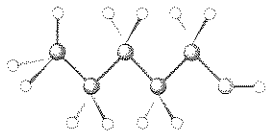
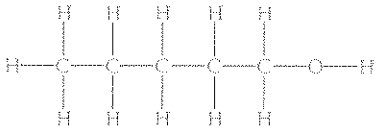
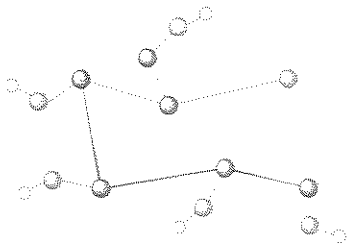
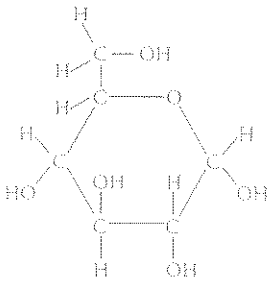
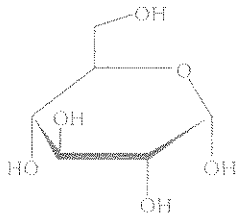
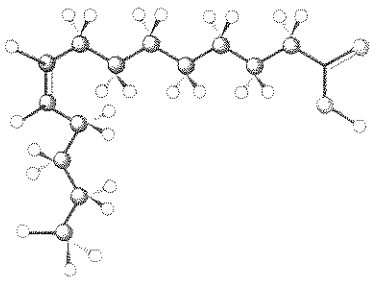
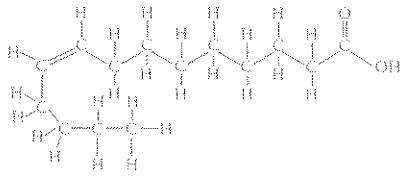
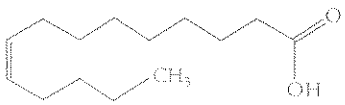
Biochemistry Basics

What concepts from chemistry are helpful in studying biology?

Why?

Typically chemistry is a prerequisite course for advanced biology courses. This is because everything in your body, everything in a plant, everything in a virus, etc. is made of atoms. The structures and properties of the molecules in an organism determine the features and properties of the organism. Which molecules are polar, which are nonpolar? Which molecules have acidic properties, which have basic properties? A quick review of these concepts at the beginning of your advanced biology course will help you to understand the molecular basis for life.

Model 1 – Molecular Drawings

Ball-and-stick model of 1-pentanol 	Lewis structure of 1-pentanol 	Line drawing of 1-pentanol 
Ball-and-stick model of glucose 	Lewis structure of glucose 	Line drawing of glucose 
Ball-and-stick model of unsaturated fatty acid 	Lewis structure of unsaturated fatty acid 	Line drawing of unsaturated fatty acid 

1. Name the three molecules that are illustrated in Model 1.

2. Name the three types of drawings that are used to illustrate the molecules in Model 1.

3. How many bonds are typically formed by each of the following atoms:

   Carbon Hydrogen Oxygen

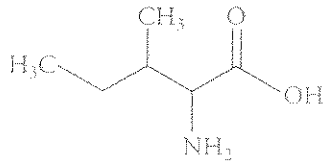
4. Which types of drawings in Model 1 provide more accurate images of the shape of a molecule? Justify your reasoning.

5. Refer to Model 1.

   a. Symbols or atoms of what element(s) are missing from the line drawings?

   b. In reading a line drawing, how do you know where atoms of these elements are in the structure if they are missing from the drawing?

6. Locate the carbon and hydrogen atoms in the line drawing of isoleucine shown below and draw them in as if the drawing were a Lewis structure.



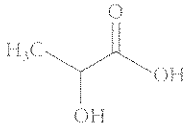
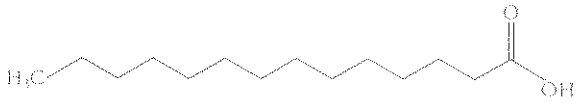
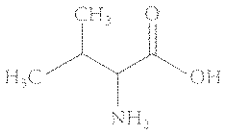
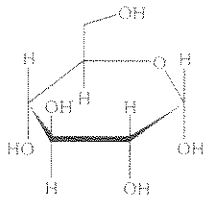
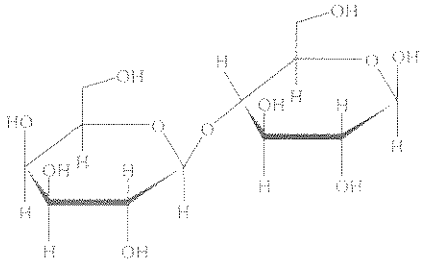
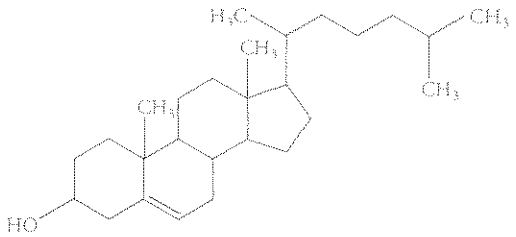
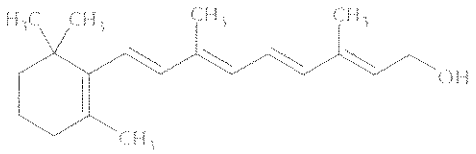
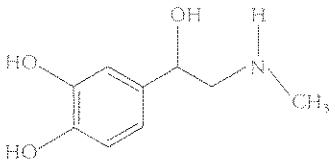
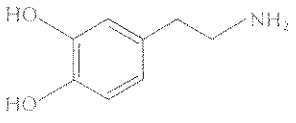
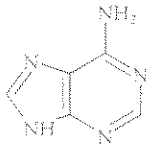
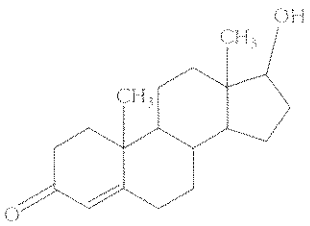
Isoleucine

7. Isopropyl alcohol is a three-carbon molecule with an –OH group attached to the middle carbon atom. Draw this molecule using all three types of drawings.

8. If you were asked to write the chemical formula for one of the compounds in Model 1, which type of the drawing would be the easiest to use? Justify your reasoning.

9. What is the advantage to a scientist in using a line drawing rather than a ball-and-stick model or Lewis structure?

Model 2 – Properties of Biological Molecules

Polar Molecules (hydrophilic)	Nonpolar Molecules (hydrophobic)
Acidic  Lactic acid	**Acidic**  Fatty acid
Neutral  Valine (amino acid)  Glucose  Lactose	**Neutral**  Cholesterol  Vitamin A
Basic  Adrenaline  Dopamine  Adenine	 Testosterone

10. Consider the polar molecules in Model 2.

    a. In general, the presence of atoms of what element(s) makes a molecule polar?

    b. What property do atoms of these elements have that helps make the molecules they are in polar?

    c. Can nonpolar molecules also have atoms of these elements? If yes, what distinguishes a nonpolar molecule from a polar molecule?

11. In chemistry there is a saying "like dissolves like," which means things will mix with or dissolve into each other best when their polarities are similar.

    a. Is water polar or nonpolar?

    b. Is oil polar or nonpolar?

    c. Which of the substances in Model 2 would dissolve well in water? Justify your reasoning.

    d. Which of the substances in Model 2 are more likely to dissolve well in oil? Justify your reasoning.

    e. Which class of substances in Model 2, polar or nonpolar, is more likely to be found in high concentrations in the bloodstream of a vertebrate? Justify your reasoning.

12. Refer to Model 2.

    a. What is another term for a polar molecule?

    b. What is another term for a nonpolar molecule?

    c. Give the literal translation for the terms you gave in parts *a* and *b* above.

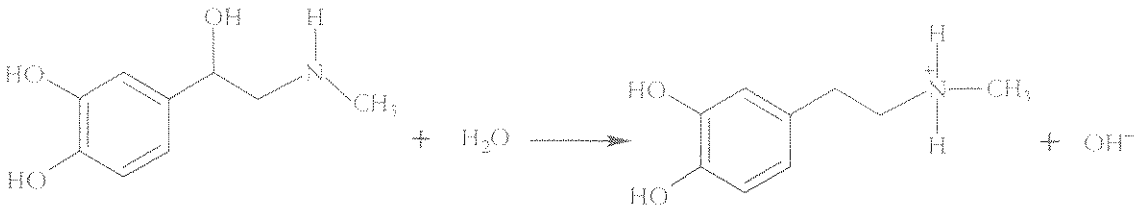
13. Functional groups are key groups of atoms in biological molecules. Describe the carboxyl functional group that both acidic molecules in Model 2 have in common.

14. Recall the definition of an acid that you learned in chemistry. Explain how the reaction below illustrates the acidic properties of lactic acid.

Lactic acid Lactate ion

15. Describe the functional group, called an amine group, that the basic molecules in Model 2 all have in common?

16. Recall the definition of a base that you learned in chemistry. Explain how the reaction below illustrates the basic properties of adrenaline.



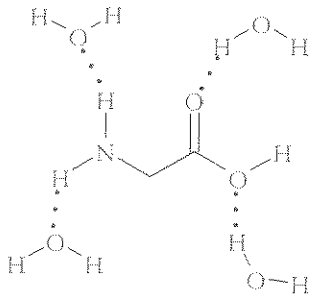
Adrenaline

17. Predict the approximate pH (pH = 7, pH > 7 or pH < 7) of fairly concentrated aqueous solutions of the following compounds from Model 2.

Lactic acid _____ Dopamine _____

Amino acid _____ Lactose _____

18. In chemistry you learned that covalent bonds are one type of intramolecular bond. They occur between nonmetal atoms in a molecule. You may have also learned about a type of intermolecular bond called a hydrogen bond. Hydrogen bonds are weak attractive forces between polar molecules containing strong polar bonds such as H-O, H-N or H-F.



a. Label at least two covalent bonds in the diagram above.

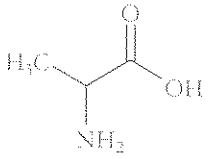
b. Label at least one hydrogen bond in the diagram above.

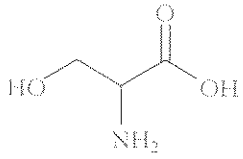
19. Which of the molecules in Model 2 would form hydrogen bonds with itself (that is, other molecules of the same type) or with water molecules if in a solution?

Extension Questions

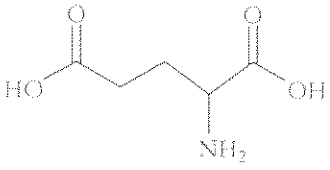
20. Although amino acids have "acid" in their name, some are acidic in water solutions, some are basic, and others are neutral. Propose an explanation for this observation based on the structures and descriptions of the amino acids below.

Neutral amino acids

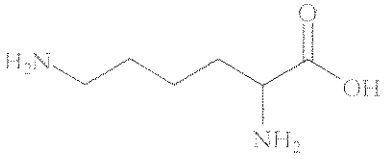




Acidic amino acid

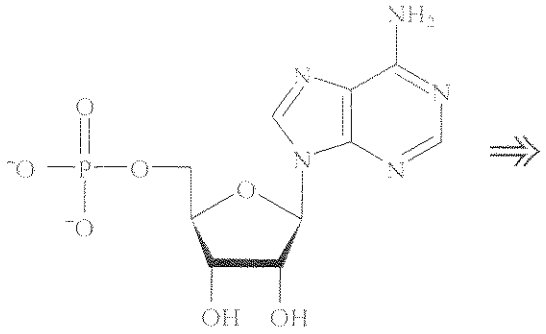


Basic amino acid



21. The structure shown below is a line drawing of noncyclic AMP, an important messenger molecule in molecular communication systems.

a. Draw the missing carbon and hydrogen atoms on the molecule.



b. Write the chemical formula for a molecule of noncyclic AMP.

22. The phosphate functional group in the noncyclic AMP molecule of Question 21 contains "acidic hydrogens."

a. Explain what this phrase means.

b. Draw the noncyclic AMP molecule after it has dissolved in water.

Protein Structure

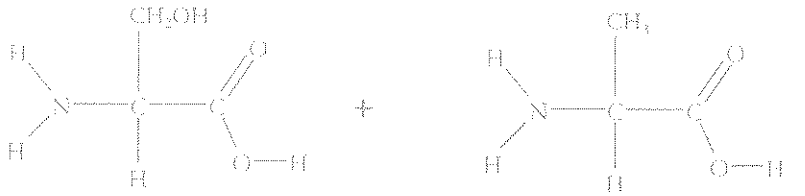
What are the levels of protein structure and what role do functional groups play?

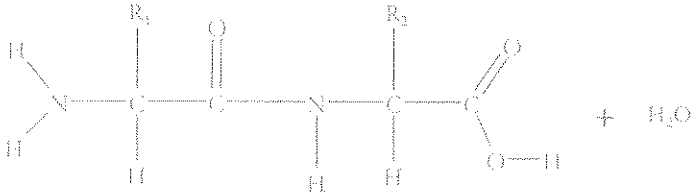
Why?

Proteins accomplish many cellular tasks such as facilitating chemical reactions, providing structure, and carrying information from one cell to another. How a protein chain coils up and folds determines its three-dimensional shape. Its shape will, in turn, determine how it interacts with other molecules and thus performs its function in the cell.

Model 1 – Formation of a Peptide Bond

Amino acid 1 Amino acid 2





Dipeptide

1. Examine the amino acids in Model 1.
   a. Circle an amine group in the diagram.
   b. Draw a triangle around a carboxylic acid (carboxyl) group.
2. How are the amino acids similar to one another?

3. How are the amino acids different from one another?

4. How many amino acids are involved in the reaction to make a dipeptide?

5. In Model 1 the original amino acids are combined through a **condensation reaction** to make the dipeptide.

   a. What does R_1 represent in the dipeptide?

   b. What does R_2 represent in the dipeptide?

6. Put a box around the atoms in the amino acids that become the H_2O molecule produced by the reaction in Model 1.

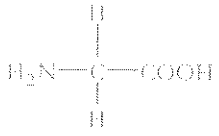
7. A peptide bond is a covalent bond linking two amino acids together in a peptide.

   a. Circle the peptide bond in Model 1.

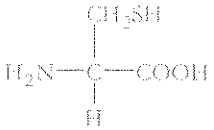
   b. Between which two atoms in the dipeptide is the peptide bond located?

   c. Between what two functional groups is the peptide bond located?

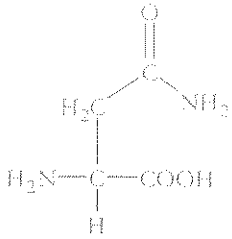
8. There are 22 different amino acids found in nature. Two were shown in Model 1. Additional examples are shown below. With your group, write one or two grammatically correct sentences to describe how these amino acids are similar and how they are different. Use the terms R-group, amine group, and carboxyl group in your description.



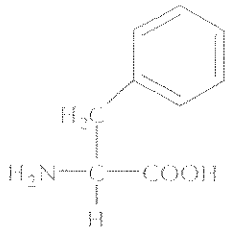
Glycine
(Gly)



Cysteine
(Cys)



Asparagine
(Asn)



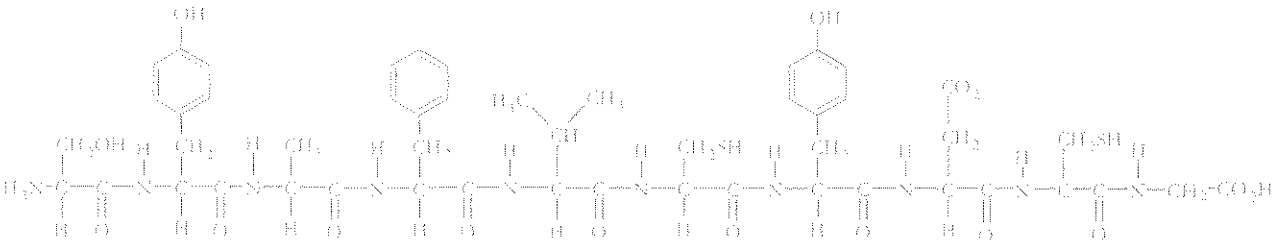
Phenylalanine
(Phe)

Model 2 – Protein Structure (Part A)

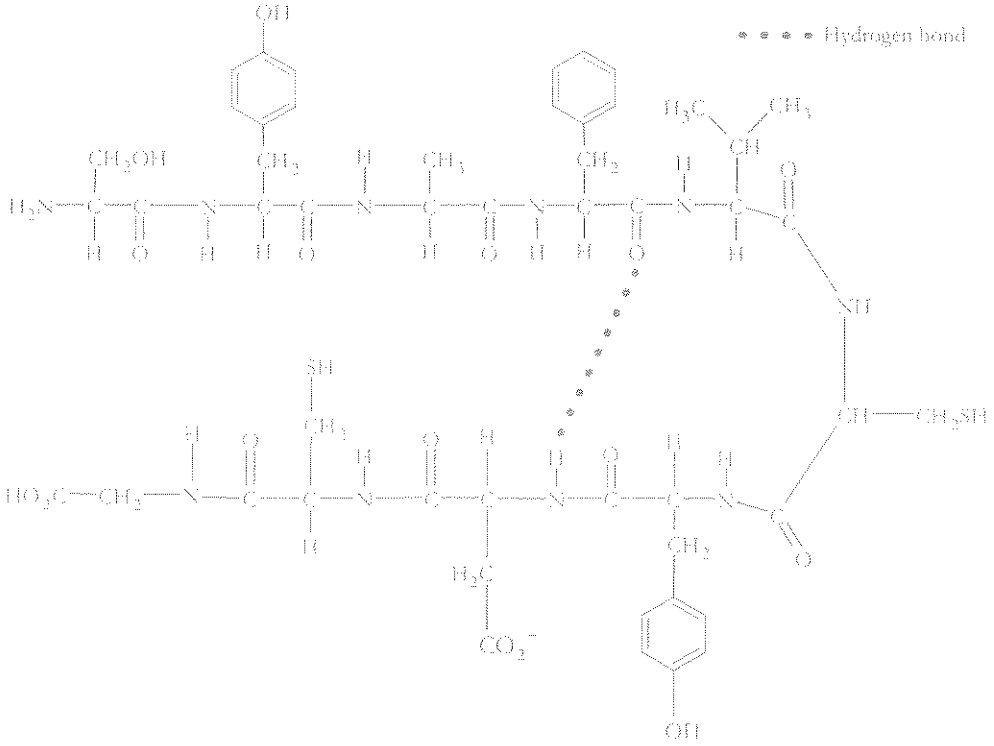
Primary Structure

Amino acid sequence: Ser – Tyr – Ala – Phe – Val – Cys – Tyr – Asp – Cys – Gly

Peptide structure:



Secondary Structure



9. Locate the **primary structure** of the polypeptide in Model 2.
   a. Draw an arrow to two different peptide bonds in the diagram.
   b. Circle three separate amino acids that were joined together to make the polypeptide.

10. The first five amino acids in this **polypeptide** are serine, tyrosine, alanine, phenylalanine, and valine, in that order (Ser-Tyr-Ala-Phe-Val). If the amino acids were changed or rearranged (i.e., to Val-Phe-Ala-Ser-Tyr), the polypeptide would have a different name and identity. With your group, use this information to write a definition of the primary structure of a protein.

11. Locate the **secondary protein structure** in Model 2.

    a. What types of bonds are holding the secondary structure in place?

    b. What groups on the amino acids are always involved in these bonds?

12. Draw a rectangle around two different R groups on the amino acids in the secondary structure in Model 2.

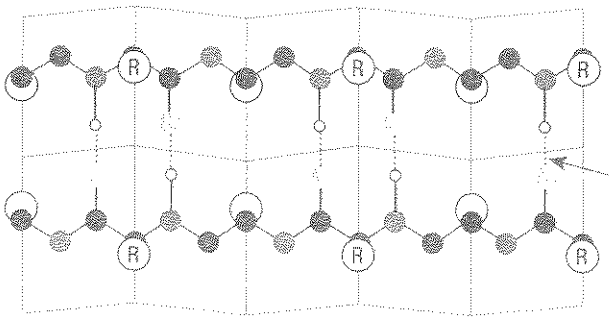
13. Is there any interaction between R groups in the secondary structure in Model 2?

14. Secondary protein structure can take the form of an alpha(α)-helix or a beta(β)-pleated sheet, as illustrated below.

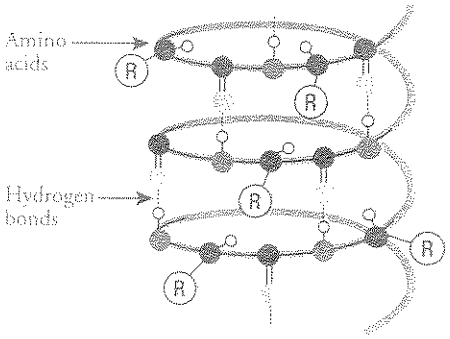
    a. Which drawing represents an α-helix, Molecule 1 or Molecule 2? Explain your reasoning.

    b. Which drawing represents a β-pleated sheet? Explain your reasoning.

Molecule 1



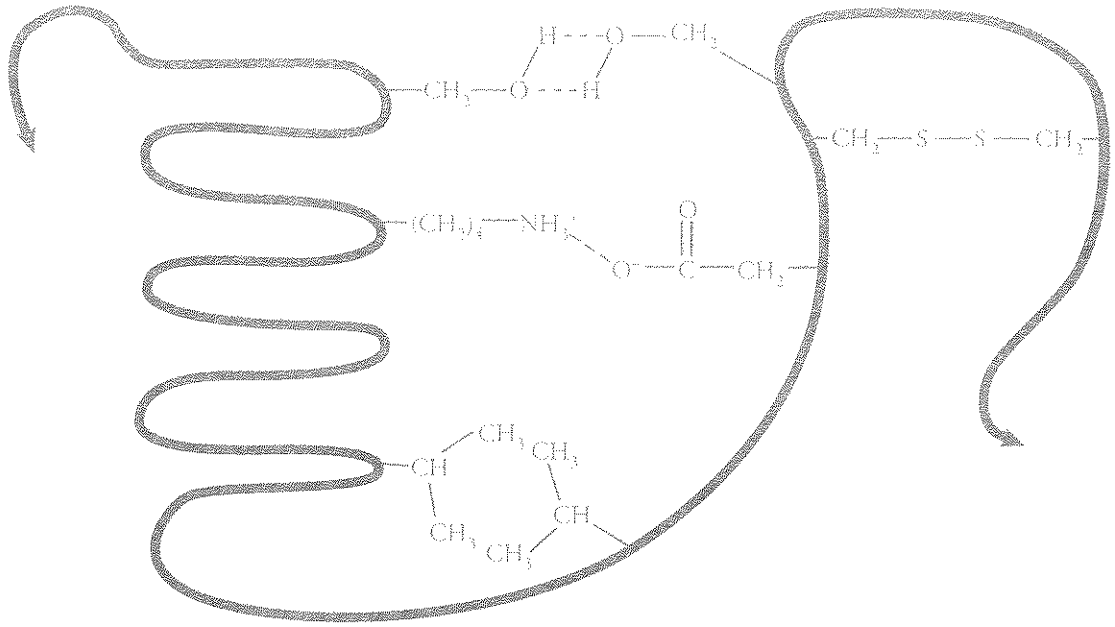
Molecule 2



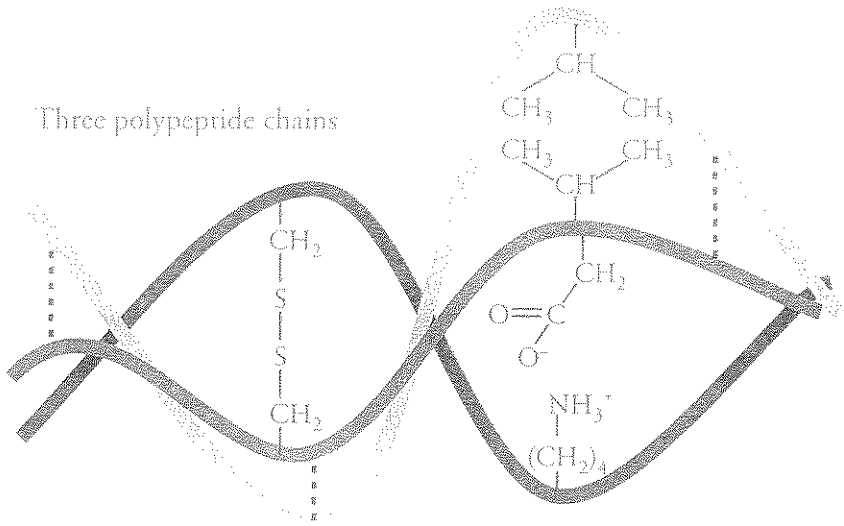
15. With your group, write a grammatically correct sentence that summarizes how the secondary protein structure is formed from the primary structure.

Model 3 – Protein Structure (Part B)

Tertiary Structure



Quaternary Structure



16. Examine the **tertiary structure** in Model 3 and note the interactions that hold this level of structure in place.

a. Four types of bonds or interactions are shown. Label them with the following terms.

Disulfide bridge	Hydrogen bond
Hydrophobic interactions	Ionic bond

b. Describe the part of the amino acid that participates in these interactions.

c. How does your answer in part *b* differ from the bonds that stabilize the secondary structure?

17. What type of functional groups or atoms would need to be present in the R-groups for hydrogen bonding to occur between two amino acids in a protein chain?

18. What type of functional groups or atoms would need to be present in the R-groups for hydrophobic interactions to occur between two amino acids in a protein chain?

19. How many polypeptide chains are shown in the tertiary protein structure in Model 3?

20. Many proteins, but not all, have a fourth level of structure termed **quaternary structure**.

a. How many polypeptide chains are shown in the quaternary structure of the protein in Model 3?

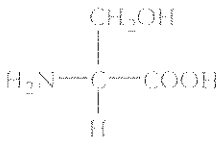
b. What types of bonds and interactions hold the quaternary structure in place?

21. With your group, using grammatically correct sentences, define the following.

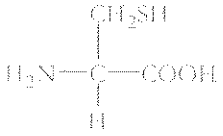
a. Tertiary protein structure.

b. Quaternary protein structure.

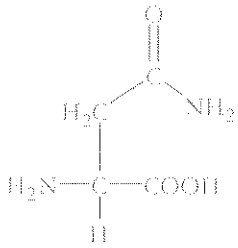
22. Imagine a protein chain that includes the following amino acids among several others.



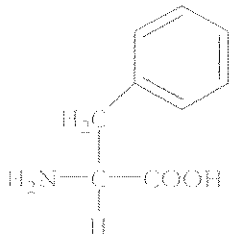
Serine



Cysteine



Asparagine



Phenylalanine

a. Which of the amino acids could form a hydrogen bond with another amino acid in the chain to stabilize the secondary structure of a β-pleated sheet?

b. Which of the amino acids could form disulfide bonds with another amino acid in the chain to stabilize the tertiary structure of the protein?

c. Which of the amino acids could participate in hydrophobic interactions with another amino acid in the chain to stabilize the tertiary structure of the protein?

d. What types of bonds or interactions could asparagine form with another amino acid in the chain in order to form a quaternary structure with another protein chain?

23. Fill in the following chart using what you've learned from Models 1–3.

Structure	Bond(s) or interactions holding the structure together	Short description	Number of polypeptide chains involved
Primary			1
Secondary			1
Tertiary			1
Quaternary			2 or more

Read This!

Heating and changing pH levels are two ways to disrupt the shape of a protein. High temperatures or pH levels that vary from the natural environment of the protein will break hydrogen bonds, ionic bonds, disulfide bridges, and hydrophobic interactions. Covalent bonds will usually remain undisturbed. This process of destroying the shape of a protein is called **denaturing**.

24. Which of the four levels of protein structure is maintained after denaturing? Explain your answer.

25. Proteins carry out a variety of functions, and their function is critically dependent upon their structure and shape. Enzymes are proteins. What would happen to the structure and function of an enzyme that was exposed to heat or a drastic change in pH?

26. When people get their hair chemically straightened, one chemical is put on the hair to break the disulfide bonds that give the hair strands their shape (curled) and a second chemical is used to reform the disulfide bonds to hold the hair in a new position (straight).

    a. What level(s) of protein structure is/are affected by these processes?

    b. Why doesn't the hair stay straight forever after this treatment?

Extension Questions

27. If a mutation in the DNA of an organism results in the replacement of an amino acid containing a polar R-group with another amino acid containing a nonpolar R-group, how might the structure of the protein be affected? Address the impact on all levels of the protein structure in your answer.

28. Egg whites are primarily composed of the protein albumin. One familiar example of the denaturing of proteins is the difference between the albumin structure in a raw egg versus a cooked egg. Using what you know about the levels of structure in proteins, propose an explanation of changes in albumin (and other proteins) that occur during cooking.

29. Predict what would happen to the egg white if a raw egg were placed in vinegar. Explain your thinking.