Grade: 11	**Subject:** Biology 20	**Unit:** Macromolecules and Digestion (Body Systems)

Rationale

Complex protein structure has always been a difficult topic to broach with Biology 20 students that don't necessarily have any chemistry background. The functional importance of protein substructure and the resulting protein shapes is hard to visualize.

In this activity, students will create a protein library as a class. Each group will assemble a protein structure beginning with its primary amino acid sequence structure. They will continue to twist and shape their molecules based on the rules outlined in the student handout (page 3-4) to develop secondary and tertiary protein structure. Next, students will explore quaternary structure by joining with another group and merging their protein subunits into a more massive protein.

Students will then papier maché their final products. This is intended to represent the 3D space their proteins would take up in a cellular environment. Though most of the papier machéd space is hollow, this is also true of the makeup of large protein molecules. The boundaries where the molecules do and don't exist are determined more by the intermolecular forces at play than by the physical space those molecules exist in. Lastly, students will paint on a few potential binding sites for their proteins. Though these are largely hypothetical, getting students to understand that unique structure and interesting shape is critical to the function of a protein is a crucial part of macromolecule biochemistry.

Background Information

The Derda research group at the University of Alberta is interested in creating a ligand search technique. To do this, Dr. Derda and his team mass produce genetically different peptides through mutation of one section of DNA on a bacteriophage. Using restriction enzymes, the lab splices multiple mutated DNA variants onto the circular DNA of a bacteriophage. The targeted restriction site adds the resulting peptide onto the end of the bacteriophage capping protein. By using a third party vector (the bacteriophage) to produce the protein, researchers ensure that the DNA responsible for the resulting peptide is protected within the capsule of the bacteriophage.

Though the chemistry involved in this process is far out of the realm of high school biology (not to mention Bio 20), protein shape and structure remains a vital element in the understanding of biochemistry. Finding a way to visualize this process is crucial to students understanding the critical nature of shape itself. It also creates a permanence of protein biochemistry when multiple senses are involved.

Prerequisite Knowledge

Students should already have had a quick lesson on protein structure. If necessary, the teacher can use the second page of this lesson (student handout) as a guide. The process of how amino acid sequences are determined (transcription and translation) is **not** a prerequisite to this lesson.

Curriculum Connections:

- **20–D1.2k** describe the chemical nature of carbohydrates, lipids and **proteins and their enzymes**; i.e., glycosylases, lipases and proteases
- **20–D1.3k** explain enzyme action and factors influencing their action; i.e., temperature, pH, substrate concentration, feedback inhibition, competitive inhibition
- **20–D1.2sts** explain that the products of technology are devices, systems and processes that meet given needs; however, these products cannot solve all problems
- **20–D1.3s** analyze data and apply mathematical and conceptual models to develop and assess possible solutions
- **20–D1.4s** work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

Lesson Objectives/Concepts

- Students will familiarize themselves with the levels of protein structure
- Students will create an object that is representative of a protein molecule
- Students will compare and contrast protein molecules and determine the cause of the differences they observe

Materials:

- Masking Tape (thin width is better)
- Wire lengths (pre-cut to 1 or 1.5m before the class)
- Black Pen/Sharpie (class set)
- Camera (Remind students to bring these)
- Papier maché paste solution (4 parts white glue - 1 part water, mixed until smooth and even)
- Newsprint or other light paper
- Margarine/Yogurt containers (class set)
- One color of paint and a paintbrush (Day 2 only), markers could be used in a pinch

Time: 1.5 - 2 class periods

Introductions

The teacher should read the student handout introduction with the class explaining the real world connections this project has. The second page of the handout is a quick review of protein structure and is there for student reference. If you wish, this might make a good review of protein structure.

Activities/Procedure

Depending on the level of your students, you may want to read through the procedure of this activity before letting your students loose. Make sure craft supplies are kept hidden away as they will not be necessary for the first ⅔ of the lesson. Ensure that students understand before beginning that they are required to document their process as they go. This is essential to completion of the activity. Otherwise, you will have very little to go off of when attempting to mark their projects.

1. **Primary Structure** - students will be adding tape flags to their wire backbones. Be sure to emphasize to students the importance of randomizing their amino acid sequence. Tell them to try and use a variety of amino acids, while making sure to include the necessary elements listed in their student handout (10 cysteine, 10 proline/serine/threonine)
2. **Secondary Structure** - students will begin twisting and folding their structures into alpha helices and beta-pleated sheets. Remind students that the majority of their protein should have these features, but that there will obviously be regions that are not contained within a secondary structure element.
3. **Tertiary Structure** - students will form right angle bends at the **proline/serine/ threonine** amino acids. They will also join sections of their molecules to form **cysteine-cysteine** disulphide bridges. After this step, students will be asked to stop and trade molecules with another group. They will do a peer assessment on their partner group's molecule before continuing. Because of this, it may be worth trying to push your students along so they finish at similar times.
4. **Quaternary Structure** - students will join with the group they just evaluated and find a way to combine their molecules. After, they will use the papier maché to coat their finished protein and turn it into a 3D object. This process is messy and should be done in a lab room if at all possible. You should remind students multiple times to try to remove as much maché liquid as possible to ensure the models dry evenly.
5. **Extension Questions** - These questions can be done with pen and paper. They are a lot more effective, however, if they are completed digitally alongside the pictures students have taken all along of their creations. Having the reference point to look back at as they go reinforces what they have learned all along.

Summary

Students will create a 3-dimensional protein model. This includes creating the initial primary structure amino acid chain right through to quaternary bonding with other protein subunits. At the end, students should have a 3-dimensional object with a unique and interesting shape and should have gained a better understanding of how protein structure is developed.

Assessment

Assessment is explained at the end of this document. It is based on a peer assessment completed part way through the activity, extension questions (teacher marked), and a general impression of the final product (teacher marked).

Extensions/Connections

Students could use this activity again when it comes time to talk about specific digestive enzymes (Digestion Unit). It could also be used to explain denaturation caused by temperature or pH (how small changes in the structural components of a protein can radically alter the finished product). These proteins could be used again when talking about immunity (Circulation and Immunity Unit) to help describe the importance of the unique shape and fit of antigens and antibodies. This could be extended to talk about auto-immune disorders, allergies, and vaccinations.

Extension Questions - Answer Key (**/15**)

1. What do the spaces between each tape flag represent? (**/1**)
   A: A peptide bond between the 2 amino acids on either side

2. Why do proteins twist and fold themselves into 3 dimensional shapes? (**/2**)
   A: They do this because linear proteins would have very limited function. Useful protein molecules are defined by their unique shape. This allows them to interact with other molecules such as enzymes, hormones, ligands, or receptors.

3. Research a protein that functions as an enzyme in the body. What is this enzyme called? What does it do? What does it need to bind snugly in its active site? (**/3**)
   A: *Multiple Answers* Eg. Lactase. Its job is to break down lactose (milk sugar) into glucose and galactose subunits. This means it would need to attach itself in some way to the lactose sugar.

4. Why does secondary structure form? How does secondary structure affect the overall shape of the protein? (**/2**)

A: Secondary structure forms because amino acids have hydrogen bond attractions to other amino acids. Depending on where these attractions are, either alpha helices or beta-pleated sheets will form. Secondary structure significantly shortens the overall length of the protein and makes it more compact.

5. In **step #14**, why did you choose the binding sites you did? Explain your logic. (**/2**)
   A: Students can't really be **wrong** here. The best answers will be ones that mention interesting and unique structure. If structural elements are unique (cavities, ridges, finger-like protrusions, etc.) they will be more likely to have behave in an interesting way.

6. Your proteins, as with most enzymes, are mostly hollow inside. Explain why we have papier machéd our structures to make them 3D even though in reality they are largely hollow. (**/2**)
   A: Enzymes, especially larger ones, are mostly empty space. That being said, they do "take up" space in the sense that they prevent other molecules, atoms, etc. from passing through them. This is because of attractive and repulsive forces and areas of electron density that exist within the molecule. Picture a crowd at a busy concert. Even though there are many spaces between the people in the crowd, it isn't necessarily that easy to fit between those spaces.

7. Take a look at some of the other proteins in the class. How do some of them differ from yours? Explain these differences in terms of the different levels of protein structure. It's a great idea to look at some of your fellow students' documented pictures. (**/3**)
   Again, answers will vary. Students need to make a few observations for the first mark. To get the remaining points, students need to explain that the primary structure is really what drives the differences in proteins. Even though all of the primary structures look the same, the sequence and identity of the amino acids is what causes differences later on. Secondary and tertiary structure is where you will start to see physical shape changes, but they are determined by the initial primary structure.

Final Product (**/5**)

When marking the final product, you are looking for signs of a complete and thorough attempt to understand the concepts of protein structure. You are not looking for excellent artwork, but rather for evidence that students have attempted to complete the assignment as intended. You should look at student pictures and the final maché product to establish this final mark out of 5.

Peer Assessment	**/15**
Extension Questions	**/15**
Final Product	**/5**
Total	**/35**