

Gene Expression—Translation

How do cells synthesize polypeptides and convert them to functional proteins?

Why?

The message in your DNA of who you are and how your body works is carried out by cells through gene expression. In most cases this means synthesizing a specific protein to do a specific job. First, mRNA is transcribed from the DNA code. Then, the mRNA sequence is translated into a polypeptide sequence.

Model 1 – Codons

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

- Model 1 defines the code scientists have discovered that relates the nucleotide sequence of mRNA to the amino acid sequence of polypeptides.
 - What do the letters U, C, A, and G in Model 1 represent?
 - What do the abbreviations such as Phe, Ile, Ala, and Gly in Model 1 represent?
 - The language of mRNA is often described as a “triplet code.” Explain the significance of this reference.

2. If an mRNA molecule had 300 nucleotides in the coding region of the strand, how many amino acids would be in the polypeptide that was synthesized? Show mathematical work to support your answer.

3. Consider the information in Model 1.
 - a. How many different **codons** (triplets) code for the amino acid Proline (Pro)?

 - b. Compare all of the codons for Proline. What are the similarities and differences?

 - c. Considering that mistakes can occur during transcription and DNA replication, what advantage is there for an organism to have multiple mRNA sequences code for the same amino acid?



4. Using the mRNA codon chart in Model 1, complete the following:

DNA → TAC CTT CGG ATG GTC ACT

mRNA →

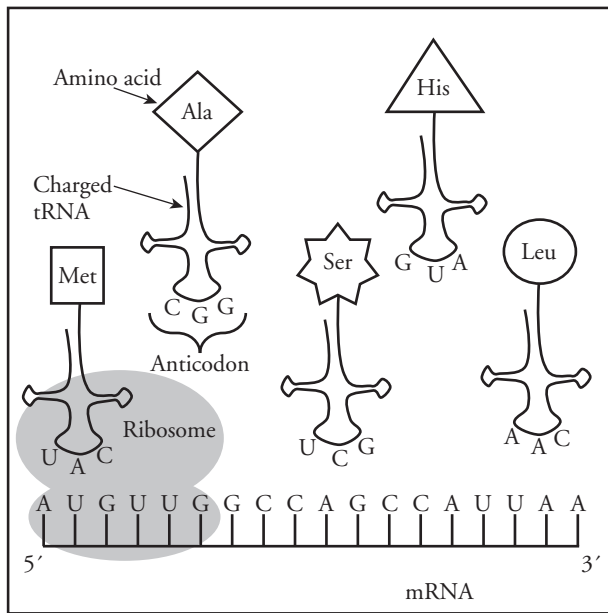
polypeptide sequence →

5. According to the table in Model 1, what amino acid is at the beginning of every polypeptide?

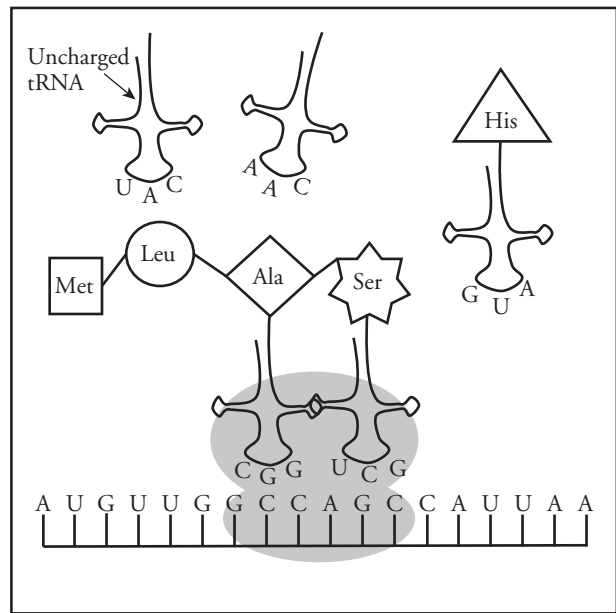
6. The codons shown in Model 1 are used in all species on Earth with very little variation. What might scientists conclude from this?



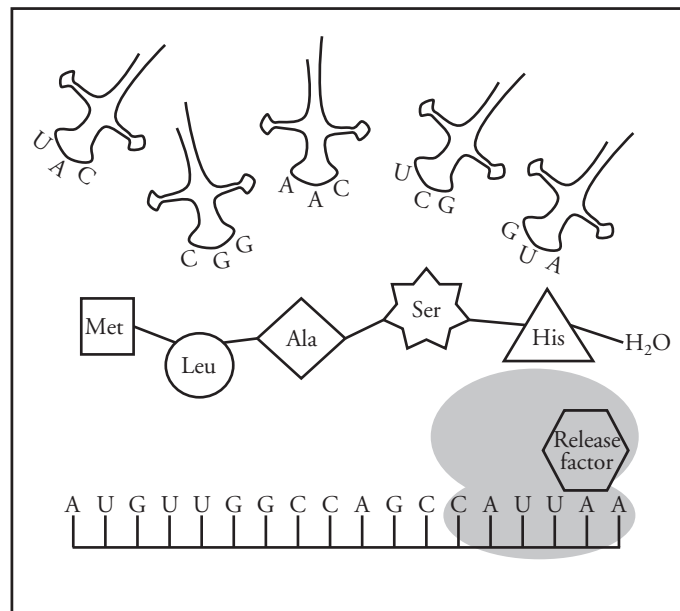
Model 2 – Translation



Initiation



Elongation



Termination

7. Refer to Model 2.

a. What are the three stages of translation?

b. Define each of the terms used in your answer to part a as they are used in everyday language.

8. According to Model 2, when the mRNA leaves the nucleus, to which cellular organelle does it attach?
9. The mRNA attaches to the organelle at the sequence AUG. What is the significance of this sequence of nucleotides?
10. Describe the movement of the ribosome as translation occurs.

Read This!

The ribosome is a large complex of ribosomal RNA (rRNA) and proteins. It consists of two subunits. The smaller subunit binds to the mRNA strand and the larger subunit holds the tRNA molecules in place while the covalent peptide bond is formed between the amino acids. Several ribosomes can attach to an mRNA molecule simultaneously. This allows for many polypeptide chains to be synthesized at once.



11. The tRNA molecules in a cell are short sequences of nucleotides (about 80 bases) that contain an **anticodon** and carry a specific amino acid.
 - a. Find the tRNA in Model 2 that is carrying the Histidine (His). What sequence of nucleotides makes the anticodon on this tRNA molecule?
 - b. What codon on mRNA would match this anticodon?
 - c. Verify that the codon you wrote in part *b* codes to Histidine by looking at the table in Model 1.
 - d. What anticodon would be found on a tRNA molecule carrying Glycine (Gly)? (*Note:* There are several correct answers here.)
12. The “t” in tRNA is short for transfer. In a complete sentence, explain why this molecule is called transfer RNA.

13. During elongation, how many tRNA molecules are held in the ribosome at the same time?

14. What will happen to the unattached tRNA once it has delivered its amino acid?

15. Describe two things that occur during termination as illustrated in Model 2.

16. Explain how the term “translation” applies to the synthesis of proteins from DNA instructions.



Extension Questions

17. The codons of mRNA are a set of three nucleotides with four possible bases in combination.
 - a. Show mathematically that there are 64 permutations possible when three bases are used.
 - b. Show mathematically that two bases as a codon would not be sufficient to code for all 20 known amino acids.
18. A silent mutation is one that does not affect protein structure. Write a code for an original DNA strand containing at least 12 bases, and then mutate the original DNA so that the final protein is unaffected.
19. In prokaryotic cells, translation begins before transcription is finished. Give two reasons why this would not be possible in eukaryotic cells.