Chapter 3
Nucleic Acids

Nucleic acids are essential organic compounds in living organisms. DNA and RNA are nucleic acids that can be found in living things.

Nucleic acids are made of nucleotides. A nucleotide is composed of 3 parts: a pentose, a nitrogenous base and a phosphate group.

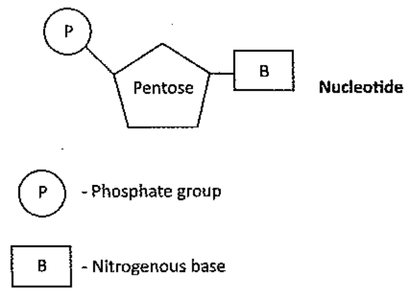

Figure 3.1 A nucleotide

Nucleotides are joined together by forming covalent bonds between the phosphate group of a nucleotide and the pentose of another nucleotide. A long chain of nucleotides is known as a nucleic acid.

One of the main differences between DNA and RNA is that DNA is double-stranded, whereas RNA is single-stranded. The following diagram shows the structure of DNA.

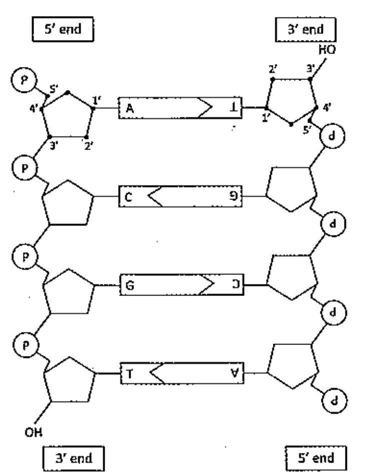

Figure 3.2 The DNA structure

The following table illustrates the differences between DNA and RNA.

	DNA	RNA
Pentose	Deoxyribose	Ribose
Nitrogenous Bases	Adenine (A), Thymine (T), Guanine (G), Cytosine (C)	Adenine (A), Uracil (C), Guanine (G), Cytosine (C)
Structure	Double helix; the two nucleic acids are complementary	Single strand
Function	Carrying genetic information	Involved in protein synthesis

Table 3.1 The differences between DNA and RNA

The two nucleic acids of DNA are complementary. Since A always pairs with T, and G always pairs with C, the sequence of one nucleic acid strand is determined by the sequence of another nucleic acid strand. In addition, the two nucleic acid strands are joined by forming hydrogen bonds between the complementary bases.

There are three types of RNA that are involved in protein synthesis; they are messenger RNA (mRNA), transfer RNA (tRNA), and ribosomal RNA (rRNA).

- Nitrogenous bases can be divided into two types: purines and pyrimidines. Adenine and guanine are purines, while thymine, uracil and cytosine are pyrimidines.
- Based on the complementary base pairing rules, purines (A and G) always pair with pyrimidines (T and C).
- The two nucleic acids in a DNA molecule coil in opposite directions, known as antiparallel. One strand is in the 5′ to 3′ direction, while the other one is in the 3′ to 5′ direction. The direction of the two nucleic acids is shown in Figure 3.2.
- The DNA in eukaryotic cells is in a structure called a nucleosome. A nucleosome contains a DNA molecule, as well as proteins called histones. Eight histones form one nucleosome. Two nucleosomes are held together by another histone protein.
- Genes are found in DNA, and they contain information that control specific traits. The whole human genome contains genes and repetitive sequences (satellite DNA), which occupy about 30% and 70% of the genome respectively. The repetitive DNA is sometimes regarded as junk DNA, but recent discoveries showed that they might be involved in the regulation of gene expression.

In cell division, DNA has to be replicated in order to produce genetically identical daughter cells; DNA replication occurs in the interphase.

DNA replication is regarded as a semi-conservative replication because the two nucleic acids of DNA act as the templates for DNA replication. By complementary base pairing (A to T, and G to C), daughter strands are formed based on the sequence of the parent strands. After DNA replication, two identical double helices are formed, and each double helix contains one parent strand and one daughter strand.

Two enzymes are involved in DNA replication: DNA helicase and DNA polymerase. The functions of the two enzymes are summarized in the following table.

Enzymes	Functions
DNA helicase	To break the hydrogen bonds between the bases of two nucleic acids in order to unwind the double helix; this allows the two parent nucleic acids to be exposed to DNA polymerase to replicate the DNA
DNA polymerase	To join nucleotides together to form daughter strands, based on the sequence of the parent strands

Table 3.2 The functions of the enzymes involved in DNA replication

Using the complementary base pairing to replicate DNA is crucial because this ensures that the daughter double helices will have the same sequence as the parent double helix. This is because A always pairs with T, and G always pairs with C.

Besides the above two enzymes, three more enzymes are involved in DNA replication, and their functions are summarized in the following table.

Enzyme	Functions
RNA primase	To synthesize a RNA primer (short nucleic acid) on DNA, in the 5' to 3' direction
DNA polymerase III	To replicate DNA in accordance with the complementary base pairing in the 5' to 3' direction
DNA polymerase I	To remove RNA primers, and replace them with DNA
DNA ligase	To join DNA fragments (Okazaki fragments) together

Table 3.3 The functions of additional enzymes involved in DNA replication.

Including DNA helicase, there are 5 enzymes involved in DNA replication, summarized in the following diagram.

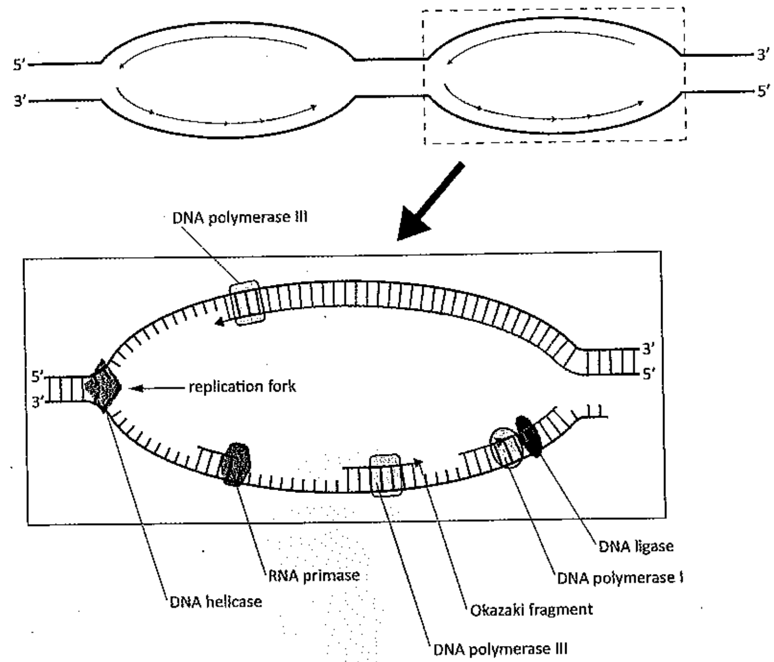

Figure 3.3 DNA replication

1. DNA helicase unwinds the double helix by breaking the hydrogen bonds between the bases of two nucleic acids.

2. DNA helicase can unwind the DNA at multiple points; this can speed up the DNA replication.

3. RNA primase produces a complementary RNA primer in the 5′ to 3′ direction; this signals the DNA polymerase III to start DNA replication.

4. DNA polymerase III binds to the RNA primer and carries out DNA replication in the 5′ to 3′ direction according to the complementary base pairing rules (A pairs with T, and G pairs with C).

5. A corresponding deoxynucleoside triphosphate is added to the 3′ end of the growing DNA strand by condensation reaction. Two phosphate groups are released from the reaction.

6. Okazaki fragments, discontinuous DNA fragments, are formed on the lagging strand.

7. DNA polymerase I removes the RNA primers on the lagging strand and fills the gaps with DNA.

8. DNA ligase joins the DNA fragments, which are located on the lagging strand, to form a continuous strand.