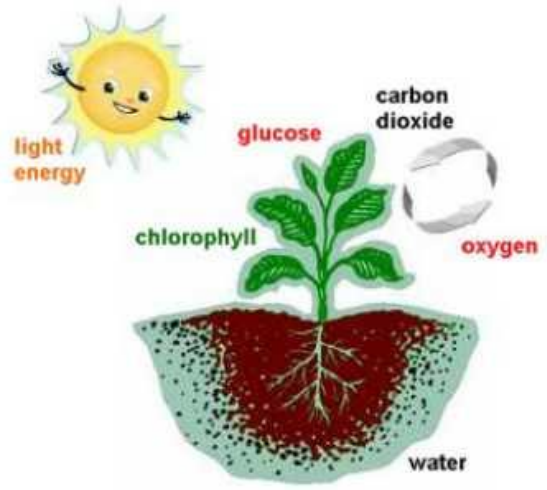
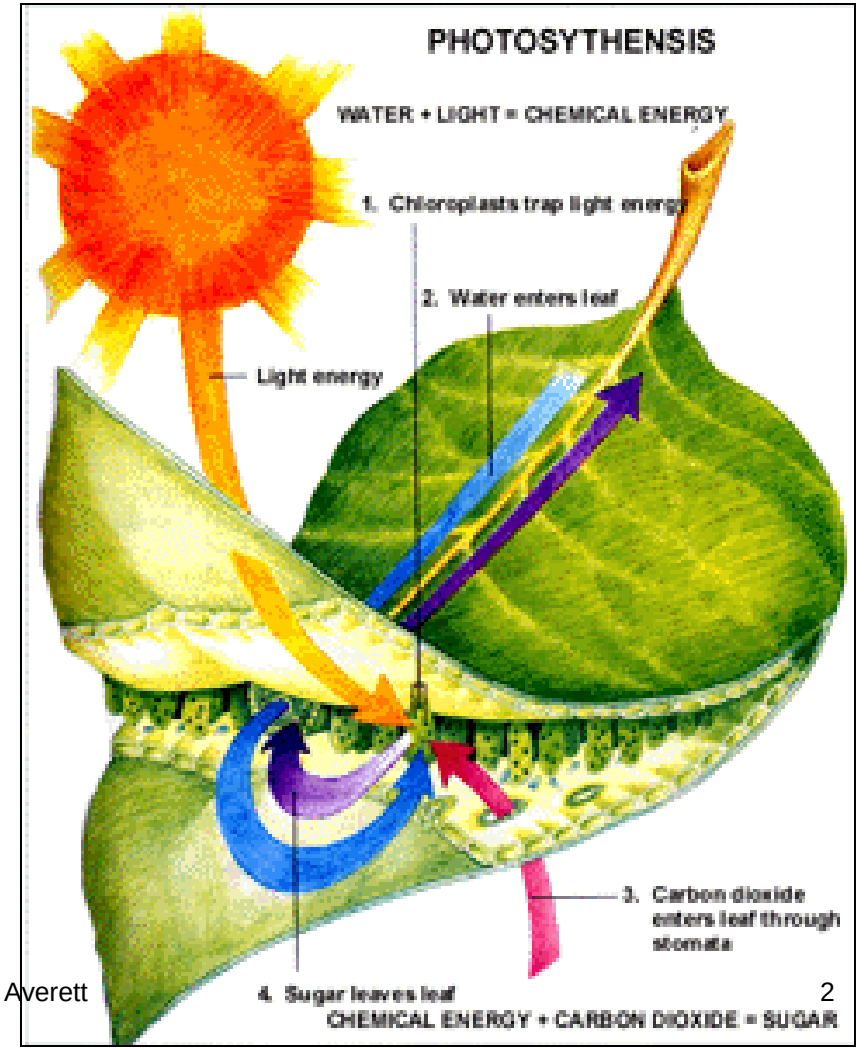
# Overview of Photosynthesis




Introduction to Biochemistry - Part II

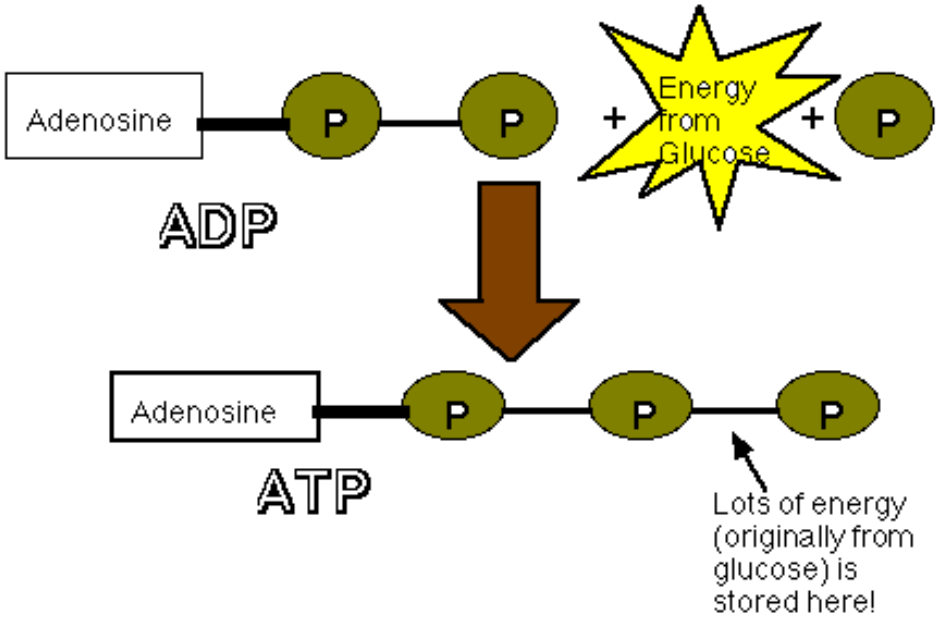
# Autotrophs & Heterotrophs

- The energy available in most food comes from the **sun**, whether directly or indirectly
  - Plants and some other types of organisms are able to use light energy to produce food (known as **autotrophs**)
  - Other organisms cannot use the sun's energy directly, but instead they must eat other organisms (known as **heterotrophs**)



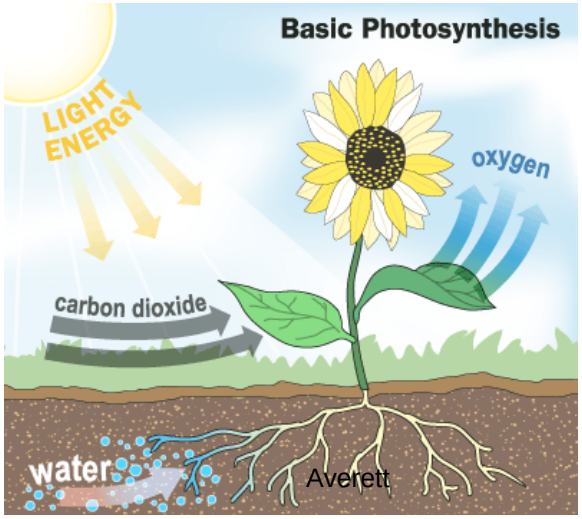
# Chemical Energy & ATP

- The activities of all cells are powered by chemical fuels
  - The principal compound that living things use to store and carry energy is adenosine triphosphate (**ATP**)
  - The characteristics of ATP make it an exceptionally useful molecule that is used by all types of cells as their basic source of energy



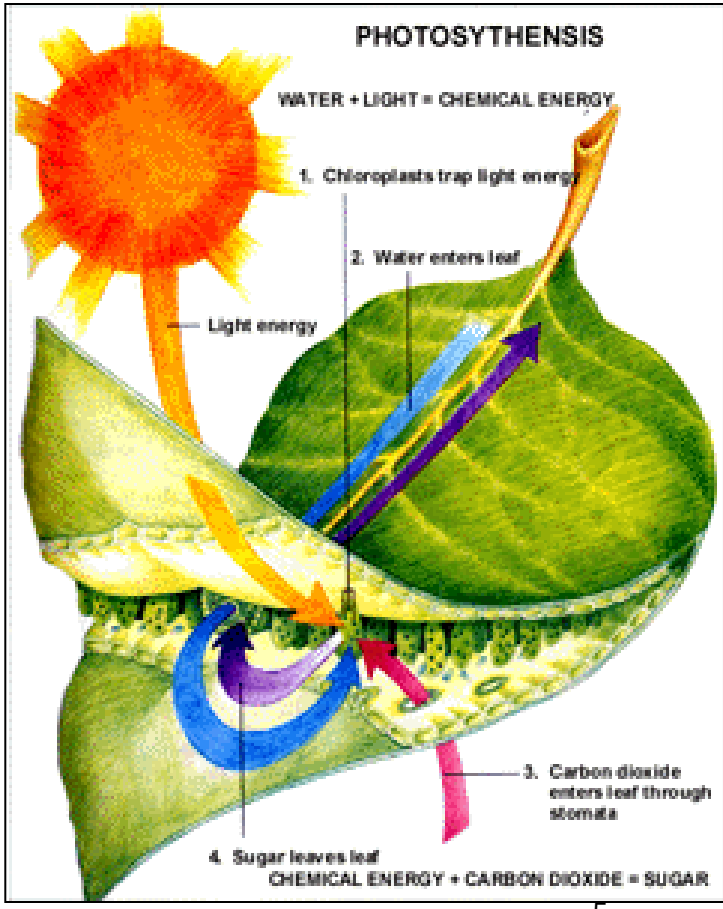
# Photosynthesis

- In the presence of light, plants, and other photoautotrophs, transform carbon dioxide and water into carbohydrates and release oxygen
  - **Photosynthesis equation**
  - **$6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$**
  - carbon dioxide + water $\xrightarrow{\text{light}}$ glucose + oxygen



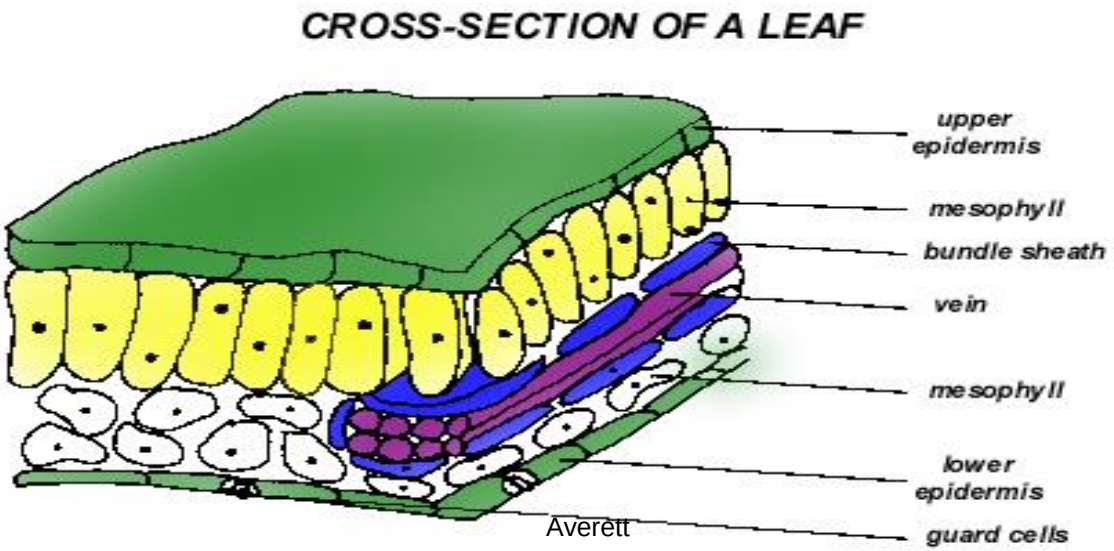
# Inside a Chloroplast

- Photosynthesis takes place inside chloroplasts
  - Leaves are made up of cells just like all living organisms are made of cells
  - Plant cells contain chloroplasts, this is where photosynthesis occurs



# Stomata

- $CO_2$ is taken in and $O_2$ is released through tiny openings in leaves called stomata
- $H_2O$ travels from the roots to the leaves

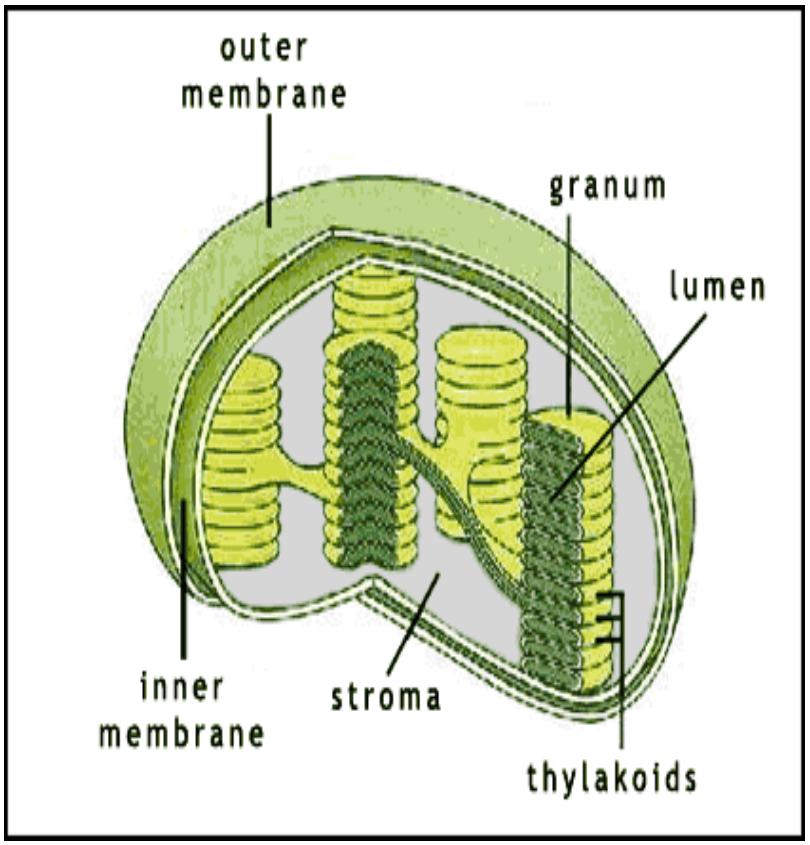


# Light and Pigments

- In addition to water and carbon dioxide, photosynthesis requires light and **chlorophyll**, a molecule found in chloroplasts
- Plants gather the sun's energy with light-absorbing molecules called **pigments**
  - A plant's principal pigment is **chlorophyll**
  - Chlorophyll is the GREEN pigment used by a plant to absorb energy from light.

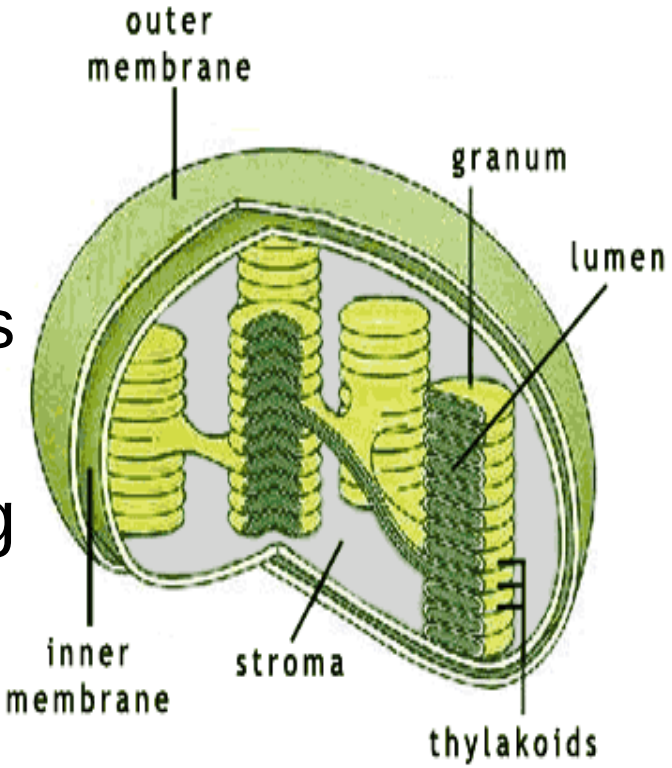
# Thylakoids

- Thylakoids
  - Saclike structures in chloroplasts
  - Made up of lipid bilayers
  - Look like coin shaped, membrane enclosed compartments
  - Membranes contain chlorophyll and other light absorbing molecules
  - Site of light dependent reactions

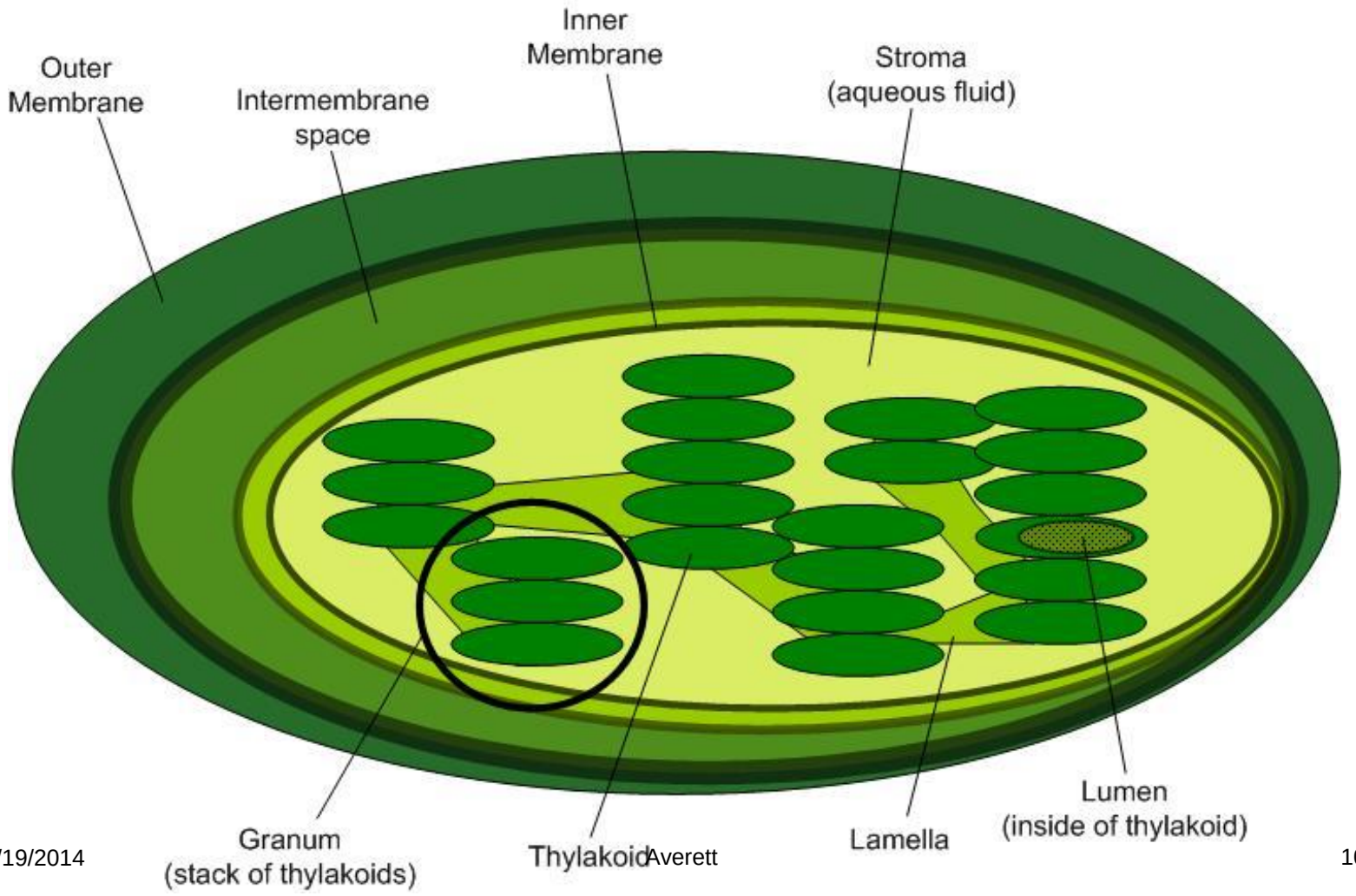


# Thylakoids, Grana and Stroma

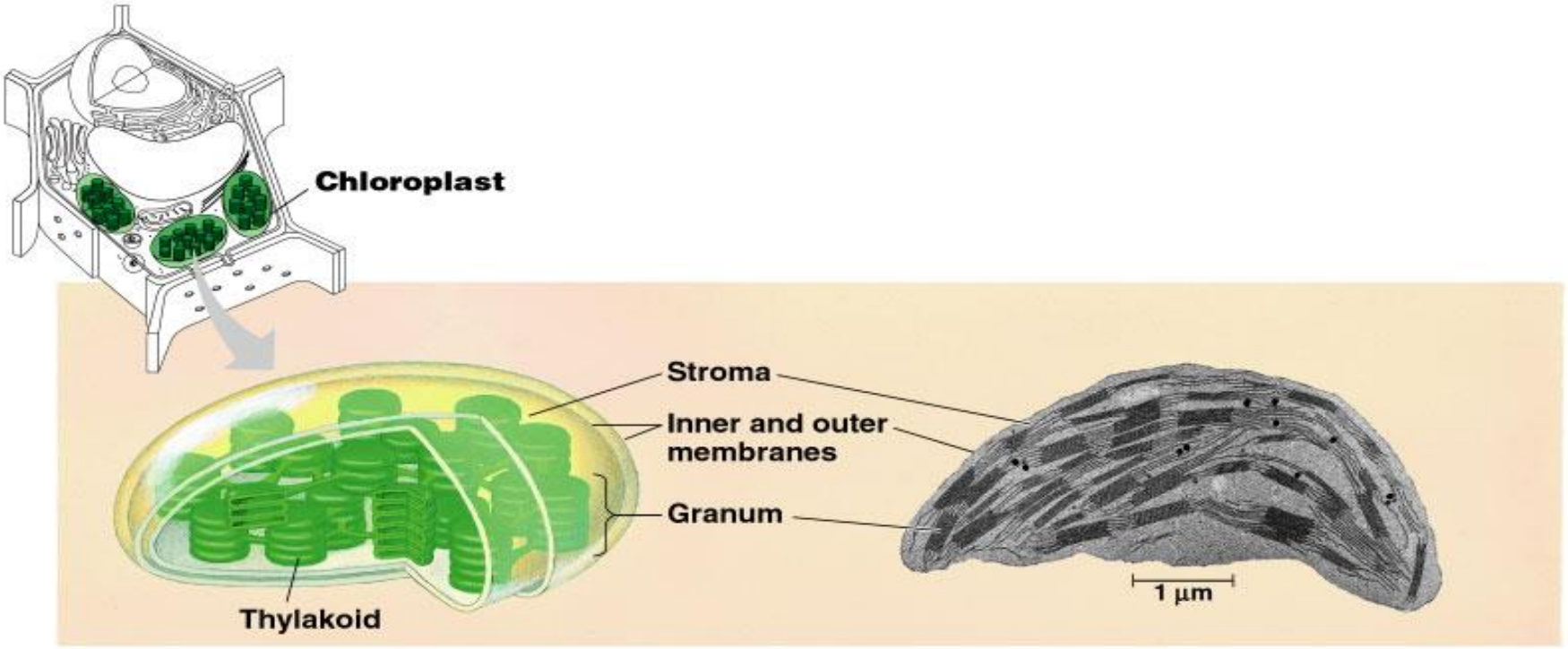
- Lumen – area inside of a thylakoid
- Lamella – internal membrane system that connects all of the thylakoids
- Granum – a stack of thylakoids
  - Plural is grana
- Stroma – the liquid surrounding the thylakoids/grana
  - Site of light independent reactions



# Inside a Chloroplast



# Plant cells contain chloroplasts



# Stages of Photosynthesis

- The reactions that occur during photosynthesis can be broken into 2 stages:
  1. **Light Dependent Reactions**
     - Take place within, and across, the **thylakoid membranes** of a chloroplast
  2. **Light Independent Reactions (Calvin Cycle)**
     - Take place in the **stroma** of the chloroplast

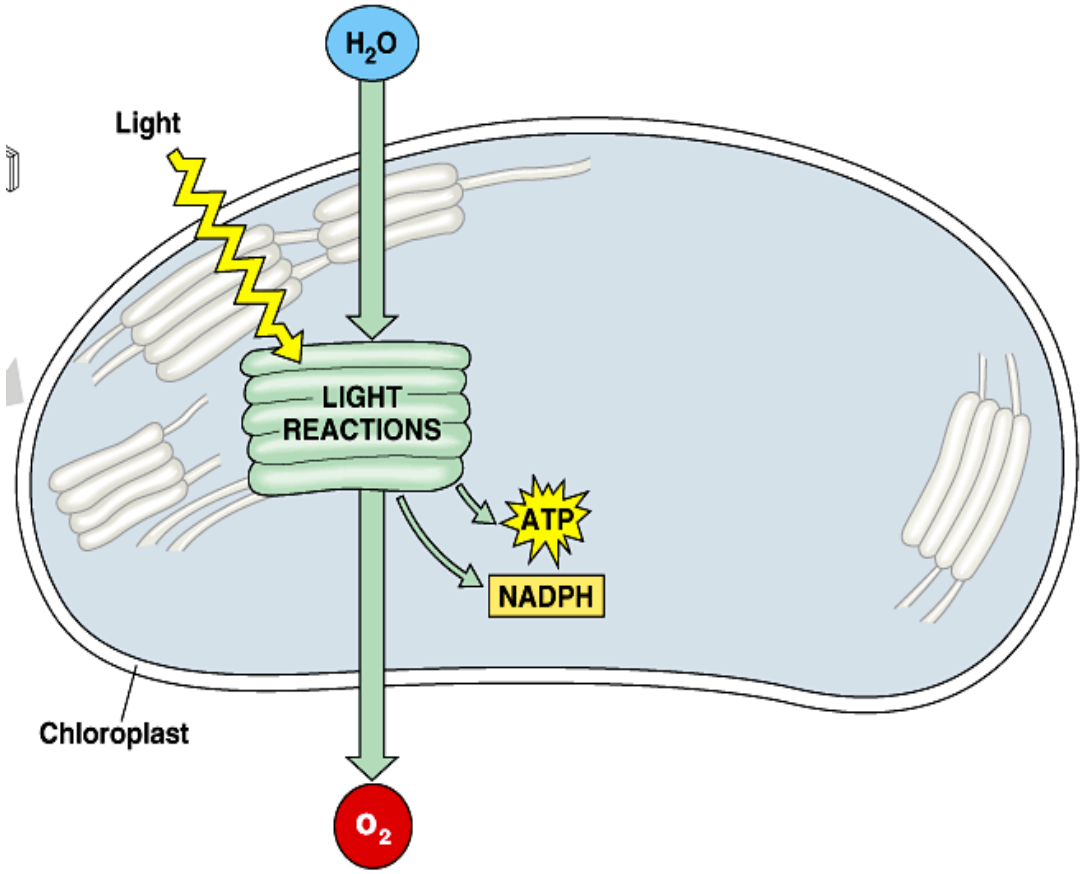
# NADPH

- When sunlight excites electrons in chlorophyll, the electrons gain a great deal of energy
  - These high energy electrons require a special carrier
  - Cells use electron carriers to transfer high energy electrons from chlorophyll to other molecules
  - A **carrier molecule** is a compound that can accept a pair of high energy electrons and transfer them along with most of their energy to another molecule
- **$NADP^+$** (nicotinamide adenine dinucleotide phosphate) is an example of a carrier molecule
  - $NADP^+$ accepts and holds 2 high-energy electrons along with a hydrogen ion ($H^+$)
  - This converts $NADP^+$ to **NADPH**, which then carries the high energy electrons to chemical reactions elsewhere in the cell

# Light Dependent Reactions

- Occur in the thylakoids
- Light dependent reactions require light
  - They use energy from light to produce ATP and NADPH
- Light dependent reactions require water
- The light dependent reactions of photosynthesis produce oxygen gas and convert ADP and $NADP^+$ into the energy carriers ATP and NADPH
- Oxygen gas is released as a waste product

# Light Dependent Reactions

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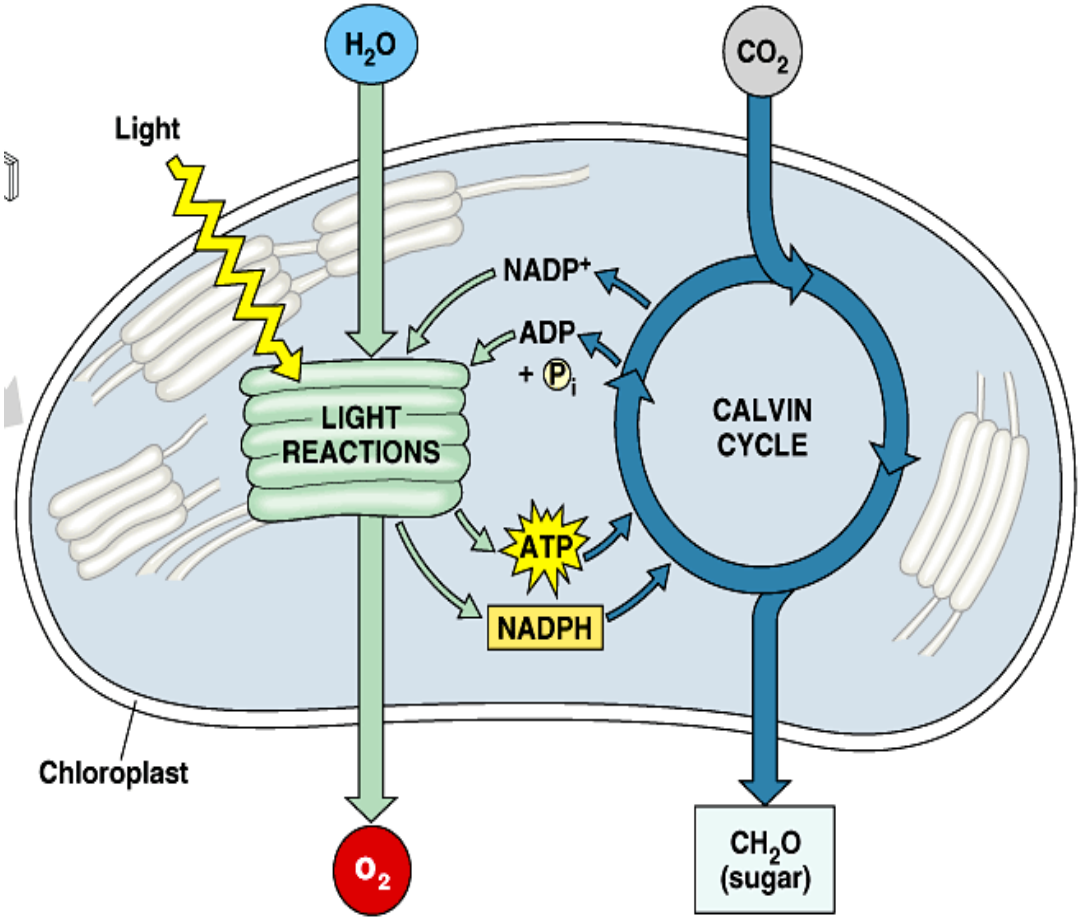
# Steps of Light Dependent Reactions

1. Pigments is photosystem II absorb light.
    1. The energy level of the electrons in ps II is increased
    2. These high energy electrons are passed on to the electron transport chain
    3. Water is split and oxygen is released into the atmosphere (and the 2 H+ ions are released inside the thylakoid membrane)
2. High energy electrons move along the ETC from ps II to ps I
3. Pigments is ps I use energy from light to reenergize the electrons and they are picked up by NADP+
    1. The electrons, along with an H+ (from when the water was split) become NADPH
4. The remaining H+ creates a difference in charges across the thylakoid membrane (which provides energy to make ATP)
5. A protein called ATP synthase allows the H+ ions to pass through it.
    1. As they pass, power is generated and ADP binds with another phosphate group and ATP is produced

# The Calvin Cycle

- Occurs in the stroma
- The Calvin Cycle uses ATP and NADPH from the light dependent reactions of photosynthesis to produce high energy sugars
  - The Calvin Cycle does not require light, and therefore is also known as the light independent reactions of photosynthesis
  - The Calvin Cycle uses 6 molecules of $CO_2$ to produce a single sugar molecule ($C_6H_{12}O_6$)

# Calvin Cycle



# Visual Overview of Photosynthesis