# Chapter 4 Enzymes and Energy

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## Enzymes

- Increase rate of chemical reactions.
- Most enzymes are proteins with diverse structure.
- Functionally are biological catalysts:
  1. Chemicals that increases the rate of a reaction.
  2. Are not changed at the end of the reaction.
  3. Do not change the nature of the reaction or final result.
  4. Lower the activation energy required.
     - Amount of energy required for a reaction to proceed.

**Fig 4.1**

Enzymes lower the activation energy required for the reaction. Reactants that can overcome the activation energy barriercan now participate in the reaction.

This increases the rate of the reaction.

http://www.youtube.com/watch?v=cbZsXjgPDLQ&feature=related
http://www.youtube.com/watch?v=z8lG8X9ZvxQ&feature=related

## Mechanism of Enzyme Action

- Ability of enzymes to lower activation energy due to structure.
- Each type of enzyme has a highly-ordered, characteristic 3-dimensional shape (conformation).
  - Ridges, grooves, and pockets lined with specific amino acids.
  - Pockets active in catalyzing a reaction are called the **active sites** of the enzyme.
- Substrates have specific shapes to fit into the active sites (lock-and-key model):
  - Substrate fits into active sites in enzyme.
  - Perfect fit may be induced:
    - Enzyme undergoes structural change

- Enzyme-substrate complex formed, then dissociates.
- Products formed and enzyme is unaltered.

**Fig 4.2**

## Naming of Enzymes

- Enzyme name ends with suffix **"-*ase*."**
    - Classes of enzymes named according to their activity or "job category."
        - May specify both the substrate of the enzyme and job category.
- Different organs may make different enzymes (**isoenzymes**) that have the same activity.
    - Differences in structure do not affect the active sites. But specific diagnostic tests can separate isoenzymes.

**Ex: Creatinine phosphokinase (CPK)**

**MM form** from diseased muscles

**BB form** from diseased brain

**MB form** from diseased heart

## Control of Enzyme Activity

- Rate of enzyme-catalyzed reactions measured by the rate substrates are converted to products.
- Factors influencing rate of enzyme activity:

- Temperature.
- pH.
- [cofactors and coenzyme].
- [enzyme and substrate].
- Stimulatory and inhibitory effects of products of enzyme action.

## Effect of Temperature

- Rate of reaction increases as temperature increases.
- Reaction rate plateaus, slightly above body temperature (37°C).
- Reaction rate decreases as temperature increases.
- Enzymes denature at high temperatures.

**Fig. 4.3**

## pH

- Each enzyme exhibits peak activity at narrow pH range (pH optimum).
- pH optimum reflects the pH of the body fluid in which the enzyme is found.
- If pH changed, so it is no longer within the enzyme range, reaction will decrease.

**Fig 4.4**

## Cofactors

- Needed for the activity of specific enzymes.
- **Cofactor:**
  - Attachment of cofactor causes a conformational change of active site.
  - Participate in temporary bonds between enzyme and substrate.
  - Ex: metal ions like $Ca^{+}$ and $Mg^{+}$

**Fig 4.5**

## Coenzymes

- Like cofactors they are needed for the activity of specific enzymes.
- **Coenzymes**:
  - Organic molecules derived from $H_20$ soluble vitamins.
  - Transport $H^{+}$ and small molecules from one enzyme to another.
  - Ex: niacin and riboflavin

## Enzyme Activation

- Enzymes may be produced in an inactive form.

- In **pancreas**, digestive enzymes are produced as inactive zymogens, which are activated in lumen of intestine.
    - This protects against self-digestion.
- In **liver** cells, enzyme is inactive when produced and is activated by addition of phosphate group.
    - Phosphorylation/dephosphorylation:
        - Activation/inactivation of an enzyme.
- Other cells need ligands to activate some inactive enzymes.
    - Ligands are small, intracellular regulatory molecules called secondary messengers.

## Substrate Concentration

- At a specific [enzyme], rate of product formation increases as the [substrate] increases.
- Plateau of maximum velocity occurs when enzyme is saturated.
- Additional [substrate] does **not** increase reaction rate.

**Fig 4.6**

## Reversible Reactions

- Some enzymatic reactions are reversible.
    - Both forward and backward reactions are catalyzed by same enzyme.

ca

- $H_20 + C0_2 \leftrightarrow H_2C0_3$

  ca = carbonic anhyd**rase**

- **Law of mass action**:
  - Principal that reversible reactions will be driven from the side of the equation where concentration is higher to side where concentration is lower.

## Metabolic Pathways

**Fig 4.7**

- Sequence of enzymatic reactions that begins with initial substrate, progresses through intermediates and ends with a final product.

**Fig 4.8**

- A branched metabolic pathway.

http://www.youtube.com/watch?v=zl2KYhgZ_u8&feature=related
http://www.youtube.com/watch?v=2DRWqBld7XU&feature=related

## End-Product Inhibition

**Fig 4.9**

- Negative feedback inhibition.

- One of the final products in a divergent pathway inhibits the activity of the branch-point enzyme.
  - Prevents final product accumulation.
  - Results in shift to product in alternate pathway.

## Inborn Errors of Metabolism

**Fig 4.10**

- Inherited defect in a gene for enzyme synthesis.
- Quantity of intermediates formed prior to the defect increases.
- Final product formed after the defect decreases, producing a deficiency.

**Ex:** Phenylketonuria (PKU)

## Bioenergetics

- Flow of energy in living systems obeys:
  - **1st law of thermodynamics:**
    - Energy can be transformed, but it cannot be created or destroyed.
  - **2nd law of thermodynamics**:
    - Energy transformations increase **entropy** (degree of disorganization of a system).

- Only **free energy** (energy in organized state) can be used to do work.
  - Systems tend to go from states of higher free energy to states of lower free energy.
- As entropy ↑, free energy ↓.
- Glucose has a molecular formula of:

  $\mathbf{C_6H_{12}O_6}$

  - Glucose has more free energy (less entropy) than six separate molecules each of water and carbon dioxide.
  - Plants use solar energy, in photosynthesis, to convert water and carbon dioxide to glucose.

– **Endergonic reactions** require energy **input.**
  - Ex: $H_2O + CO_2 \rightarrow C_6H_{12}O_6$
    – Photosynthesis (plants)

– **Exergonic reactions release** energy.
  - Ex: $C_6H_{12}O_6 \rightarrow H_2O + CO_2$
    – Cellular respiration (mitochondria)

| | Energy input or Energy released | Free Energy | Entropy |
|---|---|---|---|
| Endergonic reactions | | | |
| Exergonic | | | |

| | | | |
|---|---|---|---|
| reactions | | | |

## Review of Endergonic Reactions

- Endergonic:
  - Chemical reactions that require an input of energy to make reaction "go."
    - Products must contain more free energy than reactants.

## Review of Exergonic Reactions

- Exergonic:
  - Convert molecules with more free energy to molecules with less.
  - Release energy in the form of heat.
    - Heat is measured in calories.

**Fig 4.13**

## Coupled Reactions: ATP

- Cells must maintain highly organized, low-entropy state at the expense of free energy.
  - Cells cannot use heat for energy.

**Fig 4.14**

- Energy released in exergonic reactions is used to drive endergonic reactions.

  - Require energy released in exergonic reactions (ATP) to be directly transferred to chemical-bond energy in the products of endergonic reactions.

## Formation of ATP

- Formation of ATP requires the input of a large amount of energy.
  - Energy must be conserved, the bond produced by joining $P_i$ to ADP must contain a part of this energy.
- This energy is released when ATP is converted to ADP and $P_i$.
- ATP is the universal energy carrier of the cell.

**Fig 4.15**

**Fig 4.16**

## Oxidation-Reduction

- Reduced:
  - Molecule/atom **gains** electrons.
- Reducing agent:
  - Molecule/atom that **donates** electrons.
- Oxidized:
  - Molecule/atom **loses** electrons.

- Oxidizing agent:
  - Molecule/atom that **accepts** electrons.
- Reduction and oxidation are **always** coupled reactions.
- May involve the transfer of $H^+$ rather than free electrons.
- Molecules that serve important roles in the transfer of hydrogen are NAD and FAD.
  - Coenzymes that function as hydrogen carriers in cellular respiration.

**Fig 4.17a**
(**$NAD^+$** binds to one H and accepts the $e^-$ of the other.)

**Fig 4.17b**
(**FAD** binds both H.)

**Fig 4.18**