

## 16. DEOXY RIBOSE NUCLEIC ACID (DNA)

In 1869, Friedrich Meischer was the first person who separated cell nuclei from the cytoplasm and extracted an acidic material, nuclein, from the nuclei of pus cells. He found that the acidic material contained unusually large amounts of phosphorous and no sulphur. Later on, in 1889, Richard Altmann used the term nucleic acid in place of nuclein. Nucleic acids were found to be associated with various proteins called nucleoproteins. There are two types of nucleic acids viz., Deoxy ribose Nucleic acid (DNA) and Ribose Nucleic acid (RNA). DNA is the genetic material in most of the organisms. RNA acts as genetic material only in some viruses. DNA is mainly found in the chromosomes in the nucleus, while RNA is mostly found in the ribosomes in the cytoplasm.

Levene showed that nucleic acid can be broken into smaller molecules called nucleotides. Each nucleotide consists of a sugar, phosphate group and a nitrogenous base. The combination of nitrogenous base and sugar without the phosphate group is called nucleoside (riboside and deoxyriboside) whereas the combination of nitrogenous base, sugar and the phosphate group is called nucleotide (ribotide and deoxyribotide) (nucleotide = nucleoside + phosphate).

The 5-carbon (pentose) sugar could be either ribose as in case of RNA or deoxyribose in case of DNA. Associated with each sugar is a nitrogenous base with one or two carbons–nitrogen rings. Bases containing one carbon–nitrogen ring are called pyrimidines. The common pyrimidines present in DNA are thymine(T) and cytosine (C), while in case of RNA pyrimidine base thymine is replaced by uracil(U). Bases containing two carbon-nitrogen rings are called purines. The common purines present in nucleic acids are adenine (A) and guanine(G). See Fig.

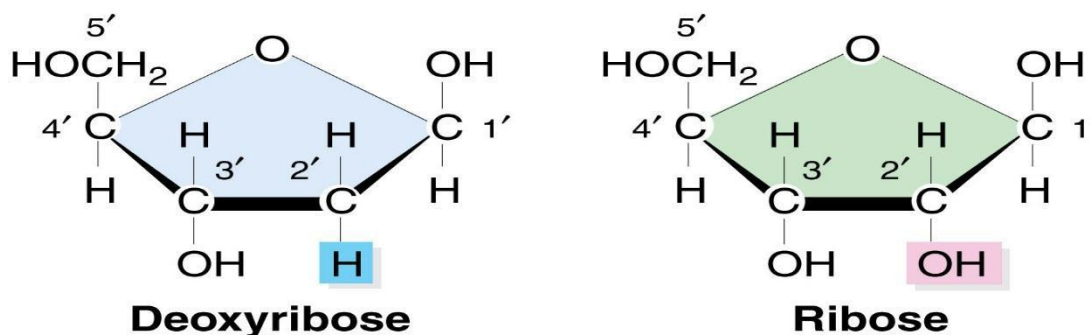
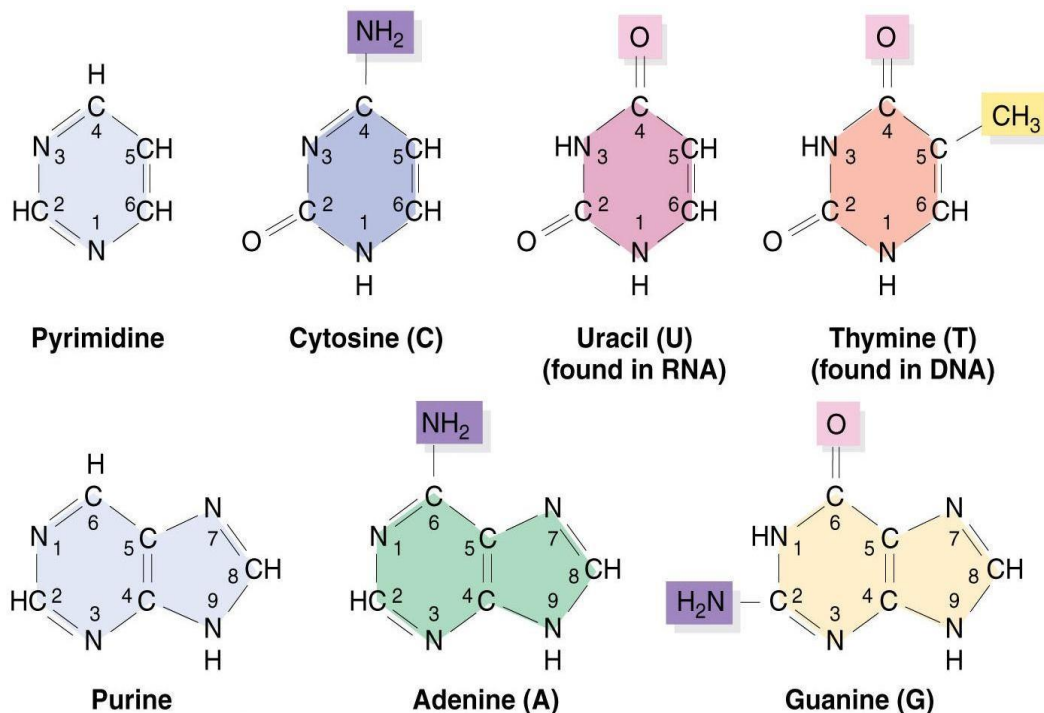


Fig: Deoxyribose and Ribose sugar



**Fig: Nitrogenous bases**

**Differences between pyrimidines and purines**

Sr.no.	Pyrimidines	Purines
1.	These are single ring (six member) compounds.	These are double ring (nine member) compounds.
2.	They are of three types, viz., cytosine, thymine and uracil	They are of two types, viz., adenine and guanine.
3.	They occupy less space in DNA structure.	They occupy more space in DNA structure.
4.	Deoxyribose is linked at position 3 of pyrimidine.	Deoxyribose is linked at position 9 of purine.

Levene proposed that each of the deoxy-ribonucleotides was present in equal amounts and connected together in chains in which each of the four different nucleotides was regularly repeated in a tetranucleotide sequence (AGCT, AGCT etc.). In 1940 Erwin Chargaff and other biochemists showed that all the nucleotide bases were not present in equal amounts and that the ratio of different bases changed between different species. It was also shown by Chargaff that the number of purine bases (A + G) is equal to the number of pyrimidine bases (C + T) i.e.  $A + G = C + T$ .

It was also shown that the ratios of adenine to thymine and guanine to cytosine are constant and close to one in various eukaryotic species. By the early 1950's X – ray studies of DNA by Wilkins, Franklin and others indicated a well-organized multiple stranded fibre of about  $22\text{\AA}$  in diameter that was also characterized by the presence of groups or bases spaced,  $3.4\text{\AA}$  apart along the fibre and occurrence of a repeating unit at every  $34\text{\AA}$ .

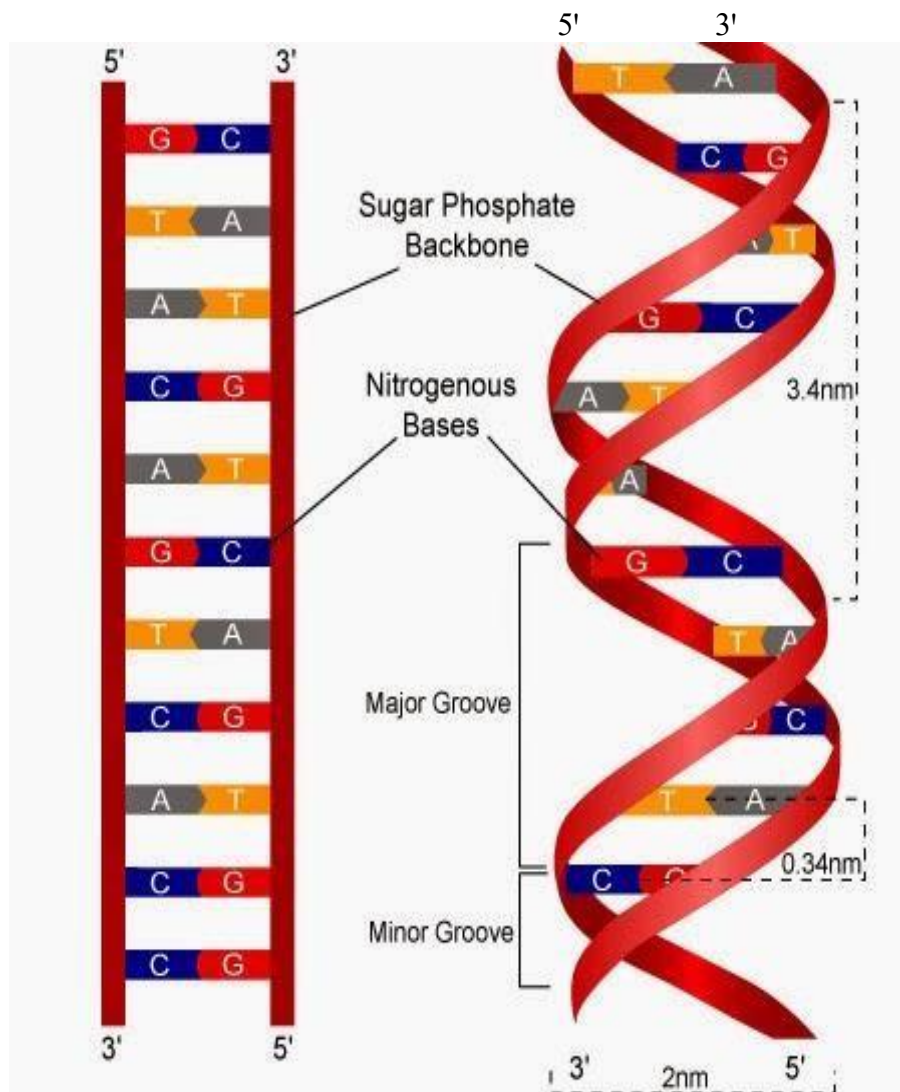
### **The DNA double helix**

Considering the facts known at that time Watson and Crick in 1953 proposed a “double helix” structure of DNA which quickly gained wide acceptance. The salient features of double helix structure of DNA are (see Fig.):

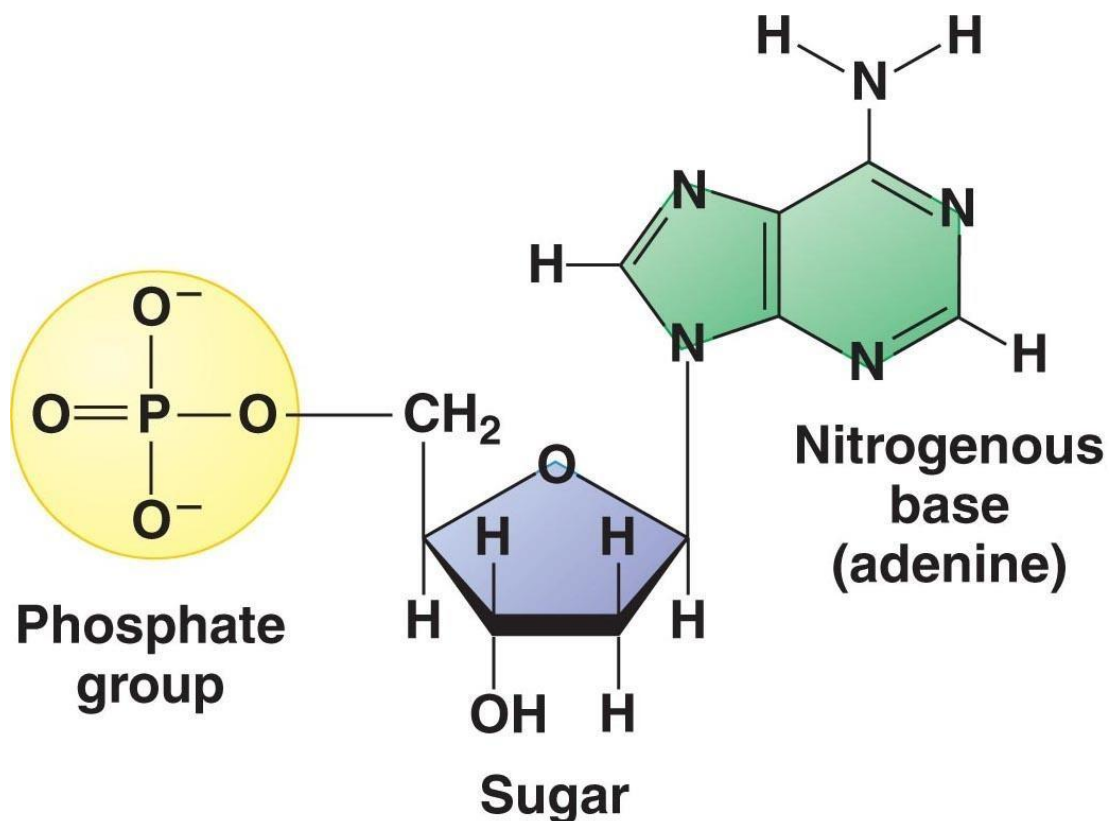
- ❖ The DNA molecule consists of two polynucleotide chains wound around each other in a right-handed double helix.
- ❖ The two strands of a DNA molecule are oriented anti-parallel to each other i.e. the 5' end of one strand is located with the 3' end of the other strand at the same end of a DNA molecule.
- ❖ Each polydeoxyribonucleotide strand is composed of many deoxyribonucleotides joined together by phosphodiester linkage between their sugar and phosphate residues and the sugar phosphate backbones are on the outsides of the double helix with the nitrogen bases oriented toward the central axis.
- ❖ The half steps of one strand extend to meet half steps of the other strand and the base pairs are called complementary base pairs. The adenine present in one strand of a DNA molecule is linked by two hydrogen bonds with the thymine located opposite to it in the second strand, and vice-versa. Similarly, guanine located in one strand forms three hydrogen bonds with the cytosine present opposite to it in the second strand, and vice-versa. The pairing of one purine and one pyrimidine maintains the constant width of the DNA double helix.
- ❖ The bases are connected by hydrogen bonds. Although the hydrogen bonds are weaker, the fact that so many of them occur along the length of DNA double helix provides a high degree of stability and rigidity to the molecule.
- ❖ The diameter of this helix is  $20\text{\AA}$ , while its pitch (the length of helix required to complete one turn) is  $34\text{\AA}$ . In each DNA strand, the bases occur at a

regular interval of  $3.4\text{\AA}$  so that about 10 base pairs are present in one pitch of a DNA double helix.

- ❖ The helix has two external grooves, a deep wide one, called major groove and a shallow narrow one, called minor groove. Both these grooves are large enough to allow protein molecules to come in contact with the bases.
- ❖ This DNA structure offers a ready explanation of how a molecule could form perfect copies of itself. During replication, the two strands of a DNA molecule unwind and the unpaired bases in the single-stranded regions of the two strands by hydrogen bonds with their complementary bases present in the cytoplasm as free nucleotides. These nucleotides become joined by phosphodiester linkages generating complementary strands of the old ones with the help of appropriate enzymes.



**Fig: The double helix model of DNA molecule as proposed by Watson and Crick**



**Fig: Chemical structure of nucleotides (Deoxyadenylic acid)**

The DNA molecule satisfies the requirement of genetic material in the following ways: -

1. It can replicate itself accurately during cell growth and division.
2. Its structure is sufficiently stable so that heritable changes i.e., mutations can occur only very rarely.
3. It has a potential to carry all kinds of necessary biological information.
4. It transmits all the biological information to the daughter cells.

Thus, the essential functions of DNA are the storage and transmission of genetic information and the expression of this information in the form of synthesis of cellular proteins.

### **Types of DNA**

The double helix described by Watson and Crick has right handed helical coiling and is called B-DNA. It is a biologically important form of DNA that is commonly and naturally found in most living systems. This double helical structure of DNA exists in other alternate forms such as A-form, C-form etc. which differ in features such as the number of nucleotide base pairs per turn of the helix. The B-form contains ~ 10

(range 10.0 – 10.6) base pairs per turn. The B-DNA is the most stable form and it can change to another form depending upon the humidity and salt concentration of the sample. The A- form is also a right-handed helix, but it has 11 base pairs per turn. The C-form of DNA has 9.3 base pairs per turn, while the D-form of DNA, which is rare form, has 8 base pairs per turn. Another form of DNA, in which the helix is left-handed, called Z-DNA was discovered by Rich. In Z-DNA sugar and phosphate linkages follow a zigzag pattern. Z-DNA plays a role in the regulation of the gene activity.

### Comparison between B-DNA and Z-DNA

Characteristic	B-DNA	Z-DNA
Coiling	Right handed	Left-handed
Pitch	34 Å <sup>0</sup>	45 Å <sup>0</sup>
Base pairs / pitch	10.4	12
Diameter	~ 20 Å <sup>0</sup>	~ 18 Å <sup>0</sup>
Rise per base pair	3.4 Å <sup>0</sup>	3.7 Å <sup>0</sup>
Sugar – phosphate backbone	Regular	Zigzag

(Pitch – The length of the helix required to complete one turn)

**Denaturation:** The hydrogen bonds between the DNA strands break on heating the DNA to high temperature (nearly 100°C). The process of separation of DNA strands is known as denaturation.

**Renaturation:** Reunion of the separated or denatured DNA strands on cooling is called renaturation or annealing. The optimum temperature for renaturation is 20 – 25°C.

