DNA TRANSCRIPTION AND TRANSLATION:

A LOOK INTO THE INTRICATE PROCESS THAT MAKES OUR DNA

WHAT IS DNA?

DNA, or ***deoxyribonucleic acid***, is a complex thing to think of. It’s the genetic material that makes us who we are. DNA is a double stranded molecule, more commonly known as a **double-helical** molecule which looks like a spiral staircase. DNA lives in our chromosomes in the nucleus of every cell in our body, and encodes our genetic information. DNA is nucleic acid, and these multiple nucleic acids are structurally known as **polymers**. If you don’t remember what a polymer is, it is basically one really big structure made up of multiple molecular units in a really long chain, i.e. DNA. These units are known as **nucleotides** in DNA, and when you link and place a bunch of them together, they are known as **polynucleotides**.

A

T

C

G

C

G

A

T

G

C

So the nucleotides in these two strands of the double-helical structure are each made up of three key ingredients: a five-carbon sugar, a phosphate group, and one of four nitrogenous bases: adenine, guanine, cytosine, and thymine. The five-carbon sugar molecule is called **deoxyribose**, which is where the “deoxyribo-” part of deoxyribonucleic acid comes from. This is one of two parts that makes up the sugar-phosphate backbone of DNA. Next, there are numerous **phosphate** **groups** that help hold deoxyribose together. This is the second part in the sugar-phosphate backbone of the two strands in DNA. Finally, there are four **nitrogenous bases**: adenine, guanine, thymine, and cytosine, which help make up a core part of DNA.

The two long chains of DNA are linked together through these pairs of nitrogenous bases and connected by weak hydrogen bonds. Each nitrogenous base has a specific partner in pairing, and cannot simply be thrown together randomly. Adenine can only be paired with thymine, and cytosine can only be paired with guanine. From this knowledge of base pairing, when given one base sequence (one chain of DNA) you can easily predict what the other half of base pairs will look like.

WAIT, WHAT ABOUT DNA’S COUSIN RNA?

RNA is ***ribonucleic acid***, and even though it sounds very similar to DNA there are a couple major components that make it distinctly different. First of all, it has a sugar-phosphate backbone just like DNA, however, the sugar component is known as ***ribose*** instead of deoxyribose. Ribose contains a hydroxyl group that deoxyribose does not. RNA also contains the base ***uracil*** instead of thymine that bonds with adenine. So, if you have a base sequence from RNA, then the matching sequence would be very different than that of DNA. Finally, RNA is ***single stranded***while DNA is double stranded. You can see that RNA holds major differences that make it unique from DNA, and it plays a very important role in replication and transcription, which we will get into later on.

REPLICATION

DNA replication occurs in the nucleus of a cell during cell division, or mitosis, and is known as the process where two exact copies of DNA are made from one DNA molecule and placed into new cells. If DNA replication confuses you, here is a step-by-step process explaining it from start to finish.

DNA replication begins when **helicase**, an enzyme, binds to nucleic acid at a point of initiation where it unwinds the double helix by cutting loose the hydrogen bonds between the nitrogenous bases. In order to break these bonds, helicase has to use energy stored up in ATP. It’s a pretty important enzyme, since it begins the process of replication. Helicases also play an important role in other DNA processes that require the double helix to be split, as well as some RNA processes that require the shaping of some RNA molecules, but for now, you just need to know that it’s an important enzyme that starts the process of replication.

So, the point where helicase begins to unwind the DNA into two strands is known as the **replication fork**, and turns the strands into a “Y” shape. The top strand occurs in the 5’ to 3’ direction, and is known as the **leading strand**. The bottom strand occurs in the opposite 3’ to 5’ direction, and is known as the **lagging strand**. Both strands serve as template strands for new DNA, which will be synthesized by **DNA polymerase**, an enzyme that helps create new DNA by adding the appropriate corresponding nucleotides to each strand. An easier way to remember this, is that the leading strand in the 5’ to 3’ direction is a nice strand because it flows in a forward direction for DNA polymerase to simply do its thing and add the right nucleotides to it. The lagging strand, however, is a drag, since it flows in the opposite 3’ to 5’ direction, and has to be synthesized by DNA polymerase in fragments.

Before DNA polymerase does its thing on each new strand, it needs a little help to hook onto each strand. This is where **RNA primase** comes in, yet another enzyme that lays a few nucleotides down at the beginning of a template strand for DNA polymerase to hook onto to start adding the correct nucleotides and synthesize new DNA. However, since this is RNA we are talking about, instead of adding the correct thymine nitrogenous base to adenine, it adds its unique nitrogenous base uracil to the beginning of the new strands instead. This causes another DNA polymerase enzyme to go back in later to find all those little uracil bases and replace them with the correct thymine base.

Since the lagging strand is such a drag, and flows in the 3’ to 5’ direction, it has to be synthesized by DNA polymerase in sections called **okazaki fragments**. The same thing occurs here in these fragments by RNA primase laying down a primer for DNA polymerase to hook onto and do its job. This is simply done in fragments instead of a nice and easy continuous way, and because of this, another enzyme called DNA ligase has to come in after the other DNA polymerase has corrected the RNA primers, and connect the okazaki fragments via phosphodiester bonds.

So, the replication process for the leading strand is called **continuous** replication, and **discontinuous** for the lagging strand.

TRANSCRIPTION AND TRANSLATION

So now that we know about DNA replication and how it takes place, we can learn about how protein synthesis and how it occurs in our body. Proteins are important because they help control and regulate a number of functions within our bodies, and help repair and create new cells as well. Without proteins, our bodies would not be able to make new DNA, which would halt healing, growth, reproduction, and a number of other functions that occur every day in our bodies to survive.

Transcription and translation play a crucial role in protein synthesis. Transcription is the process by which DNA is copied onto messenger RNA (mRNA) in the nucleus, and translation is when the information on mRNA is decoded to make a protein.

Transcription starts in the nucleus of the cell, and occurs in three steps: initiation, elongation, and termination.

**Initiation**:

* Initiation begins when RNA polymerase, a crucial enzyme in transcription, binds to a specific region of DNA called the promoter.
* The promoter is located upstream the DNA towards the 5’ end.
* Once binding occurs, DNA begins to unwind in preparation for elongation.

**Elongation**:

* When DNA unwinds, only one strand is used to begin RNA synthesis and much like DNA replication, this can only occur in the 5’ to 3’ direction.
* RNA polymerase then begins to read the DNA sequence, and add complementary nucleotides to begin making messenger RNA (mRNA).
* RNA polymerase continues until it reaches the termination point.

**Termination**

* Once the gene is copied, RNA polymerase will reach a stop (termination) signal that stops it from copying and it simply comes off.
* The new mRNA strand is released at the same time RNA polymerase is, and the double helix goes back to its normal form.

Once mRNA is released, it has to undergo a couple more refinements before it can leave the nucleus to proceed with translation. Three main processes it goes through before translation is **splicing**, **editing**, and **polyadenylation**.

Splicing is the process of removing areas of mRNA that do not code for proteins. These areas are called **introns**, and the remaining areas that do code for proteins are called **exons**.

Editing is simply the rearrangement of certain nucleotides. Because of this, multiple forms of a protein can exist.

Finally, polyadenylation simply adds a tail to the strand of mRNA that consists of multiple adenine bases. This allows the end of mRNA to be recognized and to be exported from the nucleus.

Translation occurs in the cytoplasm of the cell outside of the nucleus, more specifically in the **ribosome**. It is the process of decoding the mRNA produced by transcription into amino acids. It involves two main molecules that help carry out the process: transfer RNA (**tRNA**) and ribosomes, which is made of ribosomal RNA (**rRNA**). TRNA has one end that is an anticodon made of three nucleotides, and it can read specific mRNA **codons**. The ribosomes are made of proteins, and consist of a small and large subunit that fold around mRNA during translation. Just like transcription, translation occurs in three steps: initiation, elongation, termination.

**Initiation**:

* Here, the ribosome assembles around the mRNA strand and the first tRNA molecule, methionine, comes in and constructs the initiation complex.

**Elongation**:

* The process here is very similar to transcription elongation. Once a codon is exposed, a matching tRNA binds to it and reads and adds the amino acid coded for to the existing amino acid chain, or more commonly known as a polypeptide chain.

**Termination**:

* Elongation continues until a stop codon enters the ribosome and signals the tRNA to stop, and the amino acid chain separates from it.

After termination, the chain separates from mRNA and the ribosome dissociates.

DNA replication, transcription, and translation are all vital processes that help our body function properly, and makes us who we are. Hopefully, now you are familiar with each process and realize just how important they are!

References

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