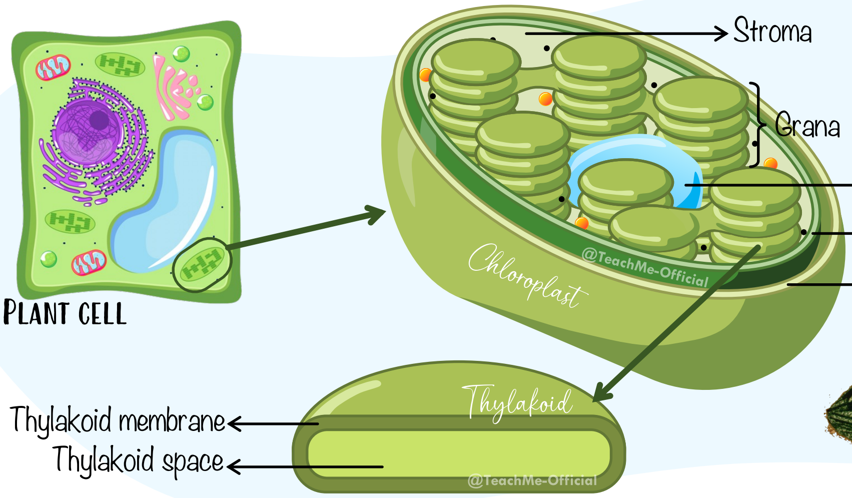
C1.3 Photosynthesis (HL)

PHOTOSYNTHESIS – Synthesis of organic molecules (e.g. GLUCOSE) from inorganic matter (LIGHT ENERGY and CARBON DIOXIDE).

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

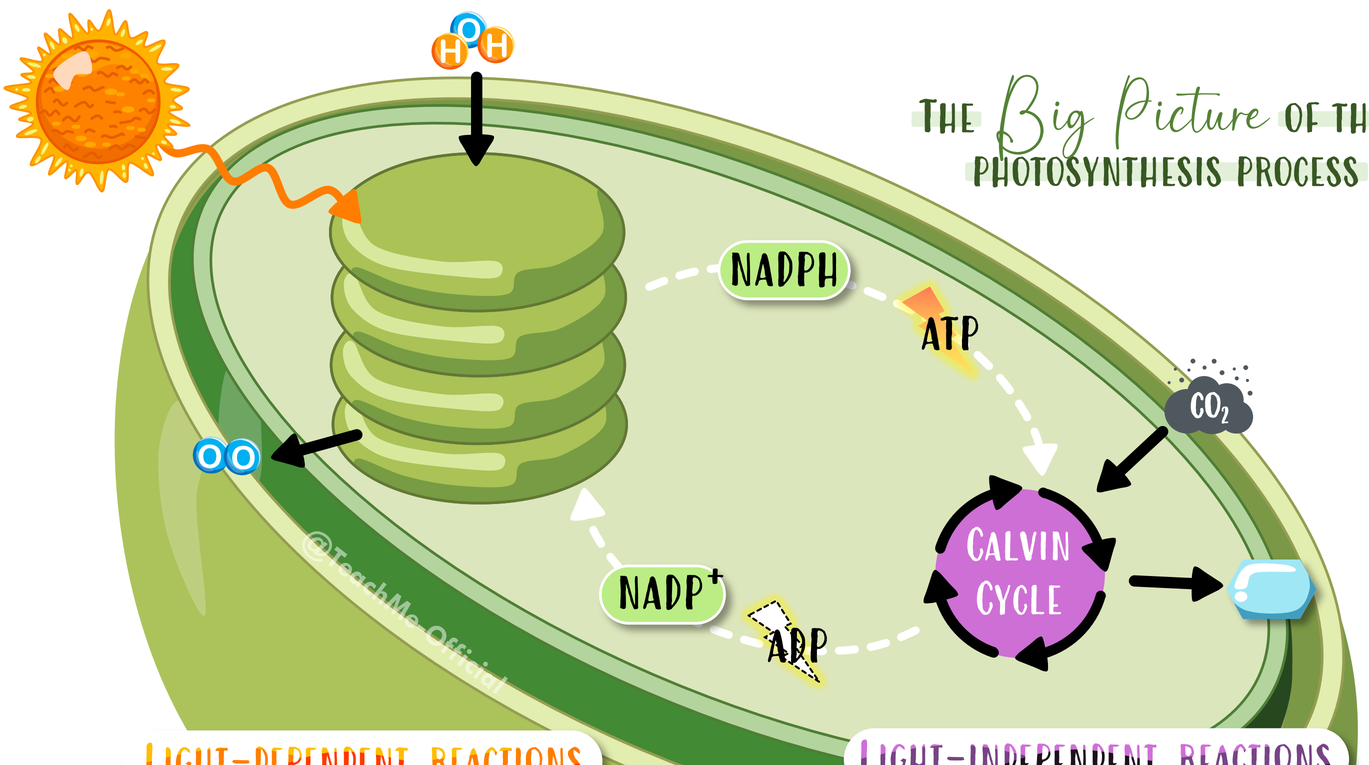
Note the similarity of the PHOTOSYNTHESIS equation with the one of CELLULAR RESPIRATION!

Structures of a Plant Cell



Electron microscope image of a chloroplast

The Big Picture of the Photosynthesis Process



Light-Dependent Reactions

Occurs in the thylakoid membranes of the chloroplasts, where light energy is absorbed by chlorophyll, leading to the production of ATP and NADPH. Water molecules (H_2O) are split, releasing oxygen (O_2) as a byproduct.

Light-Independent Reactions

Occurs in the stroma of chloroplasts. The ATP and NADPH generated in the light-dependent reactions are used to convert CO_2 into GLUCOSE. This cycle does not require light and is also known as the CALVIN CYCLE.

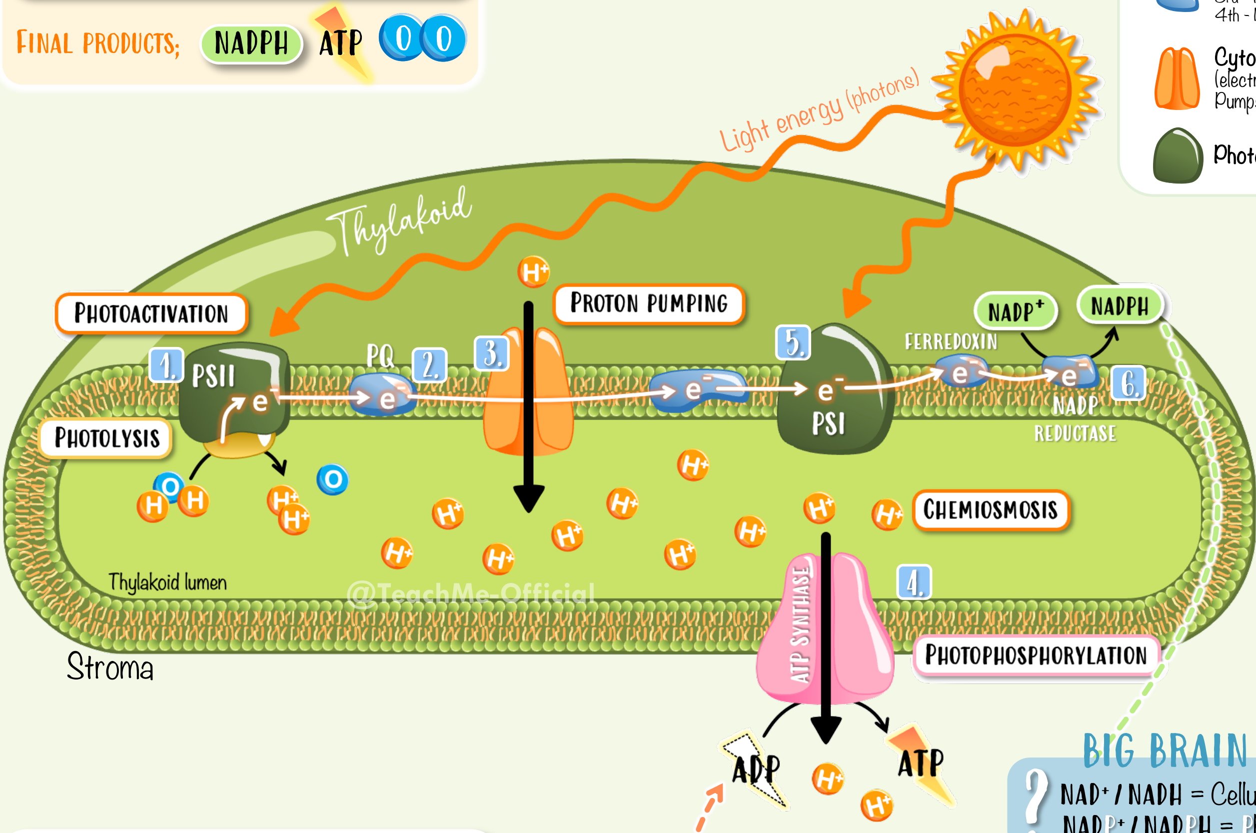
C1.3 Photosynthesis (HL)

Refer to the detailed process in **WORD FORM** on page 3 by following the numbered steps;

KEY
- Photosystem II (P680) — Water splitting enzyme
- Electron carrier proteins — 1st - Plastoquinone (PQ), 3rd - Ferredoxin, 4th - NADP reductase
- Cytochrome complex (electron carrier) — Pumps H⁺ (hydrogen)
- Photosystem I (P700)

Light-dependent reactions

Final products; NADPH ATP O O

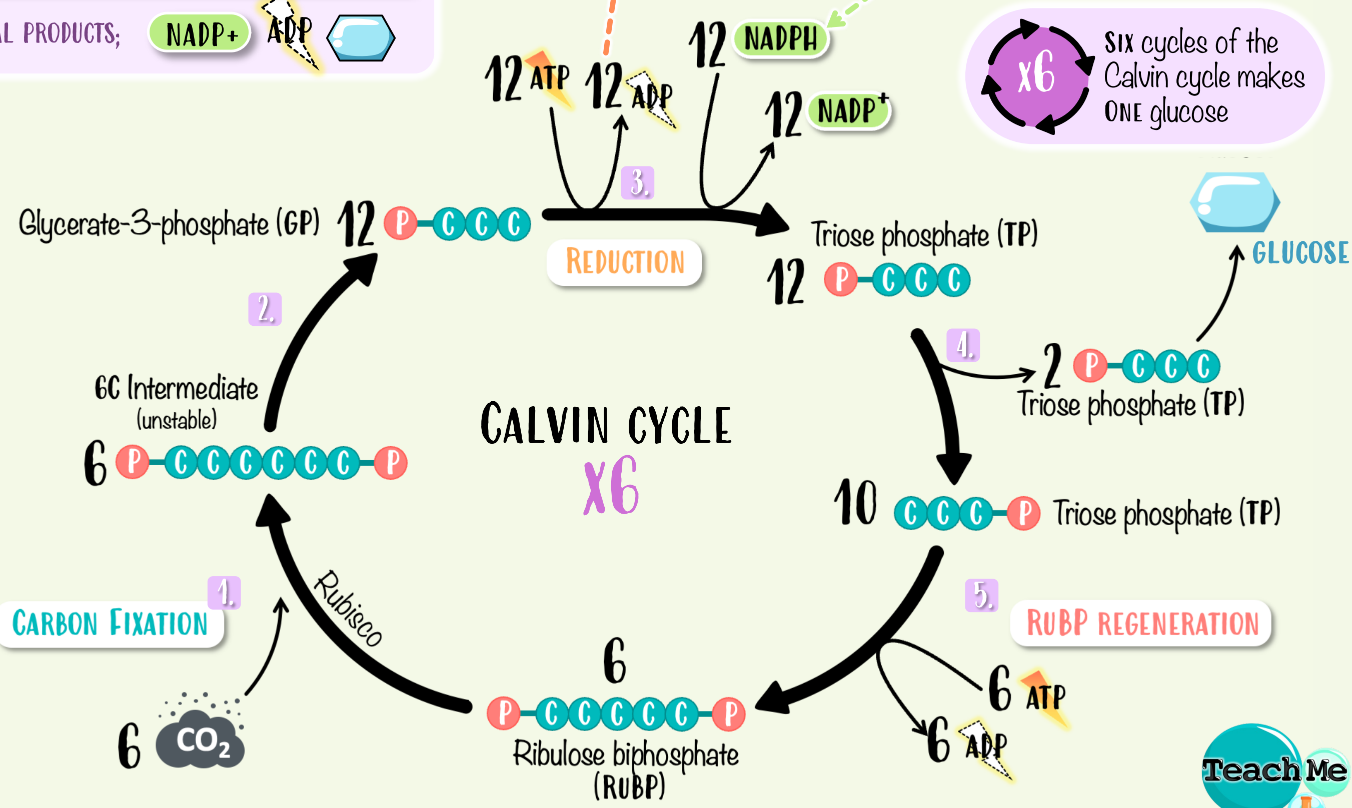


BIG BRAIN TIP!
NAD^+ / NADH = Cellular respiration
$NADP^+$ / NADPH = Photosynthesis

Light-independent reactions

Final products; NADP+ ADP

Six cycles of the Calvin cycle makes ONE glucose (x6)



Watch the video on YouTube to see the analogy we used to remember this Calvin cycle!

Photosynthesis (HL)

LIGHT-DEPENDENT REACTIONS

1. Photosystem II (P680)*
- Photon is absorbed and excites one of the electrons to a higher energy state.
- PHOTOLYSIS occurs to supply electrons to chlorophyl a.
- Oxygen is generated as waste product

2. Plastoquinone (PQ)
- The first electron carrier.
- Carries electron from PSII to the cytochrome complex.

3. Cytochrome complex
- Another electron carrier.
- Electron energy drives CHEMIOSMOSIS (proton pumping) into thylakoid space from the stroma (creating concentration gradient – high inside the thylakoid).

4. ATP Synthase
- High concentration of protons (H+) in the thylakoid space move down their concentration gradient and drive the PHOTOPHOSPHORYLATION of **ADP** into **ATP**.
- **ATP** is sent to the CALVIN CYCLE.

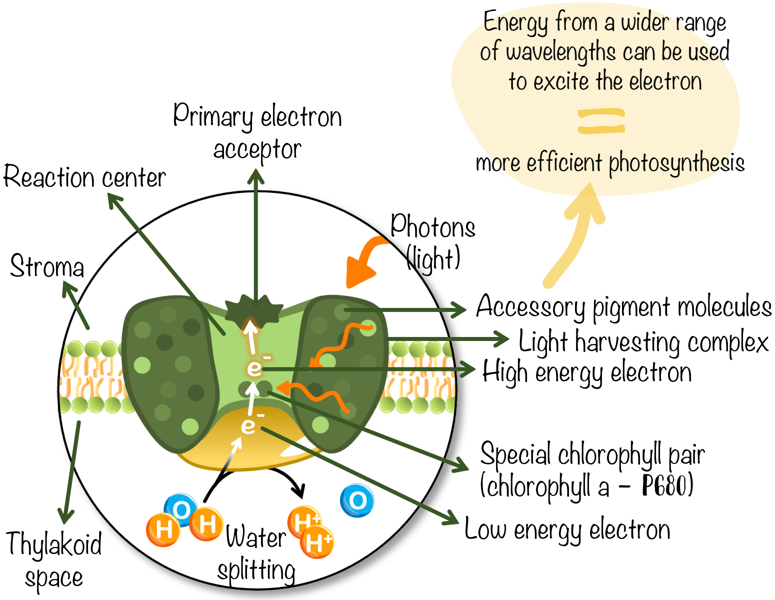
5. Photosystem I (P700)
- Light (photon) is absorbed and excites one of the electrons to a higher energy state.
- Electron from PSII (low energy) fill the void in PSI.

6. Ferredoxin and NADP reductase
- Ferredoxin is an electron carrier from PSI to the **NADP** reductase.
- **NADP** reductase reduces **NADP**$^+$ into **NADPH** using the energy of the electrons and a proton (H^+) from stroma.
- **NADPH** is sent to the CALVIN CYCLE.

* PHOTOSYSTEM II DETAILED MECHANISM

PHOTOSYSTEM II
- LIGHT (photon) is absorbed by pigment molecules (CHLOROPHYLL) in the light harvesting complex of photosystem II.
- Light is transferred to other pigment molecules, until it reaches chlorophyll a (P680) in the REACTION CENTER.
- Photon energy excites one of the electrons to a higher energy state
- This electron is captured by the electron acceptor of reaction center.
- The excited electron passes down the electron transport chain (energy loss).
- PHOTOLYSIS occurs (forming electrons, protons, and oxygen).
- Electrons supply chlorophyll a of the reaction center (replace).

PHOTOSYSTEM I
- Mechanism is similar to photosystem II
- But its chlorophyll best absorbs 700nm (thus called P700) and its electron supply comes from PSII/the electron transport chain (**NOT** photolysis)



LIGHT-INDEPENDENT REACTIONS

1.
- Ribulose biphosphate (RuBP) – a 5-carbon molecule – reacts with carbon dioxide in a process called CARBON FIXATION.
- The process uses the enzyme Rubisco (most abundant enzyme) to create a 6-carbon molecule (unstable) product.

2.
- This unstable molecule breaks down into two 3-carbon molecules: glycerate-3-phosphate (GP).

3.
- ATP and NADPH act on GP and form two other 3-carbon molecules; triose phosphate (TP) – a REDUCTION reaction.

4.
- Some of the TP molecules leave the cycle to eventually turn into glucose, most however continue in the cycle.

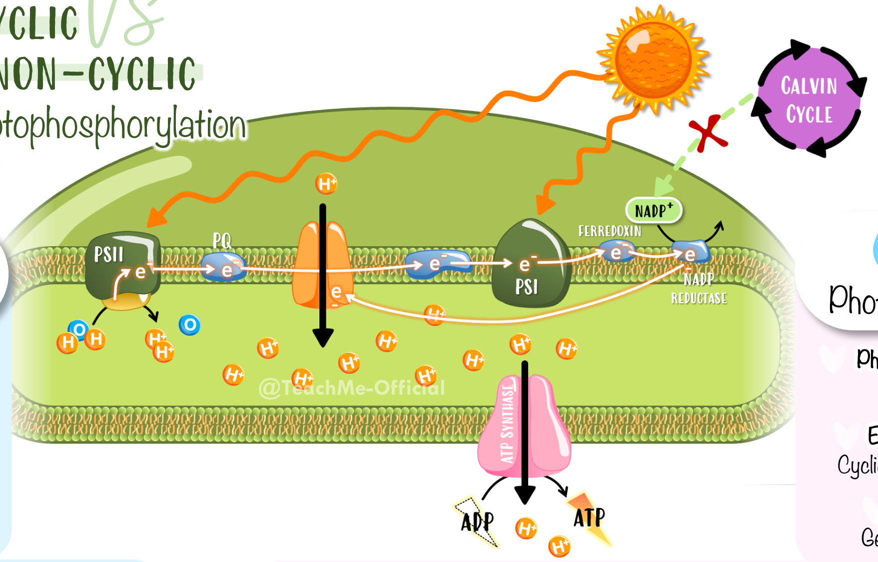
5.
- The remaining TP molecules use **ATP** to reproduce the original molecule; RuBP. This process is called RUBP REGENERATION.

C1.3 Photosynthesis (HL)

Comparaision of light-independent and light-dependent reactions;

Light-Independent Reactions	Light-Dependent Reactions
Does not use light energy	Uses light energy
Occurs in the stroma	Occurs in thylakoids
Use of of ATP and NADPH	**Formation** of ATP and NADPH
Involves the Calvin cycle	Involves electron transport chains and photosystems II and I
Uses carbon dioxide to form glucose molecules	Splits water and releases oxygen as waste

Cyclic VS Non-Cyclic Photophosphorylation



Non-Cyclic Photophosphorylation

Photosystem involved
PSII & PSI

Electron pathway
Linear flow of electrons

Products
Generates ATP, NADPH, & O_2

Cyclic Photophosphorylation

Photosystem involved
PSI only

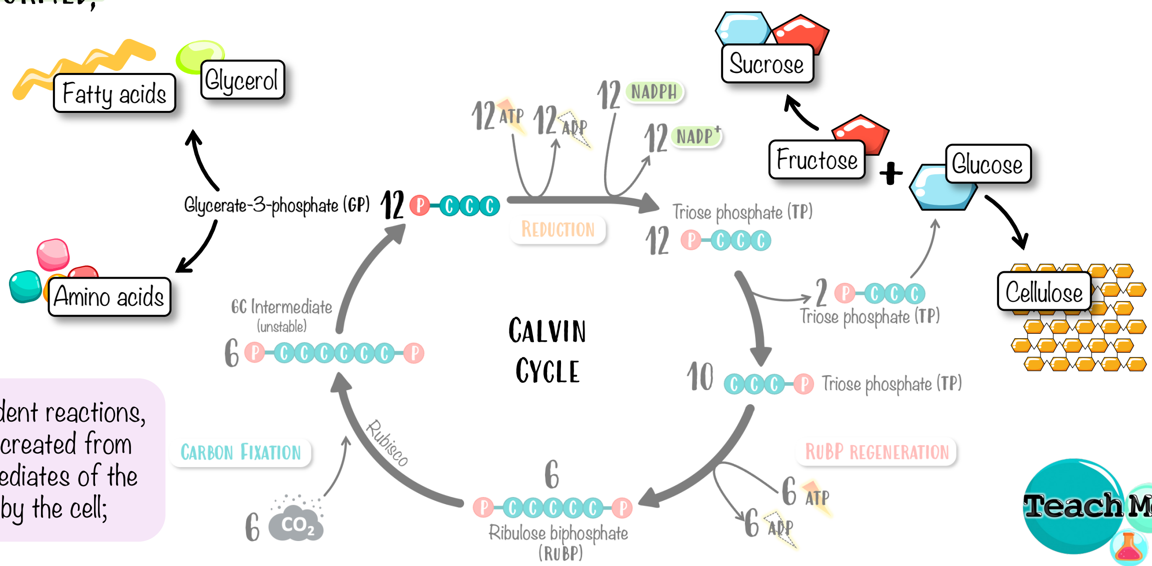
Electron pathway
Cyclical flow of electrons

Products
Generates ATP only

When LIGHT is NOT the limiting reactant, non-cyclic photophosphorylation proceeds from PSII and through PSI leading to the production of OXYGEN, ATP and NADPH.

When the CALVIN CYCLE is the limiting reactant, cyclic photophosphorylation proceeds as the electrons cannot be used to reduce NADP+, they are therefore recycled by the cytochrome complex to pump more H+ into the thylakoid space. Overall, ATP is produced but neither OXYGEN nor NADPH and produced during the cycle.

Other products formed;



During the light-independent reactions, other products can be created from glucose or other intermediates of the Calvin cycle for use by the cell;

C1.3

Photosynthesis (HL)

In sections **C1.2 HL** and **C1.3 HL** you have learned the detailed process of CELLULAR RESPIRATION and PHOTOSYNTHESIS. Both include a crutial step called "**CHEMIOSMOSIS**" (or proton pumping) but have their differences;

RESPIRATION CHEMIOSMOSIS		PHOTOSYNTHESIS CHEMIOSMOSIS
Embedded in the membrane of the cristae (mitochondria)	ETC location	Embedded in the membrane of the thylakoids (chloroplast)
Energy released when electrons are moved from one carrier to the next	Energy Source	Energy released when electrons are moved from one carrier to the next
From the matrix into the intermembrane space (to create proton gradient)	Hydrogen ions pump	From the stroma into the thylakoid space (to create proton gradient)
Hydrogen ions diffuse back into the matrix through the ATP synthase	Hydrogen ions diffusion	Hydrogen ions diffuse back into the stroma through the ATP synthase
Catalyses the phosphorylation of ADP to form ATP	ATP Synthase	Catalyses the photophosphorylation of ADP to form ATP

Teach Me

NOTES

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