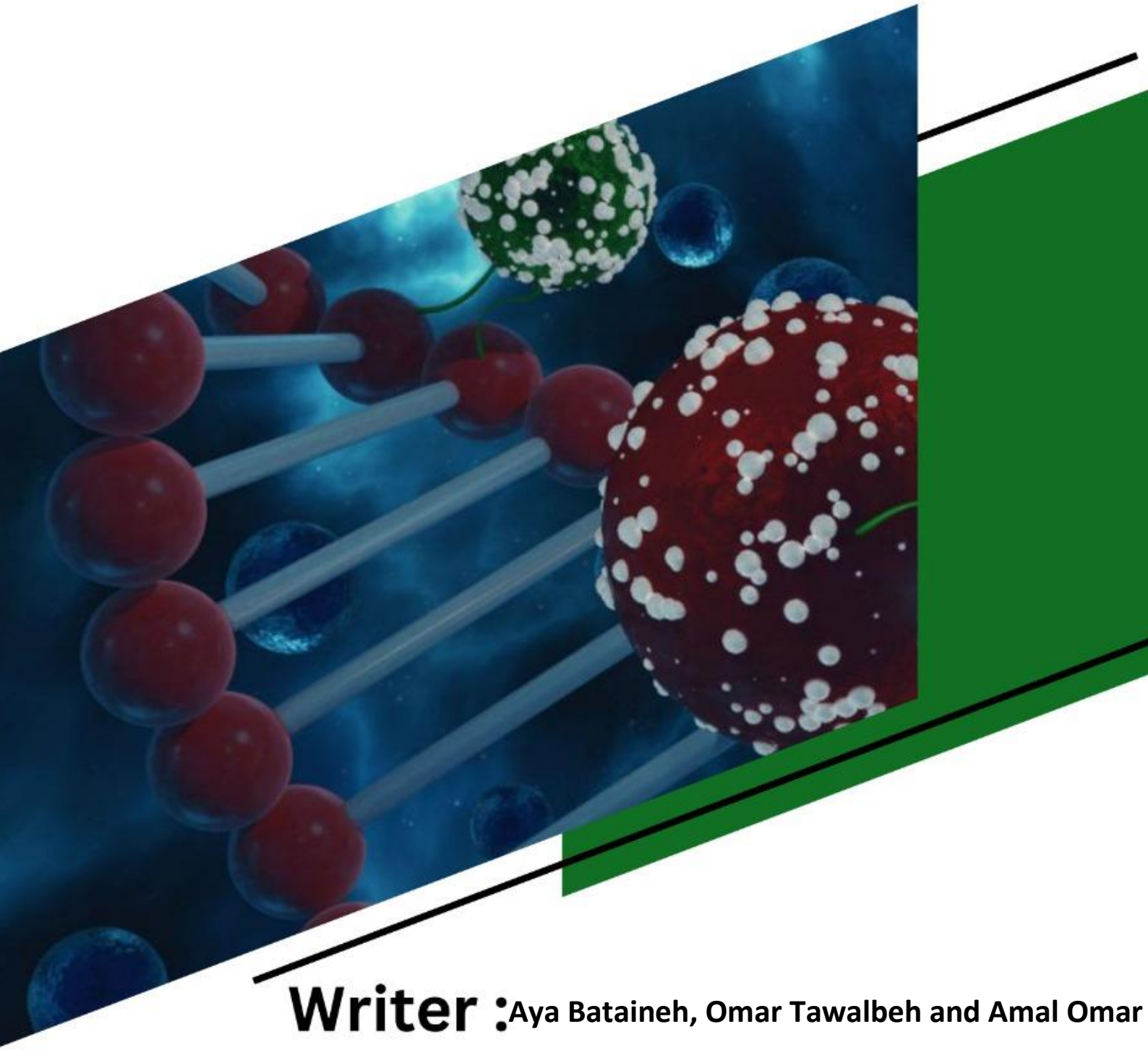
Doctor 021

METABOLISM

Sheet no. 1



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BIOENERGETICS

Bioenergetics describes the transfer and utilization of energy in biological systems.

Energy metabolism: converging point of all metabolic pathways (degradation of carbohydrates, proteins, nucleic acids to give us energy) .

ENERGY & WHY DO WE NEED IT?

Definition: Capacity to perform work.

What for? Mechanical, Active transport, biosynthesis, Heat.

THE MAJOR PURPOSE OF METABOLISM

- **Metabolism: Sum of all biochemical reactions in living organisms**
- **Mainly for energy generation**
- **Other purposes:**

  Synthesis of building blocks

  Synthesis of macromolecules

  Degradation of biomolecules
- **Bioenergetics: Energy transformations in the cell**

Types of energy:

1- Kinetic: Energy in the process of doing work or Energy of motion

Kinetic science: the science that deals with the rates of chemical reactions (pathways, steps, intermediate…)

2- Potential: Energy content stored in a matter

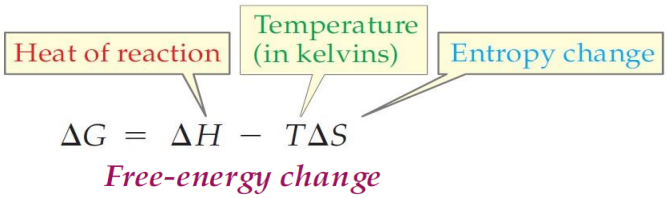
Dynamic science: it is studied reactions as a starting point and ending point regardless of the pathway, it deals with not kinetic energies, the other type of energy which is important for biochemical reactions which is named (Potential energy).

Potential energy - stored energy- which can be transformed to another energy. This is, what is interesting in? The difference between the stored energy inside the reactants and stored energy inside the products ΔG (difference in potential energies)

ΔG= ΔH-TΔS ΔH: The total energy in any system (equal ΔG+TΔS), so at the fixed temperature, ΔH=ΔG+ΔS

- ΔS =Energy difference between molecules. (entropy)

- ΔH: Bond energy between inside the molecules and bond energy in between molecules. (enthalpy)
- ΔG only thing which determines if the reactions go through or not, which is called state function -not affected by pathway- it's interested in the initial and final state only of the reaction.



WHY DO CHEMICAL REACTIONS OCCUR? CONCEPT OF FREE ENERGY, Gibbs

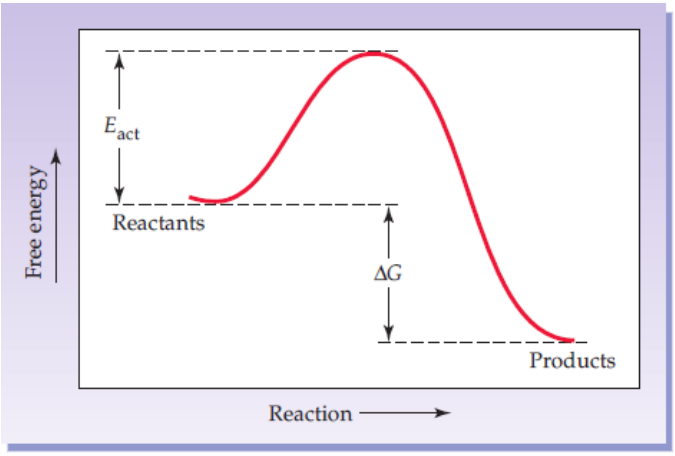
To achieve a situation with high stability, to make things more stable.

How to reach a more stable stage?

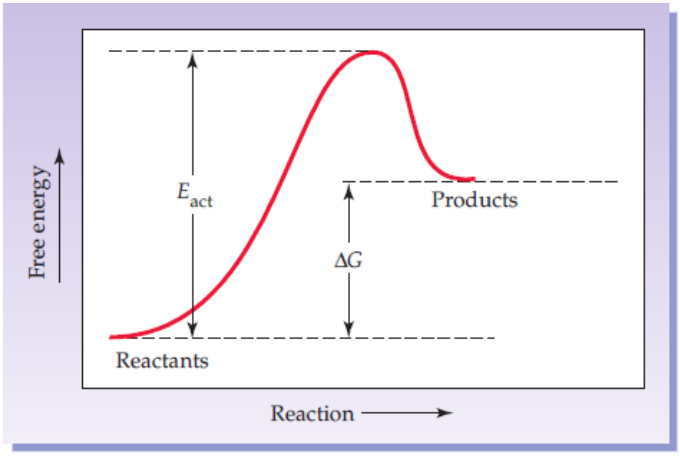
By reducing stored energy.

The higher the energy, the lower the stability (Inverse relationship). Behind chemical reactions, to go from a high energy scale to a lower energy scale (ΔG = final - initial, going from high to low, final (low) and initial (high), so the sign of ΔG will be negative (small value - big value)), we call this reaction **favorable, Exergonic -releasing energy-, spontaneous reaction.**

If we are going from low energy scale to high energy scale, we are dealing with **Unfavorable, Endergonic, Non-spontaneous reaction.**



(a) An exergonic reaction



(b) An endergonic reaction

Why this reaction occurs? To synthesis, to store energy. Degradation inside the body, it produces energy. The building up process requires energy, degrading process releases energy

(Unfavorable, Endergonic, Non-spontaneous) reaction want activation energy higher than (favorable, Exergonic -releasing energy-, spontaneous) reaction so that degradation give us energy that activate the synthesis

reactions. So Nonspontaneous reaction and spontaneous reaction can be considered as complementary reaction.

- Spontaneous reaction → Negative ΔG → Give energy
- Non-spontaneous reaction → Positive ΔG → Uptake energy

The concept of activation energy.

Energy barrier (Activation energy): The scale which is higher in energy compared to the reactants or products. In the absence of an energy barrier, all the spontaneous reactions will be in products state. Enzymes reduce this energy (Nothing to do with the starting point or ending point).

THE DIFFERENT FREE ENERGY TERMS

- **ΔG = the free energy difference of a system at any condition.**
- **ΔG° = the free energy difference of a system at standard conditions (25C° & 1 atmospheric pressure, 1M concentration of reactants & products, pH= 7)**
- **Which one of these terms determine the feasibility the reaction?**
- **ΔG depends only on initial state and final state of biochemical pathways.**

ΔG° is always a fixed value (Doesn't change) because it's under the same conditions in all reactions. So, I can compare reactions together. But the ΔG is variable value (may be different because of changing concentration or temperature, etc.)

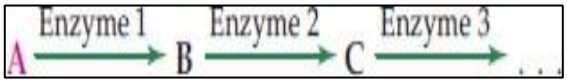
To clarify more:

ΔG = the free energy difference of a system at any condition (may be different because of changing concentration or temperature, etc.) Determine the favorability of reaction. ~ΔGo = the free energy difference of a system at standard conditions (25Co & 1 atmospheric pressure, 1M concentration of reactants & products, pH = 7). It is always constant.

IS ΔG A STATE FUNCTION?

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

ΔG is not affected by the pathway of the reactions only cares about initial and final states, so that we called it state function, so it's not a path function. (ΔG from A to B to C = ΔG from A to C)



For example: combustion of glucose outside the body will release (-680kcal/mol) ~Inside the body glucose undergo 10 steps to be oxidize, but also it will release(-680kcal/mol) So, we will repeat that ΔG cares ONLY about initial and final states.

$$A \rightarrow B \rightarrow C$$

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

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

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

- Combustion of glucose in calorimeter

$$Glucose + O_2 \rightarrow CO_2 + H_2O \qquad \Delta G = -680 \text{ kcal/mol}$$

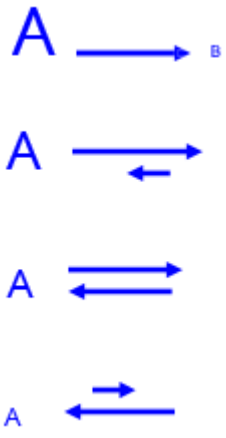
In the cell

$$Glucose \rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow CO_2 + H_2O \qquad \Delta G = -680 \text{ kcal/mol}$$

ΔG IS AFFECTED BY CONCENTRATION

When we increase concentration (no. of moles in certain volume), we are increasing the amount of bonds, accordingly the energy content will increase.

We said that ΔG is a variable measurement for the energy affected by the environment: T, P, concentration, etc. And we present the fixed value for the reaction (change in the energy) in STP (standard T and P) for 1 mole of the substance by ΔG^o. The energy we talked about is the energy stored in the bonds, so when we increase the amount of substance – by increasing the concentration – we raise the number of bonds results in increasing the energy content.



Note: As an example of a water molecule, when increasing the concentration doesn't affect the bond between Hydrogen and Oxygen because these bonds don't change, we just increase the number of these bonds by increasing the concentration.

EQUILIBRIUM

First, equilibrium deals with the energy flow not the concentration. As the doctor use an example: if I move from point A to the point B, there is nothing to prevent me from point B to A. In terms in reactions, the determining factor for the ability to reverse is the energy scale not the concentration.

لتقريب الفكرة :

ميزان ابو الكفتين في وزنة (قطعة الحديد السودا) مقدارها 1 كيلو فتوزن مثلا 300 حبة لوز. الفكرة انه صار في توازن بين الكفتين مع انه العدد مختلف لكن الوزنة وزنها 1 كيلو وال300 حبة لوز وزنهم 1 كيلو فصار توازن.

When ΔG is low, the reverse reaction happens, but when it becomes huge the reaction is irreversible. Biochemical reactions are reversible, in some reactions as in Krebs cycle they go in one way, so we consider them as irreversible reactions because of the huge difference in the free energy.

Equilibrium -In chemical terms-: The forward reaction rate is equal to the backward reaction rate so ΔG is zero.

If we decrease the concentration of A, the backward reaction rate will be faster than the forward reaction rate. Because with this decreasing, (B) energy content is more than (A) so the reaction goes from the high G to the low G – logically-. Chemical equilibrium is an active, dynamic condition.

To sum up:

The change in free energy (ΔG) occurring during a reaction predicts the direction in which that reaction will spontaneously proceed. If ΔG is negative (that is, the product has a lower free energy than the substrate), the reaction goes spontaneously. If ΔG is positive, the reaction does not go spontaneously. If ΔG = 0, the reactions are in equilibrium meaning the ΔG of the forward reaction (A → B) is equal in magnitude but opposite in sign to that of the back reaction (B → A). The ΔGs are additive in any sequence of consecutive reactions, as are the standard free energy changes (ΔG^{o}s)

QUESTIONS:

1. If a reaction has negative ΔG then it must be:
    A. Exergonic
    B. Exothermic
    C. Endothermic
    D. Endergonic

Answer: A

2. Which measure the change in the disorder of reactants and products is?
    A. Delta G
    B. Delta H
    C. Delta S
    D. Delta T

Answer: C

3- Delta G represents energy changes at constant temperature, pressure and proton concentration:

A. True
B. False

Answer: B

4- If enthalpy change for a reaction is zero, then ΔG equals to:

A. -TΔSo
B. TΔSo
C. -ΔHo
D. Inkeq

Answer: A

5- For a reaction if ΔG is positive, then:

A. The products will be favored
B. The reactants will be favored
C. The concentration of the reactants and products will be equal
D. All of the reactants will be converted to products.

Answer: B