**Chapter: Amino Acids, Proteins, and Enzymes**

Cellular functions of protein

- Enzymes
  - Biological catalysts
- Defense proteins
  - antibodies
- Transport proteins
  - Hemoglobin or myoglobin
- Regulatory proteins
  - Insulin or glucagon (hormones)
- Structural proteins
  - ketatin
- Movement proteins
  - Actin or myosin
- Nutrient proteins
  - Albumin or casein

### Functions of Proteins

Proteins perform many different functions in the body.

**Amino Acids- 20 kinds**

**Examples of Amino Acids**

**Types of Amino Acids**

**Nonpolar Amino Acids**

An amino acid is nonpolar when the R group is H, alkyl, or aromatic.

**Polar Amino Acids**

An amino acid is polar when the R group is an alcohol, thiol, or amide.

**Acidic and Basic Amino Acids**

An amino acid is

- acidic when the R group is a carboxylic acid.
- basic when the R group is an amine.

### The Peptide Bond

A **peptide bond**

- is an amide bond.
- forms between the carboxyl group of one amino acid and the amino group of the next amino acid.

```
O  CH₃  O
+  ||  +  ||
H₃N—CH₂—C—O⁻  H₃N — CH—C—O⁻
```
Formation of a Dipeptide

Primary Structure of Proteins
The primary structure of a protein is
- the particular sequence of amino acids.
- the backbone of a peptide chain or protein.
- Result of formation of covalent peptide bonds between amino acids

Primary Structures
- The nonapeptides oxytocin and vasopressin have similar primary structures.
- Only the amino acids at positions 3 and 8 differ.

Primary Structure of Insulin
Insulin
- was the first protein to have its primary structure determined.
- has a primary structure of two polypeptide chains linked by disulfide bonds.
- has a chain A with 21 amino acids and a chain B with 30 amino acids.

Secondary Structure – Alpha Helix
The secondary structure of an alpha helix is
- a three-dimensional spatial arrangement of amino acids in a polypeptide chain.
- held by H bonds between the H of −N-H group and the O of C=O of the fourth amino acid down the chain.
- a corkscrew shape that looks like a coiled “telephone cord”.
- Example. Hair, wool, nails, hooves and fur
- Results from hydrogen bonding between amide hydrogen and carbonyl oxygen's of the peptide bonds.

The secondary structure of a beta pleated sheet
- consists of polypeptide chains arranged side by side.
- has hydrogen bonds between chains.
- has R groups above and below the sheet.
- is typical of fibrous proteins such as silk.

The secondary structure of a triple helix is
- three polypeptide chains woven together.
- typical of collagen (most abundant protein in human body), connective tissue, skin, tendons, and cartilage.
Quaternary Structure
The quaternary structure
• is the combination of two or more protein units.
• of hemoglobin consists of four polypeptide chains as subunits.
• is stabilized by the same interactions found in tertiary structures.

Globular proteins
• have compact, spherical shapes.
• carry out synthesis, transport, and metabolism in the cells.
• such as myoglobin store and transport oxygen in muscle.

Fibrous proteins
• consist of long, fiber-like shapes.
• such as alpha keratins make up hair, wool, skin, and nails.
• such as feathers contain beta keratins with large amounts of beta-pleated sheet structures.

Denaturation involves
• the disruption of bonds in the secondary, tertiary and quaternary protein structures.
• heat and organic compounds that break apart H bonds and disrupt hydrophobic interactions.
• acids and bases that break H bonds between polar R groups and disrupt ionic bonds.
• heavy metal ions that react with S-S bonds to form solids.
• agitation such as whipping that stretches peptide chains until bonds break.

Applications of Denaturation
Denaturation of protein occurs when
• an egg is cooked.
• the skin is wiped with alcohol.
• heat is used to cauterize blood vessels.
• instruments are sterilized in autoclaves.

Enzymes are Biological Catalysts
Enzymes are proteins that
• Catalyze nearly all the chemical reactions taking place in the cells of the body.
• Increase the rate of reaction by lowering the energy of activation.

Names of Enzymes
The name of an enzyme
• Usually ends in –ase.
• identifies the reacting substance. For example, sucrase catalyzes the reaction of sucrose.
• describes the function of the enzyme. For example, oxidases catalyze oxidation.
• could be a common name, particularly for the digestion enzymes such as pepsin and trypsin.
Classification of Enzymes
Enzymes are classified by the reaction they catalyze.

<table>
<thead>
<tr>
<th>Class</th>
<th>Type of Reactions catalyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxidoreductases</td>
<td>Oxidation-reduction</td>
</tr>
<tr>
<td>Transferases</td>
<td>Transfer groups of atoms</td>
</tr>
<tr>
<td>Hydrolases</td>
<td>Hydrolysis</td>
</tr>
<tr>
<td>Lyases</td>
<td>Add atoms/remove atoms to or from a double bond</td>
</tr>
<tr>
<td>Isomerases</td>
<td>Rearrange atoms</td>
</tr>
<tr>
<td>Ligases</td>
<td>Use ATP to combine small molecules</td>
</tr>
</tbody>
</table>

The active site
- is a region within an enzyme that fits the shape of the reacting molecule called a substrate.
- contains amino acid R groups that bind the substrate.
- releases products when the reaction is complete.

Enzyme Catalyzed Reaction
In an enzyme-catalyzed reaction
- a substrate attaches to the active site.
- an enzyme-substrate (ES) complex forms.
- reaction occurs and products are released.
- an enzyme is used over and over.

Lock and Key Model
In the lock-and-key model
- the active site has a rigid shape.
- an enzyme only binds substrates that exactly fit the active site.
- the enzyme is analogous to a lock.
- the substrate is the key that fits that lock.

Induced-fit Model
In the induced-fit model
- enzyme structure is flexible, not rigid.
- enzyme and substrate adjust the shape of the active site to bind substrate.
- the range of substrate specificity increases.
- shape changes improve catalysis during reaction.

Diagnostic enzymes
- determine the amount of damage in tissues.
- that are elevated may indicate damage or disease in a particular organ.

Diagnostic Enzymes
Levels of enzymes CK, LDH, and AST
• are elevated following a heart attack.
• are used to determine the severity of the attack.

Isoenzymes
• catalyze the same reaction in different tissues in the body.
• can be used to identify the organ or tissue involved in damage or disease.
• such as lactate dehydrogenase (LDH), which converts lactate to pyruvate, consists of five isoenzymes.
• such as LDH have one form more prevalent in heart muscle and another form in skeletal muscle and liver.

Temperature and Enzyme Action
Enzymes
• are most active at an optimum temperature (usually 37°C in humans).
• show little activity at low temperatures.
• lose activity at high temperatures as denaturation occurs.

pH and Enzyme Action
Enzymes
• are most active at optimum pH.
• contain R groups of amino acids with proper charges at optimum pH.
• lose activity in low or high pH as tertiary structure is disrupted.

Optimum pH Values
Enzymes in
• the body have an optimum pH of about 7.4.
• certain organs, enzymes operate at lower and higher optimum pH values.

Enzyme Concentration
As enzyme concentration increases
• the rate of reaction increases (at constant substrate concentration).
• more substrate binds with enzyme.

Substrate Concentration
As substrate concentration increases
• the rate of reaction increases (at constant enzyme concentration).
• the enzyme eventually becomes saturated giving maximum activity.
Enzyme Inhibition

Inhibitors
- are molecules that cause a loss of catalytic activity.
- prevent substrates from fitting into the active sites.

\[ E + S \rightarrow ES \rightarrow E + P \]

\[ E + I \rightarrow EI \rightarrow \text{no P} \]

A competitive inhibitor
- has a structure that is similar to that of the substrate.
- competes with the substrate for the active site.
- has its effect reversed by increasing substrate concentration.

A noncompetitive inhibitor
- has a structure that is much different than the substrate.
- distorts the shape of the enzyme, which alters the shape of the active site.
- prevents the binding of the substrate.
- cannot have its effect reversed by adding more substrate.

Function of Coenzymes
A coenzyme prepares the active site for catalytic activity.

Water-soluble vitamins are
- soluble in aqueous solutions.
- cofactors for many enzymes.
- not stored in the body.

Fat-soluble vitamins
- are A, D, E, and K.
- are soluble in lipids, but not in aqueous solutions.
- are important in vision, bone formation, antioxidants, and blood clotting.
- are stored in the body.