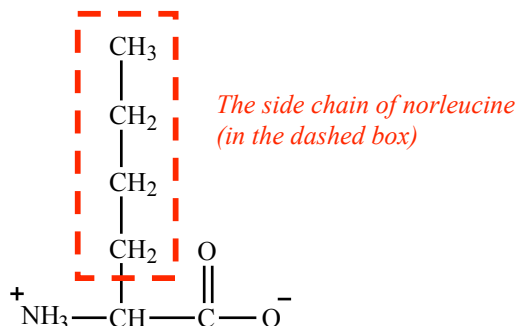


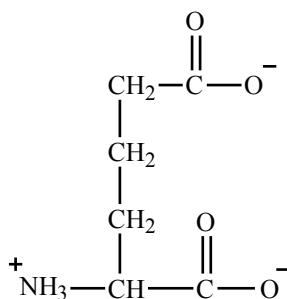
CHAPTER 13: ANSWERS TO SELECTED PROBLEMS

SAMPLE PROBLEMS (“Try it yourself”)

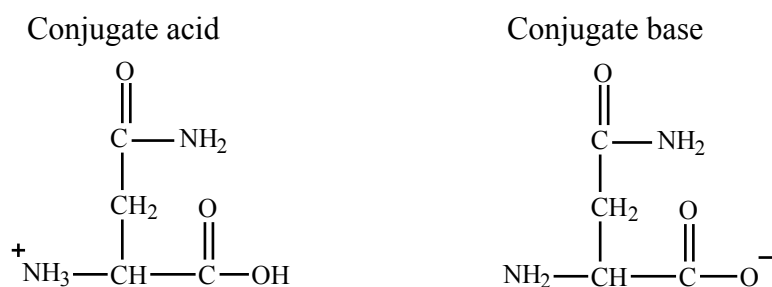
13.1



13.2 The side chain of this amino acid contains a carboxylic acid group, so this is an acidic amino acid. At pH 7, the carboxylic acid group in the side chain is ionized, as shown below.



13.3



13.4 The isoelectric point of ornithine is significantly above pH 6. The side chain of ornithine contains an amino group (which is ionized at pH 7, as shown in the structure in the problem). Amino acids with basic side chains have high isoelectric points, because the pH must be basic enough to remove the extra H^+ from the side chain.

13.5 Glutamic acid is negatively charged at pH 5.5, because this pH is higher than the isoelectric pH of glutamic acid. (Proline is positively charged at pH 5.5, because the pH is below the pK_a of proline. Phenylalanine has no charge, because the pH equals the pK_a of phenylalanine.)

13.11 The substrates are glutamine and water, the products are glutamic acid and ammonia (NH₃), and the enzyme is glutaminase.

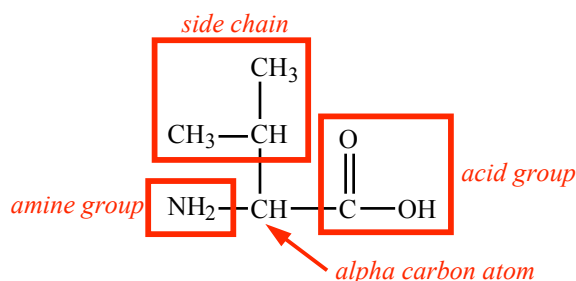
13.12 ATP is a positive effector. It does not bind to the active site, so it is an effector rather than a competitive inhibitor. Since ATP makes the enzyme more active, it is a positive effector.

13.13 A person can eat plenty of carbohydrate, fat and protein, yet still have a protein deficiency, if the person's diet does not include sufficient amounts of one or more of the essential amino acids. The person cannot make all of the proteins that her body needs, just as if she did not eat enough protein.

SECTION PROBLEMS

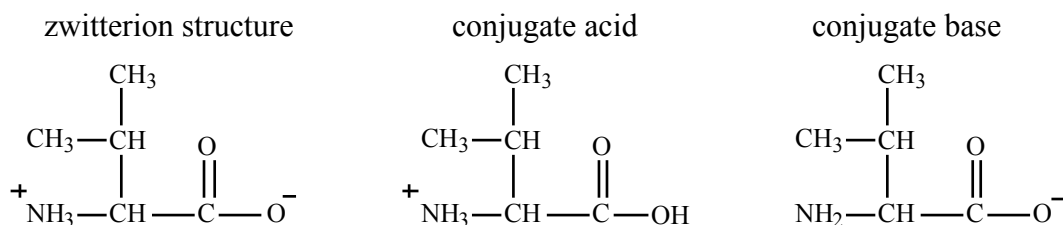
Section 13.1

13.1

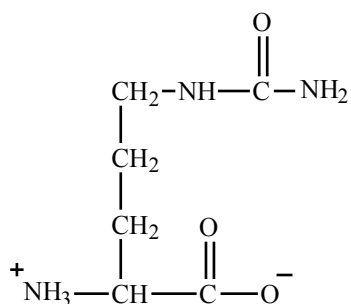


13.2 Valine is a nonpolar amino acid, because it contains a hydrocarbon side chain (see the answer to problem 13.1).

13.3

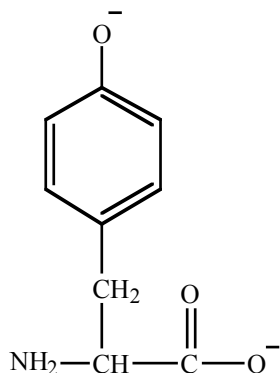


13.4



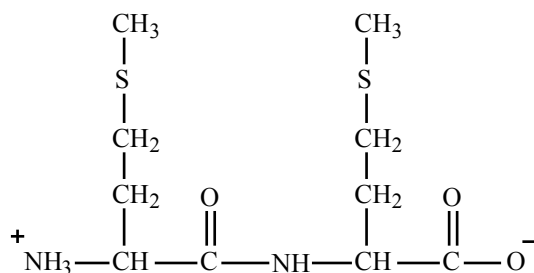
13.5 The isoelectric point of citrulline is around 6, because citrulline does not contain an acidic or basic group in its side chain. (It contains an amide group, which is not acidic or basic.)

13.6 At pH 12, the phenol OH loses its hydrogen. In addition, the carboxylic acid group loses its hydrogen (just as it does at pH 7), but the amine group does not gain hydrogen.

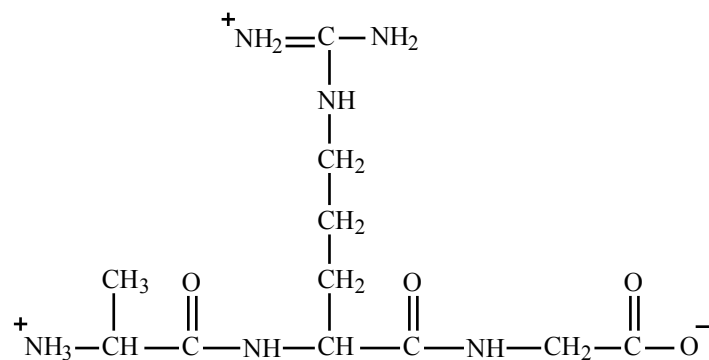


Section 13.2

13.7 a)



b)



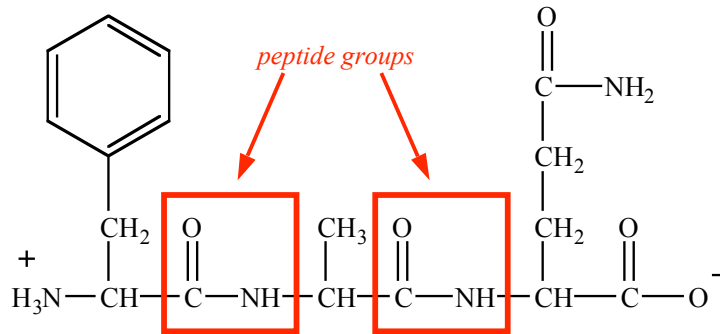
13.8 The primary structure of a protein is the sequence of amino acids.

13.9 a) This tripeptide contains phenylalanine, alanine, and glutamine.

b) There are two peptide groups, as shown on the next page.

c) The C-terminal amino acid is glutamine.

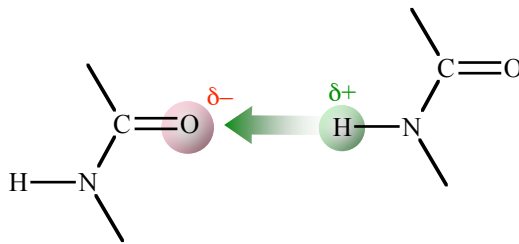
d) The N-terminal amino acid is phenylalanine.



13.10 The two common secondary structures are the alpha-helix and the beta-sheet. In the alpha-helix, the polypeptide coils like a spring, with the side chains pointing outward. In the beta-sheet, the polypeptide forms parallel rows, running back and forth, with the side chains projecting above and below the sheet.

13.11 A triple helix contains three polypeptide chains, wound around one another like braided hair. Collagen contains this type of structure.

13.12



Section 13.3

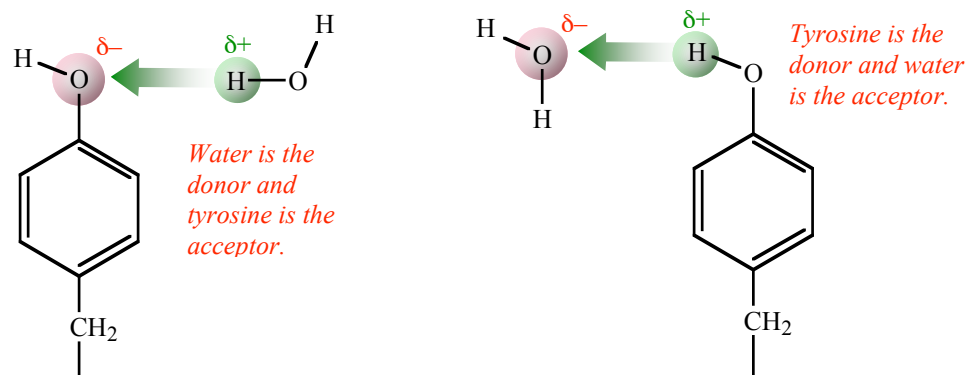
13.13 The hydrophobic interaction is important for leucine and phenylalanine.

13.14 The hydrophilic interaction is important for lysine, threonine, and glutamic acid.

13.15 Lysine and glutamic acid can form ion pairs. The side chain of lysine is a +1 ion at pH 7, and the side chain of glutamic acid is a -1 ion at pH 7.

13.16 Leucine and phenylalanine are most likely to be in the interior of a protein, because their side chains cannot form hydrogen bonds with water molecules.

13.17



13.18 Only cysteine can form a disulfide bridge.

13.19 The secondary structure is the folding or coiling of short regions of a polypeptide, and is produced by hydrogen bonds between peptide groups within the polypeptide. The tertiary structure is the way the entire polypeptide folds into its final shape, and is produced by interactions between the amino acid side chains.

13.20 All membranes are primarily nonpolar. The hydrophobic amino acids in a membrane protein allow the protein to remain embedded in the membrane, because they are not attracted to the surrounding water molecules.

13.21 This is a description of the quaternary structure of the enzyme, because it involves an interaction between two separate polypeptide chains.

13.22 This is a description of the secondary structure of the enzyme, because the alpha-helix is produced by hydrogen bonds between peptide groups.

13.23 This is a (partial) description of the tertiary structure of the enzyme, because it involves an interaction between side chains.

Section 13.4

13.24 When a protein is denatured, the secondary and tertiary structures of the protein are disrupted, so the protein folds into a different shape (or unfolds completely).

13.25 a) HCl is a strong acid, so it makes the solution very acidic. This disrupts the ion pairs within the protein, because it converts the acidic side chains from their conjugate base form (which is negatively charged and can form an ion pair) into their acid form (which has no net charge).

b) Hg^{2+} bonds to sulfur atoms, breaking the disulfide bridges in the protein.

c) Heating the protein disrupts the weak hydrogen-bonding interactions within the protein (and between the protein and water), allowing the protein to unfold.

13.26 Ethanol is an organic liquid that forms hydrogen bonds less effectively than water. As a result, adding ethanol disrupts the hydrophilic attraction that keeps the polar amino acids on the exterior of the protein. The protein denatures, making it inactive.

13.27 The secondary, tertiary, and quaternary structures of a protein are disrupted when the protein is denatured, but the primary structure is not.

13.28 When the concentration of NaCl is high, the ionized amino acids form ion pairs with Na^+ and Cl^- , rather than with each other. When we disrupt the original ion pairs, the protein denatures.

13.34 First, the substrate binds to the active site of the enzyme, forming the enzyme-substrate complex. Second, the reaction occurs within the active site, forming the enzyme-product complex. Third, the products leave the active site.

13.35 The side chain of arginine is basic and is positively charged at pH 7. This side chain is strongly hydrophilic and does not enter the hydrophilic pocket in the active site.

13.36 The activity of an enzyme is the number of reaction cycles that the enzyme can catalyze in a second, and is generally between 10 and 1000 reaction cycles per second.

13.37 Chymotrypsin does not function in the stomach, because the digestive fluids in the stomach are very acidic. The pH of the stomach contents is far below the active range for chymotrypsin (pH 7 to 8).

13.38 Most enzymes become denatured in this temperature range. The denatured form of the enzyme is not active.

13.39 A substrate is a molecule that is converted into a different substance by the enzyme. Substrates are the reactants in the balanced equation. An effector is a molecule that binds to an enzyme and makes the enzyme more or less active. The enzyme does not change the effector into another molecule, so effectors do not appear in the balanced equation.

13.40 Competitive inhibitors fit into the active site of the enzyme and prevent the substrate from entering the active site. Noncompetitive inhibitors bind to the enzyme outside the active site, so they do not block the substrate. Instead, noncompetitive inhibitors force the enzyme to change the shape of the active site, so the substrate does not fit into the active site. The structure of a competitive inhibitor resembles that of the substrate.

13.41 The structure of succinate is similar to that of oxaloacetate, so succinate should be a competitive inhibitor of succinate dehydrogenase.

Section 13.6

13.42 The two categories are the metal ions (such as Zn^{2+} , Cu^{2+} , and Mg^{2+}) and the coenzymes (organic compounds such as NAD^+ and FAD).

13.43 A cofactor is a substance that an enzyme requires in order to catalyze its reaction.

13.44 FAD is permanently bonded to all of the enzymes that require it, so there is no FAD in intracellular fluid. In contrast, NAD^+ binds reversibly to the enzymes that require it, so there is always some NAD^+ in the surrounding solution.

13.45 We obtain all of the metallic cofactors we need from our diet.

13.46 Our bodies use vitamins to build coenzymes. Each coenzyme contains a vitamin attached to some other substance that our bodies can make. Table 13.4 list some specific examples.

13.47 Plants make riboflavin from other substances, and we obtain riboflavin by eating the plants (or by eating animals that have eaten plants, or by eating animals that have eaten other animals that have eaten plants, etc.).

Section 13.7

13.48 Antibodies are molecules that bind to substances that are not normally present in the body and allow the rest of the immune system to recognize and destroy the foreign substances.

13.49 The variable region of the antibody binds to the antigen.

13.50 See Figure 13.27; I'm not going to repeat the diagram here.

13.51 The four polypeptide chains are linked to one another by disulfide bridges.

13.52 An antigen is any substance that is not normally present in the body and that is recognized by an antibody.

13.53 a) B cells contain antibodies on their surface, allowing them to recognize and bind to a specific antigen. This recognition is the first step in the immune response. When a B cell binds to an antigen, it divides into plasma cells and memory cells.

b) Plasma cells made many copies of an antibody (essentially the same antibody that was on the surface of the parent B cell) and release the antibody molecules into the body fluids, where they bind to the corresponding antigen.

c) Memory cells are similar to B cells, but they divide into plasma cells much more quickly than do B cells. Memory cells allow our bodies to become immune to a disease once we have recovered from it.

13.54 B cells build antibodies by combining five different sets of genetic instructions, selected randomly from several hundred possible choices. There are a vast number of possible combinations that can be made in this way.

13.55 In both allergic reactions and autoimmune disorders, the immune system recognizes a harmless substance as an antigen, and makes antibodies against the harmless substance. In an allergic reaction, the antigen is a substance that we encounter in our environment, such as peanuts, house dust, pollen, bee venom, and so forth. In an autoimmune disorder, the antigen is a molecule on the surface of the cells in a particular body tissue, such as joint tissue (in rheumatoid arthritis) or pancreatic tissue (in type I diabetes).

Section 13.8

13.56 The enzyme would be broken down into amino acids in our digestive tract, so none of it would be available to our bodies.

13.57 Our bodies cannot make the essential amino acids from other nutrients, so we must have a dietary source of these amino acids. However, we can make the other amino acids from other nutrients, so we do not need a dietary source of the non-essential amino acids.

13.58 Humans can make arginine from other nutrients, but children and some adults cannot make enough arginine to meet their needs, so they need a dietary source of arginine.

13.59 The nitrogen atoms come from other amino acids. The other three elements can come from amino acids or from other nutrients, primarily carbohydrates.

13.60 Our diet must include all of the essential amino acids, and it must include enough protein to supply the nitrogen we need to make the non-essential amino acids and other nitrogen-containing compounds.

13.61 We also use amino acids as an energy source, burning them to obtain energy for our bodies. If our diet does not include enough carbohydrate and fat, we break down most of the amino acids in our diet, because our very survival requires energy. As a result, we do not have enough amino acids to build proteins.

13.62 a) Nitrogen fixation is the reaction that converts atmospheric nitrogen (N_2) into ammonium ions (NH_4^+).

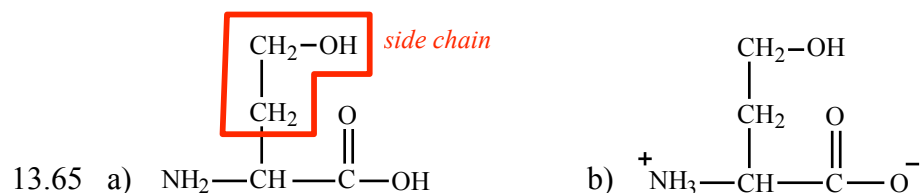
b) Nitrification is the set of reactions that convert ammonium ions into nitrite and nitrate ions (NO_2^- and NO_3^-).

c) Denitrification is the set of reactions that convert nitrite and nitrate ions back into N_2 .

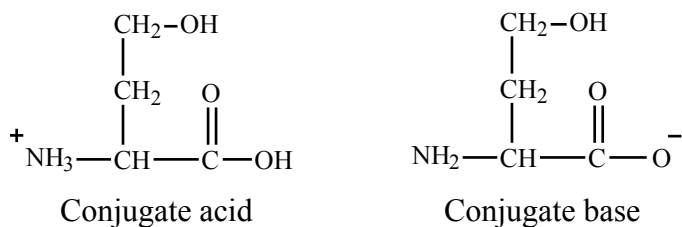
13.63 All of the reactions in Problem 13.62 can be carried out by bacteria (although only some bacteria can do so). None of these reactions can be carried out by plants. (Plants can convert nitrite and nitrate ions into ammonium ions, but not the reverse.)

13.64 We do not excrete wastes continuously, so we must store our waste products for a while before we excrete them. Ammonium ions are toxic, so our bodies cannot store significant amounts of ammonium ions. Therefore, our bodies convert ammonium ions into urea, which is relatively non-toxic, and we excrete the urea when we need to get rid of excess nitrogen.

CUMULATIVE PROBLEMS (Odd-numbered problems only)

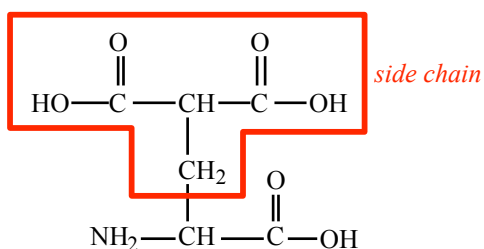


c)

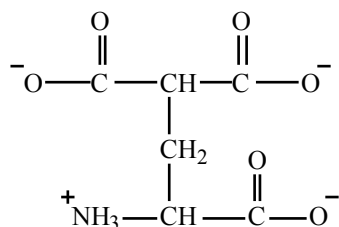


d) Homoserine is a polar amino acid, because it contains an alcohol group in its side chain. Alcohols can form hydrogen bonds, but they are not acidic or basic.

13.67 a) Gamma-carboxyglutamic acid is an acidic amino acid, because it contains two acidic groups in its side chain.



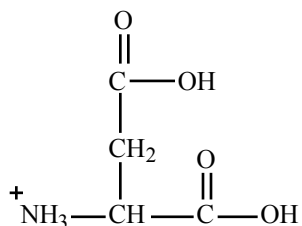
b) At pH 7, the amino group gains H^+ and all three carboxylic acid groups lose H^+ .



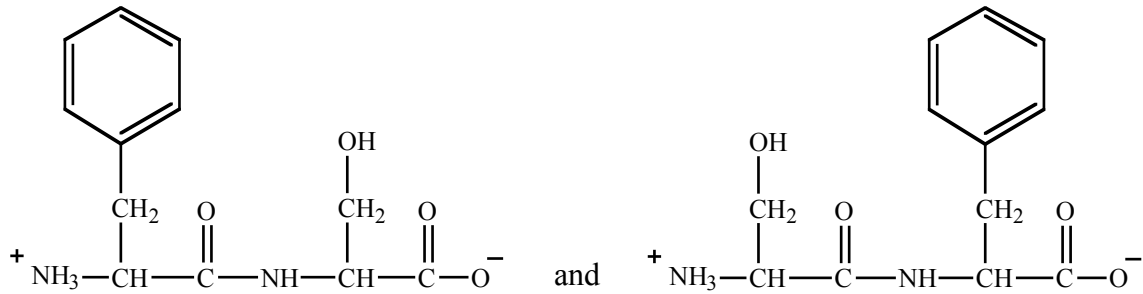
c) The isoelectric point of this amino acid is significantly below 6.0, because the side chain is acidic and is negatively charged at pH 6.0. You must add H^+ (making the solution acidic) to eliminate these negative charges.

13.69 All four of these amino acids have hydrocarbon side chains, which are neither acidic nor basic. Therefore, the acid-base behavior of these amino acids should be virtually identical.

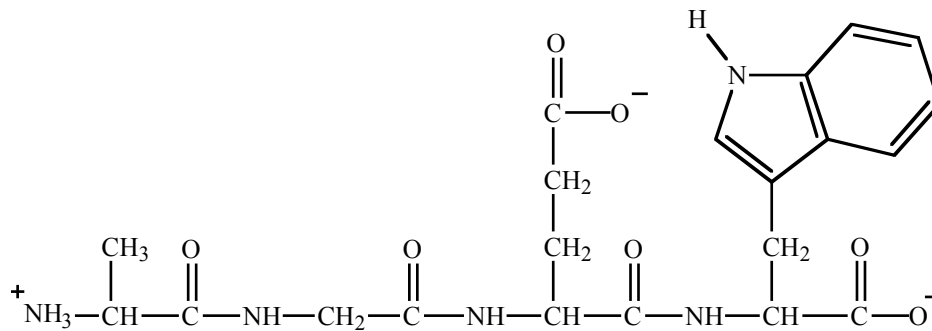
13.71 At pH 2, both of the carboxylic acid groups are in their acid form (bonded to H^+), rather than in their ionized form.



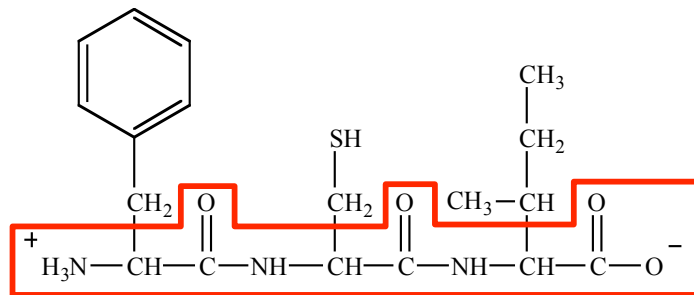
13.73



13.75



13.77 a)



- b) This tripeptide contains phenylalanine, cysteine, and isoleucine (phe-cys-ile).
 c) The N-terminal amino acid is phenylalanine.

13.79 You can make six different tripeptides. Here are their primary structures:

arg-ile-val	ile-arg-val	val-arg-ile
arg-val-ile	ile-val-arg	val-ile-arg

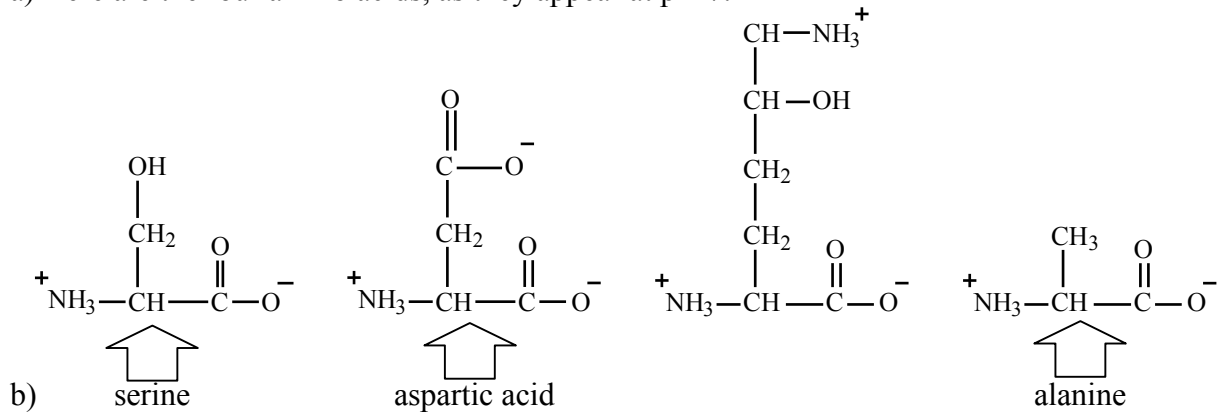
13.81 a) There are 62 nonpolar amino acids (alanine, glycine, isoleucine, leucine, methionine, phenylalanine, proline, tryptophan, and valine). There are 29 polar amino acids (asparagine, cysteine, glutamine, serine, threonine, and tyrosine). There are 11 acidic amino acids (aspartic acid and glutamic acid). There are 33 basic amino acids (arginine, histidine, and lysine).

b) There are 73 hydrophilic and 62 hydrophobic amino acids. The hydrophilic amino acids include the polar, acidic, and basic amino acids from part a.

c) Histone H3 is positively charged, because it contains more basic amino acids than acidic amino acids. Remember that the basic amino acids have a +1 charge at pH 7, and the acidic amino acids have a -1 charge at pH 7.

d) DNA is negatively charged. Opposite charges attract, allowing histone H3 to bind tightly to DNA.

13.83 a) Here are the four amino acids, as they appear at pH 7.



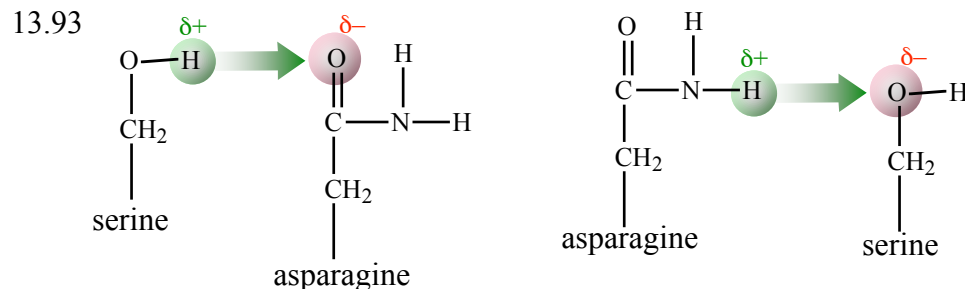
c) The other amino acid is basic. Note that at pH 7, the amino group in the side chain of this amino acid has bonded to H^+ .

13.85 Proline cannot form an alpha helix because there is no hydrogen atom bonded to the amine nitrogen when proline is incorporated into a polypeptide. (See Figure 13.7.) The alpha helix structure requires this hydrogen atom to form the hydrogen bond between peptide groups. Collagen contains a high percentage of proline, allowing collagen to form the triple helix structure instead of an alpha helix.

13.87 The hydrogen atom has a positive charge, and the oxygen atom has a negative charge. (See Figure 13.6.)

13.89 In an alpha helix, the polypeptide backbone forms a tight coil, with the side chains pointing outward from the coil.

13.91 Glycine and phenylalanine are most likely to be found in the interior, because their side chains cannot form hydrogen bonds.



Here, serine is the donor and asparagine is the acceptor.

Here, asparagine is the donor and serine is the acceptor.

(You can also form a hydrogen bond between the serine hydrogen and the asparagine nitrogen.)

13.95 Aspartic acid can form an ion pair with lysine. Lysine is a basic amino acid and is positively charged at pH 7. Only acidic amino acids (which are negatively charged at pH 7) can form an ion pair with lysine.

13.97 Lysine, threonine, and tyrosine can form hydrogen bonds with water.

13.99 To form a disulfide bridge, the amino acid must have a thiol group ($-SH$) in its side chain. Cysteine contains a thiol group, but methionine does not, so methionine cannot form a disulfide bridge.

13.101 This sequence contains eleven amino acids. Nine of these eleven have nonpolar side chains, and the other two (serine and asparagine) are polar but are not ionized. Therefore, this section of the polypeptide is not attracted to water to any significant extent, so it is probably in the interior of the protein.

13.103 a) This statement describes the quaternary structure of the protein.
b) This statement describes the tertiary structure of the protein.
c) This statement describes the secondary structure of the protein.

13.105 Ethanol disrupts the hydrophilic interaction between polar amino acids and the surrounding solvent (which is normally water). As a result, the protein becomes denatured.

13.107 Some possibilities are Mg^{2+} , Zn^{2+} , Fe^{2+} , Fe^{3+} , Cu^{2+} , and Mn^{2+} .

13.109 a) Lysine is not a cofactor; it is one of the amino acids in the polypeptide chain. Cofactors are substances that are required by an enzyme, but are not amino acids. Lysine is not a coenzyme, since a coenzyme is simply an organic cofactor.

b) Biotin is a cofactor, since it is required by the enzyme but is not an amino acid. Since biotin is an organic compound, it is a coenzyme.

13.111 The substrates are sucrose and water, the products are glucose and fructose, and the enzyme is sucrase.

13.113 Enzymes speed up reactions, and they select the correct product when more than one product is possible.

13.115 Magnesium ion is positively charged and phosphate is negatively charged, so the magnesium attracts the phosphate ion and holds it in the active site of the enzyme.

13.117 Enzymes make the activation energy smaller. Remember that the activation energy is the minimum energy that the reactants must have in order to react.

13.119 Enzyme A has the higher activity. Enzyme carries out 100 reaction cycles in a second, while enzyme B carries out only 10 reaction cycles in a second (100 cycles in 10 seconds).

13.121 Papain has the highest activity around pH 6, and catalase has the highest activity around pH 8.

13.123 The pH-activity curve of an enzyme normally peaks at the pH of the enzyme's surroundings. (If it didn't, the enzyme wouldn't work!) Therefore, it is reasonable to conclude that the typical pH inside a cell is around 7 to 8 (corresponding to the pH peak for trypsin).

13.125 The enzyme's activity increases as it is heated from 20°C to 40°C. As long as the temperature isn't high enough to denature the enzyme, enzymes work faster as the temperature increases. In this case, 40°C is not hot enough to denature enzymes (40°C is barely above body temperature).

13.127 This organism must live in an extremely hot environment, probably above 80°C. The activity of the enzyme is essentially zero at "normal" temperatures (20 to 40°C), so this enzyme will not function effectively in this temperature range. The peak activity for this enzyme is around 90°C.

13.129 NADH is a negative effector.

13.131 Since atorvastatin is a competitive inhibitor, it must fit into the active site of the enzyme. Therefore, it must resemble the substrate.

13.133 B cells can produce an enormous variety of variable regions, each of which can bind to a different antigen. This allows the body to recognize and deal with a vast array of potentially dangerous substances and microorganisms. In contrast, the structure of the constant region is the same from one antibody to another. If the constant region bound to the antigen, the body would only be able to recognize a very small number of antigens.

13.135 A surface antigen is a molecule that projects from the surface of a cell or a virus, and that is recognized and bound by an antibody.

13.137 The organism can make $9 \times 12 \times 8 = 864$ different antibodies.

13.139 When our B cells recognize the organisms that cause these diseases, some of them divide into memory cells. The memory cells are able to produce antibodies to the organisms very rapidly, allowing the body to destroy the organisms before they can cause symptoms of disease.

13.141 This is an autoimmune disease.

13.143 Antibodies are proteins, so they are broken down into amino acids in the digestive tract. As a result, none of the antibodies would reach the rabies viruses.

13.145 a) This diet would not be able to meet the person's protein needs, because the total amount of amino acids is so low that it would not satisfy the person's need for nitrogen to make the nonessential amino acids.

b) This diet would (probably) satisfy the person's protein needs, because it contains sufficient amounts of the essential amino acids both to satisfy the need for essential amino acids and to supply nitrogen for making nonessential amino acids.

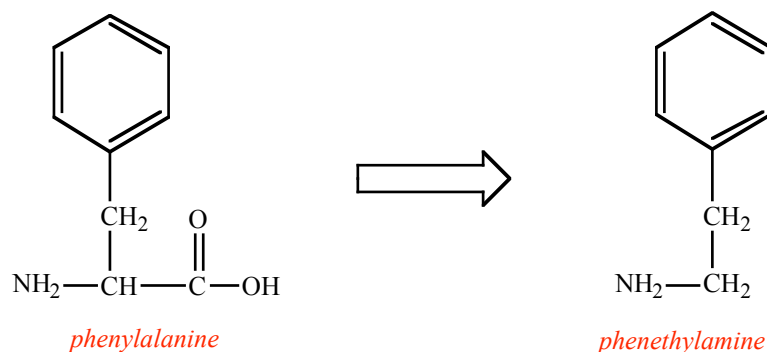
c) This diet would not be able to meet the person's protein needs, because it does not contain any of the essential amino acids. The body cannot make essential amino acids from nonessential amino acids.

13.147 Plants and microorganisms can make proteins using inorganic sources of nitrogen.

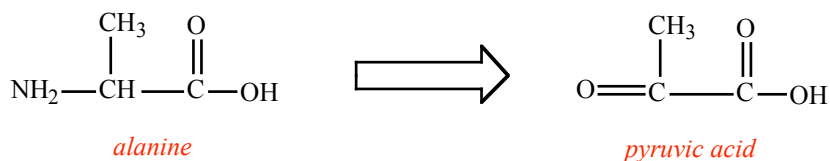
13.149 Nitrogen fixation is a series of reactions that convert gaseous nitrogen (N_2) into ammonium ions (NH_4^+). Only a few microorganisms can carry out these reactions. Most organisms cannot use N_2 to make organic compounds such as amino acids, so nitrogen fixation converts atmospheric nitrogen into a form that can be used by plants and other microorganisms.

13.151 When our bodies make asparagine from other substances, the nitrogen atoms come from other amino acids in our diet.

13.153 a) We make phenethylamine by removing CO_2 from phenylalanine.



b) We make pyruvic acid by removing NH_3 (and adding oxygen to) alanine.



13.155 A complete protein is a protein source that contains all of the essential amino acids. Meat, milk (and other dairy products), and eggs are sources of complete protein.