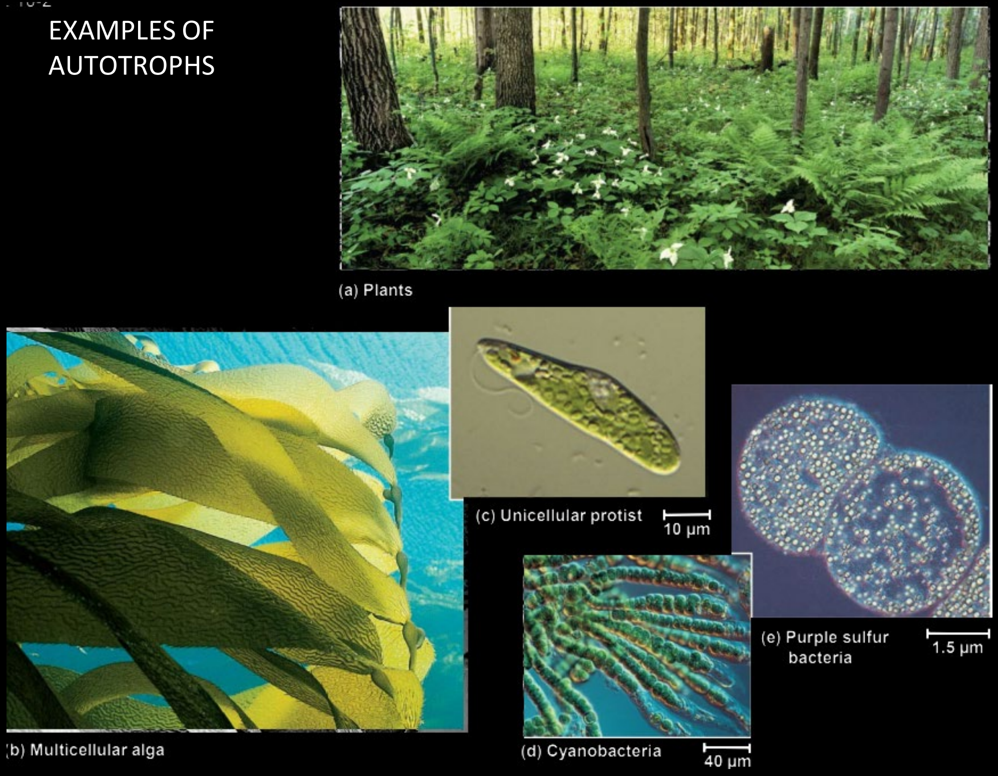
EXAMPLES OF AUTOTROPHS

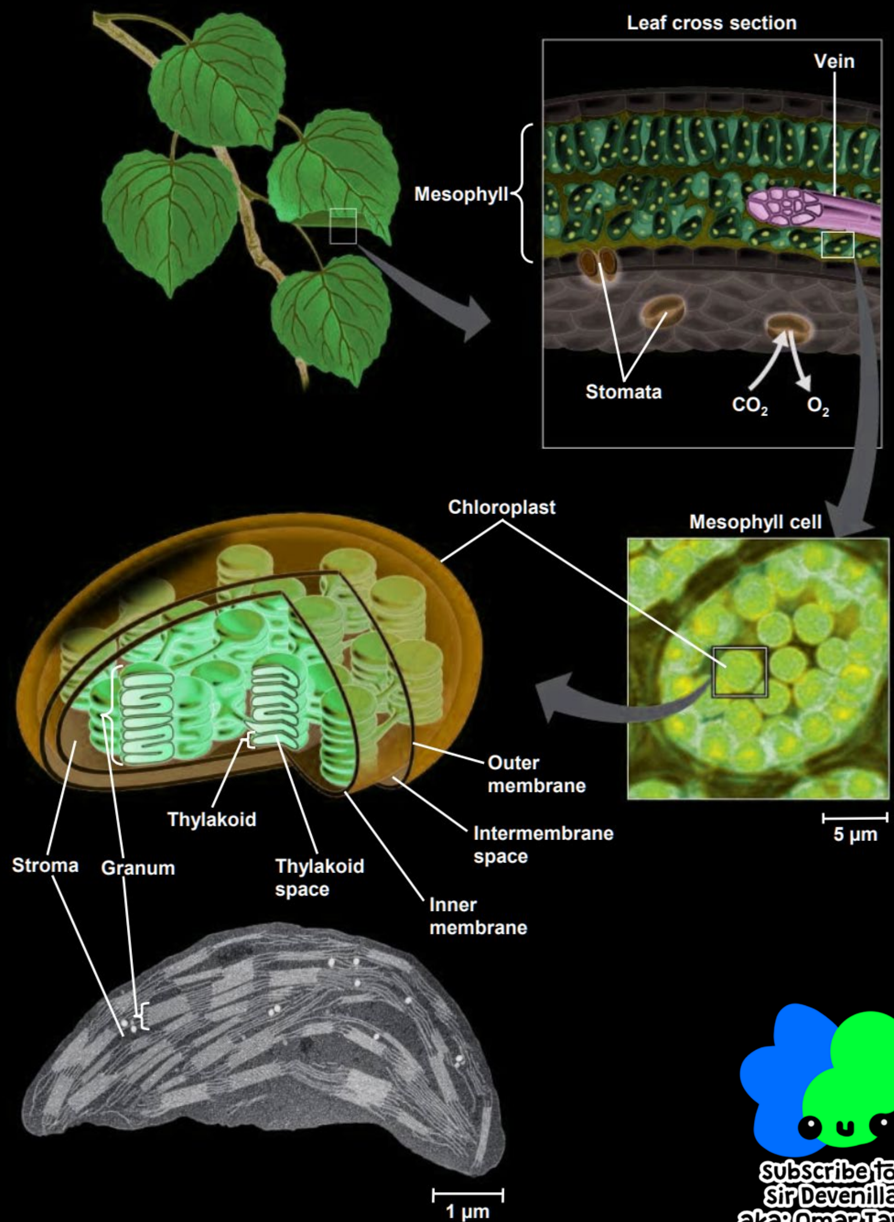


Autotrophs	Heterotrophs
Organisms that sustain themselves without eating anything derived from other organisms, they are the **producers** of the bio sphere, as they take inorganic molecules like CO_2 and other stuff to produce organic molecules	Obtain their organic material from other organisms
EXAMPLE -> plants NOTE: plants are photo-autotrophs, meaning that they take the energy from sunlight and use it in addition to H_2O and CO_2 to create the organic stuff	**EXAMPLE ->** animals, fungi
MECHANISM -> Photosynthesis, the process that converts solar energy to chemical energy with the help of H2O and CO2, the fuel for the entire living world	**Mechanism ->** so consume organic compounds and create wastes such as CO_2 and H_2O

Energy flow diagram shows that each creature tales 90% of the energy given to it and gives off only 10% to the consumer

Chloroplasts (the sites of photosynthesis)

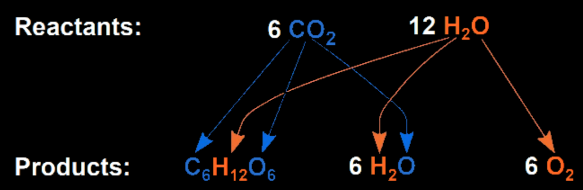
- They are structural organelles that allow the chemical reactions of photosynthesis, they seem to have evolved from a bacteria consuming a photosynthetic bacteria and the consumed bacteria turned into a chloroplast
- Leaves are the major locations of photosynthesis as they have the most chloroplasts, their **green color** is from **chlorophylls** which are green pigments within chloroplasts
- Chloroplasts in the leaf mainly exist in the interior tissue of it or **mesophyll**, a typical mesophyll has 30 – 40 chloroplasts
- Chlorophylls absorb light and they drive the synthetic reaction of photosynthesis
- **Chlorophylls** exist in the membrane of the **thylakoids**, which are connected sacs in the chloroplast, they sometimes are stacked in vertical columns called **granum**
- Chloroplasts have a dense fluid called **stroma**
- The CO_2 and O_2 enter and exit the leaf with the help of microscopic pores called **stomata**



PHOTOSYNTHESIS

Can be summarized into this equation

$6CO_2 + 12H_2O$ + Light energy -> $C_6H_{12}O_6 + 6O_2 + 6H_2O$

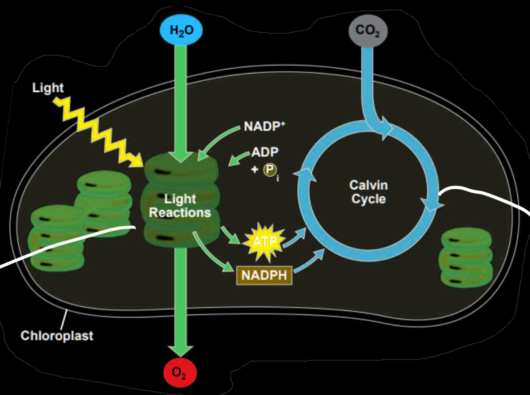


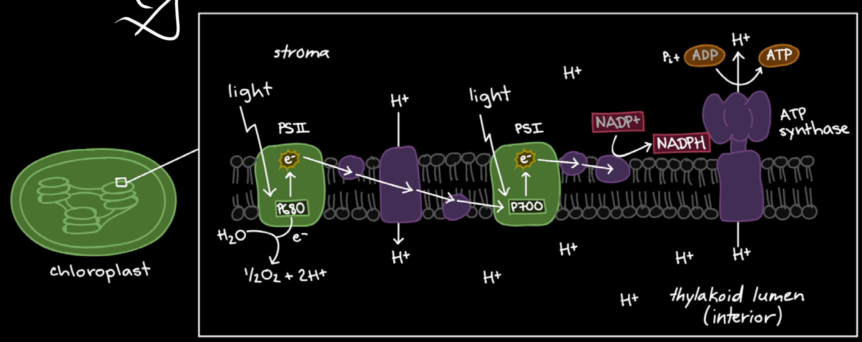
Where the chloroplast takes the water and splits it into hydrogen and oxygen, and takes the electrons of the hydrogen into sugar molecules

It is a **redox** process in which H_2O is oxidized (loses electrons) and CO_2 is reduced (gains electrons)

Photosynthesis consists of **FIRST PART : LIGHT REACTIONS**

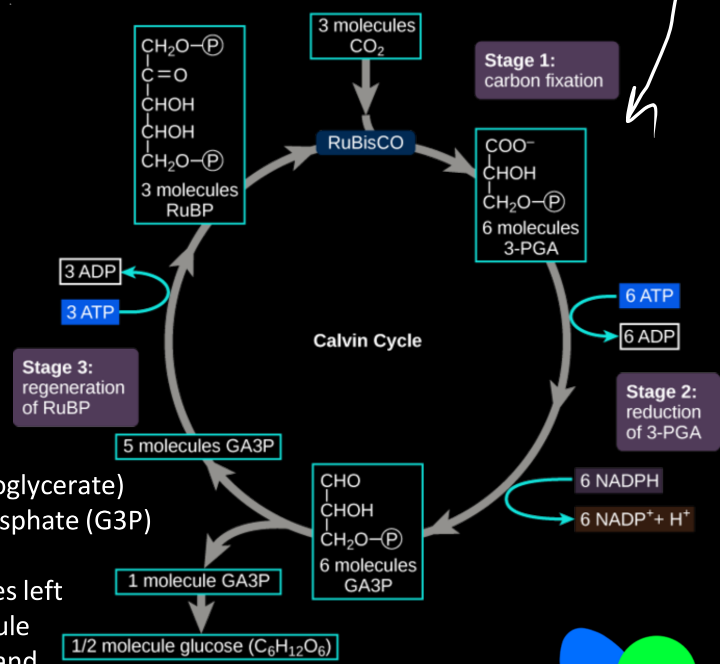
- It happens in the thylakoids (specifically in structures **photosystem I (PSI)** and photosystem II **(PSII)**)and it
    1. Splits the H_2O (Photolysis, happens in PSII)
        - Water molecules are split into
            - Oxygen in the form of O_2
            - Protons in the form of Hydrogen ions (H^+) which travel in the interior of the thylakoid until reaching ATP synthase
            - Electrons which travel in electron transport chains into PSI
        - $2H_2O \rightarrow 4H^+ + 4e^- + O_2$
        - The electrons released are used to replace the electrons in photosystem I (PSI)
    2. Releases O_2 as a byproduct into the atmosphere
    3. Reduce $NADP^+$ to NADPH (happens in PSI)
        - $NADP^+$ (nicotinamide adenine dinucleotide phosphate) is a coenzyme that gets with the electrons in PSI, and then bonds with hydrogen to create NADPH which is used to create the carbohydrates
        - $NADP^+ + 2e^- + H^+ \rightarrow NADPH + H^+$
    4. Generates ATP from ADP by **photophosphorylation**
        1. The flow of electrons in the electron transport chain and the flow of hydrogen ions make the ATP synthase protein make ATP
        2. It makes ATP by reacting ADP (Adenosine Diphosphate) with an Inorganic phosphate group (Pi)
        3. $ADP + Pi + energy \rightarrow ATP$





SECOND PART : CALVIN CYCLE

- It happens in the stroma
    1. **Carbon fixation**
        1. 3 molecules of five-carbon sugar molecule called ribulose-1,5-biphosphate (RuBP) will react with 3 molecules of CO_2
        2. The reaction will be catalyzed using the enzyme RuBisCO (Ribulose-1,5-biphosphate carboxylase/oxygenase)
        3. The reaction will lead to the creation of two molecules of 3-phosphoglycerate 3-PGA
        4. $3CO_2 + 3RuBP \xrightarrow{RuBisCO}$ 2 3-PGA
    2. **Reduction Phase**
        1. 3-PGA is reduced to glyceraldehyde-3-phosphate (G3P) using the ATP and NADPH from light reactions, two processes happen
            1. **Phosphorylation :** each 3-PGA is phosphorylated by ATP into 1,3-BGP (1,3-biphosphoglycerate)
            2. **Reduction :** 1,3-BGP is reduced by NADPH to a 3-carbon sugar glyceraldehyde-3-phosphate (G3P)
            3. The ATP and NADPH go back to ADP and $NADP^+$ and they go back to light reactions
    3. **Glucose Synthesis :** G3P molecules are used to synthesize glucose ($C_6H_{12}O_6$) with some G3P molecules left
       hint: for every 3 CO_2 molecules, 1 G3P molecule is converted to a glucose molecule
    4. **Regeneration of RuBP :** some of the G3P molecules are used to regenerate RuBP using the ATP left, and the reaction starts again



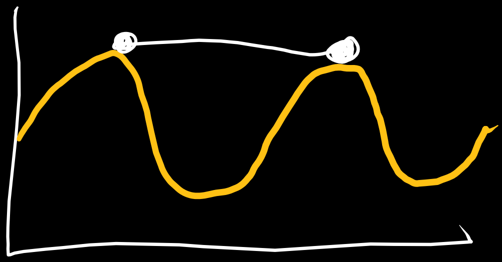
So overall, light reactions use the light to split water and use the ions and hydrogens to get ATP and NADPH and throw away oxygen, those ATP and NADPH are used to turn RuBP -> 3-PGA -> 1,3-BGP -> 3GP -> Glucose

-> RuBP (continues cycle)

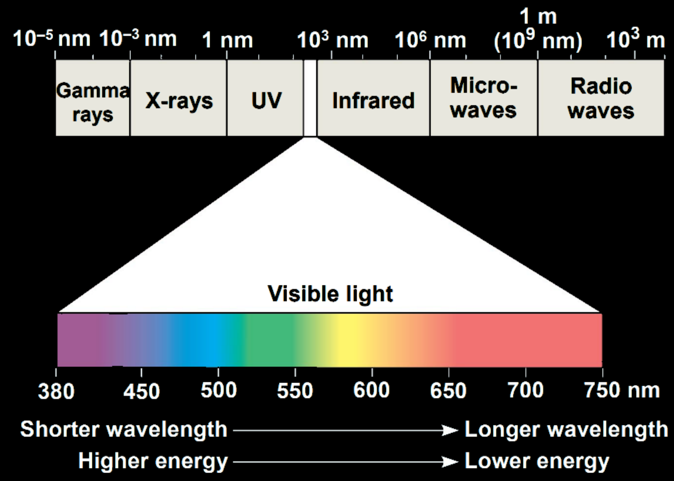
NOTE : GA3P is the same as G3P

SUNLIGHT

A form of electromagnetic energy, it travels in rhythmic waves
Wavelength is the distance between the crests of waves



The electromagnetic spectrum is the entire range of electro magnetic energy



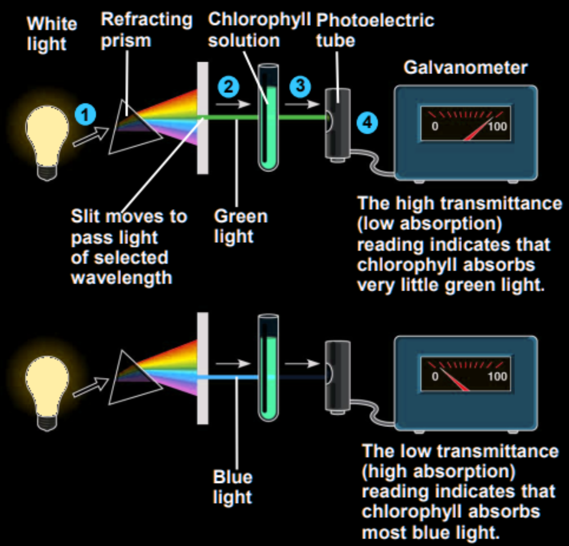
visible light is only a small range, but it includes the needed wavelengths to drive photosynthesis "and produce the colors We cans see"

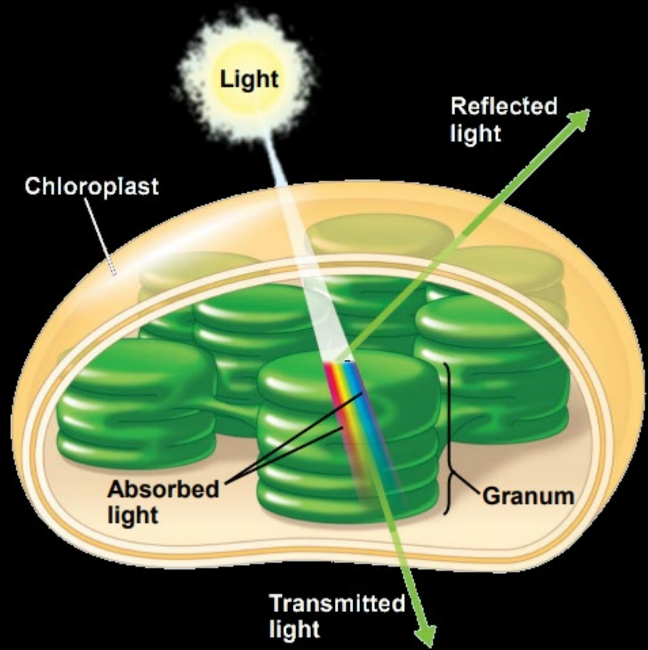
Photosynthesis pigments (the light receptors)

They are substances that absorb visible light, different pigments absorb different wavelengths and reflect wavelengths that they can't absorb

A **spectrophotometer** measures a pigment's ability to absorb various wavelengths, it works by

- sending light through pigments
- measures the fraction of light transmitted at each wavelengtl



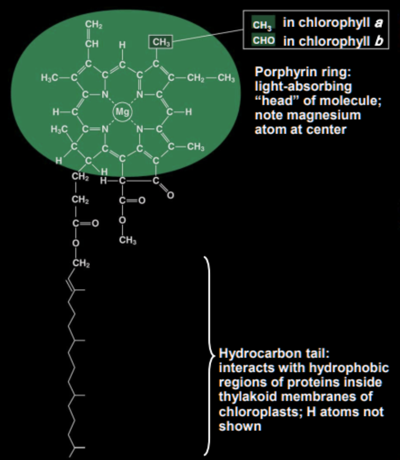


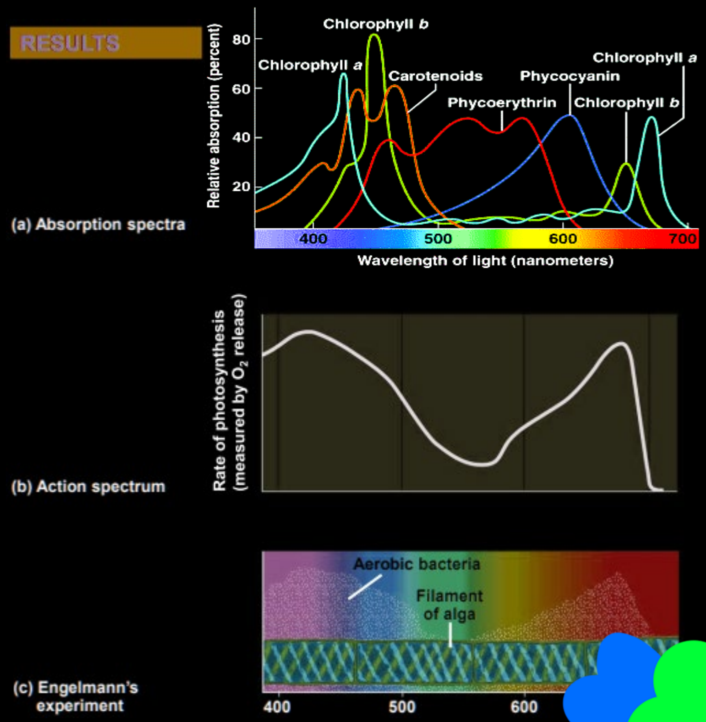
Absorption spectrum
Graph plotting a pigment's light absorption versus wavelength

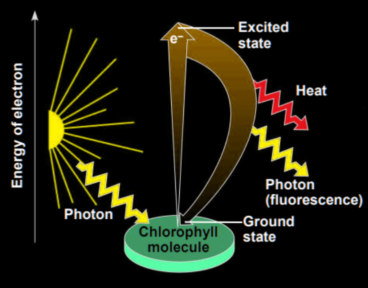
Action spectrum
Profiles the relative effectiveness photosynthesis in different wavelenths

OBSERVATIONS

- Chlorophyll a absorbs extreme violet and extreme red colors, so it reflects and appears light cyan
- Chlorophyll b absorbs blue and orange and red light so it appears **greens**
- Carotenoids absorb green, blue, violet light, so they appear **orange**
- Phycoerythrin absorb yellow, green, blue, and violet light, so it appears **red**
- Phycocyanin absorbs red, yellow, green, and light blue light, so it appears **blue**
- The action spectrum was first demonstrated in 1883 by Theodor W. Engelmann where he exposed alga to different wavelengths of light
- He measured the amount of oxygen coming from the alga's photosynthesis (photosynthesis rate) based on the growth rate of aerobic bacteria
- The most efficient colors to absorb for photosynthesis are violet, blue, orange, red
- **Chlorophyll a** is the main photosynthetic pigment
- **Chlorophyll b** is an accessory pigment and it broadens the spectrum used for photosynthesis
- **Carotenoids** absorb excessive light that would damage the plant
- when a pigment is hit by light, it goes into excited state, the excited electrons go back to ground state releasing a photon, creating an afterglow called **fluorescence,**
- illuminating an isolated solution of chlorophyll will fluoresce

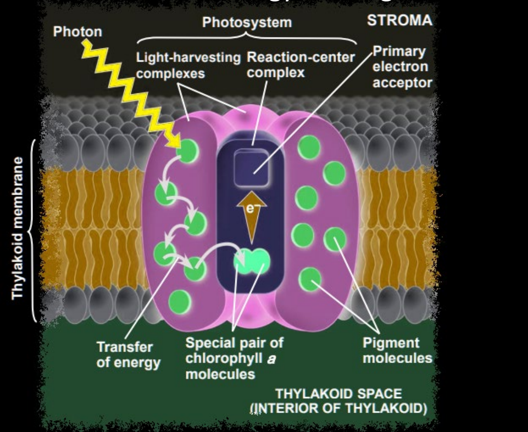






PHOTOSYSTEM

A reaction-center complex (a protein complex) surrounded by light-harversting complexes (pigments surrounding the proteins) which funnel the energy from light to the reaction-center proteins



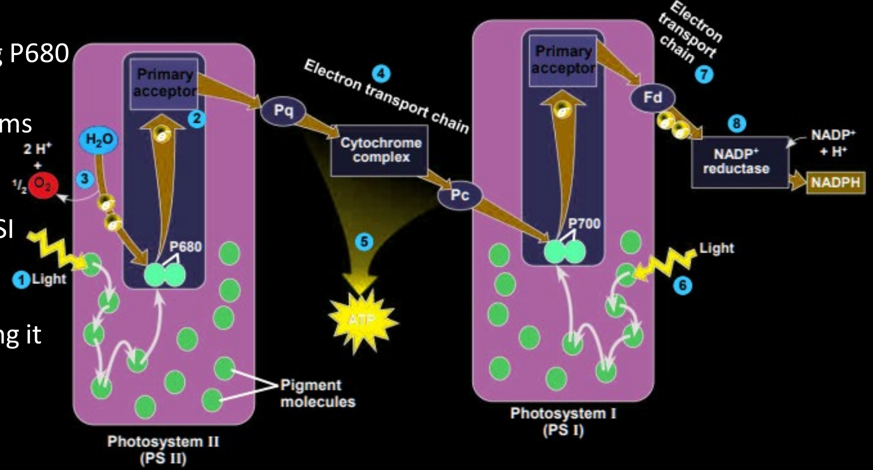
primary electron acceptors in the reaction center accept the excited electrons from chlorophyll a, which transfers the solar energy to the rest of the light reactions

There are two photosystems in the thylakoid membrane

- **PSII** functions first and is the best at absorbing wavelengths of 680nm (reddish orange) and its reaction center is called **P680**
- **PSI** functions later and is best at absorbing wavelengths of 700nm (red) and its reaction center is **P700**

During light reactions, there are two paths for the electron flow

- **Linear** -> the primary pathway that involves both systems and produces ATP & NADPH using light energy it goes like this
    1. A photon hits a pigment and the energy passes the other pigment molecules until it excites P680
    2. It transfers an electron from P680 to the primary electron acceptor of PSII turning P680 into P680⁺ which is a very strong oxidizing agent
    3. H2O is split by enzymes and the electrons are transported from the hydrogen atoms to P680⁺, reducing it into P680
    4. O2 is released
    5. Electrons go in the electron transport chain to the primary electron acceptor of PSI
    6. The energy released drives the creation of a proton gradient, leading to diffusion of H^+ across the membrane leading to ATP synthesis
    7. The energy excites the P700 in PSI, which loses an electron to the acceptor, making it into P700⁺ which accepts an electron passed down from PSII
    8. Each electron goes down the transport chain to the acceptor of PSI to the protein **ferredoxin (Fd)**
    9. The electrons are then transferred to NADP⁺ turning it into NADPH



- **Cyclic ->** uses PSI only, and produces just ATP, it generates a surplus of ATP, satisfying the higher demands of the galvanic cycle it is similar to the linear electron flow but
    - No electrons travel to NADP⁺ to turn it into NADPH, they go to PSI to just generate ATP

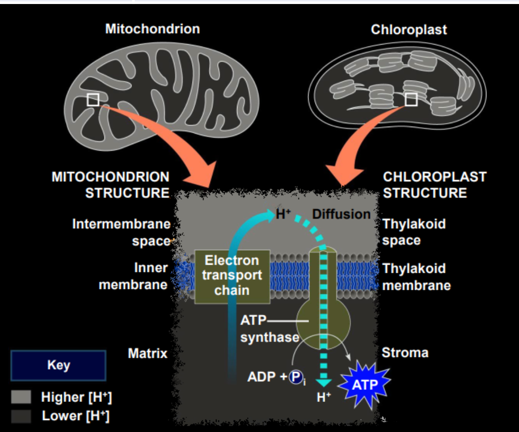
  it is the only process in organism with PSI but not PSII such as purple sulfur bacteria

  it is believed to have evolved before linear flow, and it protects the cell from light induced damage

COMPARISON OF CHEMIOSMOSIS IN MITOCHONDRIA AND CHLOROPLASTS

Both generate ATP with chemiosmosis (with chemical reactions) but in different ways

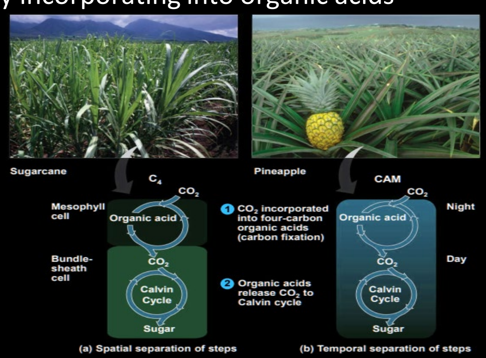
MITOCHONDRIA	CHLOROPLAST
transfers energy from food to ATP	transfers energy from light to ATP
Protons are pumped into the intermembrane space and drive ATP synthesis as they diffuse back into the mitochondrial matrix (other protons)	Protons are pumped into the thylakoid space and drive ATP synthesis as they diffuse back into the stroma

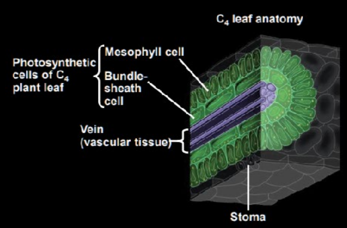


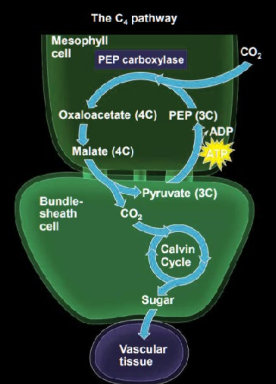
HOW PLANTS COVER CARBON SHORTAGES

Dehydration is a problem for plants, so it requires a tradeoff with other metabolic processes, hot dry plants close their stomata to keep the water in, but this leads to a carbon shortage and O_2 buildup, so plants have created ways to fix this like

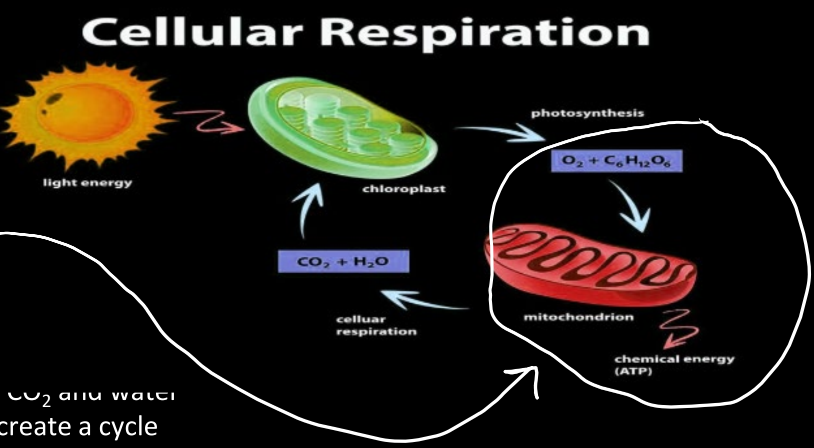
- **Photorespiration** is the process where plants' RuBisCO enzyme will use oxygen instead of CO_2 in the Calvin cycle, which will lead to the production of CO_2 without any sugars or ATP
- **C3 Plants** will initiate carbon fixation via rubisco forming a three-carbon compound
- **C4 Plnats** will minimize the cost of photorespiration by store the CO_2 Into four-carbon compounds in the mesophyll cells, which requires the enzyme **PEP carboxylase**
- Some plants will include succulents and use crassulacean acid metabolism (CAM) to fix carbon by incorporating into organic acids







The process by which cells break down glucose using oxygen to produce energy in the form of ATP, and releases CO_2 and H_2O as byproduct of the chemical burning reaction



it all happens in this part

Cellular respiration in plants is but the plants gets its glucose from photosynthesis, then the CO_2 and water are used in photosynthesis to create a cycle

Breathing	Respiration
Breathing involves the process of inhaling and exhaling the air in and out of lungs. While breathing, oxygen is inhaled and carbon dioxide is exhaled.	Respiration is the process of the breaking down the glucose to produce energy which is used by cells to carry out the cellular function.
Breathing takes place in lungs.	Respiration takes place in cells.
Breathing is a physical voluntary process.	Respiration is a chemical involuntary process.
No energy is produced during the process.	Energy is released in the form of ATP.
It is an extracellular process, as it occurs outside cells.	It is an intracellular process, as it occurs inside cells.
No enzymes are used during the process.	A large number of enzymes are used during the process.
Breathing takes places through respiratory organs like lungs, nose, etc.	Respiration takes place in cells and cell organelles like mitochondria, etc.

MITOCHONDRIA

It is the powerhouse of the cell and where cellular respiration mainly takes apart

Cellular respiration consist of 3 parts

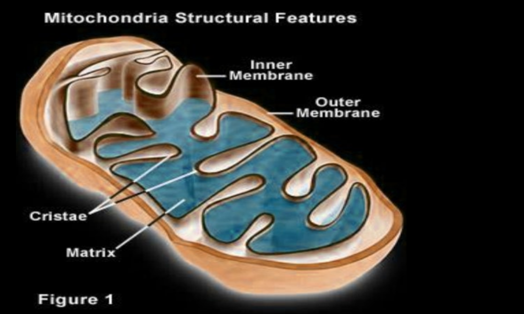
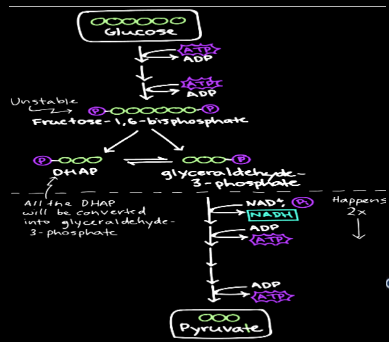


Figure 1

Glycolysis is the first stage at takes place in the cytoplasm, it breaks down glucose into 2 molecules of **pyruvate** (3C compound), it produces a net gain of two ATP molecules (because of breaking bonds) and 2 molecules of NADH (cellular respiration's version of NADPH)

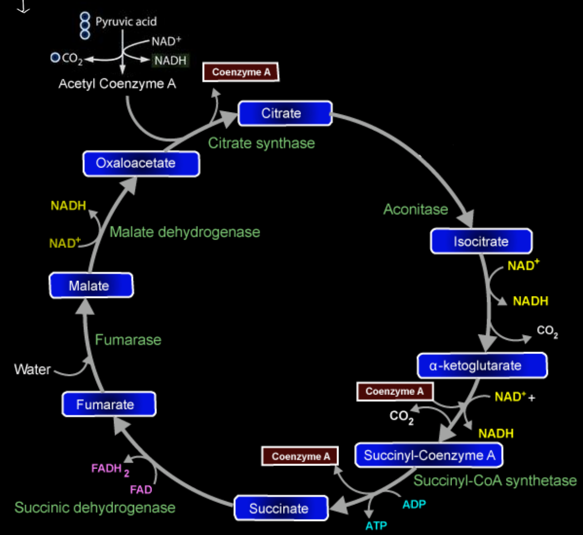
- Glucose + $2NAD^+$ + 2ADP + 2Pi → 2Pyruvate +2NADH +2ATP +$2H^+$ + 2H2O
    1. two ATP molecules help turn glucose into **fructose-1,6-biphosphate (unstable)**
    2. This step happens two times
        1. It splits into DHAP and glyceraldehyde-3-phosphate, a DHAPmolecule becoming a glyceraldehyde-3-phosphate molecule
        2. glyceraldehyde-3-phosphate turns two ADP molecules to ATP and a NAD^+ into NADH, then turning into **pyruvate**
- So we started with 1 glucose and 2 ATP molecules and got 4 ATP molecules, 2NADH, and 2 pyruvate molecules



Krebs Cycle is a series of biochemical reactions that take place in the mitochondria, it oxidizes acetyl-CoA derived from carbs, fats, and proteins to create ATP, NADH, and $FADH_2$ (something similar to NADPH and NADH), it is also called "citric acid cycle"

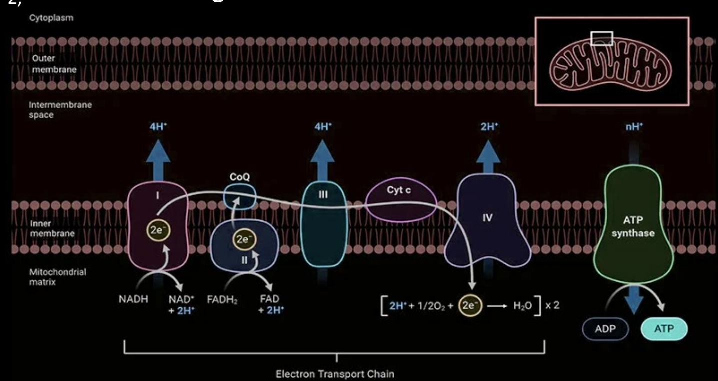
1. **Acetyl-CoA Formation** : acetyl coenzyme A is a 2 carbon molecule, it is generated when coenzyme A interacts with pyruvate, generating acetyl CoA and CO_2 as a byproduct, it also turns NAD^+ into NADH, and returns back CoA for more reactions
2. **Citrate (citric acid) formation :** acetyl coenzyme reacts with Oxaloacetate (OAA) to create citric acid
3. **Isomerization :** citric acid turns into **isocitrate** by the enzyme aconitase, which turns NAD^+ into NADH and produces CO_2 as a byproduct
4. **A-ketoglutarate formation :** isocitrate is then oxidized to form a-ketoglutarate, forming CO_2 as byproduct and turning NAD^+ into NADH
5. **Succinyl-CoA formation :** a-ketoglutarate is oxidized into succinyl-CoA using CoA, forming CO_2 as byproduct and turning NAD^+ into NADH
6. **Succinate Formation** : succinyl CoA is converted Into succinate by succinyl CoA synthase, which transfers a phosphate group from the succinyl CoA to ADP, generating ATP, and returning the CoA
7. **Fumarate formation :** succinate is reacted with enzyme **succinic dehydrogenase** to create Fumarate with the help of H2O, it also turns FAD to $FADH_2$
8. **Malate formation :** Fumarate is hydrated by H2O and fumarase/fumarate hydratase to become Malate
9. **Oxaloacetate regeneration :** malate is oxidized by malate dehydrogenase to become oxaloacetate, and also turning NAD^+ into NADH

THEN THE CYCLE CONTINUES, we entered with $3NAD^+$, 1 ADP, 1FAD, and got 3NADH, 1 ATP, 1 $FADH_2$, and $2CO_2$, and 1 GTP "we got it in the succinate formation phase and it is similar to ATP but instead of Adenine it is Guanosine"



Electron transport chain NADH & $FADH_2$ is oxidized into NAD^+ and FAD, and the electrons travel in the chain and the hydrogen ions travel in matrix, some of the hydrogen ions go into the intermembrane space through the proteins I, III, IV

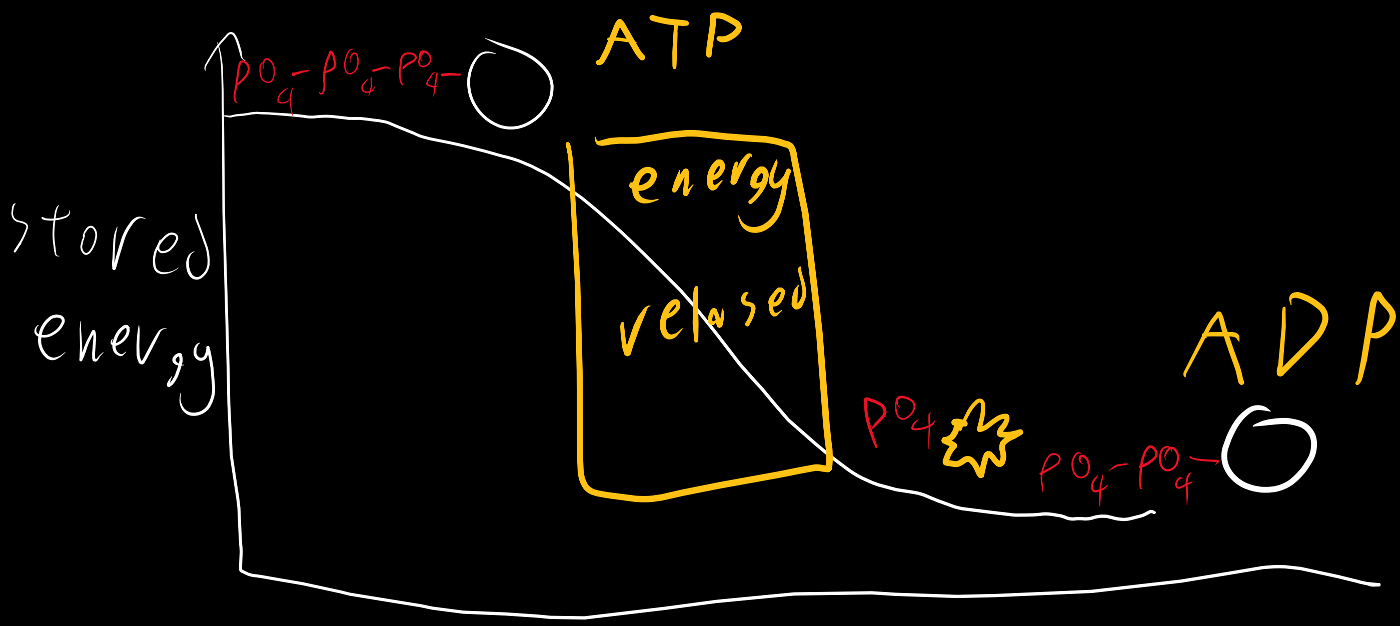
the electrons and the hydrogen ions in the matrix react with oxygen to create H_2O, then the hydrogen atoms in the intermembrane space react with ADP using ATP synthase to add a phosphate group to make ATP



HOW ATP STORES ENERGY?

When there are only 2 phosphate groups (aka ADP), The tension/potential energy needed to break them is low
But when you add another phosphate group (aka ATP), the potential energy is BIG, and the energy is released when breaking it

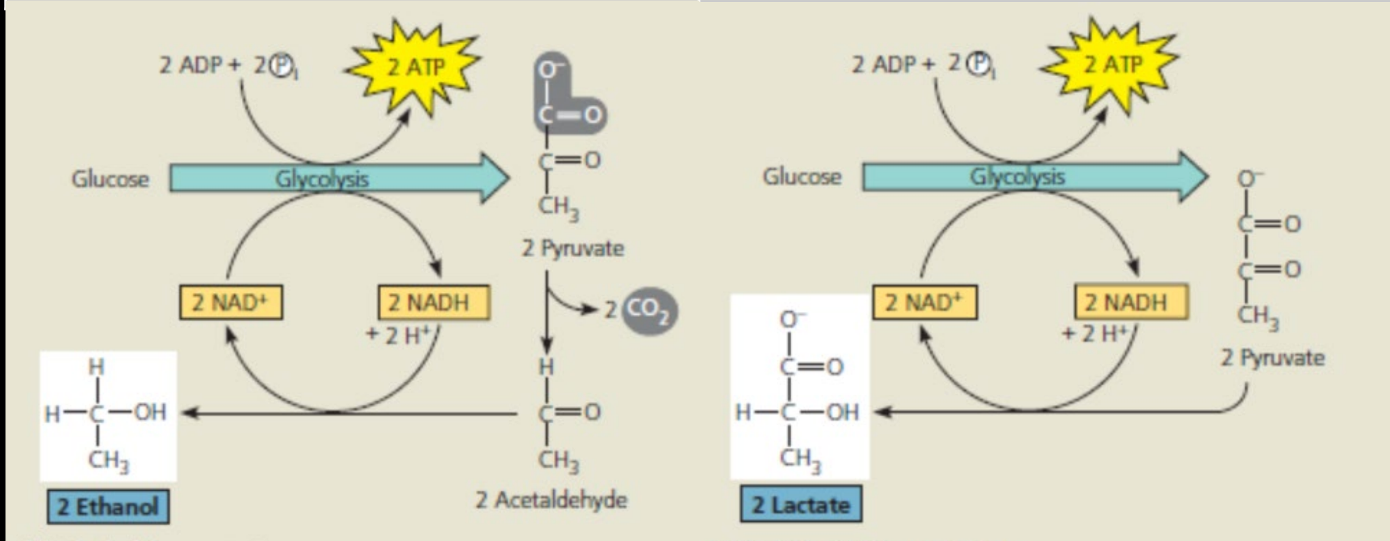
It is like a spring, it is very clamped in the form of ATP, and when broken to ADP, it is like the spring offsetting



FERMENTATION

a metabolic process that occurs in the absence of oxygen (anaerobic conditions) and involves the conversion of organic compounds, such as sugars, into simpler molecules, and it has two types we have to stsudy

ALCOHOL FERMENTATION	LACTIC ACID FERMENTATION
When pyruvate turns into alcohol by firstly getting turned to acetaldehyde with enzyme pyruvate decarboxylase which gives off CO_2, then turning into ethanol with enzyme **alcohol dehydrogenase** which oxidizes NADH to NAD^+	Where pyruvate becomes lactic acid with enzyme **lactate hydrogenase** which oxidizes NADH to NAD^+
Carried out by stuff like yeast	Carried out by certain bacteria such as lactobacillus, and muscle cells in your body when under stress
Helps with baking	Used to make yogurt



(a) Alcohol fermentation

(b) Lactic acid fermentation