UNIT 4: Nucleic acid

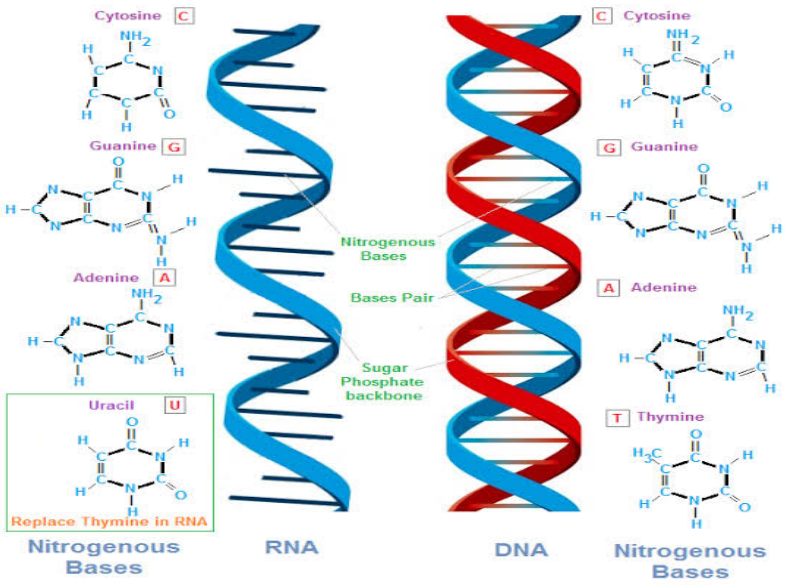
4.1: Introduction, Composition and Structure

Introduction

- **Nucleic acids** are biopolymers, macromolecules, essential to all known forms of life.
- They are composed of nucleotides, which are the monomers made of three components; a 5-carbon sugar, a phosphate group and a nitrogenous base.
- The two main classes of nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).
- If the sugar is ribose, the polymer is RNA; if the sugar is the ribose derivative deoxyribose, the polymer is DNA.
- Nucleic acids are naturally occurring chemical compounds that serve as the primary information-carrying molecules in cells and make up the genetic material.
- Nucleic acids are found in abundance in all living things, where they create, encode, and then store information of every living cell of every life-form on Earth.
- In turn, they function to transmit and express that information inside and outside the cell nucleus to the interior operations of the cell and ultimately to the next generation of each living organism.
- The encoded information is contained and conveyed via the nucleic acid sequence, which provides the 'ladder-step' ordering of nucleotides within the molecules of RNA and DNA.
- They play an especially important role in directing protein synthesis.
- Strings of nucleotides are bonded to form helical backbones typically, one for RNA, two for DNA and assembled into chains of base-pairs selected from the five primary nucleobases, which are: adenine, cytosine, guanine, thymine, and uracil.
- Thymine occurs only in DNA and uracil only in RNA.
- The specific sequencing in DNA of these nucleobase-pairs enables storing and transmitting coded instructions as genes.
- In RNA, base-pair sequencing provides for manufacturing new proteins that determine the frames and parts and most chemical processes of all life forms.

History

- Nucleic acid was first discovered by Friedrich Miescher in **1869** at the University of Tubingen, Germany. He gave its first name as **nuclein**.
- In the early **1880** Albrecht Kossel further purified the substance and discovered its highly acidic properties. He later also identified the nucleobases.



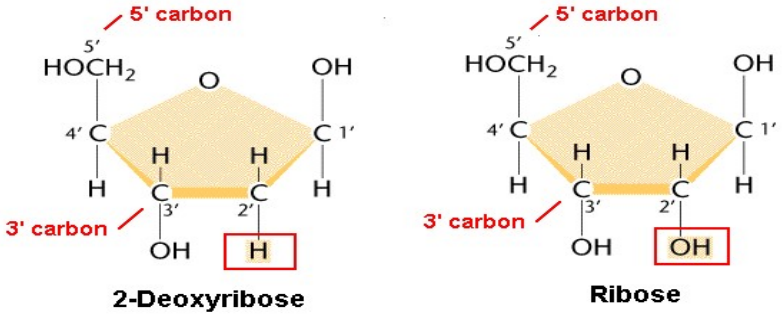
- In **1889** Richard Altmann creates the term nucleic acid at that time DNA and RNA were not differentiated.
- In **1930** Joachim Hammerling differentiate the DNA and RNA.
- In **1938** Astbury and Bell published the first X-ray diffraction pattern of DNA.
- In **1944** the Avery, MacLeod and McCarty experiment showed that DNA is the carrier of genetic information.
- In **1953** Watson and Crick proposed the double-helix structure of DNA.
- In **1960** Leslie Orgel stated that RNA is backbone of life.
- Experimental studies of nucleic acids constitute a major part of modern biological and medical research and form a foundation for genome study, forensic science, biotechnology and pharmaceutical industries.

Composition

- Nucleic acid is an unbranched, long chain polymer form by several thousand pair of monomeric units called nucleotides.
- Each nucleotide is composed of three components namely a pentose sugar, nitrogenous base and a phosphate group.

I) Pentose Sugar

- In the structure of nucleic acid a five carbon sugar molecule is involved which is ribose sugar.
- In the RNA the ribose sugar is present while in the DNA a deoxyribose sugar is present having one less oxygen atom at second carbon position.
- The pentose sugar simply acts as a support column to which nitrogenous bases are attached.



II) Nitrogenous bases

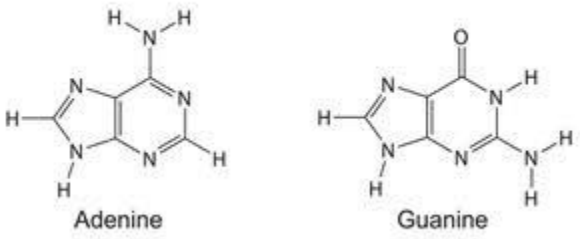
- These are cyclic compounds made up of carbon, hydrogen, oxygen and nitrogen.
- The nitrogenous bases are of two types i.e. pyrimidines and purins.

a) Pyrimidines

- Pyrimidine is a heterocyclic aromatic organic compound that is composed of carbon, hydrogen, oxygen and nitrogen.
- It comprises cytosine, thymine and uracil as a nucleobases in which cytosine and thymine present in DNA while in RNA uracil is present instead of thymine.
- It consist one hydrogen-carbon ring and two nitrogen atoms.
- The melting point of pyrimidine is 20^0-22^0C.

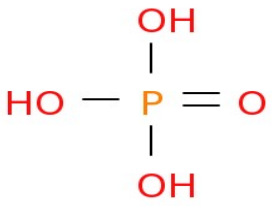
b) Purins

- Purins is a heterocyclic aromatic organic compound composed of a pyrimidine ring fused with imidazole ring.
- It comprises adenine and guanine as nucleobases.
- It consist of two hydrogen-carbon rings and four nitrogen atoms.



III) Phosphoric acid residue

- It is derived from phosphoric acid.
- It forms backbone of DNA in which sugar and phosphate groups are alternatively arranged.
- Each phosphate molecule joined to carbon atom through phosphodiester linkage.



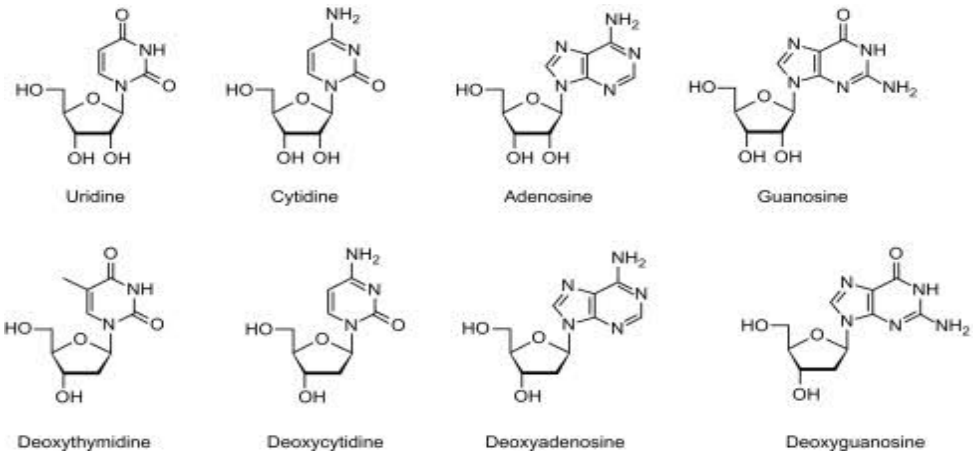
Structure

- In the formation of structure of nucleic acid first of all the nucleoside are made then nucleoside converts into nucleotide through phosphodiester linkage.
- After the nucleotide formation polynucleotide chain occurs and nucleic acid is formed.

Nucleoside

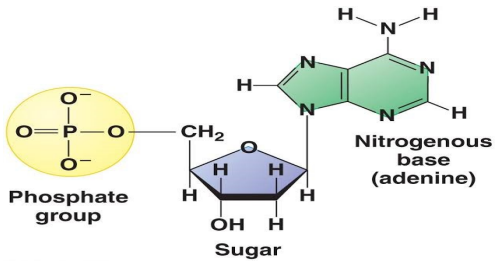
- Nucleoside is nothing but combination of nitrogenous base with pentose sugar.
- In DNA it is called deoxyribonucleoside while in RNA called ribonucleoside.
- The linkage bond between sugar and nitrogenous base through glycosidic bond. When sugar attaches to base is called…..

  Adenine + Sugar = Adenosine or Deoxyadenosine
  Gaunine + Sugar = Gaunosine or Deoxygaunosine
  Thymine + Sugar = Ribothymidine or Deoxythymidine
  Cytosine + Sugar = Cytidine or Deoxycytidine
  Uracil + Sugar = Uridine



Nucleotide

- Nucleotide is derived from a nucleoside by the addition of molecule of phosphoric acid through esterification.
- The phosphate molecule is attached to the sugar molecule at C'_5 or C'_3.
- Pentose sugar + Nitrogenous base + Phosphoric acid = Nucleotide



Polynucleotide Chain

- A polynucleotide chain is composed of monomers of nucleotide molecules.
- The structure of DNA is two nucleotide molecules wound together.
- Even RNA is made of a single chain of polynucleotides.
- Every monomer has three sections, namely a pentose sugar, a nitrogenous base and a phosphate group.
- The pentose sugar and the phosphate groups are linked by a phosphodiester linkage.
- The four nitrogenous bases are adenine, cytosine, guanine and thymine or uracil.

DNA Structure

- DNA has two polynucleotide chains wound to form a double helix structure.
- The pentose sugar molecule is deoxyribose.
- The hydroxyl group is not present in the deoxyribose. Also, the base pairs are adenine, cytosine, guanine and thymine.
- In DNA, the two strands are wound in the opposite direction. Thus, the strands are firmly held by the hydrogen bonds between the complementary base pairs.

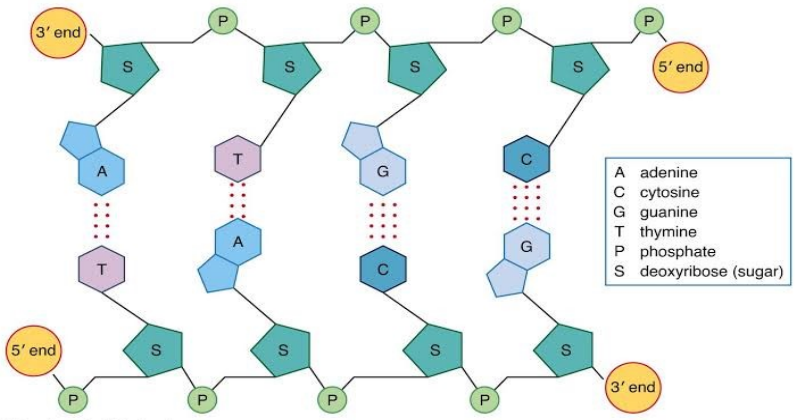
RNA Structure

- The RNA is a single chain structure of polynucleotides.
- Here, ribose is the pentose sugar.
- The ribose has the hydroxyl group on the 2' end of the carbon. Also, the base pairs here are adenine, cytosine, guanine and uracil.

Formation of Polynucleotide Chain

- The nitrogenous bases can be grouped as either purines or pyrimidines.
- The purines include adenine and guanine. The pyrimidines include cytosine, thymine and uracil.

- The first carbon of the pentose sugar is attached to the nitrogenous base with the help of an N-glycosidic linkage.
- Then phosphate group attached to 5' carbon atom of the pentose sugar through phosphodiester bond and forms a nucleotide.
- Then another nucleotide comes up and forms the phosphodiester bond between phosphate group of second nucleotide and 3' carbon atom of first nucleotide sugar molecule.
- In this way two sugar molecules linked through phosphate group.
- The phosphodiester linkage occurs in repeated manner to form polynucleotide chain.
- The chain shows definite direction and polarity, it may start from 5' carbon atom and ends with 3' carbon atom.
- In DNA double stranded structure is formed, the two strands runs parallel but opposite to each other to form complementary base pairing. One strand runs 5' - 3' and complementary strand runs 3' - 5'.
- In DNA and RNA 5' end having a phosphate group while 3' end having a free OH group in both strands.



Chargaff's Rule

- In 1950 Chargaff discovered that the amounts of adenine and thymine in DNA were roughly the same as were the amounts of cytosine and guanine.
- He stated that the ratio of purines to pyrimidines is always 1:1.
- This means the number of adenine (A) should be equal to thymine (T), and the number of guanine (G) equal to cytosine (C).