

Chapter 37

Soil and Plant Nutrition

PowerPoint® Lecture Presentations for

Biology

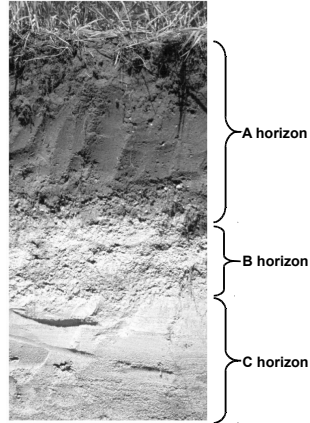
Eighth Edition

Neil Campbell and Jane Reece

Lectures by Chris Romero, updated by Erin Barley with contributions from Joan Sharp

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Fig. 37-2



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Overview: “The Nation that Destroys Its Soil Destroys Itself”

- Farmland productivity often suffers from chemical contamination, mineral deficiencies, acidity, salinity, and poor drainage
- Healthy soils improve plant growth by enhancing plant **nutrition**
- Typically, plants obtain carbon dioxide from the air, and water and minerals from the soil

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- After a heavy rainfall, water drains from the larger spaces in the soil, but smaller spaces retain water because of its attraction to clay and other particles
- The film of loosely bound water is usually available to plants
- **Loams** are the most fertile topsoils and contain equal amounts of sand, silt, and clay

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Soil Texture

- Soil particles are classified by size; from largest to smallest they are called sand, silt, and clay
- Soil is stratified into layers called **soil horizons**
- **Topsoil** consists of mineral particles, living organisms, and **humus**, the decaying organic material

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Topsoil Composition

- A soil's composition refers to its inorganic (mineral) and organic chemical components

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Inorganic Components

- Cations (for example K^+ , Ca^{2+} , Mg^{2+}) adhere to negatively charged soil particles; this prevents them from leaching out of the soil through percolating groundwater

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Fertilization

- Soils can become depleted of nutrients as plants and the nutrients they contain are harvested
- **Fertilization** replaces mineral nutrients that have been lost from the soil
- Commercial fertilizers are enriched in nitrogen, phosphorus, and potassium
- Organic fertilizers are composed of manure, fishmeal, or compost

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- During **cation exchange**, cations are displaced from soil particles by other cations
- Displaced cations enter the soil solution and can be taken up by plant roots
- Negatively charged ions do not bind with soil particles and can be lost from the soil by leaching

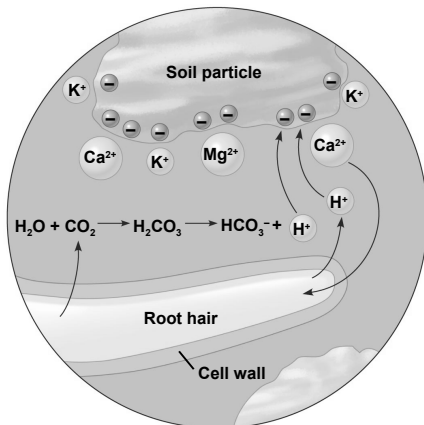
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Concept 37.2: Plants require essential elements to complete their life cycle

- Plants derive most of their organic mass from the CO_2 of air, but they also depend on soil nutrients such as water and minerals

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Fig. 37-3



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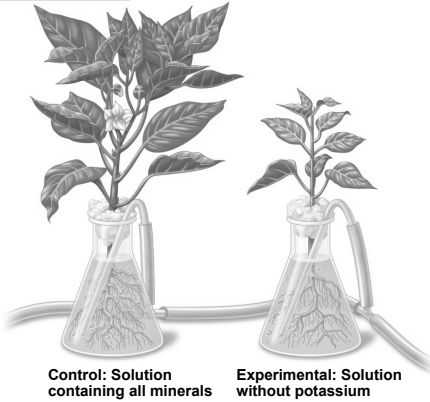
Macronutrients and Micronutrients

- More than 50 chemical elements have been identified among the inorganic substances in plants, but not all of these are essential to plants
- A chemical element is considered an **essential element** if it is required for a plant to complete its life cycle
- Researchers use **hydroponic culture** to determine which chemical elements are essential

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Fig. 37-6

TECHNIQUE



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- The remaining eight are called **micronutrients** because plants need them in very small amounts
- The micronutrients are chlorine, iron, manganese, boron, zinc, copper, nickel, and molybdenum

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Table 37-1

Essential Elements in Plants

Element	Form Available to Plants	% Mass in Dry Tissue	Major Functions
Macronutrients			
Carbon	CO ₂	45%	Major component of plant's organic compounds
Oxygen	CO ₂	45%	Major component of plant's organic compounds
Hydrogen	H ₂ O	6%	Major component of plant's organic compounds
Nitrogen	NO ₃ ⁻ , NH ₄ ⁺	1.5%	Component of nucleic acids, proteins, hormones, chlorophyll, coenzymes
Potassium	K ⁺	1.0%	Cofactor that functions in protein synthesis; major solute functioning in water balance; operation of stomata
Calcium	Ca ²⁺	0.5%	Important in formation and stability of cell walls and in maintenance of membrane structure and permeability; activates some enzymes; regulates many responses of cells to stimuli
Magnesium	Mg ²⁺	0.2%	Component of chlorophyll; activates many enzymes
Phosphorus	H ₂ PO ₄ ⁻ , HPO ₄ ²⁻	0.2%	Component of nucleic acids, phospholipids, ATP; several coenzymes
Sulfur	SO ₄ ²⁻	0.1%	Component of proteins, coenzymes
Micronutrients			
Chlorine	Cl ⁻	0.01%	Required for water-splitting step of photosynthesis; functions in water balance
Iron	Fe ³⁺ , Fe ²⁺	0.01%	Component of cytochromes; activates some enzymes
Manganese	Mn ²⁺	0.005%	Active in formation of amino acids; activates some enzymes; required for water-splitting step of photosynthesis
Boron	H ₂ BO ₃ ⁻	0.002%	Cofactor in chlorophyll synthesis; may be involved in carbohydrate transport and nucleic acid synthesis; role in cell wall function
Zinc	Zn ²⁺	0.002%	Active in formation of chlorophyll; activates some enzymes
Copper	Cu ⁺ , Cu ²⁺	0.001%	Component of many redox and lignin-biosynthetic enzymes
Nickel	Ni ²⁺	0.001%	Cofactor for an enzyme functioning in nitrogen metabolism
Molybdenum	MoO ₄ ²⁻	0.0001%	Essential for symbiotic relationship with nitrogen-fixing bacteria; cofactor in nitrate reduction

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Symptoms of Mineral Deficiency

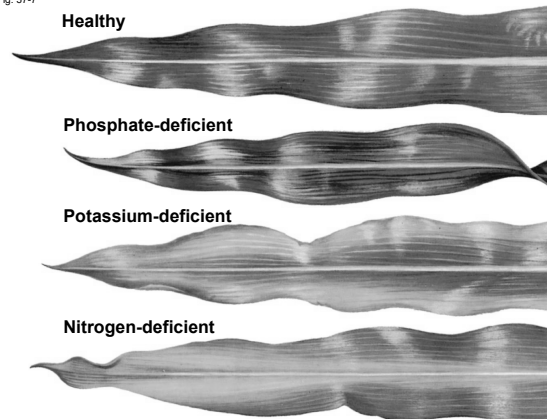
- Symptoms of mineral deficiency depend on the nutrient's function and mobility within the plant
- Deficiency of a mobile nutrient usually affects older organs more than young ones
- Deficiency of a less mobile nutrient usually affects younger organs more than older ones
- The most common deficiencies are those of nitrogen, potassium, and phosphorus

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- Nine of the essential elements are called **macronutrients** because plants require them in relatively large amounts
- The macronutrients are carbon, oxygen, hydrogen, nitrogen, phosphorus, sulfur, potassium, calcium, and magnesium

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Fig. 37-7



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Concept 37.3: Plant nutrition often involves relationships with other organisms

- Plants and soil microbes have a mutualistic relationship
 - Dead plants provide energy needed by soil-dwelling microorganisms
 - Secretions from living roots support a wide variety of microbes in the near-root environment

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- Inoculation of seeds with rhizobacteria can increase crop yields

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Soil Bacteria and Plant Nutrition

- The layer of soil bound to the plant's roots is the **rhizosphere**
- The rhizosphere has high microbial activity because of sugars, amino acids, and organic acids secreted by roots

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Bacteria in the Nitrogen Cycle

- Nitrogen can be an important limiting nutrient for plant growth
- The **nitrogen cycle** transforms nitrogen and nitrogen-containing compounds
- Most soil nitrogen comes from actions of soil bacteria

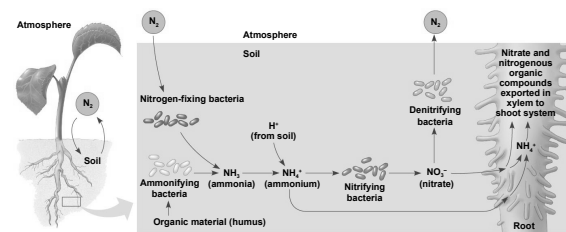
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Rhizobacteria

- Free-living **rhizobacteria** thrive in the rhizosphere, and some can enter roots
- Rhizobacteria can play several roles
 - Produce hormones that stimulate plant growth
 - Produce antibiotics that protect roots from disease
 - Absorb toxic metals or make nutrients more available to roots

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Fig. 37-9



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Nitrogen Fixation and Agriculture

- **Crop rotation** takes advantage of the agricultural benefits of symbiotic nitrogen fixation
- A non-legume such as maize is planted one year, and the next year a legume is planted to restore the concentration of fixed nitrogen in the soil

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Agricultural and Ecological Importance of Mycorrhizae

- Farmers and foresters often inoculate seeds with fungal spores to promote formation of mycorrhizae
- Some invasive exotic plants disrupt interactions between native plants and their mycorrhizal fungi

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- Instead of being harvested, the legume crop is often plowed under to decompose as “green manure” and reduce the need for manufactured fertilizer
 - Non-legumes such as alder trees, certain tropical grasses, and rice benefit either directly or indirectly from nitrogen-fixing bacteria

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Epiphytes, Parasitic Plants, and Carnivorous Plants

- Some plants have nutritional adaptations that use other organisms in nonmutualistic ways
- An **epiphyte** grows on another plant and obtains water and minerals from rain

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Fungi and Plant Nutrition

- **Mycorrhizae** are mutualistic associations of fungi and roots
- The fungus benefits from a steady supply of sugar from the host plant
- The host plant benefits because the fungus increases the surface area for water uptake and mineral absorption
- Mycorrhizal relationships are common and might have helped plants to first colonize land

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Fig. 37-14a



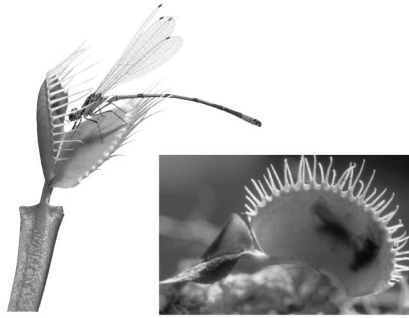
Staghorn fern, an epiphyte

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- Parasitic plants absorb sugars and minerals from their living host plant

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Fig. 37-14e-1



Venus flytrap

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Fig. 37-14b



Mistletoe, a photosynthetic parasite

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Fig. 37-14f-1



Pitcher plants

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- Carnivorous plants are photosynthetic but obtain nitrogen by killing and digesting mostly insects

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