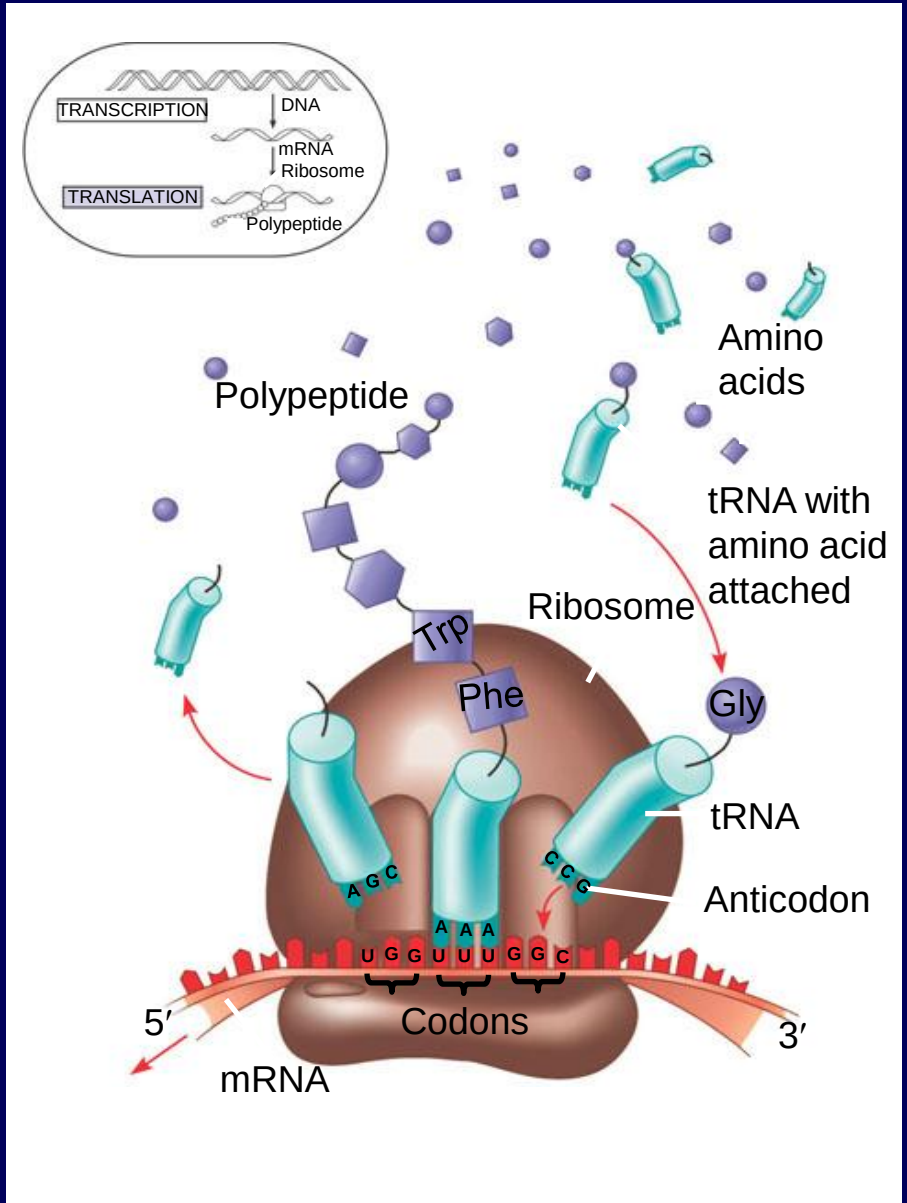
Translation

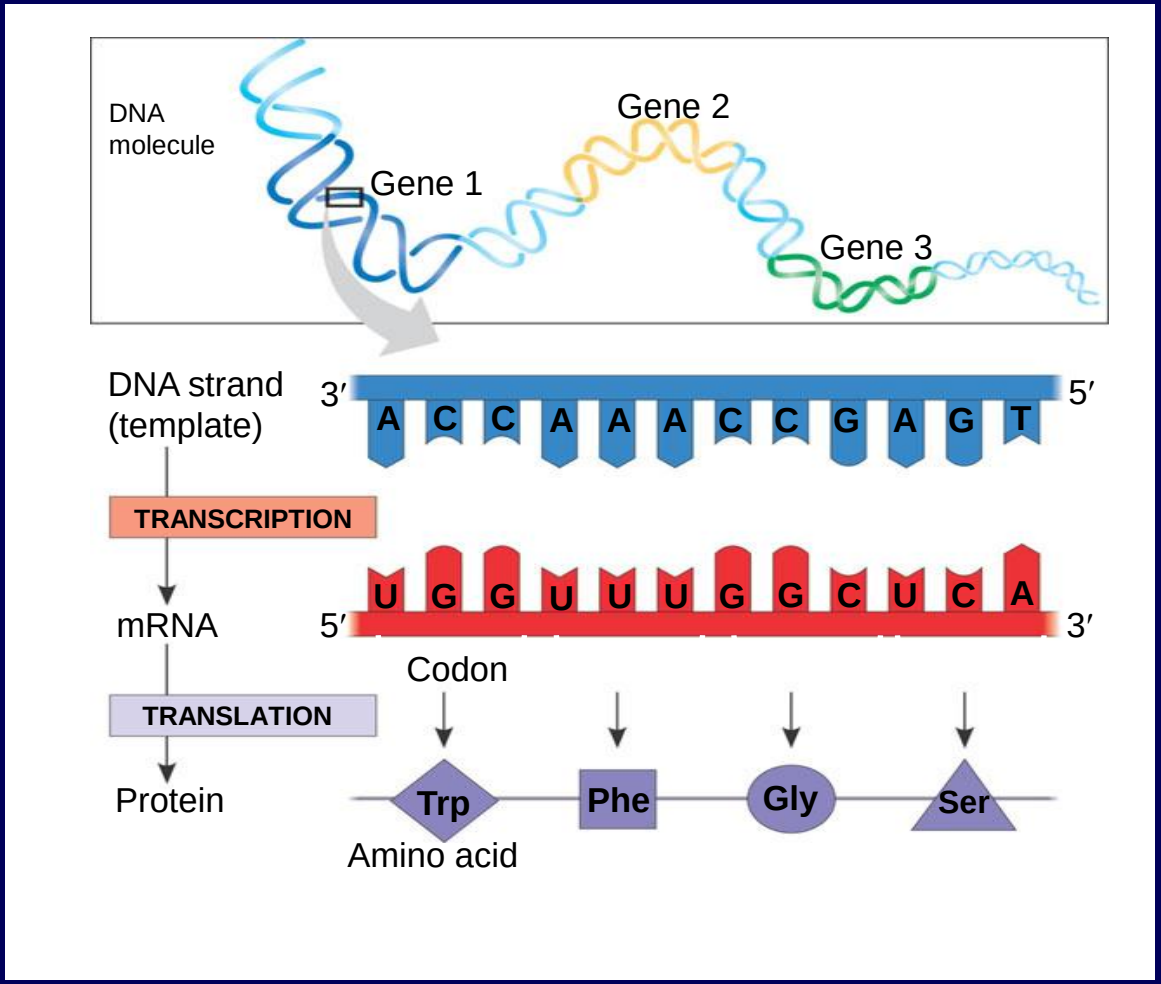
Translation

- Translation is the RNA-directed synthesis of a polypeptide
- Translation involves
  - mRNA
  - Ribosomes - Ribosomal RNA
  - Transfer RNA
  - Genetic coding - codons

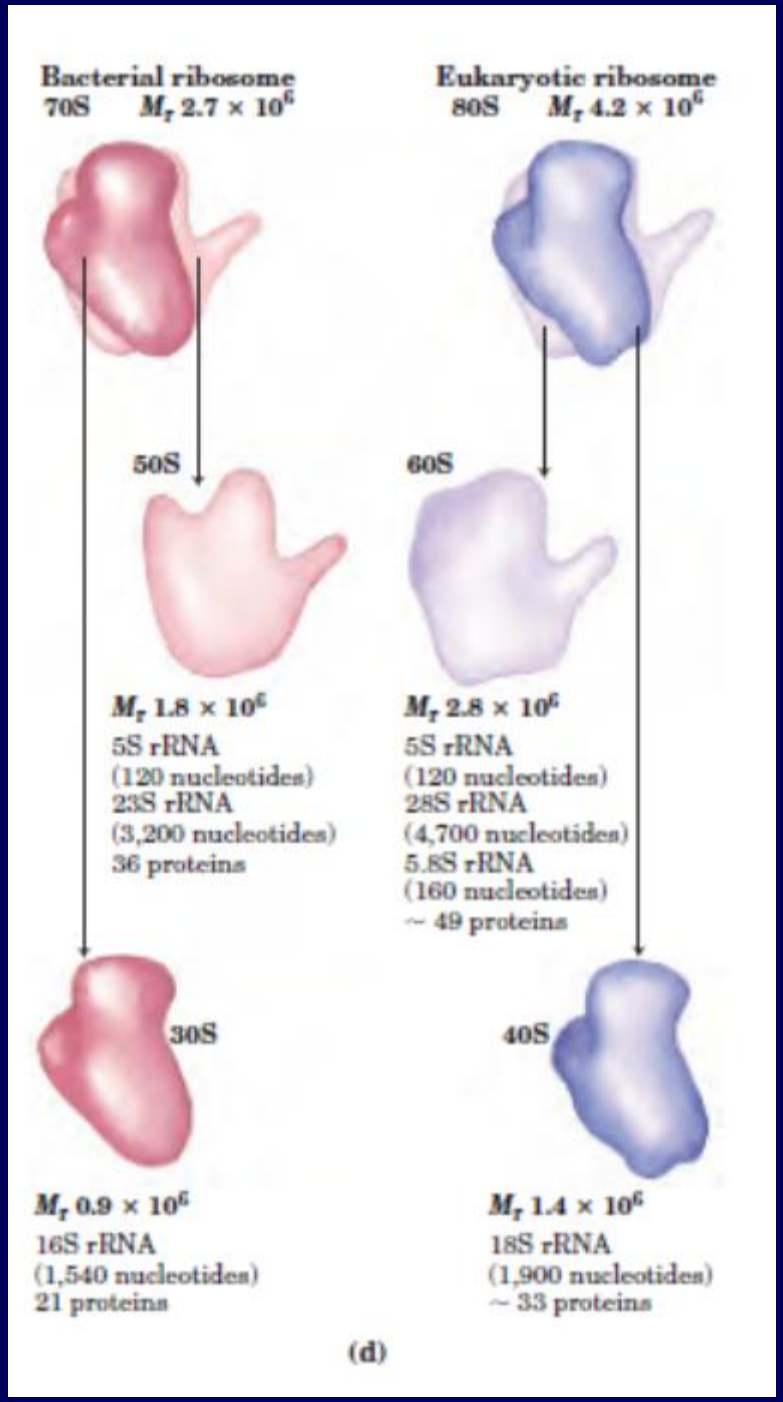


The Genetic Code

- Genetic information is encoded as a sequence of nonoverlapping base triplets, or codons



Ribosome


Bacterial ribosome
70S M_r 2.7 × 10^6
50S
M_r 1.8 × 10^6
5S rRNA
(120 nucleotides)
23S rRNA
(3,200 nucleotides)
36 proteins
30S
M_r 0.9 × 10^6
16S rRNA
(1,540 nucleotides)
21 proteins
Eukaryotic ribosome
80S M_r 4.2 × 10^6
60S
M_r 2.8 × 10^6
5S rRNA
(120 nucleotides)
28S rRNA
(4,700 nucleotides)
5.8S rRNA
(160 nucleotides)
~ 49 proteins
40S
M_r 1.4 × 10^6
18S rRNA
(1,900 nucleotides)
~ 33 proteins
(d)

Building a Polypeptide

- We can divide translation into three stages
  - Initiation
  - Elongation
  - Termination
- The AUG start codon is recognized by methionyl-tRNA or Met
- Once the start codon has been identified, the ribosome incorporates amino acids into a polypeptide chain
- RNA is decoded by tRNA (transfer RNA) molecules, which each transport specific amino acids to the growing chain
- Translation ends when a stop codon (UAA, UAG, UGA) is reached

Protein Biosynthesis Takes Place in Five Stages

- ***Stage 1: Activation of Amino Acids***
- ***Stage 2: Initiation***
- ***Stage 3: Elongation***
- ***Stage 4: Termination and Release***
- ***Stage 5: Folding & Posttranslational Processing***

Stage 1: Aminoacyl-tRNA Synthetases Attach the Correct Amino Acids to Their tRNAs

- During the first stage of protein synthesis, taking place in the cytosol, aminoacyl-tRNA synthetases esterify the 20 amino acids to their corresponding tRNAs.

- Each enzyme is specific for one amino acid and one or more corresponding tRNAs.

The reaction catalyzed by an aminoacyl-tRNA synthetase is

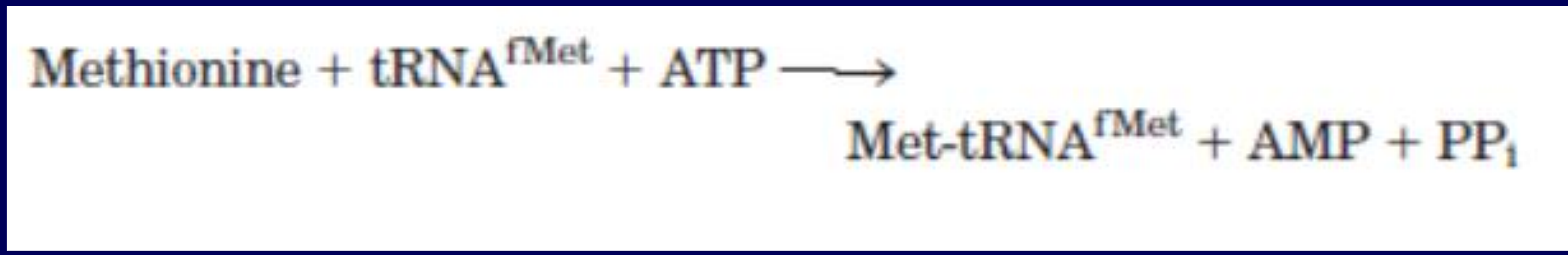
$$\text{Amino acid} + \text{tRNA} + \text{ATP} \xrightleftharpoons{Mg^{2+}} \text{aminoacyl-tRNA} + \text{AMP} + PP_i$$

Stage 2: A Specific Amino Acid Initiates Protein Synthesis

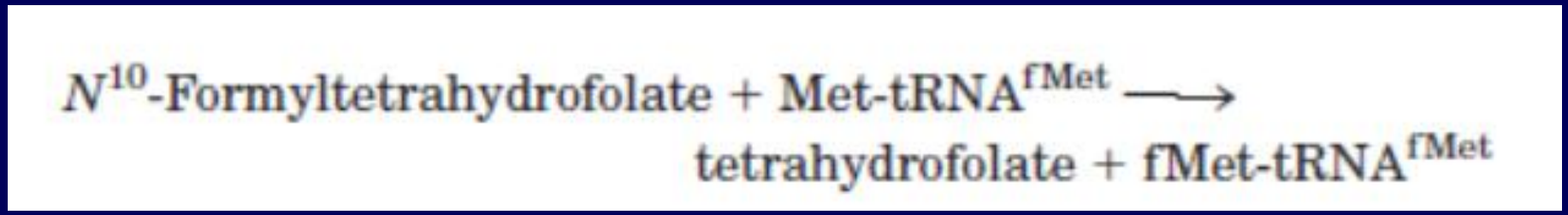
- **Protein synthesis begins at the amino-terminal end and proceeds by the stepwise addition of amino acids to the carboxyl-terminal end of the growing polypeptide**

- **Although methionine has only one codon, (5)AUG, all organisms have two tRNAs for methionine. One is used exclusively when (5)AUG is the initiation codon for protein synthesis. The other is used to code for a Met residue in an internal position in a polypeptide**

- **In bacteria, the two types of tRNA specific for methionine are designated tRNAMet and tRNAfMet. The amino acid incorporated in response to the (5)AUG initiation codon is *N formylmethionine* (fMet). It arrives at the ribosome as *N-formylmethionyl-tRNAfMet (fMet-tRNAfMet)***



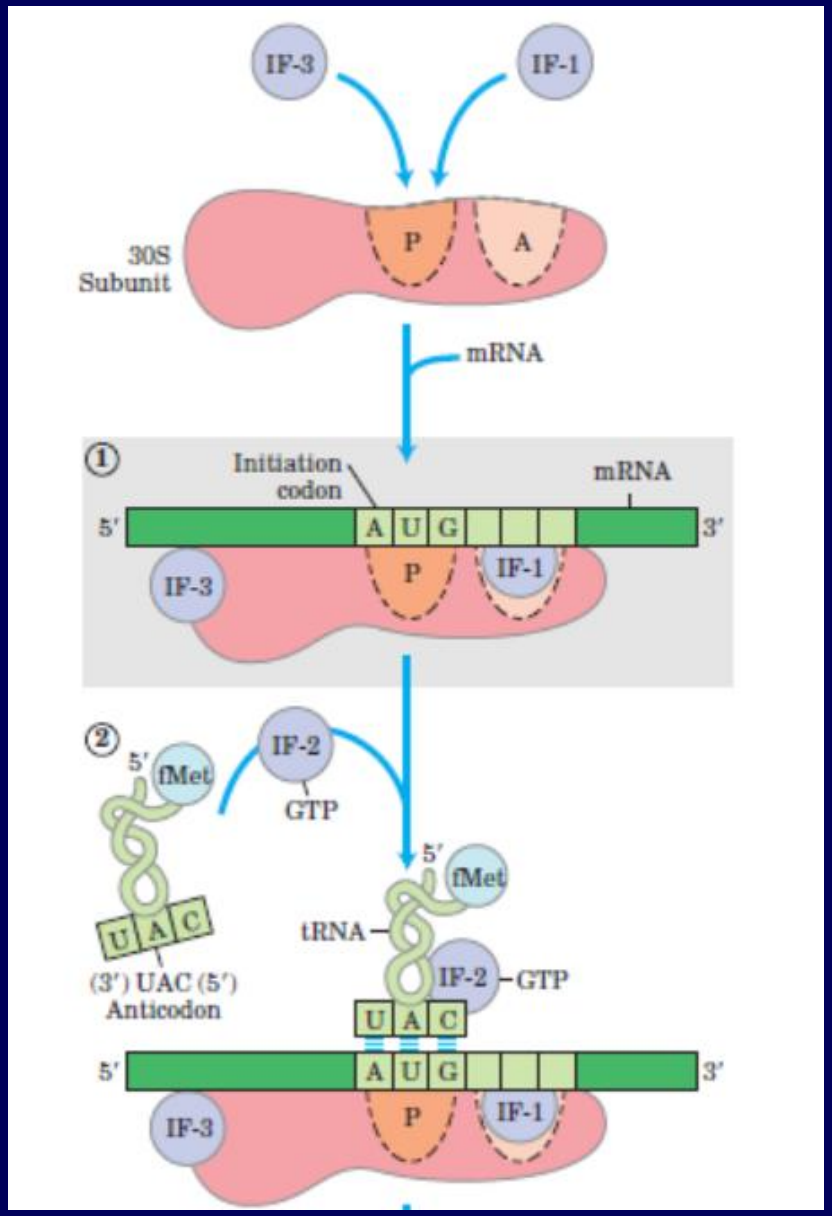
Met-tRNA synthetase

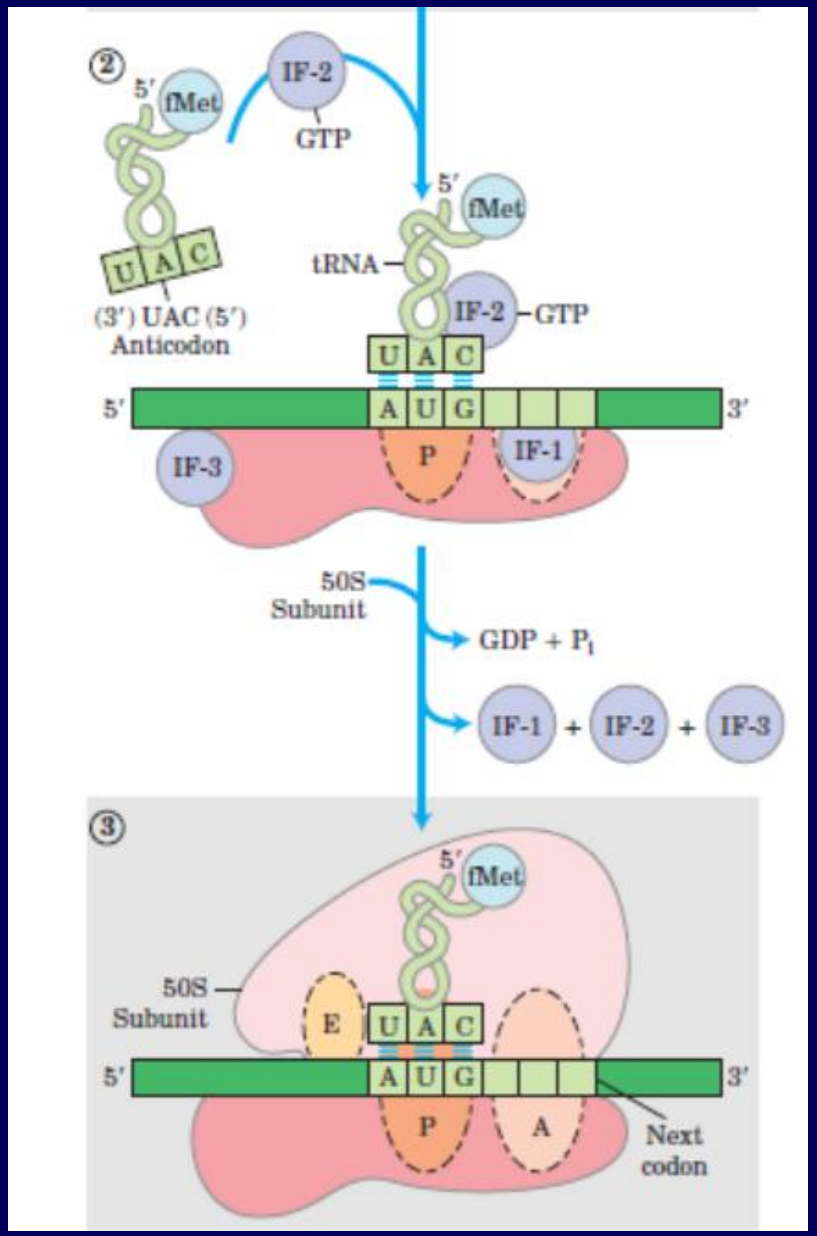


Transformylase

Eukaryotic cell uses a specialized initiating tRNA that is distinct from the tRNAMet used at (5)AUG codons at interior positions in the mRNA.

Initiation

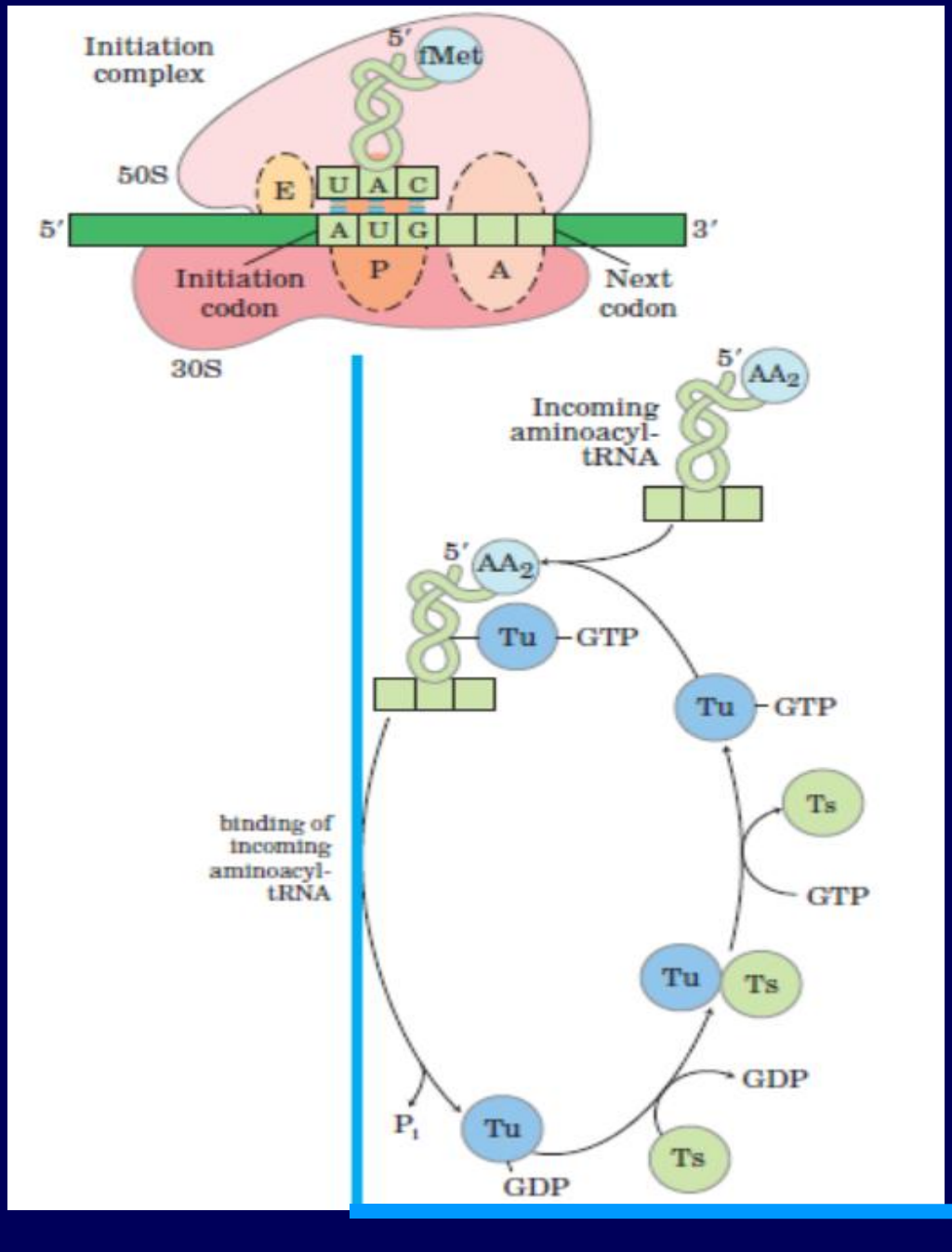

IF-3
IF-1
30S Subunit
P
A
mRNA
1
Initiation codon
mRNA
5′
A U G
3′
IF-3
P
IF-1
2
5′
fMet
IF-2
GTP
U A C
(3′) UAC (5′) Anticodon
tRNA
IF-2 GTP
5′
A U G
3′
IF-3
P
IF-1


2
5′
fMet
IF-2
GTP
U A C
(3′) UAC (5′) Anticodon
5′
fMet
tRNA
IF-2 GTP
U A C
5′
A U G
3′
IF-3
P
IF-1
50S Subunit
GDP + P$_i$
IF-1 + IF-2 + IF-3
3
5′
fMet
50S Subunit
E
U A C
5′
A U G
3′
P
A
Next codon

Elongation-2 steps

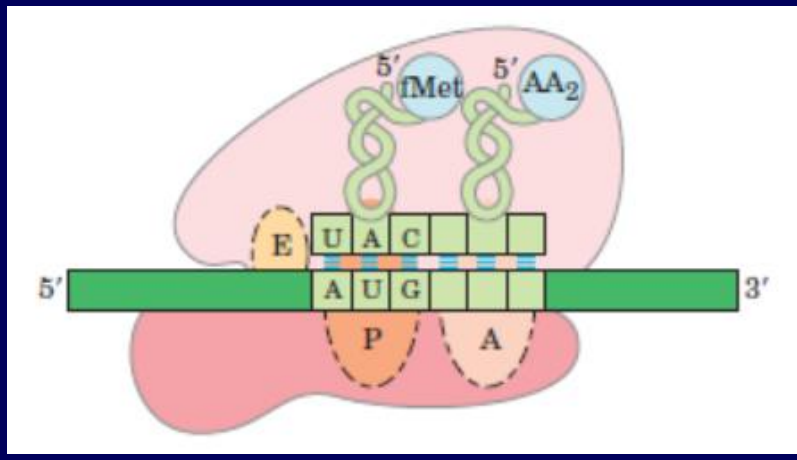
- ***Elongation Step 1: Binding of an Incoming Aminoacyl-tRNA***

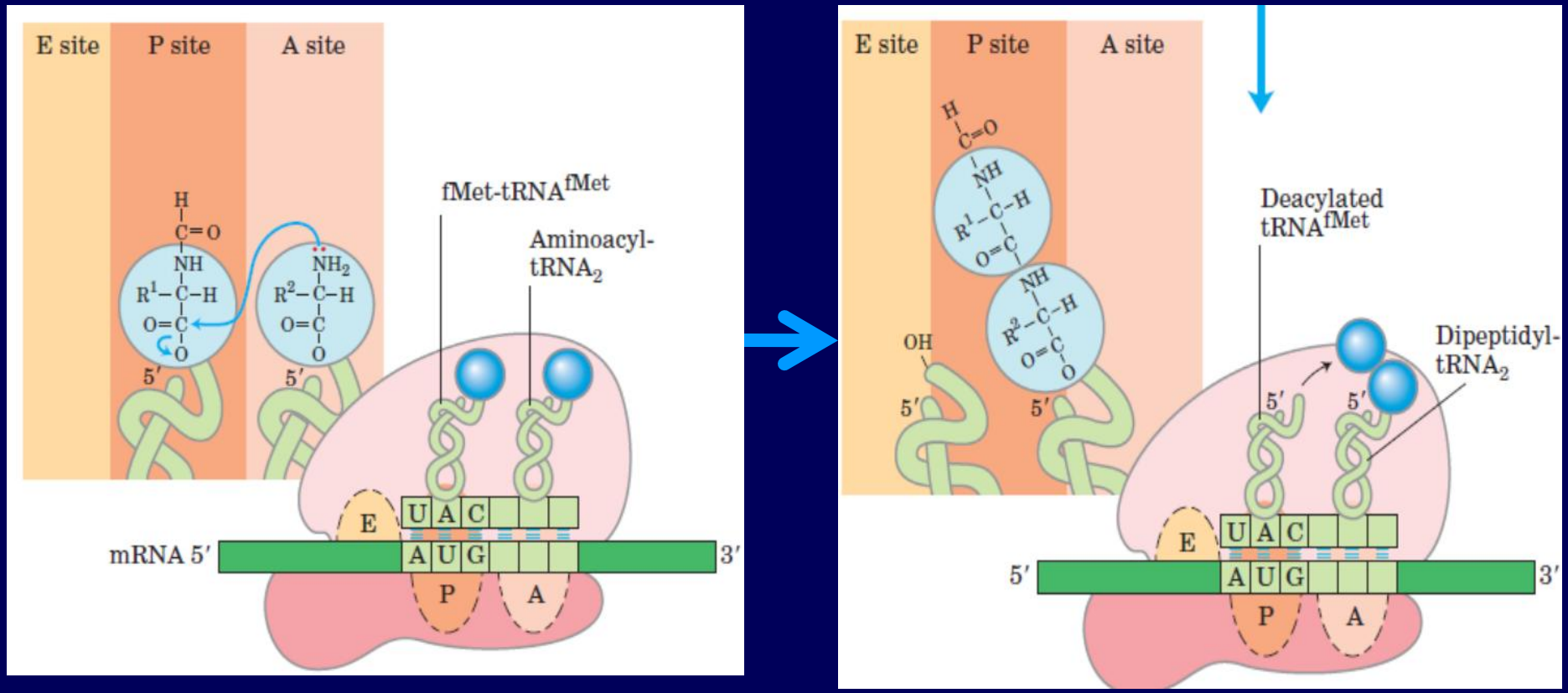
- ***Elongation Step 2: Peptide Bond Formation***



Elongation Step 1

Binding of an Incoming Aminoacyl-tRNA

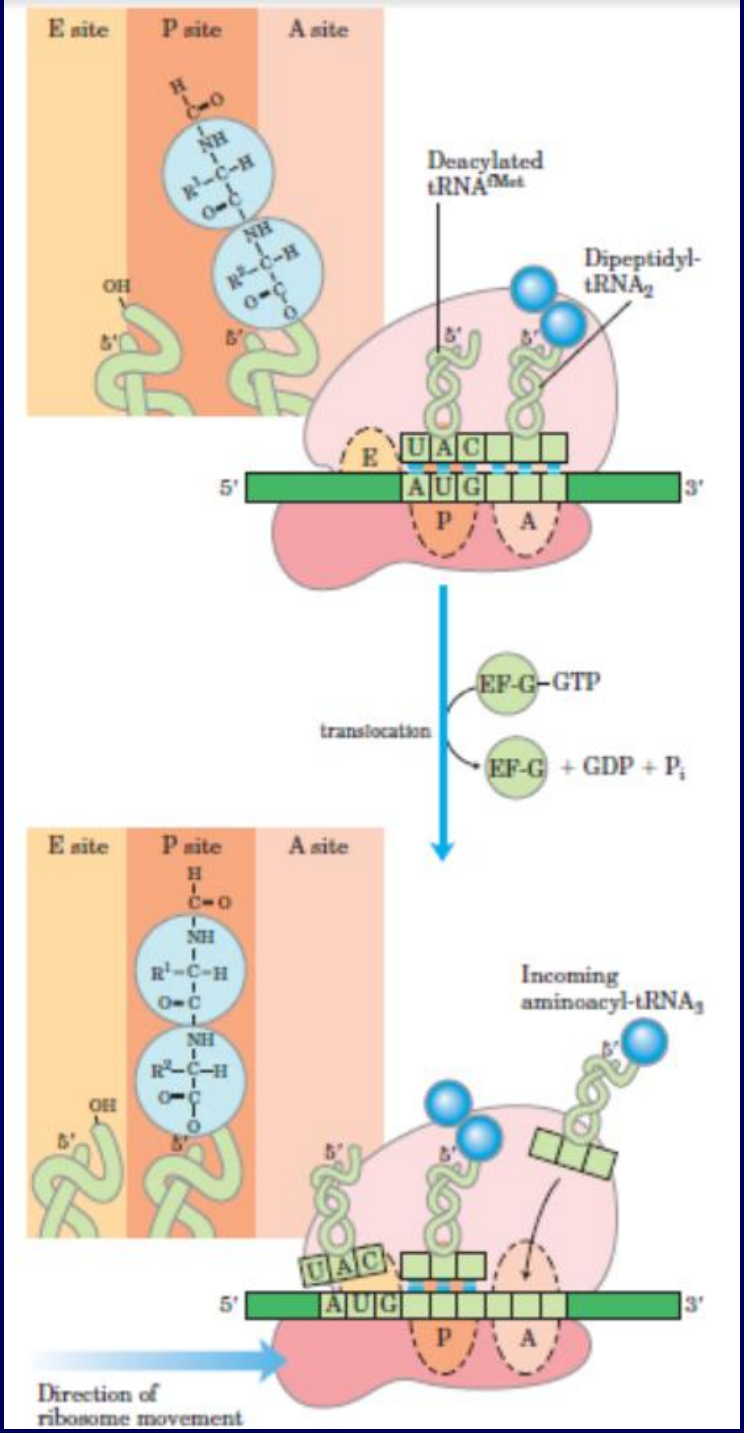




Elongation Step 2: Peptide Bond Formation

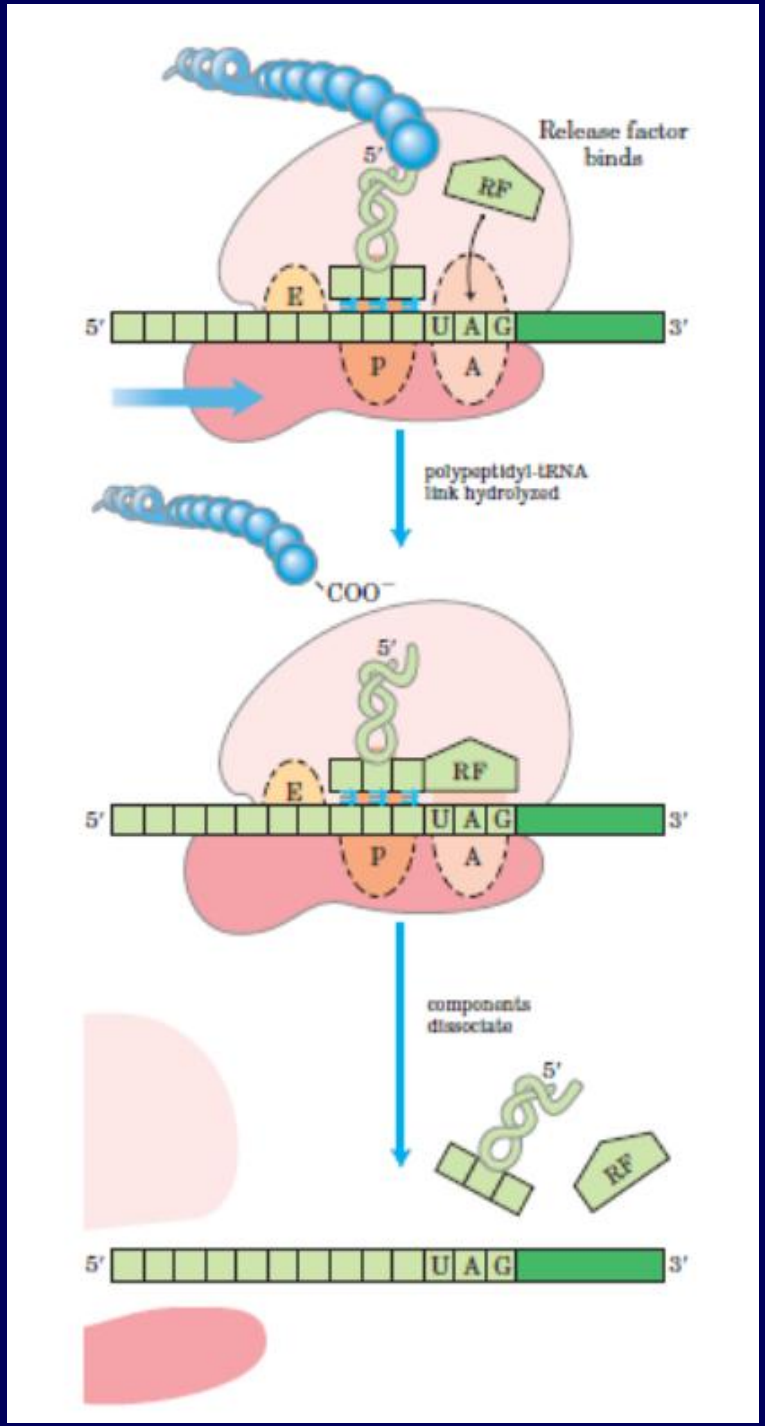
Elongation Step 3

Translocation In the final step of the elongation cycle, **translocation, the ribosome moves** one codon toward the 3 end of the mRNA



Termination of Translation

- The final stage is termination when the ribosome reaches a stop codon in the mRNA



Translation

- The final step in translation is termination. When the ribosome reaches a STOP codon, there is no corresponding transfer RNA.
- Instead, a small protein called a “release factor” attaches to the stop codon.
- The release factor causes the whole complex to fall apart: messenger RNA, the two ribosome subunits, the new polypeptide.
- The messenger RNA can be translated many times, to produce many protein copies.