Protein synthesis modeling: The making of a "Protein Beast"

How does the genetic code from DNA get communicated to the ribosomes for protein synthesis?

In this lesson, students will review how information in the genetic code through the sequence of DNA is communicated to the ribosomes so the correct proteins are produced by cells of an organism. Students will also be introduced (or review) the basic process of protein synthesis; including the roles of DNA, mRNA, tRNA, and the ribosome to protein synthesis. The processes of transcription and translation will also be discussed and/or reviewed. Students will role model the process of protein synthesis through the activity. The activity will provide students the opportunity to participate actively in the various roles being modeled, and an introduction to understanding how detailed the process is for the genetic code to be biochemically communicated to produce correct proteins that ultimately determine an organisms' traits. In addition, the activity allows for a discussion of mutations.

Ohio Standards

- B.H.2: Structure and function of DNA in cells
- B.C.1: Cell structure and function
- Structure, function and interrelatedness of cell organelles

Student prior knowledge

Basic DNA structure; cell cycle; mitosis vs. meiosis; basic genetics

Suggested timeline

40–45 minutes

Materials

- Protein Beast model created from various lab and craft supplies (such as flasks, beakers, stoppers, rubber tubing, pipe cleaners, plastic cups, feathers, soup beans, Styrofoam peanuts, Duplo/Lego blocks, and more)
- Amino Acid Supply Store supplies: Must include supplies for building Protein Beast but also include variations of the supplies, such as different colors of pipe cleaners, stoppers, Duplo/Lego blocks; different sizes of beakers, flasks, Duplo/Lego blocks, plastic cups, and different variations of Styrofoam peanuts, soup beans
- Tri-fold display board for barrier to hide the Protein Beast

Teacher preparation

1. Gather various materials to use for students to build beast; create a prototype of beast.
2. Set up areas for the following:
    - **Nucleus:** Designated space in the room where the Protein Beast is set up and protected by a tri-fold display board barrier and can not be seen by students (except for students with the role of DNA). Try to position the area called the Nucleus where others can not see behind the tri-fold display board but the DNA from each team can go behind it and see the Protein Beast. A corner of the classroom works well for this.

- **Ribosome locations:** Lab desks or desks/tables where separate teams build their Protein Beast models.
- **Amino Acid Supply Store:** Large centralized table/desk where all supplies are located. Providing a variety of items within the Amino Acid Supply Store requires description/directions to be more precise in what items are to be obtained from the store; example: is it a cork, black rubber stopper, or white rubber stopper that is needed?

mRNA and tRNA for each team are the only team members that are to be moving within the room. Sometimes the game may be ended before any teams get the correct Protein Beast built.

Procedure

1. Divide the class into teams/groups of four. Additional students can help run the "Amino Acid" Supply Store.
2. **Each team member should assume one of the following roles:**
   - **DNA:** provides the team with the DNA code or directions for building the Protein Beast; this individual can not leave the confines of the Nucleus; they are the ONLY individual who can actually view the Beast.
   - **mRNA:** may go to the DNA and request directions/details for building the Protein Beast; this individual may enter the Nucleus to get the information and take it out to their team's Ribosome and gives the information to the tRNA. mRNA can only travel between Nucleus and Ribosome. Information can only be communicated to tRNA at their team's Ribosome.
   - **tRNA:** uses the information given to them by the mRNA and goes to the Amino Acid Supply Store and acquires "amino acids" (building supplies) to build the Protein Beast. Also communicates information from mRNA as to how to build the Protein Beast. Ribosome: uses the "amino acids" (building supplies) and information given to them by the tRNA to build the Protein Beast.
   - **Ribosome:** uses the information given to them from the tRNA to build the the Protein Beast; this person can NOT leave their assigned ribosome lab table / desk. They are to only ask any questions they have about building the model protein from the tRNA.
3. The DNA can *not* leave the Nucleus and only the DNA can directly view the Protein Beast. *No one* else can go behind the tri-fold display board to view the Protein Beast.
4. mRNA is the only team member who can enter the Nucleus and get information from the DNA; the mRNA can enter and leave the Nucleus as often as they need to; the mRNA can *not* actually look at the Protein Beast. mRNA can only give information to the tRNA.
5. *Only* the tRNA can go to the Amino Acid Supply Store to obtain "amino acids" (building supplies); the tRNA *must* use manners when obtaining amino acids (begin requests with please and end with thank you when speaking to store operators); the tRNA can *not* just grab items off the table (that would be shoplifting).
6. The Ribosome can *not* leave his/her team's assigned Ribosome location (desk/table); the Ribosome gets all information to build the Protein Beast from the tRNA.
7. The Amino Acid Supply Store worker(s) should not have prior knowledge of what the Protein Beast looks like, so that as the tRNA make requests for items they are not influenced on what they give them. Workers should also be random in items given, if requests are vague; example: if a request is made for a Duplo/Lego block but color nor size are given, just randomly give any block to the tRNA.
8. Once everyone understands their roles and is in position, the teacher says "go" and everyone begins working towards building their version of the Protein Beast.
9. A team who thinks they have their Protein Beast built correctly raises their hands. The teacher checks and confirms *"yes"* they have successfully built the Protein Beast or tells the team *"no"* it is not correctly built. The teacher does *not* tell them what is wrong with their Protein Beast, but the team is allowed to continue working on their Protein Beast getting new information from their DNA.
10. The winning team is the one that builds the Protein Beast correctly first.

Suggested wrap-up

Use questions 6–9 below to wrap up the activity and help students to review roles of DNA, mRNA, tRNA, and ribosome in the process of protein synthesis. For middle school students, be repetitive in using terms, such as transcription and translation, that are being introduced maybe for the first time. This will help them connect where they fit into the process of protein synthesis and how learning basic genetics ties into the bigger picture of how the cells build proteins from the information.

Reflection

1. Where is the genetic information of an organism stored within the cells?
2. Where are proteins built within the cell using the genetic code of DNA?
3. How does the information from the DNA which is located within the nucleus get communicated out to the ribosomes in the cytoplasm?
4. The genetic code within DNA determines all the traits an organism has. These traits are determined by the specific proteins that are built from the information found in DNA. What are the basic building blocks of proteins that DNA codes for?
5. What strategies can your group use to better communicate details of the “amino acids” (classroom supplies) needed to successfully build the “Protein Beast”?
6. How does this activity demonstrate the processes involved for information located on the DNA to be correctly communicated so the correct protein is created at the ribosomes?
7. What limitations does this activity have in demonstrating protein synthesis?
8. On a scale of 1 to 5 *(1 = “a little” to 5 = “a lot”):* How well did this activity help you understand how detailed the process is for DNA to communicate the correct genetic code to produce the correct proteins during protein synthesis?
9. When the sequence of amino acids is not correct in making proteins, the process can ultimately lead to the formation of mutations in an organism. Are all mutations harmful? When can mutations be beneficial? When can mutations be passed onto offspring?

Differentiation

Divide students into groups ahead of time to make sure all students are a good mix to work together. Allow students to determine individual roles. In some cases, assign roles, such as someone with limited mobility to be in charge of the Amino Acid Supply Store.

Extensions

A high school variation of this activity could be to use Lego blocks labeled with codons (3 nucleotide sequences) on DNA to build the Protein Beast. The Amino Acid Supply Store would then have Lego blocks labeled with names of amino acids. In the game the mRNA would bring the codon from the DNA and the tRNA would use a codon / anticodon chart to determine which amino acid to obtain from the Amino Acid Supply Store and take back to the Ribosome. Then the Ribosome would put them into the correct sequence as information is given to them from the mRNA.

Support information

- Amoeba sisters: Protein synthesis: ***youtube.com/watch?v=oefAI2x2CQM***
- Ribosomes, Transcription, Translation | Learn Science at Scitable: ***nature.com/scitable/topicpage/ribosomes-transcription-and-translation-14120660/***
- The Steps of Protein Synthesis: ***azolifesciences.com/article/The-Steps-of-Protein-Synthesis.aspx***

Career connections

- **Microbiologist:** Focuses on bacteria, fungi and viruses; a broad background in human cell biology and molecular biology is needed.
- **Epidemiologist:** Applies statistical analysis to diseases in human populations; also called public health professionals; significant collaboration with data science and bioinformatics.
- **Biochemist:** Specializes in studying the composition, functions, and chemical processes of living organisms.