Structure of DNA

Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are the two types of nucleic acids found in living systems. DNA acts as the genetic material in most of the organisms. RNA though it also acts as a genetic material in some viruses, mostly functions as a messenger. RNA has additional roles as well. It functions as adapter, structural, and in some cases as a catalytic molecule.

THE DNA

DNA is a long polymer of deoxyribonucleotides. The length of DNA is usually defined as number of nucleotides (or a pair of nucleotide referred to as base pairs) present in it.

A nucleotide has three components – a nitrogenous base, a pentose sugar (ribose in case of RNA, and deoxyribose for DNA), and a phosphate group. There are two types of nitrogenous bases – Purines (Adenine and Guanine), and Pyrimidines (Cytosine, Uracil and Thymine). Cytosine is common for both DNA and RNA and Thymine are present in DNA. Uracil is present in RNA at the place of Thymine.

DNA as an acidic substance present in nucleus was first identified by Friedrich Meischer in 1869.

In 1953 that James Watson and Francis Crick, based on the X-ray diffraction data produced by Maurice Wilkins and Rosalind Franklin, proposed a very simple but famous Double Helix model for the structure of DNA.

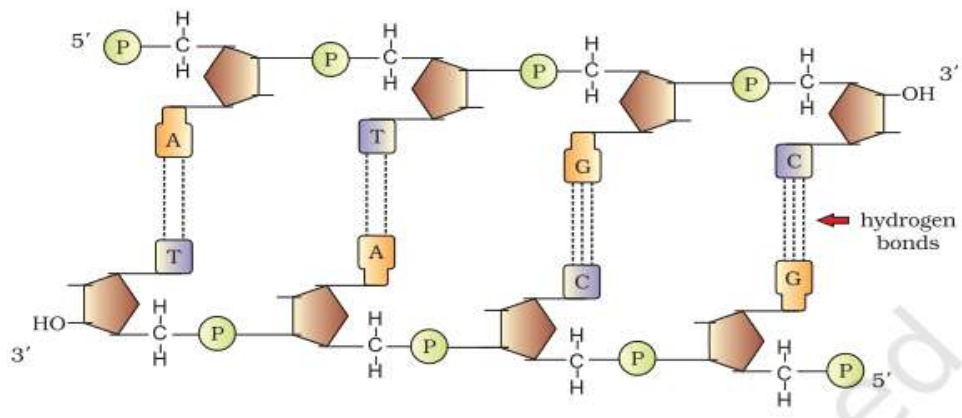
This proposition was also based on the observation of Erwin Chargaff that for a double stranded DNA, the ratios between Adenine and Thymine and Guanine and Cytosine are constant and equal one.

Each strand from a DNA (let us call it as a parental DNA) acts as a template for synthesis of a new strand, the two double stranded DNA. Thus, produced would be identical to the parental DNA molecule.

The salient features of the Double-helix structure of DNA are as follows:

a) It is made of two polynucleotide chains, where the backbone is constituted by sugar-phosphate, and the bases project inside.
b) The two chains have anti-parallel polarity. It means, if one chain has the polarity 5'$\rightarrow$3', the other has 3'$\rightarrow$5'.
c) The bases in two strands are paired through hydrogen bond (H-bonds) forming base pairs (bp). Adenine forms two hydrogen bonds with Thymine from opposite strand and vice-versa. Similarly, Guanine is bonded with Cytosine with three H-bonds. As a result,

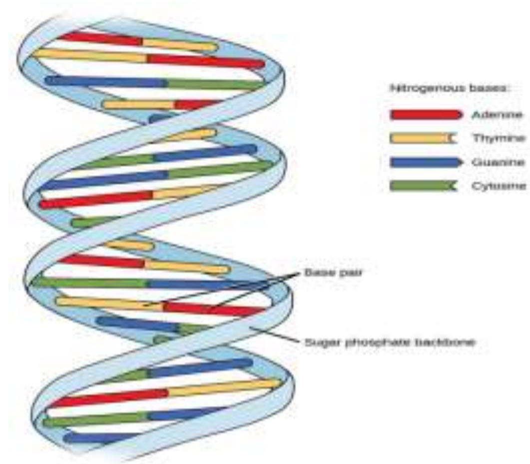
always a purine comes opposite to a pyrimidine. This generates approximately uniform distance between the two strands of the helix.



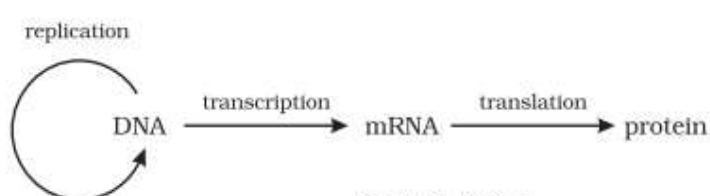
Double stranded polynucleotide chain

d) The two chains are coiled in a right-handed fashion. The pitch of the helix is 3.4 nm (a nanometre is one billionth of a metre, that is 10^{-9} m) and there are roughly 10 bp in each turn. Consequently, the distance between a bp in a helix is approximately 0.34 nm.

e) The plane of one base pair stacks over the other in double helix. This, in addition to H-bonds, confers stability of the helical structure.



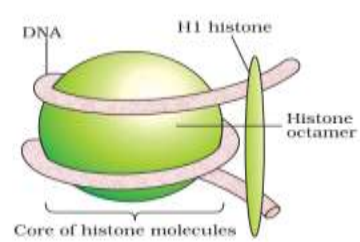
DNA double helix



Central dogma

Packaging of DNA Helix

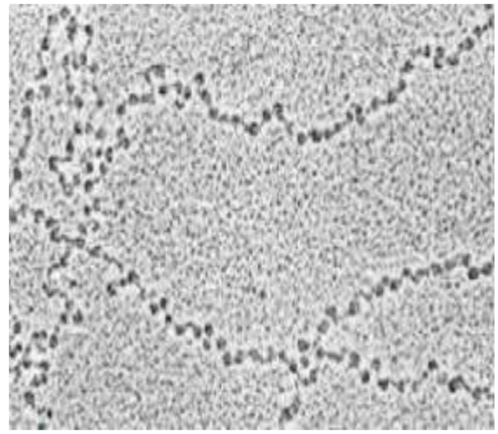
There is a set of positively charged, basic proteins called histones.



Nucleosome

Histones are organised to form a unit of eight molecules called histone octamer. The negatively charged DNA is wrapped around the positively charged histone octamer to form a structure called nucleosome.

Nucleosomes constitute the repeating unit of a structure in nucleus called chromatin, threadlike stained (coloured) bodies seen in nucleus. The nucleosomes in chromatin are seen as 'beads-on-string' structure when viewed under electron microscope (EM).



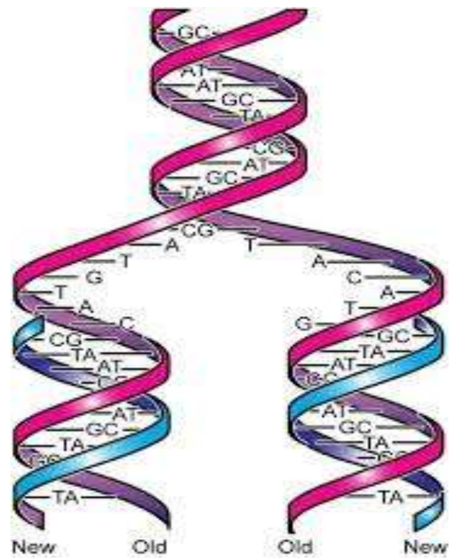
EM picture - 'Beads-on-String

REPLICATION

(Watson and Crick, 1953).

The two strands would separate and act as a template for the synthesis of new complementary strands. After the completion of replication, each DNA molecule would have one parental and one newly synthesized strand. This scheme was termed as **semiconservative** DNA replication.

Watson-Crick model for semiconservative DNA replication →



TRANSCRIPTION

The process of copying genetic information from one strand of the DNA into RNA is termed as transcription.

Adenosine complements now forms base pair with uracil instead of thymine.

Transcription only a segment of DNA and only one of the strands is copied into RNA.

Transcription Unit

A transcription unit in DNA is defined primarily by the three regions in the DNA:

a) A Promoter
b) The Structural gene

c) A Terminator

The Gene

A gene is defined as the functional unit of inheritance. Though there is no ambiguity that the genes are located on the DNA, it is difficult to literally define a gene in terms of DNA sequence. The DNA sequence coding for tRNA or rRNA molecule also define a gene.

Types of RNA

There are three major types of RNAs: mRNA (messenger RNA), tRNA (transfer RNA), and rRNA (ribosomal RNA). All three RNAs are needed to synthesise a protein in a cell. The mRNA provides the template, tRNA brings aminoacids and reads the genetic code, and rRNAs play structural and catalytic role during translation.

GENETIC CODE

There are only 4 bases and if they have to code for 20 amino acids, the code should constitute a combination of bases. He suggested that in order to code for all the 20 amino acids, the code should be made up of three nucleotides.

Providing proof that the codon was a triplet, was a more daunting task. The chemical method developed by Har Gobind Khorana was instrumental in synthesising RNA molecules with defined combinations of bases (homopolymers and copolymers).

The salient features of genetic code are as follows:

i. The codon is triplet. 61 codons code for amino acids and 3 codons do not code for any amino acids, hence they function as stop codons.
ii. Some amino acids are coded by more than one codon, hence the code is degenerate.
iii. The codon is read in mRNA in a contiguous fashion. There are no punctuations.
iv. The code is nearly universal: for example, from bacteria to human UUU would code for Phenylalanine (phe). Some exceptions to this rule have been found in mitochondrial codons, and in some protozoans.
v. AUG has dual functions. It codes for Methionine (met), and it also act as initiator codon.
vi. UAA, UAG, UGA are stop terminator codons.

TRANSLATION

Translation refers to the process of polymerisation of amino acids to form a polypeptide.