MODULE 6 LEARNING ACTIVITY SHEET (LAS)
GRADE 8 – BIOTECHNOLOGY | TERM 2
DNA REPLICATION: How DNA Makes an Identical Copy of Itself
Name: _____ Grade & Section: _____
Date: _____ Score: _____

I. Learning Objectives
At the end of this learning activity, learners should be able to:

1. Explain the importance of DNA replication in cell division and the continuity of genetic information.
2. Describe the three major stages of DNA replication: initiation, elongation, and termination.
3. Identify the different enzymes and proteins involved in DNA replication and explain their specific functions.
4. Differentiate the leading strand from the lagging strand based on their direction and process of synthesis.
5. Explain how the coordinated actions of enzymes produce two identical DNA molecules.

II. Introduction: What is DNA Replication?
DNA Structure & Replication: The Code of Life and How It Copies Itself — Texas CBE™texascbe.com

Every living organism needs DNA because it contains the genetic instructions that control its growth, development, and reproduction. DNA carries the information that determines the characteristics and functions of cells.

However, when a cell prepares to divide, it must first make a complete copy of its DNA. This process is called DNA replication.

DNA replication is the biological process in which one DNA molecule produces two identical DNA molecules. It happens during the Synthesis (S) phase of interphase, before cell division.

Imagine that you have an important book containing all the instructions needed to operate a machine. Before giving the machine to two different people, you need to make an accurate copy of the instruction book. In the same way, a cell must copy its DNA before dividing so that each daughter cell receives the necessary genetic information.

Why is DNA replication important?

- It ensures that each daughter cell receives a complete set of genetic instructions.
- It maintains the continuity of genetic information from one generation of cells to the next.
- It supports the growth, repair, and replacement of damaged or old cells.
- It helps organisms develop and reproduce properly.

The Semiconservative Model of DNA Replication

DNA replication follows the semiconservative model. The word semi means half, while conservative refers to retaining or keeping something. In semiconservative replication, each newly formed DNA molecule contains:

- One original (parental) DNA strand.
- One newly synthesized DNA strand.

This means that the two original DNA strands separate, and each serves as a template for the construction of a new complementary strand.
6.4 Double Helix Structure of DNA | BS1005 / CM1051: Biochemistry lbookdown.org

As a result, two DNA molecules are produced. Each contains one old strand and one new strand.
Remember: DNA replication does not produce two molecules made entirely of new strands. Each resulting molecule contains one original strand and one newly made strand.

III. Elaboration of the Lesson
A. The Three Major Steps of DNA Replication

DNA replication occurs through three major stages: initiation, elongation, and termination. Each stage involves specific enzymes and proteins that work together to ensure that DNA is copied accurately.
Biology: DNA Replication Infographic | LivePhysics™livephysics.com

1. Initiation – Starting the Replication Process

Initiation is the first stage of DNA replication. During this stage, the DNA molecule prepares itself for copying.

What happens during initiation?
Step 1: Identification of the origin of replication

DNA replication begins at a specific location along the DNA molecule called the origin of replication. This is the starting point where special proteins recognize and attach to the DNA to prepare it for replication.

Step 2: Unwinding of the DNA double helix

The enzyme helicase begins separating the two DNA strands by breaking the hydrogen bonds that hold the complementary nitrogenous bases together.

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Remember:

- Adenine (A) pairs with Thymine (T).
- Cytosine (C) pairs with Guanine (G).

When helicase breaks the hydrogen bonds, the two strands separate, exposing their nitrogenous bases.

Step 3: Formation of the replication fork

As the DNA strands separate, a Y-shaped structure called the replication fork is formed. This is the area where the actual copying of DNA takes place.

Step 4: Stabilization of the separated strands

Special proteins called single-strand binding proteins (SSB proteins) attach to the separated DNA strands. They prevent the strands from joining together again while replication is taking place.

Step 5: Prevention of excessive twisting

As DNA unwinds, the region ahead of the replication fork may become tightly twisted. The enzyme topoisomerase helps relieve this tension by temporarily cutting and reconnecting DNA strands.

7.5: DNA Replication in Prokaryotes - Biology LibreTextsbio.libretexts.org

Important concepts to remember:

Structure/Enzyme	Function
Origin of replication	Starting location of DNA replication
Helicase	Separates the two DNA strands
Replication fork	Y-shaped region where DNA is being copied
SSB proteins	Keep separated DNA strands from joining again
Topoisomerase	Relieves twisting and tension ahead of the replication fork

Simple analogy:
Imagine a zipper being opened. Helicase acts like the person pulling the zipper apart. The two sides of the zipper represent the separated DNA strands. Once opened, each side becomes a template for making a new matching strand.

2. Elongation – Building the New DNA Strands

Elongation is the second stage of DNA replication. During this stage, new DNA strands are constructed by adding complementary nucleotides to the original DNA templates.

Once the two parental strands have separated, each strand serves as a guide for building a new complementary strand.

How does elongation happen?

Step 1: Addition of RNA primers

The enzyme primase produces short RNA segments called RNA primers. These primers provide a starting point for DNA polymerase because DNA polymerase cannot begin building a completely new DNA strand on its own.

Step 2: Addition of complementary DNA nucleotides

The enzyme DNA Polymerase III adds complementary DNA nucleotides to the growing strand.

The pairing follows the base-pairing rules:

Original DNA Base	Complementary Base
Adenine (A)	Thymine (T)
Thymine (T)	Adenine (A)
Cytosine (C)	Guanine (G)
Guanine (G)	Cytosine (C)

For example:
If the original DNA template has the sequence:
Original DNA Template **5' A – T – G – C – C – A 3'**
New Complementary Strand **3' T – A – C – G – G – T 5'**
Each base is matched with its complementary partner.
DNA Polymerase III adds the correct nucleotides based on the sequence of the original template strand.

Step 3: Formation of the leading and lagging strands

DNA has two strands that run in opposite directions. This arrangement is called antiparallel orientation.
Because DNA polymerase can only add nucleotides in the 5' to 3' direction, the two new DNA strands are produced differently.
These two strands are called the leading strand and the lagging strand.

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a. Leading Strand

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The leading strand is the newly formed DNA strand that is synthesized continuously toward the moving replication fork. Its synthesis is relatively straightforward because DNA polymerase can continuously add nucleotides as the DNA opens.
Characteristics of the leading strand:

- Synthesized continuously.
- Grows in the 5' to 3' direction.
- Requires an RNA primer to begin synthesis.
- DNA Polymerase III adds complementary nucleotides along the template.

Example: Imagine building a long wall without stopping. As long as the materials are available, you can continue adding bricks in one direction. This is similar to how the leading strand is synthesized.

b. Lagging Strand

File:DNA replication en.svg - Wikimedia Commonscommons.wikimedia.org

The lagging strand is the newly formed DNA strand that is synthesized discontinuously, meaning it is built in short sections rather than in one continuous strand.

These short sections are called Okazaki fragments, named after the scientists who discovered them.

Why does the lagging strand form short fragments?

The two original DNA strands run in opposite directions. Since DNA polymerase can only build new DNA in the 5' to 3' direction, the lagging strand cannot be synthesized continuously toward the moving replication fork.

Instead, DNA polymerase builds short sections away from the replication fork as more of the template becomes exposed.

Characteristics of the lagging strand:

- Synthesized discontinuously.
- Formed in short sections called Okazaki fragments.
- Requires multiple RNA primers.
- DNA Polymerase III extends each fragment.
- DNA Polymerase I removes RNA primers and replaces them with DNA.
- DNA Ligase joins the fragments together.

Example: Imagine constructing a long wall using several separate sections. After all the sections are completed, you connect them to form one continuous wall. This is similar to the formation of the lagging strand.

Comparison of the Leading and Lagging Strands

Leading Strand	Lagging Strand
Synthesized continuously	Synthesized discontinuously
Built toward the replication fork	Built away from the replication fork in short sections
Requires one initial primer per continuous replication stretch	Requires multiple primers
Does not form Okazaki fragments	Forms Okazaki fragments
DNA ligase is not needed to join Okazaki fragments	DNA ligase joins the Okazaki fragments

Remember these important terms!

- 5' to 3' direction: The only direction in which DNA polymerase synthesizes a new DNA strand.
- RNA primer: A short RNA sequence that provides a starting point for DNA synthesis.
- Okazaki fragments: Short DNA sections produced on the lagging strand.
- Antiparallel: The two DNA strands run in opposite directions.

3. Termination – Completing DNA Replication

Termination is the final stage of DNA replication. During this stage, the copying process is completed, and two DNA molecules are produced.

PPT - 3.4 & 7.2 DNA Replication PowerPoint Presentation, free download - ID:2474866slideserve.com

What happens during termination?

Step 1: Completion of DNA synthesis

DNA replication continues until the entire DNA molecule has been copied. In organisms with multiple replication origins, replication forks eventually meet or reach the ends of the DNA regions being copied.

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Step 2: Removal of RNA primers

The RNA primers used to begin DNA synthesis are removed. In the simplified bacterial model, DNA Polymerase I removes the RNA primers and replaces them with DNA nucleotides.

Step 3: Joining of DNA fragments

After the RNA primers have been replaced, small breaks may remain between adjacent DNA sections. The enzyme DNA Ligase seals these breaks by forming bonds in the sugar-phosphate backbone of DNA.

Step 4: Formation of two DNA molecules

After all the necessary DNA sections have been completed and joined, two DNA molecules are produced. Each DNA molecule contains:

- One original parental strand.
- One newly synthesized complementary strand.

This confirms that DNA replication follows the semiconservative model.
The final result: One original DNA molecule produces two DNA molecules with the same base sequence, assuming no replication errors occur.

B. Enzymes and Proteins Involved in DNA Replication

DNA replication is not performed by only one enzyme. It requires several enzymes and proteins that work together. Each has a specific responsibility to make sure that DNA is copied properly.
DNA replication. Okazaki fragment and polymerase, helicase, free nucleotides, topoisomerase.

The following are the major enzymes and proteins involved in DNA replication, using the bacterial model commonly taught in introductory biology.

1. Helicase

- Separates the two DNA strands.
- Breaks the hydrogen bonds between complementary nitrogenous bases.
- Opens the DNA double helix to expose the template strands.

Easy way to remember: Helicase acts like a zipper opener.

2. Topoisomerase

- Prevents excessive twisting and tension ahead of the replication fork.
- Temporarily cuts and reconnects DNA strands to relieve the strain caused by unwinding.

Easy way to remember: Topoisomerase prevents DNA from becoming too tightly twisted.

3. Single-Strand Binding Proteins (SSB)

- Attach to the separated DNA strands.
- Keep the strands stable and prevent them from joining together again.

Easy way to remember: SSB proteins hold the separated DNA strands open.

4. Primase

- Produces short RNA primers.
- Provides a starting point for DNA polymerase to begin adding DNA nucleotides.

Easy way to remember: Primase prepares the starting point for DNA synthesis.

5. DNA Polymerase III

- The main DNA-building enzyme in bacteria.
- Adds complementary DNA nucleotides to the growing strand.
- Builds DNA in the 5' to 3' direction.
- Also helps correct some errors through proofreading.

Easy way to remember: DNA Polymerase III builds the new DNA strands.

6. DNA Polymerase I

- Removes the RNA primers.
- Replaces the removed RNA nucleotides with DNA nucleotides.

Easy way to remember: DNA Polymerase I replaces the temporary RNA primers with DNA.

7. DNA Ligase

- Joins the Okazaki fragments on the lagging strand.
- Seals breaks in the sugar-phosphate backbone of DNA.

Easy way to remember: DNA Ligase acts like glue that connects DNA fragments.

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V. Learning Activities

Activity 1

Directions: Read the following events and identify which stage of DNA replication they belong to. Write Initiation, Elongation, and Termination.

No.	Events	Answer
1	Helicase unwinds and separates the DNA strands.	
2	DNA Ligase joins the DNA fragments together.	
3	Primase produces short RNA primers.	
4	Two complete DNA molecules are produced.	
5	DNA Polymerase III adds complementary nucleotides.	
6	The replication fork is formed.	
7	DNA Polymerase I removes RNA primers and replaces them with DNA nucleotides.	
8	SSB proteins prevent separated DNA strands from joining again.	
9	The original DNA strands serve as templates for new strands.	
10	Replication forks eventually meet or reach the ends of the DNA regions being copied.	

Activity 2. Arrange the Steps of DNA Replication

Objective: Identify the correct sequence of events during DNA replication.

Directions: The following statements describe the events during DNA replication. Number them from 1 to 8 according to their correct sequence. Write your answers in the first column.

Sequence	Events
	A.DNA Ligase joins the Okazaki fragments.
	B.Helicase separates the two DNA strands.
	C.DNA Polymerase III adds complementary nucleotides.
	D.Two identical DNA molecules are produced.
	E.Primase produces RNA primers.
	F.DNA Polymerase I removes RNA primers and replaces them with DNA.
	G.SSB proteins stabilize the separated DNA strands.
	H.Topoisomerase relieves the twisting tension ahead of the replication fork.

Activity 3. Know Your Enzymes!

Objective: Identify the enzymes and proteins involved in DNA replication and understand their functions.

Directions: Choose the correct enzyme or protein from the word bank. Write your answer on the blank before each number.

WORD BANK

Helicase Primase DNA Polymerase I DNA Polymerase III

DNA Ligase Topoisomerase SSB Proteins

1. _____ Separates the two strands of DNA by breaking hydrogen bonds.
2. _____ Produces short RNA primers needed to start DNA synthesis.
3. _____ Adds complementary DNA nucleotides to the growing DNA strand.
4. _____ Removes RNA primers and replaces them with DNA nucleotides.
5. _____ Joins the Okazaki fragments to form a continuous DNA strand.
6. _____ Relieves the twisting and tension ahead of the replication fork.
7. _____ Keeps the separated DNA strands from joining together again.

Activity 4. Leading Strand vs. Lagging Strand

Objective: Differentiate the leading strand from the lagging strand.

Directions: Write LEADING if the statement describes the leading strand and LAGGING if it describes the lagging strand.

1. _____ Synthesized continuously.
2. _____ Synthesized in short sections called Okazaki fragments.
3. _____ Requires several RNA primers during replication.
4. _____ Synthesized continuously toward the moving replication fork.
5. _____ Requires DNA Ligase to connect the DNA fragments.
6. _____ Synthesized in the 5' to 3' direction.
7. _____ Synthesized discontinuously.
8. _____ Requires only one initial primer for a continuous stretch of synthesis at a replication fork.

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Activity 5. Test Your Understanding!

Objective: Apply knowledge about DNA replication to answer comprehension questions.

Directions: Read each question carefully. Choose the letter of the correct answer.

1. What is the main purpose of DNA replication?

A. To produce proteins. B. To make an identical copy of DNA.

C. To destroy damaged chromosomes. D. To produce RNA molecules.

2. During which stage does helicase separate the two DNA strands?

A. Initiation B. Elongation C. Termination D. Translation

3. What is the function of primase?

A. Joins DNA fragments. B. Separates DNA strands. C. Produces RNA primers. D. Replaces RNA primers.

4. Which enzyme is mainly responsible for adding new DNA nucleotides in bacterial DNA replication?

A. Helicase B. DNA Polymerase III C. DNA Ligase D. Topoisomerase

5. What are Okazaki fragments?

A. Short RNA primers. B. Short DNA sections formed on the lagging strand.

C. Enzymes that separate DNA. D. Proteins that stabilize DNA.

6. Why is the lagging strand synthesized in short fragments?

A. DNA polymerase can only synthesize DNA in the 5' to 3' direction.

B. Helicase cannot separate the lagging strand.

C. DNA Ligase prevents continuous synthesis.

D. Primase only works on the leading strand.

7. Which enzyme joins the Okazaki fragments?

A. Primase B. Helicase C. DNA Ligase D. Topoisomerase

8. What does semiconservative replication mean?

B. Each new DNA molecule contains one original strand and one new strand.

C. Each new DNA molecule contains two original strands.

D. Only half of the DNA is copied.

9. Which statement correctly describes the leading strand?

A. It is synthesized discontinuously. B. It contains several Okazaki fragments.

C. It is synthesized continuously toward the replication fork. D. It is made entirely of RNA.

10. What happens during termination?

A. DNA strands begin to separate. B. RNA primers are first produced.

C. DNA replication is completed and two DNA molecules are formed. D. Proteins begin producing amino acids.

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