Chapter 4 Outline

- Enzymes as catalysts
- Control of enzyme activity
- Bioenergetics

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Enzymes

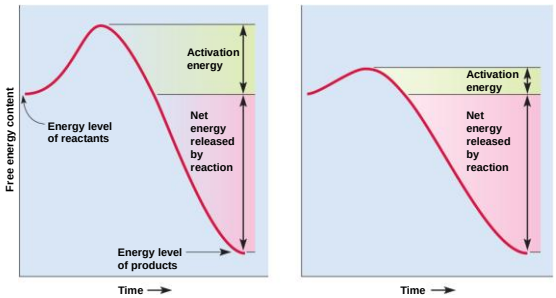
4-3

Enzymes

- **Enzymes - function as biological catalysts**
  - **permit reactions to occur rapidly**
- **Substrate: substance an enzyme acts upon**
- **Products: result of the chemical reax**
- **Naming Convention – ends in "ase"**
  - Such as phosphatases remove phosphate groups
    - (kinases add phosphate groups
    - **Lipase = enzyme digests Lipids**
    - **Deoxyribonuclease = digest ??**
    - **Lactic acid dehydrogenase???**

2-3

Enzymes and Activation Energy



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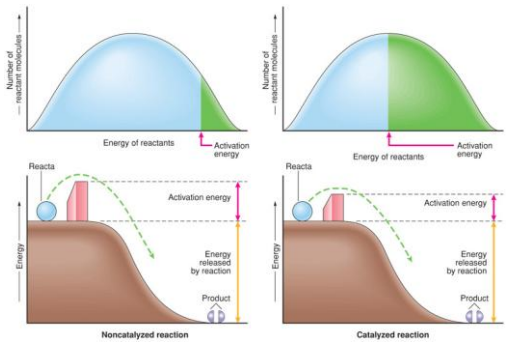
Enzymes



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Enzyme Structure and Action

- **Substrate approaches active site on enzyme molecule**
- **Substrate binds to active site forming enzyme-substrate complex**
  - **enzyme-substrate specificity**
- **Reaction products released**
- **Enzyme remains unchanged**

2-6

Mechanism of Enzyme Action

- Ability of enzymes to lower energy requirement is due to structure
- Each type of enzymes has highly-ordered characteristic 3-dimensional shapes (conformation)
  - Containing pockets called active sites into which substrates (reactants) fit

4-6

Mechanism of Enzyme Reax

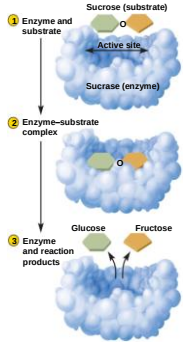

Figure 2.27

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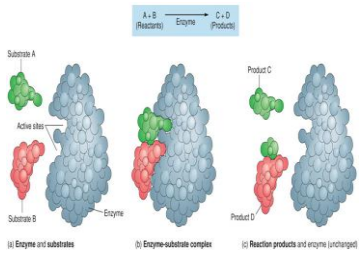
Mechanism of Enzyme Action



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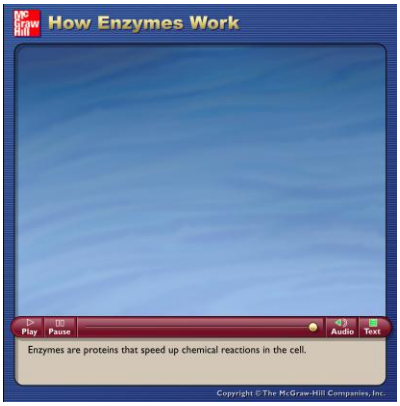

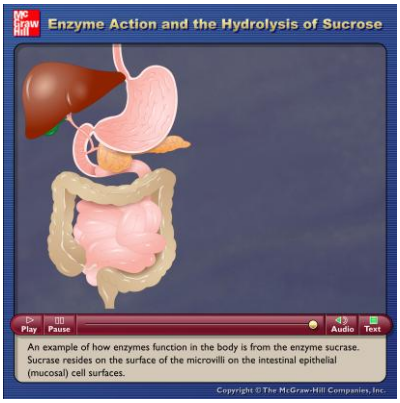

Enzyme Activation

- Many enzymes are produced in an inactive form
  - e.g. pancreatic digestive enzymes not activated until they reach intestine
  - Many are activated by phosphorylation and inactivated by dephosphorylation
  - Others activated by 2nd messengers
  - Turnover of enzymes---breakdown and re-synthesis of enzymes therefore
    - i.e., allows genes to alter enzyme activity

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Enzyme activiation - Second Messenger System

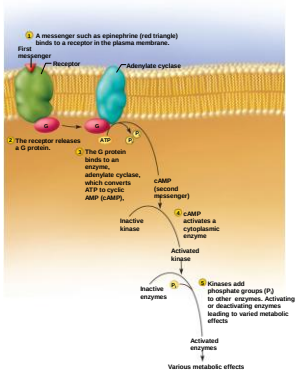
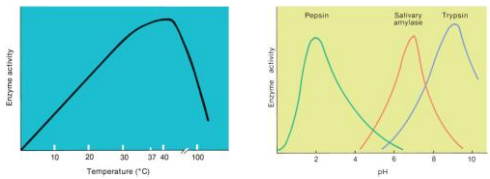


Figure 3.9

Enzyme Activity - Temperature and pH

- Enzymes have optimal temperature and pH ranges
  - Typically near normal physiological values
  - Because 3-D structure is affected outside range



4-11

Cofactors and Coenzymes

- **Cofactors:** an inorganic non-protein cofactor (helper)
  - (iron, copper, zinc, magnesium and calcium ions)
  - binds to enzyme inducing a change in shape
- Coenzymes
  - organic cofactors derived from water-soluble vitamins (niacin, riboflavin)
  - accept electrons from an enzyme in one pathway and transfer them to an enzyme in another

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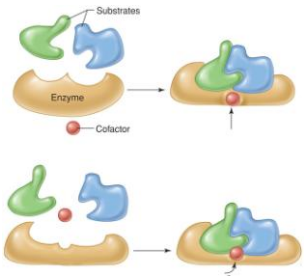
Cofactors and Coenzymes

- Cofactor binding changes conformation of active site
  - and aids in temporary bonding between enzyme and substrates



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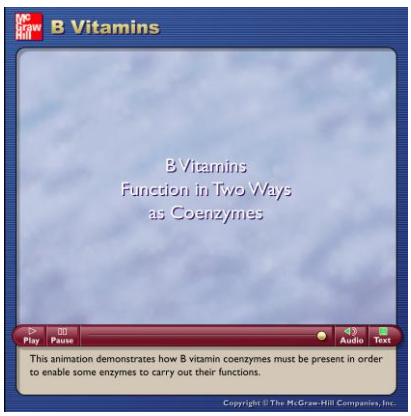

Coenzyme NAD+

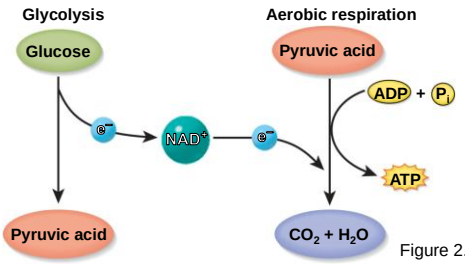

Figure 2.28

- NAD+ transports electrons from one metabolic pathway to another

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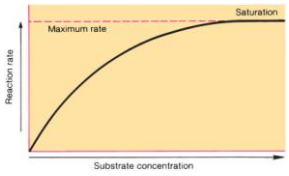
Effect of Substrate Concentration

- Rate of product formation increases as substrate concentration increases
  - Until reaction rate reaches a plateau
    - Where enzyme is said to be saturated



4-16

Binding Site Saturation

Begin

Enzymatic Action: Important Points!!

- **Reusability of enzymes**
- **Astonishing speed**
  - **one enzyme molecule can consume millions of substrate molecules per minute**
- **Factors that change enzyme shape**
  - **pH and temperature**
- **Substrate concentration affects rate**

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Reversible Reactions

- Some enzymatic reactions are reversible
  - Both forward and backward reactions are catalyzed by same enzyme
  - Law of mass action: direction of reaction is from where concentration is higher to side where concentration is lower
  - e.g. carbonic anhydrase catalyzes
    - $H_2O + CO_2 \Leftrightarrow H_2CO_3$

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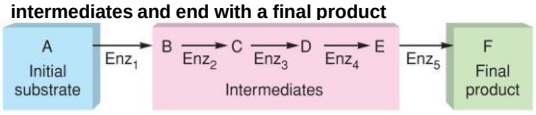
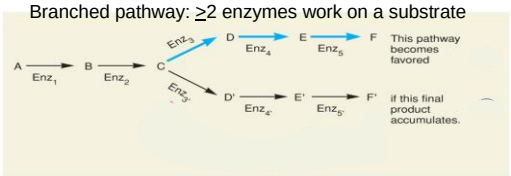
Metabolic Pathways

Reax that begin with initial substrate, progress through intermediates and end with a final product



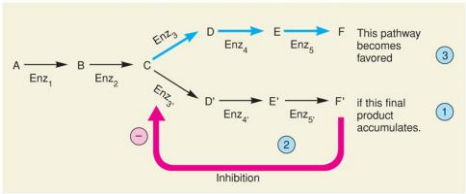
Branched pathway: ≥2 enzymes work on a substrate



4-19

End-Product Inhibition

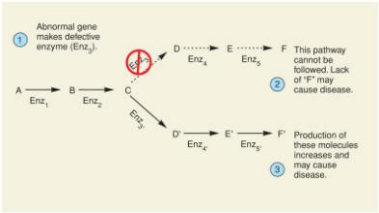
- When 1 product in a divergent pathway inhibits activity of the branch-point enzyme
  - Prevents final product accumulation
  - Causes reaction to favor alternate pathway
  - Occurs by allosteric inhibition whereby product binds to enzyme causing it to change to an inactive shape



4-20

Inborn Errors of Metabolism

- inherited defects in genes produces defective enzyme
- Metabolic disease can result from either:
  - Increases in intermediates formed prior to the defective enzyme
  - Or decreases in products normally formed after the defective enzyme



4-21

Bioenergetics

- Refers to flow of energy in living systems
- 1st law of thermodynamics: energy can be transformed but not created or destroyed
- 2nd law: 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

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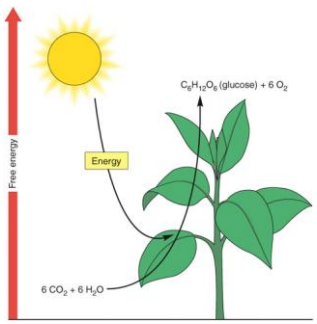
Bioenergetics

- 2nd law dictates that all living organisms require continued input of energy
- Plants obtain this from sunlight
  - Use it to make high free energy glucose from CO_2 and H_2O that have less free energy (more entropy)
    - we use energy in glucose to combat entropy and power our bodies



4-25

Metabolism

- All the chemical reactions of the body
- Catabolism
  - energy releasing (exergonic) decomposition reax
    - breaks covalent bonds
    - produces smaller molecules
- Anabolism
  - energy storing (endergonic) synthesis reax
    - requires energy input
    - production of protein or fat
    - driven by energy that catabolism releases

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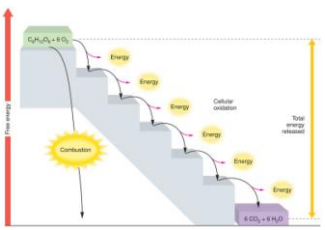
Endergonic and Exergonic Reactions

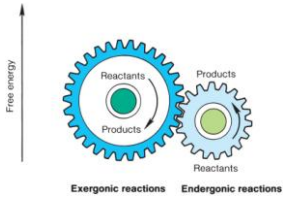
- Endergonic reactions require input of energy to proceed
  - Products contain more free energy than reactants
  - Synthesis Reax
- Exergonic reactions release energy as they proceed
  - Products contain less free energy than reactants
  - Decompisition Reax



4-26

Coupled Reactions: ATP

- Cells require constant inputs of free energy from environment to buck entropy and remain highly organized
  - Do this by coupling endergonic reactions to exergonic reactions
    - An exergonic reaction breaks down ATP - the universal energy carrier
  - Most exergonic reactions in body make ATP



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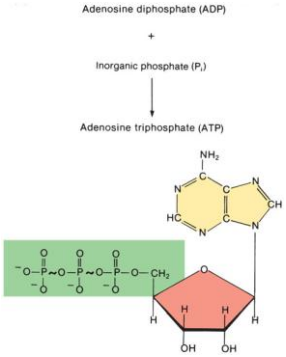
ATP



4-28

Oxidation-Reduction Reactions

- **Oxidation**
  - A molecule gives up electrons and releases energy
  - The molecule is **oxidized** in this process
    - **oxygen** is often involved as the electron acceptor
- **Reduction**
  - a molecule gains electrons and energy
  - molecule is **reduced** when it accepts electrons
- **oxidation-reduction (redox) reactions**
  - oxidation of one molecule is always accompanied by the reduction of another
  - Electrons are often transferred as **H**

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Coenzyme NAD^+

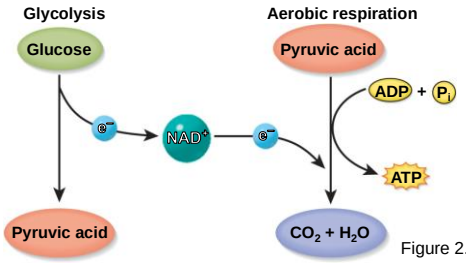

Figure 2.28

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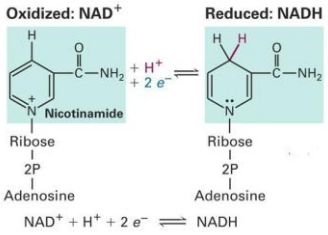

- **Redox – when NAD+ reacts with 2 H, it bonds with one and takes the others atom**

2-35