LEARNING OBJECTIVES

By the end of this lecture you will be able to:

1. Understand that ENERGY can be transformed from one form to another.
2. Know that energy exist in two forms; free energy - available for doing work or as heat - a form unavailable for doing work.
3. Appreciate that the Sun provides most of the energy needed for life on Earth.
4. Explain why photosynthesis is so important to energy and material flow for life on earth.
5. Know why plants tend to be green in appearance.
6. Equate the organelle of photosynthesis in eukaryotes with the chloroplast.
7. Describe the organization of the chloroplast.
8. Understand that photosynthesis is a two fold process composed of the **light-dependent reactions (i.e., light reactions)** and the light independent reactions (i.e. Calvin Cycle or Dark Reactions).
9. Tell where the light reactions and the CO_2 fixation reactions occur in the chloroplast.
10. Define chlorophylls giving their basic composition and structure.
11. Draw the absorption spectrum of chlorophyll and compare it to the action spectrum of photosynthesis.
12. Define the Reaction Centers and Antennae and describe how it operates.
13. Describe cyclic photophosphorylation of photosynthesis.
14. Describe noncyclic photophosphorylation of photosynthesis.

Energy can be transformed from one form to another

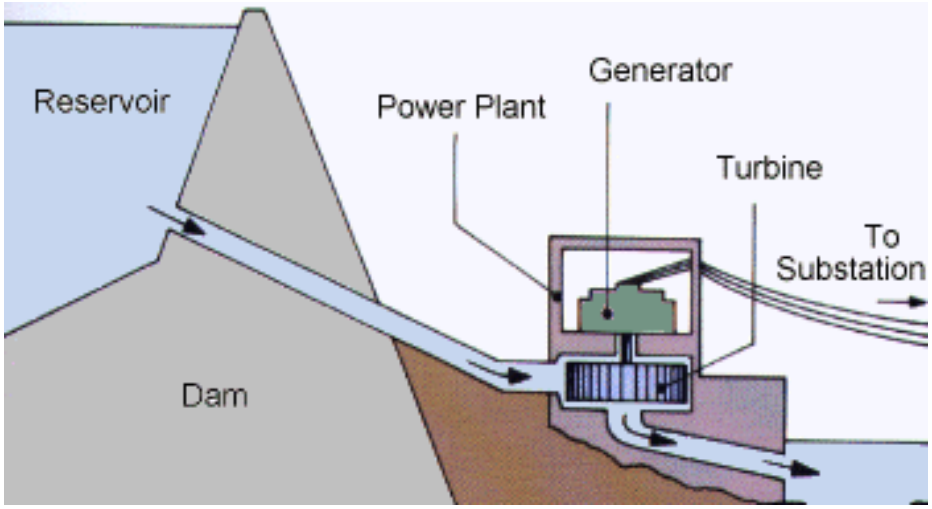
FREE ENERGY

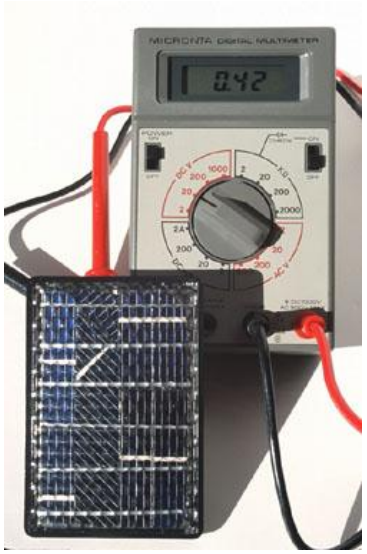
(available for work)

vs.

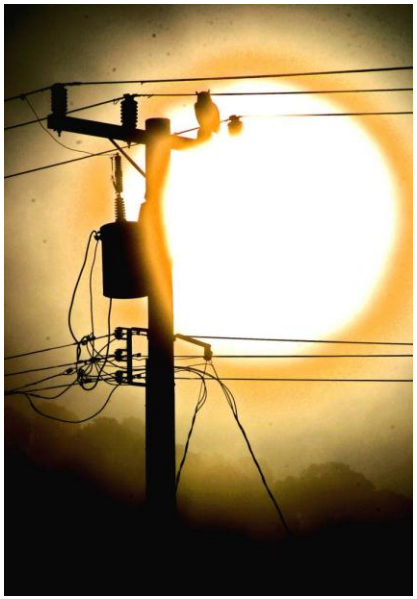
HEAT

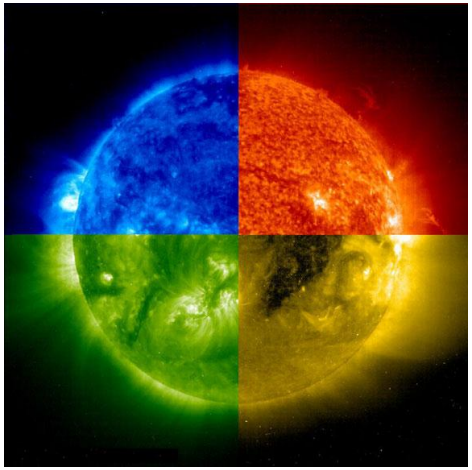
(not available for work)





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

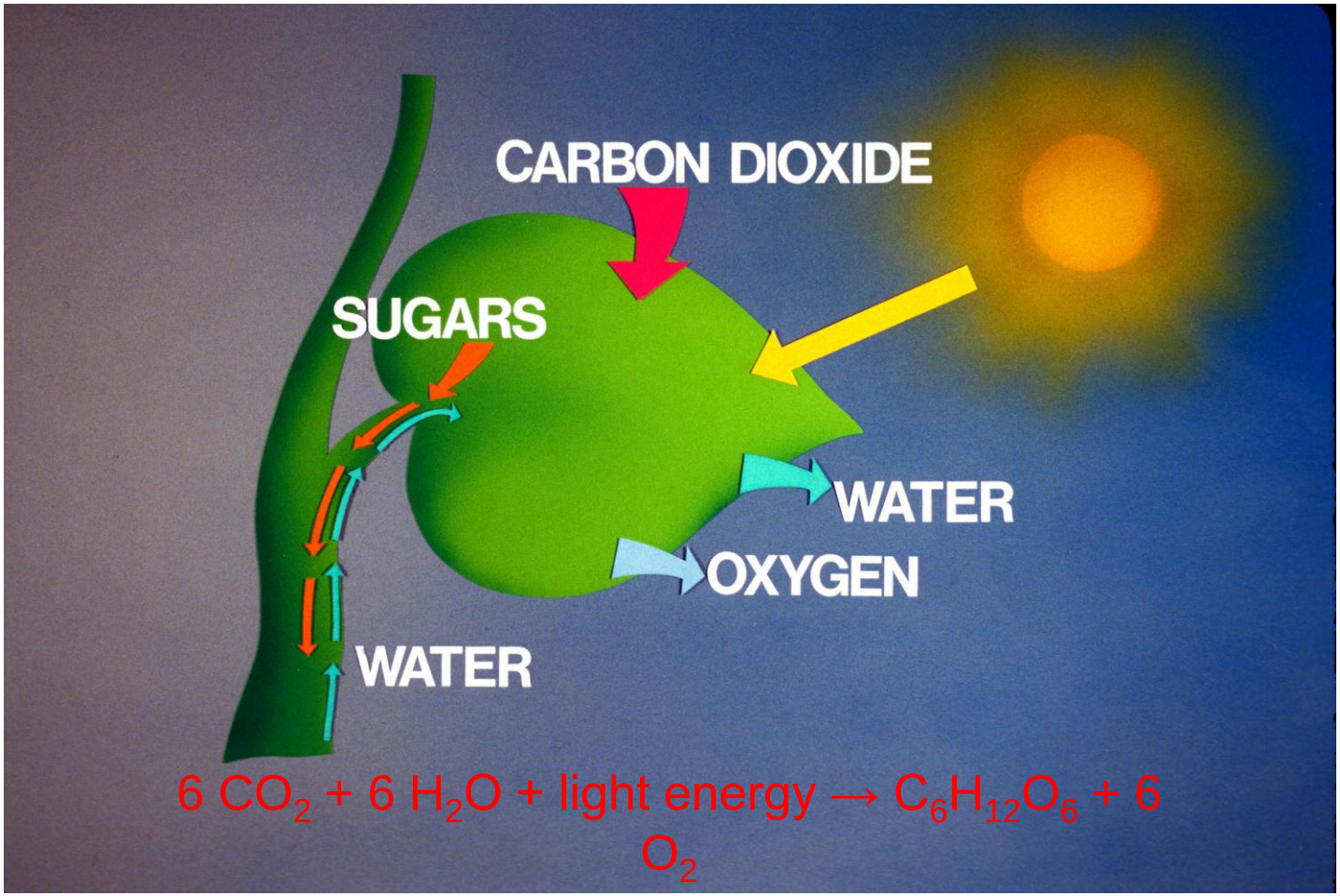
(a) Mosses, ferns, and *flowering plants*

(b) Kelp

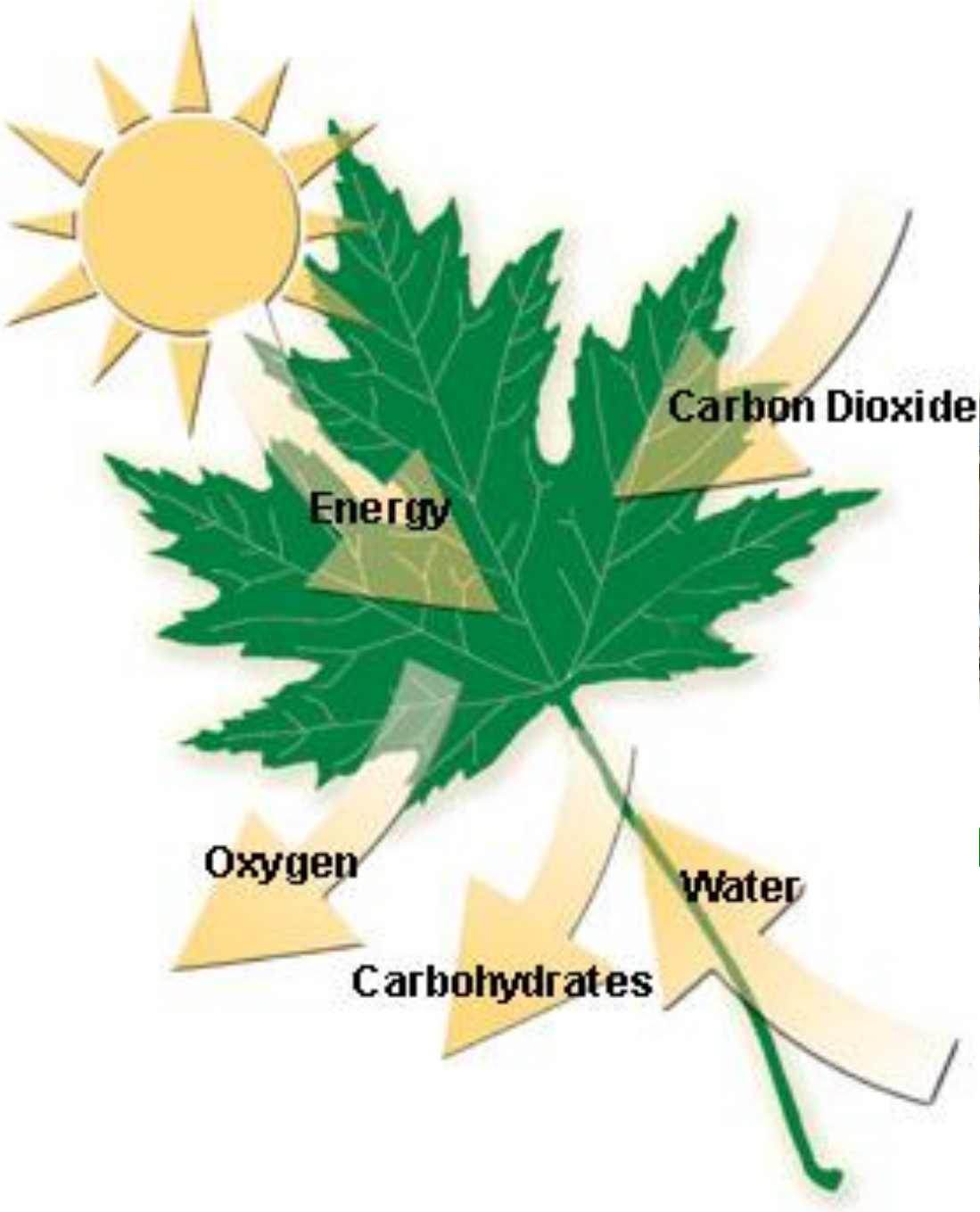
(c) *Euglena*

(d) Cyanobacteria

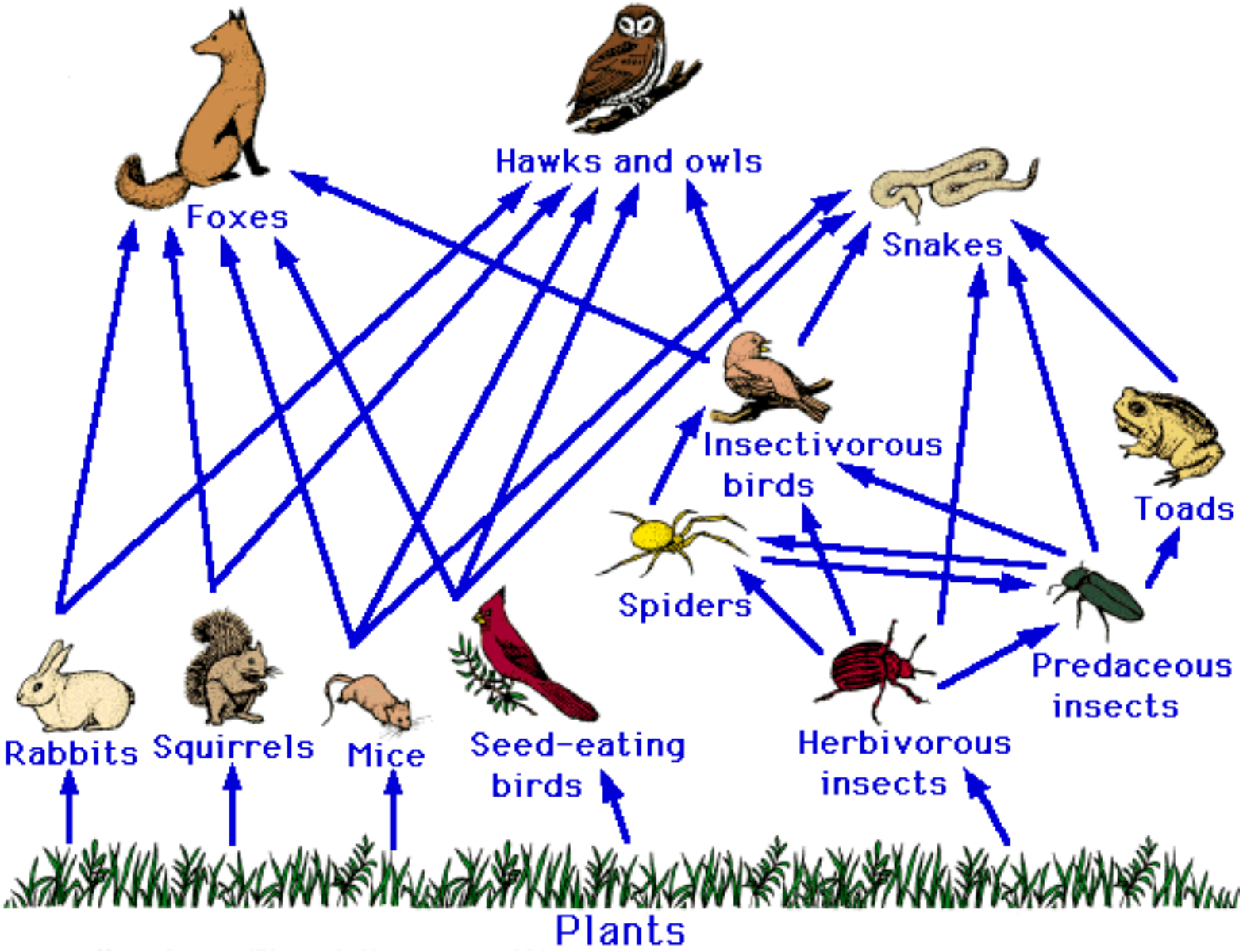
Light Energy Harvested by Plants & Other Photosynthetic Autotrophs



$6\ CO_2 + 6\ H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$


Carbon Dioxide
Energy
Oxygen
Water
Carbohydrates

THE FOOD WEB

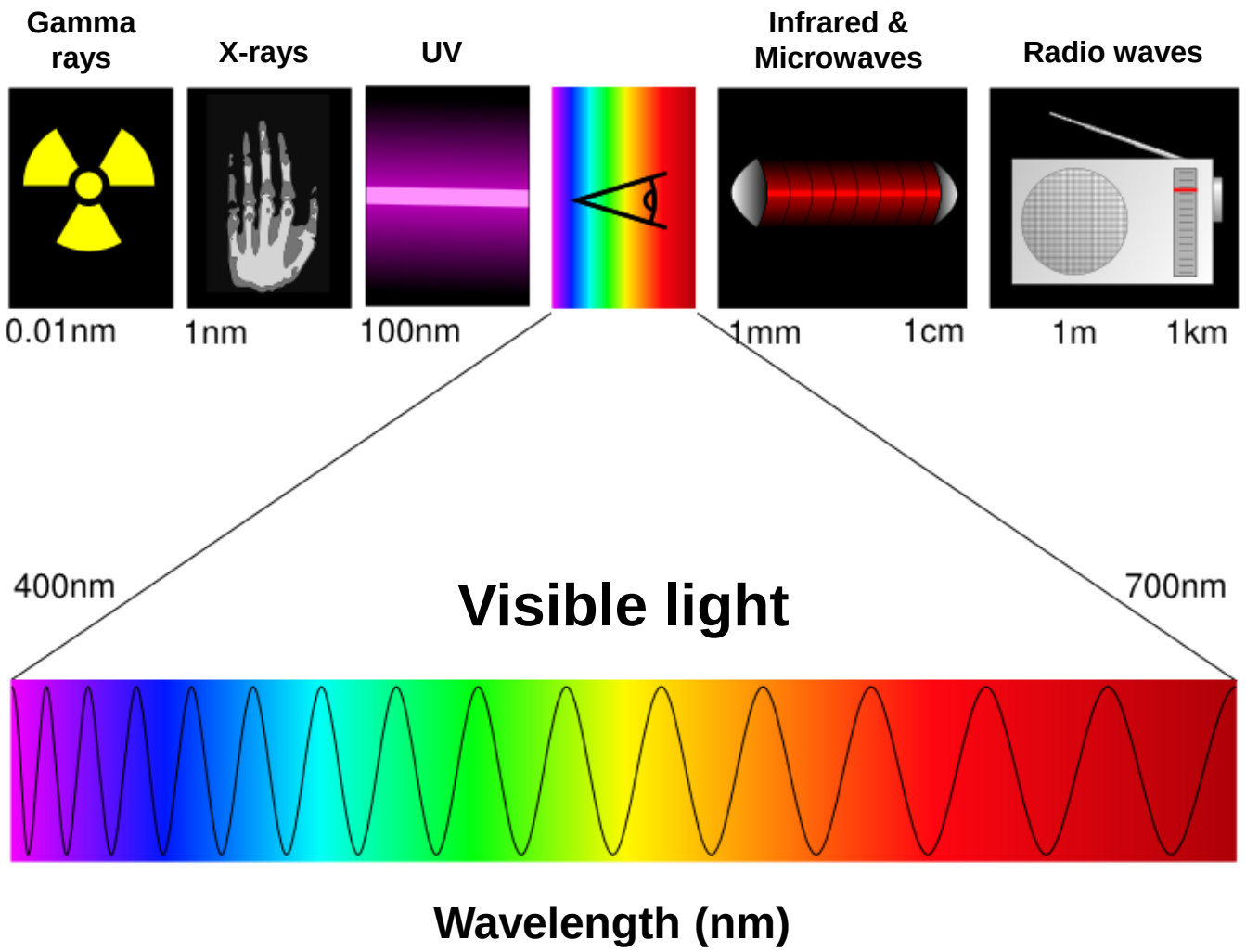

Hawks and owls
Foxes
Snakes
Insectivorous birds
Toads
Spiders
Predaceous insects
Rabbits
Squirrels
Mice
Seed-eating birds
Herbivorous insects
Plants

WHY ARE PLANTS GREEN?

It's not that easy bein' green
Having to spend each day the color of the leaves
When I think it could be nicer being red or yellow or gold
Or something much more colorful like that…

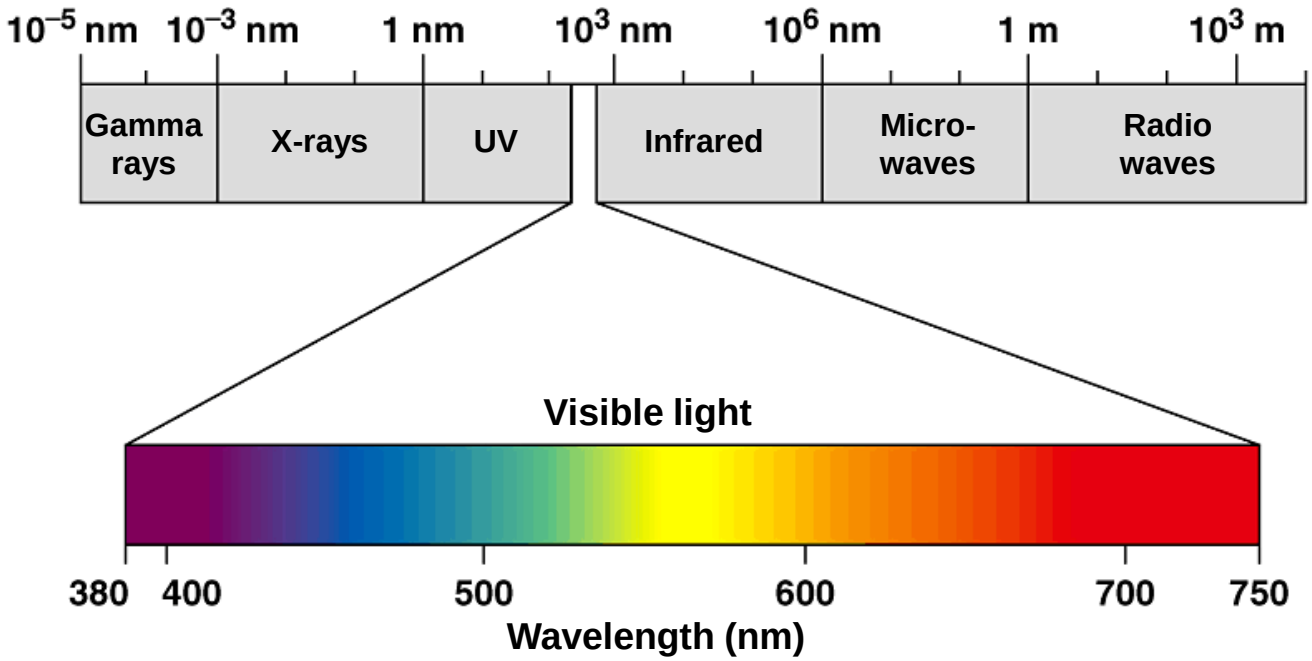
Kermit the Frog

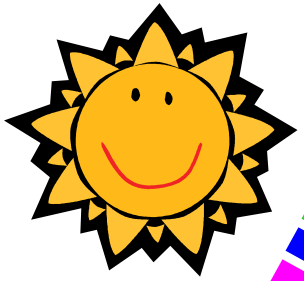
Electromagnetic Spectrum and Visible Light

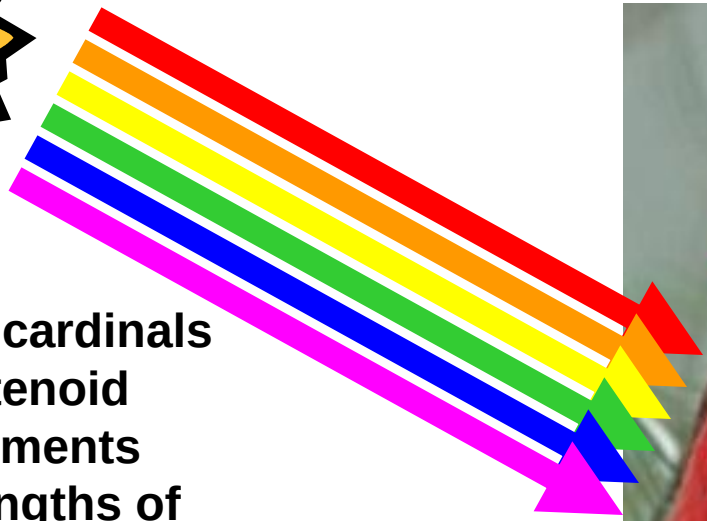


WHY ARE PLANTS GREEN?

Different wavelengths of visible light are seen by the human eye as different colors.



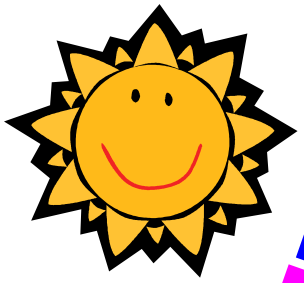


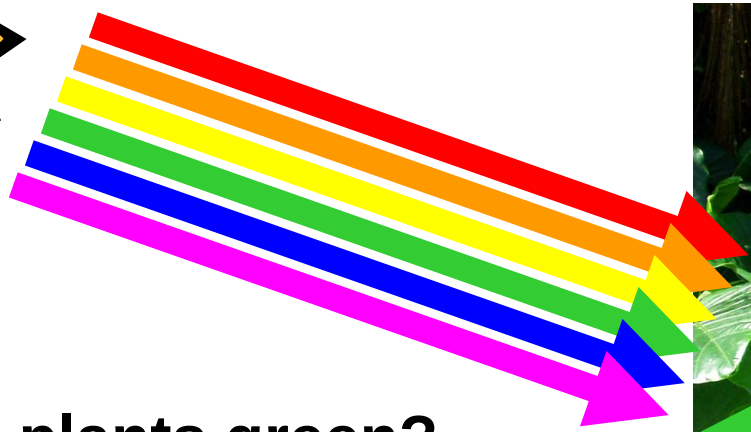


The feathers of male cardinals are loaded with carotenoid pigments. These pigments absorb some wavelengths of light and reflect others.

Reflected light

Sunlight minus absorbed wavelengths or colors equals the apparent color of an object.



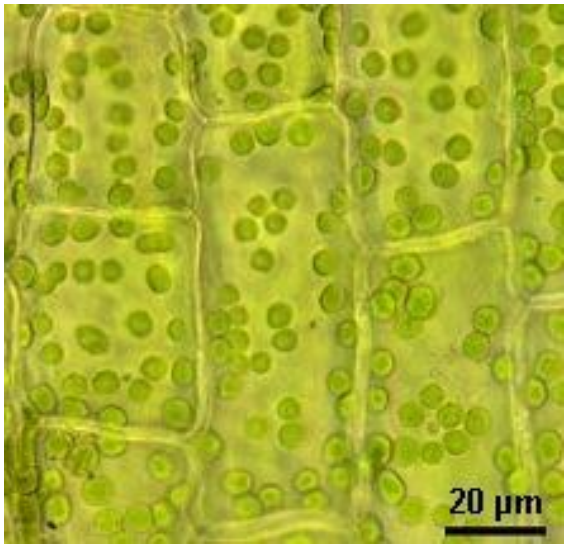


Why are plants green?

Reflected light

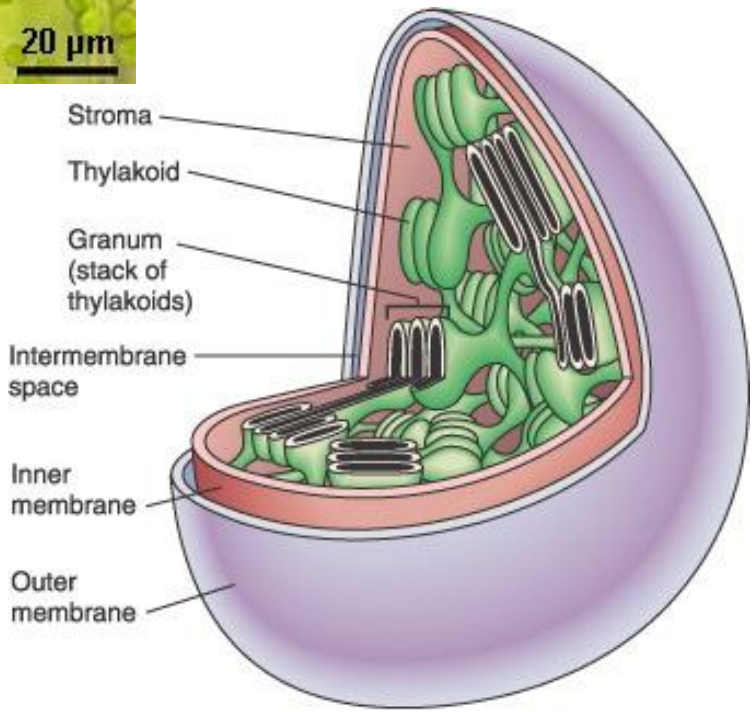
Transmitted light

WHY ARE PLANTS GREEN?



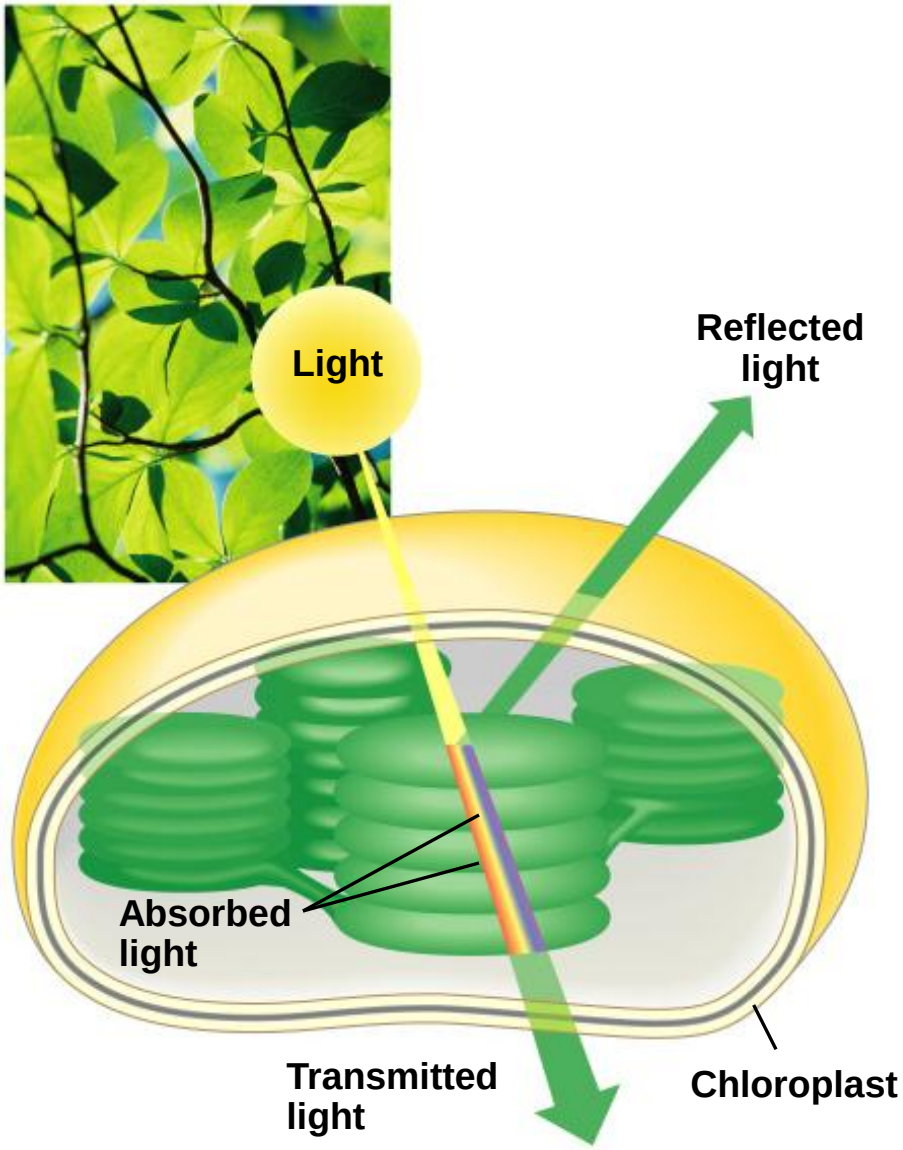
Plant Cells have Green Chloroplasts

The thylakoid membrane of the chloroplast is impregnated with photosynthetic pigments (i.e., chlorophylls, carotenoids).



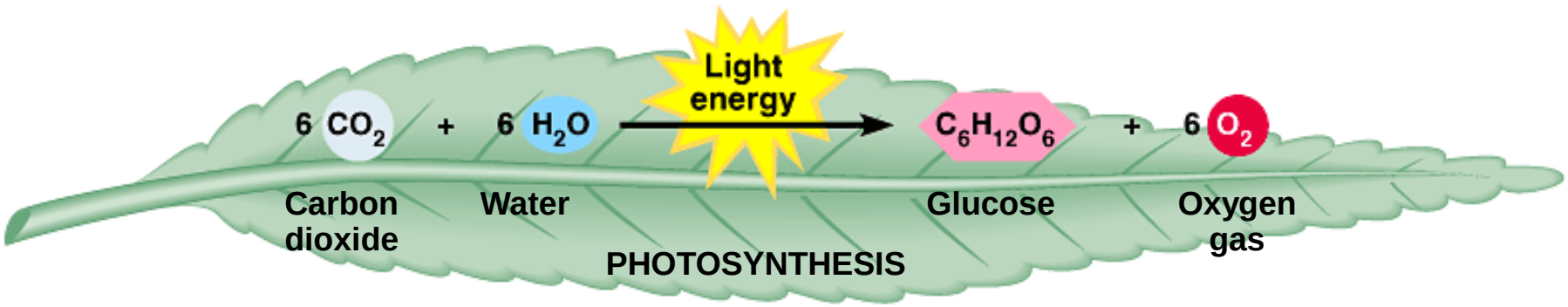
THE COLOR OF LIGHT SEEN IS THE COLOR NOT ABSORBED

- Chloroplasts absorb light energy and convert it to chemical energy



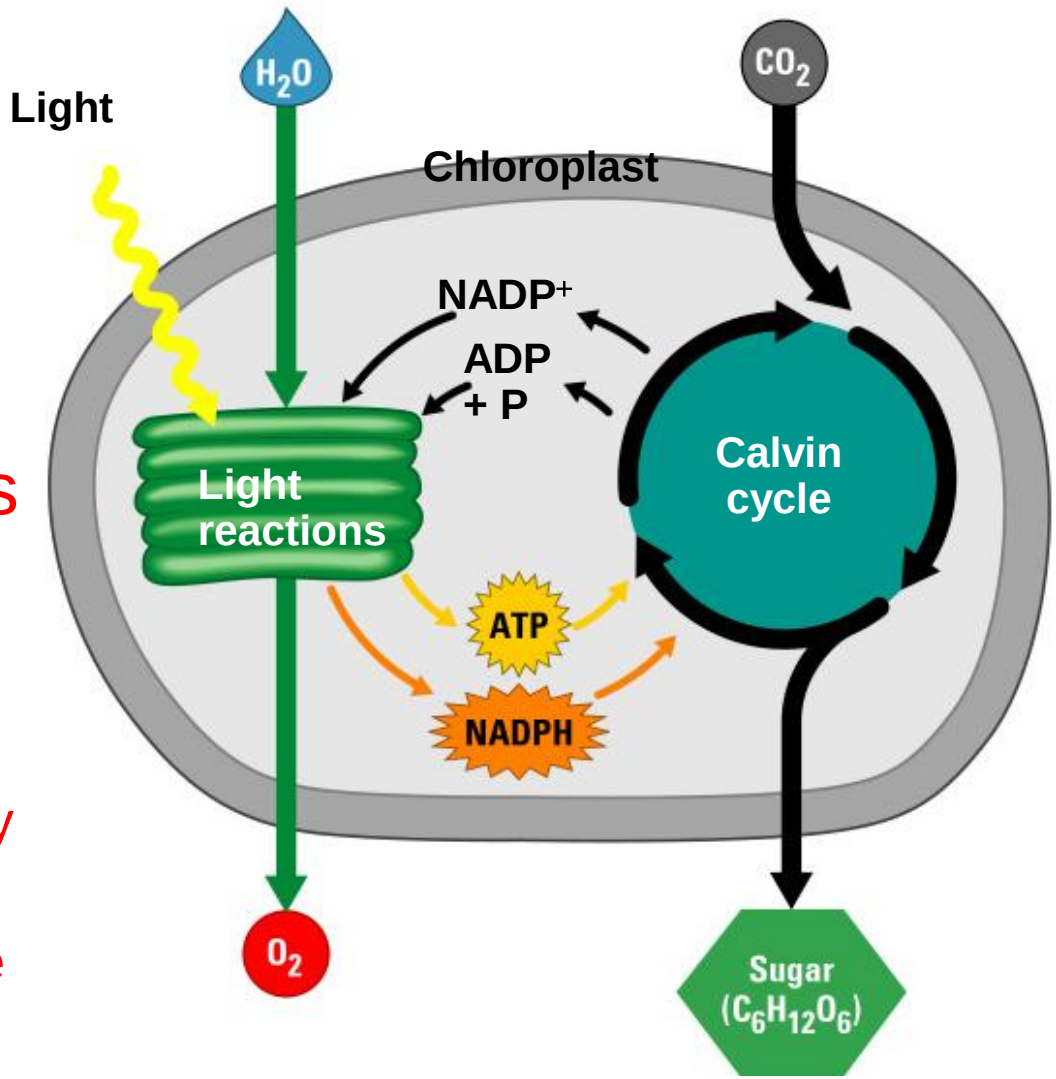
AN OVERVIEW OF PHOTOSYNTHESIS

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



AN OVERVIEW OF PHOTOSYNTHESIS

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



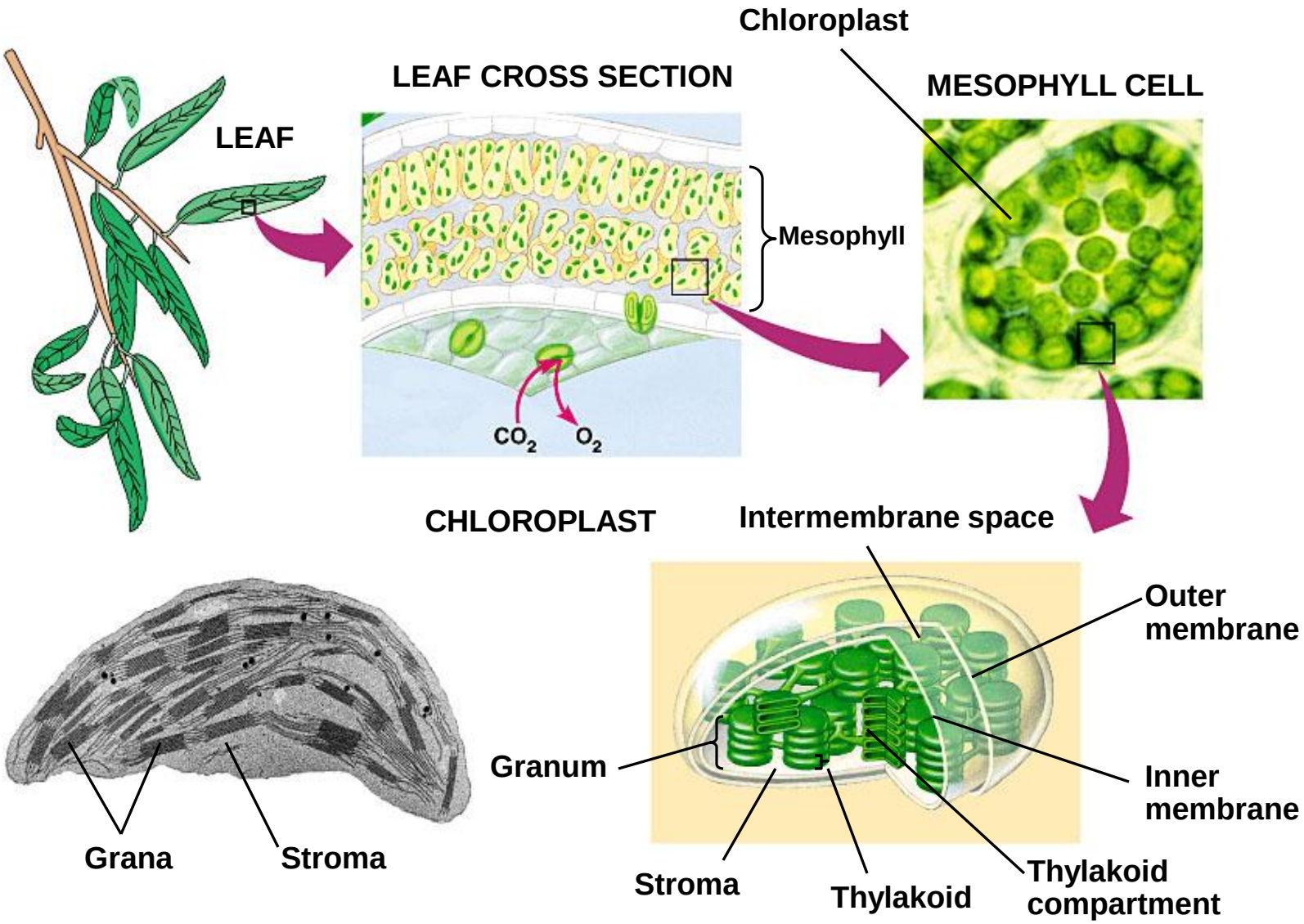
Chloroplasts: Sites of Photosynthesis

- Photosynthesis
  - Occurs in chloroplasts, organelles in certain plants
  - All green plant parts have chloroplasts and carry out photosynthesis
    - The leaves have the most chloroplasts
    - The green color comes from chlorophyll in the chloroplasts
    - The pigments absorb light energy

Photosynthesis occurs in chloroplasts

- In most plants, photosynthesis occurs primarily in the leaves, in the chloroplasts
- A chloroplast contains:
  - stroma, a fluid
  - grana, stacks of thylakoids
- The thylakoids contain chlorophyll
  - Chlorophyll is the green pigment that captures light for photosynthesis

- The location and structure of chloroplasts

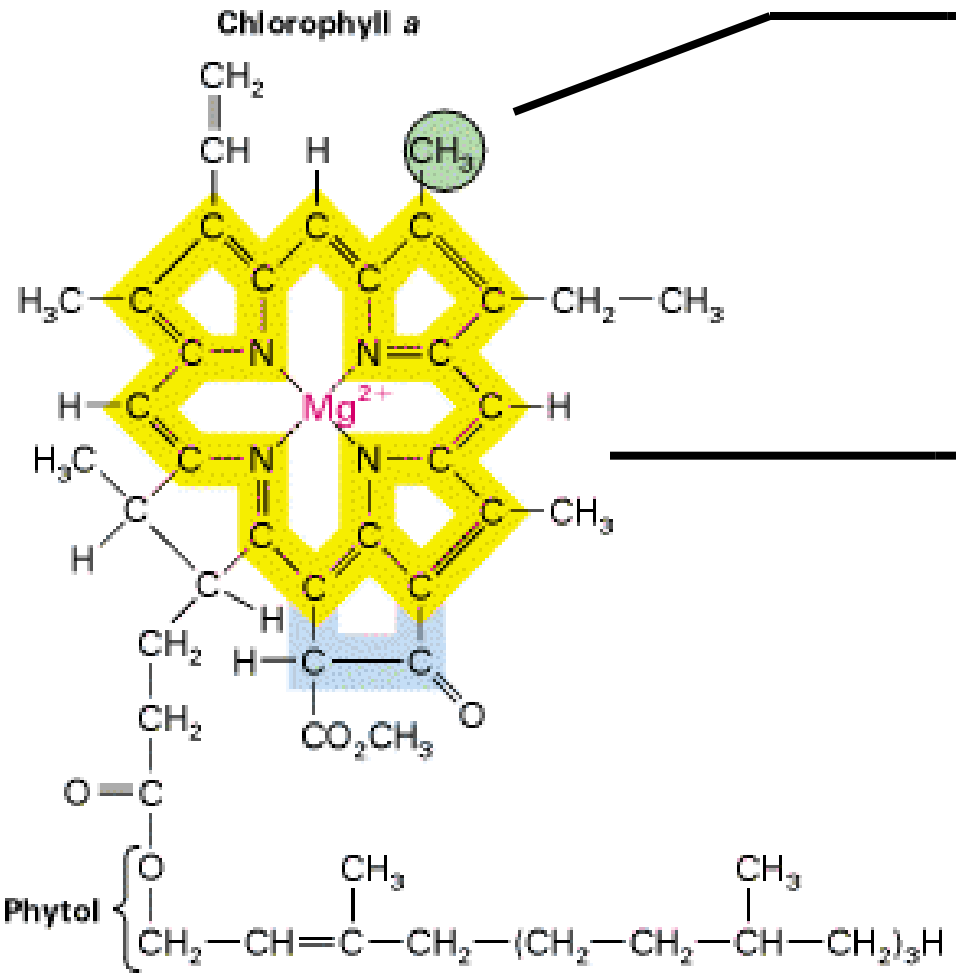


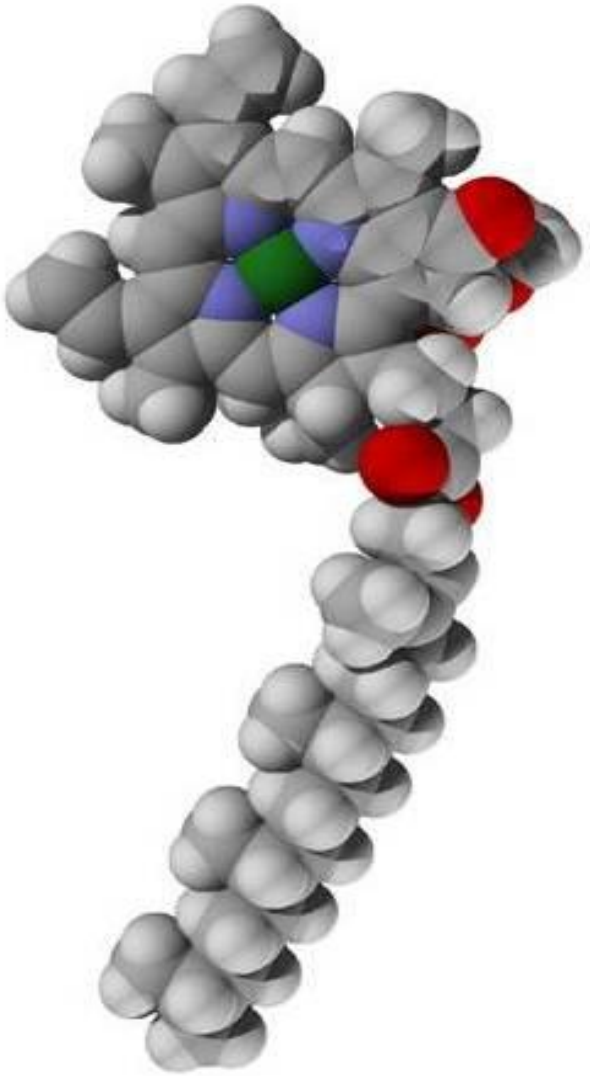
Chloroplast Pigments

- Chloroplasts contain several pigments
  - Chlorophyll a
  - Chlorophyll b
  - Carotenoids

Figure 7.7

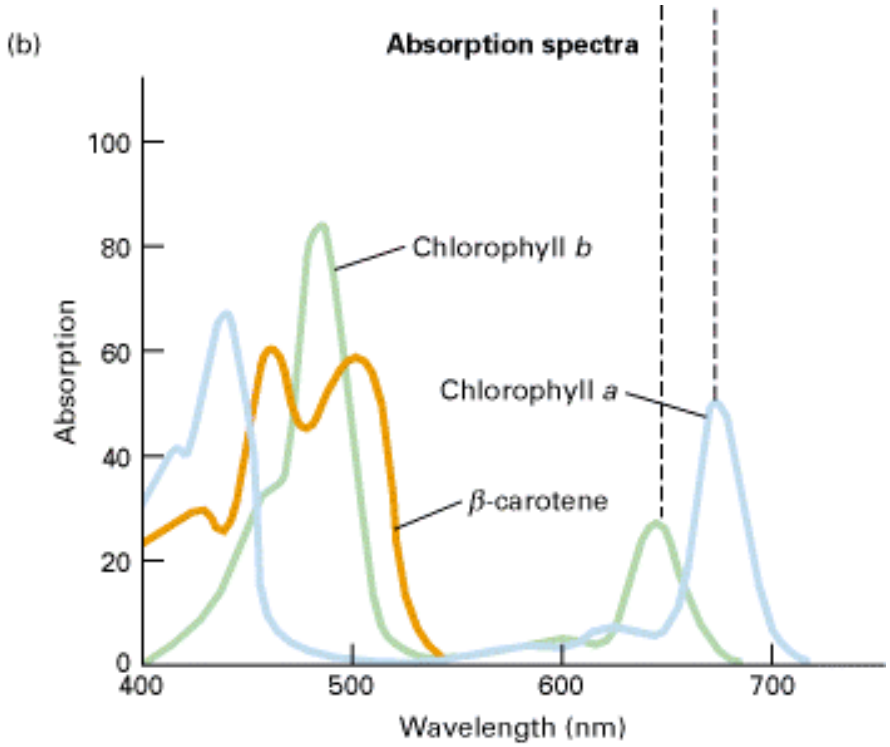
Chlorophyll a & b

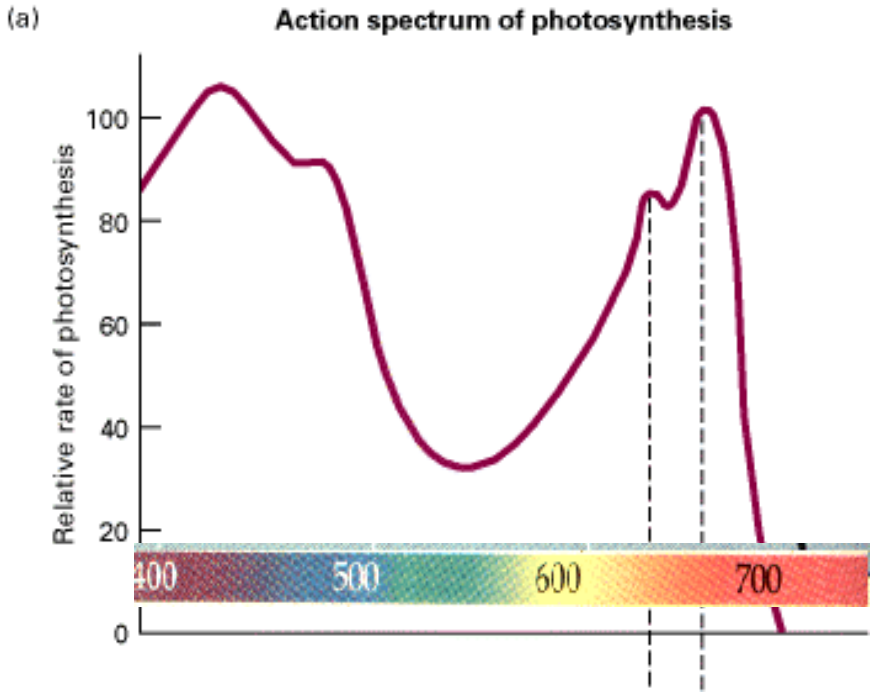




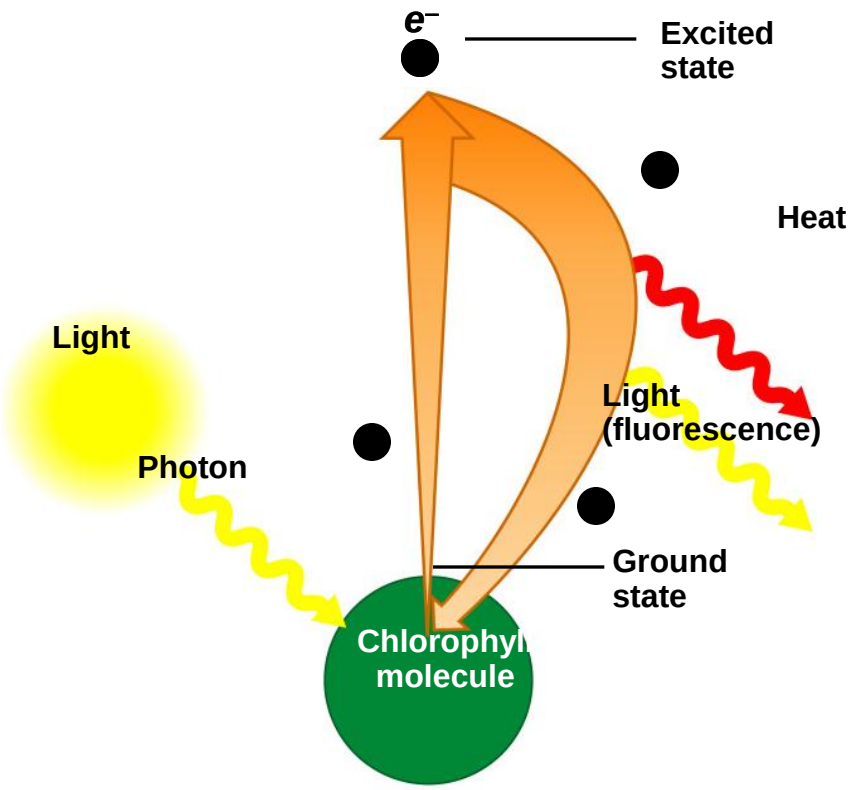
Phytol tail

Different pigments absorb light differently



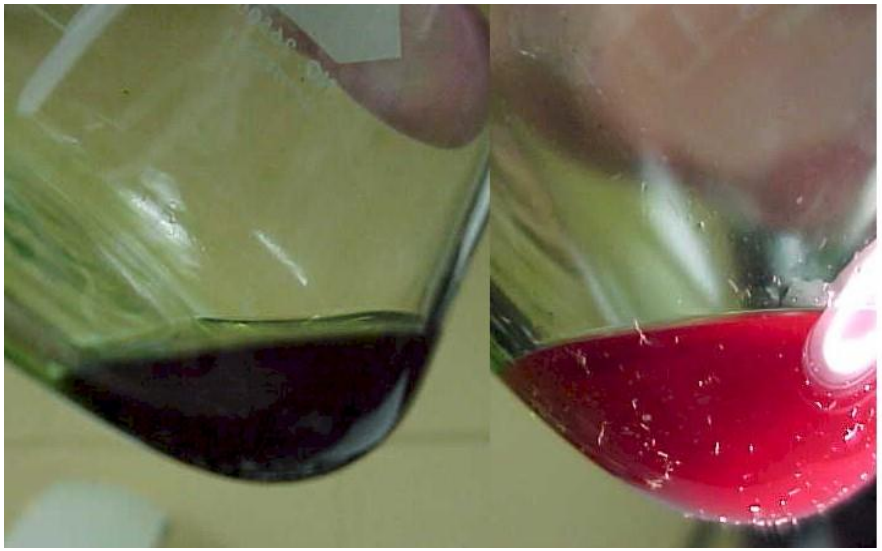


Excitation of chlorophyll in a chloroplast



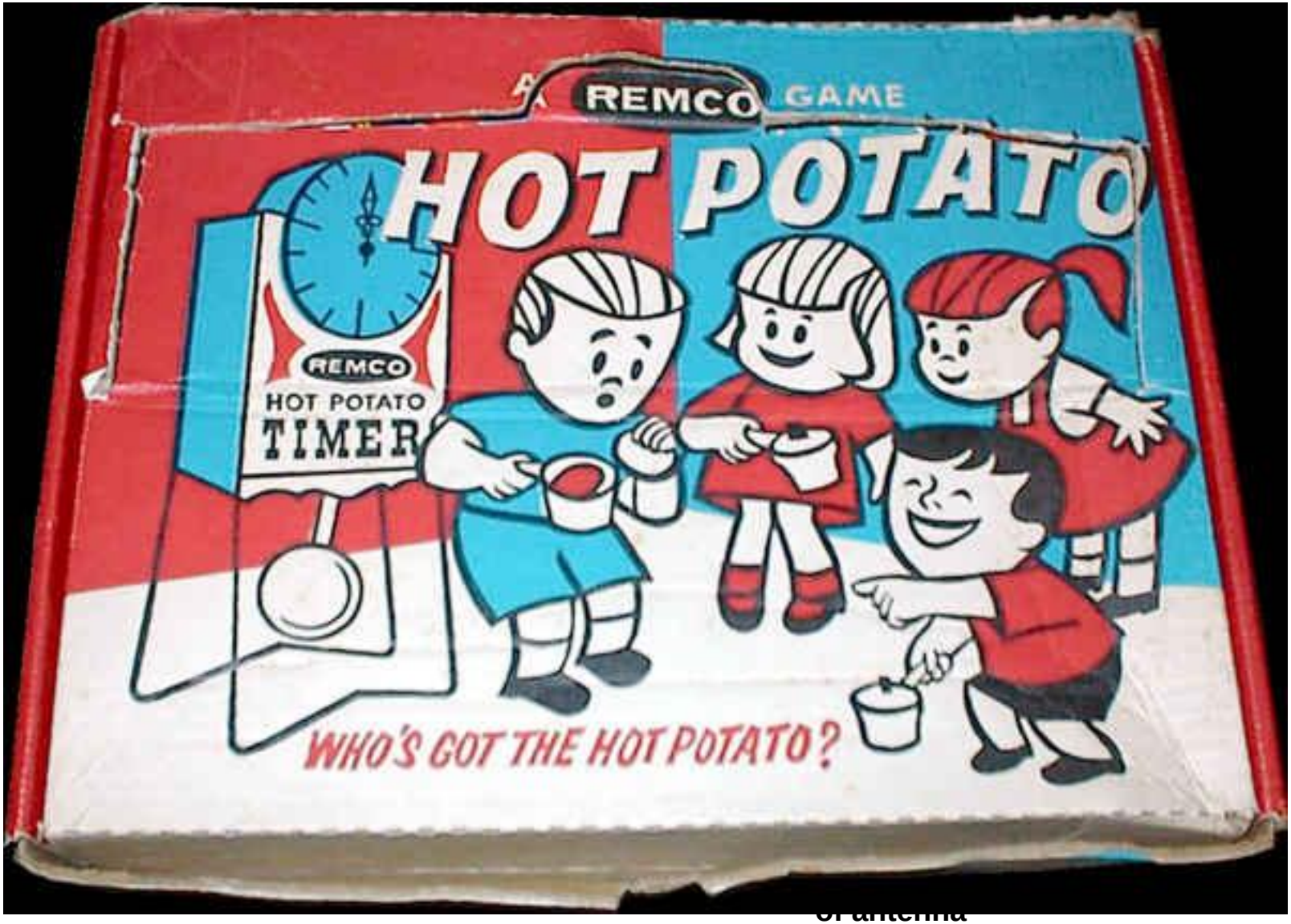
(a) Absorption of a photon

- Loss of energy due to heat causes the photons of light to be less energetic.
- Less energy translates into longer wavelength.
- *Energy = (Planck's constant) x (velocity of light)/(wavelength of light)*
- Transition toward the red end of the visible spectrum.



(b) fluorescence of isolated chlorophyll in solution

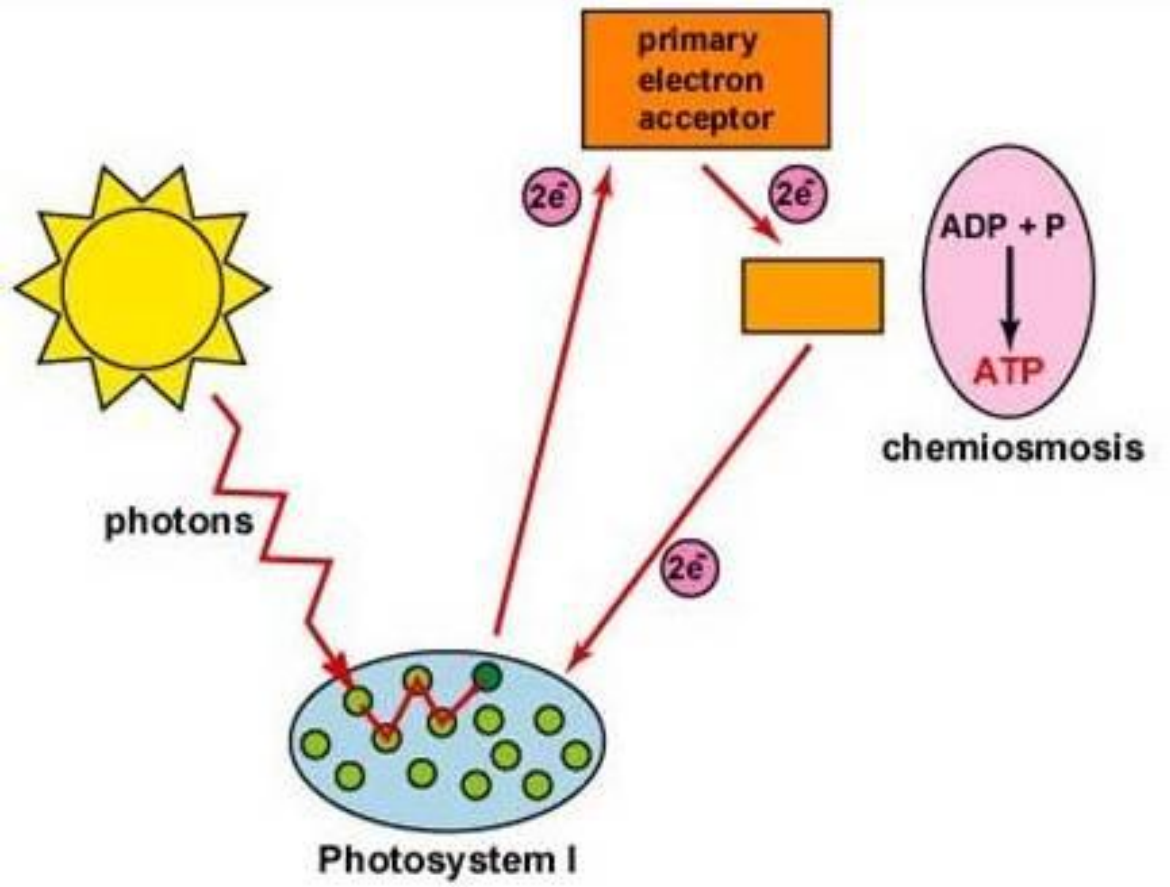
Molecular Game of “Hot Potato”



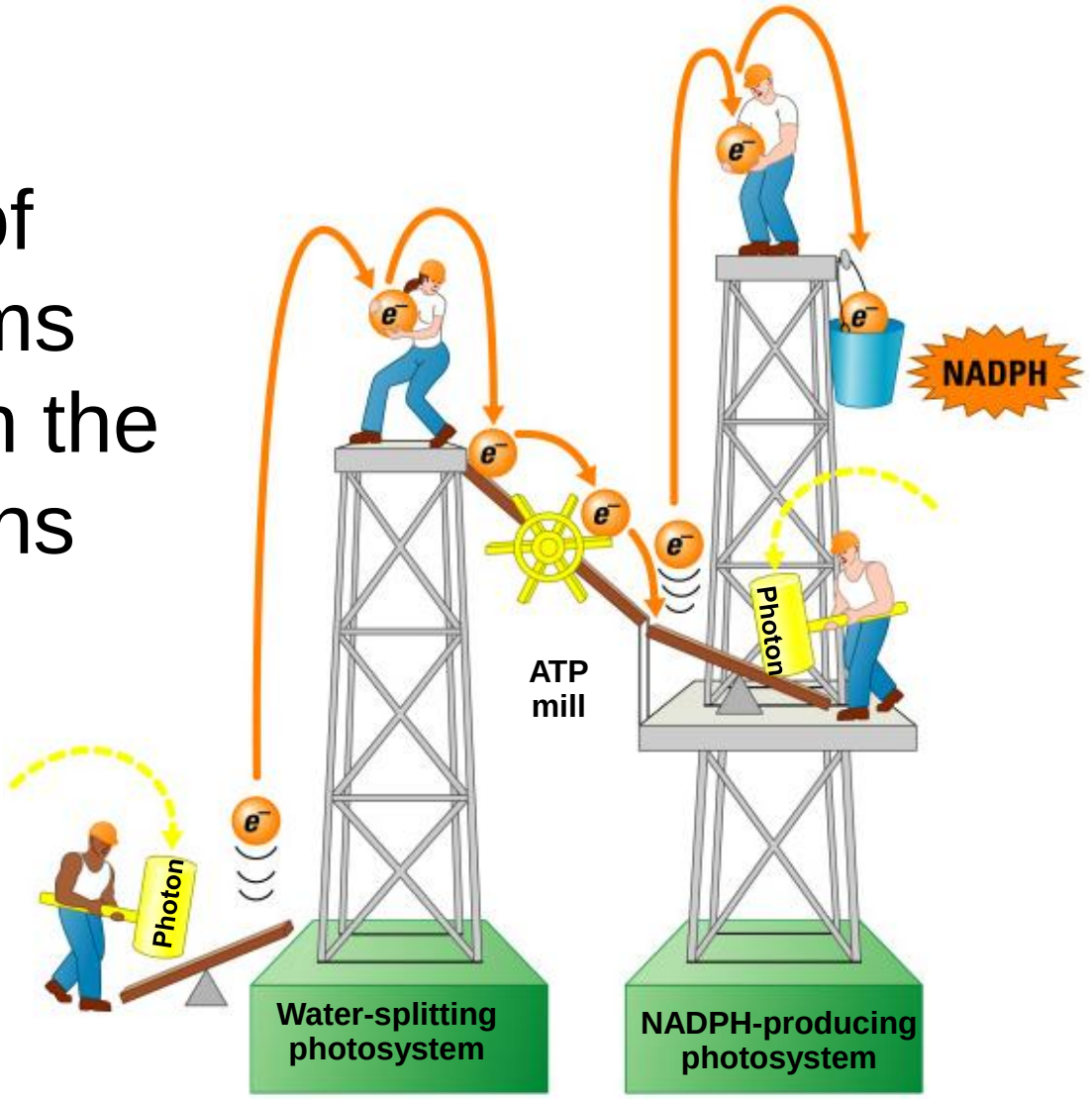
of antenna

Cyclic Photophosphorylation

- Process for ATP generation associated with some Photosynthetic Bacteria
- Reaction Center => 700 nm

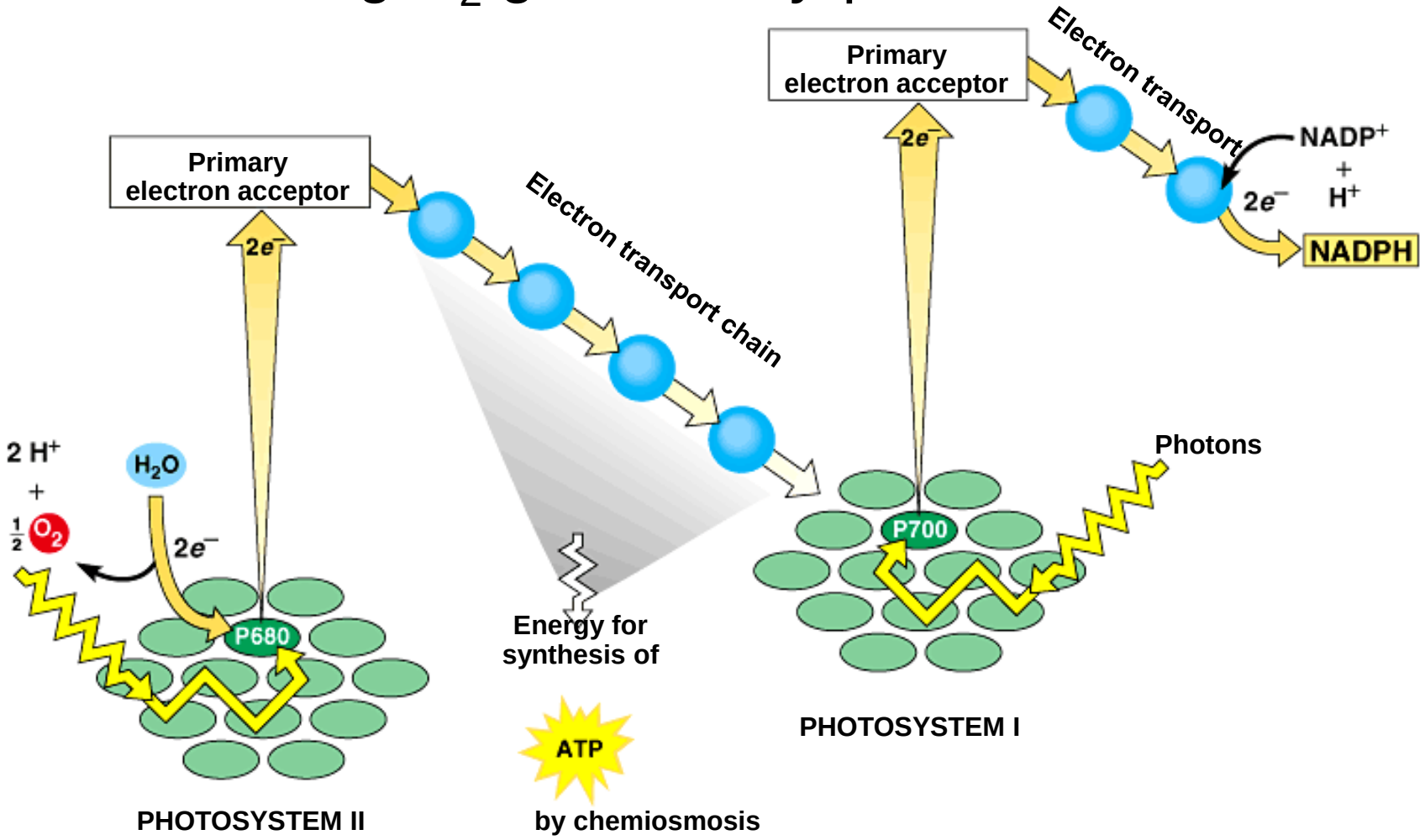


- Two types of photosystems cooperate in the light reactions



Noncyclic Photophosphorylation

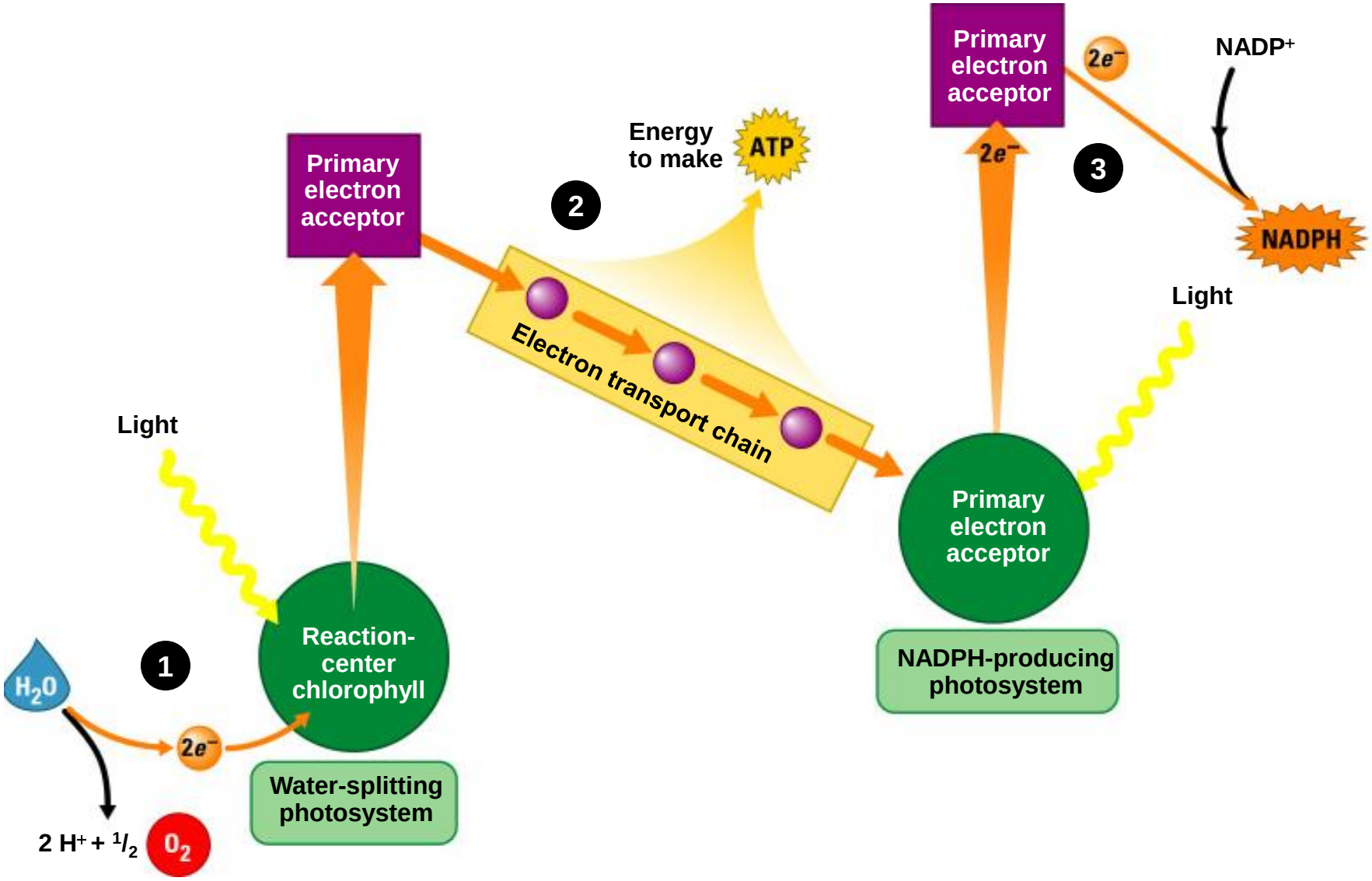
- Photosystem II regains electrons by splitting water, leaving O_2 gas as a by-product



Plants produce O_2 gas by splitting H_2O

- The O_2 liberated by photosynthesis is made from the oxygen in water (H^+ and e^-)

How the Light Reactions Generate ATP and NADPH



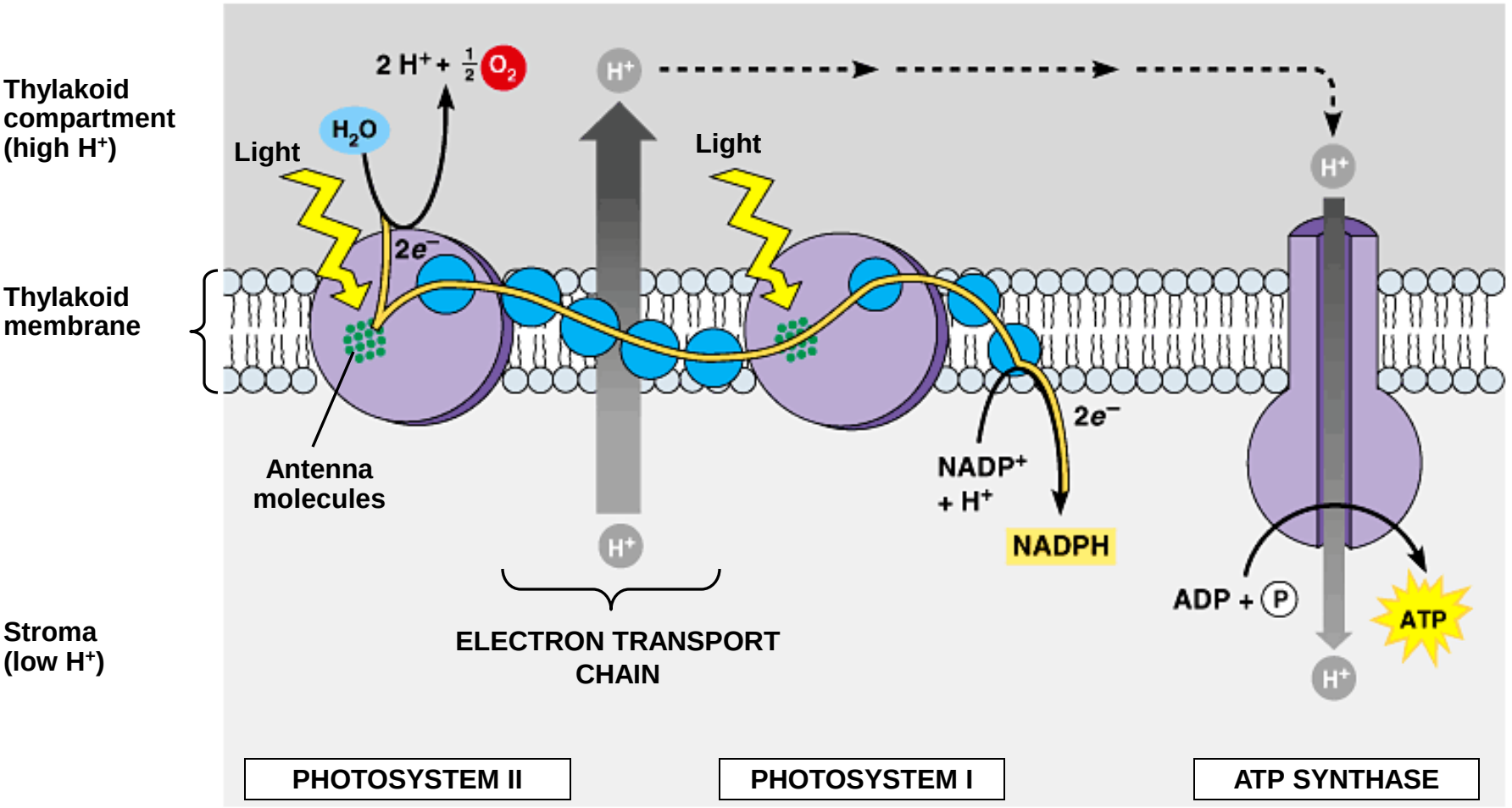
In the light reactions, electron transport chains generate ATP, NADPH, & O_2

- Two connected photosystems collect photons of light and transfer the energy to chlorophyll electrons
- The excited electrons are passed from the primary electron acceptor to electron transport chains
  - Their energy ends up in ATP and NADPH

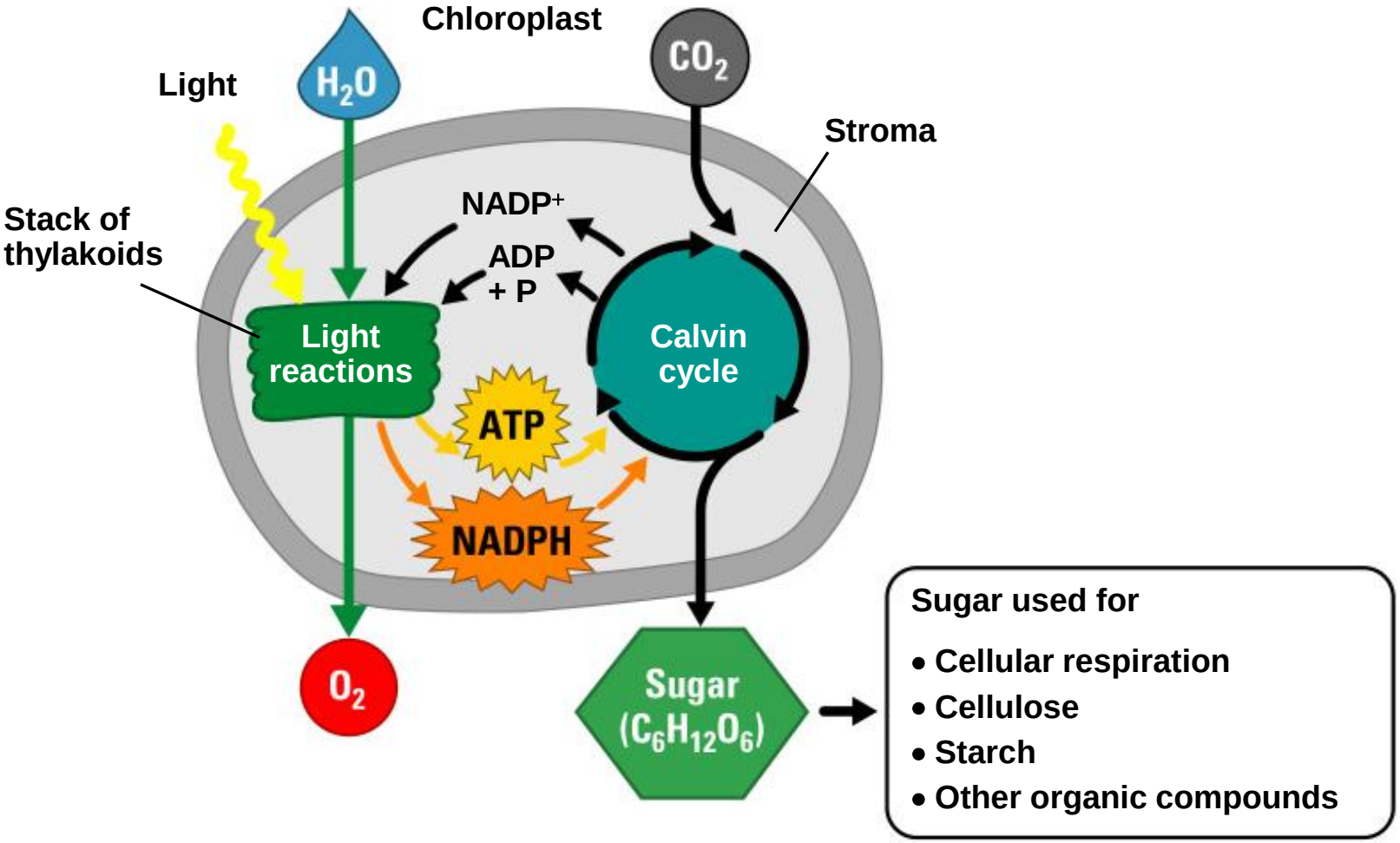
Chemiosmosis powers ATP synthesis in the light reactions

- 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

- The production of ATP by chemiosmosis in photosynthesis

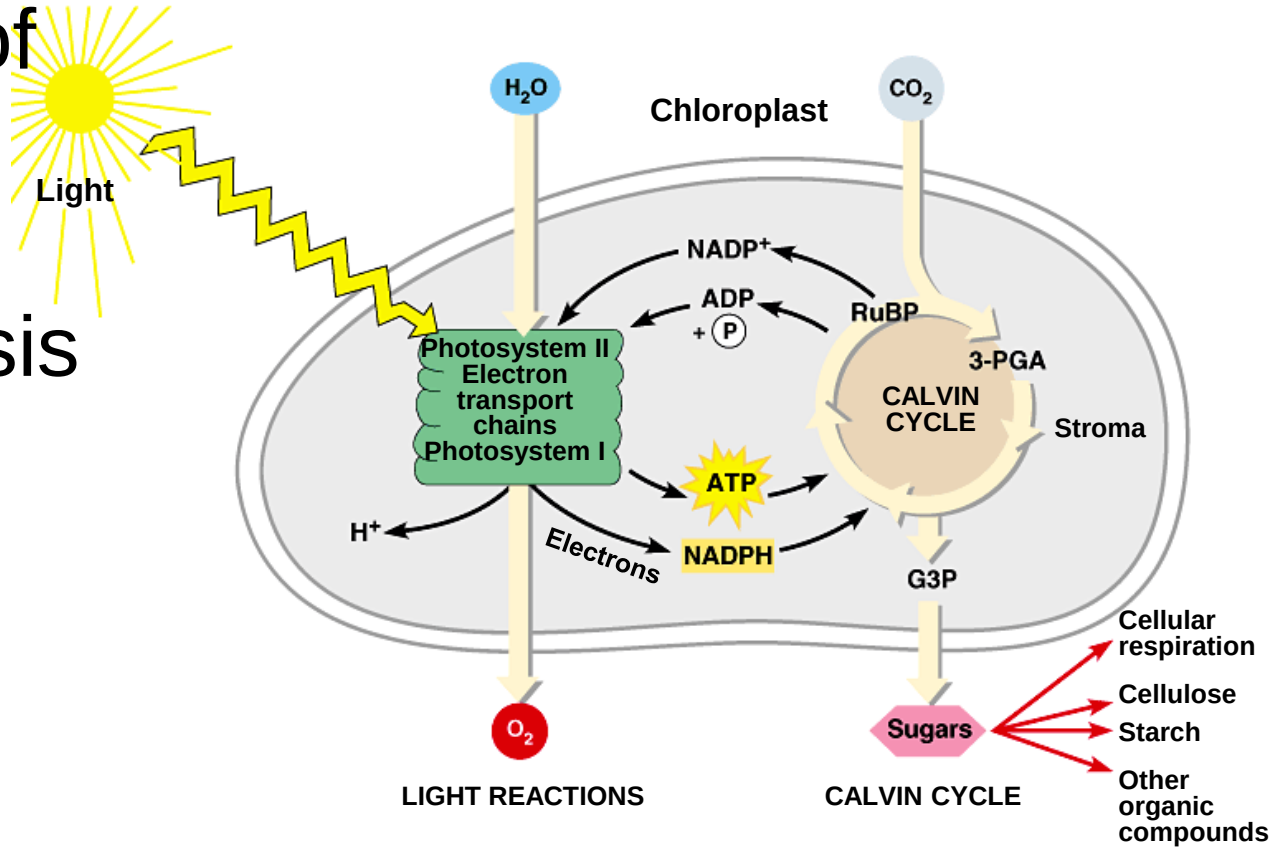


- A Photosynthesis Road Map



Review: Photosynthesis uses light energy to make food molecules

- A summary of the chemical processes of photosynthesis




It's not that
easy bein'
green... but it
is essential for
life on earth!