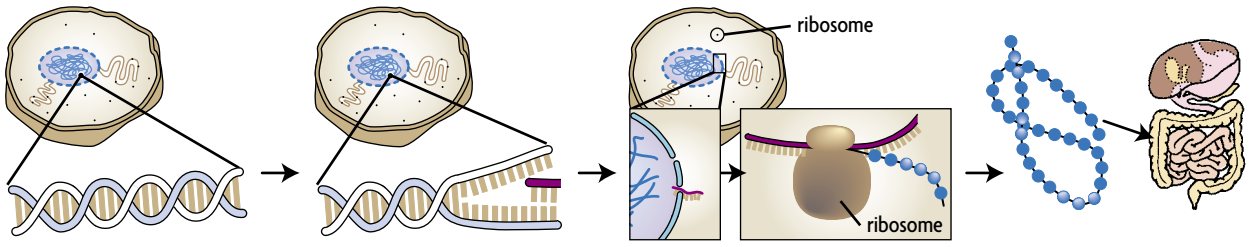
# 16 Protein Synthesis: Transcription and Translation

**Genes carry the** information that, along with environmental factors, determines an organism's traits. How does this work? Although the complete answer to this question is complex, the simple answer is that genes, along with the influence of environmental factors, direct the production of proteins in cells, and the types of proteins in a cell determine the cell's and organism's structure and function. When scientists set out to genetically modify an organism, their goal is to insert a gene or genes that code for a protein that is not normally in that organism.

While genetically modified organisms produce a protein or proteins that the original organism would otherwise not produce, the process for making the proteins is the same for any and all cells. This process is **protein synthesis.** Protein synthesis has two phases, shown in the figure below. In the first phase, the information contained in DNA is converted into a messenger molecule called messenger ribonucleic acid, or mRNA. The scientific word for this conversion is **transcription.** In eukaryotic cells transcription takes place in the nuclei. The second phase of protein synthesis is **translation,** and this happens on ribosomes in the cytoplasm of a cell. In this phase, the code in the mRNA messenger molecule is translated by transfer RNA (tRNA), which carries the amino acids used to make a protein molecule. In this activity, you will view a computer simulation of both transcription and translation. You will see that these processes occur similarly in both genetically modified and unmodified organisms.

PROTEIN SYNTHESIS




DNA resides in the nucleus.

Transcription: DNA is used as a template to make RNA.

Translation: RNA is used as a template to make proteins.

Protein is used by the organism. For example, an enzyme could be used by the digestive system.

# Challenge

How does a cell make proteins with the information from DNA?

## MATERIALS

**FOR EACH PAIR OF STUDENTS**

- set of 10 Transcription and Translation Cards (A–J)
- access to online protein synthesis simulation
- bag containing DNA model kit pieces
  - 36 black deoxyribose sugars pentagons
  - 36 white phosphate tubes
  - various orange, yellow, blue, and green nitrogenous base tubes
  - 18 white hydrogen bond rods
- bag containing transcription model kit pieces
  - 9 purple ribose sugar pentagons
  - 5 purple uracil nitrogenous base tubes
- bag containing translation model kit pieces
  - 3 purple tRNA molecules (diamond, oval, rectangle)
  - 3 black amino acids (diamond, oval, rectangle)
  - 2 gray polypeptide bond tubes

**FOR EACH STUDENT**

- Student Sheet 16.1, "Transcription and Translation"
- Student Sheet 2.3, "Genetics Case Study Comparison," from Activity 2
- 3 sticky notes

# Procedure

## Part A: Transcription and Translation

1. With your partner spread out the 10 Transcription and Translation cards in front of you on the table. Look closely at the cards. Discuss what each card shows and how the images on the cards differ.

2. To make a protein, a cell must convert the information contained in DNA into a messenger molecule. Then the code in the messenger molecule is translated into a string of amino acids that will make a certain protein. Place the cards in the order that you think shows this process. Record the order of the cards on the back of Student Sheet 16.1, "Transcription and Translation."

3. The first stage of protein synthesis is transcription. During transcription, the information in DNA instructs the cell to make a messenger molecule, mRNA. With your partner, visit the *Science and Global Issues* page of the SEPUP website *(sepuplhs.org/sgi)*, and go to the protein synthesis simulation. Student Sheet 16.1, "Transcription and Translation," will guide you through the simulation.

4. Look at the order in which you placed the cards in Step 2. Based on what you viewed in the animation, was your ordering of the cards correct? If necessary, discuss with your partner any changes you need to make, and rearrange the cards to reflect the correct order of events in transcription. On the back of Student Sheet 16.1, "Transcription and Translation," record the revised order of cards.

5. Based on what you observed in the animation and the information on the cards, fill in the transcription section of Student Sheet 16.1, "Transcription and Translation."

6. The second stage of protein synthesis is translation. During translation, the information in the messenger molecule mRNA translates into a chain of amino acids that will make a protein. Return to the *Science and Global Issues* page of the SEPUP website *(seuplhs.org/sgi)* and the protein synthesis simulation. Again, Student Sheet 16.1, "Transcription and Translation," will guide you through the simulation.

7. Look at the order in which you placed the cards in Step 4. Based on what you viewed in the simulation, was your ordering of the cards correct? If necessary, discuss with your partner any changes you need to make, and rearrange the cards to reflect the correct order of events in translation. On the back of Student Sheet 16.1, record the revised order of translation cards.

8. Based on what you observed in the animation, and the information provided on the cards, fill in the translation section of Student Sheet 16.1, "Transcription and Translation."

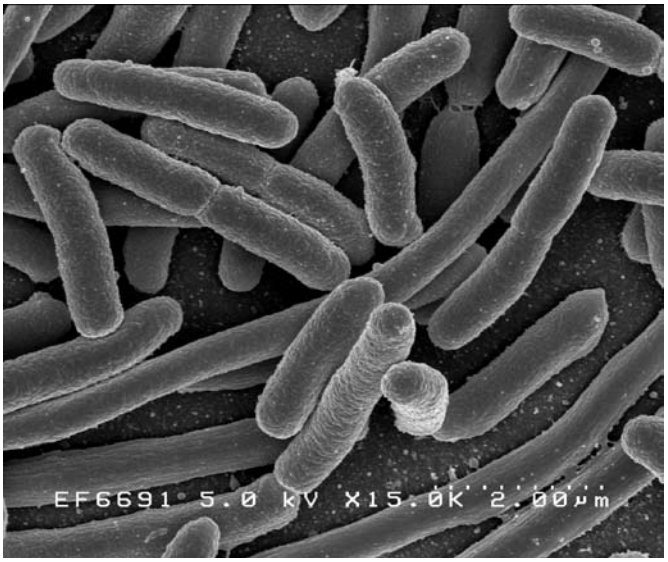
9. From the information you recorded on Student Sheet 16.1, in your science notebook write a description of what is shown on each card. Be sure to include

   a. the name of each molecule involved.

   b. a description of what each molecule does.

## Part B: Mutations

As you saw in Part A of this activity, DNA is a template that provides information for creating messenger RNA. The information in mRNA is then converted into an amino acid sequence, which is then turned into a protein. Occasionally during this process a mutation occurs. **Mutations** are changes in the sequence of nucleotides in a strand of DNA. In this part of the activity, you will investigate the effect of DNA mutations on protein synthesis.




*Mutations can be harmful, neutral, or beneficial. Certain strains of* E. coli *bacteria have mutations that allow them to withstand extreme temperatures.*

**10.** Copy the table below into your science notebook.

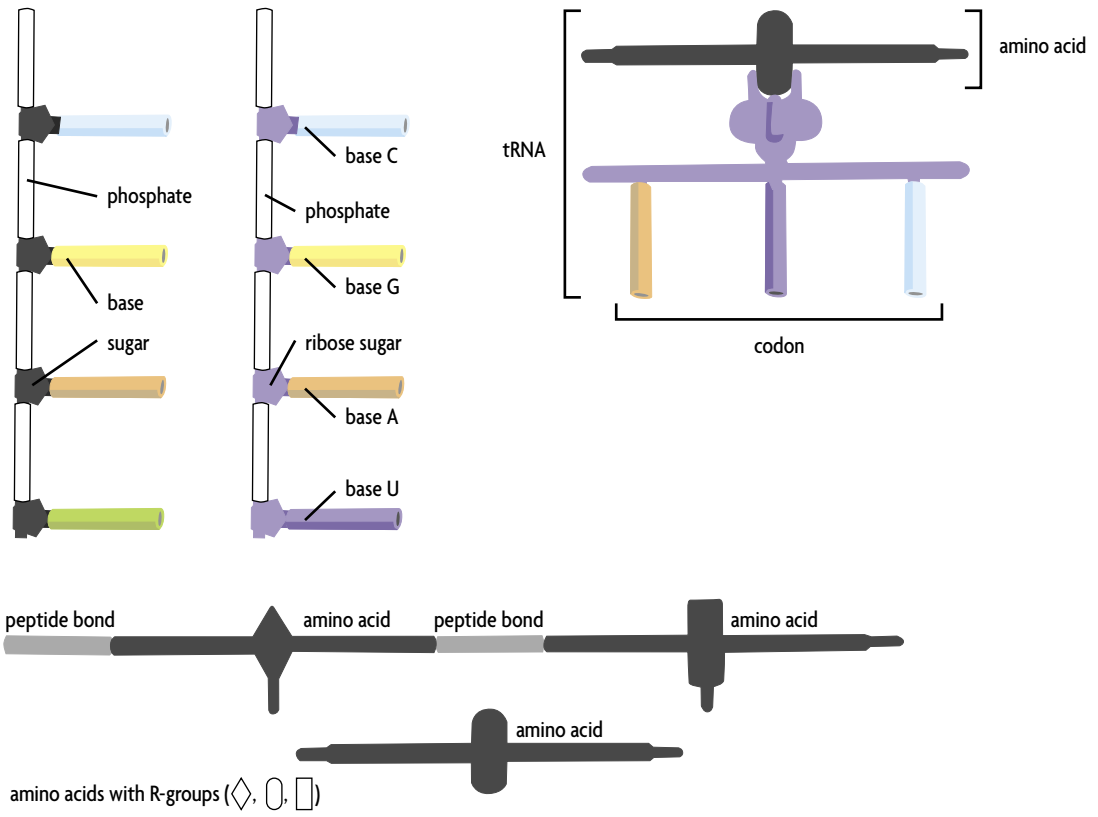
| *Mutation* | *DNA sequence resulting from DNA mutation indicated in table* | *mRNA transcript* | *Amino acid sequence* | *Effect on amino acid sequence* |
|---|---|---|---|---|
| ***Original strand*** | *5' TACCTAGCCAGTCGG 3'* | | | |
| ***Base insertion (frameshift)*** | | | | |
| ***Base deletion (frameshift)*** | | | | |
| ***Substitution*** | | | | |
| ***Three-base insertion*** | | | | |

**11.** With your partner, select the appropriate pieces of the Protein Synthesis Model, and build a single strand of DNA with the following sequence of bases:

5' TACCTAGCCAGTCGG 3'

Use the Protein Synthesis Model Key below to identify each molecule.

PROTEIN SYNTHESIS MODEL KEY



**12.** Work through the steps to translate and transcribe the DNA. Record your results in your data table, using the information in the chart on the next page to identify the amino acids.

Second letter

| First letter | U | C | A | G | |
|---|---|---|---|---|---|
| U | UUU, UUC — Phenyl-alanine<br>UUA, UUG — Leucine | UCU, UCC, UCA, UCG — Serine | UAU, UAC — Tyrosine<br>UAA — Stop codon<br>UAG — Stop codon | UGU, UGC — Cysteine<br>UGA — Stop codon<br>UGG — Tryptophan | U<br>C<br>A<br>G |
| C | CUU, CUC, CUA, CUG — Leucine | CCU, CCC, CCA, CCG — Proline | CAU, CAC — Histidine<br>CAA, CAG — Glutamine | CGU, CGC, CGA, CGG — Arginine | U<br>C<br>A<br>G |
| A | AUU, AUC, AUA — Isoleucine<br>AUG — Methionine Start codon | ACU, ACC, ACA, ACG — Threonine | AAU, AAC — Asparagine<br>AAA, AAG — Lysine | AGU, AGC — Serine<br>AGA, AGG — Arginine | U<br>C<br>A<br>G |
| G | GUU, GUC, GUA, GUG — Valine | GCU, GCC, GCA, GCG — Alanine | GAU, GAC — Aspartic acid<br>GAA, GAG — Glutamic acid | GGU, GGC, GGA, GGG — Glycine | U<br>C<br>A<br>G |

**13.** The chart Selected DNA Mutations on the next page describes types of DNA mutations. According to your teacher's instructions, explore how each type of mutation affects the production of an amino acid sequence. To do this

**a.** as described by each row in the Selected DNA Mutations chart, sequence the DNA mutations.

**b.** work through the steps to translate and transcribe the DNA. Record in your data table the amino acid sequence that results.

**c.** repeat Steps 13a and b for each type of mutation listed in the chart, starting each time with the original strand of DNA from Step 10.

14. Compare the amino acid sequence that resulted from each mutation to the original sequence. Based on your work, what can you say about the effect of DNA mutations on the production of amino acid sequences and proteins? Summarize your ideas in your science notebook.

**Selected DNA Mutations**

| CATEGORIES OF DNA MUTATIONS | CHANGE IN DNA | CHANGE TO DNA MODEL |
|---|---|---|
| Base insertion (frameshift) | One nucleotide is inserted into the DNA sequence. | Insert a thymine after the first cytosine. |
| Base deletion (frameshift) | One nucleotide is deleted from the DNA sequence. | Delete the first cytosine. |
| Substitution | One nucleotide is substituted for a different nucleotide. | Change the first cytosine to a thymine. |
| Three-base insertion | Three nucleotides are added or deleted to the DNA sequence. | After TAC, insert three additional nucleotides, CTG. |

## Part C: Gene Therapy Case Study

15. Individually read the case study on the following pages. As you read, follow the literacy strategy, "Read, Think, and Take Note."

16. Share your thinking with your group. Place your sticky notes on the table in front of you. Look for connections between your notes and the notes of others in your group.

    **Hint:** Were there common questions people asked? Were people unfamiliar with the same words? Did people react differently to statements in the reading?

17. Place your sticky notes in your science notebook. Below each, write a short summary of what your group discussed and any conclusions you came to.

18. Record the appropriate information from this case study on Student Sheet 2.3, "Genetics Case Study Comparison."