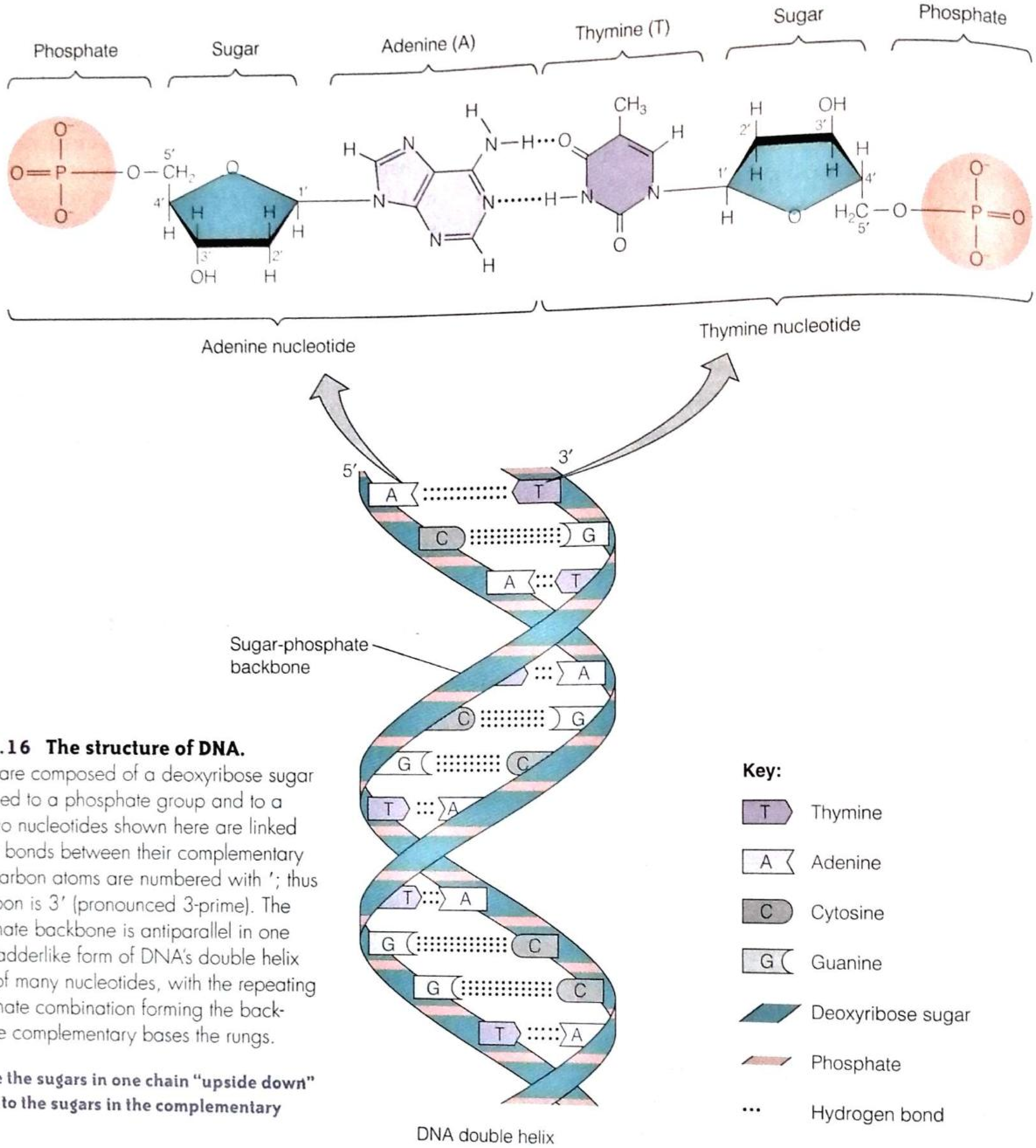

FIGURE 2.16 The structure of DNA. Nucleotides are composed of a deoxyribose sugar molecule linked to a phosphate group and to a base. The two nucleotides shown here are linked by hydrogen bonds between their complementary bases. The carbon atoms are numbered with ′; thus the third carbon is 3′ (pronounced 3-prime). The sugar-phosphate backbone is antiparallel in one strand. The ladderlike form of DNA's double helix is made up of many nucleotides, with the repeating sugar-phosphate combination forming the backbone and the complementary bases the rungs.

Q Why are the sugars in one chain "upside down" relative to the sugars in the complementary chain?

structures called **purines,** whereas T, C, and U are single-ring structures referred to as **pyrimidines.**

Nucleotides are named according to their nitrogen-containing base. Thus, a nucleotide containing thymine is a *thymine nucleotide*, one containing adenine is an *adenine nucleotide*, and so on. The term **nucleoside** refers to the combination of a purine or pyrimidine plus a pentose sugar; it does not contain a phosphate group.

DNA

According to the model proposed by Watson and Crick, a DNA molecule consists of two long strands wrapped around each other to form a **double helix** (Figure 2.16). The double helix looks like a twisted ladder, and each strand is composed of many nucleotides.

Every strand of DNA composing the double helix has a "backbone" consisting of alternating deoxyribose sugar and phosphate groups. The deoxyribose of one nucleotide is joined to the phosphate group of the next. (Refer to Figure 8.3, page 219, to see how nucleotides are bonded.) The nitrogen-containing bases make up the rungs of the ladder. Note that the purine A is always paired with the pyrimidine T and that the purine G is always paired with the pyrimidine C. The bases are held together by hydrogen

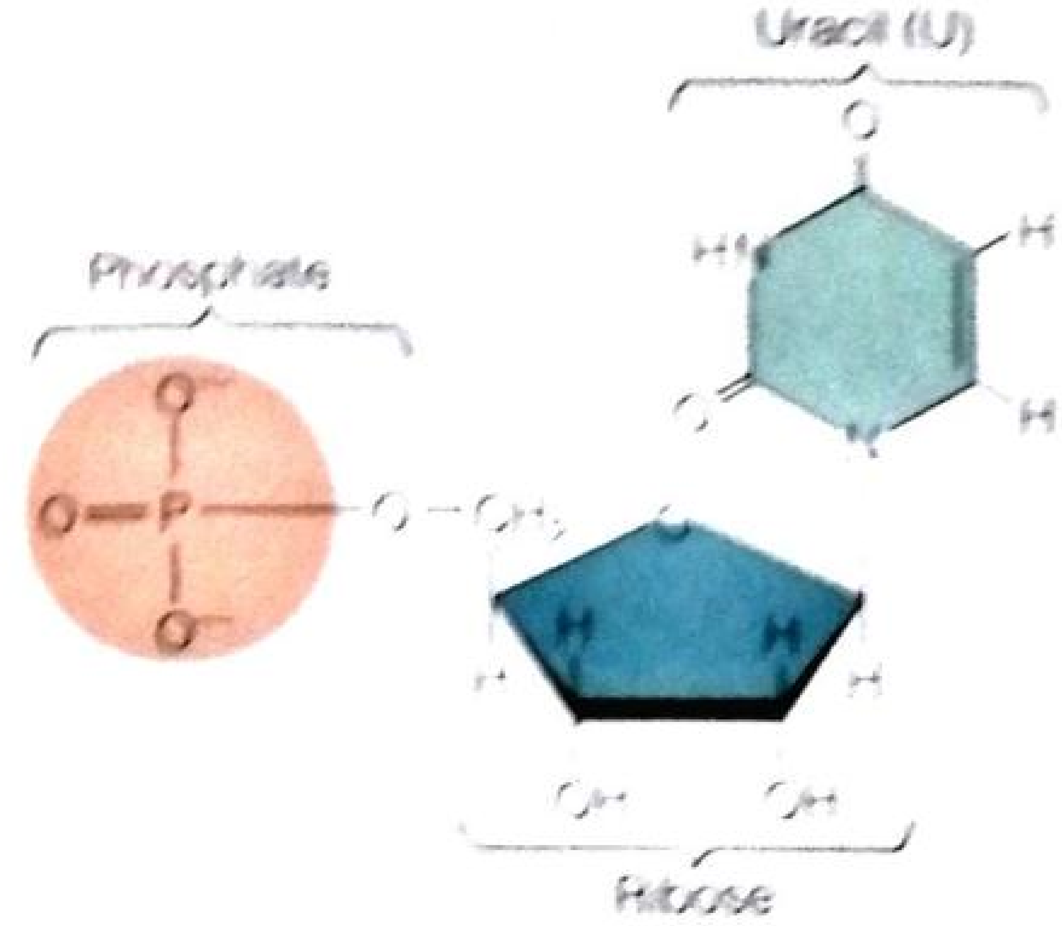

FIGURE 2.17 A uracil nucleotide of RNA.

Q How do DNA and RNA differ in structure?

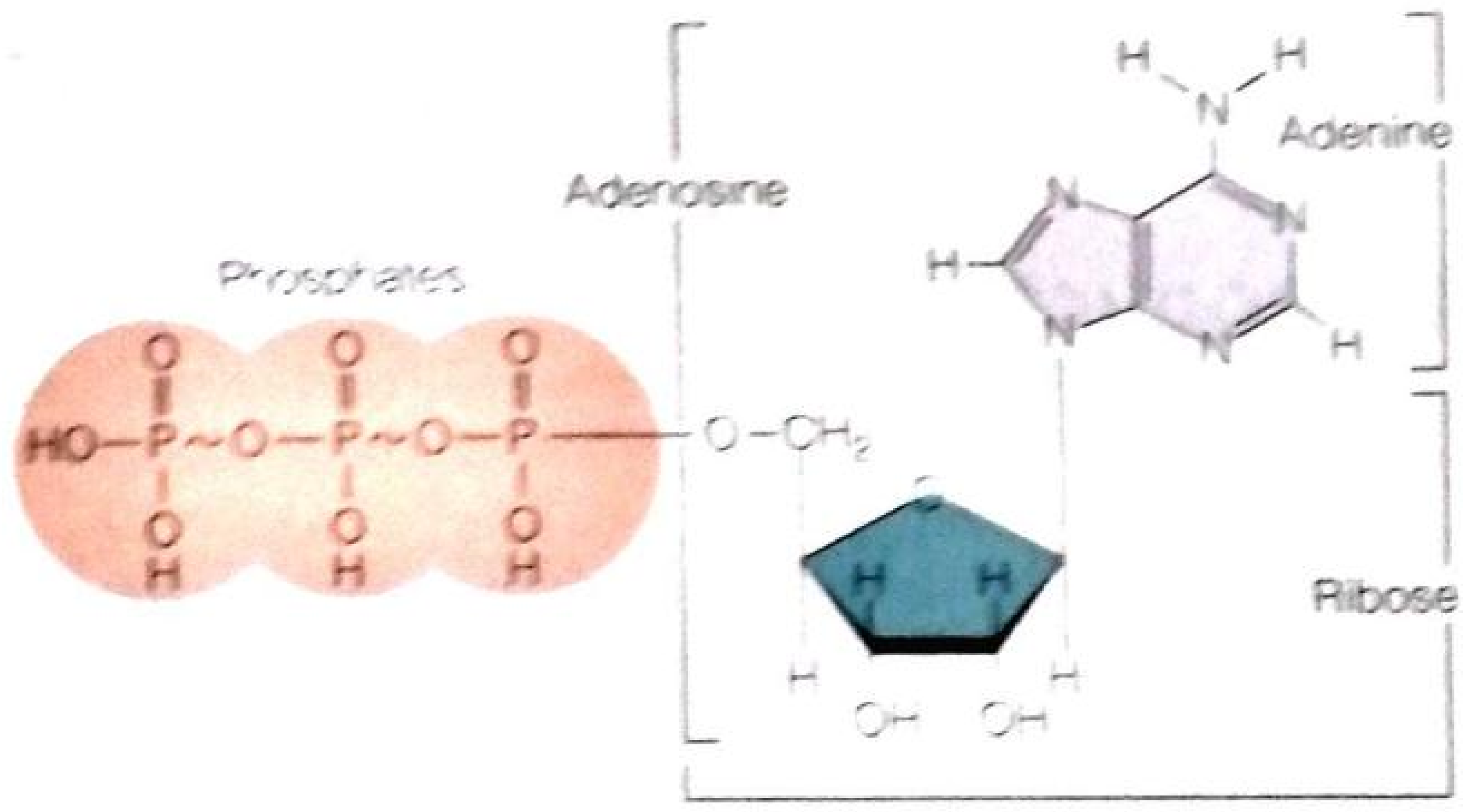

FIGURE 2.18 The structure of ATP. High-energy phosphate bonds are indicated by wavy lines. When ATP breaks down to ADP and inorganic phosphate, a large amount of chemical energy is released for use in other chemical reactions.

Q How is ATP similar to a nucleotide in RNA? In DNA?

bonds; A and T are held by two hydrogen bonds, and G and C are held by three. DNA does not contain uracil (U).

The order in which the nitrogen base pairs occur along the backbone is extremely specific and in fact contains the genetic instructions for the organism. Nucleotides form genes, and a single DNA molecule may contain thousands of genes. Genes determine all hereditary traits, and they control all the activities that take place within cells.

One very important consequence of nitrogen-containing base pairing is that if the sequence of bases of one strand is known, then the sequence of the other strand is also known. For example, if one strand has the sequence . . . ATGC . . . , then the other strand has the sequence . . . TACG. . . . Because the sequence of bases of one strand is determined by the sequence of bases of the other, the bases are said to be *complementary*. The actual transfer of information becomes possible because of DNA's unique structure and will be discussed further in Chapter 8.

RNA

RNA, the second principal kind of nucleic acid, differs from DNA in several respects. Whereas DNA is double-stranded, RNA is usually single-stranded. The five-carbon sugar in the RNA nucleotide is ribose, which has one more oxygen atom than deoxyribose. Also, one of RNA's bases is uracil (U) instead of thymine (Figure 2.17). The other three bases (A, G, C) are the same as DNA. Three major kinds of RNA have been identified in cells. These are referred to as **messenger RNA (mRNA), ribosomal RNA (rRNA),** and **transfer RNA (tRNA).** As we will see in Chapter 8, each type of RNA has a specific role in protein synthesis.

ADENOSINE TRIPHOSPHATE (ATP)

LEARNING OBJECTIVE

- Describe the role of ATP in cellular activities.

Adenosine triphosphate (ATP) is the principal energy-carrying molecule of all cells and is indispensable to the life of the cell. It stores the chemical energy released by some chemical reactions, and it provides the energy for reactions that require energy. ATP consists of an adenosine unit, composed of adenine and ribose, with three phosphate groups (abbreviated Ⓟ) attached (Figure 2.18). In other words, it is an adenine nucleotide (also called adenosine monophosphate, or AMP) with two extra phosphate groups. ATP is called a high-energy molecule because it releases a large amount of usable energy when the third phosphate group is hydrolyzed to become **adenosine diphosphate (ADP).** This reaction can be represented as follows:

$$\underset{\text{Adenosine triphosphate}}{\text{Adenosine} - Ⓟ - Ⓟ - Ⓟ} + \underset{\text{Water}}{H_2O} \rightleftharpoons \underset{\text{Adenosine diphosphate}}{\text{Adenosine} - Ⓟ - Ⓟ} + \underset{\text{Inorganic phosphate}}{Ⓟ_i} + \text{Energy}$$

A cell's supply of ATP at any particular time is limited. Whenever the supply needs replenishing, the reaction goes in the reverse direction; the addition of a phosphate group to ADP and the input of energy produces more ATP. The energy required to attach the terminal phosphate group to ADP is supplied by the cell's various oxidation reactions, particularly the oxidation of glucose. ATP can be stored in every cell, where its potential energy is not released until needed.