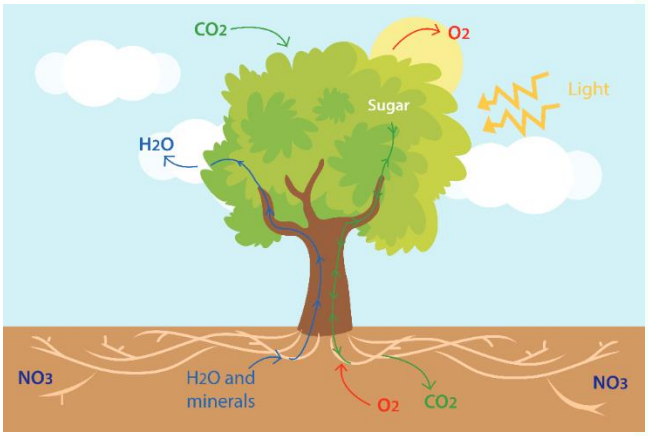
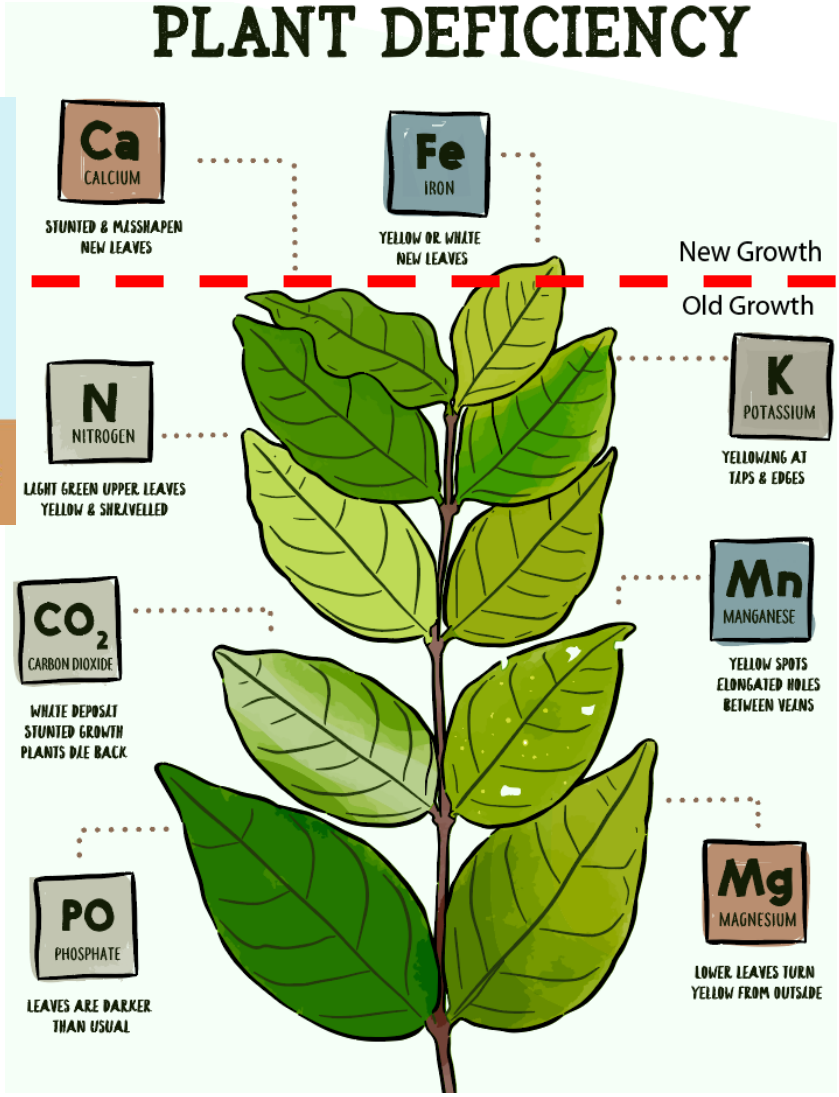
**CONCEPT:** SOIL AND NUTRITIENTS

- Plants produce sugars from photosynthesis, but still have many nutritional requirements
  - □ C, H, and O account for ~95% of a plant's dry weight, and are obtained from $CO_2$ and $H_2O$
  - □ Vascular plants require 17 essential nutrients
- ***Macronutrients*** – nutrients required in large quantities, include N, P, K, Ca, S, and Mg
  - □ ***Limiting nutrients*** – availability of these nutrients limits plant growth, usually N, P, and/or K
- ***Micronutrients*** – nutrients needed in small quantities, include B, Cl, Mn, Fe, Zn, Cu, Na, Mo, and Ni
  - □ Present only in trace amounts in plants, yet essential to life
  - □ Nutrients can potentially be toxic to plants in high concentration
- Some nutrients are mobile, and can be transported around the plant, others are immobile
  - □ Old leaves will often transport nutrients to sustain the young leaves, dying off in the process
  - □ Young leaves are the first to show nutrient deficiencies

**EXAMPLE:**

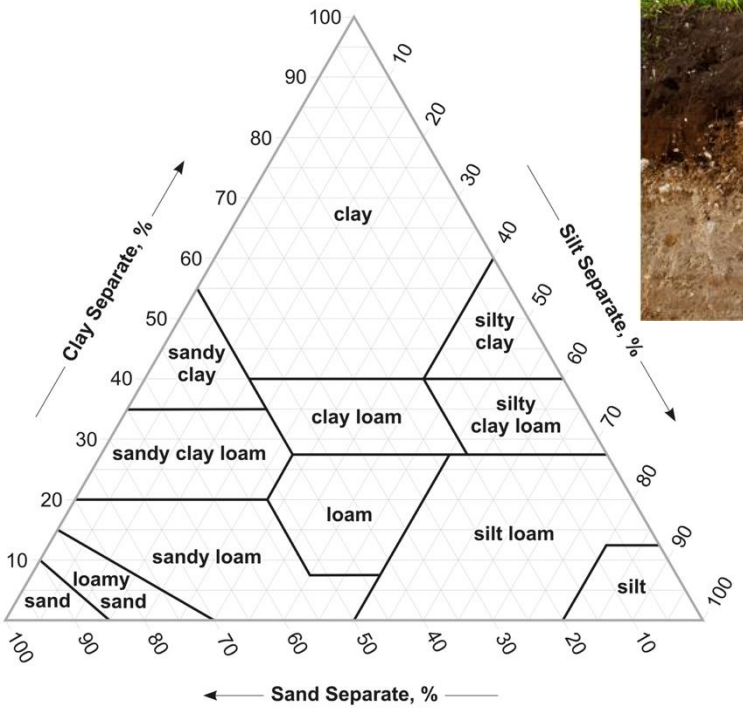


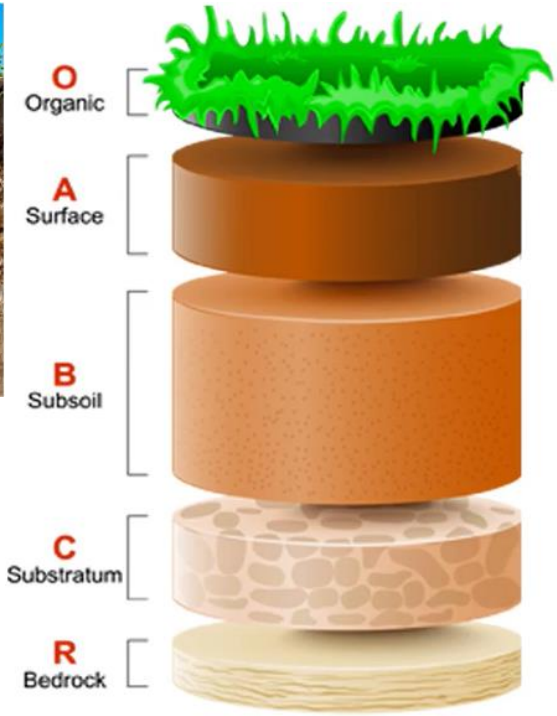



**CONCEPT:** SOIL AND NUTRITIENTS

- Soil is composed of inorganic minerals, organic matter, trapped gases, liquids like water, and many living organisms
    - □ Weathered rock breaks up into gravel, sand, silt, and clay, composing the base of soil
    - □ ***Humus*** – decaying organic matter, organisms add dead cells and feces to the soil, enriching it
    - □ ***Texture*** – proportions of soil components like gravel, sand, silt, and clay
        - Affects roots ability to penetrate and absorb nutrients
        - Affects ability of soil to hold water and oxygen
    - □ ***Loam*** – contains roughly equal portion of sand, silt, and clay, with lots of humus, very good soil
- ***Topsoil*** – outermost layer of soil with the highest concentration of humus and microorganisms
    - □ Composed of many living organisms like bacteria, archaea, fungi, algae, nematodes, protists, insects, and worms
        - Worms help move soils around, cycle nutrients, and break it up for better water and gas retention
- ***Soil horizons*** – soil layers like topsoil, subsoil, and bedrock

**EXAMPLE:**



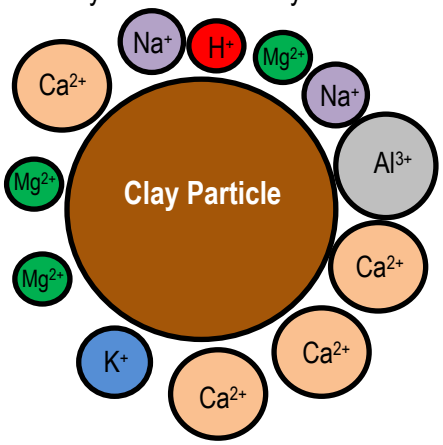

USDA / Natural Resources Conservation Service:
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054311

- Soil pH varies greatly and affects nutrient absorption
    - □ Acidic soil – lots of decaying organic matter producing organic acids
    - □ Alkaline soil – limestone, $CaCO_3$, leads to bicarbonate ($HCO_3^-$) formation
- ***Soil erosion*** – wind and water carrying soil away from a site
    - □ Roots helps prevent soil erosion, and the excrete acids, lowering pH

**CONCEPT:** SOIL AND NUTRITIENTS

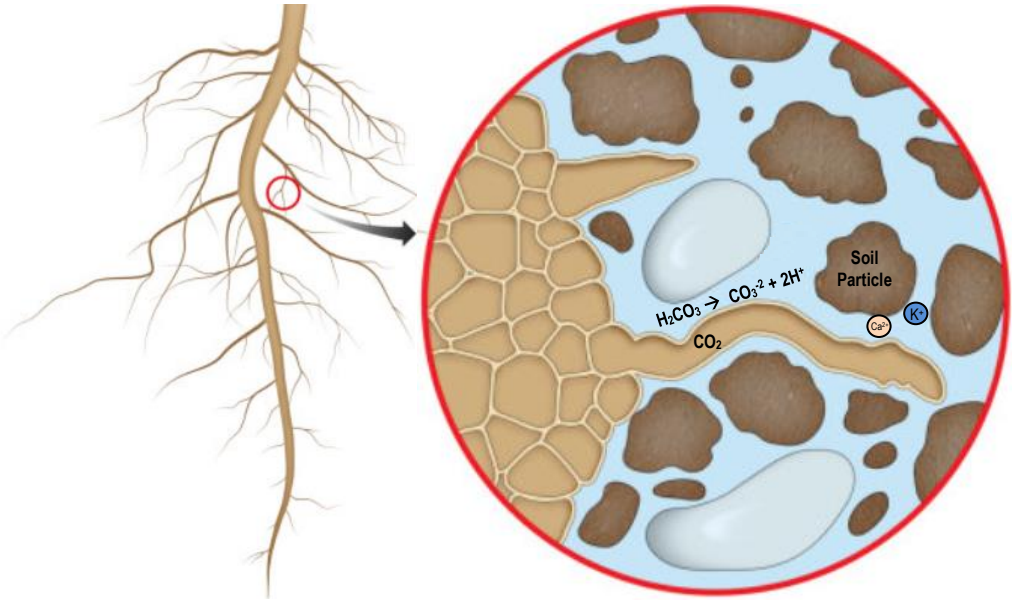
- Plants extract soil nutrients as ions
    - □ Most nutrient uptake occurs in the zone of maturation, behind the root tip, where root hairs are found
    - □ Root hairs significantly increase the surface area available for water and nutrient absorption
    - □ Anions – negatively charged, dissolved in water in soil and readily available to plants for absorption
        - Ions dissolved in water are also easily leached form soil
        - ***Leaching*** – loss of nutrients through the movement of water
        - Phosphate is an anion, but is not dissolved in water in soil, forms complexes with Fe and Ca cations
    - □ Cations – dissolve in water, but usually interact with clay anions or organic acids, harder for plants to extract

**EXAMPLE:**




- ***Cation exchange*** – soluble cations, like protons, bind to negatively charge soil particles, causing cations like $Mg^{+2}$ and $Ca^{+2}$ to be released from soil, allowing plants to absorb them
    - □ Humus has higher cation exchange capacity that does clay
- Plants influence cation exchange by releasing $CO_2$, a byproduct of cellular respiration
    - □ $CO_2$ forms carbonic acid in water, releasing protons to cause cation exchange
    - □ If soil is too acidic, rain can wash cations away

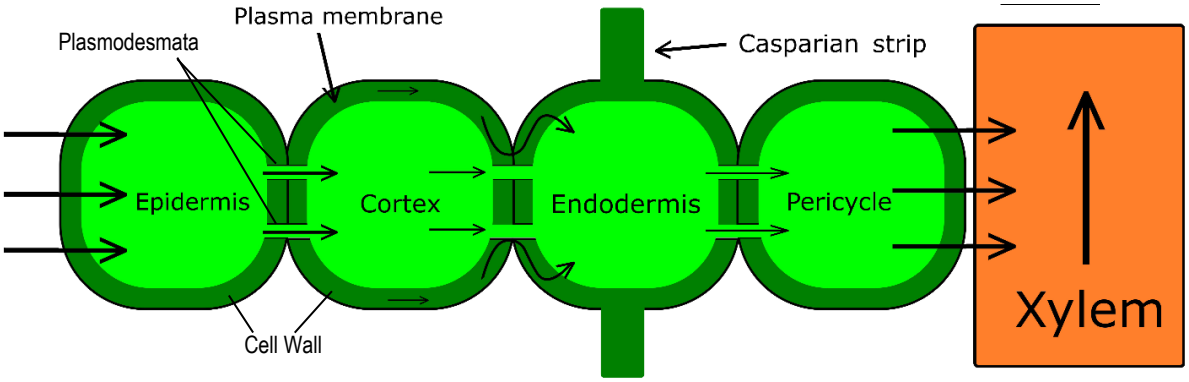
**EXAMPLE:**



**CONCEPT:** SOIL AND NUTRITIENTS

- Nutrients can easily pass through the cell wall, but the plasma membrane acts as a filter (selective permeability)
- Plants use proton pumps to create electrochemical gradients outside of the cell to allow ions to enter through transporters
    - □ Electrochemical gradient strong enough to overpower counteracting forces, like pH gradient
    - □ Cations like $K^+$ move through channels
    - □ Anions like $NO_3^-$ use cotransporters that often use the proton gradient, and bring $H^+$ into the cell as well
- ***Ion exclusion*** – plants filter harmful ions and poisonous metals
    - □ ***Passive exclusion*** – membrane lacks the transporter necessary to allow ion to pass through
        - Casparian strip forces ions through endodermal cells, from apoplast to symplast

**EXAMPLE:**




- □ ***Active exclusion*** – antiporters at tonoplast (vacuole membrane) remove material from the cytoplasm
    - $H^+$ pumps and $Na/H^+$ antiporters help prevent sodium from poisoning plant cell
- □ Metallothioneins – cysteine-rich proteins that bind metals to prevent them from poisoning the organism

**EXAMPLE:**