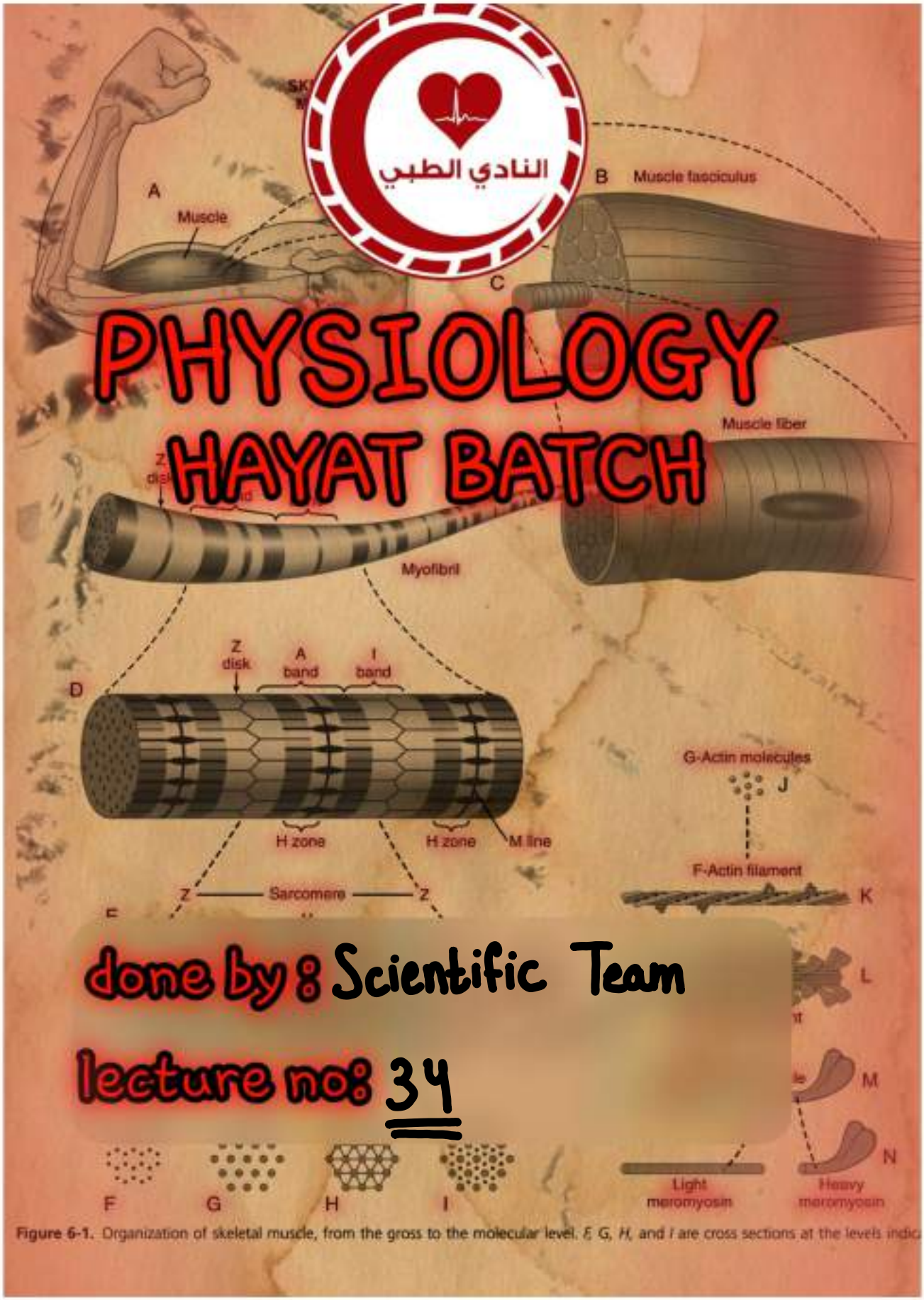
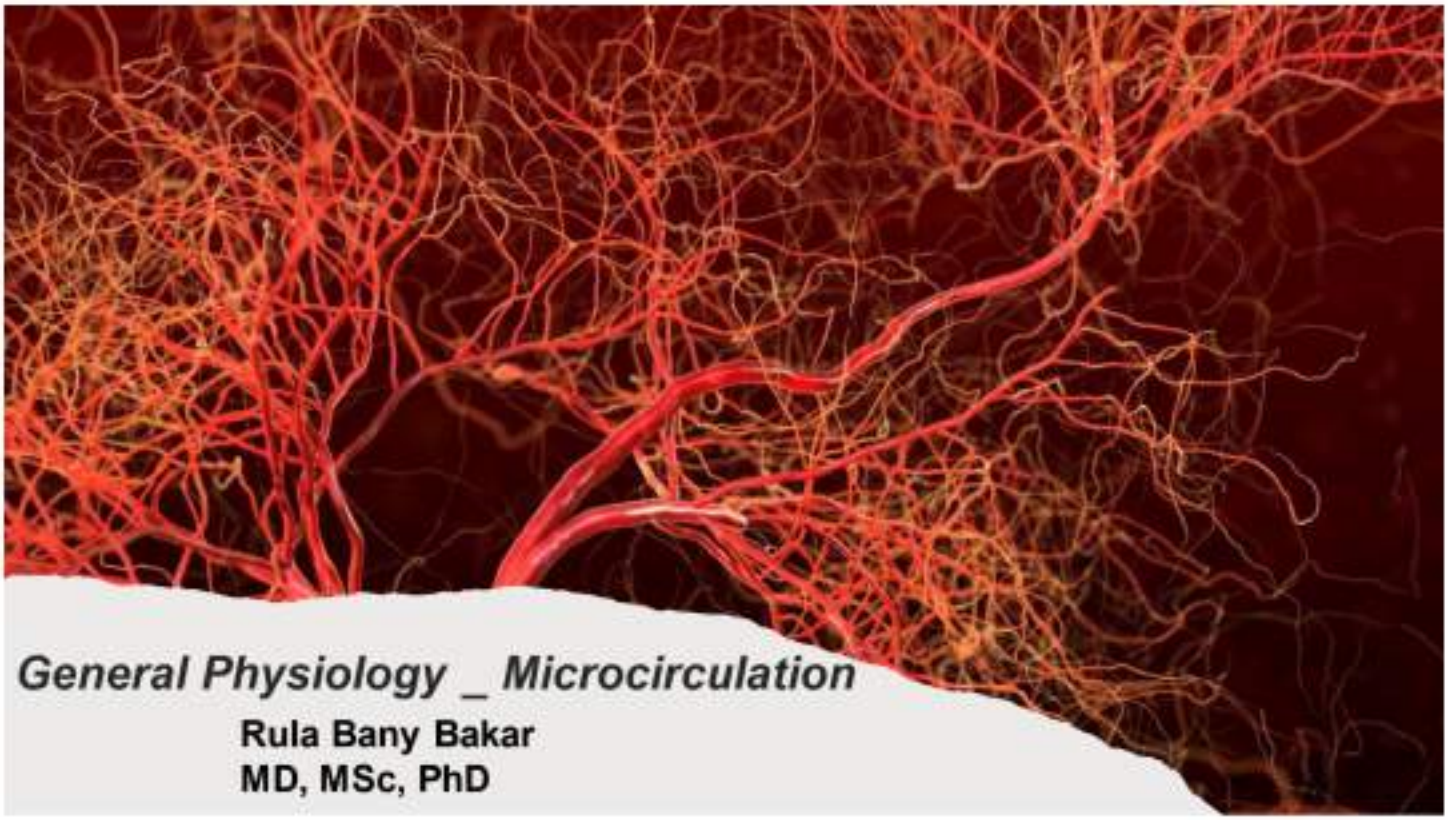


Figure 6-1. Organization of skeletal muscle, from the gross to the molecular level. *E*, *G*, *H*, and *I* are cross sections at the levels indic



General Physiology _ Microcirculation

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Objectives:

1- Quick and Basic Introduction:

- **The human circulatory system**
- **Blood vessels layers**
- **Arteries, Arterioles, Veins, Venules.**

2- Microcirculation: Definition, Significance, Examples.

3- Types of Capillaries.

4- Interstitial Fluid

5- Exchange of Substances Across the Capillary Wall.

6- Fluid Exchange Across Capillaries.

7- Summary

The Human Circulatory System:

Definition: The human circulatory system: is a vast (واسع) network that carries blood throughout the body.

- ❑ **The Heart**: The heart is a muscular organ that acts as the pump of the circulatory system.
- ❑ **Blood Vessels**: These are the pathways through which the blood travels. They include:
  1. ***Arteries:*** These are large, thick-walled vessels that carry blood away from the heart.
  2. ***Veins:*** These are vessels that return blood to the heart. They are generally thinner and less muscular than arteries. Small veins, called venules, merge into larger veins.
  3. ***Capillaries:*** These are the smallest and most numerous of the blood vessels, forming vast networks throughout the body
- ❑ **Blood**: This is the life-sustaining fluid that circulates throughout the circulatory system. It is composed of red blood cells, white blood cells, platelets, and plasma.

* Notice that Anatomy of Blood Vessels is not included it's just an introduction to the topic

Blood Vessels:

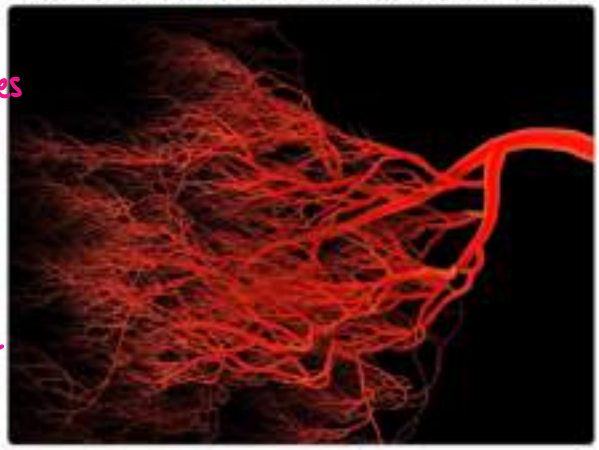
- Arteries → carry blood
- Arterioles → control blood flow into
- Capillaries → Exchange of substances → Main Focus
- Venules → start to carry away deoxygenated blood
- Veins → continue to carry deoxygenated blood back to the heart

Microcirculation:

❖ ***Definition:***

- The term "microcirculation" refers to the functions of the smallest blood vessels (***the capillaries***) and the neighbouring lymphatic vessels.

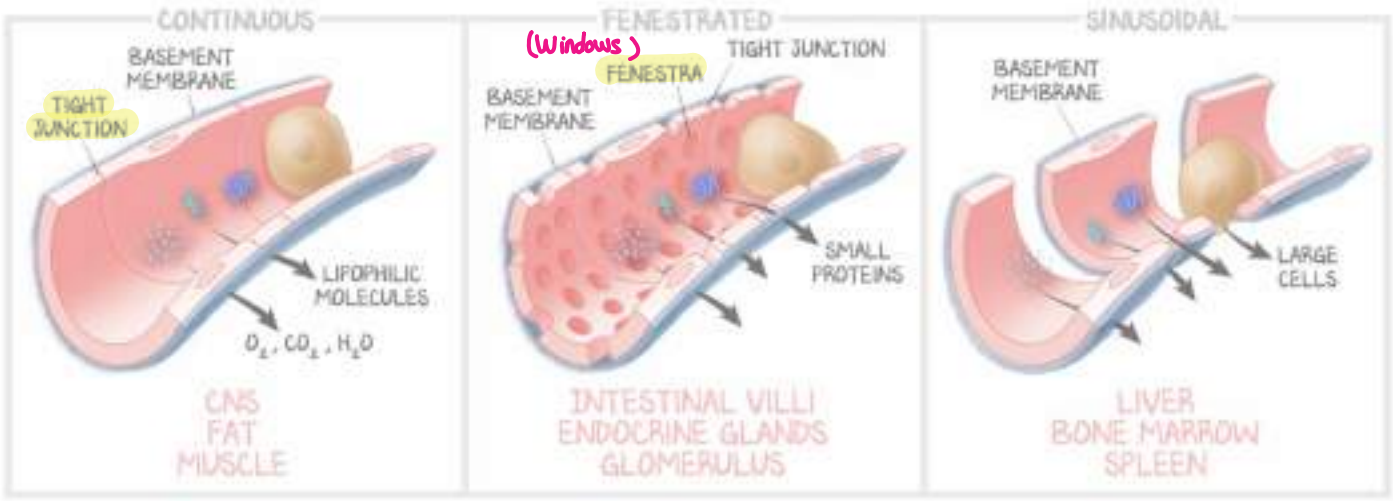
- Capillaries: Composed of a unicellular layer of endothelial cells surrounded by a basement membrane. → It lacks two layers → Adventitia, Smooth muscles



❖ ***Significance:***

The site of exchange of fluids, nutrients and waste products in the tissues, → because of that it's a thin layer of epithelial tissue

Types of Capillaries:



Continuous Capillary

- No pores in the middle
- Endothelium is very adjacent to each other

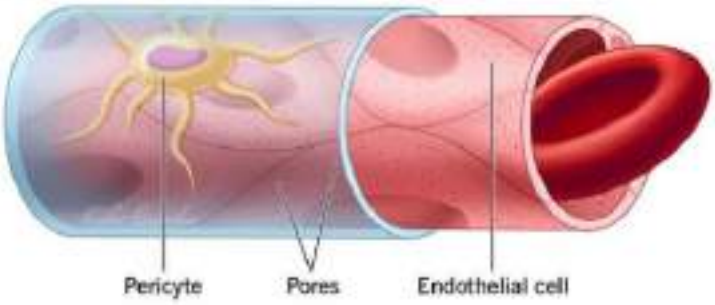
Fenestrated Capillary

Sinusoidal Capillary

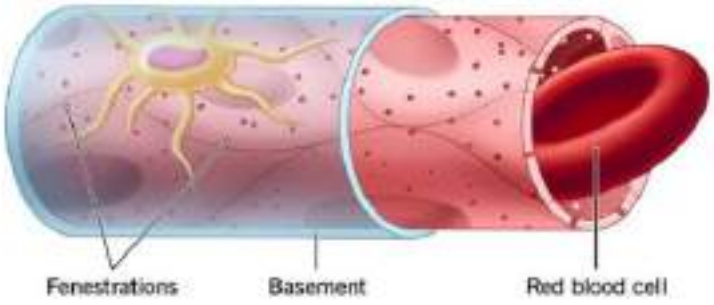
→ huge gaps between endothelial cells

Types of Capillaries:

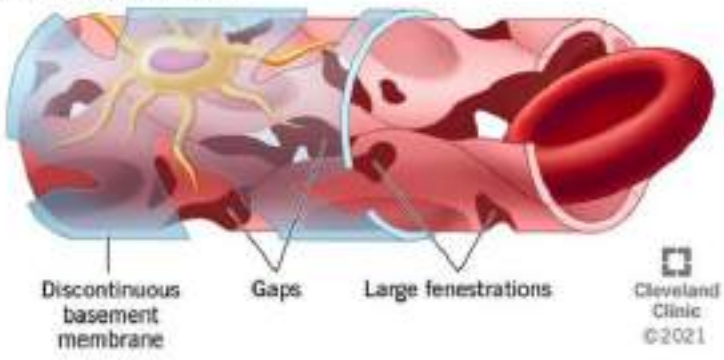
1) Continuous Capillary



2) Fenestrated Capillary

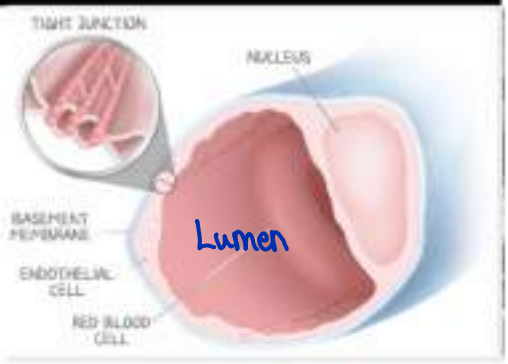


3) Sinusoidal Capillary

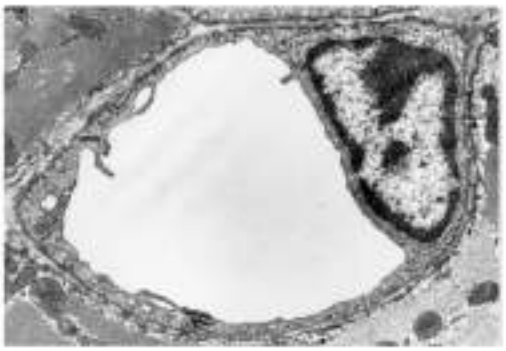


Types of Capillaries:

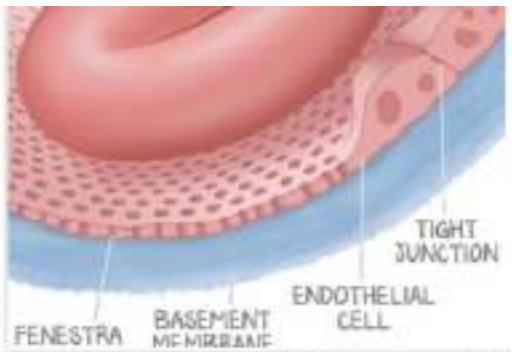
❑Continuous Capillaries:



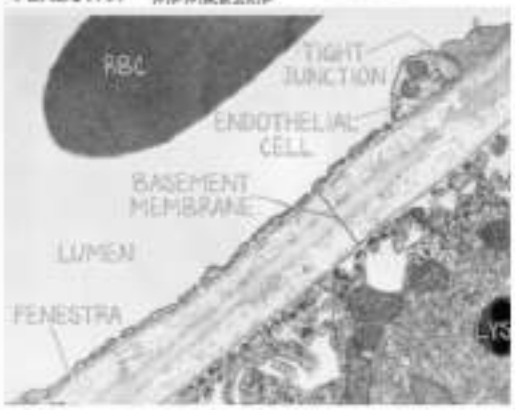
- ✓ Designed to separate compartments and prevent molecular passage between them
- ✓ Example: Blood-brain barrier
- ✓ Endothelial cells adhere tightly via tight junctions, leaving no gaps.
- ✓ Only molecules capable of diffusing through a plasma membrane can exit, such as Water, Oxygen, Carbon dioxide. CO_2
- ✓ No fenestrations and no gaps between cells.



❑Fenestrated Capillaries:



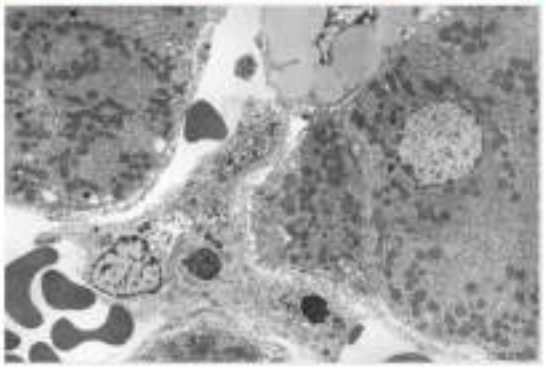
- ✓ Permit diffusion of small hydrophilic molecules such as peptides
- ✓ Essential for cells receiving or releasing peptide hormones → in Kidney/Endocrine System
- ✓ Enable filtration in the glomerulus of the kidney
- ✓ Have holes known as fenestrations (fenestra means "window". → No gaps



Types of Capillaries:

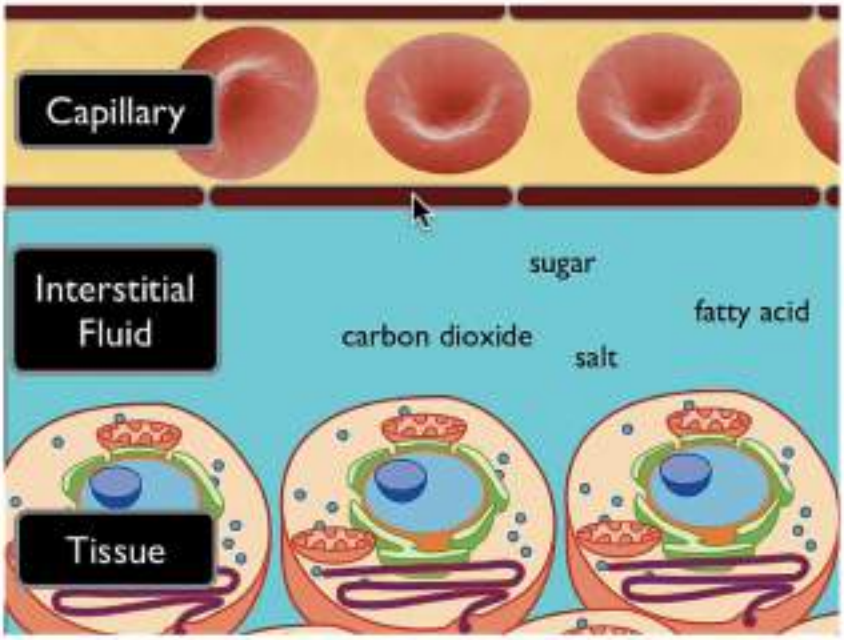
❑Sinusoidal Capillaries:

- ✓ Primarily found in the "reticuloendothelial system" (hematopoietic organs like the liver, spleen, and bone marrow)
- ✓ Characterised by large gaps between endothelial cells, large enough to allow whole cells through.

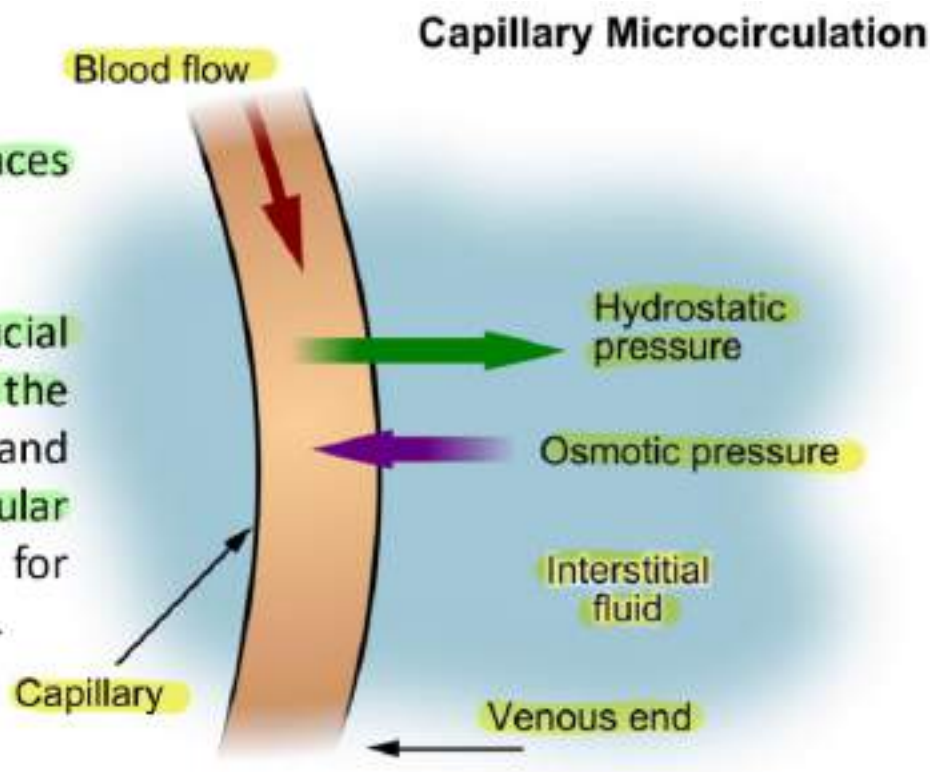


* Kupffer cells → can go in & out through gaps

Interstitial Fluid:



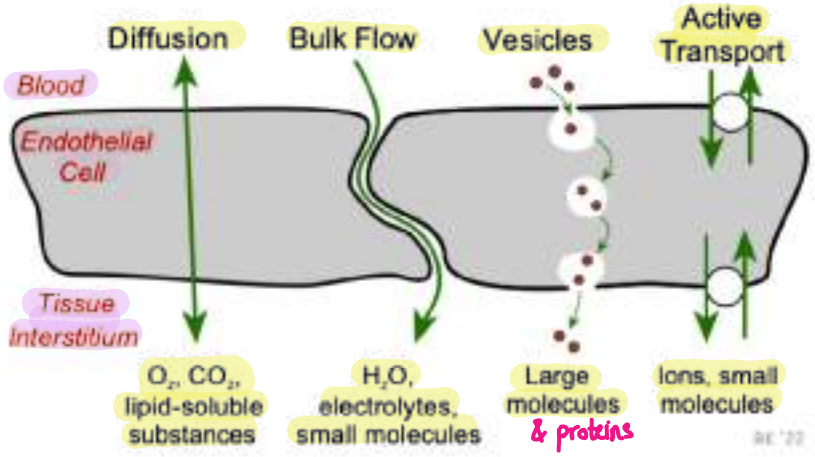
- Fluid that exists in the spaces between cells
- The interstitial fluid plays a crucial role in delivering nutrients to the cells, carrying away waste, and maintaining a stable, extracellular environment, which is crucial for the proper functioning of cells.



Exchange of Substances Across the Capillary Wall:

1) *Simple Diffusion*:

- ✓ The process by which solutes are moved along a concentration gradient.
- ✓ It does not require the assistance of membrane proteins.
- ✓ The exchange of solutes and gases (Lipid soluble substances) directly through the cell membrane of capillaries (CO2, O2)



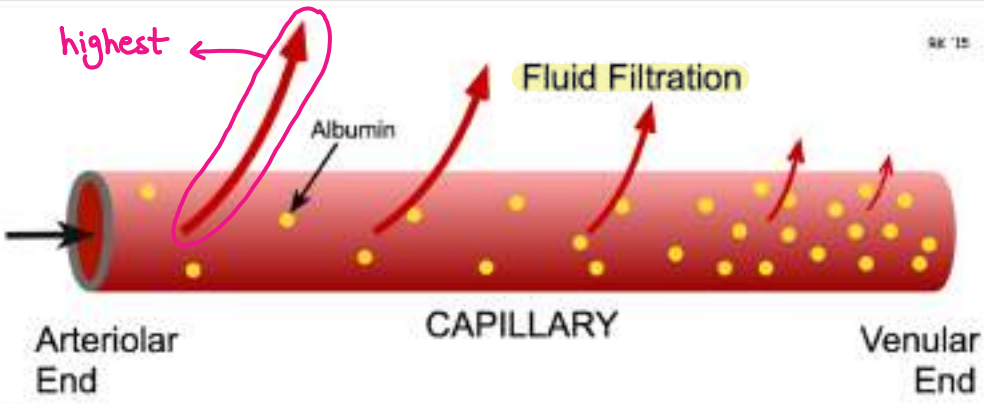
2) *Vesicular Transport*

- ✓ Proteins are generally too large to cross the capillary walls via the clefts between endothelial cells.
- ✓ They are moved across cell membranes within small vesicles, which are tiny, membrane-enclosed sacs within the cell.

3) *Bulk Flow*:

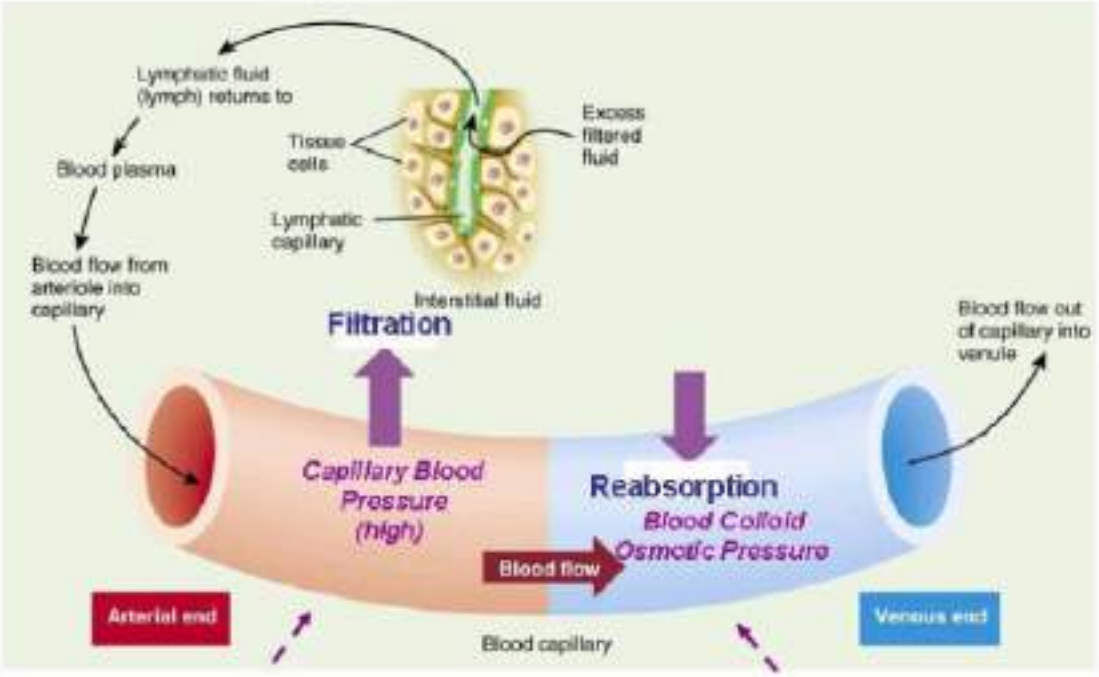
Water-soluble substances (e.g. water, ions, glucose, amino acids) that are not lipid soluble can't cross the endothelial cell membranes and diffuse through the aqueous clefts between cells.

Fluid Movement Across Capillaries: → Continous Capiliary → most common type of capiliaries



- **Filtration:**
  - Fluid and small solutes move out of the capillary and into the interstitial space.
  - Caused by hydrostatic pressure (Blood pressure).
  - Primarily occurs at the arterial end of a capillary.
  - Large substances like proteins, however, are typically too big to be filtered and remain in the capillary. → e.g: Albumin
- **Reabsorption:**
  - Fluid and small solutes fluid and small solutes are drawn back into the capillary.
  - Caused by the osmotic pressure created by the proteins that were not filtered out.
  - Primarily occurs at the venous end of the capillary.

- 90 % of Filtered fluid is reabsorbed on the venous end.
- The remaining 10% of the filtered fluid is returned to circulation via lymphatics

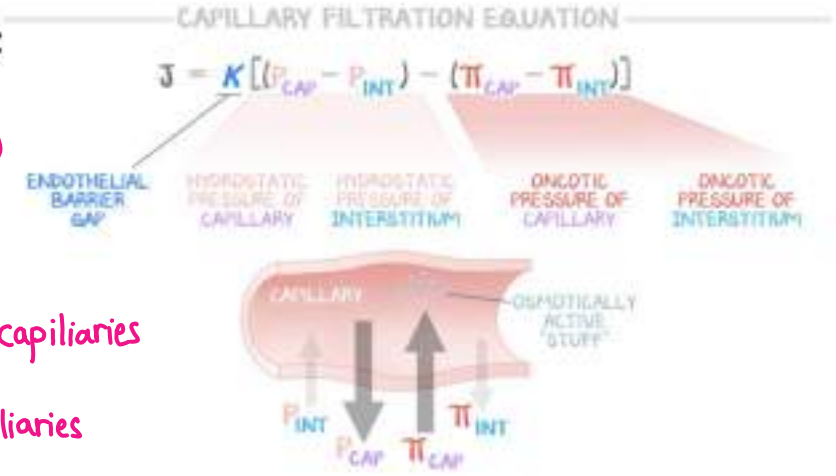


Fluid Movement Across Capillaries:

❑ The balance between diffusion and perfusion is known as Starling's Law of the Capillary.

❖ Two compartments are involved:

1. The capillary compartment. (c)
2. The interstitial compartment. (i)



❖ Each compartment:

a) Hydrostatic forces (pushing forces represented by P) outside capiliaries

b) Oncotic forces (pulling forces represented by π). inside the capiliaries

❖ ***Starling equation:***

$$J_v = K_f[(P_c - P_i) - (\pi_c - \pi_i)]$$

where

J_v = Fluid movement (mL/min)

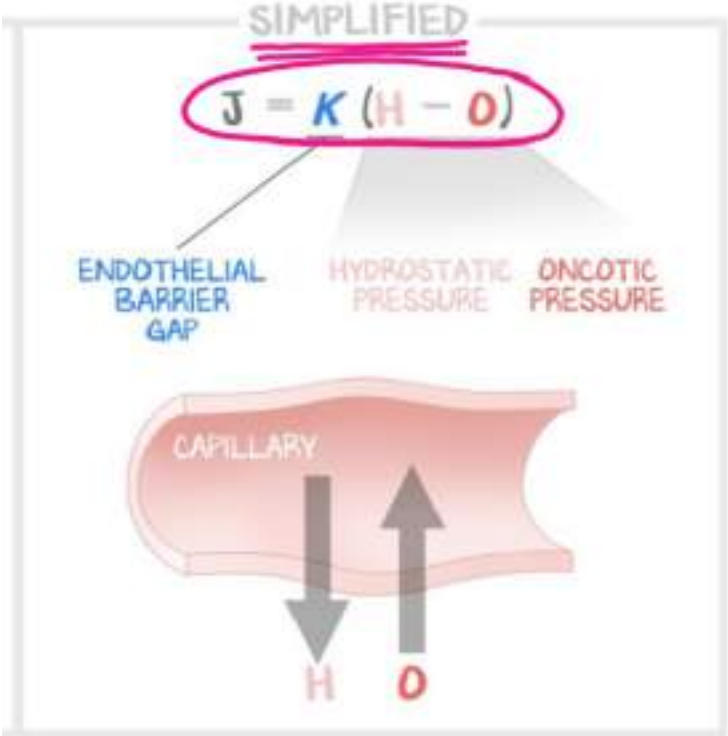
K_f = Hydraulic conductance (mL/min per mm Hg) ⟵ يعتمد على نوع الخلايا

P_c = Capillary hydrostatic pressure (mm Hg)

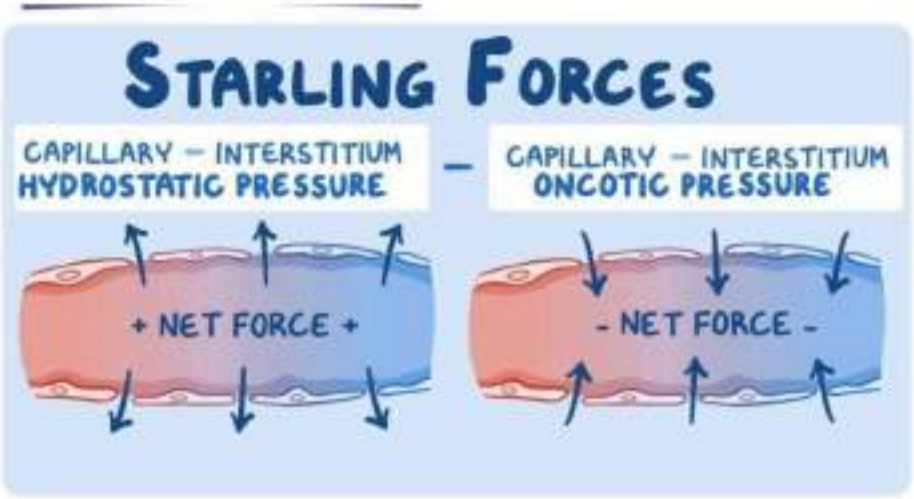
P_i = Interstitial hydrostatic pressure (mm Hg)

π_c = Capillary oncotic pressure (mm Hg)

π_i = Interstitial oncotic pressure (mm Hg)



Fluid Movement Across Capillaries:



Clinical relevance :

Edema is an abnormal presence of excessive fluid in the interstitial space.

Case 1

↓

Unilateral Edema

Case 2

↓

pitting edema

Fluid Movement Across Capillaries: Summary

- ✓ Fluid exchange across capillaries enables nutrient, gas, and waste exchange between blood and tissues.
- ✓ The process primarily involves filtration and reabsorption.
- ✓ Filtration happens at the arterial end of a capillary, driven by high hydrostatic pressure.
  - This forces fluid and small solutes out of the capillary into the interstitial space.
  - Larger substances like proteins remain in the capillary.
- ✓ Reabsorption occurs at the venous end of the capillary, driven by osmotic pressure from proteins.
  - Fluid and small solutes are drawn back into the capillary.
- ✓ Starling's Law of the Capillary governs this balance: → $J = K(H-O)$
  - Net filtration equals the difference between hydrostatic and osmotic pressures.
  - The amount filtered out at the arterial end equals the amount reabsorbed at the venous end.
- ✓ Disruption of this balance (e.g., due to injury or disease) may lead to edema or fluid accumulation in the interstitial space.

- ✓ Filtration and absorption processes are crucial for fluid movement across capillaries.
- ✓ Fluid movement is influenced by two main forces: Hydrostatic forces (pushing forces represented by P) and Oncotic forces (pulling forces represented by π).
- ✓ Two compartments are involved: the capillary compartment (within the capillary lumen) and the interstitial compartment (the space outside the lumen).
- ✓ Hydrostatic pressure pushes fluid into or out of the capillary, while Oncotic pressure pulls fluid in the opposite direction.
- ✓ Net fluid movement depends on the balance of these four forces: capillary hydrostatic, interstitial hydrostatic, capillary oncotic, and interstitial oncotic.
- ✓ This balance can be represented by the formula: $J = k [(Pcap - Pint) - (\pi cap - \pi int)]$, where J is the fluid flow, k is the permeability, Pcap and Pint are the capillary and interstitial hydrostatic pressures, and πcap and πint are the capillary and interstitial oncotic pressures.
- ✓ In most cases (except ascites and obstructive uropathy), the interstitial forces are negligible, → هنتجاهلها simplifying the equation to consider only capillary pressures.

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- ✓ This understanding of hydrostatic and oncotic pressures is crucial to discuss physiology and pathology of fluid exchange in capillaries.