Metabolism: Sum of all biochemical reaction in living organisms (anabolism or catabolism)

Bioenergetics: is the study of energy transformation in cellsfrom the thermodynamic point of view (potential energy not kinetic energy)

♡ Energy is the life ♡

So, many processes in our body need energy: Mechanical, Active transport, Biosynthesis, Heat

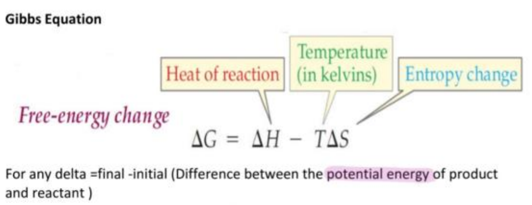
Types of energy are:

1-Kinetic energy : the energy during motion

2-potential energy : energy stored within materials that can be converted to kinetic energy if needed .

(Energy has inverse relationship with stability)

Main concept or causes for chemical reaction is to achieve more stable situation



Enthalpy change(ΔH) : **regular**

bond energy **in** different atoms

Entropy change (ΔS) : **random** :

disorder between the different molecules for nature system Increase in time

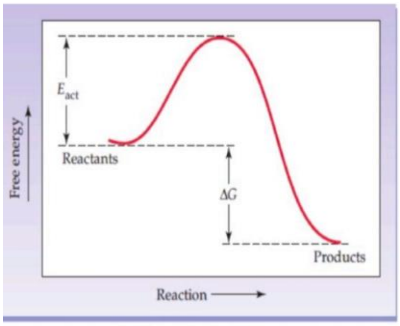
REACTION

ΔG is negative :loss of energy

(product more stable than reactant)

spontaneously (favourable) , exergonic.

Transition state → activation energy



(a) An exergonic reaction

Breaking down all molecules so, releasing energy

** Hydrolysis reactions

** Decarboxylation reactions

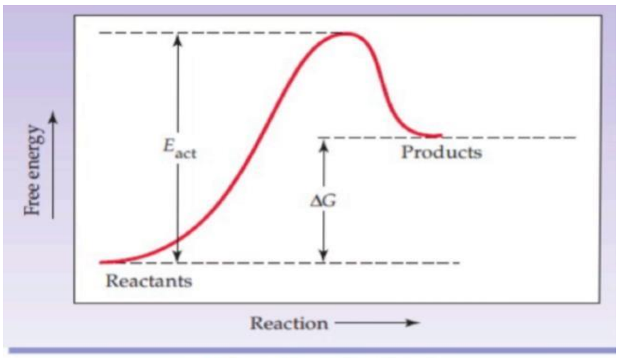
** Oxidation

ΔG is positive

Gain ofenergy (reactant more stable than product)

Not go spontaneously (unfavorable)

endergonic.



(b) An endergonic reaction

*ΔG is not affected by the mechanism of the reaction (presence or absence of enzymes)

**pathway of the reactions only cares about initial and final states " state function "

glucose #

$$A \xrightarrow{\text{Enzyme 1}} B \xrightarrow{\text{Enzyme 2}} C \xrightarrow{\text{Enzyme 3}}$$

➤ A → B → C

$\Delta G_{A \to B} = \cancel{GB} - GA$

$\Delta G_{B \to C} = GC - \cancel{GB}$

$GC - GA = \Delta G_{A \to C}$

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#Standard free energy change (ΔGo) VS Free energy change (ΔG)

ΔG = the free energy difference of a system at any condition

{ Determine the favourability of reaction }

ΔGo= the free energy difference of a system at standard conditions (25C & 1 atmospheric pressure, 1M concentration of reactants & products, pH = 7) It is always constant

Equilibrium:

State of balance when 2 rates

(doesn't equally of concentration)

Concentration affect ΔG

Delta G has nothing to do about reaction rate

At equilibrium:

ΔG=0 (since the driving force of any reaction at equilibrium is zero)

$$\cancel{\Delta G} = \Delta G^{o} + RT \ln \frac{[\text{Products}]}{[\text{Reactants}]}$$

$$K_{eq} = \frac{[\text{products}]}{[\text{reactants}]}$$

ثابتة

Rate

$\rightleftharpoons$

$\Delta G = 0$

$$\Delta G^{\circ} = -RT \ln K$$

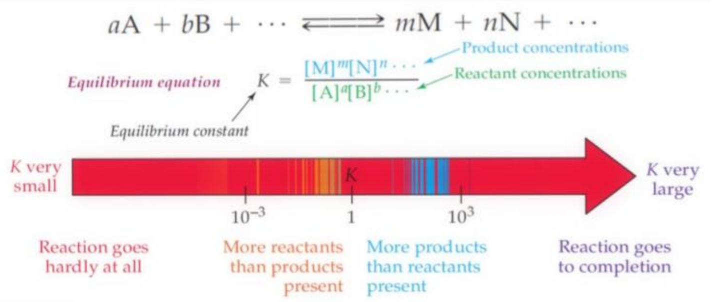
How much change in delta G compared to changes in Keq

If $K_{eq} = 1$, then $\Delta G^{o} = 0$

If Keq > 1, then $\Delta G^{o} < 0$

If Keq < 1, then $\Delta G^{o} > 0$

Keq=100 that means at equilibrium [P]=100*[R]



The Effect Of Changing Conditions On Equilibrium :

** The equilibrium shifts to relieve the stress

1)Effect Of Changes In Temperature

More reactants ($\boxed{\uparrow}$ T —> encouraging the backward direction)

More products ($\boxed{\uparrow}$ T —> encouraging the forward direction)

《 Until we reach the equilibrium state 》

endothermic/exothermic are favoured by increase/decrease in temperature, respectively

2)Effect Of Changes In Concentration

** —>Metabolic reactions sometimes take advantage of this effect

:) no effect of a catalyst (enzyme) on equilibrium ; It just helps the reaction to achieve equilibrium faster, because catalysts play on what is between the reactants and products

—>90% energy (ATP) mitochondria , (10%) glycolysis cytosol

—> The number of mitochondria is greatest in eye, brain, heart, & muscle, where the need for energy is greatest

—>mitochondria is found only in eukaryotic cells (evolution theory)

Reproduction of mitochondria

—>Reproduction of mitochondria is governed (determined) by the need of energy

this is why athletes behave better in exercises than ordinary people, (they have more mitochondria, more oxygen supplies, more ATP)

Maternal inheritance

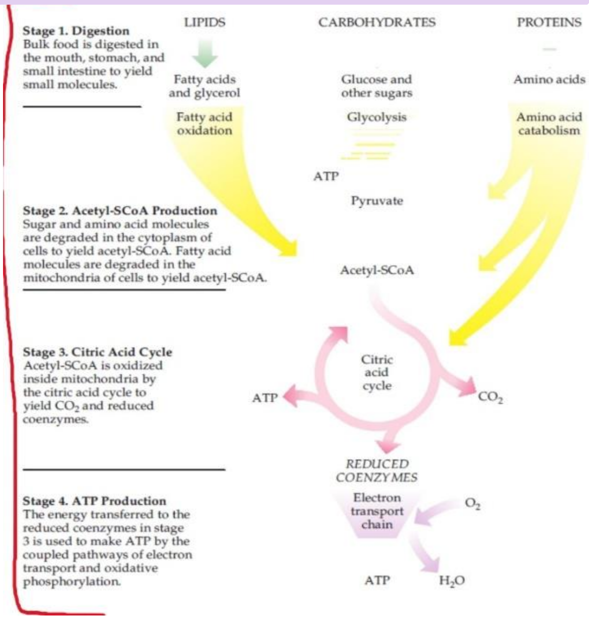
During cell division the mitochondria segregate randomly between the two new cells

As DNA is copied when mitochondria proliferate, they can accumulate random mutations, a phenomenon called heteroplasmy.

○ Mutation (DNA) → all over body [mitosis]

○ Mutation (mitochondria) → one daughter cell

ATP



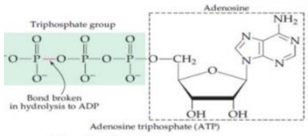
ATP

What determines the amount of energy a bond stores ? atoms / atoms around bond

ATP is the energy currency

—Why ATP is the energy currency of the cell? because it has an intermediate energy value, can be broken down and resynthesized easily

ATP



What determines the amount of energy a bond stores —>is the atoms that are involved directly in the bond (phosphate and oxygen for example in ATP) and the distribution of atoms around this bond which makes strain on the bond so it changes the energy of the bond.

A-R-O-P-O-P-O-P-O⁻ + HOH → ADP + H-O-P-O⁻
(ATP) (P_i)

-7.3 kcal/mole
-3.4 kcal/mole

Compound $+H_2O$	Product + phosphate	ΔG°
Phosphoenol pyruvate	Pyruvate	-14.8
1,3 bisphosphoglycerate	3 phosphoglycerate	-11.8
Creatine phosphate	Creatine	-10.3
ATP	ADP	-7.3
Glucose 1- phosphate	Glucose	-5.0
Glucose 6- phosphate	Glucose	-3.3

ATP is the energy currency of the cell, it has a triphosphate group and breaking down each P-O bond gives energy

ATP عملة الطاقة في أجسامنا

There is no place where ATP is stored in the body, energy is stored as bonds in (carbohydrates , lipids ,....) ...Why??

Breakdown ATP → ADP $+P_i$ [20 Kcal/mol]

Synthesis ATP ← ADP $+P_i$ [20 Kcal/mol]

There are also many reactions that give the same amount of energy that ATP produces so it can compensate ATP. تعويضه

Because we consume a huge amount of ATP everyday that equals 90.6 moles /day

So , you need 49,920 g ATP (approximately 50,000 g ATP)!!!

** That means if your body store energy as ATP molecules you'll add 50 Kg to your weight , also your size after eating will be increased and when you're hungry it'll decrease(unreality) Pathways

Why dowel you like need energy?

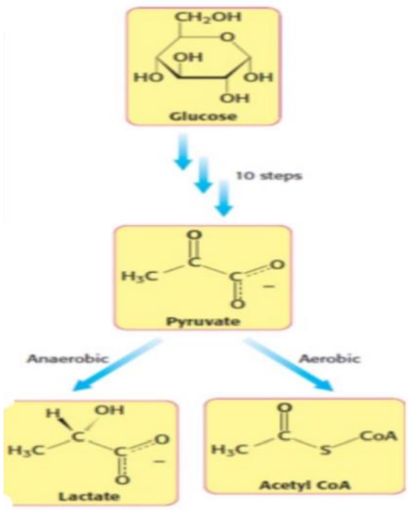
1. mechanical work
2. active transport
3. synthesis of macromolecules

Sun is the main source of energy

plants (autotrophs)

animals (heterotrophs)

human can eat both of them to get his food.



Pathways in our body ;

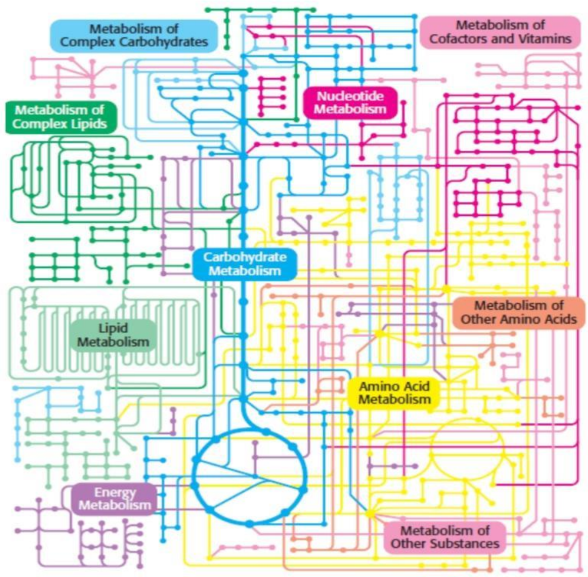
1.Linear pathway : every material converted to another material (different enzymes)

2.cyclic pathway : by the end of pathway , first material (different enzymes)

3.spiral pathway : different materials , same set of enzymes

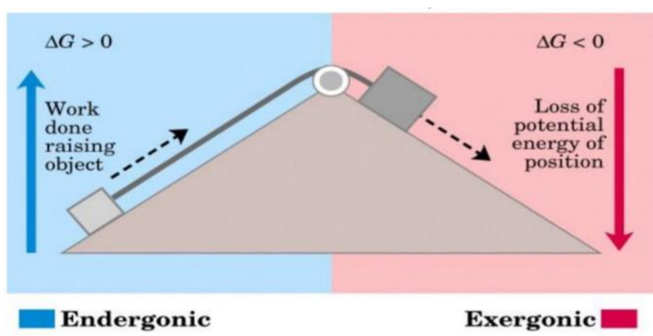
All pathways in our body need to understand each other to conserve energy from loosing , allosteric enzyme helps in this process… How?

Allosteric enzyme : enzyme that have multiple binding sites for different molecules from different pathways and areas ,that helps molecules to collaborate with each other and conserve energy



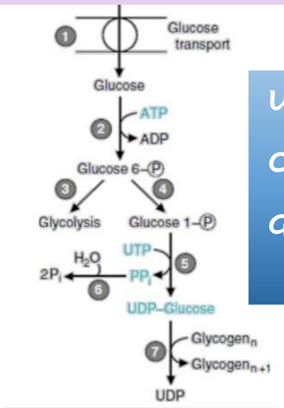
Coupling a reaction consume energy to Add certain material and other reaction release energy and that material, too.

(REALEASE ENERG , MATERIALS)



EXAMPLE : Phosphorylation transfer reaction

Thermogenesis:



UTP = SUGAR

CTP = LIPID SYNTHESIS

GTP = PROTEIN SYNTH

Thermogenesis:

✓ Is the first law of thermodynamics

- It is the energy expended for generating heat (37oC) in addition to that expended for ATP production الطاقة المستهلك في توليد حرارة الجسم الطبيعية 27 °و طاقة

Shivering thermogenesis	Non-shivering thermogenesis
(ATP utilization)	(adaptive thermogenesis)
asynchronous muscle contraction due to sudden change in the body temperature	the percentage of energy that you are ingesting inside your body to make heat (ATP production efficiency)
# More ATP and generate heat	♡ الطاقة الحرارة العادية
(Heat production is a natural consequence of "burning fuels")	

Thermogenesis: توليد الحرارة

✓ Is the first law of thermodynamics

مفهوم ✓ It is the energy expended for generating heat (37oC) in addition to that expended for ATP production الطاقة المستهلكة في توليد حرارة 37°C ، ATP

✓ it has 2 types:

غير متزامن

1. shivering thermogenesis (الارتعاش) (ATP utilization) = asynchronous muscle contraction due to sudden change in the body temperature (usually decrease), thus making more ATP and generate heat as a byproduct of making ATP to return the body temp to the normal situation.

(Heat production is a natural consequence of "burning fuels")

2. Non-shivering thermogenesis (adaptive thermogenesis): the percentage of energy that you are ingesting inside your body to make heat (ATP production efficiency) كمية الطاقة والحرارة الذي ننتجها بشكل عام، وهي مختلفة من شخص لآخر

Oxidation reduction reactions:

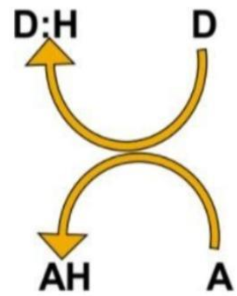
we are studying them now because they exist in most of the metabolism of energy reactions

مفهوم ✓ Oxidation reduction reactions include moving of electrons without changing the chemical structures

e^- without.

ΔG: the difference in bond energies between materials

مفهوم **redox potential (E) (THE POTENTIAL ENERGY): the driving force** of moving the electrons from one atom to another, these electrons are hold on chemical structures which has the ability to donate its electrons or accept its electrons.



✓ redox Potential measures the tendency of oxidant/reductant to gain/lose electrons, to become reduced/oxidized

✓ Electrons move from compounds with lower reduction potential (more negative) to compounds with higher reduction potential (more positive) ↓ reduction potential. more -ve

ΔE = the difference in electrecal potentials between two points.

or مثال: اللي بخلي الكهربا توصل للبيت هو فرق الجهد بين أعمدة الكهرباء

there is a difference in the ability of accepting donating electrons between any 2 chemical materials

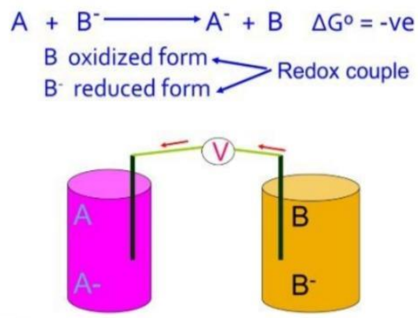
✓ The electrons move from the material that has a higher ability to donate electrons to the one which has a lower ability to donate electrons.

✓ **Oxidation and reduction must occur simultaneously**

بنفس الوقت

- **Oxidation:**
- Gain of Oxygen
- Loss of Hydrogen
- Loss of electrons
- **Reduction:**
- Gain of Hydrogen
- Gain of electron
- Loss of Oxygen

Now look at this redox couple: (A) accepts electrons and is converted to the reduced form A- so we have a redox couple (A , A-).



Now, can we measure redox potential experimentally?

yes. Scientists were able to measure reduction potential for a wide variety of materials with respect to hydrogen electrode (as a standard electrode Eo=0) and they arranged these values from the more negative to the more positive value in a large scale.

استنادا

The -ve = high Capacity to loss electrons
The +ve = high Capacity to gain electrons.

why H^+_2?

The importance of this standard electrode is to obtain the exact value of reduction potential ① ② . Another advantage of using hydrogen is that **most materials can gain/lose hydrogen.**

, **oxygen** is the final electron acceptor for electrons most positive reduction potential **NADH** has a reduction potential (Eo) of -320 mv thus it gives electrons to oxygen with Eo =+820mv.

Reduction potential: Ability to accept electrons

Oxidized + e^-	→ Reduced	ΔE^o (V)
Succinate	α ketoglutarate	- 0.67
Acetate	Acetaldehyde	- 0.60
NAD^+	**NADH**	**- 0.32**
Acetaldehyde	Ethanol	- 0.20
Pyruvate	Lactate	- 0.19
Fumarate	Succinate	+ 0.03
$Cytochrome^{+3}$	$Cytochrome^{+2}$	+ 0.22
oxygen	**water**	**+ 0.82**

Kreps Cycle.
NADH $\xrightarrow{e^-}$ Oxygen
Donator acceptor.
electron Transport Chain

ΔG is not only concerned with bond energy. The reduction potential, not bond energy, is the driving force for electrons movement. Therefore, **if we inverted the sign of reduction potential value then electrons will move in the backward direction**. There must be a mathematic relation that governs the direction of electrons movement. Moreover, it should not contain any variable other than $\boxed{\Delta G \text{ and } \Delta E.}$

$$\Delta G^o = -\, n f \Delta E^o$$

- F = Farady constant = 23.06 kcal/*Volt*

(n) constant: the number of electrons moving

Also, the following relation can be used:

$$\Delta G = -\, n f \Delta E$$

For a reaction to be favorable, spontaneous and exergonic (-ve ΔG) then ΔE must have a +ve value. The following example supports the previous statement.

NADH has a reduction potential Eo= -320 mv thus it gives electrons to oxygen with Eo = +820mv. **ΔEo = Eo (final oxygen) – Eo (initial NADH) = +820 – (-320) = +1140 mv (positive value and spontaneous reaction)**

As we seen before, the sign of ΔE o is +ve thus when scientists wrote equation, they inserted the -ve sign to fit the real situation.

Question:

Calculate ΔG° of the following reaction

$$NADH + 1/2O_2 \longrightarrow NAD^+ + H_2O$$

$$NADH \longrightarrow NAD^+ + 2e^- \quad \Delta E^o = +0.32\,V$$

$$O + 2e^- \longrightarrow O^{2-} \quad \Delta E^o = +0.82\,V$$

Solution: ΔE o =1140 mv

= 1.14 volt

ΔG o = -nf ΔE o

= -(2) (23.06)(1.14) ➔ ΔG° = - 52.6 kcal/mol

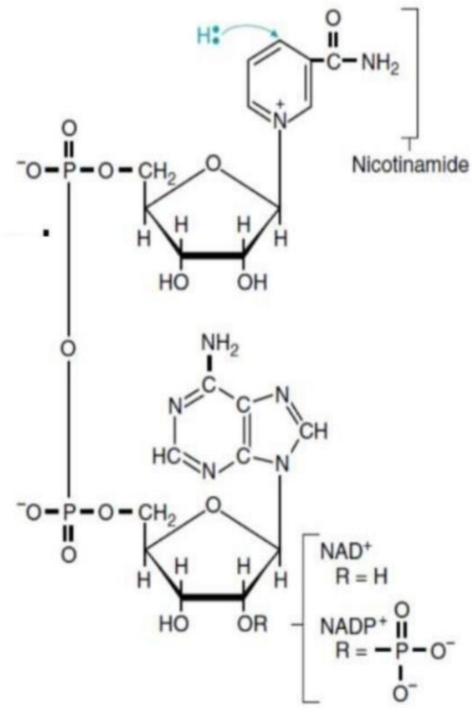
Now, let us talk about **electron carriers** (that transports electrons to ETC).

There are 2 main electron carriers:

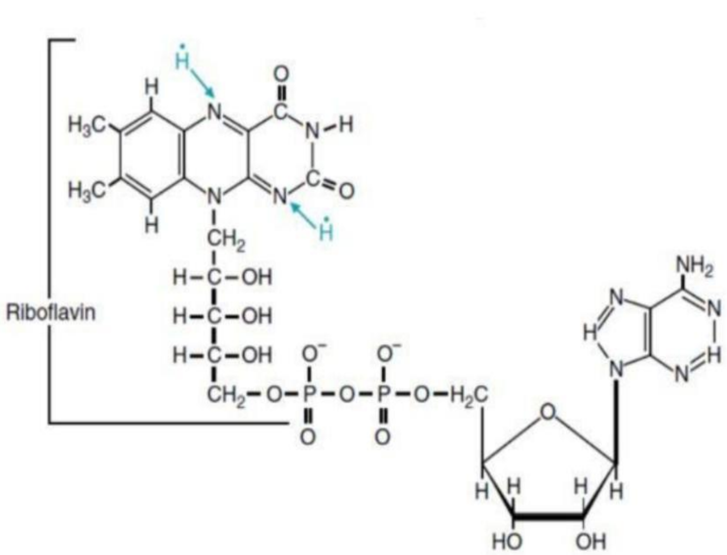
✓ NAD+ (niacin, B3) & FAD (riboflavin, B2).

NAD+ accepts a single hydride ion H - (2 electrons) on nicotinic ring with one step, so it does not form a radical (will not be harmful) and thus can be found free as both NAD+/NADH in mitochondria/cytosol, as a result, it has a fixed reduction potential.

-NADP+ is different from NAD+ only by **a ssphosphate group** instead of **a hydrogen atom** as shown in the previous figure. Both of them carries 2 electrons but NAD+ participates in **catabolism** while NADP+ participates in **anabolism**. So, different structures that do the same function for better organization and regulation.



✓ FAD accepts 2 protons (2 electrons) sequentially since there are 2 Hatoms thus it forms a radical intermediate and passes through (one electron/free radical state) that is harmful. Therefore**, it cannot be found free in the cytosol** and is always bound to proteins. Also, its reduction potential depends on the protein it is bound to. **FMN** also carries 2 electrons sequentially, but for better organization: one works in anabolic reactions while the other in catabolic reactions.



Past papers