VulaLearn

Life Sciences, Grade 11, Photosynthesis

Definitions

Photosynthesis: A process that makes glucose (an energy-rich molecule) from carbon dioxide and water, requiring radiant energy trapped by chlorophyll, and releasing oxygen.

Radiant Energy: Energy from the sun, required for photosynthesis.

Chlorophyll: Green pigment in chloroplasts that traps radiant energy.

Thylakoid membranes: Location within the chloroplast where the light-dependent phase of photosynthesis occurs.

Photolysis: The splitting of water molecules into hydrogen and oxygen using light energy during the light phase of photosynthesis.

ATP (Adenosine Triphosphate): An energy carrier molecule formed during photophosphorylation in the light phase, used in the dark phase.

NADPH: Energized hydrogen acceptor molecule formed in the light phase, released and passed on to the dark phase.

Stroma: The fluid-filled space within the chloroplast where the dark (light-independent) phase of photosynthesis occurs.

Limiting Factor: A factor that restricts the rate of a process when it is in short supply (e.g., CO2, temperature, light intensity for photosynthesis).

Denature: To alter the natural shape of an enzyme, rendering it ineffective, typically due to extreme temperature.

Concepts

What is Photosynthesis?

- Photosynthesis is a process that synthesizes glucose (an energy-rich molecule) from carbon dioxide and water.
- Requires radiant energy (from the sun), which is trapped by chlorophyll.
- Oxygen is released as a byproduct.

- **Chemical Equation**: $6CO_2 + 6H_2O$ + Radiant Energy (Chlorophyll) $\rightarrow C_6H_{12}O_6 + 6O_2$
- **Word Equation**: CARBON DIOXIDE + WATER $\rightarrow$ GLUCOSE+ OXYGEN

Requirements for Photosynthesis

- **Carbon dioxide**: From the air, enters leaves through stomata.
- **Water**: From the soil, carried by xylem.
- **Radiant energy**: From the sun.
- **Chlorophyll**: In the chloroplasts of the leaves, traps radiant energy.
- **Enzymes**: Facilitate the chemical reactions.

Products of Photosynthesis

- **Glucose**: Stored as starch, transported by phloem.
- **Oxygen**: Released back into the atmosphere. Used by the plant for cellular respiration.

Reactions:

- **Anabolic:** A chemical reaction where enzymes are used to build up complex products from simpler substances (photosynthesis)
- **Catabolic:** A chemical reaction where enzymes convert the energy from nutrients into energy that can be used by the cell (ATP) – involves breaking down the substrate (cellular respiration)

Where does Photosynthesis take place?

- Inside the chloroplast
    - Made u of stacks of thylakoids called grana
    - Chlorophyll is located inside the thylakoids
    - Chloroplast is filled with watery stroma (cytoplasm)
    - Surrounded by a double membrane

Phases of Photosynthesis

- **Two Phases**:
    1. **Light (or Light-Dependent) Phase**:
        - Requires the presence of light.
        - Takes place in the chloroplast on **thylakoid membranes**.
        - **Steps**:
            1. Photons (light packages) are trapped by chlorophyll, giving electrons high energy.
            2. This energy splits water molecules into hydrogen and oxygen (**photolysis**).
            3. Oxygen is released into the atmosphere.
            4. Energized H-atoms bond to the H-acceptor, NADP, forming **NADPH**, which is released and passed to the dark phase.
            5. The same energy from the "excited electron" is used in **photophosphorylation** where ADP combines with a phosphate to form the energy carrier, **ATP**, which is used in the dark phase.
    2. **Dark (or Light-Independent) Phase**:
        - Can occur with or without light.
        - Can only take place after the light phase has occurred.
        - Takes place in the **stroma** of the chloroplast.
        - **Steps:**
            1. Carbon dioxide diffuses into the chloroplast.
            2. Where it is reduced (it gains H-atom or electron) not simple sugars through a series of enzyme controlled reactions called the Calvin cycle.
            3. The energy from ATP is used and is dephosphorylated: ATP □ ADP + P which returns to light phase

4. NADPH loses an H atom: NADPH □ NADP + H (NADP returns to light phase)
5. Excess glucose is stored as starch

Importance of photosynthesis

- Photosynthesis makes energy rich compounds that fuel life and provide the basis of our food webs
- Life depends on photosynthesis because almost all organisms obtain their nutrients (therefore energy), directly or indirectly from green plants
- Organisms from higher trophic levels obtain their energy from stored organic compounds either from plants directly (herbivores) or indirectly (carnivores)
- Photosynthesis plays an NB role in maintaining a constant global level of oxygen + carbon dioxide:
    - The O2 that is given off as a by-product during pls is available for cellular respiration
    - The CO2 that is produced during cellular respiration + from the combustion of · fuels is used in pls
- This helps stop the levels of CO2 in the atmosphere from rising too high

Photosynthesis Experiments

- **1. Destarching a Plant**:
    - **Aim**: To ensure no starch is present in the plant before an experiment, so any new starch detected is formed during the experiment.
    - **Method**: Place the plant in a dark cupboard for 48 hours. Starch will be converted to glucose and used in cellular respiration.
- **2. Starch Test (Iodine Test)**:
    - **Aim**: To test for the presence of starch in a leaf.
    - **Method**:

1. Place the leaf in boiling water for 5-10s (stops metabolic reactions breaks down cell wall, makes cell membrane permeable)
2. Place the leaf in hot alcohol to remove chlorophyll.
3. Dip the leaf in hot water again to rinse off ethanol and rehydrate leaf.
4. Spread the leaf on a white tile and add iodine solution.

- **Results**:
  - **Positive (starch present)**: Iodine solution turns from brown to blue/black.
  - **Negative (no starch)**: Iodine solution remains brown/yellow.

- **3. Chlorophyll Experiment**:
  - **Aim**: To investigate whether chlorophyll is necessary for photosynthesis to occur.
  - **Method**:
    - Place a potted plant with variegated leaves in a sunny place for a few hours.
    - Remove a leaf and test for starch.
  - **Control**: Parts of the leaf that don't contain chlorophyll (white part).
  - **Experiment**: Parts of the leaf containing chlorophyll (green part).
  - **Independent variable**: Presence or absence of chlorophyll.
  - **Dependent variable**: Presence or absence of starch.
  - **Fixed variables**: Same amount of iodine solution, same environment, same time, same person.
  - **Results**: White part of leaf: Iodine remains brown. Green part of leaf: Iodine turns blue/black.

- **Conclusion**: Chlorophyll is necessary for photosynthesis to occur.

- **4. Carbon Dioxide Experiment**:
  - **Aim**: To investigate whether carbon dioxide is necessary for photosynthesis to occur.
  - **Method**:
    - Destarch two potted plants (place in dark cupboard for 48 hours).
    - Set up apparatus with one plant in an environment where CO_2 is absorbed (e.g., by soda lime), and another where CO_2 is present (e.g., by adding $NaHCO_3$).
    - Expose both to light for 48hrs
    - Test leaves for starch.
  - **Control**: Plant with CO_2 absent.
  - **Experiment**: Plant with CO_2 present.
  - **Independent variable**: Presence or absence of CO_2.
  - **Dependent variable**: Presence or absence of starch.
  - **Fixed variables**: Size of plant, light, temperature, amount of water.
  - **Results**: Plant exposed to CO_2: starch present. Plant with CO_2 absorbed: no starch.
  - **Conclusion**: Carbon dioxide is necessary for photosynthesis to occur.

- **5. Light Experiment**:

- **Aim**: To investigate whether light is necessary for photosynthesis to occur.
- **Method**:
  - Destarch a potted plant.
  - Cover part of a leaf with aluminum foil (blocking light).
  - Expose the plant to light for 48 hours, then test the leaf for starch.
- **Control**: Covered part of the leaf.
- **Experiment**: Exposed part of the leaf.
- **Independent variable**: Presence or absence of light.
- **Dependent variable**: Presence or absence of starch.
- **Fixed variables**: Time, water, CO2, temperature.
- **Results**: Covered part: no starch. Uncovered part: starch present.
- **Conclusion**: Light is necessary for photosynthesis to occur.

- **6. Oxygen Experiment**:
  - **Aim**: To investigate whether oxygen is released during photosynthesis.
  - **Method**:
    - Place the apparatus in a sunny area for a few hours.
    - A small amount of sodium bicarbonate can be dissolved in the water. (It will add carbon dioxide to the water)
    - After a while, gas bubbles will start to form. These gas bubbles will collect in the test tube.
    - Once enough gas has been trapped in the test tube, remove the test tube from the funnel but keep the opening of the test tube submerged under the water.
    - Seal the tube using a rubber stopper while under the water.

        - Once it has been sealed, remove the test tube from the water.
        - Insert a glowing wooden splint into the test tube.
    - **Control:** no plant present
    - **Experiment**: plant present.
    - **Fixed variables**: Same beaker, same amount of water, same person doing investigation
    - **Results**: Glowing splint will reignite and burn more brightly, therefore proving the oxygen is present in the test tube
    - **Conclusion**: Oxygen is released during p/s.

Factors Affecting the Rate of Photosynthesis

1. **Effect of CO2**
    - The CO2 concentration in the atmosphere is 0,04%
    - CO2 is a requirement for p/s □decrease in CO2 □decrease in rate of p/s
        1.
            1. At a low CO2 concentration, the rate of p/s is low (less than 0,04%)
            2. As the CO2 level increases, the rate of p/s also increases. This will happen up to a certain point
            3. When the optimum amount of CO2 is present, p/s will occur most rapidly
            4. If the CO2 concentration is higher than the optimum amount, then the rate of p/ s will remain constant - light, water and temperature become limiting factors
2. **Effect of Temperature**:
    - The optimum temperature for p/s = 25 C

- >25 C there is a decrease in the rate of photosynthesis --> enzymes start to denature

    1. Low temperature: low rate of photosynthesis.
    2. As temperature increases (10-25°C), the rate increases.
    3. **Optimum temperature for photosynthesis is 25°C**, where the rate reaches its maximum.
    4. Above 25°C, the rate decreases because enzymes involved start to **denature** and no longer function.

3. **Effect of Light Intensity**:

    - At the optimum temp the rate of p/s increases as the light intensity increases
    - Light intensity continues to increase the rate of p/s even when temp are lower than optimum but it's lower

        1. At low light intensity, the rate of photosynthesis is low.
        2. As light intensity increases, the rate also increases, but only up to a certain point (optimum amount).
        3. If light intensity increases past the optimum, the rate remains constant, as other factors (like CO2 and temperature) become **limiting factors**.
        4. At high light intensities, stomata can shut, making CO2 a limiting factor.