Section B and C

Volume-02

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E. BIOENERGETICS (Continued….)

Concept of energy and Thermodynamic Principles in Biology:

Thermodynamics is the branch of physical chemistry that deals with the thermodynamics, or biochemical energetics or bioenergetics, as (it is also called) is the field of biochemistry concerned with the transformation and use of energy by living cells. The chemical reactions occurring in living beings (or biochemical reactions) are associated with the liberation of energy as the reacting system moves from a higher to a lower energy level. Most often, the energy is liberated in the form of heat. In nonbiologic systems, heat energy may be transformed into mechanical or electrical energy. Since the biologic systems are isothermic, the heat energy cannot be used to drive the vital processes (such as synthesis, active transport, nerve conduction, muscular contraction etc.) obtain energy by chemical linkage (or coupling) to oxidation reactions. The simplest type of coupling may be represented by the equation.

A + C → B + D + HEAT

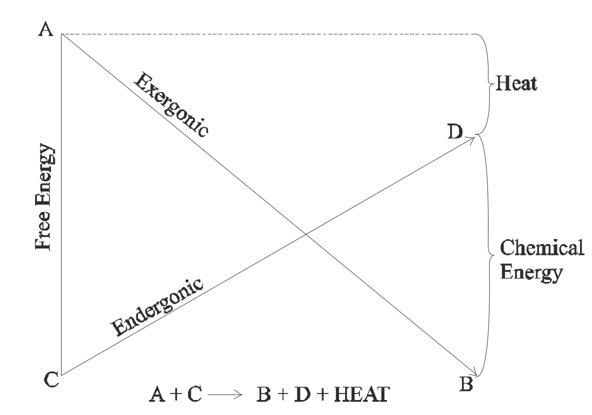

Fig. 37: Coupling of exergonic to endergonic reactions

The conversion of metabolite A to metabolite B occurs with the release of energy. It is coupled to another reaction, wherein energy is required to convert metabolite C to metabolite D.

Concept of Energy:

Energy is defined as the capacity to do work, which is the product of a given force acting through a given distance:

Work = Force x Distance

It is one of the fundamental components of any system. Energy exists in a variety of forms, such as electrical, mechanical, chemical, heat and light energy. These different forms of energy are inter-convertible, for example, an electric motor converts electric into mechanical energy, a battery changes chemical into electrical energy and a steam engine transforms heat into mechanical energy. Some of the common examples of transformations of energy in biological systems. Besides, these various forms of energy are also interrelated quantitatively, for example, 1.0 calorie of heat energy = 4.185 x 10 ergs of mechanical energy

(a) The running horse represents conversion of chemical energy to mechanical energy.

(b) The electric fish (*Torpedinidae*) converts chemical energy to electrical energy.

(c) The phosphorescent bacteria convert chemical energy into light energy.

Furthermore, during conversion of one form of energy to the other, there is always some loss. As an example, when an electric motor transforms electric into mechanical energy, the output of useful energy is always less than the input. This is due to friction in the motor which generates heat. The heat, in turn, is dissipated in the environment and is no longer useful. Thus, when a work is done or when one form of energy is changed to the other, there is a loss of useful energy.

Thermodymamic Principles:

Many quantitative observations made on the interconversion of various forms of energy have led scientists to the formulation of two fundamental laws of thermodynamics, the first and second. These laws help us understanding:

(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.

The First Law: Principle of Conservation of Energy

In thermodynamics, a system is a matter within a defined region. The matter in the rest of the universe is called the surroundings. Thus, the system plus the surroundings constitute the universe, which literally includes the entire earth, rather even the outer space.

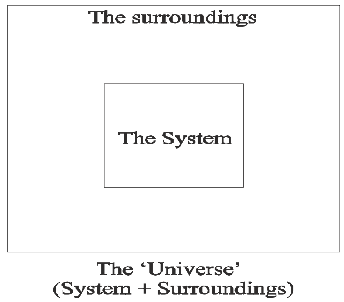

Fig. 38: Schematic representation of a reacting system and its surroundings energy can be exchanged between the system and the surroundings but only according to the laws of thermodynamics.

Some physical or chemical processes can be made to take place in isolated systems which are unable to exchange energy with their surroundings. But in the biological world, the reacting system do exchange energy, and often matter also with their surroundings. The principle of conservation of energy was first formulated by V. Mayer in 1841 as a result of a study of energy transformation in the inanimate world, but it is equally applicable to living systems.

The first law of thermodynamics states that the total amount of energy in the universe (i.e., the system + surroundings) remains constant. Paraphrased, it says that energy cannot be created or destroyed. To date, there is no known exception to this law. Thus, whenever energy is used to do work or is converted from one to the other form, the total amount of energy is unchanged. The mathematical expression of the first law is:

$$\Delta E = E_B - E_A = Q - W$$

Where ,

ΔE = change in internal energy

ΔE_A = energy of a system at the start of a process

ΔE_B = energy of a system at the end of a process

Q = heat absorbed by the system,

W = work done by the system.

A noteworthy point about equation 1 is that the change in energy of a system depends only on the initial and the final stages and not on the path of transformation.