BIOMOLECULES

NUCLEIC ACIDS

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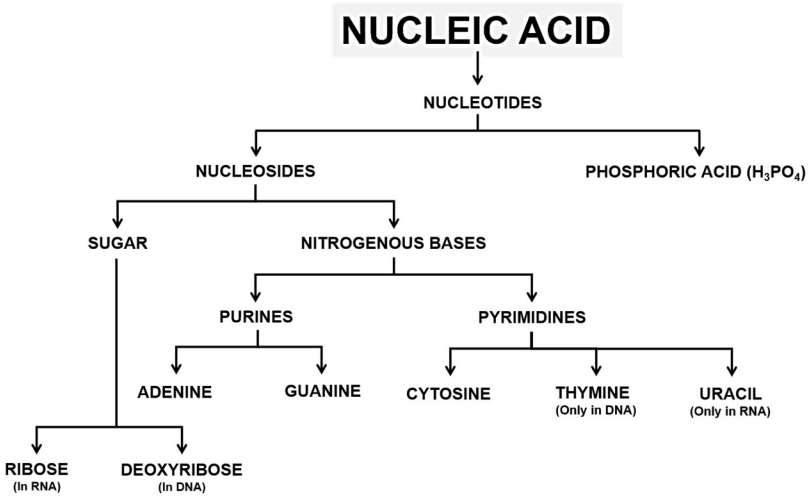
- The other type of macromolecule that one would find in the acid insoluble fraction of any living tissue is the nucleic acid.
- These are polynucleotides (monomer = Nucleotide).
- Nucleotide = Nitrogenous Base + Sugar + Phosphate group (PO_4^{-3}).
- Together with polysaccharides and polypeptides these comprise the true macromolecular fraction of any living tissue or cell.
- A nucleotide has three chemically distinct components. One is a heterocyclic compound, the second is a monosaccharide and the third a phosphoric acid or phosphate.
- It is of two types:
  - DNA
  - RNA



A. DNA (Deoxyribonucleic Acid)

- It is found in the cells of all living organisms except plant viruses (where RNA forms the genetic material).
- In bacteriophages and viruses there is a single molecule of DNA, which remains coiled and is enclosed in the protein coat.
- In bacteria, mitochondria, plastids and other prokaryotes, DNA is circular and lies naked in the cytoplasm.
- In eukaryotes, it is found in nucleus and known as carrier of genetic information and capable of self-replication.

1. Chemical Composition

The chemical analysis has shown that DNA is composed of three different types of compounds.

(i) Sugar molecule

A five carbon sugar in nucleic acid. It is represented by a pentose sugar.

This sugar is deoxyribose or 2-deoxyribose which is derived from ribose.

(ii) Phosphoric acid: H_3PO_4 that makes DNA acidic in nature.

(iii) Nitrogenous base

- Two pyrimidines (cytosine and thymine) and two purines (adenine and guanine) in DNA.
- These are nitrogen containing ring compounds.
- They are classified into two groups:

a. Purines: Two ring compounds namely Adenine and Guanine.

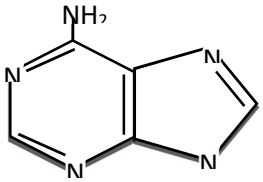
b. Pyrimidine: One ring compounds and include Cytosine and Thymine. In RNA, Uracil is present instead of Thymine.

Nucleosides:

- Nucleosides are formed by a purine or pyrimidine nitrogenous base and pentose sugar.
- DNA nucleosides are known as deoxyribose nucleosides.
- Nucleoside = Sugar + Nitrogenous Base.

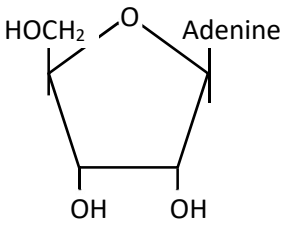
Nucleotides:

- In a nucleotide, purine or pyrimidine nitrogenous base is joined by deoxyribose pentose sugar (D).
- It is further linked with phosphate (P) group to form nucleotides.
- Nucleotide = Nucleoside + Phosphate group (PO_4^{-3})



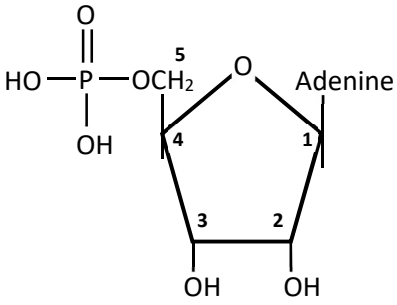
Adenine

Nitrogenous



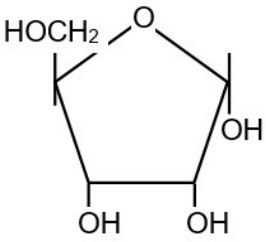
Adenosine

Nucleoside

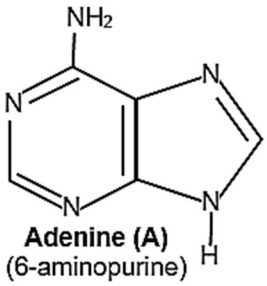


Adenylic acid

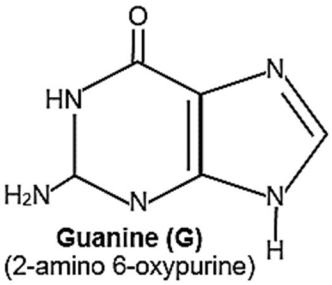
Nucleotide



Pentose sugar = Ribose



Adenine (A)
(6-aminopurine)



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

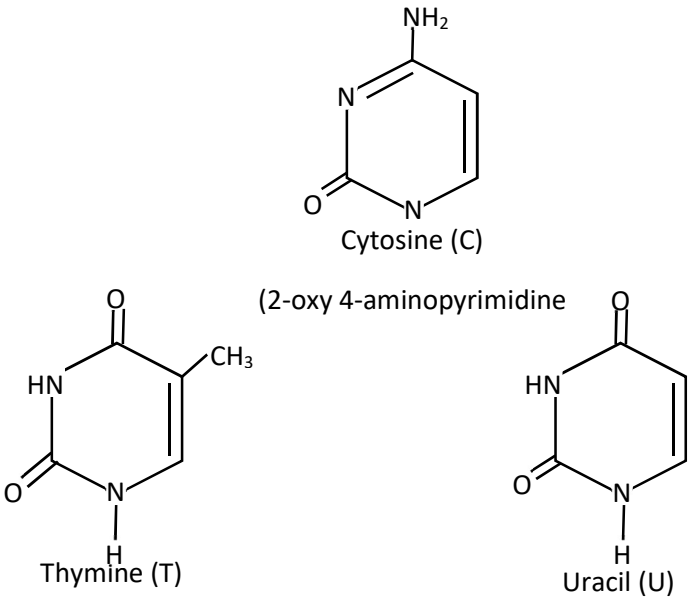


Figure: Structures of major purines (A, G) and pyrimidines (C, T, U) found in nucleic acids

2. Watson and Crick's model of DNA

- In 1953 James Watson and Francis Crick suggested that in a DNA molecule there are two polynucleotide chains arranged antiparallal or in opposite directions *i.e.*, one polynucleotide chain runs in $5^{'}$ to $3^{'}$ direction, the other in $3^{'}$to $5^{'}$ direction.
- It means the $3^{'}$ end of one chain lies beside the $5^{'}$ end of other in right handed manner.

Important features

- Nucleic acids exhibit a wide variety of secondary structures.
- For example, one of the secondary structures exhibited by DNA is the famous Watson-Crick model.
- This model says that DNA exists as a double helix.
- The double helix comprises of two polynucleotide chains.
- The two strands (polynucleotide chains) of double helix are anti-parallel due to phosphodiester bond.
- Each polynucleotide chain has a sugar-phosphate 'backbone' with nitrogenous bases directed inside the helix.

- The nitrogenous bases of two antiparallel polynucleotide strands are linked through hydrogen bonds. There are two hydrogen bonds between A and T, and three between G and C.
- The two polynucleotides in a double helix are complementary.
- Complementary base pairing is of fundamental importance in molecular genetics.

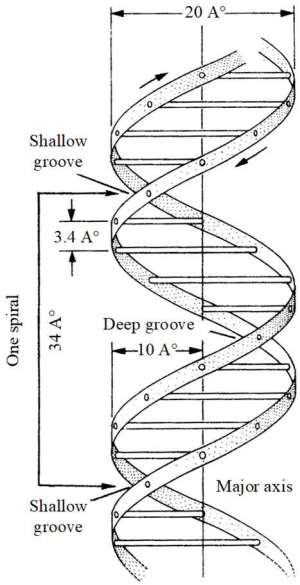


Fig. Double helical structure of DNA

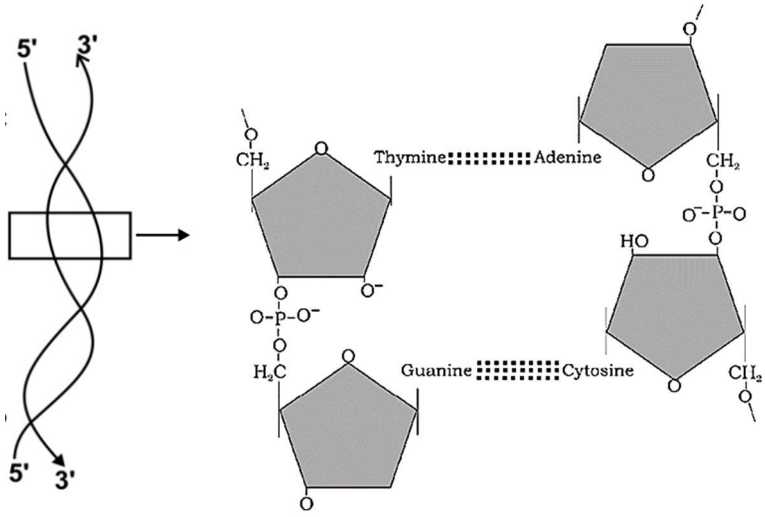


Fig. Diagram indicating secondary structure of DNA

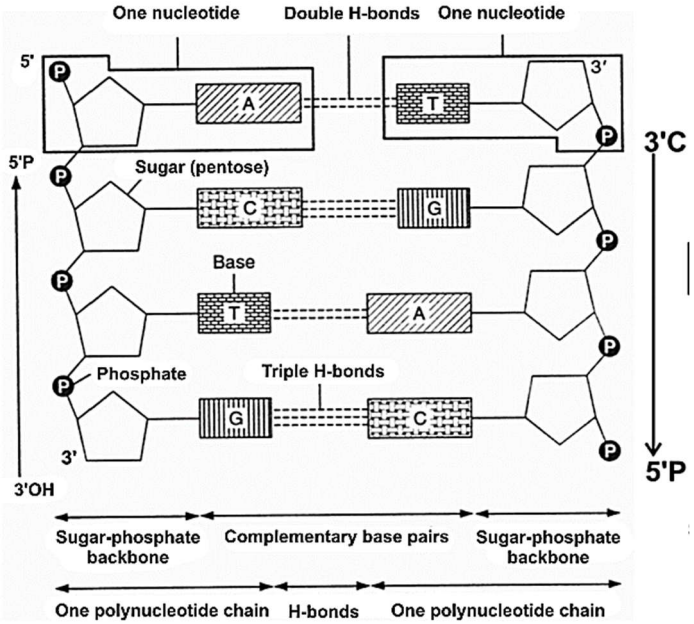


Figure: Diagrammatic representation of Watson and Crick's model of DNA

- **Erwin Chargaff** (1950) made quantitative analysis of DNA and proposed "base equivalence rule" stating that molar concentration of A = T & G ≈ C or $\frac{A+G}{C+T}=1$ irrespective of species and $\frac{A+T}{G+C}$ is constant for a species. Sugar deoxyribose and phosphate occur in equimolar proportion.
- Ten base pairs occur per turn of helix (abbreviated 10bp). The distance between adjacent base pairs is approximately 3.4 Å. The helix is 20 Å (19.8 Å) in diameter.
- Purine = Pyrimidine
- A + G = T + C
- $\frac{A+G}{T+C}=1$

B. RNA (Ribonucleic Acid)

1. Structure of RNA

- More commonly RNA is a single stranded structure consisting of an unbranched polynucleotide chain, but it is often folded back on itself forming helices.
- RNA is made up of:

(i) **Sugar:** Ribose

(ii) **Phosphoric acid:** (H_3PO_4)

(iii) **Nitrogenous bases** are two types:

a. Purines **b.** Pyrimidines

a. Purines are further divided into Adenine and Guanine.

b. Pyrimidines are divided into Cytosine and Uracil.

Types of RNA

(i) **Genetic RNA**

- In most of the plant viruses, some animal viruses and in many bacteriophages, DNA is not found and RNA acts as hereditary material.
- This RNA may be single stranded or double stranded.

(ii) Nongenetic RNA

- In the all other organisms where DNA is the hereditary material, different types of RNA are nongenetic.
- In general, three types of RNAs have been distinguished.

a. Messenger RNA (mRNA)

- It forms 5% of total RNA.
- It is complementary strand to DNA template and carries genetic information to the cytoplasm for the synthesis of proteins.
- It acts as a template for protein synthesis and has a short life span.

b. Ribosomal RNA (rRNA)

- rRNA constitutes upto 80% of total RNA of the cell.
- Inside the ribosomes of eukaryotic cells rRNA occurs in the form of the particles of four different dimensions.
- These are designated 28S, 18S, 5.8S and 5S. The 28S, 5.8 S and 5S molecules occur in large subunit (60S subunit) of ribosome, whereas 18S molecule is present in the small subunit (40S subunit) of ribosome.

c. Transfer RNA (tRNA)

- It is about 10-15% of RNA of the cell.
- tRNA molecules have been variously termed as soluble RNA or supernatant RNA or adapter RNA.
- tRNA molecules are smallest.