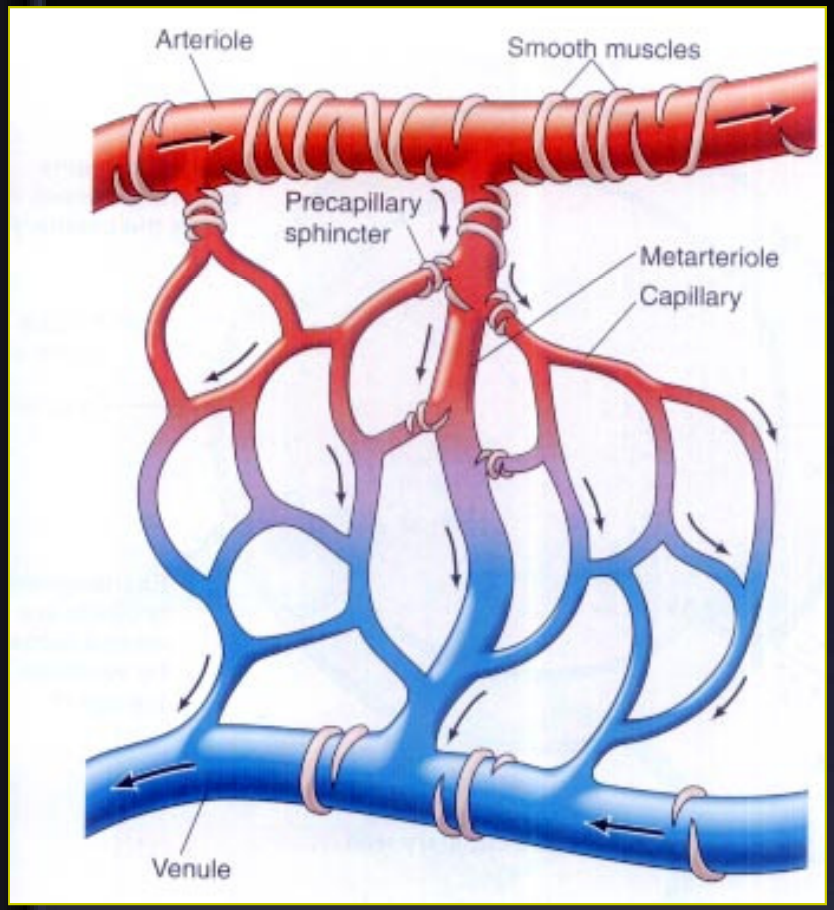
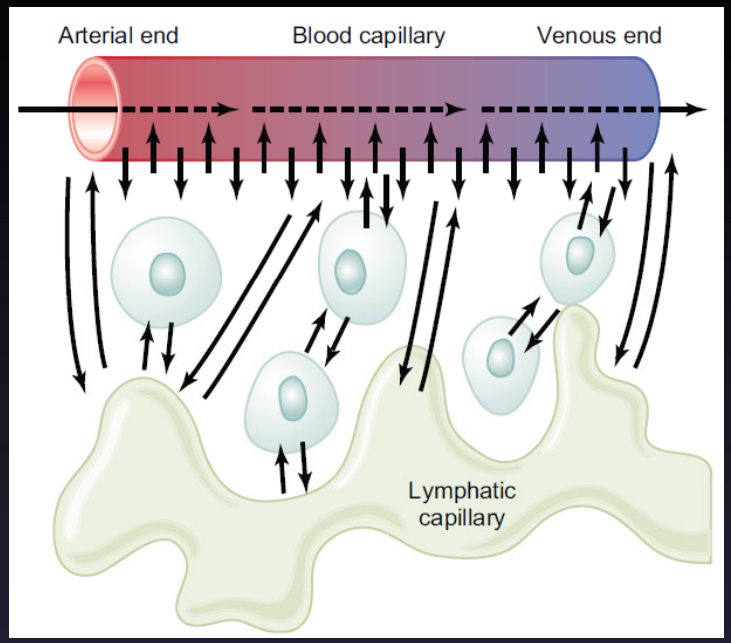
CARDIOVASCULAR PHYSIOLOGY
CAPILLARY CIRCULATION





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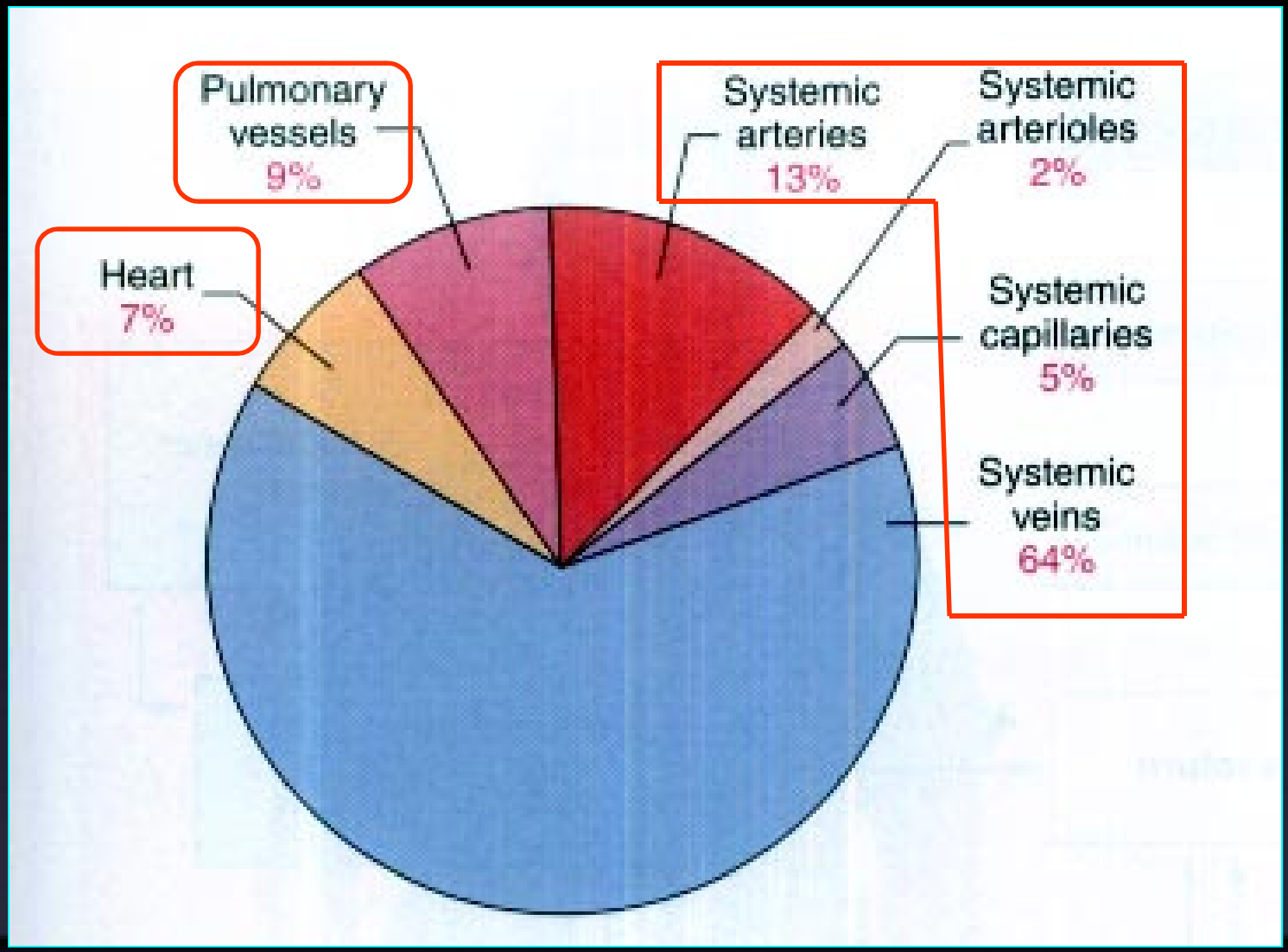
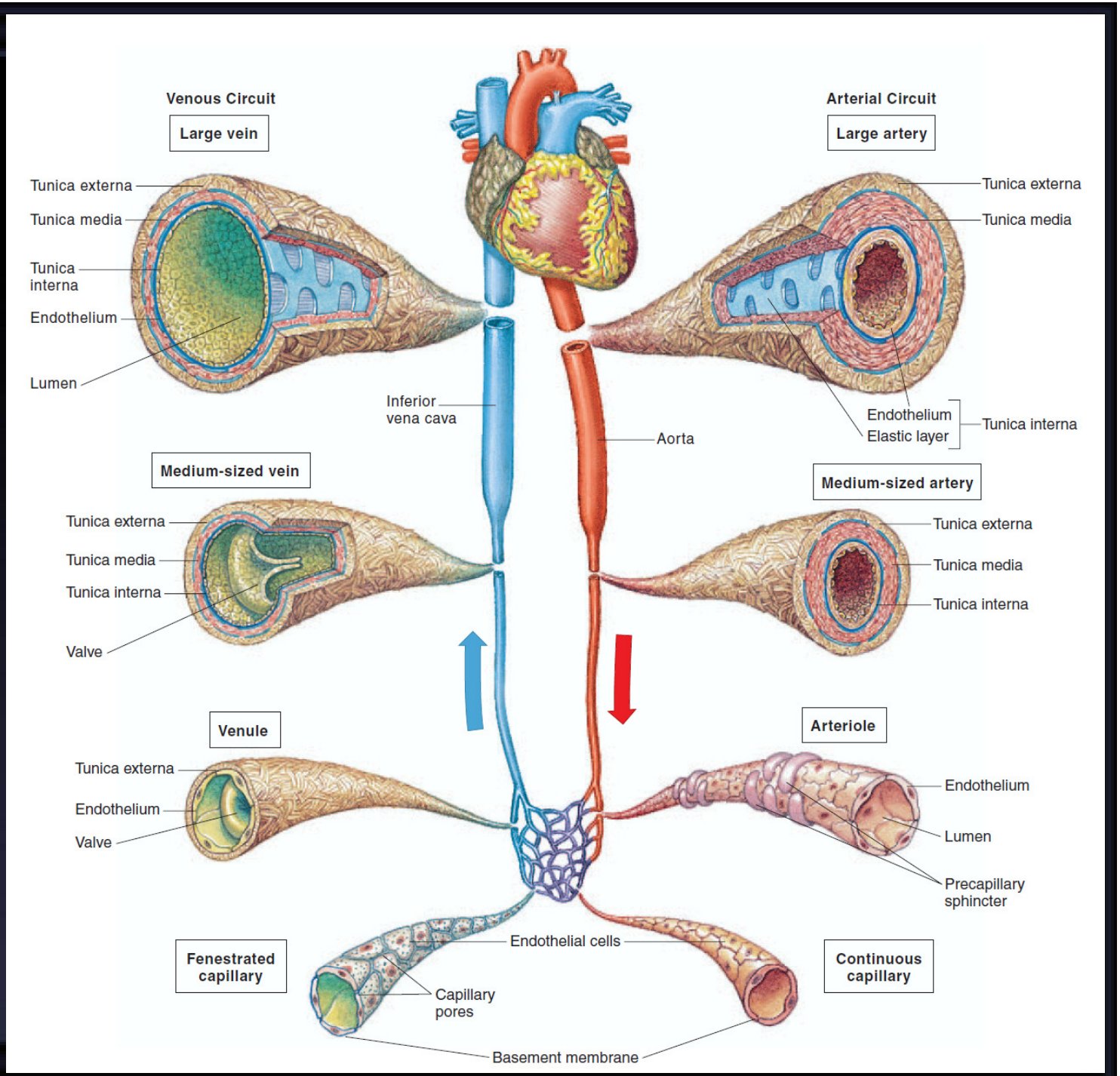
OBJECTIVES

At the end of this lecture you should be able to

- Describe the structure of the Microcirculation and Capillary System
- Explain type of Blood Flow in the Capillaries (Vasomotion) and its regulation
- Know Four Primary Hydrostatic and Colloid Osmotic Forces that Determine Fluid Movement Through the Capillary Membrane
- Role of the Lymphatic System
- List Causes of Extracellular Edema and factors that Increase Capillary Filtration

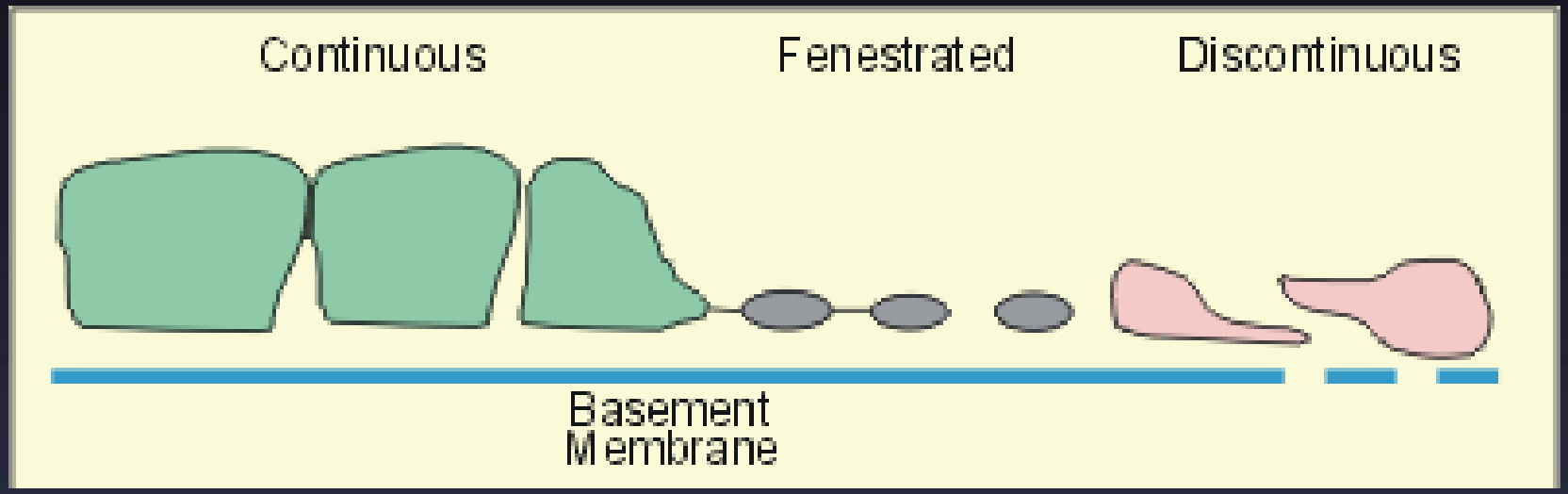
DISTRIBUTION OF BLOOD



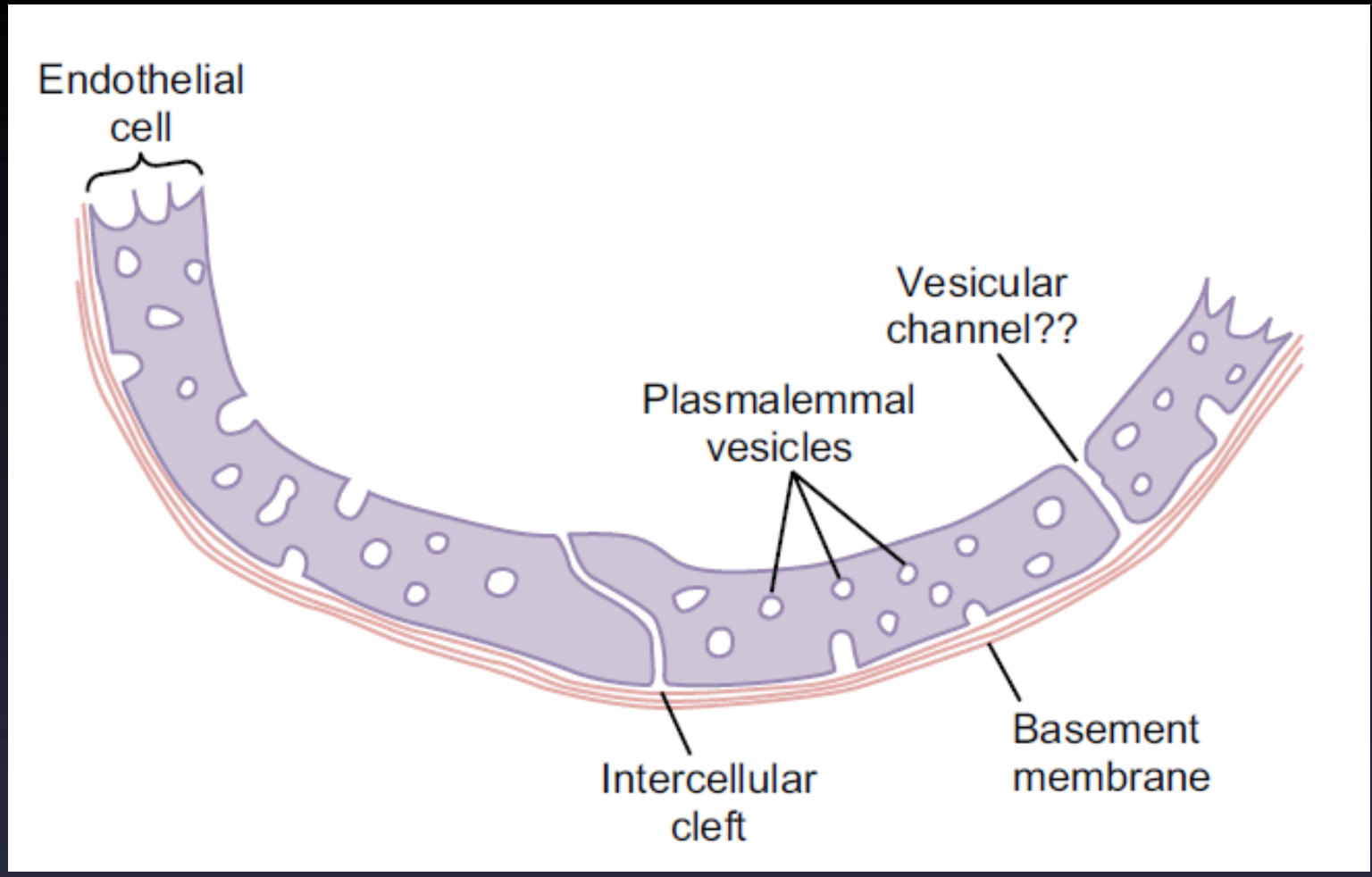

Venous Circuit
Large vein
Tunica externa
Tunica media
Tunica interna
Endothelium
Lumen
Inferior vena cava
Arterial Circuit
Large artery
Tunica externa
Tunica media
Endothelium
Elastic layer
Tunica interna
Aorta
Medium-sized vein
Tunica externa
Tunica media
Tunica interna
Valve
Medium-sized artery
Tunica externa
Tunica media
Tunica interna
Venule
Tunica externa
Endothelium
Valve
Arteriole
Endothelium
Lumen
Precapillary sphincter
Fenestrated capillary
Endothelial cells
Capillary pores
Continuous capillary
Basement membrane

Types of Capillaries

Continuous: muscles, lungs, adipose tissue, and central nervous system
Fenestrated: kidneys, endocrine glands and intestines
Discontinuous: bone marrow, liver, and spleen



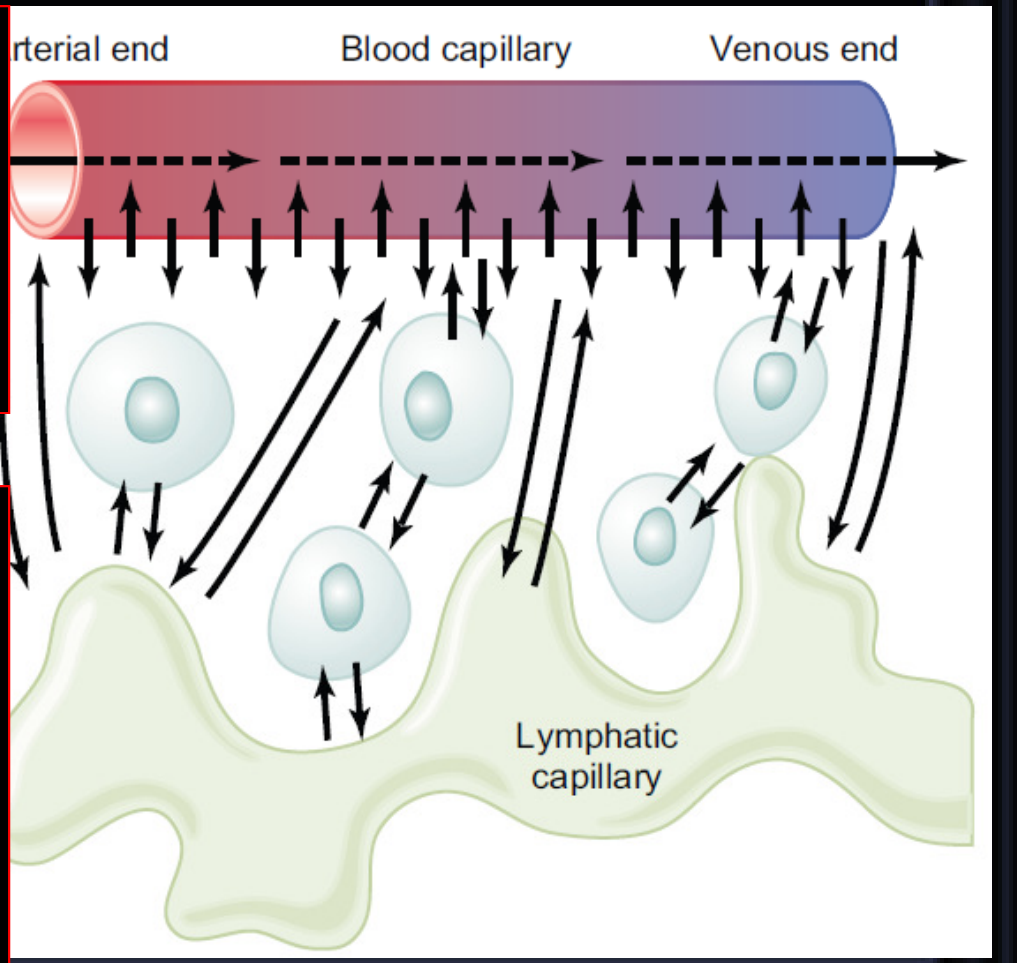
Structure of the capillary wall



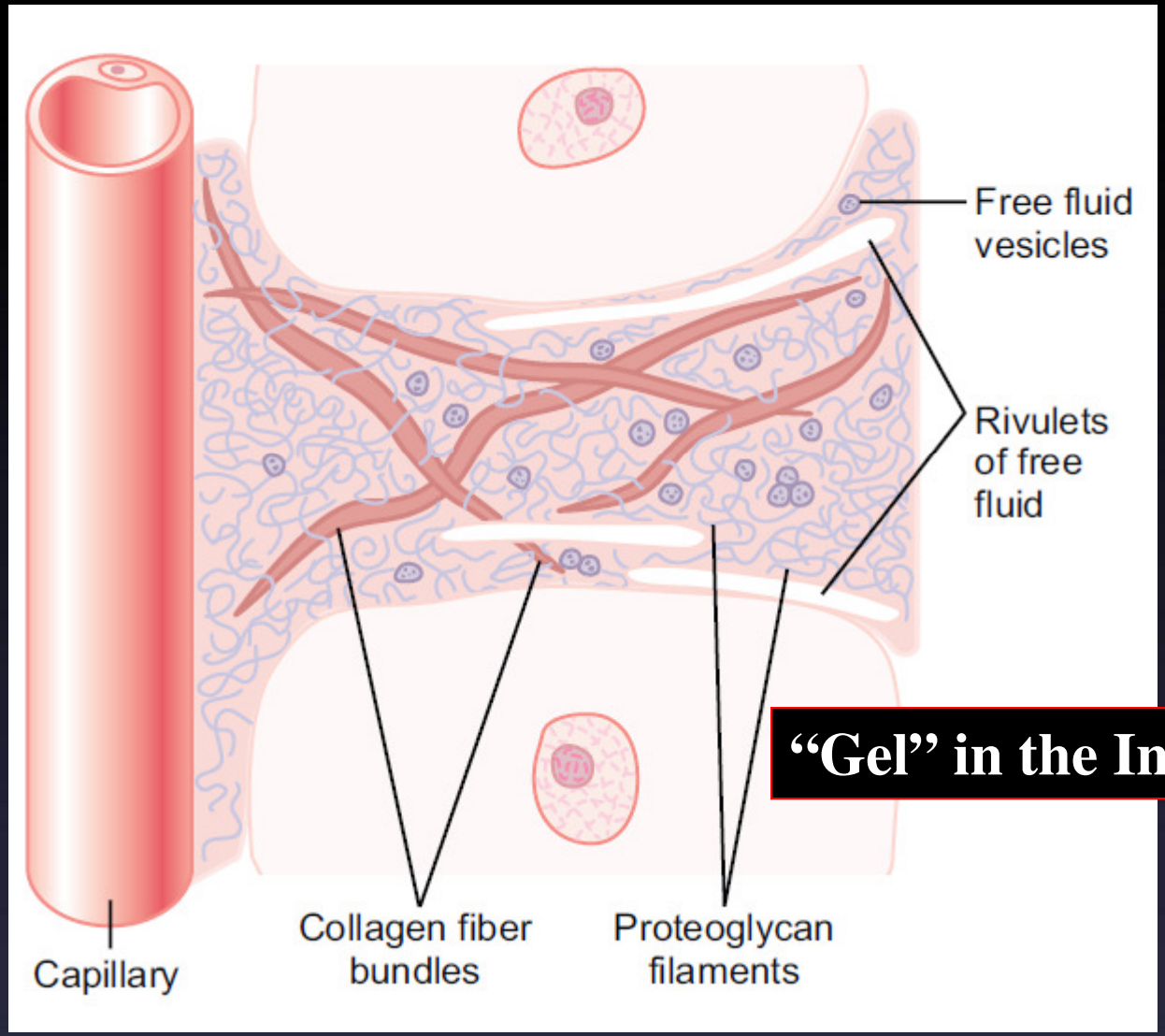
Diffusion Through the Capillary Membrane

Lipid-Soluble Substances Can Diffuse Directly Through the Cell Membranes of the Capillary Endothelium

Water-Soluble, Non-Lipid-Soluble Substances Diffuse Only Through Intercellular "Pores" in the Capillary Membrane



Structure of the interstitium



"Gel" in the Interstitium

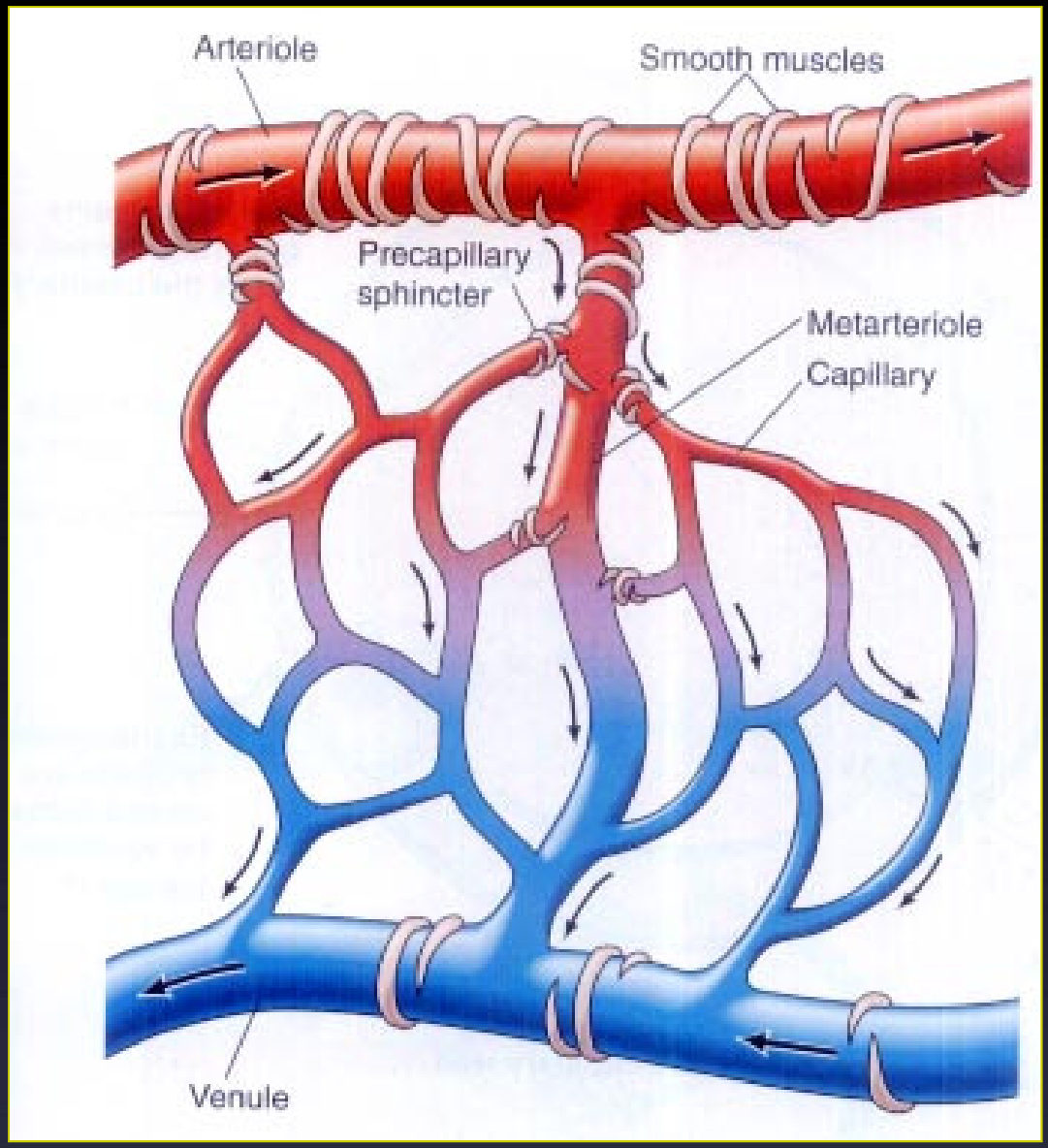
Table 16–1

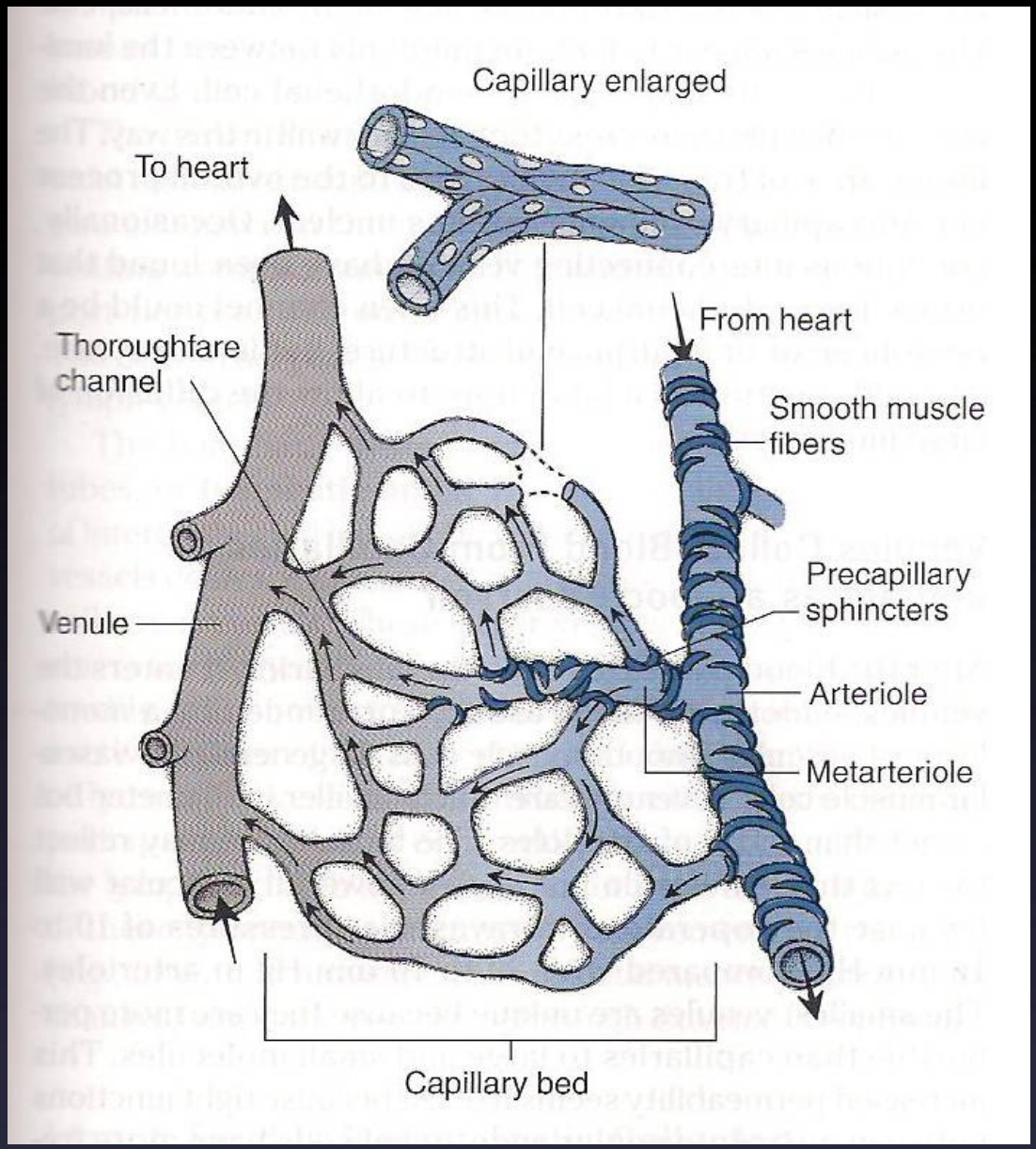
Relative Permeability of Skeletal Muscle Capillary Pores to Different-Sized Molecules

Substance	Molecular Weight	Permeability
Water	18	1.00
NaCl	58.5	0.96
Urea	60	0.8
Glucose	180	0.6
Sucrose	342	0.4
Inulin	5,000	0.2
Myoglobin	17,600	0.03
Hemoglobin	68,000	0.01
Albumin	69,000	0.001

Plasma Colloid Osmotic Pressure

	g/dl	Πp (mm Hg)
Albumin	4.5	21.8
Globulins	2.5	6.0
Fibrinogen	0.3	0.2
Total	7.3	28.0


Arteriole
Smooth muscles
Precapillary sphincter
Metarteriole
Capillary
Venule


Capillary enlarged
To heart
From heart
Thoroughfare channel
Smooth muscle fibers
Precapillary sphincters
Venule
Arteriole
Metarteriole
Capillary bed

MECHANISM OF LOCAL BLOOD FLOW CONTROL

ACUTE CONTROL

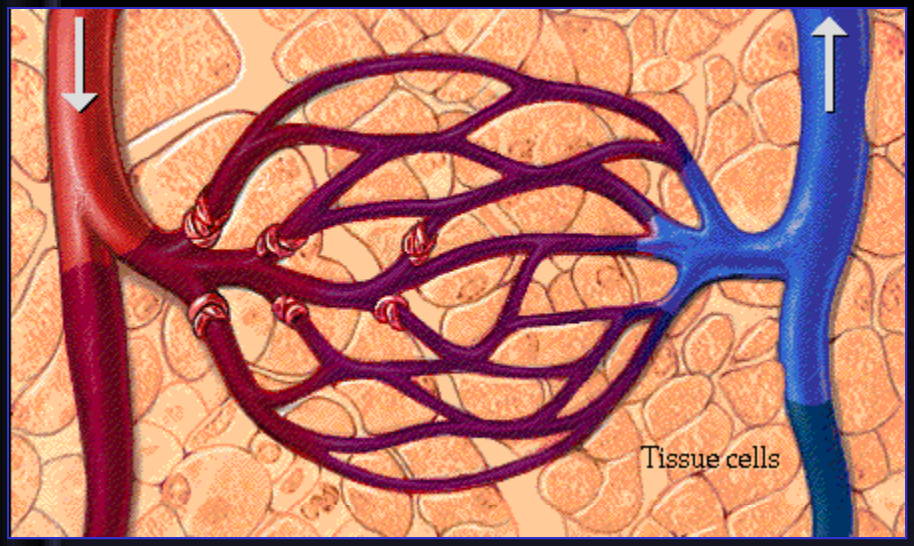
- **OXYGEN DEMAND THEORY**
- **VASODILATOR THEORY**
  - Adenosine
  - Carbon Dioxide
  - Lactic Acid
  - Adenosine PO4 Compounds
  - Histamine
  - Potassium
  - Hydrogen

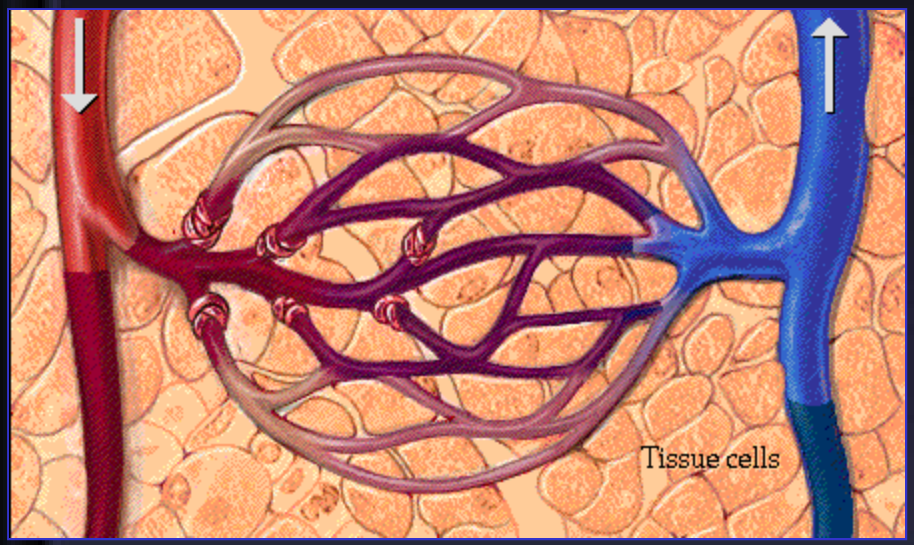
Metabolic Verses Myogenic Mechanism

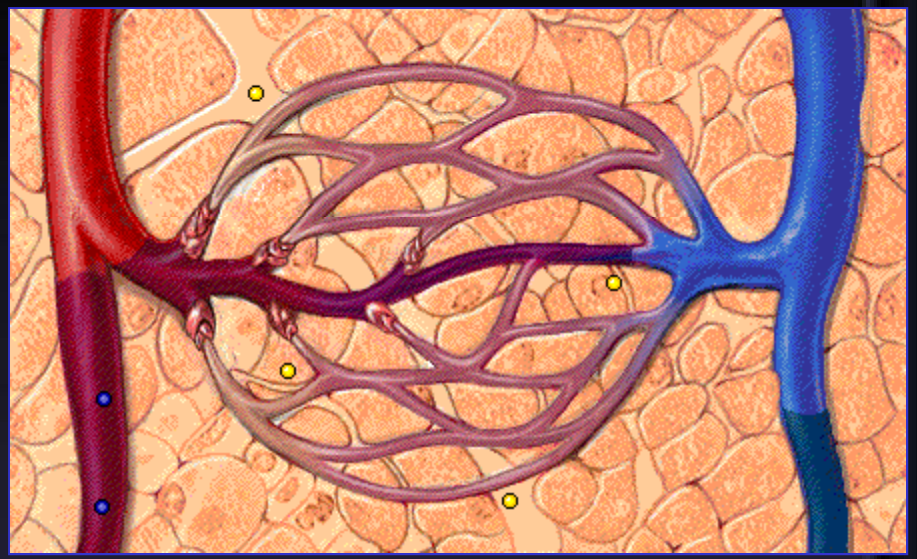
LONG TERM CONTROL

CHANGE IN TISSUE VASCULARITY
(Angiogenesis & Angiogenic Factors)

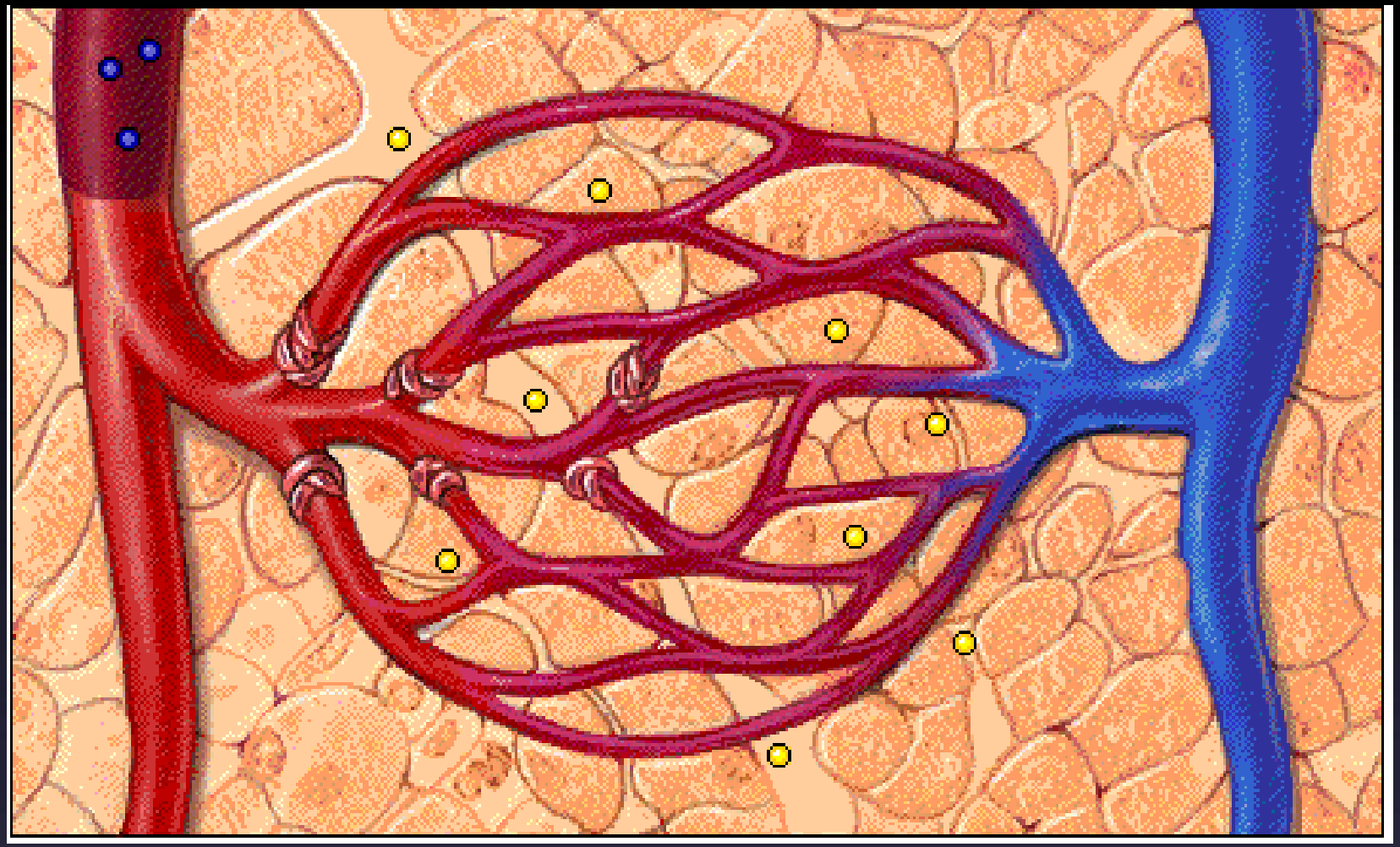
VASOMOTION

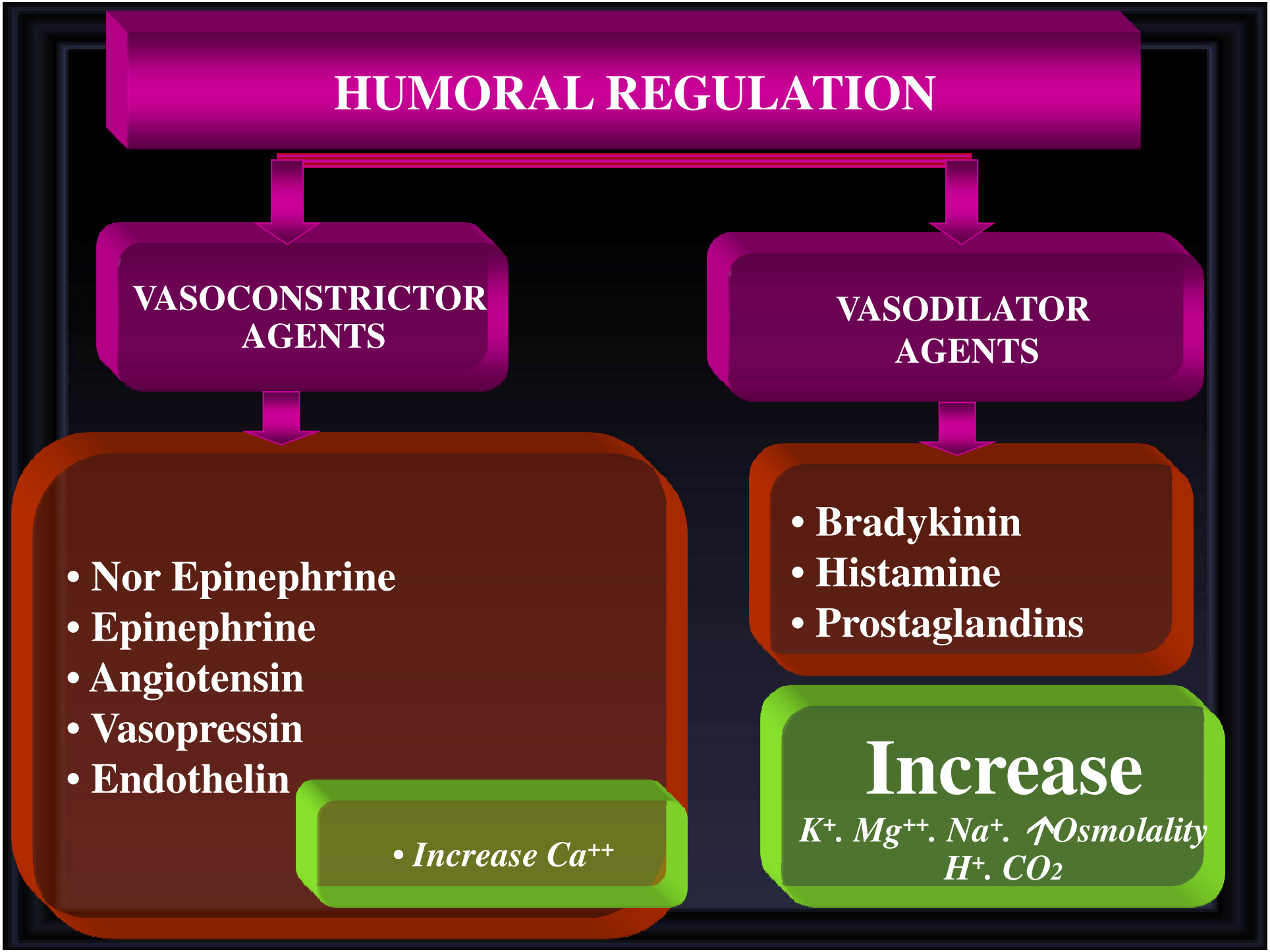






VASOMOTION

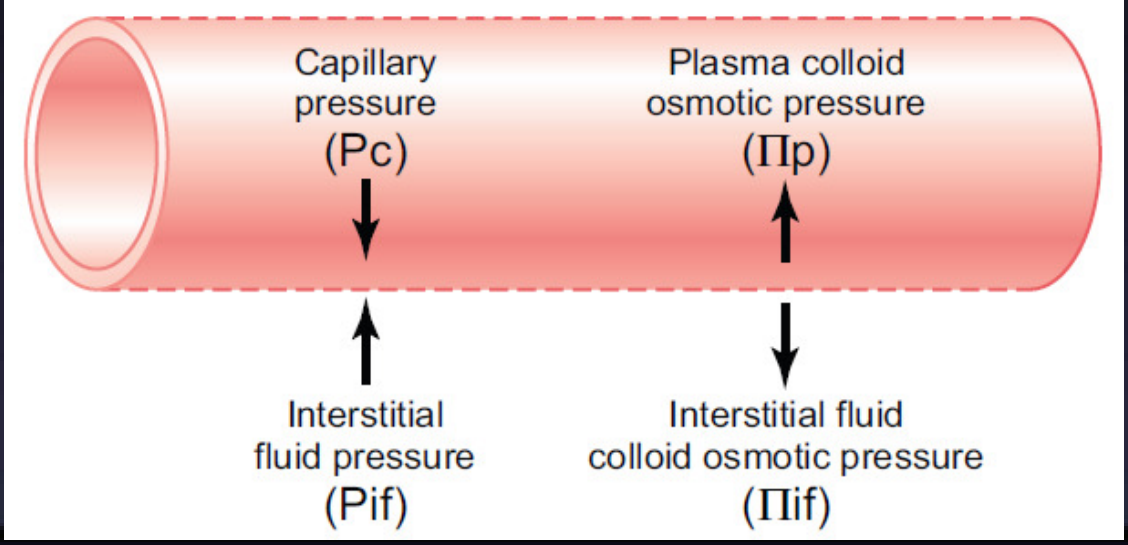



HUMORAL REGULATION
VASOCONSTRICTOR AGENTS
VASODILATOR AGENTS
• Nor Epinephrine
• Epinephrine
• Angiotensin
• Vasopressin
• Endothelin
• Increase Ca++
• Bradykinin
• Histamine
• Prostaglandins
Increase
K+. Mg++. Na+. ↑Osmolality
H+. CO2

Four Primary Hydrostatic and Colloid Osmotic Forces Determine Fluid Movement Through the Capillary Membrane

1. The capillary pressure (Pc
2. The interstitial fluid pressure (Pif
3. The capillary plasma colloid osmotic pressure (Pp)
4. The interstitial fluid colloid osmotic pressure (Pif),

$$NFP = Pc - Pif - Pp + Pif$$



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

	mm Hg
Forces tending to move fluid outward:	
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

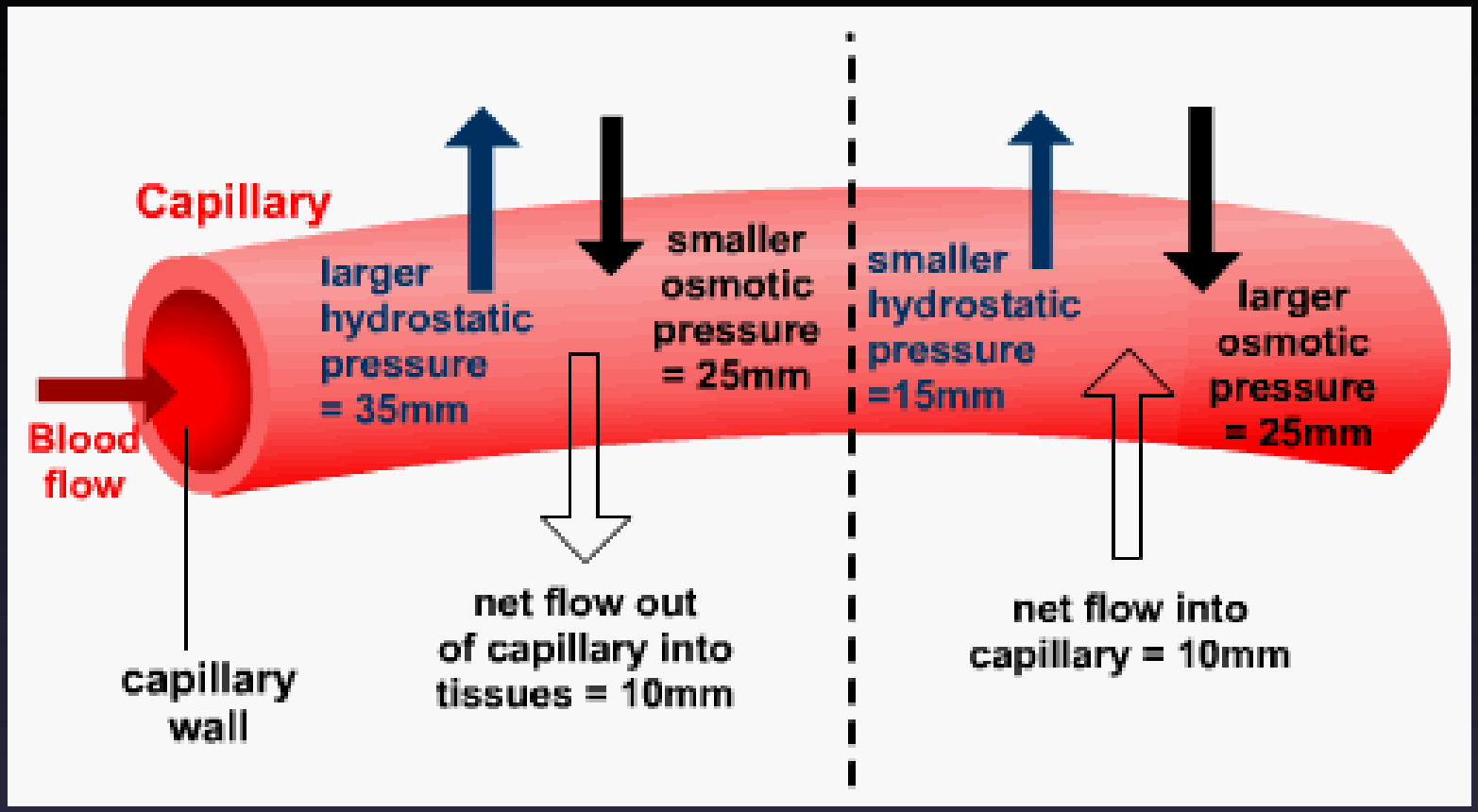
Analysis of Reabsorption at the Venous End of the capillary

	mm Hg
Forces tending to move fluid inward:	
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

Starling Equilibrium for Capillary Exchange

	mm Hg
Mean forces tending to move fluid outward:	
Mean capillary pressure	17.3
Negative interstitial free fluid pressure	3.0
Interstitial fluid colloid osmotic pressure	8.0
TOTAL OUTWARD FORCE	28.3
Mean force tending to move fluid inward:	
Plasma colloid osmotic pressure	28.0
TOTAL INWARD FORCE	28.0
Summation of mean forces:	
Outward	28.3
Inward	28.0
NET OUTWARD FORCE	0.3

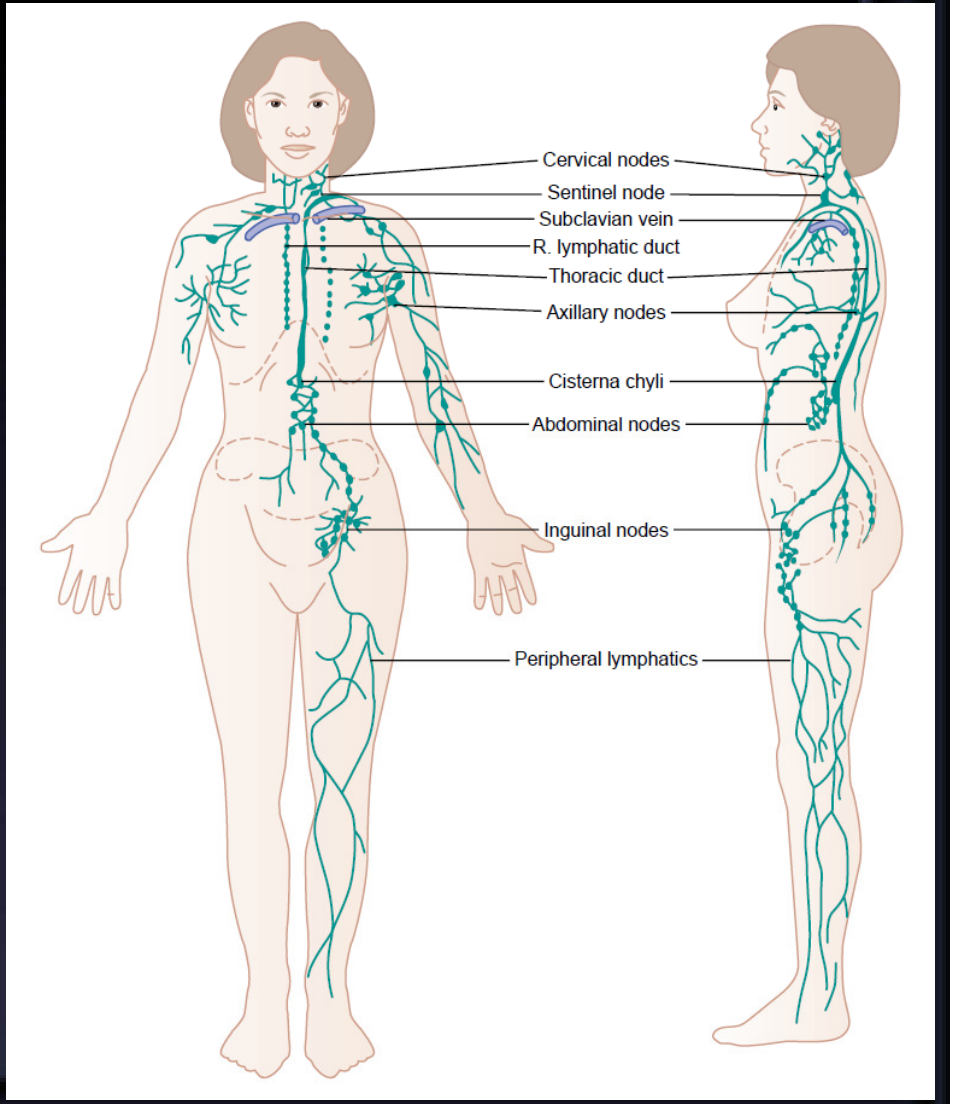
Hydrostatic and Colloid Osmotic Forces at the Capillary Membrane



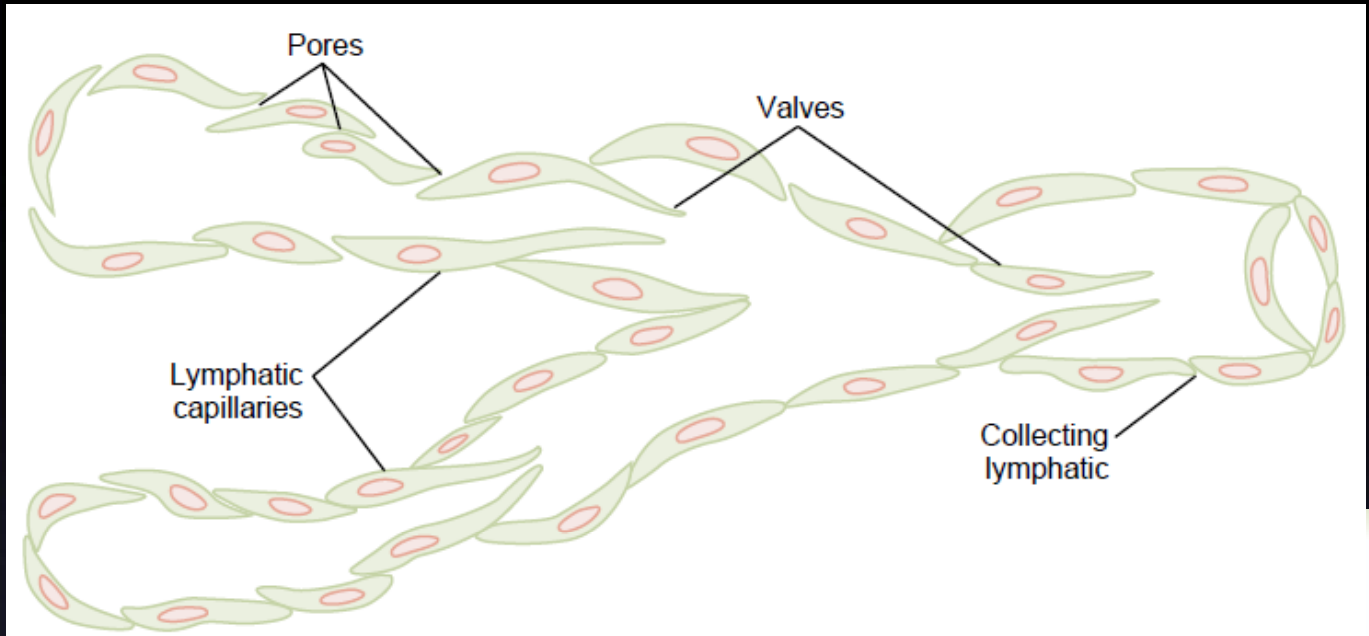
Lymphatic System

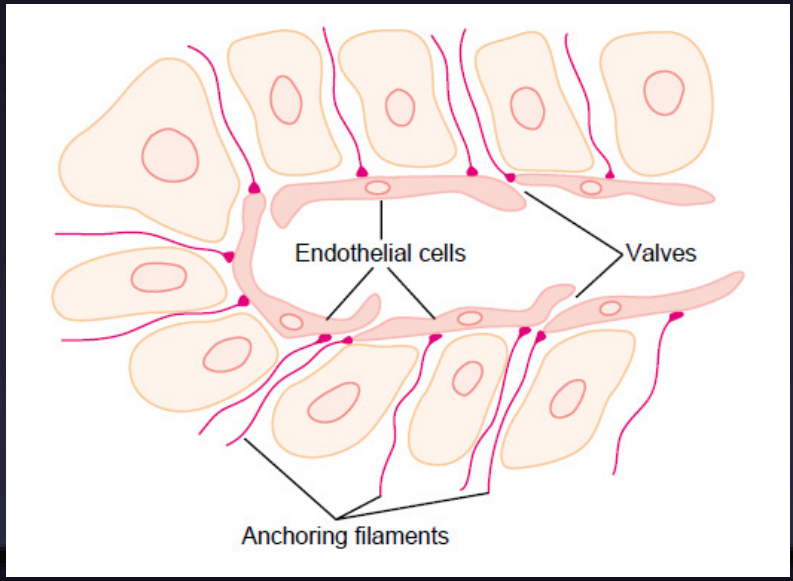
- **Carry protein** and large particulate matter can flow from the interstitial spaces into the blood
- **Absorption of nutrients** from the gastrointestinal tract, especially for absorption of virtually **all fats** in food

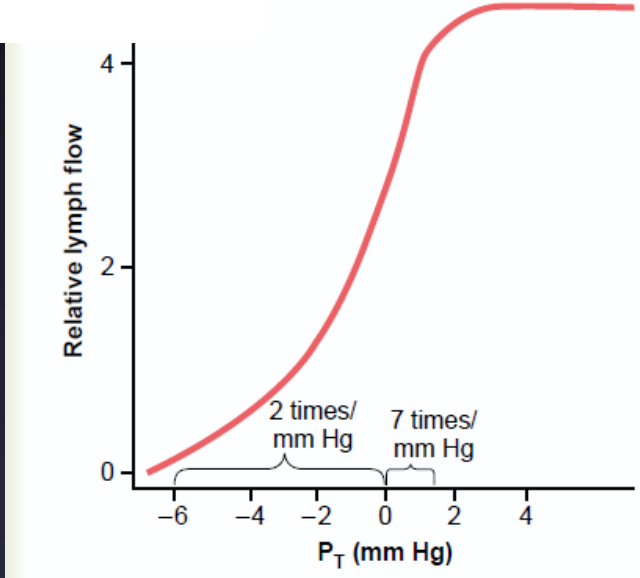
2 to 3 liters each day



Special structure of the lymphatic capillaries







Edema

Edema refers to the presence of excess fluid in the body tissues

- **Intracellular Edema:**
- **Extracellular Edema:** Extracellular fluid edema occurs when there is excess fluid accumulation in the extracellular spaces
- **Abnormal leakage of fluid from the plasma to the interstitial spaces across the capillaries**
  - Increased capillary filtration coefficient.
  - Increased capillary hydrostatic pressure.
  - Decreased plasma colloid osmotic pressure
- **Lymphatic Blockage Causes Edema***filaria nematodes*

Causes of Extracellular Edema

I. Increased capillary pressure
   A. Excessive kidney retention of salt and water
      1. Acute or chronic kidney failure
      2. Mineralocorticoid excess
   B. High venous pressure and venous constriction
      1. Heart failure
      2. Venous obstruction
      3. Failure of venous pumps
         (a) Paralysis of muscles
         (b) Immobilization of parts of the body
         (c) Failure of venous valves
   C. Decreased arteriolar resistance
      1. Excessive body heat
      2. Insufficiency of sympathetic nervous system
      3. Vasodilator drugs

II. Decreased plasma proteins
   A. Loss of proteins in urine (nephrotic syndrome)
   B. Loss of protein from denuded skin areas
      1. Burns
      2. Wounds
   C. Failure to produce proteins
      1. Liver disease (e.g., cirrhosis)
      2. Serious protein or caloric malnutrition

Causes of Extracellular Edema

III. Increased capillary permeability
  A. Immune reactions that cause release of histamine and other immune products
  B. Toxins
  C. Bacterial infections
  D. Vitamin deficiency, especially vitamin C
  E. Prolonged ischemia
  F. Burns
IV. Blockage of lymph return
  A. Cancer
  B. Infections (e.g., filaria nematodes)
  C. Surgery
  D. Congenital absence or abnormality of lymphatic vessels


THANKS