PEER-LED TEAM LEARNING
ANATOMY & PHYSIOLOGY

WORKSHOP MODULE 6: DNA, RNA AND PROTEINS

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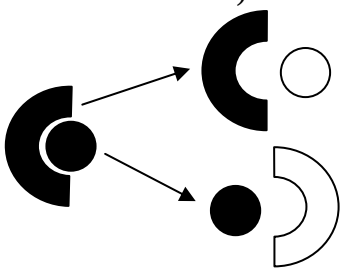
I. Introduction

The discovery of DNA structure as a double helix and its function as the genetic material of the cell were major scientific achievements of the 20th century. Countless scientists have contributed to our understanding of the process by which DNA is replicated prior to cell division, and the functional role that DNA plays in the synthesis of RNA, which eventually results in the synthesis of proteins.

The goal of this workshop is to master the basics of three processes: **DNA replication**, the formation of RNA by **transcription**, and the synthesis of proteins through **translation.** These three processes are bound by a universal genetic code that is common to most living things. Part of what makes this system so powerful is the concept of complementary base pairing. In complementary base pairing, adenosine always pairs with thymine (or uracil in RNA) and guanine always pairs with cytosine (think of straight letters versus round letters). This allows the cell to make copies of its genetic material. For instance, in the diagram to the right, two complementary shapes are bound together (the black circle and "C"). If these two shapes were to separate, then each could then bind its complementary shape and we would then have two copies of what we started with. This is essentially what happens when a cell divides; it makes a copy of the DNA (by using complementary nucleotides) in order that each daughter cell will contain the same genetic information. This process is called **DNA replication**.



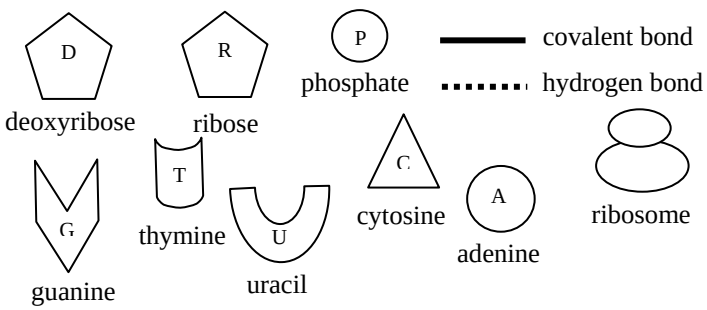
Aside from cell division, the cell also has to make copies of DNA in order to make proteins (DNA is like the recipe, and the protein is like the final dish). To make a protein, the cell must first make a complementary copy of a specific gene in the DNA using a slightly different kind of nucleic acid. This nucleic acid (RNA) uses ribose sugar instead of deoxyribose and is single stranded instead of a double helix. The complementary copy is called mRNA or "*messenger* RNA," and the process of forming RNA from DNA is called **transcription**. The mRNA leaves the nucleus where it is threaded into a ribosome. The ribosome is made of rRNA (*ribosomal* RNA) and proteins. The ribosome then reads the sequence of the mRNA (a codon) and matches it to a complementary sequence (anticodon) of tRNA—or *transfer* RNA. Each tRNA carries with it a specific amino acid which the ribosome links together (with amino acids from other tRNAs) to form a protein. This process is called **translation**.

Prepare for your workshop by reading assignments in your textbook (Chapter 4: 129-142) and completing the Pre-Workshop Activities below. Show your work on these pages.

II. Pre-Workshop Activities

Activity A. Molecules and Symbols. Draw your answers to each of the problems in this section using the following symbols. Do your work on a piece of paper so that you can share it with the other students during the workshop.

1) A single DNA nucleotide with a guanine base
2) A single strand of DNA with the base sequence ATCG
3) A strand of mRNA with the base sequence UACG.
4) A DNA template with the sequence ACGT attached to the complementary mRNA strand.
5) A double strand of DNA. One strand has the base sequence TTAG.
6) A codon of mRNA with the base sequence GCU with the anticodon of tRNA attached as it would be in translation.



Activity B. DNA Replication.

Below is a ladder model of a DNA double helix. From left to right the base sequence of the top strand is **ATGGCTTGAGAATCCAG.**

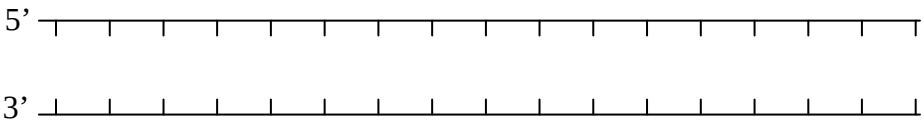
a. Fill in the bases in the top strand.

b. Fill in the bases on the complementary bottom strand.

c. Mark off the triplets in the bottom strand. How many are there?

d. Extend the figure to the right to show how DNA replication takes place (you'll have to make up the new DNA sequence—just make sure that you have complementary base pairing). Show both new strands.

e. What is the name of the enzyme that replicates DNA?



Activity C. Transcription of RNA from DNA

The figure below illustrates the transcription of mRNA from DNA. Complete the following:

a. Where does this process take place?

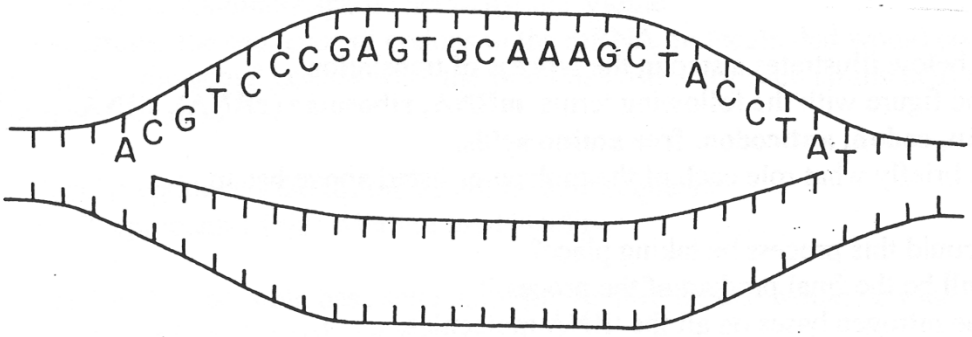
b. Describe the journey of mRNA after it is synthesized.

c. Label the mRNA and the DNA template.

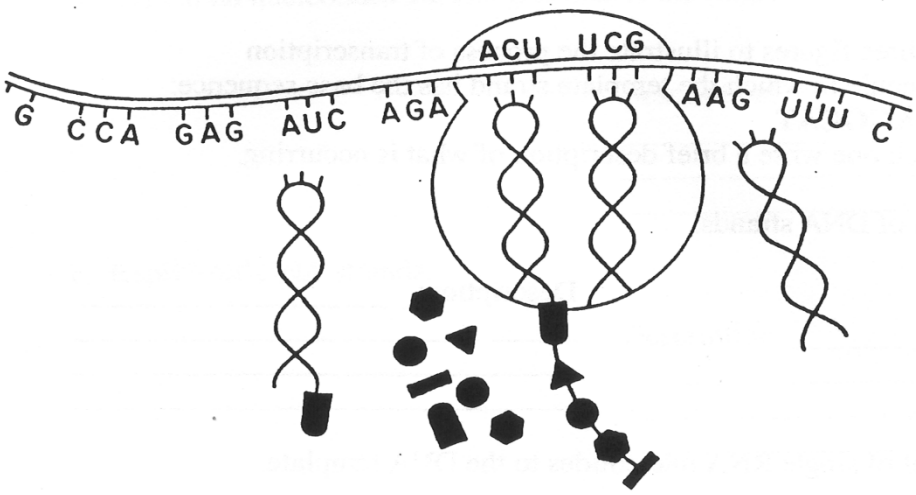
d. Fill in the base sequence on the unlabeled DNA strand that acted as a template for making the mRNA.

e. Fill in the base sequence for the newly synthesized strand of mRNA.

f. Mark off the codons on the mRNA strand. How many are there?



Activity D. Translation: Synthesis of Proteins



The figure below illustrates a step in the process of translation.

a. Label the figure with the following terms: **mRNA, ribosome (rRNA), tRNA, polypeptide chain, codon, anticodon, free amino acids.**

b. Show the complementary sequence of the anticodons on all of the tRNA molecules.

c. Put a star next to the tRNA which has just released the amino acid chain.

d. Circle the tRNA which will be the next one to bind to the mRNA.

e. Explain briefly what role each of the molecules listed above has in this process.

f. Where could this process be taking place?

g. What will be the final product of the process?

III. Workshop Activities

Activity A. Pre-workshop Review.

1. Work with one or two other students to review your answers to the four activities of the pre-workshop. If there are differences, resolve them or make notes about them. A general discussion will follow your work in pairs. Identify any questions that are unanswered and raise them when the large group convenes.

2. In the large group discussion, go over questions from the pre-workshop that remain to be clarified. Be prepared to share your work in response to requests by the peer leader.

Activity B. Scholarly definitions: Your peer leader will assign items to each pair of students. Evaluate the definitions in # 1 - 9. Circle any items that are incorrect and change the words to make them correct. Write TRUE if the entire definition is already correct. Be prepared to share your work with the group. In the large group, do a round robin to go over each item.

1. DNA is a polymer made of amino acids which is located in the nucleus. Each DNA nucleotide contains ribose, phosphate group, and nitrogenous bases. During DNA replication one strand of DNA acts as a template for mRNA replication. The nucleotide sequences can be divided into 3-base sequences called codons.

2. mRNA (**m** stands for "messenger") is synthesized in the nucleus by a process called translation. It is composed of 3-base units called codons which code for polysaccharide synthesis on ribosomes in the cytoplasm. mRNA is single stranded and has **T** substituted for **U** when it is synthesized from DNA.

3. Codons are sets of three nucleotides (an example would be ATC) that occur in sequence on mRNA molecules. They serve as the sites of attachment for the anticodons of tRNA and ultimately determine the order in which amino acids attach to form a polypeptide. They are complementary to the DNA triplets from which they were formed initially.

4. tRNA (**t** stands for transport) carry a sugar at one end for polysaccharide synthesis and at the other end of the molecule is an anticodon for attachment to codons of mRNA. Every tRNA can carry any type of amino acid. If the mRNA codon were AUG, the anticodon of tRNA would be UAC.

5. Transcription is the manufacture of proteins using mRNA and tRNA, and it occurs on ribosomes in the rough endoplasmic reticulum. It involves the encoding of a sequence of triplets into a complementary sequence of codons.

6. Translation occurs on free ribosomes or ribosomes of the rough endoplasmic reticulum. The raw materials for the process are free-floating amino acids in the cytoplasm and the final product is a protein. The process requires enzymes to attach amino acids to one another. mRNA and tRNA each play an important role, but DNA is only involved if RNA cannot finish the job.

7. In DNA replication a double-stranded DNA molecule separates into two single strands, and each single strand attracts complementary nucleotides which attach by hydrogen bonding. The enzyme RNA polymerase hooks adjacent nucleotides together forming the new double strand. This process occurs before a cell divides in mitosis.

8. Nucleotides are the monomers from which DNA and RNA are synthesized and they occur in four different varieties in DNA, and three varieties in RNA. Each one includes a sugar, nitrogenous base and a phosphate group. Cytosine pairs with Thymine or Uracil, and Adenine pairs with Guanine.

9. Ribosomes are made of rRNA (which is manufactured in the nucleus) and proteins (which is manufactured in the smooth ER). They serve as a location for protein synthesis, and are found floating free in the cytoplasm and attached to the walls of the rough endoplasmic reticulum.

Activity C. Short Problems. Organize into small groups 2-4 students. Solve the problems assigned to you by your peer leader. Following the problem solving period, your group will present the solution to the other students. If another group presents a problem that you have worked on, your job will be to make any corrections and additions that are appropriate or show an alternative way to represent the problem.

1) A newly formed complementary strand of DNA has the base sequence **AGGTCTGAG.** What is the sequence of bases in the template from which it was synthesized?

2) An mRNA strand has the base sequence: **AUGACCUUA**. How many codons are present? What is the sequence of triplets for the DNA strand that acted as a template for its synthesis?

3) A very small gene has the base sequence **TAGTAGCAT**. What is the mRNA molecule that it could give rise to which would direct protein synthesis.?

4) Using the table to the right, determine the amino acid sequence of a polypeptide synthesized from the following mRNA strands:

   a. CGU CGC UCU GUG CAU UAA

   b. UGG GCA GUA CAA CCU UAG

5) For each of the molecules in question #4, determine the **anticodons** are for the tRNAs that attach to them in protein synthesis.

Second nucleotide

First nucleotide	U	C	A	G	Third nucleotide
U	Phe	Ser	Tyr	Cys	**U**
	Phe	Ser	Tyr	Cys	**C**
	Leu	Ser	STOP	STOP	**A**
	Leu	Ser	STOP	Trp	**G**
C	Leu	Pro	His	Arg	**U**
	Leu	Pro	His	Arg	**C**
	Leu	Pro	Gln	Arg	**A**
	Leu	Pro	Gln	Arg	**G**
A	Ile	Thr	Asn	Ser	**U**
	Ile	Thr	Asn	Ser	**C**
	Ile	Thr	Lys	Arg	**A**
	Met	Thr	Lys	Arg	**G**
G	Val	Ala	Asp	Gly	**U**
	Val	Ala	Asp	Gly	**C**
	Val	Ala	Glu	Gly	**A**
	Val	Ala	Glu	Gly	**G**

6) A strand of DNA has the following sequence of bases: **GCC GAC GAT AGA**

   a. determine the sequence of the mRNA strand that will be transcribed from the DNA.

   b. determine the amino acid sequence of the polypeptide that will be translated from the mRNA.

7) The following polypeptide has the amino acid sequence Leu-Ala-Asp-Gly-Val. Determine the sequence of codons in the mRNA molecule that would code for this polypeptide. Notice that there are multiple codons that code for any one amino acid. Choose the top one listed when you have more than one option.

8) A polypeptide has the following amino acid sequence Trp-Lys-Met-His
   a. List two possible base sequences for the mRNA that could be used to produce this polypeptide.

   b. Using one of the mRNA sequences determined in part a), figure out the DNA code for that molecule.

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