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AN INVESTIGATIVE STUDY FOR ORGANIZATIONAL STRUCTURE AND FUNCTION OF NUCLEIC ACID DNA AND ITS BIOCHEMICAL PROPERTIES

Dr. Hasan Al-hayali
Cyprus International University- Department Of Bioengineering
Isfahan University Of Technology- University of Isfahan -Faculty of Biological Sciences and Technology-Department of Cell and Molecular Biology and Microbiology
ORCID . https://orcid.org/0000-0001-7909-0878
hasanalialhayali@gmail.com

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Abstract:

The goal of this study was to adopt a comprehensive approach to understanding nucleic acids' reality and function in the body of the organism, in addition to their biological and chemical characteristics. For all living things, nucleic acids serve as essential macromolecules or biological polymer components. They are made up of nucleotide-based units or monomers. Phosphate group, nitrogenous base, and ribose sugar make up each of their three constituent elements. Generally speaking, there are just two essential types of nucleic acids. If the sugar is the ribose derivative deoxyribose, the polymer is (DNA) or deoxyribonucleic acid, and if the sugar is ribose, the polymer is (RNA) or ribonucleic acid. In actuality, the basic information-carrying molecules in cells, known as nucleic acids or genetic materials, are chemical substances. Friedrich Miescher, a scientist, was the first to discover and identify nucleic acids, naming them nuclein, while Watson and Crick proposed the double-helix structure of DNA. In this regard and historically speaking.

Keywords: Definition of DNA, structure, function and replication

1- INTRODUCTION

DNA and nucleic acids in general are important biomacromolecules for the persistence of life and living things. DNA stores the genetic information that is carried from one generation to the next. It contains the directions for making the numerous proteins required to create and sustain healthy cells, tissues, and organisms. It is possible for organisms to pass genetic information from one generation to the next thanks to molecules called nucleic acids. The genetic data that determines characteristics and enables protein synthesis is stored in these macromolecules. Around 1870, Johann Friedrich Miescher succeeded in isolating the first piece of what is now known as DNA. Some scientists discovered a mildly acidic chemical called "nuclein" in the nuclei of human white blood cells, and announced its discovery. Miescher divided nuclein into its protein and nucleic acid components a few years later (Cejka & Symington, 2021). In the 1920s, it was discovered that chromosomes, which are tiny gene-carrying structures in the nucleus of complex cells, are largely composed of nucleic acids. Nucleic acids' elemental analysis revealed the presence of phosphorus in addition to the typical C, H, N, and O (Audry, *et.al.* 2015). Nucleic acids did not include sulfur, in contrast to proteins. Chromosome nucleic acids were fully hydrolyzed to provide inorganic phosphate, 2-deoxyribose (a previously unidentified sugar), and four distinct heterocyclic bases (two pyrimidines and two purines). RNA also contains uracil. Nucleic acids may be the genetic material, according to the first experimental findings. Frederick Griffith made the discovery that bacteria could be made to switch strains in 1925. Griffith was a British health official who was involved in the creation of a pneumococcus

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infection vaccine. Some researchers were curious as to why different strains of Streptococcus pneumoniae, some virulent and others nonvirulent, were frequently present during the course of the illness. A number of academics considered the possibility that a particular bacterial type could transform into another (rather than patients being infected simultaneously by multiple types at the onset of disease) A virulent strain known as S (for smooth) and a nonvirulent strain known as R had been identified by Griffith (for rough). Knowing and studying the biological and chemical makeup of nucleic acids, as well as their structural components, is crucial for this study's goal (Chen, *et.al.* 2016).

2- LITERATURE REVIEW

2.1: Nucleotide Definition:

An chemical molecule known as a nucleotide serves as the foundation for nucleic acids (both DNA and RNA). Additionally, they are crucial for metabolism, enzyme activities, and cell signaling. Three structures or components make up a nucleotide: a phosphate group, a 5-carbon sugar, and a nitrogenous base. Adenine, cytosine, guanine, and thymine are the four nitrogenous bases found in DNA (Ausio, 2015). While uracil, in addition to adenine, cytosine, and guanine, is present in RNA instead of thymine. All known living things have genetic material made up of a chain of nucleotides. They perform numerous other tasks, such as acting as molecules that move energy and as messengers, in addition to storing genetic information. The genetic code is a system of principles utilized by living cells to interpret information encoded in genetic material into proteins. Codons are three-nucleotide sequences found in DNA that instruct the cell's proteins to bind a particular protein to a series dictated by the rest of the DNA. Even where to halt and start the process is specified to the machinery by certain codons. As it is recognized, DNA translation is a specialized process that transforms information from DNA into proteins. When this chain of amino acids is appropriately folded (in particular ways), it can perform one of the many tasks required by the cell (Rebbeck, 2018).

2.2: Nucleotide Function

A nucleotide is crucial for many additional processes in addition to serving as the building block of all living creatures' genetic material. Adenosine triphosphate (ATP), the primary energy molecule of the cell, is an example of a nucleotide that can act as a base in another molecule. Additionally, they are present in coenzymes like NAD and NADP, which are derived from ADP and are used in a variety of processes (chemical reactions) that are crucial to metabolism. Cyclic AMP (cAMP), a messenger molecule that is crucial in many activities including the control of metabolism and the delivery of chemical signals to cells, is another molecule that contains a nucleotide. In addition to serving as the life's fundamental building blocks, nucleotides also serve as the basis for a wide variety of other compounds (Borza, *et.al.* 2022).

2.3: Nucleotide Structure

The three unique chemical structures that make up a nucleotide are a five-carbon sugar molecule, a nitrogenous base referred to as a nucleoside when two are combined), and one phosphate group. A nucleotide is also known as a when all three are connected" nucleoside (Glycosylamines known as nucleosides can be thought of as nucleotides devoid of a phosphate group. A nucleoside is made up of just a nucleobase, often known as a nitrogenous base. Nucleosides can also take the form of monophosphate, diphosphate, or triphosphate "depending on how many phosphates are present in the phosphate group (Vogel, *et.al.* 2022). The precise makeup of a nucleotide consists of:

2.3.1: Nitrogenous Base:

An organic molecule having a nitrogen atom that possesses the chemical characteristics of a base is referred to as a nitrogenous base, sometimes known as a nitrogen-containing base. A nitrogenic base's main biological role is to link nucleic acids together. The single pair of electrons in a nitrogen atom are responsible for a nitrogenous base's fundamental characteristics. Pyrimidine (such as thymine-cytosine) and purine are the two primary chemicals that commonly make up nitrogenous bases (such as adenine -guanine). They are planar and non-polar due to their aromaticity. Purines and pyrimidines are similar to pyridine, making them both weak bases that are generally resistant to electrophilic aromatic substitution (Sajid, *et.al.* 2019).

a- **Adenine:** One of two families of nitrogenous bases known as a purine. The double-ringed structure of purines. Adenine and thymine form a link in DNA. Adenine forms a link with uracil in RNA. Adenine serves as the base of adenosine triphosphate. Three phosphate groups can then be joined from there. As a result, the bonds may

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store a lot of energy. Therefore, the bonds in ATP are strong and robust for the same reasons that the sugar-phosphate backbone is. It can be transmitted to other reactions and molecules when paired with unique enzymes that have developed to release the energy (Vogel, *et.al*. 2022).

b- **Guanine:** Possesses a double ring shape and is a purine nucleotide. It binds to cytosine in both RNA and DNA. Three hydrogen bonds help guanine and cytosine link. Since the thymine-adenine bond only generates two hydrogen bonds, the cytosine-guanine link is proximally stronger as a result (Sajid, *et.al.* 2019).

c- **Cytosine**: The second category of nucleotides is pyrimidine. The pyrimidine nucleotide cytosine has a single ring in its structure. As a result, three hydrogen bonds hold cytosine and guanine together in RNA and DNA. As a result of their strong pairing, guanine and adenine form a strong bond (Sajid, *et.al.* 2019).

d- **Thymine:** Is nitrogen base is a pyrimidine nucleotide and has one ring, similar to the nucleotide cytosine. In DNA, it binds to adenine. Just found in DNA, thymine establishes only two hydrogen bonds with adenine, making them the weaker pair. Thymine is not present in RNA (Vogel, *et.al*. 2022).

2.3.2: Sugar

The sugar makes up the second component of a nucleotide. No matter what nucleotide is used, the sugar remains constant. RNA and DNA are different from one another. Deoxyribose is the 5-carbon sugar in DNA, whereas ribose is the 5-carbon sugar in RNA. This gives genetic molecules their names; RNA and DNA are both officially known as deoxyribonucleic acid and ribonucleic acid, respectively (Bhowmik & Krishnamurthy, 2019).

2.3.3: Phosphate Group

The phosphate group, the final component of the nucleotide structure, is probably well-known from ATP, another significant chemical. The majority of life on Earth uses the energy molecule adenosine triphosphate, or ATP, to store and transport energy between reactions. Three phosphate groups—which make up ATP—can store a significant amount of energy in their bonds. I believe that unlike ATP, phosphordiester linkages are produced between the phosphate group and the sugar molecule in a nucleotide (Borza, *et.al.* 2022).

3- PROPERTIES OF NUCLEIC ACID DNA.

As a macromolecule, DNA possesses numerous unique biological, chemical, and physical characteristics that are crucial to its structure and operation. The phrases are crucial to our understanding of DNA and its various applications today, even if they may sound extremely alien and confusing. Physical properties: DNA is discovered as a pair of molecules rather than a single molecule in living organisms like humans. The double helix formed by these intertwined strands is stabilized by hydrogen bonds between the bases that are joined to the two strands. base coupling In terms of genetic theory, the ratio of adenine to thymine is equivalent to the ratio of cytosine to guanine. Complementary base pairing is another name for this base pairing. Although the idea is really straightforward, it is important for DNA (Xiao, *et.al.* 2019). DNA has two different types of grooves, both of which are crucial to its proper operation. Major and minor grooves are features that allow specialized and unique contact between bases and the essential proteins in your body. These DNA grooves, which can be seen in DNA's structure, make it easier for proteins to connect to DNA, such as transcription factors, which keeps your body's cellular processes running smoothly. DNA Supercoiling is a unique characteristic of topologically derived, circular, double-stranded DNA. It offers brand-new energetic and structural properties. The two strands of a linear DNA molecule get entwined, much like the links of a chain, in this aspect, and will stay that way unless one of the strands is damaged. This is known as a covalently closed circle (Chen, *et.al.* 2018).

4- MOLECULAR COMPOSITION AND SIZE:

A single molecule called chromosome 1 houses 246 million base pairs. The majority of the time, single-stranded RNA molecules and double-stranded DNA molecules can be found in nature. There are many exceptions, but some viruses have single-stranded DNA genomes and some have double-stranded RNA genomes. Additionally, under certain conditions, nucleic acid structures with three or four strands can also form (Bruininks, *et.al.* 2020).

5- TOPOLOGY:

The study and discussion of the geometry and topology of nucleic acids offers instances and ideas of how cutting-edge experimental data and powerful computer tools can be combined with deep and current mathematical methodologies, such as those derived from low-dimensional topology. A varied and highly interdisciplinary set of researchers have recently

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joined the subject of DNA topology, and while significant progress has been done, there are still a lot of unanswered concerns. In addition to reviewing issues with DNA packing and the ways that enzymes alter DNA's structure (Neuberger, *et.al.* 2021).

6- Nucleic Acid Metabolism:

The process through which nucleic acids (RNA and DNA) are created and broken down is known as nucleic acid metabolism. Polymers of nucleotides make up nucleic acids. A nitrogenous base, pentose sugar, and phosphate are typically involved in the chemical reaction that constitutes the anabolic mechanism known as nucleotide synthesis. A catabolic process occurs when nucleic acid is destroyed. In order to manufacture new nucleotides, portions of nucleotides or nucleobases can also be salvaged. Specific enzymes must play a part in both reactions—synthesis and degradation—to help the process. There is little doubt that these enzyme shortages or defects can result in a wide range of illnesses or ailments (Zhou, *et.al.* 2020).

7- Synthesis of nucleic acids:

Pyrimidine and purines are two categories for nucleotides. Both of these substances are predominantly produced in the liver of more complex multicellular organisms. They both have phosphate and sugar, but they undoubtedly have nitrogenous bases of various sizes. The two distinct groups are synthesized in various ways as a result of this. However, phosphoribosyl pyrophosphate (PRPP), which provides the ribose and phosphate needed to synthesize a nucleotide, is required for all nucleotide synthesis (Musumeci, *et.al.* 2020).

8- OLIGONUCLEOTIDE SYNTHESIS:

Small molecules called oligonucleotides, which range in size from 8 to 50 nucleotides, interact with target RNA by Watson-Crick base pairing to either promote or suppress its expression. The chemical synthesis of relatively short nucleic acid fragments with clearly defined chemical structures is known as oligonucleotide synthesis (sequence). The method is very helpful in modern laboratory practice since it gives quick, low-cost access to oligonucleotides manufactured to order with the necessary sequence. Chemical oligonucleotide synthesis does not have this restriction, but enzymes can only manufacture DNA and RNA in a 5' to 3' direction, even though it is typically done in the opposite, 3' to 5' manner (Jensen & Davis, 2018).

a- **Purine synthesis:** As was already explained, the two nucleotides known as purines are guanine and adenine. Phosphoribosyl pyrophosphate (PRPP) is converted into inosine monophosphate, or IMP, during the purine synthesis process. Among other things, aspartate glycine, glutamine, and 6 ATP are needed for the production of IMP from PRPP. Then, utilizing GTP and aspartate, which is changed into fumarate, IMP (inosine monophosphate) is changed into AMP (adenosine monophosphate). The creation of GMP (guanosine monophosphate) involves an intermediate step in which NAD+ is utilized to create the intermediate xanthosine monophosphate, or XMP, whereas IMP can be immediately converted to AMP (Ali, *et.al.* 2020). The hydrolysis of 1 ATP and the conversion of glutamine to glutamate are then used to turn XMP into GMP. Then, kinases that add more phosphates to AMP and GMP can transform them into ATP and GTP, respectively. Adenosine triphosphate, or ATP, encourages the synthesis of guanosine triphosphate, or GTP, whereas GTP stimulates the synthesis of ATP. Because of this cross control, the proportions of ATP and GTP remain constant. The chance of DNA mutations, where the incorrect purine nucleotide is introduced, could increase if either nucleotide is present in excess (Pareek, *et.al.* 2020).

b- **Pyrimidine synthesis:** Thymidine, uridine, and cytidine are examples of pyrimidine nucleotides. Any pyrimidine nucleotide can be made by first creating uridine. certainly Aspartate, bicarbonate, glutamine, two ATP molecules (to supply energy), as well as phosphoribosyl pyrophosphate (PRPP), which supplies ribose-monophosphate, are all needed for this reaction. The sugar/phosphate group from PRPP is introduced to the nitrogenous base later in the process than it is in purine synthesis. After being created, uridine-monophosphate can combine with two ATP to create uridine-triphosphate, or UTP (Wang, *et.al.* 2019). CTP synthetase can catalyze the conversion of UTP to CTP (cytidine-triphosphate). Prior to the base being methylated to form thymidine, the uridine must first be reduced to deoxyuridine. On the flip side, hereditary disorders can result from deficiencies of enzymes involved in pyrimidine production. increased excretion of orotic acid in the urine due to orotic aciduria (Kaymak, *et.al.* 2020).

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9- NUCLEIC ACID THERMODYNAMICS:

The study of how temperature affects the double-stranded DNA's nucleic acid structure is known as nucleic acid thermodynamics (dsDNA). The temperature at which half of the DNA strands are in the random coil or single-stranded (ssDNA) form is known as the melting temperature (Tm) in chemistry. The length of the DNA molecule and its unique nucleotide sequence affect the melting temperature (Tm) (Randeria, *et.al.* 2020). When the two strands of DNA are separated, or when the dsDNA molecule has two distinct strands, this state of DNA is referred to as being denatured by the high temperature. One area where the fundamentals of thermodynamics are widely applicable is in the science of nucleic acid folding. For example, Vitravene, the first FDA-approved therapeutic nucleic acid targeting cytomegalovirus in the human eye, is one example of an RNA thermodynamic parameter. Other examples include models of structural elements of the HIV-1 RNA, target specificity of cancer microRNA, mechanisms for RNA interference, the mechanism of group I introns, the discovery of non-coding RNAs in genomes, and tRNA codon recognition (Pasek, 2019). The populations of structures that will be present at equilibrium can theoretically be predicted by thermodynamics, but the precision of those predictions is now limited by our understanding of the nucleic acid thermodynamic sequence dependency. Optical melting, which has a number of benefits over the more accurate calorimetric techniques, was used to measure a large portion of the known thermodynamics. It only takes a tiny amount of samples, and the experiments go quickly (Pasek, 2019; Randeria, *et.al.* 2020).

10- NUCLEIC ACID QUANTITATION:

In molecular genetics, the quantification of nucleic acids (DNA and RNA) is a standard procedure to ascertain the average amounts of each nucleic acid present in a mixture as well as its purity. Nucleic acid-based reactions frequently need specific concentrations and purity for best results. There are now two basic approaches that scientists employ to measure the concentration of nucleic acids (such RNA or DNA) in a solution. These include UV fluorescence tagging and spectrophotometric quantification when a DNA dye is present. Analysis using spectrophotometry is Using a spectrophotometer to measure DNA or RNA is one of the more popular methods. The average concentrations of the RNA or DNA contained in a sample, as well as their purity, can be found using a spectrophotometer (Pareek, *et.al.* 2020). The fundamental idea behind spectroscopic analysis is that nucleic acids absorb ultraviolet light in a particular way. A photo-detector is used to quantify the light that goes through the sample when RNA and DNA samples are exposed to ultraviolet light with a wavelength of 260 nanometers (nm). The (DNA/RNA) will absorb part of the UV light while allowing some of it to flow through. The concentration of nucleic acids in the sample increases with the amount of light absorbed by the sample. After all, As a result, the photodetector will get less light, which will increase the optical density (OD) (Li, *et.al.* 2019).

11- REPLICATION DEFINITION AND MACHINERY

Very obvious, DNA replication is semiconservative. Additionally, each strand of the double helix acts as a template for the creation of a new, complimentary strand. And DNA polymerases, which need a template, a primer (starter), and perform DNA synthesis in the 5' to 3' direction, are responsible for creating new DNA. During DNA replication, the Leading strand is continuously produced as one new strand. Small pieces make up the opposite strand, often known as the lagging strand. In actuality, in addition to DNA polymerase, DNA primase, DNA helicase, DNA ligase, and topoisomerase are also necessary for DNA replication. Each DNA double helix strand is semi-conservative, which is the fundamental concept of DNA replication. serves as a template for the synthesis of a new, complementary strand (Cortez, 2019).

One beginning molecule of DNA is transformed into two "daughter" molecules during DNA replication, each of which has a double helix made up of one new and one old strand. The biological process that creates two identical DNA replicas from a single original DNA molecule is called DNA replication. All living things have replicating DNA, which serves as the most significant component of biological legacy. DNA replication is crucial because cells have the unique ability to divide. DNA replication-related components that are present on ssDNA templates make up the replication machinery. Primosotor replication enzymes, polymerase DNA, DNA helicases, DNA clamps, DNA topoisomerases, and replicative proteins, such as single-stranded DNA binding proteins, are all examples of replication machines (SSB). These components work together during the replication cycle. All the components necessary for DNA replication are found on replication forks in the majority of bacteria, and the

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complexes stay on the forks during DNA replication (Van*, et.al.* 2018; Liu, *et.al.* 2021).

DNA replisomes, also known as replicase systems, are these replication tools. These words are widely used to describe how proteins are replicated on forks. Replisomes in eukaryotic and other bacterial cells are unformed. The lagging strands are loaded into the base of the DNA, and helicases alternately travel between the DNAs (Cortez, 2019). For the remainder of the replication process, the helicases remain attached. Green fluorescent protein (GFP)-tagged DNA polymerases were directly observed at replication sites in budding yeast by Peter Meister et al. They noticed tagged loci during DNA replication. This is referred to as a replication factory since the replication equipment does not move in relation to the template DNAs like factories (Liu, *et.al.* 2021). The idea that DNA factories are like projectors and DNAs are like movies is an alternate perspective. Within the replication factory model, the projectors are continually fed in, and after all DNA helicases and the lagging strands have been loaded onto the DNA base, the helicases run in tandem along the DNAs for the leading strands. For the remainder of the replication process, the helicases remain attached. Directly at the budding yeast replication sites are green fluorescent protein (GFP)-tagged DNA polymerases, according to Peter Meister et al. They observed the symmetrical separation of tagged loci from a replication origin and discovered that the distance between the pairs dropped noticeably over time. This finding implies that DNA factories and DNA replication mechanisms are related (Van*, et.al.* 2018).

CONCLUSION: Nucleic acids are molecules made up of structural building blocks called nucleotides. They play a function in controlling biological processes like protein synthesis and cell division. A nitrogenous base, a pentose sugar, and a phosphate group make up each nucleotide. RNA and DNA are the two different kinds of nucleic acids. The genetic material of a cell is carried by DNA, which parents pass on to their children (in the form of chromosomes). According to the Watson-Crick model, DNA has a double-helical structure with two strands that are complementary to one another, running counterclockwise, and joined by hydrogen bonds. A pentose sugar called ribose, a nitrogenous base, and a phosphate group are the components of single-stranded RNA. Protein synthesis and its control both involve RNA. The instructions for building proteins are included in messenger RNA (mRNA), which is exported from the nucleus to the cytoplasm. Transfer RNA (tRNA) transports the amino acid to the site of protein synthesis, whereas ribosomal RNA (rRNA) is a component of the ribosomes at the site of protein synthesis. MicroRNA controls how mRNA is used to make proteins.

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