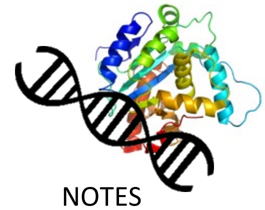

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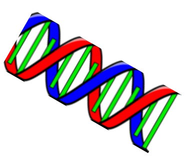
Objectives:

- Articulate an understanding of DNA base pairing, transcription and translation, and represent the process of protein synthesis using a series of models.
- Investigate the composition and properties of amino acids, and model the folding of a protein based on these characteristics.
- Interpret, classify and evaluate proteins according to functions.
- Generalize the relationship between cellular DNA and a unique protein structure.

Background Information



DNA, or deoxyribonucleic acid, can be thought of as the code of life. A molecule containing instructions that make each species unique, DNA is tightly coiled into one or more **chromosomes** and is made of chemicals called nucleotides. **Nucleotides** consist of three parts linked together: a phosphate group, a sugar group, and one of four nitrogen bases. The four nitrogen bases are adenine (A), thymine (T), guanine (G), and cytosine (C). The arrangement of these bases determines the **genetic code**. A particular sequence of DNA that has instructions to make a protein is known as a **gene**. In humans, the DNA instruction book is referred to as the *human genome*. This genome contains about 3 billion bases and 20,000 genes on 23 pairs of chromosomes. In contrast, an *E. coli* bacterium has a genome consisting of a singular, circular chromosome and approximately 4600 genes. (Source: *DNA Fact Sheet*)

Making proteins involves the processes of **transcription** and **translation**. Each DNA molecule contains two copies of the genetic code, found on the **coding**, or sense, **strand** and **template**, or antisense, **strand**. RNA polymerase initiates transcription in a **promoter** region before the transcription start sequence, ATG, unzipping the two strands of DNA. In the nucleus, RNA polymerase then uses the template strand to generate a copy of the sequence in messenger RNA (mRNA). The key difference in the pairing of these bases is that DNA's adenine pairs with mRNA's uracil instead of thymine. After this process is complete, as indicated by a **terminator**, or stopping sequence, the mRNA copy leaves the nucleus and travels out into the cytoplasm of the cell.

In the cytoplasm, the mRNA strand encounters the protein-building machinery, or **ribosomes**. In a process known as translation, the mRNA code is decoded by ribosomes into a series of **codons**, or sets of three nucleotides, resulting in a

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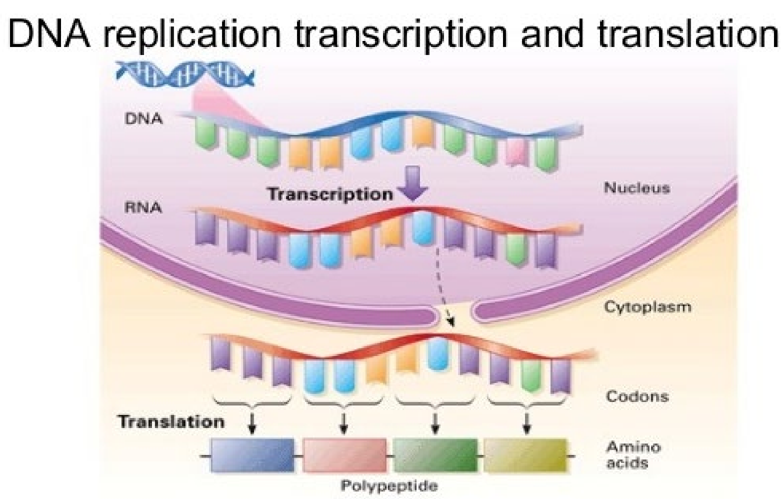
chain of amino acids. After a "stop" codon is encountered, the amino acid chain is released from the ribosome as an active protein. **Proteins** are vital to living cells surviving since they control almost every aspect of life.

A protein is able to carry out its function only after it takes on a particular shape. Proteins take their shapes on their own and are very sensitive to manipulation. This process is called **protein folding**, and occurs in the cytoplasm of a cell. Each amino acid in a protein strand has specific characteristics that influence how the protein folds (ex., hydrophobic, hydrophilic, charge, etc.). Mathematically, there are an extremely large number of ways that a protein may fold, and researching this process can be challenging due to the complexity of the process and the speed at which folding occurs. The process of how proteins misfold, rather than just the end result of misfolded proteins, is believed to be the cause of several diseases, such as Alzheimer's, cystic fibrosis, some cancers, Huntington's, and Mad Cow.

Proteomics is the study of proteins, their structures and functions. According to the Office of Cancer Clinical Proteomics Research (2015) the total number of proteins in human cells is estimated to be between 250,000 to one million. Proteins continually undergo change and concentrations vary from one organism to another. A vast amount of data is generated through the study of proteomics.



Source: https://goo.gl/epmjNw

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Inquiry Overview

In the following activities, students will investigate the protein synthesis process through the development, manipulation and analysis of several hands-on models and exploration opportunities. **It is important for students to realize that throughout this unit, as well as Unit 6, they will be building and studying an actual protein found in a real organism.** This protein will be constructed in Unit 5 and with the assistance of a DNA sequencing tool, identified in Unit 6.

First, students will build a three-dimensional model of a fragment of a DNA molecule, which highlights the significance of nitrogen base pairing and introduces the coding and template strands. These strands will play an important role in the protein synthesis and DNA sequencing processes.

Next, students will use the template strand of their DNA bead model to investigate transcription and translation. In this activity, students will generate a copy of the DNA molecule fragment by pairing each nitrogen base with its corresponding mRNA base. Then, with the assistance of the *Amino Acid Wheel,* students will identify the unique codons, or sequences of three bases, that make up individual amino acids. This activity will conclude with students reviewing the protein synthesis process from initiation (DNA molecule) to completion (chain of amino acids).

In the final activities, students will continue to develop their understanding of proteins while learning about the prevalence and roles of proteins in organisms. Students will analyze their specific protein to determine the manner in which it will fold – a process that must occur in order for a protein to function properly. They will also brainstorm a list of definitions for a series of protein categories. This exercise will pool students' prior knowledge, challenge them to infer meaning, and ultimately come to a consensus to establish a description for each category. Then, after receiving a deck of *More Than Meat Cards*, student teams will work collaboratively to draw connections between a set of proteins and their representative category.

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Activities

Activity 1: Double Your Strand

Objectives:

- Articulate an understanding of DNA base pairing, transcription and translation, and represent the process of protein synthesis using a series of models.

Standards:

NGSS Science and Engineering Practices: SEP1, SEP2, SEP5, SEP8, Crosscutting Concept: Patterns, Structure and Function, HS-LS1.A
Common Core State Standards Mathematics: MP2, MP3, MP8
Common Core State Standards ELA/Literacy: SL.6-8.1, RST.6-8.4

Estimated Time: 45 Minutes

- **5 minutes – Introductory Discussion**
- **20 minutes – DNA Base Pairing Model**
- **15 minutes – Discussion**
- **5 minutes - Debrief**

***Double Your Strand* Materials:**

for each student:
- Student Pages

for each partner team:
- 1, 12" piece of black plastic craft lace
- 1, 12" piece of white plastic craft lace
- 15-20 Green pony beads
- 15-20 Blue pony beads
- 10-15 Yellow pony beads
- 10-15 Red pony beads
- 1 *Double Your Strand* Instruction Card
- 1 Cell Template

for the teacher:
- Roll of masking tape (to be cut into 2" sections)

Advanced Preparation:

- ❑ Organize the pony beads so that each partner team has a collection of 15-20 green and blue and 10-15 yellow and red pony beads. You may choose to place each team's beads in individual plastic cups for ease of distribution.
- ❑ Prepare a T-chart on chart paper to record student responses about DNA and proteins. This document will be referred to throughout Unit 5 and 6. Title one section of the chart "DNA" and the other "Protein".
- ❑ Each partner team will need three 2" pieces of masking tape to create identification flags and secure their DNA strands together. You may choose to prepare these in advance, or simply pass them out while students are working.

Note: Students who are color blind may need the individual pony bead colors separated and labeled.

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Suggested Inquiry Approach:

Host a class discussion to uncover students' initial ideas about DNA and proteins. Record student responses in the appropriate section of the prepared T-chart. Use the following questions if needed to prompt participation:

- **What do you know about DNA?**
- **Why is DNA important?**
- **Where is DNA found?**
- **What do you know about protein(s)? Where have you heard this word?**
- **Where can you find protein(s)?**
- **What do proteins do for you and your body?**

At this time, arrange students into partner teams and distribute the student pages to each learner. Ask a volunteer to read the background information aloud while the other students follow along.

Then, ask students to turn to a partner and summarize what they will be investigating throughout the next several activities. Student answers should indicate that they will they will investigate the process of building a protein from a basic DNA molecule (protein synthesis).

To begin the exploration, distribute a pony bead collection, a white and black plastic craft lace piece, and one *Double Your Strand* Instruction Card to each partner team. *Verify that all teams record the* **color** *of their instruction card onto their student pages – this information will be important as students complete Unit 5 and 6.*

Instruct the students to carefully follow the procedure outlined in their student pages. As students work, circulate the room to answer questions, informally assess learning, and distribute small pieces of masking tape.

Specific information about the coding and template strands is not highlighted in this unit. Student exposure to this concept will be limited to how each strand is involved in the protein synthesis and DNA sequencing processes.

Once students have created the coding and template strands of their DNA molecule fragment, they will take several minutes to make observations. Once students have recorded their thoughts, ask learners to share their findings. Students may notice:

- **Each strand consists of 24 pony beads.**
- **The coding and template strands contain pony beads of different colors (they are not a replica of each other).**
- **There does not seem to be a pattern in the arrangement of pony beads from the beginning of the strands to the end of the strands.**

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- **The red and yellow pony beads appear to "match" while the green and blue beads are paired between the strands.**

Next, students will further investigate the relationship between the nitrogen bases that make up their DNA molecule fragment. Encourage the students to determine which pony bead color represents each nitrogen base by studying the relationship between their bead model and the provided chart. **Students should cautiously record the sequence of the nitrogen bases for each strand – the correct order of these bases is critical!**

Partner teams will then meet with another team with a different colored instruction card to compare their DNA molecule fragments. This opportunity will afford students to verify or refute the ideas that were initially considered when analyzing their own DNA molecule fragment, as well as develop an understanding for several key ideas related to nitrogen base pairs and DNA molecules. Students should finalize their observations and generate additional questions in their student pages. Student comments may suggest:

- **Green represents the base** *Guanine*, **and pairs with** *Cytosine.*
- **Blue represents the base** *Cytosine,* **and pairs with** *Guanine.*
- **Yellow represents the base** *Thymine*, **and pairs with** *Adenine.*
- **Red represents the base** *Adenine*, **and pairs with** *Thymine.*

At this time, inform students that matching nitrogen bases are referred to as **base pairs.**

- **Both DNA molecule fragments have a coding strand that begins with the sequence "ATG". Students may wonder if every coding strand begins with this sequence, and if this is true, if all coding strands also end with the same sequence.**

This question may be further explored by comparing all four DNA molecule fragments (constructed from the four colors of instruction cards). An image of all four molecules being compared side-by-side, titled, "DNA Molecule Comparison", is available in the Teacher Resource folder for this unit at learning.imsa.edu. This would be an appropriate time to verify that all coding strands begin with the same sequence, **ATG**, and therefore it is reasonable to assume that they also end with a "stop" sequence.

Once students have completed the investigation, pass out the Cell Template to each partner team. Then, reconvene all small groups for a large class discussion.

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Debrief Activity 1:

Pose the following questions to review student insights and understandings regarding DNA:

- ***What is DNA and where is it located within a cell?***
- ***How are DNA nitrogen bases arranged?***
- ***What did you notice when you observed your DNA molecule fragment and compared it to that of another partner team? What was similar? What was different?***
- ***Do you believe that your model represents an entire DNA molecule or just a piece of one? What makes you think this?*** [Note: Students will eventually evaluate their entire DNA sequence in Unit 6: DNA Detective.]
- ***What do you think would happen if one of the nitrogen base pairs was matched incorrectly? What could be the significance of this error?***
- ***DNA is the code of life. Your DNA sequence represents a piece of an actual DNA molecule that codes for a protein found in a real organism. In this activity, you will construct the protein, and in the next unit, you will use a DNA sequencing tool to determine the name of the protein and the organism it came from. What do you think your DNA sequence represents?***

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Finally, partner teams will illustrate the first step of protein synthesis on their Cell Template. This template was designed as a tool for students to document each step of the protein synthesis process as discussed in Unit 5.

Ask students to complete the instructions at the bottom of their student page to illustrate **Step 1: DNA Molecule**. While student illustrations and information summaries will vary, all partner teams should illustrate a DNA Molecule twisted into a double helix accompanied by a brief description that may answer several of the questions suggested in the student pages.

Important: Verify that students complete this task within the nucleus, toward the top of the organelle. This will ensure enough space to add the remaining steps as discussed in ensuing activities.

Note: A sample of a completed Cell Template is available in the Teacher Resource folder for this unit at learning.imsa.edu

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Activity 2: Transcription and Translation

Objectives:

- Articulate an understanding of DNA base pairing, transcription and translation, and represent the process of protein synthesis using a series of models.

Standards:

NGSS Science and Engineering Practices: SEP2, SEP3, SEP6, SEP7, SEP8, Crosscutting Concept: Patterns, Structure and Function, HS-LS1-1, HS-LS1.A
Common Core State Standards Mathematics: MP3, MP8
Common Core State Standards ELA/Literacy: RI.6.7, RI.7.7, SL.6-8.1, RST.6-8.4,

***Transcription and Translation* Materials:**
for each student:
- Student Pages

for each partner team:
- 1 Cell Template
- 1 pair of scissors
- 1 *Amino Acid Wheel*
- DNA bead model from Activity 1
- 1 *Transcription and Translation Worksheet*

Estimated Time: 60 Minutes

- **5 min - Introduction**
- **15 min – Transcription**
- **20 min – Translation**
- **20 min – Debrief**

Advanced Preparation:

Prior to beginning the activity, print one *Transcription and Translation Worksheet* for each student. This document, found in the Teacher Resources folder of the Content Classroom for this unit, can be printed in black and white on plain copy paper.

Suggested Inquiry Approach:

Students will continue working in the same partner teams as Activity 1. Verify that all small groups have their Cell Template and DNA molecule fragment (pony bead model) accessible. Also, distribute a *Transcription and Translation Worksheet* to each partner team.

Begin the activity by having a student volunteer read the background information aloud. Then, pose the following questions for students to consider:

- **What do you think the word *transcribe* means? Where have you heard this word before?**
- **What do you think the word *translate* means? Where have you heard this word before?**

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- **Can you predict what happens when a strand of a DNA molecule is *transcribed* and *translated*? Explain.**

Students will work together to complete the **transcription** process, which occurs in the nucleus of the cell. This will entail following a series of instructions that explain how a copy of the template strand is made using mRNA (messenger RNA). Through observation, students will determine the DNA and mRNA base pairs.

At this time, introduce students to **Uracil**, the mRNA nitrogen base that pairs with DNA's adenine.

Once students have completed these steps, take several minutes to discuss the following questions as included in the student pages:

- **What differences do you notice between the DNA bases and mRNA bases? Why do you think there is a difference?**
- **Does the DNA sequence determine the mRNA sequence or does the mRNA sequence determine the DNA sequence? Explain your idea. Why would this be important?**
- **Compare your mRNA sequence to the DNA coding strand sequence of your bead model. What do you notice? Why do you think this occurs?**
- **Where does transcription occur within a cell?**

Next, students will **translate** their mRNA sequence into a strand of amino acids with the help of a tool. At this time, pass out an *Amino Acid Wheel* to each partner team. Select one student to read the background information aloud.

The *Amino Acid Wheel* can be located in the Teacher Resources file in the Content Classroom. There is also a PowerPoint slide available for display.

Allow partner teams adequate time to investigate the *Amino Acid Wheel*. Encourage them to record all observations and questions. When all students have finished, have partner teams take turns sharing one observation and/or question regarding the *Amino Acid Wheel*. Additional questions that could be posed to elicit in-depth student discussion include:

- **What does each of the "letters" within the wheel represent?**
- **What are the words on the outside edge of the wheel? What do you notice about their arrangement?**
- **What do you notice about the pictures, or structures, that correspond to each amino acid?**
- **What do you think an amino acid is made of?**
- **How can we use this resource? What do you think it represents?**

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Students will then translate their mRNA sequence using the *Amino Acid Wheel* by identifying each set of codons, or group of three mRNA bases. This information will be recorded on the *Transcription and Translation Worksheet*. Finally, review student understanding with the following questions:

- **What is the significance of the first amino acid that is joined to the mRNA strand?**
- **Why do you think START and STOP sequences are necessary when a sequence is being read to construct a protein?**
- **Do you believe that your sequence represents a complete protein? Why or why not?**
- **Where does translation occur within the cell?**

Debrief Activity 2:

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Complete this lesson by providing student teams an opportunity to document **Step 2: Transcription** and **Step 3: Translation** processes on their Cell Template.

Students will begin by securing the separated or "unzipped" DNA bead strands to the template in the correct area of the cell. Then, using a pair of scissors, they will cut out the *DNA Template Strand, Transcription,* and *Translation* pieces of the worksheet and arrange these in the correct order and within appropriate locations on the Cell Template. Next to these illustrations, students should include a brief description of what occurs between and within each step. As students complete their work, circulate around the room to check for understanding and answer student questions.

Extension:

If students are interested in viewing additional resources addressing the transcription and translation process, navigate to: https://www.youtube.com/watch?v=bKIpDtJdK8Q. This video does a good job explaining these processes while incorporating illustrations and summarizing key information.

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Activity 3: Protein Folding

Objectives:

- Investigate the composition and properties of amino acids, and model the folding of a protein based on these characteristics.
- Generalize the relationship between cellular DNA and a unique protein structure.

Standards:

NGSS Science and Engineering Practices: SEP1, SEP2, SEP3, SEP5, SEP6, SEP8, Crosscutting Concept: Structure and Function, Cause and Effect, HS-LS1-1, HS-LS1.A
Common Core State Standards ELA/Literacy: SL.6-8.1, RST.6-8.4

Estimated Time: 75 Minutes

- **10 min - Introduction**
- **30 min – Folding Activity (Part 1)**
- **20 min – Folding Activity (Part II)**
- **15 min – Debrief**

***Protein Folding* Materials:**

for each student:

- Student Pages

for each partner team:

- 1 2-foot piece of foam-coated wire
- 1 pair of scissors
- 2 white and black pipe cleaners
- 1 orange, purple and pink pipe cleaner
- 1 Cell Template (with DNA bead model and Steps 1-3 completed)

Advanced Preparation:

- ❑ Create four labels to identify each color of identification cards from Activity 1 (blue, red, yellow and green). Place these signs in each corner of the room.

Suggested Inquiry Approach:

Students will continue working in the same partner teams as they did for Activity 1 and 2. They should also have access to their Cell Template and DNA bead model (which may be attached to their Cell Template). Steps 1-3 of the protein synthesis process should be completed on their template.

Review with students what they have learned about proteins thus far. Suggested questions for discussion include:

- **What is DNA and why is it important?**
- **Describe what happens during transcription and translation.**
- **Summarize how a protein is formed, beginning with a DNA molecule.**

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- **What do you know about protein(s)?**
- **What types of functions may a protein perform?**

Explain to students that in order to for a protein to function, it must take on a particular shape. In this activity, students will determine how their specific protein, generated in Activity 2, will fold as determined by the amino acids that make up their protein strand.

Distribute the student pages to each learner and a piece of foam-coated wire, scissors and pipe cleaner collection to each partner team. Ask a volunteer to read the background information aloud.

Students will first predict what factors might affect the shape that a protein takes when it folds, and why these factors may be significant. Allow time for students to generate and record ideas, and then share out ideas as a whole class.

In the first part of this activity, students will investigate the five main characteristics of amino acids that influence the manner in which proteins fold.

Once students have randomly tied one color of each pipe cleaner piece onto their foam-coated wire, encourage partner teams to brainstorm what action(s) each amino acid will take during the protein folding process. Then, holding a class discussion, allow students to express their ideas. Eventually the whole class should reach consensus to develop a definition or description of each characteristic and record this information in the **action** column of their table.

Students should conclude:

- ***Hydrophobic***: Separating this word into its two parts, *hydro* (water) and *phobic* (fear or dislike), these amino acids naturally do not like water.
- ***Hydrophilic***: Amino acids with this characteristic have an affinity for water.
- ***Cysteine***: This amino acid can interact with another cysteine to form a bond that helps stabilize the protein.
- ***Positively and Negatively Charged:*** Similar to the polar ends of magnets, these amino acids attract each other.

These actions and overall discussion will also be helpful in establishing the rules as written in Step 5 of the student pages.

The rules that are developed should be consistent amongst all partner teams:

- **Hydrophobic amino acids should face inside.**
- **Hydrophilic amino acids should face outside.**
- **Cysteine amino acids may attract each other. Otherwise, they are left alone.**
- **Positive and Negative amino acids should attract.**

Students will then fold their foam-coated wire to reflect the properties of the amino acids as represented by the pipe cleaners. You may choose to allow students the opportunity to present their folded protein, observe similarities and differences amongst various examples, and address any remaining questions.

In the second part of this activity, students will return to their specific protein model that was created in Activity 3 (**Translation**). This information may be attached to their Cell Template.

Students will recall the specific amino acids that make up their protein sequence. Then, using the information provided in the table, they will determine the specific characteristics of each protein which influence the manner in which their protein will fold.

As students are collecting and completing this part of the activity, circulate around the room to assist with challenges and observe student work.

Once all students have illustrated and labeled their folded protein, instruct each partner team to stand in the corner that corresponds to the original color of their instruction card from Activity 1. **Explain to the students that all partner teams in their corner have the same specific protein**.

Allow students to compare the composition and shape of their protein. Encourage them to record similarities and differences amongst the various models in their student pages.

Next, ask students to convene into another small group, verifying that at least one of each color instruction card is represented. **Explain to the students that all partner teams in this group have different proteins.** Once again, students should take time to compare folded protein models and record their observations.

Once students have had adequate time to make observations and record information, reconvene all partner teams for a whole class debriefing session.

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Note: Students may tie the ends of their negative and positive charged amino acids together to represent their bond. The pipe cleaner pieces representative of hydrophilic and hydrophobic properties may be pointed toward the inner and outer part of the water-filled cell.

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***Debrief Activity 3*:**

Pose the following questions for discussion and consideration:

- ***Why do you think proteins fold? Why do they take on a specific shape?***
- ***What influences the way(s) in which a protein folds?***
- ***When you compared multiple models of the same protein, what similarities did you observe? Differences?***
- ***When you compared models of different proteins, what similarities did you observe? Differences?***
- ***Do you think that proteins always fold correctly? Why or why not?***
- ***What do you think happens when proteins fold incorrectly?***

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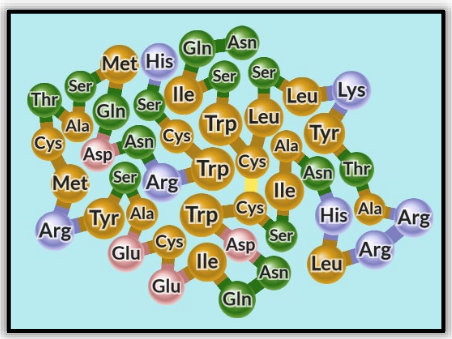
Students will complete this activity by illustrating **Step 4: Protein Folding** on their Cell Template. They may choose to illustrate their folded protein, or simply attach the foam-coated wire to the template. All protein folding materials should be placed in the appropriate locations of the cell. Next to these items, a brief description of how specific characteristics of amino acids influence the way in which a protein may fold should be included.

Extension:



Students interested in additional examples and illustrations of the protein folding process may navigate to: https://learn.concord.org/resources/787/protein-folding. This online simulation allows students to manipulate the properties of the amino acids within a protein to observe how these changes influence the way in which folding occurs. This resource is suitable for a variety of electronic platforms.

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Activity 4: Protein Functions

Objectives:

- Interpret, classify and evaluate proteins according to functions.
- Generalize the relationship between cellular DNA and a unique protein structure.

Standards:

NGSS Science and Engineering Practices: SEP1, SEP5, SEP6, SEP7, SEP8, HS-LS1-1
Common Core State Standards Mathematics: MP2, MP3, MP7
Common Core State Standards ELA/Literacy: RI.6.7, RI.6-8.4, SL.6-8.1, RST.6-8.1, RST.6-8.4, RL.6-8.1, RI.6-8.7, SL.6-8.2, SL.6-8.4

Estimated Time: 60 Minutes

- **10 min - Introduction**
- **20 min – Categorizing**
- **20 min – Matching Activity**
- **10 min – Debrief**

***Protein Functions* Materials:**

for each student:

- Student Pages

for each team of four:

- 1 set of *More Than Meat Cards*
- Approximately 10 sticky notes of one color

for each partner team:

- 1 Cell Template (with DNA bead model and Steps 1-4 completed)

for each partner team:

- *Protein Categories Class Display* PowerPoint

Suggested Inquiry Approach:

Students should continue working in the same partner teams as they did in Activity 1-3. All pairs should also have access to their Cell Template and associated materials.

Review with students what they have learned about proteins thus far. Then, ask students how they believe proteins fit in cells, and how each protein "knows" what function it will perform. Explain to students that they will have a chance to investigate the various functions that a protein may perform.

At this time, arrange two pairs of partner teams together to form a small group of four students. Distribute one color of sticky notes to each small group and set of student pages to each learner. Ask a student volunteer to read the background information aloud.

After reading the procedure detailed on the first student page, student teams will work collaboratively to brainstorm a definition, or list, of characteristics

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they believe a protein within each category may exhibit. All ideas should be recorded on an individual sticky note.

As students work, display the *Protein Categories Class Display.* Then, once all groups have recorded their thoughts, ask a volunteer from each group to place each sticky note next to its corresponding category.

Teacher Note: This pedagogical strategy allows you to verify that all student groups have contributed to the class discussion. Color-coordinated sticky notes hold each group accountable for adding thoughts, observations and/or questions to the conversation.

In a whole class discussion, review the sticky notes for each category. Encourage the students to listen for common words or short phrases that adequately describe the definition or characteristics of a given category. Then, using class consensus, establish the meaning of each category. Students will record this information in the "**Meaning**" column of the table in their student pages.

Student definitions may reflect:

- ***Defense Proteins*** *(Sometimes called antibodies): Ward off invasive agents within a cell or organism, can be used to protect against predators, or to catch prey. For example, lysozyme is a protein in tears responsible for killing fungus and bacteria.*
- ***Structural Proteins:*** *Provide support and shape to strengthen cells, tissues, organs and more. They are fibrous and stringy. For example, keratin strengthens hairs, quills, feathers, & beaks.*
- ***Signaling Proteins:*** *Enable cells to communicate with each other, transferring information from the outside of a cell to the inside. Signals, receptors and relay proteins are responsible for communication. For example, insulin, released into the blood stream after a meal, activates a receptor to store blood sugar.*
- ***Regulatory or Hormonal Proteins****: Send messages to coordinate activities and bind DNA to turn genes on and off. For example, somatotropin is a growth hormone in muscle cells.*

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- ***Sensory Proteins:*** *Help the cell or organism interpret the surrounding environment. They allow organisms to detect light, sound, touch, smell, taste, pain and heat. For example, TRPA1 is a protein which allows rattlesnakes to sense body heat & find prey.*

- ***Motor Proteins:*** *Provide movement of molecules and nutrients throughout the body and cells. For example, myosin is a protein responsible for contracting muscles.*

- ***Enzymes:*** *Break molecules down or apart and help control the speed at which chemical reactions happen. Lactase, for example, breaks down sugar in milk. Without enzymes, chemical reactions would happen too slowly to sustain life.*

- ***Storage Proteins:*** *These proteins reserve nutrients and energy-rich molecules for later use. For example, ovalbumin is a protein found in egg whites that serves as an energy source for growing chicks.*

Explain to students that they will now complete a matching activity about proteins and their functions. Provide each small group with a deck of *More Than Meat Cards*. Then, instruct students to divide their small group of four students into two partner teams.

Spreading the cards out on their working surface, students should arrange the cards with the names and descriptions of the proteins face up. The objective of the activity is to pick up cards in pairs of proteins that match based on their function and category. In order to make a match, they may use the categories previously defined in the table on their student pages.

In order to keep a match, two requirements must be met:

- First, students must to explain to the rest of the group why the pair of proteins is a match.
- Second, the rest of the group must accept the justification or provide a counter argument.
- If an agreement cannot be made by the group, they must work together to determine a system for handling stalemates.

Assist the groups as necessary while they play the game. When all groups have completed their exercise, reconvene the whole class to participate in a debriefing session.

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Debrief Activity 4:

In a whole class discussion, address the following questions:

- ***Why do you think there are so many proteins?***
- ***What was the most interesting protein? Why?***
- ***How important do you think proteins are for humans? Other animals? Plants?***
- ***Do you think more proteins will be discovered? Explain your ideas.***
- ***Congratulations! You just discovered a new protein. What is the function of this protein? What is the name of this new protein? Where is this protein found?***
- ***Summarize the protein synthesis process from a simple DNA strand to a functional protein.***

CT

Students should then summarize **Step 5: Protein Function** on their Cell Template. Narratives should include what must occur for a protein to function, as well as the various categories in which a specific protein may be classified. This should be completed in the cytoplasm of the Cell Template. Partner teams should work closely to accomplish this task.

Extension:

An extension investigating Chargaff's base pairing data can be found in the Teacher Resource folder at learning.imsa.edu..

Resources:

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