

20.20: The Double Helix

There is more to the structure of DNA than just the primary sequence of nitrogenous bases. Secondary structure also plays a crucial biochemical role. Each DNA molecule consists of two nucleotide chains wrapped around each other in a double helix and held together by hydrogen bonds. This hydrogen bonding involves only the nitrogenous bases. Each of the purine bases can hydrogen bond with one and only one of the pyrimidine bases.

Thus adenine can hydrogen bond with thymine and guanine with cytosine, as shown in Figure 20.20.1. Note that in both cases there is an exact match of hydrogen atoms on the one base with nitrogen or oxygen atoms on the other. Note also that the distance from sugar linkage to sugar linkage across each of the base pairs in Figure 20.20.1 is almost exactly the same. This explains why only these two combinations occur in DNA. Other combinations (i.e., adenine-cytosine) are not nearly so favorable energetically.

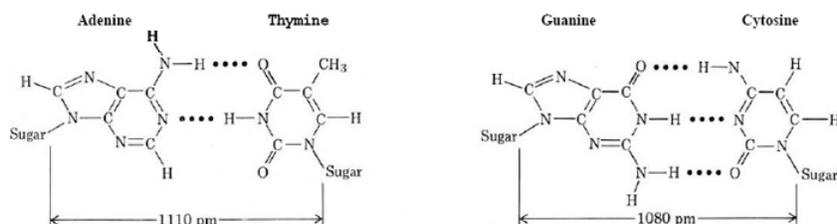


Figure 20.20.1 Hydrogen-bonded base pairs of DNA. Note the nearly equal separations between points where the bases connect to sugars in the DNA backbone. A pair of purines would have much larger and a pair of pyrimidines much smaller separation, making it difficult for such pairs to fit between the two strands.

The overall geometry of the two nucleotide chains in the DNA molecule is in the form of the double helix shown in Figure 20.20.2. Each helix corresponds to a nucleotide chain, and the two chains are joined throughout their length by adenine-thymine or guanine-cytosine pairs. These base pairs are stacked one above the other with their planes perpendicular to the axis of the two spirals. This places the hydrophobic base pairs inside the structure and allows the hydrophilic sugar and phosphate groups to contact water on the exterior. The whole helix will just fit inside a cylinder 2000 pm in diameter.

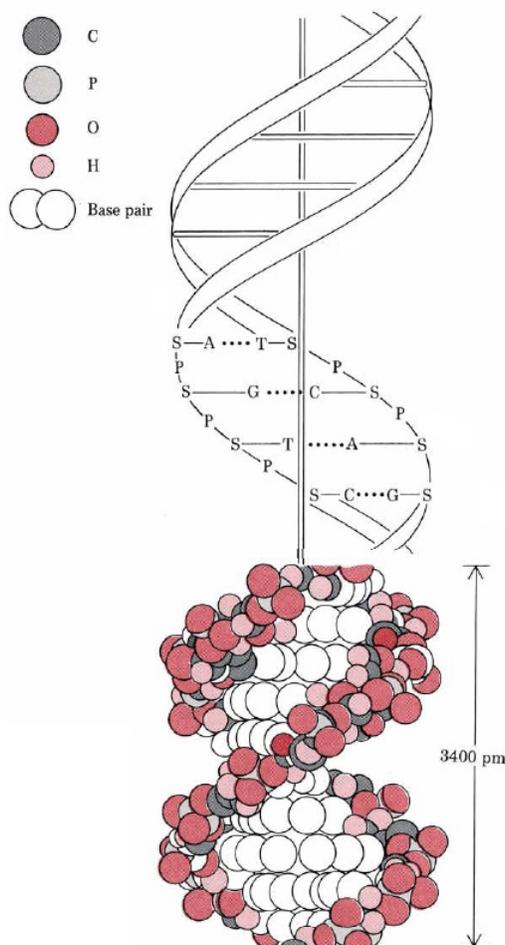


Figure 20.20.2 The double helix of DNA. Three different representations are shown. At the bottom the atoms are shown as space-filling spheres; in the middle the sugar and phosphate groups are identified by S and P and the nitrogenous bases by A, C, G, and T. In the topmost section the base pairs are represented by crossbars.

The spacing between base pairs is 340 pm, and there are 10.5 base pairs in one full turn of the helix.

The two nucleotide chains in the double helix are said to be **complementary** to each other. Because of the exact pairing of the bases we can always tell the sequences of bases in the one chain from that in the other. Thus if the first six bases in one chain are AGATCC, we know that the first six bases in the other will be TCTAGG. Both chains are therefore alternative representations of the same information. If one or two bases become misplaced in either strand, this can be recognized because of mismatching with the complementary strand. Repair enzymes can then correct the sequence of bases along the incorrect strand. A final point to make is that the two strands are **antiparallel**. This means that one strand, from bottom to top is going from the 5' carbon to the 3' carbon, while the complementary strand is going 3' to 5' from bottom to top.

This double-helix model for DNA was first suggested in 1953 by James D. Watson (born 1928) and Francis Crick (1916 to 2004). It was an important milestone in the history of science, since it marked the birth of a new field, molecular biology, in which the characteristics of living organisms could at last begin to be explained in terms of the structure of their molecules. In 1962 Crick and Watson shared the Nobel Prize with M. F. H. Wilkins, whose x-ray crystallographic data had helped them to formulate their model. Rosalind Franklin (1920-1958) who performed the x-ray crystallography experiments did not win the Nobel Prize, as they are not awarded posthumously, but should be included in any discussion on the discovery of the double helix. A fascinating account of this discovery, which does not always put the author in a favorable light, can be found in Watson's book "The Double Helix."

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