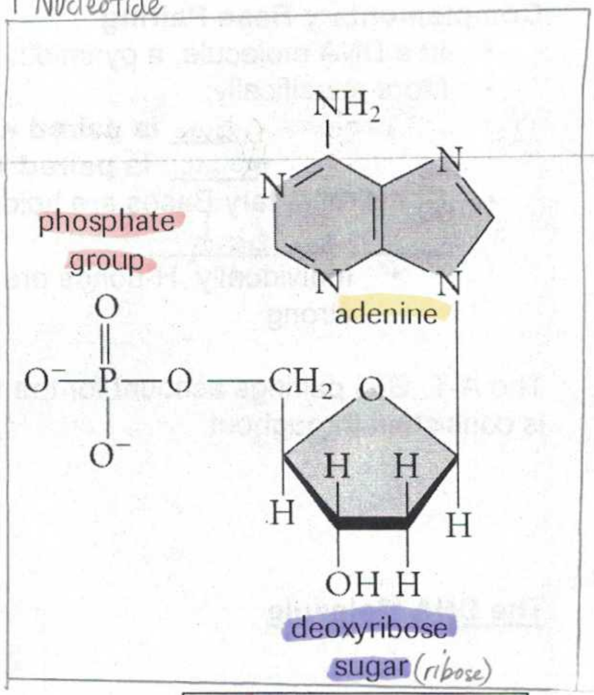
DNA Structure

The monomer unit of Nucleic Acids is a **NUCLEOTIDE.**

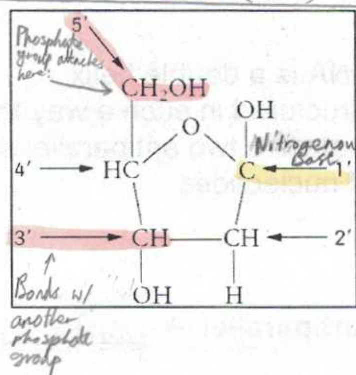
1 Nucleotide



Structure of a DNA Nucleotide:

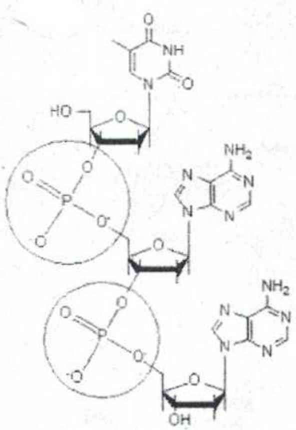
1. Deoxyribose Sugar
   - A 5 carbon sugar molecule that lost an Oxygen from a hydroxyl group on its 2' carbon
2. Phosphate group
   - 4 oxygen atoms surrounding a central Phosphorus atom
3. Nitrogenous Bases
   - An alkaline, cyclic molecule containing nitrogen
   - There are four different ones in a DNA molecule:

     Adenine, Guanine, Thymine, Cytosine

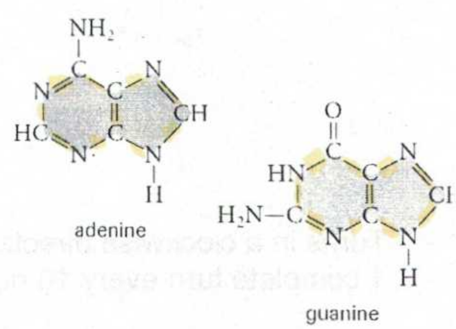


Altogether, these three components make a nucleotide:

- A 5-C sugar with a nitrogenous base attached to their 1' carbon and a phosphate group attached to their 5' carbon



Nucleotides are linked together by phosphodiester bonds
- This is a result of a dehydration synthesis between a phosphate group and a hydroxyl group

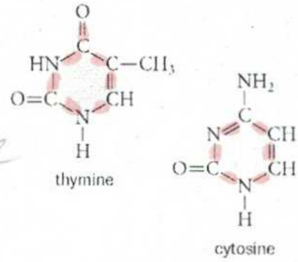


Nitrogenous Bases (four in total)

Purines:
- Adenine (A) and Guanine (G) ← Purine
- Double-ring structures → 2 rings

:
- Thymine (T) and Cytosine (C)
- Single-ring structures

Pyramidine

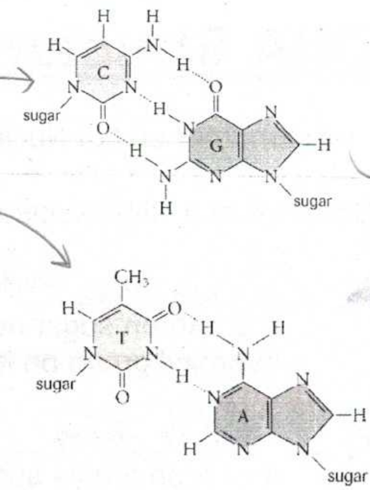


Complementary Base Pairing

- In a DNA molecule, a pyrimidine is always paired with a purine
- More specifically:

  Pyrimidine Cytosine **is paired with** Guanine G → C

  Adenine **is paired with** Thymine A → T
- Complementary Bases are held together through hydrogen bonds
  - Individually, H-bonds are weak → but together, they are very strong



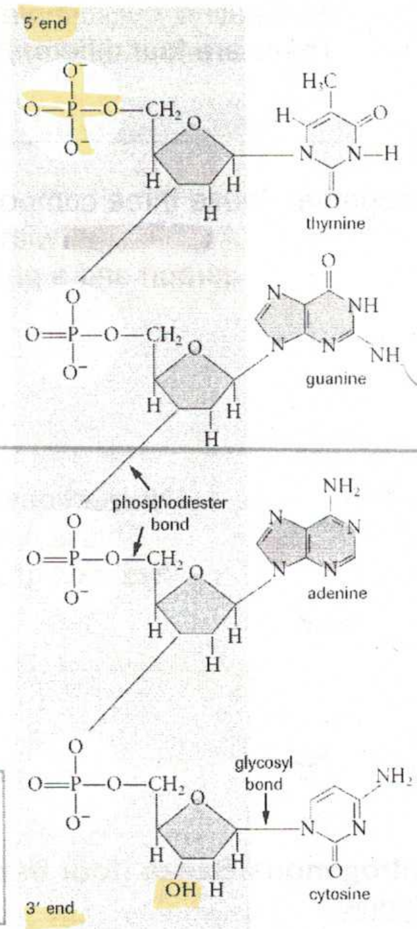
The A-T, G-C pairings account for the fact that the width of a DNA molecule is consistent throughout.

The DNA Molecule

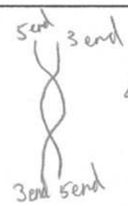
DNA is a double helix structured in such a way that there are two antiparallel strands of nucleotides

5' End

- Phosphate group with only one sugar bonded to it is found at the 5' carbon in deoxyribose



Antiparallel → parallel but running in different directions (5 end aligns w/ 3 end)



← Antiparallel

3' End

- Hydroxyl group found on 3' carbon in deoxyribose

- Turns in a clockwise direction
- 1 complete turn every 10 nucleotides

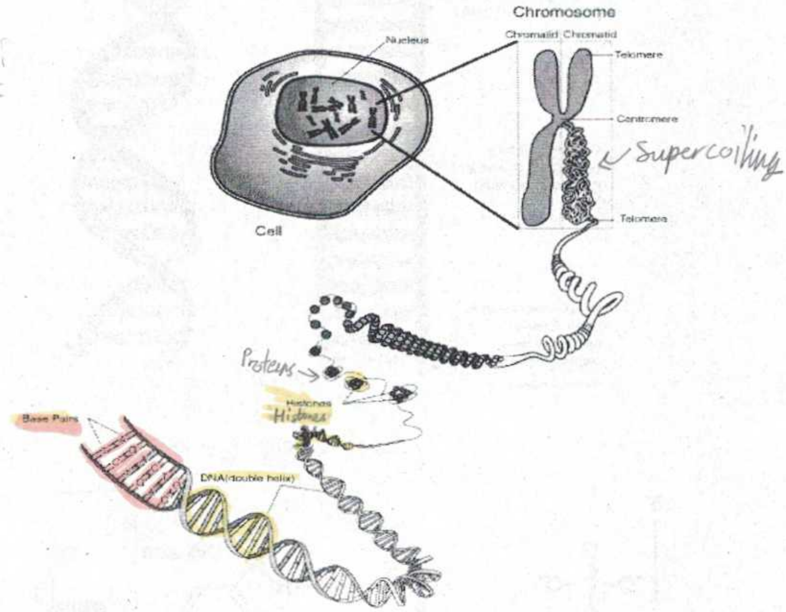
Glycosyl = glycosidic bond that is between sugar and nitrogen base.

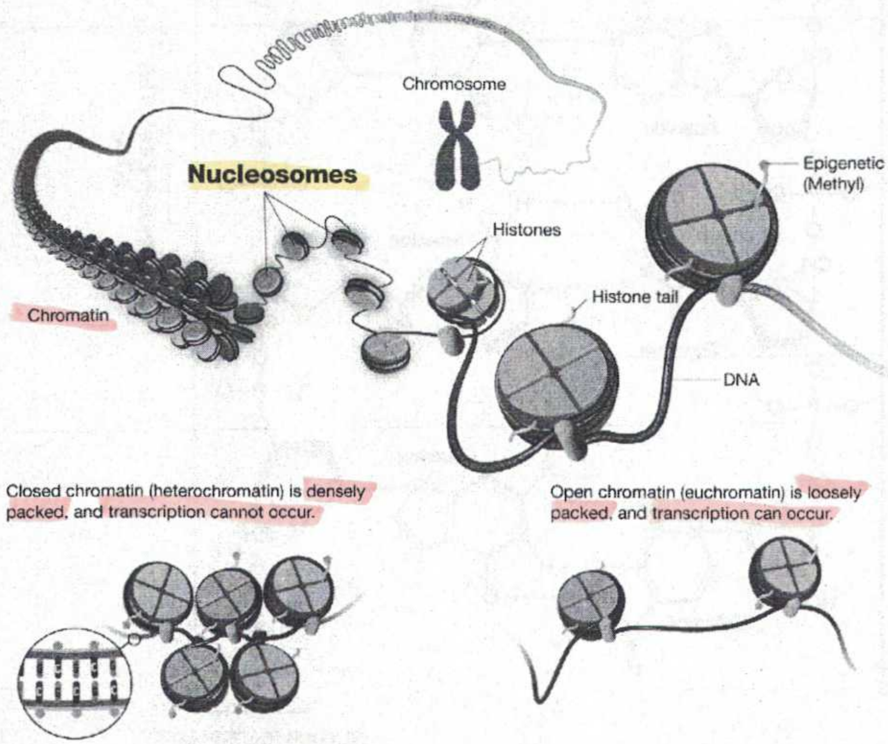
Example of sequence:
5'-ATGCCGTTA-3' ← "Prime"
3'-TACGGCAAT-5'

↑ Antiparallel

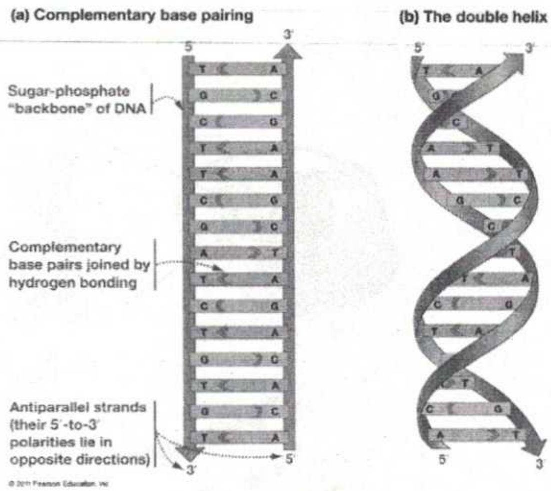
Gene Organization and Chromosome Structure

Annotate the diagram below:

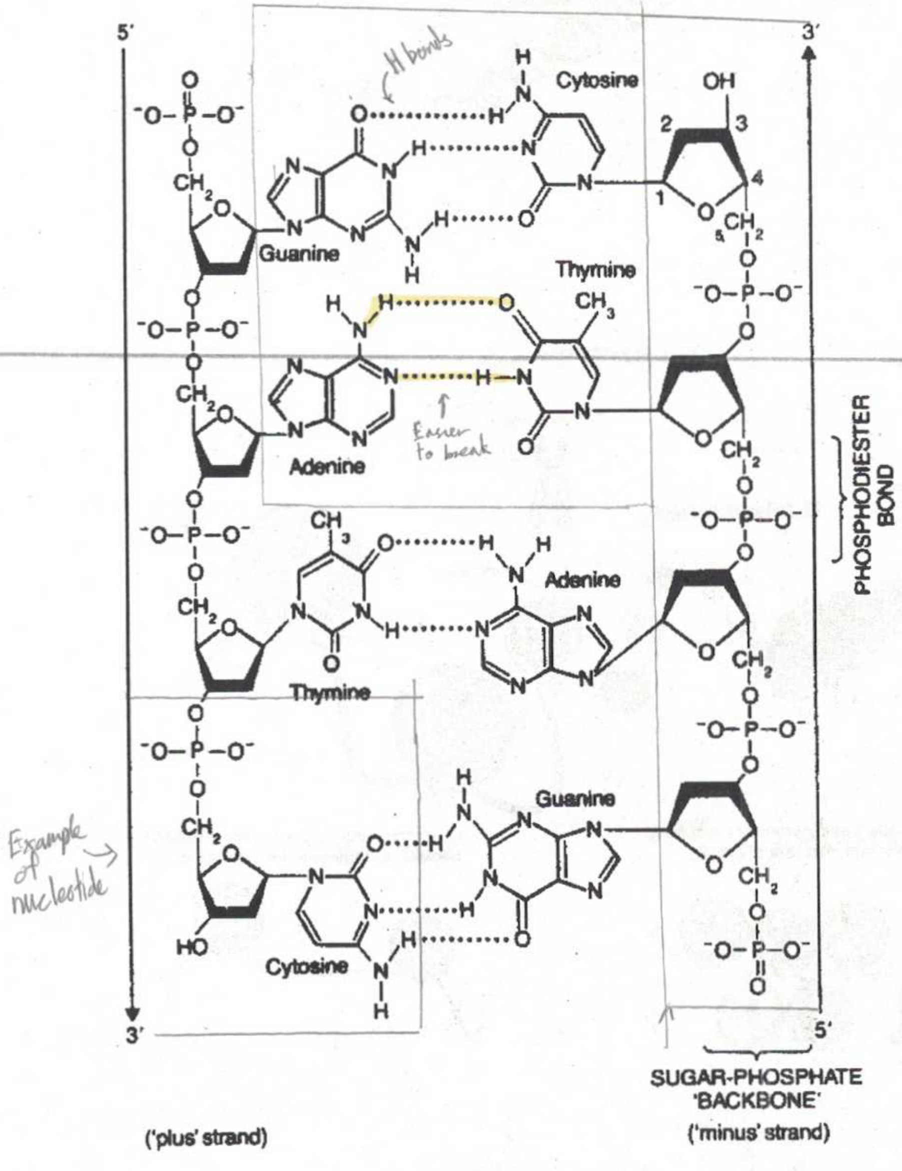




DNA Structure



Complementary Base Pairing



DNA Replication – A Summary

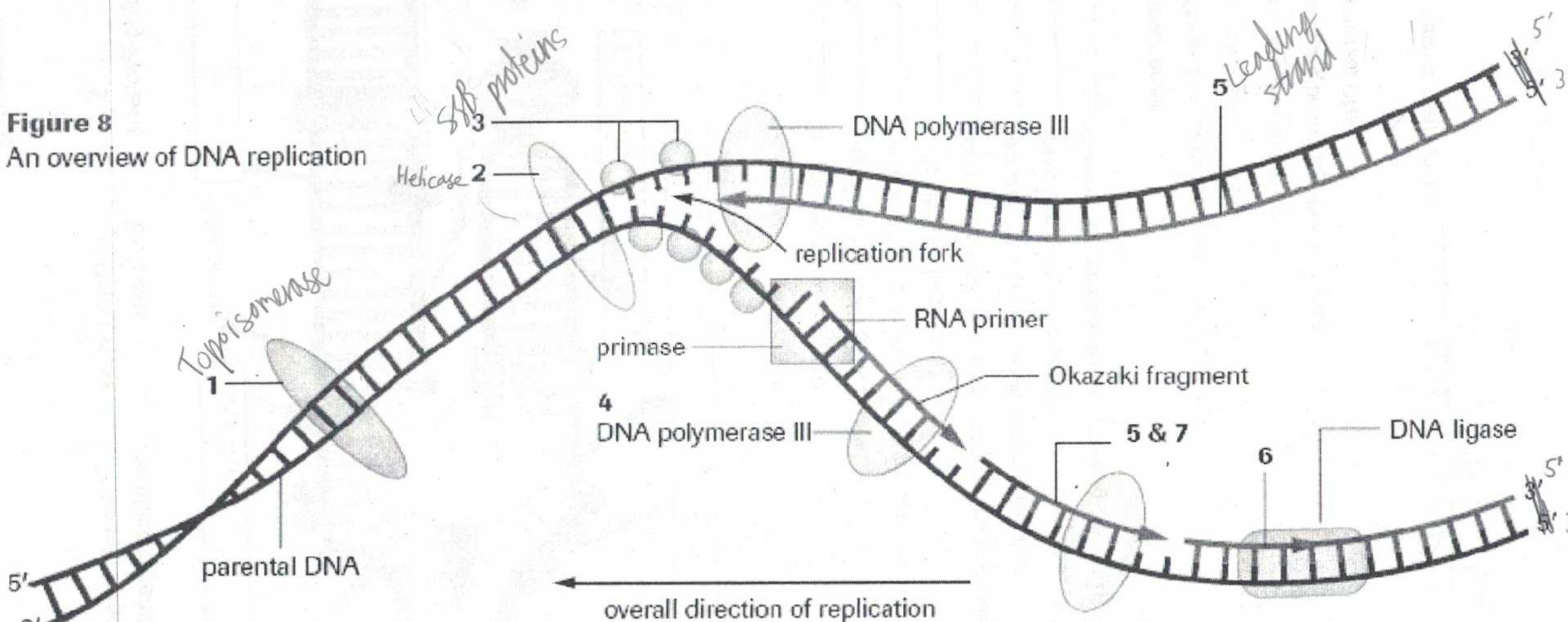
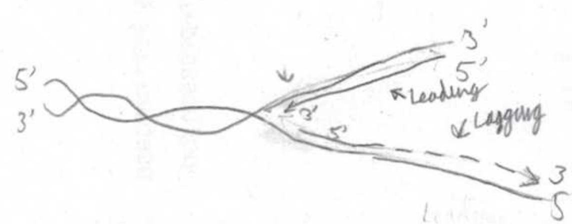


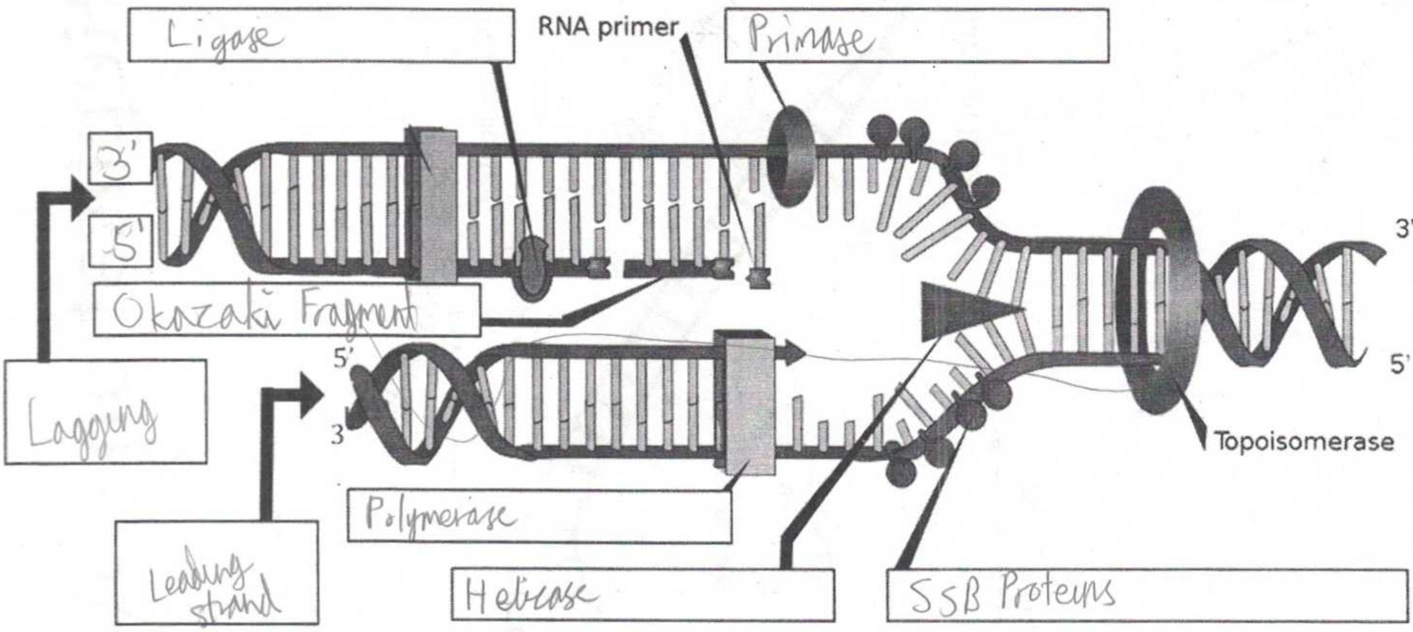
Figure 8
An overview of DNA replication



DNA Replication - Labeling

WORD BANK:

~~DNA polymerase~~ 3' 5' ~~DNA Ligase~~ ~~Okazaki fragment~~ ~~DNA Primase~~
Single Strand Binding ~~Proteins~~ ~~Helicase~~ ~~Leading Strand~~ ~~Lagging Strand~~



Identify the structure

1. Helicase Enzyme that unwinds DNA
2. Okazaki Fragments Fragments of copied DNA created on the lagging strand
3. Leading Fragments The strand that is copied in a continuous way, from the 3' to 5' direction
4. Ligase Binds Okazaki fragments
5. Polymerase Builds a new DNA strand by adding complementary bases
6. Topoisomerase Stabilizes the DNA molecule during replication
7. Lagging strand Strand that is copied discontinuously because it is traveling away from helicase
8. Primase Initiates the synthesis DNA by creating a short RNA segment at replication fork

9. Place the events in the correct order:

 4 DNA polymerase adds nucleotides in the 5' to 3' direction
 2 Replication fork is formed
 3 DNA polymerase attaches to the primer
 5 Okazaki fragments are bound together by ligase
 1 DNA helicase unwinds DNA

10. Why is replication called "semi-conservative?" One strand is used as a template & so each dupe DNA has an original strand.

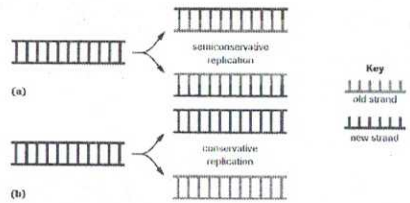
DNA Replication

Recall from grade 11 genetics:
- All cells give rise to new cells by undergoing cell division (**mitosis** and **cytokinesis**)
- It is important that each daughter cell has an exact copy of the parent cell's DNA
- For this to occur, the DNA molecule must replicate

Watson and Crick's model of DNA structure suggested how DNA could replicate:
- H bonds between N bases break
- Helix unzips
- Each strand acts as a template to build new strand
- At the time there was no experimental results to support this hypothesis

Template (1 per cell)

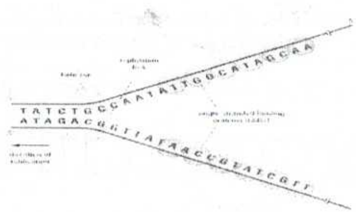
In 1958, Meselson & Stahl concluded that DNA replication is semiconservative
- Each DNA strand following a replication is composed of one parent strand and one newly synthesized strand



Watch the animation in the PowerPoint note for a detailed explanation of the Meselson and Stahl experiment

DNA Replication Overview:
What needs to happen:
- Replication needs to begin
  - begins when proteins bind to the replication origin sites of DNA
  - Prokaryotes have one replication origin site, while eukaryotes have many
- The two DNA strands cannot just be pulled apart – the hydrogen bonds holding them together must be broken
- Specific enzymes work to pull apart the DNA template strands and to keep them separate and untangled
- The two antiparallel strands act as templates as new complementary bases are added to complete the 2 new (identical) DNA molecules

DNA Replication – Details



The enzyme helicase breaks the hydrogen bonds holding the two complementary parent strands together, resulting in an unwound, unzipped helix that terminates at the ____________

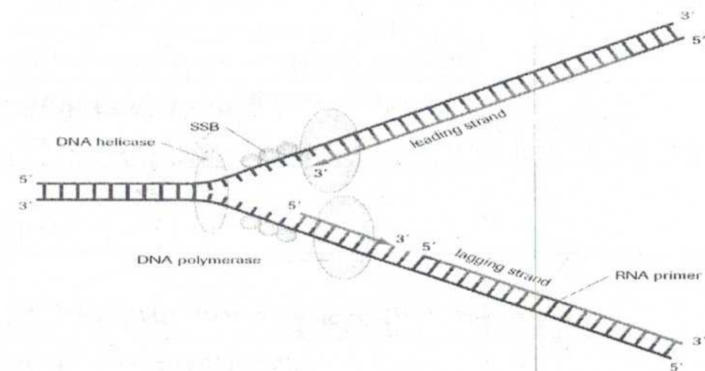
The Single Stranded Binding (SSBs) **anneal** to the newly exposed template strands
- This prevents the strands from rebonding to one another by blocking the hydrogen bonding

Topoisomerase makes sure the DNA doesn't supercoil behind the replication fork

- In prokaryotes, there are 3 DNA Polymerase enzymes involved in replication.
- In eukaryotes, there are 5 DNA Polymerase enzymes involved in replication.

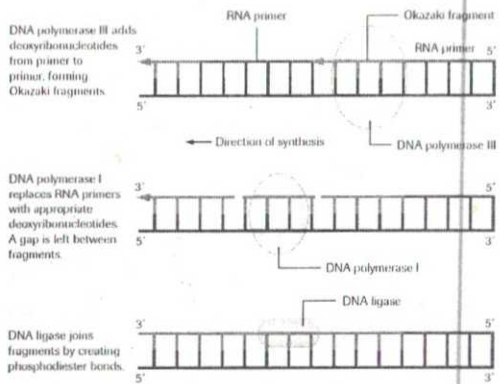
(we are just going to lump these all together as 'a DNA polymerase....')

- DNA Polymerase can only make new strands in the 5' to 3' direction
- DNA polymerase cannot initiate a new strand by itself, so an RNA primer (placed via primase) is required
- The enzyme primase lays down RNA primers that will be used by DNA polymerase as a starting point to build the new complementary strands.
- In a eukaryotic cell, more than one replication fork can exist at once because there are many sites of origin
- Once the RNA primer is placed, DNA Polymerase binds at the site of the primer and starts synthesizing the new strand of DNA:
  - DNA Polymerase moves along the existing strand (the template strand strand) in the 3' → 5' (template) direction
  - Because DNA strands are antiparallel, the new DNA is synthesized 5' – 3'
- Only one strand is able to be built continuously
  - The leading strand is built continuously toward the replication fork.
  - A lagging strand is synthesized discontinuously away from the replication fork
  - Primers are continuously added as the replication fork forms
  - DNA polymerase therefore can only build short segments of DNA, known as Okazaki Fragments
  - **Why the lagging strand?**
    - DNA polymerase can only bind to 3' & so cannot continuously be synthesized



Once the strands have been copied, some 'final touches' need to be made:

- In eukaryotes,



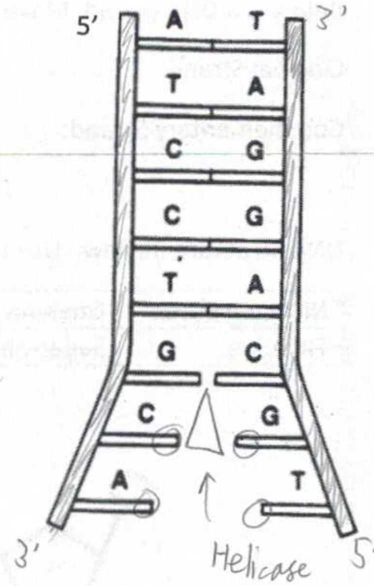
RNase H removes the RNA primers (in prokaryotes this is done by one of the DNA polymerases – as pictured to the right)
- DNA Ligase joins the gaps in the Okazaki fragments by the creation of a Phosphodiester (between a phosphate group and a hydroxyl group of two nucleotides).
- DNA polymerase proofread the replicating strands
  - This is done by acting as an ____________________
  - This cuts out incorrectly paired nucleotides at the end of the complementary strand and adding the correct nucleotides
  - Errors that are missed by this process can be corrected after DNA replication by other repair mechanisms

Extra Resources:
- Amoeba sisters: https://www.youtube.com/watch?v=5qSrmeiWsuc
- Crash Course: https://www.youtube.com/watch?v=8kK2zwjRV0M

Summary Table – DNA Replication

Term or Enzyme	Function and Explanation of Significance
Helicase	Unzips DNA strand by breaking H-bonds
Replication Fork	Place DNA strands fork off. Used as point of reference
SSBs	Prevents nitrogenous bases from rebonding
Anneal	11
DNA Polymerase	Binds to RNA primer to start synthesizing DNA strand using DNA nucleotide. Starts 5' to 3' only (towards replication fork.)
Primase	Starts assembling new DNA strand using RNA primers & nucleotides. These RNA components will eventually be removed
RNA Primer	Initiates new strand for polymerase to build
Leading strand	Towards replication fork
Lagging strand	Away from replication fork
Okazaki Fragments	Small chunks of DNA nucleotides & RNA primer formed due to non-continuous assembly
Rnase H	Removes RNA primers in eukaryotes
DNA ligase	Joins the gaps between okazaki fragments
Exonuclease	Removes defective elements of the strand.

SBI 4U - DNA Replication Review



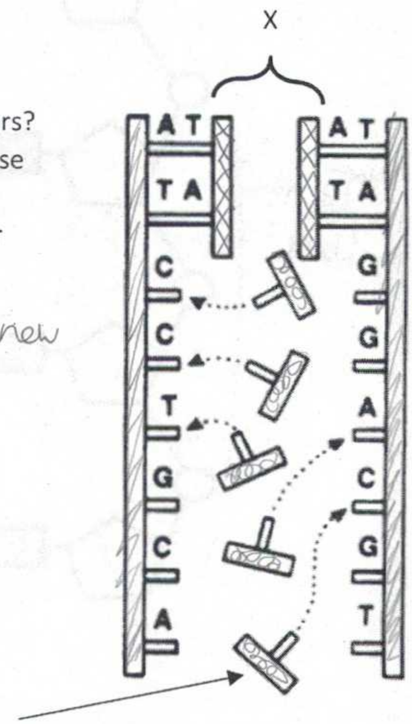
Directions:

Diagram A: The following diagram represents a segment of DNA that is undergoing replication.

a. Colour this DNA segment red. This represents the parent/template strands.
b. Label the orientation/direction of the template strands. One has been done for you.
c. Add helicase and SSBs. What are their functions?

Helicase: Unzips/breaks down H bonds between N bases
SSBs: Prevents strands from rebonding

Diagram B: The following diagram represents the addition of primers.



a. Colour the parent strands red.
b. 'X' represents primers, which are nucleotides. What is the purpose of the primers? What is different about these nucleotides compared to the ones DNA polymerase adds. Colour these nucleotides (primers) blue.
c. 'Y' represents DNA nucleotides. These were added by DNA polymerase. Colour these green.

b. Polymerase requires a primer to initialize the building of a new strand. This primer is made of RNA rather than DNA.

c

Answer the following questions:

1. What does semiconservative replication mean? 1 New, 1 old strand
2. Why are RNA primers added to the parent strand? To place a point for polymerase
3. Where does DNA replication happen in eukaryotes? Nucleus
4. During what part of the cell cycle does DNA replication happen? Interphase
5. (True or False) The process of DNA replication results in a copy of the original DNA molecule. T
6. (True or False) DNA does not have to break apart to be copied. F
7. (True or False) After DNA replication is complete, there are two new DNA molecules; one molecule has both original strands, and one molecule has two new strands of DNA. F

Place the steps of DNA replication in the correct order.

2	a. The enzyme DNA polymerase moves along the exposed strands and add complementary nucleotides to each nucleotide in each existing strand.
1	b. The DNA double helix breaks or unzips down the middle between the base pairs.
3	c. A complementary strand is created for each of the two strands of the original double helix.
4	d. Two new identical DNA molecules have been produced.

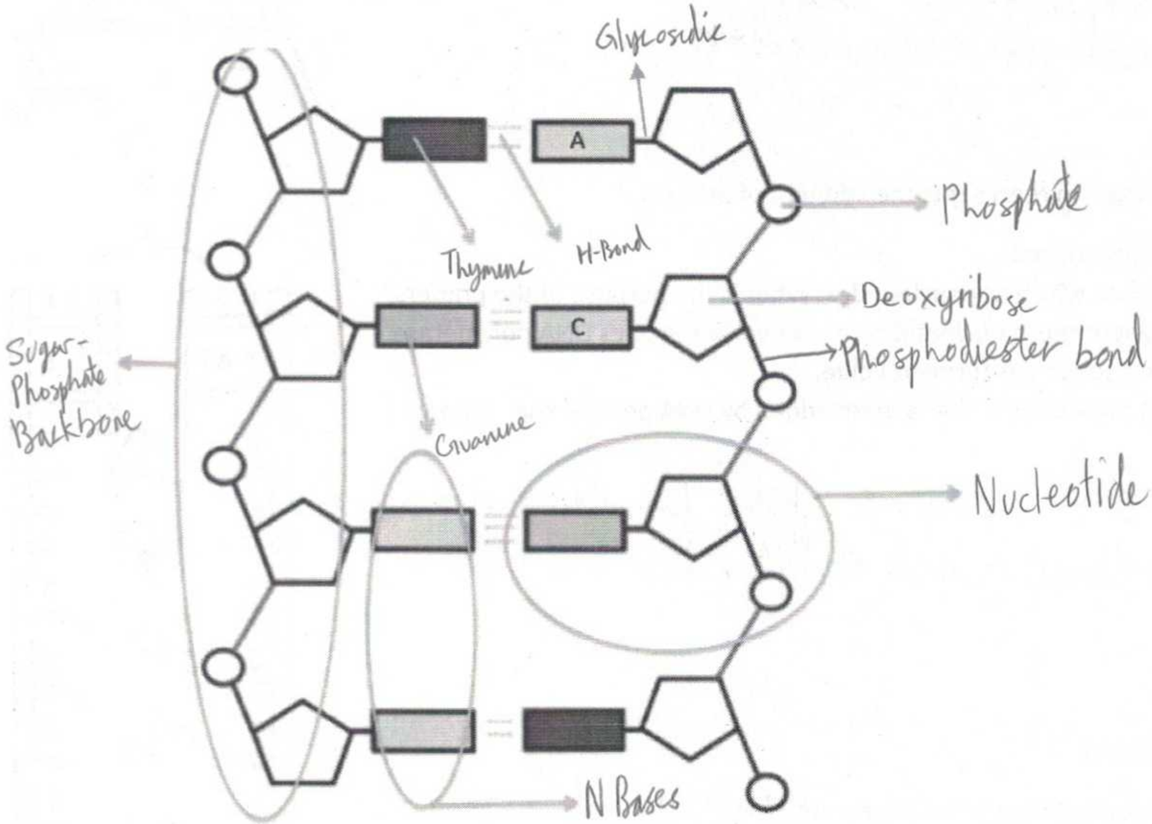
Below is a DNA strand. Make the complementary DNA strand.

Original Strand: 5' - A T G C A A A T T G C T C A C C G G G G A T C A G C A C C G G – 3'

Complementary Strand: 3'-T AC G T T T A A C G A G T G G C C C C T A G T C G T G G C C - 5'

DNA Structure Review. Use the following word bank to label the DNA molecule below.

~~Nitrogen bases~~	~~Guanine~~	~~Hydrogen bonds~~	~~Phosphate~~	~~Phosphodiester bond~~
~~Thymine~~	~~Sugar-phosphate backbone~~	~~Deoxyribose~~	~~Nucleotide~~	~~Glycosidic bond~~



Hershey & Chase
Discovered DNA is genetic material, not protein

Miescher
Looked at nuclei of pus cells & concluded they were filled with nuclein, not protein.
Dubbed the substance he found "nuclein"

Watson & Crick
Analyzed data to prove the double helix structure of DNA

Chargaff
Found the proportion of Adenine = Thymine & Cytosine = Guanine

Franklin & Wilkins
Examined DNA molecules using x-rays to get an image
Suggested DNA has a helical structure.

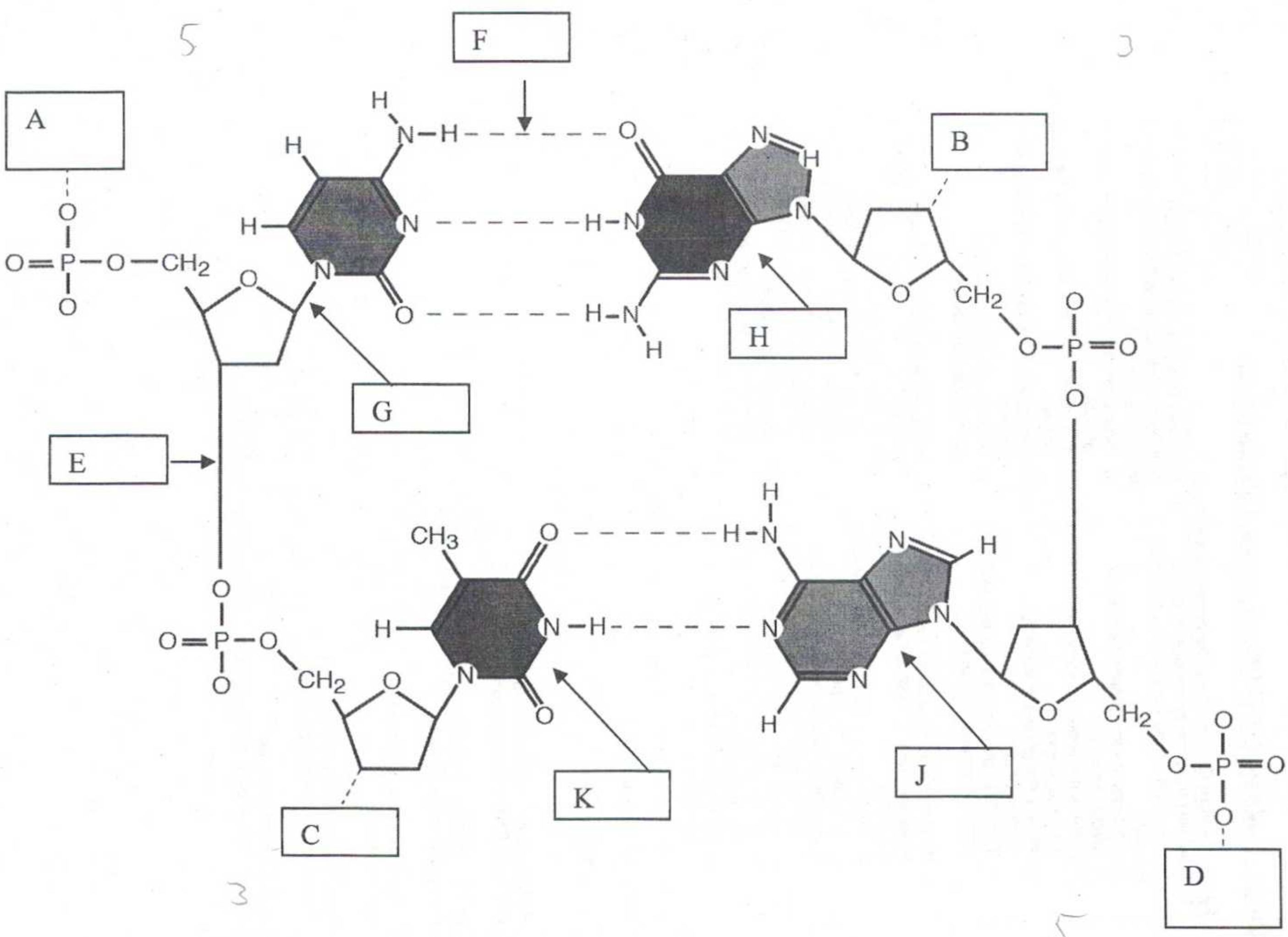
Meselson & Stahl
Concluded & proved DNA replication is semi-conservative

Name: ______________________________

The diagram represents a segment of DNA. Using the diagram, answer the questions below. (6)

a. Which letter represents the five-prime end of DNA?	D
b. What bond is represented by the letter 'E'?	Phosphodiester Bond
c. What bond is represented by the letter 'F'?	Hydrogen Bond
d. What is the name of the sugar found in this molecule?	Deoxyribose Sugar
e. How many nucleotides are in the diagram?	4
f. What is the **name** of the nitrogenous base found at letter 'H'? Hint - You didn't have to memorize the structure to figure this out.	Guanine

6



Name: Ryan Sirisena

Quiz – History, DNA Structure and Replication

20 /20

Part A – Multiple Choice: Circle the correct answer. (4)

1. What was the primary conclusion of the Hershey and Chase experiment conducted in 1952?
   a. Proteins are the genetic material of bacteriophages.
   b. DNA is the genetic material of bacteriophages.
   c. RNA is the genetic material of bacteriophages.
   d. Both DNA and proteins are the genetic material of bacteriophages.

2. What was Rosalind Franklin's most significant contribution to the discovery of the DNA structure?
   a. She developed the double helix model of DNA.
   b. She discovered the base pairing rules of DNA.
   c. She produced X-ray diffraction images of DNA.
   d. She identified the chemical composition of DNA.

3. What significant discovery did Friedrich Miescher make in 1869 while studying pus cells?
   a. He discovered that pus cells contain large amounts of protein.
   b. He found that the nuclei of pus cells contain a phosphorus-rich substance he called nuclein.
   c. He identified the presence of RNA in the nuclei of pus cells.
   d. He discovered the double helix structure of DNA.

4. Which of the following is paired incorrectly?
   a. Watson and Crick – Produced double-helix structure of DNA
   b. Chargaff – proportion of adenine always equals that of thymine and proportion of guanine = cytosine
   c. Meselson and Stahl – semiconservative replication
   d. All are paired correctly

4

Part B - Terminology (8):

Name a pyrimidine.	Thymine
Proteins found in DNA that package and order DNA into nucleosomes.	Histones
Enzyme that lays down RNA primers during DNA replication.	Primase
Enzyme that prevents DNA from supercoiling.	Topoisomerase
Short, discontinuous segments of DNA found on the lagging strand.	Okazaki Fragments
Type of bond that holds complementary base pairs together.	Hydrogen Bonds

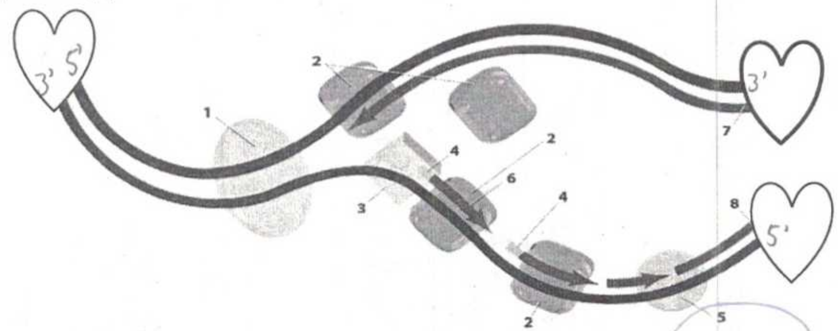
6

Name:

Direction in which DNA polymerase reads the strand being copied in DNA replication.	3'-5'
Enzyme that unzips the DNA molecule by breaking bonds.	Helicase

2

Part C - Diagram. Study the diagram below and then answer the following questions in the space provided. (2):



a. What number represents the leading strand?	7
b. Identify the 3' and 5' ends of the template strands. Place your answer in the hearts on the diagram. (1)	

2

14