محاضرة البايولوجي النظلري –5

What is DNA?

DNA, or deoxyribonucleic acid, is the hereditary material in humans and almost all other organisms. Nearly every cell in a person's body has the same DNA. Most DNA is located in the cell nucleus (where it is called nuclear DNA), but a small amount of DNA can also be found in the mitochondria (where it is called mitochondrial DNA or mtDNA).

What is DNA important?

DNA is important to our growth, reproduction. It contains the instructions **necessary** for your cells to produce proteins that affect many different processes and functions in your body. Because **DNA** is so **important**, damage or mutations can sometimes contribute to the development of disease.

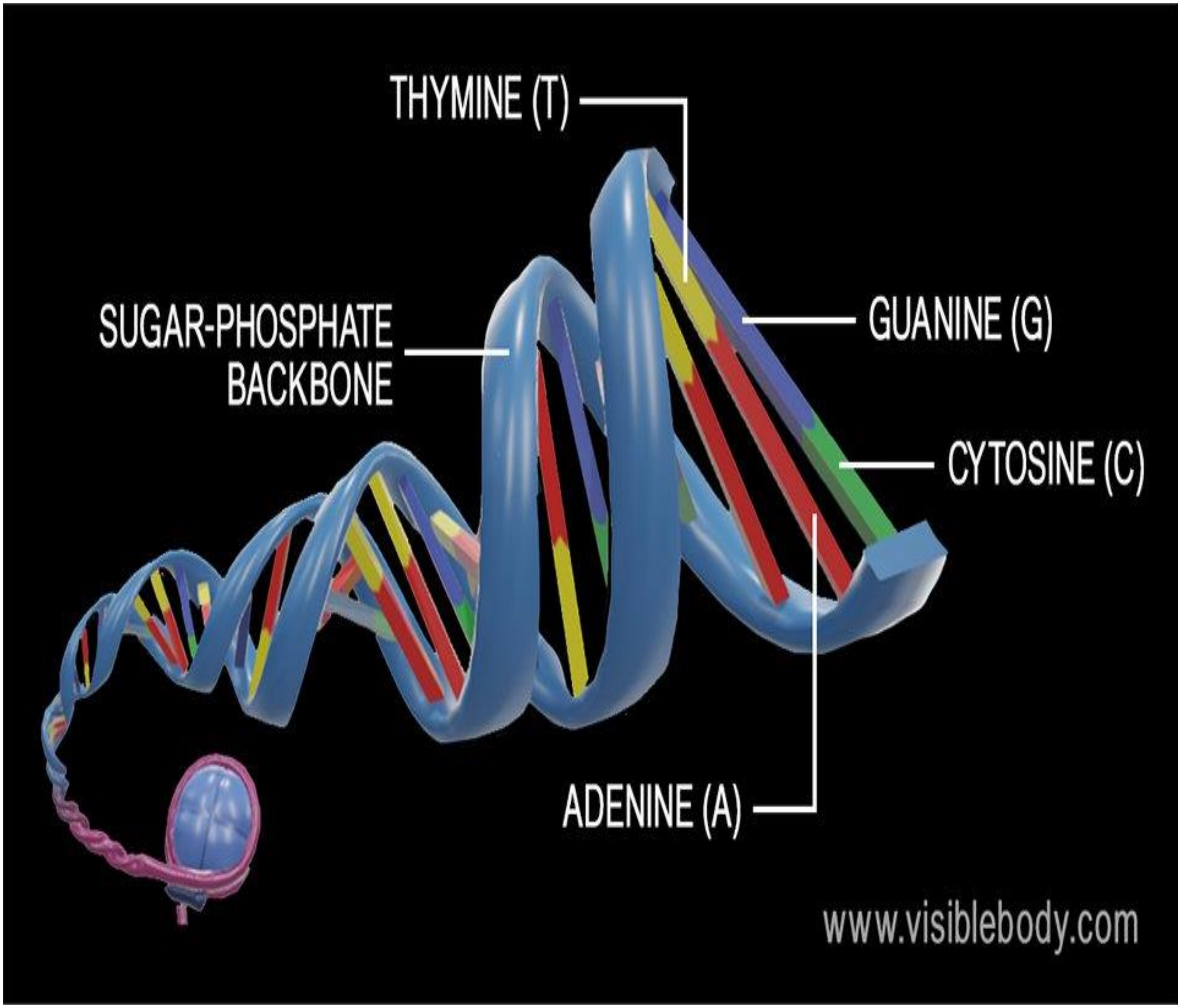
DNA Structure

A molecule of DNA consists of two strands that form a double helix structure.

DNA is a macromolecule consisting of two strands that twist around a common axis in a shape called a **double helix**. The double helix looks like a twisted ladder—the rungs of the ladder are composed of pairs of nitrogenous bases (**base pairs**), and the sides of the ladder are made up of alternating sugar molecules and phosphate.

Each DNA strand is composed of nucleotides—units made up of a sugar (deoxyribose), a phosphate group, and a nitrogenous base.

The sugar in DNA's nucleotides is called deoxyribose—DNA is an abbreviation for deoxyribonucleic acid. A **nitrogenous base** is an organic molecule that contains nitrogen and has the chemical properties of a base. There are four nitrogenous bases that occur in DNA molecules: cytosine, guanine, adenine, and thymine (C, G, A, and T). RNA molecules contain cytosine, guanine, and adenine, but they have a different nitrogenous base, uracil (U) instead of thymine.



RNA .

Is a polymer of nucleotides .unlike DNA however RNA is single stranded Also the base thymine is replaced by the base uracil and the sugar ribose is used instead of deoxyribose .

RNA Types:

There are various types of RNA, out which most well-known and most commonly studied in the human body are :

- tRNA – Transfer RNA

The transfer RNA is held responsible for choosing the correct protein or the amino acids required by the body in-turn helping the ribosomes. It is located at the endpoints of each amino acid.

- rRNA-Ribosomal RNA

The rRNA is the component of the ribosome. In all living cells, the ribosomal RNA plays a fundamental role in the synthesis and translation of mRNA into proteins.

mRNA – Messenger RNA.

This type of RNA functions by transferring the genetic material into the ribosomes and pass the instructions about the type of proteins, required by the body cells. Based on the functions, these types of RNA is called the messenger RNA. Therefore, the mRNA plays a vital role in the process of transcription or during the protein synthesis process.

Functions of RNA

The ribonucleic acid – RNA, which are mainly composed of nucleic acids, are involved in a variety of functions within the cell and are found in all living organisms including bacteria, viruses, plants, and animals. These nucleic acid functions as a structural molecule in cell organelles and are also involved in the catalysis of biochemical reactions. The different types of RNA are involved in various cellular process. The primary functions of RNA:

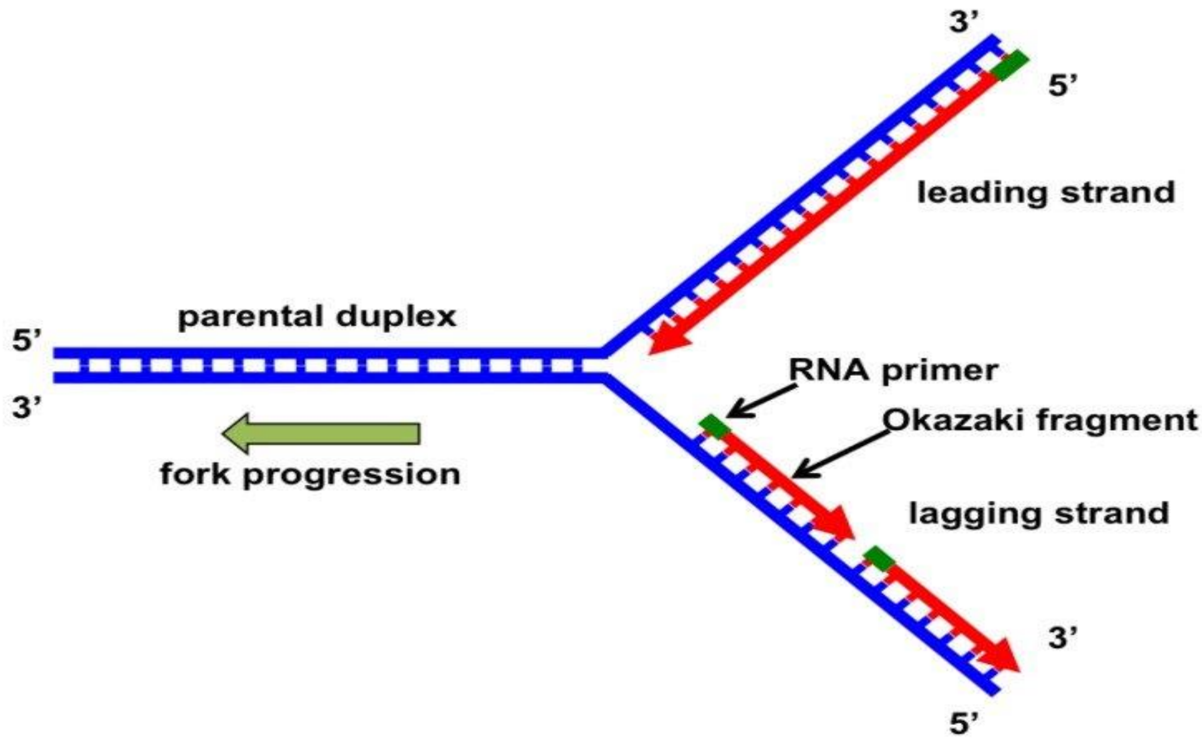
- Facilitate the translation of DNA into proteins
- Functions as an adapter molecule in protein synthesis
- Serves as a messenger between the DNA and the ribosomes.
- They are the carrier of genetic information in all living cells

Steps of DNA Replication

Step 1: Replication Fork Formation

Before DNA can be replicated, the double stranded molecule must be "unzipped" into two single strands. DNA has four bases called **adenine (A)**, **thymine (T)**, **cytosine (C)** and **guanine (G)** that form pairs between the two strands. Adenine only pairs with thymine and cytosine only binds with guanine. In order to unwind DNA, these interactions between base pairs must be broken. This is performed by an enzyme known as DNA **helicase**. DNA helicase disrupts the hydrogen bonding between base pairs to separate the strands into a Y shape known as the **replication fork**. This area will be the template for replication to begin.

DNA is directional in both strands, signified by a 5' and 3' end. This notation signifies which side group is attached the DNA backbone. The **5' end** has a phosphate (P) group attached, while the **3' end** has a hydroxyl (OH) group attached. This directionality is important for replication as it only progresses in the 5' to 3' direction. However, the replication fork is bi-directional; one strand is oriented in the 3' to 5' direction **(leading strand)** while the other is oriented 5' to 3' **(lagging strand)**. The two sides are therefore replicated with two different processes to accommodate the directional difference.



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Step 2: Primer Binding (Replication Begins)

The leading strand is the simplest to replicate. Once the DNA strands have been separated, a short piece of RNA called a **primer** binds to the 3' end of the strand. The primer always binds as the starting point for replication. Primers are generated by the enzyme **DNA primase**.

Step 3: Elongation

Enzymes known as **DNA polymerases** are responsible creating the new strand by a process called elongation. There are five different known types of DNA polymerases in bacteria and human cells. In bacteria such as E. coli, **polymerase III** is the main replication enzyme, while polymerase I, II, IV and V are responsible for error checking and repair. DNA polymerase III binds to the strand at the site of the primer and begins adding new base pairs complementary to the strand during replication. In eukaryotic cells, polymerases alpha, delta, and epsilon are the primary polymerases involved in DNA replication. Because replication proceeds in the 5' to 3' direction on the leading strand, the newly formed strand is continuous.

The **lagging strand** begins replication by binding with multiple primers. Each primer is only several bases apart. DNA polymerase then adds pieces of DNA, called **Okazaki fragments**, to the strand between primers. This process of replication is discontinuous as the newly created fragments are disjointed.

Step 4: Termination

Once both the continuous and discontinuous strands are formed, an enzyme called **exonuclease** removes all RNA primers from the original strands. These primers are then replaced with appropriate bases. Another exonuclease “proofreads” the newly formed DNA to check, remove and replace any errors. Another enzyme called **DNA ligase** joins Okazaki fragments together forming a single unified strand. The ends of the linear DNA present a problem as DNA polymerase can only add nucleotides in the 5′ to 3′ direction. The ends of the parent strands consist of repeated DNA sequences called telomeres. Telomeres act as protective caps at the end of chromosomes to prevent nearby chromosomes from fusing. A special type of DNA polymerase enzyme called **telomerase** catalyzes the synthesis of telomere sequences at the ends of the DNA. Once completed, the parent strand and its complementary DNA strand coils into the familiar double helix shape. In the end, replication produces two DNA molecules, each with one strand from the parent molecule and one new strand.

Replication Enzymes

DNA replication would not occur without enzymes that catalyze various steps in the process. Enzymes that participate in the eukaryotic DNA replication process include:

- **DNA helicase** - unwinds and separates double stranded DNA as it moves along the DNA. It forms the replication fork by breaking hydrogen bonds between nucleotide pairs in DNA.
- **DNA primase** - a type of RNA polymerase that generates RNA primers. Primers are short RNA molecules that act as templates for the starting point of DNA replication.
- **DNA polymerases** - synthesize new DNA molecules by adding nucleotides to leading and lagging DNA strands.
- **Topoisomerase or DNA Gyrase** - unwinds and rewinds DNA strands to prevent the DNA from becoming tangled or supercoiled.
- **Exonucleases** - group of enzymes that remove nucleotide bases from the end of a DNA chain.
- **DNA ligase** - joins DNA fragments together by forming phosphodiester bonds between nucleotides.

Summary of Differences Between DNA and RNA

1. DNA contains the sugar deoxyribose, while RNA contains the sugar ribose.
2. DNA is a double-stranded molecule, while RNA is a single-stranded molecule.
3. DNA is stable under alkaline conditions, while RNA is not stable.

4. DNA and RNA perform different functions in humans. DNA is responsible for storing and transferring genetic information, while RNA directly codes for amino acids and acts as a messenger between DNA and ribosomes to make proteins.
5. DNA and RNA base pairing is slightly different since DNA uses the bases adenine, thymine, cytosine, and guanine; RNA uses adenine, uracil, cytosine, and guanine. Uracil differs from thymine in that it lacks a methyl group on its ring.