Chapter 10.1 – 10.2
Photosynthesis:
Life from Light

Energy needs of life
- All life needs a constant input of energy
  - Heterotrophs
    - get their energy from eating others: “other feeders”
    - consumers of other organisms
    - consume organic molecules
  - Autotrophs
    - get their energy from “self”
    - get their energy from sunlight
    - use light energy to synthesize organic molecules

How are they connected?

Heterotrophs
making energy & organic molecules from ingesting organic molecules

\[
\text{glucose + oxygen} \rightarrow \text{carbon + water + energy} \rightarrow \text{dioxide}
\]
\[
\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{ATP}
\]

Autotrophs
making energy & organic molecules from light energy

\[
\text{carbon dioxide} + \text{water + energy} \rightarrow \text{glucose + oxygen}
\]
\[
6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2
\]

What does it mean to be a plant?
- Need to...
  - collect light energy
  - transform it into chemical energy
  - store light energy
    - in a stable form to be moved around the plant
    - also saved for a rainy day
  - need to get building block atoms from the environment
    - C, H, O, N, P, S
  - produce all organic molecules needed for growth
    - carbohydrates, proteins, lipids, nucleic acids

How are they connected?
Plant Structure
- Obtaining raw materials
  - sunlight
    - leaves = solar collectors
  - $\text{CO}_2$
    - stomates = gas exchange
  - $\text{H}_2\text{O}$
    - uptake from roots
    - ‘nutrients’
    - uptake from roots

Photosynthesis Overview
- "Light" reactions (Light-Dependent Rxns)
  - convert solar energy to chemical energy
  - sun $\rightarrow$ ATP
- Calvin cycle
  - uses chemical energy (NADPH ATP) to reduce $\text{CO}_2$ to build $\text{C}_6\text{H}_12\text{O}_6$ (sugars)

A Look at Light
- The spectrum of color
  - Shorter wavelength $\rightarrow$ Longer wavelength
  - Higher energy $\rightarrow$ Lower energy

Light: Absorption Spectra
- Photosynthesis performs work only with absorbed wavelengths of light
  - chlorophyll a — the dominant pigment — absorbs best in red & blue wavelengths & least in green
  - other pigments with different structures have different absorption spectra

Chloroplasts
- Chloroplasts are green because they absorb light wavelengths in red & blue and reflect green back out
  - structure $\leftrightarrow$ function
Chloroplast Structure

- Chloroplasts
  - double membrane
  - stroma
  - thylakoid sacs
  - grana stacks
- Chlorophyll & ETC in thylakoid membrane
  - H⁺ gradient built up within thylakoid sac

Pigments of Photosynthesis

- chlorophyll & accessory pigments
  - “photosystem”
  - embedded in thylakoid membrane
  - structure → function

Photosystems

- Collections of chlorophyll molecules
- 2 photosystems in thylakoid membrane
  - act as light-gathering “antenna complex”
    - Photosystem II
      - chlorophyll a
      - P₆₈₀ = absorbs 680nm wavelength red light
    - Photosystem I
      - chlorophyll b
      - P₇₀₀ = absorbs 700nm wavelength red light

Light Reactions

- Similar to ETC in cellular respiration
  - membrane-bound proteins in organelle
  - electron acceptor
    - NADPH
  - proton (H⁺) gradient across inner membrane
  - ATP synthase enzyme

The ATP that Jack built

- moves the electrons
- runs the pump
- pumps the protons
- forms the gradient
- releases the free energy
- allows the Pᵢ to attach to ADP
- forms the ATP

ETC of Respiration

- Mitochondria transfer chemical energy from food molecules into chemical energy of ATP
  - use electron carrier NADH

... that evolution built
**Chloroplasts** transform light energy into chemical energy of ATP
- use electron carrier NADPH

**ETC of Photosynthesis**

- **ETC produces from light energy:**
  - ATP & NADPH
  - NADPH (stored energy) goes to Calvin cycle
- **PS II absorbs light**
  - excited electron passes from chlorophyll to “primary electron acceptor”
  - need to replace electron in chlorophyll
  - enzyme extracts electrons from H₂O & supplies them to chlorophyll
    - splits H₂O
    - O combines with another O to form O₂
    - O₂ released to atmosphere
    - and we breathe easier!

**Experimental Evidence**

- **Where did the O₂ come from?**
  - radioactive tracer = O₁₈

- **Experiment 1**
  - 6CO₂ + 6H₂O + light energy → C₆H₁₂O₆ + 6O₂

- **Experiment 2**
  - 6CO₂ + 6H₂O + light energy → C₆H₁₂O₆ + 6O₂

Proved O₂ came from H₂O not CO₂ = plants split H₂O

**2 Photosystems**

- Light reactions elevate electrons in 2 steps (PS II & PS I)
  - **PS II** generates energy as ATP
  - **PS I** generates reducing power as NADPH

**Cyclic Photophosphorylation**

- If PS I can’t pass electron to NADP, it cycles back to PS II & makes more ATP, but no NADPH
  - coordinates light reactions to Calvin cycle
  - Calvin cycle uses more ATP than NADPH
**Photophosphorylation**

**cyclic photophosphorylation**

**noncyclic photophosphorylation**

---

**Photosynthesis summary**

Where did the energy come from?
Where did the $\text{H}_2\text{O}$ come from?
Where did the electrons come from?
Where did the $\text{O}_2$ come from?
Where did the $\text{H}^+$ come from?
Where did the ATP come from?
Where did the $\text{O}_2$ go?
What will the ATP be used for?
What will the NADPH be used for?

...stay tuned for the Calvin cycle