Lab 6: The Central Dogma — From DNA to Protein

BIOL-8

Name: _____ **Date:** _____

Name: _____ **Date:** _____

Objectives

By the end of this lab, you will be able to:

- **Model DNA replication** by physically separating and rebuilding complementary strands
- **Perform transcription** by converting a DNA template strand into an mRNA sequence
- **Perform translation** by decoding mRNA codons into an amino acid chain
- **Trace the flow of genetic information** from DNA → RNA → Protein (the Central Dogma)
- **Use a codon table** to identify amino acids from mRNA triplets
- **Explain the significance** of start and stop codons in protein synthesis

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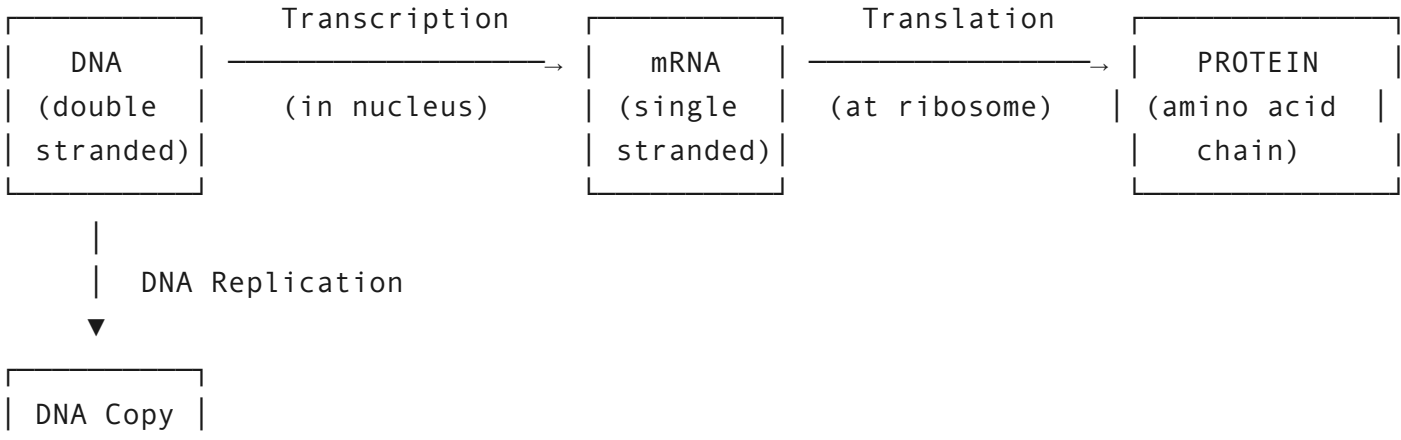
Introduction

The **Central Dogma of Molecular Biology** describes the flow of genetic information in living cells:



```
| (double  |
| stranded)|
└──────────┘
```

In this lab, you will use **paper cutouts** of nucleotides and amino acids to physically walk a short DNA sequence through all three processes: **replication**, **transcription**, and **translation**.

Key Terms:

Term	Definition
Nucleotide	Building block of DNA/RNA (base + sugar + phosphate)
Complementary base pairing	A pairs with T (DNA) or U (RNA); G pairs with C
Template strand	The DNA strand read by RNA polymerase (3'→5')
Coding strand	The DNA strand with the same sequence as mRNA (except T→U)
Codon	Three-nucleotide sequence on mRNA that codes for an amino acid
Anticodon	Three-nucleotide sequence on tRNA that is complementary to a codon
Start codon	AUG — signals the beginning of translation (codes for methionine)
Stop codon	UAA, UAG, or UGA — signals the end of translation

Materials

- Scissors
- Tape or glue stick
- Colored pencils or markers (4 colors recommended)
- **Appendix A**: Printable DNA nucleotide cutouts (A, T, G, C)
- **Appendix B**: Printable RNA nucleotide cutouts (A, U, G, C)
- **Appendix C**: Printable amino acid cards
- **Appendix D**: Standard genetic code (codon table)
- Blank paper or lab worksheet for assembling sequences

Safety Considerations

- Use scissors carefully
- Keep workspace clear and organized

The Sequence We Will Use

Throughout this lab, you will work with the following **18-base DNA sequence** (template strand):

```
Template strand (read 3'→5'):
    3'— T A C   A A G   T T T   G C A   C C G   A T T —5'
         ↑               ↑                       ↑
       START         (4 codons)                STOP
     (will produce                          (will produce
      AUG = Met)                            UAA = Stop)
```

This codes for a small protein: **Start + 4 amino acids + Stop**

The complementary **coding strand** is:

```
Coding strand (5'→3'):
    5'— A T G   T T C   A A A   C G T   G G C   T A A —3'
```

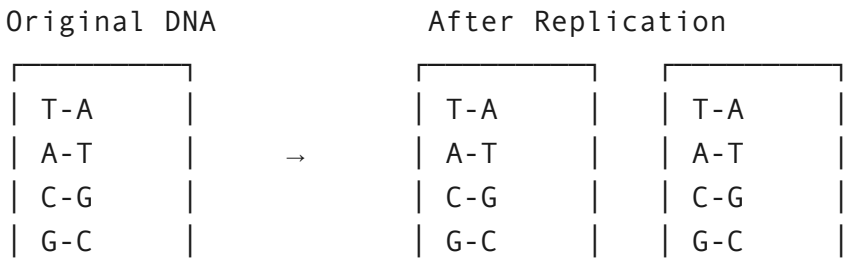
Part 1: DNA Replication

> ***Learning Goal:*** *Model the semi-conservative process of DNA replication using paper nucleotide cutouts.*

Background

Before a cell divides, it must copy its DNA. During **DNA replication**:

1. **Helicase** unwinds and separates the two strands (breaks hydrogen bonds)
2. **DNA polymerase** reads each template strand and adds complementary nucleotides
3. **Ligase** seals any gaps in the new strands
4. Result: **Two identical double-stranded DNA molecules**



```
└──────────┘              └──────────┘    └──────────┘
 (1 molecule)              (2 identical molecules)
```

Procedure

1. **Cut out** 18 DNA nucleotide pieces for the **template strand**: T-A-C-A-A-G-T-T-T-G-C-A-C-C-G-A-T-T
2. **Cut out** 18 DNA nucleotide pieces for the **coding strand**: A-T-G-T-T-C-A-A-A-C-G-T-G-G-C-T-A-A
3. **Arrange** them as a double-stranded DNA molecule, pairing each base with its complement
4. **Simulate helicase**: Physically separate the two strands by pulling them apart
5. **Simulate DNA polymerase**: For each separated strand, cut out NEW complementary nucleotides and pair them
6. **Tape** the new nucleotides in place to form two complete double-stranded molecules

Data Collection

DNA Replication Results

#	DNA Molecule	Strand 1 Sequence (top)	Strand 2 Sequence (bottom)	Identical to Original?
1				
2				

Analysis

1. Why is DNA replication called "semi-conservative"?

2. Each new DNA molecule contains one original strand and one new strand. Which strand is original and which is new in each copy?

3. What would happen if DNA polymerase made an error and inserted the wrong nucleotide?

Part 2: Transcription — DNA → mRNA

Learning Goal: *Convert the DNA template strand into a complementary mRNA sequence, simulating transcription.*

Background

During **transcription**, the enzyme **RNA polymerase** reads the DNA template strand and builds a complementary **mRNA** molecule. Key differences from DNA replication:

- RNA uses **uracil (U)** instead of **thymine (T)**
- RNA is **single-stranded**
- Only **one strand** of DNA (the template strand) is read

Base pairing rules for transcription:

DNA Template Base	mRNA Base
A	U
T	A
G	C
C	G

Procedure

1. **Take your template strand** from Part 1:

```
3'— T A C A A G T T T G C A C C G A T T —5'
```

1. **Cut out RNA nucleotides** (from Appendix B) to build the complementary mRNA
2. Apply the base pairing rules: A→U, T→A, G→C, C→G

3. **Arrange the mRNA nucleotides** in a single row next to the DNA template, reading 3'→5' on the template to produce the mRNA 5'→3'
4. **Tape** the mRNA strand together in order

Build Your mRNA

Transcription: DNA → mRNA

#	Position	DNA Template Base	→	mRNA Base
1				
2				
3				
4				
5				
6				

Write your complete mRNA sequence here:

5'— _____ —3'

Which base in RNA replaces thymine (T) from DNA?

_____

Analysis

1. Transcription occurs in which part of the cell?

_____

2. Why does the cell make an mRNA copy rather than using the DNA directly for protein synthesis?

3. Compare the mRNA sequence you built to the coding strand of DNA. What do you notice?

Part 3: Translation — mRNA → Protein

Learning Goal: *Decode the mRNA message into a chain of amino acids, simulating translation at the ribosome.*

Background

During **translation**, the ribosome reads the mRNA **three nucleotides at a time** (codons). Each codon specifies an amino acid. **tRNA** molecules carry amino acids to the ribosome and match their **anticodon** to the mRNA **codon**.

```
mRNA:     5'—  A U G   U U C   A A A   C G U   G G C   U A A  —3'
                  ↓       ↓       ↓       ↓       ↓       ↓
Amino           Met     Phe     Lys     Arg     Gly    STOP
acids:        (start)                                  (release)
```

The Standard Genetic Code (Codon Table)

Use this table to decode each mRNA codon into its amino acid:

First Position	Second Position: U	C	A	G
	UUU Phe	UCU Ser	UAU Tyr	UGU Cys

	U	C	A	G
U	UUC Phe	UCC Ser	UAC Tyr	UGC Cys
	UUA Leu	UCA Ser	UAA STOP	UGA STOP
	UUG Leu	UCG Ser	UAG STOP	UGG Trp
C	CUU Leu	CCU Pro	CAU His	CGU Arg
	CUC Leu	CCC Pro	CAC His	CGC Arg
	CUA Leu	CCA Pro	CAA Gln	CGA Arg
	CUG Leu	CCG Pro	CAG Gln	CGG Arg
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser
	AUC Ile	ACC Thr	AAC Asn	AGC Ser
	AUA Ile	ACA Thr	AAA Lys	AGA Arg
	AUG Met/START	ACG Thr	AAG Lys	AGG Arg
G	GUU Val	GCU Ala	GAU Asp	GGU Gly
	GUC Val	GCC Ala	GAC Asp	GGC Gly
	GUA Val	GCA Ala	GAA Glu	GGA Gly
	GUG Val	GCG Ala	GAG Glu	GGG Gly

Procedure

1. **Take your mRNA strand** from Part 2
2. **Divide it into codons** — group the mRNA into sets of three nucleotides
3. **For each codon**, look up the amino acid in the codon table above
4. **Cut out the corresponding amino acid cards** (from Appendix C)
5. **Assemble the polypeptide chain** — line up the amino acid cards in order, left to right
6. **Stop** when you reach the stop codon — do not add an amino acid for it

Decode Your mRNA

Translation: mRNA → Amino Acids

#	Codon #	mRNA Codon	Amino Acid	tRNA Anticodon
1				
2				
3				
4				
5				
6				

Write your final amino acid sequence (polypeptide) here:

How many amino acids are in your polypeptide (not counting the stop)?

Analysis

1. What is the start codon, and what amino acid does it always code for?

2. What happens at the ribosome when a stop codon is reached?

3. The codon table shows that multiple codons can code for the same amino acid (e.g., UUU and UUC both code for Phe). Why might this "redundancy" be beneficial?

4. What is the role of tRNA in translation?

Part 4: Mutation Simulation

Learning Goal: *Observe how a single base change in DNA can alter the protein produced.*

Procedure

1. **Start with the original DNA template strand**: 3'–TAC AAG TTT GCA CCG ATT–5'
2. **Introduce a mutation**: Change the 10th base (G) to an A, so position 10–12 becomes **ACA** instead of **GCA**
3. **Transcribe** the mutated template strand into mRNA
4. **Translate** the mutated mRNA into amino acids

Mutated Sequence

Mutation Analysis

#	Codon Position	Original DNA Template	Mutated DNA Template	Original mRNA	Mutated mRNA	Original AA	Mutated AA
1							
2							
3							
4							
5							
6							

Analysis

1. Did the mutation change the amino acid at position 4? If so, what changed?

2. What type of mutation is this (substitution, insertion, or deletion)?

3. Would a single base change always change the amino acid? Why or why not?

4. How might a changed amino acid affect the function of the protein?

Part 5: Summary — Tracing the Central Dogma

Complete the Flowchart

Fill in each step of the central dogma for your original sequence:

DNA Template Strand: 3'— _____ —5'

↓ Transcription (by RNA polymerase, in the nucleus)

mRNA: 5'— _____ —3'

↓ Translation (by ribosomes, in the cytoplasm)

Amino Acid Sequence: _____

Number of amino acids in final protein: _____

Conclusions

1. In your own words, explain the central dogma of molecular biology and why it is important:

2. Why does the cell transcribe DNA into mRNA rather than using DNA directly at the ribosome?

3. If a gene has 300 nucleotides (excluding start and stop), how many amino acids would the resulting protein contain? Show your reasoning:

4. A classmate says "DNA makes protein." Is this statement accurate? How would you correct or clarify it?

5. How does what you learned in this lab connect to the concept of genetic mutations and inherited diseases?

Quick Reference

Central Dogma Summary

Process	Location	Enzyme	Input	Output
DNA Replication	Nucleus	DNA polymerase	1 DNA molecule	2 identical DNA molecules
Transcription	Nucleus	RNA polymerase	DNA template strand	mRNA
Translation	Ribosome (cytoplasm)	—	mRNA + tRNA + amino acids	Polypeptide (protein)

Base Pairing Rules

DNA Replication	Transcription
A ↔ T	A (DNA) → U (mRNA)
T ↔ A	T (DNA) → A (mRNA)

DNA Replication	Transcription
G ↔ C	G (DNA) → C (mRNA)
C ↔ G	C (DNA) → G (mRNA)

Connection to Module 07: This lab directly applies the Central Dogma concepts from Module 07 (Genetics). Understanding how DNA encodes proteins through transcription and translation is foundational for genetics, inheritance (Module 09), and understanding how mutations cause disease. Every protein in your body — from hemoglobin to digestive enzymes — is built through this process.

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