

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ
(وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيمٌ)



HLS Physiology | MID 10

Lymphatic System



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بسم الله الرحمن الرحيم،

نرجو منكم الدعاء لزميلنا في الدفعة
عون العدوان، الذي وافته المنية.

اللهم ارحمه واغفر له، وأسكنه فسيح جناتك، وأنر قبره وأنس وحشته، واجعل قبره روضةً من رياض الجنة.

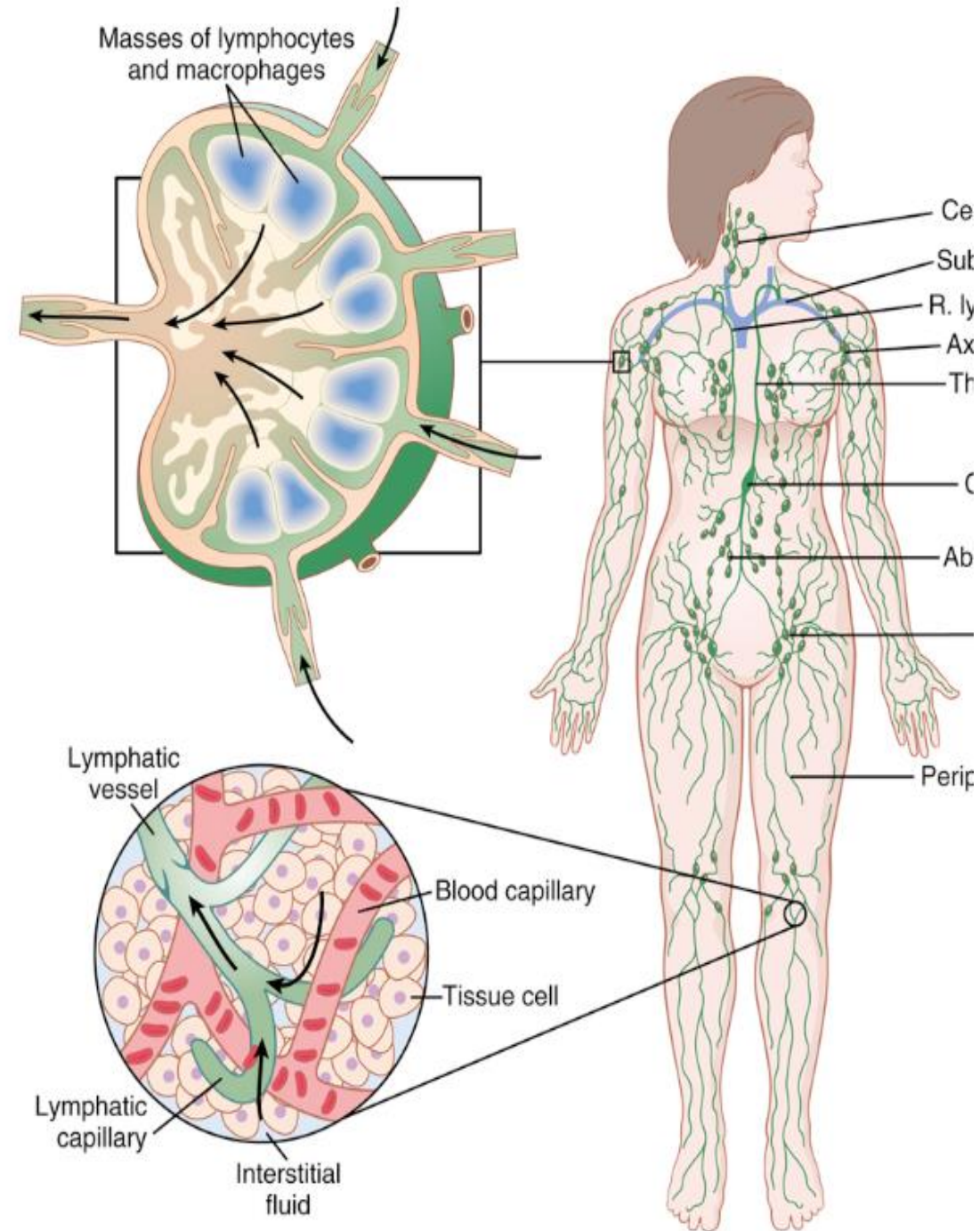
اللهم اجبر قلوب أهله وذويه، وارزقهم الصبر والسلوان، وألهمهم جميل الصبر وحسن العزاء.

رحمه الله رحمةً واسعةً وأسكنه الفردوس الأعلى من الجنة...

Lymphatic System:

Fatima Daoud, MD, PhD.

PowerPoint Notes are in Red

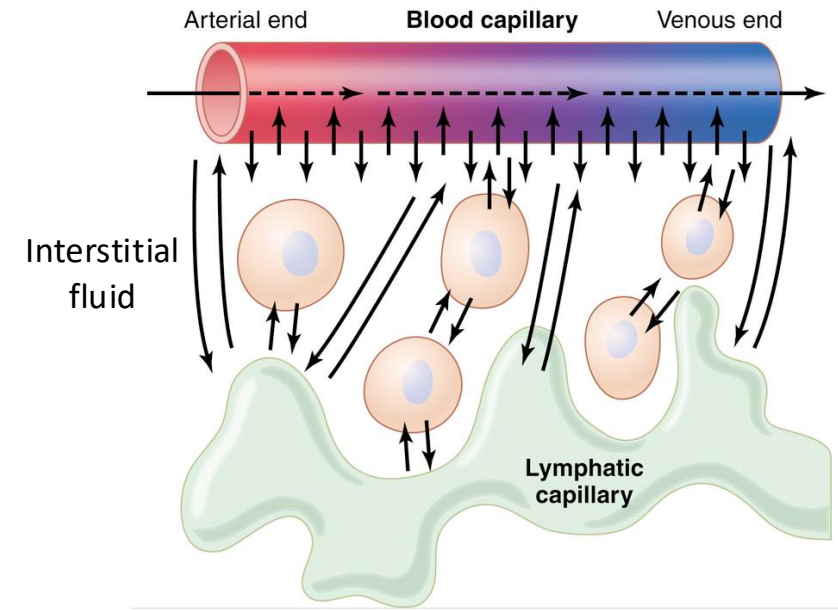


Lymphatic System:

- While we typically think of circulation as a simple loop from arteries to veins, some fluid naturally escapes the blood vessels and enters the spaces between tissue cells. **The lymphatic system** serves as a crucial secondary route that collects this escaped fluid and safely returns it to the circulatory system.
- The name of this fluid changes depending on its exact location. Inside the blood vessels, the liquid component of blood is called **plasma**. Once it moves into the spaces surrounding the tissue cells, it becomes **interstitial fluid**—the immediate environment where substances are exchanged between the blood and cells. When this interstitial fluid is finally absorbed into the lymphatic vessels, it becomes known as **lymph**.
- Because lymph originates directly from the interstitial fluid, its chemical composition closely reflects the **specific tissues** from which it was collected. The lymphatic system then transports this lymph away from the tissues and empties it back into the **venous circulation**.

Lymph

Lymph is derived from interstitial fluid that flows into the lymphatics. Therefore, lymph as it first enters the terminal lymphatics has almost the same composition as the interstitial fluid.



**** Diffusion Through the Capillary Membrane** Is the Most Important Means of Transferring Substances Between Plasma and Interstitial Fluid

As the blood flows along the lumen of the capillary, tremendous numbers of water molecules and dissolved particles diffuse back and forth through the capillary wall, providing continual mixing between the interstitial fluid and plasma. Electrolytes, nutrients, and waste products of metabolism all diffuse easily through the capillary membrane. The **proteins** are the only dissolved constituents in the plasma and interstitial fluids that do not readily pass through the capillary membrane.

Lymphatic System:

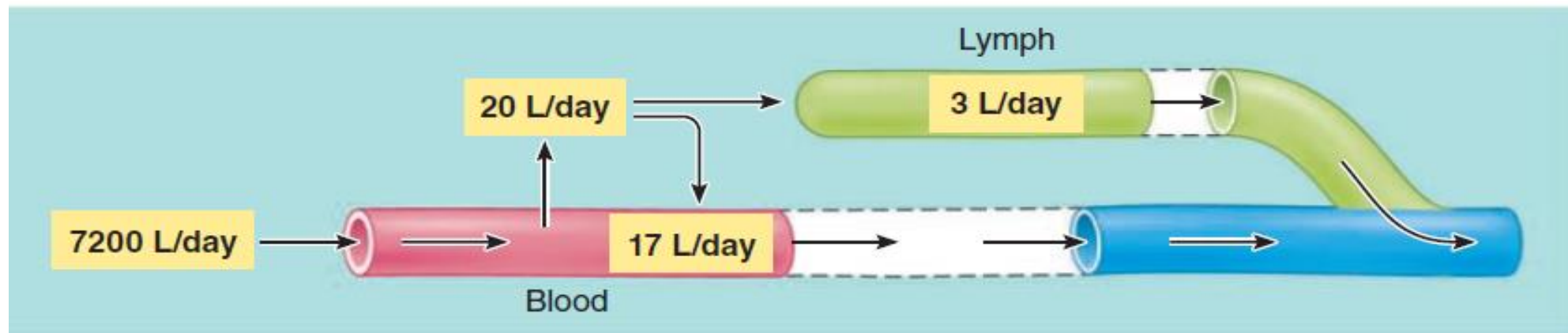
- Every day, approximately **20 liters** of fluid are filtered out of the blood capillaries and into the surrounding tissues. While **17 liters** are directly reabsorbed back into the bloodstream, the remaining **3 liters** are left behind in the tissue spaces. The lymphatic system is responsible for collecting these remaining 3 liters and returning them to the circulation.
- Returning this lymph is absolutely essential for maintaining the **body's fluid balance**. Because this filtration process is continuous, even a tiny disruption in fluid return would become highly significant within just a few hours.
- Without the lymphatic system continuously clearing and returning this fluid, massive amounts of liquid would rapidly accumulate in the tissues, causing **severe swelling (edema)**. At the same time, the circulating blood plasma volume would dangerously decrease, severely compromising the entire cardiovascular system.

Hematology

Lymph

- 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.
- On average, about one tenth of the fluid instead enters the lymphatic capillaries and returns to the blood through the lymphatic system rather than through the venous capillaries. The total quantity of all this lymph is normally only 2 to 3 L/day.

**** 3 liters per day, compared with 7200 liters per day through the circulatory system.**



Lymph

Function

- Return of excess interstitial filtered fluid to blood to maintain tissue fluid balance and plasma volume.
- Return of filtered protein that escaped from blood capillaries (Important to prevent edema).
- Transport of absorbed fat from intestines.
- Defense against disease by carrying material through lymph nodes where immune cells can recognize and respond to foreign material.

****Lymph formed in the **liver** has a protein concentration as high as 6 g/dl, and lymph formed in the **intestines** has a protein concentration as high as 3 to 4 g/dl. Because about two thirds of all lymph normally is derived from the liver and intestines, the thoracic duct lymph, which is a mixture of lymph from all areas of the body, usually has a protein concentration of 3 to 5 g/dl.**

**** The lymphatic system is also one of the major routes for absorption of nutrients from the **gastrointestinal tract**, especially for absorption of virtually all fats in food.**

**** Finally, even large particles, such as **bacteria**, can push their way between the endothelial cells of the lymphatic capillaries and in this way enter the lymph. As the lymph passes through the lymph nodes, these particles are almost entirely removed and destroyed.**

Lymph

Initial Lymphatic Capillaries

These lymphatic valve-like openings are larger than the pores in blood capillaries. Consequently, large particles in the interstitial fluid, such as escaped plasma proteins and bacteria, can gain access to initial lymphatics but are excluded from blood capillaries.

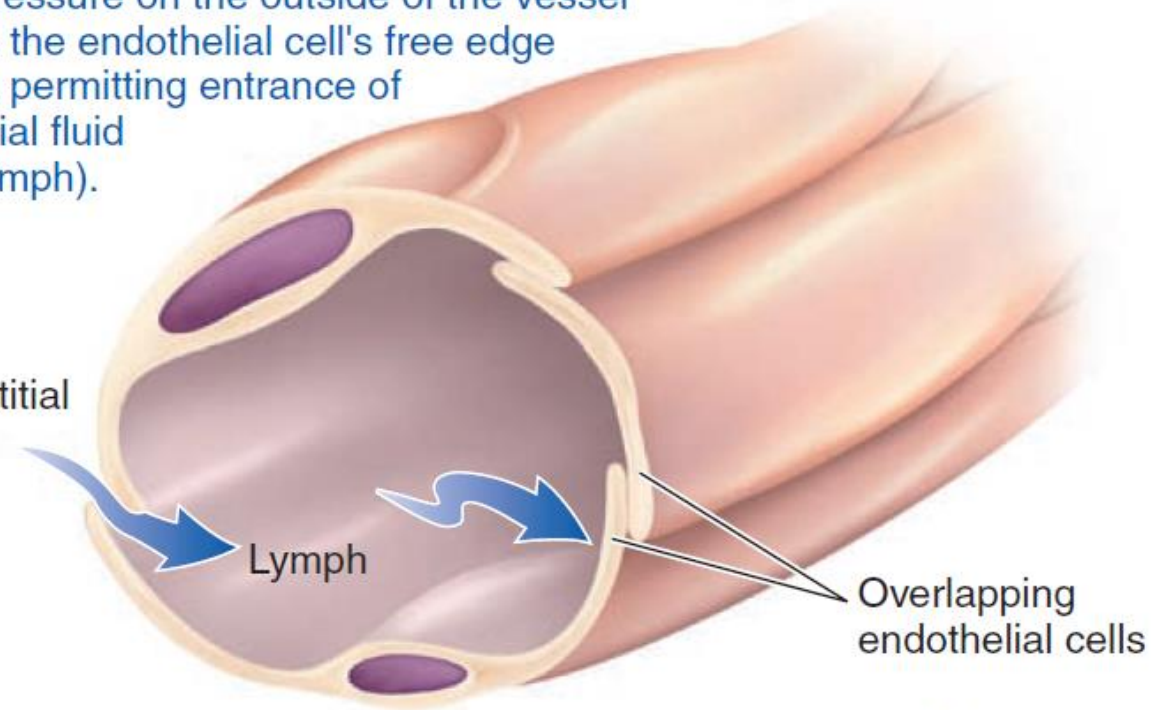
Fluid pressure on the outside of the vessel pushes the endothelial cell's free edge inward, permitting entrance of interstitial fluid (now lymph).

Interstitial fluid

Lymph

Overlapping endothelial cells

Fluid pressure on the inside of the vessel forces the overlapping edges together so that lymph cannot escape.



Initial Lymphatic Capillaries

- **Initial lymphatic capillaries** are the small vessels where fluid drainage begins. Unlike blood capillaries, which form a continuous loop connecting arterioles to venules, lymphatic capillaries are "**blind-ended**." This means they act as one-way collection points that originate directly within the tissue spaces rather than bridging two separate blood vessels. Their primary function is to collect excess fluid from the interstitial space, which officially becomes lymph once it enters the vessel.
- These initial capillaries connect and merge to form **progressively larger collecting vessels** that eventually return the lymph to the venous circulation. Their unique, highly permeable structure is crucial. It allows them to easily absorb not only fluids but also escaped plasma proteins and relatively large particles that are too big to re-enter standard blood capillaries.

Lymph

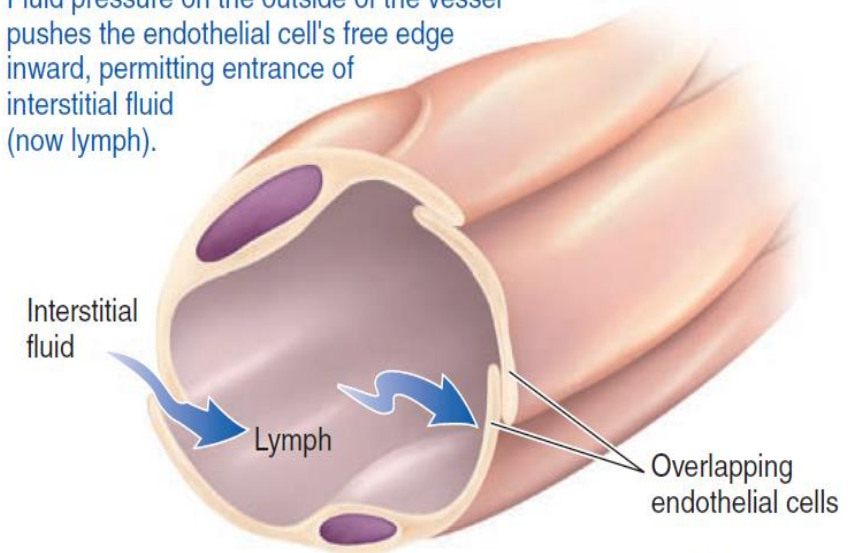
Initial Lymphatic Capillaries

The endothelial cells that make up the walls of lymphatic capillaries have a unique, highly specialized arrangement. Instead of being tightly joined together, the edges of these cells **overlap one another, creating functional one-way entry valves**.

The movement of fluid through these valves is driven entirely by **pressure differences across the vessel wall**. When the fluid pressure outside in the interstitial space is higher than the pressure inside the capillary, the overlapping flaps are pushed inward, opening the valve and allowing fluid to enter. Conversely, if the pressure inside the capillary becomes higher, the fluid pushes the overlapping edges tightly together. This seals the valve closed, strictly preventing the newly collected lymph from leaking back into the surrounding tissue.

Because these one-way openings are quite large when pushed open, they allow escaped plasma proteins and large molecules to enter the lymphatic system very easily. These same proteins are generally too large to cross the tighter walls and re-enter standard blood capillaries, making this lymphatic drainage system essential for returning them to the circulation.

Fluid pressure on the outside of the vessel pushes the endothelial cell's free edge inward, permitting entrance of interstitial fluid (now lymph).

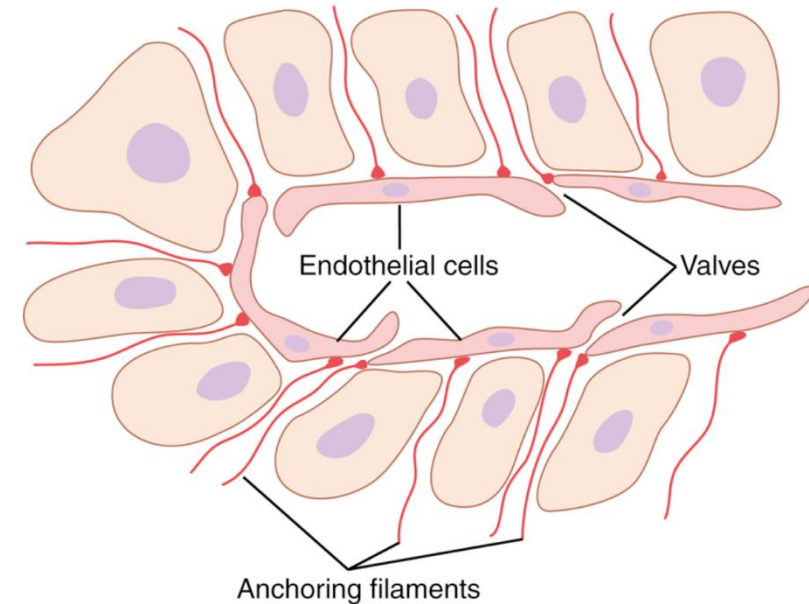


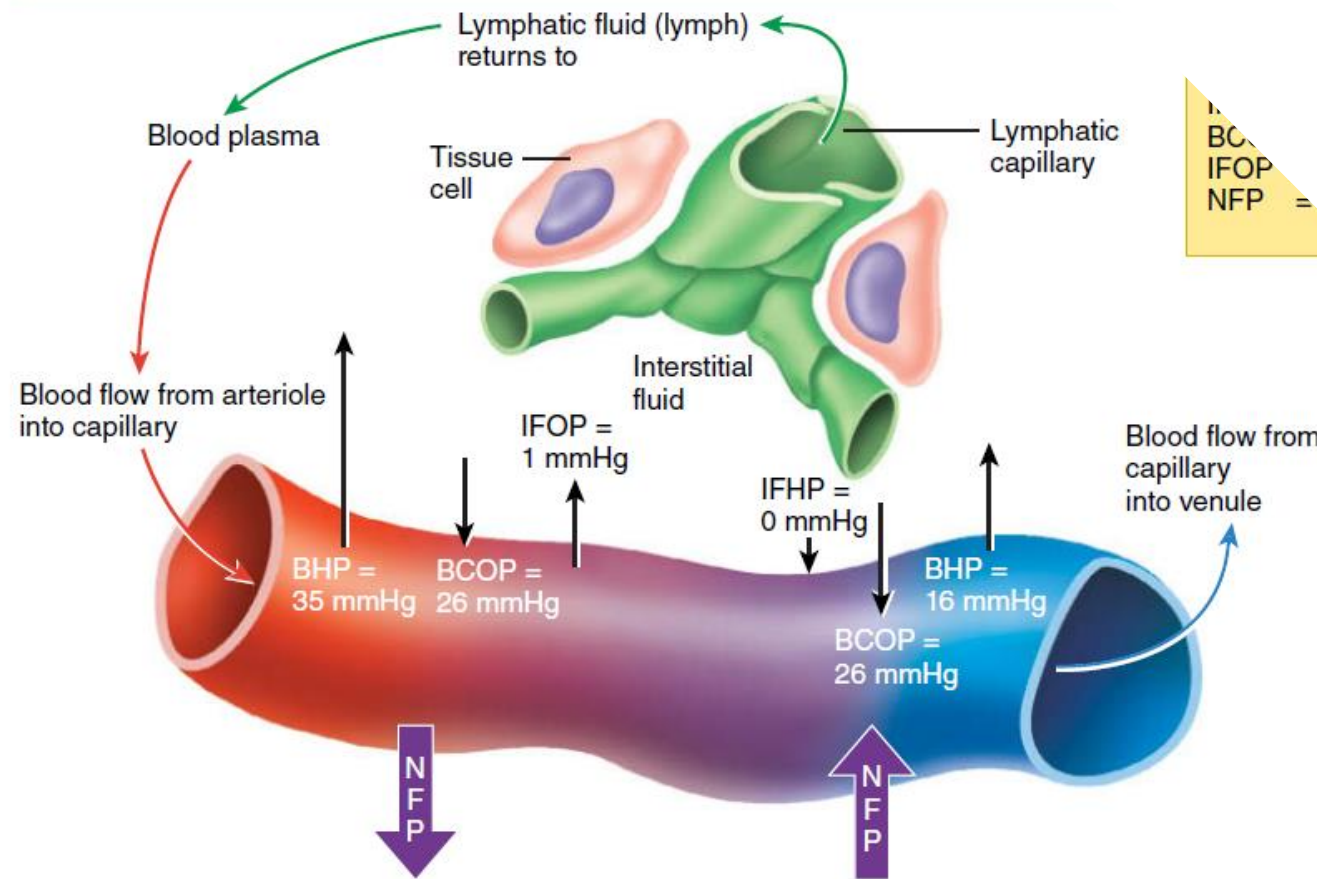
Fluid pressure on the inside of the vessel forces the overlapping edges together so that lymph cannot escape.

Lymph

Anchoring filaments

- Connective tissue is attached to the endothelial cells of the lymphatic wall by tiny threads known as **anchoring filaments**. As interstitial fluid accumulates and the surrounding tissue expands, it physically pulls on these filaments. **This outward tension** is crucial because it prevents the delicate capillaries from collapsing under the rising tissue pressure, holding the vessels wide open so that excess fluid can easily enter.
- Once the fluid is inside, if it attempts to flow backward into the tissue, the internal pressure pushes the **one-way valves** tightly shut. This ensures the collected fluid remains securely trapped inside the lymphatic vessel. In short, the anchoring filaments pull the entry **gates** open when fluid builds up outside, while the **valves** themselves physically block any fluid from leaking back out.





BHP =
 BCOP =
 IFOP =
 NFP =

Key:

- BHP = Blood hydrostatic pressure
- IFHP = Interstitial fluid hydrostatic pressure
- BCOP = Blood colloid osmotic pressure
- IFOP = Interstitial fluid osmotic pressure
- NFP = Net filtration pressure

**The processes of filtration, reabsorption, diffusion, and osmosis allow continual exchange of water and solutes among body fluid compartments . Yet the volume of fluid in each compartment remains remarkably stable.

Net filtration at arterial end of capillaries (20 liters per day)

Net reabsorption at venous end of capillaries (17 liters per day)

Net filtration pressure (NFP)

$$= (BHP + IFOP) - (BCOP + IFHP)$$

Pressures promoting filtration

$$= (BHP + IFOP) - (BCOP + IFHP)$$

Pressures promoting reabsorption

Arterial end
$NFP = (35 + 1) - (26 + 0)$ $= 10 \text{ mmHg}$
Net filtration

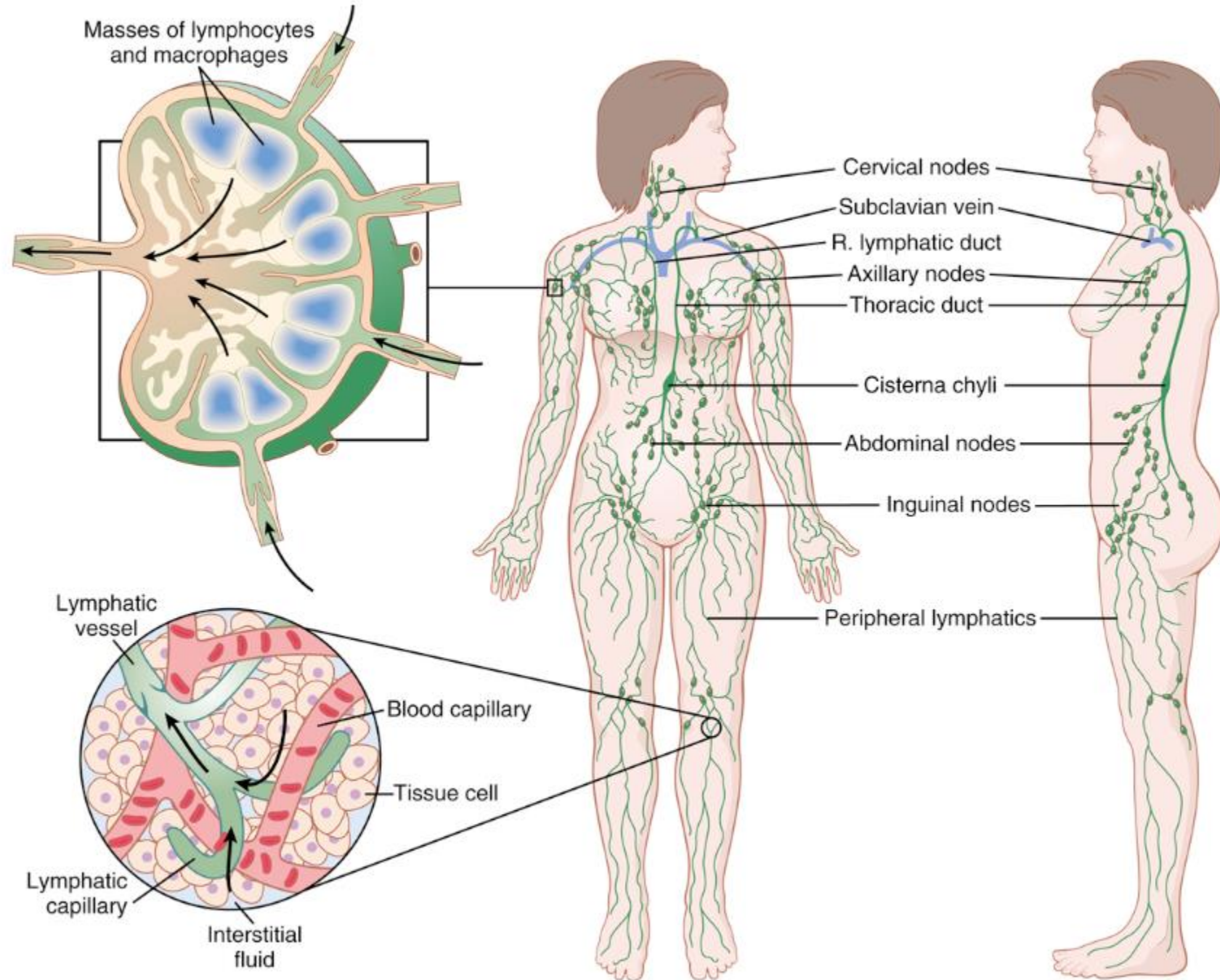
Venous end
$NFP = (16 + 1) - (26 + 0)$ $= -9 \text{ mmHg}$
Net reabsorption

Lymphatic System:

- Returning escaped plasma proteins to the bloodstream is absolutely essential for **maintaining fluid balance**. When proteins leak into the interstitial space, they are too large to pass back through standard blood capillary walls. Instead, they must be collected by the highly permeable lymphatic vessels.
- If these proteins were left behind in the tissues, they would **increase the interstitial colloid pressure**—essentially creating a strong "pulling" force. Because proteins naturally attract water, this increased pulling pressure draws even more fluid out of the bloodstream and into the tissue spaces, causing severe swelling (**edema**).
- Therefore, the lymphatic system continuously clears both excess fluid and trapped proteins to prevent this accumulation. If lymphatic vessels are damaged or blocked, it creates a dangerous, two-fold problem: normal fluid drainage completely stops, and the retained proteins pull even more water into the tissue, making the swelling significantly worse.

- Almost all tissues of the body have special lymph channels that drain excess fluid directly from the interstitial spaces

****The exceptions include the epidermis, central nervous system, endomysium of muscles, and bones.**



Lymphatic System:

Because lymph forms directly from interstitial fluid, its initial chemical composition closely reflects the **specific tissue it drains from**. This means the exact makeup of lymph varies significantly throughout the body, depending entirely on the **local tissue's primary function**.

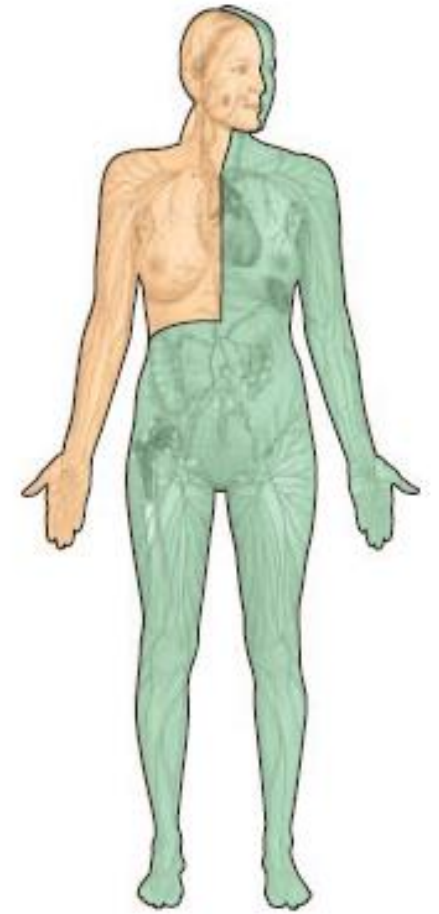
For example, the protein concentration in lymph collected from most peripheral tissues is relatively low, at about 2 grams per deciliter. However, this concentration is naturally higher in lymph draining from the intestines, and higher still in lymph originating from the liver. As these different regional fluids travel through the body, they eventually merge and mix together within the larger collecting lymphatic vessels.

The composition of lymph can also change dynamically based on the body's activities. A prime example is the **intestinal lymph after a fatty meal**, which becomes heavily loaded with newly absorbed dietary fats before transporting them safely back into the main circulation.

Lymph

Major Drainage Routes

- Lower part of the body → empty into the thoracic duct → empties into the blood venous system.
- Left side of the head, left arm, and parts of the chest region → thoracic duct before it empties into the veins.
- Right side of the neck and head, right arm, and parts of the right thorax enters the right lymph duct.



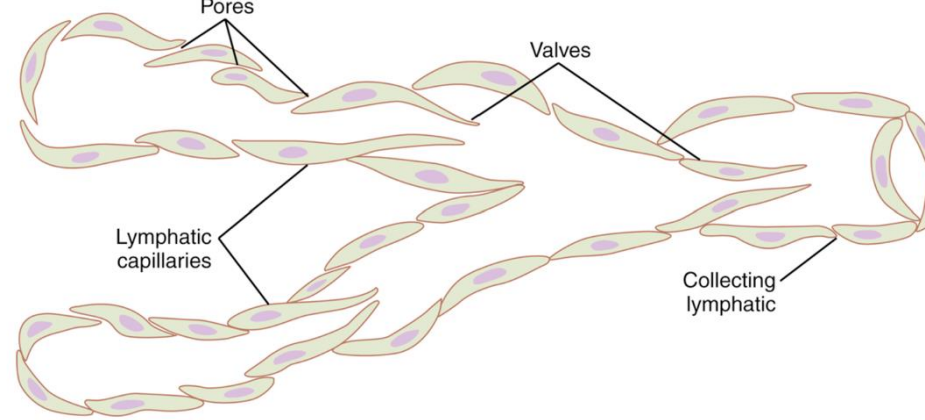
(b) Areas drained by right lymphatic and thoracic ducts

-  Area drained by right lymphatic duct
-  Area drained by thoracic duct

□ Thoracic Duct and Lymph Drainage:

- **The thoracic duct** receives lymph from the lower body (both legs and abdomen), the left upper limb, and the left side of the head and thorax, emptying into the venous circulation where the left internal jugular vein joins the left subclavian vein. Most lymph returns to the blood through the thoracic duct.
- **The smaller right lymphatic duct** drains the right upper region, the right upper limb, and the right side of the head, neck, and thorax, entering the corresponding venous junction on the right.
- ❖ These ducts do not drain equal halves of the body; for example, lymph from the right leg returns through the thoracic duct on the left.

Lymph



Initial lymphatic capillary	Collecting lymphatic vessel
Overlapping endothelial edges form entry flaps in the wall.	Valves inside the lumen separate successive vessel segments.
Allow fluid to move from the tissue into the vessel.	Allow lymph to move forward toward the venous circulation.
Close to resist leakage back into the tissue.	Close to prevent backward flow along the vessel.

First arrangement: Overlapping endothelial flaps in initial lymphatics control entry from the tissue and resist leakage back out.

Second arrangement: Valves along collecting lymphatic vessels direct flow toward the venous circulation.

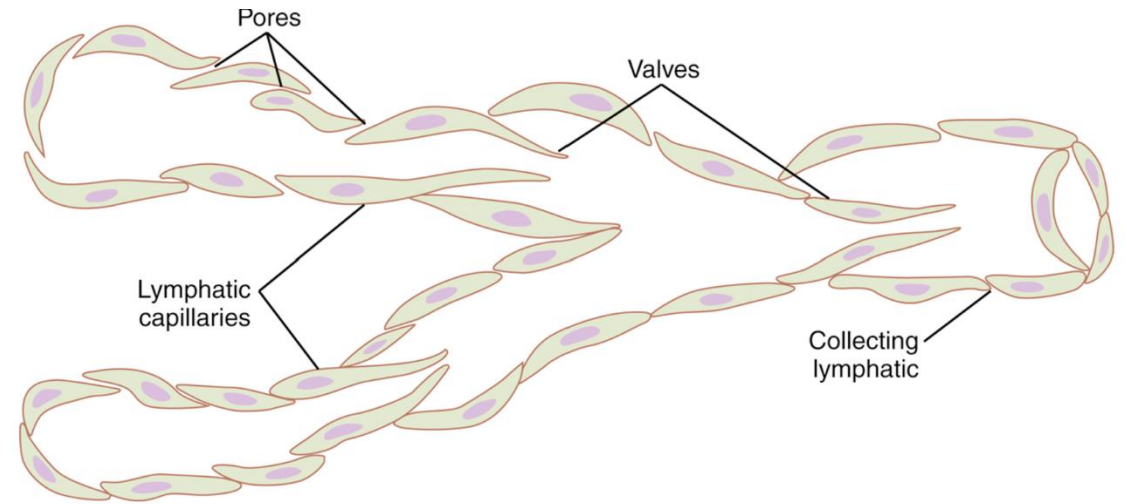
Both arrangements help maintain one-way movement by operating at different locations (entry flaps let fluid in; collecting vessel valves help move it along)

Lymph

The Intrinsic Lymphatic Pump

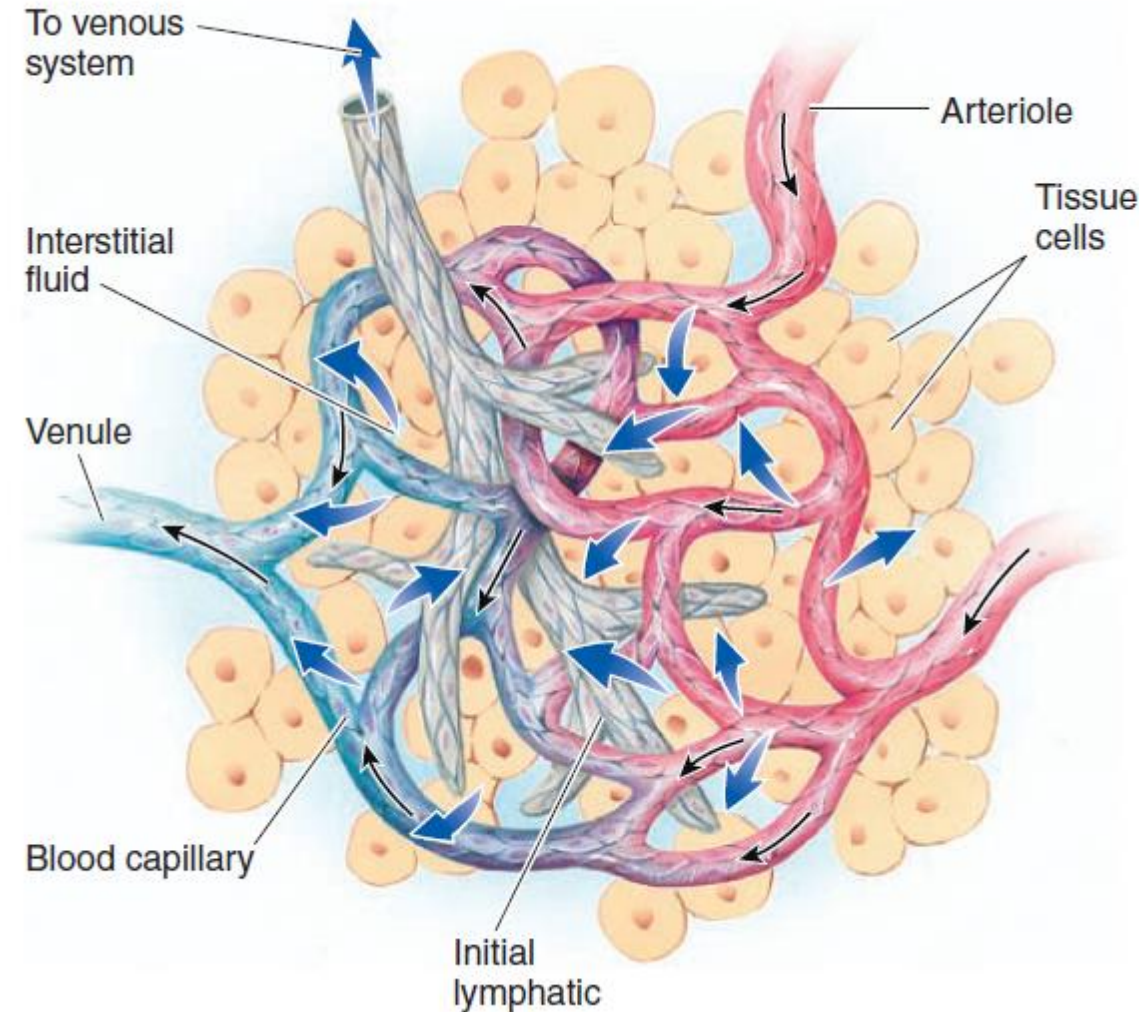
There is no single lymphatic heart, but lymphatic vessels can actively pump.

- Collecting lymphatic vessels contain smooth muscle in their walls.
 - Lymph entering a vessel stretches the wall, triggering contraction.
 - Contraction raises pressure and pushes lymph forward.
 - One-way valves prevent backflow.
 - Repeated filling and contraction move lymph toward the venous circulation.
- Contraction raises pressure inside the segment, closing the valve behind it and opening the valve ahead when pressure is sufficient.
- Each segment between successive valves acts as a small pumping unit, and greater filling stimulates a stronger pumping response to handle increased fluid load.



- Contraction of skeletal muscles squeezes the lymph out of the vessels.

- ❑ **External help comes from surrounding tissues:** skeletal muscle contraction squeezes nearby vessels, and body movement and pulsation of nearby arteries produce intermittent compression (one reason physical movement increases lymph flow).
- ❑ Continuous compression is different from intermittent compression; if a vessel remains compressed, its lumen narrows and drainage becomes restricted.



Relationship between interstitial fluid pressure and lymph flow

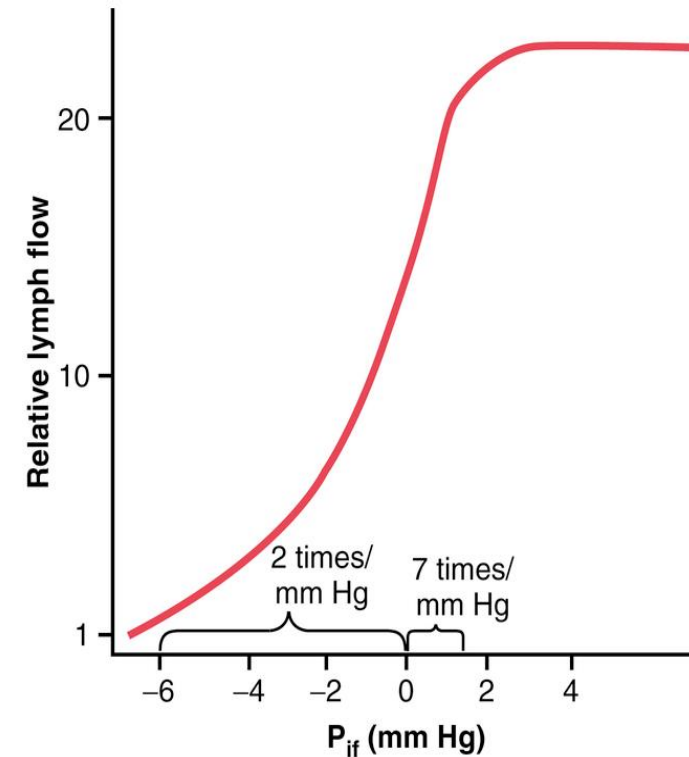
Increase net fluid movement into the interstitial, would increase interstitial fluid volume, interstitial fluid pressure, and lymph flow all at the same time.

□ Response to Increased Filtration and Edema:

- When more fluid filters out of blood capillaries, interstitial fluid volume and pressure increase, encouraging more fluid to enter initial lymphatics.
- Collecting vessels fill, stretch, and increase their pumping activity, resulting in greater lymph flow and return of fluid to the blood, protecting against edema.
- Increased filtration does not necessarily cause immediate visible swelling because a functioning lymphatic system can initially compensate by increasing drainage.
- **Lymphatic compensation limit:** If fluid continues to enter faster than it can leave, it accumulates, and lymphatic compensation has a limit.

□ Relationship Between Interstitial Fluid Pressure and Lymph Flow:

- Initially, increasing tissue pressure produces a marked increase in lymph flow, but eventually the curve reaches a plateau.
- Higher tissue pressure helps fluid enter initial lymphatics, but it can also compress larger lymphatic vessels and make onward flow more difficult.



**** The interstitial fluid hydrostatic pressure, which tends to force fluid inward through the capillary membrane when is positive but outward when is negative**

ne might formulate a general rule that the normal interstitial fluid pressure is usually several millimeters of mercury negative with respect to the pressure that surrounds each tissue.

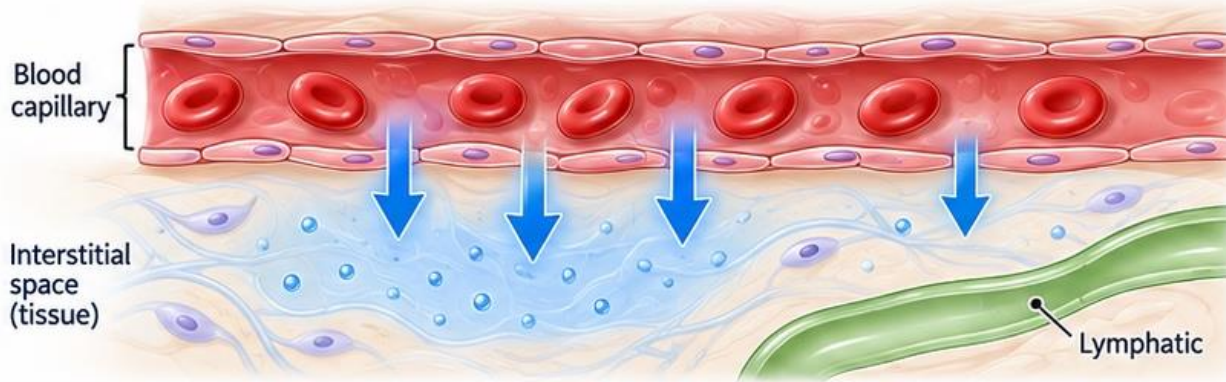
****when the interstitial fluid hydrostatic pressure becomes 1 or 2 mm Hg greater than atmospheric pressure (>0 mm Hg), lymph flow fails to rise any further at still higher pressures. This results from the fact that the increasing tissue pressure not only increases entry of fluid into the lymphatic capillaries, but also compresses the outside surfaces of the larger lymphatics, thus impeding lymph flow.**

How Edema Develops

Edema is the excessive accumulation of fluid in the interstitial space.

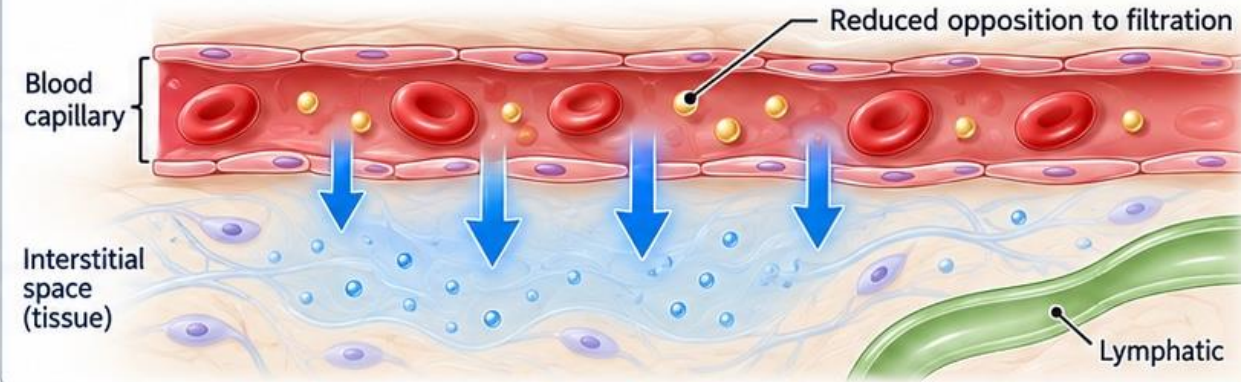
1 Increased capillary hydrostatic pressure

More fluid is pushed into the tissues



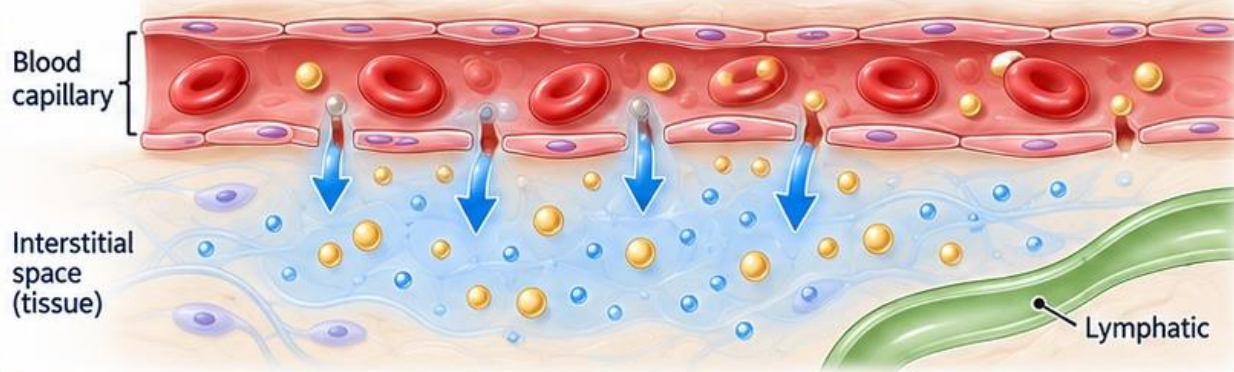
2 Reduced plasma protein concentration

Lower plasma colloid osmotic pressure



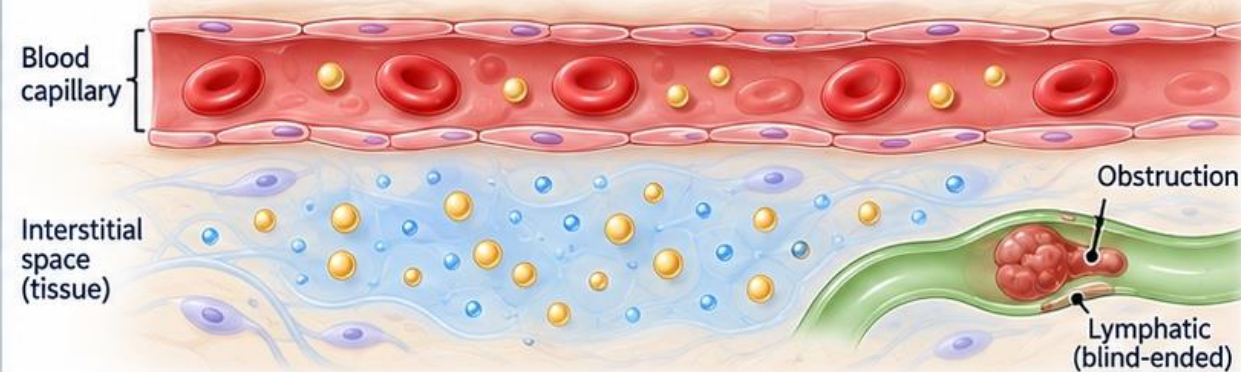
3 Increased capillary permeability

More fluid and protein enter the tissues



4 Impaired lymphatic drainage

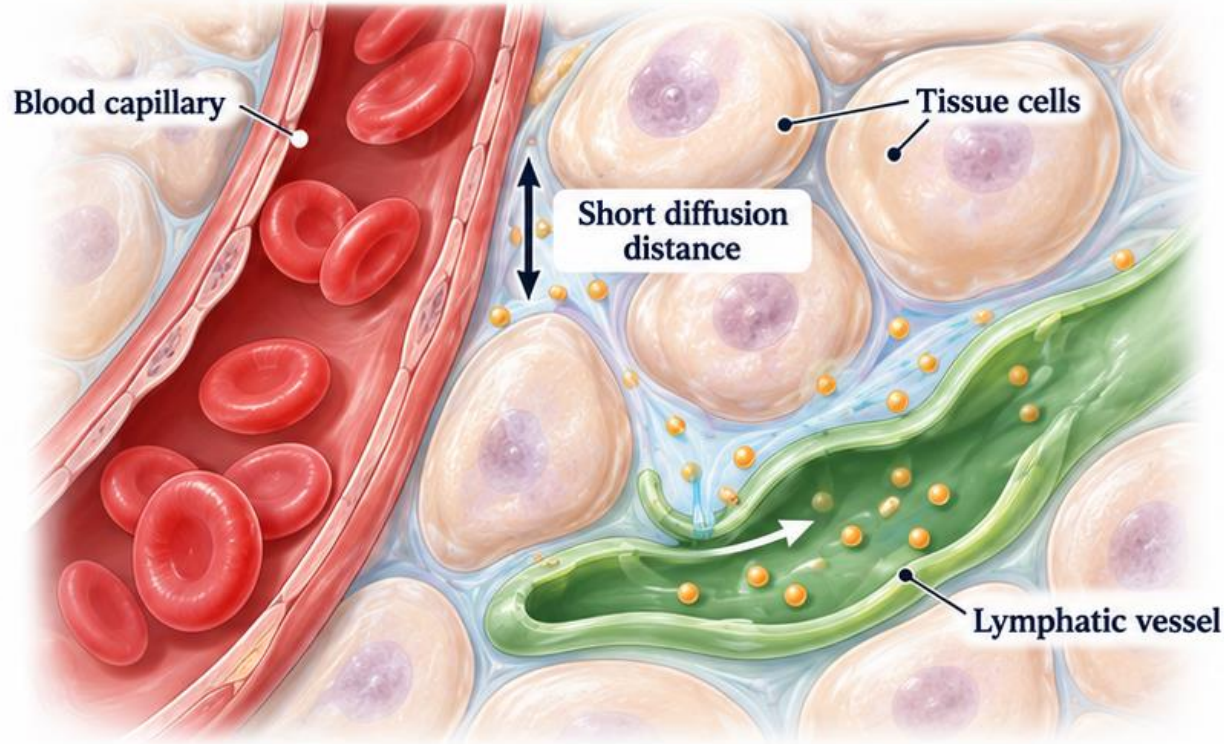
Reduced removal of fluid and protein



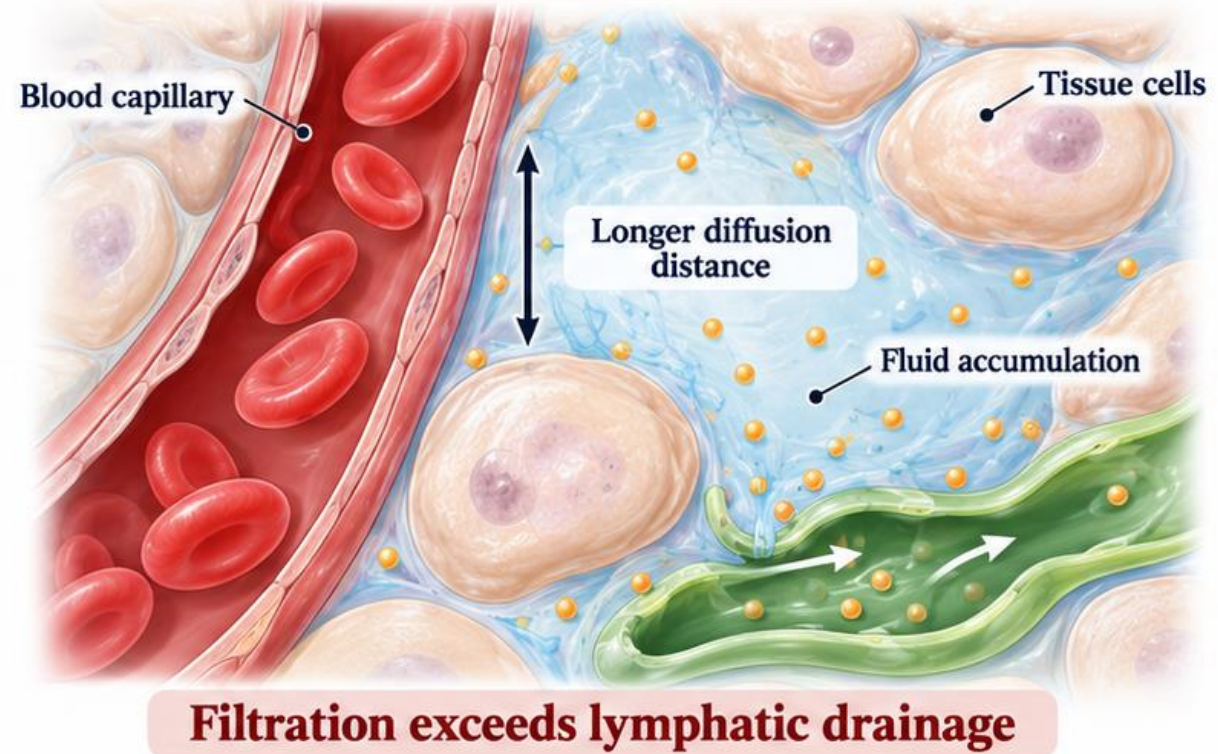
The first three mechanisms increase the load the lymphatics must handle, while the fourth reduces their ability to remove that load.

Why tissue fluid balance matters

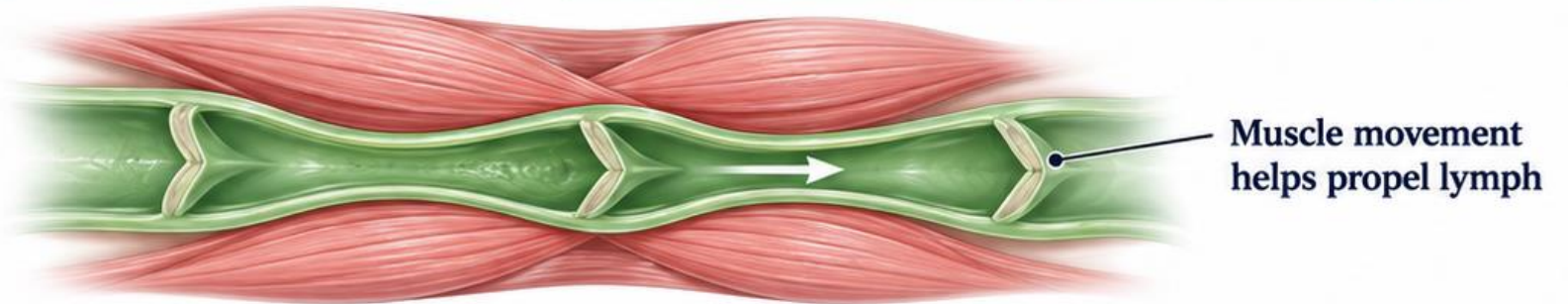
Effective lymphatic drainage



Edema



Lymphatics return fluid and proteins to the blood



Balanced tissue fluid supports effective exchange

❑ Why Tissue Fluid Balance Matters:

- Edema affects more than just the appearance of a tissue.
- As interstitial fluid accumulates, the distance between blood capillaries and tissue cells increases.
- Oxygen, nutrients, and wastes must travel a greater distance, making diffusion less efficient.

❑ Concluding Questions and Answers:

1) Why must lymphatics return proteins as well as water?

- ✓ Because proteins retained in the interstitium increase its colloid osmotic pressure and favor further fluid accumulation.

2) Why does movement increase lymph flow?

- ✓ Because muscle contractions intermittently compress lymphatic vessels, while one-way valves direct the fluid forward.

3) Why can edema develop even when lymph flow has increased?

- ✓ Because increased drainage may still be insufficient to match the increased filtration.
- ✓ Ultimately, the lymphatic system helps maintain the tissue environment needed for effective exchange between blood and cells.

رسالة من الفريق العلمي:

كان ابنُ عُمر - رضي الله عنهما - يقول: " إذا أمسيت
فلا تنتظر الصباح، وإذا أصبحت فلا تنتظر المساء،
وخذ من صحتك لمرضك، ومن حياتك لموتك".

For any feedback, scan the code or click on it.



Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			
V1 → V2			