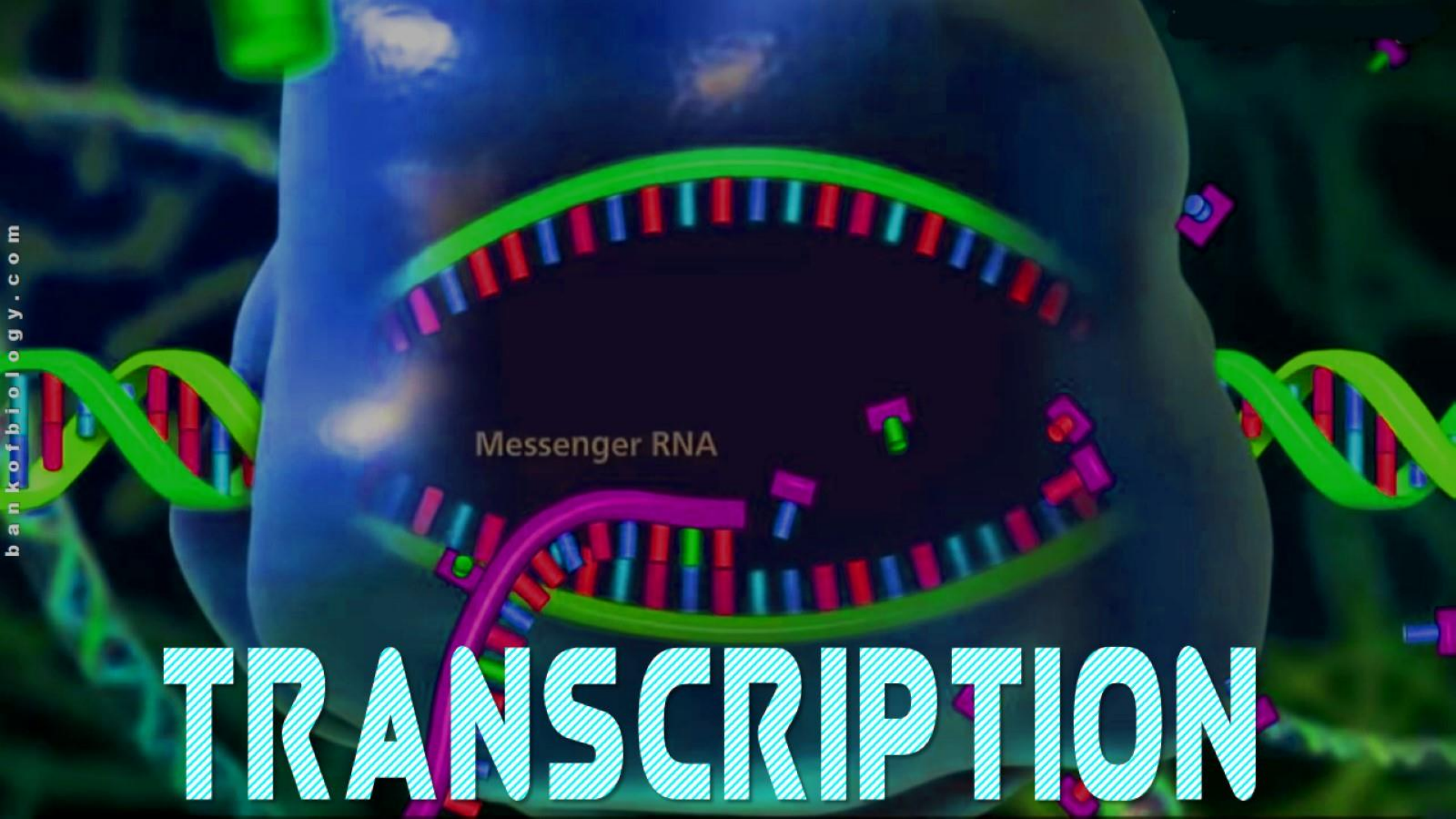


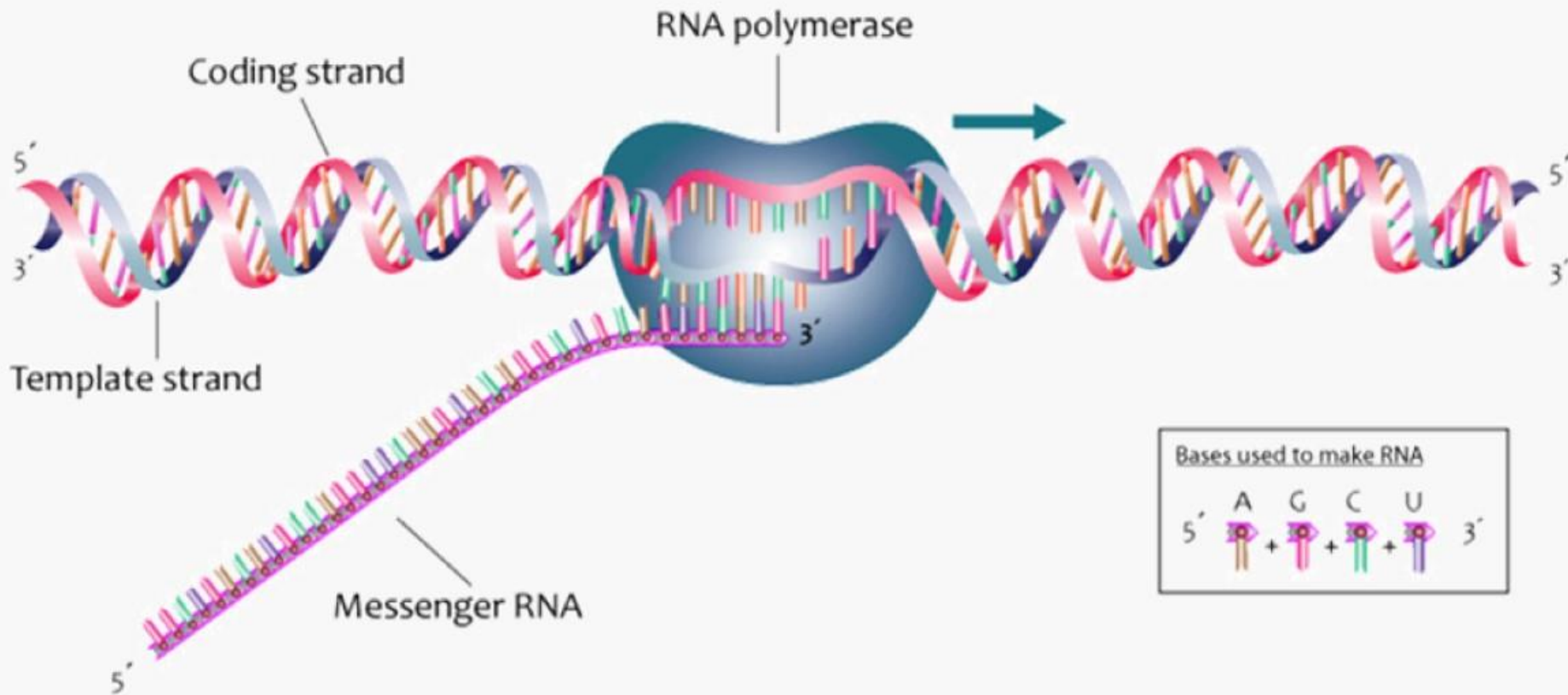
Messenger RNA

TRANSCRIPTION



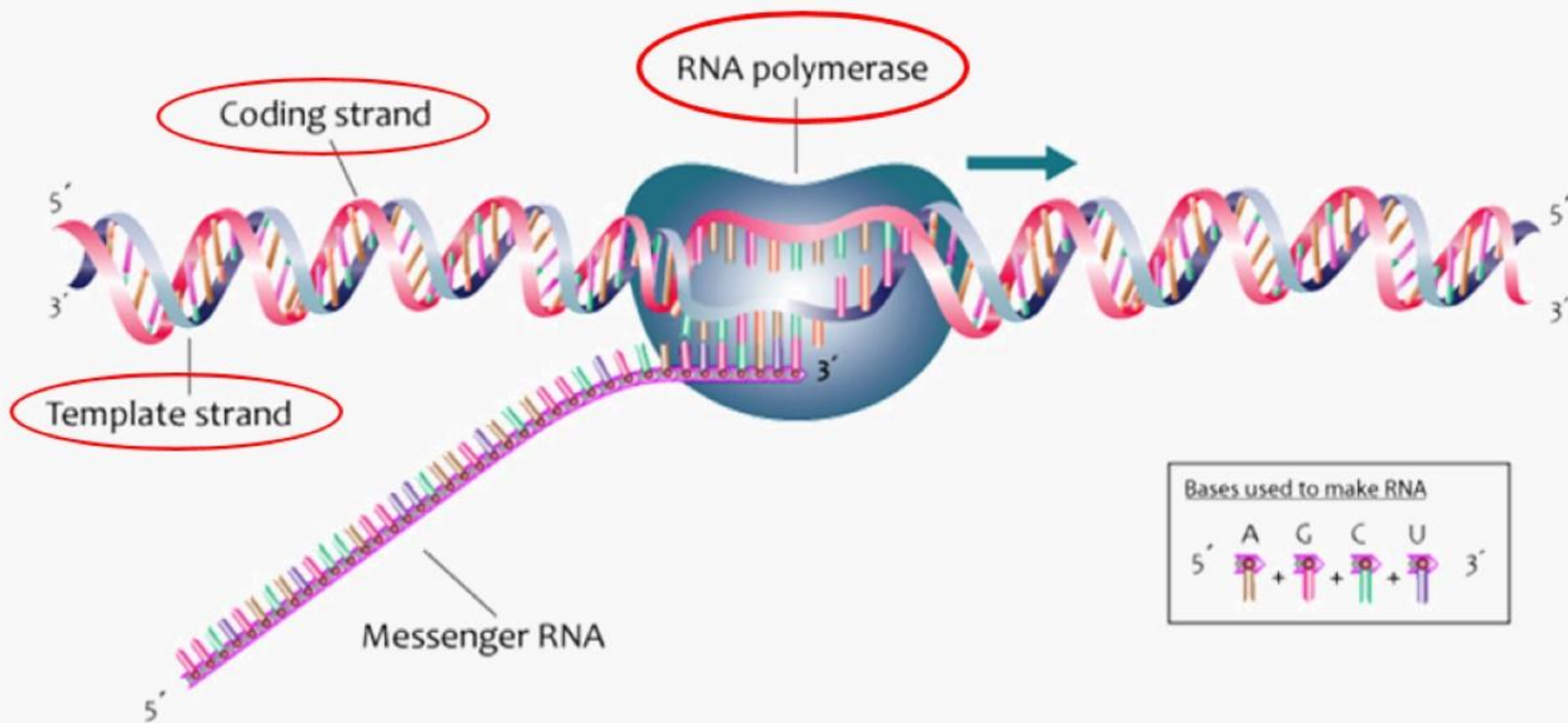
TRANSCRIPTION

- It is the process of **copying genetic information** from one strand of the **DNA into RNA**.
- Here, **adenine** forms base pair with **uracil** instead of **thymine**.



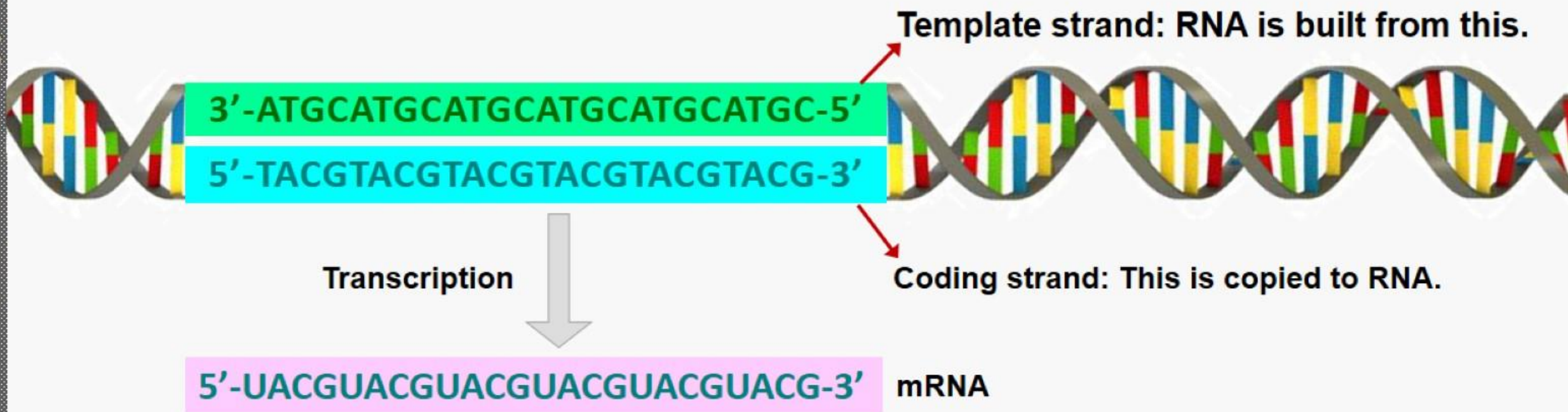
TRANSCRIPTION

- The *DNA-dependent RNA polymerase* catalyzes polymerization only in $5' \rightarrow 3'$ direction.
- $3' \rightarrow 5'$ acts as **template strand** and $5' \rightarrow 3'$ acts as **coding strand**.



TRANSCRIPTION

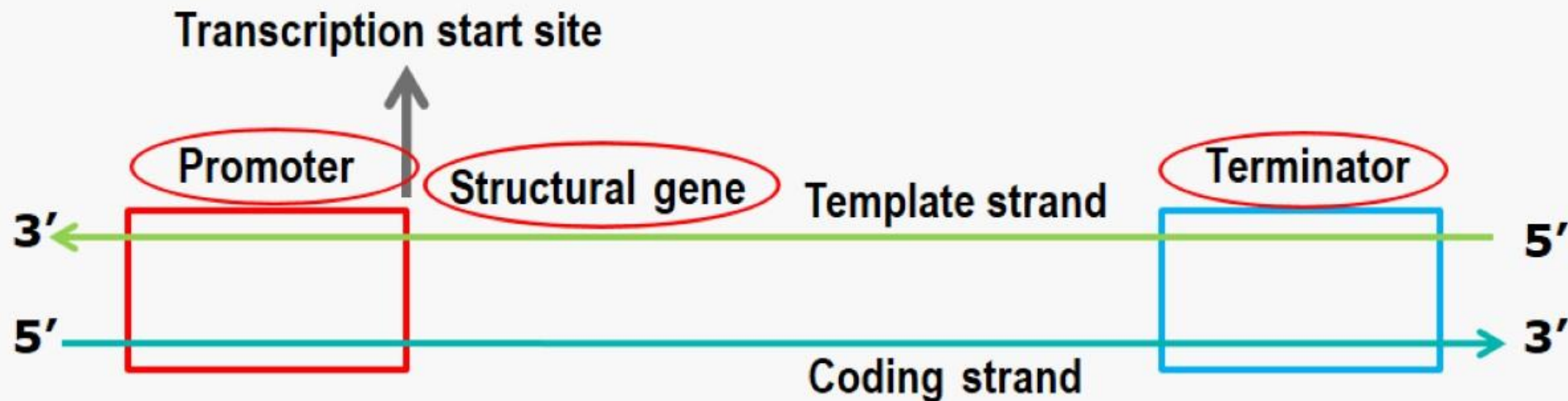
- Both strands are not copied during transcription, because
 - ❖ The **code for proteins is different in both strands**. This complicates the translation.
 - ❖ If **2 RNA molecules** are produced simultaneously, this would be **complimentary** to each other. It forms a **double stranded RNA** and prevents translation.



TRANSCRIPTION

TRANSCRIPTION UNIT

- It is the segment of DNA between the sites of initiation and termination of transcription.
- It consists of 3 regions:
 - **A promoter:** Binding site for *RNA polymerase*. Located towards 5'-end (upstream).
 - **Structural gene:** Region b/w promoter & terminator where transcription takes place.
 - **A terminator:** The site where transcription stops. Located towards 3'-end (downstream).

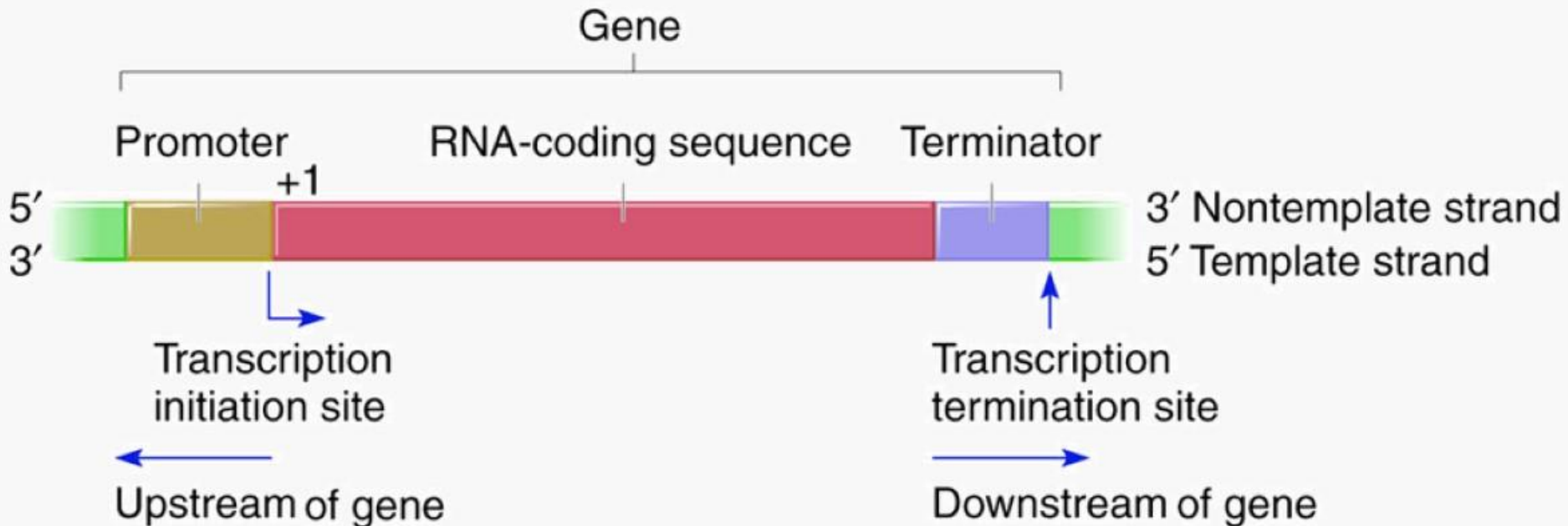


SCHEMATIC STRUCTURE OF A TRANSCRIPTION UNIT

TRANSCRIPTION

TRANSCRIPTION UNIT

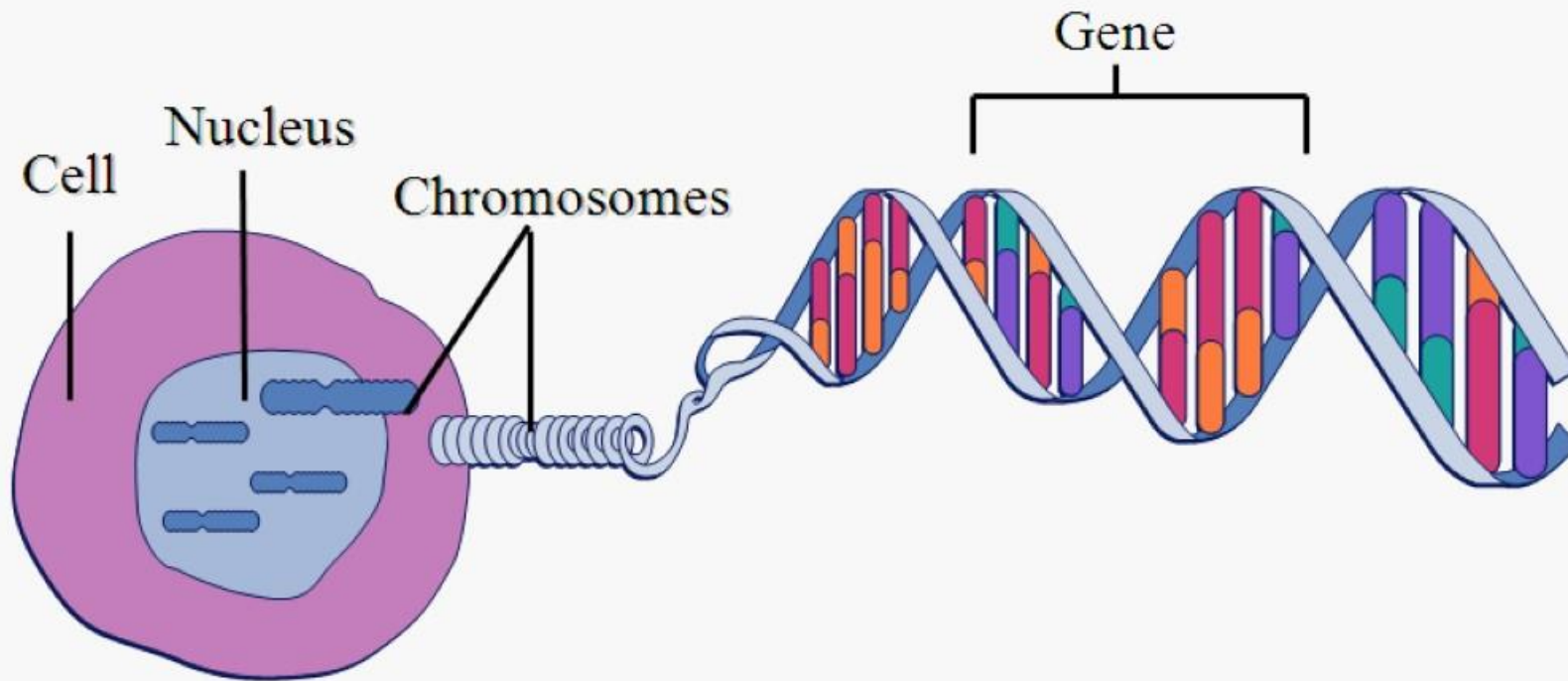
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 - **A terminator:** The site where transcription stops. Located towards 3'-end (downstream).



TRANSCRIPTION

TRANSCRIPTION UNIT & GENE

- **Gene** is a functional unit of inheritance. It is the DNA sequence coding for an RNA (mRNA, rRNA or tRNA).
- **Cistron** is a segment of DNA coding for a polypeptide during protein synthesis. It is the largest element of a gene.



TRANSCRIPTION

TRANSCRIPTION UNIT & GENE

Structural gene in a transcription unit is 2 types:

➤ **Monocistronic structural genes (split genes):**

- It is seen in **eukaryotes**.
- Here, coding sequences (**exons or expressed sequences**) are interrupted by **introns (intervening sequences)**.
- Exons appear in processed mRNA. Introns do not appear in processed mRNA.

➤ **Polycistronic structural genes:**

- It is seen in **prokaryotes**. Here, there are no split genes.



Monocistronic structural gene



Polycistronic structural gene

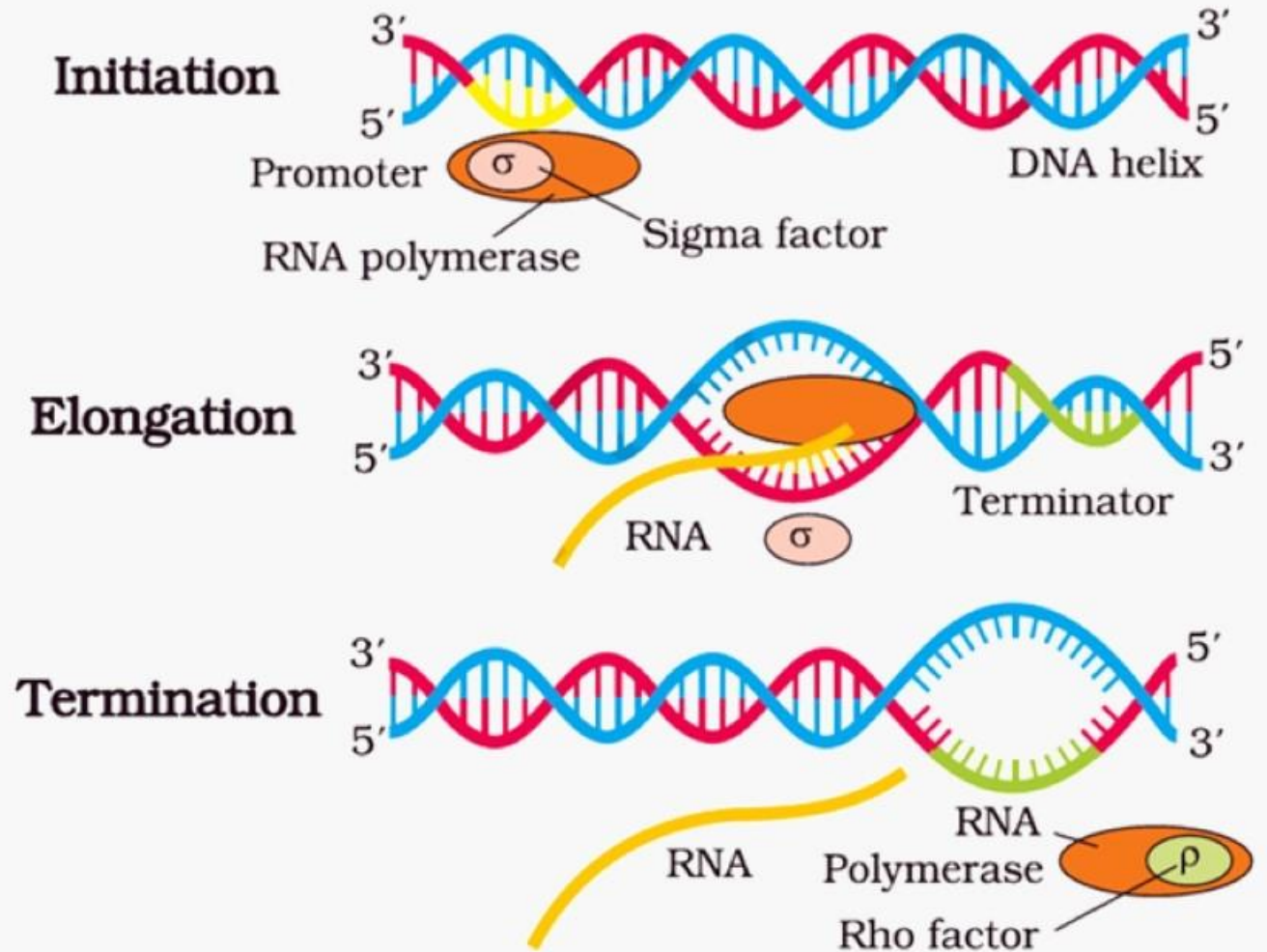
TRANSCRIPTION

TRANSCRIPTION IN PROKARYOTES

- In bacteria (Prokaryotes), synthesis of all types of RNA are catalysed by a single **RNA polymerase**.

Transcription has 3 steps:

- ✓ **Initiation**
- ✓ **Elongation**
- ✓ **Termination**

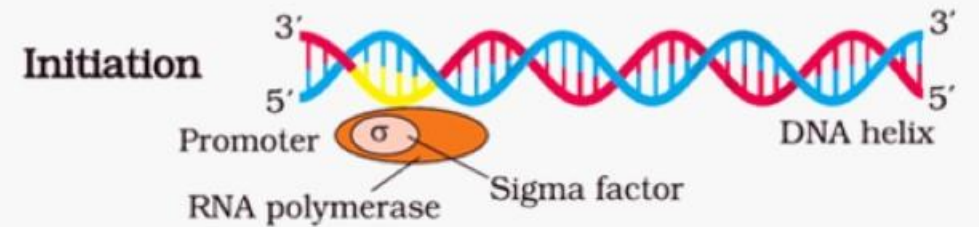
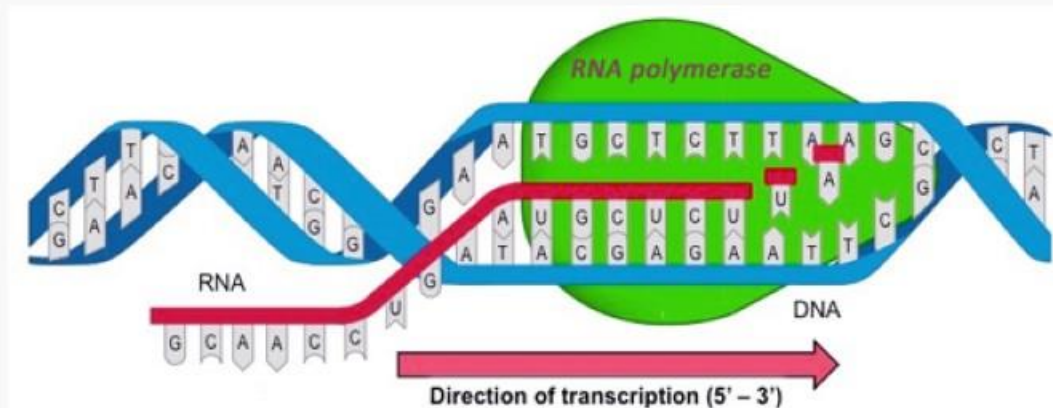
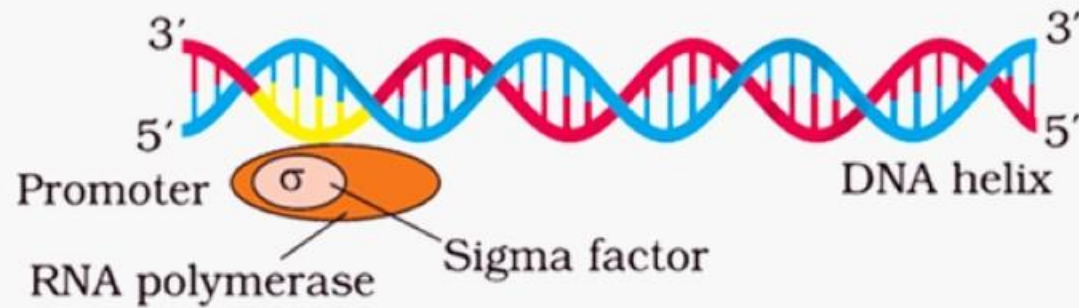


TRANSCRIPTION

TRANSCRIPTION IN PROKARYOTES

Initiation

- Here, *RNA polymerase* enzyme binds at the **promoter site** of DNA.
- This causes the local **unwinding** of the DNA double helix.
- An **initiation factor (σ factor)** present in *RNA polymerase* initiates the RNA synthesis.

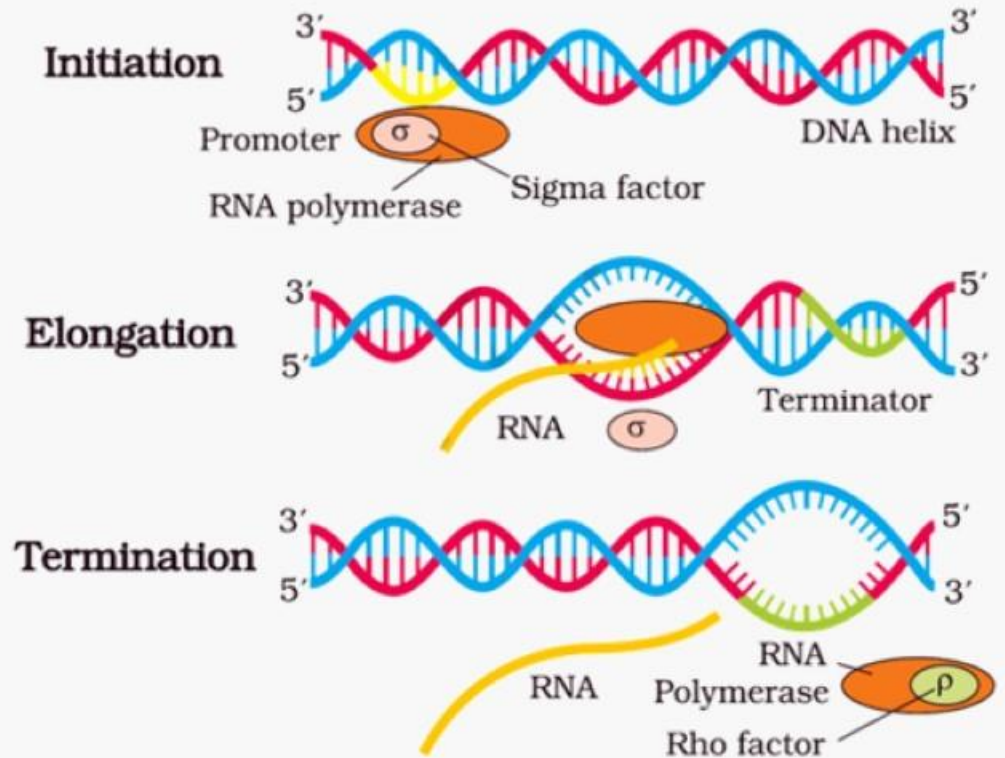
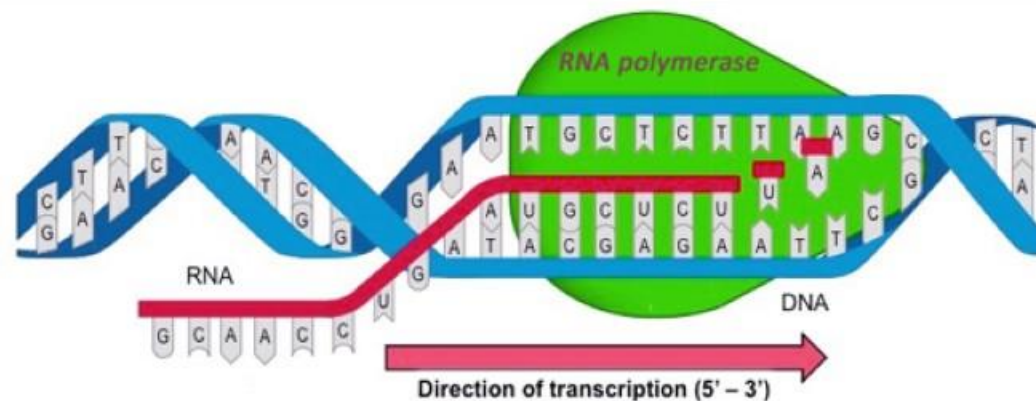
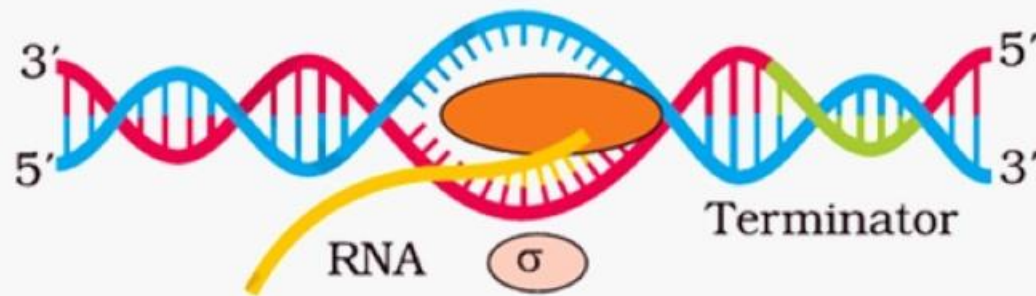


TRANSCRIPTION

TRANSCRIPTION IN PROKARYOTES

Elongation

- RNA chain is synthesized in **5'-3'** direction.
- In this process, activated **ribonucleoside triphosphates (ATP, GTP, UTP & CTP)** are added. This is complementary to the base sequence in the DNA template.

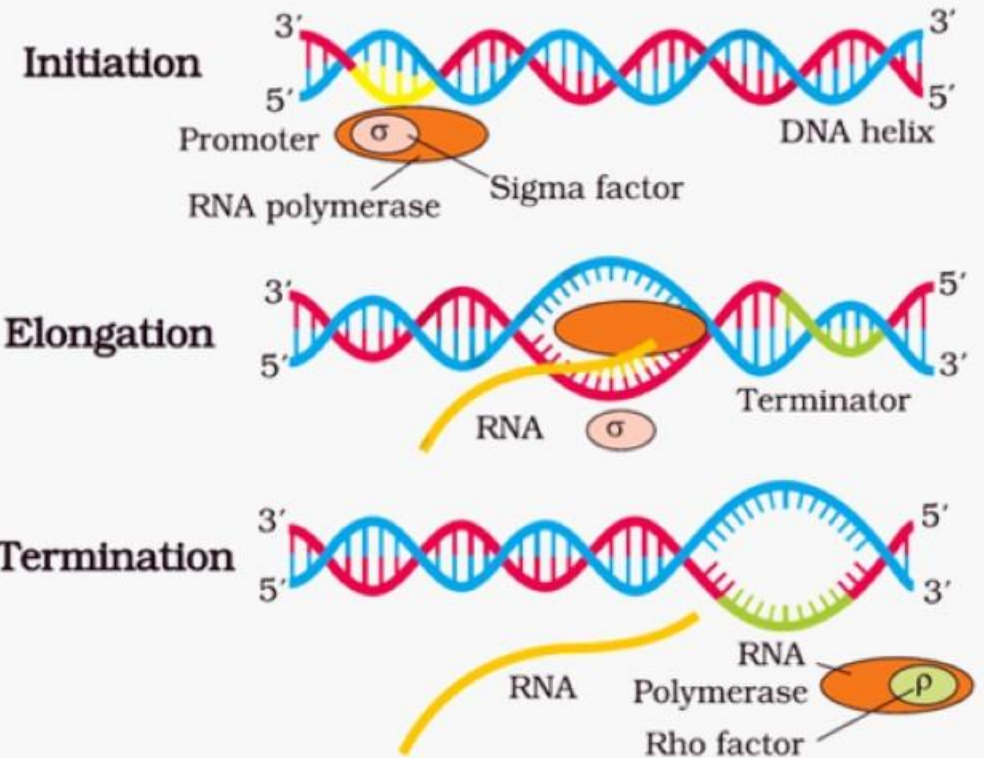
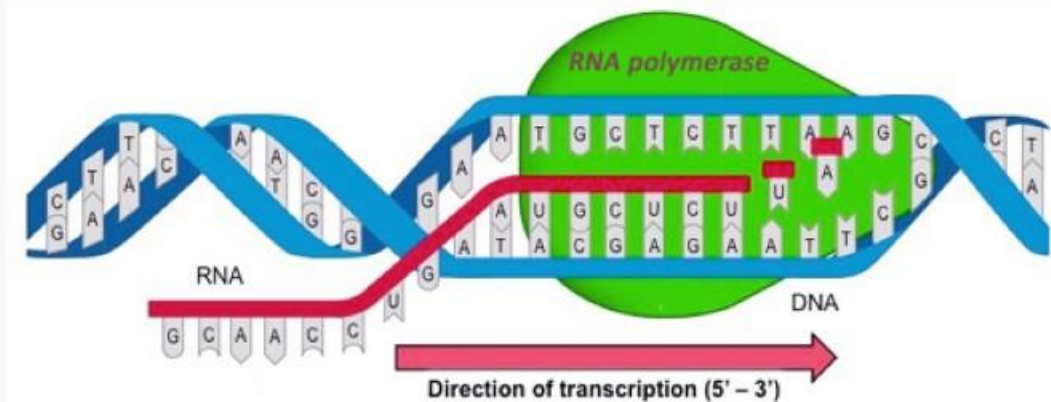
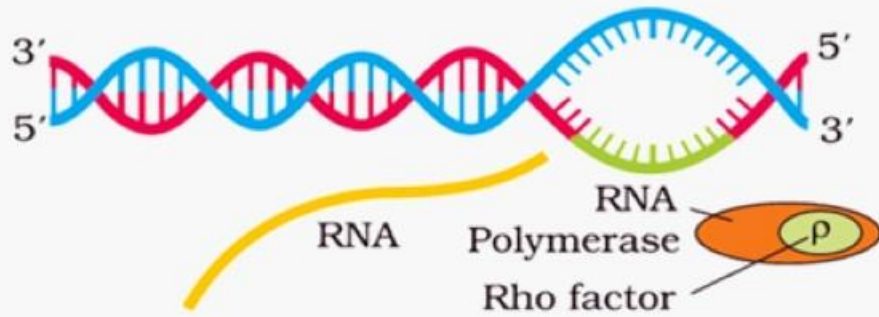


TRANSCRIPTION

TRANSCRIPTION IN PROKARYOTES

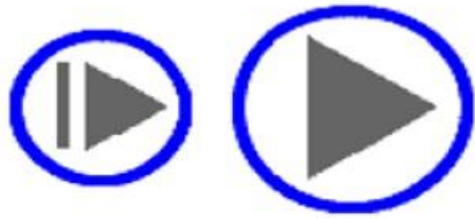
Termination

- A **termination factor (ρ factor)** binds to the **RNA polymerase** and terminates the transcription.

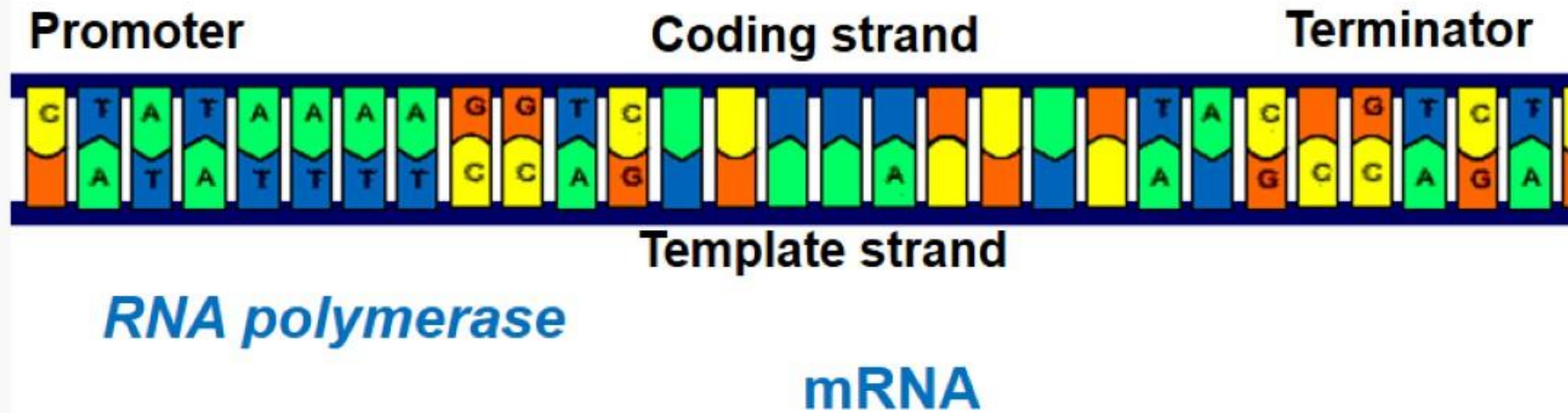


TRANSCRIPTION

TRANSCRIPTION IN PROKARYOTES



Transcription



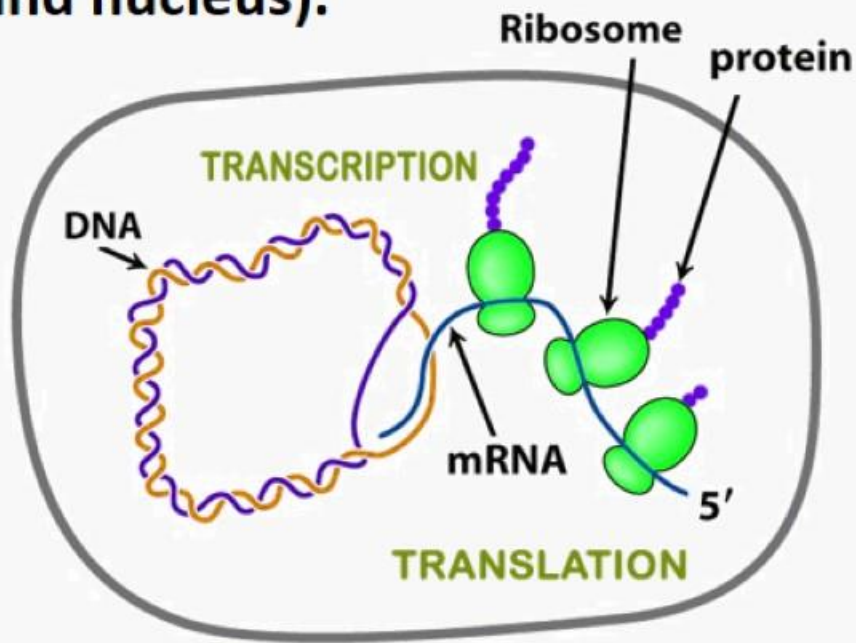
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TRANSCRIPTION

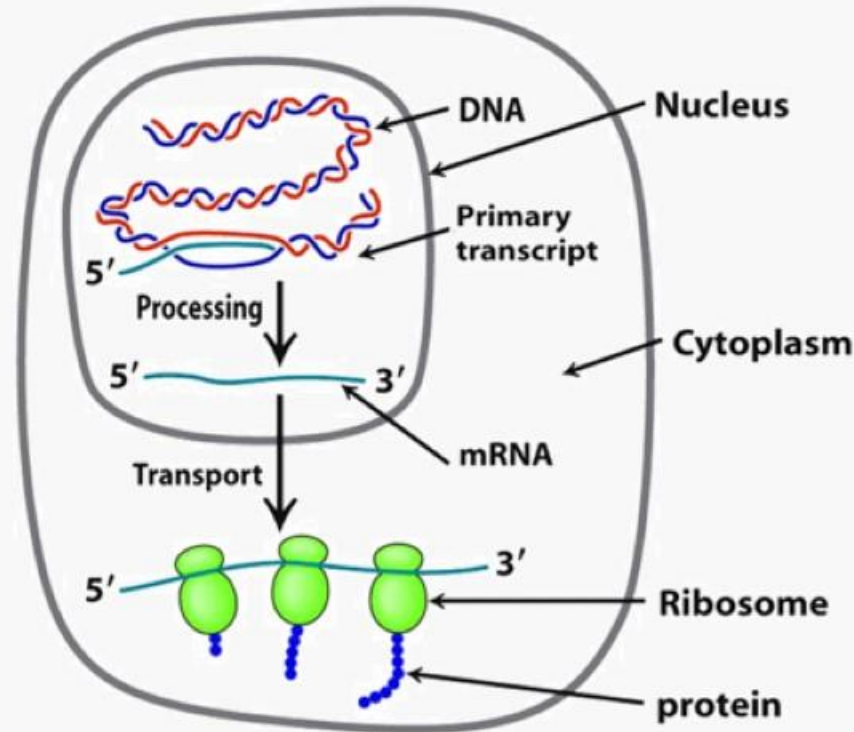
TRANSCRIPTION IN PROKARYOTES

In bacteria, **transcription and translation can be coupled** (translation begins before mRNA is fully transcribed) because

- ✓ mRNA requires **no processing** to become active.
- ✓ **Transcription & translation** take place in **same compartment** (no separation of cytosol and nucleus).



Bacterial cell (Prokaryote)



**Eukaryotic cell.
No coupling of
transcription
and translation**

TRANSCRIPTION

TRANSCRIPTION IN EUKARYOTES

In eukaryotes, there are 2 additional complexities:

1. There are **3 RNA polymerases**.
2. The **primary transcripts (hnRNA) contain exons and introns** and are non-functional. Hence introns must be removed.



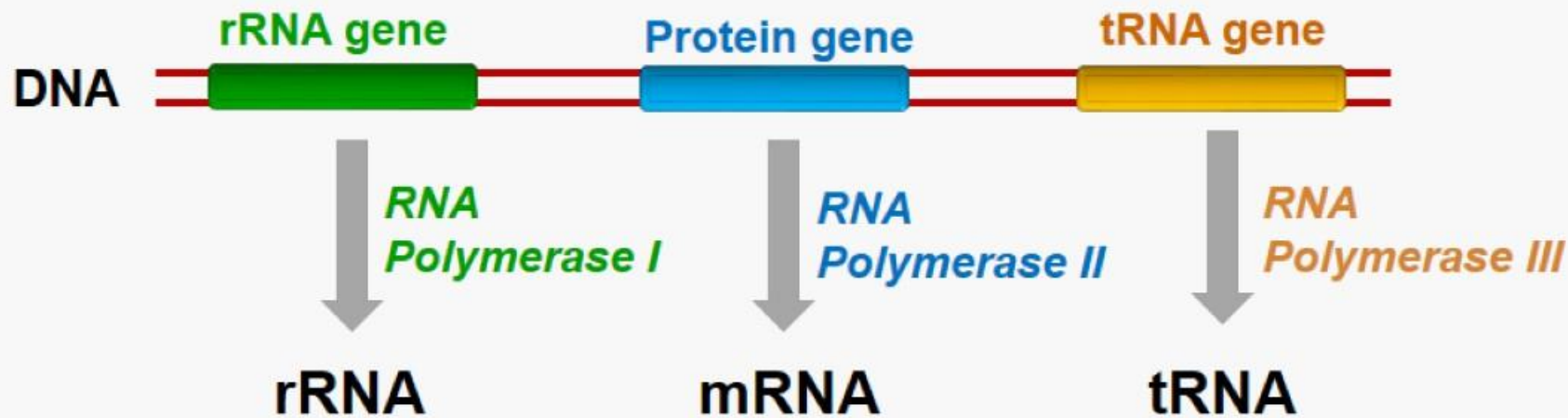
Primary transcripts (hnRNA)

TRANSCRIPTION

TRANSCRIPTION IN EUKARYOTES

3 RNA polymerases in eukaryotes:

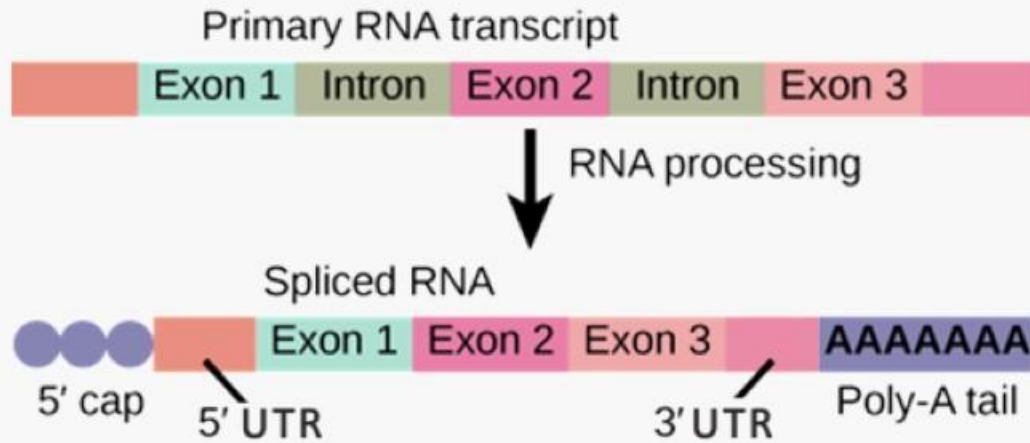
- **RNA polymerase I:** Transcribes **rRNAs** (28S, 18S & 5.8S).
- **RNA polymerase II:** Transcribes the **heterogeneous nuclear RNA (hnRNA)**. It is the precursor of mRNA.
- **RNA polymerase III:** Transcribes **tRNA, 5S rRNA and snRNAs** (small nuclear RNAs).



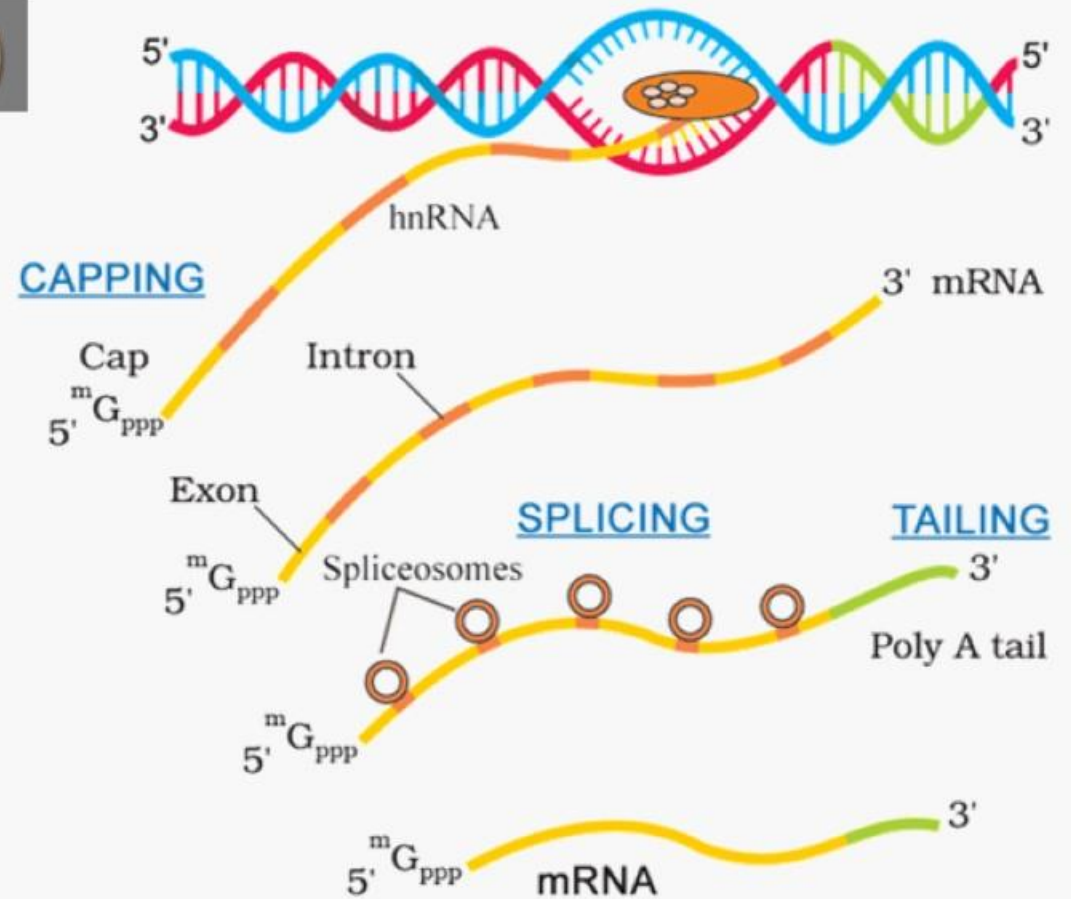
TRANSCRIPTION

TRANSCRIPTION IN EUKARYOTES

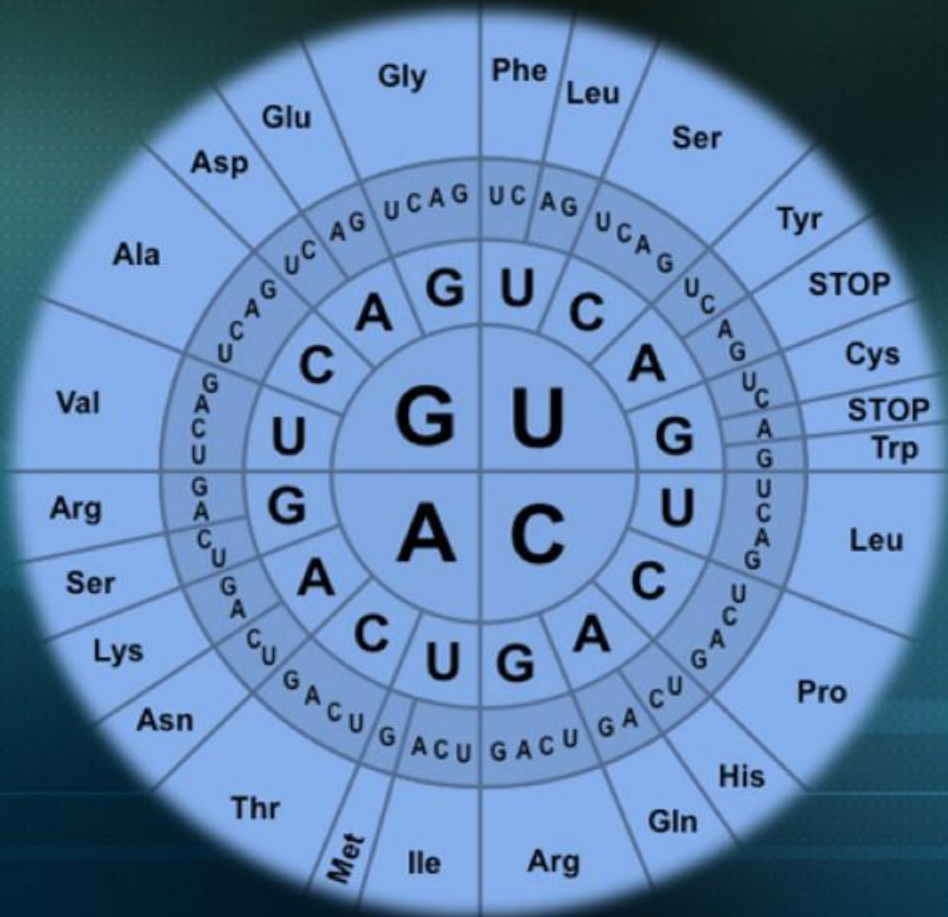
Processing of primary transcripts (hnRNA)



- 1. Splicing:** From hnRNA, introns are removed (by spliceosome) and exons are spliced together.
- 2. Capping:** Here, a nucleotide methyl guanosine triphosphate (cap) is added to 5' end of hnRNA.
- 3. Tailing (Polyadenylation):** Here, adenylate residues (200-300) are added at 3'-end.



Now, it is the fully processed hnRNA, called mRNA.



The genetic code is a set of rules that defines how sequences of nucleotide base pairs (A, C, G, T) are translated to amino acids, which are the building blocks of proteins. The code is universal, meaning that it is shared by all living organisms. The code is also degenerate, meaning that multiple codons can code for the same amino acid. The code is also non-overlapping, meaning that each nucleotide is only part of one codon.

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GENETIC CODE

GENETIC CODE

- It is the **sequence of nucleotides (nitrogen bases) in mRNA** that contains information for protein synthesis (translation).
- The sequence of 3 bases determining a single amino acid is called **codon**.

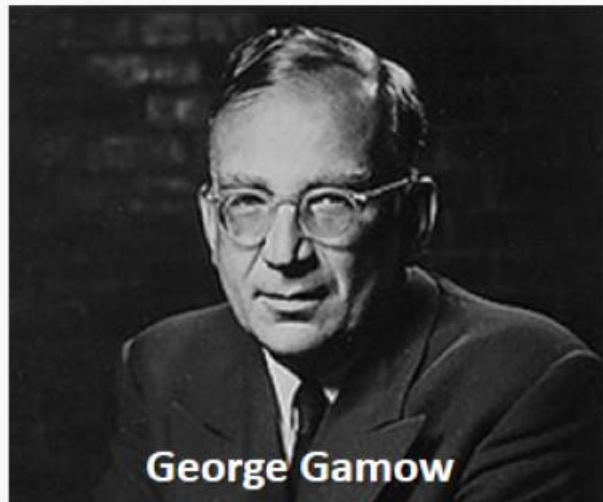
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GENETIC CODE

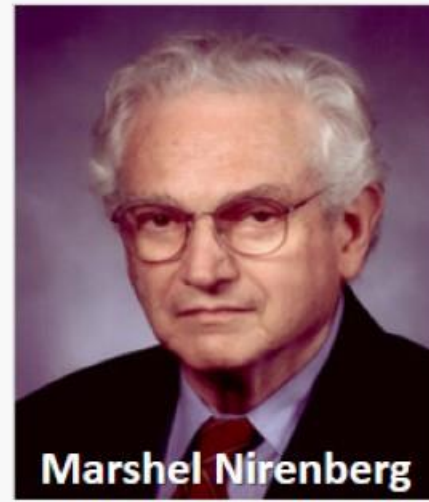
- **George Gamow** suggested that for coding 20 amino acids, the code should be made up of 3 nucleotides. Thus, there are **64 codons** ($4^3 = 4 \times 4 \times 4$).
- **Har Gobind Khorana** developed the chemical method in synthesizing RNA molecules with defined combinations of bases (homopolymers & copolymers).
- **Marshall Nirenberg** developed cell-free system for protein synthesis.
- **Severo Ochoa enzyme (*polynucleotide phosphorylase*)** is used to polymerize RNA with defined sequences in a template independent manner.



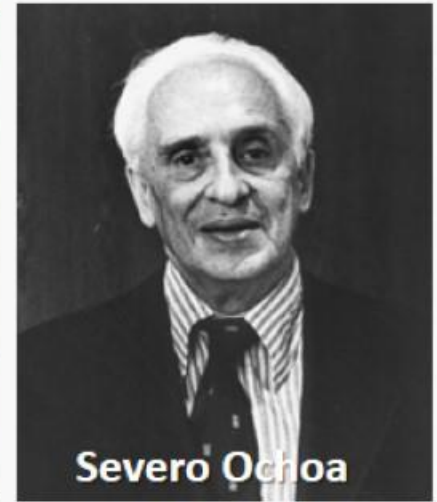
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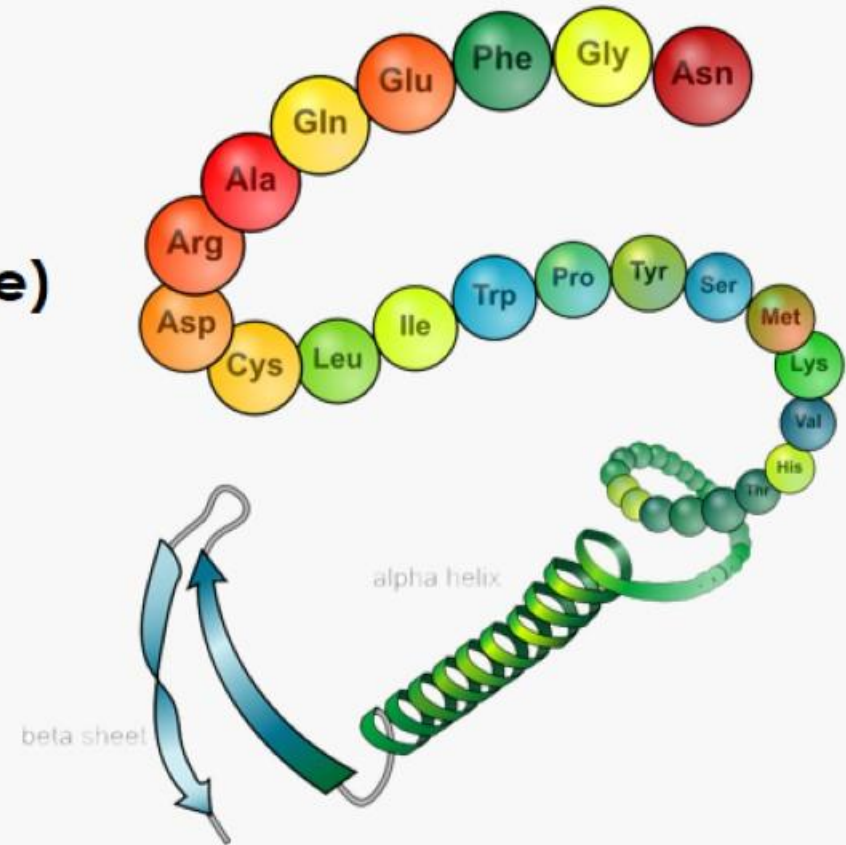


Severo Ochoa

GENETIC CODE

20 types of amino acids involved in translation

1. Alanine (ala)
2. Arginine (arg)
3. Asparagine (asn)
4. Aspartic acid (asp)
5. Cystein (cys)
6. Glutamine (gln)
7. Glutamic acid (glu)
8. Glycine (gly)
9. Histidine (his)
10. Isoleucine (iso)
11. Leucine (leu)
12. Lysine (lys)
13. Methionine (met)
14. Phenyl alanine (phe)
15. Proline (pro)
16. Serine (ser)
17. Threonine (thr)
18. Tryptophan (trp)
19. Tyrosine (tyr)
20. Valine (val)



GENETIC CODE

CODONS FOR VARIOUS AMINO ACIDS

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THE GENETIC CODE DICTIONARY

	U	C	A	G	
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	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

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GENETIC CODE

SALIENT FEATURES OF GENETIC CODE

- **Codon is triplet** (three-letter code).
- **61 codons** code for amino acids. 3 codons (**UAA, UAG & UGA**) do not code for any amino acids. They act as **stop codons (Termination codons or non-sense codons)**.
- **AUG** has dual functions. It codes for Methionine and acts as **initiator codon**. In eukaryotes, **methionine** is the first amino acid and **formyl methionine** in prokaryotes.
- An amino acid is coded by many codons (except AUG for methionine & UGG for tryptophan). Such codons are called **degenerate codons**.



GENETIC CODE

SALIENT FEATURES OF GENETIC CODE

- **No punctuations** b/w adjacent codons (comma less code). The codon is read in mRNA in a contiguous fashion.
- Genetic code is **universal**. E.g. From bacteria to human UUU codes for Phenylalanine. Some exceptions are found in mitochondrial codons, and in some protozoans.
- Genetic code is **non-overlapping**.
- Genetic code is **unambiguous & specific**. i.e. one codon specifies only one amino acid.

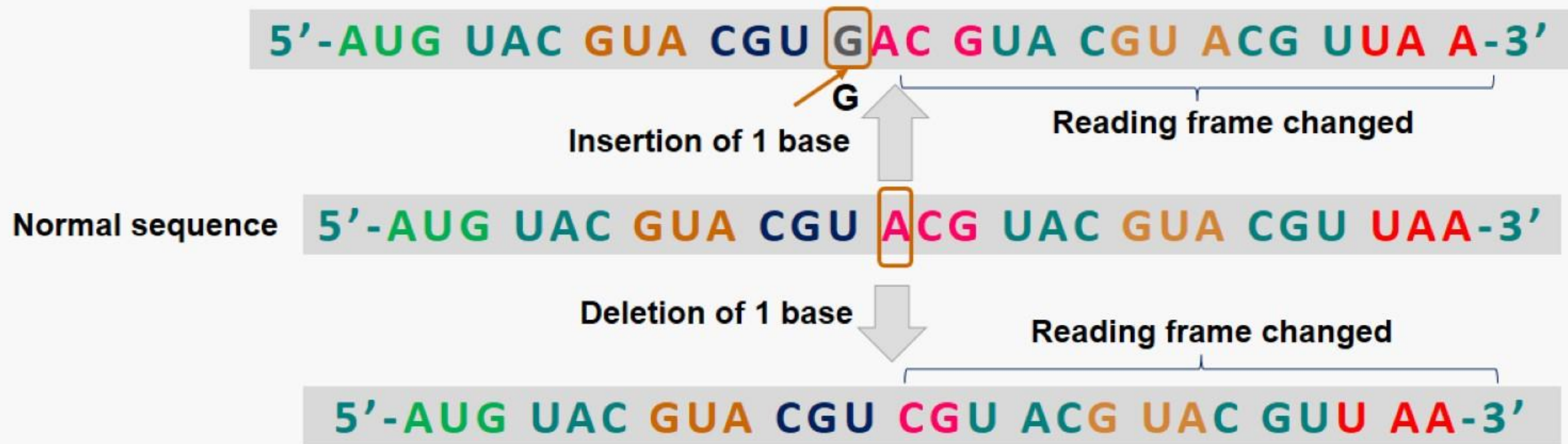
No base ("comma") b/w adjacent codons



GENETIC CODE

MUTATION AND GENETIC CODE

- Relationship between genes & DNA are best understood by mutation studies. Deletions & rearrangements in a DNA may cause loss or gain of a gene and so a function.
- **Insertion or deletion of one or two bases** changes the reading frame from the point of insertion or deletion. It is called **frame-shift insertion or deletion mutations**.

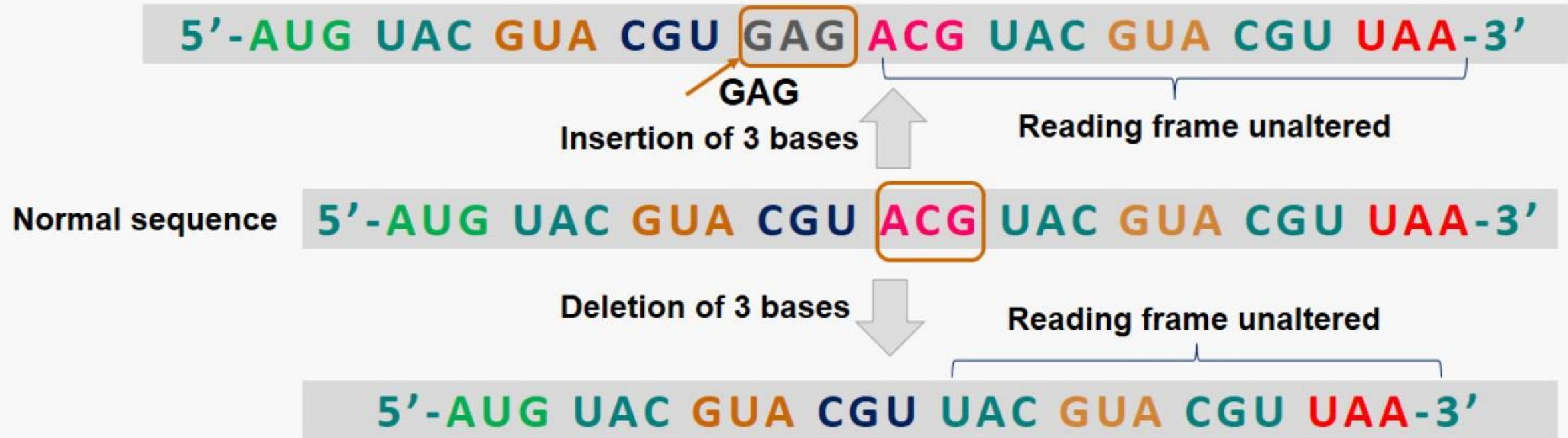


GENETIC CODE

MUTATION AND GENETIC CODE

- Insertion/ deletion of **three or its multiple bases** insert or delete one or multiple codon. The reading frame remains unaltered from that point onwards. Hence one or multiple amino acids are inserted /deleted.
- It proves that codon is a triplet and is read contiguously.

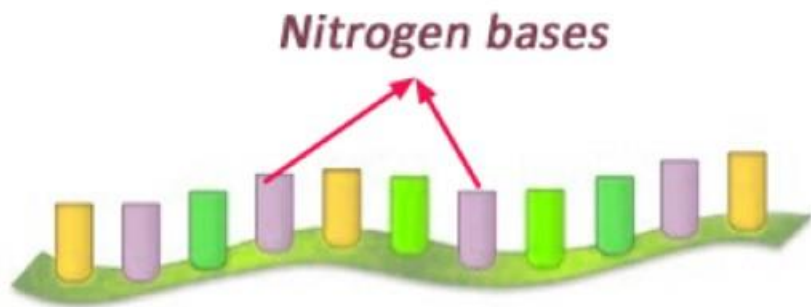
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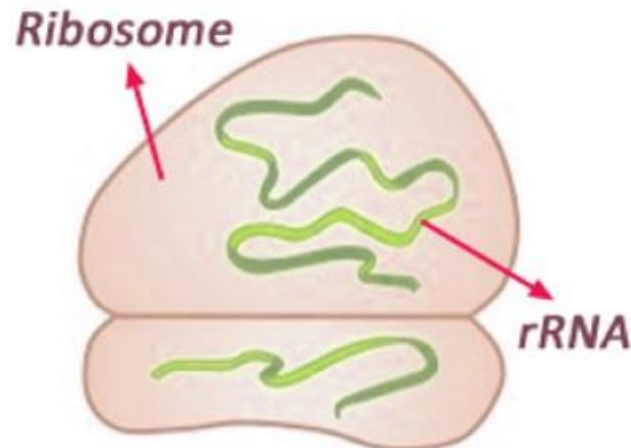
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TYPES OF RNA

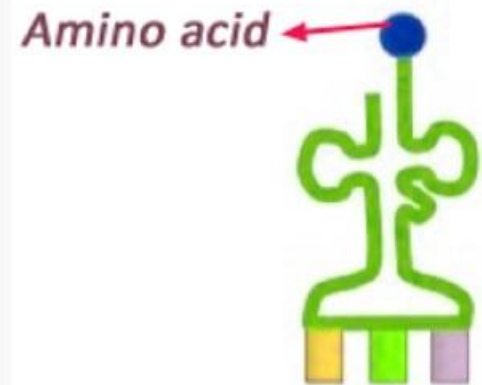
- **mRNA (messenger RNA):** Provide template for translation (protein synthesis).
- **rRNA (ribosomal RNA):** Structural & catalytic role during translation. E.g. 23S rRNA in bacteria acts as ribozyme.
- **tRNA (transfer RNA or sRNA or soluble RNA):** Brings amino acids for protein synthesis and reads the genetic code.



Messenger RNA (mRNA)



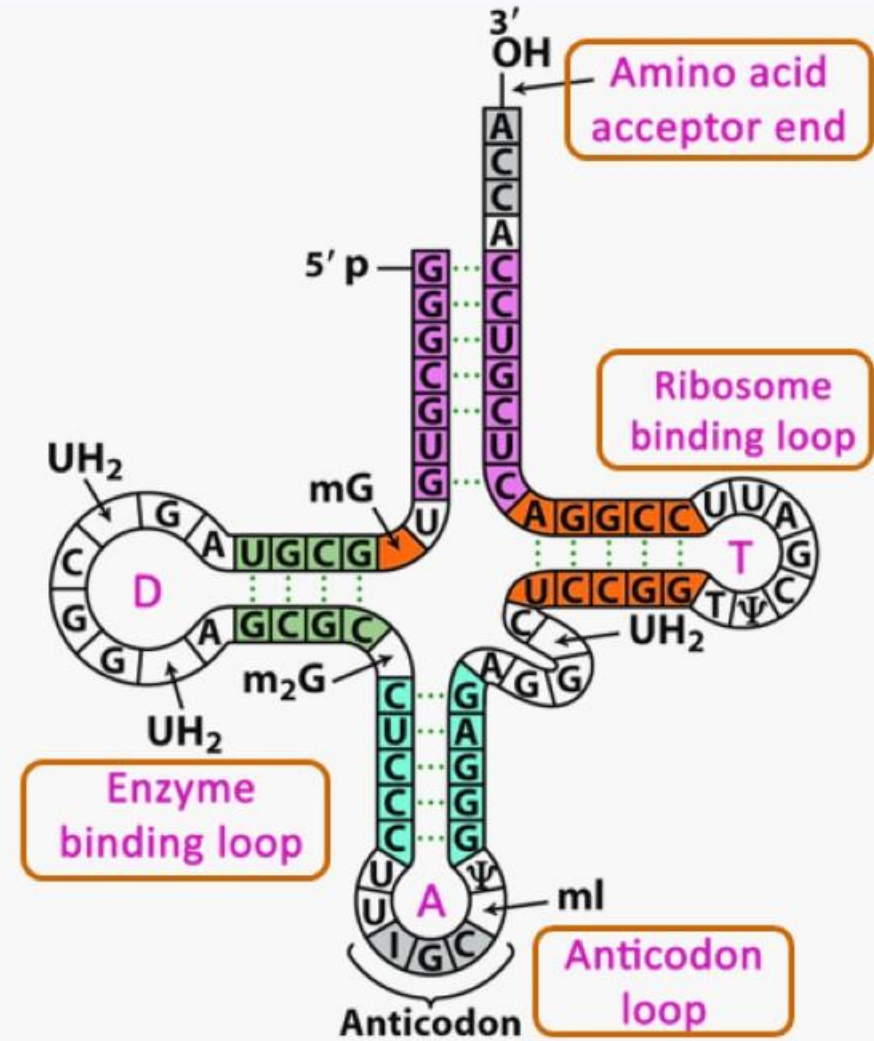
Ribosomal RNA (rRNA)



Transfer RNA (tRNA)

TYPES OF RNA

- **Francis Crick** postulated presence of an adapter molecule that can read the code and to link with amino acids.
- tRNA is called **adapter molecule** because it has
 - **An Anticodon (NODOC) loop** that has bases complementary to the codon.
 - **An amino acid acceptor end** to which amino acid binds.
 - **Ribosome binding loop.**
 - **Enzyme binding loop.**

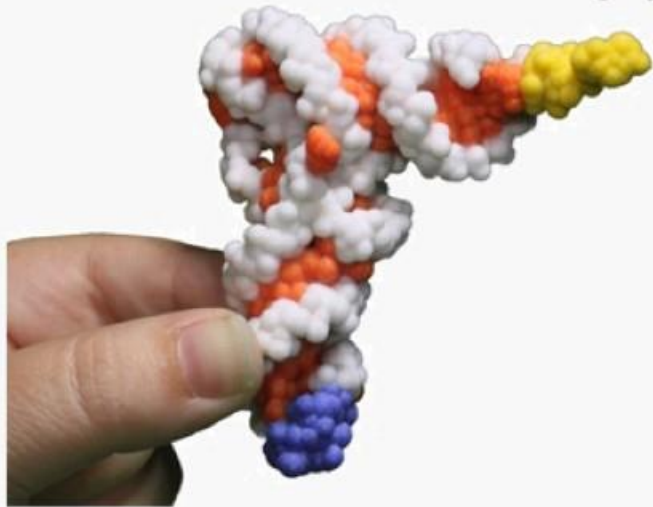


Clover leaf model of tRNA

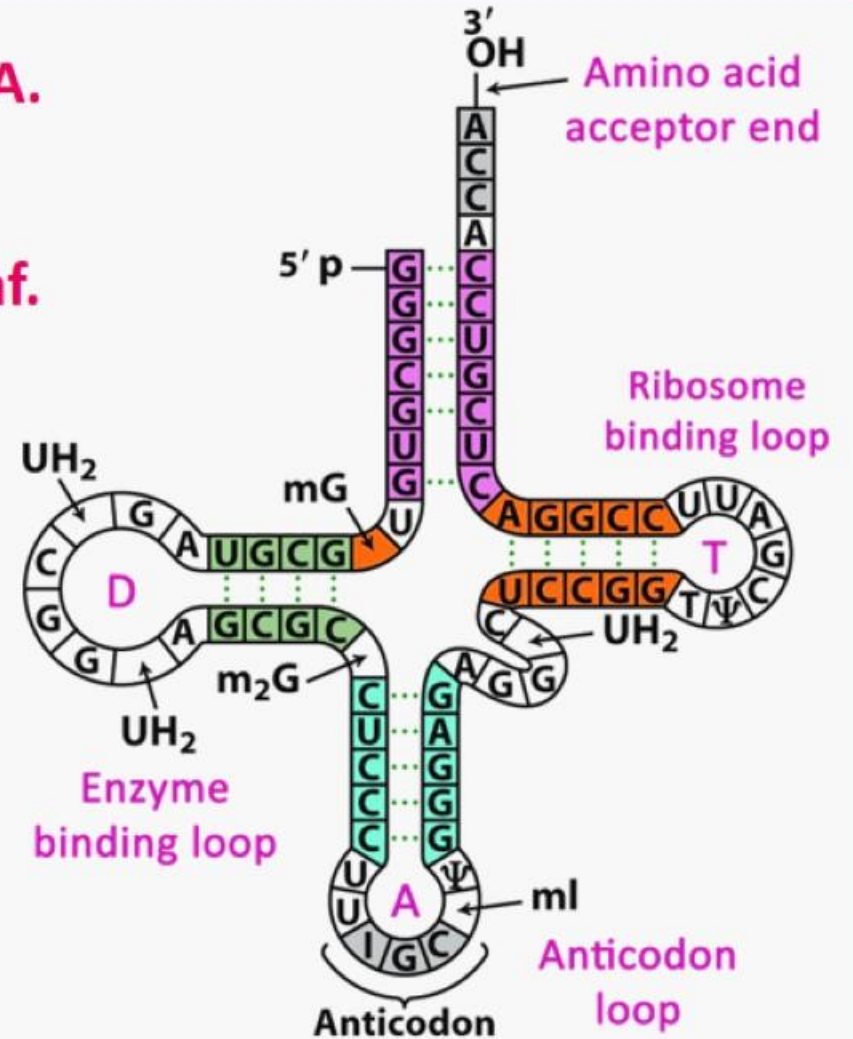
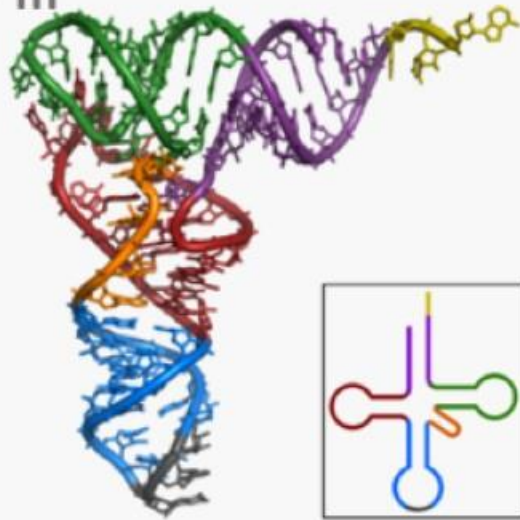
TYPES OF RNA

- For initiation, there is another tRNA called **initiator tRNA**.
- There are no tRNAs for stop codons.
- **Secondary (2-D)** structure of tRNA looks like a **clover-leaf**.
- **3-D structure** looks like **inverted 'L'**.

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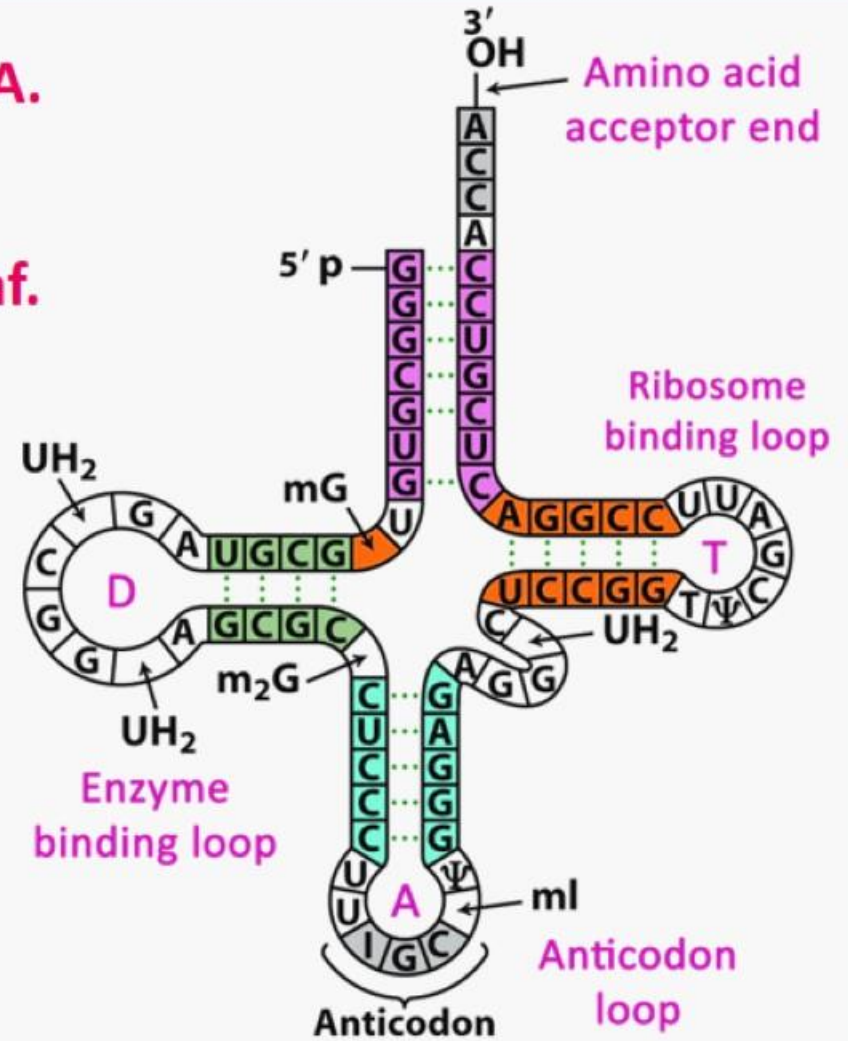
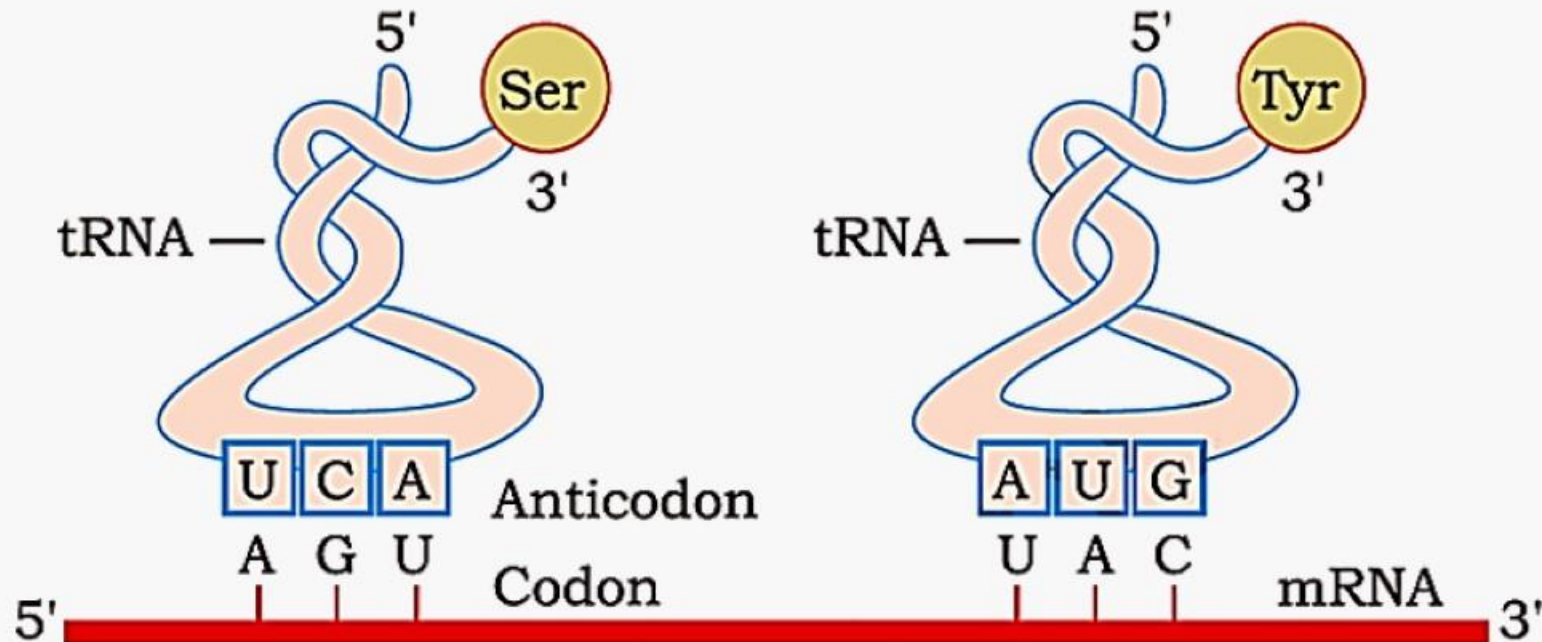
3D model of tRNA



Clover leaf model of tRNA

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Clover leaf model of tRNA