Chapter 5
Microbial Metabolism

Catabolic and Anabolic Reactions

- **Metabolism**: The sum of the chemical reactions in an organism
- **Catabolism**: Provides energy and building blocks for anabolism.
  - Catabolic reactions = exergonic = break-down
- **Anabolism**: Uses energy and building blocks to build large molecules
  - Anabolic reactions = endergonic = synthesis

Catabolic and Anabolic Reactions

- A **metabolic pathway** is a sequence of enzymatically catalyzed chemical reactions in a cell
- Metabolic pathways are determined by enzymes
- Enzymes are encoded by genes

Collision Theory

- The **collision theory** states that chemical reactions can occur when atoms, ions, and molecules collide
- **Activation energy** is needed to disrupt electronic configurations
- **Reaction rate** is the frequency of collisions with enough energy to bring about a reaction.
- Reaction rate can be increased by enzymes or by increasing temperature or pressure

Enzyme Components

- Biological catalysts
  - Specific for a chemical reaction; not used up in that reaction
- **Apoenzyme**: Protein
- **Cofactor**: Nonprotein component
  - Coenzyme: Organic cofactor
- **Holoenzyme**: Apoenzyme plus cofactor

Important Coenzymes

- NAD^+
- $NADP^+$
- FAD
- Coenzyme A

Enzyme Specificity and Efficiency

- The **turnover number** is generally 1 to 10,000 molecules per second

Enzyme Classification

- **Oxidoreductase**: Oxidation-reduction reactions
- **Transferase**: Transfer functional groups
- **Hydrolase**: Hydrolysis
- **Lyase**: Removal of atoms without hydrolysis
- **Isomerase**: Rearrangement of atoms
- **Ligase**: Joining of molecules, uses ATP

Factors Influencing Enzyme Activity

- Temperature
  - denature proteins
- pH
- denature proteins
  - Substrate concentration
- Inhibitors
  - Competitive Inhibitors
  - Noncompetitive Inhibitors
  - Feedback Inhibitors

Ribozymes

- RNA that cuts and splices RNA

Oxidation-Reduction Reactions

- **Oxidation**: Removal of electrons
- **Reduction**: Gain of electrons
- **Redox reaction**: An oxidation reaction paired with a reduction reaction

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Oxidation-Reduction Reactions
- In biological systems, the electrons are often associated with hydrogen atoms. Biological oxidations are often **dehydrogenations**.

The Generation of ATP
- ATP is generated by the **phosphorylation** of ADP

Substrate-Level Phosphorylation
- Energy from the transfer of a high-energy PO_4– to ADP generates ATP

Oxidative Phosphorylation
- Energy released from transfer of electrons (oxidation) of one compound to another (reduction) is used to generate ATP in the **electron transport chain**

Photophosphorylation
- Light causes chlorophyll to give up electrons. Energy released from transfer of electrons (oxidation) of chlorophyll through a system of carrier molecules is used to generate ATP.

Metabolic Pathways of Energy Production

Carbohydrate Catabolism
- The breakdown of carbohydrates to release energy
  - **Glycolysis**
  - **Krebs cycle**
  - **Electron transport chain**

Glycolysis
- The oxidation of glucose to pyruvic acid produces ATP and NADH

Preparatory Stage of Glycolysis
- 2 ATP are used
- Glucose is split to form 2 glucose-3-phosphate

Energy-Conserving Stage of Glycolysis
- 2 glucose-3-phosphate oxidized to 2 pyruvic acid
- 4 ATP produced
- 2 NADH produced

Glycolysis
- Glucose + 2 ATP + 2 ADP + 2 PO_4^- + 2 NAD^+ → 2 pyruvic acid + 4 ATP + 2 NADH + 2H^+

Alternatives to Glycolysis
- **Pentose phosphate pathway**
  - Uses pentoses and NADPH
  - Operates with glycolysis
- **Entner-Doudoroff pathway**
  - Produces NADPH and ATP
  - Does not involve glycolysis
  - *Pseudomonas, Rhizobium, Agrobacterium*

Cellular Respiration
- Oxidation of molecules liberates electrons for an electron transport chain
- ATP is generated by oxidative phosphorylation

Intermediate Step
- Pyruvic acid (from glycolysis) is oxidized and decarboyxlated

The Krebs Cycle
- Oxidation of acetyl CoA produces NADH and $FADH_2$

The Electron Transport Chain
- A series of carrier molecules that are, in turn, oxidized and reduced as electrons are passed down the chain
- Energy released can be used to produce ATP by **chemiosmosis**

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A Summary of Respiration
- **Aerobic respiration**: The final electron acceptor in the electron transport chain is molecular oxygen (O_2).
- **Anaerobic respiration**: The final electron acceptor in the electron transport chain is not O_2. Yields less energy than aerobic respiration because only part of the Krebs cycles operates under anaerobic conditions.

Carbohydrate Catabolism
- Energy produced from complete oxidation of one glucose using aerobic respiration
- ATP produced from complete oxidation of one glucose using aerobic respiration
- 36 ATPs are produced in eukaryotes

Fermentation
- Any spoilage of food by microorganisms (general use)
- Any process that produces alcoholic beverages or acidic dairy products (general use)
- Any large-scale microbial process occurring with or without air (common definition used in industry)
- Scientific definition:
  - Releases energy from oxidation of organic molecules
  - Does not require oxygen
  - Does not use the Krebs cycle or ETC
  - Uses an organic molecule as the final electron acceptor

Fermentation
- **Alcohol fermentation**: Produces ethanol + CO_2
- **Lactic acid fermentation**: Produces lactic acid
  - Homolactic fermentation: Produces lactic acid only
  - Heterolactic fermentation: Produces lactic acid and other compounds

Biochemical Tests
- Used to identify bacteria.

Photosynthesis
- Photo: Conversion of light energy into chemical energy (ATP)
  - **Light-dependent (light) reactions**
- Synthesis:
  - **Carbon fixation**: Fixing carbon into organic molecules
  - **Light-independent (dark) reaction**: Calvin-Benson cycle
- Oxygenic:
- Anoxygenic:

Photosynthesis Compared
Chemotrophs
- Use energy from chemicals
- **Chemoheterotroph**
  - Energy is used in anabolism
- **Chemoautotroph**, *Thiobacillus ferrooxidans*
  - Energy used in the Calvin-Benson cycle to fix CO_2

Phototrophs
- Use light energy
- **Photoheterotrophs** use energy in the Calvin-Benson cycle to fix CO_2

The Integration of Metabolism
- **Amphibolic pathways**: Metabolic pathways that have both catabolic and anabolic functions