



**Biological
Sciences
Initiative**



3-Dimensional Protein Structure

SUMMARY

This activity is designed to help students understand how proteins assume a unique 3-dimensional structure. In addition, this activity covers how a mutation can lead to a change in the 3-dimensional structure of a protein.

LEARNING OBJECTIVES

- Understand that proteins are made of amino acids
- Be familiar with the characteristics of the different classes of amino acids
- Understand that each protein has a unique 3-dimensional structure.
- Understand why it is important that each protein has a unique 3-dimensional structure.
- Understand how the different classes of amino acids contribute to the unique 3-dimensional structure of a protein.
- Explore how changes in the amino acid sequence of a protein (due to a mutation) can alter the 3-dimensional structure of a protein.

INTENDED GRADE LEVEL(S)

Advanced high school biology
AP biology

COLORADO STATE STANDARDS ADDRESSED

- STANDARD 3: Life Science: Students know and understand the characteristics and structure of living things, the processes of life, and how living things interact with each other and their environment.

MATERIALS INCLUDED IN THIS ACTIVITY PACKET

(Include only those items in list that are part of the activity packet)

- Pre-activity Exploration
- Background and Review Information
- Student Activity Worksheet(s)
- Teacher Worksheet Key



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3-Dimensional Protein Structure Pre-Activity Exploration

Materials:

Each student will need
2 pieces of origami paper
instructions for folding origami paper

Instructions:

Compare your two pieces of origami paper. An unfolded protein is a long chain of amino acids and is represented by the unfolded piece of origami paper.

Do your two pieces of origami paper look the same or different?

Do you think that two unfolded proteins would look the same or different?

Next, choose one of the animals described in the directions. Fold one piece of origami paper into the shape of the animal you chose.

Choose a second animal described in the directions and fold your second piece of origami paper into that shape.

Now, do your two pieces of origami paper look the same or different?

Do you think that two folded proteins would look the same or different?

Observe how pieces of paper that had the same shape at the beginning can be folded into very different shapes. The same is true of proteins. They all start out as long chains of amino acids but end up having very different 3-dimensional shapes.



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3-Dimensional Protein Structure Background and Review Information

Review:

Before you begin this activity, you should be familiar with the following terms and concepts:

- What is a protein?
- What is an amino acid?
- Proteins are composed of long chains of amino acids.
- Be familiar with the following abbreviations for common elements
 - C – carbon
 - O – oxygen
 - N – nitrogen
 - P – phosphate
 - H – hydrogen

Background Information

Protein function and specificity

Most people think of proteins being found in muscle and for allowing us to move. This is just one of the many functions of proteins. Proteins do everything for us! Some of the many functions proteins serve are listed below

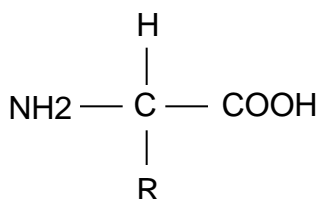
- Muscles are proteins that allow movement.
- Enzymes are proteins and control all the chemical reactions in our bodies.
- Hormones are proteins and act as signals to tell the cells of our body what to do when.
- Receptors are proteins that are found on the surface of our cells and allow our cells to respond to different signals.
- Hemoglobin is a protein that carries oxygen to the cells of our bodies.
- Antibodies are proteins that allow our bodies to fight off invaders.

Since there are many different proteins in our body, each serving a different function, it is important that each protein have a unique structure so that it can serve its unique function.

All proteins are long chains of amino acids. The unique structure of each different protein is determined by how this protein folds. This situation is similar to that you observed in the exploration activity, where two pieces of origami paper that looked the same could be folded into two unique looking animals.

Amino acids

There are 20 different amino acids. All amino acids have a similar structure. Each is composed of an amino (NH₂) group, a carboxyl (COOH) group, and an R group. The R group varies from amino acid to amino acid. Each of the 20 amino acids has a different R group.



The different R groups have different sizes, shapes, and charges. The R group gives each amino acid its individual characteristics.

The different amino acids are shown on the last page of the background information.

Different classes of amino acids

Amino acids can be grouped together based on the characteristics of their R groups. The different amino acids in each group are shown on the last page of the background information.

Non-polar amino acids are hydrophobic. “Hydrophobic” means fear of water. Hydrophobic, or non-polar, amino acids are those that do not like to be in contact with water because their R groups have no areas that are charged. These amino acids have no oxygen (O), nitrogen (N) or phosphate (P) in their R groups. Instead these amino acids have R groups primarily composed of carbon (C) and hydrogen (H) or ring structures.

Look at the sheet of amino acids on the last page. Note three non-polar amino acids below.

- 1.
- 2.
- 3.

Polar amino acids are hydrophilic or water loving. These amino acids have OH or SH groups in their R groups. These OH or SH groups carry a partial charge, and are thus attracted to water.

Look at the sheet of amino acids on the last page. Note three polar amino acids below.

- 1.
- 2.
- 3.

Charged amino acids have either a positive or negative charge in their R groups.

Look at the sheet of amino acids on the last page. Note three charged amino acids below. Following each amino acid listed, note whether it has a positive or negative charge.

- 1.
- 2.
- 3.

Protein folding and 3-dimensional shape

Proteins are composed of long chains of amino acids. The order in which these different amino acids appear will determine the 3 dimensional shape of the protein. Interactions between the different R groups will cause the protein to assume and maintain a specific structure. When proteins fold, different amino acids that are distant from each other in the long chain of amino acids, may be near each other. This is analogous to the way in which folding the origami paper brought opposite corners in contact with one another.

Because the human body is composed primarily of water, most proteins in the human body are dissolved in water. Thus, when proteins fold, they will assume a structure such that the side chains of most hydrophobic amino acids are on the inside of the molecule near each other. This is because they want to avoid water.

Polar amino acids will like to be near water and thus will be found on the portions of the protein in contact with water.

Positively charged side groups will repel one another. Instead the positively charged side groups will be attracted to negatively charged side groups. The attractive force between positive and negative charges are some of the forces which help a protein maintain its structure.

Di-sulfide bonds can lead to bridges between cysteines found in different portions of the protein. The bond between the two sulfurs is a covalent bond and forms a yet stronger force holding the shape of the protein.



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3-Dimensional Protein Structure Student Worksheet

LEARNING OBJECTIVES

- Understand that proteins are made of amino acids
- Be familiar with the characteristics of the different classes of amino acids
- Understand that each protein has a unique 3-dimensional structure.
- Understand why it is important that each protein has a unique 3-dimensional structure.
- Understand how the different classes of amino acids contribute to the unique 3-dimensional structure of a protein.
- Explore how changes in the amino acid sequence of a protein (due to a mutation) can alter the 3-dimensional structure of a protein.

MATERIALS

Each student will need
the origami animals they folded earlier in the pre-activity exploration.
A copy of the myosin folding exercise (if you are doing this portion)

INSTRUCTIONS

Start with one of your folded animals. Choose a place on the animal where two parts of the paper have been brought into contact during the folding process. In a protein, these parts would be held together by an attractive force. With a pen, mark a “-“ on one part and a “+” on the other part.

Repeat this process for five other areas brought into contact during the folding process.

With the second folded animal, similarly mark five pairs of “-“s and “+”s.

Unfold your two animals. Look at the pattern of positive and negative charges.

Do the two pieces of paper show positive and negative charges in the same place?

The two pieces of paper with the differently placed positive and negative charges are representative of two different unfolded proteins. Although unfolded proteins are all long chains of amino acids, the order in which positively and negatively charged amino acids occur differs. Because of differences in the order of amino acids, the folded proteins will differ.

If you tried to fold these two pieces of paper into the same animal (two identical animals), would the pattern of positive and negative charges fit? (would you end up with two positive charges repelling each other?)

The affect of mutations on protein folding

Change one of your positive signs to a negative sign. Try to refold your animal.

Note that there are now two negatively charged portion next to each other. In a protein these two negative charges would repel one another and would prevent the protein from folding in this manner. This is representative of one of the ways that mutations lead to changes in protein structure that result in a loss of function of that protein, or altered function of that protein.



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**Title of Activity Packet
Teacher Worksheet Key**

Answers to pre-activity exploration

Instructions:

Compare your two pieces of origami paper. An unfolded protein is a long chain of amino acids and is represented by the unfolded piece of origami paper.

Do your two pieces of origami paper look the same or different?

They should look basically the same, color may differ

Do you think that two unfolded proteins would look the same or different?

Answers may vary. Unfolded proteins are all long chains of amino acids, length may differ and the order of amino acids will differ.

Next, choose one of the animals described in the directions. Fold one piece of origami paper into the shape of the animal you chose.

Choose a second animal described in the directions and fold your second piece of origami paper into that shape.

Now, do your two pieces of origami paper look the same or different?

They should now look quite different.

Do you think that two folded proteins would look the same or different?

One would expect two folded proteins to look different.

Observe how pieces of paper that had the same shape at the beginning can be folded into very different shapes. The same is true of proteins. They all start out as long chains of amino acids but end up having very different 3-dimensional shapes.

Different classes of amino acids

Amino acids can be grouped together based on the characteristics of their R groups. The different amino acids in each group are shown on the last page of the background information.

Non-polar amino acids are hydrophobic. "Hydrophobic" means fear of water. Hydrophobic, or non-polar, amino acids are those that do not like to be in contact with water because their R groups have no areas that are charged. These amino acids have no oxygen (O), nitrogen (N) or phosphate (P) in their R groups. Instead these amino acids have R groups primarily composed of carbon (C) and hydrogen (H) or ring structures.

Look at the sheet of amino acids on the last page. Note three non-polar amino acids below.

Glycine, alanine, valine, leucine, isoleucine, methionine, phenylalanine, tryptophan, proline

Polar amino acids are hydrophilic or water loving. These amino acids have OH or SH groups in their R groups. These OH or SH groups carry a partial charge, and are thus attracted to water.

Look at the sheet of amino acids on the last page. Note three polar amino acids below.

Serine, threonine, cysteine, tyrosine, asparagine, glutamine

Charged amino acids have either a positive or negative charge in their R groups.

Look at the sheet of amino acids on the last page. Note three charged amino acids below. Following each amino acid listed, note whether it has a positive or negative charge.

Positively charged – aspartic acid, glutamic acid

Negatively charged – lysine, arginine, histidine