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المرحلة الاولى/ بايلوجية الخلية

المحاضرة السادسة: البناء الضوئي

# Photosynthesis

## What is Photosynthesis?

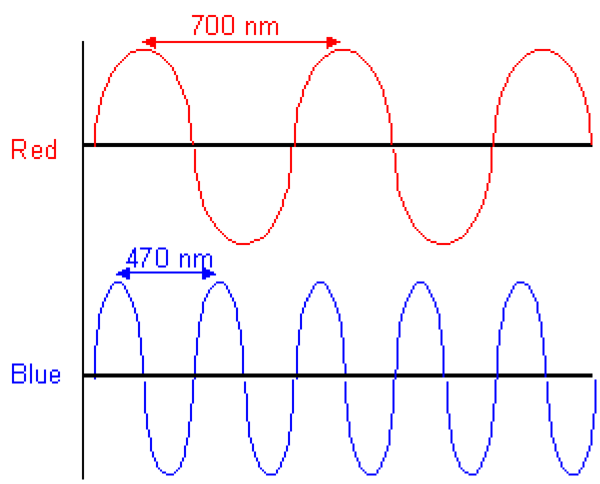
All organisms require energy for their chemical reactions. These reactions may be involved with reproduction, growth, or other activities. Photosynthetic organisms such as plants use light energy to produce carbohydrate (glucose). Glucose can be used at a later time to supply the energy needs of the cell. Photosynthesis is therefore a process in which the energy in sunlight is stored in the bonds of glucose for later use.

## Light

### Electromagnetic Spectrum

Light behaves as if it were composed of "units" or "packets" of energy that travel in waves. These packets are ***photons***.

The ***wavelength*** of light determines its color. For example, The wavelength of red is about 700 nm and the wavelength of blue light is about 470 nm.



Visible light is a part of a larger spectrum of radiation called the electromagnetic spectrum.

Ultraviolet radiation (UV) is dangerous to cells because it breaks chemical bonds.

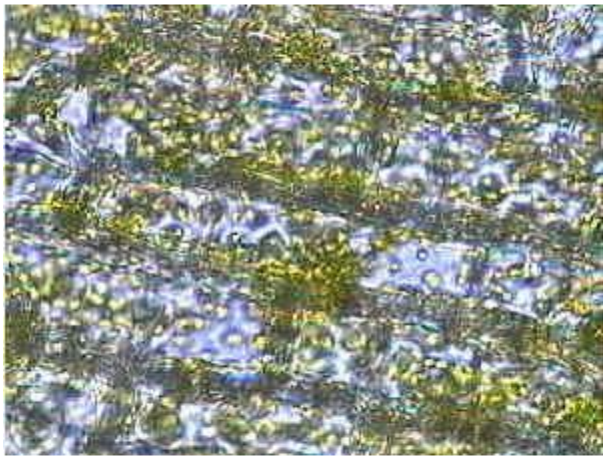
## Photosynthetic Pigments

*Chlorophyll A* is the main photosynthetic pigment in all organisms except bacteria. Other pigments called ***accessory pigments*** absorb slightly different wavelengths of light. The combination of all of the pigments increases the range of colors that plants can use in photosynthesis.

Accessory pigments include chlorophyll b and a group of pigments called ***carotenoids***. They do not participate directly in photosynthetic reactions but are able to pass their energy to chlorophyll a.

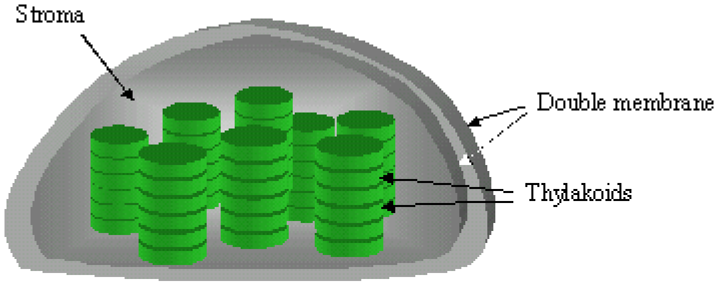
## Chloroplast structure

The photograph below is an elodea leaf X 400. Individual cells are clearly visible. The tiny green structures within the cells are chloroplasts.



***Thylakoids*** are membranous disk-like structures that are stacked together in larger structures that resemble stacks of coins. Chlorophyll and carotenoid pigments are located in the membranes of the thylakoids. The thylakoid membranes also contain the electron transport system.

The diagram below is a drawing of a chloroplast showing the thylakoids.




The fluid-filled space surrounding the grana is the ***stroma***. Many enzymes needed in photosynthesis are found in the stroma.

## 2 Sets of Reactions

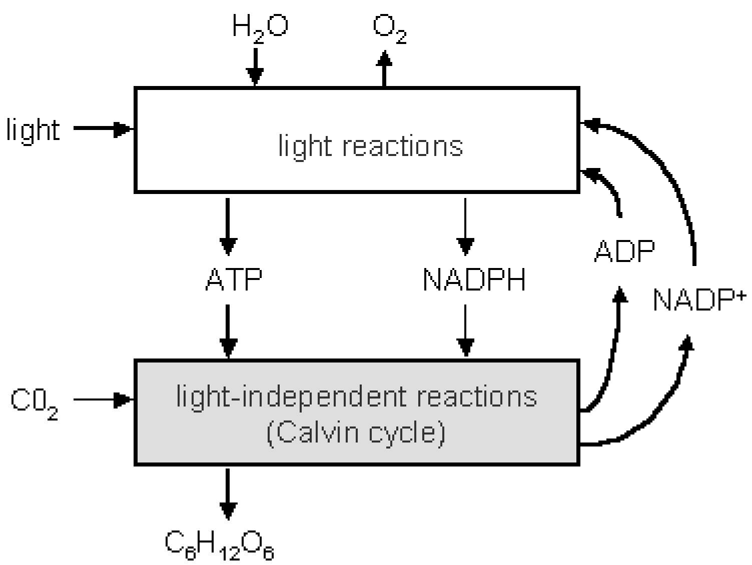
### Light-Dependent Reactions

The light-dependent reactions require light.

These reactions occur in the thylakoid membrane.

They produce ATP and NADPH, which are needed to produce glucose in the light-independent reactions (below).

Notice how the equation for photosynthesis relates to the reactions shown in the diagram below.
$6CO_2 + 6H_2O + \text{Energy} \rightarrow C_6H_{12}O_6 + 6O_2$




### Light-Independent Reactions

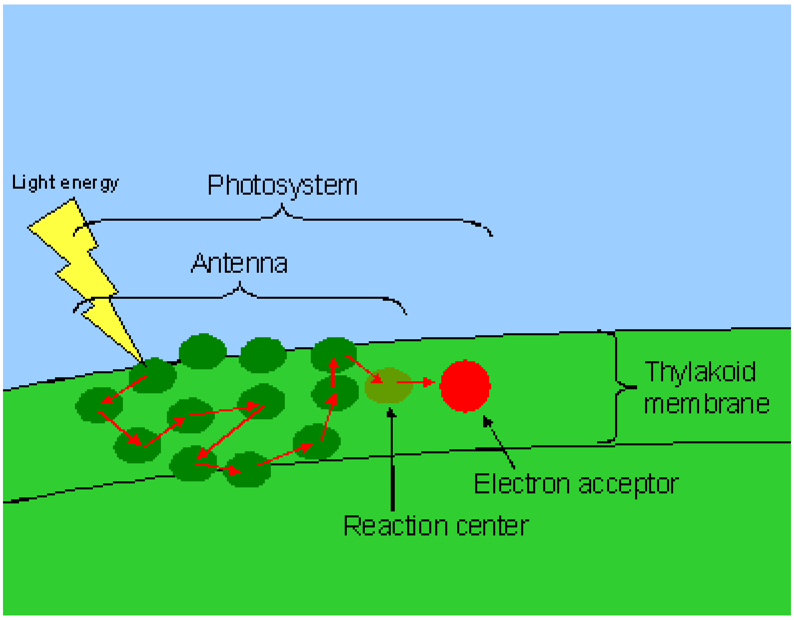
Light-independent reactions occur in stroma of the chloroplast in light or dark conditions.

They function to reduce $CO_2$ to glucose.

## Photosystems

The closely packed pigment molecules and the reaction center form a unit referred to as an ***antenna complex***.

Photons of light that are picked up by any of the pigment molecules in the antenna pass their energy to nearby pigment molecules until it is eventually passed to a special molecule of chlorophyll a called the ***reaction center***.




The reaction center molecule becomes ionized and it loses its electron to an electron acceptor. This electron will need to be replaced.

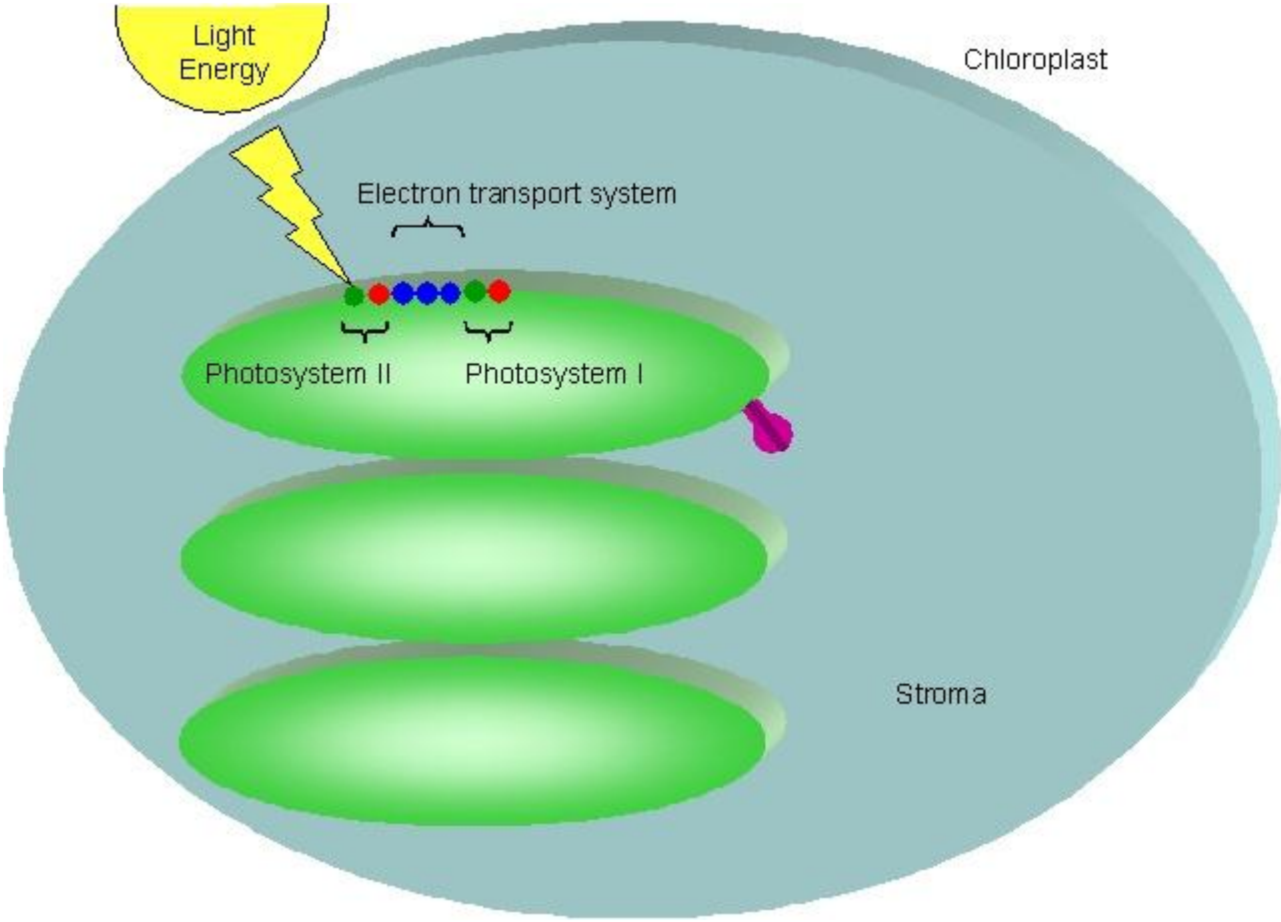
The antenna, the reaction center, and the electron transport molecules make up a photosystem. There are two kinds of photosystems in eucaryotes. The reaction center chlorophyll molecule of photosystem I absorbs 700 nm light best and is therefore called $P_{700}$. The reaction center of photosystem II absorbs 680 nm light best and is called $P_{680}$.

Photosystem I evolved very early; photosystem II evolved later.

## Details of the Light-Dependent Reactions

### Photosystem II

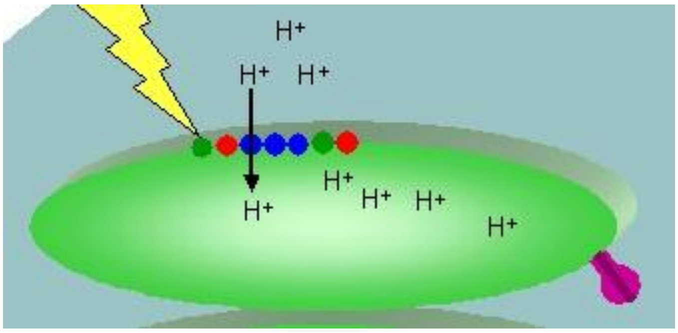
The diagrams that follow are less magnified views of the chloroplast and thylakoid shown in the diagram above. The antenna shown above is represented by a single green circle below. Notice that there are two photosystems and therefore two antennas. The blue circles represent the electron transport system (discussed later).



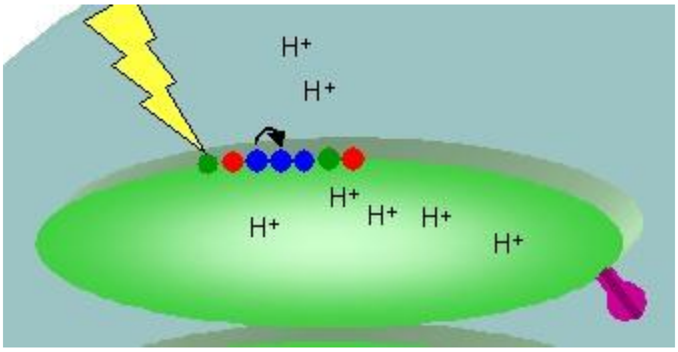

During the light reactions, pigment molecules within the $P_{680}$ antenna absorb a photon of light energy. The energy from that molecule is passed to neighboring molecules and eventually makes its way to the reaction center molecule as previously described. When the reaction center molecule becomes excited, it loses its electron to an electron acceptor.

## Photophosphorylation

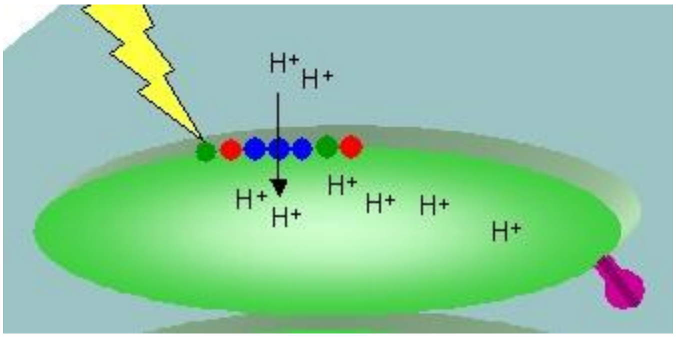
The ***electron transport system*** is found embedded within the thylakoid membrane and functions in the production of ATP. The system contains membrane-bound electron carriers that pass electrons from one to another. As a result of gaining an electron (reduction), the first carrier of the electron transport system gains energy. It uses some of the energy to pump $H^+$ into the thylakoid.



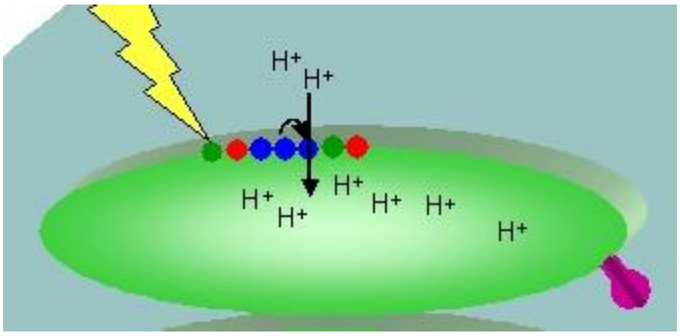

The carrier then passes the electron to the next carrier. Because it used some energy to pump $H^+$, it has less energy (reducing capability) to pass to the next $H^+$ pump.




This carrier uses some of the remainder of the energy to pump more $H^+$ into the thylakoid.

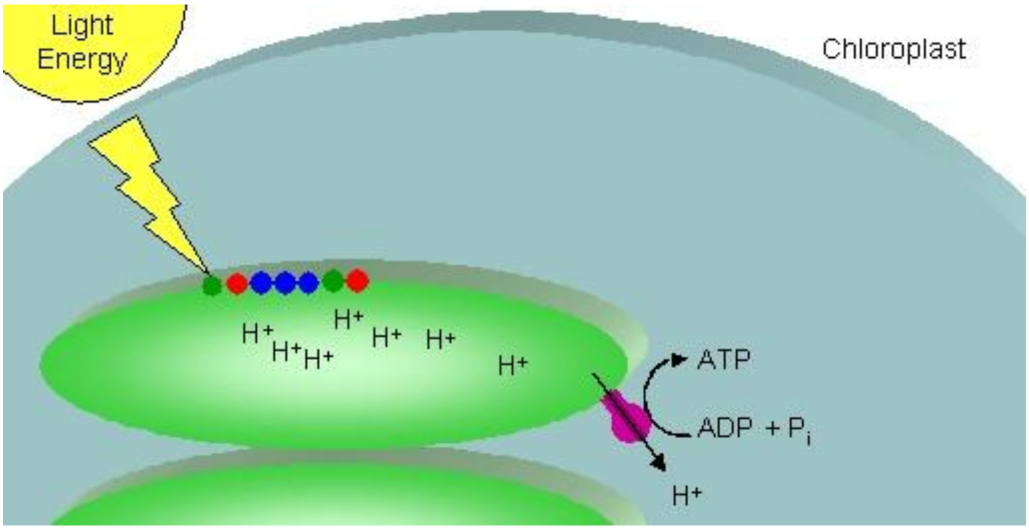



The electron is passed to the next carrier which also pumps $H^+$.



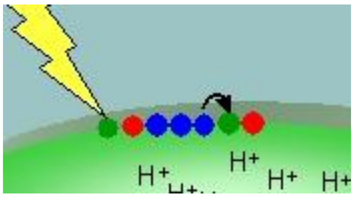
The electron transport system functions to create a concentration gradient of $H^+$ inside the thylakoid. The concentration gradient of $H^+$ is used to synthesize ATP.

ATP is produced from ADP and $P_i$ when hydrogen ions pass out of the thylakoid through ***ATP synthase***. This method of synthesizing ATP by using a H+ gradient in the thylakoid is called ***photophosphorylation***.

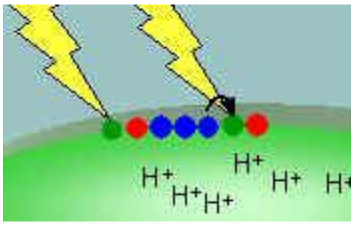



## Photosystem I

At this point, the electron has little reducing capability (little energy is left). It is passed to the P700 antenna.

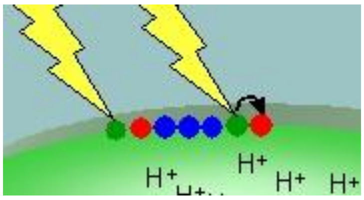


A pigment molecule in the P700 antenna absorbs a photon of solar energy.



The energy from that molecule is passed to neighboring molecules within the antenna. The energy is eventually passed to the reaction center of this antenna.

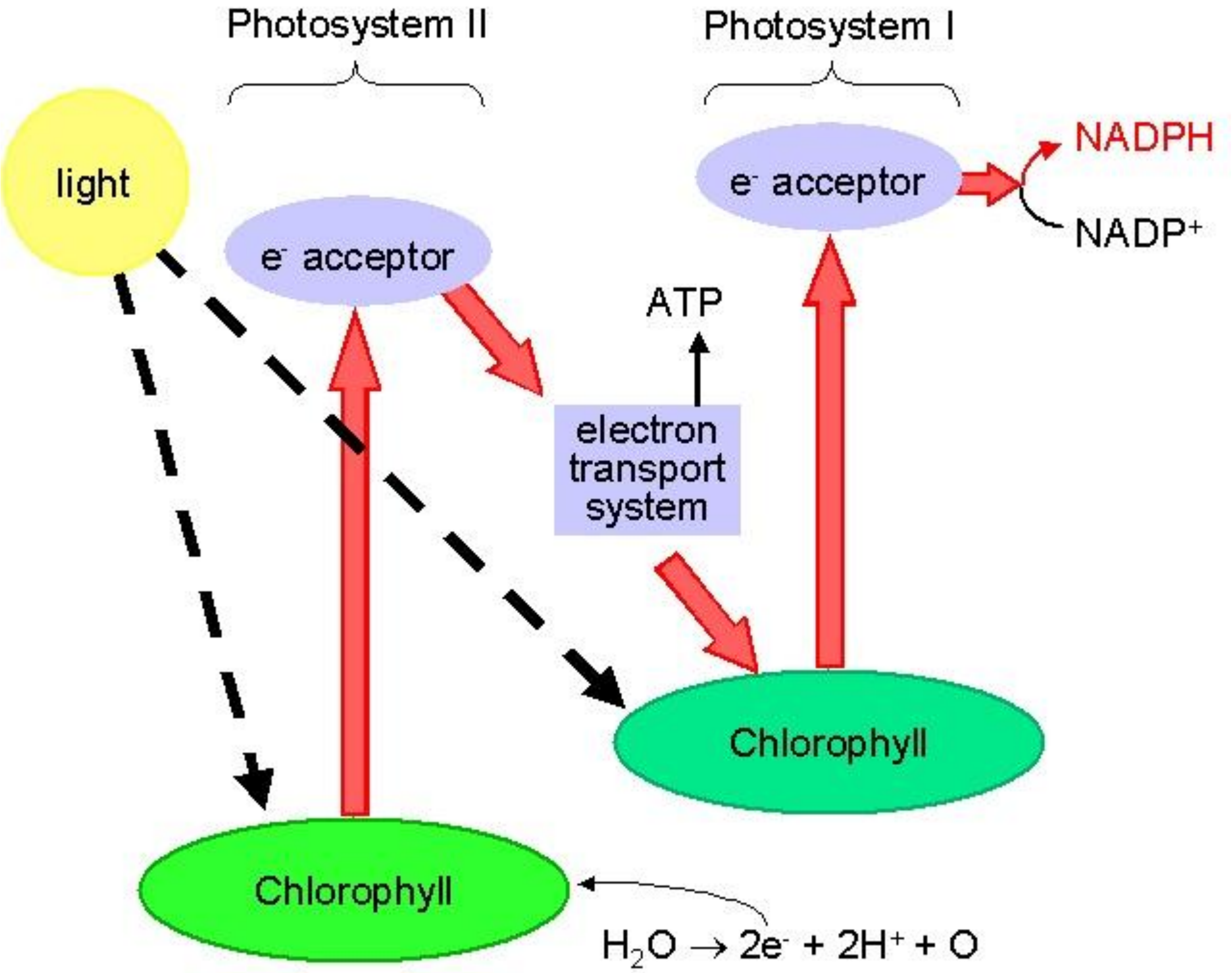
As a result of being energized, the P700 reaction center loses the electron to an electron acceptor.




The acceptor passes it to NADP$^+$, which becomes reduced to NADPH. According to the following equation, NADP$^+$ has the capacity to carry two electrons. $NADP^+ + 2e^- + H^+ \rightarrow NADPH$

The electron transport system and photophosphorylation in the chloroplast is similar to the system found in the mitochondria to produce ATP during cellular respiration.

The diagram below is a summary of the light reactions. High-energy components of the system are shown near the top of the diagram.



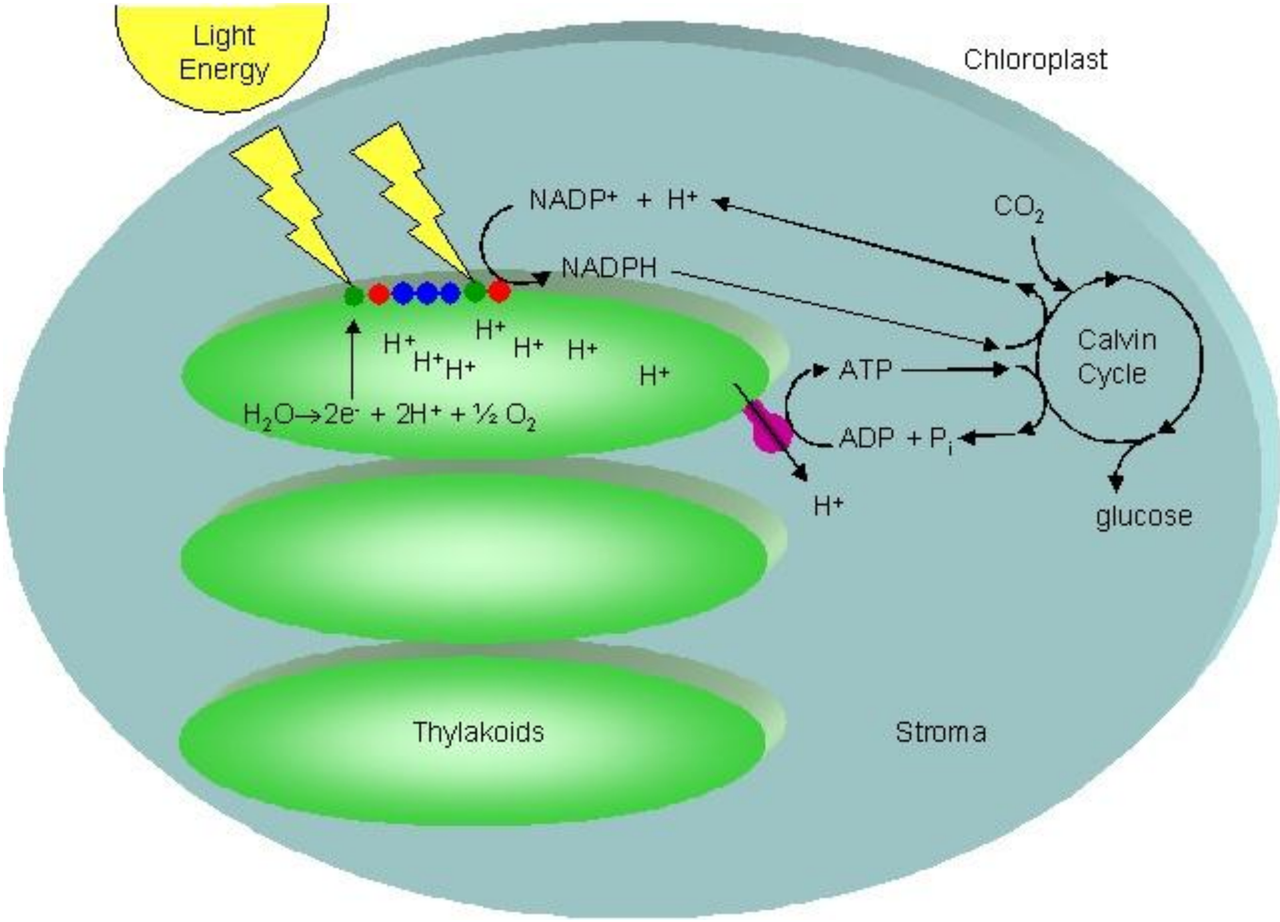
### Water

The electron that was lost from the antenna complex of photosystem I is replaced by splitting water (see diagram above).

In the light reactions, electrons move one way from water to NADPH and the energy of sunlight is used to produce ATP.

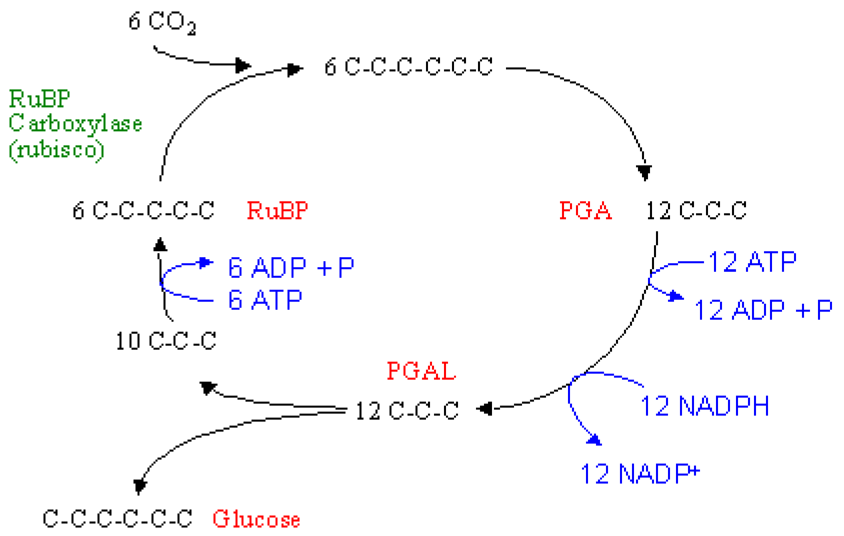
### Calvin Cycle (Light-independent Reactions)

The products of the light reactions (ATP and NADPH) are used to reduce $CO_2$ to carbohydrate in the Calvin cycle.




The words "$CO_2$ fixation" refer to the attachment of $CO_2$ to an organic compound: each $CO_2$ binds to a 5-carbon ***ribulose biphosphate (RuBP***) molecule.

Carbon dioxide fixation is catalyzed by RuBP carboxylase (***rubisco***).




For each six $CO_2$ molecules that enter the cycle one glucose molecule is produced.

About 30% of the energy available in ATP and NADPH is finally present in the glucose produced.

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References المصادر

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