INTRODUCTION TO BIOENERGETICS AND THERMODYNAMICS

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INTRODUCTION

Cells need energy to do all their work

- To generate and maintain its highly ordered structure (biosynthesis of macromolecules).
- To generate all kinds of movement.
- To generate concentration and electrical gradients across cell membranes.
- To maintain a body temperature.
- To generate light in some animals.
- The "energy industry"(production, storage and use) is central to the economy of the cell society
- **Bioenergetics** : the field of biochemistry concerned with the transformation and use of energy by living cells and the chemical nature underlying these processes.

CELLS HAVE TO USE CHEMICAL ENERGY TO DO ALL THEIR WORK

- Antoine Lavoisier`s insight on animal respiration in the 18th century: it is nothing but a slow combustion of carbon and hydrogen (the same nature as a lighting candle).
- Living cells are generally held at constant temperature and pressure: chemical energy (free energy) has to be used by living organisms, no thermal energy, neither mechanical energy is available to do work in cells.

THERMODYNAMIC PRINCIPLES

- Biological energy transformation obey the two basic laws of thermodynamics revealed by physicists and chemists in the 19th century:
- These laws help us to understand

(a) the direction of a reaction, whether from left to right or vice versa

(b) the accomplishment of work, whether useful or not and

(c) Whether the energy for driving a reaction must be delivered from an external source

THERMODYNAMIC PRINCIPLES

- **The first law of thermodynamics:**

For any physical or chemical change, the total amount of energy in the universe remains constant; energy may changed from or it may be transported from one region to another, but it can not be created or destroyed

THERMODYNAMIC PRINCIPLES

- **The second law of thermodynamics**

The universe always tends toward increasing disorder: in all natural processes the entropy of the universe increases

SYSTEM AND ITS SURROUNDINGS

- The reacting system may be an organism, a cell or two reacting compounds. The reacting system and its surroundings together constitute the universe.
- In the laboratory, some chemical or physical processes can be carried out in closed systems and no material or energy is exchanged with the surroundings
- However living organisms are open systems. They exchange both material and energy with their surroundings
- Living systems are never at equilibrium with their surroundings

THERMODYNAMIC QUANTITIES

- **Gibbs free energy (G):** expresses the amount of energy capable of doing work during a reaction at constant temperature and pressure
- When a reaction proceeds with the release of free energy (that is, when the system changes so as to posses less free energy) ΔG has a negative value and the reaction is said to be exergonic
- In endergonic reactions, the system gains free energy and ΔG is positive
- The unit of ΔG is joules/mole or calories/mole

THERMODYNAMIC QUANTITIES

- **Enthalpy (H):** H is the heat content of the reacting system. H reflects the number and kinds of chemical bounds in the reactants and products.
- When a chemical reaction releases heat, it is said to be exothermic, the heat content of the products is less than that of the reactants and ΔH has a negative value
- Reacting systems that take up heat from their surroundings are endothermic and have positive values of ΔH

THERMODYNAMIC QUANTITIES

- The unit of ΔH is joules/mole or calories/mole

Entropy (S): S is a quantitative expression for the randomness or a disorder in a system

- The unit of ΔS is joules/mole. Kelvin

- Under the constant temperature and pressure changes in free energy, enthalpy and entropy in biological systems are related to each other by the equation
- $\Delta G = \Delta H - T\Delta S$
- ΔG= Change in Gibbs free energy of the reacting system (Gproducts– G reactants)
- ΔH =Change in enthalpy of the reacting system (H products - Hreactants)
- T= Absolute temperature
- ΔS= Change in entropy of the reacting system(Sproducts - Sreactants)

THERMODYNAMIC QUANTITIES

- **Living organisms preserve their internal order by taking free energy from their surroundings in the form of nutrients or sunlight and returning to their surroundings an equal amount of energy as heat and entropy**

CONCEPT OF FREE ENERGY

- Free energy is the portion of a system's energy that is able to perform work when temperature and pressure is uniform throughout the system, as in a living cell
- Free energy also refers to the amount of energy actually available to break and subsequently form other chemical bonds
- Gibbs' free energy (G) – in a cell, the amount of energy contained in a molecule's chemical bonds (T&P constant)
- Change in free energy - ΔG
- Endergonic - any reaction that requires an input of energy
- Exergonic - any reaction that releases free energy