Ch 4: Cellular Metabolism, Part 1

- **Energy** as it relates to Biology
  - Energy for synthesis and movement
  - Energy transformation

- **Enzymes** and how they speed reactions

- **Metabolism** and metabolic pathways
  - Catabolism (ATP production)
  - Anabolism (Synthesis of biologically important molecules)
Energy in Biol. Systems:

- General definition of energy: Capacity to do work
  - Chemical, transport, movement
- First Law of Thermodynamics: Energy can neither be created nor destroyed
- Ultimate source of energy: Sun!

2 types of energy:

- Kinetic energy = motion
  - examples?
- Potential energy = stored energy
  - examples?
Energy (E) Transfer Overview

Figure 4-1

Photosynthesis takes place in plant cells, yielding:
- Oxygen (O₂)
- Energy stored in biomolecules

Respiration takes place in human cells, yielding:
- Energy for work
- Energy stored in biomolecules

Diagram key:
- Indicates a transfer of energy

Climate-related processes:
- Heat energy
- Energy lost to environment

Environmental inputs:
- Sun
- Radiant energy
- Carbon dioxide (CO₂)
- Water (H₂O)
- Nitrogen (N₂)
Potential Energy

Kinetic Energy

WORK

heat (~ 70% of energy used in physical exercise)
Bioenergetics = study of energy flow through biol. systems

Chemical reactions transfer energy

\[ A + B \rightleftharpoons C + D \]

Substrates or reactants

Products

Speed of reaction = Reaction rate
Initial force = Activation Energy
Potential Energy Stored in Chemical Bonds of Substrate can be . . .

1. transferred to the chemical bonds of the product
2. released as heat (usually waste)
3. used to do work (= free energy)
Chemical Reactions

- Activation energy
- Endergonic vs. exergonic reactions
- Coupled reactions
  Direct coupling vs. indirect coupling
- Reversible vs. irreversible reactions
Activation Energy

Fig 4-3
Endo- and Exergonic Reactions

Which is which??

ATP + H₂O → ADP + P_i + H⁺ + Energy
Enzyme (= Biol. Catalyst)

Some important characteristics of an enzyme:

1. **Enzymes are proteins**
2. ↑ rate of chemical reaction by lowering activation energy
3. is **not changed** itself
   1. It may change DURING the reaction
4. does not change the nature of the reaction nor the result
5. is specific

*Fig 4-6*
Enzymes lower activation energy:

All chemical reactions in body must be conducted at body temp.!!

How do enzymes lower activation energy?
Some more characteristics of enzymes:

- Usually end in –ase
- Inactive form: -ogen
- In few cases RNA has enzymatic activity (e.g., rRNA → peptide bond)
- Isoenzymes may be produced in different areas of the body
  - E.g., LDH
Active Site:

Small region of the complex 3D structure is active (or binding) site.

Enzymes bind to substrate

Old: Lock-and-key model / New: Induced-fit model
Enzyme-substrate interaction: The old and the new model

Lock and Key:

Induced fit:
Naming of Enzymes

mostly suffix -ase
first part gives info on function

examples

- Kinase
- Phosphatase
- Peptidase
- Dehydrogenase
Isoenzymes = different models of same enzyme (differ in 1 or few aa)

Catalyze same reaction but under different conditions and in different tissues/organs

Examples:
1. Amylase
2. LDH → importance in diagnostics
Enzyme Activity depends on

1. **Proteolytic activation** (for some)
2. **Cofactors & coenzymes** (for some)
3. **Temperature**
4. **pH**
5. **Other molecules** interacting with enzyme
   1. Competitive inhibitors
   2. Allosteric modulators
1) Proteolytic Activation

Also
1. Pepsinogen → Pepsin
2. Trypsinogen → Trypsin
2) Cofactors & Coenzymes

**structure:**
Inorganic molecules (?)

**function:**
conformational change of active site

**structure:**
Organic molecules (vitamin derivatives, FADH$_2$ ....)

**function:**
act as receptors & carriers for atoms or functional groups that are removed from substrate
Effect of pH on Enzymatic Reactions

Rate of Reaction
(product per unit of time)

pH
0 1 2 3 4 5 6 7 8 9 10 11 12

pepsin

trypsin
4) Molecules interacting with enzyme

**Competitive inhibitors:**

bind to active site

block active site

E.g.: Penicillin binds covalently (= irreversibly to important bacterial enzyme active site)
4) Molecules interacting with enzyme, cont’d

**Allosteric modulators (fig 4-14):** bind to enzyme away from active site change shape of active site (for better or for worse)

Special case: = end product inhibition
Allosteric Modulation

[Diagram showing the allosteric modulation of enzyme activity.]

- **Inactive Enzyme**: Inactive enzyme with no activator bound.
- **Active Enzyme**: Active enzyme with an activator bound.
- **Product Formation**: Formation of product when enzyme is active.
- **Inactive Enzyme with Inhibitor**: Inactive enzyme with an inhibitor bound.

Key Features:
- **Active Site**: Location where substrates bind.
- **Binding Site for Activator**: Location where activator binds to activate the enzyme.
- **Binding Site for Inhibitor**: Location where inhibitor binds to inactivate the enzyme.

**Allosteric Activator** and **Allosteric Inhibitor** indicate the sites where allosteric effectors act.
Reaction Rate Depends on Enzyme & Substrate Concentration

In this experiment, the substrate amount remained constant.
In this experiment, the amount of enzyme was constant. At the maximum rate the enzyme is said to be saturated.
Reversible Reactions follow the Law of Mass Action

(a) $A + B \rightleftharpoons C + D$

Reaction at equilibrium

Rate of reaction in forward direction ($r_1$) = rate of reaction in reverse direction ($r_2$)

(b) Add $A$ and $B$ to system

$A + B \rightleftharpoons C + D$

Equilibrium disturbed $r_1 > r_2$

(c) $A + B \rightleftharpoons C + D$

Equilibrium restored $r_1 = r_2$
Three Major Types of Enzymatic Reactions:

1. **Oxydation - Reduction reactions**
   (transfer of electrons or protons (H\(^{+}\)))

2. **Hydrolysis - Dehydration reactions**
   (breakdown & synthesis of water)

3. **Addition-Subtraction-Exchange (of a functional group) reactions**
Dehydration Synthesis—Peptide Bond

Amino acid + Amino acid → Dipeptide molecule + Water

Peptide bond
Metabolism

Catabolism

Anabolism

next time