

NUTRIOPHYSIOLOGY

18.1 PHYSIOLOGY OF NUTRIENT UPTAKE

Mineral nutrients are found either as soluble fractions of soil solution or as adsorbed ions on the surface of colloidal particles. Various theories proposed to explain the mechanism of mineral salt absorption can be placed in two broad categories:

I) Passive Absorption

II) Active Absorption

ION UPTAKE IS BOTH ACTIVE AND PASSIVE:

After several decades of research on this process of ion uptake it is now believed that the process involves both passive and active uptake mechanisms.

Whether a molecule or ion is transported actively or passively across a membrane (casparian band, plasma membrane or tonoplast) depends on the **concentration** and **charge** of the ion or molecule, which in combination represent the **electrochemical driving force**.

Passive transport across the plasma membrane, occurs along with the electrochemical potential. In this process ions and molecules diffuse from areas of high to low concentrations. It does not require the plant to expend energy.

Active transport: In contrast, to passive transport energy is required for ions diffusing against the concentration gradient (electro chemical potential). Thus active transport requires the cell to expend energy.

18.1.1 PASSIVE TRANSPORT MECHANISM:

A) Diffusion: Simple **diffusion** to membranes occurs with small, non polar molecules (i.e O₂, CO₂). In this process ions or molecules move from the place of higher concentration to lower concentration. It needs no energy.

B) Facilitated diffusion: For small polar species (i.e H₂O, ions and amino acids) **specific proteins** in the membrane facilitate the diffusion down the electrochemical gradient. This mechanism is referred to as **facilitated diffusion**.

a) Channel proteins: The specific proteins in the membrane form channels (**channel proteins**), which can open and close, and through which ions or H₂O molecules pass in single file at very rapid rates.

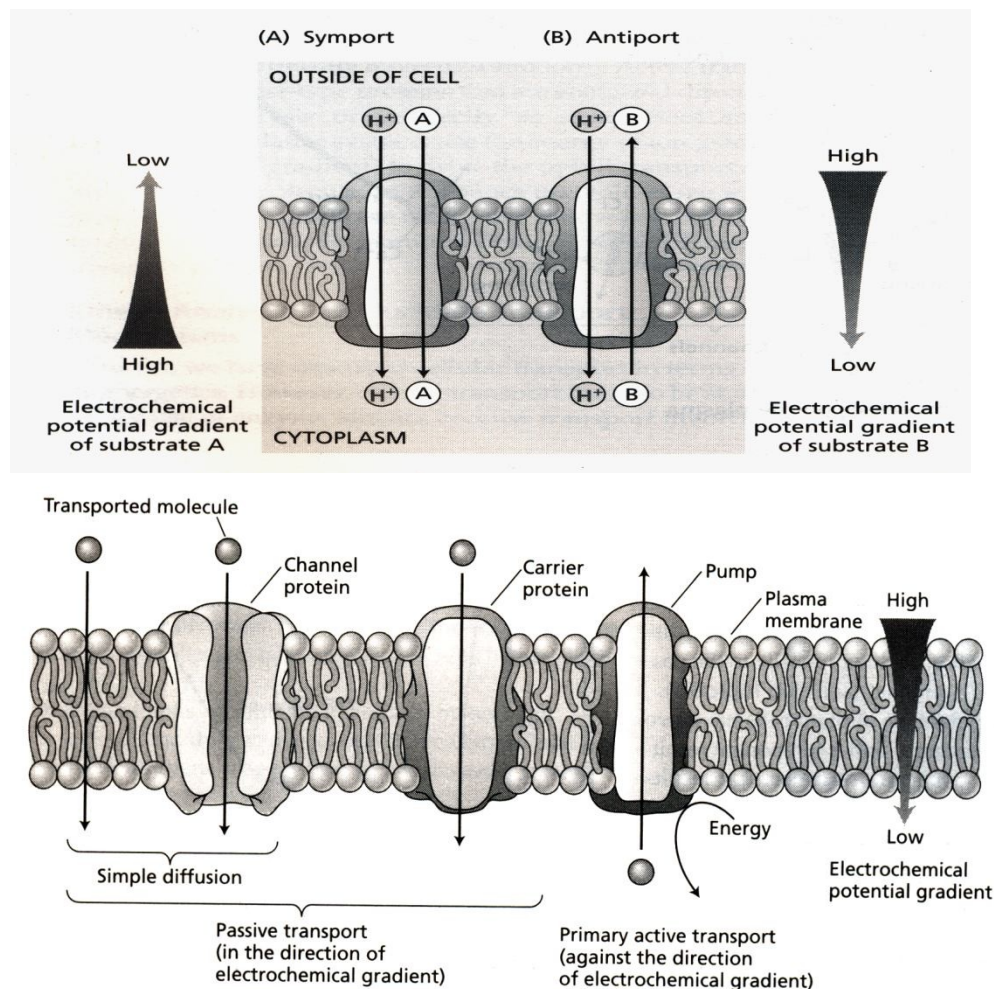
A K⁺ and NH₄⁺ channel also operates by the same process of facilitated diffusion. In addition Na⁺ can also enter the cell by this process.

b) Transporters or Contransporters: Another mechanism involves *transporters or contransporters* responsible for the transport of ions and molecules across membranes. Transporter proteins, in contrast to channel proteins, bind only one or a few substrate molecules at a time. After binding a molecule or ion, the transporter undergoes a **structural change** specific to a specific ion or molecule. As a result the transport rate across a membrane is slower than that associated with channel proteins.

Three types of transporters have been identified.

- **Uniporters** transport one molecule (i.e. glucose, amino acids) at a time down a concentration gradient.
- **Antiporters** : catalyze movement of one type of ion or molecule against its concentration gradient. This is coupled with the movement of a different ion or molecule in the **opposite direction**. Examples of antiporter transport are $H^+ - Na^+$ and $H^+ - Ca^{+2}$ transport into the vacuole.
- **symporters** catalyze movement of one type of ion or molecule against its concentration gradient coupled to movement of a different ion or molecule down its concentration gradient in the **same direction**. The high H^+ concentration in the apoplast provides the energy for symporter transport of NO_3^- and the other anions.

Therefore, the energy for *antiporter* and *symporter* transport originates from the **electric potential** and/or **chemical gradient** of a secondary ion or molecule, which is often H^+ .



*Figures are from reference 6

18.1.2 ACTIVE TRANSPORT MECHANISM: Larger or more-charged molecules have great difficulty in moving across a membrane, requiring active transport mechanisms (i.e., sugars, amino acids, DNA, ATP, ions, phosphate, proteins, etc.) Active transport across a selectively permeable membrane occurs through **ATP-powered pumps** that transport ions against their concentration gradients. This mechanism utilizes energy released by

hydrolysis of ATP. The Na⁺ - K⁺ ATP pump transports K⁺ into the cell and Na⁺ out of the cell, another example is the Ca⁺² ATP pump.

Thus, it can be understood from the above discussion that the ion transport mechanisms operate both actively and passively. For some of the ions the uptake mechanism is active and for some others it is passive.

18.2 FUNCTIONS OF ESSENTIAL ELEMENTS

The functional roles of essential elements in plants vary greatly from element to element.

A) Nitrogen

Nitrogen is the fourth most abundant element in plants following C, O and H.

1. N is a major structural constituent of the cell. The cytoplasm and the cell organelles contains varying amount of nitrogen largely in combination with C, H, O, P and S.
2. It is an essential constituent of the different types of metabolically active compounds, like amino acids, proteins, nucleic acids, porphyrins, flavins, enzymes and co-enzymes.
3. Being essential for the formation of protoplasm, the deficiency of N inhibits cell enlargement
4. As much as 70 Per cent of the total leaf N may be in chloroplast. Thus the early symptoms of N deficiency are **general yellowing or chlorosis**.
5. Plants contain about 1 to 3 per cent of N on dry weight basis.

B) Phosphorus

1. It is a structural component of the membrane systems of the cell and the mitochondria.
2. It is an essential constituent of nucleoproteins, organic molecules (ATP, ADP etc) which play an important role in the **energy transfer reactions** of cell metabolism, nucleic acids, and coenzymes like NADP.
3. Phosphorus in the phytin of seeds is regarded as a reserve.
4. The unique functions of phosphate in metabolism are its formation of pyrophosphate bonds which allow energy transfer, Uridine triphosphate (UTP) Cytidine triphosphate (CTP) and guanosine triphosphate (GTP) are involved in the synthesis of ribonucleic acids (RNA).
5. Being a constituent of ADP, Phosphoglyceradehyde and ribulose phosphate, P is involved in the basic reactions of photosynthesis.
6. Phosphorus is relatively more abundant in the growing an storage organs.

C) Potassium:

1. K plays a significant role in **stomatal opening and closing**. The mechanism of stomatal closure and opening depends entirely on the K flux.

2. K^+ enhances the translocation of assimilates and promotes rate of CO_2 assimilation.
3. K activates the number of enzymes involved in incorporation of amino acids into proteins and the synthesis of peptide bonds.
4. Potassium regulates the membrane permeability and keeps the protoplasm in proper degree of hydration.
5. Potassium is known to increase the resistance of plants to moisture stress, to heat and to diseases caused by pathogenic fungi and other microorganisms.
6. Inadequate K restricts the formation of xylem and phloem tissue. Lignification of the vascular bundles is generally impaired by K^+ deficiency. This effect probably makes K deficient crops more prone to lodging.

D) Calcium

1. Calcium is required for cell elongation and cell division
2. Calcium plays an essential role in biological membranes. Calcium is deposited in the cell wall as calcium pectate. Ca deficiency obviously impairs membrane permeability and membranes become more leaky.
3. **Germination and growth of pollen** as well as the growth of rhizobium root nodules is affected under low levels of Ca^{2+} supply.
4. Ca appears to play a role in the inhibition of abscission and delays leaf senescence.
5. Calcium is an essential co-factor or an activator of a number of enzymes concerned with hydrolysis like lipase and α -amylase
6. Ca is a structural component of the chromosomes. Where in it possibly binds the DNA to protein. Ca deficiency is known to result in chromosomal abnormality.
7. Calcium plays an important role in neutralizing acids. Particularly citric acid, malic acid, oxalic acid which may become injurious to plants.

E) Magnesium

1. The most well known role of magnesium is **its occurrence at the centre of the chlorophyll molecule**. It is therefore essential for photosynthesis.
2. Mg is a constituent part of the chromosomes and also **essential constituent of poly ribosomes**, the key organelle concerned in protein synthesis.
3. Magnesium is known to play a catalytic role as an activator of a number of enzymes, most of which are concerned in carbohydrate metabolism, phosphate transfer and decarboxylations. The enzyme inorganic pyrophosphatase, as such is inactive. It becomes functional only in the presence of Mg.
4. It is also required for the activation of the enzyme **RuBP carboxylase**.
5. Nitrogen metabolism is also influenced by Mg nutrition.

F) Sulphur

Plants mainly absorb S in the form of SO_4^{2-}

1. Sulphur is a constituent of amino acids, **cystine, cysteine, and Methionine**.
2. The characteristic odour of cruciferous plants, onion and garlic is due to the presence of sulphur as a constituent of volatile oils.
3. Several other biological active compounds like vitamins (Thiamine and biotin), lipoic acid, acetyl co-enzyme A, ferredoxin and glutathione contain sulphur as an essential part.
4. The active adenosine-5-phospho sulphate (APS) is an important sulphate donor which is involved in the synthesis of glycosides in mustard oil. Being involved in the activation of number of enzymes, participating in the dark reactions of photosynthesis, sulphur is involved in carbohydrate metabolism of the plants.
5. The total S content in plant tissues is in the order of 0.2 to 0.5 percent in the dry matter.
