

## Nucleic acids

Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are made up of nucleic acids found in the nuclei of living cells. They are the vehicles of genetic inheritance.

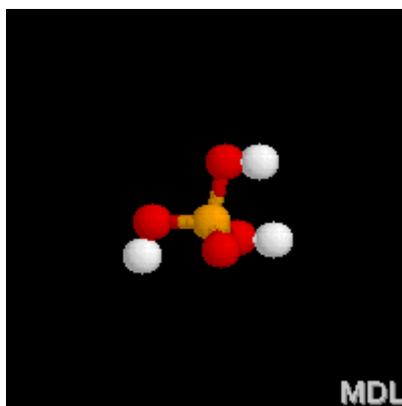
Nucleic acids are condensation polymers of nucleotides. To understand their functions you will find it helpful to look at how their molecules are built up and the structures of these molecules.

### The building blocks

Three types of chemicals make up the building blocks for nucleic acids.

#### Phosphates

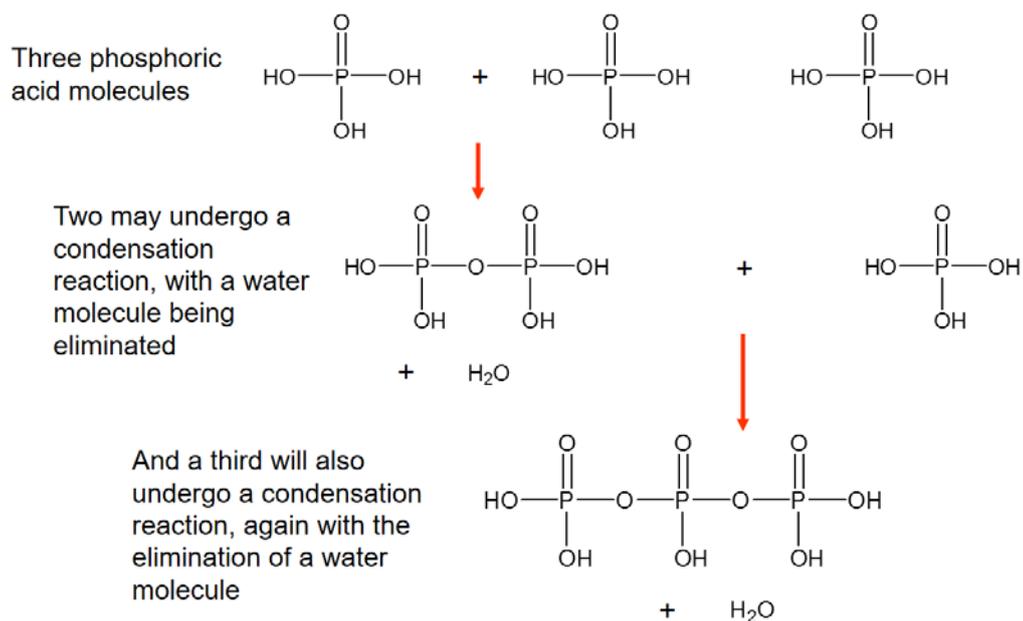
These are based on the inorganic acid  $\text{H}_3\text{PO}_4$  (phosphoric acid).



*Phosphoric acid*

Two other acids may be formed from phosphoric acid by condensation reactions

## Condensation of phosphoric acid



Two important reactions of the hydroxyl groups in phosphoric acid are:

- with alcohols to form ester groups
- with amines to form amide groups

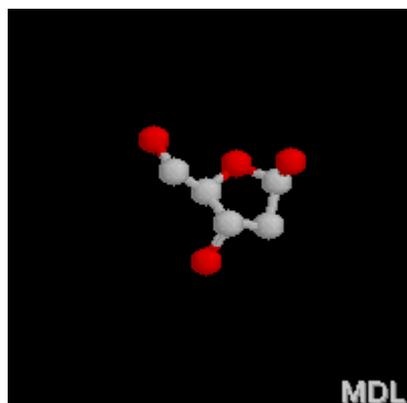
## Sugars

The sugars in DNA and RNA are pentoses.

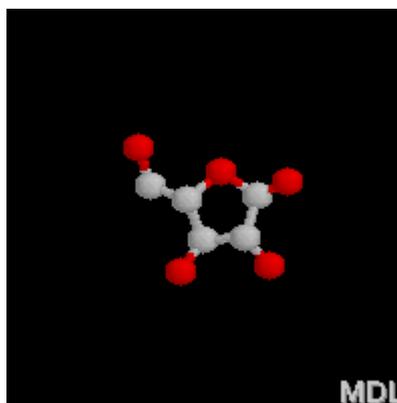
> See the topic about [Carbohydrates](#)

- in **DNA** the sugar is **deoxyribose**
- in **RNA** the sugar is **ribose**

Both these sugars have hydroxyl groups. Ribose has four and deoxyribose has three (hence the prefix 'deoxy'). These groups can react with carboxylic acids and phosphoric acid to form esters.



Deoxyribose (hydrogens not shown for clarity)

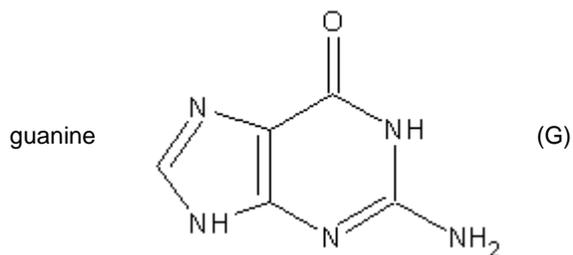
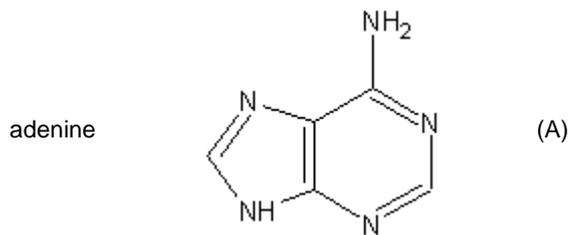


Ribose (hydrogens not shown for clarity)

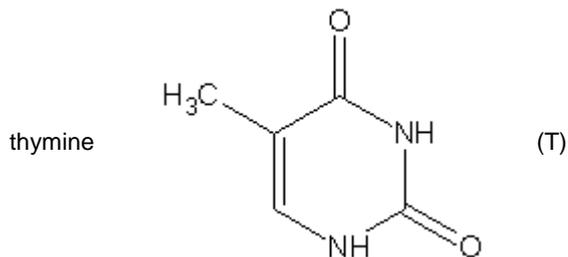
## Organic bases

There are four organic bases involved in the formation of DNA molecules:

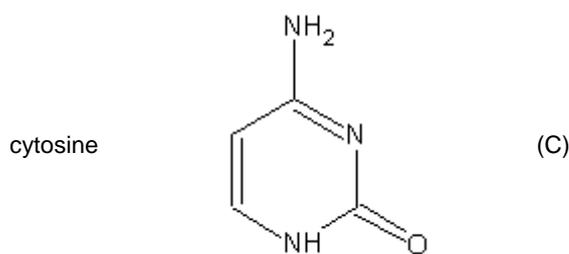
- adenine and guanine (both purines containing two rings in their structures)
- thymine and cytosine (both pyrimidines containing only one ring in their structures)

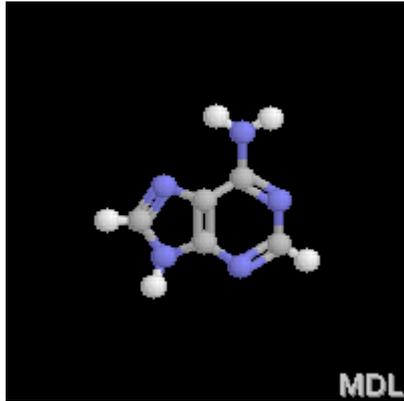


A and G are double-ring **purine**bases.

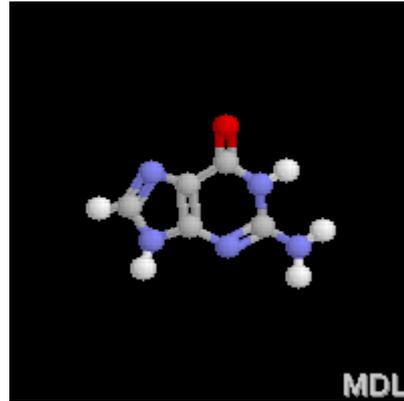


T and C are single-ring **pyrimidine**bases.

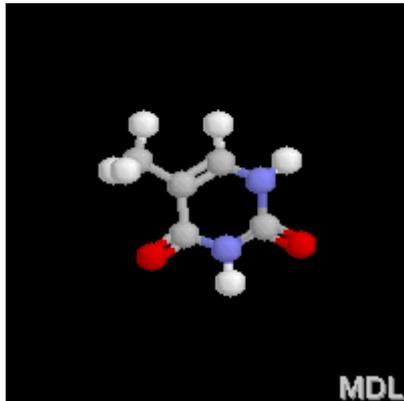




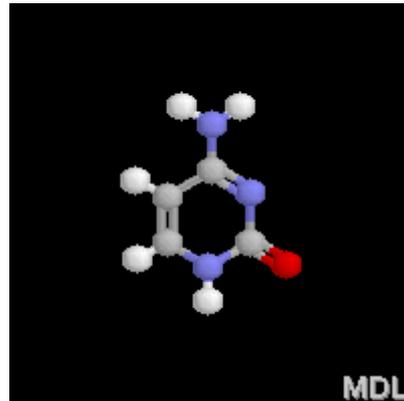
*Adenine*



*Guanine*

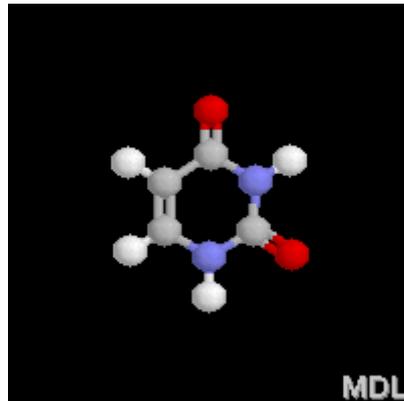


*Thymine*



*Cytosine*

In RNA the four bases are the same except for thymine which is replaced by uracil (U), a pyrimidine base.



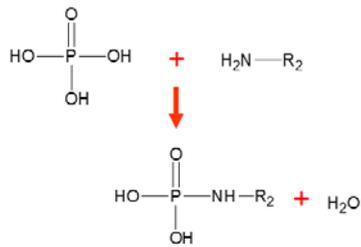
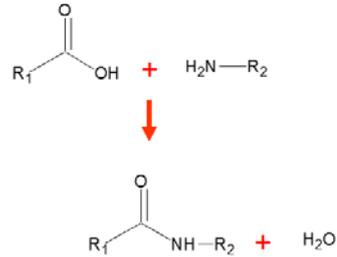
*Uracil*

Adenine, guanine, thymine, cytosine and uracil are bases because of the presence of one or more of the following groups: - NH<sub>2</sub>, - NH - and = N - groups. Importantly, - NH<sub>2</sub> and - NH - groups can react with carboxylic acids and phosphoric acid to form amides.

## Formation of amides

The condensation reaction between a carboxylic acid and an amine produces an **amide**.

A water molecule is eliminated.

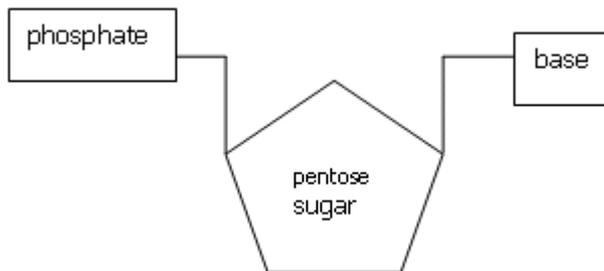


A condensation reaction between phosphoric acid and an amine similarly produces an amide.

And water is eliminated.

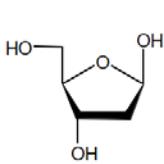
## Putting the building blocks together

The basic structure of a nucleotide is shown below.

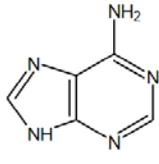


In all nucleotide molecules the bonds holding the phosphate group to the sugar and the base to the sugar are both products of condensation reactions. Water is eliminated when they form. In both cases the oxygen to form the water has come from the sugar's -OH groups.

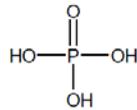
# Formation of a nucleotide



Deoxyribose sugar

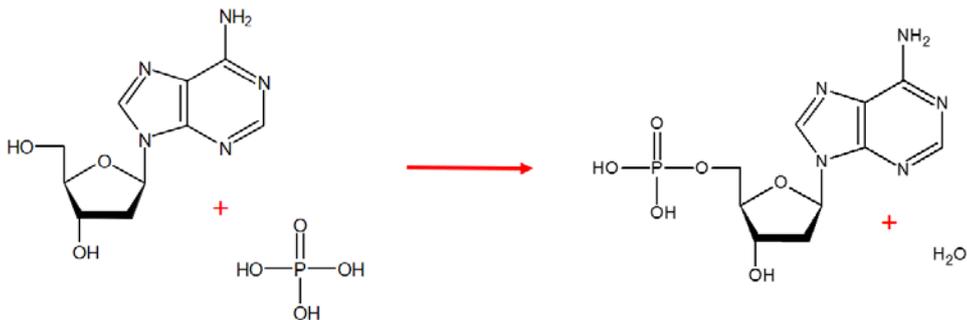
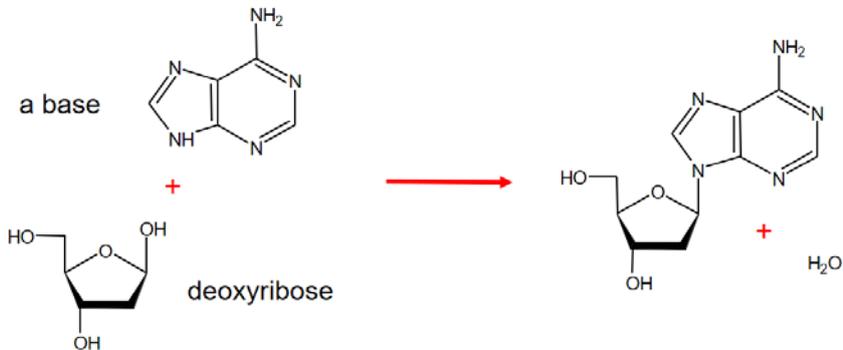
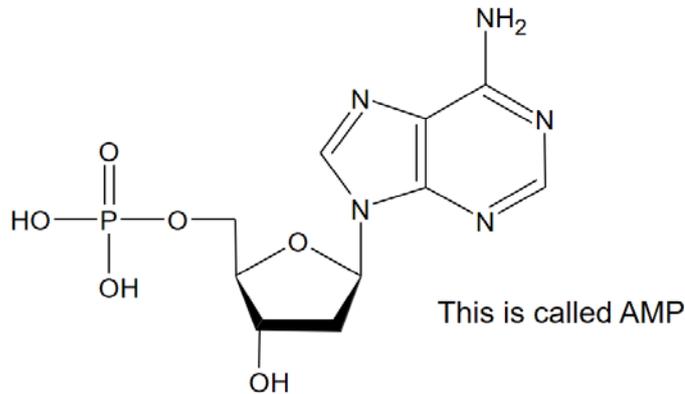


Nitrogenous base  
(here adenine)



Phosphoric acid

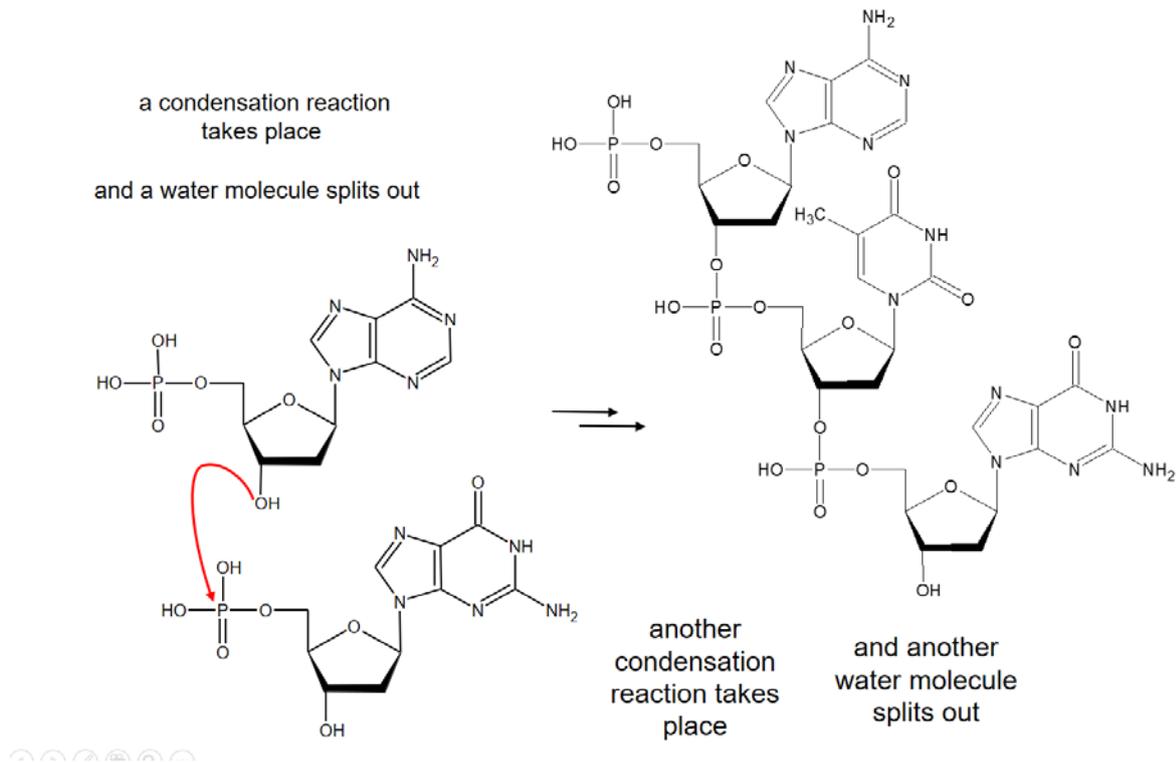
Three compounds are needed to make a nucleotide, they combine through two condensation reactions...



## Nucleic acids

Nucleotides can link together by the formation of phosphate ester bonds. The hydroxyl group of a phosphate on one nucleotide undergoes a condensation reaction with the hydroxyl group on the carbohydrate ring of another nucleotide. The process may continue, building up nucleic acid molecules. These are polymers called **polynucleotides**.

### Formation of a polynucleotide



Nucleic acids are the 'building blocks' of DNA and RNA.

## The structure of DNA

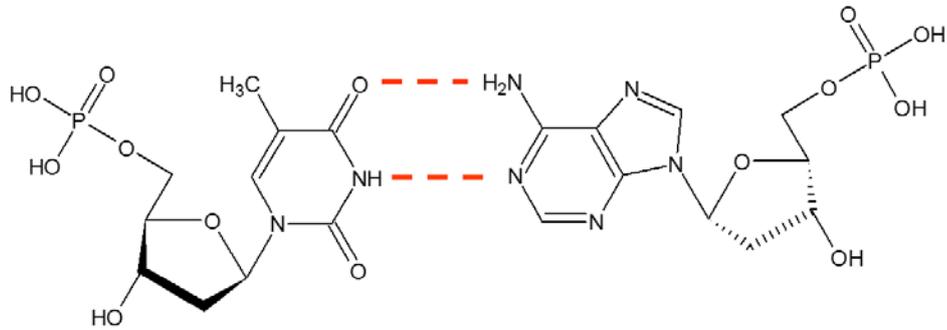
DNA is formed from two polynucleotide chains. Each chain has a helical structure (a helix), in other words the molecule is coiled like a spring.

The two helices are then intertwined to give a double helix. The bases are on the inside of the helix and the phosphate groups are on the outside.

The two helices are held together by pairing of the nucleotides' bases through hydrogen bonding. Because the double ring **purines** are bigger than the single ring **pyrimidines** the structure can only form with purine bases opposite pyrimidine bases. A big one complements a little one to take up about the same space.

## Hydrogen bonding between nucleotides

Hydrogen bonding takes place between an adenine-thymine base pair

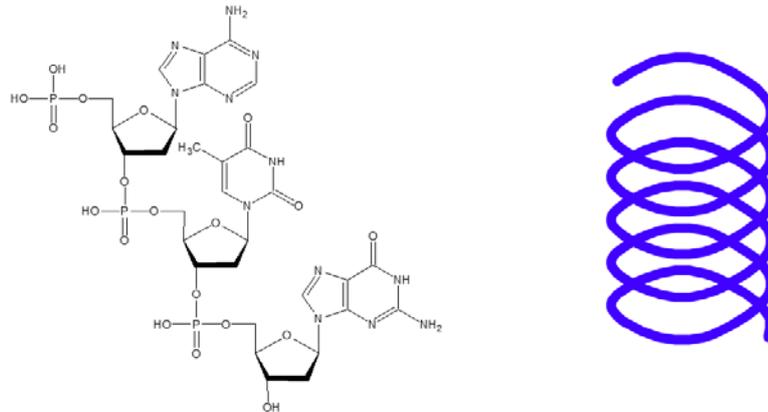


The two molecules must be correctly orientated for hydrogen bonding to occur

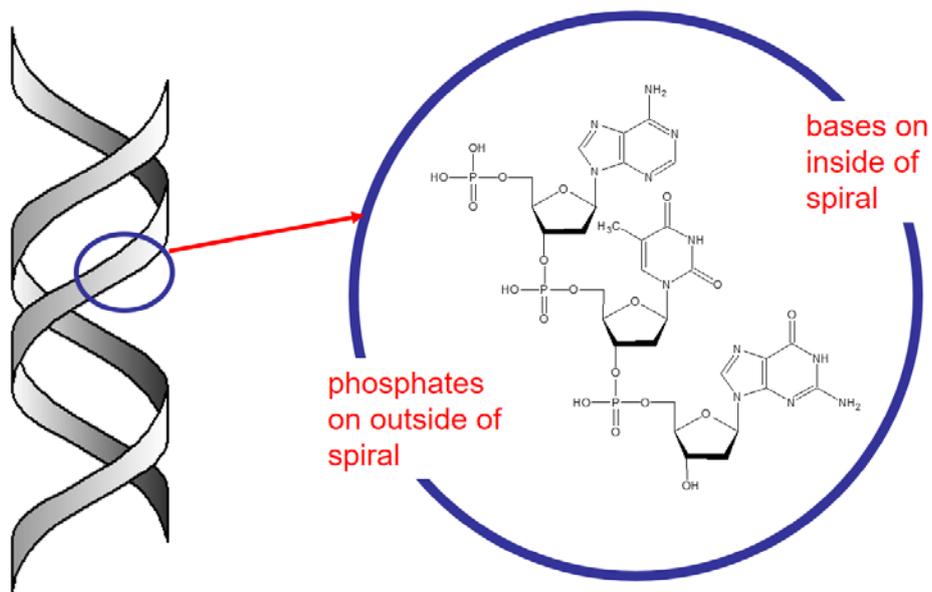
The structure is sometimes described as a ladder where the sugar-phosphate chains are the sides of the ladder and the base-base bonds are the rungs. Intermolecular forces twist the ladder into a double helix shape.

## Hydrogen bonded helix

The product coils into a helix, held in place by hydrogen-bonds



Two helices are held in place by hydrogen-bonding to form DNA



## The structure of RNA

The structure of RNA differs fundamentally from that of DNA in three ways:

- It forms a single strand sugar-phosphate chain
- The sugar in its nucleotides is ribose
- The base thymine is replaced by the base uracil

Although RNA is single stranded it can form helical loops by folding back on itself. Hydrogen bonding between base pairs holds the strand in shape. This allows RNA to carry out its important function in protein synthesis.

## Test your knowledge

[Take quiz on \*Nucleic acids\*](#)