Where It Starts –

*Photosynthesis*

Chapter 6

**Before you go on:**

Review the answers to the following questions to test your understanding of previous material.

1. What are coenzymes (a.k.a. carrier molecules) and how do they function in metabolic pathways?

2. What structural feature(s) of cells enable photosynthesis? What structural feature(s) of cells enable aerobic respiration? For each of the following descriptions, provide at least one example of a cell that can perform:
   a) photosynthesis and aerobic respiration
   b) aerobic respiration, but not photosynthesis

3. Both chloroplasts and mitochondria have specializations for a large amount of surface area. Describe these structural specializations and why they are important to the function of these organelles.
Learning Objectives

1. List the balanced equation that summarizes the complete process of photosynthesis.
2. Describe visible light. What portion of this spectrum of energy is utilized by photosynthetic organisms?
3. What is the relationship between wavelength and light energy?
4. What are pigments and how do they function in photosynthesis?
5. Describe the structure of a leaf. Relate this structure to leaf function as an organ of photosynthesis.
6. Describe the energy capturing reactions (light reactions) of photosynthesis: the precise location, key “players”, products, etc. Briefly describe the two alternative mechanisms (patterns of electron flow) that may produce ATP directly during the light reactions.
7. List and briefly describe the role of the coenzyme NADP in photosynthesis reactions.
8. Describe carbon fixation (dark reactions) of photosynthesis: the precise location, key “players”, products, etc.

Energy Acquisition

- Heterotrophs:
  Consume food to acquire energy
  Is this potential energy or kinetic energy?

- Autotrophs:
  Make their own food (carbohydrates)
  What do autotrophs need to do with these molecules in order to get usable energy?
Sunlight as an Energy Source

- The atom is the source of all electromagnetic radiation
  - Gamma and x-rays from nuclear instability
  - UV, visible light, IR, microwaves and radio waves from electrons changing energy levels
- Photosynthesis runs on a fraction of the electromagnetic spectrum, or the full range of energy radiating from the sun

Are wavelengths other than those in the visible spectrum used by living things? How?

Would animals survive if the amount of visible light reaching the earth’s surface were to dramatically decrease? Why or why not?

Photons

- Packets of light energy
  Photons possess energy and momentum, but no mass
- Each type of photon has fixed amount of energy, related to its wavelength

- Photons having most energy travel as shortest wavelength (blue-green light)
Where are photosynthetic pigments located? Why do they look green?
How do these pigments work in photosynthesis?

T.E. Englemann’s Experiment

Photosynthesis produces O₂ needed by aerobic bacteria

p. 95
Chlorophylls
The main pigments in most photoautotrophs

What wavelengths (colors) are reflected by chlorophylls?

If you’re looking at a red flower, what wavelengths are reflected? Are chlorophylls responsible for this color?

Photosynthesis: Summary Equation

In this metabolic pathway, early reactions depend directly on light (light-dependent); others are fueled by the energy captured by these early reactions (light independent).
How do plants get the necessary ingredients?

- Sun
- CO₂
- H₂O

Stomata

Light-Dependent Reactions

- Pigments absorb light energy, give up e⁻ which enter electron transfer chains
- Pigments that gave up electrons get replacements …from?
- Water molecules are split and oxygen is released, ATP and NADPH are formed …are these stable molecules?

\[
12\text{H}_2\text{O} + 6\text{CO}_2 \xrightarrow{\text{light energy}} \text{enzymes} \xrightarrow{\text{ATP}} \text{oxygen}
\]

Is the CO₂ used in the light reactions? Where are the light reactions taking place?
Photosystems in the Light Reactions

Pigments are molecules that absorb light, arranged in clusters in the thylakoid membranes; called Photosystems (I & II).

1. When a photon of light strikes a photosynthetic pigment, an electron becomes “boosted” to a higher energy level.

2. Energized electrons move further from the nucleus of the atom.

Electron Transfer Chains

- Adjacent to photosystem
- The excited (energized) molecule can pass the energy to another molecule or release it in the form of light or heat.
- As electrons flow through chain, energy they release is used to produce ATP and, in some cases, NADPH
Electron Transport Chain provides the energy to create ATP p. 99

Electron “bucket brigade” drives H⁺ into thylakoid compartment

ATP synthase **turns** with the diffusion of H⁺ to drive ATP formation.

Capturing the Energy of Sunlight in the Thylakoid Membrane

[Diagram of electron transport and ATP synthesis]
Two Stages of Photosynthesis

**Light-Derpendent Reactions**
- Synthesis part of photosynthesis
- Can proceed in the dark
- Take place in the stroma
- Calvin-Benson cycle (Reducing Carbon Dioxide)

**Light-Independent Reactions**

1. $12H_2O + 6CO_2 \rightarrow \text{enzymes} \rightarrow 6O_2 + C_6H_{12}O_6 + 6H_2O$
2. Carried by NADPH
3. Enters through open stomata
Using the Products of Photosynthesis

- Phosphorylated glucose is the building block for:
  - Sucrose
    - The most easily transported plant carbohydrate
  - Starch
    - The most common storage form
  - All other organic compounds: lipids, amino acids, etc.