# Lab 6: The Central Dogma — From DNA to Protein

*BIOL-8*

**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:

**DNA** (Nucleus) —> **mRNA** (Nucleus → Cytoplasm) —> **PROTEIN** (Ribosome)

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) |

| Term | Definition |
|---|---|
| **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 |

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## 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

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## 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'
```

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## Part 1: Preparation — Cutting Out Materials

> ***Learning Goal:*** *Prepare the physical models needed to simulate the Central Dogma processes.*

### 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. **Cut out** RNA nucleotides (from Appendix B) to be used for building the complementary mRNA.
4. **Cut out** the amino acid cards (from Appendix C). Keep these organized for later use.

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## Part 2: 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**

## Procedure

1. **Take your cut-out DNA nucleotides** from Part 1.
2. **Arrange** them as a double-stranded DNA molecule, pairing each base with its complement.
3. **Simulate helicase**: Physically separate the two strands by pulling them apart
4. **Simulate DNA polymerase**: For each separated strand, cut out NEW complementary nucleotides and pair them
5. **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 3: 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 used for Transcription:**

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

### Procedure

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

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

1. **Use your RNA nucleotide cutouts** from Part 1.
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?**

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## Part 4: 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)
```

Use the **Codon Table** (Appendix) to decode your sequence.

### Procedure

1. **Take your mRNA strand** from Part 3.
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 (Appendix).
4. **Select the corresponding amino acid cards** from your prepared set.
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?**

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## Part 5: 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 6: 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?**

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## 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) |

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**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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# Appendix: Codon Table (Tear-off Sheet)

Standard Genetic Code

| First Position (5' end) | Second Position: U | Second Position: C | Second Position: A | Second Position: G |
|---|---|---|---|---|
| U | UUU Phe | UCU Ser | UAU Tyr | UGU Cys |
| | 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 |