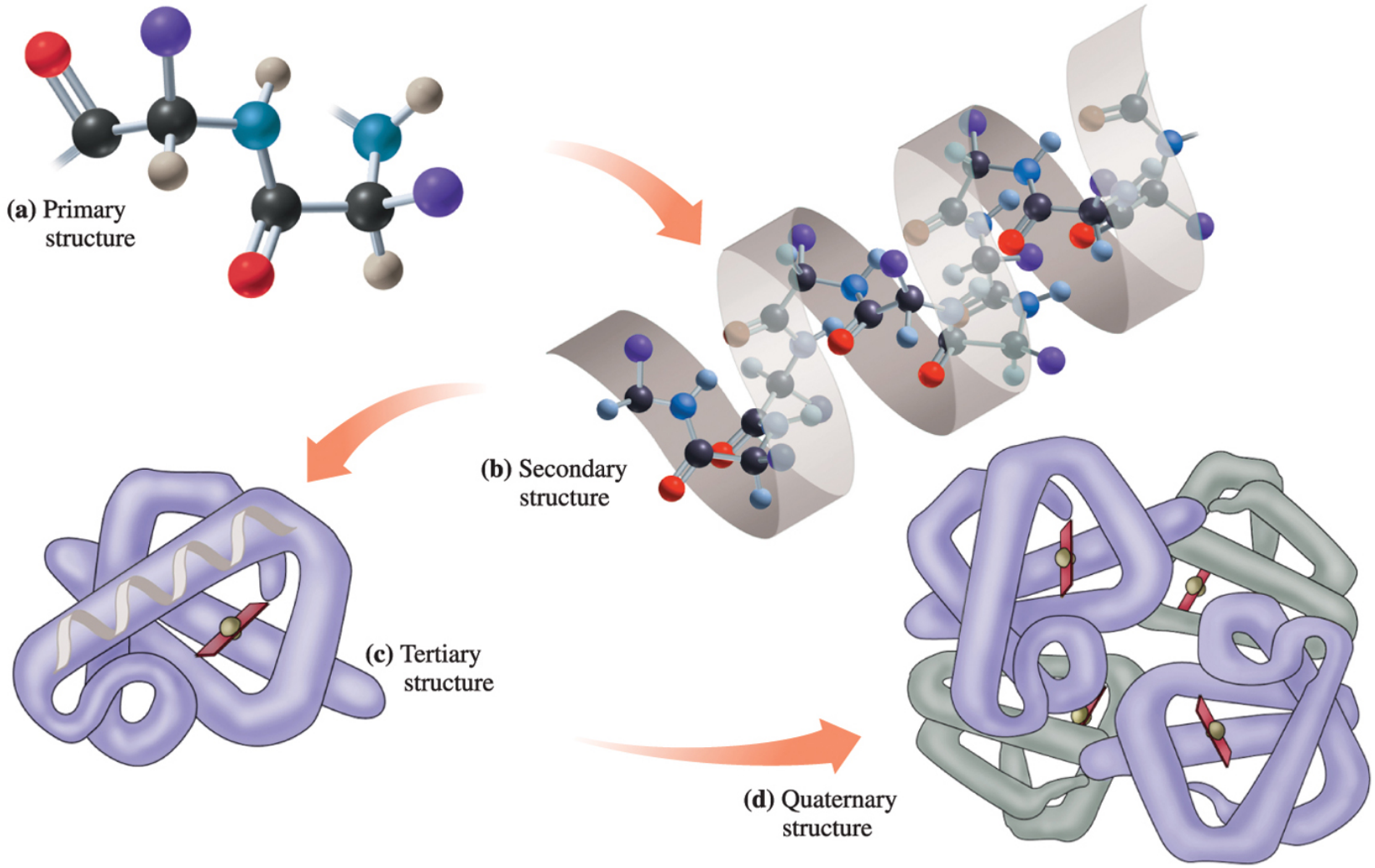
10.3 The Three-Dimensional Structure of Proteins



10.4 Denaturation of Proteins

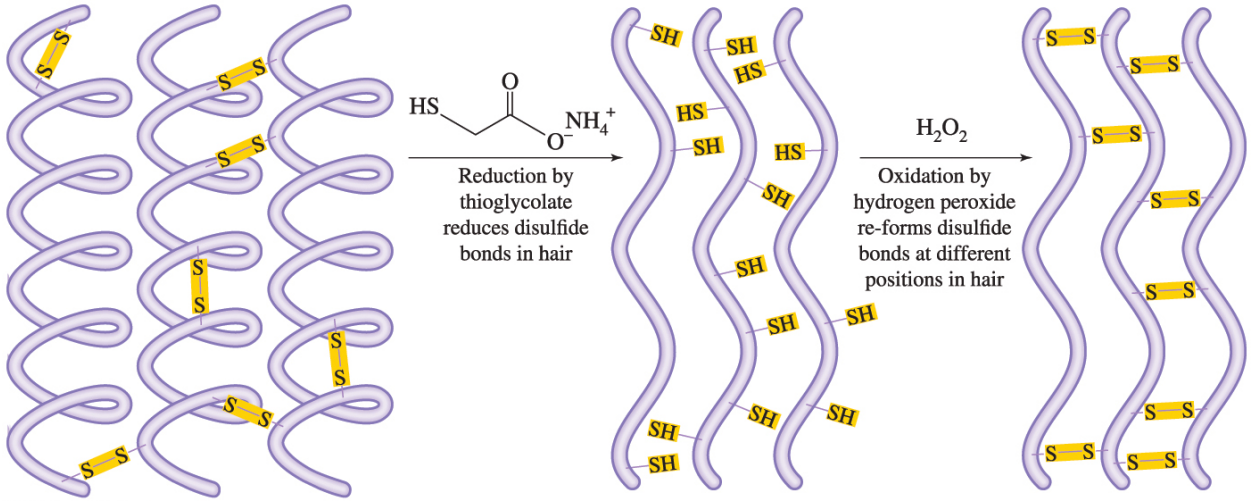
- Denaturation is a process that disrupts the stabilizing attractive forces in the secondary, tertiary, or quaternary structure.
- When a protein is denatured, its primary structure is not changed, but it loses its biological activity.

TABLE 10.4 Examples of Protein Denaturation

Denaturing Agent	Forces or Bonds Disrupted	Examples
Heat above 50 °C	Hydrogen bonds, hydrophobic interactions	Cooking food
Acids, bases, ionic compounds	Salt bridges, hydrogen bonds	Lactic acid from bacteria, which denatures milk proteins in the preparation of yogurt and cheese
Reducing agents	Disulfide bonds	Thiols, which are used in hairstyling for hair straightening or permanent waves
Detergents	Hydrophobic interactions	Membrane proteins
Heavy metal ions Ag^{+}, Pb^{2+}, Hg^{2+}	Disulfide bonds, salt bridges	Mercury and lead poisoning
Mechanical agitation	Hydrogen bonds, London forces	Whipped cream and meringue made from egg whites

10.4 Denaturation of Proteins

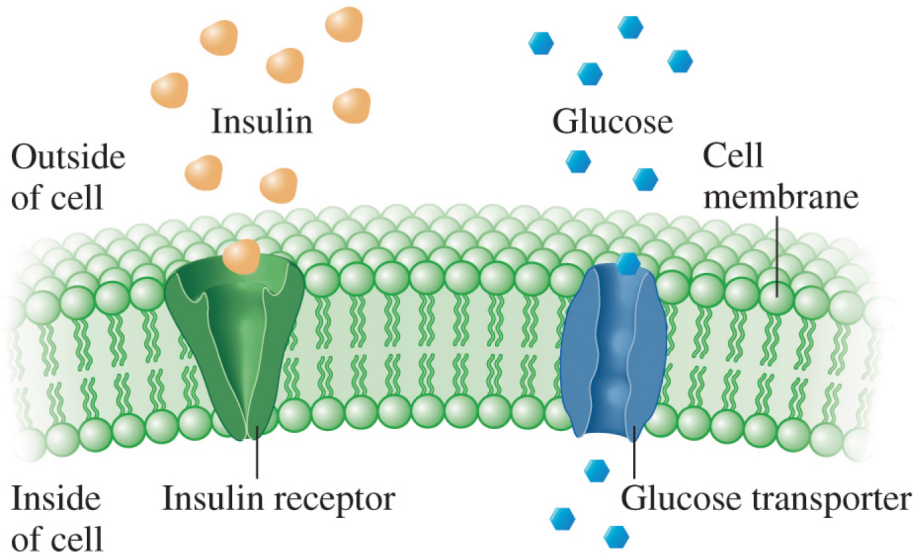
- Hair relaxing and perming involve protein denaturation: relaxing and permanent waves both involve denaturing the proteins in hair by disrupting the disulfide bonds found in the keratin, reshaping the keratin, and forcing the disulfide bonds to reform.
- A person who has ingested lead or mercury is given egg whites to drink. The proteins in the egg whites are denatured by the mercury or lead and the combination forms a precipitate. An emetic is then administered to induce vomiting.



10.5 Protein Functions

Messengers, Receptors, and Transporters

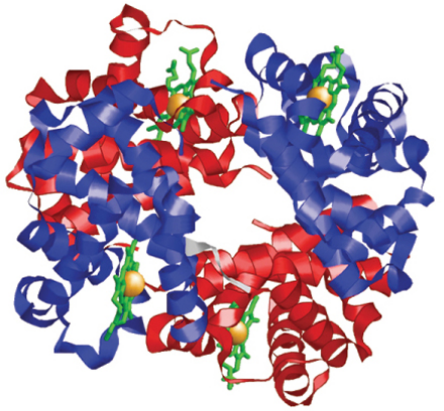
- A **hormone** is a chemical, sometimes a peptide or protein, created in one part of the body that affects another part of the body.
- **Receptors** are proteins facing the outer surface of a cell that bind to a hormone or other messenger, triggering a signal inside the cell.
- A **transporter** is an integral membrane protein spanning a phospholipid bilayer.



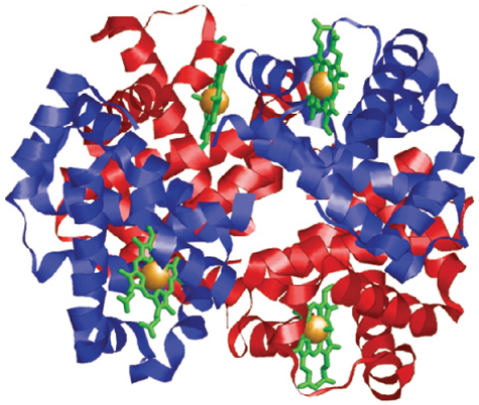
10.5 Protein Functions

Hemoglobin

- Four subunits of hemoglobin are attracted to each other through hydrogen bonds, London forces, and salt bridges.
- Each subunit contains a heme prosthetic group.
- Each heme group binds Fe^{2+}, which, in turn, binds oxygen (O_2).
- Each Fe^{2+} can bind one oxygen molecule: one hemoglobin can transport four molecules of oxygen.
- The binding of O_2 to the hemoglobin induces a conformational change.
- At the tissues, the oxygen dissociates from the hemoglobin, and the shape of the hemoglobin changes back to its deoxygenated form.



Oxygen unbound
(Deoxygenated state)

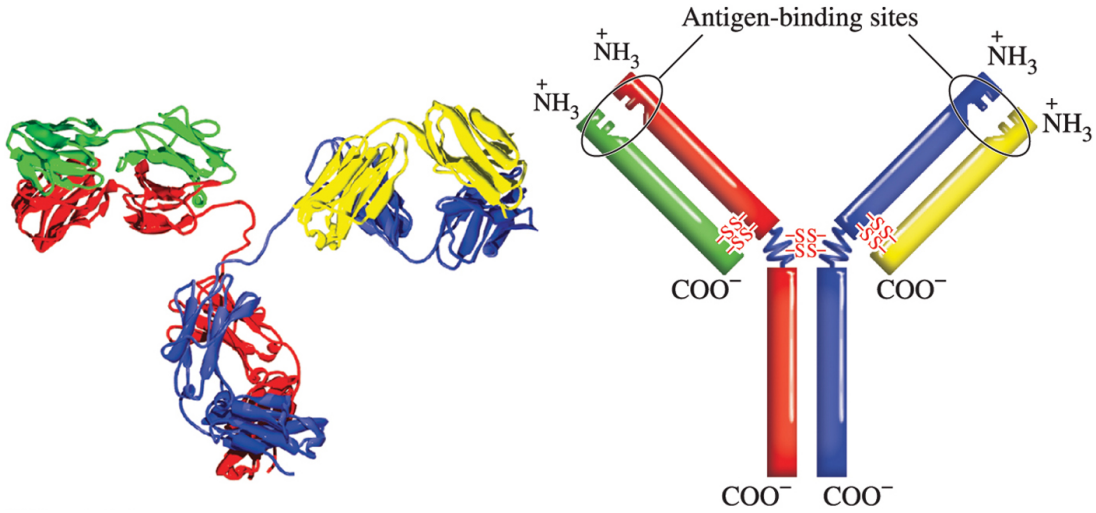


Oxygen bound
(Oxygenated state)

10.5 Protein Functions

Antibodies

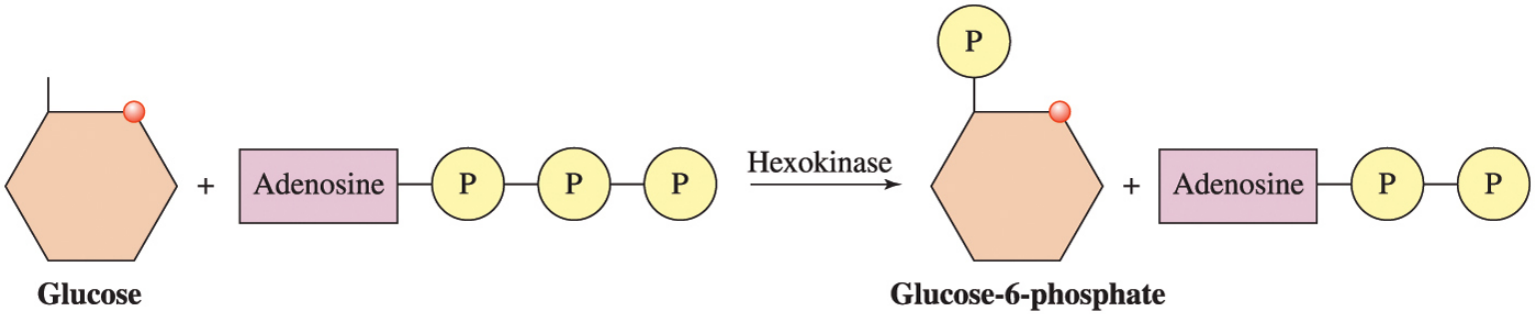
- The substance recognized by an antibody is called an antigen.
- An antibody consists of four polypeptide subunits, two heavy chains and two light chains.
- The secondary structure contains β-pleated sheets (represented by the flat ribbons) that are stacked tightly together.
- The quaternary structure is held together through disulfide bridges between the polypeptide chains.
- The stem of the Y is similar in all antibodies and can bind to receptors on a variety of cells in the body. Antibodies bind antigens at the top of each arm of the Y.



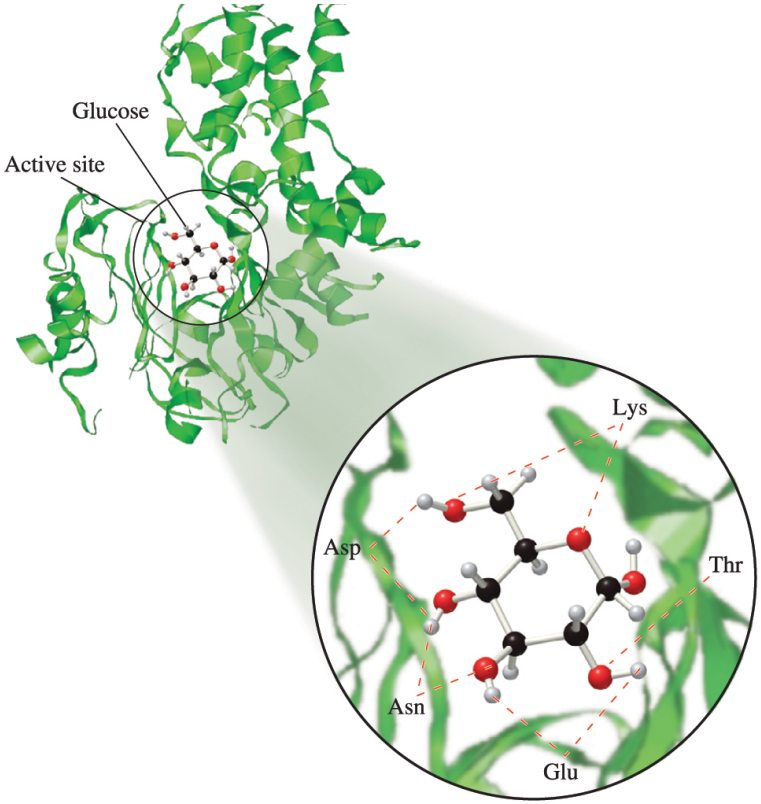
10.6 Enzymes—Life's Catalysts

- Enzymes are typically large globular proteins and are present in every cell of the body.
- Enzymes act as catalysts, compounds that accelerate the reactions of metabolism but are not consumed or changed by those reactions.
- An enzyme cannot force a reaction to occur that would not normally occur. An enzyme simply makes a reaction occur faster.
- The tertiary structure of an enzyme plays an important role in its function.

10.6 Enzymes—Life's Catalysts



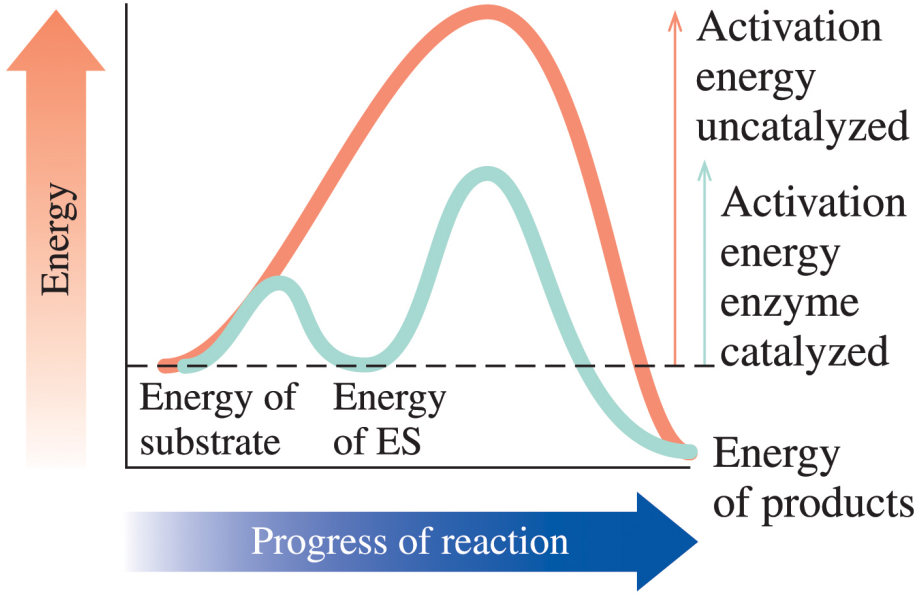
- The enzyme name usually appears above or below the reaction arrow.
- The reactant is called the **substrate**.
- Cofactors are inorganic substances like magnesium ion.
- Coenzymes are small organic molecules.
- The active site of hexokinase fits D-glucose only.



10.6 Enzymes—Life's Catalysts

Rates of Reaction

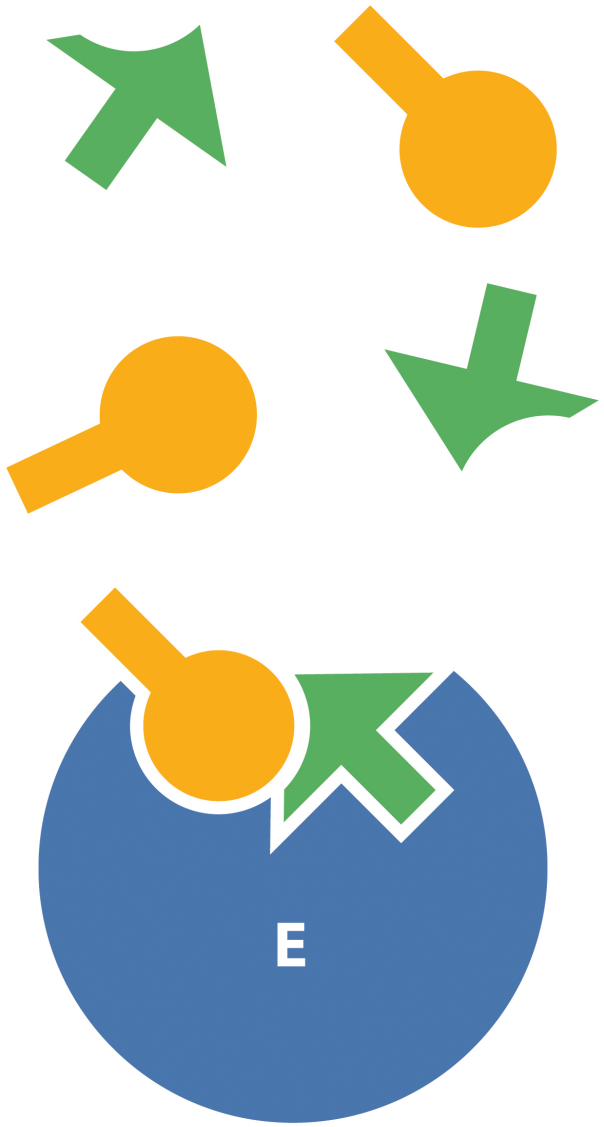
- Activation energy lowering is accomplished during the formation of ES through interactions between the enzyme and the substrate.
- **Proximity:** When the ES forms, the substrates are in close proximity: they don't have to find each other as they would in solution.



10.6 Enzymes—Life's Catalysts

Rates of Reaction

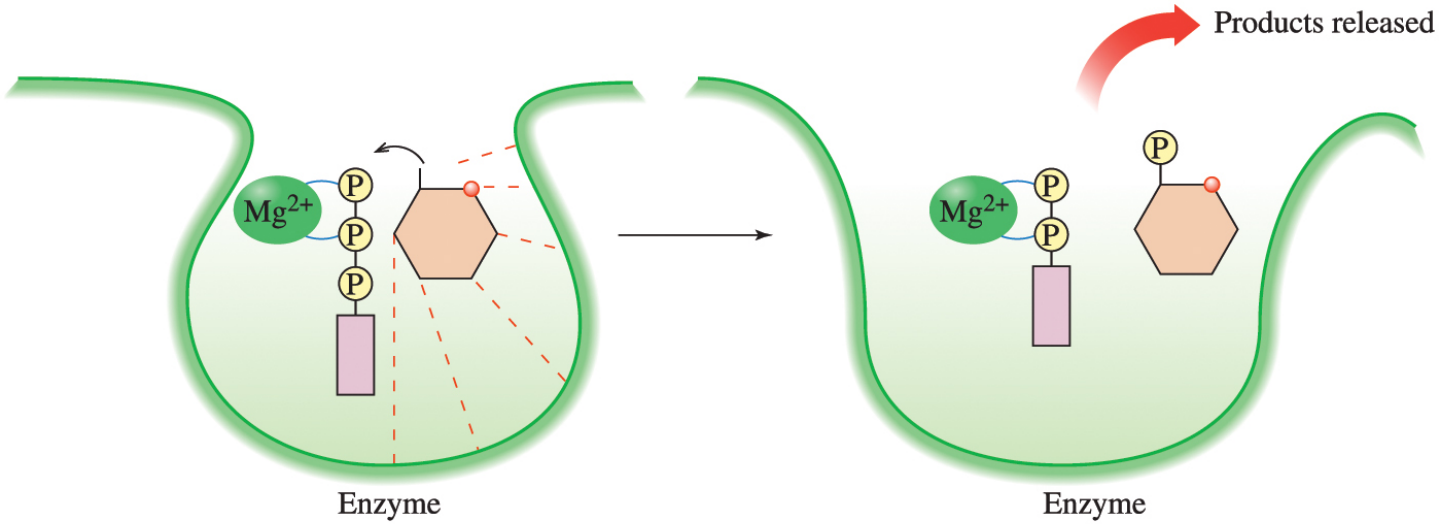
- **Orientation:** In the active site of an enzyme, substrate molecules are held at the appropriate distance and in correct alignment to each other to allow the reaction to occur.
- The arrangement of amino acid side chains in the active site creates interactions that orient the substrates so they will react.
- Correct orientation helps lower the activation energy required.



10.6 Enzymes—Life's Catalysts

Rates of Reaction

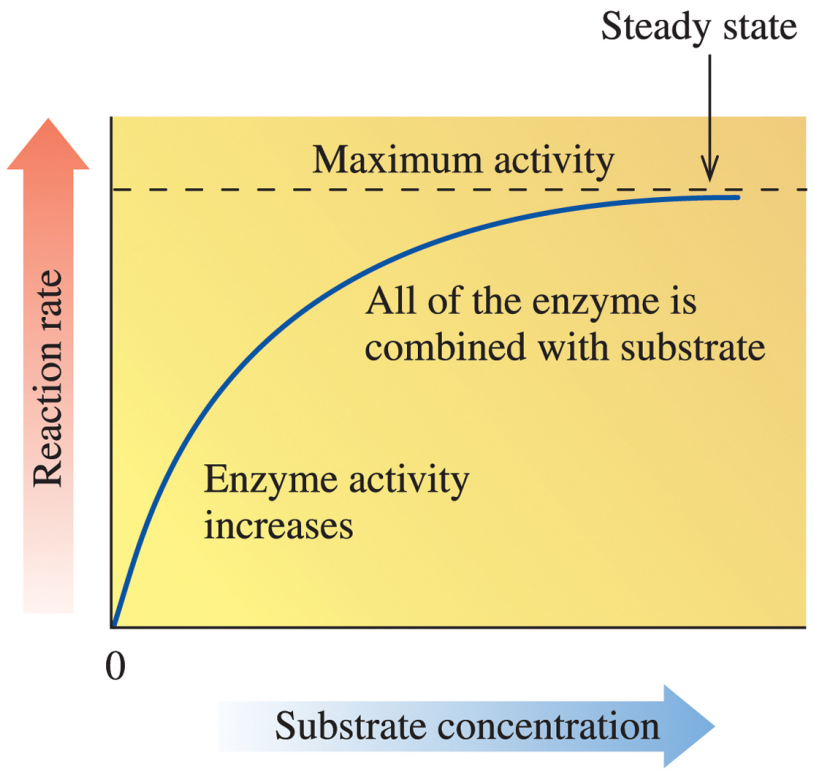
- **Orientation:** when an enzyme interacts with its substrate to form ES, the bonds of the substrate molecule(s) are weakened (strained).
- The weakening of the bonds means that they will more readily react: weaker bonds break more easily and the activation energy is lowered by this effect.



10.7 Factors That Affect Enzyme Activity

Substrate Concentration

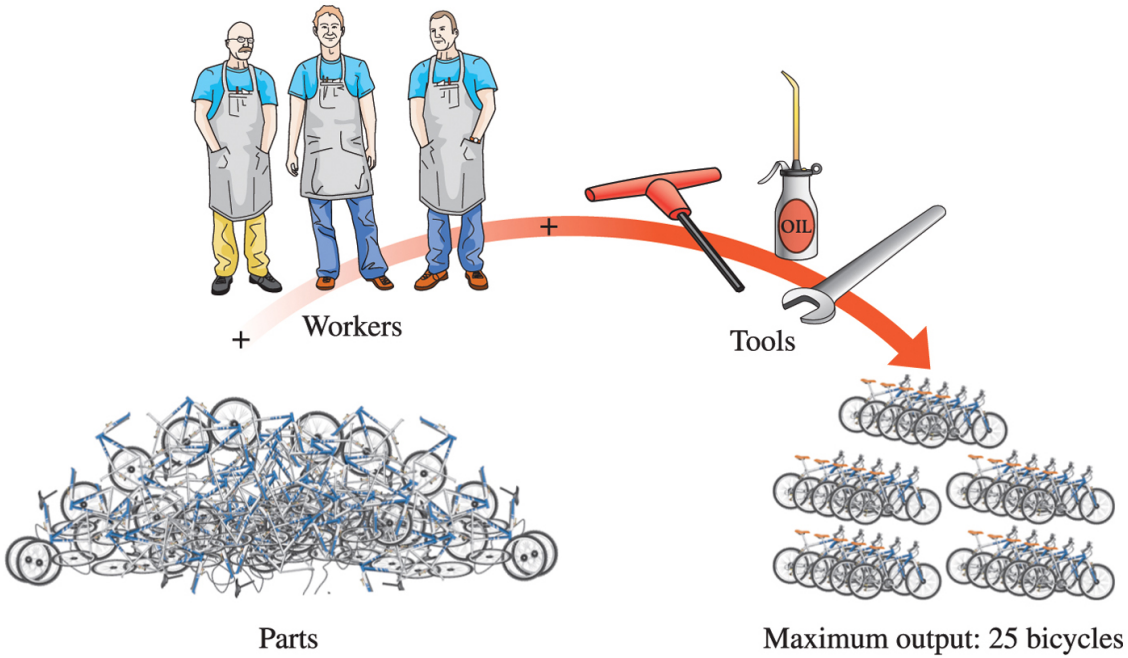
- The first step in an enzyme-catalyzed reaction is the formation of ES.
- If the amount of enzyme remains unchanged, an increase in the substrate concentration increases the enzyme's activity up to the point where the enzyme becomes saturated with its substrate.



10.7 Factors That Affect Enzyme Activity

Substrate Concentration

- At maximum activity, the conditions under which the enzyme is operating are considered to be in a **steady state**.
- Under steady-state conditions, substrate is being converted to product as efficiently as possible.



10.7 Factors That Affect Enzyme Activity

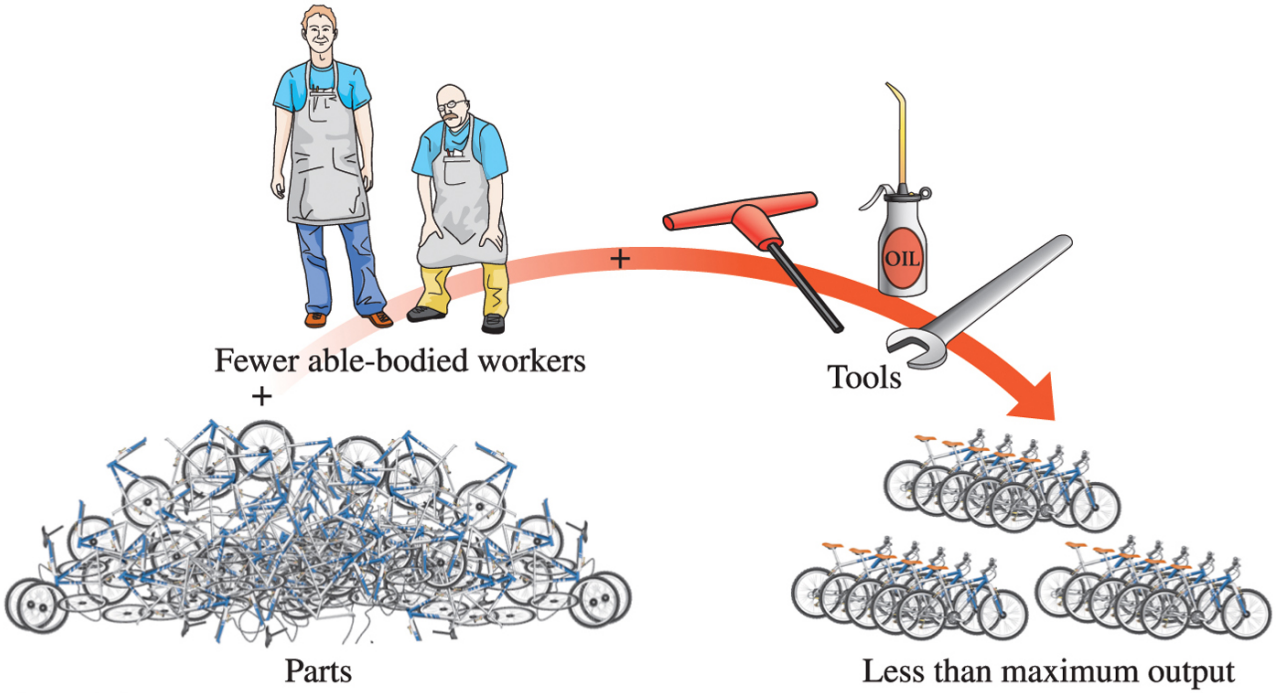
pH Optimum

- Enzymes are most active at their pH optimum.
- At this pH, the enzyme maintains its tertiary structure and, therefore, its active site.
- Changes in the pH may change the nature of an amino acid side chain.
- If an enzyme requires a carboxylate ion (–COO^-), lowering the pH could convert the carboxylate ion to carboxylic acid (–COOH).
- This change would cause enzyme activity to decrease.

10.7 Factors That Affect Enzyme Activity

pH Optimum

- In the body, an enzyme's pH optimum is based on the location of the enzyme. For example, enzymes in the stomach function at a much lower pH because of the acidity.



10.7 Factors That Affect Enzyme Activity

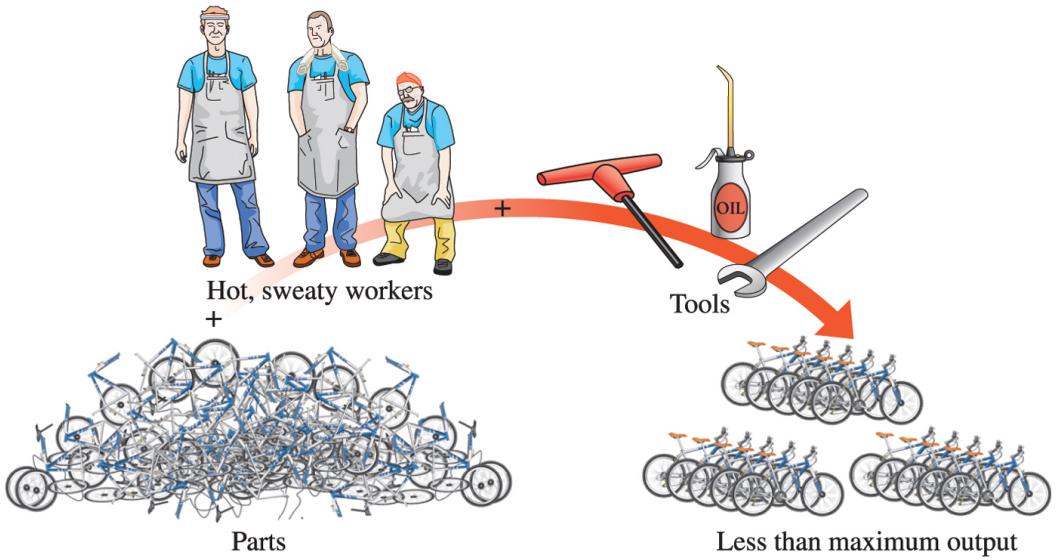
TABLE 10.6 pH Optimum for Selected Enzymes

Enzyme	Location	Substrate	pH Optimum
Pepsin	Stomach	Peptide bonds	2
Sucrase	Small intestine	Sucrose	6.2
Urease	Liver	Urea	7.4
Hexokinase	All tissues	Glucose	7.5
Trypsin	Small intestine	Peptide bonds	8
Arginase	Liver	Arginine	9.7

10.7 Factors That Affect Enzyme Activity

Temperature

- The temperature optimum for most human enzymes is normal body temperature, 37°C.
- Above their optimum temperature, enzymes lose activity due to the disruption of the attractive forces stabilizing the tertiary structure. At high temperatures, an enzyme denatures.
- At low temperatures, enzyme activity is reduced due to the lack of energy present for the reaction to take place at all.



10.7 Factors That Affect Enzyme Activity

Temperature

- Because enzymes are major culprits in food spoilage, we store foods in a refrigerator or freezer to slow the spoilage process.
- The enzymes present in bacteria can also be destroyed by high temperatures, in processes like boiling contaminated drinking water and sterilizing instruments and other equipment in hospitals and laboratories.

10.7 Factors That Affect Enzyme Activity

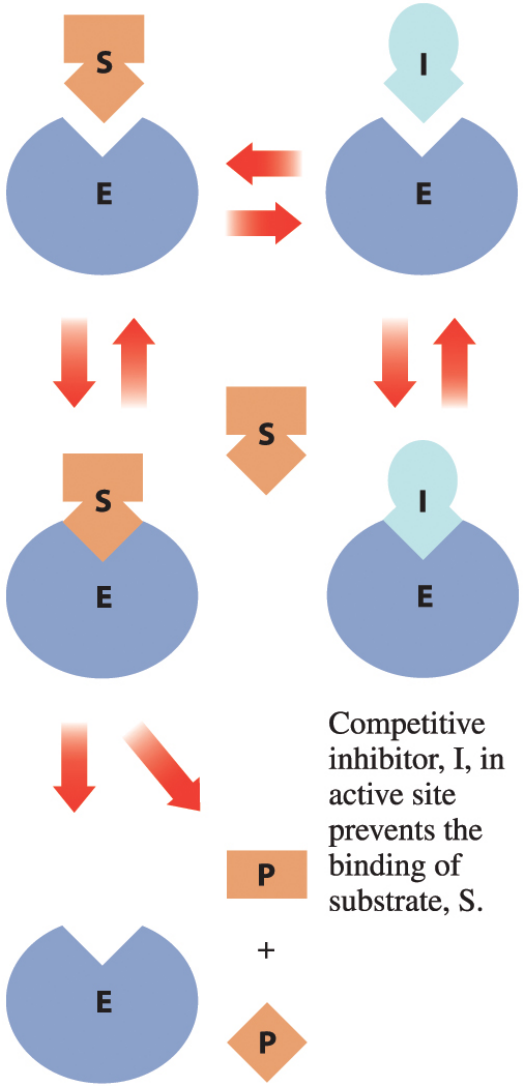
Inhibitors

- Enzyme inhibitors prevent the active site from interacting with the substrate to form ES.
- Some inhibitors cause enzymes to lose catalytic activity temporarily, while others cause enzymes to lose activity permanently.
- In reversible inhibition, the inhibitor causes the enzyme to lose catalytic activity. If the inhibitor is removed, the enzyme becomes functional.
- Reversible inhibitors can be competitive or noncompetitive.

10.7 Factors That Affect Enzyme Activity

Inhibitors

- A competitive inhibitor has a structure that resembles the substrate.
- The competitive inhibitor will form an enzyme–inhibitor complex, but no reaction will take place.
- As long as the inhibitor remains in the active site, the enzyme cannot interact with its substrate and form product.
- Inhibition caused by a competitive inhibitor can be reversed by adding more substrate.

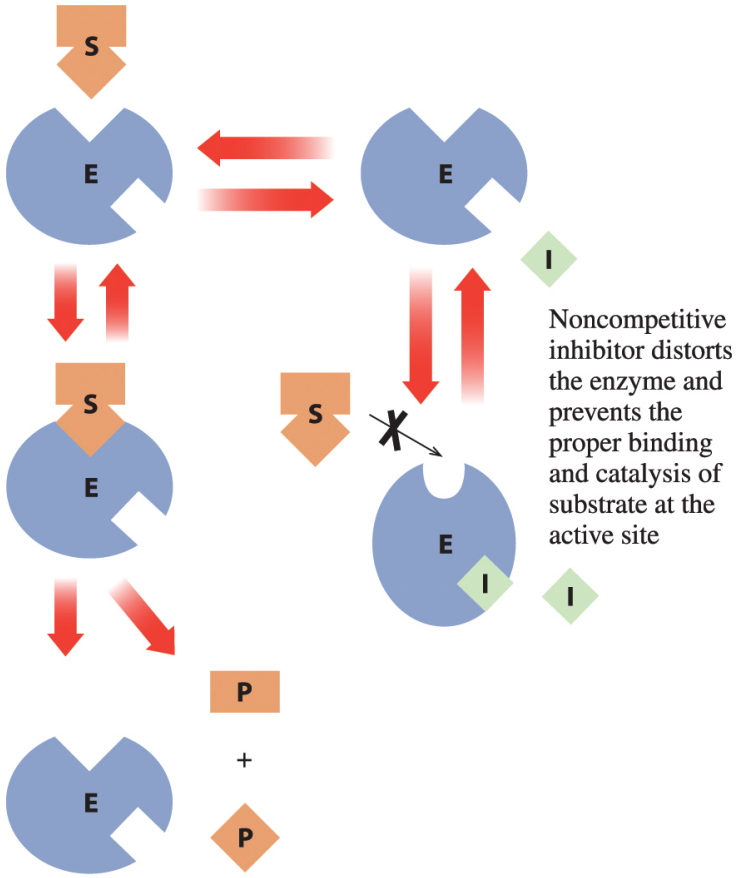


Competitive inhibitor, I, in active site prevents the binding of substrate, S.

10.7 Factors That Affect Enzyme Activity

Inhibitors

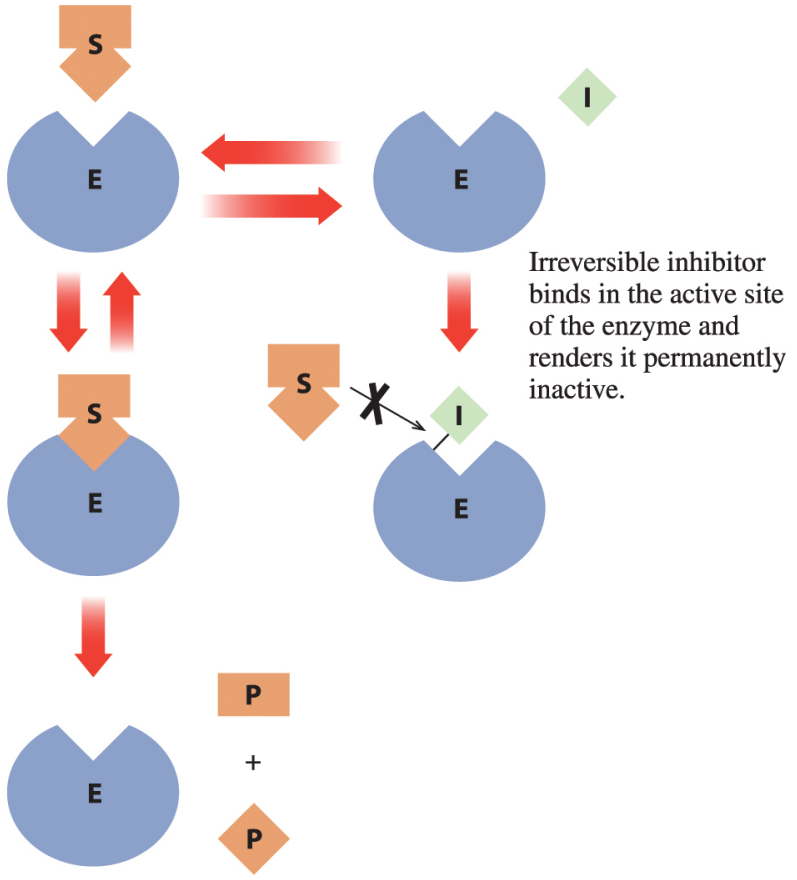
- Noncompetitive inhibitors bind to another site on the enzyme, changing its shape.
- In the case of a noncompetitive inhibitor, adding more substrate has no effect.
- Regardless of the amount of enzyme, a certain portion of the enzyme is inactivated by the inhibitor.



10.7 Factors That Affect Enzyme Activity

Inhibitors

- In irreversible inhibition, the inhibitor forms a covalent bond with an amino acid side chain in the active site.
- The substrate is excluded or the catalytic reaction blocked.
- Irreversible inhibitors permanently inactivate enzymes.

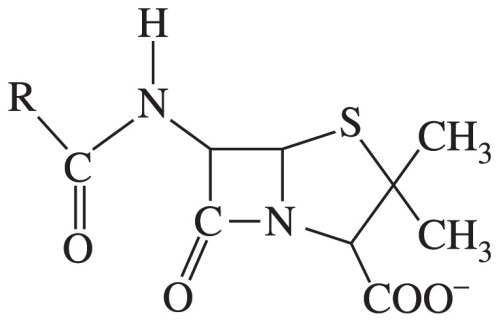


10.7 Factors That Affect Enzyme Activity

Antibiotics Inhibit Bacterial Enzymes

- Penicillin is an irreversible inhibitor.
- Penicillin binds to the active site of an enzyme that bacteria use in the synthesis of their cell walls.
- When the bacterial enzyme bonds with penicillin, the enzyme loses its catalytic activity, and the growth of the bacterial cell wall slows.
- Without a proper cell wall for protection, bacteria cannot survive, and the infection stops.

(R is a variable group)



Penicillin

Chapter Ten Summary

10.1 Amino Acids—A Second Look

- Amino acids contain a central carbon atom, called the α carbon, bonded to four different groups—a protonated amine (amino) group, a carboxylate group, a hydrogen atom, and a side chain.
- Amino acids, with the exception of glycine, are chiral compounds. The L-enantiomers of amino acids are the building blocks of proteins. The 20 different amino acids are found in most proteins.
- They are characterized by various side chains. The side chains determine whether the amino acids are classified as nonpolar or polar.

10.2 Protein Formation

- Amino acids join through a condensation reaction of the protonated amine group of one and the carboxylate group of the other.
- The bond that forms between the two amino acids is called a peptide bond, and the new structure is a dipeptide. The newly formed dipeptide has an N-terminus with a free protonated amine group and a C-terminus with a free carboxylate group.
- A compound containing 50 or more amino acids linked by peptide bond is a polypeptide and if it has biological activity is called a protein. Proteins are polymers of amino acids.

Chapter Ten Summary

10.3 The Three-Dimensional Structure of Proteins

- The primary structure (1°) is the sequence of the amino acids that form the protein backbone. The bonding interaction is the peptide bond.
- The secondary structure (2°) involves the interactions of amino acids near each other in the primary structure and describes patterns of regular or repeating structure. The most common secondary structures are the α helix and the β-pleated sheet. The secondary structure is stabilized by hydrogen bonding between atoms in the backbone.
- The tertiary structure (3°) is formed by folding the secondary structure onto itself and is driven by the hydrophobic interactions of amino acid side chains with their aqueous environment. This level is stabilized by the attractive forces between side chains and disulfide bonds.
- Proteins that fold into a roughly spherical shape are globular proteins. Proteins that maintain elongated structures are fibrous proteins.
- Some proteins have a quaternary structure (4°), which involves the association of two or more peptides to form a biologically active protein. The same forces stabilize the quaternary structure as the tertiary structure.

Chapter Ten Summary

10.4 Denaturation of Proteins

- Denaturation of a protein disrupts the stabilizing attractive forces in the secondary, tertiary, or quaternary structure, often unfolding the protein.
- When a protein is denatured, its primary structure is not changed. Proteins can be denatured by heat, a change in the pH of their environment, reaction with small organic compounds and heavy metals such as lead or mercury, or mechanical agitation.
- A denatured protein is no longer biologically active.

10.5 Protein Functions

- Proteins act as messengers between cells, receptors on the surface of cells, and transporters through the body or across the cell.
- Proteins are used to store nutrients, contract muscles, protect the cell, and support its structure.
- Proteins catalyze biochemical reactions as enzymes.

Chapter Ten Summary

10.6 Enzymes—Life's Catalysts

- Enzymes are proteins that serve as catalysts in biological systems.
- The functional part of an enzyme is the active site, which is a small groove or cleft on the surface of the molecule where catalysis occurs.
- Substrates are the reactants in the reactions catalyzed by enzymes.
- Because of the three-dimensional shape of the active site, few substrates will bind and react. The lock-and-key and induced-fit models explain how an enzyme interacts with its substrate to form ES.
- The formation of ES lowers the activation energy for the catalyzed reaction in several ways. These include increasing proximity, optimizing orientation, and modifying bond energy.

Chapter Ten Summary

10.7 Factors That Affect Enzyme Activity

- Enzyme activity is measured by how fast an enzyme catalyzes a reaction.
- Substrate concentration, pH, temperature, and the presence of inhibitors can affect enzyme activity. Enzymes have a pH optimum and temperature optimum.
- Inhibitors decrease or eliminate an enzyme's catalytic abilities. The effect of an inhibitor can be reversible or irreversible.
- Reversible inhibitors can be competitive inhibitors, which compete with the substrate for the enzyme's active site, or noncompetitive inhibitors, which bind to the enzyme at a site other than the active site, changing the shape of the active site.

Chapter Ten Study Guide

10.1 Amino Acids—A Second Look

- Draw the general structure of an amino acid.
- Identify amino acids based on their polarity.

10.2 Protein Formation

- Predict the products of a biological condensation or hydrolysis reaction.
- Form a peptide bond between amino acids.

10.3 The Three-Dimensional Structure of Proteins

- Distinguish the levels of protein structure.
- Describe the attractive forces present as a protein folds into its three-dimensional shape.

10.4 Denaturation of Proteins

- Define protein denaturation.
- List the causes of protein denaturation and the attractive forces affected.

Chapter Ten Study Guide

10.5 Protein Functions

- Identify various functions of proteins.
- Provide examples of protein structure dictating protein function.

10.6 Enzymes—Life's Catalysts

- Define active site and substrate.
- Distinguish the lock-and-key model from the induced-fit model.
- Discuss factors that lower the activation energy and speed reaction for an enzyme-catalyzed reaction.

10.7 Factors That Affect Enzyme Activity

- Describe how substrate concentration, pH, temperature, and inhibition affect enzyme activity.
- Distinguish competitive, noncompetitive, and irreversible inhibition.