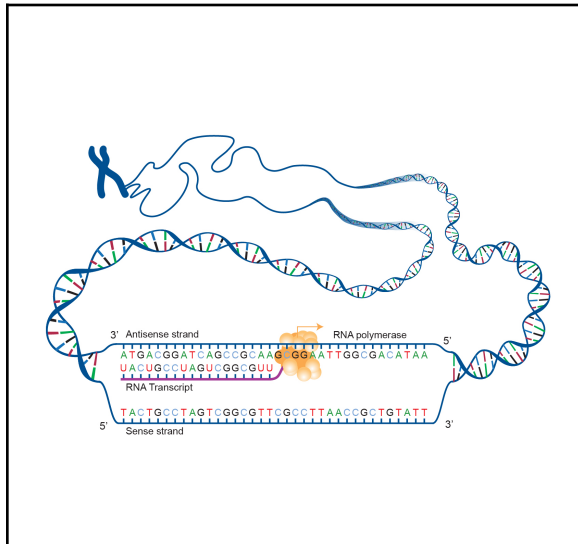


Protein Synthesis: A One Act Play

Format: In-person



RNA polymerase carrying out transcription.

Author: Melissa Artstein-McNassar

Time needed: 45 minutes

Learning Objectives

- Demonstrate the processes of transcription and translation
- Identify the roles of the molecules involved in protein synthesis

Supplies Needed

- Printed badges identifying each actor (included):
 - DNA (A, T, C, G)
 - Ribosomes
 - mRNA
 - tRNA
 - RNA polymerase
 - Choice of amino acids (1-4)
- Chalk, masking tape, or small sports cones to map out the stage for the play
- Tape for student badges
- Amino acid chart
- Blank cards (badges) and a sharpie

Readings

- Mann, Hayley, et al. 2019. Chapter 3: Molecular Biology and Genetics. *Explorations*

Introduction

In this activity, students put on a play to perform what is happening inside their bodies. Students are given roles to act out the process of protein synthesis (specifically, transcription and translation). Students wear badges to distinguish their role from the roles of their peers. The goal of this play is to create a fictional protein. The instructor serves as play director and narrator.

Minimum required number of students: 11

Preferred number of students: 20 - 25

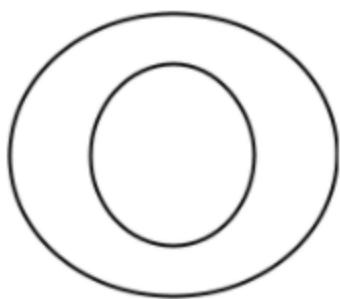
The Stage

Establish a cell that students can walk into. It is important to represent the boundaries of cell structure (nucleus and cell membrane) on the stage. Find a suitable space for the entire class to fit comfortably.

Outside: If conditions are favorable, this activity can be completed outdoors. Find a concrete or blacktop surface and use chalk to draw a rather large cell that includes two concentric circles that represent the boundaries of the nucleus and cell membrane. I recommend drawing the nucleus approximately six feet in diameter to accommodate students with an additional two or three feet around it to enclose the cell for students to fit within the cytoplasm.

Inside: Small soccer cones or tape on the floor can be used indoors to represent the boundaries of the cell (as indicated above). Furniture, such as chairs, or stools, can be used as well.

Boundaries should look like this:



Procedure: Setting Up

1. **Assign Roles.** Prior to showtime, assign student roles. List the various roles on the board and ask students to volunteer for each role. A minimum of eleven students are needed to successfully produce one amino acid for protein building, with roles assigned to students as follows:

Minimum Role to Student Ratio

Role	Minimum Students Required
DNA to make one codon	6
mRNA	1
tRNA	1
Ribosome	1
Amino acid	1
RNA polymerase	1

For larger class sizes (24 or more students), I recommend the following student assignments. Students can take turns being the “active” actor (for instance, the ribosome stringing together the two amino acids or RNA polymerase transcribing DNA).

Role to Student Ratio for Larger Classes

Role	Minimum Students Required
DNA to make two codons	12
mRNA	2
tRNA	2
Ribosome	2
Amino acid	2 (or more)
RNA polymerase	2

2. **Prepare students.** Students should be familiar with protein synthesis prior to the activity. See “For Further Exploration” (below) for a list of sources to introduce protein synthesis. You may wish to give students a bit of time to research their roles in or before class.

In addition, before showtime, students should know:

- a. Where they need to start out on stage (for example, in the cell nucleus or in the cytoplasm).
- b. Which other actors they will interact with during the play (for example, tRNA will need to find an amino acid and bring it to a ribosome).

Special note on DNA and amino acid roles: These two roles are linked. The DNA actors must arrange themselves so that they can be transcribed into a specific codon (amino acid). Students can take the lead on this and decide on one or two amino acid products. They will then need to arrange themselves in the correct order so that when RNA polymerase transcribes one half, it will correspond to the appropriate amino acid. Students who are the amino acids need to have the appropriate signage so that they can be found in the cytoplasm when tRNA looks for them.

3. **Set the stage.** Identify the boundaries of the nucleus and cell. Refer to recommendations in the section labeled “The Stage” above.

Once students are comfortable with their roles, have them either hold their pieces of paper that indicate their roles visibly, or tape them onto their chests like a badge. RNA polymerase should have a blank badge and pen to record their transcription of DNA. RNA polymerase can record one codon on each blank badge. Ribosomes should have a codon to amino acid chart to consult to assist them in translating the mRNA message.

Lead the actors to the stage (the cell). All students initially stand outside the cell. First, point to the stage and explain the basic structure of the cell (e.g., nucleus, cytoplasm). Then, call students to take their places by introducing each role:

1. Narrator: “DNA will take their place in the nucleus and arrange themselves in a distinct way that will transcribe and translate to two (or one) amino acids”
 - a. Students who play the DNA nucleotides (A, T, C, or G) line up in pair bonds, shoulder to shoulder, in a ladder-like formation in the nucleus.
2. Narrator: “RNA polymerase and mRNA will take their place along the edge of the nucleus.”
 - a. Students who are RNA polymerase and mRNA enter the nucleus. Keep in mind, students may not be able to fit in the nucleus.
3. Narrator: “Ribosomes will take their place in the cytoplasm.”
 - a. Students who are ribosomes will enter the cytoplasm area.
4. Narrator: “tRNA will take their place in the cytoplasm.”
 - a. Students who are tRNAa will enter the cytoplasm area.

Do this until all actors are on the appropriate areas of the stage.

Showtime: The Play

Once students are staged on the cell, the play will begin. Here is the basic narration of each step:

1. RNA polymerase breaks the bonds between bases throughout the DNA molecule.
2. RNA polymerase copies the DNA message and attaches it to mRNA.
3. mRNA leaves the nucleus and a ribosome approaches and attaches to the mRNA.
4. The ribosome read the mRNA code and give instructions to tRNA.
- 5a. tRNA takes the amino acid from the cytoplasm and shuffles it to the ribosome.
- 5b. If two amino acids are being called: The ribosome reads another mRNA codon and gives instructions to tRNA.
6. Ribosomes string the amino acids together to build a protein.

As the narrator is calling out the process, the students move and act accordingly. Here is an example of both the narration and student actions (movements):

1. **Narrator:** "RNA polymerase break the bonds between bases throughout the DNA molecule."
 - **Action:** RNA polymerase actor(s) begin to walk through the two rows of DNA base pairs, breaking the bond.
2. **Narrator:** "As the bonds break, RNA polymerase copies the DNA message to create mRNA"
 - **Action:** RNA polymerase actors begin at the beginning of the DNA message and, with pen and paper in hand, transcribe one side of the DNA. RNA polymerase then attach the message to mRNA.
 - *Note: If there are more than one RNA polymerase actors, they can check their work with one another to make sure the message is correct.*
3. **Narrator:** "mRNA leaves the nucleus and attaches to a ribosome."
 - **Action:** mRNA actor leaves the nucleus area and arrives in the cytoplasm, seeks out a ribosome, and gives the message they have just transcribed to the ribosome.
4. **Narrator:** "The ribosome reads the mRNA code and gives instructions to tRNA."
 - **Action:** ribosome actor translates the mRNA code and yells out the appropriate amino acid that is needed.
5. **Narrator:** "tRNA takes the amino acid from the cytoplasm and shuffles it to the ribosome."
 - **Action:** tRNA actor hears the ribosome's call for an amino acid and searches the cytoplasm for the identified amino acid. tRNA actor takes the amino acid actor to the

ribosome who yelled for the amino acid.

- *Note: If two amino acids are being called, the ribosome may read both amino acids at one time and two tRNA actors may assist with finding and taking them to the ribosome.*

6. **Narrator:** “Ribosomes string the amino acids together to build a protein.”

- **Action:** The ribosome actor places the two amino acid actors side by side representing a protein.

Consider repeating the play a few times. The first time is slow, and then the second and third times are faster.

A note on “mistakes”:

The first time through it will go a bit slower. The narrator may need to provide direction as to where the actors go, or to make sure each actor’s signage is visible to others.

A common mistake that occurs is the mRNA polymerase does not transcribe the DNA correctly and/or the ribosome cannot translate the amino acid correctly. These are great examples of possible hiccups in the protein synthesis process that may account for a mutation. What an excellent teaching moment!

Review Questions

1. Protein synthesis is a 2 step process that includes transcription and translation. Where does each step take place within the cell?
2. Protein synthesis relies on many molecules and organelles in the cell. Identify the molecules and organelles found in each step. What part of this process seems the most vulnerable to mutation?

Adapting for Online Learning

1 Not adaptable

2 Possible to adapt

3 Easy to adapt

For Further Exploration

Stated Clearly. What is DNA and How Does it Work?

<https://www.youtube.com/watch?v=zwibgNGe4aY>

Amoeba Sisters. Protein Synthesis (Updated).

<https://www.youtube.com/watch?v=oefAl2x2CQM>

References

Mann, Hayley, Xazmin Lowman, and Malaina Gaddis. 2019. "Chapter 3: Molecular Biology and Genetics." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. <http://explorations.americananthro.org/>

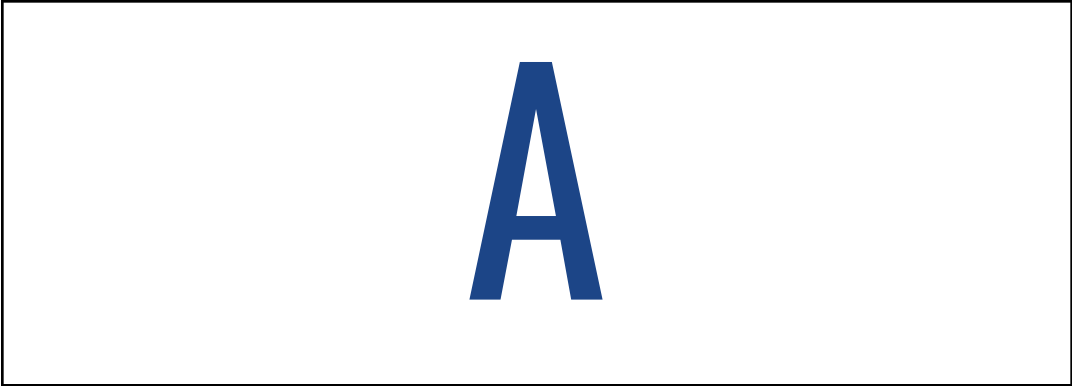
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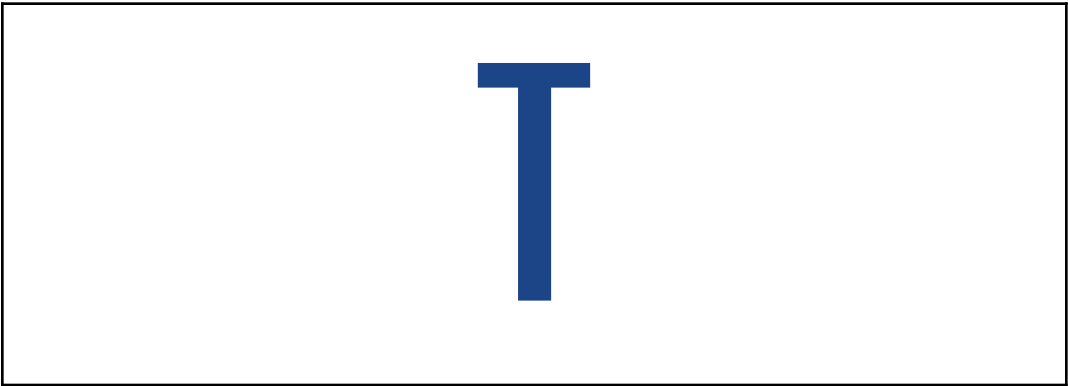
mRNA Codon chart by Becky Boone is used under a CC BY-SA 2.0 license.

Badges

Print out the following roles and give them to students who will fill the roles. You may need to copy and paste several of the roles if you have multiple actors. Badges can be taped to actor's shirts.



A



T



C

G

Ribosome

mRNA

tRNA

RNA Polymerase

Methionine

Lysine

Proline

Leucine

Key

While there are many ways you can run your play to produce any of the 20 amino acids, below are four possibilities that correspond with the provided labels.

		SECOND NUCLEOTIDE									
		U		C		A		G			
FIRST NUCLEOTIDE	U	UUU	Phenylalanine (Phe)	UCU	Serine (Ser)	UAU	Tyrosine (Tyr)	UGU	Cysteine (Cys)	U	THIRD NUCLEOTIDE
		UUC		UCC		UAC		UGC		C	
		UUA	Leucine (Leu)	UCA		UAA	STOP	UGA	STOP	A	
		UUG		UCG		UAG		UGG		Tryptophan (Trp)	
	C	CUU	Leucine (Leu)	CCU	Proline (Pro)	CAU	Histidine (His)	CGU	Arginine (Arg)	U	THIRD NUCLEOTIDE
		CUC		CCC		CAC		CGC		C	
		CUA		CCA		CAA	Glutamine (Gln)	CGA	Arginine (Arg)	A	
		CUG		CCG		CAG		CGG		G	
	A	AUU	Isoleucine (Ile)	ACU	Threonine (Thr)	AAU	Asparagine (Asn)	AGU	Serine (Ser)	U	THIRD NUCLEOTIDE
		AUC		ACC		AAC		AGC		C	
		AUA		ACA		AAA	Lysine (Lys)	AGA	Arginine (Arg)	A	
		AUG	Methionine (Met) START	ACG		AAG		AGG		G	
	G	GUU	Valine (Val)	GCU	Alanine (Ala)	GAU	Aspartic Acid (Asp)	GGU	Glycine (Gly)	U	THIRD NUCLEOTIDE
		GUC		GCC		GAC		GGC		C	
		GUA		GCA		GAA	Glutamic Acid (Glu)	GGA	Glycine (Gly)	A	
		GUG		GCG		GAG		GGG		G	

mRNA Codon Chart

Amino Acid	DNA	mRNA
Methionine	TAC	AUG
Lysine	TTT	AAA
Proline	GGA	CCU
Leucine	GAA	CUU