

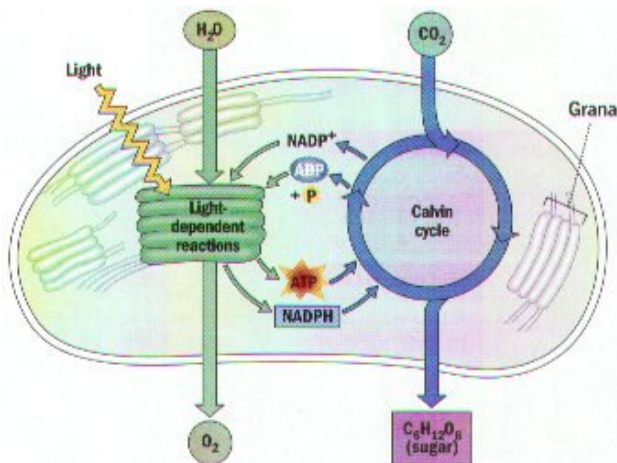
OVERVIEW OF PHOTOSYNTHESIS

"THE BIG PICTURE"

1. Photosynthesis is the process that provides energy for almost all Life.
2. During Photosynthesis, Autotrophs use the Sun's Energy to make Carbohydrate Molecules from Water and Carbon Dioxide, Releasing Oxygen as a Byproduct.
3. **The Process of PHOTOSYNTHESIS CAN BE SUMMARIZED BY THE FOLLOWING EQUATION:**



4. In this equation the Six-Carbon Sugar GLUCOSE and Oxygen are the Products.
5. The Energy Stored in Glucose and other Carbohydrates can be used later to produce ATP during Cellular Respiration.

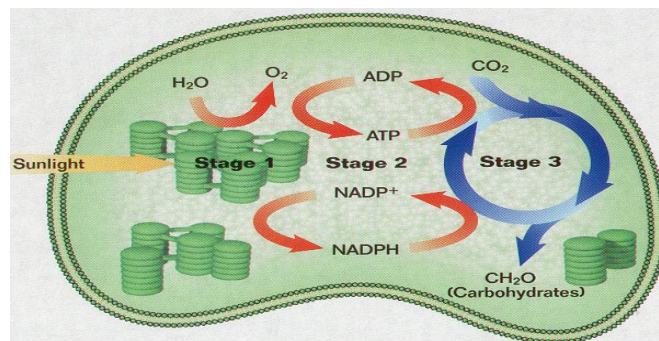


6. The Process of Photosynthesis does NOT Happen all at Once; rather it occurs in **THREE STAGES**:

STAGE 1 - CALLED THE **LIGHT DEPENDENT REACTIONS**. Energy is Captured from Sunlight. Water is Split into Hydrogen Ions, Electrons, and Oxygen (O₂). The O₂ Diffuses out of the Chloroplasts (Byproduct).

STAGE 2 - The Light Energy is Converted to Chemical Energy, which is Temporarily Stored in **ATP and NADPH**.

STAGE 3 - CALLED THE **CALVIN CYCLE**. The Chemical Energy Stored in ATP and NADPH powers the formation of Organic Compounds (Sugars), Using Carbon Dioxide, CO₂.

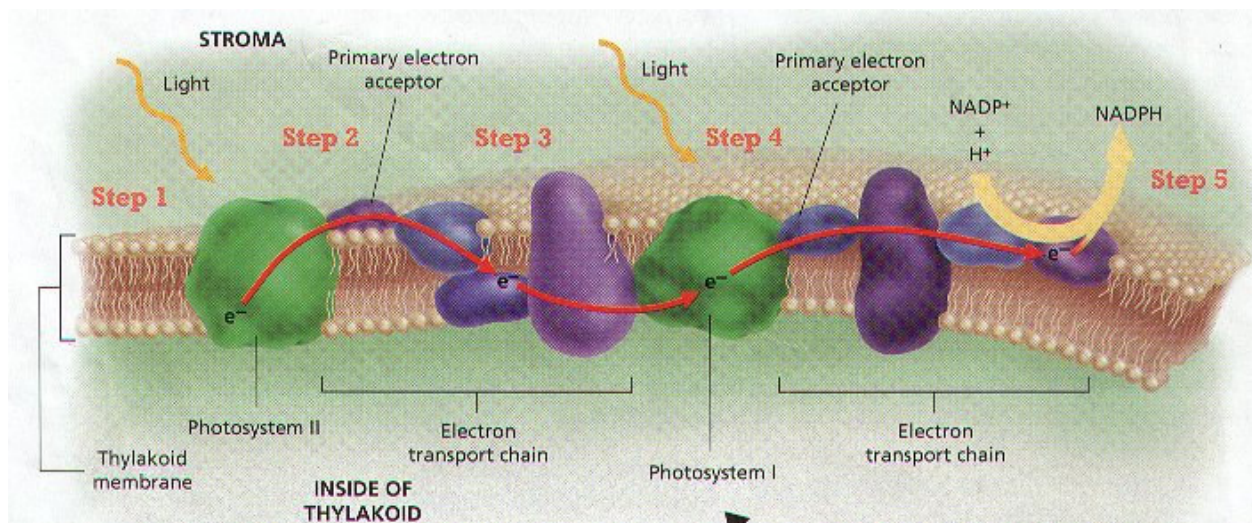




7. Photosynthesis occurs in the Chloroplasts of Plant Cells and Algae and in the Cell Membranes of certain Bacteria.

ELECTRON TRANSPORT - LIGHT REACTIONS

1. The Chlorophylls and Carotenoids are grouped in Cluster of a Few Hundred Pigment Molecules in the Thylakoid Membranes.
2. Each Cluster of Pigment Molecules is referred to as a PHOTOSYSTEM. There are Two Types of Photosystems known as PHOTOSYSTEM I AND PHOTOSYSTEM II.
3. Photosystem I and Photosystem II are similar in terms of pigments, but they have Different Roles in the Light reactions.
4. The Light Reactions BEGIN when Accessory Pigment molecules of BOTH Photosystems Absorb Light.
5. By Absorbing Light, those Molecules Acquire some of the Energy that was carried by the Light Waves.
6. In each Photosystem, the Acquired Energy is Passed to other Pigment Molecules until it reaches a Specific Pair of CHLOROPHYLL *a* Molecules.
7. The Events occur from this point on can be Divided into 5 STEPS. (Refer to Figure 6-5)



STEP 1 - Light Energy Forces Electrons to enter a Higher Energy Level in the TWO Chlorophyll *a* Molecules of Photosystem II. These Energized Electrons are said to be "EXCITED".

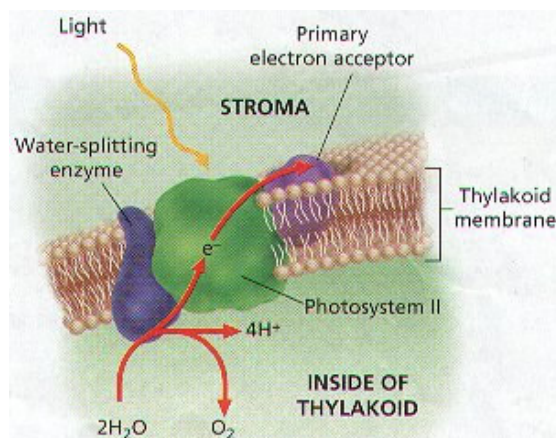
STEP 2 - The Excited Electrons have enough Energy to Leave Chlorophyll *a* Molecules. Because they have lost Electrons, the Chlorophyll *a* Molecules have undergone an OXIDATION REACTION (lost of Electrons). Each Oxidation Reaction must be accompanied by a REDUCTION REACTION (some substance must Accept the Electrons). The Substance is a Molecule in the Thylakoid Membrane Known as a PRIMARY ELECTRON ACCEPTOR.

STEP 3 - The Primary Electron Acceptor then Donates (gives) the Electrons to the First of a Series of Molecules located in the Thylakoid. This Series of Molecules is called an **ELECTRON TRANSPORT CHAIN**, because it Transfers Electrons from One Molecule to the Next in Series. As the Electrons are pass from molecule to molecule, they LOSE most of the Energy they acquired when they were Excited. The Energy they LOSE is Harnessed to Move Protons into the Thylakoid.

STEP 4 - At the same time Light is Absorbed by Photosystem II, Light is also Absorbed by Photosystem I. Electrons move from a Pair of Chlorophyll *a* Molecules in Photosystem I to another Primary electron Acceptor. The electrons that are LOST by these Chlorophyll *a* Molecules are REPLACED by the Electrons that have passed through the electron Transport Chain from Photosystem II.

STEP 5 - The Primary Electron Acceptor of Photosystem I donates Electrons to different Electron Transport Chain. This Chain brings Electrons to the side of the Thylakoid Membrane that FACES THE STROMA. There Electrons COMBINE with a PROTON and NADP+. NADP+ is an Organic Molecule that ACCEPTS Electrons during REDOX Reactions. This reaction causes NADP+ to be Reduced to NADPH.

RESTORING PHOTOSYSTEM II - PHOTOLYSIS



1. The Electrons from Chlorophyll Molecules on Photosystem II REPLACE the Electrons that Leave Chlorophyll Molecules in Photosystem I.

2. If the electrons were NOT Replaced, both Electron Transport Chains would STOP, and Photosynthesis would NOT Occur.

3. The Replacement Electrons are provided by **WATER MOLECULES**. **Enzymes (RuBP carboxylase or Rubisco)** inside the Thylakoid SPLITS Water Molecules into PROTONS, ELECTRONS, AND OXYGEN.



4. For Every TWO Molecules of Water that are Split, FOUR Electrons become available to Replace those lost by Chlorophyll Molecules in Photosystem II.

5. The PROTONS that are produced are left inside the Thylakoid, while Oxygen Diffuses out of the Chloroplasts and can Leave The Plant.

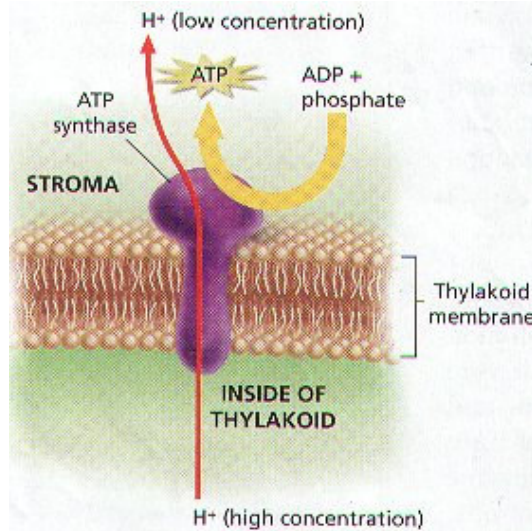
6. **OXYGEN** can be regarded as a Byproduct of the Light Reaction - it is NOT Needed for Photosynthesis.

7. The Oxygen that results from Photosynthesis is ESSENTIAL for Cellular Respiration in most organisms, including Plants.

8. The photochemical splitting of water in the light-dependent reactions of photosynthesis, catalyzed by a specific enzyme is called **Photolysis**.

9. The enzyme that speeds up this reaction, called **RuBP carboxylase (Rubisco)**, about 20-50% of the protein content in chloroplast, and it may be one of the most abundant proteins in the biosphere.

CHEMIOSMOSIS (KEM-ee-ahz-MOH-suhs)



1. An important part of the Light Reaction is the SYNTHESIS of ATP through a process called **CHEMIOSMOSIS**.
2. Chemiosmosis Relies on a CONCENTRATED GRADIENT of Protons Across the Thylakoid Membrane.
3. Protons are Produced from the Breakdown of Water Molecules, Other Protons are Pumped into the Thylakoid from the Stroma during Photosystem II.
4. Both these mechanisms act to build up a Concentration Gradient of Protons. The Concentration of Protons is HIGHER in the Thylakoid than in the Stroma.
5. The Concentration Gradient Represents Potential Energy.

The energy is Harnessed by a Protein called **ATP SYNTHASE**, which is located in the Thylakoid Membrane.

6. ATP Synthase makes ATP by ADDING a PHOSPHATE GROUP to **ADENOSINE DIPHOSPHATE, OR ADP**. By Catalyzing the Synthesis of ATP from ADP, ATP Synthase functions as an Enzyme.

7. ATP Synthase Converts Potential Energy of the Protons Concentrated Gradient into Chemical Energy of ATP.

8. Together, NADPH and ATP Provide Energy for the Second Set of Reactions in Photosynthesis.