3.6 Biological Molecules - Nucleic Acids

Learning objectives

By the end of this section, you will be able to:

- *Recognize the monomer and polymer for nucleic acids*
- *Describe the structure of a nucleic acid*
- *Explain DNA's structure and role*
- *Explain RNA's structure and roles*
- *Be able to define and explain all bolded terms*

Nucleic acids are essential macromolecules that allow cells to survive. They carry the cell's genetic blueprint and contain instructions that allow cells to function properly.

The two main types of nucleic acids are **deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA)**. DNA is the genetic material found in all living organisms. DNA contains the "instructions" on how the cell makes different proteins necessary for maintaining homeostasis. DNA is located in the nucleus of eukaryotes and in two eukaryotic organelles, chloroplasts and mitochondria. Prokaryotes also possess DNA, however it is not enclosed in a membrane-bound organelle.

The second type of nucleic acid, RNA, is mostly involved in protein synthesis and regulation. In eukaryotic cells, DNA never leaves the nucleus, so a specific type of RNA, messenger RNA (mRNA), helps to relay information from the nucleus to other parts of the cell. Transfer RNA (tRNA) and ribosomal RNA (rRNA) are essential in protein synthesis and will be discussed in chapter 10.

DNA and RNA are polymers made up of monomers called **nucleotides**. The nucleotides combine with each other to form a polynucleotide, DNA or RNA. Each nucleotide is made up of three components: a nitrogenous base, a pentose (five-carbon) sugar, and a phosphate group. Each nitrogenous base in a nucleotide is attached to a sugar molecule, which is attached to a phosphate group (Figure 3.36).

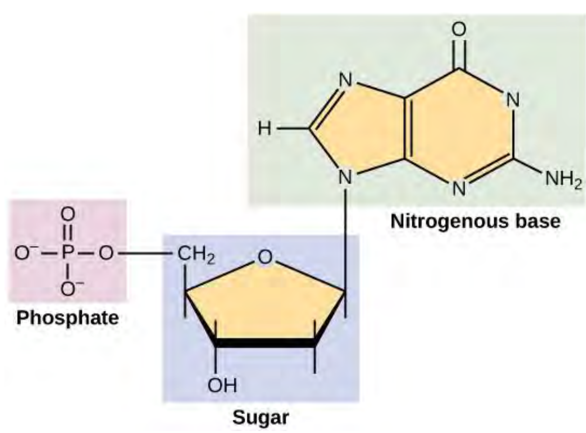

Figure 3.36 A nucleotide is made up of three components: a nitrogenous base, a pentose sugar, and a phosphate group. (credit: Fowler et al. / Concepts of Biology OpenStax)

Although both DNA and RNA are made of nucleotides, there are distinct differences. First, DNA and RNA are made up of different types of pentose sugars. DNA contains the sugar deoxyribose (so-called because it has one less oxygen atom), whereas RNA is made using the sugar ribose. Each DNA nucleotide contains one of the following nitrogenous bases: adenine, cytosine, guanine, and thymine. RNA nucleotides also use the bases: adenine, cytosine, guanine, however, instead of the base thymine, RNA uses the base uracil. Notice that the nucleotides that makeup DNA never contain the nitrogenous base uracil, and nucleotides that makeup RNA never contain the base thymine. The nitrogen-containing bases adenine and guanine are classified as purines. The bases cytosine, thymine and uracil are pyrimidines (Figure 3.37).

Structurally, DNA is shaped like a double helix, which we will discuss later. RNA is usually singled stranded and performs several different roles important for generating proteins. Take some time to review Table 3.2 which shows the features of both DNA and RNA.

DNA and RNA Features

	DNA	RNA
Function	Carries genetic information	Involved in protein synthesis
Location	Remains in the nucleus of eukaryotes	Leaves the nucleus in eukaryotes
Structure	Double helix	Usually single-stranded
Sugar	Deoxyribose	Ribose
Pyrimidines	Cytosine, thymine	Cytosine, uracil
Purines	Adenine, guanine	Adenine, guanine

Table 3.2 shows the features of both DNA and RNA. (credit: Clark et al./ Biology 2E OpenStax)

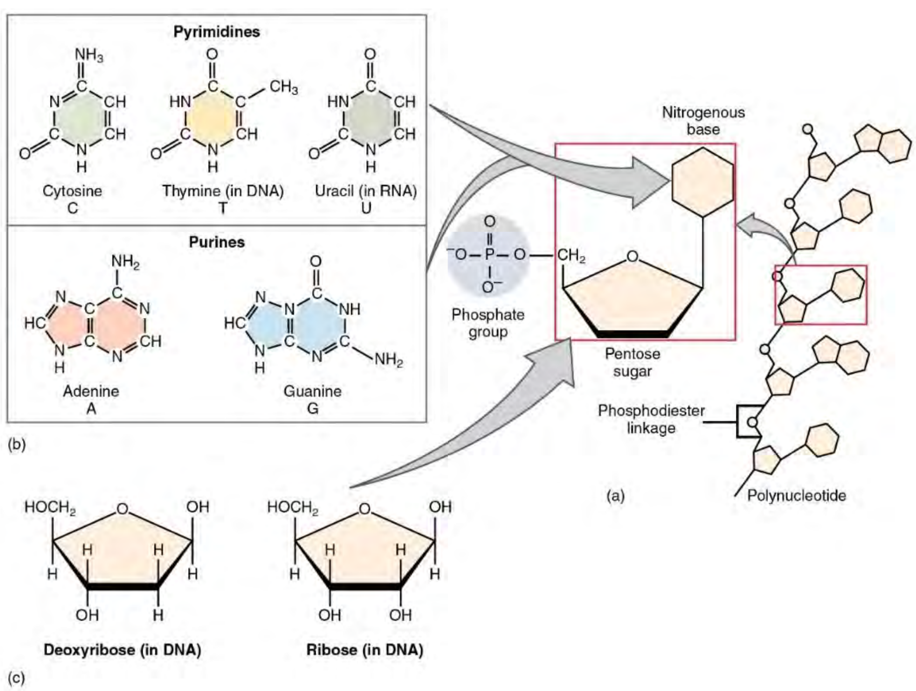

Figure 3.37 (a) A nucleotide. (b) The nitrogen-containing bases of nucleotides. (c) The two pentose sugars of DNA and RNA (credit: Betts et al. / Anatomy and Physiology OpenStax)

DNA Double-Helical Structure

DNA is shaped like a double helix (Figure 3.38). It is composed of two strands of nucleotides. Each DNA strand is formed with covalent bonds between the phosphate and sugar groups of adjacent nucleotides. The bonds between the sugar and phosphate make up the "sugar-phosphate backbone." The two separate DNA strands are held together by hydrogen bonds between nitrogenous bases (Figure 3.38). The strands usually coil, hence the “double helix” description.

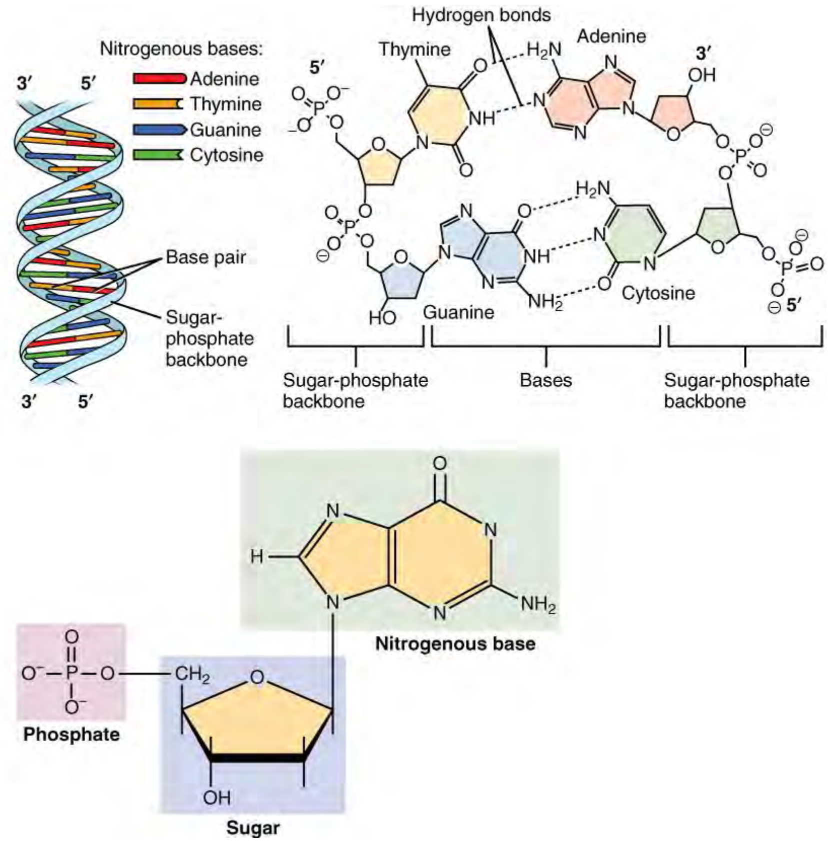

Figure 3.38 Molecular Structure of DNA. The DNA double helix is composed of two complementary strands. The strands are bonded together via their nitrogenous base pairs using hydrogen bonds. (credit: Betts et al. / [Anatomy and Physiology OpenStax](#))

DNA and RNA are both examples of nucleic acids that perform unique functions that allow cells to survive. The flow of information within a cell or organism usually begins with DNA, which is used to make RNA, which is necessary to synthesize protein. DNA dictates the structure of mRNA in a process called **transcription**, and RNA dictates the protein's structure in a process called **translation**. This is the Central Dogma of Life, which holds true for many organisms (Figure 3.39). However, exceptions to the rule occur with some viral infections. The flow of information will be examined in chapter 10.

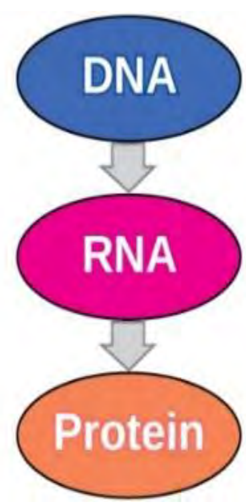

Figure 3.39 The central dogma states that DNA encodes RNA, which in turn encodes protein. (credit: Fowler et al. / [Concepts of Biology OpenStax](#))