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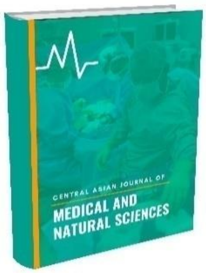

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The Importance of The Process of Metabolism on The Body

1. **Dalimova M.**

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[1] Senior lecture of Andijan State Medical Institute

Abstract: Metabolism, the sum of the chemical reactions that take place within each cell of a living organism and that provide energy for vital processes and for synthesizing new organic material.

Key words: **organism, lipid, acid, metabolism, energy.**

Living organisms are unique in that they can extract energy from their environments and use it to carry out activities such as movement, growth and development, and reproduction. But how do living organisms—or, their cells—extract energy from their environments, and how do cells use this energy to synthesize and assemble the components from which the cells are made?

The answers to these questions lie in the enzyme-mediated chemical reactions that take place in living matter (metabolism). Hundreds of coordinated, multistep reactions, fueled by energy obtained from nutrients and/or solar energy, ultimately convert readily available materials into the molecules required for growth and maintenance.

The physical and chemical properties of the components of living things dealt with in this article are found in the articles carbohydrate; cell; hormone; lipid; photosynthesis; and protein.

At the cellular level of organization, the main chemical processes of all living matter are similar, if not identical. This is true for animals, plants, fungi, or bacteria; where variations occur (such as, for example, in the secretion of antibodies by some molds), the variant processes are but variations on common themes. Thus, all living matter is made up of large molecules called proteins, which provide support and coordinated movement, as well as storage and transport of small molecules, and, as catalysts, enable chemical reactions to take place rapidly and specifically under mild temperature, relatively low concentration, and neutral conditions (i.e., neither acidic nor basic). Proteins are assembled from some 20 amino acids, and, just as the 26 letters of the alphabet can be assembled in specific ways to form words of various lengths and meanings, so may tens or even hundreds of the 20 amino-acid "letters" be joined to form specific proteins. Moreover, those portions of protein molecules involved in performing similar functions in different organisms often comprise the same sequences of amino acids.

There is the same unity among cells of all types in the manner in which living organisms preserve their individuality and transmit it to their offspring. For example, hereditary information is encoded in a specific sequence of bases that make up the DNA (deoxyribonucleic acid) molecule in the nucleus of each cell. Only four bases are used in synthesizing DNA: adenine, guanine, cytosine, and thymine. Just as the Morse Code consists of three simple signals—a dash, a dot, and a space—the precise arrangement of which suffices to convey coded messages, so the precise arrangement of the bases in DNA contains and conveys the information for the synthesis and assembly of cell components. Some primitive life-forms, however, use RNA (ribonucleic acid; a nucleic acid differing from DNA in containing the sugar ribose instead of the sugar deoxyribose and the base uracil instead of the base thymine) in place of DNA as a primary carrier of genetic information. The replication of the genetic material in these organisms must, however, pass through a DNA phase. With minor exceptions, the genetic code used by all living organisms is the same.

The chemical reactions that take place in living cells are similar as well. Green plants use the energy of sunlight to convert water (H_2O) and carbon dioxide (CO_2) to carbohydrates (sugars and starches), other organic (carbon-containing) compounds, and molecular oxygen (O_2). The process of photosynthesis requires energy, in the form of sunlight, to split one water molecule into one-half of an oxygen molecule (O_2; the oxidizing agent) and two hydrogen atoms (H; the reducing agent), each of which dissociates to one hydrogen ion (H^+) and one electron. Through a series of oxidation-reduction reactions, electrons (denoted e^-) are transferred from a donating molecule (oxidation), in this case water, to an accepting molecule (reduction) by a series of chemical reactions; this "reducing power" may be coupled ultimately to the reduction of carbon dioxide to the level of carbohydrate. In effect, carbon dioxide accepts and bonds with hydrogen, forming carbohydrates ($C_n[H_2O]_n$).

Living organisms that require oxygen reverse this process: they consume carbohydrates and other organic materials, using oxygen synthesized by plants to form water, carbon dioxide, and energy. The process that removes hydrogen atoms (containing electrons) from the carbohydrates and passes them to the oxygen is an energy-yielding series of reactions.

In plants, all but two of the steps in the process that converts carbon dioxide to carbohydrates are the same as those steps that synthesize sugars from simpler starting materials in animals, fungi, and bacteria. Similarly, the series of reactions that take a given starting material and synthesize certain molecules that will be used in other synthetic pathways are similar, or identical, among all cell types. From a metabolic point of view, the cellular processes that take place in a lion are only marginally different from those that take place in a dandelion.

The energy changes associated with physicochemical processes are the province of thermodynamics, a subdiscipline of physics. The first two laws of thermodynamics state, in essence, that energy can be neither created nor destroyed and that the effect of physical and chemical changes is to increase the disorder, or randomness (i.e., entropy), of the universe. Although it might be supposed that biological processes—through which organisms grow in a highly ordered and complex manner, maintain order and complexity throughout their life, and pass on the instructions for order to succeeding generations—are in contravention of these laws, this is not so. Living organisms neither consume nor create energy: they can only transform it from one form to another. From the environment they absorb energy in a form useful to them; to the environment they return an equivalent amount of energy in a biologically less useful form. The useful energy, or free energy, may be defined as energy capable of doing work under isothermal conditions (conditions in which no temperature differential exists); free energy is associated with any chemical change. Energy less useful than free energy is returned to the environment, usually as heat. Heat cannot perform work in biological systems because all parts of cells have essentially the same temperature and pressure.

At any given time, a neutral molecule of water dissociates into a hydrogen ion (H^+) and a hydroxide ion (OH^-), and the ions are continually re-forming into the neutral molecule. Under normal conditions (neutrality), the concentration of hydrogen ions (acidic ions) is equal to that of the hydroxide ions (basic ions); each are at a concentration of 10^{-7} mole per litre, which is described as a pH of 7.

All cells either are bounded by membranes or contain organelles that have membranes. These membranes do not permit water or the ions derived from water to pass into or out of the cells or organelles. In green plants, sunlight is absorbed by chlorophyll and other pigments in the chloroplasts of the cells, called photosystem II. As shown previously, when a water molecule is split by light energy, one-half of an oxygen molecule and two hydrogen atoms (which dissociate to two electrons and two hydrogen ions, H^+) are formed. When excited by sunlight, chlorophyll loses one electron to an electron carrier molecule but quickly recovers it from a hydrogen atom of the split water molecule, which sends H^+ into solution in the process. Two oxygen atoms come together to form a molecule of oxygen gas (O_2). The free electrons are passed to photosystem I, but, in doing so, an excess concentration of positively charged hydrogen ions (H^+) appears on one side of the membrane in the chloroplast, whereas an excess of negatively charged hydroxide ions (OH^-) builds up on the other side. The free energy released as H^+ ions move through a specific “pore” in the membrane, to equalize the concentrations of ions, is sufficient to make some biological processes work, such as the uptake of certain nutrients by bacteria and the rotation of the whiplike protein-based propellers that enable such bacteria to move. Equally important, however, is that this gradient across the membrane powers the formation of adenosine triphosphate (ATP) from inorganic phosphate (HPO_4^{2-}, abbreviated P_i) and adenosine diphosphate (ADP). ATP is the major carrier of biologically utilizable energy in all forms of living matter. The interrelationships of energy-yielding and energy-requiring metabolic reactions may be considered largely as processes that couple the formation of ATP with its breakdown.

Synthesis of ATP by green plants is similar to the synthesis of ATP that takes place in the mitochondria of animal, plant, and fungus cells, and in the plasma membranes of bacteria that use oxygen (or other inorganic electron acceptors, such as nitrate) to accept electrons from the removal of hydrogen atoms from a molecule of food (*see below* Biological energy transduction). Through these processes most of the energy stored in food materials is released and converted into the molecules that fuel life processes. It must also be remembered, however, that many living organisms (usually bacteria and protozoa) cannot tolerate oxygen; they form ATP from inorganic phosphate and ADP by substratelevel phosphorylations (the addition of a phosphate group) that do not involve the establishment and collapse of proton gradients across membranes. (Such processes are discussed in detail below in The catabolism of glucose.) It must also be borne in mind that the fuels of life and the cellular "furnace" in which they are "burned" are made of the same types of material: if the fires burn too brightly, not only the fuel but also the furnace is consumed. It is therefore essential to release energy at small, discrete, readily utilizable intervals. The relative complexity of the catabolic pathways (by which food materials are broken down) and the complexity of the anabolic pathways (by which cell components are synthesized) reflect this need and offer the possibility for simple feedback systems to control the rate at which materials travel along these sequences of enzymic reactions.

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