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?

   Those letters represent the nucleotides in mRNA.

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

   Those are abbreviations for amino acids.

   c. The language of mRNA is often described as a "triplet code." Explain the significance of this reference.

   Three nucleotides are needed to code for one amino acid.

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.

   300 nucleotides / 3 nucleotides per codon = 100 amino acids

3. Consider the information in Model 1.

   a. How many different **codons** (triplets) code for the amino acid Proline (Pro)?

   There are four codons for Proline.

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

   All of the Proline codons start with CC. Only the third base is different.

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

   If a mistake occurred during transcription or replication, the codon in mRNA may still translate to the same amino acid. For example, CCG may be mistakenly transcribed as CCU, but it would still code for Proline.

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

DNA →	TAC	CTT	CGG	ATG	GTC	ACT
mRNA →	*AUG*	*GAA*	*GCC*	*UAC*	*CAG*	*UGA*
polypeptide sequence →	*Met (start)*	*Glu*	*Ala*	*Tyr*	*Gln*	*[Stop]*

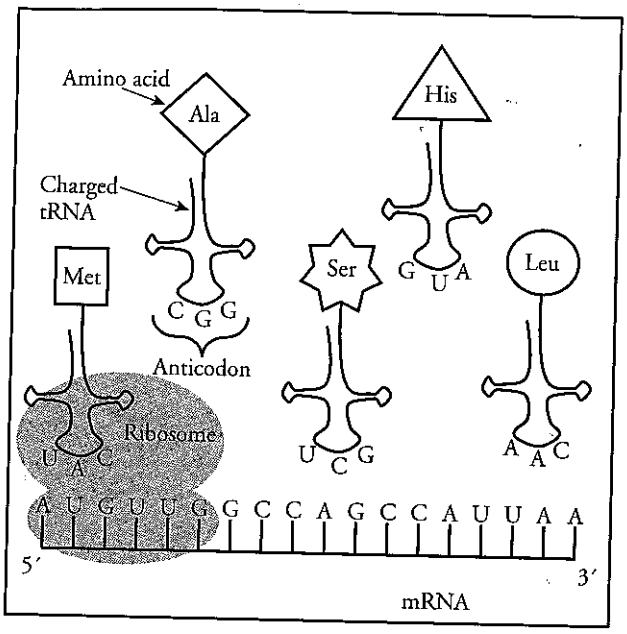
5. According to the table in Model 1, what amino acid is at the beginning of every polypeptide?

   Methionine.

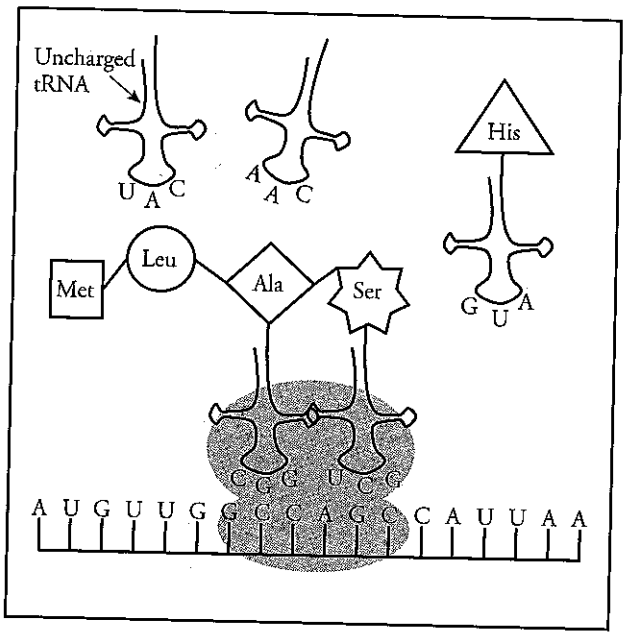
6. The codons shown in Model 1 are used in all species on Earth with very little variation. What might scientists conclude from this?

   This supports the theory of evolution—that these systems have been passed down through generations of animals even through changes in species.

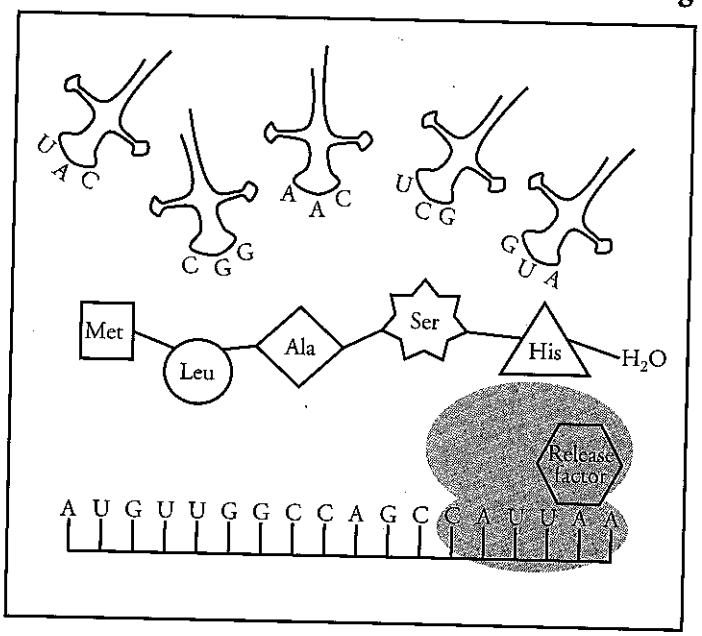
Model 2 – Translation



Initiation



Elongation



Termination

7. Refer to Model 2.

   a. What are the three stages of translation?

   Initiation, elongation, and termination.

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

   Initiation—to start. *Elongation—to make longer, to add on.* *Termination—to end.*

8. According to Model 2, when the mRNA leaves the nucleus, to which cellular organelle does it attach?

   Ribosome.

9. The mRNA attaches to the organelle at the sequence AUG. What is the significance of this sequence of nucleotides?

   According to Model 1, that is the "start" codon.

10. Describe the movement of the ribosome as translation occurs.

    The ribosome moves along the mRNA chain from the 5' end to the 3' end.

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?

    GUA.

    b. What codon on mRNA would match this anticodon?

    CAU.

    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.)

    mRNA codons → *GGU GGA GGC GGG*

    tRNA anticodons → *CCA CCU CCG CCC*

12. The "t" in tRNA is short for transfer. In a complete sentence, explain why this molecule is called transfer RNA.

    It is transferring the correct amino acids in the correct sequence to the ribosome to produce the functional protein.

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

Two tRNA molecules are in the ribosome at the same time.

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

It is released from the ribosome and is free to pick up and carry another amino acid.

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

A release factor binds to the last codon which stops the process of adding more amino acids to the polypeptide. A water molecule is added to the end of the amino acid chain.

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

The language of DNA, in the form of nitrogen bases read in sets of three called codons, is being translated into the language of proteins, i.e., amino acids.

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.

    4 × 4 × 4 = 64

    b. Show mathematically that two bases as a codon would not be sufficient to code for all 20 known amino acids.

    4 × 4 = 16 *This is not enough codons to account for all 21 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.

    Accept any answer that shows the student understands the concept of silent mutations, such as the one below:

	Original	Mutated
DNA	*TACAAACCCGGA*	*TACAA**G**CCCGGA*
mRNA	*AUGUUUGGGCCU*	*AUGUU**C**GGGCCU*
Amino acid	*Met-Phe-Gly-Pro*	*Met-**Phe**-Gly-Pro*

19. In prokaryotic cells, translation begins before transcription is finished. Give two reasons why this would not be possible in eukaryotic cells.

    Eukaryotic cells have a nucleus, and transcription takes place in the nucleus while translation takes place on the ribosome in the cytoplasm of the cell. Eukaryotic cells have introns that need to be removed from the pre-mRNA before translation can happen.