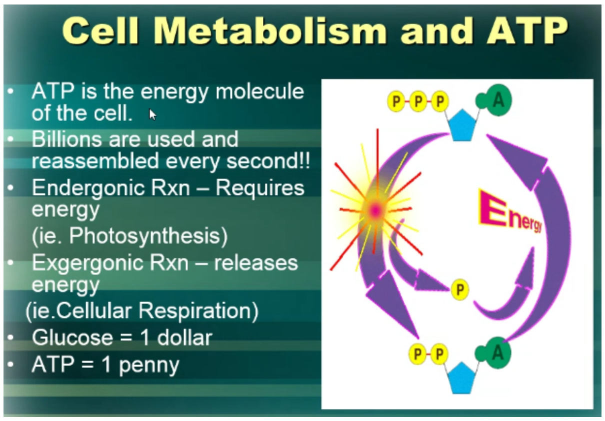
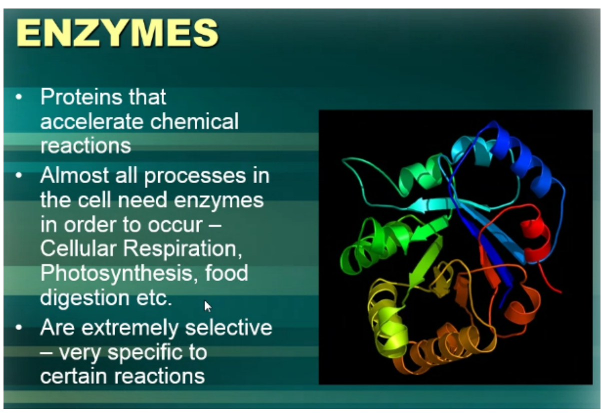
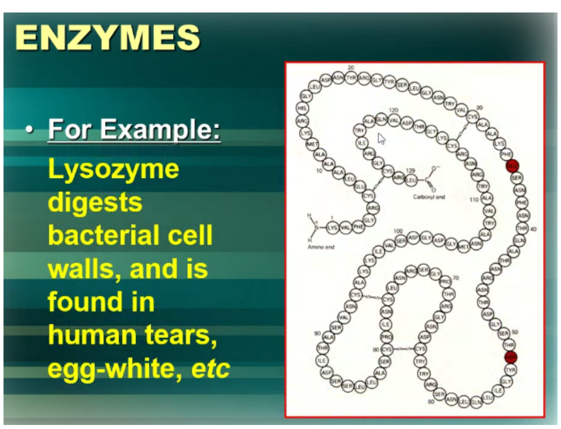
Metabolic Processes

Cells at work (WORK WORK)

- 

- Enzymes → key to biochemical reactions
  - 

  - 

ENZYMES

- Enzymes are known to catalyze about 4,000 reactions in the human body
- Remain unchanged after reactions
- Most are named after the reaction they catalyze and their names end in "-ase"
  Ex: Lactase breaks down lactose

-

HOW ENZYMES WORK:

- By providing a lower activation energy for a reaction and dramatically accelerating its rate
- *For example…*

  the reaction catalysed by orotidine-phosphate decarboxylase will consume half of its substrate in 78 million years if no enzyme is present. However, when the decarboxylase is added, the same process takes just 25 milliseconds

-

HOW ENZYMES WORK:

$$\text{SUBSTRATE} \xrightarrow{\text{Enzyme}} \text{PRODUCT(S)}$$

reactant

Eg:

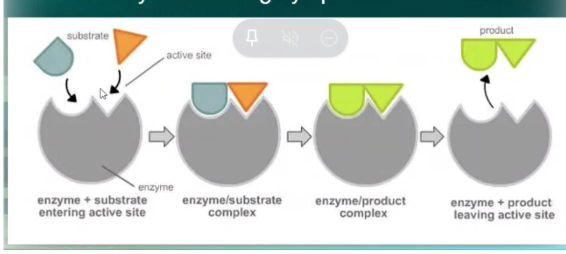
$$\text{Sucrose + Water} \xrightarrow{\text{Sucrase}} \text{Glucose + Fructose}$$

Enzymes help a reaction to occur … without being directly involved!!!

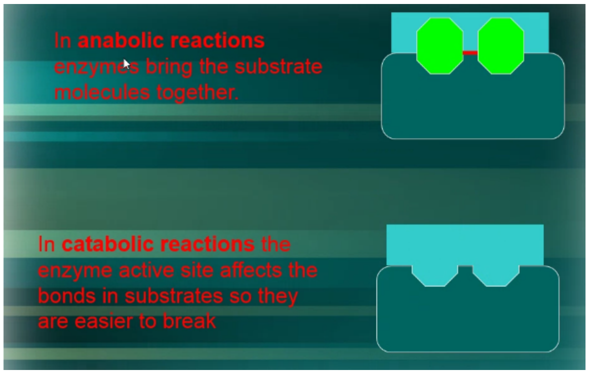
-

Enzyme Structure

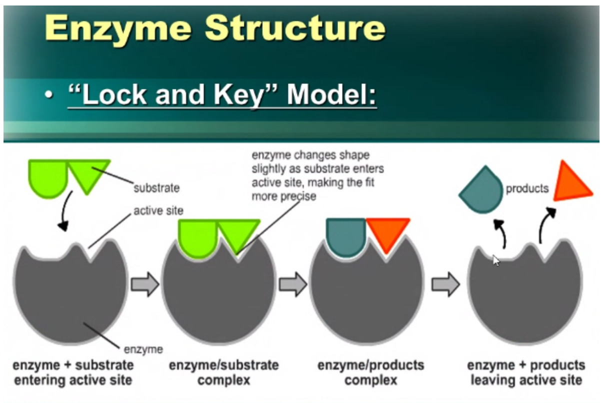
- The substrate must fit precisely in the active site in order for the reaction to proceed
- All enzymes are highly specific!



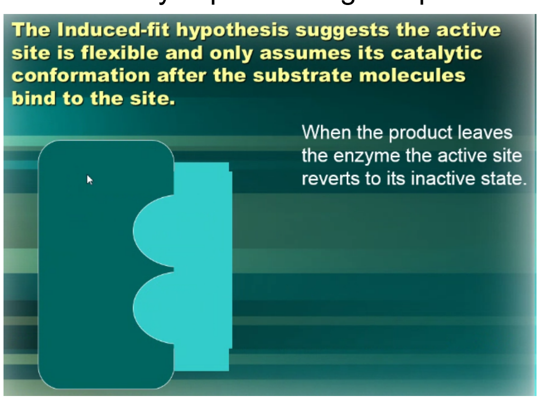
-

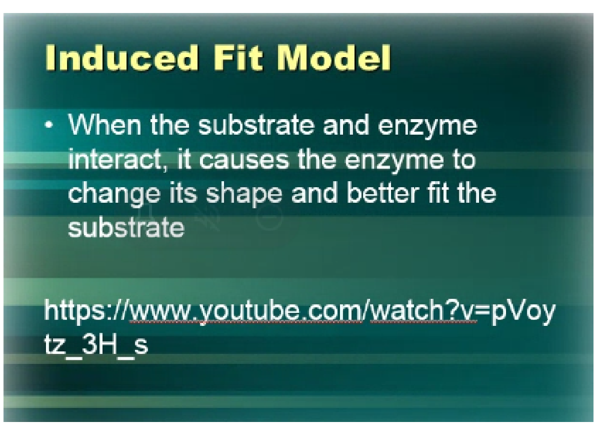
- 

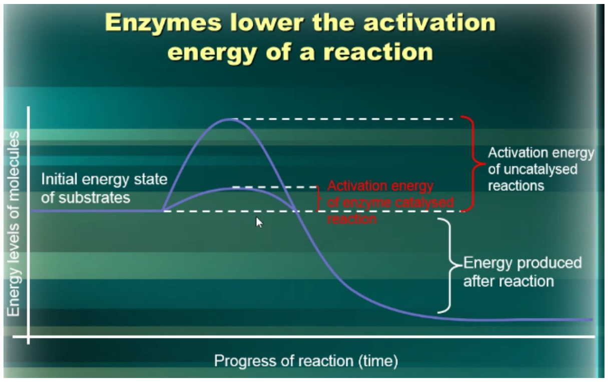
    - A is like add, C is like cut

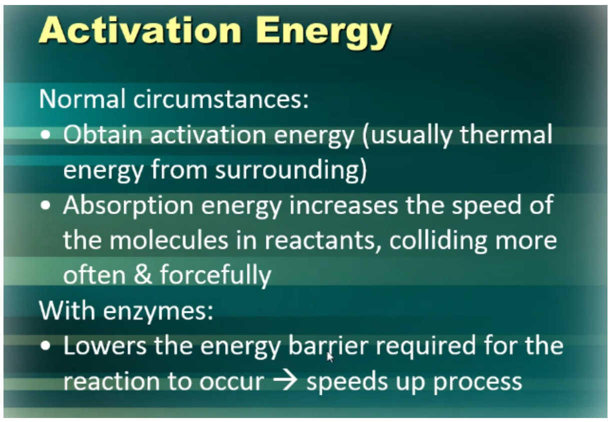
- 

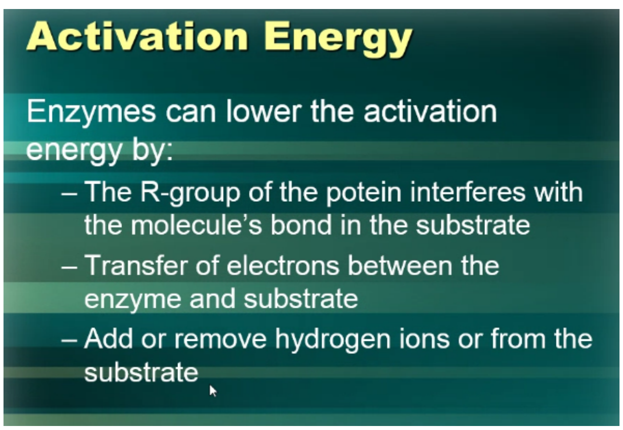
- Lock and key is prob wrong cuz proteins have been proven to be flexible

- 

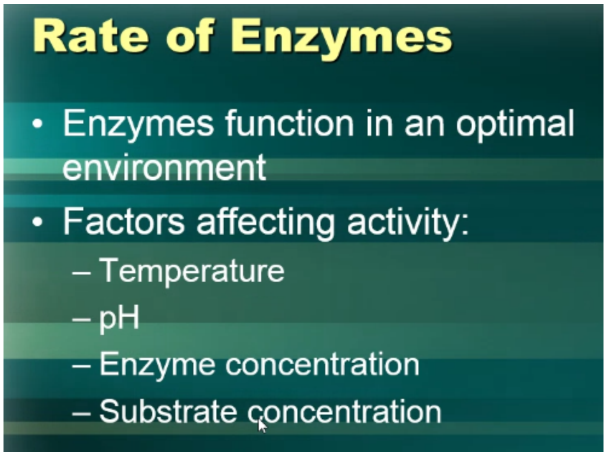
- 

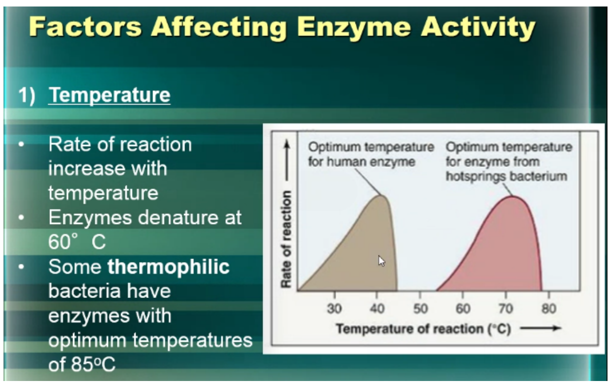
- 

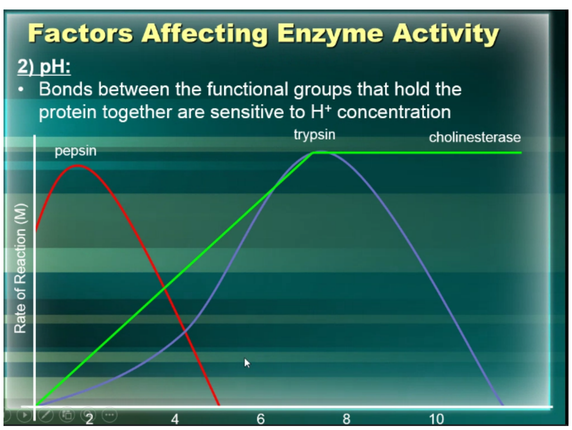
- 

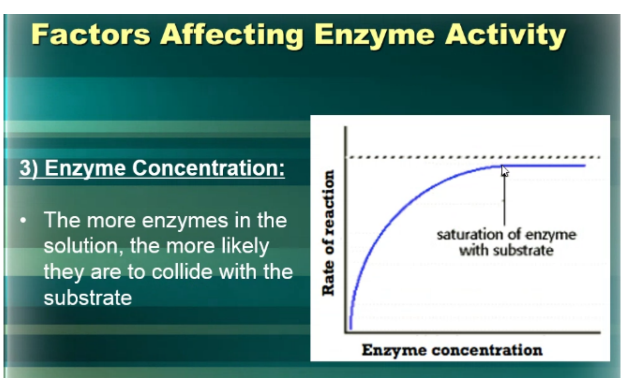
- 

- Factors affecting enzyme activity

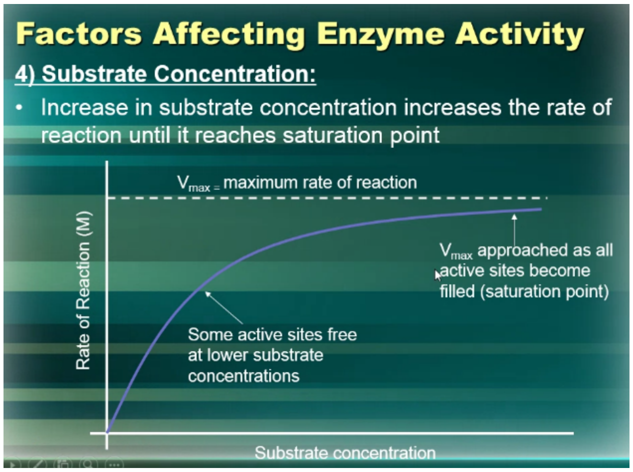
- 

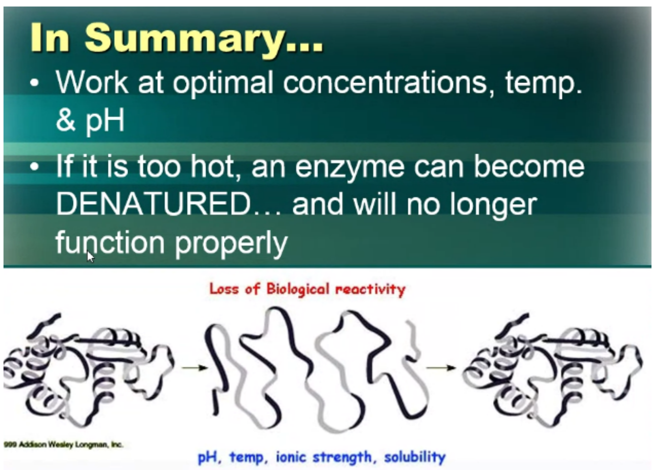
- 

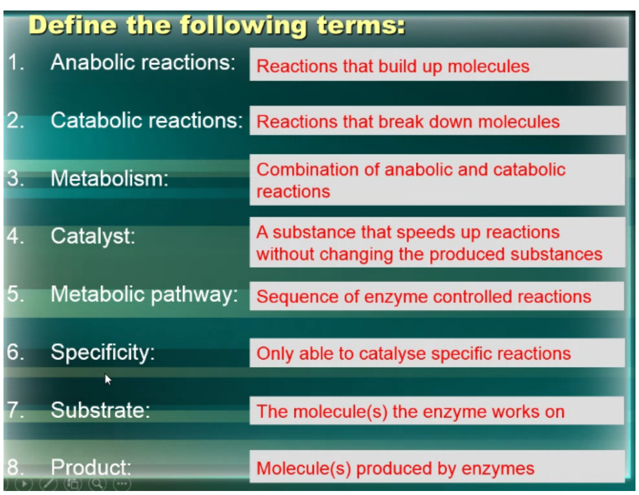
- 

- 

- The more seats u have in a movie theater, the more people that can sit

- 

- Summary
  - 

  - 

- Enzyme regulation

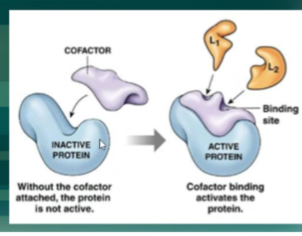
Enzyme Regulation

- Regulation mechanisms:
  - Cofactors/ Coenzymes
  - Competitive inhibitors
  - Non-Competitive inhibitors
  - Allosteric Changes
  - Feedback Inhibition
  - Precursor Activation

-

1. Cofactors/Coenzymes

- Non-protein helper
- Enzymes can't speed up reaction without them



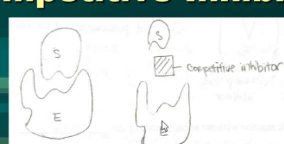
-

1. Cofactors/Coenzymes

- Example: Vitamin B_2 (riboflavin)
- Involved in energy metabolism (ie. metabolism of fat, carbohydrates and proteins)
- Deficiency: body will have problem metabolizing (fats, carbs, proteins)
- Often caused by dietary inadequacy
- Can be obtained from meat, nuts, cheese, eggs
- Diagnosis: measure activity of enzyme gluthathione
- Symptoms: bloodshot eyes, mouth, inflammation, sores, burning tongue
- Not common because most countries fortify their breads and cereals with vitamin B_2

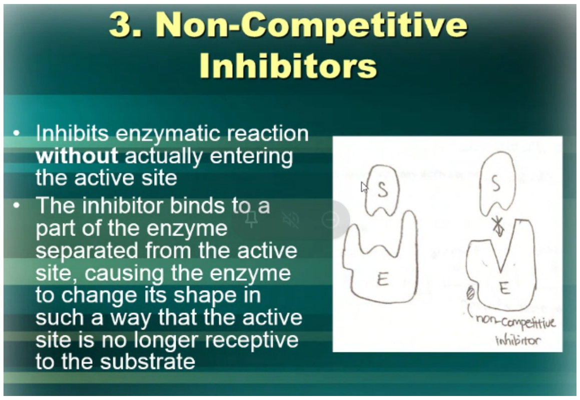
-

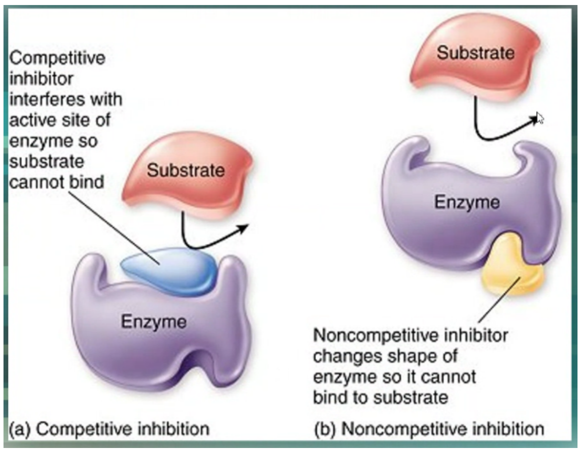
2. Competitive Inhibitors

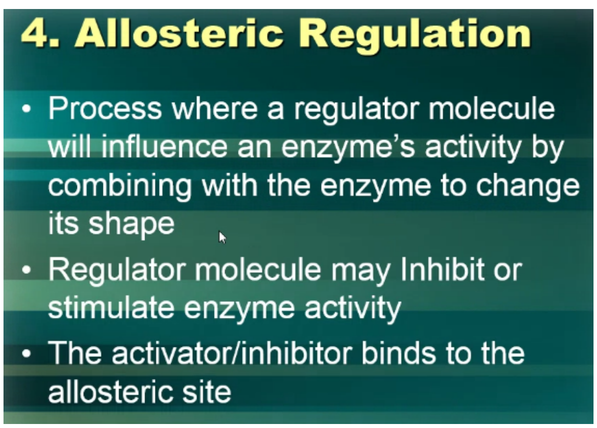


- Resembles the normal substrate and compete for admission into the active site
- Reduces the productivity of the enzyme by locking the active site from substrate
- If the inhibitor attaches to the enzyme by covalent bond, the inhibition is usually irreversible (ex. nerve gas, cyanide, arsenic)
- If the inhibitor bins to the enzyme by a weak bond, the inhibition is reversible, it can be overcomed by increasing the concentration of substrate

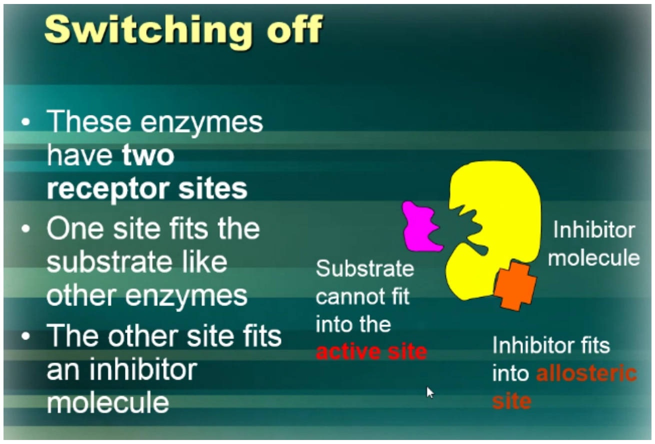
-

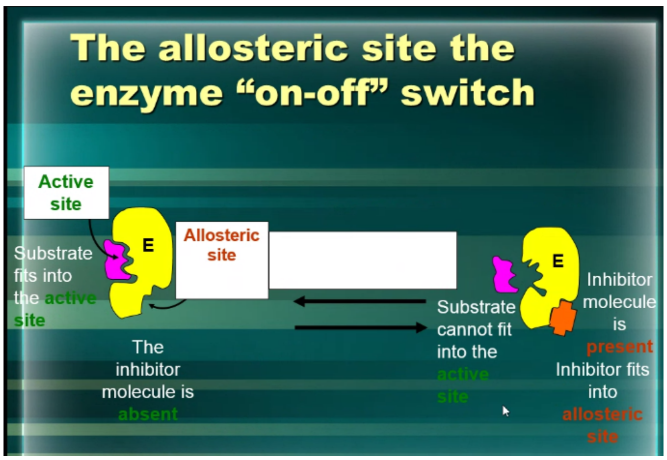
- 

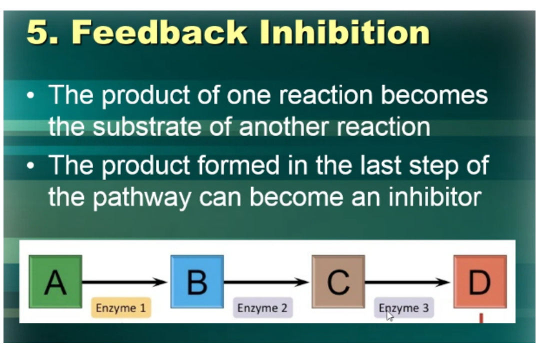
- 

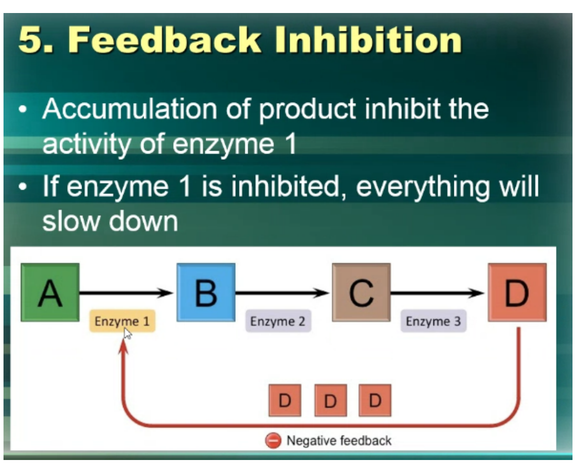
- Inhibitors r there to either poison or to save energy
- 

    - This one can also start the reaction
- Missed one

- 
Switching off
• These enzymes have **two receptor sites**
• One site fits the substrate like other enzymes
• The other site fits an inhibitor molecule
Substrate cannot fit into the active site
Inhibitor molecule
Inhibitor fits into allosteric site

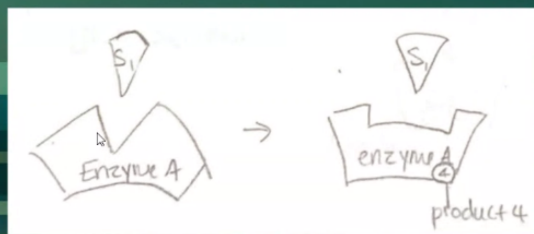
- 
The allosteric site the enzyme "on-off" switch
Active site
Allosteric site
E
Substrate fits into the active site
The inhibitor molecule is absent
E
Substrate cannot fit into the active site
Inhibitor molecule is present
Inhibitor fits into allosteric site

- 
5. Feedback Inhibition
• The product of one reaction becomes the substrate of another reaction
• The product formed in the last step of the pathway can become an inhibitor
A
Enzyme 1
B
Enzyme 2
C
Enzyme 3
D

- 
5. Feedback Inhibition
• Accumulation of product inhibit the activity of enzyme 1
• If enzyme 1 is inhibited, everything will slow down
A
Enzyme 1
B
Enzyme 2
C
Enzyme 3
D
D D D
Negative feedback

5. Feedback Inhibition

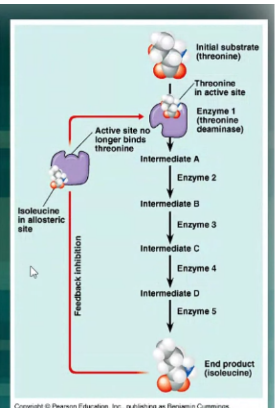
- Product 4 binds to allosteric site of enzyme 1, changing its shape



-

This example demonstrates how an end product can inhibit the first step in its production.

1. Isoleucine binds to the allosteric site of threonine deaminase and prevents threonine from binding to the active site because the shape of the active site is altered.
2. When the level of isoleucine drops in the cell's cytoplasm, the isoleucine is removed from the allosteric site on the enzyme, the active site resumes the activated shape and the pathway is "cut back on" and isoleucine begins to be produced.

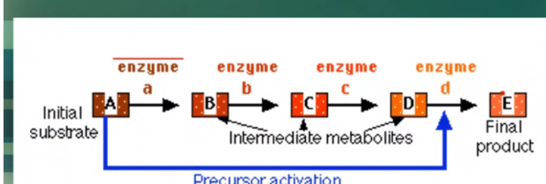


-

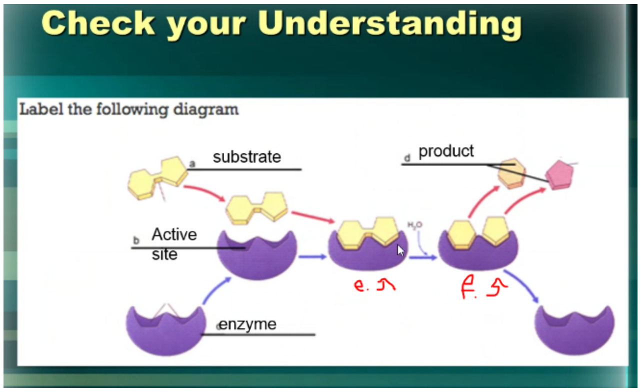
6. Precursor Activation

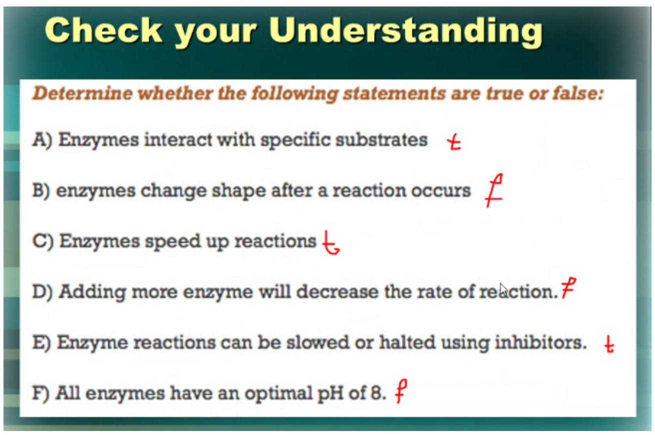
- Requires a reactant to activate enzyme further along a reaction series
- It may combine with the enzyme, changing its shape, so that the active site fits with its substrate
- Substrate 1 activates enzyme C

-



-

- 

    - E. substrate-enzyme complex
    - F. product-enzyme complex
- 

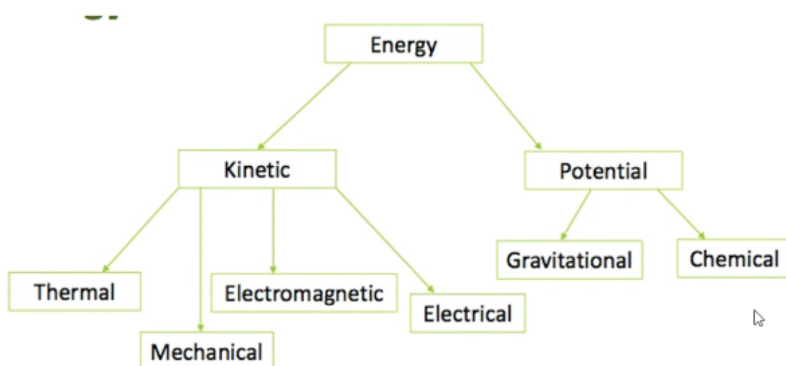
Homework
- 50 - 56 textbook
- Optional enzyme worksheet
- Enzyme gizmo lab → for marks

Nomenclature Functional Group Priority for Bio
- Carboxylic Acid + derivatives like ester
- Amino
- Aldehyde
- Ketone
- Alcohol
- Alkyne
- Alkene
- /33, 10 marks for MC, 3 naming diagrams,
- Acetone is the common name for 2-propanone
- Prioritize triple over double bonds

Metabolism

Energy

- Ability to do work
- Must continuously capture, store and use energy
- Organisms do majority of work on a cellular level
- Must manage amount of energy used w amount produced
- Anabolic reactions:
    - Energy + small molecules → larger molecules
- Catabolic reactions:
    - Large molecules → energy + smaller molecules
- Kinetic energy (Ek) has to do with movement, potential energy (Ep) is stored



-

Laws of Thermodynamics

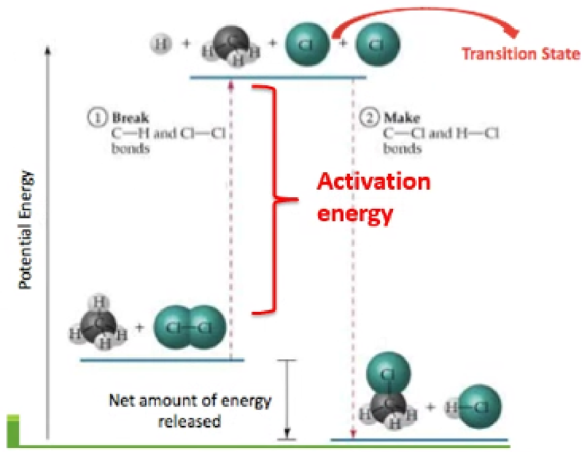
- Looks at physical rules of organisms and how energy is transferred between them

1. Total amount of energy in any closed system is constant. Energy cannot be created or destroyer, only converted from one form to another
    - Bond energy
        - Measured in kJ/mol
        - Farther the electrons away from nucleus the more potential energy
        - Energy is released when bonds break and is absorbed when they form new bonds
        - Enthalpy: sum of internal energy (heat content) of a system
            - $H = U + P(v)$
            - Energy is absorbed when reactant bonds break and energy is released when product bonds form

Enthalpy

A few terms…

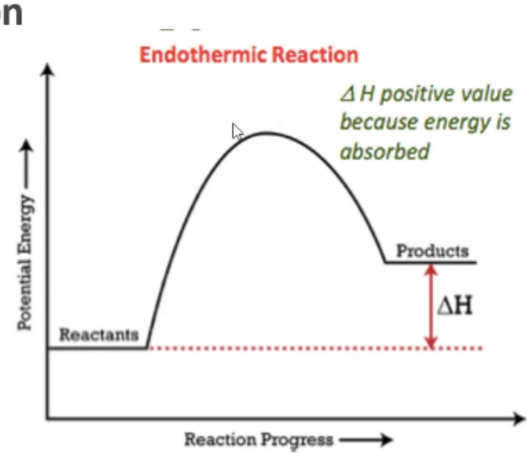
- Activation energy (E_a) – the minimum amount of energy that reactants must absorb to start a reaction
- Transition state – a temporary condition during a chemical reaction in which the bonds in the reactants are breaking and the bonds in the products are forming
- Change in potential energy (ΔH)



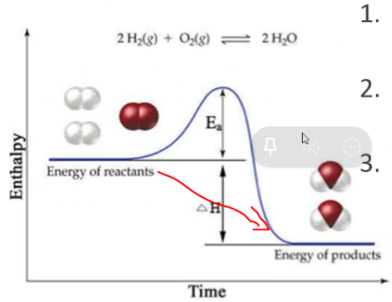
- Exothermic reactions
  -

Endothermic Reaction

- energy absorbed, products have higher E_p than reactant
- Positive ΔH



-



1. What does E_a stand for?
2. What does ΔH stand for?
3. Is this endothermic or exothermic? Why?

-

2. In every transfer or conversion, some of the useful energy in the system becomes unusable and increases the entropy
    a. Energy transformation in never 100% efficient
    b. Entropy is a measure of disorder in a system
    c. Think of a room and how it always gets messier
    - Entropy: in chemical reactions, entropy will increase in following circumstances
        - Solid becomes liquid
        - Liquid becomes gas
        - Complex molecule becomes simpler
        - .
    - Catabolic reaction → energy released, entropy increases
        - exothermic reaction and spontaneous process
    - Anabolic reactions → cells trying to become less messy as their building things
        - While it seems this way, its prob not cuz anabolic reactions require energy which they most likely get from catabolic reactions
        - There is order within the disorder
    - Look at cells and atp using entropy tomorrow
    - Gibbs free energy
        - Gibbs discovered relationship between energy change and temperature of reaction n how relationship could help determine…

• The free energy change can be calculated:

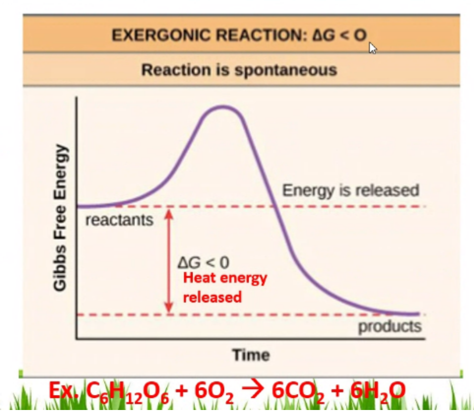
$$\Delta G = \Delta H - T\Delta S$$

Where
ΔG = change in free energy
ΔH = change in enthalpy
T = Temperature in Kelvin
ΔS = change in entropy

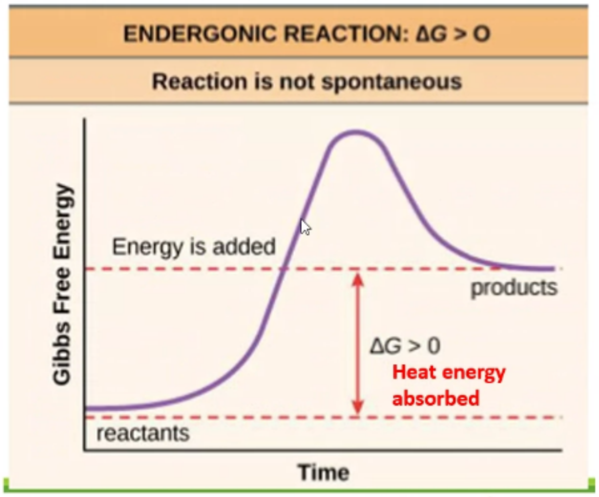
Gibb's Free Energy $\Delta G = \Delta H - T\Delta S$

	$\Delta H < 0$	$\Delta H > 0$
$\Delta S > 0$	$\Delta G < 0$	$\Delta G < 0$ at higher temp $\Delta G > 0$ at lower temp
$\Delta S < 0$	$\Delta G < 0$ at lower temp $\Delta G > 0$ at higher temp	$\Delta G > 0$

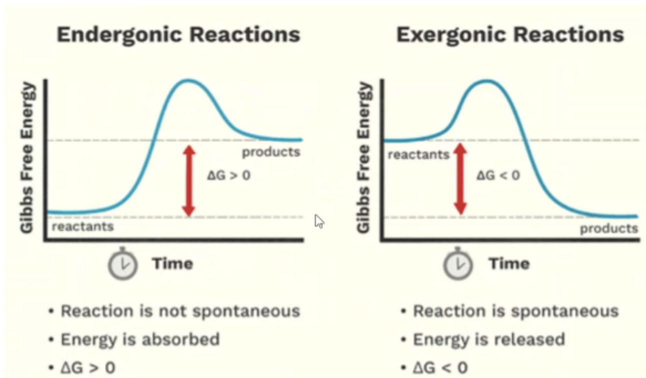
    -



    -
    - Exergonic means like if theres free energy

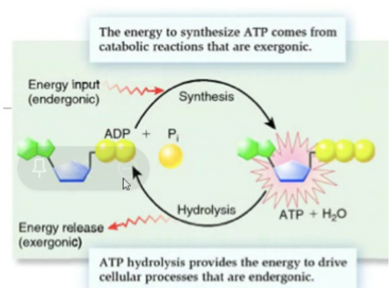


- Ex. $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
- So many words starting with E → review lol



- Delta G not affected by enzyme
- Coupled reactions
    - Cells are able to make endergonic reactions from the energy supplied by the exergonic reactions.

      Energy coupling is the transfer of energy from one reaction to another in order to drive the second reaction.



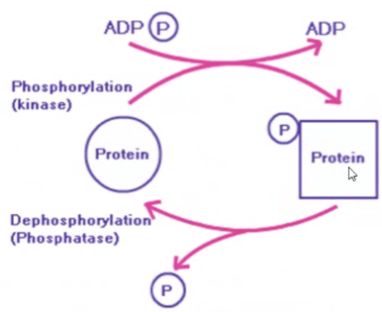
ADP and Inorganic Phosphate

The inorganic phosphate can participate in a wide range of chemical reactions:

1. Phosphorylation
2. Substrate level Phosphorylation
3. Oxidative phosphorylation

-

1. Phosphorylation



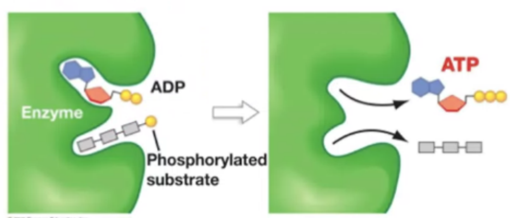
The inorganic phosphate attaches to a protein. This process is known as ***phosphorylation.***

-

2. Substrate Level Phosphorylation

Used to form ATP directly in an enzyme-catalyzed reaction.

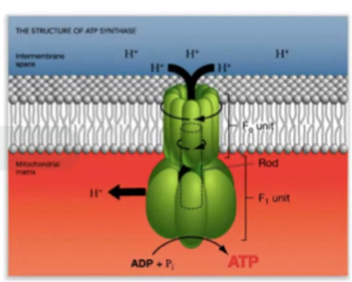
The inorganic phosphate is removed from the protein and attached to ADP to make ATP.



-

3. Oxidative Phosphorylation

- Used in cellular respiration within mitochondria to produce ATP
- Channel opens when there is a high concentration of H^+ in the intermembrane space
- H^+ are pumped back in to create ATP



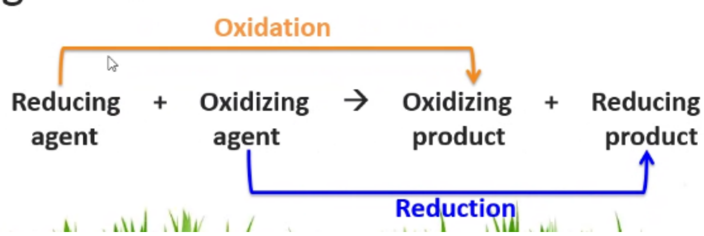
-

- Redox oml LEO says GER
    - Oxidation or “Ox”
        - Energy metabolism in cells involves oxidation reactions
        - Oxidation involves the transfer of an electron from a molecule which is said to be oxidized to another molecule which is said to be reduced
        - .
    - Reduction
        - Overall charge is reduced i.e. gains electrons

Oxidation	Reduction
Addition of Oxygen	Removal of Oxygen
Removal of Hydrogen	Additional of Hydrogen
Loss of electron	Gain of electron

-

In general:



-

Redox Reactions & Coenzymes

The redox reactions of cellular respiration commonly involve the following coenzymes:

1) NAD: Nicotinamide adenine dinucleotide

$$NAD^+ + H^+ + \frac{1}{2}O_2 \rightarrow NADH + H^+$$

3ADP 3ATP

Oxidative phosphorylation

2) FAD: Flavin adenine dinucleotide

$$FADH_2 + \frac{1}{2}O_2 \rightarrow FAD + H_2O$$

2ADP 2ATP

-

LEO the lion says GER

- Lose
- Electrons
- Oxidized!

SAYS...

- Gain
- Electrons
- Reduced!

OIL RIG

- Oxidation
- Is
- Loss of electron
- Reduction
- Is
- Gain of electron

-
-

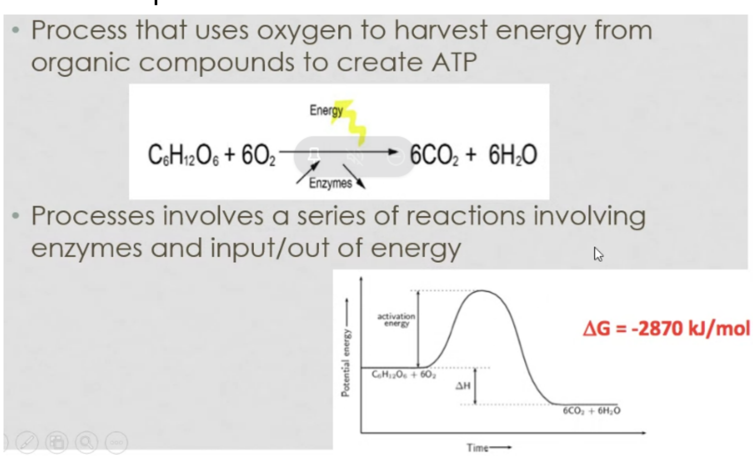
3. a

Cellular respiration

Introduction

- Most energy entering the biosphere is solar radiation
- Energy from food → stored as ATP
- Obligate aerobes → animals that require oxygen

Aerobic cellular respiration

- 

- Exothermic reaction
- Recall in cellular respiration:
    - Many exothermic reactions in this process are REDOX reactions
    - Redox involves the transfer of electrons between 2 molecules
    - NAD and FAD are electron carriers and become NADH and FADH2

3 main goals of cellular respiration:

Three main goals:

1. To break the bond in glucose (6C molecule) to create $6CO_2$ molecules
2. To move hydrogen atoms from glucose to oxygen to create $6H_2O$ molecules
3. To trap a large quantity of free energy so that it can be used to create ATP

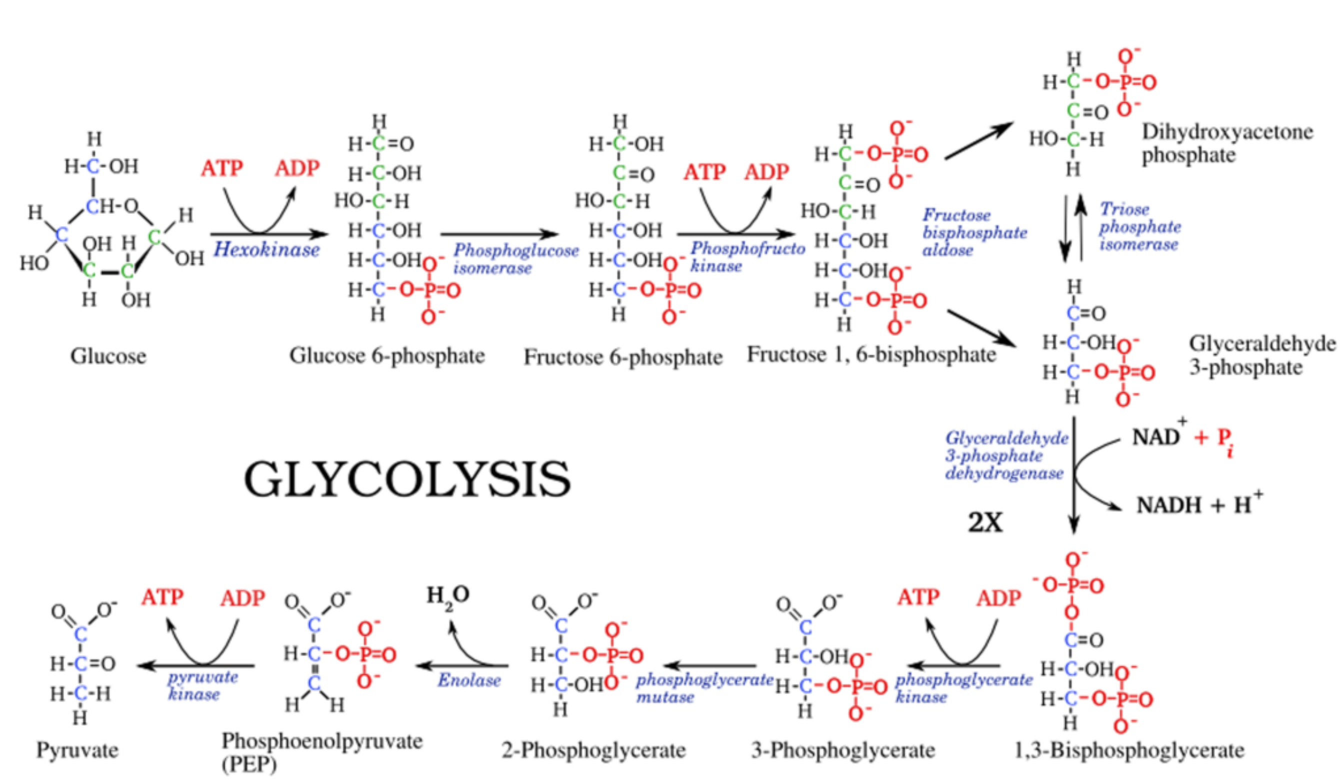
-

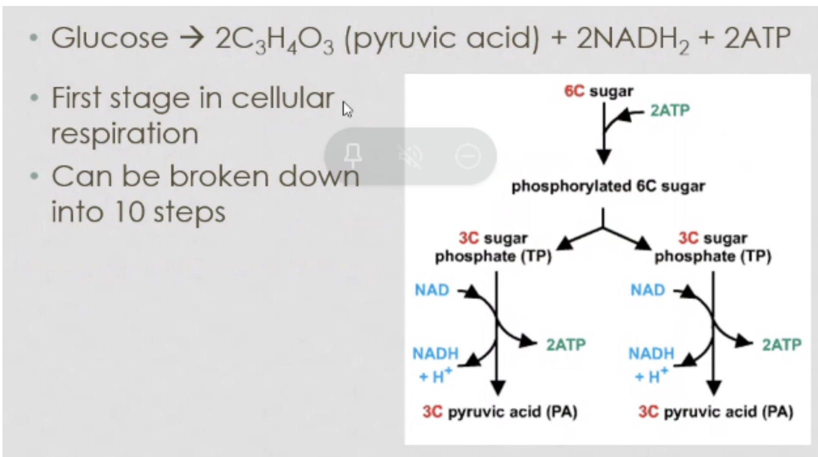
4 stages of cellular respiration

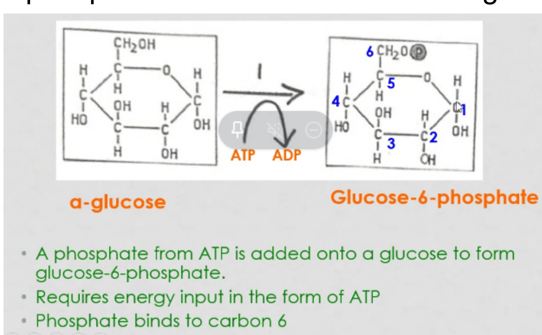
- Glycoiss
- Pyruvate oxidation
- Krebs cycle (citric acid cycle)
- Electron transport chain and chemiosis (ETC)

- Make sure u didnt miss anythign

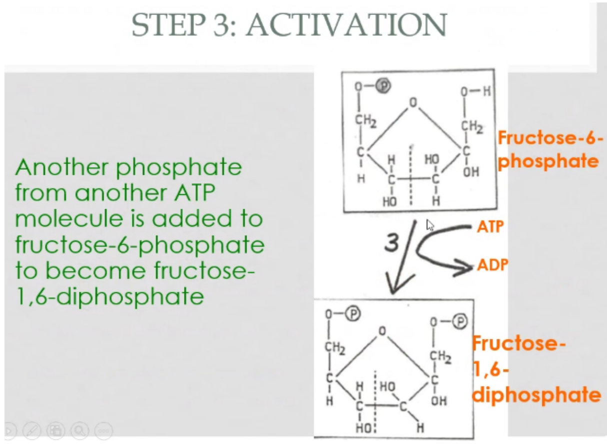
Glycolysis



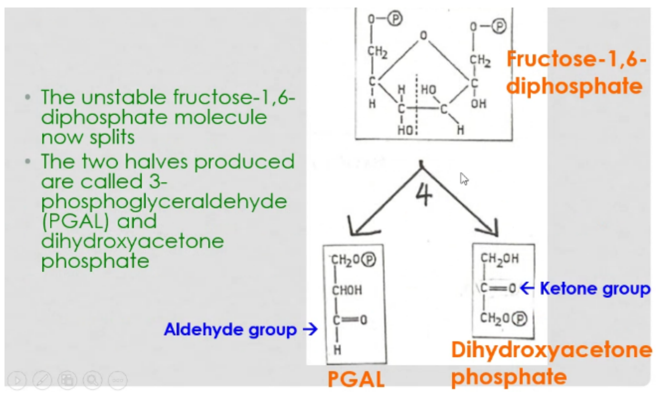
- 

- Step 1: activation
    - A phosphate from ATP is added on a glucose to form glucose 6-phosphate
    - 

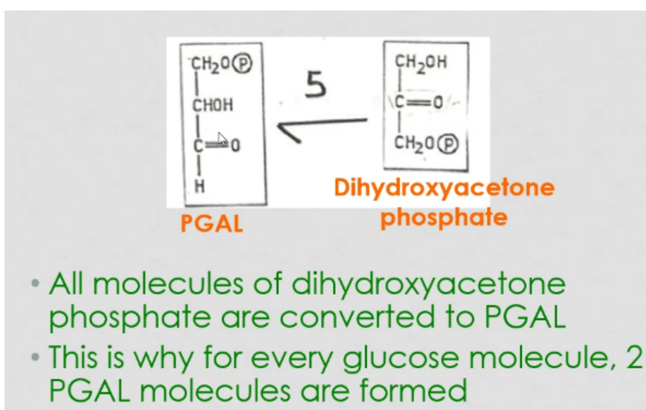
- Step 2: isomerization
    - Glucose 6 phosphate is rearranged to become fructose phosphate
- Step 3:



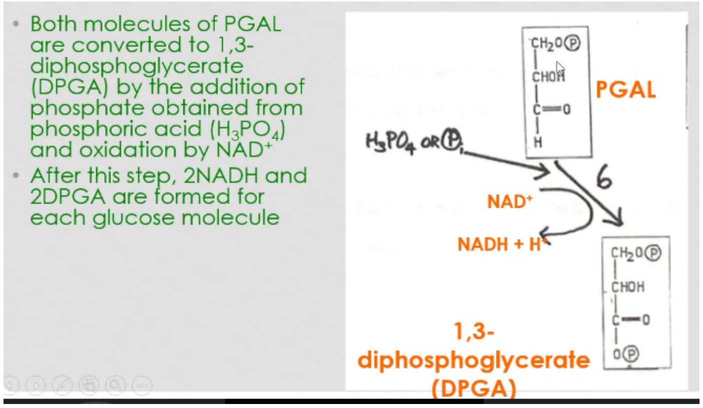
- -
- Step 4 - cleavage

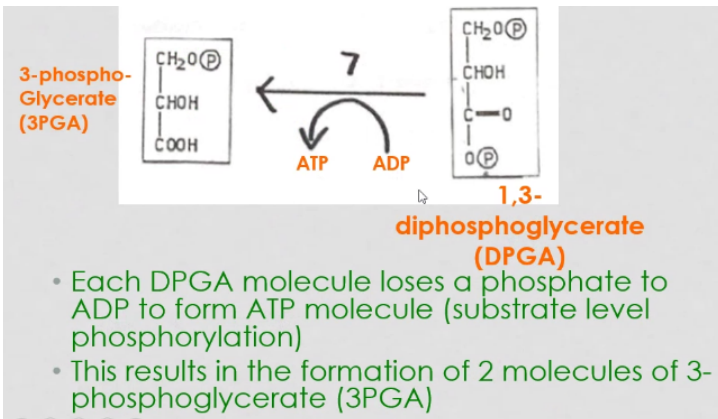


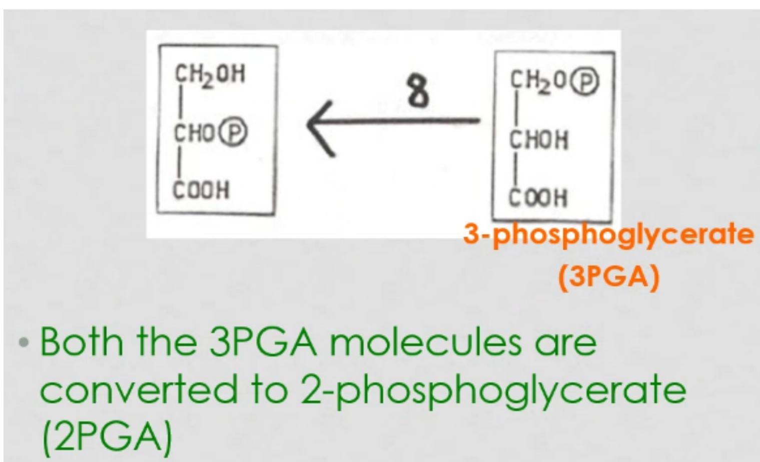
  - -
  - Just call it PGAL and dihydroxyacetone phosphate :_)
- Step 5: isomerization



  - -
- Step 6: phosphorylation oxidation

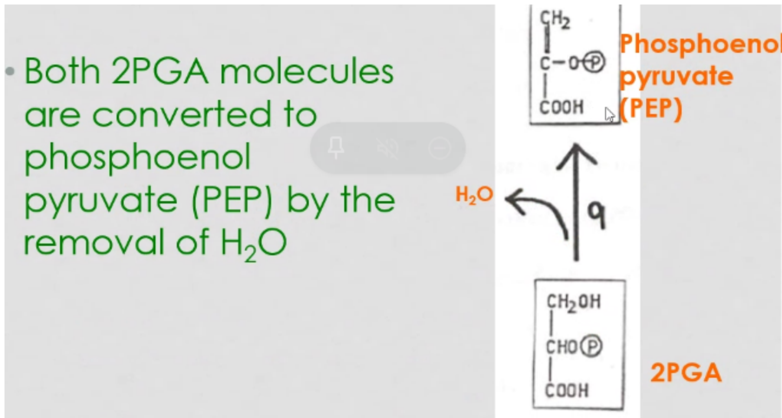
- 

- Step 7: phosphorylation
    - 

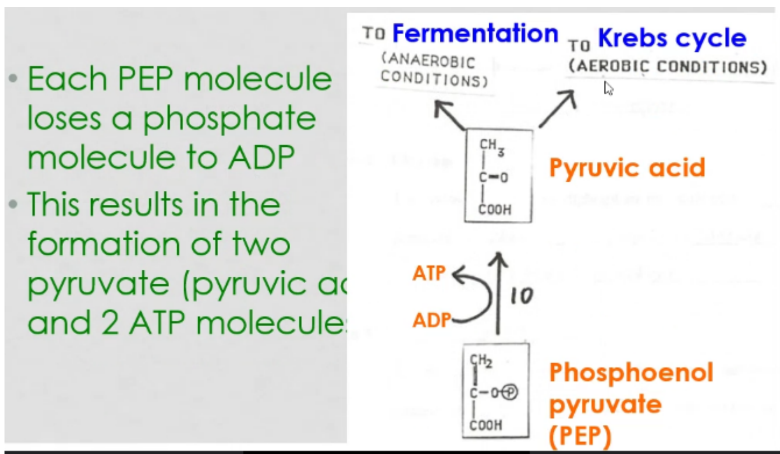
- Recall substrate level phosphorylation
- Step 8: isomerization
    - 

    - Not losing a P, just moving it
- Step 9: dehydration

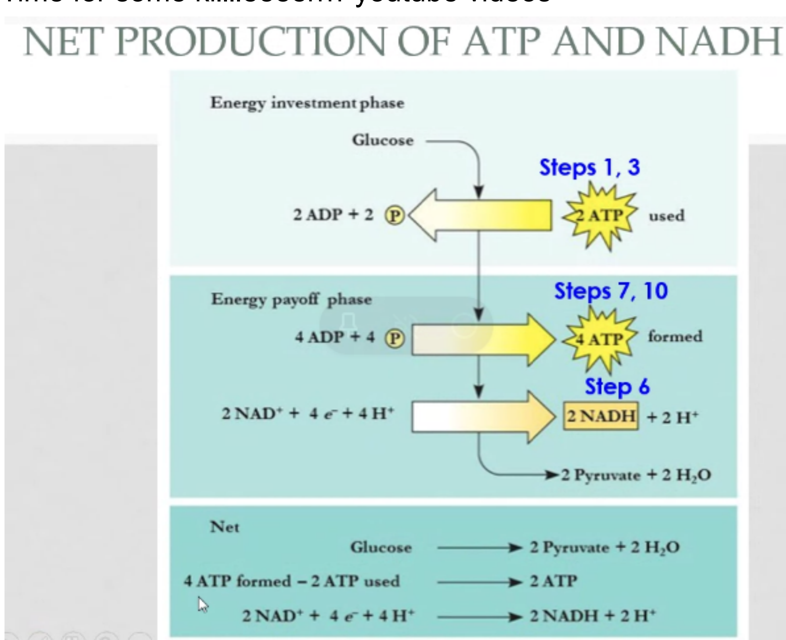
-



- Step 10: phosphorylation



- Time for some killlleeeerrrr youtube videos



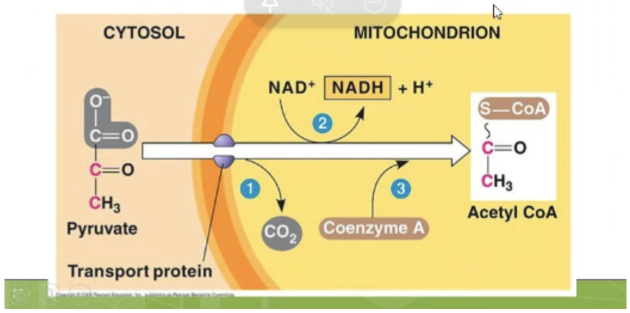
-

Homework - 172-174
Complete the puzzle name and structure
Glycolysis fill in the blank worksheet

Krebs Cycle

2. Pyruvate oxidation

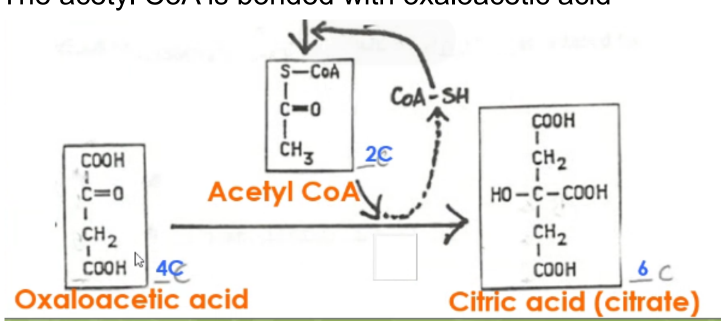
- Two pyruvate molecules actively transported into mitochondrial matrix
- Carboxyl group of the pyruvate acid loses a CO_2
- The remaining 2C fragment ix oxidized to acetyl CoA while NAD^+ is reduced to NADH + H^+



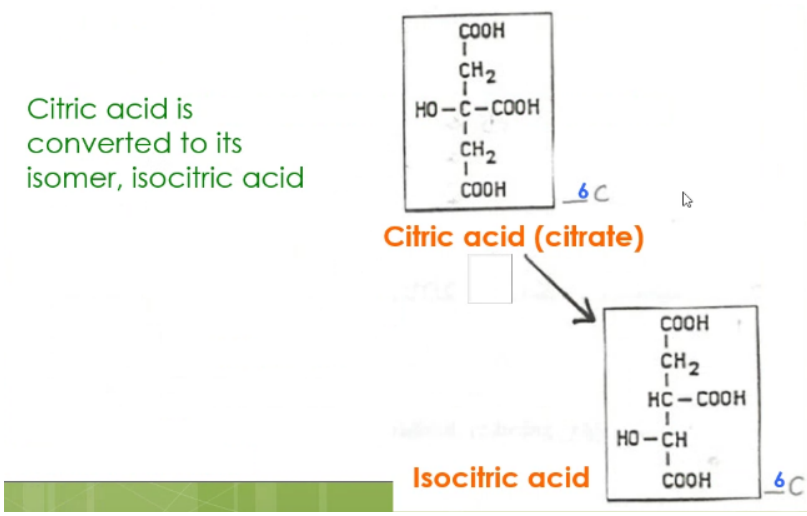
- At the end you have Acetyl CoA left

3. Krebs cycle

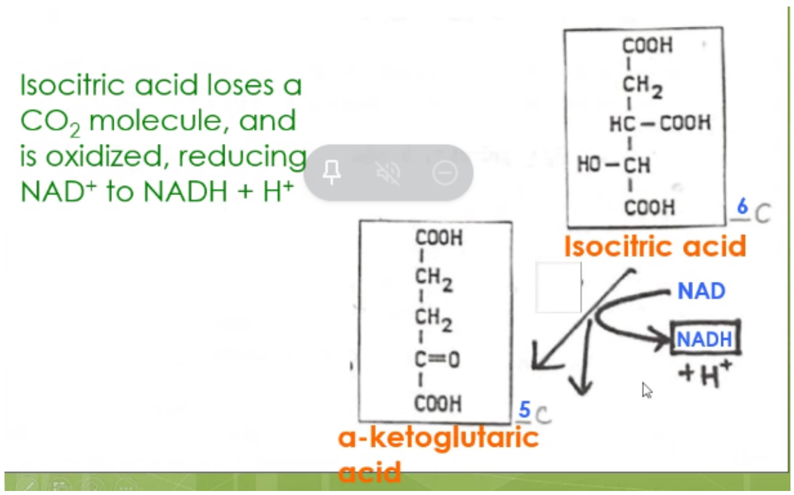
- Aka citric acid cycle
    - Occurs in the mitochondrial matrix
    - Main goal is to produce energy
    - Many enzymes, coenzymes and other molecules are in an organized pattern on the inner membrane.
    - Can be divided into 8 steps.
- Step 1 - formation of citric acid cycle
    - The acetyl CoA is bonded with oxaloacetic acid



- Step 2 isomerization

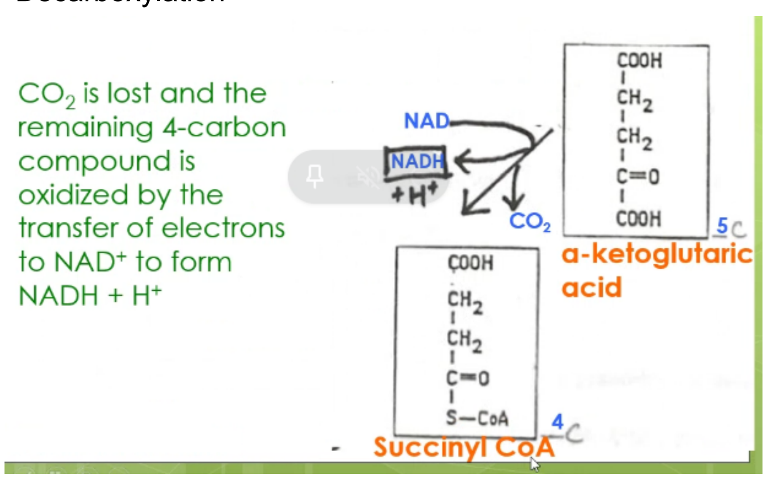


- Step 3 - Decarboxylation

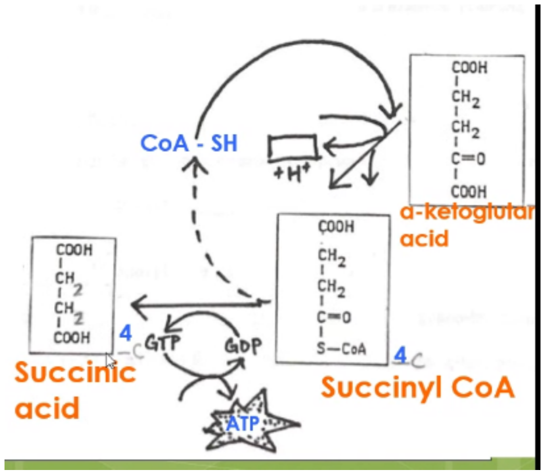


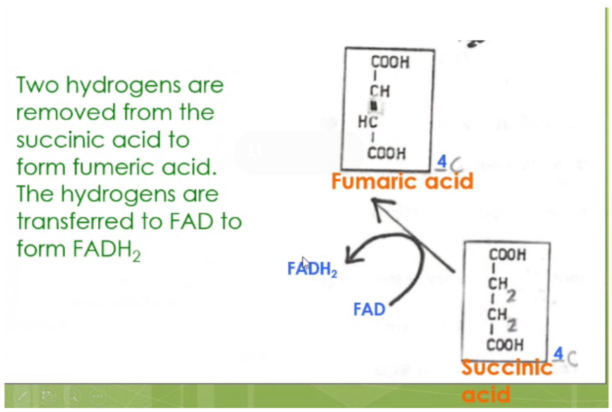
- NADH will be later used to help make ATP

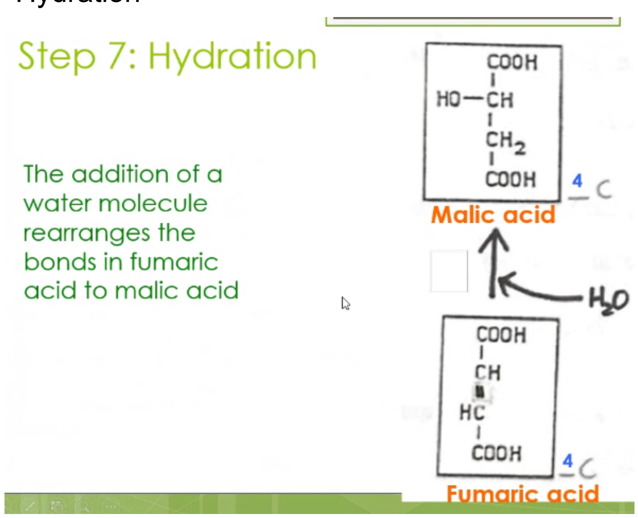
- Step 4 - Decarboxylation



- Step 5 - Substrate level phosphorylation
  - CoA is displaced by a phosphate group to form guanosine triphosphate (GTP)
  - GTP is similar to ATP which is formed when GTP donates a phosphate to ADP

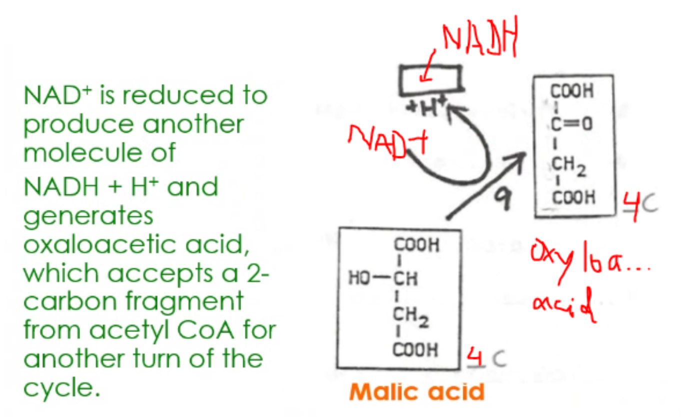
- 

- Step 6 - Decarboxylation (again yay)
    - Two hydrogens are removed from the succinic acid to form fumeric acid
    - The hydrogens are transered to FAD to form FADH
    - 

- Step 7 - Hydration
    - 

- Step 8 - formation of oxaloactetic acid

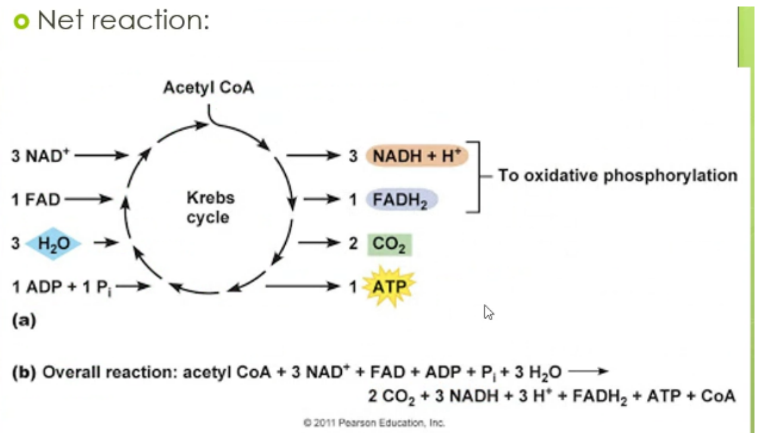
-



-

Krebs Cycle (again?)

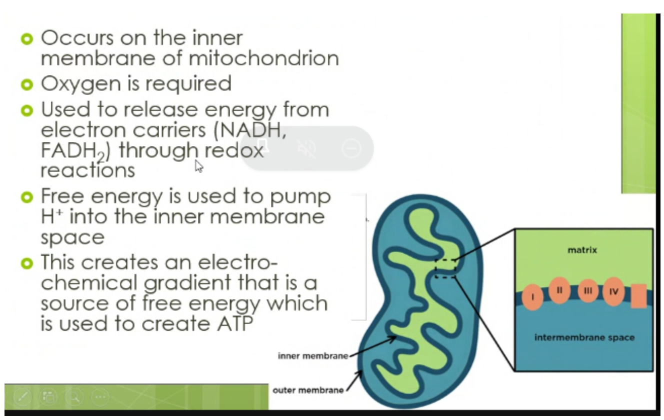
- Net reaction



-
- She's going to put up a sheet that has the entire cycle
- Glycolysis
    - In assignments somewhere

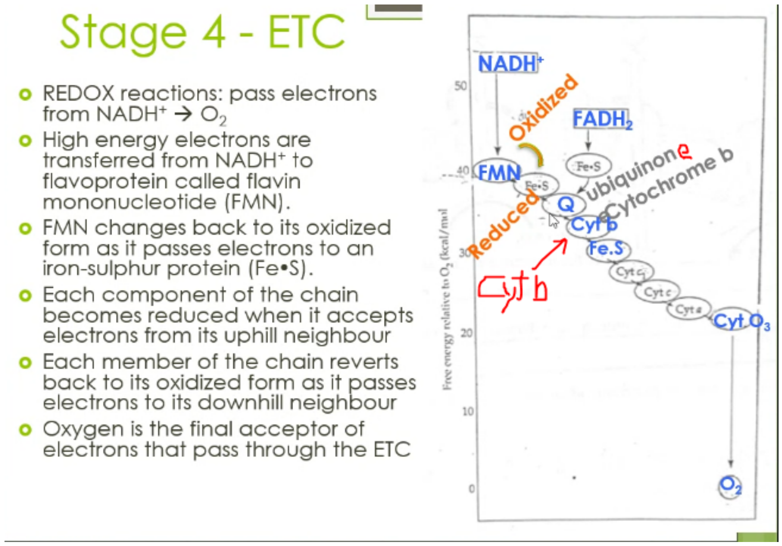
Stage 4: Electron transport chain (ETC)

- Occurs on inner membrane of mitchondria

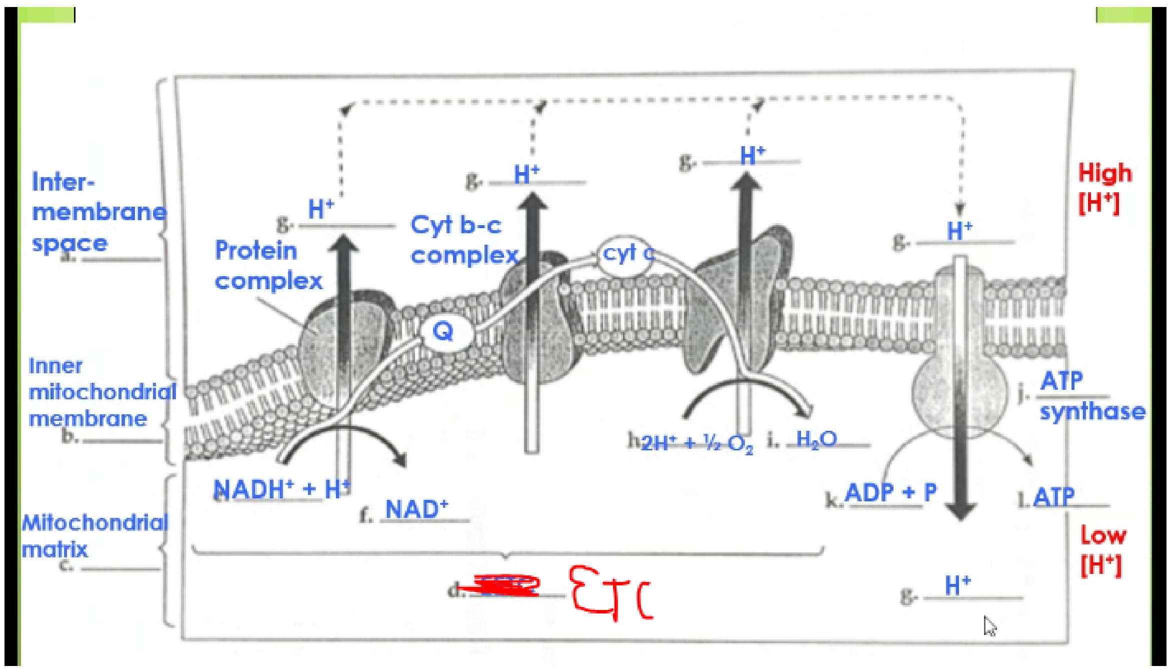


-

-



- ^Overall energy drop:
    - Just know what these stand for, don't need to memorize this process

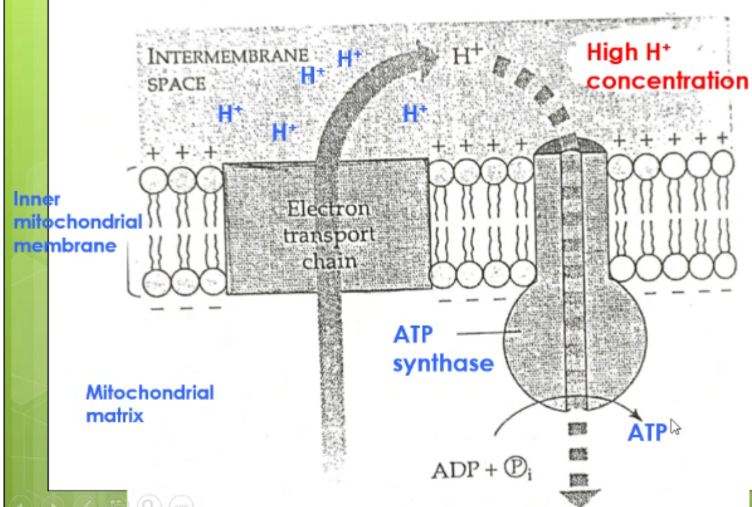


-
- Stage 4: Chemiosmosis

Stage 4: Chemiosmosis

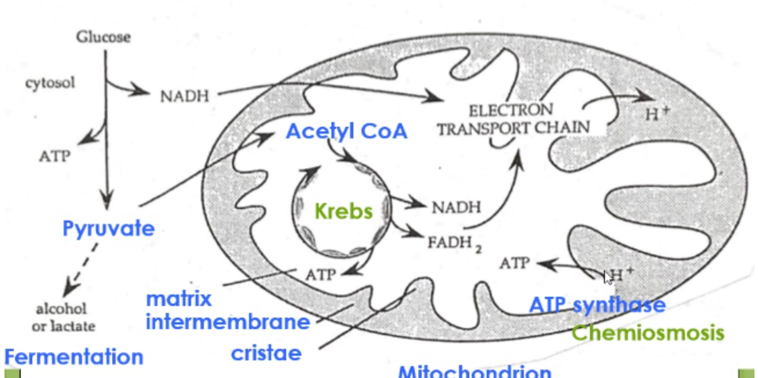
- As the protons are pumped out of the matrix to the intermembrane space, it creates an electrochemical gradient
- The potential energy stored in the proton gradient is called proton motive force
- Protons can diffuse back into the matrix through ATP synthase molecule channels
- As the protons diffuse back into the matrix, they lose their energy, permitting the ATP synthase to make ATP through chemiosmosis

Stage 4: Chemiosmosis

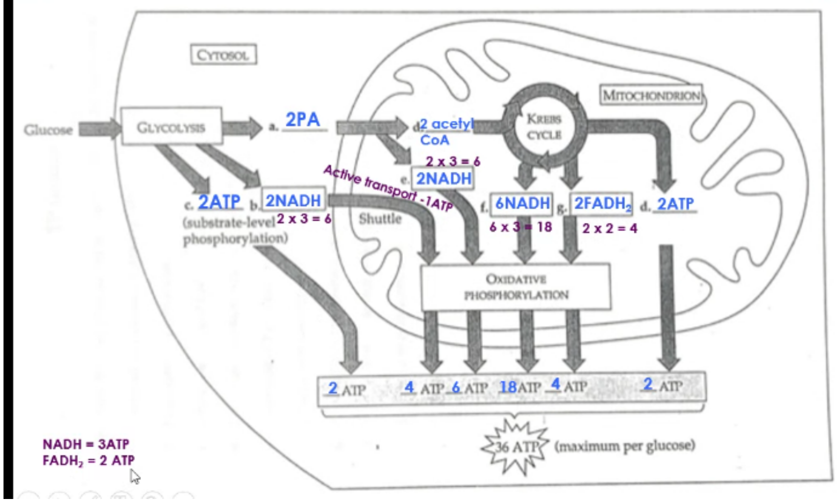


Summary

Glycolysis



Counting ATP



-

ATP Games

How many ATP's would be gained by a cell from the aerobic respiration of:

a) 1 molecule of fructose-1,6-disphosphate?

b) 2 molecules of phosphoenol pyruvate?

-

ATP Games

How many ATP's would be gained by a cell from the aerobic respiration of:

a) 1 molecule of fructose-1,6-disphosphate?

Glycolysis: 2 NADH – 2ATP = 4 ATP

4 ATP = 4 ATP

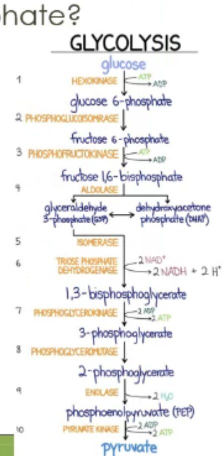
Krebs Cycle:

8 NADH = 24 ATP

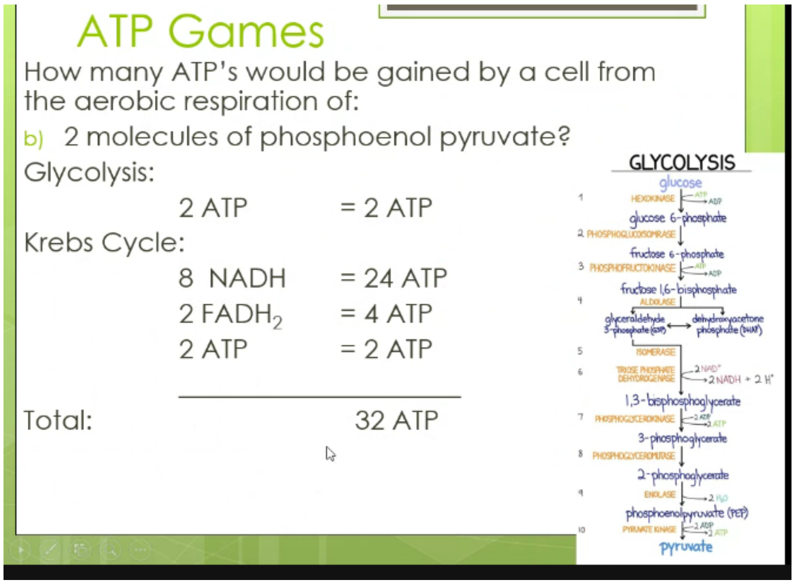
2 $FADH_2$ = 4 ATP

2 ATP = 2 ATP

Total: 38 ATP



-



-
- Homework
- Potato lab

Anaerobic pathways

- Where does this take place?
  - Human gut
  - Wet environment (swamps, waterlogged soils)
  - Deep oceans
  - Deep underground

- Lower energy yield
- Uses the ETC that employs an inorganic substance rather than oxygen as he terminal electron acceptor (ie. sulfate, nitrate, iron ions)

- Can be used to fossilive urself
  - Step 1 → die

Fermentation

- Occurs when there's abundant of glucose but no oxygen
- Glycolysis requires glucose and NAD^+. The cells must find a way to generate NAD^+.
  - Ex. Yeast & bacteria
- Two forms of fermentation:
  1. Alcohol (ethanol fermentation
  2. Lactate (lactic acid) fermentation
- may occur under aerobic circumstances as a supplementary pathway to generate more ATP (ie. intense exercise)

Alcoholic fermentation

- Process in which pyruvate is decarboxylated
- Pyruvate + NADH + H^+ → CO_2 + ethanol + NAD^+
  - Numbers are doubled when including glycolysis since 2 pyruvate molecules are produced
- Low efficiency because ethanol is produced as a waste product
- Ethanol contains lots of energy
- Applications: baking, brewing alcohol
- Organisms can survive through fermentation, but can easily be outcompeted by other more efficient organisms

Lactate fermentation

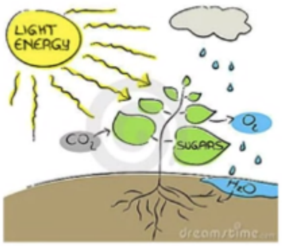
- Process in which pyruvate reacts with NADH and is converted directly into lactate and regenerates NAD^+
- Ex. bacteria, supplemental system
- Humans: during strenuous activities muscle cells demand ATP that exceeds the rate we can supply oxygen to ETC. Glycolysis proceeds quickly, producing 2ATP for every glucose and any excess pyruvate formed is converted into lactate
  - Pyruvate + NADH + H^+ → NAD^+ + lactate
- Following strenuous activity, oxygen content returns to normal, regenerates pyruvate and NADH from lactate which then goes through the Krebs cycle
- Lactate produced is transported to liver so it does not build up in muscle cells. The transport continues until lactate threshold is reached.

DONE CELLULAR RESPIRATION

NOW ON TO PHOTOSYNTHESIS

Overview

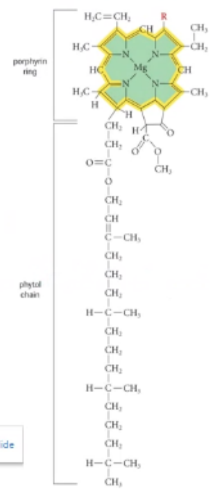
- A series of chemical reactions in which light energy is converted into chemical energy



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

Carbon dioxide from the atmosphere | Water | Organic matter | Oxygen

- Photosynthesis is carried out by a number of different organisms
- All contain chlorophyll
  - Absorbs light energy and begins process of photosynthesis
  - Chlorophyll *a* (blue green)
  - Chlorophyll *b* (yellow green)
  - They absorb different wavelengths of light

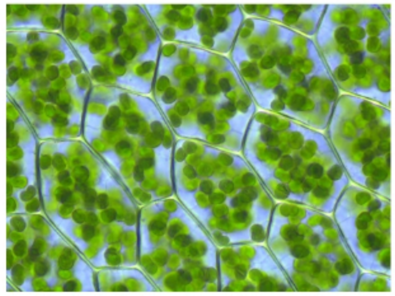


Prokaryotic Autotrophs - Cyanobacteria

- Make up largest group of photosynthesizing prokaryotes
- First organisms to harness the sun's energy
- Unicellular, but may grow in colonies
- Live in many different environments
- Grow rapidly in nutrient rich water (known to cause algal blooms)
  - can be toxic to fish, birds, humans, and other mammals

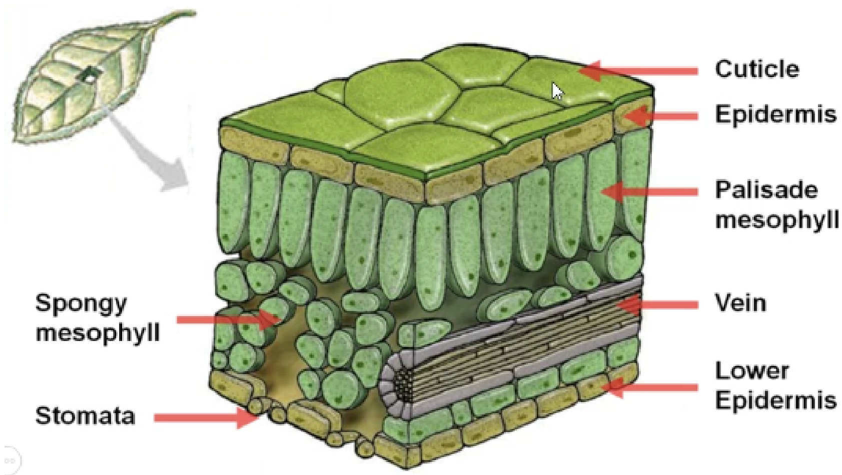
Eukaryotic Autotrophs - Algae, photosynthetic protists, plants

- Unlike cyanobacteria, algae, some protists, and plant cells contain chlorophyll within the photosynthetic membranes of discrete organelles called **chloroplasts**
  - gives leaves, stems and un-ripened fruit their characteristic green colour!

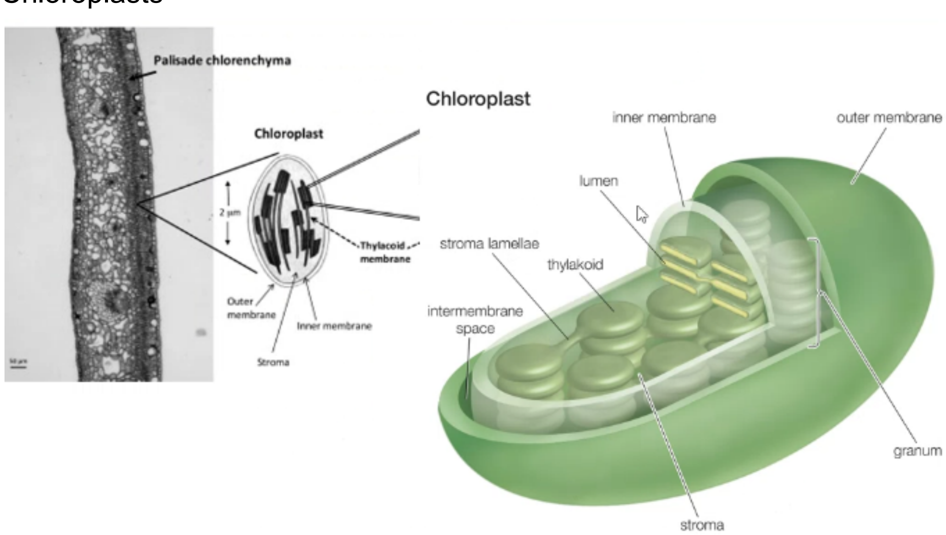


- Occurs in all green plants

Plant structure



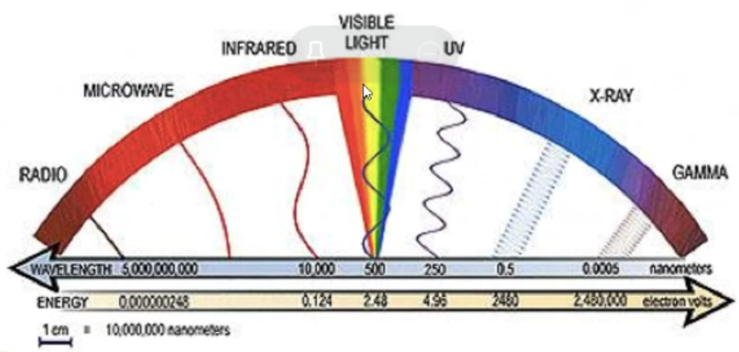
Chloroplasts



- Typical plant cell chloroplast approx. 3um to 8um in length and 2 um to 3 um in diameter
- Have two limiting membranes (outer and inner) enclosing an interior space filled with a liquid **stroma**
- Within the **stroma**, a system of membrane bound sacs called **thylakoids** stack on top of one another to form characteristic columns called **grana**
  - typical chloroplast has 60 grana each consisting of 30-50 thylakoids
- Adjacent **grana** connected to one another by unstacked **thylakoids** called lamellae
- Inside the thylakoids is a water filled space called the **Lumen**
- Chloroplasts have there own DNA and ribosomes, reproduce via fission

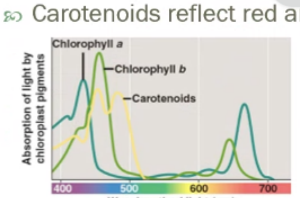
Absorption of energy as light

Each wavelength is associated with a certain amount of energy in its photons. The longer the wavelength, the smaller the amount of energy

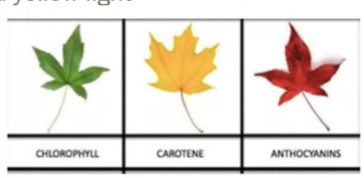


Pigments and absorption

- Pigments absorb different wavelengths of visible light. Depending on the pigment, it can absorb different combinations of colours.
- Chlorophyll a absorbs strongly red and blue light but does not absorb green or yellow light
- Carotenoids reflect red and yellow light



__Absorbance spectrum:__ a graph that shows the relative amounts of light of different wavelengths that a compound absorbs.



Depending on the time of the year, different pigments will be exposed and absorb and emit different wavelengths of light.

1. Englemann's Experiment
- Results show red and blue are preferred
- The bacteria are aerobic so they are attracted to areas where more oxygen is produced

//

Homewokr

- Potato Lab
- Read textbook p. 190 – 193
- Answer the following questions:
  1. What is the difference between fermentation and glycolysis?
  2. Describe one advantage and one disadvantage of a species that is able to perform fermentation. How do the advantage and disadvantage influence the energy efficiency of the species and where the species can live?
  3. Using what you know about lactic acid fermentation, explain why a person could not perform strenuous exercise indefinitely.

Pot lab

1. To make the saltwater solution. Bring 500mL of water to a boil, remove from heat, and then gradually add salt to the water, one teaspoon at a time, until you start seeing the little grains of salt floating on the bottom that can't dissolve, meaning the mixture is now pure salt water. Let the mixture cool until it is at room temperature to avoid cooking the potato. Label each 500mL cup with 1%, 5%, 10%, and pure water while you wait for it to cool.

2. To make saltwater variations of 1%, 5%, 10%, use an accurate measuring device to pour the appropriate amount of salt water into each cup, and then add the appropriate amount of freshwater to make up the remainder of the solution. For example, to make 10% saltwater solution, pour 10mL of saltwater into the cup, and then put 90mL of freshwater into the cup, to add up to 100%. To make 50% saltwater solution, pour 50mL of saltwater and add 50mL of freshwater into the cup.

- How much water & salt water to add to get 1%?
- 1mL salt water + 99 mL freshwater
- How much water & salt water to add to get 25%?
- 25mL salt water + 75 mL freshwater

- What if I don't have a measuring cup?
- 100%: full cup of salt water
- 50%: half cup of salt water + half freshwater
- 25%: quarter cup of salt water + ¾ freshwater

//

Photosynthesis

- Converts light energy into the chemical bonds of glucose (plants are Autotrophs).
- Occurs in 2 main steps:
  1. "Photo' – Light dependent reactions: uses energy to make ATP and NADPH
  2. 'Synthesis' – light independent reactions: uses CO_2 and NADPH to make glucose
- The overall rxn is:

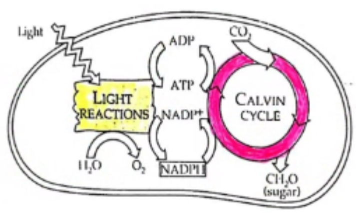
$$6CO_2 + 6H_2O + \text{Light Energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

Glucose

Light dependent reaction

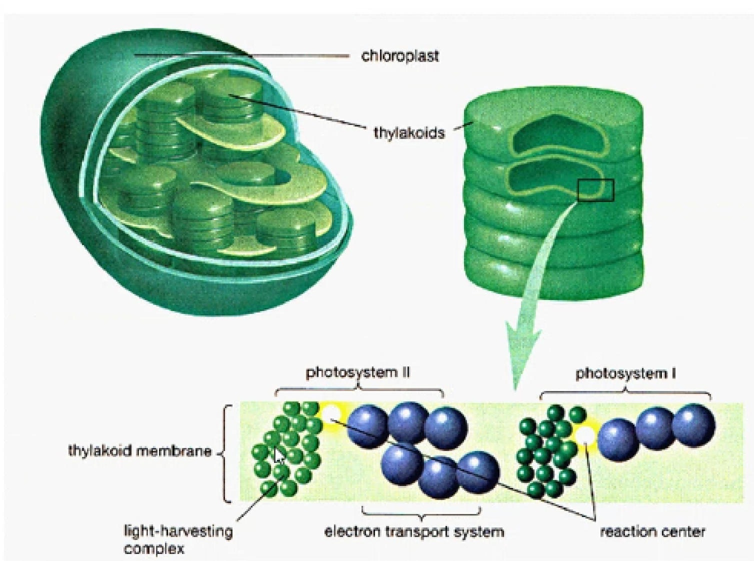
- Occurs in the Thylakoid Membrane of the chloroplast
- They are a series of chemical reactions in which light energized the electrons of chlorophyll molecules.
- The chlorophyll captures light energy and uses it to break down water molecules and create ATP and NADPH.
- The oxygen is released as a product.
- The ATP and NADPH are carried over to the Light Independent Rxn.
- Two types of light dependent reactions:
  1. Non-cyclic photophosphorylation
  2. Cyclic photophosphorylation

- 1. Non cyclic photophosphorylation
  - A process where chlorophyll electrons are passed to $NADP^+$
  - It is non-cyclic because the chlorophyll electrons are replenished from the decomposition of water molecules and ATP is produced
  - 3 Parts:
    - 1. PHOTOEXCITATION
    - 2. ELECTRON TRANSPORT
    - 3. CHEMIOSMOSIS



-

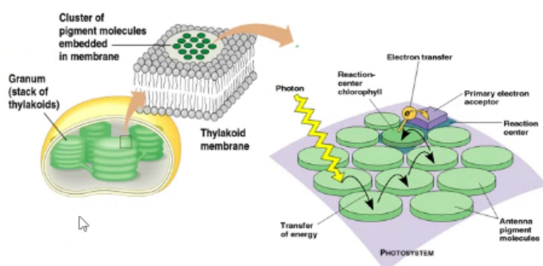
The Photosystems are imbedded in the thykaloid membrane



-

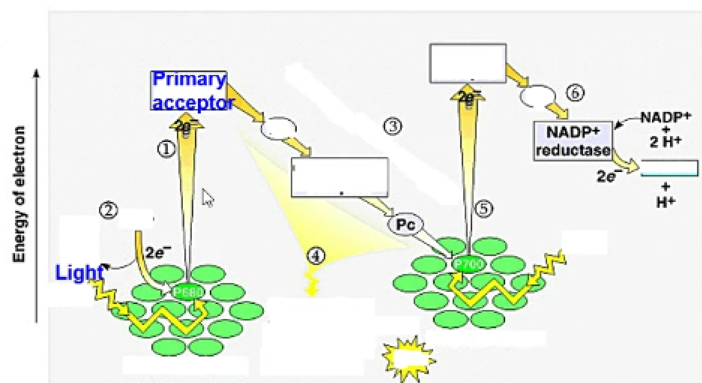
- a. Photoexcitation
  - Photon = Packets of electromagnetic radiation
  - Occurs in Photosystems (clusters of photosynthetic pigments embedded in the thylakoid membranes
  - Photosystems absorb photons of particular wavelengths
  - Consist of an antenna complex and rxn centre

  - Two types: 700, 680 refers to wavelength absorbed (nm)
    - PS I (P700)
    - PS II (P680)
-
  - Antenna complex absorbs a photon of light
  - Transfers the energy from pigment to pigment until it reaches a chlorophyll a molecule in the centre of the rxn centre
  - The electron of this chlorophyll moves from ground state to a higher potential energy level (excitation)



-
Photoexcitation

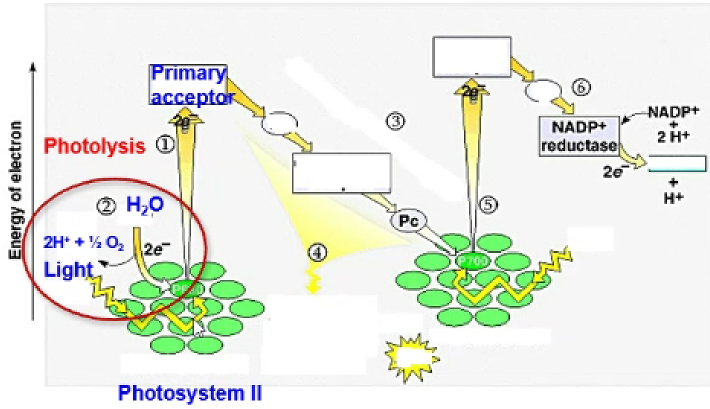
- Photons strikes the chloropyll a which prefers a wavelength of 680 (P680)
- The accessory pigments (chlorophyll b & carotenoids) help collect light and direct it to the reaction centre
- Excited electrons oxidize P680 molecule, transferring electrons to the primary acceptor
- This happens twice sending 2 electrons to primary acceptor



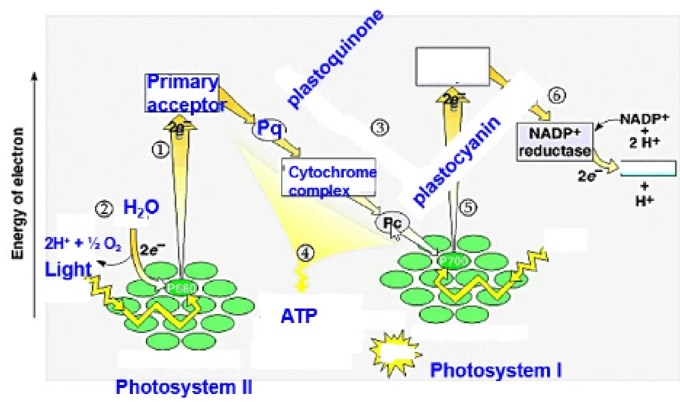
9

-

- Photolysis is the break down of water in presence of light
- It produces oxygen as a by-product
- The process also releases 2 electrons to replace those that have left PS II
- The protons remain in Thylakoid space, contributing to H+ gradient that drives chemiosmosis

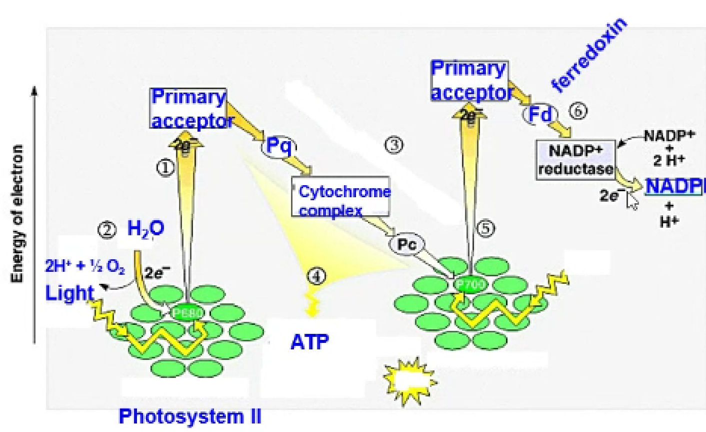


- The excited electrons from P680 flow down an electron transport chain to P700
- providing energy for ATP synthesis, and regenerating the lost electrons that P700 used to reduce $NADP^+$
- PQ gain protons from the stroma and releases them into the lumen
- Pc shuttles electrons to PS I



11

- Photons strike PSI boosting electrons to a high-energy state again, and these electrons are passed to primary acceptor
- Electrons move down transport chain to $NADP^+$, reducing it to NADP
- A second electron and a proton from stroma are added to NADP by $NADP^+$ reductase forming NADPH



- Further reduces concentration of protons outside the thylakoid, making outside thylokoid further concentrated in protons
- Non Cylcic summary

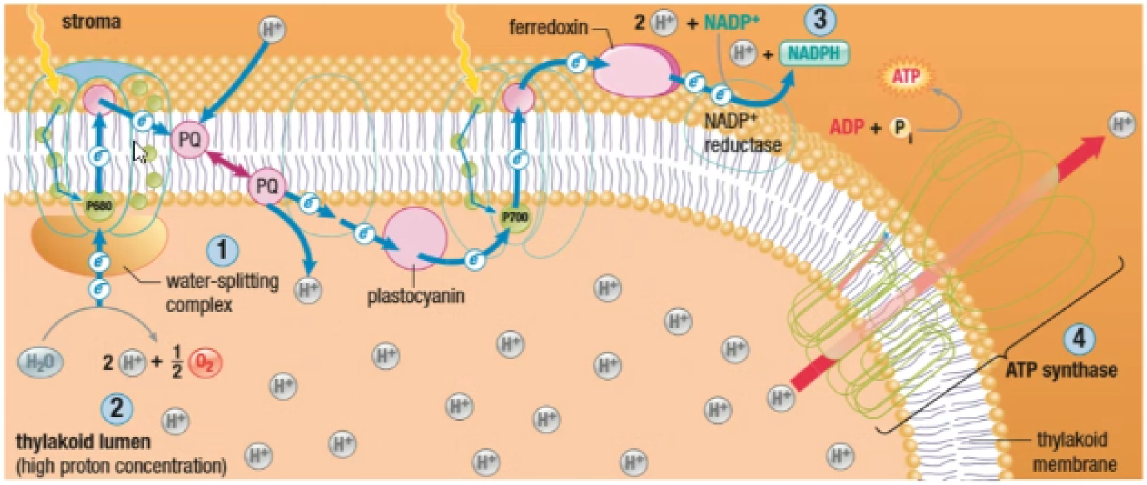


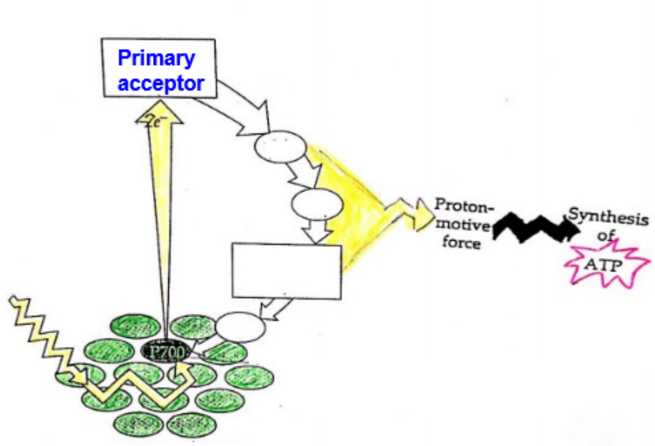
Figure 4 (1) A proton gradient is established by the carrying of protons across the membrane by PQ, (2) by the releasing of protons into the lumen during the oxidation of water, and (3) by the removal of protons from the stroma during the reduction of $NADP^+$. (4) ATP is then synthesized as protons move through the ATP synthase complex.

- 2. Cyclic photophosphorylation
  - Most plants perform non-cyclic
  - Under some circumstances when plants need more ATP, they will perform cyclic photophosphorylation
  - This process does not involve PS II and its product is ATP.

Cyclic Photophosphorylation	Non-Cyclic Photophosphorylation
Only PS I is involved	PS I and PS II are both involved
Water is not required	Photolysis of water is required
Oxygen is not evolved	Oxygen is evolved
NADPH is not synthesized	NADPH is synthesized
Used to produce additional ATP in order to meet cell energy demands	Products can be used for the light independent reactions

-

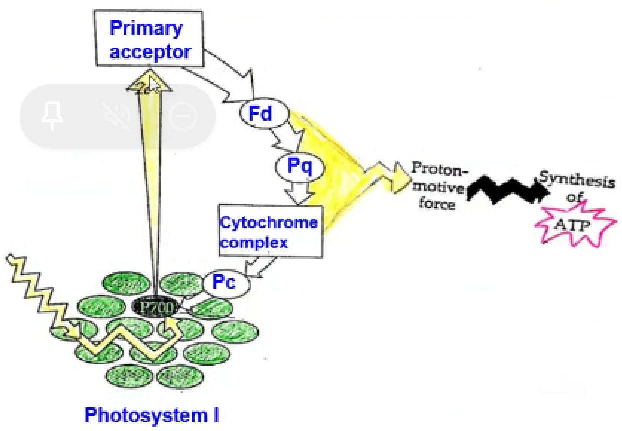
- Pigments of the antenna assembly of PS I absorb light
- The energy reaches P700 (chlorophyll a) at the reaction centre
- The electrons are trapped by the primary



16

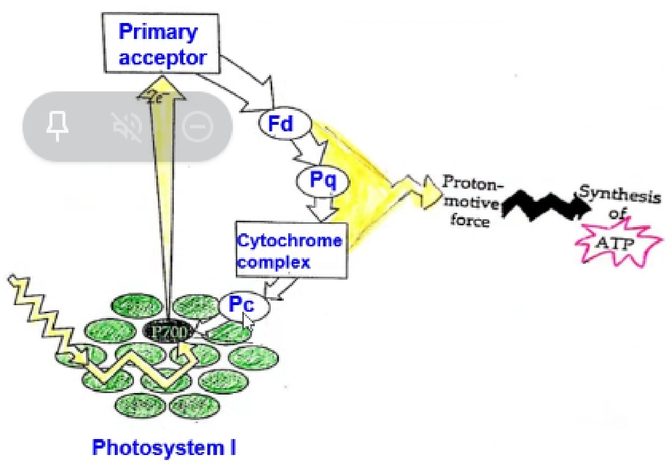
-

- The primary electron acceptor brings the electrons to a chain that includes
  - Fd (ferredoxin)
  - Pq (plastoquinone)
  - Cytochrome complex
  - Pc (plastocyanin)

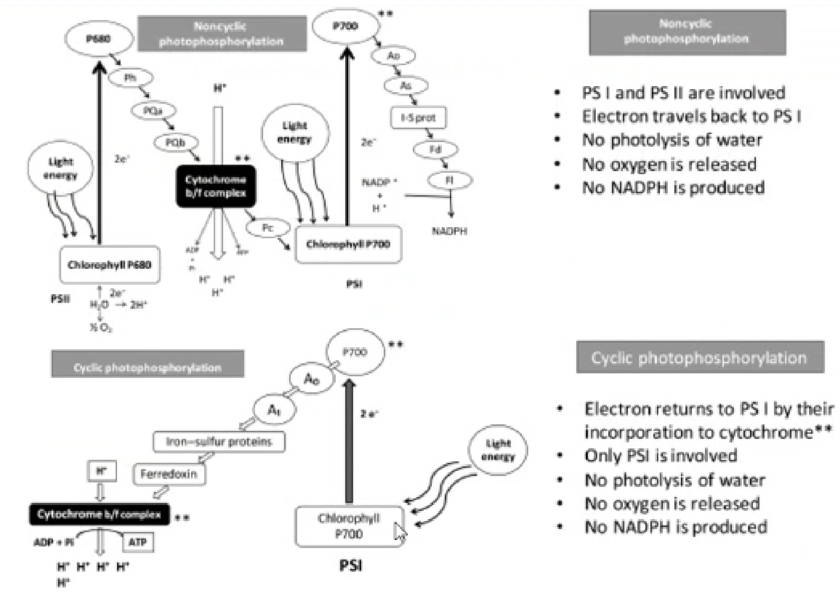


-

- After the electrons have "fallen" down the chain, P700 accepts the electrons from Pc
- The fallen electrons are coupled with the synthesis of ATP (chemiosmosis)



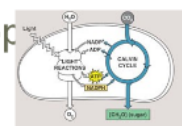
-
- Comparison

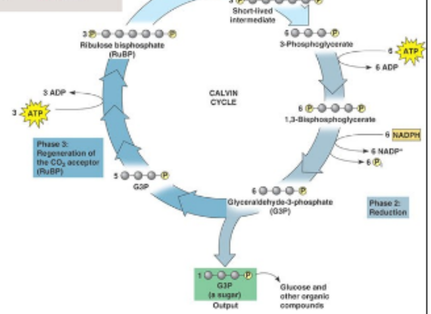


-

- Light independent Rxn - Calvin Cycle / Dark reactions

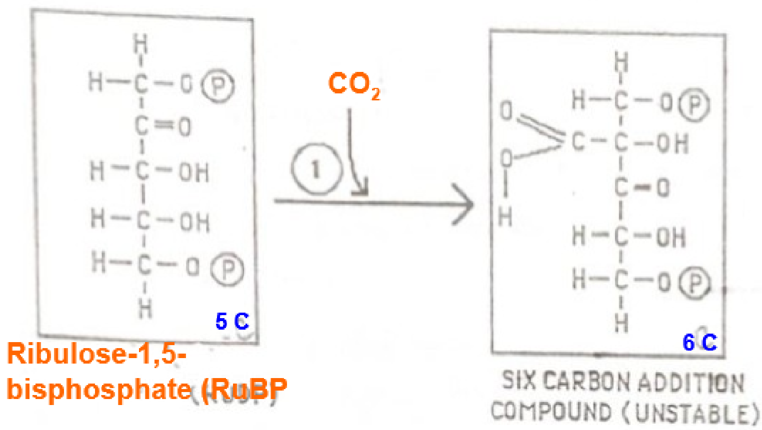
- Calvin Cycle (aka. Dark reactions)
- Also called C_3 photosynthesis (since first compound formed is a 3C molecule
- Occurs in stroma of chlorop
- Cyclic series of reactions
- Consists of 8 steps



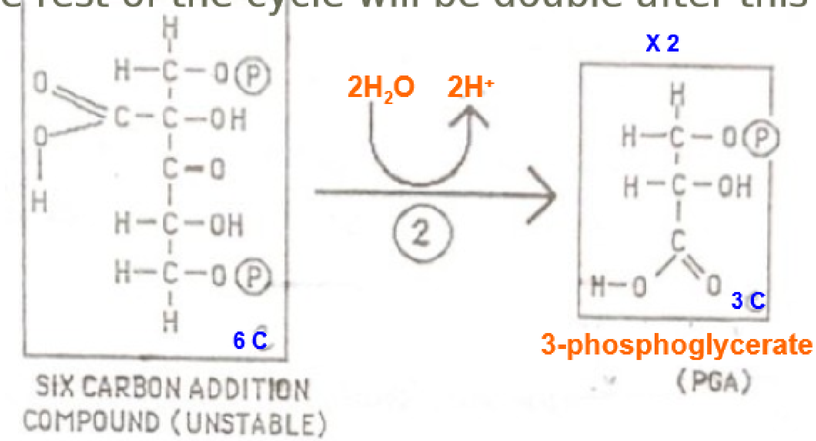


-

- Step 1: Carbon Fixation
  - CO_2 joins with 5C compound – ribulose-1,5-bisphosphate (RUDP) to create an unstable 6C compound



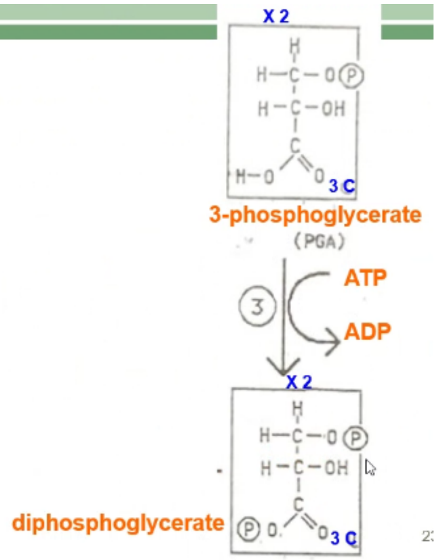
- Step 2: Hydrolysis
  - Water enters here, breaking the unstable 6C molecule into 2 molecules of 3-phosphoglycete (3PGA)
  - The rest of the cycle will be double after this step



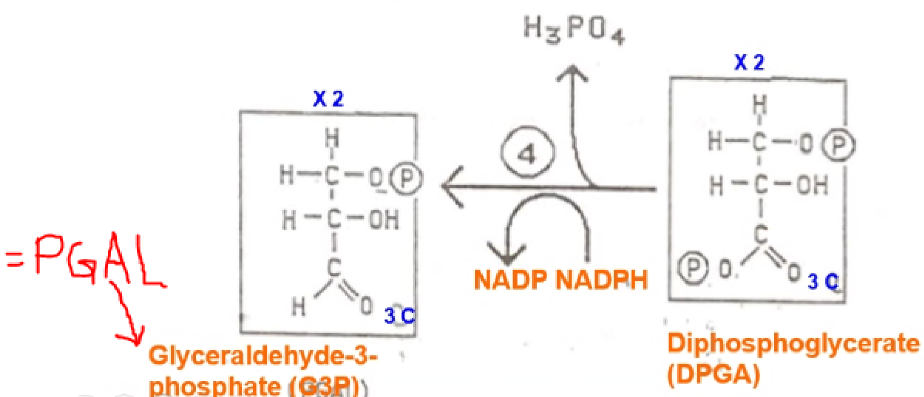
22

- Step 3

ATP (from the light reactions) enters here to phosphorylate PGA to form diphosphoglycerate (DPGA)

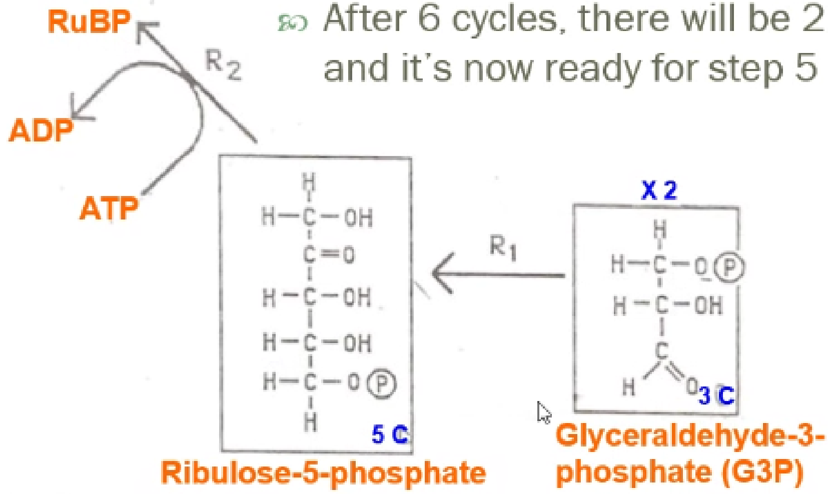


- Recall: in REDOX, addition of H is reduction
- A phosphate is removed and NADPH is oxidized to $NADP^+$, reducing the DPGA into PGAL.



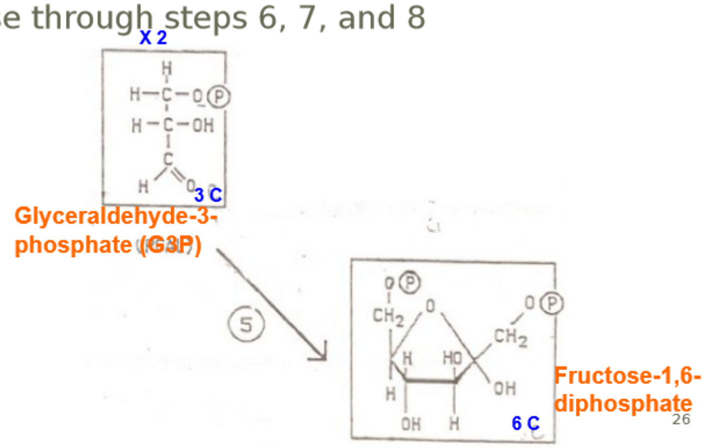
- Step R1 and R2: Regeneration

- 2 molecules of G3P continue to recycle in an effort to regenerate RUDP for another cycle
- The extra carbon remains and forms 1 G3P after 3 cycles
- After 6 cycles, there will be 2 G3P and it's now ready for step 5

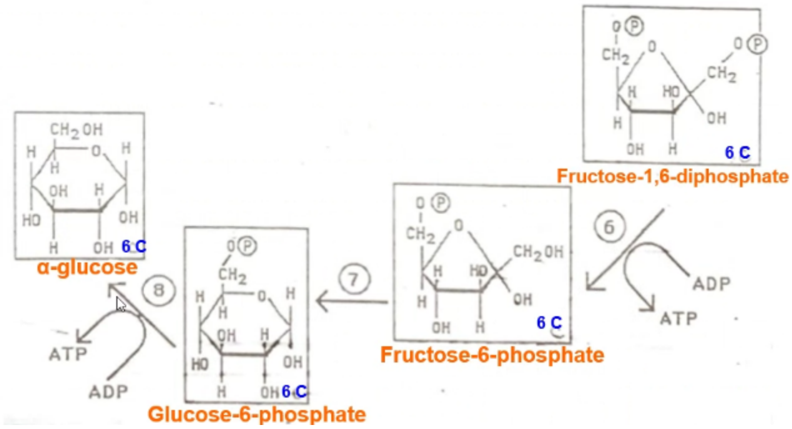


-

- Step 5-8: Formation of Glucose
  - For every 6 molecules of CO_2, there will be a net gain of 2 PGAL, the two PGAL will go make 1 glucose through steps 6, 7, and 8



-

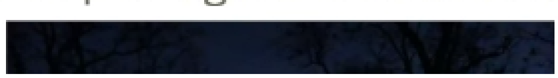
- 

    - Similar to glycolosis
- G3P
    - Is the primary end product of photosynthesis
    - It may be converted into glucose and polymerized into starch w/in the stroma
    - Or it may be transported to the cytoplasm and used to produce glucose and sucrose.
    - Sucrose is the main carb transported from mesophyll cells of the leaf to other cells of the plant
-

Alternative Method of Carbon Fixation

Preventing water loss

- All land plants have adaptations the prevent water loss
- Some adaptations may reduce the plant's ability to exchange gas
- Water lost from stomata is replaced by water taken up from roots
- Photosynthesis stop at night and stomata close to conserve water



-

Photorespiration with rubisco

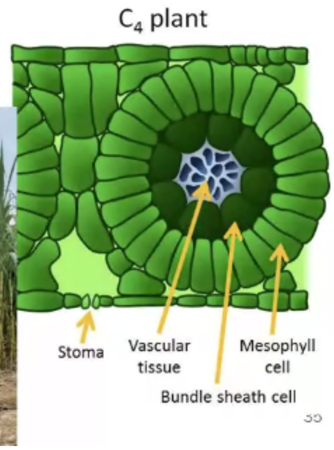
- Ribulose-1,5-bisphosphate carboxylase oxygenase (Rubisco) is a slow enzyme which catalyze reaction involving either CO_2 or O_2
- Abundant in plant cells
- It works at a slow rate: catalyze the fixation of 3 CO_2 molecules per second

- Under lab conditions when concentration of CO_2 and O_2 are equal, rubisco will bind to CO_2 rather than O_2 due to stronger attraction
- Rubisco will bind to CO_2 80 times as fast as they bind to O_2
- In nature, atmosphere does not have equal concentrations: 21% O_2, 0.04% CO_2
- Under normal concentration and moderate temperatures, rubisco will bind with CO_2 about 75% of the time

- When catalyze reaction between O_2 and RuBP, it creates a molecule that is not useful to the cell
- This molecule must be converted back to prevent RuBP from being wasted
- The reaction pathway of recovering this molecule consumes ATP and releases CO_2 – similar to respiration!

C4 Plants

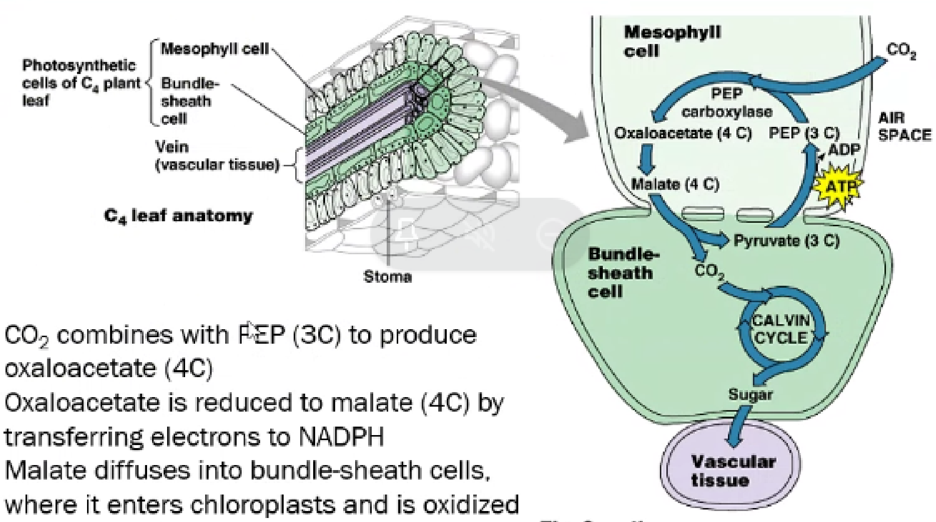
- Found in hot, dry environments (tropical plants & temperate crops species)
- Calvin cycle are performed by bundl surround the leaf veins



Ways to reduce photorespriration:

1. Bundle-sheath cells are surrounded by mesophyll cells that separate them from air spaces. The separation reduces exposure of rubisco's exposure to oxygen gas - reducing rate of photorespiration
2. C_4 cycle – an alternative form of carbon fixation that C_4 plants use, particularly in hot weather, to increase the concentration available for Calvin cycle.

C4 cycle



The C_4 pathway

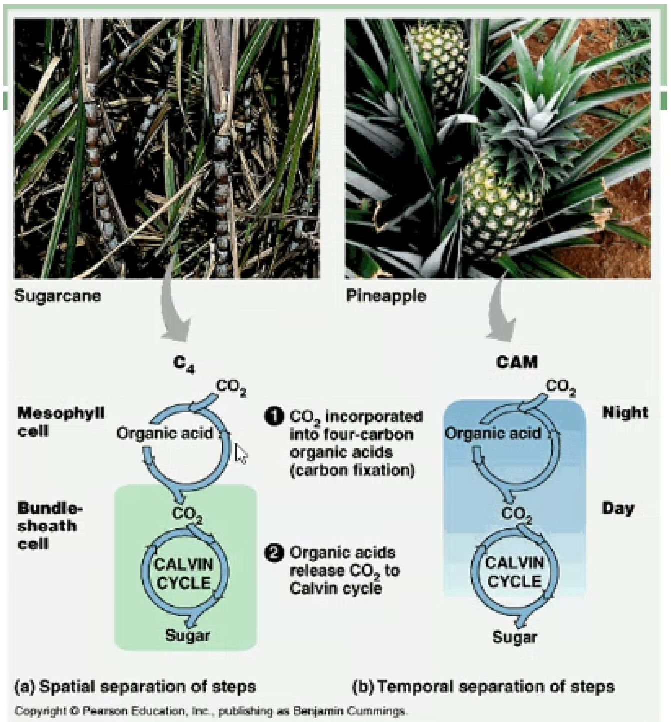
1. CO_2 combines with PEP (3C) to produce oxaloacetate (4C)
2. Oxaloacetate is reduced to malate (4C) by transferring electrons to NADPH
3. Malate diffuses into bundle-sheath cells, where it enters chloroplasts and is oxidized to pyruvate, releasing CO_2
4. CO_2 can now be used for Calvin cycle

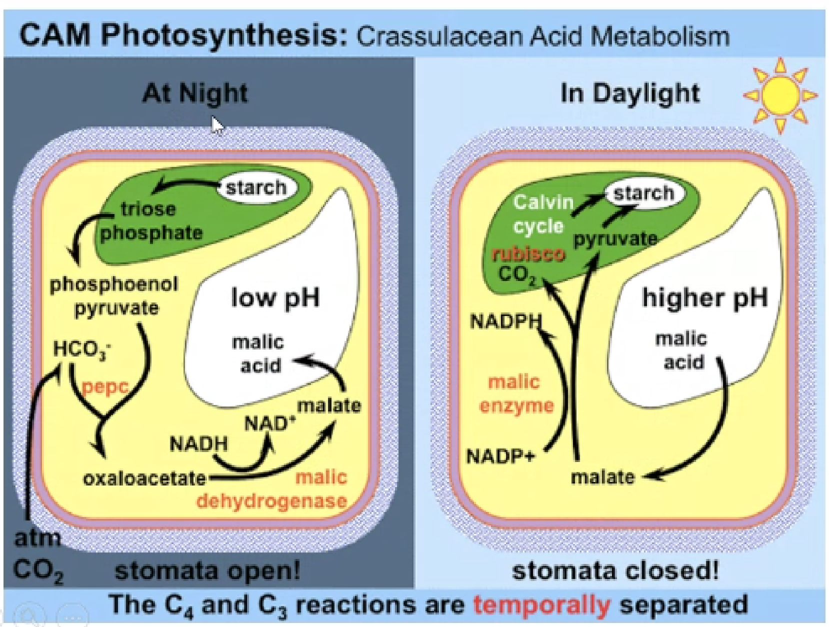
- C_4 plants still uses Calvin cycle
- It is not widespread among plants due to its additional energy requirement: extra 3ATP required for each G3P produced
- Hot climate tend to receive lots of sunshine so the additional ATP use is easily met by the cyclic light reactions
- Requires less rubisco and lower nitrogen demand
- Can survive in more nutrient-poor soil conditions

CAM Plants

- Crassulacean acid metabolism - CAM

- Plants in hot, dry, desert environments in day, cool at night
- Different from C_4 plants, CAM plants run Calvin and C_4 cycles in the same cells, but at different times of the day
- Have fewer stomata, lower surface to volume ratio leaves
- Stomata open at night to take in CO_2 and incorporate it into organic (malic) acids, and close during the day to allow the acids to release CO_2 into the Calvin Cycle.


Sugarcane
Pineapple
C_4
CAM
CO_2
Mesophyll cell
Organic acid
Bundle-sheath cell
CALVIN CYCLE
Sugar
1 CO_2 incorporated into four-carbon organic acids (carbon fixation)
2 Organic acids release CO_2 to Calvin cycle
Night
Day
(a) Spatial separation of steps
(b) Temporal separation of steps
Copyright © Pearson Education, Inc., publishing as Benjamin Cummings.


CAM Photosynthesis: Crassulacean Acid Metabolism
At Night
In Daylight
starch
triose phosphate
phosphoenol pyruvate
low pH
malic acid
HCO_3^-
pepc
malate
NAD^+
NADH
oxaloacetate
malic dehydrogenase
atm CO_2
stomata open!
Calvin cycle
rubisco
CO_2
pyruvate
higher pH
NADPH
malic enzyme
NADP+
stomata closed!
The C_4 and C_3 reactions are temporally separated

For work:

Factors Affecting Rate of Photosynthesis

- Read over this webpage to learn more!
- https://www.bbc.co.uk/bitesize/guides/z9pjrwx/revision/5

Quiz on photosynthesis → TDB, not next week but the week after

Homework:

- OPTIONAL: Read textbook p. 220 – 227
- Complete & submit Photosynthesis Questions
- Visit the webpage: https://www.bbc.co.uk/bitesize/guides/z9pjrwx/revision/5 to learn more about factors affecting rate of photosynthesis
- Continue to work on the potato lab
- Cellular Respiration Assignment

Cellular respiration Assignment:
→ check docx

Rosalind Franklin

About Franklin

- Was a woman scientist which was a real shock to all of her male scientist counterparts because she was incredibly smart
- Studied at Cambridge
- By 26 had published 5 papers on coal and charcoal
    - Helped in the WW2 with masks
    - Revolutionized the field of high strength carbon fibers
    - Had a PhD in this ^ field

NEXT

- After the war she starts working on X-Ray diffraction
    - Looking at very small things like molecules and crystals with X-Rays

- After spending some time in France, she goes to King's College in London to study living cells
    - The boys at the office get their knickers in a twist and she clashed with all the male scientists who worked with her
    - She ends up using her X-Ray diffraction techniques to the clearest picture of DNA ever recorded at the time on 6 May 1952
    - So of course the bois steal it from her and do a very surface level report on the picture and its qualities as well as a 3D model of what they believed DNA looked like
        - Maurice Wilkins, James Watson and Francis Crick
    - Meanwhile she writes a super in depth paper and it gets published after them, making it look like shes confirming their suspicions

NEXT

- With all the work she did in X-Ray diffraction, gets ovarian cancer
    - Of course she still publishes 17 papers in the next 5 years also advancing the field of structural virology
    - She died at the 37 in 1958

- Wilkins, Watson and Crick win a Nobel prize
- It is said that Franklin would have also won a nobel prize except if she lived long enough
- And she most likely would have won a 2nd one as well for her work in virology

- Her picture of DNA, coined Photo 51, essentially allowed for the discovery of the double helix structure of DNA, along with photographic evidence, making this one of the most contributable findings in the study of DNA, and yet also one of the most shameful.