2011

The Importance of Hydrogen Bonds in DNA

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Introduction

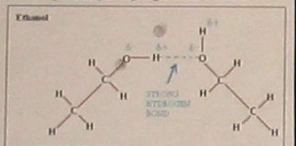
Many people have a basic understanding about why DNA is important to them, but not many know about what is important to DNA. Simple but important forces, called hydrogen bonds, help it to perform its tasks and maintain its stability.

What is a Hydrogen Bond?

A hydrogen bond is a bond that forms when a hydrogen atom from one polar molecule becomes electrically attracted to an electronegative atom, such as an oxygen or nitrogen atom, in another polar molecule[1].

They are represented in diagrams by dashed or dotted lines to distinguish them from covalent bonds[1]. [Fig. 1]

Fig. 1: Example of Hydrogen Bonds in Ethanol



The strength of a hydrogen bond is only a small fraction of the energy required to break a covalent bond[1]. Collectively, however, many hydrogen bonds add up to a strong force that helps maintain the three-dimensional structure of a molecule.

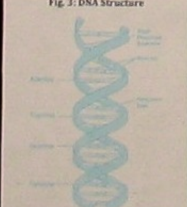
This is particularly true in deoxyribonucleic acid (DNA)[2].

What Role Do Hydrogen Bonds Play in DNA?

Francis Crick and James Watson first realized in 1953 that hydrogen bonds were responsible for interlinking the two strands of DNA, basing their speculations on the experimental X-ray work of Maurice Wilkins and Rosalind Franklin[1]. [Fig. 2]

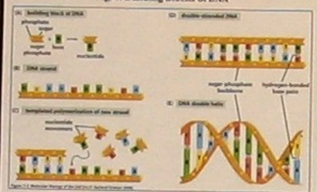
Fig. 2: Watson and Crick with their DNA Model

Fig. 3: DNA Structure



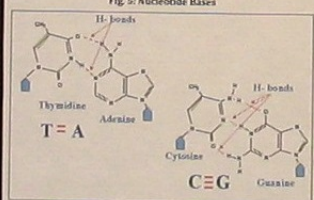
DNA is a long chain, or strand, of nucleotides. Each nucleotide has a pentose sugar, inorganic phosphate group and organic base[2]. The phosphates and sugar molecules form the backbone of a DNA strand, while the bases project from the backbone[3]. [Fig. 3 and 4]

Fig. 4: Building Blocks of DNA



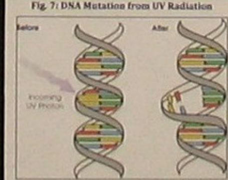
A molecule of DNA has two types of purine bases, adenine (A) and guanine (G), and two types of pyrimidine bases, cytosine (C) and thymine (T) [2]. This structure is stabilized by hydrogen bonding between the bases in opposite strands to form a double helix that is antiparallel, resembling a staircase[2]. [Fig. 5]

Fig. 5: Nucleotide Bases



A distinguishing feature of base pairing is its specificity[4]. An adenine base in one strand forms two hydrogen bonds with a thymine base in the opposite strand, or a guanine base forms three hydrogen bonds with a cytosine[2]. This keeps the width of the double helix relatively constant.

Fig. 7: DNA Mutation from UV Radiation

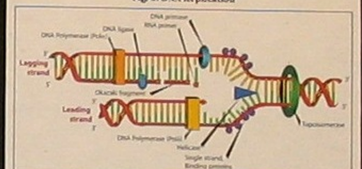


How Do Hydrogen Bonds Aid in DNA Replication?

The structure of DNA suggests that it can be copied in a process called DNA replication. During this process, the original DNA strands are used as templates for constructing new DNA strands[2].

The enzyme DNA helicase binds to one of the DNA strands and uses energy from ATP hydrolysis to run along the strand and break apart (denature) the hydrogen bonds between the nucleotide bases, unzipping the DNA[2]. Another enzyme DNA polymerase later attaches free nucleotides to the unzipped strand and hydrogen bonds can form again between the opposite strands[2]. [Fig. 6]

Fig. 6: DNA Replication



The weakness of the hydrogen bonds is important for this process and the stability of the hydrogen bonds between A and T or between G and C prevent permanent mistakes from happening.

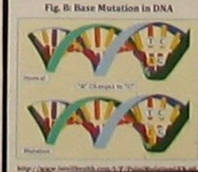
Mutations in DNA

One important property of hydrogen bonding is that when heated, the bond denatures and becomes nonfunctional.

- A physical application of this occurs from an overexposure to UVB radiation. With prolonged exposure to this radiation, heat causes enough energy for the hydrogen bonds to lose stability in DNA, which prevents the DNA from properly functioning and coding for protein. It can also cause mutations if duplication is in progress[5]. [Fig. 7]

- A chemical application occurs in gene mutations. These mutations can cause two basic types of changes to a gene; the base sequence within a gene can be changed or one or more nucleotides can be added to or removed from a gene[2]. In a base substitution, a single nucleotide is replaced with a different nucleotide[2]. This is also commonly caused by chemical mutagens or radiation[2]. Because of the weakness of the hydrogen bonds between the base pairs on complementary DNA, these bonds can break and base shifting can occur. [Fig. 8]

Fig. 8: Base Mutation in DNA

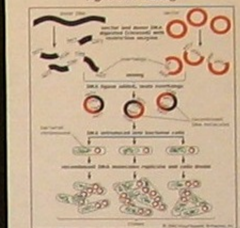


What is the Role of Hydrogen Bonds in Gene Coding?

Another application of hydrogen bonds in DNA is its involvement in genetic engineering and gene cloning.

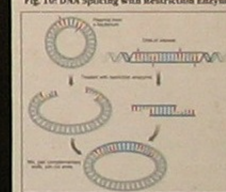
Gene cloning is the process of making multiple copies of a gene of interest[2]. An important step in gene cloning involves cutting the DNA of interest and a vector (DNA carrier) with a restriction enzyme that break the hydrogen bonds between several base pairs into many fragments with short single-stranded regions called sticky ends[2]. The stick ends of the DNA and vector then hydrogen bond with each other forming a recombinant vector that is introduced into a host cell where it can divide and produce many cells[2]. [Fig. 9 and 10]

Fig. 9: Gene Cloning



This process allows scientists to study genetic disorders and puts genes to work in production of proteins and other compounds needed in medicine and industrial processes[6]. Although this technique was first applied several decades ago, future advances are being made today that may revolutionize the future of medicine[6].

Fig. 10: DNA Splicing with Restriction Enzyme



Conclusion

Hydrogen bonds, although weak in forces, are very important to the structure and function of DNA, which is the blueprint that stores the information needed to construct the components of cells in the body[2]. Without these weak hydrogen bonds, DNA replication cannot occur and complementary strands of DNA would not form its helical structure[3].

Because of the significance of hydrogen bonds, scientists are able to amplify DNA and closely study its properties and behaviors. With the genetic coding technique, there is potential for scientists to discover cures for diseases in the future. That alone would improve the quality of life on a global level.

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