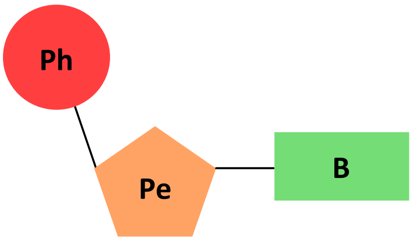
3.7 Nucleic Acids

The coding molecules nucleotides and their polymerisation into nucleic acids

A **nucleic acid** comes in two different forms: as **DNA** (**deoxyribose nucleic acid**) and as **RNA** (**ribose nucleic acid**). They are both the *macromolecules* which are formed by the *polymerisation* of molecules known as **nucleotides**.

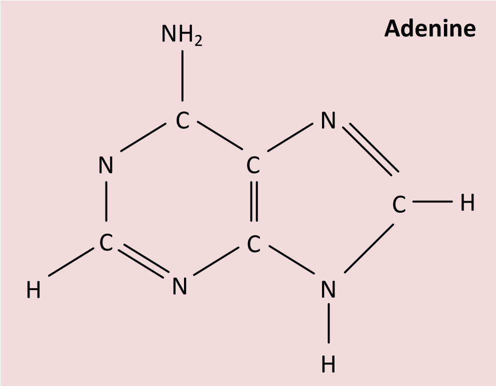
A single nucleotide is made up of three individual sections.

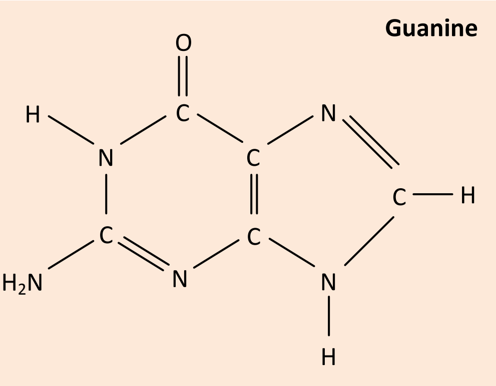


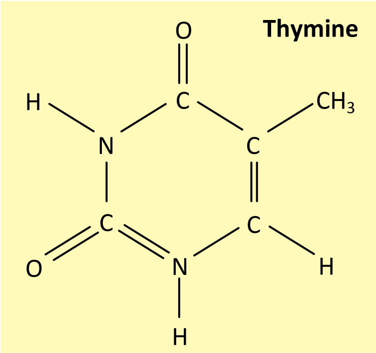
One subunit is a single **phosphate group** (*Ph*). Another is a sugar molecule, **pentose** (*Pe*), which is a five-carbon sugar – this will be either *deoxyribose* or *ribose*. The third subunit is an *organic* **nitrogenous base** (*B*), of which there are five possible bases it can be, which are covered below.

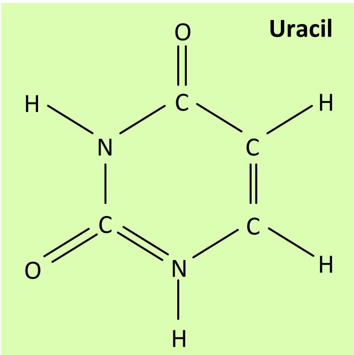
The three subunits join together, forming covalent bonds, to form a single nucleotide molecule.

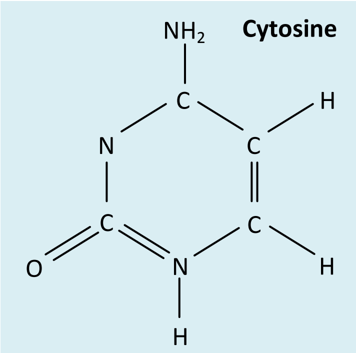
The five bases which can be found in a nucleotide are **adenine**, **cytosine**, **guanine**, **thymine** and **uracil**. Their chemical structures are drawn below. The two larger molecules are called **purines**. The three small molecules are **pyrimidines**.







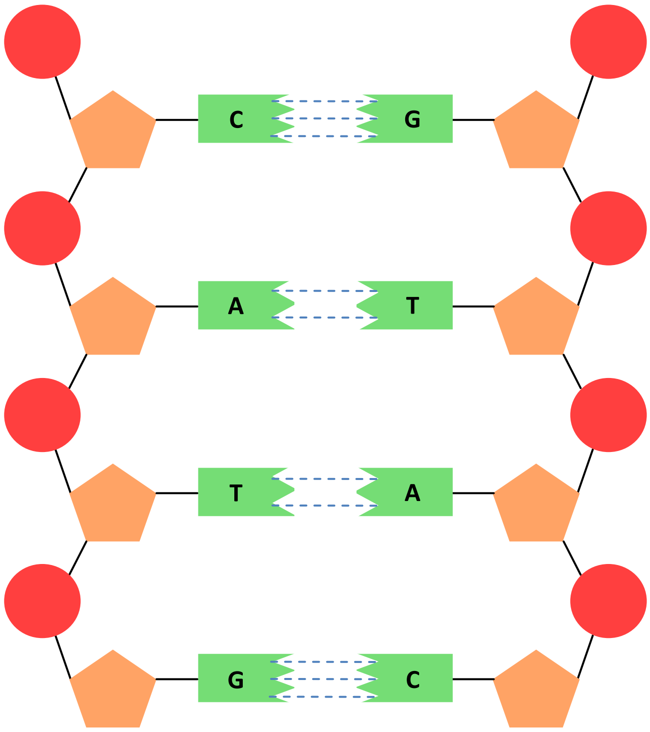




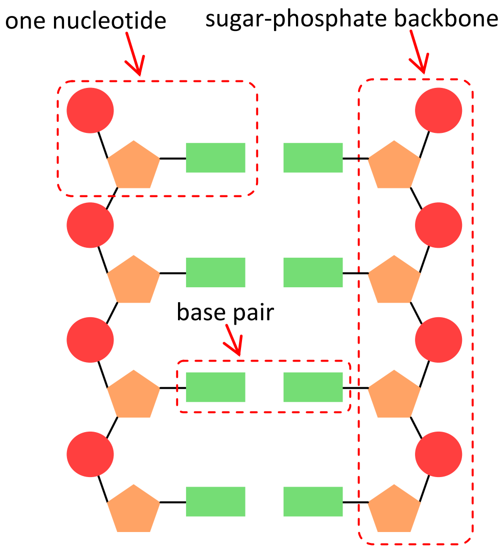
It is a **condensation reaction** which joins the phosphate group of one nucleotide to the sugar of another. As more and more nucleotides join together, they begin to form a **sugar-phosphate backbone**. This structure consists of a long chain of the nucleotides, composed purely of the sugar groups and phosphate groups – the nitrogenous bases stick in towards the middle.

A chain of nucleotides bonded together is called a *nucleic acid*. Only molecules carrying the same sugar are able to bond together, therefore only nucleotides of all ribose or all deoxyribose sugars can join together.

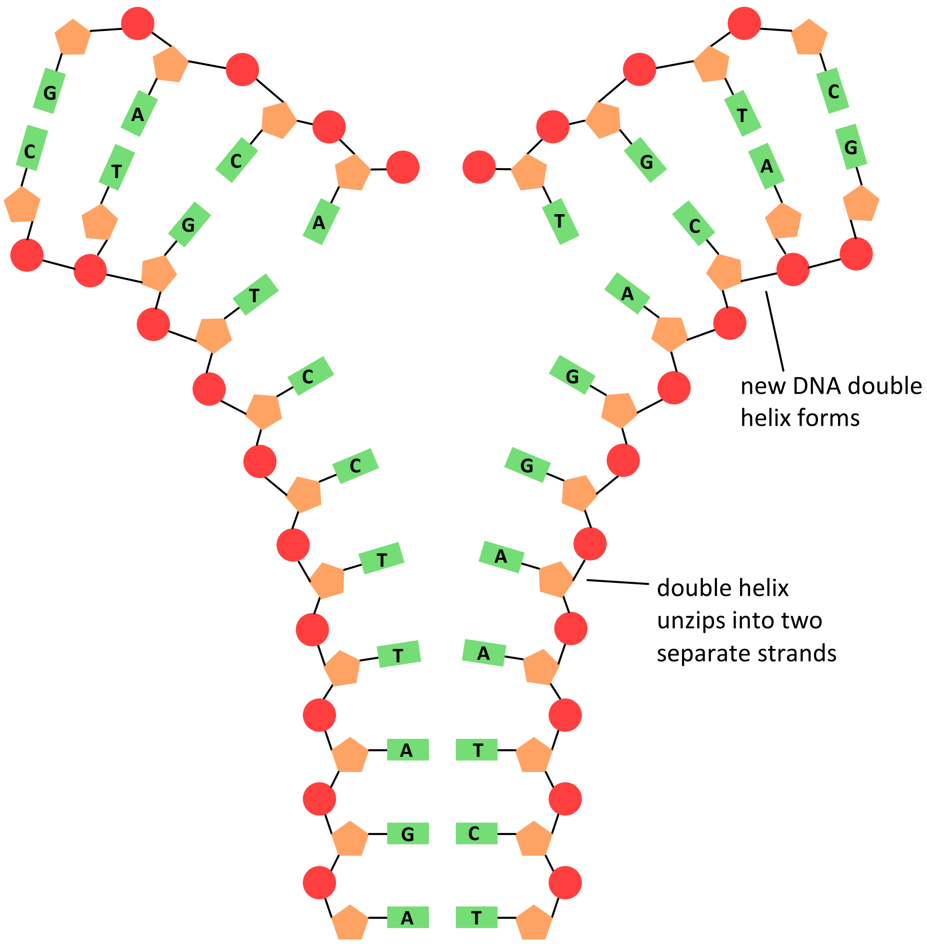
This means that a nucleic acid is described as DNA when the nucleotides contain the sugar deoxyribose, and RNA when they contain the sugar ribose.



The diagram shows some DNA. DNA is made of a double strand (**double helix**) where *hydrogen bonding* holds together the two antiparallel strands.



The two chains or "backbones" are always equidistant from each other. This is due to the way the **base pairs** form. As the different bases pair up, they follow set rules. The purine adenine always pairs up with the pyrimidine thymine (A-T) and the purine guanine always pairs up with the pyrimidine cytosine (C-G). As the strands come together, hydrogen bonds between the bases form. The term **complementary** is used to describe the preference of A joining to T and C joining to G.



When DNA replicates to form two separate DNA molecules from one original molecule, it is called **semi-conservative replication**.

This process involves a double-stranded molecule of DNA "unzipping" to become two single strands. Free nucleotides then join to the bases of the individual strands, and all of these new nucleotides form a new chain, creating two brand new DNA (double-helix) molecules.

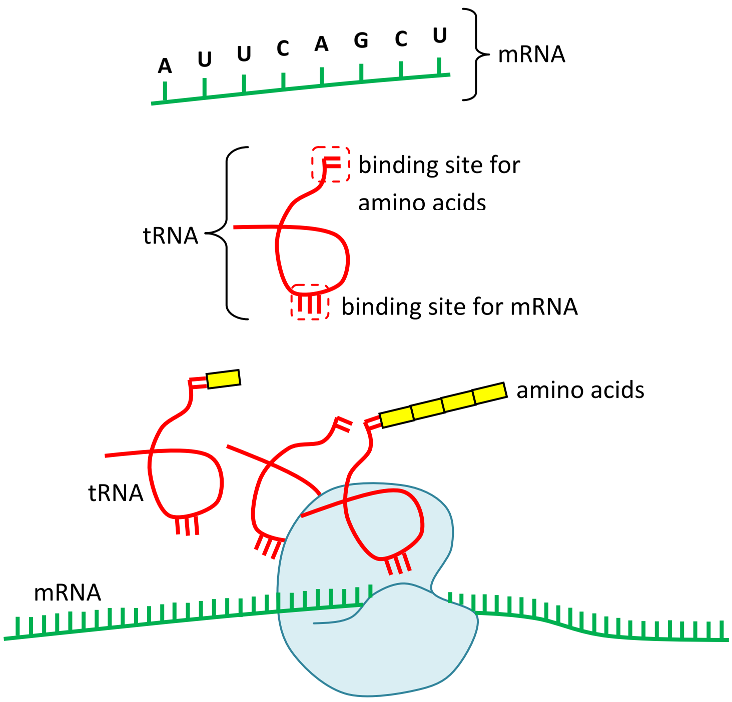
It is important to note that each of the two new DNA double-strands which are produced will be *identical*. This is because, as the original molecule unzips, there will be complementary bases on each strand, and complementary bases to those bases will bond to them. Therefore, as is shown in the diagram, each produced strand will be chemically identical.

Ribose nucleic acid (RNA) is different from DNA in three principal ways:

- the *pentose sugar* is **ribose**, instead of deoxyribose
- the molecule is single-stranded, whereas DNA is double-stranded
- the nitrogenous base **uracil** is found in RNA, instead of the base thymine

RNA only contains the nitrogenous bases adenine and guanine (purines) and cytosine and uracil (pyrimidines). Again, the bases cytosine and guanine are complementary to each other, and so hydrogen bonds between C-G can be made. Uracil, a base very similar to thymine, is able to make hydrogen bonds with adenine also, so with RNA, A-U bonds are made.

RNA is involved in a process called **protein synthesis**. This involves the production of proteins. RNA comes in three different forms, and these are all involved in individual parts of this process.



DNA is too large to escape from the nucleus – because it cannot fit through the **nuclear pores**. Instead, a new strand is developed which is small enough to fit through the pores. In this process, the double-stranded DNA molecule is unzipped (as with replication), and then a new nucleotide chain forms alongside it, which is complementary to the DNA sequence of nucleotides. Therefore, *adenine* in the DNA bonds to *uracil*, *thymine* in DNA bonds with *adenine*, and cytosine and guanine bond to each other. This process is called **transcription**. This new chain is called **messenger RNA** (or **mRNA**). This nucleotide chain is able to escape the nucleus. It is important that you know an mRNA strand is a *copy of one gene*. mRNA is delivered to the ribosomes, on the rough ER or dispersed around the cellular cytoplasm. The ribosomes are where proteins are synthesised, and ribosomes are made from **ribosomal RNA** (or **rRNA**) with proteins.

The third type of RNA is called **transfer RNA** (or **tRNA**). These have two binding sites: one for amino acids, and one for mRNA. Transfer RNA works by bringing in the correct amino acids to the ribosome in the correct sequence in order to be synthesised into proteins. But the binding site for the mRNA allows tRNA to attach to the mRNA so it can obtain those codings. The tRNA sequence will be *complementary* to the mRNA, so not identical. We call the sequence of amino acids produced for mRNA the **mRNA codon**, and the sequence for the ribosome use **tRNA anticodon**. We call the shape of the tRNA molecule a **hairpin loop**, which is shown in the above diagram.

The diagram above shows the mRNA entering the ribosome (these are normally simplified into two-lobed structures) and the tRNA binding to it. The tRNA molecule has brought the correct sequence of amino acids with it into the ribosome so that the protein can be synthesised. This process is called **translation**.

In the exam, you may be asked to provide the coding for various DNA and RNA molecules. If the DNA sequence is as follows, then we can work out what the mRNA and tRNA sequences will be:

DNA	A	G	C	A	A	T	G	T	C	A	G	A	C	T	T
mRNA	U	C	G	U	U	A	C	A	G	U	C	U	G	A	A
tRNA	A	G	C	A	A	U	G	U	C	A	C	A	G	U	U

If we know the DNA sequence is as shown, the mRNA must be complementary to that, and then the tRNA to the mRNA.