Fundamentals of Organic Chemistry

CHEM 109

For Students of Health Colleges

Credit hrs.: (2+1)

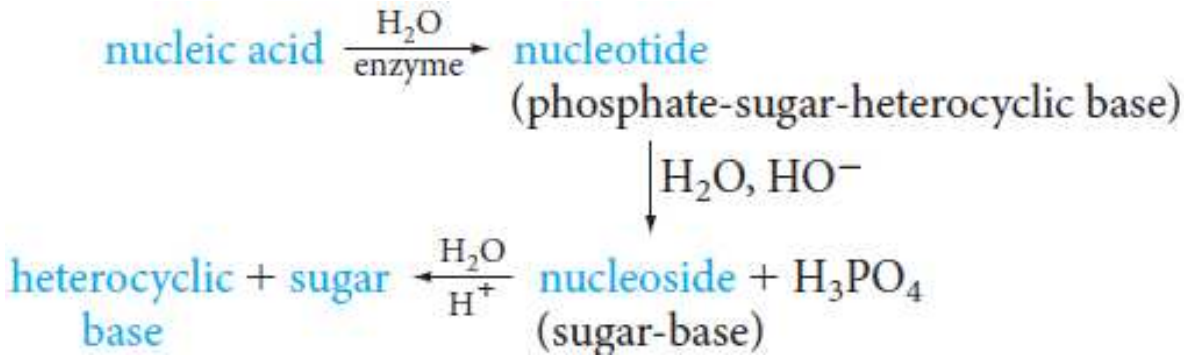
King Saud University

College of Science, Chemistry Department

CHAPTER 10: Nucleic Acids

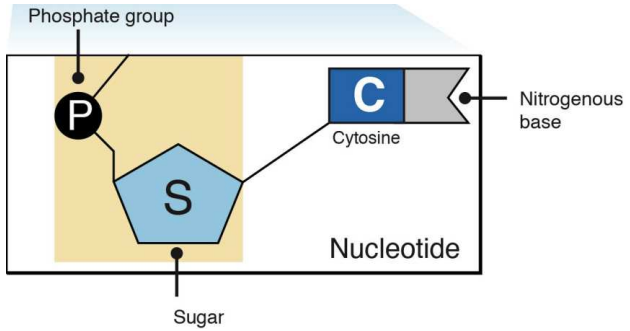
The General Structure of Nucleic Acids

- ***Nucleic acids*** are molecules that allow organisms to transfer genetic information from one generation to the next.
- ***Nucleic acids***, are linear polymers (chains) made out of units called nucleotides.
- Hydrolysis of nucleic acids gives nucleotides, which are the building blocks of nucleic acids.

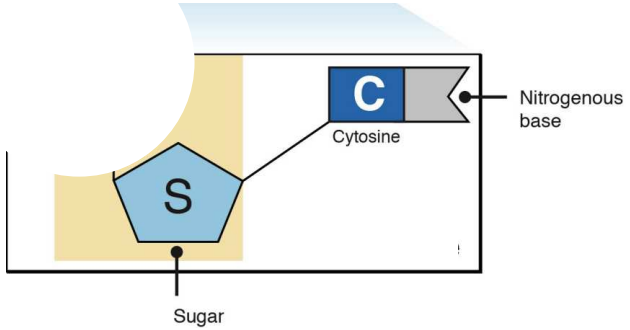


The General Structure of Nucleic Acids

- ***Nucleotides :*** contain three parts:
  - **A Nitrogenous Base (Nucleobase)**
  - **A Five-Carbon Sugar (Pentose)**
  - **A Phosphate Group**

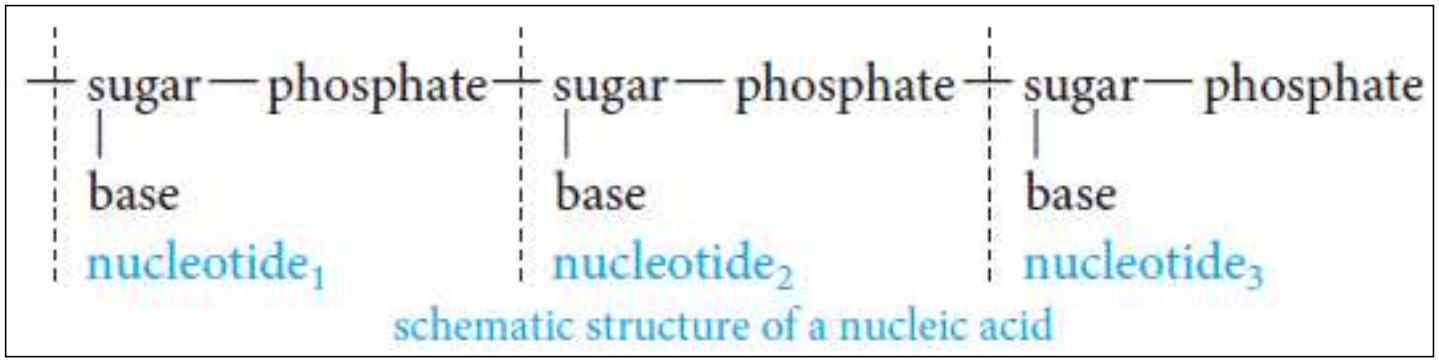


- ***Nucleosides :*** contain two parts:
  - **A Nitrogenous Base (Nucleobase)**
  - **A Five-Carbon Sugar (Pentose)**



The General Structure of Nucleic Acids

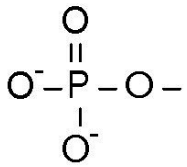
- **The overall structure of the nucleic acid** is a macromolecule with a backbone of sugar molecules connected by phosphate links and with a base attached to each sugar unit.



schematic structure of a nucleic acid

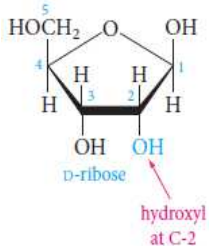
The General Structure of Nucleic Acids

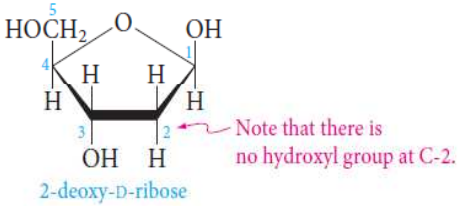
Phosphate group



Pentose Sugar

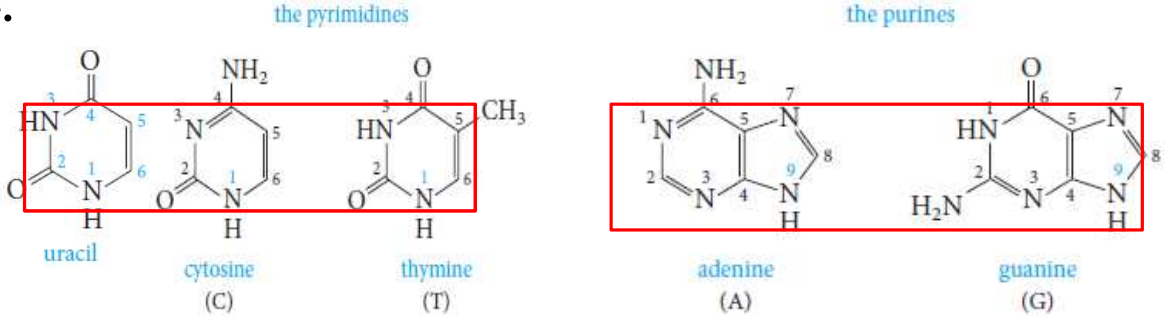
- **Ribonucleic acid (RNA)** contains the pentose ribose.
- **Deoxyribonucleic acid (DNA)** contains the pentose deoxyribose.





Heterocyclic Base

The sugars also contain a **pyrimidine or purine base** present on the 1-carbon replacing the hydroxyl group with a base.



The General Structure of Nucleic Acids

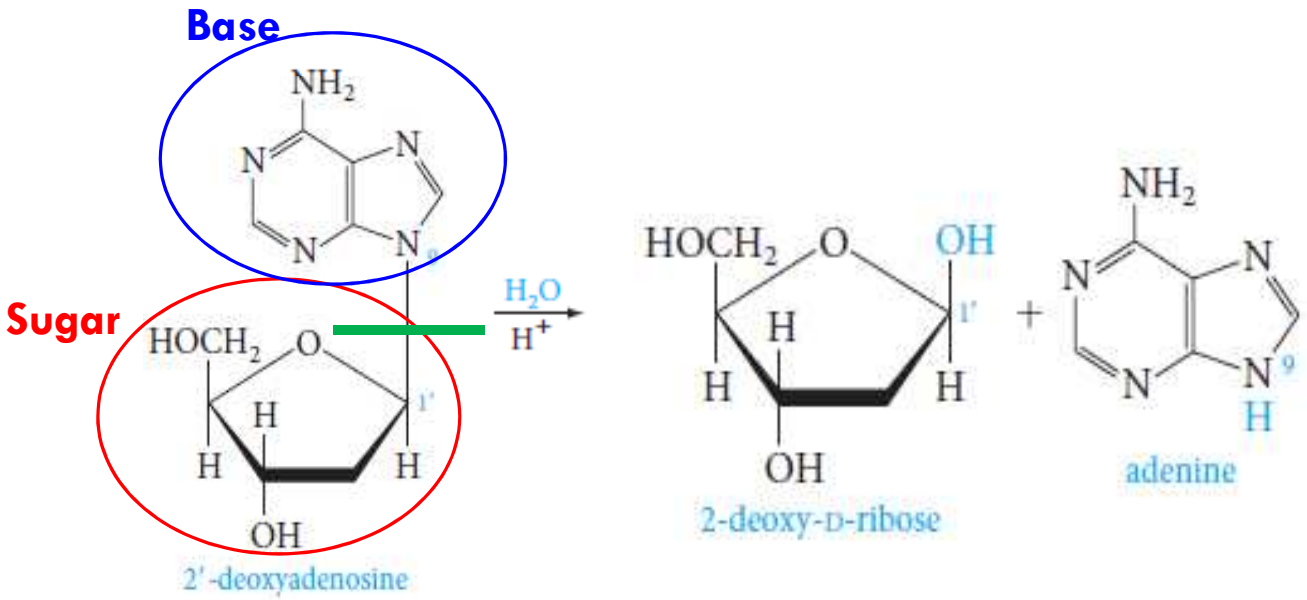
Differences Between DNA and RNA Composition

	DNA	RNA
Five-Carbon Sugar	Deoxyribose	Ribose
Nitrogenous Bases	Adenine, Guanine, Cytosine, and Thymine or methyluracil	Adenine, Guanine, Cytosine, and Uracil

The General Structure of Nucleic Acids

- **Nucleoside**

*The **combination of the pentose sugar and** a purine or pyrimidine **base**.*



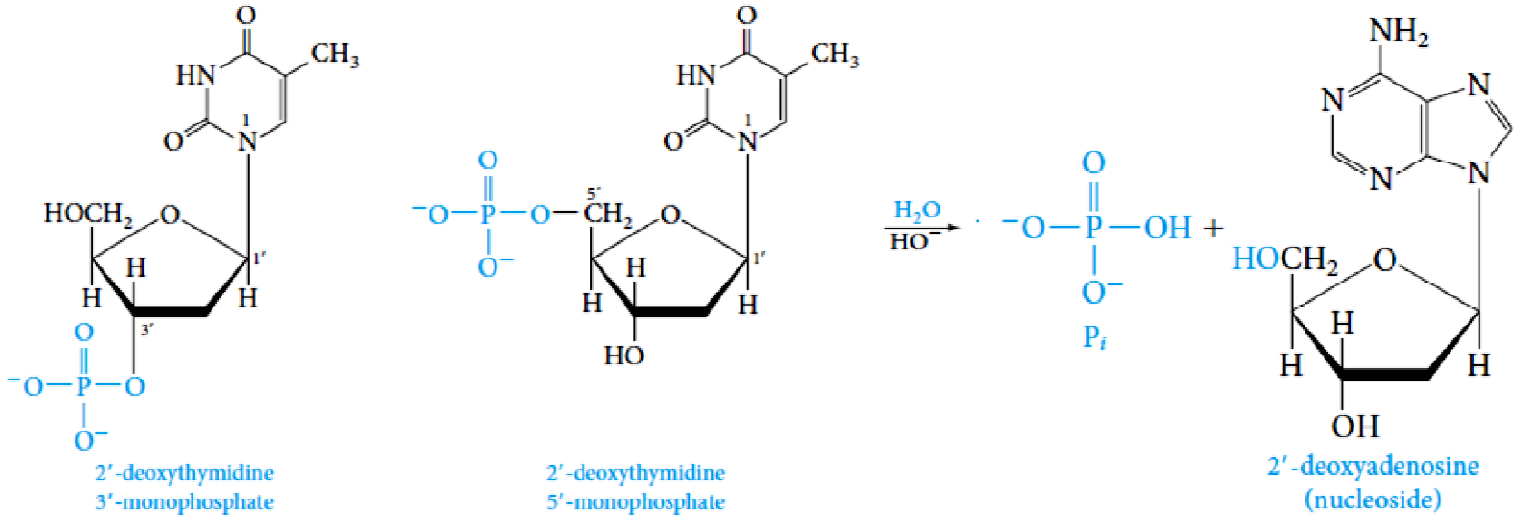
The General Structure of Nucleic Acids

- **Nucleotides** are **phosphate esters of nucleosides**.

  A hydroxyl group in the sugar part of a nucleoside is esterified with phosphoric acid.

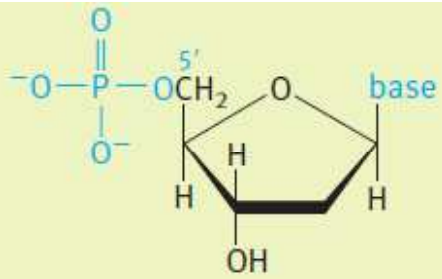
  In DNA nucleotides, either the 3' or the 5' hydroxyl group of 2-deoxy-d-ribose is esterified.

- **Nucleotides** can be hydrolyzed by aqueous base (or by enzymes) to nucleosides and phosphoric acid.



The General Structure of Nucleic Acids

- In these abbreviations, letter d stands for 2-deoxy-d-ribose, the next letter refers to the heterocyclic base, and MP stands for monophosphate.



Base	Monophosphate name	Abbreviation
cytosine (C)	2′-deoxycytidine 5′-monophosphate	dCMP
thymine (T)	2′-deoxythymidine 5′-monophosphate	dTMP
adenine (A)	2′-deoxyadenosine 5′-monophosphate	dAMP
guanine (G)	2′-deoxyguanosine 5′-monophosphate	dGMP

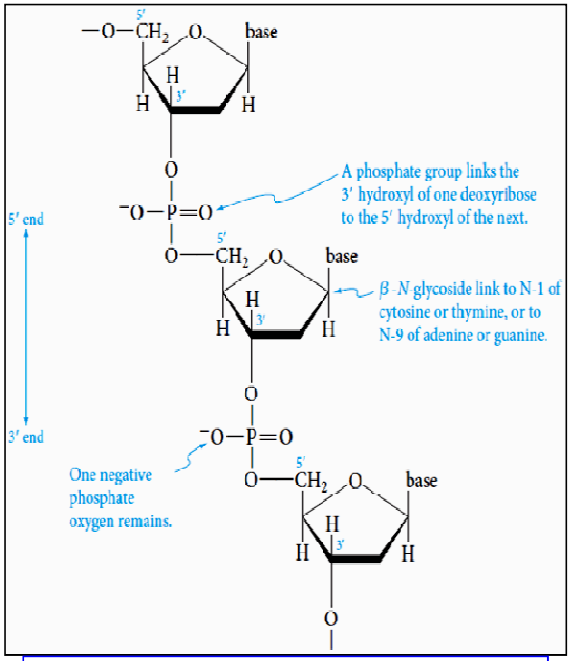
The General Structure of Nucleic Acids

- **Nucleic acids** are polynucleotides attached by the phosphate moieties through the 3′ and 5′ sites on the pentose.
- The **name nucleic acid** is derived from the fact that they are acidic, containing a phosphoric acid moiety, and are found in the nuclei of cells.
- **Pure nucleic acid** was isolated by Levene in the early 1900s.
- He showed that either D-ribose or D-deoxyribose was present in what are now known as **ribonucleic acid (RNA)** **and** **deoxyribonucleic acid (DNA)**.
- **There are two major types of nucleic acids:**
  - **Deoxyribonucleic acid (DNA)**
  - **Ribonucleic acid (RNA).**

The Primary Structure of DNA

Deoxyribonucleic Acid (DNA)

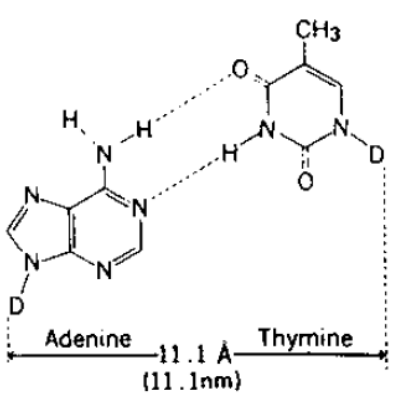
- In DNA, **2-deoxy-d-ribose** and **phosphate units** alternate in the backbone.
- The 3' hydroxyl of one ribose unit is linked to the 5' hydroxyl of the next ribose unit by a **phosphodiester bond**.
- The **heterocyclic base** is connected to the anomeric carbon of each deoxyribose unit by a ***β*-*N*-glycosidic bond**.
- In DNA, there are **no remaining hydroxyl groups** on any deoxyribose unit.
- Each phosphate, however, still has one acidic proton that is usually ionized **at pH 7**, leaving a negatively charged oxygen.
- A **complete description of any particular DNA molecule**, which may contain thousands or even millions of nucleotide units, would have to include the exact **sequence of heterocyclic bases** (**A, C, G, and T**) along the chain.



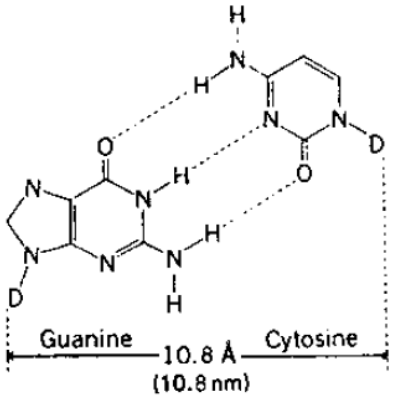
A segment of a DNA chain

Secondary DNA Structure; the Double Helix

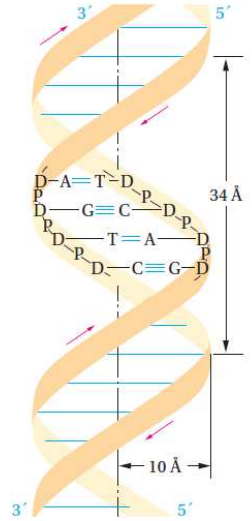
Deoxyribonucleic Acid (DNA)

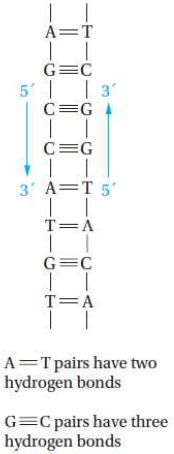


Two hydrogen bonds



Three hydrogen bonds





Model and schematic representations of the DNA double helix.

The space-filling model at the left shows the base pairs in the helix interior, in planes perpendicular to the main helical axis. The center drawing shows the structure more schematically, including the dimensions of the double helix. At the far right is a schematic method for showing base pairing in the two strands.

Secondary DNA Structure; the Double Helix

Deoxyribonucleic Acid (DNA)

- In 1953, when Watson and Crick, working together in Cambridge, England, proposed the double helix model for DNA.
- The important features of their model follow:

1. DNA consists of two helical polynucleotide chains coiled around a common axis.
2. The helices are right-handed, and the two strands run in opposite directions with regard to their 3' and 5' ends.
3. The purine and pyrimidine bases lie *inside* the helix, in planes perpendicular to the helical axis; the deoxyribose and phosphate groups form the outside of the helix.
4. The two chains are held together by;
   - *Purine–pyrimidine base pairs* connected by hydrogen bonds.
     - *Adenine is always paired with thymine, and*
     - *Guanine is always paired with cytosine.*
5. The diameter of the helix is 20 A.
   Adjacent base pairs are separated by 3.4 A and oriented through a helical rotation of 36°.
   There are therefore 10 base pairs for every turn of the helix (360°), and the structure repeats every 34 A.
6. There is no restriction on the sequence of bases along a polynucleotide chain. The exact sequence carries the genetic information.

Ribonucleic Acid (RNA)

- **Ribonucleic acids (RNA) differ from DNA in three important ways:**

  (1) The sugar is D-ribose;

  (2) Uracil replaces thymine as one of the four heterocyclic bases

  (3) Many RNAs are

  - Single-stranded segments,
  - Combinations of complementary two-stranded helices,
  - Complex structures.