Photosynthesis – Chapter 8

How does the plant use the sun's energy to make food?

8.1Energy and life
Autotroph vs. Heterotroph

- **<u>Autotrophs/Producers</u>**-organisms that make their own food.
  - Plants and other types of organisms use light energy (sun) to produce food.
- **<u>Heterotrophs/Consumers</u>**-obtain energy from foods they consume.
  - Animals, fungi, and some protists

Living Things Use Chemical Fuels for Energy

- ATP is the principal chemical compound that cells use to store and release energy.

- Adenosine triphosphate (adenine, ribose, 3 phosphates)

- The 3 phosphates are the **key** to energy storage and release.

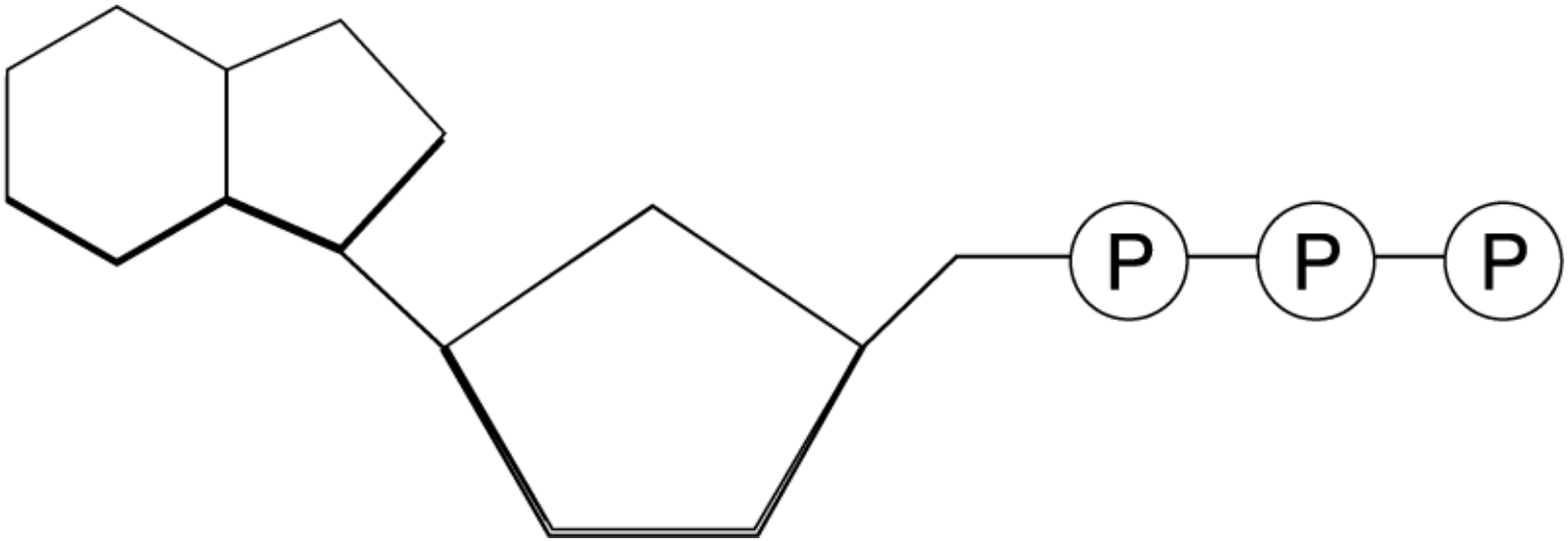
Batteries of Life

- Adenosine Triphosphate – ATP
- Adenosine Diphosphate – ADP

What's the difference?

ATP

- Adenine
- Ribose
- 3 Phosphate groups



ADP

- Adenine
- Ribose
- 2 Phosphate groups

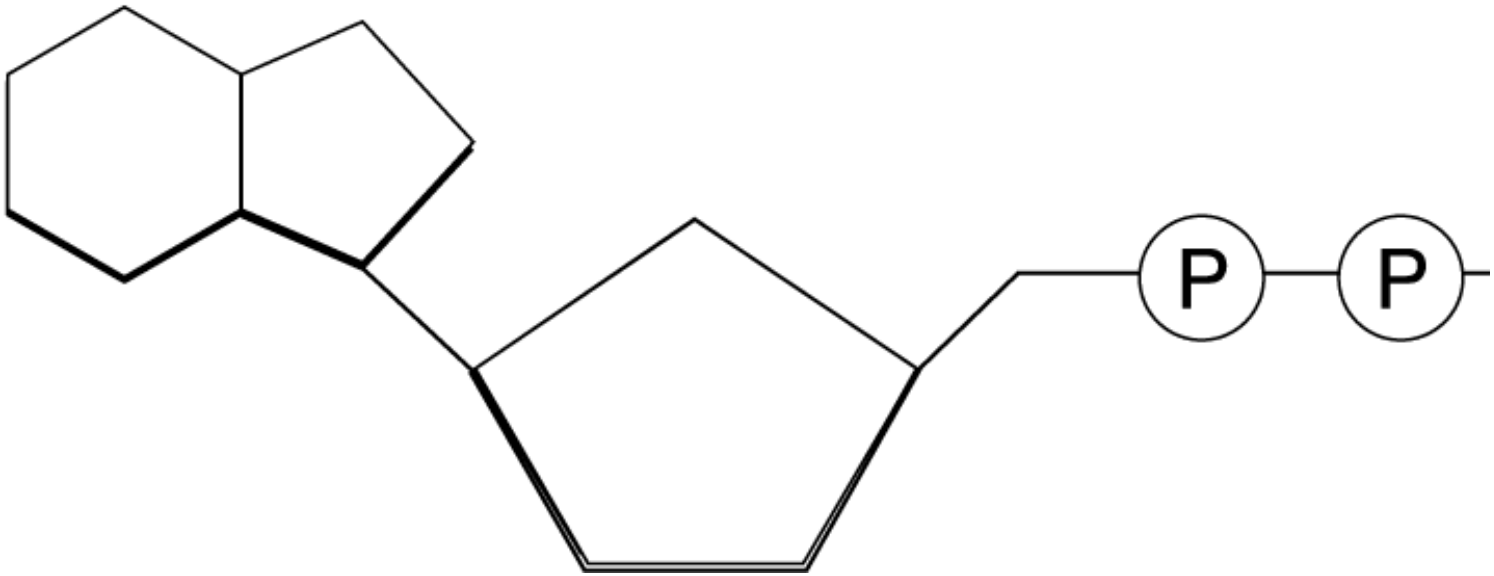


Figure 8-3 Comparison of ADP and ATP to a Battery

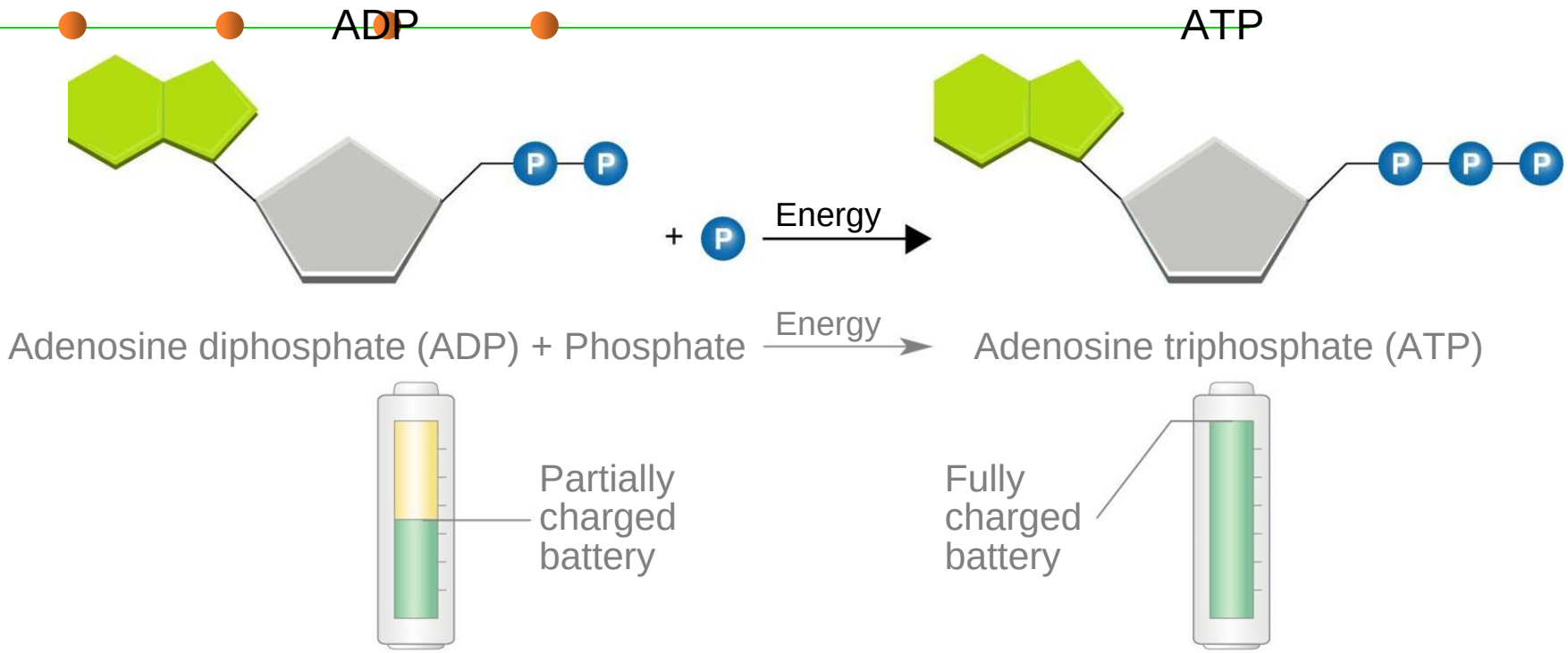
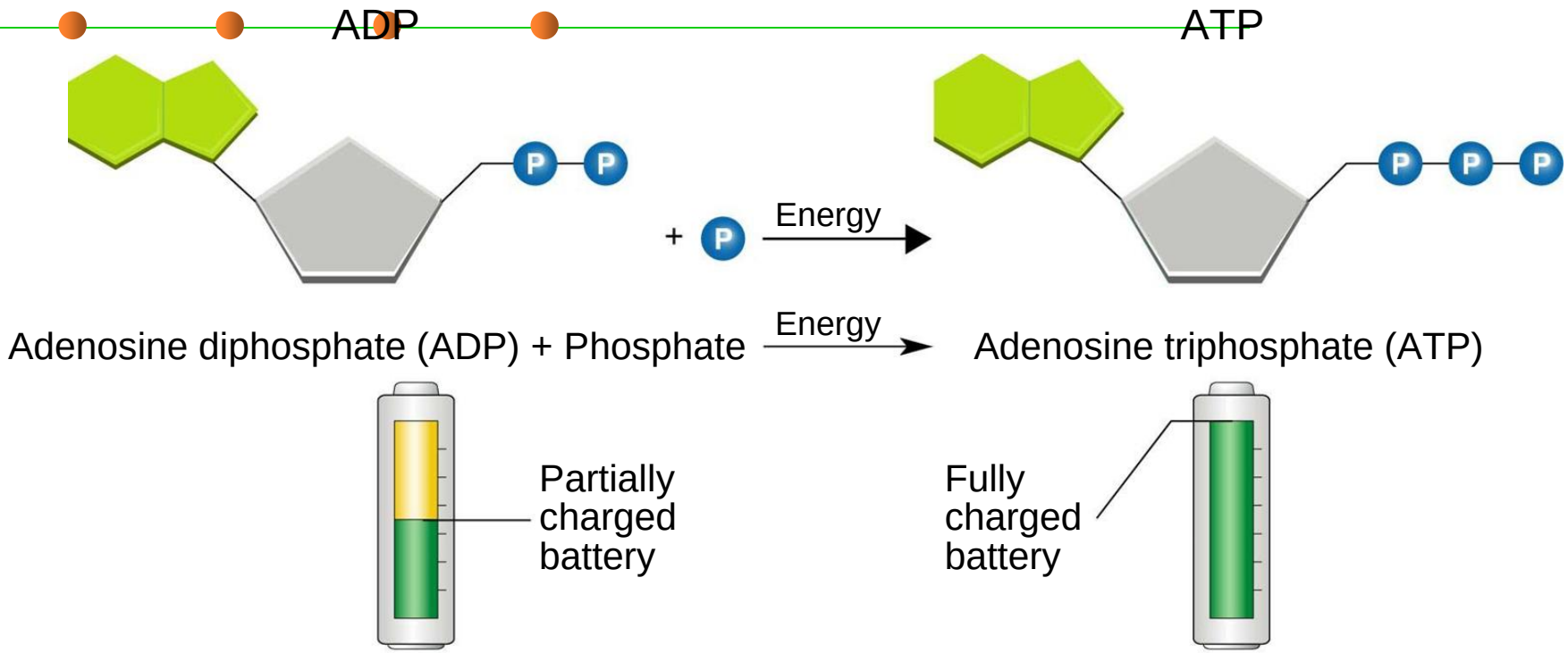


Figure 8-3 Comparison of ADP and ATP to a Battery



ATP continued…

- Although ATP powers many important events in the cell, most cells only have a small amount of ATP.
- ATP is great for transferring energy, NOT for storing
- Glucose is 90X more efficient at energy storing, therefore storage of ATP is kept small.

8.2 An overview of Photosynthesis

- Plants use the energy of the sunlight to convert water and carbon dioxide into sugars and starches, and release oxygen in the process

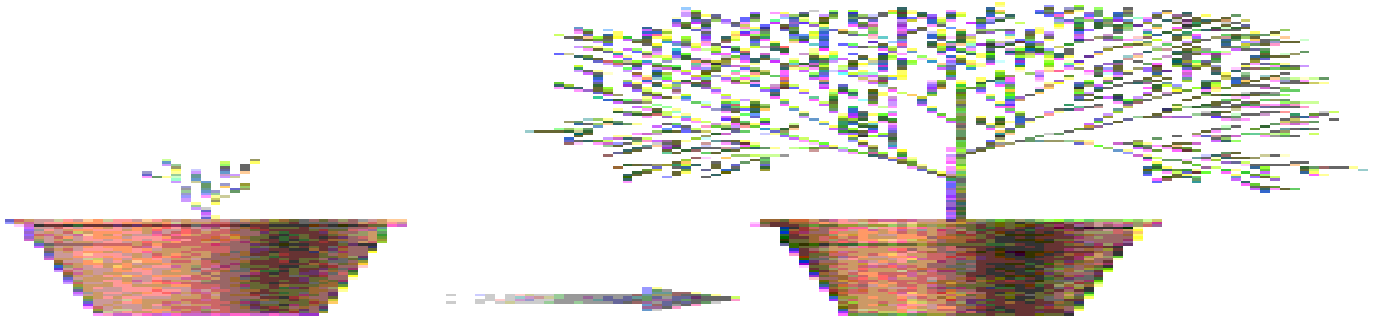
Investigation

- 1600's questions were asked
- How does a large tree grow from a tiny seed?
- Where does the increase in mass come from?
  - Soil?
  - Water?
  - Air?

History

Jan van Helmont's Experiment (1643)

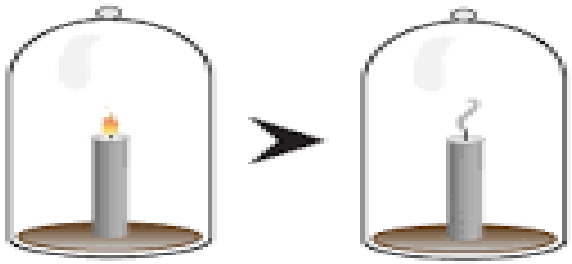
- Do plants grow by taking material out of the soil?
- Determined mass of soil and seedling
- Watered every day for 5 years
- Mass of soil did not change–plant gained 75 kg
- **Conclusion:** plants incorporate water into themselves, water accounted for most of mass increase, the remaining was carbon dioxide uptake from air.



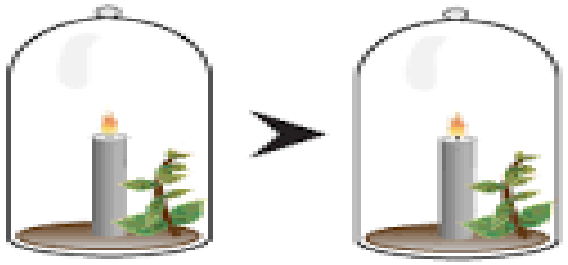
Joseph Priestley – (1771)

- Using a bell jar, a candle and plant he found that plant's release a substance that keeps a candle burning.

- **Conclusion:** Plants release oxygen



After a short time, the candle went out.



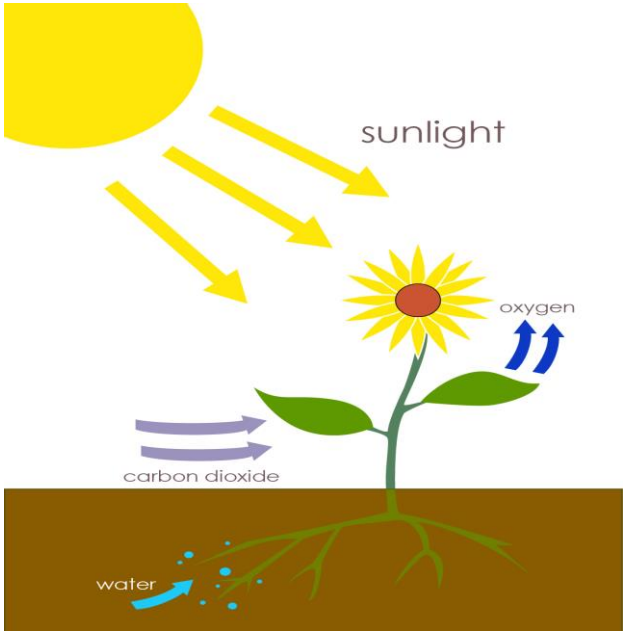
A mint plant was added to the container. The candle continued to burn after several days.

Jan Ingenhousz – (1779)

- Found that Priestley's experiment only worked when the plant was exposed to light.
- **Conclusion**: Plants need light to produce oxygen

Overall Conclusion

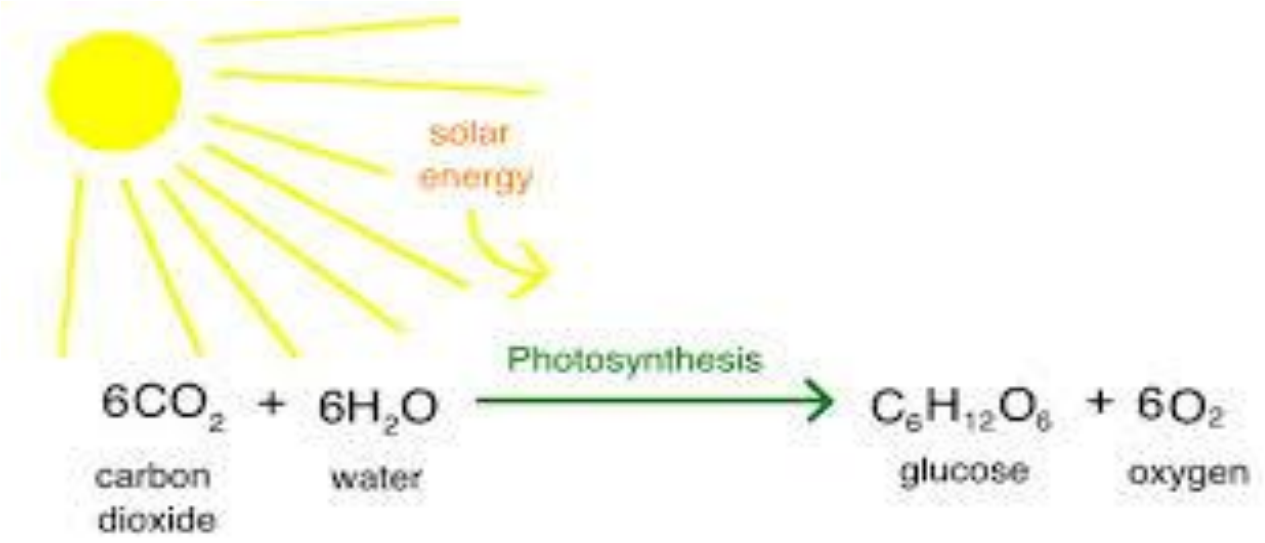
- In presence of light (energy)→plants transform carbon dioxide (CO_2) and water (H_2O) into carbohydrates (like glucose=$C_6H_{12}O_6$) and release oxygen (O_2).



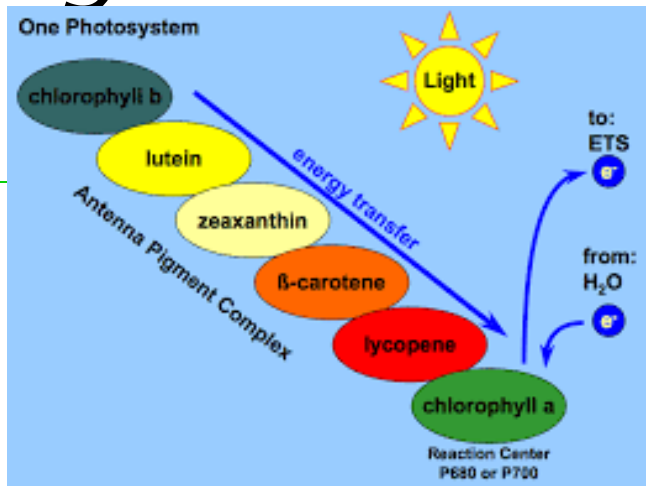

Discovery
EDUCATION

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

Carbon dioxide + water _light_>sugars + oxygen

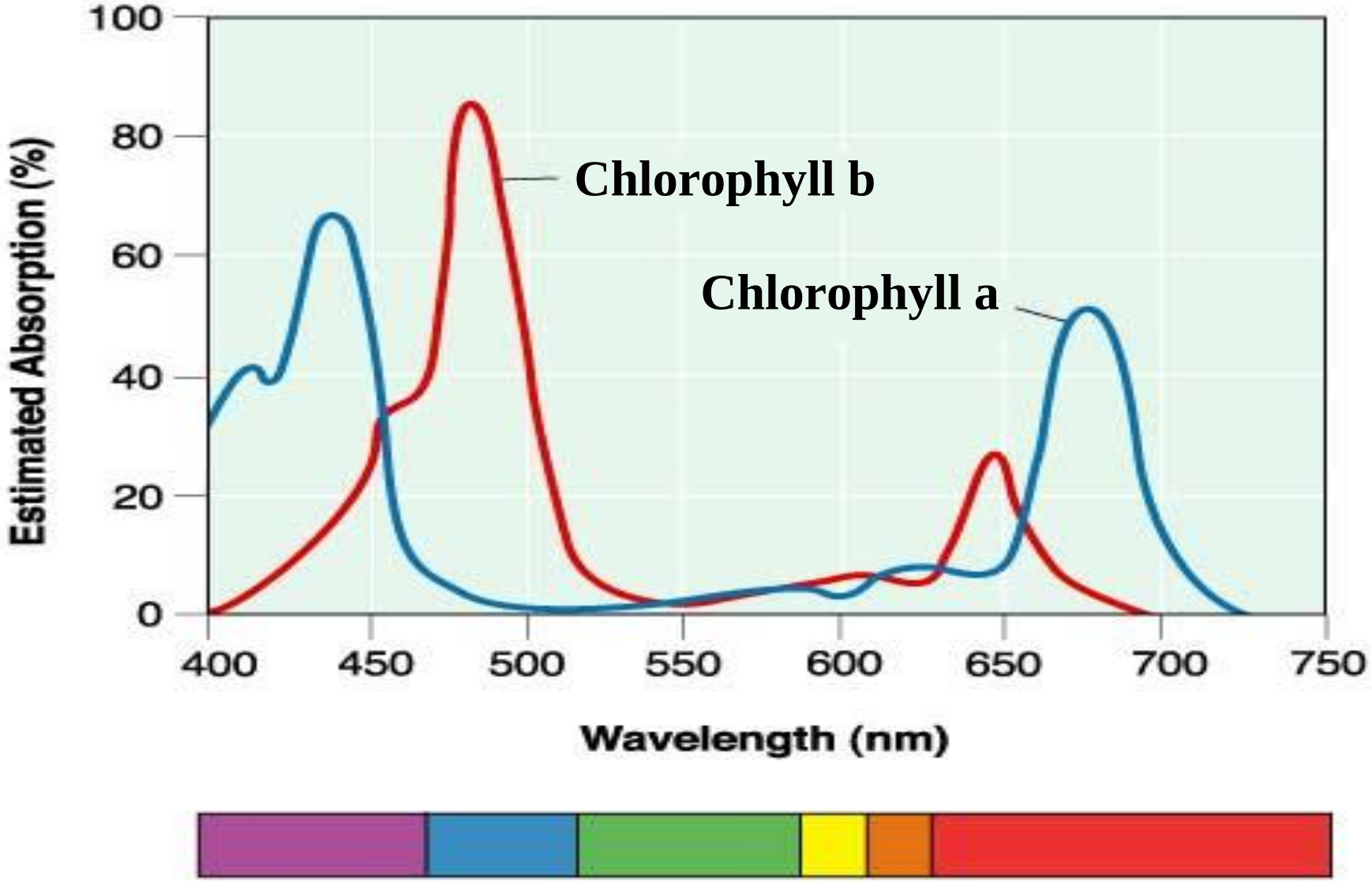


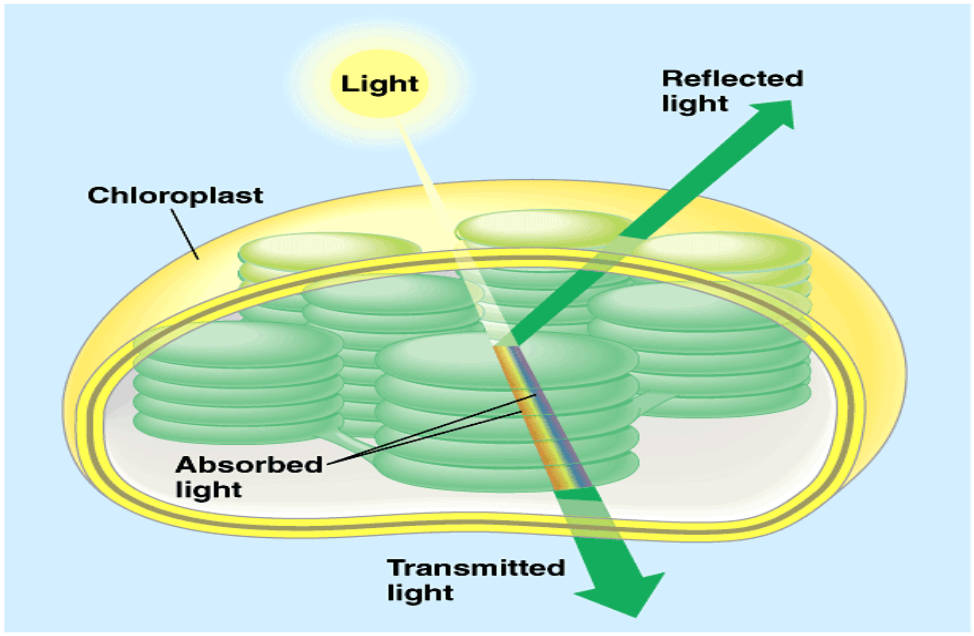
How do plants convert *light* into food?

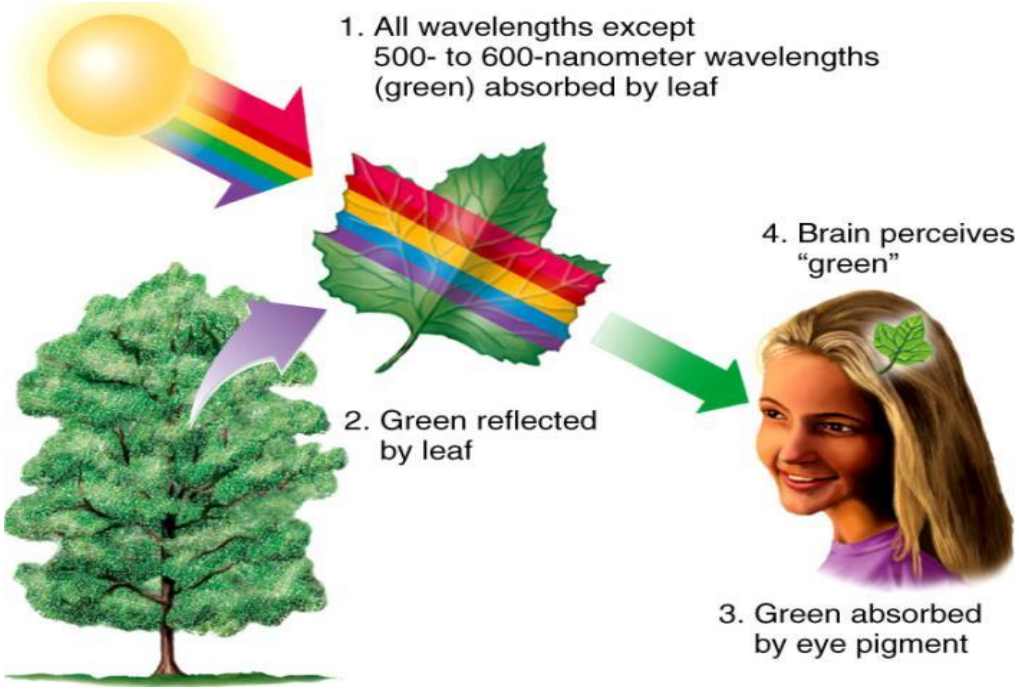


- Gather sun's energy using light absorbing molecules called **pigments.**
- The principal pigment is **chlorophyll.**
  - Chlorophyll *a* and Chlorophyll *b*

Which visible light does chlorophyll best/least absorb? Figure 8-5


Chlorophyll b
Chlorophyll a
Estimated Absorption (%)
100
80
60
40
20
0
400
450
500
550
600
650
700
750
Wavelength (nm)





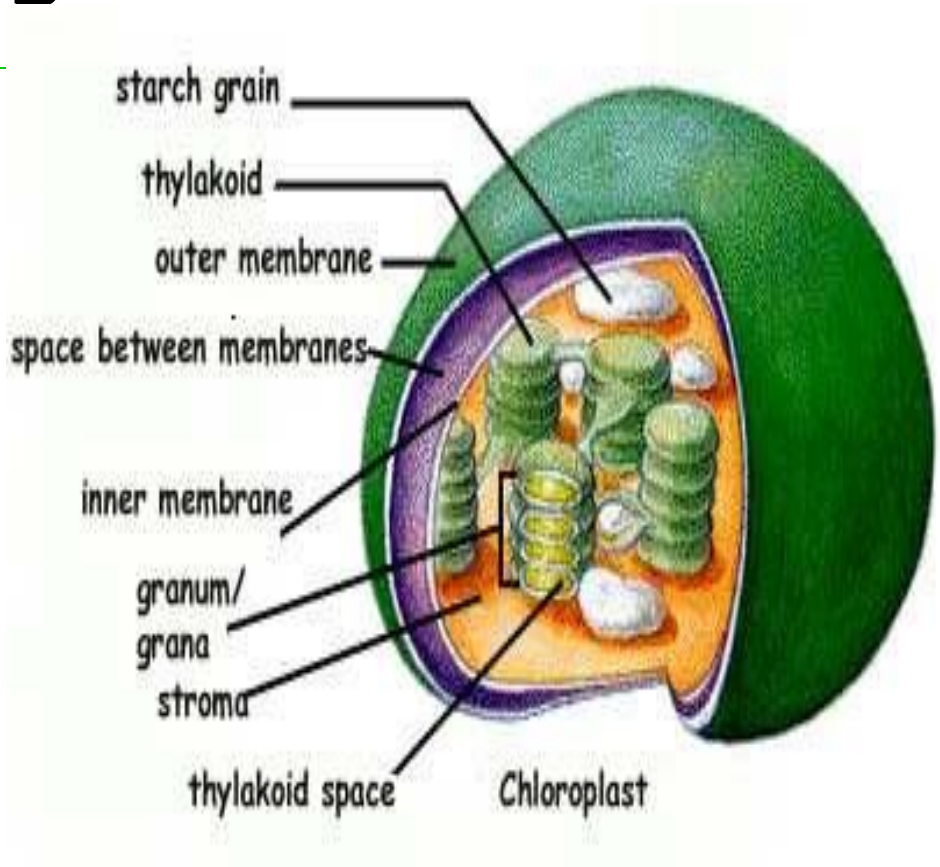
Notice that green light is reflected!

What does that explain to you?

*Remember that light is a form of ENERGY! So when light is absorbed, so is energy.

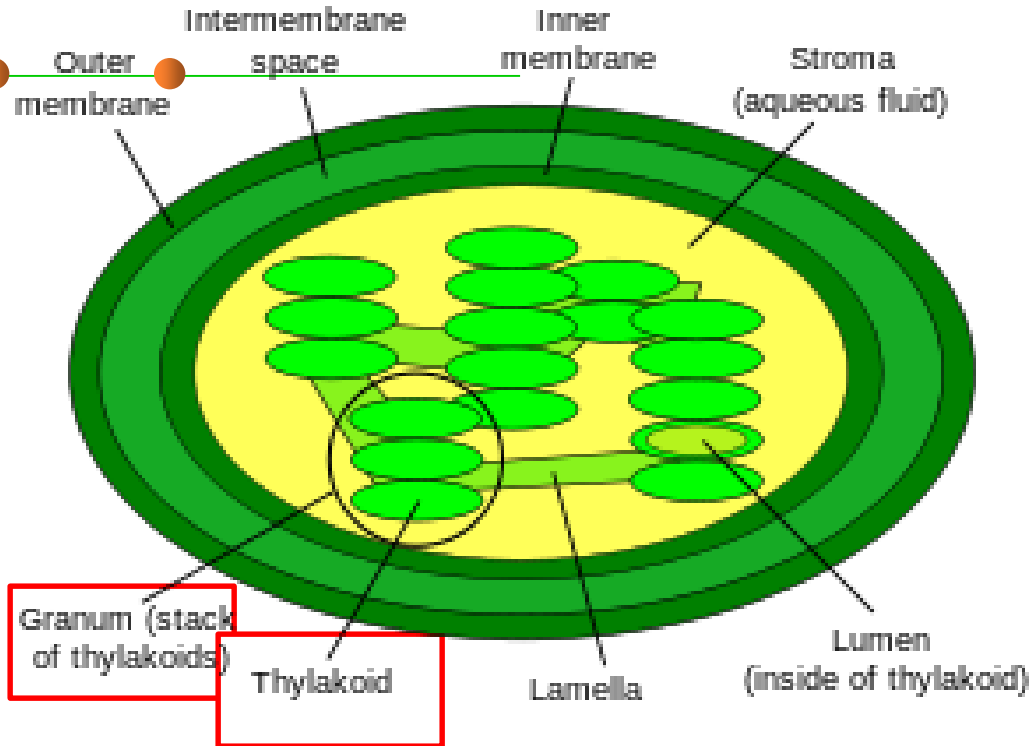
Inside a chloroplast
8-3

- **Thylakoids**: saclike photosynthetic membranes; arranged in stacks called **grana.**
  - Contains the pigment chlorophyll
- **Stroma:** space outside the thylakoid membrane



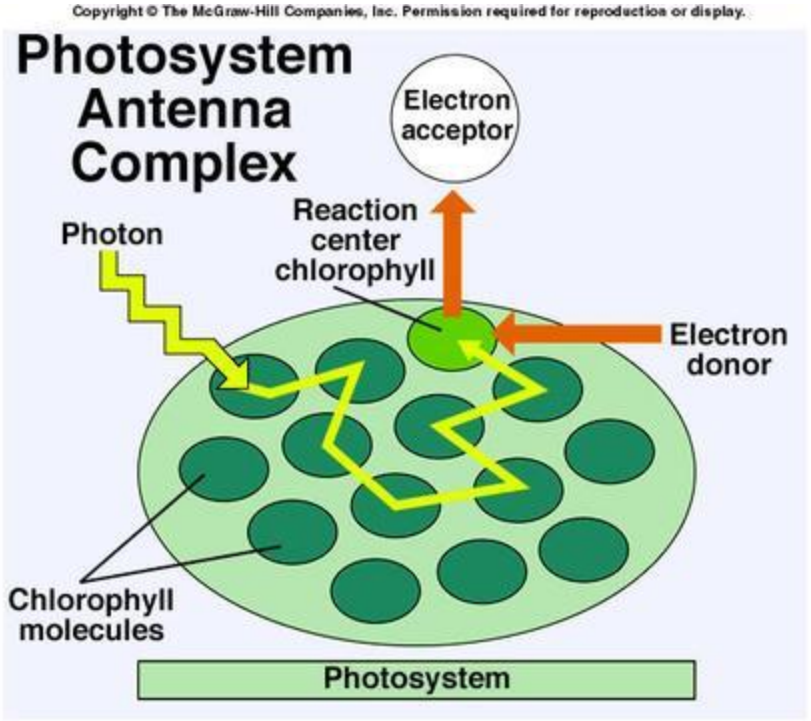
Inside a Chloroplast 8-3

- 1. Photosynthesis takes place in chloroplasts.
- 2. Chloroplasts contain saclike photosynthetic membranes called thylakoids (stacks are called grana).



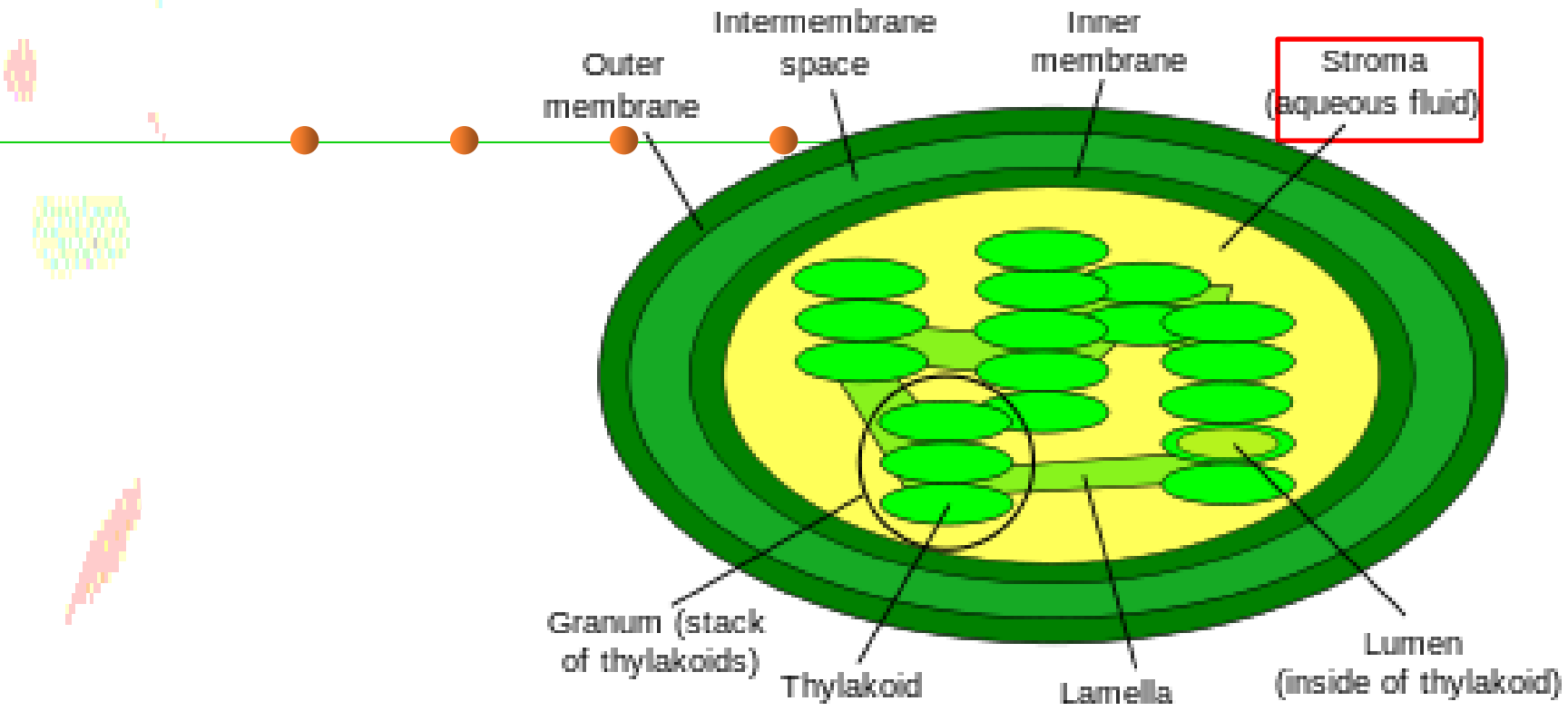
A. Inside a Chloroplast

- 3. Proteins in thylakoid membranes organize pigments, including chlorophyll, into groups called photosystems.

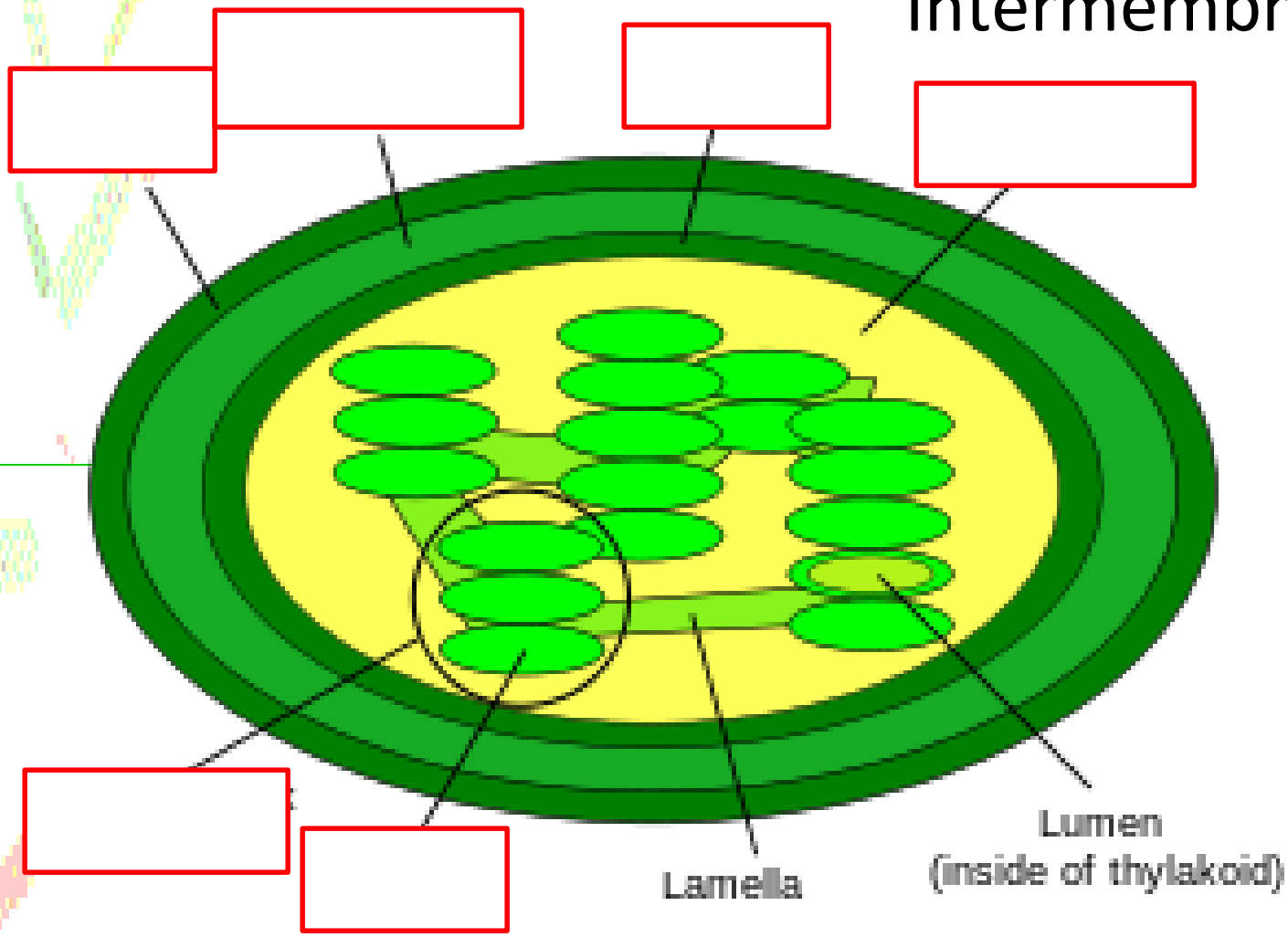


A. Inside a Chloroplast

- 4. Area outside of the thylakoid membranes are called the stroma.

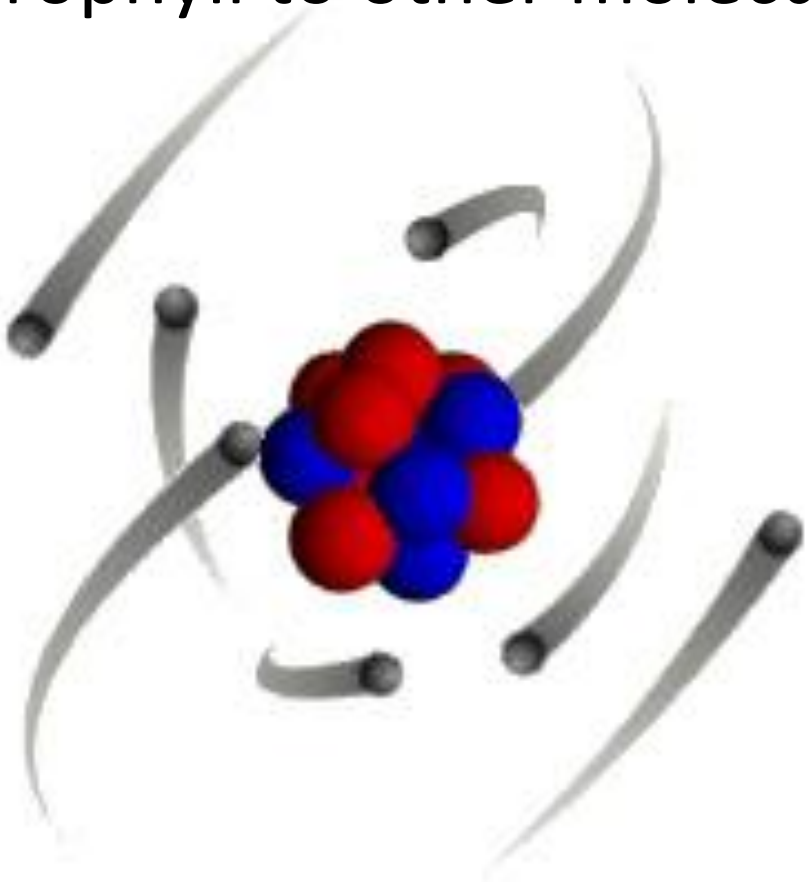


Thylakoid, Stroma, Grana, Inner membrane, Outer membrane, Intermembrane space



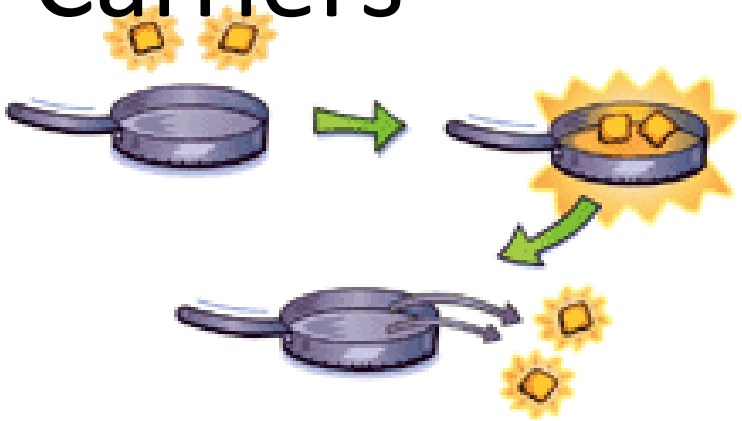
B. Electron Carriers

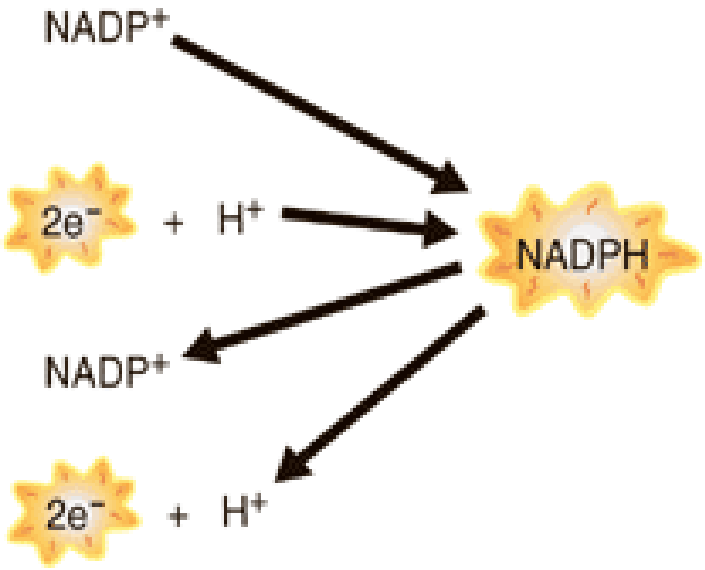
- 1. High energy electrons need to be carried from chlorophyll to other molecules.



B. Electron Carriers

- 2. NADP+ holds 2 high energy electrons by changing to NADPH.





B. Electron Carriers

- How does NADP+ become NADPH?

- How does ADP become ATP?

Electron Carriers

- When the sun excites electrons in chlorophyll, the electrons gain a large amount of energy
- High energy electrons need a carrier to transport them from chlorophyll to other areas
- Called electron transport chain which is facilitated by electron carriers

One Electron Carrier

NADP$^+$

Its job:

- Accepts and holds 2 high energy electrons along with an H+.
- Then converts NADP$^+$ to NADPH
- The energy of sunlight is now trapped in chemical form
- NADPH can now carry high energy electrons from chlorophyll to chemical reactions elsewhere in the cell.
    - Helps to make glucose

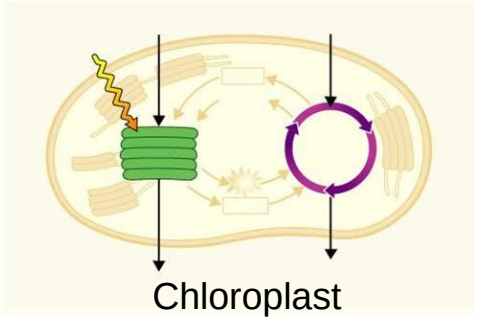
How does photosynthesis work?

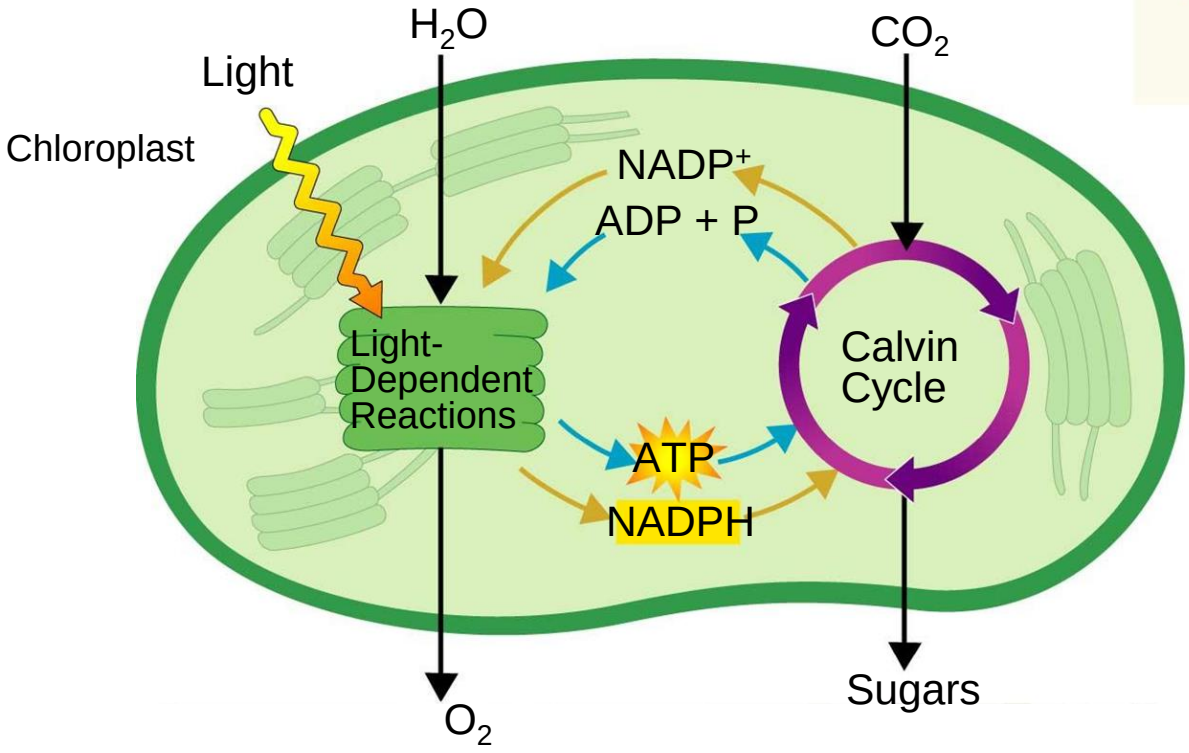
- Electrons from absorbed energy (sunlight) power photosynthesis
- Takes place in a chloroplast
- Proteins in the thylakoid membrane organize chlorophyll into clusters called **photosystems.**
  - **Light collecting units of the chloroplast**

2 stages of photosynthesis

- Step 1: Light dependent reaction
  - Takes place in the thylakoid membranes
- Step 2: Calvin cycle (light independent reaction)
  - Takes place in the stroma

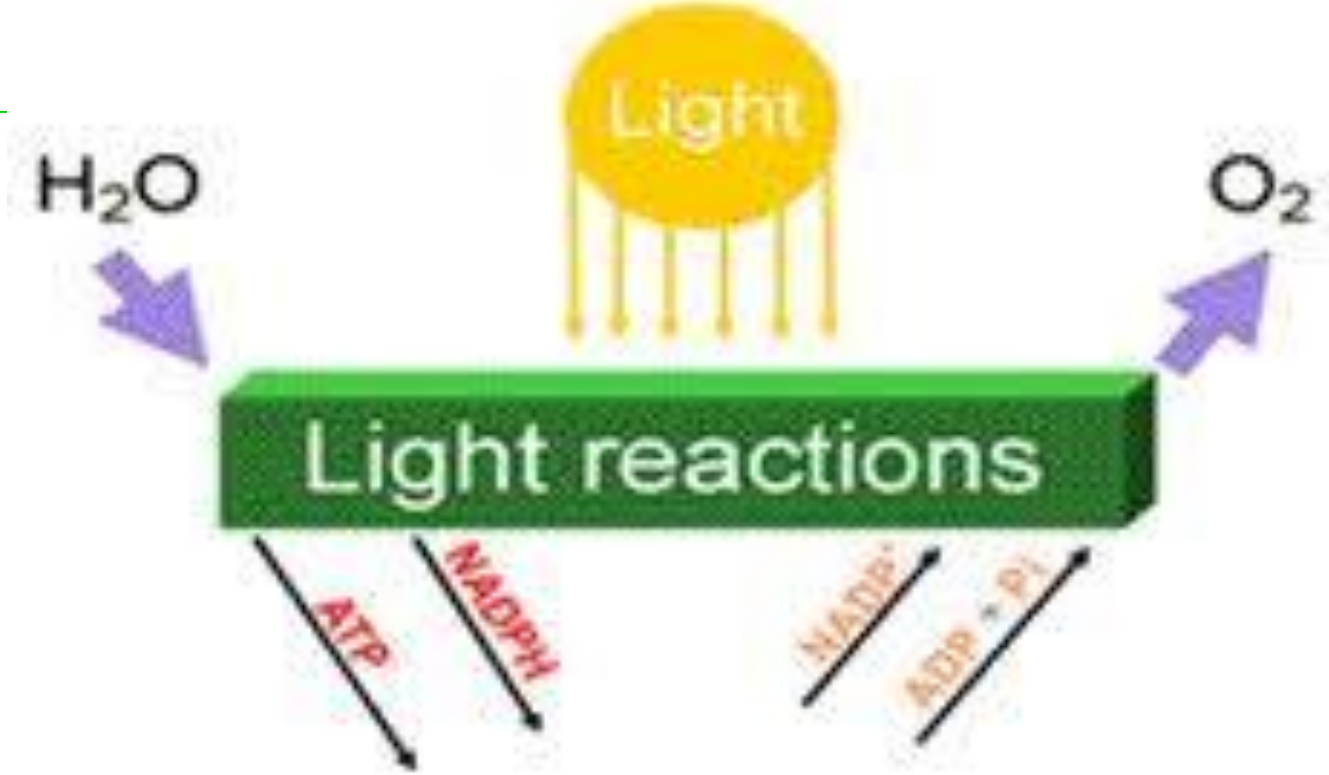
Figure 8-7 Photosynthesis: An Overview





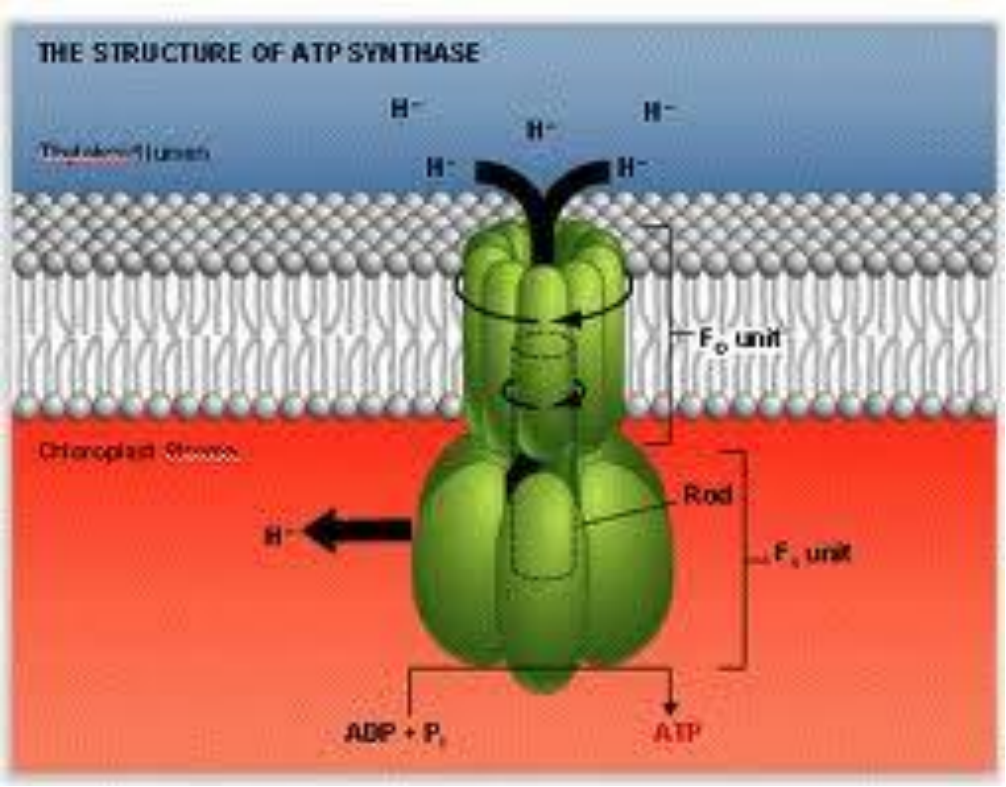
C. Light-Dependent Reactions

- 1. Light-dependent reactions require light and produce oxygen gas and change ADP and NADP+ into energy carriers ATP and NADPH.



C. Light-Dependent Reactions

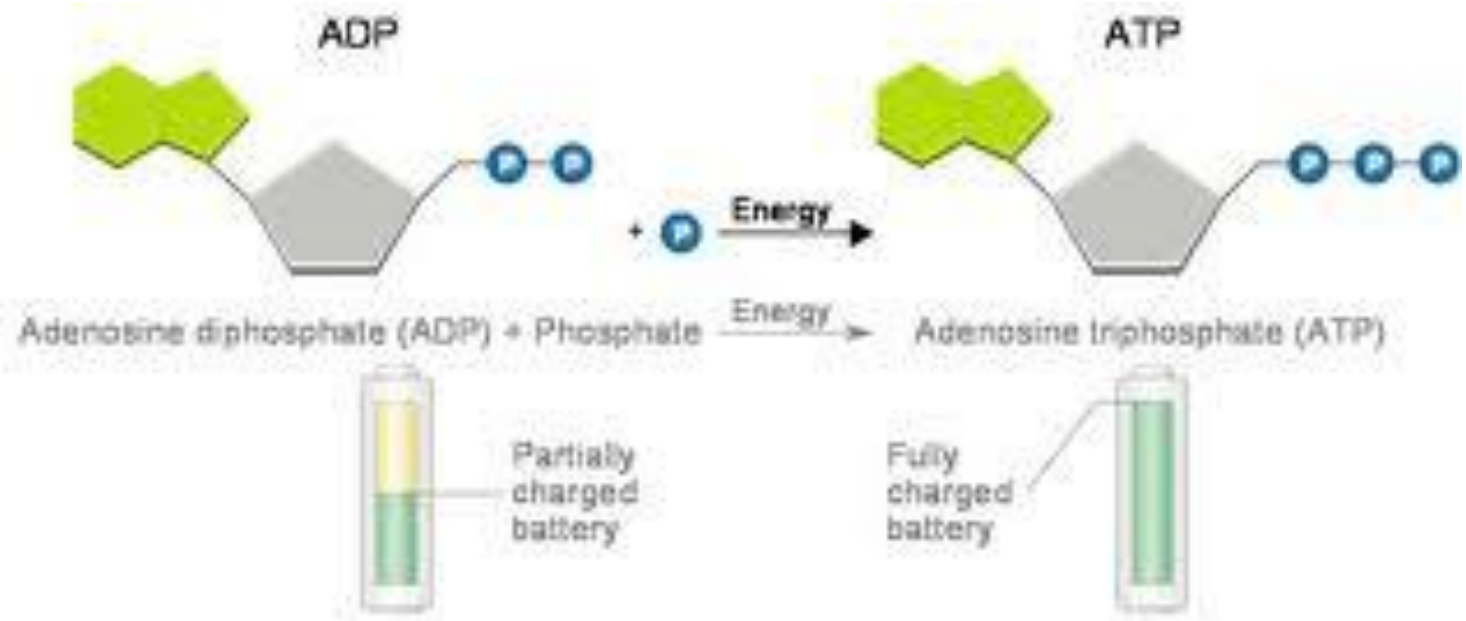
- 2. ATP Synthase is located on the thylakoid membrane.



Videohttp://www.youtube.com/watch?v=PjdPTY1wHdQ

C. Light-Dependent Reactions

- 3. ATP Synthase binds ADP and a phosphate group to make ATP.



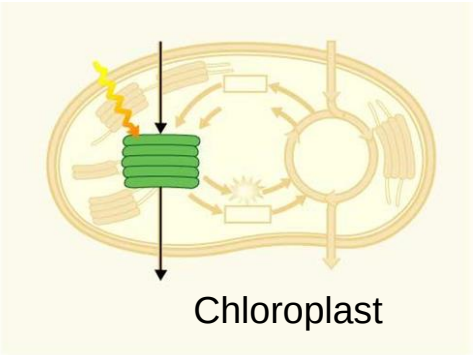
Light Dependent Reaction

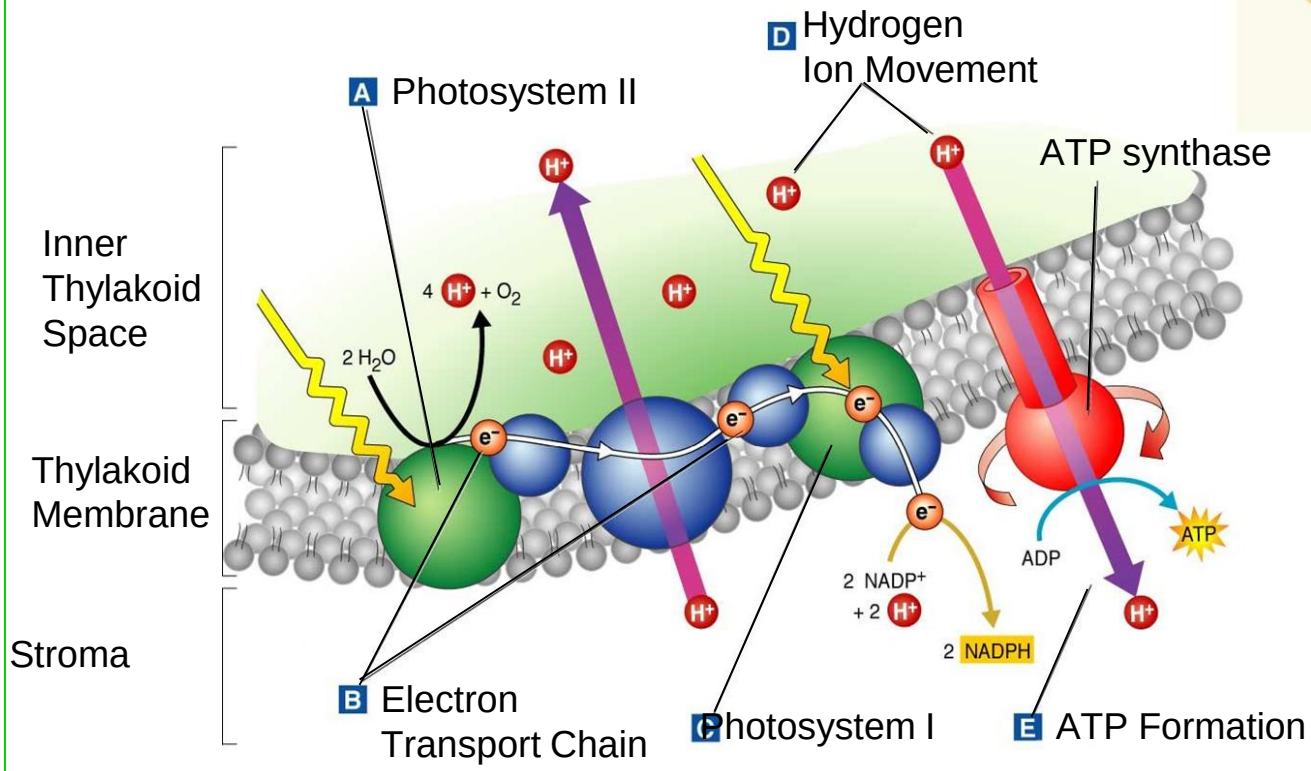
- Required light
- Produces oxygen gas (O_2) and converts ADP and $NADP^+$ into ATP and NADPH

ADP → ATP

$NADP^+$ → NADPH

Figure 8-10 Light-Dependent





LDR

- Takes place in the thylakoid membranes
- High energy electrons move from photosystem II to photosystem I
- A charge difference outside membrane takes place, which provides energy to make ATP.
  - Cannot take place w/o ATP Synthase

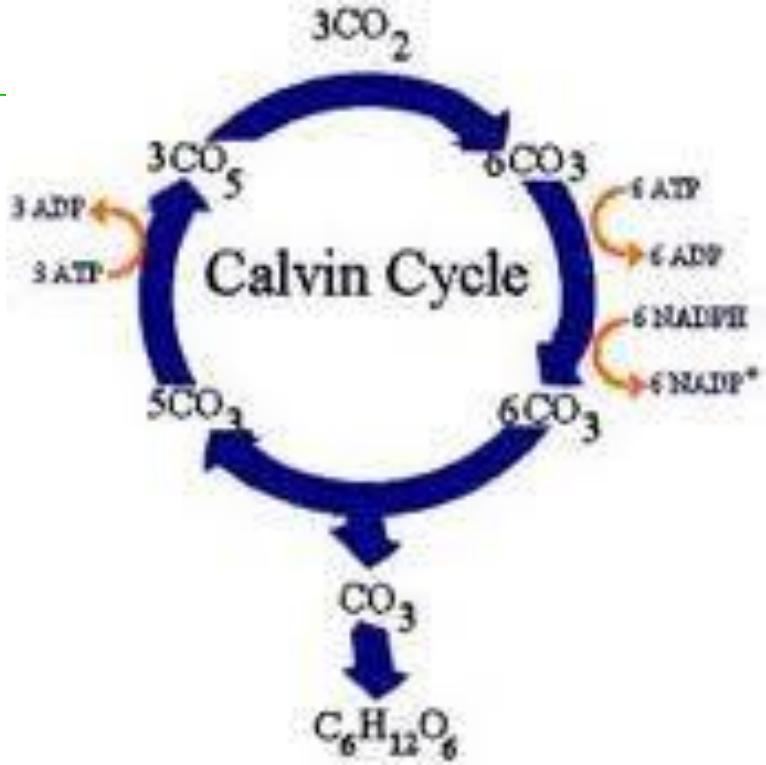
ATP synthase

So how does ATP synthase do it?

- ATP synthase allows H+ ions to pass through the thylakoid membrane.
- As the ions pass through, ATP synthase rotates.
- This binds ADP and a phosphate group together to produce ATP.

D. The Calvin Cycle

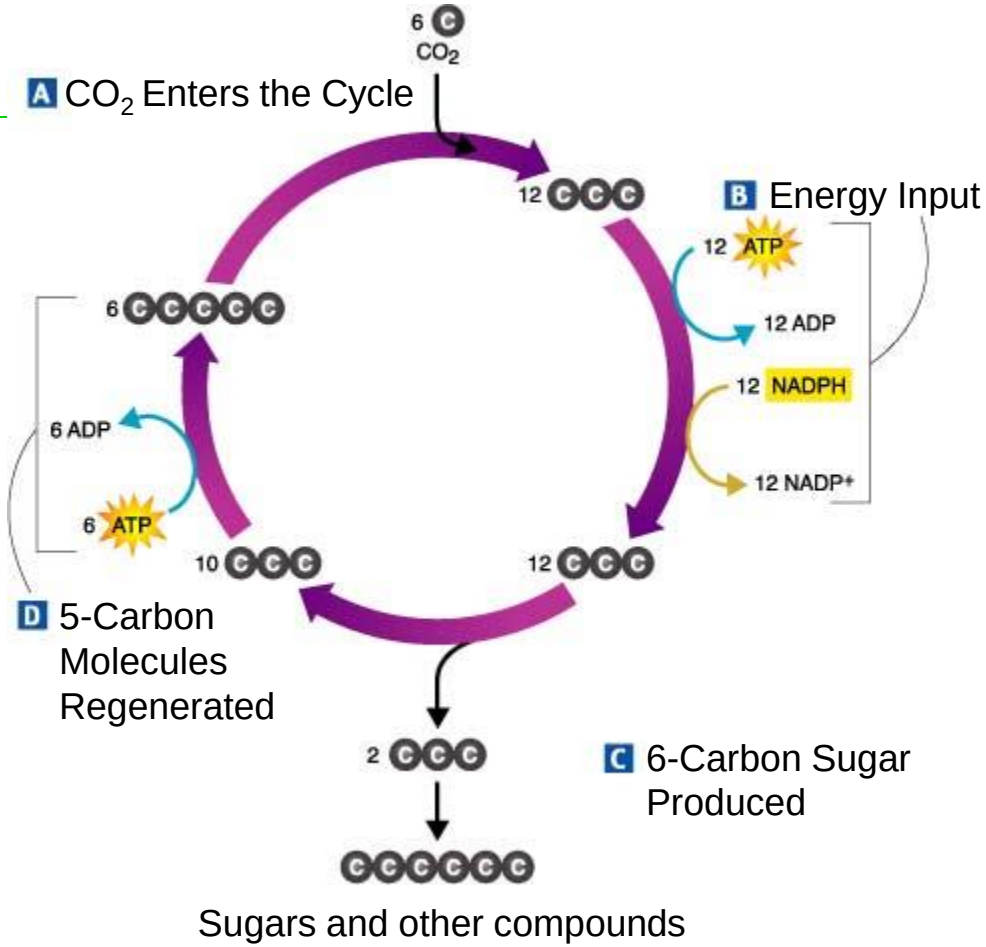
- 1. Plants use energy contained in ATP and NADPH from the light-dependent reactions during the calvin cycle to make high-energy sugars (glucose).

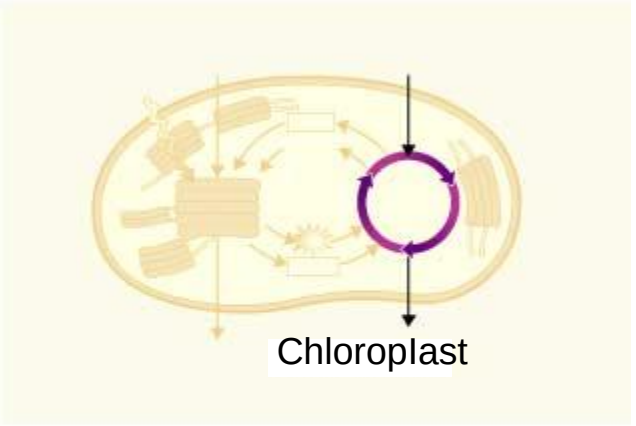


The Calvin Cycle

- Named after Melvin Calvin; also called light independent reaction
  - Does not need/use light
- Uses ATP and NADPH formed from LDR, cannot store their energy for long
- Uses carbon dioxide from atmosphere
  - Uses 6 CO_2 molecules to make 1 sugar molecule
- Calvin cycle uses that energy to build high energy compounds (sugars)

Figure 8-11 Calvin Cycle-Uses






The Calvin Cycle

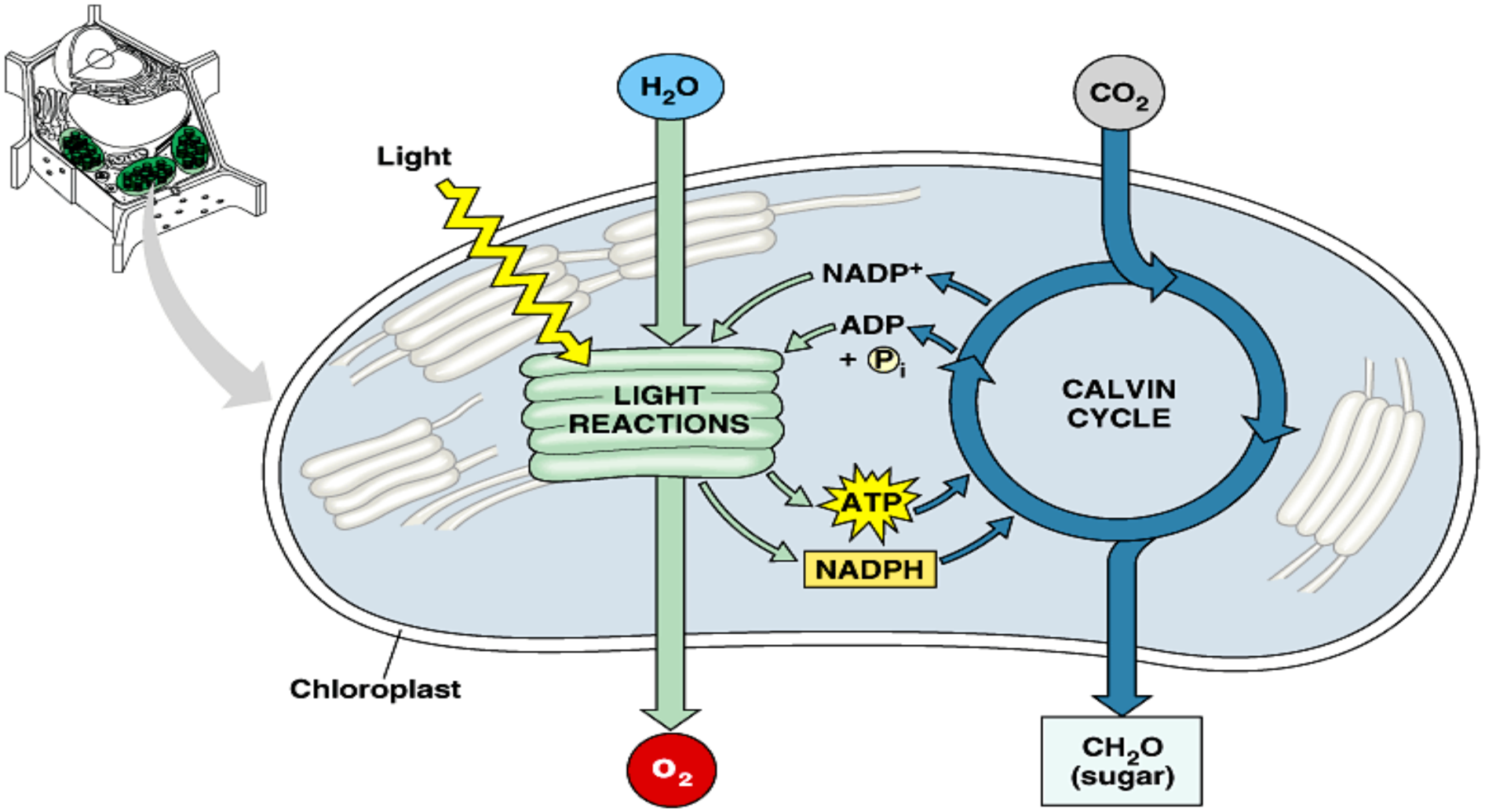
Can you put these in order??

- Six Carbon Sugar produced
- Five Carbon Molecule Regenerated
- Energy Input from ATP and NADPH
- Six Carbon Dioxide molecule enters from atmosphere

Can you put these in order??

- 1. Six Carbon Dioxide molecules enter from atmosphere
- 2. Energy Input from ATP and NADPH
- 3. Six Carbon Sugar produced ($C_6H_{12}O_6$)
- 4. Five Carbon Molecule Regenerated

Photosynthesis: An overview



Similar to Figure 8-7

Brainstorm

- Make a list of three factors that you think can impact the process of photosynthesis.

Factors that affect photosynthesis

- Amount of water
  - How do plants live in dry temperatures?
- Temperature
  - Depends on enzymes that work best between 0^{o}C and 35^{o}C
  - Above or below these temperatures will cause the slowing of photosynthesis
  - At very low temperatures, photosynthesis may stop
- Amount of light
  - Increasing light will increase photosynthesis, however at a certain point, it will reach its maximum rate of photosynthesis

Summary

- The two sets of reactions, LDR & LIR, work together.
- LDR trap the energy of sunlight in chemical form
- LIR uses that energy to produce stable, high energy sugars from carbon dioxide and water.
- And we, in turn, get lots of oxygen at our disposal!

Exit Ticket

- Pg. 216 Complete the Flow Chart
- WORD BANK (Only use 5 of the words below)
- Light, NADP+, Light-dependent reactions, NADPH, Chloroplasts, Carbon Dioxide, Photosystem, Sugars, Chlorophyll