Chapter 6

Metabolism: Energy and Enzymes

Life & the Flow of Energy

- Energy is the ability to do work or bring about change
- Cells need a constant supply of energy to carry out cellular processes (growth, development, metabolism, respiration, reproduction)
- Life on Earth is dependent on solar energy
  - Photosynthesis
  - Name edible items not associated w/sun

Forms of Energy

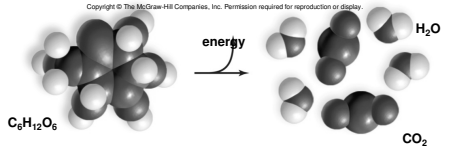
- Kinetic energy – energy of motion
  - Mechanical energy
- Potential energy – stored energy
  - Chemical energy – (food)

2 Laws of Thermodynamics

1. Energy cannot be created or destroyed, but it can be changed from one form to another
   - Known as Law of Conservation of Energy
2. Energy cannot be changed from one form to another without a loss of usable energy
   - Energy is usually lost as heat
   - Because energy is eventually lost to the environment and can't be used , it is not recyclable.

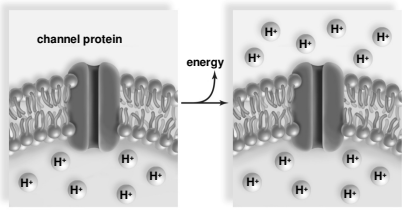
Cells & Entropy

- The 2nd law can be stated another way:
- Every energy transformation makes the universe less organized and more disordered
- Entropy – relative amount of disorganization



Glucose
- more organized
- more potential energy
- less stable (less entropy)

Carbon dioxide and water
- less organized
- less potential energy
- more stable (more entropy)



Unequal distribution of hydrogen ions
- more organized
- more potential energy
- less stable (less entropy)

Equal distribution of hydrogen ions
- less organized
- less potential energy
- more stable (more entropy)

b.

Energy Transformations & Metabolism

- Metabolism is the sum of all the chemical reactions that occur in a cell
- Catabolism – breaking down molecules
- Anabolism – building molecules
- Reactant – left side of equation
- Product – right side of equation

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Free Energy

- Free energy (ΔG) is the amount of energy available to do work.
  - Exergonic reactions are ones where energy is released (ΔG is negative)
    - Products have less free energy than reactants
  - Endergonic reactions require an input of energy (ΔG is positive)
    - Products have more free energy than reactants

Exergonic & Endergonic Reactions

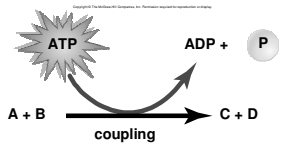
- Exergonic reactions
  - Spontaneous
  - Release energy
- Endergonic
  - Require an input of energy (ATP) to run
  - Cellular processes such as protein synthesis, contractions, nerve impulses

Cellular Energy

- ATP – adenosine triphosphate
  - Cells energy source
  - ADP – adenosine diphosphate
  - AMP – adenosine monophosphate
  - Only 39% of glucose is converted to ATP; rest is lost as heat
- ATP is a nucleotide composed of:
  - Adenine (a N-containing base)
  - Ribose (a 5-carbon sugar)
  - 3 phosphate groups
    - Energy stored in chemical bonds

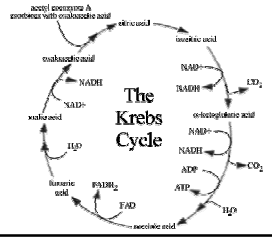
Coupled Reactions

- Energy released by an exergonic reaction is used to drive an endergonic reaction



Metabolic Pathways

- Metabolic pathways are a series of linked reactions.
  - Begin with a specific reactant and produces an end product



Enzymes

- Proteins that function to speed a chemical reaction
  - Enzymes serve as catalysts
    - Participates in chemical reaction, but is not used up by the reaction
  - Substrate – reactants in an enzymatic reation; what the enzyme acts upon

Energy of Activation (E_a)

- Energy that must be added to cause molecules to react with one another
  - Need a match to start wood burning
  - Enzymes lower the energy of activation
    - Do not change the end result of the reaction
    - Increase the reaction rate

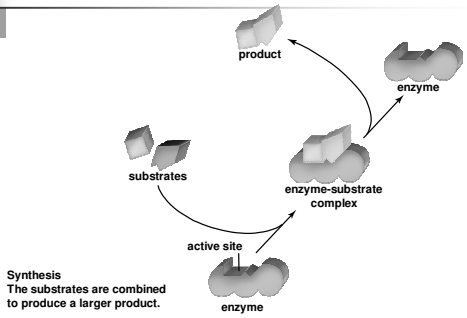
Enzyme Function

- Enzyme binds substrate at the active site to form a complex
  - Specific shape for enzyme & substrate

Enzyme + Substrate → ES complex → E + P

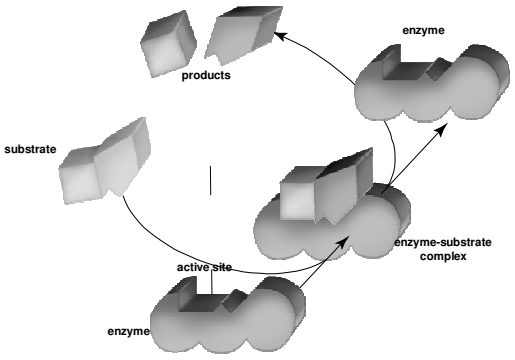
Enzyme + Substrate ⟶ ES complex ⟶ Enzyme + Product

Synthesis Reaction



Synthesis
The substrates are combined to produce a larger product.

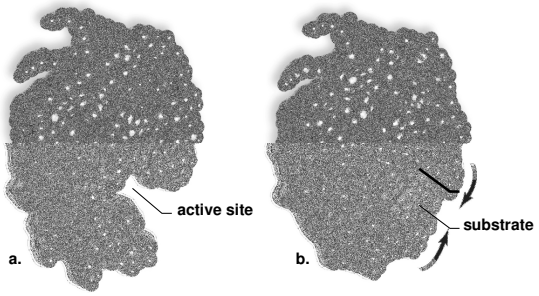
Decompostion Reaction



How Enzymes Function

- Induced fit model
  - Substrate & active site shapes don't match exactly
  - Active site is induced to undergo a slight change in shape to accommodate substrate binding
  - Change in shape facilitates reaction

Induced Fit Model



Examples of Enzymes

- Reaction requires specific enzyme
- Enzymes often named for their substrate
  - Lipid – lipase
  - Urea – urease
  - Maltose – maltase
  - Lactose – lactase
  - Sucrase – sucrose

Factors affecting enzymatic reaction rates

- Substrate Concentration - ↑as conc. ↑ due increased collisions occuring
- Temperature - ↑ as temp ↑ to a certain pt. Enzymes denature at extreme temp. (lose shape)
- pH – each enzyme has preferred pH range
- Enzyme Activation – some enzymes must be activated to before they become functional
- Enzyme Inhibition – blocks active site of enzyme until needed
- Enzyme Cofactors – Coenzymes assist the enzymes (vitamins)

Oxidation-Reduction

- Oxidation-Reduction or Redox
  - When atoms gain or lose electrons they are called IONS
  - Oxidation is the loss of electrons
  - Reduction is the gain of electrons
  - Ex: when oxygen combines with Mg
    - Oxygen gains electrons – becomes reduced
    - Mg loses electrons – becomes oxidized
  - LEO – lose electrons is OXIDATION
  - GER – gain electrons is REDUCTION
  - Ex: $Na^+ + Cl^- \rightarrow NaCl$
    - Sodium is oxidized
    - Chlorine is reduced

Photosynthesis

- Energy + $6CO_2+6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
- Radiant energy comes from the sun
- H atoms are transferred from H_2O to CO_2 to form $C_6H_{12}O_6$
- Chloroplasts convert energy to ATP which is then used along with H to reduce CO_2 to $C_6H_{12}O_6$

Cell Respiration

- $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy
- $C_6H_{12}O_6$ is oxidized (lost H atoms)
- O_2 is reduced to form H_2O (gained H atoms)
- Energy produced is used to form ATP
- The oxidation of $C_6H_{12}O_6$ to form ATP is done is a series of small steps to increase efficiency