Translation

In order to complete protein synthesis, the language of mRNA must be translated into the language of proteins. How does a language consisting of only four characters translate into a language of 20 amino acids? Just as letters are strung together in the English language to make words, nucleotides are strung together to code for amino acids.

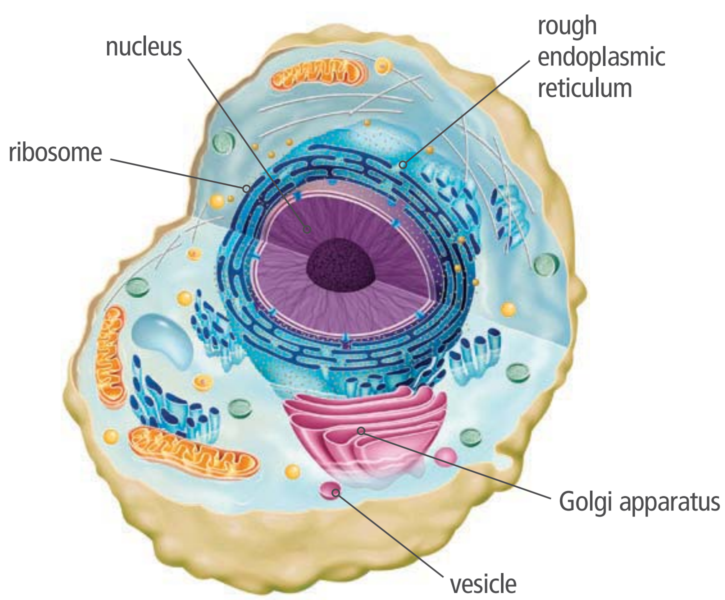
So far, you have learned that transcription uses DNA to produce a complementary strand of RNA. In eukaryotes, this stage of protein synthesis occurs in the nucleus. Once the RNA is processed and leaves the nucleus through pores, it enters the cytoplasm. This is where the process of translation decodes the mRNA to produce a protein. Translation occurs in the cytoplasm of both prokaryotic and eukaryotic cells.

Collaborate In everyday language, translation means to express words in another language. Give an example of a message that would need to be translated.

Ribosomes

Once it is in the cytoplasm, the mRNA binds to organelles called ribosomes, which are made of rRNA and proteins. In plant and animal cells, ribosomes may be found floating free in the cytoplasm of the cell, or they may be attached to an organelle called the rough endoplasmic reticulum (rough ER). As proteins are being made, they enter the rough ER. Once inside, the proteins fold into their three-dimensional shapes, and some are modified by the addition of carbohydrate chains.

FIGURE 10: Animal Cell



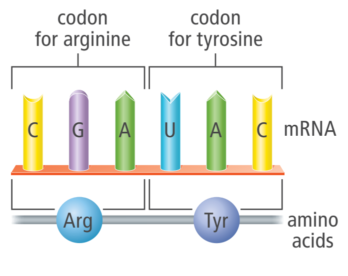
From the ER, proteins generally move to the Golgi apparatus to be processed, sorted, and delivered. Some packaged proteins are stored within the Golgi apparatus for later use. Others are transported to different organelles within the cell. Still others are carried to the membrane, where the vesicles carrying the proteins merge with the cell membrane, releasing the protein outside the cell through exocytosis.

Model Draw a flow chart to show the flow of RNA and proteins through the cell during protein synthesis.

Codons and Amino Acids

The translation of RNA into protein is similar to what happens in a computer code. The information encoded in the nucleic acids of an mRNA molecule is “read” in groups of three nucleotides called codons. This is similar to the way a computer interprets the zeroes and ones of binary code strings into a program you can use. A codon is a three-nucleotide mRNA sequence that codes for an amino acid. Amino acids are the subunits, or monomers, that make up polypeptides. One or more polypeptides make up a protein.

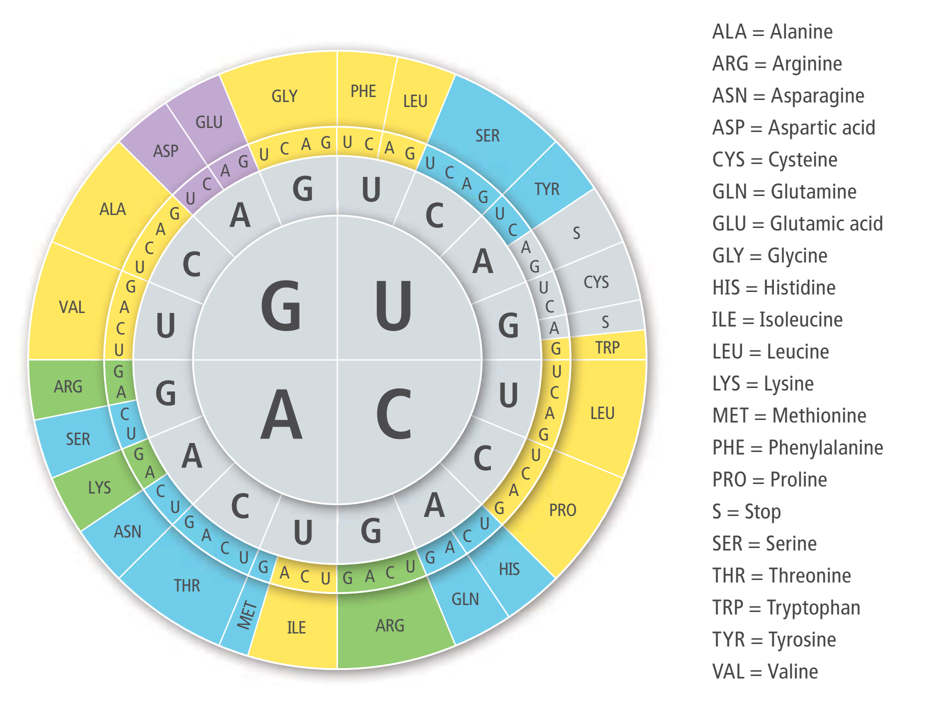
FIGURE 11: A codon is a sequence of three nucleotides that code for an amino acid.



Math Connection Suppose an mRNA molecule in the cytoplasm had 300 nucleotides. How many amino acids would be in the resulting polypeptide?

Scientists have determined what each combination of nucleotides in RNA code for in a protein and used this information to develop codon charts. A codon chart is used to identify which mRNA codons code for which amino acids. To read a circular codon chart, begin in the center and work outward. Start with the first letter of the codon, and pick the correct letter in the middle of the circle. Next, select the second letter of the codon, then follow to the third letter of the codon, and select the appropriate amino acid. Notice that many amino acids are coded for by more than one codon.

FIGURE 12: A codon chart shows which mRNA codons code for which amino acids.



Analyze There is one start codon, AUG, which identifies where translation will begin. Which amino acid corresponds to the start codon?

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Hands-On Activity

Modeling Protein Synthesis and Mutations Model transcription and translation by analyzing a DNA sequence and writing the corresponding mRNA codons and amino acid sequence. Then, build a model of the protein and fold it into its final shape. Finally, introduce a mutation and use your model to determine how the mutation affects the protein’s structure.

The genetic code is shared by almost all living organisms, as well as viruses. That means, for example, that the codon UUU codes for phenylalanine when that codon occurs in an armadillo, a cactus, a yeast, or a human. The common nature of the genetic code suggests that organisms arose from a common ancestor. It also means that scientists can insert a gene from one organism into another organism to make a functional protein. For these reasons, we say that the genetic code is nearly universal. There are, however, a few exceptions to the genetic code. For example, in one species of bacterium, UGA codes for tryptophan instead of functioning as a stop codon.

Steps of Translation

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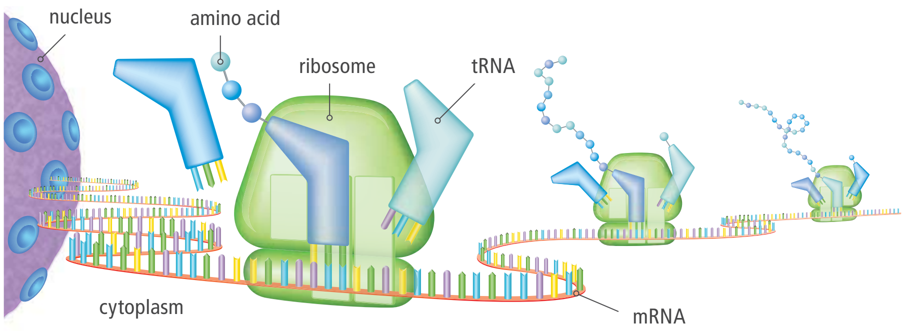
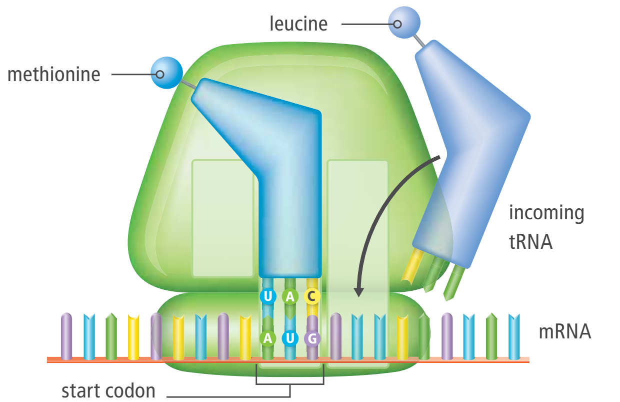
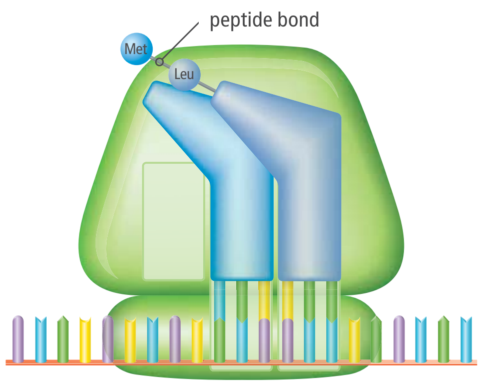
FIGURE 13: Translation converts an mRNA transcript into a polypeptide to build a protein.



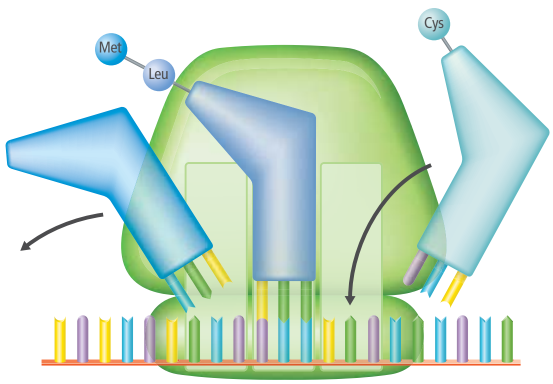
1 Before translation begins, a small ribosomal subunit binds to an mRNA strand in the cytoplasm. Then a tRNA with methionine attached binds to the AUG start codon. This binding signals a large ribosomal subunit to join. The ribosome pulls the mRNA strand through itself one codon at a time. The tRNA acts as a translator between mRNA and amino acids.



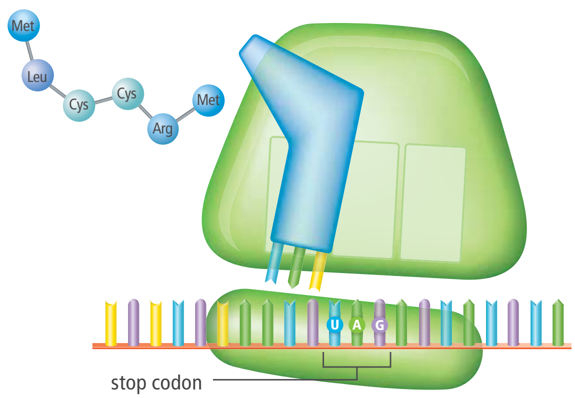
2 The exposed codon in the first site attracts a complementary tRNA molecule carring an amino acid. The tRNA pairs with the mRNA codon, bringing it very close to the other tRNA molecule.



3 The ribosome helps form a peptide bond between the two amino acids and breaks the bond between the tRNA and its amino acid.



4 The ribosome pulls the mRNA strand along the length of one codon. The first tRNA is shifted into the exit site, where it leaves the ribosome and returns to the cytoplasm to pick up another amino acid. The first site is empty again, exposing the next mRNA codon.



5 The ribosome continues to translate the mRNA strand, attaching new amino acids to the growing protein, until it reaches a stop codon. Then the ribosome lets go of the new protein and breaks apart.

Explain An adapter can be thought of as a tool that converts an input to a new or modified use. Explain how the structure of the tRNA molecule helps it function as an adapter to translate the mRNA code into a sequence of amino acids.

Mutations and Proteins

Sometimes a mutation changes the sequence of nucleotides in an organism's DNA. Mutations that occur during replication can be classified as point mutations and frameshift mutations. In a point mutation, one nucleotide is replaced with a different nucleotide.

Structure and Function

FIGURE 14: Mutations alter nucleotide sequences.

Original DNA Sequence
TAC AGA GGC CGT
Mutated DNA Sequence
TAC AGT GAC CGT

Explain Determine the amino acid sequence that would be formed before and after two point mutations. Complete the following:

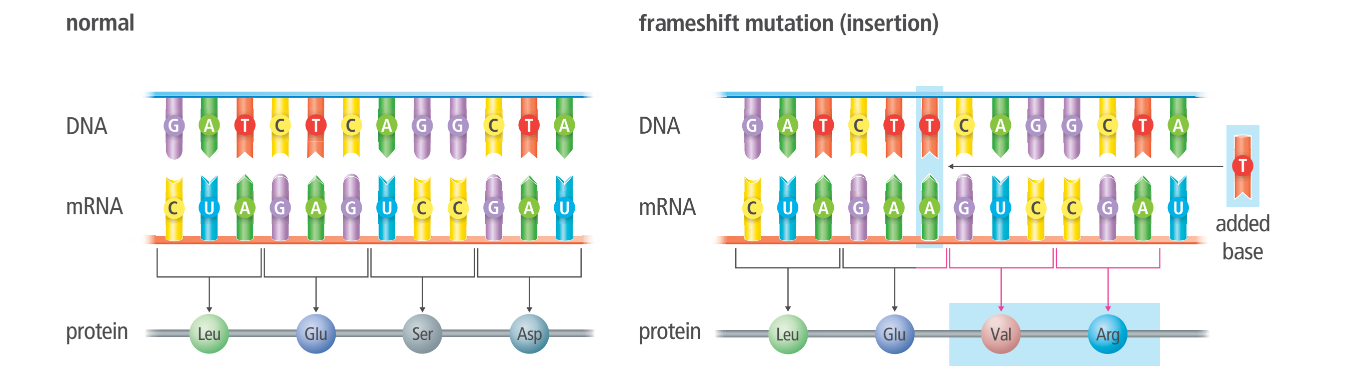
1. Two DNA sequences are shown in Figure 14. Write the complementary mRNA sequence for each DNA sequence, and then use the codon chart to translate the mRNA code into a sequence of amino acids.
2. Based on the amino acid sequences you wrote, does a point mutation always result in a change to the amino acid sequence? Support your answer with evidence.
3. Suggest a specific scenario in which the DNA sequence could be mutated, but the structure and function of the resulting protein would not change.

Nucleotides must be correctly arranged for the protein to have the correct amino acid sequence. This order is called the reading frame. A change in the reading frame is called a frameshift mutation. A frameshift mutation involves the insertion or deletion of a nucleotide in the DNA sequence.

Analyze Could there be a frameshift mutation that would not affect the structure and function of the resulting protein? Explain your answer.

In an insertion mutation, an extra nucleotide is added into the DNA sequence. In a deletion mutation, a nucleotide is deleted from the DNA sequence. Because mRNA is read in groups of three nucleotides, the insertion or deletion of a nucleotide can affect the entire resulting amino acid sequence. For example, if an extra "a" is inserted into the sentence, "The cat ate the rat," the sentence becomes, "The caa tat eth era t."

FIGURE 15: Frameshift mutations change the reading frame, which results in changes in the sequence of amino acids.



Explain Summarize what you have learned so far to begin constructing an explanation for how the "language" of DNA is translated into the "language" of proteins. Construct a graphic organizer to compare the two phases of protein synthesis in terms of their function, where each process occurs in the cell, and final products.