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DNA in Action Kit

Student Laboratory Kit

Introduction

DNA, deoxyribose nucleic acid, is the genetic instructions used in the development and functioning of every living organism. Knowledge of its structure and functions is key to an understanding of molecular biology.

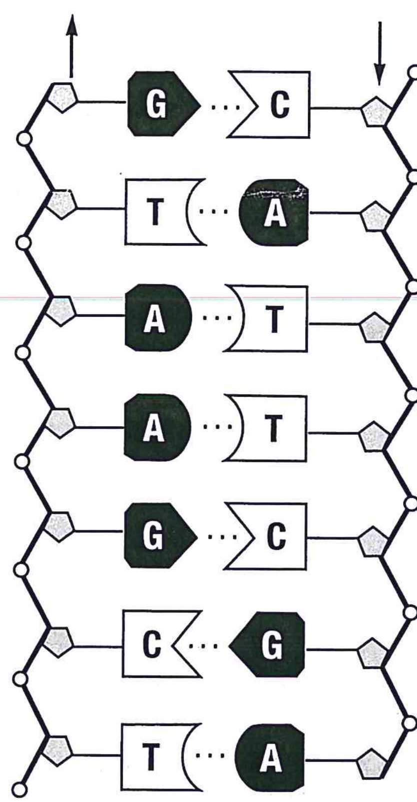
Concepts

- Double helix
- Genetic code
- Replication
- Transcription and translation

Background

Less than fifty years ago the nature of the genetic code still eluded scientists. In the fifty years since the structure of DNA was first hypothesized, it has become the most significant biological topic of the century. Understanding the structure of DNA helps to explain many life processes and why we are who we are. In this activity, the major processes of DNA will be modeled. Each step of the procedure will simulate a key DNA structure or process.

A simplified diagram of a short section of DNA is shown in Figure 1. The diagrammed segment contains seven base pairs. A real chromosome may contain a single DNA molecule with as many as 10^8 (100 million) base pairs or even more! Since the base pairs represent the genetic code, the chromosomes can store a lot of messages! Figure 2 on page 2 shows a summary of some of the processes of DNA. Refer to these diagrams throughout the activities.



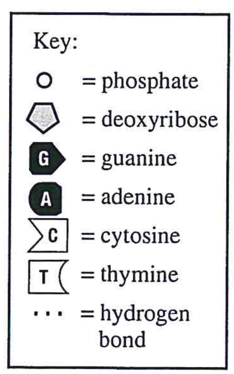


Figure 1. Short DNA sequence.

Materials

Blue pop beads (thymine)

Green pop beads (guanine)

Orange pop beads (cytosine)

Pink pop beads (uracil)

Plastic connectors (hydrogen bonds)

Red pop beads (phosphate)

White pop beads (deoxyribose)

Yellow pop beads (adenine)

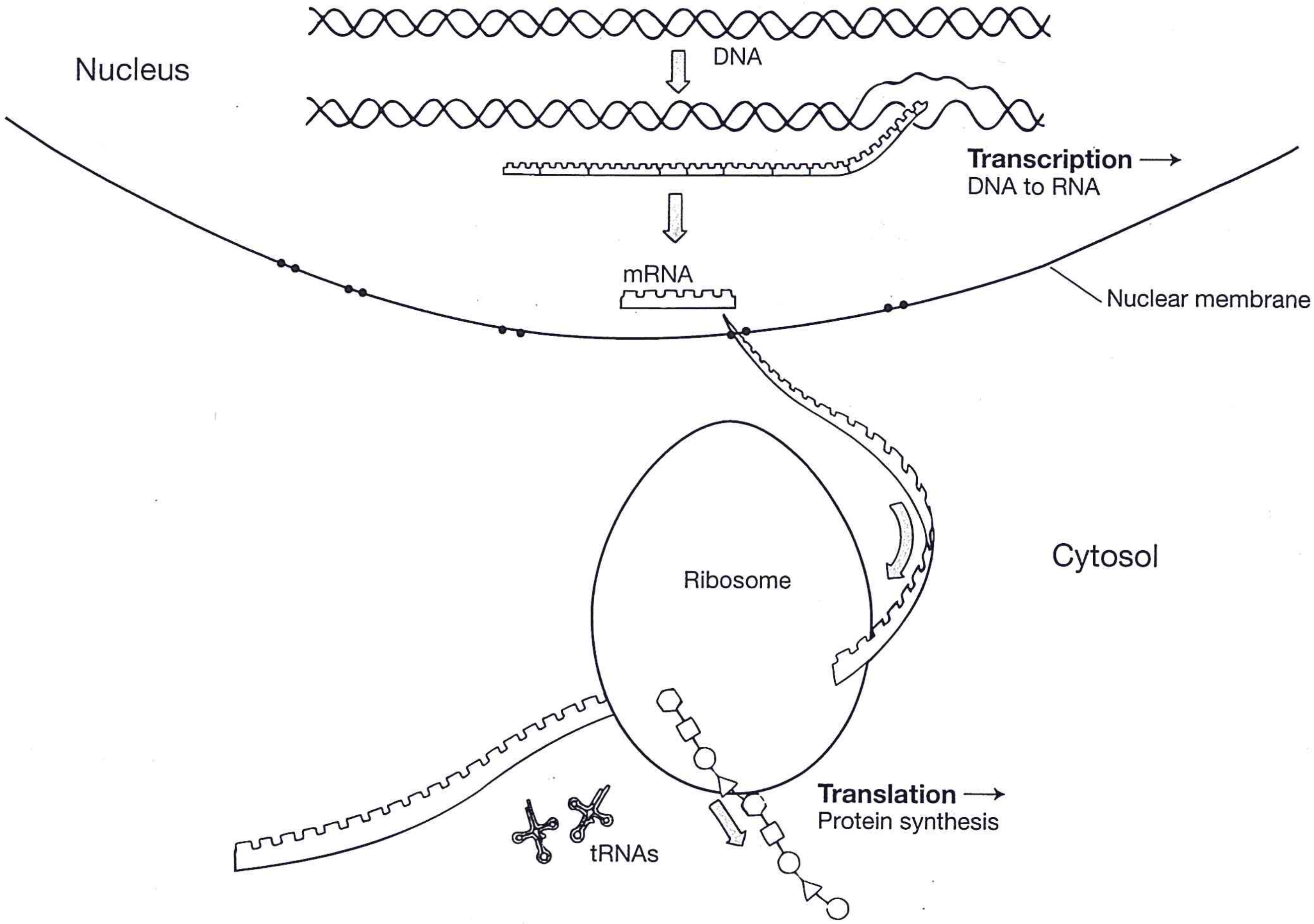


Figure 2. Summary of events in transcription and translation in a cell.

Procedure

Part A. Structure of the DNA Molecule

1. Using the color code for the pop beads shown in the materials list, make a DNA molecule using the following base pair pattern:

$$^{5'}\text{TTCCCCACATAGGCT}^{3'}$$
$$^{3'}\text{AAGGGGTGTATCCGA}^{5'}$$

   Remember that the base pairs must be paired via hydrogen bonds with their complement, that is, adenine with thymine and guanine with cytosine. Connect the two strings of base pairs using the plastic connectors to represent the hydrogen bonds.

2. Twist your molecular model 360° from the top rung of the ladder to the bottom rung. DNA is often called a "twisted" ladder. A complete 360° rotation actually occurs every 11 steps (base pairs) of the ladder.
3. When all teams have constructed their DNA model, a longer segment can be visualized by laying them all on one table at the same time.

Part B. DNA Replication

DNA is a self-replicating molecule, i.e., it can create an exact copy of itself. This is very important when cells divide. The replicated molecules (with their genetic code) are directed into each new cell during mitosis.

1. Separate an end base pair by pulling the hydrogen bond (plastic connector) apart.
2. Find a complementary base pair for each of the separated bases and connect each to its complement using new pop beads and plastic connectors.
3. Disconnect the next base pair and find the complementary base pairs.
4. Continue to "unzip" the DNA molecule and add complementary base pairs. As each pair is complete, connect the pair to the DNA backbone chain by adding the appropriate replacement phosphates and deoxyribose sugars to complete each new DNA strand.
5. Complete this process for the entire length of the DNA strand. What is the final result after the complete "unzipping" and synthesis process? How does each strand compare to its original strand?

Part C. Transcription

DNA serves as the genetic template and storage place for genetic messages. In order for the messages to be processed RNA (ribonucleic acid) becomes involved. The first step involves the synthesis of messenger RNA (mRNA) from the DNA template. This mRNA then carries the transcripted message to the ribosomes where proteins are synthesized. In RNA, thymine is replace by uracil (represented by the pink pop beads) as the base complement to adenine.

1. Starting at the 5′ end of one of your DNA molecules, break the hydrogen bonds for the first nine base pairs.
2. Build a messenger RNA molecule on the 3′ template. Your model should look like Figure 3.

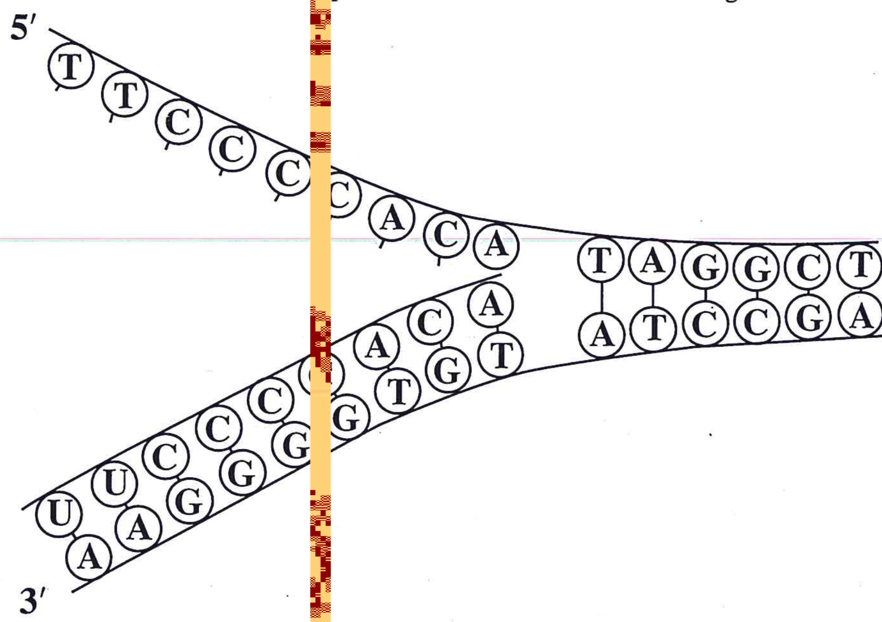


Figure 3. Synthesis of a segment of an mRNA complement from a DNA template.

Part D. Translation

The code in the newly synthesized mRNA is next translated and used to produce a specific sequence of amino acids, i.e., a specific protein. This translation process involves another type of RNA, called transfer RNA (tRNA). The tRNA molecule is a single-stranded nucleic acid with 73 to 93 nucleotides. tRNA is shaped somewhat like a cloverleaf. The anticodon is on the primary loop of the tRNA molecule. The amino acid attachment site is at the opposite 3′ end.

1. Detach your mRNA molecule (from Part C, Step 2) and build a tRNA model with an anticodon to match the first codon on the 3′ end of your mRNA. Use Figure 4 as a guideline to build one tRNA molecule with an AAG anticodon.

2. Use the mRNA decoding chart on page 5 to determine which amino acid your tRNA molecule should be carrying on its 3′ end.

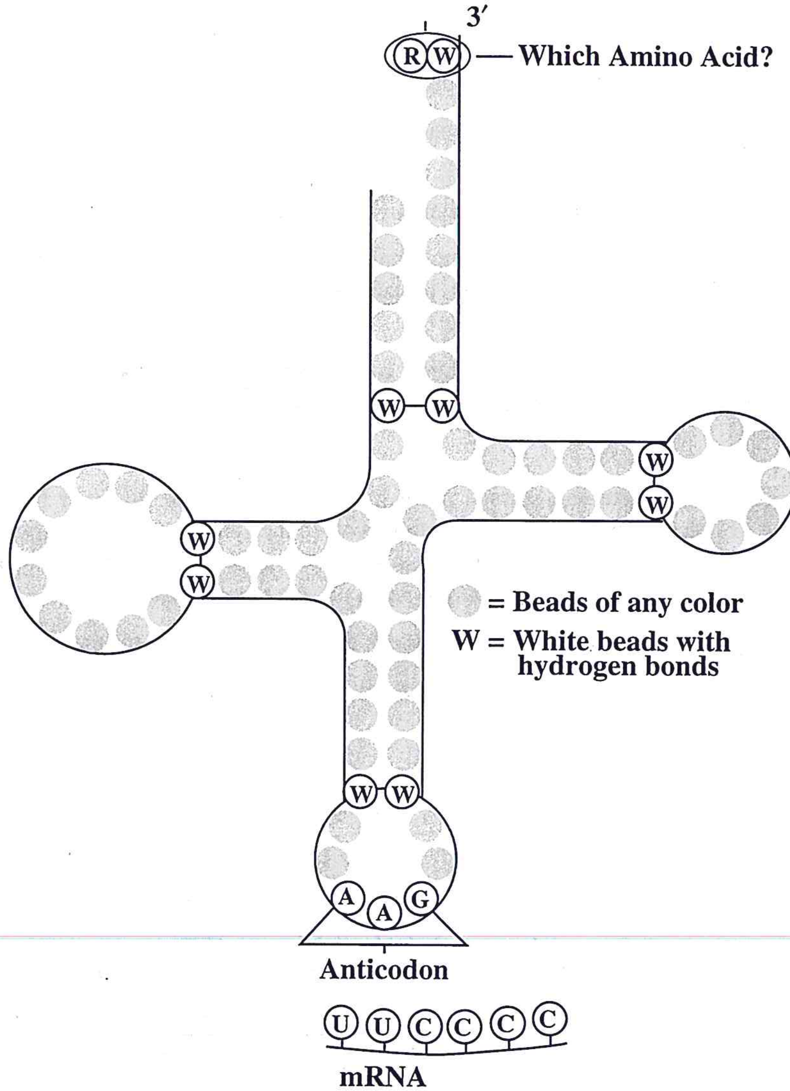


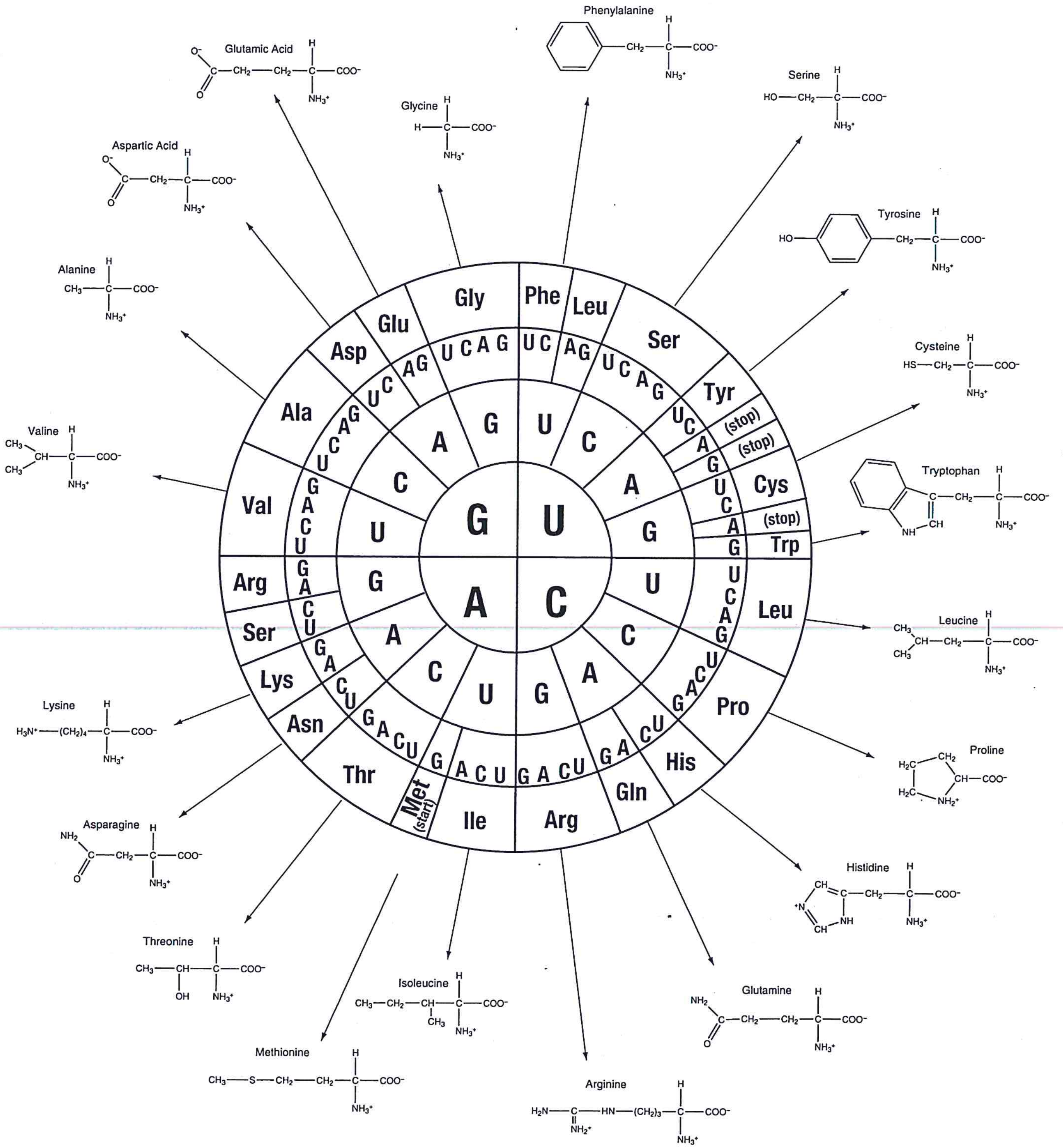
Figure 4. tRNA generalized structure pattern.

Part E. Protein Synthesis

The information encoded in the mRNA (as dictated by the base sequence in the original DNA) is translated and used to produce a specific sequence of amino acids. This synthesis occurs on the ribosomes in the cytoplasm of the cell. The amino acids are carried by their specific tRNA molecules and are placed in order as dictated by the base pair order of the mRNA. The specific amino acids for each mRNA codon are shown on the mRNA Decoding Chart.

1. Summarize your DNA simulation work by completing the DNA Worksheet.

mRNA Decoding Chart



Name: ______________________________

DNA Worksheet

1. Draw a DNA molecule that would code for the following amino acid sequence from its 3′ end.

   proline—tyrosine—alanine—valine—threonine

2. Draw the mRNA and tRNA's for the amino acid sequence in question 1.

3. The codons, UAG, UGA, and UAA are "stop" codons. What might a stop codon specify and of what value might it serve?

4. The codon CCA specifies proline in all life forms on this planet. Why might this "universal" code be significant? Useful?