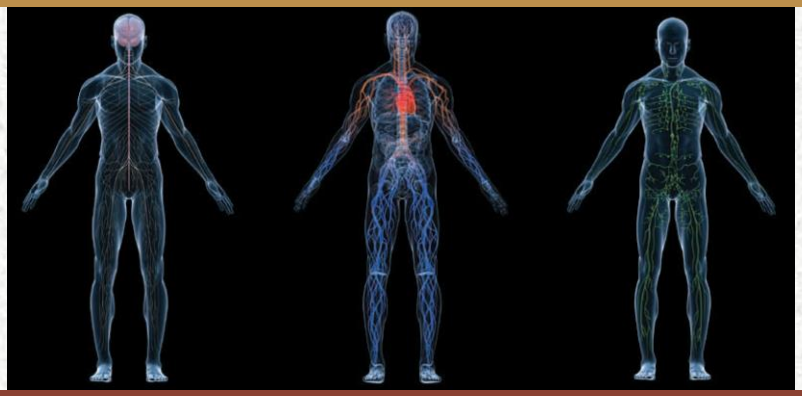
UNIT IV

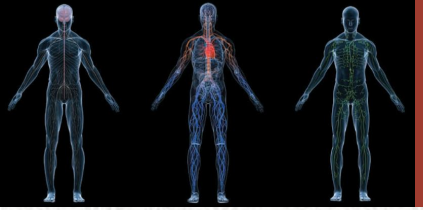
GUYTON AND HALL *Textbook of*
Medical Physiology
TWELFTH EDITION



Chapter 16:

The Microcirculation and Lymphatic System: Capillary Fluid Exchange, Interstitial Fluid, and Lymph Flow

Dr. Ebaa Alzayadneh, PhD



Overall Objectives

- Know the structure and function of the microcirculation
- Know how solutes and fluids are exchanged in capillaries
- Know what determines net fluid movement across capillaries

The Microcirculation

- Important in the transport of nutrients to tissues
- Site of waste product removal
- Over 10 billion capillaries with surface area of 500-700 square meters perform function of solute and fluid exchange

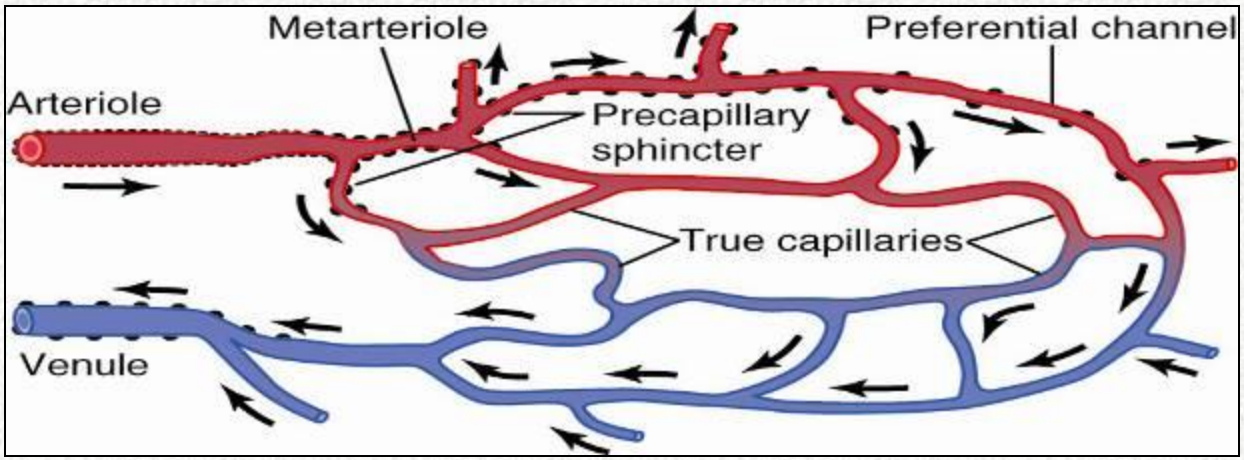
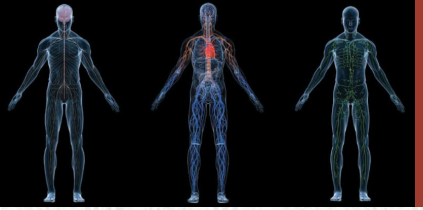
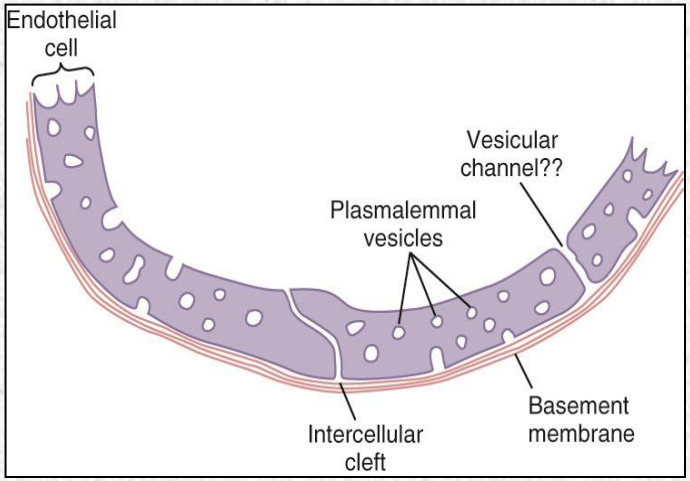


Figure 16-1



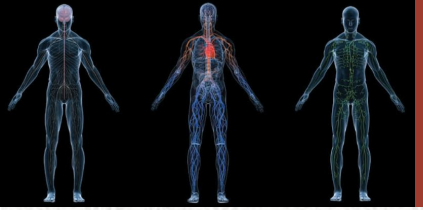
Structure of Capillary Wall

- Composed of unicellular layer of endothelial cells surrounded by a basement membrane



- Diameter of capillaries is 4 to 9 microns

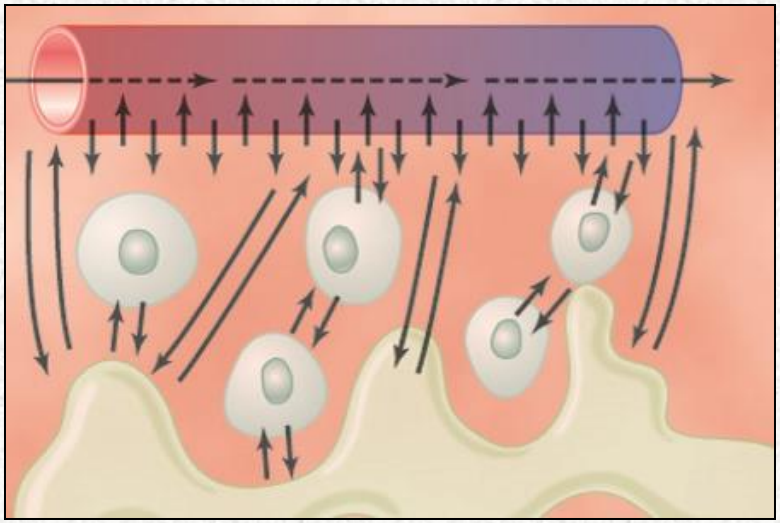
- Solute and water move across capillary wall via *intercellular cleft* (space between cells) or by *plasmalemma vesicles (Caveolae)*



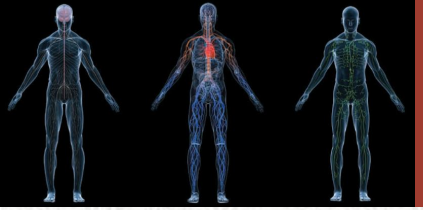
Solute and Fluid Exchange Across Capillaries

- Most important means by which substances are transferred between plasma and interstitial fluid is by *diffusion*

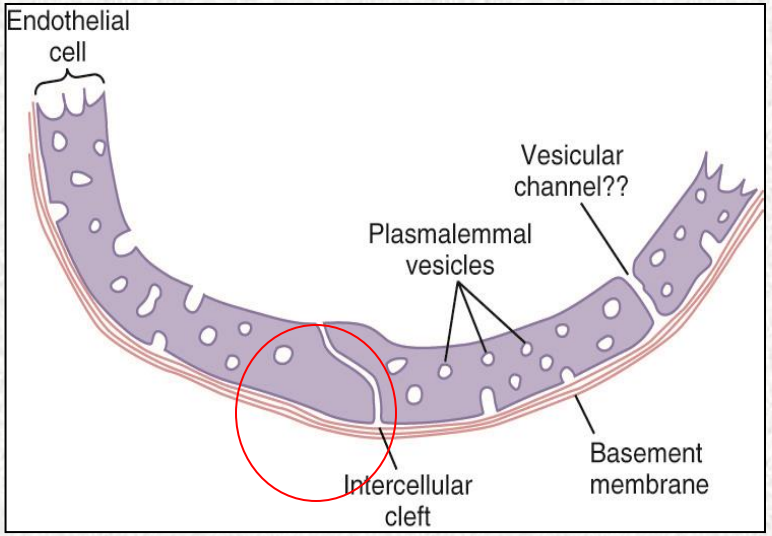
(Bulk diffusion)



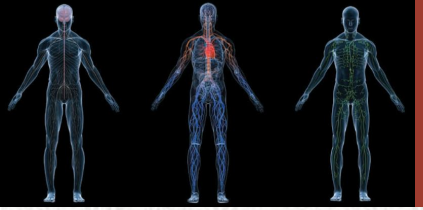
- *Lipid soluble* substances diffuse directly through cell membrane of capillaries (I.E.CO2, O2) (more rapidly)
- *Lipid insoluble* substances such as H2O, Na, Cl, glucose cross capillary walls via intercellular clefts (80 times more than bld flow in cap)
- *Concentration differences* across capillary enhances diffusion (only slight is enough)



Effect of Molecular Size on Passage Through Capillary Pores

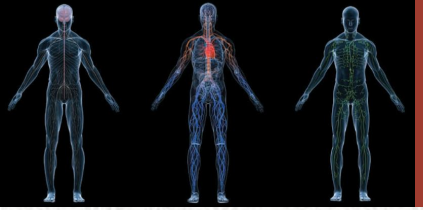


- The *width of capillary intercellular slit* pores is 6 to 7 nanometers
- The *permeability* of the capillary pores for different substances varies according to their *molecular diameters*
- The capillaries in different tissues have *extreme differences* in their permeabilities (brain, liver, kidney)



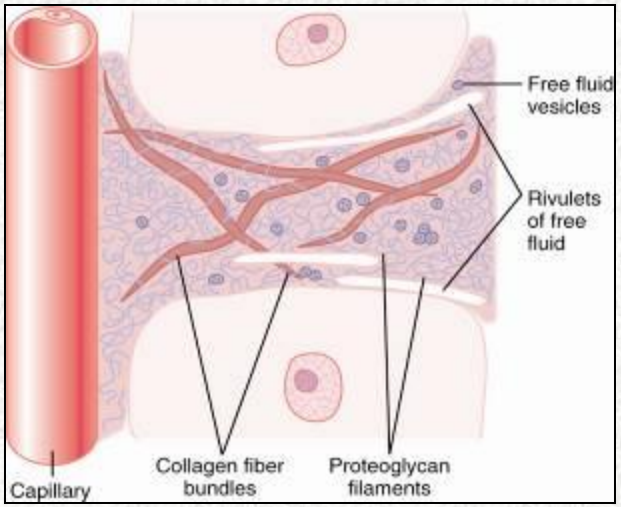
Relative Permeability of Muscle Capillary Pores to Different-sized Molecules

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
Insulin	5000	0.2
Myoglobin	17,600	0.03
Hemoglobin	69,000	0.01
Albumin	69,000	.0001



Interstitium and Interstitial Fluid

- Space between cells is called *interstitium*; fluid in this space is called *interstitial fluid*



- Two major types of solid structures in interstitium are *collagen* fibers and *proteoglycan* filaments (coiled molecules composed of hyaluronic acid)

- Almost all fluid in interstitium is in form of *ge*l (fluid proteoglycan mixtures); there is very little free fluid under normal conditions

Determinants of Net Fluid Movement across Capillaries

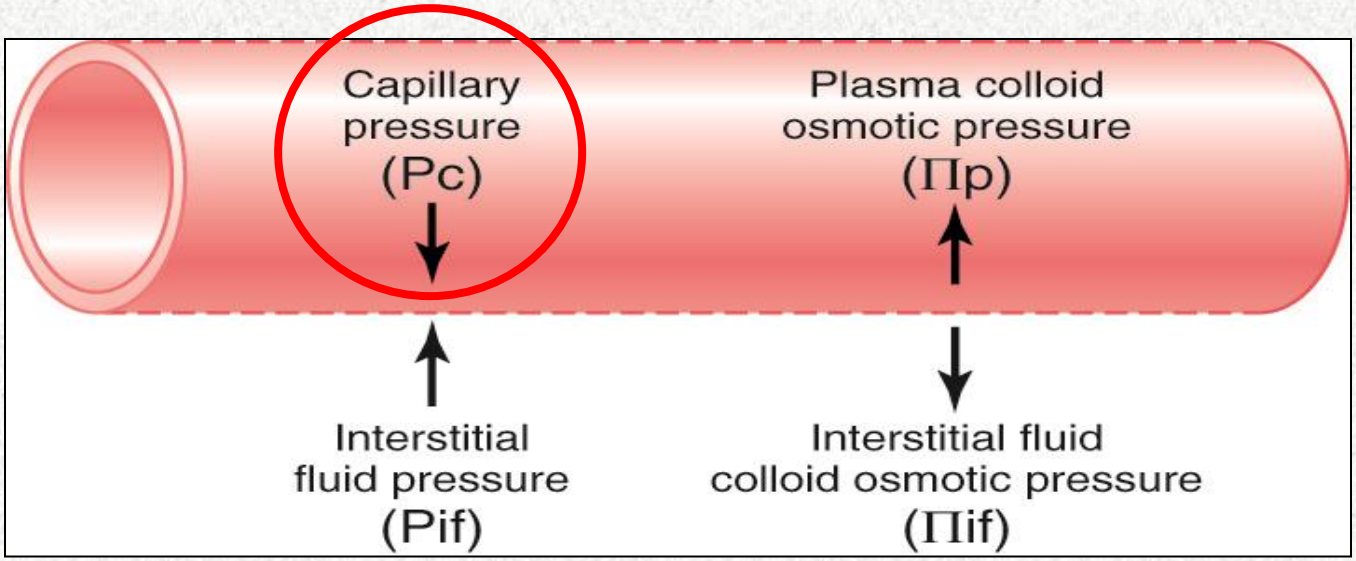
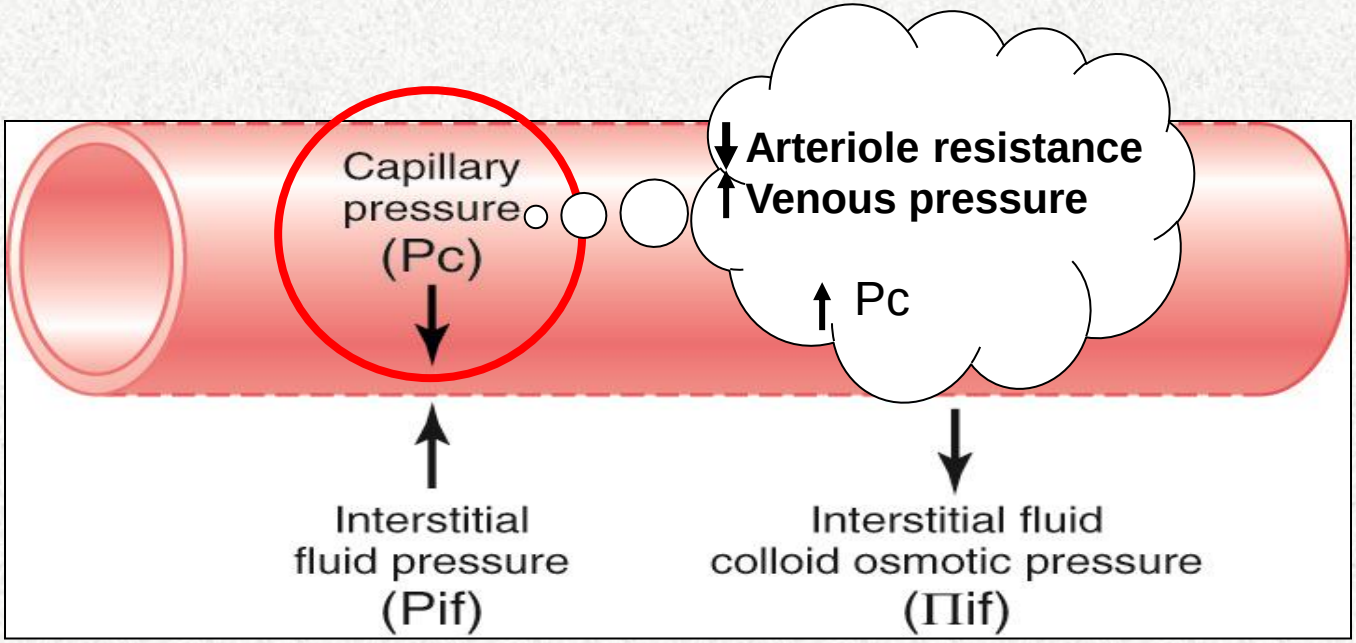


Figure 16-5

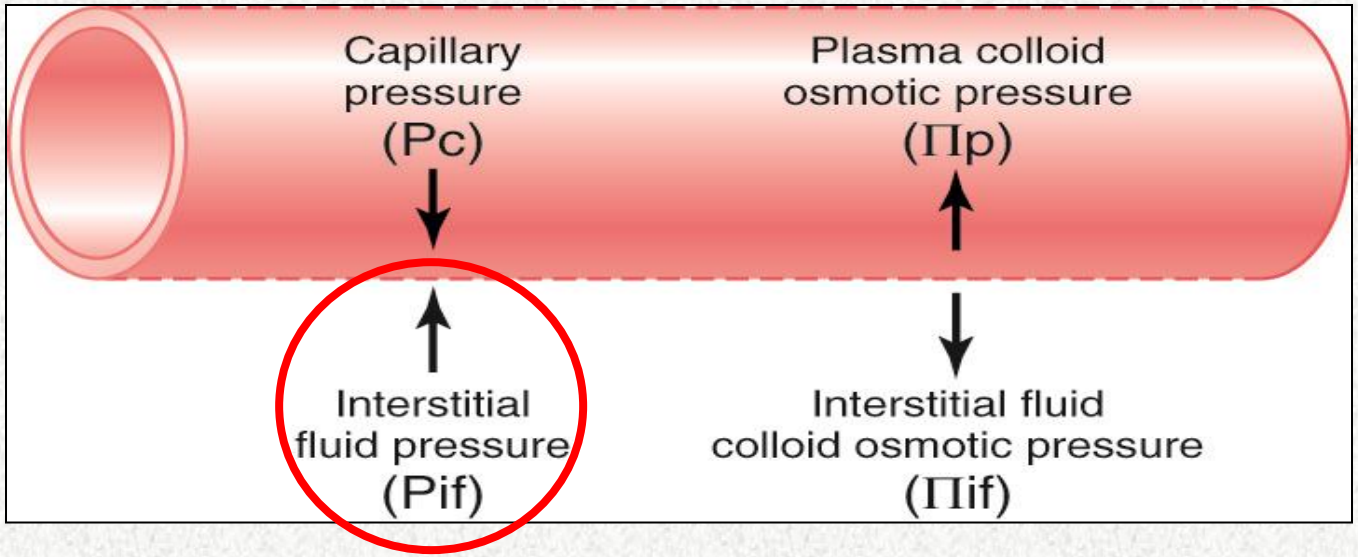
- *Capillary hydrostatic pressure* (Pc)-tends to force fluid outward through the capillary membrane

Determinants of Net Fluid Movement across Capillaries



- *Capillary hydrostatic pressure* (Pc)-tends to force fluid outward through the capillary membrane

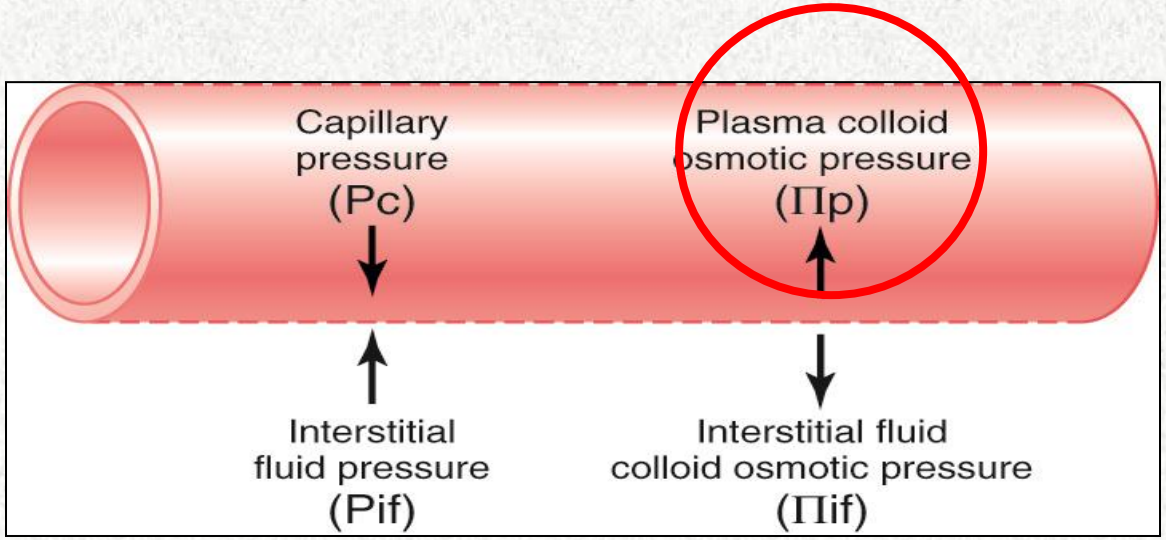
Determinants of Net Fluid Movement across Capillaries



- *Capillary hydrostatic pressure* (Pc)-tends to force fluid outward through the capillary membrane

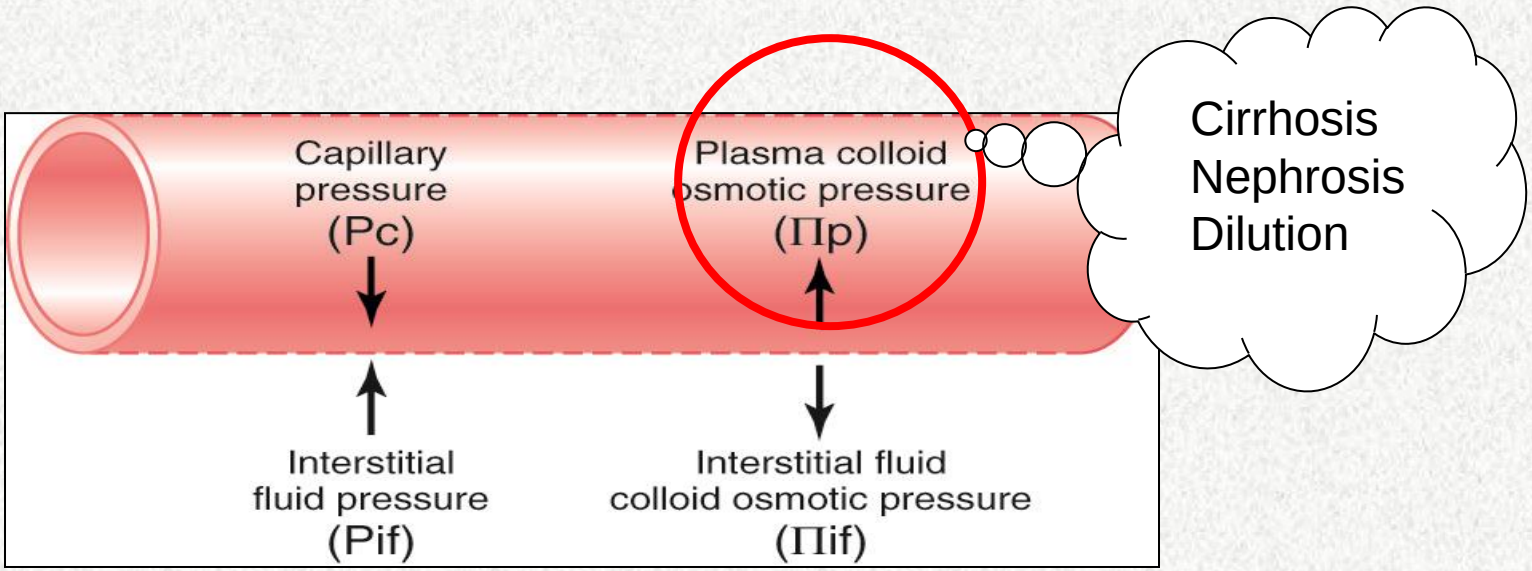
- *Interstitial fluid pressure* (Pif)- opposes filtration when value is positive

Determinants of Net Fluid Movement across Capillaries

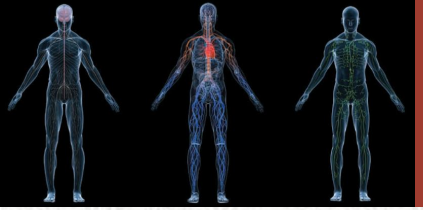


- *Plasma colloid osmotic pressure* - opposes filtration causing osmosis of water inward through the membrane

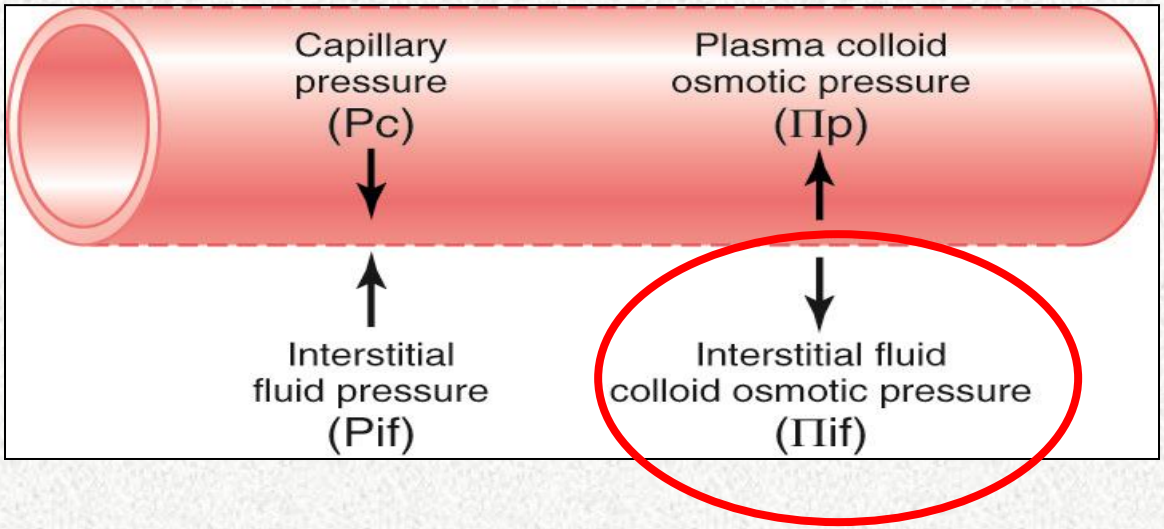
Determinants of Net Fluid Movement across Capillaries



- *Plasma colloid osmotic pressure* - opposes filtration causing osmosis of water inward through the membrane

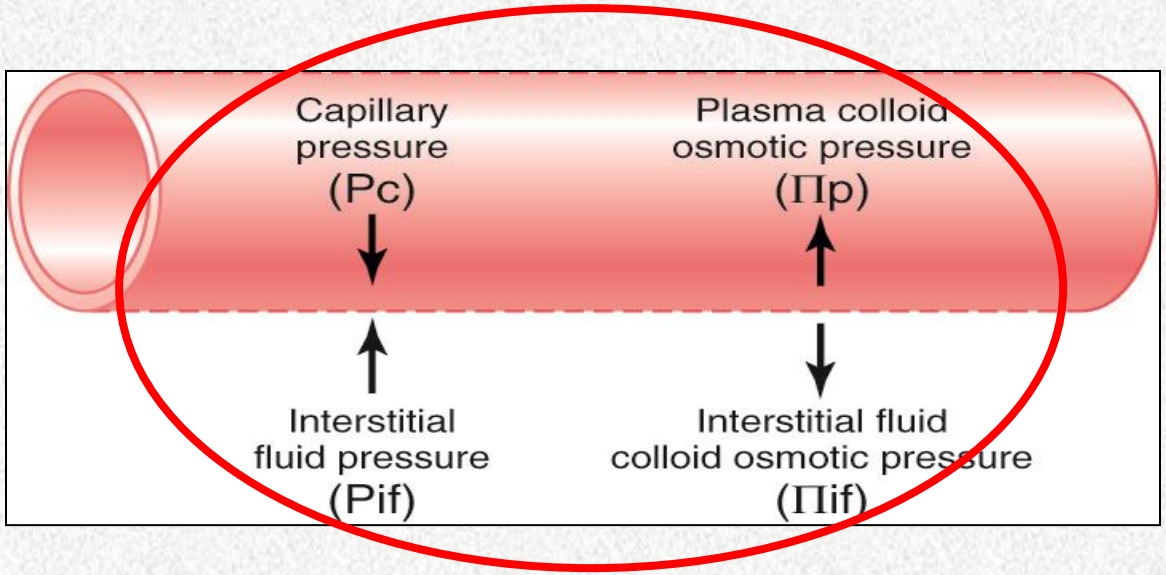


Determinants of Net Fluid Movement across Capillaries

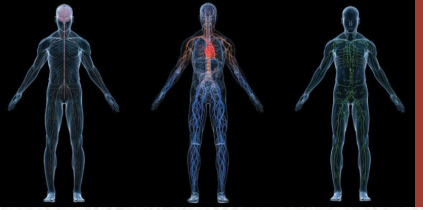


- *Interstitial fluid colloid pressure*- promotes filtration by causing osmosis of fluid outward through the membrane

Determinants of Net Fluid Movement across Capillaries

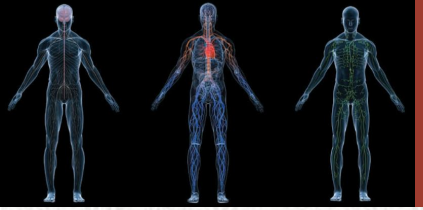


$$NP = Pc - \pi p - Pif + \pi if$$



Starling Forces (Part I)

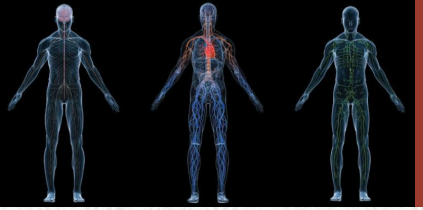
- Normal *Capillary hydrostatic pressure* is approximately 17 mmHg
- *Interstitial fluid pressure* in most tissues is negative 3. Encapsulated organs have positive interstitial pressures (+5 to +10 mmHg)
- Negative interstitial fluid pressure is *caused by pumping of lymphatic system*
- *Colloid osmotic pressure* is caused by presence of large proteins



Plasma Proteins and Colloid Osmotic Pressure

- 75% of the total colloid osmotic pressure of plasma results from the presence of *albumin* and 25% is due to *globulins*

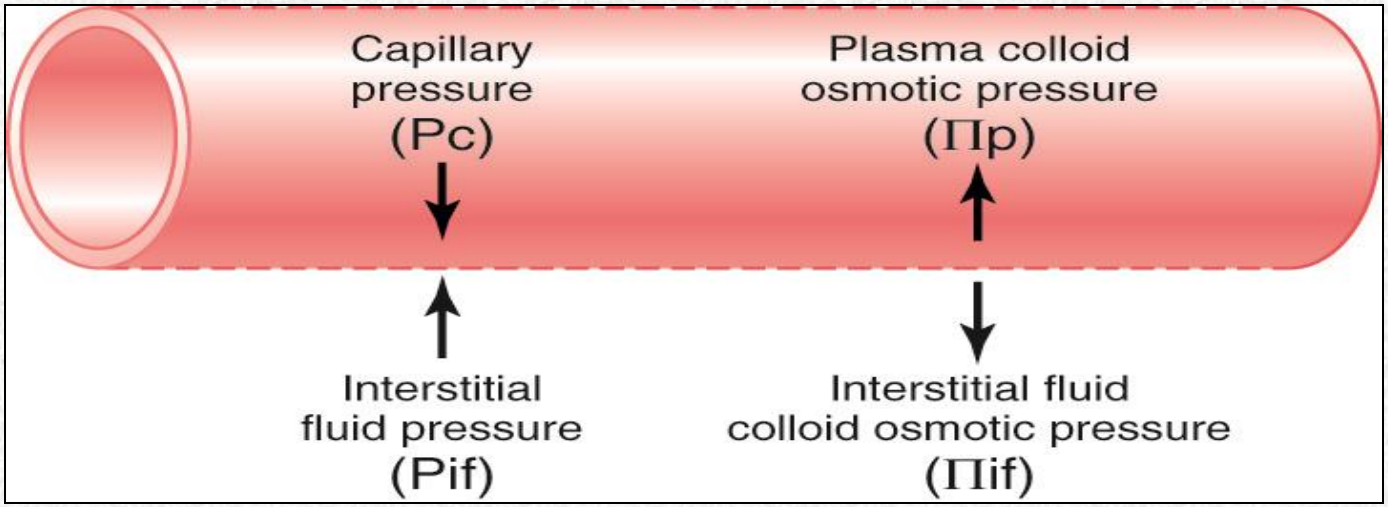
	gm/dl	*πp(mmHg)*
Albumin	4.5	21.8
Globulins	2.5	6.0
Fibrinogen	0.3	0.2
Total	7.3	28.0



Interstitial Colloid Osmotic Pressure

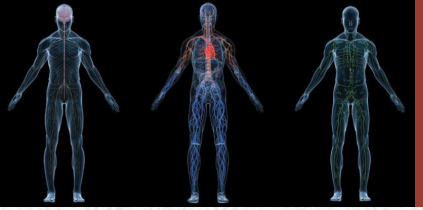
- *Interstitial protein conc.* is approx. 3gm/dl
- The interstitial colloid osmotic pressure is normally 8mmHg

Determinants of Net Fluid Movement Across Capillaries

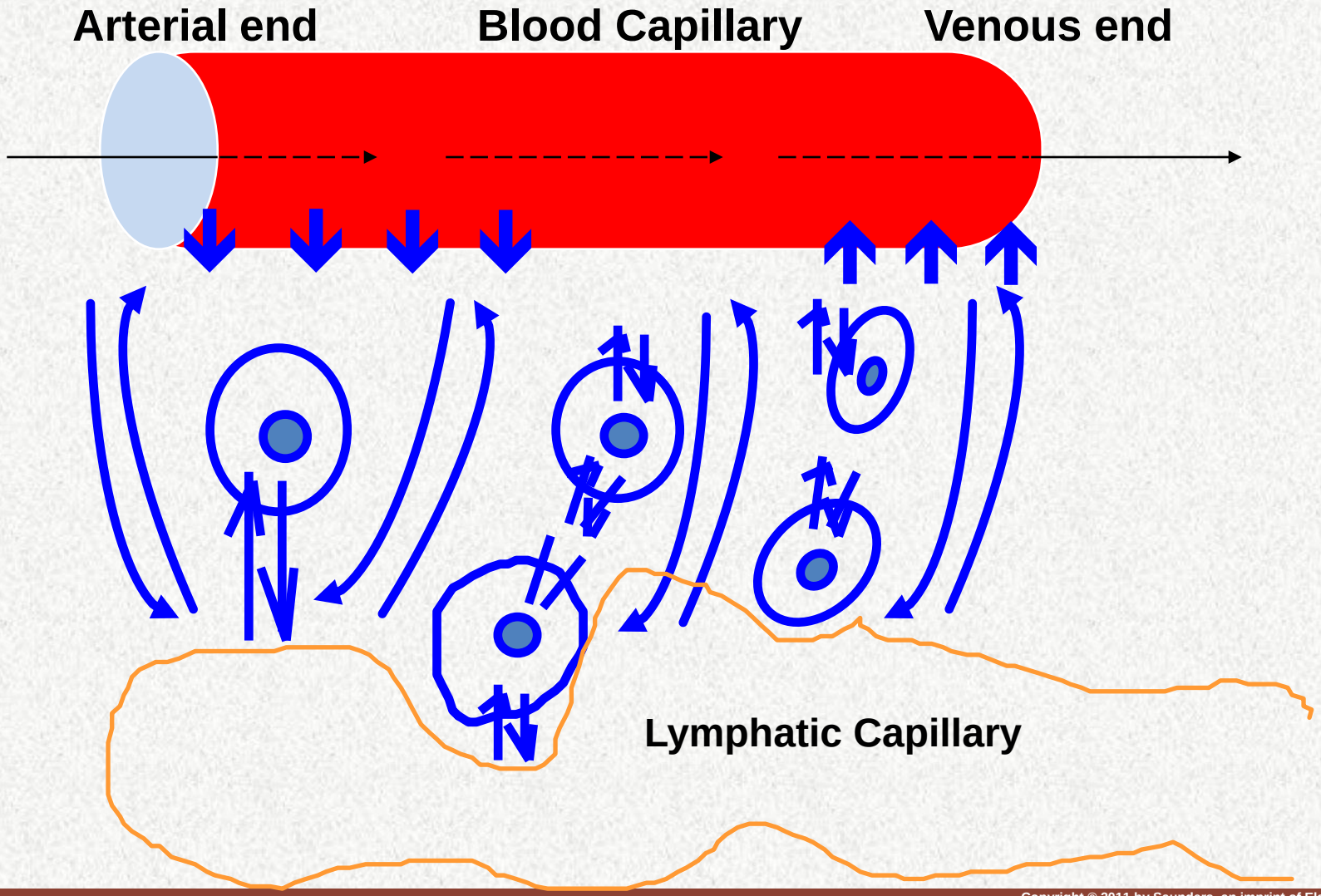


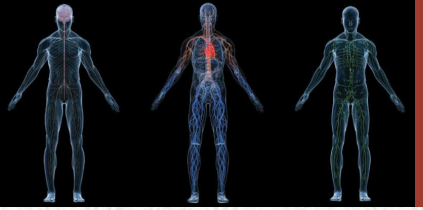
$$NFP = Pc - Pif - \Pi p + \Pi if$$

- *Filtration rate* = net filtration pressure *(NFP)* multiplied by the filtration coefficient
- *Filtration coefficient (Kf)* is a product of surface area times the hydraulic conductivity of membrane

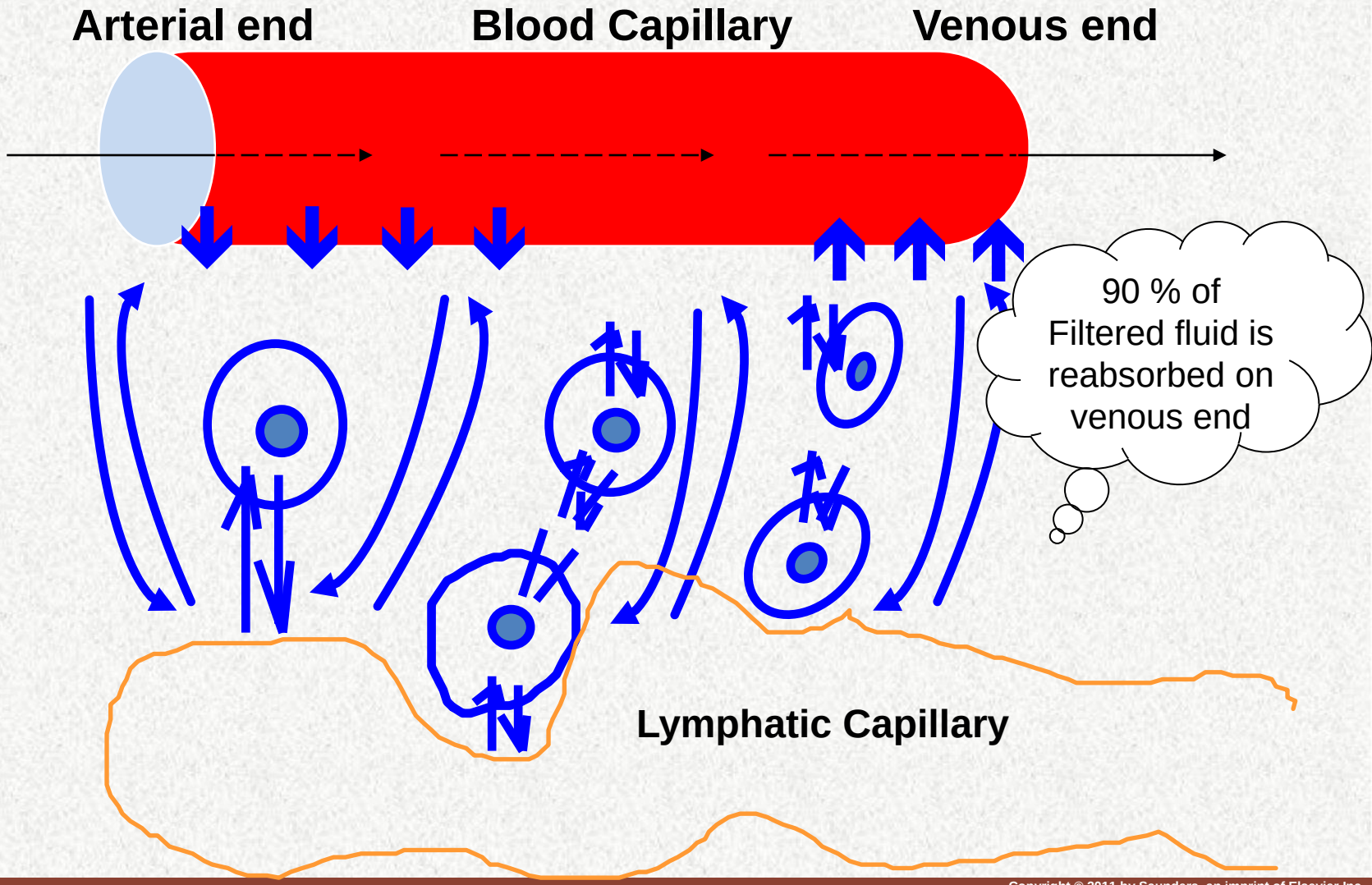


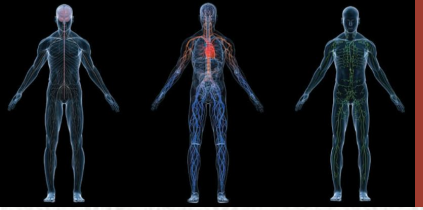
Solute and Fluid Exchange Across Capillaries



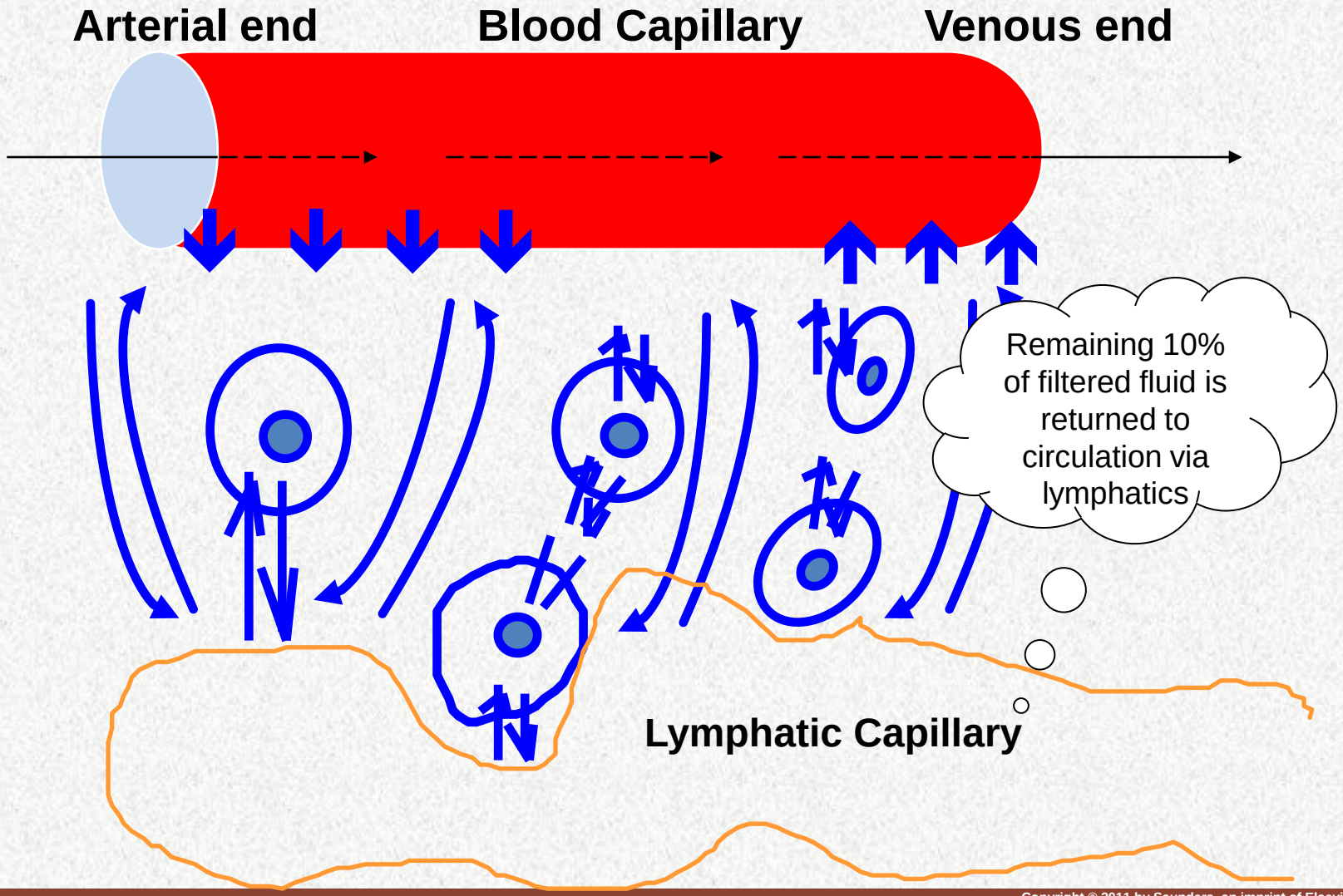


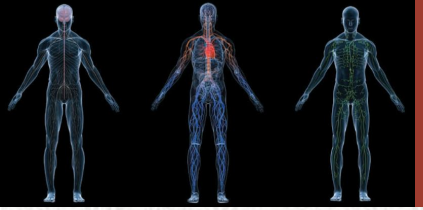
Solute and Fluid Exchange Across Capillaries





Solute and Fluid Exchange Across Capillaries

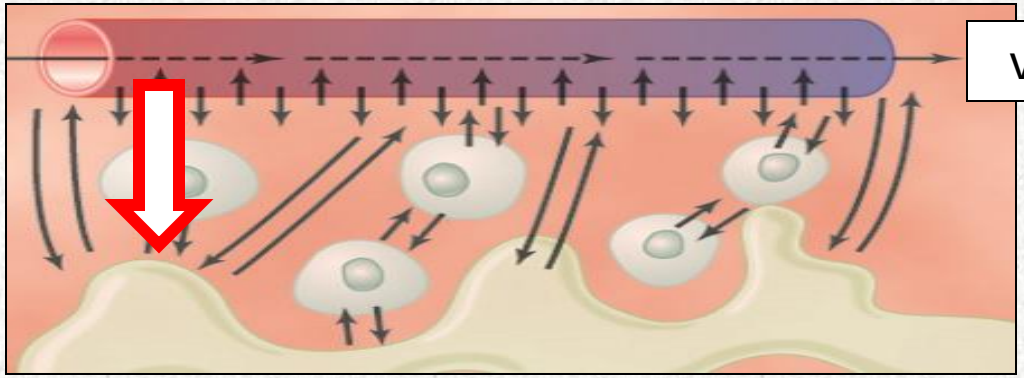




Forces Causing Filtration at the Arteriole End of the Capillary

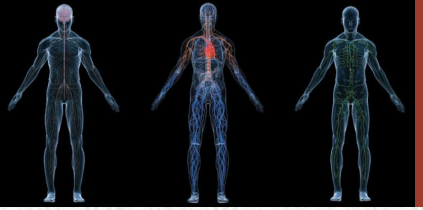
	mmHg
Forces tending to move fluid outward:	
Capillary pressure	30
Negative interstitial free fluid pressure	3
Interstitial fluid colloid osmotic pressure	8
TOTAL OUTWARD FORCE	41
Forces tending to move fluid inward:	
Plasma colloid osmotic pressure	28
TOTAL INWARD FORCE	28
Summation of forces:	
Outward	41
Inward	28
NET OUTWARD FORCE	13

arteriole



venous

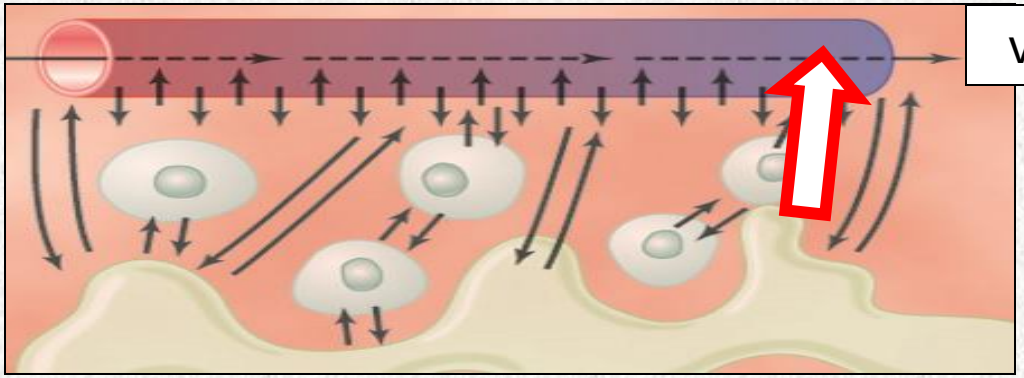
	mmHg
Forces tending to move fluid outward:	
Capillary pressure	30
Negative interstitial free fluid pressure	3
Interstitial fluid colloid osmotic pressure	8
TOTAL OUTWARD FORCE	41
Forces tending to move fluid inward:	
Plasma colloid osmotic pressure	28
TOTAL INWARD FORCE	28
Summation of forces:	
Outward	41
Inward	28
NET OUTWARD FORCE	13



Forces Causing Reabsorption at the Venous End of the Capillary

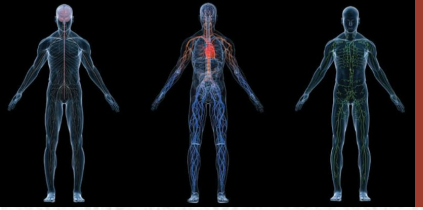
	mmHg
Forces tending to move fluid inward:	
Plasma colloid osmotic pressure	28
TOTAL INWARD FORCE	28
Forces tending to move fluid outward:	
Capillary pressure	10
Negative interstitial free fluid pressure	3
Interstitial fluid colloid osmotic pressure	8
TOTAL OUTWARD FORCE	21
Summation of forces:	
Outward	21
Inward	28
NET INWARD FORCE	7

arteriole



venous

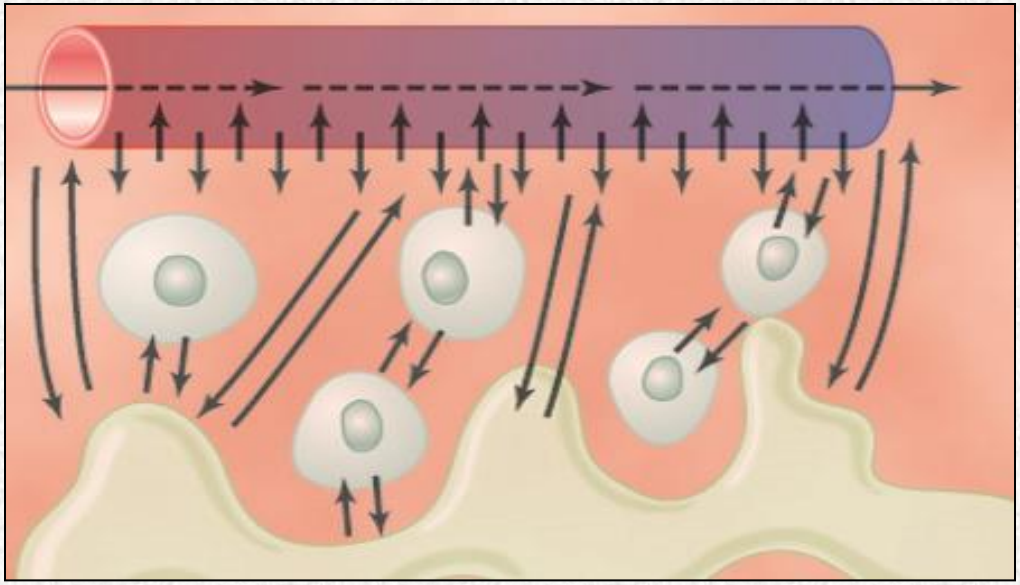
	mmHg
Forces tending to move fluid inward:	
Plasma colloid osmotic pressure	28
TOTAL INWARD FORCE	28
Forces tending to move fluid outward:	
Capillary pressure	10
Negative interstitial free fluid pressure	3
Interstitial fluid colloid osmotic pressure	8
TOTAL OUTWARD FORCE	21
Summation of forces:	
Outward	21
Inward	28
NET INWARD FORCE	7



Net Starting Forces in Capillaries

	mmHg	
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

Net Starling Forces in Capillaries



- *Net filtration pressure* of .3 mmHg which causes a net filtration rate of 2ml/min for entire body

Lymphatic System

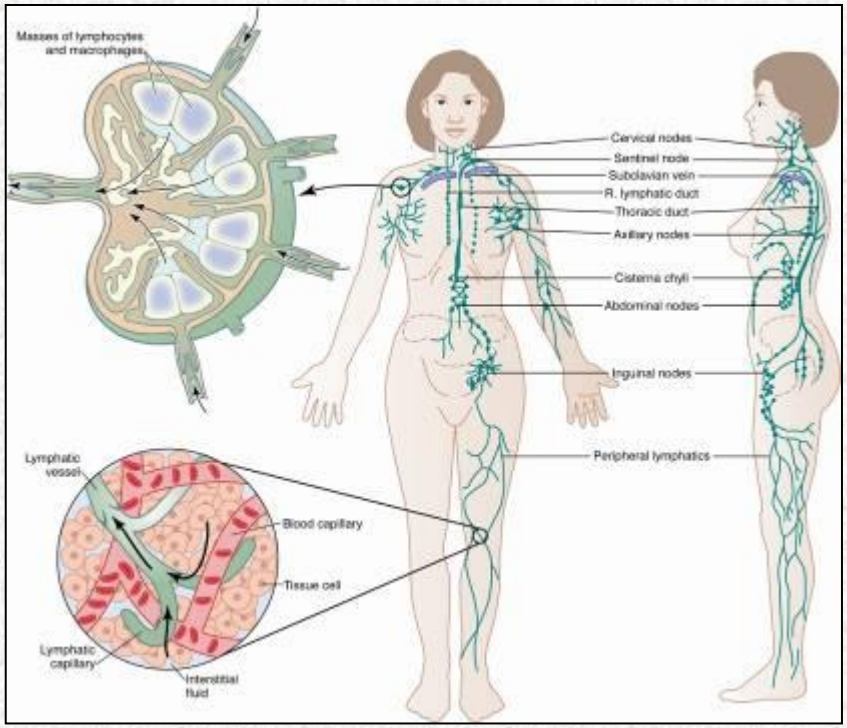
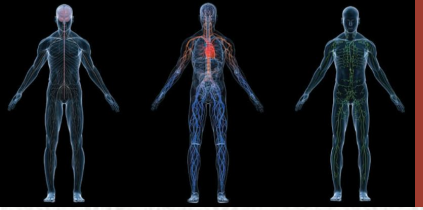


Figure 16-7

- An accessory route by which fluid and protein can flow from interstitial spaces to the blood
- Important in preventing *edema*
- Lymph is derived from interstitial fluid that flows into the lymphatics
- Major route for absorption of nutrients from the GI tract
- Plays important role in the immune system



Determinants of Lymph Flow

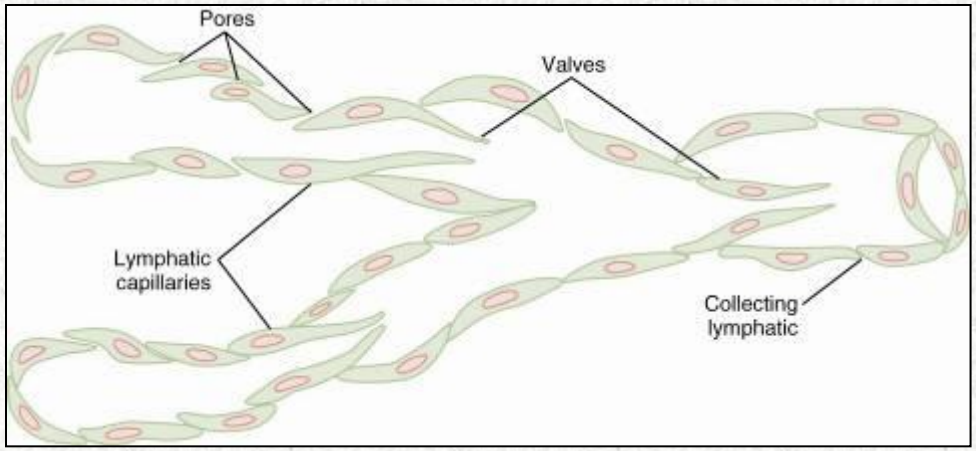


Figure 16-10

- The degree of activity of the lymphatic pump
  - Smooth muscle filaments in lymph vessel cause them to contract
  - External compression also contributes to lymphatic pumping

Determinants Of Lymph Flow

↑ Interstitial fluid hydrostatic pressure → ↑Lymph Flow

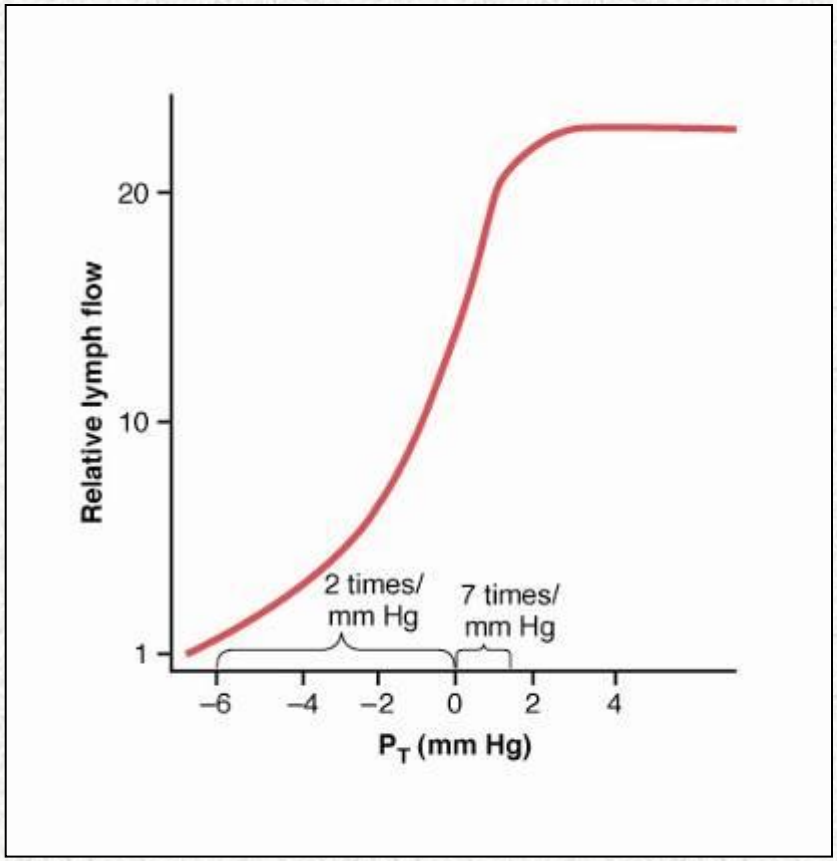


Figure 16-9

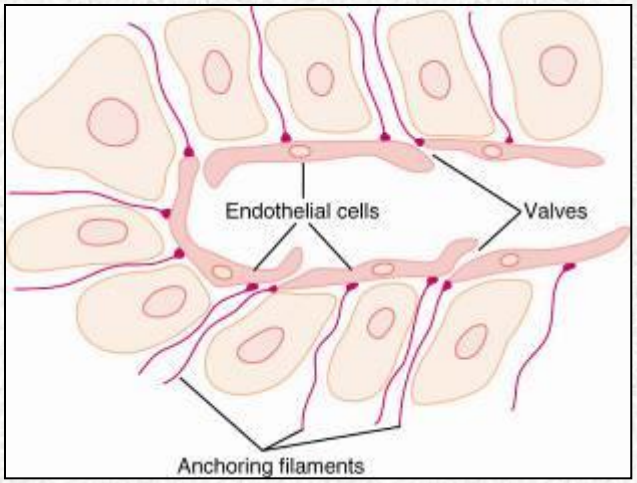
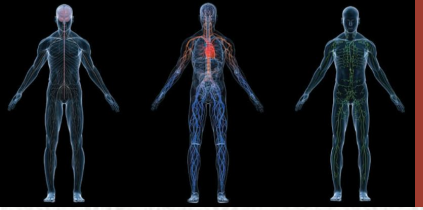


Figure 16-8



YOU SHOULD KNOW

- ✓ Know the structure and function of the microcirculation
- ✓ Know how solutes and fluids are exchanged in capillaries
- ✓ Know what determines net fluid movement across capillaries
- ✓ Describe the function of the lymphatic system
- ✓ Know what determines lymph flow
- ✓ Know how lymph flow changes in pathophysiology