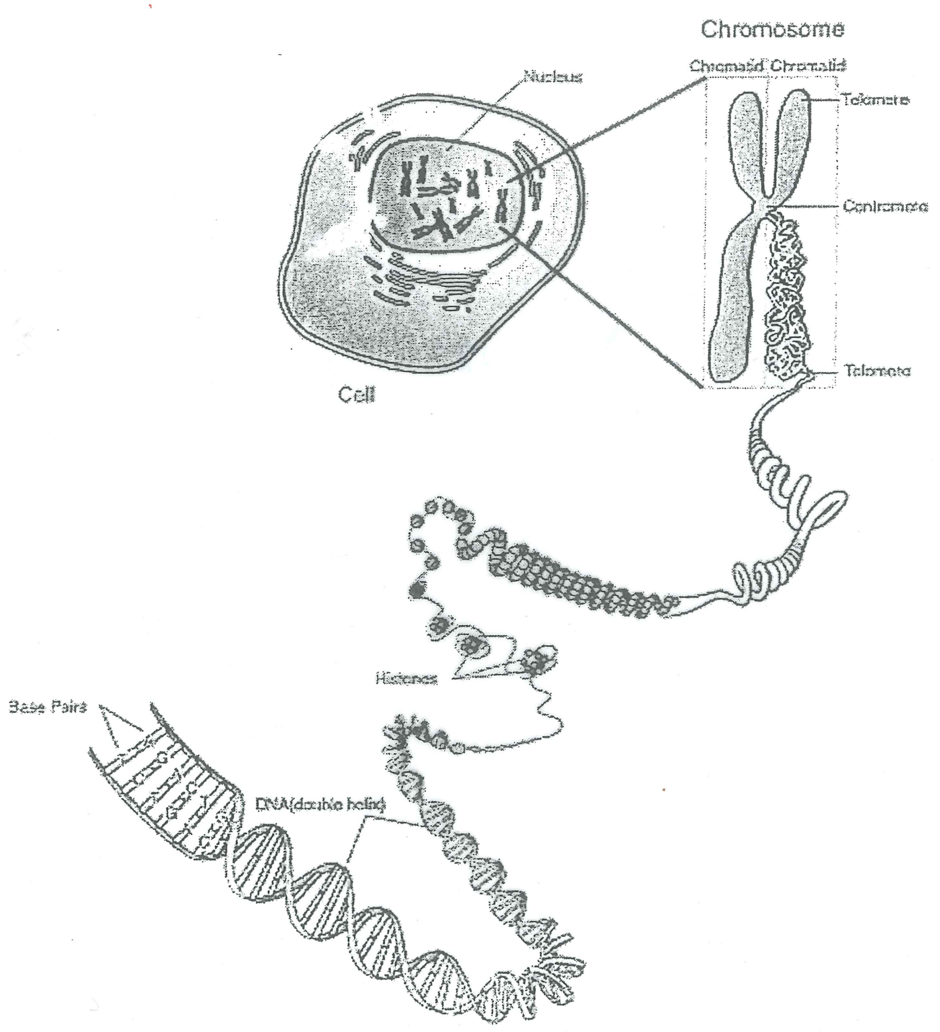
BIOLOGY 12 — UNIT 4: DNA and PROTEIN SYNTHESIS
NOTES: PART I

DNA is a very important molecule. In many ways it is the key to life.

1. **DNA controls cellular activities**. DNA is able to do this because it carries coded instructions. The code is 'written' in the sequence of bases on the DNA molecule. The code carries instructions for making proteins which are the building blocks of all forms of life.
DNA is the blueprint/pattern.
Proteins are the building material.

2. **DNA is capable of making exact copies of itself** to pass on to daughter cells during cell division. The copying process is called replication. DNA is the only molecule known with this ability. Because of its ability to self-copy, DNA ensures the continuity of life.

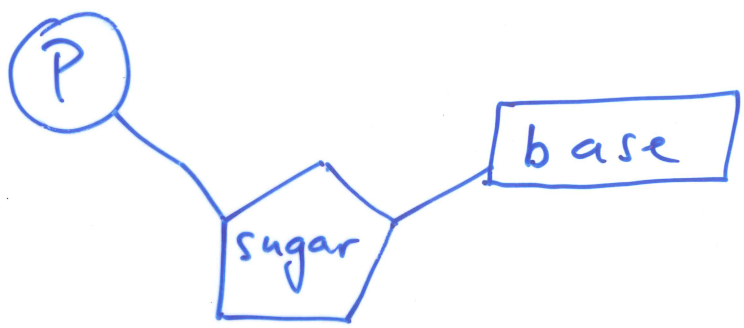
3. **DNA undergoes mutations**. Mutations and the recombination of genes that occurs during sexual reproduction are the source of life's diversity.



I. THE STRUCTURE OF DNA

- DNA is a polymer of nucleotides
- A DNA nucleotide is composed of three parts:
  - a) 5-carbon sugar → deoxyribose
  - b) phosphate group
  - c) nitrogenous base
- The four bases in DNA are: Adenine (A)
  Thymine (T)
  Guanine (G)
  Cytosine (C)

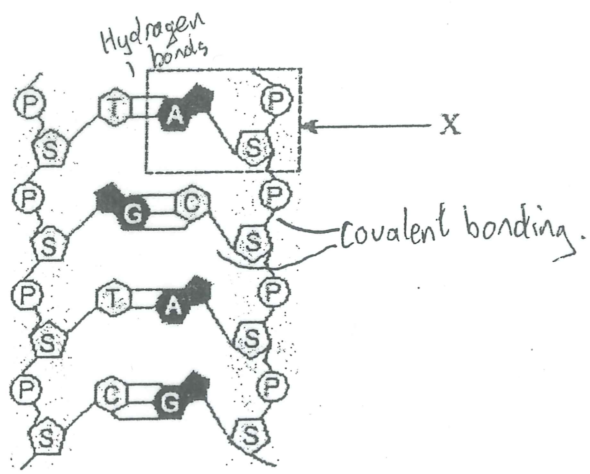
A **DNA nucleotide** looks like this:



- A strand of DNA consists of a long chain of nucleotides linked together. Each strand is made of a backbone of alternating sugar and phosphate molecules.
  The nitrogenous bases are attached to the sugar molecules and "project" (stick out) to one side.
- DNA molecules are composed of 2 strands. The strands twist around each other to form a spiral structure called a double helix.

A section of a molecule of DNA showing the double helix:

An unwound section of DNA looks like a ladder:



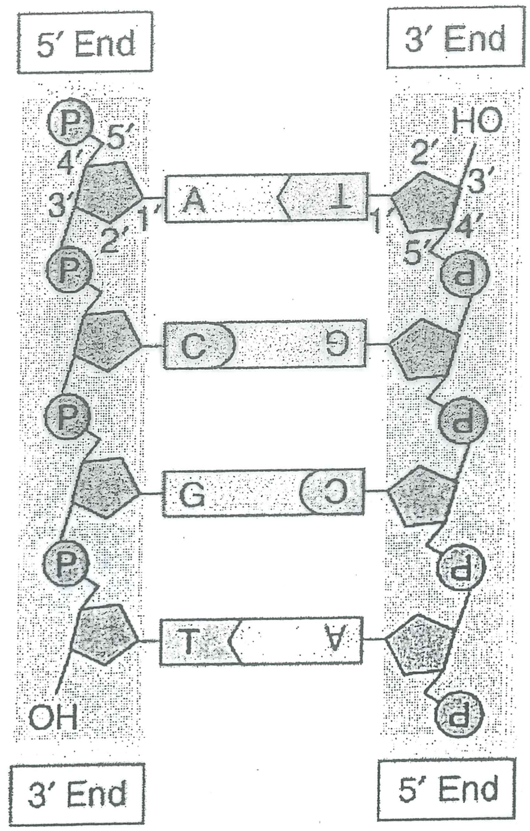
In the diagram above, X is pointing to a single nucleotide.

P indicates the phosphate group

S indicates the sugar

T, A, G, and C indicate the nitrogenous bases

The two strands of DNA are antiparallel.
This means that they run in opposite directions.
The carbon atoms in the deoxyribose sugar molecule are numbered from 1' to 5'.
The phosphate molecules are always attached to carbons 3' and 5'. The bases are always attached to carbon 1'. The ends of the DNA strand are either 3' or 5' depending on which carbon atom is uppermost.
In the double-stranded DNA molecule, one strand has its 5' end uppermost; while the other strand has its 3' end uppermost. Like this…

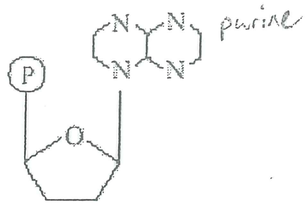


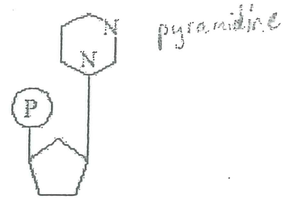
The two strands of DNA are held together by hydrogen bonding between the nitrogenous bases.

COMPLEMENTARY BASE PAIRING:

Adenine always binds with Thymine
Cytosine always binds with Guanine

There are two kinds of nitrogenous bases: **purines** and **pyrimidines**.
Purines are double ring structures. Adenine and Guanine are purines.
Pyrimidines are single ring structures. Thymine and Cytosine are pyrimidines.





A purine always binds with a pyrimidine during complementary base pairing.
This ensures that the DNA molecule maintains a constant diameter.
The number of purine bases always equals the number of pyrimidine bases.

<u>Provincial Exam Alert</u>

In a solution of nucleotides made from a ground-up segment of DNA, adenine makes up 33% of the solution. What percentage of the solution would be guanine?

A. 17%   B. 33%   C. 34%   D. 67%

A - 33% → T - 33% → G and C each 17%

The bases in a DNA molecule can be in any order, but they are always paired according to the rules of complementary base pairing.
It is the sequence of bases that carries hereditary information in the genetic code.

Review the rules of complementary base pairing by completing the lower strand of the DNA molecule shown below:

5'														3'	
	A	T	G	T	G	A	T	C	C	A	C	G	C	G	T
	II	II	III	II	III	II	II	III	III	II	III	III	III	III	II
	T	A	C	A	C	T	A	G	G	T	G	C	G	C	A
3'														5'	

DNA molecules are extremely long, each one containing millions of atoms.
Every human cell contains about 1 metre of DNA organized into 46 chromosomes.

II. DNA REPLICATION

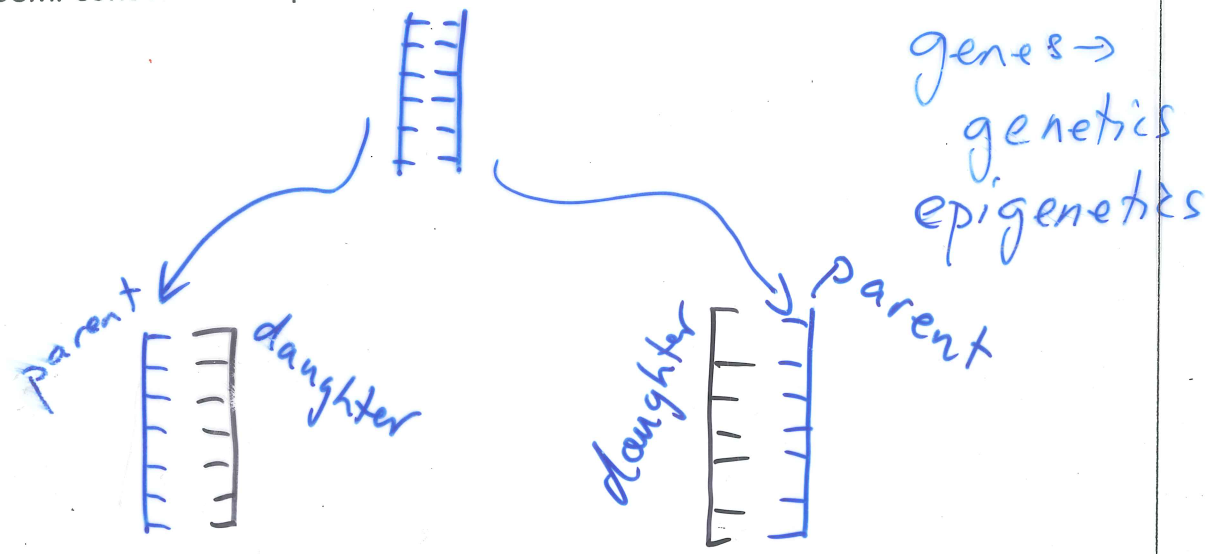
Before a cell can divide, all of its DNA must be duplicated. The duplication process is called **REPLICATION**. Replication occurs in the nucleus of the cell.

The mechanism for reproducing itself is built into the structure of the DNA molecule.

Each strand of DNA serves as a template for the formation of a complementary DNA strand. The complementary strand is like a 'reverse image' of the original strand.

DNA replication is called semi-conservative because each new DNA molecule contains one old or parent strand and one new or daughter strand. In other words, one parental strand is kept or *conserved* in each of the two new DNA molecules.

Semi-conservative replication:



Steps in Replication:

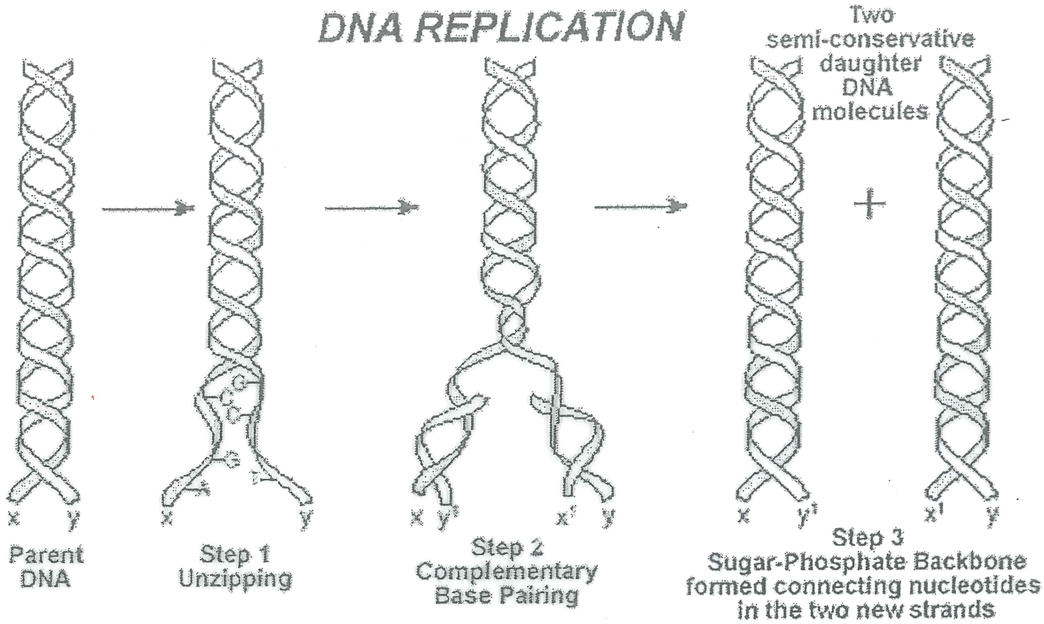
1. Prior to replication, the two strands of DNA are held together by hydrogen bonding between complementary base pairs. During replication, the DNA double helix unwinds and unzips/opens up. The two strands of DNA separate as the weak hydrogen bonds between the bases are broken. An enzyme called helicase (DNA helicase) separates the two DNA strands.

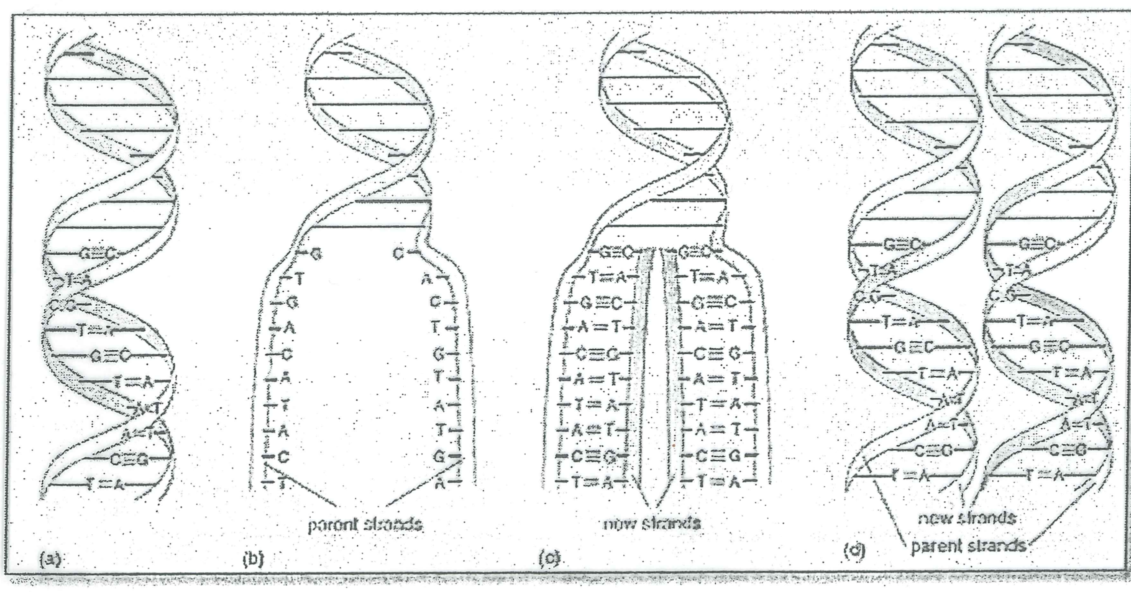
2. New nucleotides move into position to pair with their complementary bases on each of the exposed strands of parent DNA. These new nucleotides are always present in the nucleoplasm of the nucleus. The enzyme DNA polymerase attaches the new nucleotides to the parent strands of DNA.

3. Adjacent nucleotides bond together as their sugar and phosphate molecules join. The enzymes DNA polymerase, ligase joins the sugar-phosphate backbone of the new DNA strands. Other enzymes proofread the new DNA strands checking for and correcting any mismatched base pairs.

4. The two new daughter DNA molecules rewind into identical double helices.

Study the following diagrams carefully:





Semi-conservative replication is very accurate.
Only about 1 in 1 billion nucleotides is incorrectly paired.
Each parental strand ensures the pairing of the correct nucleotides into the new daughter strands.

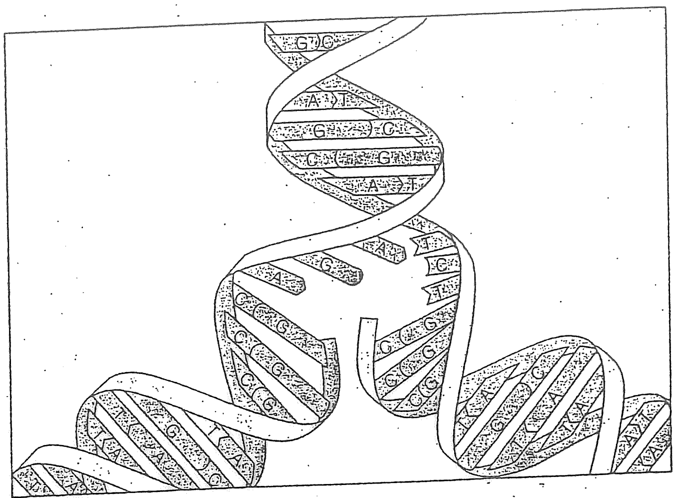


Figure 10.4B Untwisting and replication of DNA

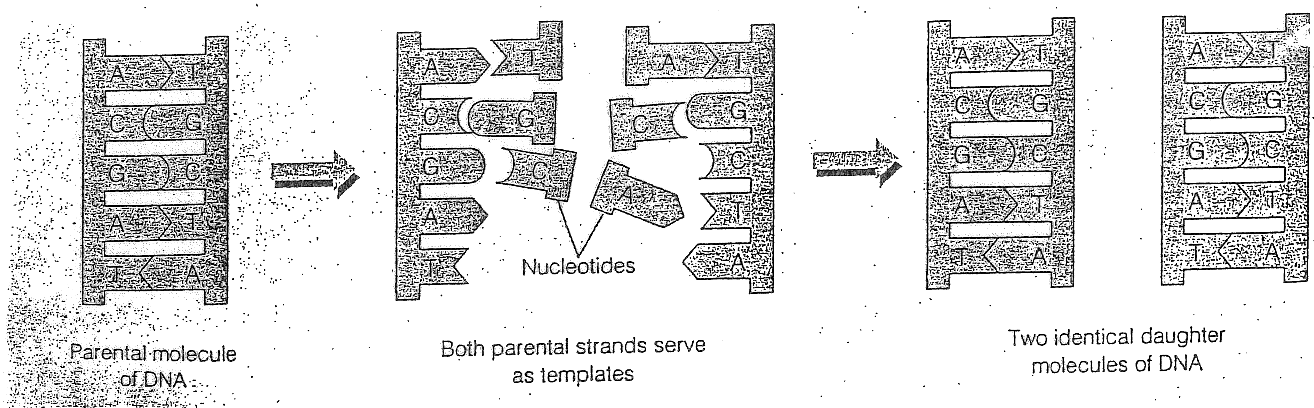
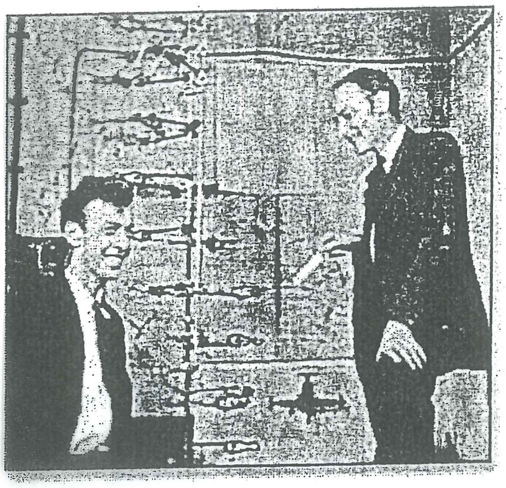


Figure 10.4A A template model for DNA replication

The process of replication requires the action of more than a dozen different enzymes (helicase, polymerase, ligase).
Some of the enzymes unwind and unzip the DNA parent molecule; other enzymes position and attach the new nucleotides to the exposed parental strands of DNA; still other enzymes join adjacent nucleotides in the daughter strands of DNA; and some enzymes proofread for errors in base pairing.

DNA replication is very fast – in mammals, new nucleotides are added at the rate of about 50 per second.

This is a very famous photograph of James Watson and Francis Crick, the scientists who unraveled the structure of DNA.



James Watson and Francis Crick in 1953 with the double helix model of DNA, which they built to help them to determine its structure; the model was assembled from metal clamps used to hold test-tubes and other bits of laboratory apparatus.
Watson and Crick, along with Maurice Wilkins, were awarded the Nobel Prize for Medicine with Physiology in 1962.

III. RNA STRUCTURE

RNA, like DNA, is a polymer of nucleotides.

Unlike DNA, the nucleotides in RNA contain the sugar ribose.

The bases in RNA also differ from those in DNA. In RNA, the nitrogenous bases are:

cytosine

adenine

guanine

uracil

Note that in RNA the base uracil replaces the base thymine in DNA.

(OUT)

An RNA molecule is single-stranded so does not form a double helix as does the DNA molecule.

A comparison of DNA and RNA:

	DNA	RNA
Sugar:	deoxyribose	ribose
Nitrogenous bases:	A C G T A-T C-G	A C G U A-U G-C
Number of Strands:	2	1
Double helix:	yes	no
Location in the cell:	nucleus, mitochondria	nucleus, cytoplasm

There are 3 main types of RNA. Each has a different function in protein synthesis.

a) messenger RNA (mRNA) carries a coded set of instructions from DNA in nucleus to the ribosomes in cytoplasm

b) ribosomal RNA (rRNA) combines with proteins to make up the ribosomes

c) transfer RNA (tRNA) carries amino acids to the ribosomes where they are connected together to make proteins