Key

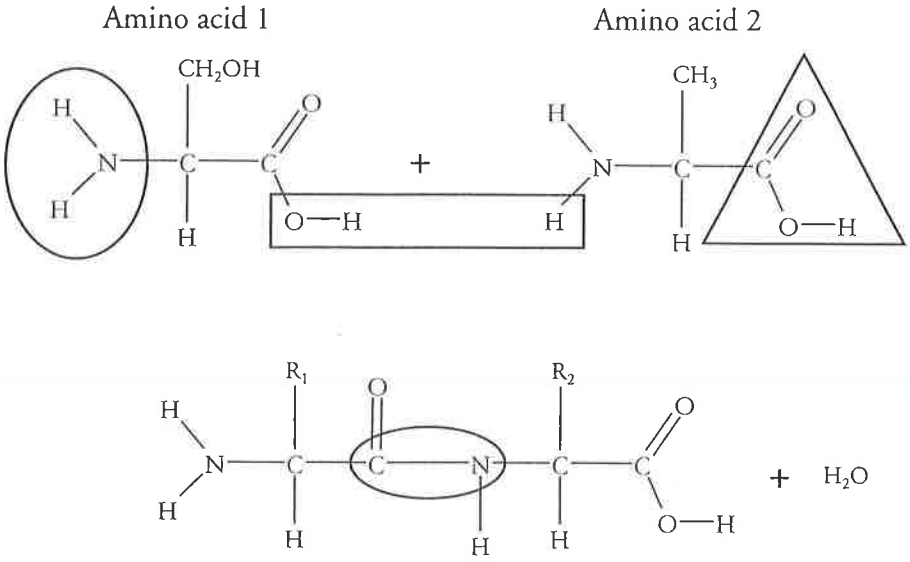
Protein Structure

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



Dipeptide

1. Examine the amino acids in Model 1.
   a. Circle an amine group in the diagram.

   See Model 1.

   b. Draw a triangle around a carboxylic acid (carboxyl) group.

   See Model 1.
2. How are the amino acids similar to one another?

   Answers will vary, but should include that each amino acid contains a central carbon atom attached to an amine group, a carboxyl group, and a hydrogen atom.
3. How are the amino acids different from one another?

   Answers will vary, but should focus on the difference between the R groups in the two amino acids ($-CH_2OH$ and $-CH_3$).

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

   Two.

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?

   $-CH_2OH$

   b. What does R_2 represent in the dipeptide?

   $-CH_3$

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

   See 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.

   See Model 1.

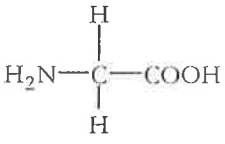
   b. Between which two atoms in the dipeptide is the peptide bond located?

   Carbon and nitrogen.

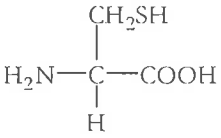
   c. Between what two functional groups is the peptide bond located?

   A carboxylic acid and an amine.

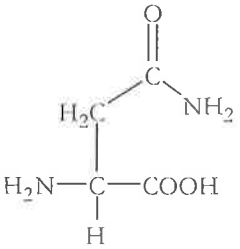
8. There are 22 different amino acids found in nature. Two were shown in Model 1. Additional examples are shown below. With your group, write one or two grammatically correct sentences to describe how these amino acids are similar and how they are different. Use the terms R-group, amine group, and carboxyl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



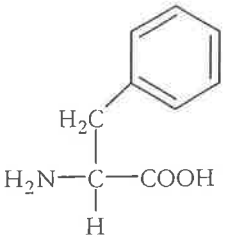
Glycine (Gly)



Cysteine (Cys)



Asparagine (Asn)



Phenylalanine (Phe)

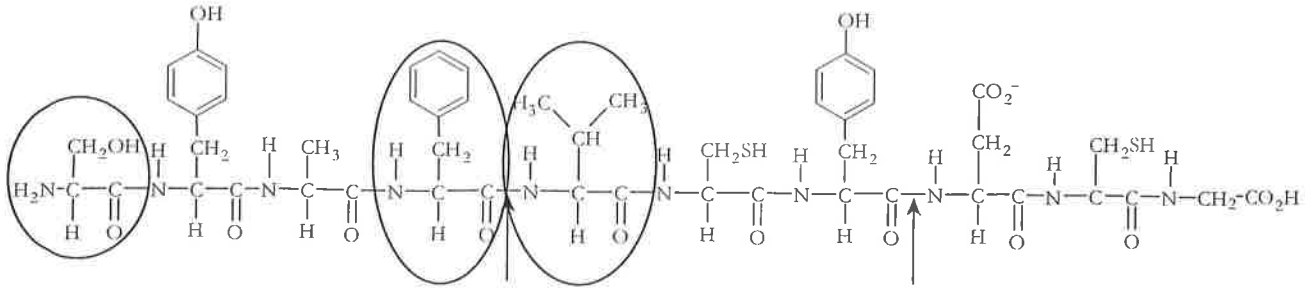
Amino acids have a central carbon with a hydrogen, amine, carboxyl group, and R-group attached. The R-group varies from one amino acid to another.

Model 2 – Protein Structure (Part A)

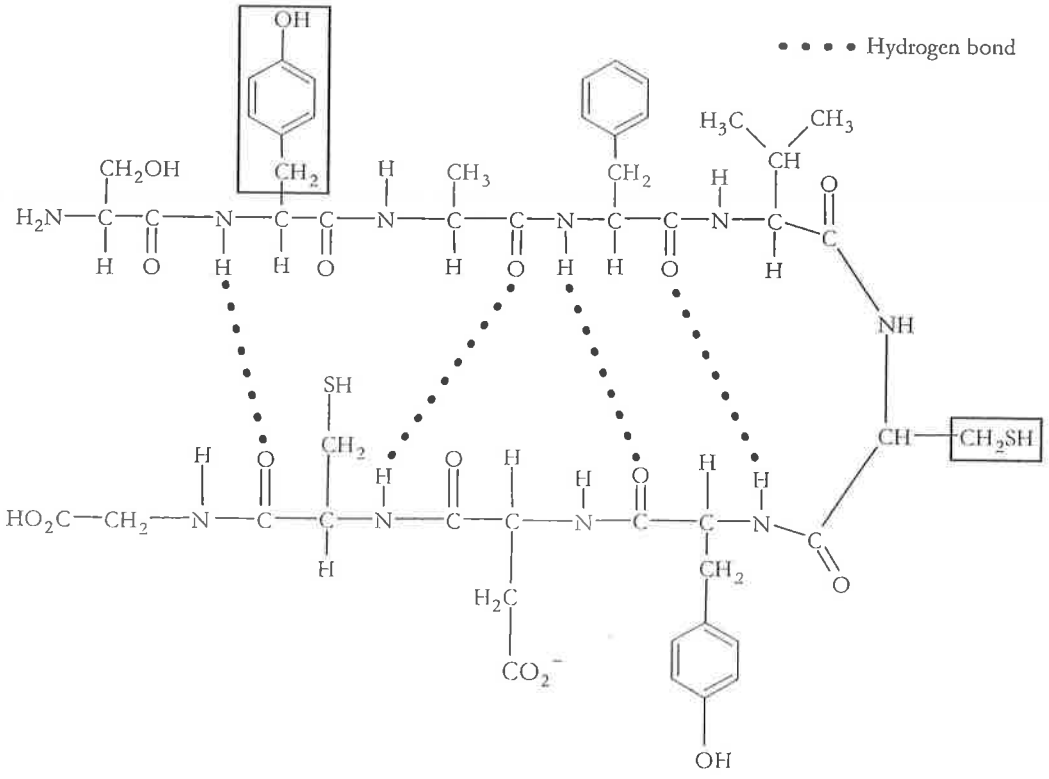
Primary Structure

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.

   See Model 2.

   b. Circle three separate amino acids that were joined together to make the polypeptide.

   See Model 2.

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.

    The primary structure of a protein is the sequence of the amino acids that make up the protein chain.

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

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

    Hydrogen bonds.

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

    The hydrogen bond goes from the hydrogen atom in the N—H group in the peptide bond to the double-bonded oxygen in the carboxyl group.

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

    Answers may vary. See Model 2.

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

    The R-groups do not interact in the secondary structure as shown.

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

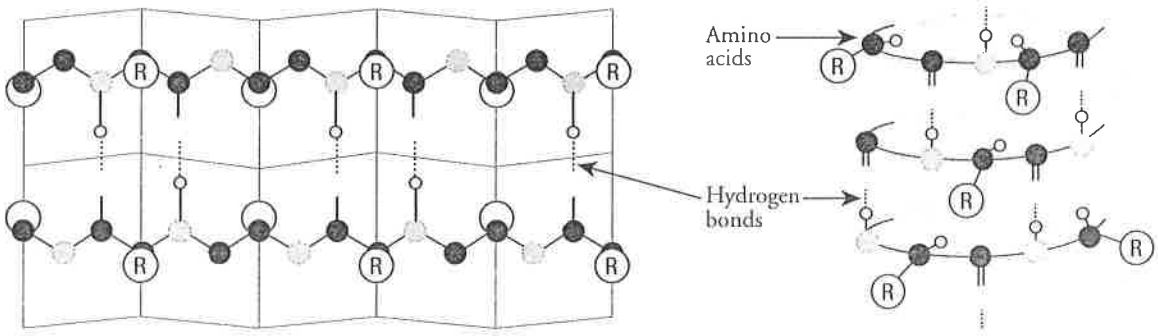
    a. Which drawing represents an α-helix, Molecule 1 or Molecule 2? Explain your reasoning.

    Molecule 2 is the α-helix because it is coiled, i.e. in a helical shape.

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

    Molecule 1 is the β-pleated sheet, because it is folded (pleated) like a fan.

Molecule 1 Molecule 2

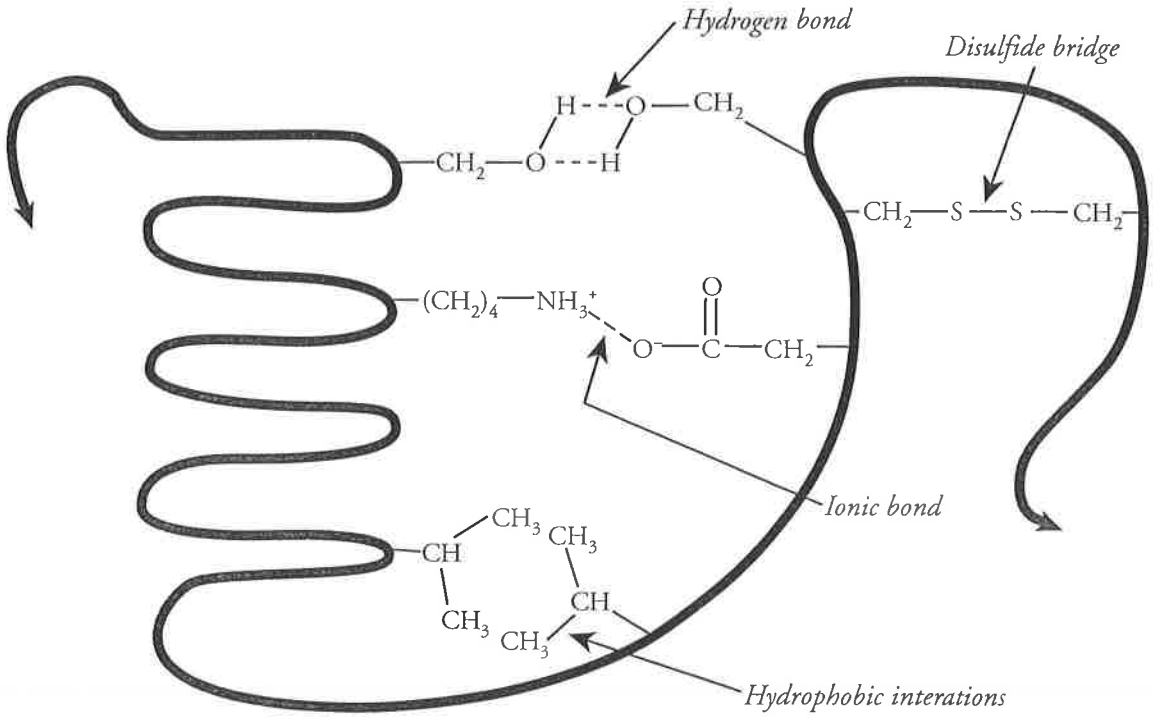


15. With your group, write a grammatically correct sentence that summarizes how the secondary protein structure is formed from the primary structure.

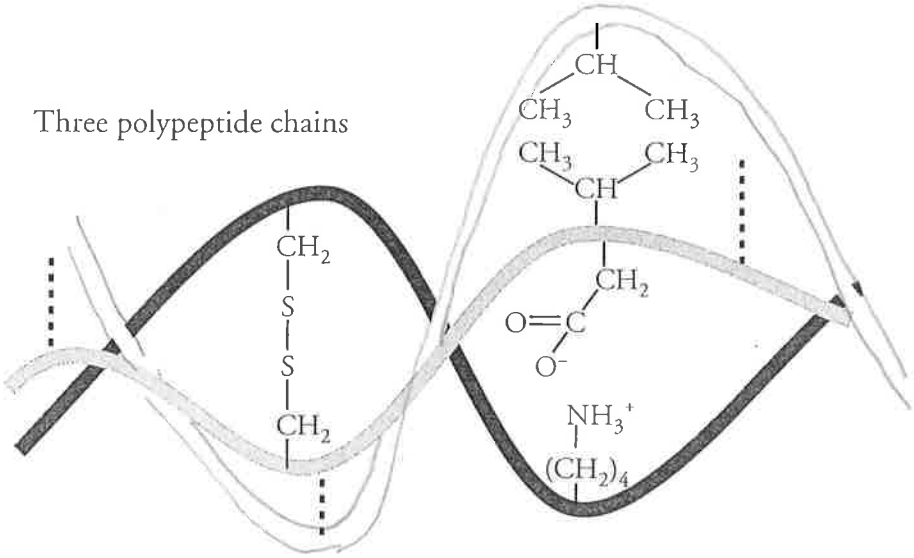
    The secondary structure is formed by hydrogen bonds holding two different parts of the primary structure together into a folded or coiled molecule.

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

    See Model 3.

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

    The bonds or interactions are between R-groups.

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

    Bonds that determine secondary structure occur between the oxygen and hydrogen atoms of the carboxyl and amine groups respectively, not the R-groups.

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?

    The R-groups would need to contain alcohols (O–H), acids (COOH) or amines (NH_2)—polar groups that would contain either oxygen or hydrogen on the end of a polar bond.

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?

    The R-groups would need to be nonpolar, containing only hydrocarbon chains or rings.

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

    One.

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?

    Three.

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

    Disulfide bridges, ionic bonds, hydrophobic interactions, and hydrogen bonds.

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

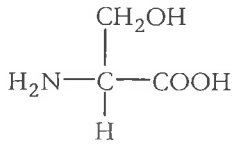
a. Tertiary protein structure.

Tertiary structure is formed by further folding of the amino acid chain (beyond secondary structure), and is held together by various types of bonds between R-groups.

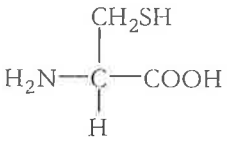
b. Quaternary protein structure.

Quaternary structure is formed when two or more polypeptide chains that make up a protein associate with one another and are held together by bonds between their R-groups.

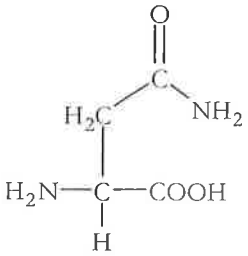
22. Imagine a protein chain that includes the following amino acids among several others.



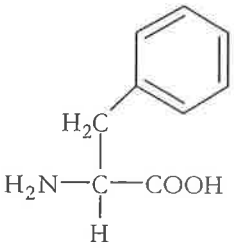
Serine



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?

All of the amino acids can participate in hydrogen bonding to stabilize secondary structure.

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?

Cysteine.

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?

Phenylalanine.

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?

Hydrogen bonds.