Gene expression: Translation

Lecture Objectives:

- What is translation?
- Understand the basic steps of translation
- Explain the roles of three types of RNA in Gene expression

What is translation?

Translation, the synthesis of protein from RNA. The coded information from DNA is copied faithfully during transcription into a form of RNA known as messenger RNA (mRNA), mRNA molecule is used as a template to build a protein from a specific sequence of amino acids encoded by the mRNA. This takes place within a complex in the cytoplasm called a ribosome.

Requirement for Translation:

1. **Ribosome:** is a large and complex molecular machine, found within all living cells.
2. **tRNA (Transfer RNA):** is an adapter molecule composed of RNA, that serves as the physical link between the nucleotide sequence of nucleic acids (DNA and RNA) and the amino acid sequence of proteins.
3. **mRNA (Messenger RNA):** Is a short copy of DNA(which carries the genetic information from DNA and is used as a template for protein synthesis).
4. **Energy source ATP:** ATP is the energy made by the body through converting sugars, they use it for energy to carry out all functions.

What is a ribosome?

Ribosomes are small factories where protein synthesis takes place. They are made of a large subunit and a small unit, comprising a binding site for mRNA and two binding sites for transfer RNA (tRNA) in the large ribosomal subunit.

The large ribosomal subunit contains three tRNA binding sites, designated A, P, and E.

The A site binds an aminoacyl-tRNA (a tRNA bound to an amino acid)

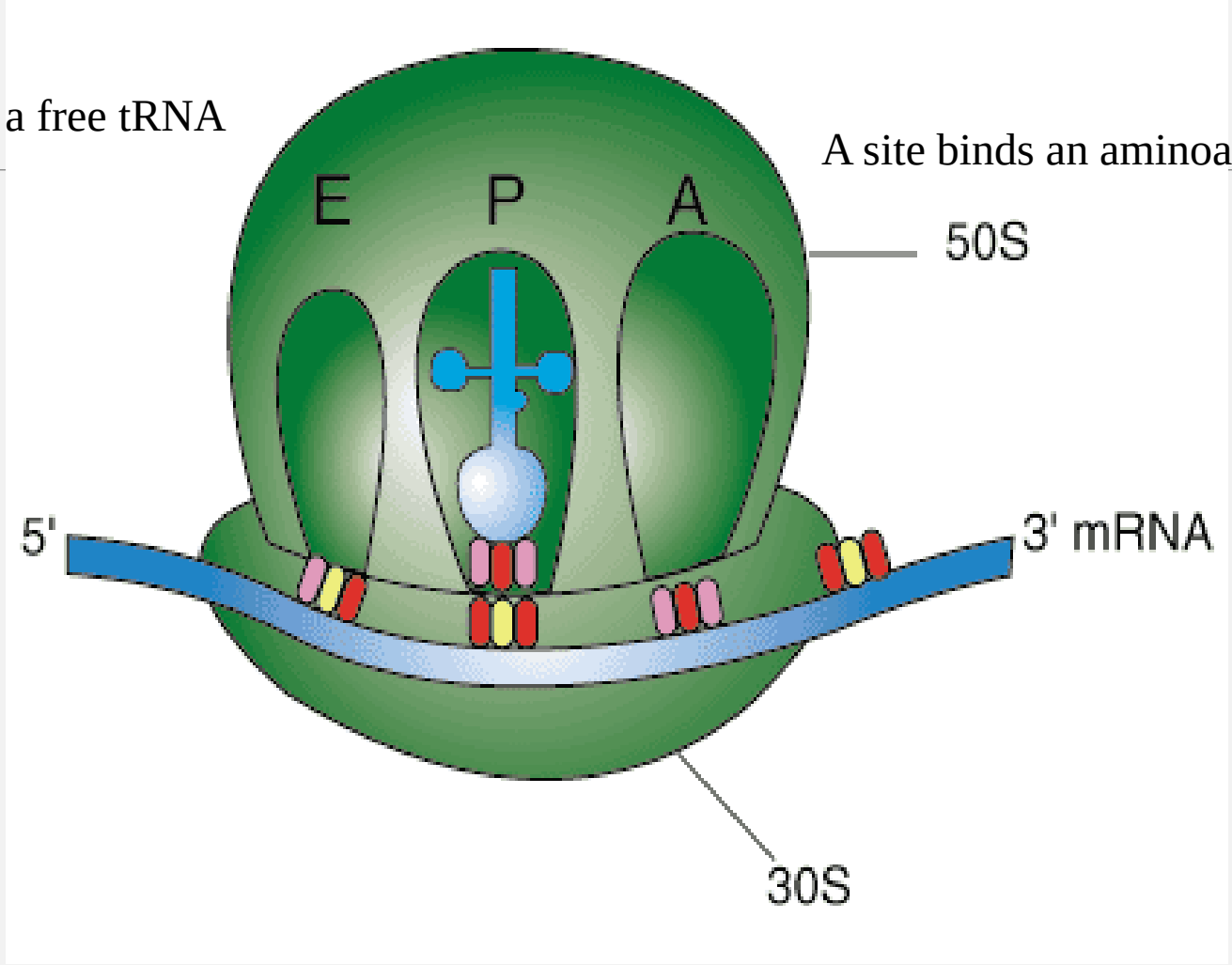
The P site binds a peptidyl-tRNA (a tRNA bound to the peptide being synthesized).

The E site binds a free tRNA before it exits the ribosome.

P site binds a peptidyl-tRNA

E site binds a free tRNA

A site binds an aminoacyl-tRNA



Eukaryotic ribosomes

The mRNA that is created in the process of transcription comprises a sequence of nucleotides. A set of three-letter combinations of nucleotides is called a **codon**. Codons can either encode a specific amino acid, a start signal for translation, or a stop signal to mark the end of translation. A tRNA molecule consists of **anticodons**. Anticodons are a sequence of three nucleotides that are **complimentary** to specific codons in mRNA, they are found in tRNAs, and allow the tRNAs to bring the correct amino acid in line with an mRNA during protein production.

START codons and STOP codons

START codons

The codon AUG is called the START codon as it the first codon in the transcribed mRNA that undergoes translation. AUG is the most common START codon and it codes for the amino acid methionine (Met) in eukaryotes and formyl methionine (fMet) in prokaryotes.

During protein synthesis, the tRNA recognizes the START codon AUG with the help of some initiation factors and starts translation of mRNA

STOP codons

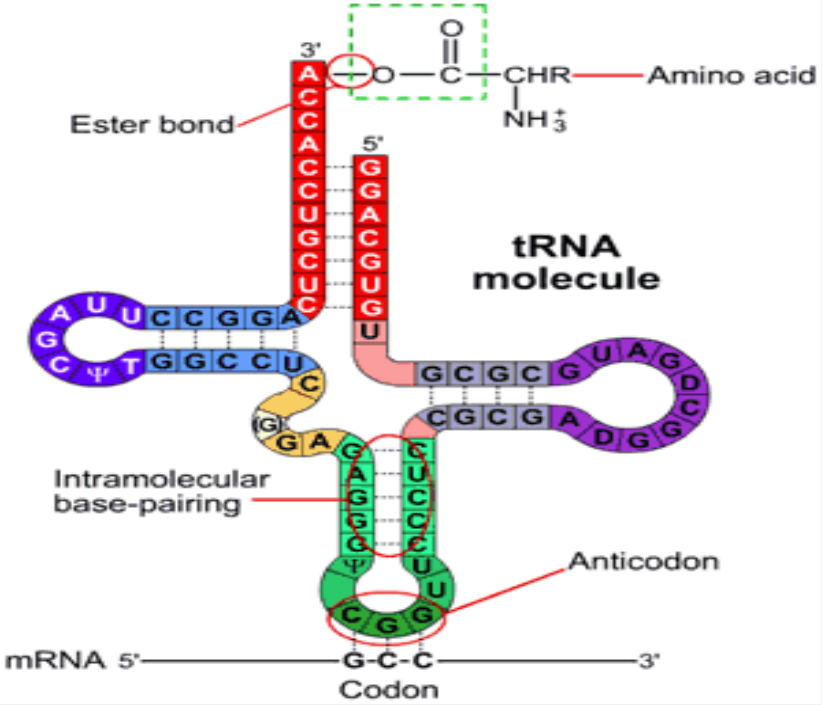
There are 3 STOP codons in the genetic code - UAG, UAA, and UGA. These codons signal the end of the polypeptide chain during translation.

During protein synthesis, STOP codons cause the release of the new polypeptide chain from the ribosome.

Two-dimensional structure of tRNA

The three loops are characteristic of all tRNAs, as is the base sequence of the amino acid attachment site at the **3′ end.**

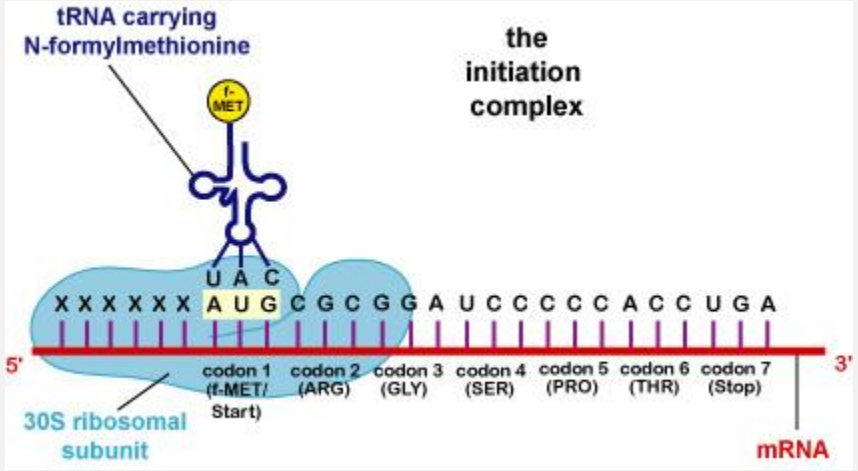
The anticodon triplet is unique to each tRNA type.

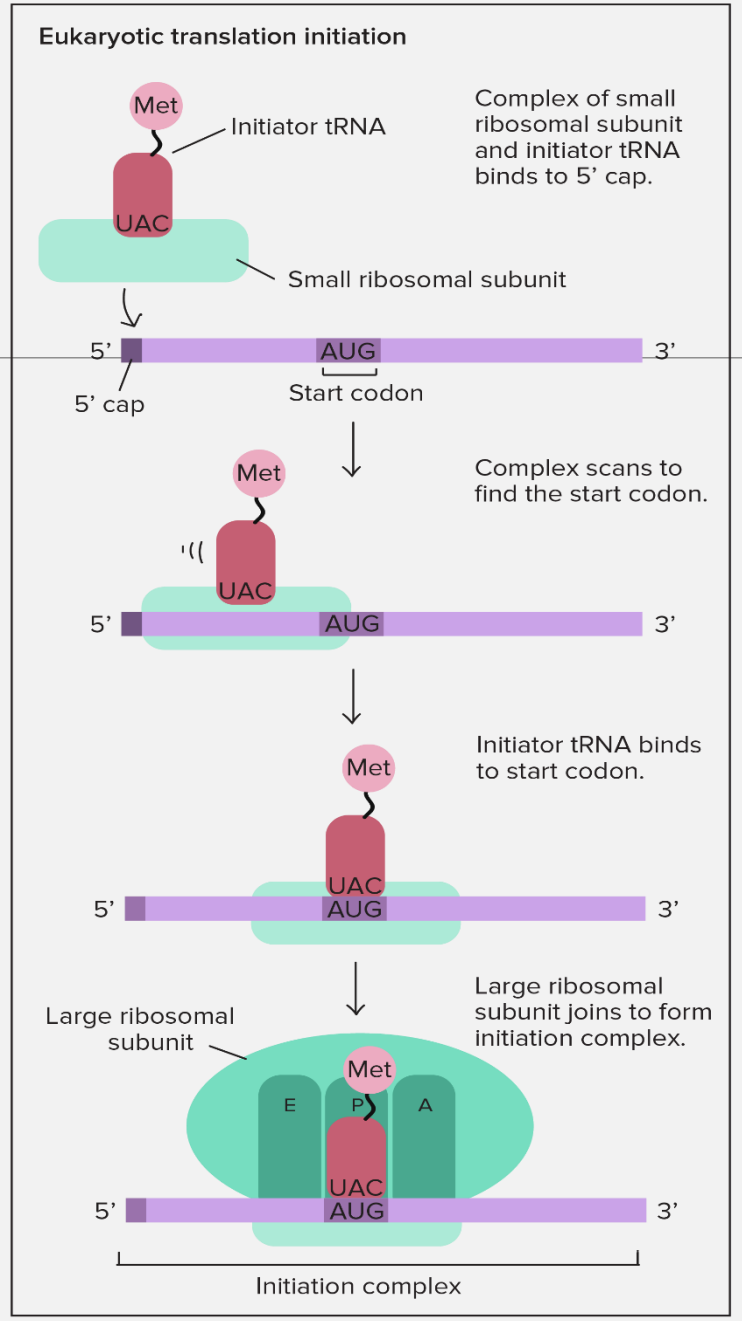


The process of translation occurs in three main stages:

1. Initiation

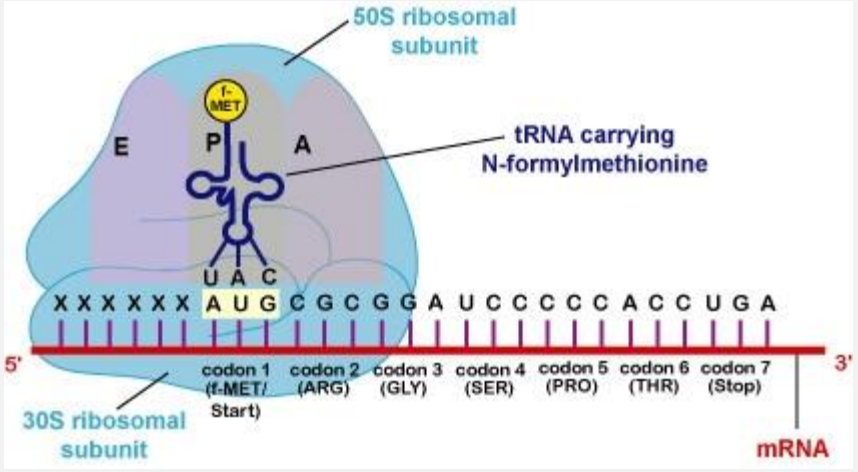
The small unit of the ribosome binds to the start of the mRNA sequence, at the location of the start codon. In all mRNA molecules, the start codon has a sequence of AUG, which codes for the amino acid methionine. The tRNA carrying the anticodon recognizes this sequence and caries the amino acid methionine to the mRNA. Then, the large subunit of the ribosome binds to form the initiation complex.

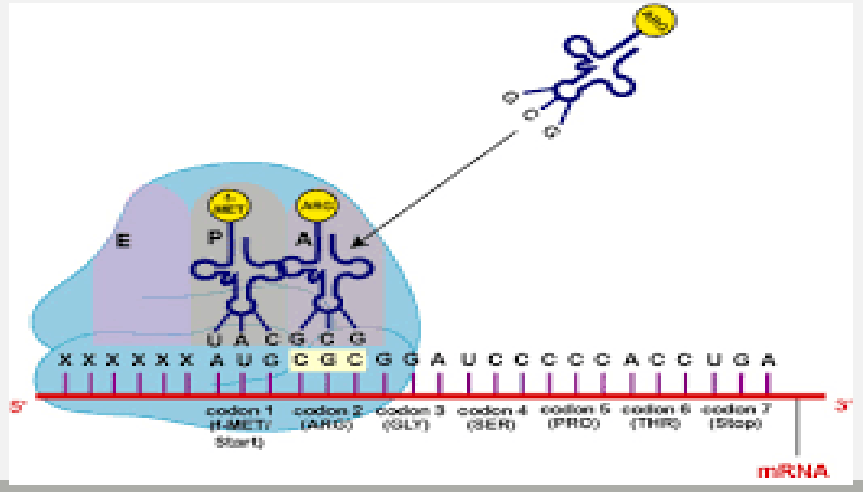



Eukaryotic translation initiation
Met
Initiator tRNA
UAC
Small ribosomal subunit
Complex of small ribosomal subunit and initiator tRNA binds to 5' cap.
5'
AUG
3'
5' cap
Start codon
Met
UAC
Complex scans to find the start codon.
5'
AUG
3'
Met
UAC
AUG
Initiator tRNA binds to start codon.
5'
3'
Large ribosomal subunit
Large ribosomal subunit joins to form initiation complex.
Met
E
P
A
UAC
AUG
5'
3'
Initiation complex

2. Elongation

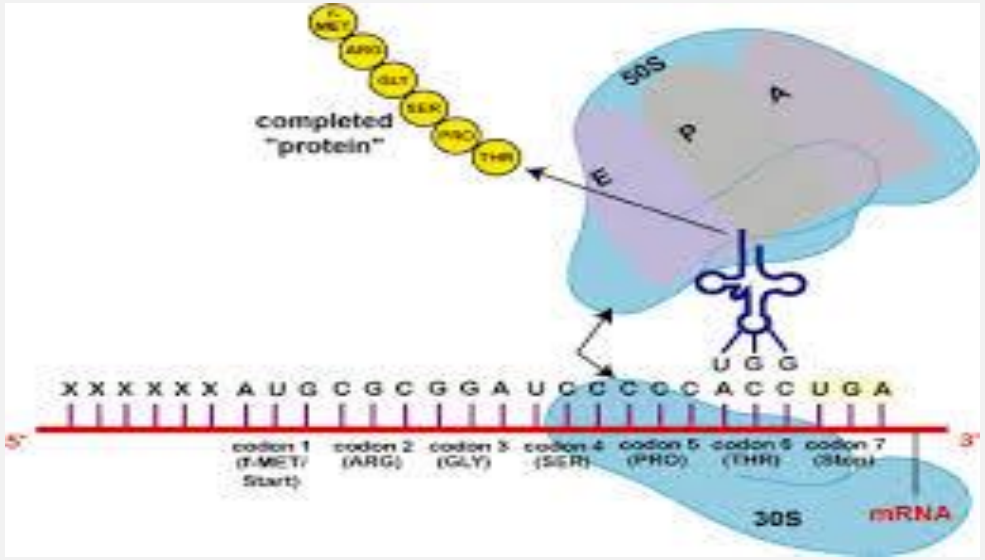
In this stage of translation, the ribosome continues down the mRNA strand translating each codon in turn. The corresponding amino acids are added by tRNA in a growing chain, linked together by peptide bonds. This continues until the entire sequence of codons is read, and the ribosome reaches a "stop" codon.

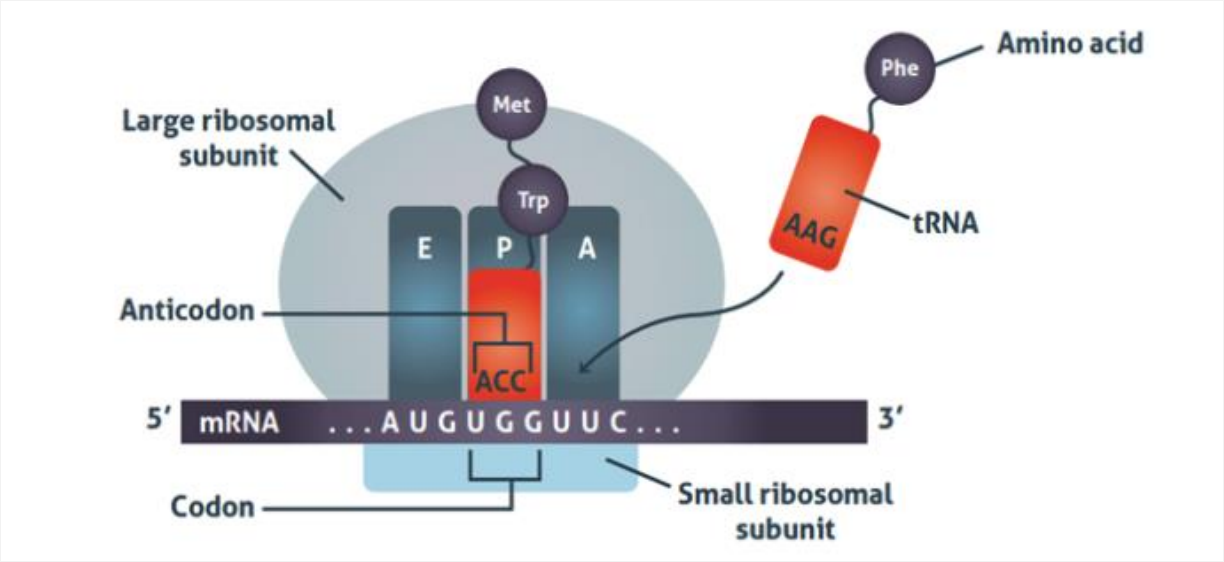




3. Termination

Stop codons include UAA, UAG, UGA. There are no tRNA's that can read and recognize these codons to recruit an amino acid, and therefore the ribosome recognizes that at this point the translation process is finished. The protein is released, and the components of the translation complex disperse.





Schematic summarizing the processes of initiation, elongation and termination in translation.

Summary of Translation

1. Translation is the RNA-directed synthesis of a polypeptide
2. A cell translates an mRNA message into protein, with the help of transfer RNA (tRNA)
3. tRNA molecule – Consists of a single RNA strand that is only about 80 nucleotides long
4. It is roughly L-shaped
5. Molecules of tRNA are not all identical
6. Each carries a specific amino acid on one end
7. The tRNA has an anticodon on its lower portion that varies according to the type of amino acid it carries ribosome binds with two codons at a time. It does this at the P site and A site.

The roles of three types of RNA in Gene expression

	Transcription	Translation
Location	Nucleus.	Cytoplasm.
Purpose and product	To use genes as a template to create several forms of RNA (such as mRNA as discussed in this article).	To synthesize proteins from an RNA template.
Initiation	RNA polymerase protein binds to the promoter region in the DNA and forms the transcription initiation complex.	Takes place when ribosome recognizes **AUG** start codon and binds the mRNA.
Elongation	RNA polymerase travels in the 5' to 3' direction and builds an RNA strand.	tRNA with complimentary anticodons to the codons within mRNA binds to mRNA and builds a chain of amino acids joined by peptide bonds.
Termination	The RNA transcript is released. RNA polymerase detaches from DNA and the DNA rewinds back into a double helix.	Ribosome encounters stop codon. No tRNAs are able to recognize stop codons and the ribosome thus dissembles tRNA and releases the polypeptide that has been built.

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