Photosynthesis

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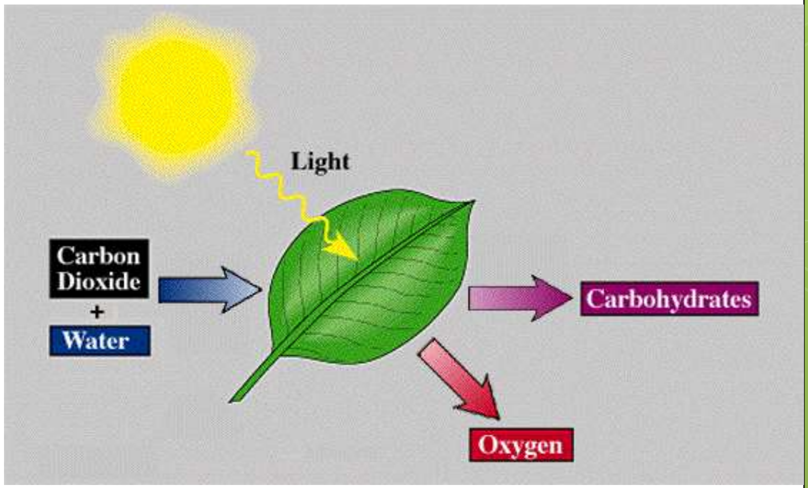
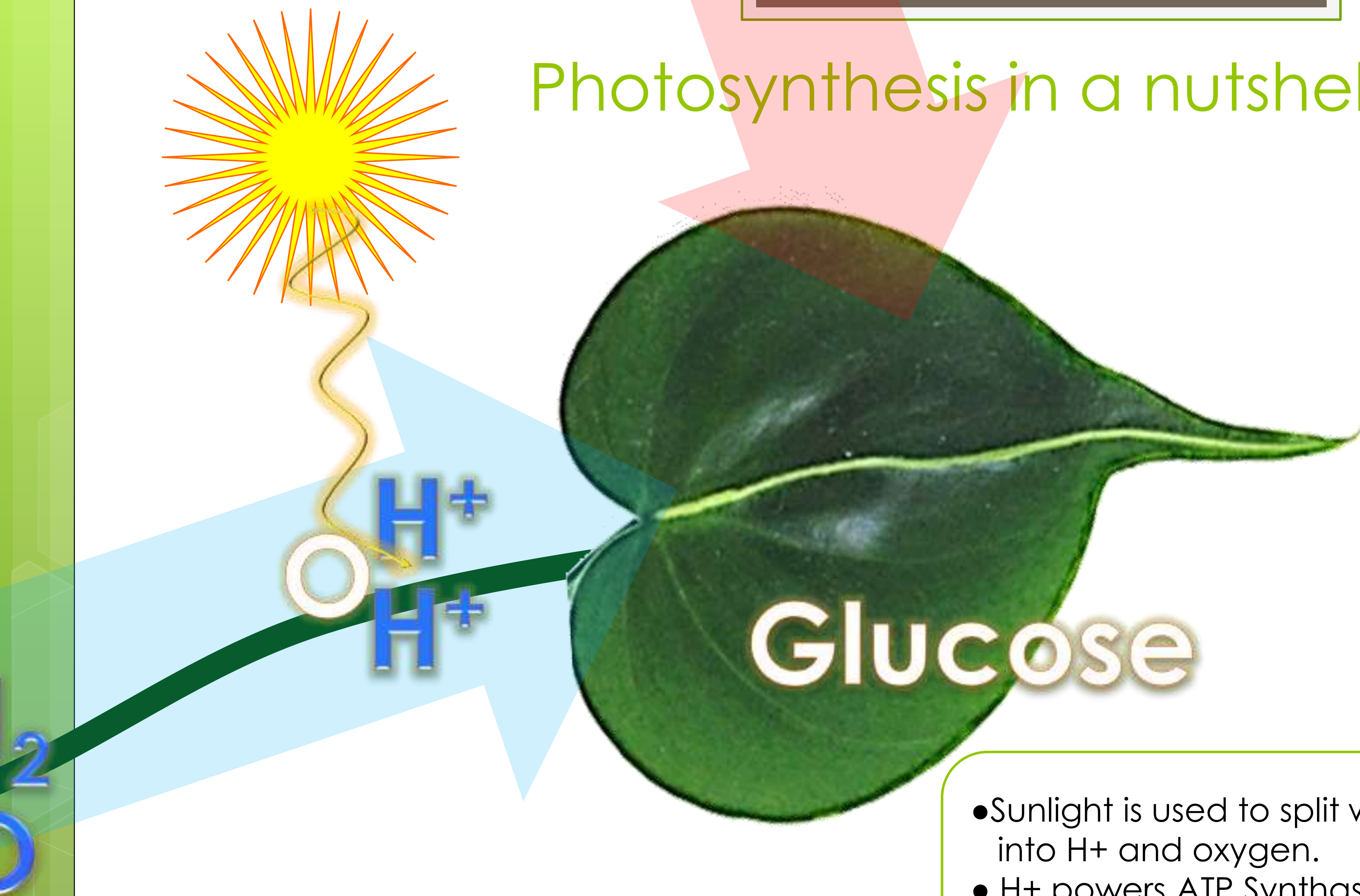
Overview of Photosynthesis

- **Photosynthesis in a nutshell:**
  - Plants absorb light and use it to separate hydrogen from a water molecule.
    - *The oxygen that remains is released as O_2.*
  - The hydrogen from water is used to turn ATP Synthase so that it can make ATP.
  - ATP powers the process that creates a glucose molecule.
- **Photosynthesis equation:**
  $6\ CO_2 + 6\ H_2O = C_6H_{12}O_6 + 6\ O_2$
  - Plants absorb H_2O and CO_2.
  - Plants produce glucose ($C_6H_{12}O_6$) and release O_2



Source: phschool.com

Photosynthesis in a nutshell…

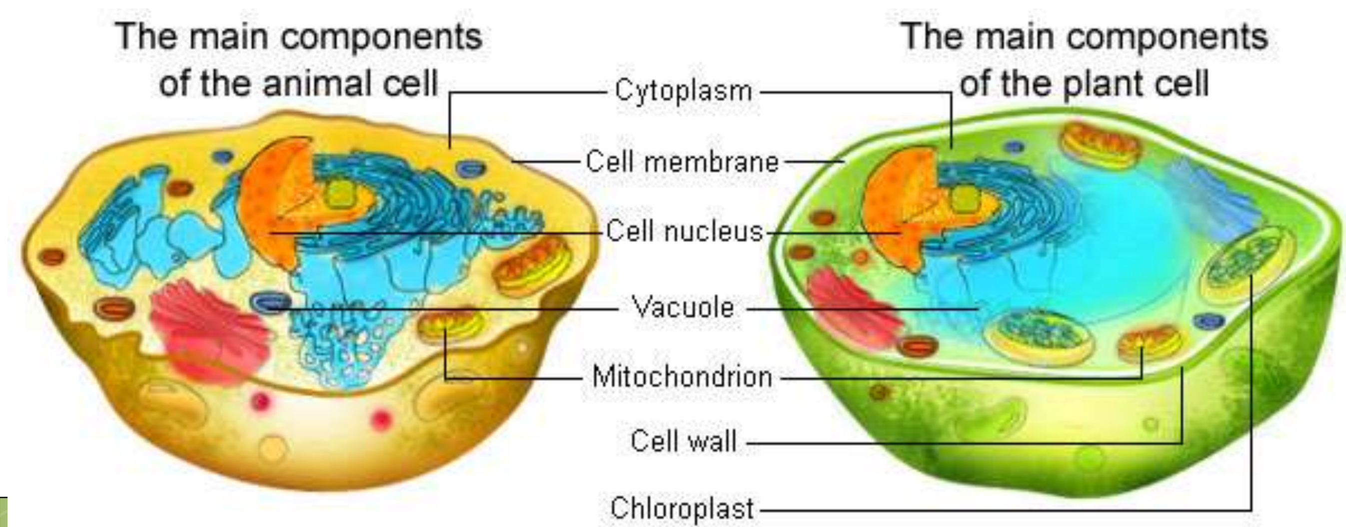


- Sunlight is used to split water into H+ and oxygen.
- H+ powers ATP Synthase.
- ATP powers the production of glucose from H+ and CO_2.

The Plant Cell

- **The plant cell.**
  - The plant cell is very similar to the animal cell.
    - *Each cell has similar organelles such as the mitochondria, the nucleus, ribosomes, and a cell membrane.*
  - Both kinds of cells use ATP as their primary source of energy.
    - *Both cells primarily use hydrogen from glucose to power the production of ATP in the mitochondria.*

- **However, there are differences (next slide).**

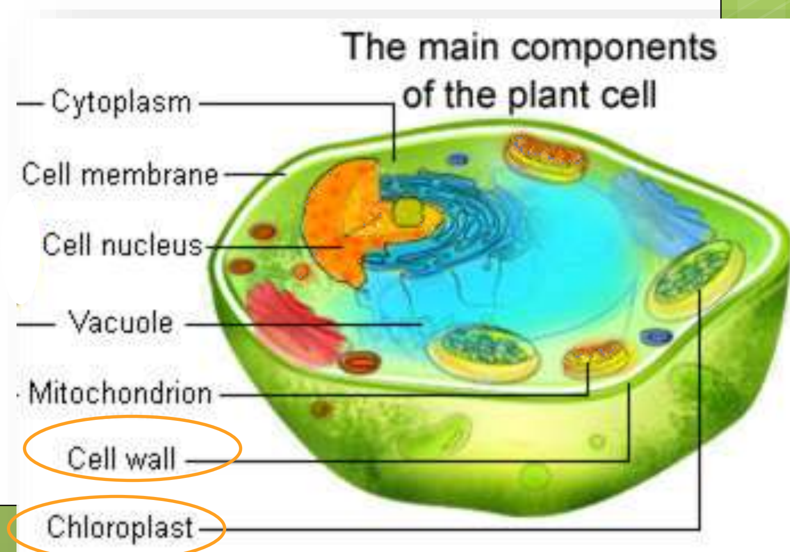


Source: ipsy2011.blogspot.com

Plant Cells vs. Animal Cells

- **Plant cells have a cell wall.**
  - Outside of their cell membrane, plants have a rigid cell wall made of cellulose.
  - This cell wall protects the plant cell inside.
  - The cell wall also provides structure and support for the plant.
    - *The cell wall acts much a like a skeleton does for vertebrate animals.*

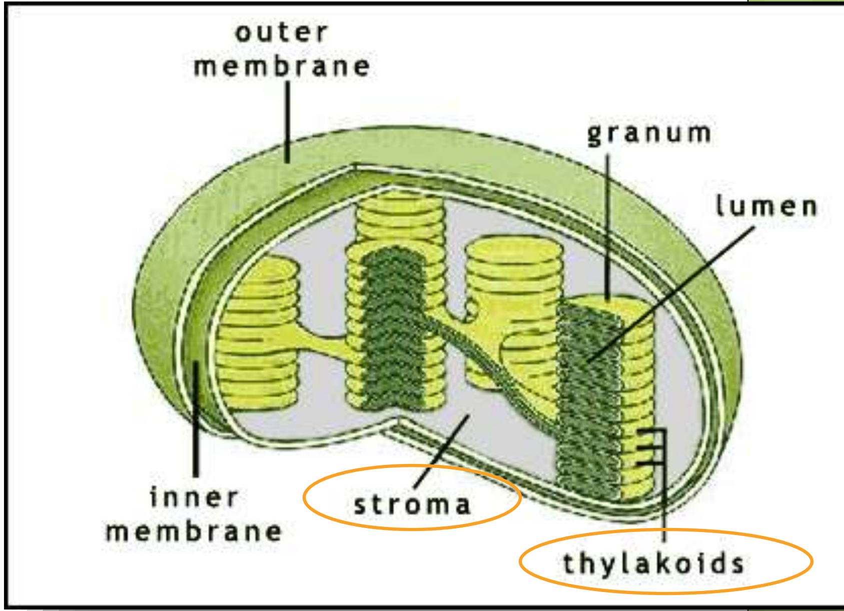
- **Plants have chloroplasts (the cellular organelle where photosynthesis occurs).**
  - Chloroplasts are a cellular organelle (just like the mitochondria is an organelle).
  - Chloroplasts can use light energy (or photons) to power the removal of hydrogen from water
    - *This hydrogen is used to turn ATP synthase to make ATP.*
  - The ATP is used to power the assembly of a glucose molecule.



Source: ipsy2011.blogspot.com

Parts of a Chloroplast

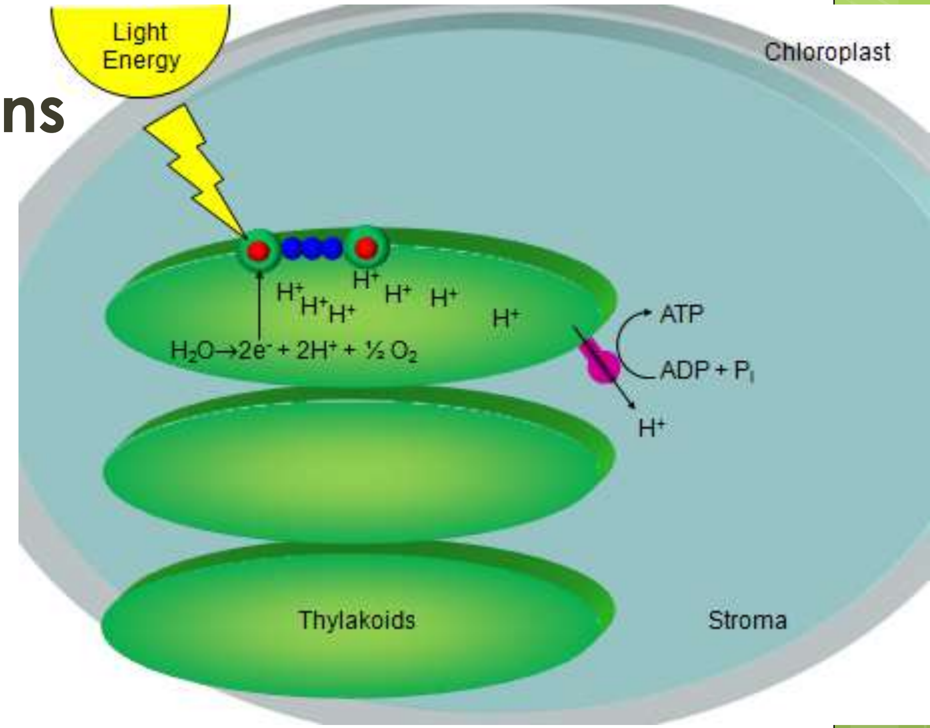
- **The chloroplast has two main parts:**
  - The thylakoids: these look like stacks of green pancakes.
    - *This is where water molecules are split, hydrogen is stored, and where ATP Synthase produces ATP.*
  - The stroma: this is the 'empty space' around the thylakoids.
    - *This is where the glucose molecule is assembled.*



Source: withfriendship.com

Thylakoids

- **The thylakoids store hydrogen.**
  - Thylakoids are lined with a green pigment called chlorophyll.
    - *Chlorophyll can absorb the energy of the light (photons).*
- **The energy of light photons is used to separate the hydrogen from the oxygen on a water molecule.**
  - The hydrogen is stored inside the thylakoids.
  - The oxygen is released as O_2.

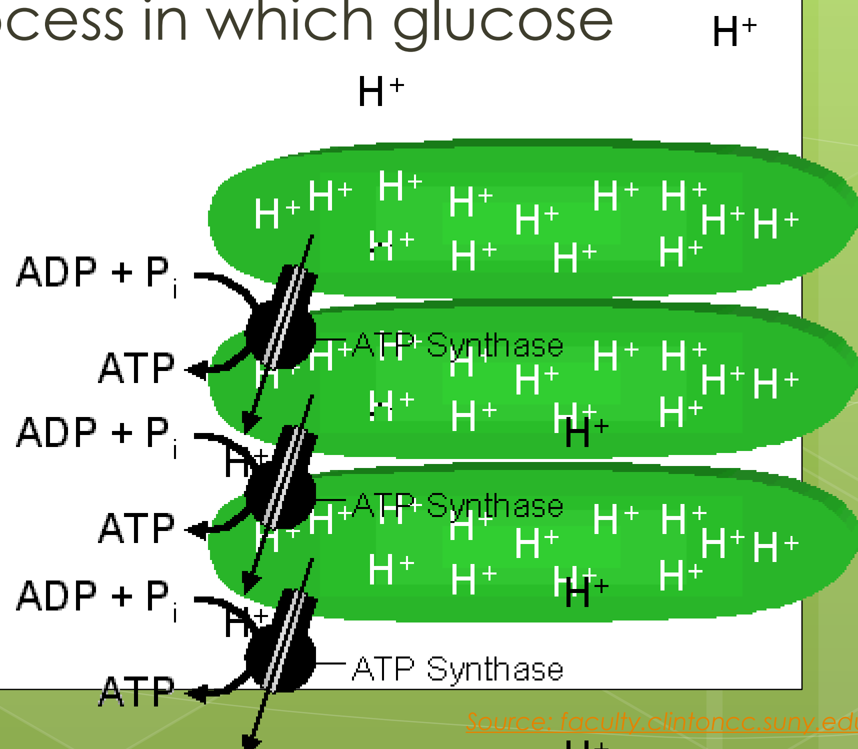


Source: faculty.clintoncc.suny.edu

Thylakoids and ATP Synthase

- **Thylakoids have ATP Synthase on their outside membrane.**
  - The hydrogen from water is used to turn this ATP Synthase to make ATP.
  - The ATP from the thylakoids will be used for only one purpose: to power the process in which glucose molecules are produced.

- **Thylakoids are found in ‘stacks’ called <u>grana</u>.**
  - The <u>th</u>ylakoid is the ‘<u>th</u>in green pancake’.
  - The <u>g</u>rana is the ‘<u>g</u>roup of pancakes’



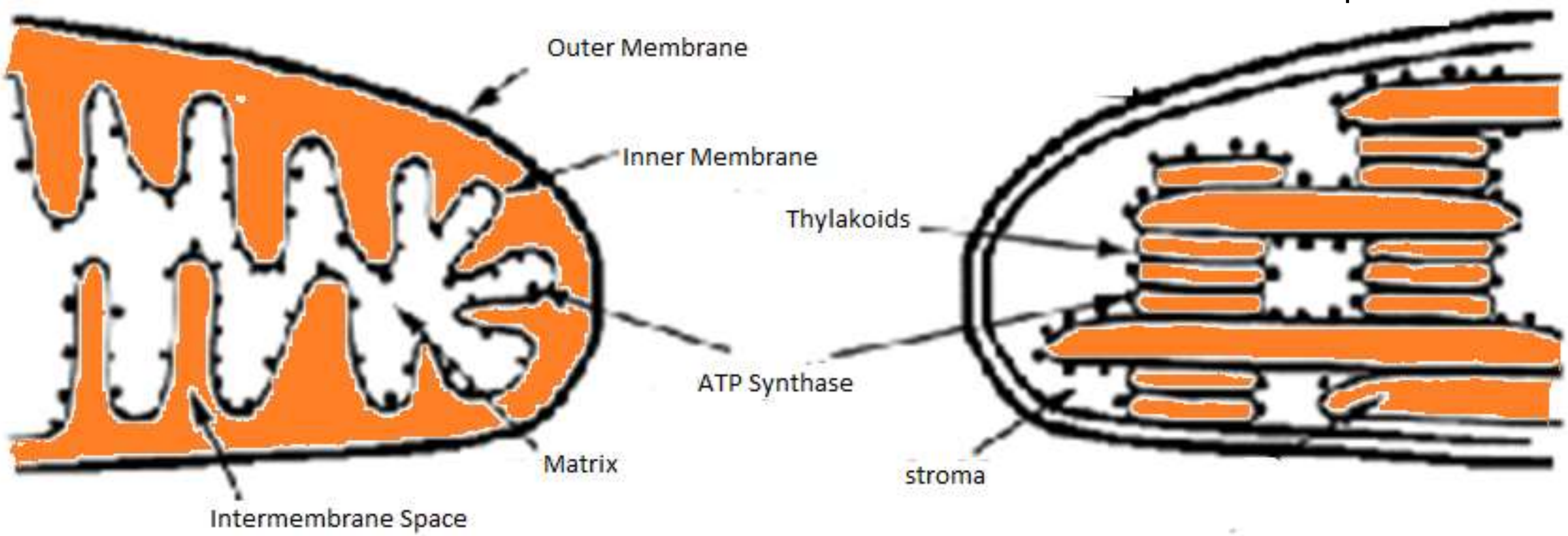
Source: faculty.clintoncc.suny.edu

Chloroplasts vs. Mitochondria

- **The** thylakoids **of chloroplasts have the same function as the** intermembrane space **of the mitochondria: they store hydrogen so that it can turn ATP Synthase and make ATP.**
  - However, the ATP in the chloroplast has only one purpose – to power the assembly of glucose molecules.
  - The chloroplast ATP is not used for any other purpose than this.

Mitochondria

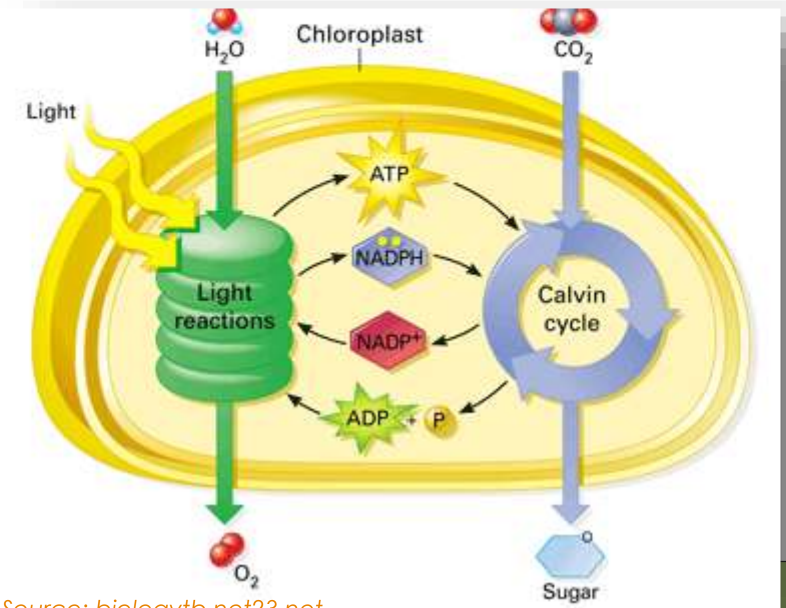
Chloroplast



Source: www.eplantscience.com

Light Reaction & Calvin Cycle

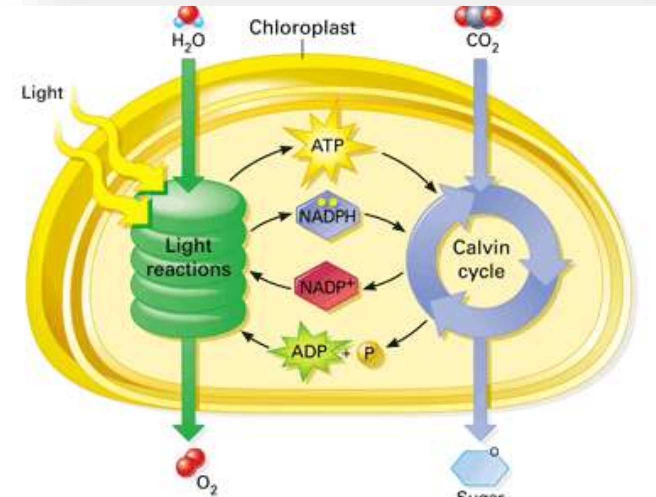
- **Photosynthesis is composed of two processes: the Light Reaction and the Calvin Cycle.**
- **The first process is called the Light Reaction. This process occurs in the thylakoids.**
  - In this process, photons (light energy) are absorbed by the chlorophyll pigments found on the surface of the thylakoid.
    - *This light energy is used to remove the hydrogen from water.*
    - *Hydrogen is then moved inside the thylakoid.*
- **Similar to respiration, the hydrogen protons want to get out of the thylakoid.**
  - The only way for hydrogen to escape is through ATP Synthase that is found on the membrane of the thylakoid.



Source: biologytb.net23.net

Light Reaction

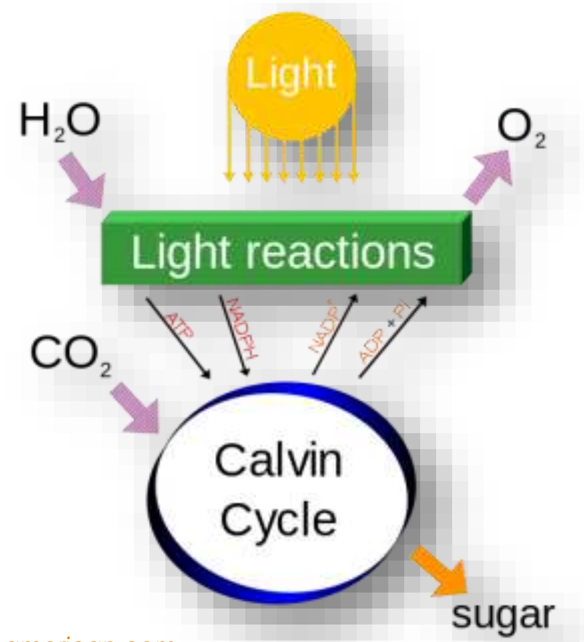
- **As hydrogen moves through ATP Synthase, it turns this molecule.**
  - As ATP Synthase turns, it produces ATP from ADP and P_i.
  - When this happens in a chloroplast, it is called photophosphorylation (which literally means 'phosphorylation by light energy').
- **ATP produced during the Light Reaction will be used to power the assembly of glucose during the Calvin Cycle.**
  - The hydrogen that powered ATP Synthase during photophosphorylation is then added to the glucose molecule during the Calvin Cycle



Source: biologytb.net23.net

Calvin Cycle

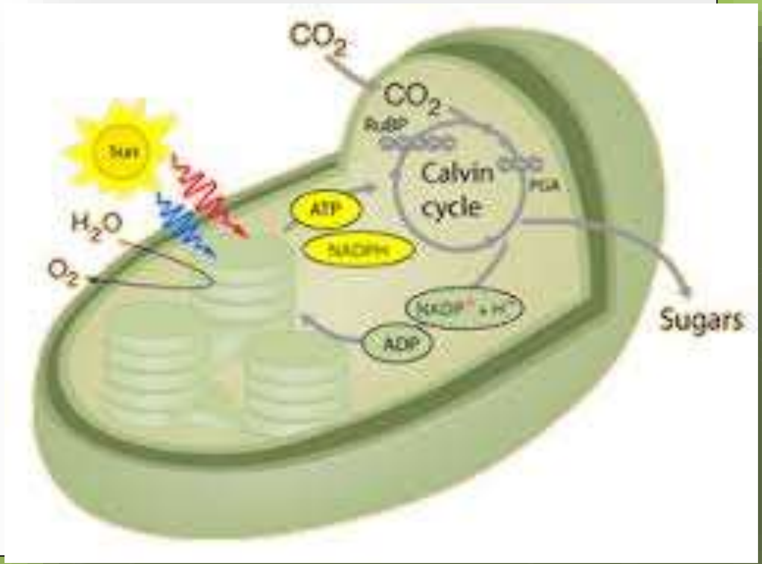
- **The second process is called the <u>Calvin Cycle</u>.**
  - The Calvin Cycle is the process in which glucose is assembled from CO_2 and hydrogen.
  - While the light reaction occurred in the <u>thylakoid</u> (green pancakes), the Calvin Cycle occurs in the <u>stroma</u> (empty space around the thylakoids).
  - Hydrogen used during the Light Reaction will be picked up by a molecule called <u>NADP+</u> after it passes through ATP Synthase.
    - *NADP+ will "take on" hydrogen and electrons.*
    - *These will be combined with carbon dioxide during the Calvin Cycle to produce glucose.*



Source: blogs.scientificamerican.com

Calvin Cycle

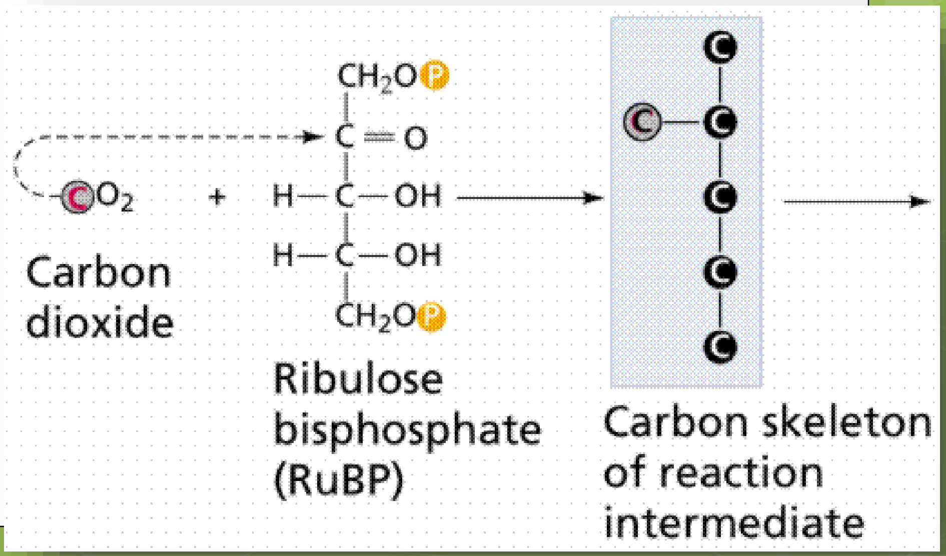
- **As NADP+ and ADP bump into the thylakoid membrane, they will continue to be re-converted into NADPH and ATP by the processes of the Light Reaction.**
  - NADP+ is almost identical to NAD+ from cellular respiration.
  - NADP+ performs the same function as NAD+: the transport of hydrogen.



Source: hyperphysics.phy-astr.gsu.edu

Absorption of CO2

- **The Calvin Cycle begins by absorbing CO_2 from the air.**
  - The carbon and oxygen molecules are separated, and the oxygen is released.
- **Carbon (from carbon dioxide) is then added to a molecule called <u>RuBP</u>.**
  - RuBP is a five carbon molecule that accepts the carbon from CO_2.
    - *"RuBP: the five-carbon cookie"*

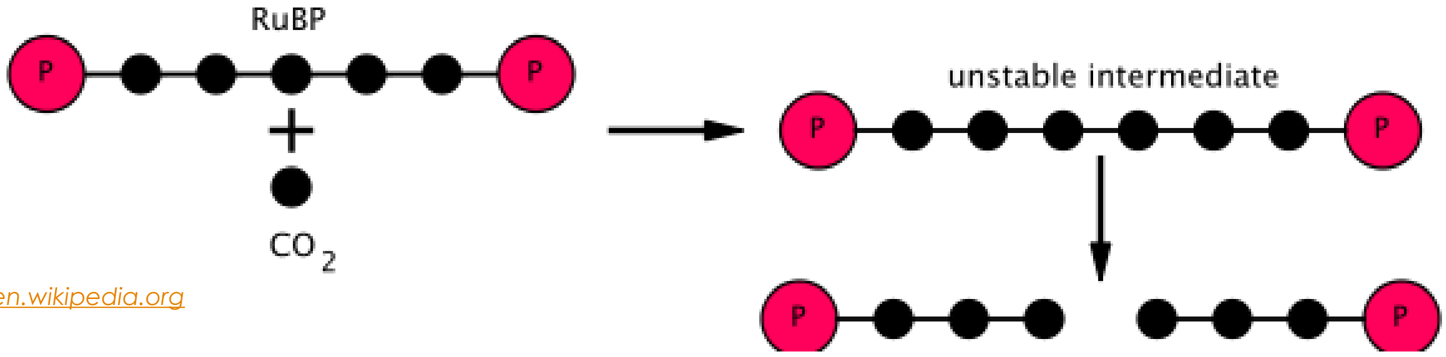


Source: www2.estrellamountain.edu

RuBP and G3P

- **Once hydrogen and a carbon atom are added to RuBP (which now has 6 carbon atoms), this molecule will split in half.**
  - Each 3-carbon molecule is called G3P.
  - G3P is the precursor to all molecules produced by a plant cell.

- **Each of the two G3P's that form has a specific job:**
  - One G3P will be used to re-form RuBP so that it can continue to accept carbon from carbon dioxide.
  - The other G3P will be combined with another G3P to form glucose.
    - *G3P's can also be used to make any other molecule produced by the plant cell.*



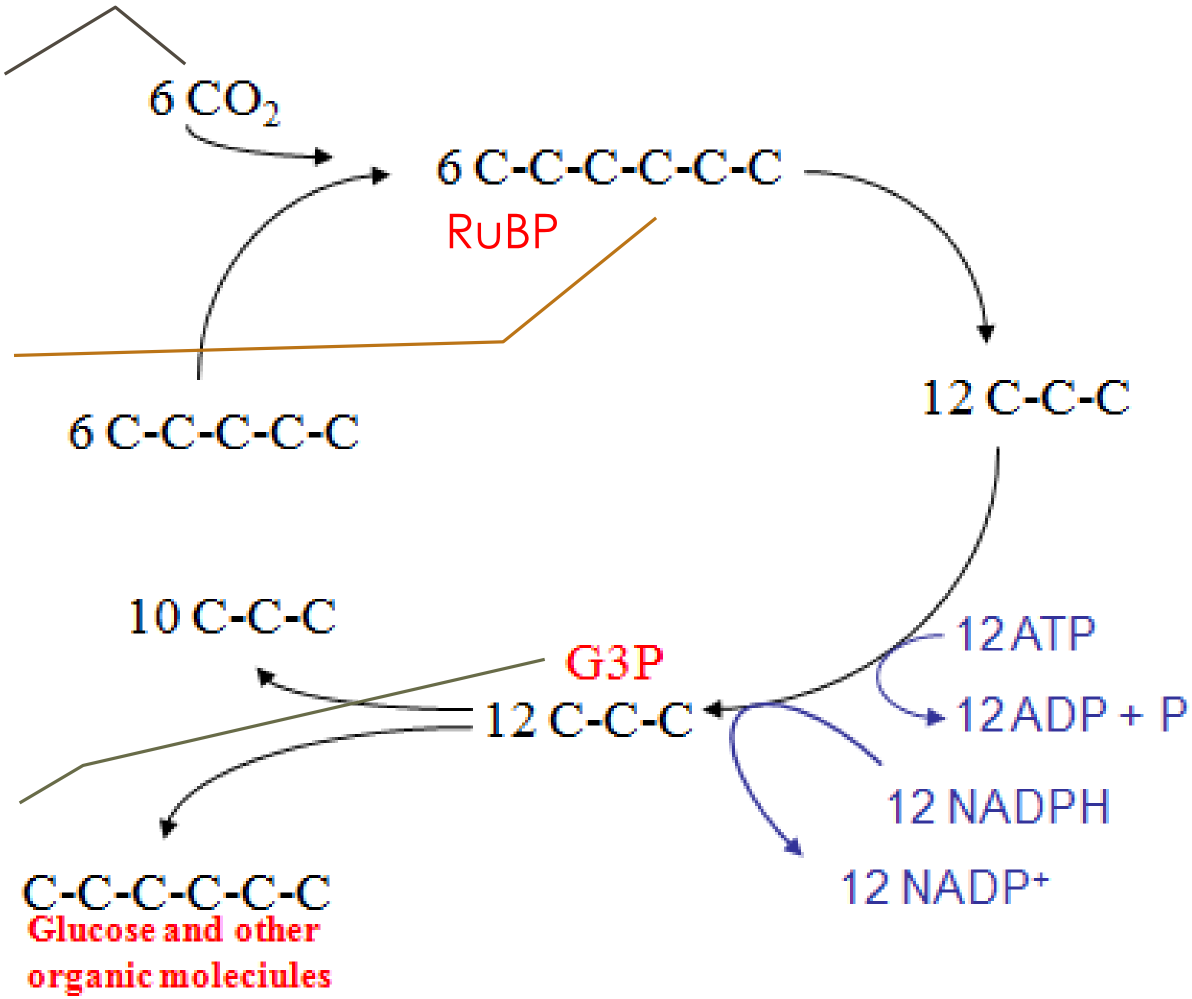
Source: en.wikipedia.org

Calvin Cycle, in detail

1. CO_2 is absorbed. Carbon is separated from oxygen. O_2 is released.

2. The carbon atom separated from CO_2 is combined with 5-carbon RuBP.

3. The 6-carbon molecule is split into two 3-carbon molecules (G3P). One G3P is used to make sugars or other plant molecules. The other is used to re-make RuBP.



Calvin Cycle

The Calvin Cycle is powered by ATP (not shown)

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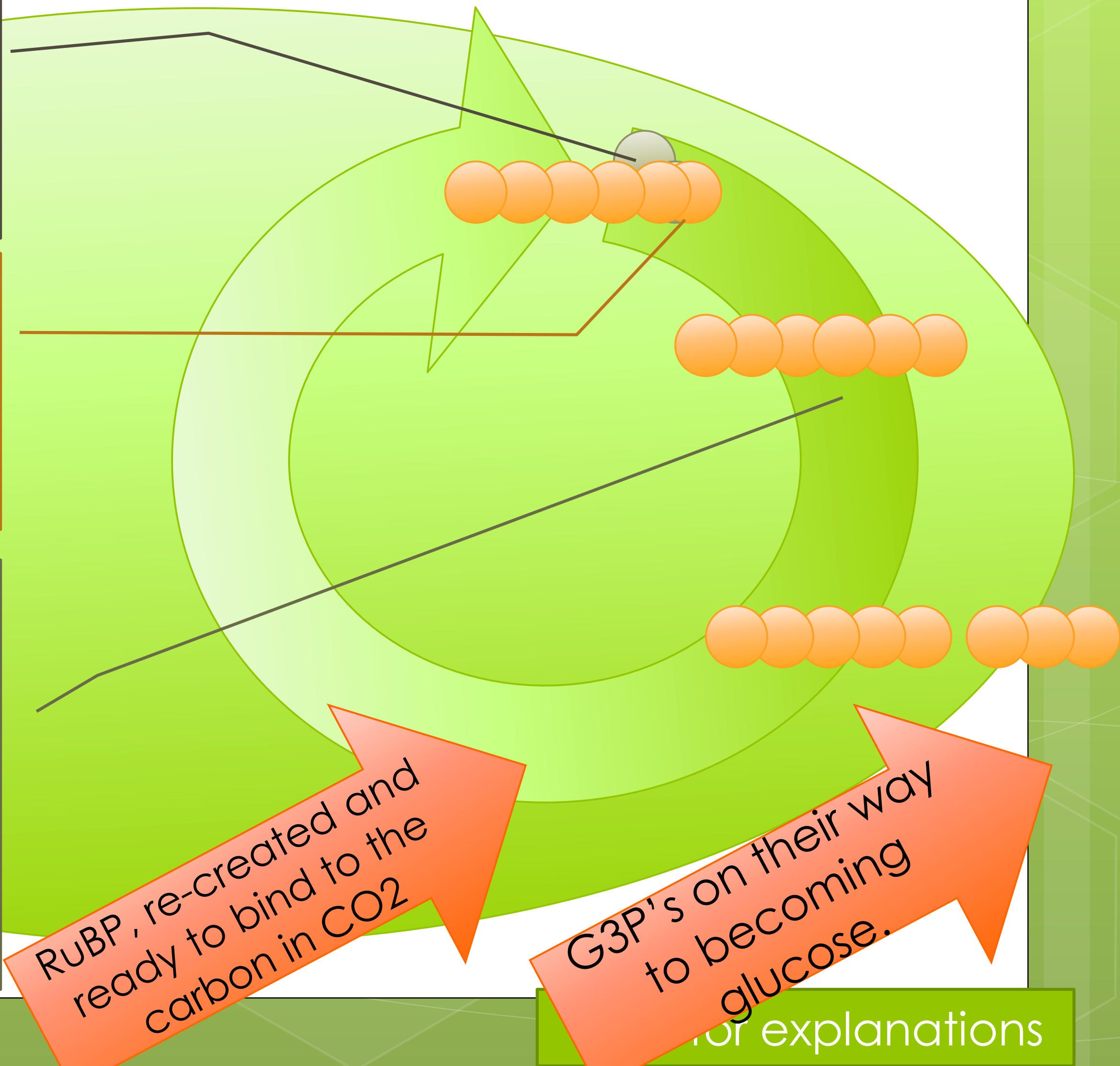


or explanations

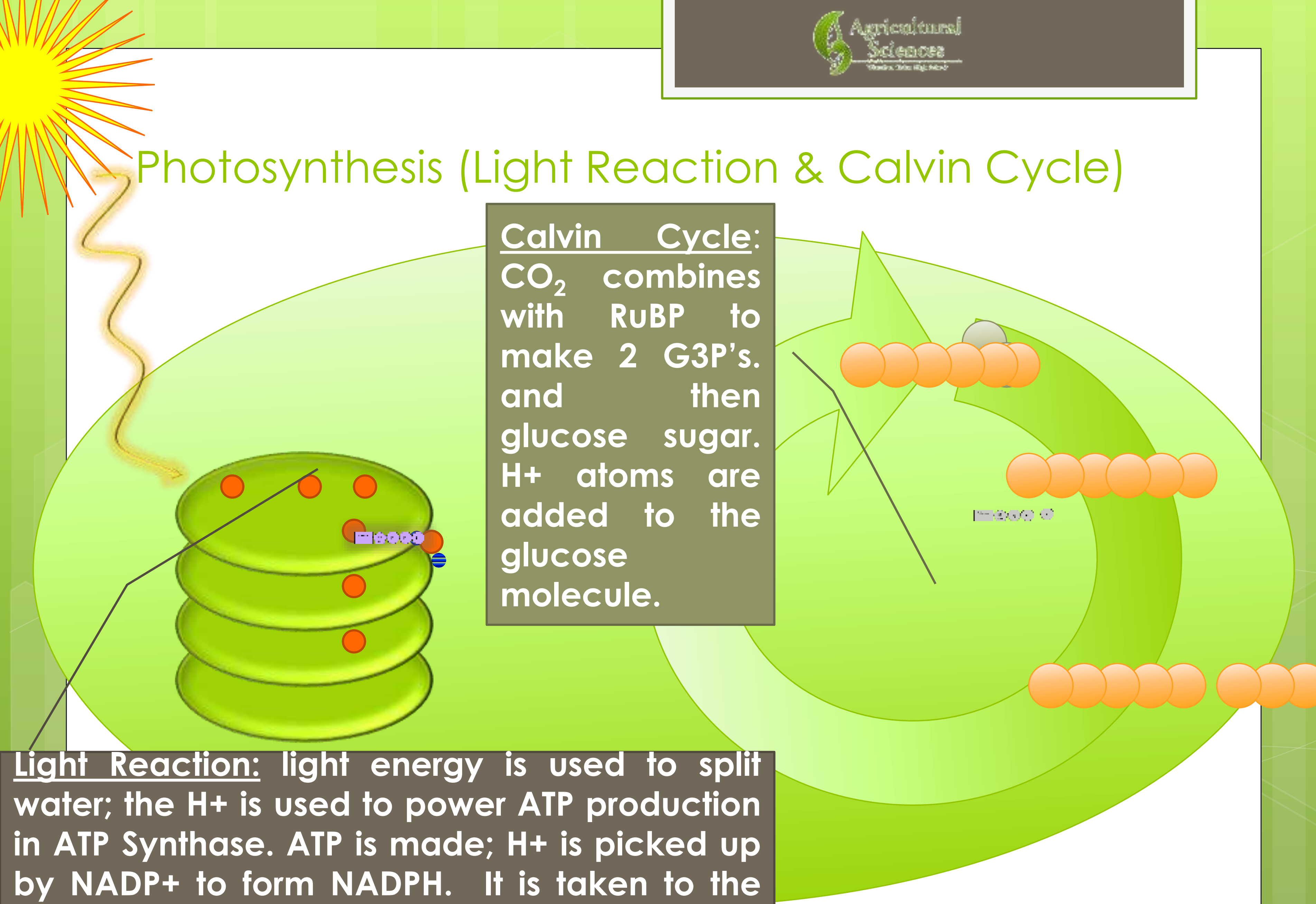
Steps of Photosynthesis

- **Step 1:** water is absorbed by the chloroplast of a plant cell.
- **Step 2:** (light reaction) a water molecule is split into hydrogen and oxygen by the energy of photons.
  - This light energy absorbed by the chlorophyll pigment.
- **Step 3**: (light reaction) hydrogen is moved into the thylakoids by the electron transport system.
- **Step 4**: (light reaction) hydrogen moves through ATP Synthase; as it turns, ATP Synthase produces ATP from ADP and P_i through a process called photophosphorylation.
- **Step 5:** (light reaction) NADP+ picks up hydrogen that has moved through ATP Synthase.

Steps of Photosynthesis

- **Step 6:** (Calvin Cycle) CO_2 is absorbed by the chloroplast organelle.
- **Step 7:** (Calvin Cycle) the carbon atom is removed from CO_2 and added to five-carbon RuBP molecule.
- **Step 8:** (Calvin Cycle) RuBP is split in half to form two G3P molecules.
- **Step 9:** (Calvin Cycle) one G3P is combined with another different G3P to form glucose.
  - *Note: many G3P's are produced simultaneously in the stroma.*
- **Step 10:** (Calvin Cycle) the other G3P bonds with more G3P's to reform RuBP.
  - If RuBP was not reformed, the Calvin Cycle would stop.

Photosynthesis (Light Reaction & Calvin Cycle)



Calvin Cycle: CO_2 combines with RuBP to make 2 G3P's. and then glucose sugar. H+ atoms are added to the glucose molecule.

Light Reaction: light energy is used to split water; the H+ is used to power ATP production in ATP Synthase. ATP is made; H+ is picked up by NADP+ to form NADPH. It is taken to the stroma to be added to CO2 to make glucose.

Applications to Agriculture

- **Photosynthesis and respiration are the key motivations behind many practices in crop production.**
  - Crops need proper **soil moisture** in order to provide a source of hydrogen to power the ATP production needed for photophosphorylation.
  - Crops need **sunlight** in order to power the removal of hydrogen from water during photophosphorylation.
  - Crops need proper **soil aeration** to provide oxygen to their roots (which cannot photosynthesize) so that they can acquire the oxygen they need for cellular respiration.
  - Soils need to have **adequate levels of phosphorus** from fertilizers so that plant cells have access to the phosphate they need to produce ATP (for both respiration and for photosynthesis).