Protein synthesis

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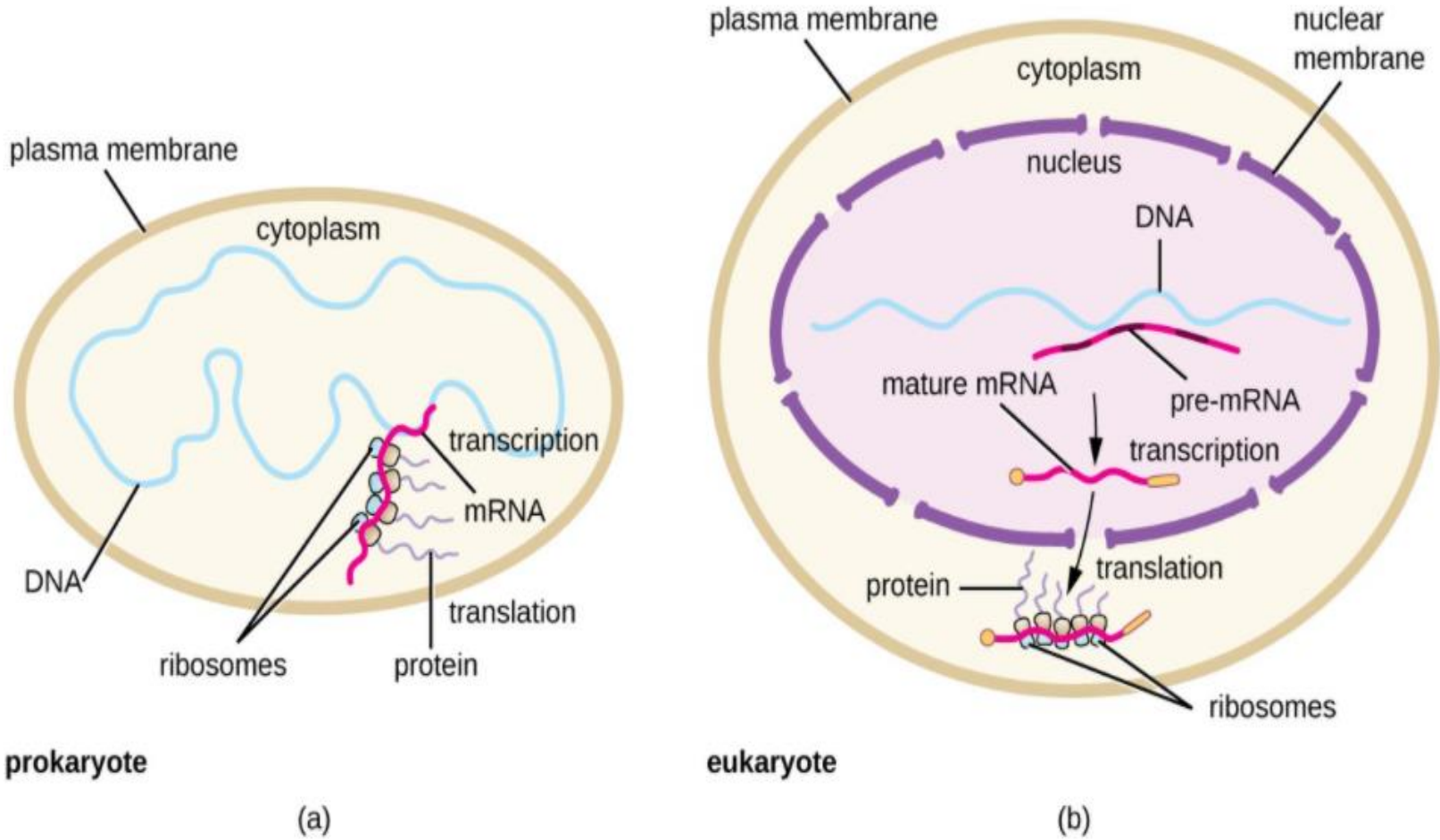
Definition: Is the process in which polypeptide chains are formed from coded combinations of single amino acids (AA) inside the cell. The synthesis of new polypeptides requires a coded sequence, enzymes, and mRNA, rRNA, and tRNA. Protein synthesis takes place within the nucleus and ribosomes of a cell and is regulated by DNA and RNA.

Protein synthesis, consists of two processes — transcription and translation.

In eukaryotic cells, transcription takes place in the nucleus. While translation occurs in ribosomes that located either free floating in the cytoplasm or attached to the endoplasmic reticulum.

In prokaryotic cells, which lack a nucleus, the processes of both transcription and translation occur in the cytoplasm.

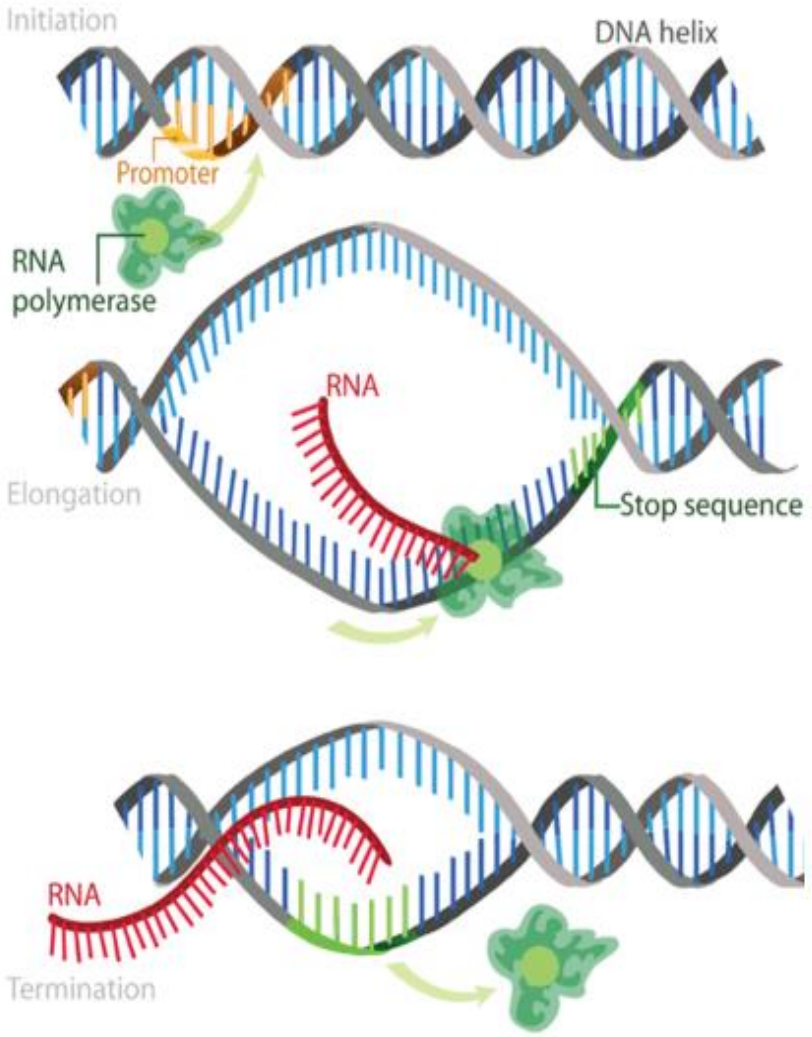

plasma membrane
cytoplasm
transcription
mRNA
DNA
translation
ribosomes
protein
prokaryote
(a)
plasma membrane
nuclear membrane
cytoplasm
nucleus
DNA
mature mRNA
pre-mRNA
transcription
protein
translation
ribosomes
eukaryote
(b)

Protein synthesis in eukaryotic cells

Transcription: DNA is used as a template to make a molecule of messenger RNA (mRNA). It is the transfer of genetic instructions in DNA to mRNA (a strand of mRNA is made to complement a strand of DNA).

Steps of Transcription:-

Transcription takes place in nucleus and it's three steps: initiation, elongation, and termination.



a. **Initiation** is the beginning of transcription. It occurs when the enzyme RNA polymerase binds to a region of a gene called the **promoter**. This signals the DNA to unwind so the enzyme can "read" the bases in one of the DNA strands. The enzyme is ready to make a strand of mRNA with a complementary sequence of bases.

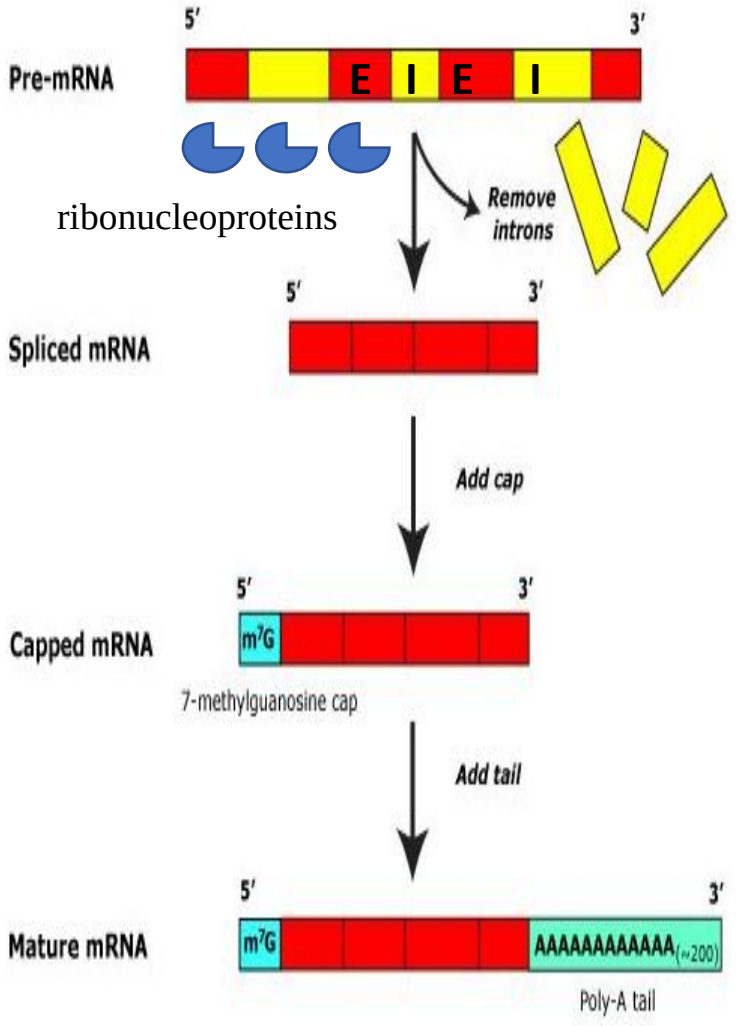
b. **Elongation** is the addition of nucleotides to the mRNA strand.

c. **Termination** is the ending of transcription. The mRNA strand is complete, and it detaches from DNA.

Processing mRNA

The new mRNA is not yet ready for translation. At this stage, it is called pre-mRNA, and it must go through more processing before it leaves the nucleus as mature mRNA. The processing may include splicing, editing, and polyadenylation. These processes modify the mRNA in various ways. mRNA molecules are monocistronic containing coding sequence just for one polypeptide.

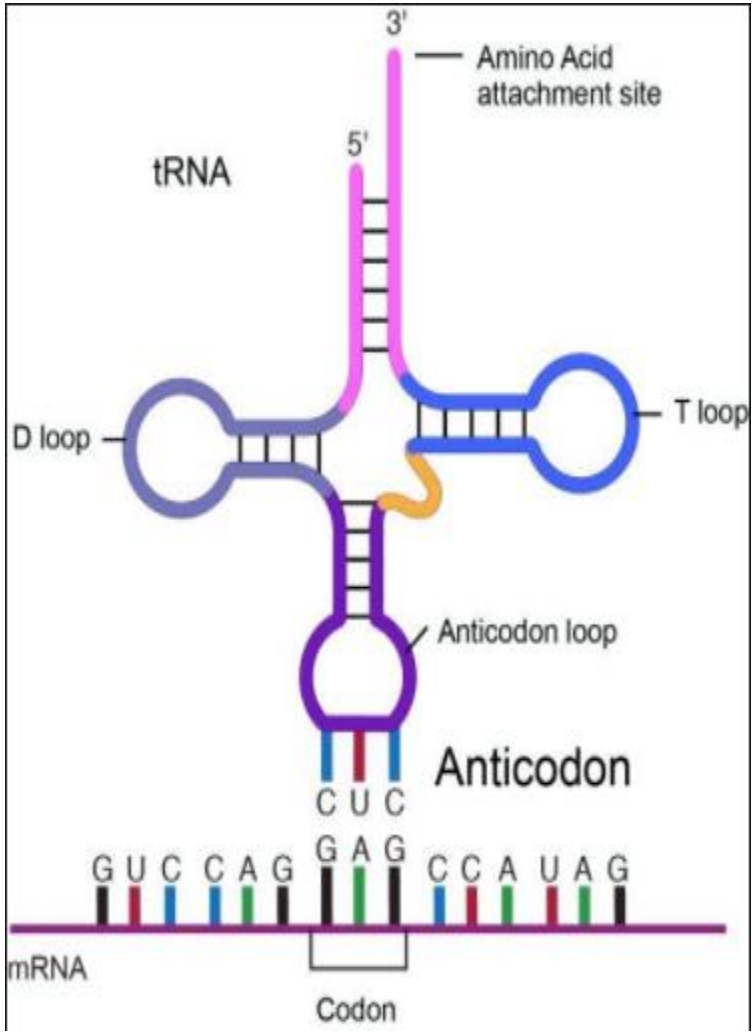
- **Splicing** removes introns from mRNA. **Introns** are regions that do not code for the protein. The remaining mRNA consists only of regions called **exons** that do code for the protein. The ribonucleoproteins are small proteins in the nucleus that contain RNA and are needed for the splicing process.
- **Editing** changes some of the nucleotides in mRNA. For example, a human protein called APOB, which helps transport lipids in the blood, has two different forms because of editing. One form is smaller than the other because editing adds an earlier stop signal in mRNA.
- **Polyadenylation** adds a "tail" to the mRNA on 3' position. The tail consists of a string of As (adenine bases). It signals the end of mRNA. It is also involved in exporting mRNA from the nucleus, and it protects mRNA from enzymes that might break it down.

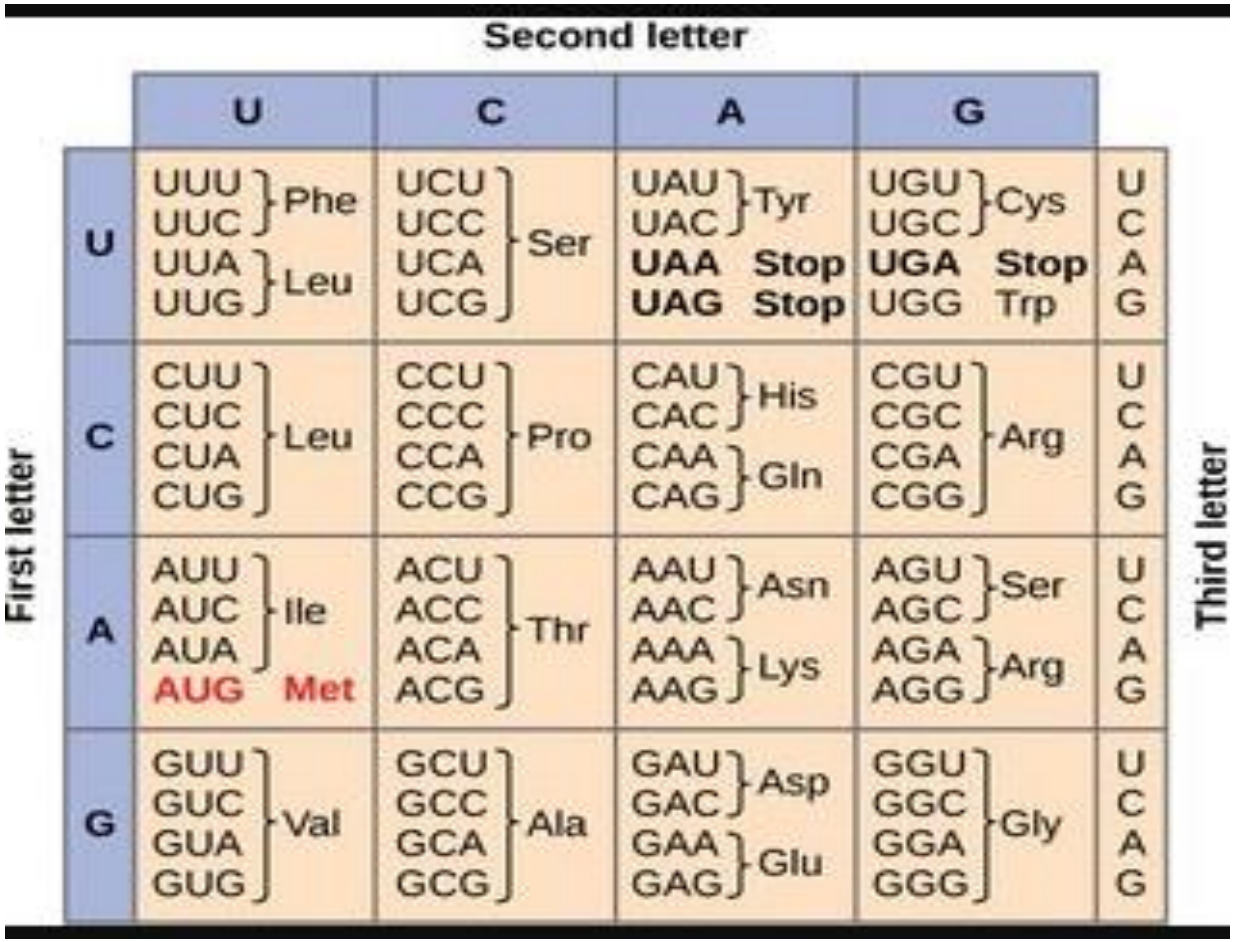


Translation

It is the process in which the genetic code in mRNA is read to make a protein. After mRNA leaves the nucleus, it moves to a ribosome, which consists of rRNA and proteins. The ribosome reads the sequence of codons in mRNA, and molecules of tRNA bring amino acids to the ribosome in the correct sequence.

- Each tRNA molecule has an anticodon for the amino acid it carries. An **anticodon** is complementary to the codon for an amino acid. For example, the amino acid lysine has the codon AAG, so the anticodon is UUC. Therefore, lysine would be carried by a tRNA molecule with the anticodon UUC. Wherever the codon AAG appears in mRNA, a UUC anticodon of tRNA temporarily binds. While bound to mRNA, tRNA gives up its amino acid. With the help of rRNA, bonds form between the amino acids as they are brought one by one to the ribosome, creating a polypeptide chain. The chain of amino acids keeps growing until a stop codon is reached.




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

Protein synthesis (or translation) takes place in three stages: Initiation, Elongation, and Termination

1. Initiation:

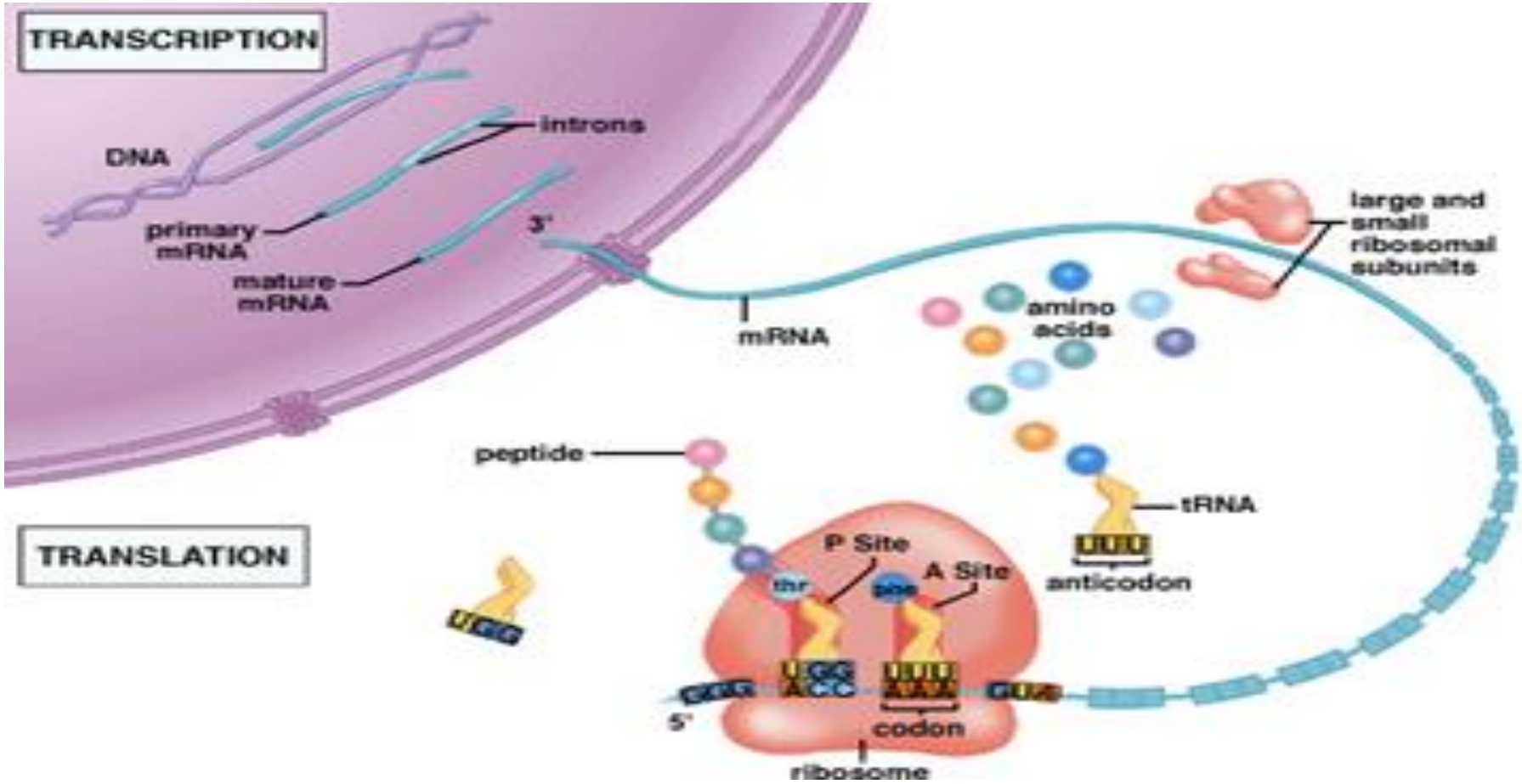
- The first step is the formation of a pre-initiation complex consisting of the small ribosomal subunit, GTP (that acts as an energy source) and other initiation factors.
- The pre-initiation complex binds to the 5’ end of the eukaryotic mRNA.
- The complex then moves along the mRNA in a 5’ to 3’ direction until it locates the AUG initiation codon (i.e., scanning). Is methionine (Met)
- Once the complex is positioned over the initiation codon, the large ribosomal subunit binds to form an initiation complex, a step that requires the hydrolysis of GTP and leads to the release of several initiation factors.

2. Elongation:

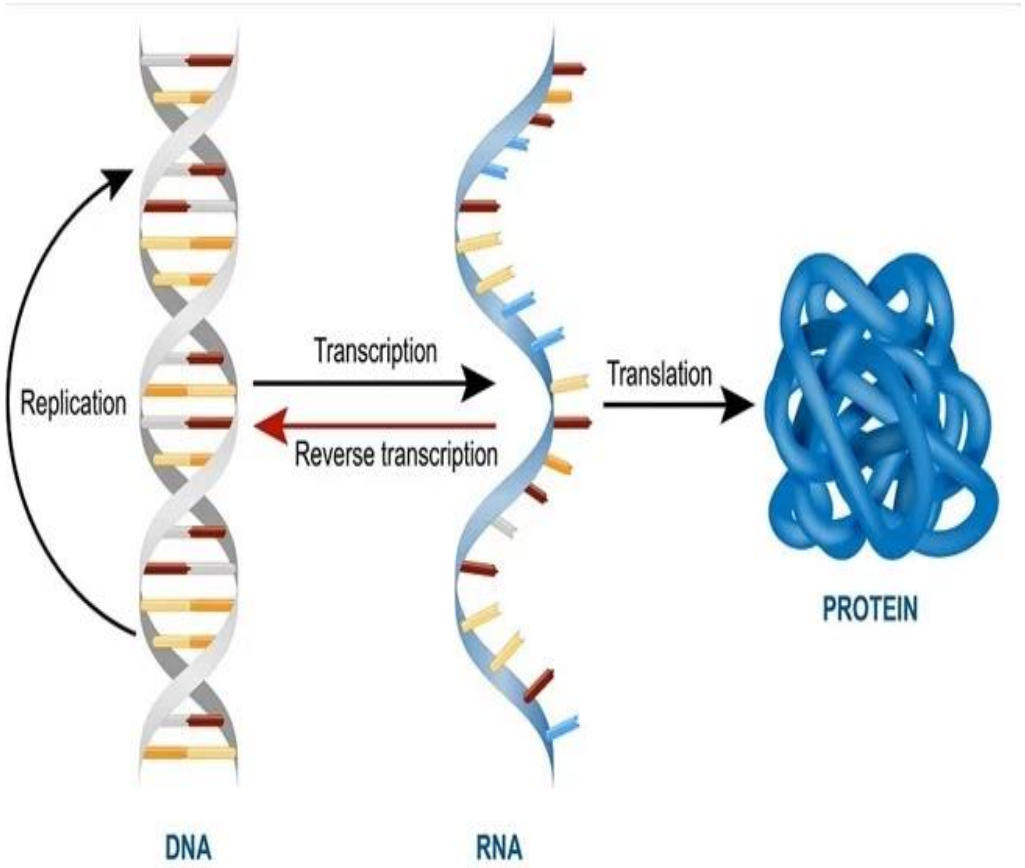
- Elongation depends on eukaryotic elongation factors.
- At the end of the initiation step, the mRNA is positioned so that the next codon can be translated during the elongation stage of protein synthesis.
- The initiator tRNA occupies the P site in the ribosome, and the A site is ready to receive an aminoacyl-tRNA.

3. Termination:

- Termination of elongation depends on eukaryotic release factors.
- In eukaryotes, eukaryotic release factor eRF-1 recognizes all three termination (stop) codons (UAA, UAG and UGA) and, with the help of a type of protein, terminates translation.
- Upon termination, the ribosome is dissociated, and the completed polypeptide is released.



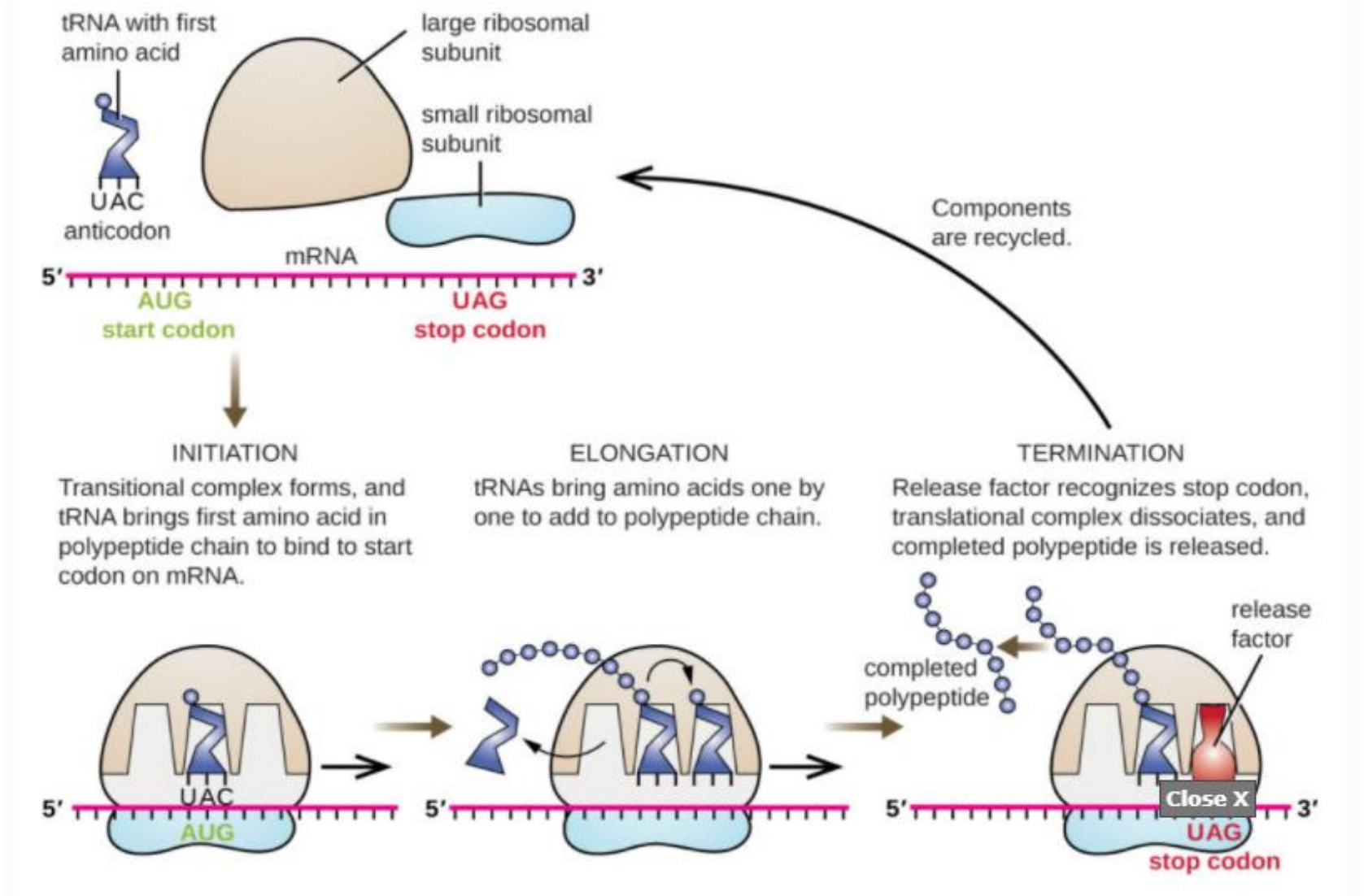
After a polypeptide chain is synthesized, it may undergo additional processes. For example, it may assume a folded shape due to interactions between its amino acids. It may also bind with other polypeptides or with different types of molecules, such as lipids or carbohydrates. Many proteins travel to the Golgi apparatus within the cytoplasm to be modified for the specific job they will do.



Prokaryotic Protein Synthesis

- In prokaryotes, the transcription and translation processes happen in the cytoplasm, mRNA molecules are polycistronic, that means they contain the coding sequence of many genes. Prokaryotic protein synthesis begins even before transcription of mRNA is finished and thus, we call this phenomenon as coupled transcription-translation. mRNA processing in prokaryotes is not required because they do not have introns in them. But archaebacteria does contain intron.
- Ribosomes often line up when a strand of mRNA is being transcribed. The rapid change from gene to mRNA to protein can only happen in prokaryotes and not in eukaryotes.
- The intuition codon in prokaryote is modified methionine (f Met) AUG
- During the **elongation** stage of translation, a **charged tRNA** binds to mRNA in the **A site** of the ribosome; a peptide bond is catalyzed between the two adjacent amino acids, breaking the bond between the first amino acid and its tRNA; the ribosome moves one codon along the mRNA; and the first tRNA is moved from the **P site** of the ribosome to the **E site** and leaves the ribosomal complex.

- **Termination** of translation occurs when the ribosome encounters a **stop codon**, which does not code for a tRNA. Release factors cause the polypeptide to be released, and the ribosomal complex dissociates.



Homework

- What are the differences between protein synthesis in prokaryote and eukaryote? Make a table.
- What dose tRNA bind with?
- If codon on an mRNA read CUA, from left to right, what would the complementary sequence of the Anticodon be on tRNA?
- What is coupled transcription-translation?

Good Luck

Thanks for attention

Questions