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Lecture title: Capillary and Venous Circulation:

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Summary: Capillaries enable fluid and nutrient exchange via diffusion, filtration, and pinocytosis; venous return is aided by pumps and valves.

Capillary circulation:

Microcirculation refers to flow of blood through the minute blood vessels such as arterioles, capillaries and venules. Capillary circulation forms the major part of microcirculation.

Features of capillaries:

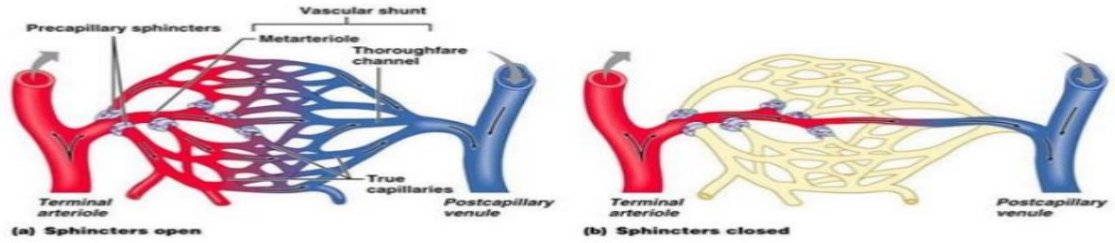
Capillaries arise from arterioles and form the actual functional area of circulatory system, i.e., exchange of materials between blood and tissues.

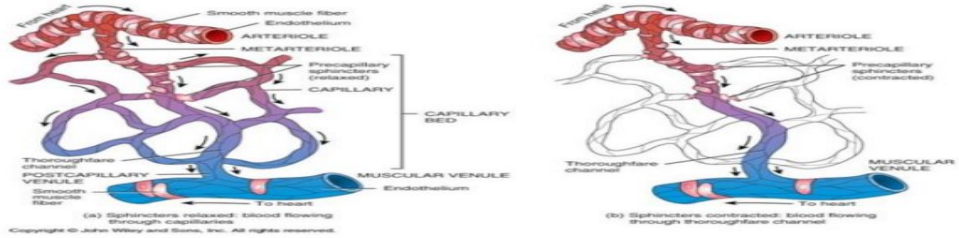
They consist of only single layer of endothelial cells.

Structurally, capillaries are very narrow and short. However, quantitatively, these vessels outnumber the other blood vessels. About10 billion capillaries are present in the body.

Each capillary lies in a very close proximity to the cells of the tissues at a distance of about 20-30mm. This enables easy and rapid exchange of substances between blood and the tissues through interstitial fluid.

The capillary net link is the link between the arterial and venous sides of circulation provided by the meta-arteriole. Many tissues of the body, such as muscles, do not have anatomical shunts. However, the meta-arteriole in these tissues acts as the physiological shunt between the arterial and venous sides of the circulation.





Functions of capillaries

Most important function of capillaries is *the exchange of substances between blood and tissues*. Oxygen, nutrients and other essential substances enter the tissues from capillary blood; carbon dioxide, metabolites and other unwanted substances are removed from the tissues by capillary blood.

Exchange of materials across the capillary endothelium occurs by the following processes:

1. *Diffusion* (Diffusion is the main process for exchange of gases, water, glucose, sodium, urea and many other sub stances). These substances diffuse through the inter cellular clefts present in the endothelial wall of the capillaries. Diffusion occurs because of concentration gradient across the capillary wall.

2. *Filtration* (Filtration of substances through capillary endothelium depends upon the net filtration pressure. Net filtration pressure is the balance between the driving pressures and the opposing pressures).

- Two types of pressure interact to drive each of these movements: ***hydrostatic pressure and osmotic pressure.***
- The ***rate of filtration*** *along a capillary depends upon a* ***balance of forces*** (sometimes called the **starling forces**).

1- The capillary hydrostatic pressure, which tends to move fluid outward through the capillary membrane.
2- The interstitial fluid hydrostatic pressure, which tends to move fluid inward through the capillary membrane.
3- The plasma colloid osmotic pressure of the capillary, which tends to cause osmosis of fluid inward through the membrane.

4- The interstitial fluid colloid osmotic pressure, which tends to cause osmosis of fluid outward through the membrane.

starling forces: The physical forces that control the flow of fluid between tissues and capillaries. The hydrostatic and oncotic pressures are the two major starling forces.

Note:

Oncotic pressure is a form of osmotic pressure exerted by proteins either in a fluid (the blood plasma or interstitial fluid) tend to pull water into circulatory system.

Hydrostatic pressure is a force generated by the pressure of fluid on the capillary walls either by the blood plasma or interstitial fluid, usually forcing the water out of the circulatory system.

3. *Pinocytosis* (Larger molecules (e.g. y-globulin, large proteins) are transported across the capillary endothelium in the form of vesicles. Large molecules are packed as vesicles in the capillary endothelial cells. These vesicles are transported across the endothelial membrane by the process called pinocytosis).

Types of capillaries:

1. Continuous or non-fenestrated capillaries, here single layer of endothelial cells is almost continuous except at the intercellular regions which is 10 nm wide. These capillaries allow exchange of fluid and lipid soluble substances within interstitial fluid by simple diffusion. Most of body capillaries are of this type.
2. Fenestrated capillaries, here, fenestrations or pores (20-l00 nm in diameter) seen are intracellular openings which serve the function of rapid and large transudation of fluid. Sites: Renal glomeruli, vasa recta

of renal medulla, endocrine and exocrine glands, choroid plexuses, intestinal villi.

3. Discontinuous capillaries or Sinusoids, these capillaries possess a thin endothelial layer with large gaps between individual cells. Therefore, allow, easy exchange of large protein molecules and RBCs. Sites: bone marrow, liver and spleen.

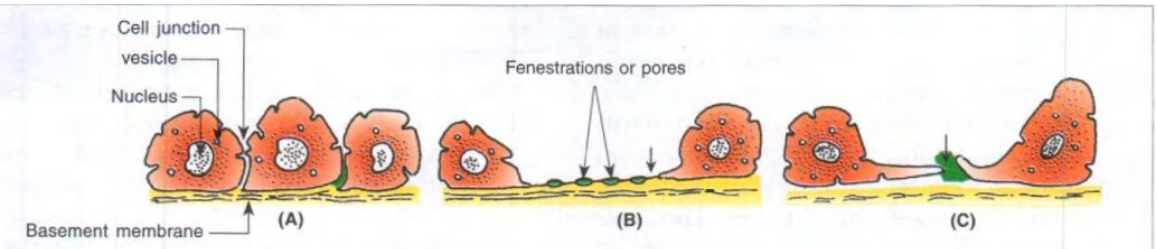


Fig. 38.4 Classification of capillaries: Continuous or non-fenestrated (A); Fenestrated (B) and Discontinuous or sinusoids (C)

Capillary Exchange

I. Capillaries are the site where nutrients and waste products are exchanged between blood and tissues.

II. Blood flows through the capillaries **more slowly** than through any other part of the vascular system *because of the huge cross-sectional area of the capillaries.*

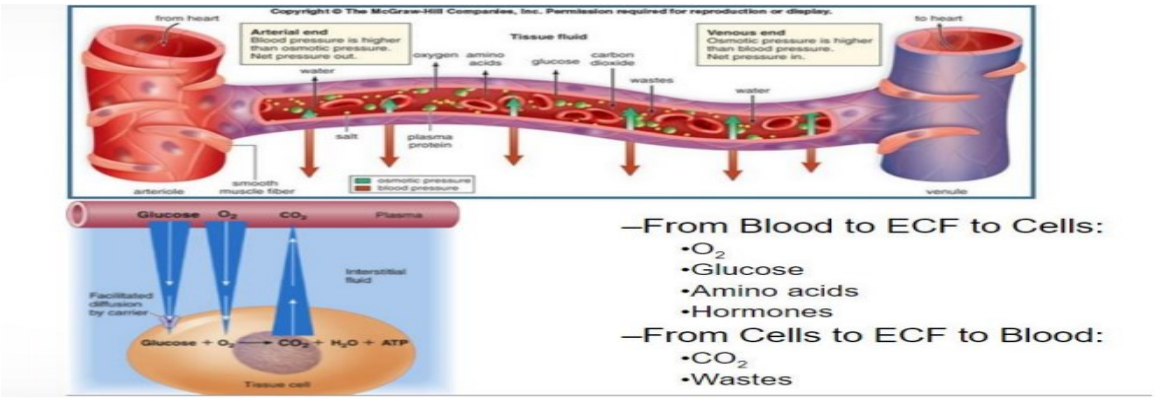
I. Capillary blood flow is determined by the resistance of the arterioles supplying the capillaries and by the number of open precapillary sphincters.

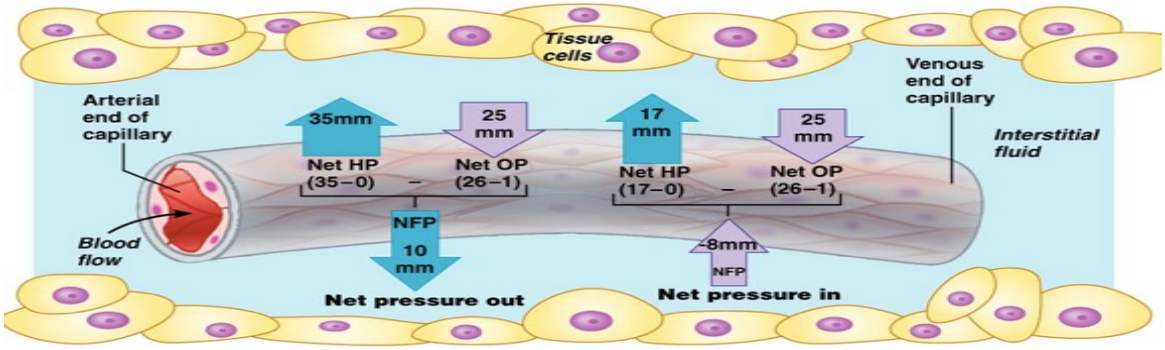
IV. a) Diffusion is the mechanism that exchanges nutrients and metabolic end products between capillary plasma and interstitial fluid. (It means depend on concentration gradient)

b) Lipid-soluble substances move across the entire endothelial wall, whereas ions and polar molecules move through water-filled intercellular clefts or fused-vesicle channels.

c) Plasma proteins move across most capillaries only very slowly, either by diffusion through water-filled channels or by vesicle transport.
d) The diffusion gradient for a substance across capillaries arises as a result of cell utilization or production of the substance. Increased metabolism increases the diffusion gradient and increases the rate of diffusion.

V. Bulk flow of protein-free plasma or interstitial fluid across capillaries determines the distribution of extracellular fluid between these two fluid compartments. (It means depend on pressure and is more about fluid with Solutes in it.)
a) **Filtration** from plasma to interstitial fluid is favored by **the hydrostatic pressure** difference between the capillary and the interstitial fluid. **Absorption** from interstitial fluid to plasma is favored by **the protein concentration difference** between the plasma and the interstitial fluid.
b) Filtration and absorption do not change the concentrations of crystalloids in the plasma and interstitial fluid because these substances move together with water.
c) There is normally a small excess of filtration over absorption, which returns fluids to the bloodstream via lymphatic vessels.





Factors controlling capillary circulation:

Capillaries are mainly supplied by the nervous and chemical factors.

- Nervous factors: capillaries are mainly supplied by the sympathetic vasoconstrictor fibers.
- Chemical factors: many chemical factors such as excess of Carbone dioxide, increased hydrogen ion concentration, lack of oxygen, histamine and metabolites like lactic acid cause dilation of capillaries. Serotonin causes concentration of capillaries.

Venous circulation:

The pressure in the venules is 12-18mmHg.it falls in the larger veins to about 5.5 mmHg. The pressure in the great veins at their entrance into the right atrium (central venous pressure) averages 4.6 mmHg. Peripheral venous pressure is affected by gravity.

Venous return to the heart depends on various factors:

1. Thoracic pump:

During inspiration, the intra pleural pressure falls from -2mmHg to-6mmHg. This negative pressure is transmitted to the great veins, so that central venous pressure fluctuates from about 6 mmHg during expiration to about

2mmHg during quit inspiration. The decrease in venous pressure during inspiration aids venous return. When the diaphragm descends during inspiration intra-abdominal pressure rise, and this squeezes blood toward the heart because backflow into the leg veins is prevented by the venous valves.

2. Cardiac pump:

Atrial pressure drops sharply during the ejection phase of ventricular systole because the AV valves are pulled downward, increasing the capacity of the atria. this action sucks blood into the atria from the great veins.

3. Muscular pump:

In the limbs, the veins are surrounded by skeletal muscles, and contraction of these muscles during activity compresses the veins. Pulsations of nearly arteries may also compress vein.

4. Action of valves:

The valves in muscular veins allow the blood to pass in one direction only. In persons with incompetent valves, large amounts of blood may pool in the lower extremities during prolonged standing, resulting in swollen veins (varicose veins).