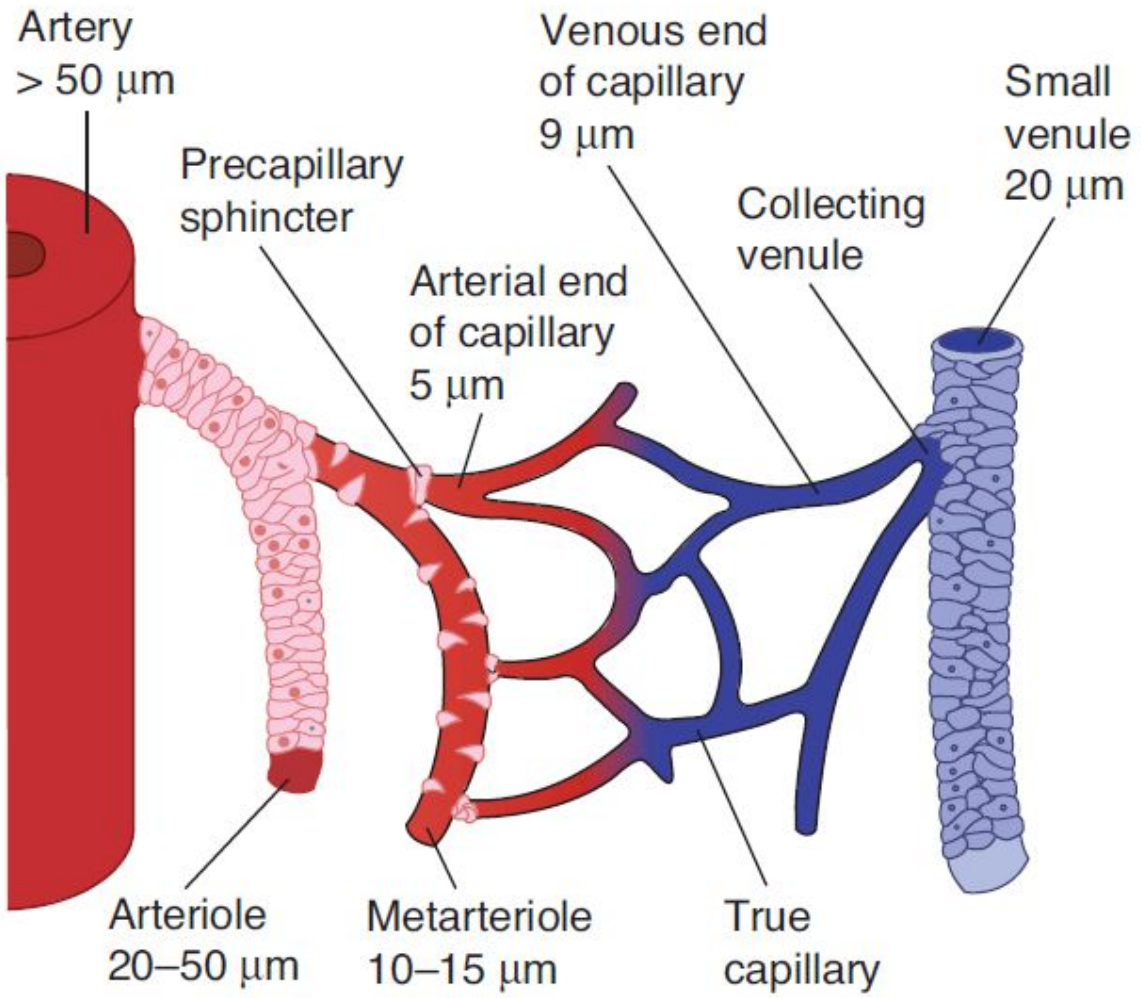
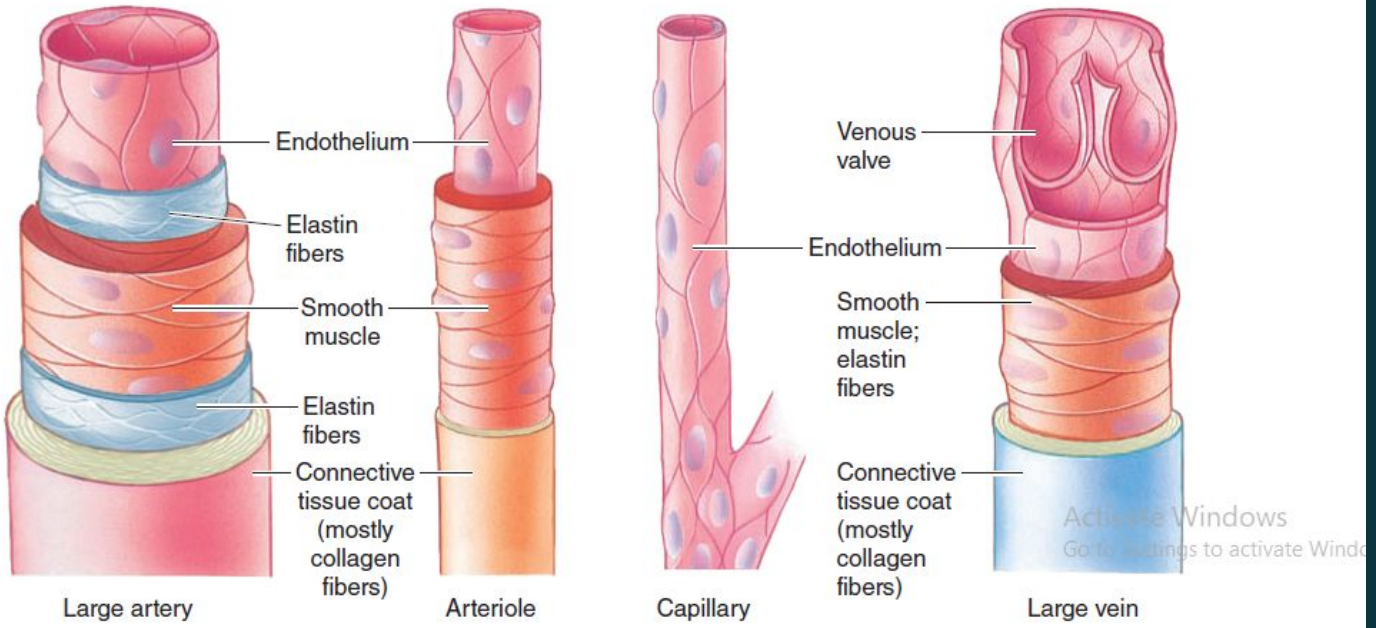
Microcirculation
L9

- Artery
- Arteriole
- Metarteriole
- Precapillary sphincter
- Capillary
- Venule
- Vein



Feature	Arteries	Arterioles	Capillaries	Veins
Number	Several hundred*	Half a million	10 billion	Several hundred*
Special features	Thick, highly elastic, walls; large radii*	Highly muscular, well-innervated walls; small radii	Very thin walled; large total cross-sectional area	Thin walled compared to arteries; highly distensible; large radii*
Functions	Passageway from the heart to organs; pressure reservoir	Primary resistance vessels; determine distribution of cardiac output	Site of exchange; determine distribution of extracellular fluid between plasma and interstitial fluid	Passageway to the heart from organs; blood reservoir
Structure				



Capillaries

- Capillaries, the sites for exchange of materials between blood and tissue cells.
- Branch extensively to bring blood within the reach of essentially every cell

TABLE 32–9 Characteristics of various types of blood vessels in humans.

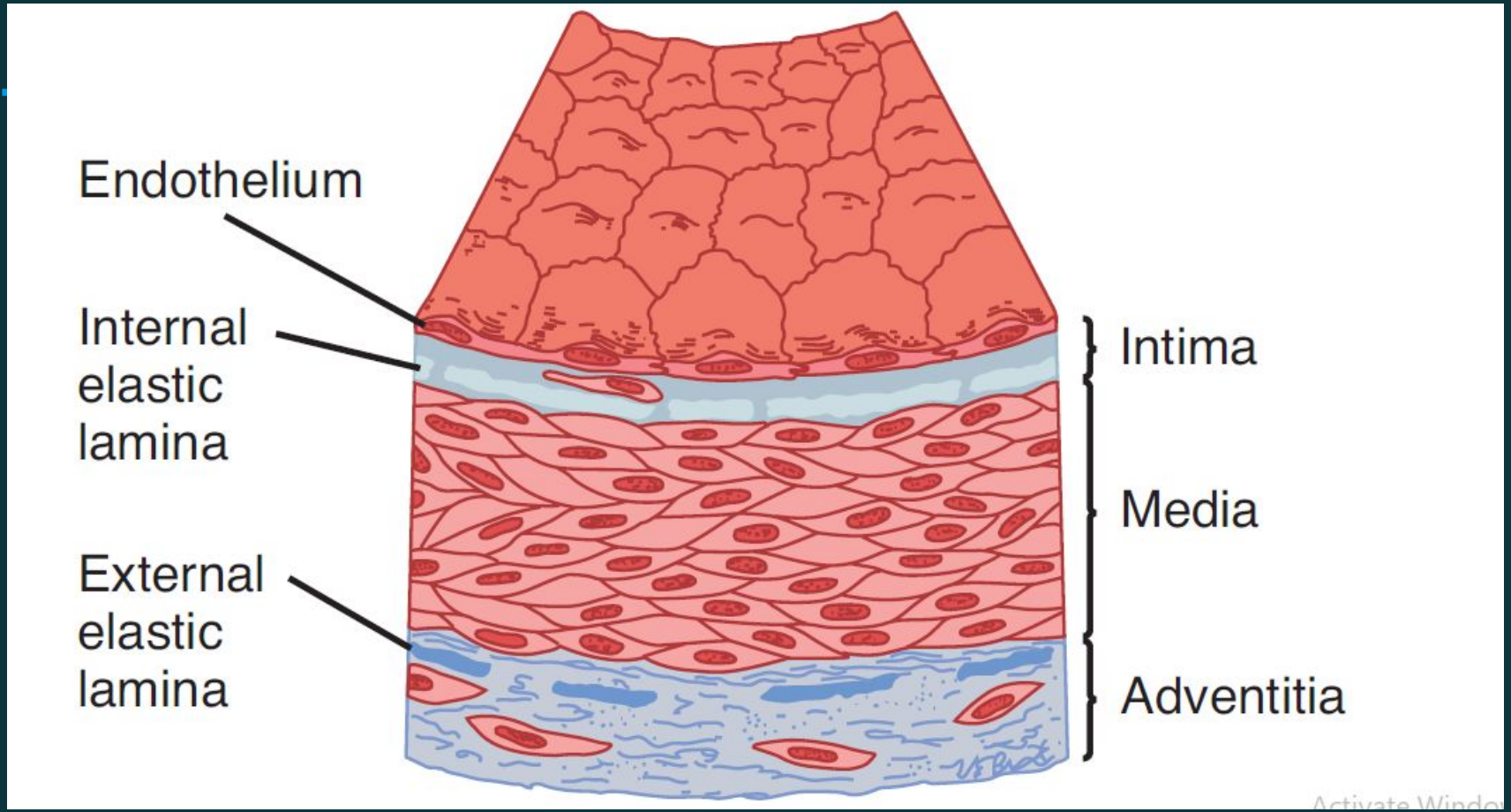
Vessel	Lumen Diameter	Wall Thickness	All Vessels of Each Type: Approximate Total Cross-Sectional Area (cm^2)	All Vessels of Each Type: Percentage of Blood Volume Contained[a]
Aorta	2.5 cm	2 mm	4.5	2
Artery	0.4 cm	1 mm	20	8
Arteriole	30 µm	20 µm	400	1
Capillary	5 µm	1 µm	4500	5
Venule	20 µm	2 µm	4000	
Vein	0.5 cm	0.5 mm	40	54
Vena cava	3 cm	1.5 mm	18	

[a]In systemic vessels; there is an additional 12% in the heart and 18% in the pulmonary circulation.

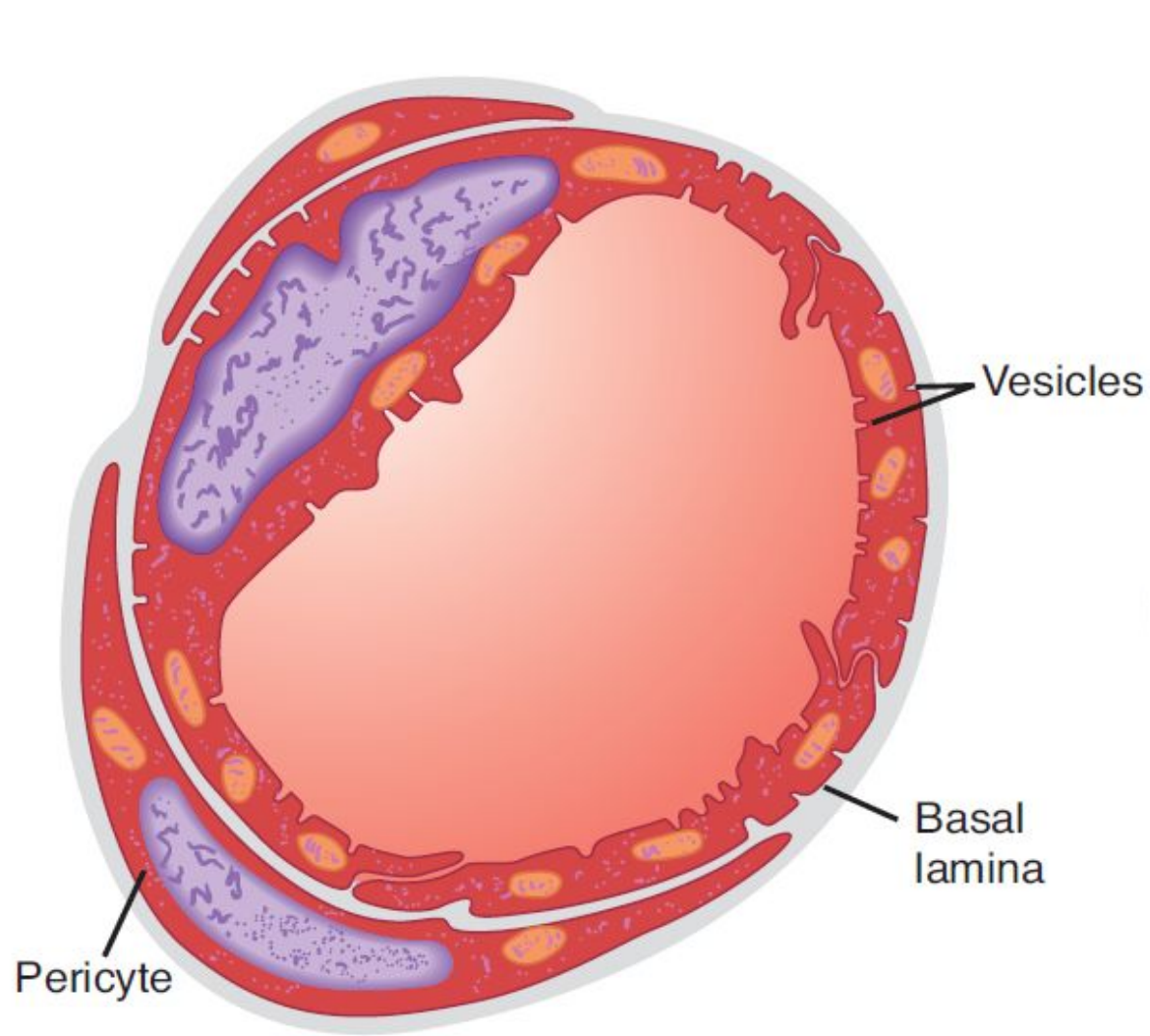
Structure of the Capillary Wall

- The wall is composed of a unicellular layer of endothelial cells and is surrounded by a thin basement membrane on the outside of the capillary.
- The total thickness of the capillary wall is only about 0.5 micrometer.
- The internal diameter of the capillary is 4 to 9 micrometers, barely large enough for red blood cells and other blood cells to squeeze through.

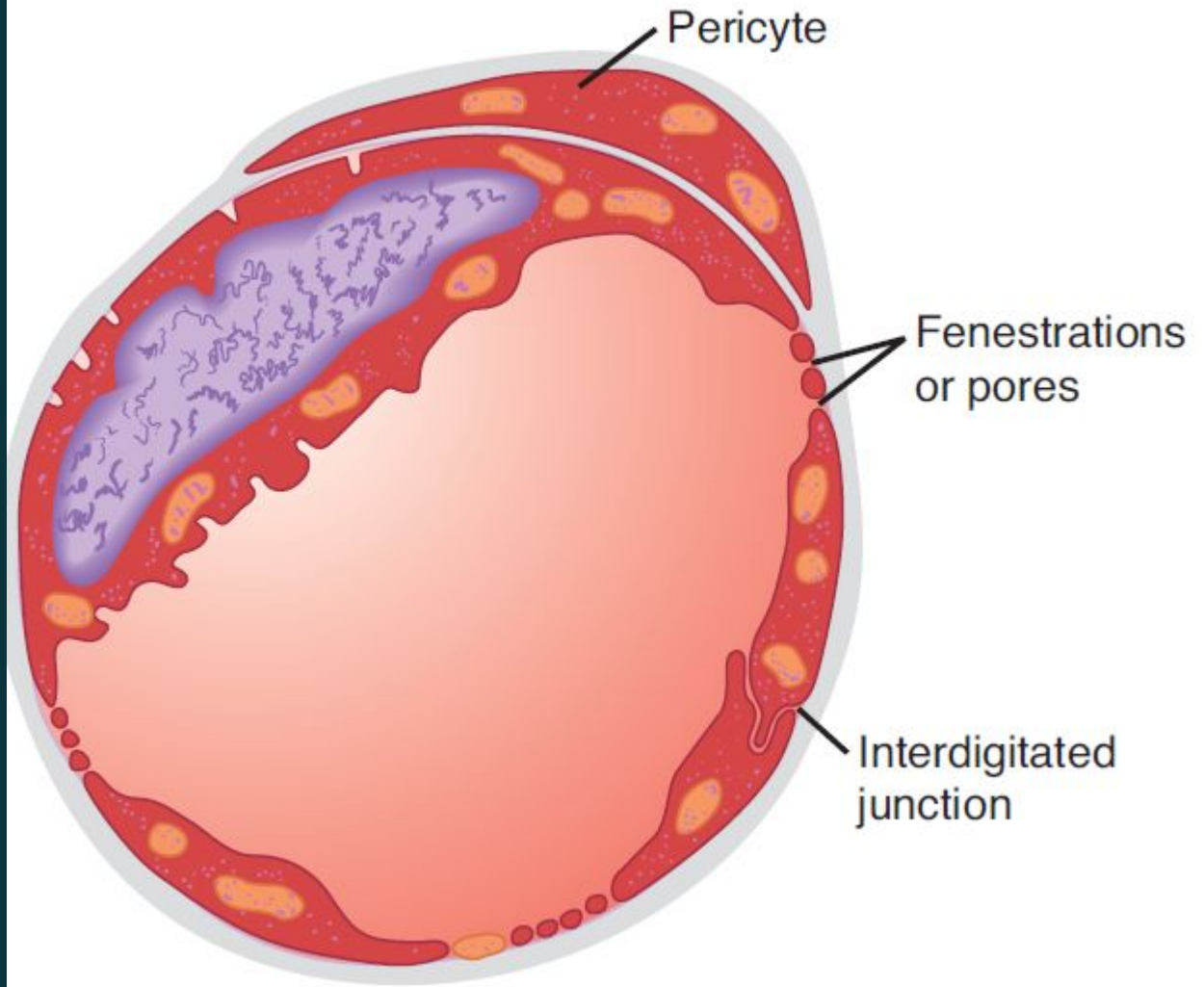
Structure of normal muscle artery



Cross-section of capillary



Cross-section of capillary



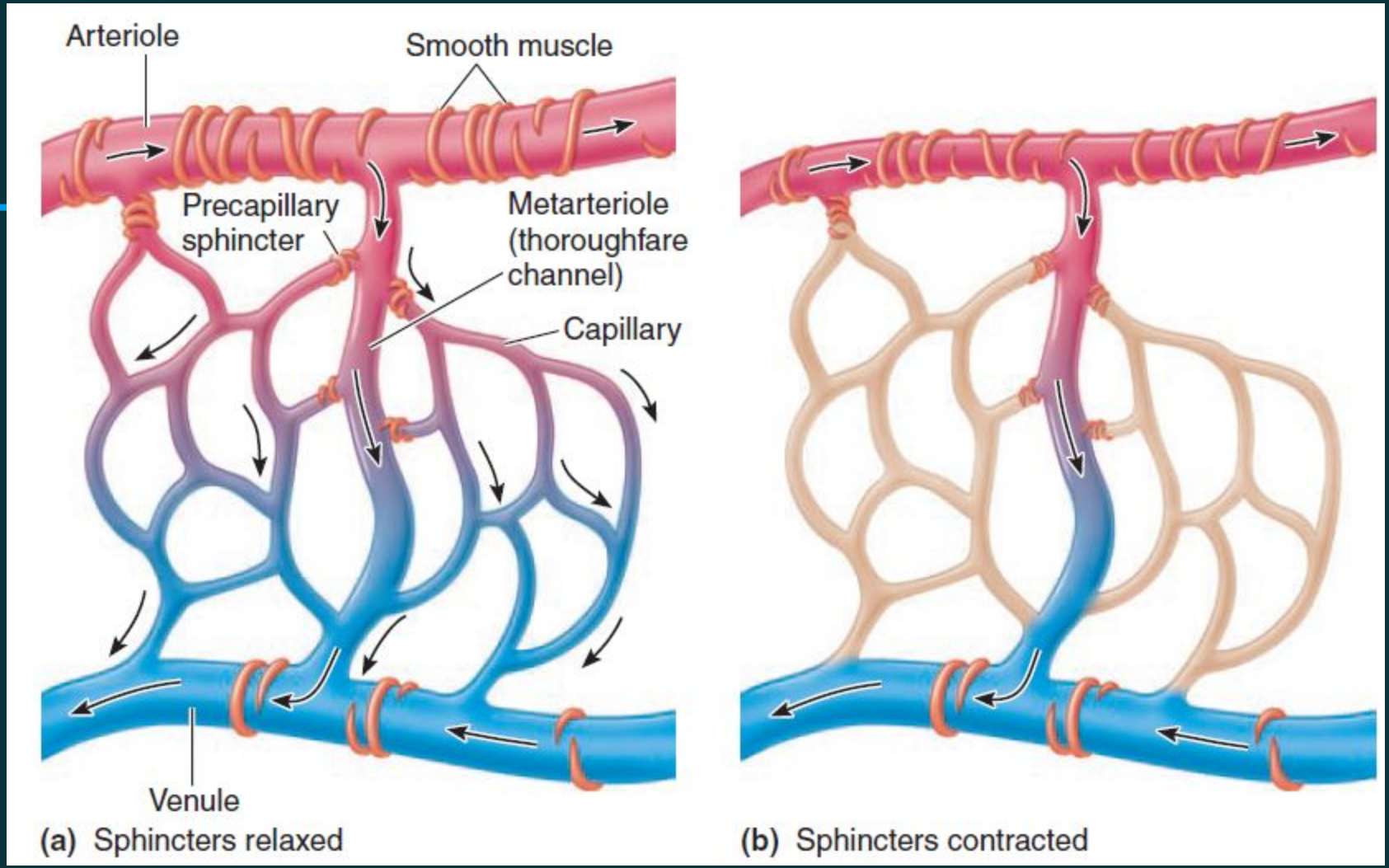
Vasomotion

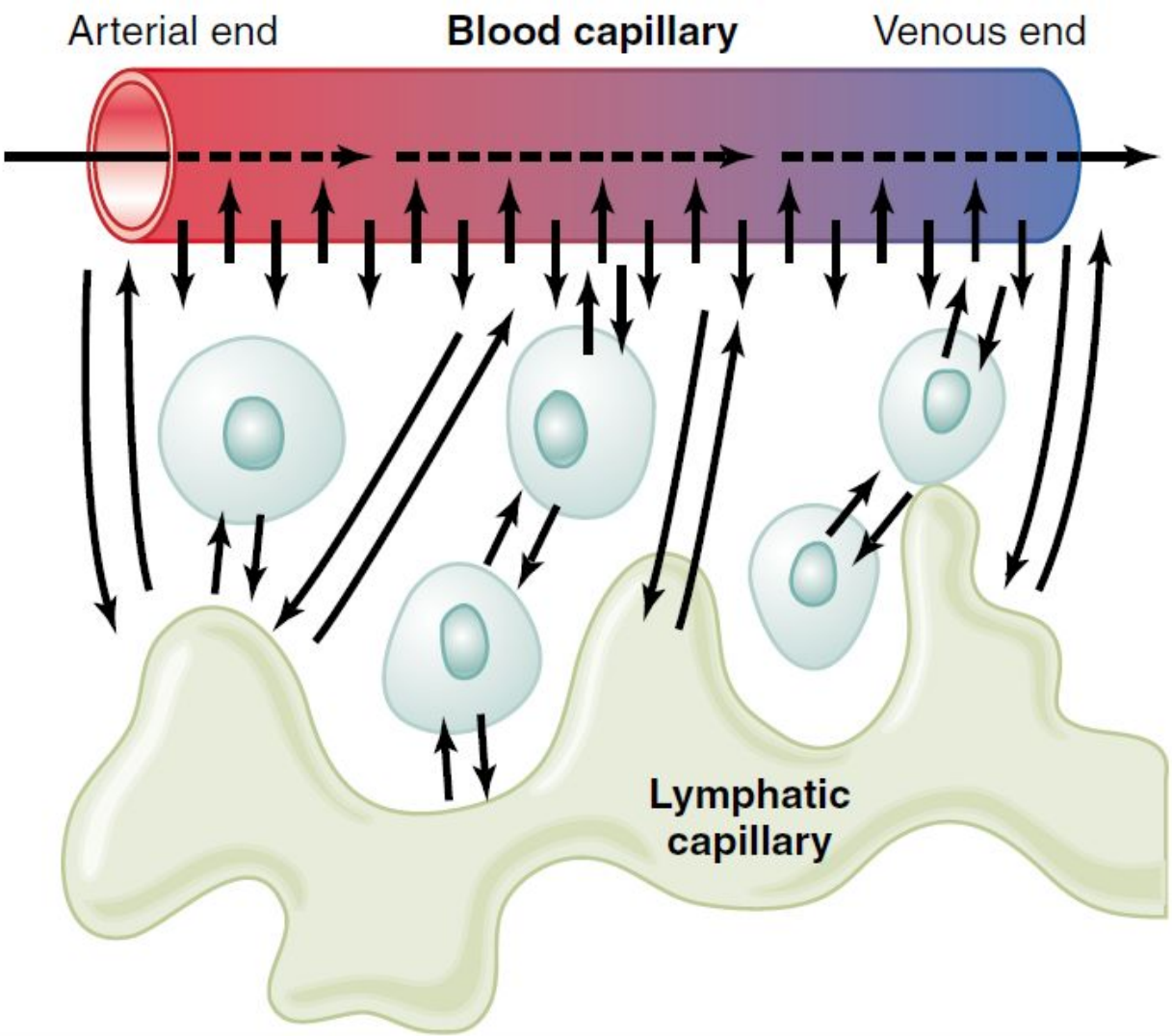
- Blood usually does not flow continuously through the capillaries.
- Instead, it flows intermittently, turning on and off every few seconds or minutes.
- The cause of this intermittency is the phenomenon called vasomotion, which means intermittent contraction of the metarterioles and precapillary sphincters (and sometimes even the very small arterioles as well).

Vasomotion

- Precapillary sphincters are not innervated, but they have a high degree of myogenic tone and are sensitive to local metabolic changes.

- The most important factor regulates the vasomotion is: the concentration of oxygen in the tissues.

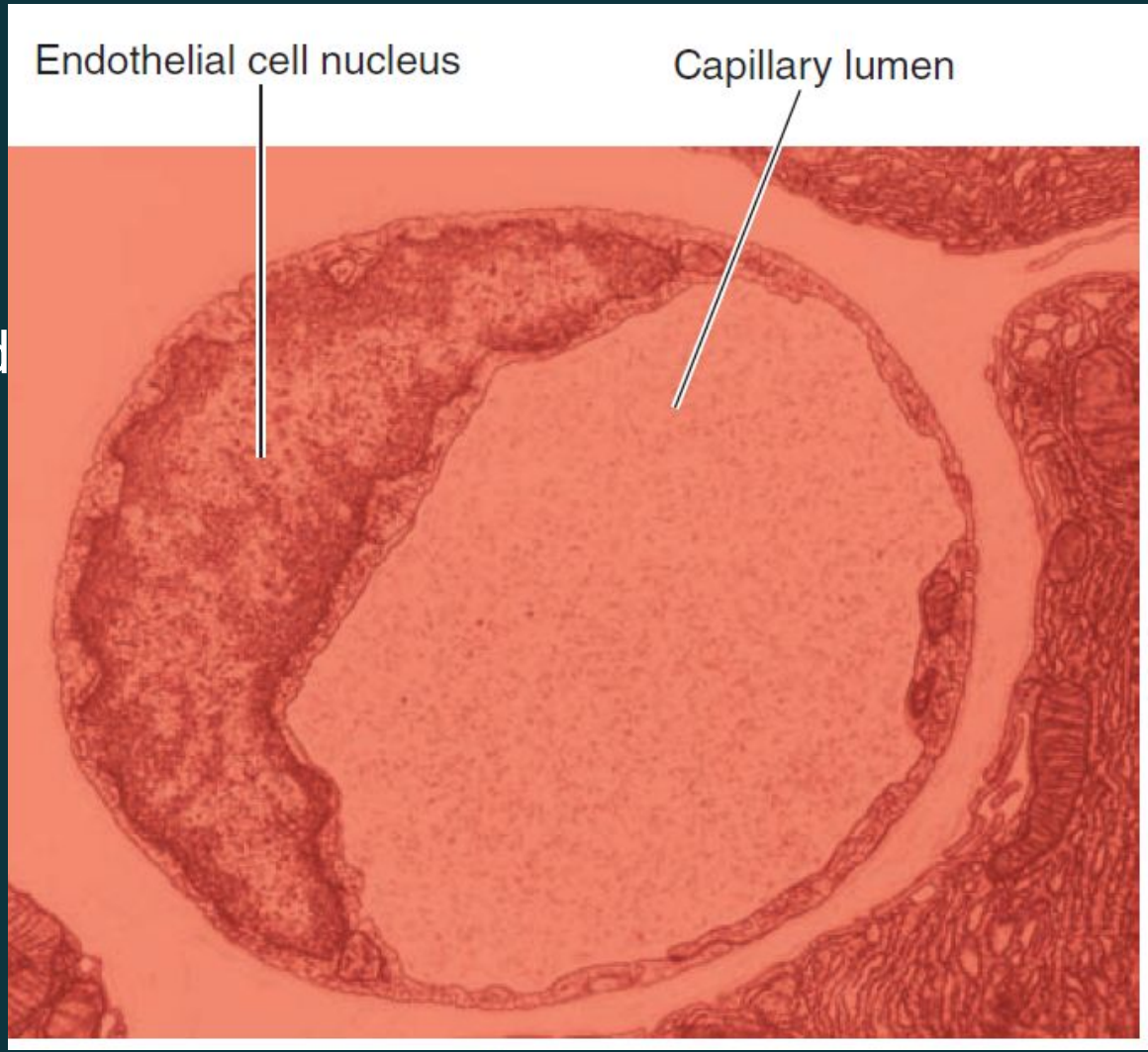

Arteriole
Smooth muscle
Precapillary sphincter
Metarteriole (thoroughfare channel)
Capillary
Venule
(a) Sphincters relaxed
(b) Sphincters contracted


Arterial end
Blood capillary
Venous end
Lymphatic capillary

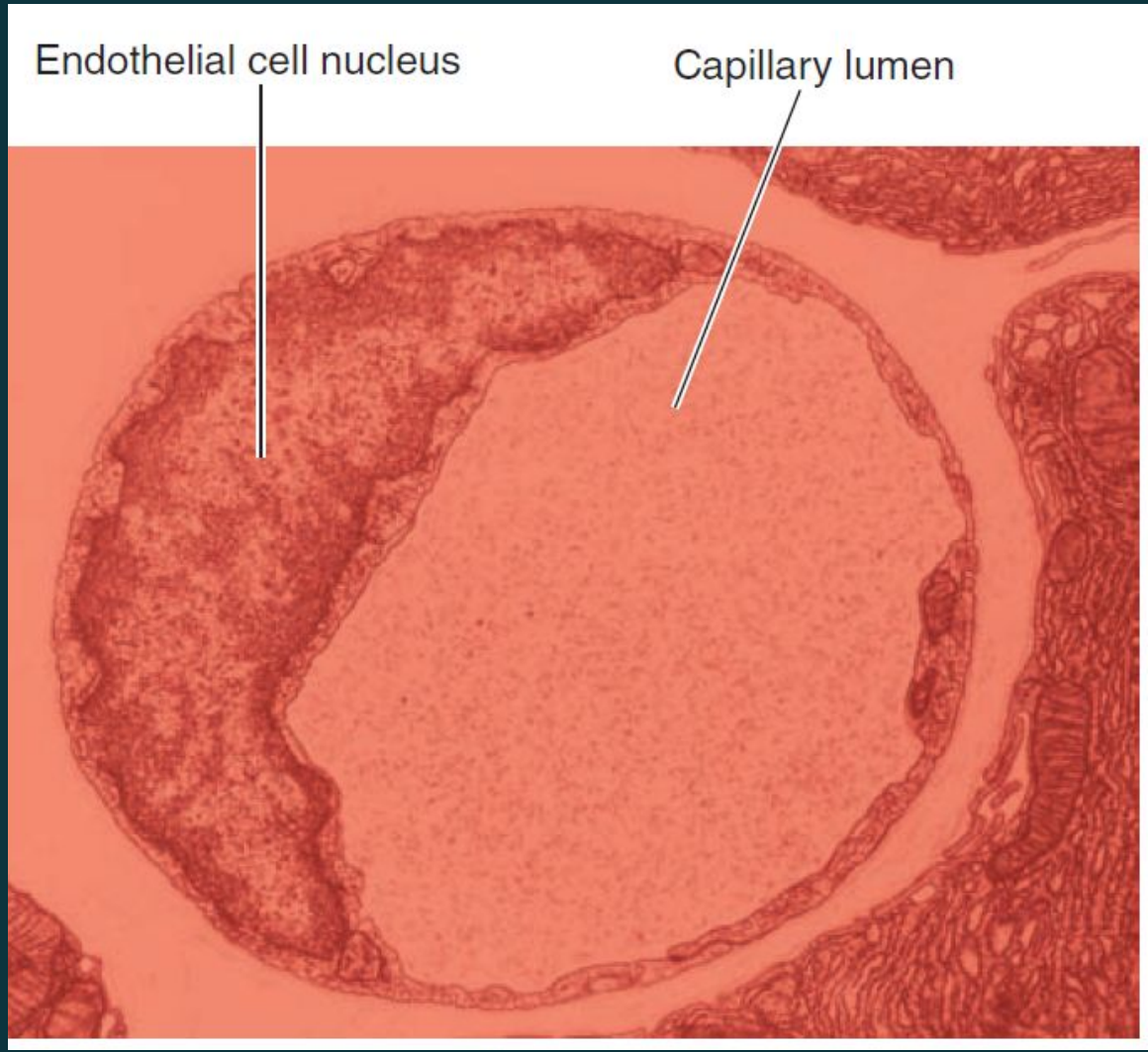
- Capillaries are ideally suited to serve as sites of exchange.
- There are no carrier-mediated transport systems across capillaries, with the exception of those in the brain that play a role in the blood–brain barrier.
- Materials are exchanged across capillary walls mainly by diffusion.

Capillaries are ideally suited to enhance diffusion by:

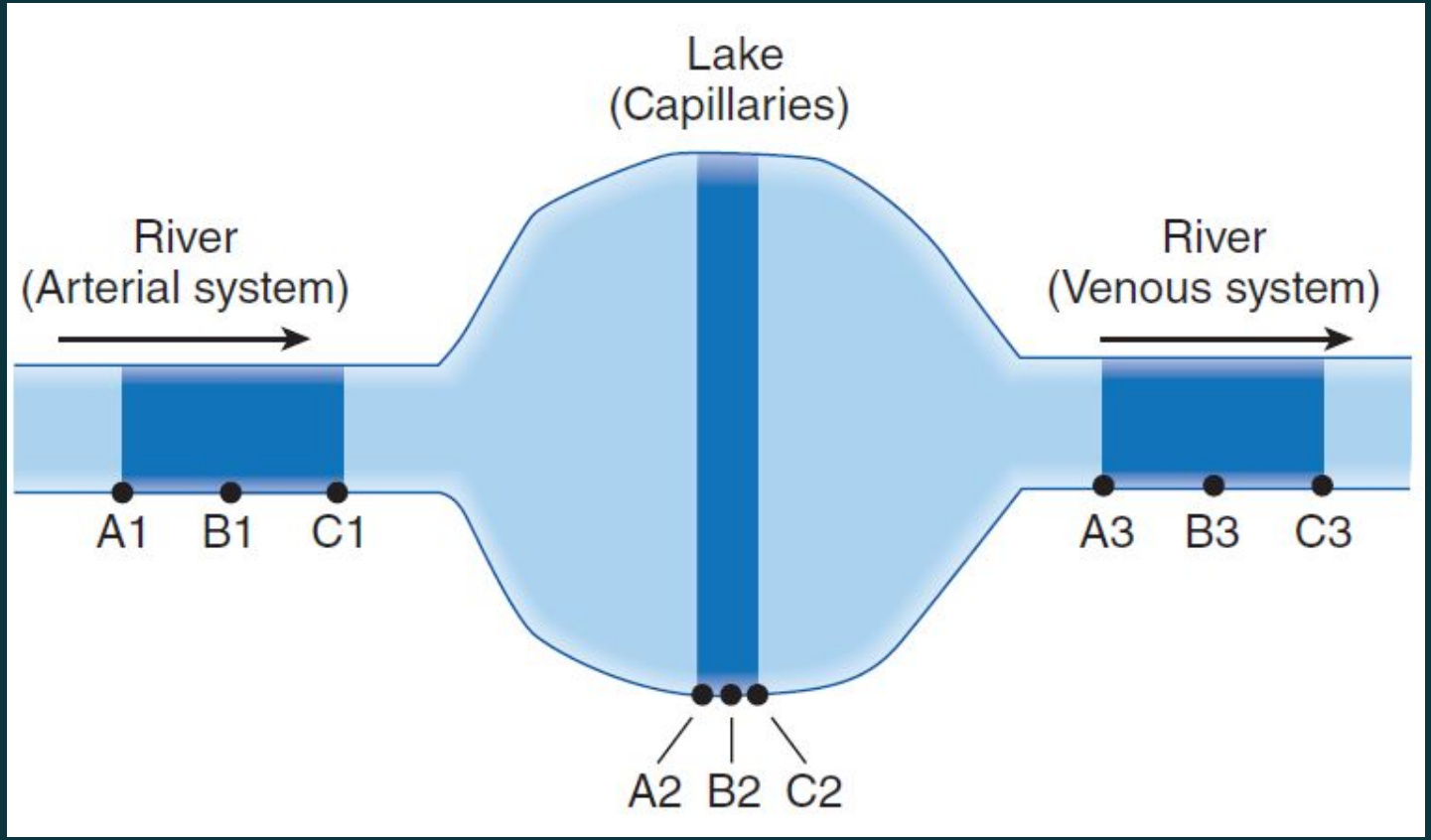
- minimizing diffusion distances while maximizing surface area and time available for exchange.

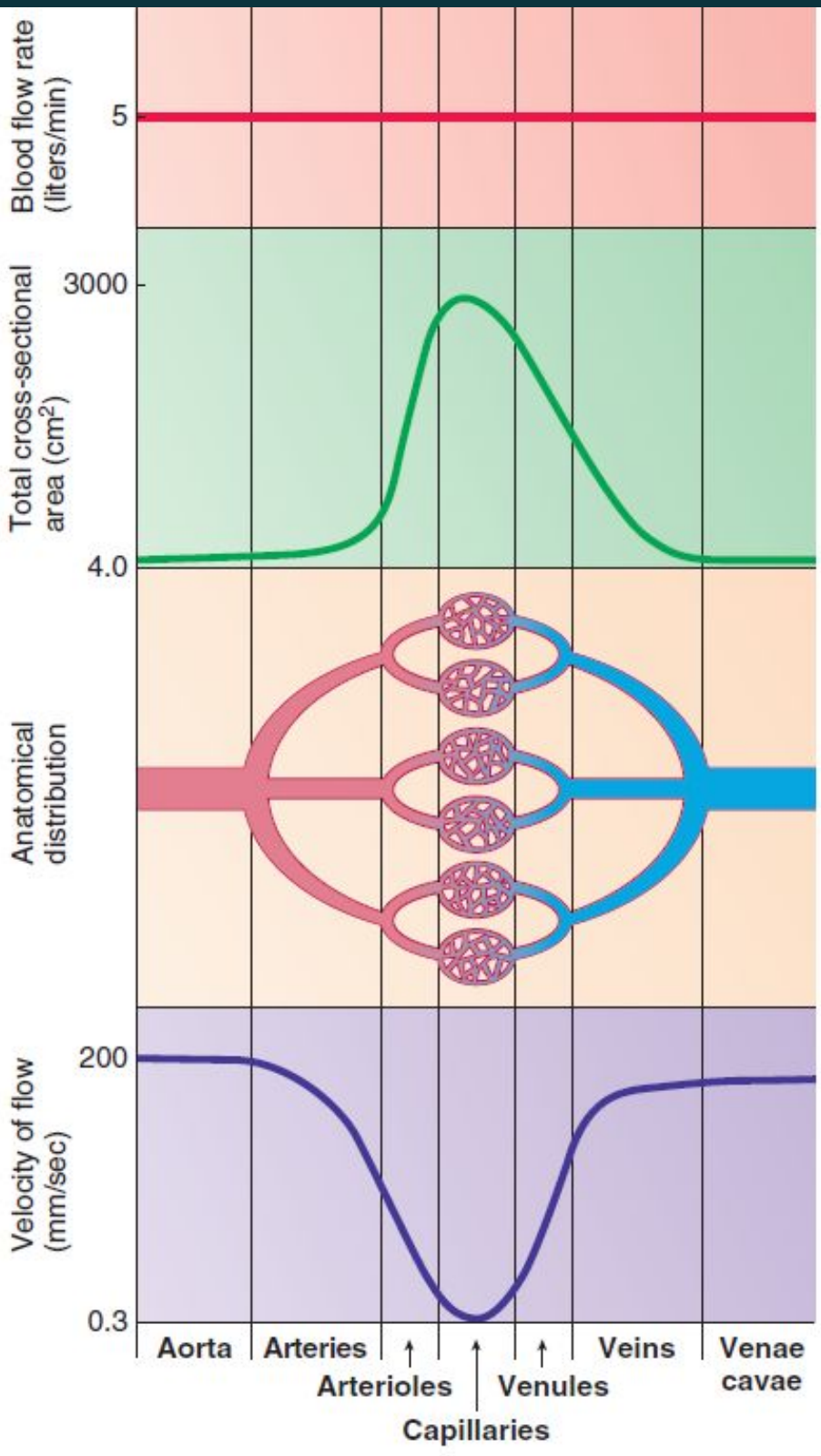


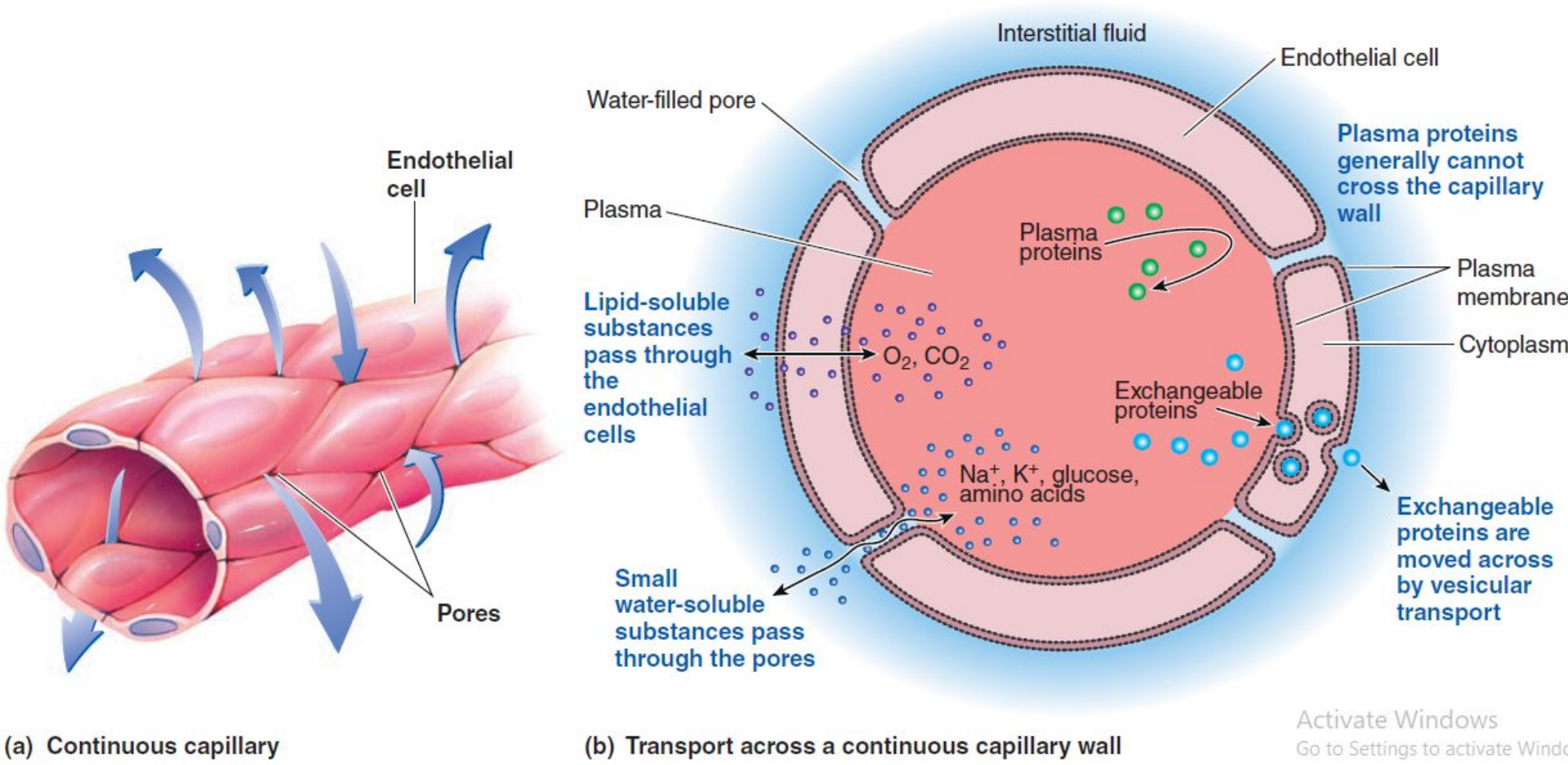
- Slow velocity of capillary blood flow allows adequate time for exchange of nutrients and metabolic end products between blood and tissue cells—the sole purpose of the circulatory.system.



Relationship between total cross-sectional area and velocity of flow.




Blood flow rate (liters/min)
5
Total cross-sectional area (cm²)
3000
4.0
Anatomical distribution
Velocity of flow (mm/sec)
200
0.3
Aorta
Arteries
Arterioles
Capillaries
Venules
Veins
Venae cavae



(a) Continuous capillary

(b) Transport across a continuous capillary wall

- In most capillaries (for example, in skeletal muscle and in lung tissue), small, water-soluble substances such as ions, glucose, and amino acids can readily pass through the water-filled pores, which are about 4 nm wide, but large, water-soluble materials such as plasma proteins are kept from passing through.

- Lipid-soluble substances, such as O_2 and CO_2, can readily pass through the endothelial cells themselves by dissolving in the lipid bilayer barrier of the plasma membrane surrounding the cells.

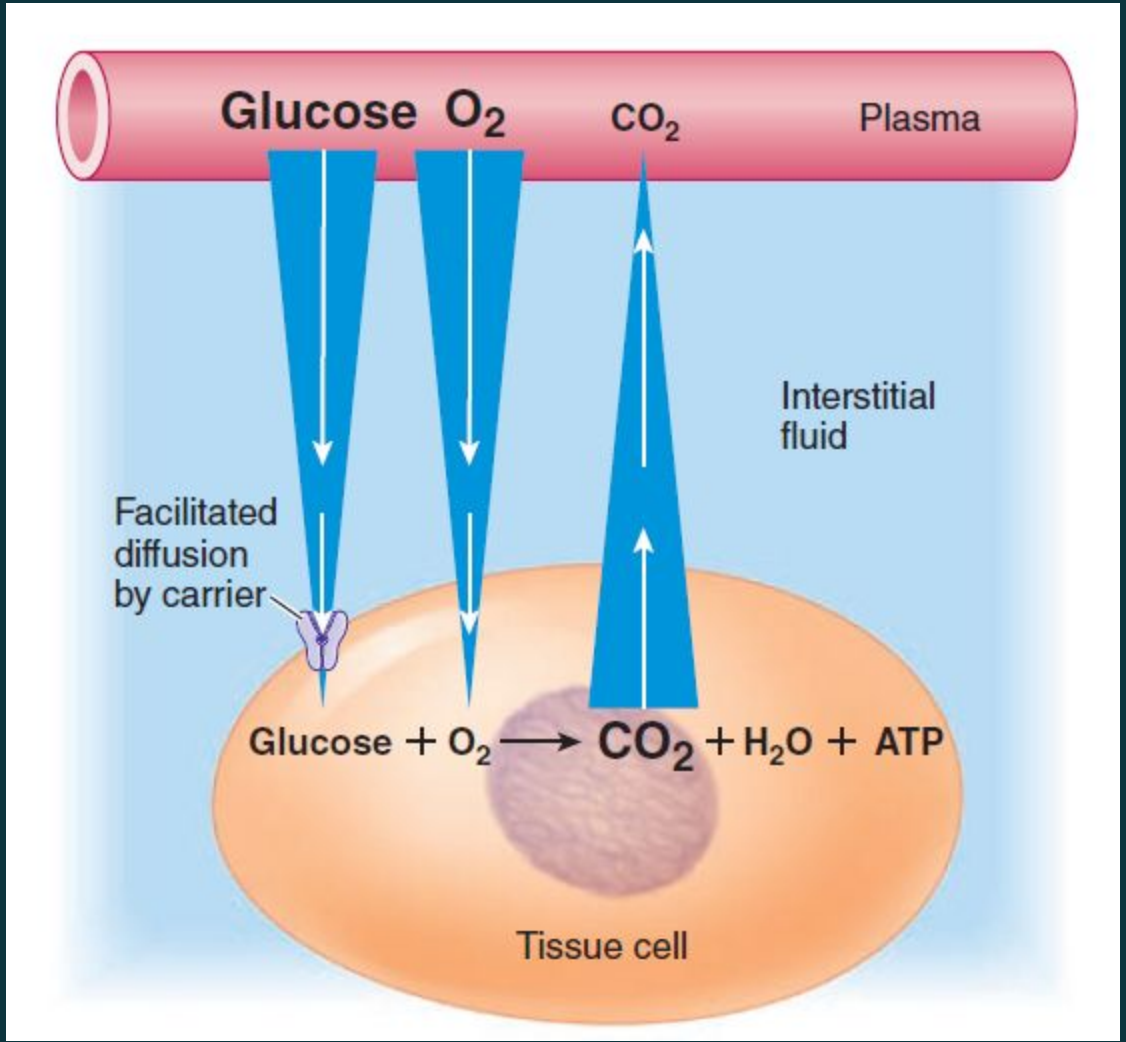
- Vesicular transport also plays a limited role in passage of materials across the capillary wall.

- Large molecules that are not lipid-soluble, such as protein hormones that must be exchanged between blood and surrounding tissues, are transported from one side of the capillary wall to the other in endocytic–exocytic vesicles, a process called transcytosis.

Interstitial fluid

- Exchanges between blood and tissue cells are not made directly.

- Interstitial fluid, the true internal environment in immediate contact with the cells, acts as the go-between.


Glucose
O_2
CO_2
Plasma
Interstitial fluid
Facilitated diffusion by carrier
Glucose + O_2 → CO_2 + H_2O + ATP
Tissue cell

- Because most capillary walls have no carrier-mediated transport systems, solutes cross primarily by diffusion down concentration gradients.

- When pressure inside the capillary exceeds pressure on the outside, fluid is pushed out through the pores in a process known as ultrafiltration.

- Most plasma proteins are retained on the inside during this process because of the pores' filtering effect.

- So, the filtrate is essentially protein-free plasma.

- When inward-driving pressures exceed outward pressures across the capillary wall, net inward movement of fluid from the interstitial fluid into the capillaries takes place through the pores, a process known as reabsorption.

Forces Influencing Bulk Flow

Bulk flow occurs because of differences in hydrostatic and colloid osmotic pressures between plasma and interstitial fluid.

1. Capillary blood pressure (Pc) is the fluid or hydrostatic pressure exerted on the inside of the capillary walls by blood.

On average, the hydrostatic pressure is 37 mm Hg at the arteriolar end of a tissue capillary.

It declines even further, to 17 mm Hg, at the capillary's venular end.

Forces Influencing Bulk Flow

2. Plasma-colloid osmotic pressure (π_p), also known as oncotic pressure, is a force caused by colloidal dispersion of plasma proteins.

It encourages fluid movement into the capillaries. π_p averages 25 mm Hg.

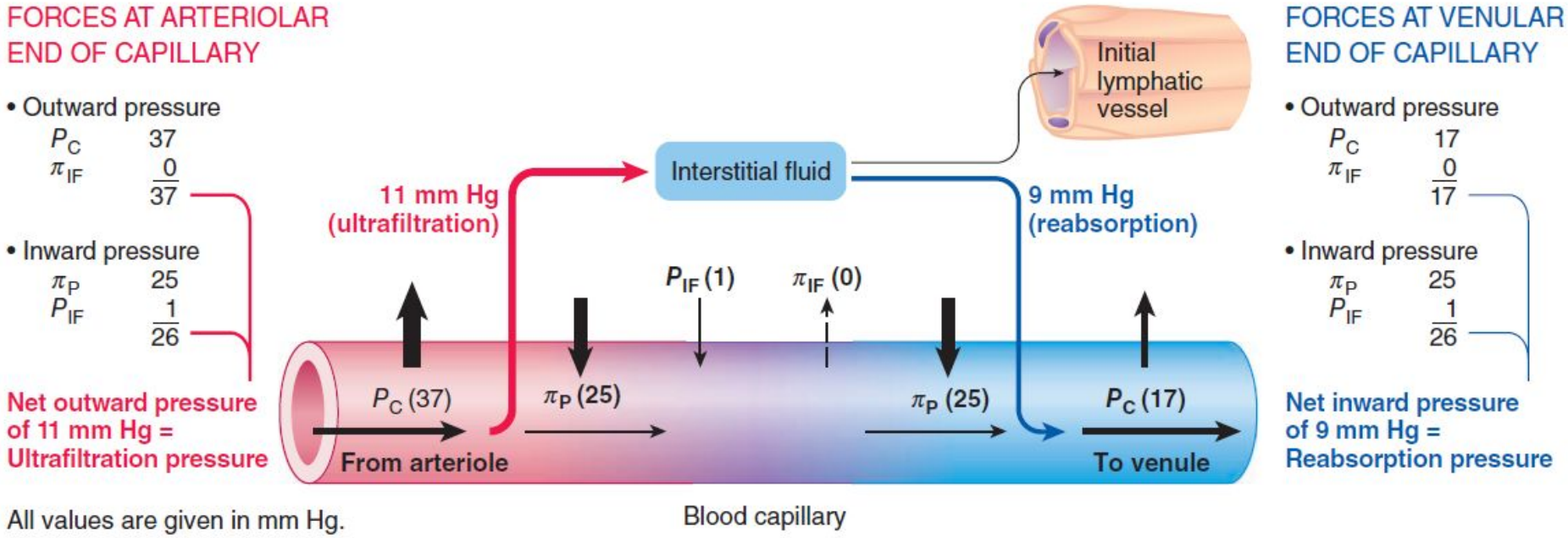
3. Interstitial fluid hydrostatic pressure (P_{IF}) is the fluid pressure exerted on the outside of the capillary wall by interstitial fluid.

4. Interstitial fluid–colloid osmotic pressure (π_{IF}).

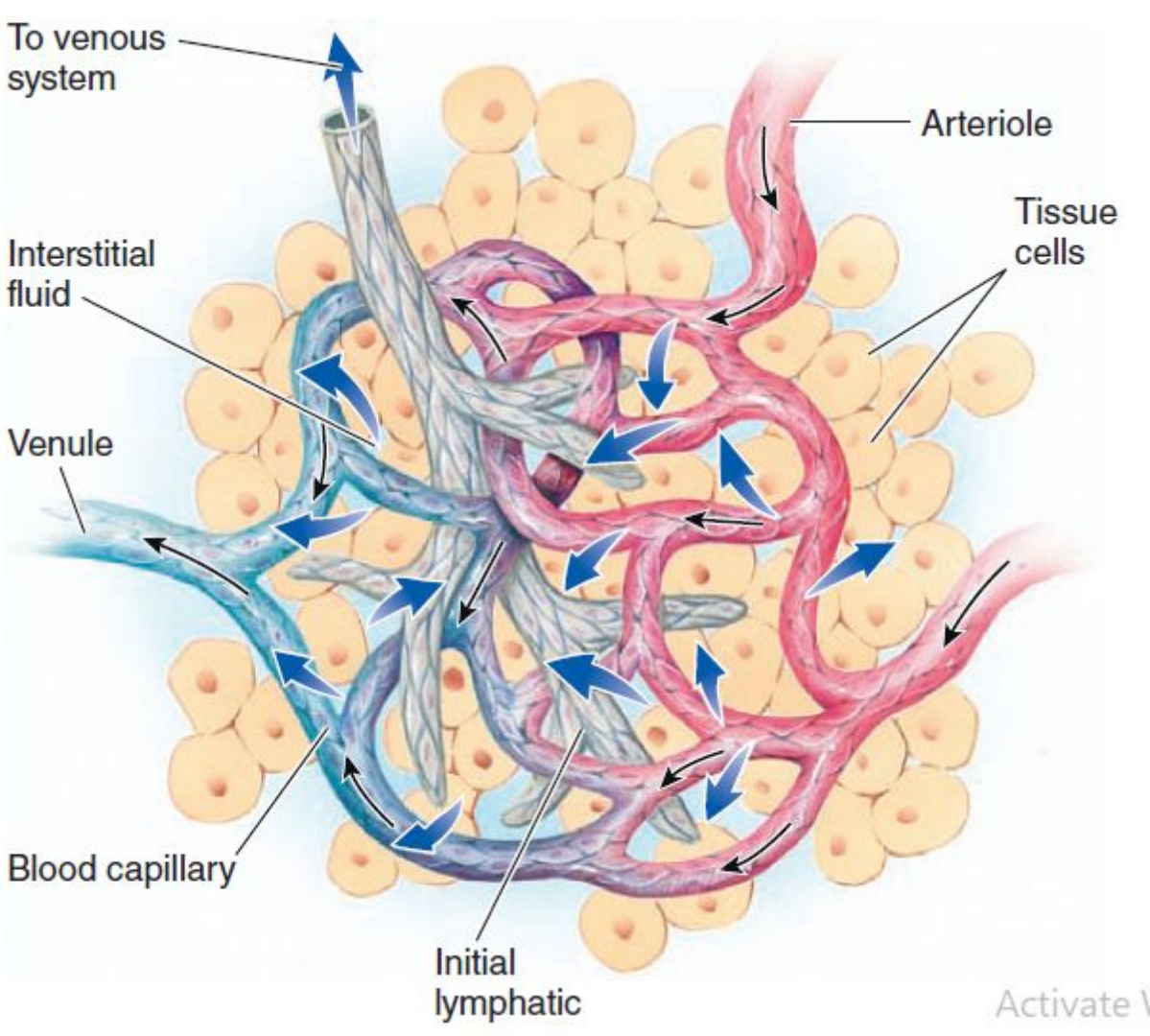
Net Exchange of Fluid Across the Capillary Wall

Net exchange pressure = $(P_c + \pi_{IF})$ - $(\pi_p + P_{IF})$

(outward pressure) (inward pressure)

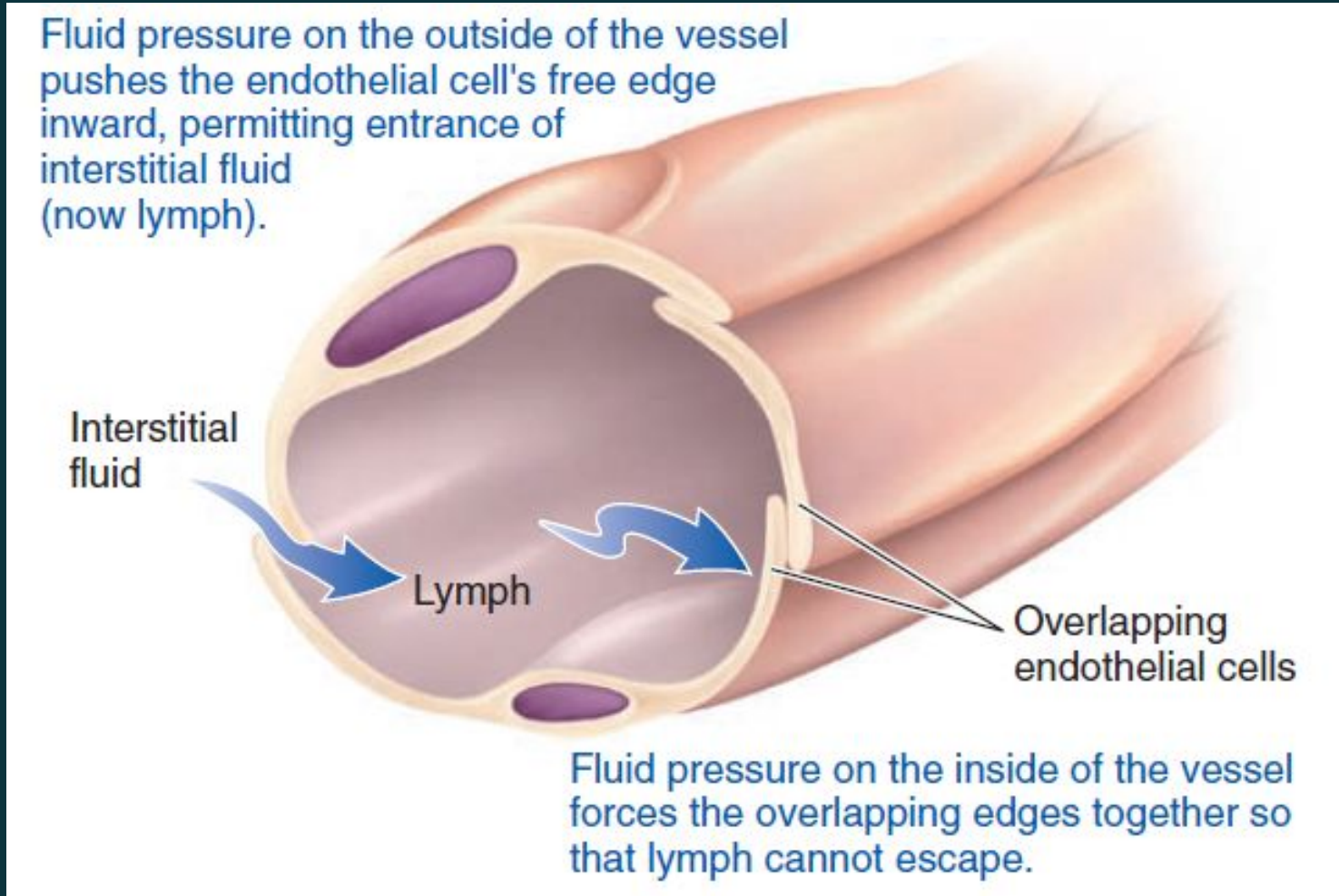

FORCES AT ARTERIOLAR END OF CAPILLARY
• Outward pressure
P_C 37
π_{IF} 0
37
• Inward pressure
π_P 25
P_{IF} 1
26
Net outward pressure of 11 mm Hg = Ultrafiltration pressure
11 mm Hg (ultrafiltration)
Interstitial fluid
Initial lymphatic vessel
9 mm Hg (reabsorption)
P_{IF} (1)
π_{IF} (0)
P_C (37)
π_P (25)
π_P (25)
P_C (17)
From arteriole
To venule
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
All values are given in mm Hg.
Blood capillary

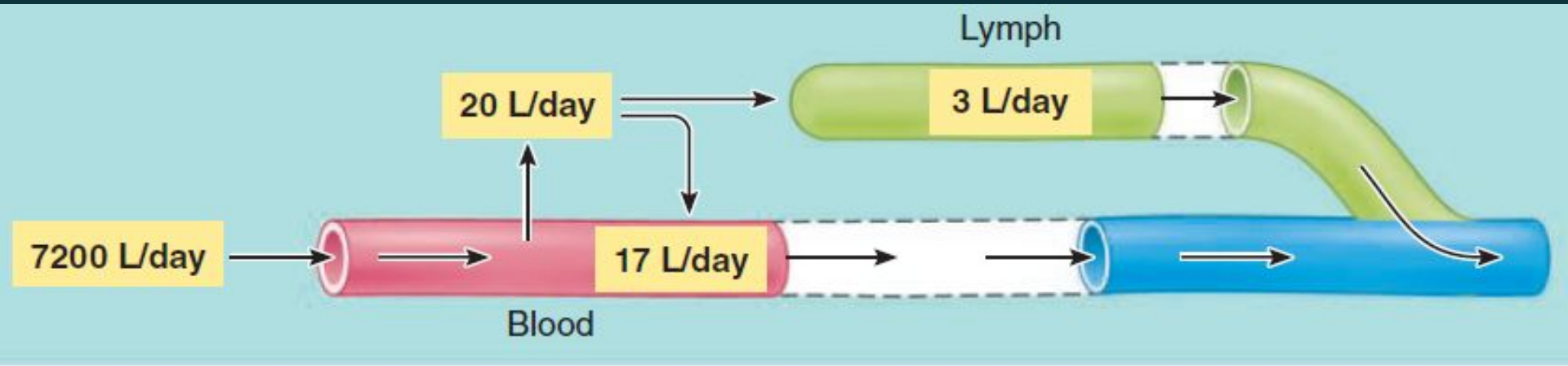
The lymphatic system is an accessory route for return of interstitial fluid to the blood.



- Even under normal circumstances, slightly more fluid is filtered out of the capillaries into the interstitial fluid than is reabsorbed from the interstitial fluid back into the plasma.

- The extra fluid filtered out as a result of net filtration-reabsorption imbalance is picked up by the lymphatic system.


Fluid pressure on the outside of the vessel pushes the endothelial cell's free edge inward, permitting entrance of interstitial fluid (now lymph).
Interstitial fluid
Lymph
Overlapping endothelial cells
Fluid pressure on the inside of the vessel forces the overlapping edges together so that lymph cannot escape.


Lymph
20 L/day
3 L/day
7200 L/day
17 L/day
Blood

Edema

Definition:

Accumulation of excessive amounts of interstitial fluid.

Causes:

An increase of capillary hydrostatic pressure: due to elevation of venous pressure (e.g. venous obstruction and right sided heart failure) or arteriolar V.D.

- Decreased plasma colloid osmotic pressure: due to hypoproteinemia.
- Increased capillary permeability: as in allergic reactions (histamine),

Edema

Causes:

- An increase of capillary hydrostatic pressure: due to elevation of venous pressure (e.g. venous obstruction and right sided heart failure) or arteriolar V.D.
- Decreased plasma colloid osmotic pressure: due to hypoproteinemia.
- Increased capillary permeability: as in allergic reactions (histamine).
- Inadequate lymph drainage (lymphedema) : blockage of lymph vessels that often occurs in cancer.
- Salt and water retention in body.

THANK YOU