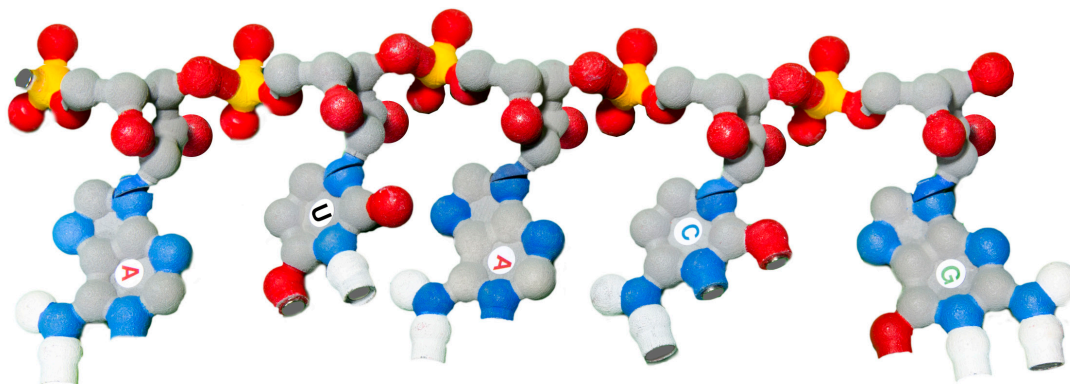


Transcription Activity Guide

Student Handout



Ribonucleic Acid (RNA)

Introduction

Central Dogma: DNA to RNA to Protein

Almost all dynamic functions in a living organism depend on proteins. Proteins are molecular machines that perform a wide variety of essential functions, including:

- Support
- Transport
- Movement
- Metabolic Regulation
- Coordination
- Control
- Defense

Scientists currently believe that there are approximately 100,000 different proteins in the human body. Given the important role that these molecules play in an organism's survival, it is understandable that scientists focus a considerable amount of attention studying them. Central to their study is the question of how these molecules are produced in a cell. The molecular chain of command that dictates the directional flow of genetic information from DNA to RNA to protein was dubbed the **central dogma** by Francis Crick in 1956.

DNA Is the Universal Code

DNA carries all of the instructions for making the proteins found in our bodies. In fact, DNA is the universal code for the characteristics of simple organisms such as bacteria, and for complex organisms such as plants or animals. DNA codes for the characteristics of all living things! In this lesson you will learn how to interpret the DNA code to make the proteins that determine these characteristics. In the process of protein synthesis there are two important types of nucleic acids: DNA and RNA.

DNA has only four nitrogen bases: A, T, G, and C. But there are 20 amino acids that serve as the building blocks (monomers) for all proteins. How can only four letters (bases) code for all of these amino acids? The key to deciphering DNA is called a **triplet code**, in which the sequence of three adjacent DNA nitrogen bases (nucleotides) codes for a specific amino acid.

Transcription Continued

1. How many possible triplet codes can be generated from these four base letters?

2. Given that there are more possible combinations for amino acids than amino acids themselves, what does this imply about the number of codes for each amino acid?

The process of deciphering DNA to produce a protein requires two major stages: (1) **transcription** and (2) **translation**. Transcription is the process in which DNA is used as a template to produce a single-stranded RNA molecule. Translation is the process in which the DNA code, now contained in the single-stranded RNA, is deciphered into a sequence of linked amino acids that become a protein.

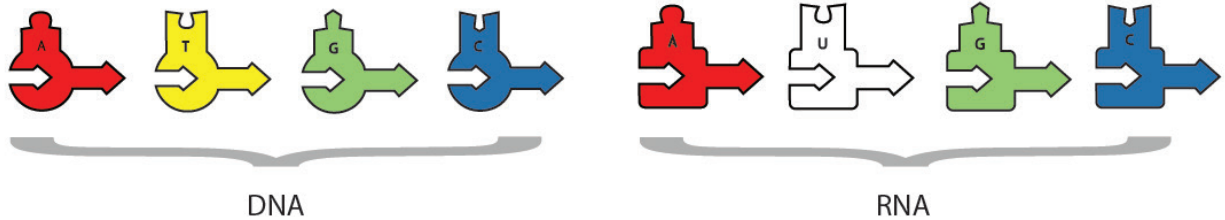
In eukaryotic cells, DNA is found in the nucleus, chloroplasts, and mitochondria, and cannot leave these structures. As a result, transcription occurs inside these organelles in eukaryotic cells. A **eukaryote** is an organism composed of cells which contain a nucleus and other membrane-bound organelles. An **organelle** is a differentiated structure within a cell, such as a mitochondrion, vacuole, or chloroplast that performs a specific function (examples include the nucleus, mitochondria or Golgi apparatus).

3. Why can't DNA leave the nucleus?

Proteins are made by ribosomes (workbenches) that are outside of the nucleus in the cytoplasm, in a process called protein synthesis. **Synthesis** refers to linking together individual monomer subunits (nucleotides or amino acids) into a larger polymer (mRNA or protein).

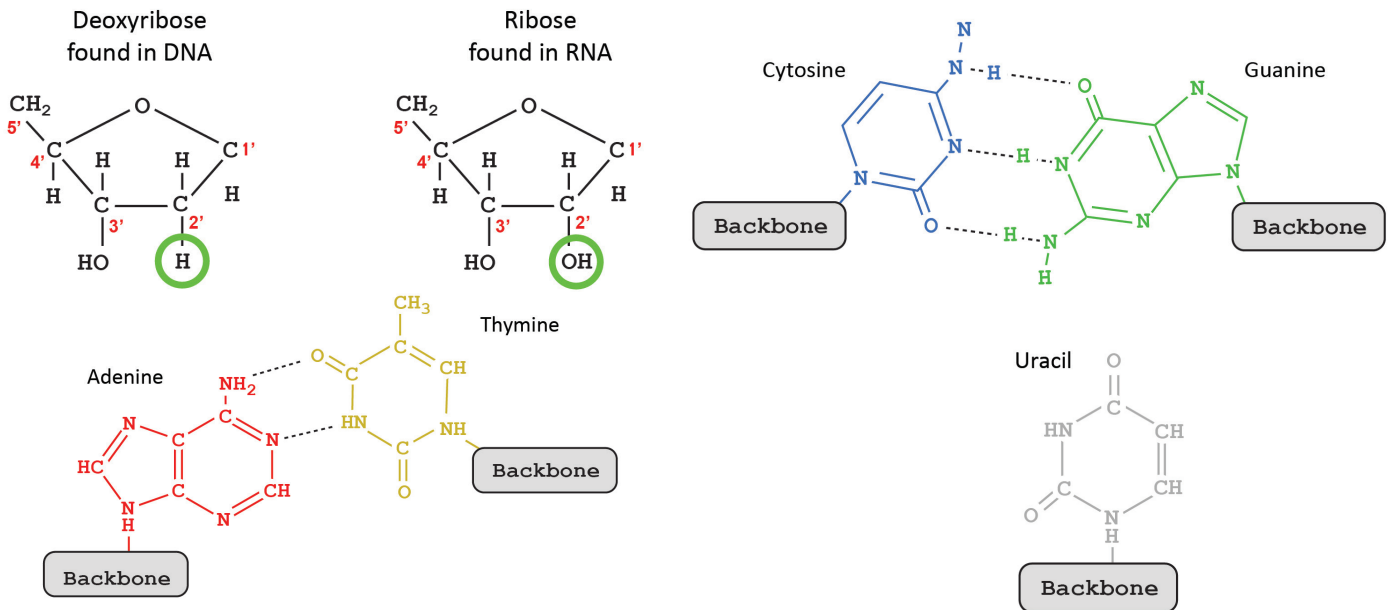
How does the information carried by DNA get to the ribosomes? The code has been transcribed from the DNA to RNA. RNA must leave the nucleus and carry the code to the ribosome for proteins to be synthesized. The RNA carrying the code is called **messenger RNA** (mRNA). It is one of three types of RNA (mRNA, tRNA, and rRNA) that play major roles in protein synthesis. Note that the mRNA code is not identical to the DNA code.

Transcription Continued



4. Compare the foam DNA and mRNA kit pieces. Identify any similarities and differences.

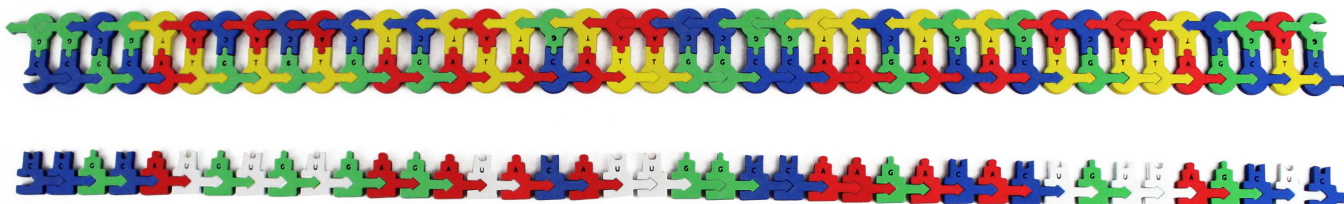
Other differences between RNA and DNA are not apparent in the model. The RNA backbone contains the sugar ribose, which has an extra oxygen atom not found in the deoxyribose sugar of DNA. The model depicts this difference in the rounded shape of the DNA nucleotides, compared to the squared shape of the RNA nucleotides.



5. Which carbon contains the extra oxygen in the RNA molecule?

Transcription Continued

DNA and RNA



6. Complete the following chart by matching the correct RNA complementary base to the DNA base:

| DNA Base | RNA Base |
|----------|----------|
| T | |
| G | |
| C | |
| A | |
| C | |
| A | |

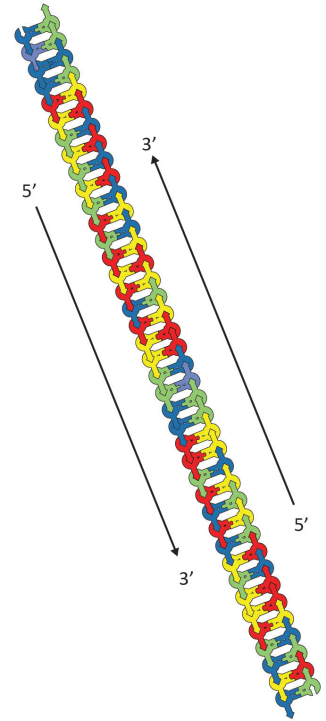
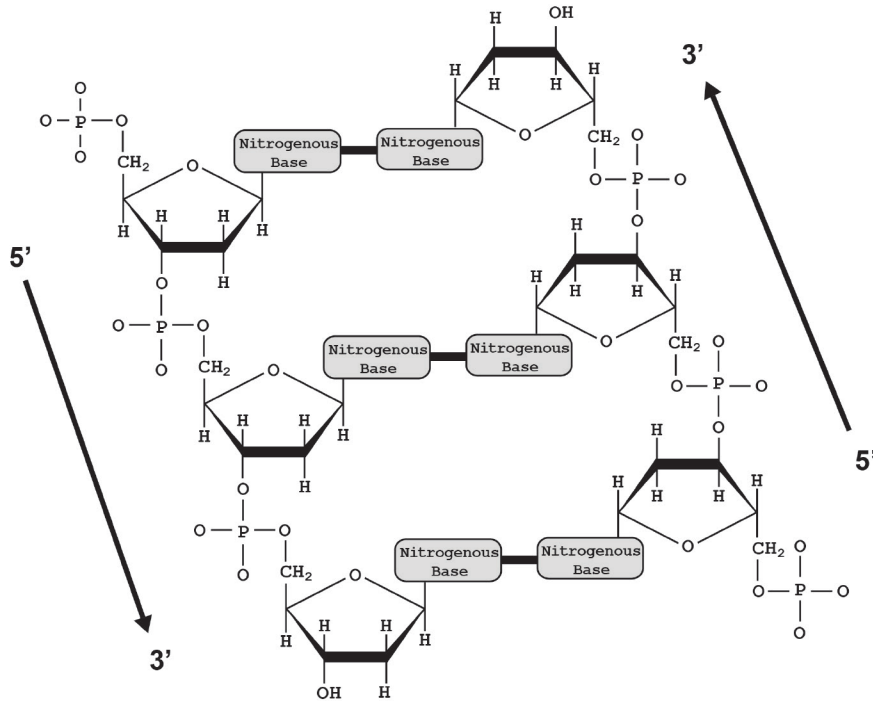
Using the rounded DNA foam pieces and following the code listed in question 6, construct a **non-template strand** of DNA. On the DNA backbone the hydroxyl end is the 3' end (arrow end of the foam piece) and the phosphate end is the 5' end.

7. Fill in the correct base pairs in the template strand below and build the DNA template strand. Keep in mind that DNA is synthesized from its 5'→3' end.



Construct the template strand of DNA to complete the double-stranded DNA model. Be sure the two strands of DNA are attached together following the rules of complementary DNA base pairing. Recall the antiparallel nature of the DNA molecule.

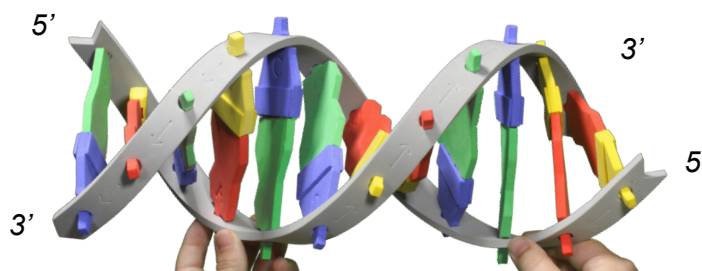
Transcription Continued



8. Recalling the lesson on DNA structure, identify the type of bond that holds the two strands of DNA together.

← **Transcription Continued** →

Compare and contrast the foam model to the DNA Discovery Kit® and DNA Starter Kit® models shown below.



9. Identify two similarities and two differences between these models.

The transcription process occurs in three stages: (1) initiation, (2) elongation and (3) termination.

In eukaryotes, initiation begins with a collection of proteins called transcription factors, which facilitate the binding of the enzyme **RNA polymerase** to the DNA. After the two strands of DNA are separated, RNA polymerase joins the RNA nucleotides as they base pair along the DNA template. When this happens, only one side of the DNA is used as a template to form mRNA nucleotides to complementary base pair to the DNA.

Base-pairing rules still apply with one exception:

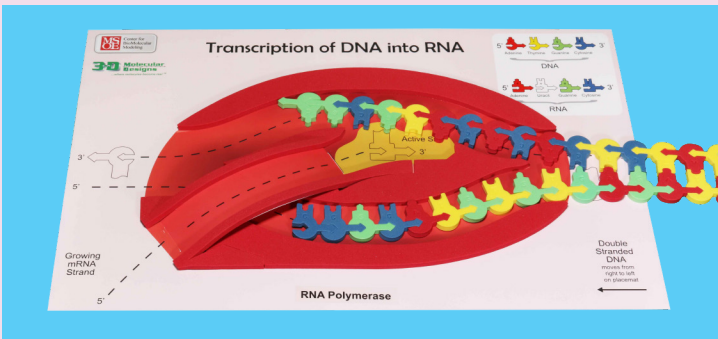
- Guanine pairs with cytosine
- Adenine pairs with **uracil**.

(Recall that RNA contains the base uracil instead of the base thymine.)

← **Transcription Continued** →

Transcription: Initiation

Like DNA polymerases that function in DNA replication, RNA polymerases can assemble mRNA only in its 5'→3' direction. In order for this to properly occur, the template strand of DNA must be oriented in the top slot with the 3' end (arrow end) entering the polymerase first. (Please refer to the photo to ensure proper setup.)



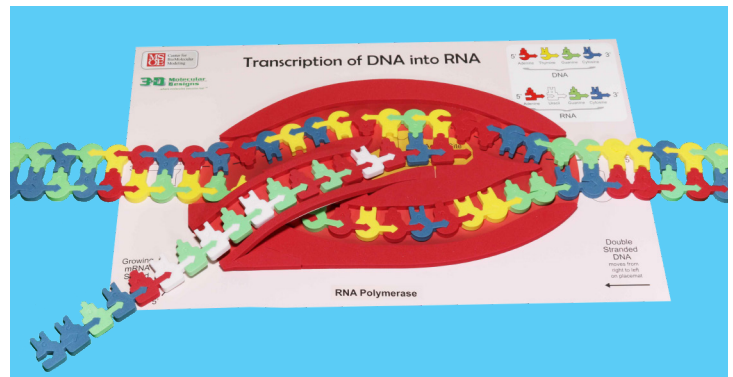
10. Label the DNA **template strand** and **non-template strand** in the photo left.

Transcription: Elongation

Feed the DNA into the RNA polymerase.

11. What will happen when RNA polymerase acts on DNA?

Sprinkle free RNA nucleotides around the enzyme. RNA polymerase uses the template strand of DNA to synthesize the mRNA. You will use the template strand of DNA to complementary base pair the correct sequence of mRNA nucleotides. Complete the base-pairing process on your placemat.



12. Note: The DNA template strand does NOT begin with the code for the start of the codon of the mRNA. What 3'→5' DNA code functions as the start signal or initiation codon?

← **Transcription Continued** →

13. What is the mRNA complementary codon?

Transcription: Termination

At this point the mRNA will separate from the DNA and may be processed into its final form. The template strand of DNA will rejoin with the non-template strand. Complete this step with your model.

14. Using your mRNA model, record the correct sequence of mRNA base pairs:
 5' ----- 3'

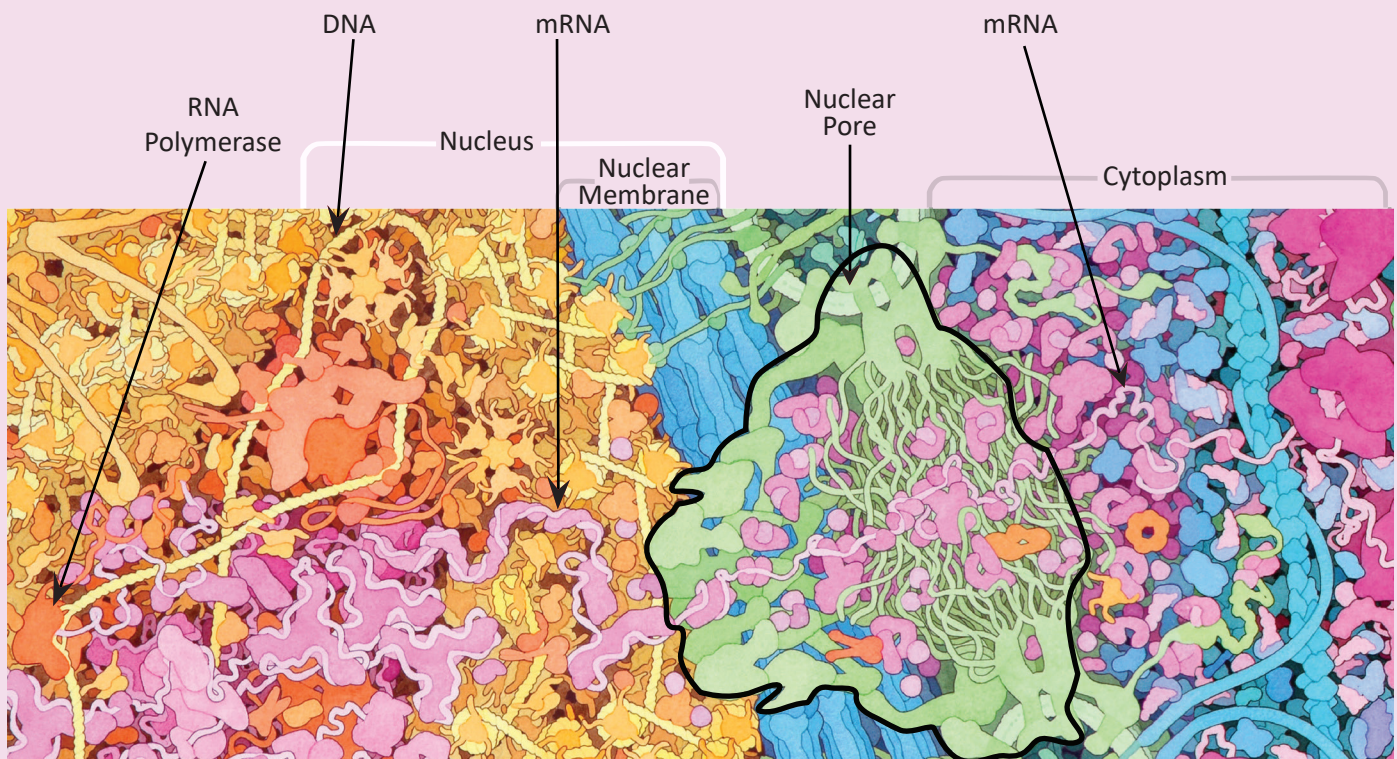


15. What type of bond is broken when mRNA separates from DNA and what characteristic of this bond allows for this separation?

Transcription Continued

In eukaryotic cells the mRNA leaves the nucleus through nuclear pores after being processed into its final form.

16. Trace the mRNA from the arrow point in the nucleus, through the nuclear pore and to the arrow point in the cytoplasm.



This image is an excerpt from *Tour of a Human Cell* by David Goodsell, as shown in 3D Molecular Designs' *Tour of a Human Cell*® poster and David Goodsell's book, *The Machinery of Life*.

Big Ideas

The sequence of nucleotides in your DNA encodes the sequence of amino acids in your proteins. The overall process of making a protein, using the information contained in a gene, is referred to as **gene expression**. In the first step in this process – known as **transcription** – an RNA polymerase uses one strand of a gene as a template for the synthesis of a strand of messenger RNA. In the next step in this process – known as **translation** (or **protein synthesis**) – the ribosome translates the sequence of nucleotides in the messenger RNA into the sequence of amino acids that make up the protein.