Nucleic acids.

In every living cell there are found nucleo-proteins which are made up of proteins and natural polymers of great biological importance called nucleic acids. Nucleic acids are complex compounds of carbon, hydrogen, oxygen, nitrogen and phosphorus. They play an essential role in transmission of the hereditary characteristics and biosynthesis of proteins. The genetic information coded in nucleic acids programmes the structure of all proteins including enzymes and thereby all metabolic activity of living organisms.

Two types of nucleic acids are found in biological systems, these are

Deoxyribonucleic acid (DNA) and

Ribonucleic acid (RNA)

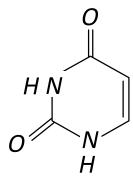
The nucleic acid was first isolated by Friedrich Miescher in 1868 from the nuclei of pus cells and was named nuclein. The term nuclein was given by Altman.

(1) **Composition: Nucleic acids like proteins and carbohydrates are polymers**. The simple units that make up the nucleic acid are called **nucleotides**. Nucleotides are themselves composed of following three simple molecules.

(i) **Nitrogenous base:**These are heterocyclic organic compound having two or more nitrogen atoms in ring skeleton. These are called bases because the lone pairs of electrons on the nitrogen atoms make them as Lewis bases.

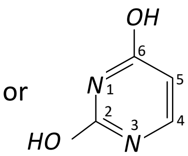
Their structures are given below

(a) Pyrimidine derivatives



Uracil (U)

or



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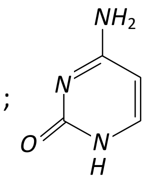
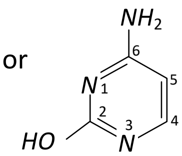


Cytosine (C)

RNA

or



Cytosine (C)

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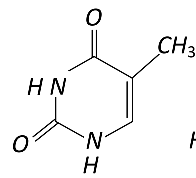
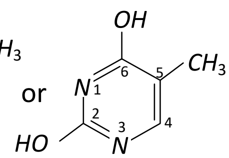
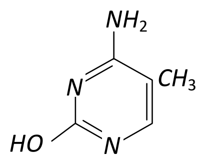


Thymine (T)

or





5-Methyl cytosine

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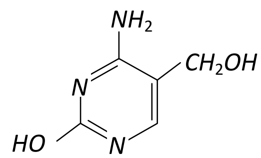
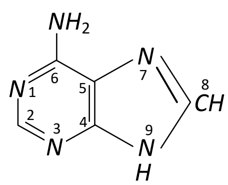


5-Hydroxy methyl cytosine

(b) Purine derivatives



Adenine (A)

DNA

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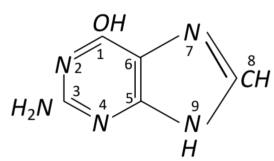
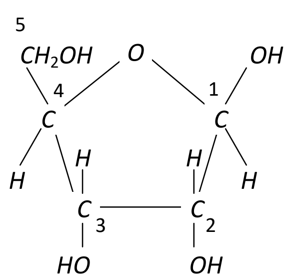


Guanine (G)

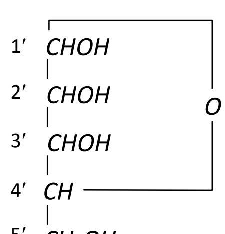
DNA

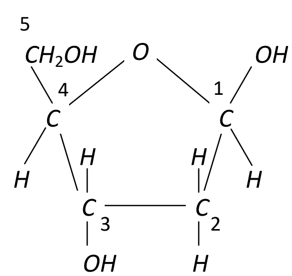
(ii) **Five carbon sugar (Pentose):** In RNA, the sugar is ribose where as in DNA, the sugar is deoxyribose.



Ribose

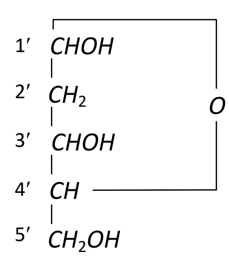
or





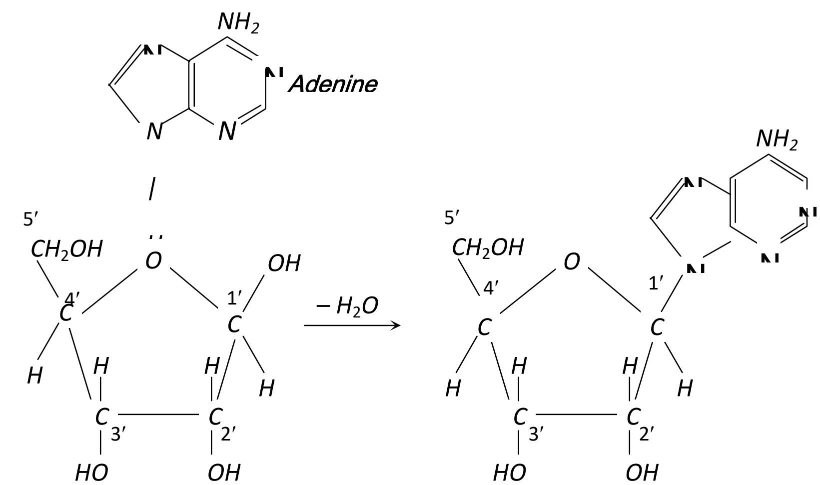
Deoxyribose

or



Both differ only at carbon atom $2'$ in the ring.

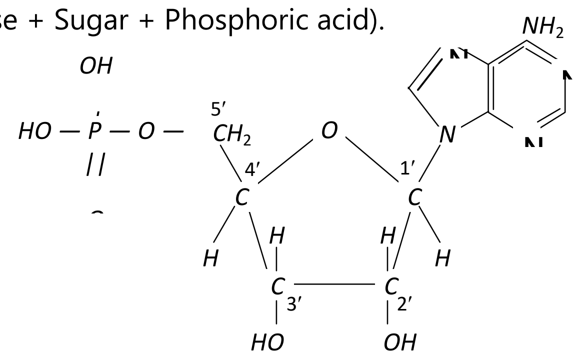
(iii) **Phosphoric acid, H_3PO_4:** Phosphoric acid forms esters to –OH groups of the sugars to bind nucleotide segments together. A molecule called **nucleoside** is formed by condensing a molecules of the base with the appropriate pentose. (i.e., Base + Sugar).



Ribose

Adenosine (nucleoside)

A **nucleotide** results when the nucleoside combined with phosphoric acid mainly at carbon 5′ of the pentose. (i.e., Base + Sugar + Phosphoric acid).



Nucleotide-adenosine 5′-phosphoric acid

This nucleotide is the building block of both DNA and RNA. The nucleic acids are condensation polymers of the nucleotide monomers and are formed by the creation of an ester linkage from phosphoric residue on one nucleotide to the hydroxy group on carbon 3′ in the pentose of the second nucleotide. The result is a very long chain possessing upto a billion or so nucleotides units in DNA.

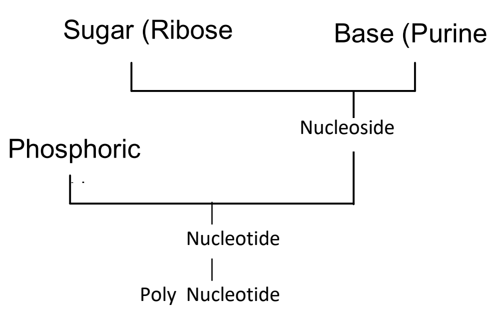
|
HO – *P* – *O* – Sugar – Base
|| |

|
HO – *P* – *O* – Sugar – Base
|| |

|
HO – *P* – *O* – Sugar – Base
|| |

|
HO – *P* – *O* – Sugar – Base
|| |
O *O*

Thus, the formation of a nucleic acid can be summarised in the following general way



RNA nucleotides

Base	+	Ribose	→	(Nucleoside)	+	Phosphoric acid	→	Nucleotide
Adenine	+	Ribose	→	(Adenosine)	+	Phosphoric acid	→	Adenylic acid
Guanine	+	Ribose	→	(Guanosine)	+	Phosphoric acid	→	Guanylic acid
Cytosine	+	Ribose	→	(Cytidine)	+	Phosphoric acid	→	Cytidylic acid
Uracil	+	Ribose	→	(Uridine)	+	Phosphoric acid	→	Uridylic acid

DNA nucleotides

Adenine	+	Deoxy ribose sugar	+	Phosphate	→	Adenosine phosphate
Guanine	+	Deoxy ribose sugar	+	Phosphate	→	Guanosine phosphate
Cytosine	+	Deoxy ribose sugar	+	Phosphate	→	Cytosine phosphate
Thymine	+	Deoxy ribose sugar	+	Phosphate	→	Thymidine phosphate

(2) **Structure:** The sequence of bases along the DNA and RNA chain establishes its primary structure which controls the specific properties of the nucleic acid. An RNA molecule is usually a single chain of ribose-containing nucleotides. DNA molecule is a long and highly complex, spirally twisted, double helix, ladder like structure. The two polynucleotide chains or strands are linked up by hydrogen bonding between the nitrogenous base molecules of their nucleotide monomers. Adenine (purine) always links with thymine (pyrimidine) with the help of two hydrogen bonds and guanine (purine) with cytosine (pyrimidine) with the help of three hydrogen bonds. Hence, the two strands extend in opposite directions, i.e., are antiparallel and complimentary. The following fundamental relationship exist.

Note: Thymine combines only with deoxyribose sugar and uracil only with ribose sugar. Other bases can combine with either of the two sugars.

- The sum of purines equals the sum of pyrimidines.
- The molar proportion of adenine equals to that of thymine.
- The molar proportion of guanine equals to that of cytosine.

The double helix is 20 Å. It completes a spiral at every 10 nucleotide pairs at a length of 34 Å. Sequences of monomers (nucleotides) may present innumerable variations. Evidently, innumerable varieties of DNA exist in the organism.

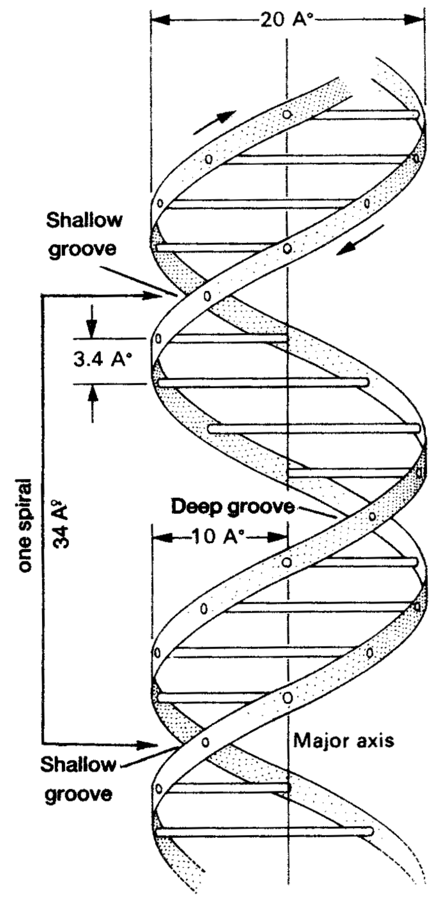


Fig : Helical structure of DNA

Watson, Crick and Witkins were awarded Noble prize in 1962 for suggesting the structure of DNA.

Difference between DNA and RNA

DNA	**RNA**
It has a double helix structure.	It has a single helix structure.
Sugar unit is deoxyribose.	Sugar unit is Ribose.
Base units are adanine, guanine, thyamine and	It contains uracil base instead of thyamine, other

cytosine.	bases being same as those in DNA.
Responsible for inheritance of character.	It is responsible for protein synthesis.

(3) **Functions of nucleic acid:** Nucleic acid have two important functions

(i) Replication and
(ii) Protein synthesis

(i) **Replication:** The genetic information for the cell is contained in the sequence of the bases A, T, G and C (adenine, thymine, guanine and cytosine) in the DNA molecule. The sequence of bases in one chain of the double helix controls the sequence in other chain. The two chains fit together like a hand and a glove. They separate and about the hand is formed a new glove, and inside the glove is formed a new hand. Thus, the pattern is preserved in the two new molecules of DNA.

[If one strand of DNA has the sequence ATGCTTGA, then the sequence of complimentary strand will be TACGAACT].

(ii) **Synthesis of proteins:** The DNA contains the genetic code and directs protein synthesis through RNA. The double helix of DNA partially uncoils and about the individual strands are formed chains of RNA. The new chains contain ribose instead of deoxyribose and the base sequence is different which is determined by DNA, i.e., opposite each adenine of DNA, there appears on RNA a uracil; opposite guanine, cytosine; opposite thymine, adenine, opposite cytosine, guanine. Thus, AATCAGTT on DNA becomes UUAGUCAA on RNA.

One kind of RNA, called messenger RNA, carries a message to the ribosome, where protein synthesis actually takes place. At the ribosome, messenger RNA calls up a series of transport RNA molecules, each of which is loaded with a particular amino acid. The order in which the transport RNA molecules are called (–the sequence in which the amino acids are arranged to form the protein chain) depends upon the sequence of bases along the messenger RNA chain. Thus GAU is the code for aspartic acid; UUU, phenyl alanine; GUG, valine. There are 64-three letter code words (codons) and only 20-odd amino acids, so that more than one codon call the same amino acid.

The relation between the nucleotide triplets and the amino acids is called Genetic code. Nirenberg, Hollay and Khorana presented the genetic code for which they were awarded Noble prize in 1968.

(4) **Mutation:** A mutation is a chemical or physical change that alters the sequence of bases in DNA molecule. Anything that causes mutation is called **mutagen**. A mutation results from ultraviolet light, ionisation radiations, chemicals or viruses. The changes in sequence of bases in DNA are repaired by special enzymes in the cell. If it is not, the protein produced has no biological activity and the cell dies.

These mutations often prove harmful and give rise to symptoms that cause diseases. Sickle-cell anaemia is one such example. Such disease is passed on from one generation to the next generation.