Principles of Life
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Answers to the Do You Understand the Concept Questions

Chapter 3: Proteins, Nucleic Acids, and Enzymes

Do You Understand Concept 3.1?

• List the key differences between DNA and RNA and between purines and pyrimidines.

Answer: DNA and RNA have three (adenine, cytosine, guanine) of four bases in common, but DNA contains thymine and RNA contains uracil for the fourth bases. The sugar in DNA is deoxyribose, whereas the sugar in RNA is ribose. The structure of DNA is less flexible than that of RNA due to its lack of a hydroxyl group at the 2′ position. DNA usually has two complementary strands. Purines and pyrimidines differ in their structure: pyrimidines have a six-member single-ring form, and purines have a fused double-ring structure.

• What are the differences between DNA replication and transcription?

Answer: DNA replication occurs during cell reproduction and the DNA is completely replicated. During transcription, only part of the DNA is copied as RNA, encoding genes for specific proteins.

• If one strand of a DNA molecule has the sequence 5′-TTCCGGAT-3′, what is the sequence of the other strand of DNA? If RNA is transcribed from the 5′-TTCCGGAT-3′ strand, what would be its sequence? And if RNA is transcribed from the other DNA strand, what would be its sequence?

Answer: The other DNA strand will be 3′-AAGGCCTA-5′. The RNA sequence would be 3′-AAGGCCUA-5′. RNA transcribed from the complementary DNA strand, 3′-AAGGCCTA-5′, would be 5′-UUCCGGAU-3′.

• How can DNA molecules be so diverse when they appear to be structurally similar?

Answer: The diversity of the DNA molecule lies in the different information carried in different sequences of base pairs.

Do You Understand Concept 3.2?

• What attributes of an amino acid’s R group would make it hydrophobic? Hydrophilic?

Answer: If a side chain (R group) were nonpolar it would be hydrophobic, and if the side chain were polar and/or charged, it would be hydrophilic.

• Sketch the bonding of two amino acids, glycine and leucine, by a peptide linkage. Now add a third amino acid, alanine, in the position it would have if added within a biological system. What is the directionality of this process?

Answer: Refer to Table 3.2, amino acid structures, and Figure 3.6.

• Examine the structure of sucrase (see Figure 3.9). Where in the protein might you expect to find the following amino acids: valine, proline, glutamic acid, and threonine? Explain your answers.

Answer: Valine is hydrophobic and would be in the interior of the protein; proline would be at bends, forming a ring structure by covalently bonding with the hydrocarbon side chain and stabilizing bends and loops; glutamic acid is negatively charged and hydrophilic and would be on the outside of the protein; threonine is polar, uncharged, but also hydrophilic and would be on the outside of the protein.

• Detergents disrupt hydrophobic interactions by coating hydrophobic molecules with a molecule that has a hydrophilic surface. When hemoglobin is treated with a detergent, the four polypeptide chains separate and become random coils. Explain these observations.

Answer: The hydrophobic surfaces' interactions are essential to maintain the quaternary structure of hemoglobin. By replacing those surfaces with hydrophilic ones, the interactions of the hydrophobic groups are disrupted and the structure is not maintained.

Do You Understand Concept 3.3?

• Explain how the structure of an enzyme makes that enzyme specific.

Answer: The structure of the enzyme determines the specific reactants that can bind to it and participate in the reaction.

• What is activation energy? How does an enzyme lower the activation energy needed to start a reaction?

Answer: Activation energy is the energy input required to initiate a reaction. Enzymes lower this by binding to reactants and bringing them together, making it easier for reactants to react.

• Compare coenzymes with substrates. How do they work together in enzyme catalysis?

Answer: Coenzymes and substrates are similar in that they bind to the enzyme's active site, change during the reaction and then separate from the enzyme. They are different in that coenzymes are small molecules that are not proteins and are not as specific as substrates so they can participate in reactions with many different enzymes.

• Compare the state of an enzyme active site at a low substrate concentration and at a high substrate concentration. How does this affect the rate of the reaction?

Answer: The rate of the reaction will increase with the concentration of the substrate until the enzyme's active site is saturated, and no more substrate molecules are able to bind.

Do You Understand Concept 3.4?

• Explain and give examples of irreversible and reversible enzyme inhibitors.

Answer: Irreversible enzyme inhibition occurs when a substance binds at the active site of an enzyme, preventing it from interacting with its substrate. An example is DIPF, which inhibits acetylcholinesterase. A reversible enzyme inhibitor is similar to the enzyme's substrate and can bind to the active site, but is different enough so that no subsequent reaction occurs. Depending on where it binds, it may be competitive or noncompetitive.

• The amino acid glutamic acid (see Table 3.2) is at the active site of an enzyme. Normally the enzyme is active at pH 7. At pH 4 (higher concentration of H^+), the enzyme is inactive. Explain these observations.

[Note to the Instructor: This question has been revised from the version appearing in the first printing of the textbook: "lysine" has been replaced with "glutamic acid" and "pH 5" has been replaced with "pH 4."]
Answer: pH affects enzymatic reactions by altering the charge of amino acids in the protein, and thus the protein's shape and chemical reactivity. Glutamic acid has a carboxylic acid in its "R" group, which at pH 7 is likely to be dissociated (COO^-), making the amino acid negative in charge. At pH 4 it is more likely that the R group will be protonated (COOH). This makes the amino acid more likely to be uncharged, and thus changes the structure of the active site.

• An enzyme is subject to allosteric regulation. How would you design an inhibitor of the enzyme that was competitive? Noncompetitive? Irreversible?

Answer: A competitive inhibitor would bind to the active site, preventing substrate binding. A noncompetitive inhibitor would bind to a region other than the active site but cause a change in the shape of the enzyme that prevents substrate binding at its active site. An irreversible inhibitor covalently alters the active site, preventing substrate binding.

• Some organisms thrive at a pH of 2; other organisms thrive at a temperature of 65°C. Yet mammals cannot tolerate either environment in their tissues. Explain.

Answer: Both pH and temperature are strong influences on enzymatic reactions and protein structure. A pH of 2 would change ionization of amino acids, altering three-dimensional protein structures. High temperatures could cause inactivation of enzymes by breaking some of their hydrogen bonds and changing their secondary structure, and thus their function. Organisms that thrive at environmental extremes have proteins that do not change structure when pH and/or temperature change. In some cases, the organisms make molecules that "coat" proteins, preventing denaturation.