Name:

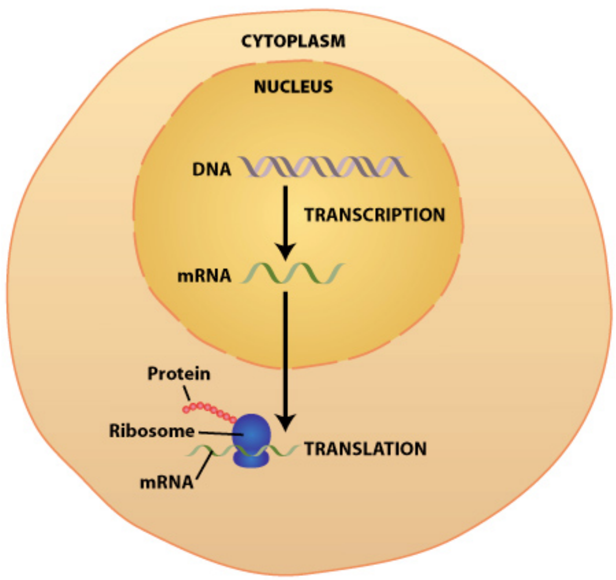
Modeling Activity for Protein Synthesis

Time required: two 50-minute periods

Introduction

Protein synthesis is the process in which cells make proteins. It occurs in two stages: transcription and translation. Transcription is the transfer of the genetic information code of deoxyribonucleic acid (DNA) to messenger ribonucleic acid (mRNA). During transcription, DNA is used as a template to make a molecule of mRNA. In eukaryotic cells, transcription takes place in the nucleus. The molecule of mRNA then leaves the nucleus and travels to a ribosome in the cytoplasm, where translation occurs. During translation, the genetic code in mRNA is read by transfer ribonucleic acid (tRNA) and used to make a protein.

Figure 1: Transcription and Translation in a eukaryotic cell



In this activity, you will:

- build a single strand of DNA.
- use complimentary base pairing to model transcription by constructing a strand of mRNA.
- use complimentary base pairing to determine the anticodon in tRNA which matches the mRNA codon during translation.
- bond the amino acids together to form a protein.

Deoxyribonucleic acid (DNA) is a molecule that directs cell functions and transmits genetic information to the next generation. DNA consists of two strands twisted around each other to form a double helix. The molecule's "sides" are made from deoxyribose sugar and phosphoric acid, while the "rungs" are formed by four nitrogenous bases: cytosine (C), guanine (G), adenine (A), and thymine (T). Each structural unit, or nucleotide, is composed of deoxyribose, phosphoric acid, and one of these bases. Groups of nucleotides form genes, which encode proteins. Proteins serve multiple roles, including structural proteins that build cells and enzymes that drive cellular chemical reactions. To protect DNA's crucial role, it is securely housed within the cell nucleus.

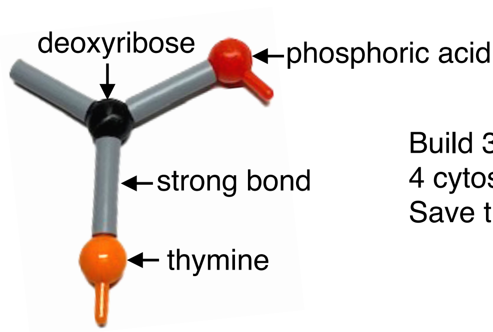
Part 1: How To Build A DNA Nucleotide

Table 1: The Parts of a DNA Nucleotide

Deoxyribose	Phosphoric Acid	Bases	
black 	red 	 adenine yellow	 thymine orange
		 cytosine green	 guanine blue

To build a nucleotide, join together 3 molecules: 1 deoxyribose, 1 phosphoric acid, and 1 base. The strong bonds between the molecules are represented by gray links. A nucleotide is named for the base that joins with the deoxyribose. For example, if thymine attaches to deoxyribose, the compound is called a thymine nucleotide.

Figure 2: Thymine DNA Nucleotide



Build 3 thymine DNA nucleotides, 3 adenine DNA nucleotides, 4 cytosine DNA nucleotides, and 2 guanine DNA nucleotides. Save the nucleotides for the next part of this activity.

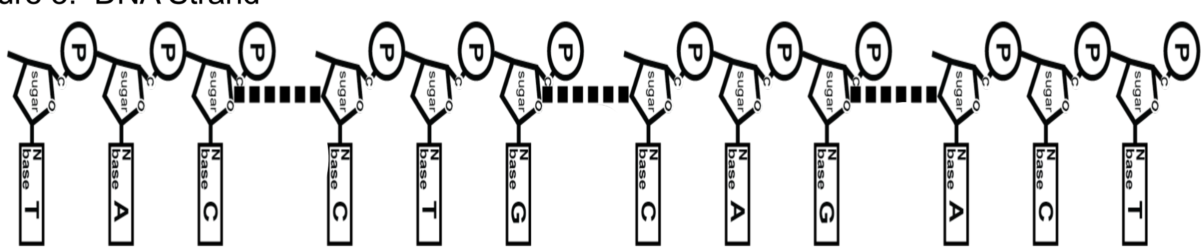
Part 2: How To Build A Single Strand of DNA

Use the nucleotides from Part 1 to build a single strand of DNA in the order of nucleotides shown below. Join the phosphoric acid of the thymine nucleotide to the deoxyribose of the adenine nucleotide. Continue to build the DNA strand by joining the phosphoric acid of one nucleotide to the deoxyribose of the next nucleotide.

T-A-C-C-T-G-C-A-G-A-C-T

This strand is one of the two strands that make up the DNA molecule. The DNA molecule has already been "unzipped" or separated, and now will be used as the template to build mRNA, one nucleotide at a time.

Figure 3: DNA Strand



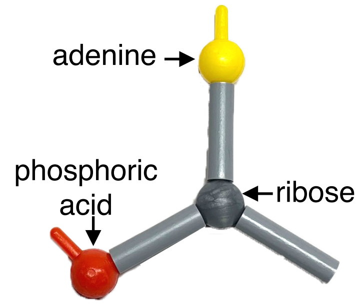
Part 3: How To Build A RNA Nucleotide

RNA is similar to DNA in that it is formed from nucleotides. However, RNA nucleotides do not have deoxyribose or thymine. Instead, deoxyribose is replaced by ribose and thymine is replaced by uracil.

Figure 4: RNA Nucleotide

ribose - silver

uracil - purple

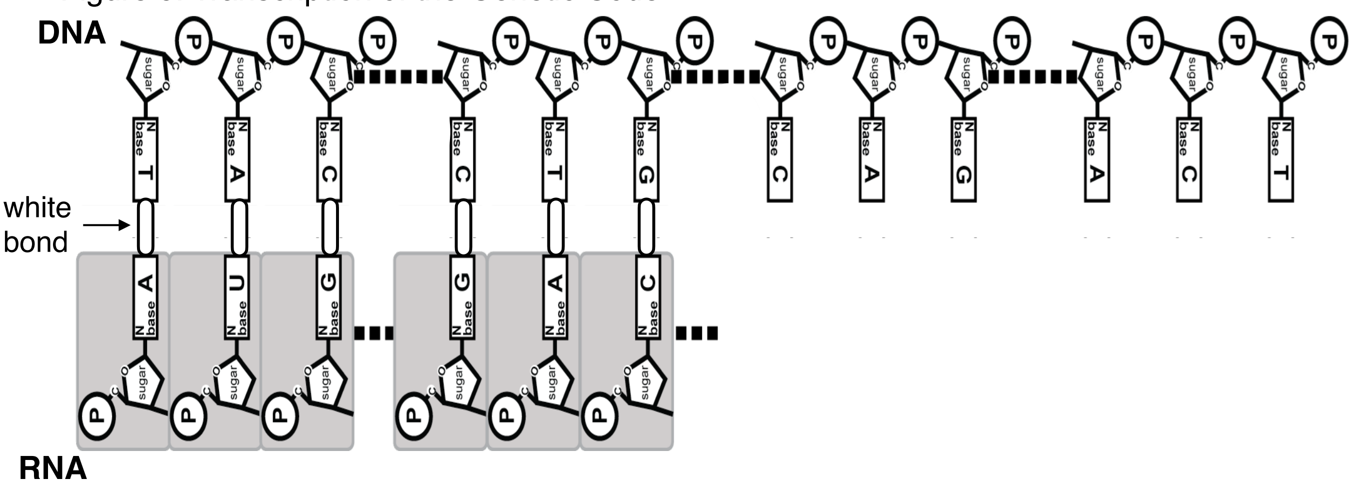


Build 3 adenine RNA nucleotides, 3 uracil RNA nucleotides, 2 cytosine RNA nucleotides and 4 guanine RNA nucleotides. Save these nucleotides for the next part of the activity.

Part 4: Transcription Of The Genetic Code From DNA To mRNA

Proteins are made in the cytoplasm by ribosomes. Because DNA does not leave the nucleus, the information in DNA must be transferred from the nucleus to the cytoplasm. Messenger RNA transfers the genetic code of DNA to the ribosome in the cytoplasm of eukaryotic cells. Messenger RNA is constructed using complimentary base pairing. In complimentary base pairing, **adenine always pairs with uracil** and **guanine always pairs with cytosine**. Complimentary base pairing ensures that information coded in the DNA is transferred accurately during protein synthesis. Messenger RNA nucleotides are assembled along one strand of DNA, leading to the production of a complimentary copy of the base sequence of the gene.

Figure 5: Transcription of the Genetic Code



Use the single strand of DNA to build a strand of mRNA in the order of nucleotides shown in Figure 5. Bond the phosphoric acid of the adenine nucleotide to the ribose of the uracil nucleotide. Continue building the strand of mRNA by joining phosphoric acid of one nucleotide to the ribose of the next nucleotide. White bonds are used to represent weaker attractions between complimentary base pairs of DNA and mRNA. Continue adding RNA nucleotides until you have transcribed the entire length of the DNA gene. When the mRNA is completed the weak bonds (white) between the complimentary base pairs are released from the mRNA. The mRNA now leaves the nucleus and carries the code for making the protein from the DNA gene in the nucleus to the ribosome in the cytoplasm.

Part 5: Reading The mRNA Code At The Ribosome

During translation, the ribosome reads the sequence of bases on the mRNA in sets of three nucleotides. The three bases are read as a unit called a codon. The codon chart is used to determine the amino acids from the sequence of bases in mRNA. For example, the first codon in the mRNA strand is A-U-G. Use the left side of the chart to find the first letter in the codon, the top to find the second letter, and the right side to find the third letter. Find the amino acid in the box where all three overlap on the chart.

The codon A-U-G codes for methionine. Methionine is called the start amino acid because it is the first amino acid of the protein.

Table 2: The Codon Chart

First	**Second Letter**				**Third**
Letter	**U**	**C**	**A**	**G**	**Letter**
U	phenylalanine	serine	tyrosine	cysteine	**U**
	phenylalanine	serine	tyrosine	cysteine	**C**
	leucine	serine	(stop)	(stop)	**A**
	leucine	serine	(stop)	tryptophan	**G**
C	leucine	proline	histidine	arginine	**U**
	leucine	proline	histidine	arginine	**C**
	leucine	proline	glutamine	arginine	**A**
	leucine	proline	glutamine	arginine	**G**
A	isoleucine	threonine	asparagine	serine	**U**
	isoleucine	threonine	asparagine	serine	**C**
	isoleucine	threonine	lysine	arginine	**A**
	(start) methionine	threonine	lysine	arginine	**G**
G	valine	alanine	aspartic acid	glycine	**U**
	valine	alanine	aspartic acid	glycine	**C**
	valine	alanine	glutamic acid	glycine	**A**
	valine	alanine	glutamic acid	glycine	**G**

Analysis of the mRNA Code

DNA gene sequence: T - A - C - C - T - G - C - A - G - A - C - T

1. Write the mRNA sequence:

____

2. Divide the mRNA sequence into the triplet codons and list them in order below.

________________, ________________, ________________, ________________

3. Record the amino acids in the order as coded for by the mRNA .

________________, ________________, ________________, ________________

The last codon of the mRNA strand is U-G-A. The mRNA codon, U-G-A, is one of three codons which signals that the protein is complete.

Part 6: Building The tRNA Molecule

At one end of the tRNA molecule is the amino acid attachment site. This site attaches to a specific amino acid. The middle of the tRNA molecule is a folded structure that is represented by red tubing. The tRNA anticodon is a sequence of three nucleotides. During protein synthesis, the tRNA anticodon pairs with its complementary codon in the mRNA to ensure the correct amino acid is added to the growing polypeptide.

Build the tRNA anticodon, U-A-C. Add the folded section of the tRNA molecule that is represented by red tubing to the anticodon. This tRNA molecule bonds with the amino acid, methionine. Methionine is represented by a purple model with 4 attachment sites. Add the purple model of methionine to the red tubing.

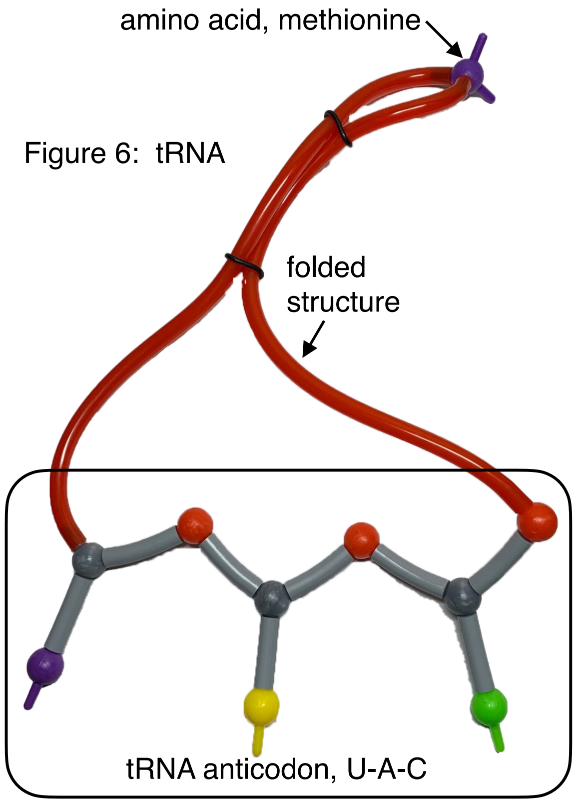
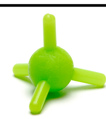


Figure 6: tRNA

Use complimentary base pairing to determine the anticodons for the three additional mRNA codons. Build three more tRNA molecules with anticodons to match the codons in the strand of mRNA. Use Table 2 to determine the amino acid that is coded for by the mRNA codon. Use Table 3 to determine the color of the amino acid model that attaches to the tRNA molecule.

Table 3: Amino Acid Models

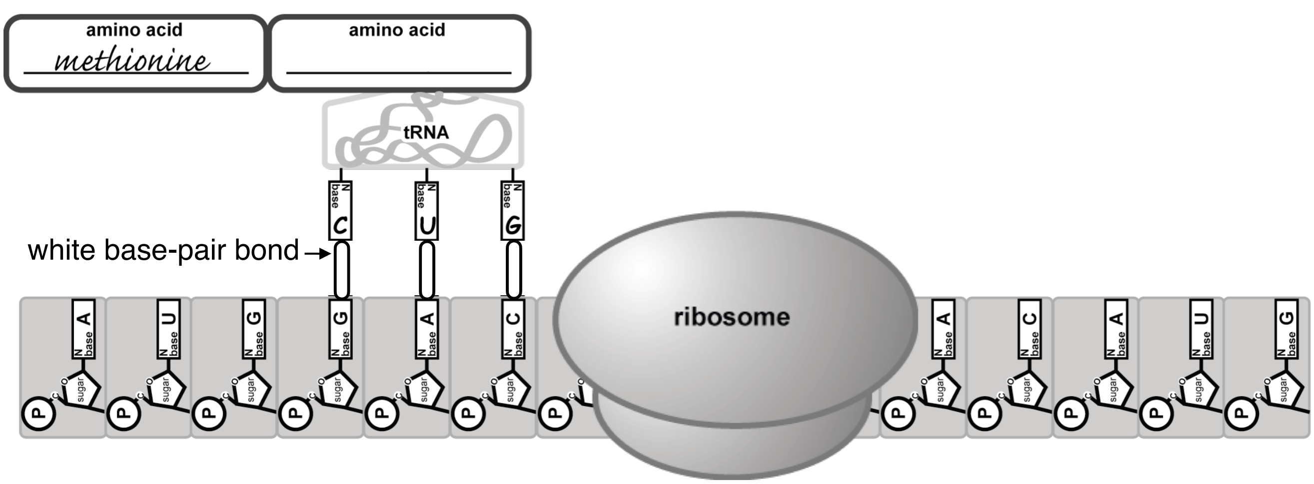
Name of Amino Acid	Color of Amino Acid Model
methionine	purple 
aspartic acid	green 
valine	orange 

STOP anticodon
The anticodon of tRNA that is complimentary to the last mRNA codon, U-G-A, is a continuous folded structure that does not bond to an amino acid. It signals that the protein is complete.

Part 7: Translation Of The Genetic Code

A tRNA molecule transports an amino acid to the ribosome according to the codon sequence on the mRNA. The anticodon of the tRNA pairs with the complementary codon on the mRNA. White bonds indicate the weak attractions between complementary bases. The amino acids link together, forming the protein specified by the DNA gene. These strong amino acid bonds are shown as gray bonds. Once the amino acids are bonded, the tRNA releases its amino acid and detaches from the mRNA, breaking the weak white base-pair bonds. The tRNA then returns to the cytoplasm to be reused. Figure 7 illustrates the process of protein synthesis at the ribosome. Use the models to demonstrate each step.

Figure 7: Protein Synthesis



Analysis of Protein Synthesis

4. Complete Table 4 by using check marks to indicate if the characteristic applies to DNA and/or RNA.

Table 4: Similarities and Differences Between DNA and RNA		
Characteristic	**DNA**	**RNA**
Ribose present		
Phosphoric acid present		
Formed from nucleotides		
Double stranded		
Moves out of the nucleus to the ribosome		
Contains adenine		
Contains thymine		
Contains uracil		
Deoxyribose present		
Transports amino acids to the ribosome		

5. Transcribe the DNA strand into mRNA. Then translate the mRNA into tRNA and its amino acid sequence.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
DNA	T	A	C	T	G	A	G	C	T	G	A	G	C	T	G	C	A	G	A	G	C	A	C	T
mRNA																								
tRNA																								
amino acids																								

A mutation is a change in the DNA sequence of nucleotides. Mutations can result from DNA copying mistakes made during cell division, exposure to ionizing radiation, exposure to chemicals called mutagens, or infection by viruses. Mutations cause changes to the gene and therefore can alter the protein that is made from that gene. This may affect the organism, since the protein will not be able to perform its normal function.

When only one DNA base is copied incorrectly during DNA replication, it is called a point mutation. In the strand of DNA a point mutation has occurred at the 13th base. The cytosine nucleotide was accidentally changed to thymine.

6. Transcribe the DNA strand into mRNA. Then translate the mRNA into its amino acid sequence.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
DNA	T	A	C	T	G	A	G	C	T	G	A	G	T	T	G	C	A	G	A	G	C	A	C	T
mRNA																								
amino acids																								

7. Did the mutation in the DNA sequence cause a change to the protein produced? Explain.