Biology 112 – Ch. 10: Photosynthesis

Plants make all complex organic molecules on their own!
The overall chemical reaction of photosynthesis:

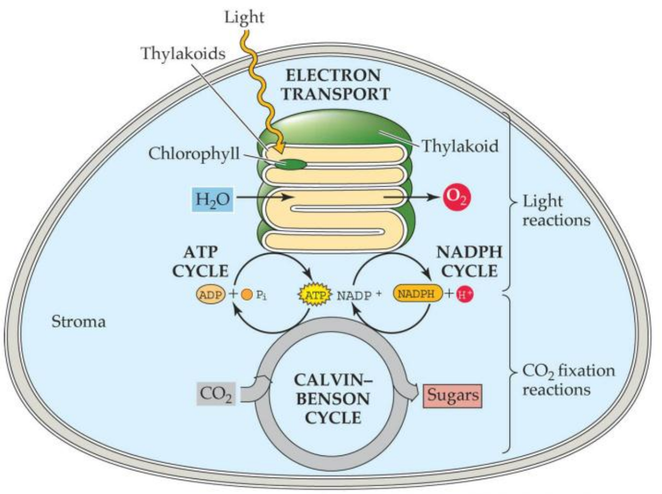
$$6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$$

The reverse reaction is respiration:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

Photosynthesis can be divided into two pathways:

- The **light reaction** is driven by light energy captured by chlorophyll – it produces ATP and NADPH + H+
- The **Calvin-Benson cycle** does not use light directly; it uses ATP, NADPH + H+, and carbon dioxide to produce sugars



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 8.3 An Overview of Photosynthesis (Part 1)

Difference between NAD and NADP

NAD and NADP have the same properties and occur in plants and animals, but are made by separate pathways and are independently regulated

NADP is used exclusively for anabolic (biosynthetic) pathways: excess of NADPH (high [NAPH]/[NADP] ratio) to drive biosynthetic reduction

NAD is used exclusively for catabolic pathways: excess of NAD) low [NADH]/[NAD] ratio) to accelerate oxidation of sugars and generation of NADH

Capture of Light Energy

→ Is it a coincidence that photosynthesis takes place in the same narrow range of wavelength as vision?

X-rays = damage, **visible light = electron transitions that can be transformed into chemical energy**, IR/microwaves = vibrational energy (heat) only

- Plants have two predominate chlorophylls: chlorophyll a and chlorophyll b
- These chlorophylls absorb blue and red wavelengths, which are near the ends of the visible spectrum
- Other **accessory pigments** (e.g. carotenoids) absorb photons between the red and blue wavelengths and then transfer a portion of that energy to the chlorophylls
- Absorption Spectrum: plot of light absorbed by a purified pigment against wavelength

- Action Spectrum: is a plot of the biological activity of an organism as a function of the wavelengths of light to which it is exposed

The light-harvesting complex

- Pigments in photosynthetic organisms are arranged into **antenna systems**
- In these systems, pigments are packed together and attached to thylakoid membrane proteins to enable resonance transfer energy
- The excitation energy is passed to the **reaction center** of the antenna complex (100 chlorophylls plus carotenoids in antenna, but only one chlorophyll is attached to electron acceptor)
- In plants, the pigment molecule in the center is always a special molecule of chlorophyll a; chlorophyll in the reaction center acts like a sink because its excited states has the lowest energy (680nm); all other pigments have excitation wavelengths shorter than 680nm
- Antenna is required because individual chlorophyll molecules are excited too rarely
- Excitation travels from one molecule to the next by resonance energy transfer

Transfer of light energy into chemical energy occurs when the reaction center chlorophyll gives up its excited electron to reduce the first member of the electron transport chain

→ The lose of one electron makes chlorophyll such a strong oxidizing agent that it takes electrons from water

The Light Reactions

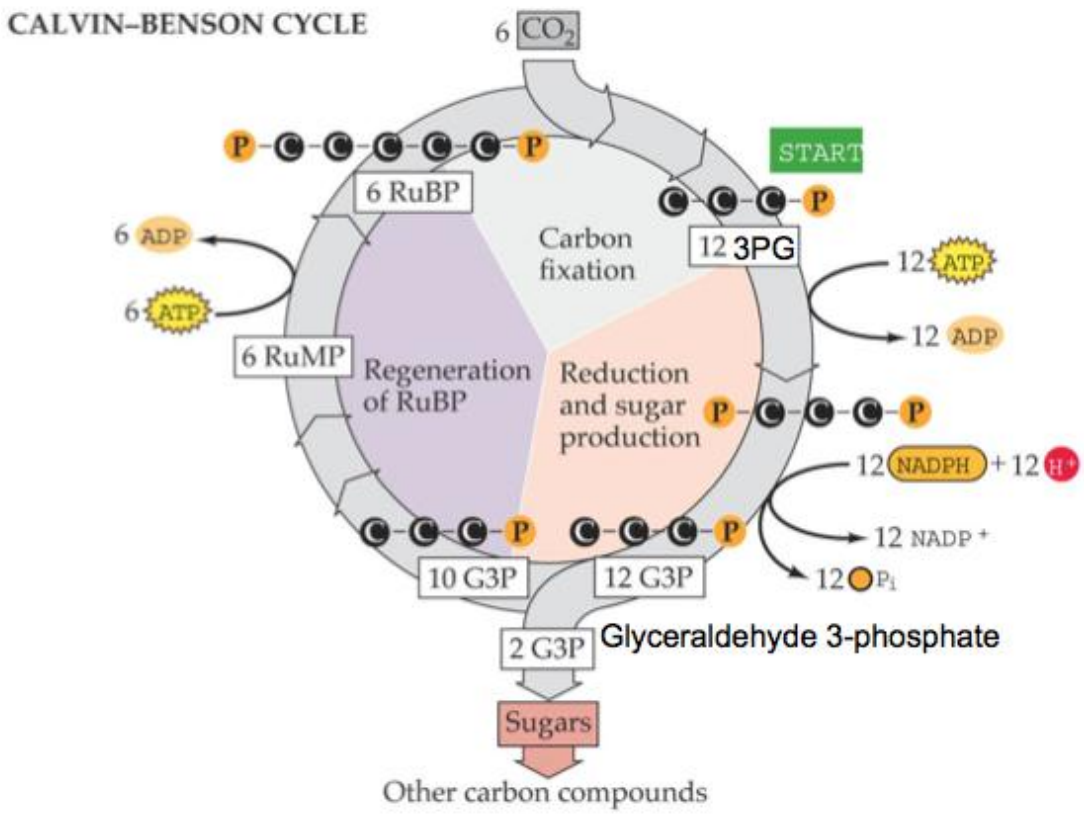
There are two different systems for transport of electrons in photosynthesis

- **Non-cyclic electron transport** produces NADPH + H+ and ATP and oxygen
    - 2 systems required because on quantum of light has not enough energy to transfer electrons from water to NADP+ to make ATP
    - **Photosystem II** uses light energy to oxidize water molecules, producing electrons, protons, and oxygen
    - The reaction center contains a chlorophyll a molecule called P_{680} because it best absorbs light at a wavelength of 680 nm
    - **Photosystem I** uses light energy to reduce NADP+ to NADPH + H+
    - To keep non-cyclic electron transport going, both photosystems must constantly be absorbing light
- **Cyclic electron transport** produces only ATP
    - **Photosystem I only →** electron cycle back to P_{700}; no water is split, no oxygen released; PS1 acts on its own

Proton gradient formation by electron transport chain and synthesis of ATP in the thylakoid membrane is called **photophosphorylation**

Carbon Fixation → Calvin-Benson Cycle

- The reactions of the Calvin-Benson cycle take place in the stroma of the chloroplasts
- This cycle does not use sunlight directly; but it requires the ATP and NADPH + H+ produced in the light reactions, and these can not be "stockpiled"
- Thus, the Calvin-Benson reactions require light indirectly and take place only in the presence of light (like the citric acid cycle, which runs only in the presence of oxygen)



RuBP is the Carbon Dioxide Acceptor → Rubisco is the most abundant protein in the world

Rubisco is a **carboxylase**, adding carbon dioxide to RuBP. At low [CO2] and high [O2] it can also be an **oxygenase,** adding oxygen to RuBP

Photorespiration: light-driven uptake of oxygen and release of carbon dioxide, the carbon being derived from the early reactions of photosynthesis → uses the ATP and NADPH produced in the light reaction without fixing carbon dioxide

Photorespiration becomes a problem in hot weather when stomata are closed to prevent water loss