Outline
- Photosynthesis
  • Major Steps of Photosynthesis
    - Light-Dependent Reactions
    - Light-Independent Reactions
  • Alternate pathways
    - C_4 Photosynthesis
    - CAM Photosynthesis
  • Respiration

Enzymes regulate most metabolic activities
- Anabolism
- Catabolism
- The energy produced in catabolic reactions is transferred to be used in anabolic reactions
  • The role of ATP and NADPH

Photosynthesis
- Occurs in chloroplasts
- \[ 6 \text{CO}_2 + 12 \text{H}_2\text{O} + \text{light} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 + 6\text{H}_2\text{O} \]

Ingredients: Carbon Dioxide
- How does carbon dioxide reach the chloroplasts?
  • Fun Fact: Carbon dioxide is increasing in the atmosphere
    - Does it enhance photosynthesis?
    - NO!
      - Plants may counter-balance by developing fewer stomata.

Water
- How does water get to the mesophyll for photosynthesis?
- Fun fact: Less than 1% of all the water absorbed by plants is used in photosynthesis.
- If water is in short supply, stomata close.
- What is the consequence of this?
Light (from the sun or a lamp***)

- About 40% of the radiant energy received on earth is in the form of visible light.
- Leaves commonly absorb about 80% of the visible light reaching them.
- What factors do you think cause variation in light intensity?
- How do you think this affects photosynthetic rates?

Effects of Light and Temperature on Photosynthesis

- Figure 10.6: Why leaves are green: interaction of light with chloroplasts

Light Wavelengths

- Chlorophyll and other pigments
  - Types of chlorophyll.
    - chlorophyll a and chlorophyll b
    - Accessory pigments: carotenoids, phycobilins.
    - About 250-400 pigment molecules group as a photosynthetic unit.

Light Dependent Reactions - In Depth

- Each pigment has its own distinctive pattern of light absorption.
Major Steps of Photosynthesis

- **Light Dependent Reactions**
  - Water molecules split apart.
  - Electrons passed along electron transport.
  - ATP produced.
  - NADPH produced.

- **Light Independent Reactions**
  - Carbon dioxide combined with RuBP and then combined molecules are converted to sugars (Glucose).
  - Energy furnished by ATP and NADPH from Light-Dependent Reactions.

**Light Dependent Reactions - In Depth**

- Two types of photosynthetic units present in most chloroplasts make up photosystems.
  - Photosystems I and II
    - Both can produce ATP.
    - Only organisms with both photosystem I and photosystem II can produce NADPH and oxygen as a consequence of electron flow.
Light Independent Reactions - In Depth

- Calvin Cycle
  - Six molecules of CO₂ combine with six molecules of RuBP with the aid of rubisco.
  - Resulting complexes split into twelve 3PGA molecules.
  - NADPH and ATP supply energy and electrons that reduce 3PGA to 12 GA3P.
  - Ten of the twelve GA3P molecules are restructured into six RuBP molecules.

Photorespiration

- Stomata usually close on hot, dry days.
- What happens (or does not happen when they are closed)?
- When carbon dioxide levels drop below about 50 parts per million, photorespiration is initiated.
  - Rubisco fixes oxygen instead of carbon dioxide.
**Light Independent Reactions - In Depth**

- **4-Carbon Pathway**
  - Plants have **Kranz Anatomy**.
    - Large chloroplast with few to no grana in the bundle sheath cells surrounding the veins.
    - Smaller chloroplasts with well-developed grana in the mesophyll cells.

**Corn (Zea Mays) Cross-Section**

**4-Carbon Pathway**

- Plants with Kranz Anatomy produce **oxaloacetic acid** (4-carbon compound).
  - Phosphoenolpyruvate (PEP) and carbon dioxide combined in mesophyll cells with the aid of PEP carboxylase.
  - Provides a major reduction in photorespiration.

**CAM Photosynthesis**

- Similar to C4 photosynthesis in that 4-carbon compounds are produced during the light-independent reactions.
  - However, in CAM, the organic acids accumulate at night and break down during the day, releasing carbon dioxide.
  - Allows plants to function well under limited water supplies, as well as high light intensity.
**CAM Photosynthesis**

- Light-dependent reactions occur during the day when stomata are open, allowing CO₂ entry into the cells.
- CO₂ is fixed during the day and stored as malic acid.
- Malic acid is converted to O₂, CO₂, and PEP during the night, with stomata closed and CO₂ stored during the day.
- CO₂ is released to the atmosphere during the night.

**Respiration**

- Respiration is essentially the release of energy from glucose molecules that are broken down to individual carbon dioxide molecules.

\[
\text{C}_6\text{H}_12\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy}
\]

- **Fermentation**
  \[
  \text{C}_6\text{H}_12\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2 + \text{ATP}
  \]
  \[
  \text{C}_6\text{H}_12\text{O}_6 \rightarrow 2\text{C}_3\text{H}_6\text{O}_3 + \text{ATP}
  \]

- **Factors Affecting the Rate of Respiration**
  - Temperature
  - Water
  - Oxygen

**Major Steps of Respiration**

- **Glycolysis**
  - Glucose molecule becomes a fructose molecule carrying two phosphates.
  - Fructose molecule is split into two GA3P molecules.
  - Some hydrogen, energy, and water are removed, leaving pyruvic acid.

- **Aerobic Respiration**
  - **Citric Acid (Krebs) Cycle**
    \[
    \text{O.A.} + \text{acetyl CoA} + \text{ADP+P} + 3\text{NAD} + \text{FAD} \rightarrow \\
    \text{O.A.} + \text{CoA+ATP+3NADH+H}^+ + \text{FADH}_2 + 2\text{CO}_2
    \]
  - **Electron Transport**
    - Oxidative Phosphorylation
    - Chemiosmosis

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Assimilation and Digestion

• **Assimilation** is the process of using organic matter produced through photosynthesis to build protoplasm and cell walls.

• **Digestion** is the conversion of starch and other insoluble carbohydrates to soluble forms.
  - Nearly always hydrolysis.