Physiology Team 434

Capillary Circulation

Microcirculation

Color index

- Important
- Further Explanation

Only in Boys' Slides

Explained in:
-Guyton Ch.16 P.177
-Linda's Ch.4 P.163

Physiology Team 434
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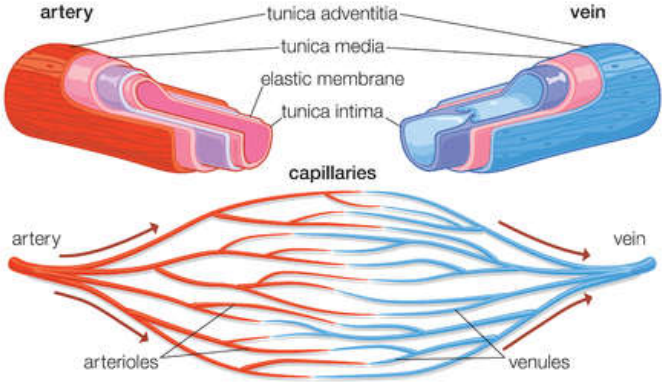
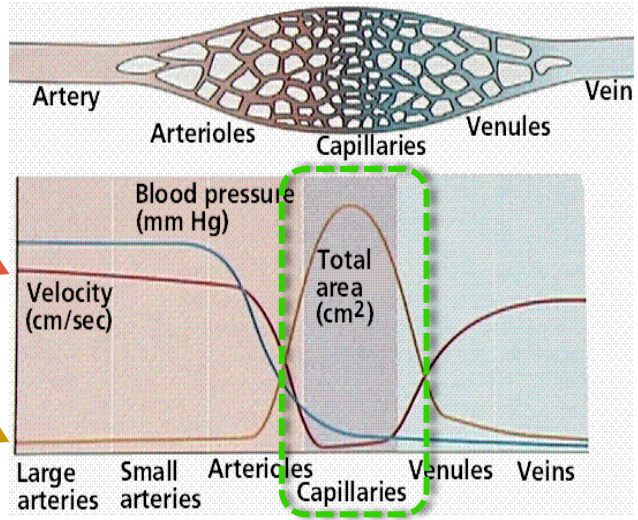
The Microcirculation

- The microcirculation refers to the microscopic divisions of the vascular system that function to bring exchange of materials between the blood and various body cells.
- **Blood flow velocity in the capillaries?**

= note: velocity is low due to perfect exchange.

- Note: area is large due to cross section difference.





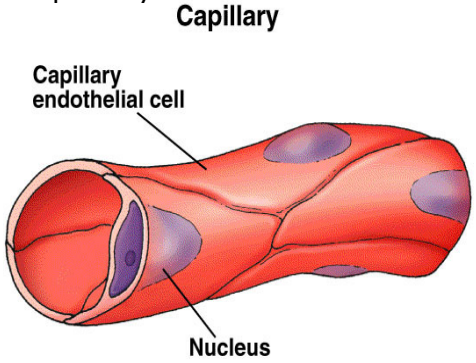
Capillaries

✧ Structure:

They are small blood vessels 0.5-1mm long, 0.01mm diameter. They consist of the tunica interna only with a single layer of endothelial cells surrounded by a basement membrane.

✧ Functions:

- ✓ Sites of exchange between blood and tissues (nutrients & Oxygen).
- ✓ Drainage of body waste products.
- ✓ Temperature regulation
- ✓ The arterial system delivers blood to > I billion capillaries throughout the body. Total capillary surface area=1000 m2.



Note:

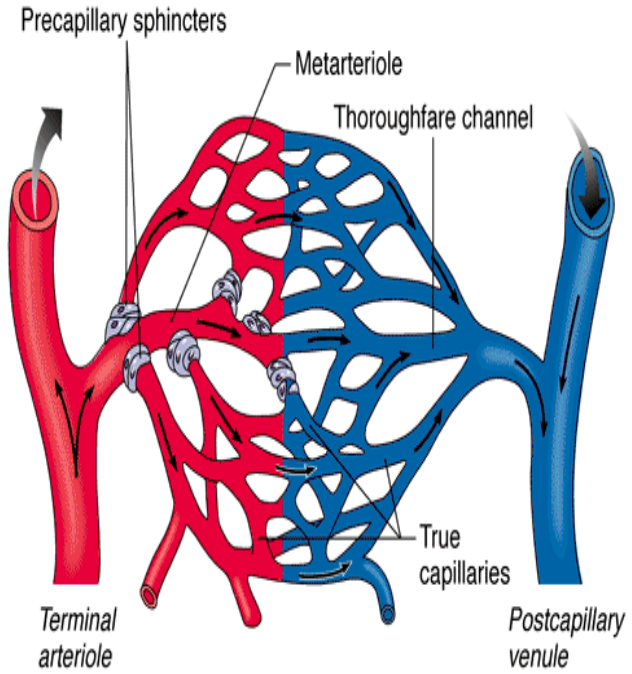
Arterioles → Meta.arterioles → capillaries

↓

has sphincter at the end

Capillary Beds

- There are 10 billion capillaries in the body.
- Capillaries tend to be arranged in capillary beds; only about 5% of blood volume is in the capillaries at any time.
- Note: A capillary bed is a concentration of capillaries which supply blood to a specific organ or area of the body.
- The arteriole divides into a number of metarterioles which do not have a continuous smooth muscle coat.
- Blood leaves the metarterioles and enters capillary bed via precapillary sphincters.



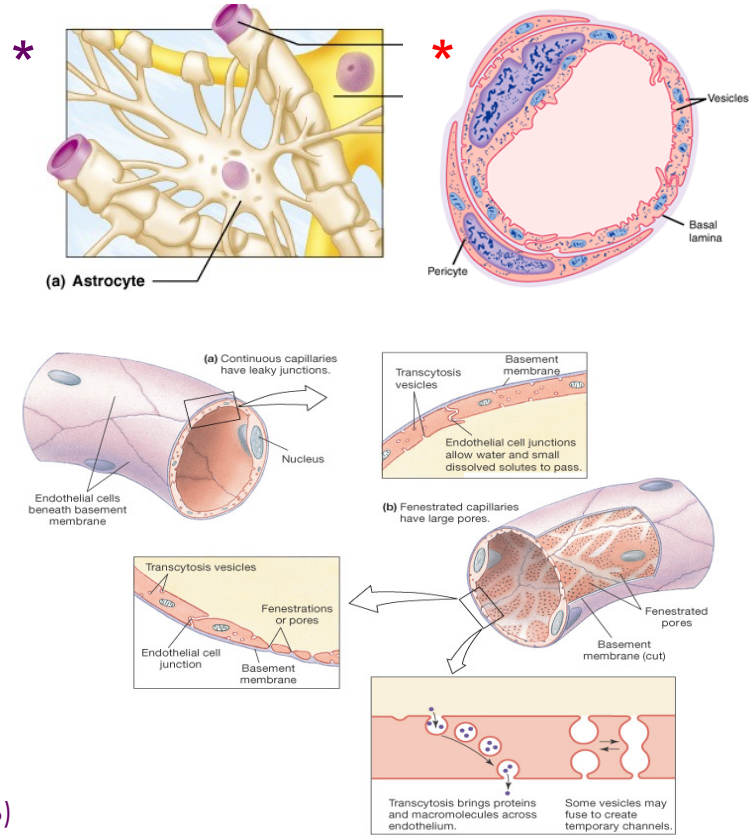
(a) Sphincters open

Types of Body Capillaries

Three structural types: 1-Continuous capillaries. 2-Fenestrated capillaries. 3- Sinusoids.

Continuous Capillaries

- These capillaries are present in most body tissues, e.g., muscle, lung, and adipose tissue.
- They have continuous endothelial lining and adjacent endothelial cells are closely joined together by tight junctions.
- There are thin intercellular slits (clefts) 2-10 nm in width in-between the endothelial cells that allow bulk flow of water and water soluble small ions (e.g., Na+, Cl-, and glucose).
  - intercellular slits (clefts) are gaps in tight junctions.
  - tight junctions are continuous in brain and do not allow passage of water soluble molecules. They form part of the blood-brain barrier.



*Continuous type of capillary found in skeletal muscle.

*Blood brain barrier (astrocyte: is supporting cell and works as blood BB)

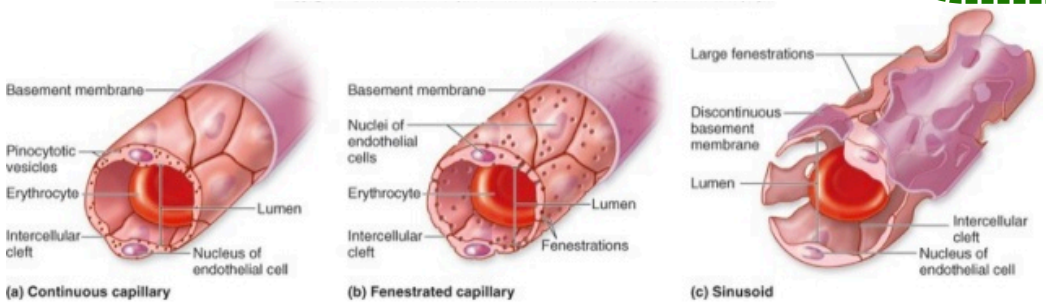
Cont.

Fenestrated Capillaries

- These are found in the kidney glomeruli, small intestine, and endocrine glands.
- Some endothelial cells have wide intercellular pores
- Very permeable – allow even large substances to pass but not plasma proteins.

Sinusoids

- In these capillaries the endothelial cell are widely spaced.
- These have large irregular lumens →slows blood flow.
- Located in liver, spleen, bone marrow, lymphoid tissue, some endocrine glands.
- Few tight junctions → allow large molecules (e.g., proteins) to pass through.



Mechanisms of Transcapillary Exchange

Transport of substances across the capillary wall occurs by 3 major mechanisms:

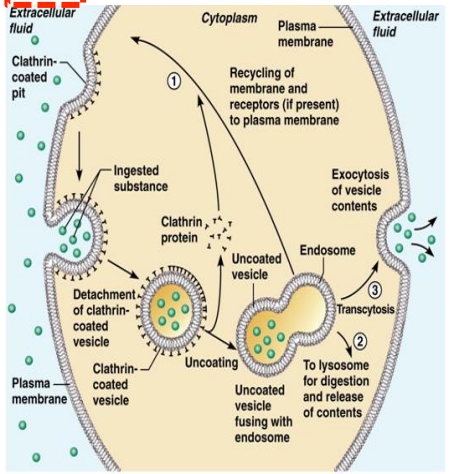
1- Diffusion (according to concentration gradient).

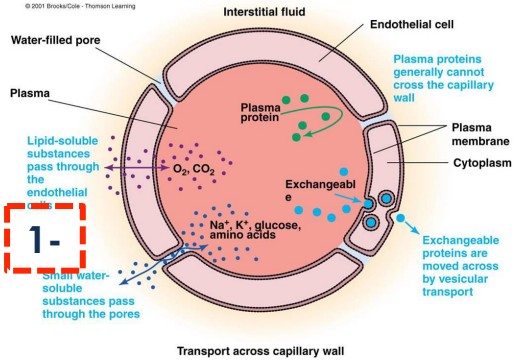
2- Filtration (according to pressure gradient).

3- Vesicular transport (transcytosis).

4- Mediated (membrane) transport: This occurs in capillaries of brain only and involves secondary active transport e.g., transport of glucose; moves by co-transporters in cell membrane.

3-





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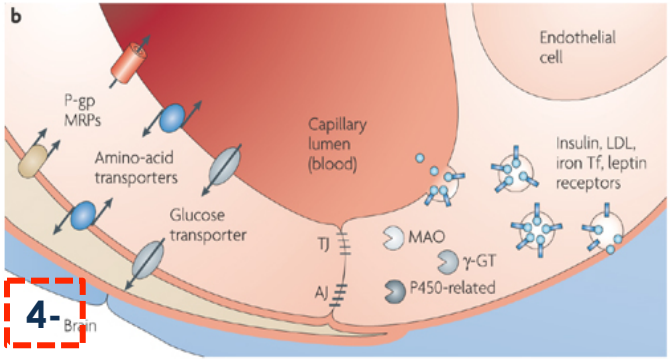

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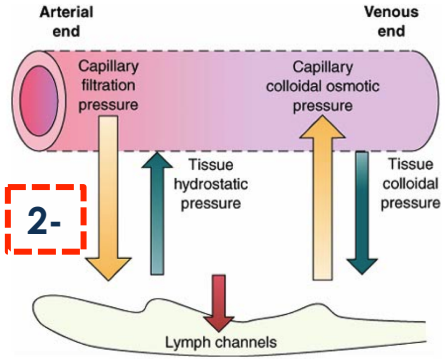

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+The images are only to clarify the transcapillary exchange mech.

Cont.

Diffusion

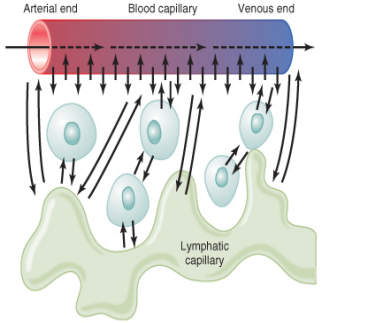
- This is the process of movement of particles between the capillaries and interstitium across the capillary membrane according to their concentration (chemical) gradients.
- It is the major process by which most nutritional substances and waste products cross the capillary membrane.
- The diffusion is dependent on:

- Water & lipid solubility
- Molecular size of the particles
- Concentration gradient

- Rate of diffusion for water over the whole body approximately 250 l/min.

Vesicular transport (transcytosis)

- This is an active process by which large molecules can be transported across the capillary membrane.
- It includes the formation of vesicles from the endothelial membrane to surround the required particle (endocytosis). The vesicle separates and migrates across the cell to release its contents to the other side (exocytosis)



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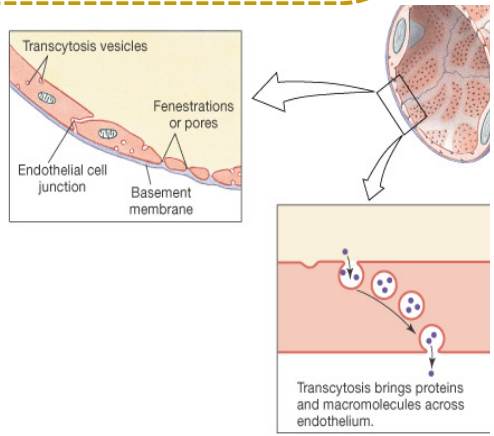


Filtration

Filtration is the process by which plasma and its dissolved crystalloids (electrolytes and glucose) can filter across the capillary according to pressure gradient. Filtration is determined by Starling forces.

The movement of water drags along with it dissolved substance to which the membrane is permeable.

Although the amount of materials exchanged by filtration are small compared to diffusion, however filtration aids diffusion by keeping the fluid across the capillary membrane in a state of continuous motion.

Starling's Forces

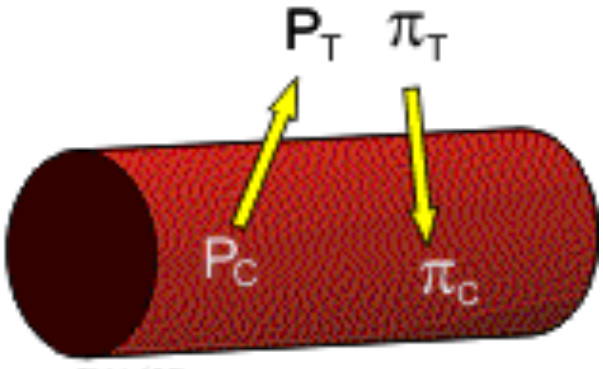
4 Forces determining fluid movement through the capillary membrane:

1)Capillary hydrostatic pressure (Pc)
is the force that is exerted by a fluid against the capillary wall

2) Interstitial fluid pressure (PT)
tends to force fluid inward through the capillary, but actually this pressure is negative comparing to the atmospheric pressure

3) Plasma colloid osmotic pressure (π_C)
is a form of osmotic pressure exerted by proteins, notably albumin, in a blood vessel's plasma (blood/liquid) that usually tends to pull water into the circulatory system.

4) Interstitial fluid colloid pressure (π_T)
is a form of osmotic pressure exerted by proteins that are usually found in the interstitial that usually tends to pull water into the interstitial .

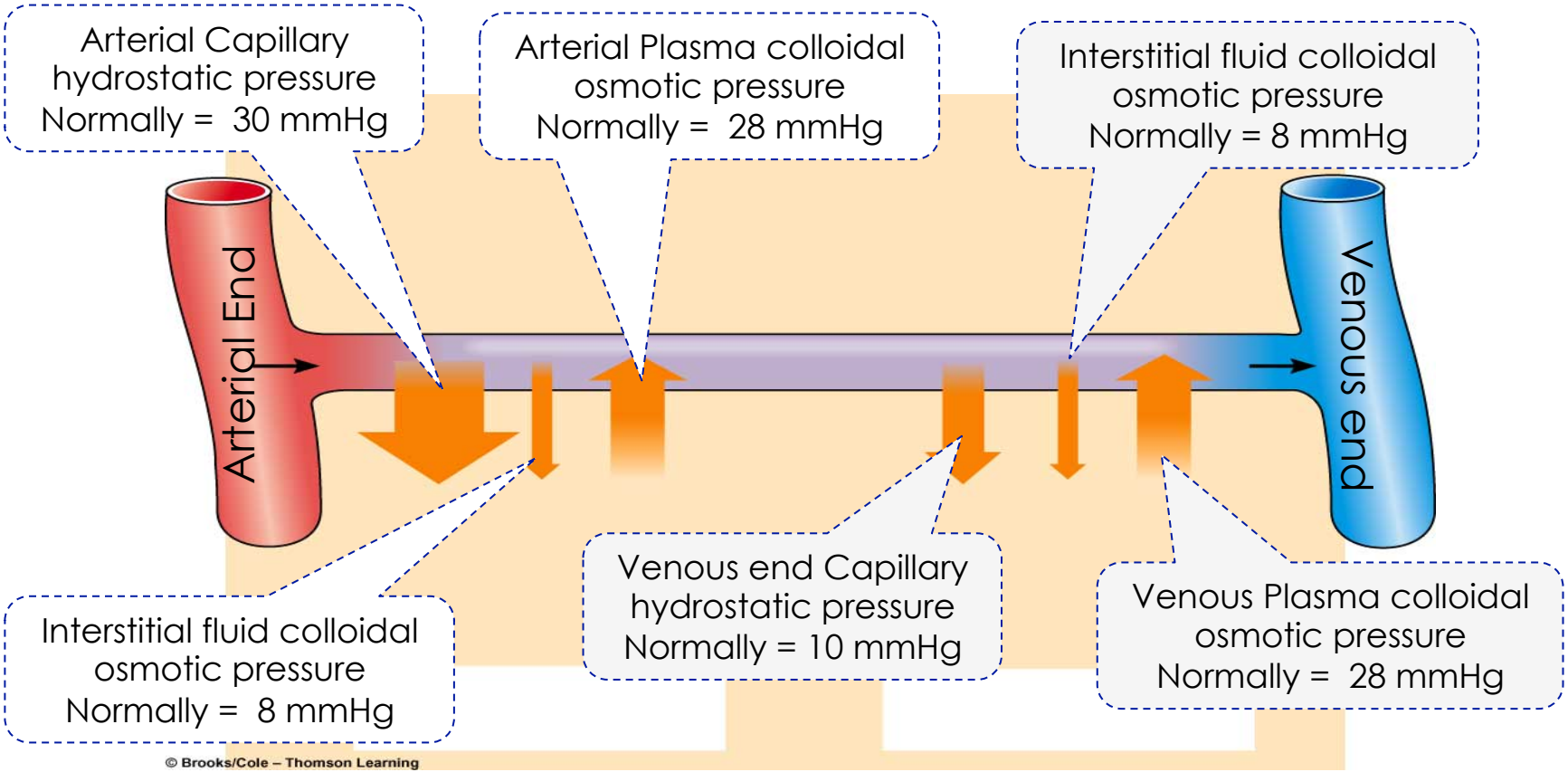


$$NDF = (P_C - P_T) - \sigma(\pi_C - \pi_T)$$

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

The Net Driving Force can be measured though this equation

Forces That Control Filtration



Forces causing **Filtration** at the arterial end

- Arterial End hydrostatic pressure = 30mm Hg
- Arterial Interstitial fluid colloidal osmotic pressure = 8mm Hg
- Negative interstitial free fluid pressure = 3mm Hg
- Arterial Plasma colloidal osmotic pressure Normally = 28mm Hg

NET Filtration pressure = 30 + 8 + 3 – 28= 13mm Hg

Reabsorption at the venous end of the capillary

- Venous ends Plasma colloidal osmotic pressure Normally = 28mm Hg
- Venous End hydrostatic pressure = 10mm Hg
- Negative interstitial free fluid pressure = 3mm Hg
- Venous end Interstitial fluid colloidal osmotic pressure = 8mm Hg

NET Reabsorption pressure = 28 -10-3-8 = 7mm Hg

The values of pressures is taken from the reference book : Guyton & hall medical physiology

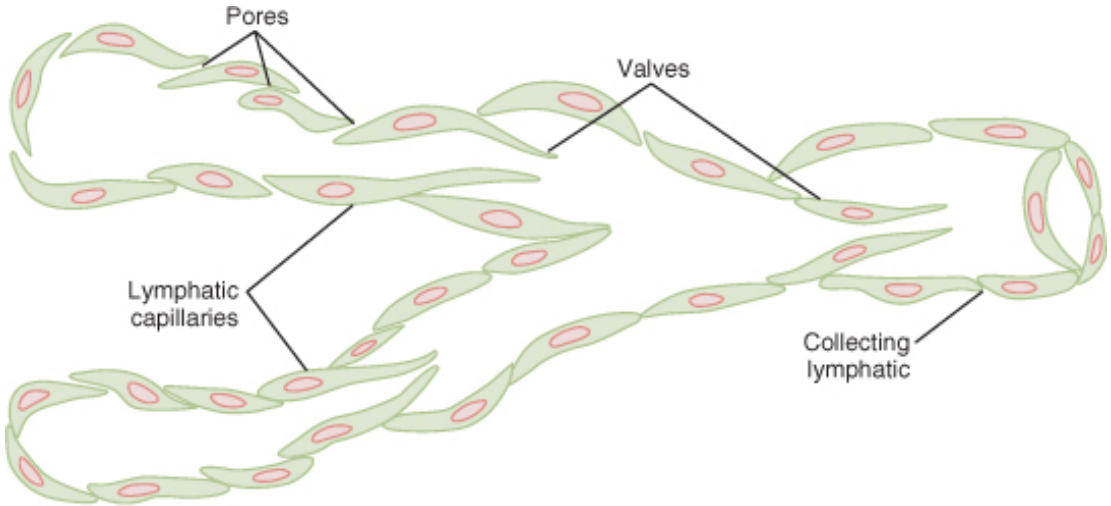
Why there isn't development of edema when the filtration pressure is more than reabsorption pressure?

- Ernest H. Starling pointed out more than a century ago that under normal conditions, a state of near-equilibrium exists in most capillaries.
- That is, the amount of fluid filtering outward from the arterial ends of capillaries equals almost exactly the fluid returned to the circulation by absorption.
- The slight disequilibrium that does occur accounts for the fluid that is eventually returned to the circulation by way of the lymphatics.

- The amount of water and its dissolved electrolytes that getting filtrated is 20ml fluid/min, in contrast the amount that getting reabsorbed is 18ml fluid/min, so 2ml of fluid is returned to the venous system by lymphatics

Lymphatic vessels: Lymphatic Capillaries

- These are blind sacs that collect excess tissue fluid.
- They consist of simple squamous epithelium (endothelium).
- Cells overlap to form valves within lumen.
- Cells connected by filaments to structures within tissue.
- The gaps between the endothelial cells are very large.



Lymphatic vessels: Lymphatic Capillaries

Lymphatics: originate as lymph capillaries that unite to form larger vessels.

- Resemble veins in structure but with thinner walls, less muscle, less connective tissue, and more valves.
- Connect to lymph nodes at various intervals
- Lymphatic trunks: These are formed by the union of lymphatics They carry lymph to lymphatic ducts.
- Lymphatic ducts: these are formed by the union of lymphatic trunks. They empty into large veins just before they join the superior vena cava

Edema

Is abnormal increase in the interstitial fluid volume.

Causes of Edema:

1- Increase in Capillary Hydrostatic Pressure

A. Excess retention of salt and water by kidney

- Renal failure.
- Excess aldosterone.
- Heart failure

B. Increased venous pressure

- Heart failure
- Venous obstruction. e.g. thrombus, pregnancy, tumor, etc..
- Failure of venous pump e.g. varicose veins.

C. Decreased arteriolar resistance

- Vasodilator drugs.
- Excess body heat.

2- Low Plasma Proteins Level (Hypoproteinemia)

- Loss of proteins in urine.
- Loss from the skin (burns)
- Failure to produce proteins either due to liver disease or Malnutrition

3- Increased Capillary Permeability

- Release of histamine in allergy.
- Toxins
- Infections
- Vit C deficiency
- Burns

4- Lymphatic Obstruction

- Cancer blocking lymphatic channel.
- Filariasis is a parasitic disease caused by an infection with roundworms of the Filarioidea type that block a lymphatic capillary.
- Congenital

MCQs

1-A patient diagnosed with Filariasis a parasitic disease causing edema to his left leg, What is the mechanism that this parasite work to cause edema.

A. This parasite increase the permeability of capillaries.
B. This parasite block the venous system.
C. This parasite block the lymphatic capillaries.
D. The toxins of this parasite cause low proteins levels.

2-A patient having excess amount of renin released , and he developed an edema in the abdominal wall, The cause for this edema:

A. Increasing the protein level in the blood.
B. retention of the fluid and sodium.
C. increase the permeability of the capillaries.
D. Decreased arteriolar resistance

1.C
2.B

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BEST OF LUCK