

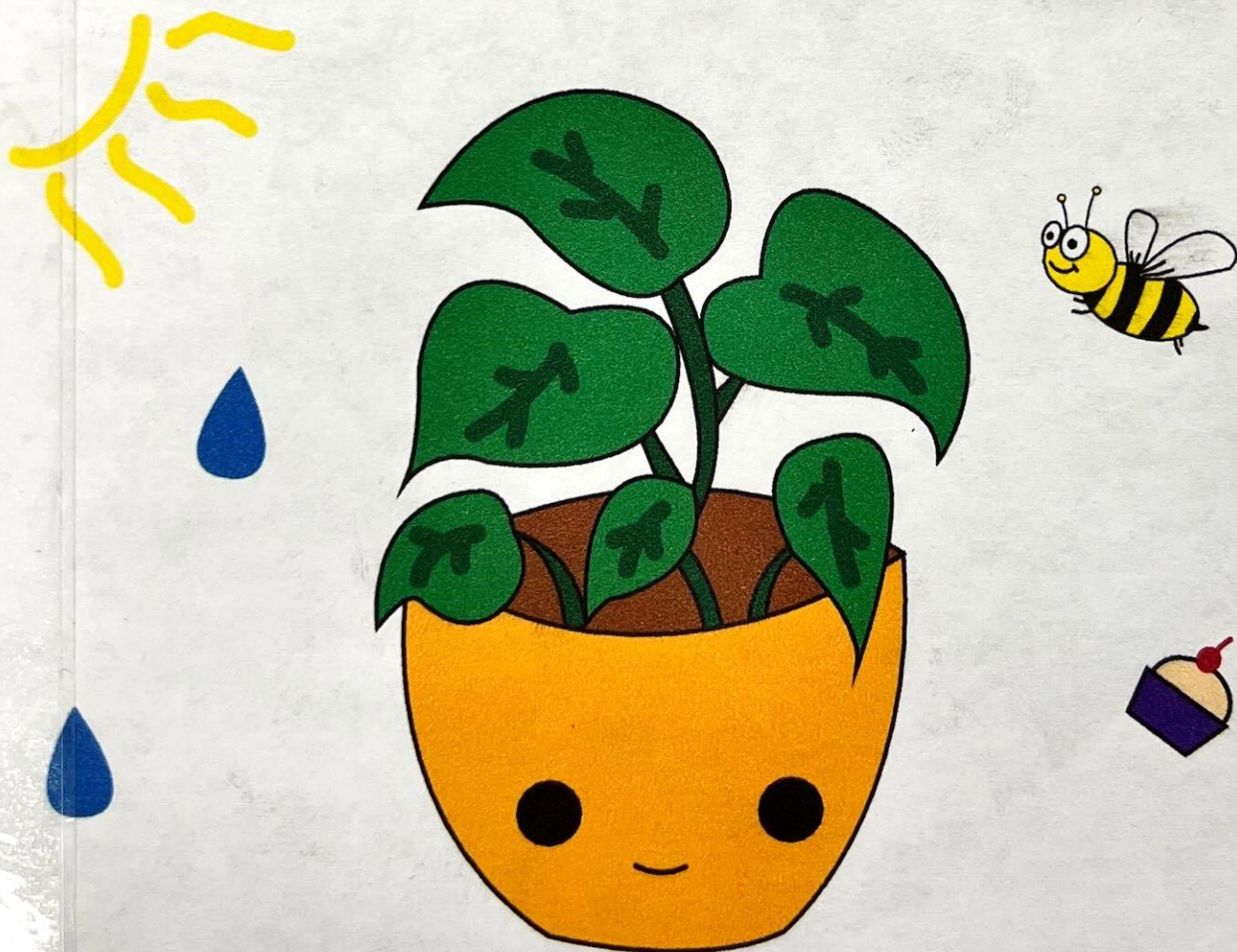
How A Plant

a cookbook for autotrophs 🌱

Makes Food

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Bio 2/3



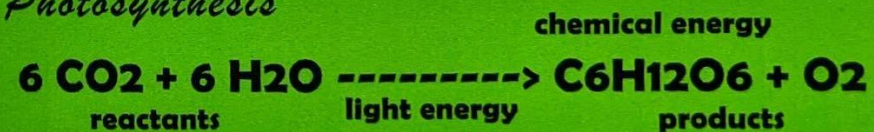
* to explain the cutting board
and serving tray to plants :)

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Photosynthesis



Cellular Respiration



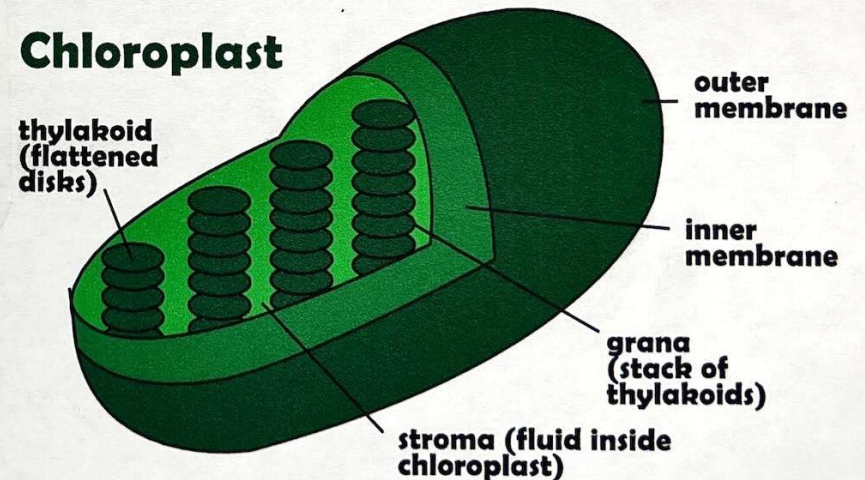
introduction



Hi! I'm Planty, and I will be teaching you how to cook like a plant. But before we get started, here's some helpful information!

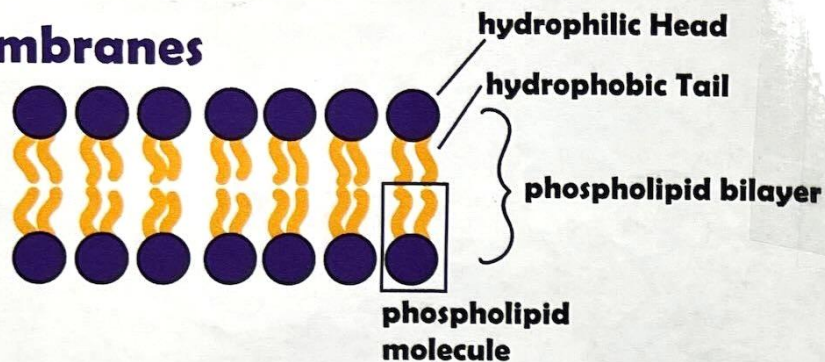
Photosynthesis is the process where green plants use energy from the sun along with water and carbon dioxide to create glucose (chemical energy), their food. The process takes place in the chloroplast.

Chloroplast



The light reaction takes place on the thylakoid's membranes, which contains a light absorbing pigment called chlorophyll. During photosynthesis, chlorophyll becomes energized by absorbing energy from blue and red waves, and reflects green, making the plant green. Membranes are made from phospholipids.

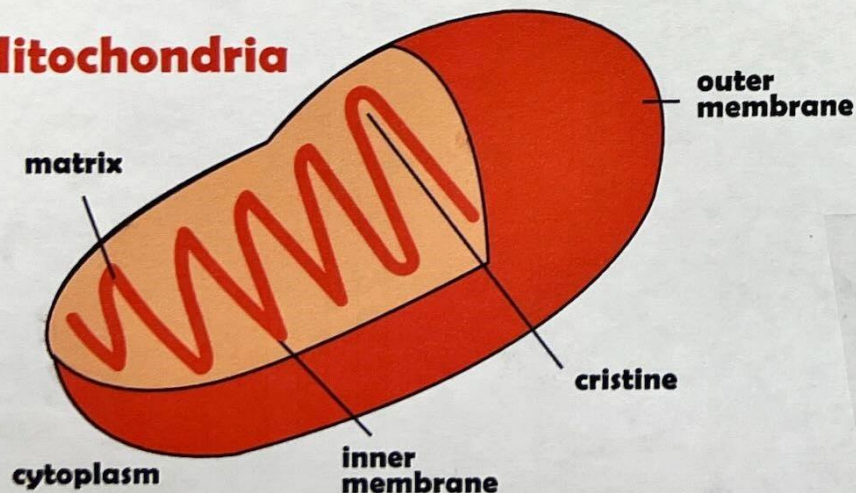
Membranes



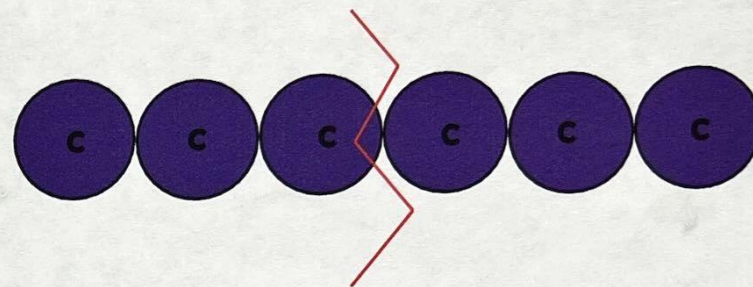
The dark reaction, or Calvin Cycle, takes place in the stroma. In this process, energy from ATP and NADPH molecules is used to assemble carbohydrate molecules, like glucose, from carbon dioxide and carbon molecules.

Cellular Respiration is the process where food (glucose - a type of sugar, which is a form of carbohydrate) is broken down into CO_2 and H_2O to release energy. This process takes place in the mitochondria... power house of the cell!!! (ahh, the elementary chool days :)

Mitochondria



Glycolysis takes place the cell's cytoplasm. In this process, glucose is broken down into two PGALS (G3P) and converted into pyruvate. Glycolysis is anaerobic respiration, it occurs even when oxygen is not present.



The Kreb's Cycle, (aka Citric Acid Cycle and aka Tricarboxylic Acid Cycle) takes place in the mitochondria matrix and happens when oxygen is present (aerobic respiration). In this process, a lot more ATP is made than in glycolysis, CO_2 is released, and NAD and FAD are reduced.

The Electron Transport Chain is in the inner mitochondria membrane and it is a series of molecules that accepts and donates electrons. In the process, NADH and FADH_2 are oxidized into NAD and FAD, ADP is turned into ATP, and H_2O is made.

PHOTOSYNTHESIS

the cutting board explained

Overview:

Reactants:

6 CO₂
6 H₂O
Light Energy (photons)

Products:

Glucose - C₆H₁₂O₆
Oxygen - O₂

Time:

Depends on plant

Serving Size:

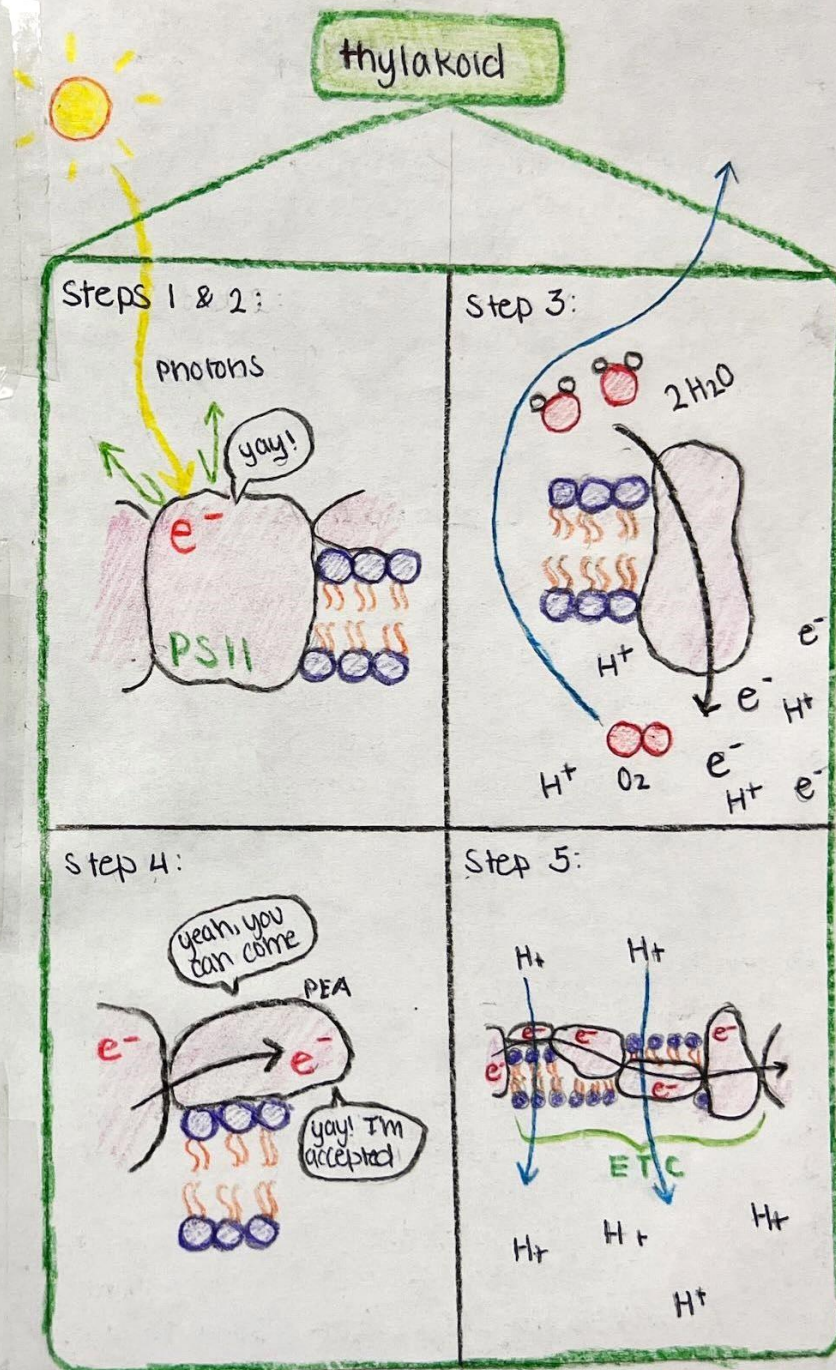
1 glucose (repeat
process as necessary)

* Photosynthesis is an endergonic reaction because the system gains energy as the reaction progresses.

Light Reaction

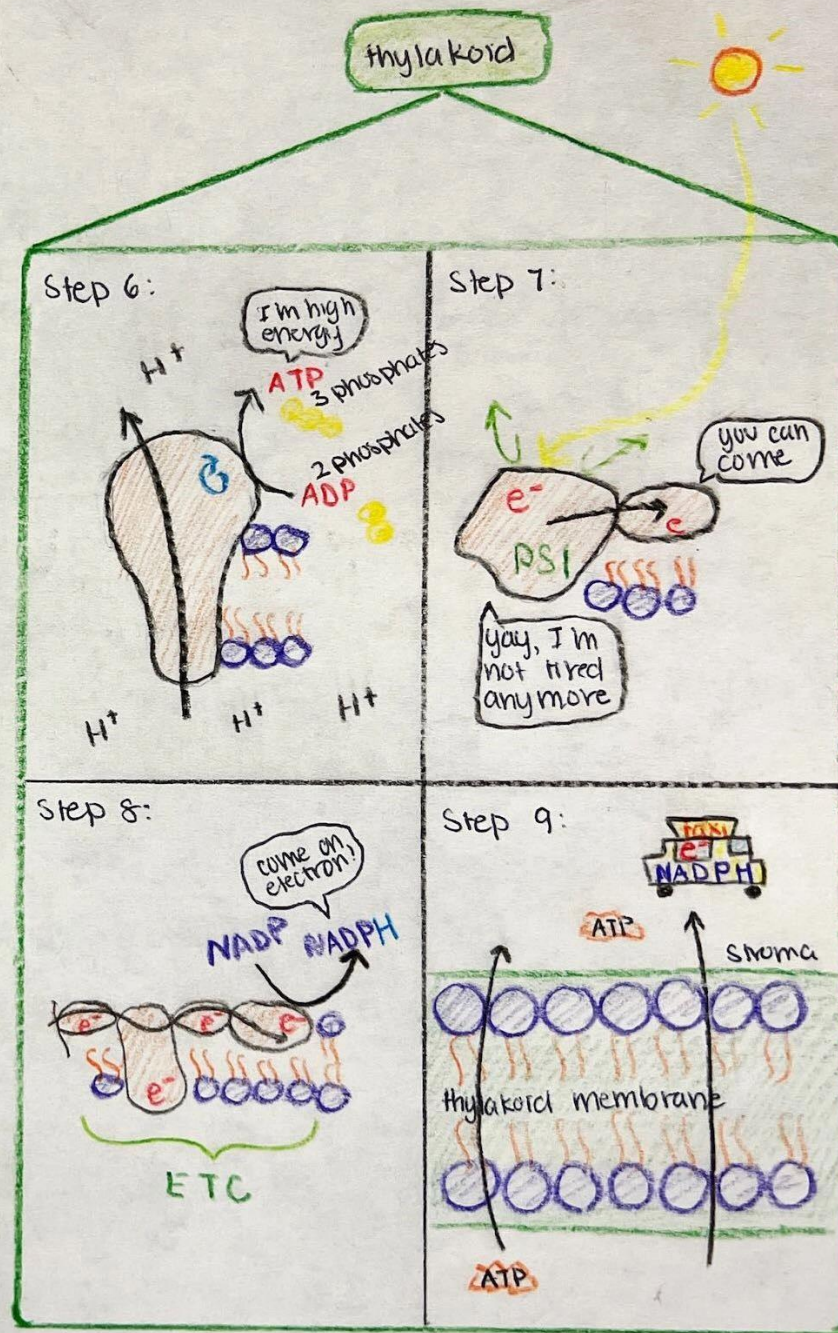
1. In your thylakoid membrane, energize your chlorophyll in photosystem II by absorbing light energy, or photons. Make sure to reflect the green waves though!
2. As your chlorophyll absorbs the energy, the electrons will get excited by absorbing photons carrying energy. As the electrons of the chlorophyll pigments get excited, give up those electrons.
3. Now you need to compensate for the loss of electrons in PSII. Do this by splitting water (H_2O) molecules through the water splitting enzyme (multi-subunit enzyme). Two water molecules are split into 4 H^+ ions, 4 e^- ions, and O_2 . The O_2 is released into the atmosphere.

$$2 H_2O \rightarrow 4 H^+ + 4 e^- + O_2$$
4. The excited electron gets accepted by the primary electron acceptor (PEA).
5. Move your excited electron down the proteins of the electron transport chain (ETC). As the electron moves down the ETC, use its energy to pump hydrogen ions (H^+) across the membrane into the thylakoid. * This is active transport! – using energy to move particles from low concentration to high concentration.



LIGHT REACTION cont.

6. Now there is a lot of H^+ in the thylakoid space. So it will naturally flow out from high to low concentration through diffusion. This is passive transport! But H^+ can only flow out through a protein called ATP Synthase. As H^+ flow through ATP Synthase, it rotates, turning ADP into ATP (low energy to high energy)! The ATP will be used in the Calvin Cycle.
7. The electron continues moving to photosystem I, but it is tired now. To make it excited again, absorb more photons! And get accepted by another PEA!
8. Move your electrons down a second ETC, and use them to reduce $NADP^+$ to form NADPH, which is an electron carrier. The NADPH will now carry your electron into the Stroma for the Calvin Cycle!
9. Go to the stroma for the Calvin Cycle (dark reaction). Don't forget to take your ATP and NADPH with you!



DARK REACTION

1. Carbon Fixation:

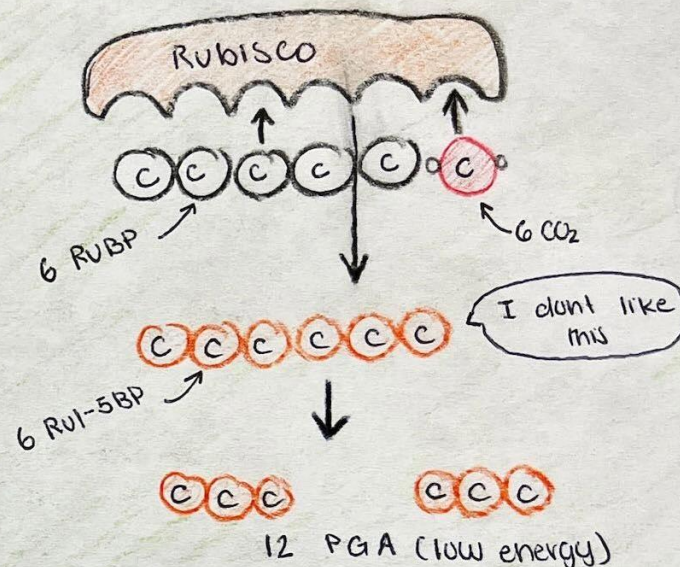
- Put a molecule of RuBP (Ribulose 1, 5-biphosphate) and CO₂ into your Rubisco enzyme. This turns the RuBP from 5-carbon to 6-carbon (Ru1-5BP)! Do this five more times.
- However, 6-carbon is unstable, so break apart each 6-carbon molecule into 2 molecules of 3 phosphoglycerate.
(3 carbon molecule – PGA) → 12 PGA

2. Reduction:

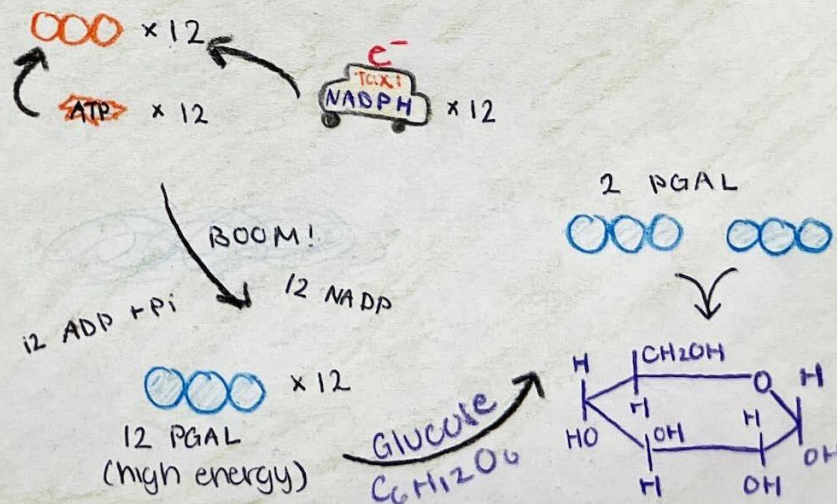
- Reduce the 3-phosphoglycerates by using 12 molecules of ATP from the light reaction. This forms glycerate-1 3-biphosphate and by products ADP and Pi.
- Use the 12 NADPH from the light reactions to reduce the glycerate-1 3-biphosphate to form 3-carbon sugar (glyceraldehyde 3-phosphate, or PGAL). The NADPH oxidizes to NADP⁺.
- Combine two of the PGAL to form glucose (C₆H₁₂O₆), which is a 6-carbon compound.
 - Fructose-1, 6-biphosphate (F1, 6BP) catalyzed by aldolase.
 - Dihydroxyacetone phosphate (DHAP) catalyzed by triose phosphate isomerase.
 - 1, 3-bisphosphoglycerate (1, 3BPG), catalyzed by glyceraldehyde 3-phosphate dehydrogenase.
 - Finally, the glucose you want! C₆H₁₂O₆

Carbon Fixation:

Stroma



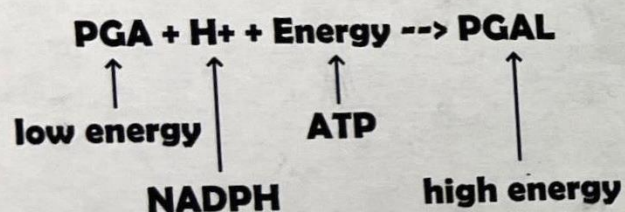
Reduction:



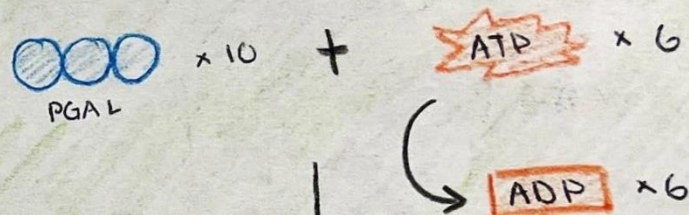
DARK REACTION cont.

3. Regeneration:

- The rest of the PGAL (10 of them) will be used to regenerate RuBP so that the cycle can continue.
- Use 6 molecules of ATP from the light reactions and 10 PGAL to synthesize ribulose biphosphate into RuBP.
- Now the RuBP can bind with incoming CO₂ to restart the cycle!



Regeneration:



I can now go back to carbon fixation to start the process all over again!

Carbon Fixation

CELLULAR RESPIRATION

the serving tray explained

Overview:

Reactants:

Glucose - $C_6H_{12}O_6$
6 O_2

Products:

6 CO_2
6 H_2O
ATP - energy!

Time:

Depends on plant

Serving Size:

38 ATP (repeat process until energized!)

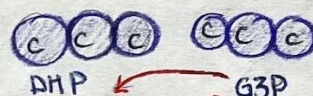
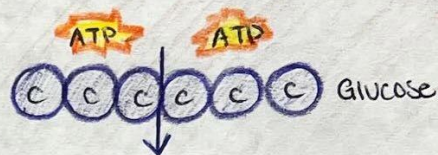
* Respiration is an exergonic reaction because the system releases energy as the reaction progresses. Exergonic reactions are spontaneous because once started, they happen on their own.

GLYCOLYSIS

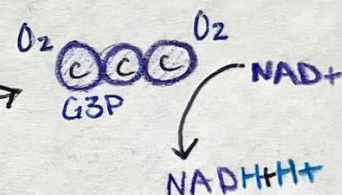
1. In your cytoplasm, use 2 ATP to break apart one molecule of $C_6H_{12}O_6$ in two 3 carbon molecules - dihydroxyacetone phosphate (DHAP) and glyceraldehyde-3-phosphate (G3P).
2. DHAP and G3P are isomers of each other. Convert the DHAP into G3P because only G3P can continue to the next step of glycolysis.
3. Oxidize your G3P and reduce a molecule of NAD^+ to $NADH + H^+$. This reaction is exergonic because it releases energy to form 1-3 biphoglycerate.
4. Turn your 1-3 biphosphoglycerate into 3-phosphoglycerate. This turns ADP into ATP. Repeat steps 3 and 4 with your other G3P from steps 1-2.
5. Convert 3-phosphoglycerate to its isomer, 2-phosphoglycerate. Let your 2-phosphoglycerate let a water molecule go. This will turn it into phosphoenolpyruvate, which is unstable.
6. Your phosphoenolpyruvate is too unstable, so throw away its phosphate group to stabilize it - turning ADP into ATP. This turns it into pyruvate! Repeat steps 5-6.

cytoplasm

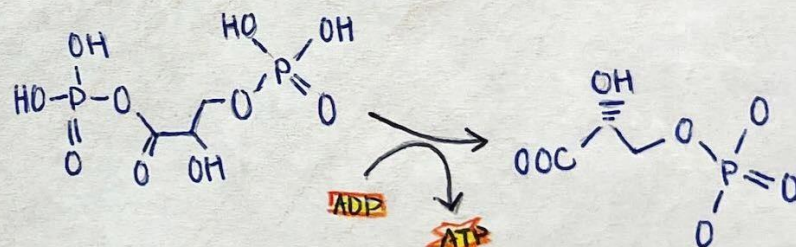
Steps 1 and 2:



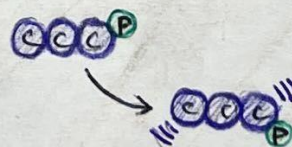
Step 3:



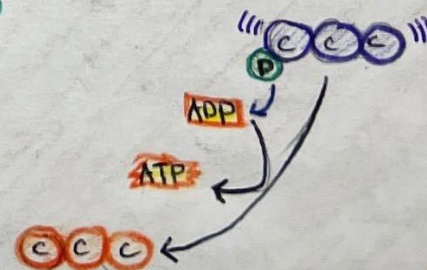
Step 4:



Step 5:



Step 6:



GLYCOLYSIS cont.

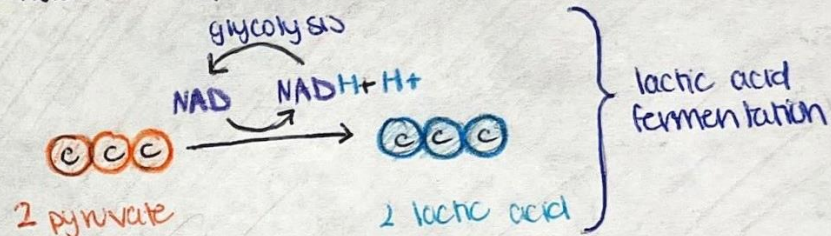
When oxygen is not present: anaerobic respiration
 - breakdown your pyruvic acid into lactic acid (lactic acid fermentation).

If oxygen is present: aerobic respiration

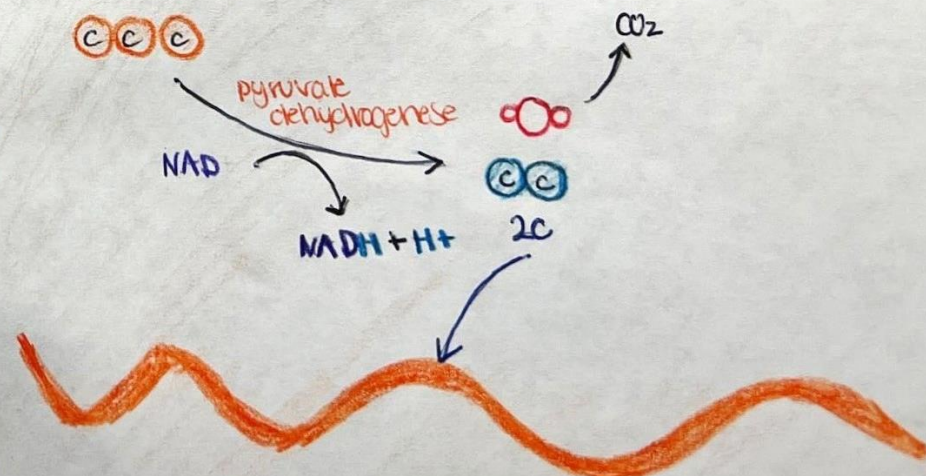
- Use the enzyme pyruvate dehydrogenase to break one carbon off of pyruvate. Attach the single carbon to oxygen to form CO_2 and send the two carbon (Acetyl-CoA) to your mitochondria matrix for the Krebs' Cycle! During this process, NAD^+ is reduced to $\text{NADH} + \text{H}^+$.

You have just used 2 ATP (step 1), but gained 4 more (steps 4 and 6) --> 2 ATP Net Gain

anaerobic respiration:



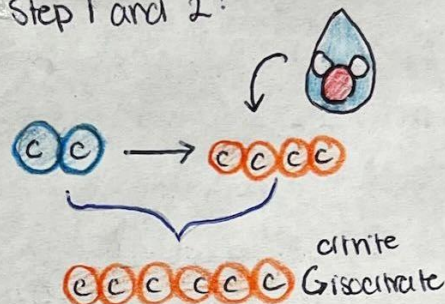
aerobic respiration:



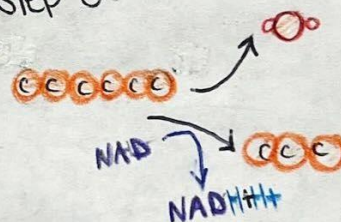
KREB'S CYCLE

1. In your mitochondria matrix, attach your Acetyl-CoA (from glycolysis) to oxaloacetate, a four carbon molecule and let go of your CoA group. This creates citrate, a 6 carbon molecule! Also add a H_2O molecule to the system in this step (2 hydrogens and an oxygen).
2. Convert your citrate to isocitrate (they are isomers)!
3. Oxidize your isocitrate and release a carbon. Attach the carbon to oxygen and release it as CO_2 . This leaves you with a 5 carbon, ketoglutarate. As this happens, NAD^+ is reduced to $NADH + H^+$.
4. Repeat step 3. This leaves you with a 4 carbon, which is picked up by Coenzyme A, forming an unstable compound, succinyl CoA.
5. Replace the CoA group of your 4 carbon with a phosphate group. Then transfer the phosphate group to ADP, turning it into ATP.

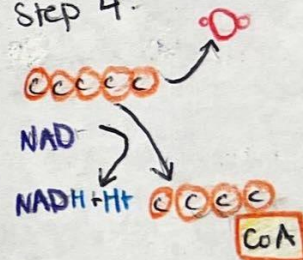
Step 1 and 2:



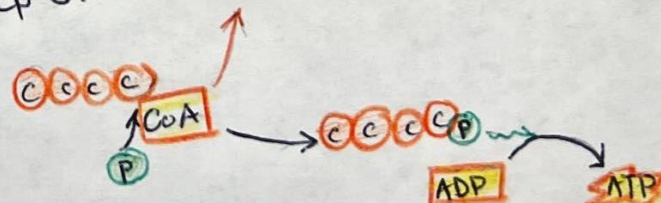
Step 3:



Step 4:



Step 5:

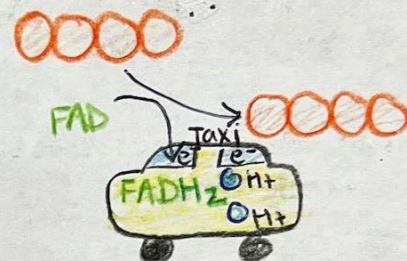


KREB'S CYCLE cont.

6. Oxidize your succinate, creating another four carbon (fumarate). During this reaction, two hydrogen atoms are transferred to FAD, creating FADH₂, an electron carrier (like NADPH).
7. Add water to your fumarate, which converts it to another 4 carbon molecule called malate.
8. Oxidize your malate to regenerate the original 4 carbon molecule that started the cycle, oxaloacetate. During this process, NAD⁺ is reduced to NADH + H⁺.

Now you can repeat the process over and over again!

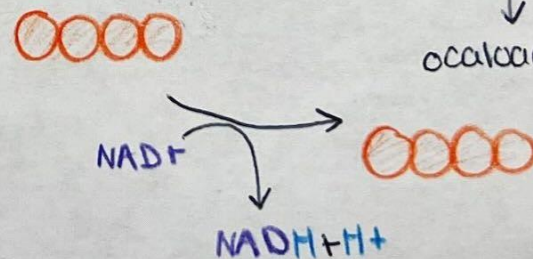
Step 6:



Step 7:



Step 8:



mitochondria matrix

succinate

fumarate

malate

oxaloacetate **START!**

24 Electron Transport Chain

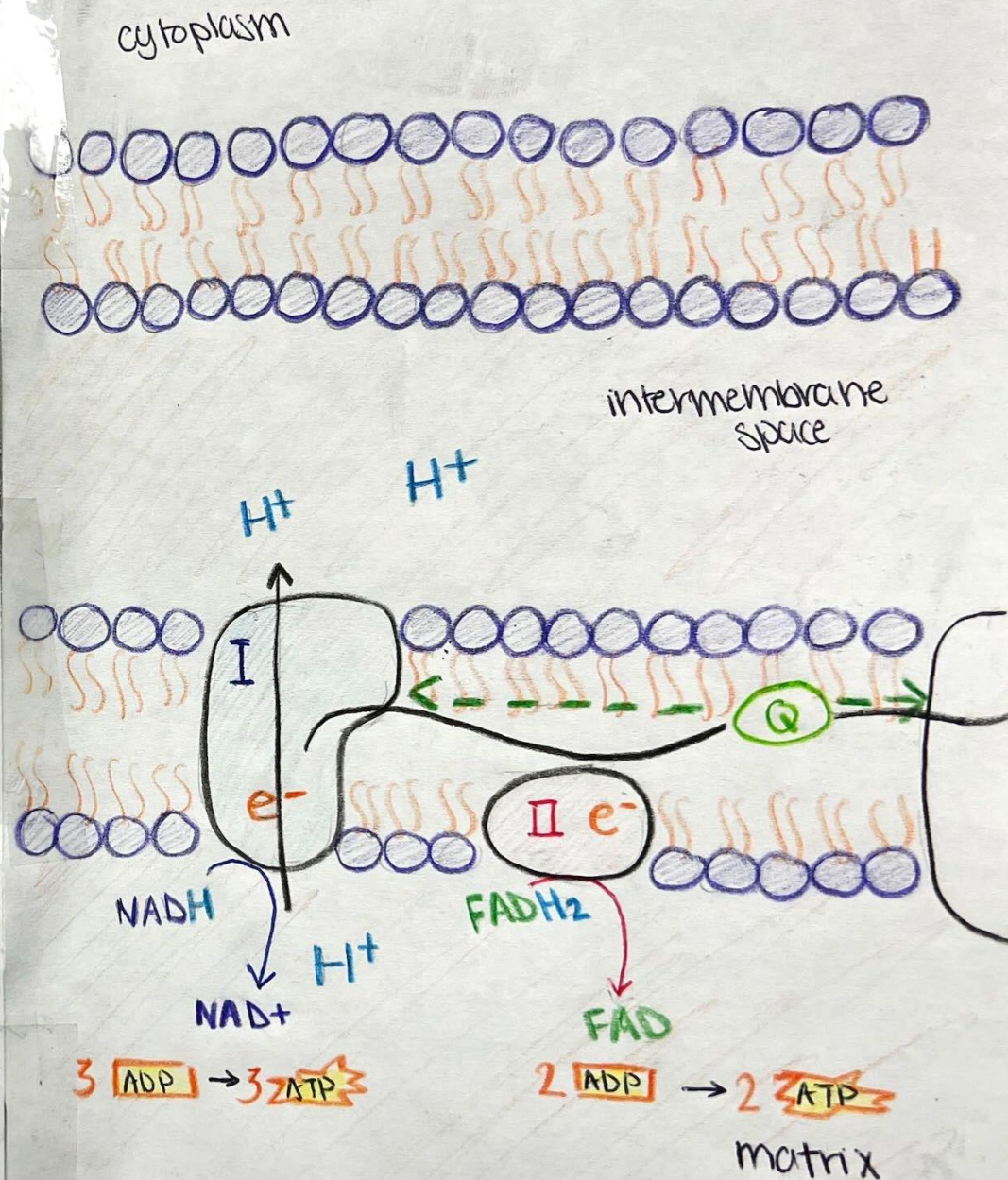
In your inner mitochondria membrane:

Complex I:

- Known as NADH dehydrogenase, which catalyzes the removal of hydrogen atoms from a particular NADH molecule, particularly in the ETC reactions of cell respiration in conjunction with the coenzymes NAD and FAD.
- In Complex I, oxidize your NADH from the Krebs' Cycle into NAD. One conversion of NADH to NAD turns 3 ADP into 3 ATP molecules.
- Complex I is a hydrogen pump: use the energy from your electron to move the H^+ from low concentration (mitochondria matrix) into the intermembrane space.
- * Coenzyme Q:
- This is a small molecule that can move across the membrane.
- Go back and forth from Complex I to Complex III picking up and dropping off electrons between the two complexes.

Complex II:

- Known as Succinate reductase w/ Succinate dehydrogenase inside: *oxidizes succinate to fumarate which donates electrons to the system. Those electrons get picked up by coenzyme Q.
- Oxidize your $FADH_2$ from the Krebs' Cycle into FAD. This turns 2 ADP into 2 ATP.



Complex III:

- Known as **Cytochrome c oxidoreductase (Cytochrome bc)**: important for generation of ATP.
- In Complex III, accept the electrons that get taxied over from Complex I by coenzyme Q.
- This complex is also a proton pump. Use the energy from the electron to pump hydrogen across the membrane.

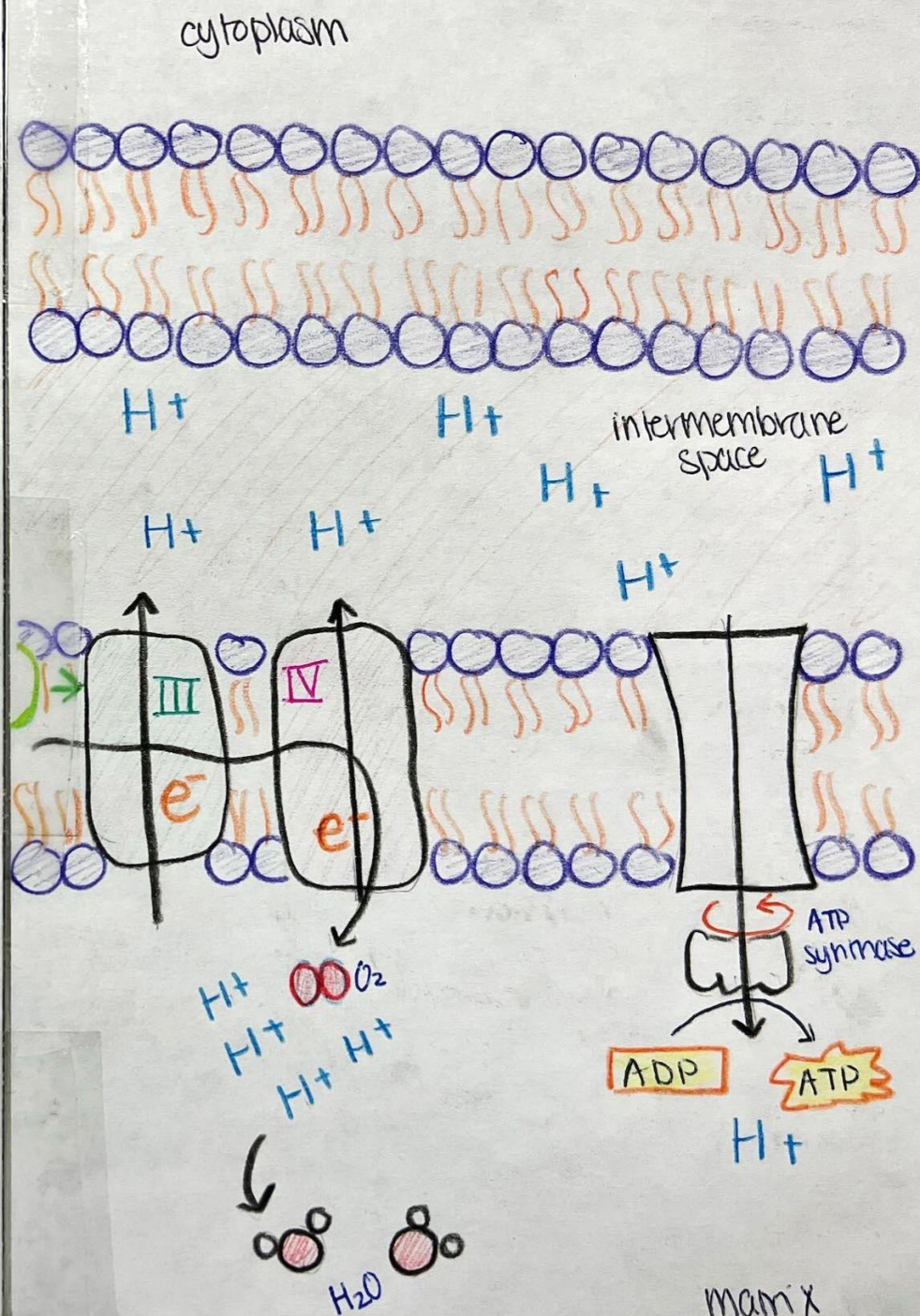
Complex IV:

- Known as **Cytochrome c oxidase**: last enzyme in the ETC, it promotes the transfer of a hydrogen atom from a particular substrate to an oxygen molecule, forming water or hydrogen peroxide.
- When it gets the electrons, transfer them to one O_2 (oxygen) molecule and four H^+ (hydrogen protons) to make two water molecules.
- This complex is also a proton pump.

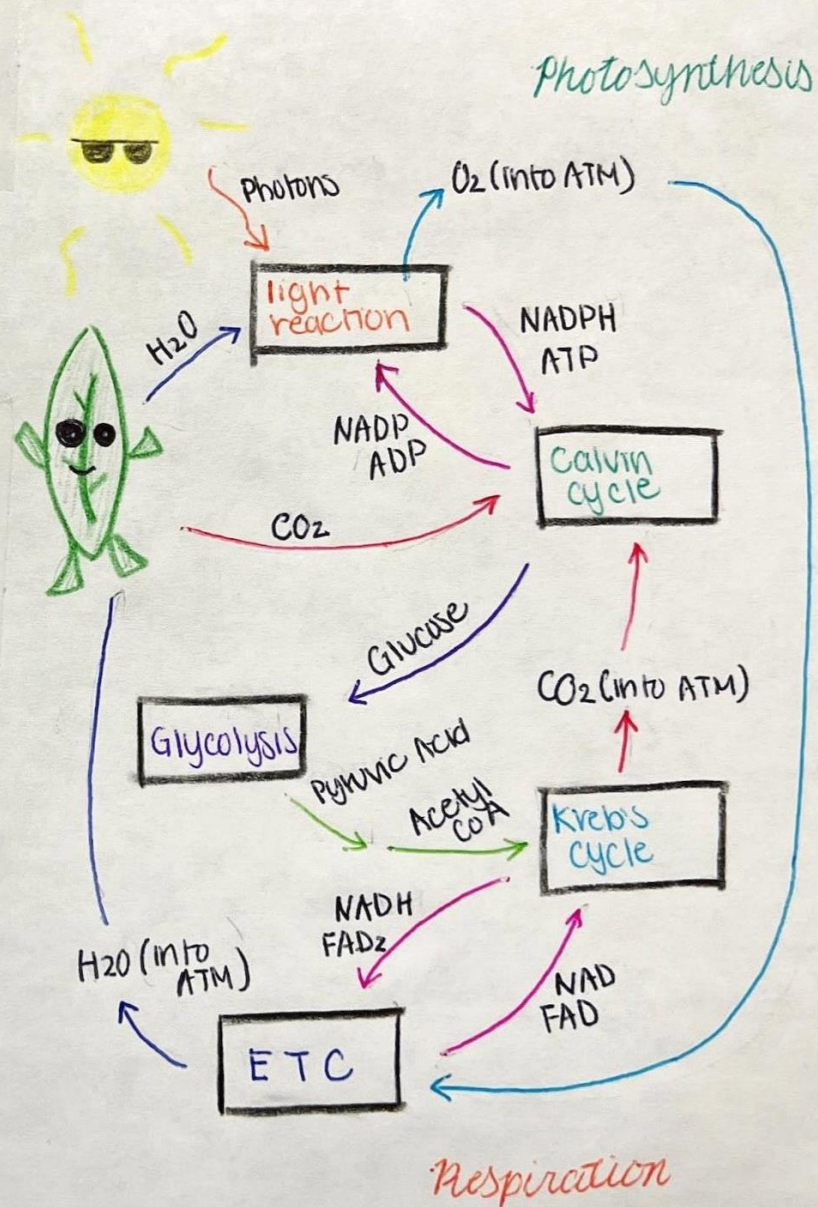
ATP Synthase:

- Now, there is a lot of H^+ in the intermembrane space, so they will naturally flow from high concentration to low concentration (into the mitochondria matrix). As they flow through ATP synthase, rotate the mechanism inside and turn ADP into ATP!

* Send the NAD and FAD back to the Krebs's Cycle so they can be reduced to NADH and FADH₂ again!
Big cycle of the small cycles!



Big Picture



CITATIONS:

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