Nucleic acids are the organic compounds

Nucleic acids were discovered by Friedrich Miescher, a Swiss biochemist, in 1869. He called them “ nucleic” because he believed that they occurred only in the nucleus of the cell [1].

Nucleic Acids are the organic compounds found in the chromosomes of living cells and in viruses. The structure of the nucleic acids in a cell determines the structure of the proteins produced in that cell. Since proteins are the “ building blocks” of life, nucleic acids can be considered the “ blueprints” of life. But chemically we can define nucleic acids as molecules that are comprised of monomers known as nucleotides.[2, 3]

The two main types of nucleic acids are:-

Deoxyribonucleic acid (DNA) :-It ordinarily occurs only in the cell nucleus.

Ribonucleic acid (RNA):-It is found both in the nucleus and in the cytoplasm (the main part of the cell exclusive of the nucleus).

Both DNA and RNA combine with protein materials to carry out cell division and cell repair processes. [4]

Deoxyribonucleic acid (DNA)

A type of nucleic acid that constitutes the molecular basis of heredity. It is found principally in the nucleus of all cells where it forms part of the chromosome, or in the cytoplasm of cells lacking a nucleus, such as bacteria. It acts as the carrier of genetic information containing the instructions (code) to make proteins. It consists of two single chains of nucleotides, which are twisted round each other to form a double helix or spiral. The nucleotides contain sugar (deoxyribose), phosphate and the bases (adenine, cytosine, guanine and thymine). The two strands of DNA are held together by hydrogen

bonds located between specific pairs of bases (adenine to thymine and cytosine to guanine). The sequence of bases and consequently gene sequence is sometimes altered, causing mutation. DNA includes the sugar deoxyribose, which has one less oxygen atom than ribose the sugar found in RNA, hence the name is deoxy-ribose nucleic acid.[6, 7]

Each DNA molecule is a long two-stranded chain. The strands are made up of subunits called nucleotides, each containing a sugar (deoxyribose), a phosphate group, and one of four nitrogenous bases, adenine, guanine, thymine, and cytosine, denoted A, G, T, and C, respectively. A given strand contains nucleotides bearing each of these four. The information carried by a given gene is coded in the sequence in which the nucleotides bearing different bases a soccur along the strand.

The chemical and physical properties of DNA suit it for both replication and transfer of information .

Fig 1. A 3D rendered computer model of the DNA double helix. [16]

Structure Of DNA

Its structure, with two strands wound around each other in a double helix to resemble a twisted ladder, was first described (1953) by Francis Crick and James D. Watson and they named it as Watson and Crick model of DNA which states that:

Fig 2. Double helix structure of DNA[

It is a double helix with two right handed helical polydeoxy ribonucleotide strands twisted around the same central axis.

The two strands are anti parallel. The phosphodiester linkages of one of these strands run in 5′ to 3′ direction while the other strand runs in 3′ to 5′ direction. The bases are stacked inside the helix in planes perpendicular to the helical axis.

These two strands are held together by hydrogen bonds. In addition to hydrogen bonds, other forces e. g., hydrophobic interactions between stacked bases are also responsible for stability and maintenance of double helix.

Adenine always pairs with thymine while guanine always pairs with cytosine.

A-T pair has 2 hydrogen bonds while G-C pair has 3 hydrogen bonds. Hence, G C is more stronger than A= T.

The content of adenine is equal to the content of thymine and the content of guanine is equal to the content of cytosine. This is Chargaff’s rule, which is proved by the complementary base pairing in DNA structure.

The genetic information is present only on one strand known as template strand.

The double helix structure contains major and minor grooves in which proteins interact with DNA.

The diameter of double helix is 2nm. The double helical structure repeats at intervals of 3. 4 nm (one completer turn) which corresponds to 10 base pairs. [7, 8, 9]

Different forms of DNA

Double helical structure exists in six different forms. They are A-DNA, B-DNA, C-DNA, D-DNA, E-DNA and Z-DNA. Among these only 3 forms of DNA are important. They are B-DNA, A-DNA and Z-DNA.

5. 1 B-DNA:-This is nothing but the double helical structure described by Watson and Crick. It has 10 base pairs in each turn.

5. 2 A-DNA:-This is also a right handed helix. It has 11 base pairs per turn.

5. 3 Z-DNA:-This is a left handed helix. It has 12 base pairs per turn. The strands in this form move in a ‘ zig-zag’ manner and hence it is called as Z-DNA.[12, 13]

Properties of DNA

The properties shown by DNA that allows for transmission of genetic information to new cells are as follows:-

Replication

Transcription

Translation

6. 1 Replication

An important property of DNA is that it can replicate, or make copies of itself. Each strand of DNA in the double helix can serve as a pattern for duplicating the sequence of bases. This is critical when cells divide because each new cell needs to have an exact copy of the DNA present in the old cell.

Fig3. Replication Process in DNA [30]

6. 2 Transcription

Transcription is the process in which DNA nucleic acids transfer the cell’s genetic information into RNA materials. In essence, each DNA strand manufactures a corresponding RNA strand. Three types of RNA are manufactured within this process. [13]Messenger RNAs (mRNA) are designed to carry the genetic information received from the DNA strands. Ribosomal RNAs (rRNA) reside in the cell’s cytoplasm, and are

responsible for decoding, or translating the genetic instructions into cell processes. Transfer RNAs (tRNA) are responsible for gathering whatever amino acids are needed for protein synthesis.[14]

Fig4. Transcription In DNA [20]

6. 3 Translation

Translation is the process in which RNA molecules create the proteins needed to sustain necessary cell functions. This is accomplished by converting the genetic code contained in the messenger RNAs into amino acid strings, which is what make protein molecules. This conversion process takes place within the ribosomes, which are located in the cell's cytoplasm. [14]

Functions of DNA (deoxyribonucleic acid):

DNA is a permanent storage place for genetic information.

DNA controls the synthesis of RNA (ribonucleic acid).

The sequence of nitrogenous bases in DNA determines the protein development in new cells.

The function of the double helix formation of DNA is to ensure that no disorders occur. This is because the second identical strand of DNA that runs anti-parallel to the first is a backup in case of lost or destroyed genetic information. Ex. Down's Syndrome or Sickle Cell Anemia.[16, 17]

RNA(ribonucleic acid)

It is another type of nucleic acid which functions in cellular protein synthesis in all living cells. They play an essential role in the synthesis of proteins. On hydrolysis they yield the pentose sugar ribose, the purine bases adenine and guanine, the pyrimidine bases cytosine and uracil, and phosphoric acid. RNA occurs mostly in the cytoplasm in the eukaryotic cells. A small amount occurs in the nucleus of the cell, as a constituent of nucleolus. RNA is a single polynucleotide chain composed of nucleotides of adenine, guanine, cytosine and uracil. Thymine nucleotides are absent.

Structure of RNA

RiboNucleic Acids consist of:

Ribose (a pentose = sugar with 5 carbons)

Phosphoric Acid

Organic (nitrogenous) bases: Purines (Adenine and Guanine) and Pyrimidines (Cytosine and Uracil)

An RNA molecule is a linear polymer in which the monomers (nucleotides) are linked together by means of phosphodiester bridges, or bonds. These bonds link the 3′ carbon in the ribose of one nucleotide to the 5′ carbon in the ribose of the adjacent nucleotide.

Fig 5. Chemical Structure of RNA [19]

Purines:

Adenine A Guanine G

Pyrimidines:

Uracil U Cytosine C

Fig 6. Organic Bases Structure of RNA [21]

Structural Difference between RNA and DNA

RNA differs, however, from DNA because it does not form an analogous double helical structure. The pyrimidine base thymine is modified in that it lacks a methyl group and the resulting uracil takes its place in base pairing. Together, the presence of uracil in place of thymine, and the 2′-OH in the ribose constitute the two chemical differences between RNA and DNA which is shown in Fig 7.

Fig7. Structural difference between RNA and DNA [19]

Types Of RNA

11. 1 Messenger RNA (mRNA)

It represents about 5 to 10% of the total RNA. It is synthesised from DNA as and when necessary. It carries the genetic information in the form of a specific sequence of nitrogen bases arranged in triplet codons, which are copies from the code in DNA.

11. 2 Transfer RNA (tRNA)

It represents about 10 to 15% of the total RNA in the cell. It has the shortest molecule having only about 80 to 100 nucleotides. The polynucleotide chain is folded on itself to have the shape of a cloverleaf. The molecule has three lateral loops, a DHU loop, a t loop and an anticodon loop. The anticodon loop bears a triplet combination of nitrogen bases, called anticodon. It is complementary to a codon of mRNA.

The tRNA molecule is meant for recognising and carrying particular types of amino acids to the sites of protein synthesis.

11. 3 Ribosomal RNA (rRNA)

It represents nearly 80% of the total RNA in the cell. It always occurs bound to basic proteins in ribosomes. It takes part in assembling the amino acids brought by tRNA, into a polypeptide chain, based on the sequence of codons in mRNA. [19, 20]

Functions of RNA

RNA serves the following functions:

mRNA has a significant role in genetic code.

tRNA is responsible for transferring amino acids to the site of protein synthesis (ribosomes).

rRNA assembles the amino acids into a polypeptide chain. It also serves as a primer for replication of DNA.

RNA serves as the genetic material in some plant viruses. [21]

Applications of Nucleic Acid

Nucleic acids find a number of exciting applications in various fields. .

13. 1 Microarrays and biosensors

PNA(peptide nucleic acid) can be used on microarrays and other biosensors. PNA microarray combined with PCR could detect genetically modified organisms (GMOs) in food

13. 2 Imaging probes and FISH

PNA is especially good for FISH because it can bind to DNA or RNA quickly even under low salt or other unfavorable conditions for DNA. PNA s specificity was utilized to

discriminate 16S rRNA of bacteria species in drinking water. PNA probes also have been used for in vivo imaging of mRNA for cancer research. [23]

13. 3 Catalysts and receptors

Nucleic acids can also be employed as enzymes (for catalysis) and receptors (for ligand binding). Increasingly, researchers are making interesting use of these molecules, now collectively called functional nucleic acids.

13. 4 Body functions

Essential bodily functions such as growth, repair and reproduction all rely on nucleic acid for direction and support. Nucleic acid is in nearly every cell of the body. [24]

13. 5 Medicinal Uses

Gen-Probe Inc. (San Diego, California) introduced nucleic acid probe-based diagnostic products for gonorrhea and chlamydia. It is a direct test based on DNA ribosomal RNA hybridization, with demonstrated sensitivity of 89. 9% to 97. 1%, and specificity of 93% to 98%. [23, 26]

FUTURE PROSPECTS OF NUCLEIC ACID

Nucleic-acid-amplification test (NAAT) is used for the diagnosis of TB(tuberculosis) by the new method instead of conventional smear/culture method. So NAAT will simply take us to a new era of advanced, effective, and rapid TB diagnosis.

Attempts are done to employ nucleic acids in effective gene therapy which is believe to become commonplace in recent years.

At the same time, however, the study of nucleic acids has revealed remarkable properties of DNA and RNA molecules that could make them attractive therapeutic agents, independent of their well-known ability to encode biologically active proteins. In

future we will find alternative uses of nucleic acids that do not rely on virus-based vectors or even on gene transfer.

Tuberculosis (TB) is an important target for clinical testing due to the increase in incidence of the disease in this decade. Both Roche and Gen-Probe, great are developing kits for rapid TB testing. The Roche kit is based on PCR technology, while Gen-Probe’s kit uses transcription mediated amplification. [27, 28, 29]