THE MICROCIRCULATION

PRESENTED BY

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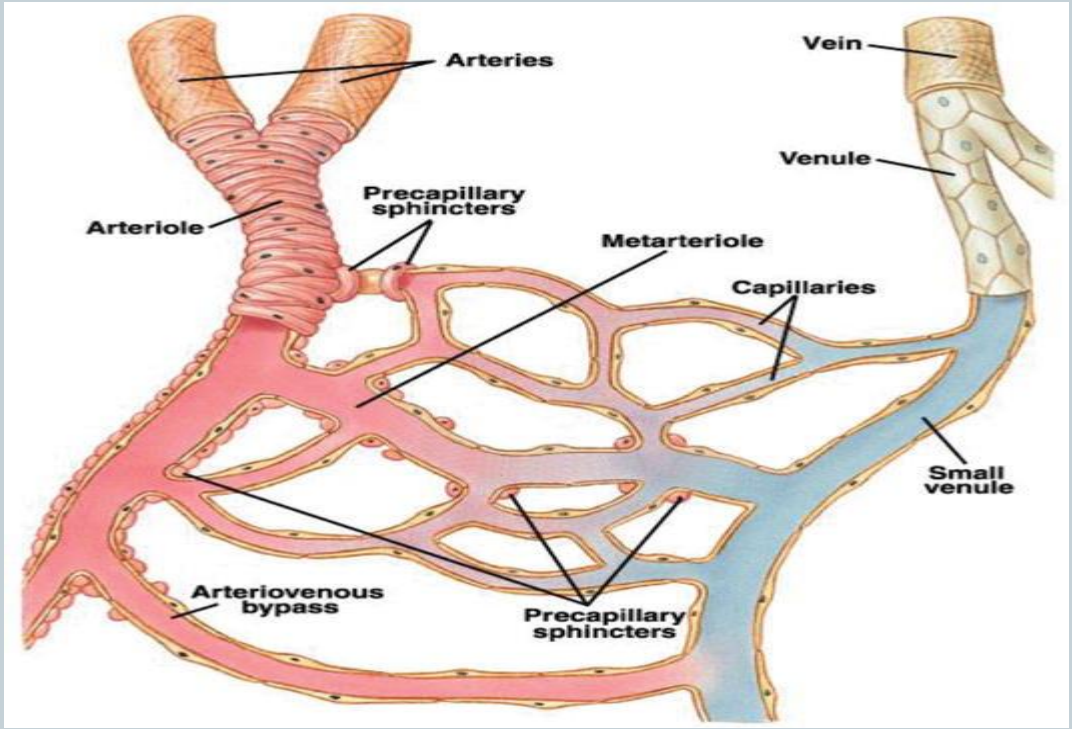
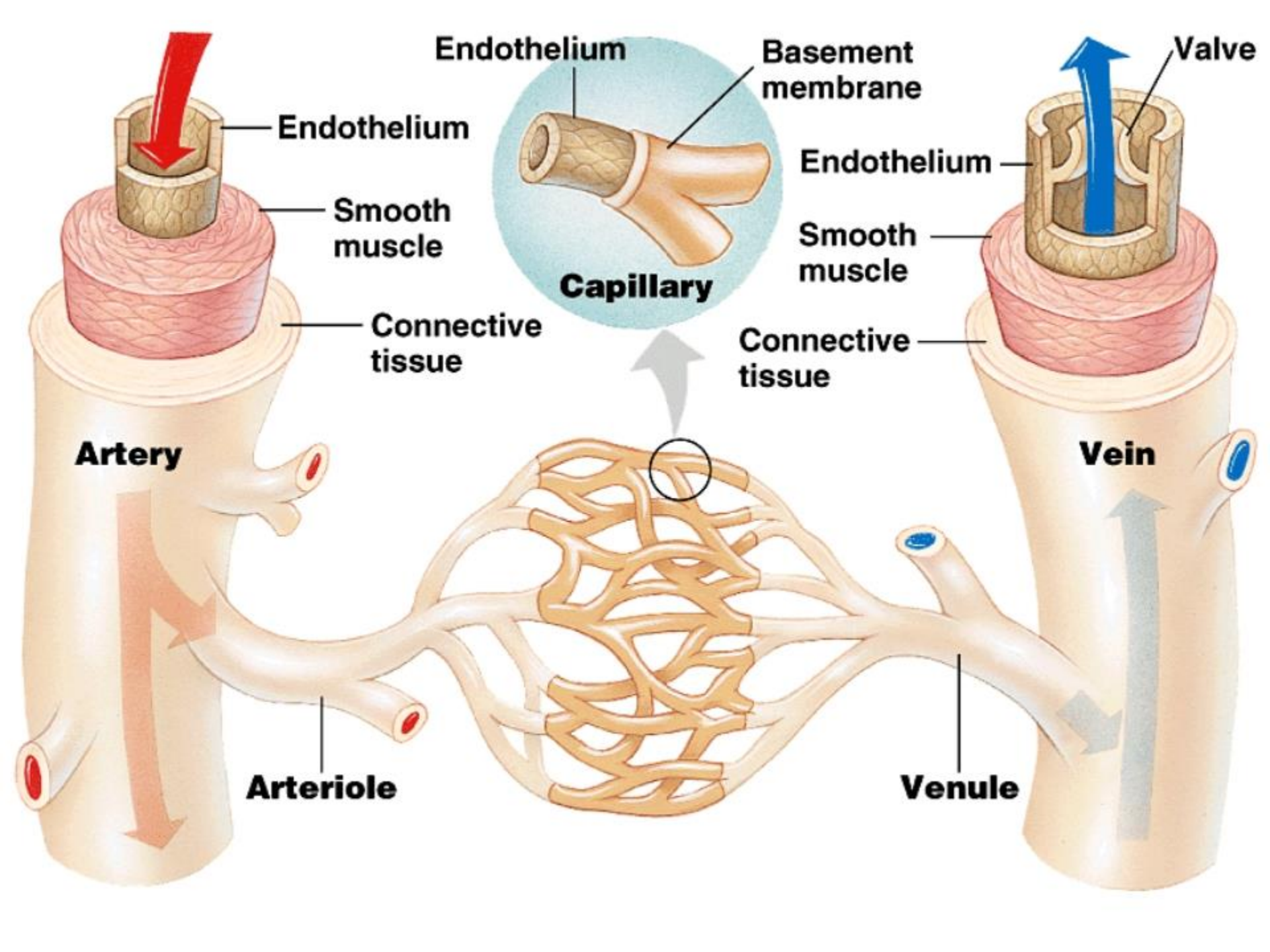


CAPILLARY CIRCULATION (MICROCIRCULATION)

Structure of microcirculation

- The arterioles divide into smaller muscle walled vessels called metarterioles, and capillaries arise from both the arterioles and metarterioles.
- The cross sectional area of the open capillaries is 3000-4500 cm^2 with an average velocity of blood flow 0.2-0.3 mm/second.
- Their walls are about 0.5-1 micron thick, and each is about 0.7 mm long.
- The **openings of capillaries** are surrounded by minute small muscles called **precapillary sphincters** which respond to various stimuli.
- **The capillary walls contain no smooth muscle fibers**, they are passive (i.e. they don't contract or relax) and their dilatation or constriction depends on the state of **precapillary sphincters (their contraction leads to capillary constriction while their relaxation leads to capillary dilatation)**.


Endothelium
Basement membrane
Valve
Endothelium
Endothelium
Smooth muscle
Smooth muscle
Capillary
Connective tissue
Connective tissue
Artery
Vein
Arteriole
Venule

VASOMOTION

- Vasomotion means intermittent opening and closure of the capillaries (intermittent blood flow).
- It is a normal phenomenon that occurs at variable rates (i.e. every few seconds to few minutes).
- It occurs as a result of rhythmic contraction and relaxation of precapillary sphincters.
- Its rate is controlled mainly by oxygen level in the tissues (O_2 lack prolongs the capillary opening periods and shortens their closure period and vice versa).

Capillary blood flow

- Very slow (0.2-0.3 mm/second).
- Intermittent (vasomotion).

Capillary Functions

- Capillaries contain about **5%** of blood volume at time.
- However, they perform the main function of CVS because they constitute the site at which **exchange** of various substances between the blood and interstitial fluid occurs.
- It is across the capillary walls that O_2 and various nutrients enter the interstitial fluid, while CO_2 and various waste products enter the blood, and such exchange is essential to life. Therefore, capillaries **maintain** constant **communication** between **plasma** and **interstitial fluid**.

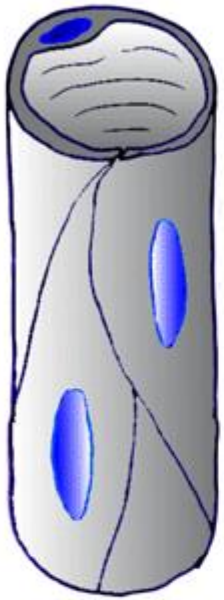
Transcapillary exchange mechanisms

The transport of fluids and various materials across the capillary walls occurs by the following mechanisms:

1. Diffusion
2. Filtration
3. Transcytosis(vesicular transport)
4. Diapedesis

CAPILLARY TYPES

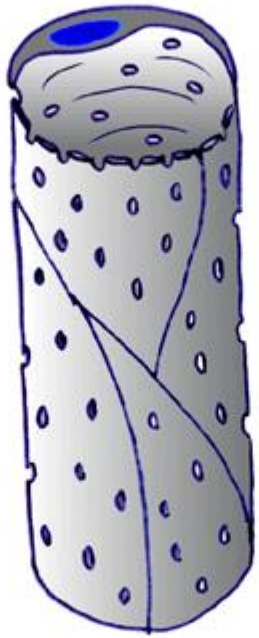
Continuous Capillary



Typical Locations

fat
muscle
nervous system

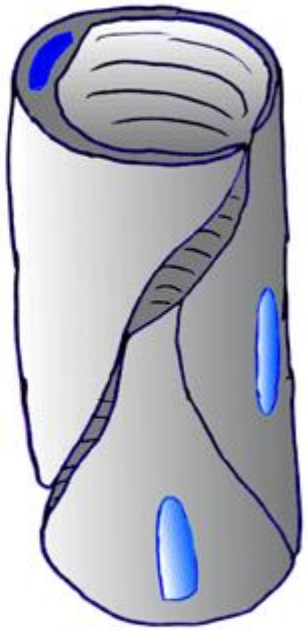
Fenestrated Capillary



Typical Locations

intestinal villi
endocrine glands
kidney glomeruli

Discontinuous Capillary



Typical Locations

liver
bone marrow
spleen

1. Diffusion

- This is the process by which substances move down their concentration gradient (passive transport for small molecules).
- Water and water soluble substances (e.g. glucose, urea, Na^+, Cl^- & K^+) diffuse only through slit pores and fenestrae.
- Fat soluble substances diffuse across the whole capillary wall (through pores as well as cytoplasm of capillary endothelial cells). Since they dissolve in the phospholipid bilayer of endothelial cell membranes.
- Thus, the diffusion of fat soluble substances and gases (O_2 and CO_2) is normally greater and faster than water-soluble substances.

2. Filtration

- This is the process by which fluid and dissolved solutes are forced through the pores in the capillary membrane due to a difference in hydrostatic pressure on the 2 sides.

- The force of filtration is opposed by the force of osmosis, and both forces are concerned with the bulk flow of fluids and solutes across the capillary walls through formation and drainage of the interstitial fluid.

Two main factors affect tissue fluid formation and drainage. These are:

1. Starling's forces (= the hydrostatic and osmotic forces that act across the capillary walls).
2. The capillary permeability.

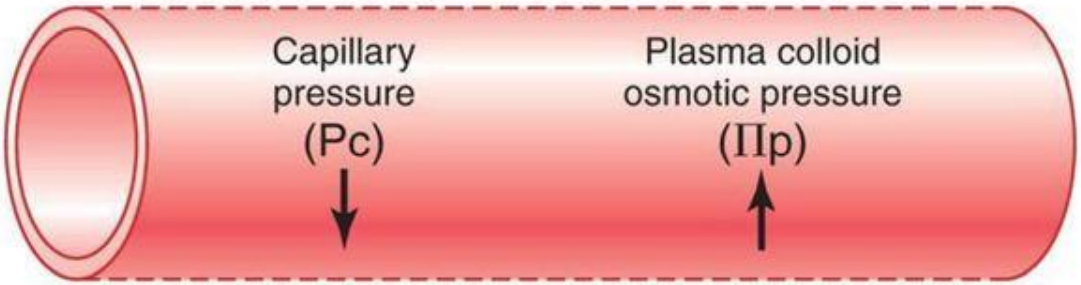
Starling forces

1) The **hydrostatic capillary pressure (hcp):** this forces fluid **outwards** through the capillary membranes, and it normally averages **35 mmHg at the arteriolar ends** of capillaries and **12 mmHg at their venular ends**.
2) The **interstitial fluid colloid osmotic pressure (ifop):** this causes osmosis of fluid **outwards** through the capillary membranes, and it normally averages **3 mmHg**.
3) The **plasma colloid osmotic pressure (pop):** this is produced mainly by plasma albumin. It averages **25 mmHg** and it causes osmosis of fluid **inwards** through the capillary membranes.
4) The **interstitial fluid pressure (ifp):** this forces fluid **inwards** through the capillary membranes, and it normally averages **+1mmHg**.

At the arteriolar ends: (35+3)-(25+1) = 12 mmHg
The filtering forces exceed the reabsorbing forces by about 12 mmHg, resulting in fluid filtration.
At the venous ends: (25+1)-(12+3)= 11 mmHg
The reabsorbing forces exceed the filtering forces by about 11 mmHg resulting in fluid absorption.

Normally, about 24 liters of fluid are filtered daily through capillaries. However, since the net reabsorbing force at the venular ends of capillaries is less than the net filtering forces at their arteriolar ends, only about 85% of the filtered fluid is reabsorbed into the venular ends of the capillaries and the remainder returns to the circulation via the lymph vessels.

Starling Forces Acting Across Capillary Membrane



- Four primary forces determine whether fluid moves in or out of blood "***Starling forces***":
  - Capillary "***hydrostatic***" pressure → out of blood.
  - IF "***hydrostatic***" pressure → into blood if +ve and out of blood if -ve.
  - Plasma ***colloid osmotic*** pressure → into blood.
  - IF ***colloid osmotic*** pressure → out of blood.

N.B.

The Starling forces vary greatly in different organs depending on their functions e.g. the balance of forces cause fluid filtration from almost the entire length of the renal glomerular capillaries.

Capillary permeability (CP)

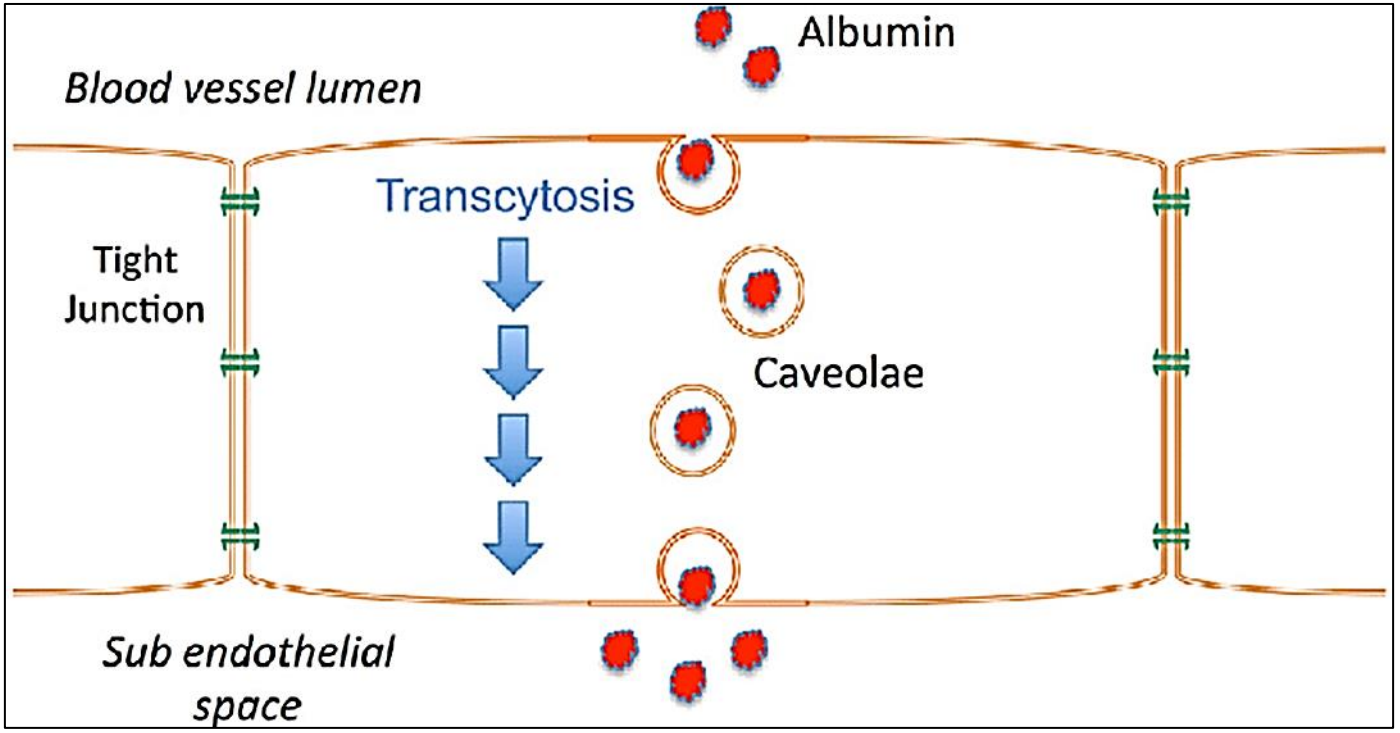
- The capillary permeability varies in different organs depending on their function.
- Together, with the area available for filtration, it determines the capillary filtration coefficient i.e. volume of fluid filtered/1 mmHg/min.
- The highly-permeable capillaries allow more protein filtration into the tissue spaces, and the protein concentration in lymph drained from a certain organ is an indicator of the degree of permeability of its capillaries.

3. Transcytosis (vesicular transport)

This is the mechanism of transport of **large molecules** across the capillary membrane.

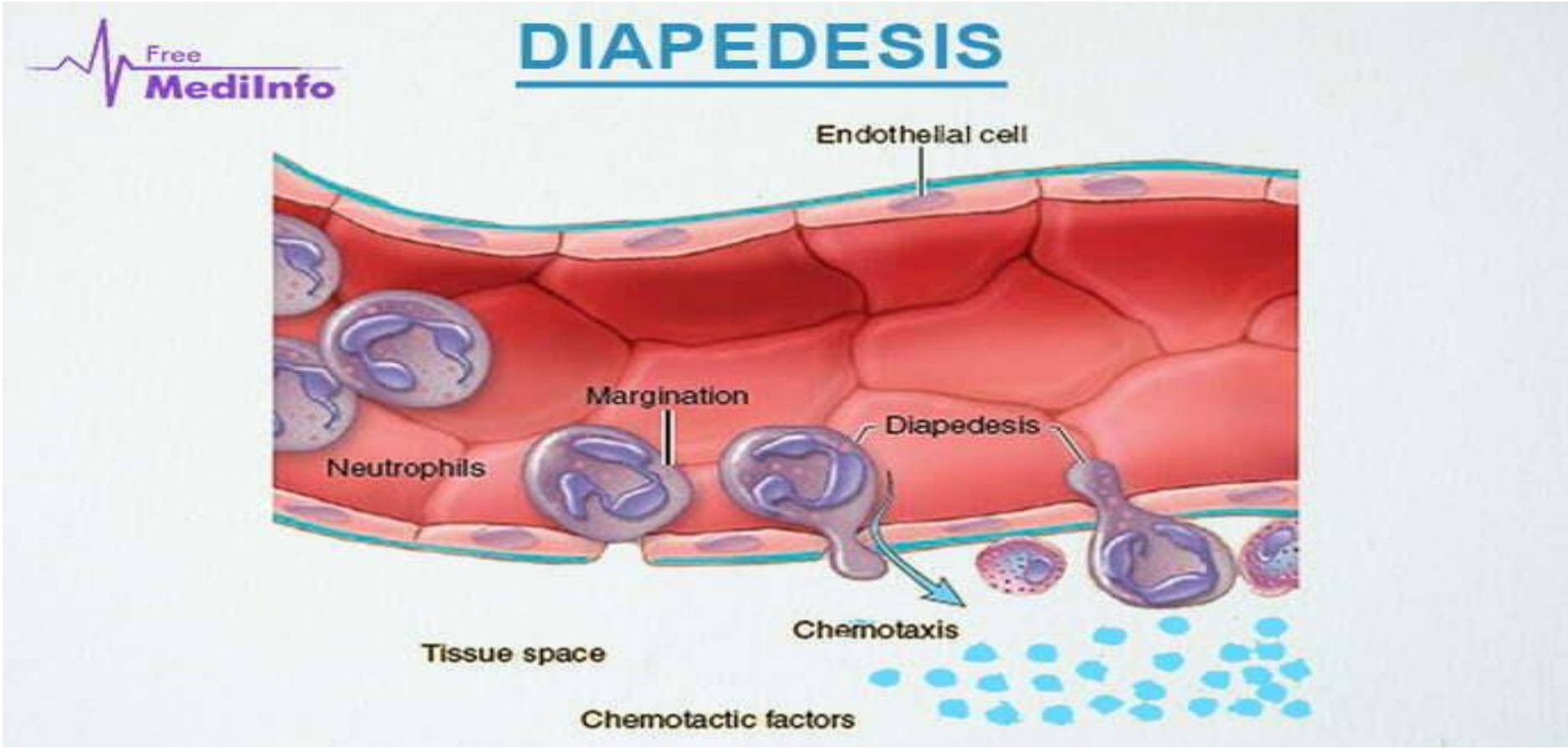
The large molecules are transported by endocytosis at the endothelial side followed by exocytosis at the interstitial side.

Normally, small amounts of **proteins** are transported by this mechanism.



4. Diapedesis

This is the mechanism by which WBCs (Leucocytes) are transported across the capillary membrane to areas of inflammation.



Response of capillaries to mechanical stimuli

White line (reaction):

Stroking the skin lightly with a blunt pointed object leads to pallor of the stimulated part within 15 seconds. This is due to direct contraction of precapillary sphincters by the mechanical stimulus.

Triple response:

A response that commonly occurs in skin as a result of either injury (heavy stroking) or insect bites. It consists of 3 reactions:

- Red Line (appears in about 10 seconds): Due to capillary dilatation secondary to relaxation of precapillary sphincters as a direct response to heavy stroke.
- Spreading Flare: diffuse reddening that appears within about half a minute around the area of injury due to arteriolar vasodilatation.
- Wheal (swelling): Local oedema that appears within a few minutes around the injured area due to increased capillary permeability (extravasation of fluid from capillaries) due to liberation of vasodilators (histamine and substance P).

Capillary Fragility (CF)

The capillaries are normally not fragile i.e. not vulnerable to rupture although they are very delicate. This is because according to Laplace's law the tension in their walls is very low due to their extremely small radius. (can withstand very high pressure).

The CF is increased in many diseases e.g. scurvy (vitamin C deficiency) and purpura.

CF can be checked by Hess test (tourniquet test).

Hess test (tourniquet test)

- The sphygmomanometer cuff is wrapped around the arm and the ABP is measured.
- The cuff is inflated to a pressure midway between SBP and DBP for 8-10 min.
- The number of petechiae is counted at the cubital fossa in a circular area of 5 cm in diameter.
- CF is considered high if the number is more than 10.
- The test is +ve in some diseases as scurvy and purpura.

Edema

Definition:

Accumulation of excessive amounts of interstitial fluid (mostly in the dependent parts of body by effect of gravity).

Causes:

- An increase of capillary hydrostatic pressure: due to arteriolar dilatation or elevation of venous pressure (venous obstruction and right sided heart failure).
- Decreased plasma colloid osmotic pressure: due to hypoproteinemia.
- Increased capillary permeability: as in allergic reactions (histamine).
- Inadequate lymph drainage (lymphedema) : blockage of lymph vessels that often occurs in cancer.
- Salt and water retention in body.


THANK
YOU