Physiology Team 431

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Capillary Circulation
&
Edema Formation

Dr. Eman El Eter

Functions of capillaries

Exchange between blood & tissues:

Nutrients,

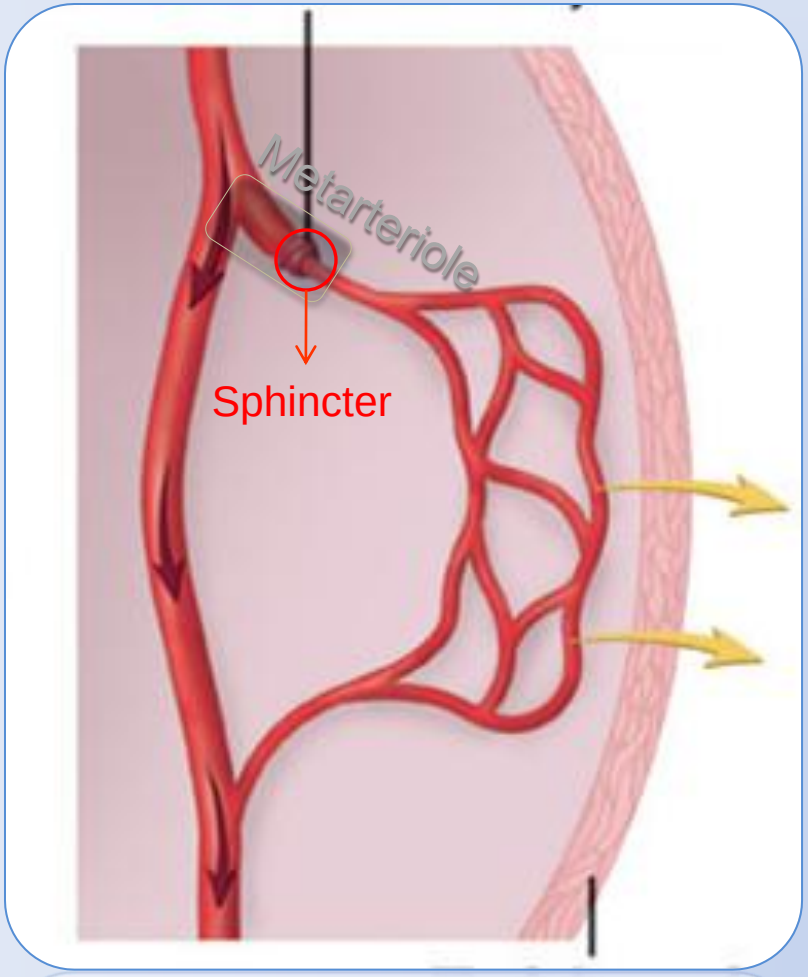
Oxygen

Drainage of waste products: tissues….to blood

Capillary tone

- **Capillary tone** refers to the number of closed capillaries at rest. Normally about 80%-85% of the capillaries are closed and 20%-15% are open.
- If 50% of capillaries are opened, this leads to shock.
- Capillary tone is important because it maintain pressure for perfusion.
- Only 5% of blood found in the capillaries.

Auto-regulation : ability of tissues to regulate blood flow according to its metabolic needs.

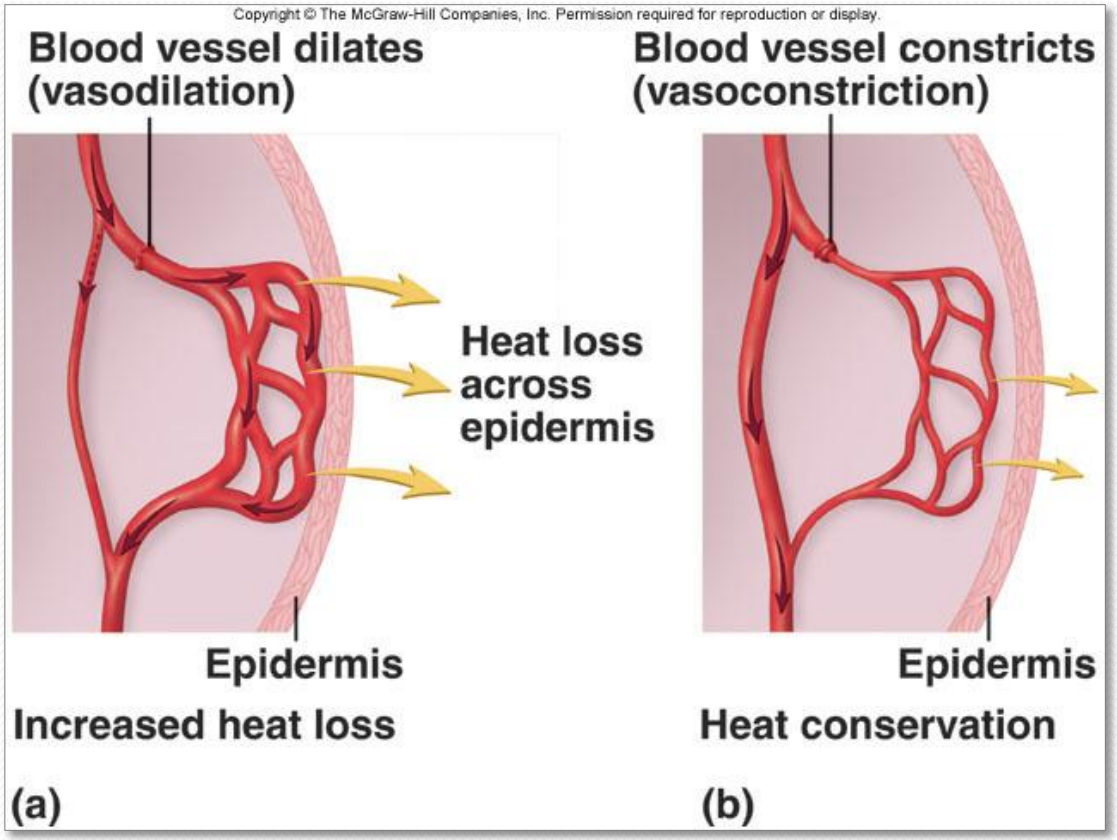


•This selected area of the blood vessel called (Metarteriole) , it contain a Sphincter that contact and relax according to the metabolic needs of the tissue.

•This sphincter called **precapillary sphincter** because it located before the beginning of capillary.

•Capillary doesn't have a vascular smooth muscle.

Temperature regulation



- **In hot weather** > sphincter relaxes > increase blood flow > get rid of excess heat.
- **In cold weather** > sphincter contracts > decrease blood flow > conserve heat

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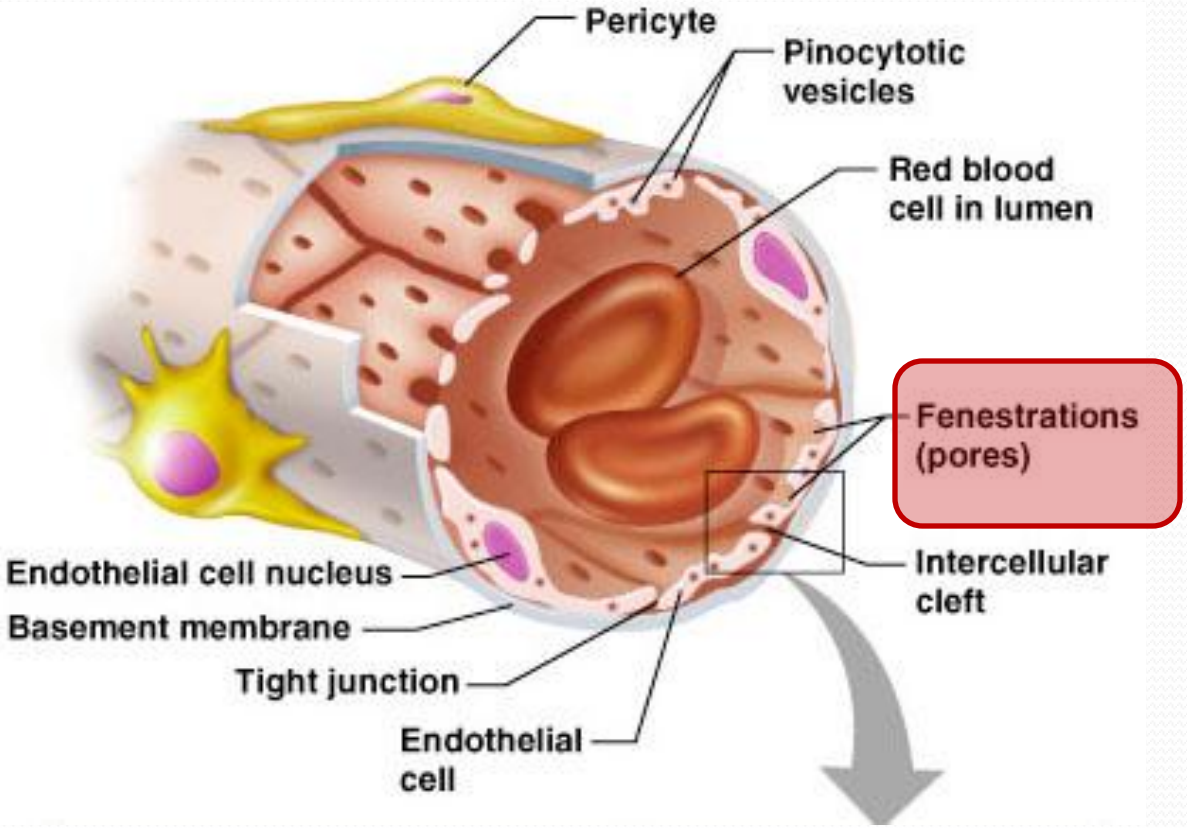
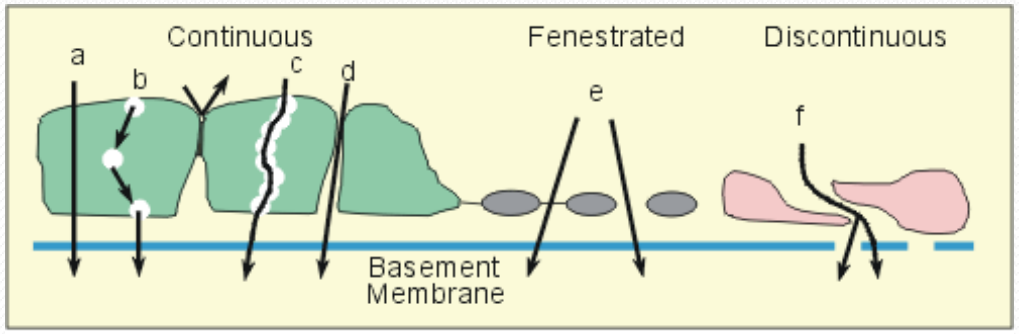
Capillary exchange of gases& nutrients

- Systemic capillaries have fenestrations (pores) that help in exchange materials.
- Capillaries are different depending on organ supplied.
- Ex. Renal capillaries have higher number of fenestrations to help in filtration in glomerus.



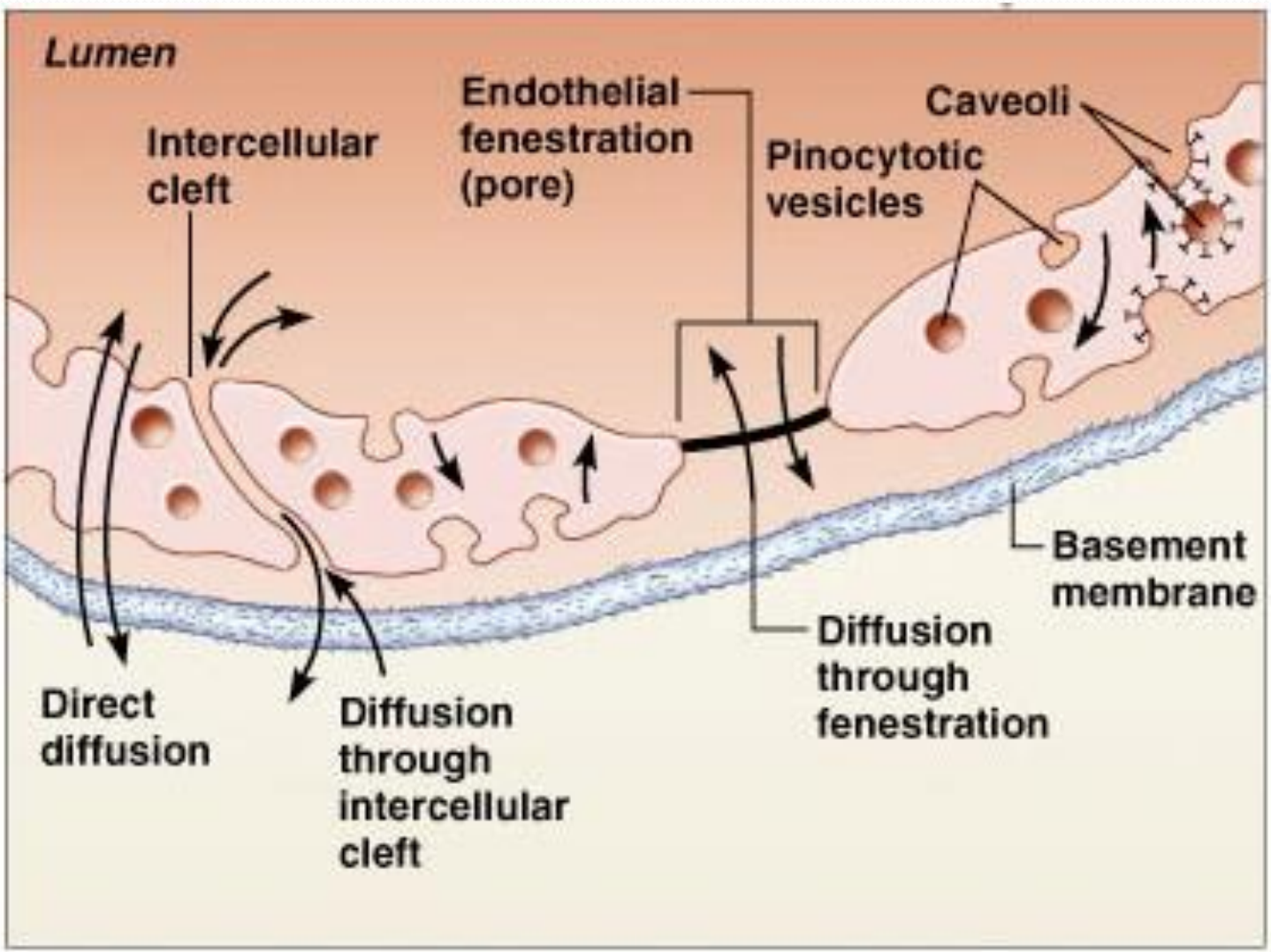
Movement across capillaries



- Fluid, electrolytes, gases, small and large molecular weight substances can transverse the capillary endothelium by several different mechanisms : diffusion, bulk flow, vesicular transport, and active transport.

•Interstitial fluid (Extracellular Fluid) is continuously exchanged, it never stays in stagnant state .
•This movement are maintained by several mechanisms.

Capillary exchange of gases and nutrients



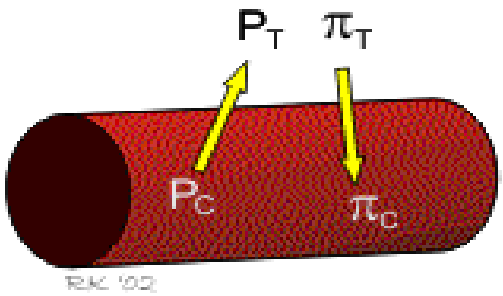
Forces determining tissue fluid formation
Starling's Forces

- There is a free exchange of water, electrolytes, and small molecules between the intravascular and extravascular compartments of the body.

- The primary site of this exchange is capillaries and small post-capillary venules.

- Several mechanisms are involved in this exchange; however, the most important are bulk flow and diffusion.
- The rate of exchange, in either direction, is determined by Starling 's Forces..

Forces determining tissue fluid formation: Starling's Forces



P_C = capillary hydrostatic pressure
P_T = tissue hydrostatic pressure
π_C = capillary plasma oncotic pressure
π_T = tissue fluid oncotic pressure

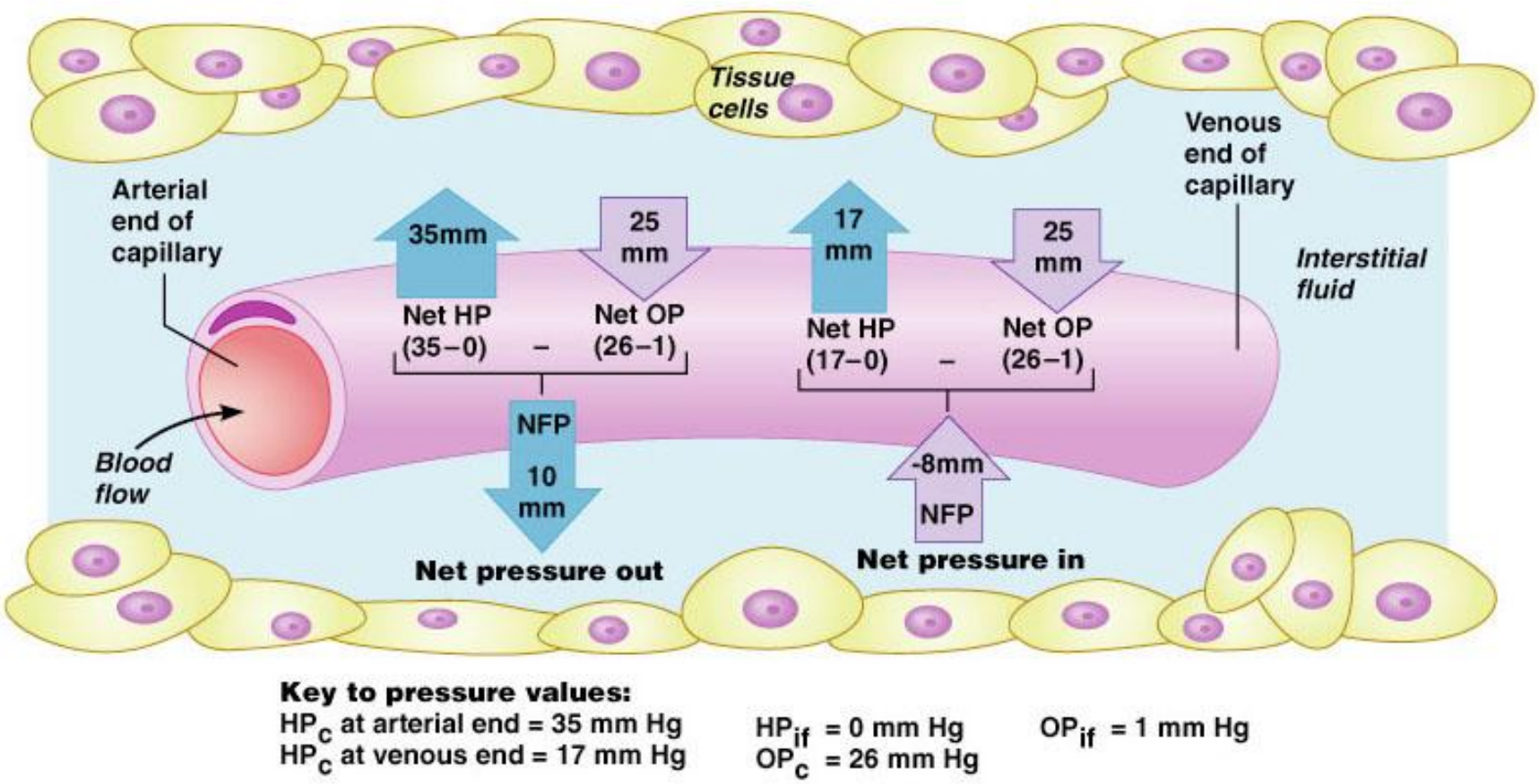
$$NDF = (P_C - P_T) - \sigma(\pi_C - \pi_T)$$

When NDF > 0 → Filtration
When NDF < 0 → Reabsorption

Hydrostatic (P) and oncotic (π) pressures within the capillary and tissue interstitium (T) determine the net driving force (NDF) for fluid movement into the capillary (reabsorption) or out of the capillary (filtration). The oncotic pressure difference is multiplied by the reflection coefficient (σ) that represents the permeability of the capillary barrier to the proteins responsible for generating the oncotic pressure.

- **Capillary Hydrostatic P. :** pressure caused by blood flow in capillary.
- **Tissue Hydrostatic P.**: pressure caused by intestinal fluid in interstitial space.
- **Capillary plasma oncotic P.**: pressure caused by proteins in plasma.
- **Tissue plasma oncotic P.** : pressure caused by proteins in intestinal fluid

Net Filtration Pressure



Forces at arteriolar end and venular end of capillaries

Analysis of forces causing filtration at the arteriolar end of the capillary	Analysis of forces causing reabsorption at the venular end of the capillary

Forces tending to move fluid outward:

Capillary hydrostatic pressure	30 mmHg	10 mmHg
Negative interstitial fluid pressure	3 mmHg	3 mmHg
Interstitial fluid colloidal osmotic pressure	8 mmHg	8mmHg
Outward force	41 mmHg	21 mmHg

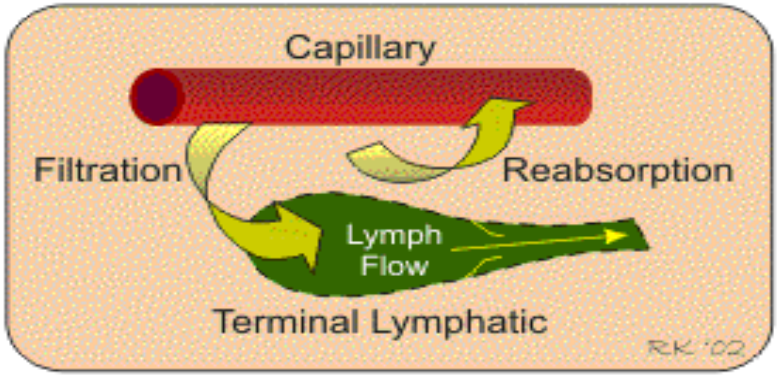
Forces tending to move fluid inward:

Plasma colloidal osmotic pressure	28 mmHg	28 mmHg

Net Force:

41- 28 = 13 mmHg This is an outward force helping filtration at arteriolar end	28 – 21 = 7 mmHg This is an inward force helping absorption at venular end.

Edema Formation



The interstitial volume (bounded area) depends on the rates of filtration, reabsorption, lymph flow, and the compliance of the interstitial compartment.

- **Edema** : accumulation of fluids in extracellular space.
- **In Venous obstruction:** when vein is obstructed > no reabsorption > accumulation of fluid in extracellular space > Edema..
- **In Lymphatic obstruction** > no drainage >lead to accumulation of fluid > **Lymphedema**

- ***Factors Precipitating Edema***
- Increased capillary hydrostatic pressure) as occurs when venous pressures become elevated by gravitational forces, in heart failure or with venous obstruction.
- Decreased plasma oncotic pressure (as occurs with hypoproteinemia during malnutrition).
- Increased capillary permeability caused by proinflammatory mediators (e.g., histamine, bradykinin) or by damage to the structural integrity of capillaries so that they become more "leaky" (as occurs in tissue trauma , burns, and severe inflammation)
- Lymphatic obstruction (as occurs in filariasis or with tissue injury).

Causes of Edema:

Edema means accumulation of fluid in the ECF space

Causes:

A. Increased capillary pressure:

1. Excess retention of salt and water by kidney:

a. Renal failure

b. Excess aldosterone. Ex. Because of tumor .

c. Heart failure.

Causes of edema, continued,…

2. Increased venous pressure:

a. Heart failure

b. Venous obstruction. e.g. thrombus, pregnancy, tumor, etc..

c. Failure of venous pump e.g. varicose veins.

•Veins contain valves, when valves are damaged > accumulation of blood in veins > increase venous pressure.

3. Decreased arteriolar resistance:

a. Vasodilator drugs.

b. Excess body heat.

Causes of edema, continued,…

B. Low plasma proteins:

1. Loss of proteins in urine.
2. Loss from the skin (burns)
3. Failure to produce:

a. Liver diseases

b. Malnutrition.

Causes of edema, continued,…

C. Increased capillary permeability:

1. Release of histamine in allergy.
2. Toxins.
3. Infections
4. Vit C deficiency

- Vit C is important for endothelial cells to stick on the basement membrane.

5. Burns

Causes of edema, continued,…

D. Lymphatic obstruction:

1. Cancer
2. Filaria

- Filariasis : is a parasitic disease, an infectious tropical disease.

3. congenital

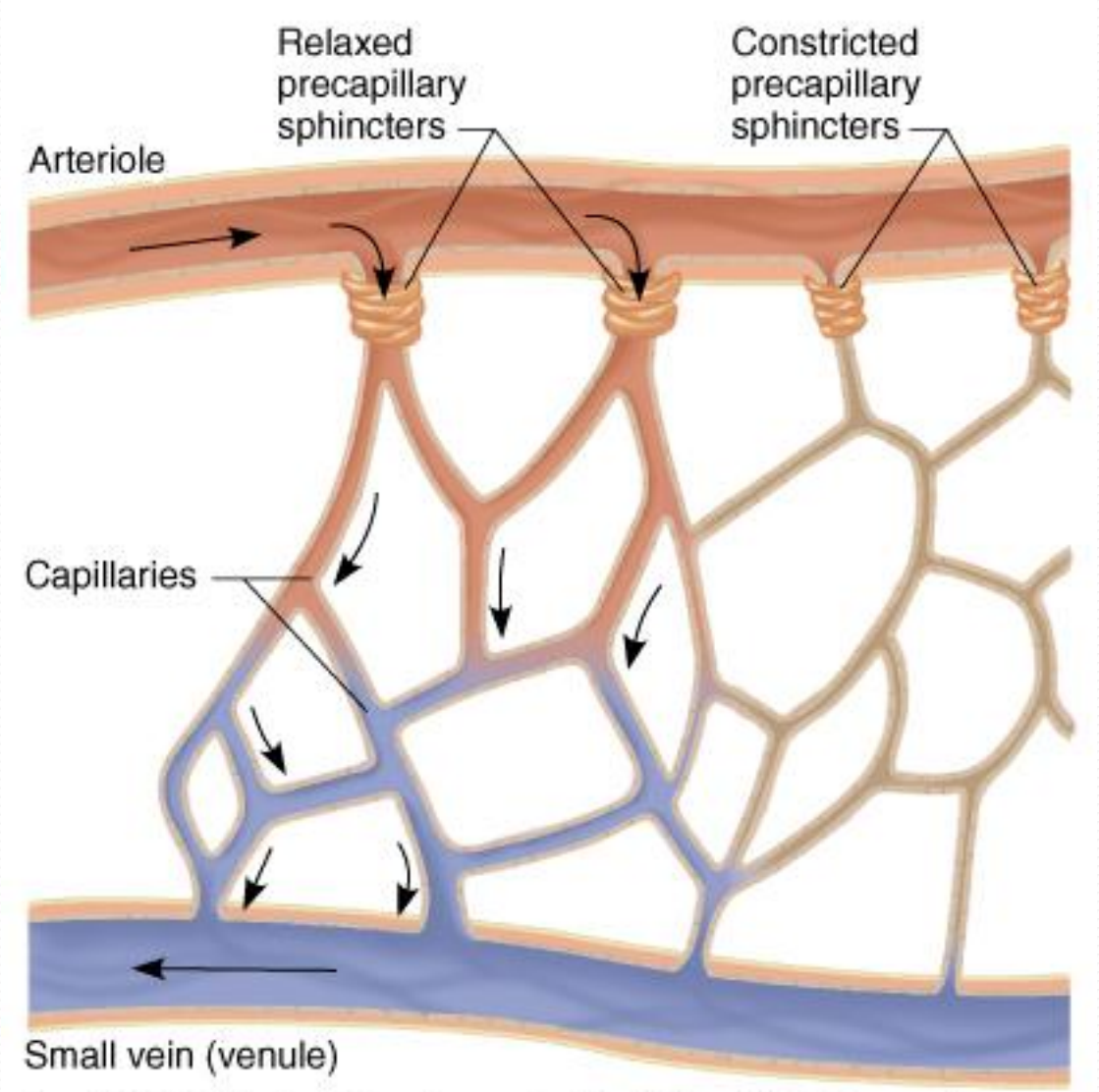
There are several points that have been discussed in male lecture and were not included in female slides.

Precapillary sphincter: smooth muscles which acts as a janitor. If they relax, more blood will flow to the tissue. If they constrict, less blood will flow to the tissue.

-The blood flow in the capillaries is efficiently regulated by the precapillary sphincter.

-The precapillary sphincter is highly regulated by humoral regulation. "Chemicals Regulation"

-The precapillary sphincter is sensitive to oxygen and carbon dioxide. If the tissue contains low amount of Oxygen and high amount of Carbon Dioxide, the smooth muscles will relax and more blood will flow to the tissue. And vice versa.



HOW DIFFUSION OCCURS?

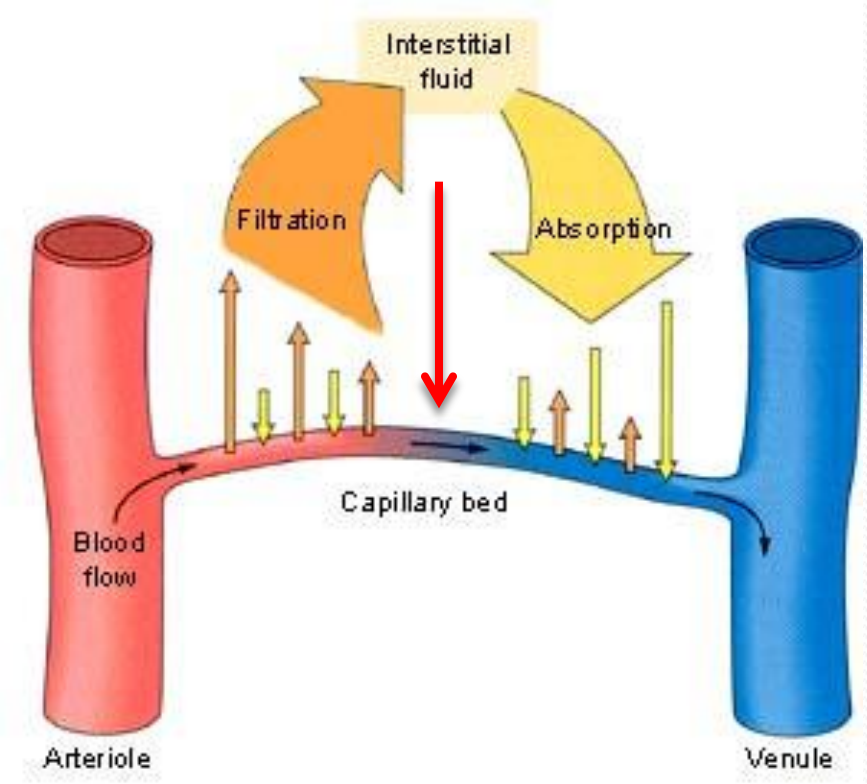
Lipid soluble substances diffuse directly through the endothelial cells. While water soluble substances will pass through the pores or the intercellular cleft of the capillary.

The amount of fluid filtered depends on the tissue need. "Vasomotion"

The plasma colloidal osmotic pressure is 28 mmHg.

Albumin is responsible of 80% of the plasma colloidal osmotic pressure.

- In any condition where the Albumin amount will be less than normal (liver disease, malnutrition, …etc), the plasma osmotic pressure will fall and there will be an abnormal fluid exchange, and as a result, edema develops.



The starling equilibrium point: there is no net outward or inward movement. Forces are equal.

Lymphatic circulatory system

-It is a separate circulatory system in the body.
-It has two main uses:

1- move large protein molecules.
2- move fats.

-It finally inters the thoracic duct which directly drains into the subclavian vein.

Useful links

http://highered.mcgraw-hill.com/sites/0072507470/student_view0/chapter21/animation__fluid_exchange_across_the_walls_of_capillaries.html

http://www.cvphysiology.com/Microcirculation/M010.htm

http://ylearnonline.com/page.php/resources/view_all?id=arteries_arterioles_capillaries_colloidal_osmotic_pressure_endothelium_pulse_veins_venules_t_page_13&from=search