Unit 5: Cellular Respiration and Photosynthesis

How do cells obtain energy from food molecules?

1. Cellular respiration release energy from food molecules
2. Glycolysis begins the production of Energy
3. The Krebs Cycle completes the breakdown of glucose
4. The Electron Transport System packages energy from glucose to ATP
5. Anaerobic respiration works in the absence of oxygen

How do plants use photosynthesis to convert solar energy to chemical energy?

1. Photosynthesis harnesses light energy
2. The Calvin Cycle combines hydrogen with Carbon Dioxide to produce sugars.
3. Environmental factors affect the rate of photosynthesis

It is an extremely simple cellular process.

That is also extremely important

It takes place in the Chloroplasts

And requires the green pigment **Chlorophyll.**

It was used to create the oxygen in the Earth's atmosphere.

It transformed the way organisms **use energy.**

And it requires **light.**

It takes place in two phases.

It takes place in two phases.

The light dependent reactions capture light and turn it into ATP and NADPH

The Calvin Cycle uses ATP and NADPH to make glucose.

The formula is the thinnest and most light (dependent) yet

$$6\ CO_2 + 6\ H_2O \xrightarrow{light} C_6H_{12}O_6 + 6O_2$$

And heterotrophs can’t wait to see where it turns up next.

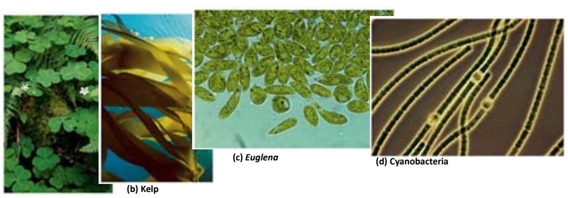
Introducing…

Photosynthesis

Designed by Leaf in Connecticut

THE BASICS OF PHOTOSYNTHESIS

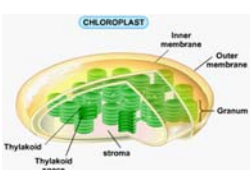
- Green plants are photosynthetic autotrophs, as are some bacteria and protists
  - Autotrophs generate their own food through photosynthesis
  - Solar energy is transferred to the chemical bonds in sugar

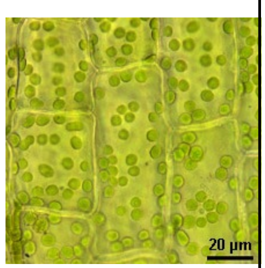


(a) Mosses, ferns, and *flowering plants* (b) Kelp (c) *Euglena* (d) Cyanobacteria

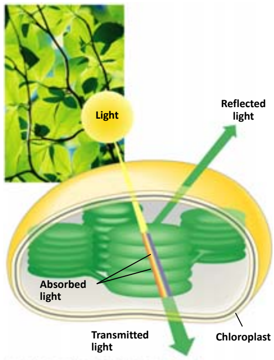
Plant Cells have Green Chloroplasts

The membranes inside the chloroplast are impregnated with the green photosynthetic pigment chlorophyll.





Chloroplasts absorb **light energy** and convert it to **chemical energy**

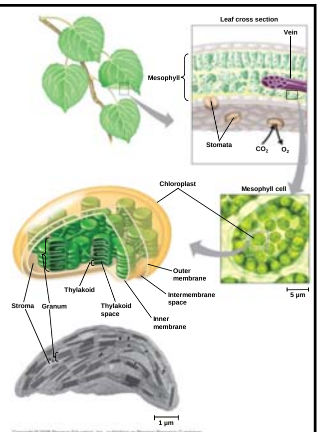


Light energy absorbed by chlorophyll drives the synthesis of organic molecules in the chloroplast

A typical leaf cell has 30–40 chloroplasts.

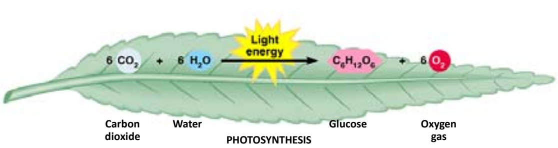
The chlorophyll is in the membranes of **thylakoids** (sacs).

Chloroplasts also contain **stroma**, a dense fluid

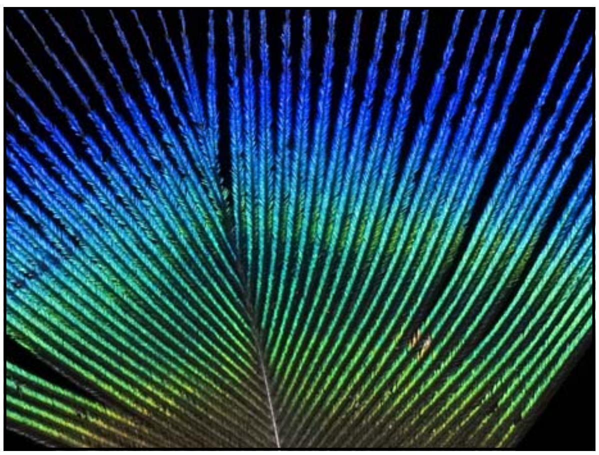


PHOTOSYNTHESIS

Photosynthesis is the process by which autotrophic organisms use light energy to make sugar and oxygen gas from carbon dioxide and water



Why do plants look green?

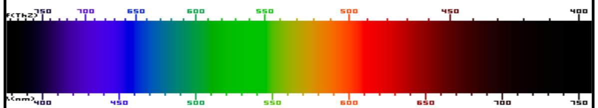


In order to understand the plant's relationship to light you must first understand light itself.

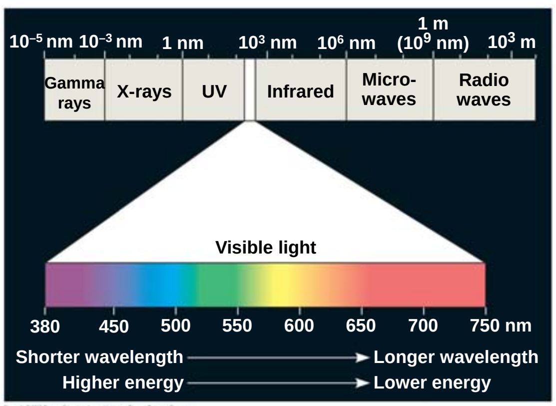
Light is electromagnetic radiation

Light is **electromagnetic radiation** with a wavelength that is visible to the eye.

A typical human eye will respond to wavelengths from 400 to 700 nm.



The different wavelengths are detected by the human eye and then interpreted by the brain as colors, ranging from red at the longest wavelengths to violet at the shortest wavelengths.



Physically surfaces can be said to have the color of the light reflecting off them.

In other words a green plant is green because it *reflects green light*

Physically surfaces can be said to have the color of the light reflecting off them.

A white object reflects all colors of light and a black object absorbs all the colors.

When using the additive method, the primary colors are red, blue, and green. The more additive primaries you add, the lighter the resultant color. Mix all three and you get white.

The subtractive primaries are red, blue, and yellow--to be exact, magenta, cyan (light blue), and yellow. These are the colors that, together with black, are used in color printing.

The more subtractive primaries you mix, the **darker the color**. Mix all three and you get black (OK, brown, but with the school's art supplies budget you can't expect miracles).

In general additive primaries involve adding more LIGHT (as in a color TV), while subtractive primaries involve mixing more PIGMENT (as in paints and crayons).

How do we make yellow?

By adding full-strength red and full-strength green. Adding two-thirds strength blue gives us a lighter (not darker) yellow.

This is a counterintuitive result if you learned your color-mixing skills in kindergarten. But we know that white light can be broken into all the colors of the rainbow. So we shouldn't be surprised to learn the process also works in reverse, the colors of the rainbow can be combined to make white.

Besides, it only stands to reason that the more light you shine on something, the brighter (that is, closer to white) it gets.

Using the additive color system:

Green + red = yellow
Green + blue = cyan (light blue)
Red + blue = magenta
Red + blue + green = white

Every year in the early spring, Hindus observe Holi—the festival of colors.

wait….where were we?

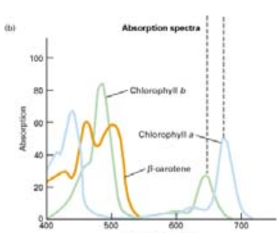
Plants use pigments to absorb light energy

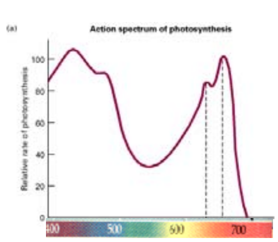
Each pigment absorbs light differently

There are several kinds of chlorophylls. The two most common types are **chlorophyll a** and **chlorophyll b**. A slight difference in molecular structure between a and b causes the two molecules to **absorb different colors of light.**

- Chlorophyll a absorbs less blue light but more red light than chlorophyll b does.

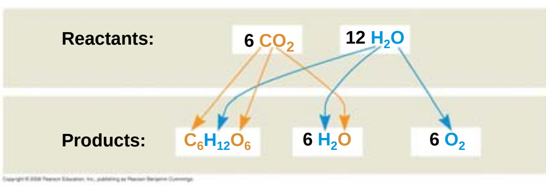
Neither chlorophyll a nor chlorophyll b absorbs much green light.





Other compounds found in the thylakoid membrane, including the yellow, orange, and brown carotenoids function as accessory pigments. In the fall the chlorophylls are broken down and stored underground for the winter leaving the accessory pigments visible.

Photosynthesis is a redox process in which H_2O is oxidized and CO_2 is reduced

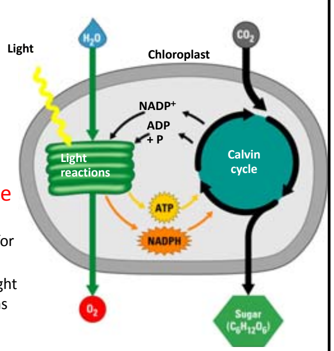


Chloroplasts split H_2O into hydrogen and oxygen, incorporating the electrons of hydrogen into sugar.

PHOTOSYNTHESIS in TWO STEPS

1
- The light reactions convert solar energy to chemical energy
  - Produce ATP & NADPH

2
- The Calvin cycle makes sugar from carbon dioxide
  - ATP generated by the light reactions provides the energy for sugar synthesis
  - The NADPH produced by the light reactions provides the electrons for the reduction of carbon dioxide to glucose



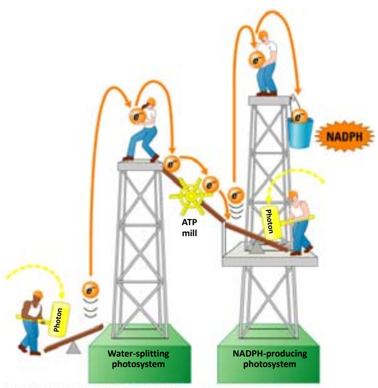
Step One

In the light reactions, light hits reaction centers of chlorophyll, found in chloroplasts

Chlorophyll "vibrates" and causes **water to break apart**.

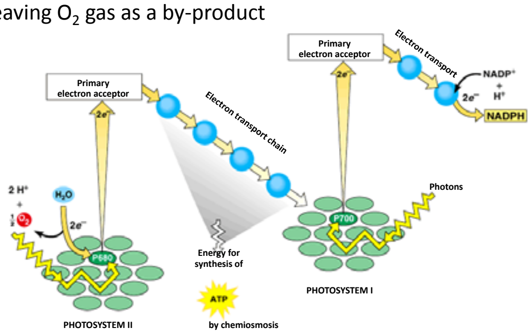
The Oxygen (from H_2O)is released into air and the Hydrogen remains in chloroplast where it is attached to NADP **to form NADPH**

Two photosystems cooperate in the light reactions

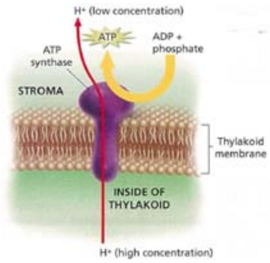


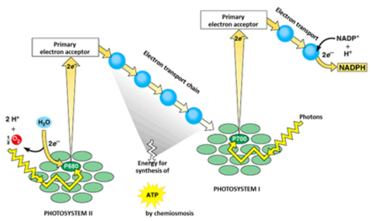
Noncyclic Photophosphorylation

Photosystem II regains electrons by splitting water, leaving O_2 gas as a by-product



The photosystems build up a concentration gradient of protons inside the thylakoid

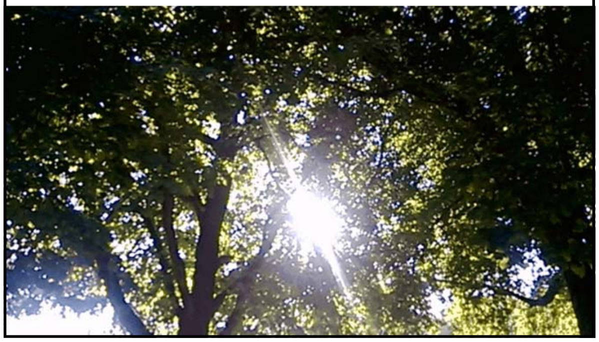




- The concentration gradient of protons represents potential energy.
- A thylakoid membrane protein called ATP synthase makes ATP by adding a phosphate group to adenosine diphosphate (ADP).
- The energy that drives this reaction is provided by the movement of protons from the inside of the thylakoid to the stroma.
- In other words ATP synthase converts the potential energy of the proton concentration gradient into chemical energy stored in ATP.

Plants produce O_2 gas by splitting H_2O

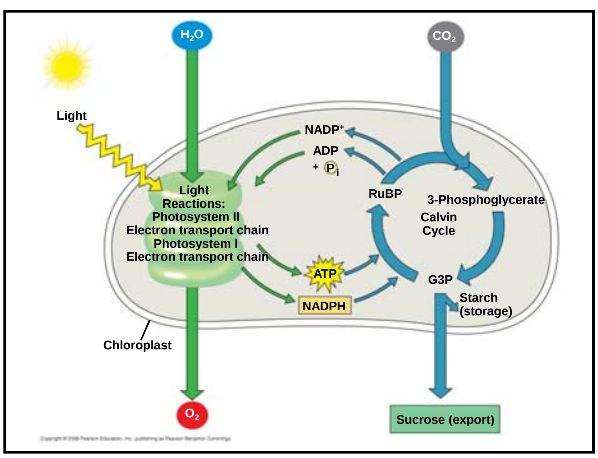
In summary, light reactions generate ATP and increase the potential energy of electrons by moving them from H_2O to NADPH



Steps of Photosynthesis

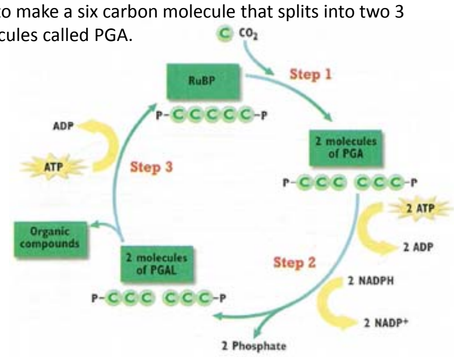
The DARK Reactions = The Calvin Cycle

CO_2 from the atmosphere is joined to H from the water molecules (NADPH) to form glucose



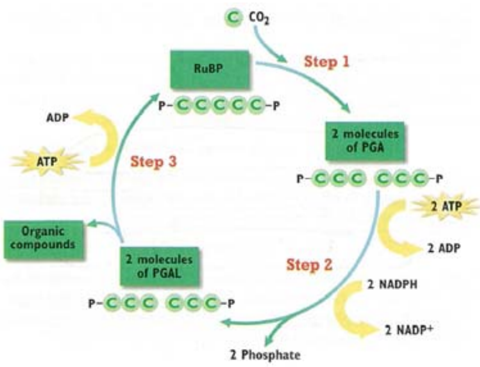
Calvin Cycle

Step 1: An enzyme combines the CO_2 with a five carbon molecule called RuBP to make a six carbon molecule that splits into two 3 carbon molecules called PGA.



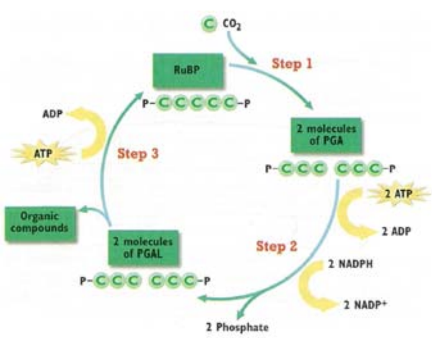
Calvin Cycle

Step 2: Each PGA is converted into a molecule of PGAL.



Calvin Cycle

Step 3: Most of the PGAL is converted into RuBP in a complicated series of reactions. PGAL can also be used to eventually make glucose.



The Two Stages of Photosynthesis

- Photosynthesis consists of the **light reactions** (the *photo* part) and **Calvin cycle** (the *synthesis* part)
- The light reactions (in the thylakoids):
  - Split H_2O
  - Release O_2
  - Reduce **NADP⁺** to NADPH
  - Generate ATP from ADP by **photophosphorylation**
- The Calvin cycle (in the stroma) forms sugar from CO_2, using ATP and NADPH
- The Calvin cycle begins with **carbon fixation**, incorporating CO_2 into organic molecules

C4 plants

In photosynthesis, carbon dioxide from the air is added to organic molecules. This process, called carbon fixation, occurs during the Calvin cycle. Because the product of carbon fixation by the Calvin cycle is a three-carbon compound, **plants that use only the Calvin cycle to fix carbon are called C3 plants**. More than 90 percent of all plants are C3 plants.

Plants such as corn and sugar cane use another chemical process to fix carbon before the Calvin cycle. **The first products of this process are four-carbon compounds, so these plants are called C4 plants**. The leaves of C4 plants have a different internal structure. C4 plants are plentiful in the tropics because they conduct photosynthesis efficiently in high heat and intense light.