Miss. Pooja Kanse

BIOLOGICAL TRANSPORT MECHANISMS – Paper 2 (unit 3)

Transport in plants:

Plants have two systems for the transportation of substances - using two different types of transport tissue. Xylem transports water and solutes from the roots to the leaves, while phloem transports food from the leaves to the rest of the plant. These systems use continuous tubes called xylem and phloem, and together they are known as vascular bundles.

Transpiration is the process by which water evaporates from the leaves, which results in more water being drawn up from the roots. Plants have adaptations to reduce excessive water loss.

Xylem

Xylem vessels are involved in the movement of water through a plant - from its roots to its leaves via the stem.

During this process:

1. Water is absorbed from the soil through root hair cells.
2. Water moves by *osmosis* from root cell to root cell until it reaches the xylem.
3. It is transported through the xylem vessels up the stem to the leaves.
4. It *evaporates* from the leaves (transpiration).

Phloem

Phloem vessels are involved in translocation. Dissolved sugars, produced during *photosynthesis*, and other soluble food molecules are moved from the leaves to growing tissues (eg the tips of the roots and shoots) and storage tissues (eg in the roots).

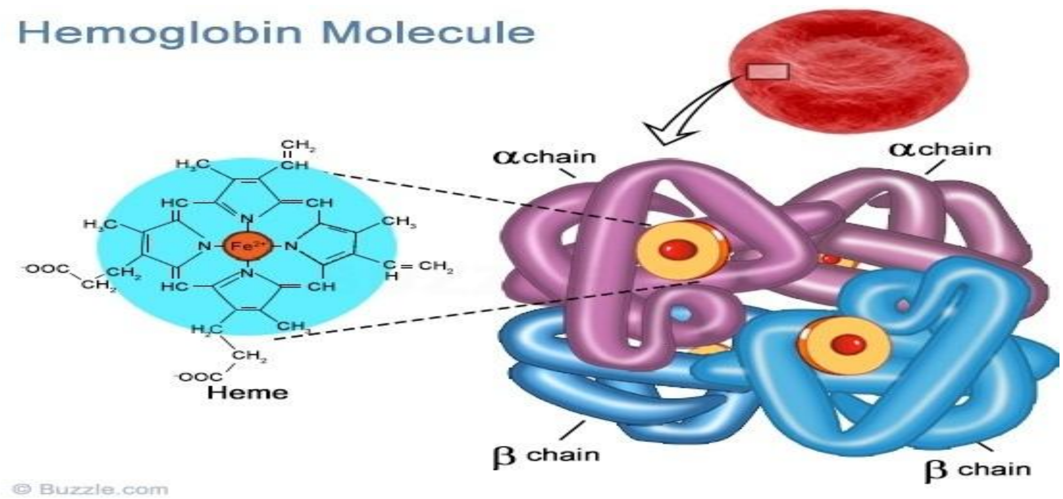
Transport in blood:

The blood transport gases which are oxygen and carbon dioxide between the lungs and other tissues throughout the body. Hemoglobin is largely responsible for the transport of O_2 from lungs to tissue and CO_2 from the tissue to the lungs.

Oxygen transport: - O2 transported by the blood either,

a) combined with Hb in the RBC (98%)
b) dissolved in the blood plasma (2%)

Hemoglobin is a protein, containing globin (apoprotein) & the heme (non-protein part). Globin consist of 4 polypeptides chains of two α Chains & β chains. Each α chain contain 141 amino acids while β chains contain 146 amino acids. The 4 subunits of hemoglobin are held together by non-covalent interactions. Each subunit contain heme group. Heme contains a porphyrin molecule with iron at its center.



Binding of O_2 to hemoglobin:-

- One molecule of hemoglobin can bind with 4 molecules of O_2.
- Binding of oxygen to one heme increases the binding of oxygen to other hemes.
- Thus, the affinity of hemoglobin for the last O_2 is about 100 times greater than the binding of the first O_2 to Hg. This phenomenon is called co-operative binding of O_2 to Hg.
- On the other hand, release of O_2 from one heme facilitates the release of O_2 from others.

Transport:-

- Oxygen diffuses across the respiratory membrane it also diffuses into RBC & bound to Hb this is called oxyhemoglobin (Hg- O_2).
- When oxygen binds to first heme, it can form conformational change for 2^{nd} one & when 4 site of Hb are occupied by heme, is called saturation.
- In lungs, where the concentration of O_2 is high (high PO_2), the hemoglobin gets fully saturated with O_2.
- Conversely, at the tissue level, where the O_2 concentration is low (hence low PO_2), the oxyhemoglobin releases its O_2 for cellular respiration.

T and R forms of hemoglobin:-

The four subunits (α_2 β_2) of hemoglobin are held together by weak forces.

1) T form – the deoxyhemoglobin exists in a T (tense) form. T form of Hb has low oxygen affinity.
2) R form- the binding of O_2 destabilizes some of the hydrogen & ionic bonds particularly between …dimmers. These results in a relaxed form called R form. R form has high oxygen affinity.

Oxygen dissociation curve:-

- The binding ability of Hb with O_2 at different partial pressure of oxygen (PO_2) can be measured by graphic representations known as O_2 dissociation curve.

- Each Hb has limited capacity for holding oxygen. So the capacity that is filled by oxygen bound to the Hb is called oxygen saturation. It is represented as %.
- Amount of oxygen bound to Hb is called partial pressure of O_2.
- In the lungs, PO_2 is high so Hb affinity for O_2 is greater. In tissue, PO_2 is low, Hb release the O_2 in tissue because of less affinity.
- The curve obtained is sigmoid shape curve.
- As per graph, in lungs, when PO_2 is 100 mmHg. So, Hg has high affinity to bind O_2 & 98% saturated with O_2.
- In tissues, when PO_2 is 40 mmHg, it shows lower affinity for Hb and releases some O_2 in tissue with 75% saturation.
- At pressure above 60 mmHg, the curve is flat & pressure below 50 mmHg, the steep area curve is observed.
- The partial pressure of oxygen in blood at which the Hb is 50% saturated, typically about 26.6 mmHg for a healthy person, is known as the p50.

Factors affecting on the oxygen dissociation curve:-

Oxygen dissociation curve can be shifted right or left by a variety of factors. A right shift indicates decreased oxygen affinity of hemoglobin allowing more oxygen to be available to the tissue. A left shift indicates increased oxygen affinity of hemoglobin alloing less oxygen to be available to the tissue.

1] pH – increasing in pH shifts the curve to the right, while an increases pH shifts the curve to the left. This occurs because a higher H+ ion causes alteration in amino acid that stabilize deoxyhemoglobin in a T-state. The right shift is referred to as the Bohr effect.

2] CO_2 - Decreasing in **CO_2** shifts the curve to the left, while increasing **CO_2** shifts curve to the right. Accumulation of **CO_2** causes carbamino compounds to be generated which bind to oxygen forms carbaminohemoglobin and it stabilize in T-form.

3] Temperature – increases in temperature shifts the curve to the right, and a decrease in temperature shifts the curve to the left. increasing the temperature denature the bond between oxygen and hemoglobin.

4] Organic phosphate – 2,3-diphosphoglycerate(2,3-DPG) is the primary organic phosphate. Increases in 2,3-DPG shift curve to the right and decreases in 2,3-DPG shifts left. When 2-3 DPG bind hemoglobin & decrease its affinity for oxygen.

Bohr effect :-

- The binding of oxygen to hemoglobin decreases with increasing H+ concentration or when PCO_2 increased.
  This phenomenon is known as Bohr effect.
- It is due to a change in the binding affinity of oxygen to hemoglobin.
- Bohr effect causes a shift in the oxygen dissociation curve to the right.
- Bohr effect is primarily responsible for the release of $O_2$from the oxyhemoglobin to the tissue.

$$\underset{\text{Oxyhemoglobin}}{HbO_2 + H^+} \underset{\textbf{In the lungs}}{\overset{\textbf{In the tissues}}{\rightleftharpoons}} \underset{\text{Deoxyhemoglobin}}{HHb + O_2}$$

TRANSPORT OF CO_2 –

Hemoglobin participates also in the transport of CO_2 from tissue to lungs. About 15% of CO_2 bind Hb & rest is transported as bicarbonate (HCO3). In aerobic metabolism, for every molecule of O_2 utilized.

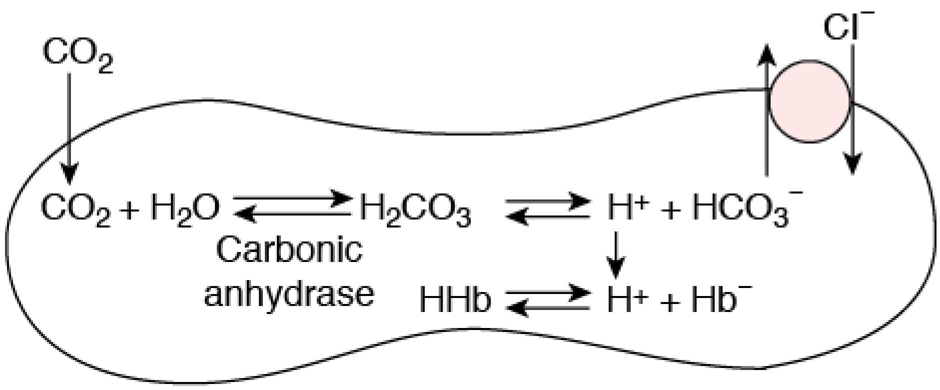
A] CO_2 bind with Hb - CO_2 molecule are bound to the uncharged α amino acids of Hb to form carbamyl Hb. The binding of CO_2 stabilize the T-form of Hb structure, resulting in decrease O_2 affinity for Hb.

B] CO_2 transport as a bicarbonate –

- As the **CO_2** enters the blood from tissue, the enzyme carbonic anhydrase present in erythrocytes catalyses the formation of carbonic acid.(H_2CO_3).
- Bicarbonate & H+ are released on dissociation of carbonic acid.
- Hb acts as a buffer and immediately binds with protons.
- for every 2 protons, H+ bound to Hb, 4 oxygen molecule are released to the tissue
- In the lungs, binding of **O_2** to Hb results in the release of protons.
- the bicarbonate and protons combine to form carbonic acid. The latter is acted upon by carbonic anhydrous to release CO_2, which is exhaled.

Chloride shift:-

- The entry of cl^- into the RBC cells from the surrounding plasma for release of bicarbonate (HCO_3^-).
- Bicarbonate is freely permeable across the RBC membrane.
- When bicarbonate concentration increased in RBC as the surrounding plasma. As a result, some of the bicarbonate leave from RBC with exchange of cl^- ions from the surrounding plasma.
- cl^- enters the RBC and binds with deoxyhemoglobin.
- H^+ in RBC combine with oxyhemoglobin & stimulating to release of O_2 in fluid.
- It occurs to maintain the pH of the blood.



Source: Barrett KE, Barman SM, Boitano S, Brooks HL: *Ganong's Review of Medical Physiology:* www.accessmedicine.com

Transport of Ions: Fe -Ferritin and transferrin

Iron found in ferric form in food and it is bounded by protein or other molecules. When it is contact with gastric Hcl, it is converted into Fe^{2+} and release from food.

A] Ferritin –

- It is a protein that stores iron and release it in a controlled fashion.
- Structurally it is a hollow sphere shape & inside the sphere, Fe^{3+} stored as in the ferric form.
- To release iron Fe^{3+} converted into Fe^{2+} is must.
- In humans, iron act as a buffer against iron deficiency or overloaded.
- The ferritin that is not combined with iron is called apoferritin.

B] Transferrin:-

- Iron- binding blood plasma glycoprotein that control the level of free iron in biological fluid.
- Transferring can bind to iron tightly but reversibly.

- When it is not bound to iron is called apotransferrin.
- Transferrin is produced by liver & binds 2 irons at a time.
- Transferrin delivers iron from absorption centers in the duodenum and WBC, macrophages to the all tissues.
- It can transport iron from tissue to bone marrow.

Iron transport using ferritin and transferrin-

- Iron found in ferric form in food and it is bounded by protein or other molecules. When it is contact with gastric Hcl, it is converted into Fe^{2+} and release from food.
- The iron Fe^{2+} entering the mucosal cells by absorption is oxidized to ferric form by the enzyme ferroxidase.
- Fe^{3+} then combines with apoferritin to form ferritin which is the temporary storage form of iron.
- From the mucosal cell, iron may enter the blood stream or lost when the cells are desquamated.
- The iron enters the plasma in ferrous state. Here, it is oxidized to ferric form by a copper-containing protein, which possesses ferroxidase activity.
- Ferric iron then binds with a specific iron-binding protein, namely transferrin.
- Each transferring molecule can bind with 2 atom of ferric iron. then this iron released from transferring in Fe^{3+} state & provided the tissues or bone marrow.

CALCIUM

The calcium in the blood is important for a number of functions, including blood clotting, transmission of nerve impulses, muscle contraction, stability of cell membranes, and cell metabolism. The remaining 99% of the calcium in the body is contained in the bones.

The calcium **in the body fluids** can exist in three forms:
(1) as the free cation Ca^{2+} (about 50% of the calcium in the fluids)
(2) bound to proteins (about 40% of the calcium in the fluids)
(3) complexed with other ions (about 10% of the calcium in the fluids).

Of these three, the free cation is the most important for the physiological functions and its concentration must be carefully maintained. For instance, muscle contraction is initiated by a sudden increase in calcium concentration in the muscle cells. \

The Cell Membrane

The cell membrane is composed of a double layer of phospholipids. Each phospholipid molecule contains a phosphate head and two lipid, or fatty, tails. Transmembrane proteins in cell membrane, creating pores that can help ions and other molecules avoid the lipid barrier.

Ion Channels

Ion channels are a class of transmembrane proteins that allow a high rate of ion flow powered by the electrochemical gradient across the cell membrane.. Different channels are specific for different ions, although some channels can handle more than one type of ion. Ion channels are structured like tiny gates that open or close to allow an ion to pass through.

Primary Active Transport

Ion pumps are proteins that expend energy to allow ions to bypass the lipid bilayer, with or without the help of the concentration gradient. Primary active transport uses pumps made from enzymes known as ATPases that liberate energy from the cell's primary energy molecule, adenosine triphosphate, or ATP. The protein uses the freed energy to shift its shape, in the process translocating an ion from one side to the other. Primary active transport helps the cell regulate sodium and potassium levels by moving ions against the concentration gradient.

Secondary Active Transport

Secondary active transport involves the simultaneous transport of two different substances. One substance is transported down the concentration gradient, providing the energy needed to transport the second substance against the gradient. Antiport proteins move two substances in opposite directions. For example, the sodium-calcium antiport allows three sodium ions into the cell for each exported calcium ion. Symport proteins move the two substances in the same direction. Secondary active transport doesn't use ATP.

Lipoprotein:-

Lipids absorbed from diet & synthesized by the liver & adipose tissue must be transported between various cells and organs.

Lipids are insoluble in water; the problem is transportation of lipids via plasma. This problem is solved by lipoporotein.

Lipoprotein structure-

Lipoprotein is produced by liver. it is made up of lipid and protein. It is consist of non-polar core & single surface layer of amphipathic lipids. Non- polar lipid core consist of triacylglycerol & cholesterol ester and this core is surrounded by single layer of amphipathic pospholipid & some cholesterol. In this layer, polar groups are face outwards. The outer layer of the lipoprotein also had protein part which is apolipoprotein.

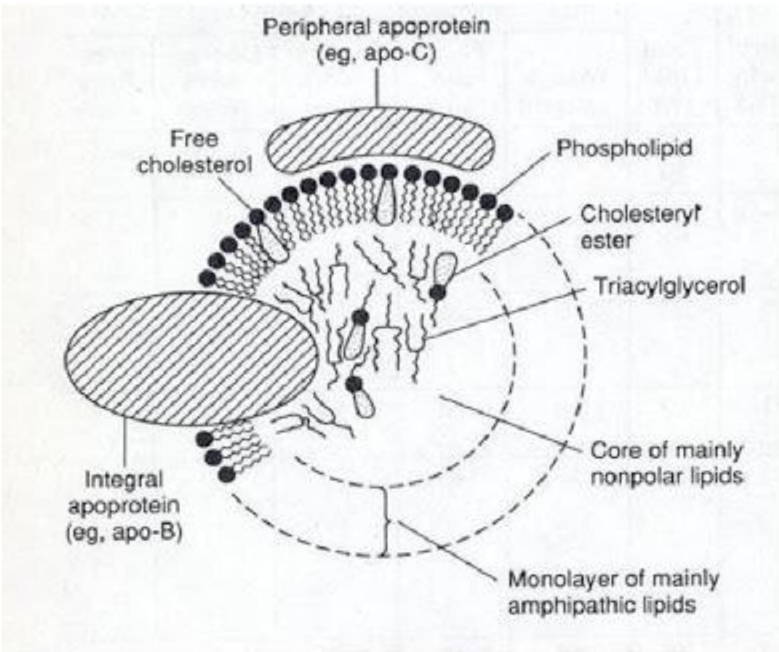


Figure : LIPOPROTEIN STRUCTURE www.toosogie-lipid-diagnostic.blogspot.com/

Classification of protein:-

Classification of lipoprotein is based on density with its formation, function & transport.

1] chylomicrons:- it is made from triacylglycerol & other lipids. They are least dense & largest in size. They contain highest quantity of lipids (99%) & lowest concentration of protein.

Function:-chylomicrons are transport triglycerides from the intestine to the liver, muscle & adipose tissue.

Transport:- it transport lipids absorbed from the intestine to adipose, cardiac & skeletal muscle, where there triglycerides components are hydrolyzed by the lipoprotein lipase and allowing the released fatty acid. These fatty acid absorbed by tissue. When large portion is hydrolyzed & remaining small part of its called remants. This remants are taken up by liver.

2] VLDL:-very low density lipoprotein. This lipoprotein is made by liver by excess diatery carbohydrate. They are very low dense lipoprotein. They contain lesser degree of cholesterol.

Function: - They transport triglycerides from the liver to adipose tissue where it can be stored.

Transport:- Nascent VLDL released from the liver. This nascent VLDL contains cholesterol, cholesterol ester & triglycerides. Then, nascent VLDL mature & form mature VLDL. This mature VLDL made contact with lipoprotein lipase. By the action of lipase, VLDL removes triglycerides from it. Once much triglycerides looses from it, then it form LDL.

3] LDL: - low density lipoprotein. It's known as bad cholesterol. They are containing highest cholesterol content.VLDL is converted directly into LDL.

Function:- LDL transport of fat molecule such as phospholipids, cholesterol & triglycerides from the liver to other tissues.

Transport:- when cell require additional cholesterol, it synthesize the necessary LDL receptor. These receptors inserted into the plasma membrane & diffuse freely. When LDL receptor bind LDL in blood & endocytosed into the cell.

LDL delivered to the endosomes where cholesterol esters in LDL are hydrolyzed & free cholesterol used by the cell. LDL receptors again back to plasma membrane. When excess amount of LDL is formed, Atherosclerosis occur.

4] HDL:- High density lipoprotein.It is known as good cholesterol. HDL synthesized in liver. HDL is composed of 80-100 proteins per particles. It is more dense.

Function :- HDL removes fat from cells. Fat are cholesterol, phospholipid & triglycerides. HDL collects fat from tissue & take it back to the liver.
Transport:- this lipoprotein complexes synthesize in liver. They are disk shape made up of phospholipid bilayer. This complexes are capable of picking up cholesterol by interaction with ATP- binding transporter.

Plasma enzyme lecithin-cholesterol acyltransferase convert free cholesterol into cholesterol ester. HDL size increased when they incorporate more cholesterol. This accumulated cholesterol push phospholipid bilayer of HDL outward & make it sphere shape.

Cholesterol esters are transferred to other lipoprotein in exchange of triglycerides by using cholesterol-ester transfer protein (CETP). Uptake of HDL is mediated by hepatic lipase in liver.

PLASMA PROTEIN –

Protein present in blood plasma called plasma protein. These proteins are synthesized in liver. One of the most important functions of plasma proteins us to transport lipids and lipid soluble substances in the body.

Plasma proteins are:- serum albumin(55%), globulin(38%), fibrinogen(7%), regulatory protein(1%)

Role of plasma protein in transport:-

1. Fatty acid and bilirubin are transported mainly by albumin.
2. Calcium , magnesium, some drugs and dyes, and cations, anions are transported by albumin.
3. cholesterol and phospholipids are carried by the lipoproteins present in β-globulins also transport fat soluble vitamins (A, D, K and E)
4. plasma proteins also transport several metals and other substances α2-Globulins transport copper (Ceruloplasmin), bound hemoglobin (haptoglobin) and thyroxine (glycoprotein) and non-heme iron is transported by transferrin present in β-globulin fraction.