Lecture Outline: Resource Acquisition, Nutrition, And Transport In Vascular Plants

I. **Introduction to Resource Acquisition**
   A. Unusual Cactus Adaptation (Example)
      1. Most of the organism’s bulk is underground (shoot system, not root system).
      2. The shoot system usually functions above ground for photosynthesis and reproduction.
      3. Underground photosynthetic tissue is possible because the tips of the structures are translucent (window-like lenses).
   B. Plant Resources and Chemical Processes
      1. Light is a non-material resource required for photosynthesis.
      2. Summary Reaction for Photosynthesis
         a. Inputs: Energy (Light), 6 CO_2, and 6 H_2O.
         b. Outputs (Goal): Glucose ($C_6H_{12}O_6$); Oxygen (O_2) is a waste product.
      3. Photosynthesis has a reciprocal relationship with the complete oxidation of fuel (Glycolysis and Cellular Respiration).

II. **Gas and Material Exchange**
   A. Carbon Fixation and CO_2 Intake
      1. CO_2 provides the source of carbon for building organic molecules.
      2. Incorporating inorganic carbon (CO_2) into organic compounds is called **carbon fixation**.
   B. Water and Mineral Movement (Transpiration)
      1. Water and dissolved minerals (solutes) enter the root system.
      2. Flow is one-way and continuous through xylem vessels up the plant body and out the leaves.
      3. This continuous movement of water is called **transpiration**.
   C. Cellular Respiration in Roots
      1. Roots are living cells that undergo glycolysis and cellular respiration, requiring O_2 and producing CO_2 waste.
      2. Since roots are in the total dark, they do not photosynthesize.
   D. Sugar Transport
      1. Sugars are produced where photosynthesis occurs (e.g., leaves), known as **sugar sources**.
      2. Excess sugar is transported through the phloem to **sugar sinks** (parts needing fuel, like

roots).

3. Sugar flow is bidirectional, depending on the plant's need.

III. **Plant Structure and Intercellular Compartments**
   - A. Phyllotaxy (Leaf Arrangement)
     1. Definition: The specific, highly ordered arrangement of leaves on a plant stem (often a spiral).
     2. Advantage: Maximizes the chance that each leaf receives its own sunlight (prevents shadowing).
   - B. Compartmentalization and Junctions
     1. Intercellular junctions called **plasmodesmata** act as little tunnels connecting adjacent cells.
     2. This connectivity means the cytoplasm is shared among all connected cells.
   - C. Major Compartments of the Plant Body
     1. **Symplast**: The combined compartment of all intracellular cytoplasm.
     2. **Apoplast**: The extracellular compartment, including the cell wall.
   - D. Three Routes for Particle Travel
     1. Symplastic route: Travels exclusively through the cytoplasm (via plasmodesmata).
     2. Apoplastic route: Travels exclusively through the extracellular space (e.g., cell walls).
     3. Transmembrane route: Crosses a plasma membrane at least once, spending time in both compartments.

IV. **Transmembrane Transport**
   - A. Categories of Transport Processes
     1. Transmembrane Transport
        - a. Passive transport.
        - b. Active transport.
     2. Vesicular Transport (Transport without passing through the membrane)
        - a. Endocytosis (inward): Phagocytosis (cell eating, solids) or Pinocytosis (cell drinking, liquids).
        - b. Exocytosis (outward).
   - B. Passive Transport (Diffusion)
     1. Requires energy that is already built into the system, provided by a **gradient** (potential energy).
     2. Movement occurs down the gradient (from high concentration to low concentration).
     3. Direct diffusion through the phospholipid bilayer requires particles to be **small enough** and **non-polar enough** (charged/polar particles are blocked).
     4. **Facilitated diffusion**: Passive movement requiring the help of a transport protein.

1. Channel proteins: Form open tunnels.
2. Carrier proteins: Temporarily bind the particle (ligand) and change shape to drop it off on the other side.

C. Active Transport
1. Requires expenditure of additional outside energy (e.g., ATP).
2. Moves substances **against their gradient** (from low concentration to high concentration).
3. Active transport proteins are called **pumps**; only carrier proteins can function as pumps.

D. Co-transport Terminology
1. Uniport: Moves only one type of particle.
2. Co-transport: Moves two different kinds of particles simultaneously.
    1. Symport: Both particles move in the **same direction**.
    2. Antiport: Particles move in **opposite directions**.

E. Primary and Secondary Active Transport in Plants
1. **Primary Active Transport**: Often involves a proton pump that spends ATP to pump protons (H^+) out of the cell, establishing an electrochemical gradient.
2. **Secondary Active Transport**: Uses the potential energy stored in the H^+ gradient (diffusion of H^+ back into the cell) to drive the pumping of another molecule (e.g., sucrose or nitrate) against its gradient.

V. **Osmosis and Water Movement**

A. Osmosis Defined
1. Special case of diffusion involving the movement of a **solvent** particle (water in biology) through a membrane down its gradient.

B. Tonicity (Refers to the cell's **environment**)
1. Hypotonic: Environment has a lower solute concentration (more watery) than the cell; water moves **into** the cell.
2. Hypertonic: Environment has a higher solute concentration (less watery) than the cell; water moves **out of** the cell.
3. Isotonic: Environment has the same solute concentration (equally watery); water enters and leaves at the same rate.

C. Plant Cell Responses to Tonicity
1. In Hypertonic environments: Plant cells undergo **plasmolysis** (plasma membrane shrinks away from the cell wall).
2. In Isotonic environments: Cells are **flaccid** (limp); ideal for animal cells.
3. In Hypotonic environments: Cells swell (**turgid**) because the strong cell wall prevents bursting (lysis); this is the **ideal situation** for plants.
4. Turgor: Pressure from swollen, turgid cells pressing on each other, allowing non-woody

plants to stand upright.

VI. **Plant Nutrition and Soil Resources**

- A. Hydroponics Technique
  1. Method of growing plants in water solutions without soil.
  2. Allows scientists to precisely manipulate components and determine **essential elements**.
- B. Essential Elements Classification
  1. **Macronutrients**: Needed in large quantities (e.g., Carbon, Oxygen, Hydrogen, Nitrogen, Phosphorus).
  2. **Micronutrients**: Essential, but only needed in trace amounts (e.g., metal ions often functioning as co-factors for enzymes).
  3. Nitrogen is vital for nucleic acids and proteins.
- C. Cation Exchange (Uptake of positive ions)
  1. Soil particles are negatively charged and hold desirable cations (e.g., K^+, Ca^{2+}, Mg^{2+}) via electrostatic attraction.
  2. Plants perform **cation exchange** by releasing protons (H^+) to trade for the needed cations, freeing them into solution.
  3. Source of Protons:
     - a. CO_{2} produced by root cellular respiration reacts with water: $\text{H}_{2}\text{O} + \text{CO}_{2} \leftrightarrow \text{H}_{2}\text{CO}_{3}$ (Carbonic acid).
     - b. Carbonic acid dissociates into H^{+} and bicarbonate (HCO_{3}^{-}).
     - c. Proton pumps actively pump H^+ out of root hairs to increase efficiency.

VII. **Nitrogen Acquisition and Cycling**

- A. Problem of Elemental Nitrogen
  1. The atmosphere is mostly pure nitrogen (N_{2}), but N_{2} has a strong triple covalent bond, making it inert and unusable by most organisms, including plants.
- B. Nitrogen Fixation (Bacteria mediated)
  1. Only certain species of **nitrogen-fixing bacteria** can break the N_{2} bond.
  2. They convert N_{2} into ammonia (NH_{3}).
  3. Ammonia reacts with soil protons to form ammonium ion (NH_{4}^{+}).
  4. Plants utilize some NH_{4}^{+}.
  5. Nitrifying bacteria convert remaining NH_{4}^{+} to nitrate (NO_{3}^{-}), which is the preferred nitrogen source for plant uptake.
  6. Dinitrifying bacteria complete the loop by converting NO_{3}^{-} back into N_{2}.
- C. Symbiotic Nitrogen Fixation

1. Legumes (e.g., peanuts, soybeans) form root **nodules**.
2. Nodules house nitrogen-fixing bacteria (endosymbiosis), making nitrogen acquisition highly efficient.
3. This process naturally enriches the soil with usable nitrogen.

VIII. **Plant Ecological Interactions**

A. Mycorrhizae (Fungus-Root Symbiosis)

1. A mutualistic relationship important for nearly all plants.
2. Two Major Categories:
    a. Ectomycorrhizae: Fungus forms a thick mat on the root exterior; little cell penetration.
    b. Arbuscular Mycorrhizae: Fungus forms branched, tree-like structures (arbuscular) that penetrate tissue and achieve greater surface area contact.

B. Other Plant Lifestyles

1. Epiphytes: Plants that live **on** other plants, using them only for structural support, not stealing nutrients.
2. Parasitic Plants: Grow on hosts and physically tap into vessels to steal water or nutrients (e.g., Mistletoe).
    a. Some parasitic plants have given up photosynthesis entirely and rely solely on the host.
3. Carnivorous Plants: Supplement nutrients obtained from photosynthesis by trapping and digesting small creatures (usually insects) using various traps (e.g., pitcher plants, Venus fly traps).

IX. **Specialized Transport Structures and Mechanisms**

A. Casparian Strip (Root Core Barrier)

1. Location: A ring of cells surrounding the vascular tissue in the root core.
2. Function: Blocks the **apoplastic route** to the xylem vessels.
3. Control: Any substance entering the rest of the plant must enter a cell and use the symplastic route, allowing the plant to control uptake.

B. Cohesion-Tension Hypothesis (Transpiration Pull)

1. Transpiration is the "engine" that **pulls** water from the leaves, not pushing it from the roots.
2. Evaporation at the leaf surface causes water molecules to leave, creating surface curvature.
3. **Cohesion** (attraction between water molecules via hydrogen bonds) drags the entire column of water behind the evaporating molecules.
4. **Adhesion** (attraction of water molecules to the xylem walls) assists the pull.
5. The force generated fights gravity to move water up very tall trees.

C. Stomatal Regulation (Control of Gas Exchange)

1. Stomata are openings in the leaf surface guarded by two **guard cells**.
2. Stomatal opening is caused by the bulging of guard cells due to water uptake (turgid state).

3. Control Mechanism:
    a. Opening: K^{+} ions are actively pumped into the guard cells; water follows osmotically, causing the cells to swell.
    b. Closing: K^{+} ions diffuse back out; water leaves, and the stoma closes.

X. **Transport of Sugars (Pressure Flow)**

- A. Phloem Loading
    1. Sucrose is moved into the phloem sieve tubes.
    2. This movement often involves **secondary active transport** (Sucrose/H^+ symport).
- B. Pressure Flow Hypothesis
    1. Phloem and xylem vessels run side-by-side.
    2. At the sugar source (e.g., leaf), continuous sucrose production builds pressure.
        1. Water moves by osmosis from the watery xylem into the sugary phloem, further pressurizing the source end.
    3. At the sugar sink (e.g., root), sucrose is removed, reducing pressure.
    4. The high-pressure source and low-pressure sink maintain a pressure gradient, forcing the bulk flow of phloem sap.

XI. **Plant Adaptations to Arid Environments**

- A. Ocotillo: Sheds leaves most of the year to conserve water (dormancy); explodes with leaves to photosynthesize when water is present.
- B. Oleander: Stomata are recessed within **crypts** (cave-like structures) below the leaf surface, reducing evaporation caused by wind.
- C. Old Man Cactus: Covered in soft, white spines (modified leaves) that reflect light and heat to stay cool and minimize water loss.