Name _____
Date _____

DNA and RNA Structure and DNA Replication with the LEGO Model

Summary of the Lab Work: With the DNA set, you will have the opportunity to: learn the structure of the DNA and mRNA nucleotides, and create a model of the famous double helix; observe the complementary base pairing structure and the antiparallel sugar/phosphate strands in the LEGO model; and simulate the process of DNA replication using a photo sequence for instruction. A helicase molecule will be used to separate the double strands. Nucleotides will add on only to the free 3' ends, creating the leading and lagging strands in the region of the replication fork.

1) Check your DNA set. Use the *Advanced Student Instructions* pages 2-7 to check the configuration of the nucleotides as well as the nucleotide count. It is important that each molecule be correctly assembled before starting.

2) Review the chemical structure of the nucleotides and their complementary features. Use the *Advanced Student Instructions* pages 2 and 3 to review how the LEGO elements model the three components of a nucleotide – the sugar, the base, and the phosphate. Page 12 may also be helpful. The size of the color-coded base indicates whether it is a pyrimidine or a purine. Purines have a double ring structure and they are larger than the one ring pyrimidines. The magnetic attractions of the bases model the presence of the hydrogen bonds that occur between paired bases. Draw one LEGO nucleotide and label the basic chemical components modeled below.

Complete the Experiment and Discover One on page 8. List in pairs all the LEGO DNA nucleotides that attract each other.

Circle those that are used in a normal DNA molecule. What happens when the uncircled pairs are incorporated into a double strand?

3) Record your understanding. The 3' and 5' concept is important to understanding the antiparallel nature of DNA and the synthesis of DNA and mRNA polymers. Refer to *Advanced Student Instructions* page 11. Draw the chemical structure of two RNA or two DNA nucleotides below. Label the carbons with prime designations. Next, add an arrow to indicate the site of possible connection between the nucleotides.

Lab Sheet

4) Build a single-strand of DNA with the following sequence:

5'–ACGGTACGCTAT–3' Notice that all the sugars run in the same direction.

5) Build the other DNA strand properly base-paired to the one you made in Step 4. What does the structure of the double-stranded DNA molecule look like now? Note that the strands must be anti-parallel (run 5'→ 3' in opposite directions) **and** to keep the sugar/phosphate sides equidistant, **A** will pair with **T** and **C** will pair with **G.** Draw the structure of the double-stranded DNA molecule using straight lines and letters below. Include the prime designations at the ends.

What is the sequence of the second DNA strand you added?

5'– –3'

Check your answer above.
By convention, single strands are always written with the 5' starting on the left. Also, in double stranded DNA diagrams, the 5' can be positioned on either the top or bottom strand; however, top left is the convention.

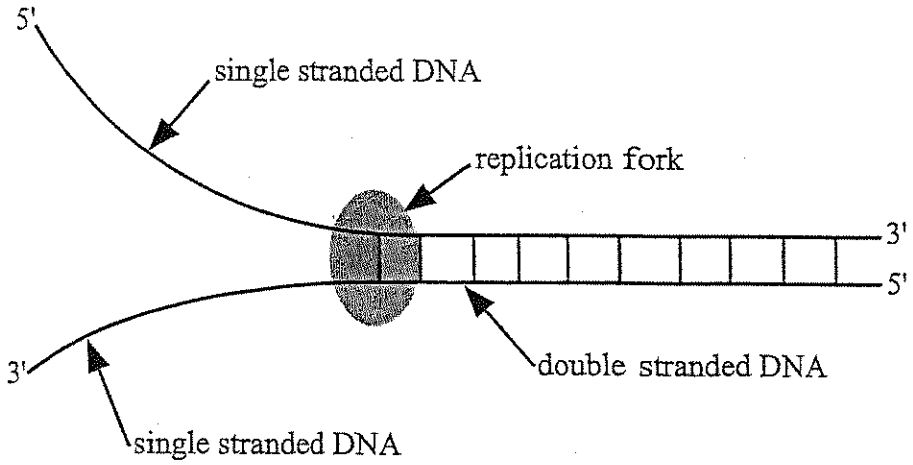
6) Observe the famous double helix. Pick up the double stranded DNA and twist the strands to see the famous double helix. Note that DNA does one complete turn in about 10 nucleotide base pairs. The LEGO DNA makes a close approximation. It takes _____ base pairs to complete one full helical turn.

7) Discover why DNA replication can not be a symmetrical process for the separated single strands. Refer to Experiment and Discover Two on page 14. Position the nucleotides so that the upper left strand of the double strand begins with bases ACGG. Unzip the base pairs as shown. (Unzipping means breaking the hydrogen bonds.) This region is the called the replication fork, and it includes some amazing molecular machinery. These molecules will not be modeled with LEGO, so be sure to read about the replication fork in your textbook.

Experiment by placing one complementary base pair nucleotide on the free end of both strands. Remember the base pairs must be antiparallel. (The 3' and 5' ends of the base-paired sugars are aligned in opposite directions and do not match in orientation.) The enzyme DNA polymerase can only add to the 3' end of a nucleotide. Which strand, the top or the bottom single strand, could proceed from this step?

8) Summarize and complete the diagram on the next page.. Show the important difference in the direction that the complementary DNA strand can grow. The lines on the diagram, represent the original DNA strands. Draw in, as two new straight lines, two new complementary DNA strands. Indicate the 5' and 3' ends. Also, indicate with an arrowhead on each line the direction that the strand can continue to grow (5'→3').

Lab Sheet



9) Simulate the replication of this DNA molecule. Use the *Advanced Student Instructions* pages15–18. The photo sequences will introduce the concept of leading and lagging strands. Add these labels to the diagram above.

10) Make a list of differences between leading and lagging strands.

11) Reflect. Take time (in the future if need be) to reflect and integrate the basic concepts from this LEGO Lab replication with your textbook's detailed description of DNA replication. Here are some sample questions for resolution. Which important replication enzymes are not represented by LEGO in the simulation? How long is a typical lagging strand fragment (measured in base pairs) in DNA replication?

12) Clean up. Disassemble the nucleotides correctly. Leave the phosphate (cylinders) attached at the 5' ends only and return the materials to the set.

Name_____
Date_____

Transcription with LEGO DNA and mRNA

Summary of the Lab Work: With the DNA Set, you will model DNA transcription with a small DNA gene and a mRNA molecule. The remaining steps of translation and protein synthesis will be completed on paper to produce a protein. You will also explore the effects of a DNA point mutation using the nucleotides. The lab assignment: Write a DNA code for your own protein.

1) Check your LEGO DNA set.

Use the LEGO DNA *Advanced Student Instructions* pages 2–7 to check the number and configuration of the molecules. It is important that each nucleotide be correctly assembled.

2) Build the following small gene with your lab group.

Start with a single-strand of DNA with the sequence given below. This is the coding sequence. Check that your letters read from left to right and that the magnets are pointed down or towards you. The gaps in the DNA sequence shown below are there only to help you create the sequence.

5'- CTA TAA GCA TGC CCC TAT GAG GGT -3'

After you have built this first strand, go back and add the complementary DNA strand on the bottom. This is the template strand. Now if you have done everything correctly, you will not have any DNA nucleotides leftover in the set. Notice the antiparallel nature of the side chains. (Antiparallel means parallel but running in opposite directions.) If you have not seen the LEGO DNA in a double helix configuration yet, be sure to pick up the assembled molecule and give it a twist.

3) Transcribe this gene into mRNA.

Before you begin, read all the instructions for starting and terminating the mRNA. This includes reading both A and B below. Also, do not begin until you have checked the photographs in the *Advanced Student Instructions* page 19 for how the mRNA polymerase will be used.

A) Start the transcription of this gene.

Transcription in this organism, a LEGO fish, starts at the first nucleotide after the promoter. In this organism, promoters have this sequence, TATAA. (This is a common promoter sequence in many organisms.) Locate the sequence in the DNA top strand.

DNA bases:

5' – T A T A A .....–3' ←—— this is the promoter
3' –A T A T T .....–5'

Insert the RNA polymerase molecule to the right of the promoter. You will proceed from left to right, shifting over the polymerase molecule one base at a time. Base pair the mRNA with the DNA. Choose and create the mRNA chain that can follow the RNA polymerase and that can proceed by adding on to the 3' end of the nucleotides.

Why doesn't the mRNA use the other DNA strand?_____

_____

B) Halt the transcription of this gene

In a long DNA molecule, terminators are needed to signal the end of each gene. A terminator sequence is included here. This portion of the DNA is not transcribed into mRNA.

DNA bases:

5' - x G G G T .....-3' ⟵ This is the terminator sequence
3' - y C C C A .....-5'

4) Record the sequence of the mRNA nucleotides.

5' - _____ - 3'

5) The mRNA leaves the Nucleus and Binds to a Ribosome.

This mRNA molecule exits the nucleus of the cell through a pore in the nuclear membrane. Next, the mRNA is found in the cytoplasm by a ribosome and is translated in a sequence of amino acids on the ribosome.

6) Read the mRNA. The mRNA strand has the start and stop signals for the translation process.

All ribosomes start at the 5' end of the mRNA and look for the start codon on the mRNA. The start codon on the mRNA is this sequence: 5'–AUG–3'. This is the code for an amino acid called methionine. The translation of the mRNA into amino acids will be halted by the presence of stop codon, another sequence of three nucleotides.

Three codons commonly signal stop in translation. Refer to the *Advanced Student Instructions* page 21 or 22 and look up the codons in the Genetic Code Table.
Include the 5' and 3' notations with the codons below.

_____
_____
_____

7) Act as a ribosome and translate the mRNA.

First record the four codons:

5'_____ _____ _____ _____ **3'**

Second, record the resulting sequence of amino acids in this protein. Refer to the Genetic Code found in the *Advanced Student Instructions* on page 21 or 22.

N _____ _____ _____ C
(amino-end) (acid-end)

Lab Sheet

8) Explore the results of a mutation in the gene.
Mutations are alterations in the sequence of DNA nucleotides. Simulate an example that changes one base pair. Make the following changes:

The 12th base pair in your DNA strand was: 5'...T G C C C...3'
3'...A C G G G...5'

The base pair is bold and underlined
Change it to: 5'...T G G C C...3'
3'...A C C G G...5'

A) Record the resulting mRNA sequence. (You can reinsert the mRNA in the DNA and adjust the altered base pair.)

5' - _____ - 3'

B) Record the resulting amino acid sequence.

N _____ _____ _____ C
(amino-end) (acid-end)

Check your results in this lab with the instructor. If your answers are not correct, receive some hints and repeat as necessary.

9) Disassemble the LEGO strands carefully. The phosphates (cylinders) should remain attached to the 5' ends of the nucleotides and returned to the set.

10) Lab Assignment: Code a DNA for your own protein.
Note: On computers – you will find it easier to use a font like Courier that keeps the spacing the same for all letters. (This will match the DNA nucleotide letters for this exercise.)

A) Create a protein that is five amino acids long.

B) Write out the sequence of the amino acids, with the N and C termini.

C) Write out one possible sequence of the codons. (More than one version is possible.)
Be sure to mark the 5' and 3' ends.

D) Write out the double stranded DNA molecule that would produce this mRNA.
Be sure to mark the 5' and 3' ends.
Use the convention of this LEGO lab, with the format like this for the DNA.
(The 5' end is at the top left.)
5'...T G C C C...3'
3'...A C G G G...5'