



# MEDICAL CHEMISTRY GENERAL CHEMISTRY



University Of Fallujah  
College Of Medicine

Lecture : **Medical Chemistry (4) ( Nucleic Acids )**

Stage : 1<sup>st</sup> Stage

Lecturer : **Dr. Waleed Khalid Ahmed**

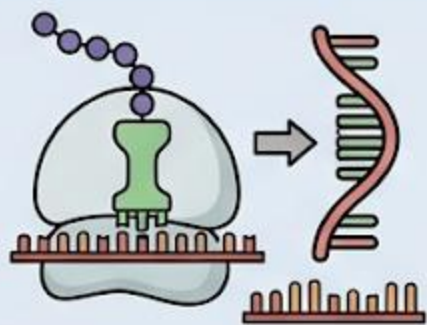
Department: **Chemistry and Biochemistry department**

Date: **14 / 5 / 2026**

## Learning Objective :

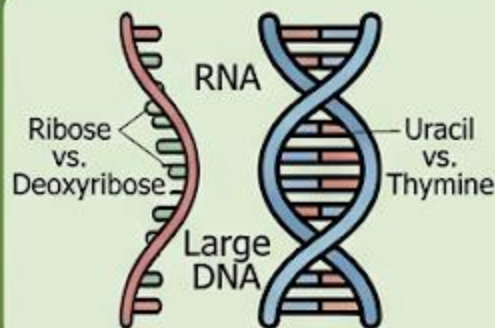
- *Understand the Structure and Types of RNA.*
- *Define the genetic code and explain how codons (triplet nucleotide sequences) correspond to specific amino acids.*
- *Outline the Steps of Protein Synthesis (Replication, Transcription & Translation)*
- *Classify and Analyze Mutations.*

# STRUCTURE OF RNA



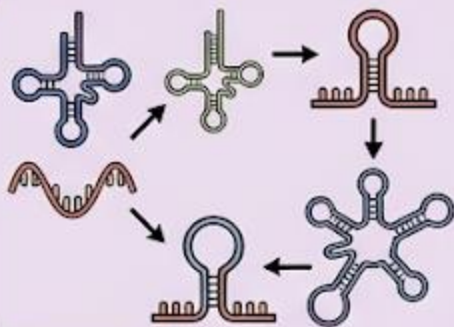
## 1. Types of RNA

There are **three** major types of RNA that participate in the process of protein synthesis: **ribosomal RNA (rRNA)**, **transfer RNA (tRNA)**, and **messenger RNA (mRNA)**.



## 2. Differs from DNA

They differ as a group from DNA: they are considerably **smaller**, contain **ribose** instead of deoxyribose, and **uracil** instead of thymine.



## 3. Major RNA Differences

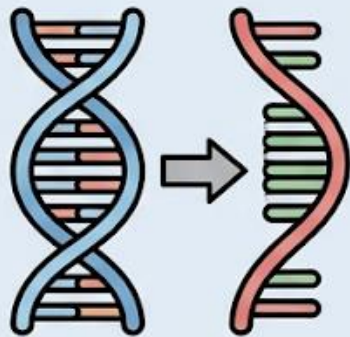
The three major types of RNA exist as capable **single strands** and also differ from each other in **size**, **function**, and **special structural modifications**.

# Types of RNA

**Table 22.3** Types of RNA Molecules

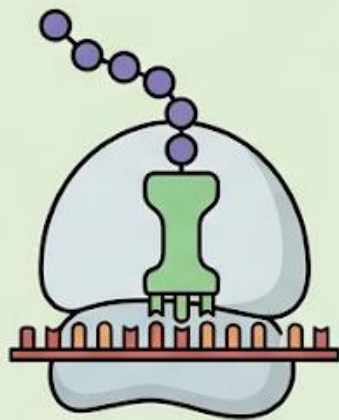
| Type          | Abbreviation | Percentage of Total RNA | Function in the Cell   |
|---------------|--------------|-------------------------|--|
| Ribosomal RNA | rRNA         | 75                      | Major component of the ribosomes   |
| Messenger RNA | mRNA         | 5–10                    | Carries information for protein synthesis from the DNA in the nucleus to the ribosomes |
| Transfer RNA  | tRNA         | 10–15                   | Brings amino acids to the ribosomes for protein synthesis                              |

# Messenger RNA (mRNA)



## 1. Sequence Origin

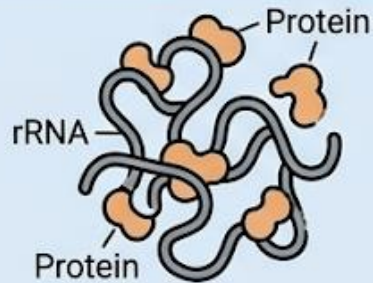
Its sequence is copied from genetic DNA.



## 2. Function & Location

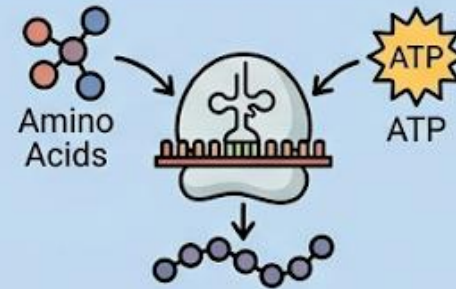
It travels to ribosomes, small granular particles in the cytoplasm of a cell where protein synthesis takes place.

# Ribosomal RNA (rRNA)



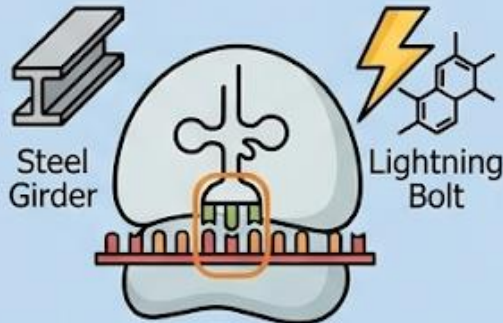
## 1. Ribosome Composition

Ribosomes are a complex of proteins and rRNA



## 2. Protein Synthesis

The synthesis of proteins from amino acids and ATP occurs in the ribosome



## 3. rRNA Function

The rRNA provides both structure and catalysis

# Transfer RNA (tRNA)



## 1. Transport

Transports amino acids to the ribosomes where they are joined together to make proteins.



## 2. Specificity

There is a specific tRNA for each amino acid.

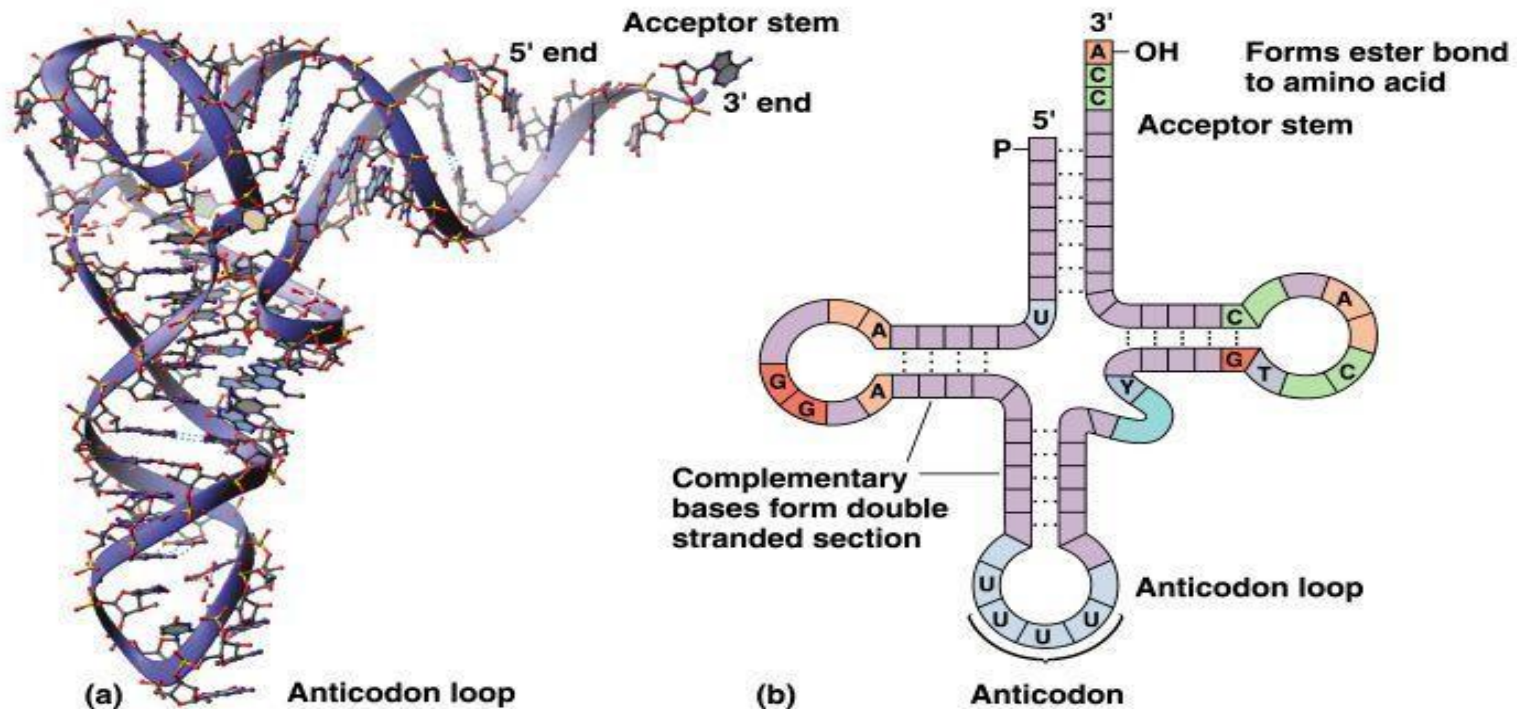


## 3. Recognition

Recognition of the tRNA at the anti-codon communicates which amino acid is attached.

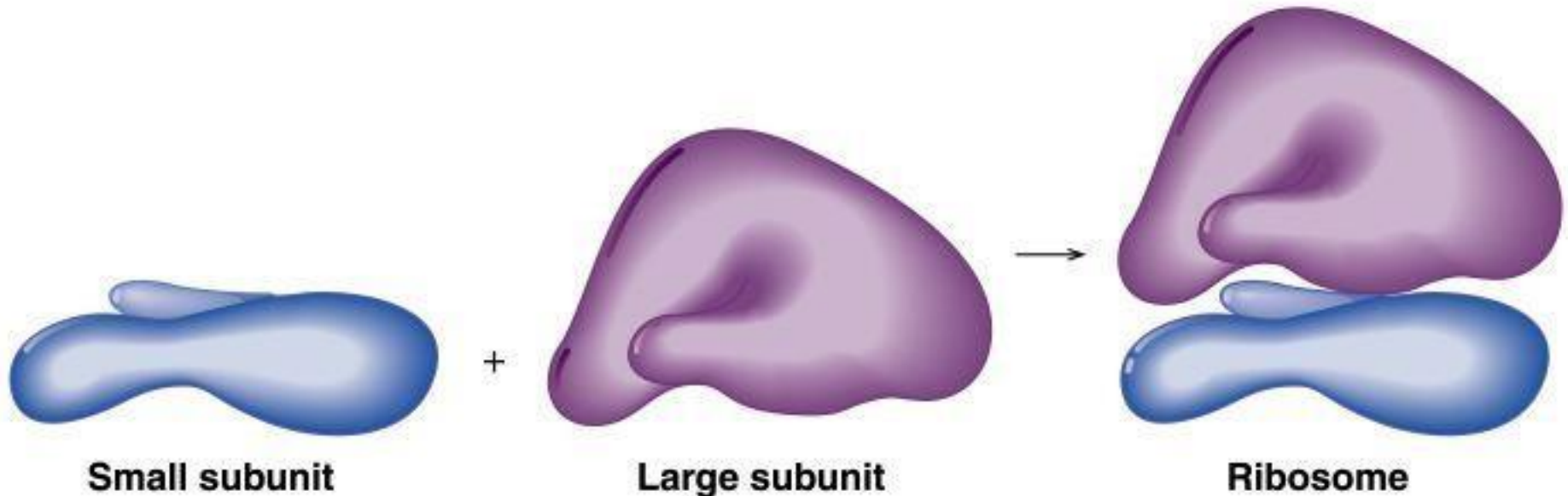
# Transfer RNA

- **Transfer RNA** translates the genetic code from the messenger RNA and brings specific amino acids to the ribosome for protein synthesis
- Each amino acid is recognized by one or more specific tRNA
- tRNA has a tertiary structure that is L-shaped
  - one end attaches to the amino acid and the other binds to the mRNA by a 3-base complementary sequence



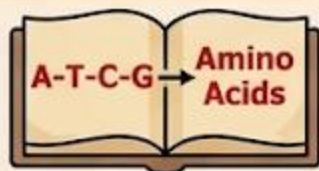
# Ribosomal RNA and Messenger RNA

- **Ribosomes** are the sites of protein synthesis
  - they consist of **ribosomal DNA** (65%) and proteins (35%)
  - they have two subunits, a large one and a small one
- **Messenger RNA** carries the genetic code to the ribosomes
  - they are strands of RNA that are complementary to the DNA of the gene for the protein to be synthesized



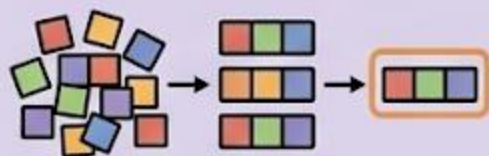
# Protein synthesis and the genetic code

## The genetic code



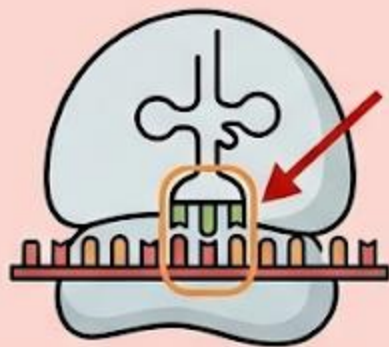
### 1. Code Dictionary

The genetic code is a dictionary that identifies the correspondence between a sequence of nucleotide bases and a sequence of amino acids.



### 2. Code Words

Each individual word in the code is composed of three nucleotide bases.



### 3. The Codon

These genetic words are called codons.

## Codons :

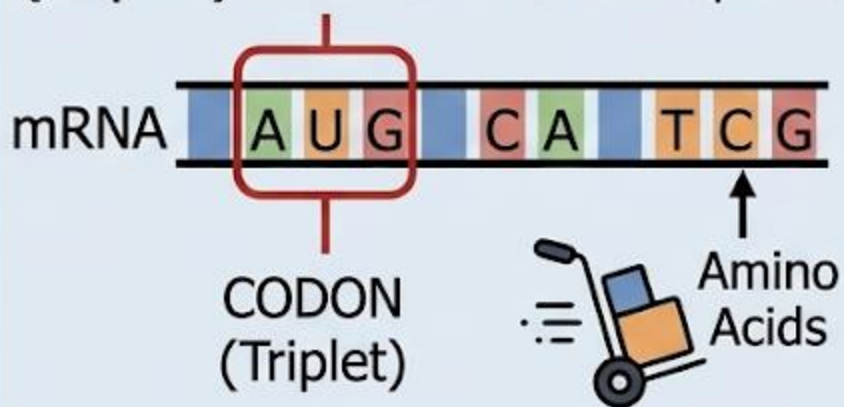
codon consists from three nucleotides (triplet) and provides informations for the sequence of amino acids in the protein synthesis.

Because of codon is degenerated each amino acid has more than one codon e.g. valine has three codons: GUC, GUA, and GUU, in addition to that, there are amino acids like methionine and tryptophan have single codon.

# Codons and Genetic Information

## 1. DEFINITION AND COMPOSITION

**Codon (Triplet)** Consists of three nucleotides (**triplet**) and provides information for the sequence.

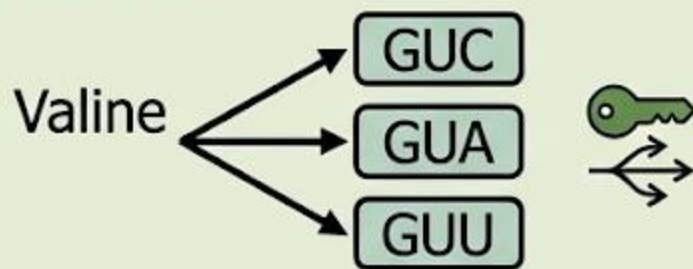


- Consists of three nucleotides (**triplet**) and provides information for the sequence of amino acids in protein synthesis.

## 2. DEGENERACY AND EXAMPLES

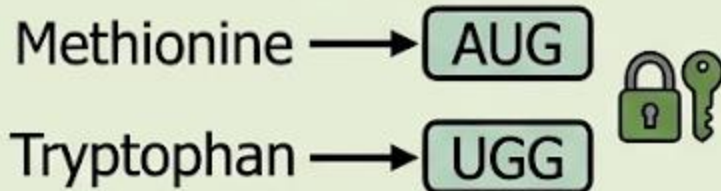
Multiple Codons for One Amino Acid

- e.g. valine has three codons: **GUC**, **GUA**, and **GUU**.



2b. Single Codon for One Amino Acid

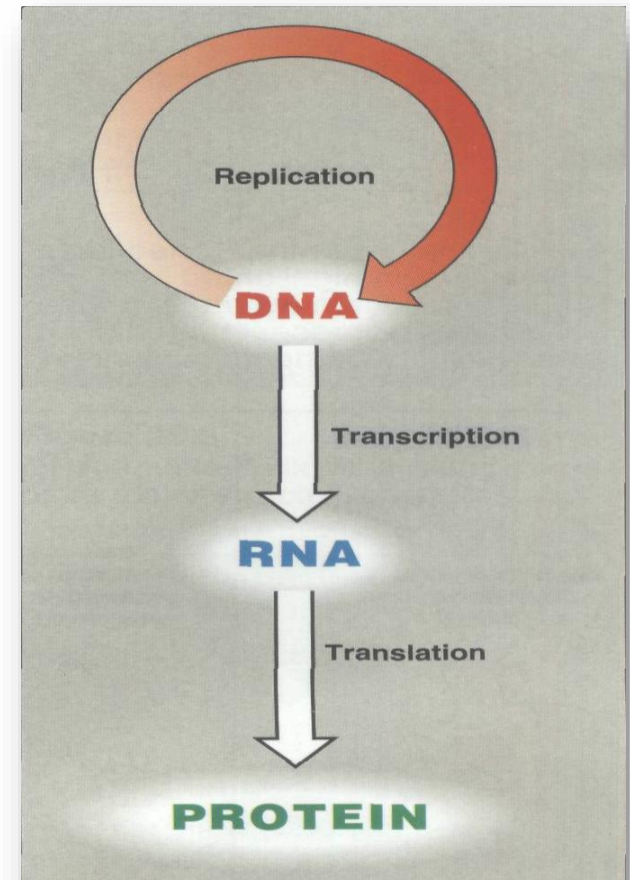
- In addition, methionine and tryptophan have single codon.



# Protein synthesis and genetic code

## Main step in protein synthesis

- 1/ Replication
- 2/ transcription
- 3/ translation



**Figure 29.1**

The “central dogma” of molecular biology.

**1/ Replication:** this process is the production of two double strand DNA molecules that are identical in every way to the parent DNA. Each daughter DNA contains one strand of parent DNA and one synthesized daughter strand.

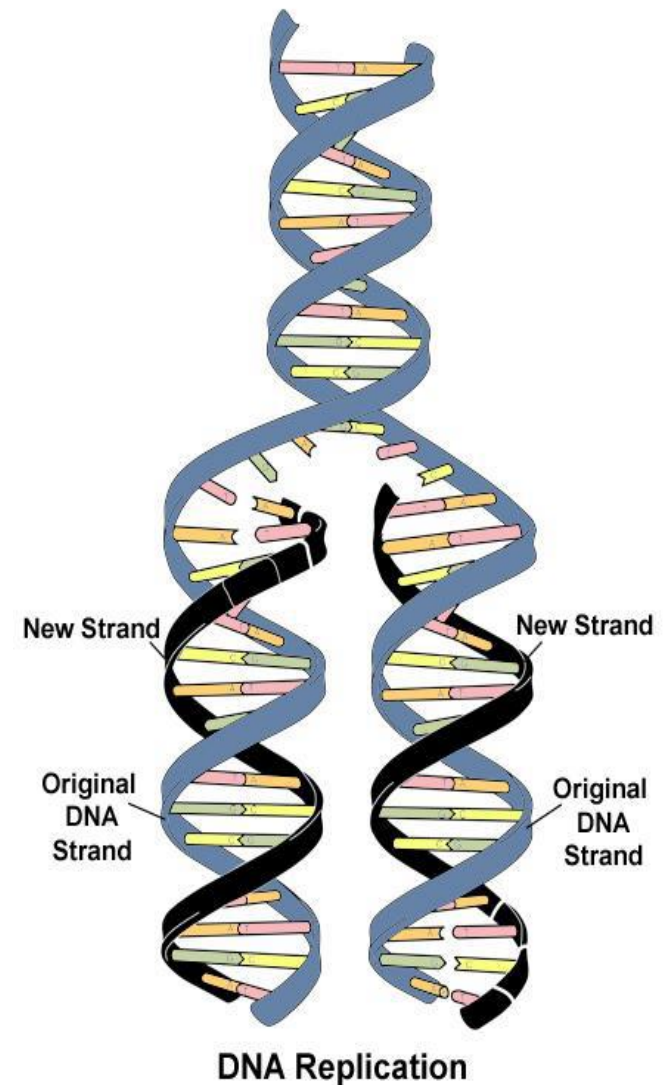
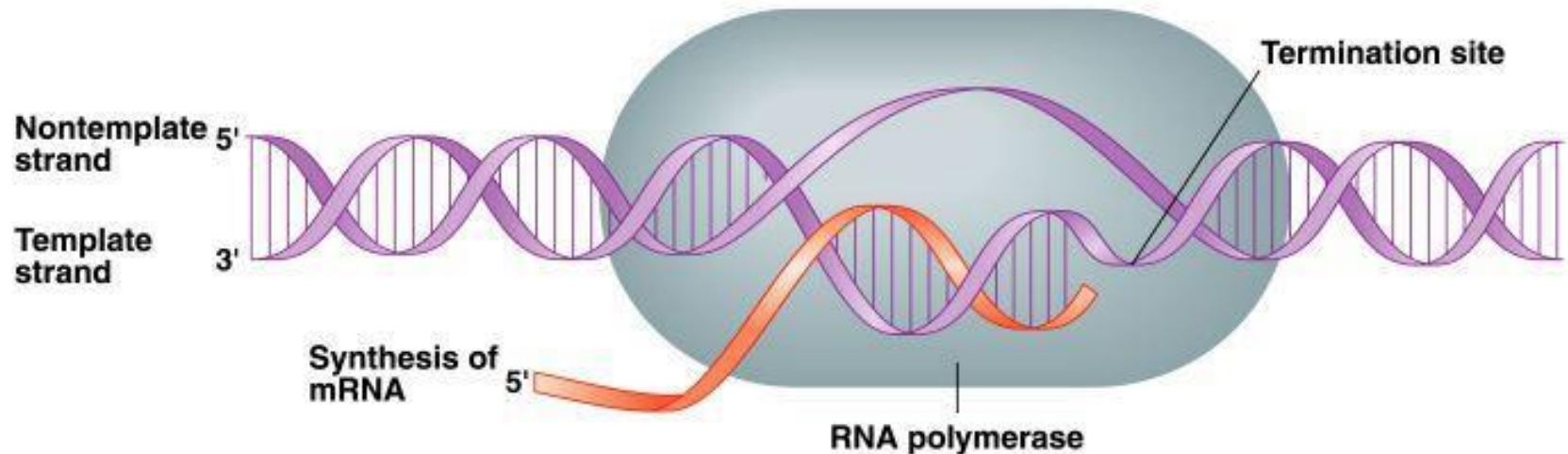


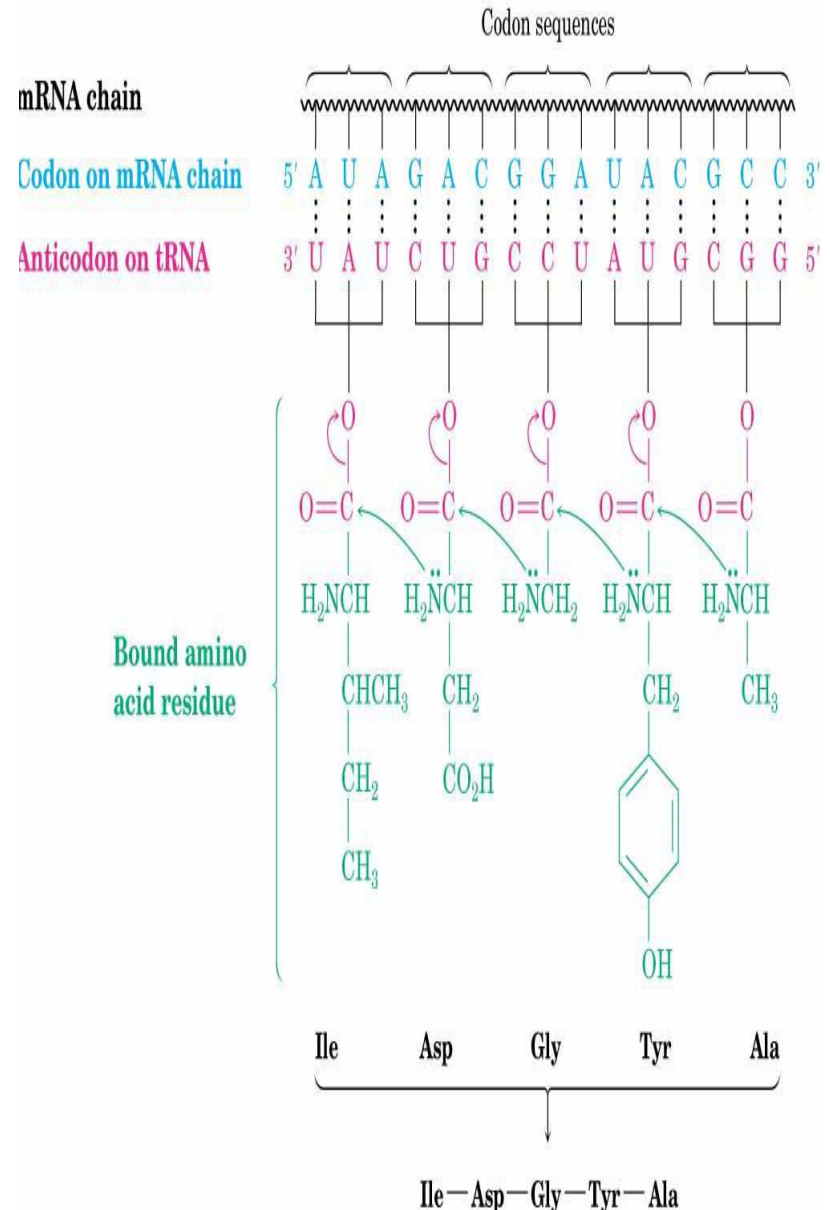
Image adapted from: National Human Genome Research Institute.

**2/ Transcription:** This process lead to the **synthesis of RNA**, with a sequence that is complementary to that of the DNA template. **RNA polymerases (RNAPs)** catalyze transcription, in eukaryotes there are four types of (RNAPs) enzymes each one responsible for the synthesis of certain RNA type.



The informations in DNA are transcribed as mRNA, therefore mRNA acts as a template, and transports the genetic code from the nucleus into cytoplasm and there are four steps to the occurrence of transcription :

- Binding:** RNAP binds to DNA to begin transcription.
- Initiation:** Involves the formation of the first phosphodiester bond.
- Elongation.**
- termination.**

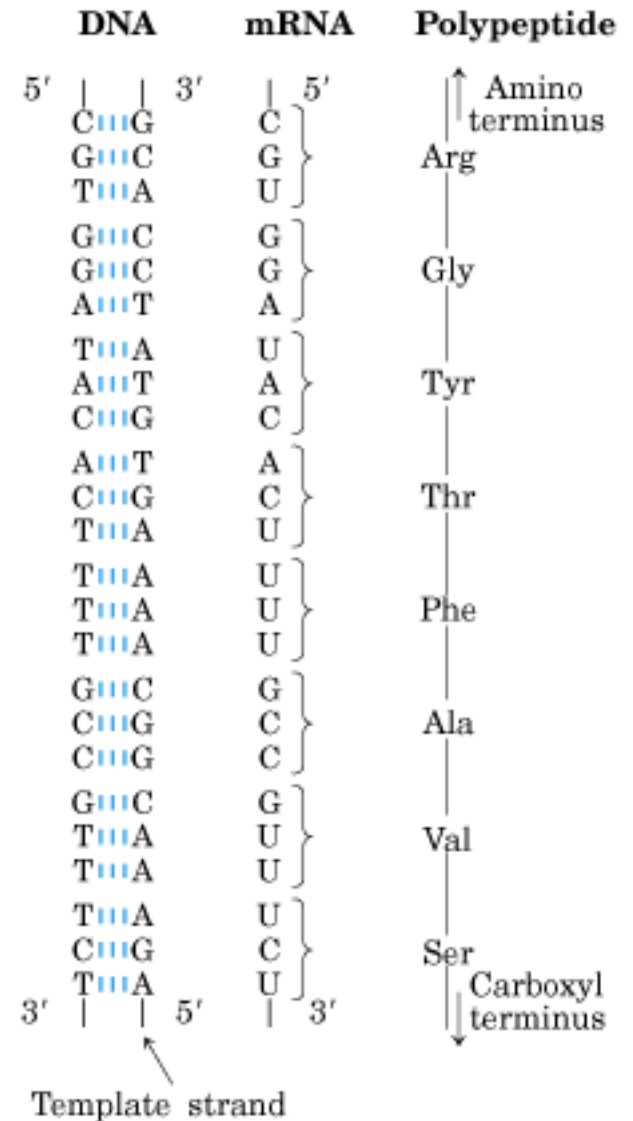


### 3/ translation (protein synthesis).:

This involves the polymerization of amino acids in a precise sequence directed by the sequence of bases in mRNA. **Protein synthesis** occurs in the following steps:

**(1) Activation of amino acids:** the enzyme aminoacyl-tRNA synthetase link amino acids to their specific tRNA to form aminoacyl-tRNA (fig. 10-10).

Each aminoacyl-tRNA synthetase joins specific amino acid to the 3-terminal OH of a specific tRNA.



# TRANSLATION (PROTEIN SYNTHESIS): INITIATION

## 1. REQUIRED COMPONENTS

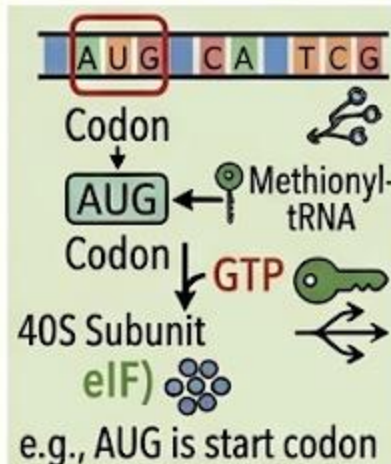
### Initiation Needs

- Amino Acids
- mRNA
- Small Subunit (40S)
- Ribosome Subunits (60S & 40S)
- mRNA (Large Subunit 60S & Small Subunit 40S)
- GTP (Guanosine Triphosphate)
- Earil Dalge GTP (eIFs)
- Amino Acids (a.a.)
- tRNA (including-tRNA)
- (including Methionyl-tRNA)
- Methionyl-tRNA
- rRNA
- Large Subunit
- Ribosomes
- Subunit rRNAs
- Initiating Factors (eIFs)

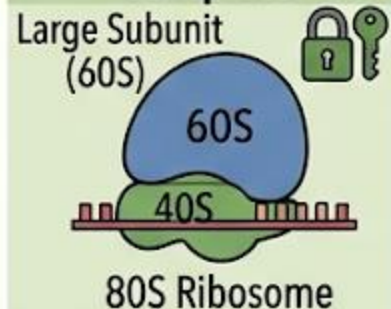
## 2. INITIATION COMPLEX FORMATION

- Ribosome activation begins by association into two parts: 60S and 40S.
- Formation of 40S Initiation Complex:** mRNA, small ribosomal subunit (40S), eIF, GTP, and methionyl-tRNA.
- Formation of 80S Initiation Complex:** The 40S caril complex binds to the large 60S subunit.
- Formation of 80S Initiation Complex:** The 40S complex binds to the large 60S subunit.

### tRNA & mRNA Assembly



### Ribosome Assembly Complete



# Translation (Protein Synthesis): Initiation

## 1. REQUIRED COMPONENTS

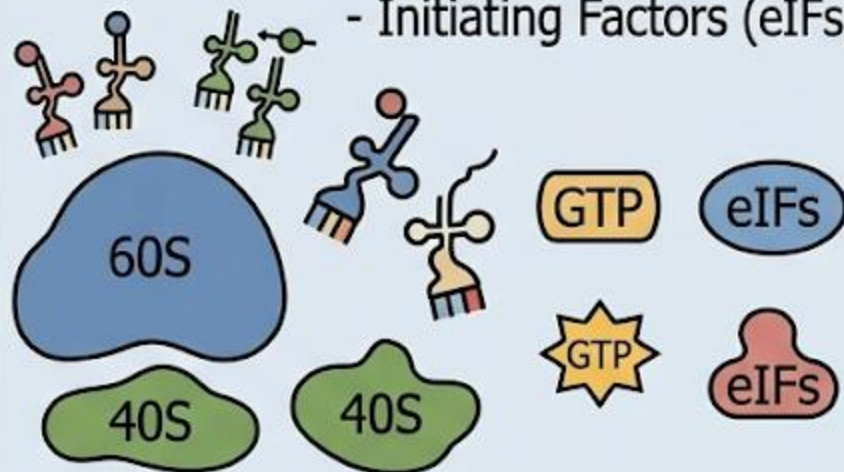
### Initiation Needs



This step requires:

- amino acids (a.a.)
- tRNA (incl. methionyl tRNA)
- mRNA
- rRNAs (large 60S & small 40S subunits)
- GTP (Guanosine triphosphate)
- Initiating Factors (eIFs)

AUG CA TCG

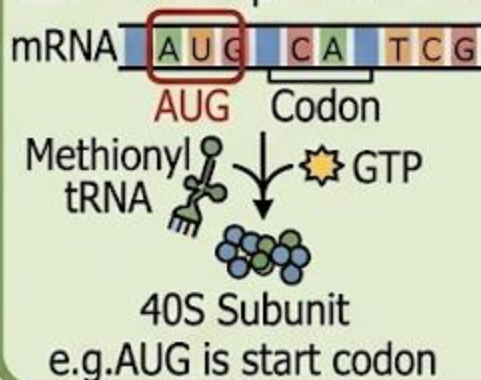


## 2. INITIATION COMPLEX FORMATION

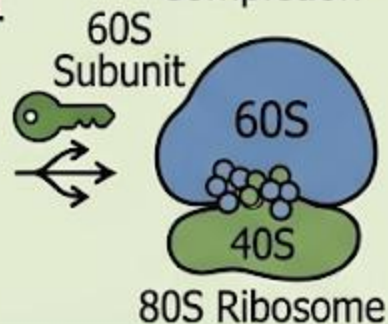
### The Initiation Process

- Activation of ribosome begins by its association into two parts: 60S and 40S subunits.
- **Formation of 40S Initiation Complex:** Includes mRNA, small ribosomal subunit (40S), eIF, GTP, and methionyl tRNA.
- **Formation of 80S Initiation Complex:** The 40S complex binds to the large 60S subunit.

#### 2a. 40S Complex Assembly



#### 2b. 80S Complex Completion



# TRANSLATION (PROTEIN SYNTHESIS): ELONGATION

## 3. ELONGATION STEPS

**(3) Elongation:** elongation occurs in a **three-step cycle** that repeats each time an amino acid is added.

Amino Acids  
mRNA



mRNA

GTP  
Protein factors  
EFs

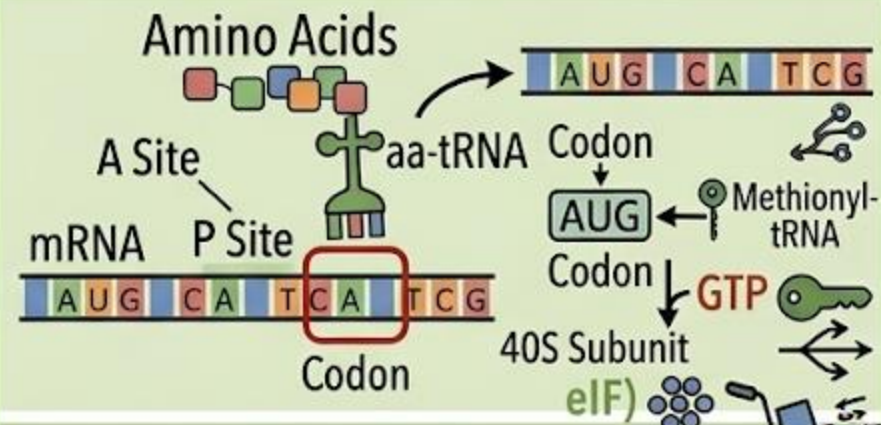


**(a)** Incoming aa-tRNA binds to the aminoacyl (A) site of the large ribosomal subunit.

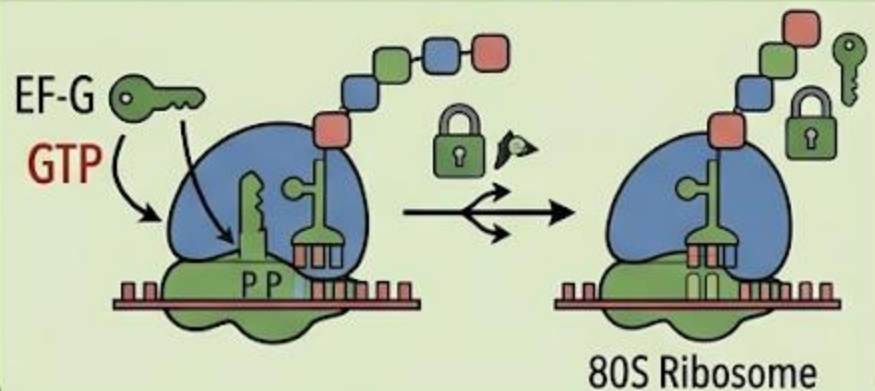
- This requires several protein elongation factors (EFs).
- Requires hydrolysis of GTP.

## 4. ELONGATION CYCLE DIAGRAM

**(a) aa-tRNA Binding (Step 1)**



**(b) Chain Extends (Step 2 & 3)**



### 3/ translation (protein synthesis).:

**(3)Elongation:** elongation occurs in a three steps, cycle that repeat each time an amino acid is added. (a) the incoming of aa-tRNA binds to the aminoacyl site of the large 80s ribosomal subunit. This requires several protein elongation factors (EFS) and the hydrolysis of GTP (fig. 2).

# TRANSLATION (PROTEIN SYNTHESIS): TERMINATION

## 5. TERMINATION STEPS

(4) **Termination** begins when a **stop codon** on mRNA is reached after the addition of the last amino acid.



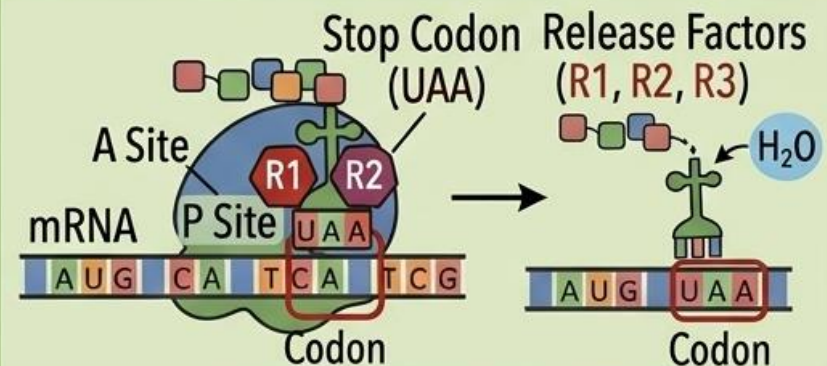
- Release of the completed peptide chain begins from the ribosome.
- Process requires three specific release factors (**R1, R2, R3**).
- Factors **R1, R2, and R3** bind to the ribosome and facilitate the final transport of peptidyl tRNA from **A** site to **P** site.
- Finally, all components (factors, chain, mRNA, tRNA) are separated from the ribosome.
- Components stay inactive and ready for reactivation.



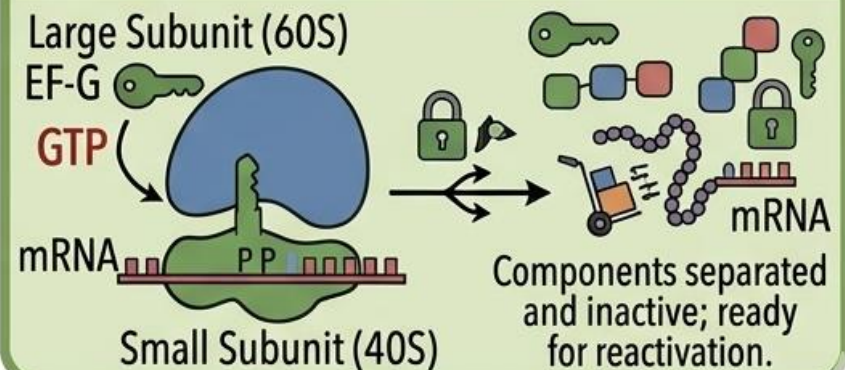
Separated & Inactive Components

## 6. TERMINATION DIAGRAM

### (a) R Factor Binding & Cleavage



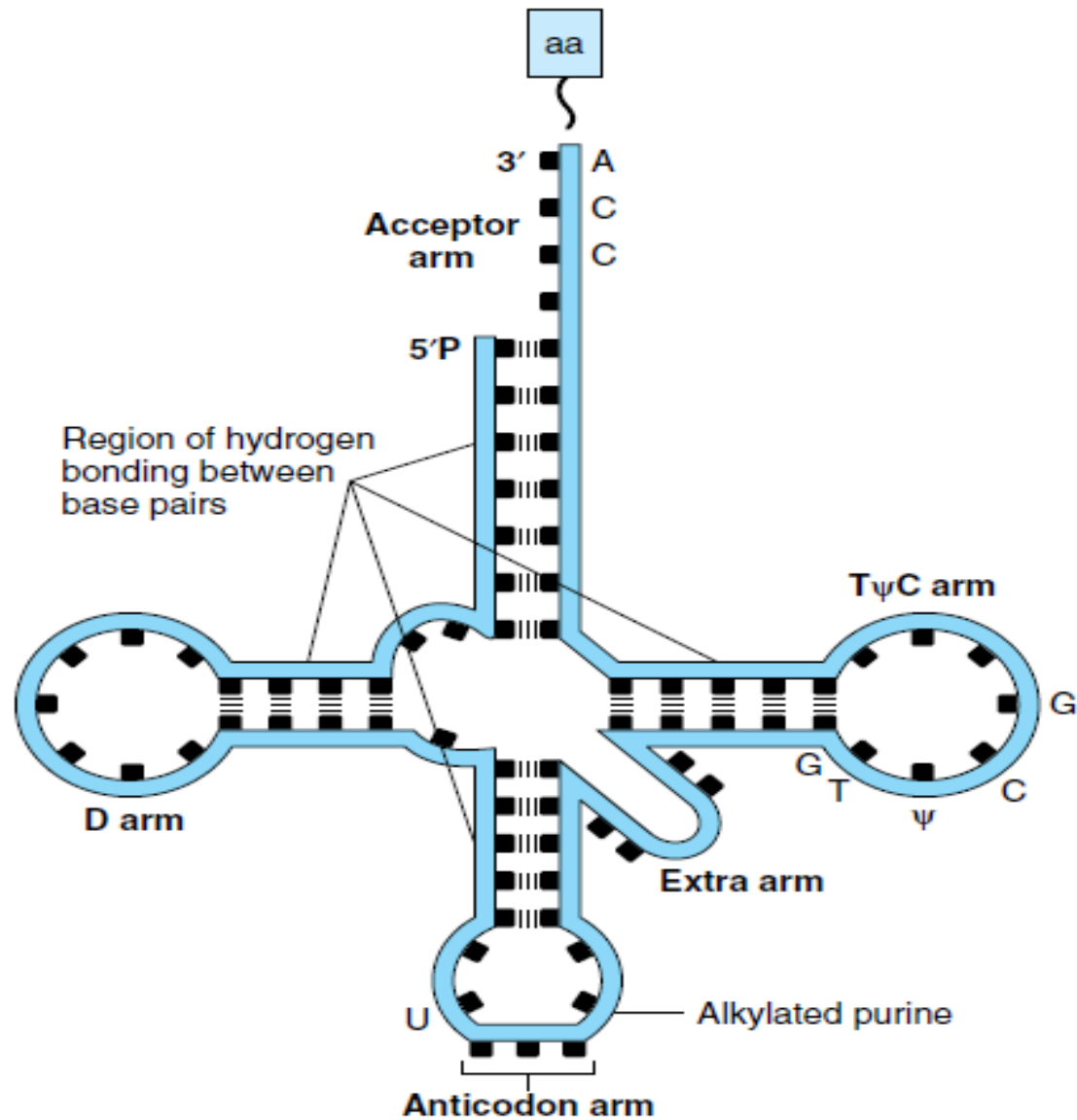
### (b) Dissociation & Inactive End State



### 3/ translation (protein synthesis).:

**(4) Termination:** the termination begins by the termination of all mRNA codons after the addition of last amino acid, and the releasing of peptide chain begins from the ribosome. This process requires three factors **R1, R2 and R3** which bind to ribosome and transport peptidyl tRNA from **A** site to **P** site.

Then **(R1, R2, R3)**, peptide chain, mRNA, and tRNA are separated from ribosome to stay inactive alone and ready for the activation again.



# Mutations

**Mutations** are change in the DNA of cell and are caused by radiation, viruses, and mutagenic chemicals, as well as errors that occur during meiosis and DNA replication.

## Classification of mutations:

A gene is essentially a sentence made up of the bases **A, T, G, and C** that describes how to make a protein. Any changes to those instructions can alter the genes meaning and change the protein that is mad, or how or when a cell makes that protein. There are many different ways to alter a gene. In the following examples of some types of mutations, we use the sentence " the fat cat ate the wee rat" as a sample gene

# Mutations

## Point mutation

A point mutation is a simple change in one base of the gene sequence. This is equivalent to changing one letter in a sentence, such as this example, where we change the 'c' in cat to an 'h' :

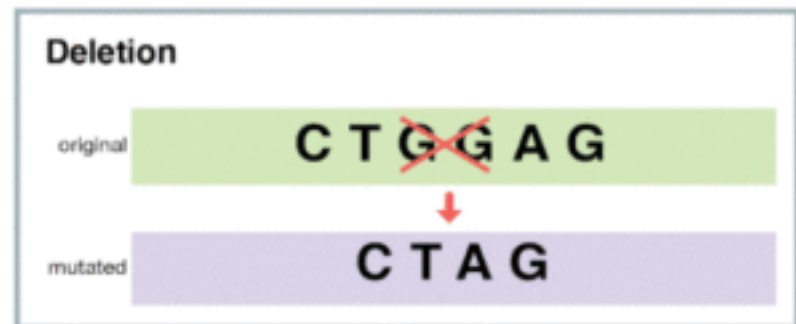
**Original**                      the fat cat ate the wee rat.

**Point mutation**              the fat **hat** ate the wee rat.

# Mutations

## Deletions

Mutations that results in missing DNA are called deletions. These can be small, such as the removal of just one "word", or longer deletions that affect a large numbers of genes on the chromosome. Deletion can also cause frame shift mutation.



# Mutations

## Insertion

Mutations that result in the addition of extra DNA are called insertions. Insertions can also cause frame shift mutations, and general result in a nonfunctional protein.



# Mutations

## Inversion

In an inversion mutation, an entire section of DNA is reversed. A small inversion may involve only a few bases within a gene, while longer inversions involve large regions of a chromosome containing several genes.

# Point mutations

No mutation

Silent

Nonsense

Missense

conservative

non-conservative

DNA level

TTC

TTT

ATC

TCC

TGC

mRNA level

AAG

AAA

UAG

AGG

ACG

protein level

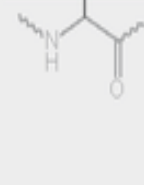
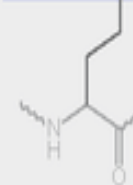
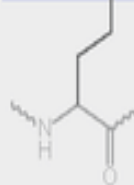
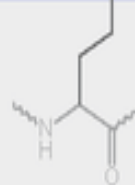
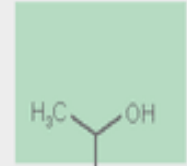
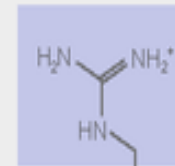
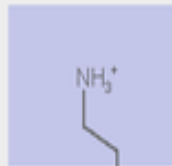
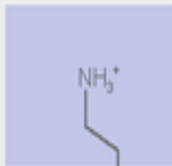
Lys

Lys

STOP

Arg

Thr



basic   
polar 

# Mutations

## Causes of mutation :

Two classes of mutations are spontaneous mutations (molecular decay), and induced mutations caused by mutagens.

**1-Spontaneous mutations on the molecular level include:**

- **Tautomerism:** a base is changed by the repositioning of hydrogen atom, altering the hydrogen bonding pattern of that base resulting in incorrect base pairing during replication.
- **Depurination:** loss of a purine base (A or G) to form an apurinic site (AP site).

# Mutations

## Causes of mutation :

- **Deamination:** hydrolysis changes a normal base to an a typical base containing a keto group in place of the original amino group.
- **Transition:** a purine changes to another purine, or pyrimidine to another pyrimidine.
- **Transversion:** a purine becomes a pyrimidine, or vice versa.

# Mutations

Causes of mutation :

**2-Induced mutations** on the molecular level can be caused by:

- **Chemicals:** like nitrous acid which converts amine groups on A and C to diazo groups, altering their hydrogen bonding patterns which leads to incorrect base pairing during replication.
- **Radiation:** like ultraviolet radiation and ionizing radiation.
- **Viral infection.**

# Mutations

Harmful mutations :

Changes in DNA caused mutation can cause errors in protein sequence, creating partially or completely non-functional proteins, if a mutation does change a protein, this will probably be harmful, **for example certain mutations can cause the cell to become malignant, and thus cause cancer.**

# Mutations

## Beneficial mutations :

Although most mutations that change protein sequences are harmful, some mutations have a **positive effect on an organism**. In this case, the mutation may enable the mutant organism to withstand particular environment stresses, or reproduce more quickly.

**Example:** a sickle cell anemia is an inherited disease, caused by mutation (substitution of valine instead of glutamic acid), in this case strange type of hemoglobin appears, consisting of normal and mutant strand. This mutation decreases the solubility of deoxyhemoglobin so that makes fibrous precipitate, changing the erythrocytes to a sickle shape. The human infected with sickle cell anemia are protected from the lethal malaria infection.

## Examples

In humans, genetic disorders are often due to a mutation involving an altered gene or chromosomal aberration.

- **Sickle-cell disease**, for instance, occurs when the 20th nucleotide of the gene for the beta chain of hemoglobin on chromosome 11 is changed from the codon GAG to GTG so that when translated the 6th amino acid is now a valine instead of glutamic acid (non functional protein) (**missense mutation**)
- cystic fibrosis (**deletion**) .
- Some cancers like breast cancer caused by **duplication**.
- Beta-Thalassemia (**insertion**).
- A mutation in the gene controlling the cell division leads to cancer, including oncogenes and tumor suppressor genes .



**THANK YOU  
FOR YOUR  
ATTENTION**