Photosynthesis

- $6\ CO_2 + 6\ H_2O$ + light energy → $C_6H_{12}O_6 + 6\ O_2$
- Photosynthesis is a complex biochemical pathway.
- Photosynthesis consists of two independent pathways called the **light-dependent reaction** (light reaction) and the **light-independent reaction** (dark reaction).
  - Light Reactions: the energy in sunlight is trapped, O_2 is released, and both ATP and NADPH (hydrogen-carrier molecule) are formed
  - Dark Reactions: the ATP and NADPH react with CO_2 from the atmosphere and form glucose
- The entire process results in the transformation of light energy from the sun into energy stored in the bonds of the glucose molecule.

Structure of a Chloroplast

- double membrane
- thylakoid: a flattened sac that contains chlorophyll
- lumen: an internal reservoir in a thylakoid
- granum: a stack of thylakoids in a chloroplast
- stroma: a solution surrounding the grana

The light reactions take place in the thylakoid membrane
The dark reactions take place in the stroma

Chlorophyll & Accessory Pigments

- Photosynthesis requires the presence of pigments that are acted upon by sunlight.
  - Sunlight consists of particles of energy that move in waves of different wavelengths (visible light is part of the electromagnetic spectrum).
    - Wavelength (λ) is the distance between the crests of successive waves.
    - The shorter the wavelength, the more energy the light has.
    - Therefore, violet light (shorter λ) has more energy than red light (longer λ).
  - Pigments are light-absorbing compounds.
    - Pigments appear colored because they absorb light of certain wavelengths and reflect that of others.
    - Chlorophyll *a* is the primary pigment in green plants that absorbs red and blue/violet light and reflects green light.
    - Chloroplasts also contain other pigments called accessory pigments.
      - Accessory pigments trap wavelengths of light that cannot be absorbed by chlorophyll *a* and then transfer the energy to chlorophyll *a* molecules for use in photosynthesis.
      - Accessory pigments enable plants to use a greater amount of the sun's energy than is available to chlorophyll alone.
      - The most common accessory pigments in green plants are chlorophyll *b* (green), carotenes (orange), xanthophylls (yellow), and anthocyanins (red)

Light Reaction (Light-Dependent Reaction)

-photosystem I (**PSI**)
-photosystem II (**PSII**)

- Pigments that are in the chloroplasts accept light and begin the light reactions of photosynthesis.
- The light reactions occur in two photosystems (located in the thylakoid membrane):
  - Photosystem: a unit of several hundred chlorophyll *a* molecules and acceptor molecules
- **Steps:**
  1. Sunlight strikes PSII. The light boosts the energy level of the electrons in the chlorophyll molecules to such a high level that the electrons can escape the chlorophyll.
  2. Two excited electrons pass down the electron transport chain (a series of electron carrier molecules) to PSI.
  3. As the electrons move along the electron transport chain, hydrogen ions (H^+) are pumped across the thylakoid membrane. The energy that the electrons release as they flow down the ETC is used to power this pump.
  4. Sunlight strikes PSI (remember that PSI has two extra electrons from PSII). The two excited electrons pass through a series of molecules until they reach an electron acceptor called $NADP^+$. H^+ is added to form NADPH (a product of the light reaction).
  5. The pumping of hydrogen ions into the thylakoid creates a gradient. As the hydrogen ions leave the thylakoid, ADP is phosporylated to ATP by ATP synthetase (enzyme/channel).
  6. When light struck PSII, a water molecule split into 2 H^+, 1 O, and 2 electrons. These electrons pay back the two electrons that PSII lost in Step 1. The hydrogen ions join the hydrogen ions that were pumped in during Step 3. The oxygen joins with another oxygen atom and O_2 is released into the atmosphere.
- Products: ATP, NADPH, and O_2
- ATP and NADPH are released into the stroma, and are used to power the dark reaction.

Dark Reaction (Light Independent Reaction)

- The dark reaction is also known as the Calvin Cycle, after an American scientist (Melvin Calvin) who figured out the pathway.
- The Calvin Cycle occurs in the stroma.
- **Steps:**
  1. Carbon dioxide in the air, energy from ATP, and electrons and hydrogen atoms from NADPH produce a series of organic molecules.
  2. Some of these molecules are used to make glucose while others return to the beginning of the cycle to repeat the capture of carbon dioxide.
- Six turns of the Calvin Cycle are required to produce one molecule of glucose.
- Product: Glucose