Photosynthesis: Using Light to Make Food
Chapter 7

Introduction: Plant Power

- Plants use water and atmospheric carbon dioxide to produce a simple sugar and liberate oxygen
  - Earth’s plants produce 160 billion metric tons of sugar each year through photosynthesis, a process that converts solar energy to chemical energy
  - Sugar is food for humans and for animals that we consume

7.1 Autotrophs are the producers of the biosphere

- Autotrophs are living things that are able to make their own food without using organic molecules derived from any other living thing
  - Autotrophs that use the energy of light to produce organic molecules are called photoautotrophs
  - Most plants, algae and some other protists, and some prokaryotes are photoautotrophs
7.1 Autotrophs are the producers of the biosphere

- The ability to photosynthesize is directly related to the structure of chloroplasts
  - **Chloroplasts** are organelles consisting of photosynthetic pigments, enzymes, and other molecules grouped together in membranes

7.2 Photosynthesis occurs in chloroplasts in plant cells

- Chloroplasts are the major sites of photosynthesis in green plants
  - **Chlorophyll**, an important light absorbing pigment in chloroplasts, is responsible for the green color of plants
  - Chlorophyll plays a central role in converting solar energy to chemical energy

- Chloroplasts are concentrated in the cells of the mesophyll, the green tissue in the interior of the leaf
- **Stomata** are tiny pores in the leaf that allow carbon dioxide to enter and oxygen to exit
- Veins in the leaf deliver water absorbed by roots
7.2 Photosynthesis occurs in chloroplasts in plant cells

- An envelope of two membranes encloses the stroma, the dense fluid within the chloroplast
- A system of interconnected membranous sacs called thylakoids segregates the stroma from another compartment, the thylakoid space
  - Thylakoids are concentrated in stacks called grana

7.3 Plants produce O\textsubscript{2} gas by splitting water

- Scientists have known for a long time that plants produce O\textsubscript{2}, but early on they assumed it was extracted from CO\textsubscript{2} taken into the plant
  - Using a heavy isotope of oxygen, \textsuperscript{18}O, they showed with tracer experiments that O\textsubscript{2} actually comes from H\textsubscript{2}O

\begin{align*}
\text{Experiment 1} & \quad 6 \text{CO}_2 + 12 \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{H}_2\text{O} + 6 \text{O}_2 \quad \text{Not labeled} \\
\text{Experiment 2} & \quad 6 \text{CO}_2 + 12 \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{H}_2\text{O} + 6 \text{O}_2 \quad \text{Labeled}
\end{align*}
7.5 Overview: The two stages of photosynthesis are linked by ATP and NADPH

- Actually, photosynthesis occurs in two metabolic stages
  - One stage involves the light reactions
  - In the **light reactions**, light energy is converted in the thylakoid membranes to chemical energy and O$_2$
  - Water is split to provide the O$_2$ as well as electrons

- The second stage is the **Calvin cycle**, which occurs in the stroma of the chloroplast
  - It is a cyclic series of reactions that builds sugar molecules from CO$_2$ and the products of the light reactions
  - During the Calvin cycle, CO$_2$ is incorporated into organic compounds, a process called **carbon fixation**
  - The Calvin cycle is often called the dark (or light-independent) reactions

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**THE LIGHT REACTIONS**: CONVERTING SOLAR ENERGY TO CHEMICAL ENERGY
7.6 Visible radiation drives the light reactions

- Sunlight contains energy called electromagnetic energy or radiation
  - Electromagnetic energy travels in waves, and the **wavelength** is the distance between the crests of two adjacent waves
  - Light behaves as discrete packets of energy called **photons**

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7.6 Visible radiation drives the light reactions

- Pigments, molecules that absorb light, are built into the thylakoid membrane
  - Plant pigments absorb some wavelengths of light and transmit (or reflect) others
  - We see the color of the wavelengths that are transmitted; for example, chlorophyll transmits green
7.6 Visible radiation drives the light reactions

- Chloroplasts contain several different pigments and all absorb light of different wavelengths
  - Chlorophyll \(a\) absorbs blue violet and red light and reflects green
  - Chlorophyll \(b\) absorbs blue and orange and reflects yellow-green
  - The carotenoids absorb mainly blue-green light and reflect yellow and orange

7.7 Photosystems capture solar power

- Pigments in chloroplasts are responsible for absorbing photons (capturing solar power), causing release of electrons
  - The electrons jump to a higher energy level—the excited state—where electrons are unstable
  - The electrons drop back down to their “ground state,” and, as they do, release their excess energy

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7.7 Photosystems capture solar power

- The energy released could be lost as heat or light, but rather it is conserved as it is passed from one molecule to another molecule
  - All of the components to accomplish this are organized in thylakoid membranes in clusters called **photosystems**
7.8 Two photosystems connected by an electron transport chain generate ATP and NADPH

- NADPH, ATP, and O$_2$ are the products of the light reactions
- ATP synthase couples the flow of H$^+$ to the phosphorylation of ADP
  - The chemiosmotic production of ATP in photosynthesis is called **photophosphorylation**

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THE CALVIN CYCLE: CONverting CO$_2$ TO SUGARS

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7.10 ATP and NADPH power sugar synthesis in the Calvin cycle

- The Calvin cycle makes sugar within a chloroplast
  - To produce sugar, the necessary ingredients are atmospheric CO$_2$, ATP, and NADPH, which were generated in the light reactions
  - Using these three ingredients, an energy-rich, three-carbon sugar called glyceraldehyde-3-phosphate (G3P) is produced
    - A plant cell may then use G3P to make glucose and other organic molecules
7.11 Review: Photosynthesis uses light energy, CO\(_2\), and H\(_2\)O to make food molecules

- The chloroplast, which integrates the two stages of photosynthesis, makes sugar from CO\(_2\)
  - All but a few microscopic organisms depend on the food-making machinery of photosynthesis
  - Plants make more food than they actually need and stockpile it as starch in roots, tubers, and fruits