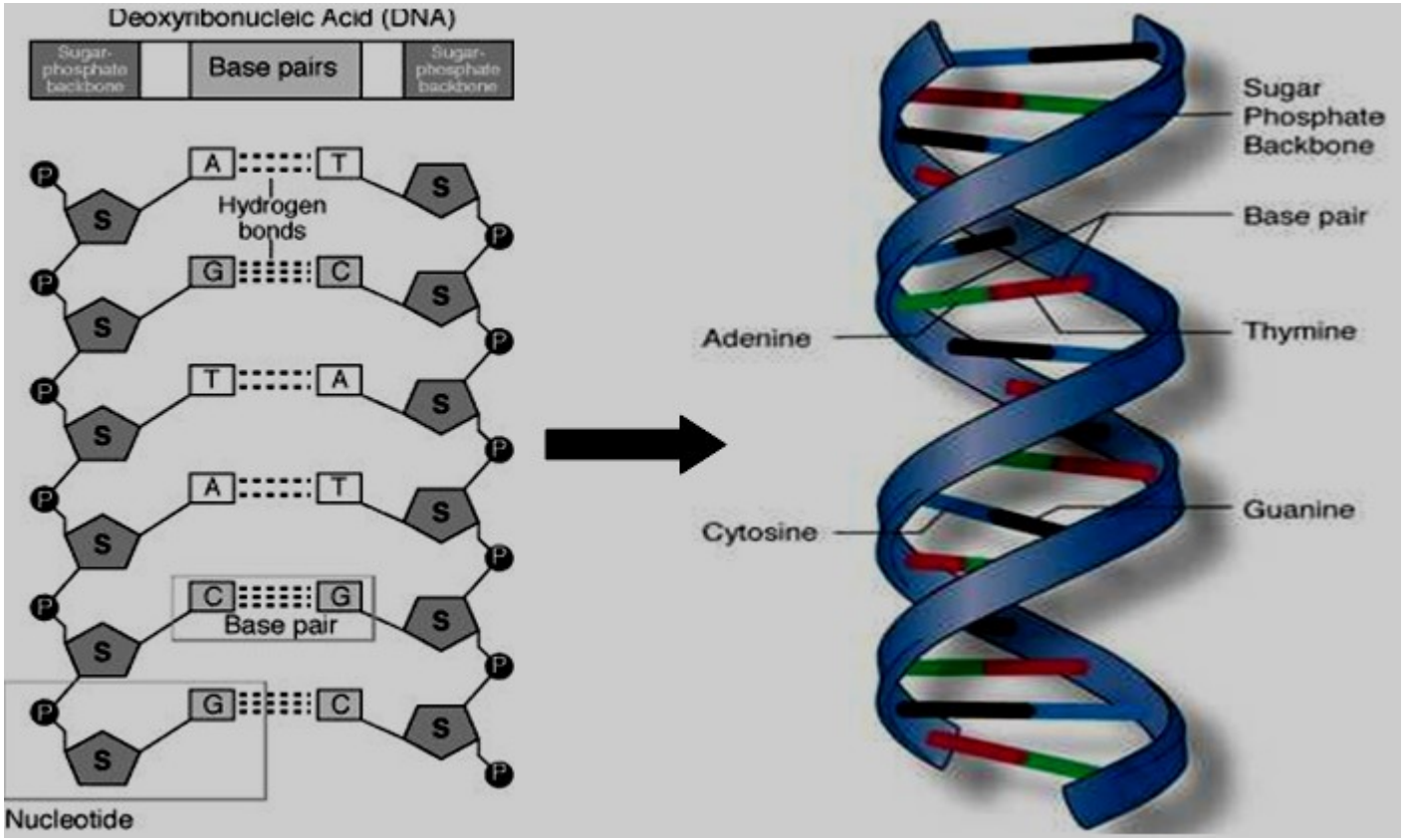
# Chapter Five
# Genetics



- **Genetic:** is the study of inheritance and how the characteristics of living thing are transmitted from one generation to the next.
- The characters of parents are passed to the offspring through Gametes or sex cells.
- **Inheritance** : is the process by which genetic information is passed on from parent to child.
- **Chromosome**: is a thread-like structure of DNA and protein found in the Nucleus of most living cells, carrying genetic in formation.

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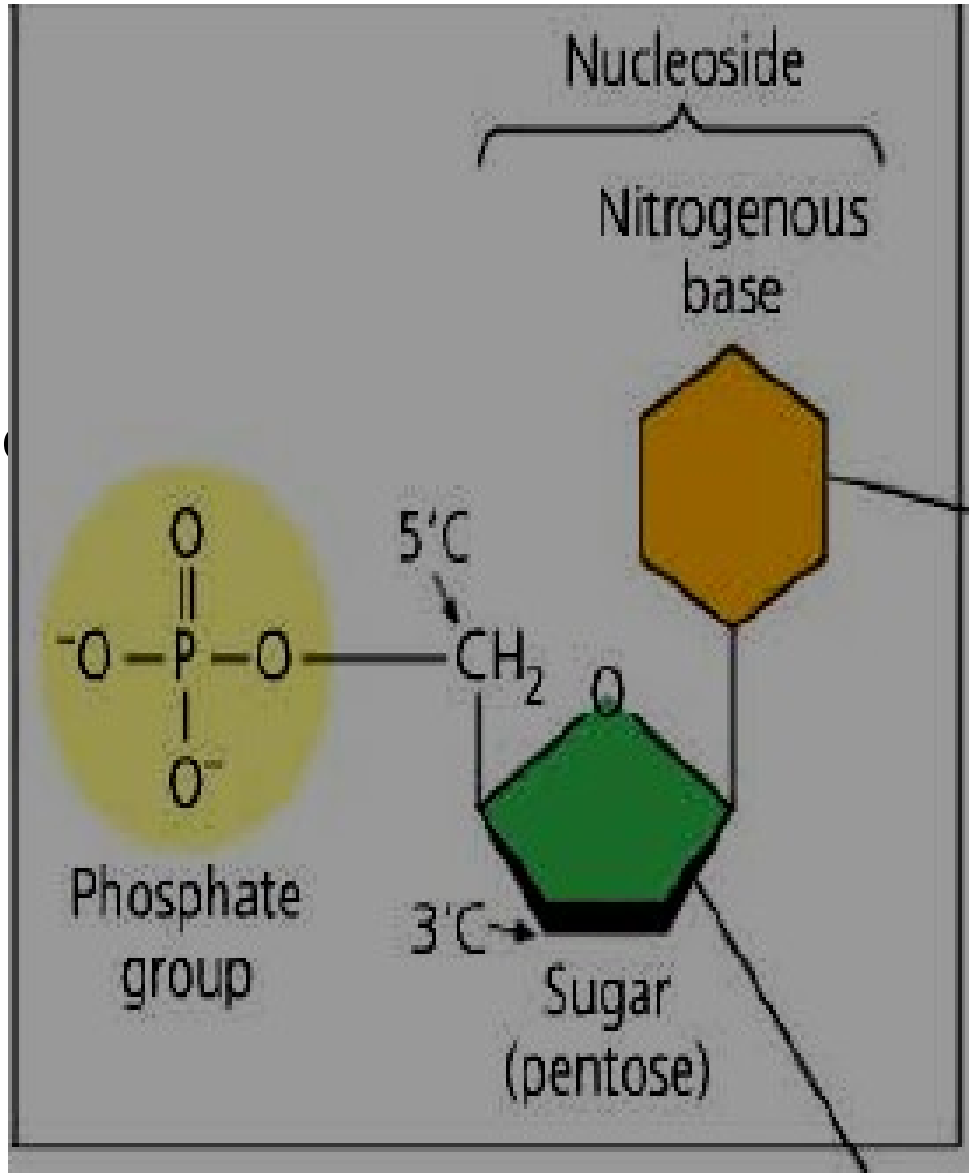
**Gene**: is a portion of a chromosome that serves as the basic unit of heredity.

**Genome**: is an Organism`s complete set of DNA, including all of its genes.

**Nucleic Acid**: a complex organic Molecules present in living cells, especially DNA & RNA, whose molecules consist of many Nucleotides linked in a long chain.

# The Structure of Nucleic Acids

- Nucleic acids exist as polymers called **polynucleotides** that consist of monomers called **nucleotides**. Each nucleotide is itself composed of the following three parts which are held together by **Covalent Bonds**
- A nitrogenous base
- A five-carbon sugar (a pentose)
- A phosphate group.

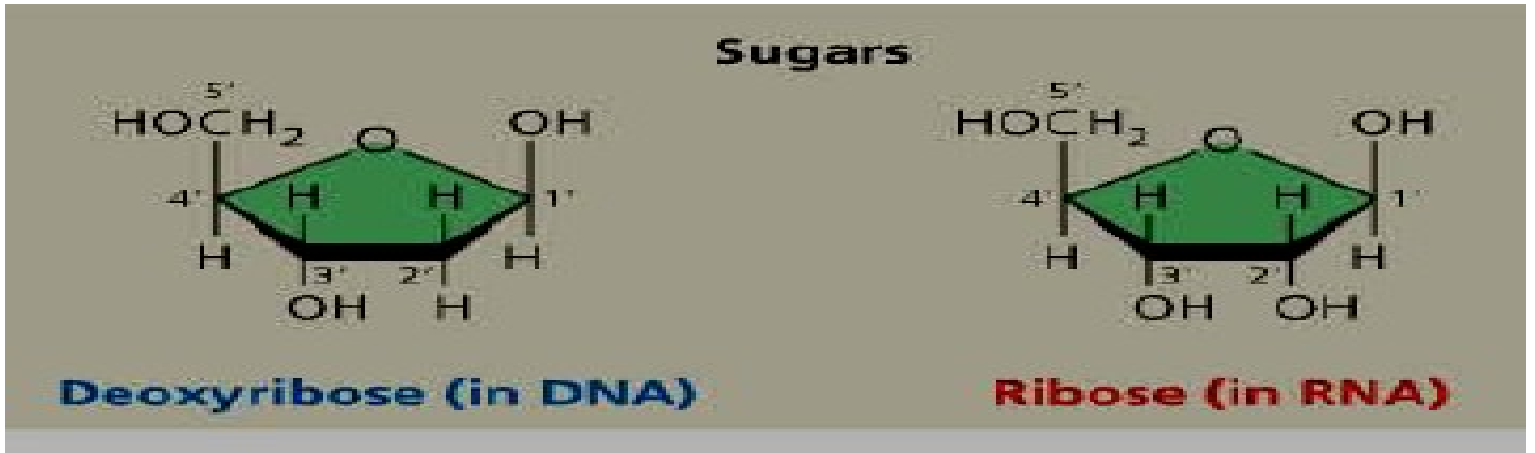


# CONT……..

- Let’s discuss in detail, the components of the nucleotide
- **Nitrogenous bases**
- There are two families of nitrogenous bases which are **pyrimidine bases** and **purine bases**.
- The **pyrimidine** bases made up six-membered ring of carbon and nitrogen atoms. The members of the pyrimidine family are cytosine (C), thymine (T), and uracil (U).
- The **Purines** bases are larger than pyrimidines bases, and made up of six-membered ring of carbon and nitrogen atoms fused to five-membered ring of carbon and nitrogen atoms. The purines are adenine (A) and guanine (G).
- The bases adenine, guanine, and cytosine are found in both in DNA and in RNA while thymine is found only in DNA and uracil is found only in RNA.

# Pentose sugar

- **Pentose sugar**
- The pentose sugar in RNA is called **ribose** and that in DNA is called **deoxyribose**. The only difference between these two sugars is that deoxyribose lacks an oxygen atom



# Phosphate group

- The phosphate group is attached to the 5' carbon of the sugar. A molecule that contains, nitrogenous base, pentose sugar and one phosphate group is called nucleoside mono phosphate, which is better called a **nucleotide**

# DNA Structure and Function

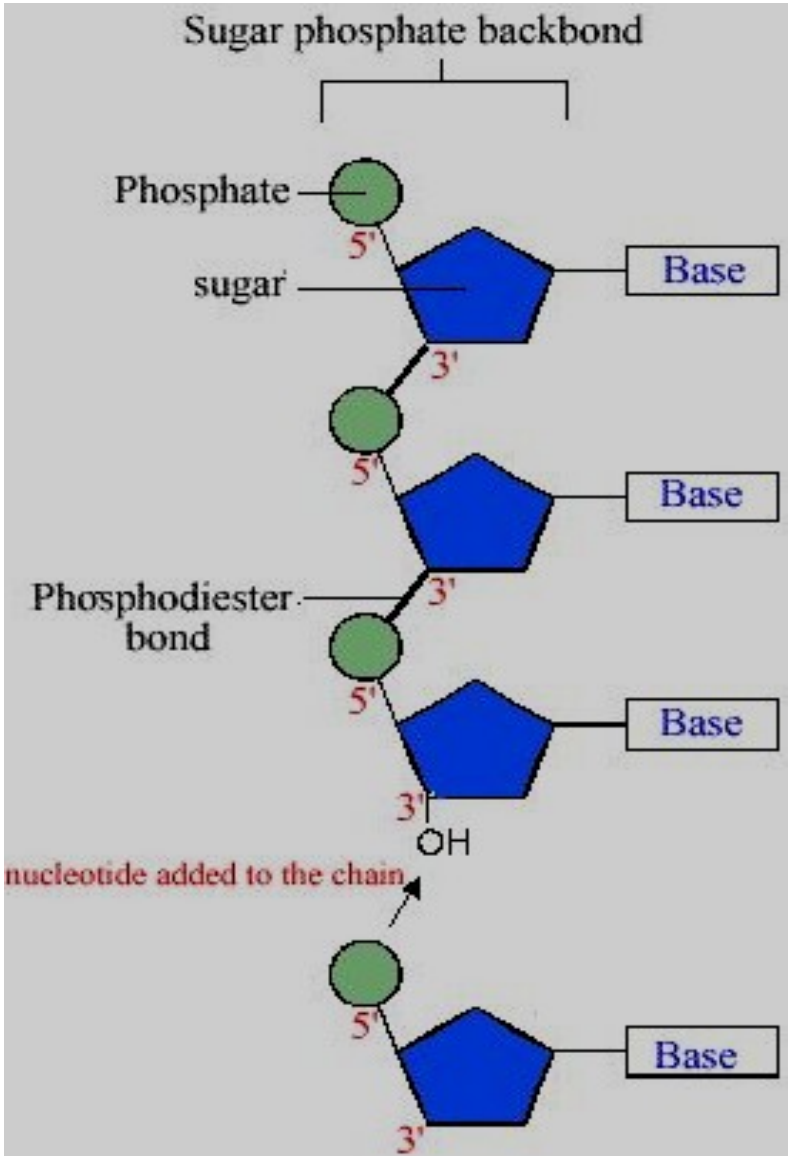
Deoxyribonucleic Acid or DNA is a molecule that contains the instructions an organism needs to develop, live and reproduce. These instructions are found inside every cell and passed down from parents to their children.

## DNA Structure

DNA is made up of smaller molecules called nucleotides. Each nucleotide contains a Phosphate group, a pentose sugar and nitrogen base which are held together by Covalent bonds.

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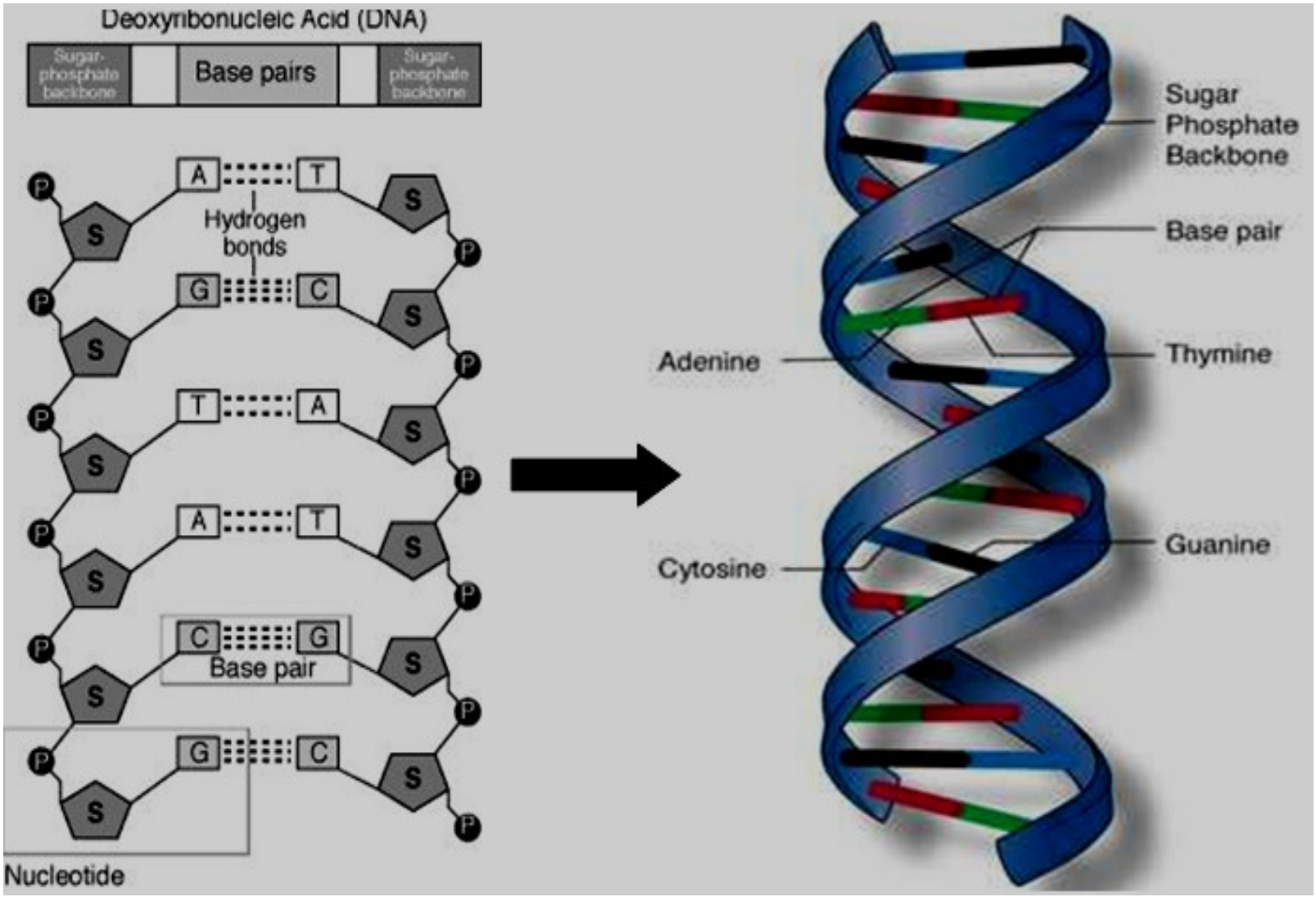
- The DNA strand is built along its sugar-phosphate backbone, from 5' to 3', somewhat like a one-way street. The nitrogenous bases are attached to this sugar-phosphate backbone.



## The DNA Double Helix and Base Pairing

- The DNA molecules consist of two polynucleotide stands that spiral around an imaginary axis, forming a **double helix**. James Watson and Francis Crick, working at Cambridge University, first proposed the double helix as the structure of DNA in 1953. In contrast to DNA molecules, the RNA molecules consist of a single polynucleotide strand like the one shown in the above figure.

- The two sugar-phosphate backbones of the DNA double helix run in opposite (5'  3') directions which are referred to as **anti-parallel**, somewhat like a divided highway. The sugar-phosphate backbones are on the outside of the helix, and the nitrogenous bases are paired in the interior of the helix. The two strands are held together by **hydrogen bonds** between the paired bases and by vander Waals interactions between the stacked bases.
- Only certain bases in the double helix are compatible with each other, this is called base-pairing
- Adenine (A) pairs with thymine (T) by two hydrogen bonds
- Guanine (G) pairs with cytosine (C) by three hydrogen bonds.


Deoxyribonucleic Acid (DNA)
Sugar-phosphate backbone
Base pairs
Sugar-phosphate backbone
A
T
Hydrogen bonds
G
C
T
A
A
T
C
G
Base pair
G
C
Nucleotide
Sugar Phosphate Backbone
Base pair
Adenine
Thymine
Guanine
Cytosine

# DNA Function

- DNA Controls all the activities of the cell
- DNA Codes for proteins
- DNA is capable of self-replication
- DNA controls the development, reproduction and the characteristics of organism.
- DNA forms ribonucleic acid.

# DNA Replication

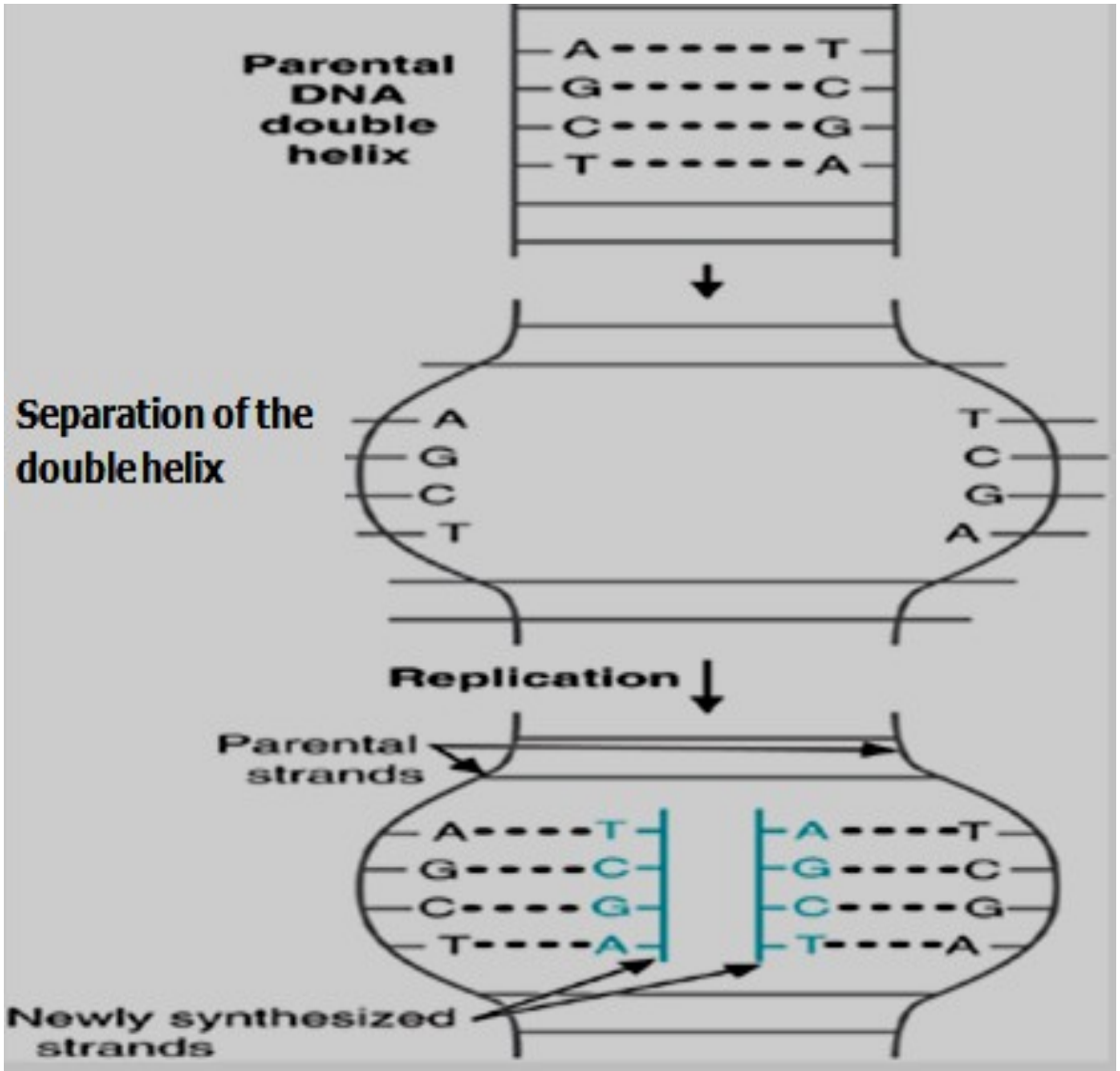
- DNA replication is the process by which DNA molecule makes a copy of itself during cell division. . The process of DNA replication occurs as follows (see the figure on the next page)

1- The replication process begins at special sites called **origins of replication**. In here, an enzyme called **helicase** breaks the hydrogen bonds b/w the bases and the double helix uncoils into two separate strands.

2- Each strand becomes a template for the formation of new complementary strand and synthesis of new strand results in **Replication forks**

3- Two extra phosphates carry free nucleotides and attach them to the template strand to form new strand. An enzyme called **DNA-polymerase** catalysis the attachment of the new nucleotides to the template strand

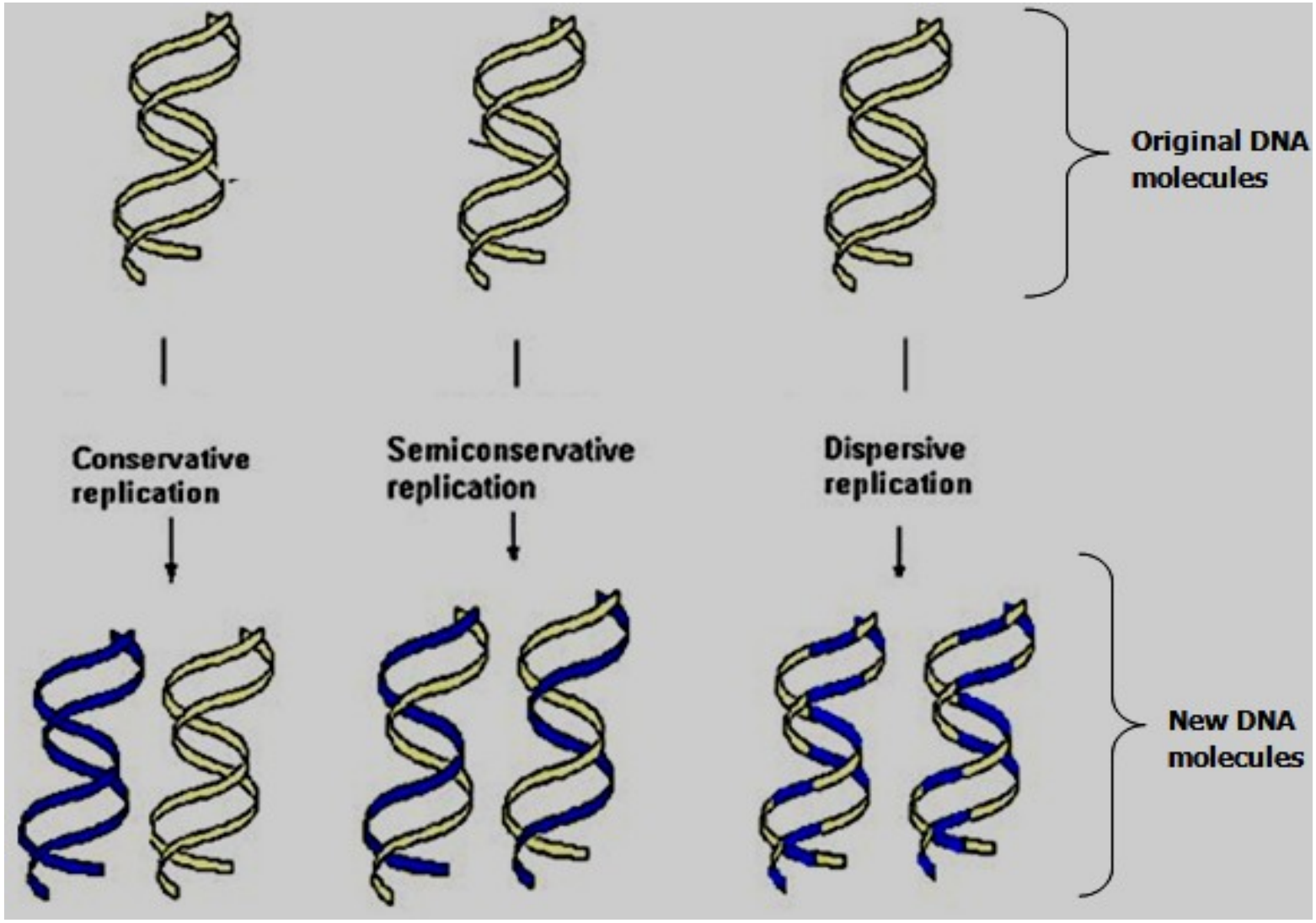
# Newly synthesized strand in Replication Fork



The Common way which DNA replicates Known as Semi-conservative replication.

**But the DNA replication can occur the following possible ways**

- **Conservative replication**: Produces completely new DNA molecule from the original one
- **Semi-conservative replication**: Produces two new DNA molecules where each new molecule contains one old strand and one new strand
- **Dispersive replication**: Produces two new DNA molecules, where each new molecule contains strands of old bits and new bit scattered through the molecule


Original DNA molecules
Conservative replication
Semiconservative replication
Dispersive replication
New DNA molecules

# PROTEIN SYNTHESIS

The major function of RNA is the proteins synthesis of the cell.

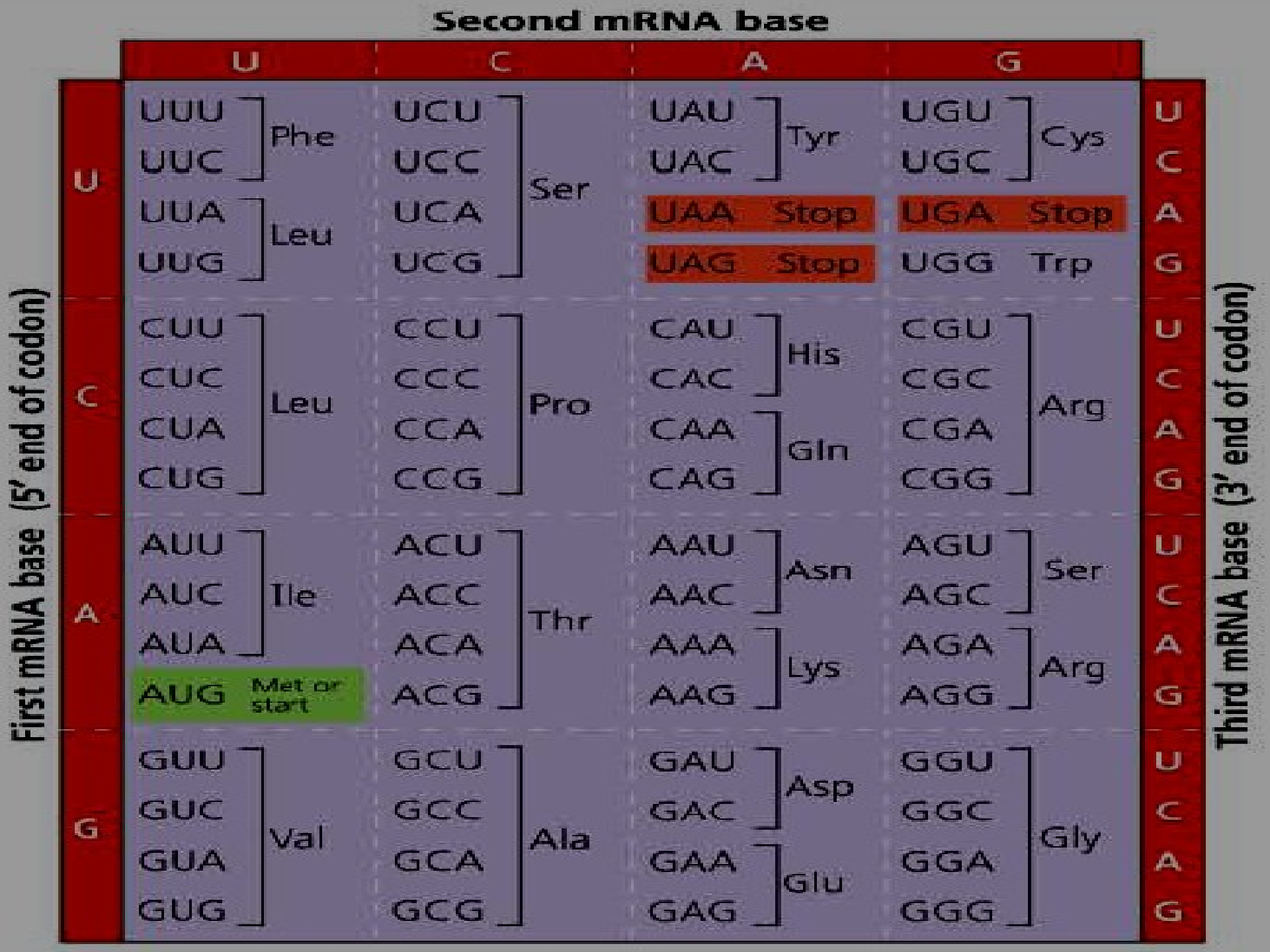
The two important processes involve in protein synthesis are transcription and translation

**1- Transcription**: This process occurs in the nucleus of the cell were the information programmed in a specific region of DNA is transcribed (copied) to produce a specific molecule of RNA called mRNA

**2- Translation**: This process occurs in the cytoplasm, were the mRNA attaches to a ribosome and the information contained in it is translated into a corresponding sequence of amino acids to form a new protein molecule

Before we start the process of protein synthesis lets us closely look what is called the triplets of bases.

- **The Triplet of Bases**
-
- The triplet of bases is a sequence of three nucleotides in DNA and RNA. If each nucleotide base were attached into one amino acid, only 4 of the 20 amino acids could be possible to attach the nucleotides but if each three consecutive bases specifies to one amino acid, there can be 64 possible code words which is more than enough to specify all the 20 amino acids this is called a **base triplet**. The table below shows the codes of the 20 amino acids. The names of the amino acids are abbreviated by three letters


Second mRNA base
U
C
A
G
First mRNA base (5′ end of codon)
Third mRNA base (3′ end of codon)
UUU Phe
UUC Phe
UUA Leu
UUG Leu
UCU Ser
UCC Ser
UCA Ser
UCG Ser
UAU Tyr
UAC Tyr
UAA Stop
UAG Stop
UGU Cys
UGC Cys
UGA Stop
UGG Trp
CUU Leu
CUC Leu
CUA Leu
CUG Leu
CCU Pro
CCC Pro
CCA Pro
CCG Pro
CAU His
CAC His
CAA Gln
CAG Gln
CGU Arg
CGC Arg
CGA Arg
CGG Arg
AUU Ile
AUC Ile
AUA Ile
AUG Met or start
ACU Thr
ACC Thr
ACA Thr
ACG Thr
AAU Asn
AAC Asn
AAA Lys
AAG Lys
AGU Ser
AGC Ser
AGA Arg
AGG Arg
GUU Val
GUC Val
GUA Val
GUG Val
GCU Ala
GCC Ala
GCA Ala
GCG Ala
GAU Asp
GAC Asp
GAA Glu
GAG Glu
GGU Gly
GGC Gly
GGA Gly
GGG Gly

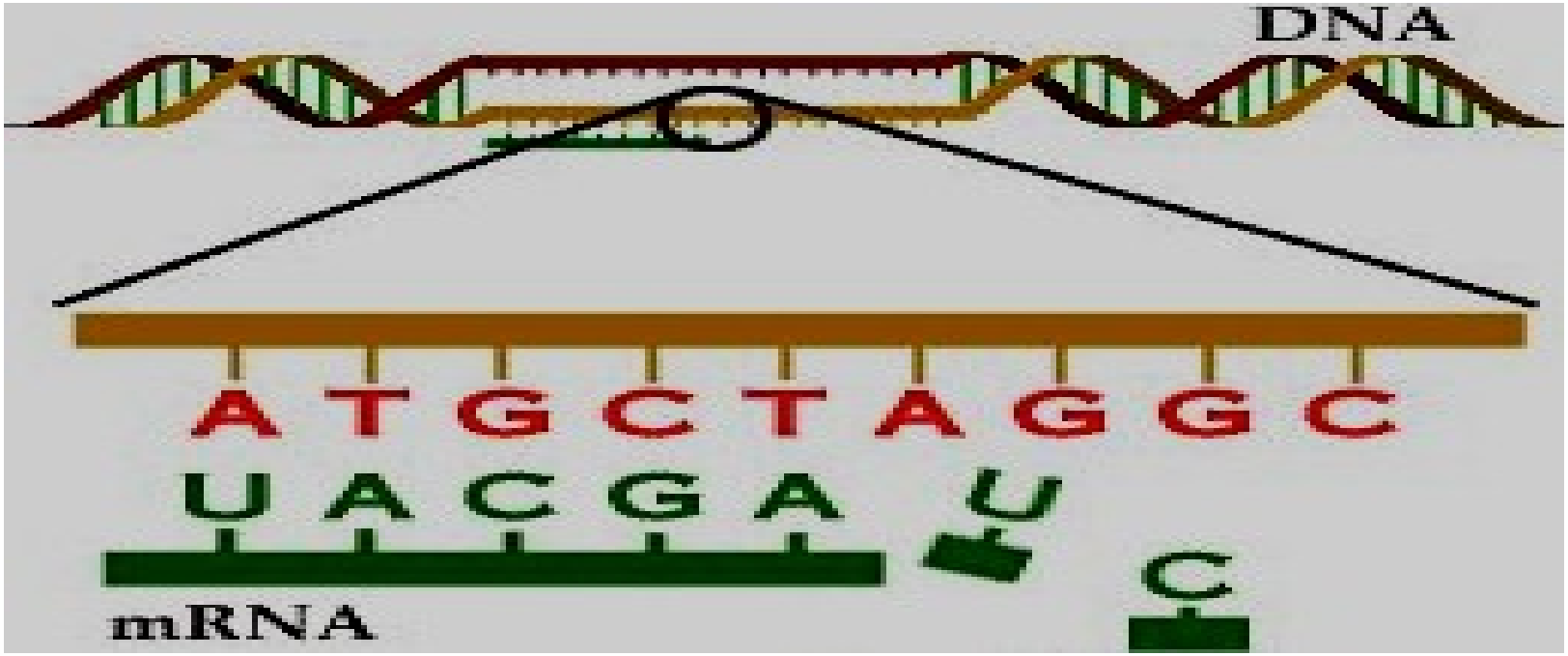
# Types of RNA

- RNA molecules made from DNA templates are include Messenger RNA (mRNA) and transfer RNA (tRNA).

**1- Messenger (mRNA)**

- **Messenger RNA** is a type of RNA found in the nucleus of the cell that it is copied from a template strand of DNA. It carries information from DNA to the ribosome

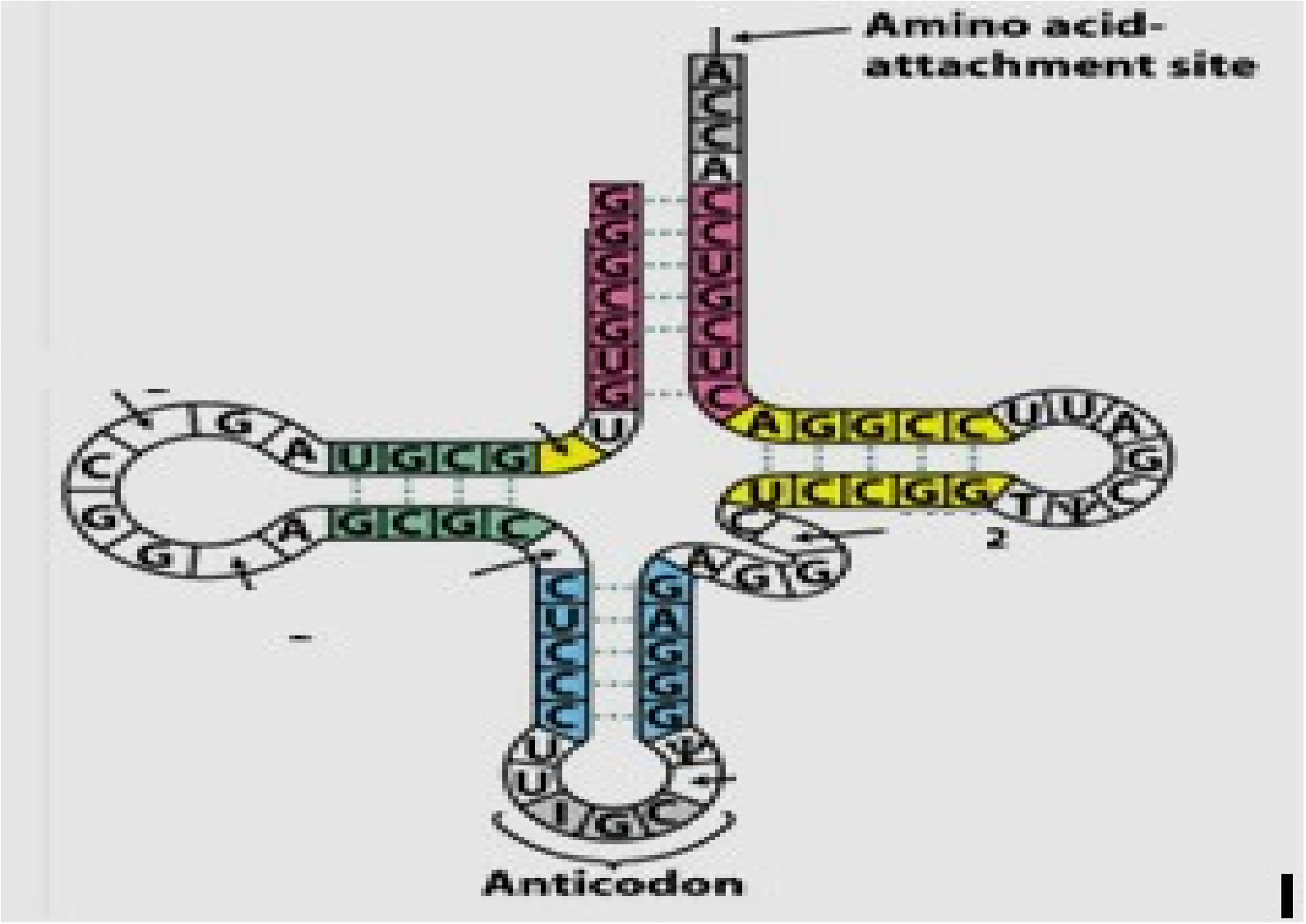
# mRNA



# Transfer RNA (tRNA)

- Transfer RNA is another type of RNA that is found in the cytoplasm of the cell. Its main function is to transfer amino acids from the cytoplasm to a ribosome. One end of the tRNA consists of a triplet of nucleotides called **an anticodon** which attaches to mRNA codon and the opposite end carries a specific amino acid. Each tRNA carries only one of the 20 different amino acids. For example the tRNA having AAA anticodon binds to the mRNA having UUU codon and carries the amino acid phenylalanine its other end and.
- **Hydrogen bonds held** the anticodon andthe codon together while ovalent bonds held together the tRNA and the amino acid it carries.

# tRNA

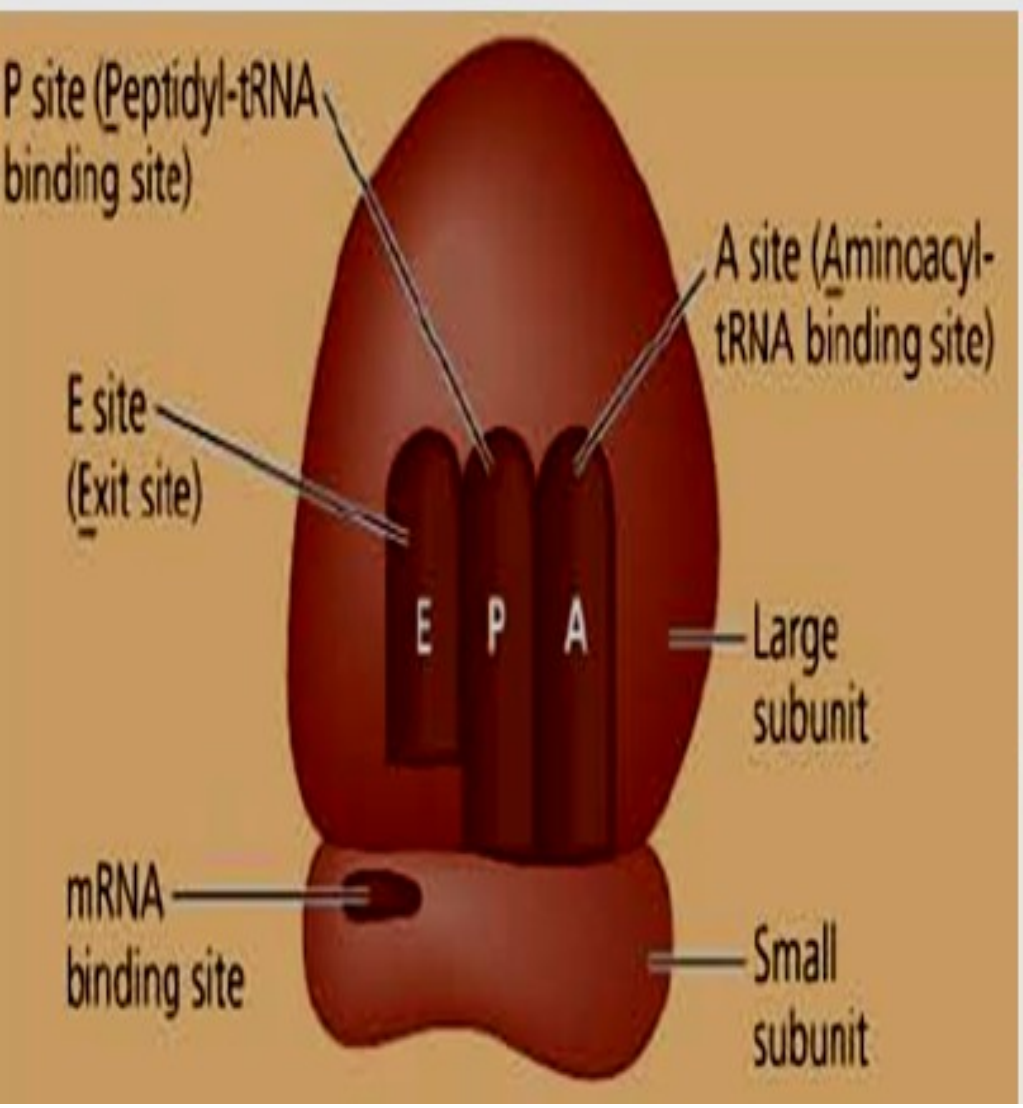


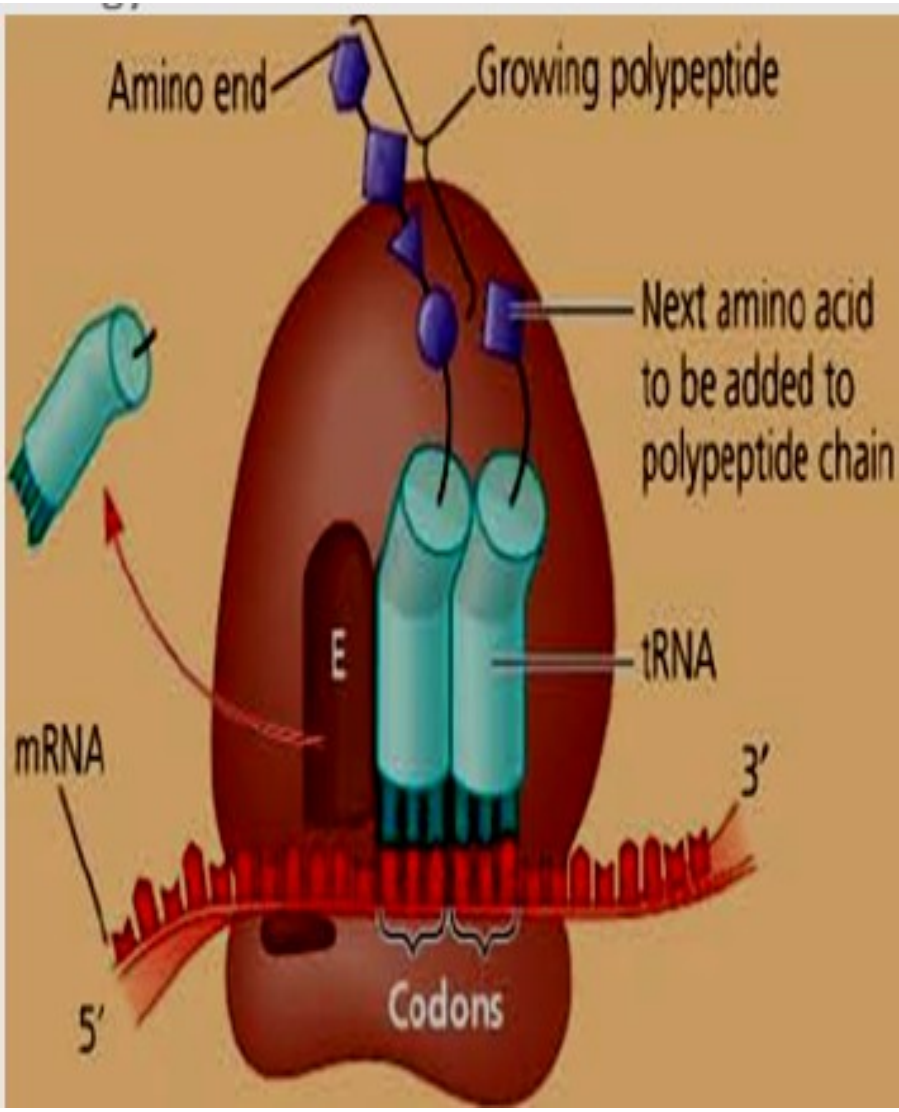
# Ribosomes

- A ribosome is an organelle made up of two subunits, called the **large and small subunits**. It facilitates the union of tRNA anticodons with mRNA codons during protein synthesis. The two subunits of the ribosome are constructed of proteins and RNA molecules named ribosomal **RNAs (rRNAs).** In eukaryotes, the subunits are made in the nucleolus

- The large sub unit of the ribosome has the following three binding sites for tRNA.
- **P site** (peptidyl tRNA site) holds the tRNA carrying the growing polypeptide chain
- **A site** (aminoacyl-tRNA site) holds the tRNA carrying the next amino acid to be added to the chain.
- **E site** (exit site) discharges tRNA leaving the ribosome
- The small sub unit of ribosome has a binding site for mRNA.

# rRNA


P site (Peptidyl-tRNA binding site)
A site (Aminoacyl-tRNA binding site)
E site (Exit site)
E P A
Large subunit
mRNA binding site
Small subunit


Amino end
Growing polypeptide
Next amino acid to be added to polypeptide chain
E
tRNA
mRNA
3′
5′
Codons

# Steps of translation

Translation occurs in the following five steps

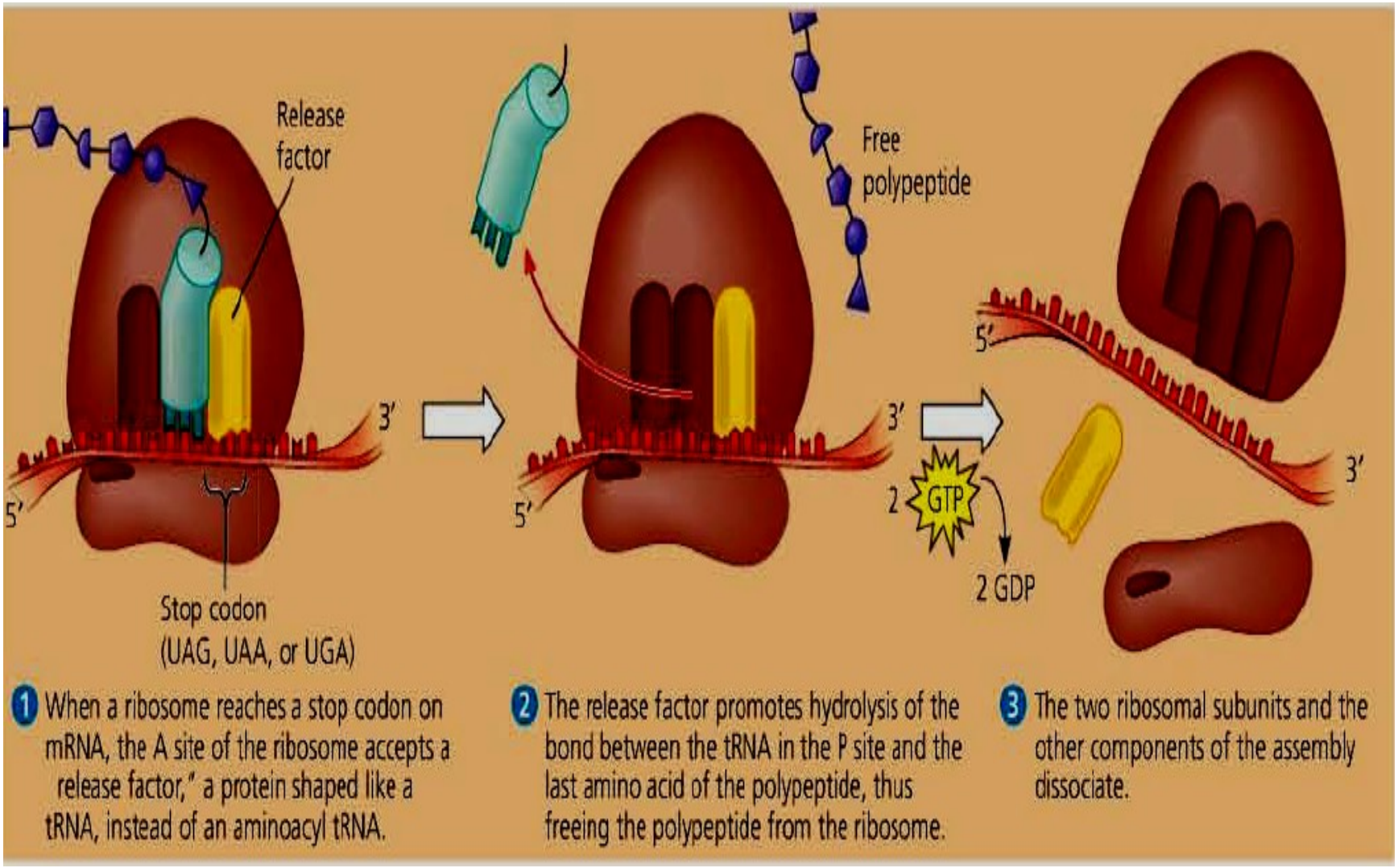
1- A mRNA molecule binds to the small sub unit of the ribosome, then the anticodon (UAC) of tRNA called **initiator tRN** binds to the start codon on mRNA, which is usually AUG and the translation begins. The initiator tRN carries the amino acid called **methionine**. Thus, methionine is always the first amino acid in a growing polypeptide.

2- The anticodon of another tRNA with its attached amino acid pairs with the second mRNA codon at the A site of the ribosome.

3- Enzymes catalyzes the formation of a peptide bond between methionine and the second amino acid carried by the tRNA at the A site.

4- After peptide bond formation, the tRNA at the P site detaches from the ribosome, and the ribosome shifts the mRNA strand by one codon. The tRNA in the A site bearing the two-peptide protein shifts into the P site, allowing another tRNA with its amino acid to bind to a newly exposed codon at the A site. Steps 3 through 5 occur repeatedly, and the protein lengthens progressively.

5- The elongation continues until a **stop codon** in the mRNA reaches the A site of the ribosome. The codons UAG, UAA, and UGA do not code for amino acids but act as signals to stop translation. A protein called a **release factor** binds directly to the stop codon in the A site and adds a water molecule to the polypeptide chain. The water breaks (hydrolyzes) the bond between the completed polypeptide and the tRNA in the P site, releasing the polypeptide through the exit site of the ribosome's large subunit


Release factor
3′
5′
Stop codon (UAG, UAA, or UGA)
Free polypeptide
3′
5′
2 GTP
2 GDP
5′
3′
1 When a ribosome reaches a stop codon on mRNA, the A site of the ribosome accepts a "release factor," a protein shaped like a tRNA, instead of an aminoacyl tRNA.
2 The release factor promotes hydrolysis of the bond between the tRNA in the P site and the last amino acid of the polypeptide, thus freeing the polypeptide from the ribosome.
3 The two ribosomal subunits and the other components of the assembly dissociate.