**DNA Replication and Protein Synthesis**

**Introduction to DNA**

DNA is what makes us who we are and what makes us so unique from one another. It is the combination of both our parents’ DNA that gives rise to us, which further explains why people take from both parents’ physical features. DNA plays a very large role in increasing the likelihood of acquiring diseases through genes. It is clear that to understand who we are that we understand how DNA works. Every living organism has DNA in each cell of any living organism. Furthermore, each cell has all DNA required by the organism to even exist! Rosalind Franklin was among the first to use X-rays as a form of molecular photography to analyze genetic material. It was James Watson and Francis Crick also determined the shape of DNA as well. This line of research revealed to be one of the most profound scientific discoveries of the 20th century, which was that **DNA exists as a double helix.**

Each strand of DNA consists of building blocks called nucleotides. Each nucleotide consists of three components: 1) phosphate 2) sugar molecule 3) a base. There are four different bases in DNA: Adenine, Guanine, Cytosine, and Thymine. The spiral shape of DNA taught researchers a fundamental lesson about genetics. This was that the two strands of DNA were **complementary** to each other. Meaning that Adenine (A) always binds with Thymine (T) and Cytosine (C) always with Guanine (G). For example, if one of the DNA strands were to read ATTGACCCG, the other strand would read TAACTGGGC. These nucleotides then tightly pack together in the nucleus in structures called **chromosomes**.

If you were to uncoil and stretch the strings of chromosomes, DNA would be about 6 feet long. Now, if you were to stretch all DNA in your body, it would stretch to about 67 billion miles! This is where the structure of chromosomes helps compact all a living organisms’ DNA into a cell. This makes the study of genetics very appealing to scientists, because of the endless possibilities that are possible when these genes are manipulated.

**DNA Replication**

The double stranded structure of DNA is key for replication. The two strands are then separated using each strand as a template used in creating a duplicate strand. The separation of the strands is done by an enzyme called **DNA helicase.** Another enzyme then makes the complement strand by finding the correct base in the mixture and bonding it with the original strand. By doing this, the base on the old strand dictates which base appears on the new strand, and the cell ends up with an extra copy of its DNA.

DNA replication is the process of copying the double-stranded DNA before the cell divides, which is known as cell division. The new double-strands made are almost identical to the original strands, but due to mutations errors while replicating, it can result in a less than perfect copy. These changes are known as **mutations**. Each new strand then joins one of the original strands which is known as **semi-conservative replication**.

DNA is split using an enzyme called **DNA helicase.** Imagine a zipper of your favorite hoodie that you zip up, the zipper would be the DNA helicase**.** This opens the strands in a Y-shape known as a replication fork. For DNA replication to occur, one of the two strands of the original DNA is needed.DNA polymerase is the enzyme responsible for the actual replication. Since DNA is the information store of the cell, DNA polymerase not using template strands would lead to loss of this information. Each individual DNA strand runs antiparallel – meaning the leading strand goes one way while the lagging strand goes the opposite direction. This is important because this shows how the lagging is **discontinuous-** that is, short strands of DNA are made and subsequently matured by joining them together. The lagging strand is made at intervals of 100-200 nucleotides. These nucleotides are called Okazaki fragments, and since they are made discontinuously, DNA Primase is the enzyme that is responsible for making RNA primers which start the Okazaki Fragments on the lagging strand. There are other enzymes and subunits that assist in replication. An RNA primer initiates each of these small pieces of DNA. The small fragments are joined together using **DNA ligase.**

**Structure of Ribonucleic Acid**

Ribonucleic acid (RNA) is a single stranded nucleic acid polymer consisting of nucleotide monomers. RNA nucleotides contain ribose rings and uracil, while DNA contains deoxyribose and thymine. DNA is converted to RNA acids to the ribosome to form proteins, and also translating the transcript into proteins.

RNA uses the same four nucleotides as DNA except for thymine which is replaced by uracil.

**Messenger Ribonucleic Acid (mRNA)**

mRNA is an RNA that encodes and carries information from the DNA to the ribosome, where they specify the amino acid sequence of the protein products of gene expression. RNA is transcribed in the nucleus. **Transcription** is the process of when DNA is converted into RNA. Once completely processed, it is transported to the cytoplasm and translated by the ribosome. **Translation** involves the production of proteins according to the information in the mRNA. Once translation is done, the mRNA is degraded. The process of translation of codons into amino acids requires two other types of RNA: Transfer RNA (tRNA) and ribosomal RNA (rRNA).

**Transfer Ribonucleic Acid (tRNA)**

tRNA serve as a physical link between the mRNA and the amino acid sequence. The amino acids depend on the codon that results from the mRNA. tRNA uses an **anticodon,** which is represented by three nucleotides that correspond to the three bases of the codon on the mRNA. Some anticodons can pair with more than one codon due to a phenomenon known as **wobble base pairing**. This phenomenon simply explains how once the first two positions are paired, exact base pairing of the third position is less critical. 61 tRNA molecules are required per cell, however most cells are capable of binding to several codons due to the wobble position.

**Mutations**

The process of DNA replication is never 100% accurate. A change in a nucleotide can have substantial effect on the protein being encoded for. Mutations involve a permanent change in the sequence of DNA. Mutations can also have no effect on a phenotype, depending on the type of mutation. Phenotype is the combination of a person’s genetic make-up with the environment which affects an individual’s physical features. It can have an effect on how the protein can encode, if at all. The loss of a protein function is very detrimental to organisms. There are cases where mutations are beneficial. For example, let’s say a mutation happens to where an organism cannot produce melatonin in its skin. If its population moves to an area of a lighter colored environment, individuals with the mutation have the advantage with being better camouflaged. In this case, the mutation was beneficial.

There are many types of methods for mutation possible, either by a single nucleotide or even by more serious methods. There are ways where DNA segments can be deleted, duplicated, inverted, or inserted in the wrong place. There are two classes of mutation: **point mutations** and **frameshift mutations**.

**Point mutations** affect single base changes, but the new codon still encodes for the same protein as the old. There are three types of mutations: 1) Silent mutation 2) Missense mutation 3)Nonsense mutation. Silent mutation is the type of mutation that does not affect an organism’s phenotype, meaning they do not affect the protein encoded. Missense mutation is a more serious type that involves changing one nucleotide in a codon that affects the protein that was meant to be encoded. For example if AAC encodes Asparagine, missense mutation would make it AAA which encodes Lysine. This kind of mutation is very detrimental to an organism. Nonsense mutation involves the premature signaling of a stop codon, meaning that the type of protein encoded is non-functional.

**Frameshift mutations** alter the reading frame of the DNA. They do so in 2 ways: 1) Insertion 2) Deletion.

Insertion inserts a random base pair into a sequence, shifting everything to the right or left by one base pair. Deletion deletes a base pair (or more) by shifting everything to the opposite direction. Therefore for mutation to occur, replication must occur. Mutations can occur randomly to anyone and at any point. Mutations that occur from the environment are known as **mutagens**.Tobacco smoke and radiation are examples of mutagens.

**Protein Synthesis**

Each strand of DNA has multiple sequences that code for a specific protein. Products of these proteins are called **genes**. Amino acids are multiple monomers that make up a protein. Expression of genes can be thought of as genes being turned on or off like a light switch.

Proteins are not made in the nucleus, but on the ribosomal in the cytoplasm. Three types of RNA are involved in protein synthesis as mentioned earlier. This process is known as translation**.**

**Transcription and Translation**

For genetic code to be passed on the mRNA, one strand of DNA will pair with mRNA using the same base pairing moves as DNA replication, except Uracil pairs with each Adenine in DNA. This process of constructing an mRNA molecule from DNA is known as transcription. The genetic code in mRNA is read in triplets called **codon.** It is universal-meaning its found everywhere and is present in almost all human beings. These codons are read in the ribosome by tRNA. Each tRNA carries only one type of amino acid. The process of reading the mRNA in the ribosome to produce a protein is called translation. All proteins being made has a start codon, AUG, which encodes for methionine. There are 3 stop codons that signal for termination which are UAA, UGA, UAG.

**Summary**

DNA replication is a double stranded helix shaped structure that contains genetic code. This genetic code is very diverse and makes us who we are. DNA replication is a very complex process that involves multiple enzymes that assist in the process. While replicating, mutations may occur that can have either little effect to very adverse problems. DNA has multiple ways with proofreading as it replicates. When DNA replicates, it is converted to RNA which is known as transcription. When the tRNA comes into contact with the mRNA, a protein is encoded. This process occurs at the ribosome.

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**Chromosomes:** Thread-like structure that is present in the nucleus which contains genetic material.

**DNA Helicase:** Enzyme responsible for “unzipping” DNA.

**Mutations:** Changes that occur in the nucleotides in the DNA.

**DNA Ligase:** Enzyme responsible for joining together DNA strands.

**Anticodon:** Triplet set of nucleotides present on the tRNA.

**Mutagens:** Anything that causes mutation in DNA.

**Genes:** Part of DNA that encodes for a protein.

**Transcription:** Process of where DNA is copied onto an mRNA.

**Codon:** Triplet set of nucleotides present on the mRNA.

**Translation:** mRNA produced from transcription that produces a specific protein at the ribosome.

**Okazaki Fragments:** Small strand of nucleotides that is formed on the lagging strand.

**DNA Primase:** Enzyme responsible for starting the synthetization of Okazaki Fragments.

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