L14 S1

Plant Nutrition

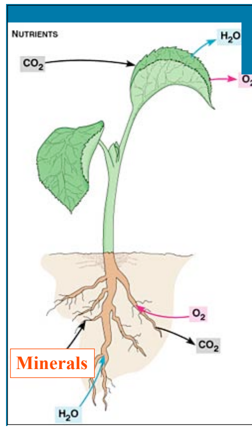
The important elements required by plants

How those elements become available in the soil

How plants take those elements up from the soil

Nitrogen fixation in the soil and its importance

L14S2



What is meant by "plant nutrition"

Uptake from the soil of mineral elements

"Plant nutrition" specifically does *not* refer to photosynthesis.

In this lecture the uptake of nutrients from the soil directly by roots

The chemical elements required by plants

L14S3

Plants **require** 13 mineral nutrient elements for growth.

The elements that are required or necessary for plants to complete their life cycle are called **essential plant nutrients**.

Each has a critical function and are required in varying amounts, see table on next slide for typical amounts relative to nitrogen and the function of essential nutrients .

The nutrient elements differ by their functions, by their mobility, and characteristic deficiency or toxicity symptoms characteristic of the nutrient.

L14S4

Essential Elements	Chemical symbol	Relative % in plant to N	Function in plant
Primary macronutrients (1)			
Nitrogen	N	100	Proteins, amino acids (4)
Phosphorus	P	6	Nucleic acids, ATP (5)
Potassium	K	25	Catalyst, ion transport (6)
Secondary macronutrients (2)			
Calcium	Ca	12.5	Cell wall component
Magnesium	Mg	8	Part of chlorophyll
Sulfur	S	3	Amino acids
Iron	Fe	0.2	Chlorophyll synthesis (7)
Micronutrients (3)			
Copper	Cu	0.01	Component of enzymes
Manganese	Mn	0.1	Activates enzymes
Zinc	Zn	0.03	Activates enzymes
Boron	B	0.2	Cell wall component
Molybdenum	Mo	0.0001	Involved in N fixation
Chlorine	Cl	0.3	Photosynthesis reactions

How plants take up mineral elements from soil

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A. Bulk flow: Uptake in the transpiration stream

Nutrients diffuse to regions of low concentration and roots grow into and proliferate in soil zones with high nutrient concentrations (horse manure in sand).

Dominant in mineral soils:

B. Mycorrhizae: symbiotic relationship with fungi

Roots are slow growing but mycorrhizal fungi proliferate and ramify through the soil. Symbiotic relationship: carbon-nitrogen exchange.

Dominant in organic soils:

Mineral soils

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Nutrients are available through WATER in the soil

Soil acidity determines how nutrients become available to plants

Small quantities of water molecules dissociate:

$$H_2O \longleftrightarrow OH^- + H^+$$

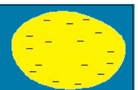
The concentration of dissociated water in freshly-distilled water is 10^{-7} M. This is used to describe acidity-alkalinity, originally called the *pouvoir Hydrogéne,* which we know now as pH.

$$pH = -\log [H^+] = -\log [10^{-7} M] = 7 \text{ for fresh distilled water}$$

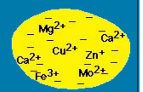
Small values for **acid**, e.g., the water in Sphagnum bogs can be ~3

Large values for **alkaline**, e.g., soils on limestone ~8

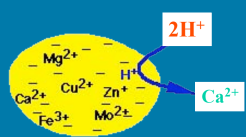
A clay particle (much enlarged here) is covered with negative charges, anions:



Opposites attract, so metal ions with positive charge(s), cations, stick all over the surface of the clay particle:



The root hair cells of plant roots secrete H^+ into the water around nearby clay particles. These smaller H cations replace the larger macro- and micro-nutrient cations:



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The released cations are now available for uptake into roots.

In this summary occurrence of H+ in soil water is shown as the result of respiration of CO_2 and disassociation of carbonic acid H_2CO_3 that forms

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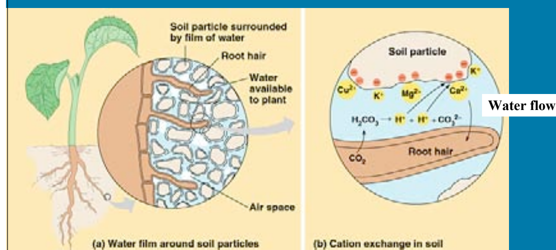
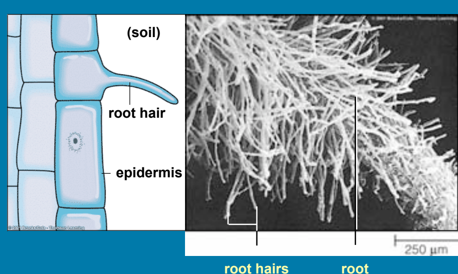


Hydrogen ions released into the water by respiration or decomposition of organic material exchange with cations on soil particles so releasing them into the soil water solution



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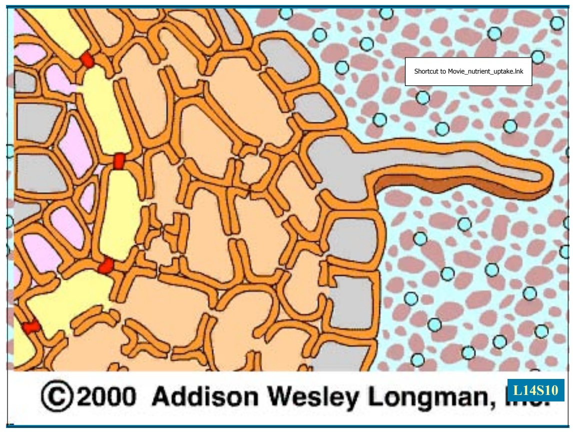

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Apoplastic and Symplastic Transport

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Water and cations can be taken up by roots:

1. **apoplastically** i.e. through the cell walls and intercellular spaces,

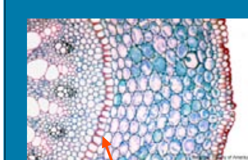
2. **symplastically**, i.e. from protoplast to protoplast *via* plasmodesmata

However, at the endodermis the apoplastic pathway is blocked by a waxy deposit of the wall called the **Casparian strip**

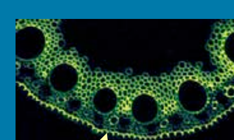
In some plants is the Casparian strip located in the exodermis so that the barrier to apoplastic works sooner.

Cross section of endodermis with the Casparian strip stained pink. The Casparian strip contains suberin and lignin

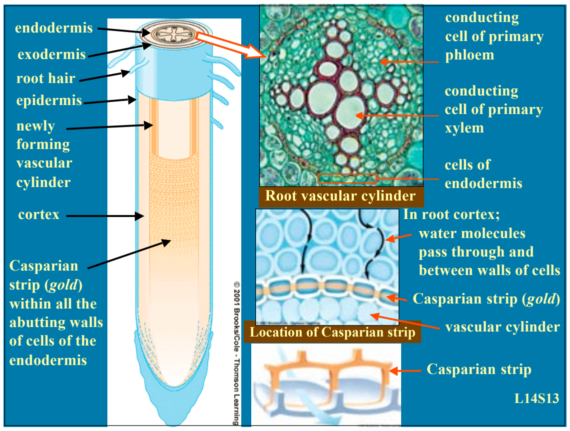
L14S12



Cross section of *Smilax* root showing heavily thickened endodermis walls



Cross section of Zea mays root using fluorescence microscopy showing thickened cell walls on the inside of endodermis



Nitrogen is the element most required by plants, in terms of weight.

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It is **not** a product of weathering of soil particles.

There are two sources: **fixation** of atmospheric nitrogen by bacteria

decomposition of organic matter, usually decaying plant material.

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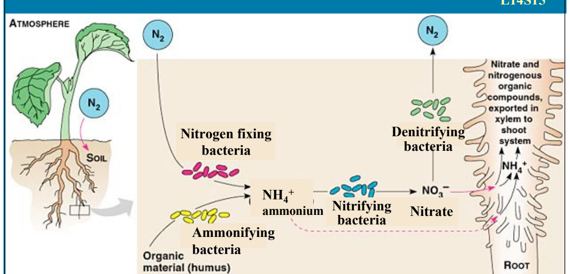

Most uptake from the soil is in the form of nitrate

L14S16

Things you need to know

UNDERSTAND how nutrients are released by weathering from the soil and be able to describe the principal reactions using appropriate formulea.

Be able to label the components of L3 S12

Know the classes of plant nutrients, L3 S4, define the primary macro-nutrients and representatives of the other categories, and know their functions in the plant

Describe how plants take up nutrients from mineral soils, and say how this may differ from the process in organic soils.

Define apoplastic and symplastic transport of nutrients and *UNDERSTAND* the structure and function of the Casparian strip.

UNDERSTAND the particular problem of Nitrogen uptake by plants and how nitrogen changes its chemical association in soil and the microbial transformations involved