TRANSCRIPTION & TRANSLATION

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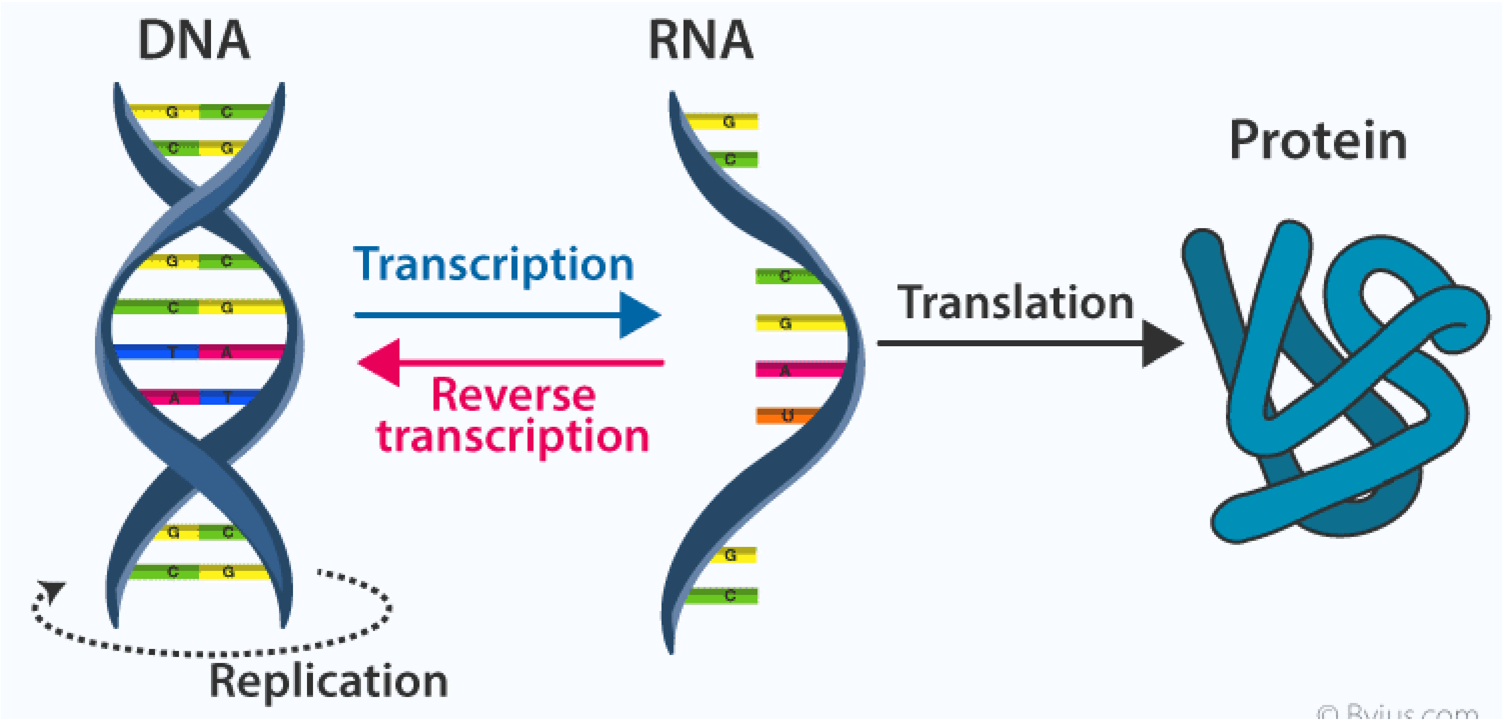
CENTRAL DOGMA OF LIFE

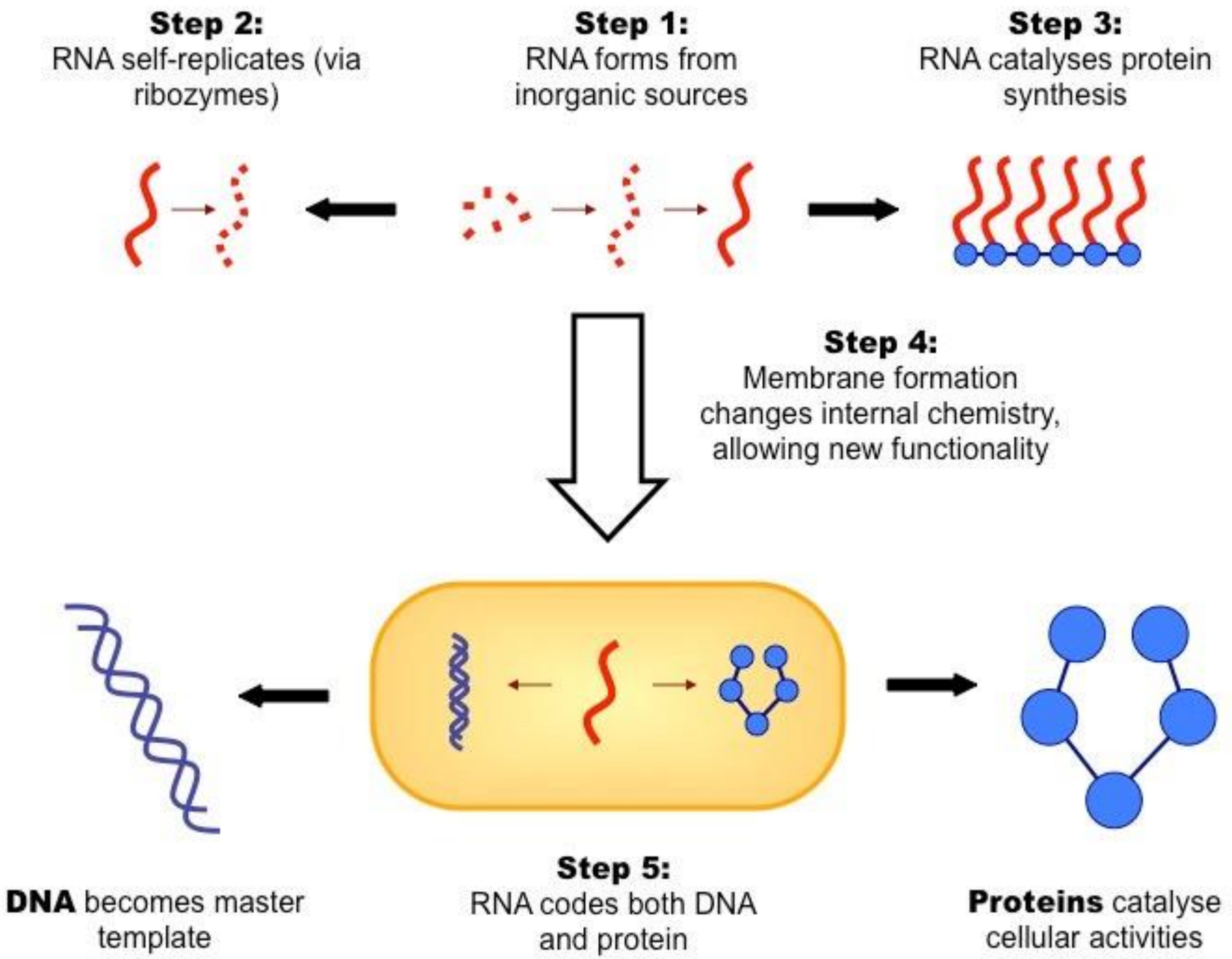
All organisms, from the simplest bacteria to ourselves, use the same basic mechanism of reading and expressing genes, so fundamental to life:



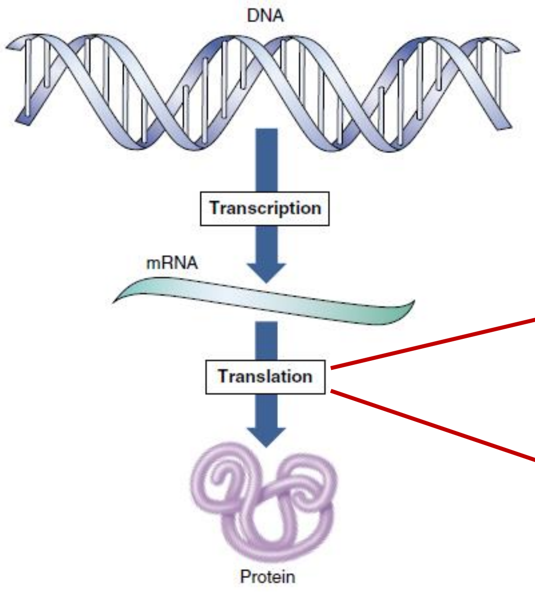
RNA WORLD HYPOTHESIS

The RNA world hypothesis proposes that:

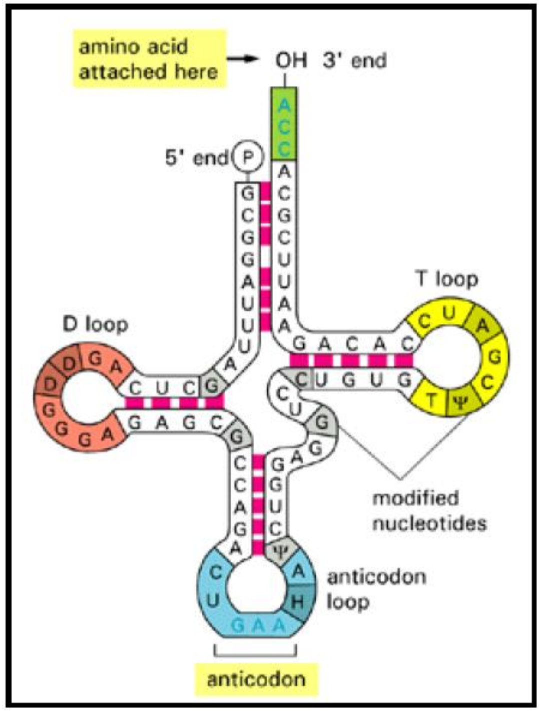
- self-replicating ribonucleic acid (RNA) molecules were precursors to current life, which is based on DNA, RNA & proteins
- Current life on Earth descended from an RNA world



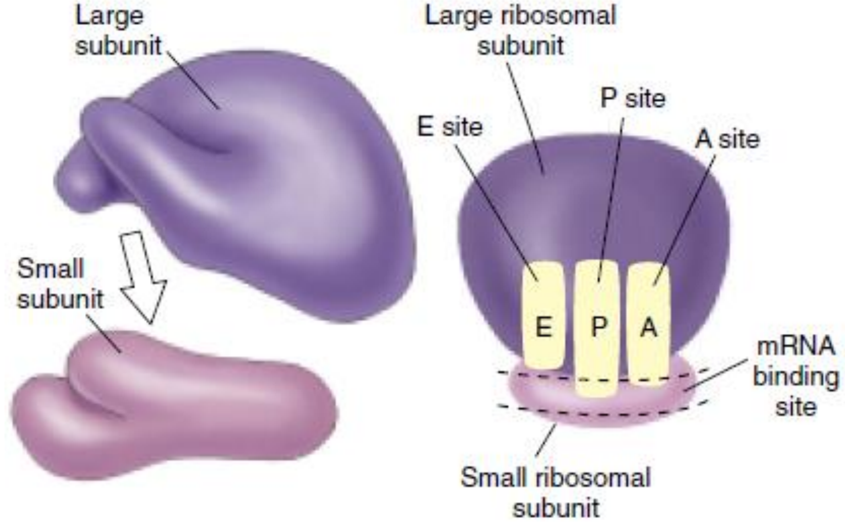
TYPES OF RNA



messenger RNA
mRNA

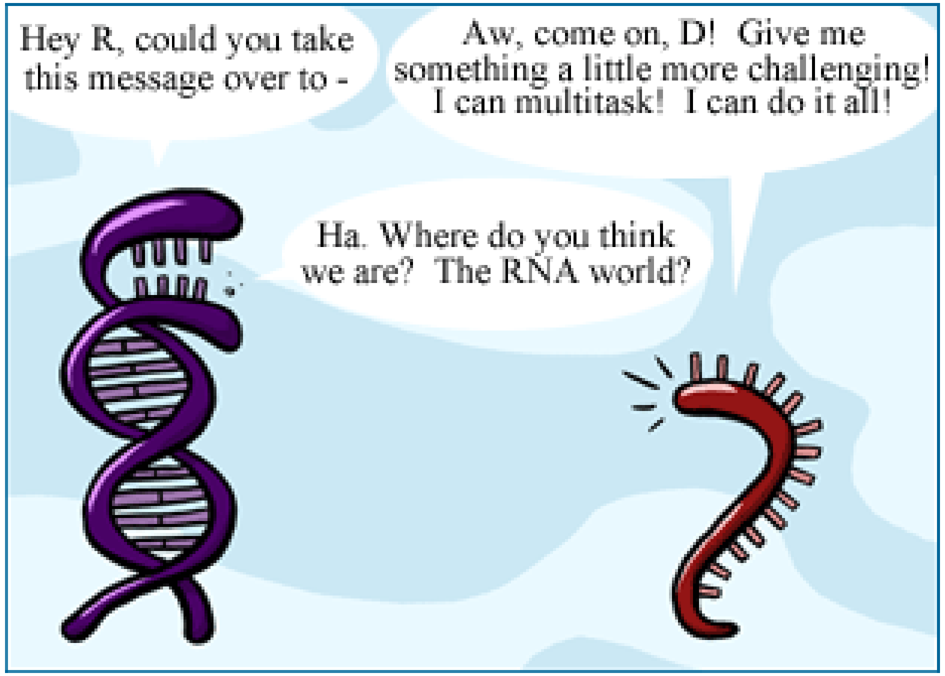


transfer RNA
tRNA

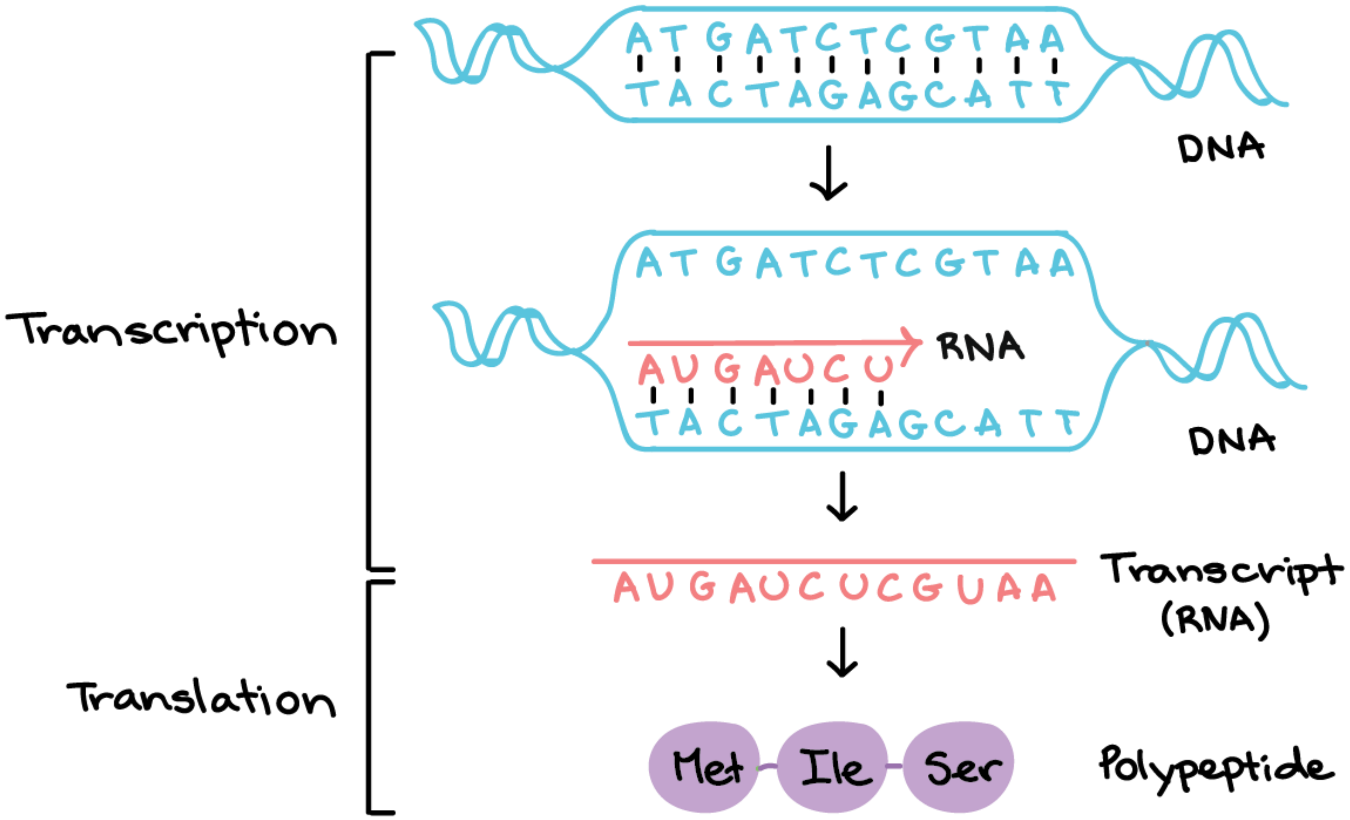


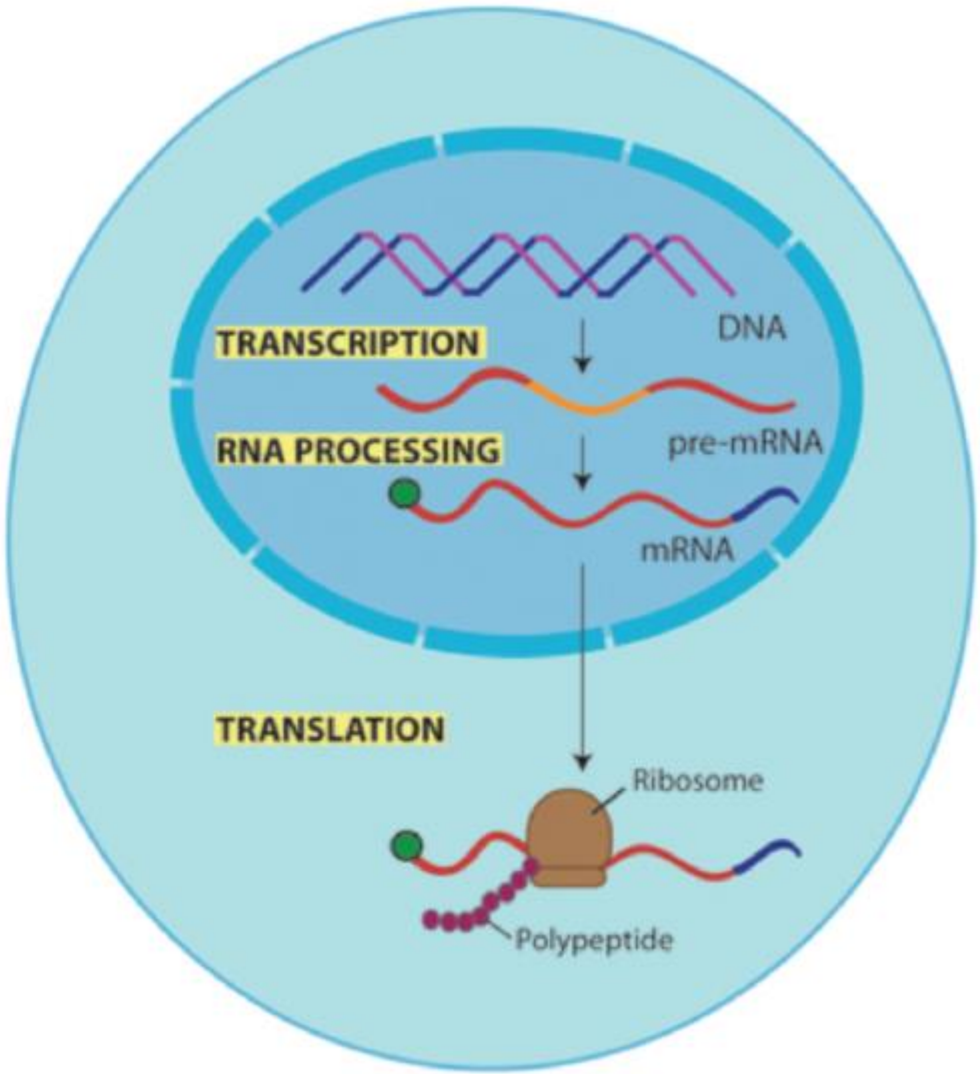
Ribosomal RNA
rRNA

RNA WORLD HYPOTHESIS



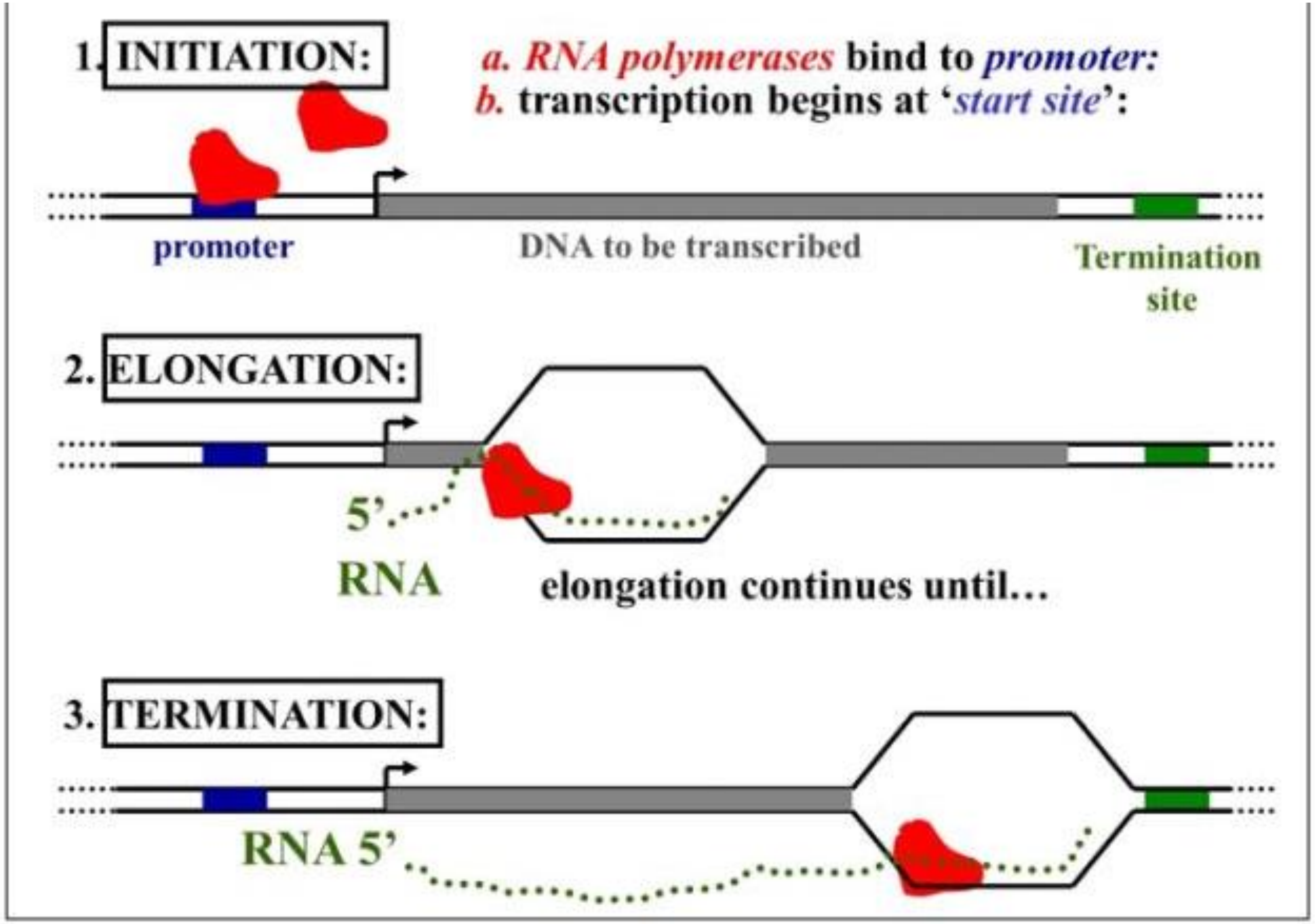
TRANSCRIPTION





TRANSCRIPTION

- Initiation:
  - Sigma brings RNA polymerase holoenzyme to promoter region of DNA.
  - DNA helix is opened and transcription begins.
  - Sigma releases and transcription continues.
- Elongation:
  - Complementary ribonucleotides are added to the growing mRNA transcript as specified by the DNA template strand.
- Termination:
  - RNA polymerase reaches a termination signal in the DNA template.
  - mRNA forms a hairpin loop.
  - mRNA dissociates from RNA polymerase.



TRANSCRIPTION

```
5'- A T G C A T G C -3'  Sense (Partner)
    | | | | | | | |
3'- T A C G T A C G -5'  Template (Antisense)
    | | | | | | | |
5'- A U G C A U G C -3'  Messenger RNA
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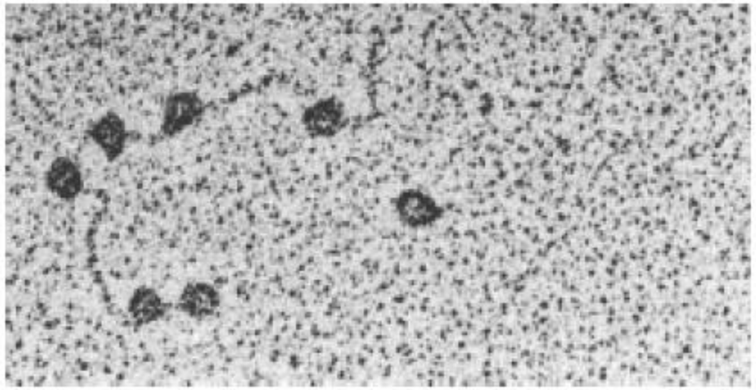
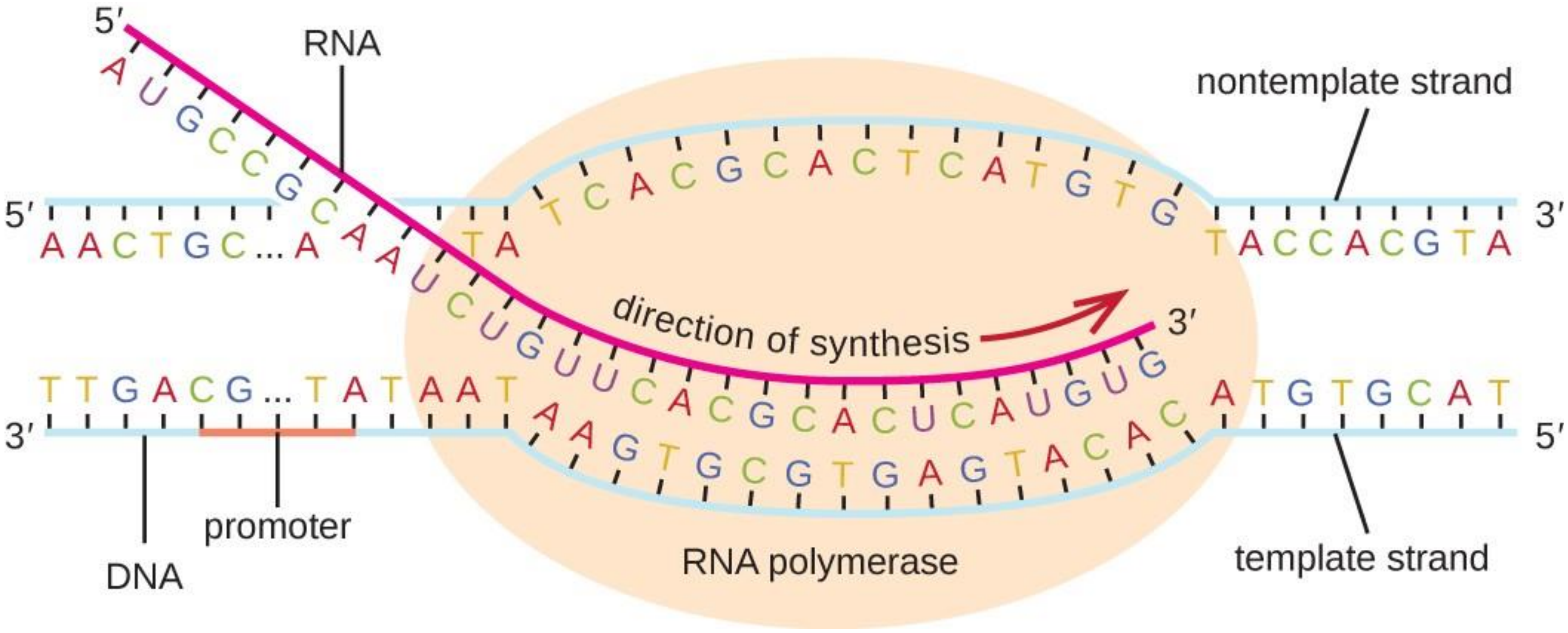


FIGURE 15.7
RNA polymerase. In this electron micrograph, the dark circles are RNA polymerase molecules bound to several promoter sites on bacterial virus DNA.

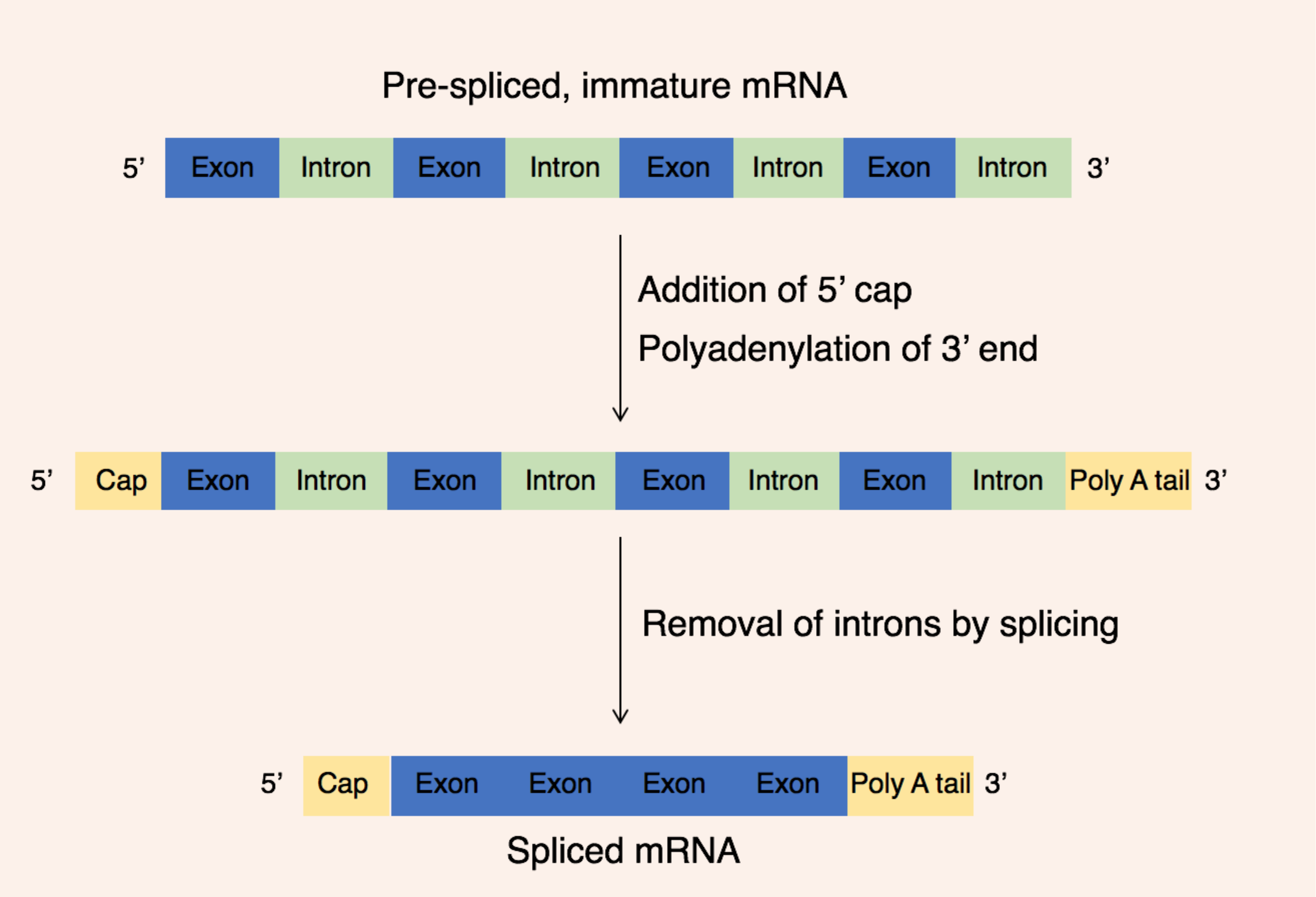
- **Only one of the two strands of DNA, called the template strand, is transcribed.**
- **The RNA transcript's sequence is complementary to the template strand.**
- **The strand of DNA that is not transcribed is called the coding strand. It has the same sequence as the RNA transcript, except T takes the place of U.**
- **The coding strand is also known as the sense (+) strand, and the template strand as the antisense (–) strand.**

TRANSCRIPTION SNAPSHOT



POST-TRANSCRIPTIONAL MODIFICATION

- **Polyadenylation**
- **Capping**
- **Splicing**

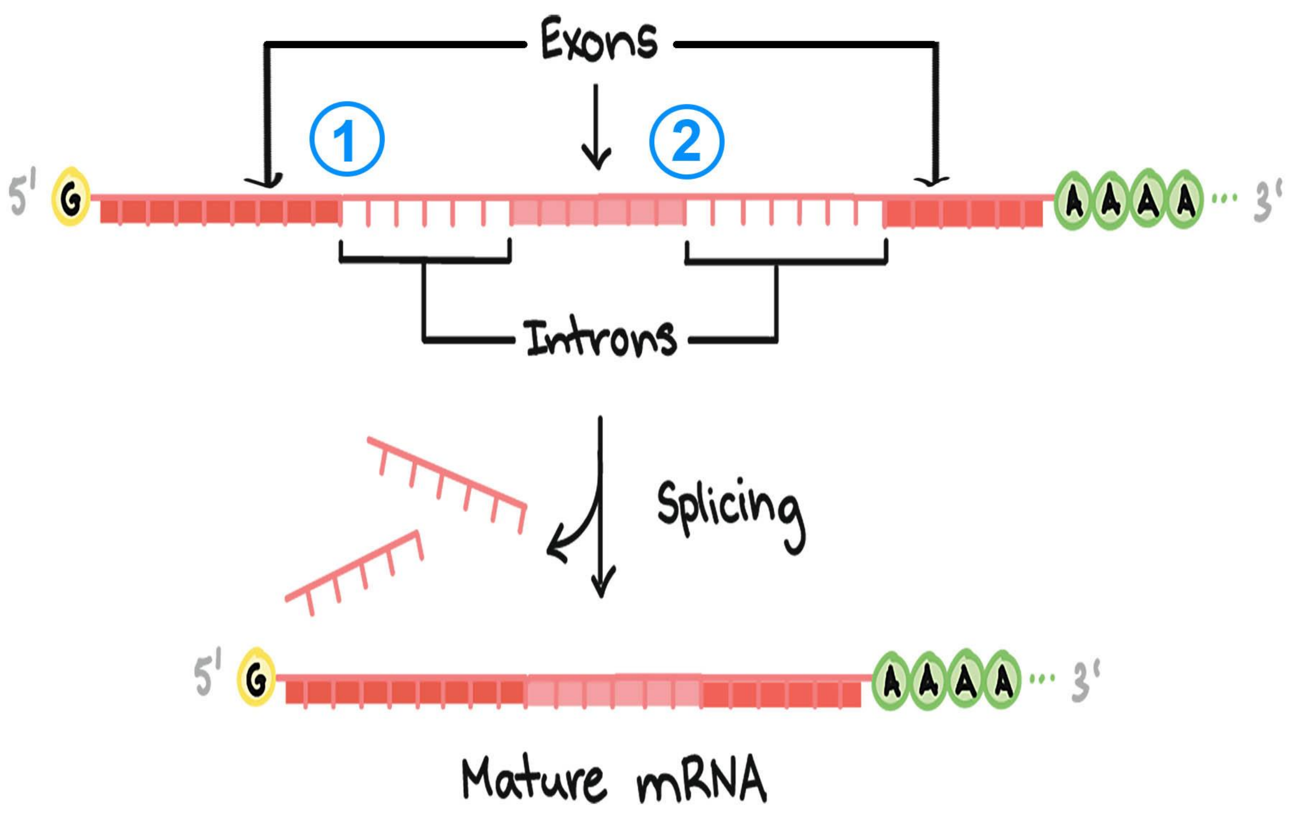


SPLICING

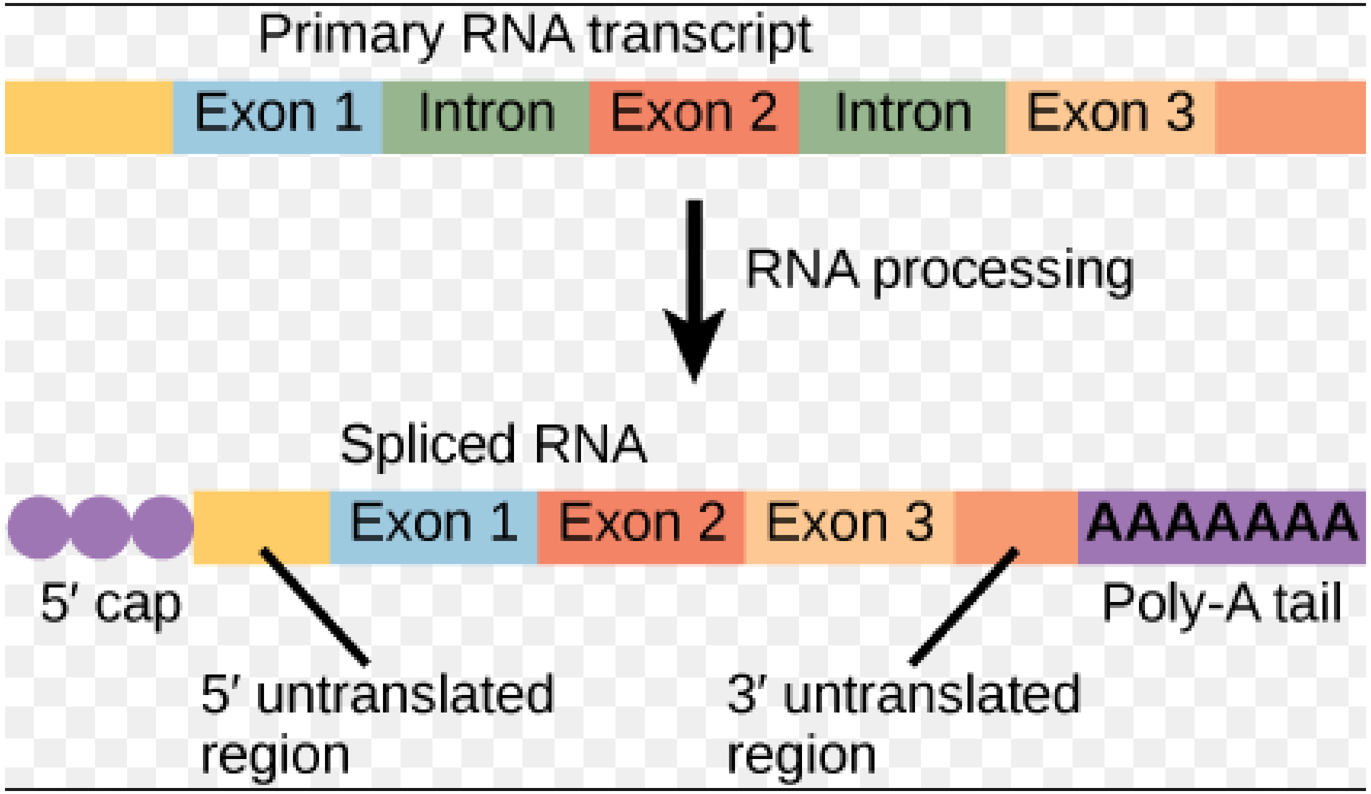
- Process of cutting introns out of immature RNAs and stitching together the exons to form final **product is RNA splicing**

- **Introns are transcribed along with exons in the primary transcript**

- **Introns are removed as the exons are spliced together**



SPLICING



INTRONS VERSUS EXONS

INTRONS	EXONS
Introns are the DNA segments which do not encode any amino acid sequence in the coding region	Exons are the DNA segments which encode a part of an amino acid sequence of a complete protein
Belong to the non-coding DNA	Belong to the coding DNA
Considered as the bases located between two exons	Considered as the bases which encode an amino acid sequence of a protein
Found in eukaryotes	Found in both prokaryotes and eukaryotes
Stay in the nucleus by splicing out from the mRNA primary transcript during mRNA processing inside nucleus	Leave the nucleus to the cytoplasm after the production of the mature mRNA
Found in DNA and mRNA primary transcript	Found in both DNA and mRNA
The sequences are less conserved	The sequences are highly conserved

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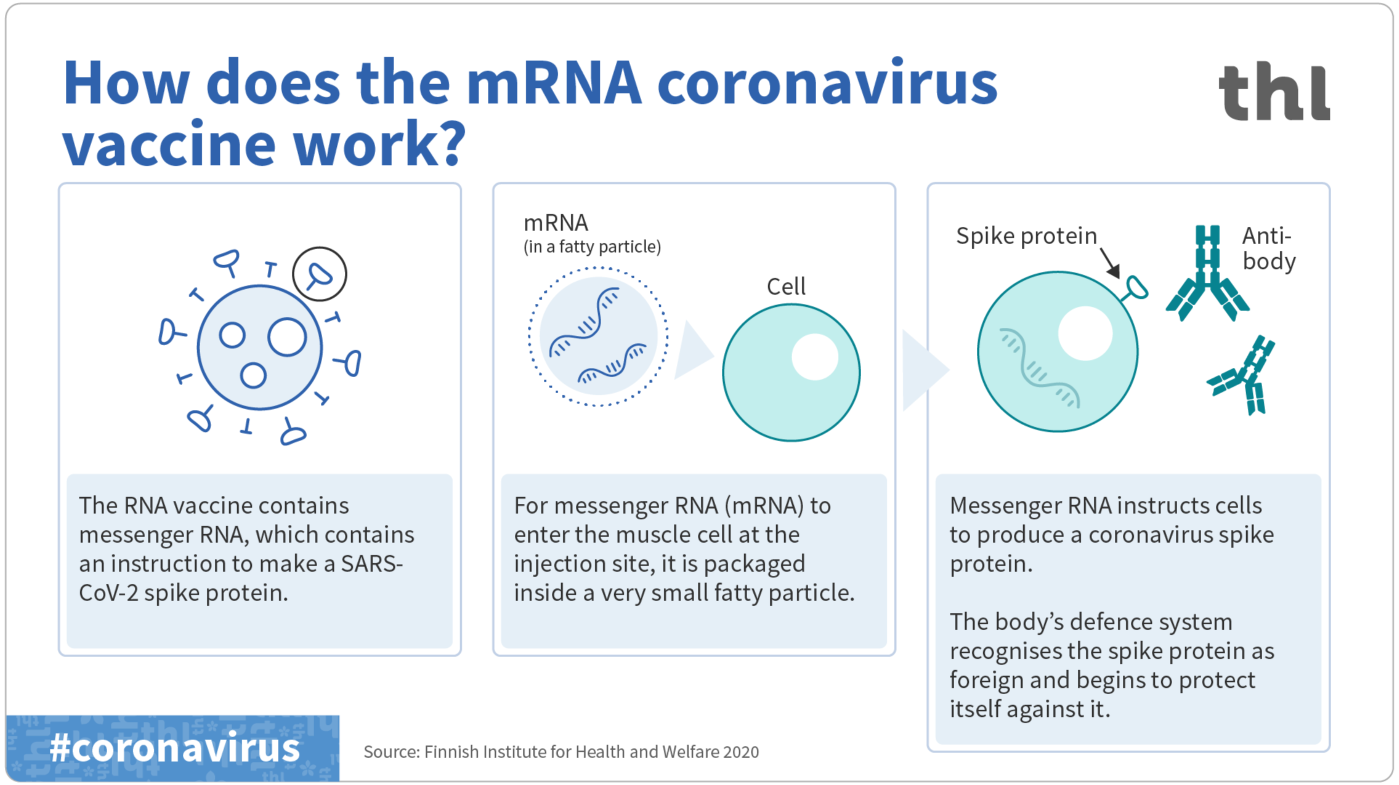
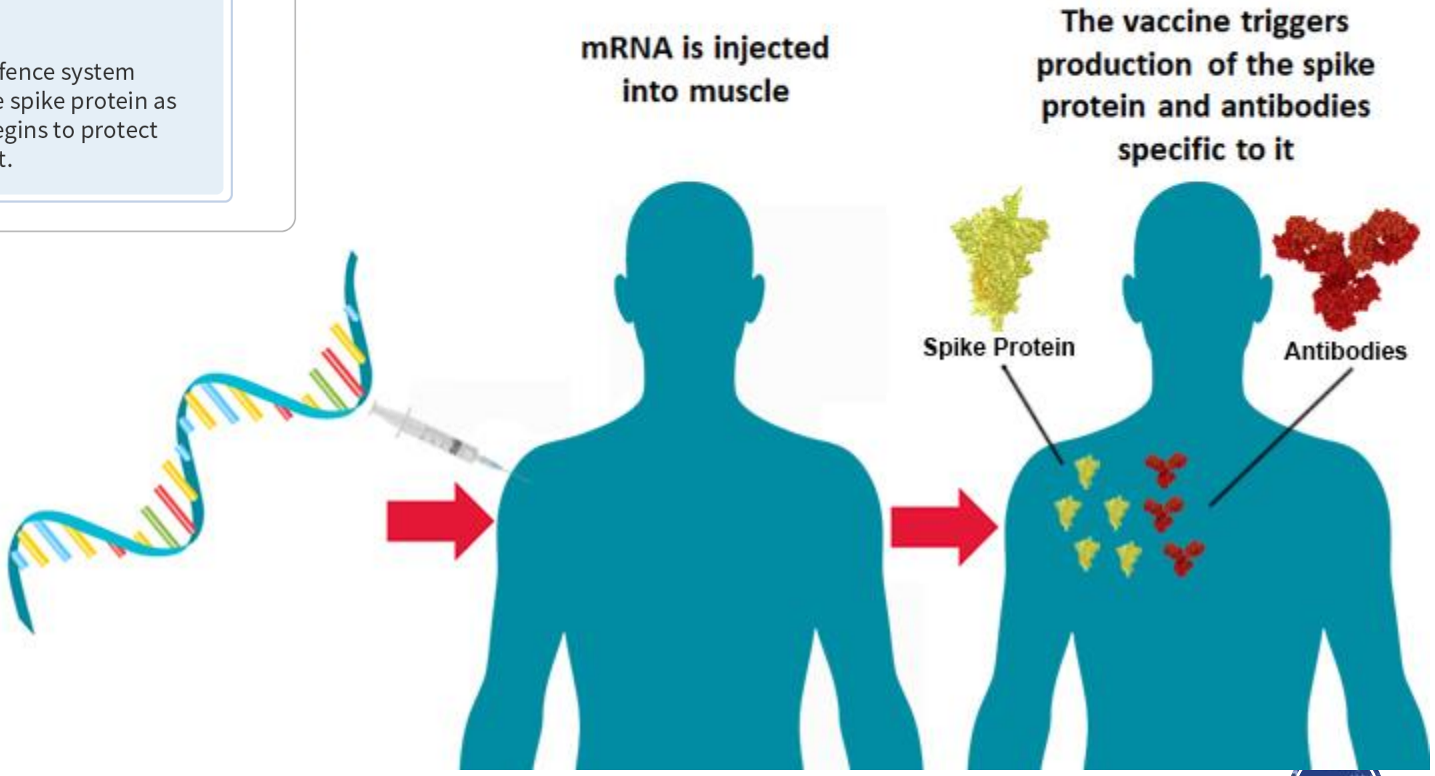
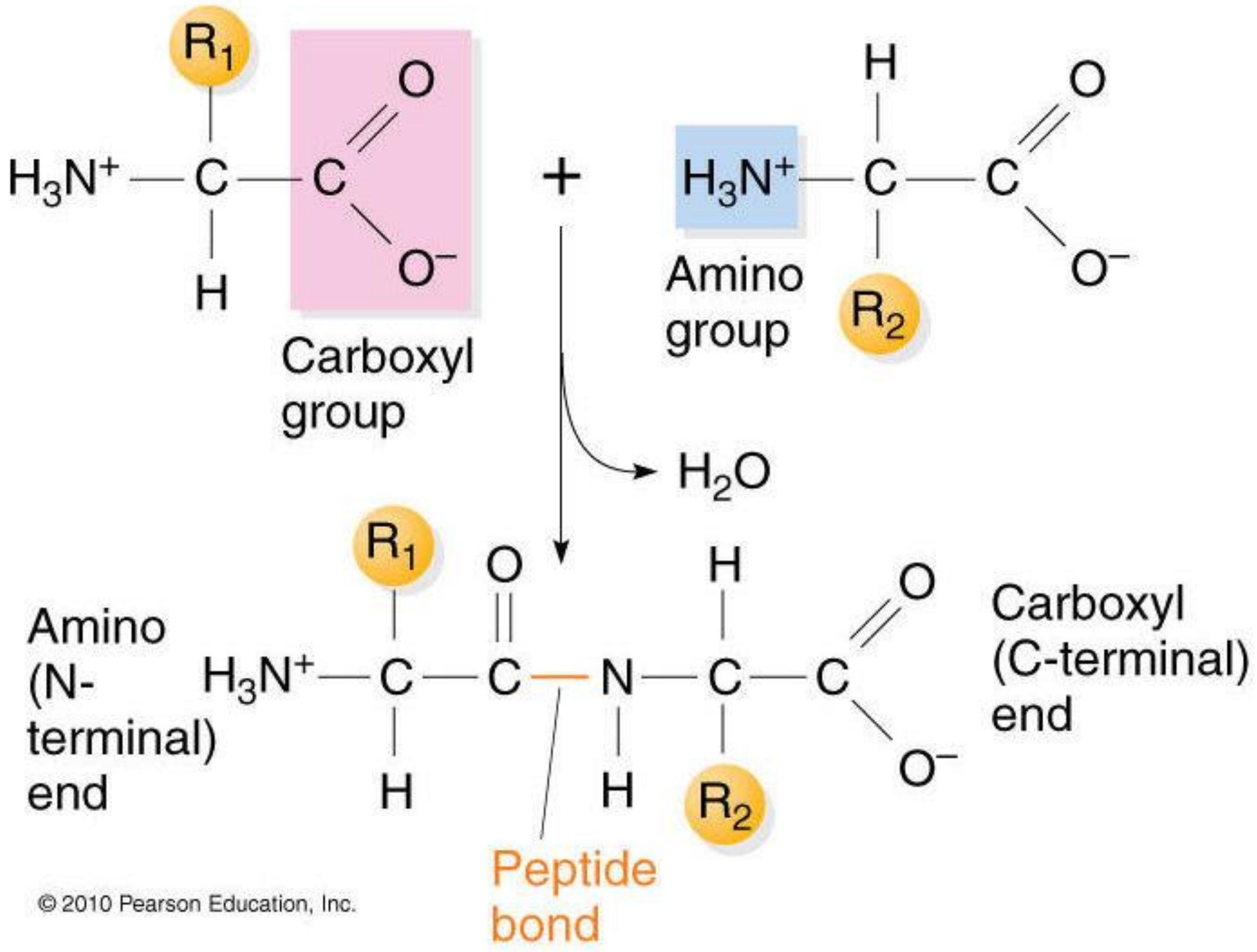


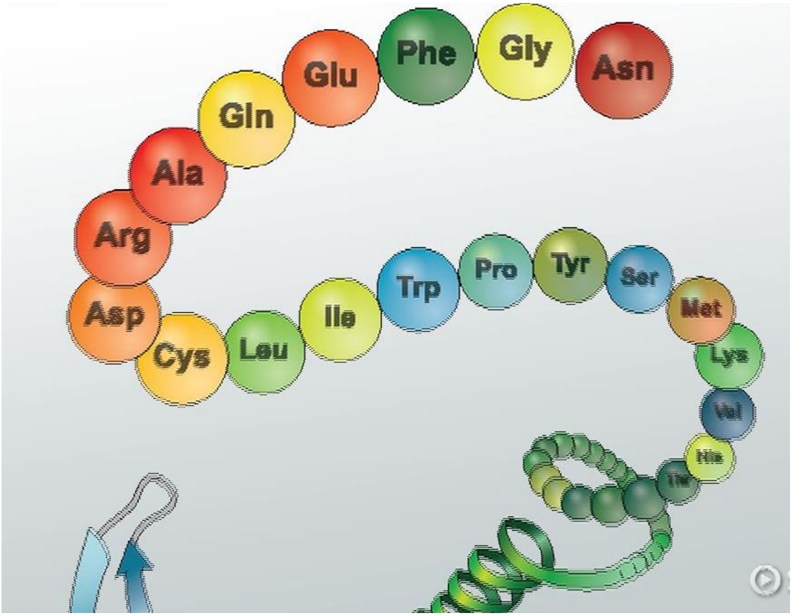
MRNA VACCINE



- Moderna
- Pfizer/ BioNTech
- CureVac

PROTEIN (RECAP)





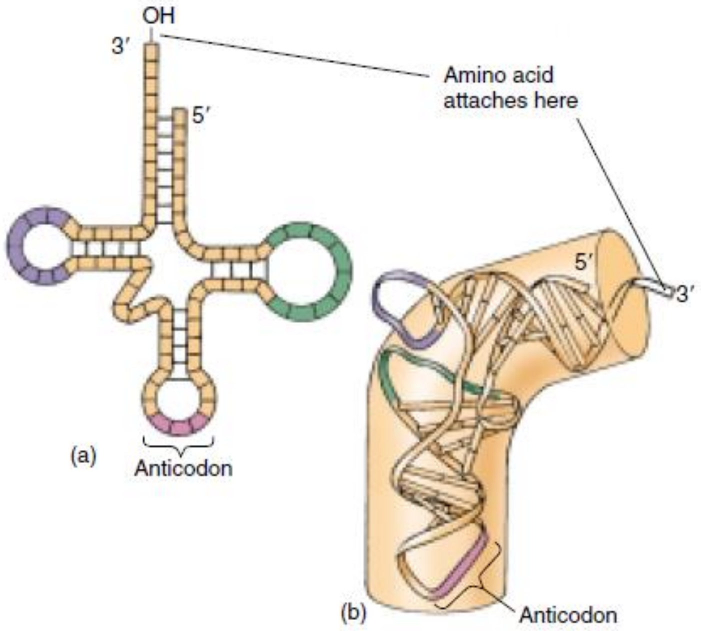
Polypeptide

tRNA

Table 15.1 The Genetic Code

First Letter	Second Letter: U		Second Letter: C		Second Letter: A		Second Letter: G		Third Letter
U	UUU	Phenylalanine	UCU	Serine	UAU	Tyrosine	UGU	Cysteine	U
	UUC		UCC		UAC		UGC		C
	UUA	Leucine	UCA		UAA	Stop	UGA	Stop	A
	UUG		UCG		UAG	Stop	UGG	Tryptophan	G
C	CUU	Leucine	CCU	Proline	CAU	Histidine	CGU	Arginine	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	Glutamine	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	Isoleucine	ACU	Threonine	AAU	Asparagine	AGU	Serine	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	Lysine	AGA	Arginine	A
	AUG	Methionine; Start	ACG		AAG		AGG		G
G	GUU	Valine	GCU	Alanine	GAU	Aspartate	GGU	Glycine	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	Glutamate	GGA		A
	GUG		GCG		GAG		GGG		G

A codon consists of three nucleotides read in the sequence shown. For example, ACU codes for threonine. The first letter, A, is in the First Letter column; the second letter, C, is in the Second Letter column; and the third letter, U, is in the Third Letter column. Each of the mRNA codons is recognized by a corresponding anticodon sequence on a tRNA molecule. Some tRNA molecules recognize more than one codon in mRNA, but they always code for the same amino acid. In fact, most amino acids are specified by more than one codon. For example, threonine is specified by four codons, which differ only in the third nucleotide (ACU, ACC, ACA, and ACG).



TRANSLATION (PROTEIN SYNTHESIS)

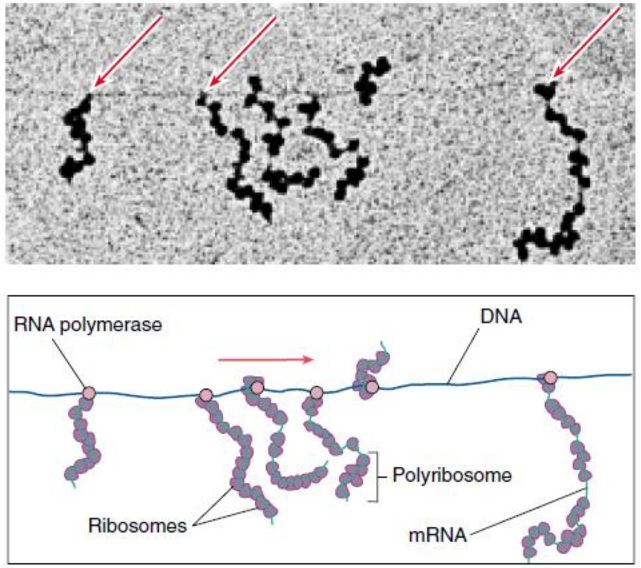
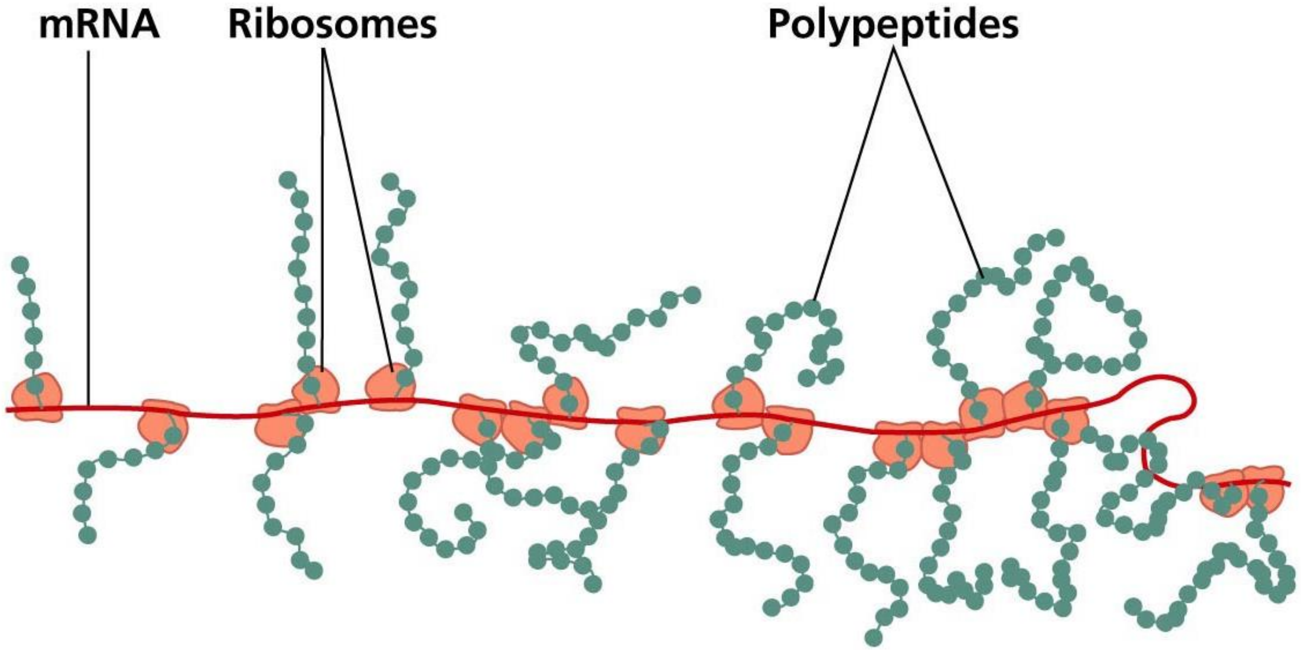
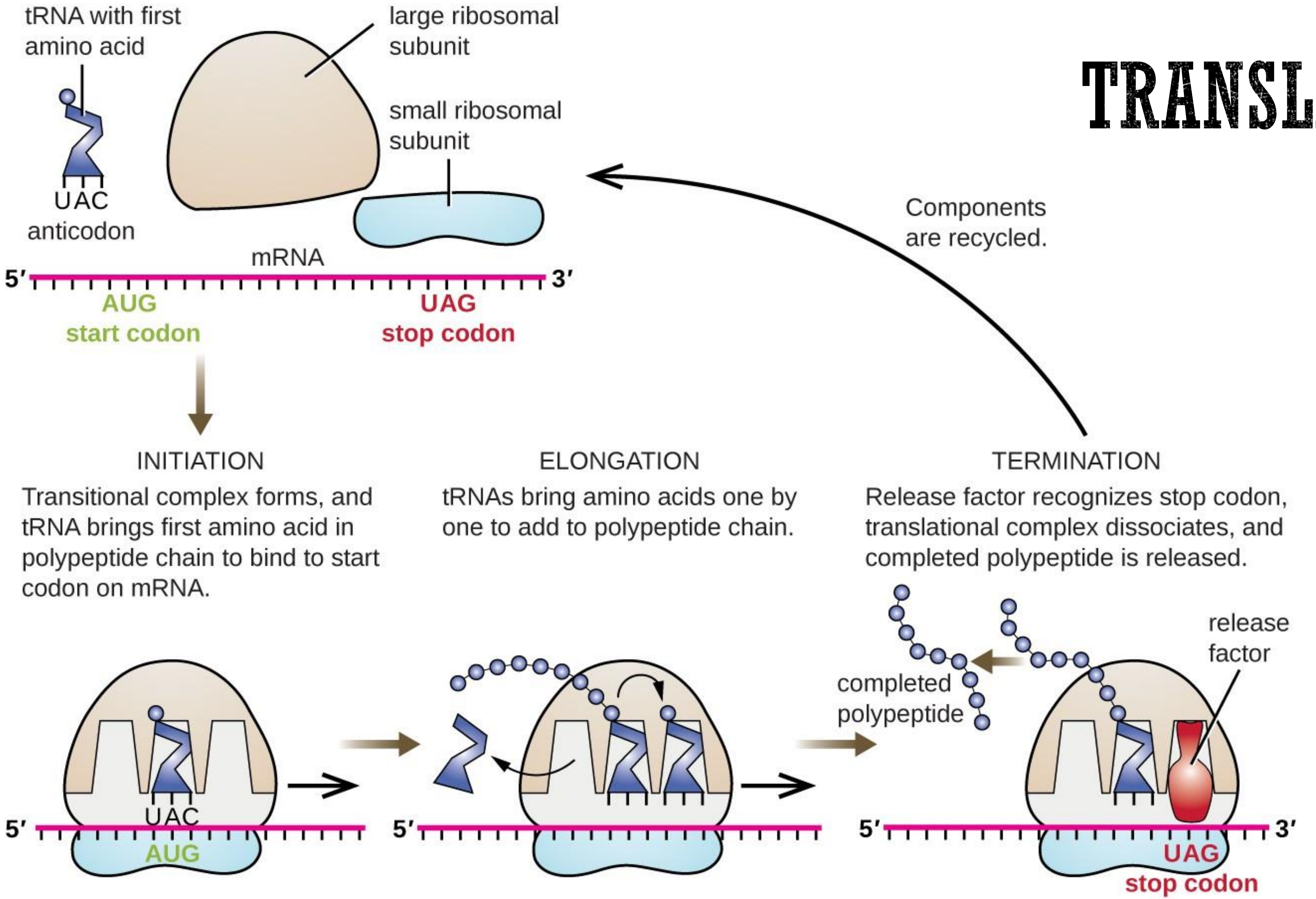


FIGURE 15.10
Translation in action. Bacteria have no nucleus and hence no membrane barrier between the DNA and the cytoplasm. In this electron micrograph of genes being transcribed in the bacterium *Escherichia coli*, you can see every stage of the process. The arrows point to RNA polymerase enzymes. From each mRNA molecule dangling from the DNA, a series of ribosomes is assembling polypeptides. These clumps of ribosomes are sometimes called "polyribosomes."



TRANSLATION



TRANSFER RNA (T-RNA)

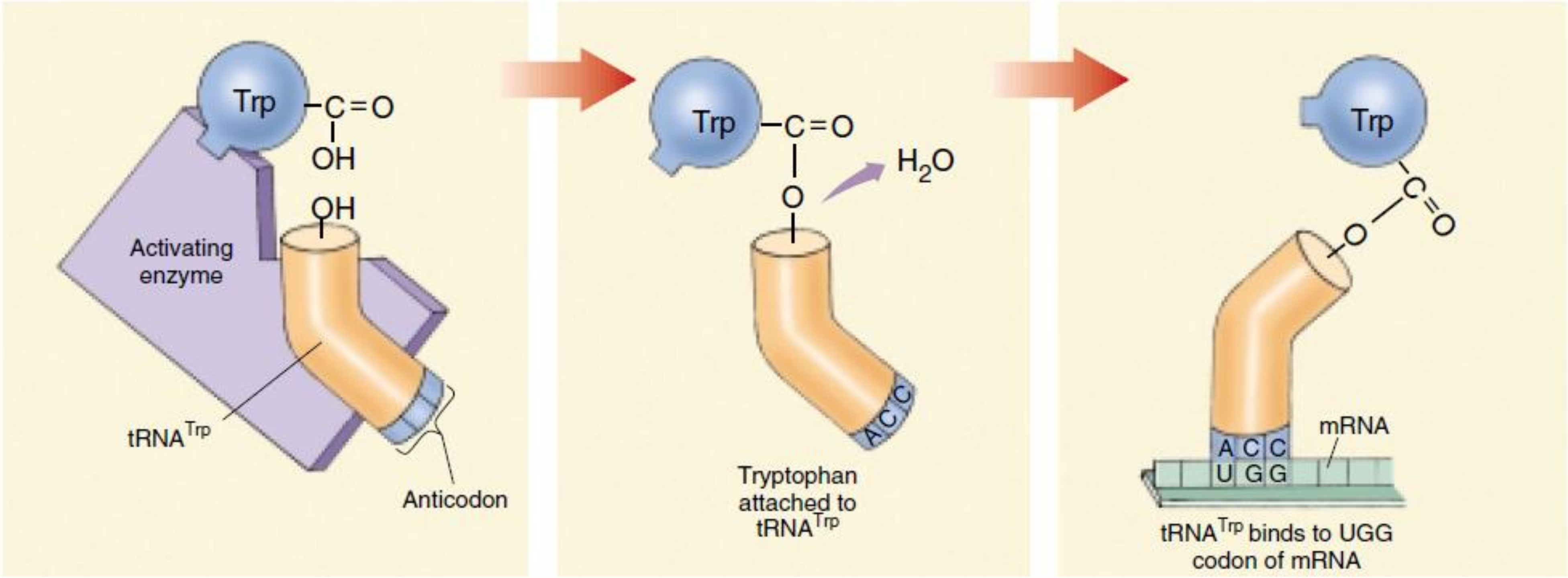


FIGURE 15.11
Activating enzymes "read" the genetic code. Each kind of activating enzyme recognizes and binds to a specific amino acid, such as tryptophan; it also recognizes and binds to the tRNA molecules with anticodons specifying that amino acid, such as ACC for tryptophan. In this way, activating enzymes link the tRNA molecules to specific amino acids.

INITIATION

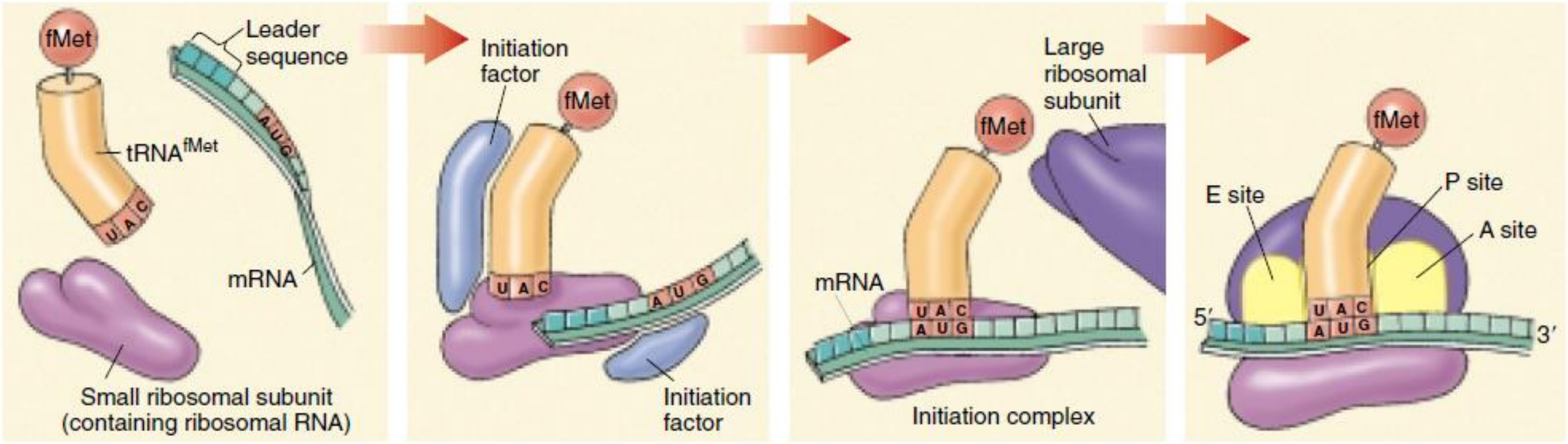
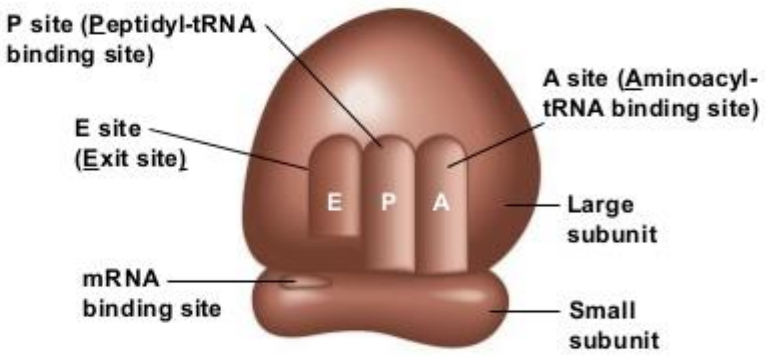


FIGURE 15.12
Formation of the initiation complex. In prokaryotes, proteins called initiation factors play key roles in positioning the small ribosomal subunit and the *N*-formylmethionine, or tRNA^{fMet}, molecule at the beginning of the mRNA. When the tRNA^{fMet} is positioned over the first AUG codon of the mRNA, the large ribosomal subunit binds, forming the P, A, and E sites where successive tRNA molecules bind to the ribosomes, and polypeptide synthesis begins.

BINDING SITES ON RIBOSOME

Schematic model showing binding sites on ribosome



The assembled ribosome has one exit site and two tRNA-binding sites, which are called A- and P-site, for aminoacyl and peptidyl sites respectively.

Only fMet-tRNA^{fMet} can be used for initiation by 30S subunits; all other aminoacyl-tRNAs are used for elongation by 70S ribosomes.

TRANSLOCATION

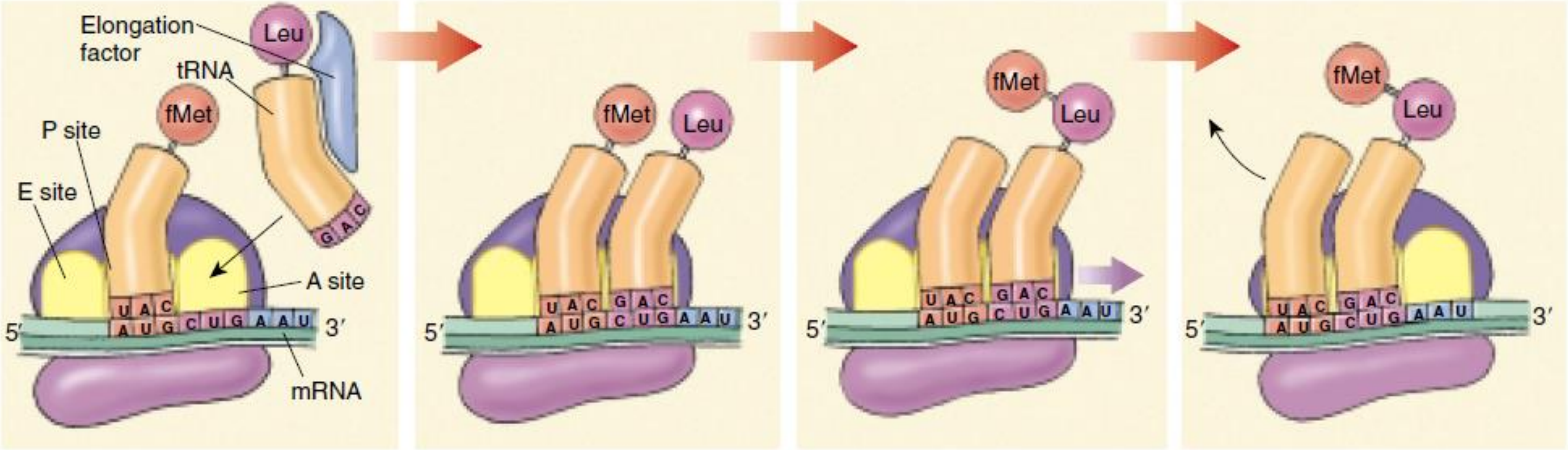


FIGURE 15.13

Translocation. The initiating tRNA^{fMet} in prokaryotes (tRNA^{fMet} in eukaryotes) occupies the P site, and a tRNA molecule with an anticodon complementary to the exposed mRNA codon binds at the A site. fMet is transferred to the incoming amino acid (Leu), as the ribosome moves three nucleotides to the right along the mRNA. The empty tRNA^{fMet} moves to the E site to exit the ribosome, the growing polypeptide chain moves to the P site, and the A site is again exposed and ready to bind the next amino acid–laden tRNA.

TERMINATION

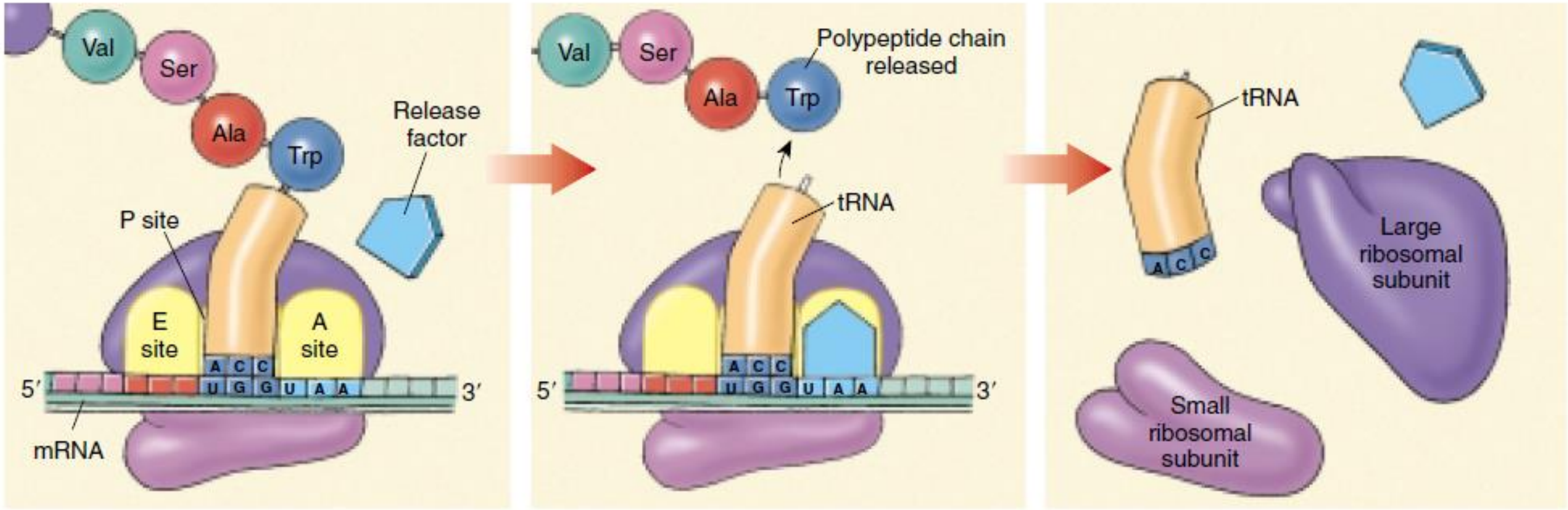
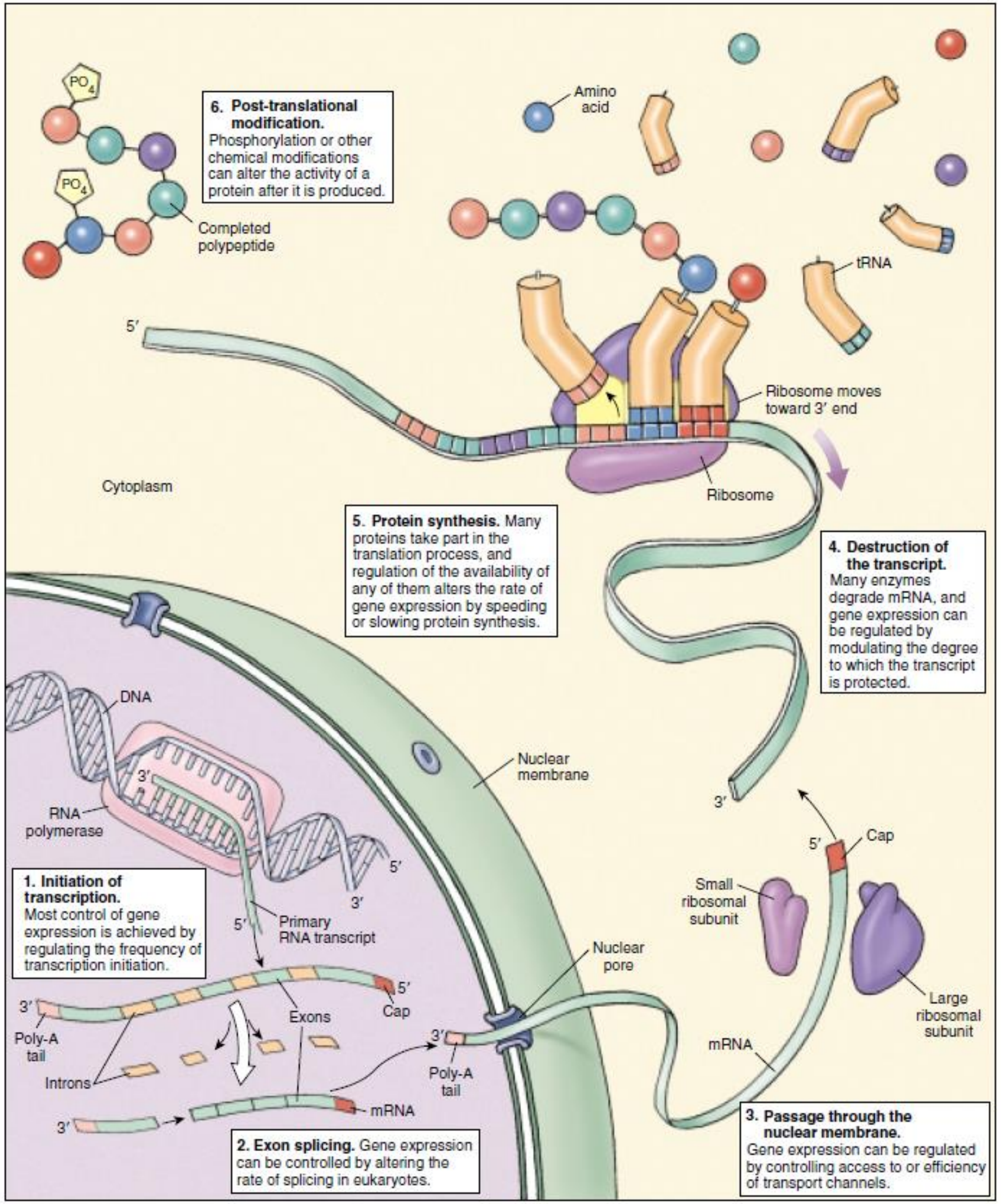
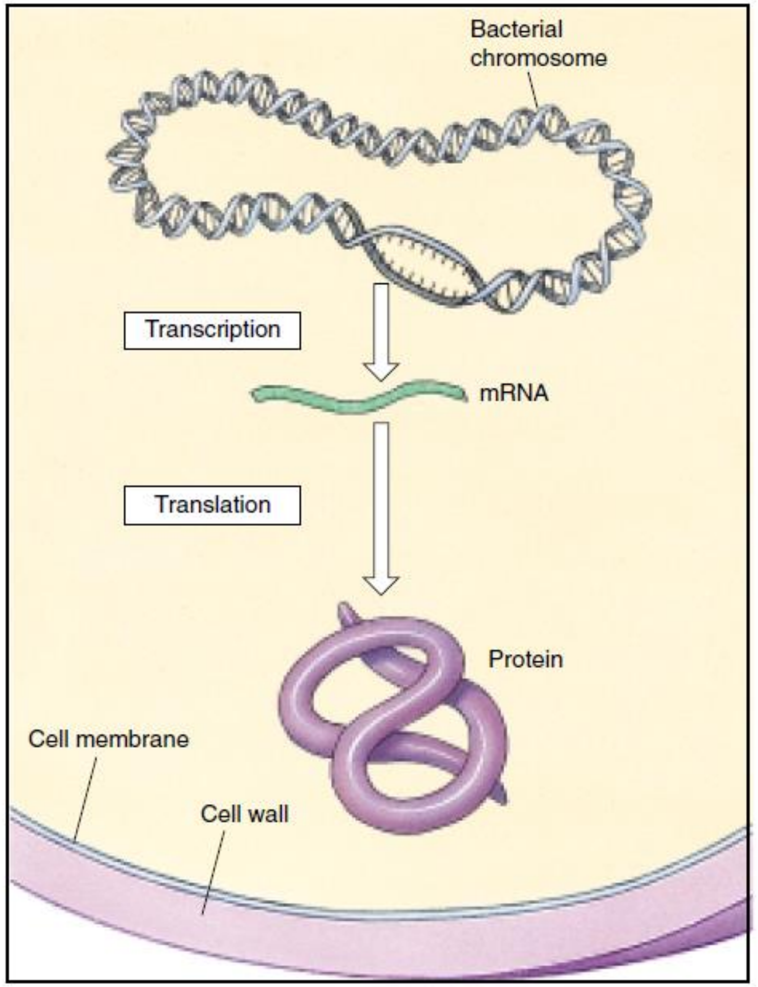


FIGURE 15.14
Termination of protein synthesis. There is no tRNA with an anticodon complementary to any of the three termination signal codons, such as the UAA nonsense codon illustrated here. When a ribosome encounters a termination codon, it therefore stops translocating. A specific release factor facilitates the release of the polypeptide chain by breaking the covalent bond that links the polypeptide to the P-site tRNA.

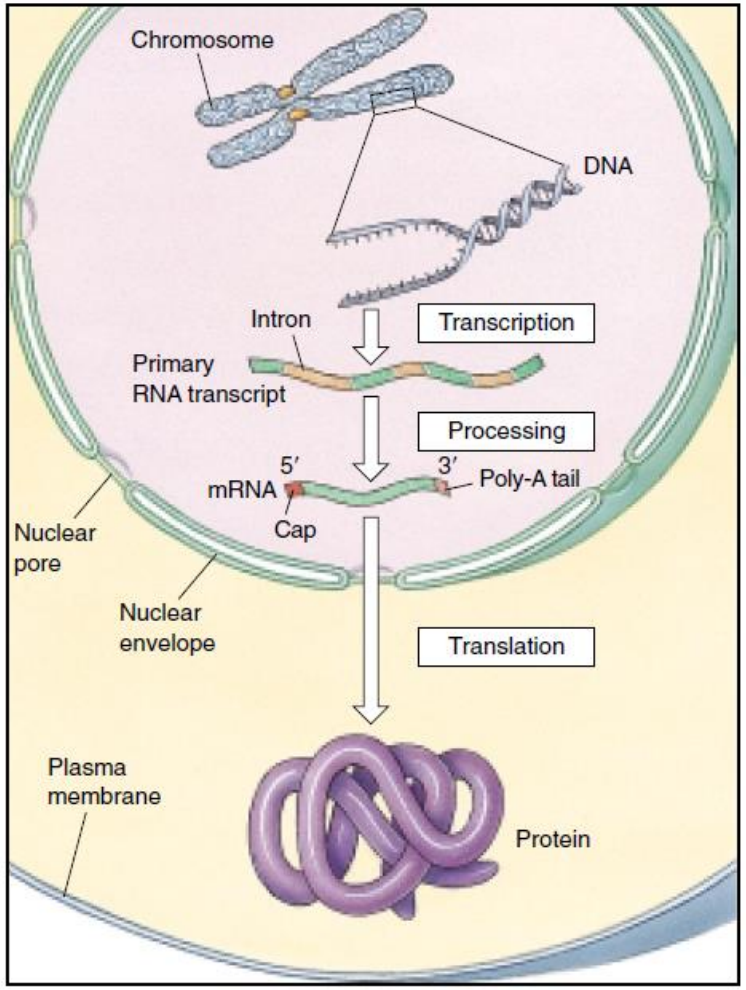


- ✓ Transcription: DNA → mRNA
- ✓ Splicing
- ✓ Translation: mRNA → Protein
- ✓ Post-translational modifications

PROKARYOTES VS EUKARYOTES



(a)



(b)

Reference: Raven & Johnson Biology
Chapter 15- Genes and How they work?
Covers Transcription and Translation

Questions?