MEGA MOLECULES

Name:

Modeling Activity for Protein Synthesis

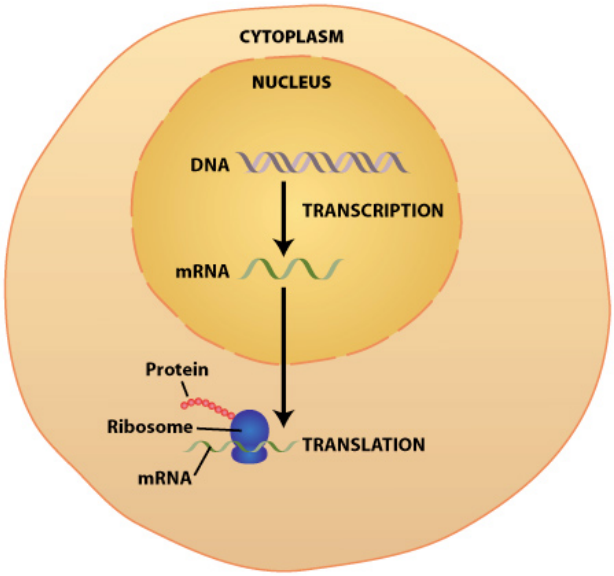
Time required: two 50-minute periods

Introduction

Protein synthesis is the process in which cells make proteins. It occurs in two stages: transcription and translation. Transcription is the transfer of genetic instructions in 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.

In this activity, you will:

- build a single strand of DNA.
- 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.



The molecule, deoxyribonucleic acid (DNA), directs the functions of the cell and passes the genetic information to the next generation. The DNA molecule is made of two strands that wind around one another to form a shape known as a double helix. Deoxyribose and phosphoric acid are joined to form the “sides” or outer portion of the DNA molecule. The bases of DNA, C (cytosine), G (guanine), A (adenine), and T (thymine), form the “rungs” or connections between the sides of the DNA molecule. A nucleotide is the structural unit of DNA. Deoxyribose, phosphoric acid, and 1 of the bases join to form a nucleotide. A group of nucleotides of the DNA molecule function as a gene. Genes code for proteins. One type of protein is a structural protein. Structural proteins serve as the building blocks of cells. Proteins also function as enzymes, directing all the chemical reactions in cells and living organisms. Because DNA plays a critical role in all the functions of the cell, DNA is protected within the nucleus of cells.

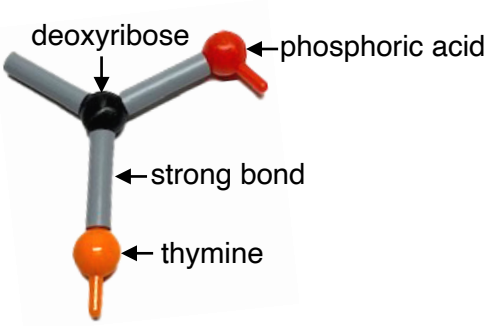
Part 1: How To Build A DNA Nucleotide

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 1: Thymine DNA Nucleotide



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

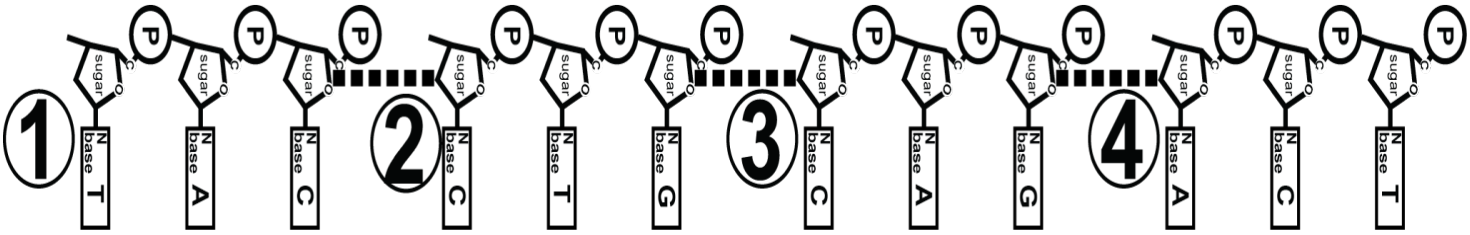
Part 2: How To Build A Single Strand of DNA

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 2 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.

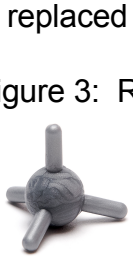
Figure 2: DNA Strand



Part 3: How To Build A RNA Nucleotide

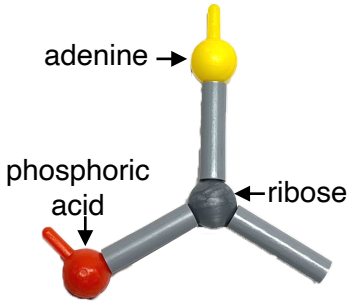
RNA is similar to DNA in that it is formed from nucleotides. However, RNA nucleotides do not have deoxyribose or thymine. Instead, deoxyribose is replaced by ribose and thymine is replaced by uracil.

Figure 3: RNA Nucleotide



ribose - silver

uracil - purple



Build 3 adenine nucleotides, 3 uracil nucleotides, 2 cytosine nucleotides and 4 guanine 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.

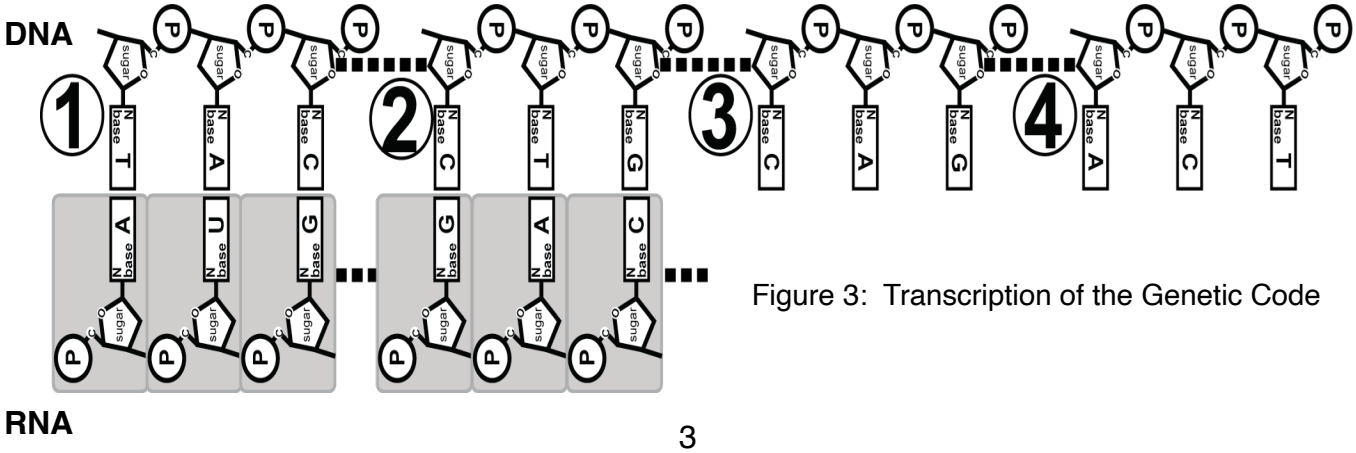


Figure 3: Transcription of the Genetic Code

Use the single strand of DNA to build a strand of mRNA in the order of nucleotides shown in Figure 3 on the previous page. 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 3 nucleotides. The 3 bases are read as a unit called a codon. The codon chart on the next page 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.

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.

Table 3: Codon Chart

First Letter	Second Letter				Third Letter
	U	C	A	G	
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

Part 6: Building The tRNA Molecule

At one end of the tRNA molecule is a sequence of 3 bases called the anticodon. Complimentary base pairing determines the anticodon in tRNA which bonds with the mRNA codon. The middle of the tRNA molecule is a folded structure that is represented by red tubing. The opposite end of the tRNA molecule is the amino acid attachment site. This site attaches to a specific amino acid. The colors of the models used to represent the amino acids are listed in Table 4. Each amino acid model has 4 attachment sites.

Table 4: Amino Acids

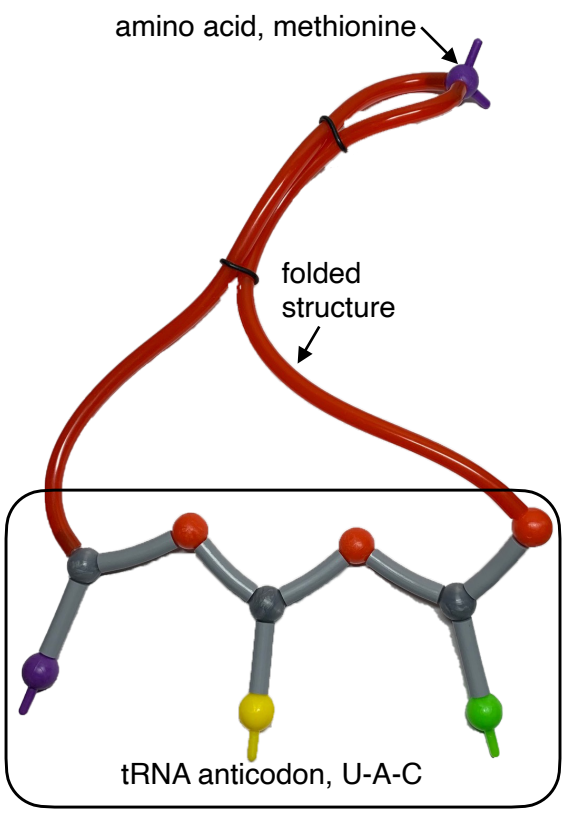
Name of Amino Acid	Color of Amino Acid Model
aspartic acid	green
methionine	purple
valine	orange

The model of a tRNA molecule is shown in Figure 4. The anticodon, U-A-C, is the compliment for the first codon in the mRNA strand. 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.

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 Tables 3 and 4 to determine the colors of the amino acid models that are coded for by the mRNA codon and attaches to the tRNA molecule.

The anticodon of tRNA that is complimentary to the 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.

Figure 4: tRNA



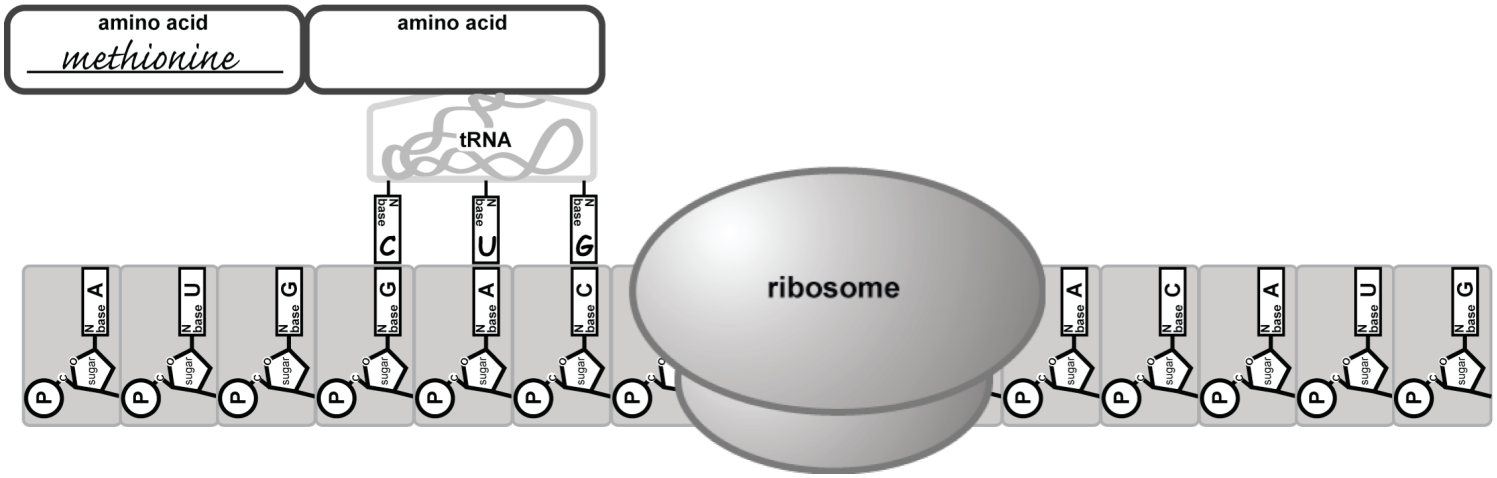
4. Record the tRNA anticodons in order as coded for by the mRNA.

_____, _____, _____, _____

Part 7: Translation Of The Genetic Code

A tRNA molecule brings an amino acid to the ribosome as coded for by the codon on the mRNA. The tRNA molecules's anticodon attaches to the codon of mRNA with white bonds used to represent weak attractions between complimentary base pairs. The amino acids bond together to form the protein coded for by the gene located on the DNA. The strong bonds between the amino acids are represented by gray bonds. Once the amino acids are bonded to each other, tRNA releases the amino acid. The weak bonds between the complimentary base pairs are removed as the tRNA detaches from the mRMA. Transfer RNA now moves back into the cytoplasm. Figure 6 shows the process of protein synthesis at the ribosome. Use the models to illustrate the process.

Figure 6: Protein Synthesis



Analysis

5. Complete Table 5 by using check marks to indicate to which molecule each characteristic applies.

Table 5: Similarities and Differences Between DNA and RNA		
	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		

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	C	T	G	C	A	G	A	G	C	A	C	T
mRNA																								
amino acids																								

A mutation is a permanent 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.

7. 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																								

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