Mineral Salt Absorption

The mineral salts are present in the soil solution in dissociated condition. The essential ions are absorbed by the roots hairs and are then translocated through the xylem steam to the different parts of the plant body.

Mechanisms for ion uptake:
I. non mediated uptake and
II. mediated uptake.

Non mediated transport is always passive whereas mediated transport may be either passive or active.

I. Non-mediated or Passive Uptake

If ion transport in and out of cells occurs spontaneously along its a gradient of electrochemical potential energy it is called passive uptake.

Passive uptake is explained as follows:

a. Diffusion

When a plant cell or tissue is transferred from a low-salt concentration medium to a relatively high-salt concentration medium, there is an initial uptake of ions due to diffusion. This is temperature independent and it is not affected by metabolic inhibitors. If the above cell or tissue is again returned to a lower-salt solution, some of the absorbed ions will diffuse out into the external medium. This process of free diffusion of solutes follows the simple laws of diffusion. The part of the tissue for free diffusion shows an equilibrium with the external medium. This part of a cell or tissue is referred to as outer space.

Ion Exchange

In the ion exchange mechanism, the ions within the cells are exchanged for the ions of equivalent charge of the external solution.

The total concentration of salts on either side is not affected by the exchanges of ions. Exchange involves equivalent electrical charge, so that two univalent ions are exchanged for one bivalent.

Donnan Equilibrium

The Donnan equilibrium theory is based on the effect of fixed or non-diffusible ions and explains the co-operation of both electrical as well as diffusion phenomena. It is a complex ion-exchange system in which the membrane is impermeable to certain ions called fixed ions.

In the following case $X^+$ is fixed ions and cannot move from right to left. Due to the presence of these fixed ions some extra ions are absorbed against the concentration gradient. In this case where $X^+$ is fixed, equal numbers of cations and anions from the left-hand side will diffuse across the membrane until an equilibrium is established. The equilibrium would also be electrically balanced.

However, additional anions are needed to balance the positive charges of the fixed cations on the right-hand side of the membrane. Since the concentration of mobile ions are unequal on the two sides of the membrane in a Donnan system at equilibrium there is an electrical potential difference between the two sides. This is sometimes called their Donnan membrane potential.

Mass Flow of Ions

Many workers believe that ions are absorbed by the roots along with the mass flows of water influenced by the transpiration
stream. The theory states that, an increased transpiration rate causes an increase in absorption of ions.

**II. Mediated Transport**

When ions are driven up against such a gradient by a process coupled to metabolism it is called metabolic or active uptake. All the experimental findings suggest the concept of mediated transport which states that the transport is accelerated due to the presence of carriers substances in the membrane, which interact with the transported ions or molecules. Ions form a complex with the carrier on the outer side of the membrane. This complex is broken down on the inner side. The following reaction takes place inside the membrane:

\[ C + S = CS \]

where \( S \) = Substance and \( C \) = Carrier

The concept has been supported by the
(1) radioactive ions exchange,
(2) saturation effect, and
(3) specificity.

**Radioactive Ion Exchange**

Using radioactive ions, Legget and Epstein (1956) observed that the movement of ions across the impermeable membrane might be accomplished by the intervention of carriers.

**Saturation Effect**

It has been observed that with the increase in salt concentration of the medium, the rates of ions absorption do not increase beyond a limit which means that, a saturation point is reached. It indicates the presence of carriers.

**Specificity**

Roots absorb ions selectively. Different ions are absorbed at different rates and show different levels of accumulation in the roots tissue.

There are different carriers for different cations and anions. They are also called transporters or permeases. They may be of different types such as uniport, symport and antiport. Transporters that carry only one substrate are called uniport systems. On the other hand, the transporters may carry two ions or solute simultaneously across a membrane, which are called cotransport systems. When two substrates move in opposite direction, the process is antiport transport whereas, in symport system, two substrates are moved simultaneously in the same direction.

Mediated transport is classified into two categories:

**Passive Mediates Transport:**

**Ionophores Facilitated ion diffusion**

Passive-mediated transport or facilitated diffusion, in which a specific molecule flows from high concentration to low concentration.

One type of carrier molecule is an ionophore, an organic molecule. Carrier ionophores increase the permeability of membranes to a particular ion by binding the ion, diffusing through the membrane, and releasing it on the other side. For net transport to occur, the uncomplexed ionophore must then return to the original side of the membrane ready to repeat the process.

Another type of ionophore called channel forming ionophores, form solvent filled, transmembrane channels or pores through which their selected ions can diffuse.

Four fundamental classes of transport system are present at all membranes. These are
1. carriers,
2. pumps,
3. ion channels and
4. aquaporins.

**Carriers**

The transport process does not involve chemical modification of any of the
compounds bound to the carrier. The carriers catalyse only vectorial reactions. The carriers exhibit Michaelis-Menten kinetics that indicate conformational changes during transport.

**Ion Channels**

Ion fluxes through channels are driven solely by electrochemical potential differences. Ion flows through channels is passive. The direction of flow of a particular ion through a channel is dictated by the electrochemical potential gradient for that ion. Most classes of ion channels in plants are of two types:
1. cations channels
2. anion channels
Cation channels are further subdivided into $K^+$ selective channels.

**Metabolic or Active Uptake**

Active transport is that in which a specific molecule is transported from low concentration to high concentration. Such an endergonic (energy requiring) process must be coupled to a sufficiently exergonic (energy generating) process to make it favourable.

The transfer of ions occurs at the expense of the free energy liberated in chemical reactions. As a rule, this is the energy released after hydrolysis of ATP.

**Mechanisms of Active Uptake**

**Primary Active transport**

The primary active transport is coupled directly to a source of energy other than electrochemical potential gradient, such as ATP hydrolysis, an oxidation reduction reaction, etc. The membrane proteins that carry out primary active transport are called pumps.

**Secondary active transport**

Secondary active transport uses the energy stored in electrochemical potential gradient.

Protons are extruded from the cytosol by electrogenic $H^+$ ATPase operating in the plasma membrane and tonoplast. Consequently, a membrane potential and a pH gradient are created at the expense of ATP hydrolysis. This gradient of electrochemical potential for $H^+$, gives rise to a proton motive force which represents stored free energy in the form of $H^+$ gradient.

**Electrogenic Pumps or Membrane-bound ATPase Mechanism**

There are many intrinsic membrane ATPase, which can transport ions in one direction across the membrane without being accompanied by an ion of opposite charge giving rise to an electrical potential difference. These intrinsic membrane proteins are either translocases, transferases or penetrases. They depend on ATP as energy source for transport. The allosteric transition of the transport ATPases from one state to other results in the movement of the ion from one boundary of the cell membrane to other.