DNA and PROTEIN SYNTHESIS

DNA, functioning as the hereditary material, ultimately determines the traits of an individual. The idea that this one type of molecule can play such a singular role in determining our characteristics is remarkable. What is still more amazing is the manner in which DNA affects these traits. DNA functions by coding for the synthesis of proteins.

The DNA (deoxyribonucleic acid) is found in the nucleus of the cell, yet protein synthesis occurs outside the nucleus on ribosomes within the cytoplasm. Molecules of RNA (ribonucleic acid) carry a transcribed genetic message from the DNA to the ribosome, where other molecules of RNA function in the actual assembly of the protein.

RNA is a second type of nucleic acid. RNA differs from DNA in that it has the base Uracil instead of the base Thymine (U pairs with A during base pairing); the sugar ribose instead of deoxyribose, and in that the RNA is usually a single stranded molecule rather than a double helix like DNA.

There are three types of RNA. Ribosomal RNA (rRNA) is the major structural component of ribosomes. Messenger RNA (mRNA) functions in carrying the genetic message from the nucleus to the cytoplasm. Transfer RNA (tRNA) brings amino acids into position on the ribosome during the construction of a protein.

The process of protein synthesis begins when a portion of the DNA double helix unzips to expose a gene. On this level of genetics we will consider a gene to be a segment of the DNA that codes for one particular protein.

The base pairs of the double stranded DNA molecule unzip down the middle as weak hydrogen bonds between the paired bases are broken and the double stranded DNA is now single stranded in this region on the chromosome only. The gene is now exposed, meaning it is single stranded and available to base pair with free RNA nucleotides.

One strand of the exposed DNA, the DNA template, will pair with the free RNA nucleotides, eventually making the mRNA molecule. The opposite exposed strand of DNA does not participate.

Free RNA nucleotides in the nucleus pair up with the exposed template strand of the DNA. Remind yourself that in a double stranded DNA molecule: A=T; C=G. But with this pairing of the single stranded DNA template to the free RNA nucleotides, the pairing will be: A=U (Uracil); C=G.

With the free RNA nucleotides paired up with the template DNA strand, each RNA nucleotide is then attached to its neighbor by a phosphate group. In this way, the mRNA is constructed. This mRNA has a "…sugar-phosphate-sugar-phosphate…" backbone, with the sugar being ribose, and attached to each ribose sugar is one of the four RNA bases: A, U, C, and G.

The production of a strand of mRNA on the DNA template is referred to as transcription.

This newly synthesized strand of mRNA separates itself from the DNA template strand by breaking weak hydrogen bonds and leaves the nucleus through nuclear pores (small openings in the nuclear membrane).

The mRNA attaches to a <u>ribosome</u> in the cytoplasm. A length of mRNA consisting of six bases will fit into the globular ribosome at one time. Each set of three bases on the mRNA (a **triplet**) is the mRNA code for a particular amino acid. Each of these three bases is called a <u>codon</u>.

There are 64 possible codons, but only 20 different amino acids. The code is therefore redundant in that several amino acids are coded for in more than one way. In addition, thre are three termination codons which stop the production of a protein. Possible codons are the amino acids for which they code are in the following table:

Second Base

First Base		U	C	A	G		Third Base
		UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U	
	U	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C	
		UUA Leu	UCA Ser	UAA Stop	UGA Stop	A	
		UUG Leu	UCG Ser	UAG Stop	UGG Trp	G	
		CUU Leu	CCU Pro	CAU His	CGU Arg	U	
	C	CUC Leu	CCC Pro	CAC His	CGC Arg	C	
		CUA Leu	CCA Pro	CAA Gln	CGA Arg	A	
		CUG Leu	CCG Pro	CAG Gln	CGG Arg	G	
		AUU Ile	ACU Thr	AAU Asn	AGU Ser	U	
	A	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C	
		AUA Ile	ACA Thr	AAA Lys	AGA Arg	A	
		AUG Met	ACG Thr	AAG Lys	AGG Arg	G	
		GUU Val	GCU Ala	GAU Asp	GGU Gly	U	
	G	GUC Val	GCC Ala	GAC Asp	GGC Gly	C	
		GUA Val	GCA Ala	GAA Glu	GGA Gly	A	
		GUG Val	GCG Ala	GAG Glu	GGG Gly	G	

The first three bases of the mRNA, the first triplet, that are found in the ribosome are paired with the three bases on a transfer RNA molecule (**tRNA**). The tRNA molecules are made and exist throughout the cytoplasm. They consist of three bases on one end and an amino acid on the opposite end. The sequence of the three bases on the tRNA is referred to as an <u>anticodon</u>. It is this specific sequence of three bases on the tRNA molecule that determines which amino acid that same tRNA molecule will carry on the other end.

The role of the ribosome is to align both the codon triplet of the mRNA and the anticodon triplet of the tRNA to see if these two triplets will pair up exactly, three for three. If the anticodon on the tRNA does not perfectly match the codon of the mRNA, the ribosomes expels this tRNA and pulls in another one to try to find a perfect match.

For example, if the codon sequence on the mRNA reads G-U-A, then the only tRNA that will match is the specific tRNA with the anticodon sequence C-A-U, since the first bases of both: the G of the G-U-A; and the C of the C-A-U naturally pair up. You'll notice that the other two bases also pair up.

Once this correct tRNA is found by the ribosome, the amino acid on that tRNA is removed by the ribosome and this amino acid is attached to the ribosome. With this completed, the next three bases of the mRNA, the next codon, moves forward into the position the previous codon was just in, and the matching of the correct tRNA begins again. Once the correct tRNA is located by the ribosome, the amino acid from this tRNA is removed by the ribosome and this amino acid is attached to the previous one.

By repeating this moving in of the next codon, matching the correct tRNA, removing and attaching the amino acid to the growing chain of amino acids, eventually a string of amino acids is found on the ribosome. Finally the entire length of the mRNA has passed through the ribosome and the process of adding amino acids is completed.

What is left is a string of attached amino acids. This is a protein. A newly synthesized protein. This process is called translation.

Overall, from start to finish, this process is called protein synthesis. Protein synthesis requires two steps: Transcription followed by Translation.

Having traveled completely through the ribosome, the mRNA is now free in the cytoplasm and may enter another ribosome and repeat the process of translation all over again.

The string of amino acids, the newly synthesized protein, will fall off of the ribosome. If the ribosome is floating free in the cytoplasm, the newly synthesized protein will then be released into the cytoplasm.

If the ribosome is attached to a membrane called the endoplasmic reticulum, the newly synthesized protein is released from the ribosome and deposited through the phospholipid wall of the endoplasmic reticulum and into the endoplasmic reticulum where it is stored and possibly transported elsewhere in the cell.