Photosynthesis
Figure 4-10 Photosynthesis: the big picture.
Photosynthesis in Overview

• Process by which plants and other autotrophs store the energy of sunlight into sugars.

• Requires sunlight, water, and carbon dioxide.

• Overall equation:

\[ 6 \text{ CO}_2 + 6 \text{ H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2 \]

• Occurs in the leaves of plants in organelles called chloroplasts.
PHOTOSYNTHESIS!

- a reaction whereby **plants** are able to **convert** the **sun’s energy** into **glucose**!

- photosynthesis happens in:
  - plants!
  - algae!
  - plant-like protists!
  - cyanobacteria!

- Photosynthesis starts when **CHLOROPHYLL** absorbs light energy and begins the process!
PHOTOSYNTHESIS!

- Chlorophyll molecules contain a **porphyrin ring** and long **hydrocarbon tail**.
- The **tail is hydrophobic** anchors the molecule into a membrane.
- The **porphyrin ring contains electrons** that absorb **light energy** and begin the process of photosynthesis.
PHOTOSYNTHESIS!

• Where does photosynthesis happen?!?!?!

IN THE LEAVES!!!

The primary function of a leaf is photosynthesis!

Their arrangement on stems and branches maximizes the surface area exposed to sunlight!
Leaf is coated with a water-resistant **waxy cuticle** layer.

**Epidermis** layer is transparent and colorless and allows light to pass freely.

**Chloroplasts** are most abundant in the **mesophyll cells** – this is where most of photosynthesis takes place!
Guard cells create microscopic openings called stomata.

Stomata = openings on the surface of the leaf that regulate the exchange of CO₂ and O₂ with the atmosphere.

Stomata = also allow water vapour to escape by transpiration.
PHOTOSYNTHESIS!

• The chloroplast is the photosynthesis factory!!!

Chloroplasts are surrounded by a double membrane.

The membranes enclose an interior space filled with a protein-rich semiliquid material called STROMA.

Within the stroma, a system of membrane-bound sacks called THYLAKOIDS stack on top of one another to form columns called GRANA.
PHOTOSYNTHESIS!

- The **chloroplast** is the photosynthesis factory!!!

  Adjacent grana are connected to one another by unstacked thylakoids called **LAMELLAE**.

Photosynthesis happens partly within the stroma and partly within the thylakoid membrane.

**The thylakoid membrane contains CHLOROPHYLL!!!**
PHOTOSYNTHESE!

- The overall process of photosynthesis is summarized in the following chemical equation:

\[ 6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l}) + \text{light energy} \rightarrow \rightarrow \rightarrow \text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) + 6\text{O}_2(\text{g}) \]

In other words, **carbon dioxide** from the atmosphere, and **water** from the soil along with the **sun’s light energy** are used by plants to produce **glucose** (plant food) and **oxygen** is released into the atmosphere.
• Photosynthesis can be divided into 2 sequential processes:

» 1. THE LIGHT REACTIONS – require chlorophyll and occur on the thylakoid membranes in chloroplasts

» 2. CARBON FIXATION (Calvin Cycle) – takes place in the stroma and require the energy of ATP and reducing power of NADPH.
The light reactions begin when photons of light strike a photosynthetic membrane.

- There are 3 steps to this process...
  - **PHOTOEXCITATION** – the absorption of a photon by an electron of chlorophyll
  - **ELECTRON TRANSPORT** – electrons are pumped through a series of electron carriers, creating an H+ reservoir
  - **CHEMIOSMOSIS** – the movement of protons (H+) through ATPase complexes to drive ADP to ATP
LIGHT REACTIONS

- The major end result of the light reaction is...

The energy of light is transferred to ATP and NADPH

ATP and NADPH head into the next step = CALVIN CYCLE
In a chloroplast molecule, light is not absorbed by independent chlorophyll pigment molecules.

Light is absorbed by a chlorophyll molecule that is associated with proteins in clusters called PHOTOSYSTEMS.

Chloroplast thylakoid membranes contain two types of photosystems:

PHOTOSYSTEM I

PHOTOSYSTEM II
Photosystem I and II have differing absorption spectrums.

**LIGHT REACTIONS**

**PHOTOSYSTEM 1** – contains chlorophyll P700 – absorbs red light

**PHOTOSYSTEM 2** – contains chlorophyll P680 – absorbs red light

Plants use Photosystems I and II to produce ATP and NADPH via non-cyclic electron flow.
LIGHT REACTIONS

- http://www.youtube.com/watch?v=hj_WKgnL6MI
**CALVIN CYCLE**

- **occurs in the stroma** of the chloroplast
- is a **cyclic series** of reactions
- CO$_2$ is converted into carbohydrates using NADPH and ATP
The Calvin Cycle can be divided into 3 phases:

- 1. CARBON FIXATION
- 2. REDUCTION REACTIONS
- 3. RIBULOSE 1,5 BISPHOSPHATE (RuBP) REGENERATION
STAGE ONE: CARBON FIXATION

**CO$_2$** adds to an already existing 5-carbon molecule (**RuBP**).

This forms an unstable 6-carbon intermediate that instantly splits into 3-carbon molecules (**3-PGA**).

These reactions are catalyzed by the enzyme **RUBISCO**.
STAGE TWO: REDUCTIONS

Each of the six PGA molecules is phosphorylated by ATP.

This results in 6 molecules of 1,3-BPG.

6 electron pairs from 6 NADPH molecules reduces the 6 molecules of 1,3-BPG.

This results in 6 molecules of G3P.

**G3P exits as a final product**
STAGE THREE: REGENERATION OF RuBP

In a series of enzyme-catalyzed reactions, the remaining 5 G3P molecules are rearranged to regenerate 3 molecules of RuBP.

3 molecules of ATP are used in this process!

Once RuBP is regenerated, the cycle can fix more CO$_2$ molecules.
• The G3P molecules that leave the Calvin Cycle are then used to synthesize carbohydrates like glucose.

• **NOTE** It takes the fixation of 3CO₂ molecules to produce ONE molecule of G3P that can leave the cycle.

• To make glucose, you require 2 molecules of G3P

• Thus, it takes 6 turns of the calvin cycle or 6CO₂ molecules to synthesize ONE glucose molecule!
CALVIN CYCLE

- http://www.youtube.com/watch?v=CUZXWHoiOSs