PEER-LED TEAM LEARNING
INTRODUCTORY BIOLOGY

MODULE 7: DNA, RNA AND PROTEINS

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I. Introduction

Two primary scientific achievements of the 20th century were the discoveries that **DNA (deoxyribonucleic acid)** is the genetic material of the cell, and that this macromolecule is organized in the form of a **double helix**. Subsequent research by numerous scientists has led us to understand how DNA is replicated prior to cell division and how it controls cell metabolism.

The goal of this workshop is to master the basics of three processes: **DNA replication**, the synthesis of RNA (ribonucleic acid) by **transcription**, and the building of proteins through **translation.** These three processes are bound by a **universal genetic code** that is common to most living things.

Prepare for your workshop by reading assignments in the textbook, reviewing your lecture notes, and completing the Pre-Workshop Activities below. Show your work on these pages.

II. Pre-Workshop Activities

Activity 1. Vocabulary Building

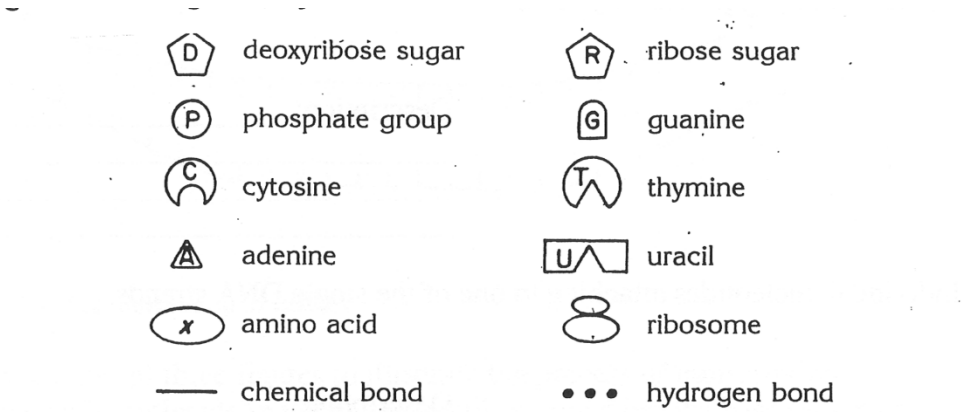
Provide a definition for each of the following terms that includes information about a) structure, b) function, c) location, and d) relationships to one or more other terms in the list.

DNA	nucleotide
deoxyribose sugar	ribose sugar
nitrogen bases	complementary base pairs
DNA replication	template
transcription	RNA
mRNA	the genetic code
rRNA	tRNA
codons	triplets
translation	anticodons
peptide bond	amino acids
proteins	macromolecule
uracil (U)	adenine (A)
thymine (T)	guanine (G)

cytosine (C)	phosphate group
free nucleotide	double DNA strand (double-stranded DNA)
single DNA strand (single-stranded DNA)	rough endoplasmic reticulum

Activity 2. Molecules and Symbols

Draw your solutions 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 polypeptide with the sequence: Alanine (Ala), serine (Ser,), tyrosine (tyr)
   (Substitute the chemical abbreviation for "X" in the oval.)

4. A strand of mRNA with the base sequence UACG.

5. A DNA template with the sequence ACGT attached to the complementary mRNA strand.

6. A double strand of DNA. One strand has the base sequence TTAG.

7. A codon of mRNA with the base sequence GCU with the anticodon of tRNA attached as it would be in translation.

Activity 3. DNA Replication

1. Fig. 7.1 is a ladder model of a DNA double helix. From left to right the base sequence of the top strand is ATGGCTTGAGAA.
   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?

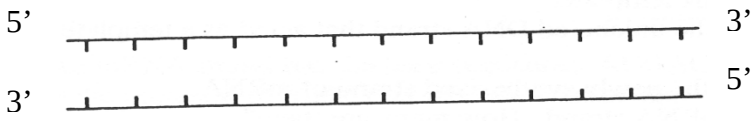


Fig. 7.1. DNA Replication

Activity 4. 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?

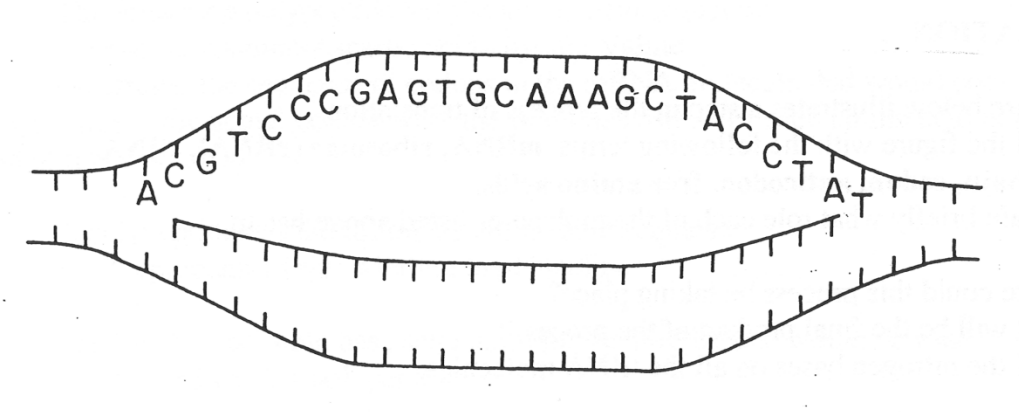


Fig. 7.2 Formation of mRNA

Activity 5. Translation: Synthesis of Proteins

Figure 7.3 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. Explain briefly what role each of the molecules listed above has in this process.
c. Where could this process be taking place?
d. What will be the final product of the process?
e. Label all the nitrogen bases shown on the tRNA molecules.

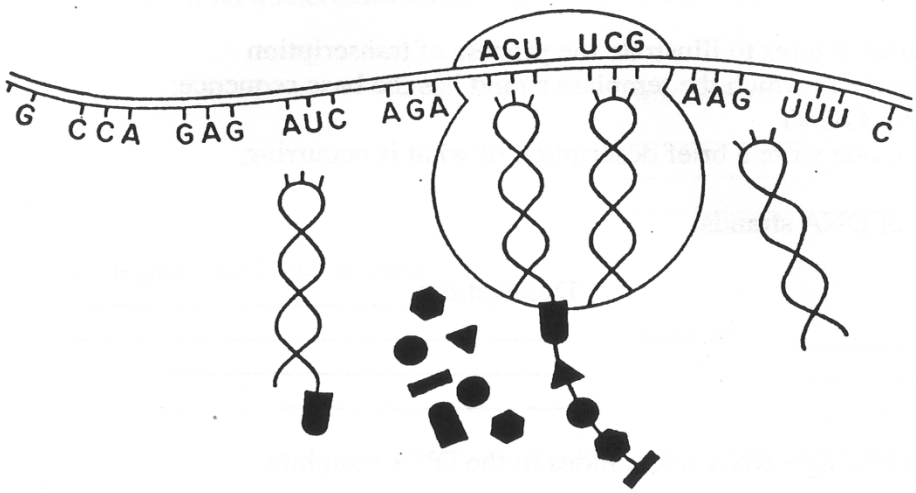


Figure 7.3. Process of Translation

III. Workshop Activities

Activity 1. Pre-workshop Review.
Small group (3-4 students) and jigsaw. Within each group, students do a round robin, and resolve answers to questions. 10-15 minutes. At the end, groups bring up items they were unable to resolve and leader asks other students to help resolve problems.

1. Work with two or three other students to review your answers to the five activities of the pre-workshop. If there are differences, resolve them or make notes for discussion later. A general discussion will follow your work in small groups.

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 2. Scholarly definitions
Pair problem solving. Your peer leader will assign several items to each pair of students. Evaluate the definitions in # 1 - 10. Circle any parts 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: located in the nucleus; a polymer made of amino acids; contains ribose, phosphate groups, and nitrogen bases; replicates during the S phase of the cell cycle; one strand acts as a template for mRNA replication; strands can be divided into 3-base sequences called codons.

2. mRNA: **m** stands for "messenger"; is synthesized in the nucleus; the process of synthesis is called translation; works in polysaccharide synthesis on ribosomes in the cytoplasm; is composed of 3-base units called codons; is single stranded; has **T** substituted for **U** when it is synthesized from DNA.

3. template: a name given to a DNA strand that serves in mRNA synthesis; has a sequence of triplets which determine the codons of mRNA; works by binding complementary nucleotides which are then linked to form the mRNA strand; binding to free nucleotides is by hydrogen bonding.

4. codons: an example would be ATC; many occur in sequence on mRNA molecules; sites of attachment for the anticodons of tRNA; determine the order in which amino acids attach to form a polypeptide; are complementary to DNA triplets from which they were formed initially.

5. tRNA: are short polynucleotide strands; **t** stands for "target"; carries a sugar at one end for polysaccharide synthesis; at the other end of the molecule is an anticodon for attachment to codons of mRNA; if the mRNA codon were AUG, the anticodon of tRNA would be UAC; occurs in many varieties to carry different amino acids.

6. transcription: manufacture of proteins using mRNA and tRNA; occurs on ribosomes in the rough endoplasmic reticulum; involves the encoding of a sequence of triplets into a comple-mentary sequence of codons.

7. translation: the raw materials for the process are free amino acids in the cytoplasm or rough ER; requires enzymes to attach amino acids to one another; occurs on free ribosomes or ribosomes of the rough endoplasmic reticulum; mRNA and tRNA each play an important role; final product is a protein; DNA is only involved if RNA cannot finish the job.

8. DNA replication: a double DNA strand separates into two single strands; each single strand attracts complementary nucleotides which attach by hydrogen bonding; an enzyme hooks adjacent nucleotides together forming the new double strand; occurs before a cell divides in mitosis.

9. nucleotides: are the monomers from which DNA and RNA are synthesized; occur in four different varieties in DNA, and three varieties in RNA; each one includes a sugar, nitrogen base and a phosphate group; are synthesized into RNA and DNA in the nucleus; occur only in the nucleus.

10. ribosome: some of its parts are manufactured in the nucleus; consists of rRNA and proteins; serves as a location for protein synthesis; has two connected parts (subunits), one large and one small; occurs free in the cytoplasm and attached to the walls of the rough endoplasmic reticulum.

Activity 3. Short Problems

Small groups 2-4 students. Solve the problems assigned to you by your peer leader. Your group will be given a second problem to solve if time allows. Following the problem solving period, your group will present the solution to the other students. When the second problem assigned to you is presented, 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 if only codons are shown? 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. Describe the mRNA molecule that it could give rise to which would control protein synthesis in the cytoplasm of the cell.

4. Using the Table 7A at the end of this workshop, determine the amino acid sequence of a polypeptide synthesized from mRNA with the following bases (all of these letters represent parts of codons):

   a. CGUCGCUCUGUGCAUUAA

b. UGGGCAGUACAACCUUAG

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

6. 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 if the actual codons were the first ones listed for each amino acid in Table 7.1 at the end of this workshop.

7. A polypeptide has the following amino acid sequence: Try-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.

8. A strand of DNA has the following sequence of bases:
   GCC GAC GAT AGA

   a) Using Table 7.1, determine the sequence of bases in 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.

Activity 4. Diagramming the Processes

Small groups of 3-4. Each group will do one of the problems below and then share their results with the other students. Make the diagrams on the blackboard or on large sheets of newsprint.

1. a. Make a rough labeled diagram of how you envision the process of DNA replication including the important molecules in the following list: DNA double helix, DNA polymerase, leading strand, lagging strand, single deoxyribonucleotides, and triplets. Optional: Okazaki fragments, DNA ligase, helicase enzyme.
   b. Indicate by arrows and numbers the sequence of the steps as they will occur.
   c. Explain the diagram to the other groups, and make any modifications that are needed.

2. a. Make a rough labeled diagram of the process of RNA transcription, including the important elements in the following list: DNA template, single ribonucleotides, RNA polymerase, promoters, initial RNA transcript, RNA splicing, mRNA, rRNA, tRNA, and codons.

b. Indicate by arrows and numbers the sequence of the steps as they will occur.

c. Explain the diagram to the other groups, and make any modifications that are needed.

3. a. Make a rough labeled diagram of how you envision the process of translation including the important elements in the following list: mRNA, ribosomes, amino acids, tRNA, anticodons, codons, aminoacyl-tRNA synthetase, peptide bond, and protein. Optional: P site and A site.

b. Indicate by arrows and numbers the sequence of the steps as they will occur.

c. Explain the diagram to the other groups, and make any modifications that are needed.

Activity 5. Integration Concept Maps

This activity can be done sequentially with the whole group in round robin fashion, or if time is limited, three small groups can be formed to do the three maps. The map should be done on a blackboard or large piece of newsprint so everyone can see the results.

1. a. Look over the following list of terms and decide what the central concept is for the list.
   b. Develop a concept map for the list with the focus on explaining the central concept.
   c. Share the map with the rest of the group and have others suggest additions, corrections or other improvements.

   List: **DNA double helix, single DNA strand, nucleotide, hydrogen bonding, DNA polymerase, leading strand, lagging strand, meiosis, 5' end, 3' end, A, T, G, C, complementary DNA strand.** Optional: **Okazaki fragments, DNA ligase, helicase enzyme**.

2. a. Look over the following list of terms and decide what the central concept is for the list.
   b. Develop a concept map for the list with the focus on explaining the central concept.
   c. Share the map with the rest of the group and have others suggest additions, corrections or other improvements.

   List: **DNA template, single ribonucleotides, RNA polymerase, promoters, initial RNA transcript, RNA splicing, mRNA, rRNA, tRNA, triplets, and codons**.

3. a. Look over the following list of terms and decide what the central concept is for the list.
   b. Develop a concept map for the list with the focus on explaining the central concept.
   c. Share the map with the rest of the group and have others suggest additions, corrections or other improvements.

   List**: mRNA, ribosomes, amino acids, tRNA, anticodons, codons, aminoacyl-tRNA synthetase, peptide bond, protein.** Optional: **P site and A site**.

IV. Post-workshop Activities

Activity 1. Connections

A list of vocabulary from the workshop is shown below

a. Make a series of "mini-concept maps" by connecting pairs of terms (concepts) and writing connector statements that show an important relationship. Add as many as you can. *(This could be done as a workshop activity in the form of a contest with pairs of students competing in a timed trial, followed by sharing and tallying of scores afterward.)*

molecular genetics	DNA
polymer	nucleotide
deoxyribose sugar	ribose sugar
nitrogen bases	complementary base pairs
DNA replication	template
complementary strand	DNA polymerase
sense strand	RNA polymerase
transcription	RNA
mRNA	the genetic code
rRNA	tRNA
codons	triplets
translation	anticodons
P site	peptide bond
amino acids	A site

hydrogen bonds
genes
uracil (U)
thymine (T)
cytosine (C)
free nucleotide
single-stranded DNA
proteins
macromolecule
adenine (A)
guanine (G)
phosphate group
double-stranded DNA
rough endoplasmic reticulum

Activity 2. Diagrams

1. Make a series of 3 diagrams using the three triplets in the Fig 7.4 to illustrate the process of DNA replication. In the space beside each illustration, write a brief description of what is happening.

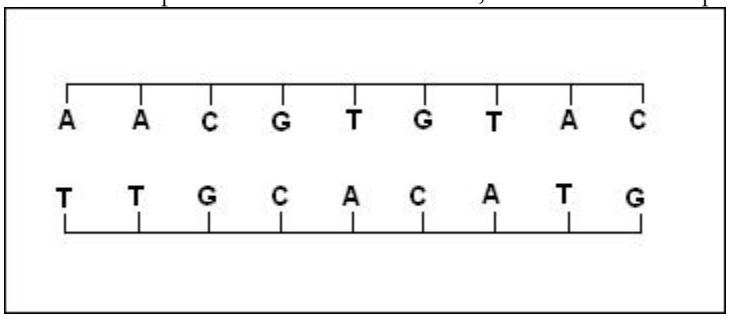


Fig. 7.4. Double stranded DNA

a. Complementary DNA strands separating:

Description: _____
_____
_____
_____

b. Individual nucleotides attaching to one of the single DNA strands.

Description: _____
_____
_____
_____

c. Replicated DNA strands.

Description: _____
_____
_____
_____

2. Draw a series of three figures to illustrate the process of transcription using a DNA molecule in which the template strand has the base sequence: **TATAGGCAT.** To the right of each one, write a brief description of what is occurring.

a. The separation of DNA strands.

Description: _____
_____
_____
_____

b. The attachment of single RNA nucleotides to the DNA template.

Description: _____
_____
_____
_____

c. The separation of the mRNA strand from the DNA template.

Description: _____
_____
_____
_____

Activity 3. DNA Replication, Transcription, and Translation in Life

Answer each of the following questions as thoroughly as possible using the correct terminology.

1. DNA replication occurs in a period of a cell's life shortly before it divides (reproduces). What do think could be the relationship between replication and cell division? What does it suggest about the two daughter cells that are produced when a cell divides?

2. a. In your own words, describe the relationships among the following term. Do not use diagrams; only use words: **DNA, mRNA, tRNA, rRNA, proteins, enzymes, metabolism**.

b. Now make a concept map that shows the relationships you described.

c. What are the advantages and disadvantages of using each way of representing relationships? Which works better for you?

3. Sometimes nucleotides in a DNA strand get replaced or deleted. These changes are called *mutations*. Suggest what you think the consequences might be in terms of mRNA transcription and protein synthesis. How do you think the mutations might effect the organism?

V. Other Resources. The following internet links provide the opportunity for further learning.

Transcription and Translation – excellent graphics and explanation:
http://www.uleth.ca/bio/sc1000/trans.html

Practice – Transcribe and Translate a gene:
http://gslc.genetics.utah.edu/units/basics/transcribe/

Concept Maps of DNA Replication, Transcription and Translation:
http://www.umaine.edu/fes/Classes/fes100/maps/map11diag.htm

More Transcription and Translation links:
http://users.tamuk.edu/kfjab02/Biology/IntroCell/b1308_ch14.htm

Hypertextbook links:
http://bioresearch.ac.uk/browse/mesh/detail/C0040711L0040711.html

How does a gene make a protein? – NIH Website:
http://ghr.nlm.nih.gov/ghr/info/basics/section/making_protein

Overview of Transcription and Translation, with a link to graphics:
http://www.people.virginia.edu/~rjh9u/trtrrev.html

Transcription and Translation:
http://www.brooklyn.cuny.edu/bc/ahp/BioInfo/SD.TransTrans.HP.html

Transcription and Translation – vocabulary words are linked to definitions, as well as a description of how these processes work:
http://www.mansfield.ohio-state.edu/~sabedon/biol1065.htm

DNA Structure, Replication, Transcription, and Protein Synthesis:
http://www.ncc.gmu.edu/dna/

Protein synthesis: Transcription and Translation Slide show:
http://www.hsu.edu/faculty/engmanj/bio2114/power/translat/

Transcription and Translation exercises to test your understanding:
http://www.swbic.org/education/ttexter.php

Transcription and Translation:
http://www.fmarion.edu/bio105k/trans.html

Replication, Transcription, and Translation quiz:
http://faculty.valencia.cc.fl.us/kmalmos/HW%2012-1010.htm

Transcription and Translation Flash quiz:
http://www.isat.jmu.edu/users/klevicca/flash/Translation.ppt

Transcription and Translation:
http://faculty.valencia.cc.fl.us/kmalmos/gene%20expression.htm

Transcription and Translation:
http://www.allsciencestuff.com/mbiology/concepts/overview

Transcription and Translation Quiz:
http://www.biology.ewu.edu/aHerr/Genetics/Bio310/PDFs/HwPDFs/Transcribe.pdf

Excellent Shockwave animations of Transcription and Translation:
http://www.csuchico.edu/~jbell/Biol207/animations/index.html

Transcription and Translation with a Self Quiz:
http://wheat.usu.edu/courses/USU1350/outline/translation.html

Quiz on DNA Replication, Transcription and Translation:
http://www.waycross.edu/faculty/gcook/biology/quiz%20on%20dna%20-%20answers.doc

Transcription and Translation Example Problems:
http://biology.umt.edu/biol221/lecture_notes/transcription_and_translation_ex.htm

Protein Synthesis:
http://old.jccc.net/~pdecell/proteinsynthesis/transcript.html

Structure and Function of Genes:
http://www.intouchlive.com/home/frames.htm?http://www.intouchlive.com/cancergenetics/genefx.htm&3

Table 7A. The Universal Genetic Code

In form of codon, Left-Top-Right (ATG is Met)

	T	C	A	G	
T	Phe	Ser	Tyr	Cys	T
					C
	Leu		Ter	Ter	A
				Trp	G
C	Leu	Pro	His	Arg	T
					C
			Gln		A
					G
A	Ile	Thr	Asn	Ser	T
					C
			Lys	Arg	A
	Met				G
G	Val	Ala	Asp	Gly	T
					C
			Glu		A
					G

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