Metabolism

Science, Biology

Now that you are familiar with the structure of prokaryotic cells, we can discuss the activities that allow these microbes to thrive. The life support activity of even the most structurally simple organism involves a large number of complex biochemical reactions. Most, although not all, of the biochemical processes of bacteria also occur in eukaryotic microbes and in the cells of multicellular organisms, including humans. However, the reactions that are unique to bacteria are fascinating because they allow microorganisms to do things we cannot do (Neidhardt & Holde, 1990). For example, some bacteria (the chemoautotrophs) can grow on diets of such inorganic substances as carbon dioxide, iron, sulfur, hydrogen gas, and ammonia.

This paper examines some representative chemical reactions that either produce energy (the catabolic reactions) or use energy (the anabolic reactions) in microorganisms. We will also look at how these various reactions are integrated within the cell.

II. Discussion

A. Catabolic and Anabolic Reactions

We use the term metabolism to refer to the sum of all chemical reactions within a living organism. Because chemical reactions either release or require energy, metabolism can be viewed as an energy-balancing act. Accordingly, metabolism can be divided into two classes of chemical reactions—those that release energy and those that require energy. In living cells, the chemical reactions that release energy are generally the ones involved in catabolism, the breakdown of complex organic compounds into simpler ones. These reactions are called catabolic, or degradative, reactions.

On the other hand, the energy-requiring reactions are mostly involved in anabolism, the building of complex organic molecules from simpler ones. These reactions are called anabolic or biosynthetic reactions (Neidhardt & Holde, 1990). Anabolic processes often involve dehydration synthesis reactions (reactions that release water) and require energy to form a new chemical bonds.

Examples of anabolic processes are the formation of proteins from amino acids, nucleic acids from nucleotides, and polysaccharides from simple sugars. These biosynthetic reactions generate the materials for cell growth. Catabolic reactions are generally hydrolytic reactions (reactions that use water to break chemical bonds). Chemical bonds store energy; when they are broken, chemical energy is released. An example of catabolism occurs when cells break down sugars into carbon dioxide and water.

Catabolic reactions furnish the energy needed to drive anabolic reactions. This coupling of energy-requiring and energy-releasing reactions is made possible through the molecule adenosime triphospahte (ATP). ATP stores energy derived from catabolic reactions and releases it later to drive anabolic reactions and perform other cellular work. A molecule of ATP consists of an adenine, a ribose, and three phosphate groups.

When the terminal phosphate group is split from ATP, adenosine diphosphate (ADP) is formed, and energy is released to drive anabolic reactions. Using P to represent a phosphate group, we can write this reaction as (ATP—> ADP +

P + energy). Then, the energy from catabolic reactions is used to combine ADP and a P to resynthesize ATP (ADP + P + energy—> ATP).

Thus, anabolic reactions are coupled to ATP breakdown, and catabolic reactions are coupled to ATP synthesis. This concept of coupled reactions is very important. For now, you should know that the chemical composition of a living cell is constantly changing; some molecules are being broken down while others are being synthesized. This balanced flow of chemicals and energy maintains the life of a cell (“ Metabolism; What is it exactly and how fast or slow should it be?”).

B. Enzymes

Chemical reactions occur when chemical bonds are formed or broken. In order for reactions to take place, atoms, ions, or molecules must collide. Whether a collision produces a reaction depends on the speed of the particles, the amount of energy required to trigger the reaction (called activation energy), and the specific configuration of the particles. The physiological temperature and pressure of organisms are too low for chemical reactions to occur quickly enough to maintain the life of the organism.

Raising the temperature and pressure and the number of reacting molecules can increase the frequency of collisions and the rate of chemical reactions. However, such changes could damage or kill the organism. The living cell’s solution to this problem is a class of proteins called enzymes. Enzymes can speed up chemical reactions in several ways. For example, an enzyme may bring two reactant molecules close together and may properly orient them to react. Whatever the method, the result is that the enzyme lowers the activation energy for the reaction without increasing the temperature or pressure inside the cell (“ Immobilized Enzymes Can Check Bioterrorism, 2003).

Substances that can speed up a chemical reaction without themselves being altered are called catalysts. In living cells, enzymes serve as biological catalysts. As catalysts, enzymes are specific. Each acts on specific substance, called the enzyme’s substrate (or substrates when there are two or more reactants), and each catalyzes only one reaction. For example, sucrose (table sugar) is the substrate of the enzyme sucrase, which catalyzes the hydrolysis of sucrose to glucose and fructose.

The specificity of enzymes is made possible by their structures. Enzymes are generally globular proteins that range in molecular weight from about 10, 000 to several million. Each of the thousands of known enzymes has a characteristics three-dimensional shape with a specific surface configuration as a result of its primary, secondary, and tertiary structures. The unique configuration of each enzyme enables it to “ find” the correct substrate from among the large number of diverse molecules in the cell (“ Immobilized Enzymes Can Check Bioterrorism, 2003).

C. Factors Influencing Enzymatic Activity

Several factors influence the activity of enzyme. Among the more important are temperature, pH, substrate concentration, and inhibitors.

a.) Temperature

The rate of most chemical reactions increases as the temperature increases. Molecules move more slowly at low than at higher temperatures and may not have enough energy to cause a chemical reaction. For enzymatic reactions, however, elevation beyond a certain temperature drastically reduces the rate of reaction. This decrease is due to the enzyme's denaturation, the loss of its characteristics three-dimensional structure (tertiary configuration). Denaturation of a protein involves breakage of hydrogen bonds and other noncovalent bonds (Neidhardt & Holde, 1990).

Most enzymes have a pH optimum at which their activity is characteristically maximal. Above or below this pH value, enzyme activity, and therefore the reaction rate, declines. When the H+ concentration (pH) in the medium is changed, many of the enzyme's amino acids are affected and the protein's three-dimensional structure is altered. Extreme changes in pH can cause denaturation (Neidhardt & Holde, 1990).

Substrate Concentration

There is a maximum rate at which a certain amount of enzymes can catalyze a specific reaction. Only when the concentration of substrate(s) is extremely high can this maximum rate be attained. Under conditions of high substrate concentration, the enzyme is said to be saturated; that is, its active site is always occupied by substrate or product molecules. In this condition, a further increase in substrate concentration will not affect the reaction rate because all active sites are already in used. If a substrate's concentration exceeds a cell's saturation level for a particular enzyme, the rate of reaction can be increased only if the cell produces additional enzyme molecules (Neidhardt & Holde, 1990). However, under normal cellular conditions, enzymes are not saturated with substrate (s). At any given time, many of the enzyme molecules are inactive for lack of substrate; thus, the rate of reaction is likely to be influenced by the substrate concentration.

Inhibitors

An effective way to control the growth of bacteria is to control their enzymes. Certain poisons, such as cyanide, arsenic, and mercury, combine with enzymes and prevent them from functioning. As a result, the cells stop functioning and die.

Enzyme inhibitors are classified according to their mechanism of action as competitive inhibitors and noncompetitive inhibitors. Competitive inhibitors fill the active site of an enzyme and compete with the normal substrate for the active site. The competitive inhibitor is able to do this because its shape and chemical structure are similar to those of the normal substrate.

Noncompetitive inhibitors do not compete with the substrate for the enzyme's active site; instead they interact with another part of the enzyme. In this process, called allosteric (" other space") inhibition, an enzyme's activity is reduced because of a change in shape caused by binding of an inhibitor at a site rather than substrate's binding site. The change in shape can be either reversible or irreversible (Neidhardt & Holde, 1990).

III. Conclusion

In conclusion, the sum of all chemical within a living organism is known as metabolism. Catabolism refers to chemical reactions that result in the breakdown of more complex organic molecules into simpler substances. Catabolic reactions usually release energy. Anabolism refers to chemical reactions in which simpler substances are combined to form more complex molecules. Anabolic reactions usually require energy. The energy of catabolic reaction is used to drive anabolic reactions. The energy for chemical reactions is stores in ATP. Moreover, the enzymes are proteins produced by living cells that catalyze chemical reactions. They are generally globular proteins with characteristic three-dimensional shapes.

Reference:

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