Name…….. Date…… Period…….

Student Laboratory Packet

Protein Synthesis

A Laboratory Activity for the Living Environment

Background

DNA carries the information for the synthesis of all the proteins of an organism. Protein molecules are large and complex, composed of hundreds of amino acid units. In each kind of protein, the amino acid units are linked together in a definite sequence. The sequence of amino acids in a protein molecule is determined by the sequence of the nucleotides in the DNA of the organism. All the different proteins that occur in organisms are composed of only twenty kinds of amino acids.

In the first step leading to protein synthesis, the nucleotide sequence of the DNA is *transcribed* (the process is called *transcription*) into a long single-stranded molecule of RNA, termed *messenger* RNA (*m*RNA). The mRNA moves out of the nucleus into the cytoplasm through pores in the nuclear membrane.

In the cytoplasm, ribosomes temporarily attach to the mRNA. Triplet sequences of nucleotides, called codons, in the mRNA form a sort of pattern, or code, that specifies the order in which the amino acids of a protein are to be linked. While a ribosome is attached at each codon along the mRNA, molecules of another kind of RNA—*transfer* RNA (*t*RNA)—bring amino acids into place, each according to the code or sequence in the mRNA. As the ribosomes move along the mRNA from codon to codon, the appropriate amino acids are brought into place and linked together according to the sequence of codons. Thus, the code in the mRNA is *translated* into a special sequence of amino acids. The order of the amino acids in the protein, therefore, is specified by the mRNA, which in turn is transcribed from the DNA.

Objectives

In this activity you will:

1. Follow the steps of protein synthesis.
2. Translate the genetic code for specific amino acids.
3. Use paper models to simulate protein synthesis.

Materials

1/2-inch transparent tape scissors

Procedures and Observations

During transcription, the DNA double helix unwinds and "unzips." The two strands separate as the hydrogen bonds binding the nitrogen bases break. Then, nucleotides present in the cell line up along one strand of the DNA, the order of the nucleotides determined by the order of the nucleotides in the DNA. As the mRNA forms, uracil (U) nucleotides match with adenine (A) nucleotides; cytosine (C) nucleotides match with guanine (G) nucleotides. **Note:** *RNA contains uracil (U) nucleotides where thymine (T) nucleotides would occur in DNA.*

The nucleotides in the newly formed mRNA are *complementary* to the nucleotides of the DNA segment on which it formed. For example, where the DNA contained guanine, the mRNA contains cytosine. Where the DNA contained adenine, the mRNA contains uracil. After the single-stranded molecule of mRNA is formed, it moves out of the nucleus into the cytoplasm.

1. One strand of DNA has the base sequence: C G A T T G G C A G T C A T. Determine the sequence of bases in the complementary strand of mRNA that would form next to this DNA strand.

   a. *Write the sequence of bases in the complementary mRNA strand below.*

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The information carried on the mRNA is in a code—the *genetic code*. A group of three nucleotides on a molecule of mRNA is called a *codon;* each codon specifies one of the 20 amino acids, except for three codons that are stop, or termination, signals. There are 64 codons in the genetic code.

2. The 64 codons are shown in Table 1. Notice that the first two nucleotides of each codon (abbreviated by their first letter) are shown in the column on the left. To find out the amino acid specified by a given codon, find the first two letters in the column on the left, then follow that row to the column showing the last nucleotide (letter) of the codon. Note that most amino acids are coded for by more than one codon.

Table 1. The Genetic Code: Codons and Their Amino Acids

First Two Nucleotides of Codons	Last Nucleotide of Codons				The Amino Acids	
	U	C	A	G		
UU	phe	phe	leu	leu	*Abbreviations*	*Names*
UC	ser	ser	ser	ser	gly	glycine
UA	tyr	tyr	term	term	ala	alanine
UG	cys	cys	term	trp	val	valine
CU	leu	leu	leu	leu	ile	isoleucine
CC	pro	pro	pro	pro	leu	leucine
CA	his	his	gln	gln	ser	serine
CG	arg	arg	arg	arg	thr	threonine
AU	ile	ile	ile	met	pro	proline
AC	thr	thr	thr	thr	asp	aspartate
AA	asn	asn	lys	lys	glu	glutamate
AG	ser	ser	arg	arg	lys	lysine
GU	val	val	val	val	arg	arginine
GC	ala	ala	ala	ala	asn	asparagine
GA	asp	asp	glu	glu	gln	glutamine
GG	gly	gly	gly	gly	cys	cysteine
					met	methionine
					trp	tryptophan
					phe	phenylalanine
					tyr	tyrosine
					his	histidine
					term	termination

3. Use Table 1 to read the codons below. Find the name of the amino acid and write it in the space provided. If the letters code for more than one amino acid, separate the names by dashes.

b. U U A: _____

c. G A G: _____

d. U A U C U A: _____

e. A U C U U G: _____

f. A A G A G U U C G: _____

g. A A A U U U G G G: _____

h. C C A G C U A G A G G G U G G C U G U C A:

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Molecules of transfer RNA (tRNA) are formed in the nucleus and migrate into the cytoplasm. There are twenty different types of tRNA, one for each kind of amino acid. The tRNA molecule has two ends. One end can carry only one kind of amino acid molecule. The opposite end has a three-base segment called an *anticodon,* which is complementary to a codon on mRNA.

In protein synthesis, with a ribosome attached to an mRNA, a tRNA molecule carrying its special amino acid molecule briefly attaches to mRNA at its complementary codon. Next, a tRNA molecule complementary to the adjacent codon briefly attaches to the mRNA. The ribosome moves along the mRNA to that point of attachment. During each brief attachment among tRNA, mRNA, and ribosome, peptide bonds form between the amino acids. As these bonds form, the tRNA molecules are released from their amino acids, and also from the mRNA. Each is free to attach to another molecule of its special amino acid and carry it to another point along the mRNA. The ribosomes move along the mRNA as amino acids are added, one at a time, to a growing chain. This continues until a termination codon is encountered.

4. Determine the anticodon for each codon below. Write it in the space provided.

i. G G U: _____

j. C G C: _____

k. A U G: _____

l. U C G: _____

m. A A A: _____

n. C U G: _____

5. Cut out the tRNA models with amino acids attached, found in Figure 1 on the last page of this activity. Then cut out the mRNA strands and tape them together, so that strand 1 forms the left end of a long strand, strand 3 forms the right end, and strand 2 is between them.
6. Starting at the left of the mRNA strand, find a tRNA molecule with an anticodon complementary to the first codon. With a small piece of tape, attach the tRNA to the mRNA strand, anticodon to codon.
7. For the next codon, find a tRNA with the complementary anticodon. Tape the tRNA in place to the mRNA. Also, use a small piece of tape between the two amino acids to represent a peptide bond.
8. Once the peptide bond has been formed, the tRNA molecule attached first is released. Carefully cut the tape attaching the first tRNA to the mRNA, and cut the line that separates the tRNA and the amino acid. You may set the tRNA model aside and discard it later.

There are three termination codons in the genetic code. When a termination codon is read, the strand of amino acids is released, folding and twisting to form the final, complex structure of the protein.

9. Repeat Steps 7 and 8 along the mRNA strand. When you have used up all the tRNA-amino acid models provided, you will notice that there is one codon left on the mRNA—a termination codon. Cut the tape between the mRNA and the tRNA, and the line between the last tRNA and amino acid, thus releasing the chain of amino acids.
   o. *Starting at the left, write the sequence of the amino acids formed by translation of the mRNA strand.*

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Analysis and Interpretations

1. Write the order of nucleotides in mRNA that would be transcribed from the following strand of DNA:

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

   Then list in order the amino acids coded by this sequence.

mRNA _____

amino acids _____

2. Sometimes a mistake occurs in the translation of an mRNA strand. Suppose that the reading of the mRNA strand in question 1 began, by mistake, at the second nucleotide instead of the first. The first codon would be AUA. Write the sequence of amino acids that would be formed.

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3. Suppose the bases of the DNA strand in question 1 were not transcribed correctly and the mRNA read:

   C A C A U G G U U A G U A A G C A G

   How many mistakes were made in transcription? Write the abbreviations for the amino acids that would be formed by translation of the mRNA.

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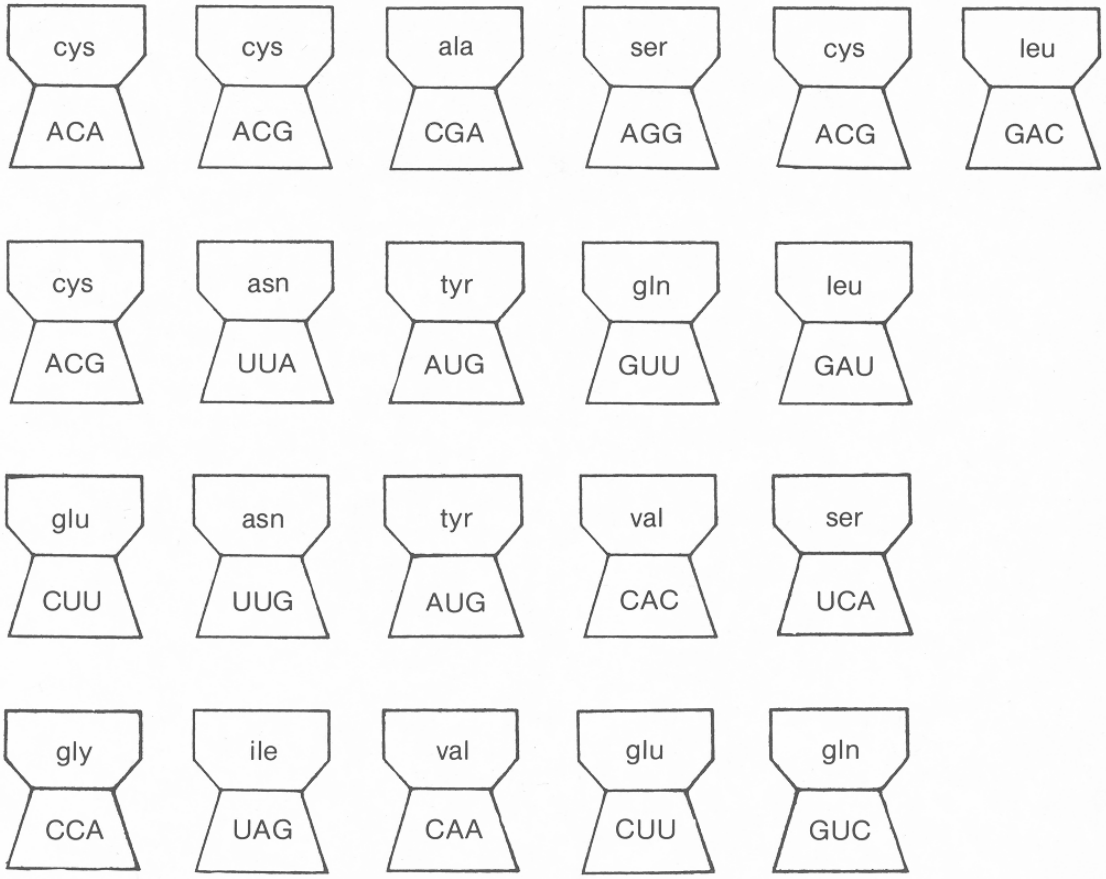
Models for tRNA attached to amino acids:



Models for mRNA (tape these, left to right, into one long strand):

GGU	AUC	GUU	GAA	CAG	UGU	UGC	GCU

UCC	GUG	UGC	AGU	CUG	UAC	CAA

CUA	GAA	AAC	UAC	UGC	AAU	UAA