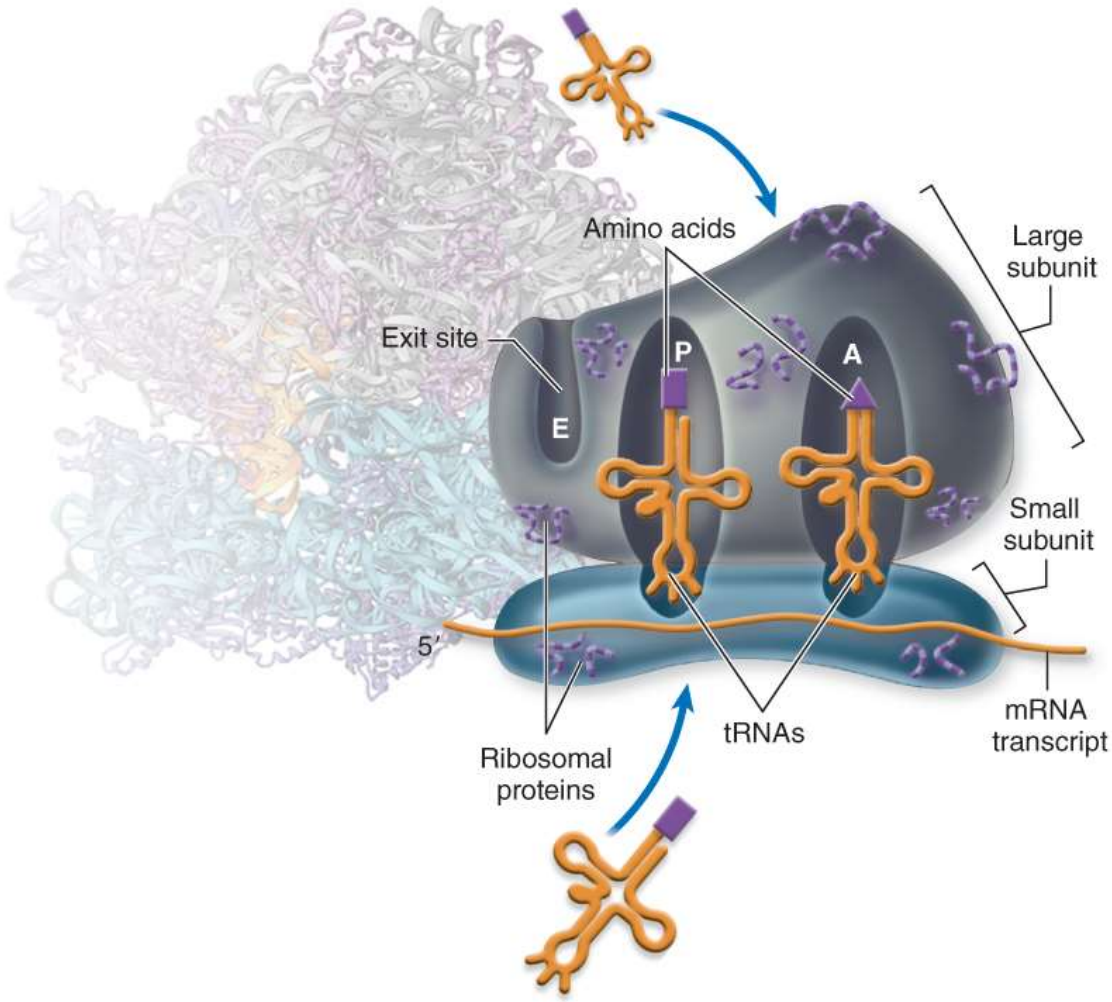
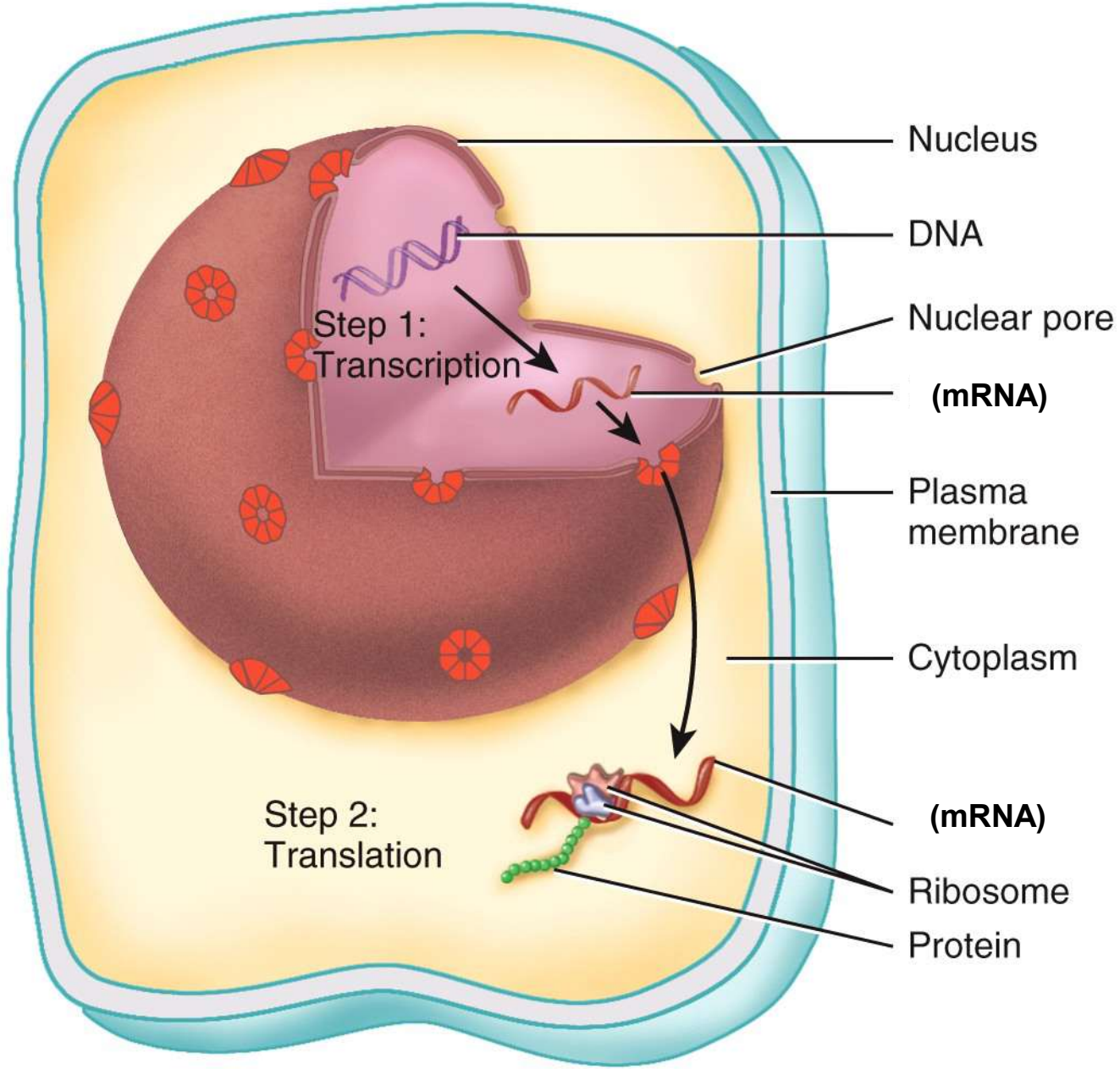
C4.2
Protein Synthesis



Summary of Protein Synthesis

- How molecular information is transferred from genes to proteins
  - **DNA** → **mRNA** → **protein**
- **Transcription** – the step from **DNA** to **mRNA**
  - This occurs in the nucleus where DNA is located
  - Transcription factors = these are molecules used to "turn on or turn off" transcription // regulators of protein synthesis /// e.g. micro-RNAs
  - e.g. change metabolism of mammary gland to make milk
- **Translation** – the step from **mRNA** to **protein**
  - This occurs in cytoplasm
  - Requires ribosomes RNA(rRNA) and transfer RNA (tRNA)
  - (Note: 15-20% of proteins are synthesized inside the nucleus)



Note: transfer RNA (tRNA) brings amino acids to mRNA–ribosome complex.

Transcription

- DNA's genes contain the “receipt” for making proteins /// the DNA molecule is to large to leave nucleus so.....
  - necessary to make a smaller mRNA copy of the DNA gene
  - mRNA migrates through a nuclear pore into the cytoplasm
  - protein synthesis takes place in the cytoplasm
- **Transcription** = copying genetic instructions from DNA to mRNA // this occurs in nucleoplasm

Information Coding Density and Coding Element Terminology

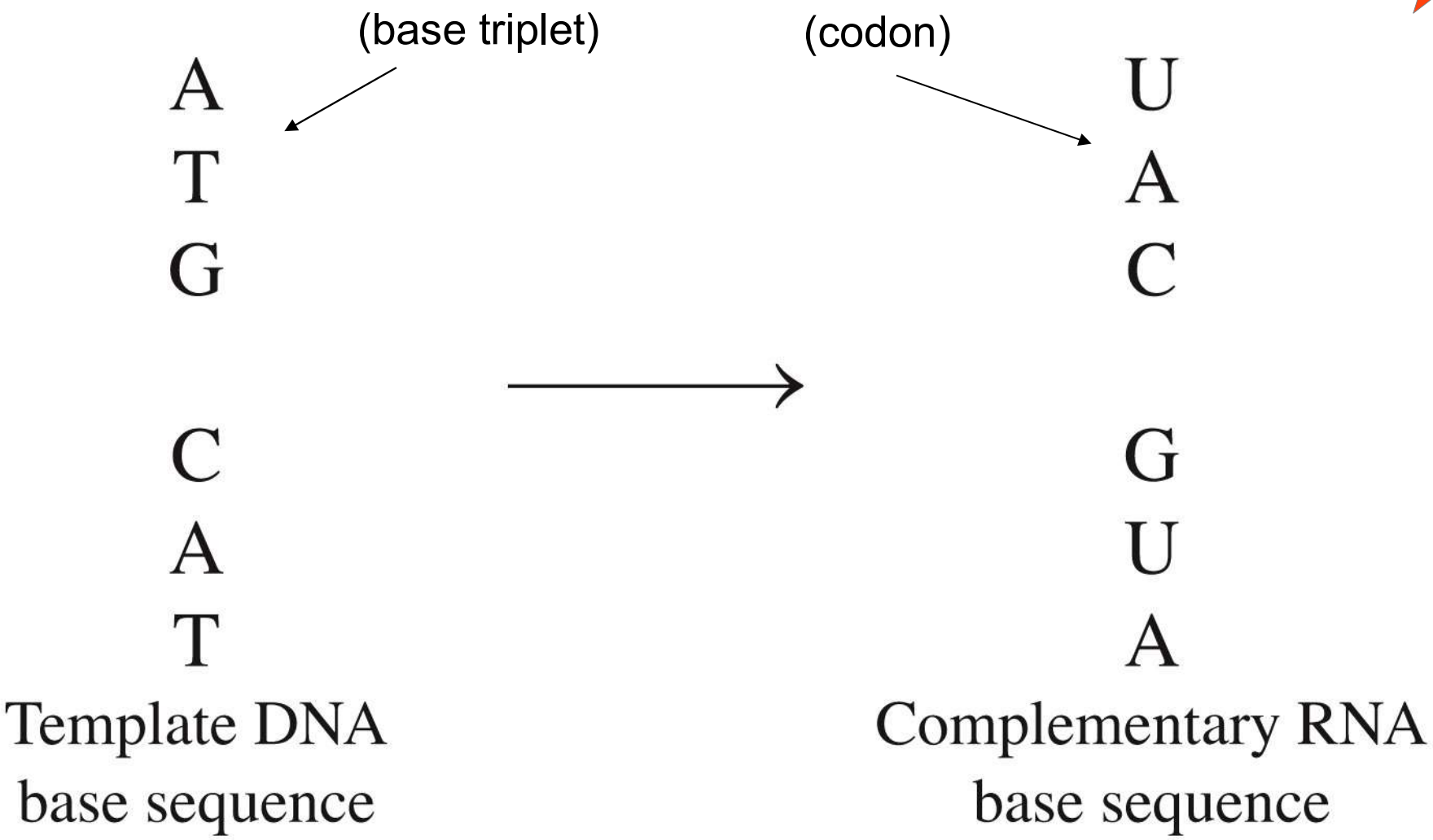
There are 20 amino acids. These are the “building blocks” of protein sysntesis. We use these 20 amino acids in unique sequences to make 100,000 different proteins. Some are functional and others are structural.

Functional proteins are enzymes // structural proteins are things like hair or finger nails.

To code for one amino acid the cell needs a sequence of three nucleiotides in the DNA. This is called a base triplet.

The DNA's base triplet is “transcribed” into mRNA. The three nucleiotide sequence in the mRNA is called a condon.

Transfer RNA (tRNA) is located in the cytoplasm. There are 20 tRNA. Eeach rRNA carries a different amino acid. A three nucleiotide sequence on tRNA complementing the mRNA condon is called the anticodon.



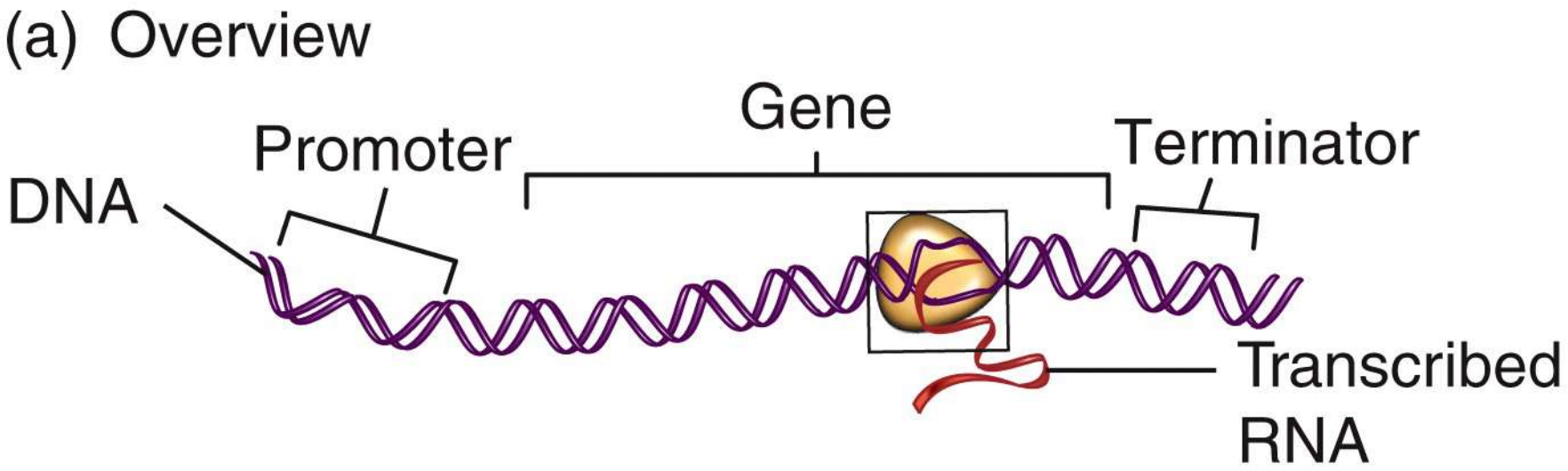
In DNA replication, A binds to T . In making a strand of RNA (making the mRNA) U substitutes for T therefore the DNA's “A” will now hydrogen bond to “U” in the newly forming mRNA

Translation

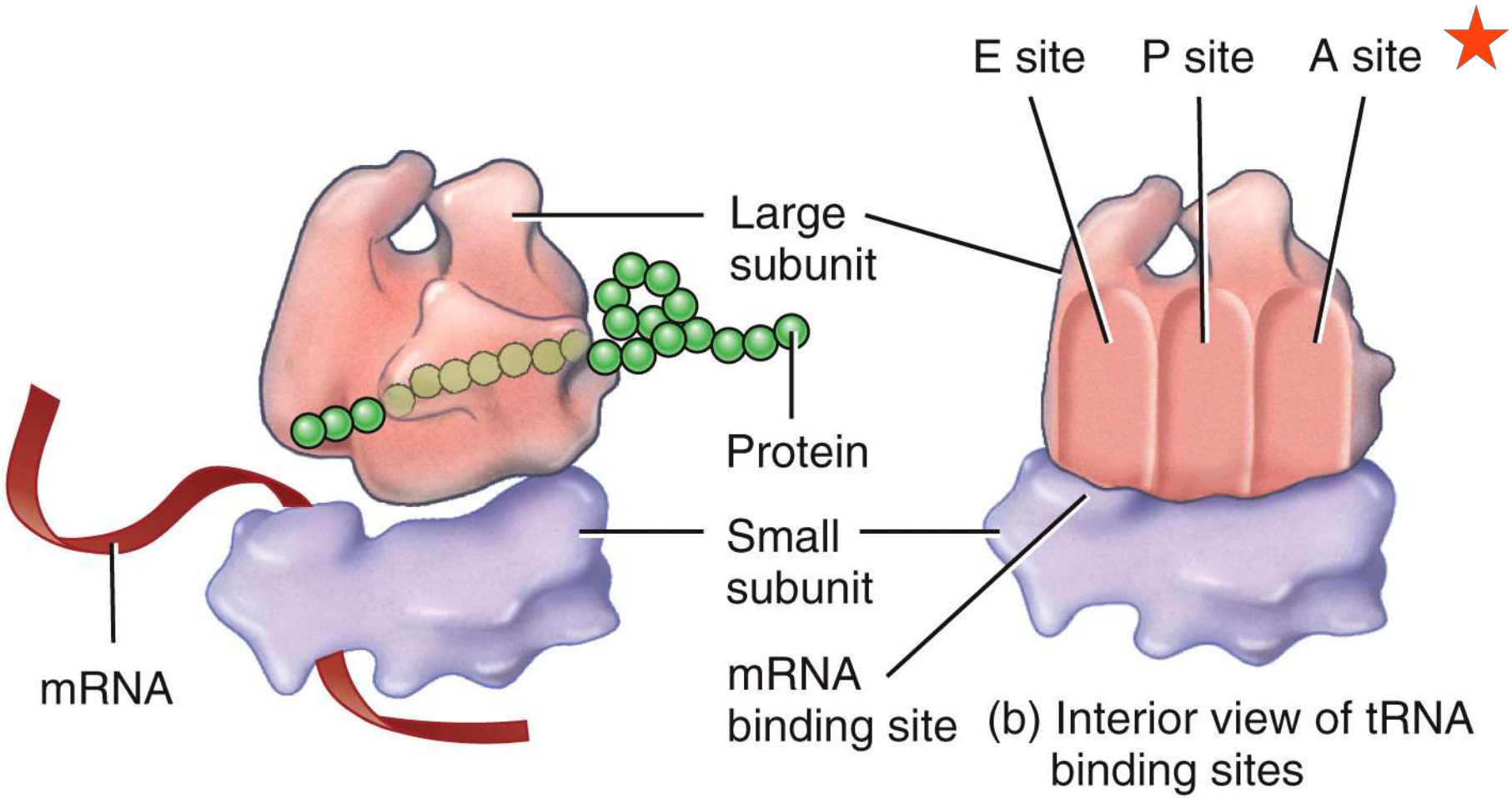
- Process that converts the language of nucleotides into the language of amino acids // occurs in cytoplasm
- Ribosomes (rRNA) = is a docking station for mRNA or a “platform” // this is where the sequence of nucleotides are “decoded” into sequence of amino acids
  - protein sysnthesis occur in cytosol
  - occurs at two different locations within cytosol
  - location determines where protein will be used // either inside cell or outside cell
    - ***on surface of rough ER (rough endoplasmic ribosomes) and nuclear envelope /// these are proteins for export***
    - ***free rRNA in cytoplasm (cytoplasmic ribosomes) // these proteins will be used inside cell***
  - Each ribosome consists of two subunits (large and small rRNA subunits) // and associated enzymes

Protein synthesis requires:

- three forms of RNA: mRNA, rRNA and tRNA
- plus a recipe (the gene on the DNA molecule to mRNA)
- end product of process is a new protein
- protein made will be either structural or functional

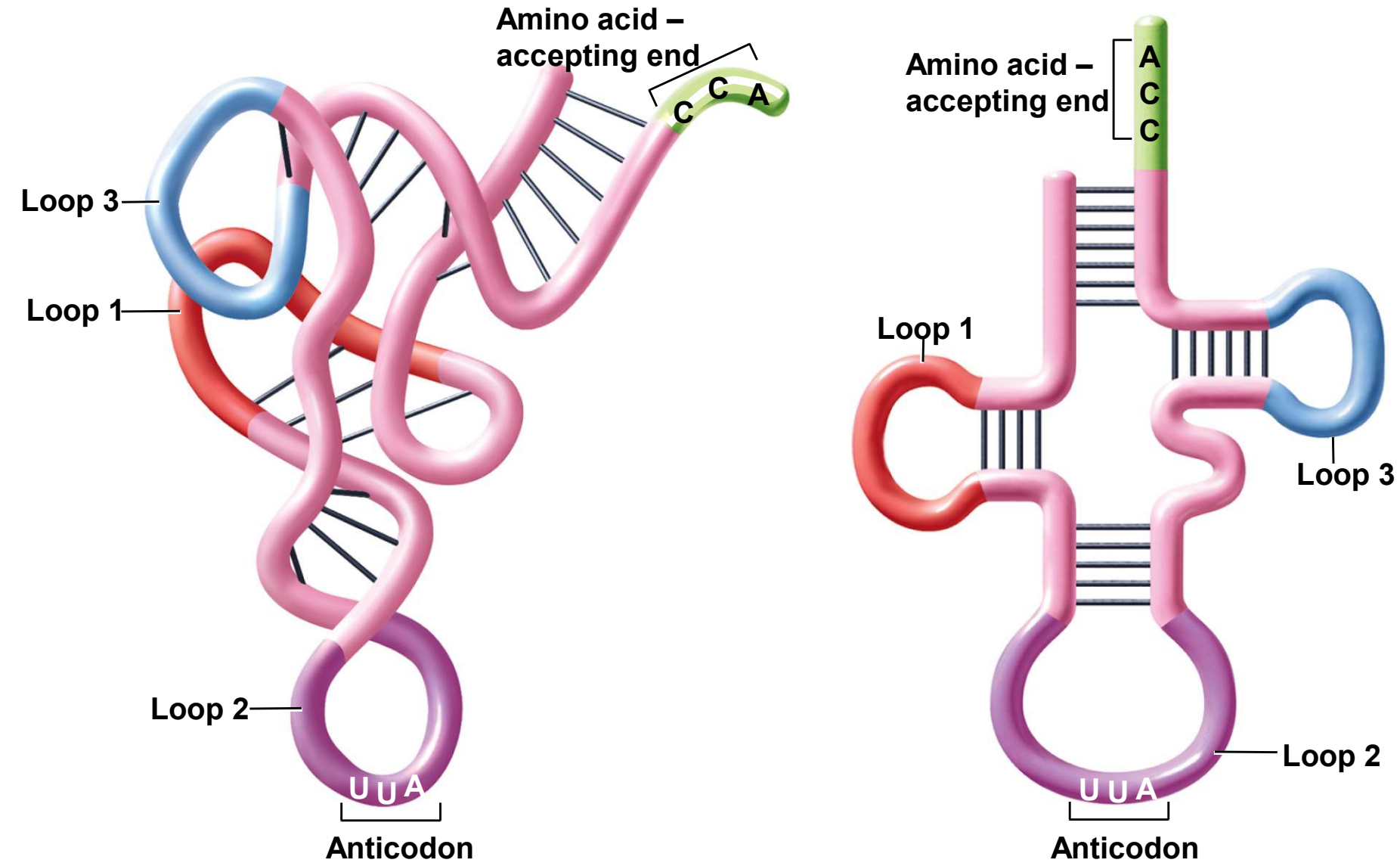


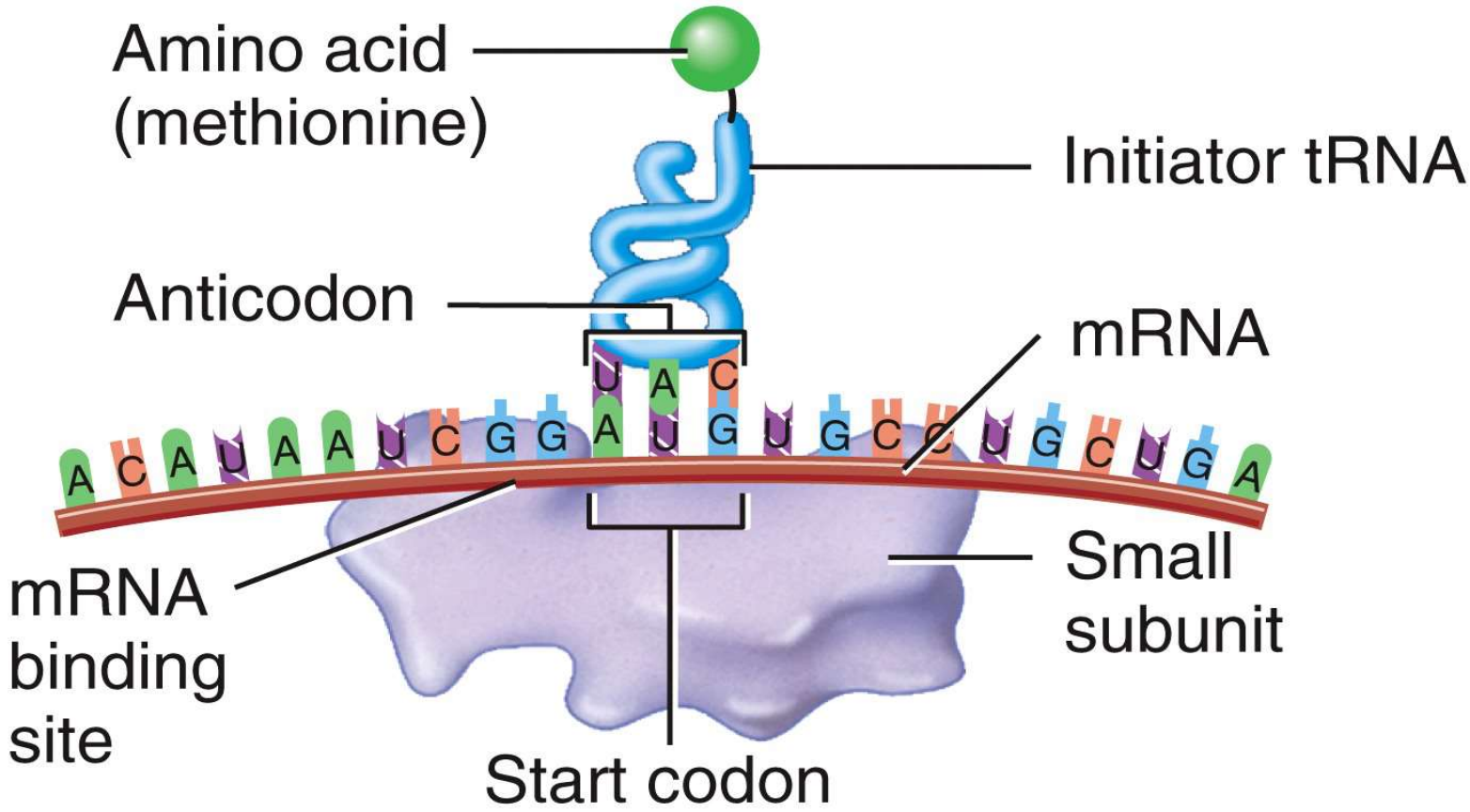
> What is the function of a transcription factor?
> What is the difference beteen a structural and functional protein?
> What is the significance of rRNA location within the cytoplasm?



(a) Components of a ribosome and their relationship to mRNA and protein during translation

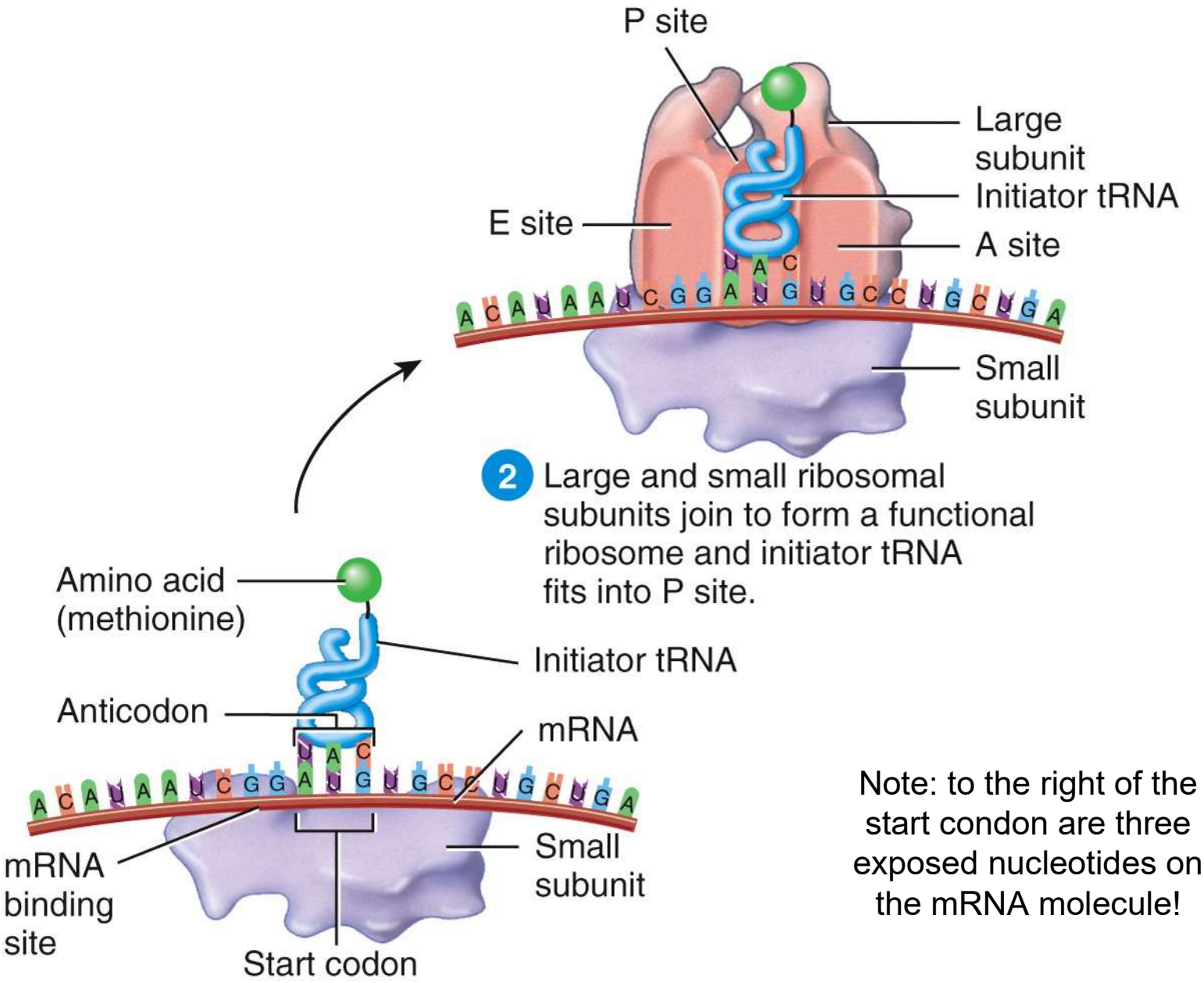
Transfer RNA (tRNA)



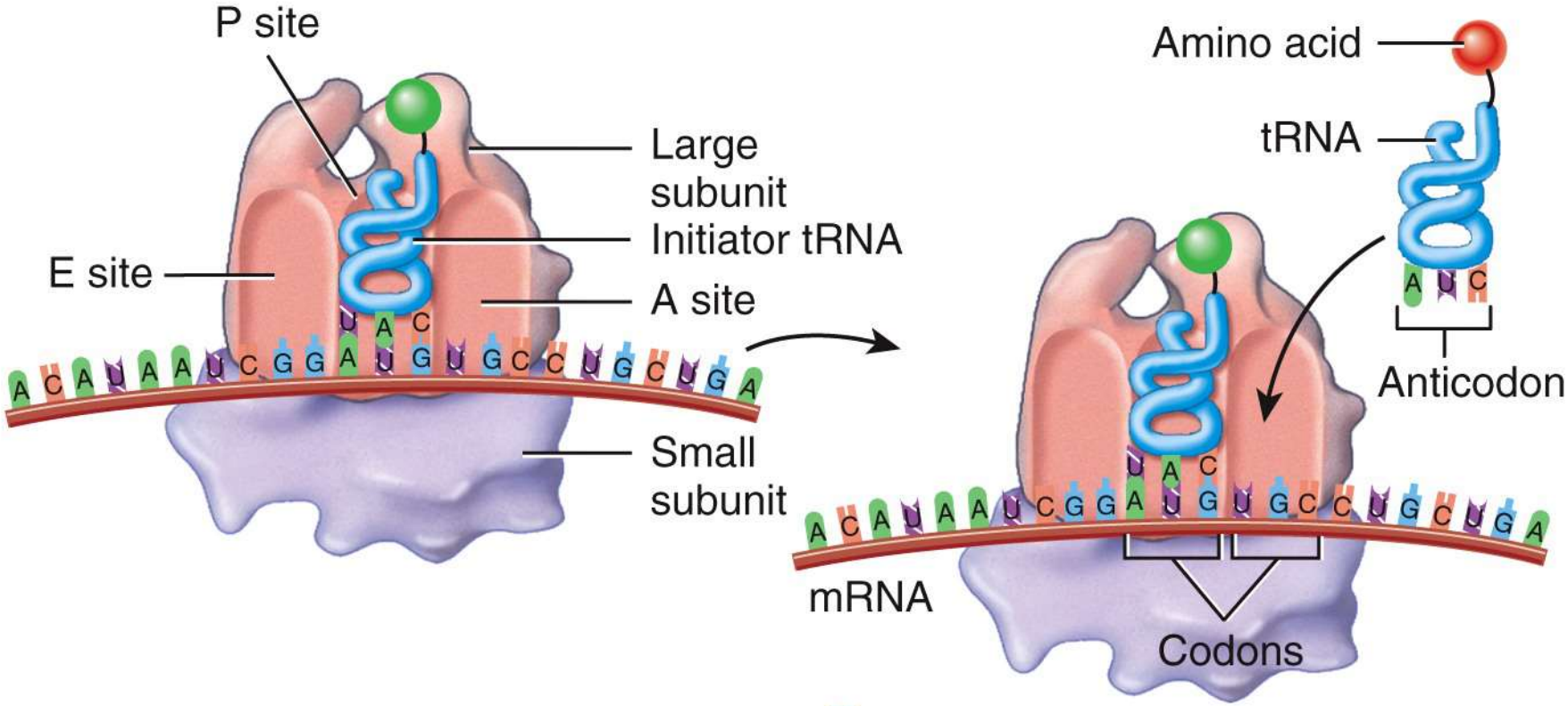


1 Initiator tRNA attaches to a start codon.

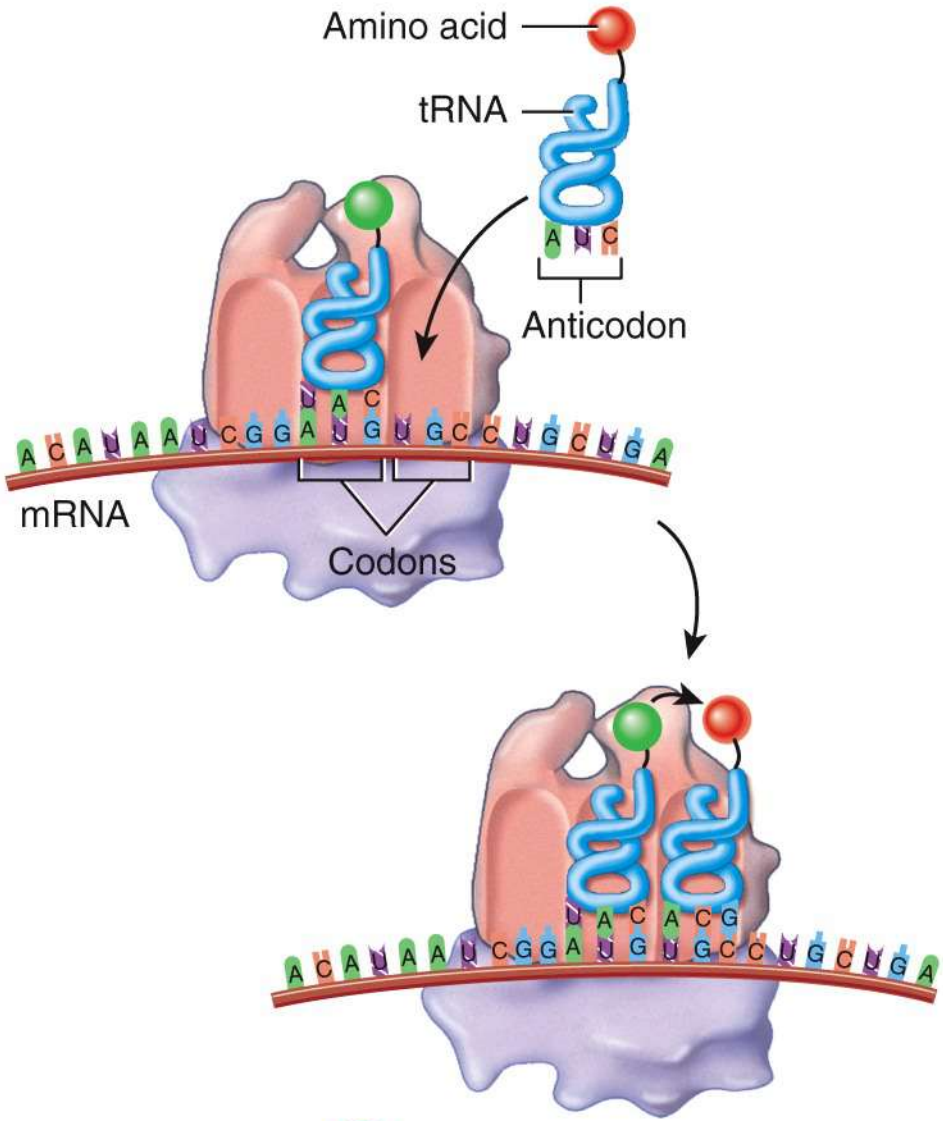
What is a base triplet?



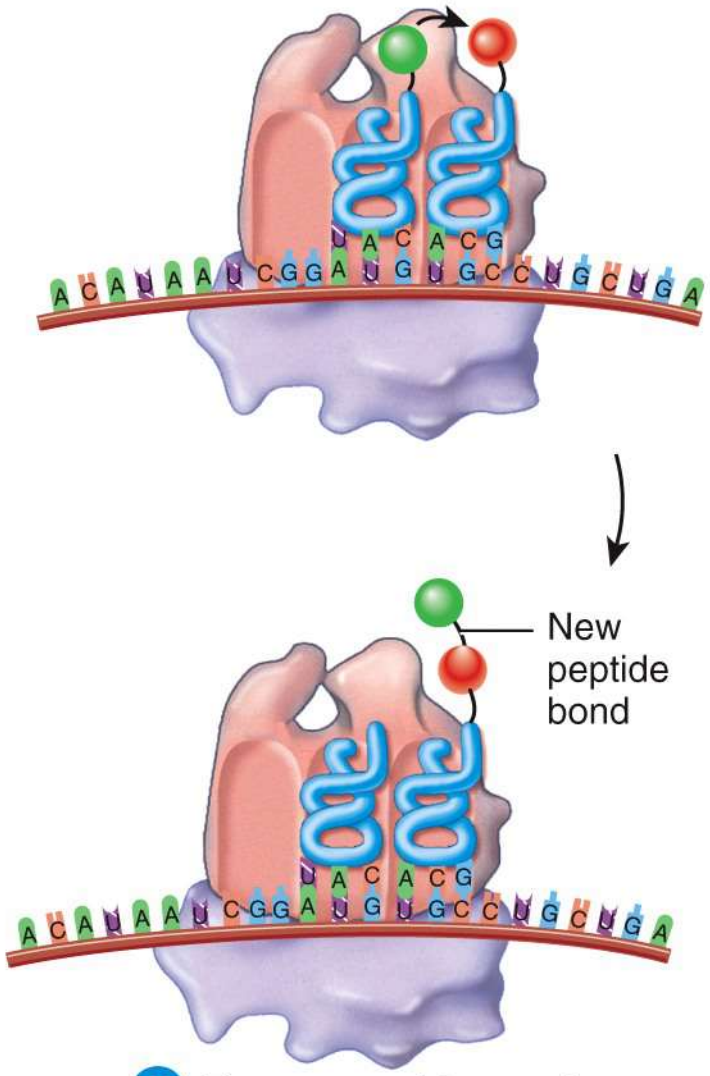
Note: to the right of the start condon are three exposed nucleotides on the mRNA molecule!



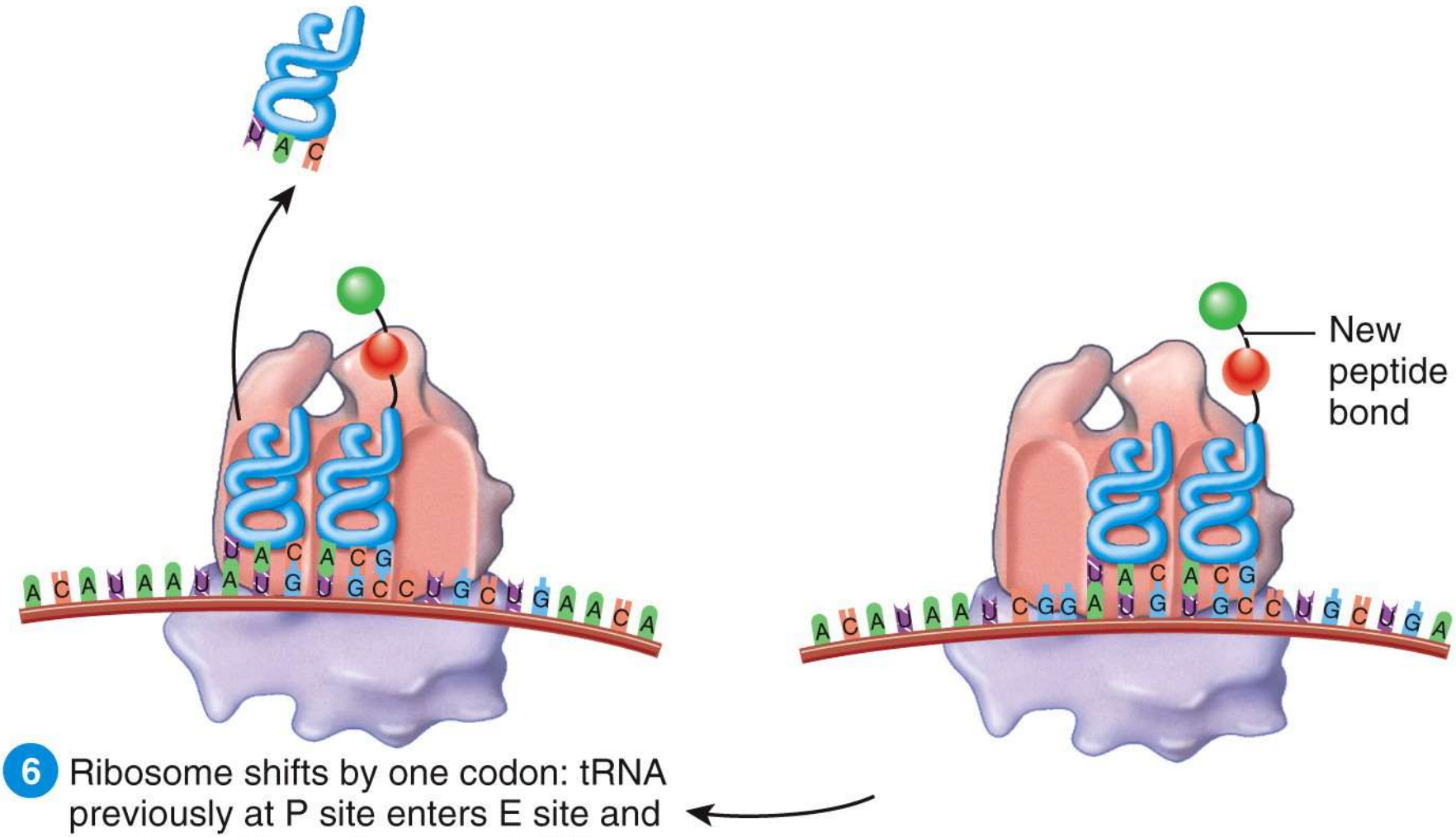
3 Anticodon of incoming tRNA pairs with next mRNA codon at A site.



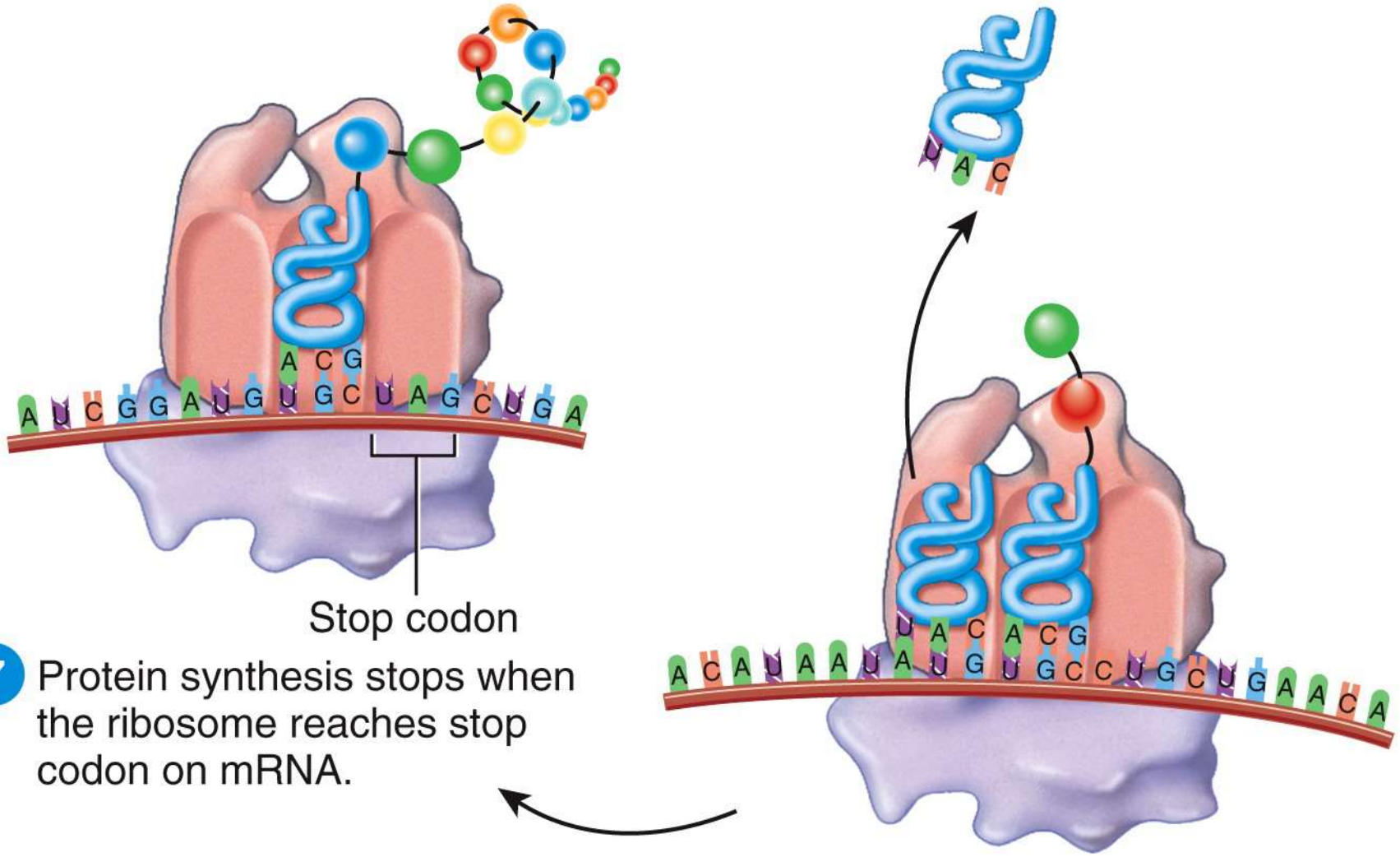
4 Amino acid on tRNA at P site forms a peptide bond with amino acid at A site.



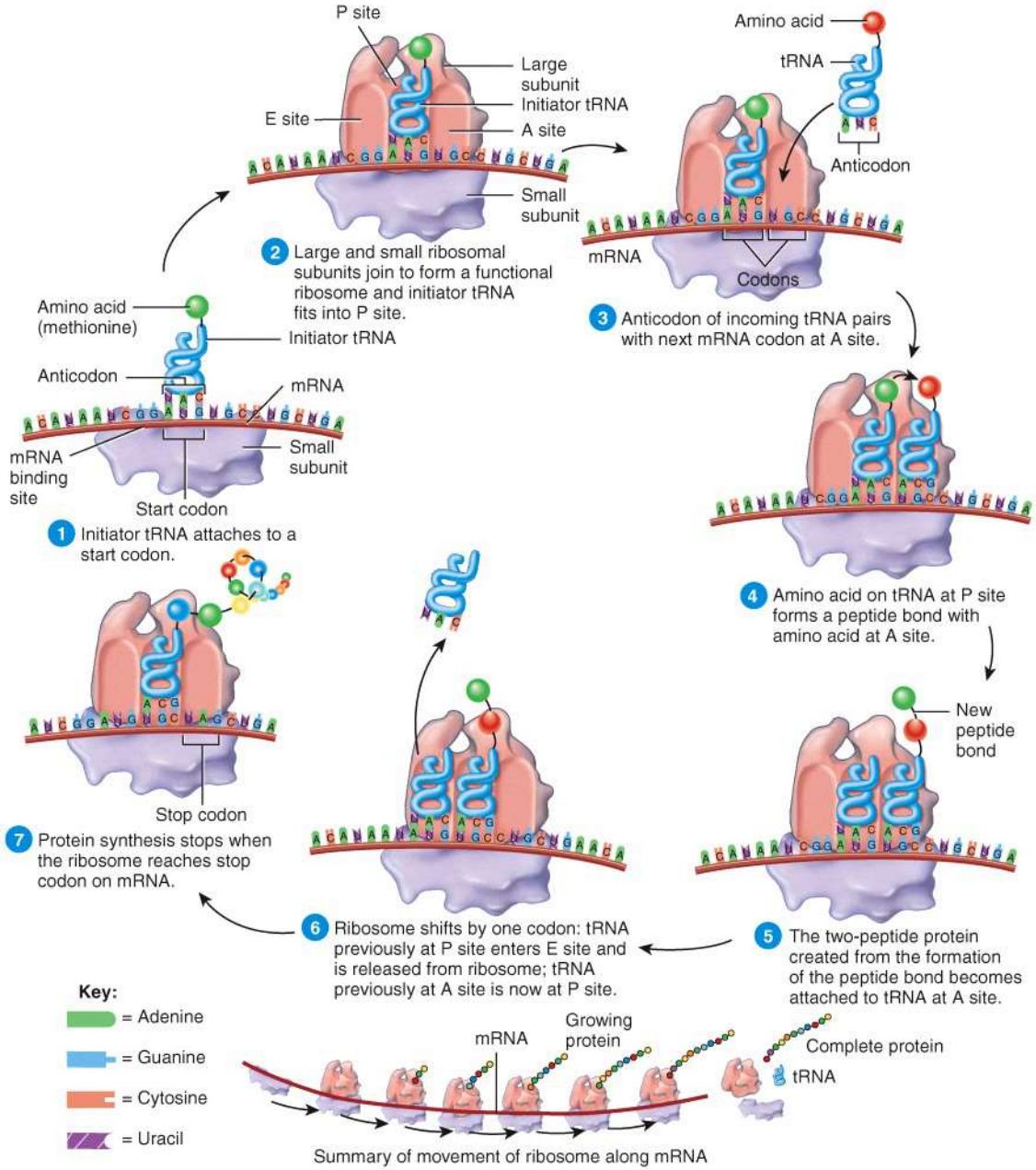
5 The two-peptide protein created from the formation of the peptide bond becomes attached to tRNA at A site.

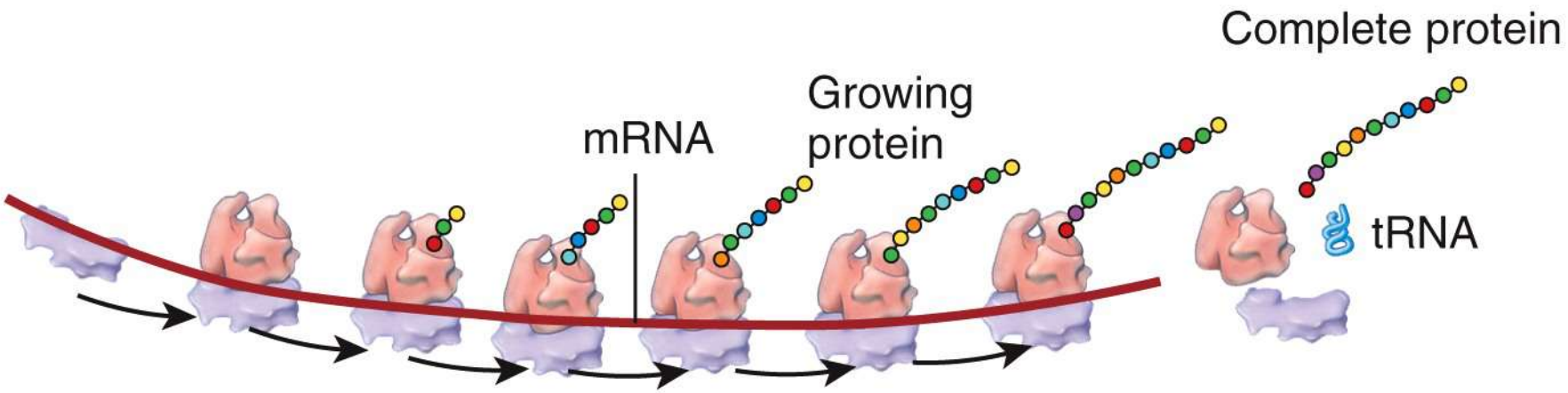


6 Ribosome shifts by one codon: tRNA previously at P site enters E site and is released from ribosome; tRNA previously at A site is now at P site.

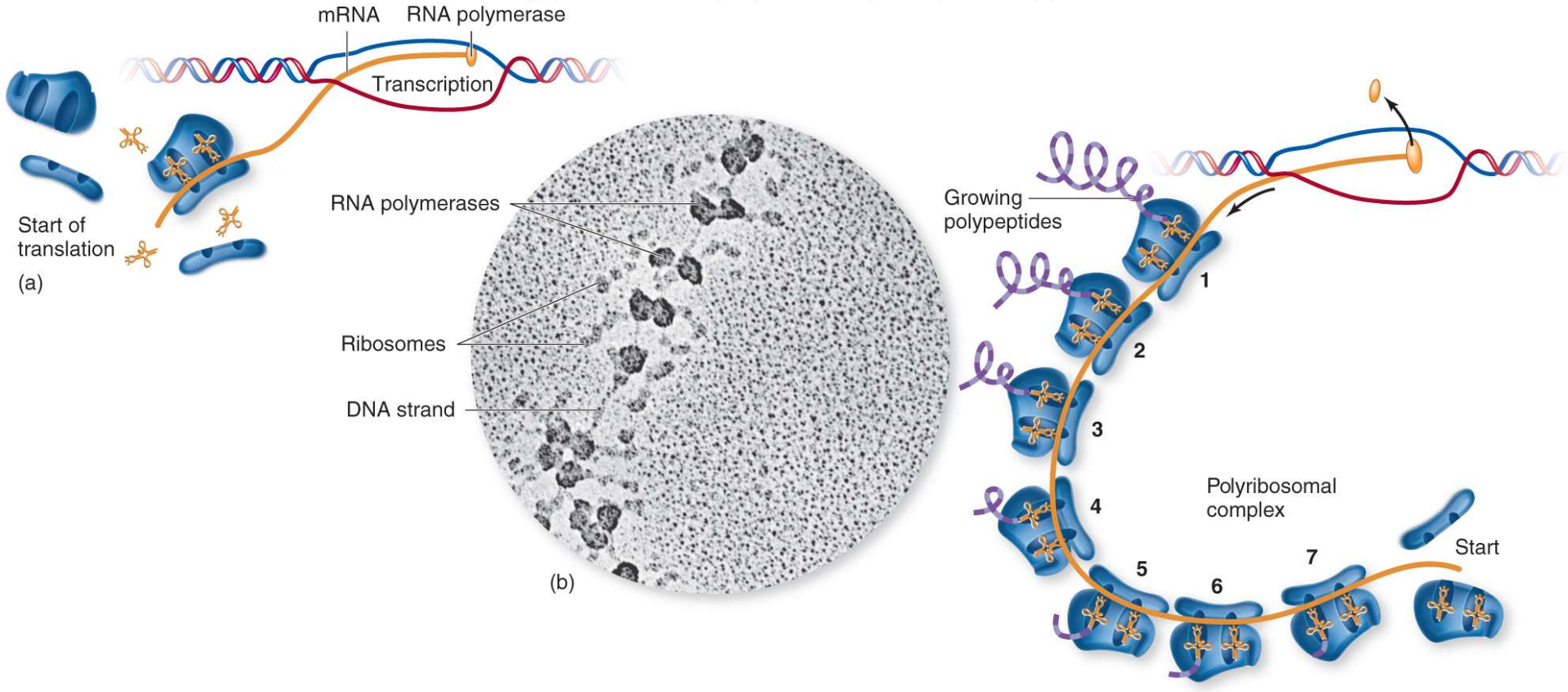


7 Protein synthesis stops when the ribosome reaches stop codon on mRNA.


Amino acid
(methionine)
Initiator tRNA
Anticodon
mRNA
mRNA
binding
site
Small
subunit
Start codon
1 Initiator tRNA attaches to a start codon.
P site
Large
subunit
Initiator tRNA
E site
A site
Small
subunit
2 Large and small ribosomal subunits join to form a functional ribosome and initiator tRNA fits into P site.
Amino acid
tRNA
Anticodon
mRNA
Codons
3 Anticodon of incoming tRNA pairs with next mRNA codon at A site.
4 Amino acid on tRNA at P site forms a peptide bond with amino acid at A site.
New
peptide
bond
5 The two-peptide protein created from the formation of the peptide bond becomes attached to tRNA at A site.
6 Ribosome shifts by one codon: tRNA previously at P site enters E site and is released from ribosome; tRNA previously at A site is now at P site.
Stop codon
7 Protein synthesis stops when the ribosome reaches stop codon on mRNA.
Key:
= Adenine
= Guanine
= Cytosine
= Uracil
mRNA
Growing
protein
Complete protein
tRNA
Summary of movement of ribosome along mRNA



Summary of movement of ribosome along mRNA



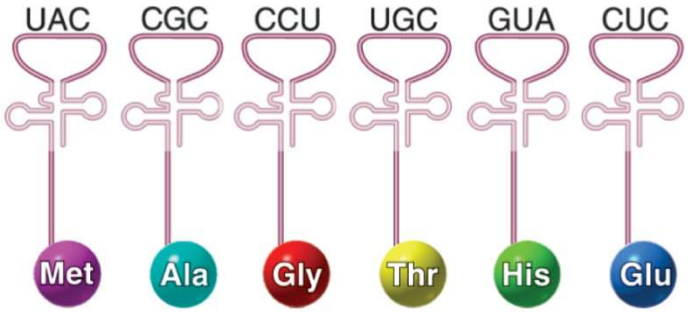
b: Courtesy of Steven McKnight, PhD

How molecular information in a gene is transferred from DNA into protein!

1. DNA double helix

2. Seven base triplets on the template strand of DNA

3. The corresponding codons of mRNA transcribed from the DNA triplets



4. The anticodons of tRNA that bind to the mRNA codons

5. The amino acids carried by those six tRNA molecules

6. The amino acids linked into a peptide chain

Protein Processing and Secretion

- Protein synthesis is not finished when the amino acid sequence (primary structure) has been assembled.

- To be functional it must coil or fold into precise
  secondary and tertiary structure

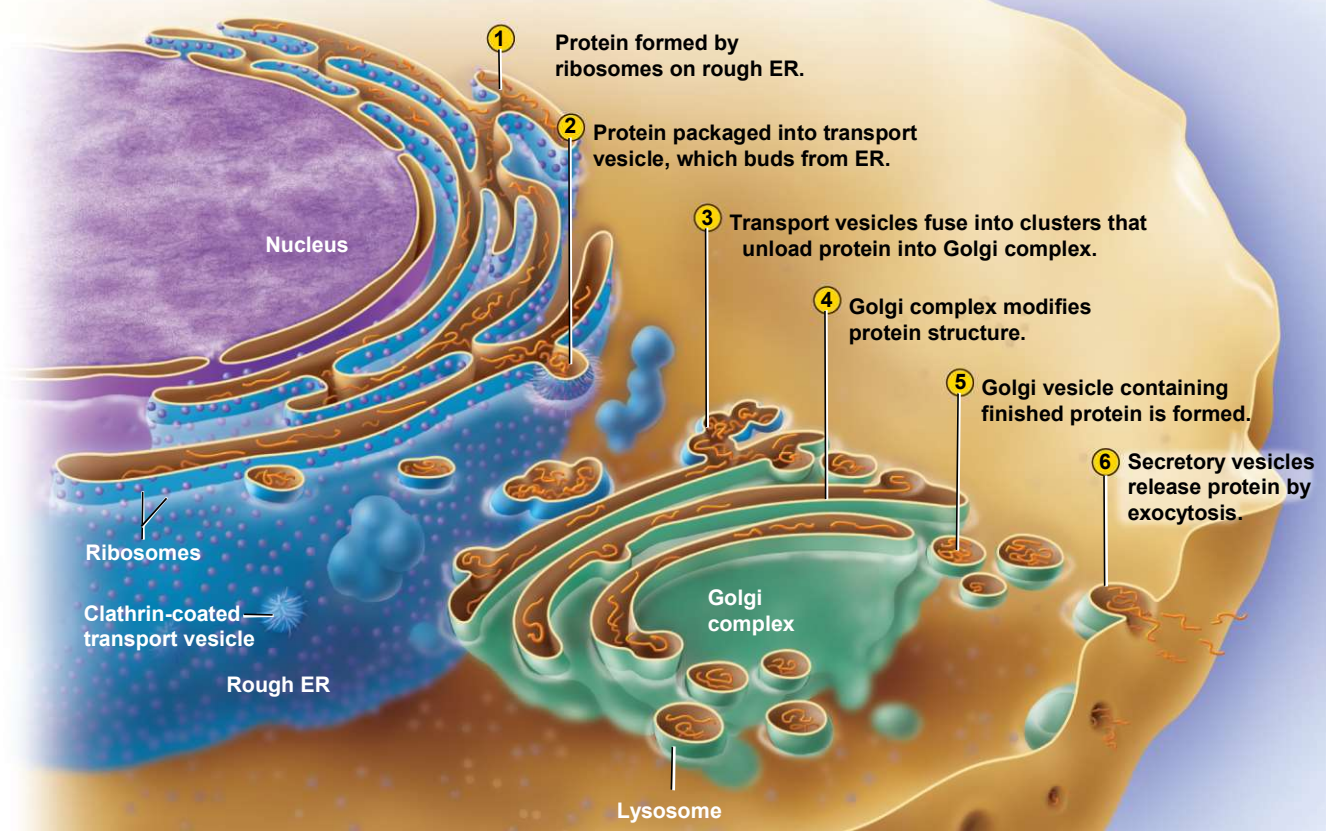
- What is the function of chaperone proteins?

  - These are pre-existing older proteins that complex with new proteins. Chaperone proteins act as a template so new protein folds into the proper shapes

  - Helps to prevent improper association between different proteins

  - Also called stress proteins or heat-shock proteins
    - chaperones produced in response to heat or stress
    - help damaged protein fold back into correct functional shapes

Secretory Proteins Site of Modification, Packaging and Exocytosis



Note: Cytoplasmic ribosomes make proteins to be used inside cell // endoplasmic reticulum ribosomes make proteins to be used in extracellular space