# RIBOSOMES

## Structure and Function *Of* Ribosomes

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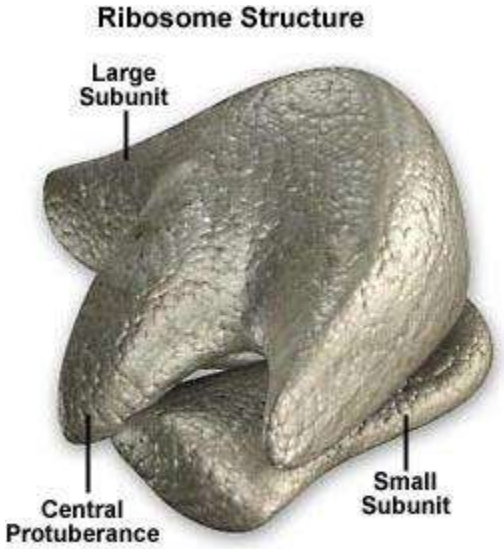
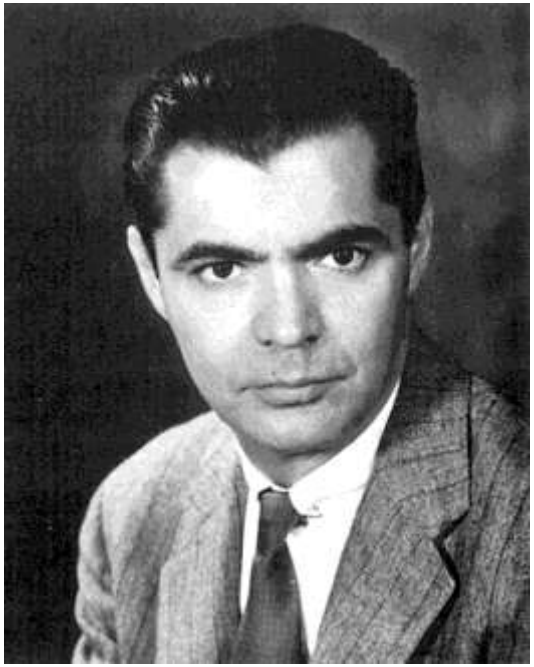
# What are Ribosomes?

- Cell have tiny granular structures known as **Ribosomes**
- Ribosomes are **Ribonucleo-Protein Particles**
- Ribosomes serves as workbenches, with mRNA acting as the blueprint in the process of protein synthesis



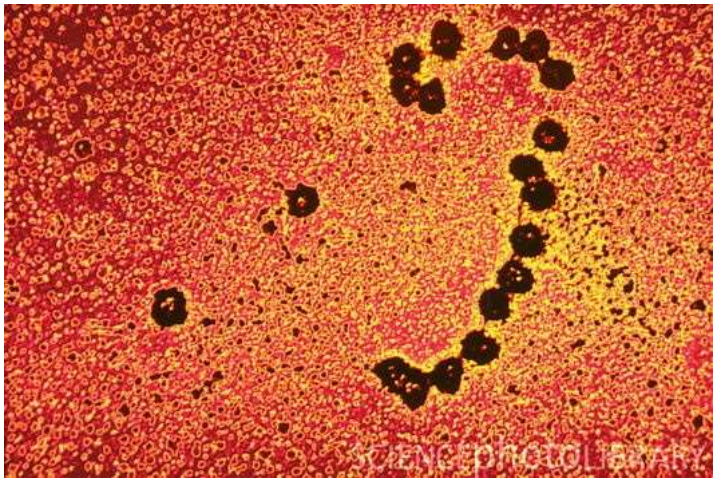
# Discovery of Ribosomes

- **Palade** was the first person to study them in 1955



# Number

- The number of Ribosomes differs greatly
- A rapidly growing **E.coli** cell may have as many as 15,000 to 20,000 ribosomes, about 15% of the cell mass



# Types of Ribosomes

- **Matrix Ribosomes:** These synthesize proteins destined to remain within the cell
- **Plasma Membrane Ribosomes:** These make proteins for transport to the outside

# Domains of Ribosomes

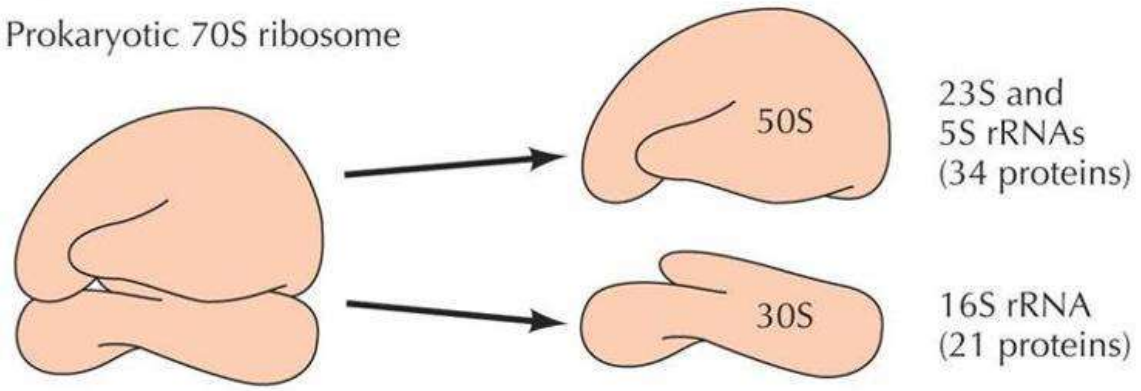
- There are two domains of Ribosomes
- **Translational Domain:** The region responsible for translation is called the Translational domain
- Both subunits contribute to this domain, located in the upper half of the small subunit and in the associated areas of the large subunit
- **Exit Domain:** The growing peptide chain emerges from the large subunit at the exit domain
- This is located on the side of the subunit

# Dimensions of Ribosomes

- Prokaryotic Ribosomes are commonly called **70S Ribosomes**
- These have **dimensions** of about 14 to 15nm by 20nm
- A **Molecular Weight** of approximately 2.7 million daltons($2.7 \times 10^6$ daltons)
- These are constructed of a 50S and a 30S subunit

# Structure of Ribosomes

- Ribosomes are not bounded by membrane
- Prokaryotic Ribosomes are smaller and less dense than Eukaryotic Ribosomes
- Ribosomes are composed of two subunits, each of which consists of protein and a type of RNA called **Ribosomal RNA (rRNA)**



# Ribosomal Subunits

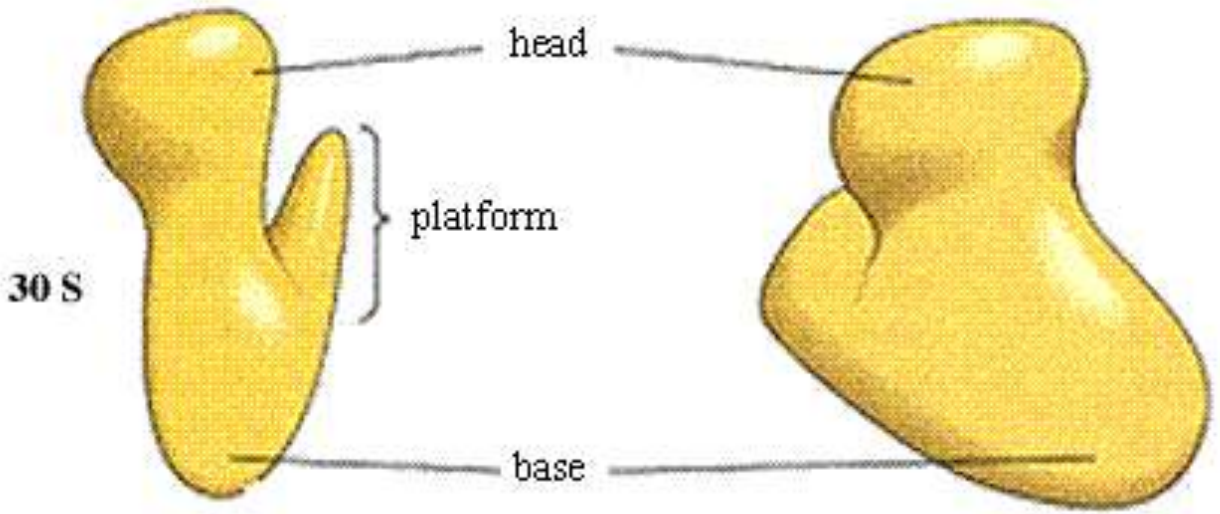
- Each subunit is constructed from one to two rRNA molecules and many polypeptides
- 30S smaller Subunit
- 50S larger Subunit

# Svedberg Unit

- The S in 70S and similar values stand for **Svedberg units**
- The faster a particle travels when centrifuged, the greater its Svedberg value or Sedimentation coefficient
- The sedimentation coefficient is a function of a particles molecular weight, volume and shape
- Heavier and more compact particles normally have larger Svedberg numbers or sediment faster

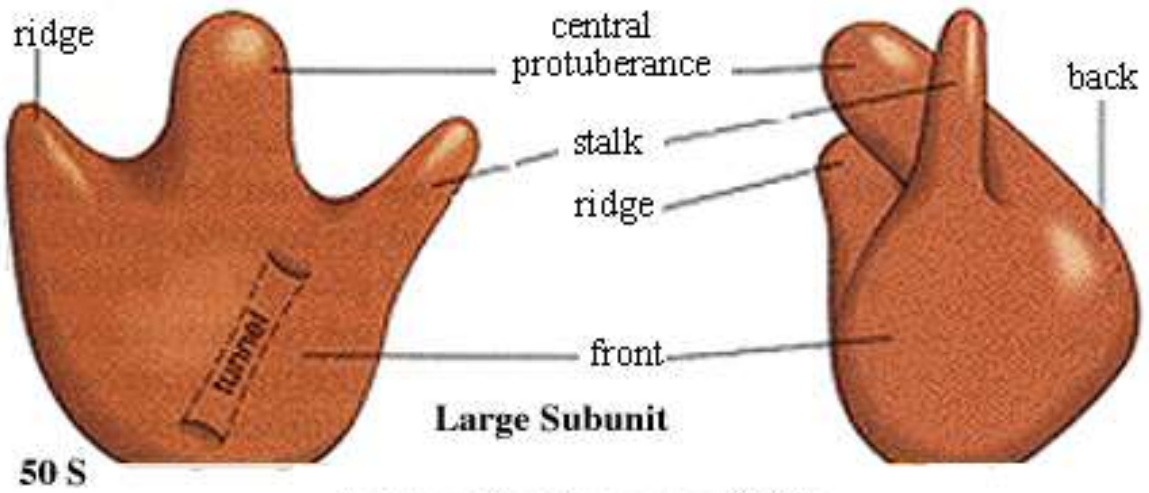
# 30S Subunit

- 30S Subunit is smaller and has a molecular weight of $0.9 \times 10^6$ daltons
- It is made up of 16S rRNA and 21 Polypeptide chains



# 50S Subunit

- The 50S subunit is larger one and has a molecular weight of about $1.8 \times 10^6$ daltons
- It consists of 5S rRNA, 23S rRNA and 34 Polypeptide chains




Prokaryotic Ribosomes (70 S)

# Ribosomal RNA and its Role

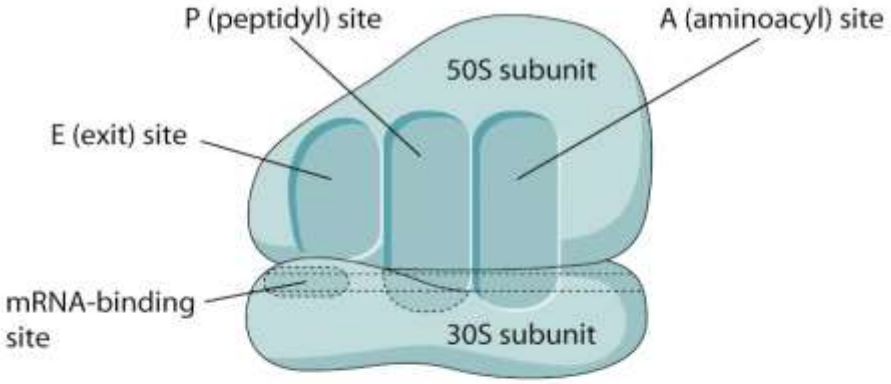
- rRNA is transcribed from certain portions of DNA by the same energy-requiring process used for the synthesis of mRNA and tRNA
- rRNA is thought to have two roles

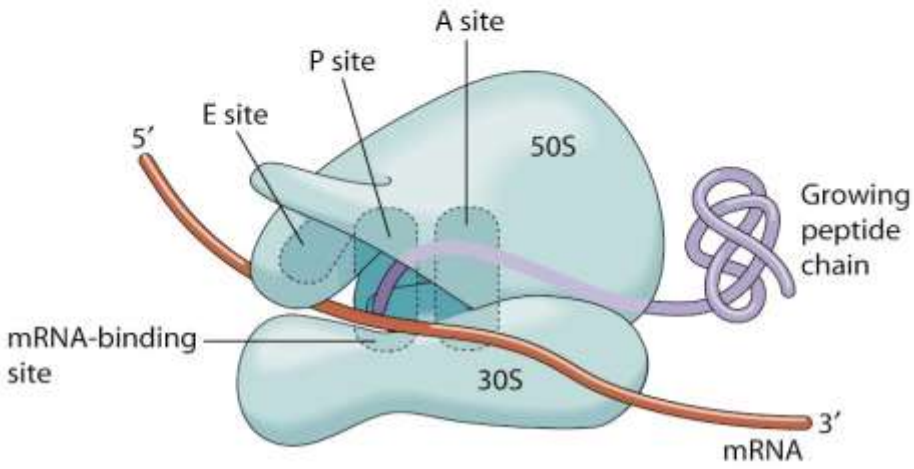
i. The 16S rRNA of the 30S subunit may aid in the initiation of protein synthesis
- The 3` end of the 16S rRNA complexes with an initiating signal site on the mRNA and helps position the mRNA on the ribosome

ii. 16S rRNA binds initiation factor-3 and the 3` CCA end of aminoacyl-tRNA

# Sites of Ribosome

- The ribosome has three sites for binding tRNA
- The Peptidyl or Donor site (the P site)
- The Aminoacyl or Acceptor Site (the A site)
- The Exit Site (the E site)



# Function of Ribosomes

- The Ribosome is involved in the process of **Protein Synthesis**
- Protein Synthesis is divided into three stages:

1. Initiation
2. Elongation
3. Termination

# 1. Initiation

- **The necessary Components Assemble:**

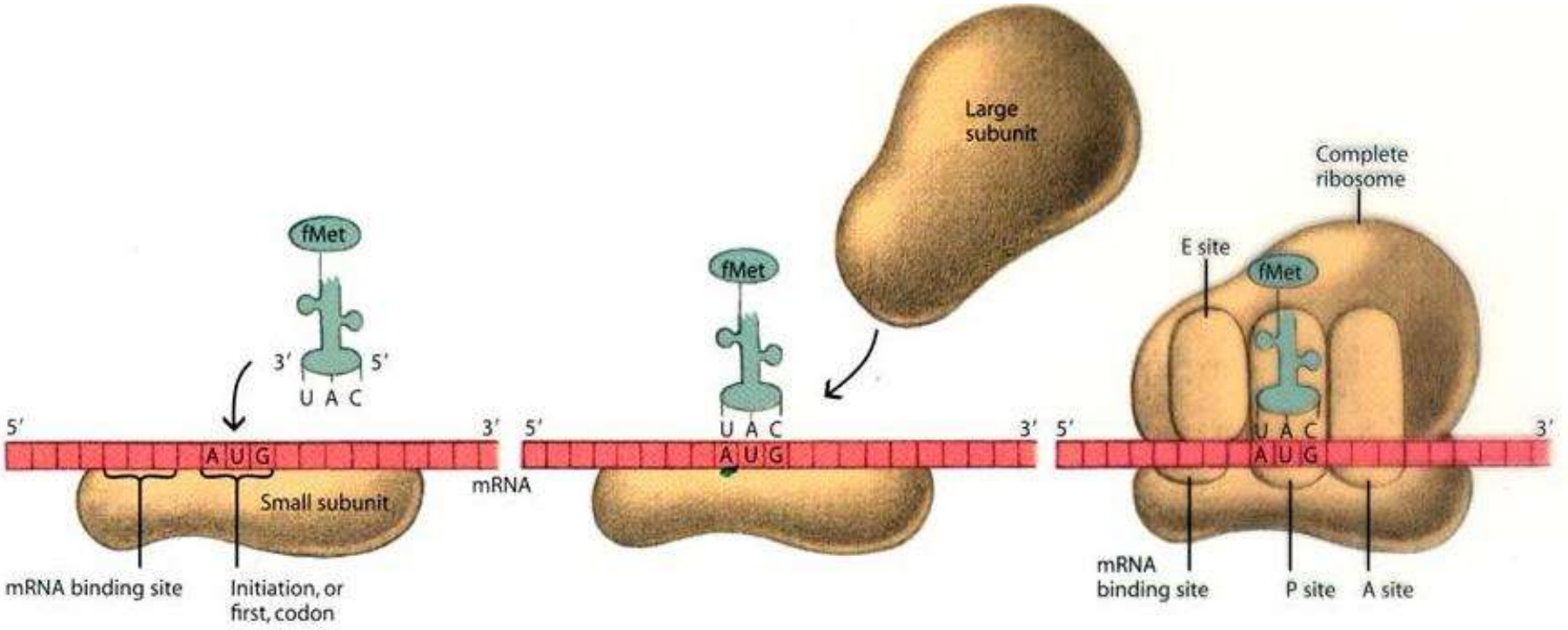
i. The two ribosomal subunits
ii. A tRNA with the anticodon UAC
iii. The mRNA molecule to be translated
iv. Along with several additional protein factors

- In **E.coli and most bacteria** translation begin with specially modified aminoacyl tRNA, N-formylmethionyl tRNA
- Because the α-amino is blocked by a formyl group, this aminoacyl tRNA can be used only for initiation
- This **N-formylmethionyl-tRNA** attaches itself to the P Site of ribosome(Peptidyl Site)

# Continued

- mRNA have a special "**Initiation Codon**" (AUG) that specifically binds with the fMet-tRNA anticodon
- Finally, the 50S subunit binds to the 30S subunit mRNA, forming an active **ribosome-mRNA complex**
- The attachment of two Subunits is controlled by **$Mg^{+2}$ ions**

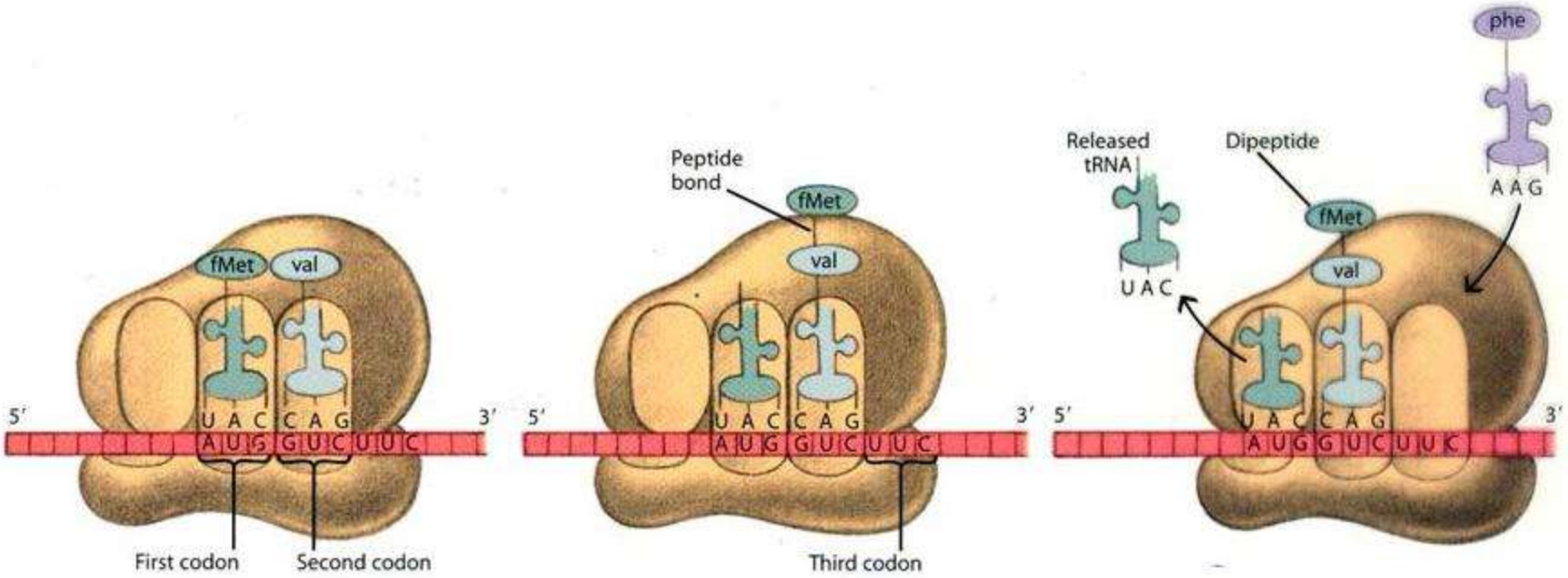
# Continued


fMet
3′
5′
U A C
5′
3′
A U G
Small subunit
mRNA
mRNA binding site
Initiation, or first, codon
Large subunit
fMet
U A C
5′
3′
A U G
Complete ribosome
E site
fMet
U A C
5′
3′
A U G
mRNA binding site
P site
A site

# 2. Elongation

- At the beginning of elongation cycle, the Peptidy Site (P Site) is filled with N-formymethionyl-tRNA and aminoacyl(A Site) with Exit Site(E Site) are empty
- **Aminoacyl-tRNA Binding:** The next codon is located with A site and is ready to direct the binding of an aminoacyl-tRNA
- GTP and Elongation factor donate the aminoacyl-tRNA to ribosomes

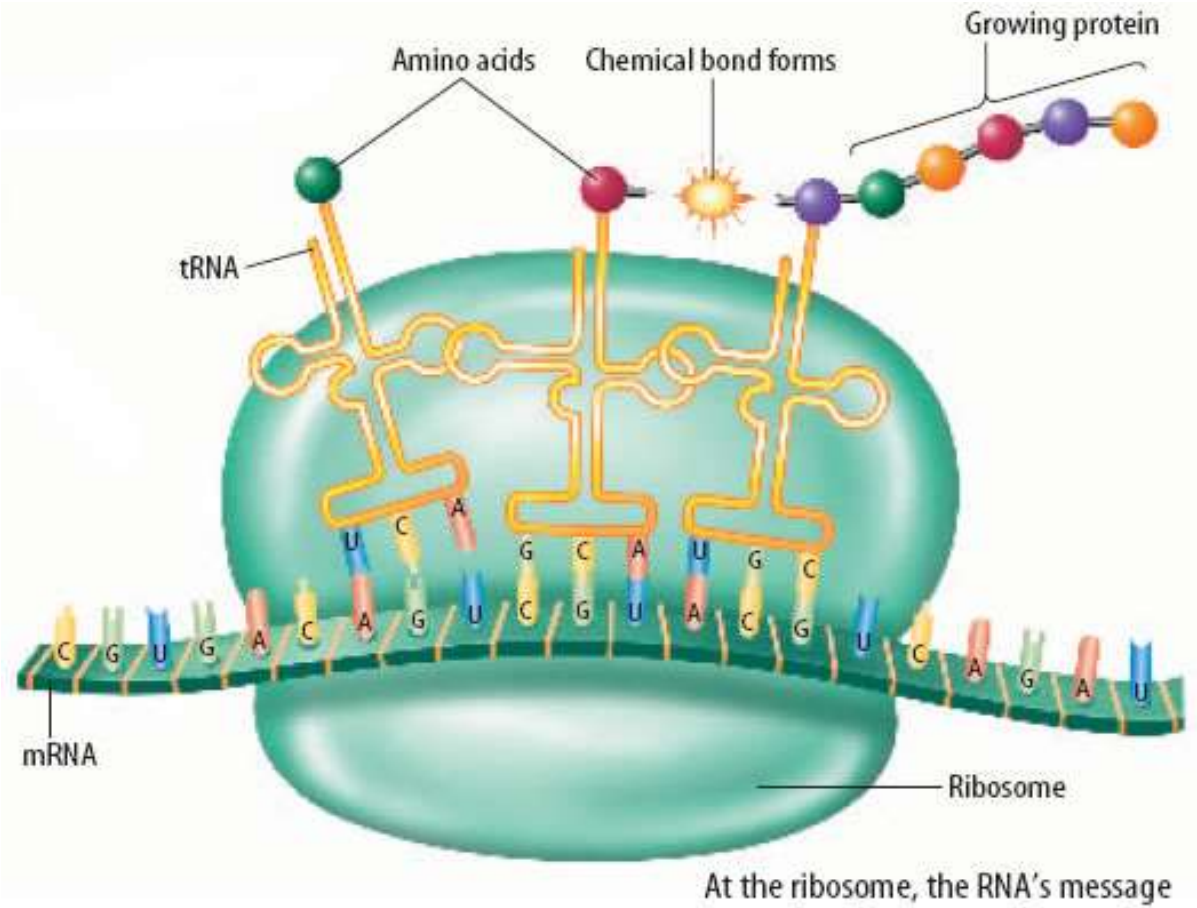
# Continued


fMet
val
5′
U A C C A G
A U G G U C U U C
3′
First codon
Second codon
Peptide bond
fMet
val
5′
U A C C A G
A U G G U C U U C
3′
Third codon
Released tRNA
Dipeptide
phe
A A G
fMet
val
U A C
5′
U A C C A G
A U G G U C U U C
3′

# Continued

- **Transpeptidation Reaction:** Peptidyl transferase, located on 50S Subunit catalyze the transpeptidation reaction
- The α-amino group of A site amino acid attacks α-carboxyl group of C-terminal amino acid on P site tRNA in this reaction resulting in peptide bond formation
- A specific **adenine base** seems to participate in catalyzing peptide bond formation

# Continued




At the ribosome, the RNA's message is translated into a specific protein.

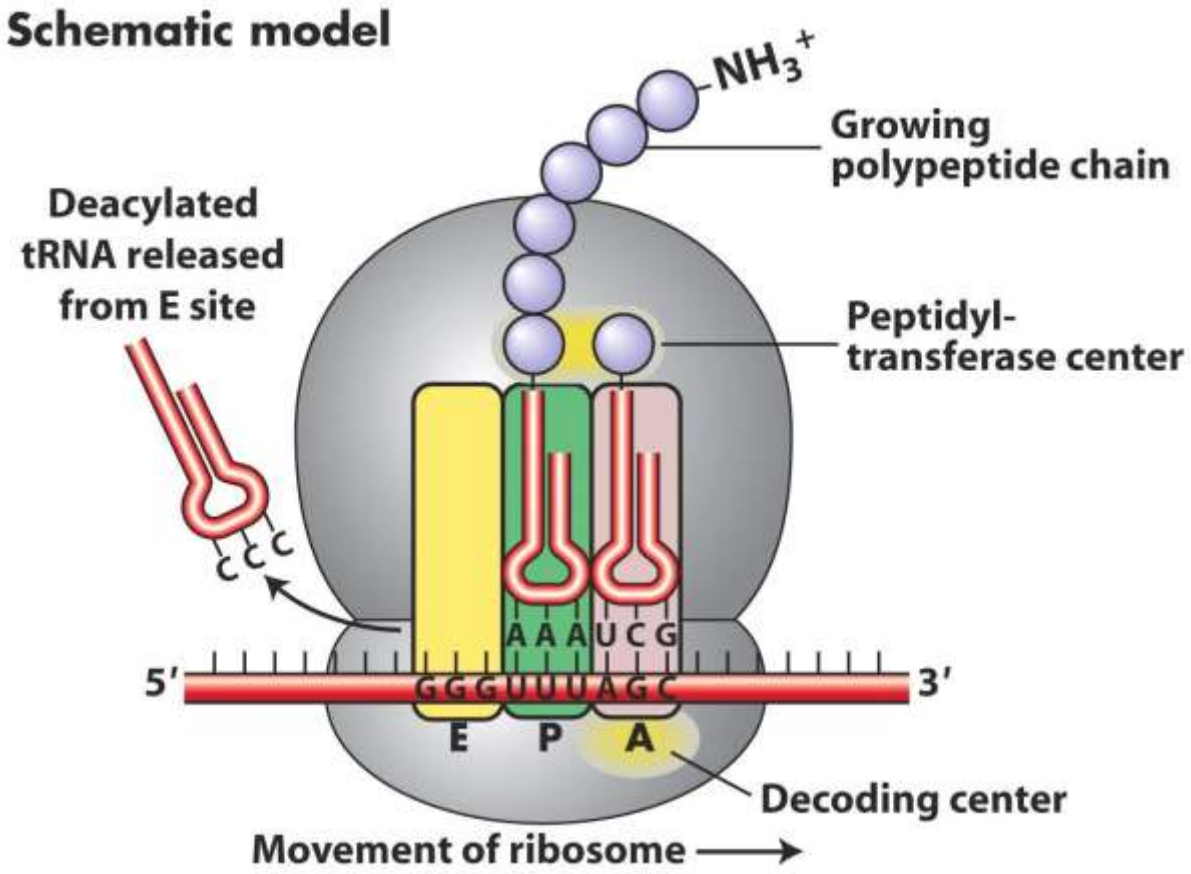
# Continued

- **Translocation:** Movement of Ribosome on mRNA is called Translocation
- There are three **Phases of Translocation**

1. The peptidyl-tRNA moves from the A site to P site
2. The ribosome moves one codon along mRNA so that a new codon is positioned in the A site
3. The empty tRNA leaves the P site

- Translocation requires GTP and elongation factor complex to proceed

# Continued


Schematic model
$NH_3^+$
Growing polypeptide chain
Deacylated tRNA released from E site
Peptidyl-transferase center
C C C
A A A U C G
5′
G G G U U U A G C
3′
E
P
A
Decoding center
Movement of ribosome

# 3. Termination

- Protein Synthesis stops when the ribosomes reaches one of three special non-sense codons- UAA, UAG, UGA
- Three **release factors**(RF-1, RF-2, RF-3) aid the ribosomes in recognizing these codons
- After the ribosome has stopped, peptidyl transferase hydrolyzes the peptide free from its tRNA, and the empty tRNA is released
- GTP hydrolyzes required for this process
- Next the ribosome dissociates from its mRNA and separates into 30S and 50S subunits. IF-3 binds to 30S subunit and prevent it from re-associating with 50S subunit till next initiation starts

# Effect of Antibiotics on Protein Synthesis

- Several antibiotics work by inhibiting protein synthesis on prokaryotic ribosomes
- Antibiotics such as **Streptomycin and gentamicin** attach to the 30S subunit and interfere with protein synthesis
- Other Antibiotics, such as **Erythromycin and Chloramphenicol**, interfere with protein synthesis by attaching to the 50S subunit

# Point to Ponder

- Because of differences in prokaryotic and eukaryotic ribosomes, the microbial cell can be killed by the antibiotic while the eukaryotic host cell remains unaffected

# Thank You