Introduction to Protein Synthesis

You have learned that DNA determines traits and codes for proteins, but how does the language of DNA translate to the language of proteins? Protein synthesis is basically a two-step process in which information flows from DNA to RNA to proteins.

The Central Dogma

Soon after discovering the structure of DNA, Francis Crick defined what he called the "central dogma" of molecular biology. Crick stated that information flowed from DNA to proteins, but not in the other direction. This flow of information from DNA to proteins is referred to as protein synthesis. Crick proposed that in the first step of this process, information flowed from DNA to an intermediate molecule of RNA. In the second step, information was transferred from the RNA to a protein molecule.

Recall that in addition to providing the template for protein synthesis, the DNA code can also be copied. Replication is the process during the cell cycle in which DNA is copied, so that when cell division occurs, each new cell receives a full set of DNA.

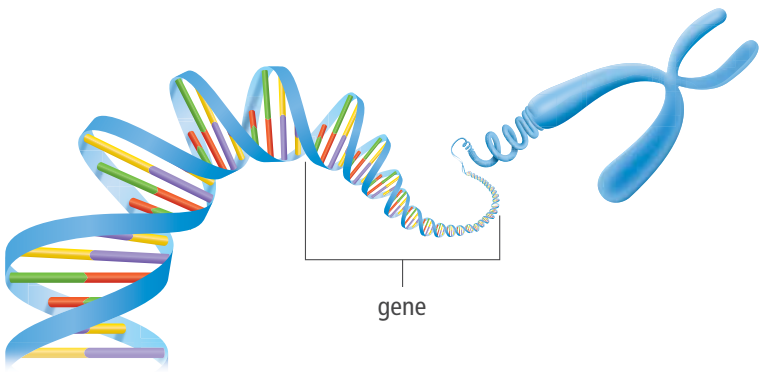
Model Create a flow chart to illustrate the flow of information in both protein synthesis and DNA replication.

Genes Code for Proteins

Each protein is coded for by a section of DNA called a gene. A gene is a piece of DNA that provides instructions for a cell to make a certain protein. Humans have around 19,000 protein-coding genes. However, the number of genes is not necessarily related to the complexity of the organism. For example, grape plants are fairly simple organisms, but they have over 30,000 genes according to the most recent count.

Genes are the most basic unit of heredity. They determine the traits of an organism because the proteins they code for carry out the work of the cell. Some proteins give cells structure, while others catalyze reactions or act as chemical messengers.

FIGURE 2: A gene is a section of DNA that codes for a certain protein.



Explain Imagine that a chromosome was compared to a novel. What could a gene be compared to?

Proteins are the connection between DNA and traits. Proteins carry out most of the tasks in the cell, and as a result, greatly influence the cell's structure and function. Whether they are catalyzing chemical reactions, transporting molecules, or helping fight infections, proteins are essential components of the cell system.

FIGURE 3: Proteins have many different functions.

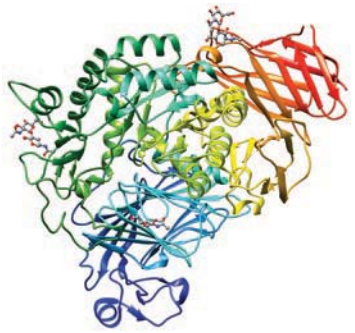
Function	Examples
Storage	Albumin (a protein found in egg whites)
Transport	Globin (a protein found in red blood cells)
Maintaining Homeostasis	Hormones (chemical messengers) Antibodies (components of the immune system that help defend the body from bacteria and viruses)
Movement	Myosin (motor protein involved in muscle movement) Kinesin (a motor protein that transports materials inside cells)
Structure	Parts of the cytoskeleton and muscle fibers Keratin (a protein that makes up hair, nails, feathers, and horns)
Catalyzing Reactions	Enzymes such as catalase, maltase, and lactase

Gather Evidence Record evidence to explain why proteins are called the "workhorses" of the cell.

Structure and Function

Protein Modeling

FIGURE 4: This computer model can be used to study the enzyme maltase.



Each protein has a specific structure, which is coded for by a gene or set of genes. The image in Figure 4 is a computer model of a protein called maltase that catalyzes chemical reactions. As the name suggests, maltase breaks down the carbohydrate maltose into molecules of the simple sugar glucose.

A protein's structure helps it carry out a specialized function. The structure of maltase allows it to catalyze particular chemical reactions properly. If the structure of the protein is altered, it may not be able to carry out its function. Scientists are particularly interested in protein structure because proteins are involved in almost every cell process. Scientists use different types of technology to determine the structure of a protein to help them make a model using computer modeling software. This gives scientists a tool for experimenting with errors in protein structure to determine how these errors affect the protein's function. For example, scientists discovered that some human diseases result from a malfunctioning protein. Computer modeling technology has allowed research on proteins to advance greatly in recent years.

Explain What types of questions could a researcher investigate using a computer model of the enzyme maltase?

Image Credits: (b) Image of PDB entry 3L4V created with Chimera (http://www.rbvi.ucsf.edu/chimera/)

Stages of Protein Synthesis

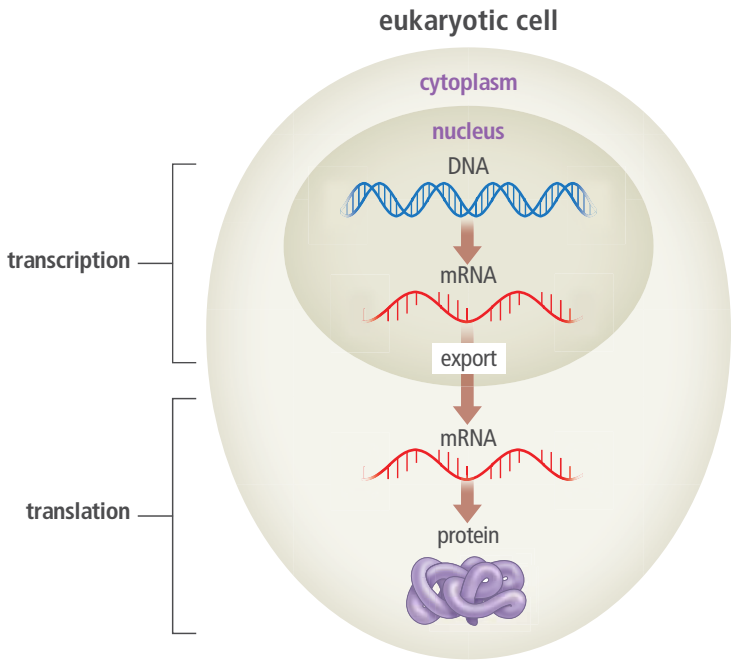
The process of constructing proteins based on the DNA code has two main stages: transcription and translation. Transcription is the process of copying a sequence of DNA into an intermediate molecule called mRNA, or messenger RNA. mRNA is like a disposable copy of the DNA message. During translation, the mRNA message is converted into a polypeptide. One or more polypeptides make up a functional protein.

Predict Why do you think a "disposable copy" of the DNA code is necessary for protein synthesis?

Recall that a prokaryotic cell does not have a nucleus; instead, DNA "free-floats" within the cell. Thus, in these cells, transcription and translation all occur in the cytoplasm at approximately the same time. The translation of mRNA begins while the mRNA is still being transcribed.

In eukaryotic cells, however, DNA is located inside the nuclear membrane, so these processes are separated in both location and time. Transcription occurs in the nucleus of the cell, whereas translation occurs in the cytoplasm. The separation of transcription and translation in eukaryotic cells allows for additional processing of the mRNA before it is translated into a protein.

FIGURE 5: Protein synthesis includes the processes of transcription and translation.



Collaborate Imagine that the DNA code was compared to a recipe in a cookbook. What could RNA be compared to? Write your answer, and then compare it with a partner's answer.

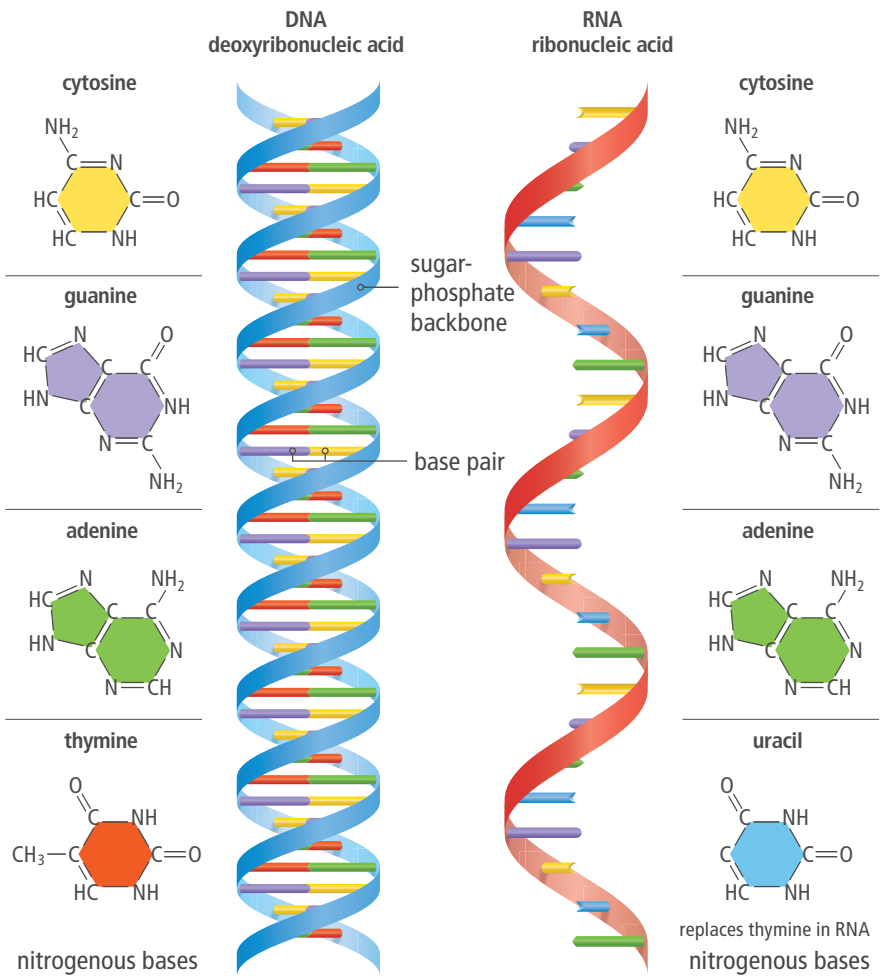
Analyze Identify the starting and ending materials for transcription and translation.

The RNA in eukaryotic cells goes through a processing step before it can be exported out of the nucleus. Before translation occurs, mRNA is "spliced" into a new combination of nucleotides. This extra modification of the mRNA code allows for the production of different proteins from a single gene. Thus, the mRNA transcript can be edited before it is translated.

Comparing DNA and RNA

RNA acts as a messenger, carrying information from DNA in the nucleus to protein synthesis in the cytoplasm. RNA is like a temporary copy of DNA that is used and then broken down. A molecule of RNA is similar to a molecule of DNA, but with some distinct differences. Figure 6 illustrates how the structures of these molecules compare. For example, DNA contains a sugar called deoxyribose, whereas RNA contains a sugar called ribose.

FIGURE 6: DNA and RNA have some similarities in their structures.



Language Arts Connection Human Immunodeficiency Virus, or HIV, is a retrovirus. Retroviruses contain RNA instead of DNA as genetic material. When HIV infects a cell, an enzyme called reverse transcriptase uses the RNA code to make a strand of DNA. This enzyme is not very precise, making lots of mistakes, allowing the virus to mutate rapidly. Using Internet resources, research HIV and reverse transcriptase. Prepare a report comparing protein synthesis in human cells to the process this retrovirus uses to transcribe its genetic material.

As you can see, RNA has one nitrogenous base, uracil, that differs from one of the bases found in DNA. This base is similar in structure to thymine, allowing it to form base pairs with adenine. RNA's unique single-stranded structure also allows some types of RNA to form complex three-dimensional shapes. As a result, some RNA molecules can catalyze reactions similar to the way in which protein enzymes do.

Explain Why is RNA necessary for protein synthesis?