8.1 Metabolism

Esential Idea: melabolic reactions are regulated in responce to the cells needs
- regulation of enzyme production → linked to how the produced enzyme controls the reactions it regulates.
- cells mantain stability → homeostasis. The main purpose of a metabolic reaction in a living organism is to sustain life which is kept by homoestasis.

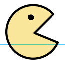
1. Thermodynamics: branch of physics that studies relationship between heat, work, temperature & energy.
- transfer energy from one place to another. energy is not build/killed but transfed
- heat is form of energy that produces work

Laws of thermodynamics

- 1st law: Law of conservation of energy: Energy cannot be created or destroyed. The total amount of energy in the universe remains constant → transfered from one system to another
- 2nd law: Hot things always cool unless you do something to stop them. In all energy exchanges, if no energy enters or leaves the system, the potential energy of the final state will always be less than that of the initial state. There is always energy loss (as heat) when energy changes form.
- we produce a lot of things in our system & we will loose heat as a waste material of everything that we do.
- 2nd law: Entropy in a closed system can never decrease

- Entropy is a measure of the number of specific ways in which a thermodynamic system may be arranged, commonly understood as a measure of disorder

2. Enzymes: Globular proteins which act as catalyzers for biological reactions



enzymes are like PAC MAN!

- Enzyme speed up chemical reactions by lowering the activation energy
- They can go through conformational changes → transform energy in other forms of energy.
- In photosynthesis, enzymes capture the energy of the sun to transform it into glucose. ojo → ATP = potential energy why? because when we consume/get ATP, we break the bond & by breaking it we produce an exorgonic reaction.
- Some enzymes are not proteins = Ribozomes which are RNA molecules.

3. Metabolism
- It's a set of life-sustaining chemical transformations within the cells of living organisms. These enzyme-catalyzed reactions allow organisms to grow & reproduce, maintain their structures, & respond to their enviorment. → organism's metabolism transforms matter & energy (subject to the laws of thermodinamics)
- In metabolism, the procursor is converted into a product through a series of metabolic intermediated called metabolites

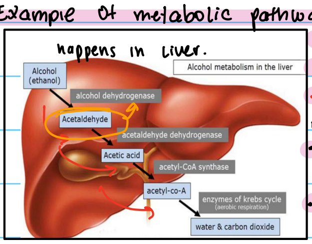
metabolism can be anabolic & catabolic ←

anabolic: build complex molecules
Catabolic: break down complex molecules

4. Metabolic pathways → roads to metabolites to travel & produce something
- Series of chemical reactions → anabolic/catabolic
- metabolic pathways consist of chains & cycles of enzyme-catalyzed reactions.

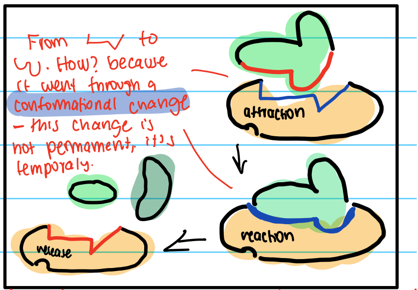
Example of metabolic pathway → the pathway/metabolism that breaks down ethanol (alcohol) into water & carbon dioxide.

metabolites → intermedrate element in a biochemical pathway.



- All these processes contain enzymes that catalyze each one of these processes = pathway.
- which enzyme has the product acetaldehyde? → alchohol dehydrogenase
- How do the enzymes link together to form a metabolic pathway? → by metabolites. Because they will be the substrate for the next reaction. These pathways are catalyzed by enzymes.
- As substrate approaches enzyme, it induces a conformational change in the active site.
- It stresses the substrate, reducing the activation energy of the reaction.

5. Induced fit model of enzyme activation



From ⌐✓ to ⩗. How? because it went through a conformational change
- this change is not permanent, it's temporaly.

6. Activation energy
- minimum energy that we need for a reaction to happen

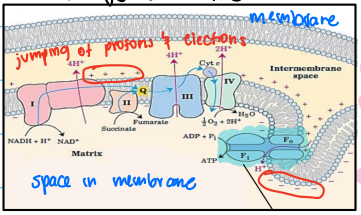
7. OIL/RIG: Oxidation Is Loss, Reduction Is Gain
- Loosing electrons (e^-) → Oxidation. - Gaining electrons (e^-) is a reduction reaction

The flow of electrons provide energy for organisms → energy will be provided by this exchange of electrons → reduction & oxidation of different molecules.
- All the reactions involving electron flow are oxidation/reduction reactions
- The flow of electrons in oxidation/reduction reactions is directly or indirectly responsable for all work done by living organi

Chemiosmotic theory: Energy (which is derived from electron transfer reactions) is temporarily stored as a transmembrane difference in charge & pH. Why pH? bcz we have a gradient of protons.

let's think with mitochondria: we know we have an internal & external membrane & a space betweeen these organelles. We will have some integral proteins that will have this jumping of electrons & protons around them & they create a gradient.

- this charge drives the formation of ATP in oxidative phosphorylation & photophosphorilation.

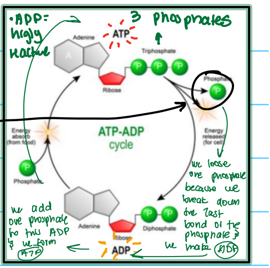


- We have a protein pump that will act in the membrane.

8. Phosphorylation:
- The adding of a phosphate to any molecule or ion.
- For example, the adding of a phosphate to ADP to form ATP = phosphorylation process. Once you phosphorelate an ion, it's gonna become less stable → & will need to react because of this instability.

Example of phosphorylation
ATP-ADP cycle: Purpose? to release energy by breaking down the bond of phosphate → Exolgonic

There are 3 types of phosphorylation: substrate level phosphorylation, Oxidative phosphorylation, & photophosphorylation.



Substrate level phosphorylation → dephosphorelation = opposite.
- Just adding a phosphate to a substrate → ATP cycle → when we break down the last phosphate we are going to dephosphorelate (opposite reaction) the ATP to produce ADP & ADP will phosphoralate itself to make ATP.
- ATP-ADP cycle. AMP can also be the case.

Oxidative & photophosphorylation
- In both cases we will have: 1. A membrane 2. Inner & outer surface 3. Matrix or stroma (it will contain a lot of ions, enzymes to promote these reactions. 4. A protein complex 5. Exited electrons jumping from one protein to another. 6. Electron accepters (will grab the electron) 7. ATP synthase (channel protein). 8. ATP being formed.
- Energy of oxidation drives the synthezis of ATP → oxidation = loss of electrons in order to give power to the reaction.
- Oxidative phosphorylation happens in the mitochondrion of eukaryotic cells → done in absence of light
- photophosphorylation happens in the chloroplast of plant cells → done in presence of light

oxygen water
↑ ↑

- oxidative phosphorylation involves the oxidation of NADH to NAD^+, & the reduction of O_2 to H_2O with the electrons donated by [NADH & $FADH_2$] molecules holding potential energy in the H's why? because the H's will release protons that will be jumping up & down.
- oxygen acts as an acceptor of the last electron in the electron transport chain. So the last electron in the last protein will be grabbed by oxygen (last molecule capturing these electrons) which forms water
- photophosphorylation involves the oxidation of water (H_2O) & oxygen (O_2)
- NAD^+ acts as the ultimate electron acceptor.

Electron carriers

All these reactions in metabolism are two big examples of metabolic reactions → cell respiration & photosynthesis.

$$NAD^+ + \overset{\text{2 hydrogen ions}}{2H^+} + \overset{\text{2 electrons}}{2e^-} \underset{\text{oxidation}}{\overset{\text{reduction}}{\rightleftharpoons}} NADH + \overset{\text{1 hydrogen ion}}{H^+}$$
(Nicotinamide adenine dinucleotide)

- this process is reduction because you're gaining electrons
- this process is oxidation because you're loosing electrons →

Oxidized Forms:	Reduced Forms:
NAD^+ & FAD	NADH & $FADH_2$

$$FAD + 2H^+ + 2e^- \underset{\text{oxidation}}{\overset{\text{reduction}}{\rightleftharpoons}} FADH_2$$
(Flavin adenine dinucleotide)

Oxidative phosphorylation
- Electrons from the reduced NADH & $FADH_2$ are passed to proteins in the respiratory chain
- In eukaryotes, oxygen (O_2) is the ultimate electron acceptor for these electrons
- Energy of oxidation is used to phosphorylate ADP

Competitive inhibition:
- the higher the concentration of inhibitor, the slower the rate of reaction

Photophosphorylation:
- In photosynthetic organisms light causes charge separation between a pair of chlorophyll molecules
- energy of oxidized & reduced chlorophyll molecules is used to drive synthesis of ATP
- water (H_2O) is the source of electrons that are passed through the chain of this protein transporters to the ultimate electron acceptor, $NADP^+$ (P for photosynthesis)

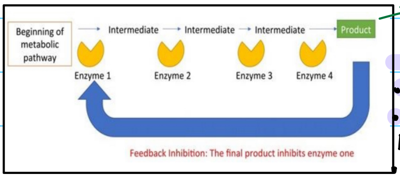
Comparing competitive vs. non-competitive inhibitors

Competitive	Non Competitive
Attaches to active site	Attaches at place other than active site
Similar in structure to substrate	not the same as substrate
doesn't change shape of enzyme	Changes shape of enzyme → bcz substrate is not similar to enzyme (conformational change)
Increases in substrate concentration, increases rate of reaction	Increases in substrate concentration, doesn't affect rate of reaction

(Week 2)

Inhibitors:

Feedback inhibition → cellular control mechanism in which an enzyme that catalyzed the production of a particular substance in the cell is inhibited when that substance has accomulated to a certain level, thereby balancing the amount provided with the amount needed



Feedback Inhibition: The final product inhibits enzyme one

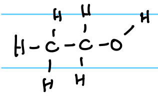
→ once we have enough product, then we will inhibit the beginning of the production of anything (enzymes) & if we have not enough, we start the production.

Relenza (example of competitive inhibition)
- relenza → synthetic drug to treat individuals infected with the influenza virus
- virions (virus particles) are released from infected cells when the viral enzyme neuraminidase cleaves (splits) an attaching protein (haemagglutinin)
- relenza competitively binds to neuraminidase active site & prevents the splitting of the attaching protein.
- consequently, virions are not released from infected cells, preventing the spread of the influenza virus.

Cyanide (non-competitive inhibitor)
- cyanide → poison which prevents ATP production via aerobic respiration, leading to eventual death
- binds to an allosteric site on cytochrome oxidase – a carrier molecule that forms part of the electron transport chain
- by changing the shape of the active site, cytochrome oxydase can no longer pass electrons to the final acceptor (oxygen). So by preventing the attaching of the oxygen, we'll kill the person bcz it cannot produce ATP & can't get O_2 in our system.
- consequently, electron transport chain can't continue to function and ATP is not produced via aerobic respiration.

Eth (1) Meth (2)

Ethanol & Methanol
- Ethanol → alcohol & is a psychoactive substance (drug that affects how the brain works & causes changes in mood, thoughts.
- also has medical applications (antiseptic & disinfectant)
- ethyl alcohol, grain alcohol or drinking alcohol)
- methanol → methyl alcohol & it's the simplest alcohol, consisting of methyl group linked to a hydroxyl group. It's a light, volatile, colorless & flamable liquid.
- more toxic than ethanol.



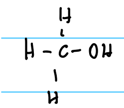
Ethanol
- 2 carbons (C)
- one alchol (O)

Ethylene glycol → $HO-CH_2CH_2-OH$ → & methanol poisoning can cause life threatening complication

Ethylene glycol metabolism & symptoms of intoxication

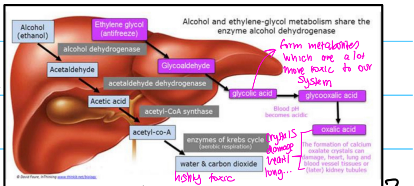
Toxicity of ethylene glycol & methanol is related to the production of toxic metabolites by the enzyme alcohol dehydrogenase (ADH) which leads to metabolic acidosis, renal failure (in EG poisoning), blindness (in methanol poisoning) & death

- ethylene glycol is water soluble, clear, colorless
- rapidly absorbed from intestines (30-60 min)
- toxicity of ethynele glycol results from it's metabolism, catalyzed by enzymes in the liver, which produce more toxic chemicals
- this metabolic pathway breaks down ethynele glycol quickly in the body (few hours) in glycoaldehyde then into acids which change blood pH.



methanol
- 1 carbon (C)

Symptoms of ethylene-glycol intoxication
- At first similar to alcohol intoxication:
  - ataxia (reduced coordination)
  - sleepiness
  - slurred speech
  - vomiting
- once glycoaldehyde begins to form the CNS can be severly depressed leading to seizure- where electrical activity in the brain changes.
- symptoms of the later metabolic products are:
  - fluid on lungs → hyperventilation
  - heart problems & problems in blood vessels → change in blood pressure



Question: why is ethylene glycol so much more dangerous than alcohol? → It is broken down into toxic products during its metabolism.

Fomepizole

- can be used as an antidote for ethynele glycol or methanol poisoning
- fomepizole is a competitive inhibitor of alcohol dehydrogenase, which catalyzes the breakdown of ethynele glyco & methanol into toxic metabolites.

Overcoming alcoholism: an example of competitive inhibition

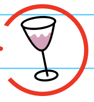
- antabuse competes with the aldehyde oxidase & prevents the acetaldehyde from being converted into acetic acid
- A build up acetaldehyde follows, resulting in a strong feeling of nause & other hangover symtomps
- Antabuse is administered as a daily pill, so its efficacy relies on the patients own motivation – if they stop taking it they can drink again

Process / pathway:

Normal metabolism of ethanol (alcohol):

ethanol $\xrightarrow{\text{oxidation}}$ acetaldehyde $\xrightarrow{\text{aldehyde oxidase}}$ acetetic acid

↑ antabuse (competitive inhibitor)



II. NAD+ & FAD+

NAD⊕ & FAD⊕ → these + here will be replaced by hydrogens to do chemiosmotic process

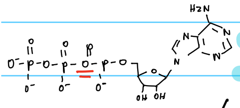
- They're cofactors:
- non-proteins that assist enzymes involved in cell respiration & photosynthesis
- they accept "high energy" electrons & carry them to electron transport chain to synthesize ATP.

Bioinformatics:

- An approach whereby multiple research groups can add info to a database enabling other groups to query the data base
- bioinformatics has facilitated research into metabolic pathways is referred to a chemogenomics.

2.8, 8.2 Cell Respiration

(Week 1)



ATP!

ATP (Adenosine Triphosphate)

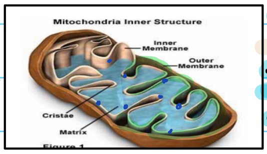
- The energy is held in the bonds between atoms, in particular the high energy bond that joins the second & third phosphate
- ATP= energy currency of the cell. Hence the efficiency of cell respiration is measured by the yield of ATP → we'll measure how many ATP's are done in the different stages of cell respiration.

Essential Idea:

1. Cell respiration supplies energy for the functions of life
2. Energy is converted to a usable form in cell respiration.

1. Mitochondria → structure & function

we have DNA material & ribosomes



- since we have endosimbiosis, we have a double membrane → external membrane, internal membrane & inter membrane space.
- matrix is the source of a lot of enzymes/ ions that will take place in the metabolic reaction.
- mitochondria have 70s ribosome & naked loops of DNA
- mitochondria has circular DNA why? according to the endosimbiotic theory, you have a primitive cell that was eaten by a big cell & became into this simbiosis which is beneficial for those organisms. The mitochondria now is an endosymbion & part of the big cell. The big cell gets the energy that mitochondrion produces & it will get the supplies of the big cell & protection.
- cristae: They will give more surface area for the different reactions happening in the internal membrane. cristae folds in the inner membrane

Electron tomography used to produce images of active mitochondria

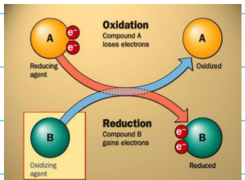
- dealing with biological materials samples are prepared by fixing & dehydrating or freezing
- thanks to this tomography we know that:
  - cristae are continuos with the internal mitochondrial membrane
  - intermembrane space is of a consistent width throughout the entire mitochondrion
  - the relative shape, position & volume of the cristae can change an active mitochondria.

Starting Cornell Notes

1. • when one element is oxidized, the other is reduced
- Oxidation Is Loss, Reduction Is Gain
- oxidated forms: NAD^+ & FAD
- reduced forms: NADH & $FADH_2$

1. What is oxidation & reduction?

- All cell processes are done by process of oxidation & reduction. when one element/molecule is oxidized, the other will be reduce



Oxidation	Reduction
Loss⁻ of electrons e	Gain⁺ of electrons e
Loss⁻ of hydrogen H	Gain⁺ of hydrogen H
Gain⁺ of oxygen O	Loss⁻ of oxygen O

Equation of cell respiration =

$$\underbrace{C_6H_{12}O_6}_{\text{glucose}} + \underbrace{6O_2}_{\text{oxygen}} \rightarrow \underbrace{6CO_2}_{\text{carbon dioxide}} + \underbrace{6H_2O}_{\text{water}} + \text{energy}$$

At the end, it's important to produce energy.

CO_2 & H_2O = waste material

x Reducing agent	y Oxidizing agen
X loses electron	y gains electrons
X oxidized y (becomes positive)	y is reduced by x (becomes negative)

Oxidation
Is
Loss
Reduction
Is
Gain

of ELECTRONS

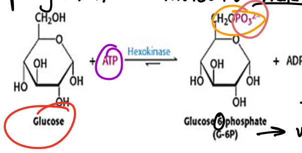
so, because oxidation is Loss, y is smaller & it becomes negative, x positive

- In the simple equation of cell respiration, glucose oxidizes on its H atoms, therefore, electrons are gradually removed & added to H acceptors

2. • Adding of phosphate to organic molecule
- phosphorylated molecules = less stable → highly reactive
- phosphorylation of glucose = 1st step in cell respiration.

2. What is phosphorylation? → The adding⁺ of an inorganic phosphate molecule to an organic molecule (Pi + R

- Phosphorylation of molecules makes them less stable⁻ & therefore, highly reactive



→ we have glucose + ATP. There's a phosphorilized type of glucose which will be unstable & want to react / break down.

→ notice that is coupled with the hydrolisis of ATP. Hydrolysis = breaking down of ATP with water molecule.

→ why 6? bcz in 6 carbon we have a phosphate.

- Phosphorylation of glucose → the 1st step of glycolisis.

3. • ATP's external phosphate leaves the molecule when hydrolyzed.

• Energy is released when ATP is hydrolyzed

• $ATP + H_2O \rightarrow ADP + pi$.

— o —

4. • NAD is a cofactor in redox reactions that accept elements.

• hydrolysis = quitar phosphate osea llegamos a ADP
 - requires water

• Phosphorylation: add p osea llegamos a ATP.
 - requires input of E
 - release water.

— o —

5. • NAD^+ = oxidated form & substrate in glycolisis

• NADH = redused form, product in glycolisis & substrate for Krebs Cycle

— o —

6. • FAD: oxidized form
 $FADH_2$ = reduced form

• usage in krebs cycle

— o —

7. • Cofactor that attaches to enzyme to secure reaction on transition stage (to go to krebs cycle)

• transfer acetyl (CoA)

• acetyl group attaches to sulphur of CoA molecule acetyl CoA is formed

— o —

8. • Flow a electrons (e-) that move through protein pumps in the semi-permeable membrane by difussion

- high concentration to low

• protons move through enzyme ATP synthase
 - ADP into ATP.

— o —

9(A) 9(B) & 9(C)

• controlled release of energy from organic compounds!

• $C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{respiration}} 6CO_2 + 6H_2O$

also

• ADP → ATP

• respiration ≠ breathing

• waste materials of all respiration = $CO_2 + H_2O$

1- glycolisis → in cytoplasm in presence of oxygen = 2 pyruvates
 2 ATP

2. preparation phase for krebs cycle
 - no ATP

3. krebs cycle
 - 2 ATP

4. ETC & OP
 - 34 ATP.

aerobic

- chemiosmosis → protons
- ATP synthase

anaerobic → no O_2

- fermentation

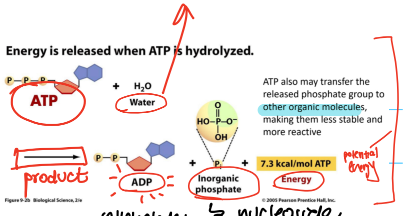
ethanol alcoholic plants

lactic acid animals

3. What is ATP hydrolized?

• When hydrolyzed, the external phosphate is broken, liberating a Pi (phosphate)

• This hydraisis reaction is highly exergonic → How does it work?


Energy is released when ATP is hydrolyzed.

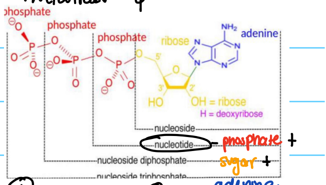
we add water to ATP in order to produce ADP

4. What is Nicotinamide Adenine Dinucleotide (NAD^+ NADH)

— we will add a hydrogen & take it to other stages in all respiration

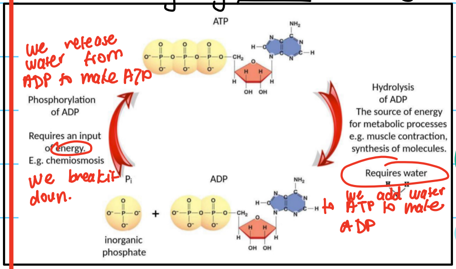
- it is a cofactor in redox reactions, that acts as electron acceptor →
- Has Vitamin B as structural component, & an ADP molecule → nicotinamide ↓ Ribose ↓ ATP →

nucleotides & nucleoside,

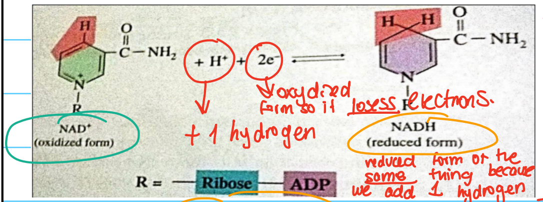


- Importon Cycle

It will be fitting any reaction in our system



5. What is NAD^+ → NADH? OIL



• The ⊕ in the $NAD^⊕$ is the positive charge in the N molecule, a cofactor

• NAD^+ is the oxidized form of the molecule, and a substrate of glycolysis (stage in all respiration)

• NADH is the reduced form of the molecule, a product of glycolisis & a substrate for the krebs cycle (stage in all respiration)

6. What is FAD^+ → $FADH_2$

→ Another cofactor that has a very similar behavior as the NAD^+

• FADH is the reduced form of the molecule while FAD^+ is the oxidized form

• It preforms important roles on the last steps of cell respiration.

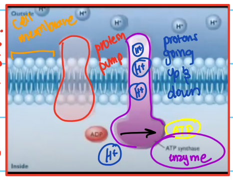
7. What is Coenzyme A (CoA)

• This is a cofactor that attaches to the enzyme to secure the reaction on its transition state

• CoA donate/accept electrons during the reaction, in this case transferring the acetyl group – $COCH_3$

• CoA acts as a coenzyme accepting first & then transferring the acetyl group (CoA)

• When an acetyl group captures a sulphur atom in one side of the CoA molecule, acetyl-CoA is formed.



8. What is chemiosmosis?

• Chemiosmosis is the flow of electrons (ions) that move, by difussion, across a semi-permeable membrane → jump up & down between the proteins.

• Electrons (ions) move through a chain of membrane bound carriers, from areas of high concentration to areas of low concentration → this process provides the free energy for synthesis of ATP.

• What are proton pumps? → protein complexes that move the protons (generated during oxidation reactions) across the cell membrane. As protons move through proton pump, the begin to build up to the outside of the membrane. Once they accumulate, on the outside, they create a concentration gradient. Membrane is NOT permeable to the charged hydrogen ion & can't go back so they must pass to a especial chanel. Protons move through this especial chanel which is the enzyme ATP syntaze. This enzyme uses the energy derived from the movement (jumping up & down) of these protons to convert ADP into ATP. The movement of protons down a concentration gradient provides the energy for ATP syntaze to form ATP. The mechanism of producing ATP = chemiosmosis

9(A) What is CELL RESPIRATION?

• "The controlled release of energy from organic compounds in cells." → glucose/carbohydrates, lipids/fatty acids, proteins → all these are source of energy, we just have to break them down & put them into the correct shape to produce energy. Using as raw material → glucose (usualy)

• The controlled release of energy from organic compounds in cells to form ATP

$C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{respiration}} 6CO_2 + 6H_2O$

glucose (organic molecule) — oxygen — carbon dioxide — water

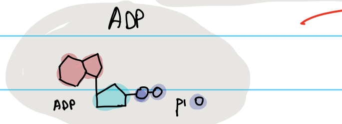
aerobic respiration (gives better yield of ATP

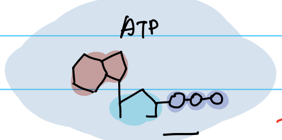
Respiration happens with the breaking down of the last bond of ATP (O) pi → which is an exergonic reaction

All the processe release heat energy

respiration is not breathing
- All organisms respire - it is the production of ATP from organic molecules

Aerobic respiration requires oxygen
ventilation & gas exchange

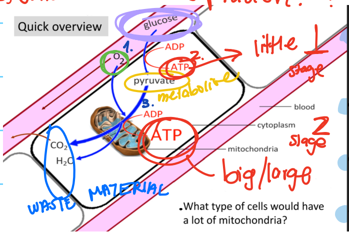




• The controlled release of energy
 → by enzymes: metabolic pathway & cycles. Why pathway? because we have one reaction, then other, then other. Cycles why? because we start with 1 metabolite that will be the objective of production of this cycle.
 → How can cells control the rate of enzyme catalysed pathways & cycles? → End product Inhibition

9(B) What is cell respiration??

? Why does it require oxygen & gives a large yield of ATP from glucose?



• What type of cells would have a lot of mitochondria?

• We have a cell inside of the cell we have mitochondrion. We will need glucose that goes into the cell (← 1.) This glucose will end up producing ATP (ADP → ATP). 2. Remember that in order to produce ATP, we need to break it down into ADP

• By breaking ADP in first stages, we will produce a metabolite called pyruvate. This will happen in the cytoplasm of the cell so glucose will break down into pyruvate.

• Pyruvate in the presence of oxygen will go into the mitochondrion (← 3.) & will give a big/large yield of ATP ↓ → in the cytoplasm of the cell

• So, in the first stages of breaking down glucose into pyruvate, we will produce ATP but little. The next stages that will be preformed in the mitochondrion will produce a large/big yield of ATP 4.

- once we do this, we have 2 waste materials → CO_2 and water O_2
- 1st stages = cytoplasm. We go into the mitochondrion in the presence of oxygen. If we don't have oxygen, we will divert into another pathway called fermentation.

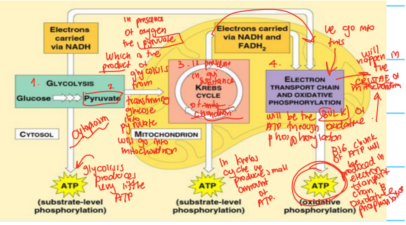
9(c) What is cell respiration?

- It's the process that breaks molecules to liberate energy, in an aerobic medium
- gives the cell enough energy to develop all living functions.

Overview of all the concepts:

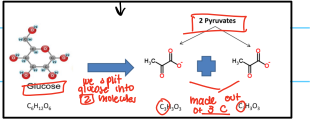
Cell respiration
- aerobic (in presence of oxygen)
  - glycolisis → Small amounts of ATP.
  - Krebs Cycle (preparation for Krebs)
  - Electron transport chain — LARGE YIELD OF ATP.
- anaerobic (in absence of oxygen) – Fermentation
  - alcoholic fermentation – In plants
  - lactic acid fermentation – In animals (humans do it too)

Stages of aerobic cellular respiration



10. What is glycolisis? → First pathway in cell respiration. Glyco = sugar lysis = break.

- Breaking sugar. Just 1 pathway. From glucose to pyruvate (2)
- reaction happens in 10 steps. One molecule of sugar breaks into two pyruvates. 1 sugar = 6 carbon compound & we end up with 3



GLYCOLYSIS sugar splitting

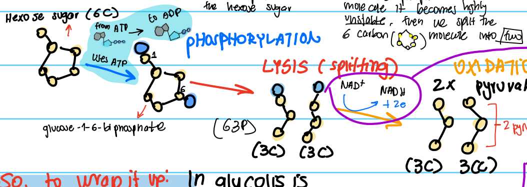
cytoplasm — Phosphorylation: we add one phosphate to each "part" of the hexose sugar

cytoplasm — Lysis: Then, since the molecule was highly reactive & unstable, when we phosphorylate a molecule it becomes highly unstable, then we split the 6 carbon molecule into two

cytoplasm — Oxidation: We will diphosphorylate these molecules to make them ~~more stable~~ & they'll end up with 2 pyruvate carbon molecules to go to end reaction

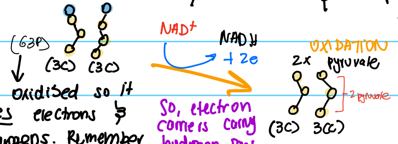
- in glycolisis water is produced as a waste material

which is a 3



NAD⁺ is reduced (it gains 2 electrons & 2 hydrogens)
- carried to ELECTRON TRANSPORT CHAIN (just the electrons & the protons).

WHAT IS THIS?



is oxidised so it losses electrons & hydrogens. Remember Oxidation Is Loss

So, electron carriers carry hydrogen ions to the ELECTRON TRANSPORT CHAIN

come together with NAD

→ Who carries the electron carriers in cell respiration? → NAD (nicotinamide Adenine Dinucleotide)

$$NAD^+/NAD + \underbrace{2H^+}_{\text{two hydrogens}} + \underbrace{2e^-}_{\text{two electrons}} \underset{\text{oxidation}}{\overset{\text{reduction}}{\rightleftharpoons}} NADH + H^+$$

So, to wrap it up: In glycolisis is

so we are using 2 ATP's to produce 4 ATP's but net gain is only 2 ATP's

3 carbon molecules that were diphosphorylized

$$Glucose + 2NAD^+ + 2ADP + 2Pi \rightarrow 2\ pyruvates + 2NADH^s + 2H + 2ATP + 2H_2O$$

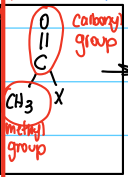
→ Summary of Glycolisis!

NET GAIN: 2ATP.

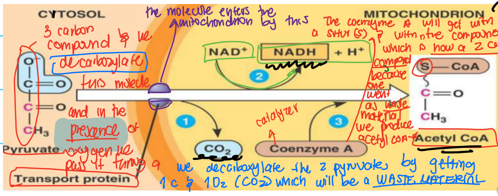
- From each molecule of glucose broken down to two pyruvates, two molecules of ATP are formed
- ATP is formed in an endorgonic reaction from ADP & pi
- 2NADH are also formed.
- Can be anaerobic or aerobic because it does not need oxygen

happens in the cytoplasm of the cell.

12. What is acetyl group & Acetyl Coenzyme A ???



- This helps with understanding of *Intermediate reaction where the 2 pyruvate get into the mitochondrion.



- Each molecule of pyruvate goes into the mitochondrion and in its matrix, the following process happen:
- Each pyruvate (2) oxidizes & combines with coenzyme A
- Acetyl CoA is formed → will be a pathway that is not glucose into cycle.
- By products NADH & CO_2 are also produced.

Preparation phase for Krebs cycle. So, to wrap it up:

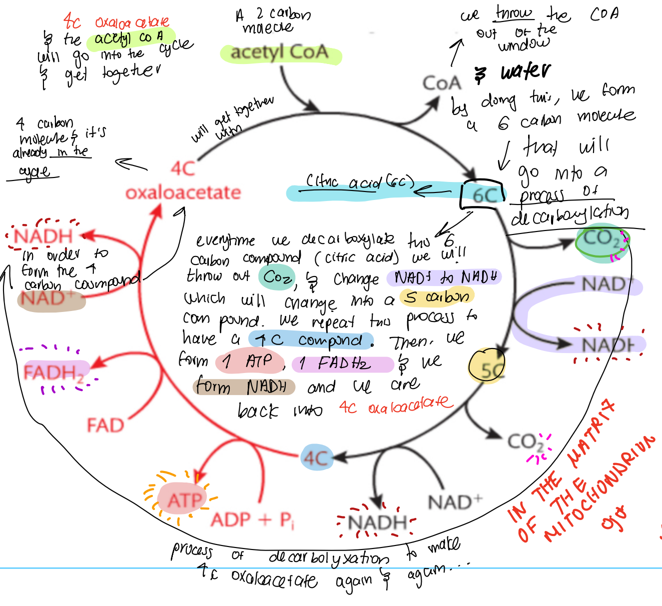
$$2\ pyruvates + NAD^+ + 2COA \longrightarrow 2\ Acetyl\ COA + 2NAD/+ + 2CO_2$$

also called cellular respiration's link reaction → link between what's glycolisis & the Krebs cycle. This reaction is done in presence of oxygen.

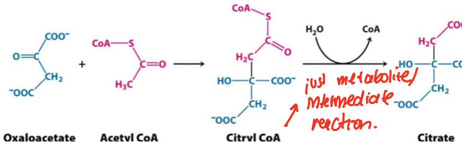
13. What is the Krebs Cycle? → Also called Citric acid cycle

- Each acetyl COA molecule oxidizes into two CO_2 molecules
- Coenzyme A acts like a transferring agent, transfers fatty acids derivates.

Complete Cycle



- Takes place in the matrix & it's a closed cycle of controlled reactions
- provides a continuous supply of reduced electron carriers for the electron transport chain → we have just produced ATP & NADH & $FADH_2$ (carriers to continue the pathway into the electron transport chain.
- ojo: since each glucose molecule produced 2 molecules of pyruvate (glycolisis) & so 2 molecules of Acetyl CoA (preparation phase for ~~krebs~~), the yield per glucose for the krebs cycle is:
  - 4 carbon dioxide
  - 6 NADH
  - 2 $FADH_2$
  - 2 ATP
- 8 steps in the process, summarized into:
  - Acetyl CoA transfers the 2C acetyl group to the oxaloacetate a 4 C compound
  - to form a citrate that is a 6C molecule



So, to wrap it up, krebs cycle produces:

$$4CO_2 + 6NADH + 2FADH_2 + 2ATP$$

11.
- Breaking sugar from glucose to pyruvate.
- happens in the cytoplasm of the mitochondrion
- hexose sugar is phosphorylized & ATP forms into ADP. Lysis happens & the hexo sugar splits into two. We have 2 molecules of 3 carbons each.
- NAD+ is reduced and it gains 2 electrons & 2 H.
- these 2 molecules get oxidized so they loose electrons & hydrogens. and we have the 2 pyruvate

Glycolisis –

$glucose + 2NAD + 2ADP + 2PI \rightarrow 2\ pyruvates + 2NADH^+ + 2ATPs + 2H_2O$

Gained → 2 ATP.

- CR link!
- preparation phase for KC

12.
- we need to get the 2 pyruvate inside mitochondria
- called → intermediate reaction
- pyruvate combines with CoA in presence of oxygen
- pyruvate enter molecule through transport protein
- Acetyl CoA is formed because CoA will get with a sulfur.
- NADH & CO2 are packed

link:

$2\ pyruvates + NAD + 2COA \rightarrow 2\ Acetyl\ COA + 2NADH^+ + 2CO_2$

- No ATP formed

13.
- citric acid cycle
- happens in matrix
- oxaloacetate and acetyl CoA get together & throw CoA & water out the window.
- Form a 6C molecule also called citric acid
- decarboxylate the 6C compound we throw the CO_2 & change NAD⁺ to NADH).
- change into 5C compound & repeat process to get 4C
- Form 1 ATP, 1 $FADH_2$ & change NAD+ into NADH. which takes us back to oxaloacetate 4C

Krebs cycle produces

$4CO_2 + 6NAD + 2FADH + 2ATP$

- energy from glucose is now high in electrons

Net production of ATP in cell Respiration

Stage / Process	ATP yield
glycolisis	2 ATP
krebs cycle	2 ATP
ETC & oxidative phosphorylation	34 ATP
Total	38 ATP

remember that glycolisis will produce 4 ATP but we will only use 2

- when the krebs cycle finishes...
- The glucose molecule has been full broken, fully catabolized. We put the potential energy in the NADH & FADH2 & produced some ATP. (ember than most is in the last stage)
- By now, 4 molecules of ATP have produced (2 from glycolisis & 2 from the Krebs cycle)
- The energy from the glucose is now in form of high energy electron in NADH & FADH2 → This energy will be used to start the electron transport chain
- There are now: 4 ATP, 10 NADH and 2 FADH2 / The 10 NADH are: 6 NADH from krebs cycle, 2 from preparation phase and 2 from glycolisis → 10 in total. we just have 2 FADH2 from the krebs cycle.

14. What is the electron transport chain and oxidative phosphorylation??? — Last pathway (produces the most ATP

Electron transport system

e^-

- The high energy from NADH & FADH2 will be used as a substrate to start the next steps.
- This high potential energy from the electron transport chain, will be gradually lowered down by the releasing energy

Electron transport system through chemiosmosis

- This process ETS & Chemiosmosis will happen in the cristae of the mitochondrion & intermembrane.
- what is Chemiosmosis? → pg 4 → 8. what is Chemiosmosis?

Electron transport Chain

- NADH oxidation loses 2 electrons (2H)]
- O2 reduction. forms H2O (water)]

NADH $\xrightarrow{\text{by liberating oxygens}}$ NADH$^+$ + H$^+$ + 2e$^-$ — These electrons will go through a set of protein chain (3) which are called cytoproms & each one of them will lower the energy of the electron until we can put energy into the water

energy

CoQ

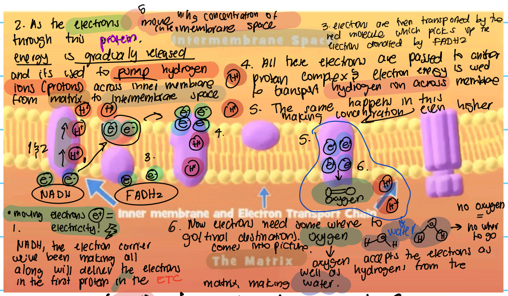
Coenzyme Q

Cytochrome

CytC

energy

2e$^-$ + H$^+$ + ½ O2 →


2. As the electrons move through this protein, energy is gradually released and its used to pump hydrogen ions (protons) across inner membrane from matrix to intermembrane space

5 which concentration of intermembrane space

3. electrons are then transported by the red molecule which picks up the electron donated by FADH2

4. All these electrons are passed to another protein complex & electron energy is used to transport hydrogen ion across membrane

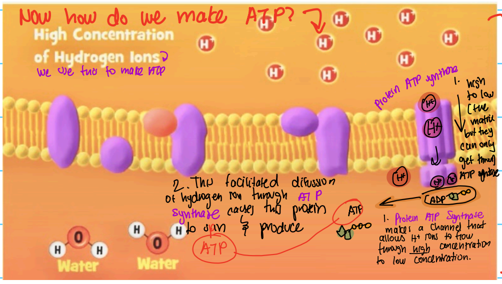
5. The same happens in this making concentration even higher

• moving electrons (e^+) = electricity!

1. NADH, the electron carrier we've been making all along will deliver the electrons in the first protein in the ETC

6. Now electrons need some where to go (final destination). oxygen comes into picture. oxygen accepts the electrons as well as hydrogens from the matrix, making water.

no oxygen = no where to go


Now how do we make ATP?

High Concentration of Hydrogen Ions?

we use this to make ATP

1. high to low (the matrix) but they can only get through ATP synthase

2. This facilitated diffusion of hydrogen ion through ATP synthase causes this protein to spin & produce ATP

1. Protein ATP Synthase makes a channel that allows H+ ions to flow through high concentration to low concentration.

This process makes about 30 - 34 ATP molecules for every glucose that enters respiration.

Protein complex in the cristae membrane

- Energy generated is used by the complex of proteins DDD to pass protons / hydrogen ions (H+) through the cristae membrane
- This way a hydrogen concentration of H protons is created in the inter membrane space (an acid medium)
- The H's should then go back to the matrix of the mitochondrion through the ATP synthase
- This process will be possible thanks to the presence of oxygen, water will release.
- Ojo! → The process where hydrogens & electrons are jumping up & down = electron transport chain (ETC). The process of making ATP through the ATP synthaze = chemiosmosis. The whole thing together = oxidative phosphorylation!

Two different Proteins → ATP synthase vs. ATPase

ATP synthase: enzyme which synthesize ATP by combining ADP & free phosphate group. ADP + Pi → ATP

ATPase: enzyme which break down ~~ATP~~ ATP into ADP & free phosphate group. ATP → ADP + Pi → [opposites!]

Ojo:
- Each NADH produces 3 ATP (total 30)]
- Each FADH2 produces 2 ATP (total 4)] NET PRODUCTION of oxidative phosphorylation 34 ATP.

ETC & OP
·last pathway & produces the most ATP.
·high energy from NADH & FADH2 will use as substrate.
·electrons move through the proteins through the semi-permeable membrane by diffusion.
- As they move, energy is released & is used to pump hydrogen ions (H+) across inner membrane from matrix to intermediate membrane
- this process repeats but with FADH+.
·The intermembrane space has a high concentration thanks to all the H+.
- now, oxygen accepts the electrons as well as hydrogens from matrix & making water.

How is ATP made?
- hydrogen ions wanna go from a high concentration gradient to a low. They can only do this through the ATP synthase protein.
- ADP forms into ATP through phosphorylation
- This facilitated process, causes the protein to spin & repeat it.
- each NADH produces 3 ATP & each FADH2 2 ATP. The net production of oxidative phosphorylation = 34 ATPs

15. What is Anaerobic pathway? → doesn't use oxygen

- Without oxygen, the krebs cycle & the ETC cannot occur.
- only glycolisis is a source of ATP. for it to continue its products of pyruvate & hydrogen must be constantly removed.
- In the absence of oxygen, fermentation prevents NADH accomulating, which wouldn't halt glycolisis & rob the cell of its energy source
- The replenishment of NAD is achieved by pyruvate accepting hydrogen from the reduced NAD

16. What is Ethanol & Lactate production in Anaerobic respiration?

Anaerobic respiration divides into two pathways → Production of Ethanol & Production of Lactate.

Production of ethanol:
- bacteria, fungi & plants produce ethanol
- pyruvate molecule made in glycolisis loses a molecule of CO2 (carbon dioxide) & accepts H (hydrogen) from reduced NAD to make ethanol
- yeast is grown in anaerobic conditions

so, pyruvate + reduced NAD → Ethanol + Carbon dioxide + NAD

Production of Lactate
- Anaerobic respiration in animals leads to lactate production to overcome temporary shortage of oxygen (breathed too much)
- lactate production commonly happens in muscles as a result of hard excersise as there is not enough oxygen being supplied which causes oxygen debt.
- reduced NAD must be removed for energy to be released. Achieved bcz each pyruvate molecule produced takes up 2 hydrogen atoms from the reduced NAD made in glycolisis to form lactate
- lactate needs to be oxidised back to pyruvate.
- lactate build up can cause cramp & muscle fight. muscles do have a certain tolerance, however it has been removed by the blood & taken to the liver to be converted to glycogen

so, Pyruvate + reduced NAD → lactate + NAD

Energy yields
- In anaerobic respiration, pyruvate is converted to either alcohol or lactate. Therefore, in anaerobic respiration, neither the krebs cycle nor the electron transport chain (ETC) can take place
- So, the only ATP that can be produced in anaerobic respiration is formed by glycolisis (2 ATP) which is a very small amount compared to aerobic respiration

15.. Anaerobic pathway doesn't need oxygen
-only glycolisis is a source of ATP.
· fermentation prevents NADH accomulating
· pyruvate accept hydrogens -
pyruvate + reduced NAD → ethanol + CO2 + NAD //

- pyruvate is converted to alcohol or lactae

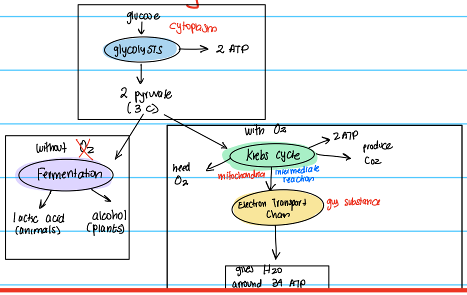
pyruvate + NADH → lactic acid (animals)

pyruvate + NADH → ethanol + CO_2 + NAD: ethanol (animals)

ATP produced → 2

- When oxygen isn't available, the ETC cannot opperate so the initial supply of NAD run out.
- to generate this, pyruvate produced in glycolisis must be reduced
- pyruvate is converted into lactic acid in animal cells.
  - pyruvate + NADH → lactic acid
- The net yield from anaerobic respiration is simply the 2 ATP produced in glycolisis, therefore, much less energy efficient
- In some plants, pyruvate is converted into ethanol
  - pyruvate + NADH → Ethanol + Carbon dioxide + NAD

Summary!



Applications, Understandings & Skills.
Metabolism:
Understandings:

2 - metabolic pathways consist of chains & cycles of enzyme-catalyzed reactions
2 - enzymes lower the activation energy of the chemical reactions that they catalyze
4 - enzyme inhibitors can be competitive or non-competitive
3 - metabolic pathways can be controlled by end product inhibition

Application:

1 - End-product inhibition of the pathway that converts threonine to isoleucine
- use of databases to identify potential new anti-malarial drugs

Skills:

1 - Calculating & plotting rates of reaction from raw experimental results
2 - Distinguishing different types of inhibition from graphs at specified substrate concentration

Four-point mastery skill

1 — Beginning
2 — Developing
3 — Proficient
4 — Mastery

Cellular respiration:

Understandings 2.8 topic

4 - Cell respiration is the controlled release of energy from organic compounds to produce ATP
4 - ATP from cell respiration is immediately available as a source of energy in the cell
4 - Anaerobic respiration gives a small yield of ATP from glucose
4 - Aerobic respiration requires oxygen & gives a large yield of ATP from glucose.

Understandings 8.2 topic

3 - Cell respiration involves the oxidation & reduction of electron carriers.
4 - phosphorylation of molecules makes them less stable
4 - In glycolisis, glucose is converted to pyruvate in the cytoplasm
4 - glycolisis gives a small net gain of ATP without the use of oxygen.
3 - In aerobic respiration pyruvate is decarboxylated & oxidized, and converted into acetyl compound and attached to coenzyme A to form acetyl co A in the link of reaction
*2 - In the krebs cycle, the oxidation of acetyl groups is coupled to the reduction of hydrogen carriers, liberating carbon dioxide
3 - Energy released by oxidation reactions is carried to the cristae of ~~the~~ mitochondria by reduced NAD & FAD.
4 - Transfer of electrons between carriers in the electron transport chain in the membrane of the cristae is coupled to proton
4 - In chemiosmosis, protons diffuse through ATP synthase to generate ATP.
4 - Oxygen is needes to bind with the with the free protons to maintain the hydrogen gradient, resulting in formation of water.
4 - The structure of the mitochondrion is adapted to the function it preforms

Applications 2.8 topic

1 - use of anaerobic cell respiration in yeast to produce ethanol & carbon dioxide in baking
3 - lactate production in humans when anaerobic respiration is used to maximaze the power of muscle contractions

Skills 2.8 topic

3 - Analysis of results from ~~experiments~~ experiments involving measurements of respiration rates in germinating seeds or invertebrates using a respirometer

Applications 8.2 topic

1 - Electron tomography used to produce images of active mitochondria

Skills 8.2 topics

1 - Analysis of diagrams of the pathways of aerobic respiration to deduce where decarboxylation & oxidation reactions occur
1 - Annotation of diagram of a mitochondria to indicate the adaptations to its functions.

Questions!

What worked well during the unit? What didn't?
What worked well during the unit was the understandings from watching videos & investigating apport from the information in the slide shows. Also the class Ivonne gave us helped me. What didn't worked well was the time management because I did my notes at last minute.
What will I do different next unit? I'd like to make some time to watch the video to not leave everything for last :)
Where and why did I got stuck? I mainly got stuck during the oxidation & reduction. Also, I'm trying to understand better all the steps in glycolisis & krebs cycle since it's A LOT of information to memorize.) understood well the ETC!!