Introduction

The term "Bioenergetics" is made up of two words:

- Bio means Life or Living
- Energetics means study of energy

So, basically Bioenergetics is "the study of energy changes in biological reactions".Bioenergetics is the field of biochemistry concerned with the transformation and use of energy by living cells.

The goal of bioenergetics is to describe how living organisms acquire, transform and utilize energy in order to perform biological work. The study of metabolic pathways is thus essential to bioenergetics.

The chemical reactions performed by an organism make up its metabolism.

- Catabolic reactions involve the breakdown of chemical molecules.
- Anabolic reactions involve the synthesis of compounds.

Adenosine triphosphate (ATP) is the main "energy currency" for organisms;

the goal of metabolic and catabolic processes are:

- To synthesize ATP from available starting materials (from the environment), and
- To break-down ATP (into adenosine diphosphate (ADP) and inorganic phosphate) by utilizing it in biological processes.

In a cell, the ratio of ATP to ADP concentrations is known as the "energy charge" of the cell. A cell can use this energy charge to relay information about cellular needs;

- If there is more ATP than ADP available, the cell can use ATP to do work, but
- If there is more ADP than ATP available, the cell must synthesize ATP via oxidative phosphorylation.

1. Types of Chemical Reactions

When one or more substances interact to produce one or more new substances, a chemical reaction is said to have occurred. The types of reactants and products, or the manner in which the reactants interact, enable chemists to classify chemical reactions and predict the outcome of similar reactions.

There are five types of chemical reactions we will use:

1. Synthesis reactions
2. Decomposition reactions
3. Single displacement reactions
4. Double displacement reactions
5. Combustion reactions

1.1.Synthesis reactions

They Occur when two simple substances combine and form a single compound

$$A + B \longrightarrow AB$$

Example:

Formation of carbon dioxide: $C + O_2 \longrightarrow CO_2$

1.2. Decomposition reactions

They are opposite of synthesis reactions. They occur when a compound breaks up into simpler compounds.

$$AB \longrightarrow A + B$$

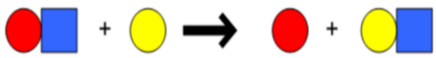
Example:

Decomposition of water $2\,H_2O \longrightarrow 2H_2 + O_2$

1.3. Single Replacement Reactions

They occur when one element replaces another in a compound.

$$BC + A \longrightarrow B + AC\ A$$



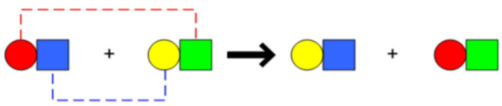
A replaced B on the product side to form AC and B ends up alone.

Examples: $Fe + CuSO4 \rightarrow FeSO4 + Cu$

1.4. Double Replacement Reactions

They occur when a metal replaces a metal in a compound and a nonmetal replaces a nonmetal in a compound forming two new compounds.

$$AB + CD \longrightarrow CB + AD$$



Example: $AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$

1.5. Combustion reactions

Tey occur when a hydrocarbon reacts with oxygen gas to produce carbon dioxide and water.

Examples: $C_5H_{12} + O_2 \longrightarrow CO_2 + H_2O$

2. Biological reactions

Chemical reactions are not just activities within scientific laboratories, they happen naturally in both living and no-living systems. Photosynthesis and respiration are spontaneous chemical reactions that are key fuels for life on the earth. But humans also use chemical reactions to extract, refine and use other fuels for heat and electricity.

2.1.Exergonic reactions

They imply the release of energy from a spontaneous chemical reaction without any concomitant utilization of energy.

- Most of these reactions involve the breaking of bonds during the formation of reaction intermediates as is evidently observed during respiratory pathways. The bonds that are created during the formation of metabolites are stronger than the cleaved bonds of the substrate.
- The release of free energy G, in an exergonic reaction (at constant pressure and temperature) is denoted as: $\Delta G = G_{products} - G_{reactants} < 0$ (ΔG negative)

2.2.Endergonic reactions

They in turn are the opposite of exergonic in being non-spontaneous and requires an input of free energy.

- Most of the anabolic reactions like photosynthesis and DNA and protein synthesis are endergonic in nature.
- Endergonic reactions (build or synthesis) and they are energy consuming reaction unlike exergonic.
- The release of free energy, G, in an exergonic reaction (at constant pressure and temperature) is denoted as: $\Delta G = G_{products} - G_{reactants} > 0$ (ΔG positive)

3.Concept of free energy

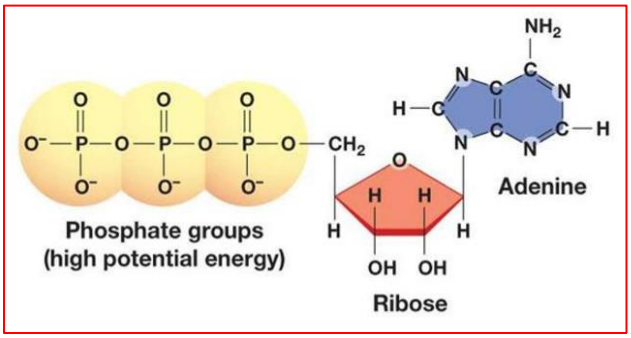
- The energy actually available to do work (utilizable) is known as free energy.
- Changes in the free energy (AG) are valuable in predicting the feasibility of chemical reactions.
- Cells are isothermal systems, meaning they function at a constant temperature & pressure.

  -Photosynthetic cells acquire free energy from absorbed solar radiation.

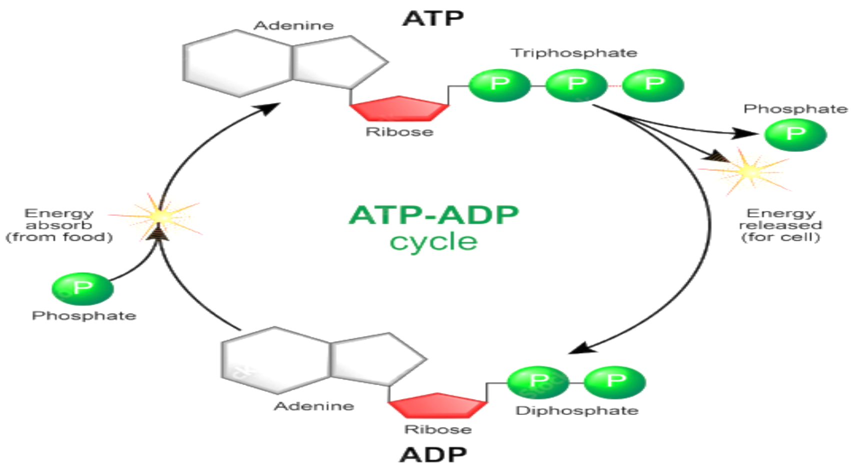
  -Heterotrophic cells acquire free energy from nutrient molecules.

4.**ATP and ADP**

- Adenosine-5'-triphosphate (ATP) is a multifunctional nucleotide used in cells as a coenzyme.



- It is often called the "molecular unit of currency" of intracellular energy transfer. ATP transports chemical energy within cells for metabolism.
- One molecule of ATP contains three phosphate groups and it is produced by ATP synthase from Inorganic Phosphate and Adenosine Diphosphate (ADP) or Adenosine Monophosphate (AMP).



- The energy released by cleaving either a phosphate (Pi) or pyrophosphate (PPi) unit from ATP at standard state of 1 M are:

  ATP + H2O ADP + Pi AGO = -30.5 kj/mol (-7.3 kcal/mol)

  ATP + H2O -> AMP + PPi AGO = -45.6 kj/mol (-10.9 kcal/mol)

- These values can be used to calculate the change in energy under physiological conditions and the cellular ATP/ADP ratio (also known as the Energy Charge).
- The three **main functions** of **ATP** in cellular function are:

-Transporting organic substances—such as sodium, calcium, potassium—through the cell membrane.

-Synthesizing chemical compounds, such as protein and cholesterol.

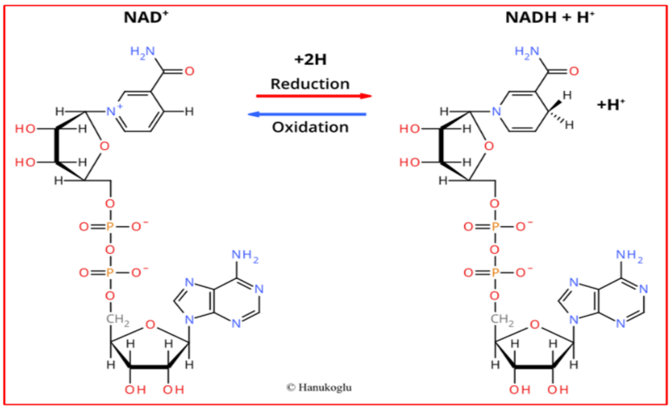
-Supplying energy for mechanical work, such as muscle contraction.

4. NADH and FADH2

- NADH and FADH2 are two main coenzymes utilized in almost all biochemical pathways.
- They are an organic non-protein molecule that is relatively small in size and has the ability to carry chemical groups between enzymes and act as an electron carrier.

4.1. NADH (Nicotinamide Adenine Dinucleotide)

It is synthesized from Vitamin B3 (Niacin) and is a coenzyme composed of ribosylnicotinamide 5′-diphosphate coupled to adenosine 5′-phosphate. It serves as an electron carrier in many reactions by alternatively converting to its oxidized (NAD+) form and the reduced (NADH) form.



4.2. FADH2 (Flavin Adenine Dinucleotide)

FAD is synthesized from riboflavin (vitamin B2) and two molecules of ATP. Riboflavin is phosphorylated by ATP to produce riboflavin 5′-phosphate (also called flavin mononucleotide, FMN). FAD is then formed from FMN by the transfer of an AMP molecule from ATP.