Scott Seiple
AP Biology Lesson Plan

Lesson: Primary and Secondary Structure of Proteins

Purpose:

1. To understand how amino acids can react to form peptides through peptide bonds.
2. Students will be able to understand how amino acids can form secondary structures through hydrogen bonds.

Objective:

Students will be able identify peptide bonds in proteins and describe the overall reaction between amino acids that create peptide bonds.

Students will be able to describe how hydrogen bonding can form the secondary structure of proteins.

Students will be able to describe alpha-helices and beta-sheets structure and formation.

Materials:

1. 3 models of α-helix
2. Protein structure guided inquiry exercise

Procedure:

1. Attendance and administrative stuff. Break students into lab groups. (5 min)
2. Review basic functions of proteins and the structure of amino acids.
3. Distribute POGIL to students. Ask students to complete the first page of the exercise. (10 min)
   a. Monitor progress/provide guidance during completion of exercise.
4. Review answers to Primary Structure POGIL. (5 min)
5. Students should work on the Secondary Structure second of the POGIL. (20 min)
   a. Three groups will start on the alpha-helix section of the exercise while three groups will start on the beta-pleated-sheet section of the exercise.
   b. After 10 minutes, groups will switch.
   c. Group progress is monitored throughout the completion of the exercise.

6. Wrap-up. Go over the answer to the last question of the POGIL. Collect group sheets. Inform students that full answers will be discussed during class the next period. Assign HW. Read p. 71-80 in Campbell and Reece. Answer 6, 11, 13 on p. 86 in Campbell and Reece

(2 min)

Assessment:

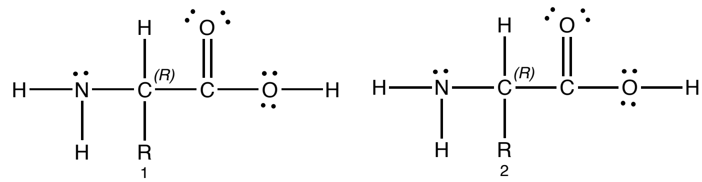
Immediate: Group answers to POGIL exercise
Next day: Answers to HW problems
Later: Unit test

Introduction to Protein Structure

Proteins are composed of extended chains of chemically bonded amino acids. All proteins are said to have at least three levels of organization: primary, secondary, tertiary. Some proteins have an even higher level of organization called the quarternary structure. In this exercise, you will investigate the primary and secondary structure of proteins.

Primary Protein Structure and the Peptide Bond

Look at the two amino acids below. These two amino acids will react with one another in such a way as to produce chemical bond between the two amino acids and water. This kind of reaction is called a dehydration or condensation reaction.



1. Circle an area between the two molecules that can easily give off a water molecule.

2. In the space below show the *dipeptide* that results when the two amino acids react with one another. Circle the peptide bond (the new bond that you formed).

3. Now show the *tripeptid*e that will form when a third amino acid reacts with your new dipeptide. Circle the peptide bonds.

The covalent sequential arrangement of amino acids joined by peptide bonds in a protein is called the primary structure of the protein. For example, if a protein has the following amino acid sequence, Ala-Tyr-Thr-Glu-Phe-Glu-Met-Leu-Ile, that sequence makes up the primary structure of that protein.

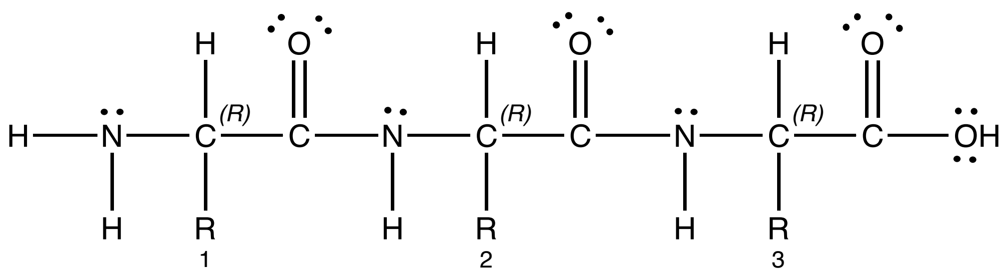
4. How are peptide bonds related to the primary structure of proteins?

5. The end of a protein containing an amino acid with a free $-NH_2$ or $-NH_3^+$ is called the N-terminus of the protein while the end of an amino acid with a free –COOH or $-COO^-$ group is called the C-terminus. By convention, proteins are always said to start with the N-terminus and end with the C-terminus. Label the N-terminus and the C-terminus of the peptide you created in problem number three.

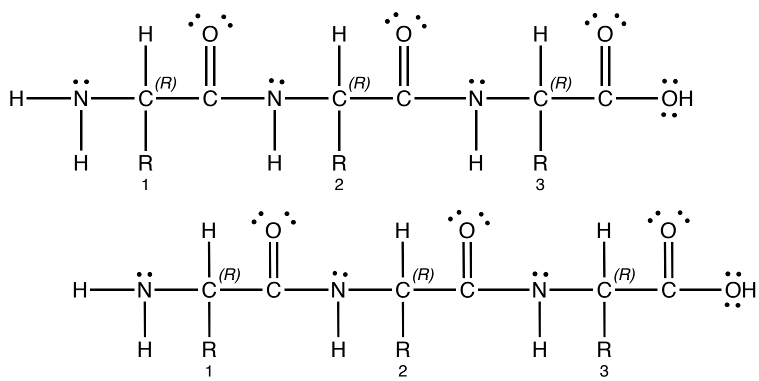
Interactions Between Amino Acids – Secondary Peptide Structure

Proteins do not exist simply as strands of amino acids, the amino acids residues within a protein are able to interact with one another in specific ways to form structures that are of greater significance than just the

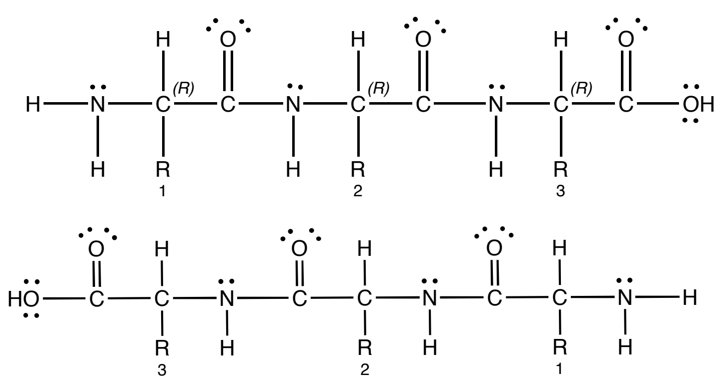
Look at the tripeptide chain below. Use δ^+ and δ^- notation to show where differences in electronegativity can be found.



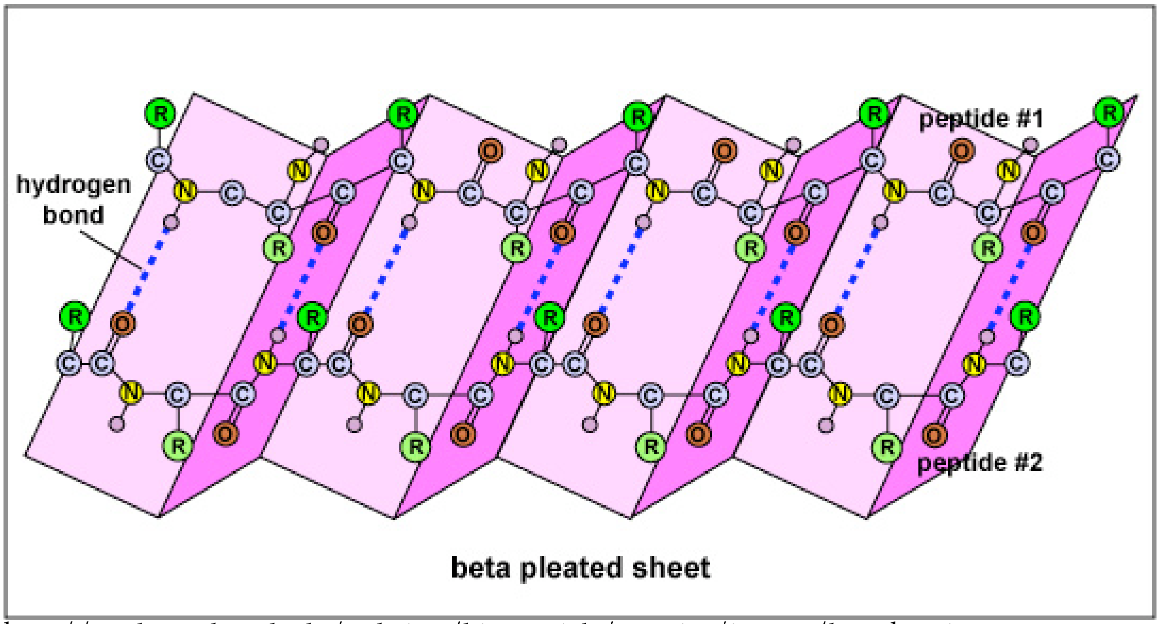
The areas you just indicated above are all areas that can potentially participate in hydrogen bonding. Now look at the two tripeptides given below. Using dashed lines, show how then can hydrogen bond with one another.



Look at the Lewis diagrams below. This time the two tripeptides are arranged differently. Is hydrogen bonding still possible? Use dashed lines to show any hydrogen bonds that can form.



In proteins, an extended chain of amino acids can fold back and come close enough to one another to form hydrogen bonds. When this happens repeatedly a sheet of amino acids joined by peptide bonds is formed. This is called a β-sheet or a β-pleated sheet. It's called a pleated sheet because proteins are, just like all structures, three-dimensional, and the three dimensional arrangement of the a β-sheet has a pleated arrangement to it. A 3-D image of a pleated sheet can be seen below.



http://student.ccbcmd.edu/~gkaiser/biotutorials/proteins/images/betasheet.jpg

A parallel pleated sheet has amino acids in an arrangement so that the nitrogen terminus of both amino acids is on the same end of the sheet while an antiparallel pleated sheet is arranged in a method so that the nitrogen terminus of the amino acid are on the opposite side the sheet.

Which of the two arrangements (parallel or antiparallel) from the previous exercise will form the stronger sheet? Explain.

Now, look at one of the three peptide models set up around the room (they are all the same). Using grammatically correct sentences, describe the structures that you see.

This is another secondary structure found in proteins called an α-helix. Look carefully at the alpha-helix. Are there any forces that can be found that might cause the helix to maintain this specific structure? What are they?

Again, using grammatically correct English, describe the origins of the forces that make would cause peptide chain to form. Be specific. For example describe exactly which atoms are participating in

α-Helices almost always rotate in a clockwise or right-handed direction. Explain why it is virtually impossible to have an alpha helix that rotates in counterclockwise or left-handed direction.

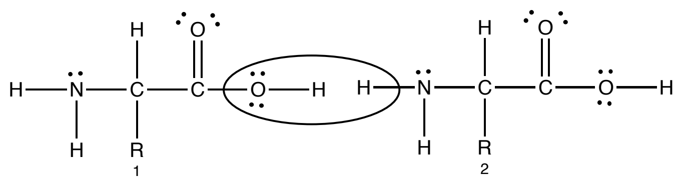
α-helices and β-pleated sheets are examples of secondary protein structures. Secondary protein structures are units that make up common structural motifs found within proteins, but they are not the overall structure of the protein. For example, β-sheets are often found in proteins, but the entire structure of the protein is not a simple β-sheet. Secondary structures of proteins are often determined by one particular type of bonding. What type of bonding is this?

Introduction to Protein Structure

Proteins are composed of extended chains of chemically bonded amino acids. All proteins are said to have at least three levels of organization: primary, secondary, tertiary. Some proteins have an even higher level of organization called the quarternary structure. In this exercise, you will investigate the primary and secondary structure of proteins.

Primary Protein Structure and the Peptide Bond

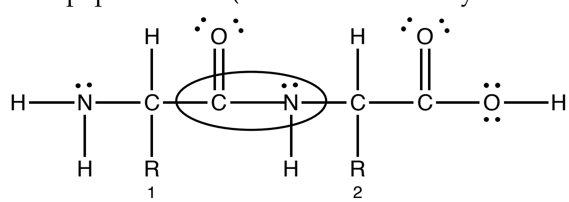
Look at the two amino acids below. These two amino acids will react with one another in such a way as to produce chemical bond between the two amino acids and water. This kind of reaction is called a dehydration or condensation reaction.



1. Circle an area between the two molecules that can easily give off a water molecule.

The –OH bond from the amino acid on the left and an H bonded to nitrogen should be circled.

2. In the space below show the *dipeptide* that results when the two amino acids react with one another. Circle the peptide bond (the new bond that you formed).



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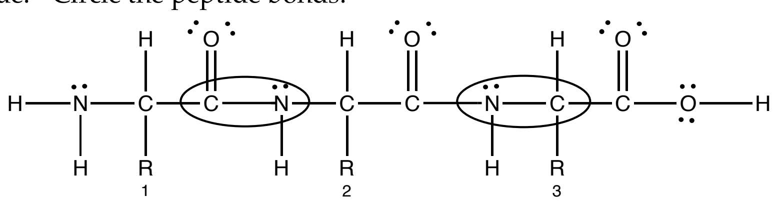
N-terminus



C-terminus

The covalent sequential arrangement of amino acids joined by peptide bonds in a protein is called the primary structure of the protein. For example, if a protein has the following amino acid sequence, Ala-Tyr-Thr-Glu-Phe-Glu-Met-Leu-Ile, that sequence makes up the primary structure of that protein.

4. How are peptide bonds related to the primary structure of proteins?

The particular order of amino acids joined by peptide bonds determines the structure of the proteins

5. The end of a protein containing an amino acid with a free $-NH_2$ or $–NH_3^+$ is called the N-terminus of the protein while the end of an amino acid with a free –COOH or $–COO^-$ group is called the C-terminus. By convention, proteins are always said to start with the

N-terminus and end with the C-terminus. Label the N-terminus and the C-terminus of the peptide you created in problem number three.

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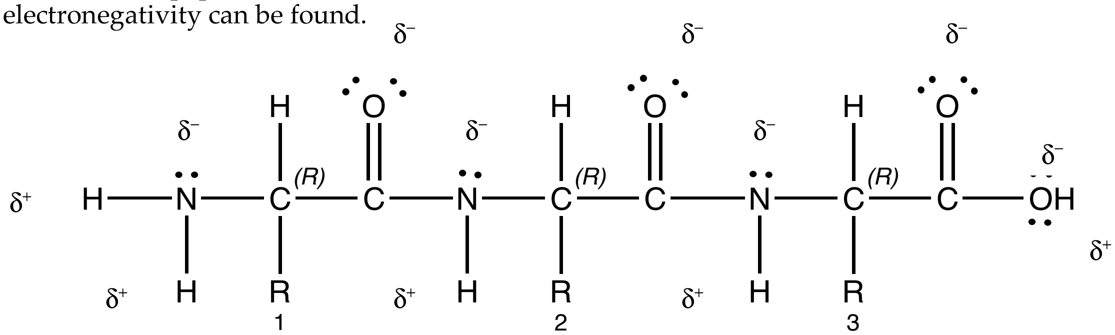

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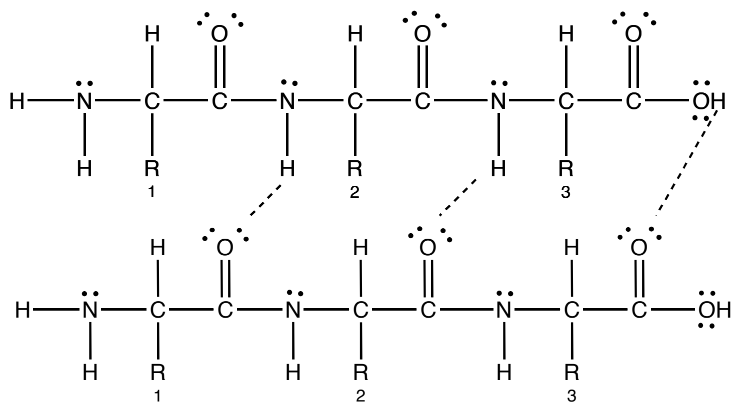

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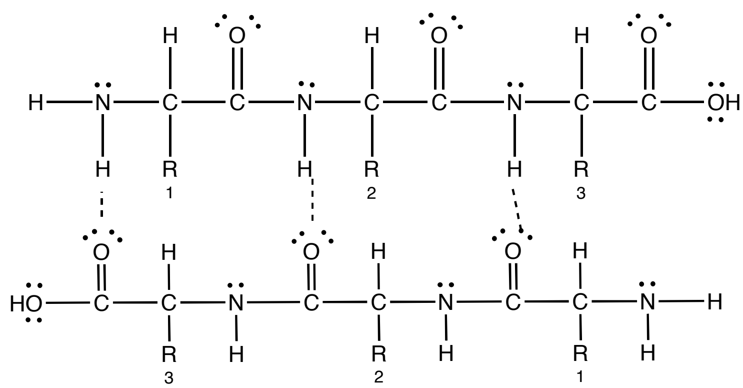
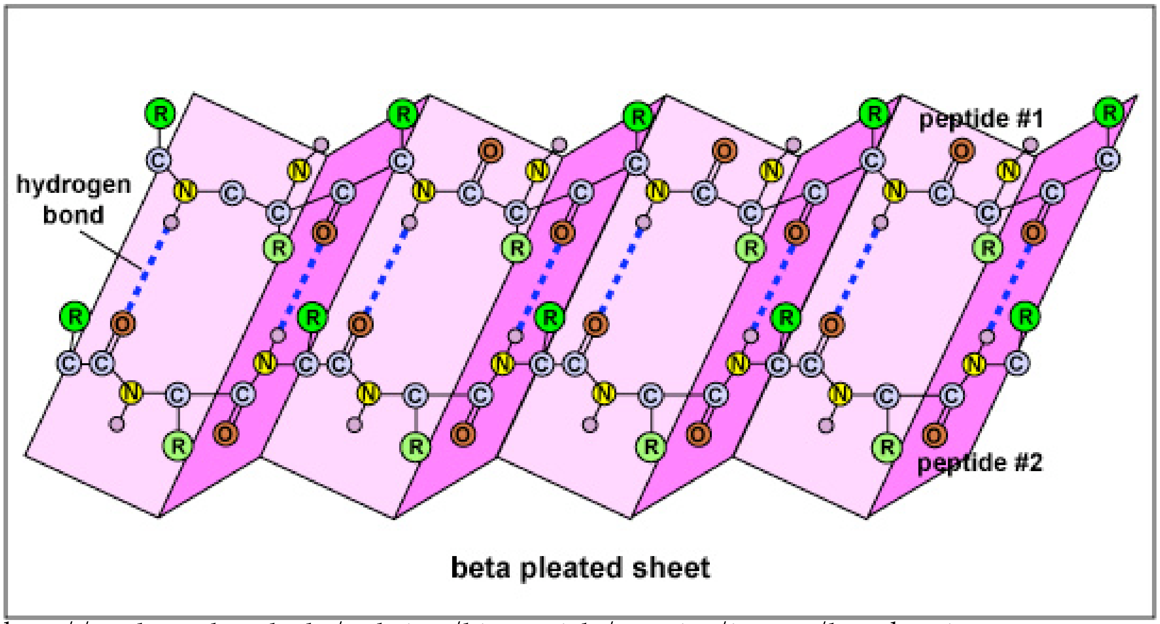


In proteins, an extended chain of amino acids can fold back and come close enough to one another to form hydrogen bonds. When this happens repeatedly a sheet of amino acids joined by peptide bonds is formed. This is called a β-sheet or a β-pleated sheet. It's called a pleated sheet because proteins are, just like all structures, three-dimensional, and the three dimensional arrangement of the a β-sheet has a pleated arrangement to it. A 3-D image of a pleated sheet can be seen below.



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A parallel pleated sheet has amino acids in an arrangement so that the nitrogen terminus of both amino acids is on the same end of the sheet while an antiparallel pleated sheet is arranged in a method so that the nitrogen terminus of the amino acid are on the opposite side the sheet.

Which of the two arrangements (parallel or antiparallel) from the previous exercise will form the stronger sheet? Explain.

The first structure is parallel. The N-terminus for each chain is on the same side.

The second structure is anti-parallel. The N-terminus for the chain are on opposite sides of the paper.

Now, look at one of the three peptide models set up around the room (they are all the same). Using grammatically correct sentences, describe the structures that you see.

The peptide forms a spiral shape. The R-groups are pointing away from the spiral.

This is another secondary structure found in proteins called an α-helix. Look carefully at the alpha-helix. Are there any forces that can be found that might cause the helix to maintain this specific structure? What are they?

There are some areas where hydrogen bonding can occur between the amino acids that make up the spiral.

Again, using grammatically correct English, describe the origins of the forces that make would cause peptide chain to take on this form. Be specific. For example describe exactly which atoms are participating in any interactions.

Hydrogen bonds are occurring. The atoms participating in the hydrogen bonds are the H from a N-H bond and the O from a C=O bond. The participants in the hydrogen binding are four amino acids apart.

α-Helices almost always rotate in a clockwise or right-handed direction. Explain why it is virtually impossible to have an alpha helix that rotates in counterclockwise or left-handed direction.

If the helices rotate in a counterclockwise direction, the R-groups will point toward the center of the spiral where strong steric interactions will occur.

α-helices and β-pleated sheets are examples of secondary protein structures. Secondary protein structures are units that make up common structural motifs found within proteins, but they are not the overall structure of the protein. For example, β-sheets are often found in proteins, but the entire structure of the protein is not a simple β-sheet. Secondary structures of proteins are often determined by one particular type of bonding. What type of bonding is this?

Hydrogen bonding