Chapter 8- An Introduction to Metabolism

(Key Concepts are <u>Underlined</u>)

Metabolism, Energy, and Life

<u>The chemistry of life is organized into metabolic pathways</u>

Metabolism- all chemical processes in an organism; concerned with the managing of material and energy

Catabolic pathways- release energy via the break down of complex molecules into simpler ones (e.g. cellular respiration)

Anabolic pathways- consume energy via to build complex molecules from simpler ones (e.g. polymerization)

Bioenergetics- study of how organisms manage their energy resources

<u>Organisms transform energy</u>

Energy

Kinetic energy

Potential energy (e.g. chemical energy)

<u>The energy transformations of life are subject to two laws of thermodynamics</u>

Thermodynamics- study of energy transformations

System

Surroundings

Universe

Closed System

Open System- energy can be transferred from system to surroundings (e.g. organisms)

First law of thermodynamics- energy of the universe is constant

Second law of thermodynamics- the **entropy** (measurement of disorder, or randomness) of the universe is always increasing (i.e. every energy transfer or transformation increases the entropy of the universe)
- the first two laws of thermodynamics govern energy transformations in organisms
- heat ("low grade" energy) is the eventual byproduct of energy transformations; organisms take organized forms of energy and matter from the surroundings and replace them with less ordered forms
- "… organisms are islands of low entropy in an *increasingly* random universe."

<u>Organisms live at the expense of free energy</u>
Spontaneous processes- (*entropy of universe must* ***increase***); "stable" to "unstable"; **free energy** of a system decreases (**ΔG = -)**
Free energy- a portion of the system's energy able to perform work (when temperature is uniform); "organisms can live only at the expense of free energy acquired from the surroundings"
$\Delta G = \Delta H - T\Delta S$
- reactions at equilibrium, $\Delta G = 0$; free energy increases when equilibrium is disturbed
Exergonic- release of free energy (**ΔG = -)**
e.g. Cellular Respiration
Endergonic- absorb free energy (**ΔG = +)**
e.g. Photosynthesis
- metabolic disequilibrium is key to life!
energy coupling- use of an exergonic process to drive an endergonic one

ATP powers cellular work by coupling exergonic reactions to endergonic reactions

ATP (adenosine triphosphate)- similar to adenine nucleotide of RNA, but it has a chain of 3 phosphate groups (as opposed to one); the terminal phosphate may be hydrolyzed to yield ADP, inorganic phosphate, and energy; the triphosphate tail is unstable due to the repulsion of the negatively charged phosphate groups, which makes it relatively easy to hydrolyze the terminal phosphate

Phosphorylation- when ATP transfers its terminal phosphate group to other molecules, the phosphorylated intermediates become energized (i.e. unstable)

- ATP can be regenerated by ADP via catabolic pathways (primarily cellular respiration)

Enzymes

Enzymes speed up metabolic reactions by lowering energy barriers

-laws of thermodynamics do not help us to understand rates of reactions

Enzymes- catalytic proteins (most names end in –*ase*)

Catalyst- changes the rate of reaction without being consumed by the reaction

Activation Energy- energy required to break bonds in the reactant molecules; most biological molecules cannot overcome this barrier without enzymes

Energy Profile (a.k.a. Reaction Coordinate, Energy Diagram)

- enzymes **cannot change ΔG**, but they can hasten reactions that would otherwise occur on their own

Substrate is what an enzyme acts on

- enzymes are **substrate-specific** due to their unique conformation (remember: they are proteins!)

The **active site** of an enzyme is typically a pocket or groove on the surface of the protein, in which it acts upon its substrate; the actual site is typically only a few amino acids long- the rest of the molecule maintains it structure; an **induced fit** (where the enzyme forms to the substrate) bring R groups (side chains) of the active site into positions where their ability to catalyze the reaction is enhanced

- enzymes work quickly (about a thousand substrate molecules acted upon per second)

How enzymes lower the activation energy:

a) provide a template for the substrates to come together

b) weakens the bonds of substrate molecules

c) H^+ transfer to substrate (if applicable)

d) direct bonding

- the rate at which an enzyme acts on its substrate is primarily a function of the substrate's concentration; enzymes can become saturated, at which point the engaged enzymes work as fast as the active sites can allow

<u>A cell's physical and chemical environment affects enzyme activity</u>

- enzymes have optimal temperature and pH ranges at which they function

Cofactors- nonprotein helpers, which may be bound to the active site or loosely bound to the substrate; may be inorganic, such as metals

Coenzymes- organic cofactor (e.g. vitamins)

Competitive inhibitors- reduce productivity of enzymes by entering their active sites, thus blocking substrates; reversible

Noncompetitive inhibitors- change the shape of enzymes and their active sites by binding to another part of the enzyme, thus disabling their catalytic abilities

The Control of Metabolism

<u>Metabolic control often depends on allosteric regulation</u>
Allosteric site- a specific receptor on the enzyme (for a regulatory molecule) separate from the active site, which may inhibit or stimulate enzyme activity
- most allosterically regulated enzymes are made up of 2 or more polypeptide subunits and oscillate between an active or inactive conformation (due to the binding of a regulatory molecule); activator or allosteric inhibitors bind to allosteric sites normally located between subunits

Feedback inhibition- the switching off of a metabolic pathway by its end-product (acts as an inhibitor); allosteric

<u>The localization of enzymes within a cell helps order metabolism</u>
- to be efficient, many times enzymes are grouped (or localized) near the site where they act on their substrates