4.0 Nucleic acids

Objectives

1. Know functions and structures of nucleotides
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3. Understand nucleic acid sequencing
4. Understand cloning, PCR, and DNA fingerprinting

4.1 Nucleic Acids - Informational Macromolecules

Deoxyribonucleic acid (DNA) and Ribonucleic Acid (RNA) are some of the most important molecules in biochemistry. These molecules are know as polynucleotides, polymers linked by phosphodiester bridges, and form the basis for all genetic information in organisms.

DNA and RNA are formed from nucleotides, which are formed from nucleosides linked to a phosphate group. All nucleotides contain three main features:

1. A purine or pyrimidine base
2. A deoxyribose or ribose sugar
3. A phosphate bond

Purine Bases

- Adenine
- Guanine

Pyrimidine Bases

- Cytosine
- Thymine
- Uracil

4.2 Primary Structure of Nucleic Acids

Polynucleotide chains have some distinct and important primary features, including *directionality* and *individuality*.

Directionality refers to the fact that the phosphodiester link is always between 3' and 5' carbons, which gives the chain two distinguishable ends.

Individuality refers to the specific sequence of nucleotide bases, also known as the primary structure of the nucleic acid.

4.3 Seconday and Tertiary Structures of Nucleic Acids

The secondary structure of a nucleic acid is the three-dimensional structure of the individual nucleotide bases, while the tertiary structure is the description of longer-range interactions such as supercoiling.

In DNA, the secondary structure is the famous double helix, deduced by scientists Watson and Crick using data such as the statistical distribution of base pairs and X-ray analysis.

The DNA commonly found in cells is known as B form, or B Helix, and is the form Watson and Crick originally studied. However, another tertiary form exists, A form, seen in double-stranded RNA molecules and DNA-RNA hybrids. DNA also often forms structures, and tightly coiled states known as *supercoiled* molecules.

4.4 Alternative Secondary Structures of DNA

Both DNA and RNA have additional alternative secondary structures. Left-handed DNA (Z-DNA) is a form of DNA that forms a zig-zag structure instead of the typical double-helix. Other atypical forms include double hairpins (cruciforms), triple helices, and g-quadruplexes.

4.5 The Helix-to-Random Coil Transition

Environmental conditions such as temperature can cause loss of secondary structure in nucleic acids, a process called denaturation. This change is often reversible, and under controlled conditions can reform in a process called renaturation, or annealing.

4.6 The Biological Functions of Nucleic Acids

DNA and RNA are required for three major biological processes, *replication*, *transcription*, and *translation*. In replication, DNA molecules are copied when a cell divides, providing each with a high-fidelity transmission of genetic information.

RNA is used in transcription in the form of messenger RNA (mRNA) to create complementary bases from DNA molecules. These mRNA molecules are then processed in translation, a process that creates amino acids from specific three-base sequences known as codons.

Cloning is a process that extracts DNA sequences from a parent cell, processes it and links it together with additional manufactured fragments, and introduces it into a host cell. In this way, genes, or even entire genomes, can be copied.

When a single strand of genetic material needs to be copied, biochemists can rely on a process known as polymerase chain reaction (PCR). This technique combines short DNA strands (primers) and a DNA polymerase in a repeated heating and cooling cycle to encourage formation of specific complementary sequences.

Since the advent of cheaper and more reliable DNA sequencing techniques, genetic material is now often used to identify individuals and unique DNA characteristics. This widely used laboratory technique is known as DNA fingerprinting.