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Click on "Play from Beginning"

DNA, RNA, and Protein Synthesis

Chapter 9

WARM-UP

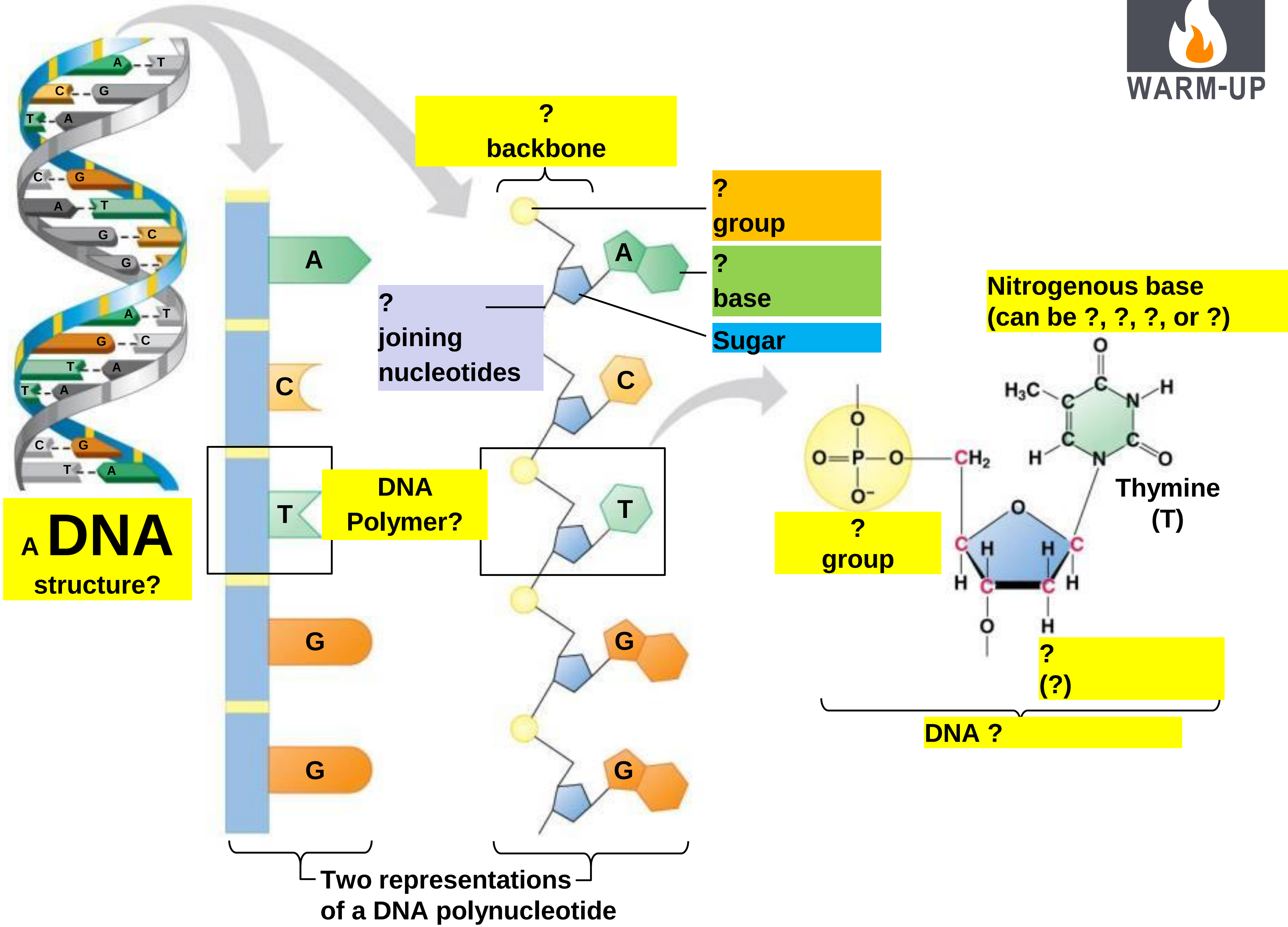
DNA and RNA

- **DNA and RNA** are ? consisting of long chains (?) of monomers called **?**.
- Each of the **#?** strands of DNA is a DNA nucleotide polymer (chain).
- A **Nucleotide** is composed of a
    - **?**
    - **?**
    - **?**
- The nucleotides are joined to one another by a **? backbone**

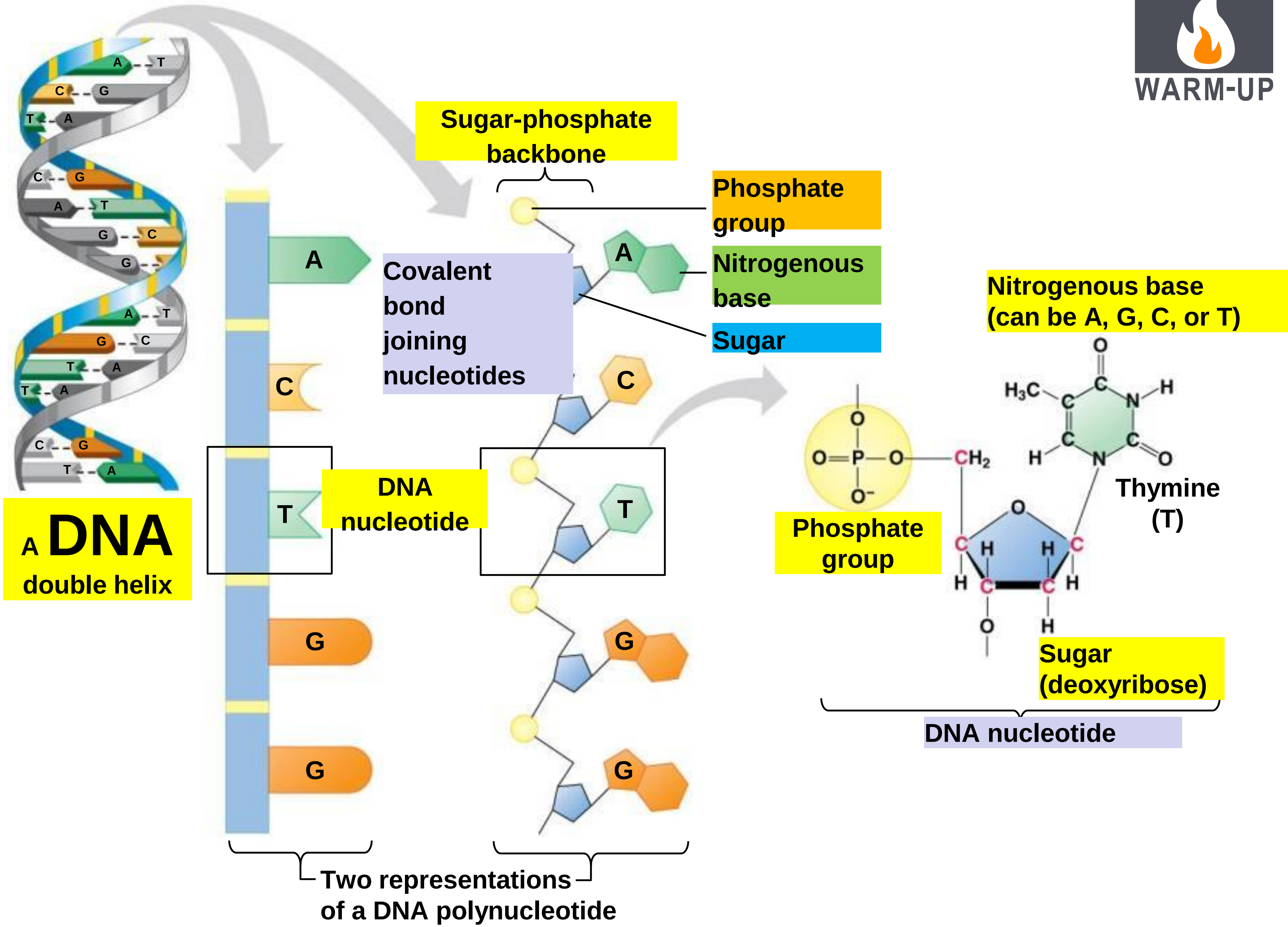
WARM-UP

DNA and RNA

- **DNA and RNA** are nucleic acids consisting of long chains (polymers) of monomers called **Nucleotides**.
- Each of the **two strands of DNA** is a DNA nucleotide polymer (chain).
- A **Nucleotide** is composed of a
  - **nitrogenous base**
  - **five-carbon sugar**
  - **phosphate group**
- The nucleotides are joined to one another by a **Sugar-Phosphate backbone**


WARM-UP
A DNA structure?
? backbone
? group
? base
Sugar
? joining nucleotides
DNA Polymer?
Nitrogenous base (can be ?, ?, ?, or ?)
Thymine (T)
? group
? (?)
DNA ?
Two representations of a DNA polynucleotide
A
C
T
G
G
A
C
T
G
G
A T
C G
T A
C G
A T
G C
G
A T
G C
T A
T A
C G
T A
O
O=P—O
O⁻
CH₂
H₃C
C
N
H
O
Thymine
H
H
H
H
H
O

WARM-UP



A DNA double helix
A
T
C
G
Sugar-phosphate backbone
Phosphate group
Nitrogenous base
Sugar
Covalent bond joining nucleotides
DNA nucleotide
Nitrogenous base (can be A, G, C, or T)
H_3C
O
N
H
C
CH_2
O^-
P
Thymine (T)
Phosphate group
Sugar (deoxyribose)
DNA nucleotide
Two representations of a DNA polynucleotide

Question:

- What would be the complementary RNA strand for the following DNA sequence?

DNA -GCGTATG-

WARM-UP

Answer:

- DNA -GCGTATG-
- RNA -CGCAUAC-

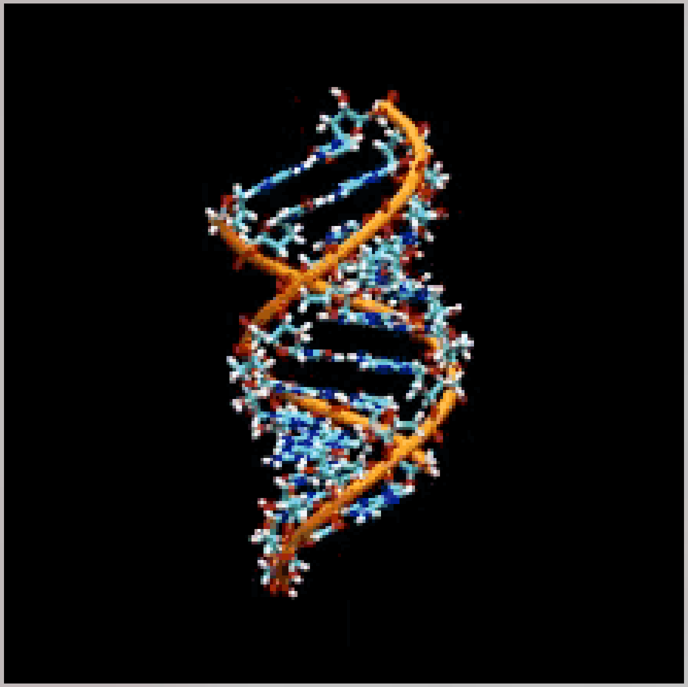
Lesson Objectives

By the end of this lesson, you should be able to:

- ❑ Discuss the overall process of protein synthesis, including where in the cell it occurs and the stages involved.
- ❑ Identify and describe DNA transcription.
- ❑ Define "genetic code".
- ❑ Identify and describe RNA translation.
- ❑ Identify and describe Protein Synthesis.
- ❑ Distinguish Prokaryotic and Eukaryotic Protein Synthesis.
- **Science Practice: Protein Synthesis**

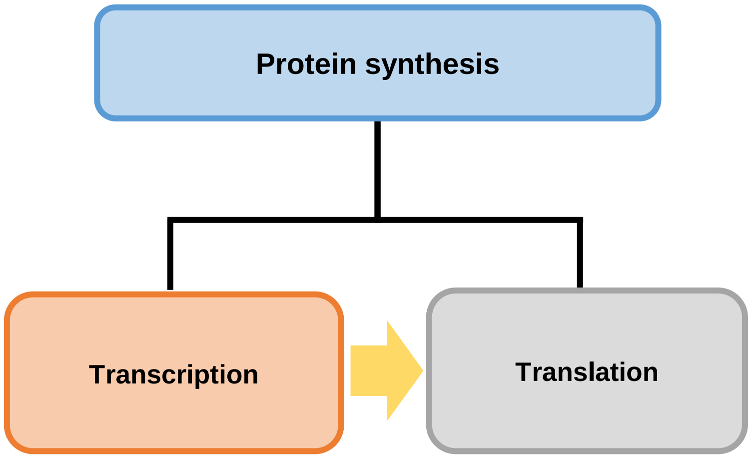
Overview

- **DNA** contains the genetic information.
- Every **trait** of an organism is controlled by DNA.



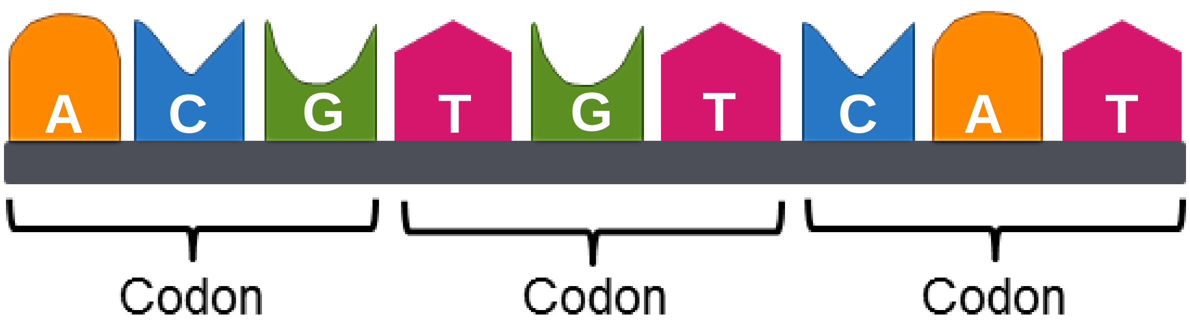
Genes control Phenotypic Traits through the Synthesis of Proteins

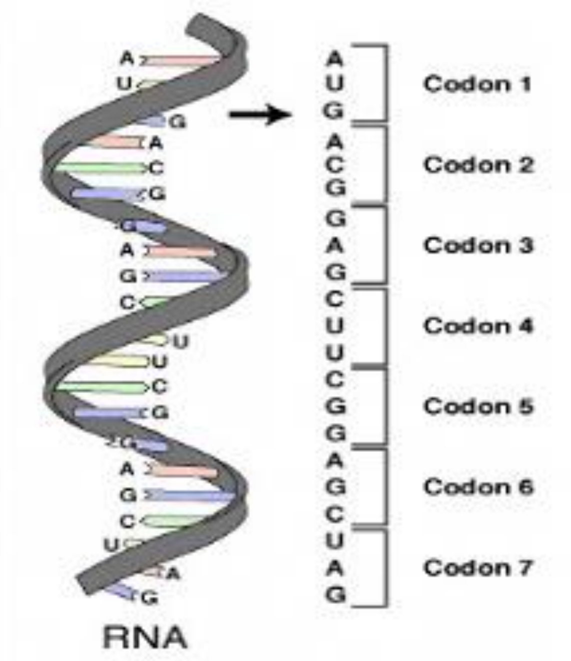
- ***TRANSCRIPTION*** is the **synthesis of RNA** under the direction of DNA.
- ***TRANSLATION*** is the **synthesis of Proteins** under the direction of RNA.
- **Genes** provide the instructions for making specific **Proteins**.

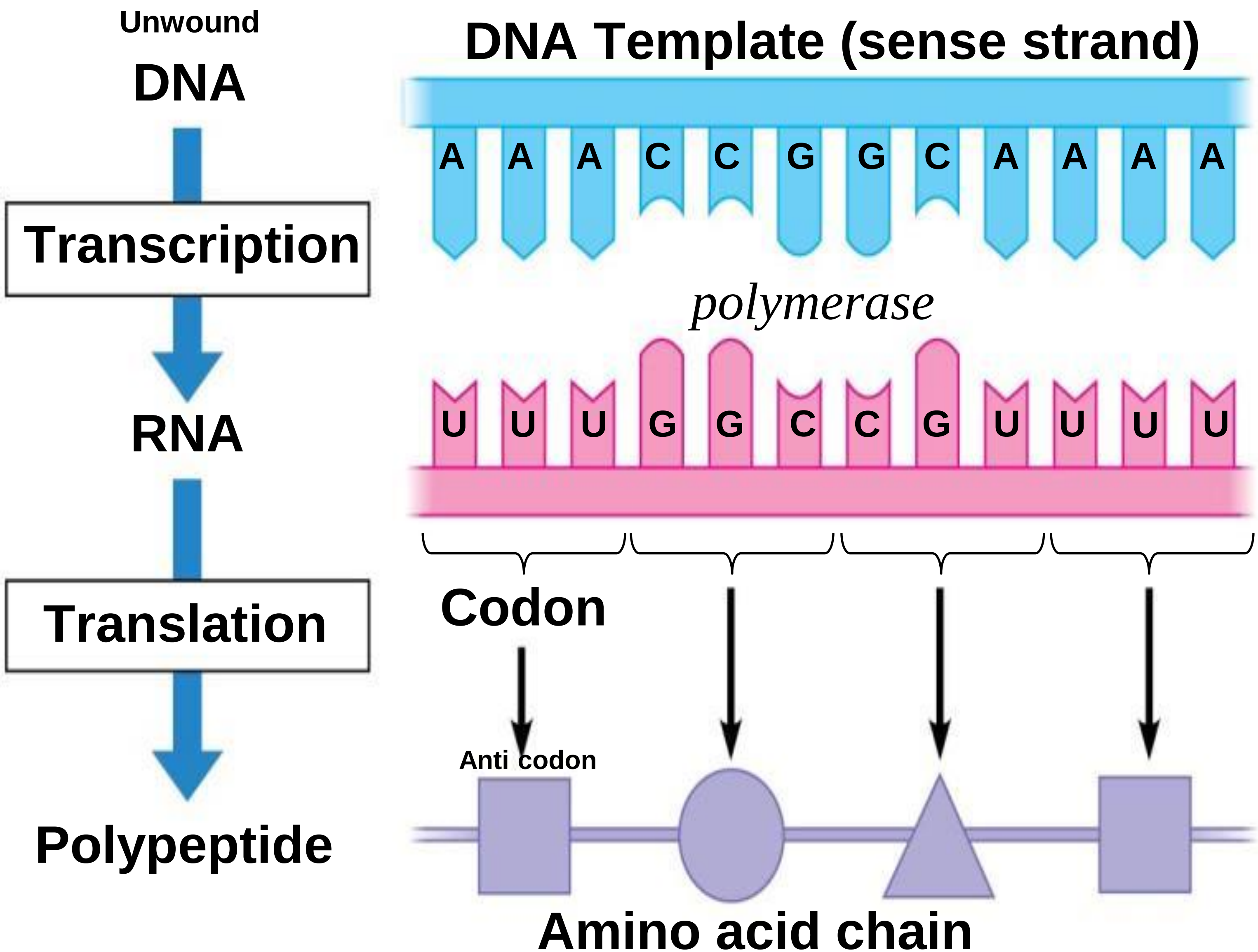


Cracking the Code

- The genetic code was discovered by Marshall Nirenberg and J. Heinrich Matthaei in 1961.
- The genetic code was based on **codons**, sequences of three bases that form a unit of the genetic code in DNA that determines a specific amino acid.
- Amino acids are used to make proteins.







Unwound
DNA
Transcription
RNA
Translation
Polypeptide
DNA Template (sense strand)
A A A C C G G C A A A A
polymerase
U U U G G C C G U U U U
Codon
Anti codon
Amino acid chain

DNA to Protein Animation

https://somup.com/c3hhF8OKq5

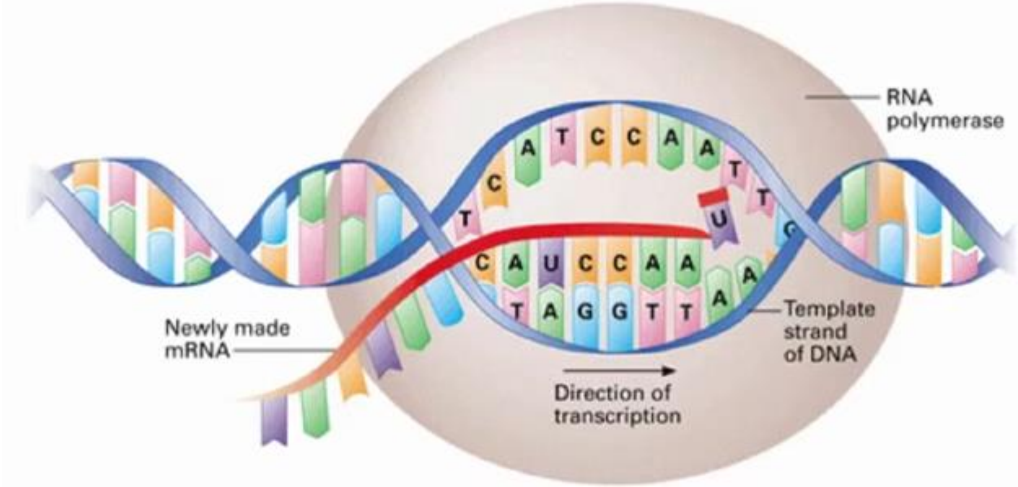
DNA to Protein (2:38)

Genetic Information written in Codons is Translated into Amino Acid Sequences

- The **sequence of nucleotides in DNA** provides a **code** for constructing a **protein**.
  - **Protein** construction requires a **conversion** of a **nucleotide sequence** to an **amino acid sequence**.
  - ***Transcription*** rewrites the **DNA code into RNA**, using the same nucleotide "language."

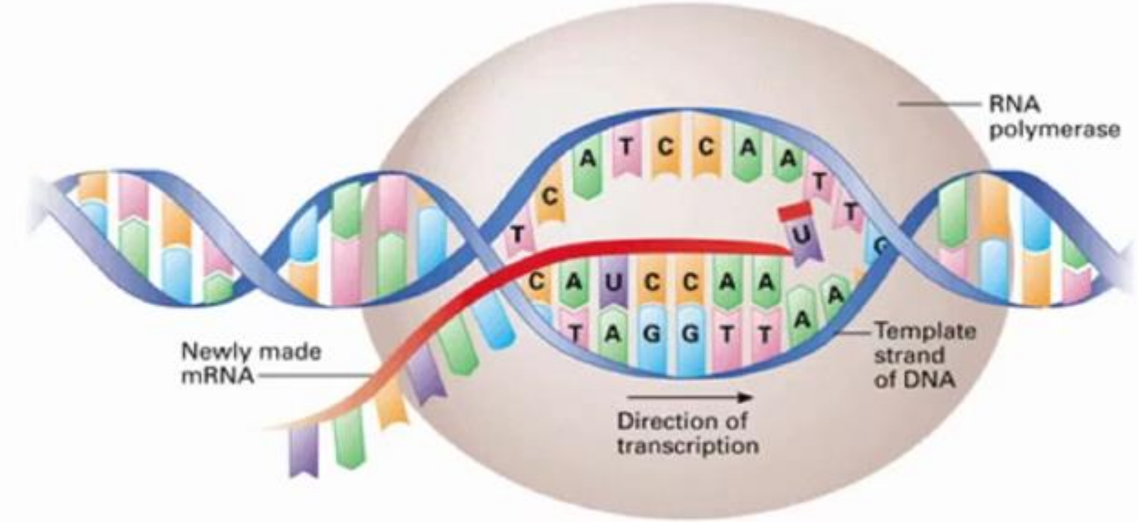
Transcription

- **Transcription** is the process of forming a strand of RNA from a strand of DNA.
- This process occurs in the nucleus (eukaryotic cells).
- Since prokaryotes do not have a nucleus, the process occurs in their cytoplasm.
- The cell must make RNA to send to the cytoplasm to tell the ribosomes how and which proteins to make.



Transcription

- The RNA molecule is a faithful copy of a gene's protein building **instructions**. This type of RNA is called **messenger RNA (mRNA)**.
- An enzyme called **RNA Polymerase** catalyzes this reaction.
- The purpose of transcription is to **copy one gene** from the DNA molecule.

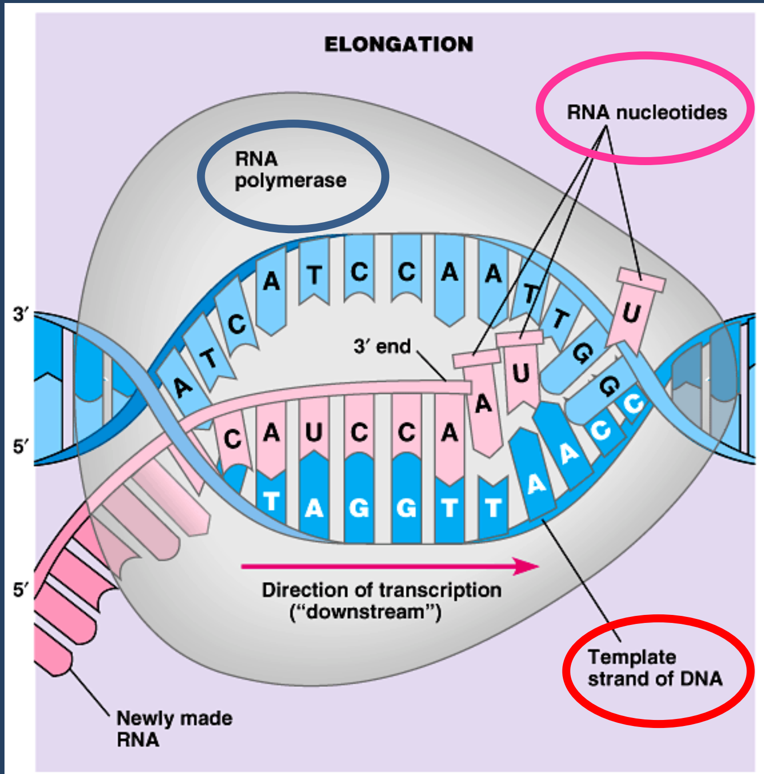


Steps of Transcription

RNA Polymerase:

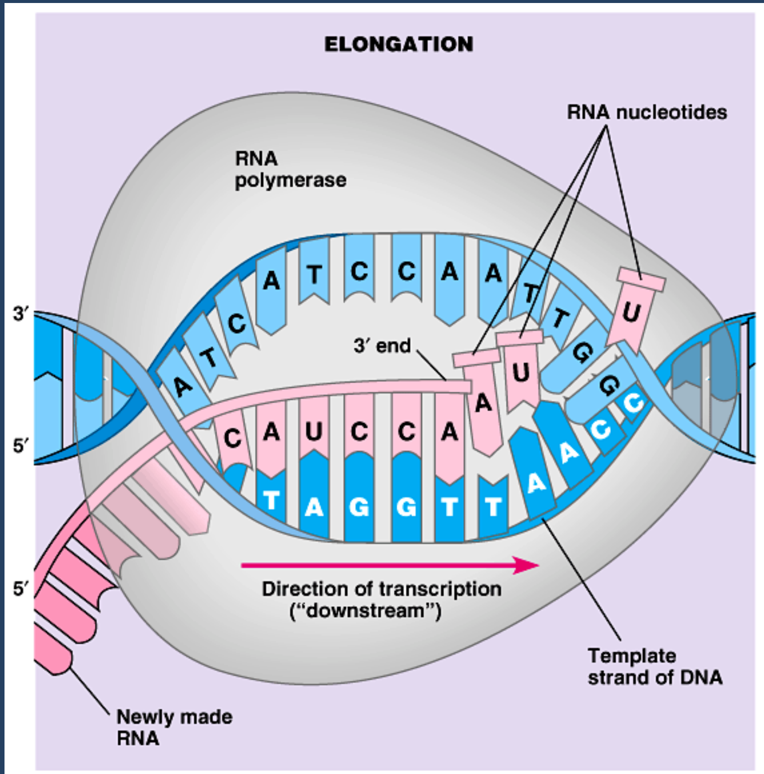
Separates the DNA strands.

- One strand of DNA is used as a template (sense strand).
- New nucleotides are inserted according to the base pairing rules.
  - When transcribing RNA, Adenine pairs with uracil;
  - Cytosine pairs with guanine.

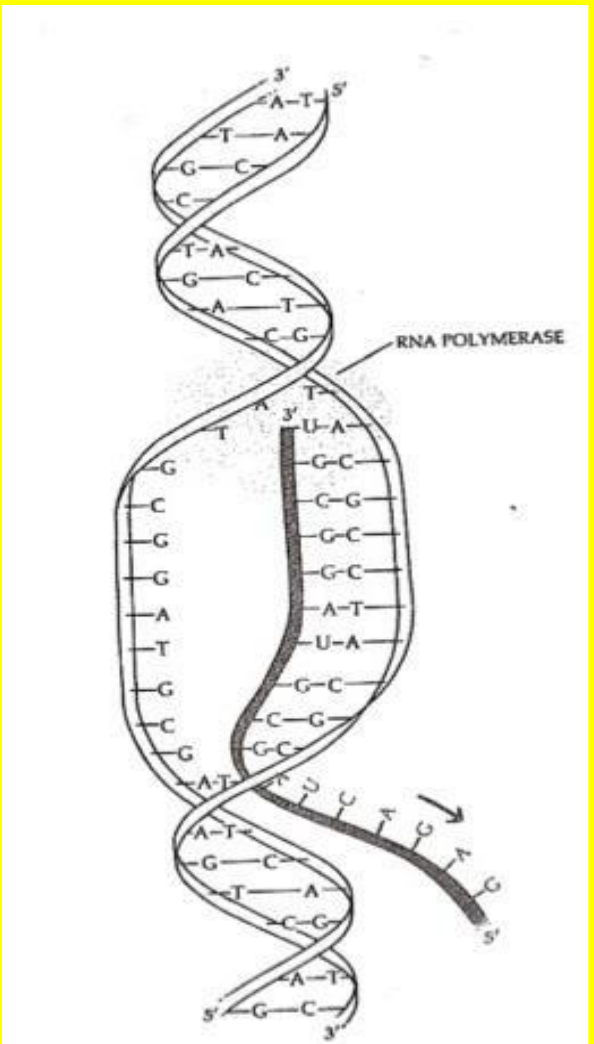


Steps of Transcription

- This continues until the end is reached.
- As the RNA polymerase moves along the DNA molecule, <u>hydrogen bonds</u> between the two strands of DNA are reformed.
- A <u>singled stranded RNA molecule</u> has been transcribed.

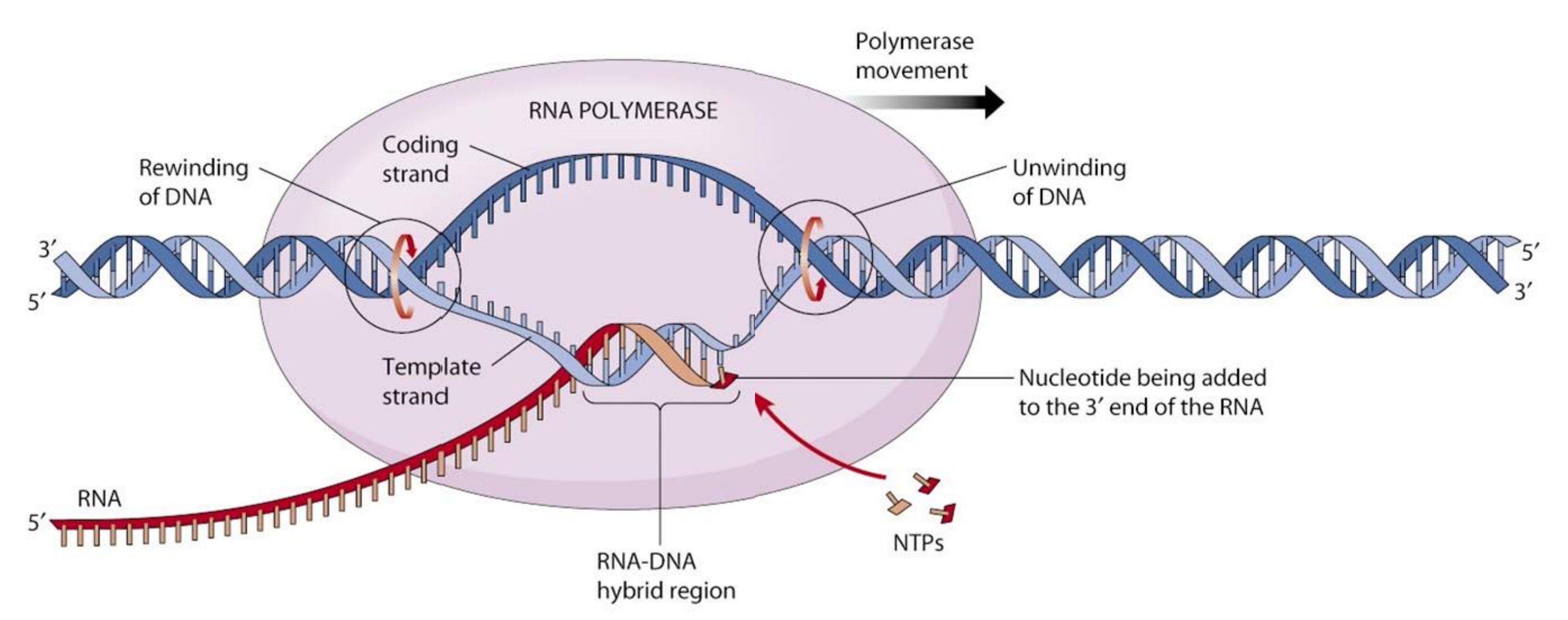


Steps of Transcription

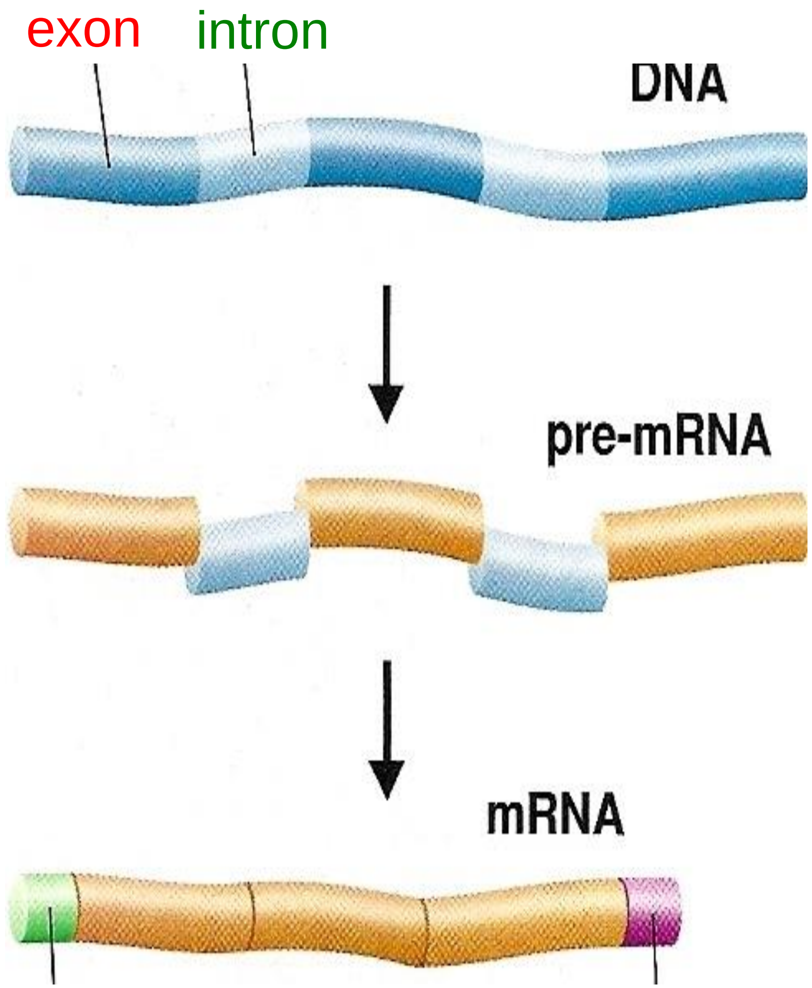


- The purpose of transcription is not to copy the entire length of the DNA molecule
- but to copy only small portions – a gene's worth
- to be sent to the ribosome as the instructions for protein synthesis.

RNA Polymerase



Eukaryotic RNA Processing and Editing



Once the **RNA** is transcribed it is not yet ready to be sent out to the cytoplasm.

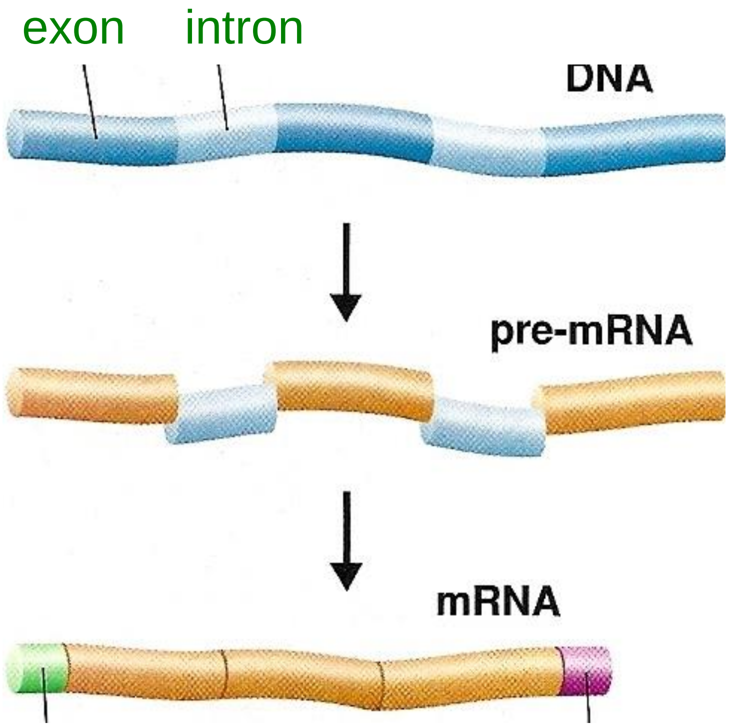
It must be modified before it is ready to serve its purpose.

The **mRNA** is a copy of a small section of DNA.

This RNA contains sections called **INTRONS.**

and other sections called **EXONS**.

Eukaryotic RNA Processing and Editing

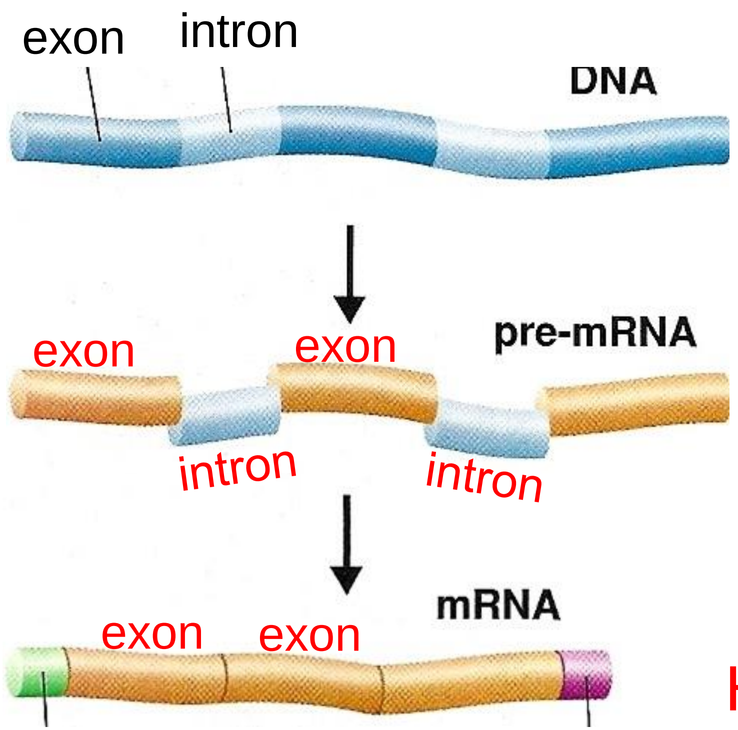


INTRONS are sequences of nitrogen bases that…

ARE NOT involved in the making of the protein.

These need to be cut out of the RNA before the RNA goes to the ribosomes.

Eukaryotic RNA Processing and Editing



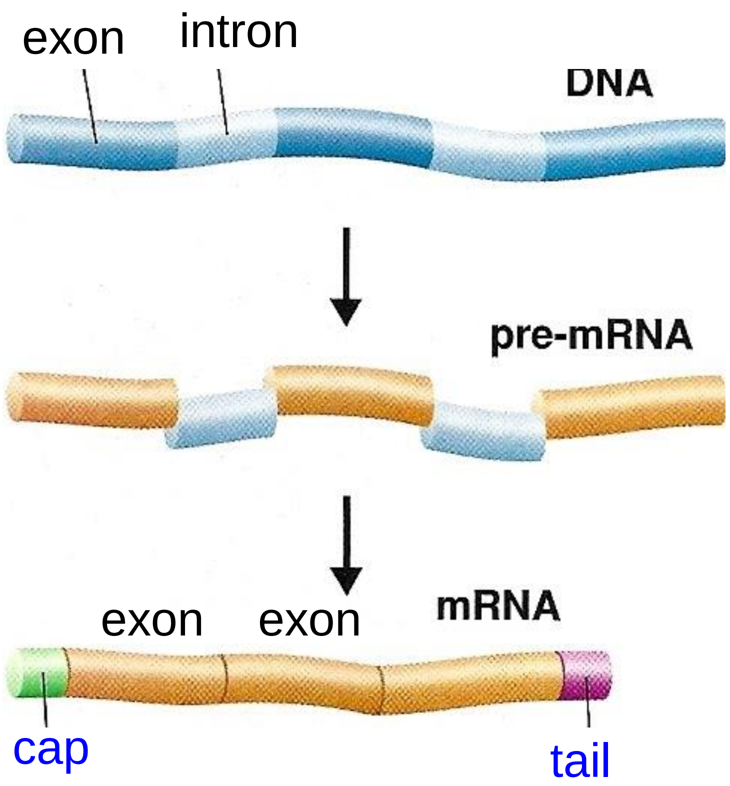
EXONS are the sequences of nitrogen bases that **ARE** involved in the making of the protein.

When mRNA is formed, both the introns and exons are copied from the DNA.

However, the introns are cut out of the RNA while the RNA is still inside the nucleus.

The remaining exons are spliced back together by the enzyme **Ligase**, to form the final RNA.

Eukaryotic RNA Processing and Editing

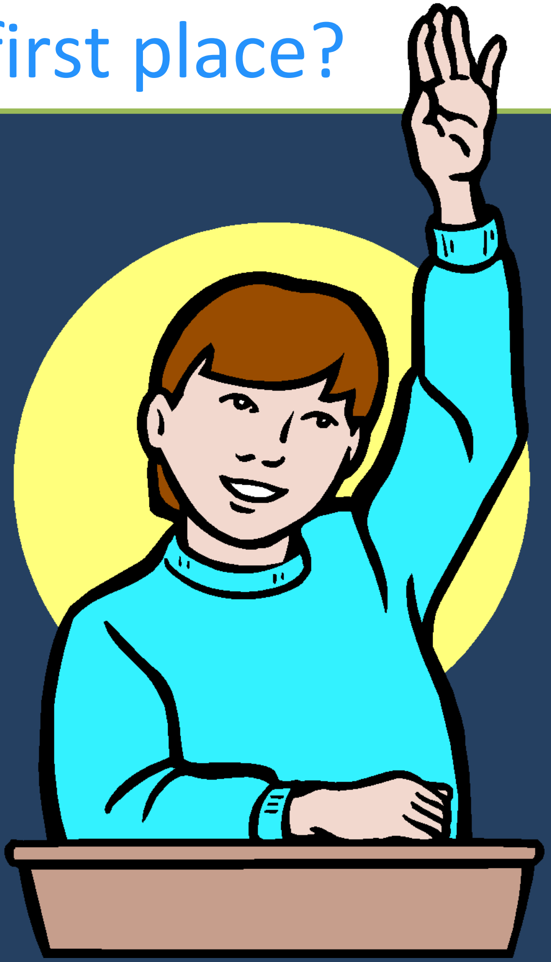


Finally, a **CAP** and **TAIL** are added to form the final RNA molecule.

The cap and tail help to identify the "front end" of the RNA from the "back end".

The cap and tail help the ribosome to identify the start of the instructions and the end of the instructions.

If introns are not needed and will be cut out of the RNA, why are they there in the first place?



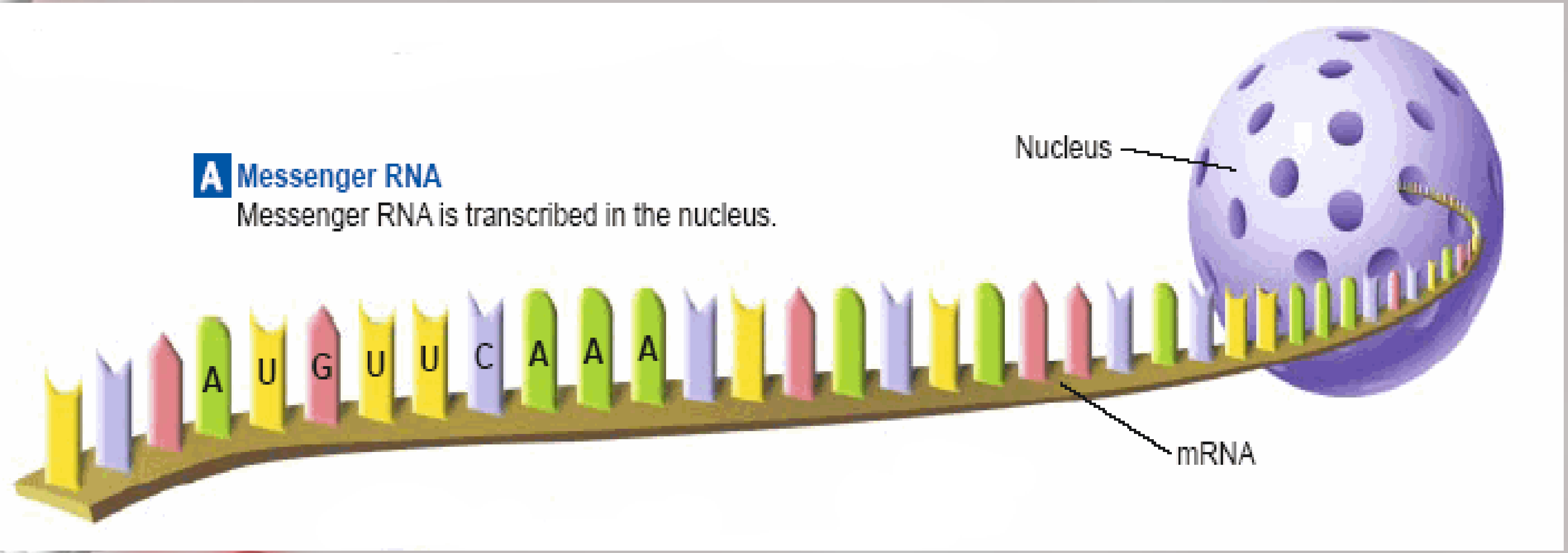
When introns are present in genes, it allows a single gene to code for more than one type of protein, depending on which segments are treated as introns and which are treated as exons.

When particular segments are cut out, one type of protein might result.

If different segments are cut out, a different type of protein would result.

mRNA Transcript

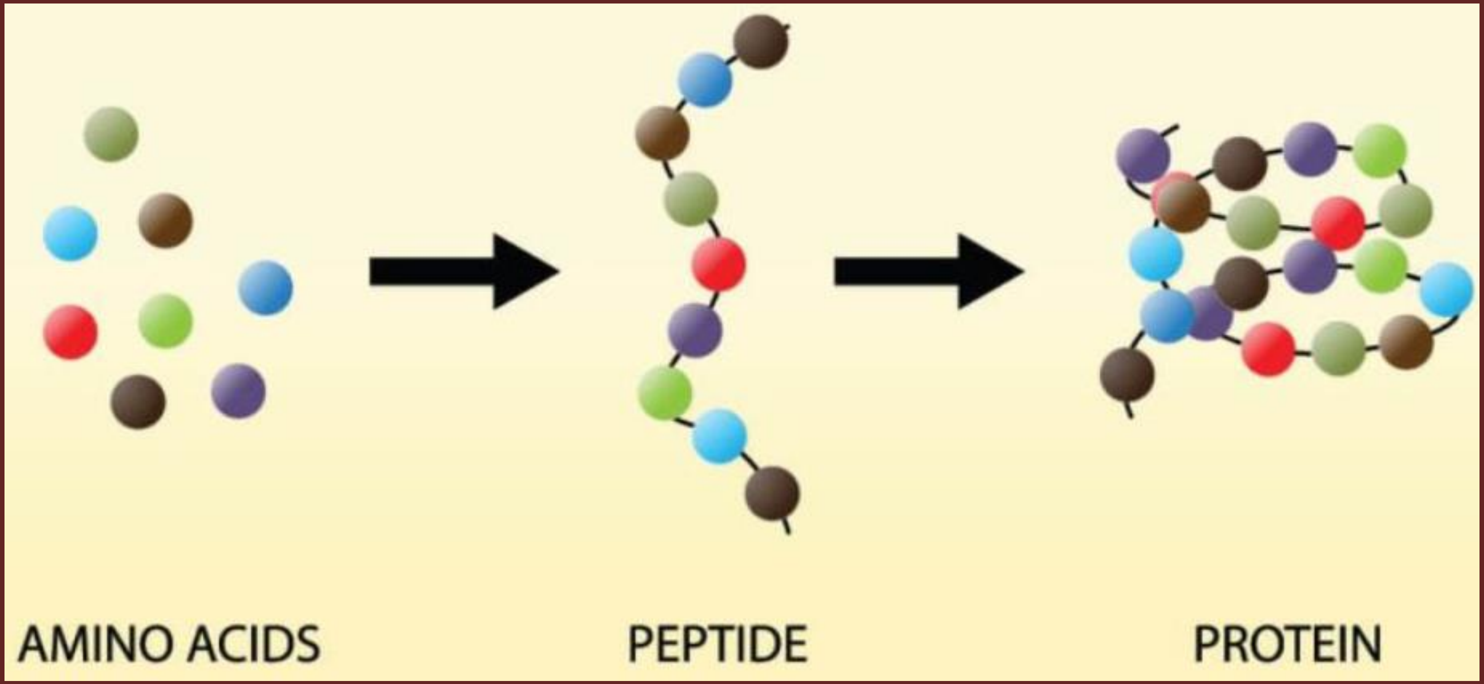
mRNA leaves the nucleus through its **pores** and goes to the **ribosomes.**



The Genetic Code

Proteins: are made by joining together long chains of amino acids.

The order in which the amino acids are joined: determines the type of protein that is made.



The Genetic Code

The “language” of **mRNA** instructions is called the **GENETIC CODE**.

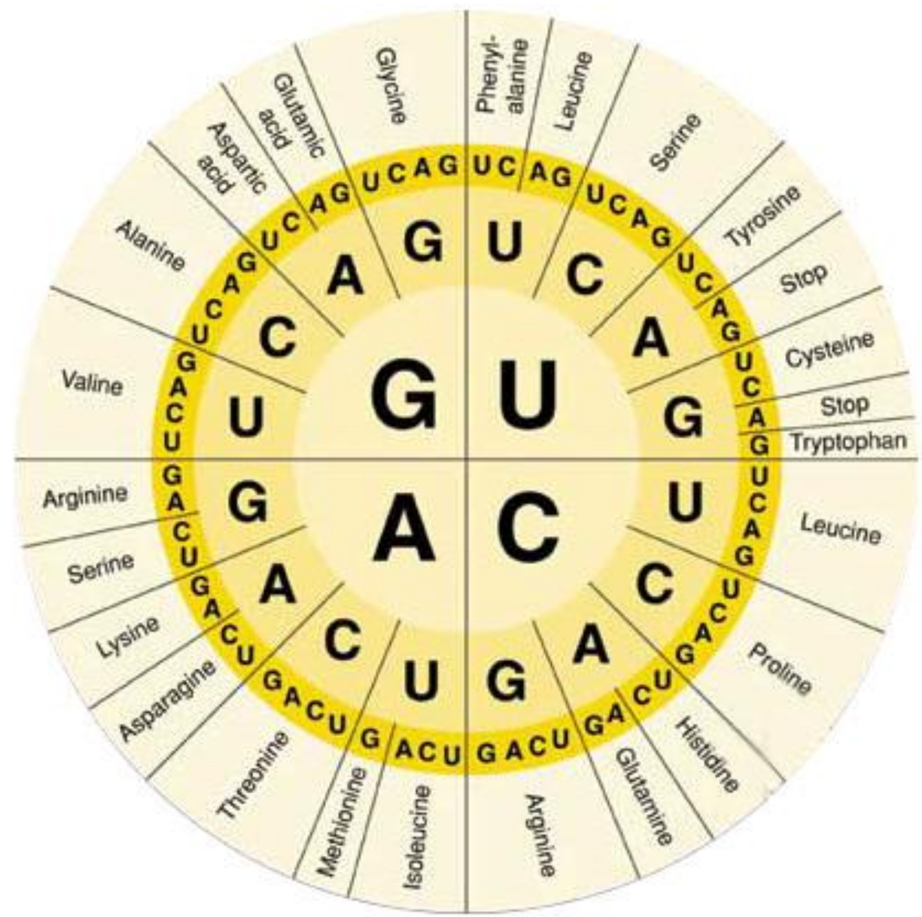
Codons:

The genetic code is read three nitrogen bases at a time.

A codon is a group of three nitrogen bases that specifies one amino acid.

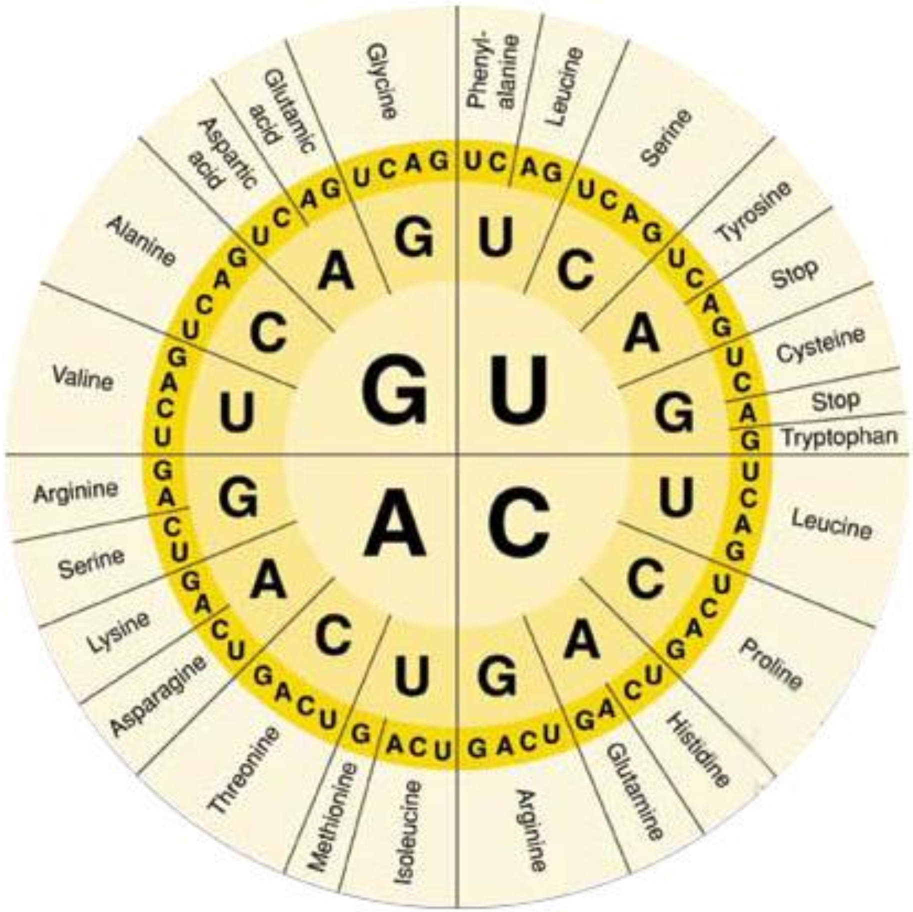
Genetic Information written in Codons is Translated into Amino Acid Sequences

- The flow of information from **gene to protein** is based on a **Triplet Code**.
- The **genetic instructions** for the **amino acid sequence of a polypeptide chain (primary structure of a protein)** are written in **DNA** and **RNA** as a series of non-overlapping three-base "words" called **CODONS**.



Genetic Information written in Codons is Translated into Amino Acid Sequences

- ***Translation*** involves switching from the **nucleotide "language"** to the **amino acid "language."**
- **Each amino acid** is specified by a ***CODON***.
  - **64 codons** are possible
  - **Some amino acids have more than one possible codon**



The Genetic Code dictates how Codons are Translated into Amino Acids

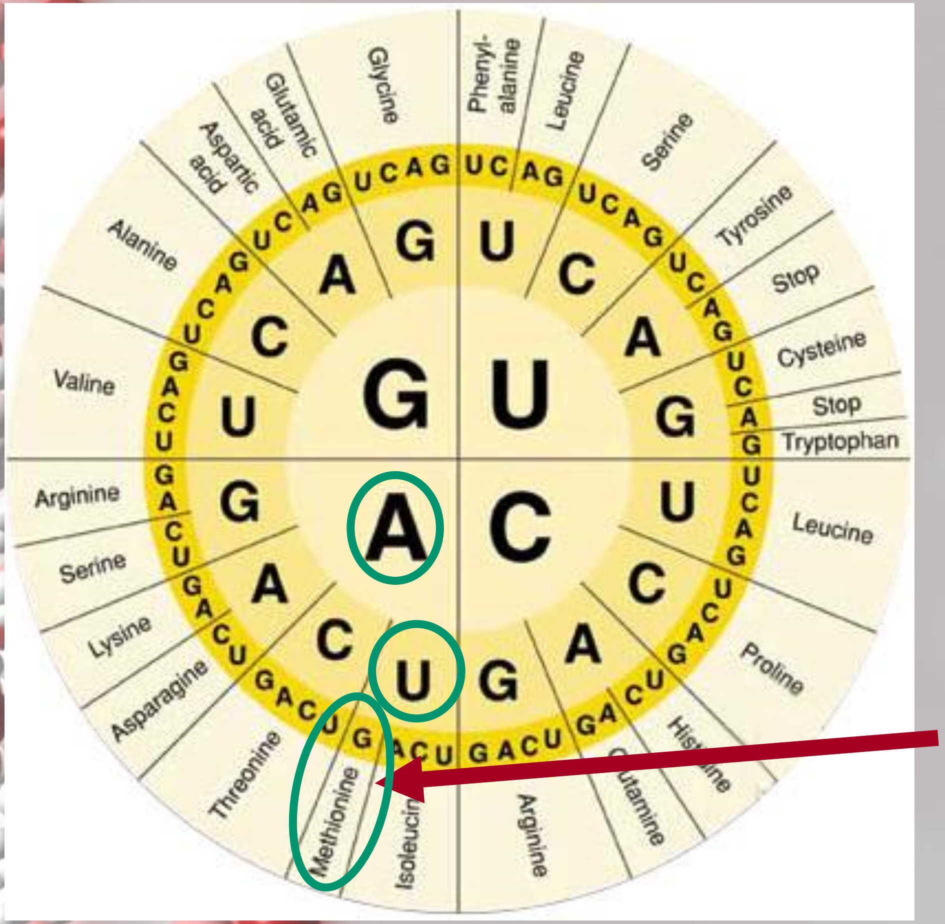
The ***Genetic Code*** is the **amino acid translations** of each of the **nucleotide triplets**.

- **Three Nucleotides specify One Amino Acid**.
- **Sixty-one codons** correspond to **amino acids**.
- **AUG** codes for **methionine** and signals the **start** of translation.
- **Three "stop" codons** signal the **end** of translation.

Second base of mRNA codon

First base of mRNA codon	U	C	A	G	Third base of mRNA codon
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
	UUA Leu	UCA Ser	UAA Stop	UGA Stop	A
	UUG Leu	UCG Ser	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
	CUC Leu	CCC Pro	CAC His	CGC Arg	C
	CUA Leu	CCA Pro	CAA Gln	CGA Arg	A
	CUG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
	AUG Met or start	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

The Genetic Code



- Use the code by reading from the **center to the outside**
- Example: **AUG** codes for Methionine

The Genetic Code dictates how Codons are Translated into Amino Acids

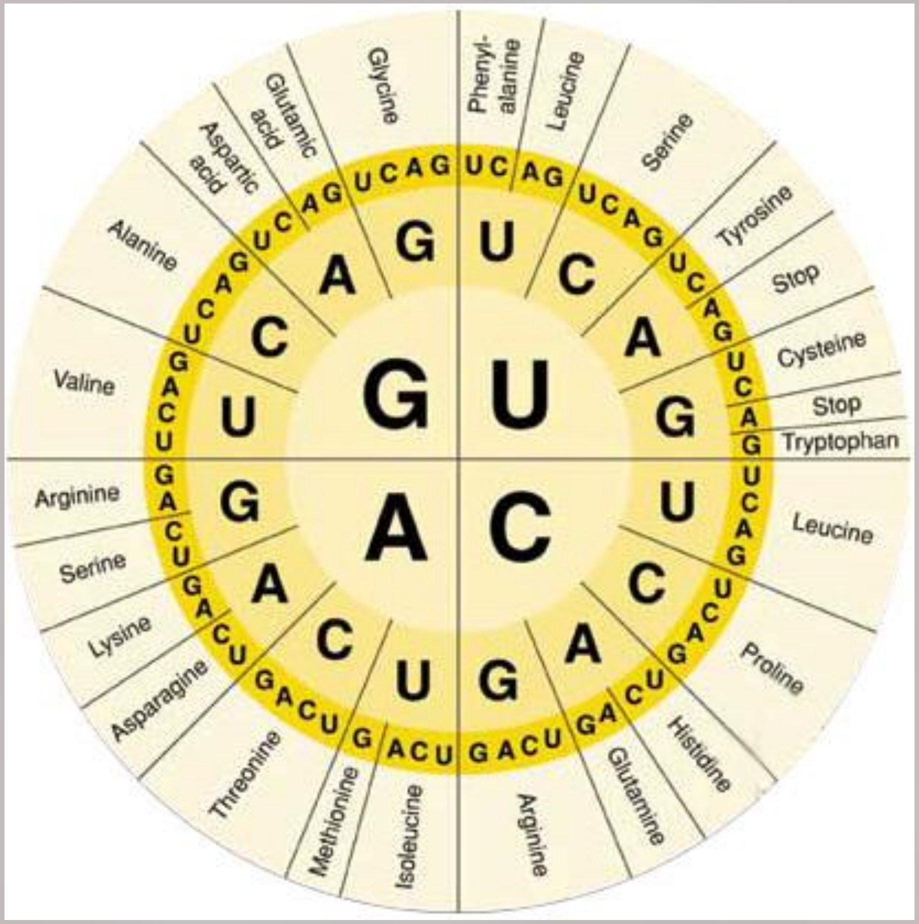
The **Genetic Code** is

- ***redundant***, with more than one codon for some amino acids.
- ***unambiguous***, in that any codon for one amino acid does not code for any other amino acid.
- ***nearly universal***, in that the genetic code is shared by organisms from the simplest bacteria to the most complex plants and animals.

TRY IT

Name the Amino Acids

- GGG?
- UCA?
- CAU?
- GCA?
- AAA?



TRY IT

Name the Amino Acids

GGG?

- glycine

UCA?

- serine

CAU?

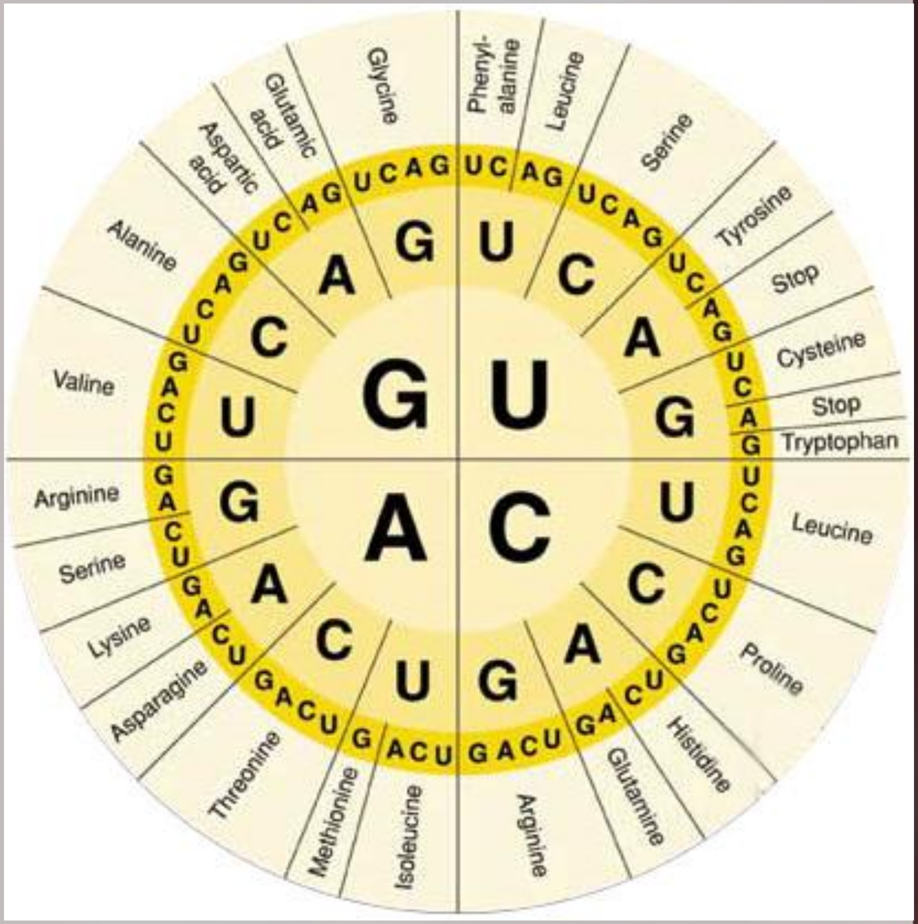
- histidine

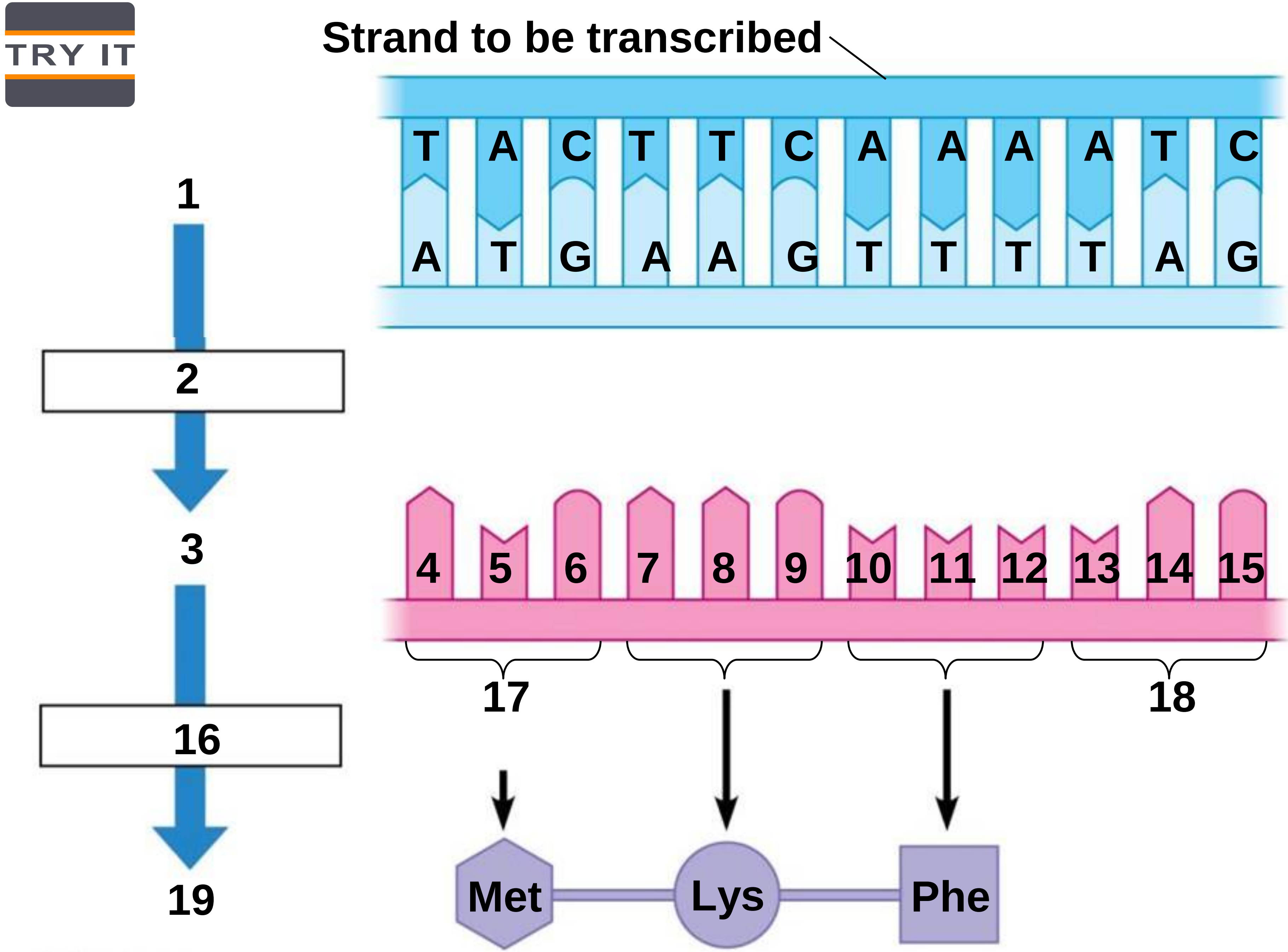
GCA?

- alanine

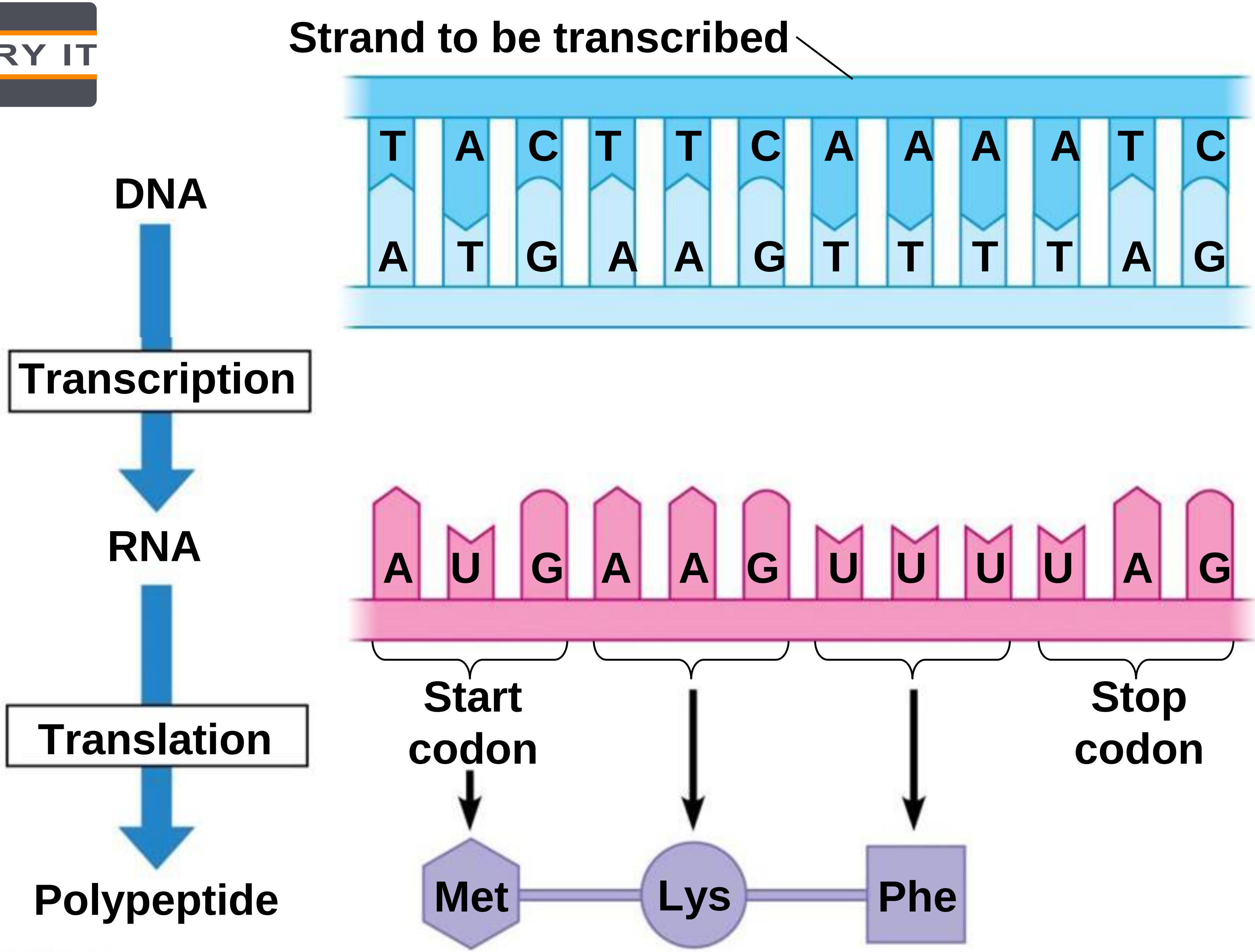
AAA?

- lysine





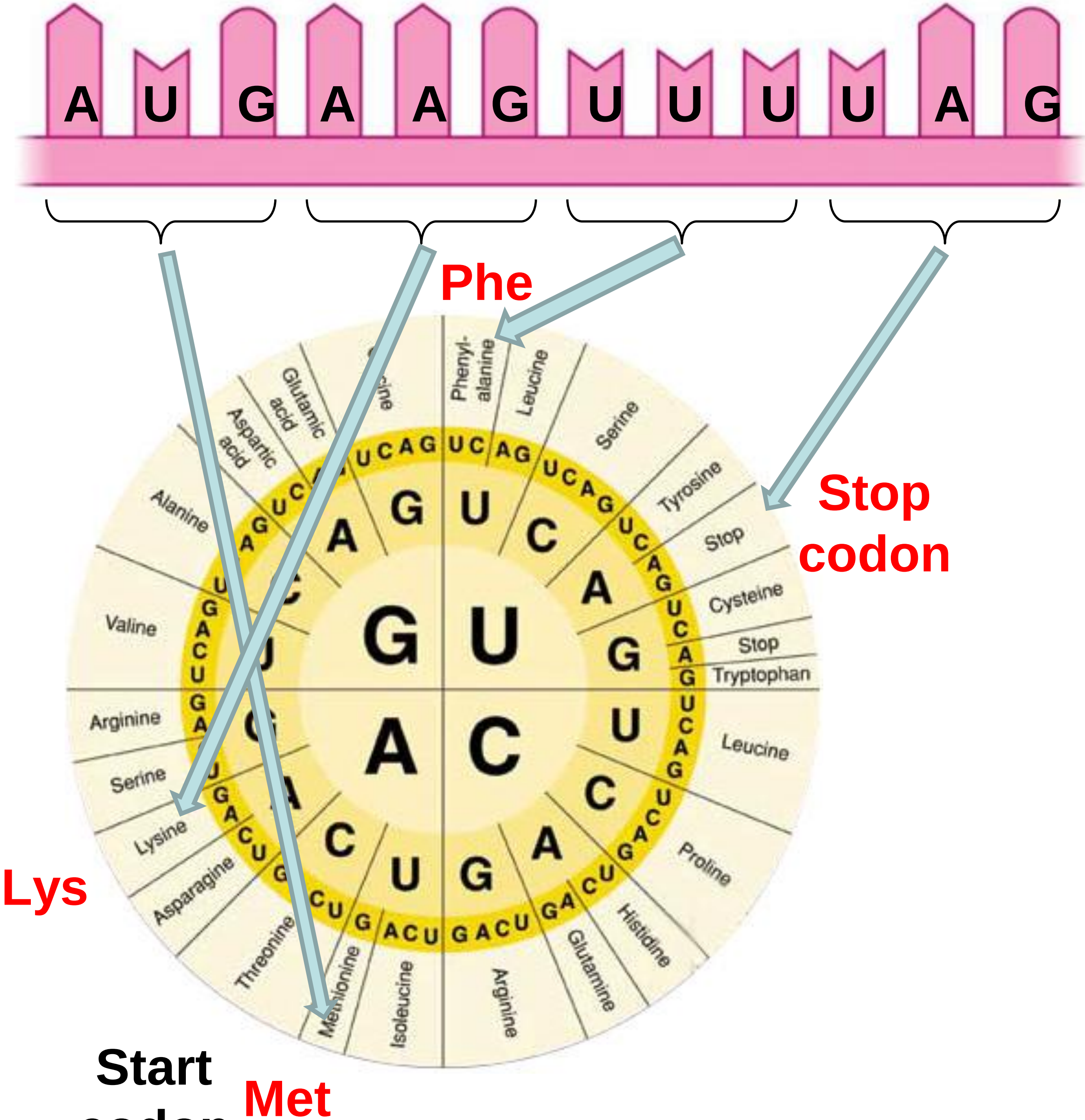
TRY IT
Strand to be transcribed
T A C T T C A A A A T C
A T G A A G T T T T A G
1
2
3
4 5 6 7 8 9 10 11 12 13 14 15
16
17
18
19
Met
Lys
Phe



Strand to be transcribed
DNA
T A C T T C A A A A T C
A T G A A G T T T T A G
Transcription
RNA
A U G A A G U U U U A G
Start codon
Stop codon
Translation
Polypeptide
Met
Lys
Phe

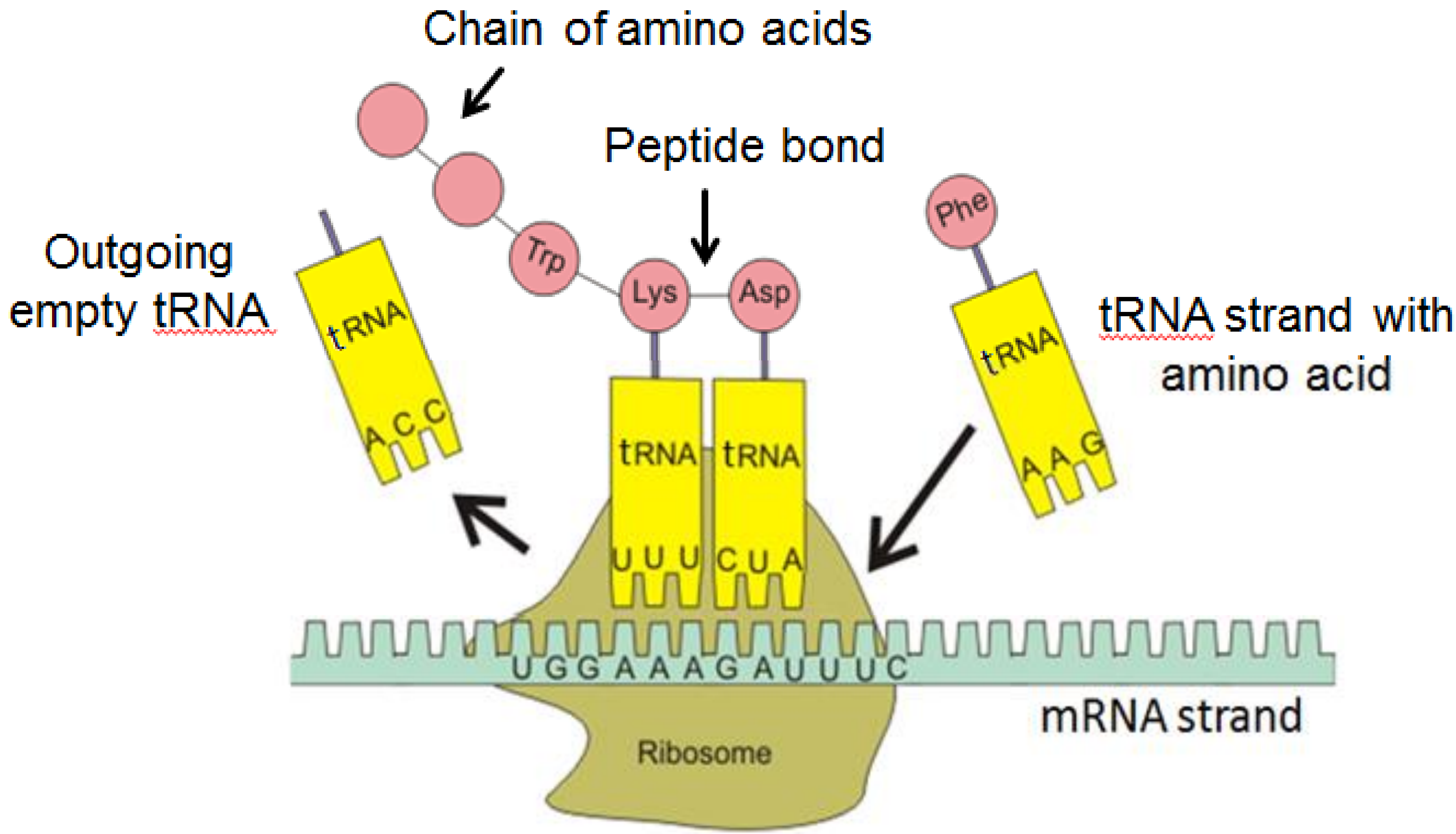
mRNA

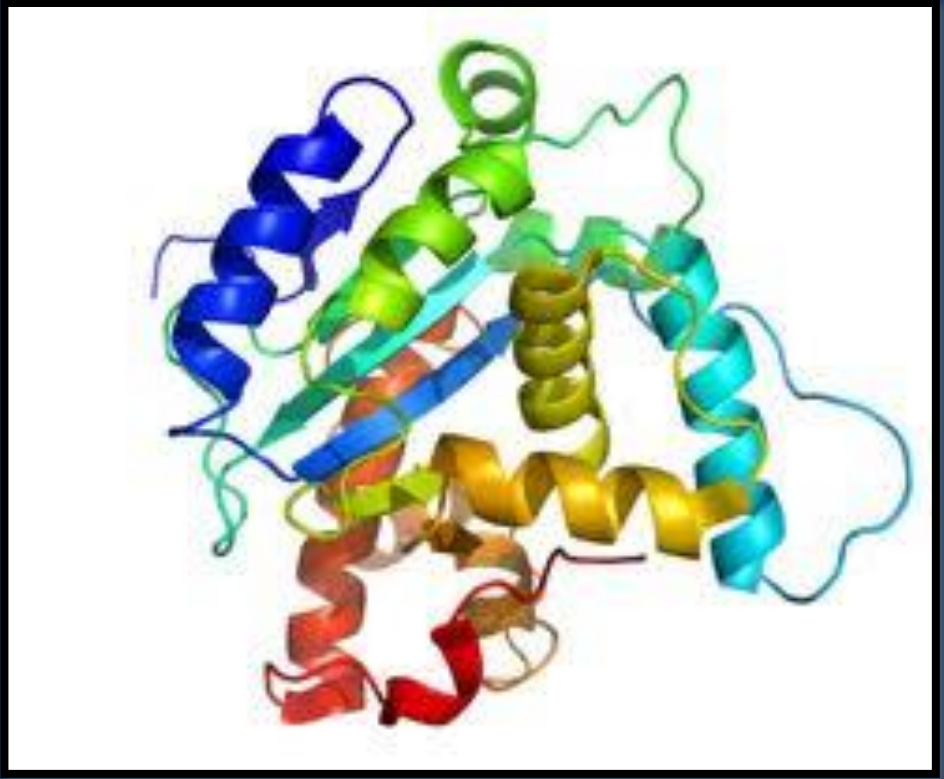
Translation



Start codon

The Steps of Translation





Protein Synthesis (Translation)

The synthesis of proteins is called **TRANSLATION**. The cell must translate the base sequence of an mRNA molecule into the amino acid sequence of a protein.

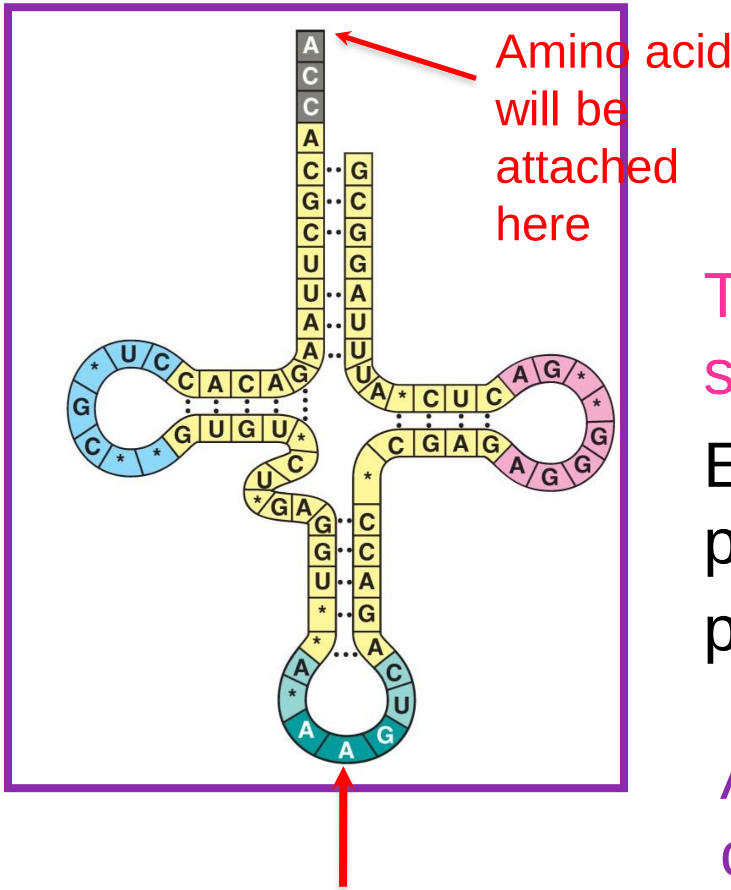
The site of translation, or protein synthesis, is the ribosome. The ribosome facilitates the orderly linking of amino acids into **proteins**.

During translation, the cell uses information from mRNA to produce **PROTEINS**.

Transfer RNA Molecules serve as Interpreters during Translation

- ***Transfer RNA (tRNA)*** molecules function as an **interpreter**, converting the genetic message of **mRNA into the language of proteins**.
- ***Transfer RNA*** molecules perform this interpreter task by:
    - picking up the appropriate **amino acid.**
    - using a special triplet of bases, called an ***Anticodon***, to recognize the appropriate **codons** in the **mRNA**.

Transfer RNA



These three bases are the "**ANTICODON**".

The function of **tRNA** is to transfer amino acids from the cytoplasm's amino acid pool to a ribosome.

Transfer RNA molecules are not all the same.

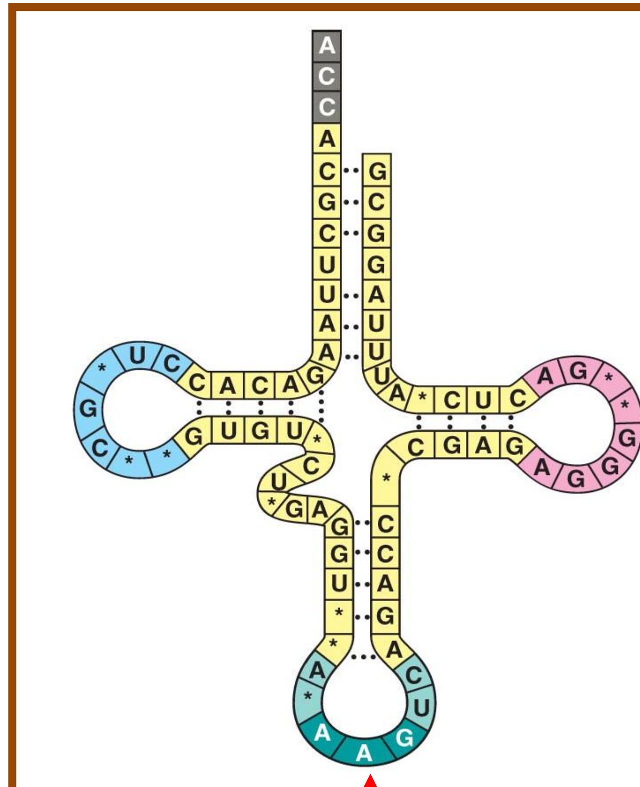
Each type of **tRNA** molecule links a particular **mRNA codon** with a particular amino acid.

As a **tRNA** arrives at a ribosome, it carries a specific amino acid at one end.

At the other end is a nucleotide triplet called an **ANTICODON**.

E.g. If an mRNA codon is UUC, this would translate as the amino acid phenylalanine.

The tRNA that delivers the amino acid phenylalanine has as its anticodon AAG.



anticodon

Phenylalanine
codon: UUC

Each tRNA is used repeatedly to locate a particular amino acid and deposit it at the ribosome.

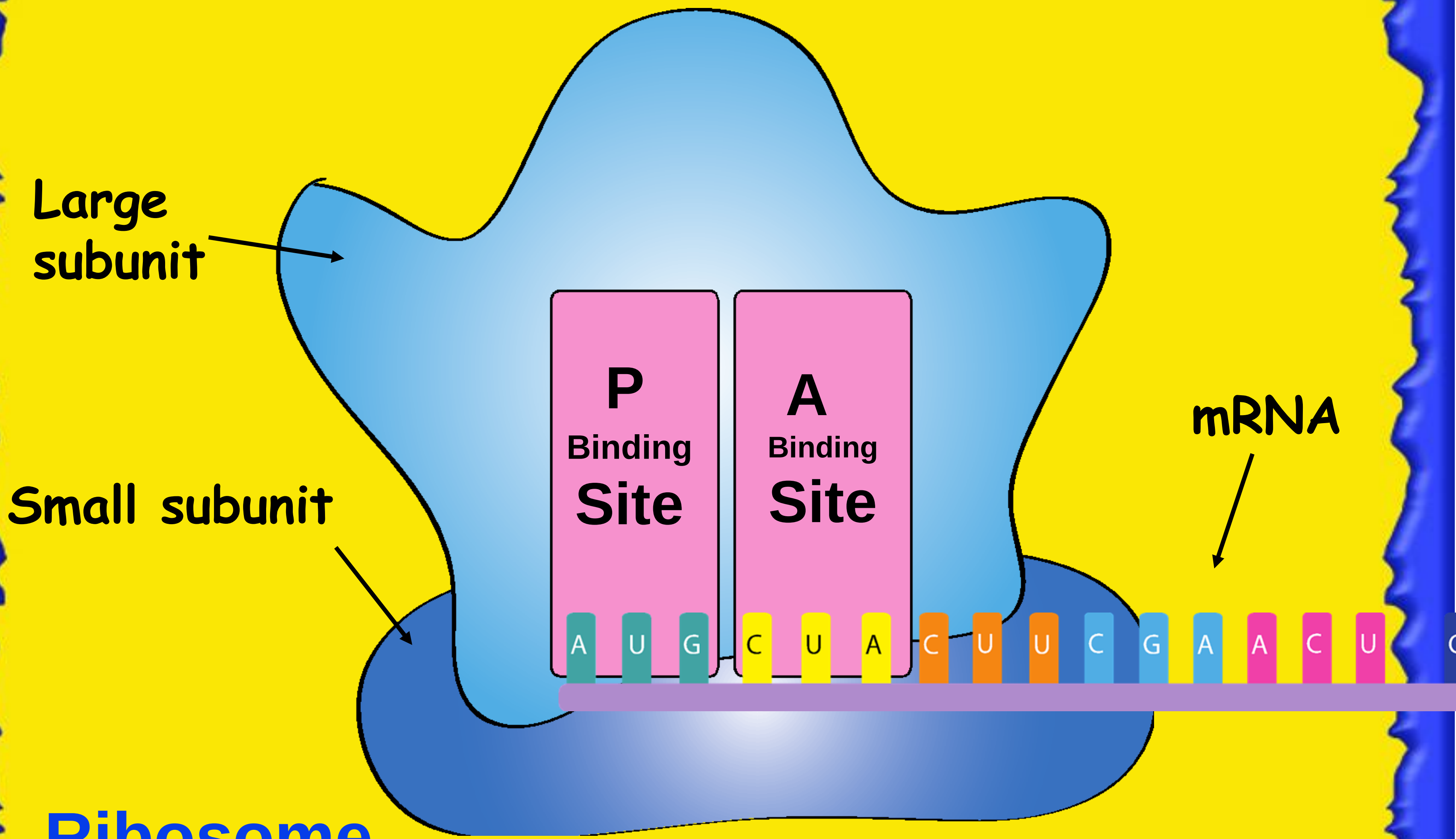
It then leaves the ribosome to go and find another amino acid.

Ribosomes build Polypeptides

Translation occurs on the surface of the **Ribosome**:

- **Ribosomes** coordinate the **synthesis of polypeptides.**
- Ribosomes have two subunits: **small and large.**
- Each subunit is composed of ***Ribosomal RNAs*** and **Proteins**.
- Ribosomal subunits come together during translation.
- Ribosomes have binding sites for mRNA and tRNAs.

Ribosomes build Polypeptides



Ribosome

Translation

Three steps:

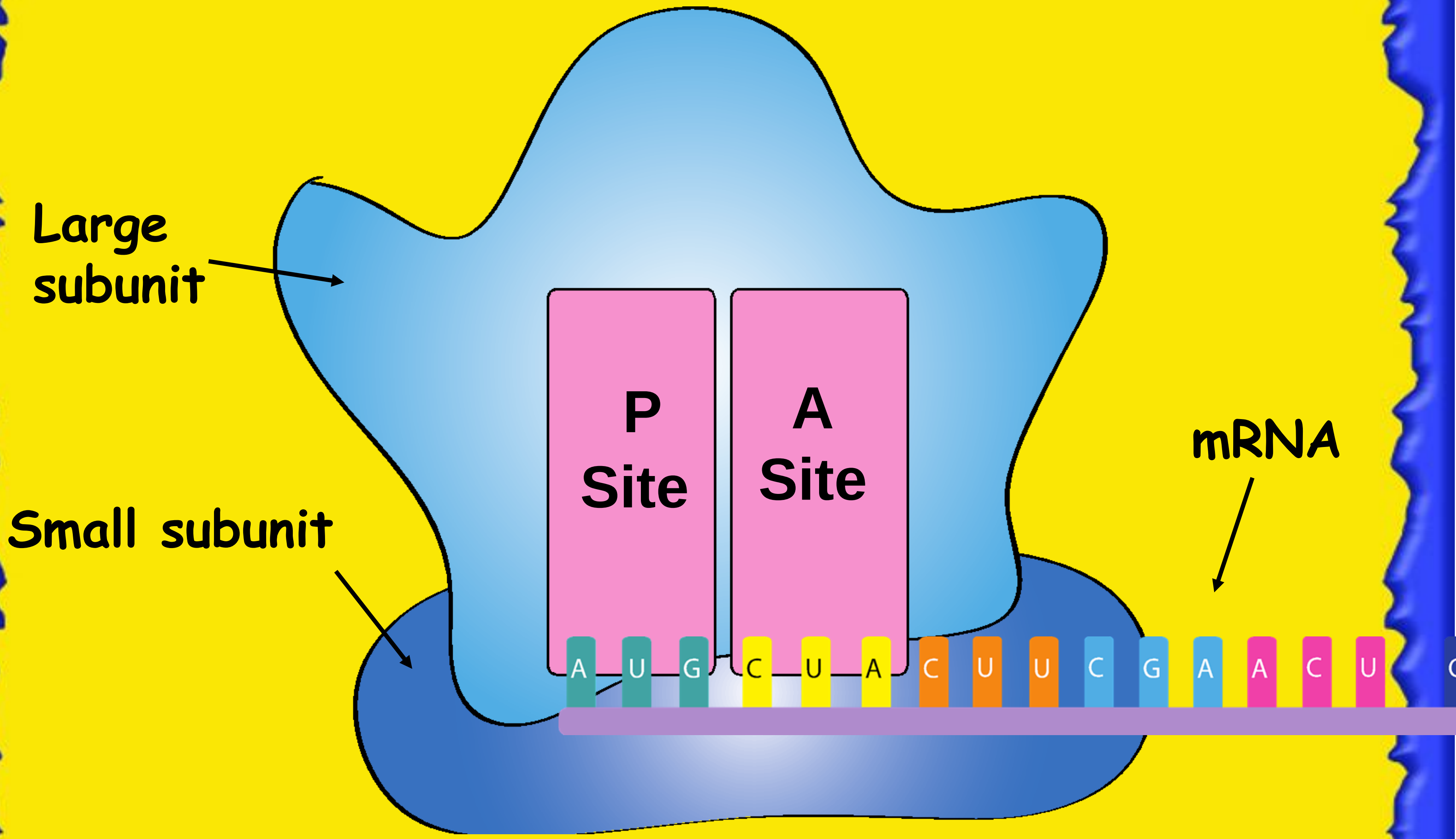
1. **initiation**: start codon (AUG)
2. **elongation**: amino acids linked
3. **termination**: stop codon (UAG, UAA, or UGA)

Let's Make a Protein !

Second base of RNA codon

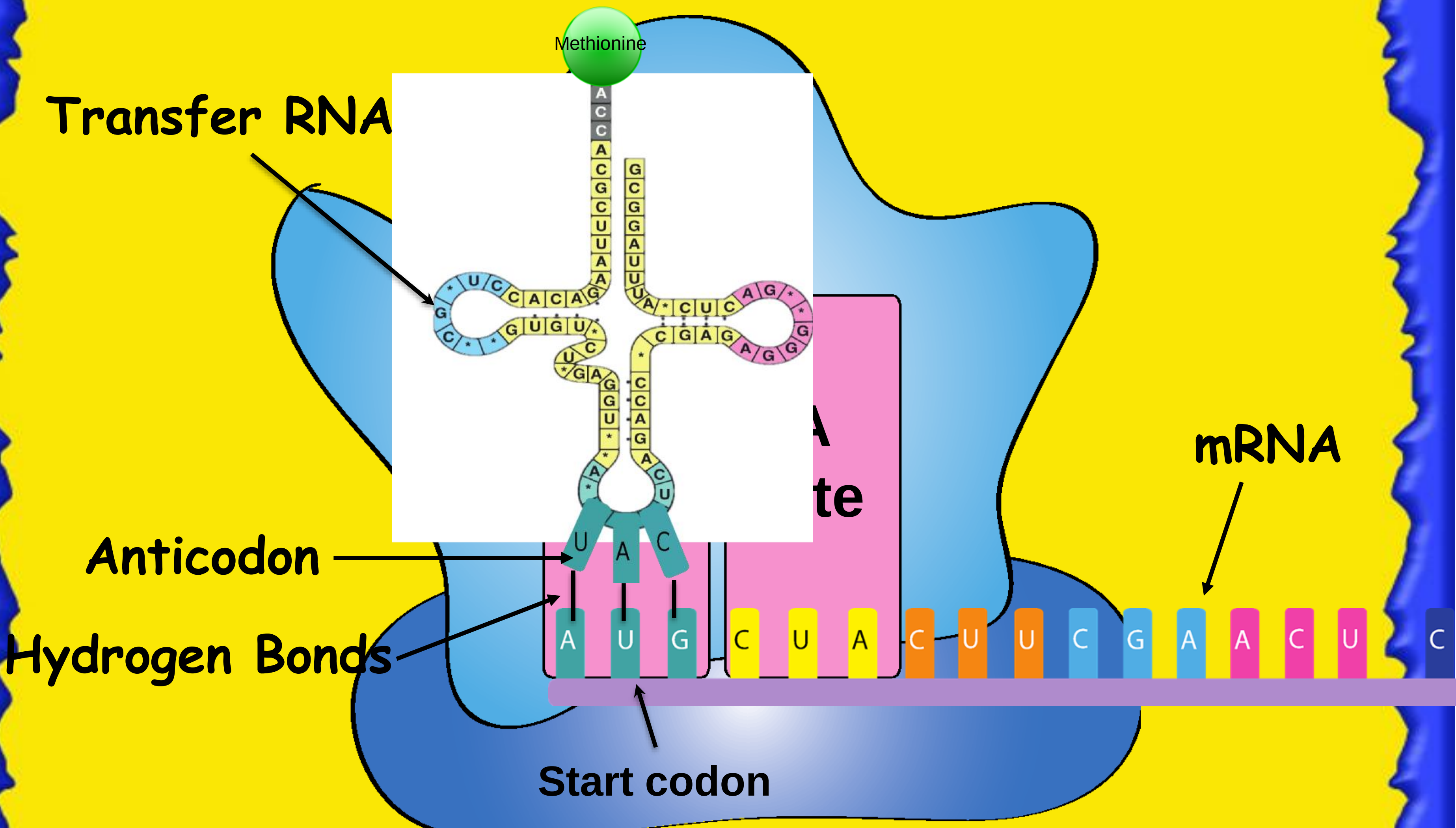
First base of RNA codon	U	C	A	G	Third base of RNA codon
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
	UUA Leu	UCA Ser	UAA Stop	UGA Stop	A
	UUG Leu	UCG Ser	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
	CUC Leu	CCC Pro	CAC His	CGC Arg	C
	CUA Leu	CCA Pro	CAA Gln	CGA Arg	A
	CUG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
	AUG Met or start	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

mRNA Joins the Ribosome



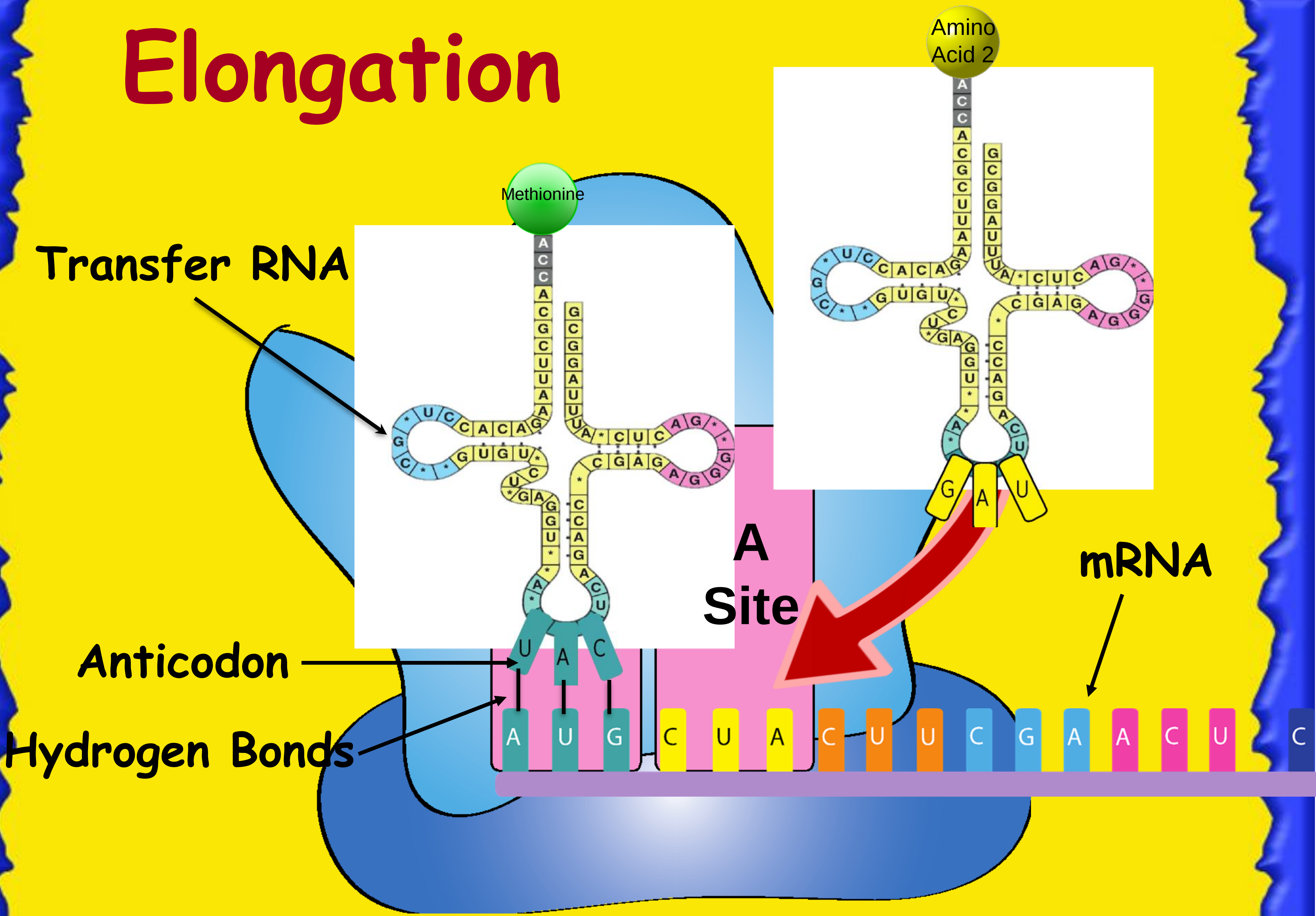
1. The large subunit and small subunit join with the mRNA.

Initiation



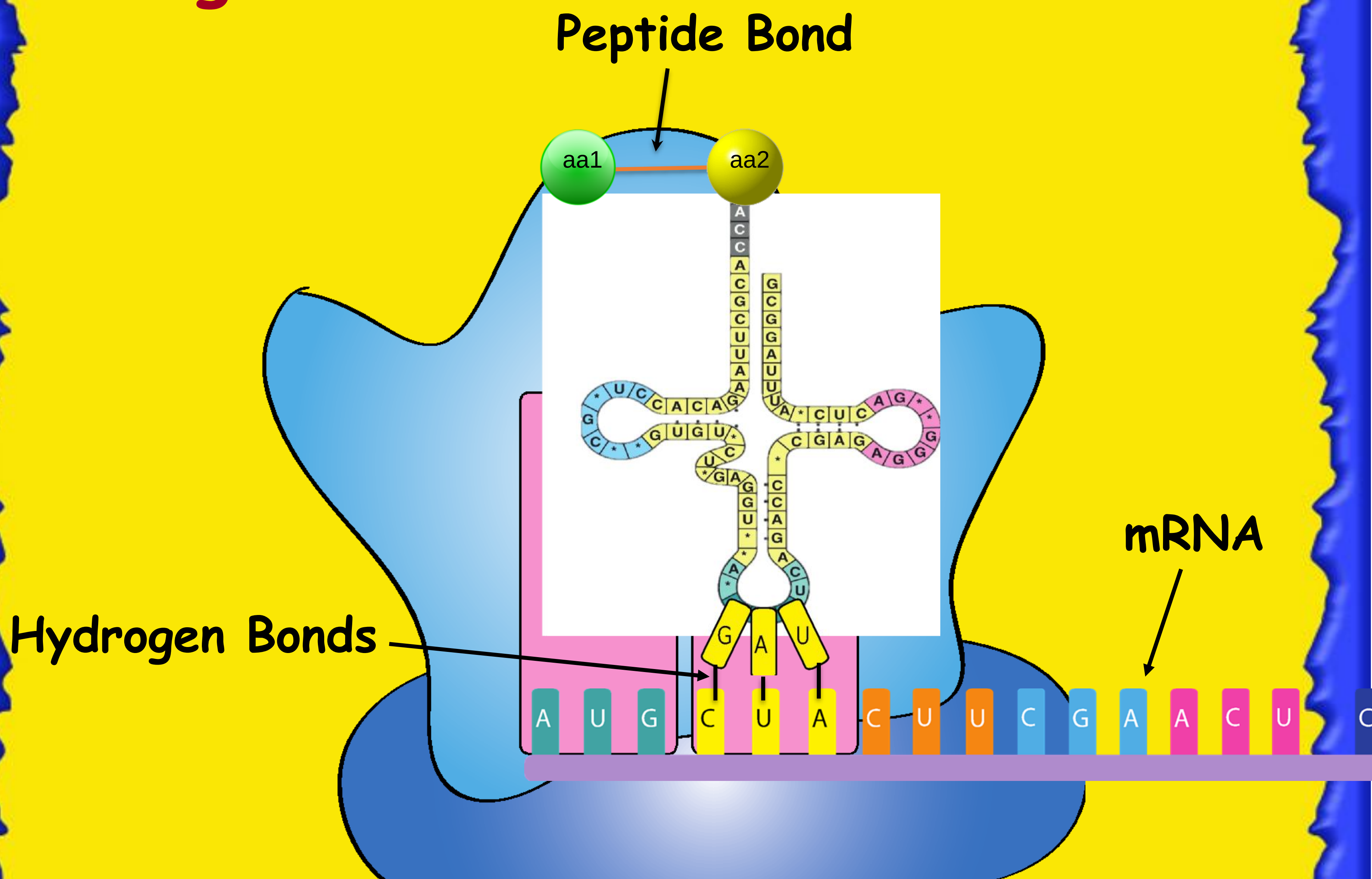
2. The tRNA carrying the **anticodon** UAC fits in the P site to start translation.
3. Hydrogen **bonds** form between UAC and **AUG (Start Codon)**.

Elongation



4. The next anticodon sits in the **A site** to start elongation.

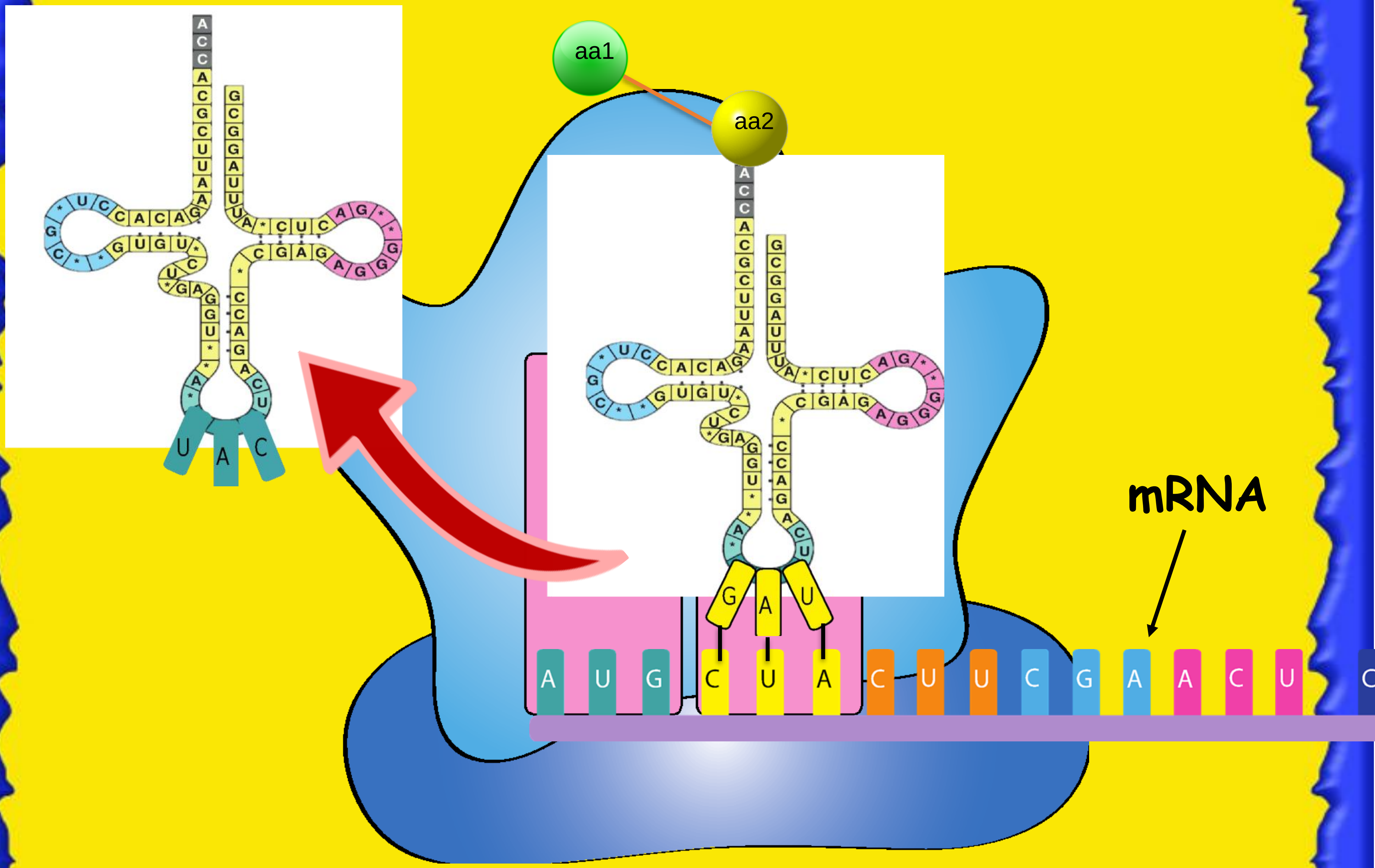
Elongation



5. Hydrogen bonds form between the **anticodons** and the mRNA bases.
6. **Peptide Bonds** from between the two **amino acids** forming a chain of 2 amino acids.

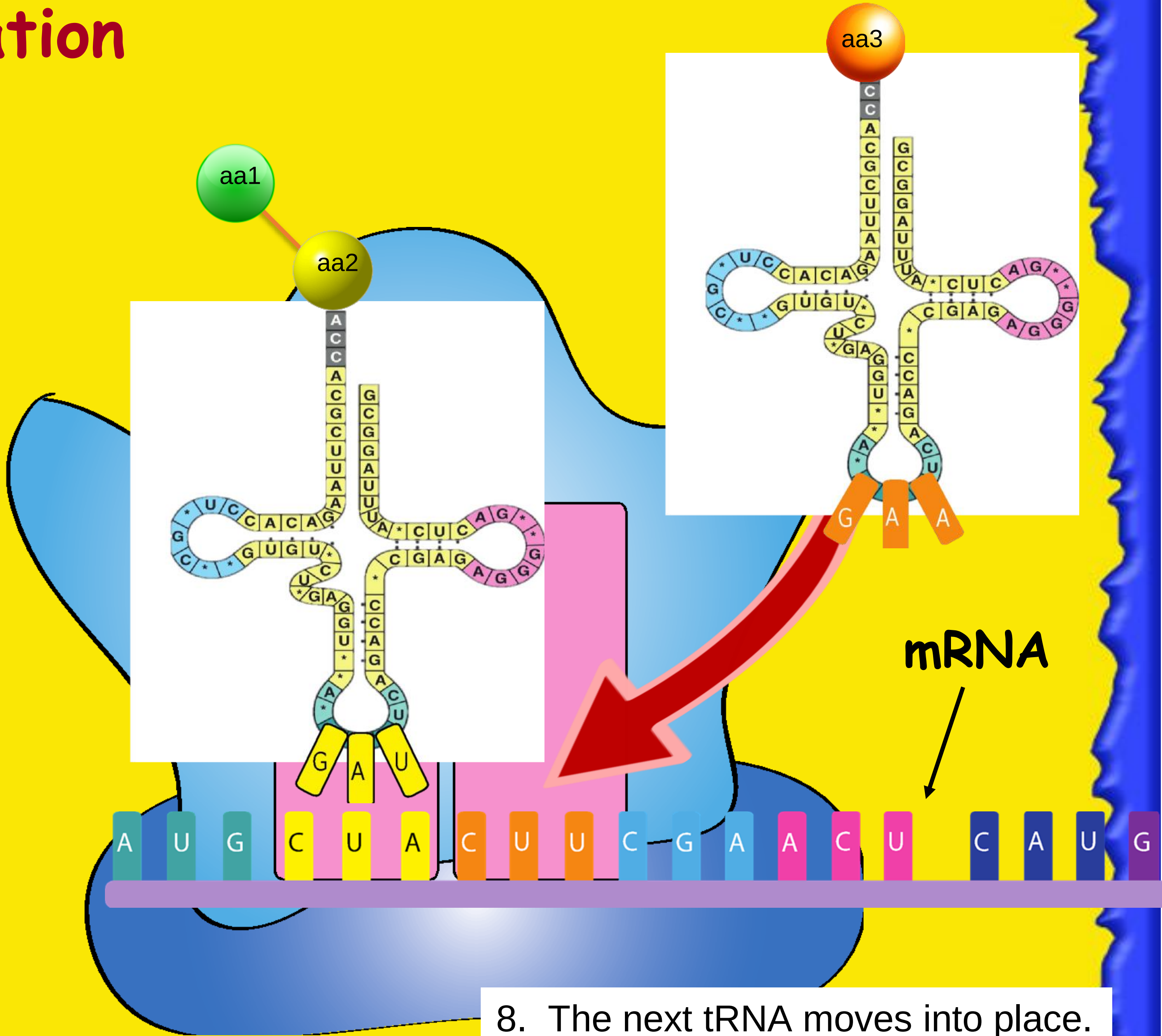
Elongation

Transfer RNA leaves



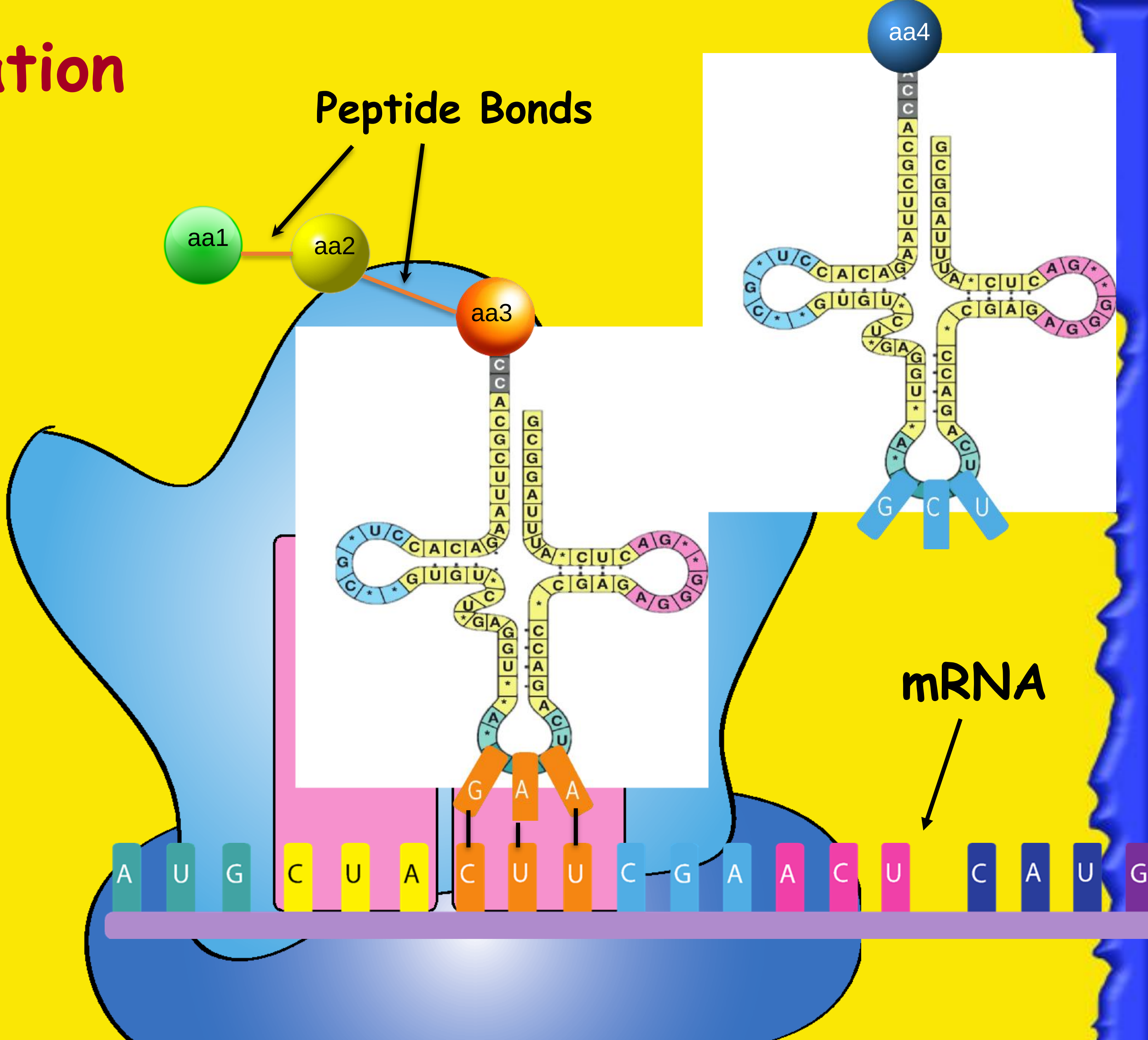
7. The mRNA moves over **one codon** moving the tRNA out of the ribosome.

Elongation



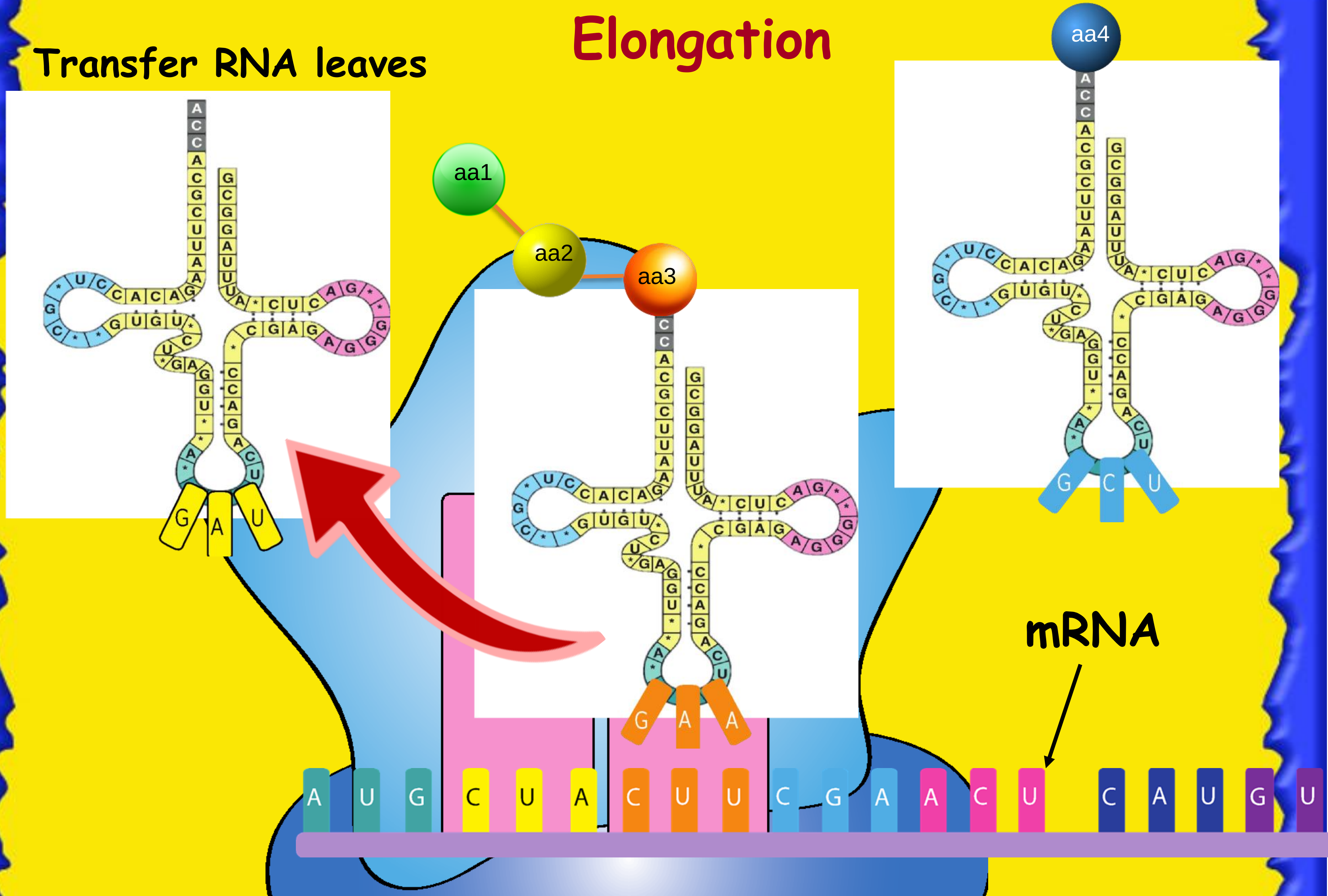
8. The next tRNA moves into place.

Elongation



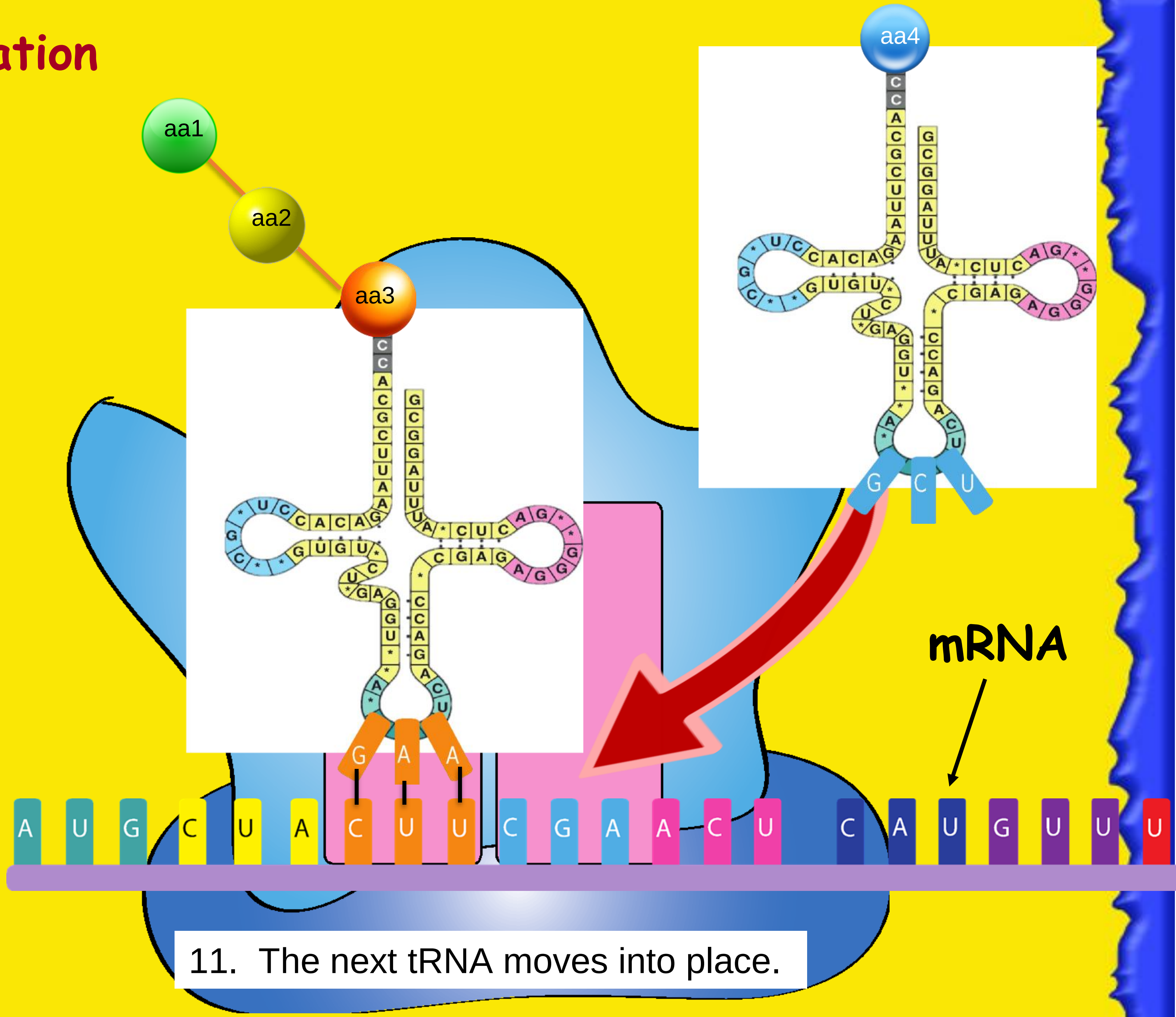
9. Peptide bonds form between the two **amino acids**, forming a chain of 3 amino acids.

Elongation



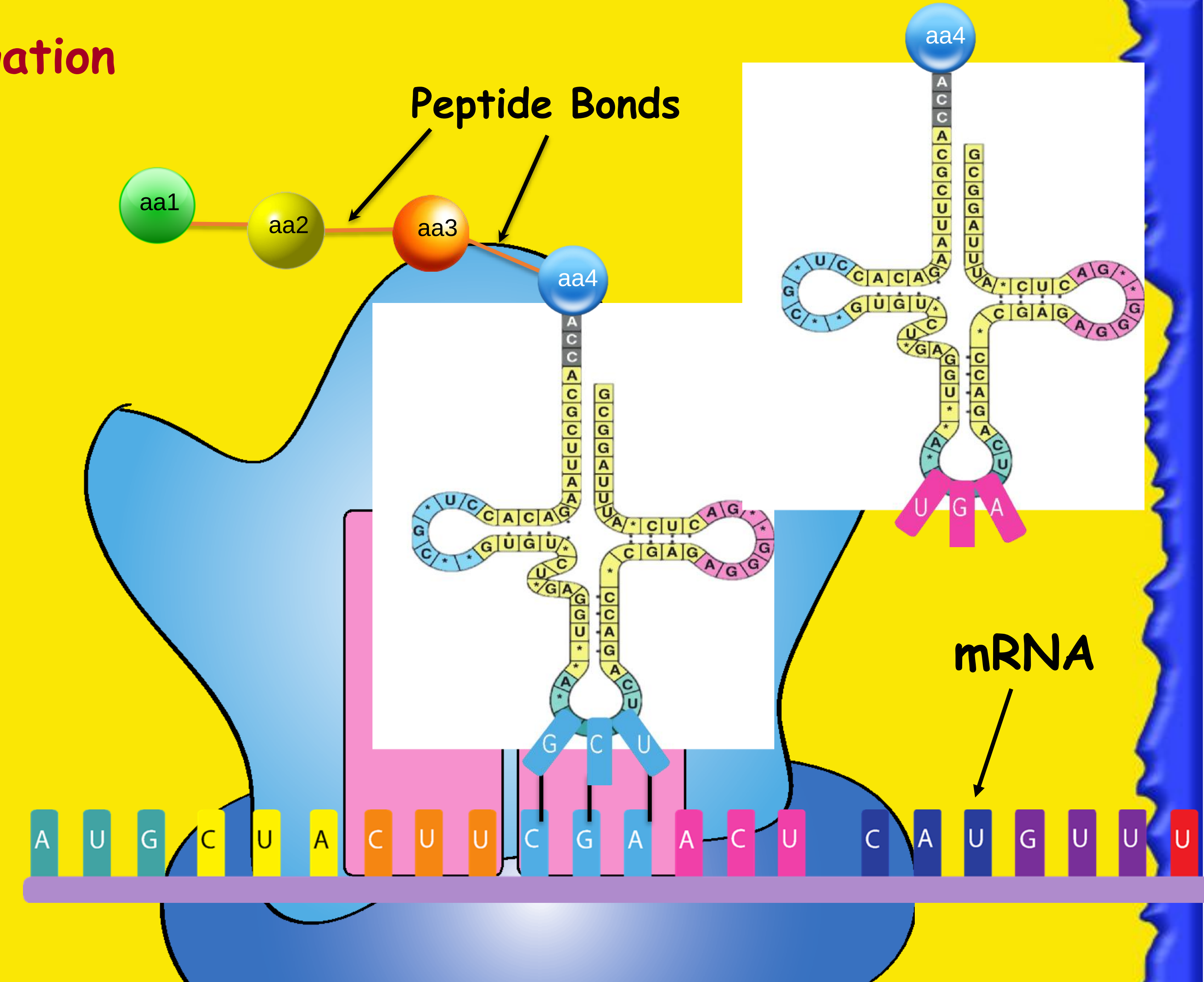
10. The mRNA moves over one codon moving the tRNA out of the ribosome.

Elongation



11. The next tRNA moves into place.

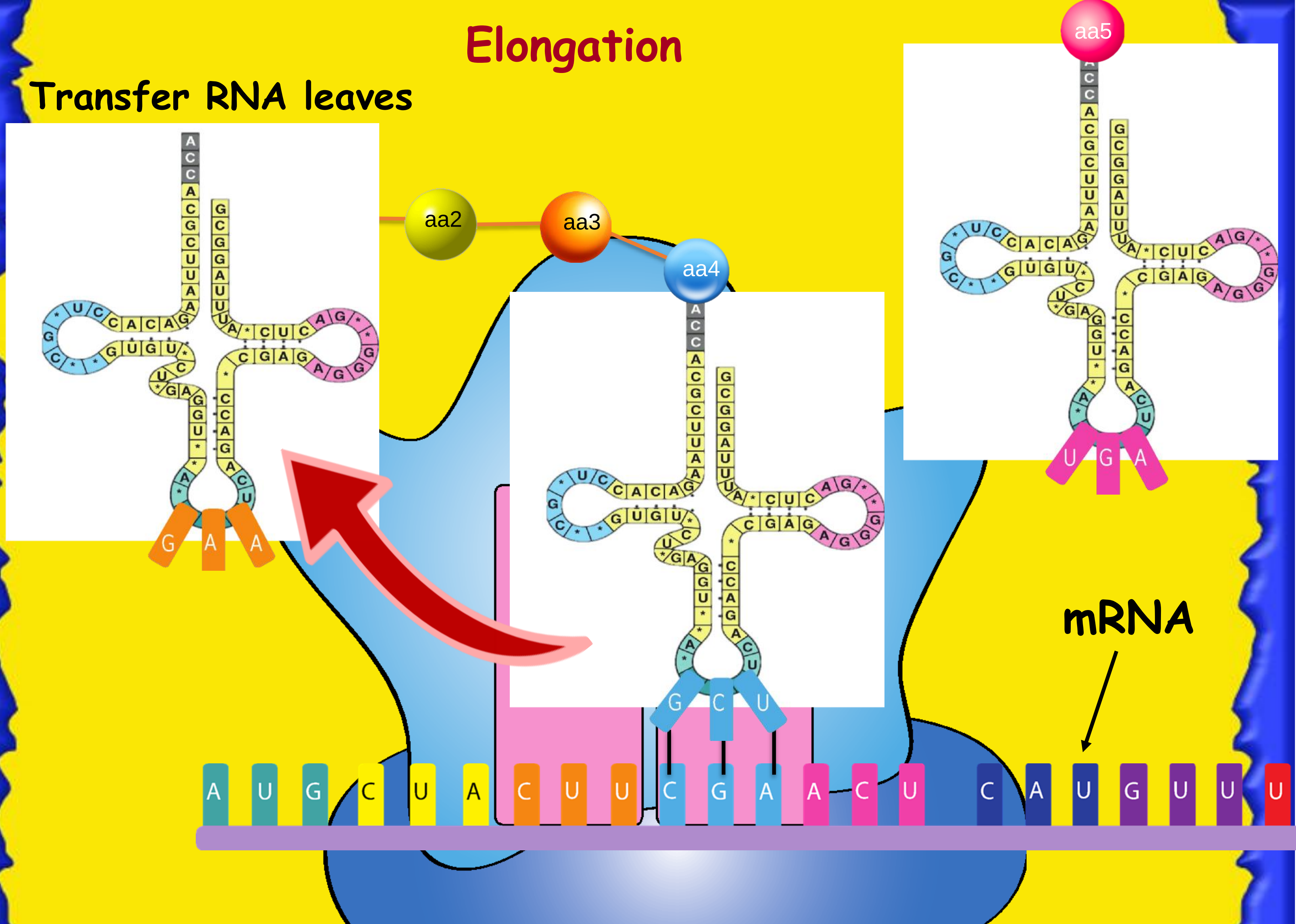
Elongation



12. Peptide bonds form between the two **amino acids**, forming a chain of 4 amino acids.

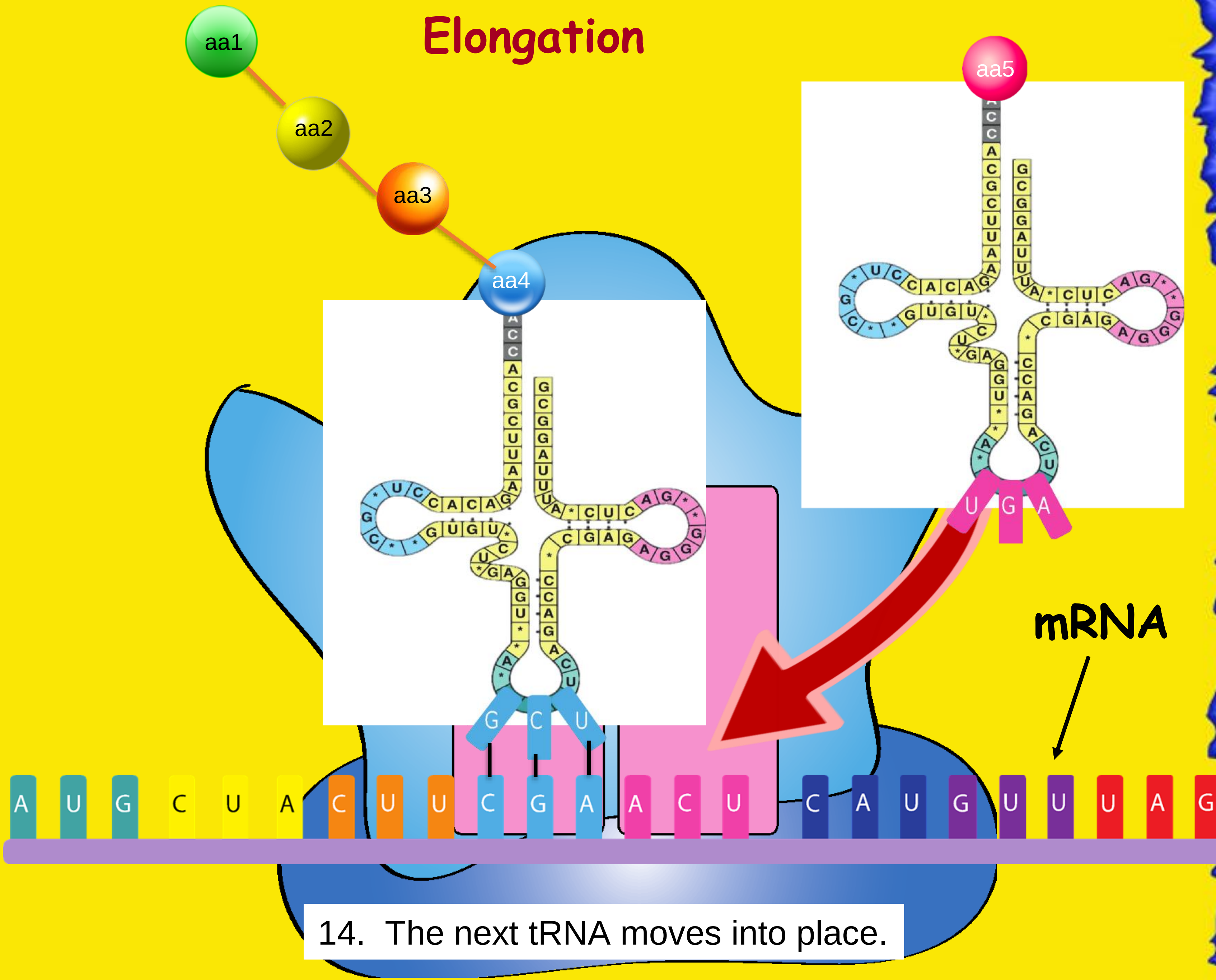
Elongation

Transfer RNA leaves



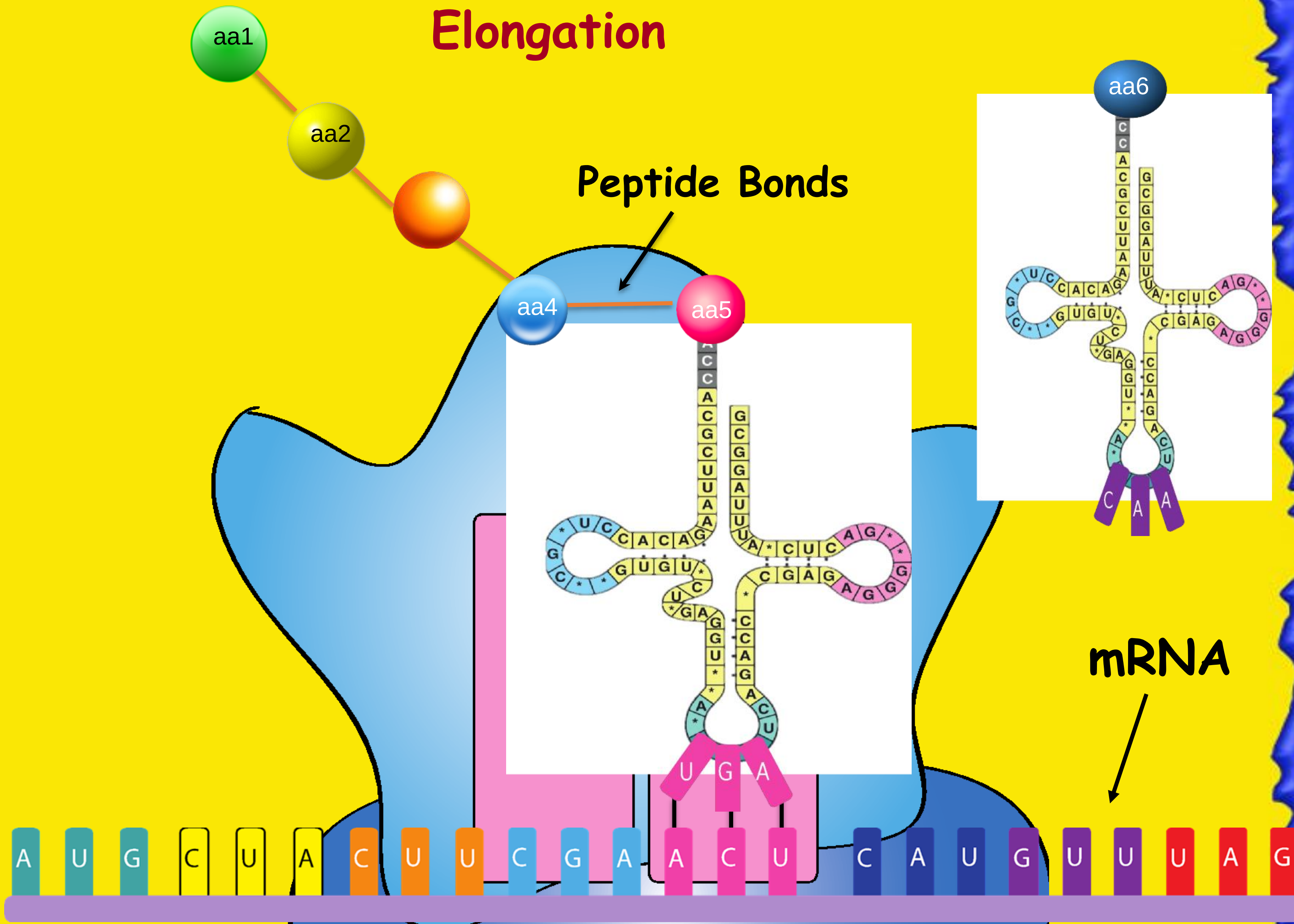
13. The mRNA moves over one codon moving the tRNA out of the ribosome.

Elongation



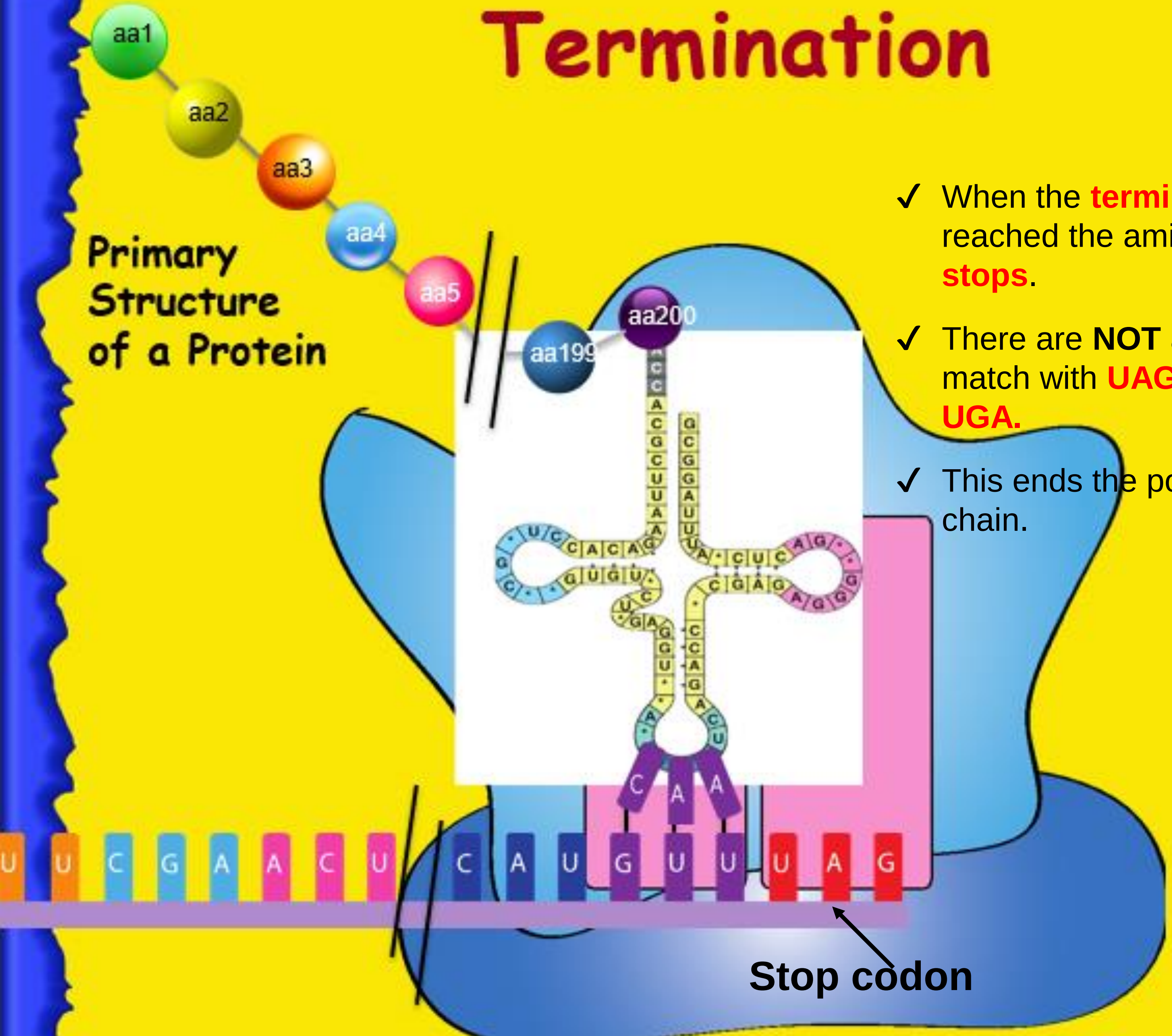
14. The next tRNA moves into place.

Elongation



15. Peptide bonds form between the two amino acids, forming a chain of 5 amino acids.

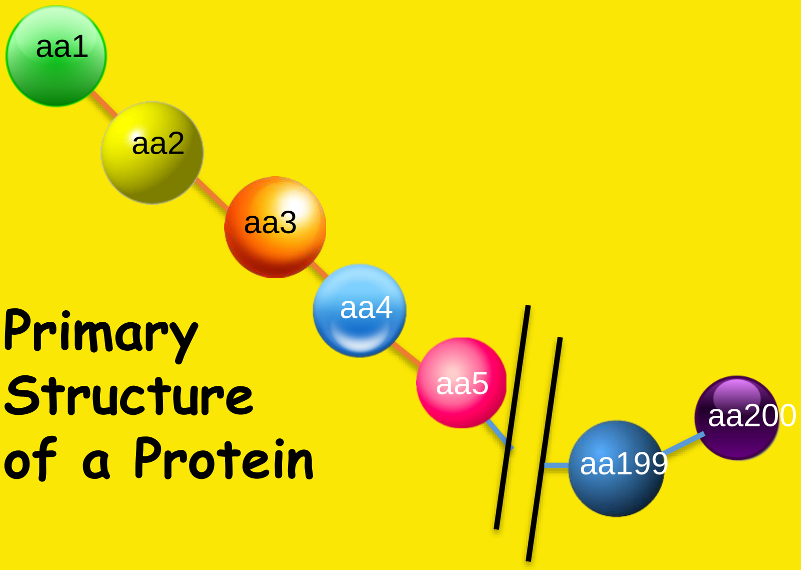
Termination



- ✓ When the **terminator codon** is reached the amino acid linking **stops**.
- ✓ There are **NOT** anticodons that match with **UAG, UAA and UGA.**
- ✓ This ends the polypeptide chain.

End Product – The Protein!

- The end products of protein synthesis is the PRIMARY structure of a protein.
- A sequence of amino acids bonded together by peptide bonds.



Primary Structure of a Protein

Translation Animation

https://somup.com/c3hhqnOKY2

Translation (Protein Synthesis) (2:38)

The Flow of Genetic Information in the cell is ***DNA → RNA → Protein***

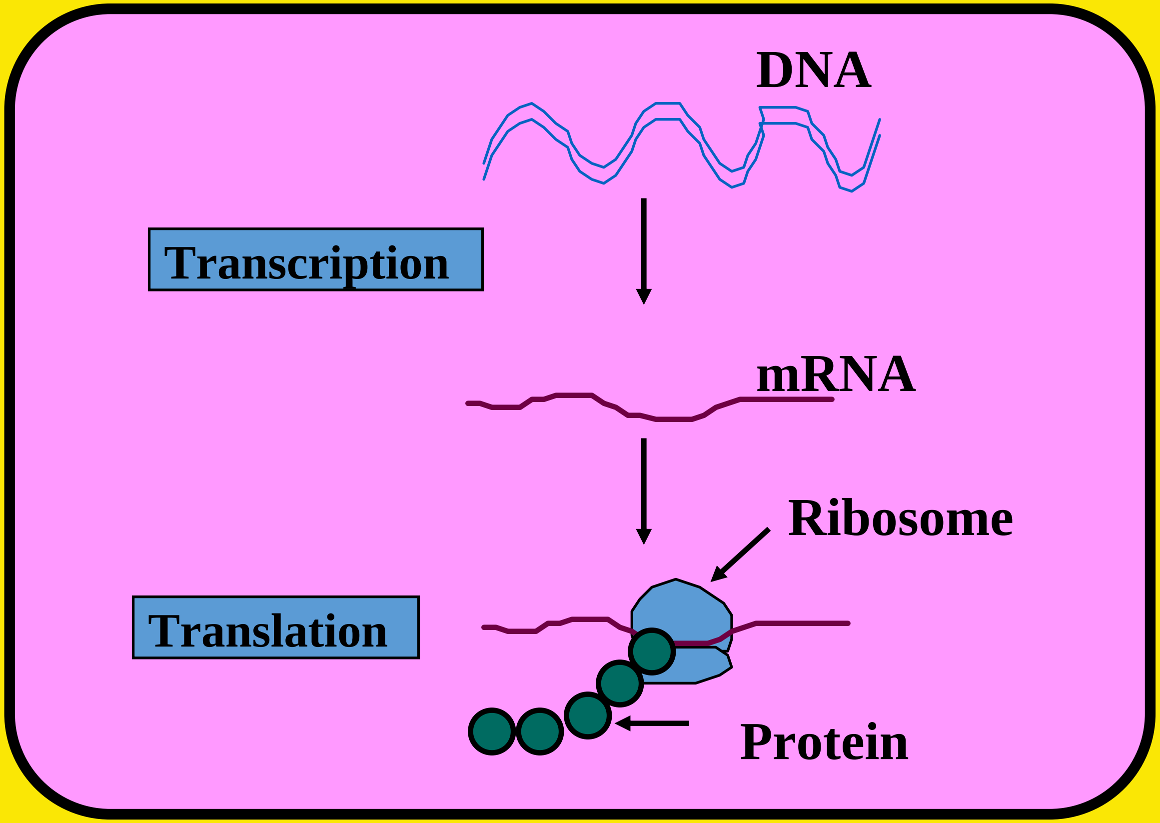
- The **Flow of Genetic Information** is from ***DNA to RNA to Protein***.
  - In **TRANSCRIPTION (DNA → RNA),** the mRNA is synthesized on a DNA template.
  - In **Eukaryotic** cells, transcription occurs in the **nucleus**, and the **messenger RNA is processed** before it travels to the **cytoplasm**.
  - In **Prokaryotes**, transcription occurs in the **cytoplasm**.

The Flow of Genetic Information in the cell is ***DNA → RNA → Protein***

- **TRANSLATION** can be divided into four steps, all of which occur in the **Cytoplasm**:

  1) **Amino acid attachment**
  2) **Initiation of polypeptide synthesis**
  3) **Elongation**
  4) **Termination**

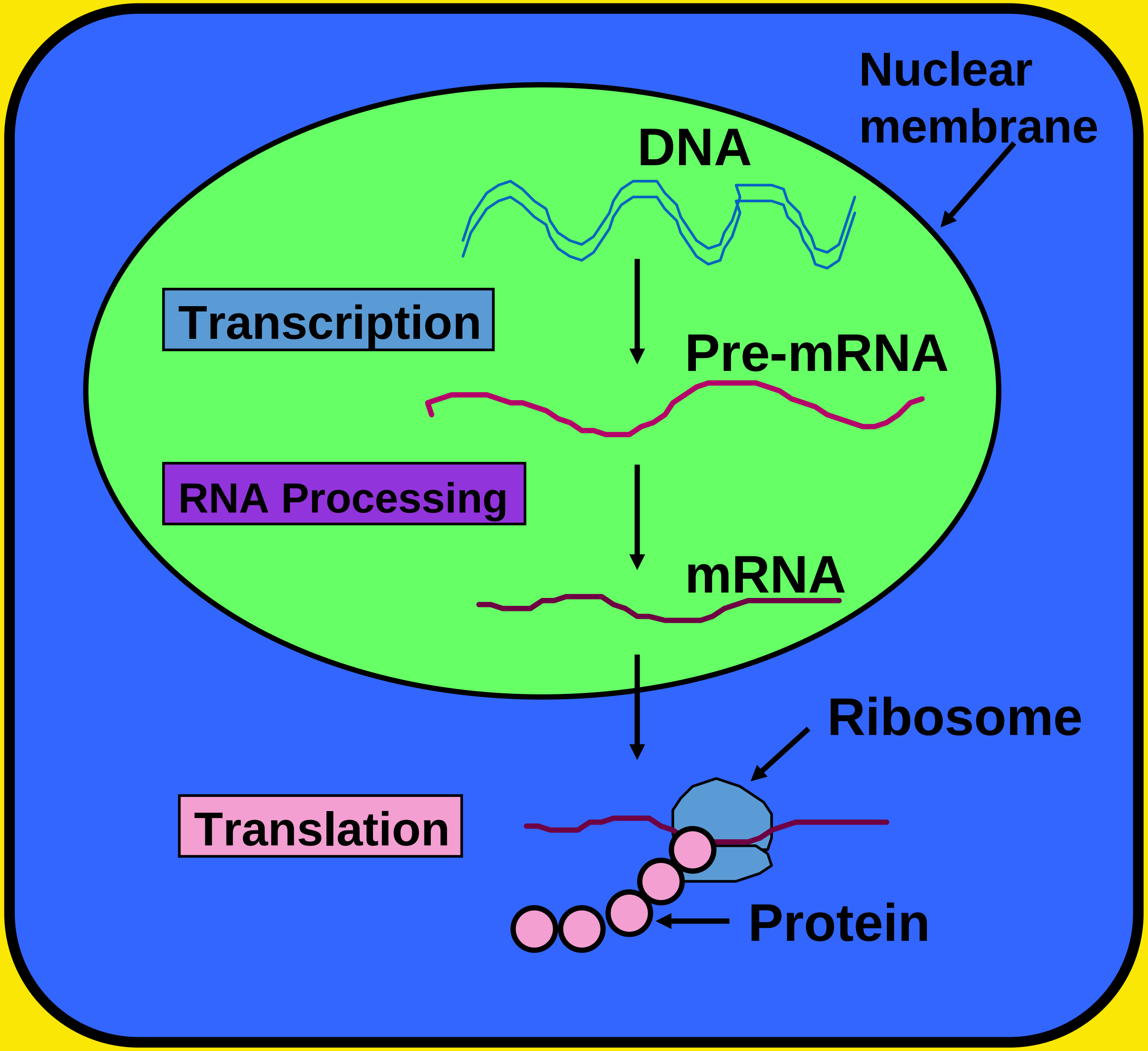
DNA → RNA → Protein



Prokaryotic Cell

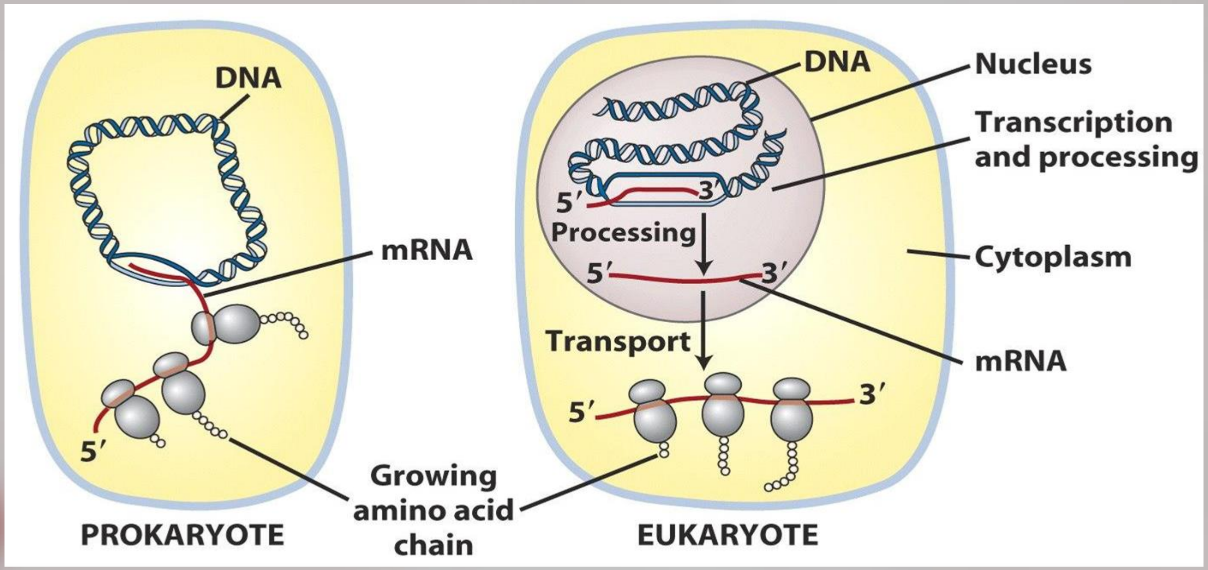
DNA → RNA → Protein

Eukaryotic Cell



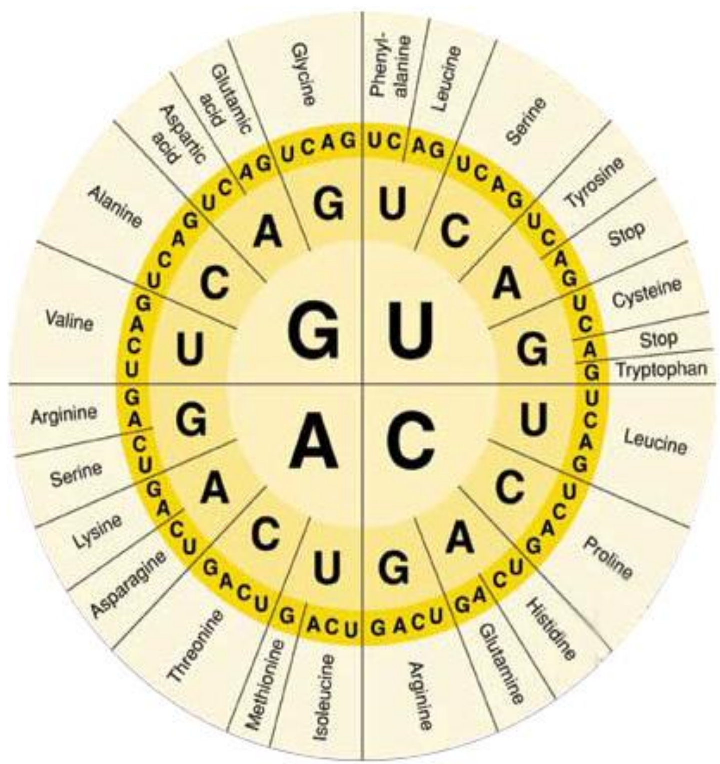
Important Note:

- In Prokaryotes, translation can begin **before** transcription is complete.
- **Why can translation begin before transcription is complete in prokaryotes but not in eukaryotes??**



Example: Putting It All together!

DNA	→	TAC	TTA	CAA	ACC	ATA	ATT
mRNA CODONS	→	AUG	AAU	GUU	UGG	UAU	UAA
tRNA ANTICODONS	→	UAC	UUA	CAA	ACC	AUA	AUU
Amino Acid Sequence	→						



Remember the codon is for mRNA.

Example: Putting It All together!

DNA	→	TAC	TTA	CAA	ACC	ATA	ATT
mRNA CODONS	→	AUG	AAU	GUU	UGG	UAU	UAA
tRNA ANTICODONS	→	UAC	UUA	CAA	ACC	AUA	AUU
Amino Acid Sequence	→	Methionine	Asparagine	Valine	Tryptophan	Tyrosine	STOP

Afterwards…

- **Signal Sequences**
  - are added to proteins in the Endoplasmic Reticulum after they are synthesized by the ribosomes.
  - direct a small number of nucleotides that are added to a protein in the ER.
  - tell the cell **where the protein is to be taken** after it is made.

Gene Expression

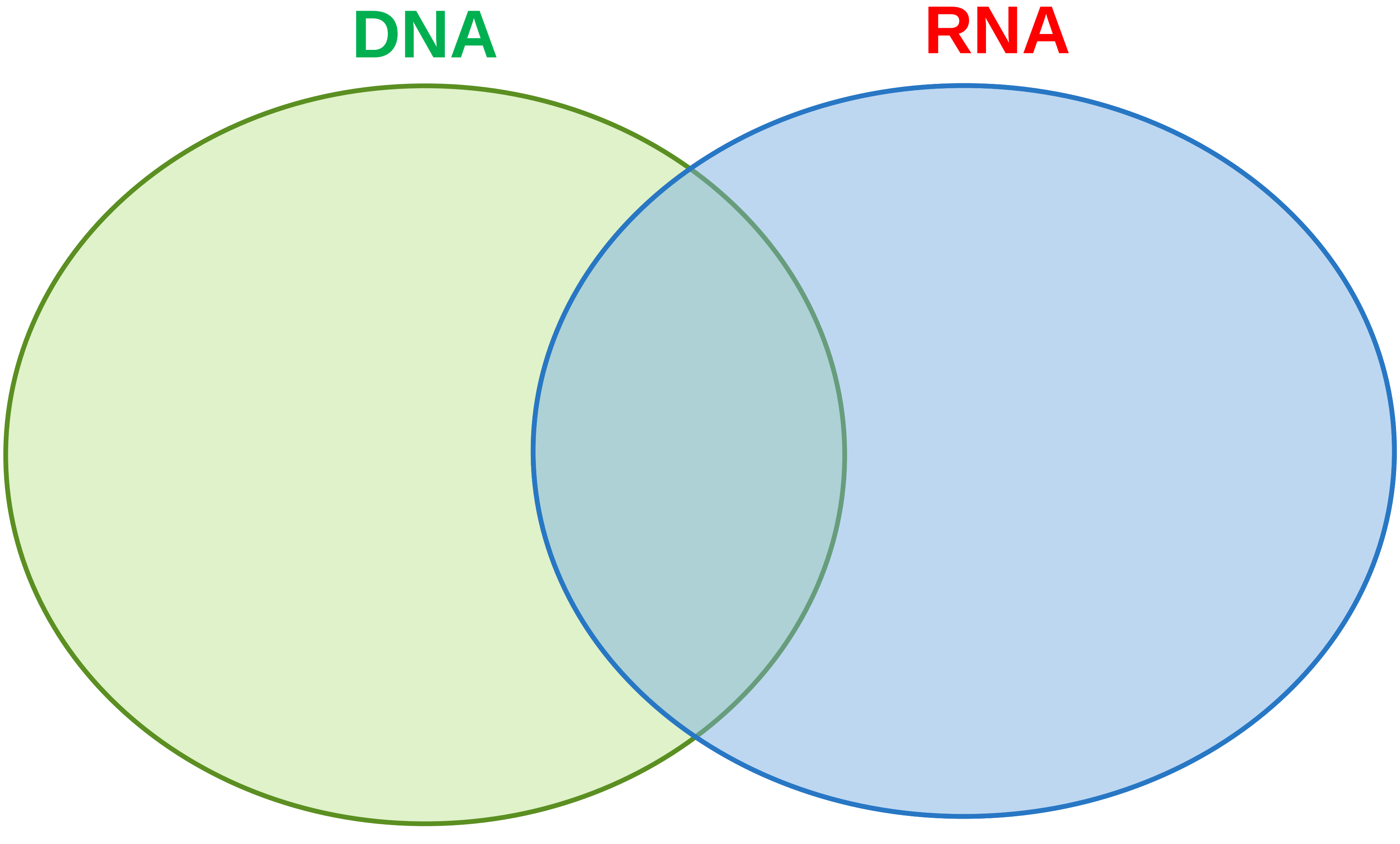
- When a gene is expressed, it means that the protein the gene codes for is being made.
- When the gene is expressed, the trait the gene codes for is visible in some way.
- All cells of the same organism contain the same exact info in their DNA.
- In multicellular organisms not all genes are expressed by every cell.

Gene Expression

- **Not all areas of the DNA that code for proteins are transcribed into mRNA.**
- **If they were, then every cell would have the same exact function and make the same exact proteins.**
- **Each cell knows exactly what type of cell it is and which proteins it should make.**
- **This allows cells to be grouped into tissue and organ systems.**

Complete the Venn Diagram:
DNA vs. RNA

QUICK CHECK



Complete the Venn Diagram:
DNA vs. RNA