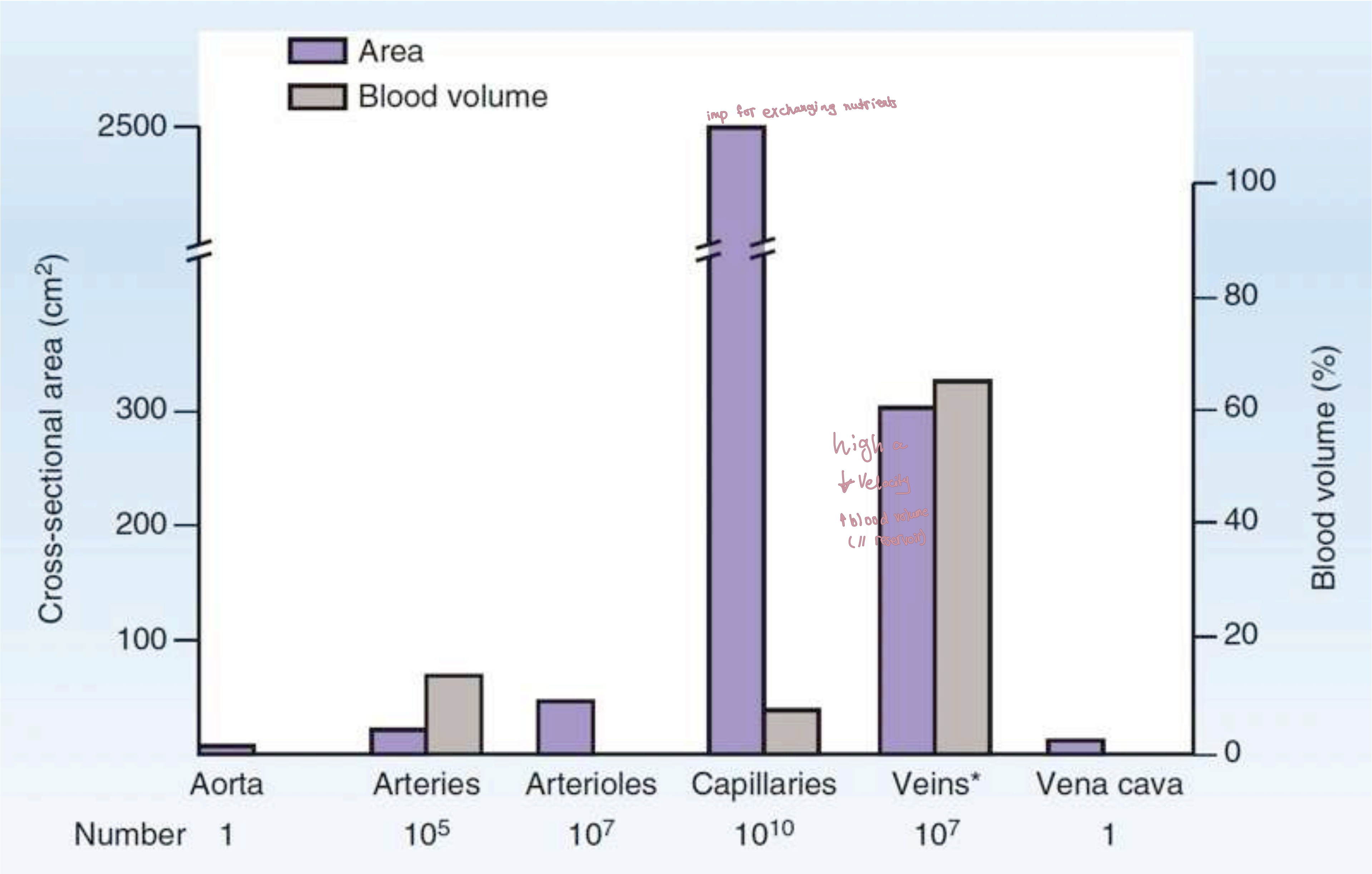


highest velocity of blood flow is in the aorta, despite the large diameter

lowest // is in capillaries? ↑#, highest cross sectional area

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.


Area
Blood volume
Cross-sectional area (cm²)
2500
300
200
100
Blood volume (%)
100
80
60
40
20
0
imp for exchanging nutrients
high a
↓ Velocity
↑ blood volume
(// reservoir)
Aorta
Arteries
Arterioles
Capillaries
Veins*
Vena cava
Number
1
10⁵
10⁷
10¹⁰
10⁷
1

venous side > arterial

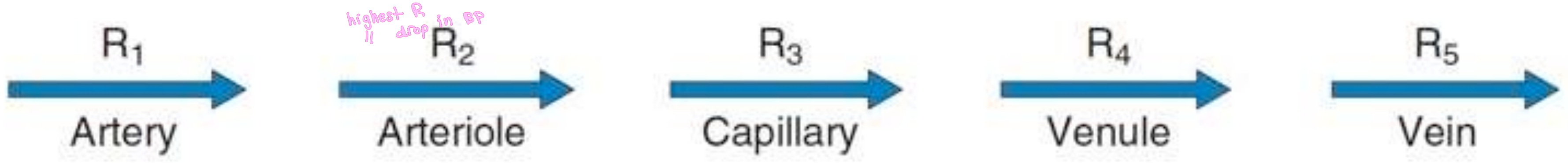
Vessel	Cross-Sectional Area (cm^2)
Aorta	2.5 lowest, highest velocity, aorta acts as a conduit that transfers blood from lt. v → smaller vessels after damping the pulsatility of blood flow
Small arteries	20
Arterioles	40
Capillaries	2500 highest, lowest velocity
Venules	250
Small veins	80
Venae cavae	8

Series resistances

- Within organ.
- The total resistance of the system arranged in series is equal to the sum of the individual resistances.
- The total resistance of a vascular bed is determined in large part by the arteriolar resistance.
- When resistances are arranged in series, the total flow at each level of the system is the same.

SERIES RESISTANCES

$$R_{total} = R_1 + R_2 + R_3 + R_4 + R_5$$



each one will has it's own resistance that is different from other segments

*any increase in R in any of these individual parts of the vasculature will result in an increase in total R

ex: chronic htn, arterioles constrict ~ ↑R ~ ↑R total (radius is the most imp. factor)

Series resistances

- Although total flow is constant at each level in the series, the pressure decreases progressively as blood flows through each sequential component.
- The greatest decrease in pressure occurs in the arterioles because they contribute the largest portion of the resistance.

Parallel resistances

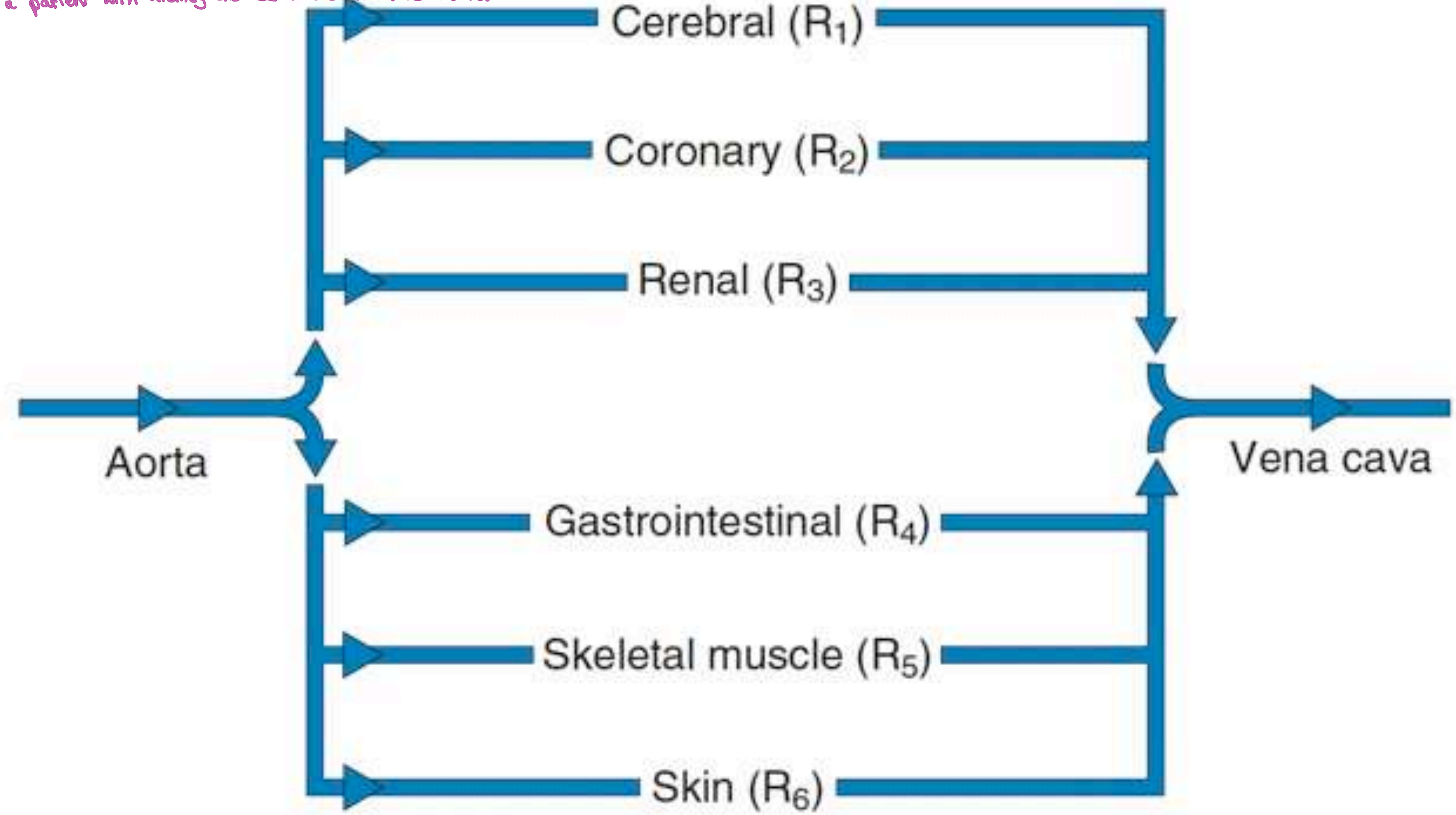
- the total resistance in a parallel arrangement is less than any of the individual resistances.
- When blood flow is distributed through a set of parallel resistances, the flow through each organ is a fraction of the total blood flow.
- The effects of this arrangement are that there is no loss of pressure in the major arteries and that mean pressure in each major artery will be the same and be approximately the same as mean pressure in the aorta.

PARALLEL RESISTANCES

(like when the aorta branches into different arteries to provide BS to these organs).
allow individualized control of blood flow, relatively independent of the other blood flows in other organs

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6}$$

if we remove one of these parallel circuits (ex: a patient with kidney disease where we have to remove the kidney) "nephrectomy"



Parallel resistances

- Another predictable consequence of a parallel arrangement is that adding a resistance to the circuit causes total resistance to decrease.
- if the resistance of one of the individual vessels in a parallel arrangement increases, then total resistance increases.

Compliance

$\frac{\Delta V}{\Delta P}$ how much volume can BV accomodate
per change of pressure

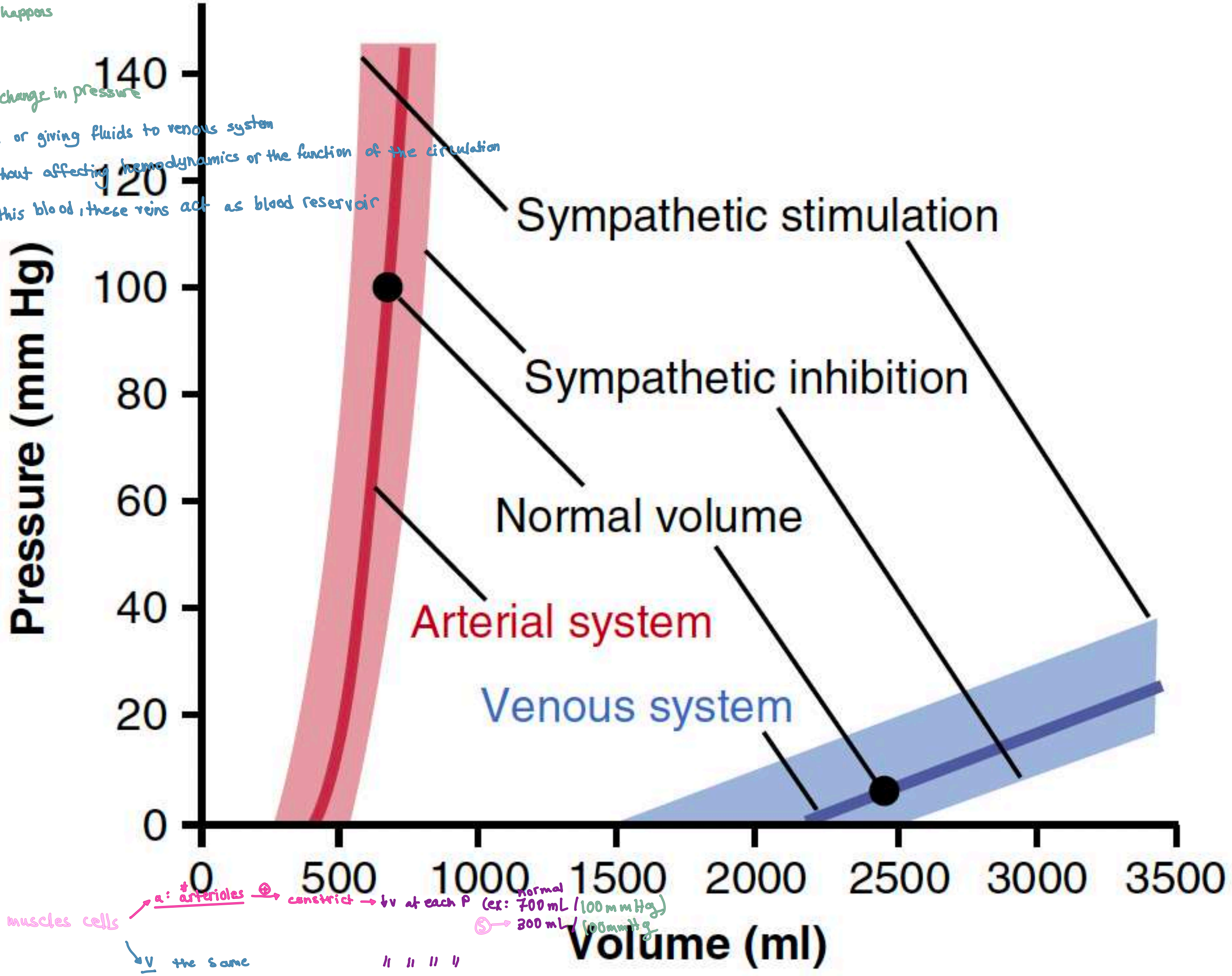
Volume-Pressure Curve

*arterial: v 400 → p 0
700 → 100
↑ 300 ml → ↑ 100 mmHg

*venous: v baseline is much higher
p values are 〃 lower

v 2200 ml → p 0
+300 ↳ 2500 ml → less than 5 mmHg change in pressure happens

* veins are more compliant
you can change more volume, accompanied by little change in pressure
you can change more volume, ...
v. imp especially when we do blood transfusions or giving fluids to venous system
you may give a large amount of these fluids without affecting hemodynamics or the function of the circulation
the same thing happens when we lose some of this blood, these veins act as blood reservoir



*Sympathetic stimulation → ⊕ vascular smooth muscles cells
↗ a: *arterioles ⊕ → constrict → ↓v at each P (ex: normal 700 mL / 100 mmHg)
Ⓢ → 300 mL / 100 mmHg
↘ V the same 〃 〃 〃 〃
imp in cases where we need to increase blood flow coming from the heart, we shift volumes

Compliance

- increase in vascular smooth muscle tone caused by sympathetic stimulation increases the pressure at each volume of the arteries or veins, whereas sympathetic inhibition decreases the pressure at each volume.
- For example, an increase in vascular tone throughout the systemic circulation can cause large volumes of blood to shift into the heart, which is one of the principal methods that the body uses to rapidly increase heart pumping.
- Sympathetic control of vascular capacitance is also highly important during hemorrhage.

Thank you