

9.1: Nucleotides

Learning Objectives

- Identify the components of nucleosides and nucleotides.
- Identify structural differences between the nitrogenous bases.
- To identify the different molecules that combine to form nucleotides.
- Differentiate between the components in DNA and RNA.
- Demonstrate naming nucleosides and nucleotides.

Nucleic acids are molecules that store and replicate information for cellular growth and reproduction. The two types of nucleic acids are **deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA)**. The repeating, or monomer, units that are linked together to form nucleic acids are known as **nucleotides**.

Structural Components of Nucleotides

The deoxyribonucleic acid (DNA) of a typical mammalian cell contains about 3×10^9 nucleotides. Nucleotides can be further broken down to phosphoric acid (H_3PO_4), a pentose sugar (a sugar with five carbon atoms), and a nitrogenous base (a base containing nitrogen atoms).



If the pentose sugar is ribose, the nucleotide is more specifically referred to as a **ribonucleotide**, and the resulting nucleic acid is ribonucleic acid (RNA). If the sugar is 2-deoxyribose, the nucleotide is a **deoxyribonucleotide**, and the nucleic acid is DNA.

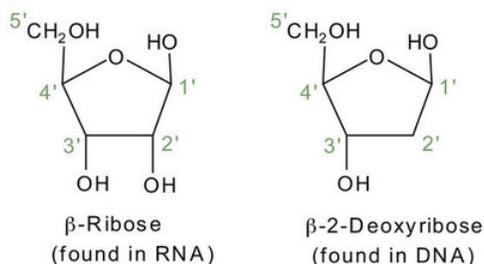


Figure 9.1.1: Structures of pentose sugar found in nucleic acids: ribose (left) and 2-deoxyribose (right).

The nitrogenous bases found in nucleotides are classified as **pyrimidines** or **purines**. Pyrimidines are heterocyclic amines with two nitrogen atoms in a six-member ring and include uracil, thymine, and cytosine. Purines are heterocyclic amines consisting of a pyrimidine ring fused to a five-member ring with two nitrogen atoms. Adenine and guanine are the major purines found in nucleic acids (Figure 9.1.2).

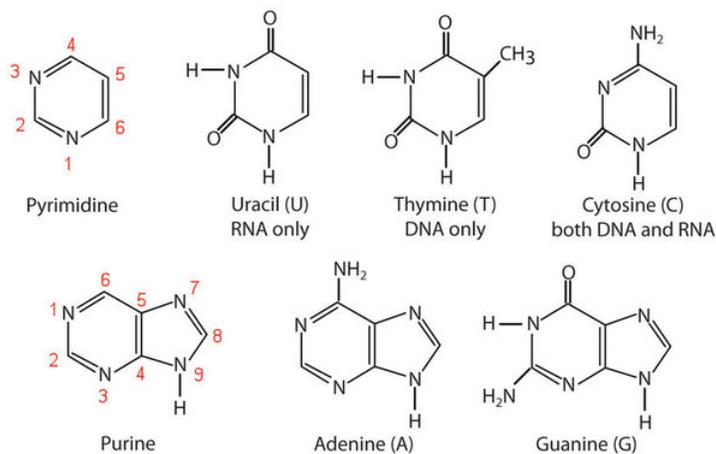


Figure 9.1.2: The Nitrogenous Bases Found in DNA and RNA

The formation of a **glycosidic bond** between C1' of the pentose sugar and N1 of the pyrimidine base or N9 of the purine base joins the pentose sugar to the nitrogenous base. In the formation of this bond, a molecule of water is removed. Table 9.1.1 summarizes the similarities and differences in the composition of nucleotides in DNA and RNA.

The numbering convention is that primed numbers designate the atoms of the pentose ring, and unprimed numbers designate the atoms of the purine or pyrimidine ring.

Table 9.1.1: Composition of Nucleotides in DNA and RNA

Composition	DNA	RNA
purine bases	adenine and guanine	adenine and guanine
pyrimidine bases	cytosine and thymine	cytosine and uracil
pentose sugar	2-deoxyribose	ribose
inorganic acid	phosphoric acid (H ₃ PO ₄)	H ₃ PO ₄

Nucleosides

A **nucleoside** is produced during the condensation reaction between the pentose and nitrogenous base.

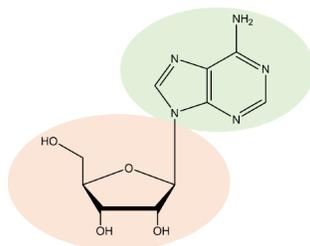


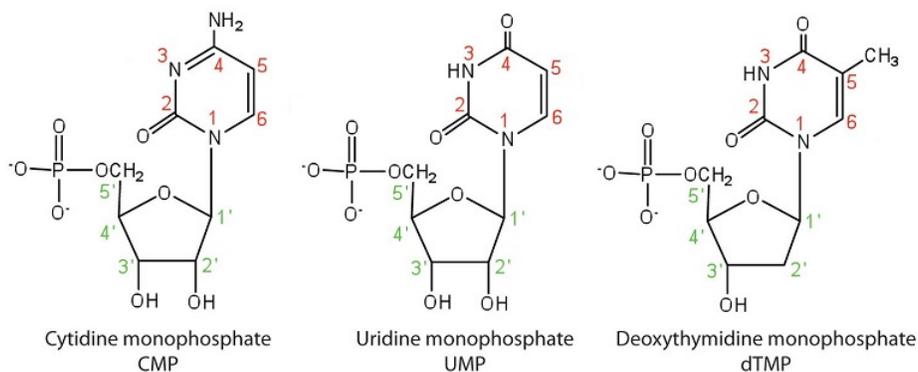
Figure 9.1.3: Structure of a nucleoside formed with the pentose sugar (shaded orange) and adenine base (shaded green).

Nucleosides are named according to the identity of the nitrogenous base, by changing the ending of the name. If the base is a purine, the -ine ending is replaced *-osine*. If the base is a pyrimidine, the -ine or -il ending is replaced with *-idine*. If the nucleotide represents a deoxyribonucleotide, the word *deoxy-* is added to the front of the name. Using these guidelines, the name of the nucleoside shown in Figure 9.1.3 is determined to be adenosine.

Naming Nucleotides

Nucleotides are named by adding monophosphate (sometimes shown as 5'-monophosphate) to the end of the name of the corresponding nucleoside. In addition to the full name, abbreviations can be used to indicate the composition of the nucleotide. If deoxyribose is present, a lower case *d* is used. The names (full and abbreviated) and structures of the major ribonucleotides and one of the deoxyribonucleotides are given in Figure 9.1.4.

Pyrimidine Nucleotides



Purine Nucleotides

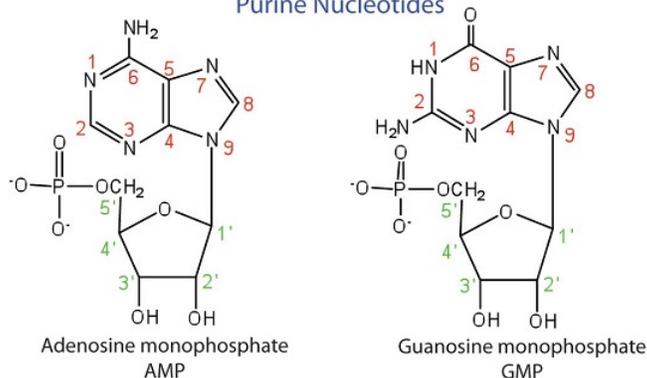


Figure 9.1.4: The Pyrimidine and Purine Nucleotides

Apart from being the monomer units of DNA and RNA, the nucleotides and some of their derivatives have other functions as well. Adenosine diphosphate (ADP) and adenosine triphosphate (ATP), shown in Figure 9.1.5, have a role in cell metabolism. Moreover, a number of coenzymes, including flavin adenine dinucleotide (FAD), nicotinamide adenine dinucleotide (NAD^+), and coenzyme A, contain adenine nucleotides as structural components.

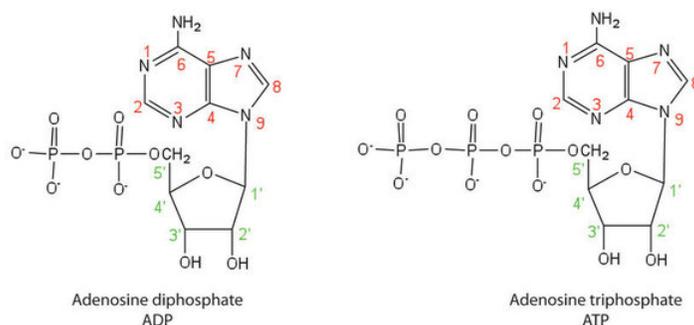


Figure 9.1.5: Structures of Two Important Adenine-Containing Nucleotides

✓ Example 9.1.1

Classify each compound as a pentose sugar, a purine, or a pyrimidine. Indicate whether it can exist in DNA, RNA, or both.

- adenine
- guanine
- deoxyribose

Solution

- purine, it can exist in both DNA and RNA
- purine, it can exist in both DNA and RNA
- pentose sugar, it can only exist in DNA

? Exercise 9.1.1

Classify each compound as a pentose sugar, a purine, or a pyrimidine. Indicate whether it can exist in DNA, RNA, or both.

- thymine
- ribose
- cytosine

Summary

Nucleosides are composed of a pentose sugar (ribose or deoxyribose) and a nitrogen-containing base (adenine, cytosine, guanine, thymine, or uracil). Nucleosides containing a purine base end with *osine* and those containing a pyrimidine end with *idine*. If the deoxyribose sugar is present, *deoxy* is added to the front of the name.

Nucleotides are composed of phosphoric acid, a pentose sugar (ribose or deoxyribose), and a nitrogen-containing base (adenine, cytosine, guanine, thymine, or uracil). Ribonucleotides contain ribose, while deoxyribonucleotides contain deoxyribose. Nucleotides are named by adding monophosphate to the end of the nucleoside name.

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