

Chapter 4 - Cellular Metabolism

4.1 Introduction (p. 74)

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

4.2 Metabolic Processes (p. 74)

- A. Metabolic reactions are of two types: in anabolic reactions, larger molecules are constructed from smaller ones, a process requiring energy; in catabolic reactions, larger molecules are broken down, releasing energy.
- B. Anabolism (p. 74; 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. 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 (p. 74)
 - 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 and split into two smaller molecules.
 - 3. The reactions of metabolism are often reversible.

4.3 Control of Metabolic Reactions (p. 75)

- A. Enzymes control the rates of all the metabolic reactions of the cell.
- B. Enzyme Action (p. 75; Fig. 4.4)
 - 1. Enzymes are complex proteins that function to lower the activation energy of a reaction so it may proceed more rapidly.
 - 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 (p. 76)
 - 1. Enzymes (proteins) can be denatured by heat, pH extremes, chemicals, electricity, radiation, and by other causes.

4.4 Energy for Metabolic Reactions (p. 77)

- 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 (p. 77)
 - 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.
- D. Anaerobic Respiration (p. 77; Fig. 4.5)
 - 1. The first part of cellular respiration is the splitting of 6-C glucose that occurs through a series enzyme-catalyzed steps.
 - 2. The result is two 3-C molecules of pyruvate.
 - 3. Glycolysis occurs in the cytosol and does not require oxygen (is anaerobic).
 - 4. Energy from ATP is used to start the process but there is a net gain of energy as

a result.

- E. Aerobic Respiration (p. 78; Fig. 4.5)
 - 1. Oxygen is needed for aerobic respiration, which occurs within the mitochondria.
 - 2. There is a much greater gain of ATP molecules from aerobic respiration.
 - 3. The final products of glucose oxidation are carbon dioxide, water, and energy.
- F. ATP Molecules (p. 78; Fig. 4.6)
 - 1. Up to 38 molecules of ATP are produced for each molecule of glucose oxidized.
 - 2. ATP molecules contain three phosphates in a chain.
 - 3. Energy is stored in the last phosphate bond.
 - 4. Energy is stored while converting ADP to ATP; when energy is released, ATP becomes ADP, ready to be regenerated into ATP.

4.5 Metabolic Pathways (p. 78; Fig. 4.7)

- 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. Carbohydrate Pathways (p. 78; Fig. 4.8)
 - 1. The average diet consists largely of carbohydrates, which are used to supply energy.
 - 2. The first phase of cellular respiration occurs in the cytosol and is anaerobic.
 - 3. Each molecule of glucose is split into two molecules of pyruvic acid.
 - 4. In the second phase of carbohydrate breakdown, pyruvic acid is oxidized to an acetyl group, combines with coenzyme A, and is carried into the mitochondrion.
 - 5. Acetyl coenzyme A enters the citric acid cycle, changing it into intermediate products, and releasing energy to be stored as ATP.
 - 6. Excess glucose may be stored as glycogen or fat.
- D. Lipid Pathways (p. 80; Fig. 4.9)
 - 1. Most dietary fats are triglycerides that can be used as an energy source only if broken down into glycerol and fatty acids.
 - 2. Beta oxidation decomposes fatty acids into segments (ketones) that are converted into acetyl coenzyme A that can then enter the citric acid cycle.
 - 3. The glycerol portion can also enter pathways leading to the citric acid cycle, or they can be used to synthesize glucose.
 - 4. Fatty acids can also combine to form fat molecules that are stored in fat tissue.
- E. Protein Pathways (p. 81; Fig. 4.10)
 - 1. Proteins provide a wide variety of functions for the cell, and can also be used as energy sources.
 - 2. To be used for energy, the nitrogen-containing groups must first be stripped from the amino acids (deamination).
 - 3. The deaminated portions of the amino acids can be decomposed to carbon dioxide and water, and enter the citric acid cycle at various sites to yield energy.
 - 4. Excess protein in the diet can enter anabolic pathways and can be converted to fat.
- F. Regulation of Metabolic Pathways (p. 82)
 - 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 Nucleic Acids and Protein Synthesis (p. 82; Tables 4.2, 4.3)

- A. Deoxyribonucleic acid (DNA) contains the genetic code needed for the synthesis of each protein (enzyme) required by the cell.

- B. Genetic Information (p. 82)
 - 1. A gene is a portion of a DNA molecule that contains the genetic information for making a single protein.
- C. DNA Molecules (p. 82; Figs. 4.11-4.14)
 - 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 complimentary to those in the other strand (adenine pairs with thymine; cytosine with guanine) and exhibit complementary base pairing.
 - 3. The DNA molecule twists to form a double helix and may be millions of base pairs long.
- D. Genetic Code (p. 86; Table 4.1)
 - 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. RNA molecules copy and transfer this information to the cytoplasm where proteins are manufactured.
- E. RNA Molecules (p. 86; Figs. 4.15-4.17)
 - 1. RNA molecules are single-stranded and contain ribose rather than deoxyribose, and uracil rather than thymine.
 - 2. Messenger RNA molecules are synthesized in the nucleus in a sequence complimentary to the DNA template in a process called transcription.
 - 3. Each amino acid corresponds to a triplet of DNA nucleotides; a triplet of nucleotides in messenger RNA is called a codon.
 - 4. 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.
- F. Protein Synthesis (p. 87; Fig. 4.18; Table 4.3)
 - 1. In the cytoplasm, a second kind of RNA, called transfer RNA, has a triplet of nucleotides called the anticodon, which is complimentary to nucleotides of the messenger RNA codon.
 - 2. 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.
 - 3. The ribosome contains enzymes needed to join the amino acids together.
 - 4. As the amino acids are joined, the new protein molecule into its unique shape.
- G. DNA Replication (p. 89; Fig. 4.19)
 - 1. Each new cell must be provided with an exact replica of the parent cell's DNA.
 - 2. DNA replication occurs during interphase.
 - 3. Each new DNA molecule consists of one parental strand and one newly-synthesized strand of DNA.

Topics of Interest:

The Human Genome Project (pp. 84-85; Fig. 4A)

Mutations (p. 92)