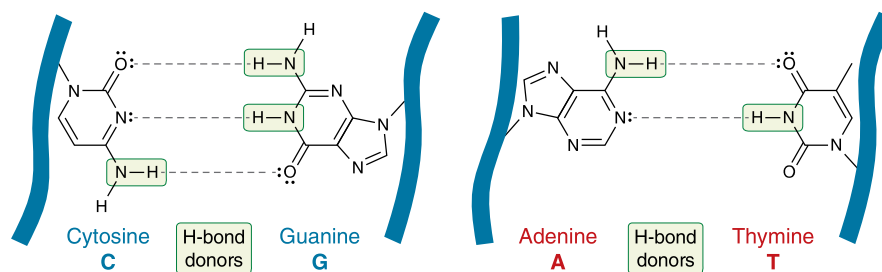


**FIGURE 1.50**  
The hydrogen-bonding interactions that exist between complementary base pairs in DNA.



It is important to point out that the term “hydrogen bonding” is somewhat misleading. A hydrogen bond is not actually a “bond” but rather, it is a type of attractive interaction. To illustrate this, compare the energy of a covalent bond with the energy of a hydrogen-bonding interaction. A typical single bond (C—H, N—H, O—H) has a bond strength of approximately 400 kJ/mol. In contrast, a hydrogen-bonding interaction has an average strength of approximately 20 kJ/mol. This leaves us with the obvious question: Why do we call them hydrogen bonds instead of just hydrogen interactions? To answer this question, consider the double-helix structure of DNA (Figure 1.46). The two strands are joined by hydrogen-bonding interactions that function like rungs of a very long, twisted ladder. The net sum of these interactions contributes to the structure of the double helix, in which the hydrogen-bonding interactions appear as if they were actually bonds. Nevertheless, it is relatively easy to “unzip” the double helix and retrieve the individual strands. The structure of DNA is explored in more detail in Section 24.9.

## BioLinks Hydrogen Bonding and Bad Hair Days



Wavy or straight or kinky or curly—each person has a certain type of hair as it grows naturally. And naturally, it’s human nature for people with straight hair to wish it was curly, and for people with curls to prefer straight hair. Heat or water can be used to style hair, but sometimes it feels like hair has a mind of its own! Perhaps if we learn about

some of the chemistry involved, we might have a better chance of avoiding bad hair days.

Hair fibers are made from long strands of  $\alpha$ -keratin, a protein that has a shape like a coiled spring (called an  $\alpha$ -helix). These long molecules are twisted together to make microscopically thin strands, which are then twisted together to make thicker filaments, and so on. Building the structure of a hair fiber is like intertwining threads to make a string, and then braiding the strings together to make a thick rope. The strands of keratin are held together with a variety of bonding and nonbonding interactions, as illustrated with two strands in the given figure. One of the strongest and most significant structural features is called a disulfide bond (a), a covalent bond between two sulfur atoms that creates a connection between two keratin strands. The resulting cross-link provides stability to the keratin structure and contributes to the curl of the hair fiber. Many of the side chain groups in the keratin protein are charged, so ion-ion attractions described as salt bridges (b) are also present. The most frequently occurring links between keratin strands are hydrogen bonds (c).

In order to add curls to straight hair, or to straighten curly hair, these intermolecular interactions must be disrupted. Chemical

treatments, such as relaxers, straighteners and “perms” cleave the covalent S—S bonds and then rebuild new disulfide bridges after the hair is repositioned. Such changes are *permanent* and will not be undone by hair washing. Other methods for styling hair, such as setting wet hair in curlers and letting it dry, or using the heat of a curling iron or a flat iron, are *temporary*. Covalent disulfide bonds are not broken by heat or water, so adding heat or water does not permanently alter the molecular structure of

keratin. Hydrogen bonds, on the other hand, will be disrupted with heat or by wetting hair, and after the hair is manipulated into a different shape and allowed to cool/dry, new hydrogen bonds will form to keep the hair fibers in the new position. The temporary nature of these styling methods becomes apparent when the hair is washed, and the style is completely undone. But sometimes when you try to style your hair, it doesn’t hold throughout the day. You may have noticed that a hairstyle is likely to be especially fleeting on a rainy or humid day. Why is this so? Because the water molecules in the air will displace all the hydrogen bonds that were so carefully positioned between the strands of keratin. This causes your hair to revert to its natural state: curls will flatten out and straightened hair will become frizzy. Now that you have some expertise in hair structure and hydrogen bonding, you can avoid future frustration on rainy days by skipping the styling and instead tying your hair back or wearing a hat.

