Stack the Deck

NOTES

Logistics: This lesson is intended for students in Grades 6 – 8 in a biology course as an investigation of proteins. This specific lesson may also be appropriate for high school biology students studying proteomics, as well as elementary students as a collaborative opportunity to explore the structures and functions of living organisms.

Materials:

per student:

1 – copy of Student Pages

per group of four students:

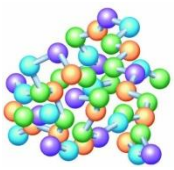
1 – Deck of *Protein Power Cards*

Time: 60 - 75 minute class period

Objectives/Standards:

- Classify and evaluate proteins according to their function(s). NGSS.SEP1, NGSS.SEP5, NGSS.SEP6, NGSS.SEP8, CCSS.ELA.RI.6.1, CCSS.ELA.RI.6-8.4, CCSS.ELA.RST.6-8.1, CCSS.ELA.RST.6-8.4, CCSS.MP2
- Work collaboratively to interpret descriptions, communicate ideas, derive meaning from, and form connections and explanations while engaging in scientific inquiry. NGSS.SEP1, NGSS.SEP6, NGSS.SEP7, NGSS.SEP8, CCSS.ELA.RL.6-8.1, CCSS.ELA.RI.6-8.4, CCSS.ELA.RI.6-8.7, CCSS.NGSS.SL.6-8.1, CCSS.ELA.SL.6-8.2, CCSS.ELA.SL.6-8.4, CCSS.MP3, CCSS.MP7

Introduction:



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** are vital to living cells surviving since they control almost every aspect of life. Proteins continually undergo changes and concentrations range from one organism to another. Ribosomes are responsible for the production of these critical structures through a process called translation. Proteins, made of amino acids, are folded into various shapes and have a multitude of jobs.

Stack the Deck

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Provided information has been adapted from *Learn.Genetics* by the University of Utah:

http://learn.genetics.utah.edu/content/basics/proteintypes/

This resource may be useful in locating additional examples and information regarding various types of proteins.

The following are some categories of proteins, their functions, and examples:

- ***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.*
- ***Sensory Proteins:*** *Help the cell or organism interpret their 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:*** *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.*

In the following activity, students will explore their understanding of proteins while learning about the prevalence and roles of proteins in organisms. Students will begin by brainstorming a list of characteristics or definitions for a series of protein categories. This exercise will pool

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students' prior knowledge, challenge them to infer meaning, and ultimately come to a consensus to establish the meaning of each category. Then, after receiving a deck of *Protein Power* cards, student teams will work collaboratively to draw connections between a set of proteins and their representative category.

Activity:

Begin with a discussion of the word "protein". Suggested questions include:

- Have you heard of the word protein? Explain.
- Where have you heard of the word protein?
- What do you know about protein(s)?
- Where can you find protein(s)?
- What do(es) protein(s) do for you and your body?

Depending upon student responses, assure students that proteins are important in their diets, but that proteins are found in their cells and all living organisms and are critical to cells functioning correctly and surviving.

At this time, arrange students into groups of four and distribute the student pages to each learner. Explain to students that they will be investigating the function of several different types of proteins.

Beginning with the first student page, ask students to individually brainstorm a definition for each protein category. Each definition should explain the protein category's function(s). Depending on the academic level of the students, these definitions may include detailed examples and explanations of associated proteins and their functions, or more simple words or phrases that may be associated with the category (i.e., "provides protection" to define the category of defense). Encourage students to record all ideas in the *My Thoughts* column of the included table.

Next, instruct students to share their ideas within their small group. Students will then use this conversation to reach consensus as to the meaning and function of each protein category. Once all members of the small group come to an agreement, they should record their ideas in the second column of their table. If student groups are unable to brainstorm a definition, function, or reach consensus, the instructor may choose to host a whole class discussion to achieve this task.

Stack the Deck

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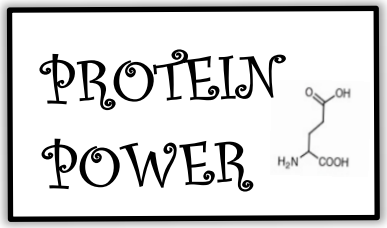

Explain to students that they will now have a chance to complete a matching activity about proteins and their functions. Provide each small group with a deck of *Power Protein Cards*. Then, instruct students to divide their small group of four students into two partner teams.

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 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.

<u>Debrief:</u>

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?*

EXTENSION:

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To extend this lesson, students may choose to investigate the folding of proteins. A long molecule or string of amino acids, 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 really sensitive to manipulation. This process is called **folding**. Mathematically, there are an extremely large number of options of folding shapes from which the protein may self-select. Research of the folding process is challenging due to the complexity of the process and the speed at which it occurs. The process of how proteins became misfolded, 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.

Students may wish to engage in an online simulation that models the folding of proteins by navigating to: http://fold.it/portal/node/996074.

RESOURCES:

Groleau, Rick. "Introduction to Proteomics." *Research Innovation*. Boston Children's Hospital, n.d. Web. 03 May 2017.

"Types of Proteins." University of Utah, n.d. Web. 03 May 2017. <http://learn.genetics.utah.edu/content/basics/proteintypes/>.

"What is Proteomics?" *What is Cancer Proteomics?* National Cancer Institute: Office of Cancer Clinical Proteomics Research, n.d. Web. 03 May 2017. <https://proteomics.cancer.gov/whatisproteomics>.

Stack the Deck

Stack the Deck

CATEGORY	MY THOUGHTS	GROUP CONSENSUS
Defense		
Signaling		
Enzyme		
Motor		
Regulatory		
Sensory		
Storage		
Structural		

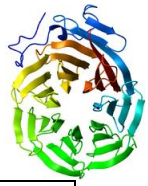
Stack the Deck Questions:

1. What surprised you about the proteins? Explain your thoughts.

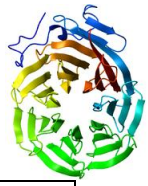
2. What was the most interesting protein? Why?

3. 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? You may choose to draw this protein.

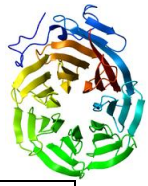
Stack the Deck
Teacher Resource – *Protein Power Cards*



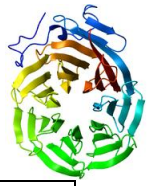
Alpha-Amylase Found in saliva, this protein breaks down sugar	**Antifreeze Protein** Prevents ice crystals from forming and destroying cells, blood and tissue in animals such as fish & snow fleas
Lysozyme In tears, kills fungus & bacteria	**Trypsin** Involved in protein digestion
Fibrin Forms blood clots to help stop bleeding, shaped like a rope	**TD (Threonine)** Makes leaf eating caterpillars get sick when they eat tomato leaves
IgG (ImmunoglobulinG) A blood antibody, this protein fights foreign harmful particles	**Thrombin** Forms blood clots to help stop bleeding



DNA Polymerase Builds DNA molecules	**Luciferase** Makes fireflies glow
Autin Helps muscles contract	**Rap6** Allows materials in and out of cells
Lactase Breaks down sugar in milk	**Pepsin** Breaks down proteins in food
Actin Helps muscles contract	**Chlorotoxin** The toxin found in the Deathstalker Scorpion, this protein makes a victim's muscles contract all at once

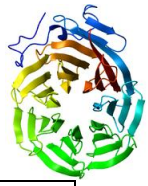


Keratin Strengthens hairs, quills, feathers, & beaks	**MaSp** **(Major Ampullate Spidrion Protein)** Allows fibers in black widow spider webs to be strong, resistant, and flexible
Tubulin Makes microtubules that give cells their shapes	**Cytochrome c** Makes energy to power cells by moving electrons
Hemoglobin Red blood cells pick up oxygen from lungs for rest of body	**Myoglobin** Responsible for oxygen collection in tissues
Porin Toxin that makes jellyfish sting	**Hyaluronidase** Enzyme rapidly spreads injected fluids, like venom, throughout the body so it is absorbed faster



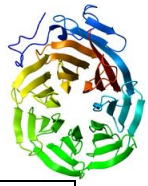
Dynein Helps carry materials around cells	**Kinesin** Helps carry materials around cells
Myosin Makes muscles contract	**Phototropin 1** Helps plants move toward & away from light
Caspases Kills old, worn out cells	**HOX** Tells developing cells what kind of cells to become
Microtubules Helps with cell division	**p53** Stops cell with damaged DNA from dividing

Stack the Deck
Teacher Resource – *Protein Power Cards*

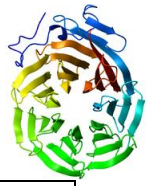


TRPA 1 Allows rattlesnakes to sense body heat and find prey	**EGF** **(Epidermal Growth Factor)** Helps to start cell growth where a wound occurs
Insulin Tells muscle & fat cells to store blood sugar	**Leptin** Makes you feel full when you eat
Ospins Converts light from eyes into electrical & chemical signals	**Cryptochrome** Helps monarch butterflies sense Earth's magnetic field so they can migrate
Circadian Clock Proteins Control the body's 24 hour clock cycle	**Rubisco** Helps build sugars in photosynthesis

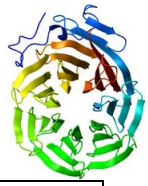
Stack the Deck
Teacher Resource – *Protein Power Cards*



Casein Helps with nutrients in mammal milk	**Ferritin** Helps with iron storage
Gluten Found in seeds, such as wheat, barley, rye and helps dough rise	**Ovalbumin** Found in egg whites, it serves as an energy source for growing chicks
Collagen Strengthens bones, cartilage, tendons and ligaments	**DNA Ligase** DNA "glue" this protein holds pieces of DNA together
Elastin Strengthens tendons & ligaments	**Fibroin** Silkworms use when making cocoons, Also in bees, wasps, ants, silverfish, mayflies, beetles, fleas and flies



Gilatoxin Lethal toxin from Gila Monster bite	**Melittin** Main toxin in bee venom
Histamine Involved in many allergic reactions and increases the expansion of blood vessels	**Reflectin** Allows animals such as squid & neon tetra to change color & reflect light
βKeratin Gives the Eastern Bluebird its brilliant colors	**Tetrodotoxin (TTX)** Neurotoxin in pufferfish, porcupine fish & blue-ringed octopus
Chitin Found in the outer skeleton of many insects, crabs, shrimp & lobsters	**Trachynilysin** Neurotoxin in stonefish



STAT5 Involved in signaling and stopping the expression of specific genes, this protein has been connected to a variety of cancer	**Atracotoxin** Venom from the Sydney Funnel Spider that hyper stimulates the nervous system, causing human lungs to burst
Dortoxin Deadly venom from the South African Fattail Scorpion or Spitting Scorpion	**Conotoxins** Cone Snail toxin that causes muscle paralysis & death
Phrixotoxin Chilean Fire Tarantula venom	**Forisomes** Found in some plants, this protein allows them to change size and help move materials through cells
Antiviral protein Found in plants and animals, this protein interferes with a virus's ability to replicate once inside a host	**Cyclin B** Involved in mitosis or cell division

Protein Separation

NOTES

Logistics: This lesson is intended for students in Grades 6 – 8 in a biology course as an investigation of proteins. This specific lesson may also be appropriate for high school biology students studying proteomics, as well as elementary students as a collaborative opportunity to explore the structures and functions of living organisms.

Materials:

per student:

1 – copy of Student Pages

per partner team:

1 – Aluminum Loaf Pan
2 – Round Balloons
2 – Coffee Filters
2 – Coffee Stir Sticks
2 – 9oz. Plastic Cups
1 – Plastic Spoon
1 – Magnet or Magnetic Wand
1 – Piece of Wool
1 – Plastic Canvas Circle
1 – Pool Toy Set (strainers)
2 – Pieces of Wax Paper
2 – 2oz. Containers of Protein Mix*

*Refer to the Materials Information list at the end of this document

Time: 60 - 90 minute class period

Objectives/Standards:

- Investigate and test tools for separating proteins. **NGSS.SEP1, NGSS.SEP3, NGSS.SEP5, NGSS.SEP6, NGSS.SEP8, CCSS.MP5, CCSS.MP6, CCSS.ELA.SL.6-8.1, CCSS.ELA.SL.9-10.1**
- Design, test, and refine a plan for separating proteins. **NGSS.SEP1, NGSS.SEP3, NGSS.SEP5, NGSS.SEP6, NGSS.SEP8, CCSS.MP3, CCSS.MP5, CCSS.MP6, CCSS.ELA.SL.6-8.1, CCSS.ELA.SL.9-10.1, CCSS.ELA.SL.6-8.4, CCSS.ELA.SL.9-10.4, CCSS.ELA.RST.6-8.3, CCSS.ELA.RST.9-10.3, MS-ETS1-3, MS-ETS1-4**
- Collect, measure, analyze, interpret and communicate results. **NGSS.SEP1, NGSS.SEP4, NGSS.SEP5, NGSS.SEP6, NGSS.SEP7, NGSS.SEP8, CCSS.MP2, CCSS.MP3, CCSS.MP6, CCSS.ELA.SL.6-8.1, CCSS.ELA.SL.9-10.1, CCSS.ELA.RST.6-8.3, CCSS.ELA.RST.9-10.3**

Protein Separation

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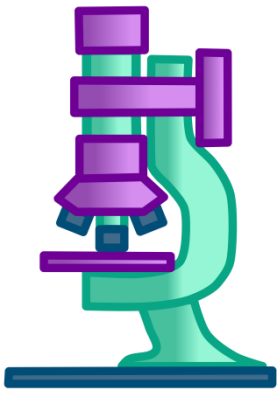
Introduction:

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** are vital to living cells surviving since they control almost every aspect of life. Proteins continually undergo change and concentrations range from one organism to another. Ribosomes are responsible for the production of these critical structures through a process called translation. Proteins, made of amino acids, are folded into various shapes and have a multitude of jobs.

Proteins are studied to see their effects on cells or organisms. A single cell is made of approximately 10,000 different proteins which vary in size, charge, and water solubility. The exact protein wanted for a study needs to be extracted from the cell and purified before its structure and the mechanism of its action can be studied. Once separated and purified, confirmation needs to occur to ensure that the correct protein has been collected. This process, referred to as **protein purification**, takes time, specific technologies, and money. Common methods used to purify proteins include repeated freezing and thawing, sonication, homogenization by pressure or grinding, centrifugation and gel electrophoresis. The ease of extracting the **protein isolate**, as well as the amount of the protein available, impacts the economics of these processes. Purified proteins range from $4 to thousands per gram.

In the following activity, students will simulate the process of separating proteins of interest from a larger "protein mix". In the first activity, students will predict, evaluate and review a variety of tools to use in the protein purification process. Then, students will collaboratively design a scientific procedure to separate specific proteins of interest, test their design, and refine their plan while considering efficiency and the quality of their separated protein sample.



Activity 1: Separation Anxiety

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Advanced Preparation:

- ☒ Prepare the Protein Mix prior to the beginning of class.
- ☒ Determine if any additional materials should be included. (i.e, water, oil, a fan, etc.)
- ☒ Determine if students will need to share any materials, and where these items should be located in the classroom.
- ☒ Determine if students should cover their work area with newspaper or towels for easier cleanup, and provide these materials if necessary.

Begin the activity by hosting a class discussion about proteins. Pose the following questions:

- **What is a protein?**
- **What are some jobs/functions of proteins?**
- **Why are proteins important?**
- **Why would scientists want to study proteins?**
- **How would we get proteins out of cells?**

Students will work through this activity in partner teams. When all groups are situated, distribute the appropriate student pages and introduce the problem to the students. Following a discussion, provide each group with one container of protein mix. Explain to students that this mix models a sample of proteins collected from a cell.

Allow several minutes for students to explore their protein mix and record observations in their student pages. Once all partner teams have finished their work, encourage student volunteers to share their observations. At this time, students may list a variety of materials found within their protein mix (i.e., pony beads, rice, pepper, beans, popcorn kernels, etc.) as well as general descriptions of the proteins: varying shapes, sizes, and colors.

Next, direct student attention to the available tools that may be used to separate proteins of interest. With their partner, students should discuss each tool and predict how they think a specific tool could be used to isolate a protein. After all students have recorded this information in their student pages, host a class discussion to share ideas and predictions.

Prior to beginning exploration, inform the students that they may decide to run multiple experiments in an attempt to separate different proteins. In

Note: If students do not identify all materials found in the protein mix, or cannot predict the use of all tools, refrain from providing them with any missing information. Students will eventually discover these ideas through exploration and investigation.

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this case, students will want to reserve portions of their protein mix accordingly. Additionally, inform students that because actual proteins are so small and can only be separated using specialized techniques and technologies, students **CANNOT USE THEIR HANDS** during this investigation.

At this time, students may begin to separate proteins of interest using their tools. Allow plenty of exploration time at this phase, as this will set the stage for the rest of the activity. Students should also record a plan for separating out the smallest, largest and oddest shaped proteins in their student pages.

Finally, have groups share their ideas for each of the three scenarios – separating the smallest, largest, and oddest shaped protein shapes. Encourage students to write down new ideas they hear from their peers.

<u>Debrief Activity 1:</u>

In a whole class discussion, allow students the opportunity to share their ideas for isolating each of the three featured proteins. Then, address the following questions:

- *What was easy about this task? Why?*
- *What was challenging about this task? Why?*
- *What new tools would be helpful to have? How would they make this process more successful?*
- *Proteins have difference sizes. How did the mixtures simulate particle size?*
- *Proteins have charges. How did the mixtures simulate charges?*
- *Proteins have different solubilities. How did the mixtures simulate solubility?*

Activity 2: Catch of the Day

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Now that students have had a chance to work with the protein mix and tools, they will select a protein of interest to isolate, devise a plan to efficiently separate the material, and then analyze the quality of their sample and efficiency of their process.

Pose the following questions to the whole class:

- What is/are the goal(s) of separating proteins?
- How would you determine if a plan for isolating a specific protein was successful? Unsuccessful?
- How might a scientist determine the overall quality of a sample of separated proteins?

Explain to students that they will now consider the efficiency of isolating proteins and quality of their separated protein sample. Provide each student with a copy of the student pages.

Challenge students to devise a quality assessment plan (i.e., rubric, scoring device or grading method) for analyzing the quality of a protein sample. Students must work collaboratively to reach consensus, as this tool will be used by all members of the class.

While there are a variety of ways to construct such rubric, students may choose to evaluate the quality of their protein sample by comparing the isolated protein collection to the "garbage" collection consisting of all discarded proteins. One way to quantify this comparison is using a percentage. For example, students may agree that if only 25% of the intended protein has been isolated (75% was discarded in the "garbage" collection), a poor quality score would be appropriate. Conversely, if a protein separation plan results in 90% of the intended protein to be isolated (with 10% discarded), students may agree that this plan produces a high quality protein sample. Students should discuss and record their quality assessment plan in their student pages.

Provide each partner team with one container of protein mix. Ask students to portion their container in half, as they will be isolating two separate proteins.

To begin, partner teams will identify one protein to collect and record this item in their appropriate student page. Students will then work collaboratively to accurately record a plan for separating the protein of interest from the mix. Documentation should include successful and failed

Note: It is suggested to discourage students from selecting the largest and easiest proteins for this challenge.

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attempts of separation, observations, tools used and results. Students will create a plan for separating two types of proteins.

Note: It is important that partner teams leave their resulting isolated protein sample on their work space. The quality of this sample will be evaluated by another partner team.

When all partner teams have finished, instruct students to leave their student pages and visit another group's work space. At this time, partner teams will evaluate the quality of the other team's protein sample using the quality assessment plan devised earlier. The evaluating partner team should record their assessment value, recommendation for increased quality or compliment in the appropriate area of the student pages for the team they are scoring.

Debrief Activity 2:

In a whole class discussion, ask students to share their quality assessment score, identify areas of weakness in their plan, and report any successes that were experienced. Suggested questions for discussion include:

- *What changes would you make to your protein separation plan?*
- *Do you feel that your quality assessment score was fair? Why or why not? How would you suggest editing the quality assessment plan?*
- *Would you consider your protein separation plan to be efficient? Why or why not?*
- *What tool do you feel was most valuable in separating proteins? Why? What tool was least valuable? Why?*

Students should also reflect on the significance of isolating proteins:

- *There is no single method used to extract proteins from a cell. Why do you think one method cannot work for all proteins?*
- *Isolated proteins range in value form $4.00 to thousands of dollars per gram. Why do you think there is such a wide range in value?*
- *Why do you think we used a model to explore this process?*

NOTES

RESOURCES:

Berg JM, Tymoczko JL, Stryer L. Biochemistry. 5th edition. New York: W H Freeman; 2002. Section 4.1, The Purification of Proteins Is an Essential First Step in Understanding Their Function. Available from: https://www.ncbi.nlm.nih.gov/books/NBK22410/

Materials:

The protein mix consists of:

- Popcorn kernels
- Pony beads (assorted colors)
- Pinto beans
- Lentil beans
- Kidney beans
- Navy beans
- Black beans
- Northern beans
- Rice
- Sprinkles
- 1/16" Steel ball bearings
- Ground pepper
- Coarse salt

Instructors may measure and mix the ingredients to their liking. All materials may be substituted for other items.

Bruin Sea Critter Bath Cups (referred to as "Pool Toys" in this activity) may be purchased at: http://www.toysrus.com/product/index.jsp?productId=71324606&cp=2255957.2273443.2255976.2256093&parentPage=family

Protein Separation

Separation Anxiety

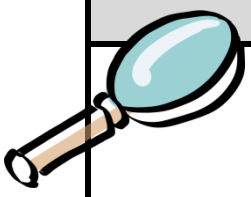
Problem: *How do you isolate a protein of interest?*

Materials:

- Protein Mix
- Assorted Tools
- Spoon
- Hand Lens

Procedure:

1. Use the hand lens to observe at the protein mix. You may wish to place a small amount on a piece of paper to closely analyze and explore the contents. **You are NOT permitted to touch the protein mix with your hands.** Record your observations in the table below.



Protein Mix Observations

2. With your partner, locate the available tools that may be used in separating materials in the protein mix.

3. With your partner, determine which tools you would like to use, why you think they may be valuable, and how you think they could be used to isolate proteins from the mix. Record your ideas in the appropriate columns of the Testing Table.

TESTING TABLE		
TOOL	**THOUGHTS**	**RESULTS**

4. Using your tools, attempt to separate different types of proteins found within the mix. Record your results in the Testing Table.

5. With your partner, devise a plan for separating these three types of proteins:

Plan for separating out the *largest proteins:*
Plan for separating out the *smallest proteins:*
Plan for separating out the *oddest shaped proteins:*

Separation Anxiety
Student Pages

Catch of the Day
Student Pages

Directions: Complete the following prompt, and use the provided tools to separate the protein of interest. Record all information in the space below.

The FIRST protein we tried to separate was _____.

Here is what we tried, our observations, and results about our protein separation.

Quality Assessment:

Directions: Complete the following prompt, and use the provided tools to separate the protein of interest. Record all information in the space below.

The SECOND protein we tried to separate was _____.

Here is what we tried, our observations, and results about our protein separation.

Quality Assessment: