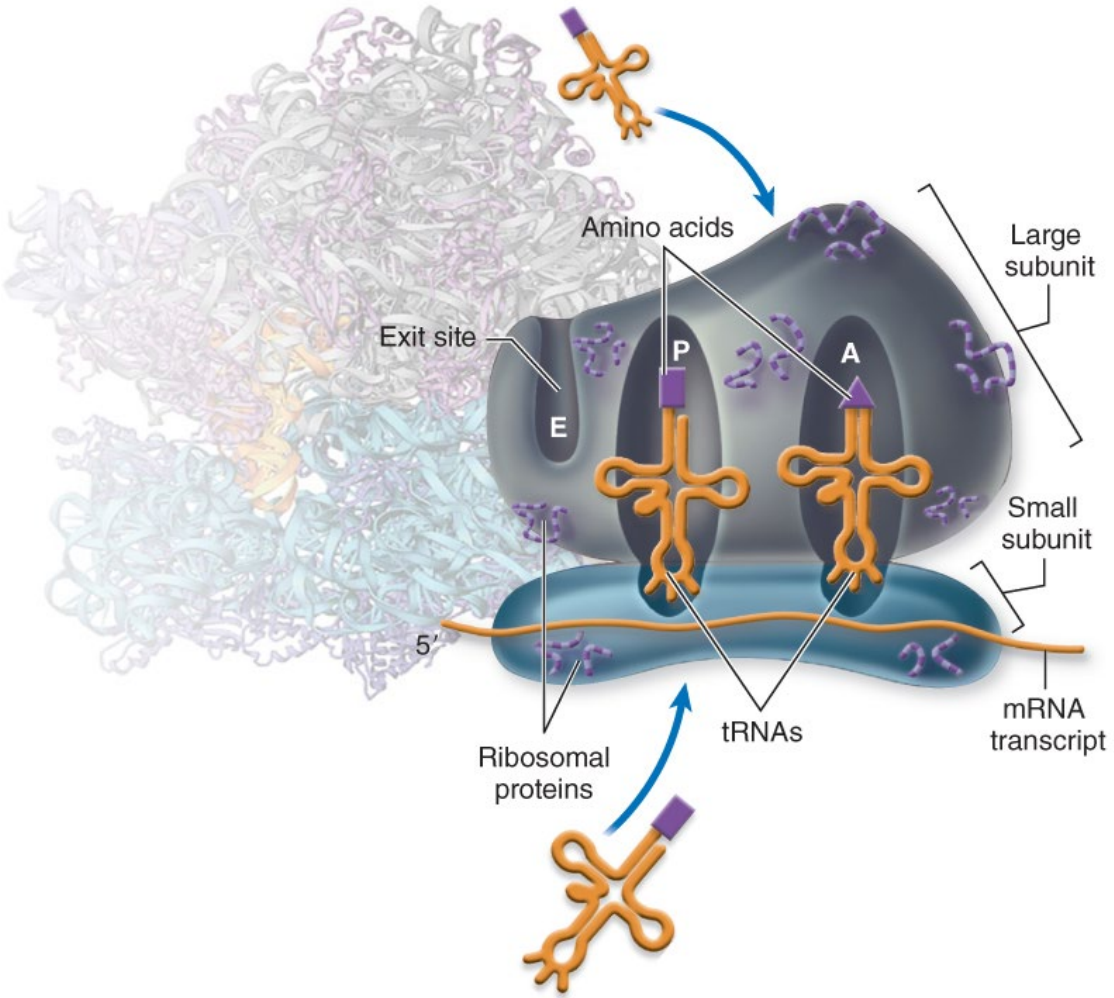
C4.2
Protein Synthesis



Protein Synthesis

How molecular information is transferred from a gene to a protein

DNA ⟶ mRNA ⟶ Protein

Transcription – the step from **DNA** to **mRNA** // This occurs in the nucleus where DNA is located

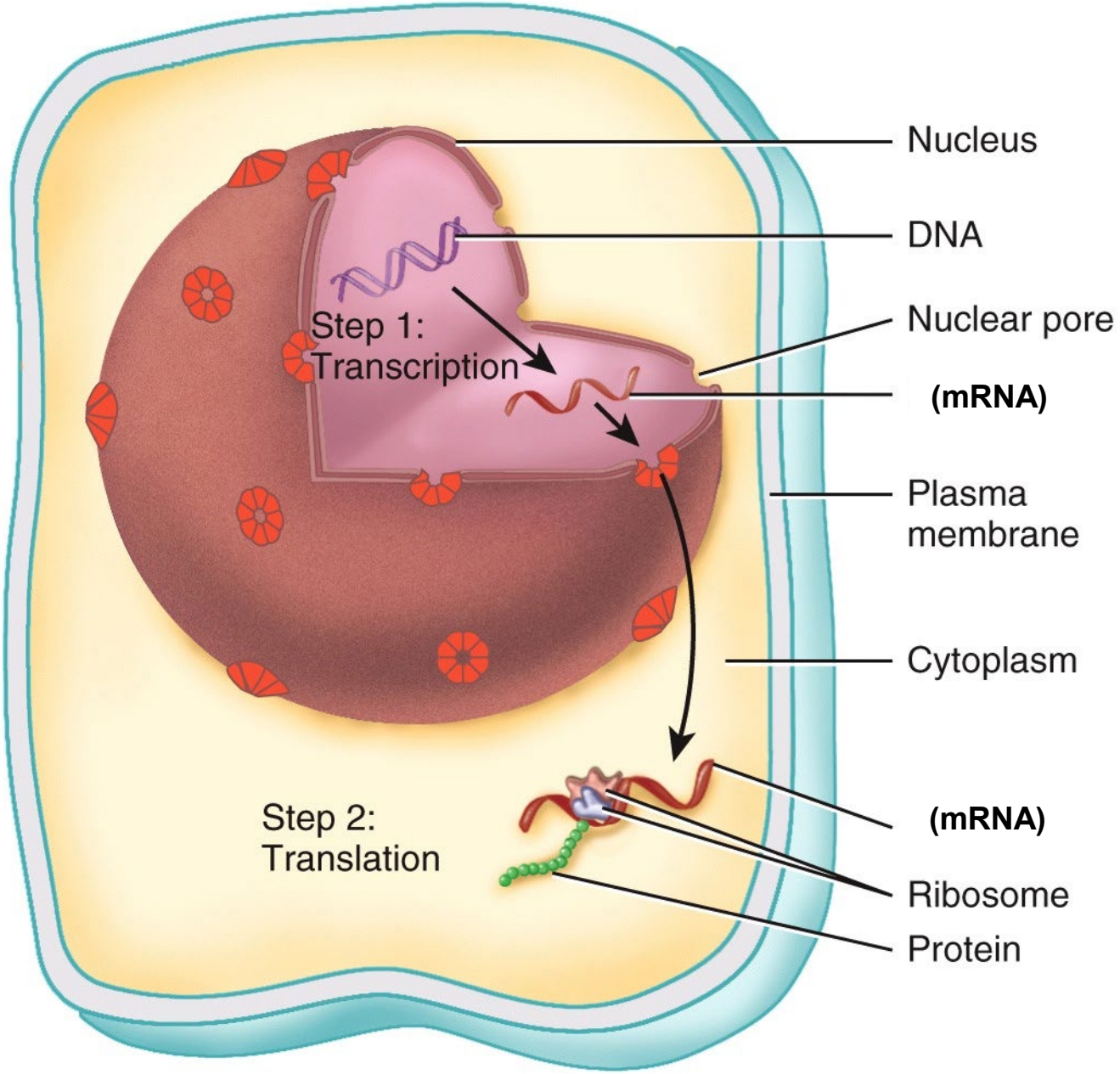
Transcription factors = these are molecules used to "turn on or turn off" gene transcription // regulators of mRNA synthesis /// e.g. micro-RNAs are transcription factors // e.g. change metabolism of mammary gland to make milk

Epigenetics = an environmental factors able to influence transcription

Translation – the step from **mRNA** to **protein** // This occurs in cytoplasm

Protein synthesis requires ribosomes RNA(rRNA), transfer RNA (tRNA), messenger RNA (mRNA) and ATP

(Note: 15-20% of proteins are synthesized nucleolus region inside the nucleus)



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

Transcription

Transcription = copying genetic instructions from DNA to mRNA // this occurs in nucleoplasm

DNA's genes are the “receipt” for making proteins // protein synthesis takes place in the cytoplasm

The DNA molecule is too large to leave nucleus, so the cell makes a mRNA copy of the gene

mRNA migrates through a nuclear pore into the cytoplasm and/or surface of the endoplasmic reticulum

Ribosome binds to mRNA and tRNA brings amino acids to rRNA-mRNA complex

Information Coding Density and Coding Element Terminology

There are 20 amino acids. These are the “building blocks” of protein synthesis

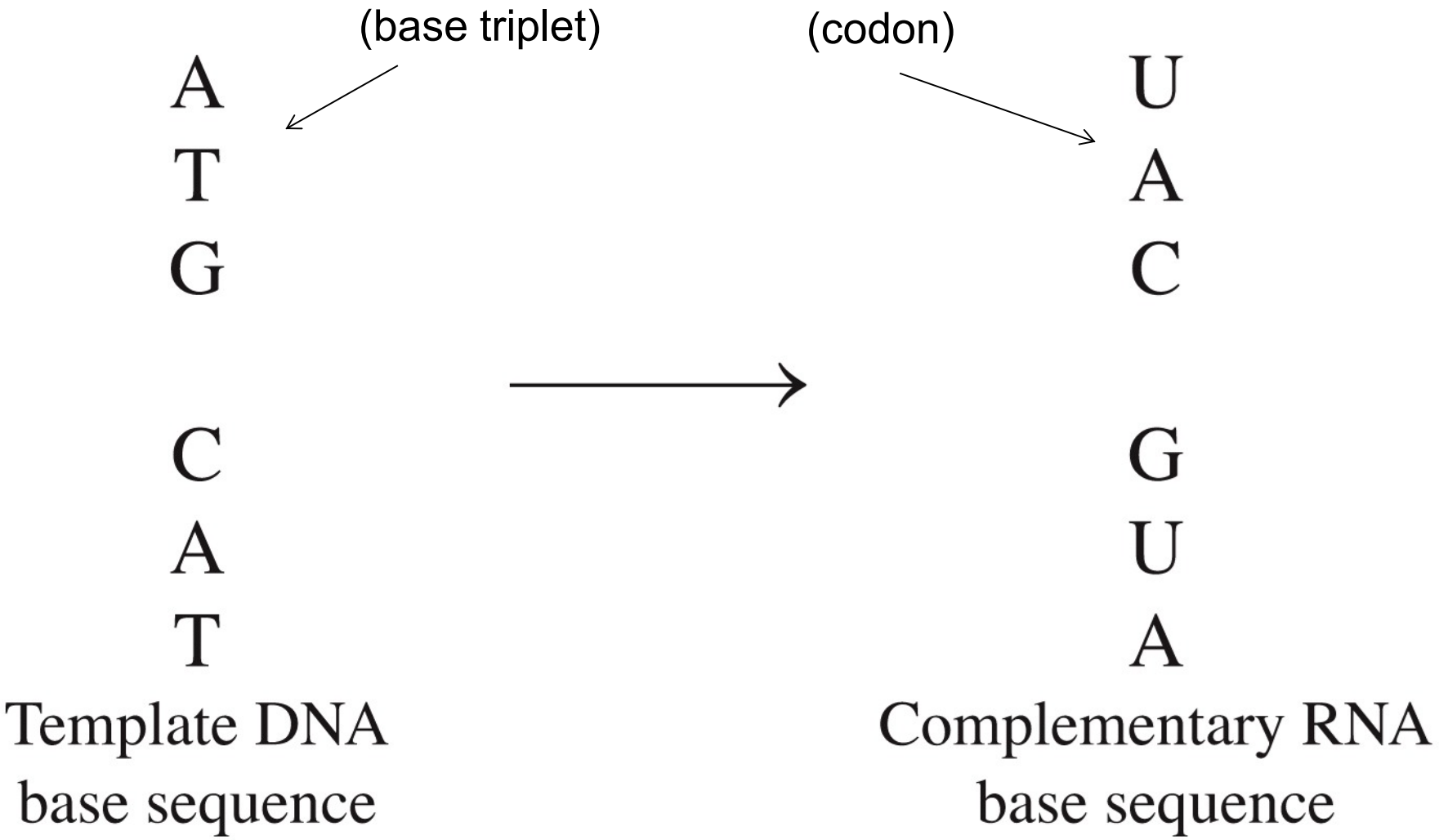
The unique sequence of these 20 amino acids make 100,000 different proteins. Some proteins are functional (enzymes) and other proteins are structural (like hair).

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

The DNA's base triplets are “transcribed” into mRNA. The three-nucleotide sequence in the mRNA is called a condon.

Transfer RNA (tRNA) is in the cytoplasm. There are 20 tRNA. Each rRNA carries a different amino acid. A three nucleotide sequence on tRNA that “complements” the mRNA codon is called the anticodon.

This entire process depends on the law complimentary base pairing



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. If you see a U in a nucleic acid, then you know it is RNA.

Translation

Converts the language of nucleotides into the language of amino acids // occurs in cytoplasm

Ribosomes (rRNA) is a docking station for mRNA (ribosomes are the “platform” where proteins are made) // this is where the sequence of nucleotides are “decoded” into a sequence of amino acids

Protein synthesis occur in cytosol // May occur at two different locations within the cytosol // location will determine where protein will be used // either inside cell or outside cell

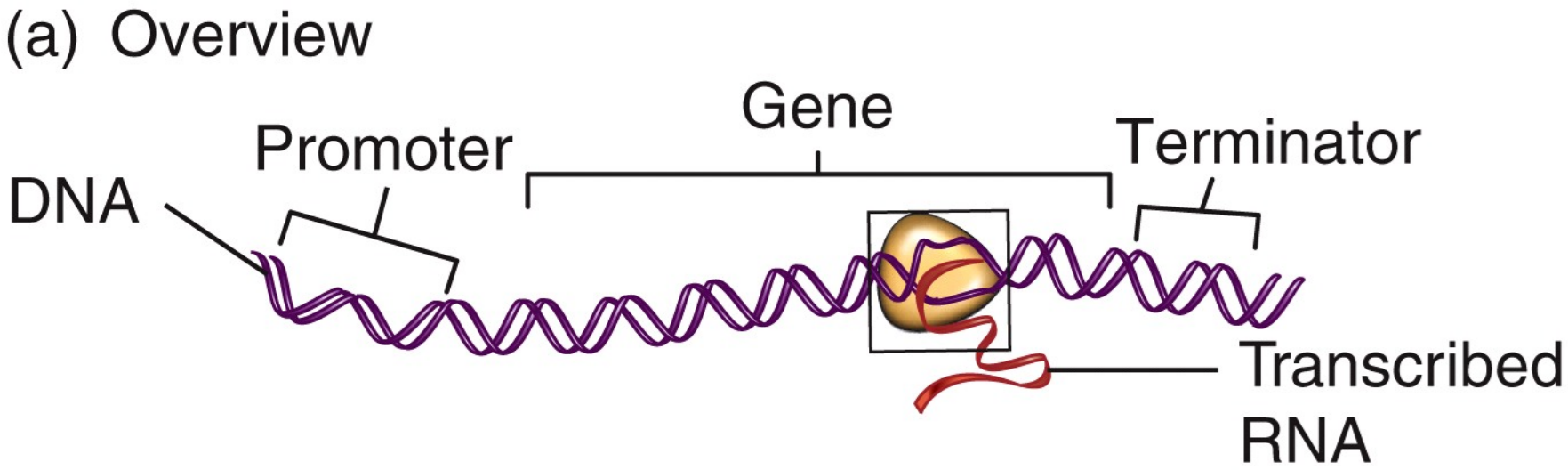
On surface of rough ER (rough endoplasmic ribosomes) and nuclear envelope /// these are proteins for export

Free rRNA in cytoplasm (cytoplasmic ribosomes) // these proteins will be used inside cell

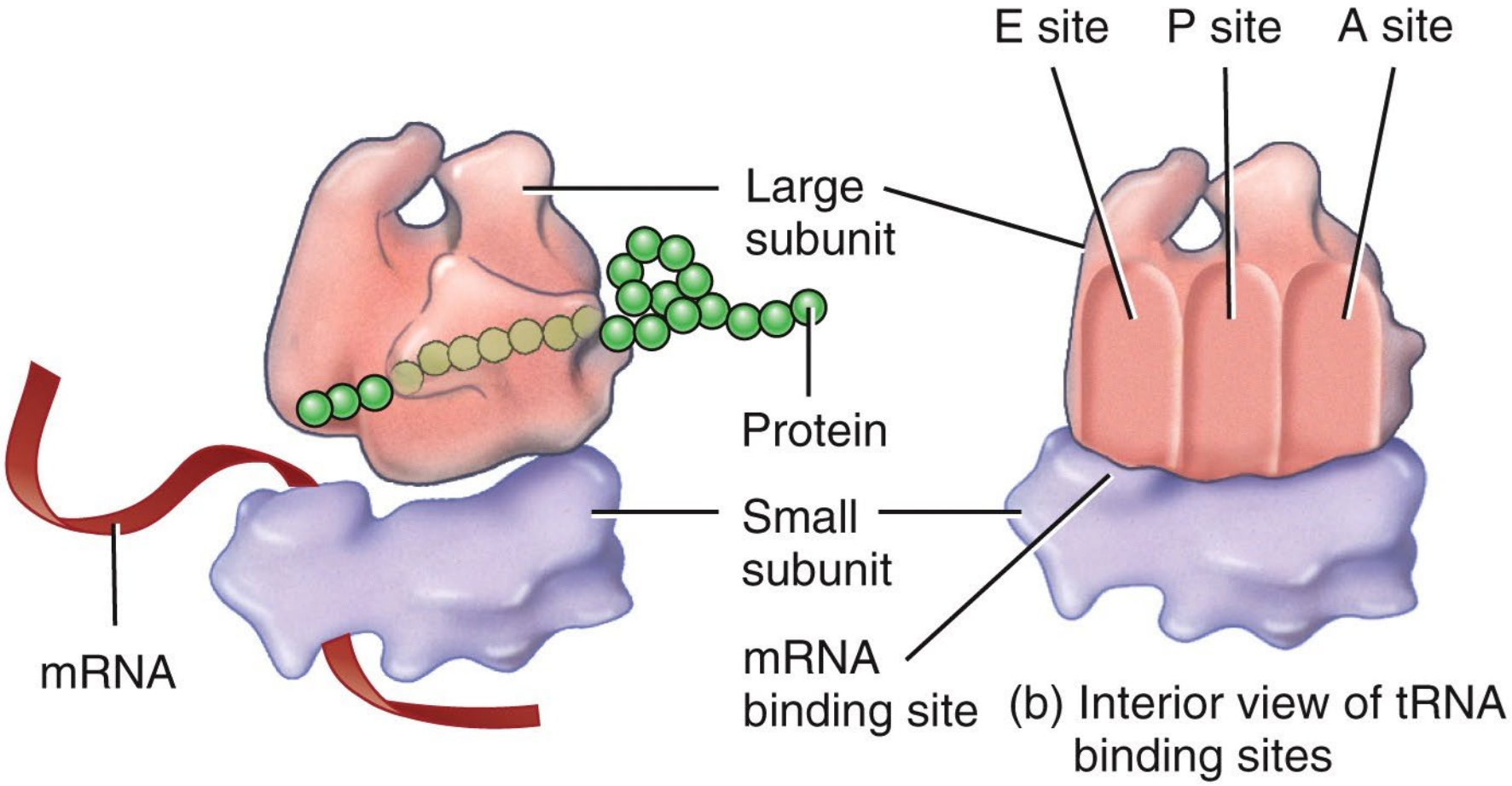
Each ribosome consists of two subunits (large and small rRNA subunits)

Protein synthesis requires:

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



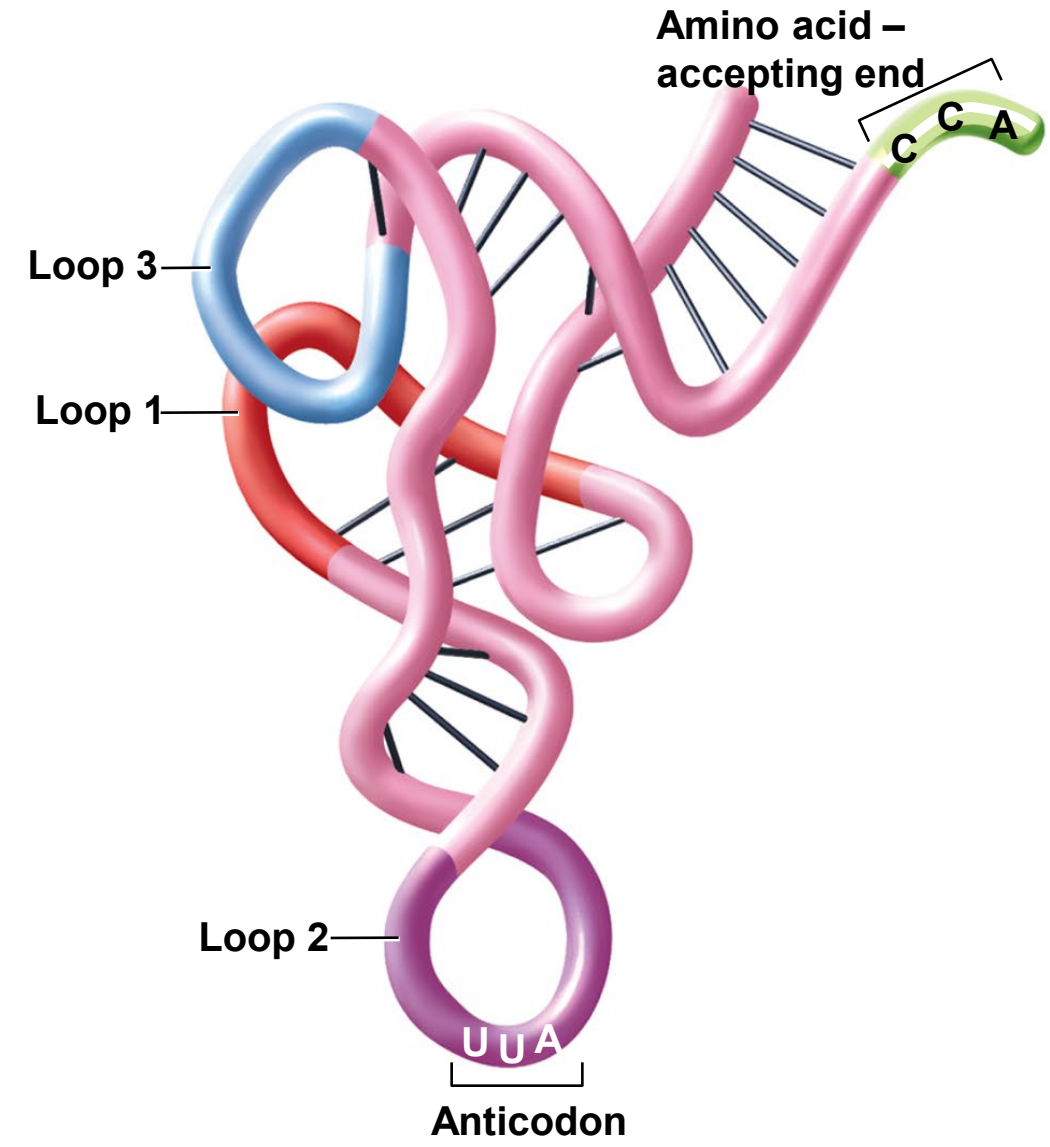
> What is the function of a transcription factor?
> What is the difference between a structural and functional protein?
> What is the significance of rRNA location within the cytoplasm?

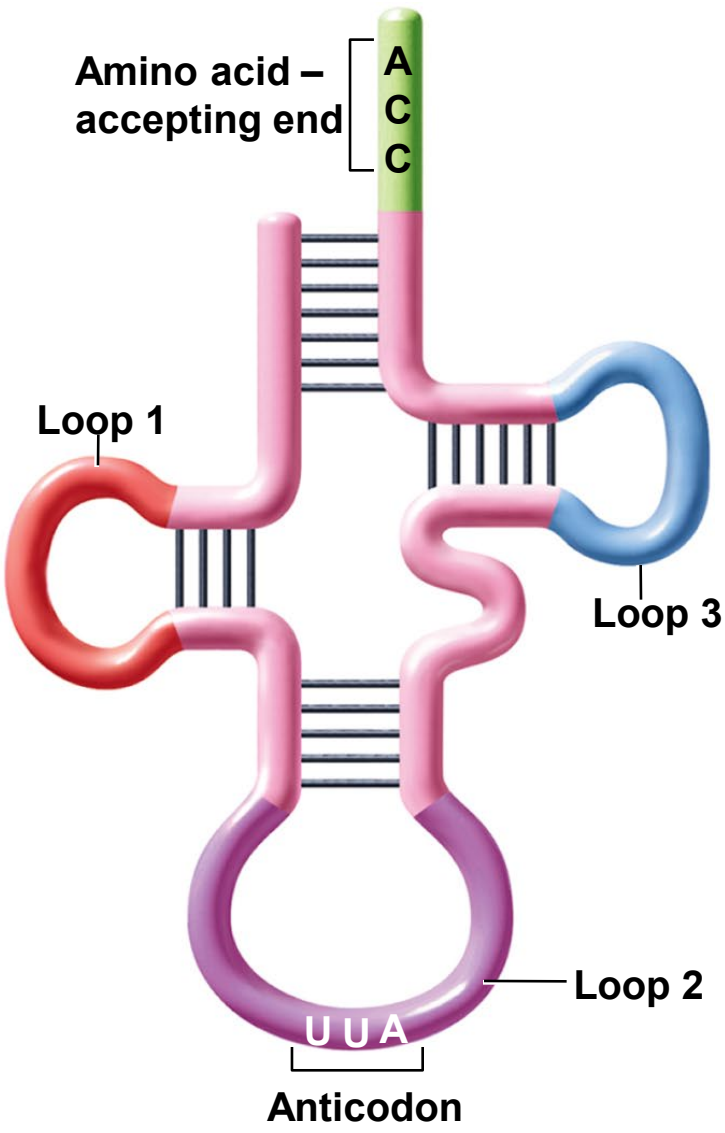


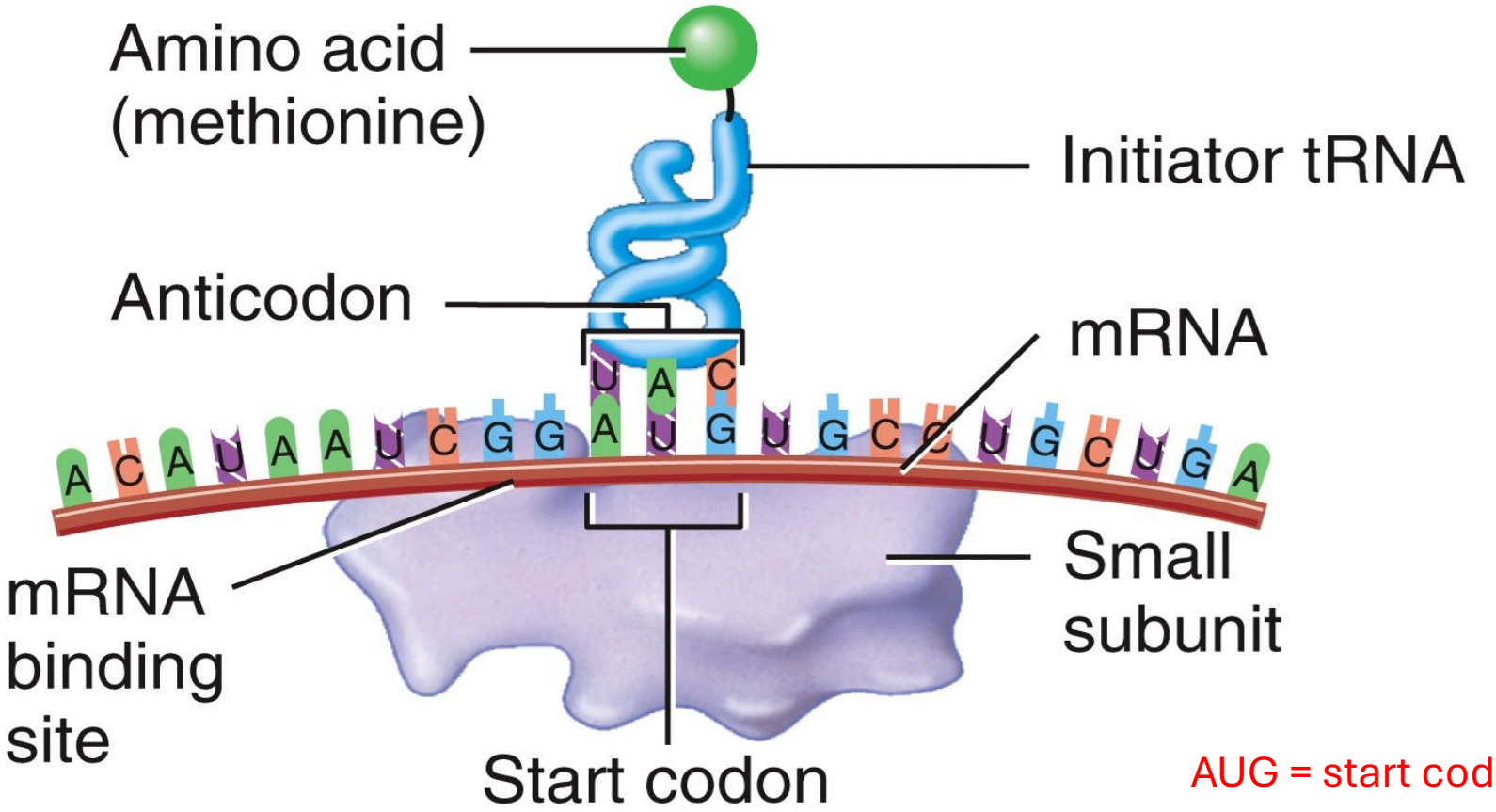
(a) Components of a ribosome and their relationship to mRNA and protein during translation

E = exit site
P = poly peptide site
A = tRNA amino acid site

Transfer RNA (tRNA)

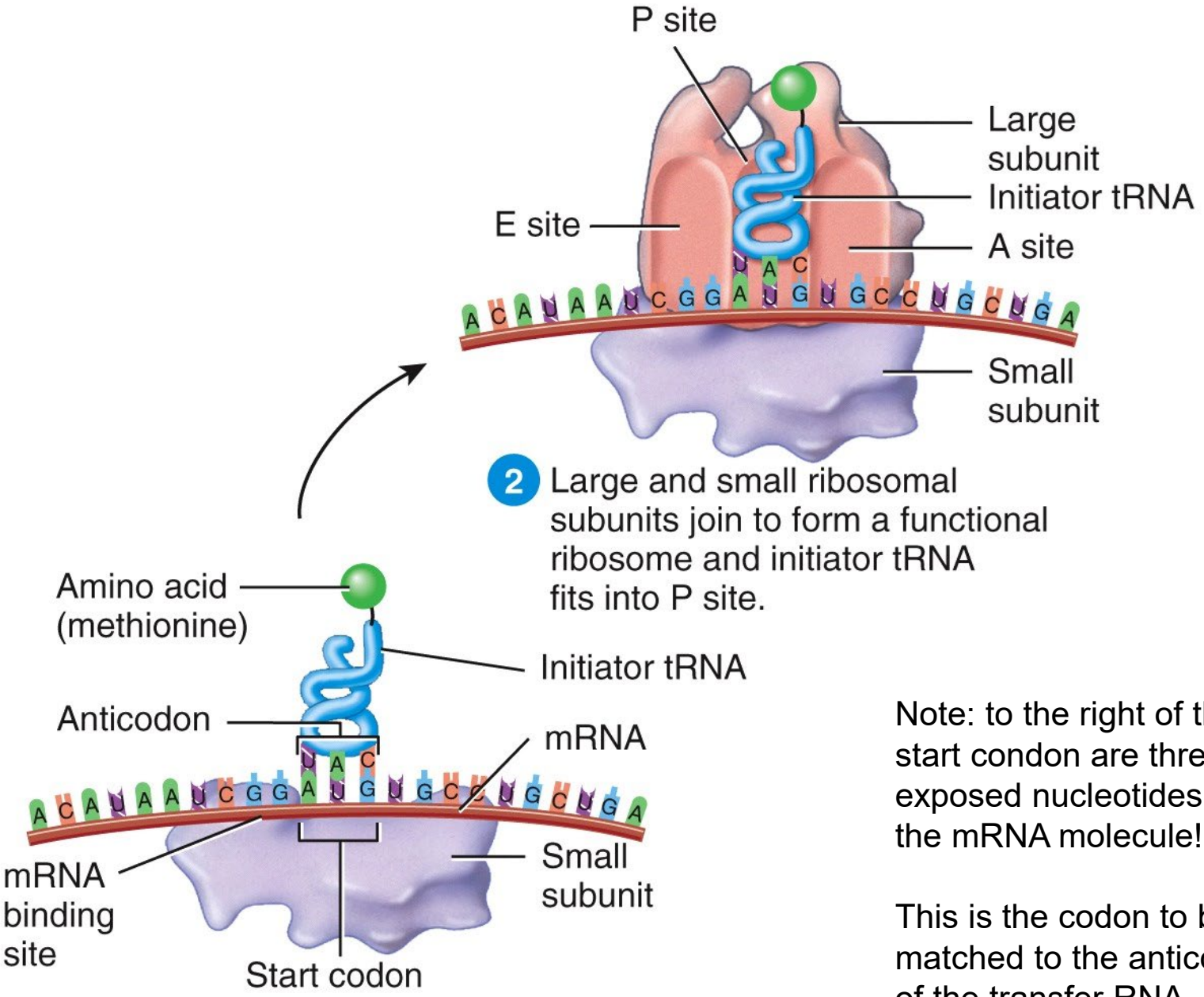






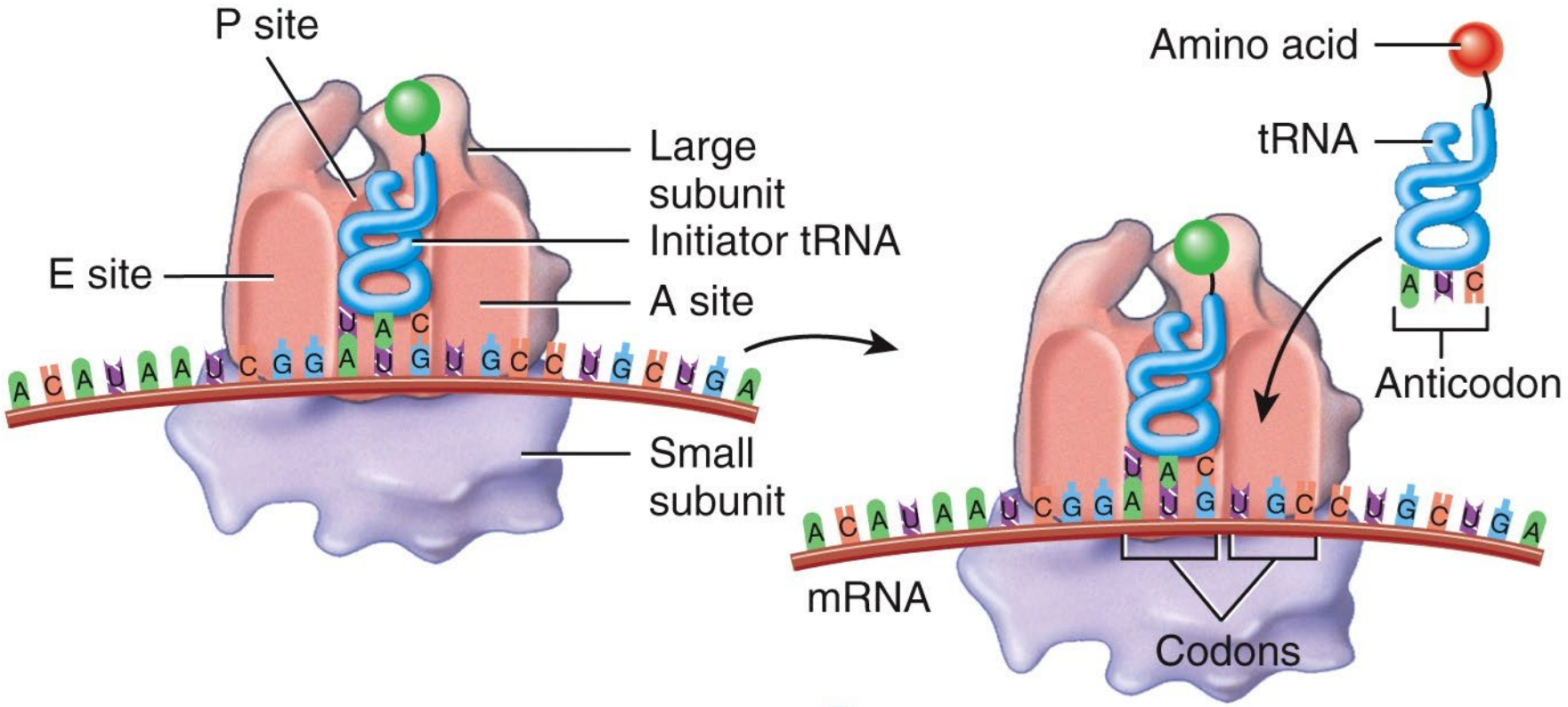
AUG = start codon

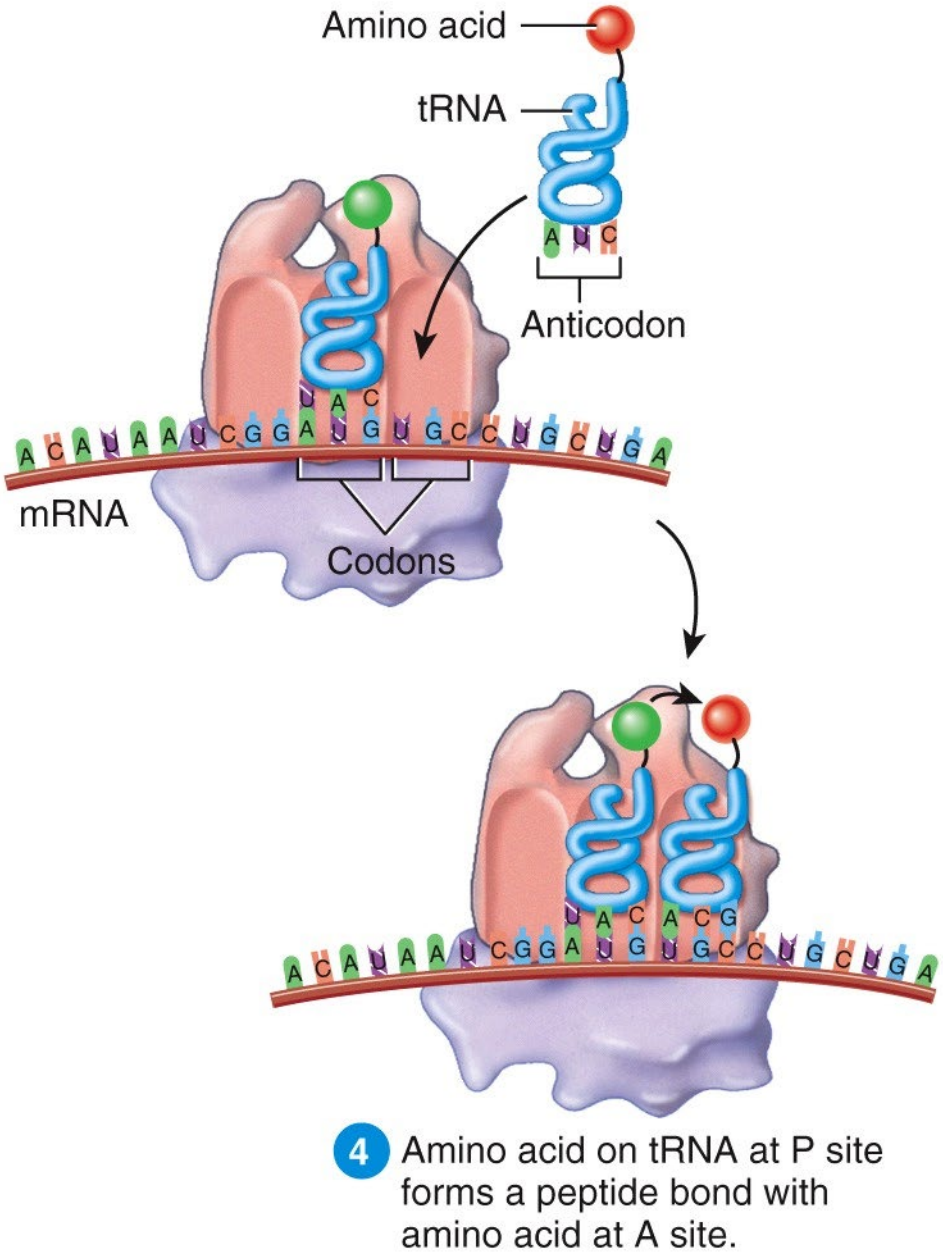
What is a base triplet?



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

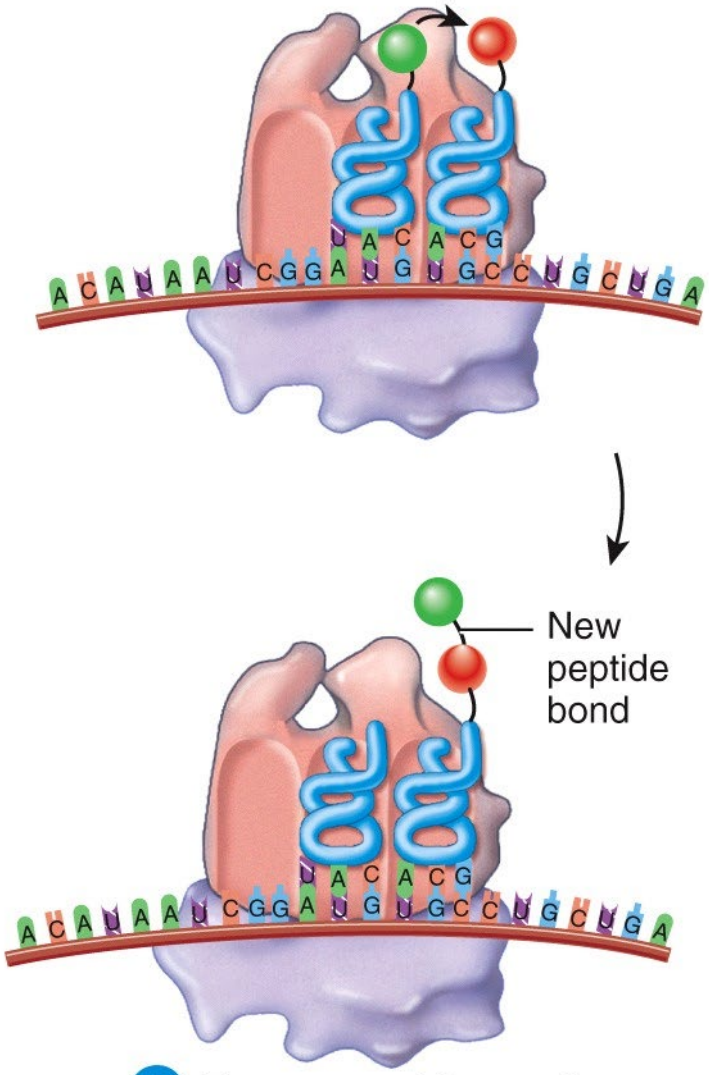
This is the codon to be matched to the anticodon of the transfer RNA.


P site
E site
Large subunit
Initiator tRNA
A site
Small subunit
Amino acid
tRNA
Anticodon
mRNA
Codons
3 Anticodon of incoming tRNA pairs with next mRNA codon at A site.



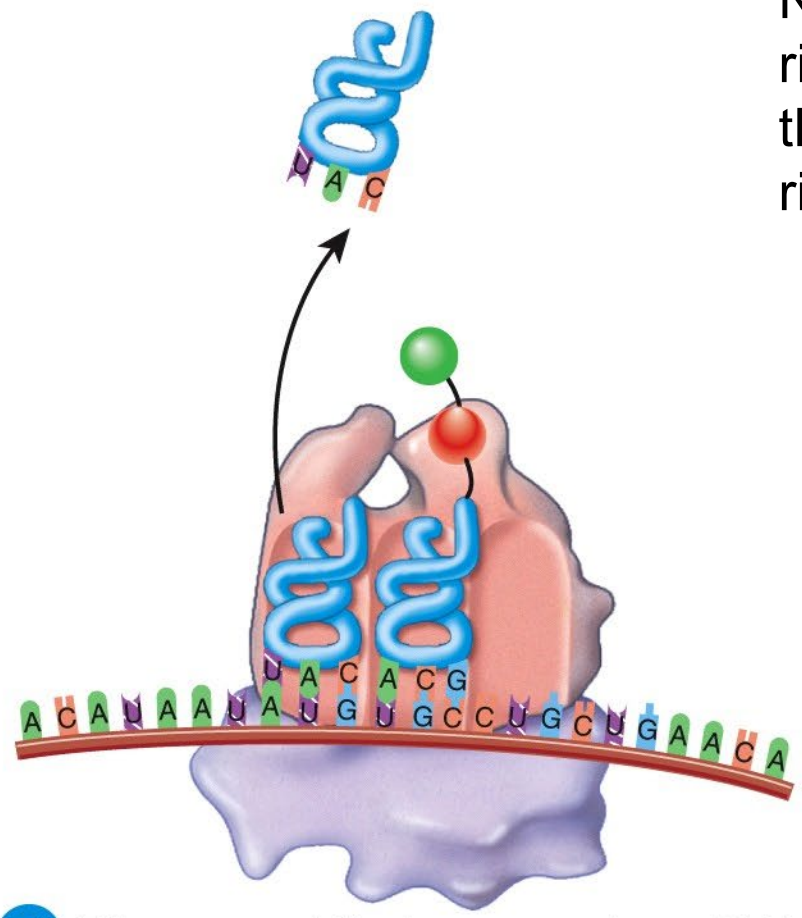
The green amino acid moves onto the red amino acid. Then the ribosome slides three nucleotides to the right.

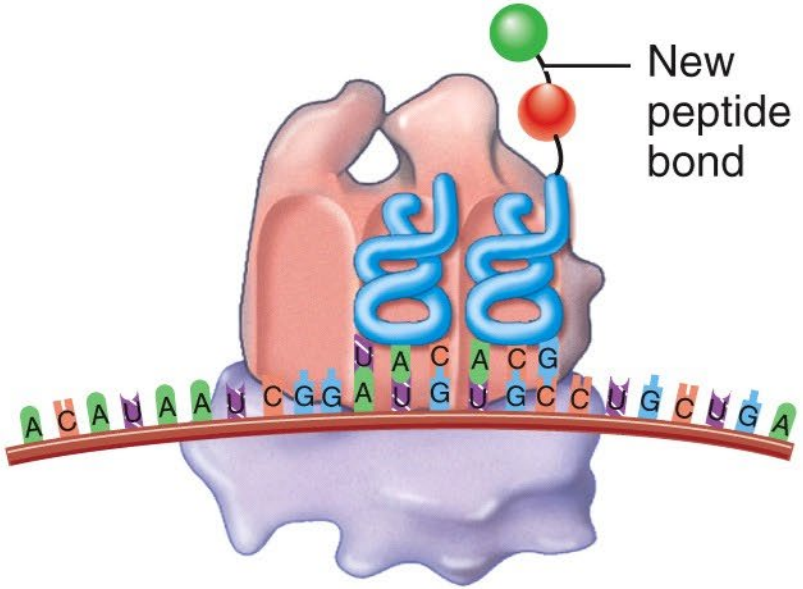
The ribosome now returns to the E-P-A alignment.



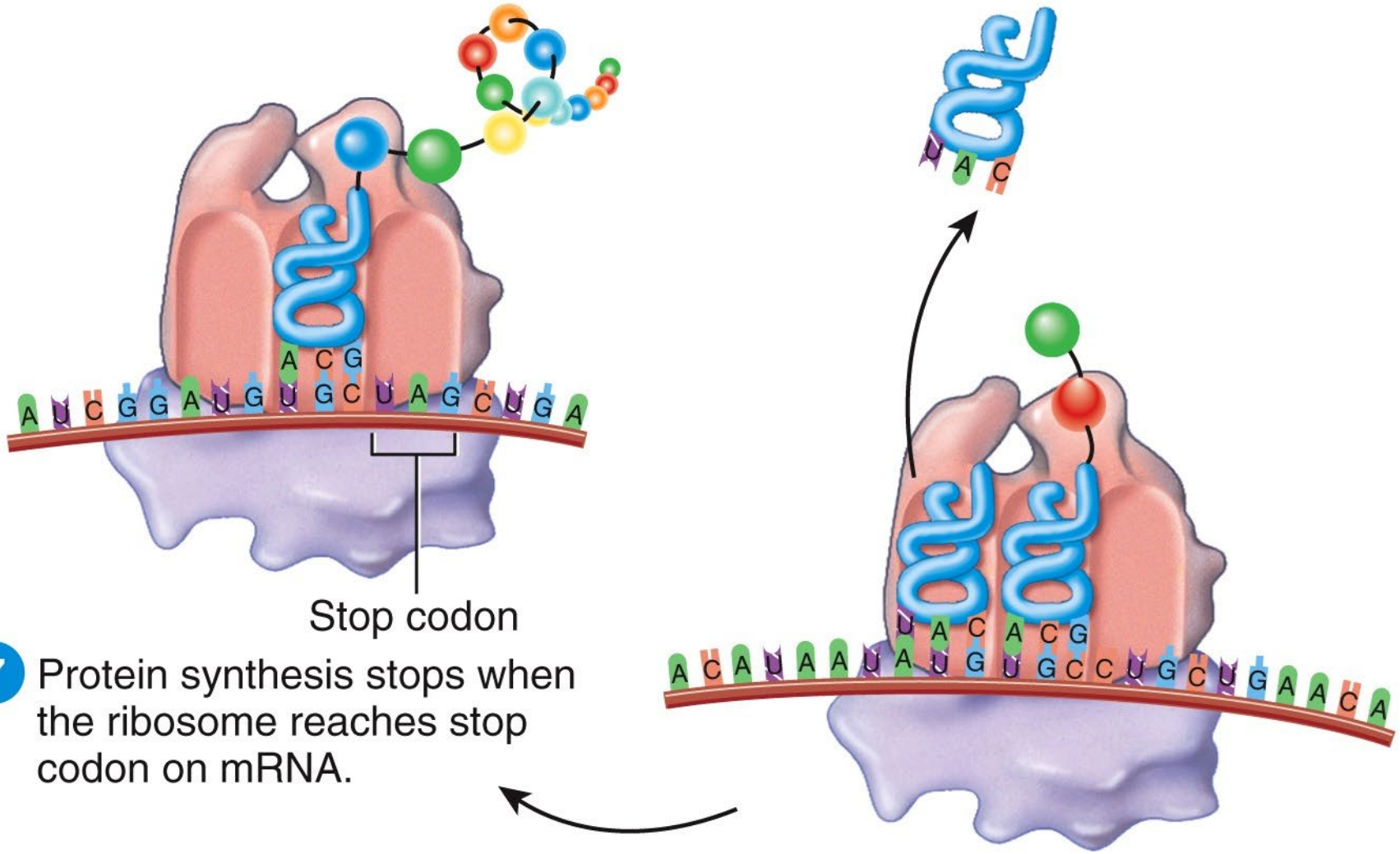
5 The two-peptide protein created from the formation of the peptide bond becomes attached to tRNA at A site.

Note: the ribosome “slides” to the right along the mRNA and the tRNAs shift positions within the ribosome.

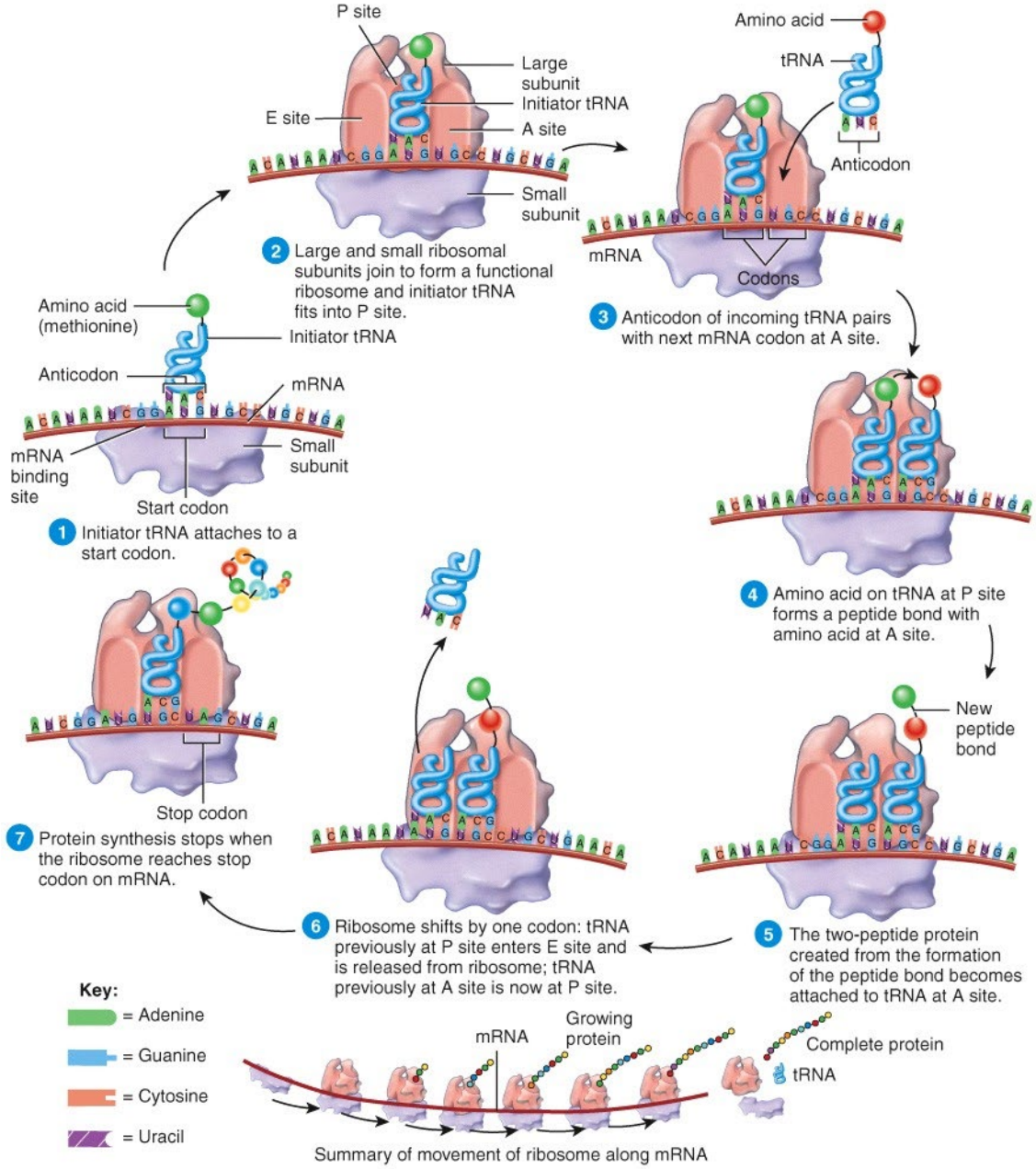


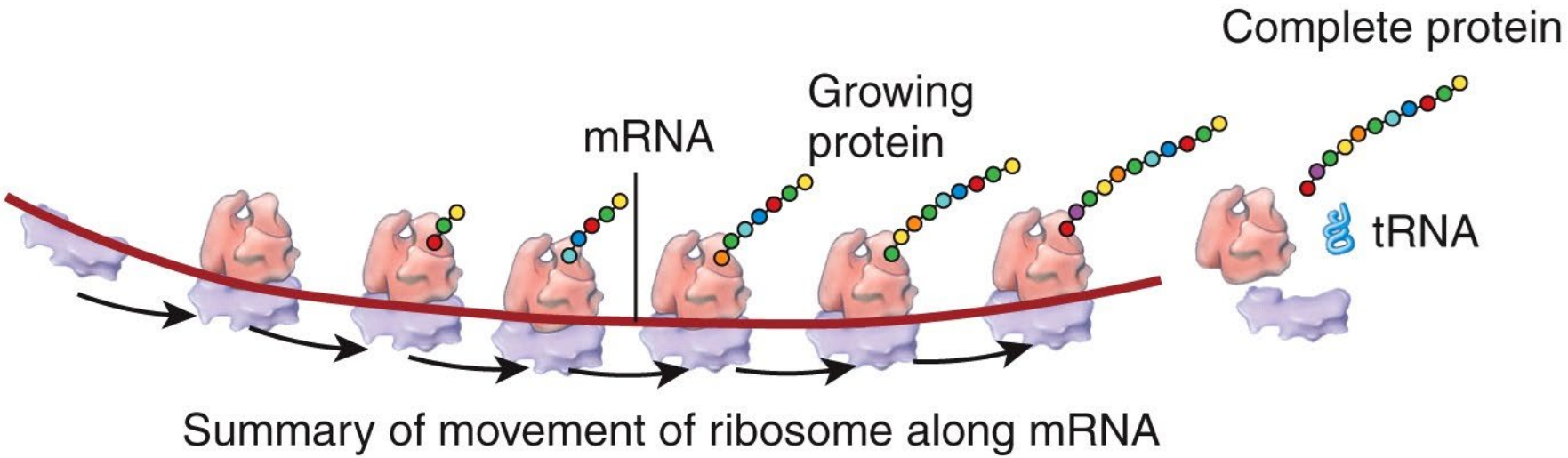


6 Ribosome shifts by one codon: tRNA previously at P site enters E site and is released from ribosome; tRNA previously at A site is now at P site.

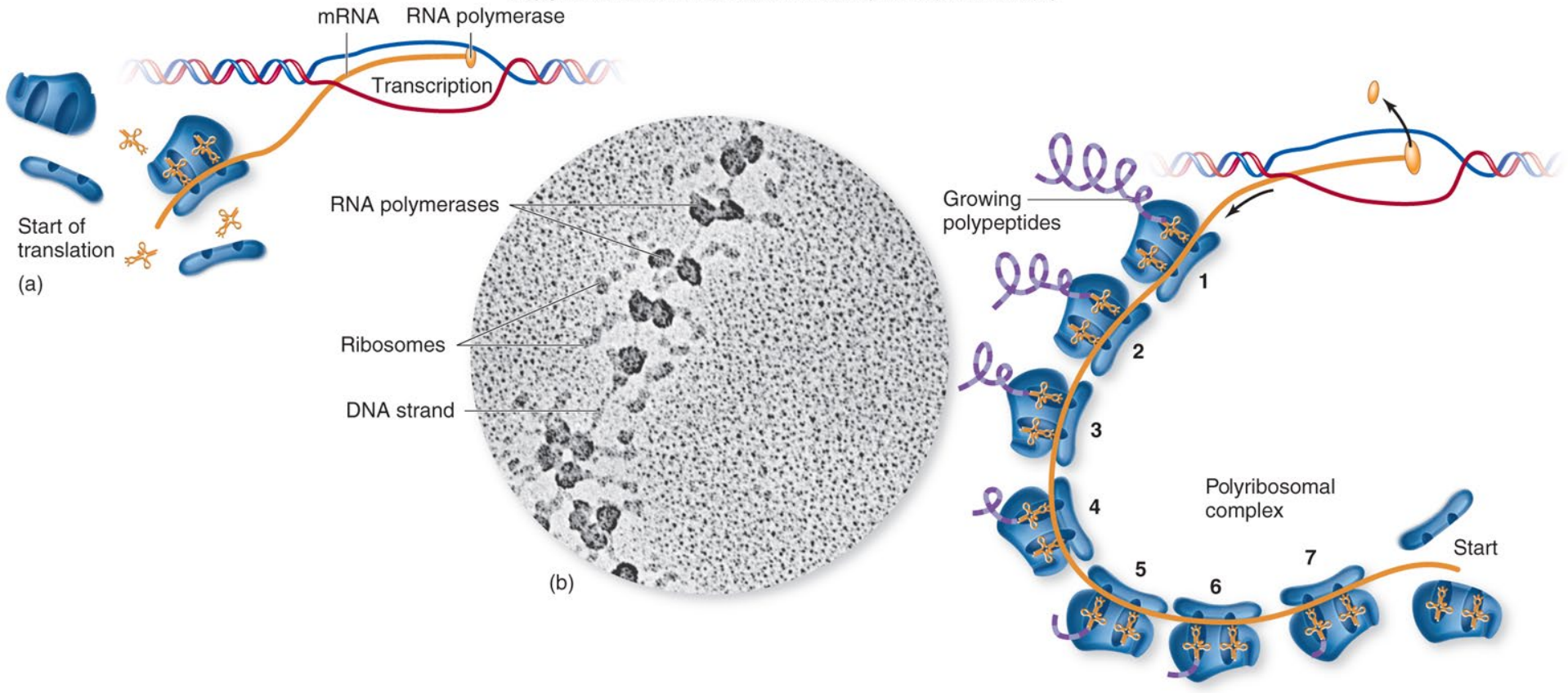


7 Protein synthesis stops when the ribosome reaches stop codon on mRNA.


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.
Amino acid (methionine)
Initiator tRNA
Anticodon
mRNA
mRNA binding site
Small subunit
Start codon
1 Initiator tRNA attaches to a start codon.
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



This is a polyribosome complex. With a single “recipe” the cell is able to make hundreds of the same protein at the same time.



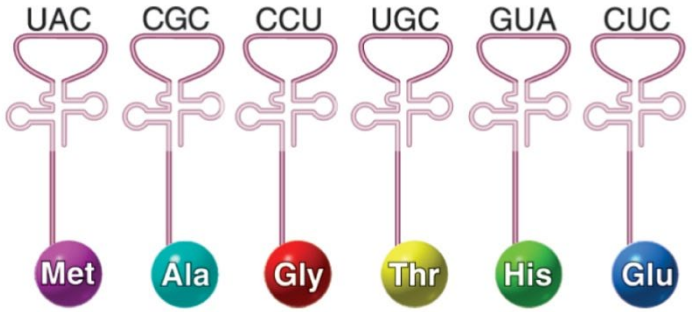
b: Courtesy of Steven McKnight, PhD

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 after the amino acid sequence (primary structure) is assembled.

To be functional the protein must coil or fold into precise secondary and tertiary structure // this requires "chaperone proteins"

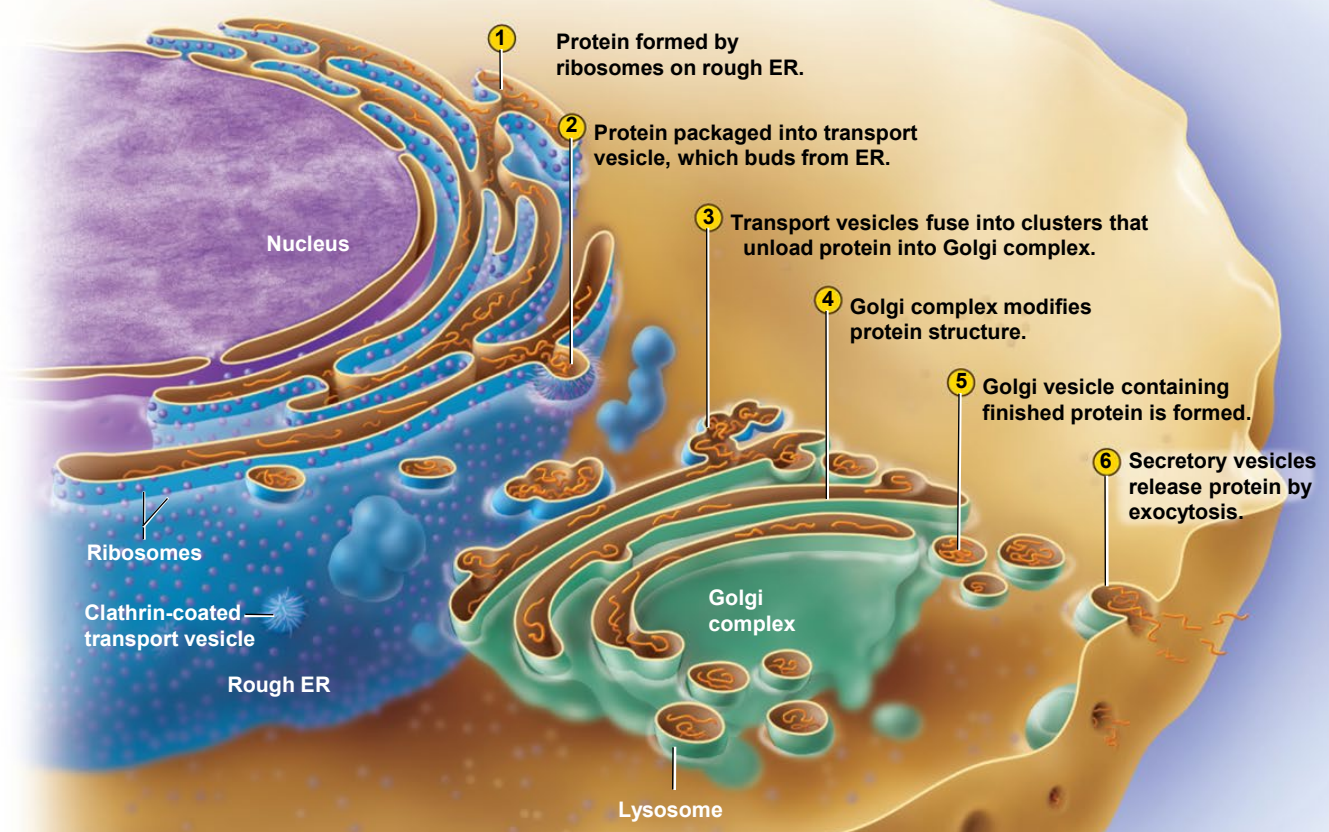
–These are pre-existing older proteins that complex with new proteins.

–Chaperone proteins act as a template so new protein folds into the proper shapes

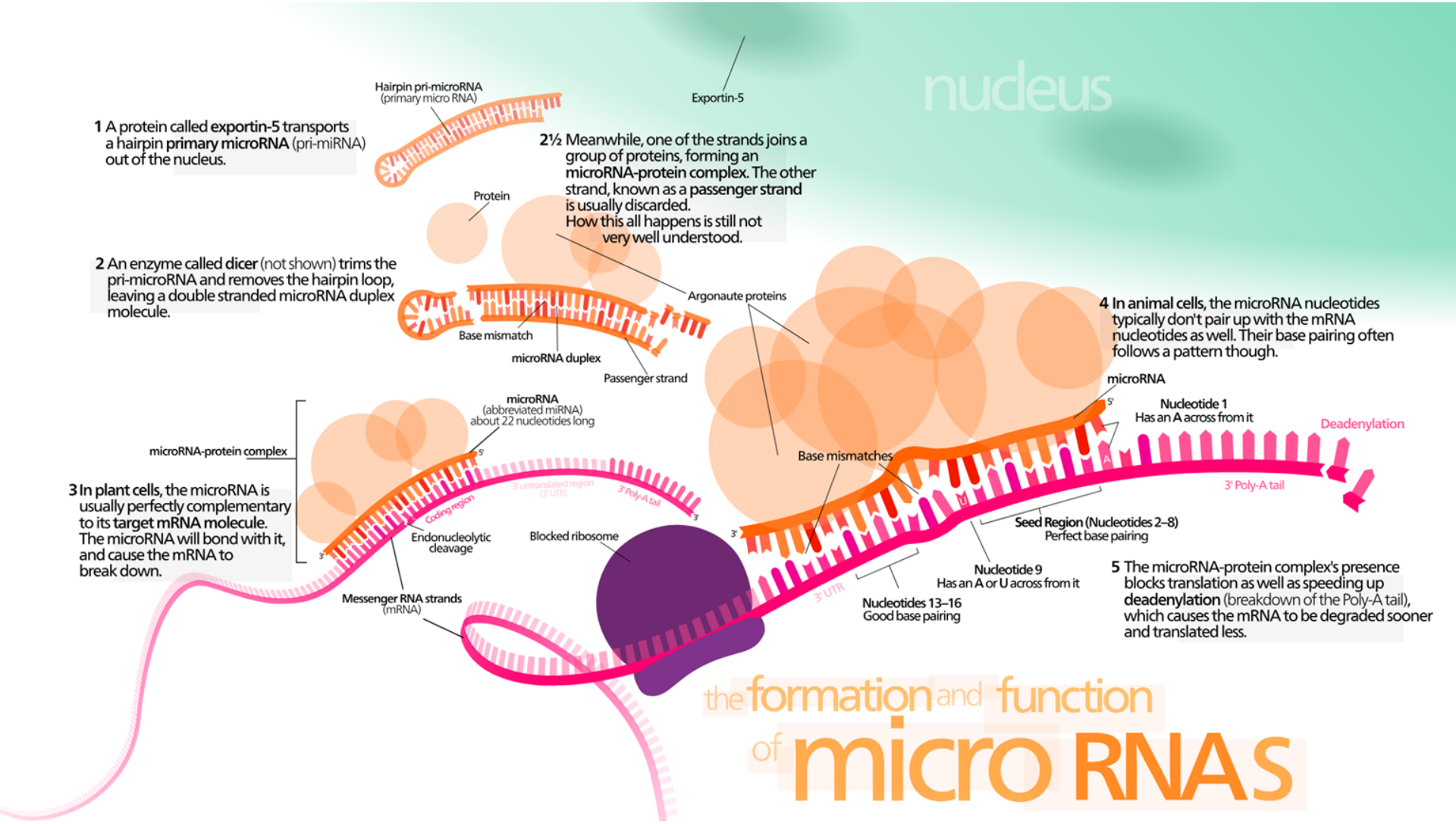
–Helps to prevent improper association between different proteins

–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



U.S. scientists Victor Ambros and Gary Ruvkun won the 2024 Nobel Prize in Medicine for the discovery of microRNA and its crucial role in how multicellular organisms grow and live.