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PLANTS TAKE UP MORE ELEMENTS THAN THEY NEED FOR GROWTH, SOME ARE BENEFICIAL TO LIVESTOCK AND HUMANS

Plant roots play an important role in absorbing water and nutrients needed for plant growth. In order for water and soluble ions to enter roots they must first come in contact with the root surface. Contact is achieved by **direct contact** as roots grow into the soil, **mass flow** of ions in soil water as transpiration of moisture out of the leaves pulls a minute stream of water from the soil, and **diffusion** within the water from locations of higher nutrient ion concentration like soil humus and mineral particles to areas of lower concentration near the roots.

Once in contact with roots, the ions can passively move into a free space between cells of the root epidermis and cortex cells. This movement is done through diffusion and surface electrostatic ion exchange. The cell surfaces of the epidermis and cortex are largely negative in charge and effectively exchange positively charges ions (cations), such as potassium (K^+), calcium (Ca^{+2}) and magnesium (Mg^{+2}). In order to maintain ion charge stability, roots will release hydrogen (H^+) ions off the cell surfaces into solution while adsorbing the cations noted above. The ions move towards the center of the roots passively until they come to a selective layer called the endodermis.

Movement past the impermeable endodermis layer requires that energy from metabolism be used to selectively move the ions across the membrane through tiny pores. Energy is needed because the osmotic concentration within plant cells is greater than soil solution. Cells outside the endodermis, such as root hairs can also actively absorb nutrient ions into themselves and pass the ions from cell to cell where the cell membranes contact each other. Movement is towards the endodermis and then towards the root and stem conductive organs called xylem that act as tiny pipes moving water and nutrient ions up from roots towards leaves.

Plants absorb many different ions needed for their growth, specifically all 14 essential mineral elements. These include the ionic forms of nitrogen (NH_4^+, and NO_3^-), phosphorus ($H_2PO_4^-$ and HPO_4^{-2}), K^+, sulfur (SO_4^{-2}), Ca^{+2}, Mg^{+2}, boron ($H_2BO_3^-$), chloride (Cl^-), copper Cu^{+2}), iron (Fe^{+3}), manganese (Mn^{+2}), molybdenum (MoO_4^{-2}), nickel (Ni^{+2}), and zinc (Zn^{+2}). Additionally there are other elements not required for plant growth that are absorbed by plant roots and end up in plant tissues.

Some of these non-plant required nutrients that are taken up by plants are needed for animal and human nutrition. Examples are sodium, cobalt, chromium, iodine, selenium, and vanadium. In some soils their natural availability in soil solution may be so low that supplements containing them are beneficial. For example, iodine is added in low concentrations to table salt. In some other situations a naturally occurring higher level of an animal-required element may have adverse effects on certain livestock species. For example, a level of selenium beneficial for cattle fed hay from a higher selenium-containing soil can have detrimental effects on horses.

There are other elements that are naturally occurring in soils that are absorbed by plant roots and are not needed for animal or human growth. Most are low in concentration and are not a concern, but some elements can occur in high enough concentrations in cultivated soils, naturally or as a result of human pollution, that there can be concerns about animal and human consumption of plant materials grown on these soils. The four main elements known to be a concern are the heavy metals lead, cadmium and mercury, and the non-metal arsenic.

In most instances crop plants take up elements in high enough levels that plant growth does well, and animals and humans consuming harvested crops do well nutritionally.

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