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

Amino acids

First Base	Second Base U	Second Base C	Second Base A	Second Base G	Third Base
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	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
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
	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
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
	AUG Met (start)	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
	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

1. Model 1 defines the code scientists have discovered that relates the nucleotide sequence of mRNA to the amino acid sequence of polypeptides.

   a. What do the letters U, C, A, and G in Model 1 represent?

   b. What do the abbreviations such as Phe, Ile, Ala, and Gly in Model 1 represent?

   c. 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

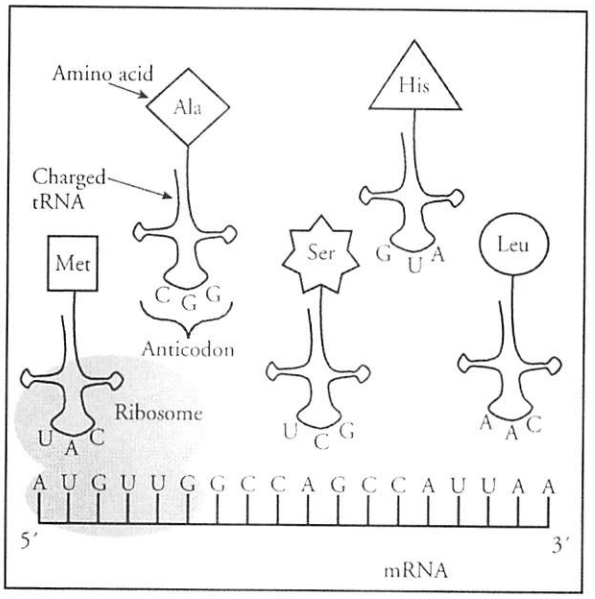
   mRNA →

   polypeptide sequence →

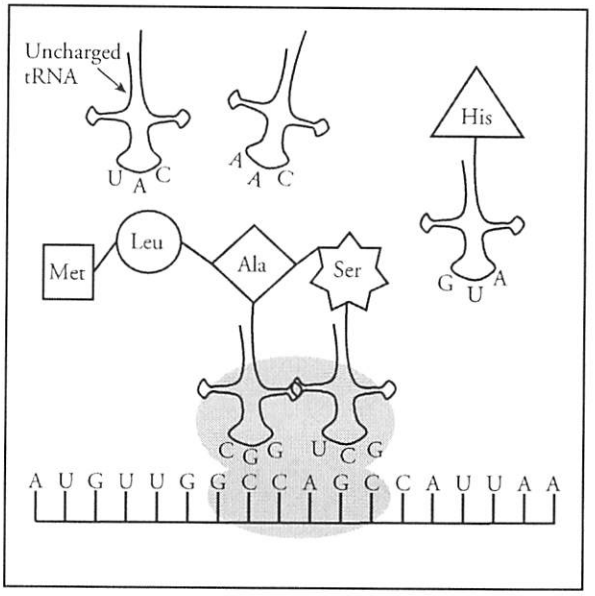
5. According to the table in Model 1, what amino acid is at the beginning of every polypeptide?

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

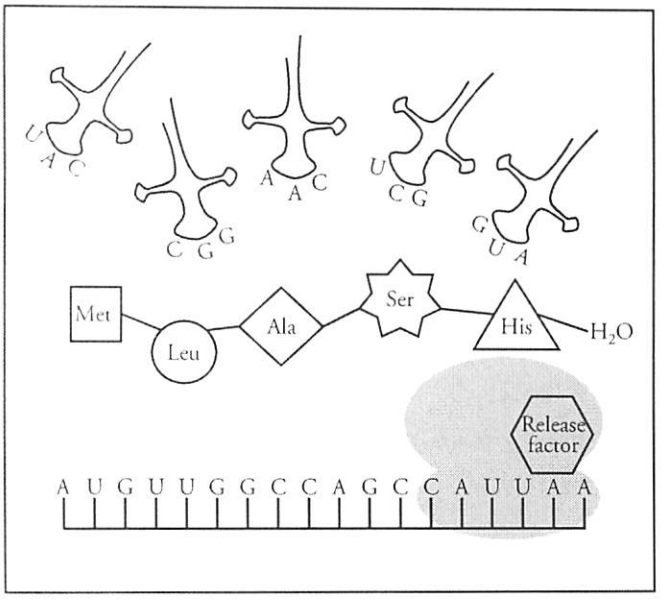
Model 2 – Translation



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.