Cell and Molecular Biology/ Theory

9- The Genome

Gene expression (Transcription and Translation)

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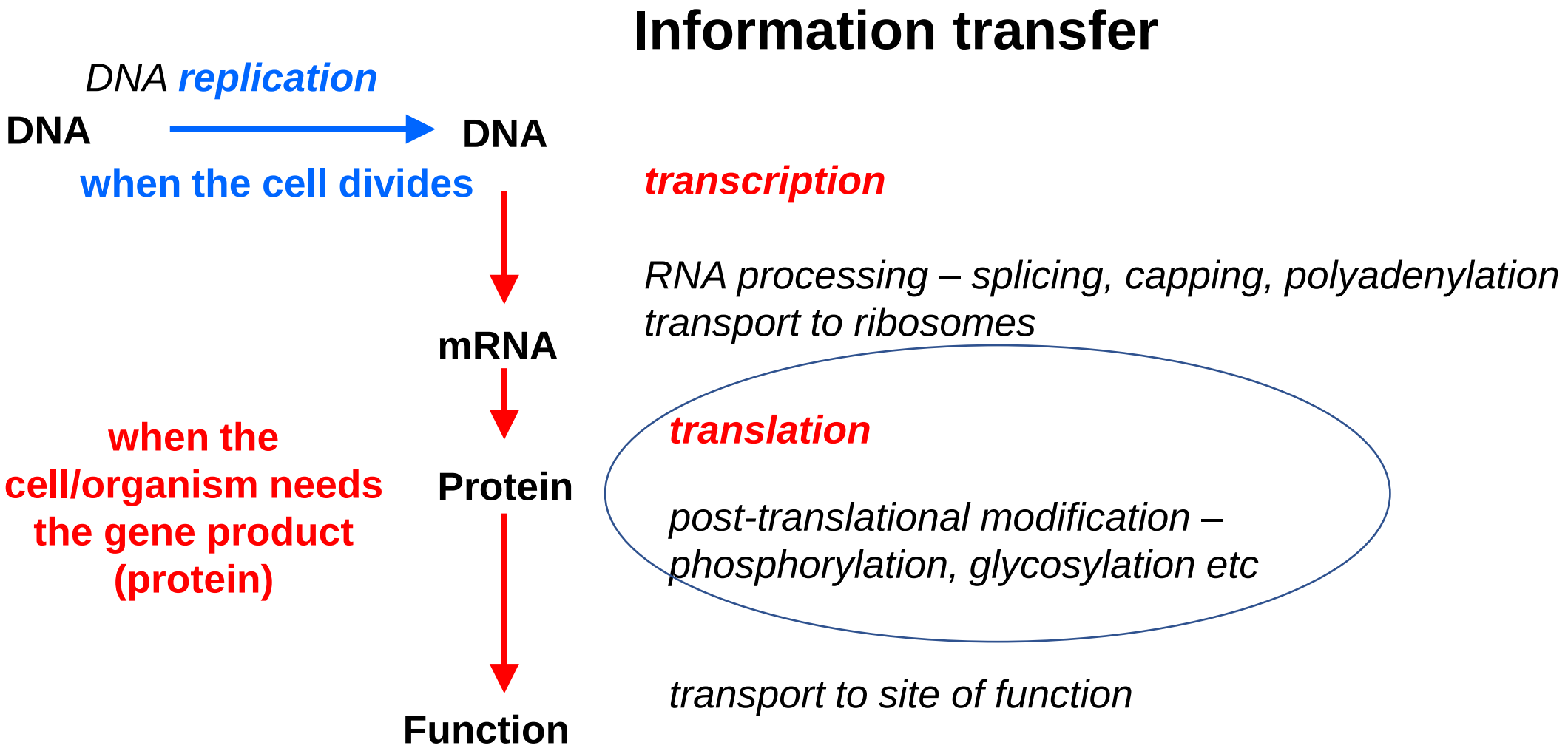
Learning objectives

- Explain the way that proteins are synthesized and targeted in a cell.

The central dogma describes the transfer of sequence information during DNA replication, transcription into RNA, and translation into amino-acid chains forming proteins.



Gene expression

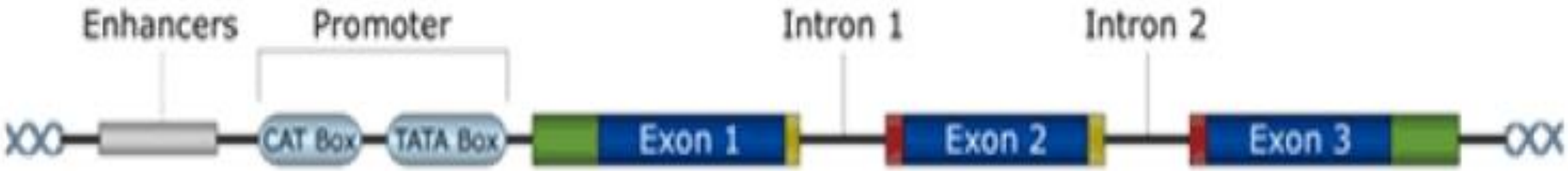
- Gene expression is the process by which the genetic code (the nucleotide sequence) of a gene (DNA) is used to direct protein synthesis.
- Genes that code for proteins are known as 'structural genes'.

Gene expression involves two main stages:

1- Transcription: Copying RNA from strand of DNA by enzyme RNA polymerases which occurs in the nucleus.

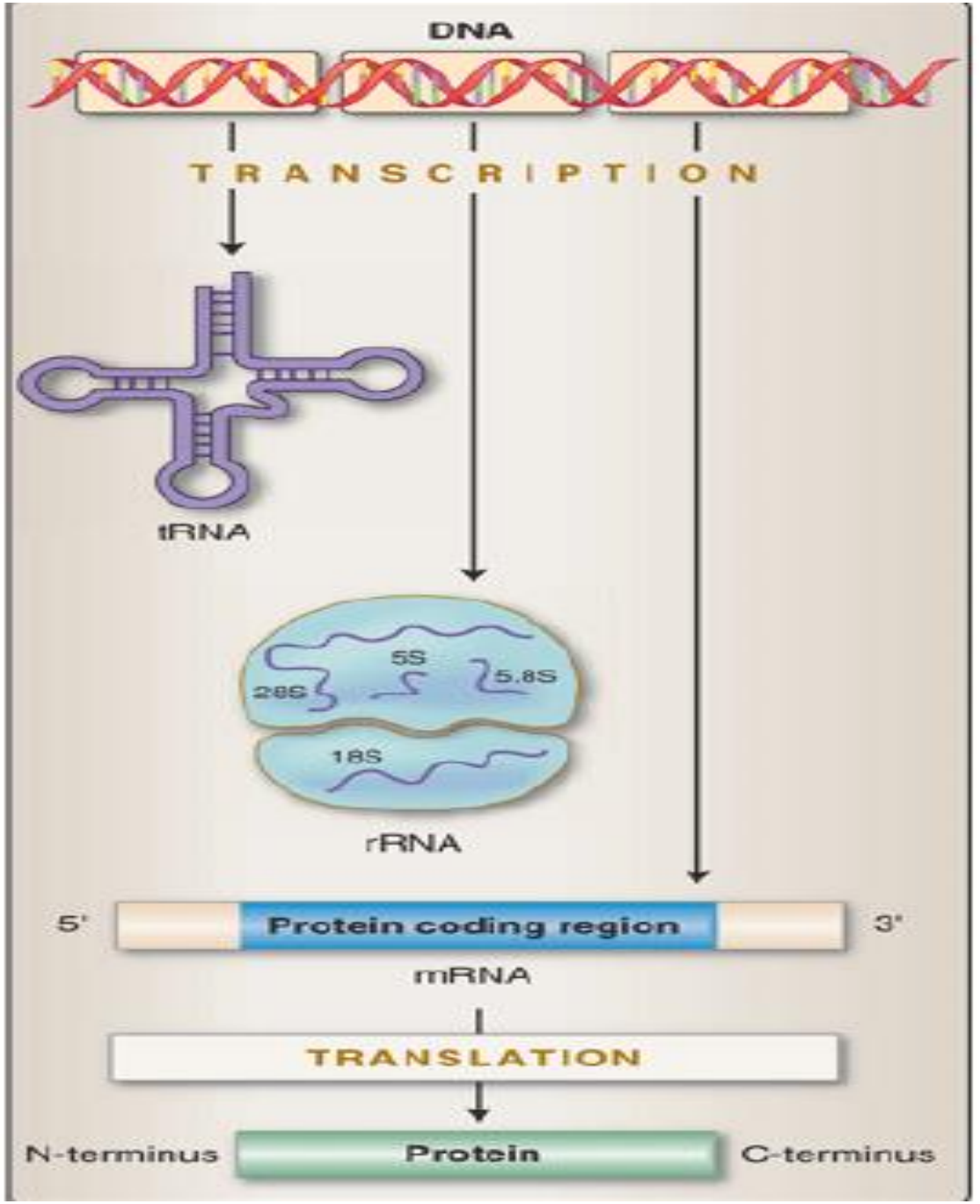
2- Translation: Using genetic information in the RNA to make a protein which happens in the cytoplasm.

Structural genes (DNA)



2- Translation

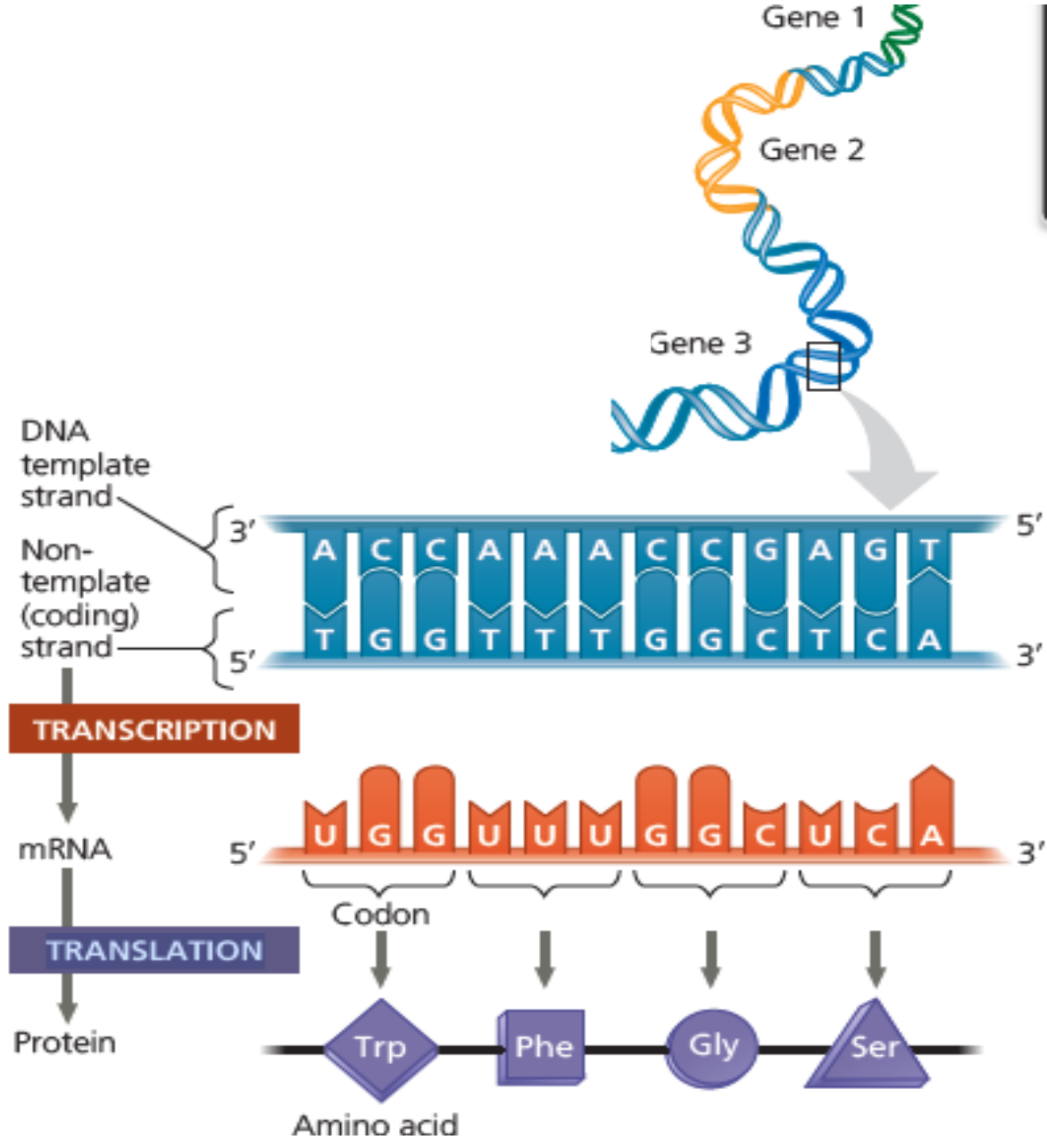
- is the synthesis of a polypeptide (protein) using the information in the mRNA which happens in the cytoplasm
- **transcription → synthesis of RNA → translation → synthesis of protein**



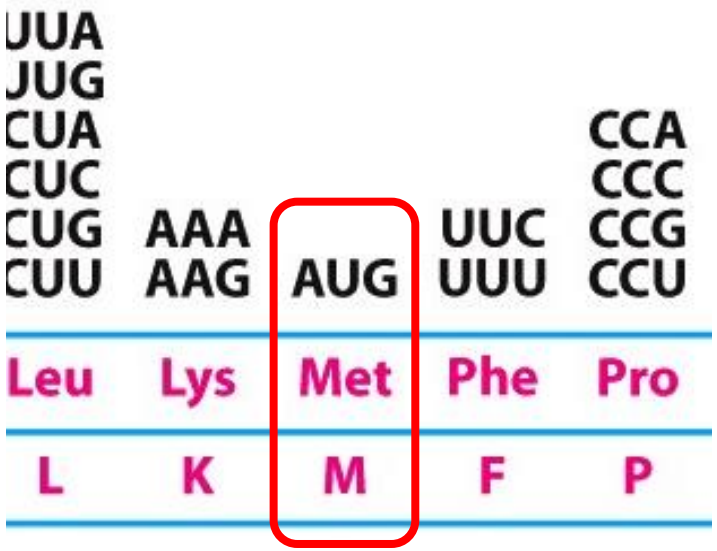
Components Needed For Translation

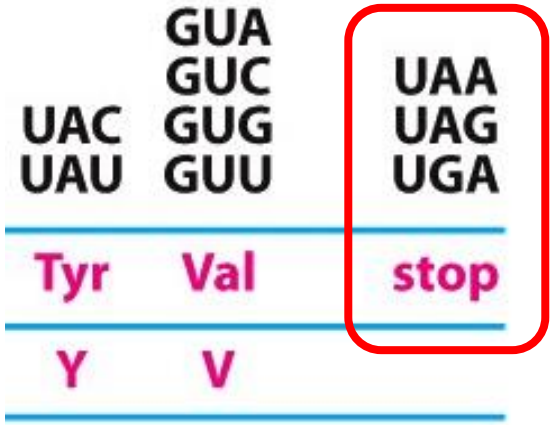
1. **Amino acid** (food or diet contains essential 20 amino acids)
2. **Three types of RNAs**: Messenger RNA (mRNA), Transfer RNA (tRNA), Ribosomal RNA (rRNA)

- **Genetic code (codon)** is a triplet code where three nucleotides specify one amino acid. Codons present in the messenger RNA (mRNA).



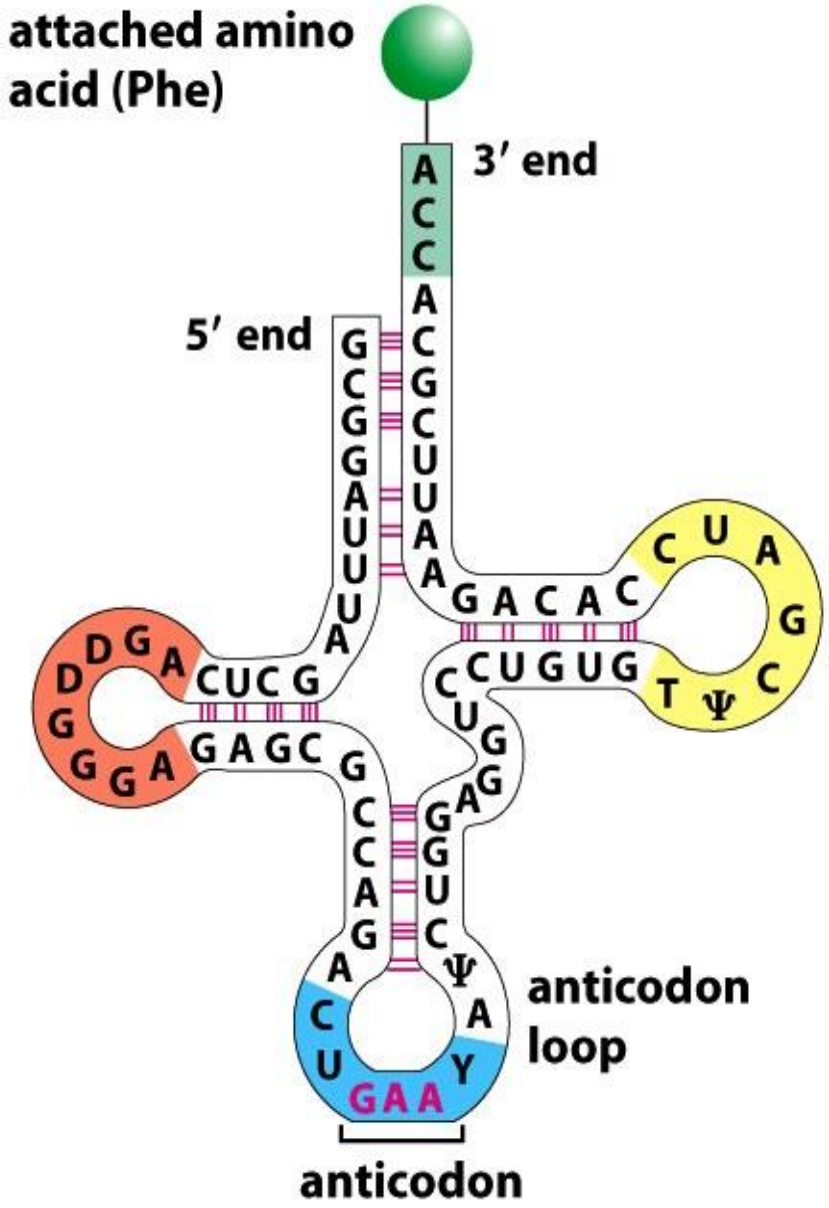
- One codon, AUG, signals the start of the protein coding sequence
  - AUG encodes methionine
- Three codons encode stop signals (UGA,UAG,UAA)





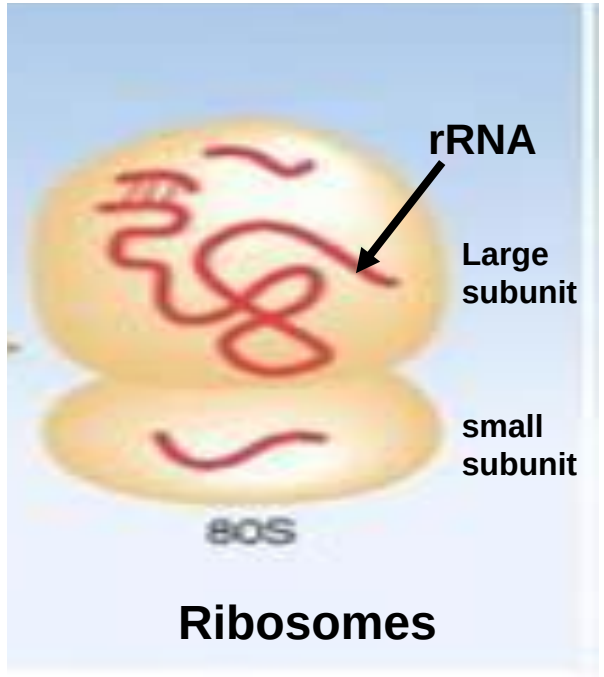
- **Anticodon** is three nucleotide bases in the tRNA that complementary to a codon in the mRNA. i.e. it recognizes a specific codon on the mRNA

3. Enzymes (Aminoacyl-tRNA synthetases): is an enzyme that links amino acids to the 3’ end of tRNAs with the correct **anticodon**



tRNA

4. Ribosomes (large complexes of protein and ribosomal RNA (rRNA) . They consist of two subunits— large and small. The ribosome has three binding sites for tRNA molecules

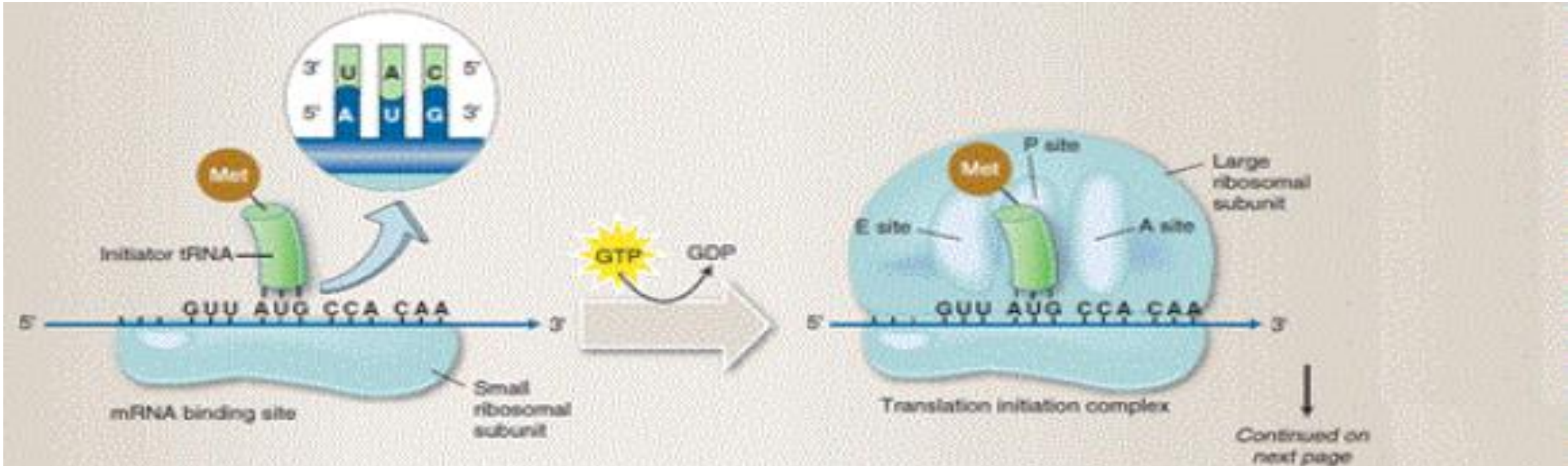


5. Source of energy (ATP and GTP) provides energy for the translation

Formation of the protein occurs in three steps

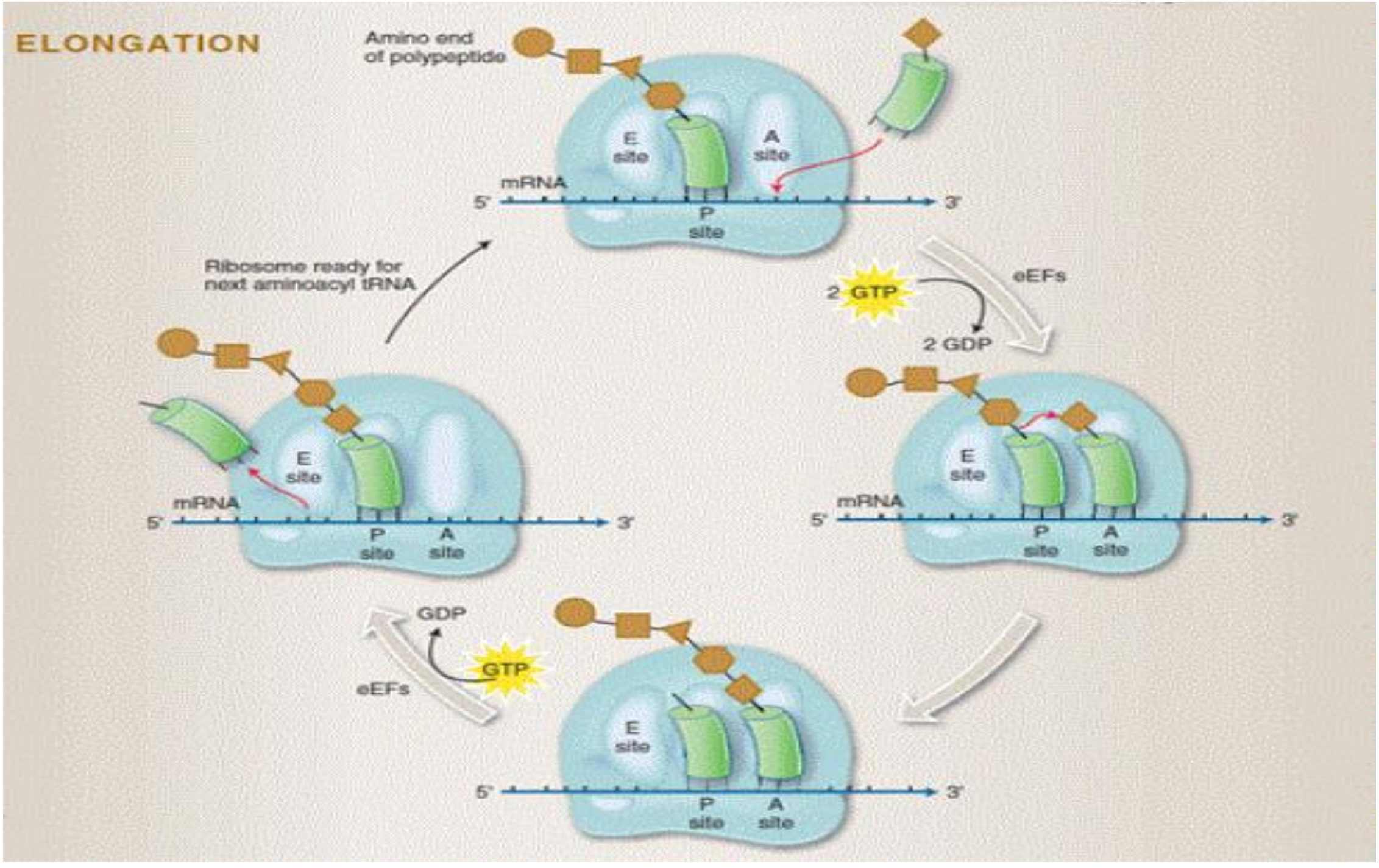
1. Initiation

- small ribosome subunit binds at the 5’ end of mRNA and move toward a start codon (AUG) at the 3 end direction which forms a complex with the large unit of the ribosome then tRNA bind to the complex and initiate translation.



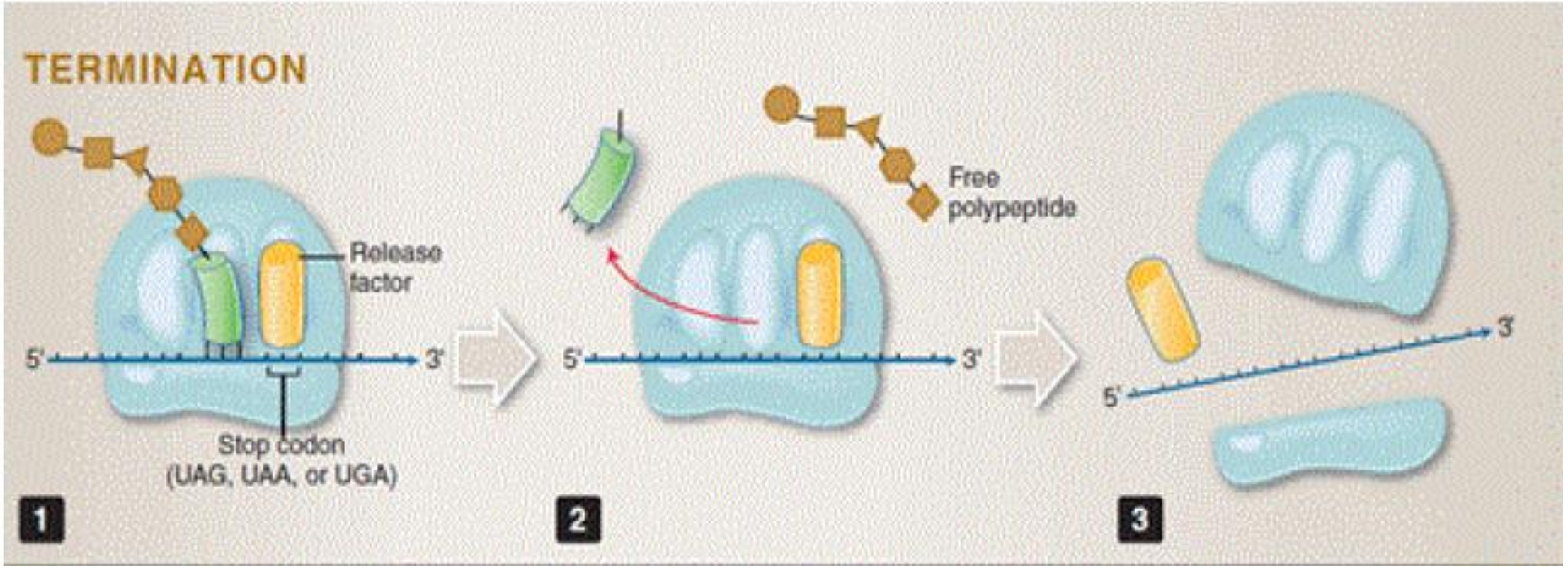
2- Elongation

- Elongation of the polypeptide chain is formed by addition of amino acids to 3 end of growing chain.
- tRNAs occupy **three sites** in the ribosomes as the ribosome moves from the 5′ end to the 3′ end of the mRNA.
    - **Site A** (aminoacyl tRNA binding site) holds the tRNA carrying the next amino acid to be added to the chain.
    - **Site P** (peptidyl-tRNA binding site) holds the tRNA carrying the growing polypeptide chain.
    - **Site E (exit site)**: empty tRNA will release


ELONGATION
Amino end of polypeptide
E site
A site
mRNA
5'
3'
P site
Ribosome ready for next aminoacyl tRNA
2 GTP
eEFs
2 GDP
E site
mRNA
5'
3'
P site
A site
GDP
GTP
eEFs
E site
5'
3'
P site
A site

3- Termination

- Elongation continues until a stop codon (UAG, UAA, and UGA) in the mRNA reaches the A site.
- Then the protein will be released and the ribosome dissociates



Composition of proteins

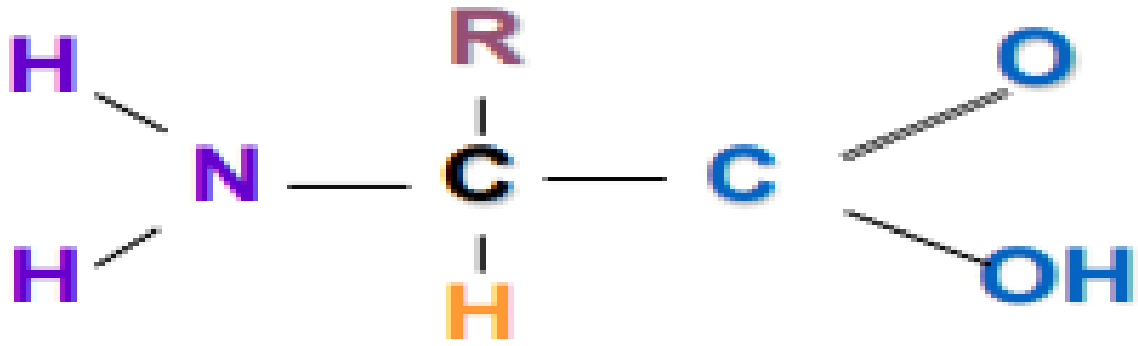
• There are 20 amino acids in proteins linked by peptide bonds

• Each amino acid has:

• an amino group (-NH2),

• a carboxyl group (-COOH),

• a Hydrogen atom



and • R is side-chain differing in each amino acid type (The R group may be as simple as a hydrogen atom, or it may be a carbon skeleton

Protein modifications

Proteins can be modified after production

protein modification: a chemical group is added to, or removed from the protein to change cell activity or function.

For examples:

- Glycoproteins and proteoglycans – addition of sugars
- Lipoproteins – addition of lipid
- Addition of fatty acid palmitate – directs protein to membrane
- Phosphorylation – addition of phosphate
- Ubiquitination – removal of bond to degrade protein
- Acetylation – addition of acetyl group

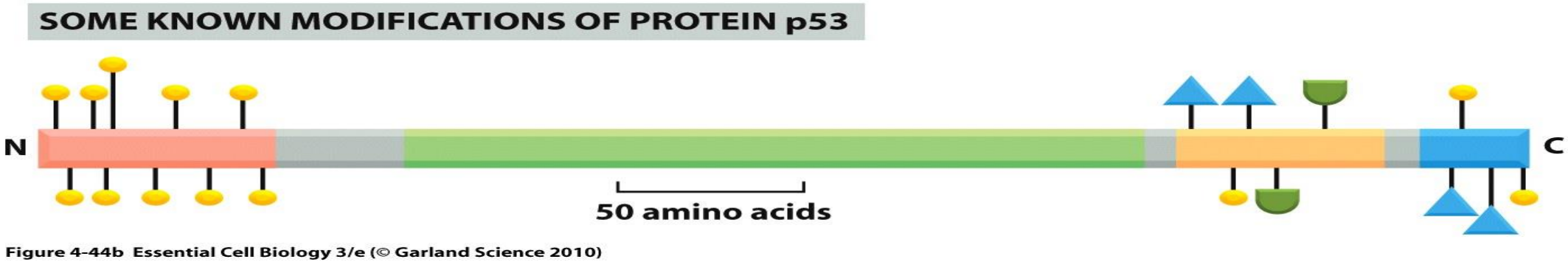


Figure 4-44b Essential Cell Biology 3/e (© Garland Science 2010)

Transcription regulation (regulation of gene expression)

It’s all about responding to changes in environment

- Cell receives a signal that something has changed
- Signal cross the plasma membrane
- Signal will stimulate **Transcription factors** are proteins that bind to specific sequences in DNA promoter known as **motifs.** They regulate gene expression by turning transcription on or off.
- Transcription will be activated so the protein product made
- The signal must be turned off again.