# Microbial Metabolism

- Metabolism: The sum of the chemical reactions in an organism
- Catabolism: The energy-releasing processes
- Anabolism: The energy-using processes
- Catabolism provides the building blocks and energy for anabolism.
- 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.
- 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.

## Enzymes

- Biological catalysts
  - Substrate specific
  - 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

## Enzymes

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

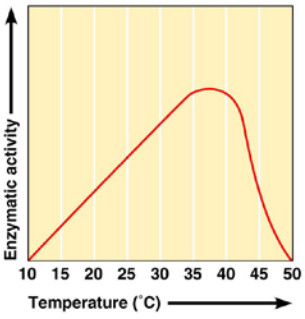
## Enzyme Classification

- Most enzymes end with –ase.
- Name usually indicates function.
  - phosphatase: removes phosphates
  - polymerase: add nucleotides to make polymers
  - amylase: breaks down starch
  - protease: breaks down protein
  - ligase: joining of molecules, uses ATP

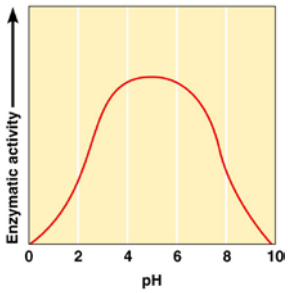
  - What are some examples of non-ase enzymes?

## Factors Influencing Enzyme Activity

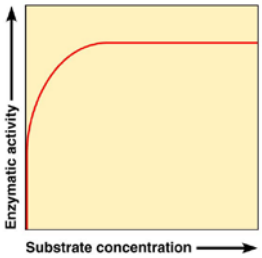
- Enzymes can be denatured by temperature and pH
- Temperature



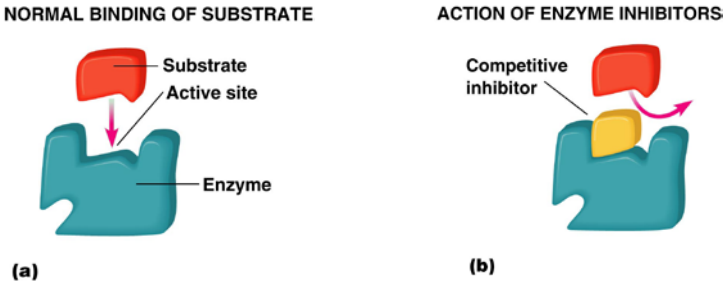
- pH



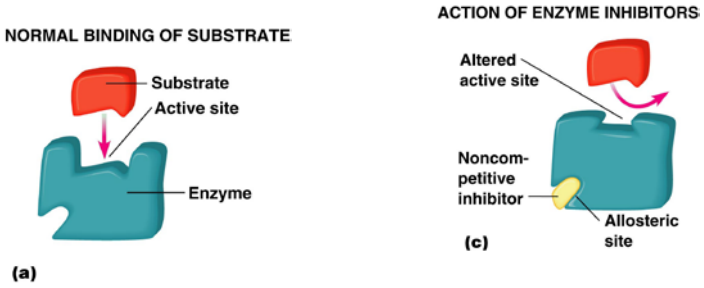

- Substrate concentration



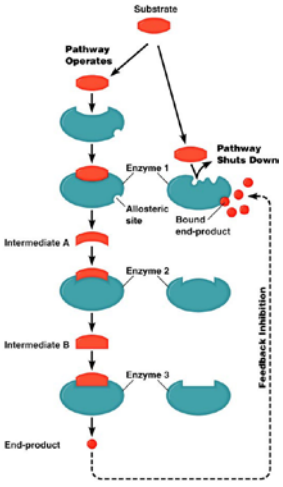

- Competitive inhibition




- Noncompetitive inhibition




- **Feedback inhibition**




- End-product (_____) of a metabolic pathway feeds back to an enzyme in pathway (usually early in path).
- Effector binds to allosteric enzyme altering shape of substrate-binding site.
- 
- Pathway turned off.
- Why does the cell want to do this?

**Oxidation-Reduction**

- Oxidation is _____.
- Reduction is _____.
- Redox reaction is an oxidation reaction paired with a reduction reaction.

- 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 is the transfer of a high-energy PO4– to ADP.
- Energy released from the transfer of electrons (oxidation) of one compound to another (reduction) is used to generate ATP by chemiosmosis. = _____
- Light causes chlorophyll to give up electrons. Energy released from the transfer of electrons (oxidation) of chlorophyll through a system of carrier molecules is used to generate ATP. = _____

**Carbohydrate Catabolism**

- The breakdown of carbohydrates to release energy
  - 
  - 
  - Electron transport chain

**Glycolysis ( )**

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

**Preparatory Stage**

- Two ATPs are used to initiate the process.

**Energy-Conserving Stage**

- End result is the production of two Pyruvic acids (pyruvate)
- Four ATP produced (net production of 2)
- 

**Alternatives to Glycolysis**

- Glycolysis is a universal pathway but glucose may have other fates.
- Pentose phosphate pathway (proks and euks)
  - Produces NADPH for biosynthesis and protection from oxidative stress ($H_2O_2$)
  - Operates with glycolysis

- Entner-Doudoroff pathway (proks only)
  - Produces one NADPH and one ATP per glucose
  - Does not involve glycolysis
  - *Pseudomonas, Rhizobium, Agrobacterium*

**Cellular Respiration**

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

Intermediate Step

- Pyruvic acid (_____) is oxidized and decarboyxlated.

- How many NADH are produced?

Krebs Cycle

- Oxidation of acetyl CoA produces NADH and $FADH_2$ and ATP.

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 _____.

**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 operations under anaerobic conditions.

Anaerobic Respiration

| **Electron acceptor** | **Products** |
|---|---|
| $NO_3^-$ | $NO_2^-$, $N_2 + H_2O$ |
| $SO_4^-$ | $H_2S + H_2O$ |
| $CO_3^{2-}$ | $CH_4 + H_2O$ |

**Summary Aerobic Respiration**

| **Pathway** | **Eukaryote** | **Prokaryote** |
|---|---|---|
| Glycolysis | | Cytoplasm |
| Intermediate step | Cytoplasm | |
| Krebs cycle | Mitochondrial matrix | Cytoplasm |
| ETC | Mitochondrial inner membrane | |

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

| Pathway | ATP produced | NADH produced | FADH2 produced |
|---|---|---|---|
| Glycolysis | 2 | 2 | 0 |
| Intermediate step | 0 | 2 | 0 |
| Krebs cycle | 2 | 6 | 2 |
| **Total** | | | |

- ATP produced from complete oxidation of one glucose using aerobic respiration.

| Pathway | By substrate-level phosphorylation | By oxidative phosphorylation | |
|---|---|---|---|
| | | From NADH | From FADH |
| Glycolysis | 2 | 6 | 0 |
| Intermediate step | 0 | 6 | 0 |
| Krebs cycle | 2 | 18 | 4 |
| **Total** | | | |

- 36

**Fermentation**

- Releases energy from oxidation of organic molecules
- 
- Does not use the Krebs cycle or ETC
- Uses an organic molecule as the final electron acceptor
- Alcohol fermentation:
- Lactic acid fermentation:
  - Homolactic fermentation: Produces lactic acid only.
  - Heterolactic fermentation: Produces lactic acid and other compounds.

What color indicates a positive fermentation test?

**Lipid Catabolism**

Why do fats yield twice as many calories as carbohydrates or proteins?

**Protein Catabolism**

Why do proteins yield as many calories as carbohydrates?

**Biochemical tests**

- 
- Look for products of enzymatic reactions.

*Halobacterium* uses bacteriorhodopsin, not chlorophyll, to generate electrons for a chemiosmotic proton pump.

**Metabolic Diversity Among Organisms**

| Nutritional type | Energy source | Carbon source | Example |
|---|---|---|---|
| Photoautotroph | | | Oxygenic: Cyanobacteria plants.Anoxygenic: Green, purple bacteria. |
| Photoheterotroph | Light | Organic compounds | Green, purple nonsulfur bacteria. |
| Chemoautotroph | Chemical | | Iron-oxidizing bacteria. |
| Chemoheterotroph | | Organic compounds | Fermentative bacteria. Animals, protozoa, fungi, bacteria. |

**Study Objectives**

1. Compare anabolism vs. catabolism. What does each one produce?

2. What functions do enzymes perform?

3. List some characteristics of enzymes.

4. How does each of the following affect enzyme activity: a) temperature, b) pH?

5. Describe the effect of a competitive inhibitor on enzyme activity.

6. Describe feedback inhibition and the terms effector and allosterism.

7. Distinguish between aerobic respiration, anaerobic respiration, and fermentation in bacteria. How are they similar and different?

8. Briefly describe the major events in glycolysis, Krebs cycle, ET, and chemisosmosis.

9. Same as above but describe in terms of energy production (ATP) and reducing power (coenzymes).

10. Give some examples of fermentation end products.

11. Where does ET occur in bacteria? In eukaryotes?

12. Distinguish between substrate level phosphorylation, oxidative phosphorylation, and photophosphorylation.

13. Distinguish among the 4 types of nutritional categories. Include energy sources and carbon sources used by each group of microorganisms.