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

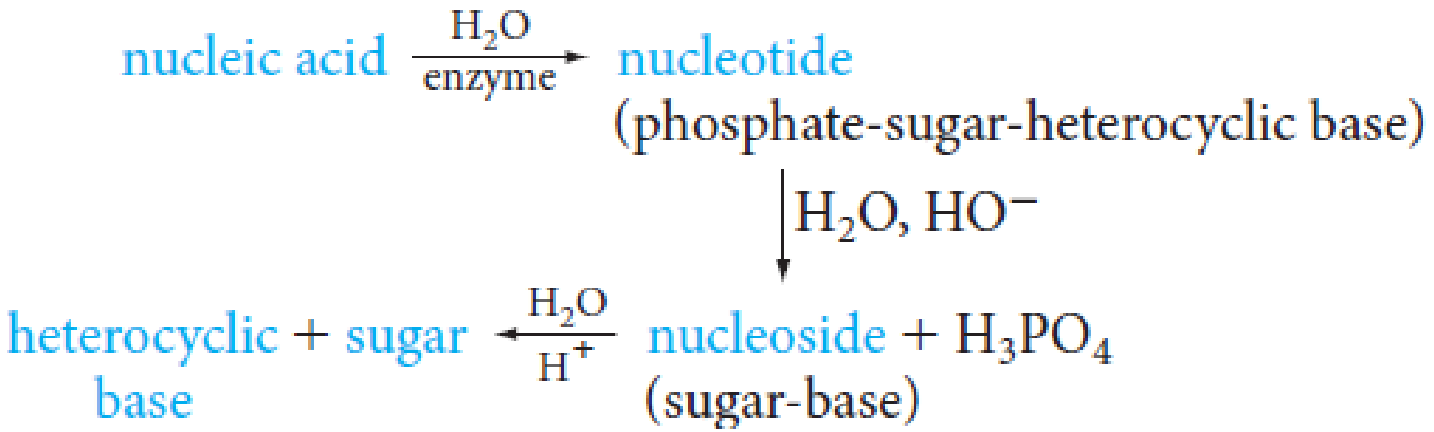
Learning Objectives

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

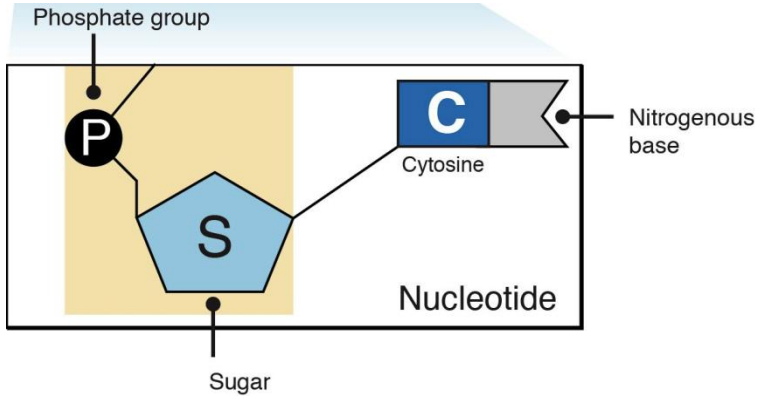
The General Structure of Nucleic Acids

- ***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.

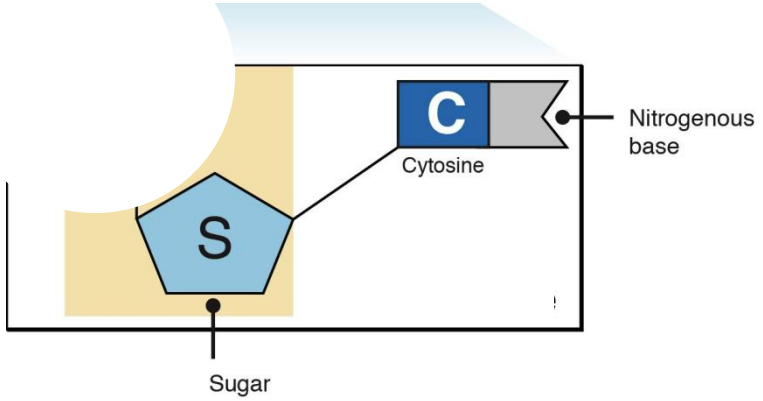


The General Structure of Nucleic Acids

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

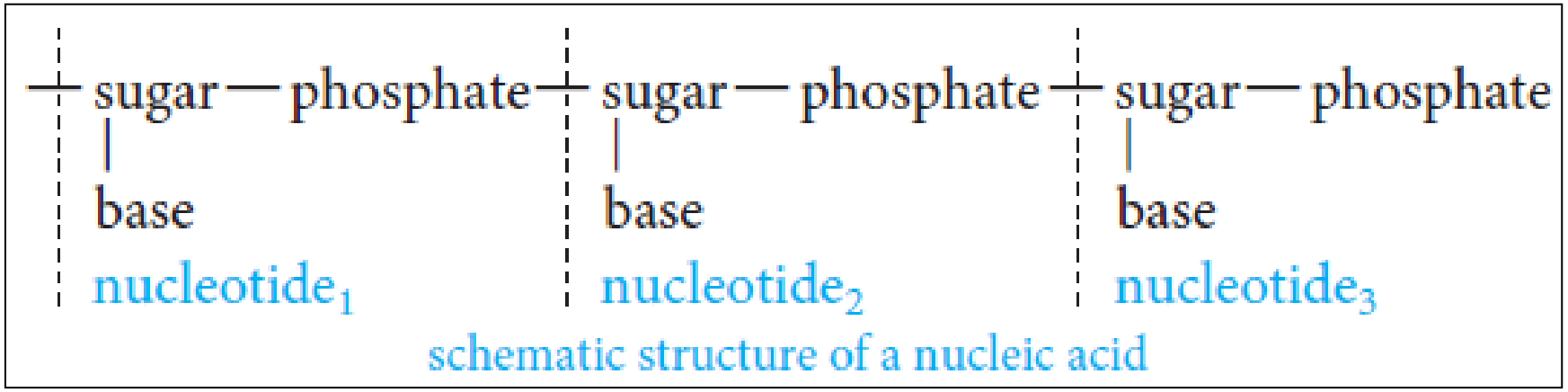


- ***Nucleosides :*** contain two parts:
  - **A Nitrogenous Base (Nucleobase)**
  - **A Five-Carbon Sugar (Pentose)**



The General Structure of Nucleic Acids

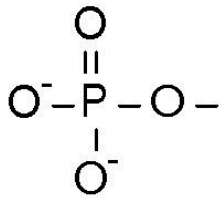
- **The overall structure of the nucleic acid** is a macromolecule with a backbone of sugar molecules connected by phosphate links and with a base attached to each sugar unit.



schematic structure of a nucleic acid

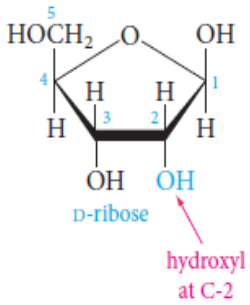
The General Structure of Nucleic Acids

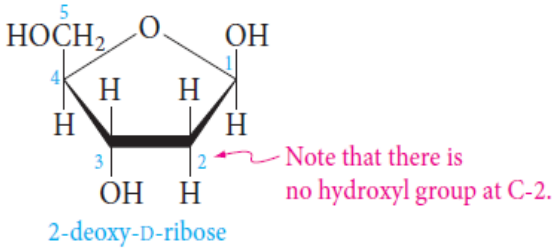
Phosphate group



Pentose Sugar

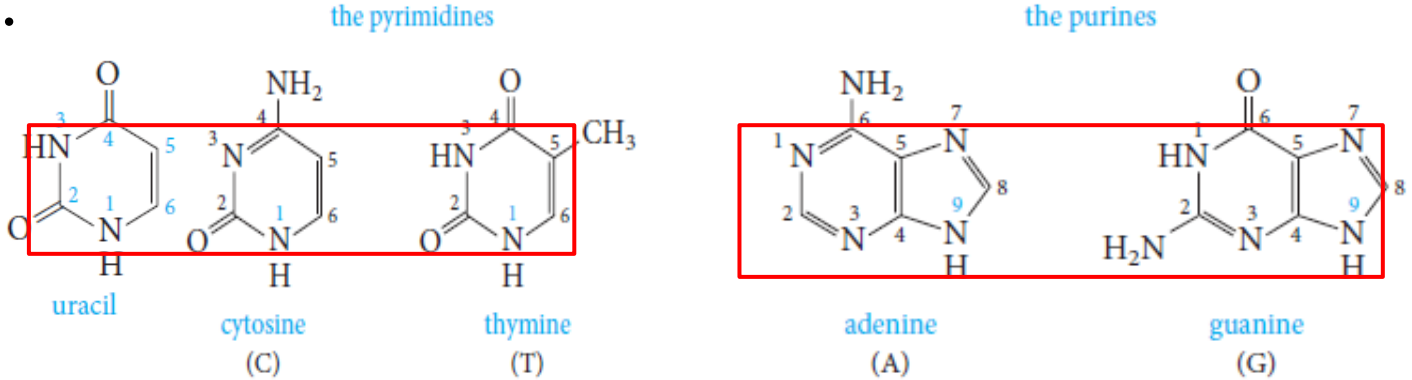
- **Ribonucleic acid (RNA)** contains the pentose ribose.
- **Deoxyribonucleic acid (DNA)** contains the pentose deoxyribose.





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

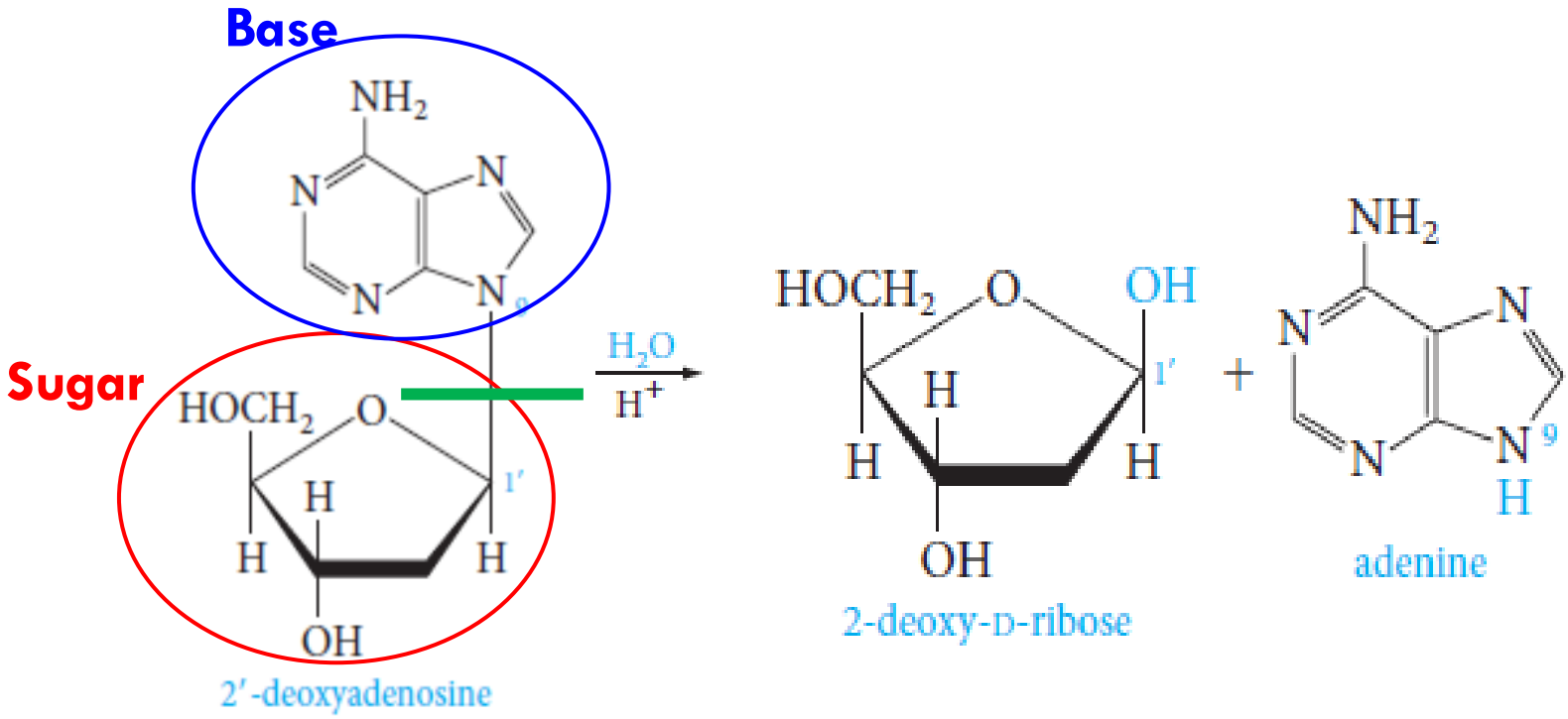
Differences Between DNA and RNA Composition

	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**.*



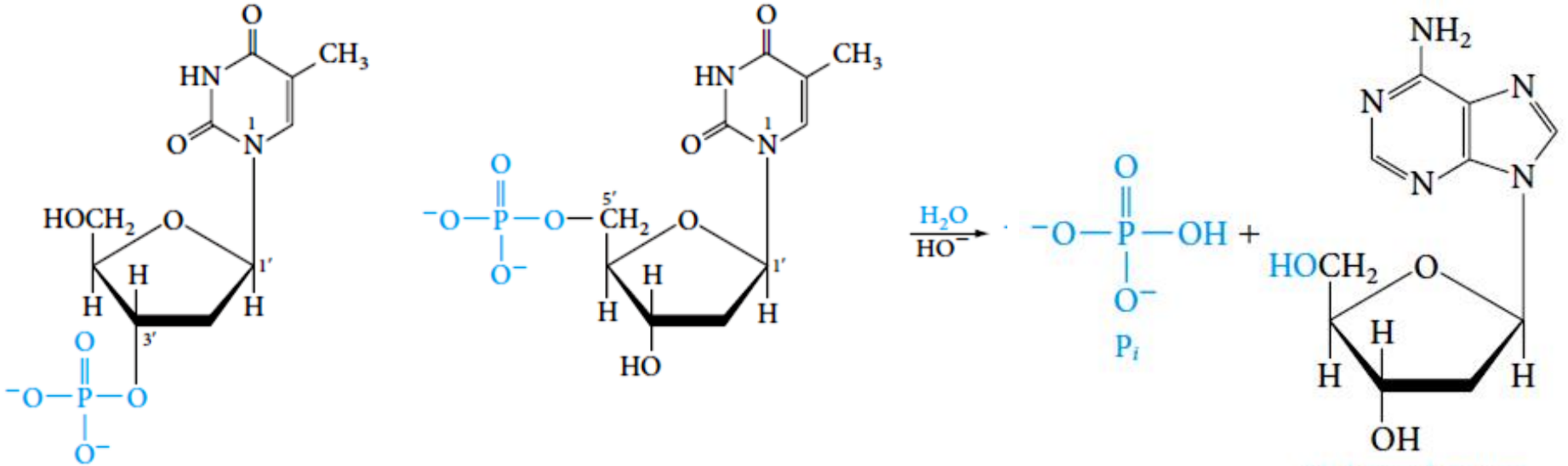
The General Structure of Nucleic Acids

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

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

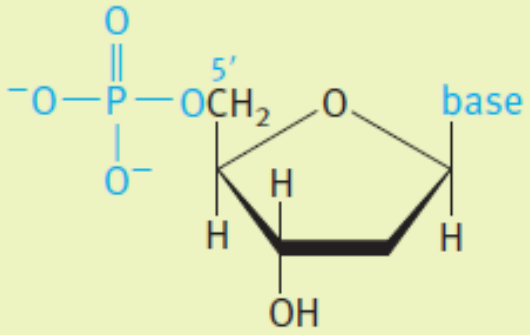
  In DNA nucleotides, either the 3' or the 5' hydroxyl group of 2-deoxy-d-ribose is esterified.

- **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

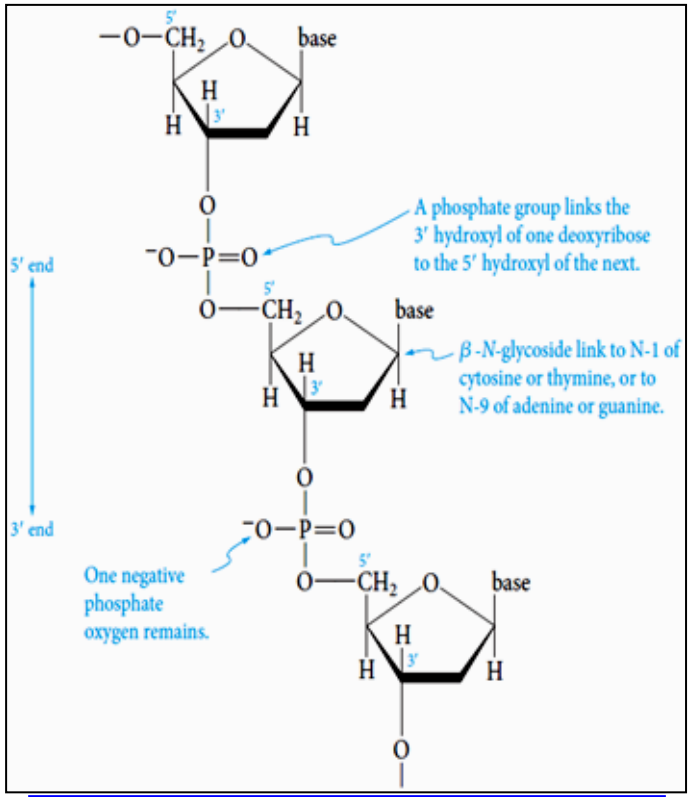
The General Structure of Nucleic Acids

- **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

Ribonucleic Acid (RNA)

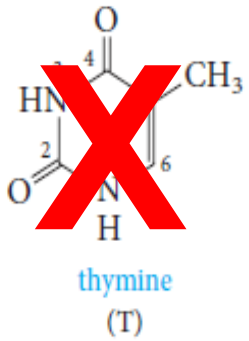
- **Ribonucleic acids (RNA) differ from DNA in three important ways:**

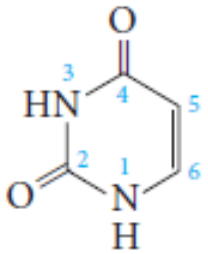
(1) The sugar is D-ribose;

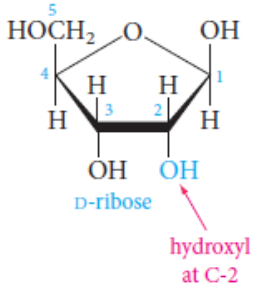
(2) Uracil replaces thymine as one of the four heterocyclic bases

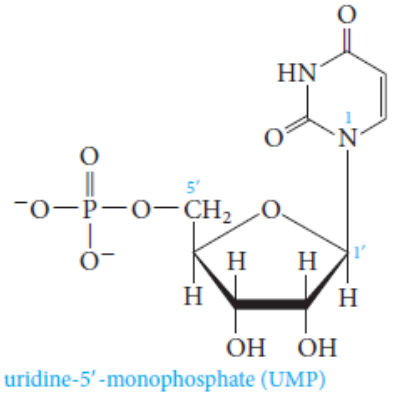
(3) Many RNAs are

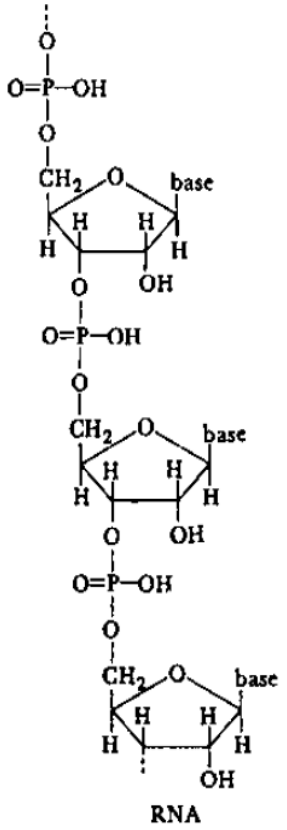
- Single-stranded segments,
- Combinations of complementary two-stranded helices,
- Complex structures.

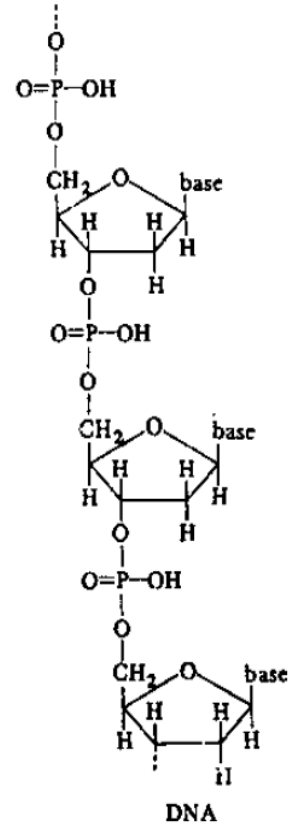












Importance of DNA and RNA

- 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.