ChemFactsheet

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Structure and Function of DNA

DNA or deoxyribonucleic acid is a *self-replicating molecule*. It passes on genetic information from one generation to the next. Every time a cell divides the genetic information is duplicated and so becomes part of the new cell which is formed.

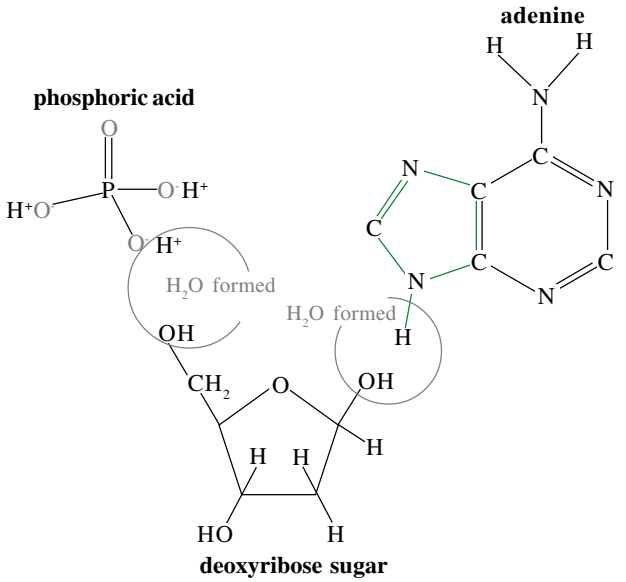
DNA also carries the code which is used to produce proteins. A sequence of three bases, called a codon, is used to code for a particular amino acid. As there are 4 bases there are $4^3 = 64$ possible triplet sequences. Two will be used as start and stop. From the known genetic code it is possible to ascertain which triplet will result in each amino acid. Thus it is possible to predict the amino acid sequence of the protein which would be produced from a given DNA base sequence.

DNA is a polymer made up of subunits called nucleotides or monomer nucleotides. Hence, DNA can be referred to as a *polynucleotide*.

Each nucleotide consists of: a deoxyribose sugar and a phosphate group plus *one* of the four natural bases : adenine, cytosine, guanine or thymine.

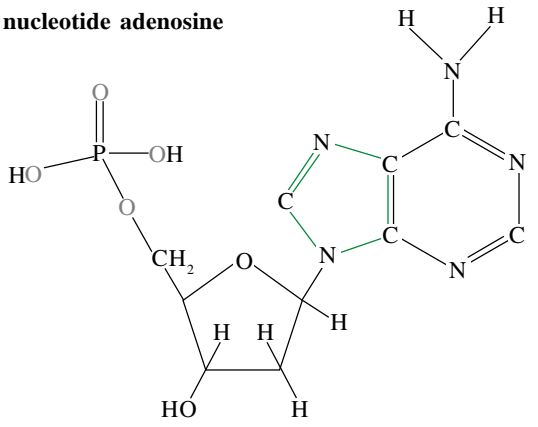
*The nucleotides are formed by **condensation polymerisation** reactions.*

The Formation of a the Nucleotide, Adenosine, from Phosphate, Deoxyribose Sugar and the Base, Adenine



A **condensation reaction** occurs. Molecules of water are formed as a by product

The nucleotide adenosine



As nucleotides form, they join together by a covalent bond between the phosphate group and the sugar.

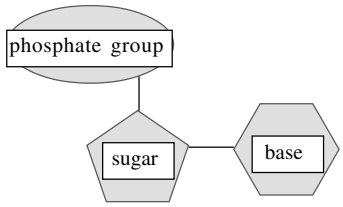
They become 'stacked up', one nucleotide on top of the other (rather like a stack of books in a cupboard, but with each book turned through an angle with respect to the next) and form *one* strand of DNA.

The strand coils as it forms to give a structure rather like a pulled out slinky spring.

The term *backbone* is often used to refer to the phosphate-sugar part of DNA.

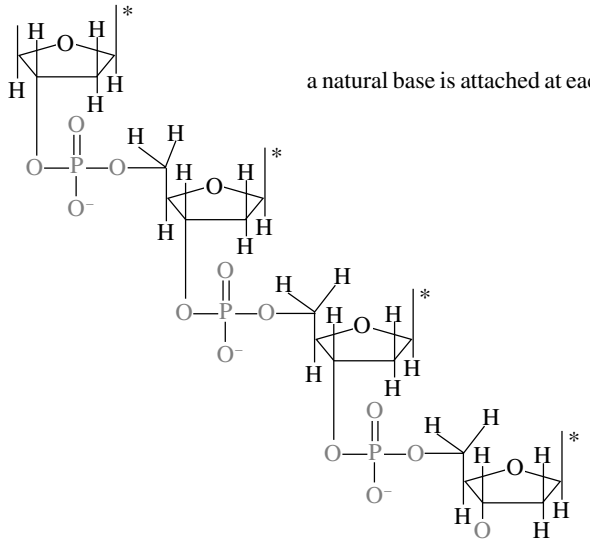
Each individual nucleotide may be represented in a simplified diagram:

Schematic Representation of a Nucleotide of DNA



In an examination the symbols will probably be different. A popular question is to ask you to identify the parts, so learn how they are linked or bonded together.

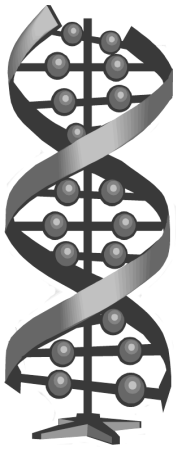
Fragment of the backbone of DNA



- *The **backbone of DNA** consists of a repeated pattern of a phosphate group and a deoxyribose sugar.*
- *The bases are attached to the backbone of DNA by **covalent bonds** (i.e. the bonds formed during condensation polymerisation) to the sugar elements of the backbone.*
- *Two of the single strands come together, one coiled like a right hand coil and the other like a left hand coil. They become twisted together in a double helix.*
- *The single strands of DNA come together in pairs to form the final DNA molecule.*
- *The two strands are held together by hydrogen bonding between base pairs.*
- *There are two types of base. One type is the larger two-ring structure of adenine and guanine (these are called purines), and the other is the single ring structure of cytosine and thymine (these are calledd pyrimidines).*

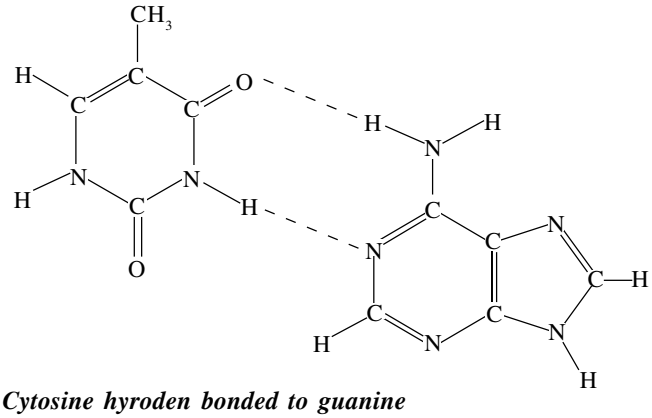
The DNA Double Helix

each dot represents one of the natural bases

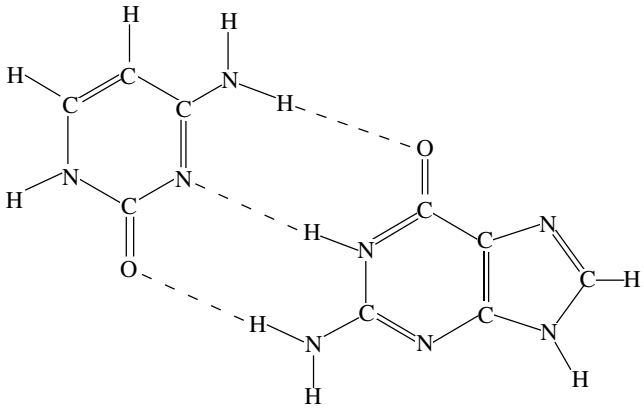


The bases pair together in a specific way:
- *adenine forms **two** hydrogen bonds with thymine;*
- *cytosine forms **three** hydrogen bonds with guanine.*

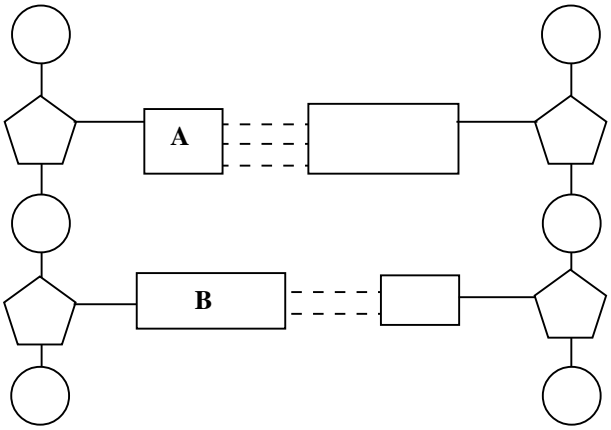
Thymine hydrogen bonded to adenine



Cytosine hyroden bonded to guanine



Quick question:
We can represent the DNA backbone and hydrogen bonding between bases schematically:



Try filling in the gaps in the following statements:

The circles represent……..…… The pentagons represent…….....……

Base A is …….....hydrogen bonded with…….....

Base B is…….....hydrogen bonded with…….....

Practice Questions

(one mark each unless otherwise indicated)

1. What type of bonding holds the two strands of DNA together?

2. What is the backbone of DNA made up of?

3. Suggest the type of interaction *between the stacked bases* of DNA which might cause the helical structure to form.

4. Name the type of chemical reaction involved in the formation of a nucleotide.

   Name the non-organic product of this reaction. (2 marks)

5. The pairing of bases in DNA is specific in that adenine always pairs with thymine and cytosine always pairs with guanine.

   Give two reasons why other base pairing would be unlikely to occur.(4 marks)

6. A sample of DNA was analysed and it was found that the molar proportions of cytosine and guanine were equal (within the limits of experimental error).

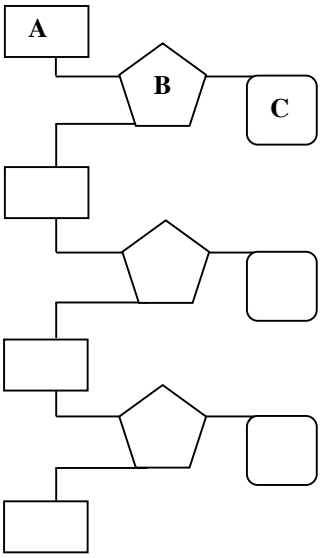
   Give a reason why you would expect these to be equal.

7. In a series of experiments, DNA molecules were heated in solution so that the two strands began to separate. The temperature at which 50% of the strands separated was recorded for each DNA molecule.The temperature was found to depend on the percentage of guanine-cytosine base pairs present.

   Suggest a reason for this. Would the temperature increase or decrease with increasing percentage of guanine-cytosine base pairs? Explain your answer. (3 marks)

8. The diagram represents a single strand of DNA.

   Identify the parts A, B and C shown. (4 marks)



Answers to quick question:

Circles are *phosphate* groups (bonded to sugar)

Pentagons are the *deoxyribose sugar* (bonded to a base).

Base A is cytosine (single ring) with three hydrogen bonds to guanine (double ring).

Base B is adenine (double ring) with two hydrogen bonds to thymine (single ring).

Answers to Practice Questions

1. Hydrogen bonding.
2. Phosphate groups and (deoxyribose) sugar.
3. Dipole – induced dipole.
4. Condensation polymerisation water.
5. The difference in the hydrogen bonds formed. (1 mark).

   Adenine H-bonded with thymine forms two hydrogen bonds whereas cytosine H-bonded with guanine forms 3 hydrogen bonds. (1 mark).

   The sizes of the bases, paired so that each base pair is approximately the same size (1 mark).

   Each pairing consists of a two ring structure and a smaller single ring structure, and this ensures that the base pairs can fit within the helical structure. (1 mark)

   (4 marks maximum total)

6. Guanine always pairs with cytosine so the number of molecules of each used would be the same. (1 mark)
7. There are 3 hydrogen bonds involved in forming the cytosine guanine base pairs, whereas only 2 hydrogen bonds are involved in forming thymine adenine base pairs. (1 mark).

   Increasing the percentage of cytosine guanine base pairs would cause the temperature to rise. (1 mark).

   This is because the cytosine guanine base pairs have three hydrogen bonds and so more energy is needed break these (than is needed to separate the thymine and adenine which have only two hydrogen bonds to be broken). (1 mark)

8. **A** is a phosphate group (1 mark).

   B is a deoxyribose sugar (1 mark).

   C is a natural base (1 mark).

   The natural base can be either adenine, cytosine, thymine or guanine) (1 mark).

Acknowledgements: *This Factsheet was researched and written by Christine Collier.*