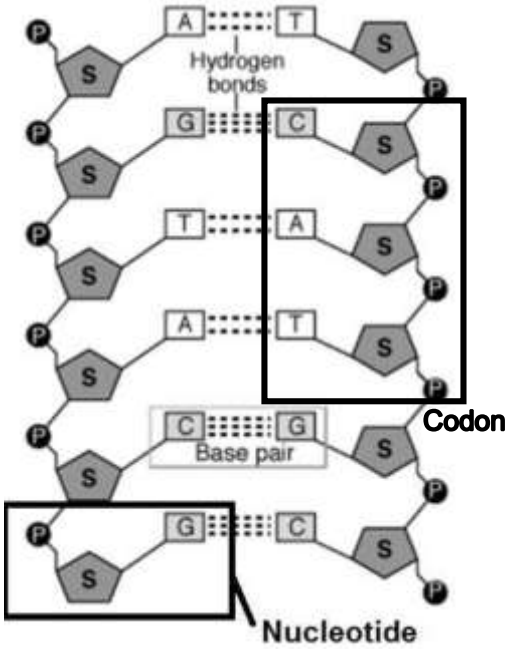
DNA & Proteins Unit Storyline

The world is home to a seemingly endless variety of life. Each organism has a unique combination of genes in their DNA. These genes code for the assembly of proteins. Proteins are primarily responsible for the unique characteristics of each species and each individual organism.

Structure & Function of DNA

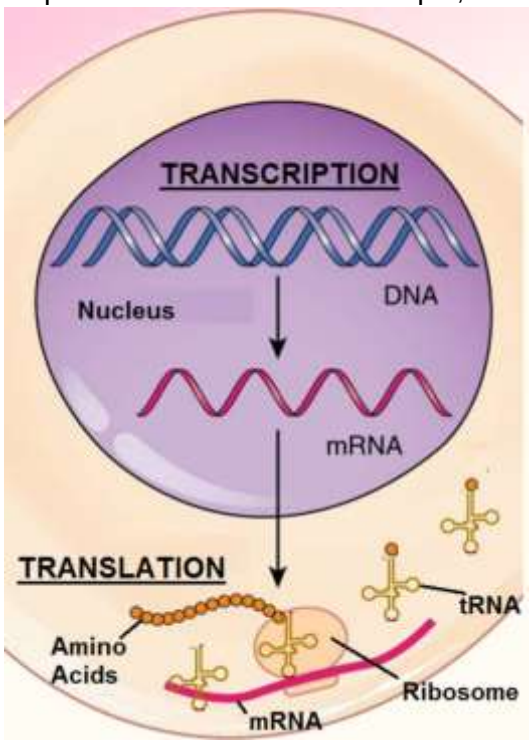
All species depend on DNA to provide the instructions for assembling their proteins. DNA in every species is made from the same three key ingredients - a phosphate, a deoxyribose sugar, and a base molecule. The phosphate and sugar molecules provide structure to DNA; the bases are what store the information needed to assemble proteins. A nucleotide is the basic building block of DNA and consists of a phosphate, sugar, and base molecule.



There are four kinds of bases in DNA - A, C, G, and T. Due to differences in size and bonding sites, there are only two possible combinations of these bases: A always binds to T, and G always binds to C. This means that if an A is on one side of double-stranded DNA, a T is on the other side. If G is on one side, C is on the other. If one side of DNA is AGTACG, the other side of DNA would be TCATGC.

This makes it easy for a cell to duplicate its DNA. A cell splits the double-stranded DNA into two single strands using a protein called helicase; another protein, called polymerase, then fills in the remaining sides to create two identical strands of DNA.

The order of bases in DNA determines the order of amino acids in a protein. All proteins are made from the same 20 amino acids. The order in which amino acids are assembled determines the type of protein created. Every combination of three bases (a *codon*) codes for a specific amino acid. For example, ATG codes for the amino acid methionine. GTA would code for valine.



Transcription & Translation

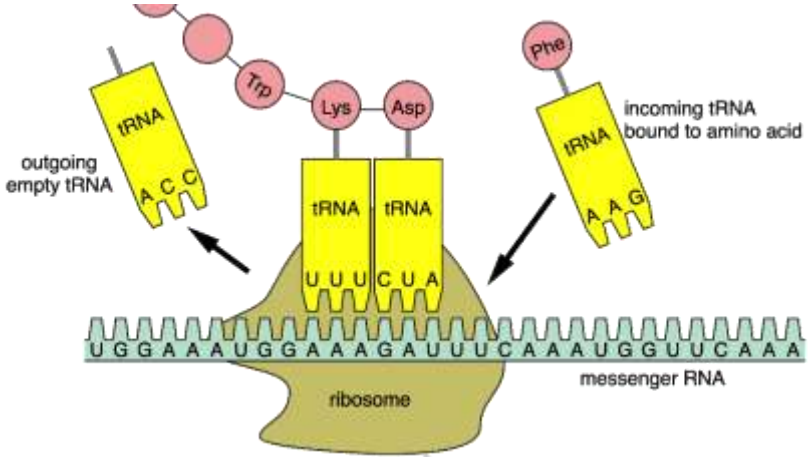
DNA must be protected in the nucleus of the cell. However, proteins are assembled outside of the nucleus in the cell's ribosomes. Cells use RNA to get the information in DNA to where the proteins are assembled. RNA is very similar to DNA. However, unlike DNA, RNA is 1) single stranded, 2) uses Uracil (U) instead of Thymine (T), and 3) has a slightly different sugar molecule.

RNA is central to two key processes: transcription and translation. Transcription is the process of producing an RNA copy of a gene. Translation when a protein is assembled using information from the RNA copy.

During transcription, the cell produces a copy of DNA called mRNA (or *messenger RNA*). RNA polymerase is the protein that produces this mRNA copy. Transcription factors are proteins that guide RNA polymerase to the gene that needs to be copied.

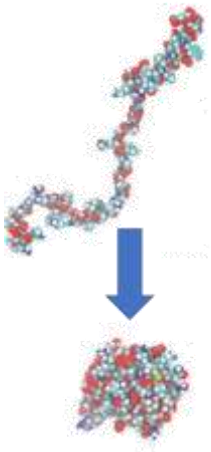
During translation, the mRNA copy leaves the nucleus and moves to a ribosome (where proteins are assembled). The mRNA copy moves through the ribosome one codon (3 bases) at a time. tRNA

(or *transfer RNA*) delivers amino acids to the ribosome based on the information copied in mRNA. Each codon codes for a specific amino acid. The tRNA carrying the needed amino acid will have a codon that is complementary to the codon in mRNA. For example, if the next codon in mRNA is CCC, the only tRNA that can bind to it is one with the codon GGG. This tRNA will carry the next amino acid needed to assemble the protein.



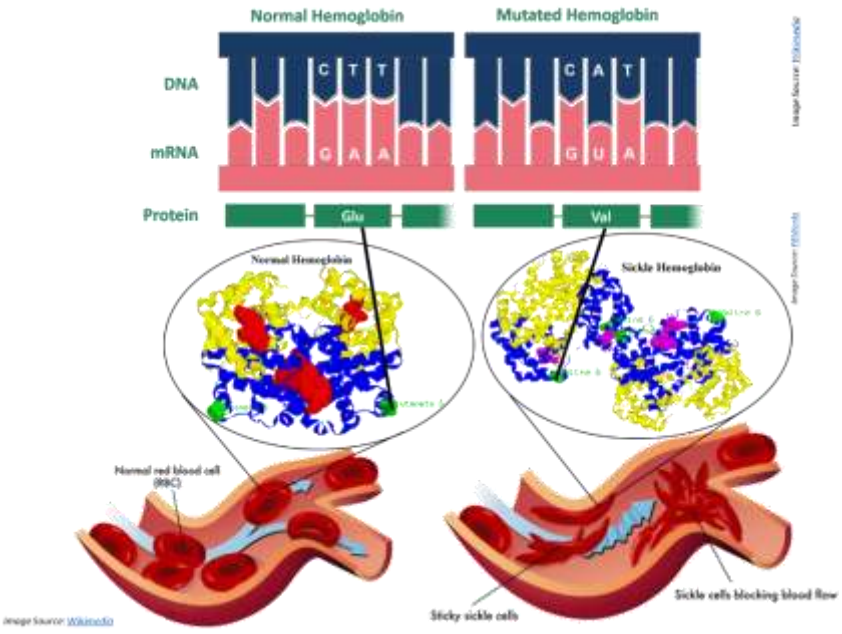
In summary, transcription is the process of making the mRNA copy of a gene.
Translation is the process of assembling a protein using the mRNA copy. Transcription and translation are sort of like using a recipe. Transcription is like making a copy of a cherished family recipe (to avoid damage to the original recipe, you need to use a copy). Translation is equivalent to using the copied recipe to combine ingredients in the correct order.

Shape & Function of Proteins
Chains of amino acids do not stay in a straight line as they leave the ribosome. Instead, they will fold into a compact blob; eventually they form a specific shape. The shape of a protein is what primarily determines its function. The properties of the amino acids in a protein determine the shape of the protein. These properties include whether individual amino acids are attracted or repelled by water, and whether they are attracted or repelled by neighboring amino acids.



Amino acids that are attracted to water are hydrophilic. These amino acids tend to contain more nitrogen and oxygen atoms. Amino acids that are repelled by water are hydrophobic. Hydrophobic amino acids will move inside to the center of a protein to avoid water; hydrophilic amino acids will move to the outside of a protein to be closer to water.

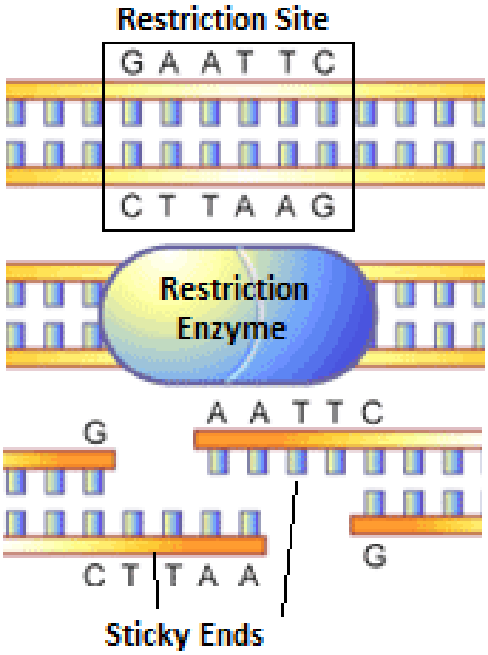
Some amino acids are positively or negatively charged; others are neutral. Oppositely charged amino acids are attracted to each other; similarly charged amino acids are repelled by each other. In addition, one specific type of amino acid, called cysteine, forms special bonds with other cysteine molecules. Two cysteine amino acids will move the whole chain of amino acids to bond together. The bonds between two cysteine amino acids is very strong and provides additional stability to a protein.



The function of a protein depends on whether a chain of amino acids folds into a correct shape as a result of these three properties. For example, hemoglobin is the protein that binds oxygen molecules on a red blood cell. Hemoglobin must form a ring shape to bind to oxygen. Small changes in amino acid sequences can have major consequences for protein folding. A mutation in the gene for the hemoglobin protein changes a single amino acid in that sequence. This causes the entire amino acid chain to fold into a different shape (resembling a sickle, or half-moon shape). This results in a disease called sickle cell anemia, causing tissue damage and reduced blood flow.

Genetic Modification

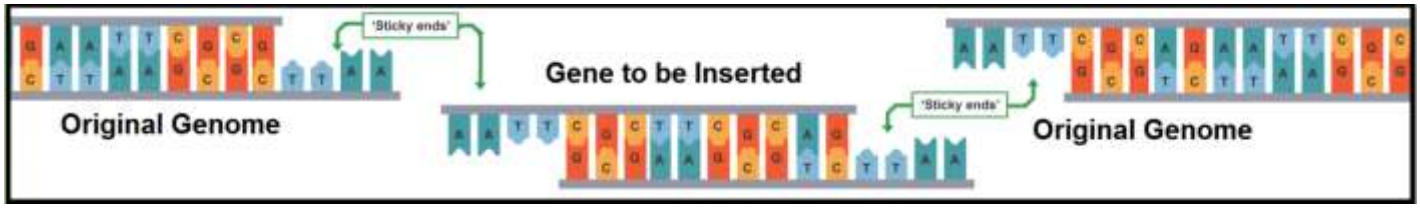
Cells perform transcription and translation in generally the same manner. Because of this, genes from one organism can be moved to the cells of another organism and will still be functional. Genetic engineering is the process of changing the DNA of an organism by adding or removing DNA from an organism's genome. A genome is the complete set of genes in an organism's cells.



Genetically modified organisms (GMOs) are organisms in which genes were added or deleted from their genome. Genetically modified organisms express an inserted gene in the same way they would express any other gene in their DNA. The added gene is copied by mRNA and moved to a ribosome. tRNA then delivers amino acids to assemble the new cellular protein.

Restriction enzymes are useful for removing and inserting new genes into an organism's genome. A restriction enzyme is a protein that cuts DNA any time it encounters a specific sequence (such as GAATTC). A restriction enzyme is like a chemical scissors for DNA. The specific sequence at which a restriction enzyme cuts DNA is called the restriction site. There are many kinds of restriction enzymes, and each one has a unique restriction site.

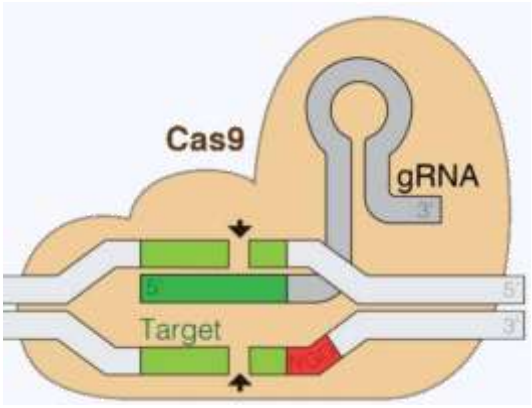
Most restriction enzymes cut DNA in a zig-zag fashion. This causes one portion of the double-stranded DNA to stick out farther than the other portion. This is called a sticky end. If both the inserted gene and the genome are cut with the same restriction enzyme, the gene will often insert itself into the genome. The sticky ends of the cut gene will be complementary to the cut genome.



GMOs are increasingly common in the United States. Roughly 70-80% of food in US grocery stores contain genetically modified ingredients. Similarly, GMOs are frequently used to produce medications. For example, most insulin used to treat individuals with diabetes is produced by genetically modified bacteria.

CRISPR-Cas9

The newest method of genetic modification is called CRISPR-Cas9. While earlier forms of genetic modification would take months or even years, CRISPR allows for a genome to be modified in a matter of days. Furthermore, CRISPR is much more precise and can be used to modify the genome of fully developed organisms (instead of only a single fertilized egg cell, as was usually the case for earlier methods).



The CRISPR-Cas9 system uses a type of RNA called gRNA (or *guide RNA*) to guide the Cas9 enzyme to the gene that needs to be removed or edited. The Cas9 enzyme attaches to the gene and cuts the DNA at this site. The cell attempts to fix the breakage. As the cell fixes the break, it can disable the gene or replace it with another gene. This can be useful for eliminating harmful genes that could cause problems or for inserting new genes where they did not exist.