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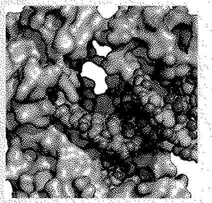
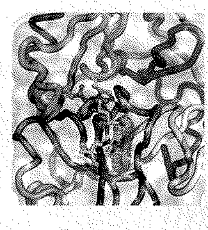
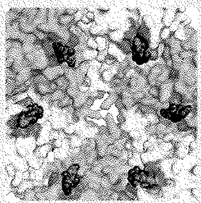
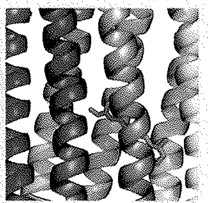
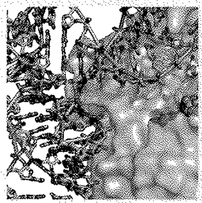
Life at the Molecular Level

Donald Voet · Judith G. Voet · Charlotte W. Pratt

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Biochemistry

LIFE AT THE MOLECULAR LEVEL

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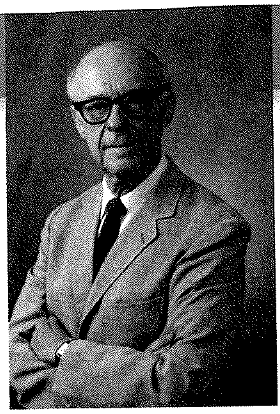

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scholar, teacher, friend

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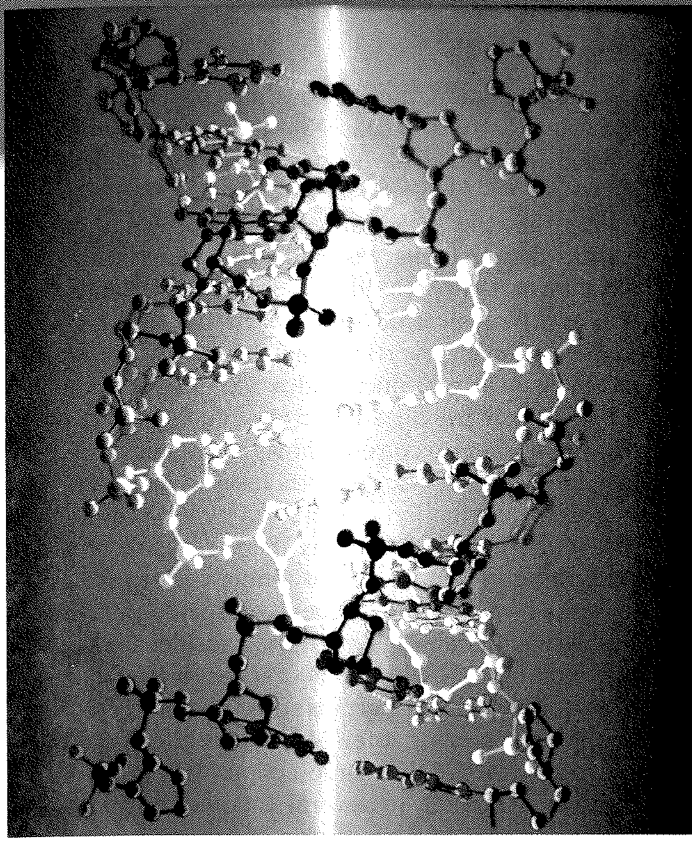

3

Nucleotides, Nucleic Acids, and Genetic Information

A DNA molecule consists of two strands that wind around a central axis, shown here as a glowing wire. [Illustration, Irving Geis. Image from the Irving Geis Collection/Howard Hughes Medical Institute. Rights owned by HHMI. Reproduction by permission only.]

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(Available at www.wiley.com/college/voet)

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Despite obvious differences in lifestyle and macroscopic appearance, organisms exhibit striking similarity at the molecular level. The structures and metabolic activities of all cells rely on a common set of molecules that includes amino acids, carbohydrates, lipids, and nucleotides, as well as their polymeric forms. Each type of compound can be described in terms of its chemical makeup, its interactions with other molecules, and its physiological function. We begin our survey of biomolecules with a discussion of the **nucleotides** and their polymers, the **nucleic acids.**

Nucleotides are involved in nearly every facet of cellular life. Specifically, they participate in oxidation–reduction reactions, energy transfer, intracellular signaling, and biosynthetic reactions. Their polymers, the nucleic acids DNA and RNA, are the primary players in the storage and decoding of genetic information. Nucleotides and nucleic acids also perform structural and catalytic roles in cells. No other class of molecules participates in such varied functions or in so many functions that are essential for life.

Evolutionists postulate that the appearance of nucleotides permitted the evolution of organisms that could harvest and store energy from their surroundings and, most importantly, could make copies of themselves. Although the chemical and biological details of early life-forms are the subject of speculation, it is incontrovertible that life as we know it is inextricably linked to the chemistry of nucleotides and nucleic acids.

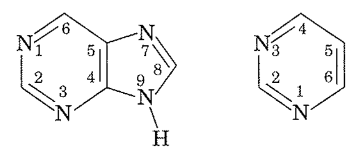
In this chapter, we briefly examine the structures of nucleotides and the nucleic acids DNA and RNA. We also consider how the chemistry of these molecules allows them to carry biological information in the form of a sequence of nucleotides. This information is expressed by the transcription of a segment of DNA to yield RNA, which is then translated to form protein. Because a cell's structure and function ultimately depend on its genetic makeup, we discuss how genomic sequences provide information about evolution, metabolism, and disease. Finally, we consider some of the techniques used in manipulating DNA in the laboratory. In later chapters, we will examine in greater detail the participation of nucleotides and nucleic acids in metabolic processes. Chapter 24 includes additional information about nucleic acid structures, DNA's interactions with proteins, and DNA packaging in cells, as a prelude to several chapters discussing the roles of nucleic acids in the storage and expression of genetic information.

1 Nucleotides

LEARNING OBJECTIVE

- Become familiar with the structures and nomenclature of the eight common nucleotides.

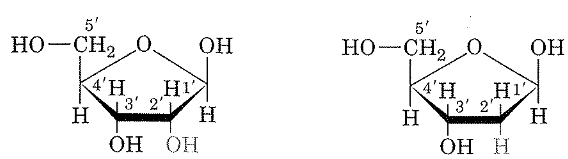
Nucleotides are ubiquitous molecules with considerable structural diversity. *There are eight common varieties of nucleotides, each composed of a nitrogenous base linked to a sugar to which at least one phosphate group is also attached.* The bases of nucleotides are planar, aromatic, heterocyclic molecules that are structural derivatives of either **purine** or **pyrimidine** (although they are not synthesized *in vivo* from either of these organic compounds).



Purine **Pyrimidine**

The most common purines are **adenine (A)** and **guanine (G),** and the major pyrimidines are **cytosine (C), uracil (U),** and **thymine (T).** The purines form bonds to a five-carbon sugar (a pentose) via their N9 atoms, whereas pyrimidines do so through their N1 atoms (Table 3-1).

In **ribonucleotides,** the pentose is **ribose,** while in **deoxyribonucleotides** (or just **deoxynucleotides**), the sugar is **2′-deoxyribose** (i.e., the carbon at position 2′ lacks a hydroxyl group).



Ribose **Deoxyribose**

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