# Fundamentals of Organic Chemistry

## CHEM 109

*For Students of Health Colleges*

Credit hrs.: (2+1)

*King Saud University*

College of Science, Chemistry Department

CHEM 109

## CHAPTER 10: Nucleic Acids

## Learning Objectives

**At the end of this chapter, students will able to:**

- Describe the structural building blocks of RNA and DNA
- Differentiate between RNA and DNA structure.
- Know the structure of nucleotides and nucleosides.
- Recognize the important of both RNA and DNA

# The General Structure of Nucleic Acids

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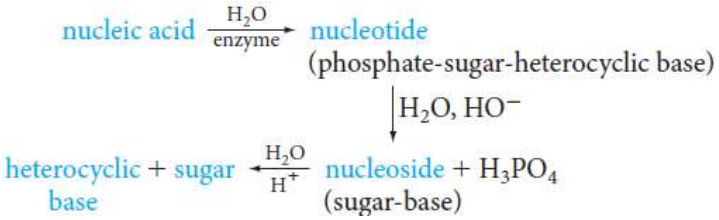
- ***Nucleic acids*** are molecules that allow organisms to transfer genetic information from one generation to the next.
- ***Nucleic acids***, are linear polymers (chains) made out of units called nucleotides.
- Hydrolysis of nucleic acids gives nucleotides, which are the building blocks of nucleic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




# The General Structure of Nucleic Acids

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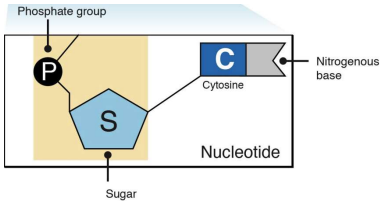
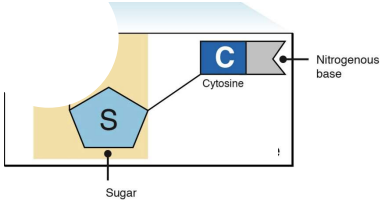
- ***Nucleotides :*** contain three parts:
  - **A Nitrogenous Base (Nucleobase)**
  - **A Five-Carbon Sugar (Pentose)**
  - **A Phosphate Group**




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



# The General Structure of Nucleic Acids

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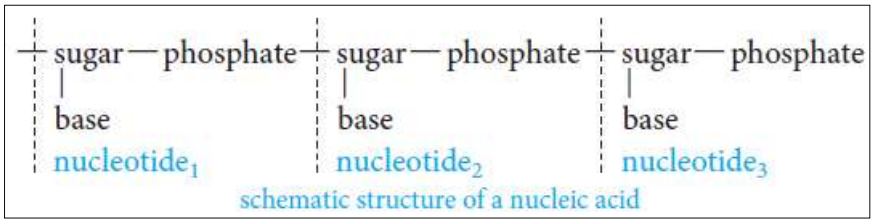
- **The overall structure of the nucleic acid** is a macromolecule with a backbone of sugar molecules connected by phosphate links and with a base attached to each sugar unit.



schematic structure of a nucleic acid

# The General Structure of Nucleic Acids

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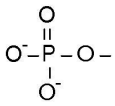
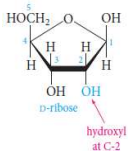
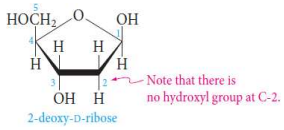
## Phosphate group



## Pentose Sugar

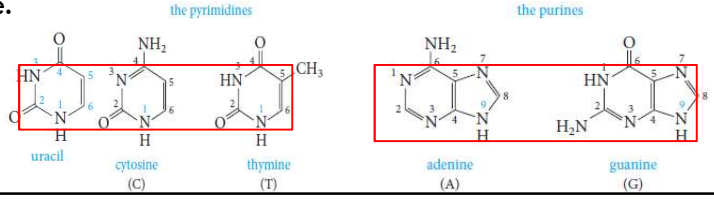
- **Ribonucleic acid (RNA)** contains the pentose ribose.
- **Deoxyribonucleic acid (DNA)** contains the pentose deoxyribose.




## 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

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**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

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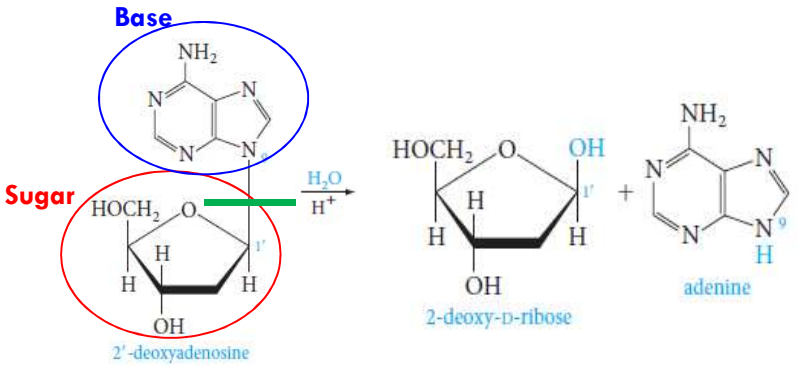
- **Nucleoside**

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



# The General Structure of Nucleic Acids

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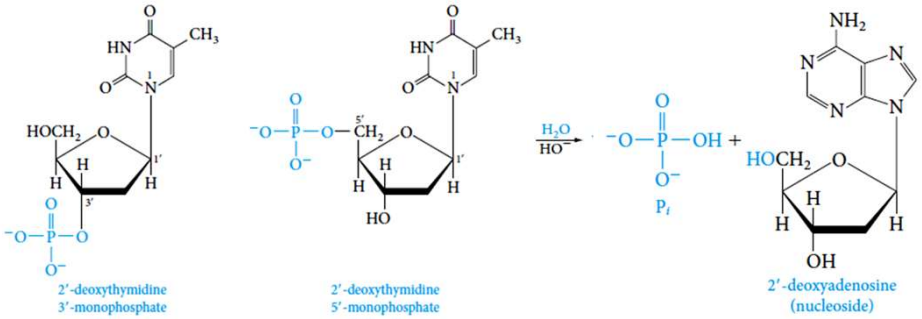
- **Nucleotides** are **phosphate esters of nucleosides**.

  *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

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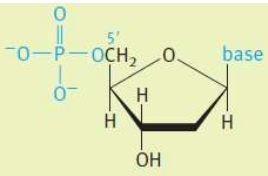
- In these abbreviations, letter d stands for 2-deoxy-d-ribose, the next letter refers to the heterocyclic base, and MP stands for monophosphate.




| 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

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- **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)

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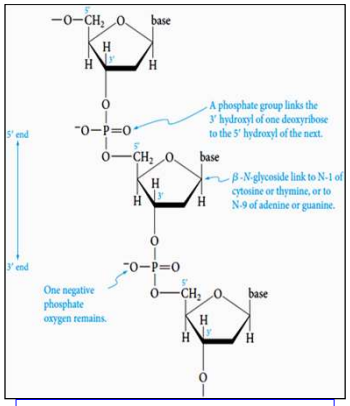
- In DNA, **2-deoxy-d-ribose** and **phosphate units** alternate in the backbone.
- The 3' hydroxyl of one ribose unit is linked to the 5' hydroxyl of the next ribose unit by a **phosphodiester bond**.
- The **heterocyclic base** is connected to the anomeric carbon of each deoxyribose unit by a ***β*-*N*-glycosidic 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

# Ribonucleic Acid (RNA)

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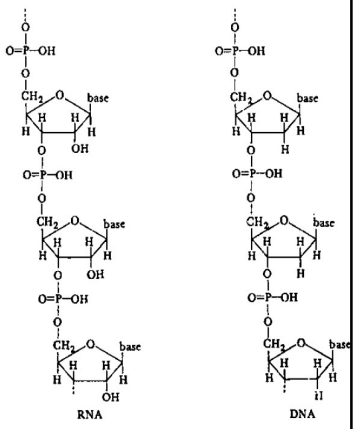
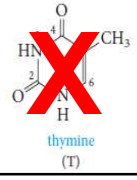
- **Ribonucleic acids (RNA) differ from DNA in three important ways:**

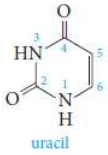
  (1) The sugar is D-ribose;

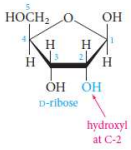
  (2) Uracil replaces thymine as one of the four heterocyclic bases

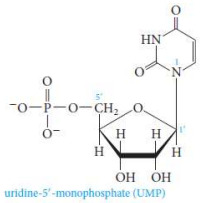
  (3) Many RNAs are
  - Single-stranded segments,
  - Combinations of complementary two-stranded helices,
  - Complex structures.




# Importance of DNA and RNA

- Heredity is encoded in DNA within the chromosomes.
- RNA (ribonucleic acid) is the messenger of DNA within the cell.
- Forms of RNA direct the cell to manufacture specific enzymes and other proteins.
- DNA functions by carrying the template or "map" of chemical compounds, amino acids, that are used to build proteins.
- DNA directs the production of proteins by providing the sequence of amino acids necessary to produce specific proteins.