Nucleic acids

DNA replication

Objectives :

Explain the process of DNA replication including :

- The replication of DNA is semi-conservative and depends on complementary base pairing.
- Helicase unwinds the double helix and separates the two strands by breaking hydrogen bonds.
- DNA polymerase links nucleotides together to form a new strand, using the pre-existing strand as a template.

Resources :

Book pages 41,42

DNA replication

https://www.youtube.com/watch?v=lSvF5-rBRGQ

The process by which the DNA is copied inside a cell as part of Its preparation for cell division . This process takes place in the cell nucleus during the interphase stage of the cell cycle.

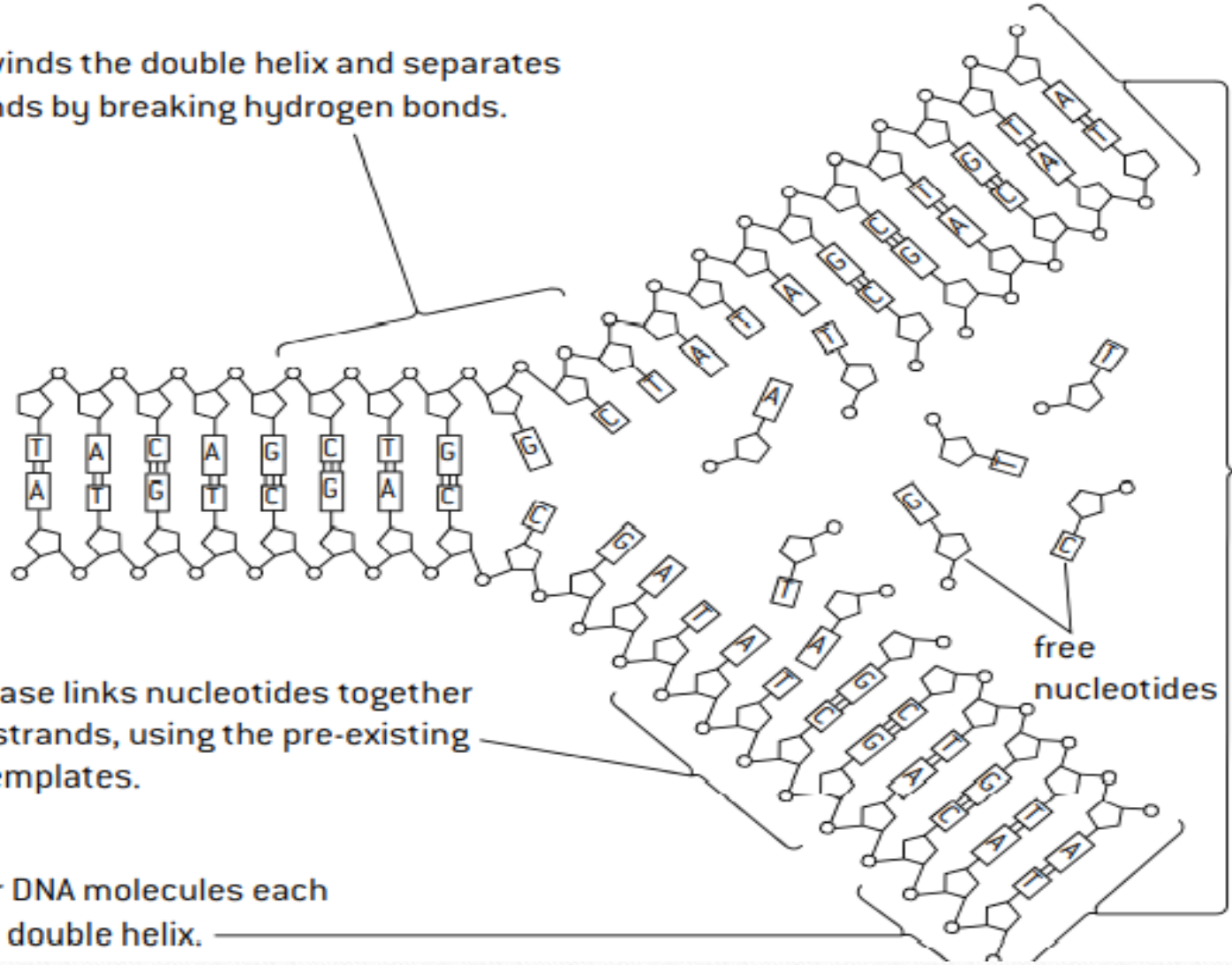
The process takes place as follows:

1. The DNA double helix is separated into two individual strands of DNA by the enzyme helicase. Helicase does this by unwinding the double helix and breaking the hydrogen bonds that hold the DNA strands together.
2. The new strand of DNA Is created by the enzyme, DNA polymerase. DNA polymerase uses one of the original DNA strands as a template and links nucleotides together, forming a new strand.

Complementary base pairing, in which adenine is bonded to thymine and guanine is bonded to cytosine, is maintained.

STAGES IN DNA REPLICATION

Stage 1
Helicase unwinds the double helix and separates the two strands by breaking hydrogen bonds.



Stage 2
DNA polymerase links nucleotides together to form new strands, using the pre-existing strands as templates.

Stage 3
The daughter DNA molecules each rewind into a double helix.

The two daughter DNA molecules are identical in base sequence to each other and to the parent molecule, because of complementary base pairing. Adenine will only pair with thymine and cytosine will only pair with guanine. Each of the new strands is complementary to the template strand on which it was made and identical to the other template strand

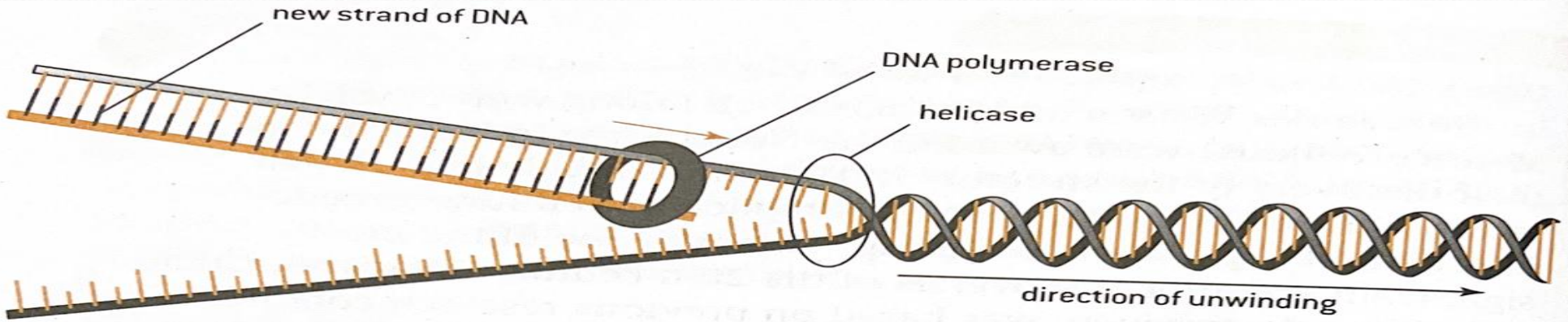


Figure 23. DNA replication

DNA replication is semi-conservative, meaning that each strand in the DNA double helix acts as a template for the formation of a new complementary strand (figure 24).

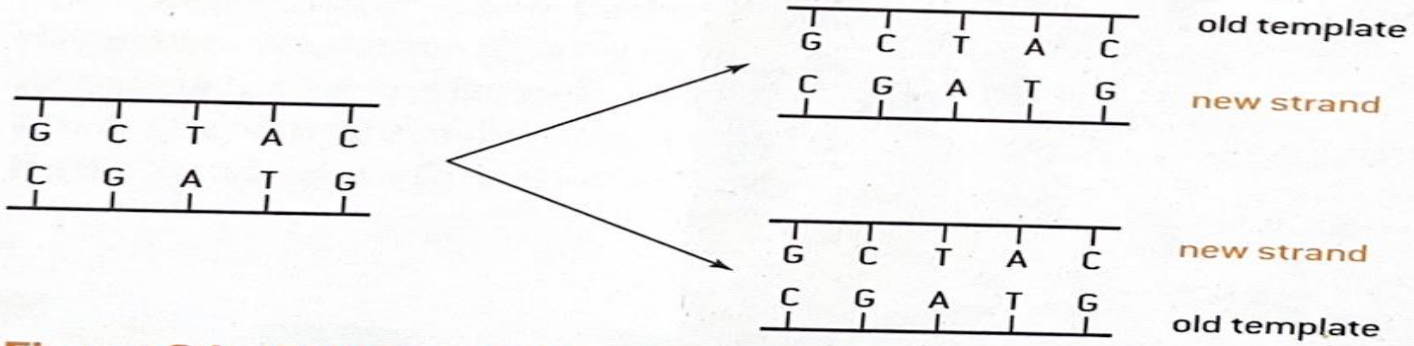
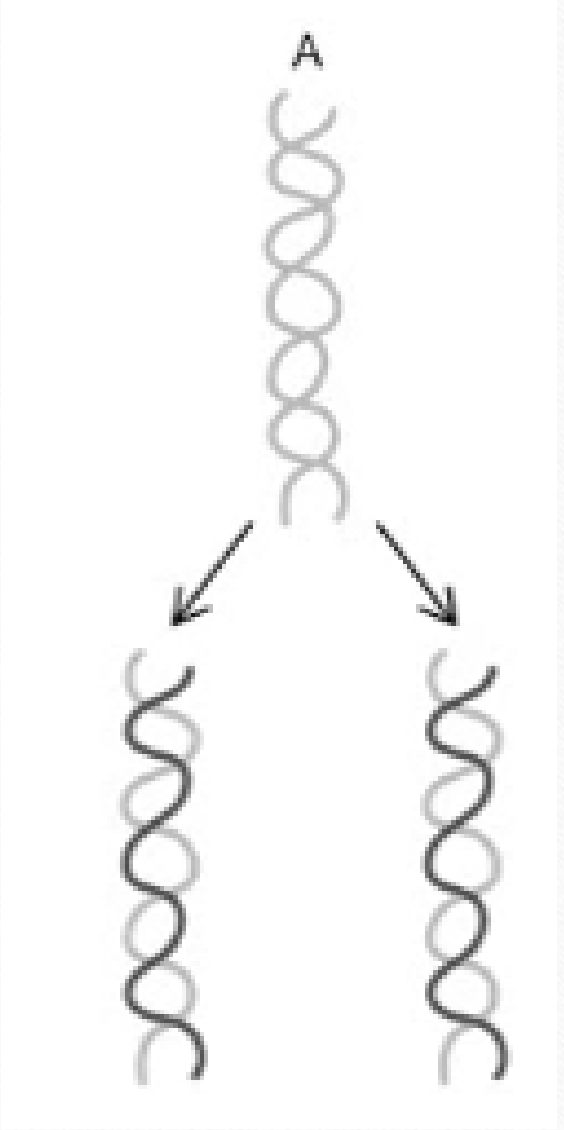


Figure 24. DNA replication is semi-conservative

Semi conservative :This means that **every double helix in the new generation of an organism consists of one complete "old" strand and one complete "new" strand wrapped around each other.**



Nucleic acids

Protein synthesis

Objectives :

- Transcription is the synthesis of mRNA copied from the DNA base sequences by RNA polymerase.

- Translation is the synthesis of polypeptides on ribosomes.

- The amino acid sequence of polypeptides is determined by mRNA according to the genetic code.

- Codons of three bases on mRNA correspond to one amino acid in a polypeptide.

- Translation depends on complementary base pairing.

Resources :

Book pages 42 , 43 , 44 , 45

Protein synthesis

Protein synthesis is one of the most vital biological processes, in which organisms build proteins which are essential for life.

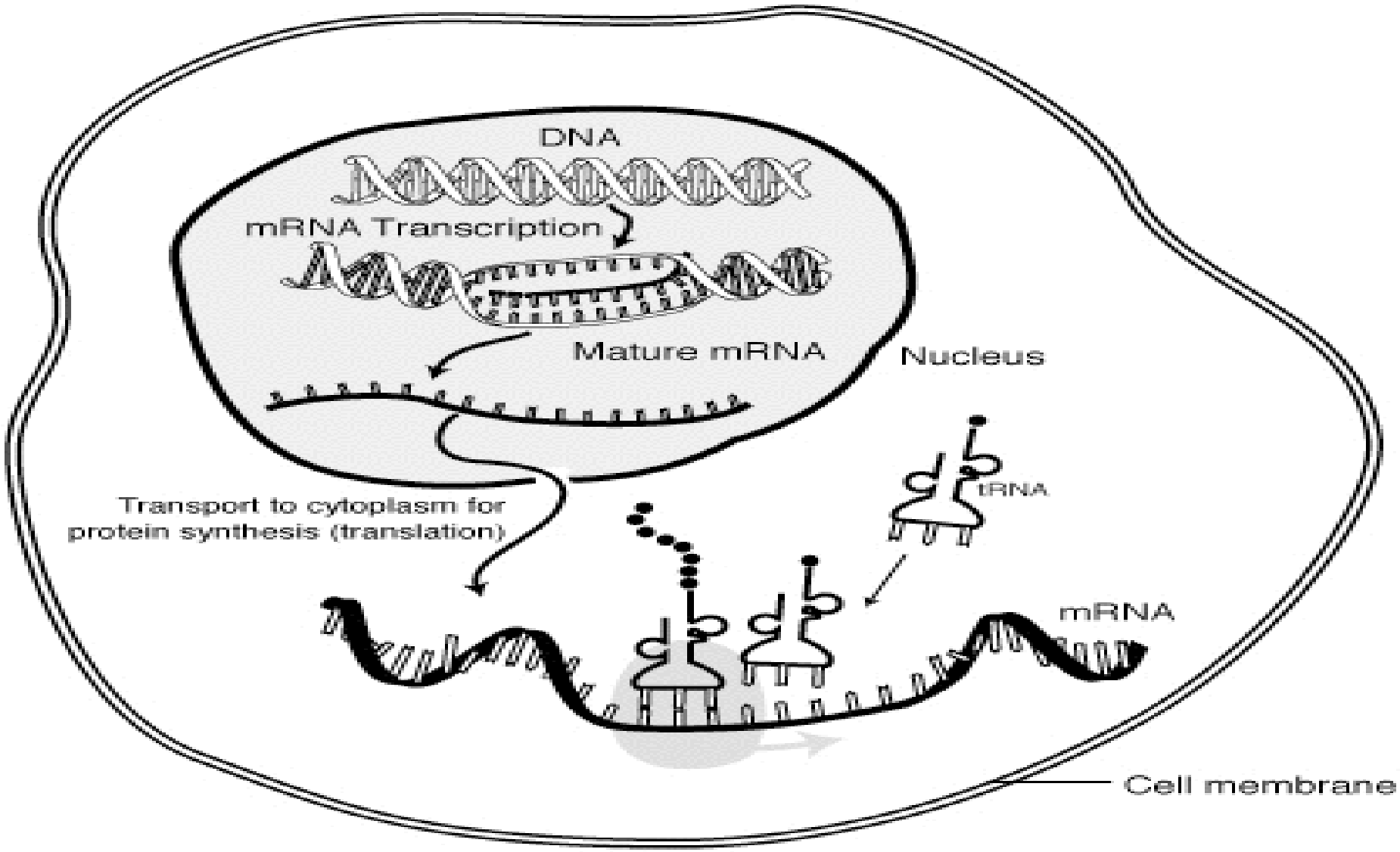
The process is initiated in the nucleus but then it is moved to the cell ***cytoplasm.***

DNA is the molecule that holds the genetic information that gives the instructions to build proteins. Since DNA cannot leave the cell, it sends a messenger outside to code for the formation of polypeptides. This messenger is called messenger RNA or mRNA.

Therefore, protein synthesis involves **two processes:**

1. Transcription = mRNA formation

2. Translation = Polypeptide formation.


DNA
mRNA Transcription
Mature mRNA
Nucleus
Transport to cytoplasm for
protein synthesis (translation)
tRNA
mRNA
Cell membrane

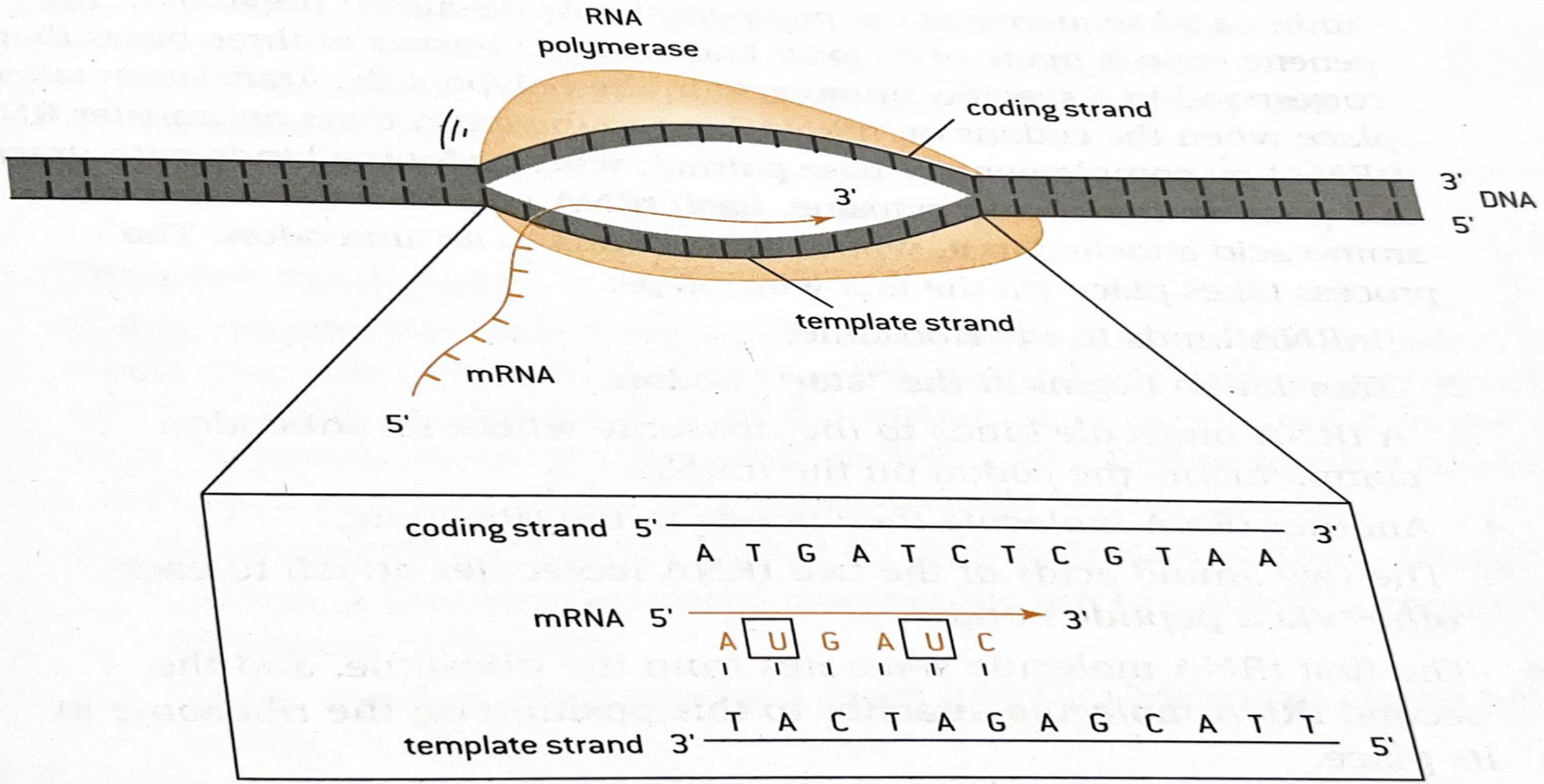
DNA transcription

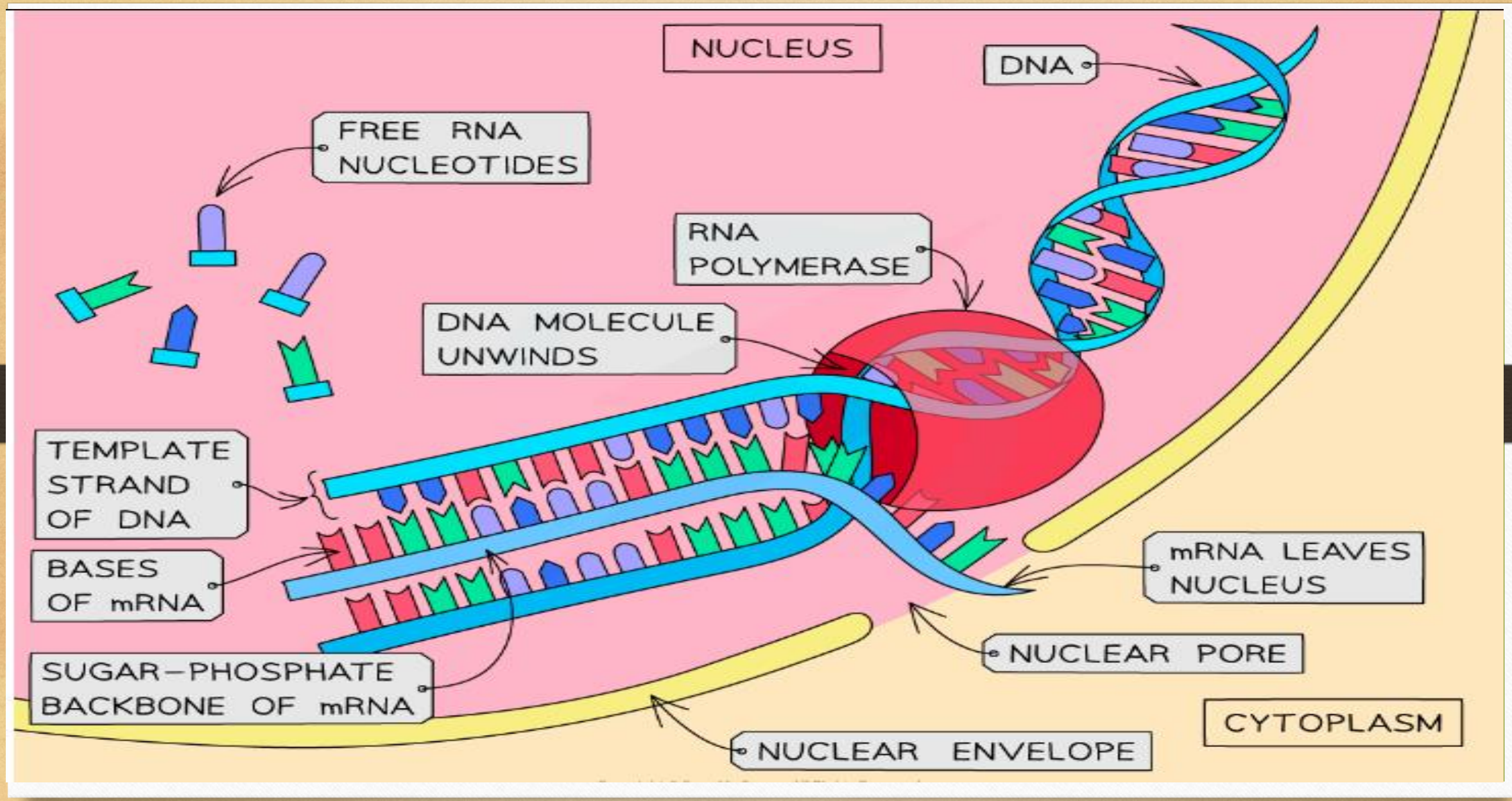
https://www.youtube.com/watch?v=YlOqI3PQwjo
https://www.youtube.com/watch?v=2zAGAmTkZNY
https://www.youtube.com/watch?v=gG7uCskUOrA&t=46s

Transcription is the copying of a DNA sequence to make mRNA, using the catalyst RNA polymerase (figure 26).

It involves the following stages:

1. RNA polymerase uncoils a section (gene) of the DNA double helix.
2. RNA polymerase links free RNA nucleotides to form an RNA strand (using a DNA strand as a template). This is done through complementary base pairing, however, in the RNA chain, the base thymine is replaced by uracil.
3. The mRNA strand then elongates and separates from the DNA template.
4. The DNA strands then reform a double helix.
5. The mRNA leaves the nucleus and moves out through the pores on the nuclear membrane.


RNA
polymerase
coding strand
3'
3'
DNA
5'
template strand
mRNA
5'
coding strand 5' A T G A T C T C G T A A 3'
mRNA 5' A U G A U C 3'
template strand 3' T A C T A G A G C A T T 5'


NUCLEUS
DNA
FREE RNA NUCLEOTIDES
RNA POLYMERASE
DNA MOLECULE UNWINDS
TEMPLATE STRAND OF DNA
BASES OF mRNA
SUGAR–PHOSPHATE BACKBONE OF mRNA
mRNA LEAVES NUCLEUS
NUCLEAR PORE
CYTOPLASM
NUCLEAR ENVELOPE

The genetic code

Each mRNA molecule carries a genetic code, which is defined by the sequence of nucleotides on the mRNA molecule. These nucleotides are arranged into triplets of base pairs knowns as codons. Here are some features of codons:

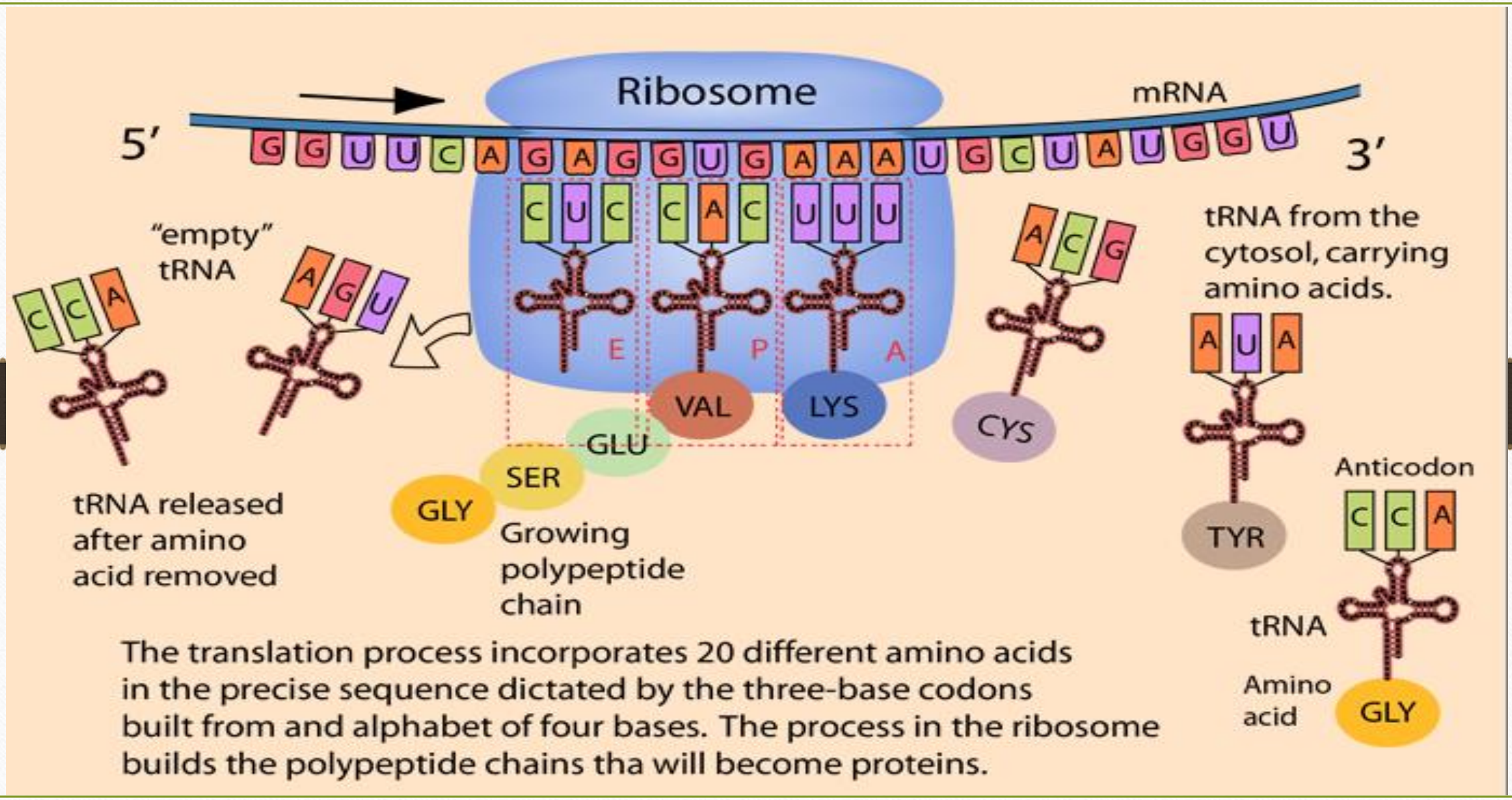
* There are 64 different codons.
* Each codon codes for a particular amino acid. There are 20 amino acids.
* There is a start codon at the start of the gene.
* There is a stop codon at the end of the gene.
* The code on mRNA determines the sequence of amino acids a the polypeptide formed.
* Codons will code for the same amino acid in all living things.
* Different codons can code for the same amino acid.

Translation : https://www.youtube.com/watch?v=Ikq9AcBcohA

is the synthesis of polypeptides on ribosomes in the cytoplasm (free ribosomes or ribosomes attached to the rough endoplasmic reticulum) . The genetic code of the mRNA determines the amino acid sequence of the polypeptide. As discussed previously, **the genetic code is made of codons**. **Each codon** consists of **three bases that correspond to a specific amino acid in the polypeptide.** Translation takes place when the codons on mRNA bind to the anticodons on transfer RNA (tRNA) by complementary base pairing, where adenine binds with uracil and guanine binds with cytosine. Each tRNA molecule has a specific amino acid attached to it, which corresponds to its anticodon. The process takes place via the following steps:

1. mRNA binds to the ribosome.
2. Translation begins at the "start" codon.
3. A tRNA molecule binds to the ribosome where its anticodon complements the codon on the mRNA.
4. Another tRNA molecule then bonds to the ribosome.
5. The two amino acids of the two tRNA molecules attach to each other via a peptide bond.
6. The first tRNA molecule separates from the ribosome, and the second tRNA molecule attaches to this position on the ribosome its place.
7. On the mRNA, the ribosome moves to the next codon to allow another tRNA to bind.

8. The amino acid of the new tRNA binds to the chain of amino acids via a peptide bond.
9. The process continues until a "stop" codon is reached, where translation is stopped.
10. This process results in the formation of a polypeptide (amino acid chain) which is the basic structure of all proteins.


Ribosome
mRNA
5′
3′
G G U U C A G A G G U G A A A U G C U A U G G U
C U C C A C U U U
E
P
A
"empty" tRNA
C C A
A G U
A C G
tRNA from the cytosol, carrying amino acids.
A U A
TYR
VAL
LYS
CYS
GLU
SER
GLY
tRNA released after amino acid removed
Growing polypeptide chain
Anticodon
C C A
tRNA
Amino acid
GLY
The translation process incorporates 20 different amino acids in the precise sequence dictated by the three-base codons built from and alphabet of four bases. The process in the ribosome builds the polypeptide chains tha will become proteins.

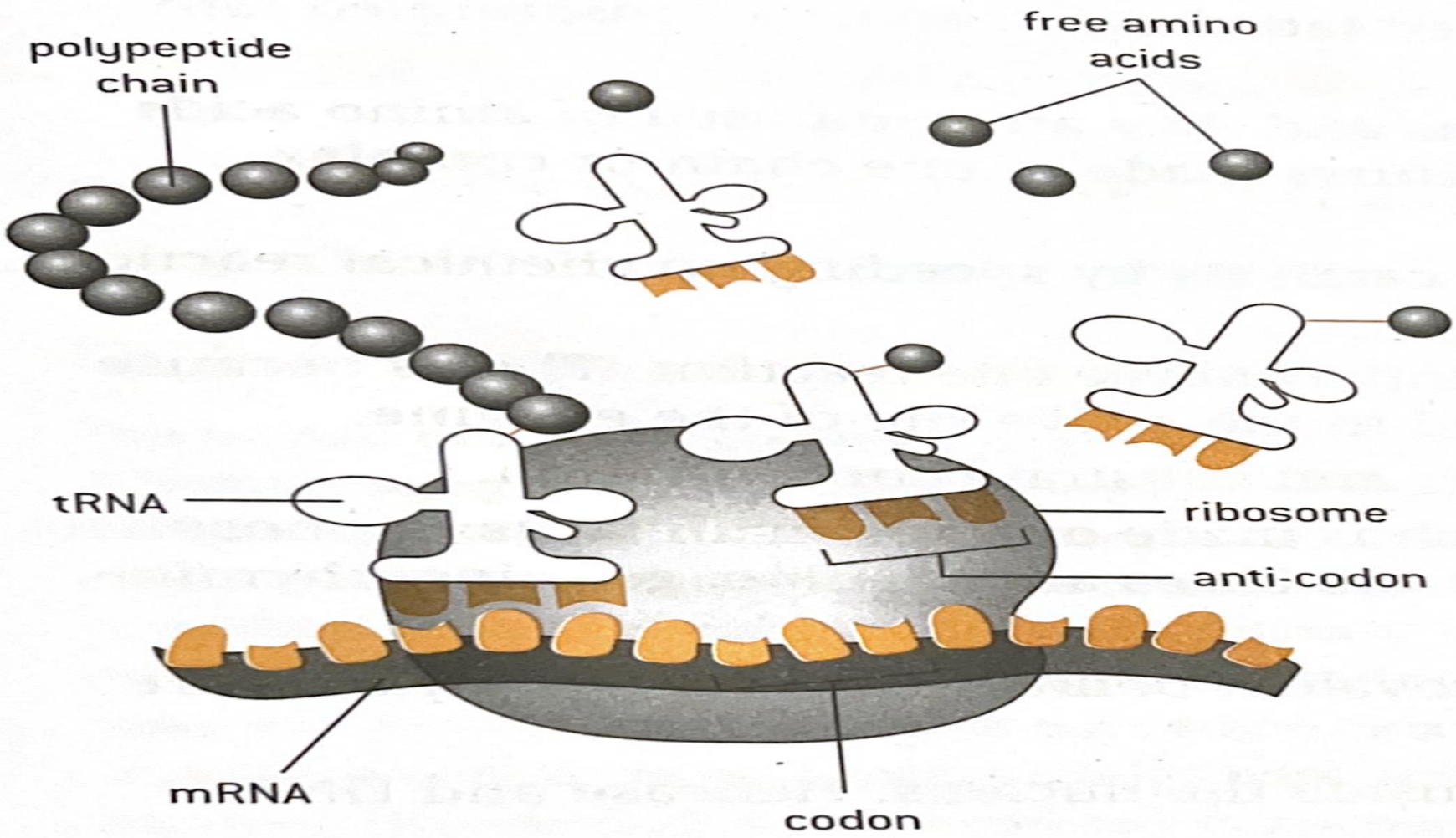
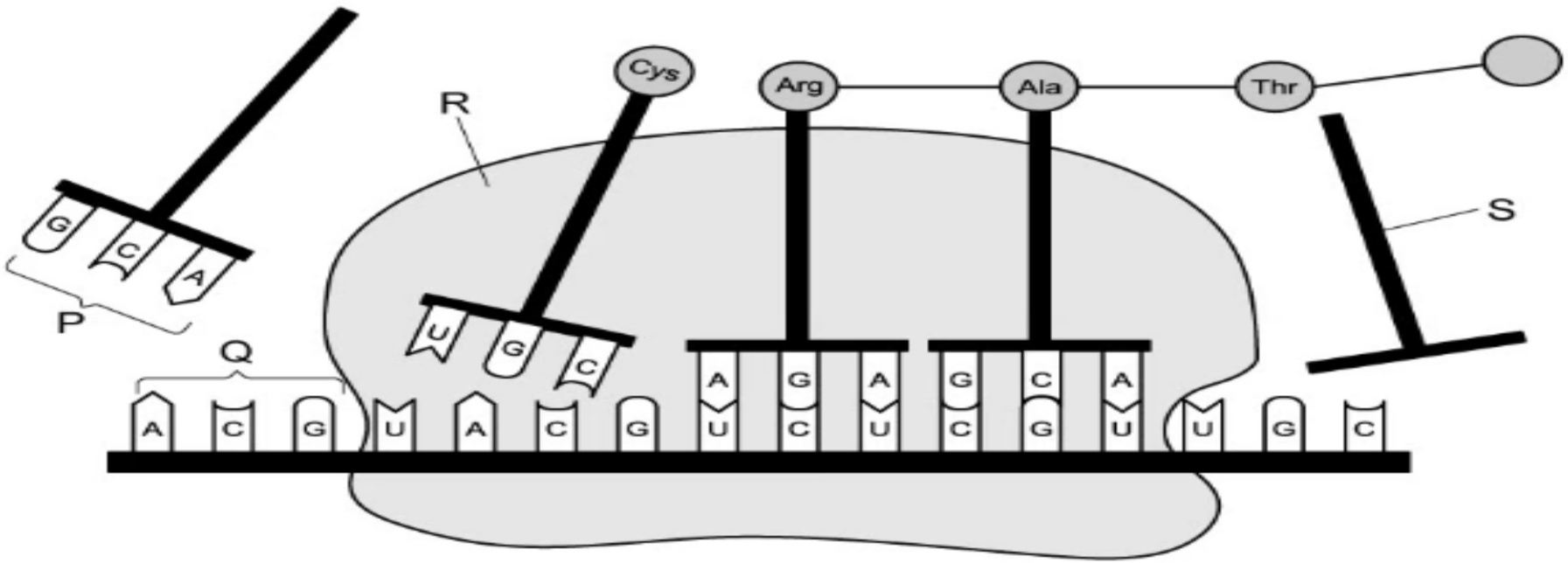


Figure 27. DNA translation

The following diagram shows the process of translation.



Which row of the following table correctly identifies the labelled components?

	P	Q	R	S
A.	anticodon	codon	ribosome	mRNA
B.	codon	anticodon	ribosome	tRNA
C.	anticodon	codon	ribosome	tRNA
D.	codon	anticodon	mRNA	ribosome

In a genetic engineering experiment, a piece of double-stranded DNA containing 18 000 nucleotides coding for a specific polypeptide is transcribed and translated.

What is the total number of amino acids in this polypeptide?

A. 3 000

B. 6 000

C. 9 000

D. 18 000

What is the correct sequence for the processes involved in the formation of a protein?

A transcription → peptide bonding → translation → ionic bonding

B transcription → translation → peptide bonding → hydrogen bonding

C transcription → peptide bonding → translation → hydrogen bonding

D translation → peptide bonding → transcription → ionic bonding

Which row of the table contains three correct statements about DNA replication, transcription and translation?

	DNA replication	Transcription	Translation
A	produces mRNA	occurs in the cytoplasm	tRNA involved
B	DNA polymerase involved	RNA polymerase involved	produces mRNA
C	is semi-conservative	produces mRNA	occurs at a ribosome
D	occurs in the nucleus	occurs in the nucleus	RNA polymerase involved

What terminates the formation of a polypeptide chain during protein synthesis in cells?

A When the ribosome reaches the end of the mRNA molecule.

B When there are no more tRNA molecules.

C When the ribosome reaches a stop codon on the mRNA.

D RNA polymerase detaches the polypeptide chain from the ribosome.