Module: Molecule, Gene and Disease
Semester: 2
Session: 4
Lecture: 7

Lecture Title:

Nucleotides and nucleic acids

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This Lecture was loaded in blackboard and you can find the material in:
(Lippincott's Illustrated Reviews: Cell and Molecular Biology Chapter 5)
For more detailed instructions, any question, or you have a case you need help in, please post to the group of session

Learning Objectives (LO)

1. Recognize the structural components of DNA and RNA molecules. (LO. 1)

2. Recognize and apply the conventions used to represent these components and the conventions used to represent DNA or RNA base sequences. (LO.2)

3. Explain polarity of a DNA or RNA chain. (LO.3)

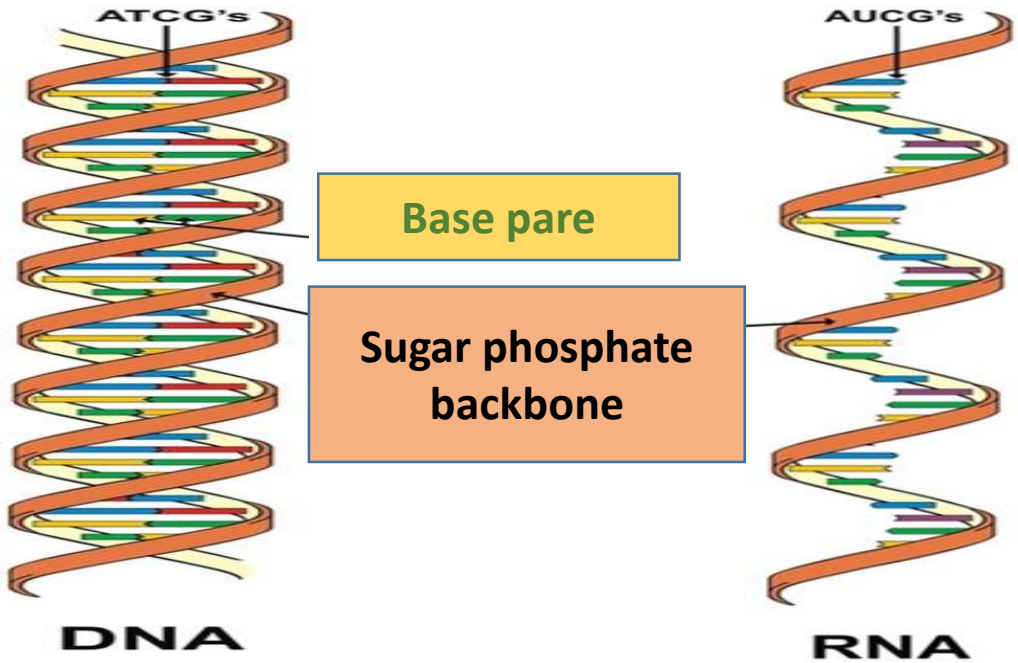
4. Explain the importance of hydrogen-bonding and base-pairing in defining nucleic acid secondary structure. (LO.4)

5. Describe the key features of the DNA double helix. (LO.5)

Nucleic acids

LO.1

- Nucleic acids are required for the storage and expression of genetic information. There are two chemically distinct types of nucleic acids: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).



Nucleic acids

LO.1

DNA

- DNA is a polymer of deoxyribonucleoside monophosphates (dNMP) covalently linked by (3-5)-phosphodiester bonds. With the exception of a few viruses that contain single-stranded DNA (ssDNA), DNA exists as a double-stranded molecule (dsDNA), in which the two strands wind around each other, forming a double helix.

- Is found in the nucleus with small amounts in mitochondria and chloroplast.

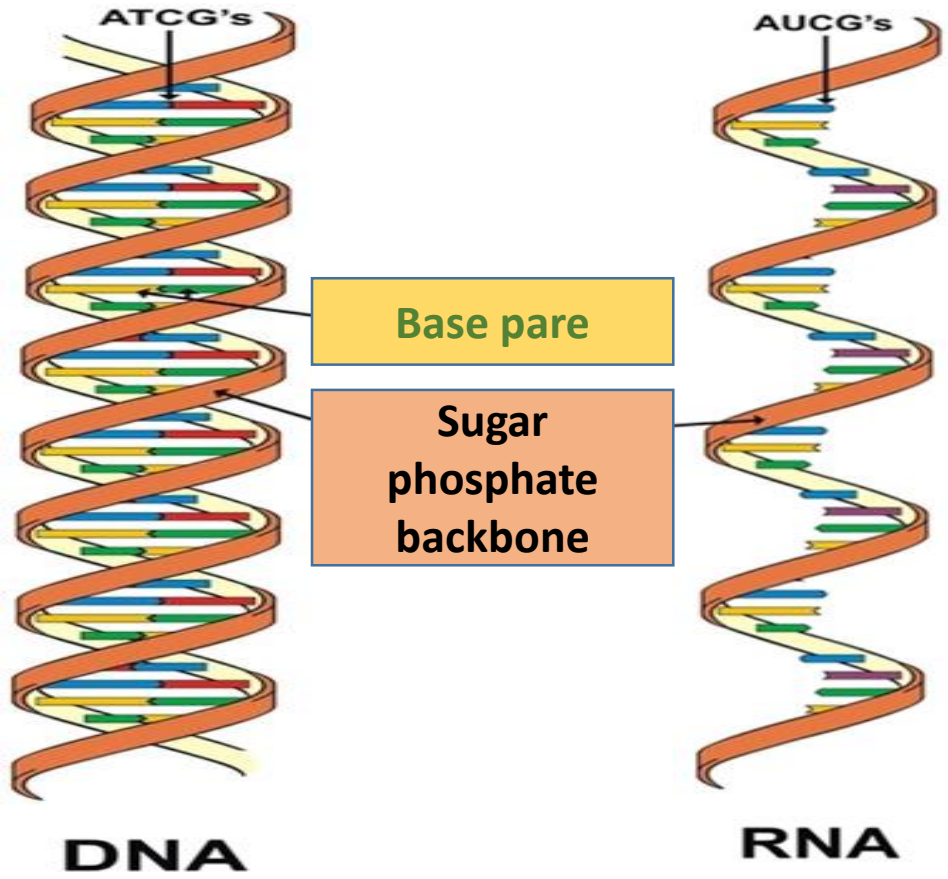
The structural components of DNA & RNA molecule

LO. 1

- **Nucleotides –** the monomer or building blocks of nucleic acids (DNA & RNA).
- **Components of nucleotide:**

Base, Sugar and Phosphate

- nucleotide serves diverse physiologic functions as protein synthesis, regulatory cascades & signal transduction pathways.

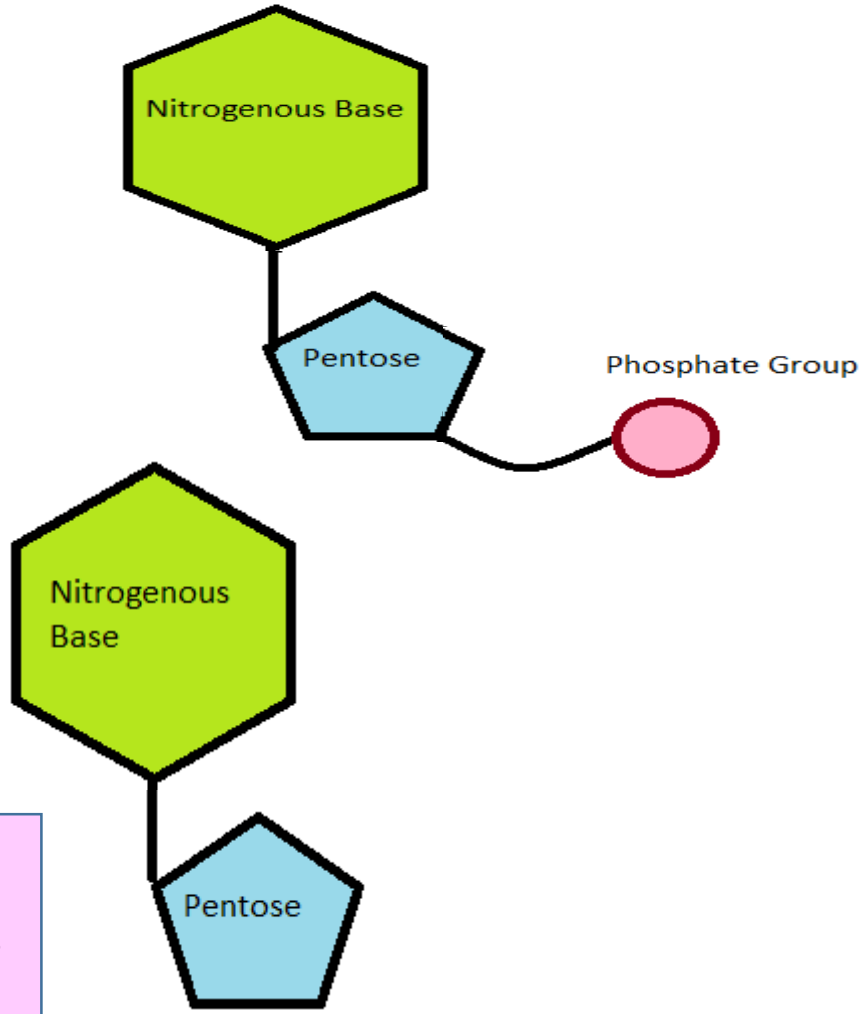


Nucleotide Vs. Nucleoside

LO. 1

Nitrogenous base + Sugar + Phosphate= Nucleotide

Nitrogenous base + Sugar = Nucleoside

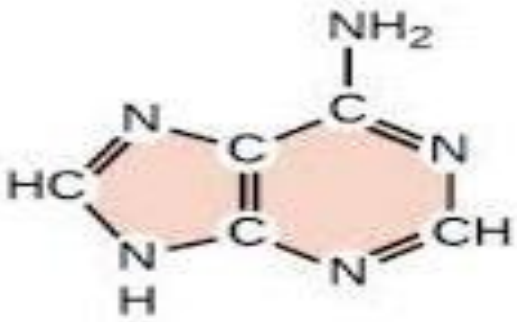


H.W.

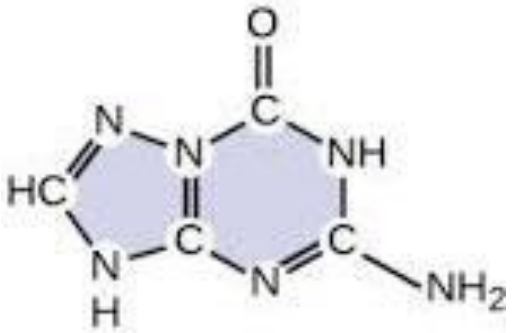
Nomenclature of Nucleotides

Types of nitrogen basis in nucleic acids LO.1

1. Purines

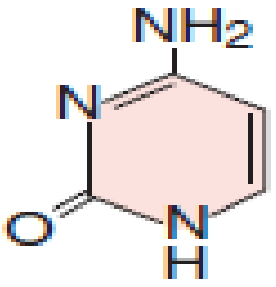


adenine

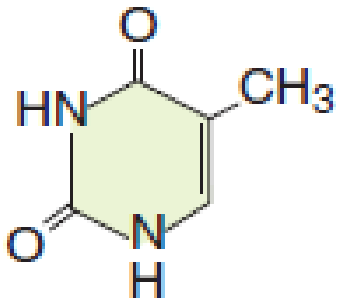


guanine

2. Pyrimidines

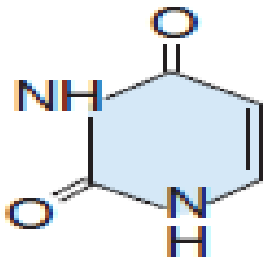


Cytosine



Thymine

DNA



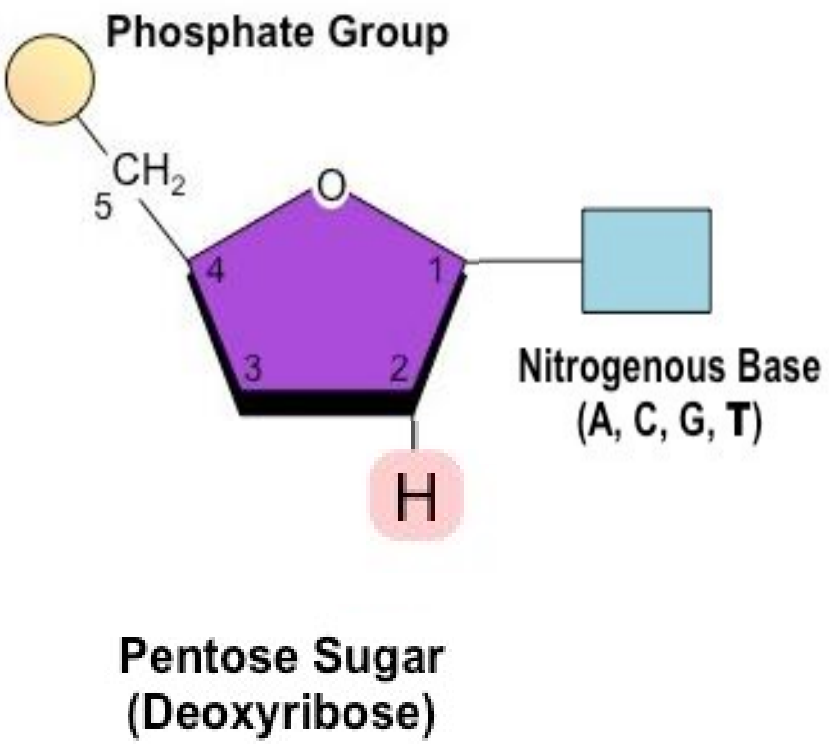
Uracil

RNA

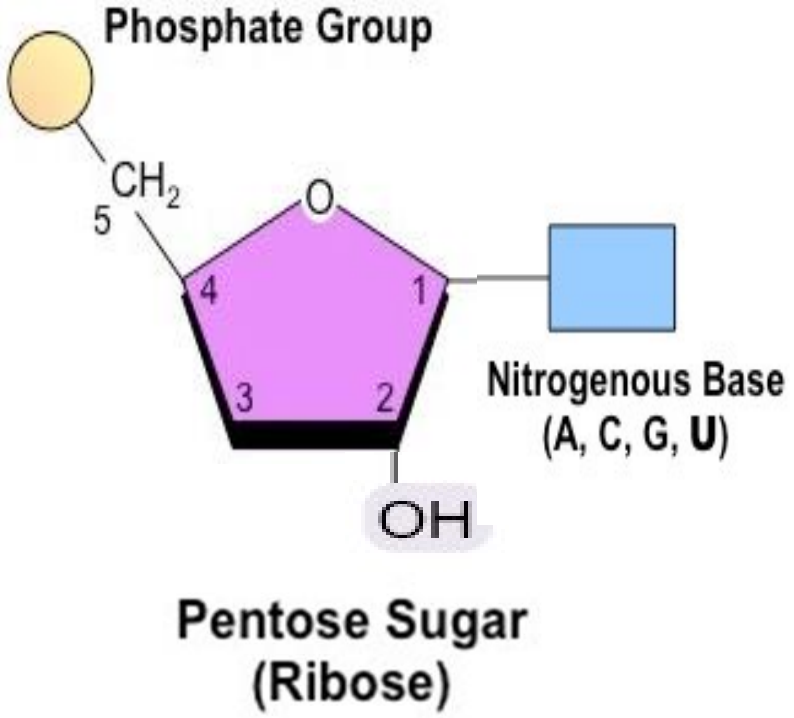
instead of Thymine

Type of sugar and nitrogen bases in DNA & RNA

LO. 1



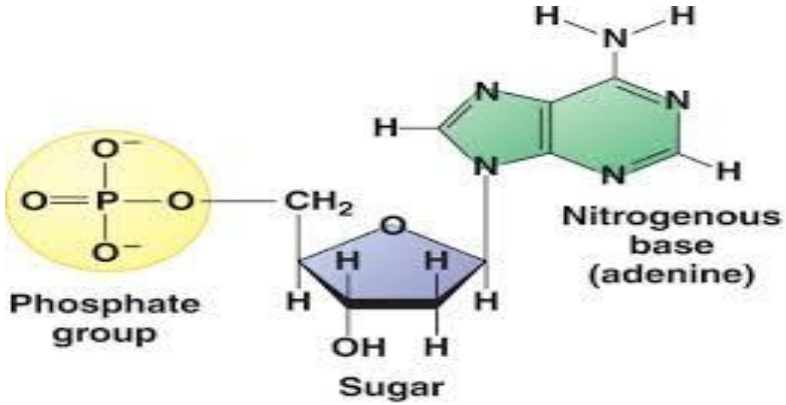
DNA Nucleotide

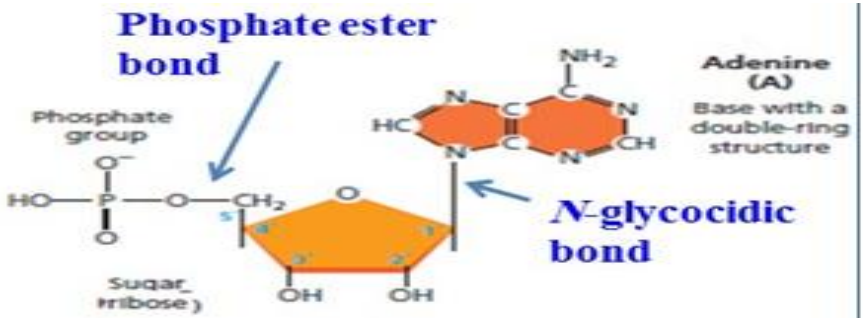


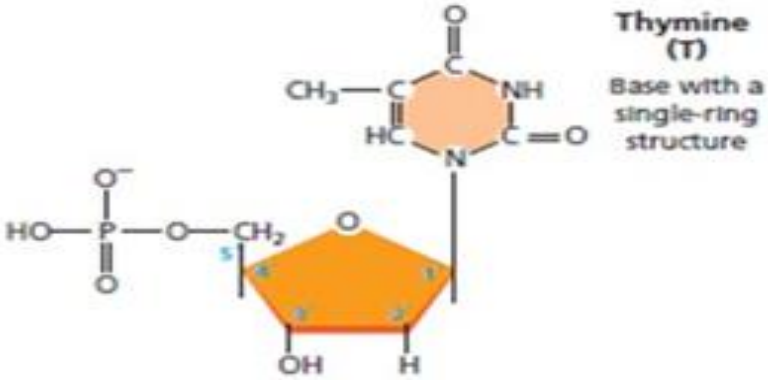
RNA Nucleotide

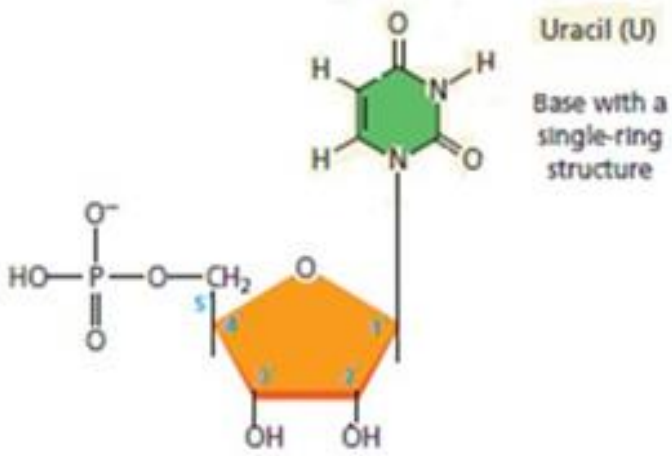
Nucleotides

LO.1









Deoxribonucleotide in DNA

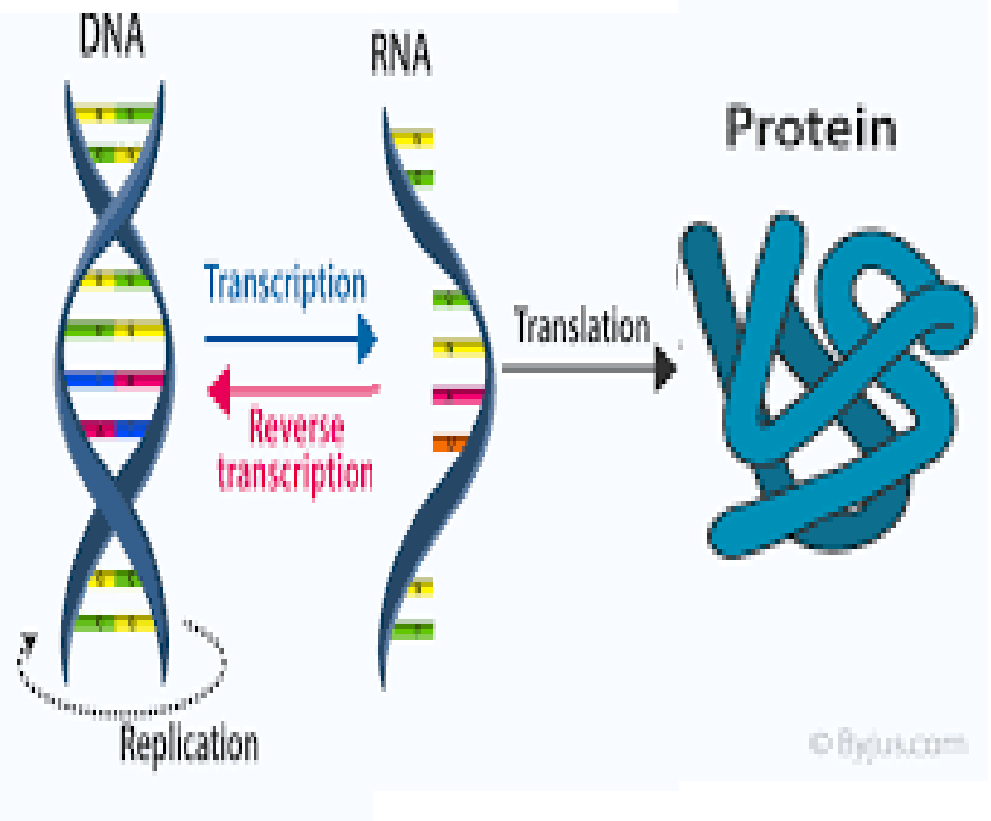
Ribonucleotide in DNA

The Central Dogma of Molecular biology

LO. 1

- In most organism DNA is the storage of genetic information with exception of RNA viruses.

- The Central Dogma: is the flow of information from DNA to RNA to Protein



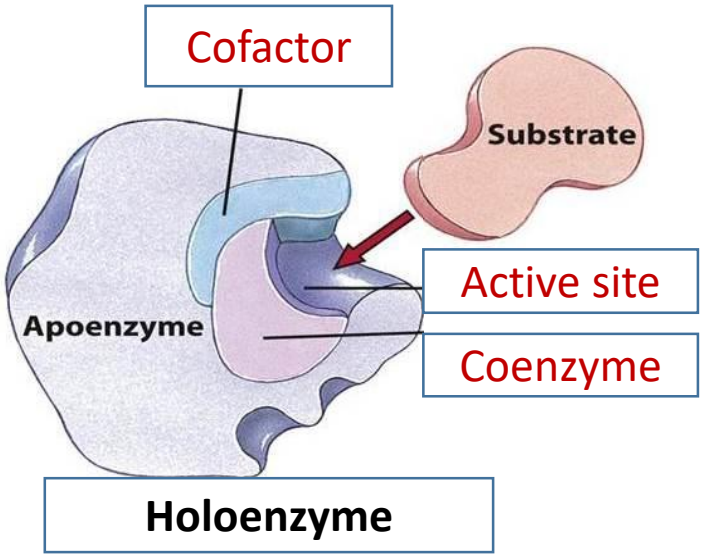
Retrovirus: ex : human immunodeficiency virus (HIV): The information flow:

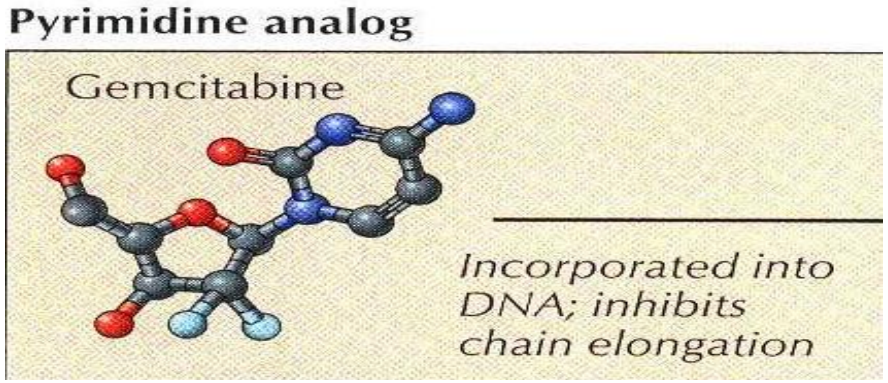
RNA → (Reverse transcription) DNA → RNA → Protein

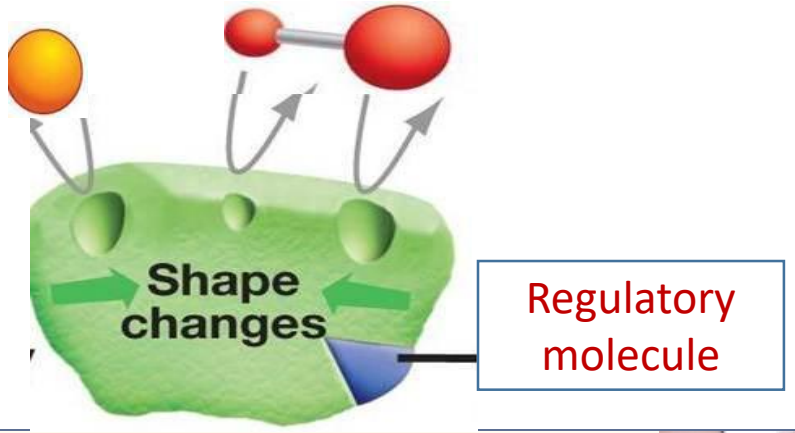
Biomedical importance of nucleotides

LO. 1

- Form part of many coenzymes
- Serve as donors of phosphoryl groups, sugars, or lipids
- Regulation of enzyme activity
- Synthetic purine & pyrimidine analogs are employed for chemotherapy of cancer & ADIS. Also as suppressors of the immune response during organ transplantation







Biomedical importance of nucleotides

LO. 1

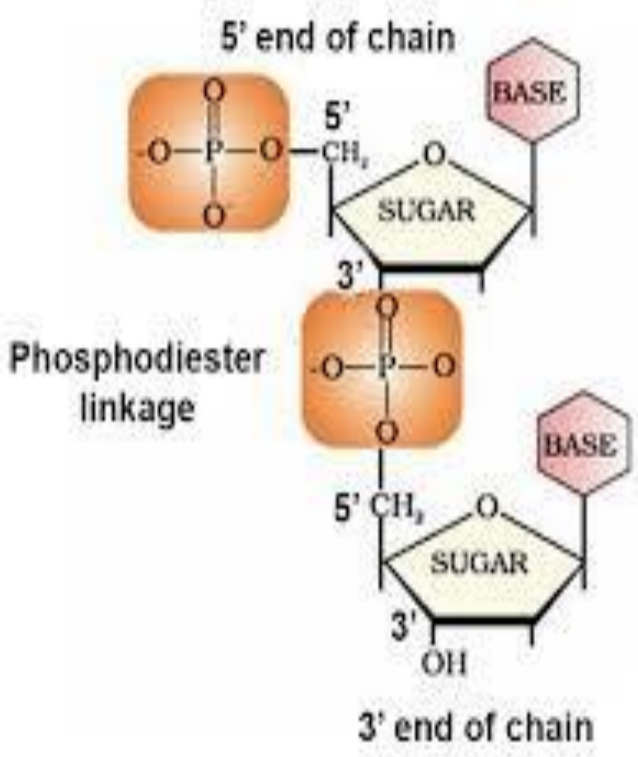
- Storage and transfer of energy (ATP & GTP)
- Precursors of nucleic acid DNA & RNA
- Storage & transfer of genetic information (DNA & RNA)
- Components of important co-enzyme (NAD, FAD, co-enzyme A)
- Metabolic regulator such as cAMP

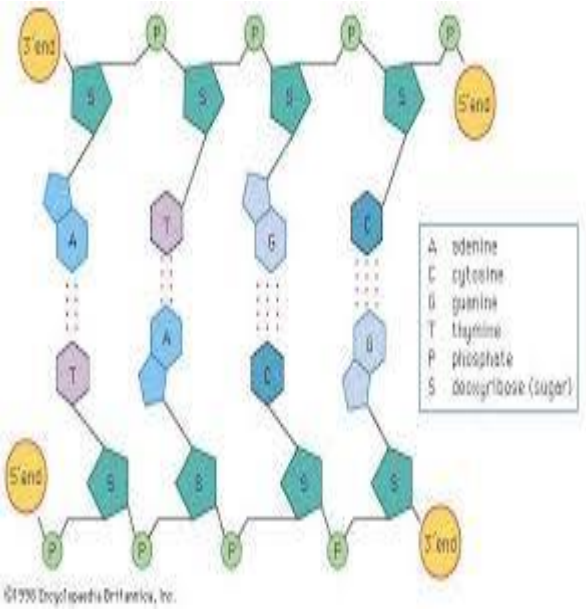
Polynucleotides

LO.1

Nucleotides are covalently linked together via **phosphodiester bonds**

5 `(Phosphoryl) end





Polynucleotides have directionality

3 `(hydroxyl) end

Nucleic acids

LO.1

RNA

- RNA like DNA, is a long, unbranched macromolecule
- RNA is found throughout the cell.
- Single strand, consisting of nucleotide joined by 3´ ⟶ 5´ phosphodiester bond.

H. W.

Compare between the nucleic acids DNA and RNA

Types of RNA and their functions

LO. 1

Type	Functions
Messenger RNA	Transfers genetics information from gene to ribosomes to synthesize protein.
Transfer RNA	Transfer amino acids to mRNA for protein synthesis.
Ribosomal RNA	Provides structural framework for ribosomes

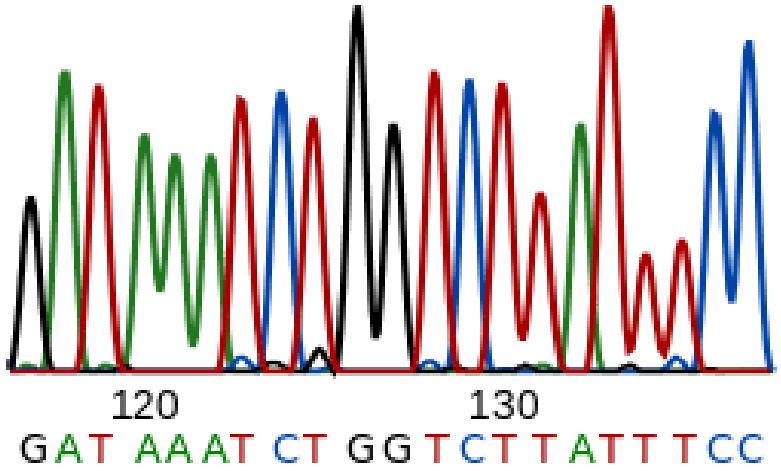
Nucleic acid sequence

LO. 2

- is a succession of letters that indicate the order of nucleotides within a DNA or RNA molecule.
- Specifying the sequence is equivalent to defining the covalent structure of the entire molecule.
- Sequences are usually presented from 5’ end to 3’ end.

5’ AGTACG 3’

3’ TCATGC 5’

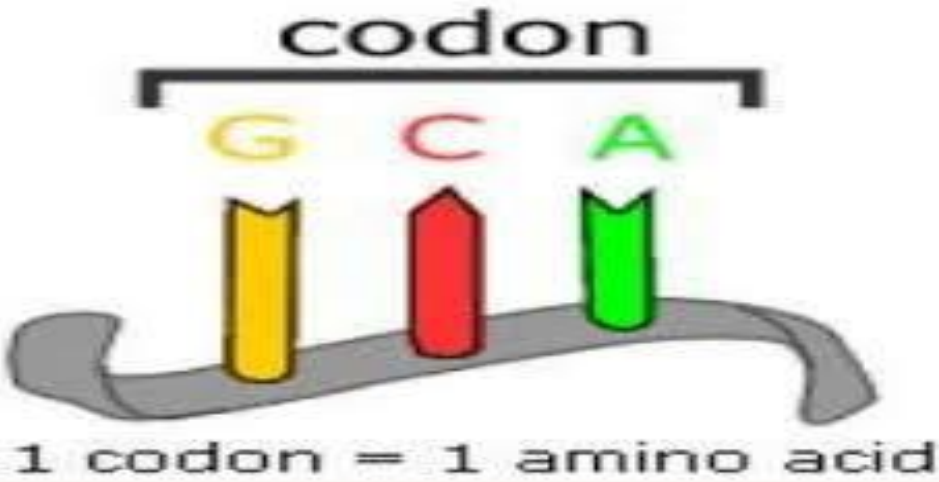


Nucleic acid sequence

LO. 2

- A nucleic acid sequence is translated into the protein it encodes by means of transfer RNAs (tRNA) interacting with the ribosomal apparatus.

- Transfer RNAs bind to three nucleotides at a time and divide the nucleic acid sequence into codons, each specifying one amino acid.

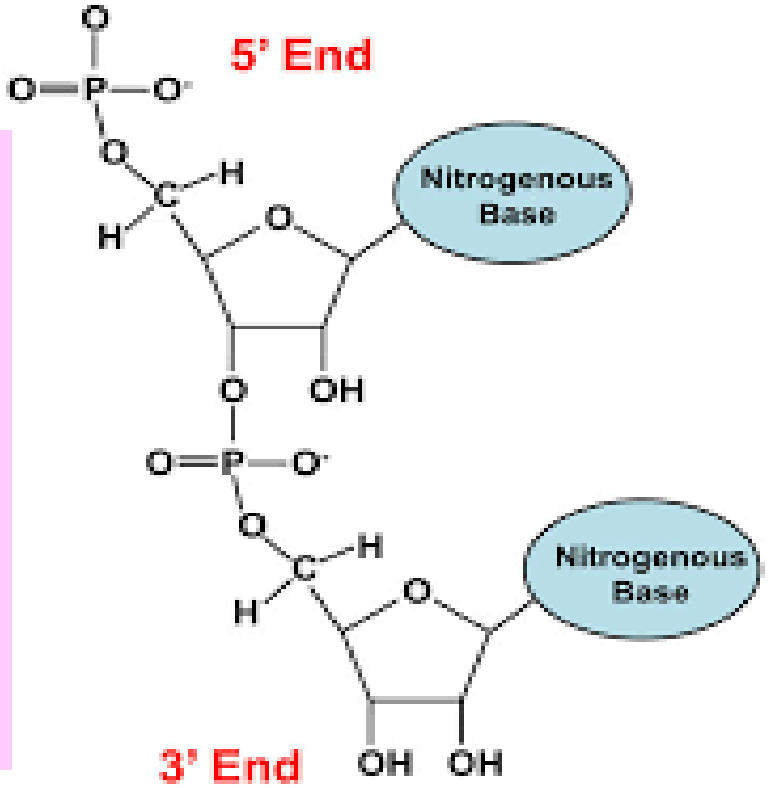


Polarity

LO. 3

- Each single-stranded nucleic acid chain has a **polarity**, two distinct ends: a 5’ end with a free phosphate and a 3’end with a free OH-group.

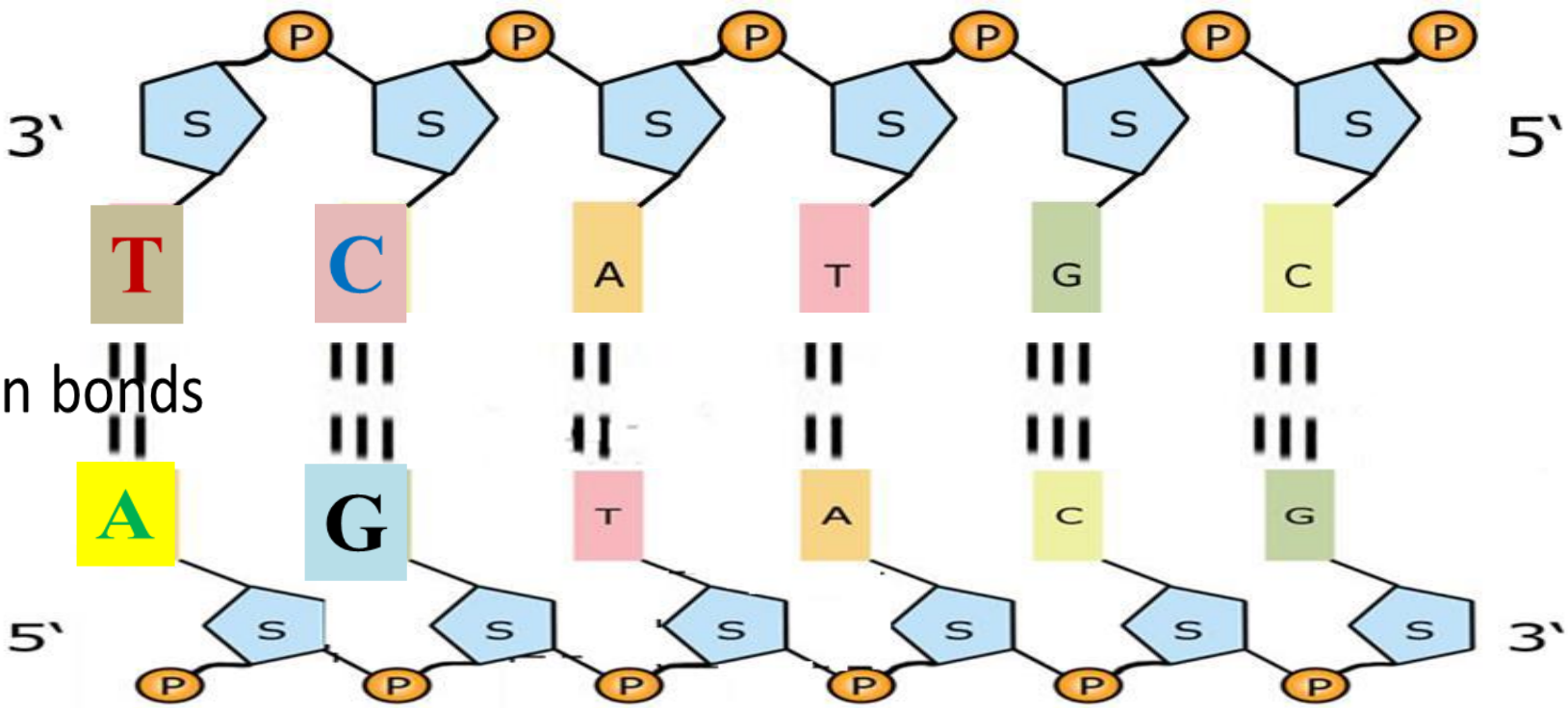
The polarity in DNA and RNA is derived from the oxygen and nitrogen atoms in the backbone. Nucleic acids are formed when nucleotides come together through phosphodiester linkages between the 5' and 3' carbon atoms.



Hydrogen bond

LO. 4

In double stranded nucleic acids the bases of each base pair is held together by hydrogen bonds, 3 hydrogen bonds in the GC-base pair and 2 hydrogen bonds for the AT- and AU-base pair.



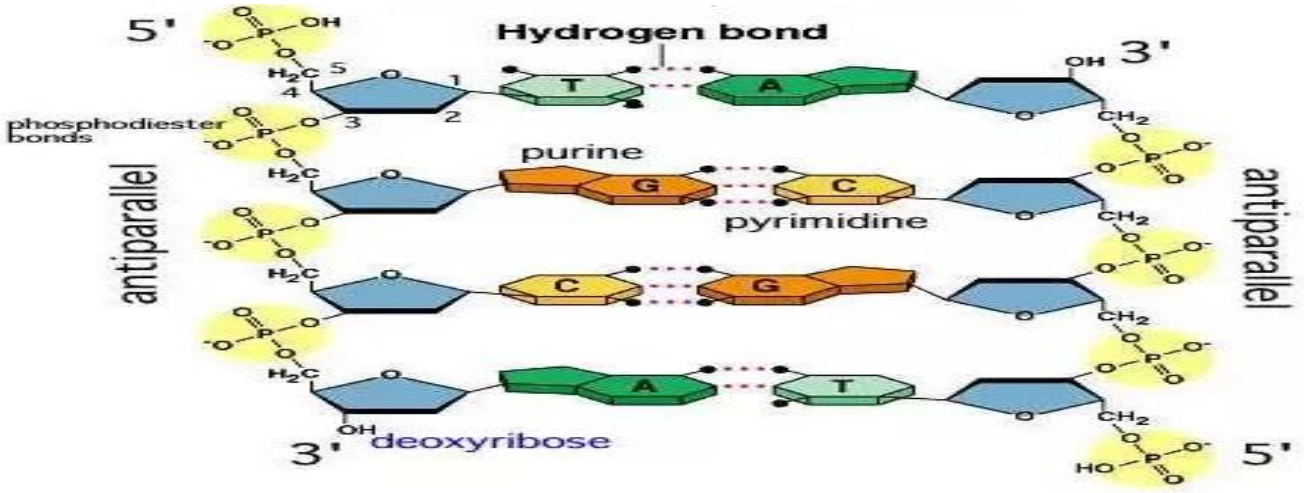
Hydrogen bonds importance

LO. 4

- Interact to stabilize and form the double helix structure.

- Hydrogen bonds between bases can be made and broken easily, allowing DNA to undergo accurate replication and repair.

(disruption the hydrogen bonds between the paired bases using acidic or alkaline pH or heating).

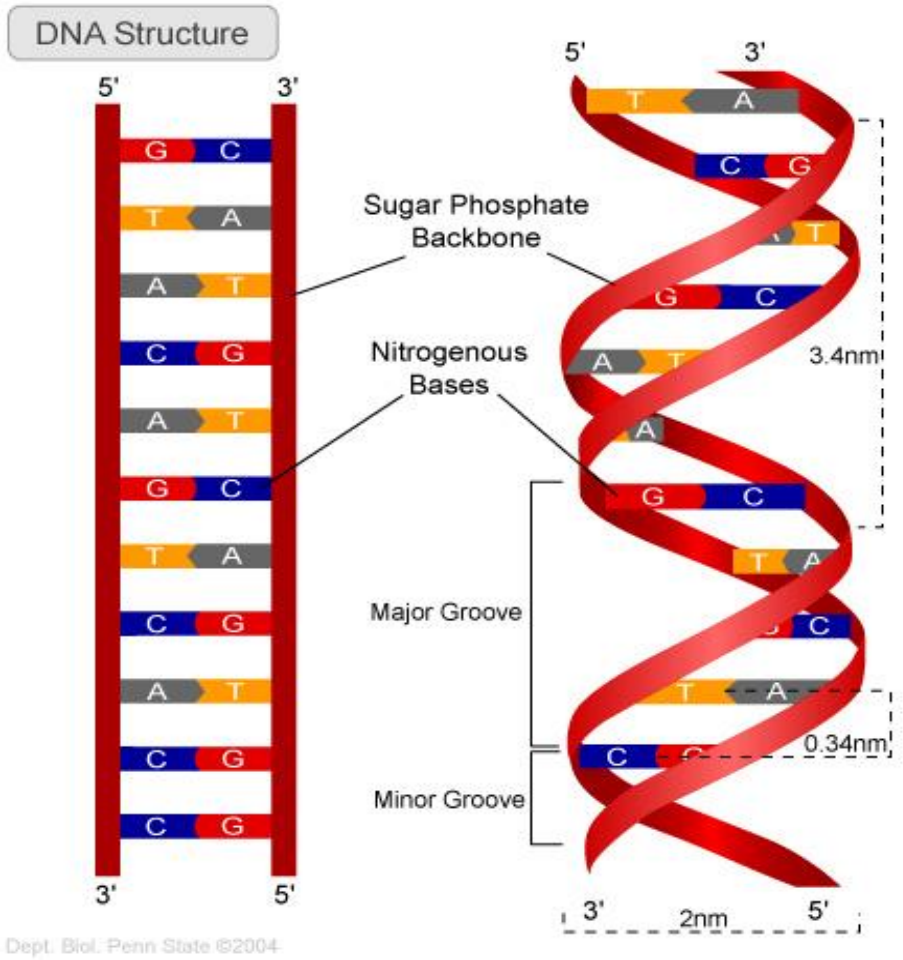


Features of DNA double helix

LO. 5

According to Watson and Crick model, DNA characterizes by:

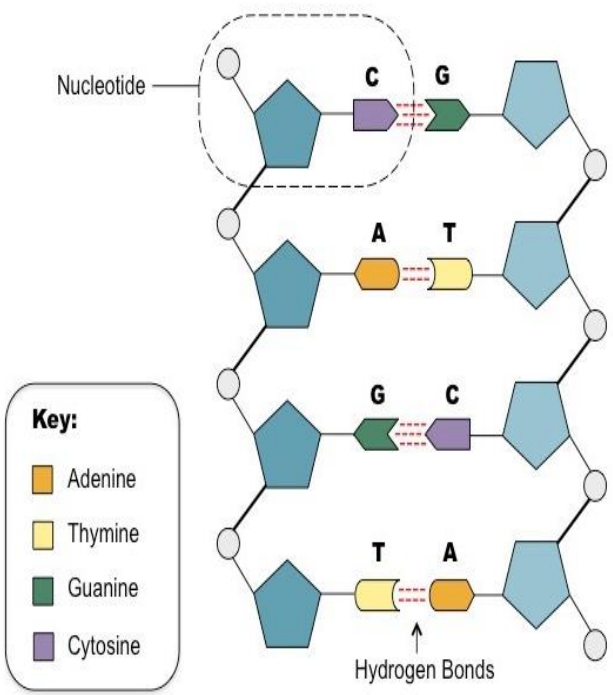
- Base pairing is highly specific: A in one chain pairs with T in the opposite chain by two hydrogen bonds, and C pairs with G by three bonds.
  - The two chains are twisted (coiled) around each other in a right-handed to form a double helix



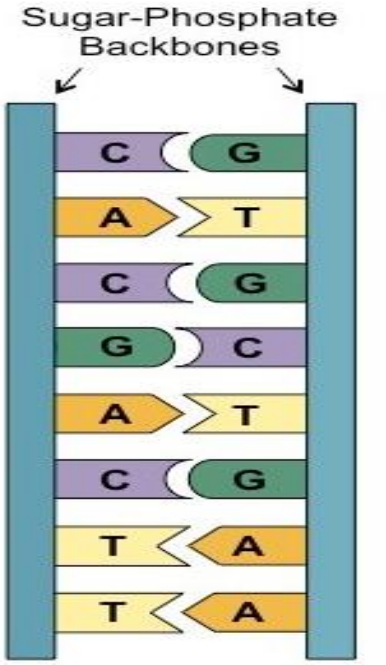
Features of DNA double helix

LO. 5

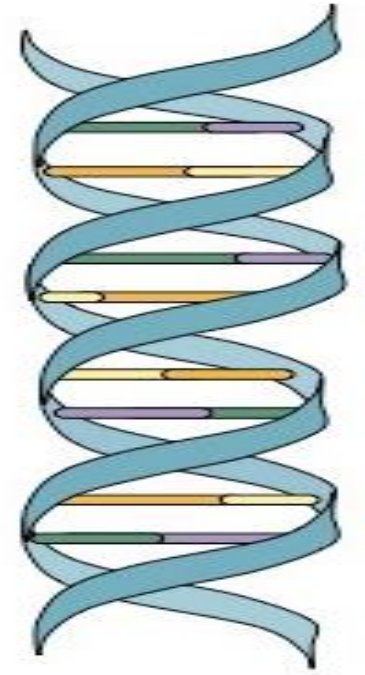
- **Antiparallel:** DNA is composed of two polynucleotide chains running in opposite directions. (Why)?



Antiparallel DNA Strands



DNA Ladder

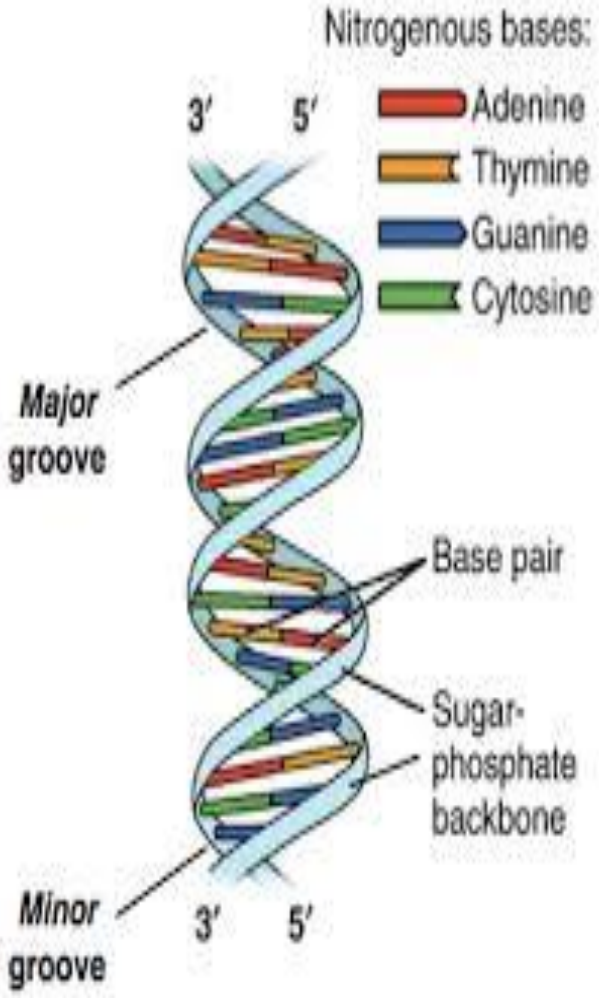


Double Helix

➢ DNA double helix

LO. 5

- The spatial relationship between the two strands creates—the major and minor grooves in DNA.
- **The hydrophobic** base pairs are packed in the interior of the double helix.
- Each base pair is of similar width, thus holding **(the hydrophilic)** sugar–phosphate back- bones an equal distance apart along the DNA molecule.



DNA double helix

LO. 5

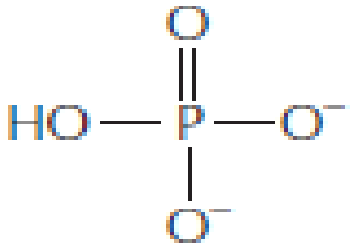
- The members of each base pair can fit together within the double helix because the two strands of the helix run antiparallel to each other—that is, they are oriented with opposite polarities

- The antiparallel sugar–phosphate strands then twist around each other to form a double helix containing 10 base pairs per helical turn.

➢ Negative charge of DNA helix

LO. 5

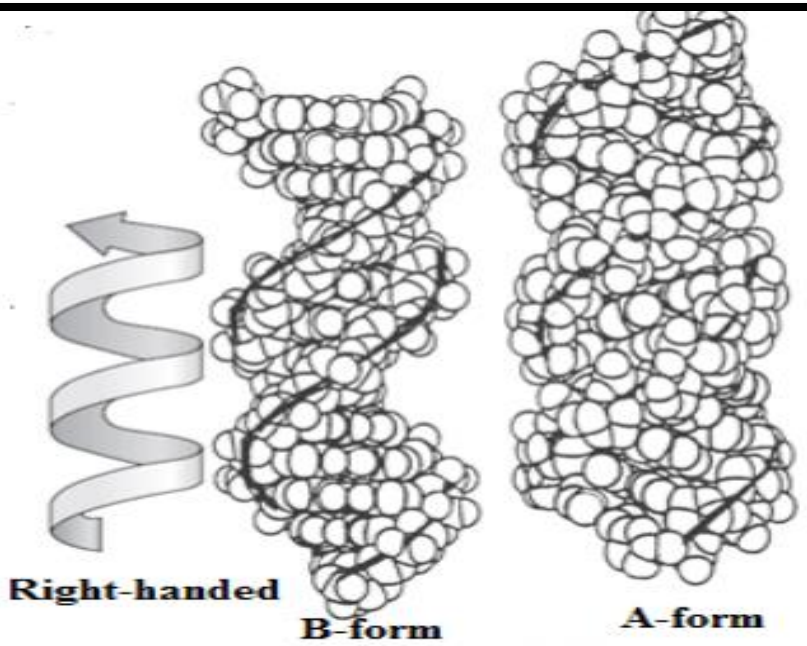
The third -OH group on the phosphate is free and dissociates a hydrogen ion at physiologic pH.

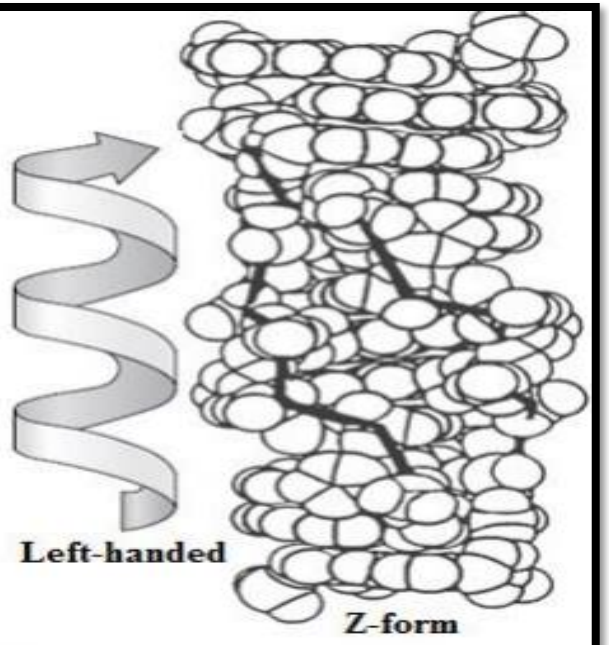


Therefore, DNA helix has negative charges coating its surface that facilitate the binding of specific proteins(histones and non-histones).

LO. 5

There are three major structural forms of DNA that all exhibit Watson and Crick complementary base pairing and antiparallel: A, B and Z forms:

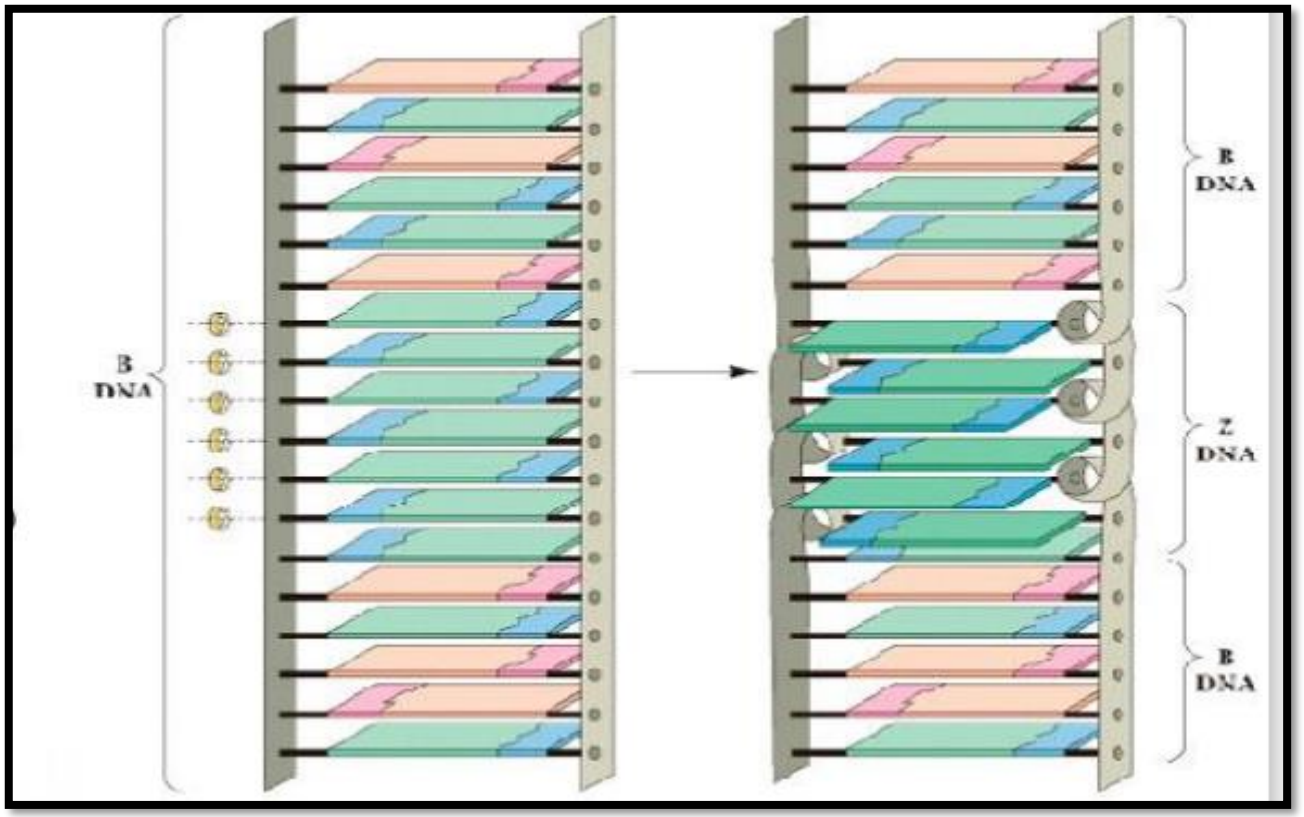




B form: is the chief form in the cells, is a right handed double helix with 10 base pair (bp) per turn of helix.

A form: is a right handed double helix with 11 base pair (bp) per turn, which produced form moderately dehydrating B form.

LO. 5



Z-form: is zigzag structure, a left handed with 12 base pair (bp) per turn, which may occur naturally in stretches of DNA that contain alternating purine and pyrimidine (ex. Poly GC),. Transition between B and Z forms may play a role in regulating gene expression

Thank you