instead, brief attachments. This helps them play particular roles in the cell. On the other hand, strong bonds—those that hold molecules together—are almost never broken simply by molecular collision. Thus they are relatively permanent. They can be broken by chemical action (the making of even stronger bonds), and this usually happens in the cell with the aid of an enzyme, which is a protein molecule.

EXAMPLE 29–1 **Nucleotide energy.** Calculate the potential energy between the C═O dipole of thymine and the H—N dipole of adenine, assuming that the two dipoles are lined up as shown in Fig. 29–11. Dipole moment measurements (see Table 17–2) give

$$q_{\mathrm{H}} = -q_{\mathrm{N}} = 0.19e = 3.0 \times 10^{-20}\,\mathrm{C},$$

and

$$q_{\mathrm{C}} = -q_{\mathrm{O}} = 0.41e = 6.6 \times 10^{-20}\,\mathrm{C}.$$

APPROACH We want to find the potential energy of the two charges in one dipole due to the two charges in the other, since this will be equal to the work needed to pull them infinitely far apart. The potential energy PE of a charge q_1 in the presence of a charge q_2 is

$$\mathrm{PE} = k\frac{q_1 q_2}{r_{12}}$$

where $k = 9.0 \times 10^9\,\mathrm{N\cdot m^2/C^2}$ (see Eqs. 17–2 and 17–5).

SOLUTION The potential energy (we use the symbol U) will consist of four terms:

$$U = U_{\mathrm{CH}} + U_{\mathrm{CN}} + U_{\mathrm{OH}} + U_{\mathrm{ON}},$$

where U_{CH} means the potential energy of C in the presence of H, and similarly for the other terms. We do not have terms corresponding to C and O, or N and H, because the two dipoles are assumed to be stable entities. Then

$$U = k\frac{q_{\mathrm{C}} q_{\mathrm{H}}}{r_{\mathrm{CH}}} + k\frac{q_{\mathrm{C}} q_{\mathrm{N}}}{r_{\mathrm{CN}}} + k\frac{q_{\mathrm{O}} q_{\mathrm{H}}}{r_{\mathrm{OH}}} + k\frac{q_{\mathrm{O}} q_{\mathrm{N}}}{r_{\mathrm{ON}}}.$$

Using the distances shown in Fig. 29–11, we get:

$$\begin{aligned} U &= \left(9.0 \times 10^9\,\mathrm{N\cdot m^2/C^2}\right)\left(\frac{(6.6)(3.0)}{0.31} + \frac{(6.6)(-3.0)}{0.41} + \frac{(-6.6)(3.0)}{0.19} + \frac{(-6.6)(-3.0)}{0.29}\right)\frac{\left(10^{-20}\,\mathrm{C}\right)^2}{\left(10^{-9}\,\mathrm{m}\right)} \\ &= -1.83 \times 10^{-20}\,\mathrm{J} \\ &= -\frac{(1.83 \times 10^{-20}\,\mathrm{J})}{(1.60 \times 10^{-19}\,\mathrm{J/eV})} = -0.11\,\mathrm{eV}. \end{aligned}$$

The PE is negative, meaning 0.11 eV of work (or energy input) is required to separate the molecules. That is, the binding energy of this "weak" or hydrogen bond is 0.11 eV. This is only an estimate, of course, since other charges in the vicinity would have an influence too.

Protein Synthesis

Weak bonds, especially hydrogen bonds, are crucial to the process of protein synthesis. Proteins serve as structural parts of the cell and as enzymes to catalyze chemical reactions needed for the growth and survival of the organism. A protein molecule consists of one or more chains of small molecules known as *amino acids*.