* 16–11 Electric Forces in Molecular Biology: DNA Structure and Replication

PHYSICS APPLIED

Inside a cell: Kinetic theory plus electrostatic force

The study of the structure and functioning of a living cell at the molecular level is known as molecular biology. It is an important area for application of physics. Since the interior of a cell is mainly water, we can imagine it as a vast sea of molecules continually in motion (as in kinetic theory, Chapter 13), colliding with one another with various amounts of kinetic energy. These molecules interact with one another in various ways—chemical reactions (making and breaking of bonds between atoms) and more brief interactions or unions that occur because of *electrostatic attraction* between molecules.

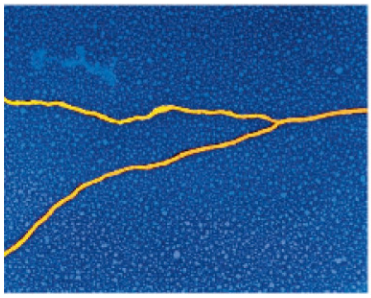

FIGURE 16–43 DNA replicating in a human HeLa cancer cell. This is a false-color image made by a transmission electron microscope (TEM; discussed in Chapter 27).

The many processes that occur within the cell are now considered to be the result of *random ("thermal") molecular motion plus the ordering effect of the electrostatic force*. We use these ideas now to analyze some basic cellular processes involving macromolecules (large molecules). The picture we present here has not been seen "in action." Rather, it is a model of what happens based on presently accepted physical theories and experimental results.

The genetic information that is passed on from generation to generation in all living cells is contained in the chromosomes, which are made up of genes. Each gene contains the information needed to produce a particular type of protein molecule. The genetic information contained in a gene is built into the principal molecule of a chromosome, DNA (deoxyribonucleic acid), Fig. 16–43. DNA molecules are made up of many small molecules known as nucleotide bases. There are four types of nucleotide bases in DNA: adenine (A), cytosine (C), guanine (G), and thymine (T).

PHYSICS APPLIED

DNA structure

The DNA of a chromosome generally consists of two long DNA strands wrapped about one another in the shape of a "double helix." The genetic information is contained in the specific order of the four bases (A, C, G, T) along the strand. As shown in Fig. 16–44, the two strands are attracted by electrostatic forces—that is, by the attraction of positive charges to negative charges. We see in Fig. 16–44a that an A (adenine) on one strand is always opposite a T on the

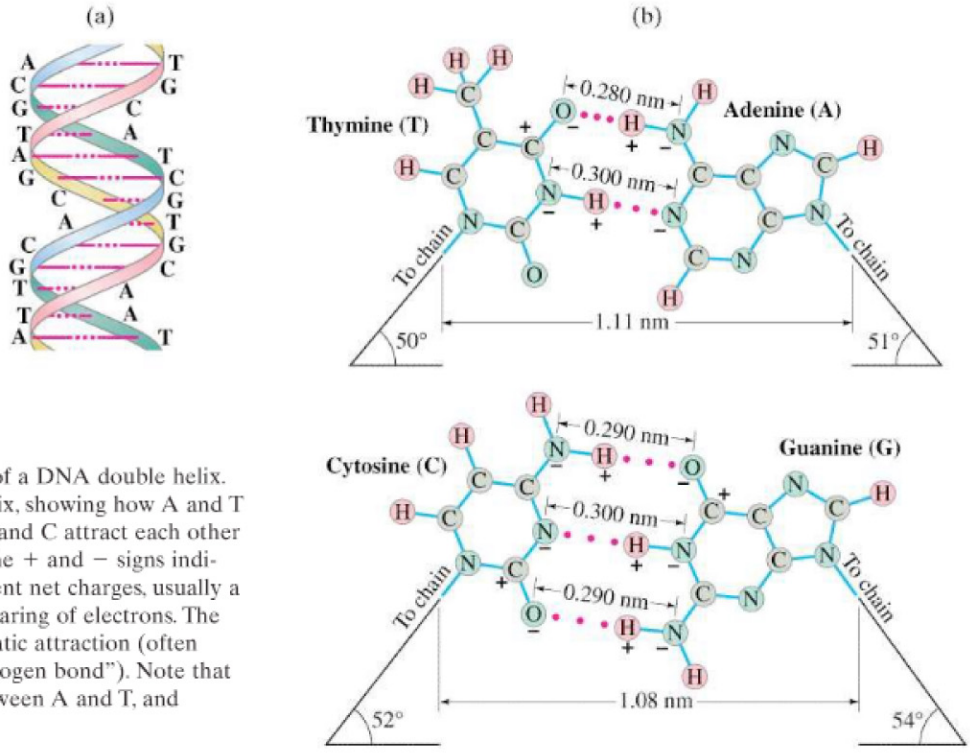

FIGURE 16–44 (a) Section of a DNA double helix. (b) "Close-up" view of the helix, showing how A and T attract each other and how G and C attract each other through electrostatic forces. The + and − signs indicated on certain atoms represent net charges, usually a fraction of e, due to uneven sharing of electrons. The red dots indicate the electrostatic attraction (often called a "weak bond" or "hydrogen bond"). Note that there are two weak bonds between A and T, and three between C and G.