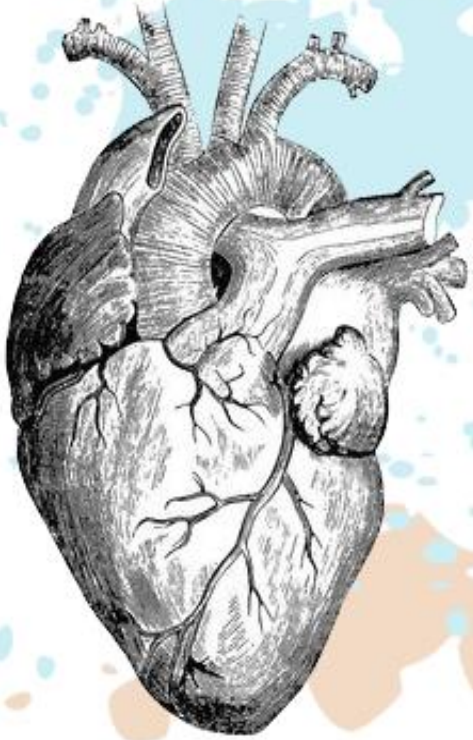


Very important

Extra information

Physiology

OF THE CARDIOVASCULAR SYSTEM

* Guyton corners, anything that is colored with grey is EXTRA explanation

Capillary Circulation

Objectives :

- Describe the structure of capillary wall: endothelial cells, basement membrane, intercellular clefts, vesicles, pores.
- Blood brain barrier to water soluble agents.
- Describe structure of liver and renal capillaries.
- Compare and contrast diffusion and filtration.
- State the Starling forces acting on the capillary wall: capillary blood pressure, interstitial fluid pressure, plasma protein colloid osmotic pressure, interstitial fluid colloid osmotic pressure.
- Describe net loss of fluid from capillaries and discuss role of lymphatics.
- Discuss importance of filtration giving clinical situations.
- Define odema, state its causes and discuss its mechanisms.

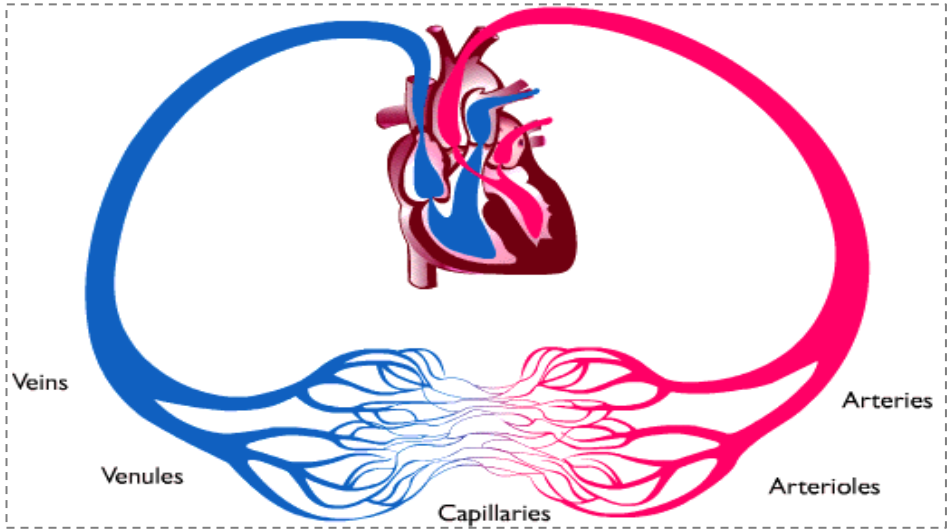
*We recommend studying Histology of Capillaries before this lecture

Contact us : Physiology435@gmail.com

Functions of the circulation

Serve the requirements of the tissues:

1- Transport nutrients & remove waste products.
2- Transport hormones, enzymes, body heat, electrolytes …etc.
3- Maintain normal homeostasis for optimal survival &function of cells.



PHYSIOLOGY TEAM 435

Functional Parts of the circulation

It is divided to :

1. **Aorta :** (Elastic recoil)

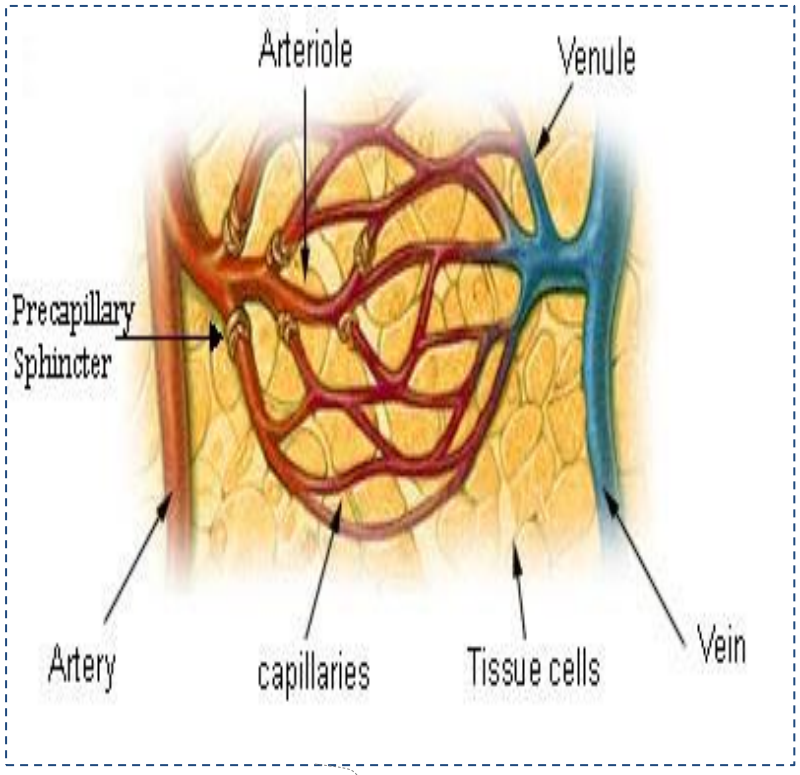
2. **Arteries :** Transport blood Rapidly under high pressure to the tissues (muscular, low resistance vessels) (Thick)

3. **Arterioles :** Can close the arteriole completely or dilate it several folds they alter blood flow to the capillaries in Response to needs(Thick).
-Arterioles & small arteries are called (Resistance vessels) (high resistance vessels).

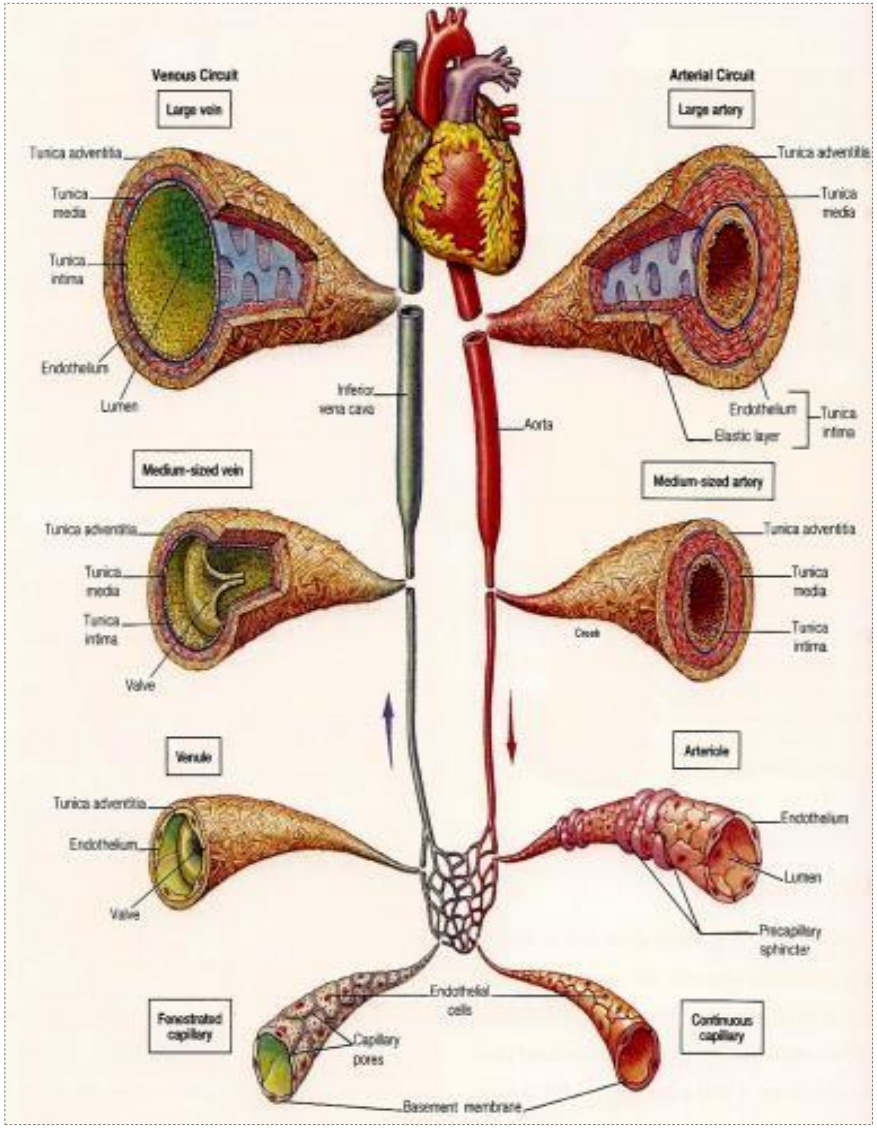
4. **Capillaries**: Have numerous Capillary pores and very large surface area (exchange blood vessels) for exchange of gases, nutrients, waste products etc. (Very thin wall with unicellular layer of endothelial cells and very small internal diameter).
-Blood flow is intermittent (discontinuous) , turn on and off every few seconds or minutes (vasomotion), determined by oxygen demand.

5. **Venules & Veins:** (Capacitance Vessels) At rest more than ⅔ rds. of total blood volume is found within the venous system. More than half of it is within venules.

Functional Parts of the circulation



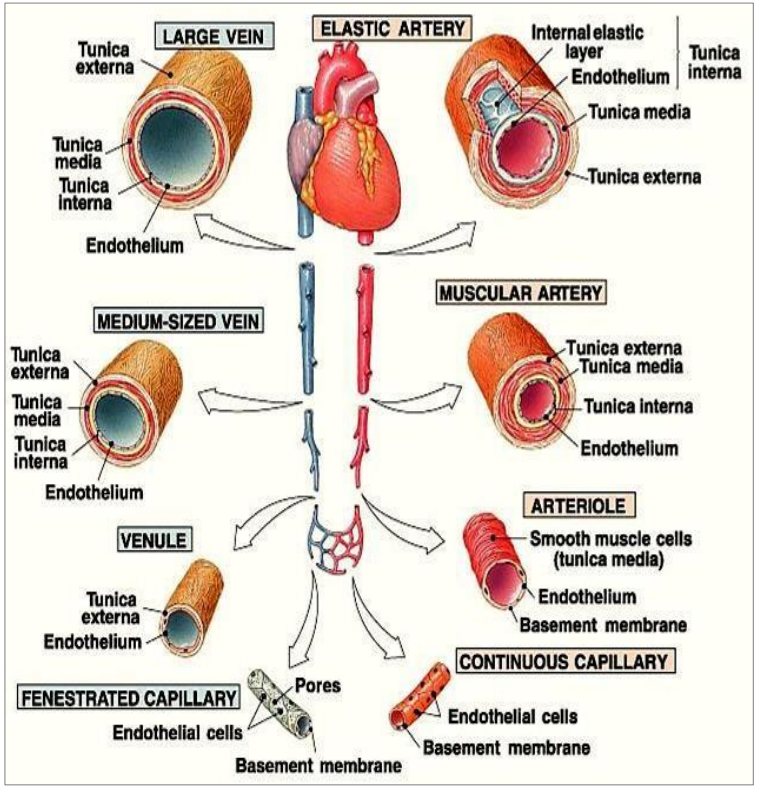
Structure of the Microcirculation

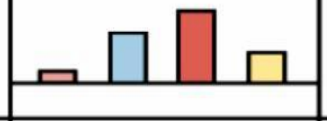
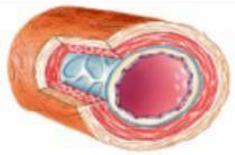
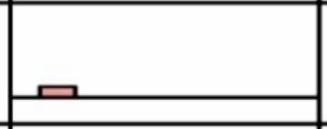
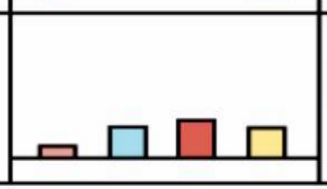
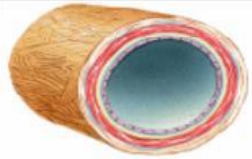


PHYSIOLOGY TEAM 435

Structure of vasculature changes in response to different needs

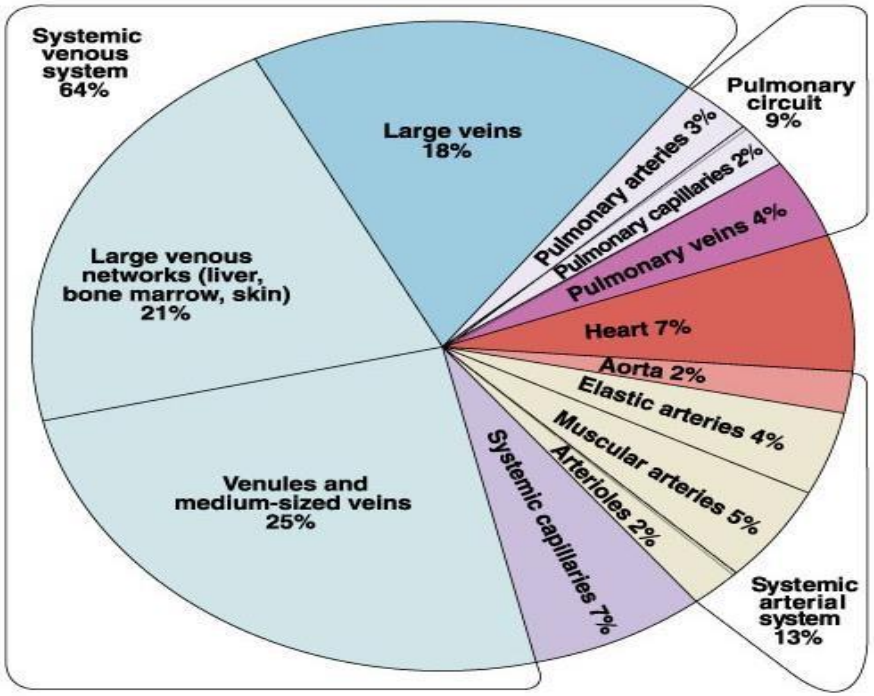
BLOOD VESSEL COMPARISON

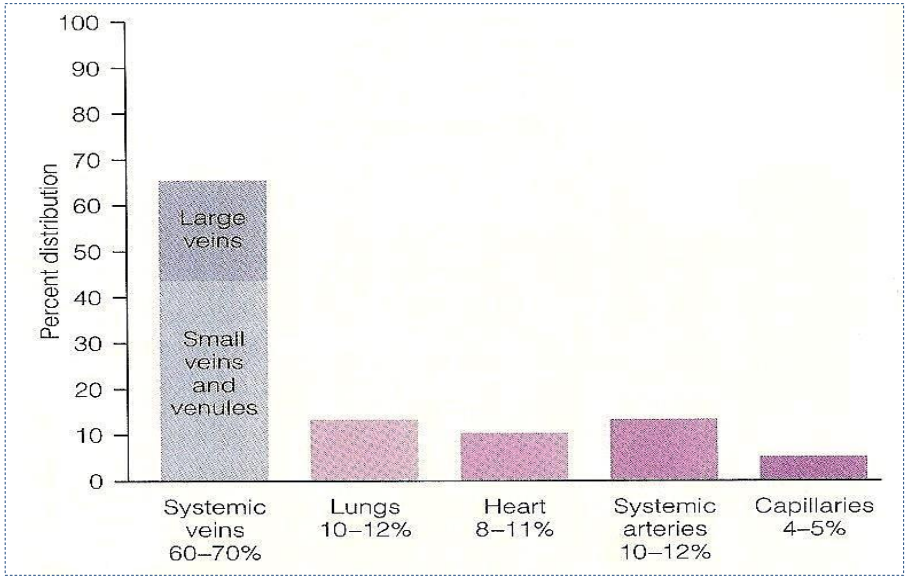


	Mean diameter	Mean wall thickness	Endothelium / Elastic tissue / Smooth muscl / Fibrous tissue	
Artery	4.0 mm	1.0 mm		
Arteriole	30.0 μm	6.0 μm		
Capillary	8.0 μm	0.5 μm		
Venule	20.0 μm	1.0 μm		
Vein	5.0 mm	0.5 mm		

PHYSIOLOGY TEAM 435

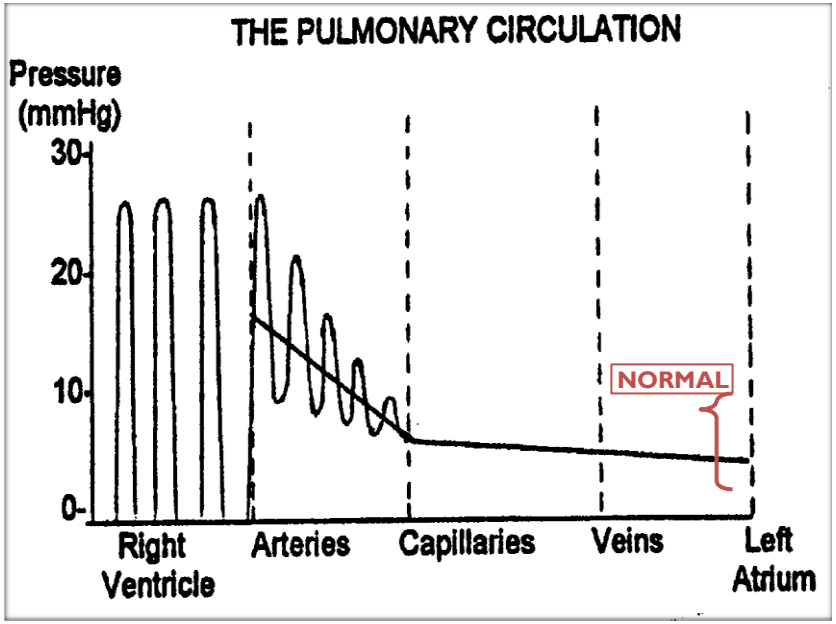
DISTRIBUTION OF BLOOD WITHIN THE CIRCULATORY SYSTEM AT REST



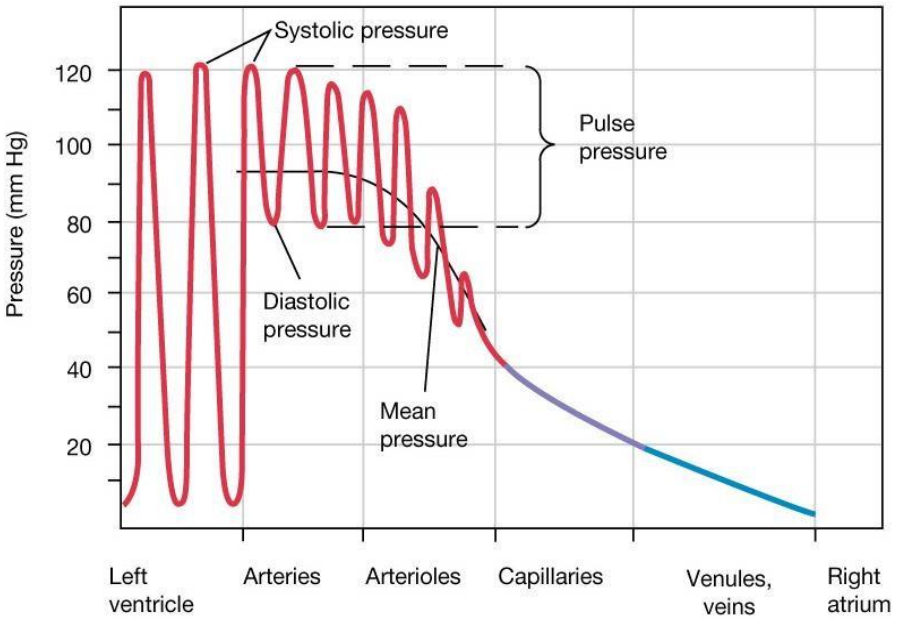


PHYSIOLOGY TEAM 435

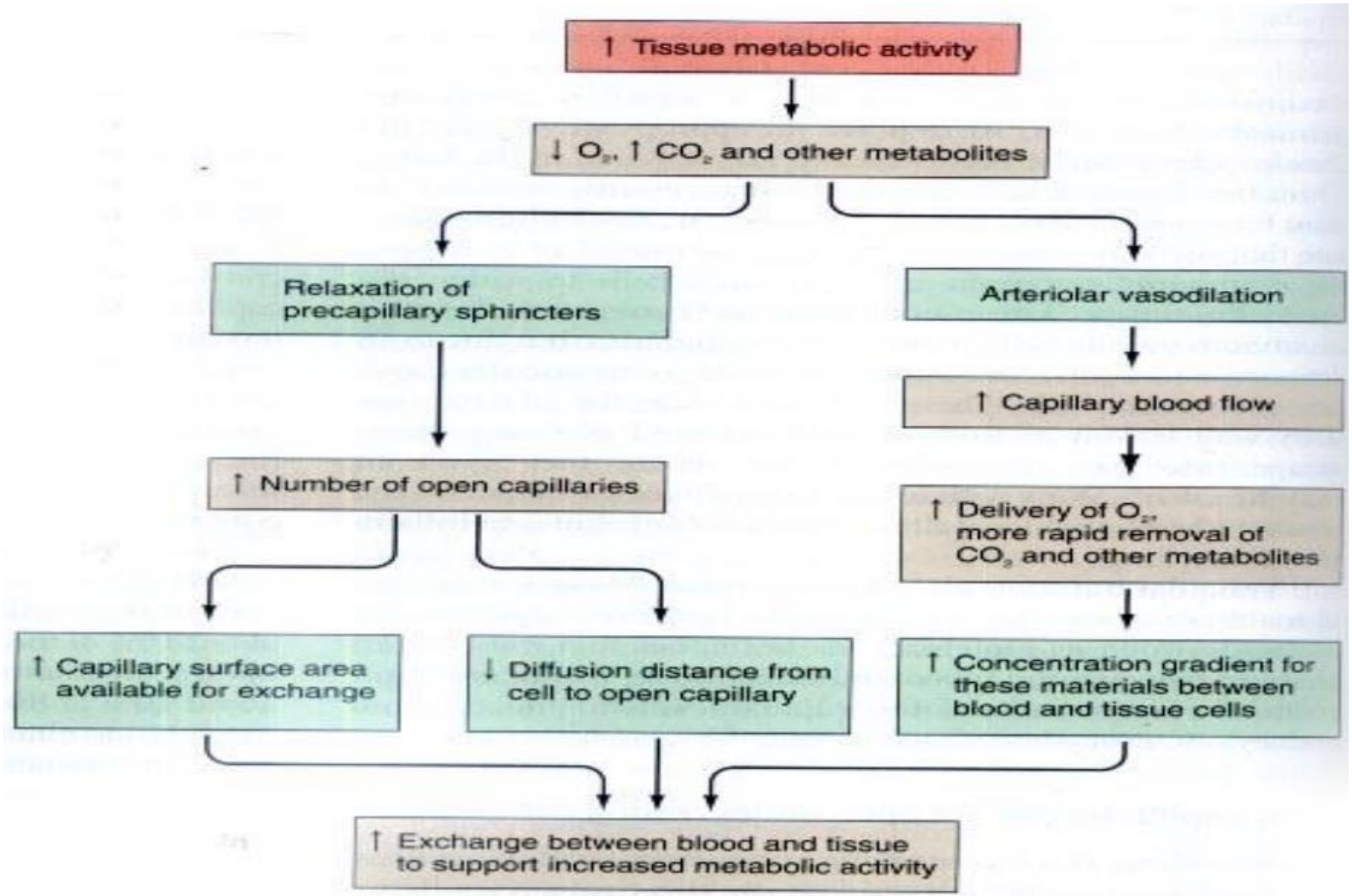
PRESSURE IN THE PULMONARY CIRCULATION



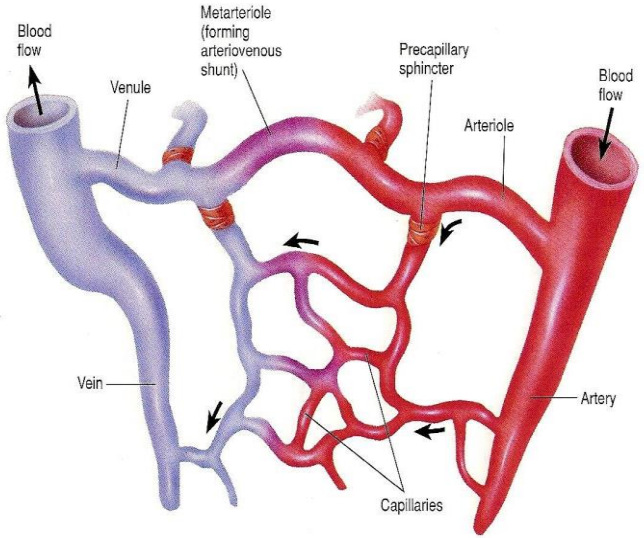
PRESSURE THROUGHOUT THE SYSTEMIC CIRCULATION

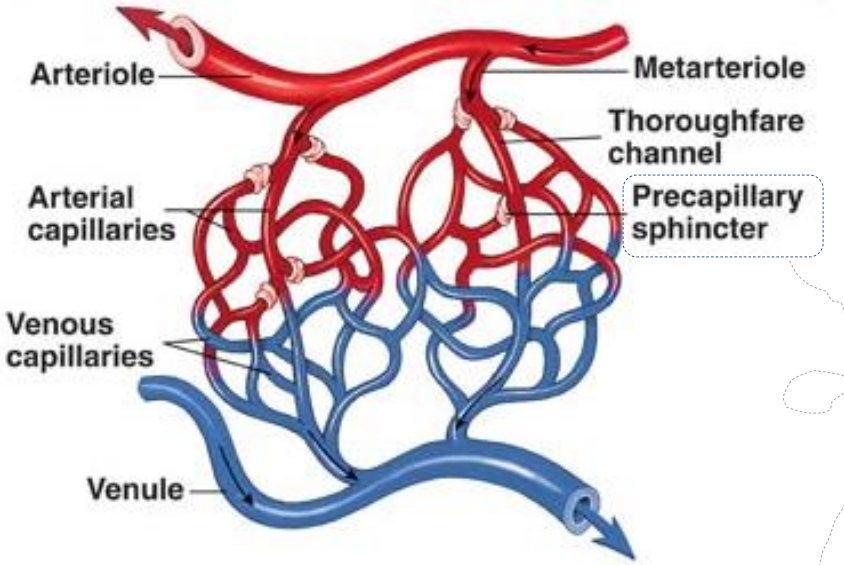


Tissue metabolic activity



Extra slide

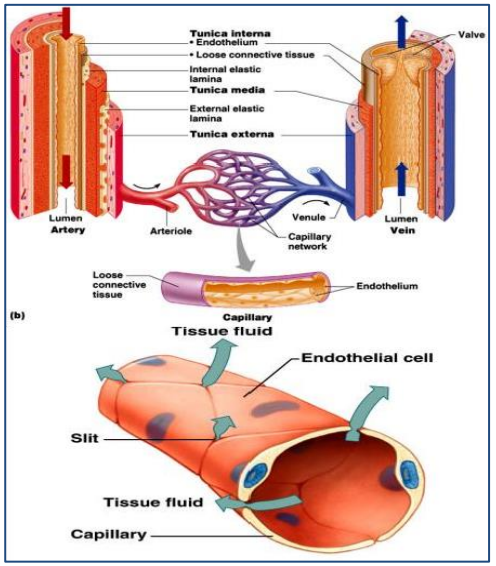




هو صمام يفتح وقت الحاجة الزائدة للأكسجين
it is small smooth muscle and occurs in exercises .

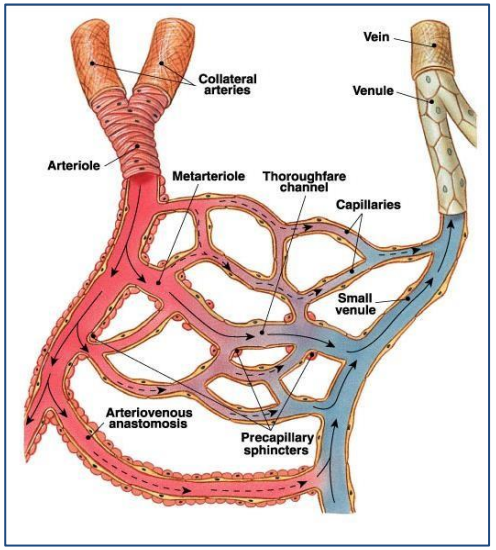
Capillaries

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



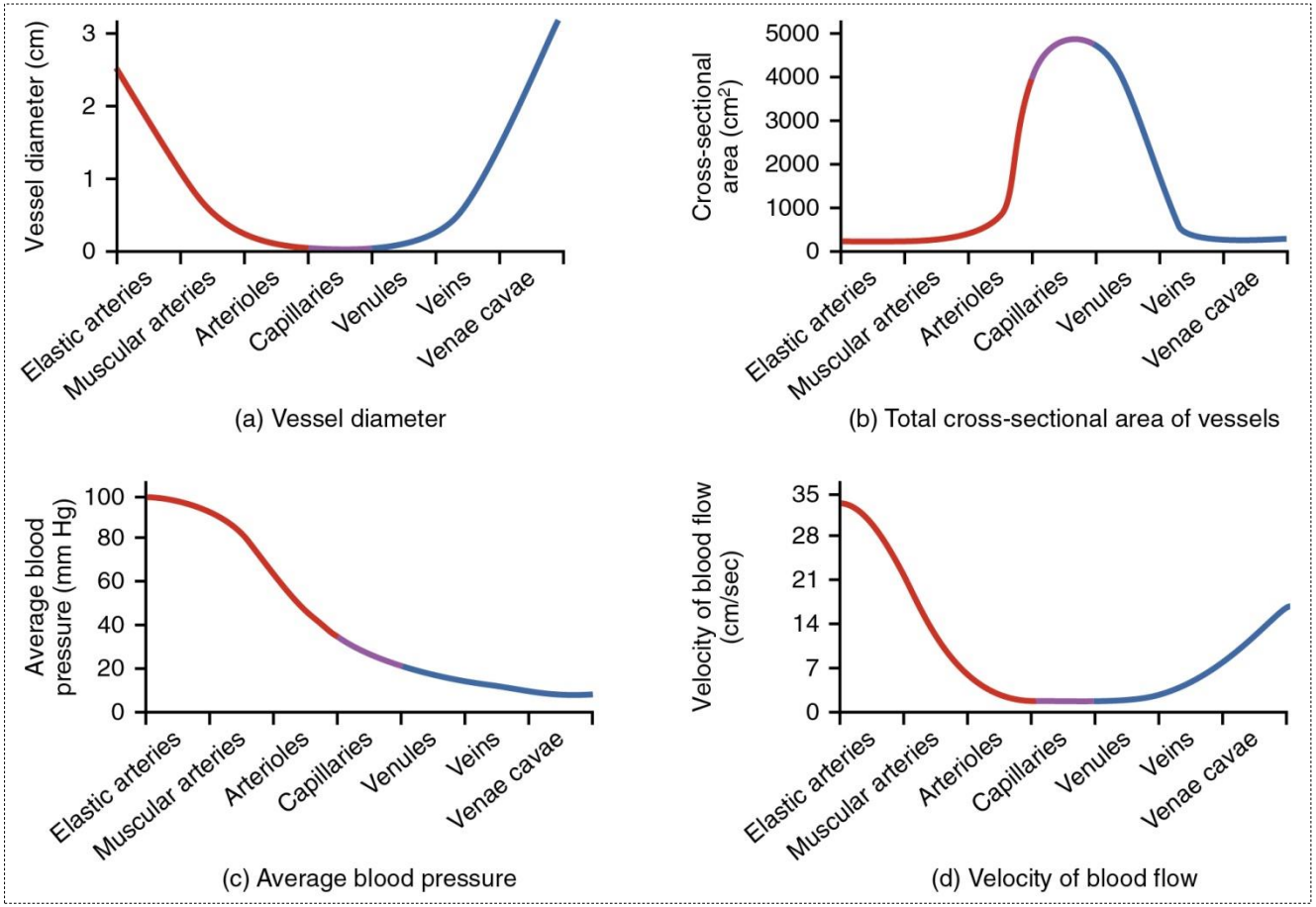
Capillary Network

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



Relationships of capillaries

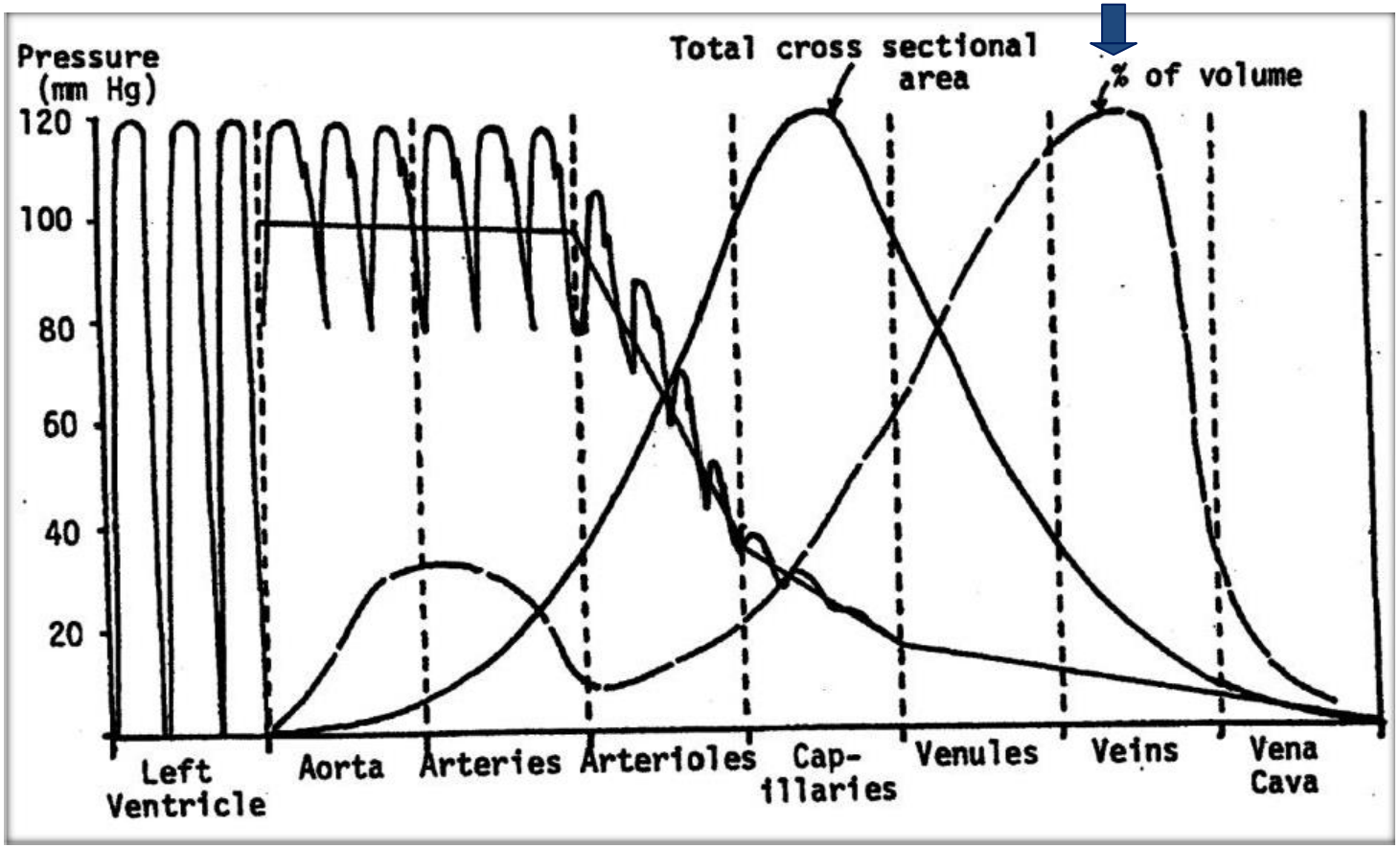
- **Relationships among Vessel Diameter, Cross-Sectional Area, Blood Pressure, and Blood Velocity :**



PHYSIOLOGY TEAM 435

Total Cross Sectional Area

Capacity Vessels



Capillary pressures and capillary exchange

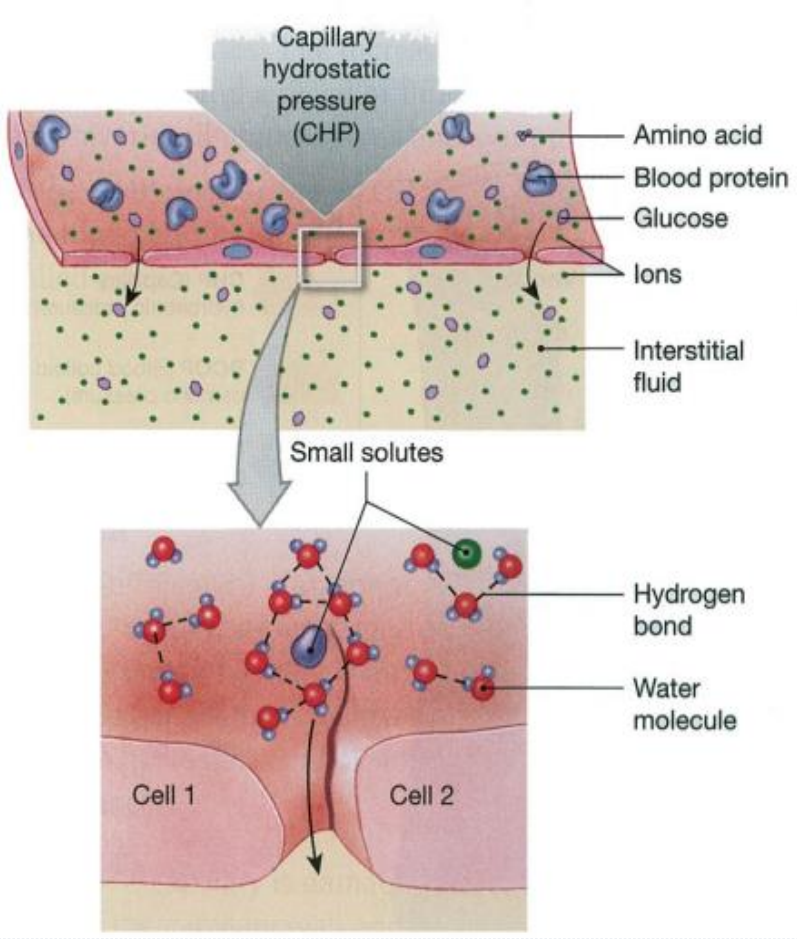
- **Capillary exchange plays important role in homeostasis.**

- **The important processes that move Materials across capillary walls are:**
  1- Diffusion
  2- Filtration
  3- Reabsorption

- **Capillary Filtration :**

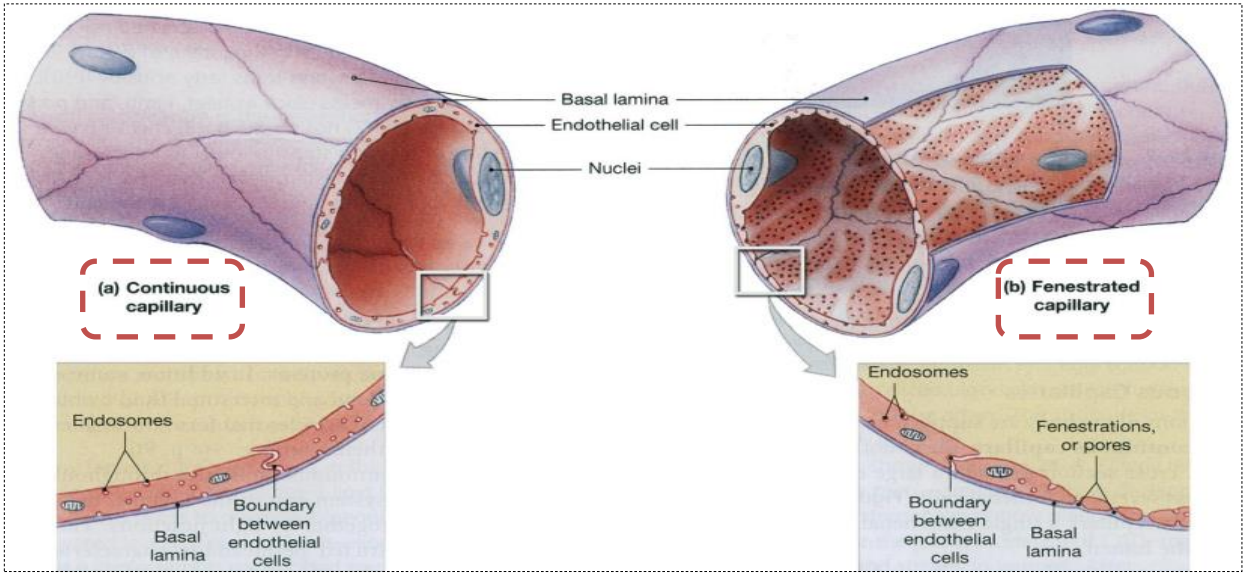
  - Capillary hydrostatic pressure (CHP) forces water and solutes through the gaps between adjacent endothelial cells in continuous capillaries.

  - The sizes of solutes that move across the capillary wall are determined primarily by the dimensions of the gaps.



Capillary Types

- **Types classified by diameter/permeability :**
  - **Continuous** Do not have fenestrae. **-Fenestrated** Have pores.
  - **Sinusoidal** Large diameter with large fenestrae.

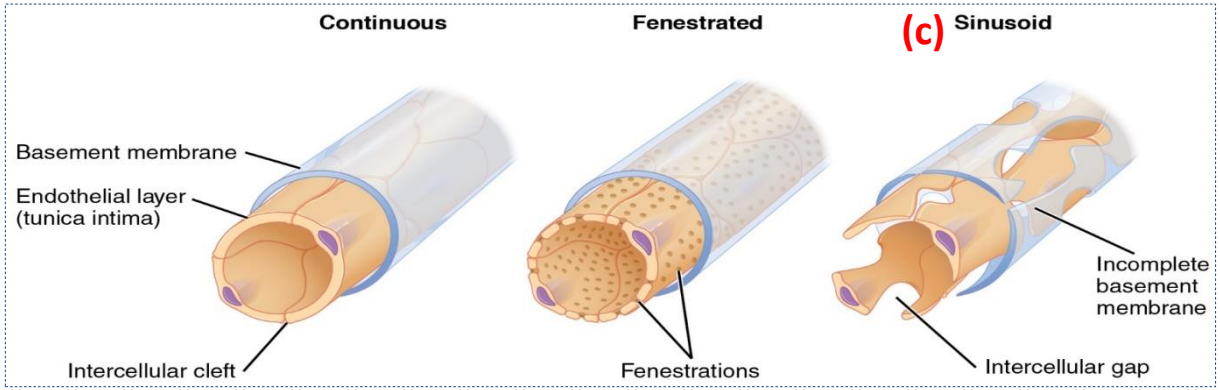


The enlargement shows routes for the diffusion of water and solutes.

Note the pores, which facilitate diffusion across the endothelial lining.

CONT. TYPES OF CAPILLARIES*

** More explanation in Histology*



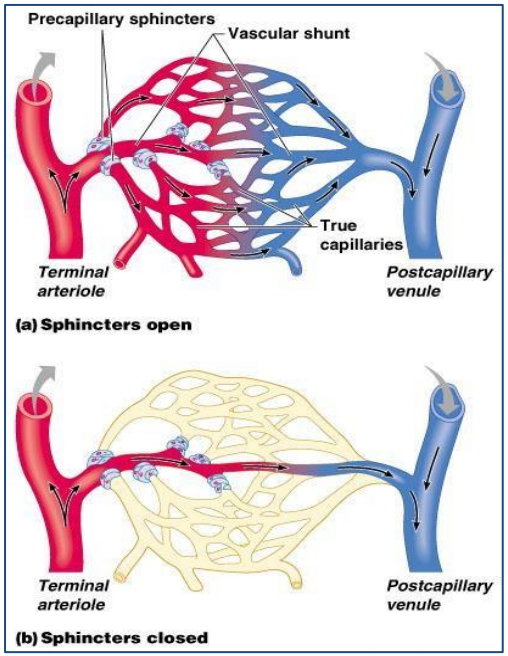
c- sinusoidal : Large diameter with large fenestrae and it is most permeable and least common.

Capillary Beds

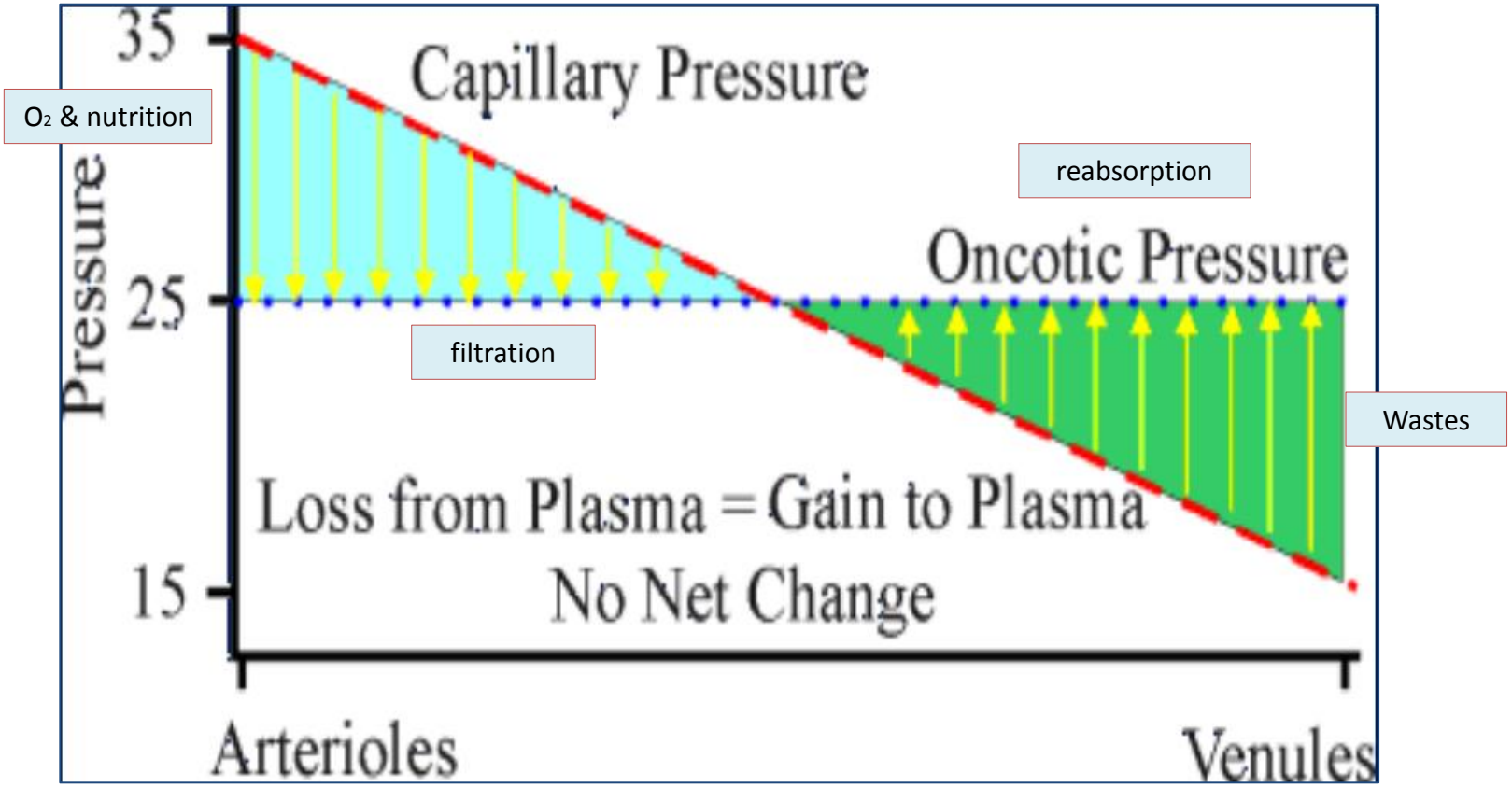
- **Capillary beds consist of two types of vessels:**
  - **Vascular shunt** – directly connects an arteriole to a venule.
  - **True capillaries** – exchange vessels.

    Oxygen & nutrients cross to cells

    Carbon dioxide & metabolic waste products cross into blood



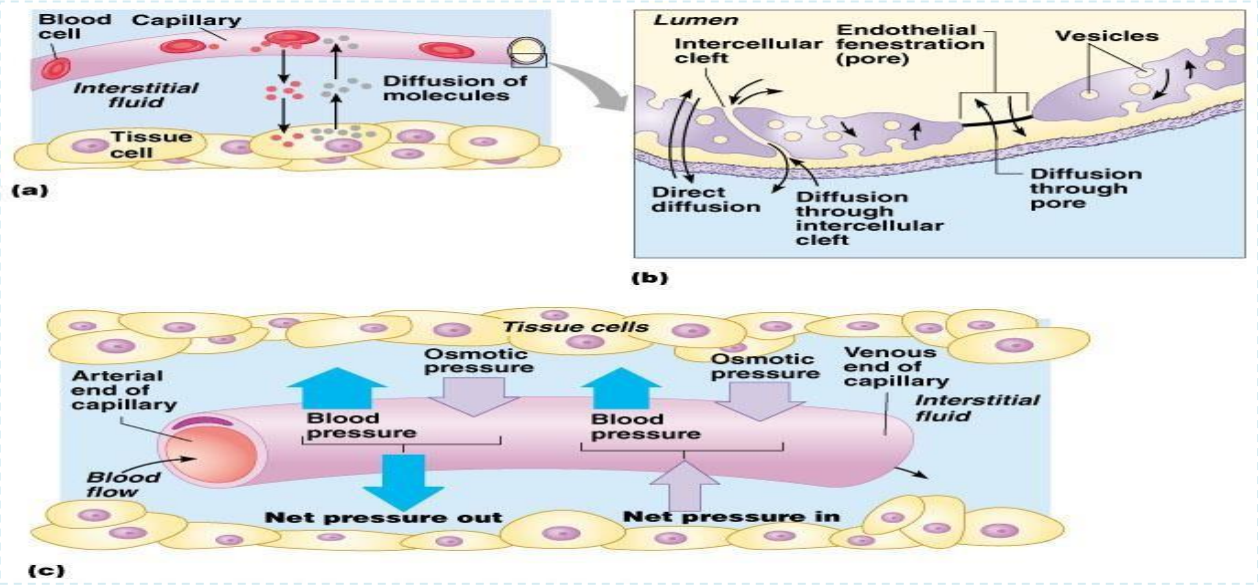
Graphic Representation of Capillary Filtration



* **Oncotic pressure**, or colloid osmotic **pressure**, 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.

Capillary exchange and interstitial fluid volume regulation

- *Blood pressure*, *capillary permeability* and *osmosis* affect movement of fluid from capillaries.
- A net movement of fluid occurs *from blood into tissues*.
- Fluid gained by tissues is removed by *lymphatic system.*



Starling Forces

There are Four Forces that determine Fluid Movement Across the Capillary Membranes:

1. **Pc** (Capillary Pressure) → Tends to move fluid out of the capillary.
2. **Pi** (Interstitial Fluid Pressure) → Tends to move fluid into the capillary.
3. **Πc** (Plasma Colloid Osmotic Pressure) → Tends to cause Osmosis of fluid into capillary.
4. **Πi** (Interstitial fluid colloid osmotic pressure) → Tends to cause osmosis of fluid out of the capillary.

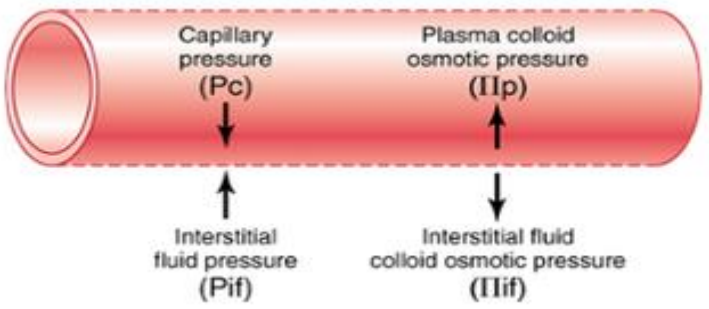


Figure 16-5 shows the four primary forces that determine whether fluid will move out of the blood into the interstitial fluid or in the opposite direction. These forces, called "Starling forces" in honor of the physiologist who first demonstrated their importance

- **Net Filtration Pressure =** P_{net} = [(Pc-Pi) – (Πc- Πi)]
- **Fluid movement =** Kf [(Pc – Pi) – (Πc - Πi)]

- **(Pc-Pi)** : Net hydrostatic pressure
- **(Πc- Πi):** Net osmotic pressure
- **Kf :** filtration coefficient

Fluid balance

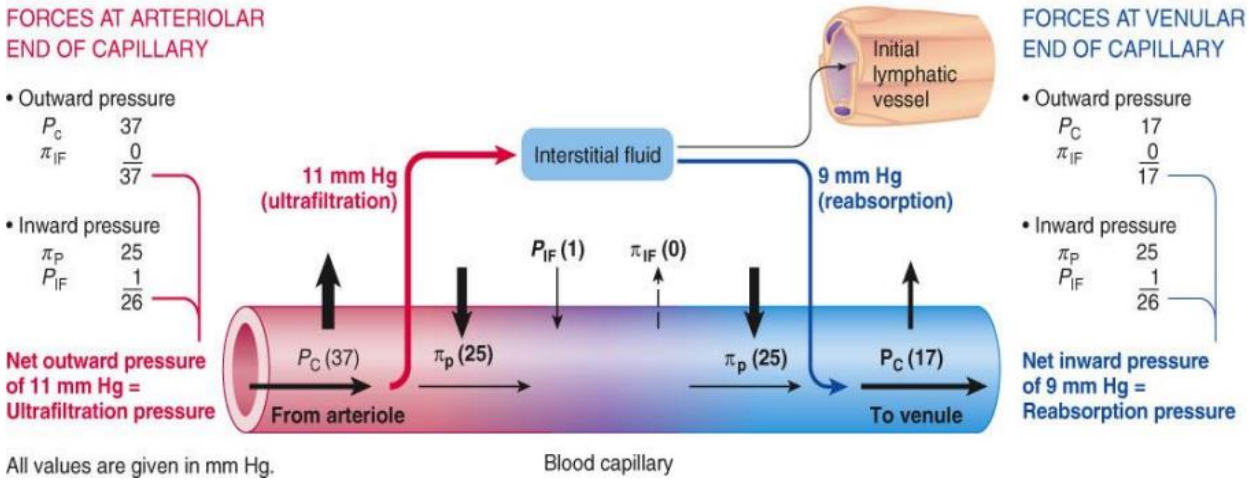
- **Outward Forces:**

1. **Capillary blood pressure :** (P_c = 30-35 to 10-15 mmHg)
2. **Interstitial fluid pressure :** (P_{IF} = 0 mmHg)
3. **Interstitial fluid colloidal osmotic pressure:** (μ_{IF} = 3 mmHg)

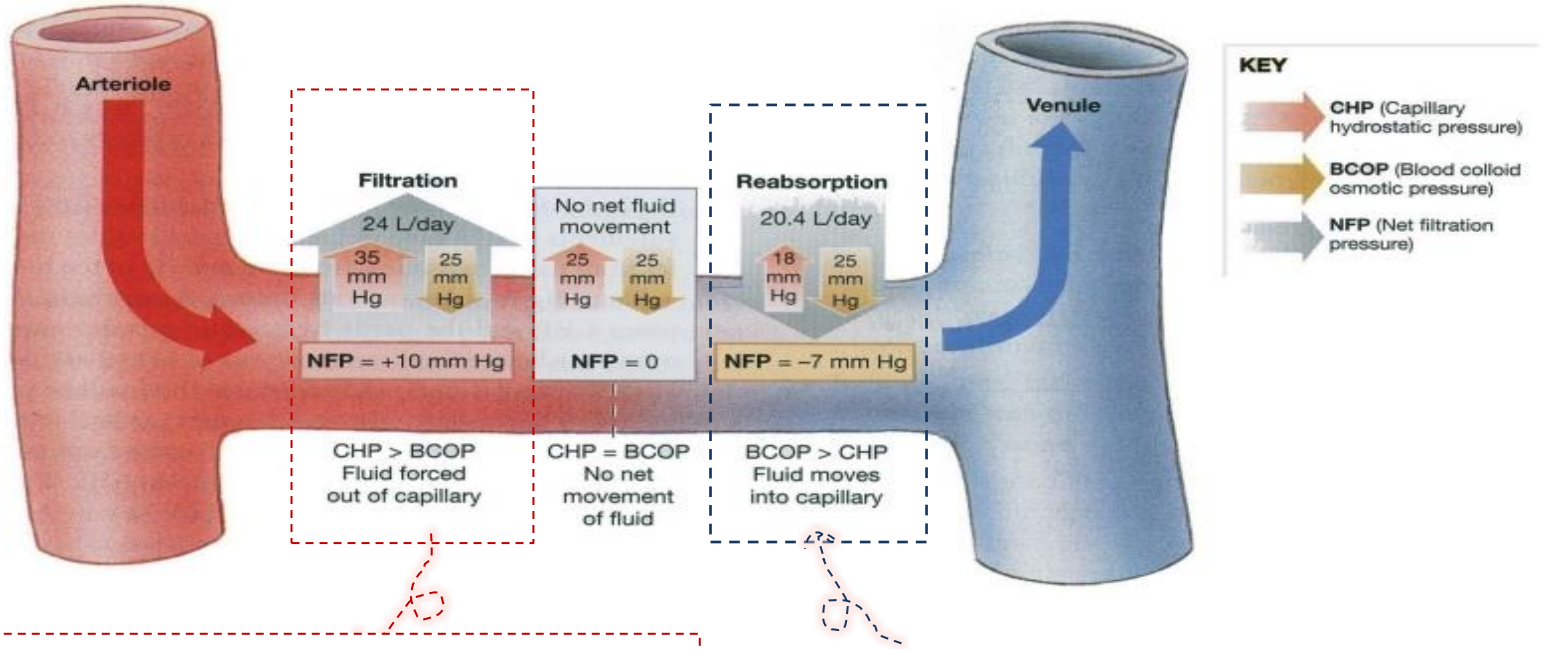
TOTAL= 38 to 18 mmHg

- **Inward Forces:**

Plasma colloidal osmotic pressure: (μ_c = 25-28 mmHg)



FILTRATION Vs REABSORPTION IN NORMAL MICROCIRCULATION



At the arterial end of the capillary, capillary hydrostatic pressure (CHP) is *greater* than blood colloid osmotic pressure (BCOP), so fluid moves out of the capillary (filtration).

Near the venule, CHP is lower than BCOP, so fluid moves into the capillary (Reabsorption).

In this model, interstitial fluid colloid osmotic pressure (ICOP) and interstitial fluid hydrostatic pressure (IHP) are assumed to be 0 mmHg and so are not shown.

FILTRATION Vs REABSORPTION

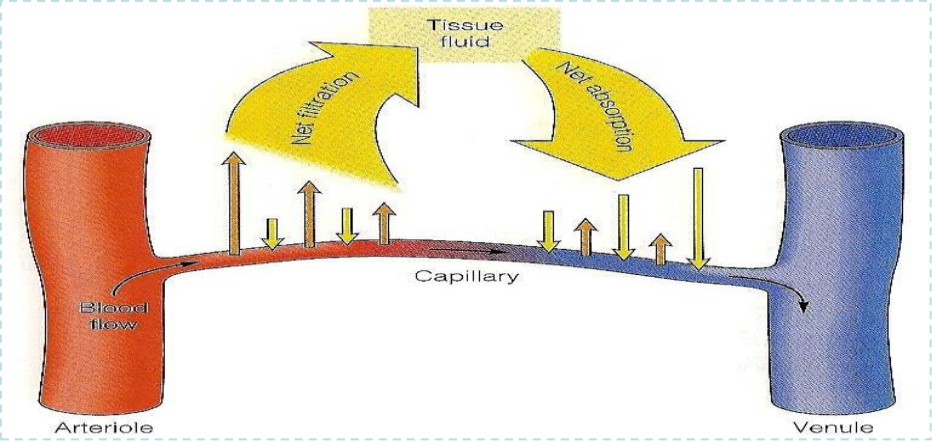
- Along the capillary, filtration occurs More than reabsorption.
- The extra amount of fluid in the interstitial spaces is carried by the lymphatic Vessels → venous circulation. *The aim is to help in :*

1- Constant exchange of fluid.

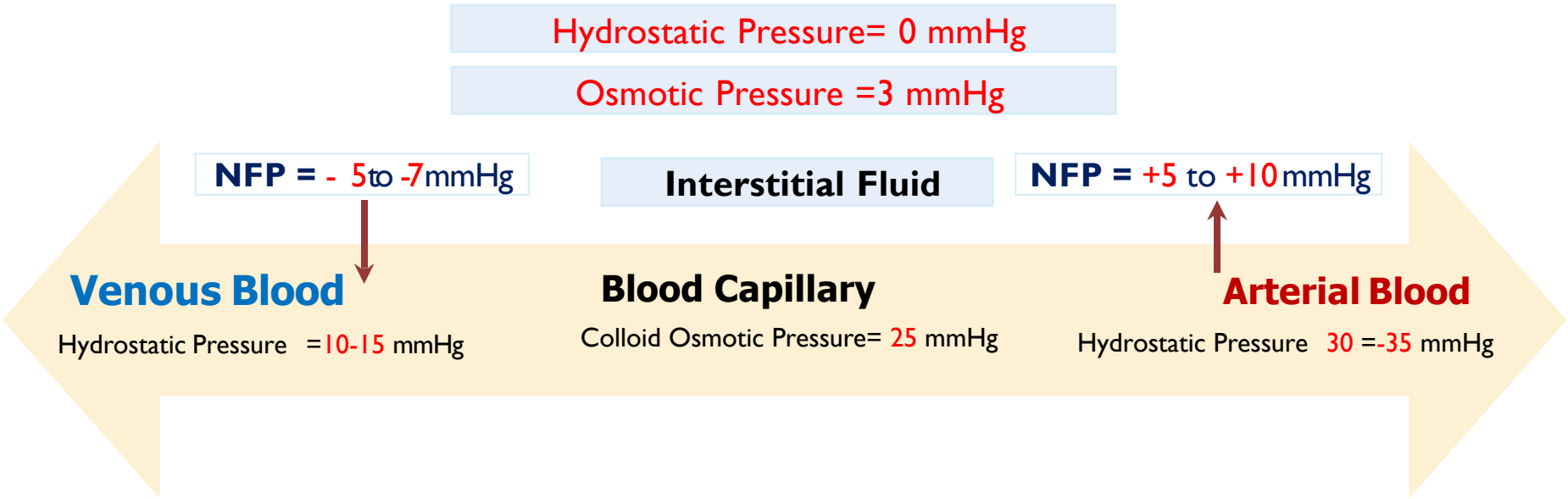
2-Transport insoluble lipids & tissue proteins

3- Accelerate distribution of substances.

4- Carry bacterial toxins to lymphoid tissues → **provide immunity.**



FLUID FILTRATION AND RESORPTION IN NORMAL MICROCIRCULATION



At arterial end:

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

At venous end:

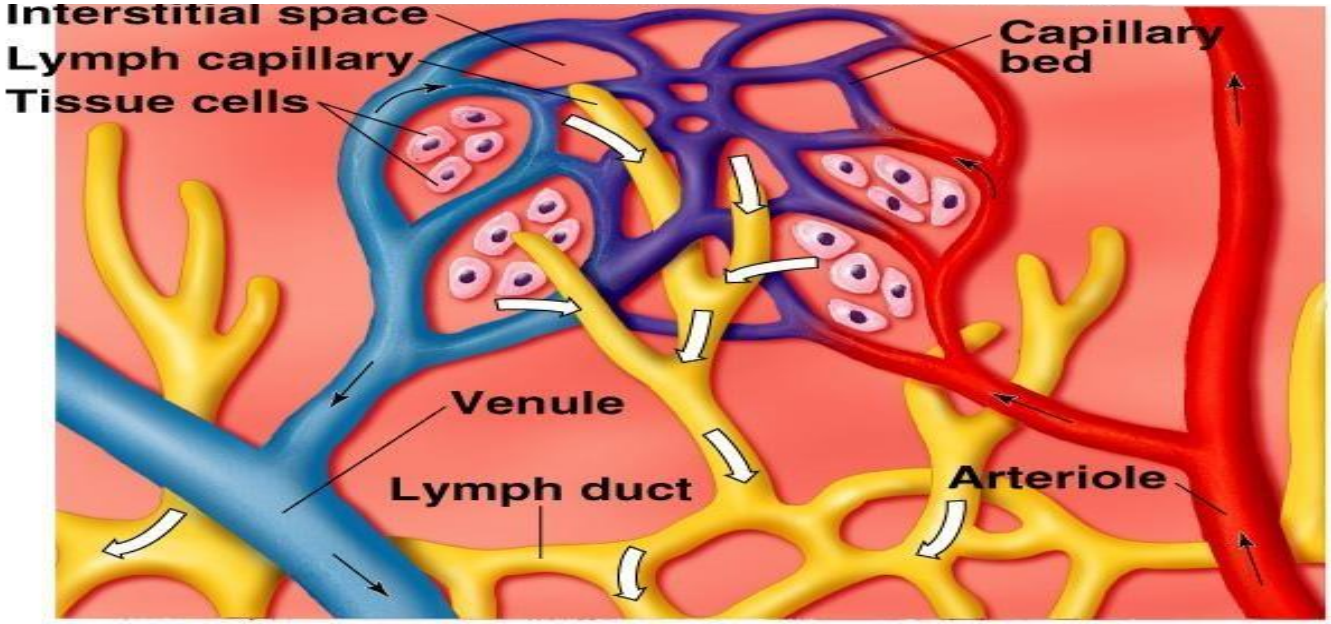
- Water moves **into** the capillary with a NFP of -5 mmHg.
- Oncotic pressure dominates at the **venous** end & net fluid will flow into the bloodstream.

* NFP = Net Filtration Pressure

Lymphatic circulation

Location of lymphatic vessels:
Lymphatic vessels present between capillaries.
Function (Aim):
1- Lymphatic system is responsible for bringing the interstitial fluid to vascular compartment. 2- Drain excess interstitial (tissue) fluid back to the blood in order to maintain original blood volume. 3- Transports absorbed fat from small intestine to the blood. 4- Helps provide immunological defenses against pathogens.
Value:
Normal 24 hours lymph flow is → 2- 4 L
Mechanism:
Lymphatic capillaries lie in interstitial fluid close to vascular capillaries ,these capillaries merge into large lymphatic vessels & eventually into largest vessel, thoracic duct *which empties into large veins* .

Lymphatic circulation

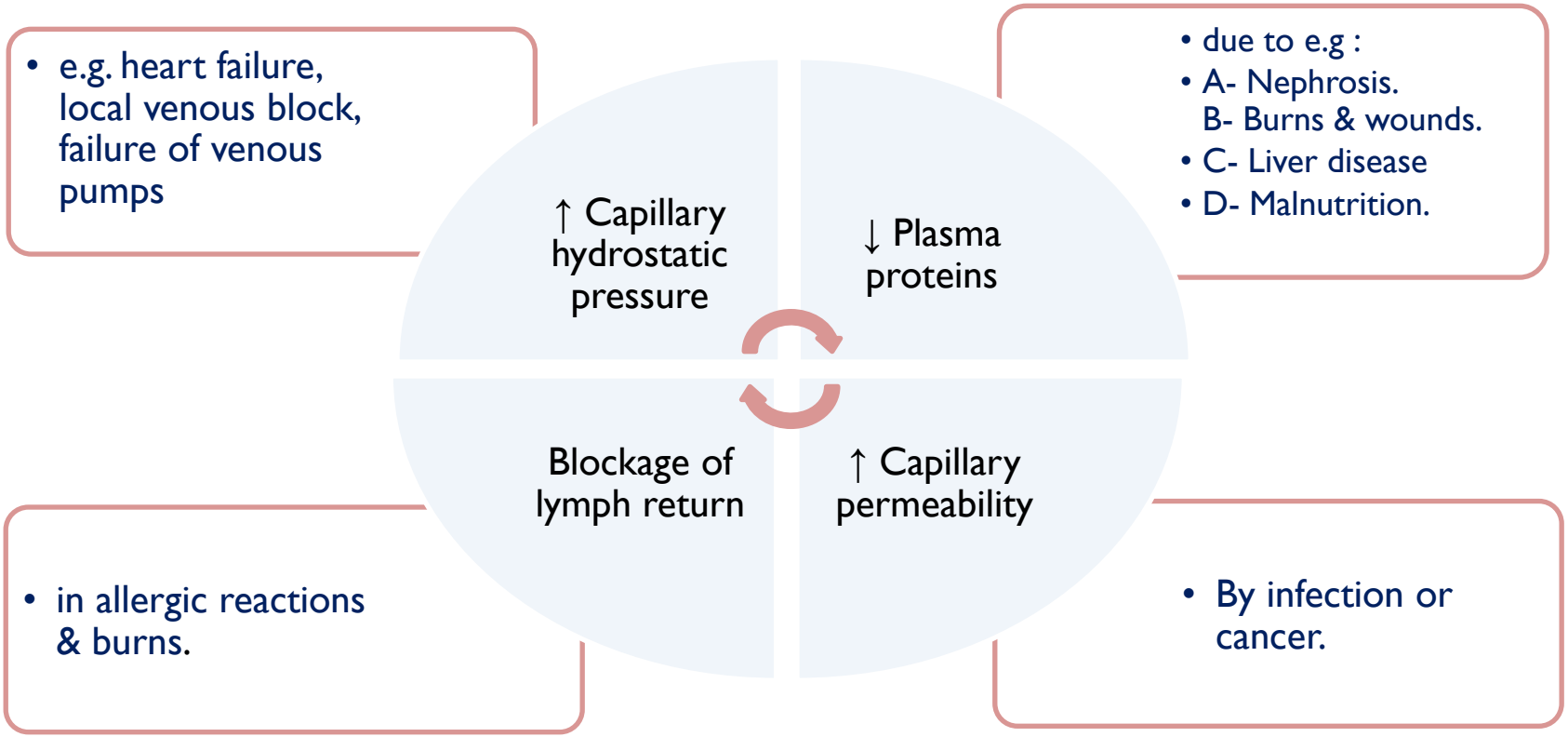


- **Guyton corner :**

The lymphatic system represents an accessory route through which fluid can flow from the interstitial spaces into the blood. Most important, the lymphatics can carry proteins and large particulate matter away from the tissue spaces, neither of which can be removed by absorption directly into the blood capillaries. This return of proteins to the blood from the interstitial spaces is an essential function without which we would die within about 24 hours.

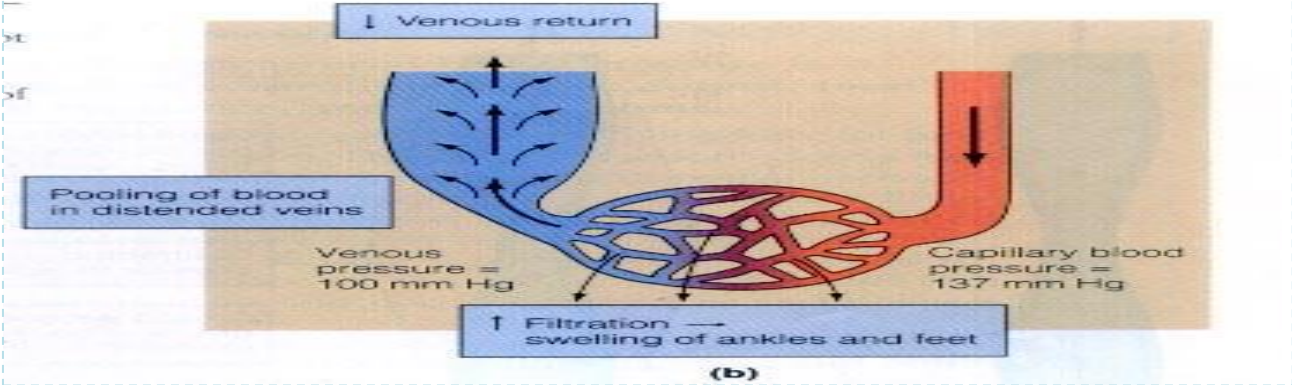
Edema

- **Is an excessive amount of fluid in the interstitial Spaces caused by:**



Edema

Mechanism:



Signs:

Pitting edema of the feet	Elephantiasis (Lymphatic filariasis)
 A Pit forms where the skin is pressured. It may remain there for a few minutes	

Causes (Pathophysiology) of edema

1- Increased hydrostatic blood pressure.	• Heart failure (left or right). • Excess fluid in the blood.
2- Decreased blood osmotic pressure.	• Liver, kidney diseases & Burn injuries. • Malnutrition (kwashiorkor*).
3- Increased interstitial hydrostatic pressure (lymphatic capillary blockage)	• Breast cancer surgery. • Elephantiasis.
4- Leaking capillary wall.	• Histamine release during allergic reaction.

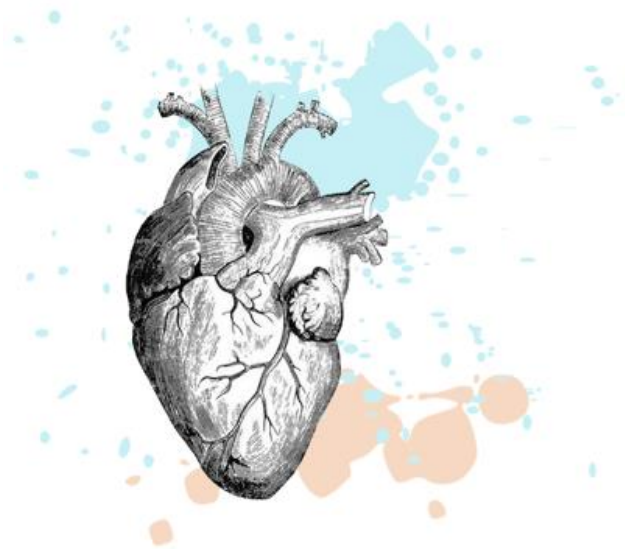
- ***kwashiorkor :**

A form of severe protein–energy malnutrition characterized by edema, anorexia, ulcerating dermatoses, and an enlarged liver with fatty infiltrates. Sufficient calorie intake, but with insufficient protein consumption, distinguishes it from marasmus. Kwashiorkor cases occur in areas of famine or poor food supply.

Physiology
OF THE CARDIOVASCULAR SYSTEM

Physiology Leaders :

Khawla Alammari
Nojood Alhaidri
Rawaf Alrawaf



Girls team :

- Atheer Alnashwan
- Asrar Batarfi
- Afnan Almalki
- Alhanouf Aljlaoud
- Deema AlFaris
- Elham Alzahrani
- Johara Almalki
- Lojain alsiwat
- Malak Alsharif
- Monirah Alsalouli
- Nora AlRomaih
- Nurah Alqahtani
- Nouf Alabdulkarim
- Nora Albusayes
- Nora Alsomali
- Norah Alakeel
- Reem Alageel
- Rawan Aldhuwayhi
- Reham Al-Obaidan
- Samar AlOtaibi
- Shamma Alsaad

Boys team :

- Abdullah Aljaafar
- Omar Alotaibi
- Abdulrahman Albarakah
- Adel Alshehri
- Abdulaziz Alghanaym
- Abdulmajeed Alotaibi
- Khalil Alduraibi
- Hassan Albeladi
- Omar Alshehri
- Saleh Alshawi
- Abdulaziz Alhammad
- Faisal Alabdulatif
- Abdulnasser Alwabel
- Saad Almutairy