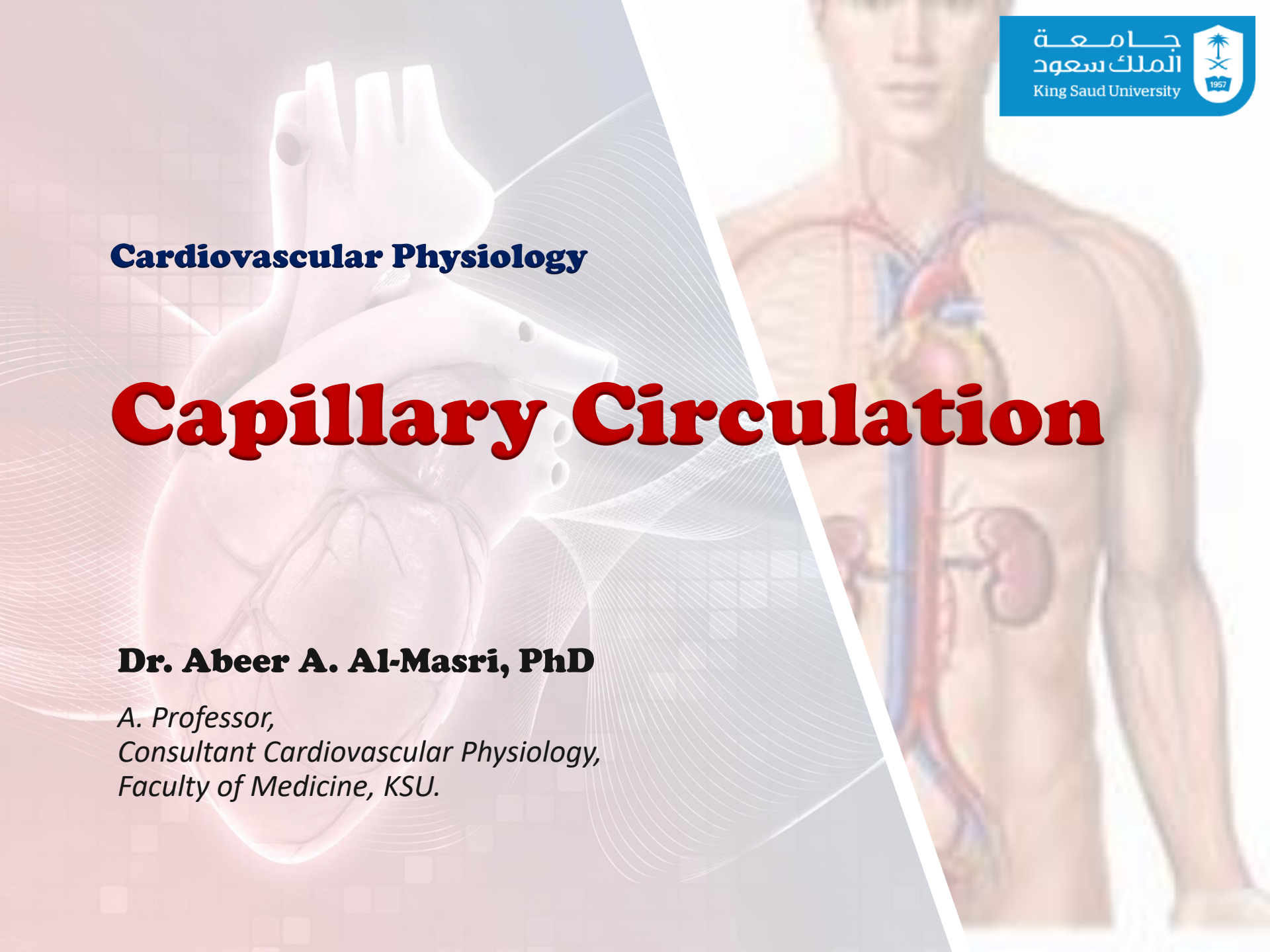

Cardiovascular Physiology

Capillary Circulation

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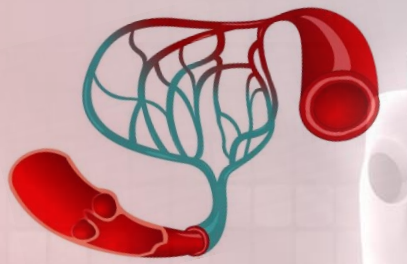
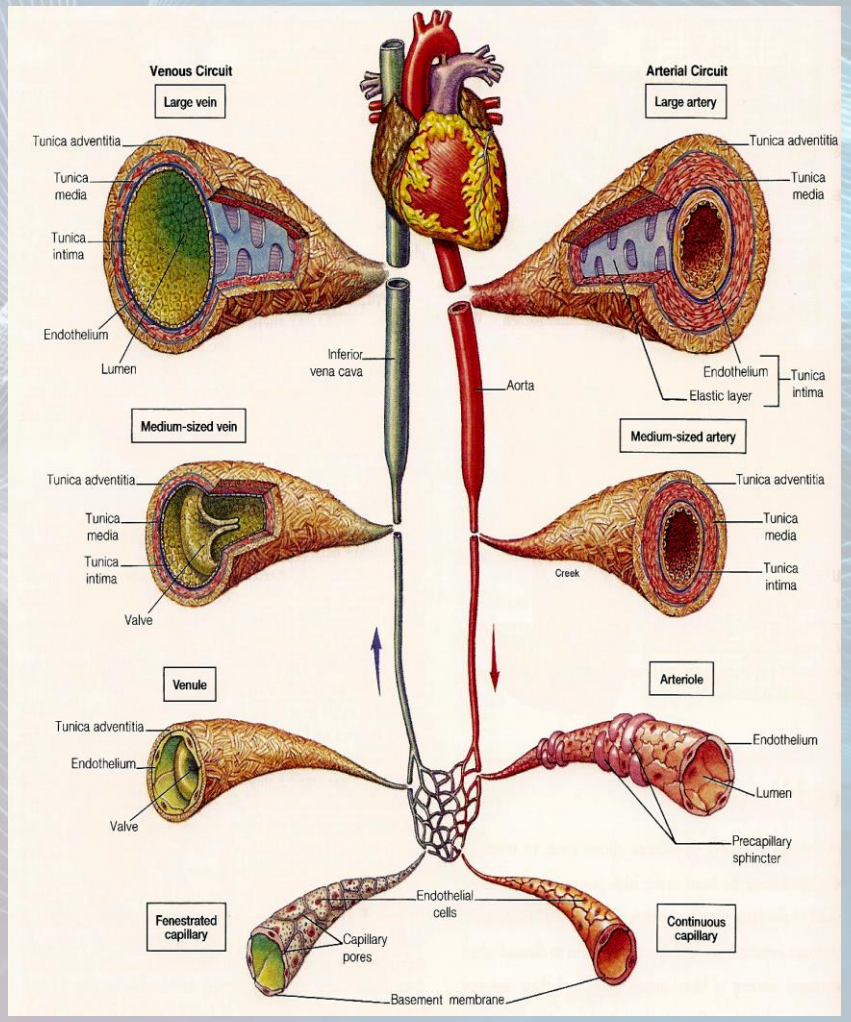


Lecture Outlines

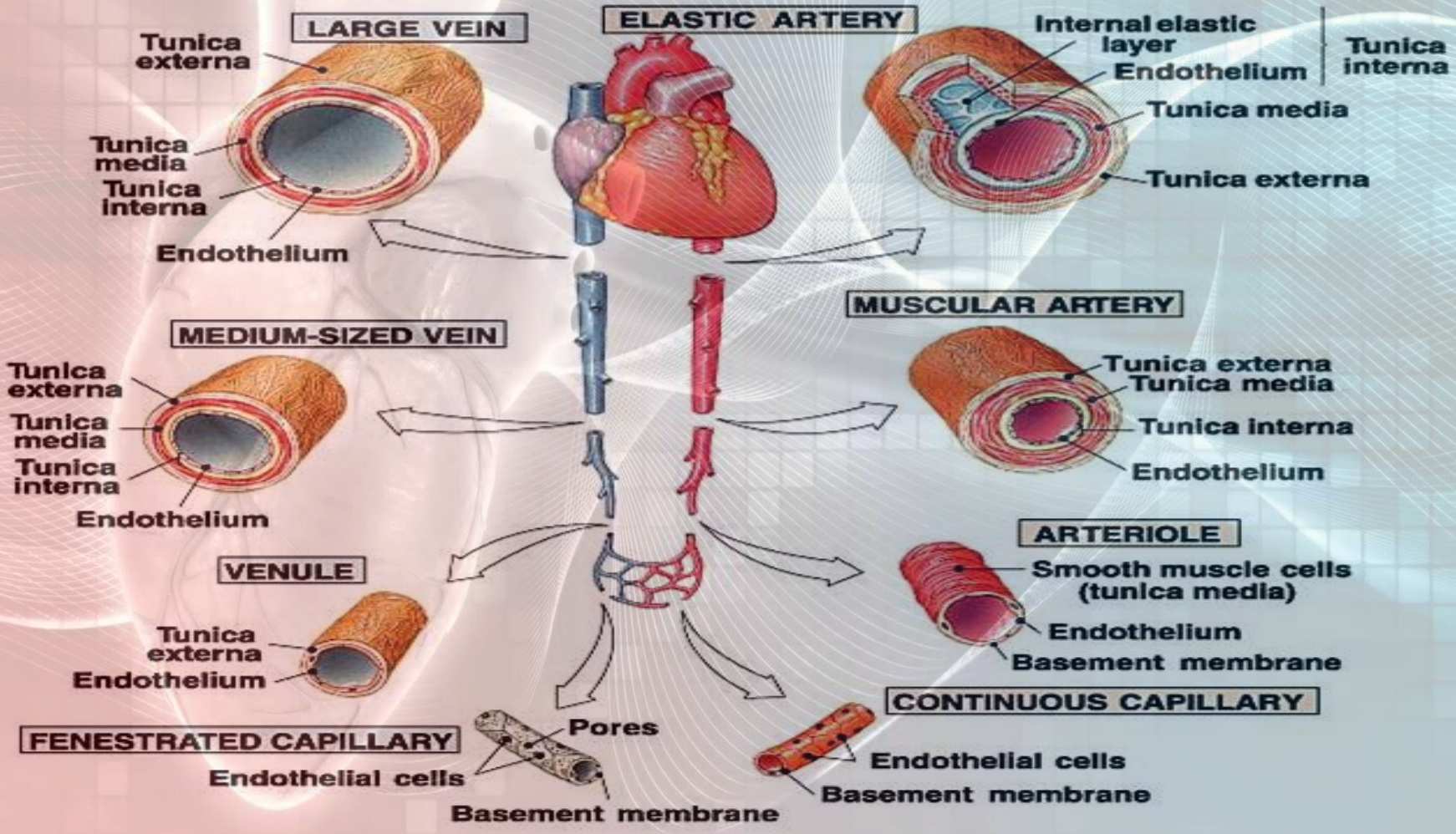
- To describe components of microcirculation.
- To recognize different types of blood capillaries.
- To understand regulation of flow in capillary beds.
- To understand formation of the interstitial fluid.
- To understand the role of lymphatics.
- To recognize mechanism of formation of edema.

Classification of the Vascular System

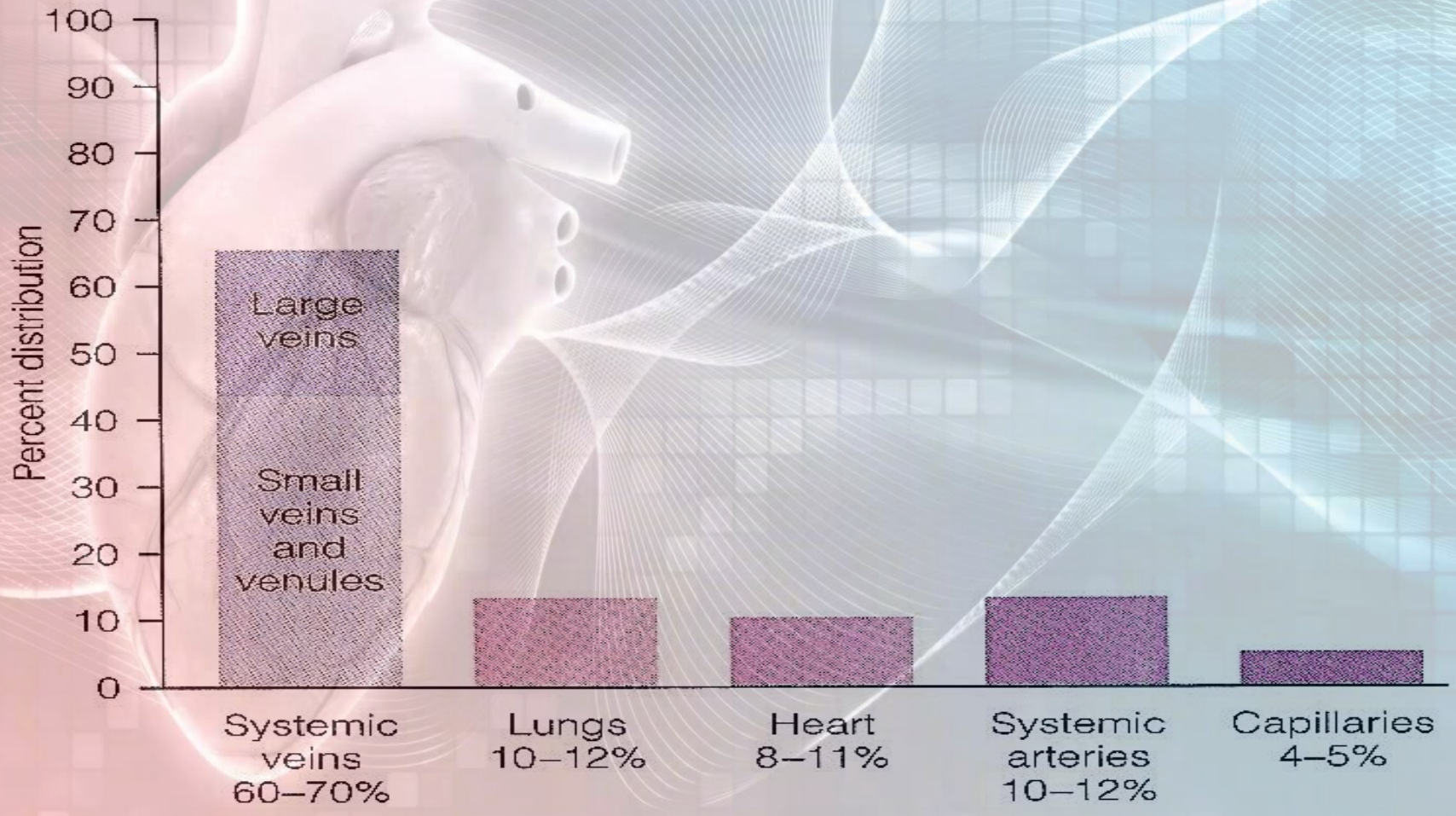
1. **Aorta:** Elastic recoil.
2. **Arteries:** Muscular, low resistance vessels.
3. **Arterioles:** High resistance vessels.
4. **Capillaries**: Exchange vessels.
5. **Venules**
6. **Veins:** Capacitance vessels.



Comparison of Blood Vessels

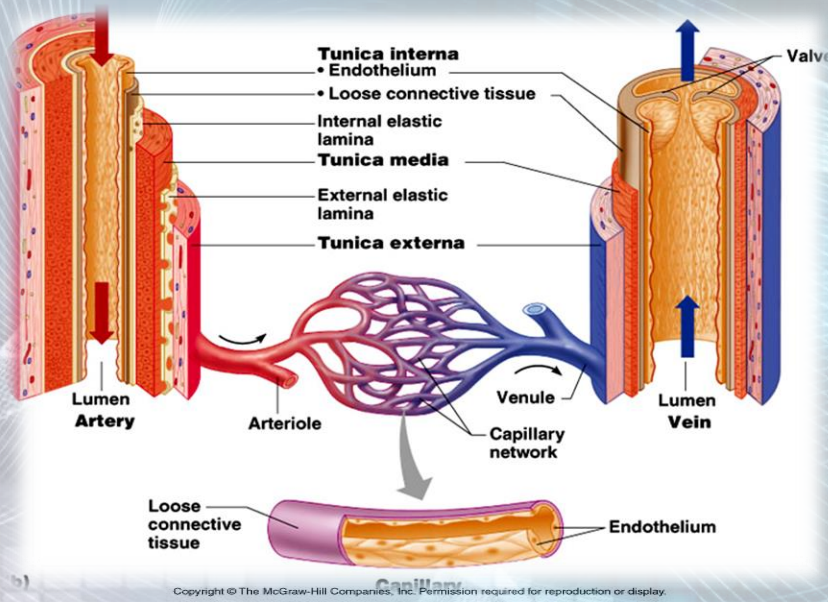


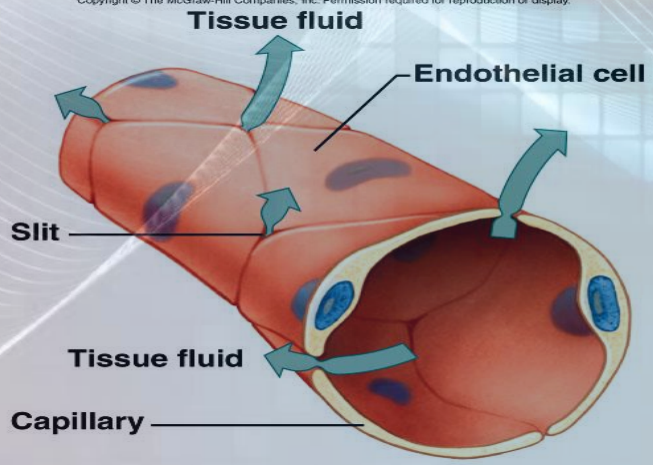
Distribution of Blood Within The Circulatory System At Rest



Capillaries

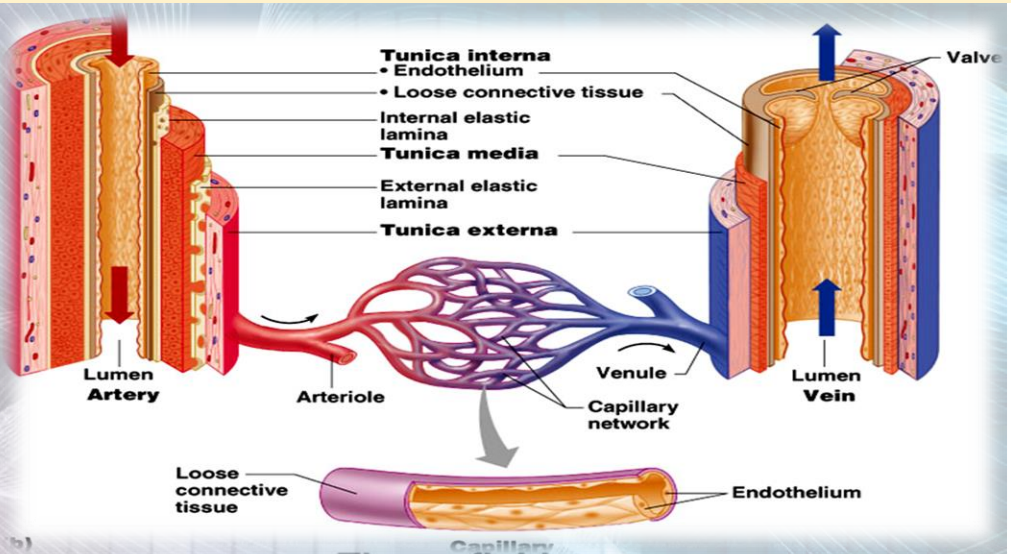
- Capillaries are the smallest blood vessels (microcirculatory vessels) in the vascular system.
- At rest, 5% of circulating blood is present in capillaries.
- There are over 10 billion capillaries in the body.
- Are exchange vessels.
- Provide direct access to the cells.
- Most permeable.
- Permits exchange of nutrients & waste products.

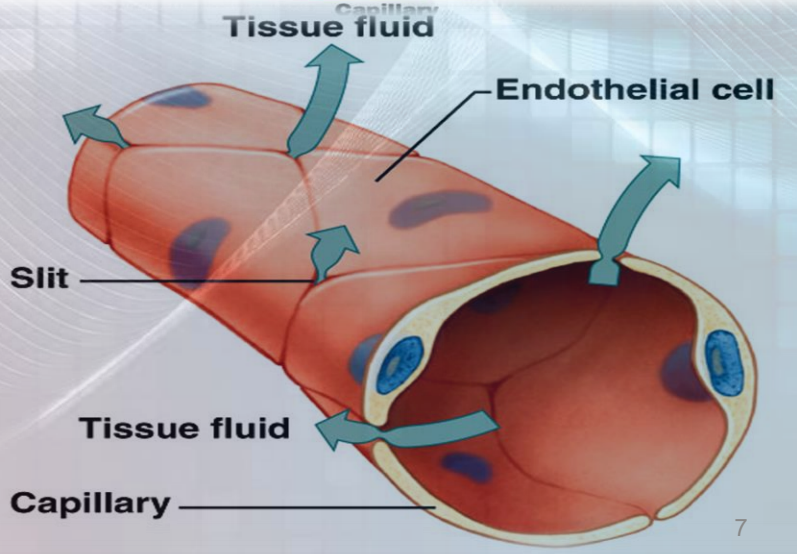




Capillary Structure

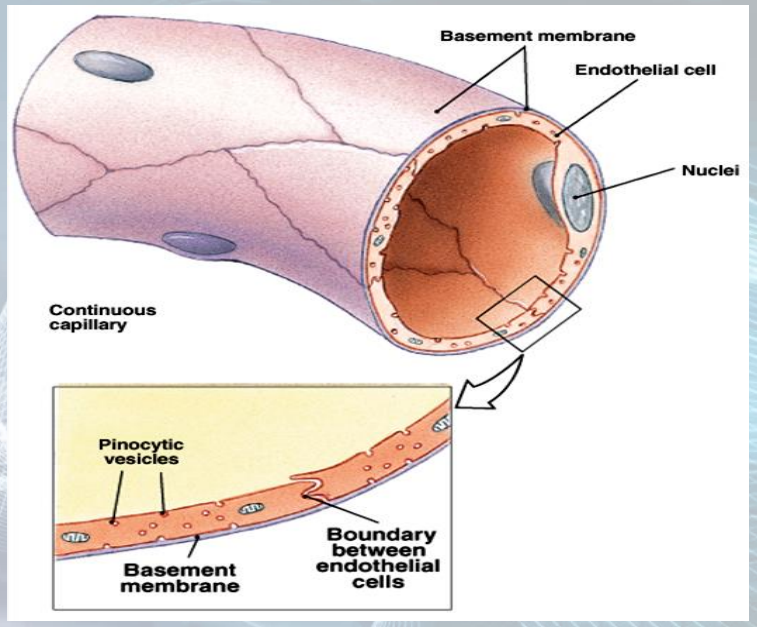
- Capillary is a small blood vessel of 0.5-1mm long, & 0.01mm in diameter.
- It consists **ONLY** of the Tunica Interna with a SINGLE Layer of endothelial cells surrounded by a basement membrane.

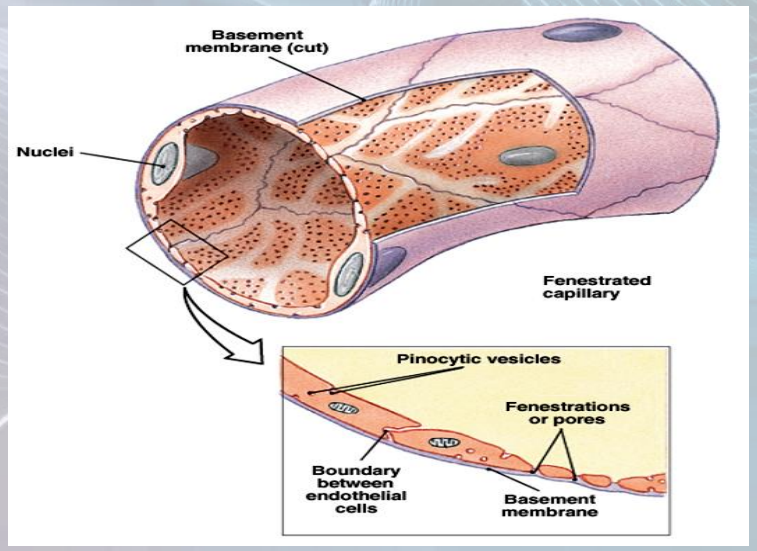




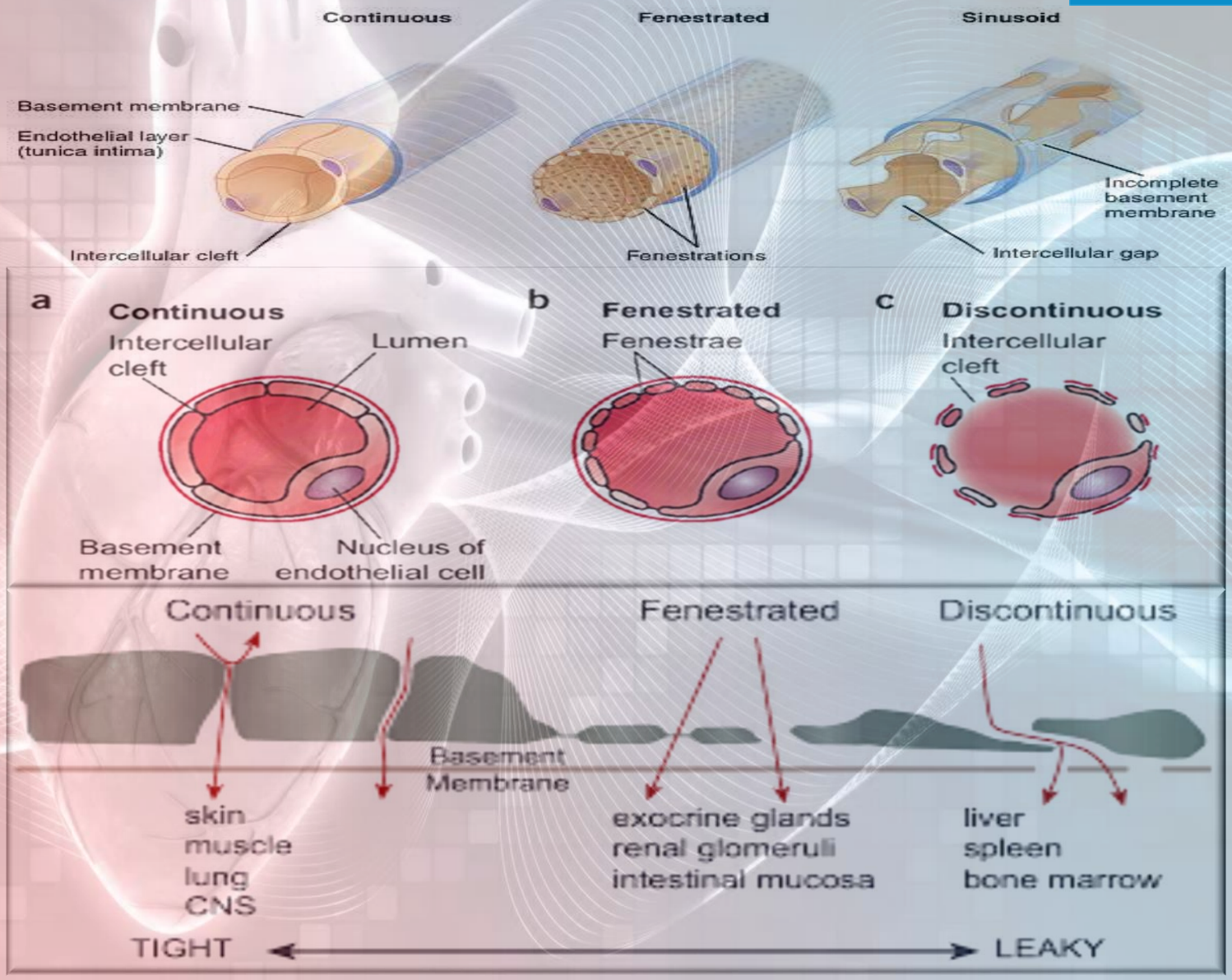
Types of Capillaries

- **Classified by permeability (size & diameter of pores):**
  - **Continuous**
    - Do not have fenestrae.
    - Allow only very small molecules to pass.
    - Found in brain, muscles, lung, & adipose tissue.
  - **Fenestrated**
    - Have wider pores.
    - Allow large substances to pass but not plasma proteins.
    - Found in kidney glomeruli, small intestine, & endocrine glands.
  - **Sinusoidal**
    - Large diameter with large fenestrae (wider gaps between the cells).
    - The endothelium is discontinuous.
    - Found in liver, spleen, bone marrow, lymphoid tissue, & some endocrine glands.





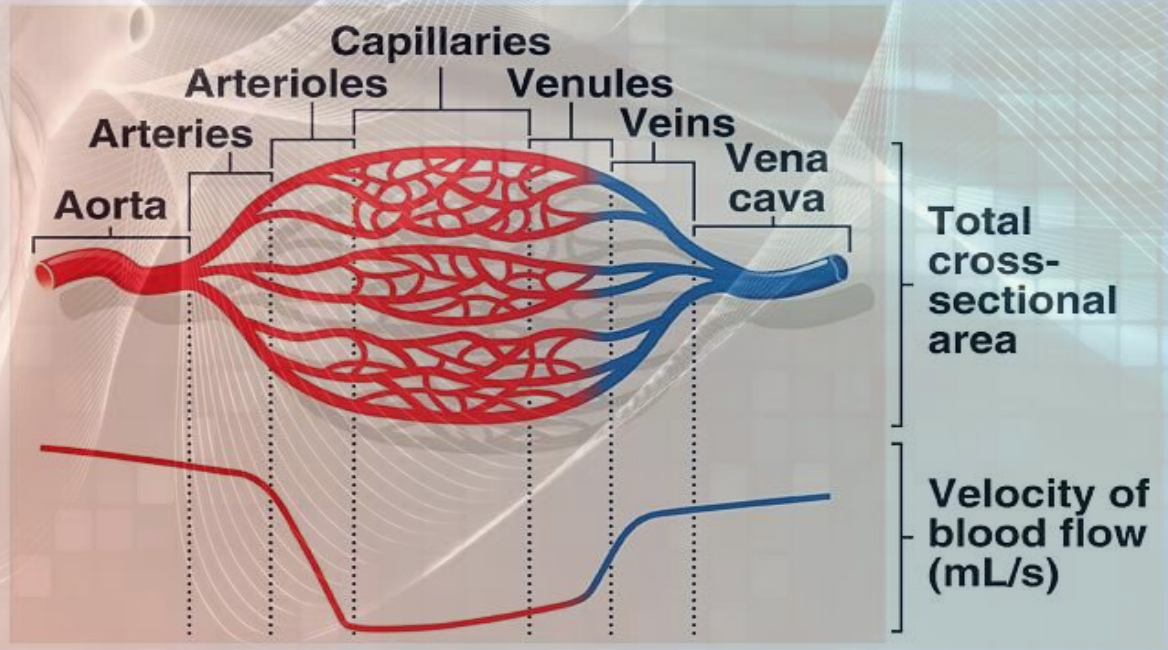
Types of Capillaries



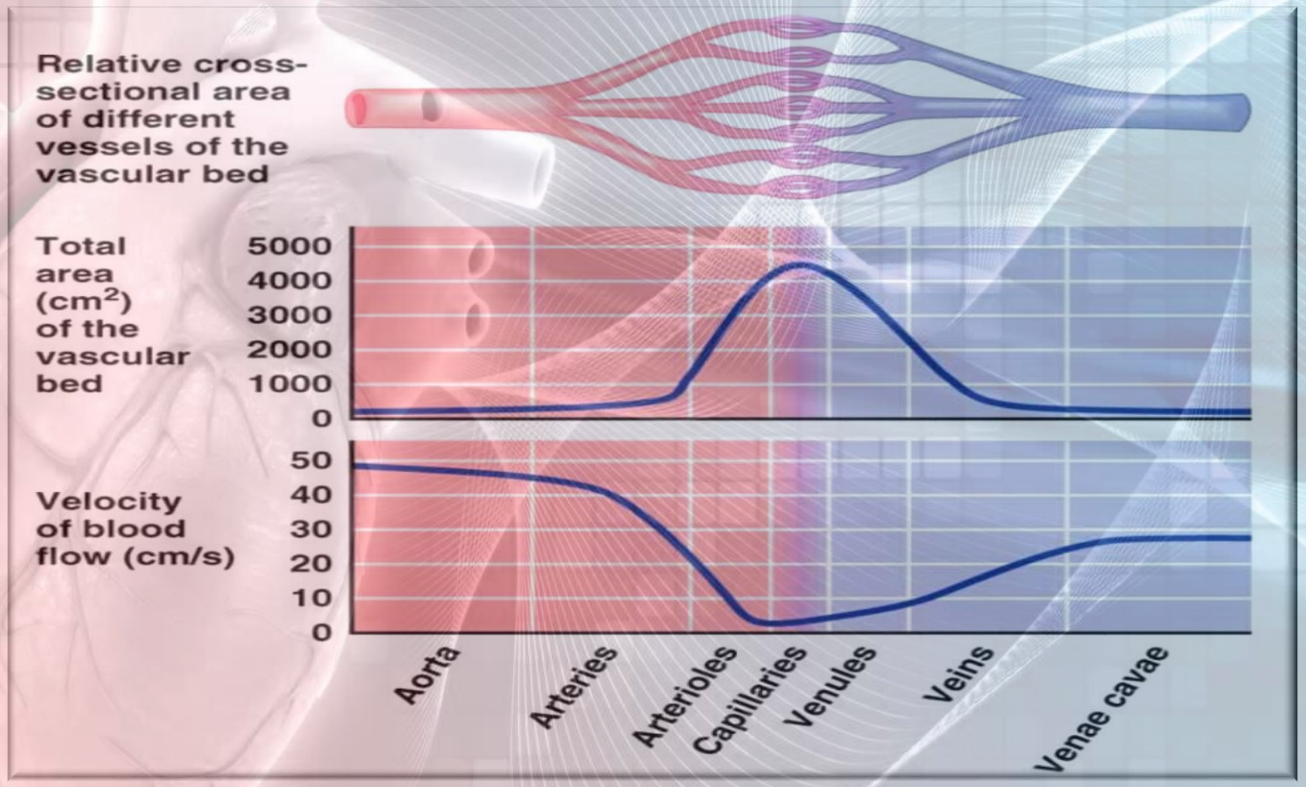
Capillaries Cross-Sectional Area

The velocity of blood flow within each segment of the circulatory system is inversely proportional to the total cross-sectional area of the segment. Because the aorta has the smallest total cross-sectional area of all circulatory segments, it has the highest velocity of blood flow.

- As the diameter of blood vessel decreases, the total cross-sectional area increases & velocity of blood flow decreases.
- Total capillary surface area of 700-1000 m^2



Capillaries Cross-Sectional Area



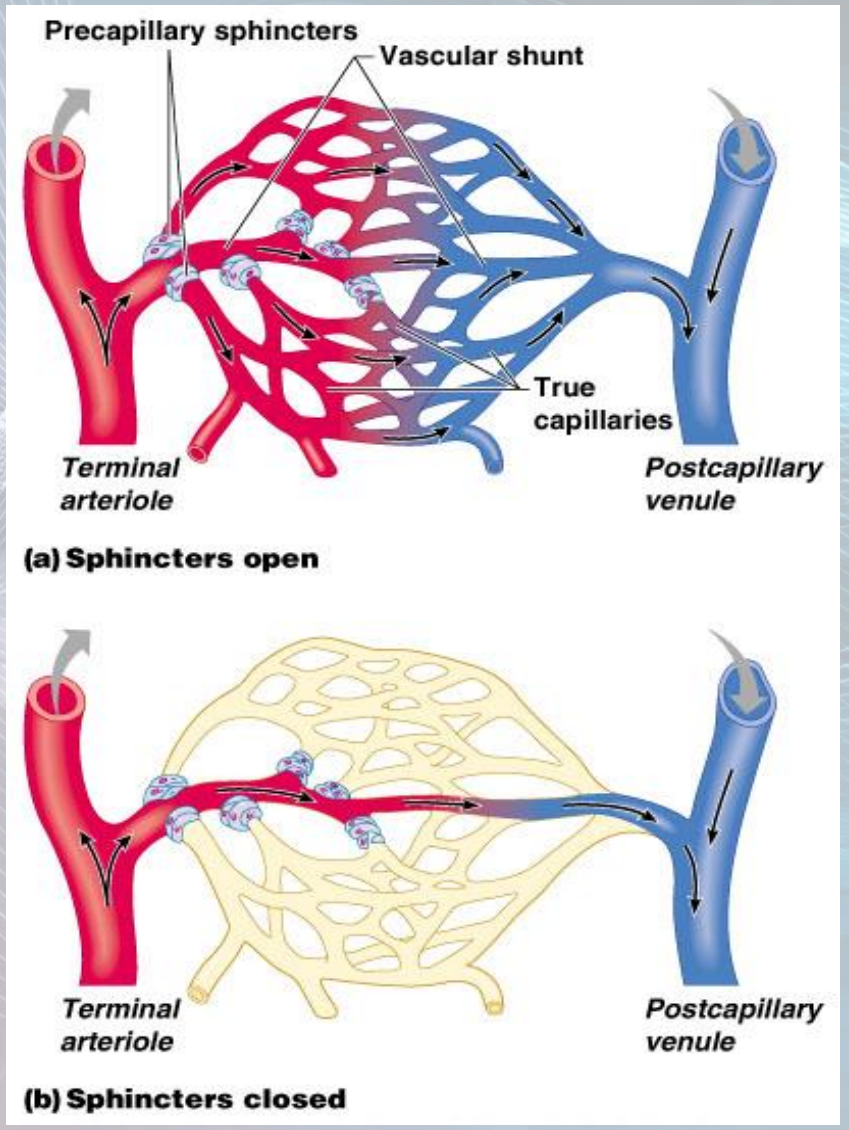
- As the diameter of blood vessel decreases, the total cross-sectional area increases & velocity of blood flow decreases.

Functions of Capillaries

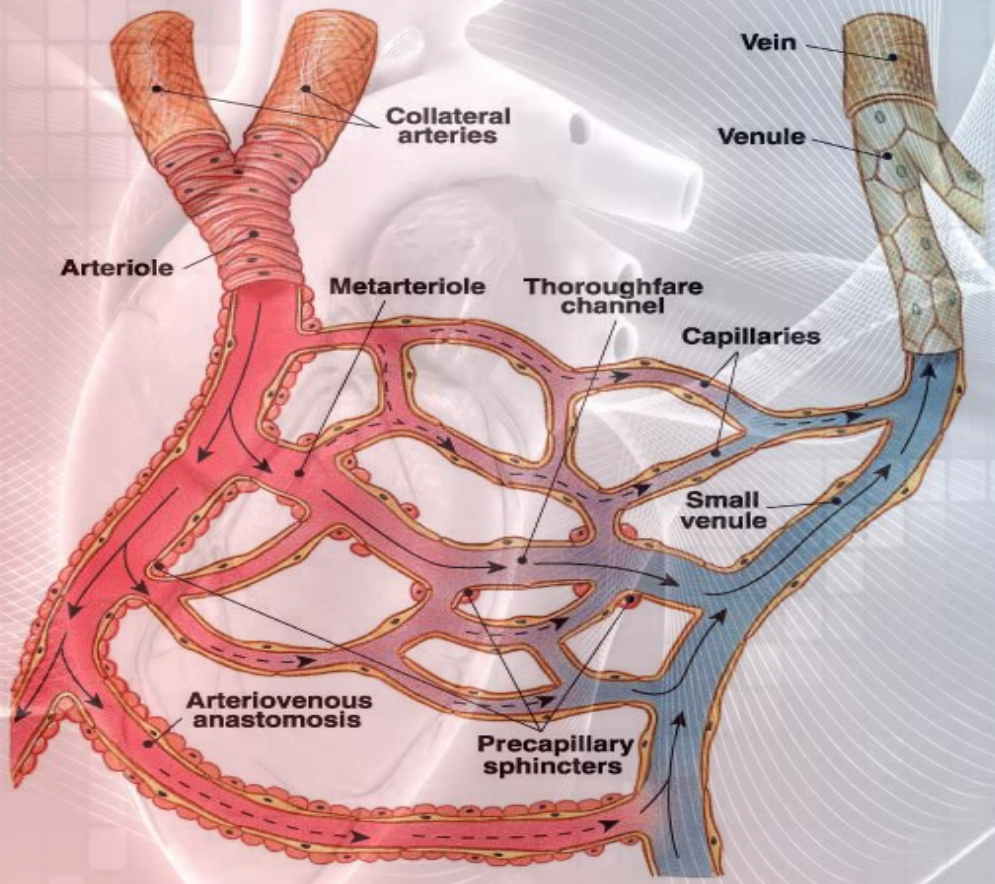
- **Exchange vessels between blood & tissues:**
  - Provide direct access to the cells.
  - Most permeable: They form a selectively permeable barrier between the circulatory system & the tissues supplied.
  - Transport nutrients & Oxygen from blood to the tissues.
  - Remove CO_2 & cellular waste products from the tissues to the blood.
- **Capillary tone.**
- **Play a metabolic role:** Produce PgI2, growth factors for blood cells, fibroblast GF, platelet GF; & in the lungs, angiotensin converting enzyme.
  - Inactivation of intercellular messengers.
  - Antithrombotic function.
- **Play role in temperature regulation:**
  - Blood vessel dilatation (vasodilatation), Increase heat loss across epidermis.
  - Blood vessel constriction (vasoconstriction), Heat conservation across epidermis.

Capillary Beds (Network)

- Capillaries are arranged in capillary beds.
- Arterioles divides into a number of metarterioles, which do not have a continuous smooth muscle coat.
- Blood flow through the metarteriole to enters capillary bed via precapillary sphincters.
- Venules drain capillary network.
- Arteriolar smooth muscle, metarterioles, & precapillary sphincters regulate the blood flow in capillary network.



Capillary Beds (Network)



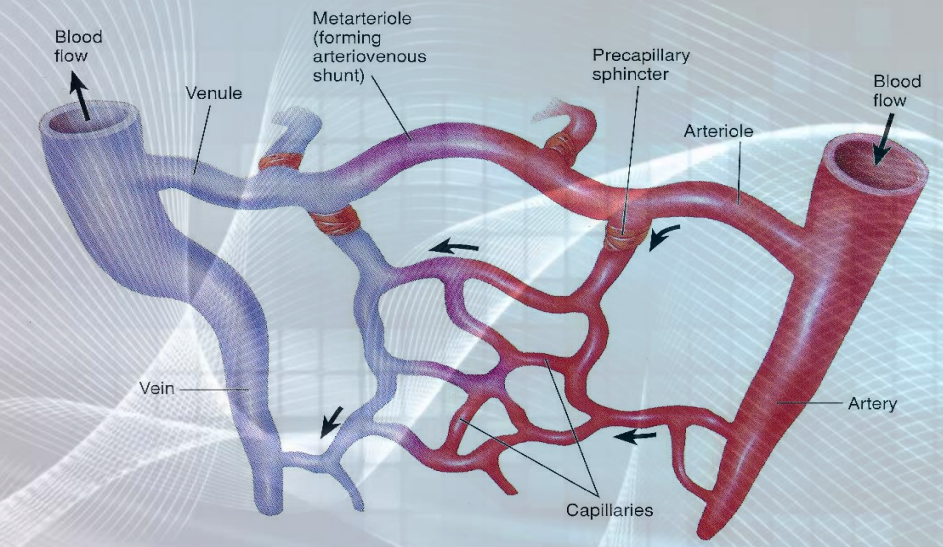
Blood flows from arterioles through metarterioles, then through capillary network

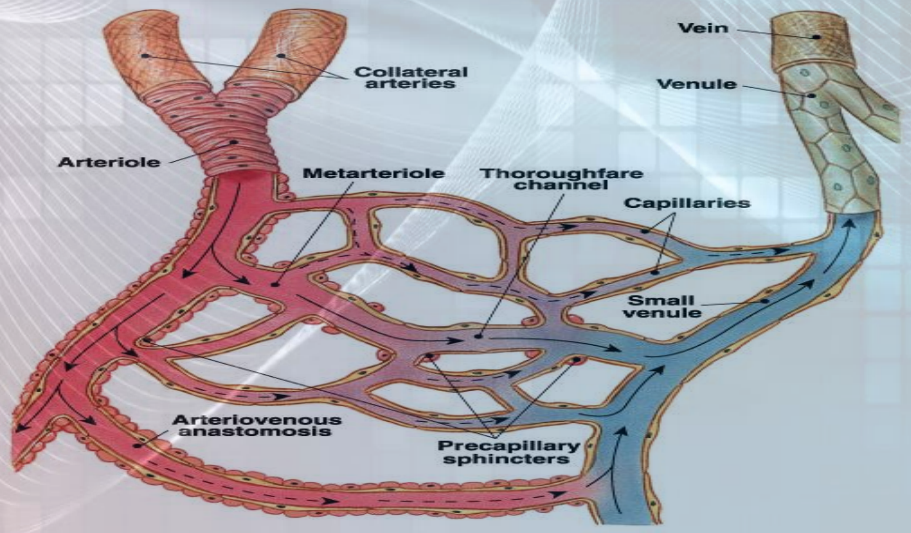
Venules drain network

Smooth muscle in arterioles, metarterioles, precapillary sphincters regulates blood flow

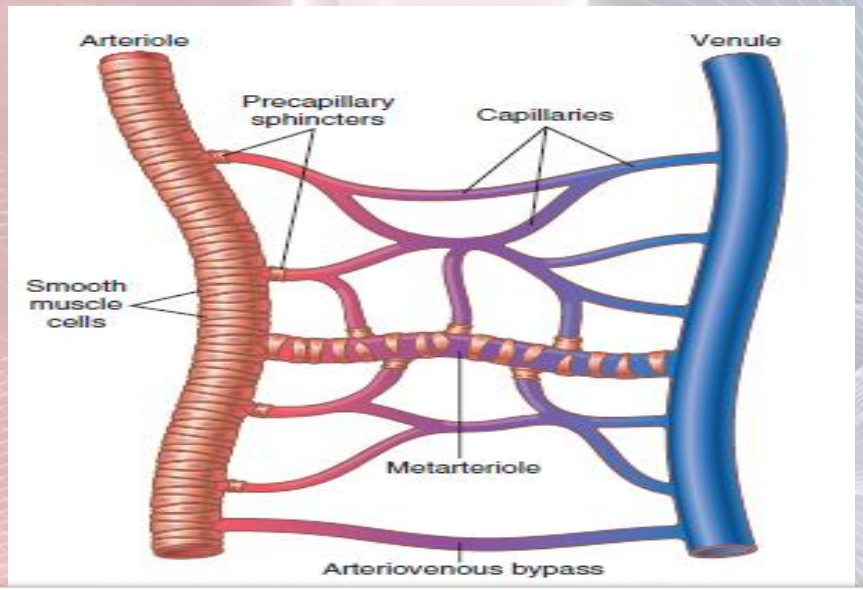
Capillary Beds (Network)

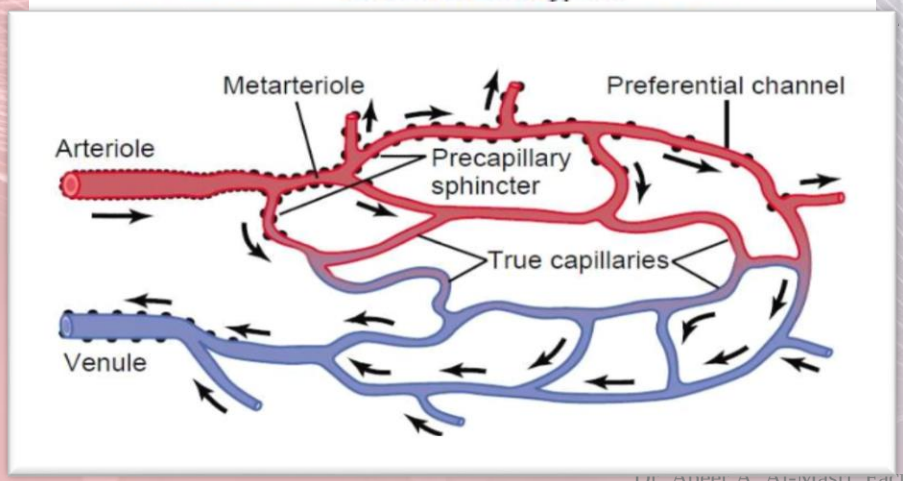
- **Capillary beds consist of two types of vessels:**
  - **Vascular shunt** – directly connects an arteriole to a venule.
  - **True capillaries** – exchange vessels.
    - O_2 & nutrients cross to cells
    - Co_2 & metabolic waste products cross into blood.

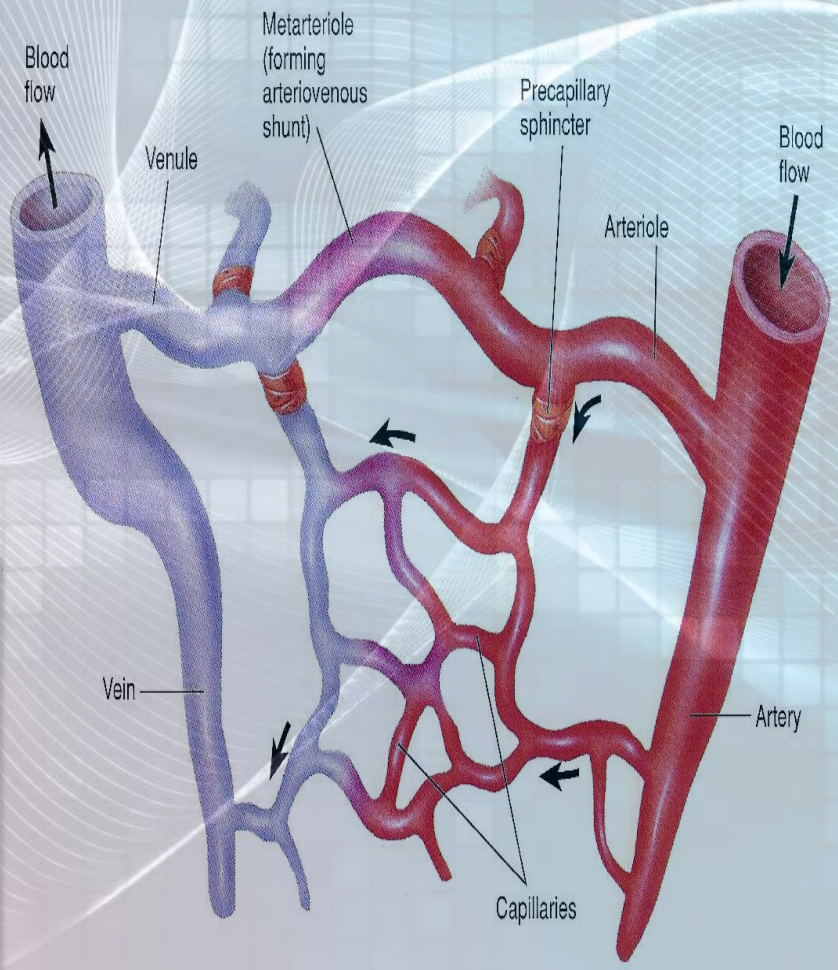




Components of Microcirculation

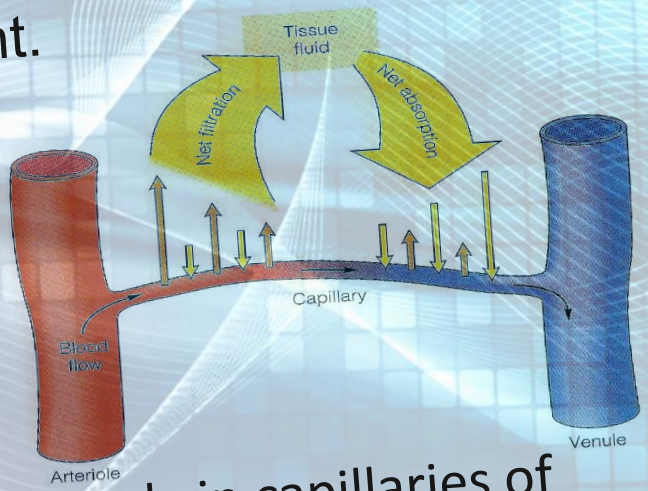






Mechanisms Of Trans-Capillary Exchange

- **Simple diffusion:** of lipid soluble gases (O_2 & CO_2) according to concentration gradient.
- **Filtration:** Bulk flow for fluid transfer by Starlings forces according to pressure gradient.
- **Vesicular transport:** Transcytosis.



- **Mediated (membrane) Transport:** Occurs only in capillaries of the brain & involves secondary active transport, e.g. transport of glucose moves by co-transporters in cell membrane..

Formation of Interstitial Fluid (IF)

- High content of proteins in plasma accounts for its higher osmotic pressure compared to that of the interstitial fluid (IF).
- High plasma osmotic pressure will attract fluid & dissolved substances from tissue spaces into the circulation.
- Opposing this osmotic force, hydrostatic pressure of the blood tends to force fluids out of the circulation into the tissue spaces.
- Equilibrium between osmotic & hydrostatic pressures is always maintained.

Diffusion at Capillary Beds

Fluid Balance – Starlings Forces

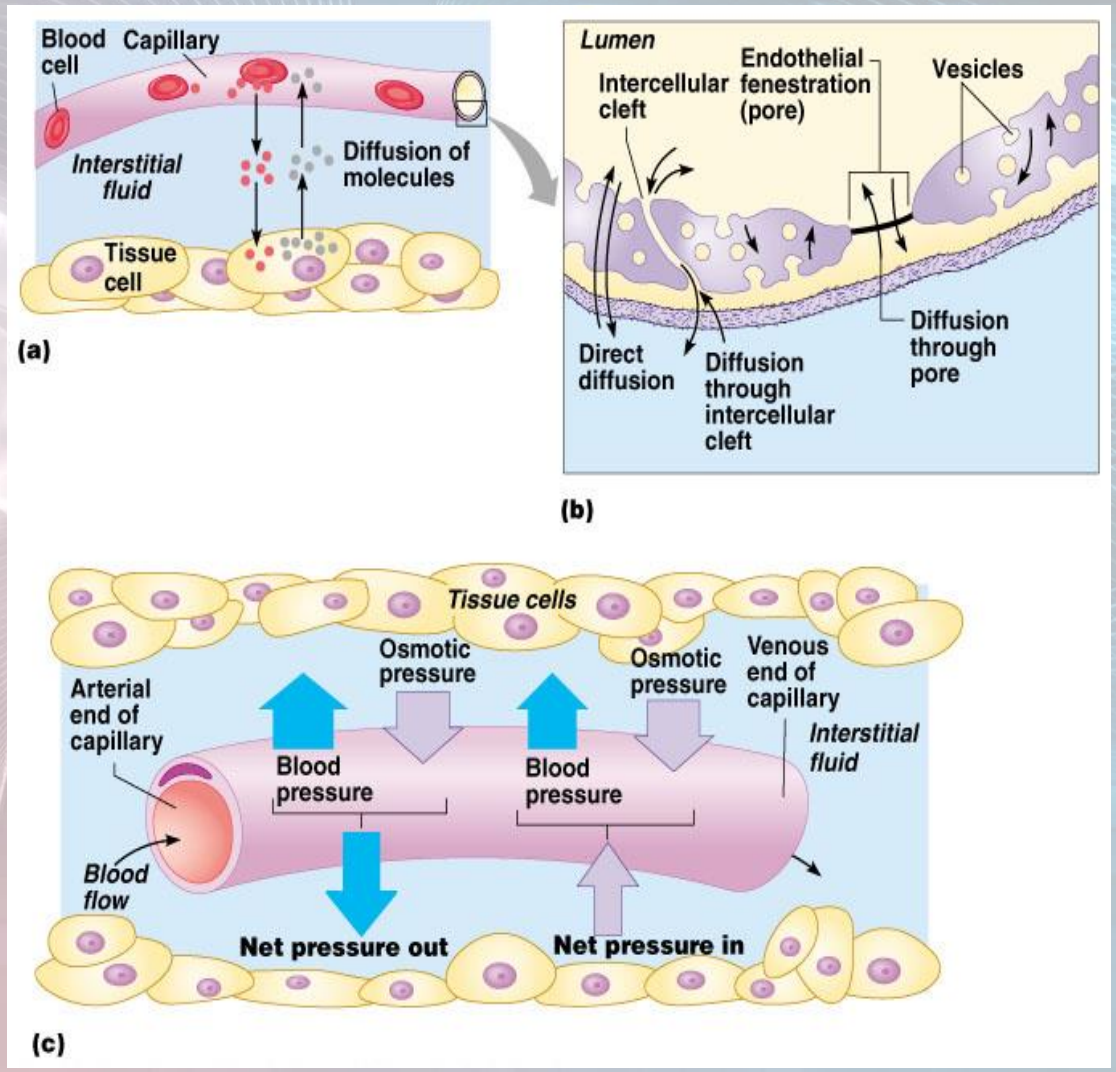
Outward Forces:

1. **Capillary blood pressure** (P_c = 35 to 15 mmHg)
2. **Interstitial fluid pressure** (P_{IF} = 0 mmHg)
3. **Interstitial fluid colloidal osmotic pressure** (μ_{IF} = 3 mmHg)

TOTAL = 38 to 18 mmHg

Inward Force:

1. **Plasma colloidal osmotic pressure** (μ_C = 25 mmHg)
2. **Interstitial hydrostatic pressure** (P_{IF} = 0 mmHg)



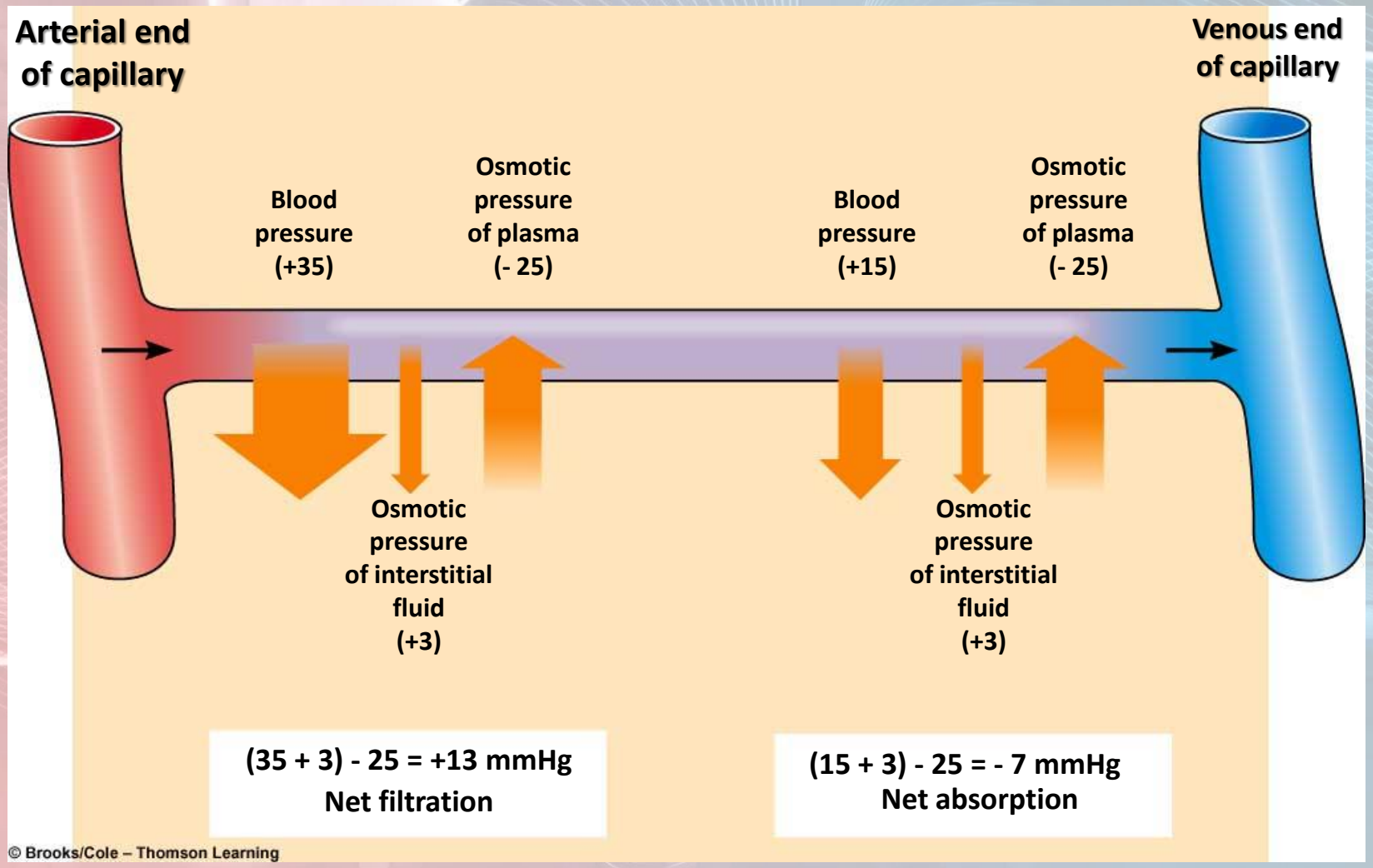
Interstitial Hydrostatic Pressure

- Interstitial hydrostatic pressure (P_{IF}) = 0mmHg.
- P_{IF} varies from one organ to another:
  - Subcutaneous tissues: -2mmHg.
  - Liver, Kidney: +1mmHg.
  - Brain: As high as +6mmHg.

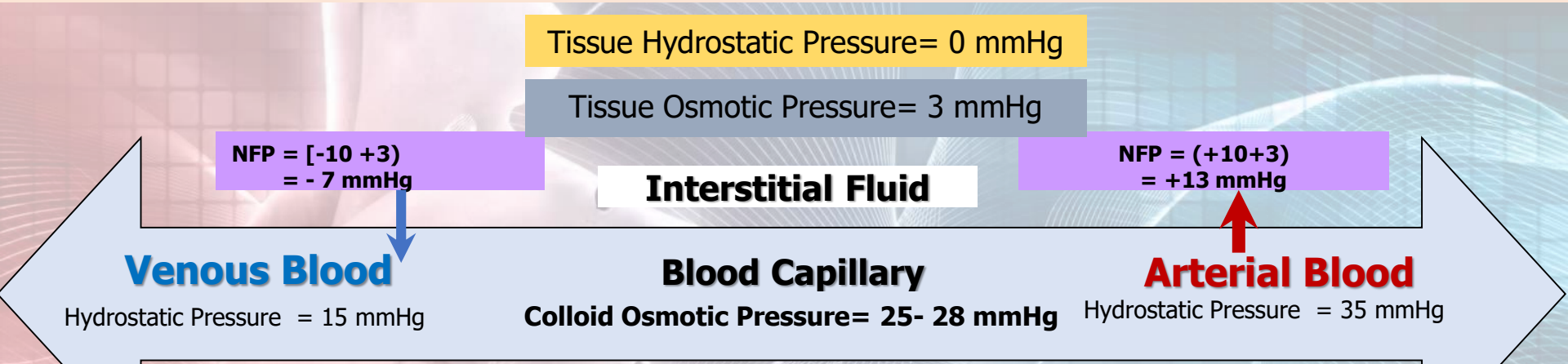
Regulation of Capillary & Interstitial Fluid Exchange

- Blood pressure, capillary permeability & osmosis affect movement of fluid from **capillaries**.
- **A net movement of fluid occurs from blood into tissues will be affected by balance of net forces found in the capillaries & tissue spaces.**
- Fluid gained by tissues is removed by **lymphatic system**.

Normal Forces at The Arterial & Venous Ends of The Capillary



Normal Forces at The Arterial & Venous Ends of The Capillary



❑ At arterial end:

- Hydrostatic pressure dominates at the arterial end, as a net sum of pressure forces (blood hydrostatic pressure + Interstitial fluid (IF) osmotic pressure) flow fluid out of the circulation.
- Water moves **out** of the capillary with a net filtration pressure (NFP) of +13 mmHg.
- 13 mmHg NFP causes an average of 1/200 of plasma in flowing blood to filter out of arterial end of the capillary into the intestinal space.

❑ At venous end:

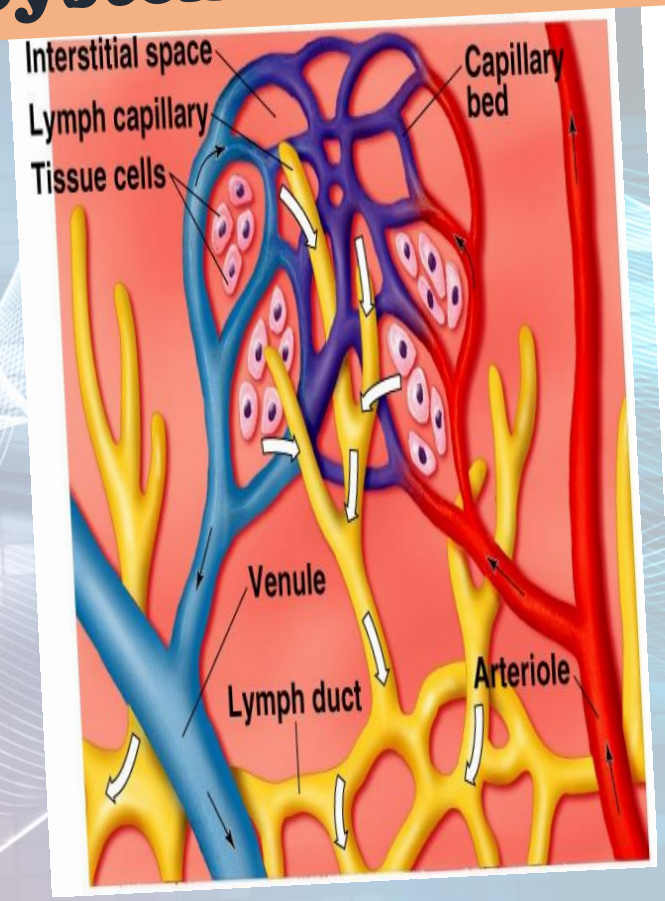
- Oncotic pressure dominates at the venous end, as a net sum of pressure forces (blood osmotic pressure + Interstitial fluid (IF) hydrostatic pressure) flow fluid into the bloodstream.
- Water moves **into** the capillary with a NFP of -7 mmHg.

Clinical Significance of Capillary Filtration

- **Blood loss:** Vasoconstriction of arterioles → decrease capillary hydrostatic pressure. Osmotic pressure of plasma proteins favours absorption of interstitial fluid →↑ blood volume.
- **Congestive heart failure:** Venous pressure rises → build-up of blood in capillaries →↑ capillary hydrostatic pressure →↑ filtration → oedema.
- **Hypoproteinemia** (Starvation, liver disease) → ↓ plasma protein colloid osmotic pressure → loss of fluid from capillaries → oedema.
- **Inflammation:** The gaps between the endothelial cells increase because of the inflammatory mediators →↑ movement of proteins into the interstitium → oedema.

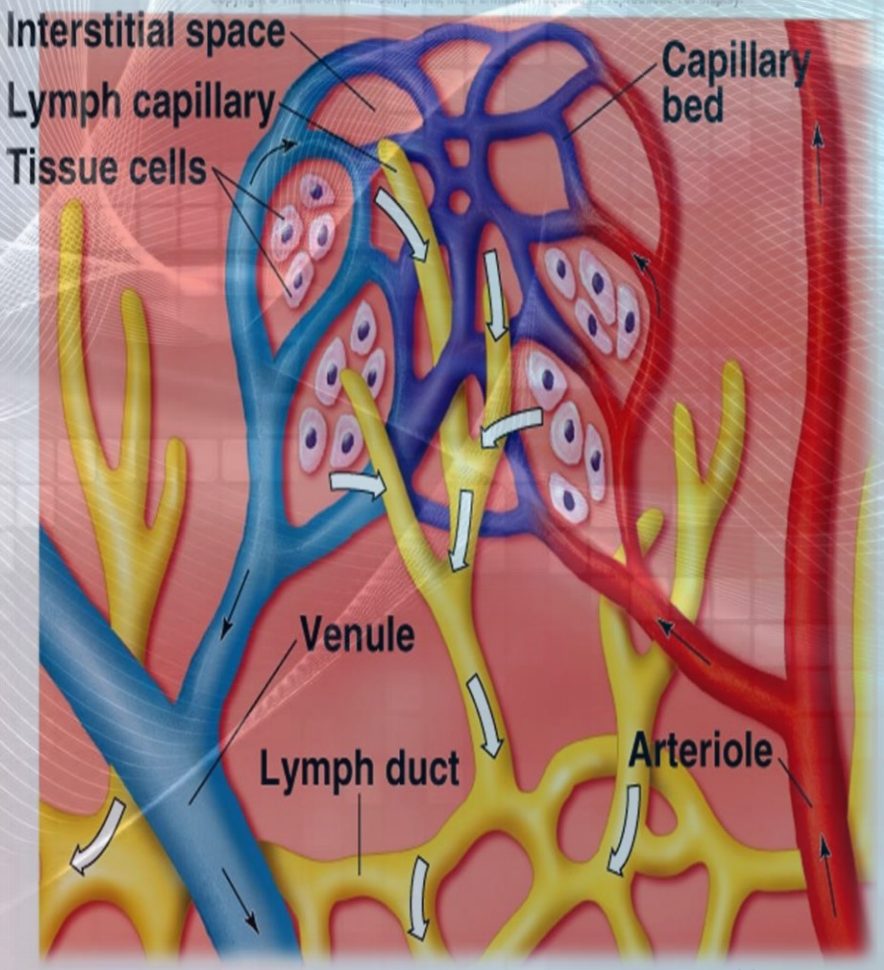
Lymphatic System

- Lymphatic vessels present between capillaries.
- **3 basic functions:**
  1. Drain excess interstitial (tissue) fluid back to the blood, in order to maintain original blood volume.
  2. Transports absorbed fat from small intestine to the blood.
  3. Helps provide immunological defenses against pathogens.



Lymphatic Capillaries System

- Interstitial fluid enter the lymphatic capillaries through loose junctions between endothelial cells.
- Lymph flow back to the thoracic duct with the help of contraction of both the lymphatic vessel wall's smooth muscle & the surrounding skeletal muscle.
- Failure of lymphatic drainage can lead to edema.



Edema

- Is the term used to describe unusual accumulation of interstitial fluid.
- Occurs when an alteration in Starlings forces balance:
  - Any **decrease in plasma protein** (albumin) concentration, will lead to a decrease in plasma osmolarity, allowing fluid to escape from circulation to the interstitial space.
  - Any **increase in capillary hydrostatic pressure**.
- **Failure of lymphatic drainage** .
- Occurs **secondary to** Histamine or Bradykinin administration, where they increase capillary permeability leading to edema.

Hormones Involved In Edema

- **Activation** of Renin-Angiotensin-Aldosterone System which will cause secondary Hyperaldosteronism, leading to Na+ retention.
- **Activation** of Anti-diuretic hormone (ADH)/Vasopressin, leading to water retention.

Thank You