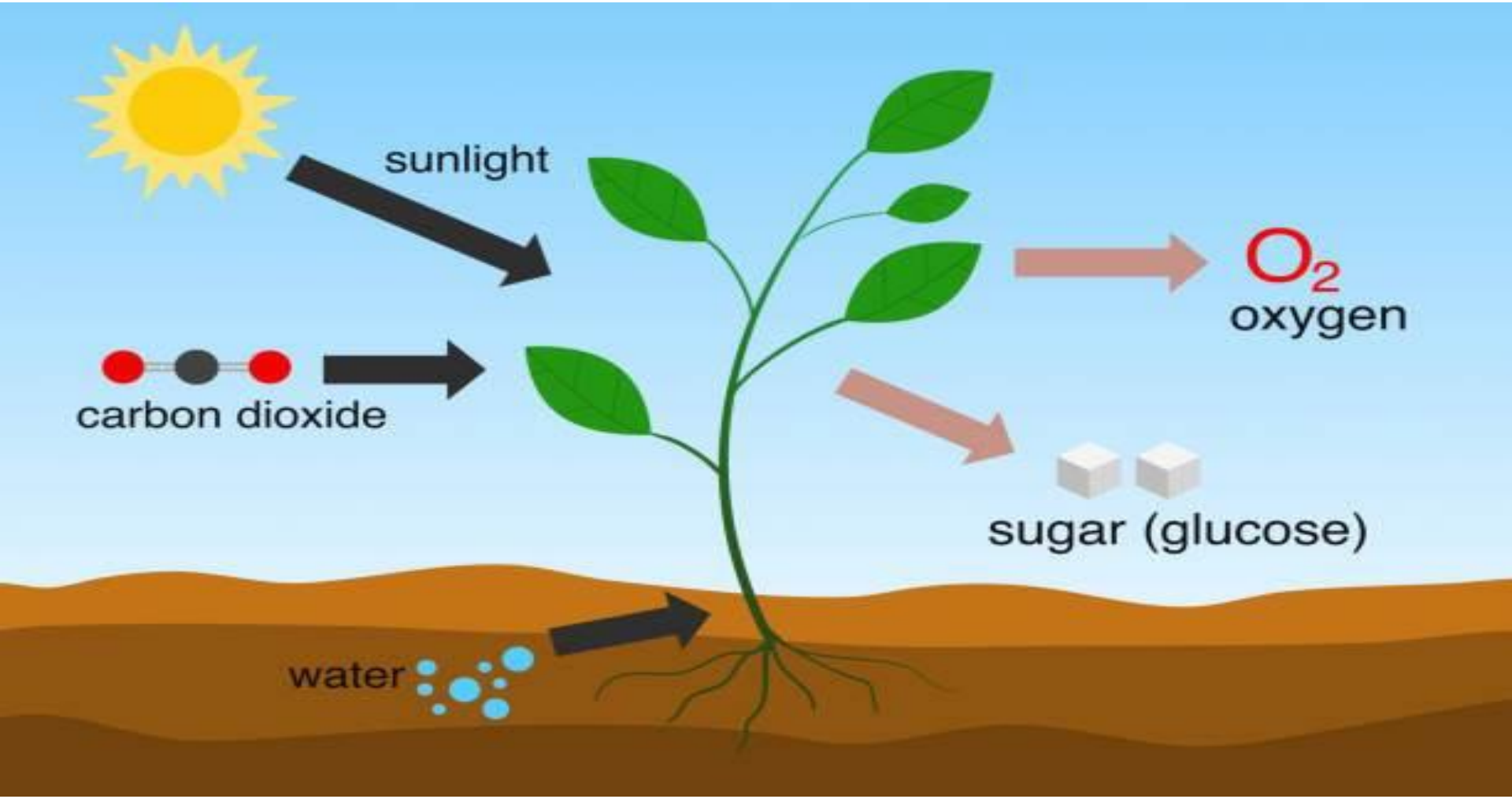
Photosynthesis in plants



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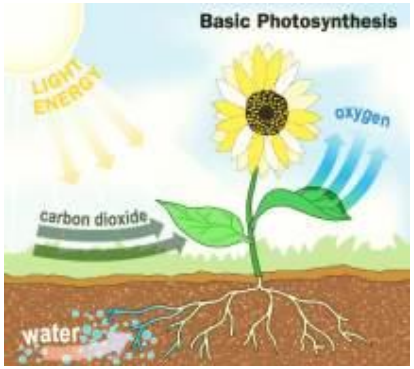
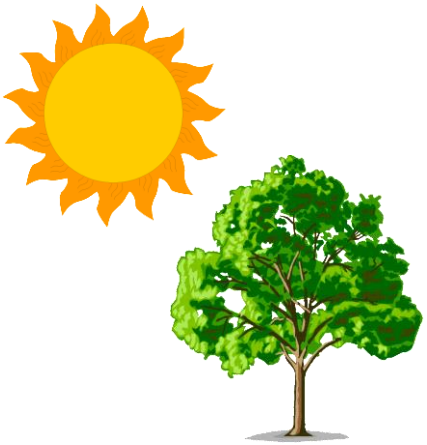
Photosynthesis

Sunshine plays a bigger role in our environment.

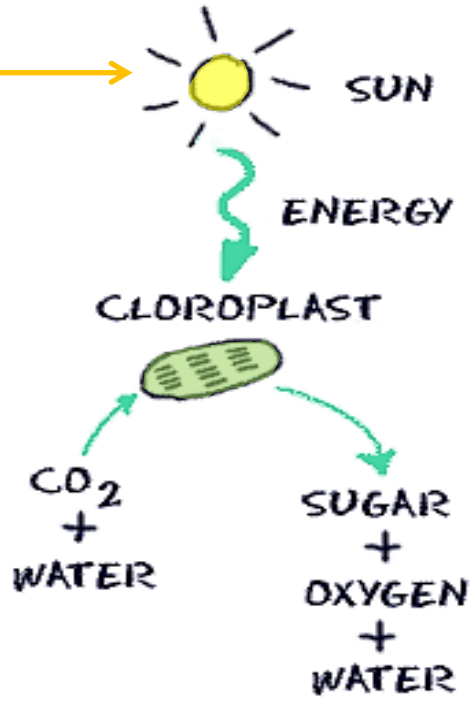




Plants turn solar energy into food.

When animals eat plants and other animals, that original solar energy is passed along the food chain.

Photosynthesis is the process that converts solar energy into chemical energy that is used by biological systems.



Photosynthesis has 3 major events:

1. Sunlight is converted into chemical energy
2. Water (H_2O) is split into oxygen (O_2)
3. Carbon dioxide (CO_2) is fixed into sugars ($C_6H_{12}O_6$)

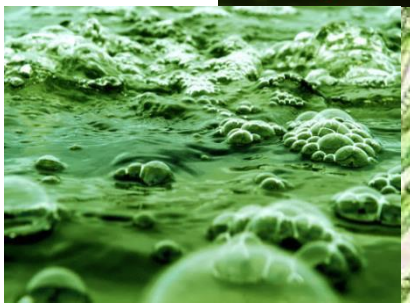
The photosynthesis reaction:

$$6\,CO_2 + 12\,H_2O + \text{sunlight} \rightarrow C_6H_{12}O_6 + 6\,H_2O + 6\,O_2$$

Photosynthesis is carried out by:

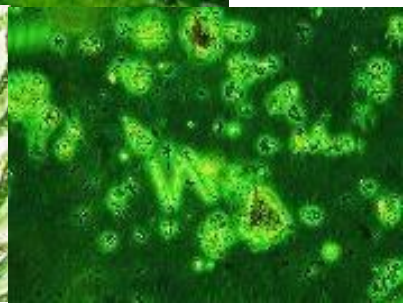
certain bacteria

plants



most algae

cyanobacteria



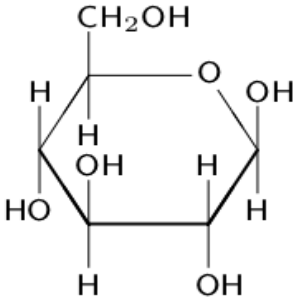
phytoplankton

These organisms are known as <u>photoautotrophs</u> or **producers.**

Consumers such as herbivores and carnivores depend on the products of photosynthesis that producers make to live.

Glucose

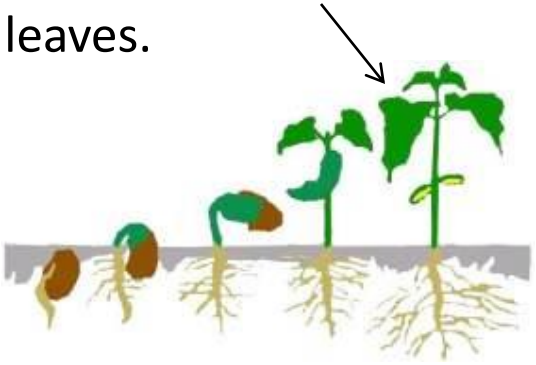
Glucose ($C_6H_{12}O_6$) is a sugar and its molecular structure looks like this.



During photosynthesis, plants produce glucose molecules when they convert light energy into chemical energy. The chemical energy is stored in the bonds of glucose.

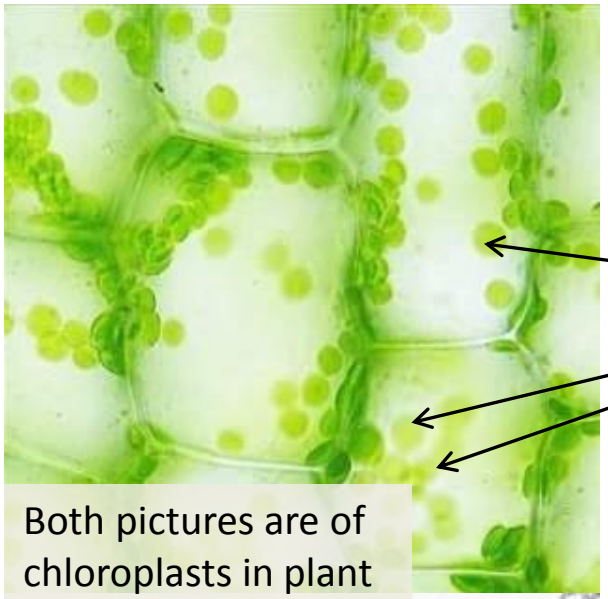
Plants produce sugars as a source of food. However, they produce way more than they need to survive. This is a great benefit for all the species that depend on glucose for energy.

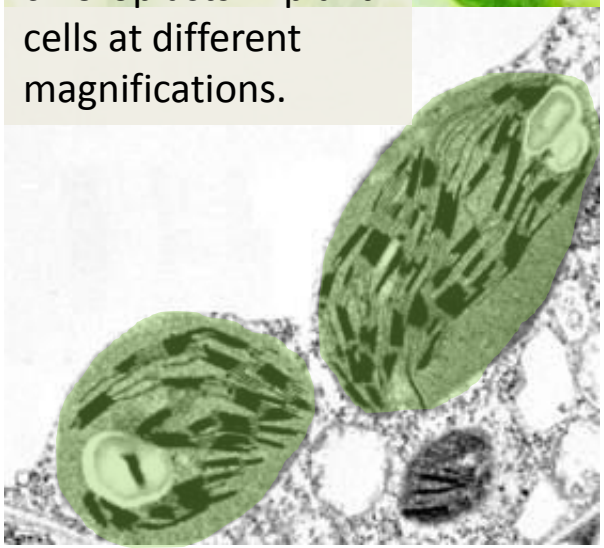
Plants also use the glucose they produce for energy. When plants produce excess glucose they store it in their leaves.



When animals digest plants, they are breaking down the glucose bonds to release stored energy to power their bodies.

All biological energy comes from glucose.





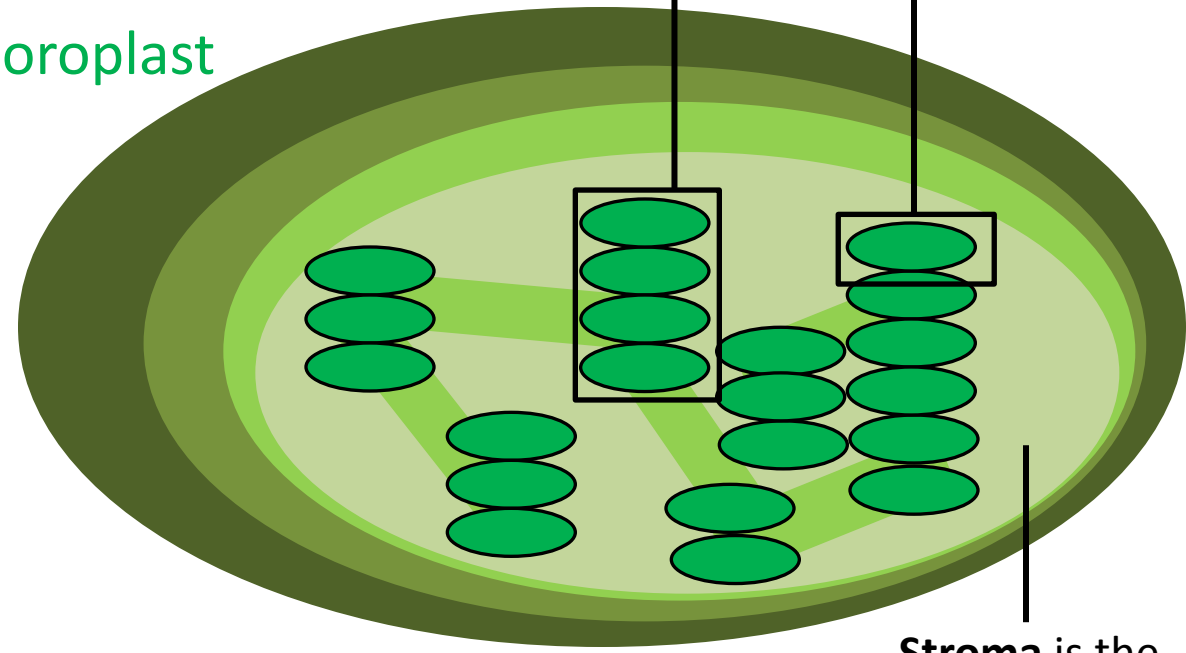
Both pictures are of chloroplasts in plant cells at different magnifications.

Through evolution, plant cells, certain bacteria and some algae have acquired chloroplasts to help carry out the photosynthetic reaction. Chloroplasts are a plastid or plant cell organelle.

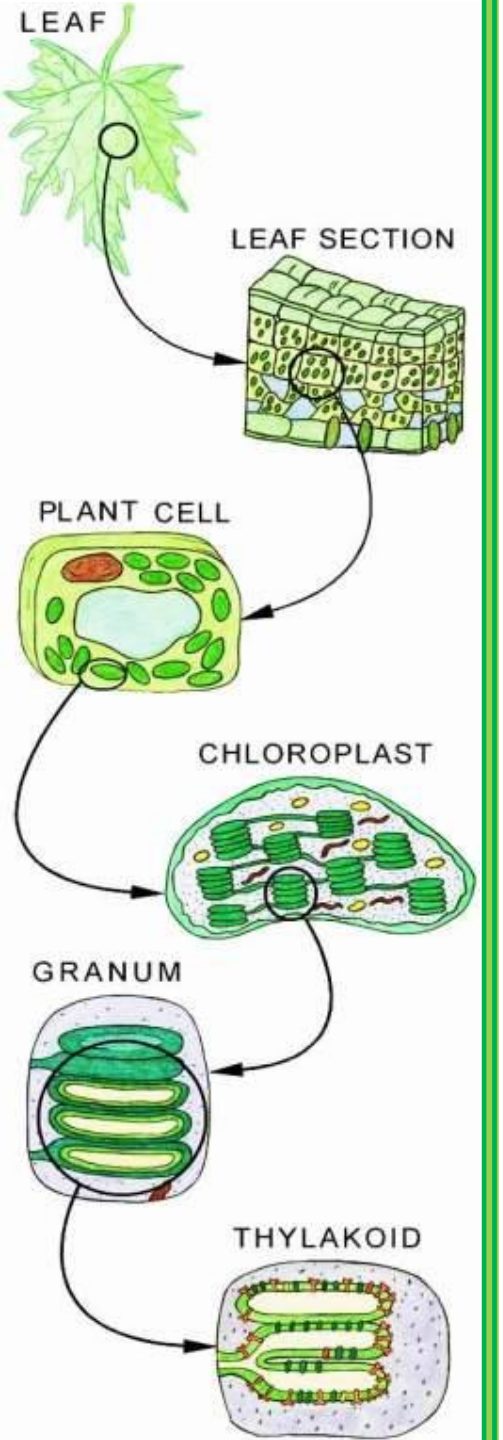
Chloroplasts are full of round flattened discs called **thylakoids**.

A stack of thylakoids is called a **granum**.

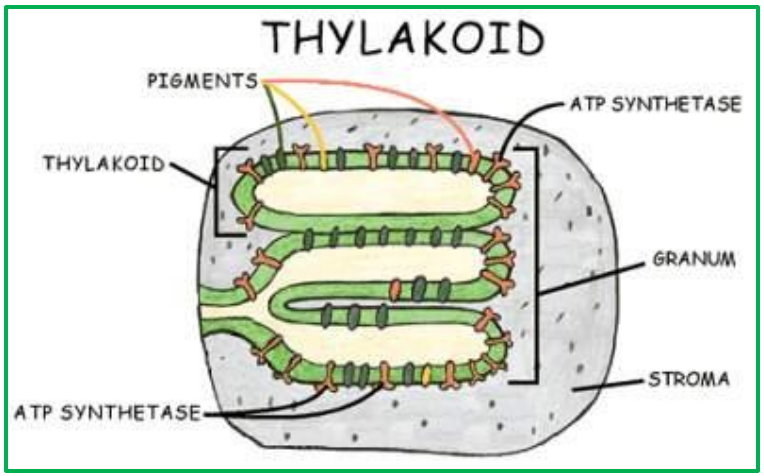
Chloroplast



Stroma is the space inside chloroplasts



Photosynthesis in plants happens in the chloroplasts. Chloroplasts are full of **thylakoids** stacked in **granum**.

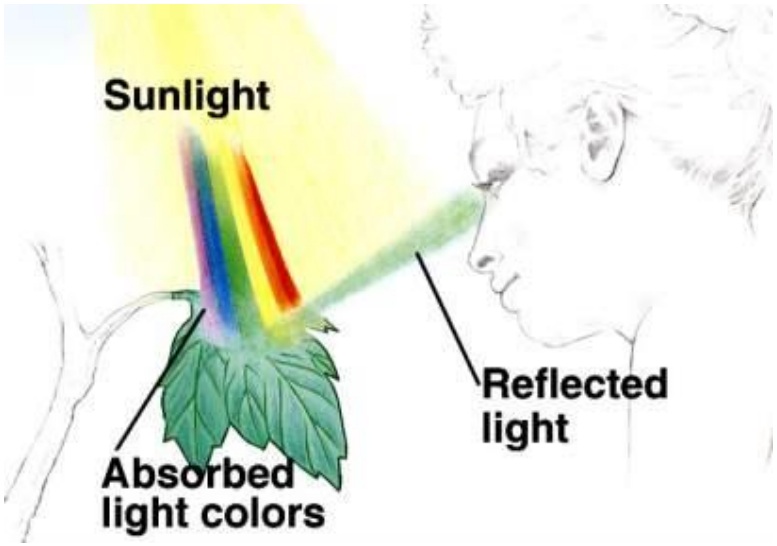


The thylakoid membranes are lined by pigments such as chlorophyll and cartenoids.

Chlorophyll is a green pigment and is the most abundant.

Chlorophyll absorbs all wavelength colors except green, which is reflected off giving plants their green appearance.

These pigments harvest light energy packets or **photons** when they absorb sunlight.



The Photosynthesis Reaction is divided into two parts:

Light Reactions

Light reactions or "light dependent reactions" capture light energy to power photosynthesis.
Light reactions occur during the day time.

They take place in the **thylakoids**.

Pigments in the thylakoid membranes form protein complexes called **Photosystem I** and **Photosystem II**.

These photosystems harvest photons to charge up energy carrying molecules that will power the dark reactions.

Dark Reactions

Dark reactions or "light independent reactions" do not need light energy to power their reactions and can occur day or night.

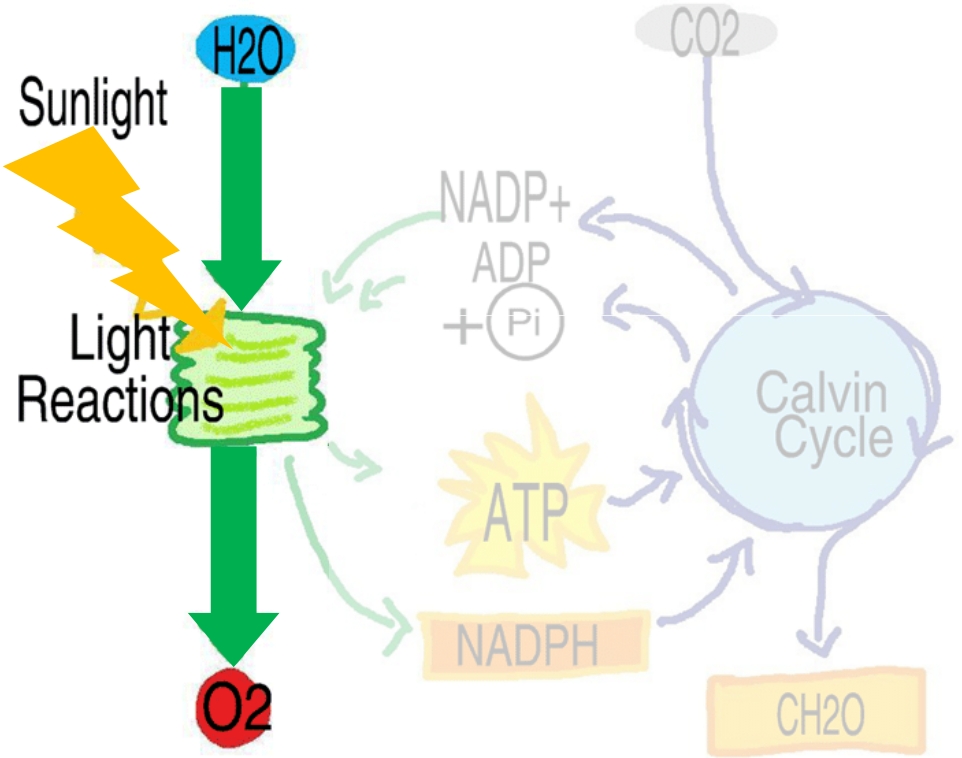
The dark reactions are also called the Calvin-Bensen-Bassham cycle or just **Calvin Cycle**.

Dark reactions occur in the **stroma** of chloroplasts (the space that surrounds thylakoids) and fix carbon dioxide into glucose.

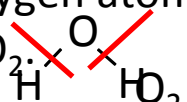
Light Reactions

The energy absorbed by the chlorophyll during the light reactions is used to power **photosystem II** that breaks the bonds of water absorbed through the plant's roots.

Photosystem II

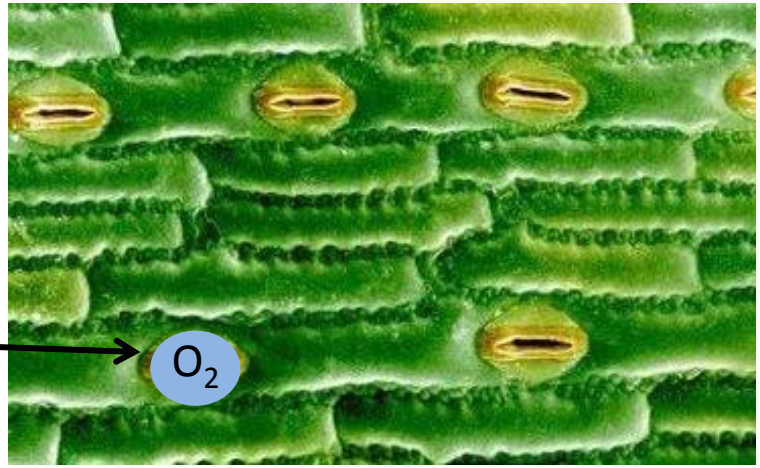


Freed oxygen atoms bind with each other to form the gas O_2.



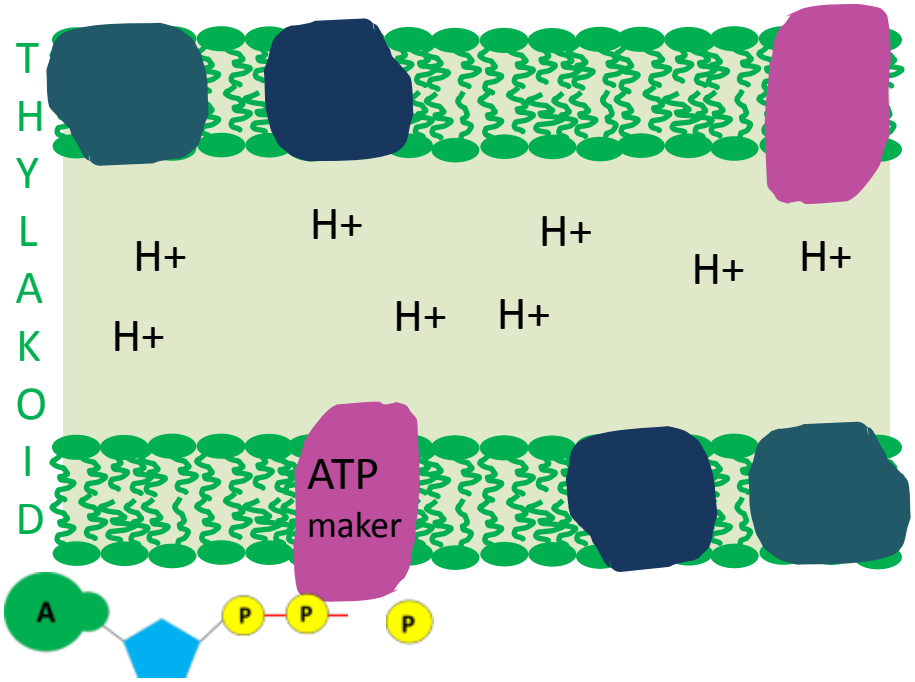
O_2 is a byproduct of photosynthesis not used by the plant so it is released through the stomata of plants.

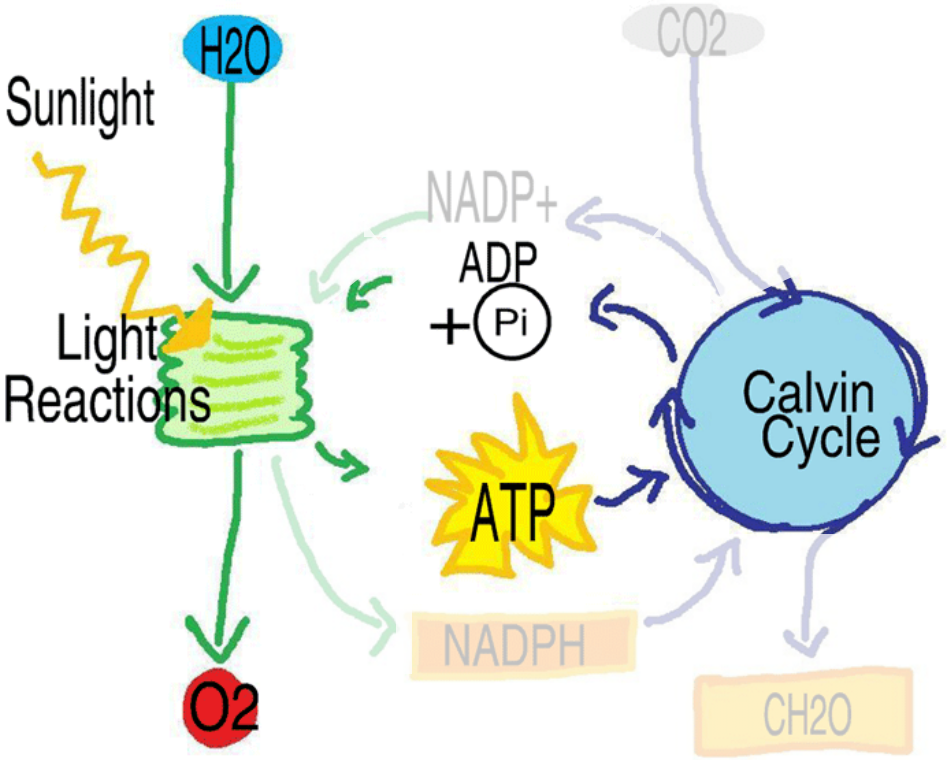
Stomata (Greek for *mouth*) are little pores in leaves that open and close to let oxygen out and carbon dioxide in.



Light Reactions

When water molecules break apart, the remaining two hydrogen atoms have a positive charge and are called **protons**. These protons are kept inside the thylakoid by the thylakoid membrane.





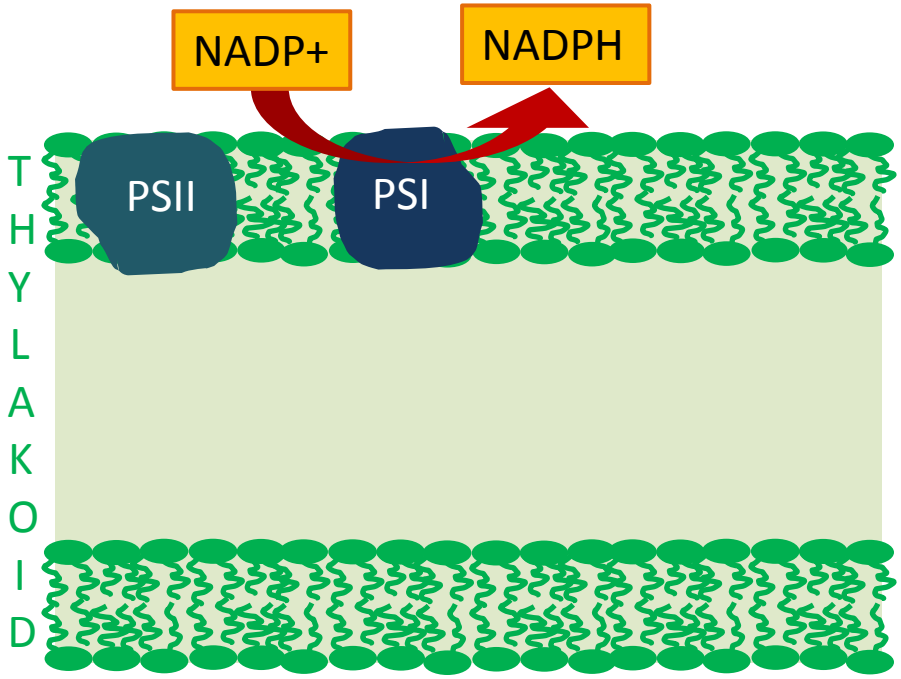
When there are more protons inside the thylakoid than in the stroma outside, protons want to leave the crowded thylakoid.

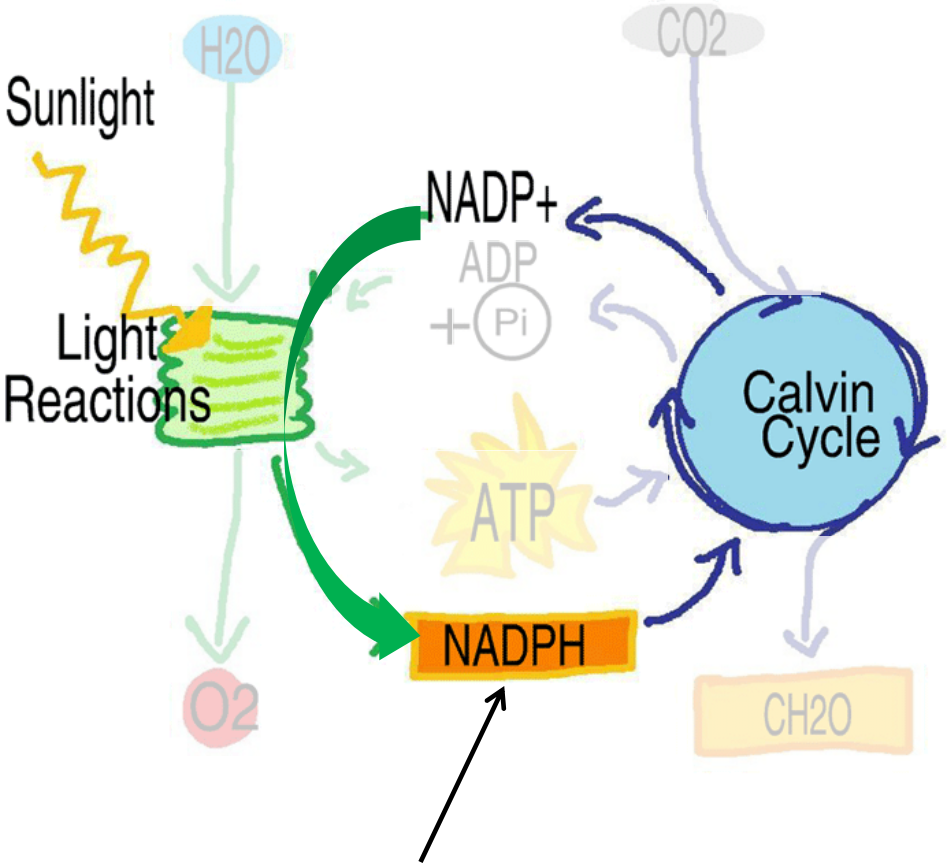
When the protons (H+) cross the membrane to leave, a protein uses their passage to power ATP production.

The protein **ATP synthase** attaches a phosphate group to ADP (D = *di* or two) making it ATP (T = *tri* or three).

Light Reactions

The light energy absorbed by chlorophyll also powers **photosystem I** that charges up the energy carrier molecule NADP+ into NADPH.





NADPH then carries its energy over to power the dark reactions or Calvin Cycle.

Light Reactions Summary

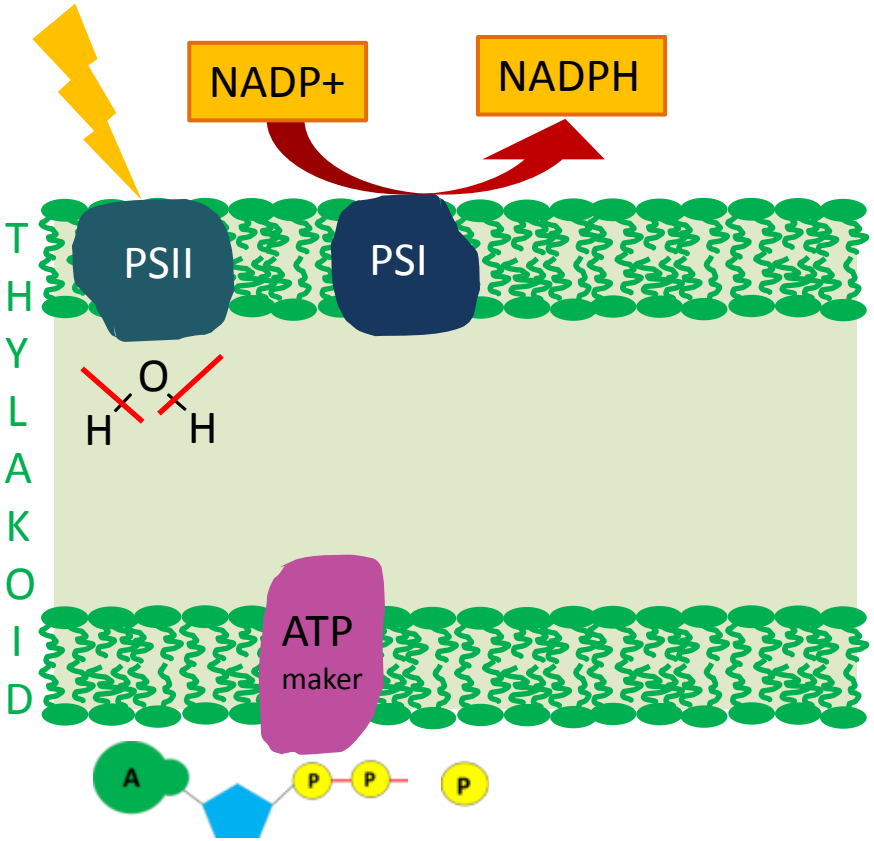
Photons are absorbed by the pigments to power photosystem I and photosystem II.

Photosystem II splits water molecules into two protons (H+) and oxygen atoms are expelled as O_2 gas through the stomata.

Protons cross the thylakoid membrane and power protein complex **ATP synthase** to make ATP.

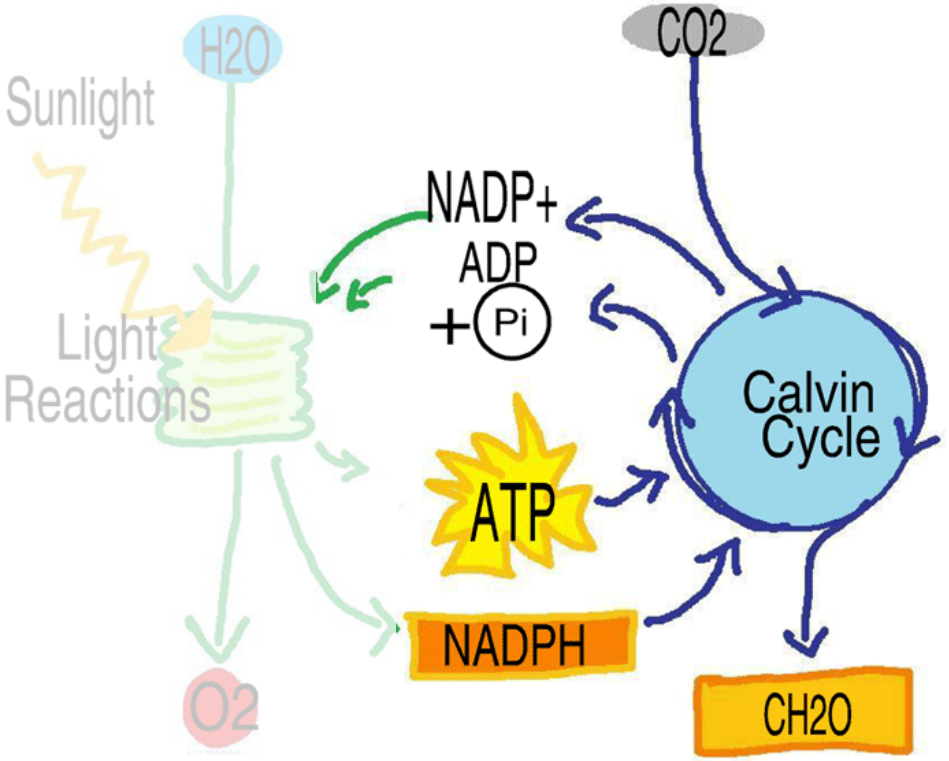
NADP+ is powered up by **photosystem I** to make NADPH to be used in the dark reactions.

Light dependent reactions finish with charged NADPH, ATP, and released O_2.

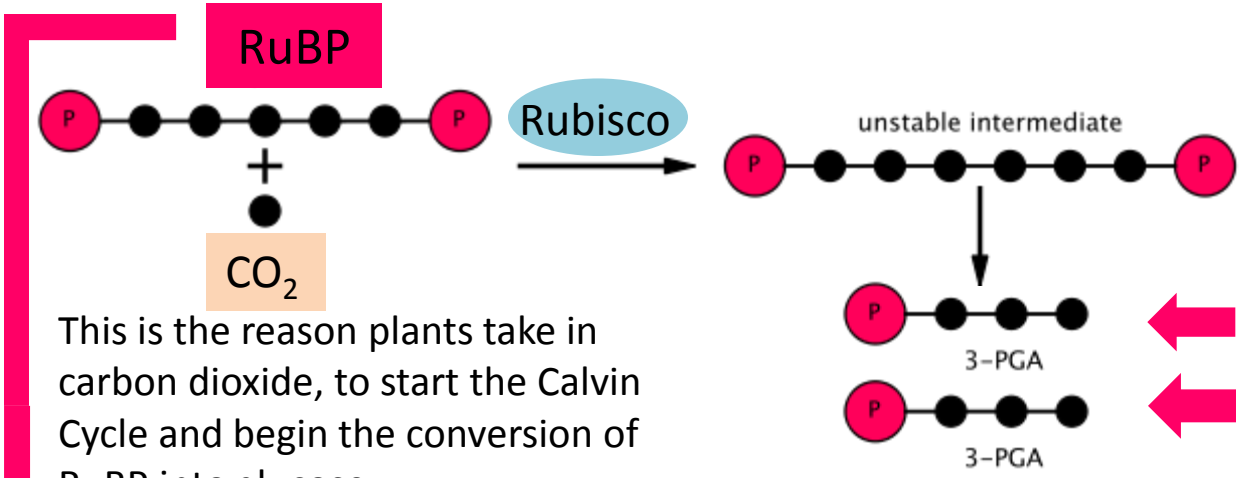


Dark Reactions

Also called the Calvin Cycle, the dark reactions start and end with the same products hence “cycle”.
All the dark reactions take place in the **stroma** of the chloroplast.



The Calvin Cycle starts with RuBP molecules and carbon dioxide molecules. An enzyme called Rubisco combines them into an unstable intermediate.

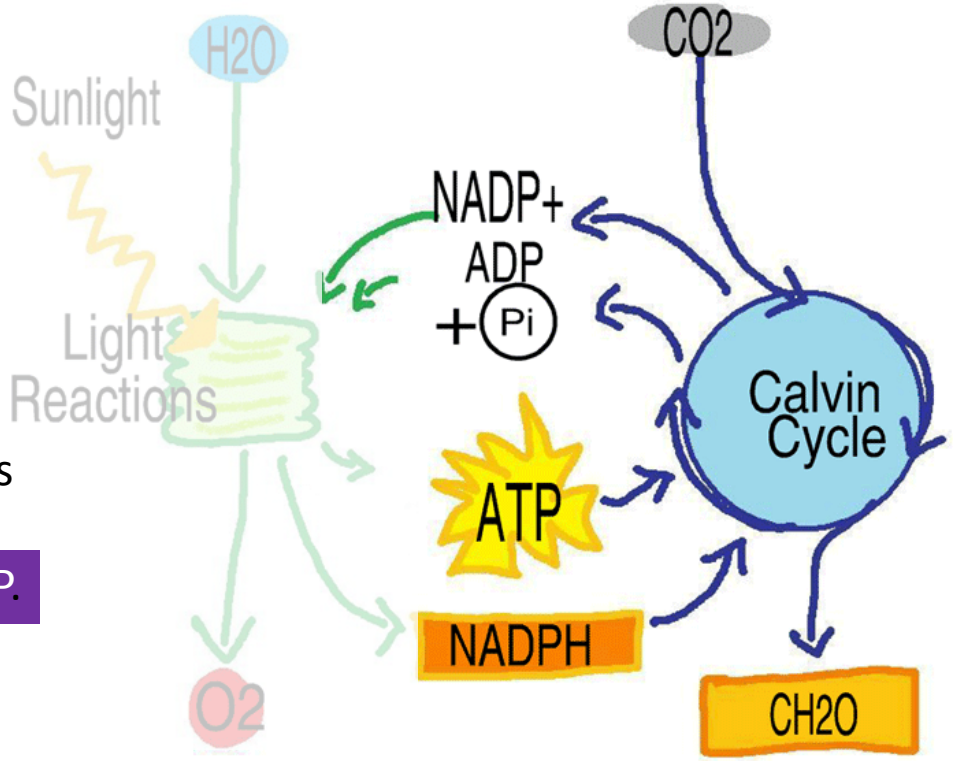


This is the reason plants take in carbon dioxide, to start the Calvin Cycle and begin the conversion of RuBP into glucose.

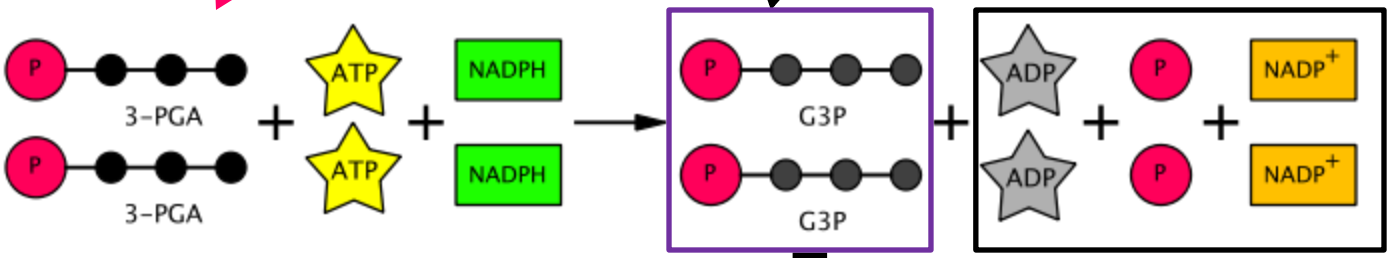
Since the intermediate of combined RuBP and CO_2 is unstable it quickly splits in half and forms 2 molecules of 3-PGA which are stable.

RuBP is the starting molecule and ending molecule of the Calvin Cycle. It will be remade at the end of the cycle so that the cycle can begin again.

Dark Reactions

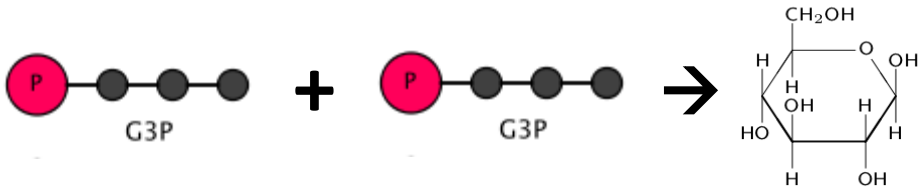


The ATP and NADPH from the light reactions provide the energy to convert the two molecules of 3-PGA into their final form G3P.



The left overs are reused in the light reactions to remake ATP and NADPH.

2 G3P are joined to make a glucose molecule.

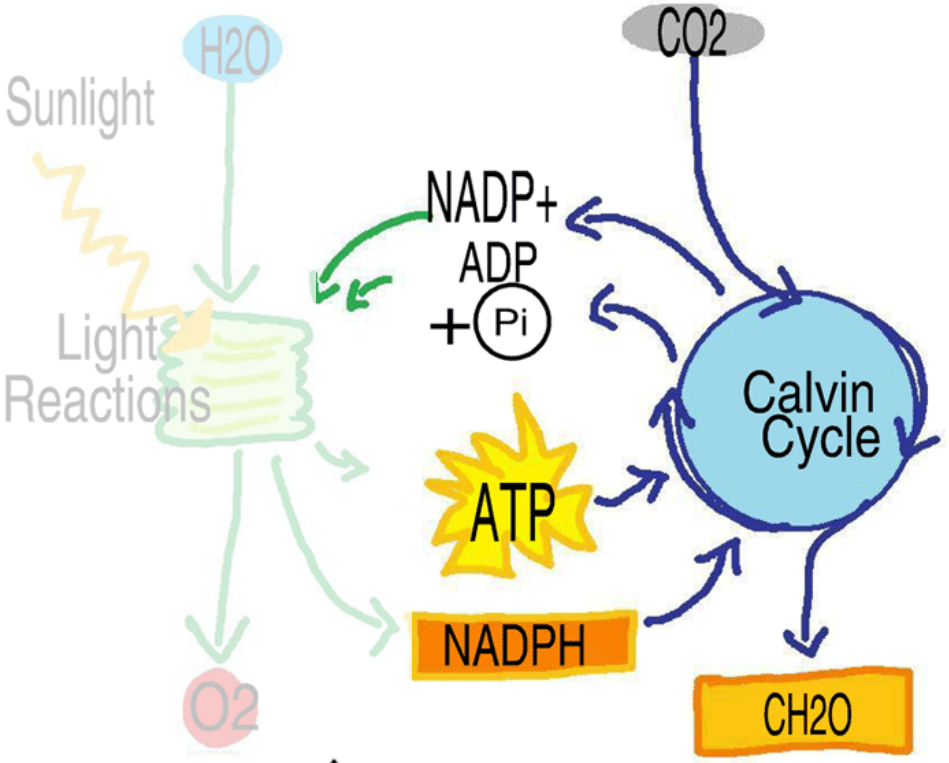


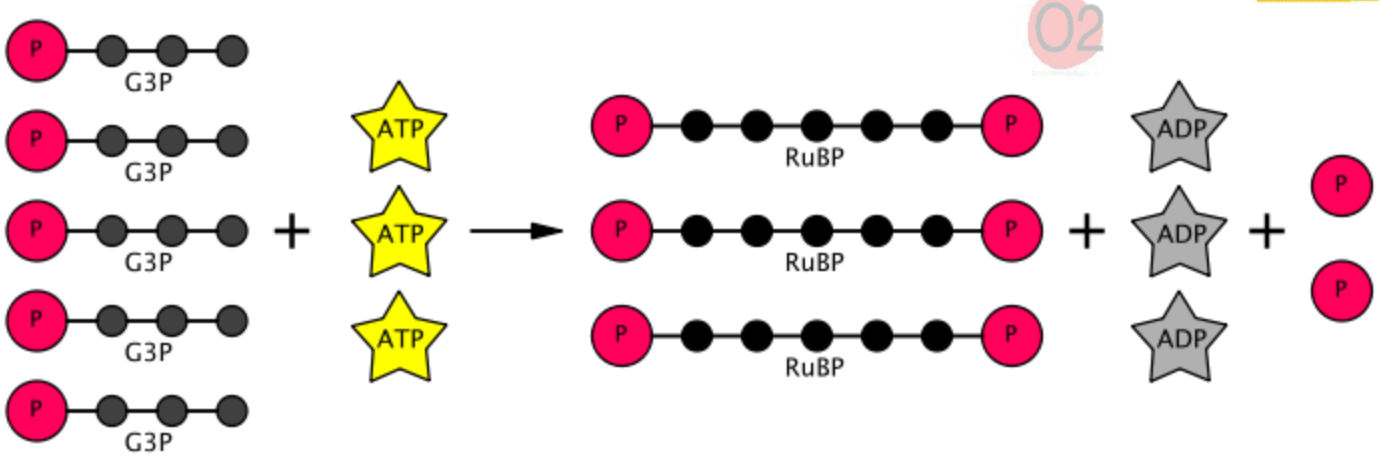
Dark Reactions

Not all G3P is made into glucose.

The Calvin Cycle occurs in every stroma in every chloroplast in every plant cell every second of every day.

That's a lot of reactions all happening simultaneously!

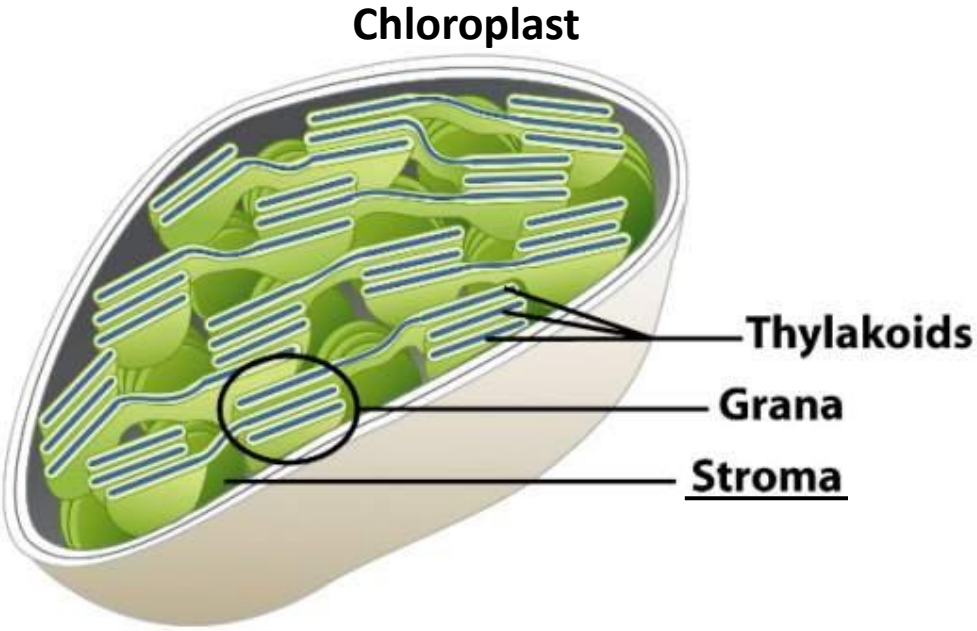




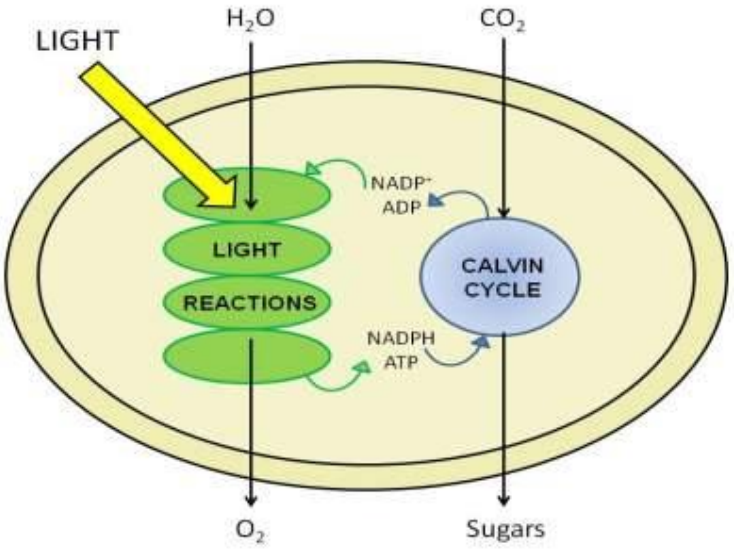
Most of the G3P made during the Calvin Cycle are made into RuBP, the starting molecule, with energy from ATP molecules.
Now the Calvin Cycle can begin again.

The spent ATP from the reaction leaves ADP and a phosphate group. These are reused in the light reactions to make more ATP.

Dark Reactions Summary



The Calvin Cycle converts the carbon from carbon dioxide into glucose in the stroma. This is called **carbon fixation** because carbon is fixed into another form.



Photosynthesis is carried out in two steps.
First, in two light dependent photosystems.
Second, in a light independent carbon fixation cycle called the Calvin Cycle. Through this process, the plant is able to convert sunlight, water, and CO_2 into glucose (or sugar) and ATP.
As a byproduct of this process, O_2 is released.

Summary

- Plants are the producers of the biosphere creating the oxygen and glucose needed for most organisms.
- Chloroplasts are the site of photosynthesis in plants.
- Chloroplasts contain thylakoids where the light reactions take place.
- Light reactions convert sunlight into ATP and NADPH.
- The dark reactions or Calvin Cycle uses ATP and NADPH to convert CO_2 into sugar.
- The light reactions and the dark reactions cooperate to convert light energy into chemical energy housed in glucose.
- Plants and animals use glucose to power metabolic processes.

Thank You