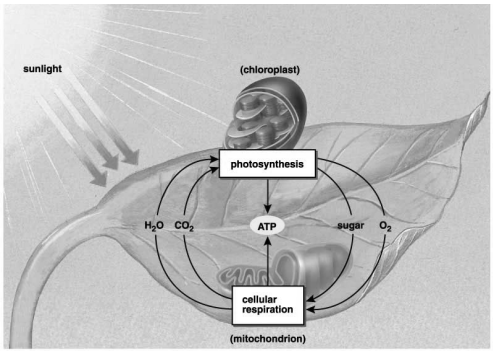
Chapter 7

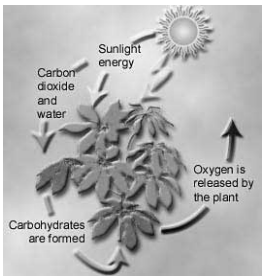
Capturing Solar Energy: Photosynthesis



Overview - the process that feeds the biosphere

Photosynthesis: transformation of solar energy into chemical energy.

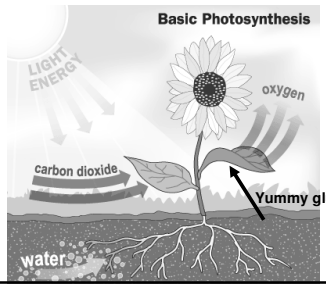
Responsible for O_2 in our atmosphere



	Autotrophs *"producers"*	*Heterotrophs* *"consumers"*
Carbon source	(phototrophs) CO_2	organic molecules "food"
Energy source	sunlight	organic molecules

Photosynthesis

- Making food out of energy
  - ❖Sunlight is the main source of energy in photosynthesis.
- Sunlight has different light wavelenths.



What is Photosynthesis?

Answer: The capture of sunlight energy and the subsequent storage of that energy in chemical bonds (glucose)

Chemical Reaction:

$$6\ CO_2 + 6\ H_2O + \text{Light Energy} = C_6H_{12}O_6 + 6\ O_2$$

Carbon Dioxide — Water — Glucose — Oxygen

Autotrophs ("self-feeders"): Make their own food using sunlight

- Plants (Eukaryotes)
- Algae (Eukaryotes)
- Bacteria (Prokaryotes)

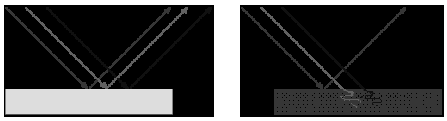
Sunlight wavelengths

- Short wavelengths: greater energy
  - ❖UV light has the greatest energy, but cannot be seen by human eye.
- Visible light (to humans): 400 – 750
  - ❖These light wavelengths are the only ones used in photosynthesis.

B. The photosynthetic pigments: light receptors

Pigment - molecule that absorbs light in the visible range.

1. wavelengths absorbed - not seen
2. wavelengths transmitted / reflected = pigment color



Not a pigment **A red pigment**

What color is **reflected** in these pigments?

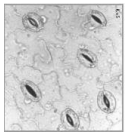
What colors are ***absorbed*** in these pigments?

Leaves and Chloroplasts are Adaptations for Photosynthesis:

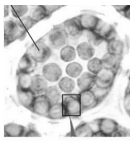
Leaf Design:

- Flattened shape (large surface area)
- Thin (light can penetrate entire leaf)
- Surrounded by a Cuticle:
  - ❖Waxy covering that prevents water loss
- Contain Stomata:
  - ❖ Adjustable openings that regulate CO_2 uptake and O_2 release
- Filled with Mesophyll Cells:
  - ❖Contain majority of chloroplast organelles
- Contain Vascular Bundles (Veins):
  - ❖Supply water / minerals; Carry away sugars

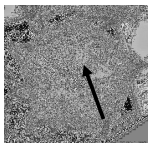
Leaf parts



Stomata



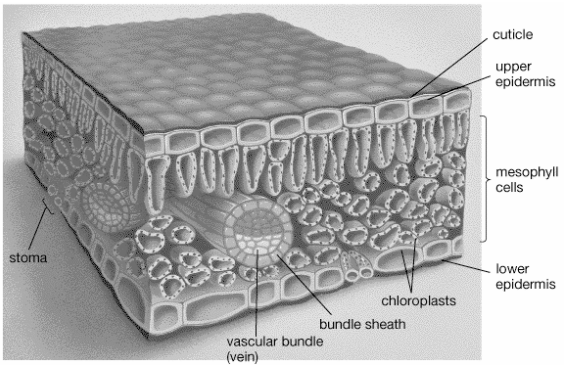
Mesophyll cell (with many chloroplasts)



Vascular bundles

(Figure 7.2)

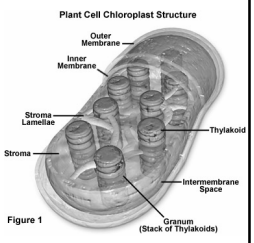
Leaf Structure:



Leaves and chloroplasts are adaptations for photosynthesis:

Chloroplast Design:

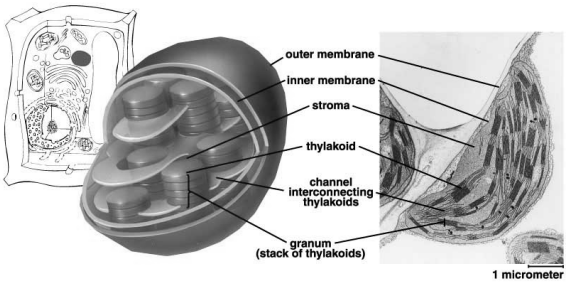
- Contain two membranes
  (inner and outer)
- Filled with **Stroma:**
  - ❖ Semi-fluid medium
    (light-independent reactions)



- Contain stacks of **Thylakoids (Grana):**
  - ❖ Location of chlorophyll
    (light dependent reactions)

(Figure 7.2)

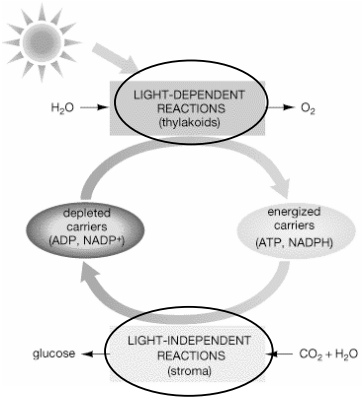
Chloroplast Structure:



Overview of Photosynthesis:

Two reactions:

1. Light dependent
2. Light independent
   AKA dark reactions



Light Dependant Reactions:
The Conversion of Light Energy to Chemical Energy

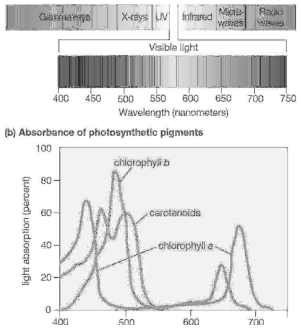
1) Light is captured by pigments in chloroplast
   - Photon: Packet of light energy
   - When photon hits leaf, the light is either:
     1) Absorbed
     2) Reflected (bounced back)
     3) Transmitted (passes through)
   - Chlorophyll and accessory pigments (*e.g.* carotenoids) absorb specific wavelengths of light

Pigment Absorption:

Chlorophyll (a vs. b):
- Blue & red light

Carotenoids:
- Blue & green light

Why do many leaves turn yellow in fall?



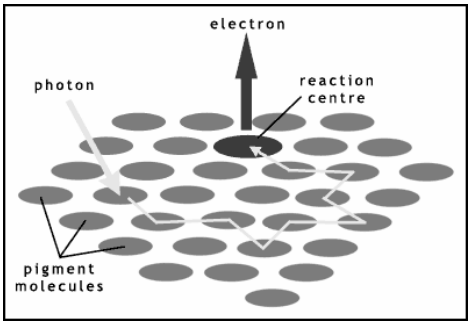
(Figure 7.5)

Light Dependant Reactions:

The Conversion of Light Energy to Chemical Energy

2) Light energy transferred to energy-carrier molecules
- Reactions clustered in Photosystems (located in Thylakoids)
  1) Light-harvesting Complex (Gathers light)
  2) Electron Transport System (Energy-carrier molecules)
- Photosystems utilize light energy to produce an energy transport molecule
  - Photosystem II generates **ATP**
  - Photosystem I generates **NADPH**

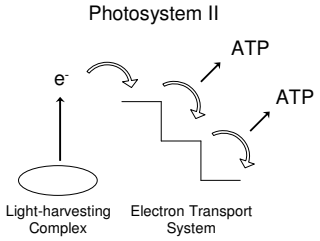
A typical photosystem in the thylakoid



Sequence of Events in Light Dependent Reactions:

Photosystem II:

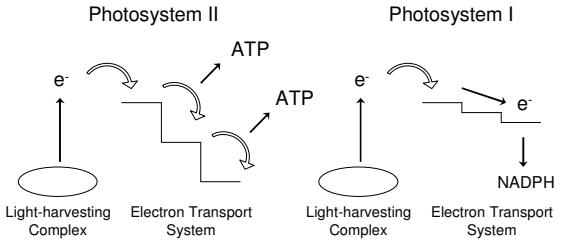
1) Light energy excites electron in light-harvesting complex
2) Electron transport system accepts excited electron
3) ETS uses electron energy to synthesis ATP (chemiosmosis)



Sequence of Events in Light Dependent Reactions:

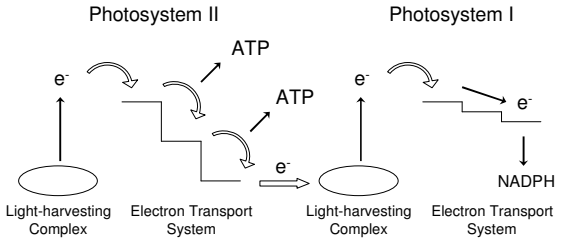
Photosystem I (same time as photosystem II):

1) Light energy excites electron in light-harvesting complex
2) Electron transport system accepts excited electron
3) ETS captures electron to form NADPH



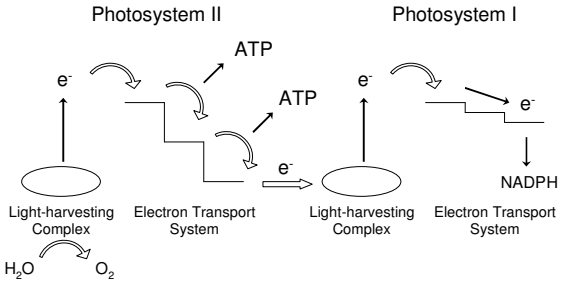
Sequence of Events in Light Dependent Reactions:

- Electrons lost in Photosystem I are replaced by electrons from Photosystem II:

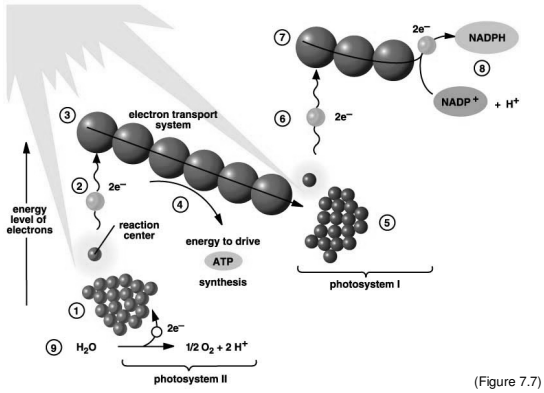


Sequence of Events in Light Dependent Reactions:

- Electrons lost from Photosystem II are replaced by splitting water to form oxygen



Light-dependant Reactions:



(Figure 7.7)

Light Independent Reactions:

Energy is Stored in Glucose Molecules

$$CO_2 + H_2O \xrightarrow{\text{ATP, NADPH}} C_6H_{12}O_6$$

Carbon Dioxide — Water — Glucose

- Energy from ATP & NADPH are necessary to drive process
- Occurs in stroma of the chloroplast

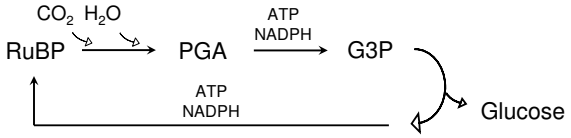
Calvin-Benson Cycle: Set of reactions which capture carbon dioxide
(C3 Cycle)

Requires:

1) Carbon Dioxide (from air) (CO_2)
2) Ribulose Bisphosphate (RuBP) : A CO_2 capturing sugar
3) Multiple enzymes (to catalyze reactions)
4) Energy (ATP & NADPH)

Sequence of Events in Calvin-Benson (C_3) Cycle:

1) Carbon Fixation
   - CO_2 combines with ribulose bisphosphate (RuBP) to form phosphoglyceric acid (PGA)
2) PGA is converted to glyceraldehyde-3-phosphate (G3P)
   - Requires energy
   - G3P converted into glucose (1 glucose from 6 CO_2)
3) G3P converted back to RuBP (requires energy)



Fate of Glucose:

1) Broken down for energy
2) Stored as starch (energy storage)
3) Converted to cellulose (structure)
4) Other chemical modifications (e.g. glycoprotein)

Plants must balance between obtaining CO_2 and H_2O loss

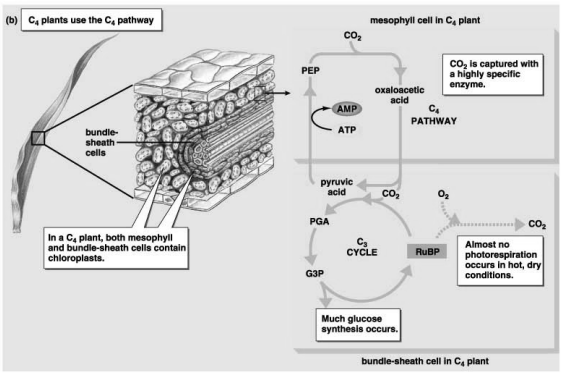
- Cool, wet conditions → stomata open (plenty CO_2)
- Hot, dry conditions → stomata close (low CO_2)
  - Photosynthesis inefficient (photorespiration)

Plants living in arid conditions (*e.g.* corn) use C_4 pathway:

- CO_2 initially captured as oxaloacetate (mesophyll cells)
- Oxaloacetate releases CO_2 to bundle-sheath cells where photosynthesis continues as normal (↑ $[CO_2]$)

C_4 Pathway:

(Figure 7.12)



(Figure 7.11)

Photosynthesis Review: