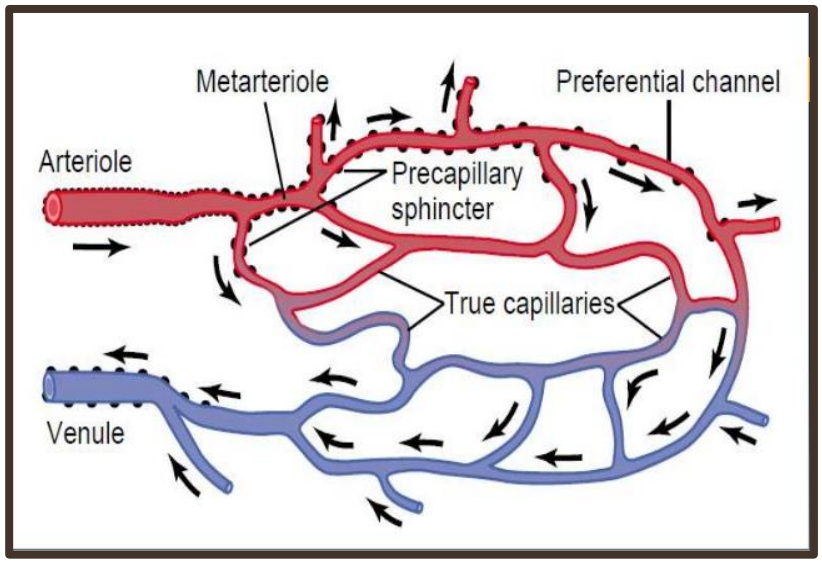

السلام عليكم ورحمة الله وبركاته

Cardiovascular Physiology



Capillary Circulation

Dr. Hayam Gad

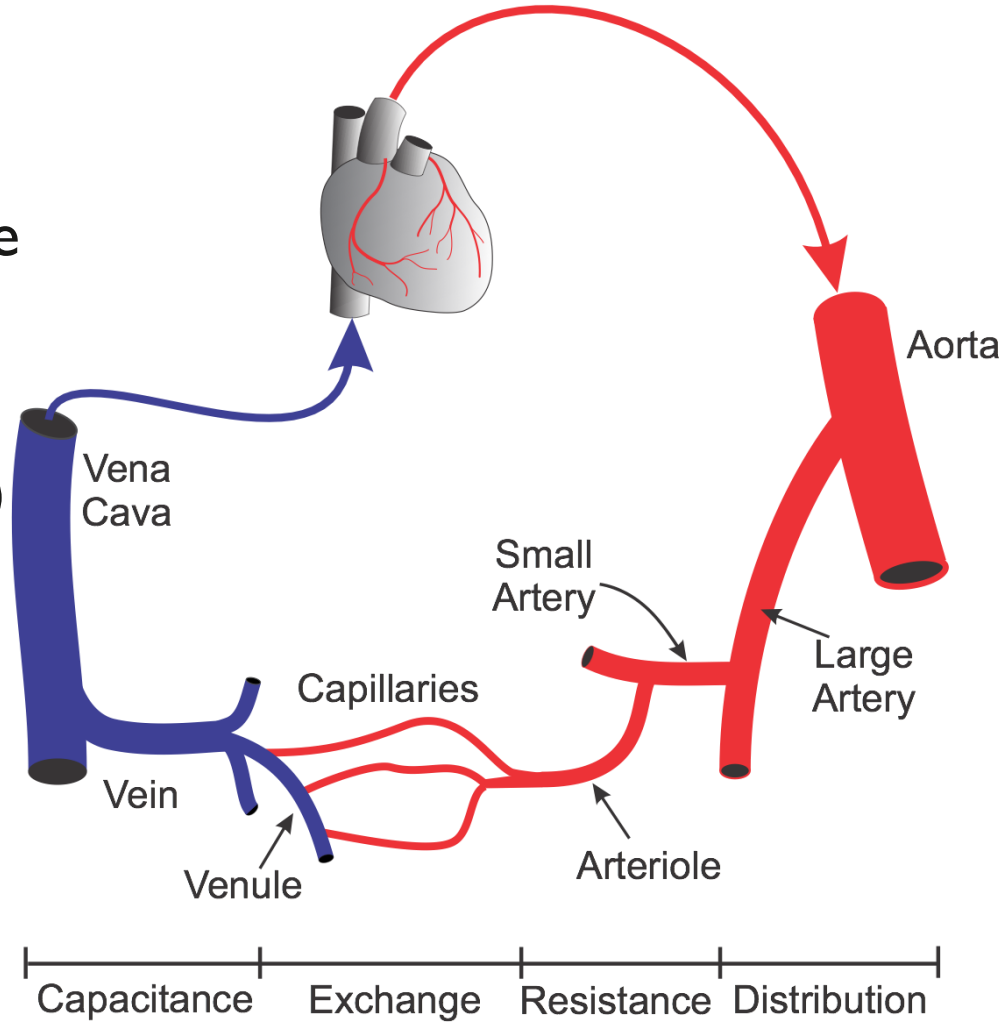
Associate Professor of Physiology, College of Medicine, KSU

Learning Objectives

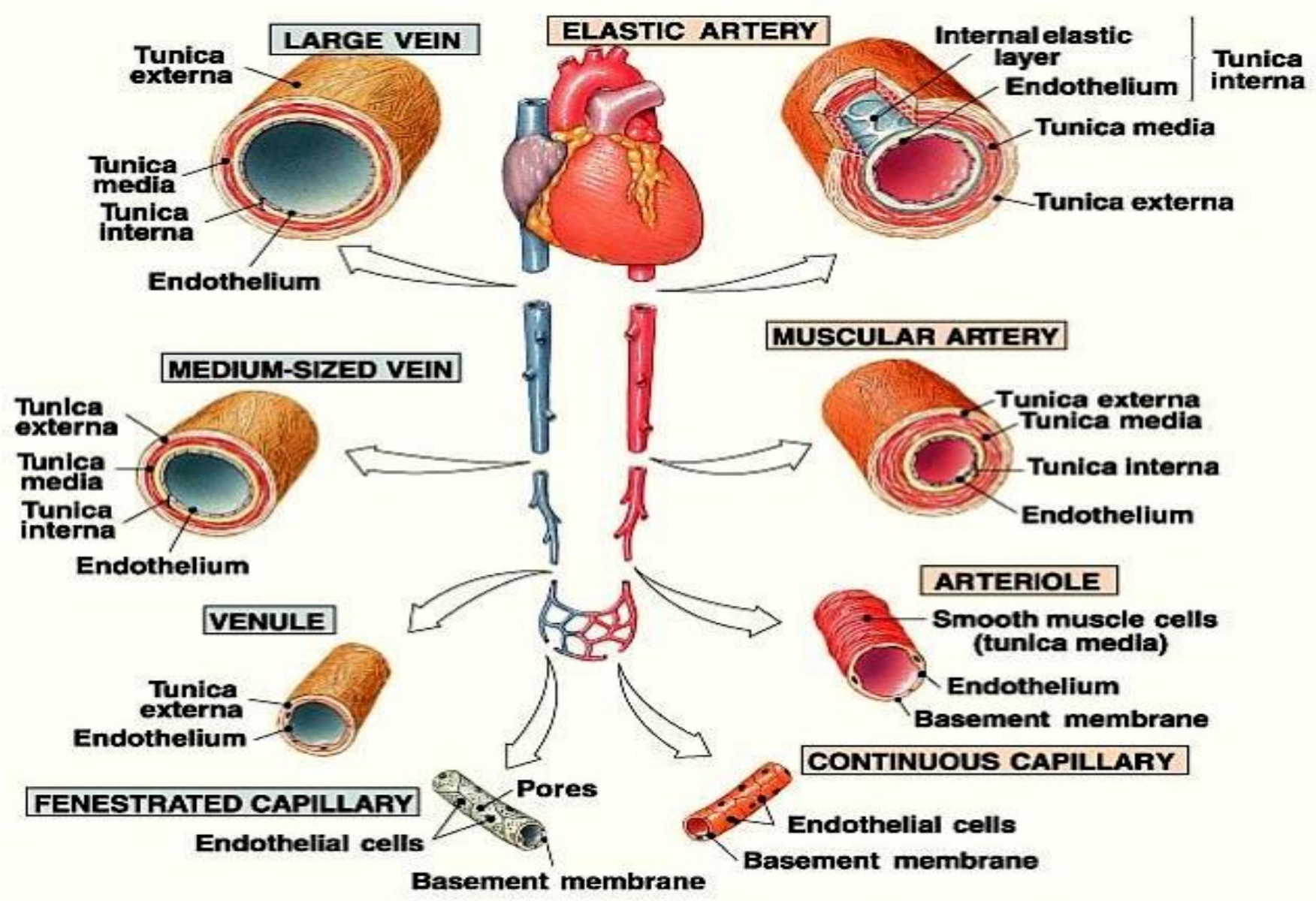
- Classification 0f The Vascular System
- Distribution 0f Blood Within the Circulatory System
- Components of the microcirculation(Capillary Beds)
- Types of Capillaries
- Structures of Capillary Wall
- Exchange of Fluid Between Capillaries & Tissues
- The Lymphatic System

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**
   … (capacitance vessels)
6. **Veins**
   …(capacitance vessels)



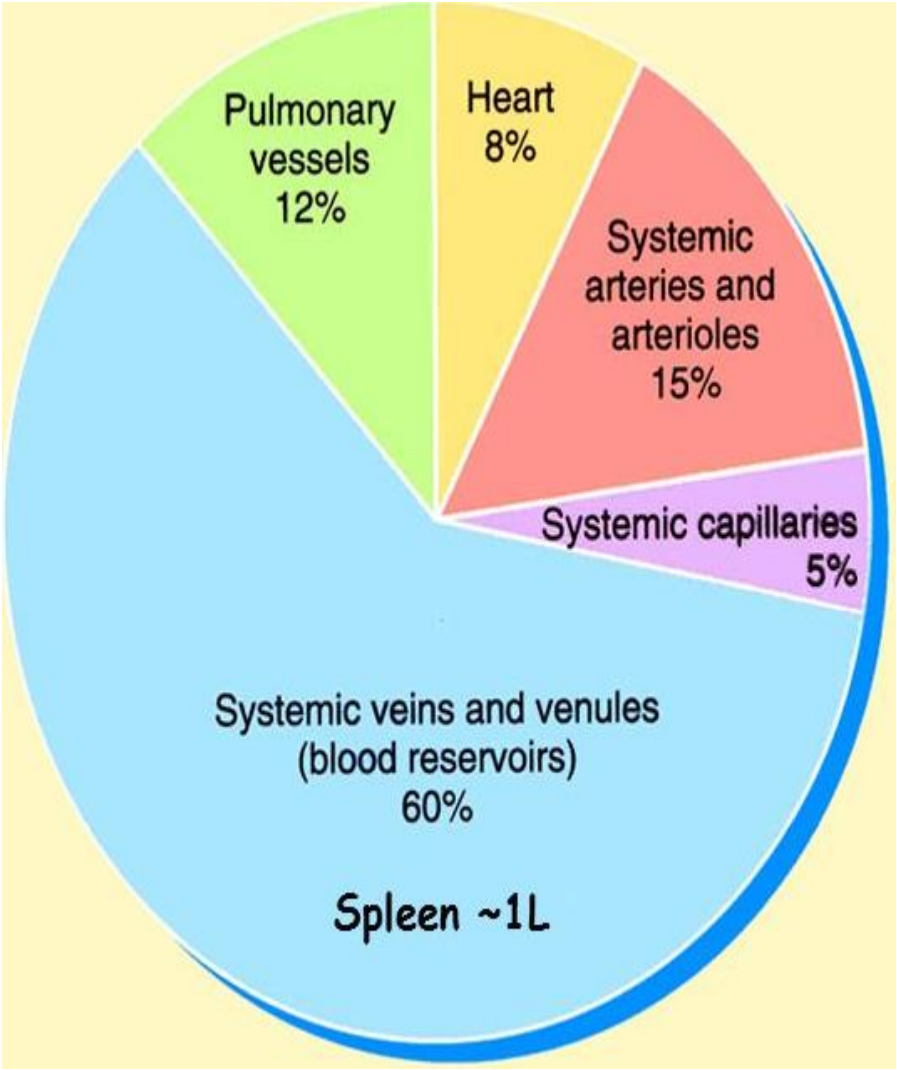
Blood Vessel Comparison



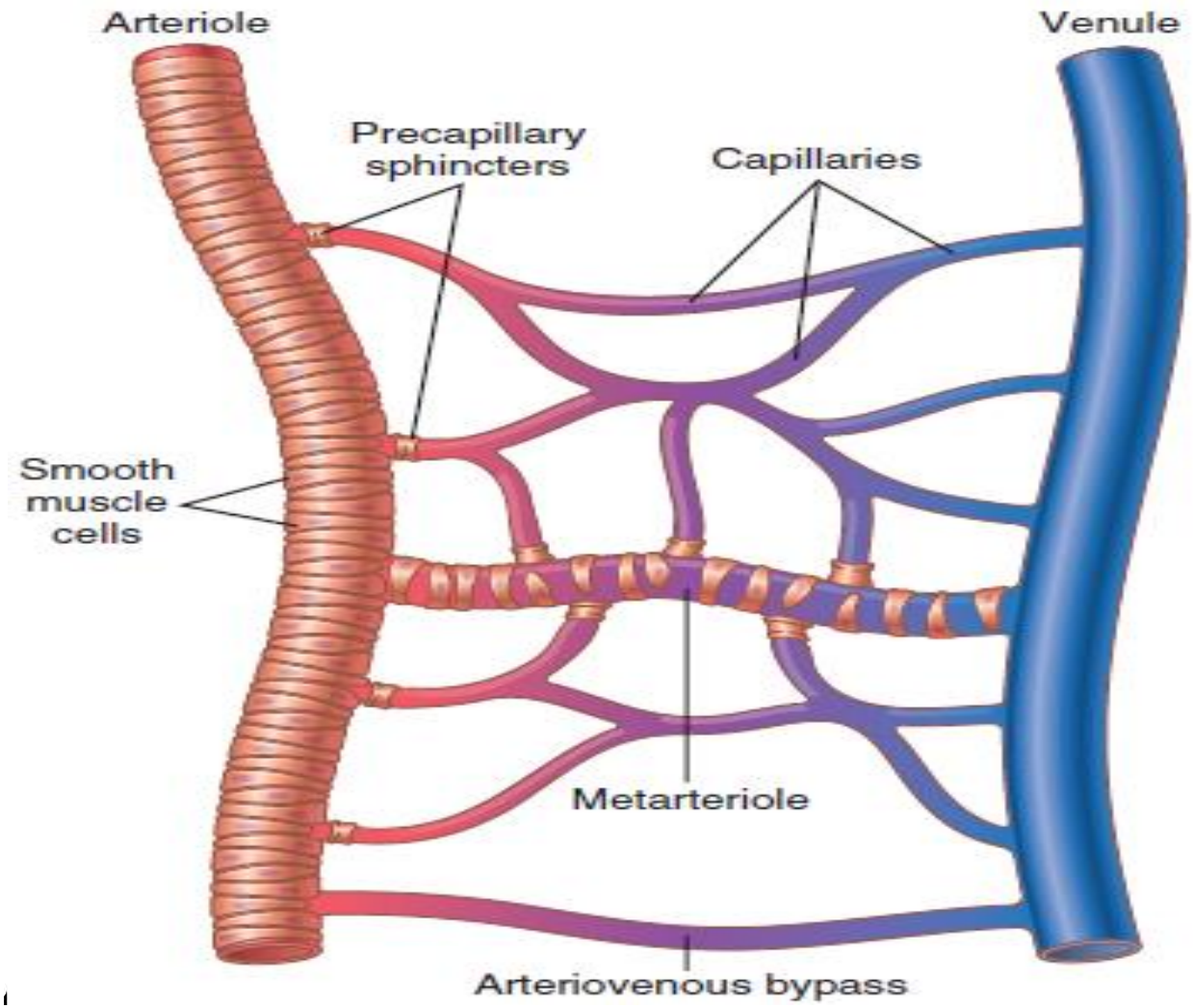
Distribution Of Blood Within The Circulatory System

At rest

- 60% of blood volume is located in veins and venules
- Venous system serves as reservoirs for blood.
- Particularly veins of the abdominal organs and skin

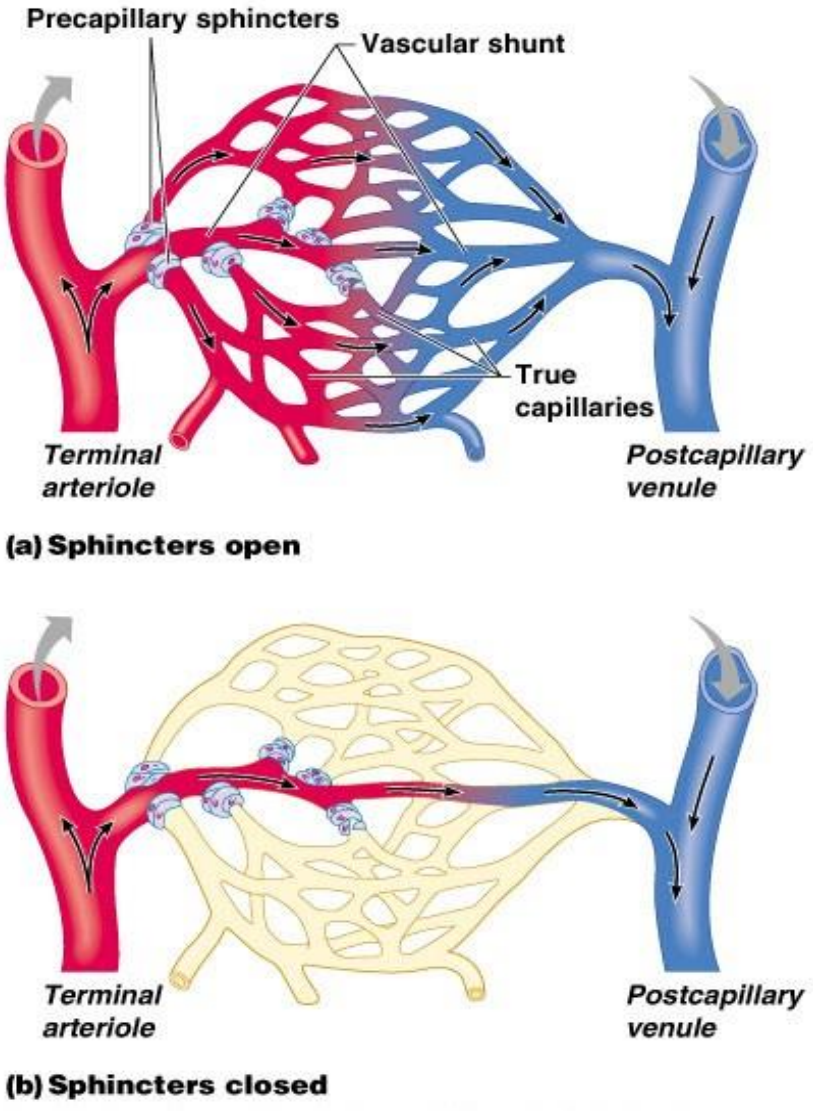


Components of the microcirculation Capillary Beds



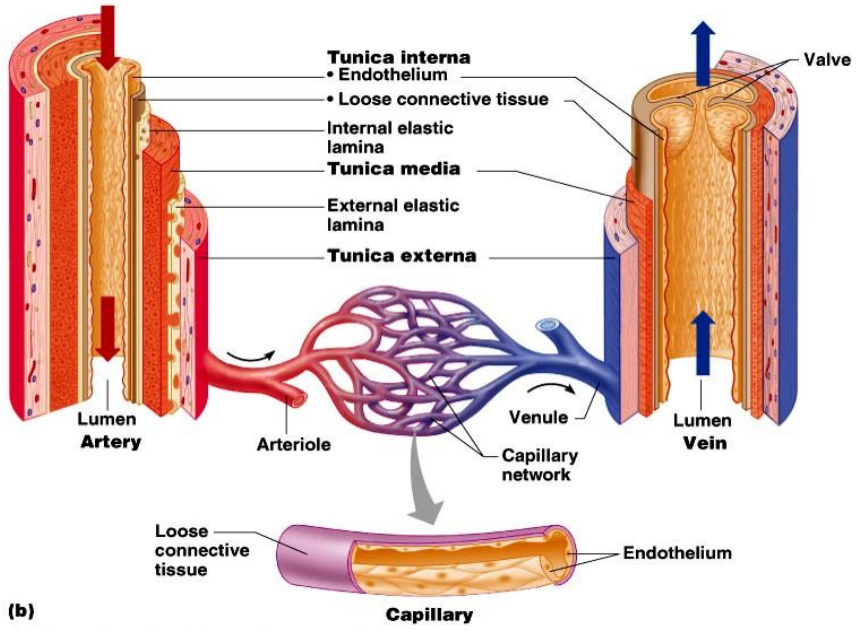
Capillary Beds

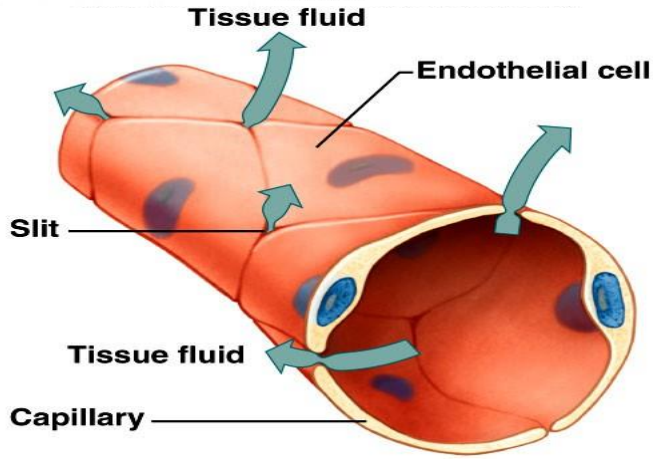
- **Capillary beds consist of two types of vessels:**
  - Vascular shunt – directly connects an arteriole to a venule.
  - True capillaries – exchange vessels.
    - Oxygen & nutrients cross to cells
    - Carbon dioxide & metabolic waste products cross into blood



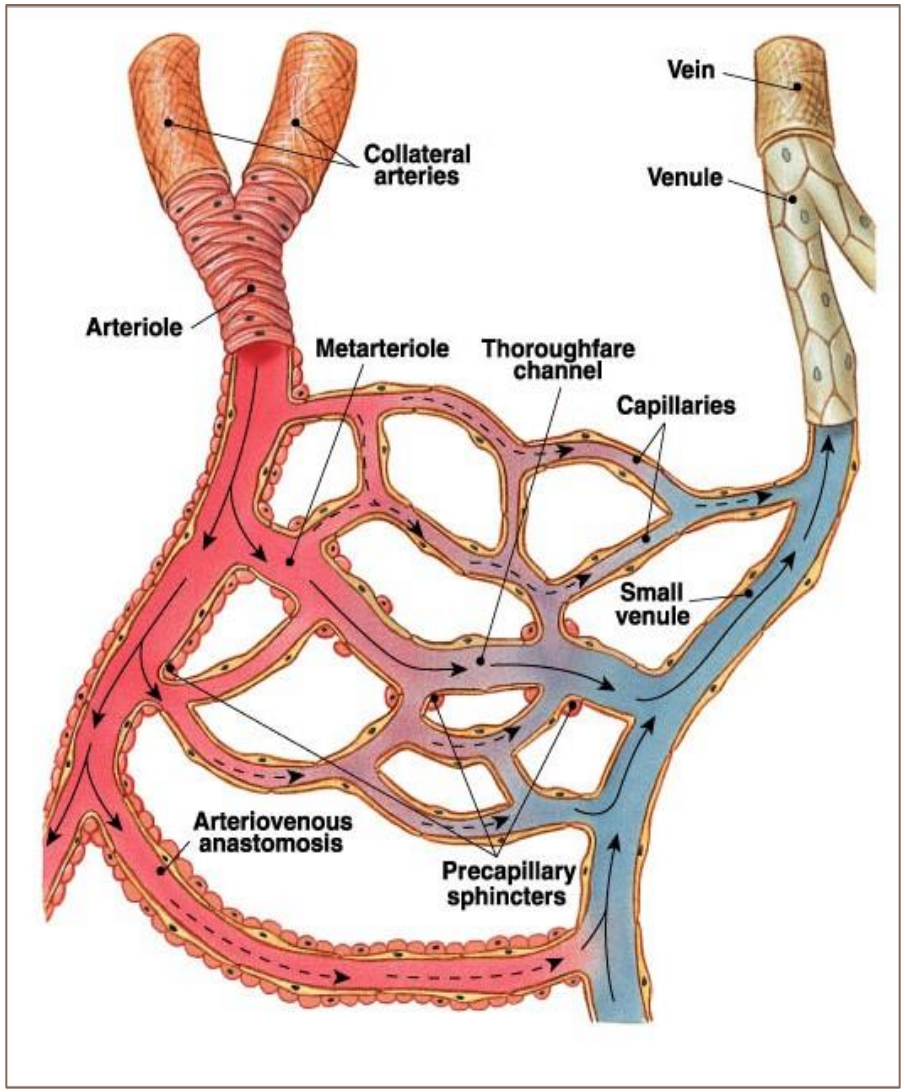
The Capillaries

- Smallest blood vessels.
  - One endothelial cell thickness.
- Exchange vessels.
  - Provide direct access to cells.
  - Most permeable.
  - Permits exchange of nutrients & wastes.



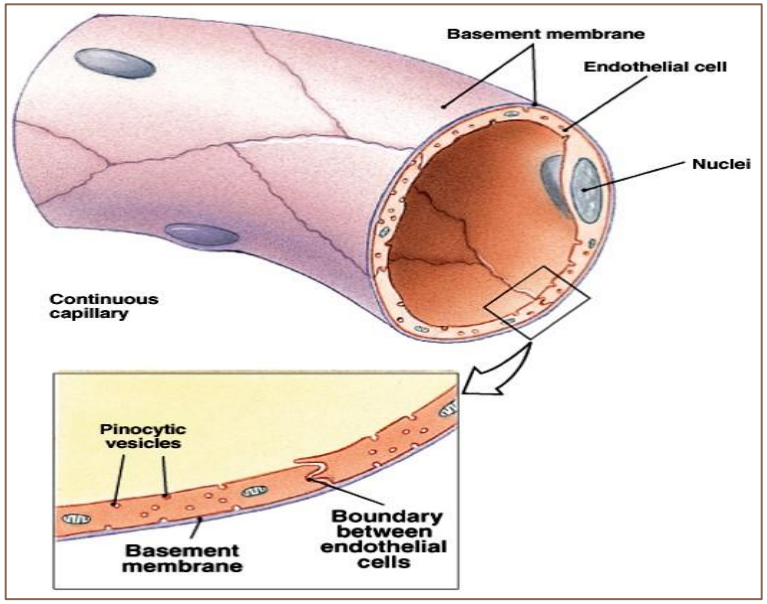


Capillary Network



- Blood flows from arterioles through metarterioles, then through capillary network
- Venules drain network
- Smooth muscle in arterioles, metarterioles, precapillary sphincters regulates blood flow

Types Of Capillaries

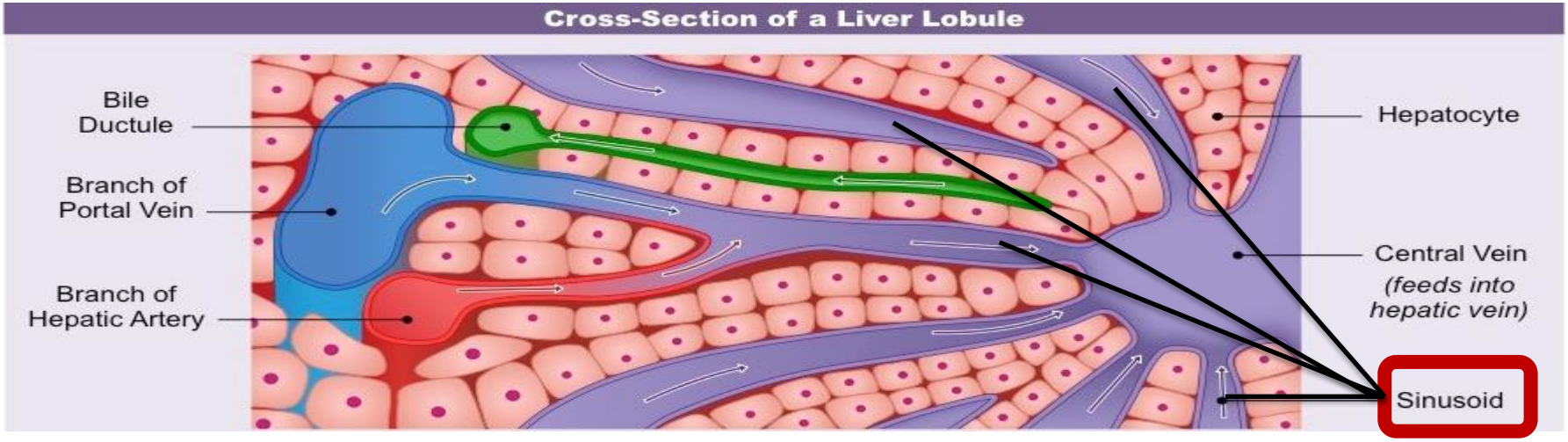


They are classified by diameter/permeability:

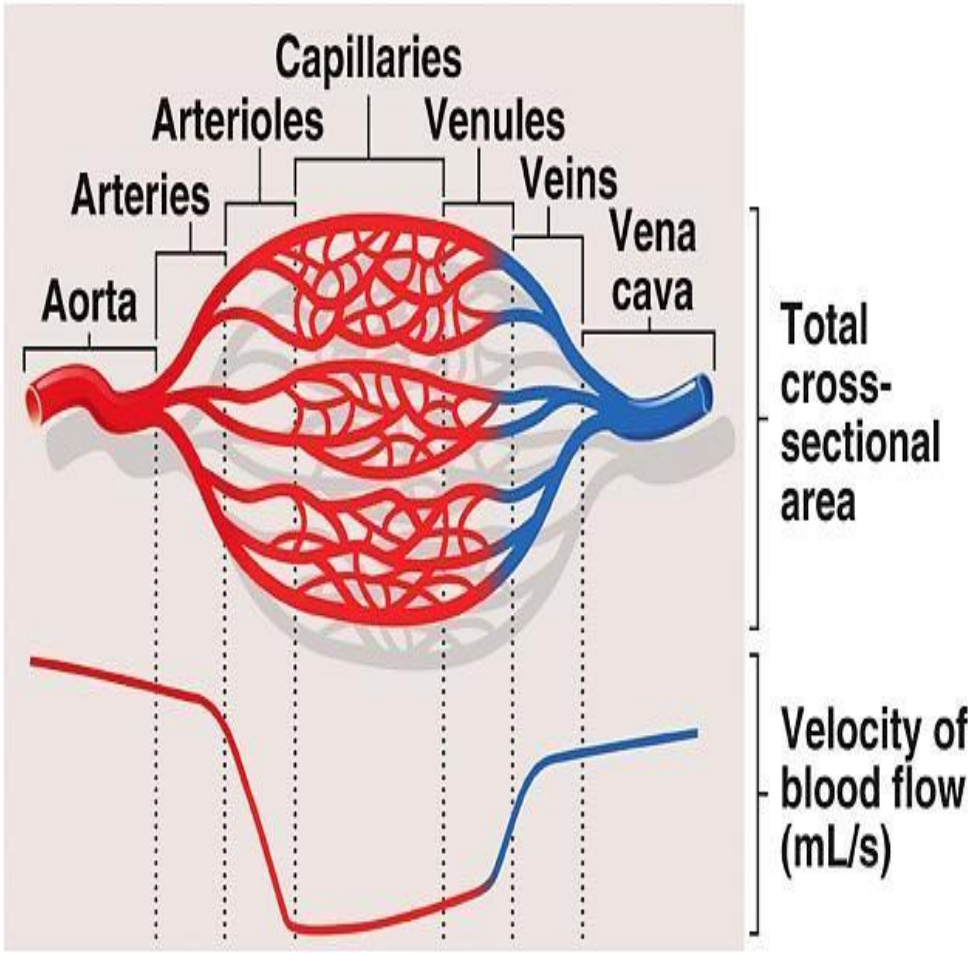
- **Continuous**
  - Do not have fenestrae.
- **Fenestrated**
  - Have pores.
- **Sinusoidal**
  - Special type of capillary that have a large diameter with large fenestrae.
  - They are found in the liver, spleen, lymph nodes, bone marrow and some endocrine glands.

What is the benefit of having sinusoidal capillaries between rows of hepatocytes?

- Sinusoids are low pressure vascular channels that receive blood from terminal branches of the hepatic artery and portal vein at the periphery of lobules and deliver it into central veins.
- Sinusoids are lined with endothelial cells, they are highly porous and can collect nutrient rich blood coming from the small intestine. Also they remove microdebris.

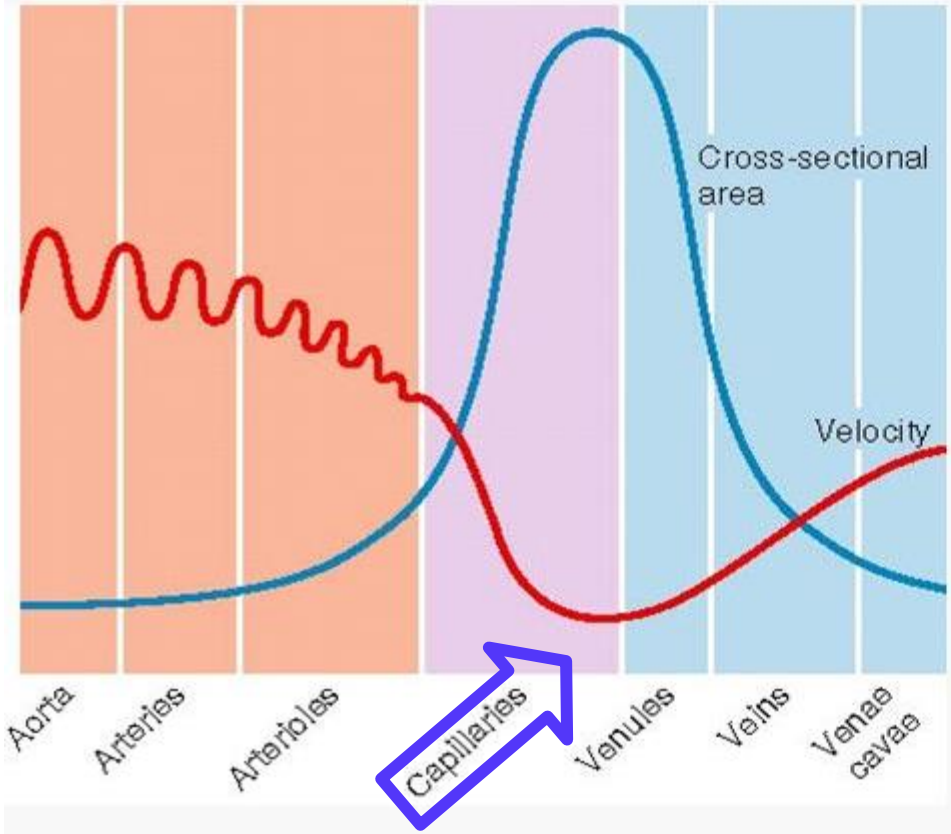


Cross-Sectional Area



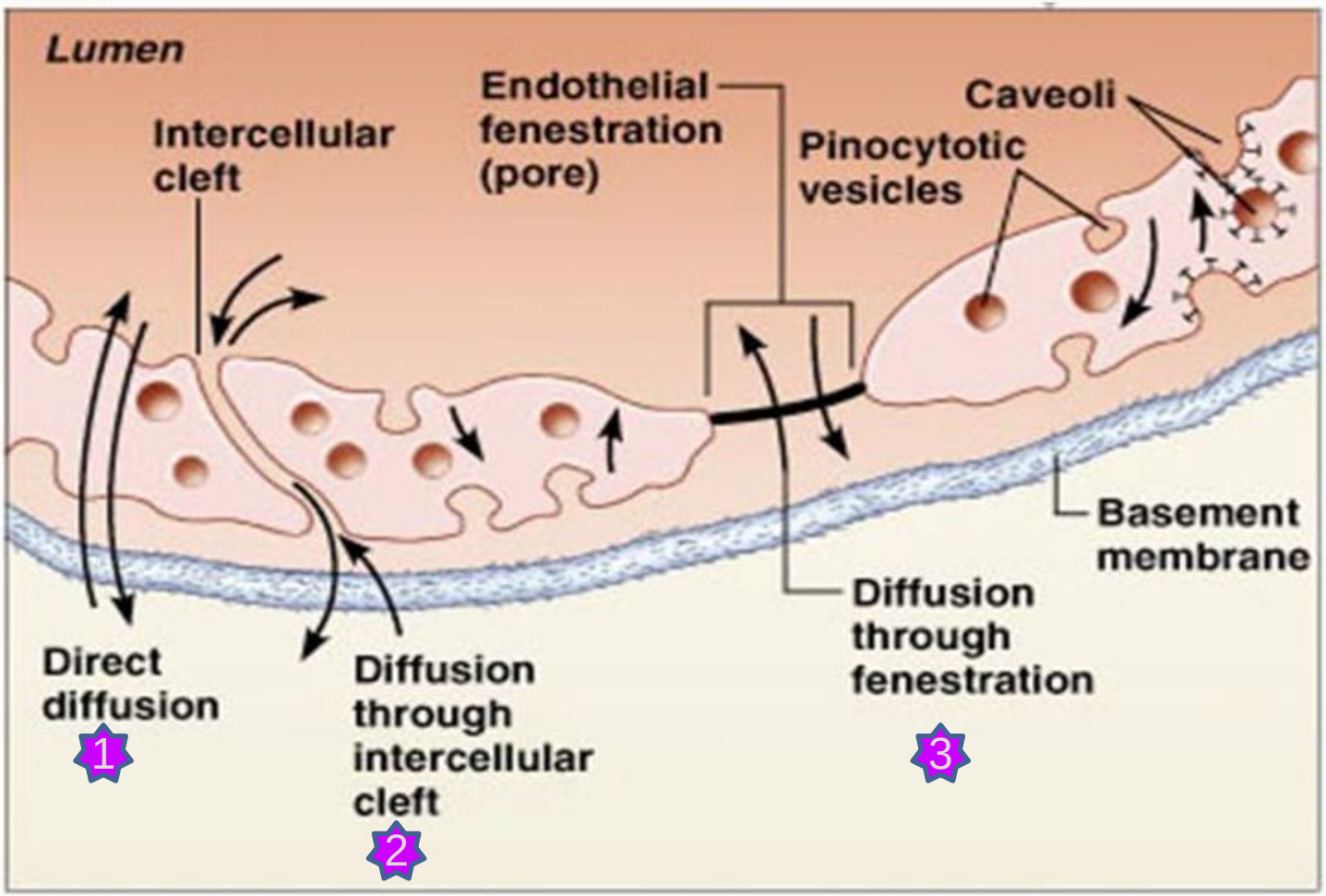
- As diameter of vessels decreases, the total cross-sectional area increases & velocity of blood flow decreases.
- Much like a stream that flows rapidly through a narrow gorge but flows slowly through a broad plane.

Total Cross Sectional Area

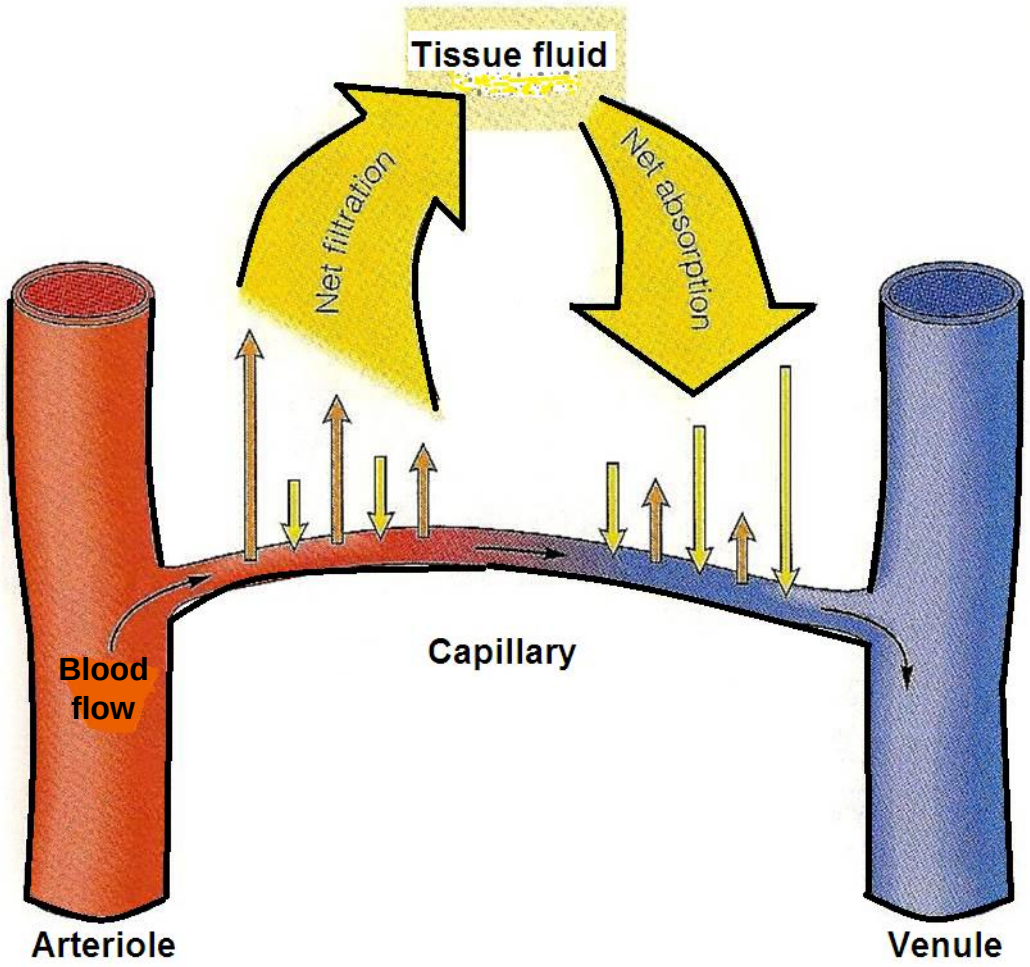


- Velocity of blood flow - inversely related to **total** cross sectional area (CSA) of vessels
- Aorta
  - Total CSA 3-5 cm^2
  - Velocity **33 cm/sec**
- Capillaries
  - Total CSA 4500-6000 cm^2
  - Velocity **0.3 cm/sec**
- Vena Cava
  - Total CSA 14 cm^2 in vena cava
  - Velocity 5-20 cm/sec

How Substances Diffuse Through Capillaries Wall?

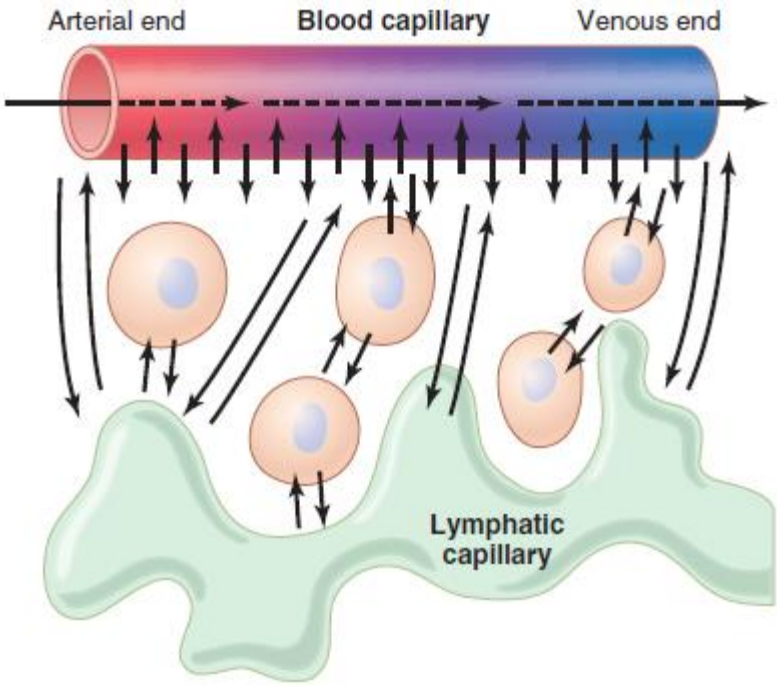


Exchange Of Fluid Between Capillaries And Tissues



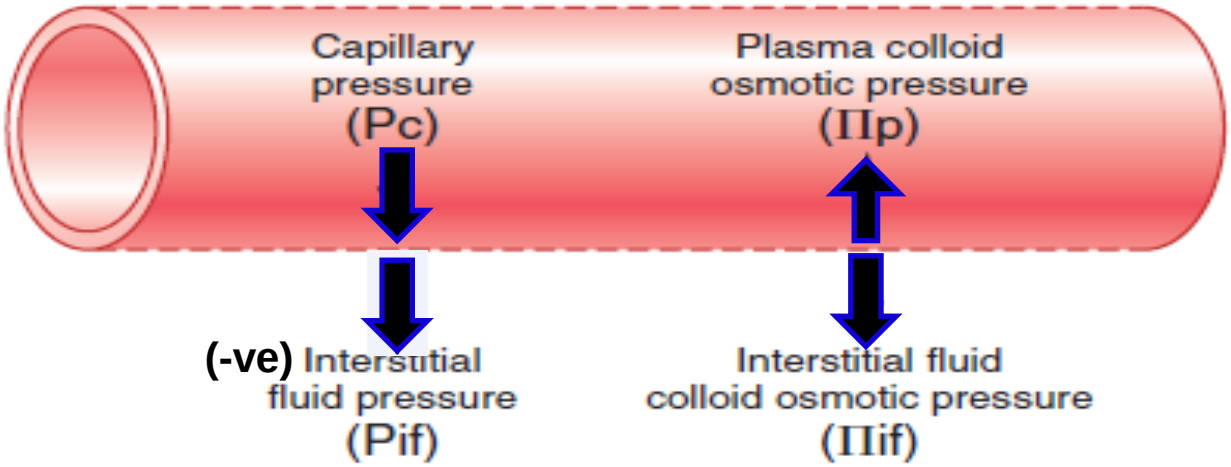
Capillary Exchange & Interstitial Fluid Volume Regulation

- Fluid pressure and colloid osmotic pressure affect movement of fluid through capillaries.
- A net movement of fluid occurs from blood into tissues.
- Excess fluid gained by tissues is removed by lymphatic system.



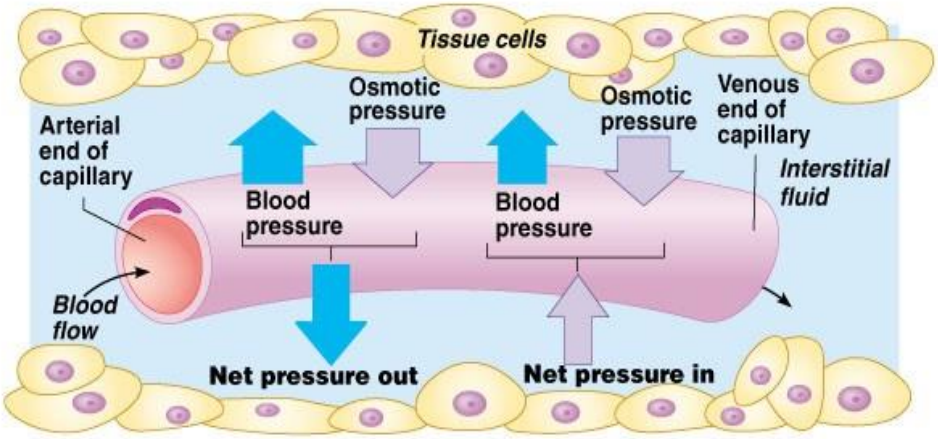
Diffusion of fluid molecules and dissolved substances between the capillary & interstitial spaces

Pressure Forces That Operate At The Capillary Membrane



Fluid pressure and colloid osmotic pressure forces operate at the capillary membrane and tend to move fluid either outward or inward through the membrane pores.

Diffusion at Capillary Beds (Fluid Balance)



Outward Forces:

1. Capillary hydrostatic pressure (P_c = 30-40 at arterial end,10-15 mmHg at venous end)
2. Negative interstitial free fluid pressure (P_{IF} = 3 mmHg)
3. Interstitial fluid colloidal osmotic pressure (μ_{IF} = 8 mmHg)

Inward Force:

1. Plasma colloidal osmotic pressure (μ_C = 25- 28 mmHg)

Analysis of the Forces Causing Filtration at the Arterial End of the Capillary

Forces Tending to Move Fluid Outward	mm Hg
• Capillary pressure (arterial end of capillary)	30
• *Negative* interstitial free fluid pressure	3
• Interstitial fluid colloid osmotic pressure	8
• TOTAL OUTWARD FORCE	41

Forces Tending to Move Fluid Inward	
• Plasma colloid osmotic pressure	28
• TOTAL INWARD FORCE	28

Summation of Forces	
• Outward	41
• Inward	28
• NET OUTWARD FORCE (AT ARTERIAL END)	13

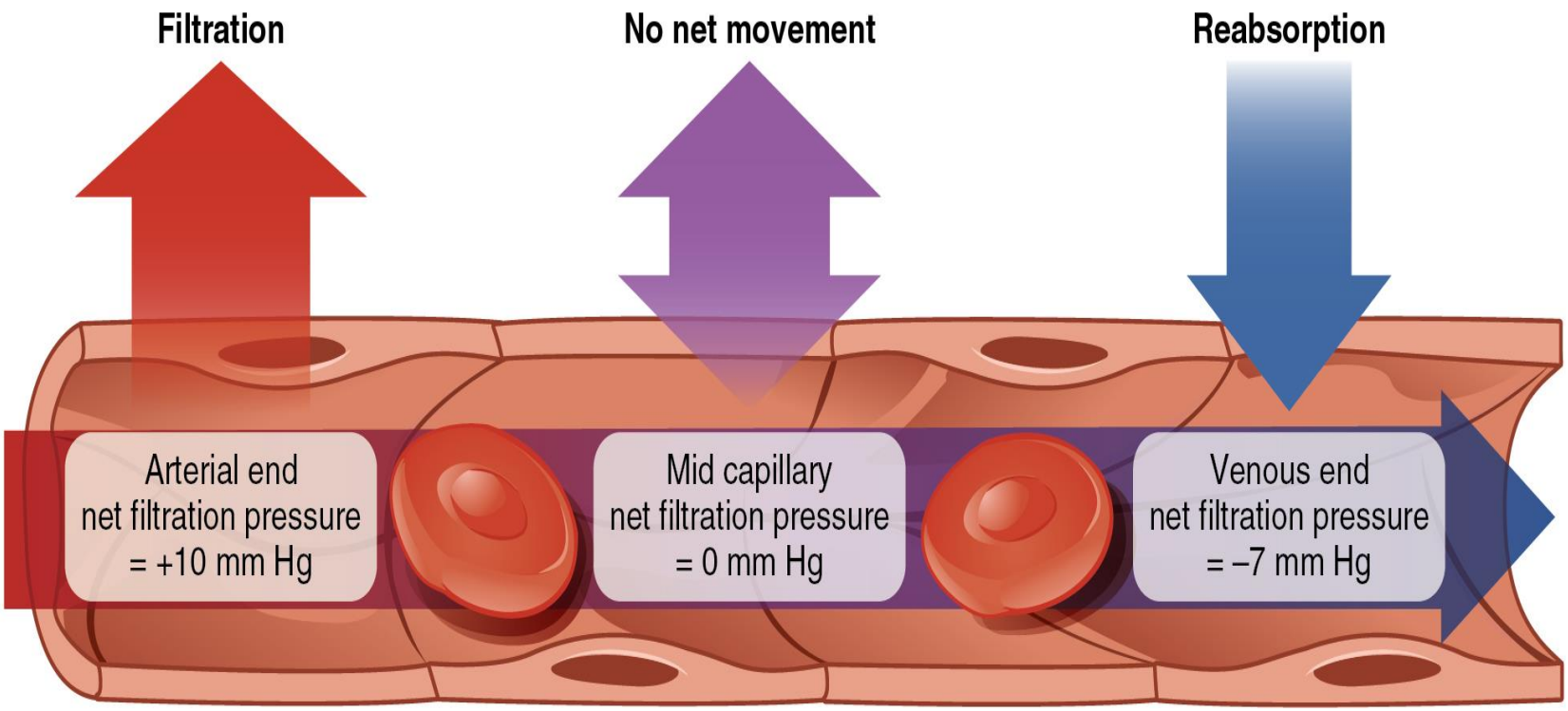
Analysis of the Forces Causing Filtration at the Venous End of the Capillary

Forces Tending to Move Fluid Inward	mmHg
• Plasma colloid osmotic pressure	28
• TOTAL INWARD FORCE	28

Forces Tending to Move Fluid Outward	
• Capillary pressure (venous end of capillary)	10
• Negative interstitial free fluid pressure	3
• Interstitial fluid colloid osmotic pressure	8
• TOTAL OUTWARD FORCE	21

Summation of Forces	
• Inward	28
• Outward	21
• NET INWARD FORCE	7

Capillary Exchange & Interstitial Fluid Volume Regulation

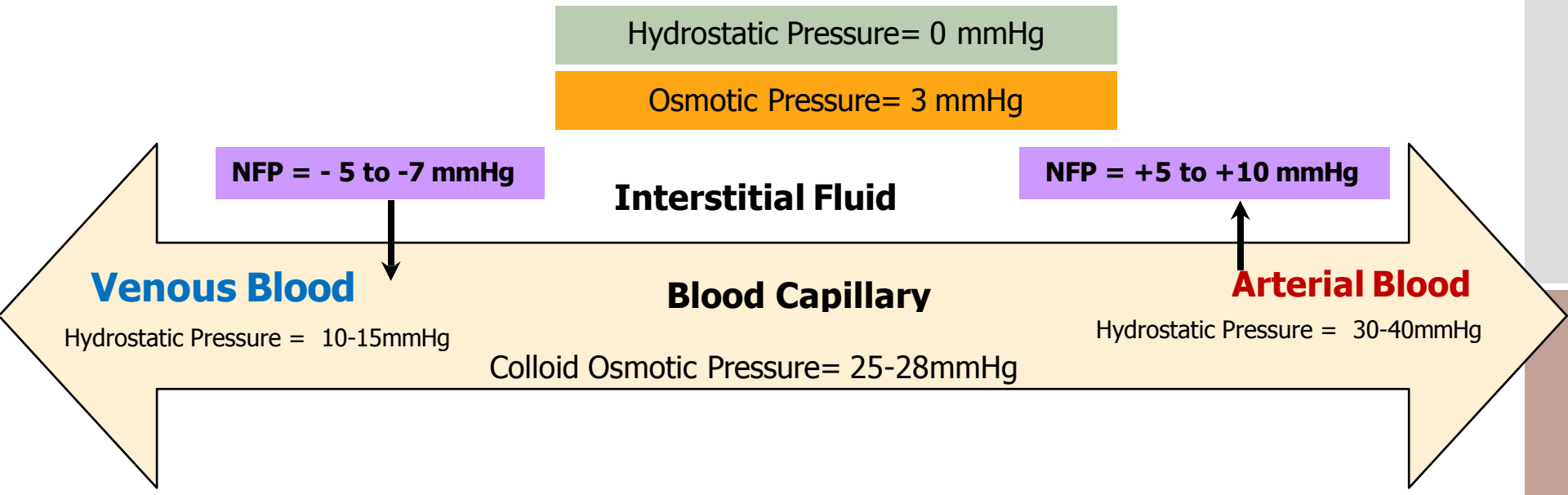


Fluid exits capillary since capillary hydrostatic pressure (35 mm Hg) is greater than blood colloidal osmotic pressure (25 mm Hg)

No net movement of fluid since capillary hydrostatic pressure (25 mm Hg) = blood colloidal osmotic pressure (25 mm Hg)

Fluid re-enters capillary since capillary hydrostatic pressure (18 mm Hg) is less than blood colloidal osmotic pressure (25 mm Hg)

Fluid Filtration & Reabsorption In Normal Microcirculation



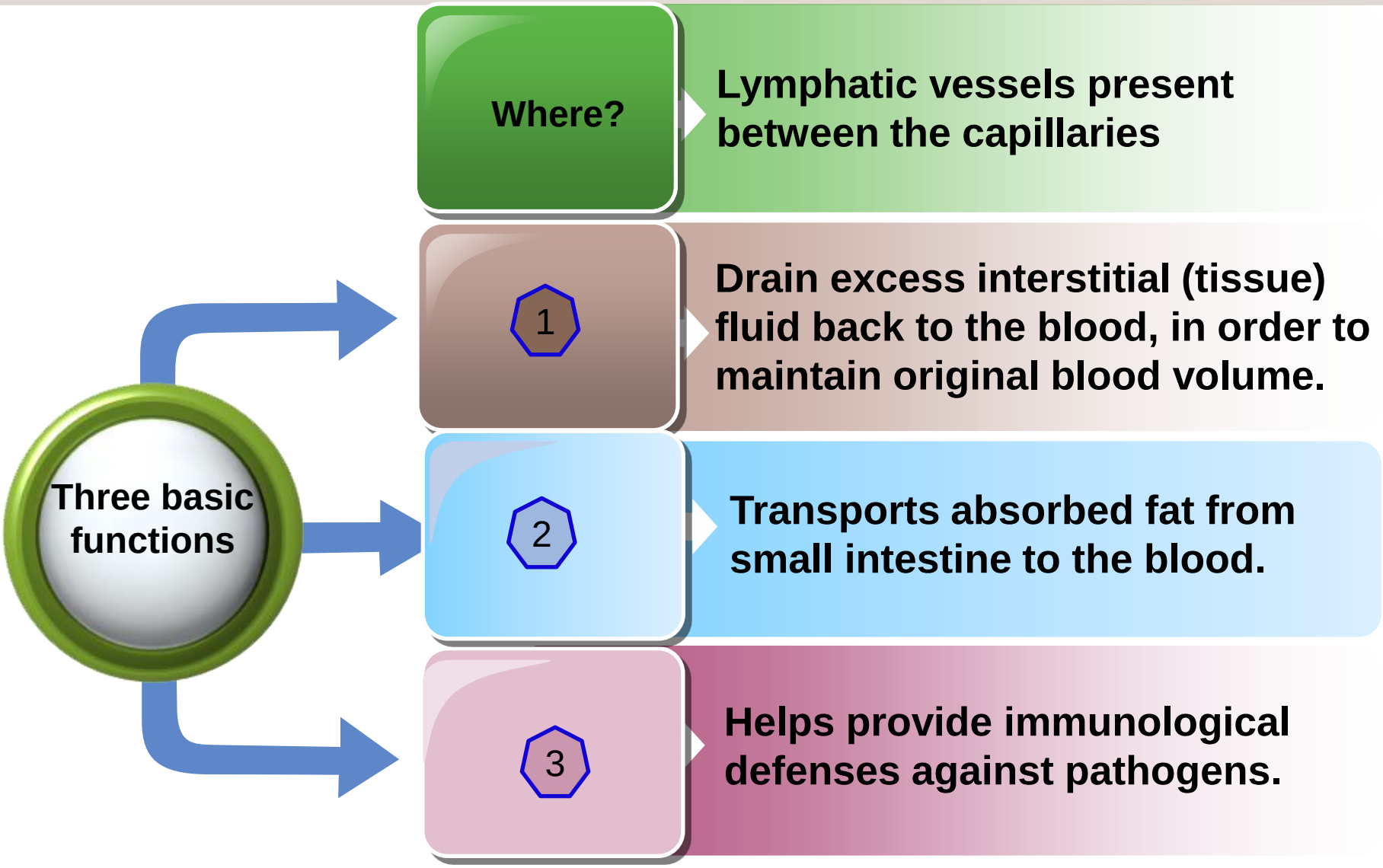
At arterial end:

- Water moves **out** of the capillary with a NFP of +5 to +10 mmHg.
- Hydrostatic pressure dominates at the arterial end & net fluid flows out of the circulation.

At venous end:

- Water moves into the capillary with a NFP of -5 to -7 mmHg.
- Oncotic pressure dominates at the venous end & net fluid will flow into the

The Lymphatic System



LYMPHATIC SYSTEM