

Chapter 4 - Cellular Metabolism

4.1 Introduction

- A. A living cell is the site of enzyme-catalyzed metabolic reactions that maintain life.

4.2 Metabolic Reactions (Figs. 4.1-4.3)

- A. Metabolic reactions are of two types:
 - 1. In anabolic reactions larger molecules are constructed from smaller ones, a process requiring energy,
 - 2. In catabolic reactions, larger molecules are broken down, releasing energy. The reactions of metabolism are often reversible.
- B. Anabolism (Figs. 4.1-4.3)
 - 1. Anabolism provides the substances needed for growth and repair.
 - 2. These reactions occur by dehydration synthesis, removing a molecule of water to join two smaller molecules.
 - 3. Polysaccharides, lipids, and proteins are constructed via dehydration synthesis.
 - a. To form fats, glycerol and fatty acids bond.
 - b. The bond between two amino acids is a peptide bond; two bound amino acids form a dipeptide, while many joined form a polypeptide.
- C. Catabolism (Figs. 4.1-4.3)
 - 1. Catabolism breaks apart larger molecules into their building blocks.
 - 2. These reactions occur by hydrolysis, wherein a molecule of water is inserted into a polymer, which is split into two smaller molecules.

4.3 Control of Metabolic Reactions (Fig. 4.4)

- A. Enzymes control the rates of all the metabolic reactions of the cell.
- B. Enzyme Action (Fig. 4.4)
 - 1. Enzymes are complex proteins that function to lower the activation energy of a reaction so it may begin and proceed more rapidly. Enzymes are called catalysts.
 - 2. Enzymes work in small quantities and are recycled by the cell.
 - 3. Each enzyme is specific, acting on only one kind of substrate.
 - 4. Active sites on the enzyme combine with the substrate and a reaction occurs.
 - 5. The speed of enzymatic reactions depends on the number of enzyme and substrate molecules available.
- C. Factors That Alter Enzymes
 - 1. Enzymes (proteins) can be denatured by heat, pH extremes, chemicals, electricity, radiation, and by other causes.
 - 2. Cofactors and coenzymes are special molecules or ions that must attach to certain enzymes before the enzyme becomes active

4.4 Energy for Metabolic Reactions

- A. Energy is the capacity to do work.
- B. Common forms of energy include heat, light, and sound, and electrical, mechanical, and chemical energy.
- C. Release of Chemical Energy - Cellular Respiration
 - 1. Release of chemical energy in the cell often occurs through the oxidation of glucose.
 - 2. Burning glucose requires energy to begin the process.
 - 3. The end products of these reactions are heat as well as stored energy.
 - 4. This stored energy is called ATP, which has a chain of three phosphates.
- D. Cellular respiration involves three interconnected series of reactions: glycolysis, the citric acid cycle, and the electron transport chain (Fig. 4.5). the end result of these reactions is that glucose is broken down to carbon dioxide and water and energy is released. Some of this energy is captured in ATP molecules.

1. ATP Molecules (Fig. 4.6-4.7)
 - a. ATP molecules contain three phosphates in a chain.
 - b. Energy is stored in the last phosphate bond.
 - c. Energy is stored while converting ADP to ATP; when energy is released, ATP becomes ADP, ready to be regenerated into ATP.
2. Glycolysis (Fig. 4.5)
 - a. Glycolysis begins in the cytosol and does not require oxygen.
3. Aerobic Respiration (Fig. 4.5)
 - a. Oxygen is needed for aerobic respiration, which occurs within the mitochondria.
 - b. There is a much greater gain of ATP molecules from aerobic respiration.
 - c. The final products of glucose oxidation are carbon dioxide, water, and energy.

4.5 Metabolic Pathways (Figs. 4.8, 4.9)

- A. The enzymes controlling either an anabolic or catabolic sequence of reactions must act in a specific order.
- B. A sequence of enzyme-controlled reactions is called a metabolic pathway.
- C. Regulation of Metabolic Pathways
 1. The rate of a metabolic pathway is determined by a regulatory enzyme responsible for one of its steps.
 2. A rate-limiting enzyme is the first step in a series.

4.6 DNA (Deoxyribonucleic Acid) (Tables 4.1, 4.2)

- A. Deoxyribonucleic acid (DNA) contains the genetic code needed for the synthesis of each protein (including enzymes) required by the cell.
- B. Genetic Information
 1. A gene is a portion of a DNA molecule that contains the genetic information for making a single protein. All of the DNA in a cell constitutes the genome.
- C. DNA Molecules (Figs. 2.20, 2.21b, 4.10)
 1. The nucleotides of DNA form a sugar-phosphate backbone with bases extending into the interior of the DNA molecule.
 2. The nucleotides of one DNA strand are compatible to those in the other strand (adenine pairs with thymine; cytosine with guanine) and so exhibit complementary base pairing.
 3. The DNA molecule twists to form a double helix and may be millions of base pairs long.
- D. DNA Replication
 1. Each new cell must be provided with an exact replica of the parent cell's DNA.
 2. DNA replication occurs during interphase.
 - a. The DNA molecule splits.
 - b. Nucleotides form complementary pairs with the original strands.
 - c. Each new DNA molecule consists of one parental strand and one newly synthesized strand of DNA.

4.7 Protein Synthesis (Tables 4.2, 4.3; Figs. 4.12, 4.13, 4.14)

- A. The Genetic Code-Instructions for Making Proteins
 1. The sequence of nucleotides in a DNA molecule gives the sequence of amino acids for a given protein.
 2. This method of storing information for protein synthesis is the genetic code.
 3. Transcription
 - a. RNA molecules are single-stranded and contain ribose rather than deoxyribose, and uracil rather than thymine.
 - b. Messenger RNA (mRNA) molecules are synthesized in the nucleus in a

sequence complementary to the DNA template in a process called transcription.

4. Translation (Tables 4.2, 4.3; Fig. 4.13)
 - a. Each amino acid corresponds to a triplet of DNA nucleotides; a triplet of nucleotides in messenger RNA is called a codon.
 - b. Messenger RNA can move out of the nucleus and associate with ribosomes in the cytoplasm where the protein will be constructed in a process called translation.
 - d. In the cytoplasm, a second kind of RNA, called transfer RNA, has a triplet of nucleotides called the anticodon, which is complementary to nucleotides of the messenger RNA codon.
 - e. The ribosome holds the messenger RNA in position while the transfer RNA carries in the correct amino acid in sequence, with anticodons matching up to codons.
 - f. The ribosome contains enzymes needed to join the amino acids together.
 - g. As the amino acids are joined, the new protein molecule folds into its unique shape.