Introduction

Photosynthesis represents for the biosphere the major source of
- Free energy ($10^{17}$ kcal/year stored)
- Carbon ($10^{10}$ tons/year assimilated)
- Oxygen

$$\text{CO}_2 + \text{H}_2\text{O} \xrightarrow{\text{light}} \text{(CH}_2\text{O}) + \text{O}_2$$

Overview

Analogous to the combination of oxidative phosphorylation and the citric acid cycle.

1. Chloroplasts

Like oxidative phosphorylation, photosynthesis is compartmentalized
Mitochondria

Mitochondria are bound by a double membrane.

2. Electron Transfer

Light absorption by chlorophyll induces electron transfer.

Absorption of light leads to photoinduced charge separation.

Absorption of light leads to photoinduced charge separation.
2.1 Bacteria vs. Green Plants

Plants have two photosystems

- Photosystem I
  - 13 polypeptide chains
  - 60 Chlorophylls
  - 3 Fe4S centers
  - 1 Quinone

- Photosystem II
  - 10 polypeptide chains
  - 30 Chlorophylls
  - 1 Non-heme Fe
  - 4 Mn2+2, Mn2+, Mn3+, Mn4+

2.1 Bacteria vs. Green Plants

Bacteria have a single system

- 4 Bacteriochlorophyll b
- 2 Bacteriopheophytin b
- 2 Quinones
- 1 Fe2+
2.3 Electron Transfer

The rate of electron transfer is dependent on two factors:

Distance | Driving Force
---|---

![Graph showing distance vs. driving force]

3.3 Q-Cytochrome c Oxidoreductase

The Q cycle:

\[ \text{QH}_2 + 2 \text{Cyt b} \rightarrow 2 \text{H}^+ + \text{Q} \rightarrow 2 \text{Cyt b} + 4 \text{H}^+ + \text{QH}_2 \]

3. Two Photosystems of Plants

In green plants there are two photosynthetic reaction centers.

![Diagram of two photosystems]

3.1 Photosystem II

The core of PSII is similar to the bacterial system.

![Diagram of PSII core]
3.1 Photosystem II

$$2Q + 2H_2O \rightarrow O_2 + 2QH_2$$

Four photons are required to generate one oxygen molecule.

The 4 Manganese center is where the electrons are extracted from the water.

An equivalent of 4 H+ are moved across the thylakoid membrane by PSII.
3.2 Cytochrome bf

The cytochrome bf complex transfers the electrons from plastocyanine to platocyanin:

$$2\text{QH}_2 + 2\text{Cu}^{2+} \rightarrow \text{Q} + 2\text{Cu}^{2+} + 2\text{H}^+ + \text{bacterio}$$

3.3 Q-Cytochrome c Oxidoreductase

The Q cycle:

$$\text{QH}_2 + 2\text{Cu}^{2+} + 2\text{H}^+ \rightarrow \text{Q} + 2\text{Cu}^{+} + 4\text{H}^+$$

3.3 Photosystem I

Though larger, the core of PSI is also similar to the bacterial system.
3.3 Photosystem I

The receptor of the electrons from PSI is the small one-electron redox protein, Ferredoxin.

3.3 Photosystem I

\[ \text{Pc}(\text{Cu}^+) + \text{Fd}_{\text{ox}} \rightarrow \text{Pc}(\text{Cu}^{2+}) + \text{Fd}_{\text{red}} \]

3.3 Photosystem I

The Z-scheme of photosynthesis

3.4 Ferredoxin-NADP\(^+\) Reductase

Ferredoxin-NADP\(^+\) reductase
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Ferredoxin-NADP\(^+\) reductase contains the coenzyme FAD.

4. The Proton Gradient

PSII, Cytochrome b\(_f\) and ferredoxin-NADP\(^+\) reductase each contribute to the proton gradient.

André Jagendorf's demonstration in 1966, was one of the earliest pieces of evidence to support Peter Mitchell's chemiosmotic hypothesis.
4.1 ATP Synthase

The ATP synthase closely resembles the ATP synthase of mitochondria.

4.1 ATP Synthase

Comparing photosynthesis to oxidative phosphorylation:

4.2 Flow of Electrons Through Photosystem I

Normally photosynthesis produces both ATP and NADPH.

When there is not NADP⁺ available, cyclic flow of electrons through PSI can be used to produce ATP without reducing NADP⁺.

4.2 Flow of Electrons Through Photosystem I

Cyclic flow of electrons through PSI:
4.3 Stoichiometry of Photosynthesis

\[ 2 \text{H}_2\text{O} + 2 \text{NADP}^+ + 10 \text{H}^+_{\text{mem}} \rightarrow \text{O}_2 + 2 \text{NADPH} + 12 \text{H}^+_{\text{mem}} \]

12 protons are expected to be used for one turn of the ATP synthase, therefore, producing 3 ATPs from 3ADP's and 3P_i's.