Lecture title: NUCLEIC ACIDS

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NUCLEIC ACIDS

(DNA and RNA)

Two types of nucleic acids are present in all animal cells. They are DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). DNA is present in nucleus and mitochondria. RNA is present in nucleus and cytoplasm. Nucleic acids are also present in bacteria, viruses and plants.

Biochemical Importance:

1. Nucleic acids serve as genetic material of living organisms.
2. Nucleic acids are involved in the storage, transfer and expression of genetic information.
3. Nucleic acids contain all the necessary information required for the formation of individual or organism.
4. Some nucleic acids act as enzymes and coenzymes. For example RNA acts as catalyst (ribozyme).

Chemical nature of nucleic acids

Nucleic acids are acidic substances containing nitrogenous bases, sugar and phosphorus. Both DNA and RNA are polynucleotides.

They are polymers of nucleotides.

Phosphodiester linkage

In polynucleotides, nucleotides are joined together by phosphodiester bond. Diester linkage of phosphate joins 3′ OH and 5′ OH belonging two separate sugars (figure).

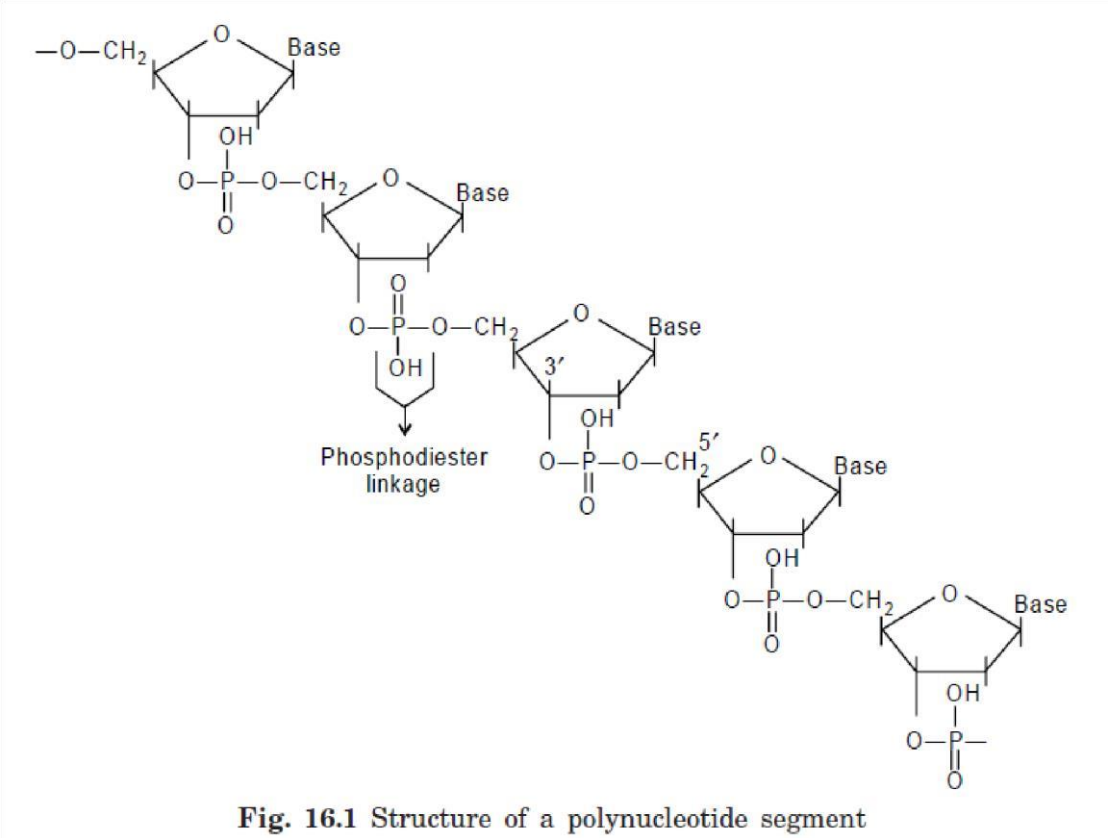
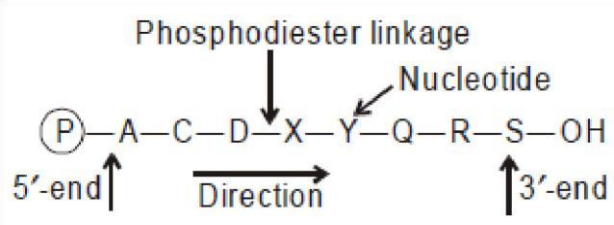


Fig. 16.1 Structure of a polynucleotide segment

Nucleic acid structure

1. Nucleotide sequence of a polynucleotide is known as primary structure of nucleic acid.
2. Polynucleotide chain has direction. They are represented in 5′ → 3′ direction only. Each polynucleotide chain has two ends. The 5′ end carrying phosphate is shown on the left hand side and 3′ end carrying unreacted hydroxyl is shown on the right hand side (Figure).



DNA structure

1. In DNA, number of adenine is equal to the number of thymine *i.e.,*

A = T. And number of guanine is equal to number of cytosine

i.e., G = C. Therefore sum of purine is equal to sum of pyrimidine (A + G = C + T).

2. DNAs from different tissues of same species have same base composition.
3. Base composition of DNA varies from one species to another species.
4. DNAs from closely related species have similar base composition.
5. DNAs of widely different species have different base composition 6. DNA base composition of a species is not affected by age, nutritional state and environment.

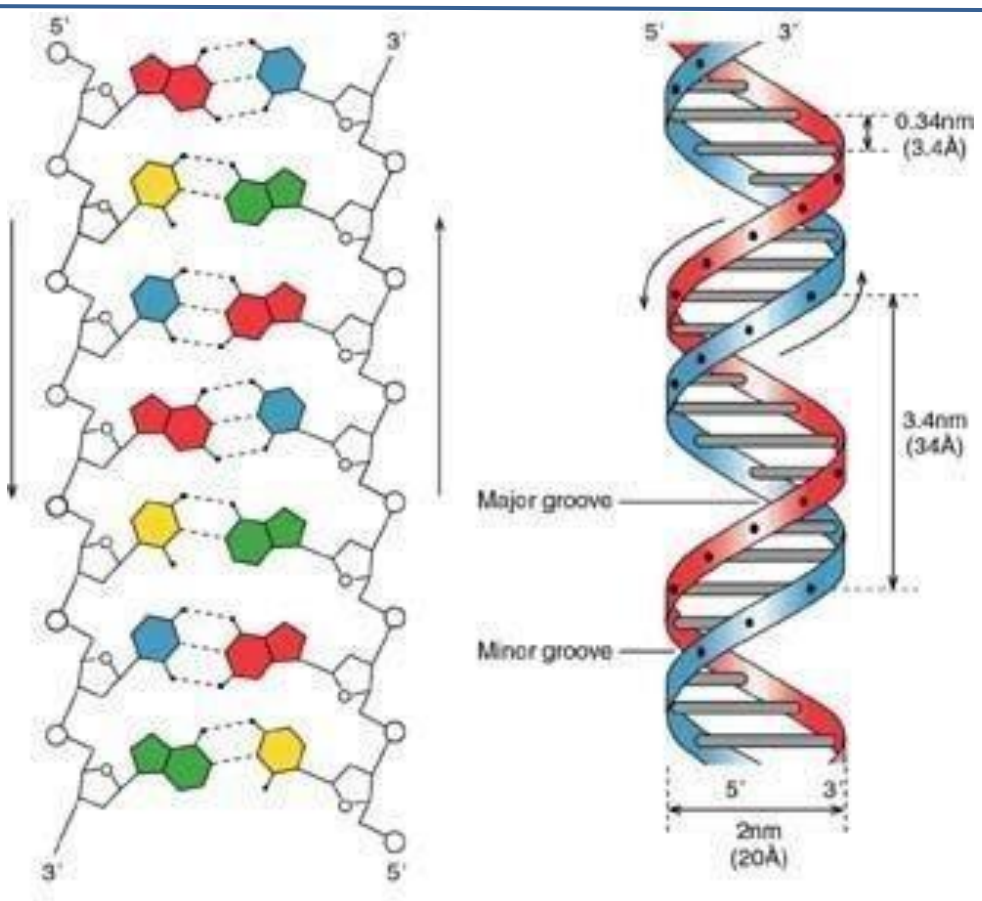
In 1953, Watson and Crick proposed precise three dimensional model of DNA structure.

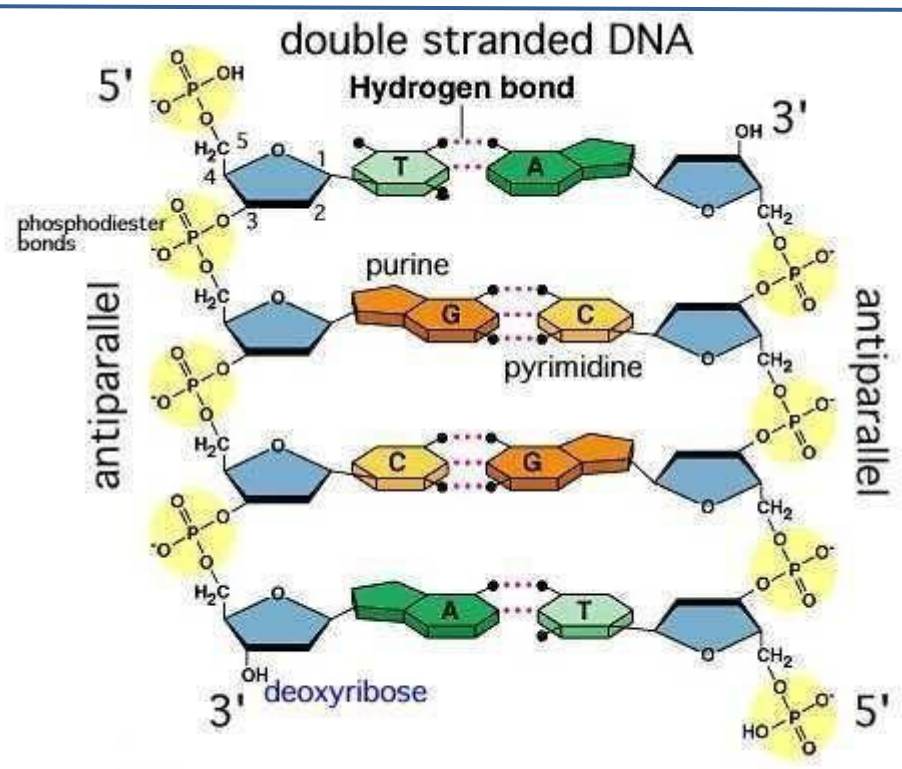
This model is popularly known as DNA double helix. Using this model, they also suggested a precise mechanism for the transfer of genetic information from parent cells to daughter cells.

Features of double helix

1. Two polynucleotide chains are coiled around a central axis in the form of right handed double helix. It represents secondary structure of DNA.

2. Each polynucleotide chain is made up of 4 types of nucleotides. They are adenylate (A), guanylate (G), thymidylate (T), and cytidylate (C).
3. Each polynucleotide chain has two directions; 5′ phosphorylated end and 3′ hydroxyl end.
4. The back bone of each strand consists of alternating sugar and phosphates.
5. The two strands run in opposite direction, i.e., they are **antiparallel.**
6. The strands are **complementary** to each other. Base composition of one strand is complementary to the opposite strand. If adenine (A) appears in one strand thymine (T) is found in the opposite strand and vice versa. Where ever guanine (G) is found in one strand cytosine (C) is present in the opposite strand and vice versa.
7. **Base pairing:** Bases of opposite strands are involved in pairing. Pairing occurs through hydrogen bonding and it is specific. Adenine of one strand pairs with thymine of opposite strand through two hydrogen bonds. Guanine of one strand pairs with cytosine of opposite strand. Three hydrogen bonds between G-C pair makes it stronger than A-T pair.
8. The large number of hydrogen bonds along entire length of DNA makes DNA molecule highly stable.
9. Major and minor grooves are present on double helix.


5'
3'
3'
5'
5'
3'
0.34nm
(3.4Å)
3.4nm
(34Å)
Major groove
Minor groove
5'
3'
2nm
(20Å)



Functions of DNA

1. DNA is the genetic material of living systems.
2. DNA contains all the information required for the formation of an individual or organism.
3. The genetic information in DNA is converted to characteristic features of living organisms like color of the skin and eye, height, intelligence, ability to metabolize particular substance, susceptibility to disease, and ability and inability to produce or synthesize certain substances etc.
4. All the above phenotype characters of living organisms are intimately related to functions of proteins. Thus, DNA is the source

   of information for the synthesis of all cellular proteins. The segment of DNA that contains information for a protein is known as ***gene***.

5. DNA is transmitted from parent to offspring and hence DNA flows from one generation to other in a given species. Further, DNA provides information inherited from parent cells to daughter cells.

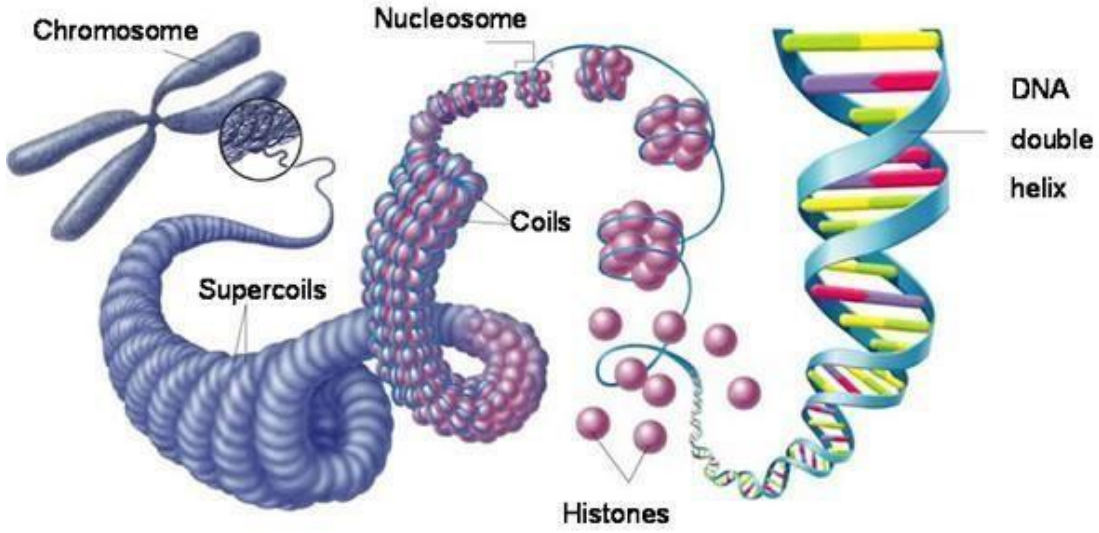
Eukaryotic DNA

In non-dividing eukaryotic cell DNA exist as nucleoprotein called ***chromatin***. Chromatin consist of DNA and basic proteins histones. This organizes into 23 pairs of chromosomes (in human) before cell division. Each chromosome represents one DNA molecule. The chromosomal DNA has length of about 30-60 mm. Such long molecule is present in nucleus, so DNA molecule is tightly packed such that it can be accommodated within nuclear limit. ***Histones*** are used for packing of DNA.

Five types of histones are used for packing of DNA. They are H1, H2A, H2B, H3 and H4.

Nucleosomes

Whole DNA is not packed as single coil, instead it is present as small coils known as ***nucleosomes***. Each nucleosome consists of histone octamer, which is made up of two units of H2A, H2B, H3 and H4 histones and DNA. Usually DNA is coiled around octamer, and it takes 1.75 turns around histone octamer. Each nucleosome is joined by ***linker DNA***.



Mitochondrial DNA (mtDNA)

Eukaryotic mitochondria contain DNA. It is different from DNA present in nucleus. It account for 1% of cellular DNA. Base composition of mtDNA is different from nuclear DNA. mtDNA is double stranded and **circular**. mtDNA inherited only ***maternally*** i.e : only mtDNA of ovum well transport to fetus .

Bacterial DNA

Bacteria like *E. coli* contains single molecule of double stranded DNA. *E. coli* DNA is 1.4 mm long which is 700 times bigger than the size of bacteria. Hence in bacteria also DNA is tightly packed or folded. In *E. coli* the two ends of DNA are joined to form ***circular DNA***.

Viral DNA

Viruses are extremely small particles. They are composed of a piece of DNA (and sometimes RNA), which is surrounded by protein coat called ***capsid***. Viral DNA may be single stranded or double stranded. Adenovirus (cold virus), Herpes virus and Pox virus are examples for double stranded viruses. Parvovirus is an example for single strand

DNA virus

Plasmids

They exist in bacteria as circular DNA molecules. A plasmid is a small DNA molecule within a cell that is physically separated from a chromosomal DNA and can replicate independently. They are most commonly found in bacteria as small, circular, double-stranded DNA molecules.
Plasmids often carry genes that may benefit the survival of the organism, for example antibiotic resistance. While the chromosomes are big and contain all the essential information for living, plasmids usually are very small and contain only additional information. They are present in antibiotic resistant bacteria. They contain genes for inactivation of antibiotics.

Denaturation of DNA

1. When DNA molecule is heated it denatures and strands separate.
2. Thermal denaturation of DNA is known as **melting** of DNA. Melting point of DNA is known as ***Tm***.
3. It is a characteristic of given DNA. If the heat denatured DNA is cooled base pairing occurs between strands and reformation of double stranded molecule takes place. This process is known as ***annealing***.

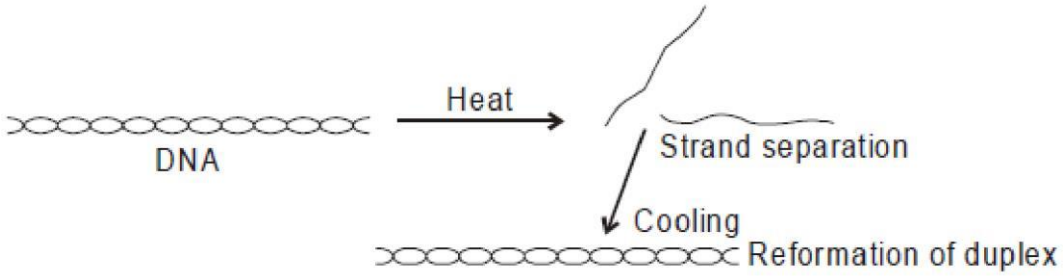


Fig. 16.6 DNA deenaturation