

Study Outline Chapter 05

Catabolic and Anabolic Reactions (pp. 112-113)

- The sum of all chemical reactions 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 reactions is used to drive anabolic reactions.
- The energy for chemical reactions is stored in ATP.

Enzymes (pp. 113-119)

- Enzymes are proteins, produced by living cells, that catalyze chemical reactions by lowering the activation energy.
- Enzymes are generally globular proteins with characteristic three-dimensional shapes.
- Enzymes are efficient, can operate at relatively low temperatures, and are subject to various cellular controls.

Naming Enzymes (p. 113)

- Enzyme names usually end in -ase.
- The six classes of enzymes are defined on the basis of the types of reactions they catalyze.

Enzyme Components (pp. 114-115)

Most enzymes are holoenzymes, consisting of a protein portion (apoenzyme) and a nonprotein portion (cofactor).

- The cofactor can be a metal ion (iron, copper, magnesium, manganese, zinc, calcium, and cobalt) or a complex organic molecule known as a coenzyme (NAD, NADP, FMN, FAD, and coenzyme A).

The Mechanism of Enzymatic Action (pp. 115-116)

- When an enzyme and substrate combine, the substrate is transformed, and the enzyme is recovered.
- Enzymes are characterized by specificity, which is a function of their active sites.

Factors Influencing Enzymatic Activity (pp. 116-118)

- At high temperatures, enzymes undergo denaturation and lose their catalytic properties; at low temperatures, the reaction rate decreases.
- The pH at which enzymatic activity is maximal is known as the optimum pH.
- Within limits, enzymatic activity increases as substrate concentration increases.
- Competitive inhibitors compete with the normal substrate for the active site of the enzyme. Noncompetitive inhibitors act on other parts of the apoenzyme or on the

cofactor and decrease the enzyme's ability to combine with the normal substrate.

Feedback Inhibition (pp. 118-119)

- Feedback inhibition occurs when the end-product of a metabolic pathway inhibits an enzyme's activity in the pathway.

Ribozymes (p. 119)

- Ribozymes are enzymatic RNA molecules that cut and splice RNA in eucaryotic cells.

Energy Production (pp. 119-121)

Oxidation-Reduction Reactions (p. 120)

- Oxidation is the removal of one or more electrons from a substrate. Protons (H⁺) are often removed with the electrons.
- Reduction of a substrate refers to its gain of one or more electrons.
- Each time a substance is oxidized, another is simultaneously reduced.
- NAD⁺ is the oxidized form; NADH is the reduced form.
- Glucose is a reduced molecule; energy is released during a cell's oxidation of glucose.

The Generation of ATP (p. 121)

- Energy released during certain metabolic reactions can be trapped to form ATP from ADP and VP (phosphate). Addition of a VP to a molecule is called phosphorylation.
- During substrate-level phosphorylation, a high-energy VP from an intermediate in catabolism is added to ADP.
- During oxidative phosphorylation, energy released as electrons are passed to a series of electron acceptors (an electron transport chain) and finally to O₂ or another inorganic compound.
- During photophosphorylation, energy from light is trapped by chlorophyll, and electrons are passed through a series of electron acceptors. The electron transfer releases energy used for the synthesis of ATP.

Metabolic Pathways of Energy Production (pp. 121-122)

- A series of enzymatically catalyzed chemical reactions called metabolic pathways store energy in and release energy from organic molecules.

Carbohydrate Catabolism (pp. 122-136)

- Most of a cell's energy is produced from the oxidation of carbohydrates.
- Glucose is the most commonly used carbohydrate.
- The two major types of glucose catabolism are respiration, in which glucose is completely broken down, and fermentation, in which it is partially broken down.

Glycolysis (pp. 123-125)

- The most common pathway for the oxidation of glucose is glycolysis. Pyruvic acid is the end-product.
- Two ATP and two NADH molecules are produced from one glucose molecule.

Alternatives to Glycolysis (p. 125)

- The pentose phosphate pathway is used to metabolize five-carbon sugars; one ATP and 12 NADPH molecules are produced from one glucose molecule.
- The Entner-Doudoroff pathway yields one ATP and two NADPH molecules from one glucose molecule.

Cellular Respiration Defined (p. 125)

- During respiration, organic molecules are oxidized. Energy is generated from the electron transport chain.
- In aerobic respiration, O₂ functions as the final electron acceptor.
- In anaerobic respiration, the final electron acceptor is an inorganic molecule other than O₂.

Aerobic Respiration (p. 125)

The Krebs Cycle (p. 125)

- Decarboxylation of pyruvic acid produces one CO₂ molecule and one acetyl group.
- Two-carbon acetyl groups are oxidized in the Krebs cycle. Electrons are picked up by NAD⁺ and FAD for the electron transport chain.
- From one molecule of glucose, oxidation produces six molecules of NADH, two molecules of FADH₂, and two molecules of ATP.
- Decarboxylation produces six molecules of CO₂.

The Electron Transport Chain (pp. 127-128)

- Electrons are brought to the electron transport chain by NADH.
- The electron transport chain consists of carriers, including flavoproteins, cytochromes, and ubiquinones.

The Chemiosmotic Mechanism of ATP Generation (pp. 128-129)

- Protons being pumped across the membrane generate a proton motive force as electrons move through a series of acceptors or carriers.
- Energy produced from movement of the protons back across the membrane is used by ATP synthase to make ATP from ADP and P_i.
- In eucaryotes, electron carriers are located in the inner mitochondrial membrane; in procaryotes, electron carriers are in the plasma membrane.

A Summary of Aerobic Respiration (pp. 129-130)

- In aerobic procaryotes, 38 ATP molecules can be produced from complete oxidation of a glucose molecule in glycolysis, the Krebs cycle, and the electron transport chain.
- In eucaryotes, 36 ATP molecules are produced from complete oxidation of a glucose molecule.

Anaerobic Respiration (pp. 130-132)

- The final electron acceptors in anaerobic respiration include NO₃⁻, SO₄²⁻, and CO₃²⁻.
- The total ATP yield is less than aerobic respiration because only part of the Krebs cycle operates under anaerobic conditions.

Fermentation (pp. 132-134)

- Fermentation releases energy from sugars or other organic molecules by oxidation.
- O₂ is not required in fermentation.

- Two ATP molecules are produced by substrate-level phosphorylation.
- Electrons removed from the substrate reduce NAD⁺.
- The final electron acceptor is an organic molecule.
- In lactic acid fermentation, pyruvic acid is reduced by NADH to lactic acid.
- In alcohol fermentation, acetaldehyde is reduced by NADH to produce ethanol.
- Heterolactic fermenters can use the pentose phosphate pathway to produce lactic acid and ethanol.

Biochemical Tests (pp. 134-135)

- Bacteria and yeast can be identified by detecting action of their enzymes.
- Fermentation tests are used to determine whether an organism can ferment a carbohydrate to produce acid and gas.

Lipid Catabolism (p. 135)

- Lipases hydrolyze lipids into glycerol and fatty acids.
- Fatty acids and other hydrocarbons are catabolized by beta oxidation.
- Catabolic products can be further broken down in glycolysis and the Krebs cycle.

Protein Catabolism (pp. 135-136)

- Before amino acids can be catabolized, they must be converted to various substances that enter the Krebs cycle.
- Transamination, decarboxylation, and dehydrogenation reactions convert the amino acids to be catabolized.

Photosynthesis (pp. 136-139)

- Photosynthesis is the conversion of light energy from the sun into chemical energy; the chemical energy is used for carbon fixation.

The Light (Light-Dependent) Reactions: Photophosphorylation (p. 138)

- Chlorophyll a is used by green plants, algae, and cyanobacteria; it is found in thylakoid membranes.
- Electrons from chlorophyll pass through an electron transport chain, from which ATP is produced by chemiosmosis.
- In cyclic photophosphorylation, the electrons return to the chlorophyll.
- In noncyclic photophosphorylation, the electrons are used to reduce NADP, and electrons are returned to chlorophyll from H₂O or H₂S.
- When H₂O is oxidized by green plants, algae, and cyanobacteria, O₂ is produced.

The Dark (Light-Independent) Reactions: The Calvin-Benson Cycle (pp. 138-139)

- CO₂ is used to synthesize sugars.

A Summary of Energy Production Mechanisms (pp. 139-142)

- Sunlight is converted to chemical energy in oxidation-reduction reactions carried on by phototrophs. Chemotrophs can use this chemical energy.
- In oxidation-reduction reactions, energy is derived from the transfer of electrons.
- To produce energy, a cell needs an electron donor (organic or inorganic), a system of electron carriers, and a final electron acceptor (organic or inorganic).

Metabolic Diversity Among Organisms (pp. 140-142)

- Photoautotrophs obtain energy by photophosphorylation and fix carbon from CO₂ via the Calvin-Benson cycle to synthesize organic compounds.
- Cyanobacteria are oxygenic phototrophs. Green sulfur bacteria and purple sulfur bacteria are anoxygenic phototrophs.
- Photoheterotrophs use light as an energy source and an organic compound for their carbon source or electron donor.
- Chemoautotrophs use inorganic compounds as their energy source and carbon dioxide as their carbon source.
- Chemoheterotrophs use complex organic molecules as their carbon and energy sources.

Metabolic Pathways of Energy Use (Anabolism) (p. 142-145)

Polysaccharide Biosynthesis (p. 144)

- Glycogen is formed from ADPG.
- UDPNAc is the starting material for the biosynthesis for peptidoglycan.

Lipid Biosynthesis (p. 144)

- Lipids are synthesized from fatty acids and glycerol.
- Glycerol is derived from dihydroxyacetone phosphate, and fatty acids are built from acetyl CoA.

Amino Acid and Protein Biosynthesis (p.145)

- Amino Acids are required for protein biosynthesis.
- All amino acids can be synthesized either directly or indirectly from intermediates of carbohydrate metabolism, particularly from the Krebs cycle.

Purine and Pyrimidine Biosynthesis (p. 145)

- The sugars composing nucleotides are derived from either the pentose phosphate pathway or the Entner-Doudroff pathway.
- Carbon and nitrogen atoms from certain amino acids form the backbones of the purines and pyrimidines.

The Integration of Metabolism (p. 145-146)

- Anabolic and catabolic reactions are integrated through a group of common intermediates.
- Such integrated metabolic pathways are referred to as amphibolic pathways.