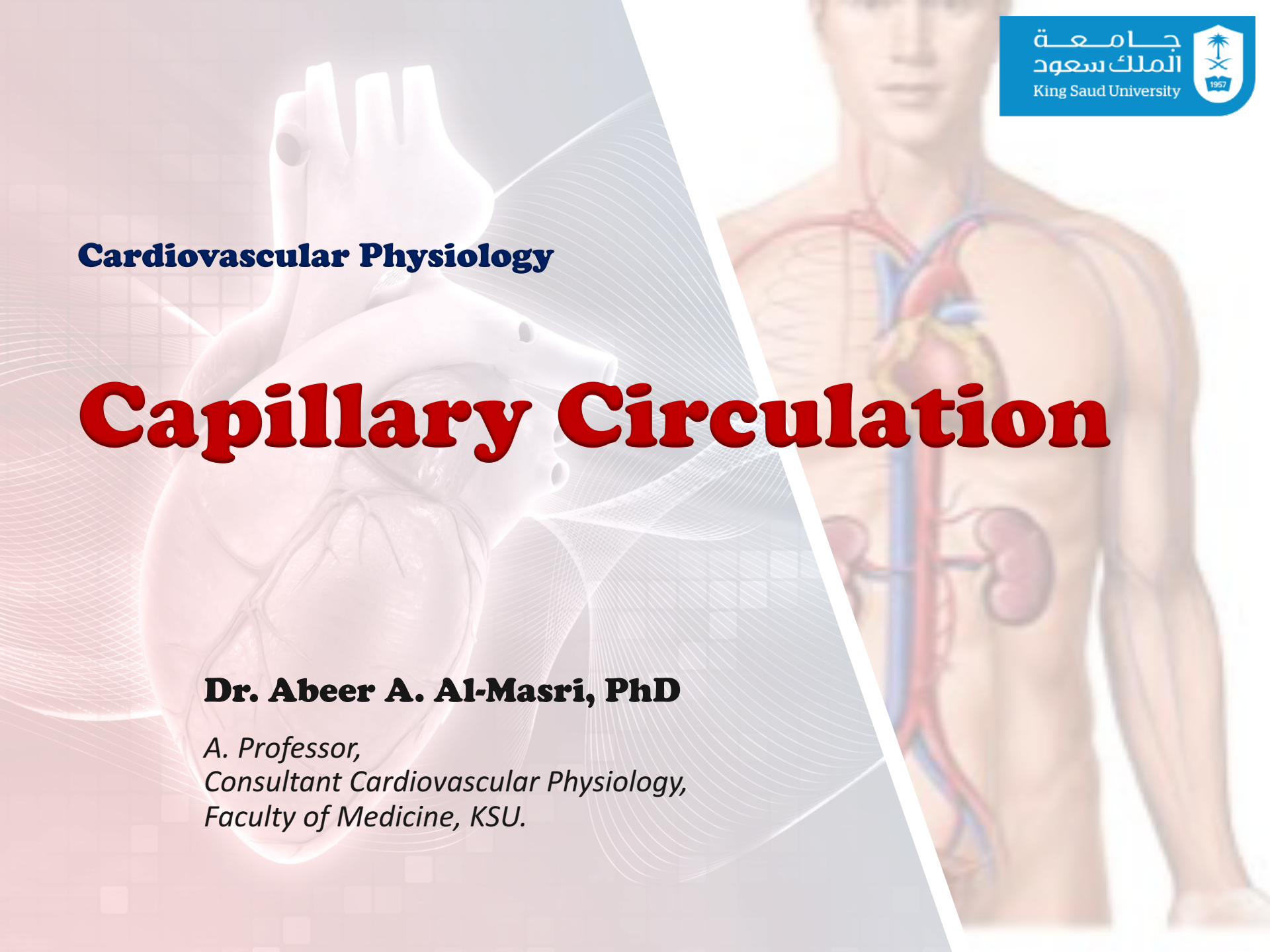


Cardiovascular Physiology

Capillary Circulation

Dr. Abeer A. Al-Masri, PhD

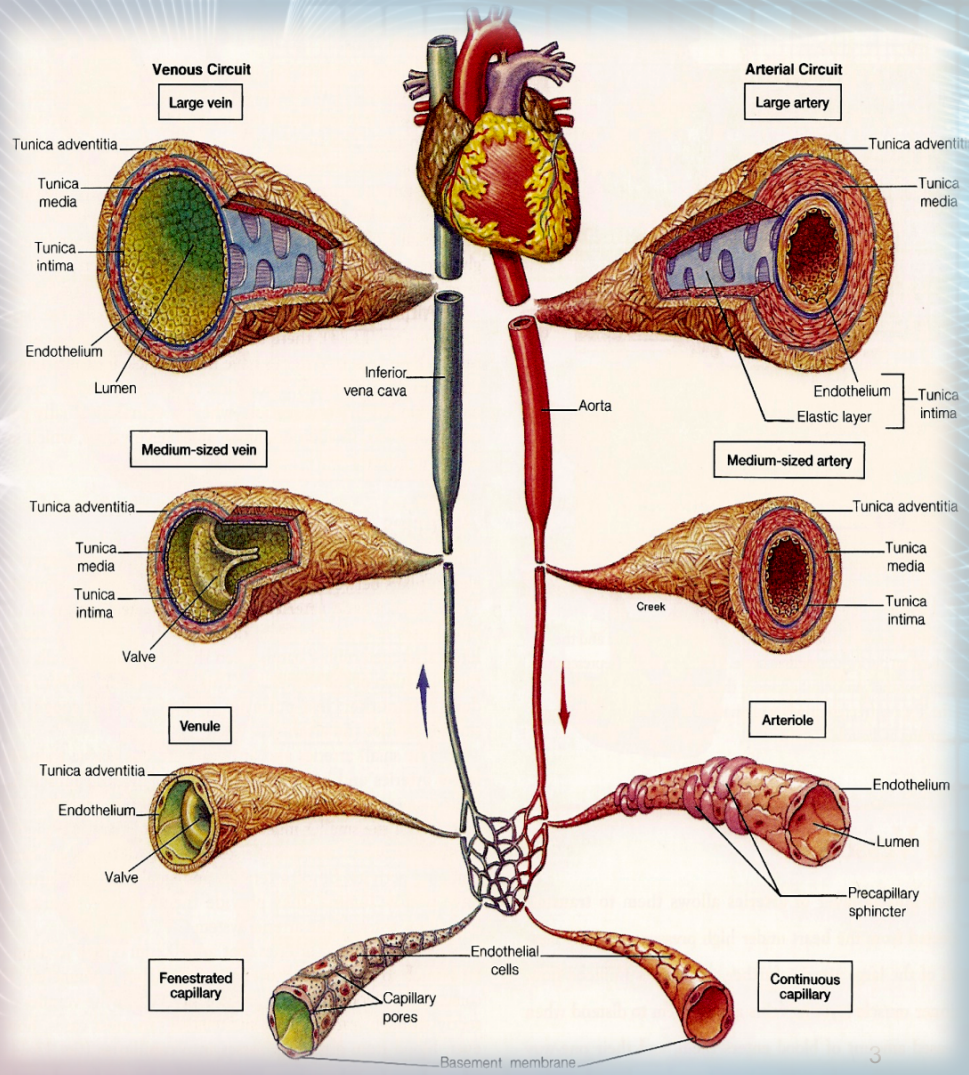
A. Professor,
Consultant Cardiovascular Physiology,
Faculty of Medicine, KSU.

Lecture Outcomes

- To describe the structure & function of capillaries.
- To define different Starling forces acting on the capillary wall.
- To understand formation of interstitial fluid.
- To understand the role of lymphatics.
- To recognize mechanism of formation of edema.

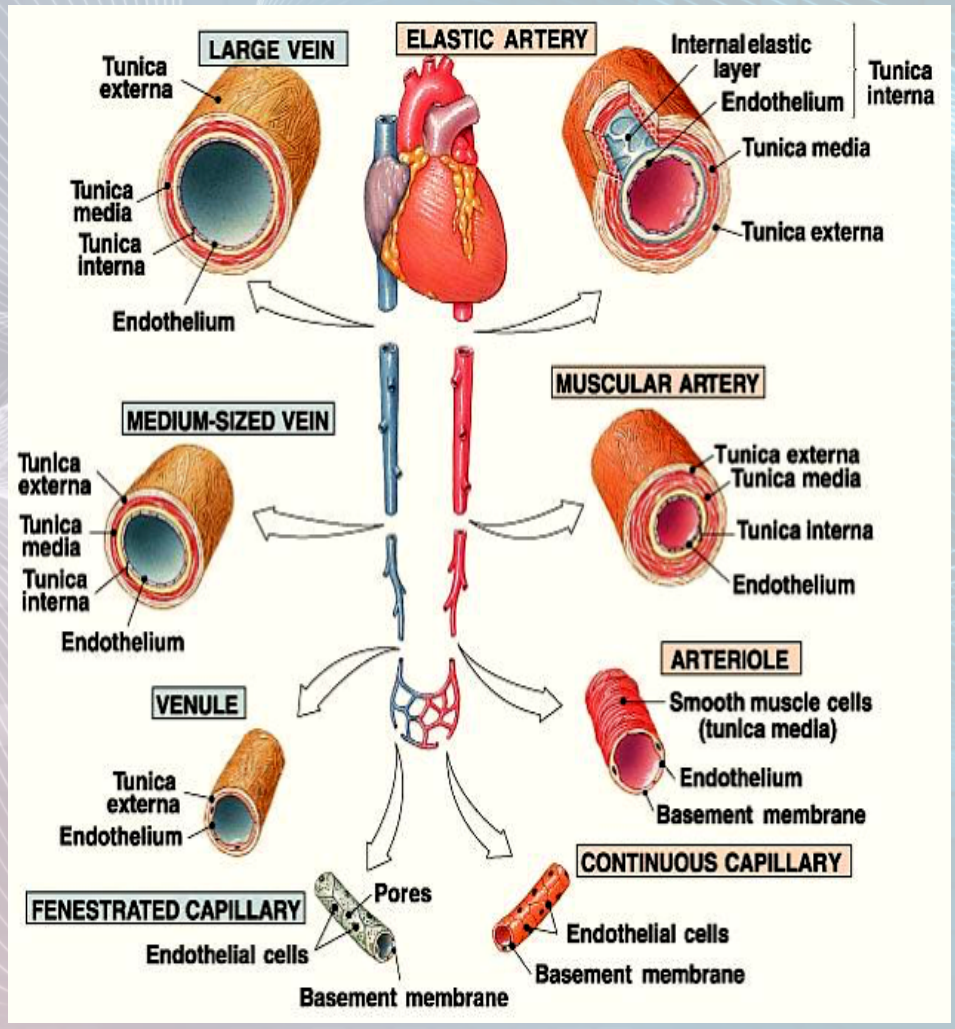
Capillaries

- Capillaries are the smallest blood vessels (microcirculatory vessels) in the vascular system.
- 5% of circulating blood volume is present in the capillaries.
- Over 10 billion capillaries in the body.

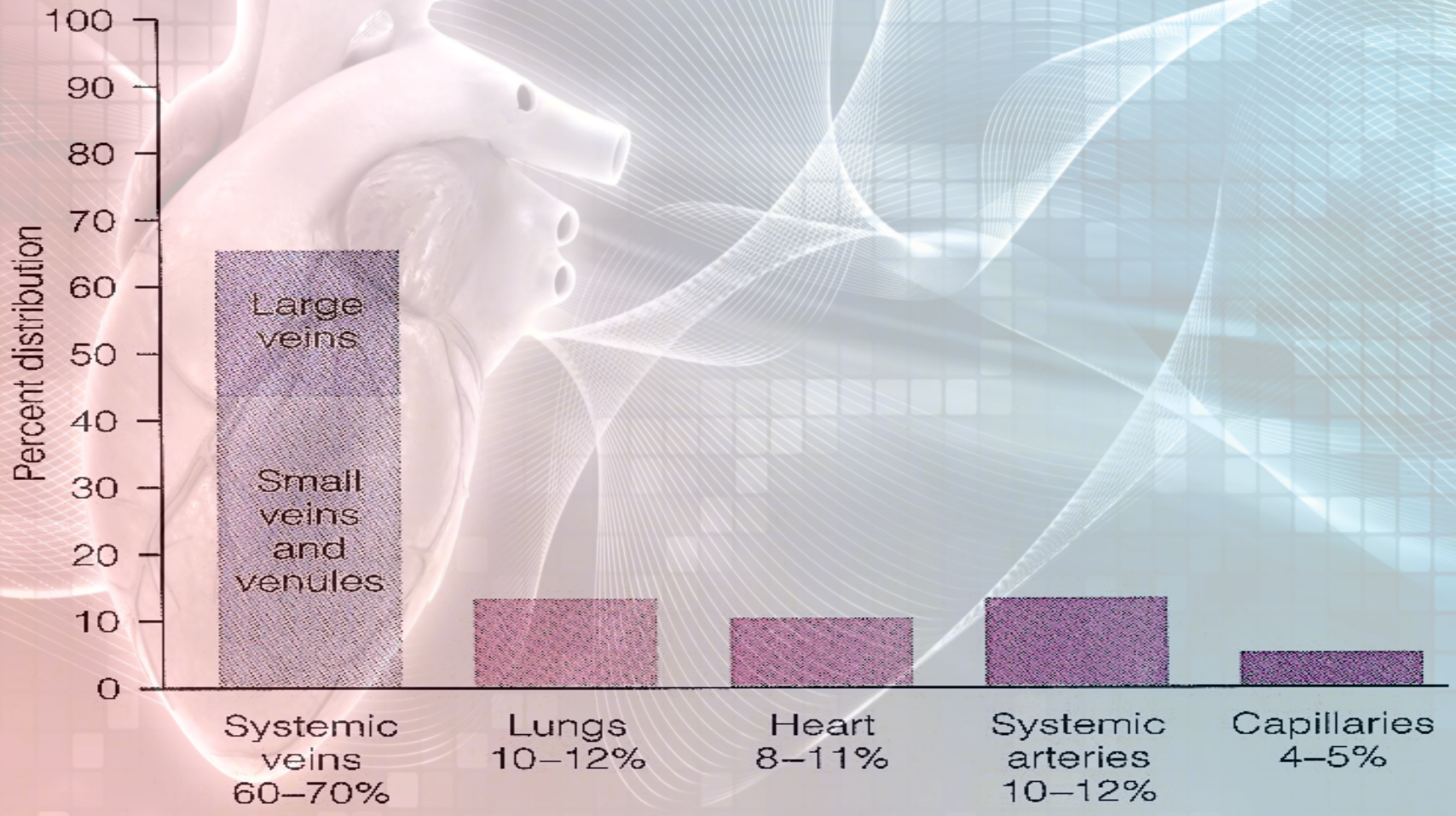


Blood Vessels Comparison

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.



Distribution of Blood Within The Circulatory System At Rest

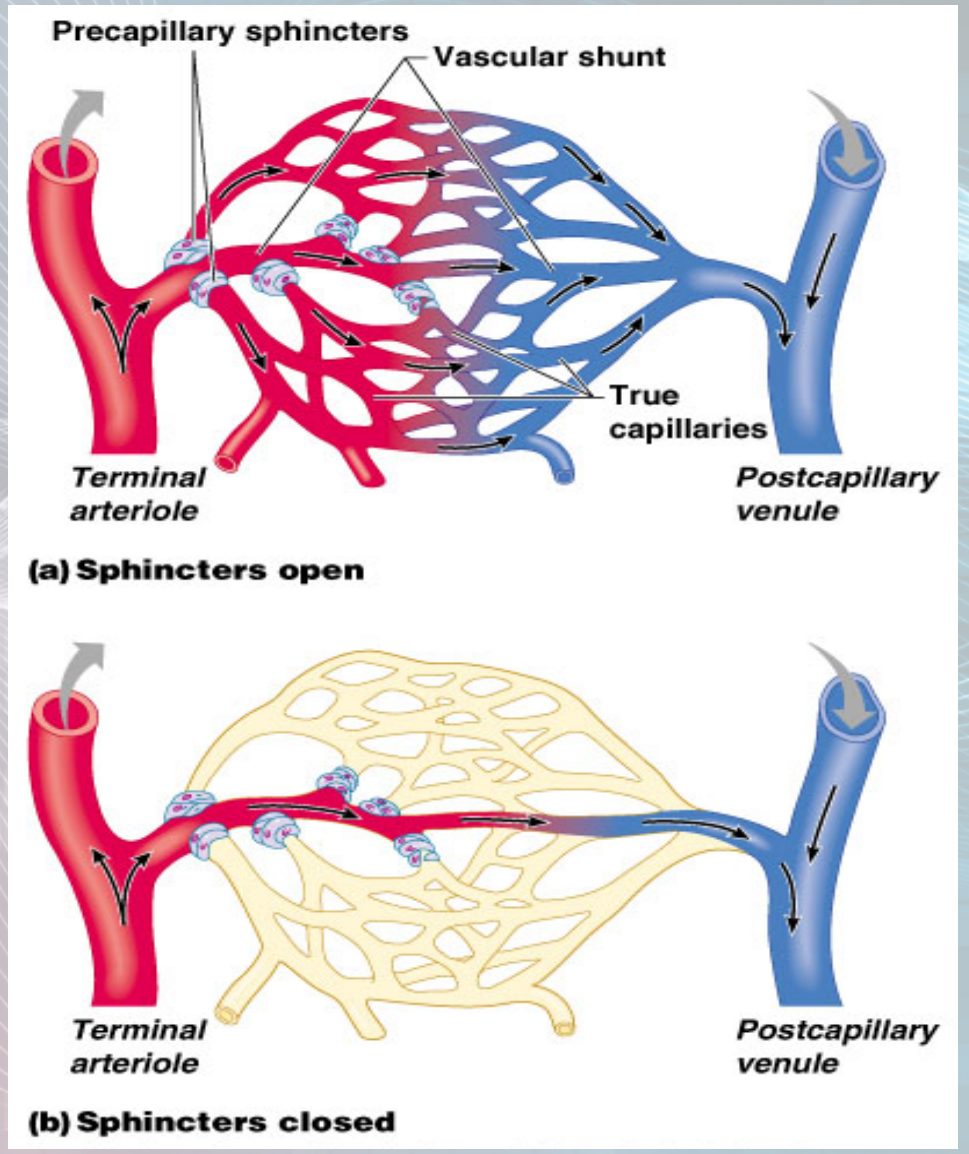


Function of Capillaries

- **Exchange vessels between blood & tissues:**
  - Provide direct access to the cells.
  - Most permeable.
  - Transport nutrients & Oxygen from blood to the tissues.
  - Remove CO_2 & cellular waste products from the tissues to the blood.
- **Capillary tone.**
- **Play role in temperature regulation:**
  - Blood vessel dilatation (vasodilatation)
    - Increase heat loss across epidermis.
  - Blood vessel constriction (vasoconstriction).
    - Heat conservation across epidermis.

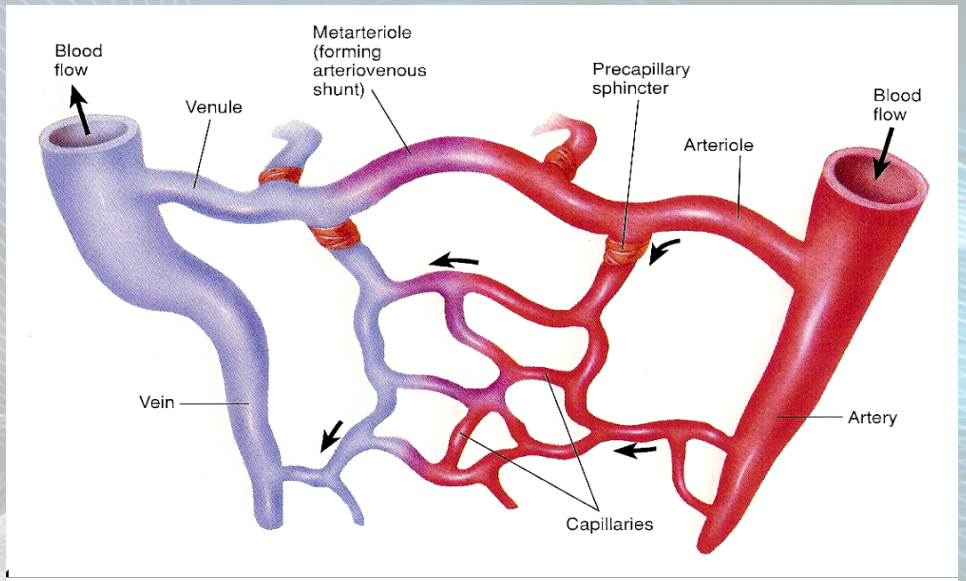
Capillary Beds (Network)

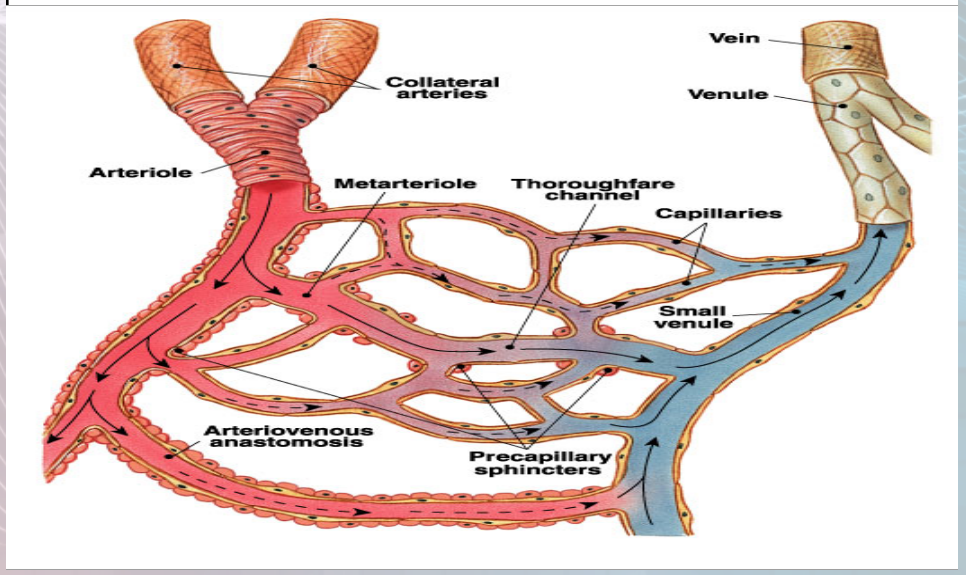
- Capillaries are arranged in capillary beds.
- Arterioles divides into a number of metarterioles, which do not have a continuous smooth muscle coat.
- Blood flow through the metarteriole to enters capillary bed via precapillary sphincters.
- Venules drain capillary network.
- Arteriolar smooth muscle,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



Capillary Bed (Network)

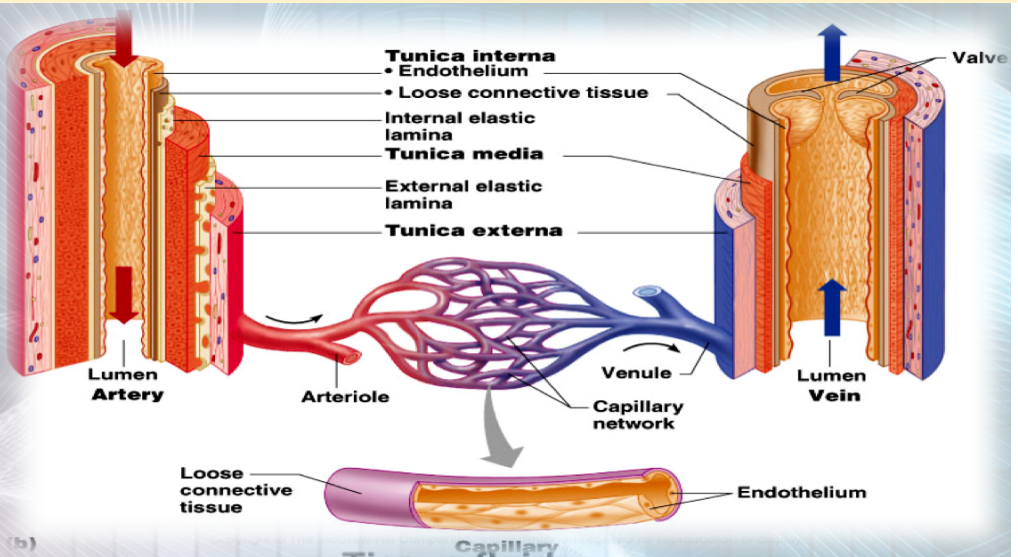
- **Capillary beds consist of two types of vessels:**
  - Vascular shunt – directly connects an arteriole to a venule.
  - True capillaries – exchange vessels.
    - O_2 & nutrients cross to cells
    - Co_2 & metabolic waste products cross into blood.

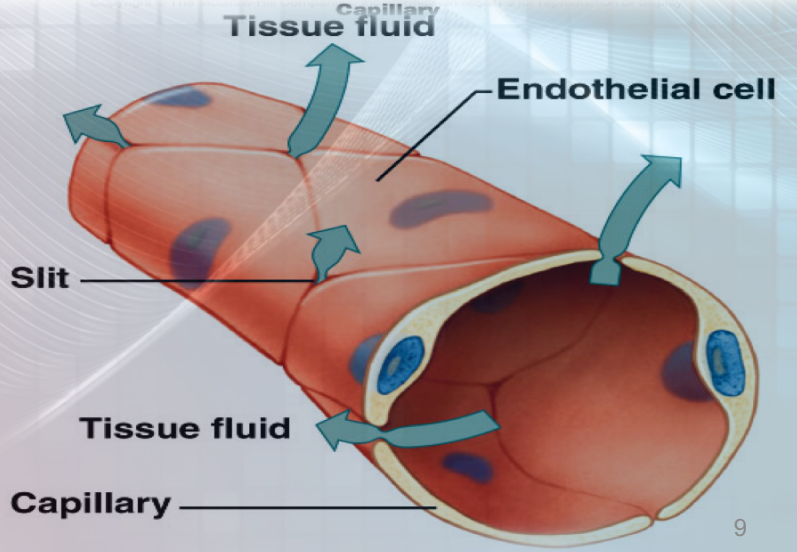




Capillary Structure

- 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.



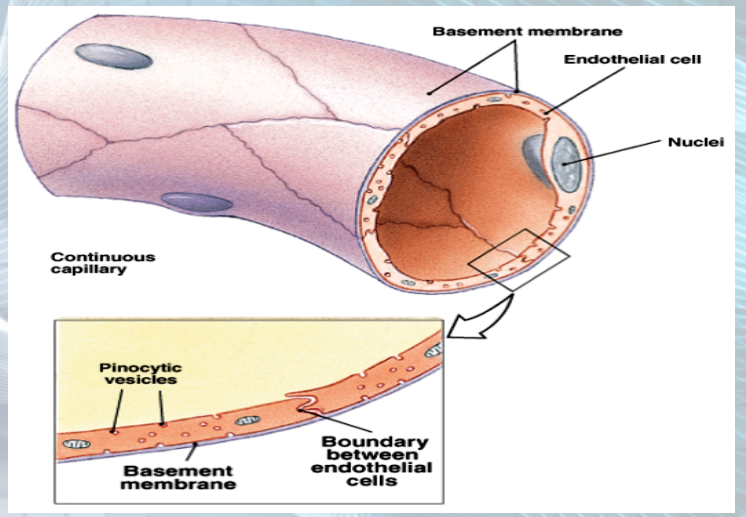


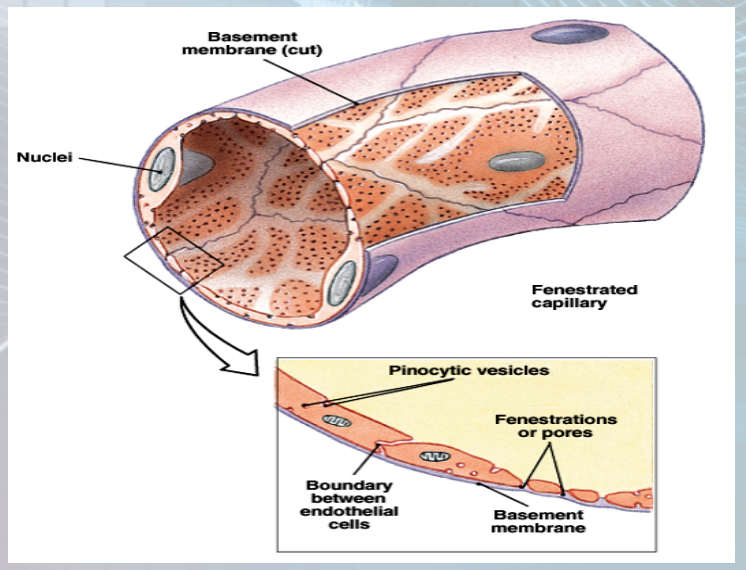
Types of Capillaries

Classified by permeability (size & diameter of pores):

1. **Continuous.**
2. **Fenestrated.**
3. **Sinusoidal.**

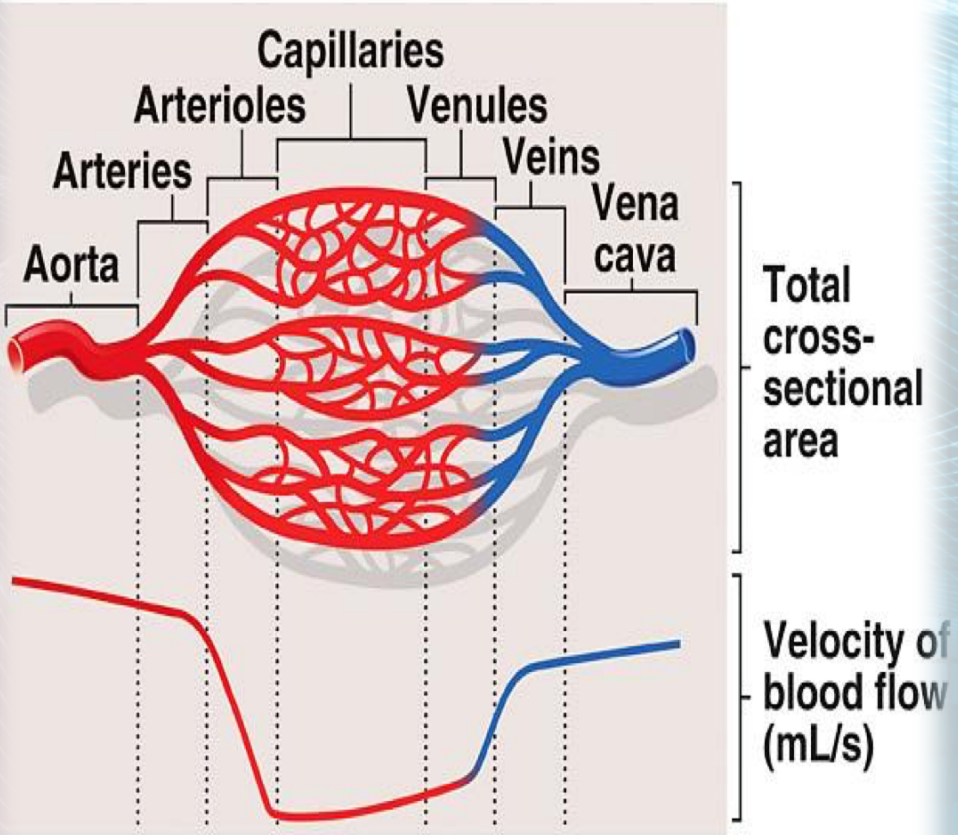
- **Brain:**
  - Very tight pores (**Continuous**).
  - Allow only very small molecules to pass.
- **Kidney & Intestine:**
  - Wider pores (**Fenestrated**).
- **Liver:**
  - The endothelium is discontinuous.
  - There are wide gaps between the cells (**Sinusoidal**).





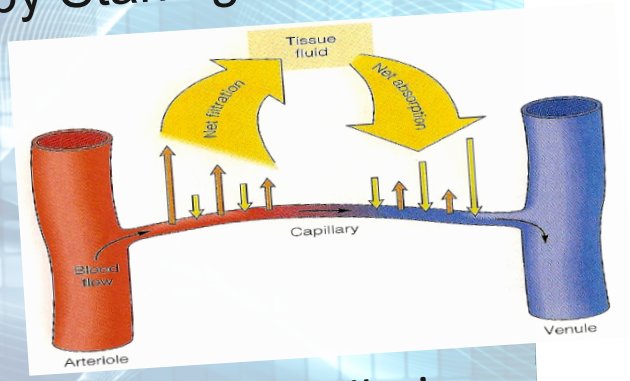
Cross- Sectional Area

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



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 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

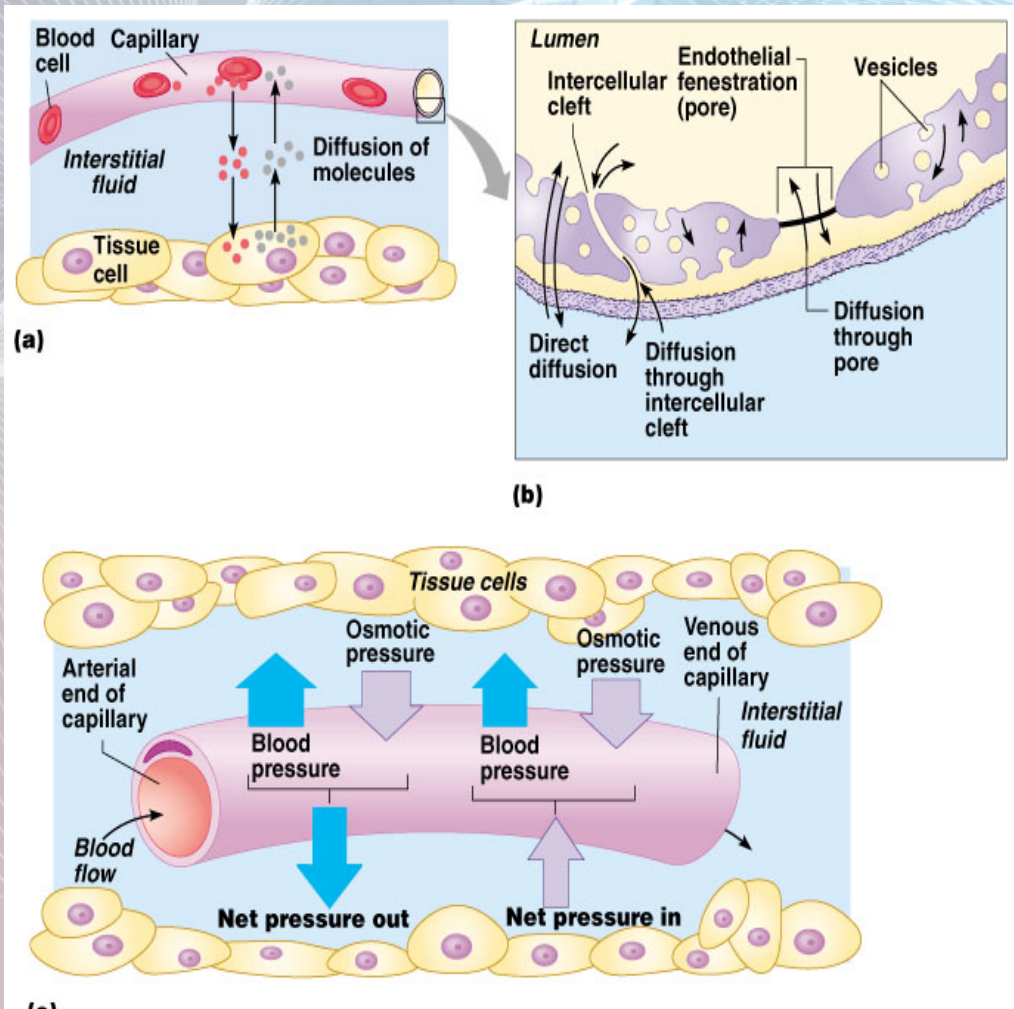
Outward Forces:

1. **Capillary hydrostatic pressure** (P_c = 30-35 to 15-20 mmHg)
3. **Interstitial oncotic (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)



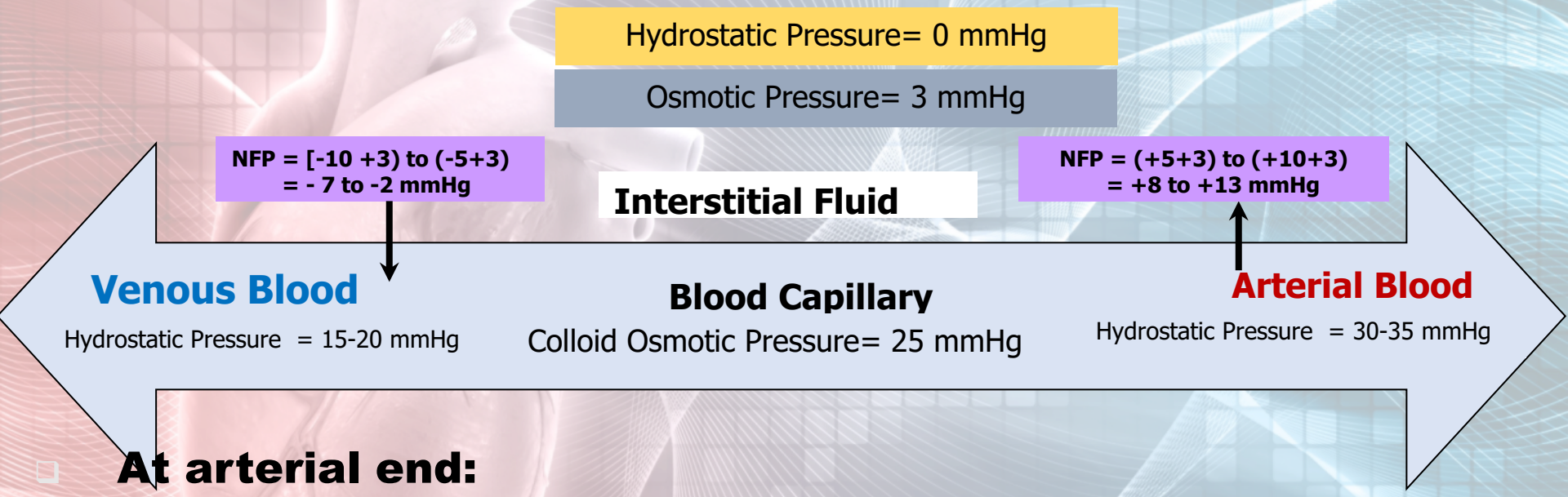
Interstitial Hydrostatic Pressure

- 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.

Capillary Exchange & Interstitial Fluid Volume Regulation

- 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**.

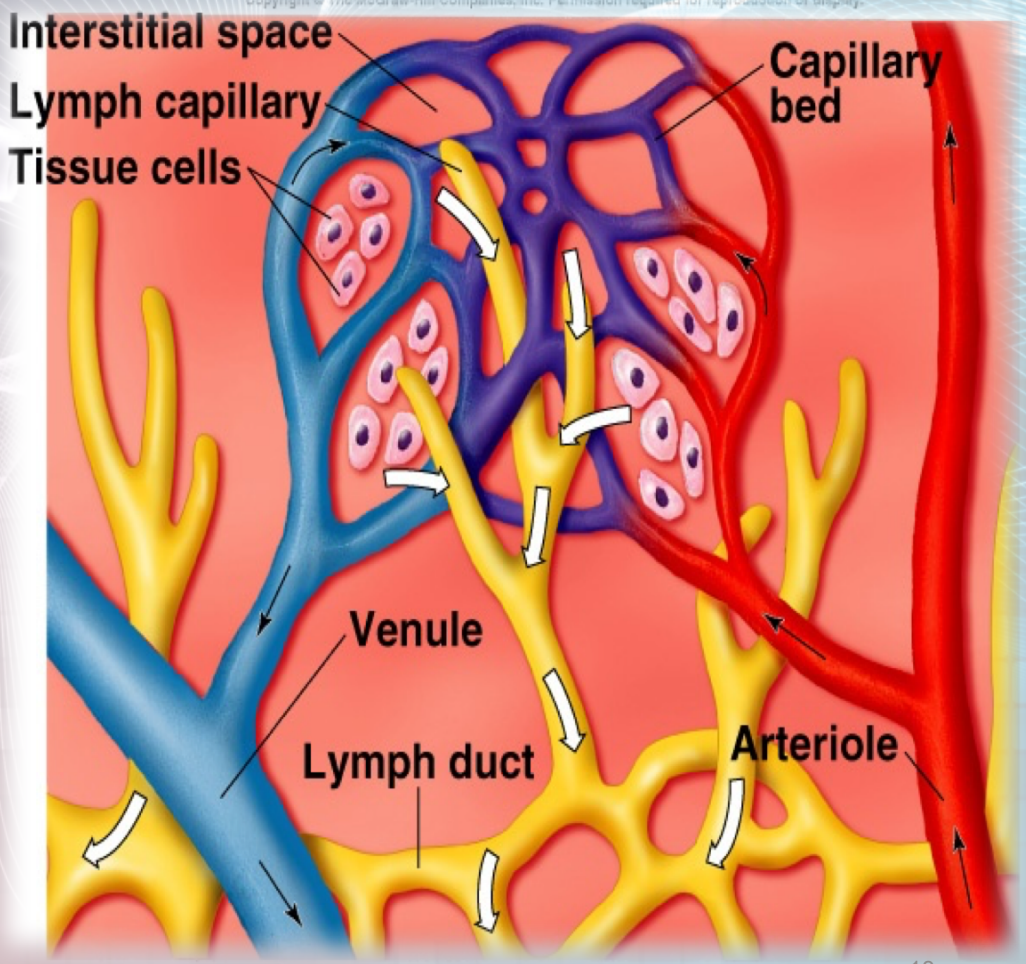
Fluid Filtration & Reabsorption In Normal Microcirculation



- **At arterial end:**
  - Water moves **out** of the capillary with a NFP of +8 to +13 mmHg.
  - Hydrostatic pressure dominates at the arterial end & a net sum of pressure forces (blood hydrostatic + IF osmotic pressures) flow fluid out of the circulation.
- **At venous end:**
  - Water moves **into** the capillary with a NFP of -7 to -2 mmHg.
  - Oncotic pressure dominates at the venous end & a net sum of pressure forces (blood osmotic + IF hydrostatic pressures) flow fluid into the bloodstream.

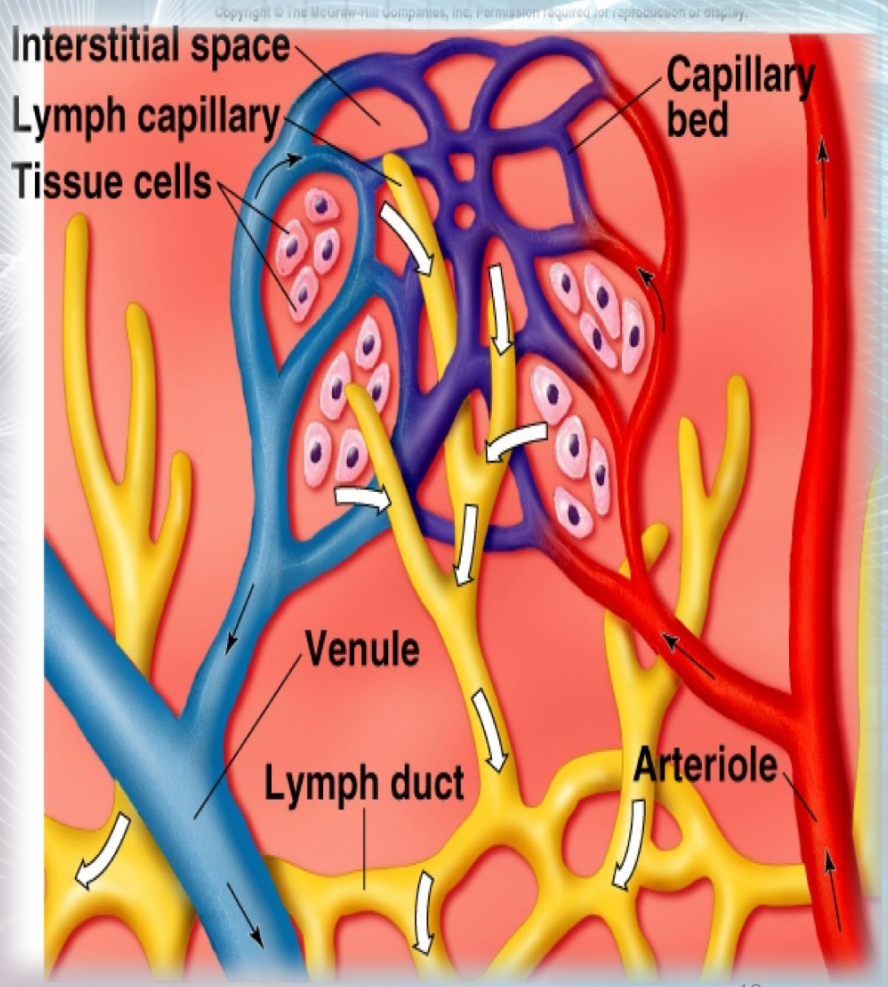
Lymphatic Capillaries System

- Lymphatic vessels present between capillaries.



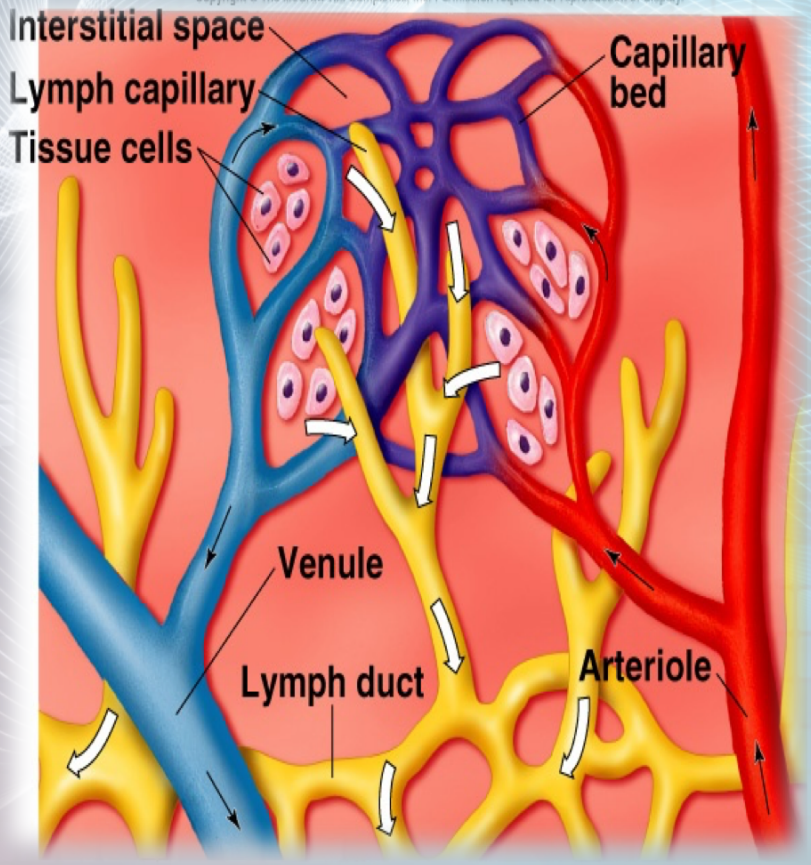
Lymphatic Capillaries System

- 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.



Lymphatic System

- **3 basic functions:**
  - Drain excess interstitial (tissue) fluid back to the blood, in order to maintain original blood volume.
  - Transport absorbed fat from small intestine to the blood.
  - Help to provide immunological defenses against pathogens.



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