Introduction:

There are two types of nucleic acids, namely deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). Primarily, nucleic acids serve as repositories and transmitters of genetic information.

Functions of Nucleic Acids:

DNA is the chemical basis of heredity and may be regarded as the reserve bank of genetic information. DNA is exclusively responsible for maintaining the identity of different species of organisms over millions of years. Further, every aspect of cellular function is under the control of DNA. The DNA is organized into genes, the fundamental units of genetic information. The genes control the protein synthesis through the mediation of RNA, as shown below

The interrelationship of these three classes of biomolecules (DNA, RNA and proteins) constitutes the central dogma of molecular biology or more commonly the central dogma of life.

Components of Nucleic Acids:

Nucleic acids are the polymers of nucleotides (polynucleotides) held by 3′ and 5′ phosphate bridges. In other words, nucleic acids are built up by the monomeric units—nucleotides (It may be recalled that protein is a polymer of amino acids).

Nucleotides:

Nucleotides are composed of a nitrogenous base, a pentose sugar and a phosphate. Nucleotides perform a wide variety of functions in the living cells, besides being the building blocks or monomeric units in the nucleic acid (DNA and RNA) structure. These include their role as structural components of some coenzymes of B-complex vitamins (e.g. FAD, NAD^+), in the energy reactions of cells (ATP is the energy currency), and in the control of metabolic reactions.

Structure of Nucleotides:

The nucleotide essentially consists of base, sugar and phosphate. The term nucleoside refers to base + sugar. Thus, nucleotide is nucleoside + phosphate.

Purines and pyrimidine's:

The nitrogenous bases found in nucleotides (and, therefore, nucleic acids) are aromatic heterocyclic compounds. The bases are of two types—purines and pyrimidine's. Their general structures are depicted in Fig. 2.1. Purines are numbered in the anticlockwise direction while pyrimidine's are numbered in the clockwise direction. And this is an internationally accepted system to represent the structure of bases.

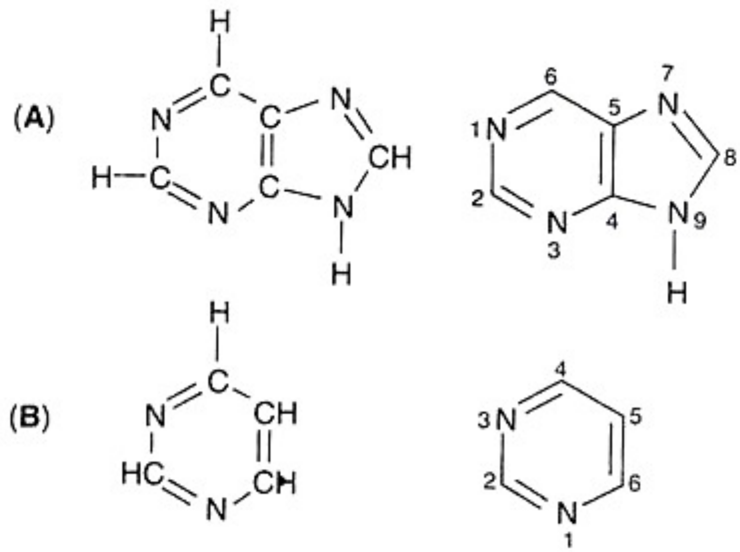

***Fig. 2.1 :** General structure of nitrogen bases **(A)** Purine **(B)** Pyrimidine (The positions are numbered according to the international system).*

Major bases in nucleic acids:

The structures of major purines and pyrimidine's found in nucleic acids are shown in Fig. 2.2. DNA and RNA contain the same purines namely adenine (A) and guanine (G). Further, the pyrimidine cytosine (C) is found in both DNA and RNA. However, the nucleic acids differ with respect to the second pyrimidine base. DNA contains thymine (T) whereas RNA contains uracil (U). As is observed in the Fig. 2.2, thymine and uracil differ in structure by the presence (in T) or absence (in U) of a methyl group.

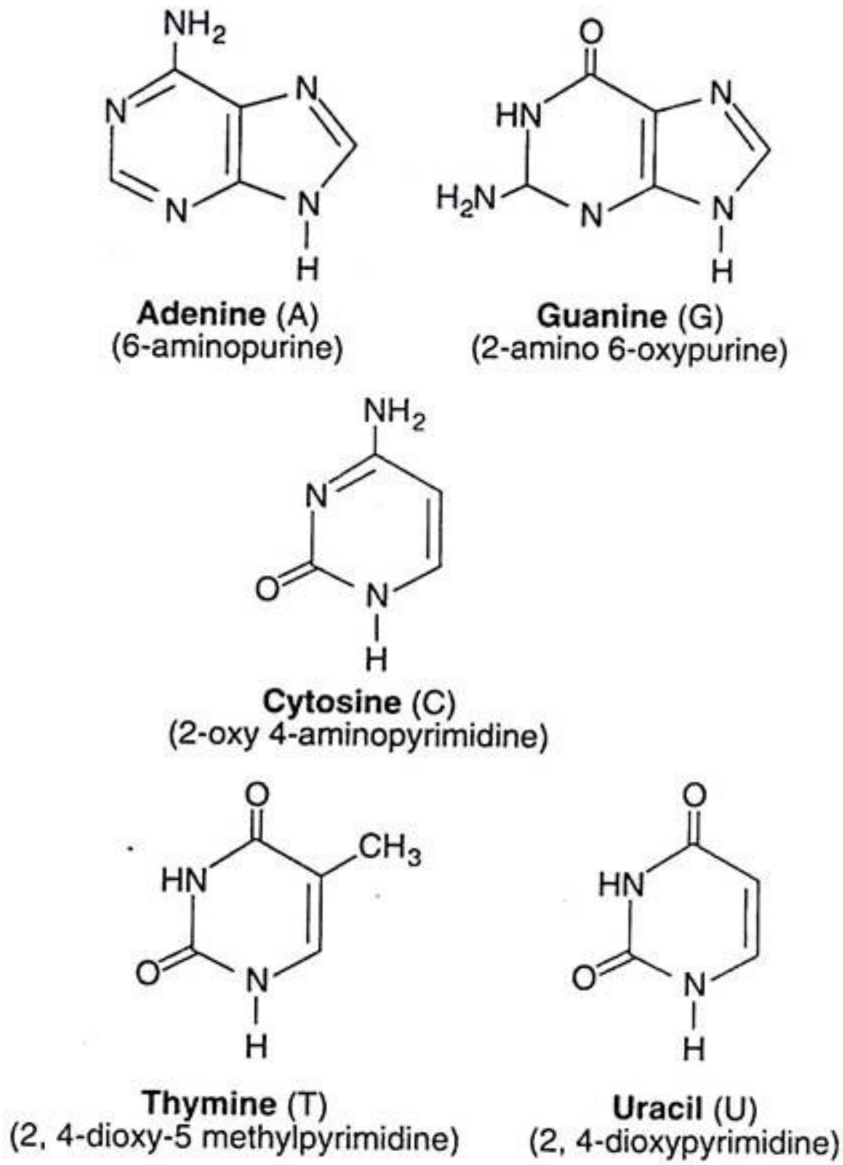

Fig. 2.2 : *Structures of major purines (A, G) and pyrimidines (C, T, U) found in nucleic acids.*

Minor bases found in nucleic acids:

Besides the bases described above, several minor and unusual bases are often found in DNA and RNA. These include 5-methylcytosine, N^4-acetylcytosine, N^6–methyladenine, N^6, N^6-dimethyladenine, pseudouracil etc. It is believed that the unusual bases in nucleic acids will help in the recognition of specific enzymes.

Sugars of Nucleic Acids:

The five carbon monosaccharide's (pentoses) are found in the nucleic acid structure. RNA contains D-ribose while DNA contains D-deoxyribose. Ribose and deoxyribose differ in structure at C_2. Deoxyribose has one oxygen less at C_2 compared to ribose (Fig. 2.4).

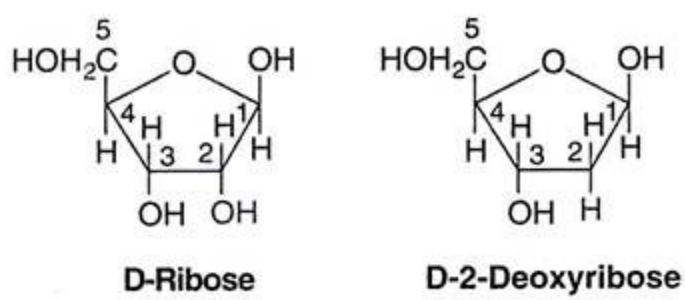

Fig. 2.4 : Structures of sugars present in nucleic acids (ribose is found in RNA and deoxyribose in DNA; Note the structural difference at C_2).

Nomenclature of Nucleotides:

The addition of a pentose sugar to base produces a nucleoside. If the sugar is ribose, ribonucleosides are formed. Adenosine, guanosine, cytidine and uridine are the ribonucleosides of A, G, C and U respectively. If the sugar is a deoxyribose, deoxyribo- nucleosides are produced.

The term mononucleotide is used when a single phosphate moiety is added to a nucleoside. Thus adenosine monophosphate (AMP) contains adenine + ribose + phosphate. The principal bases, their respective nucleosides and nucleotides found in the structure of nucleic acids are given in Table 2.1. Note that the prefix 'd' is used to indicate if the sugar is deoxyribose (e.g. dAMP).

TABLE 2.1 Principal bases, nucleosides and nucleotides

Base	*Ribonucleoside*	*Ribonucleotide (5′-monophosphate)*	*Abbreviation*
Adenine (A)	Adenosine	Adenosine 5′-monophosphate or adenylate	AMP
Guanine (G)	Guanosine	Guanosine 5′-monophosphate or guanylate	GMP
Cytosine (C)	Cytidine	Cytidine 5′-monophosphate or cytidylate	CMP
Uracil (U)	Uridine	Uridine 5′-monophosphate or uridylate	UMP
Base	***Deoxyribonucleoside***	***Deoxyribonucleotide (5′-monophosphate)***	***Abbreviation***
Adenine (A)	Deoxyadenosine	Deoxyadenosine 5′-monophosphate or deoxyadenylate	dAMP
Guanine (G)	Deoxyguanosine	Deoxyguanosine 5′-monophosphate or deoxyguanylate	dGMP
Cytosine (C)	Deoxycytidine	Deoxycytidine 5′-monophosphate or deoxycytidylate	dCMP
Thymine (T)	Deoxythymidine	Deoxythymidine 5′-monophosphate or deoxythymidylate	dTMP

Structure of DNA:

DNA is a polymer of deoxyribonucleotides (or simply deoxynucleotides). It is composed of monomeric units namely deoxyadenylate (dAMP), deoxyguanylate (dGMP), deoxycytidylate (dCMP) and deoxythymidylate (dTMP) (It may be noted here that some authors prefer to use TMP for deoxythymidylate, since it is found only in DNA). The details of the nucleotide structure are given above.

Schematic Representation of Polynucleotides:

The monomeric deoxynucleotides in DNA are held together by 3′, 5′-phosphodiester bridges (Fig. 2.6). DNA (or RNA) structure is often represented in a short-hand form. The horizontal line indicates the carbon chain of sugar with base attached to C_1-. Near the middle of the horizontal line is C_3– phosphate linkage while at the other end of the line is C_5– phosphate linkage (Fig. 2.6).

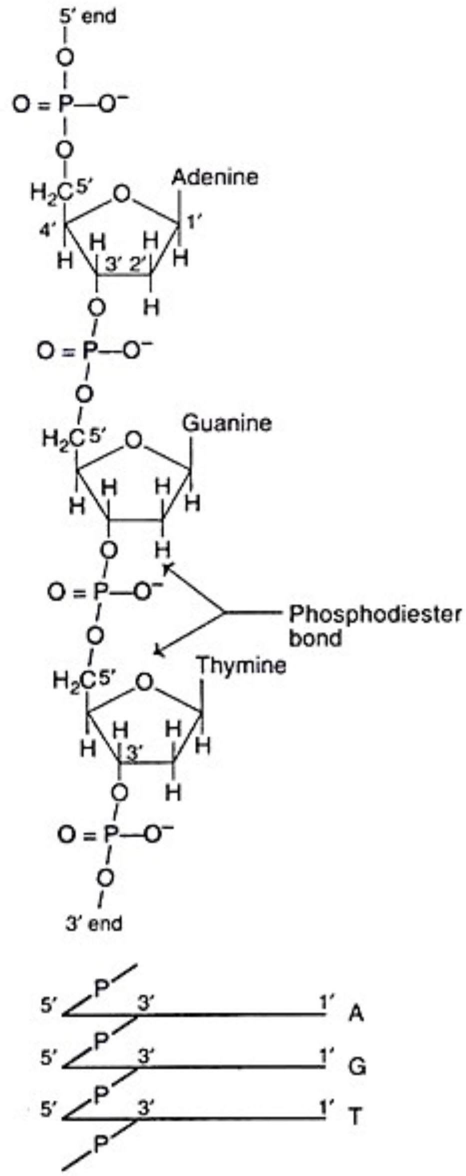

Fig. 2.6 : *Structure of a polydeoxyribonucleotide segment held by phosphodiester bonds. On the lower part is the representation of short hand form of oligonucleotides.*

Chargaff's Rule of DNA Composition:

Erwin Chargaff in late 1940s quantitatively analysed the DNA hydro lysates from different species. He observed that in all the species he studied DNA had equal numbers of adenine and thymine residues (A = T) and equal numbers of guanine and cytosine residues (G = C).

This is known as Chargaff's rule of molar equivalence between the purines and pyrimidine's in DMA structure. The significance of Chargaff's rule was not immediately realised. The double helical structure of DNA derives its strength from Chargaff's rule. Single-stranded DNA, and RNAs which are usually single-stranded, do not obey Chargaff's rule. However, double-stranded RNA which is the genetic material in certain viruses satisfies Chargaff's rule.

DNA Double Helix:

The double helical structure of DNA was proposed by James Watson and Francis Crick in 1953 (Nobel Prize, 1962). The elucidation of DNA structure is considered as a milestone in the era of modern biology. The structure of DNA double helix is comparable to a twisted ladder. The salient features of Watson-Crick model of DNA (now known as B-DNA) are given below (Fig. 2.7).

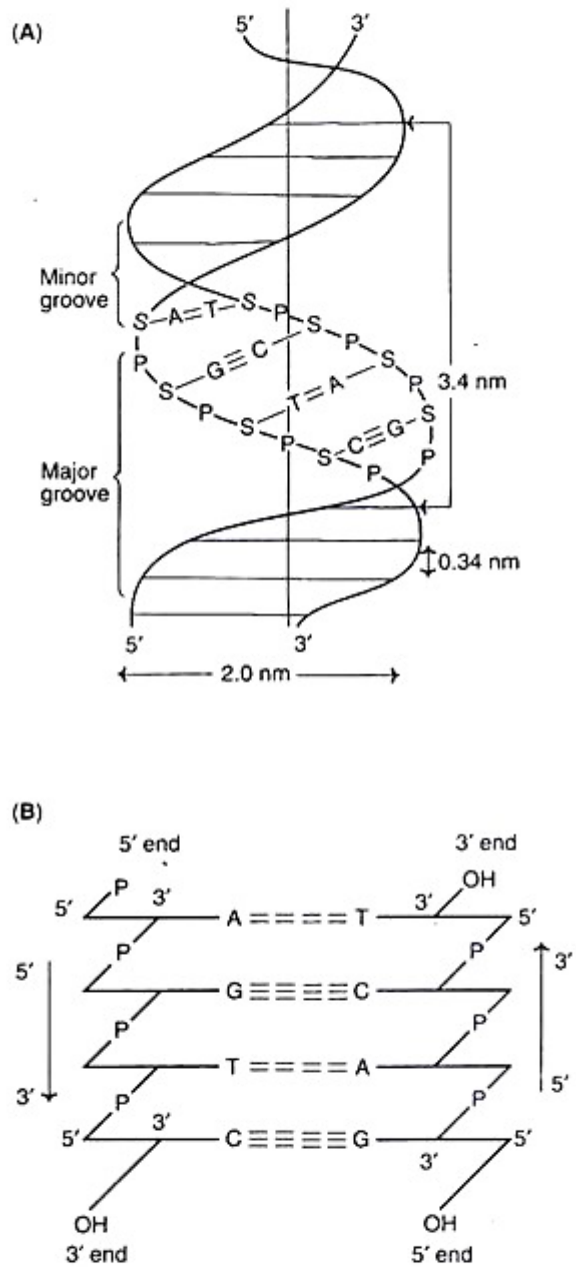

Fig. 2.7 : (A) Watson–Crick model of DNA helix (B) Complementary base pairing in DNA helix.

1. The DNA is a right handed double helix. It consists of two polydeoxyribonucleotide chains (strands) twisted around each other on a common axis.

2. The two strands are antiparallel, i.e., one strand runs in the 5′ to 3′ direction while the other in 3′ to 5′ direction. This is comparable to two parallel adjacent roads carrying traffic in opposite direction.

3. The width (or diameter) of a double helix is 20 A° (2 nm).

4. Each turn (pitch) of the helix is 34 A° (3.4 nm) with 10 pairs of nucleotides, each pair placed at a distance of about 3.4 A^0.

5. Each strand of DNA has a hydrophilic deoxyribose phosphate backbone (3'-5' phosphodiester bonds) on the outside (periphery) of the molecule while the hydrophobic bases are stacked inside (core).

6. The two polynucleotide chains are not identical but complementary to each other due to base pairing.

7. The two strands are held together by hydrogen bonds formed by complementary base pairs (Fig. 2.8). The A-T pair has 2 hydrogen bonds while G-C pair has 3 hydrogen bonds. The G ≡ C is stronger by about 50% than A = T.

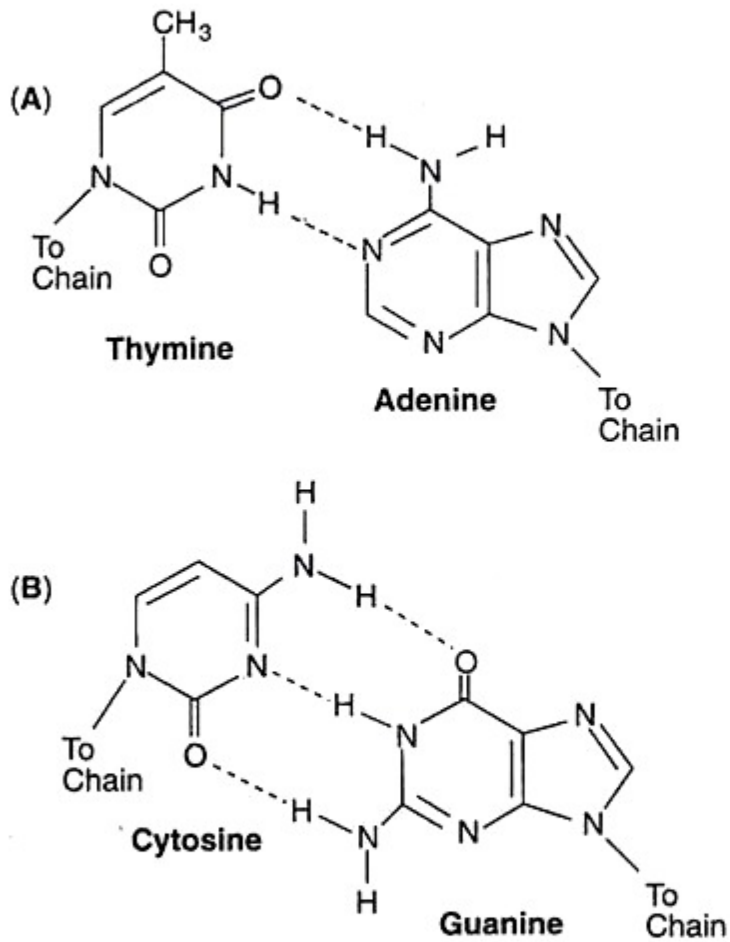

Fig. 2.8 : Complementary base pairing in DNA
(A) Thymine pairs with adenine by 2 hydrogen bonds
(B) Cytosine pairs with guanine by 3 hydrogen bonds.

8. The hydrogen bonds are formed between a purine and a pyrimidine only. If two purines face each other, they would not fit into the allowable space. And two pyrimidine's would be too far to form hydrogen bonds. The only base arrangement possible in DNA structure, from special considerations is A-T, T-A, G-C and C-G.

9. The complementary base pairing in DNA helix proves Chargaff's rule. The content of adenine equals to that of thymine (A = T) and guanine equals to that of cytosine (G = C).

10. The genetic information resides on one of the two strands known as template strand or sense strand. The opposite strand is antisense strand. The double helix has (wide) major grooves and (narrow) minor grooves along the phosphodiester backbone. Proteins interact with DNA at these grooves, without disrupting the base pairs and double helix.

Other Types of DNA Structure:

It is now recognized that besides double helical structure, DNA also exists in certain unusual structures. It is believed that such structures are important for molecular recognition of DNA by proteins and enzymes. This is in fact needed for the DNA to discharge its functions in an appropriate manner. Some selected unusual structures of DNA are briefly described.

1. Bent DNA:
2. Triple-stranded DNA:
3. Four-stranded DNA:

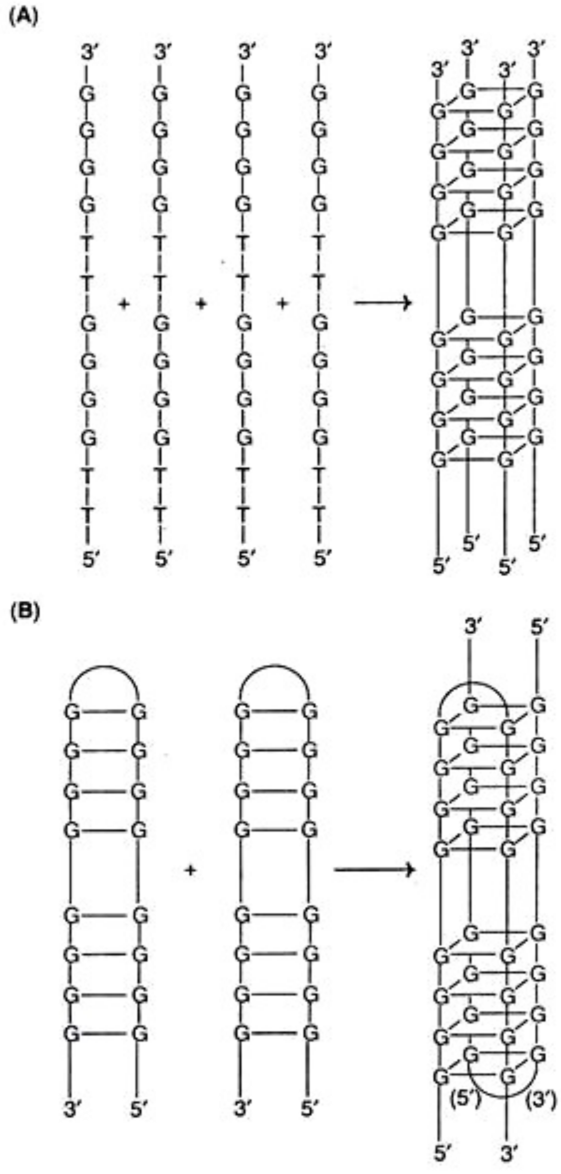

Fig. 2.10 : Four–stranded DNA structure (A) Parallel G–quartets (B) Antiparallel G–tetraplex.

The ends of eukaryotic chromosomes namely telomeres are rich in guanine, and therefore form G-tetraplexes. In recent years, telomeres have become the targets for anticancer chemotherapies. G-tetraplexes have been implicated in the recombination of immunoglobulin genes, and in dimerization of double-stranded genomic RNA of the human immunodeficiency virus (HIV).

RNA

Ribonucleic acid (RNA) is a type of molecule that consists of a long chain of nucleotide units.It have three types (r RNA , m RNA , t RNA). RNA has two main functions:

1- It mimics the information in DNA (located in the nucleus) and migrates to other parts of the cell where this information is used (messenger RNA, mRNA).

2- It has a crucial role in protein synthesis (tRNA).

Type of RNA

Of the many types of RNA, the three most well-known and most commonly studied are messenger RNA (mRNA), transfer RNA (tRNA), and ribosomal RNA (rRNA), which are present in all organisms. These and other types of RNAs primarily carry out biochemical reactions, similar to enzymes. Some, however, also have complex regulatory functions in cells. Owing to their involvement in many regulatory processes, to their abundance, and to their diverse functions, RNAs play important roles in both normal cellular processes and diseases.