Lesson 9

Genes to Proteins

Materials Needed:
pen or pencil

Traits such as hair color, eye color, and height are determined by proteins found in a set of instructions in your DNA. Proteins, as you may recall, have many different functions, including acting as enzymes and forming doorways through the cell membrane. How do these sets of instructions get communicated from the DNA? Proteins are not part of DNA, but they are the result of a message from the DNA that needs to be translated.

Just like DNA, RNA (ribonucleic acid) is a molecule made of nucleotides linked together with sugar and phosphate groups. However, RNA differs from DNA. The differences are that: (1) RNA is made of a single strand of nucleotides whereas DNA has two strands. (2) RNA contains the sugar **ribose** where DNA has **deoxyribose**. Ribose contains one more oxygen atom in its structure than deoxyribose. Notice the extra oxygen in the sugar molecule ribose than deoxyribose in Figure 9.1. (3) RNA does not contain thymine; instead it has uracil (YUR uh sihl) in place of thymine. The complementary base for uracil is still adenine. (4) Lastly, RNA is much shorter than DNA.

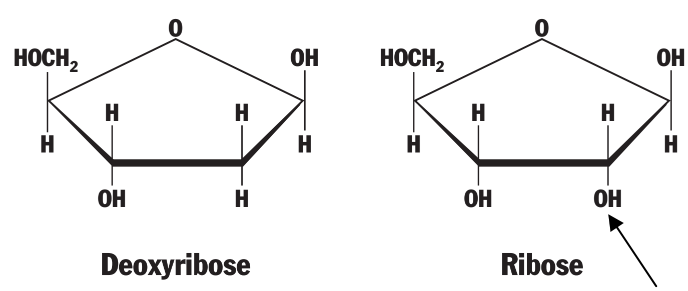


Figure 9.1

The instructions for making protein are encoded in the nucleotides in the gene. When the need for protein arises, the information is transferred from the DNA to the RNA by a process called transcription. The cell uses two different types of RNA to make the amino acids that make the proteins. This will be described a bit later.

For now, complete the Venn diagram below to show the similarities and differences between RNA and DNA. There should be a total of at least 3 listings in each section.

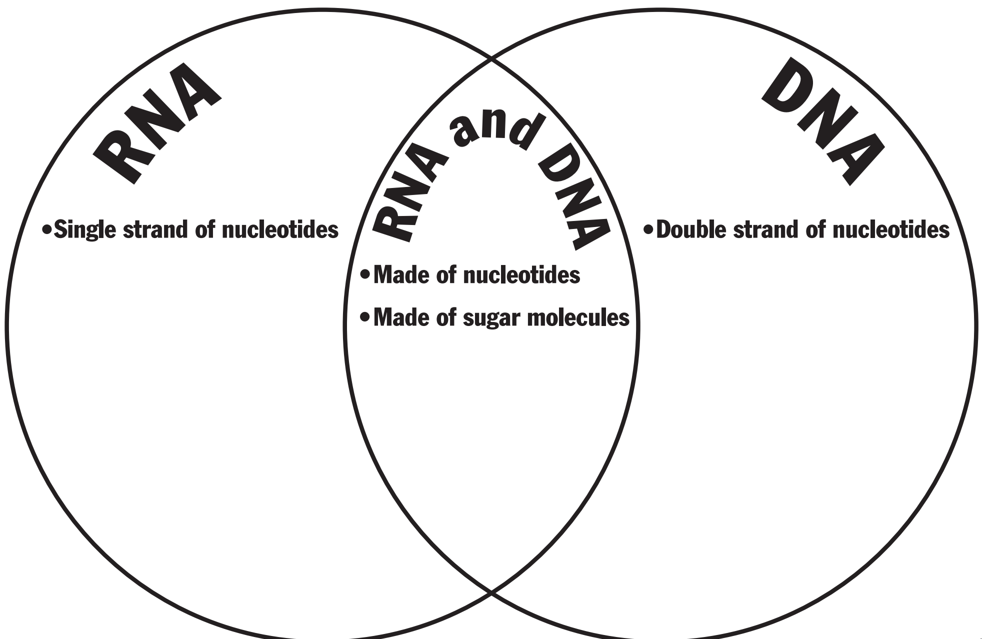


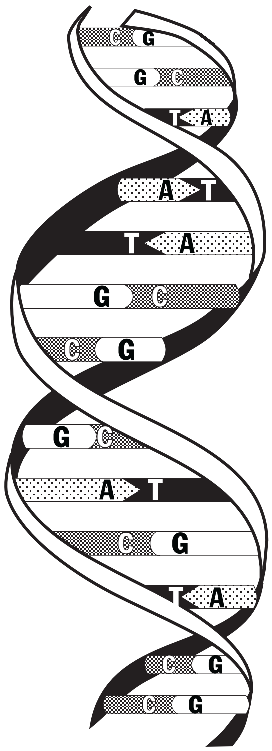
Figure 9.2

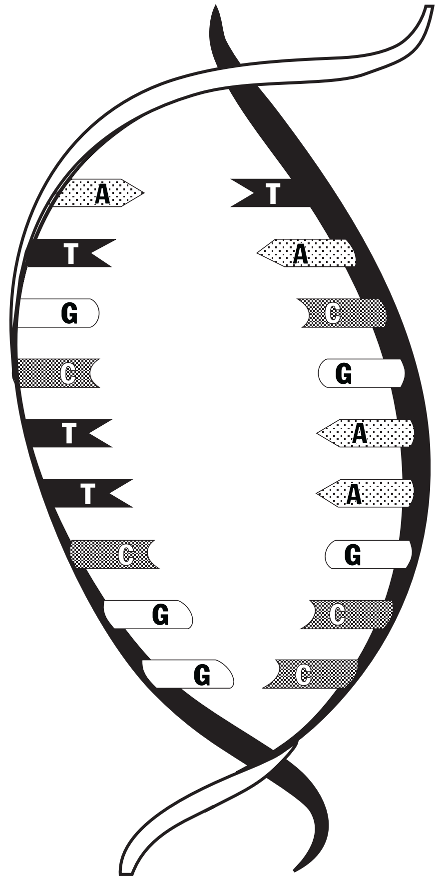
Gene Expression

Transferring Information by Transcription

The information for making proteins comes from the **transcription** of DNA to RNA. RNA can be thought of as the DNA's messenger. An enzyme called RNA polymerase is needed to add and link the complementary nucleotides. Here are three simple steps for RNA production.

Step 1	To get transcription going there needs to be a specific sequence in the gene called the *Promoter* which acts as a start signal for the RNA polymerase to bind to.
Step 2	Polymerase unwinds and splits the DNA strands, exposing the nucleotides of the DNA.
Step 3	The RNA polymerase then adds and binds complementary nucleotides as it moves along the section of DNA. Remember, uracil (U) replaces thymine and binds to adenine.





When a stop signal in the DNA is reached by the polymerase, the RNA is released and goes to the next step in gene expression.

When RNA nucleotides are added during transcription they are covalently bonded. As the polymerase moves, the RNA strand grows. Behind the polymerase the two DNA strands close, reforming the hydrogen bonds between the base pairs.

Instead of replicating, the DNA is used as a template for making a new RNA molecule. In prokaryotic cells (bacteria), RNA transcription occurs in the cytoplasm because prokaryotic cells have no nucleus. In eukaryotic cells, transcription occurs in the nucleus.

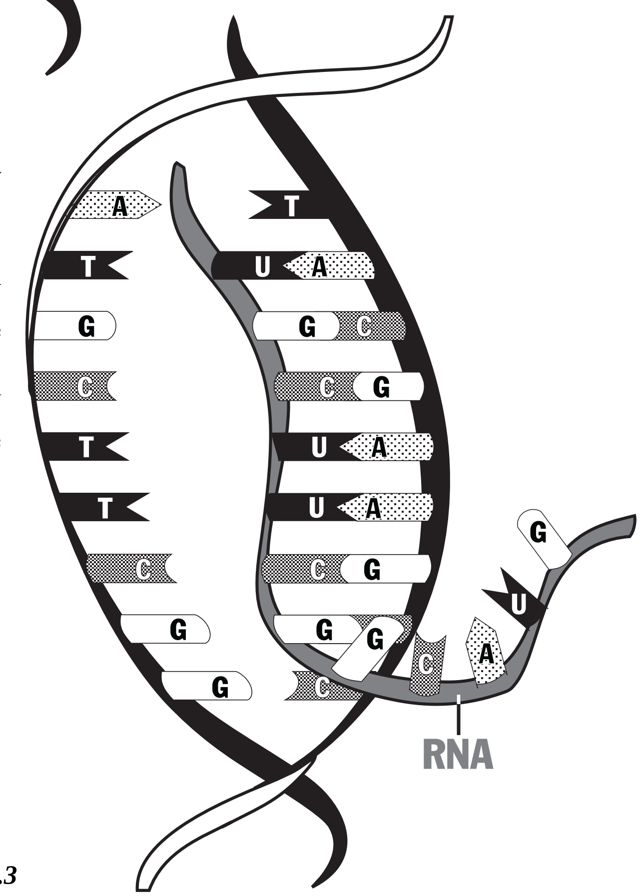
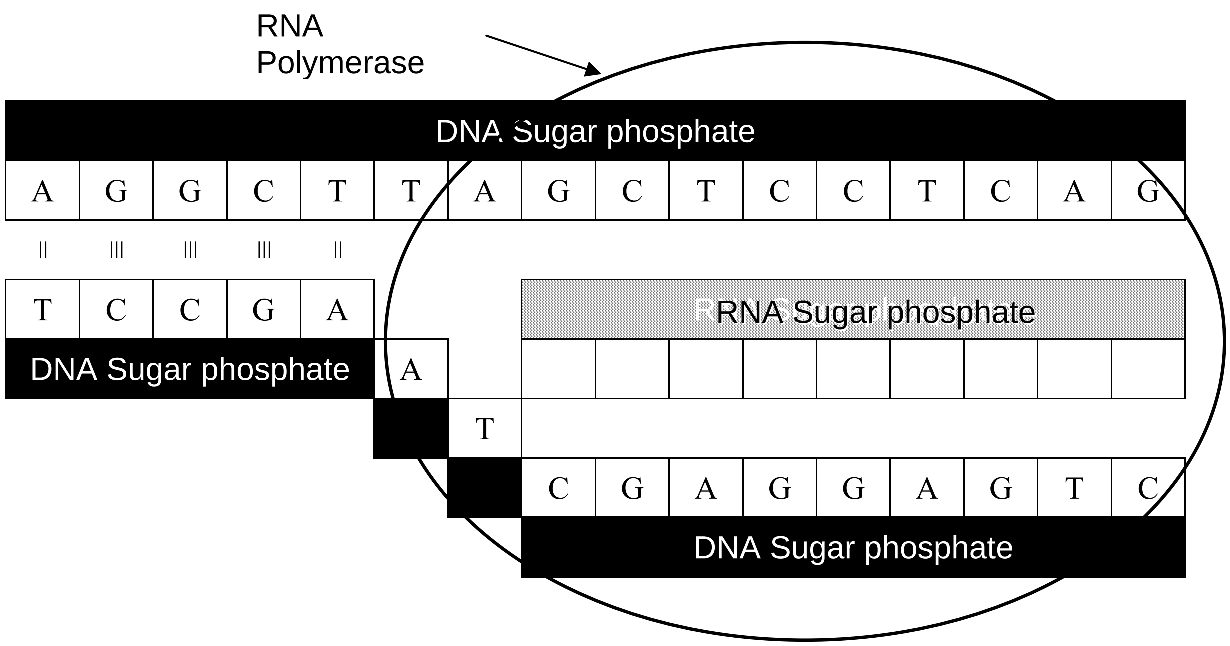


Figure 9.3

Below, the DNA is split by RNA polymerase and a new strand of RNA is forming. Fill in the RNA complementary base pairs between the RNA and DNA strands and then add the covalent bonds.



What is the base that replaces **thymine** in RNA? ___________________________________

Translating the Genetic Code

When RNA is made from transcription, the resulting strand is referred to as messenger RNA or mRNA. Once transcription of the mRNA has occurred, it must be *read* to create the amino acid sequence that makes up a protein. As you recall, RNA is composed of the nitrogenous bases: uracil (U), cytosine (C), adenine (A) and guanine (G). These base pairs are translated into a series of amino acids. In order to determine the correct sequence of amino acids, the nucleotides are read in groups of three. These groupings are called **codons**. The mRNA contains the codons that code for amino acids. For example, the codon UAC is the code to bring a specific amino acid called tyrosine to be assembled into a chain of amino acids called a **polypeptide**. Let's look at some nucleotide triplets from a sequence of mRNA.

In the genetic code, each amino acid is coded by three mRNA bases arranged in a specific sequence. Remember that the three bases are called a codon. The following chart shows which amino acid is prescribed by each codon. The name of the correct amino acid is found where the three letters of the codon intersect on the chart.

1. The first base in a codon is found along the left side of this chart.

2. The second base is at the top of the chart.

3. The third base in the codon is found along the right side of the chart.

1st ↓ / 2nd →	U	C	A	G	3rd ↓
U	phenylalanine phenylalanine leucine leucine	serine serine serine serine	tyrosine tyrosine *stop* *stop*	cysteine cysteine *stop* tryptophan	U C A G
C	leucine leucine leucine leucine	proline proline proline proline	histidine histidine glutamine glutamine	arginine arginine arginine arginine	U C A G
A	isoleucine isoleucine isoleucine methionine (*start*)	threonine threonine threonine threonine	asparagine asparagines lysine lysine	serine serine arginine arginine	U C A G
G	valine valine valine valine	alanine alanine alanine alanine	aspartic acid aspartic acid glutamic acid glutamic acid	glycine glycine glycine glycine	U C A G

Here is a sample of mRNA that has been produced. Use the table above to decode the following triplet sequences. The codons UAA, UAG, and UGA act to stop production.

Stop Codon

mRNA Strand

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

Sugar / phosphate

Beginning with the first triplet, what are the codons?	What amino acid is produced?
AUG	Methionine *(start)*
UAA	

From RNA to Proteins

The mRNA leaves the nuclear envelope and translation of mRNA takes place in the cytoplasm, where mRNA molecules and ribosomes aid in the synthesis of proteins by connecting amino acids together. This is where transfer RNA, or **tRNA**, *reads* the mRNA to begin protein production. These tRNA are single strands of RNA that are folded into a very compact shape with a specific amino acid attached at one end. Each tRNA strand has an **anticodon**—a three nucleotide sequence complementary to the codon on the mRNA. The anticodon has to match up with the codon on the mRNA. The anticodon of the tRNA brings with it the correct amino acid to add to the chain. A chain of amino acids is what makes a protein. Ensuring that the anticodon and codon pair up correctly is how the proper sequence of amino acids is created. Be sure to remember that the codon, not the anticodon, is the code for the amino acid.

The mRNA is read by the ribosomes, which are made up of both proteins and ribosomal RNA (**rRNA**). The rRNA is RNA that is part of the ribosome's structure and is only found in the ribosome. The cytoplasm of the cell contains thousands of ribosomes to read the information encoded on the strand of mRNA. Let's look at the steps needed for translation into proteins. Look at Figure 9.4 after you read each step.

Step 1	The mRNA and two ribosomal subunits carrying tRNA with the anticodon for the amino acid methionine bind together and attach to a ribosome at a P (protein) site. Methionine is the start signal triplet (AUG) on the mRNA. The P site on the ribosome is where the tRNA is oriented with the amino acid methionine.
Step 2	The next area in the ribosome, called the A site, is ready to receive the tRNA with its anticodon specific for that codon. The tRNA now has the proper amino acid.
Step 3	Both the P and A sites are holding tRNA and a peptide bond forms between the adjacent amino acids on the tRNA molecules.
Step 4	The tRNA detaches from the P site and leaves the ribosome.
Step 5	The tRNA with the chain of amino acids now moves to the P site but stays attached to the codon on the mRNA. The next tRNA enters the A site and the P site tRNA gives up its chain of amino acids to the A site.
Step 6	The tRNA detaches from the P site leaving behind its chain of amino acids.
Step 7	The process is repeated until the stop codon is reached where the ribosomal subunits fall apart releasing the new protein.

The steps are numbered on the figure to help you identify and envision the events that are occurring.

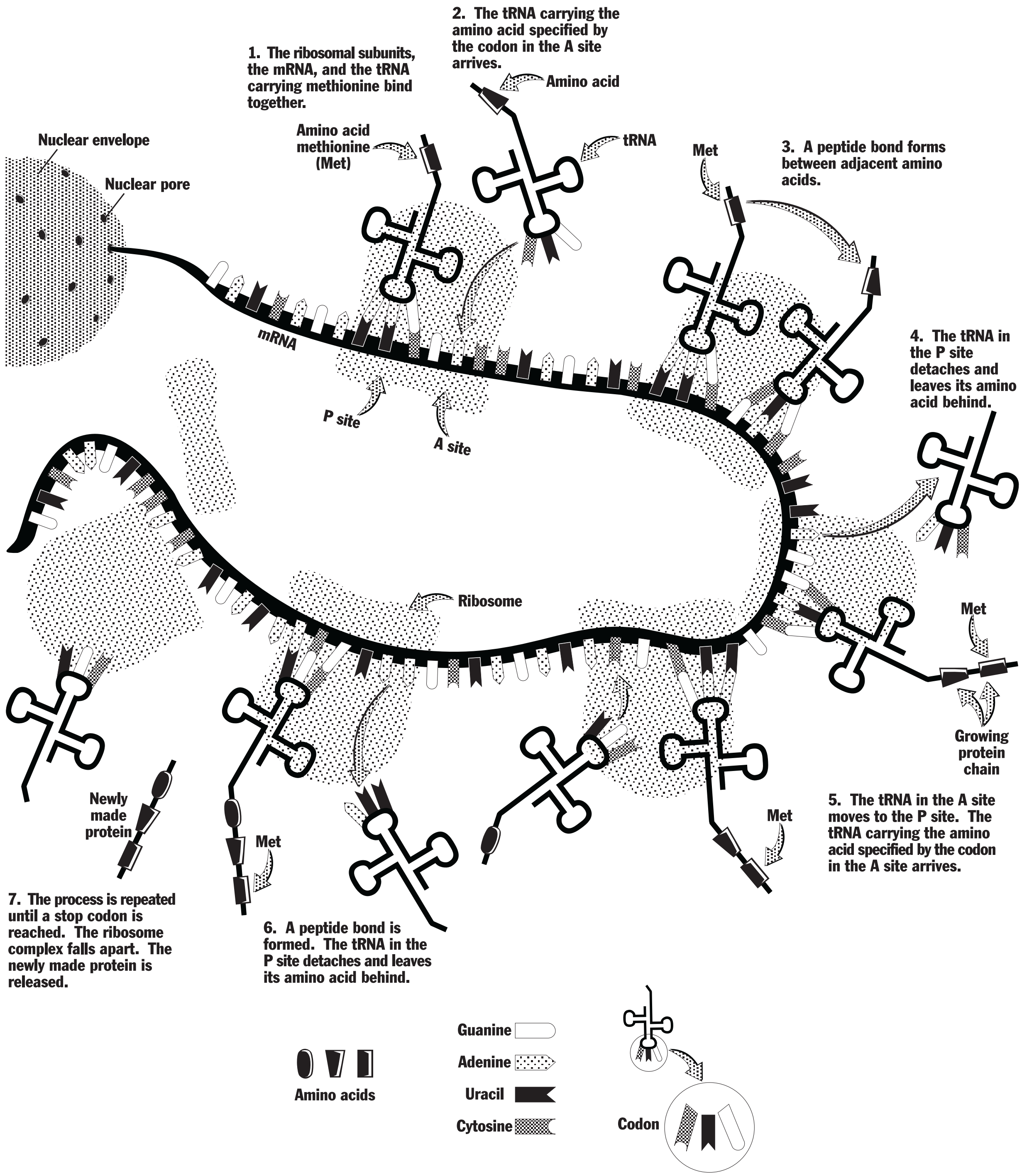


Figure 9.4 *– Translation: Assembling Proteins*

Another ribosome can find the start codon and begin making another protein from the same mRNA. Remember there are thousands of ribosomes making proteins in your cells all the time. Called **polysomes** (*poly* = many, *somes* = ribosomes), they use a strand of mRNA to make many copies of the same protein, since cells need many copies of any given protein. The genetic code is the same for all organisms. For example, the codon for aspartic acid is GAU in humans, bacteria, mice, plants, goats, etc. Therefore it appears there must be some common evolutionary ancestor to life that had this genetic code.

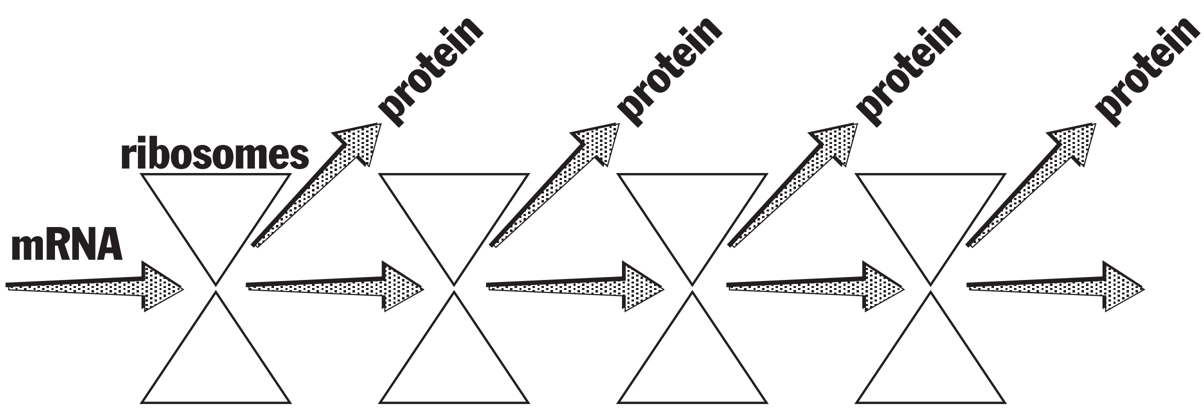


Figure 9.5

Complete the concept map on the following page based on the reading so far.

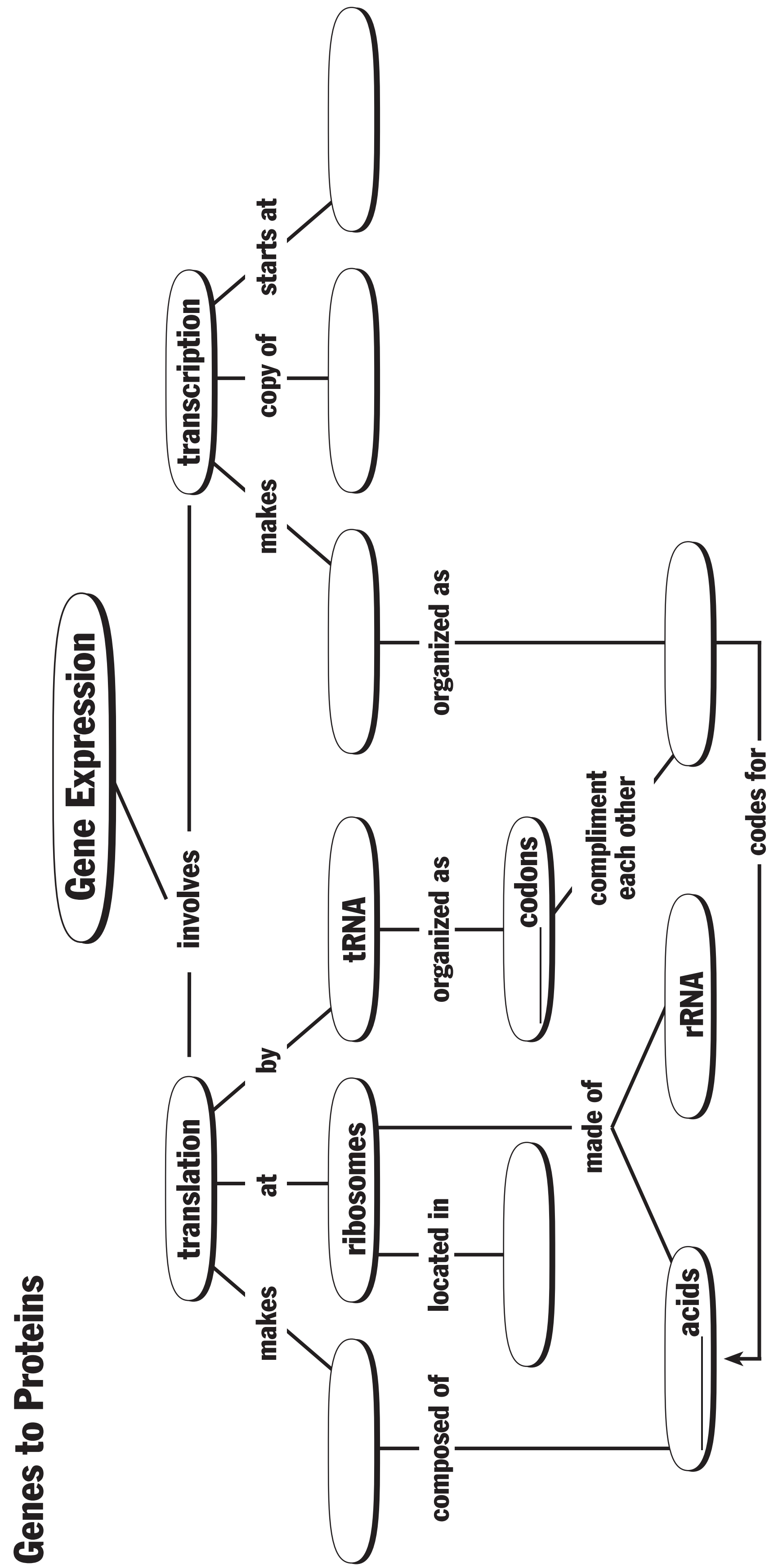

Genes to Proteins
Gene Expression
involves
translation
transcription
makes
at
by
makes
copy of
starts at
ribosomes
tRNA
located in
organized as
organized as
codons
compliment
each other
made of
rRNA
acids
composed of
codes for

Figure 9.6

Review

1. Explain how DNA and RNA are similar. Name two similarities.

2. Explain how DNA and RNA are different. Name two differences.

3. Identify where mRNA is transcribed in a eukaryotic cell.

4. Identify where mRNA is transcribed in a prokaryotic cell.

5. Explain how RNA polymerase helps make new RNA.

6. Identify where in the cell mRNA is translated.

7. Explain the purpose of nucleotide triplets.

8. Explain the purpose of tRNA in the cell.

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9. What are amino acids connected by peptide bonds called?

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Below is a series of nucleotides. One set is the mRNA that was transcribed from the DNA. The other mRNA was altered and a nucleotide was replaced.

A A A G C A C U U → nucleotide replaced → A A A *U* C A C U U

10. What would most likely happen in the production of amino acids?

a. amino acid production stops

b. amino acid production starts

c. a new amino acid is formed

d. no amino acid is formed and the codon is skipped

NOTES or questions for your mentor/teacher:

End of Lesson 9