

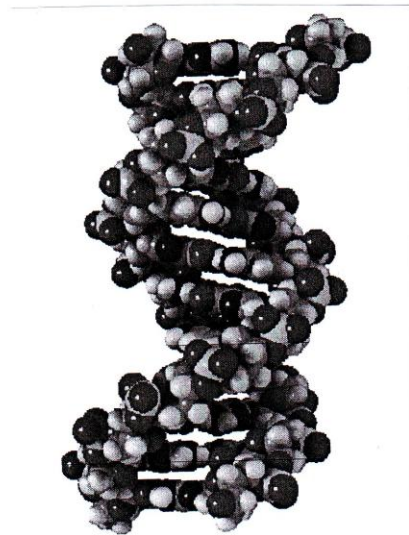
Genetic Information (A2)

Scope:

- describe the double helical structure of DNA in terms of a sugar-phosphate backbone and attached bases.
- explain the significance of hydrogen bonding in the pairing of bases in DNA in relation to the replication of genetic information.
- outline the manner DNA encodes for the amino acid sequence of proteins with reference to mRNA, tRNA and the ribosome in translation and transcription.
- explain the chemistry of DNA mutation from provided data.
- discuss the genetic basis of disease (eg. sickle cell anaemia) in terms of altered protein structure and function.
- explain a modification to protein/enzyme primary structure can result in new structure and/or function.

DNA - the source of heredity

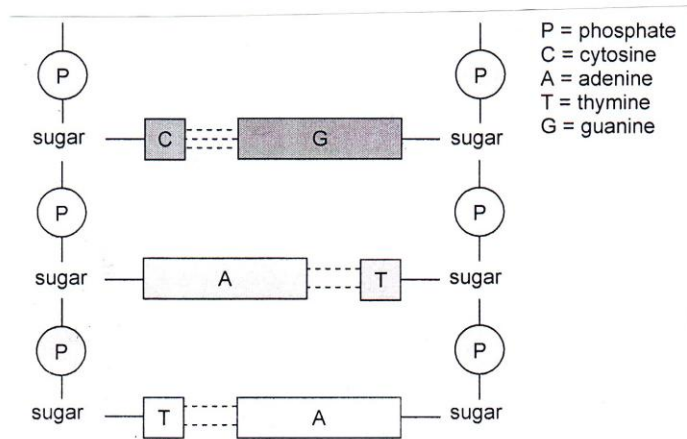
Two DNA strands, running in opposite directions, are linked together in a ladder-like molecule, but a twisted ladder and a right-handed helix.



computer-generated picture of the double helix.

Each DNA strand is a condensation polymer of sugar molecules and phosphate groups.

Attached to this sugar-phosphate backbone is a sequence of organic bases (i.e. amines) constructed from 4 alternatives - Adenine (A), Guanine (G), Cytosine (C) and Thymine (T).



the sugar-phosphate-base structure of DNA.

Hereditary information is stored as the sequence of these bases along the chain.

The genetic message is written in a language of only four letters.

Nucleic acids

Nucleic acids play an essential role in passing on genetic information from generation to generation.

This genetic information determines the structure of living things and the nature of the chemical reactions which happen in them.

The two main types of nucleic acid are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

The structure of DNA contains a genetic code that determines the specific amino acid sequence for all the proteins in the body.

Both DNA and RNA are polynucleotide, they are made by condensation polymerisation of units called nucleotides.

The structure of DNA

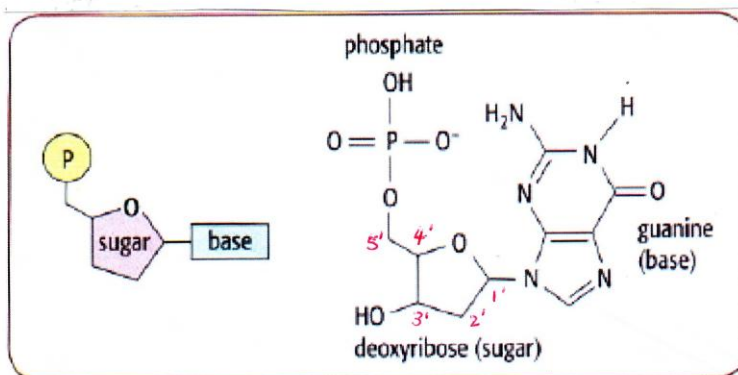
Deoxyribonucleic acid (DNA) controls heredity on a molecular level:

- It is a self-replicating molecule capable of passing genetic information from one generation to the next.
- It contains in its base sequence the genetic code used to synthesise proteins.

A strand of DNA is a macromolecule made by the condensation polymerisation of units called nucleotides.

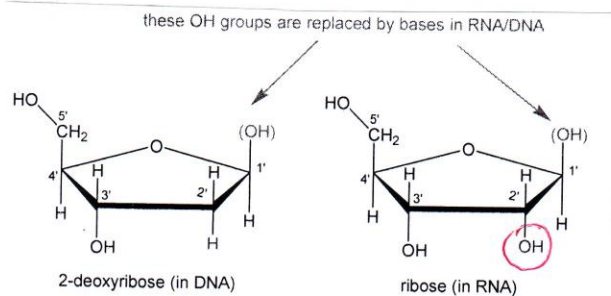
Nucleotides are themselves made from three components:

- a sugar
- a phosphate group
- a nitrogen-containing organic base.



the three components that make up a nucleotide

The sugar molecule in the nucleotides that make up DNA is deoxyribose - a pentose sugar with a five member ring.



The sugar molecule in the RNA is ribose.

The phosphate group is attached by a phosphoester link to the deoxyribose.

The final components of the nucleotides in DNA are the four different bases:

- adenine (A)
- guanine (G)
- thymine (T)
- cytosine (C)

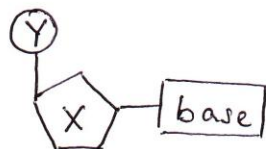
Adenine (A) and guanine (G) have planar two-ring structures — purines.

Thymine (T) and cytosine (C) are planar single-ring molecules — pyrimidines.

Each strand of DNA has a sugar-phosphate backbone with the bases hanging off the side.

Exercise 1

The diagram below represents the basic chemical unit from which DNA is formed.



- a. State the name of:
- i) the whole unit
 - ii) X
 - iii) Y
- b. Name the four nitrogen-containing bases present in DNA.

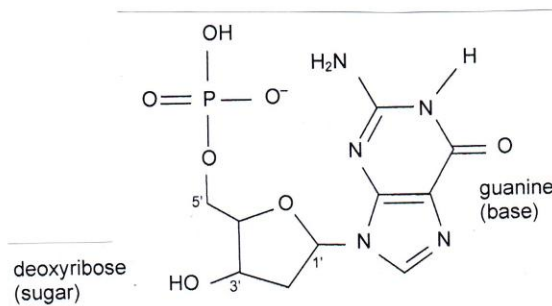
Workings

- a. i) nucleotide
- ii) deoxyribose
 - iii) phosphate group.
- b. 4 nitrogen-containing bases.
- adenine
 - thymine
 - cytosine
 - guanine.

The DNA double helix

A DNA molecule consists of two strands.

The backbone of each strand is made up of molecules of the sugar deoxyribose, connected by phosphate esters groups that join the 3'-OH of one deoxyribose molecule to the 5'-OH group of the adjacent deoxyribose.



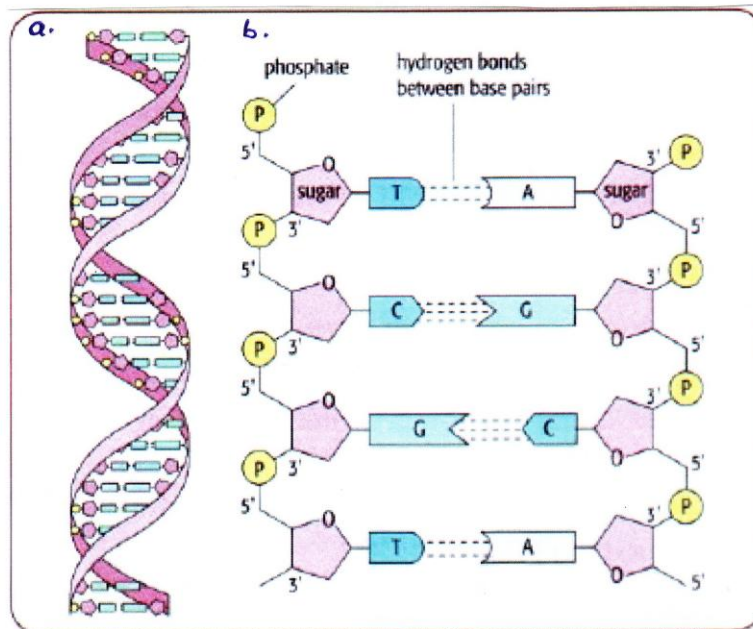
a nucleotide unit.

The two strands sit next to each other running in opposite directions.

One strand the 5'-OH phosphate is at the top, where as in the other strand the 5'-phosphate is at the bottom.

The strands are linked together by hydrogen bonding between the bases.

These two anti-parallel strands are twisted together in a double helix with the bases on the inside and the sugar-phosphate backbones on the outside.



a. part of the DNA double helix.

b. an outline structure of DNA

The bases positioned between the two chains lie at right angles to the backbone, filling the space between the strands.

The bases between the two chains are paired to fill the available space.

The bases in each pair interact with each other through hydrogen bonding.

Two hydrogen bonds form between each adenine - thymine pair ($A = T$).

Three hydrogen bonds are formed between a guanine - cytosine pair ($G \equiv C$).

The difference in the hydrogen bonding between the pairs + the size considerations because each pair of bases consists of a two-ring structure and a single-ring structure in order to fit in the space between the backbones, gives rise to the specificity of the pairing of the bases in DNA.

The pairing of bases are:

- adenine is always paired with thymine
- guanine is always paired with cytosine.

This is known as complementary base pairing and is key to the transfer of the information stored in the sequence of the bases along the DNA chains.

Hydrogen bonding and van der Waals' forces between the stacks of bases are responsible for holding the chains together.

The precise sequence of the bases carries the genetic information.

Exercise 2

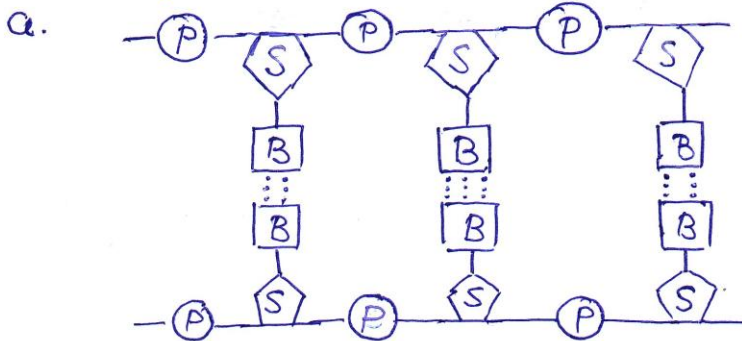
a. Representing the nitrogen-containing bases by 'B', sugars by 'S' and phosphate groups by 'P', show how these are linked in a short length of double-stranded DNA.

Use full lines (—) to show covalent bonds and dots (...) to show hydrogen bonds.

b. i) How do the two backbones in DNA differ?

ii) State how this difference is shown on diagrams of DNA.

Workings



b. (i) The chains run in opposite directions.

Related to the position of the sugars, one runs from the 5' to the 3' position and the other runs from 3' to 5'.

ii) By numbering the position of the sugars, 3' and 5'.

These numbers can be put on the ends of the individual chains in simplified diagrams.

The structure of RNA

RNA is another nucleic acid that presents in a cell.

In the genetic message expression, various forms of RNA participate directly in a system of information transfer.

The major different forms of RNA in gene expression are:

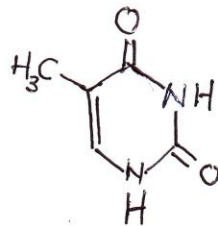
- messenger RNA (mRNA)
- ribosomal RNA (rRNA)
- transfer RNA (tRNA)

Comparison of the structures of DNA and RNA:

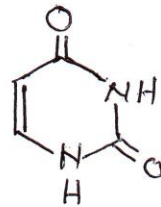
nucleic acid	DNA (deoxyribonucleic acid)	RNA (ribonucleic acid)
pentose sugar	deoxyribose	ribose
bases	<ul style="list-style-type: none">• adenine• cytosine• guanine• <u>thymine</u>	<ul style="list-style-type: none">• adenine• cytosine• guanine• <u>uracil</u>
structure	a double helix made of two anti-parallel strands	single stranded, though the chain can fold on itself to form helical loops

Like thymine, uracil is a single-ring structure and can form a complementary base pair with adenine.

Thymine and uracil only differ by a methyl group:



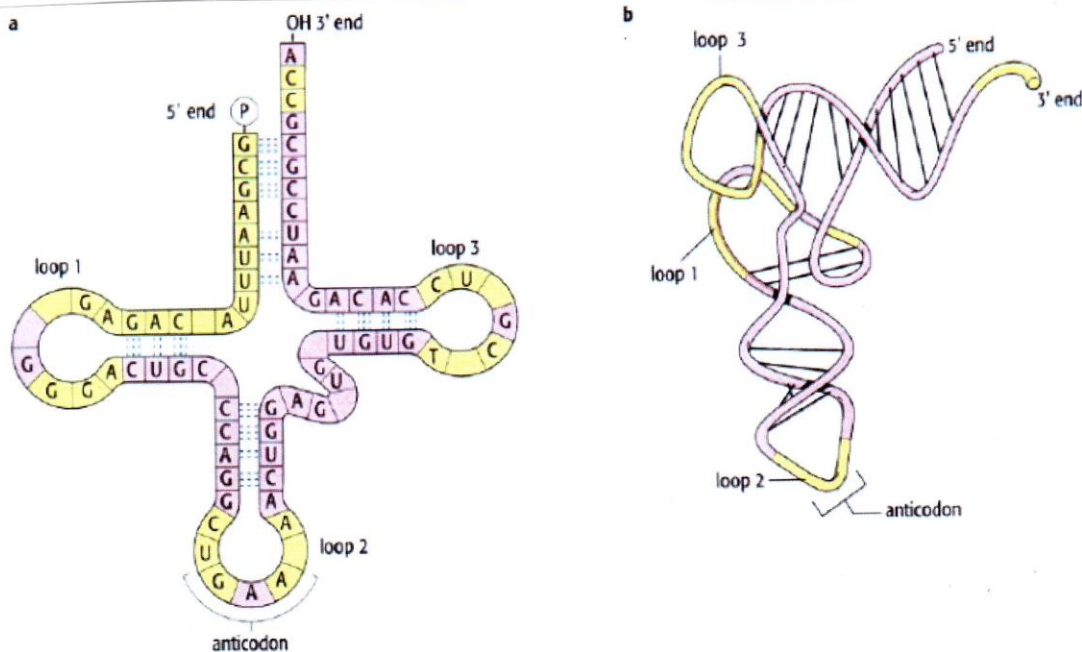
thymine (in DNA)



uracil (in RNA)

Although an RNA molecule is a single long chain, it can bend back on itself to form hairpin loops.

These loops are hydrogen bonded and are important features of the structure of r-RNA and t-RNA.



The cloverleaf structure of t-RNA molecules.

The cloverleaf folding of t-RNA molecules enables them to carry out their important function in protein synthesis.

Exercise

- State three ways in which the structure of RNA differs from DNA.
- Describe the structure of tRNA.
- Describe the role of rRNA in protein synthesis.

Workings

a.

Nucleic acid	DNA	RNA
sugar/pentose	deoxyribose	ribose
base complimentary to adenine	thymine (T)	uracil (U)
structure	double stranded	single stranded

- b. A tRNA molecule is a polynucleotide.

The polymer backbone consists of alternating ribose and phosphate groups, with an organic base (G, C, A or U) joined to each ribose.

The three-dimensional structure of a tRNA molecule is a cloverleaf structure of loops, which are folded over and stabilised by hydrogen bonding.

At one end of the tRNA is a sequence of three bases called an anticodon and the other end of the tRNA binds an amino acids.

C. The rRNA forms the skeleton for the structure of the ribosome.

It allows the attachment of mRNA to it.

The rRNA 'skeleton' allows ribosomal protein to bind to it to catalyse the various reactions occurring during protein synthesis.