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SUMMARY
BIOLOGY 101

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ACADEMY

Chapter 6:

☆ Free Energy Change (ΔG) ⇝ The energy that can do work

- difference
  - Final - Initial
  - $\Delta G = G_{products} - G_{Reactants}$

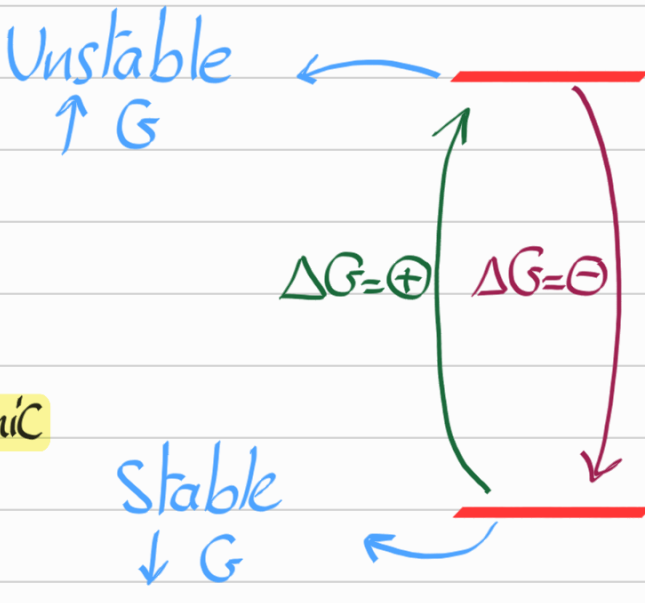
$$\Delta G = \Delta H - T\Delta S$$

- ΔH: Enthalpy, Total energy
- T: Temperature in Kelvin (K)
- ΔS: Entropy

It is a measure of instability (tendecy to become more stable)

☆ Equilibrium ⇝ Maximum stability state ⇝ lowest G

Spontaneous Reaction	Non-Spontaneos Reaction
⇒ Exergonic Reaction	⇒ Endergonic Reaction
⇒ Catabolic Reaction	⇒ Anabolic Reaction
↳ break down molecules	↳ Building molecules
⇒ ΔG = ⊖ Negative	⇒ ΔG = ⊕ Positive
⇒ Release energy	⇒ Absorbs, uses, consumes, stores energy
⇒ Decrease in free energy (↓G)	⇒ Increase in free energy (↑G)
⇒ Increase the Stability (↑ stability)	⇒ Decrease the Stability (↓ stability)
⇒ Toward equilibrium	⇒ Away from equilibrium



The magnitude of ΔG represents the amount of energy

The Reverse Reaction of an exergonic Reaction must be endergonic

☆ The release of energy during an exergonic reactions is due to the conversion from high energy (unstable) state into a less energy (↑stable) state ΔG due to breaking bonds itself

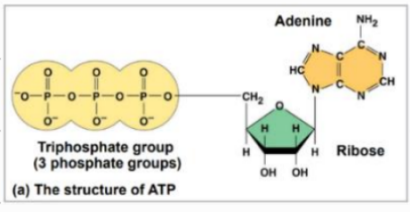
☆ Energy stored in bonds ⇝ represents the potential energy released

☆ Living cells Never reaches equilibrium ⇝ because they are open systems
↳ If a cell reached equilibrium ⇝ dead

☆ Types of work:
- Chemical work ⇝ Anabolic Reactions (synthesis of glutamine, building polymers)
- Transport work ⇝ Active transport (against gradeint, Pumping)
- Mechanical work ⇝ Muscle contraction, beating of Cilia, Moving chromosomes

☆ Energy coubling ⇝ using Exergonic + to drive Endergonic = the Overall Exergonic
↳ It is mediated by ATP

RNA nucleotide ⇜ Ribose
Adenine
3 Phosphate



ATP is used for energy coupling because:
Release a great amount of energy ⇝ due to it instability ⇝ due to repulsion between negative charges in the (P) tail

↳ Release energy by breaking the bond of the terminal (P) forming ADP + Pi
usually transferred to another molecule (Phosphorylation) forming a phosphorylated intermediate
high energy ← Unstable ← Reactive

☆ ATP hydrolysis ⇝ ΔG = -7.3 kcal/mol (under standard conditions)
↳ ΔG = -13 kcal/mol (under cellular conditions)

☆ ATP is Recycled by adding phosphate to ADP ⇝ endergonic
The energy for this reaction is aquired from catabolic reactions such as break down glucose

☆ Catalyst ⇝ chemical agent that speeds up reactions, without being consumed

⇒ Enzymes ⇝ Catalytic proteins ⇝ ends with -ase

Q) A small amount of enzymes catalyzing a huge number of reactions, Why?

Enzymes are not changed or consumed during reactions (released in its original form) so they can be used repeatedly

☆ Activation energy (EA) ⇝ Initial energy needed to start a reaction

⇒ Supplied as thermal energy ⇝ accelerating reactants & collide more until reaching transition state

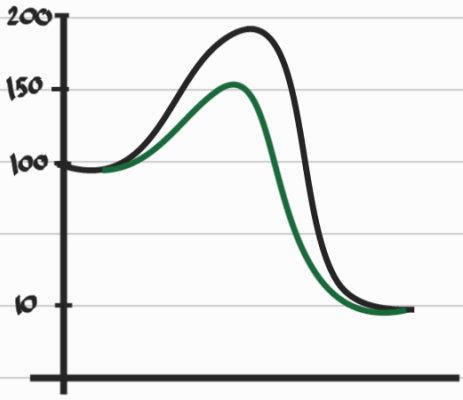
↳ Unstable (high energy) conditions of reactants

↳ It is the energy between reactants & transition state

☆ How do enzymes work?

⇒ lowering EA barrier ⇝ reaching transition state easier

⇒ Enzymes do not affect ΔG



substrate ⇝ Reactants in enzyme catalyzed reaction

enzyme-substrate complex ⇝ enzyme binding a substrate

Active site ⇝ Region (pocket, groove) on the surface of the enzyme

↳ It binds to the substrate & catalyze the reaction

Induced fit ⇝ It is the tight binding after the initial contact between substrate & enzyme

☆ How does the active site lower EA barrier ??

- Orienting substrate correctly
- Provide favorable microenvironment
- Straining bonds
- Covalent bonding with substrate

☆ Enzyme activity is affected by:

1- Environmental factors ⇝ Optimal conditions ↳ most active shape

2- Chemicals

The binding between substrate & enzyme

- Non-Covalent ⇝ Holding, initial binding
- Covalent ⇝ Catalysis method

☆ Human enzyme has optimal temperature = 35°-40°C, optimal pH = 6-8
⇒ optimal pH for pepsin (in the stomach) ⇝ very low about 2
⇒ optimal pH for Trypsin (in the intestine) ⇝ about 8
☆ optimal temperature for thermophilic bacteria = 70°C and more

Note: as temperature increases ⇝ more collide ⇝ the rate increases until reaching optimal temperature ⇝ if temperature increased ⇝ the enzyme denatures and become inactive

☆ As the concentration of the substrate increases ⇝ the rate of the reaction increases until all enzyme molecules become engaged ⇝ saturated
☆ To increase the rate of the reaction when the enzyme is saturated we have to increase the amount of the enzyme

☆ Cofactors ⇝ Non-protein enzyme helpers
- Inorganic (such as metals)
- Organic ⇝ Coenzymes (such as vitamins)

☆ Cells regulate their metabolic pathways by:
1) Switching on or of the genes that encodes a specific enzyme
2) Regulating the activity of enzymes

☆ Enzymes Inhibitors

Competitive inhibitors
⇒ Binds the active site
⇒ Blocks the entry of substrate to the active site
⇒ Can be overcome by increasing substrate conc.

Non-competitive inhibitors
⇒ Bind another site
⇒ Changes the shape making the active site less effective

If the binding is: weak ⇝ Reversible inhibition, covalent ⇝ irreversible inhibition

☆ Allosteric regulation ⇝ for enzymes compesed from more than 1 subunit

- the binding of a regulatory molecule to a site affects the function on other sites
  - activators (stimulate), inhibitors (inhibit)
- A single regulatory molecule can affect all subunits

☆ Cooperativity

- It is a type of allosteric regulation that can amplify enzyme activity
- one substrate bind to the active site of 1 subunit ⇝ increase the affinity for the substrate of all subunits
- It is explained by hemoglobin (transport protein not an enzyme)

☆ Feedback inhibition

- The end product in a pathway inhibits an early enzyme
- prevents wasting chemical resources & synthesis more products than needed

Notes:

1) Some enzymes are inserted in membranes

2) ATP acts as inhibitors for catabolic pathways
   ADP acts as activators for catabolic pathways

3) The variety between enzymes is due to mutations

4) ΔG for the hydrolysis of glucose = -686

5) Dinoflagellates are marine organisms that convert chemical energy to light by bioluminescence

Chapter 10:

Potential energy is due to the arrangment of e^-

Catabolic pathways ⇝ Break down complex molecules ⇝ Release energy

Some of this energy will be stored in ATP and the rest is dissipated (lost) as heat

☆ Energy is released due to the transfer & rearrangement of e^- ⇝ become simple, more stable with less energy

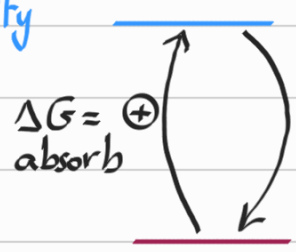
☆ Redox Reactions ⇝ Reactions involve the transfer of e^-

- Oxidation: lose electrons (e^- donor) ⇝ charge becomes more positive
- Reduction: gain electrons (e^- acceptor) ⇝ charge becomes less positive

☆ Oxidizing agent ⇝ get reduced (gain e^-)

☆ Reducing agent ⇝ get oxidized (lose e^-)

Unstable, low electronegativity
High energy, Complex



Stable, High electonegativity
low energy, Simple

Notes:

⇒ No oxidation without reduction

⇒ Some redox reactions don't involve the actual transfer of e^- Such as O_2 + Methane

☆ Oxygen has a very high electronegativity ⇝ strong pulling ⇝ ↑ Reduction

So, the strongest oxidizing agent

↳ Any transfer of electrons toward oxygen ⇝ Release energy

☆ Organic molecules acting as fuels have abundance of H atomes

↳ because H has a very low electronegativity ⇝ high-energy electrons (hilltop electrons)

☆ Catabolic pathways:

⇒ Aerobic Respiration ⇝ Uses O_2 & ETC ⇝ The most efficient
⇒ Anaerobic Respiration ⇝ Uses ETC without O_2
⇒ Fermentation ⇝ doesn't use O_2 and ETC

NAD^+ (Nicotinamide Adenine Dinucleotide): A coenzyme, e^- carrier, derivative of vitamin niacin
↳ acts with dehydrogenases
Carry e^- so represent stored energy taped to make ATP

☆ Dehydrogenase:
↳ Removes a pair of H atoms ($2e^-$, $2H^+$) from the substrate
☆ NAD^+ accepts $2e^-$ & $1H^+$ forming NADH
☆ The other proton is released H^+ ion into the solution

Note:
NAD^+ ⇝ Oxidized form
NADH ⇝ Reduced form

☆ NADH transfers the $2e^-$ to the ETC
☆ ETC transfers the $2e^-$ to Oxygen
☆ Oxygen accepts $2H^+$ forming H_2O

↳ Electron transport chain:
⇒ Consists mainly of proteins
⇒ Eukaryotes: Inner mitochondrial membrane
Prokaryotes: Plasma membrane
⇒ Transfering electrons from the

High energy end ↓ Electronegativity — Top ↓
Low energy end ↑ Electronegativity — Bottom

☆ Aerobic Respiration — Eukaryotes & Prokaryotes

3 stages:
1) Glycolysis ⇝ break down glucose into 2 pyruvate
2) TCA cycle ⇝ Completes glucose break down
3) Oxidative phosphorylation ⇝ Synthesizes most (90%) of ATP

☆ Glycolysis ☆

- Occures in the Cytoplasm
- Occures in the presence of O_2 or not
- 10 steps divided into 2 phases:

Energy investment phase	Energy pay-off phase
spend 2 ATP to break glucose into Two 3-C sugars	Repay (forming) 4 ATP Rearranging the atoms forming 2 pyruvate

↳ G3P and DHAP ⇝ (isomerase) 2 G3P

Notes:

⇒ **Oxidative phosphorylation:** adding (P_i) to ADP forming ATP, occures with ETC

⇒ **Substrate level phosphorylation:** adding phosphate from the substrate to ADP forming ATP, Occures without ETC

Very Important Notes on glycolysis:

1) Steps that consume ATP = 1 & 3 / steps that form ATP = 7 & 10
2) Step number 6 forms 2 NADH / step number 9 forms $2H_2O$
3) **Phosphofructokinase:** The enzyme that catalyze the 3rd step ⇝ transfers phosphate to (fructose 6-phosphate) forming (fructose 1,6-Biphosphate)
4) **Enolase:** The enzyme that catalyze the 9th step ⇝ forming (=) in 2-phosphoglycerate converting it to PhosphoEnolPyruvate (PEP) ⇝ a molecule with high energy
5) **G3P** = Glyceraldehyde 3-phosphate, **DHAP** = DiHydroxyAcetone Phosphate

The net products of Glycolysis per glucose molecule:

2 ATP, 2 NADH, $2H_2O$, 2 pyruvate molecules

No Release of CO_2

☆ Pyruvate oxidation

- Occures in the mitochondria (eukaryotes) but in Cytosol (prokaryotes)
  - Pyruvate enters the mitochondria by active transport
- Steps: 1) Release CO_2 2) Forming NADH 3) attaching CoA forming acetyl CoA
- Coenzyme A (CoA): Sulfur containing compound, derivative of B vitamin, has high energy

The net products of Pyruvate Oxidation per:

Pyruvate molecule: 1 CO_2 , 1 NADH , 1 acetyl CoA

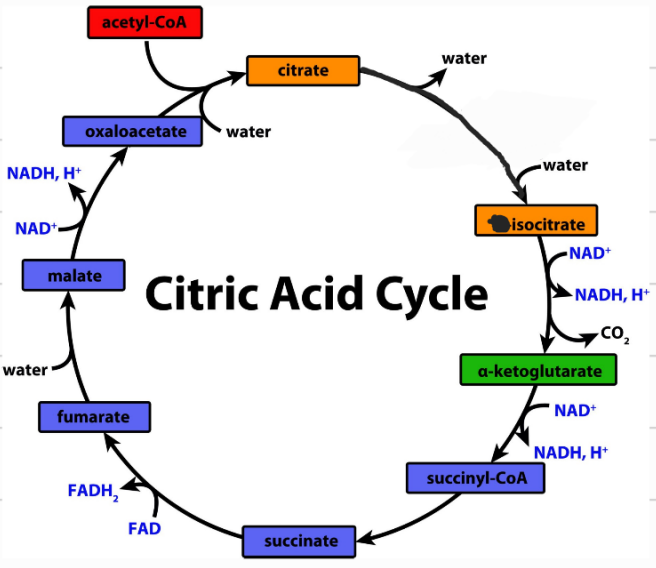
Glucose molecule: 2 CO_2 , 2 NADH , 2 acetyl CoA

No ATP Synthesis

☆ TCA cycle ☆

- Called Citric acid cycle, Kreb's cycle and Tricarboxylic acid (TCA) cycle

CIA Sent Soldiers For My OFFice



Notes:

1) TCA cycle release 2 CO_2 in steps 3 and 4
2) TCA cycle forms 3 NADH in steps 3, 4 and 8
3) TCA cycle forms 1 ATP (or GTP) in step 5
4) TCA cycle forms 1 $FADH_2$ is step 6
5) Citrate is converted to isocitrate by Removing H_2O the adding H_2O again
6) Fumarate is converted to malate by adding H_2O

All the enzymes of TCA cycle are located in the mitochondrial matrix
Except the enzyme of the 6th step (inner mitochondrial membrane)

The net products of TCA cycle per:

pyruvate molecule, per cycle: 2 CO_2 , 3 NADH , 1 $FADH_2$, 1 ATP (or GTP)

glucose molecule: 4 CO_2 , 6 NADH , 2 FADH , 2 ATP (or GTP)

☆ Oxidative Phosphorylation ☆

ETC → mainly proteins

Prosthetic group: Non-protein components

⇒ Source of e^- for ETC ⇝ NADH & $FADH_2$ (accepts $2e^-$ and $2H^+$)

⇒ NADH transfers $2e^-$ to Complex I

Complex I (FMN ⇝ Fe.S) ⇝ CoQ ⇝ Complex III and IX (cytochromes) → O_2

⇒ $FADH_2$ transfers $2e^-$ to complex II

Complex II (Fe.S) ⇝ CoQ ⇝ Complex III and IX (cytochromes) → O_2

Flavoprotein: The first molecule in ETC, Its prosthetic group is Flavin Mono Nucleotide (FMN)

Fe.S: Iron-sulfur protein, Its prosthetic groups are iron & sulfur

Coenzyme Q, Ubiquinone (CoQ): hydrophobic, mobile, the only member that isn't protein

Cytochromes (Cyt): proteins in Complexes III and IV, the last one (before O_2) is Cyt a3

Their prosthetic group is heme → contains iron

☆ ETC is important to transfer electrons step by step & release energy in a more managable way (Not in an expolsive way)

ATP synthase ⇝ It is an enzyme that makes ATP (from ADP + Pi)

↳ In the inner mitochondrial membrane (eukaryotes)

and plasma membrane (prokaryotes)

The energy released due to the transfer of e^- along ETC is used to pump proton (H^+) from the matrix to the intermembranous space forming a proton gradein ⇝ then H^+ return back to the matrix through ATP synthase ⇝ moving and spining the rotator ⇝ catalyzing ATP synthesis

→ indirect use of energy

Chemiosmosis, Proton-motive force ⇝ It is the use of proton gradeint to do a work (such as ATP synthesis)

Notes:

1) 34% of the energy in glucose is used to make ATP ⇝ the rest is lost as heat
   ⇒ Uncoupling proteins: proteins in the inner mitochondrial membrane ⇝ decrease the efficiency of ATP generation to form heat to maintain body temperature

2) the total ATP synthesized is about = 32 ATP
   ⇒ 2 (glycolysis) + 2 (TCA) + 28 (ETC + Chemiosmosis) = 32
   Substrate level phosphorylation + Oxidative phosphorylation

3) The transfer of electrons release energy enough to pump:
   ⇒ NADH (from mitochondria) ⇝ 10 H^+ ⇝ forming 2.5 ATP
   ⇒ NADH (from cytosol, glycolysis) ⇝ forming 1.5 ATP
   less because of energy used to actively transport NADH to the mitochondria
   ⇒ $FADH_2$ ⇝ 6 H^+ ⇝ forming 1.5 ATP
   less because it trasfer its e^- to a lower energy level (complex II Not I)

☆ The flow of _____ during aerobic respiration:
1) e^- ⇝ Glucose ⇝ NADH, $FADH_2$ ⇝ ETC ⇝ Oxygen
2) energy ⇝ Glucose ⇝ NADH, $FADH_2$ ⇝ ETC ⇝ Chemiosmosis ⇝ ATP

☆ Anaerobic Respiration ⇝ in certain prokaryotes

⇒ It uses ETC but doesn't use Oxygen ⇝ It use another electronegative molecule with less electronegativity (efficiency) than O_2 (such as SO^{-2})
⇒ Marin bacteria uses SO^{-2} ⇝ so the by product is H_2S not H_2O
(H_2S has rotten egg odor)

☆ Fermentation

⇒ In cellular respiration ⇝ make ATP by substrate level and oxidative phosphorylation, and NAD^+ is recycled by ETC

⇒ Fermentation ⇝ make ATP only by substrate level phosphorylation and NAD^+ is recycled by pyruvate or one of its derivatives

⇒ Fermentation = glycolysis + NAD^+ recycling (regeneration)

Alcohol Fermentation	lactic acid Fermentation
☆ Pyruvate converted to ethanol by 2 steps: 1) Release CO_2 forming acetaldehyde 2) Reducing acetaldehyde by NADH forming Ethanol + NAD^+	☆ Pyruvate is converted directly to lactate ☆ No Release of CO_2 ☆ Used by fungi, bacteria & muscles ☆ Used in making yogurt and cheese ☆ Muscles use lactic acid fermentation when O_2 is Scarce (not enough) in strenuous exercise ⇝ causing lactate accumulation ⇝ which transported to the liver to regenerate pyruvate
☆ used by yeast (fungus) & bacteria ☆ used in winemaking, brewing and baking	

☆ In fermentation ⇝ pyruvate or acetaldehyde are the last e^- acceptors

☆ In aerobic respiration ⇝ O_2 is the last e^- acceptor

☆ In anaerobic respiration ⇝ Electronegative molecule is the last e^- acceptor

Organisms are classified into:

1) Obligate anaerobe ⇝ only Anaerobic Respiration and fermentation
   ↳ Can't survive in the presence of O_2 (O_2 is toxic for them)
2) Obligate aerobe ⇝ only Aerobic Respiration (such as vertebrates brain)
3) Faculative anaerobe ⇝ Both Fermentation + Respiration (such as yeast, some bacteria & muscle cells)

☆ Glycolysis & TCA cycle have many intersections with other catabolic and anabolic pathways

Catabolic

1) Starch and glycogen ⇝ broken down into glucose ⇝ enters glycolysis
2) Proteins ⇝ broken down into amino acid ⇝ Removing their amine group by deamination ⇝ then enter TCA or glycolysis
3) Fats ⇝ Glycerol ⇝ converted to G3P ⇝ glycolysis intermediate
   ⇝ Fatty acids ⇝ broken down by beta oxidation to 2C fragments which are converted to acetyl CoA ⇝ enter TCA

Anabolic

1) Pyruvate can be used to make glucose
2) Acetyl CoA can be used to make fats
3) DHAP can be used to make fats
4) We can synthesis half of the 20 amino acid the rest are essential (only from diet)

Regulation of Respiration:

phosphofructokinase (step 3 glycolysis) ⇝ the pacemaker of respiration
Inhibited by ATP and citrate, activated by AMP and ADP

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