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 main-taining 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

As already stated, the nucleotide essentially consists of

nucleobase, ***sugar*** and ***phosphate***. The term nucleoside refers to base + sugar. Thus, nucleotide is nucleoside + phosphate.

Purines and pyrimidines

The nitrogenous bases found in nucleotides (and, therefore, nucleic acids) are ***aromatic heterocyclic compounds***. The bases are of two types—purines and pyrimidines. Their general structures are depicted in ***Fig.5.1***. Purines are numbered in the anticlockwise direction while pyrimidines are numbered in the clockwise direction.

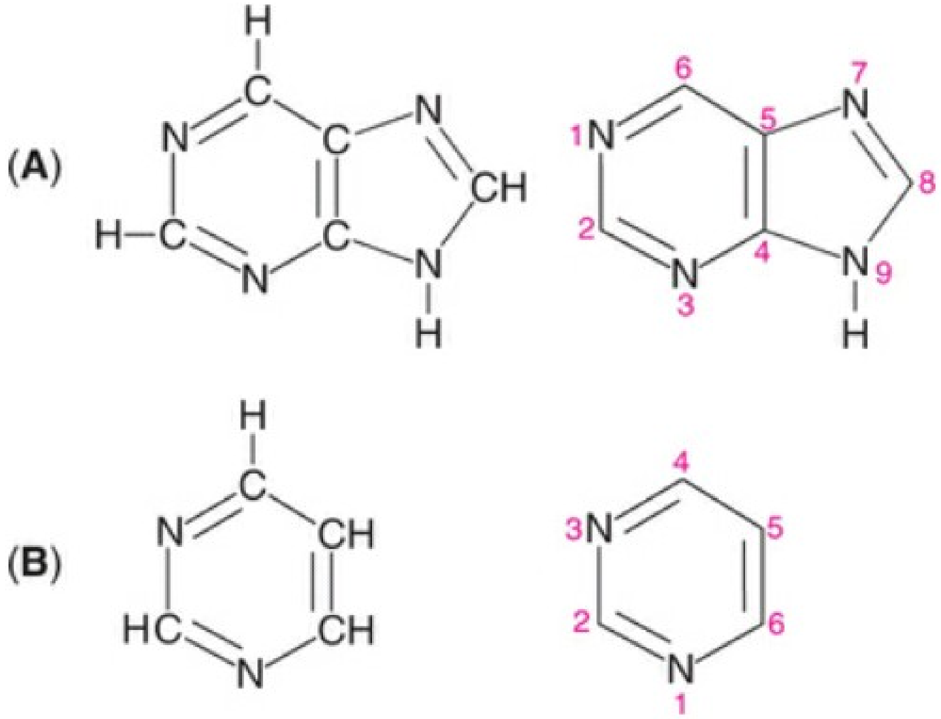
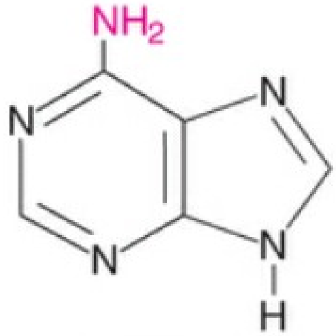


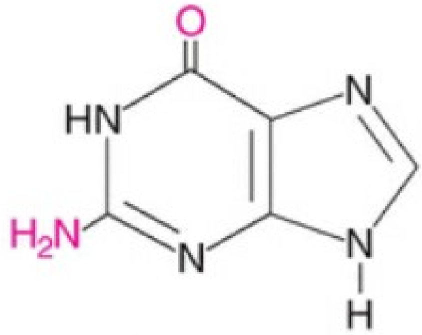
FIG. 5.1 General structure of nitrogen bases (**A**) Purine (**B**) Pyrimidine (The positions are numbered according to the international system).

Major bases in nucleic acids

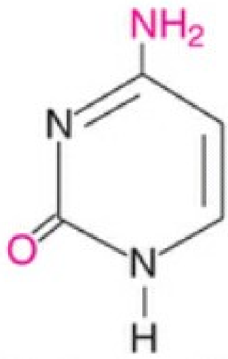
The structures of major purines and pyrimidines found in nucleic acids are shown in ***Fig.5.2***. DNA and RNA contain the same purines namely adenine (A) and guanine (G). Further, the pyrimidine cytosine (C) is found in both DNA and RNA. However, the nucleic acids differ with respect to the second pyrimidine base. ***DNA contains thymine (T) whereas RNA contains uracil (U)***. As is observed in the ***Fig.5.2***, thymine and uracil differ in structure by the presence (in T) or absence (in U) of a methyl group.



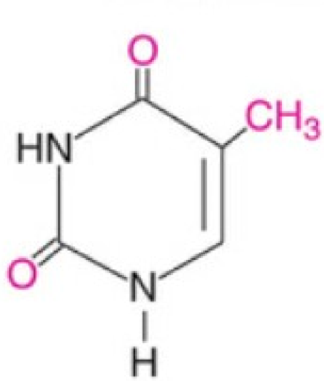
Adenine (A)
(6-aminopurine)



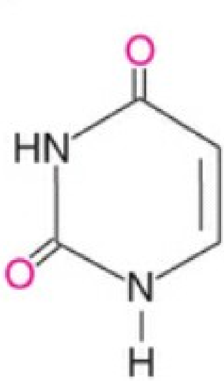
Guanine (G)
(2-amino 6-oxypurine)



Cytosine (C)
(2-oxy 4-aminopyrimidine)



Thymine (T)
(2,4-dioxy-5 methylpyrimidine)



Uracil (U)
(2,4-dioxypyrimidine)

Sugars of nucleic acids

The five carbon monosaccharides (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.5.5***).

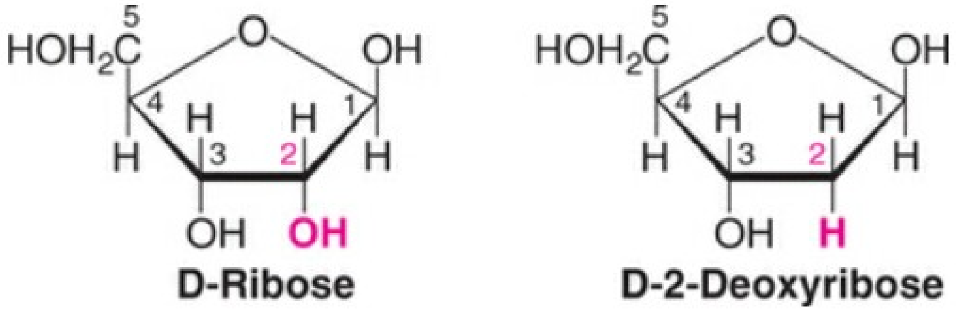


FIG. 5.5 Structures of sugars present in nucleic acids (ribose is found in RNA and deoxyribose in DNA; Note the structural difference at C_2).

The structures of two selected nucleotides namely AMP and TMP are depicted in ***Fig.5.6***.

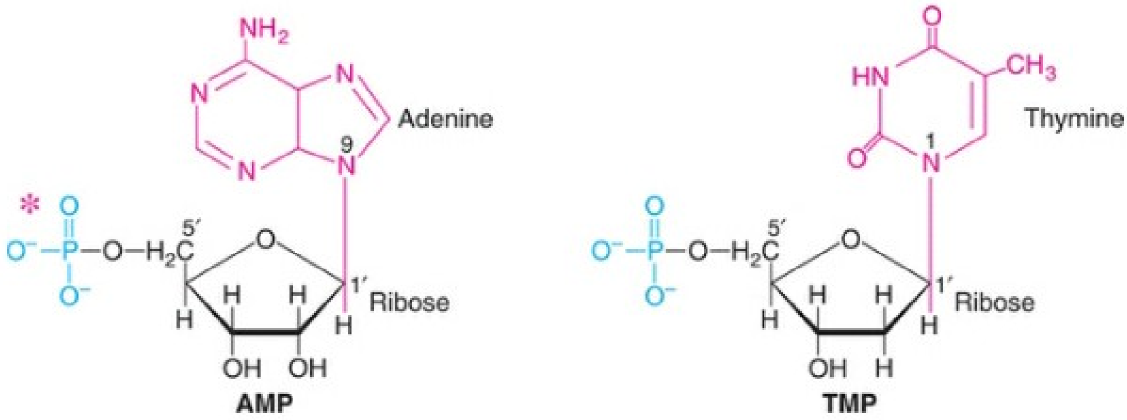


FIG. 5.6 The structures of adenosine 5'-monophosphate (AMP) and thymidine 5'-monophosphate (TMP) [*-Addition of second or third phosphate gives adenosine diphosphate (ADP) and adenosine

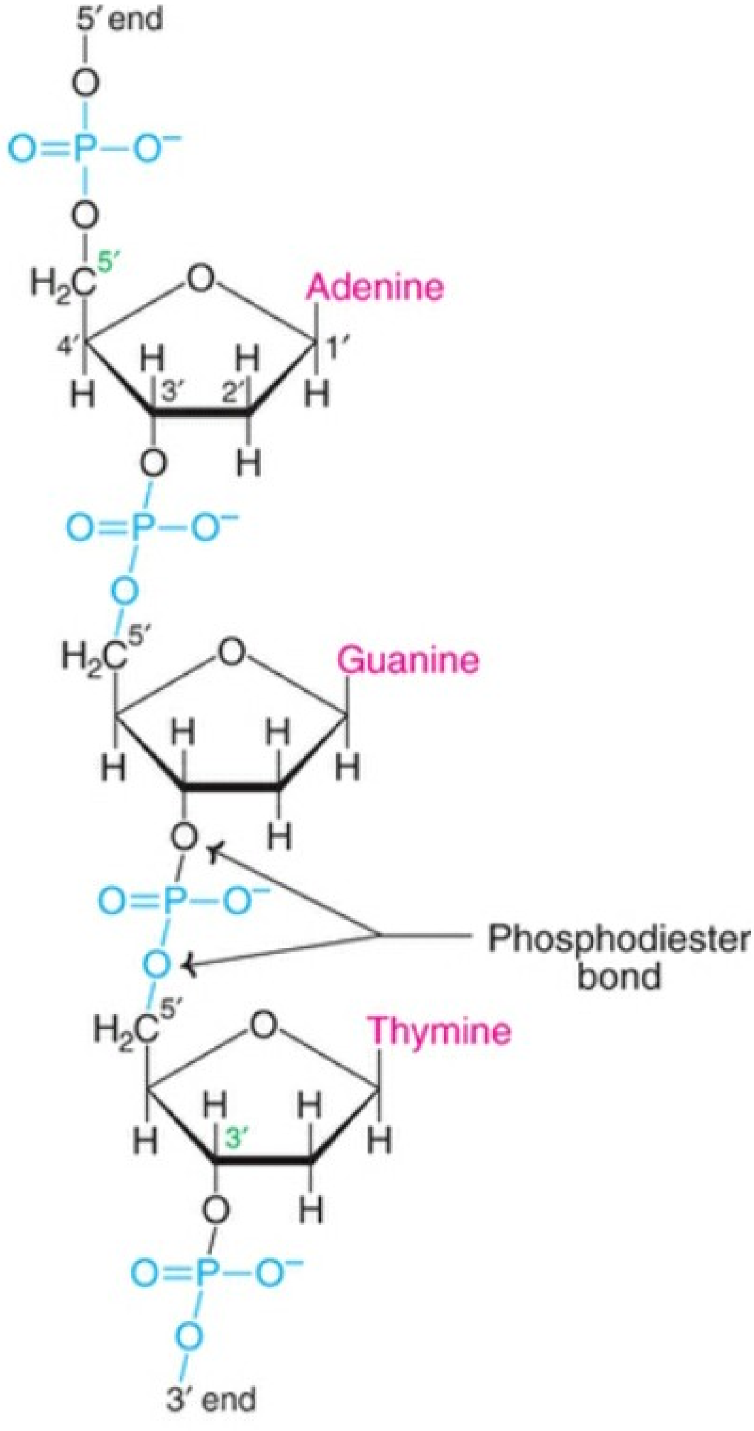
Structure of DNA

DNA is a ***polymer of deoxyribonucleotides*** (or simply deoxynucleotides). It is composed of monomeric units namely deoxyadenylate (dAMP), deoxyguanylate

Schematic representation of polynucleotides

The monomeric ***deoxynucleotides*** in DNA are ***held*** together by ***3′,5′-phosphodiester bridges*** (***Fig.5.8***). 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.5.8***).


5′ end
Adenine
Guanine
Phosphodiester
bond
Thymine
3′ end

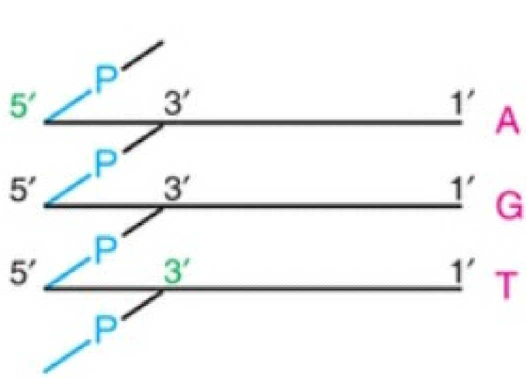

5′
3′
1′
A
5′
3′
1′
G
5′
3′
1′
T

FIG. 5.8 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 hydrolysates 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 pyrimidines in DNA*** structure. The significance of Chargaff's rule was not immediately realised. The double helical structure of DNA derives its strength from Chargaff's rule