1. **Chapter 5**
   Microbial Metabolism
2. **Catabolic and Anabolic Reactions**
   - Metabolism: The sum of the chemical reactions in an organism
3. **Catabolic and Anabolic Reactions**
   - Catabolism: Provides energy and building blocks for anabolism.
   - Anabolism: Uses energy and building blocks to build large molecules
4. **Role of ATP in Coupling Reactions**
5. **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
6. **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
7. **Energy Requirements of a Chemical Reaction**
8. **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
9. **Components of a Holoenzyme**
10. **Important Coenzymes**
    - NAD^+
    - $NADP^+$
    - FAD
    - Coenzyme A
11. **Enzyme Specificity and Efficiency**
    - The turnover number is generally 1 to 10,000 molecules per second
12. **The Mechanism of Enzymatic Action**
13. **The Mechanism of Enzymatic Action**
14. **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
15. **Factors Influencing Enzyme Activity**

- Temperature
- pH
- Substrate concentration
- Inhibitors

16 **Factors Influencing Enzyme Activity**
- Temperature and pH denature proteins

17 **Effect of Temperature on Enzyme Activity**

18 **Effect of pH on Enzyme Activity**

19 **Effect of Substrate Concentration on Enzyme Activity**

20 **Enzyme Inhibitors: Competitive Inhibition**

21 **Enzyme Inhibitors: Competitive Inhibition**

22 **Enzyme Inhibitors: Noncompetitive Inhibition**

23 **Enzyme Inhibitors: Feedback Inhibition**

24 **Ribozymes**
- RNA that cuts and splices RNA

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

26 **Oxidation-Reduction**

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

28 **Representative Biological Oxidation**

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

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

31 **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

32 **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.

33 **Metabolic Pathways of Energy Production**

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

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

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

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

38 **Glycolysis**
- Glucose + 2 ATP + 2 ADP + 2 PO_4^- + 2 NAD^+ $\rightarrow$ 2 pyruvic acid + 4 ATP + 2 NADH + 2H^+

39 **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*

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

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

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

43 **The Krebs Cycle**

44 **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

45 **Overview of Respiration and Fermentation**

46 **Chemiosmotic Generation of ATP**

47 **An Overview of Chemiosmosis**

48 **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.

49 **Respiration**

50 **Anaerobic Respiration**

51 **Carbohydrate Catabolism**

52 **Carbohydrate Catabolism**

- Energy produced from complete oxidation of one glucose using aerobic respiration

53 **Carbohydrate Catabolism**
- ATP produced from complete oxidation of one glucose using aerobic respiration

54 **Carbohydrate Catabolism**
- 36 ATPs are produced in eukaryotes

55 **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)

56 **Fermentation**
- 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

57 **An Overview of Fermentation**

58 **End-Products of Fermentation**

59 **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

60 **Types of Fermentation**

61 **A Fermentation Test**

62 **Types of Fermentation**

63 **Types of Fermentation**

64 **Lipid Catabolism**

65 **Catabolism of Organic Food Molecules**

66 **Protein Catabolism**

67 **Protein Catabolism**

68 **Protein Catabolism**

69 **Protein Catabolism**

70 **Biochemical Tests**
- Used to identify bacteria.

71 **Photosynthesis**

72 **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

73 **Photosynthesis**
- Oxygenic:
- Anoxygenic:

74 **Cyclic Photophosphorylation**

75 **Noncyclic Photophosphorylation**

76 **Calvin-Benson Cycle**

77 **Photosynthesis Compared**

78 **Chemotrophs**
- Use energy from chemicals
- Chemoheterotroph
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-
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- Energy is used in anabolism

79 **Chemotrophs**
- Use energy from chemicals
- Chemoautotroph, *Thiobacillus ferrooxidans*
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  -
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-
- Energy used in the Calvin-Benson cycle to fix CO_2

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

81 **Requirements of ATP Production**

82 **A Nutritional Classification of Organisms**

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84 **A Nutritional Classification of Organisms**

85 **Metabolic Diversity among Organisms**

86 **Polysaccharide Biosynthesis**

87 **Lipid Biosynthesis**

88 **Pathways of Amino Acid Biosynthesis**

89 **Amino Acid Biosynthesis**

90 **Purine and Pyrimidine Biosynthesis**

91 **The Integration of Metabolism**

- Amphibolic pathways: Metabolic pathways that have both catabolic and anabolic functions

92 **Amphibolic Pathways**

93 **Amphibolic Pathways**