Gene expression: Transcription

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Lecture Objectives:

- Explain some of important terms related with gene expression
- Understand the basic steps in gene expression
- Explain steps of transcription in eukaryotic

What is gene expression

When the information and instructions stored in our DNA is converted into making proteins or other molecules, it is called gene expression.

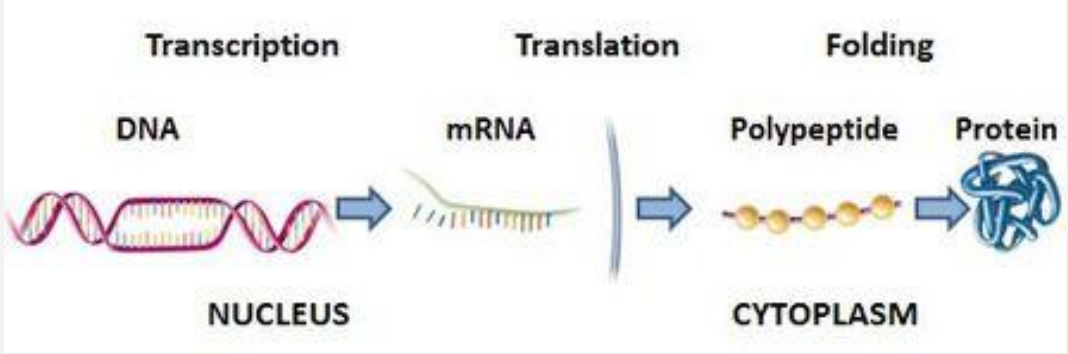
There are two key steps involved in making a protein, transcription and translation.

The stages of gene expression

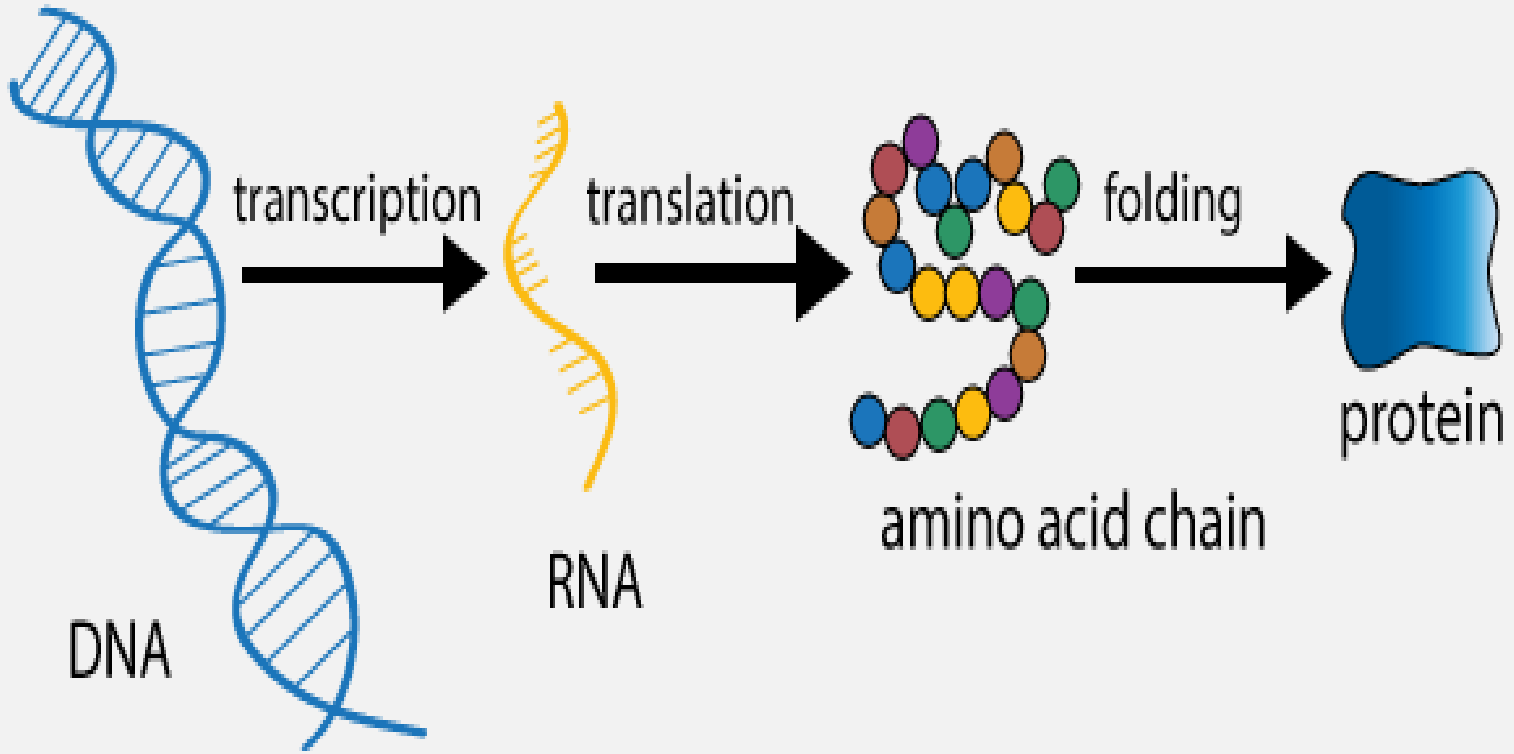
The process of gene expression involves two main stages:

Transcription: the production of messenger RNA (mRNA) by the enzyme RNA polymerase, and the processing of the resulting mRNA molecule.

Translation: the use of mRNA to direct protein synthesis, and the subsequent post-translational processing of the protein molecule.



Gene Expression (Transcription)

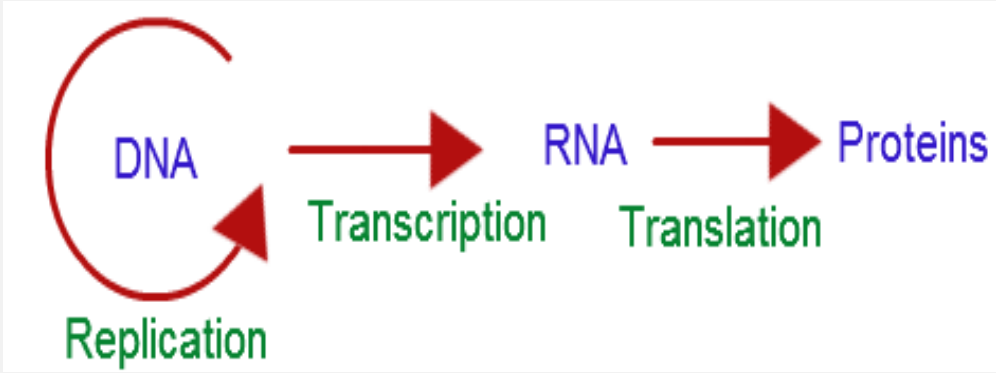


What is central dogma

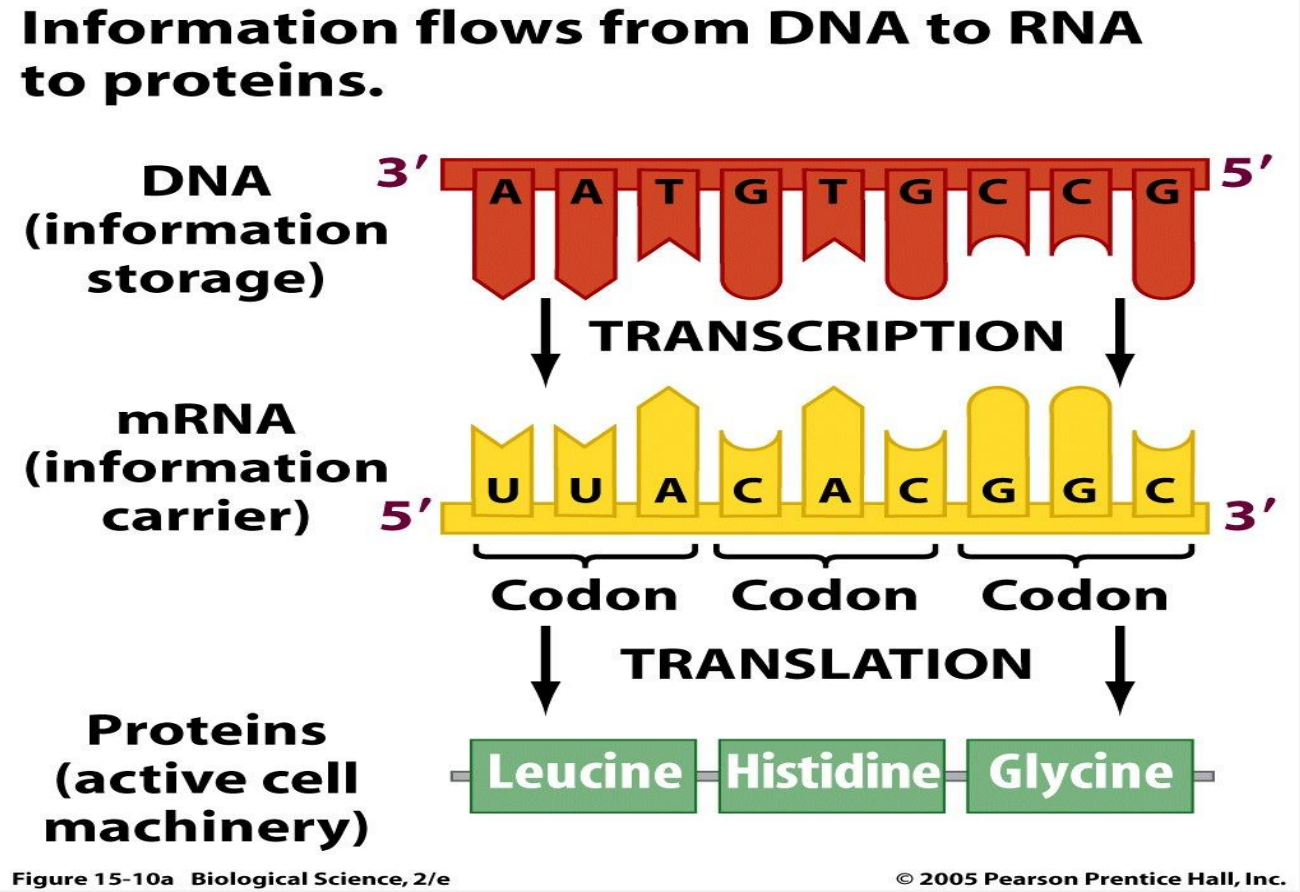
❖The set of ideas that describes how the cell uses the information stored in DNA is called the central dogma.

❖The central dogma of biology is the information in biological systems only flows one way from DNA to RNA to protein.

❖The central dogma of biology was a concept developed by Francis Crick in 1958.

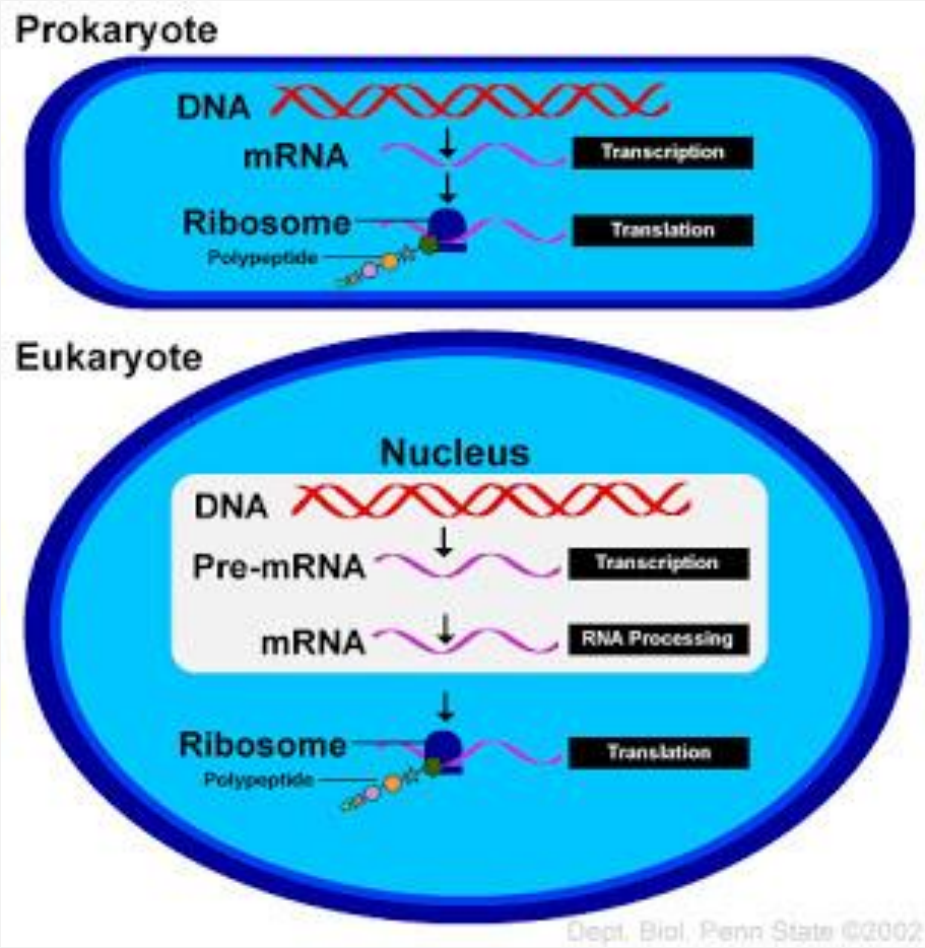


First step of central dogma is called transcription .



Where does transcription and translation occur in the cell?

Prokaryotic
transcription occurs in the cytoplasm alongside translation.



Eukaryotic
Transcription occurs in the nucleus, whereas translation occurs in the cytoplasm.

PROTEIN SYNTHESIS

Proteins are widely used in cells to serve diverse functions. Some proteins provide the structural support for cells while others act as enzymes to catalyze certain reactions. We have already seen the roles that different enzymes play in building the cell's structure and in catalyzing metabolic reactions, but where do proteins come from? Since the beginning of evolution, cells have developed the ability to synthesize proteins. They can produce new proteins either for reproduction or to simply replace a degraded one. To manufacture proteins, cells follow a very systematic procedure that first transcribes DNA into mRNA and then translates the mRNA into chains of amino acids. The amino acid chain then folds into specific proteins.

What is transcription?

- Transcription is the process of using DNA as a template to synthesize RNA.
- Because this process is reminiscent of transcribing (copying) written words, the synthesis of RNA is called transcription.
- The DNA is said to be transcribed into RNA, and the RNA is called a transcript.
- In the process of gene expression, transcription involves the production of messenger RNA (mRNA) from a DNA template. It takes place in the nucleus of a cell and is catalyzed by the enzyme RNA polymerase II.

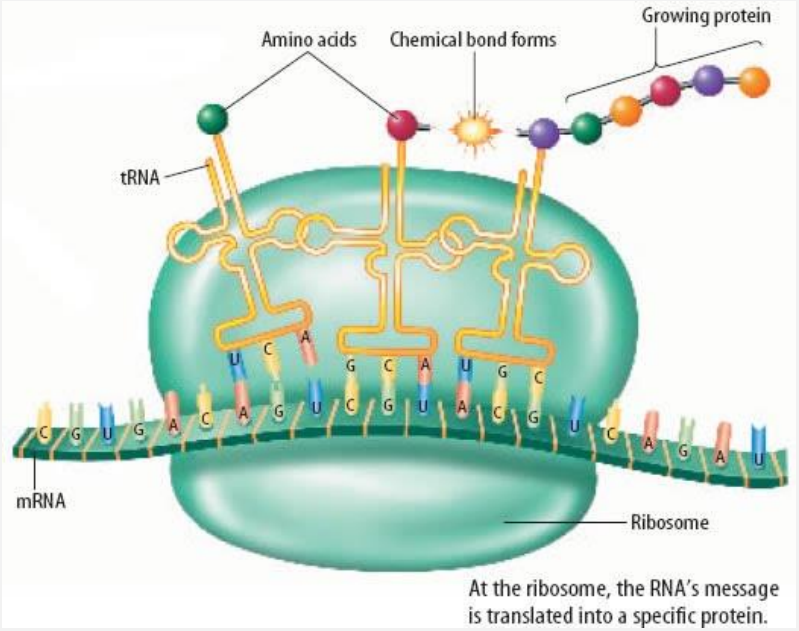
RNA polymerase

All eukaryotes have three different types of RNA polymerase:

•RNA polymerase I transcribes rRNA genes

•RNA polymerase II transcribes mRNA, miRNA, snRNA, and snRNA genes

•RNA polymerase III transcribes an array of RNA genes, including but not limited to tRNA and 5S rRNA genes.



Transcription

❖During transcription only one strand of DNA molecule (double stranded) is used.

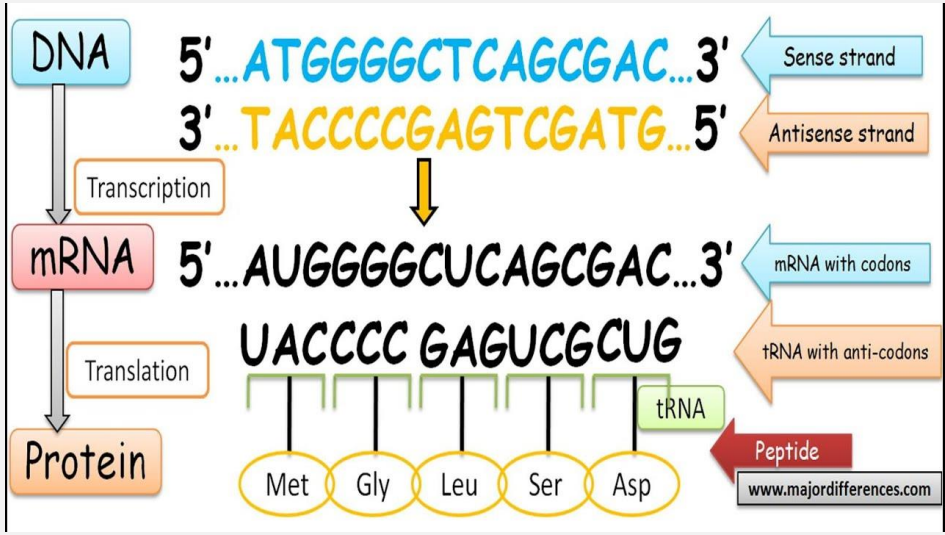
❖Small portion of genome is transcribed in response to the development requirement, physiological need and environmental changes.

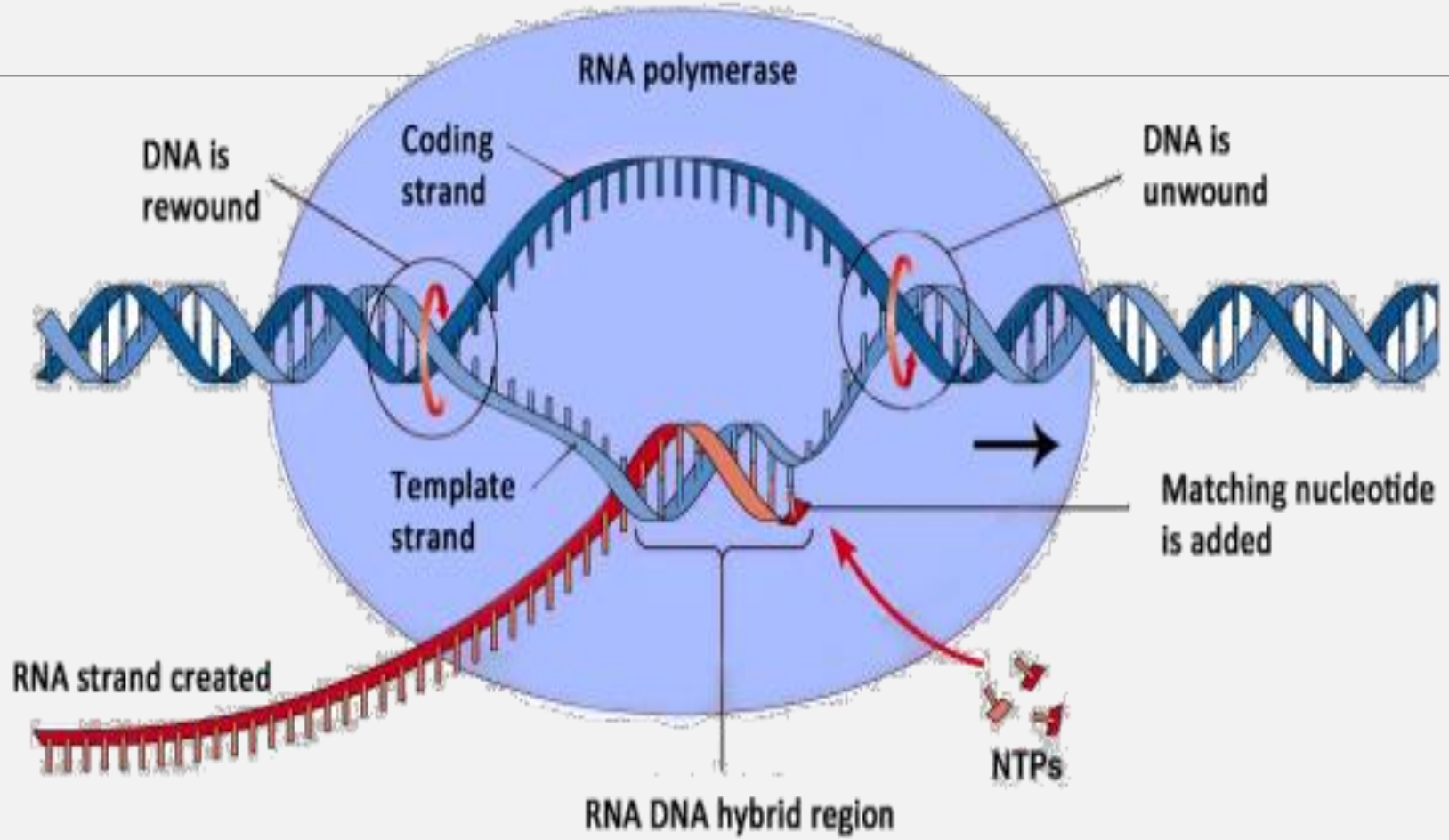
❖DNA regions that can be transcribed into RNA are called structural genes.

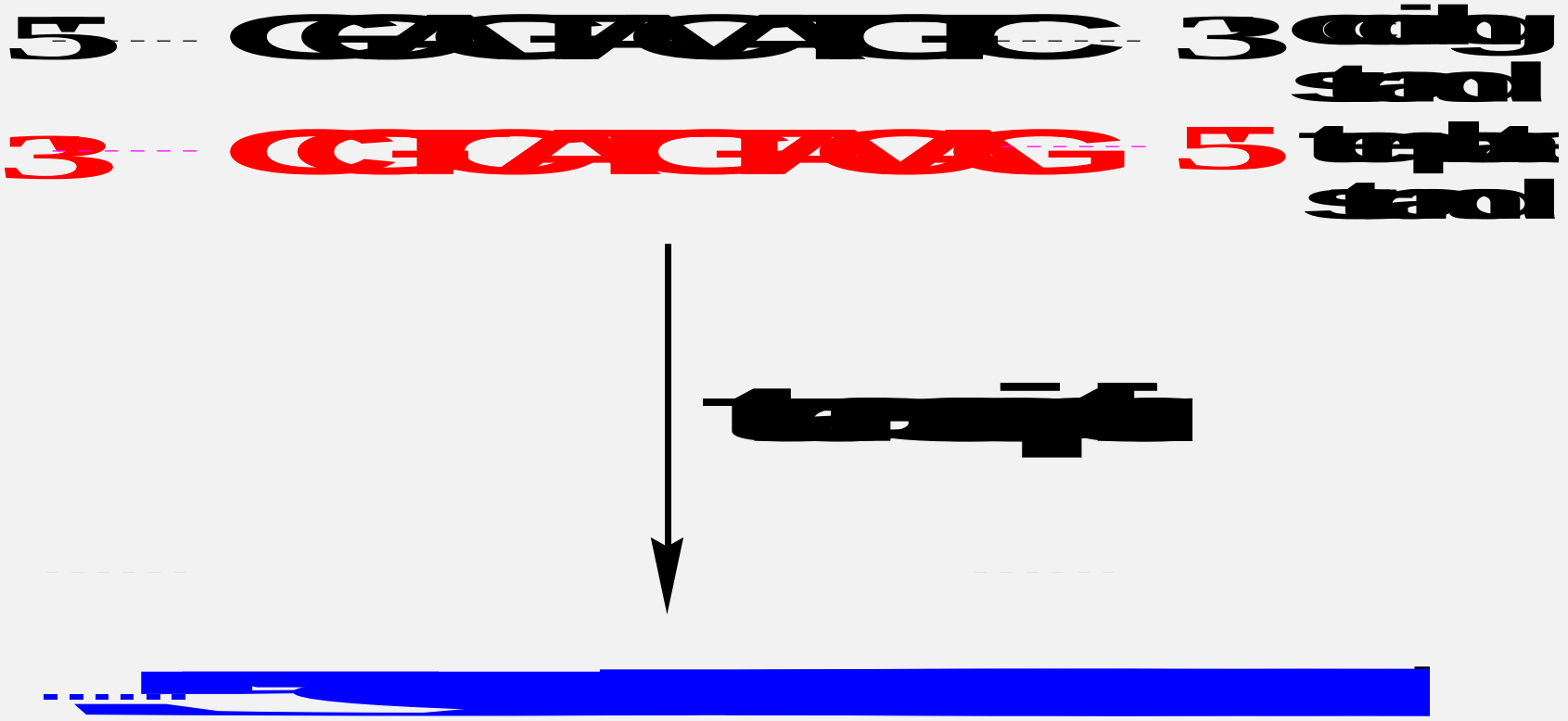
❖The template strand is the strand from which the RNA is actually transcribed. It is also termed as antisense strand.

❖The coding strand is the strand whose base sequence specifies the amino acid sequence of the encoded protein. Therefore, it is also called as sense strand.

❖The sense strand is same as mRNA except that thymine in DNA is replaced by Uracil in RNA.




RNA polymerase
DNA is rewound
Coding strand
DNA is unwound
Template strand
Matching nucleotide is added
RNA strand created
NTPs
RNA DNA hybrid region



Transcription unit

It is a sequence of DNA that is transcribed into a single RNA molecule.

A typical unit has

- **Promoter** at the beginning (At the 3’ end of its antisense strand)
- A **start point**
- A **coding region**
- A **terminator sequence** at the end
- RNA polymerase
- rNTPs (ribonucleotides triphosphates)-ATP, CTP, GTP, UTP

The steps of transcription

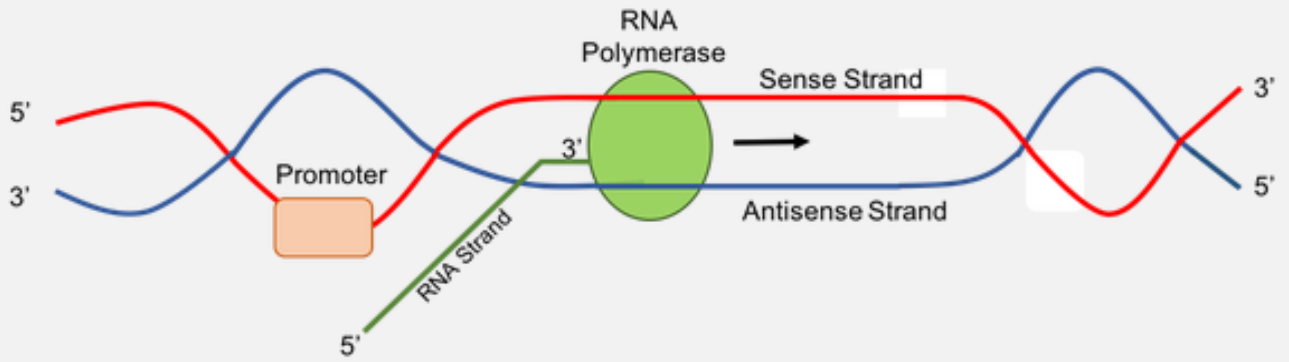
The process of transcription entails several steps:

1. Initiation

The first step of transcription to form mRNA involves RNA polymerase II binding to a **promoter region** just upstream of the gene that is to be transcribed. Promoters are often classified as strong or weak based on their effects on transcription rates and thus gene expression.

Transcription factors are proteins that help to position RNA polymerase II and assist in the breaking of the hydrogen bonds in the DNA helix.

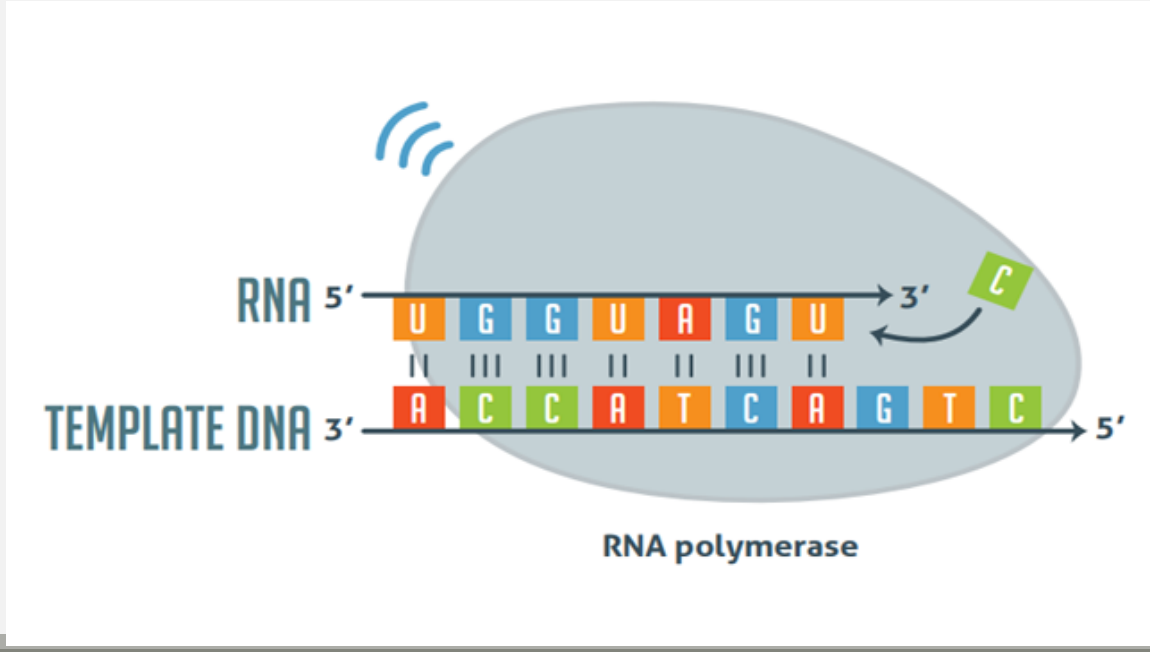
1. **This signals the DNA to unwind so the enzyme can "read" the bases in one of the DNA strands.**
2. **The enzyme is now ready to make a strand of mRNA with a complementary sequence of bases.**



a **promoter** is a region of DNA that leads to initiation of transcription of a particular gene. Promoters are located **near** the transcription start sites of genes, **upstream** on the DNA (**towards the 5' region of the sense strand**). Promoters can be about **100–1000** base pairs long

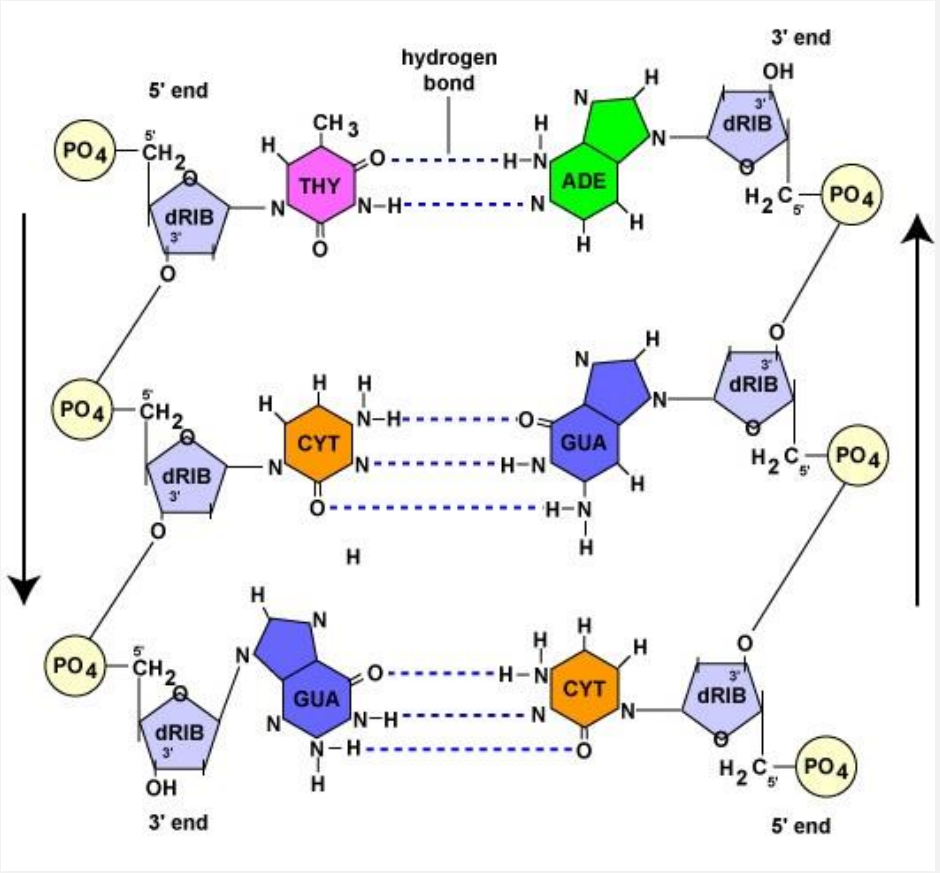
2. Elongation

RNA polymerase II breaks the hydrogen bonds connecting two strands of DNA in the double helix. The enzyme then uses the single DNA strand as a template to build an RNA strand in **the 5' to 3' direction**, adding each complementary nucleotide to **the 3' end of the strand**. In RNA, the nucleotide **thymine** is **replaced** by the **nucleotide uracil**



What do we mean by 5' and 3'?

This refers to the carbon numbers in DNA and RNA's backbone. **The 5' carbon** ribose ring frequently has **a phosphate group** attached, and **the 3' carbon** end has **a hydroxyl (-OH) group** attached. **The asymmetry** gives the DNA and RNA strands a **"direction".**



3. Termination

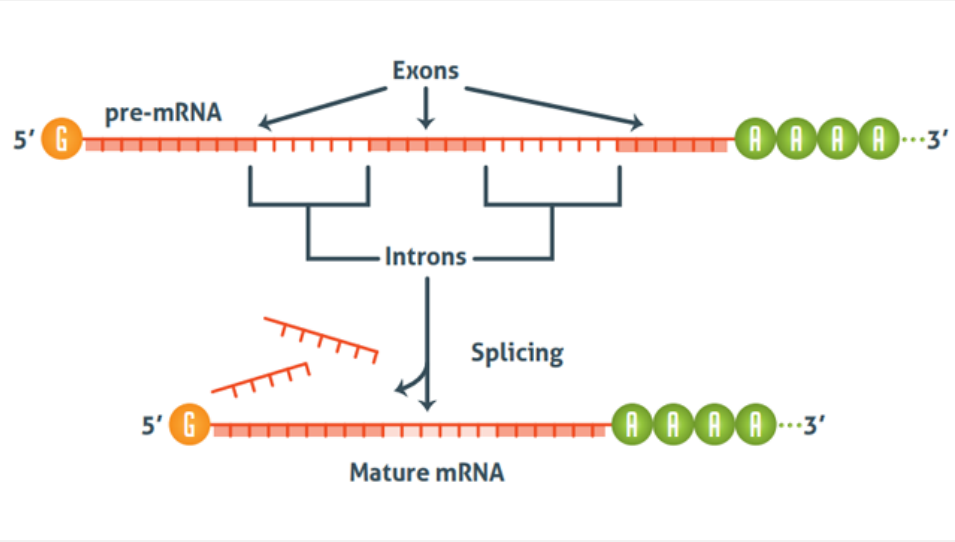
- Termination marks the end of RNA polymerase II adding nucleotides to the pre-mRNA strand and the release of the pre-mRNA. Despite extensive research, there is still ambiguity surrounding the precise physiological cause of termination.
- The primary product of RNA transcription; the heterogeneous nuclear RNAs (hnRNAs) contain both intronic and exonic sequences.
- These hnRNAs are processed in the nucleus to give mature mRNAs that are transported to the cytoplasm where to participate in protein synthesis.

From pre-mRNA to mRNA

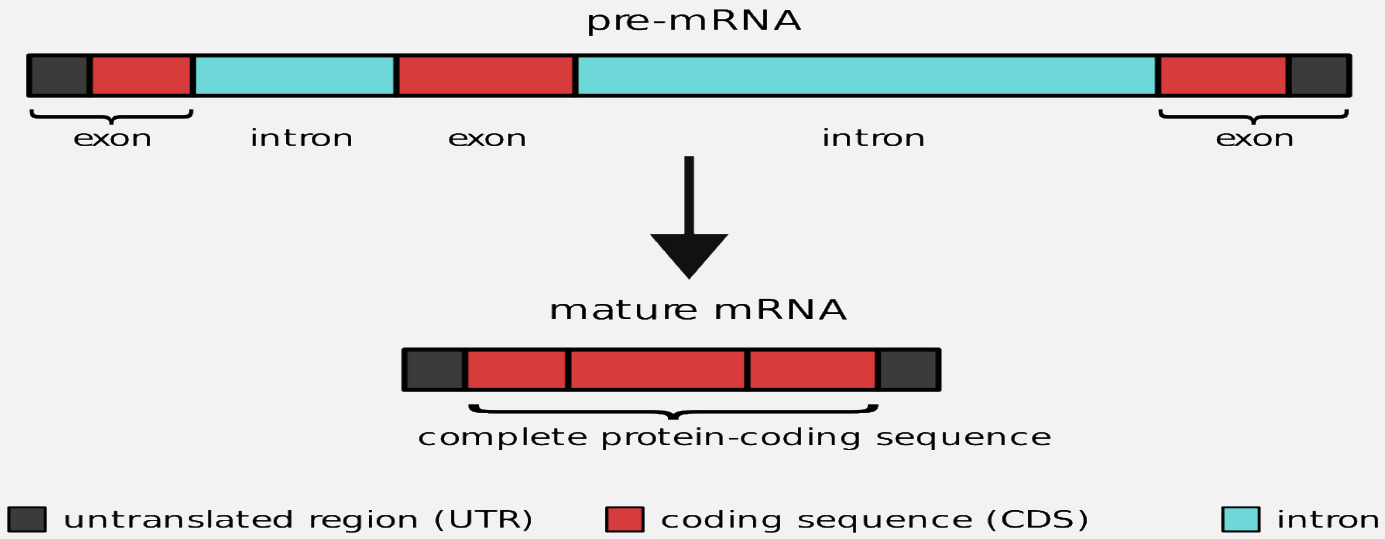
- Eukaryotic pre-mRNAs must go through several additional processing steps before translation can occur:
- Firstly, they have **a 5' cap added and a 3' poly-A-tail** added to protect against transcript degradation.

Secondly, **Addition of <u>poly(A) tail to 3' end</u>** (polyadenylation) -> increases stability and translation of mRNA.

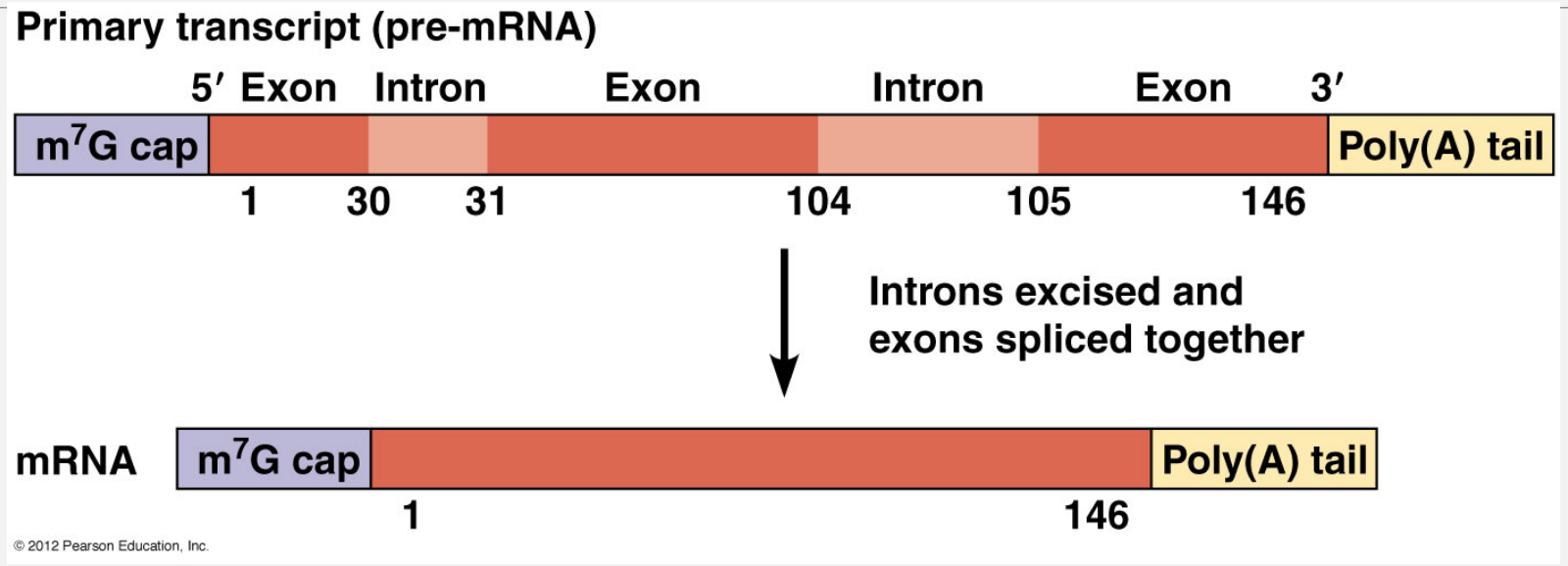
Thirdly, Many eukaryotic pre-mRNAs are subject to **splicing** (the non-coding sections of the pre-mRNA (introns) are cut out, and the coding sections (the exons) are effectively glued back together).



❖ Alternative **splicing** may also take place, whereby exons or noncoding regions within the pre-mRNA transcript are joined or skipped, resulting in multiple mRNAs being encoded by a single gene.



❖ After these modifications have taken place, the resulting strand is known as mature mRNA. This mature mRNA is then able to leave the nucleus and enter the cell cytoplasm where translation takes place.


Primary transcript (pre-mRNA)
5′ Exon
Intron
Exon
Intron
Exon
3′
m7G cap
Poly(A) tail
1
30
31
104
105
146
Introns excised and
exons spliced together
mRNA
m7G cap
Poly(A) tail
1
146
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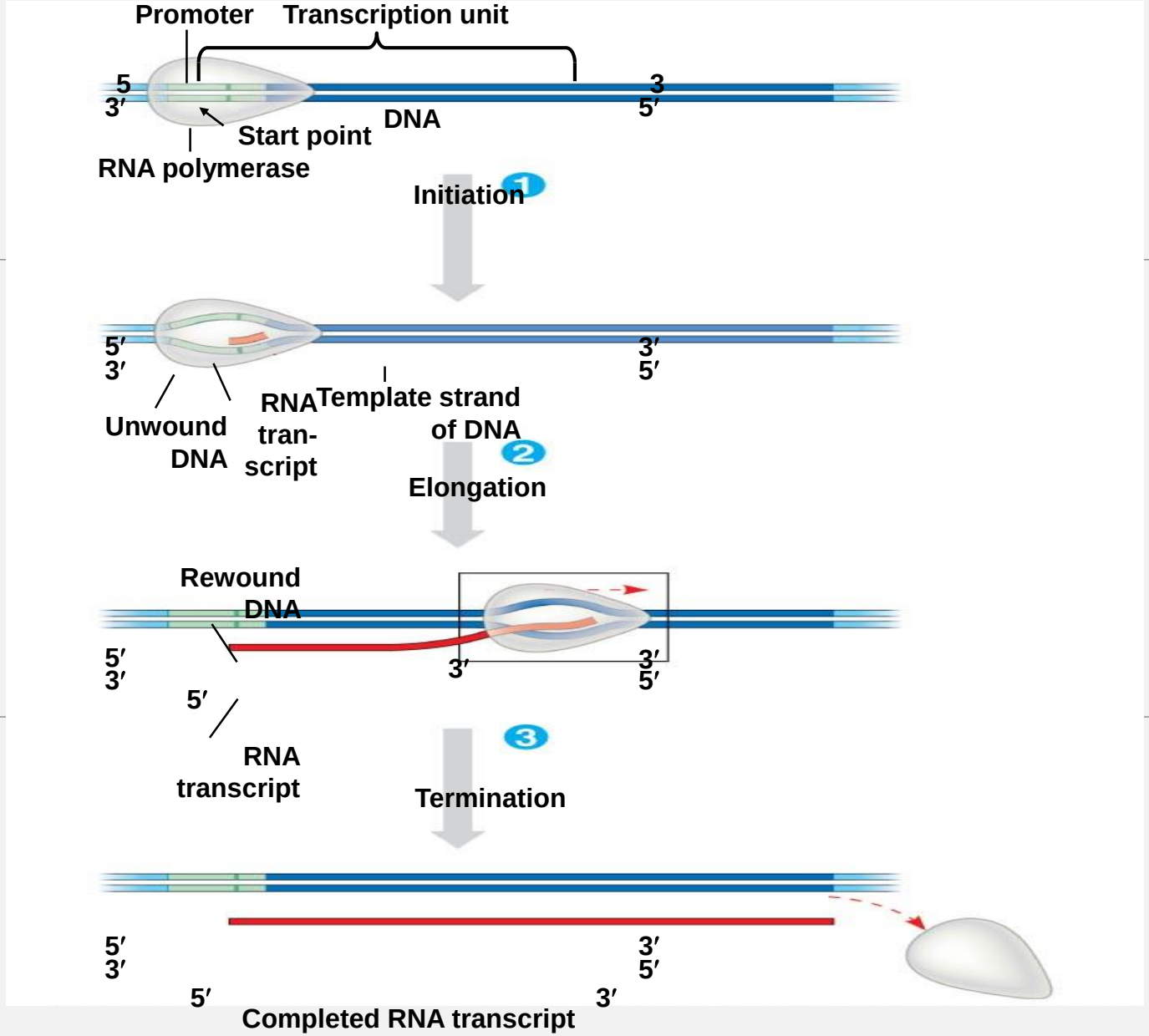
Promoter
Transcription unit
5′
3′
3′
5′
DNA
Start point
RNA polymerase
1
Initiation
5′
3′
3′
5′
Unwound DNA
RNA tran-script
Template strand of DNA
2
Elongation
Rewound DNA
5′
3′
3′
3′
5′
5′
RNA transcript
3
Termination
5′
3′
3′
5′
5′
3′
Completed RNA transcript

https://www.youtube.com/watch?v=_Zyb٨bpGMR٠

https://www.youtube.com/watch?v=vLz٢A١cjPH٨

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