**Nucleic acid:**

Nucleic acids are the biopolymers, or small biomolecules, essential to all known forms of life. The term nucleic acid is the overall name for DNA and RNA. They are composed of nucleotides, which are the monomers made of three components: a 5-carbon sugar, a phosphate group and a nitrogenous base. If the sugar is a compound ribose, the polymer is RNA (ribonucleic acid); if the sugar is derived from ribose as deoxyribose, the polymer is DNA (deoxyribonucleic acid).

Nucleic acids are the most important of all biomolecules. These are found in abundance in all living things, where they function to create and encode and then store information of every living cell of every life-form organism on Earth. In turn, they function to transmit and express that information inside and outside the cell nucleus to the interior operations of the cell and ultimately to the next generation of each living organism. The encoded information is contained and conveyed via the nucleic acid sequence, which provides the 'ladder-step' ordering of nucleotides within the molecules of RNA and DNA.

Strings of nucleotides are bonded to form helical backbones typically, one for RNA, two for DNA and assembled into chains of base-pairs selected from the five primary, or canonical, nucleobases, which are: adenine, cytosine, guanine, thymine, and uracil. Thymine occurs only in DNA and uracil only in RNA. Using amino acids and the process known as protein synthesis, the specific sequencing in DNA of these nucleobase pairs enables storing and transmitting coded instructions as genes. In RNA, base-pair sequencing provides for manufacturing new proteins that determine the frames and parts and most chemical processes of all life forms.



**History:**

* Nuclein were discovered by Friedrich Miescher in 1869.
* In the early 1880s Albrecht Kossel further purified the substance and discovered its highly acidic properties. He later also identified the nucleobases.
* In 1889 Richard Altmann creates the term nucleic acid.
* In 1938 Astbury and Bell published the first X-ray diffraction pattern of DNA.
* In 1953 Watson and Crick determined the structure of DNA.

Experimental studies of nucleic acids constitute a major part of modern biological and medical research, and form a foundation for genome and forensic science, and the biotechnology and pharmaceutical industries.

**Occurrence and nomenclature**

The term nucleic acid is the overall name for DNA and RNA, members of a family of biopolymers, and is synonymous with polynucleotide. Nucleic acids were named for their initial discovery within the nucleus, and for the presence of phosphate groups. Although first discovered within the nucleus of eukaryotic cells, nucleic acids are now known to be found in all life forms including within bacteria, archaea, mitochondria, chloroplasts, and viruses (There is debate as to whether viruses are living or non-living). All living cells contain both DNA and RNA (except some cells such as mature red blood cells), while viruses contain either DNA or RNA, but usually not both. The basic component of biological nucleic acids is the nucleotide, each of which contains a pentose sugar (ribose or deoxyribose), a phosphate group, and a nucleobase. Nucleic acids are also generated within the laboratory, through the use of enzymes (DNA and RNA polymerases) and by solid-phase chemical synthesis. The chemical methods also enable the generation of altered nucleic acids that are not found in nature, for example peptide nucleic acids.

**Molecular composition and size:**

Nucleic acids are generally very large molecules. Indeed, DNA molecules are probably the largest individual molecules known. Well-studied biological nucleic acid molecules range in size from 21 nucleotides (small interfering RNA) to large chromosomes (human chromosome 1 is a single molecule that contains 247 million base pairs.

In most cases, naturally occurring DNA molecules are double-stranded and RNA molecules are single-stranded. There are numerous exceptions, however some viruses have genomes made of double-stranded RNA and other viruses have single-stranded DNA genomes, and, in some circumstances, nucleic acid structures with three or four strands can form.

Nucleic acids are linear polymers (chains) of nucleotides. Each nucleotide consists of three components: a purine or pyrimidine nucleobase (sometimes termed nitrogenous base or simply base), a pentose sugar, and a phosphate group. The substructure consisting of a nucleobase plus sugar is termed a nucleoside. Nucleic acid types differ in the structure of the sugar in their nucleotides DNA contains 2 deoxyribose while RNA contains ribose (where the only difference is the presence of a hydroxyl group). Also, the nucleobases found in the two nucleic acid types are different: adenine, cytosine, and guanine are found in both RNA and DNA, while thymine occurs in DNA and uracil occurs in RNA.

The sugars and phosphates in nucleic acids are connected to each other in an alternating chain (sugar-phosphate backbone) through phosphodiester linkages. In conventional nomenclature, the carbons to which the phosphate groups attach are the 3'-end and the 5'-end carbons of the sugar. This gives nucleic acids directionality, and the ends of nucleic acid molecules are referred to as 5'-end and 3'-end. The nucleobases are joined to the sugars via an N-glycosidic linkage involving a nucleobase ring nitrogen and the 1' carbon of the pentose sugar ring.

Non-standard nucleosides are also found in both RNA and DNA and usually arise from modification of the standard nucleosides within the DNA molecule or the primary RNA transcript. Transfer RNA (tRNA) molecules contain a particularly large number of modified nucleosides.

**Topology:**

Double-stranded nucleic acids are made up of complementary sequences, in which extensive Watson-Crick base pairing results in a highly repeated and quite uniform double-helical three-dimensional structure. In contrast, single-stranded RNA and DNA molecules are not constrained to a regular double helix, and can adopt highly complex three-dimensional structures that are based on short stretches of intramolecular base-paired sequences including both Watson-Crick and noncanonical base pairs, and a wide range of complex tertiary interactions.

Nucleic acid molecules are usually unbranched and may occur as linear and circular molecules. For example, bacterial chromosomes, plasmids, mitochondrial DNA, and chloroplast DNA are usually circular double-stranded DNA molecules, while chromosomes of the eukaryotic nucleus are usually linear double-stranded DNA molecules. Most RNA molecules are linear, single-stranded molecules, but both circular and branched molecules can result from RNA splicing reactions. The total amount of pyrimidines is equal to the total amount of purines. The diameter of the helix is about 20Å.

**Sequences:**

One DNA or RNA molecule differs from another primarily in the sequence of nucleotides. Nucleotide sequences are of great importance in biology since they carry the ultimate instructions that encode all biological molecules, molecular assemblies, subcellular and cellular structures, organs, and organisms, and directly enable cognition, memory, and behavior. Enormous efforts have gone into the development of experimental methods to determine the nucleotide sequence of biological DNA and RNA molecules, and today hundreds of millions of nucleotides are sequenced daily at genome centers and smaller laboratories worldwide.

**Biosynthesis and degradation:**

Nucleotides are synthesized from readily available precursors in the cell. The ribose phosphate portion of both purine and pyrimidine nucleotides is synthesized from glucose via the pentose phosphate pathway. The six-atom pyrimidine ring is synthesized first and subsequently attached to the ribose phosphate. The two rings in purines are synthesized while attached to the ribose phosphate during the assembly of adenine or guanine nucleosides.

 In both cases the end product is a nucleotide carrying a phosphate attached to the 5′ carbon on the sugar. Finally, a specialized enzyme called a kinase adds two phosphate groups using adenosine triphosphate (ATP) as the phosphate donor to form ribonucleoside triphosphate, the immediate precursor of RNA. For DNA, the 2 hydroxyl group is removed from the ribonucleoside diphosphate to give deoxyribonucleoside diphosphate. An additional phosphate group from ATP is then added by another kinase to form a deoxyribonucleoside triphosphate, the immediate precursor of DNA.

**Types of nucleic acid:**

There are two types of nucleic acid: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). Both play a central role in every function of every living organism. Nucleic acids have similar basic structures with important differences. They are composed of monomer nucleotides connected like links in a chain to form nucleic acid polymers. Nucleotides consist of a nucleoside (the combination of a pentose monosaccharide molecule and a nitrogenous base) and a phosphate group. The difference between RNA and DNA lies in a single nitrogenous base and a single atom of oxygen within a sugar molecule.

**Deoxyribonucleic acid:**

DNA is the genetic blueprint of a living organism in which all information is stored and from which all information can be passed on. It has a distinctive double-helix form – two single strands which entwine around each other. A strand of DNA is much longer than that of a singular strand of RNA. This is because every strand of DNA in every cell contains the blueprint for the entire organism. Deoxyribonucleic acid is found primarily in the nucleus. However, DNA in a much shorter version can also found in the mitochondria where it supplies the genes necessary for adenosine triphosphate production, the most important source of cellular energy.

Any cell which has a nucleus contains nucleic acid in the form of DNA. There are various exceptions to the rule. Some cells lose their nucleus and DNA during the aging process, such as mature red blood cells, corneocytes, and keratinocytes. Blood platelets are sometimes mentioned as containing neither nucleus nor DNA; however, platelets are fragments of megakaryocytes and not considered to be actual cells. Single-cell organisms (prokaryotes) such as bacteria have no nucleus but contain loose strands of DNA in the cytoplasm, as shown below.



**Nucleic Acid Structure of DNA:**

The structure of DNA, a globally recognized double-helix, is based upon the two strands of a sugar-phosphate backbone held together by nitrogenous base spindles. DNA contains four nitrogenous bases, or nucleobases: adenine, thymine, cytosine, and guanine. These are naturally occurring compounds which give each nucleotide its name, and are divided into two groups pyrimidines and purines. While the pyrimidines cytosine, thymine and uracil are small, single-ringed constructions, adenine, and guanine are larger and double-ringed. This difference in shape and size and a subsequent difference in electrical charge is important, as it allows only specific complementary pairings between different group types; in DNA, adenine will only bond with thymine and cytosine will only bond with guanine. This creates nitrogenous base spindles of the same length and a mirror image on the opposite strand.

The double-helix form of DNA is caused by the shape of the monomer nucleotides. When asymmetrical molecules are stacked one on top of the other, a helix is often the result. In DNA, each strand runs antiparallel from the other, or in opposite directions.

The nucleotide monomer that makes up a single link of the DNA polymer chain is formed from a nucleobase, a phosphate group and a five-carbon (pentose) sugar called 2-deoxyribose. ‘Deoxy’ refers to the loss of an oxygen atom in relation to another form of pentose sugar known as ribose. This lack of an oxygen atom also plays a role in the helical structure of DNA. The following image shows the difference in the chemical structure of these two pentose sugars. Note the absence of the red oxygen molecule on the second carbon of deoxyribose on the left.



Deoxyribose bonds covalently with a phosphate group. This produces a chain known as the sugar-phosphate backbone. This structure leaves each nucleotide base open and free to bond with the correct nucleotide base on the opposite strand.

 **Ribonucleic acid:**

RNA is found in every type of cell. It is essential for the production of proteins via the replication of genetic information. Using the DNA blueprint, RNA in various forms copies and transfers encoded genetic data to cellular ribosomes. In turn, the ribosomes translate this data into the form of proteins. RNA is not associated with the double-helix structure of DNA. However, it has the ability to form this structure for a temporary period and exists in single strands of varying lengths. Even in denucleated red blood cells, RNA continues to carry out the process of transcription. This is because protein biosynthesis is necessary for every reaction within a living organism.

**RNA Types:**

RNA has four main forms named according to its specific role. These are known as messenger RNA (mRNA), transfer RNA (tRNA), ribosomal RNA (rRNA) and non-coding RNA (ncRNA). Three of these mRNA, tRNA, and rRNA are responsible for the production of proteins from single amino acids according to the DNA blueprint. Non-coding RNA is a broad group of ribonucleic acids which do not produce proteins through DNA codes. Research into this group is still in its infancy, and many types are relegated to a category known as ‘junk’ RNA. However, large quantities of certain RNA types may indicate functions in areas such as chromosome structure, homeostasis, and cell physiology.

Messenger RNA (mRNA) is the RNA transcript or RNA copy of the DNA message produced during DNA transcription. Messenger RNA is translated to form proteins.

Transfer RNA (tRNA) has a three-dimensional shape and is necessary for the translation of mRNA in protein synthesis.

Ribosomal RNA (rRNA) is a component of ribosomes and is also involved in protein synthesis.

MicroRNAs (miRNAs) are small RNAs that help to regulate gene expression.

**Nucleic Acid Structure of RNA**

In relation to structure, RNA is very similar to DNA. The main differences are: the absence of a double-helix structure, ribose instead of deoxyribose, and uracil instead of thymine.

RNA is primarily found in single strands or folded forms. It tends to form a double-helix only on a temporary basis. The pentose sugar in the form of ribose that forms part of the sugar-phosphate backbone of RNA has an additional oxygen atom on the second carbon atom which forms a hydroxyl group. The nucleobase uracil specific to RNA replaces the thymine found in DNA. The image below clearly shows these structural and elemental differences.



**More Macromolecules:**

Biological Polymers: macromolecules formed from the joining together of small organic molecules.

Carbohydrates: include saccharides or sugars and their derivatives.

Proteins: macromolecules formed from amino acid monomers.

Lipids: organic compounds that include fats, phospholipids, steroids, and waxes

 **Nucleic Acid Structure:**

Nucleic acids can form huge polymers which can take on many shapes. As such, there are several ways to discuss nucleic acid structure. “Nucleic acid structure” can mean something as simple as the sequence of nucleotides in a piece of DNA. Or, it could mean something as complex as the way that DNA molecule folds and how it interacts with other molecules.

**Primary Structure:**

Nucleotides the building blocks of nucleic acids, and the “letters” of the genetic “code” are made of two components:

A nitrogenous base such as adenine, cytosine, guanine, and thymine or uracil. DNA and RNA each have four possible nitrogenous bases; where DNA uses thymine, or “T,” RNA uses uracil, or “U” instead of thymine.

Each of these four bases has different bonding properties, ensuring that the cell doesn’t “mix up” one letter with the other. Thymine and uracil have almost identical structures and properties, allowing them to fulfill similar roles in the two different types of nucleic acids.

A sugar-phosphate backbone, which allows the nitrogenous bases to be strung together. Each nucleotide’s sugar can link to another nucleotide’s phosphate to become a single molecule. When many nucleotides are strung together, the angle of this phosphate-sugar bond most often makes the string into a helix. This is why DNA, which is two-stranded, naturally takes on the shape of a double helix. The primary structure of the nucleic acid refers to the sequence of its nucleotide bases, and the way these are covalently bonded to each other. The sequence of “letters” in a strand of DNA or RNA, then, is part of its primary structure, as is the helical or double-helical shape.

**Secondary Structure:**

Secondary structure refers to how nucleotide bases hydrogen bond with each other, and what shape this creates out of their two strands. The hydrogen bonds that form between complementary bases of two nucleic acid strands are quite different from the covalent bond that forms between sister monomers in a nucleic acid strand.

The bonds between bases in a single strand of nucleic acid are covalent they fully share their electrons, and are bonded in a way that’s very difficult to break. Atoms linked by covalent bonds are all part of the same molecule. Hydrogen bonds, on the other hand, are weak bonds that come from weak, temporary attractions between positively-charged hydrogen nuclei and the electrons of other atoms. The molecules don’t actually share electrons, so they can be separated fairly easily. Changes to environmental factors like acidity can also disrupt hydrogen bonds.

The most common secondary structure we’re familiar with is the double helix that forms when two complementary strands of DNA hydrogen bond with each other. Other structures are also possible, such as a “stem-loop” which occurs when a single RNA molecule folds back and hydrogen bonds with itself or a four-armed structure that can occur when four different strands of nucleic acid hydrogen bond with different parts of each other.

**Tertiary Structure:**

Tertiary structure refers to the position of the atoms of a nucleic acid in space. There are several common measurements about the tertiary structure of a nucleic acid.

* **Handedness**

Asymmetrical molecules are very much like our hands. Each of our hands has the same shape, for example the same components linked together in the same way. But our hands are clearly not interchangeable. That’s because one of our hands has the thumb on the right side, while the other has the thumb on the left. Rather than being identical, interchangeable structures, our hands are mirror images of each other. In just the same way, asymmetrical molecules with the same parts and connectivity can be identical, or they can be mirror images of each other.

 Some molecules are “right-handed” while others are “left-handed” mirror images of these. When it comes to biological molecules, “handedness” can be crucial to determining the effect that a chemical has on an organism. For some medicines and poisons, only one stereoisomer interacts with our body’s enzymes. One molecule may have no effect on us, while its mirror image may be beneficial or deadly.

* **Length of helix turn.**

While any asymmetrical molecule can have a stereoisomer, as you might guess, “length of helix turn” is fairly unique to nucleic acids. The angle of bonds between nucleotides causes most nucleic acids to form a helix shape. But small differences in the shape of the helix can cause differences in how the helix interacts with our enzymes and other molecules. So the details of this helix shape can be important.

* **Number of base pairs per turn.**

This is another measure of the exact shape and properties of a nucleic acid helix. This can be chemically and biologically important, as it determines which enzymes and molecules can affect the DNA or RNA.

**Quaternary Structure:**

Quaternary structure refers to the large shapes and structures that can be made by nucleic acids. Much like the amino acids and proteins, nucleic acids can form large structures. The shape of these structures can be important to their functions

.Examples of nucleic acid quaternary structures include chromatids huge molecules of DNA that are packed tightly for storage and transportation during cell division and ribosomes, which are organelles made partially of RNA.

Some ribozymes also accomplish their jobs partially through the use of quaternary structure. This allows them to interact with their substrates. Just like enzymes made of protein, ribozymes must precisely fit their substrate in order to catalyze its chemical reactions.

**Biological structures:**

Naturally occurring DNA molecules can be circular or linear. The genomes of single celled bacteria and archaea (the prokaryotes), as well as the genomes of mitochondria and chloroplasts (certain functional structures within the cell), are circular molecules. In addition, some bacteria and archaea have smaller circular DNA molecules called plasmids that typically contain only a few genes. Many plasmids are readily transmitted from one cell to another. For a typical bacterium, the genome that encodes all of the genes of the organism is a single contiguous circular molecule that contains a half million to five million base pairs. The genomes of most eukaryotes and some prokaryotes contain linear DNA molecules called chromosomes. Human DNA, for example, consists of 23 pairs of linear chromosomes containing three billion base pairs.

In all cells, DNA does not exist free in solution but rather as a protein-coated complex called chromatin. In prokaryotes, the loose coat of proteins on the DNA helps to shield the negative charge of the phosphodiester backbone. Chromatin also contains proteins that control gene expression and determine the characteristic shapes of chromosomes. In eukaryotes, a section of DNA between 140 and 200 base pairs long winds around a discrete set of eight positively charged proteins called a histone, forming a spherical structure called the nucleosome. Additional histones are wrapped by successive sections of DNA, forming a series of nucleosomes like beads on a string. Transcription and replication of DNA is more complicated in eukaryotes because the nucleosome complexes have to be at least partially disassembled for the processes to proceed effectively.

Most prokaryote viruses contain linear genomes that typically are much shorter and contain only the genes necessary for viral propagation. Bacterial viruses called bacteriophages (or phages) may contain both linear and circular forms of DNA. For instance, the genome of bacteriophage λ (lambda), which infects the bacterium Escherichia coli, contains 48,502 base pairs and can exist as a linear molecule packaged in a protein coat. The DNA of phage λ can also exist in a circular form that is able to integrate into the circular genome of the host bacterial cell. Both circular and linear genomes are found among eukaryotic viruses, but they more commonly use RNA as the genetic material.



**Soil Nucleic Acid Extraction:**

Nucleic acids can be extracted directly from soil to analyze the microbial community. Alternatively cells can first be separated from the soil then the nucleic acids extracted. The latter approach decreases contamination by soil components but may also be biased towards cells that are separated more easily from soil. Most researchers isolate DNA from soil because it is more stable than RNA, however protocols have been developed for soil RNA isolation. All methods for nucleic acid extraction and purification follow the same principles. Cell lysis is the first step, followed by separation of the nucleic acids from the other cellular components and finally concentrating the nucleic acids into a working volume.

 There are many papers that outline these methods and commercial kits are marketed by a number of companies. An important factor when extracting nucleic acids from soil is to ensure the approach achieves equivalent lysis of all cell types so that downstream analysis is representative of the community. This is the main source of bias in direct analyses methods of soil-extracted nucleic acids. Many laboratories have chosen to use mechanical methods, such as bead beating, to ensure cell lysis. Lysis efficiency can be determined by microscopic examination of the sample before and after the extraction procedure.

 The other factor that must be considered is soil composition because nucleic acids are charged and will bind to components, particularly clay. After the nucleic acids are extracted a number of methods can be considered that examine nucleic acids directly or indirectly after PCR amplification.

**Biochemical properties:**

**Denaturation:**

The strands of the DNA double helix are held together by hydrogen bonding interactions between the complementary base pairs. Heating DNA in solution easily breaks these hydrogen bonds, allowing the two strands to separate a process called denaturation or melting. The two strands may reassociate when the solution cools, reforming the starting DNA duplex a process called renaturation or hybridization. These processes form the basis of many important techniques for manipulating DNA. For example, a short piece of DNA called an oligonucleotide can be used to test whether a very long DNA sequence has the complementary sequence of the oligonucleotide embedded within it.

 Using hybridization, a single-stranded DNA molecule can capture complementary sequences from any source. Single strands from RNA can also reassociate. DNA and RNA single strands can form hybrid molecules that are even more stable than double-stranded DNA. These molecules form the basis of a technique that is used to purify and characterize messenger RNA (mRNA) molecules corresponding to single genes.

**Ultraviolet absorption:**

DNA melting and reassociation can be monitored by measuring the absorption of ultraviolet (UV) light at a wavelength of 260 nanometres (billionths of a metre). When DNA is in a double-stranded conformation, absorption is fairly weak, but when DNA is single-stranded, the unstacking of the bases leads to an enhancement of absorption called hyperchromicity. Therefore, the extent to which DNA is single-stranded or double-stranded can be determined by monitoring UV absorption.

**Function of Nucleic Acids:**

Broadly speaking, DNA stores information, while RNA transfers information. You might thus think of DNA as a computer hard drive or set of files, and RNA as a flash drive or jump drive.

RNA can serve as a messenger to build proteins using information coded by DNA, migrating from the nucleus where DNA "lives" to other parts of the cell to carry this out. This is, fittingly, mRNA (m stands for "messenger"). A different kind of RNA, transfer RNA (tRNA) helps in the assembly process of proteins from amino acids, and ribosomal RNA (rRNA) makes up most of the organelles called ribosomes, which also participate in protein synthesis. Many single-stranded RNA molecules form three-dimensional structures that include weak hydrogen bonds between nucleotides. As with proteins, the three-dimensional structure of an RNA molecule specifies a unique function in cells, including the degradation of enzymes.