Photosynthesis

Chloroplast structure:

- a double membrane-bound organelle
- stroma – the large fluid interior of the chloroplast
- grana – thylakoid stacks connected by membrane channels

Pigments and the Properties of Light:

- deep red (680 nm) and blue-violet (450 nm) light is absorbed by chlorophyll a, **green** light is reflected (**not used**) by chlorophyll.
- accessory pigments like chlorophyll b and carotenoids extend the efficiency of photosynthesis by capturing light in a broader range of wavelengths.
- The color of the plant we see is the color least absorbed by the plant – what is reflected. Usually yellow and green.

Overview of Process:

Photosynthesis is the process plants use to convert solar energy into chemical energy (ATP). This chemical energy (ATP) is then used to make glucose (sugar) from CO_2 and H_2O.

$$6\,CO_2 + 6\,H_2O \xrightarrow{\text{solar energy}} C_6H_{12}O_6\ \text{(glucose)} + 6O_2$$

The entire process occurs inside the chloroplast in 2 steps:

1. Light Dependent Reactions: Light is trapped by pigments in the thylakoids and converted to ATP energy. Water is also split into hydrogen, electrons, and oxygen. The oxygen is released as waste product.

2. Calvin Cycle: CO_2 and Hydrogen atoms (from water in first step) is used to form glucose ($C_6H_{12}O_6$). Making glucose is an endergonic reaction so it requires energy. ATP made in the first step (light dependent reactions) is used as an energy source to form the bonds to make the glucose.

Step 1 - Light Dependent Reactions:

- Light energy (photons) is converted to chemical energy (ATP)
- Can only happen with light (light dependent)
- Occurs in the grana (thylakoid stacks) of the chloroplast

Reactants (what goes into the reaction):

- Water – taken in by roots
- Light energy – from the sun, absorbed by pigments like chlorophyll in the plant leaf
- ADP and Phosphate (P) – available in the cell as ATP is broken down

Products (what comes out of the reaction):

- Oxygen Gas – exits the leaf (comes from the water after hydrogens removed)
- ATP – used in next stage of photosynthesis to provide energy to make sugar
- NADPH – carrier molecule that carries hydrogen from the grana to the stroma to make sugar

Process:
There are two photosystems in the chloroplast and they are connected by an electron transport chain.
1. Pigments in the **water-splitting photosystem** absorb light energy and an electron in chlorophyll is boosted to a higher energy level (the electron is "excited").

2. The excited electrons are sent down an electron transport chain to the NADPH-producing photosystem. This electron transport chain makes ATP, just like the electron transport chain in cell respiration in the mitochondria.

******So here the plant has converted the light energy from the sun to ATP. It will use this ATP to provide the energy to make sugar.**

3. The electron that was lost from the chlorophyll (the excited electron) is replaced by splitting water molecules into 2 hydrogen ions (H^+), 2 electrons, and 1 oxygen atom.
    - the electrons lost from cholorophyll are replaced by the electrons extracted from water.
    - The oxygen is released from the cell (so this is the step of photosynthesis that produces oxygen)
    - The hydrogen ions are moved through ATP synthase to make ATP

4. **The NADPH producing photosystem** receives light energy, and that light energy excites electrons in the chlorophyll. NADP+ (Nicotinamide adenine dinucleotide phosphate – in case you were wondering) accepts the excited electrons and hydrogen ions (coming through the ATP synthase) and becomes NADPH. The NADPH carries the hydrogen to the stroma for the next step of photosynthesis, where it will be used as a hydrogen source to make sugar.

5. Remember, the **NADPH producing photosystem** is at the end of the first electron transport chain, so it replaces the electrons lost from its chlorophyll with the electrons coming down the electron transport chain.

Step 2 Calvin Cycle:
- Occurs in the stroma of chloroplast
- The ATP generated in light reactions are used to "fix carbon" (make sugar)

Reactants:
- 6CO2 (from air – taken in through the leaf)
- 12NADPH (from light dependent reactions)
- 18 ATP (from light dependent reactions)

Products:
- 1 $C_6H_{12}O_6$ (glucose)

Process:
The 6CO2 are joined together along with the 12 Hydrogen provided by the NADPH carrier molecules to form glucose. ATP produced in the light reactions are used as an energy source to form the bonds to make the sugar.

What does the plant do with the glucose?
Glucose can then be used in cellular respiration to make ATP (in the mitochondria, just as it is in animals) or it can be used as a basic building block to build other molecules like proteins and lipids (may require other atoms which are attained from nutrients in the soil – nitrogen, phosphorous, etc.)