# How Cells Acquire Energy

Course: BIO 101 (Introduction to Biology)

Chapter:6 (Part 1,2&3)

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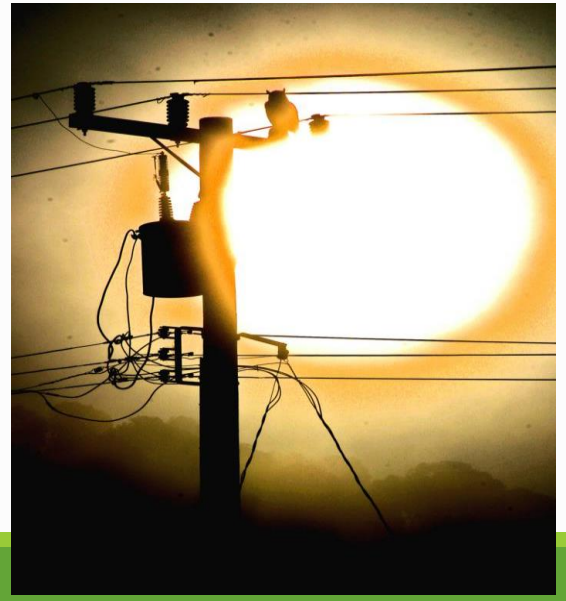
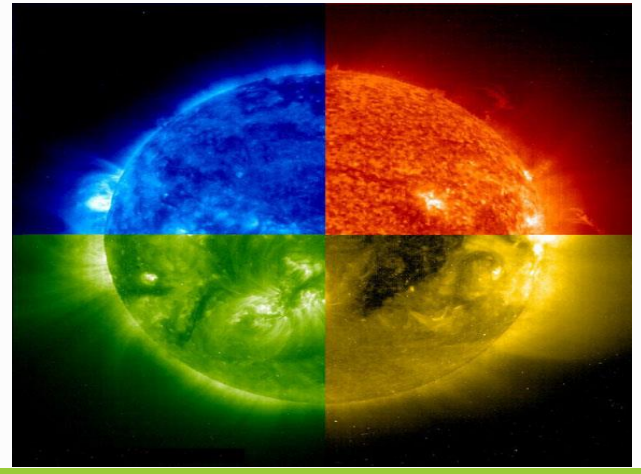
# THE SUN: MAIN SOURCE OF ENERGY FOR LIFE ON EARTH



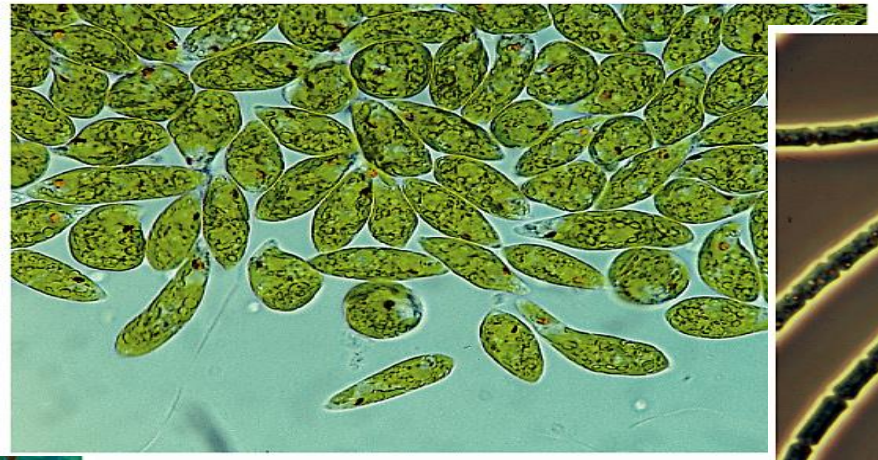


# THE BASICS OF PHOTOSYNTHESIS

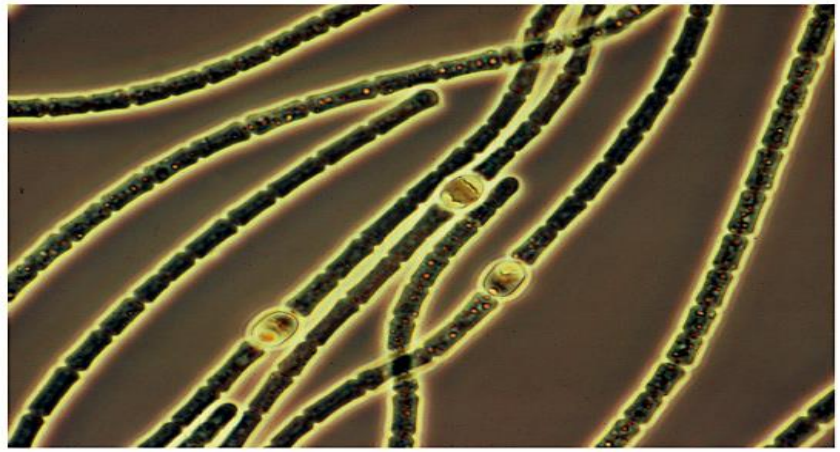
- Almost all plants are photosynthetic autotrophs, as are some bacteria and protists
  - Autotrophs generate their own organic matter through photosynthesis
  - Sunlight energy is transformed to energy stored in the form of chemical bonds

(a) Mosses, ferns, and *flowering plants*

(b) Kelp

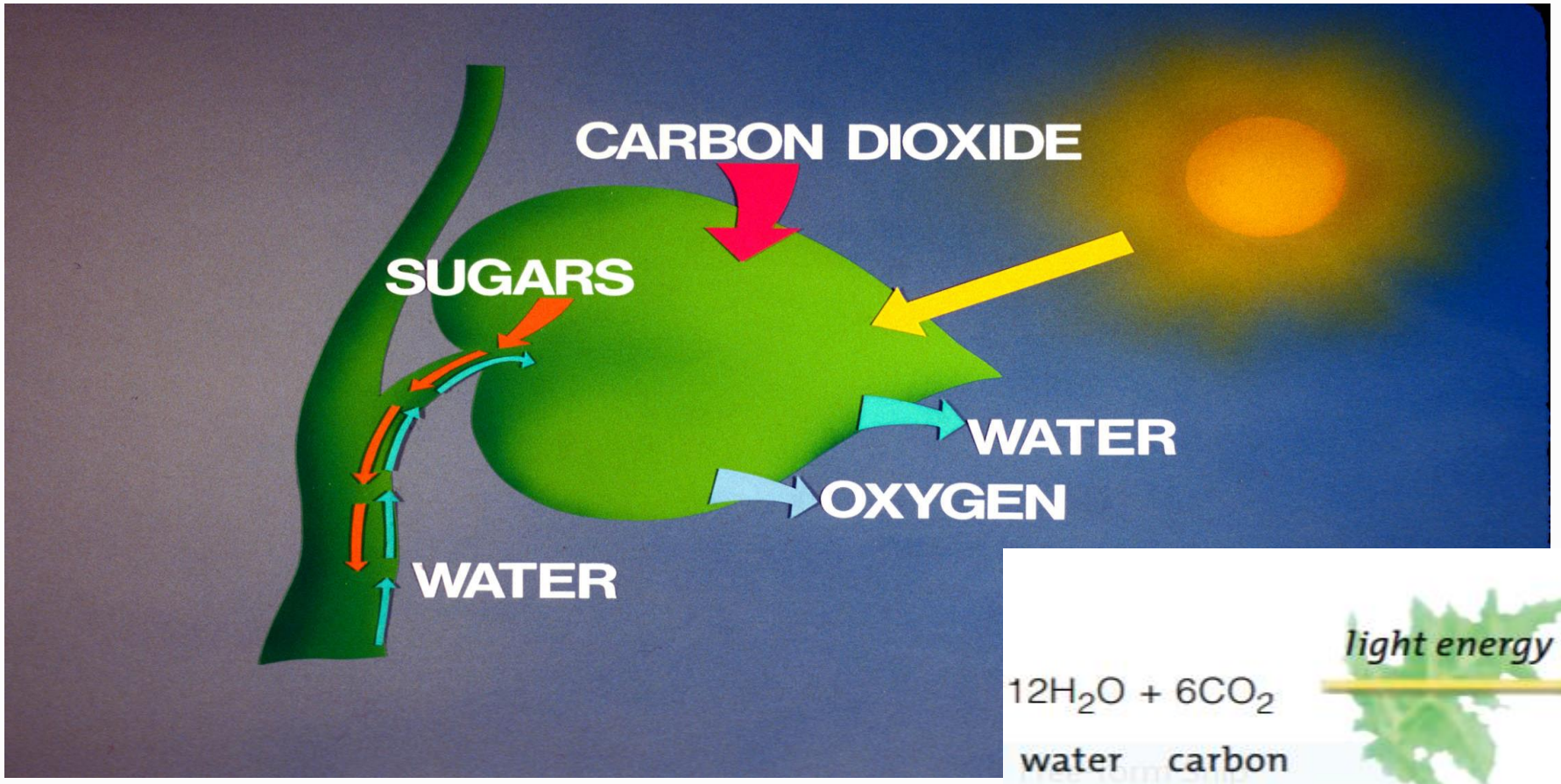


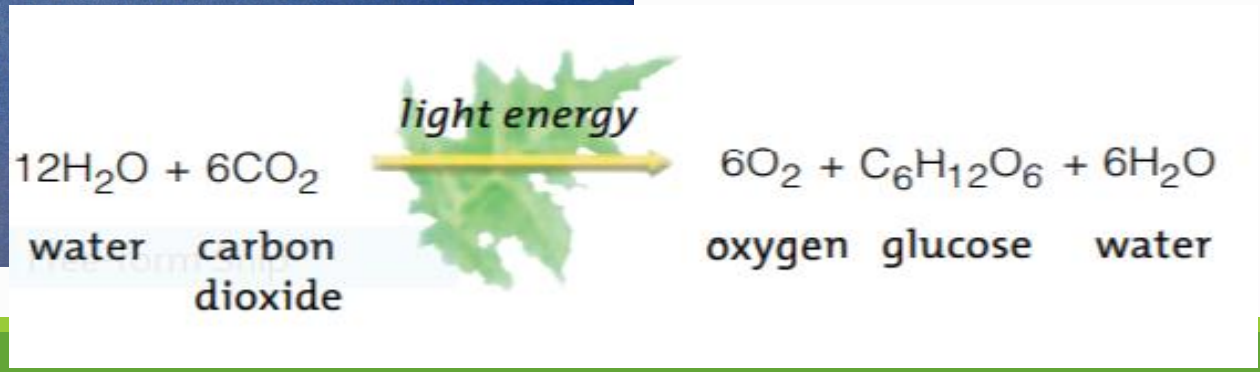
(c) *Euglena*



(d) Cyanobacteria

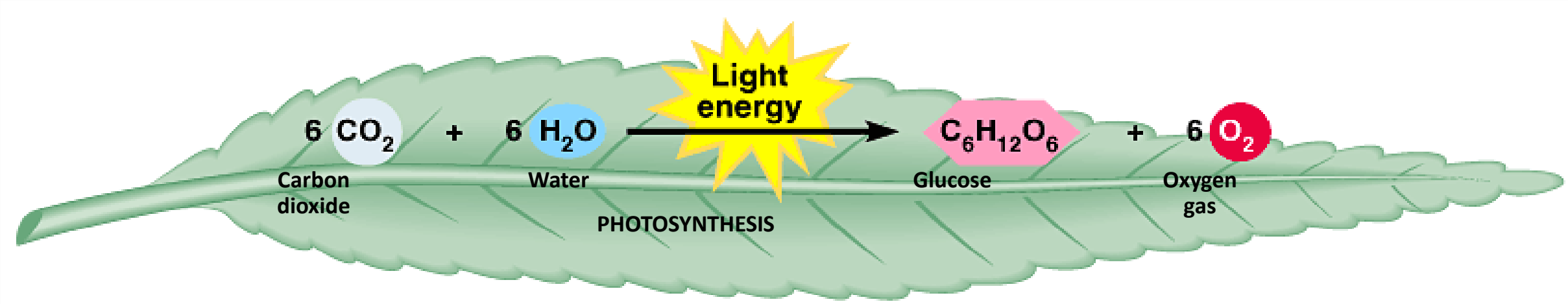
# Light Energy Harvested by Plants & Other Photosynthetic Autotrophs



# IMPORTANCE OF PHOTOSYNTHESIS

- Life on earth made possible by sun.
- All Oxygen in the atmosphere was put there by photosynthesis
- All energy stored in coal and oil was supplied by photosynthesis.



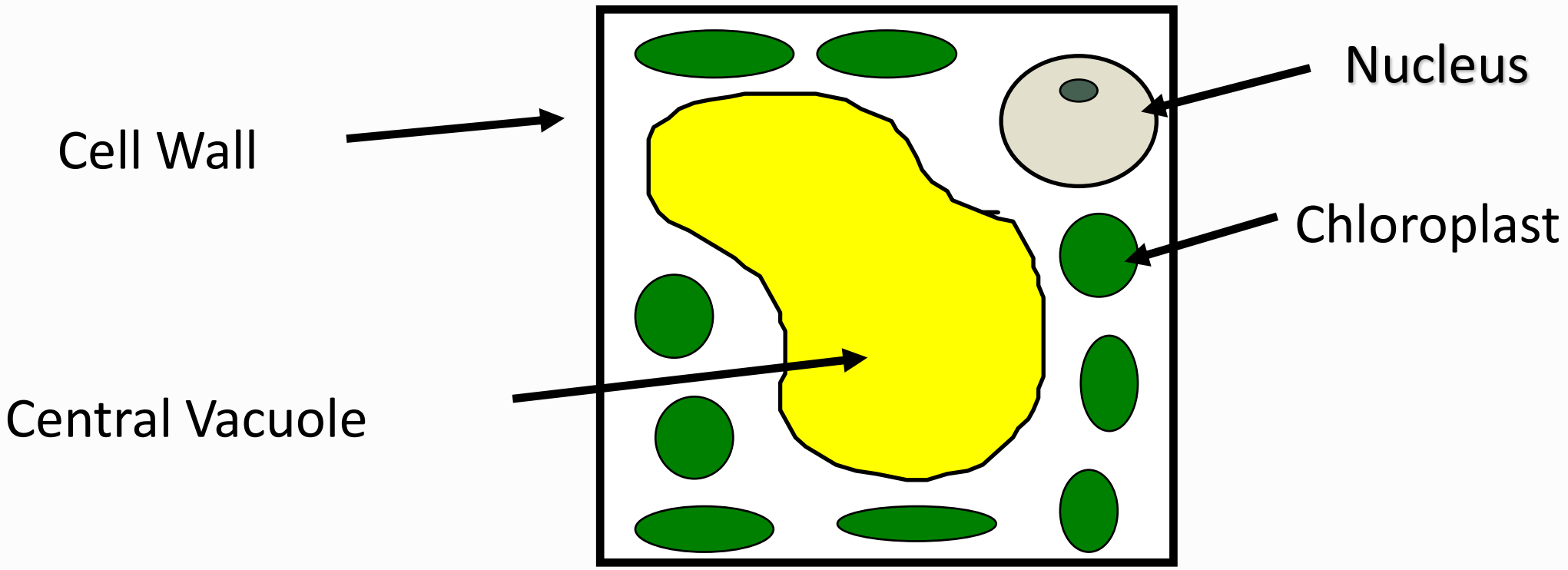
# Why do photosynthesis?

- Photosynthesis creates glucose from carbondioxide, water and light
- Plants need glucose to store energy and to build cellulose
- However, photosynthesis does not produce enough ATP for the cell's purposes
- Plant cells also have mitochondria to produce ATP

# Question:

## Where does photosynthesis take place?

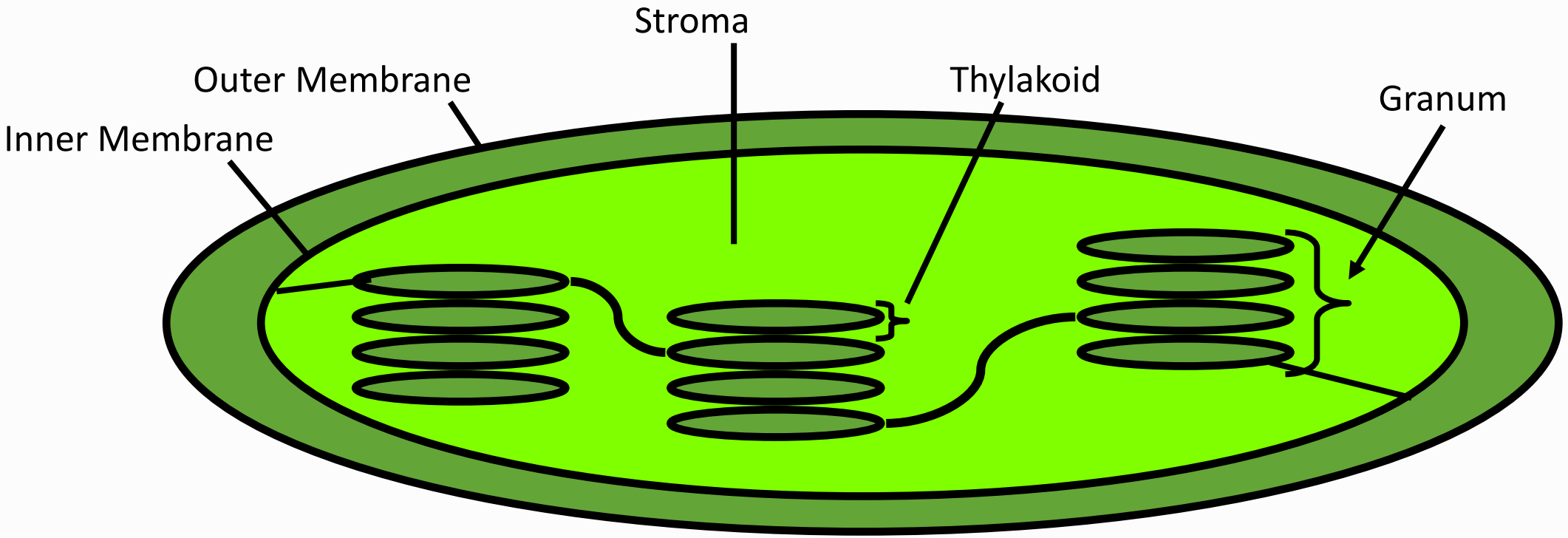
# Mesophyll Cell of Leaf




Photosynthesis occurs in these cells!

# Chloroplast

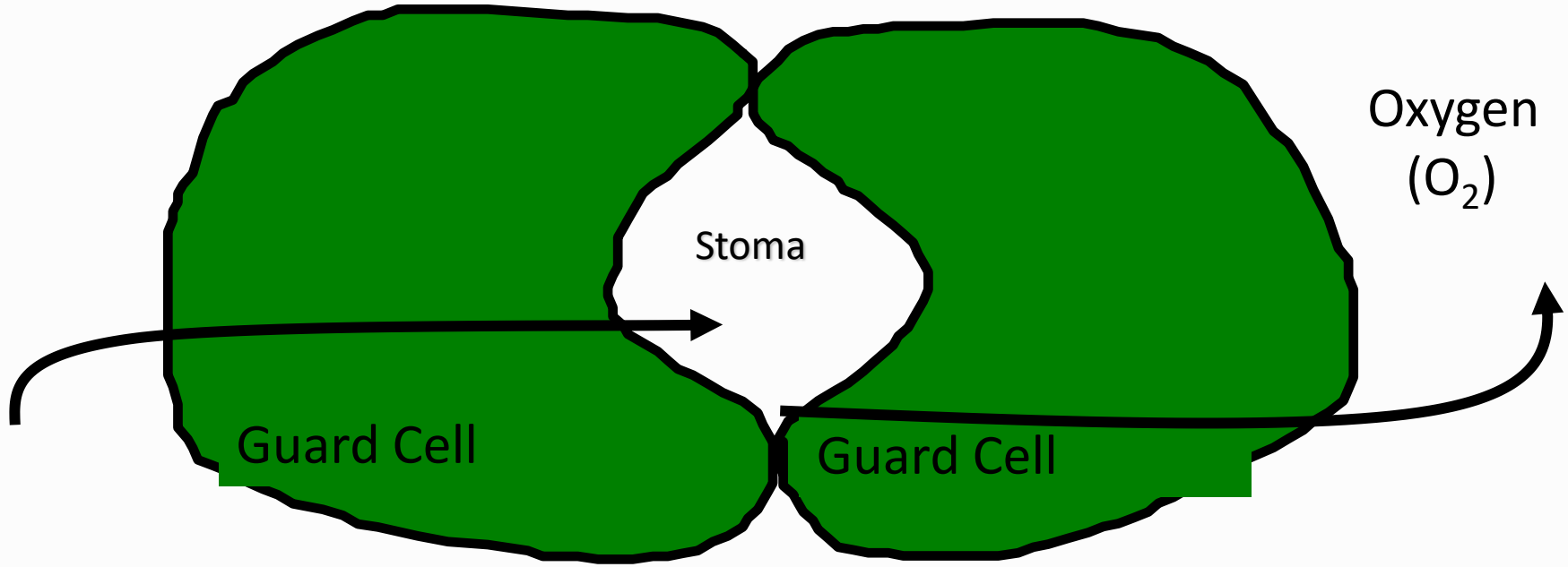
**Organelle** where **photosynthesis** takes place.




Thylakoid stacks are connected together

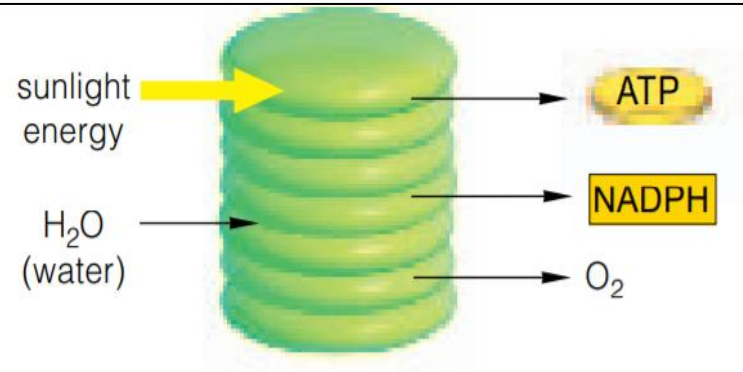
# Stomata (stoma)

**Pores** in a plant's cuticle through which **water vapor** and ***gases*** ($CO_2$ & $O_2$) are exchanged between the plant and the atmosphere.

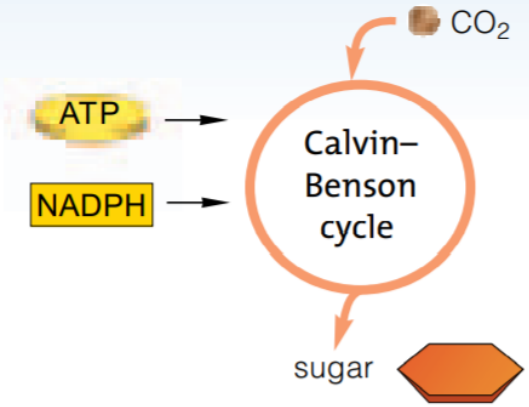



Found on the underside of leaves

# AN OVERVIEW OF PHOTOSYNTHESIS




**Making ATP and NADPH** In the first stage of photosynthesis, sunlight energy becomes converted to chemical bond energy of ATP. Water molecules are broken apart, NADPH forms, and oxygen escapes into the air.




**Making Sugars** The second stage is the "synthesis" part of photosynthesis. ATP delivers energy to reaction sites where sugars are built with atoms of hydrogen (delivered by NADPH), carbon, and oxygen (from carbon dioxide in the air).

# AN OVERVIEW OF PHOTOSYNTHESIS

Photosynthesis occurs in two stages in chloroplasts. Energy from the sun is converted to chemical energy and stored in ATP and NADPH. These molecules are later used to assemble sugars from carbon dioxide and water.

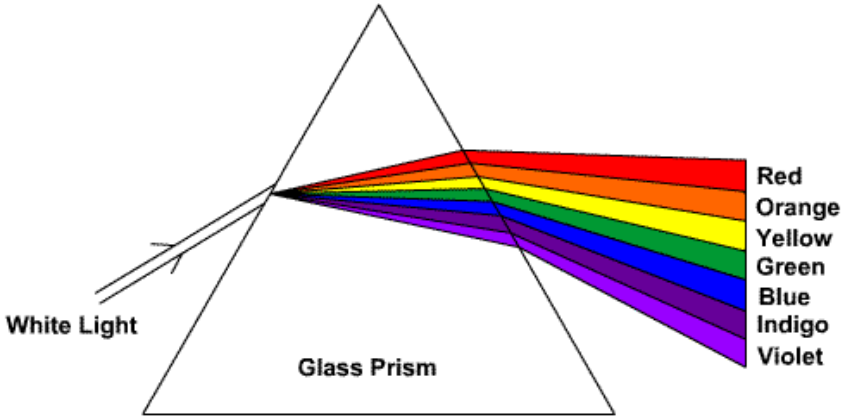
Chloroplasts split H2O into hydrogen and oxygen using light energy, incorporating the electrons of hydrogen into sugar molecules and releasing oxygen as a by-product.

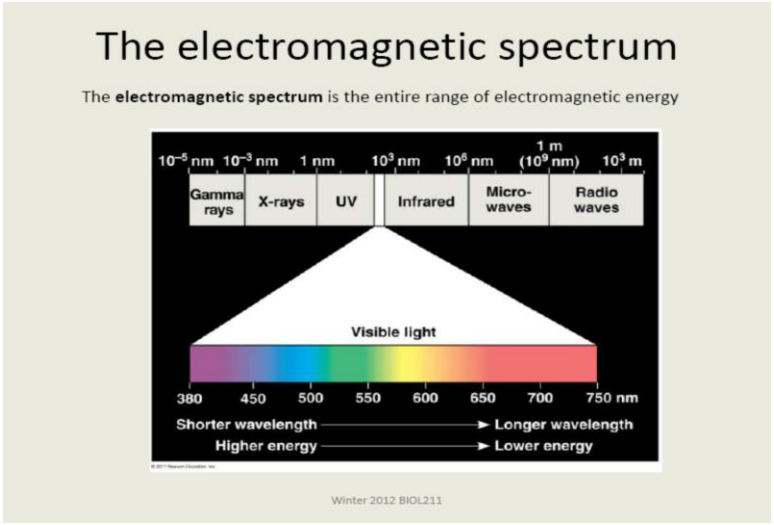
- Light
- The electromagnetic spectrum
- Pigments

# Light

Light is made of photons, which are individual packets of electromagnetic energy traveling in waves. The shorter a photon's wavelength, the higher its energy.

For example, blue light has a shorter wavelength and more energy than red light.



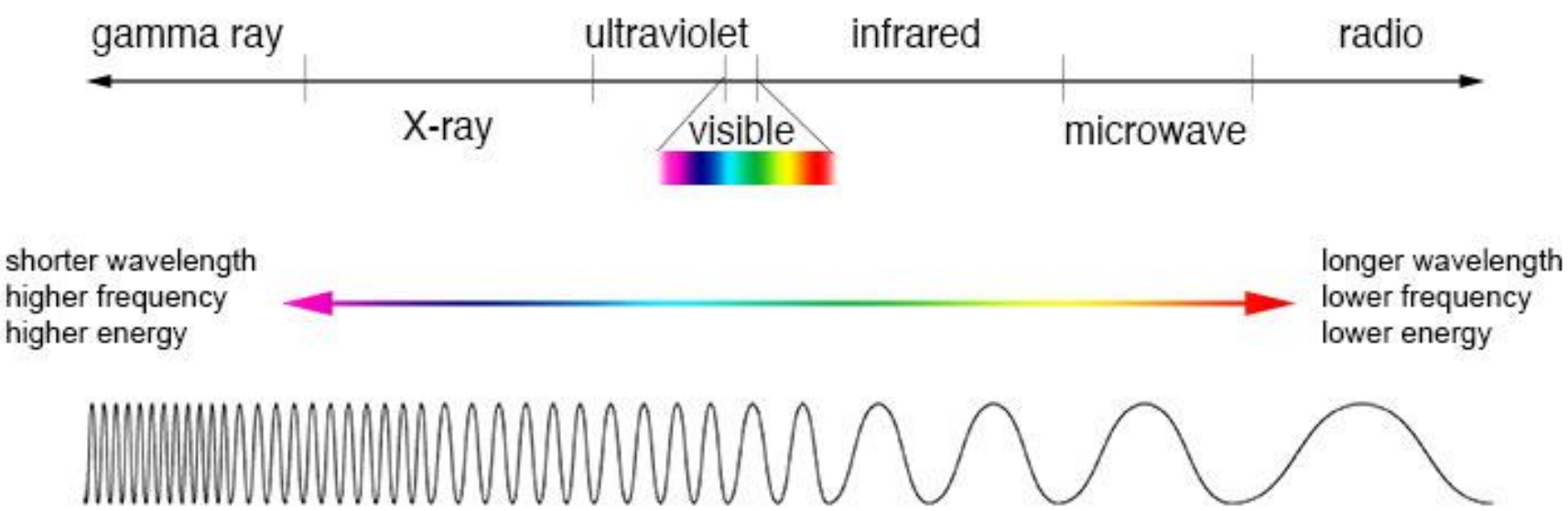

# Spectrum

When white light is passed through a prism it is resolved into various color components of different wave length, and what is obtained is called a spectrum. In the seventeenth century Newton showed that sun light is composed of various color components.

- The color we see is all about wavelength!!
- Maximum wavelength “Red”, minimum “Violet”.
- Energy goes up, wavelength goes shorter!

- Light is a form of electromagnetic energy, also called electromagnetic radiation
- Light is packaged into discrete units called photons
- Wavelength is the distance between crests of waves
- Wavelength determines the type of electromagnetic energy
- **How much we can see!?**

## The electromagnetic spectrum



# Pigments

Pigments are a class of molecules that absorb photons with particular wavelengths. Photons that a pigment cannot absorb bounce off or continue on through it; they are reflected or transmitted.

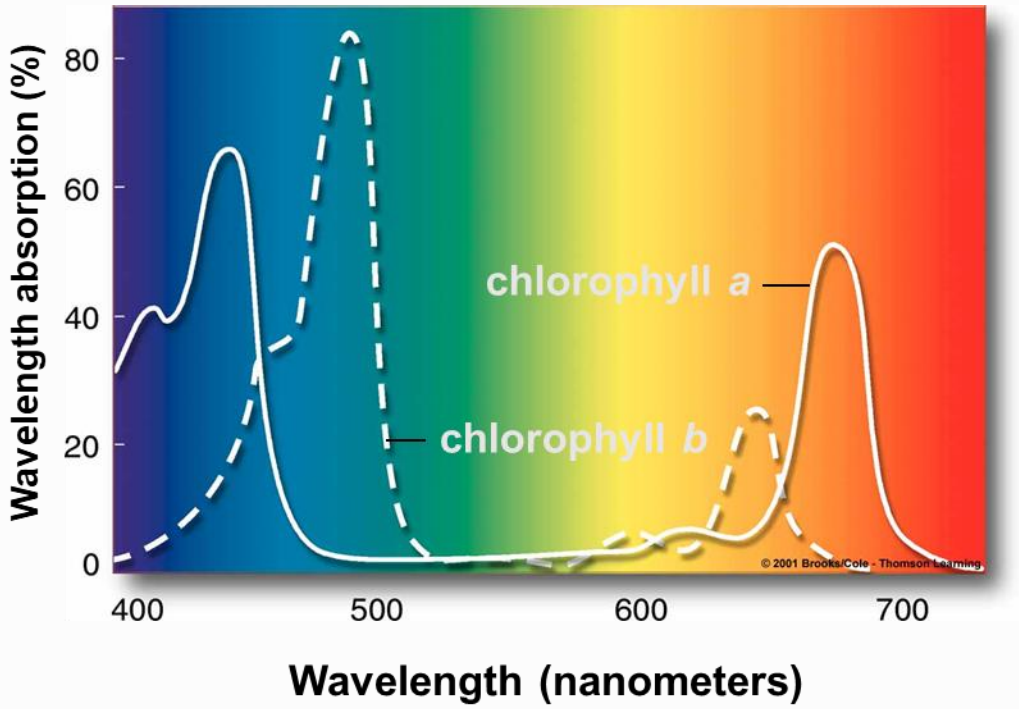
Chlorophyll a is the most abundant type in plants, green algae, and a number of photoautotrophic bacteria.

# Pigments

Pigments are light-absorbing molecules

They absorb some wavelengths and transmit others

Color you see are the wavelengths not absorbed



# Variety of Pigments

| Pigment | Colour reflected | Found in |
|---|---|---|
| Chlorophyll a | Green-yellow | Plants, algae, cyanobacteria |
| Chlorophyll b | Green | Plants |
| Carotenoids | Yellow, orange, red | Plants, algae, bacteria, fruits, vegetables, flowers |
| Anthocyanins | Red, purple, blue | Plants, fruits, flowers |
| Phycobillins | Blue, green, yellow, brown, black, red | Algae |

# Pigments in Photosynthesis

Bacteria

- Pigments in plasma membranes

Plants

- Pigments embedded in thylakoid membrane system
- Pigments and proteins organized into photosystems
- Photosystems located next to electron transport systems

# Chloroplast Pigments

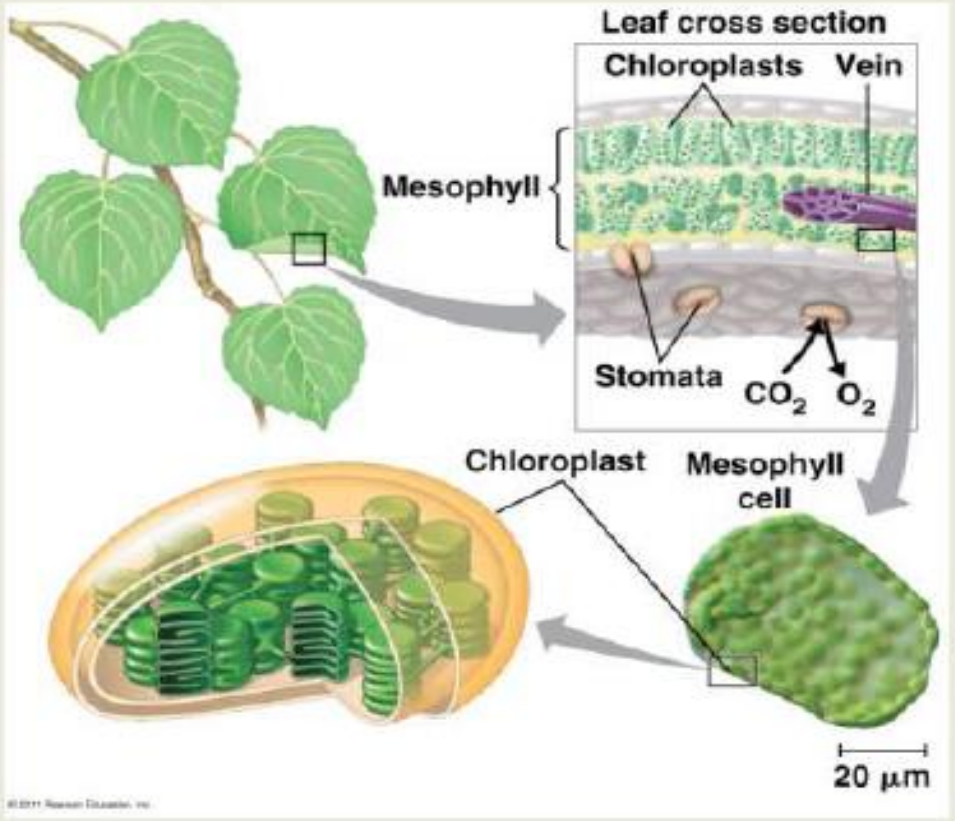
Chloroplasts contain several pigments…..

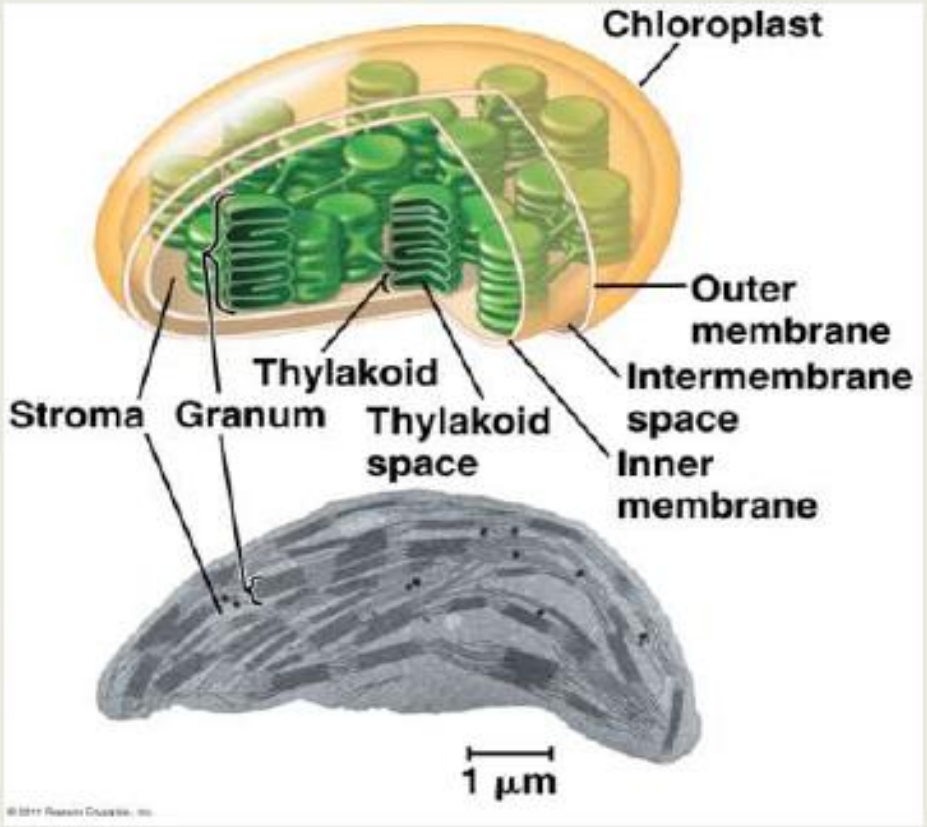
- Chlorophyll a
- Chlorophyll b
- Carotene
- Xanthophyll

Figure 7.7

# Where does photosynthesis happen?

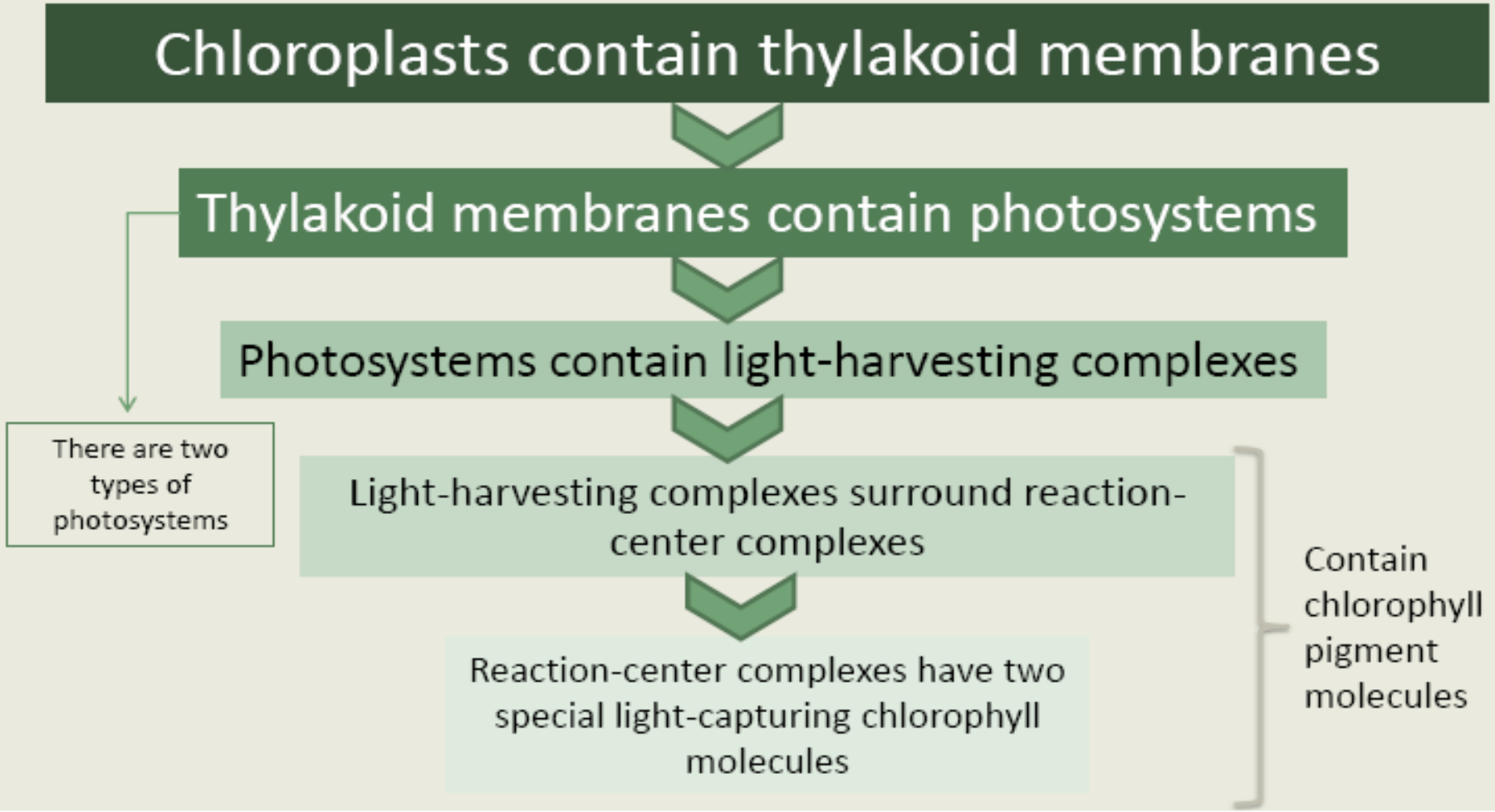
Photosynthesis takes place in the chloroplasts



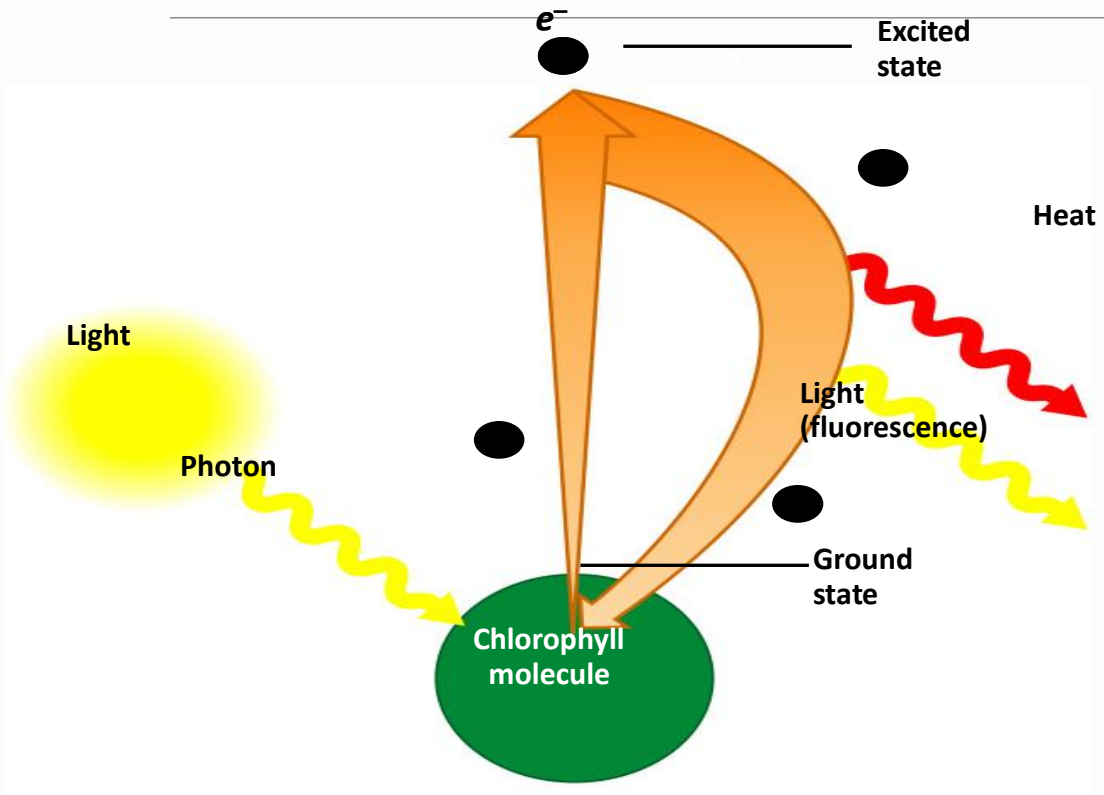



# What goes where in chloroplasts

Chloroplasts are solar-powered chemical factories



# Excitation of chlorophyll in a chloroplast




(a) Absorption of a photon

# Parts of Photosynthesis

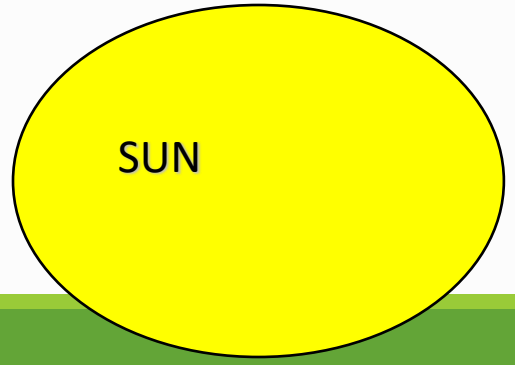
# Two Parts of Photosynthesis

Two reactions make up photosynthesis:

1. Light Reaction or Light Dependent Reaction

-

Produces energy from solar power (photons) in the form of ATP and NADPH.

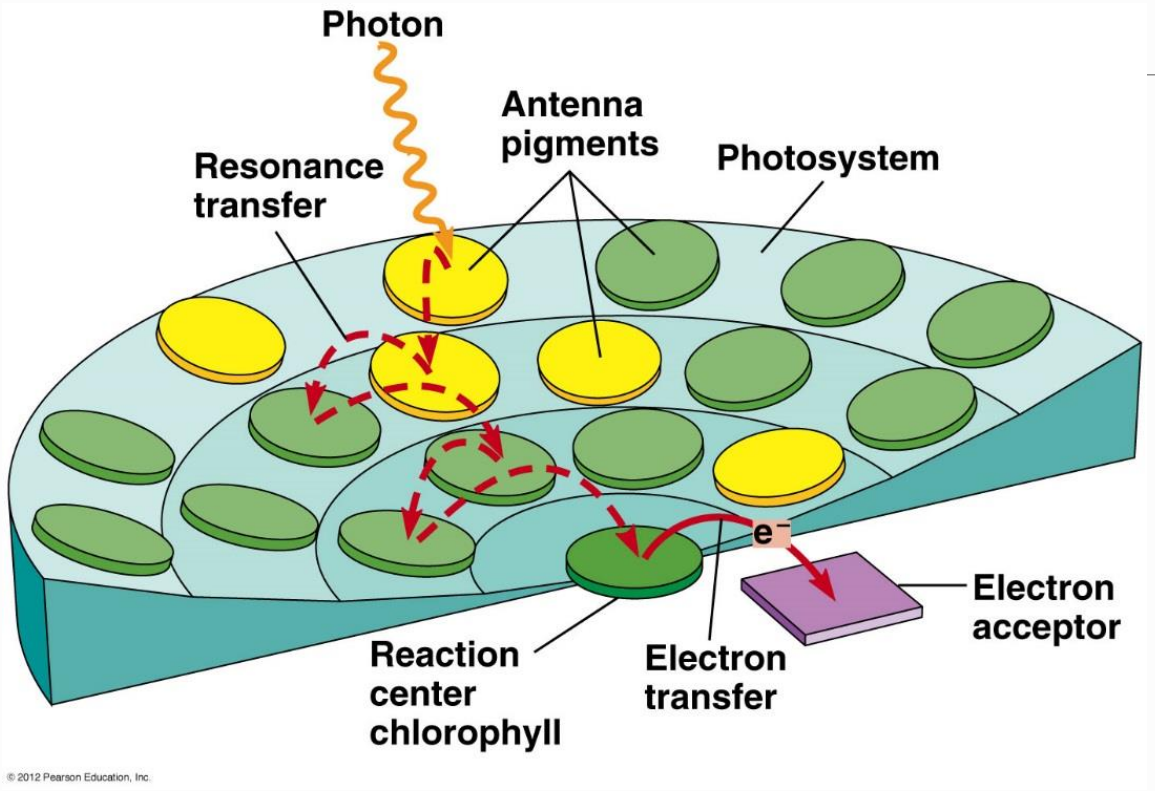


# Two Parts of Photosynthesis

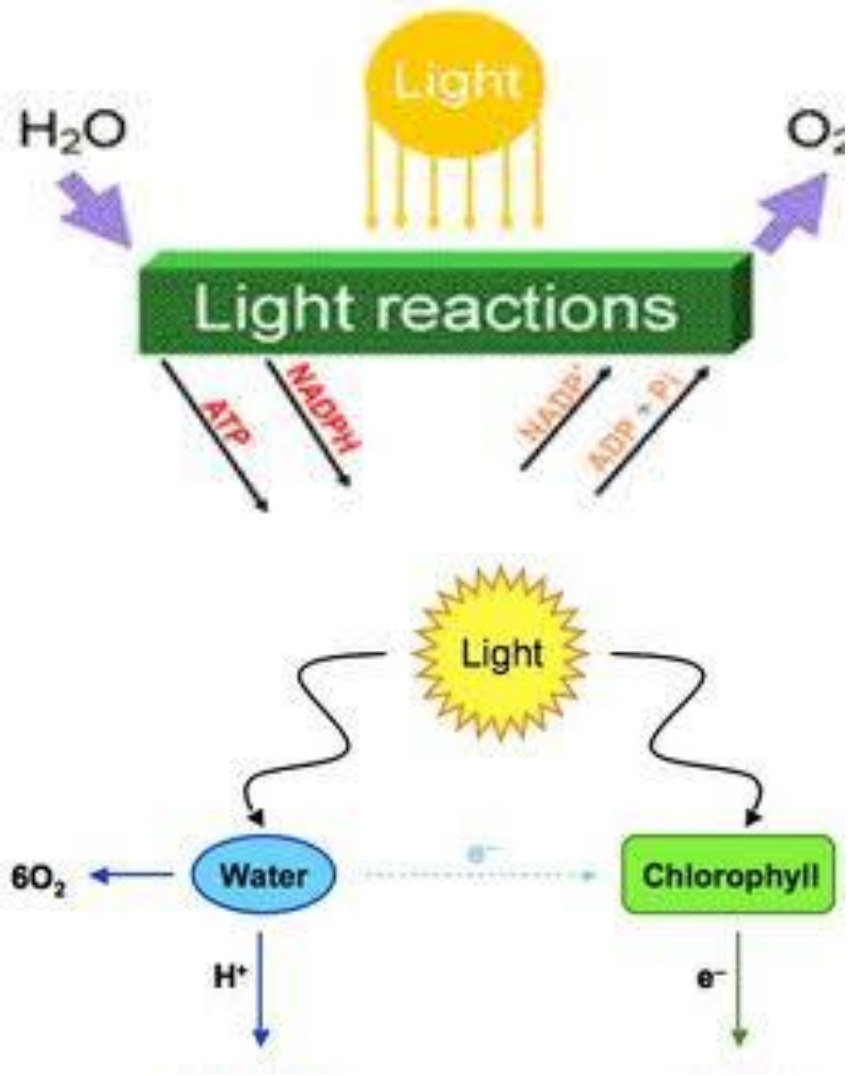
## 2. Calvin Cycle or Light Independent Reaction

- Also called Carbon Fixation or $C_3$ Fixation
- Uses energy (ATP and NADPH) from light reaction to make sugar (glucose).

# What happens inside the photosystem?




- Light energy is captured by the antenna pigments of the light-harvesting complexes
- The light energy undergoes resonance transfer and move into the reaction center
- The electrons in the reaction center are excited and are transferred to electron acceptors and passed through the electron transport chain into photosystem I
- The entry of electrons from a photosystem into an electron transfer chain is the first step in the **light-dependent reactions**—in the conversion of photon energy to chemical energy for photosynthesis.

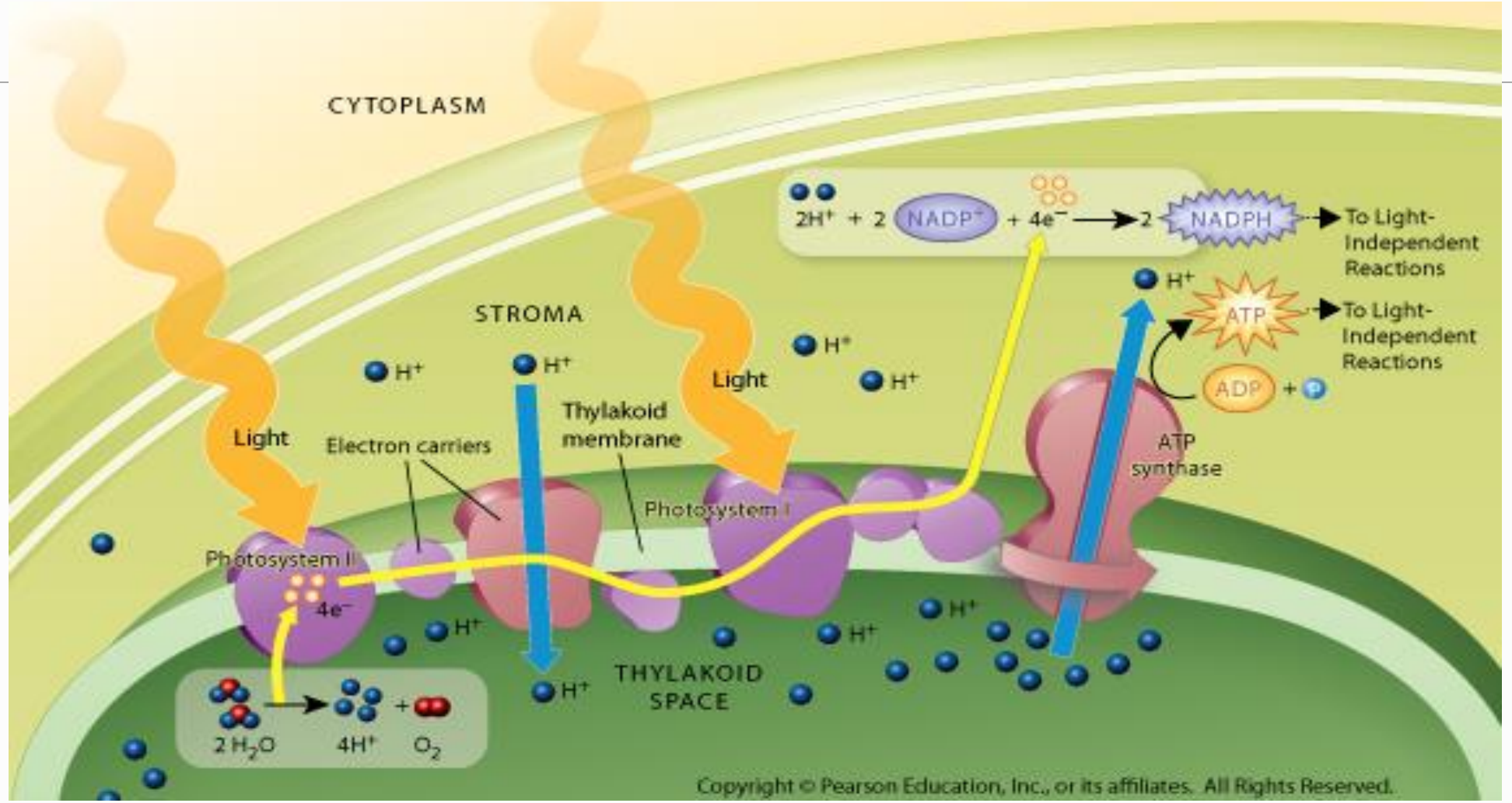



# Photolysis of Water

- Water gets split inside thylakoid

  Breaks into:
  - One oxygen atom
  - Two $H^+$ ions
  - 2 electrons
- Electrons move into the photosystem II
- $H^+$ accumulate in the thylakoids space
- The oxygen is produced by splitting water which gets released into the air
- Source of nearly all the oxygen in Earth's atmosphere!

# Overview of light dependent reaction

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# Light Reaction (Electron Flow)

- Occurs in the Thylakoid membranes
- During the light reaction, there are two possible routes for electron flow:

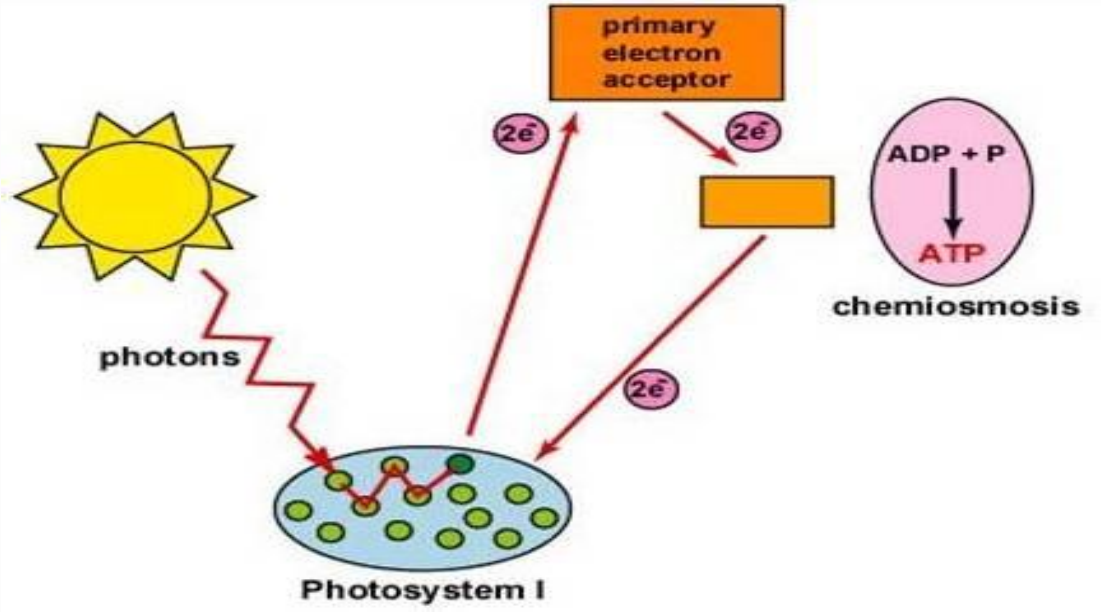
A. Cyclic Electron Flow

B. Noncyclic Electron Flow

# Cyclic Electron Flow

- Occurs in the thylakoid membrane.
- Uses Photosystem I only
- P700 reaction center- chlorophyll a
- Uses Electron Transport Chain (ETC)
- Generates ATP only

ADP + P ⟶ ATP



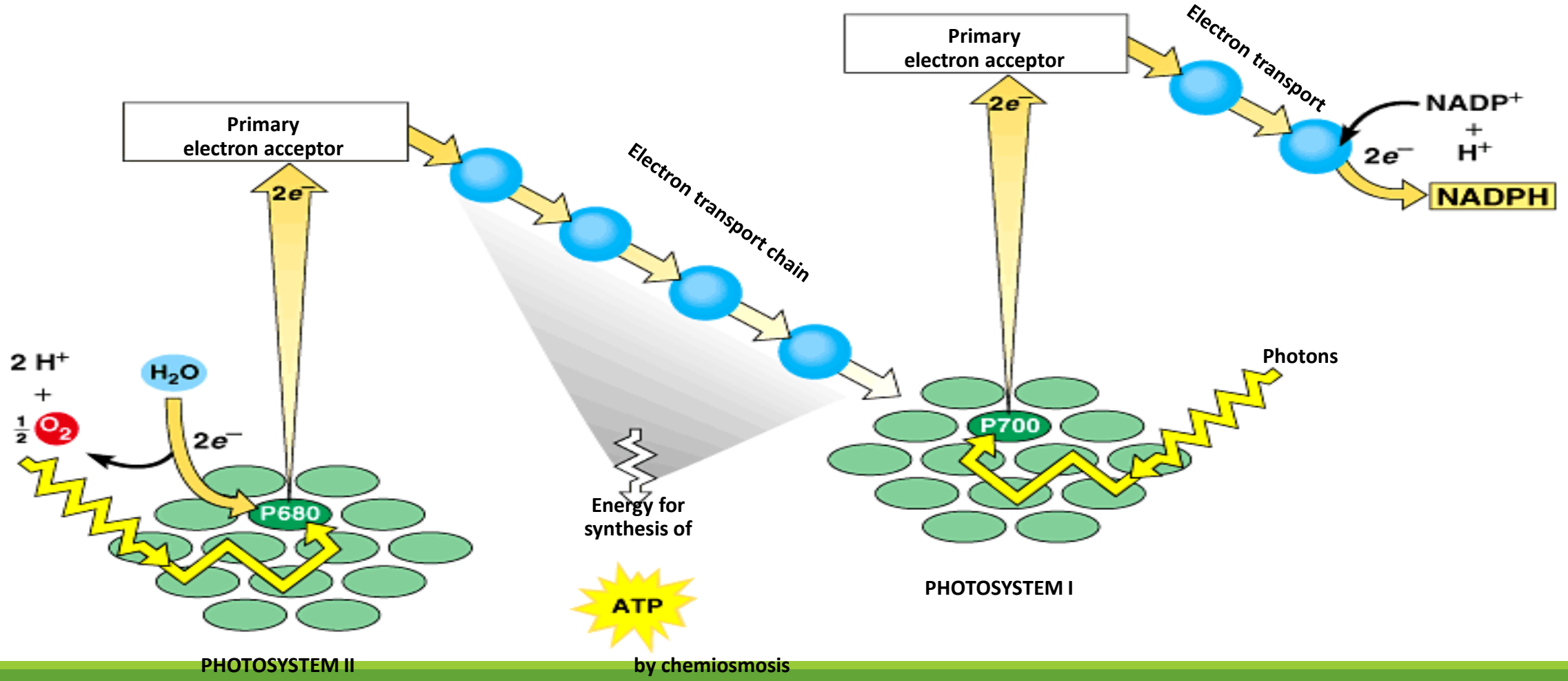
# Noncyclic Electron Flow

- ADP + P → ATP
- $NADP^+ + e^+ + H^+ \rightarrow$ NADPH
- Oxygen comes from the splitting of $H_2O$, not $CO_2$

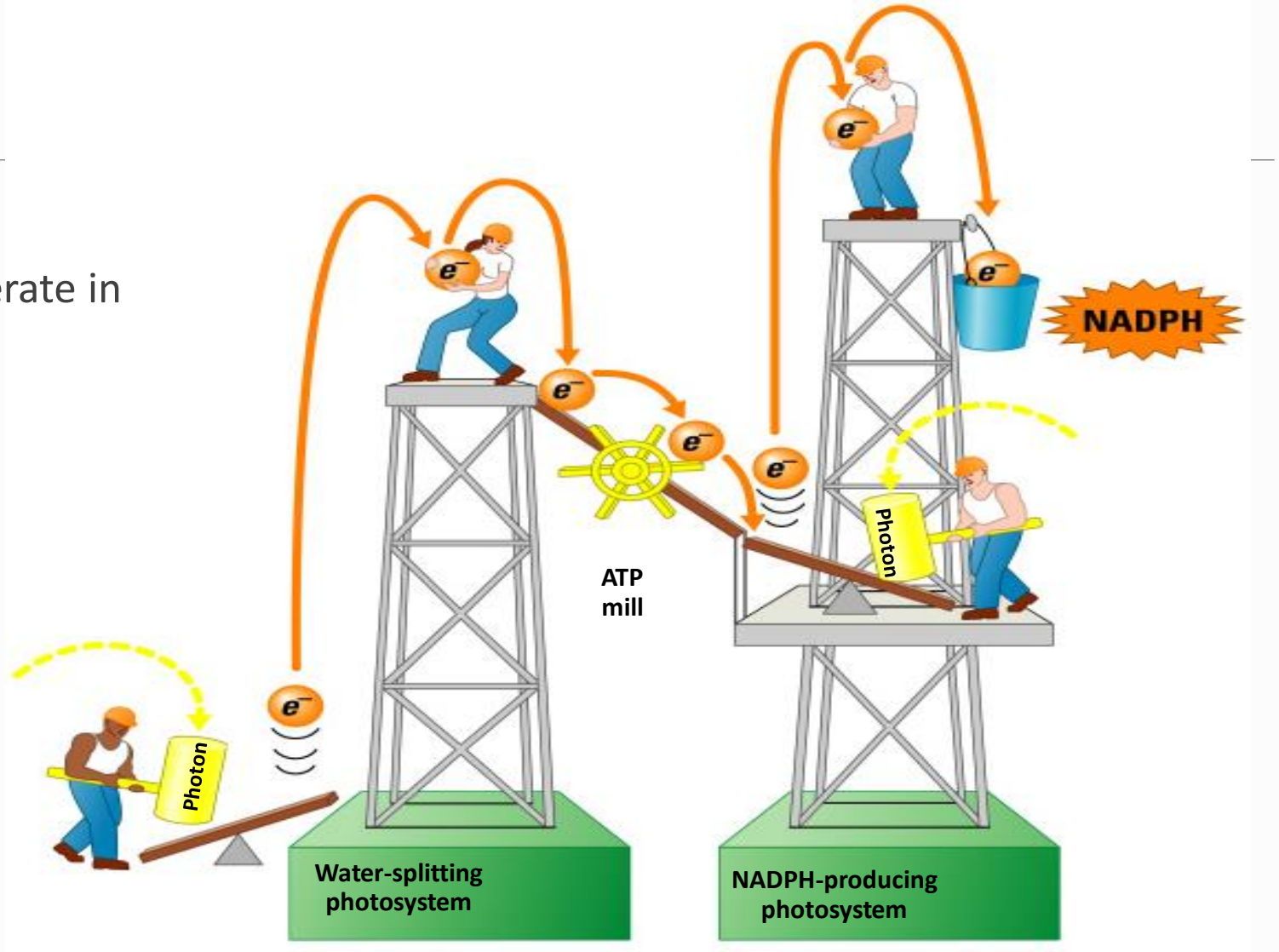
$$H_2O \rightarrow 1/2\ O_2 + 2H^+$$

# Noncyclic Photophosphorylation

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



Two types of photosystems cooperate in the light reactions



# Chemiosmosis powers ATP synthesis in the light reactions

- The electron transport chains are arranged with the photosystems in the thylakoid membranes and pump $H^+$ through that membrane
  - The flow of $H^+$ back through the membrane is harnessed by ATP synthase to make ATP
  - In the stroma, the $H^+$ ions combine with $NADP^+$ to form NADPH

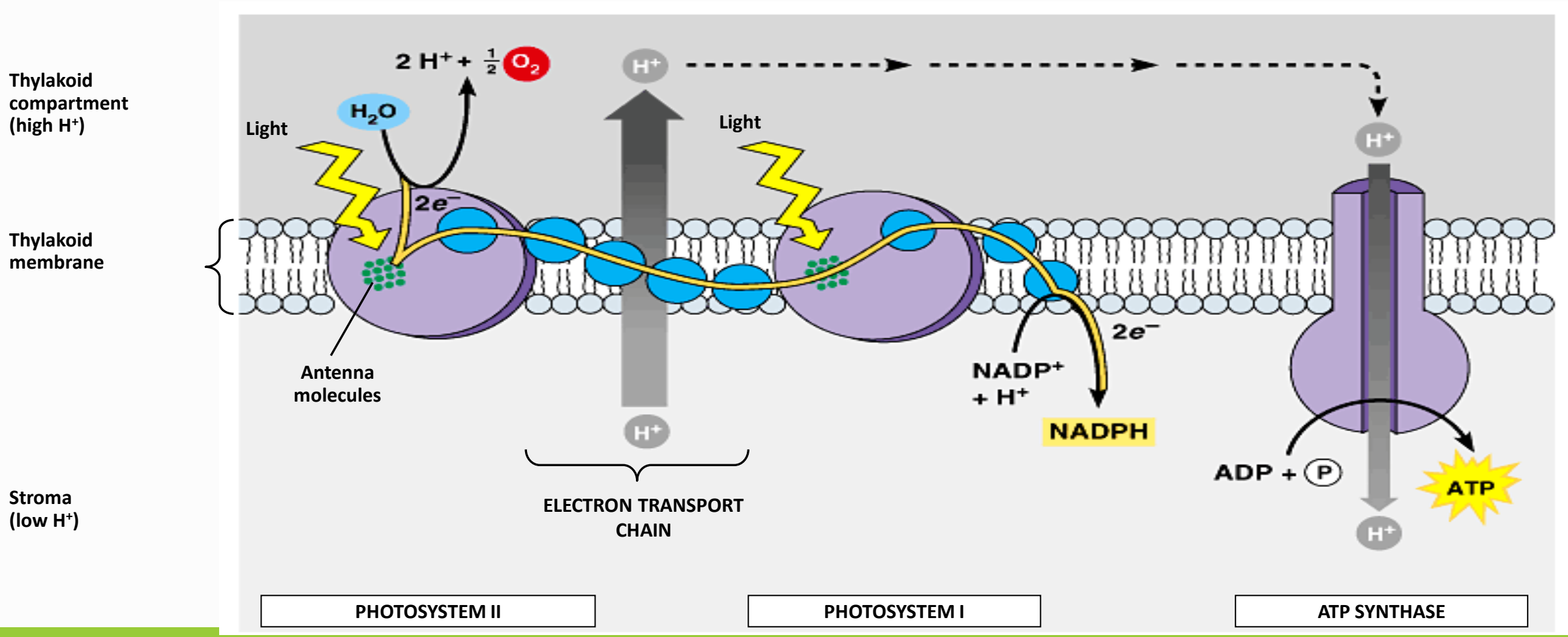
# Making ATP

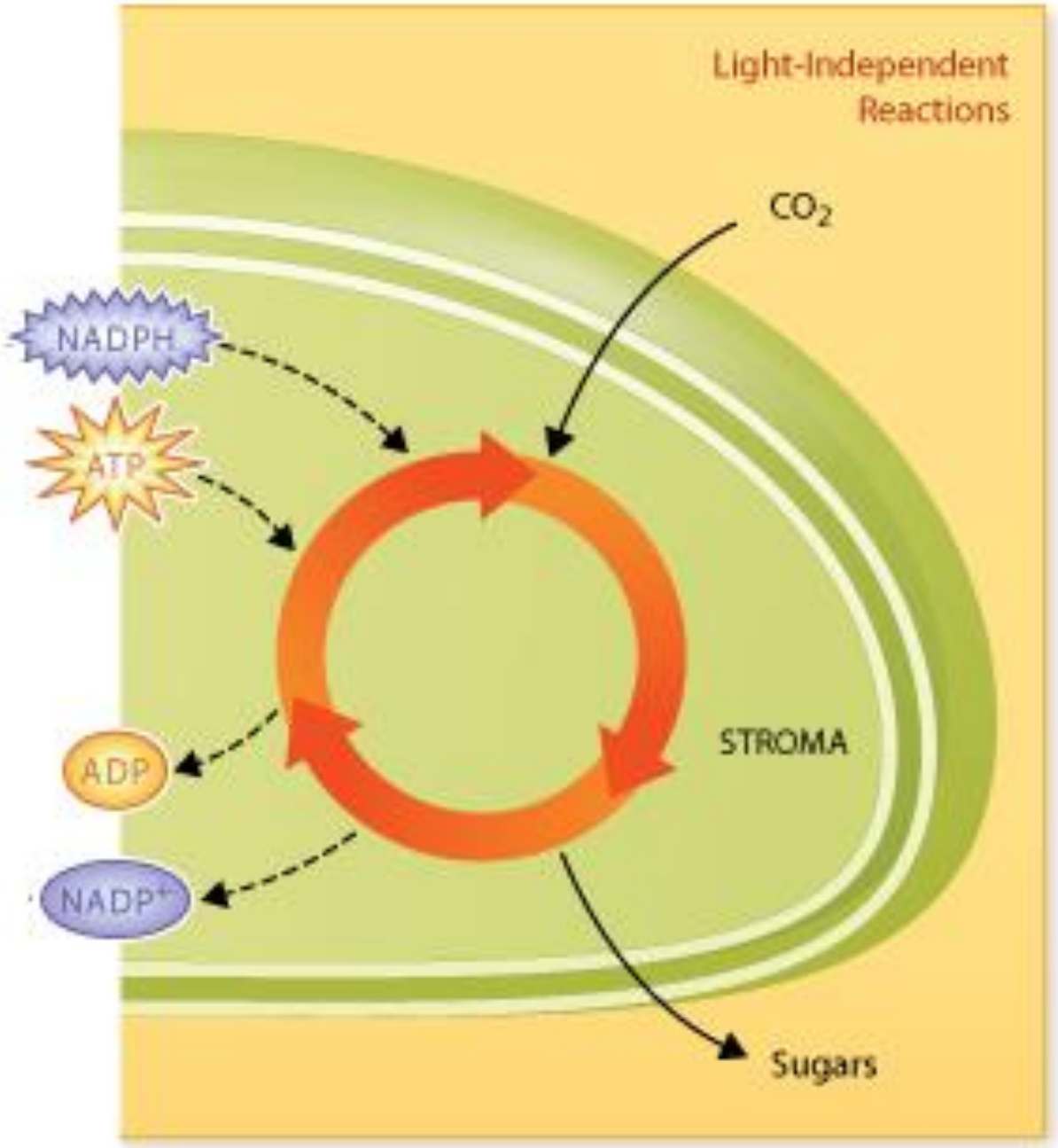
$H^+$ ions build up in the thylakoid space

They move and cross the thylakoid membrane down the concentration gradient

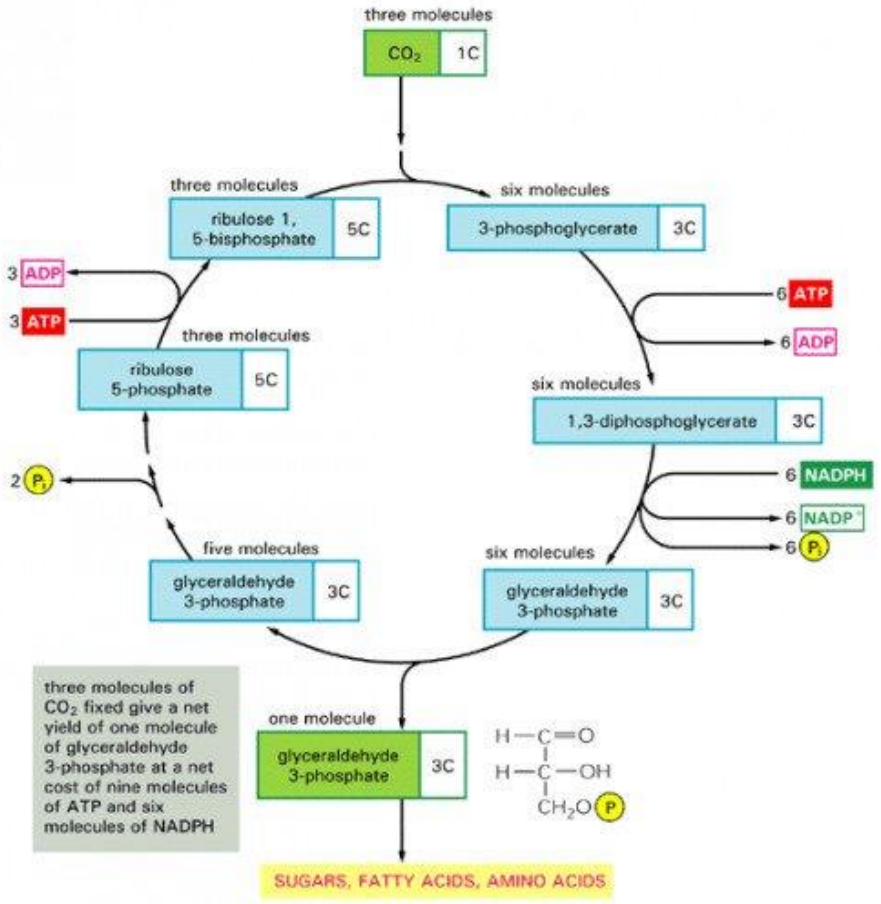
This triggers ATP to form by ATP synthase (an enzyme) that turns ADP into ATP.

# The production of ATP by chemiosmosis in photosynthesis

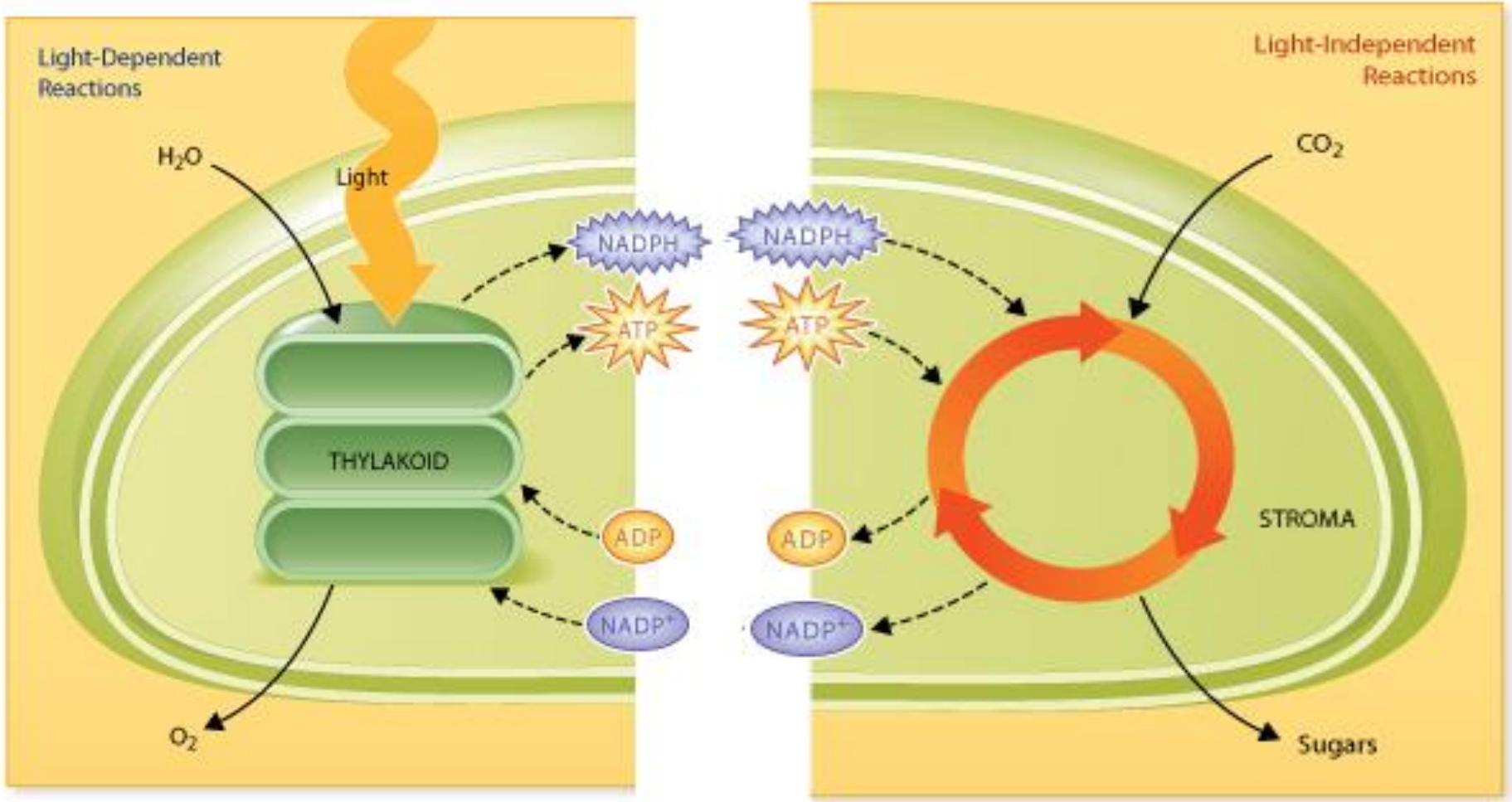




# Dark Reaction ( C3 Cycle)

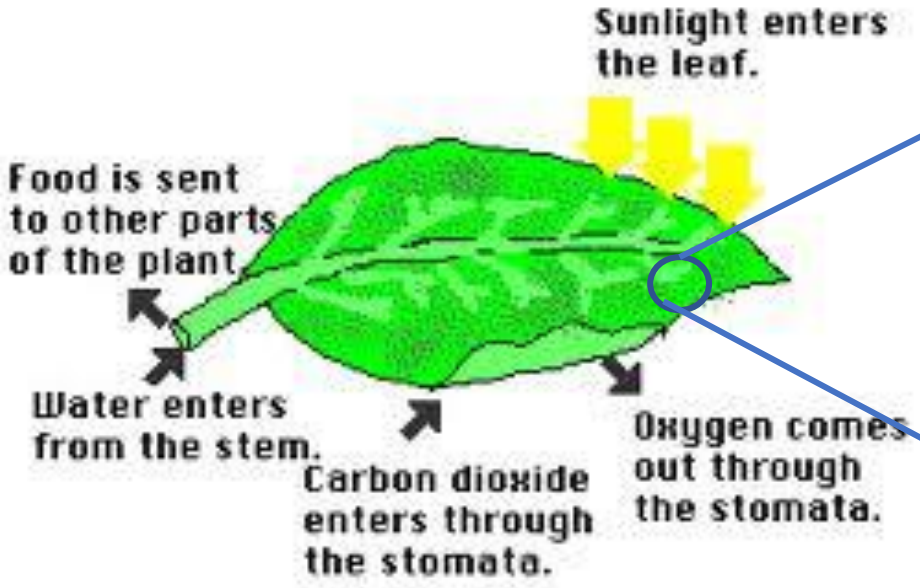


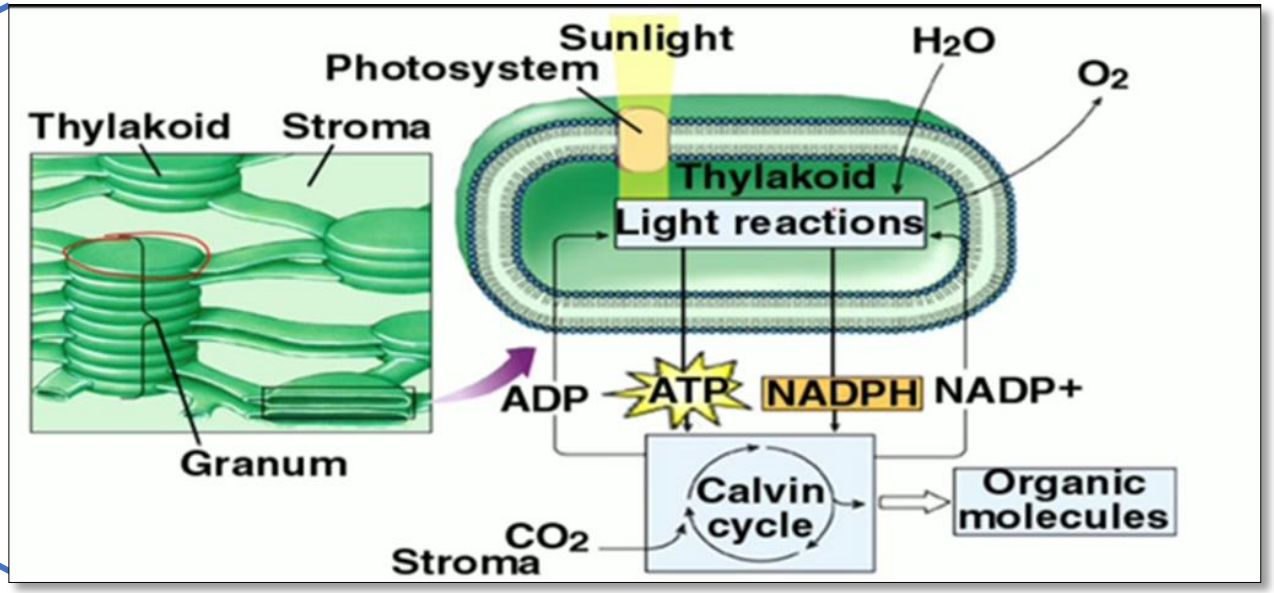
# Light vs. Dark Reactions



# The Process of Photosynthesis

- How Does the Chloroplast Work?
  - Light Dependent Reactions (Photochemical)
  - Light Independent Reactions (Carbon Fixation)

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