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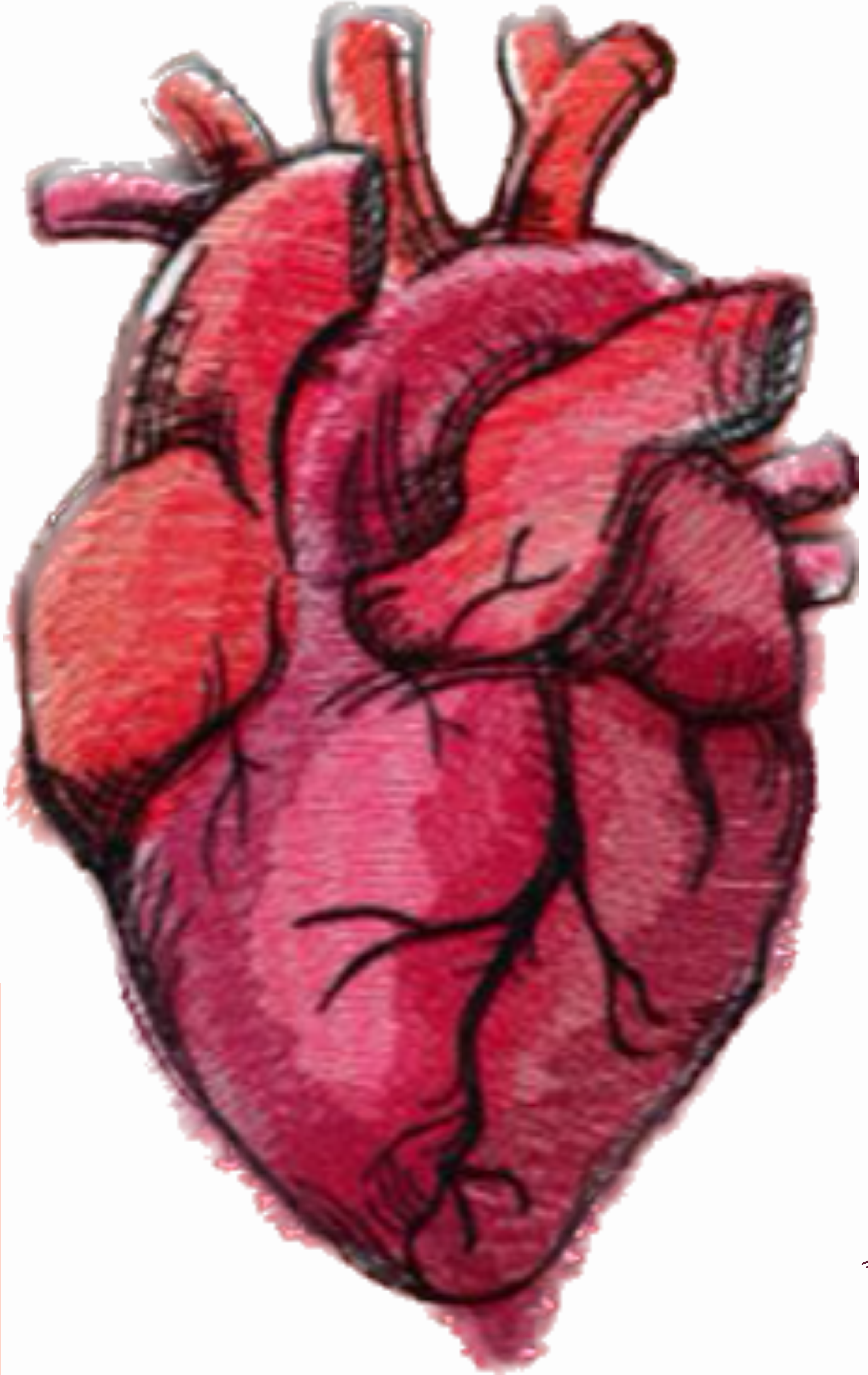

CARDIOVASCULAR SYSTEM

SUBJECT : physiology

LEC NO. : 10

DONE BY : Abdullah Bani Mustafa

وَقُل رَّبِّ زِدْنِي عِلْمًا

SCAN ME!

Haemodynamics and capillary filtration

Cardiovascular Module
Hashamite University

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capillaries are well adapted for the exchange O_2, CO_2 and nutrition material such as glucose a.a within the cappillaries

exchange substances between the blood & surrounding tissues

*site of exchange are cappillaries

the are single membrane layer to allow sufficient exchange
No elastin or smooth muscles except epithelial cells which contain pores

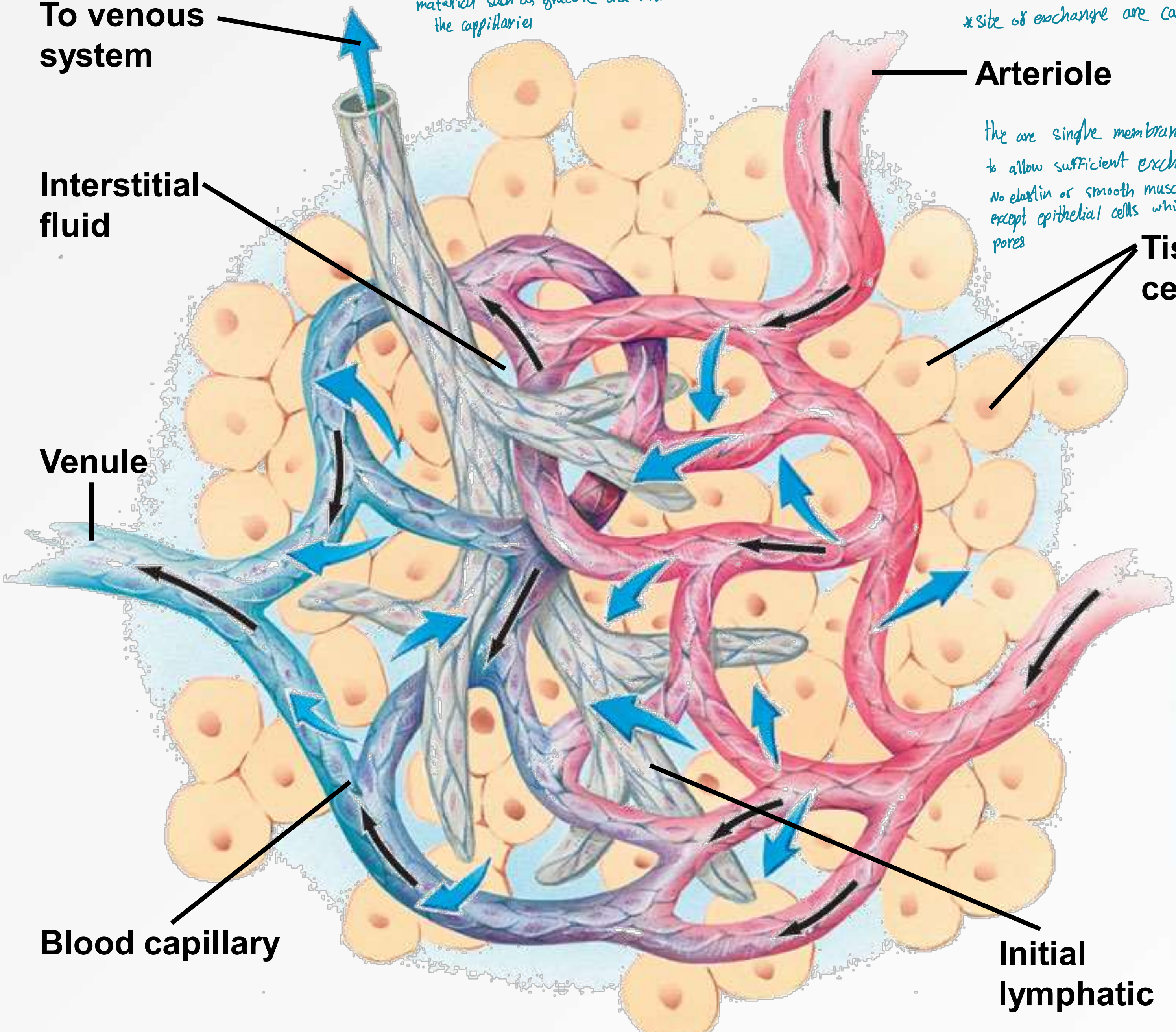

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Fig. 10-20a, p. 296

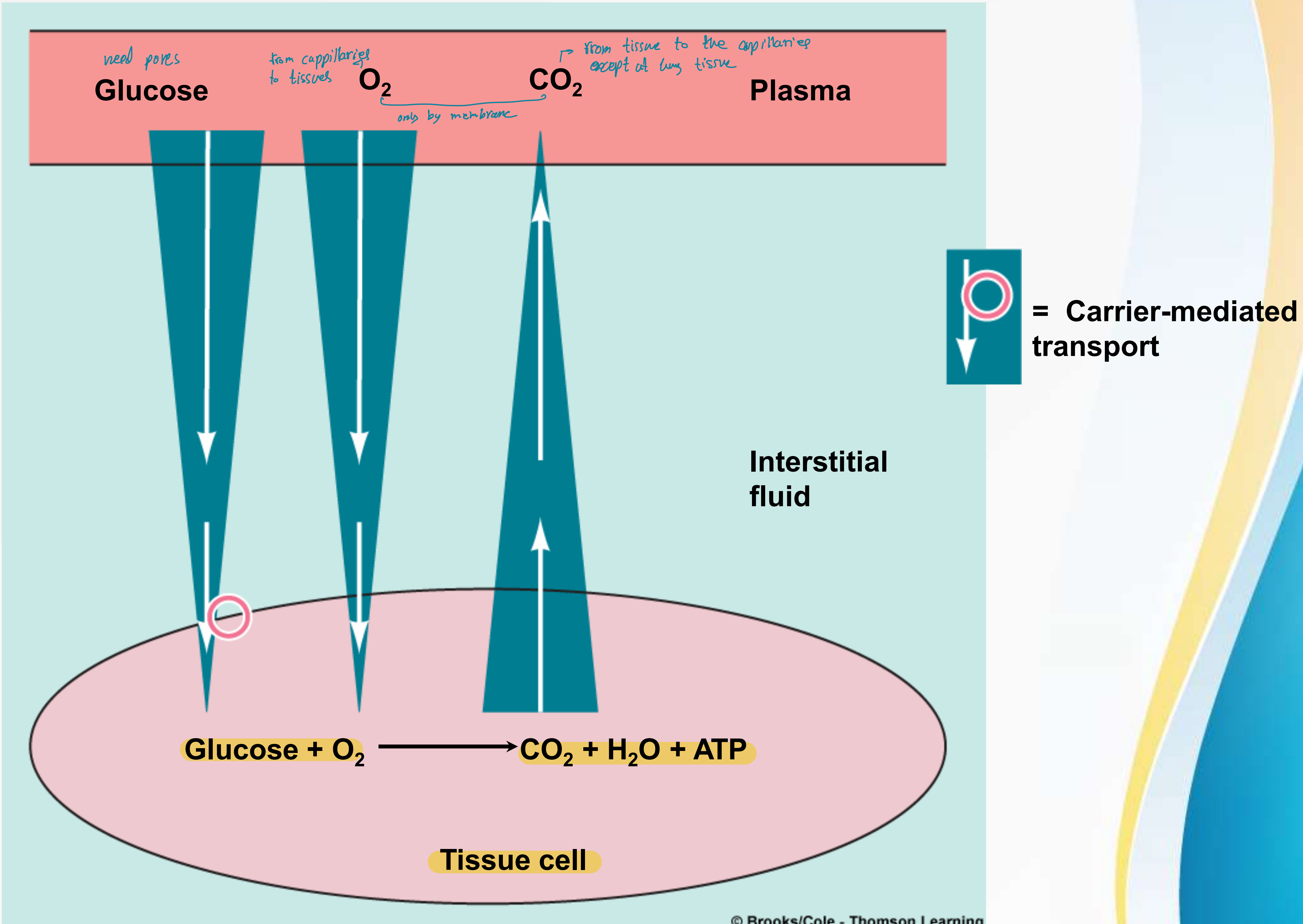

Fig. 10-17, p. 293

Capillary

pores → give them adaptability for gas exchange

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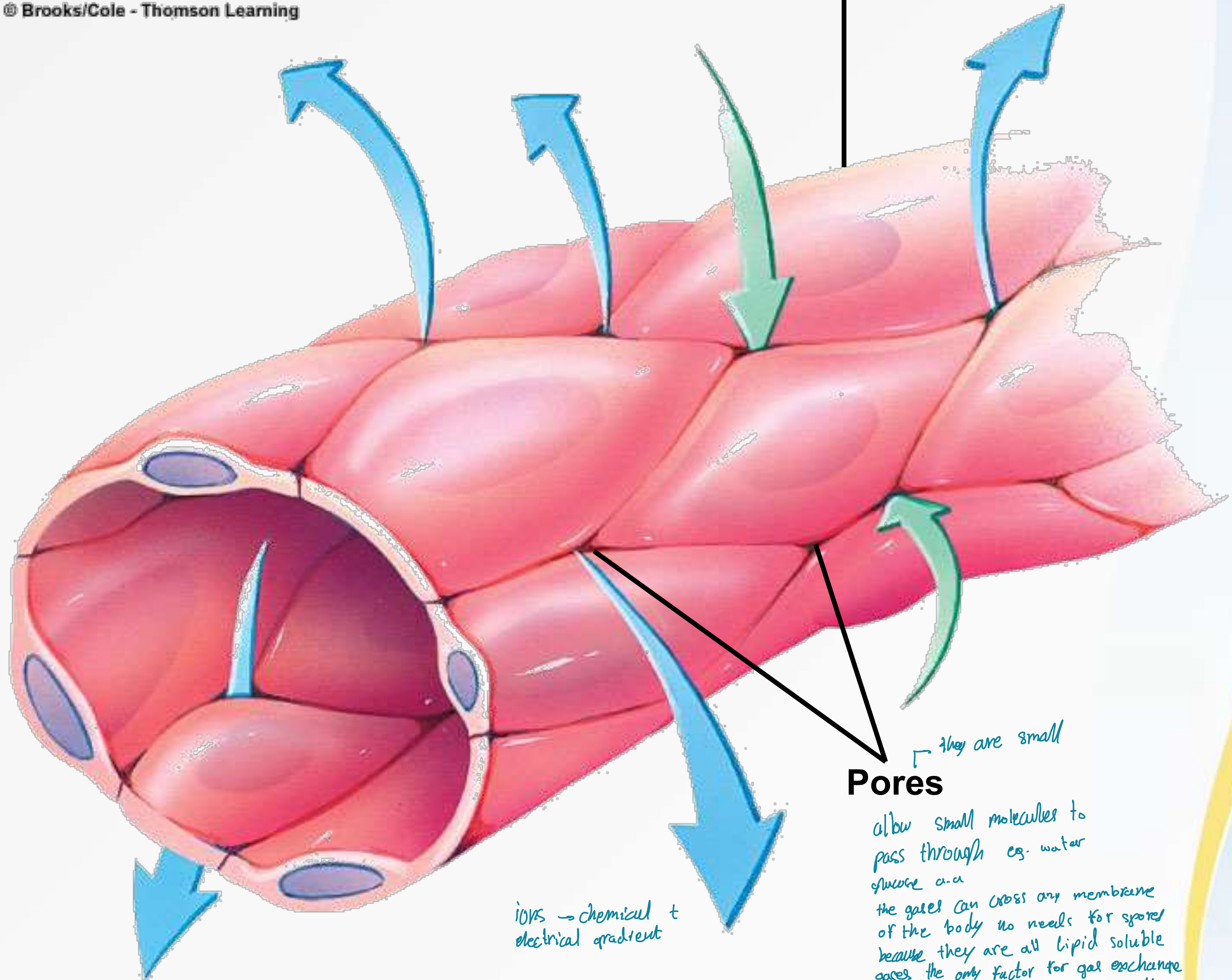


they are small

allow small molecules to pass through eg. water glucose a.a

the gases can cross any membrane of the body no needs for spores because they are all lipid soluble gases the only factor for gas exchange is their partial pressure across the membrane so no restriction to move from high to low pressure

ions → chemical + electrical gradient

Fig. 10-16a, p. 292

Types of pores:

*know that pores aren't present in every capillaries in the body but the majority of them have pores

In some organs the pores in the capillaries have special characteristics .

1 gram of fatty acids give x3 amount of energy as 1 gram of glucose

these tight junctions doesn't allow most of substances to pass through

1- In ***Brain*** the junctions between the capillary endothelial cells are tight junctions allowing only very small molecules to pass into brain cells, e.g oxygen CO2, glucose and water

water, O_2 & CO_2 have no restriction of movement in any part of the body

glucose is the only substance used by the brain to produce energy in normal conditions

only the glucose can pass through the brain blood barrier → so this is why is given in hyperglycemic shock

metabolic product contain 3 carbons result from breaking down fatty acids but they are acidic so in long run they cause acidosis resulting in coma

← ketone bodies will be allowed to cross the brain blood barrier in case of an emergency

2- In ***liver*** the clefts between the endothelial cells are wide open to allow almost all plasma components to pass including large molecular weight proteins

this is due to the function of the Liver

→ where blood is being filtered

3- In ***Kidney*** the glomerular tufts have large number of oval like windows called "***fenestrae***" which penetrate all through the endothelial wall which allows all components of plasma to filter out except large molecular weight proteins (albumin) and blood elements (blood white and red cells)

Pores in the capillaries but they are smaller than the ones in the Liver

or globulins

all these component pass to the nephrones after the glomerular but most of these components will be reabsorbed back to the blood by different mechanism, around 99% will be reabsorbed.

fenestrae is the plural of fenestra

1L of urine is excreted / day

the filtration of capillaries happen in & out of the capillaries based on some factors

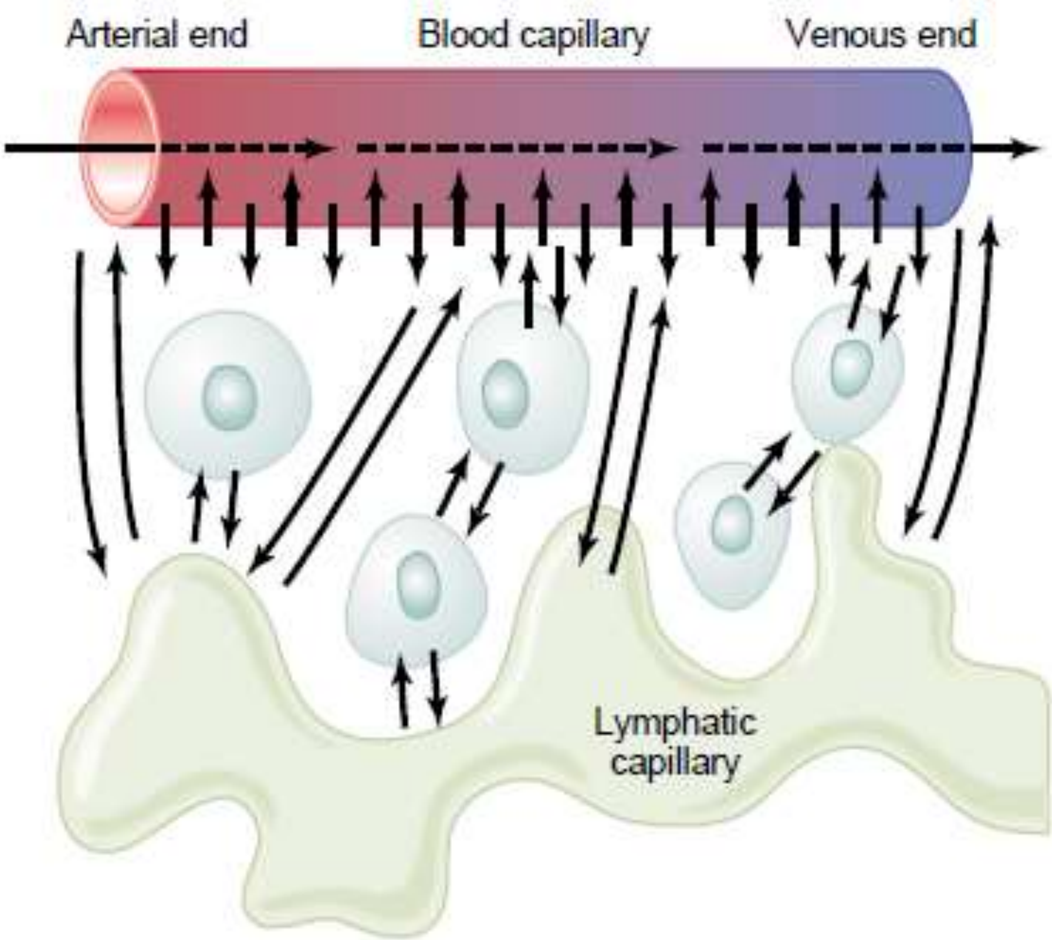


Figure 16–3

Diffusion of fluid molecules and dissolved substances between the capillary and interstitial fluid spaces.

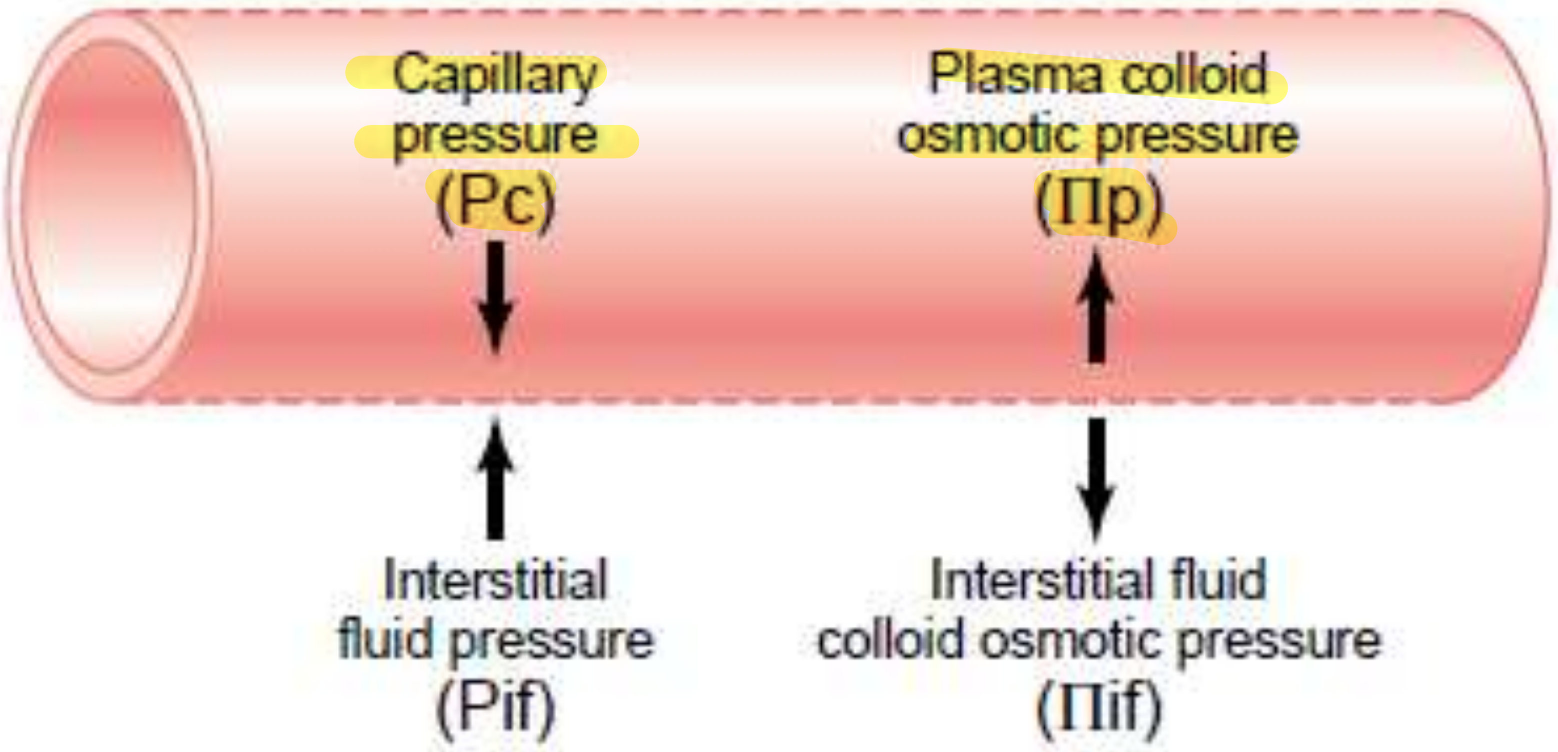
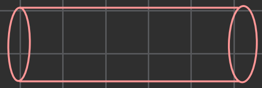


Figure 16–5

Fluid pressure and colloid osmotic pressure forces operate at the capillary membrane, tending to move fluid either outward or inward through the membrane pores.



beginning of the capillary — end of the capillary

hydrostatic pressure

at the beginning of the capillary the pressure is around ≈40 mmHg while at the end is ≈ 20 mmHg

* the pressure at the beginning of the capillary called hydrostatic capillary which favor moving substances out of the capillary to the interstitial fluid

as the blood moving it's loosing H_2O which will increase the concentrations of proteins that cannot get out such as albumins & globulins giving a colloid osmotic pressure which favor moving substances back to the capillary

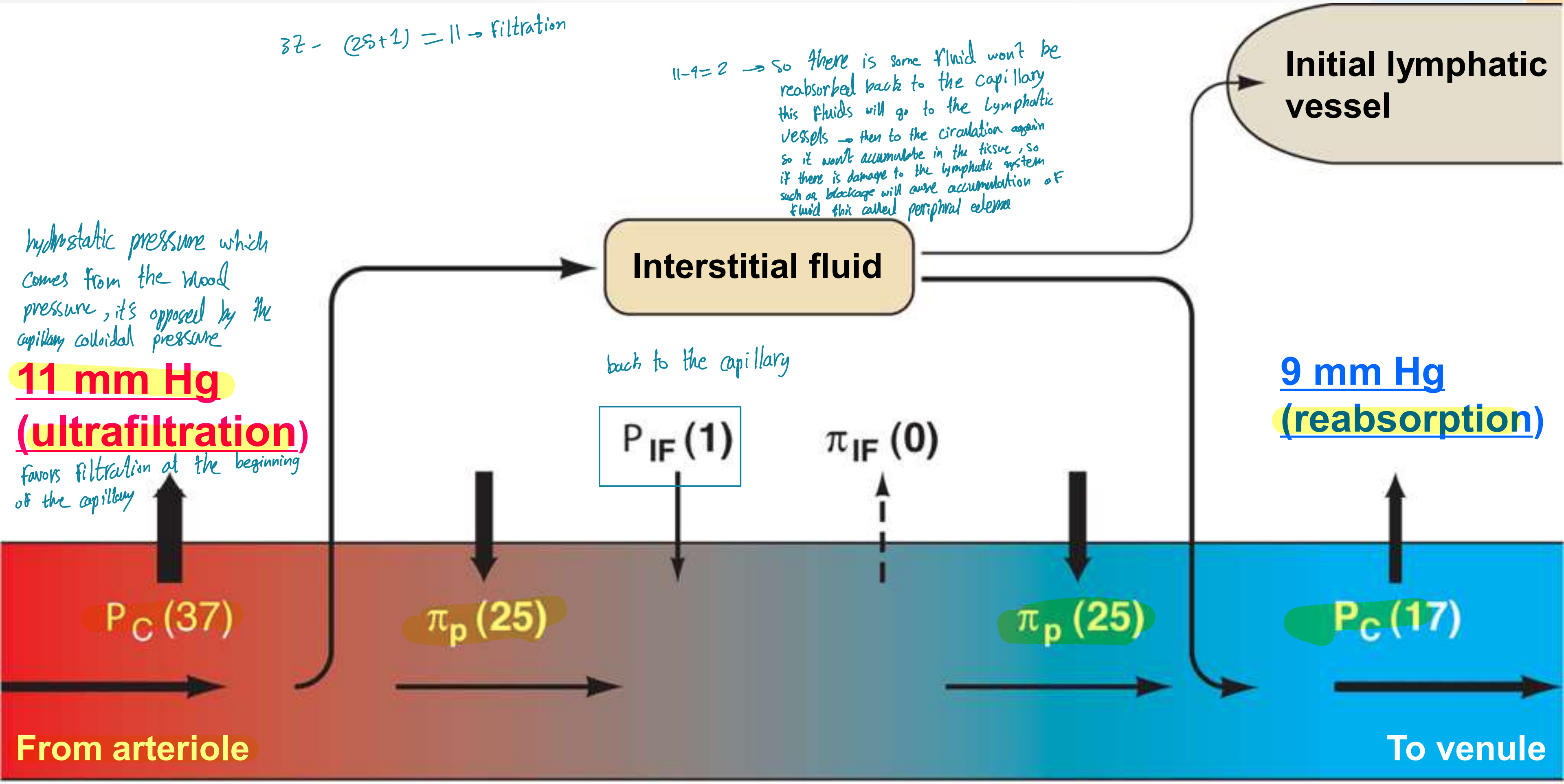
(main factors)

other factors :

① interstitial fluids : when capillary loose water to it, it increase its pressure which then tend then to push fluids back to the capillary → only 1 mmHg

② interstitial colloidal pressure : due to the presence of proteins around the tissue it's almost 0

* at the beginning of the capillary the hydrostatic pressure ≈ 40 mmHg while colloidal pressure ≈ 25 so it favors filtration outside the capillary, while at the end of the capillary the hydrostatic pressure ≈ 17 & colloidal pressure ≈ 25 so it fever reabsorption



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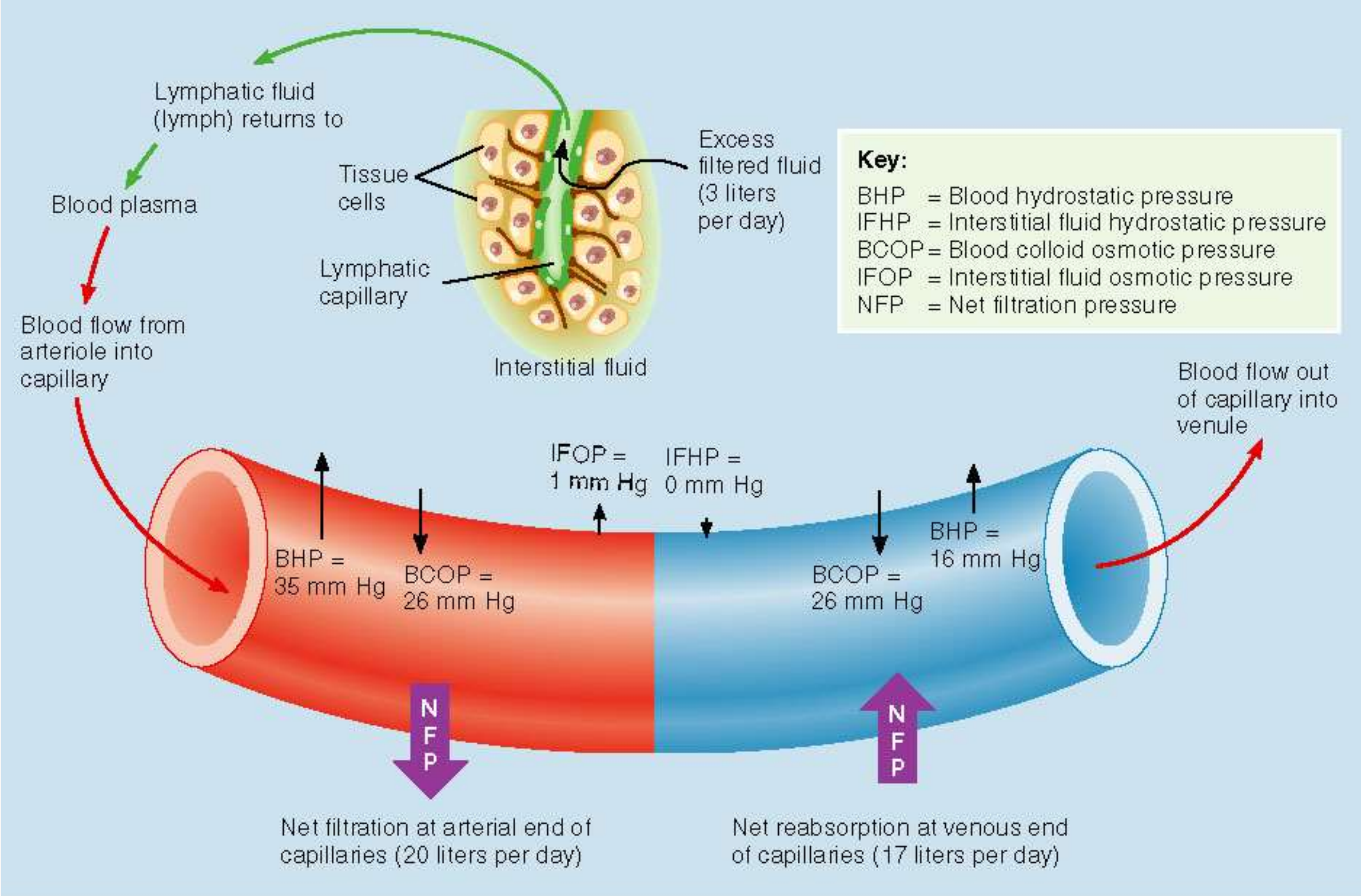
Blood capillary

→ *(See next slide)*

Fig. 10-18 (middle), p. 294

same as the previous slide but slightly changed pressure



Net filtration pressure (NFP) = (BHP + IFOP) – (BCOP + IFHP)

Pressures promoting filtration — Pressures promoting reabsorption

	Arterial end	Venous end
	NFP = (35 + 1) – (26 + 0) = 10 mm Hg	NFP = (16 + 1) – (26 + 0) = –9 mm Hg
Result	Net filtration	Net reabsorption

favor Filtration

mean favor reabsorption

Forces at arteriolar end of capillary

- **Outward pressure**

P_C	37
π_{IF}	0
	37

- **Inward pressure**

π_P	25
P_{IF}	1
	26

Net outward pressure of 11 mm Hg = Ultrafiltration pressure

(See next slide)

All values are given in mm Hg.

Fig. 10-18 (left), p. 294

Forces at venular end of capillary

- **Outward pressure**

P_C	17
π_{IF}	0
	17

- **Inward pressure**

π_P	25
P_{IF}	1
	26

Net inward pressure of 9 mm Hg = Reabsorption pressure

Fig. 10-18 (right), p. 294

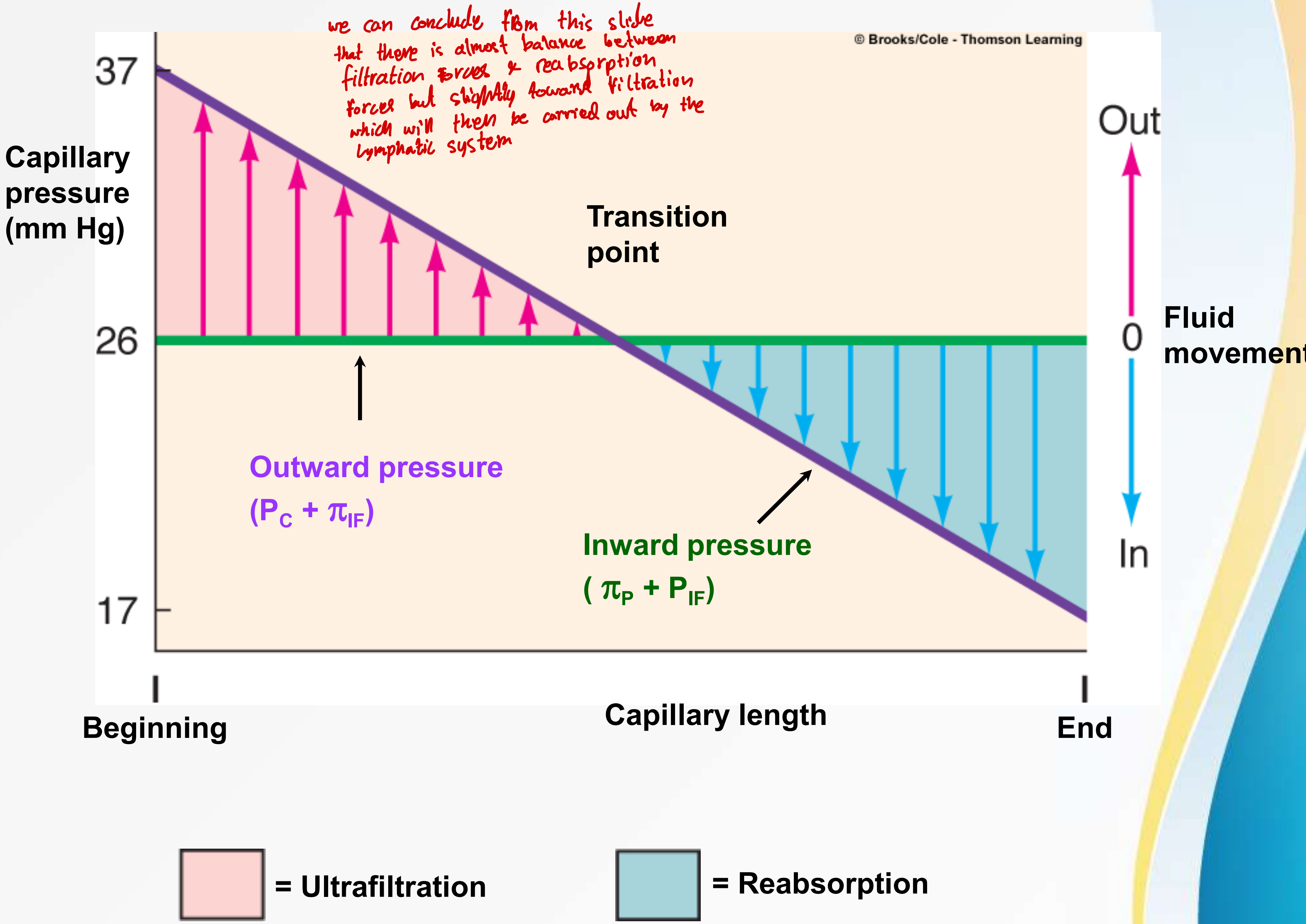


Fig. 10-19, p. 295

Regulation of cardiac output which is around 5L

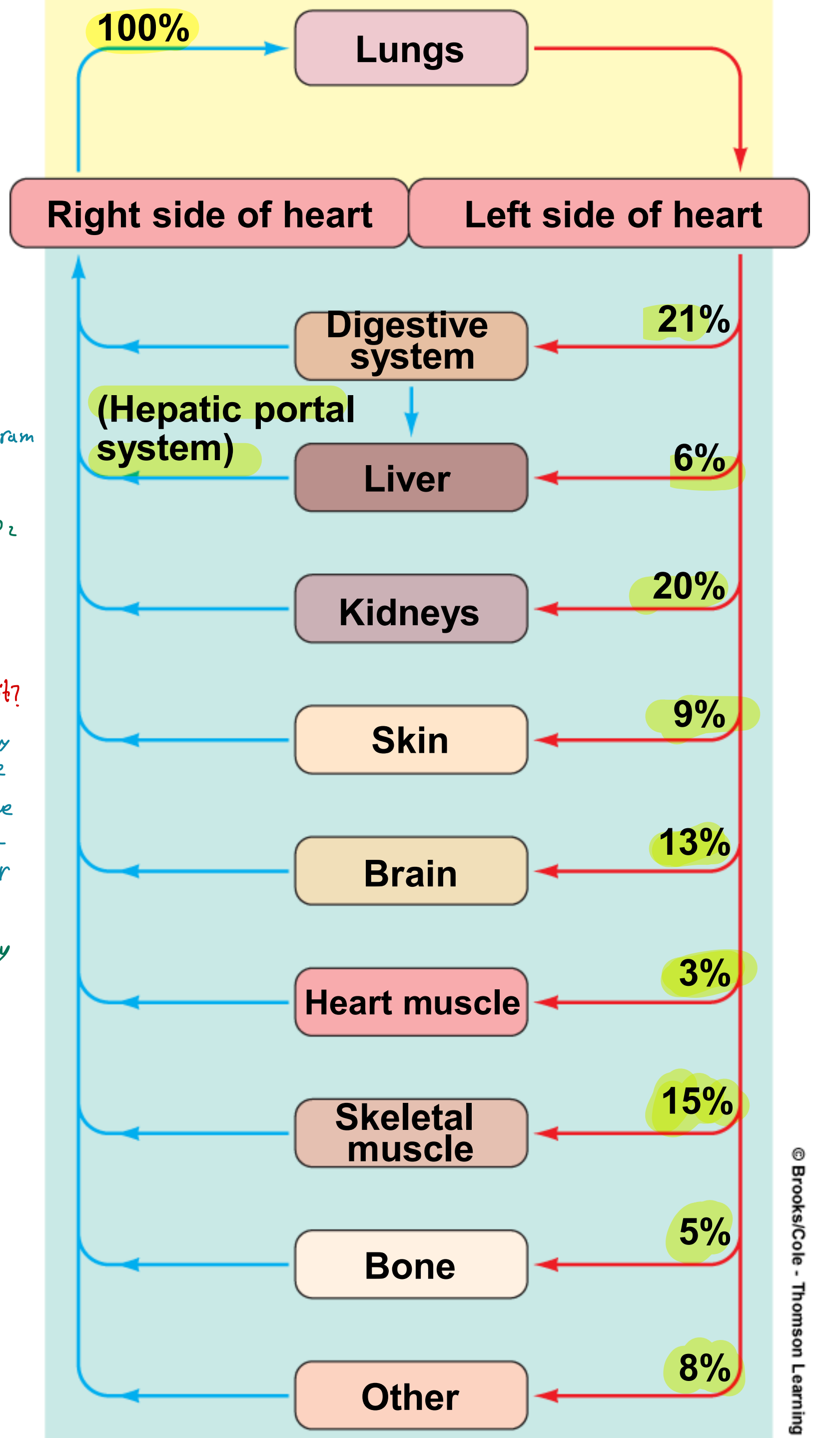
this slide is to conclude to know that the distribution is determined by the function & the metabolic rate of the organ

the organ which has the highest blood volume/gram tissue → the carotid & aortic bodies which are sensitive to the O_2 & CO_2 concentration why? because they are sensitive to the dissolved O_2 not the bounded O_2, the dissolved O_2 only represent 3% of total oxygen from the oxygen blood content so that is why they have a very high blood flow

why our body doesn't sense CO when we inhale it?

because the receptors (carotid & aortic bodies) only sense the O_2 that is dissolved in plasma not the one bounded with the Hb, and because the CO only replace the O_2 that is bounded to Hb it won't effect the concentration of the dissolved O_2 so the receptor won't sense it.

after the carotid & aortic receptors the kidney is second due to its filtration activity.



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we are not required to know the exact value of blood distribution across the body organs

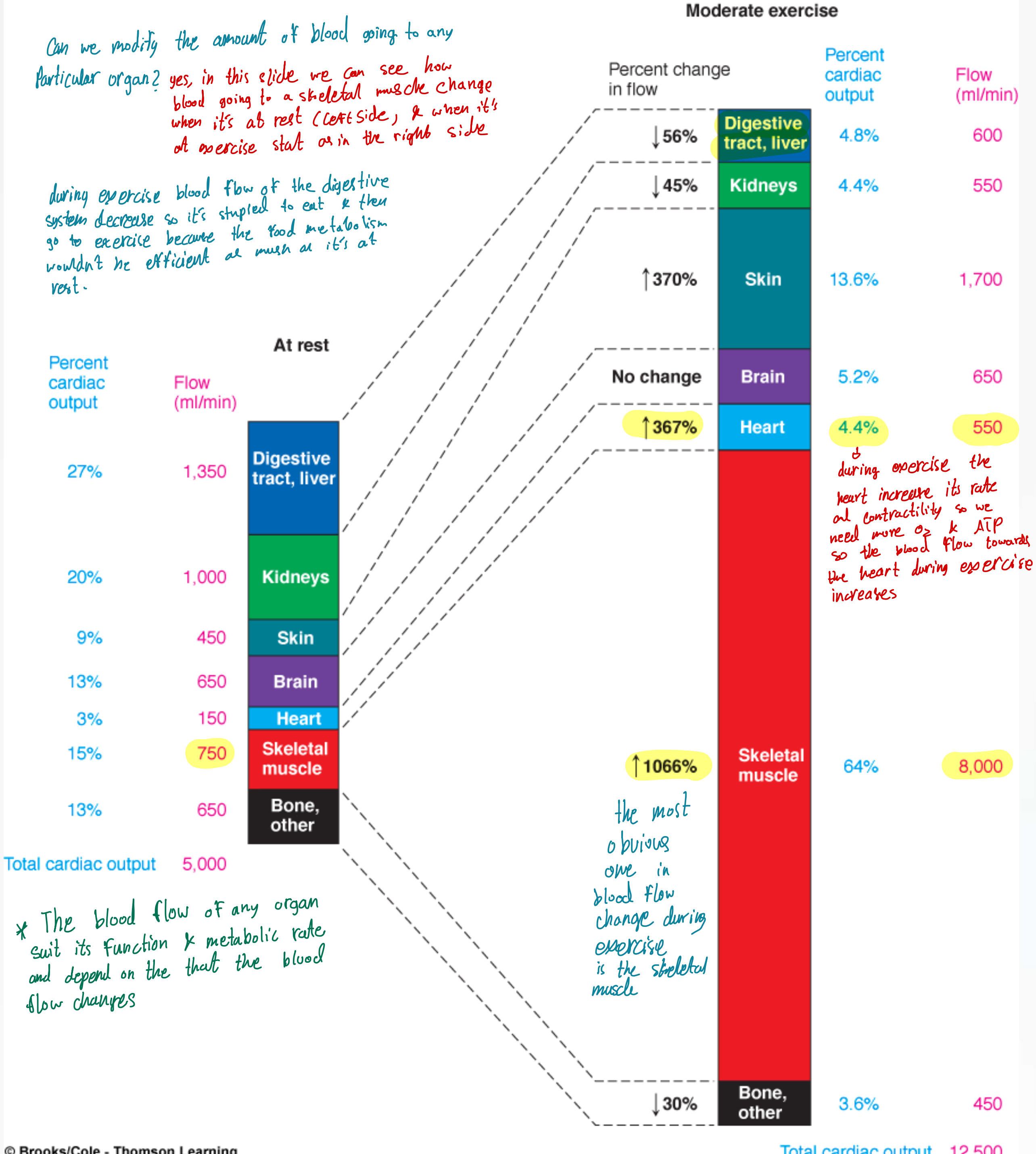
vascular tree

aorta
↓
large arteries
↓
small arteries
↓
arterioles
↓
capillaries
↓
venioles
↓
veins
↓
IVC & SVC

Fig. 10-1, p. 276

Can we modify the amount of blood going to any particular organ? yes, in this slide we can see how blood going to a skeletal muscle change when it's at rest (left side) & when it's at exercise stat as in the right side

during exercise blood flow of the digestive system decrease so it's stupied to eat & then go to exercise because the food metabolism wouldn't be efficient as much as it's at rest.



during exercise the heart increase its rate and contractility so we need more O_2 & ATP so the blood flow towards the heart during exercise increases

the most obvious one in blood flow change during exercise is the skeletal muscle

* The blood flow of any organ suit its function & metabolic rate and depend on the that the blood flow changes

Fig. 10-11, p. 286

Determinants of Blood Flow

the main factor that effect the flow is the pressure difference between two points , increase ΔP increase the flow so the pressure gradient is directly proportional to the flow , also resistance is another factor which decreases flow so resistance is inversely proportional to the flow

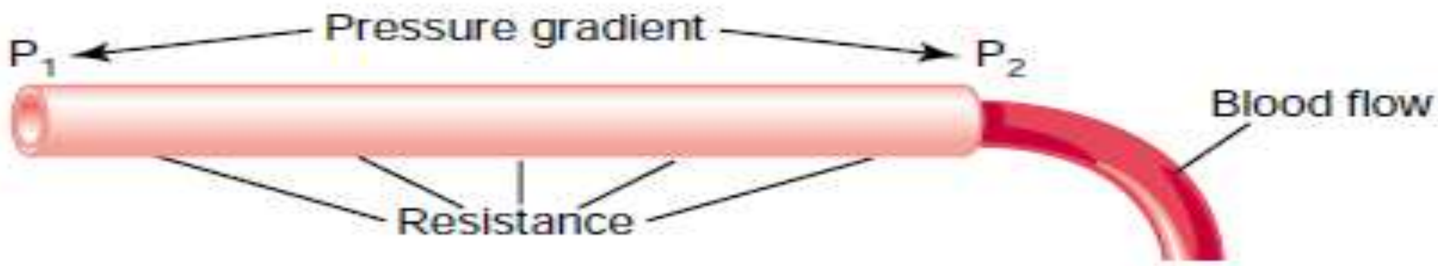


Figure 14–3

Interrelationships among pressure, resistance, and blood flow.

arterioles are the major determinance of blood flow

- Blood flow is determined by pressure gradient and peripheral resistance, therefore: $F = \frac{(P_A - P_V)}{R}$

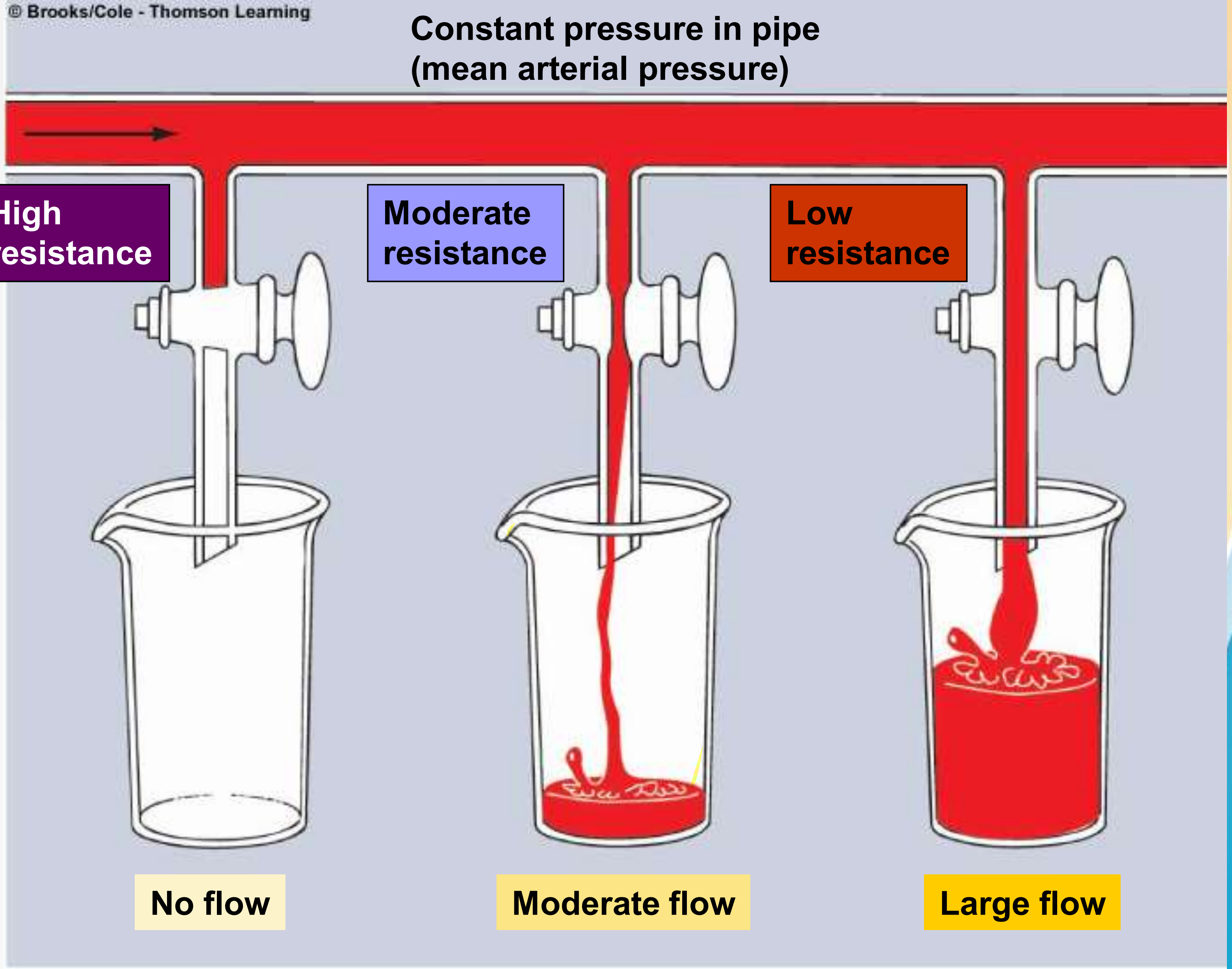
the major determent of resistance from the vascular tree 50% of the total periphral resistance found in arterioles

- Arterioles play a major role in blood distribution & control of BP.
- Arteriolar smooth muscles determine the resistance to blood flow to the tissues it supplies.

all smooth muscles of arterioles are supplied by sympathetic except
1) Salivary glands both
2) sweat gland both
3) external gentile of females & males →

if we see resistance vessels in question it refers to arterioles because the smooth muscle is the major part of it. which is innervated by the sympathetic nerves system which causes vasoconstriction → vicious sympathetic stimulation could shut down and if the sympathetic stimulation decreases the it can double the size of the arteriole → vasodilation → wider so we can conclude that when there is sympathetic stimulation the blood flow decrease

From pump (heart)



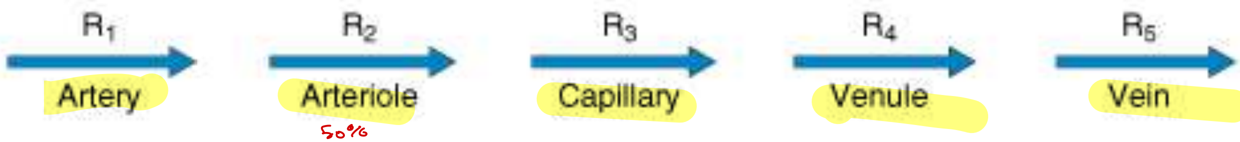
Control valves = Arterioles

Fig. 10-10, p. 285

SERIES RESISTANCES

the Summation of all blood vessel will give us the net resistance
* the total resistance is higher than the largest single resistance

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

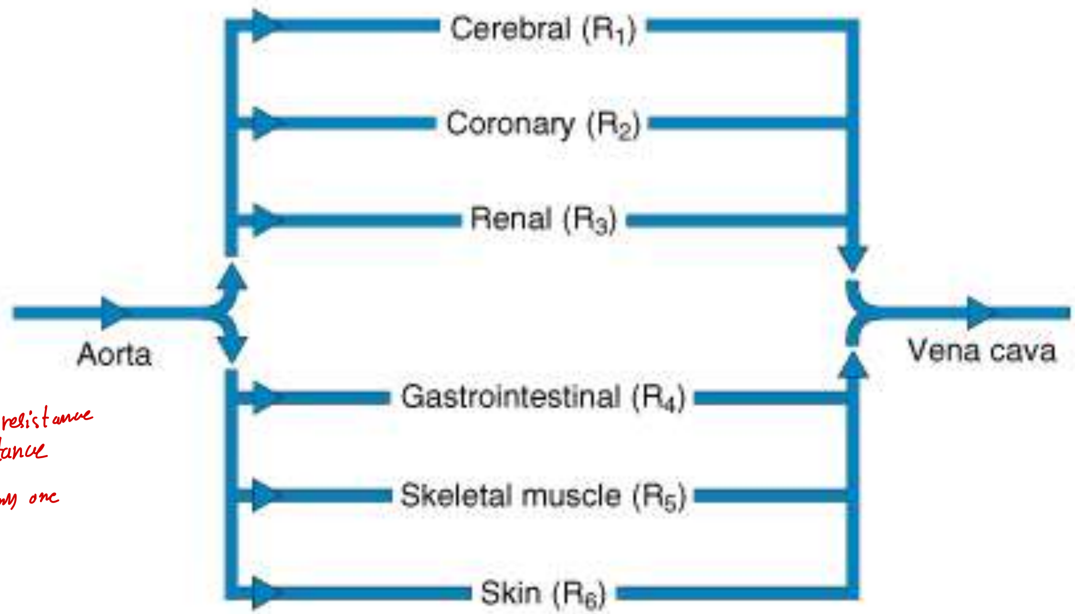


50%
each arteriole feed about 100 capillary

PARALLEL RESISTANCES

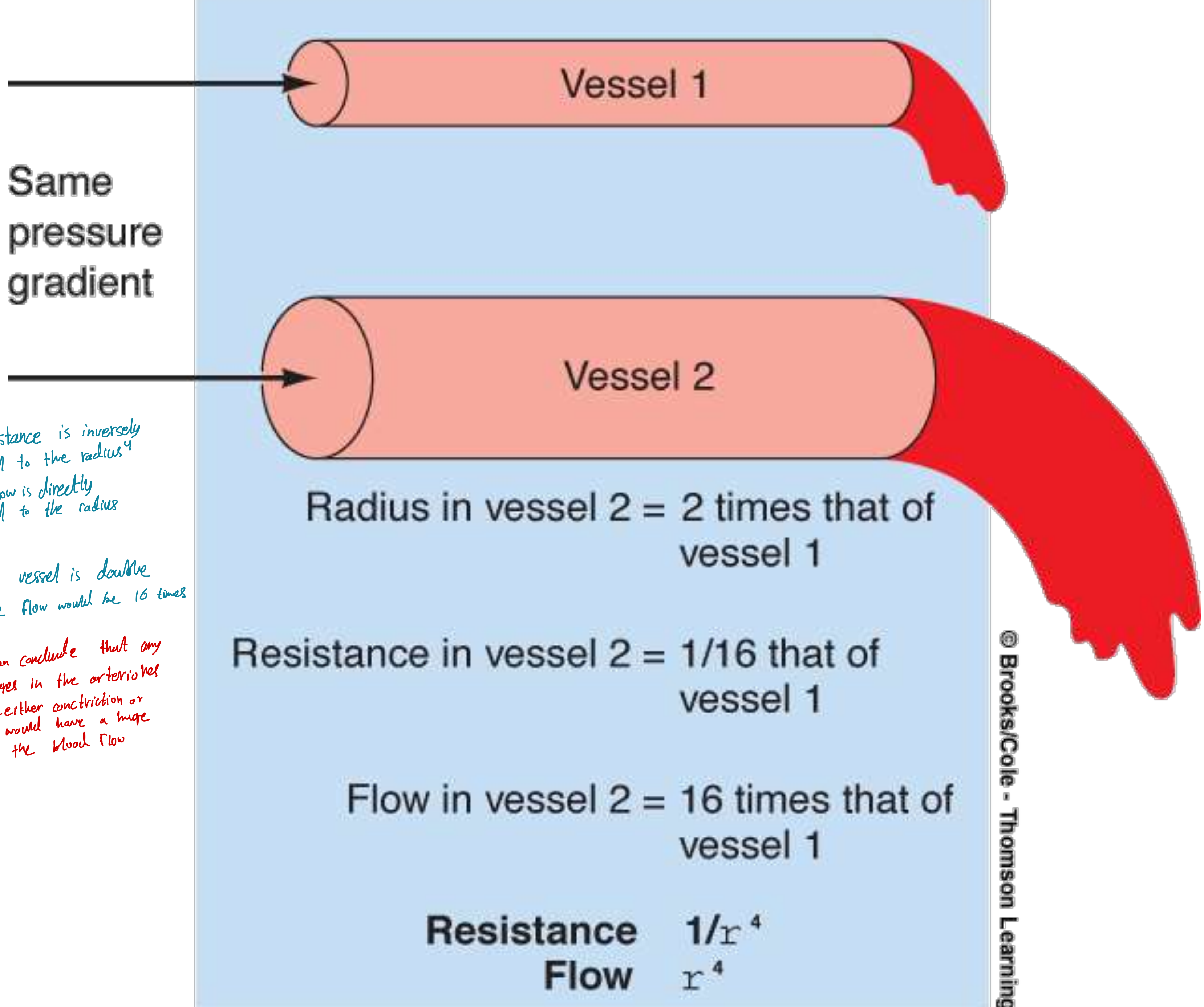
the total resistance is smaller than the single resistance

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



we can conclude that the parallel resistance is much smaller than the series resistance

* in our bodies the capillaries are the only one in parallel connections



the resistance is inversely proportional to the radius⁴ so the flow is directly proportional to the radius

* if the vessel is double in size the flow would be 16 times

* so we can conclude that any small changes in the arterioles diameter (either conctriction or dilatation) would have a huge effect on the blood flow 16 x

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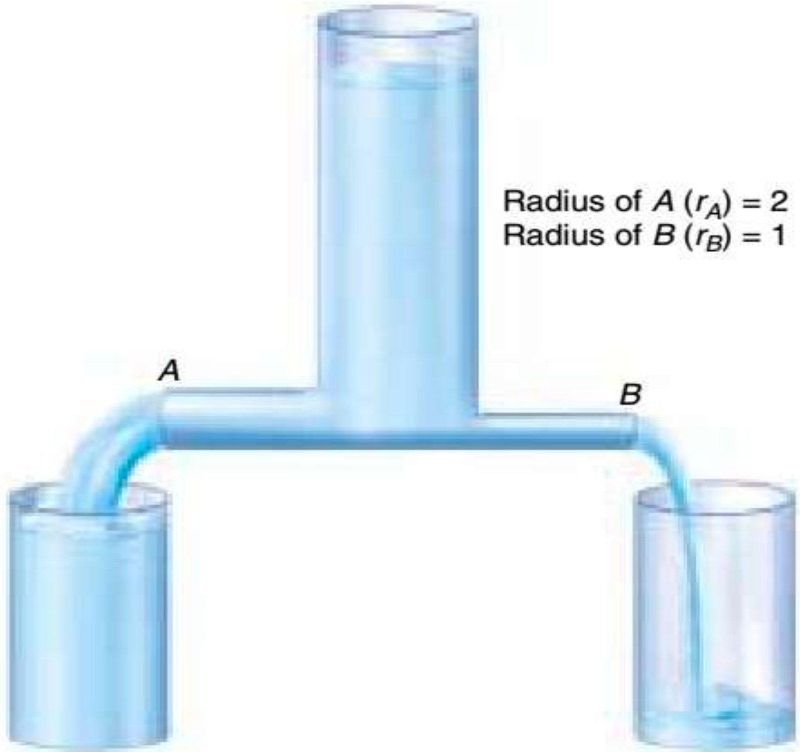
Fig. 10-3b, p. 278



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

$$R_A \propto \frac{1}{(r_A)^4} = \frac{1}{2^4} = \frac{1}{16} = 0.0625$$

$$R_B \propto \frac{1}{(r_B)^4} = \frac{1}{1^4} = \frac{1}{1} = 1.0$$

Therefore $R_B = 16\ R_A$

$$\text{Flow} = \frac{\Delta P}{R}$$

Therefore flow in $B = \frac{1}{16}$ th of flow in A

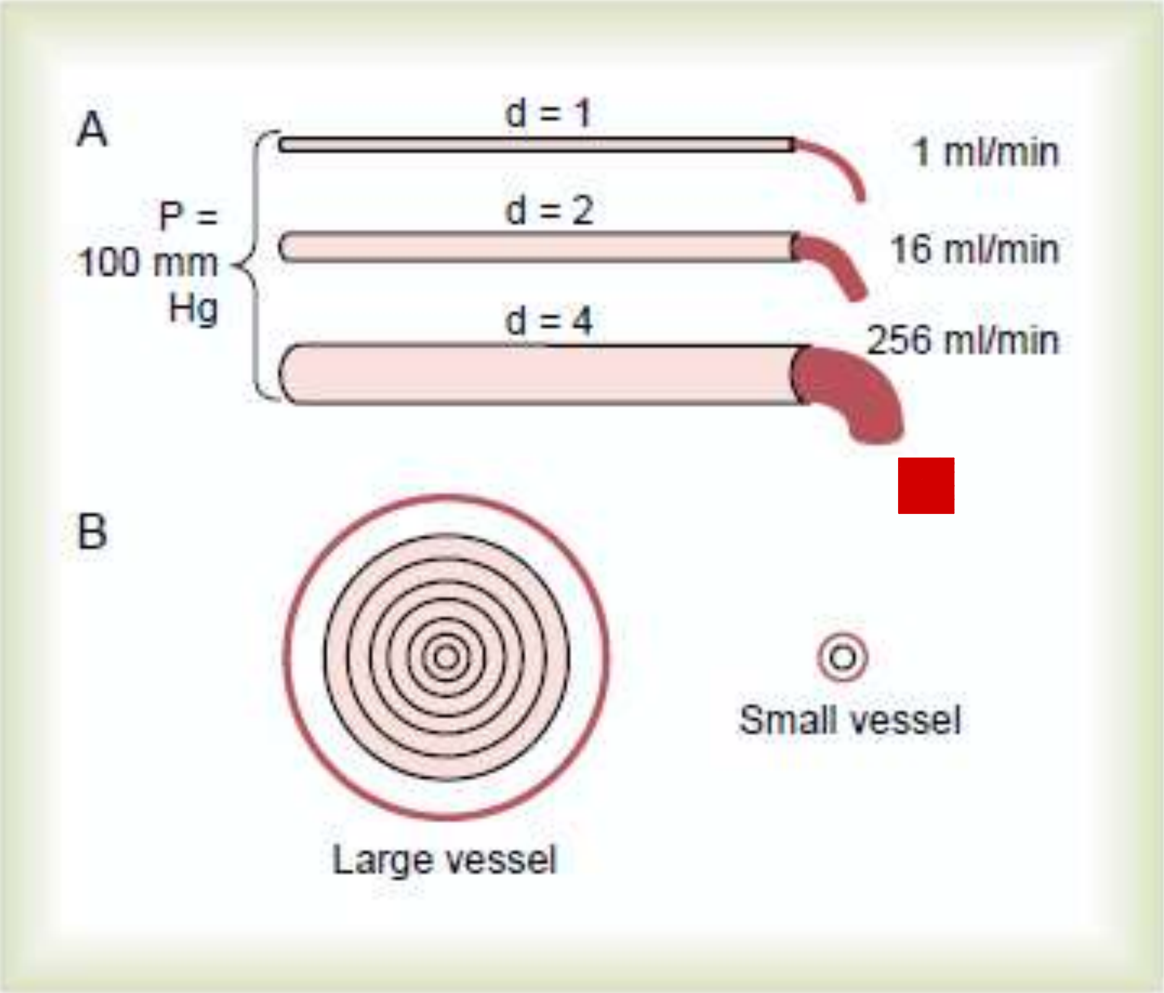


Figure 14–9

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.

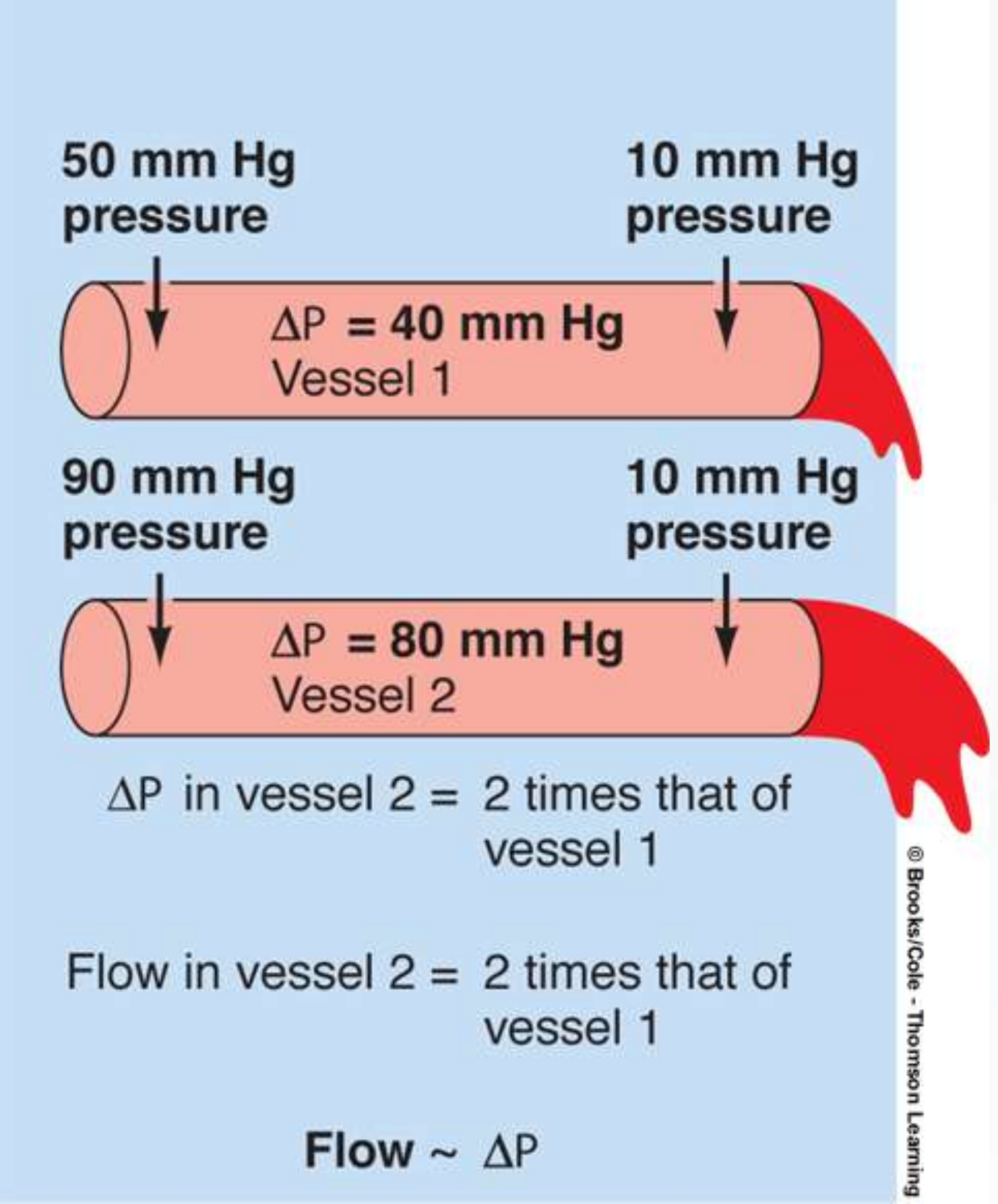


Fig. 10-2a, p. 277

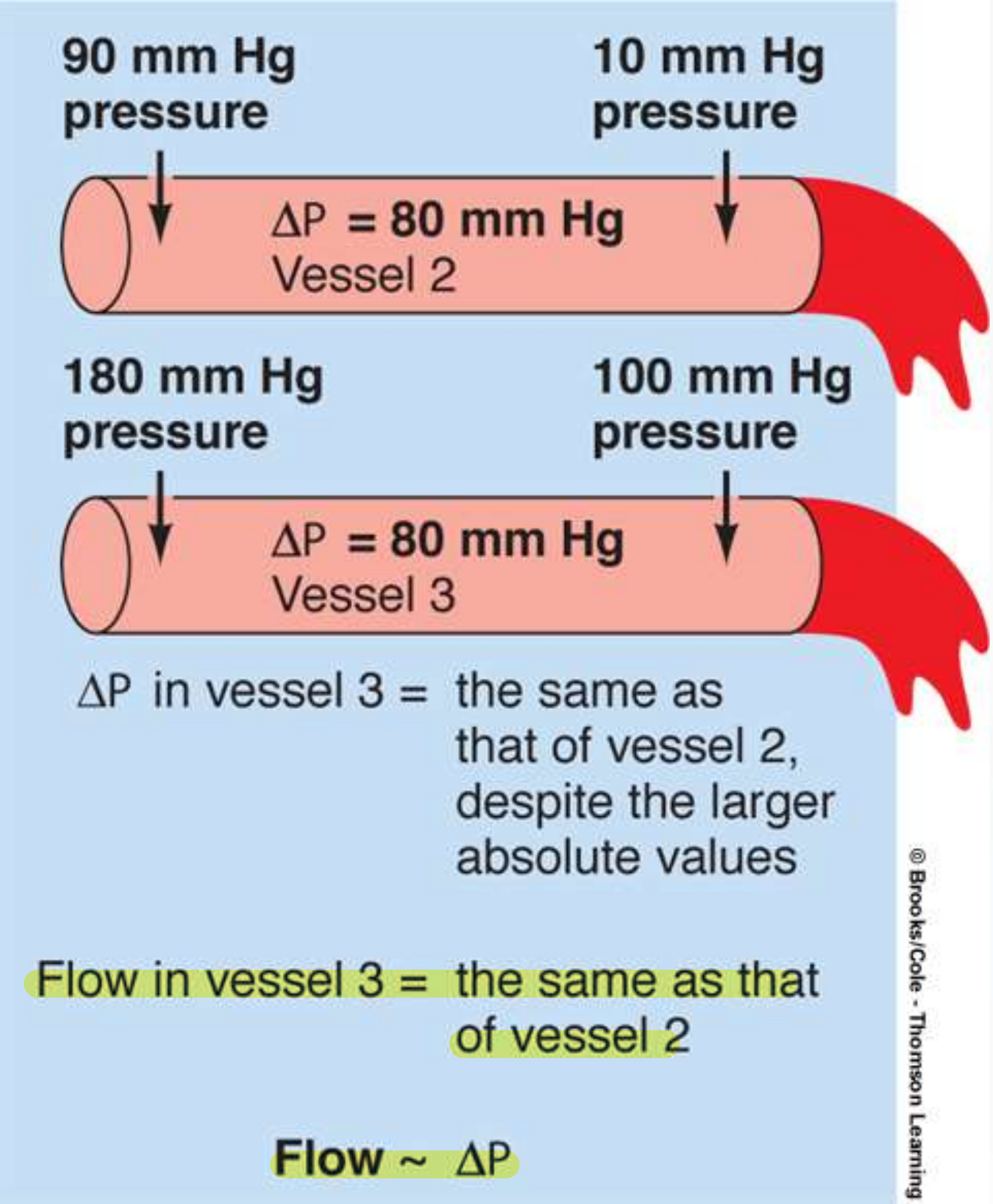


Fig. 10-2b, p. 277

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

Since **R**esistance α 1/r4 (radius to power 4)…r = radius

R inversely proportional to r4

Therefore **F = ΔP x r4**

Hence: If the **radius is doubled** the **flow will increase by 16 times**

The relationship between velocity, flow and cross sectional area

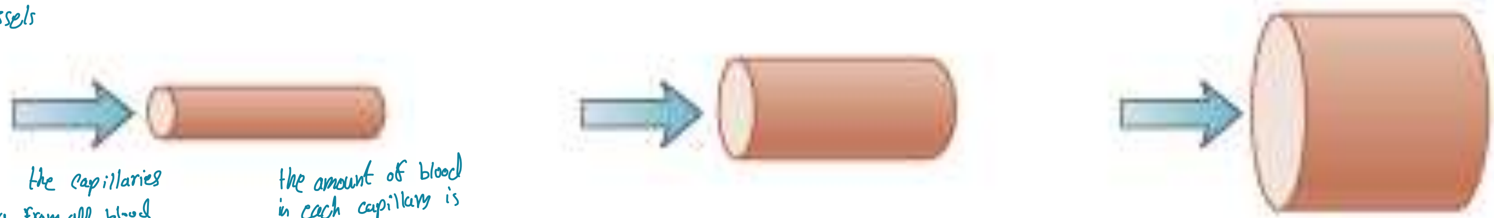
V = velocity cm/sec, Q = flow ml/sec, A = cross sectional area

the velocity is inversely proportional to the cross sectional area

$$v = Q/A$$

same flow to all vessels

10 mL/sec



* so we can conclude that the capillaries have the largest sectional area from all blood vessels so that is why they have the lowest velocity compared to other blood vessels

the amount of blood in each capillary is very small

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

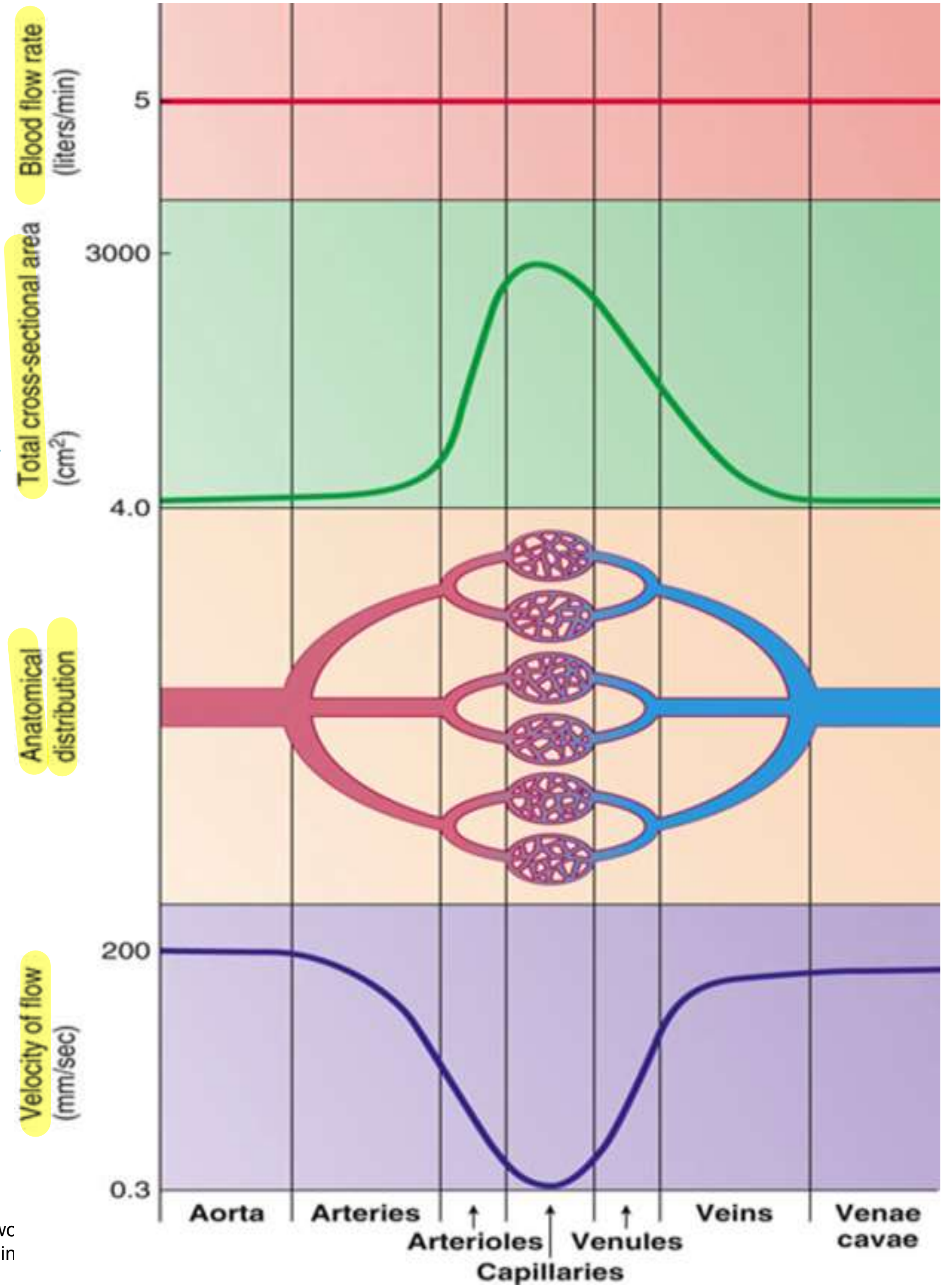
No need to remember the numbers but know which has the highest & lowest velocity
↓ aorta ↓ capillaries

* veins have slightly less velocity than arteries.

* the low velocity in capillaries enhance their function which is exchange substances between blood in the capillaries & surrounding tissues

so lets revise the factors that enhance capillaries functions

1) they are made up of a single layer of endothelial cells which ease material exchange
2) most of them contain pores to allow passage of substances such as glucose through them.
3) the velocity of the blood is slow to allow the exchange to take a place



Chapter 9 Cardiac Physiology
Human Physiology by Lauralee Sherwc
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so as we know from before the vasoconstriction & vasodilation change the resistance (after load)
↳ arterioles mostly due to their small diameter & their structure which is mainly smooth muscles innervated with sympathetic nerves

* heat & Sympathetic factors are the only ones which could cause systemic vasodilation

Vasodilation

(decreased contraction of circular smooth muscle in the arteriolar wall, which leads to decreased resistance and increased flow through the vessel)

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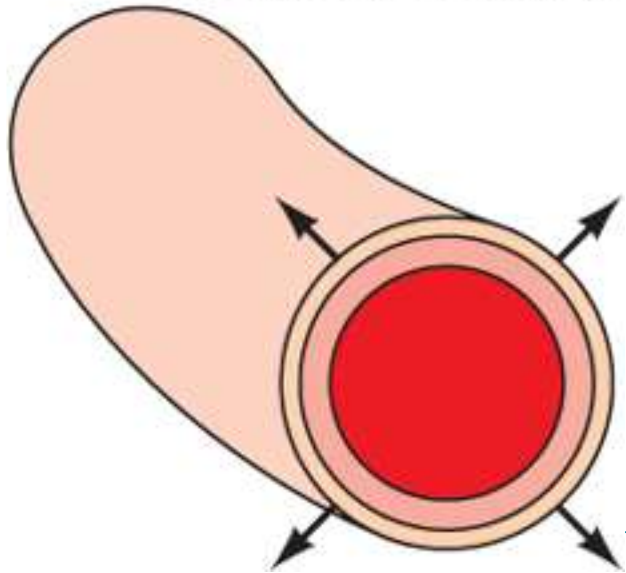

myogenic :- decrease in the tension of the blood vessels which will result in the expansion of blood vessels

factors which can cause vasodilation

Caused by:

- ↓ Myogenic activity
- ↓ Oxygen (O_2)
- ↑ Carbon dioxide (CO_2) and other metabolites
- * ↑ Nitric oxide
- ↓ Sympathetic stimulation
- Histamine release
- * Heat

it could be systematic when the center of sympathetic nerves

↓O_2 & ↑CO_2 is a result of increase metabolic activity in the muscle so we need more O_2 which is provided by vasodilation its a local Not systemic effect.

vasodilation that is caused by heat could help us to radiate more heat out of our body through the skin to decrease body temperature

* Nitric oxide it's a gas so after its release it gets broken down very quickly. it's usually produced by the endothelial cells which line the arterioles from the amino acid called arginine by a specific metabolic activity which then NO is produced as gas making vasodilation (it's the strongest vasodilation) but it's local not systemic

* Not proven but it's thought that the hypertension of the unknown reason is due to the lack of NO due to impaired of mechanism which produce NO in blood vessels
} only for your knowledge won't be asked on the exam

Fig. 10-9d, p. 284

Vasoconstriction

(increased contraction of circular smooth muscle in the arteriolar wall, which leads to increased resistance and decreased flow through the vessel)

if the heat is below 10 c° (≈) we don't freeze because then our body will send negative feed back causing vasodilation to protect our body from freezing and from hypoxia

* vasopressin : ADH → later on it was discovered that it's always found in our body & it works in water excretion in the kidney (water reabsorption in the neuphrone) → in other words it increases the water preservation in our body & decrease the amount of water loss in the urine, it's very important when we are fasting to minimize the water loss as much as possible

↳ it was named vasopressin when it was discovered it causes vasoconstriction in the abdominal arterioles

* in case of sever hypotension as an eg. during massive bleeding, ADH would be produced in large amount that is enough to cause vasoconstriction so it's an attempt from the body to increase resistance to increase the blood pressure as much as possible so the patient could survive

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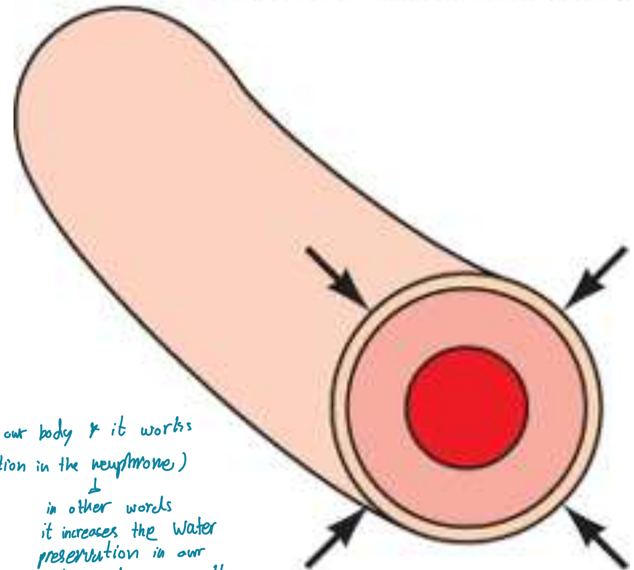


Caused by:

- ↑ Myogenic activity
- ↑ Oxygen (O_2)
- ↓ Carbon dioxide (CO_2) and other metabolites
- ↑ Endothelin
- ↑ Sympathetic stimulation
- Vasopressin; angiotensin II
- Cold

عكس الذي فوق

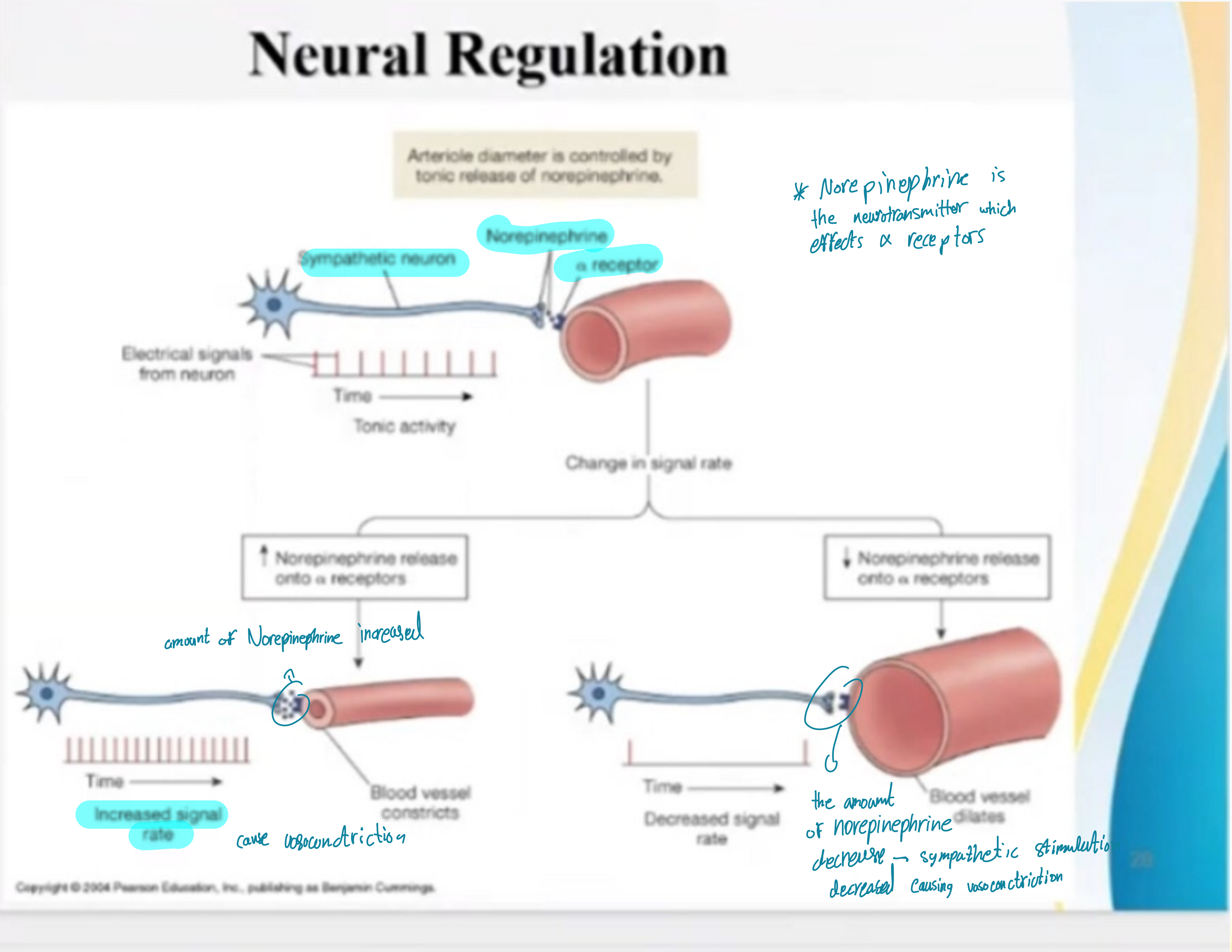
Endothelin : are group of compounds which normally are produced in response to allergic reaction, so when they are released locally they cause vasoconstriction.

angiotensin II is produced angiotensinogen (→ so it's always found in our plasma) (produced by the liver) → angiotensin I (in the kidney) → angiotensin II (in lungs) then cause vasoconstriction in systematic way

Fig. 10-9c, p. 284

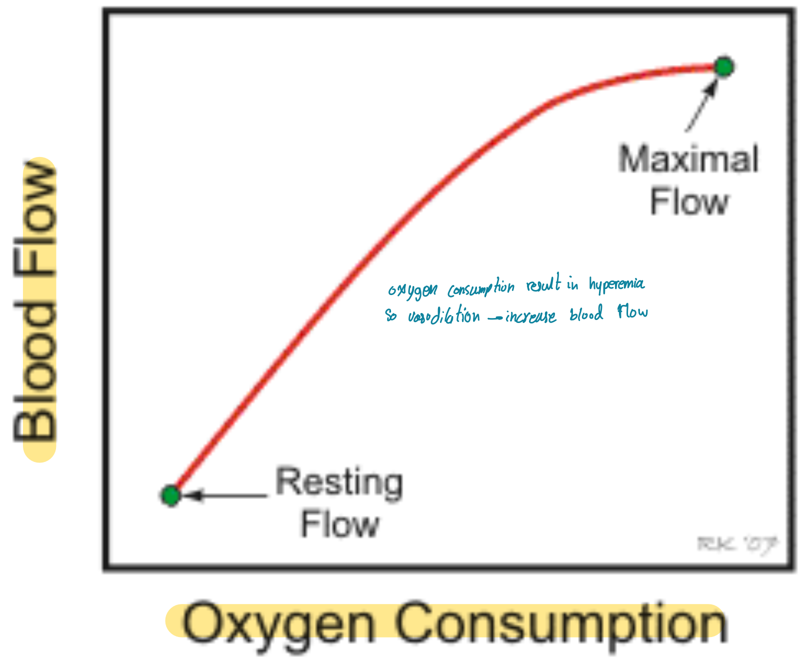
Neural Regulation

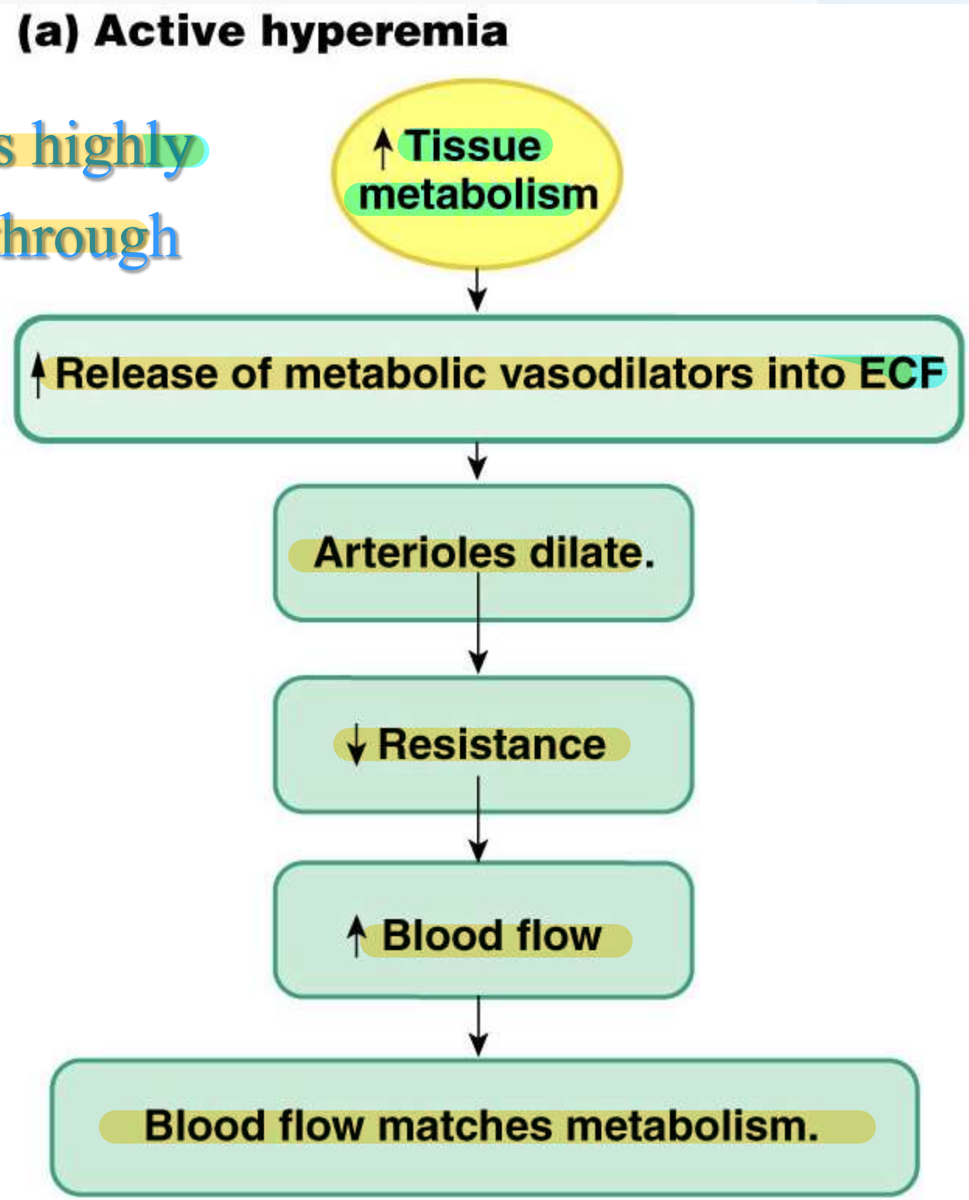
only sympathetic



Active Hyperemia (Metabolic activity)

- When a certain tissue becomes highly active, the rate of blood flow through the tissue increases.



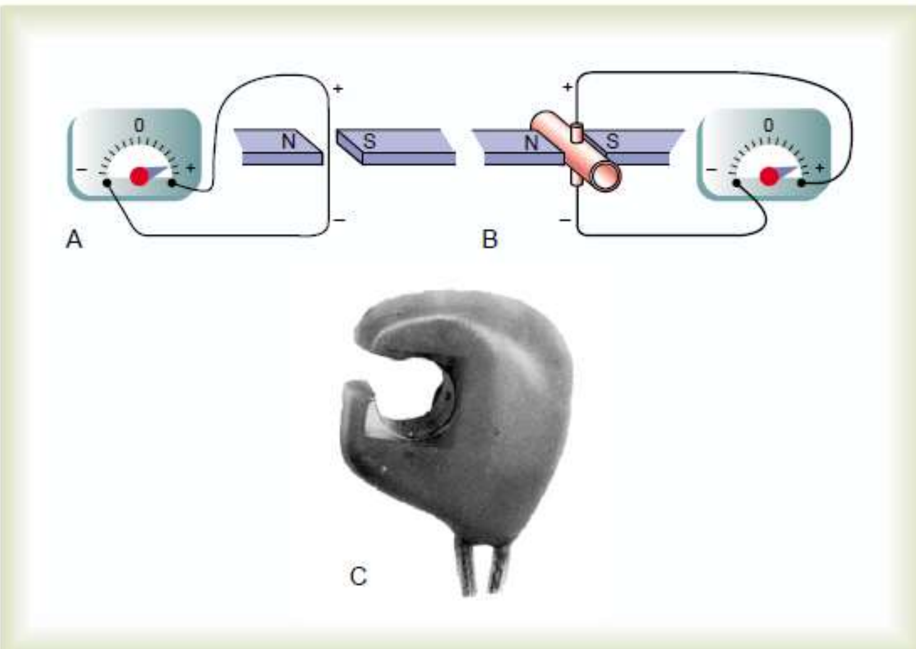


End of lecture

He didn't explain the next slides

Electro-magnetic flow meter - doppler

to measure blood flow in blood vessels



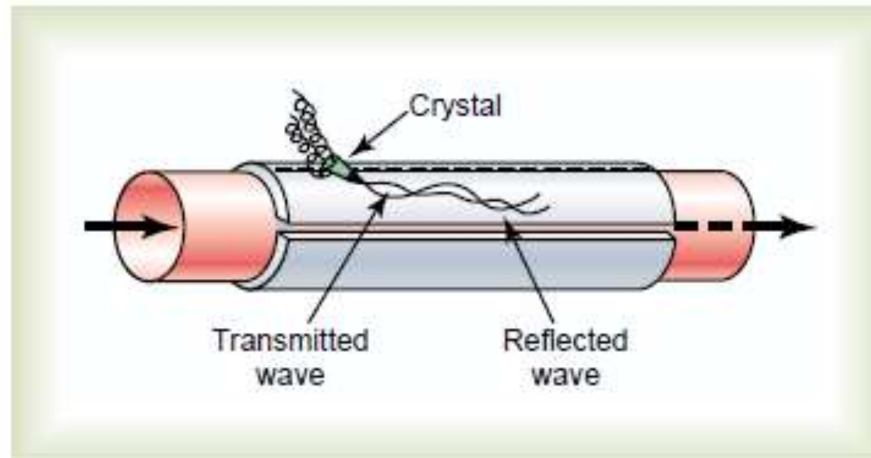
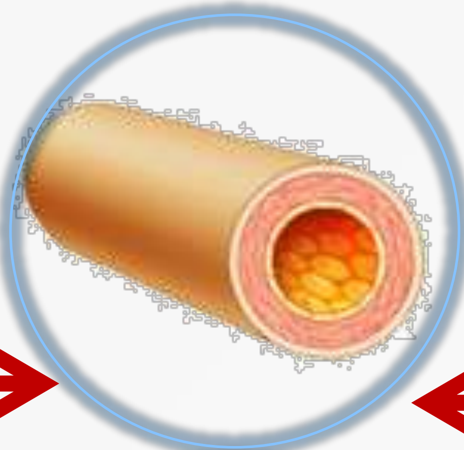


Figure 14–5

Ultrasonic Doppler flowmeter.

Control of blood flow

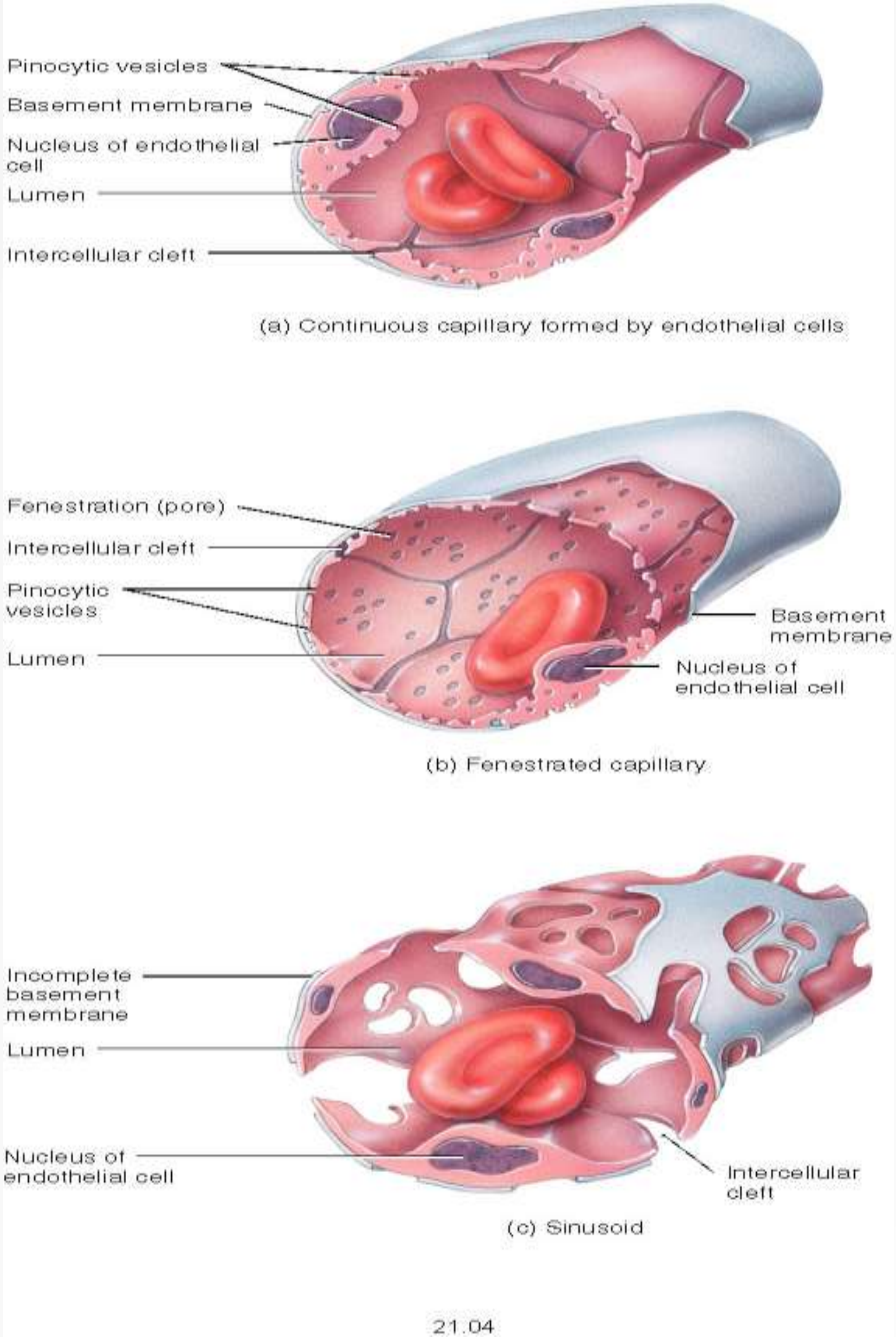


Local (intrinsic) control
- Myogenic response.
- Metabolic response.
- Endothelial response.
- Humoral mechanisms.

Extrinsic control
- Neural mechanisms.
- Humoral mechanisms

Blood flow to capillaries is controlled by caliber of arterioles.

In kidney



Pinocytic vesicles
Basement membrane
Nucleus of endothelial cell
Lumen
Intercellular cleft
(a) Continuous capillary formed by endothelial cells
Fenestration (pore)
Intercellular cleft
Pinocytic vesicles
Lumen
Basement membrane
Nucleus of endothelial cell
(b) Fenestrated capillary
Incomplete basement membrane
Lumen
Nucleus of endothelial cell
Intercellular cleft
(c) Sinusoid
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