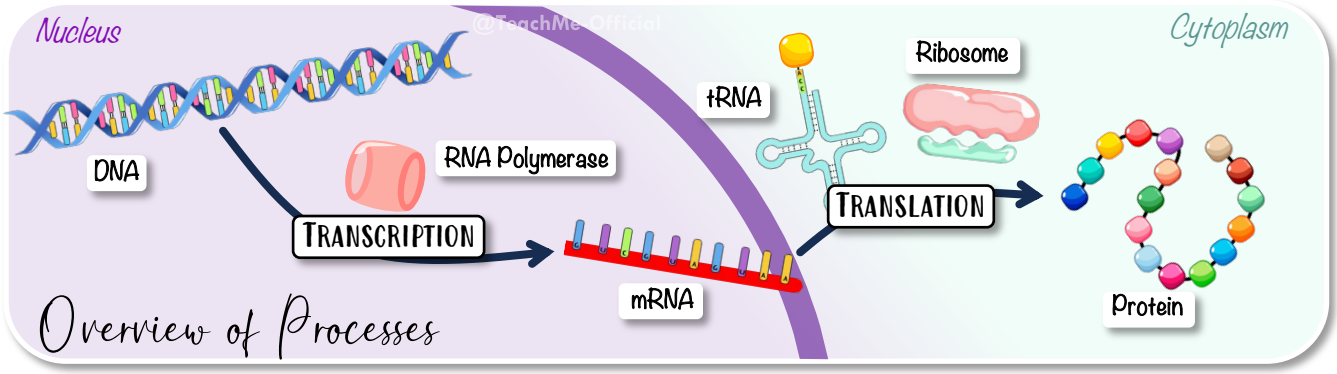
Protein Synthesis



1. TRANSCRIPTION

The process of copying a segment (gene) of DNA into mRNA within the **NUCLEUS** of the cell.

BIG BRAIN NOTE!

To create the mRNA of a gene (sense strand), the **OPPOSITE STRAND** (anti-sense strand) is transcribed. This way, the mRNA will match the code of the gene (sense strand).

Example

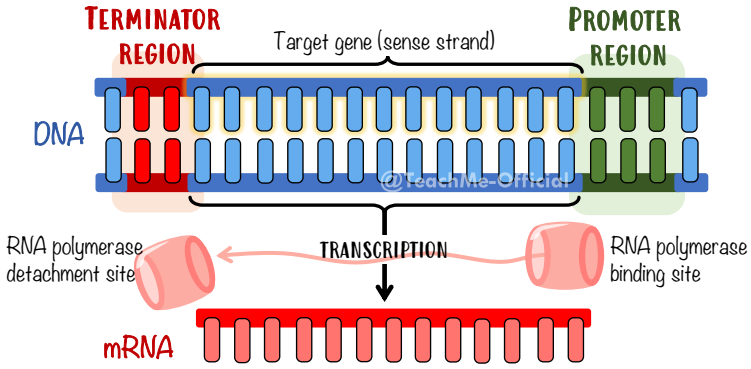
DNA { C A T T A G (Sense strand) / G T A A T C (Anti-sense strand) }

TRANSCRIPTION

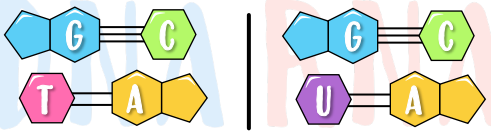
mRNA { C A U U A G }

Notice the similarities in the DNA sense strand and the mRNA! (all the Ts are Us)

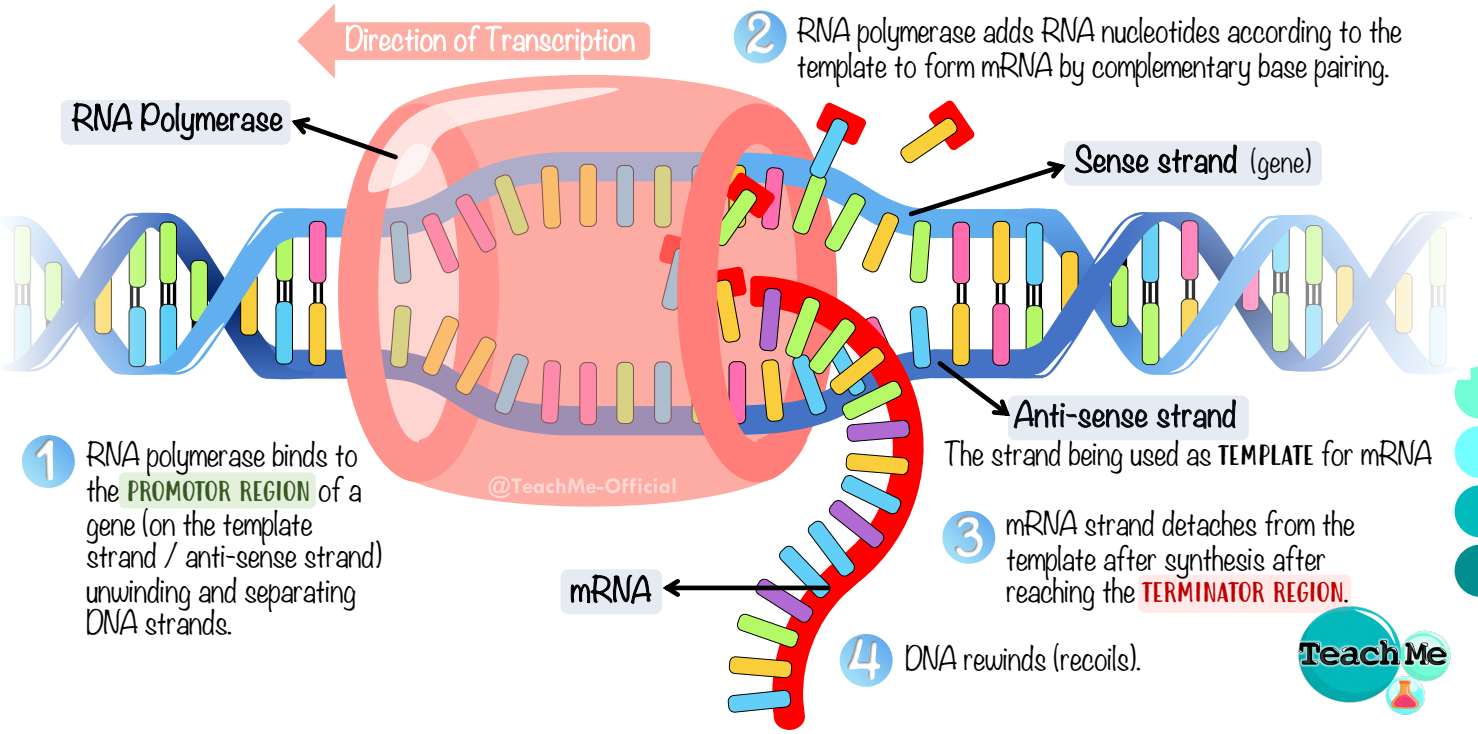
Sense-strand = coding strand
Anti-sense-strand = non-coding strand = template strand



Remember difference between DNA and RNA:
Complementary base pairing



Steps of Transcription



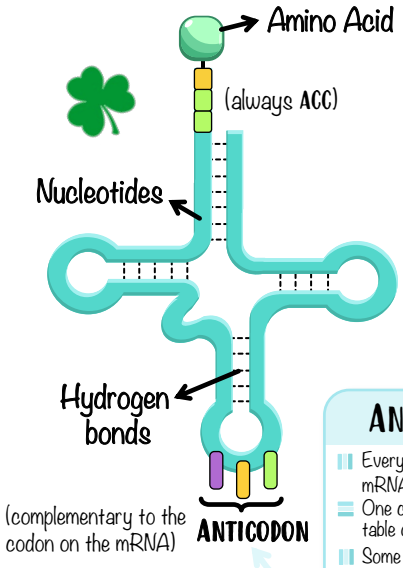
1. RNA polymerase binds to the **PROMOTOR REGION** of a gene (on the template strand / anti-sense strand) unwinding and separating DNA strands.
2. RNA polymerase adds RNA nucleotides according to the template to form mRNA by complementary base pairing.
3. mRNA strand detaches from the template after synthesis after reaching the **TERMINATOR REGION**.
4. DNA rewinds (recoils).

Protein Synthesis

II. TRANSLATION

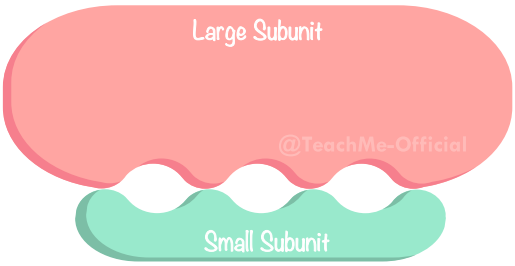
The process by which the information carried by mRNA is decoded and used to build the sequence of amino acids that eventually forms a protein molecule within the CYTOPLASM of the cell.

Structure of tRNA (Transfer RNA)
Carries amino acids according to the mRNA sequence



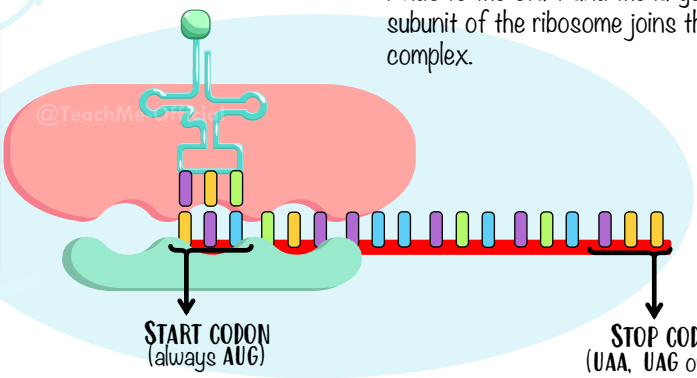
RIBOSOME synthesizes protein, composed of proteins & rRNA (ribosomal RNA)

- **BOUND** (on RER) → **USE OUTSIDE** Hormones & Enzymes
- **FREE** (Cytoplasm) → **USE INSIDE** Cytoskeleton



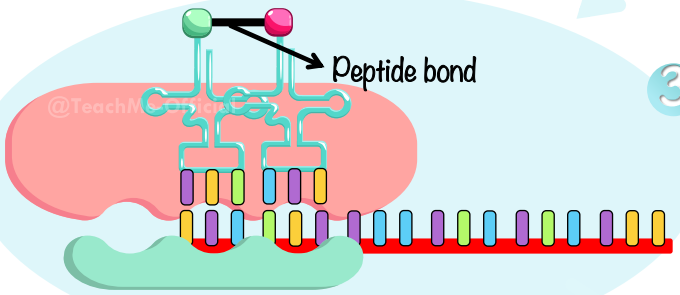
Steps of Translation

1. The small ribosomal subunit binds to the start **CODON** (**AUG**) on mRNA.
2. A tRNA molecule with the anticodon **UAC** (aa: methionine) binds to the start and the large subunit of the ribosome joins the complex.

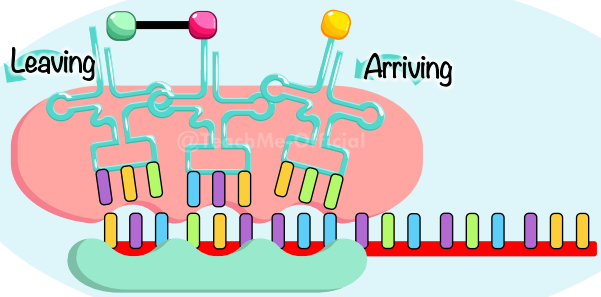


ANTICODON & CODON

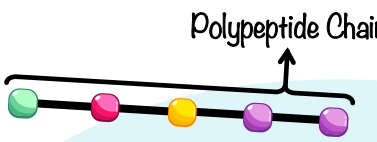
- Every three consecutive nucleotide in mRNA is called a "codon".
- One codon codes for one amino acid (see table on PAGE 3).
- Some codons do not code for an amino acid (e.g. the stop codons).
- The tRNA (carrying an amino acid) binds to a complementary codon on the mRNA via its **ANTICODON**.

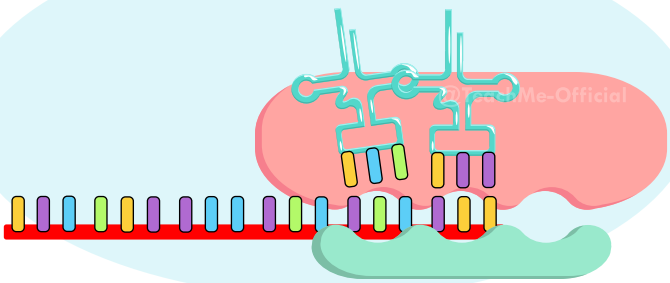


3. A tRNA carrying the next amino acid binds to the codon forming a **PEPTIDE BOND** between the two amino acids.
4. The ribosome translocates (moves), freeing a site for a new tRNA to bind. The empty tRNA then leaves.



5. This cycle repeats, elongating the polypeptide chain.





6. When the ribosome encounters a stop codon (**UAA**, **UAG**, **UGA**), the polypeptide chain is released, and the ribosomal subunits disassemble.

Protein Synthesis

You can refer to the following table to know which amino acid each mRNA codon represents:

The genetic code is **DEGENERATE:** for each amino acid there may be more than one codon. The genetic code is also **UNIVERSAL.**

NOTE! You do not need to memorise the whole table, for your reference only. But make sure you remember **AUG** (the start codon) and the stop codons.

First base	Second base: U	Second base: C	Second base: A	Second base: G	Third base
U	UUU Phenylalanine	UCU Serine	UAU Tyrosine	UGU Cysteine	U
	UUC Phenylalanine	UCC Serine	UAC Tyrosine	UGC Cysteine	C
	UUA Leucine	UCA Serine	UAA STOP	UGA STOP	A
	UUG Leucine	UCG Serine	UAG STOP	UGG Tryptophan	G
C	CUU Leucine	CCU Proline	CAU Histidine	CGU Arginine	U
	CUC Leucine	CCC Proline	CAC Histidine	CGC Arginine	C
	CUA Leucine	CCA Proline	CAA Glutamine	CGA Arginine	A
	CUG Leucine	CCG Proline	CAG Glutamine	CGG Arginine	G
A	AUU Isoleucine	ACU Threonine	AAU Asparagine	AGU Serine	U
	AUC Isoleucine	ACC Threonine	AAC Asparagine	AGC Serine	C
	AUA Isoleucine	ACA Threonine	AAA Lysine	AGA Arginine	A
	AUG Methionine	ACG Threonine	AAG Lysine	AGG Arginine	G
G	GUU Valine	GCU Alanine	GAU Aspartic acid	GGU Glycine	U
	GUC Valine	GCC Alanine	GAC Aspartic acid	GGC Glycine	C
	GUA Valine	GCA Alanine	GAA Glutamic Acid	GGA Glycine	A
	GUG Valine	GCG Alanine	GAG Glutamic Acid	GGG Glycine	G

Test Yourself!

Using the DNA sequence provided, fill in the corresponding mRNA and amino acid sequence.

DNA (anti-sense strand)	TAC	TAT	CCA	GCC	ATC
	↓	↓	Transcription ↓	↓	↓
mRNA	?	?	?	?	?
	↓	↓	Translation ↓	↓	↓
Amino Acids	?	?	?	?	?

Summary of Structures involved in protein synthesis

Structure	Function
mRNA	Carries the message from the DNA in the nucleus to the ribosomes in the cytoplasm
tRNA	Functions in the cytoplasm to carry amino acids to the ribosomes
rRNA	Combines with ribosomal proteins to construct the cytoplasmic ribosomes
RNA polymerase	Enzyme that unwinds and unzips DNA for transcription. It also function in adding RNA nucleotides to form mRNA.
Ribosome	Organelle where translation occurs. Use mRNA to synthesize a protein.

ANSWERS: mRNA: AUG, AUA, GCU, CCC, UAG Amino Acids: methionine, isoleucine, glycine, arginine, STOP

Protein Synthesis

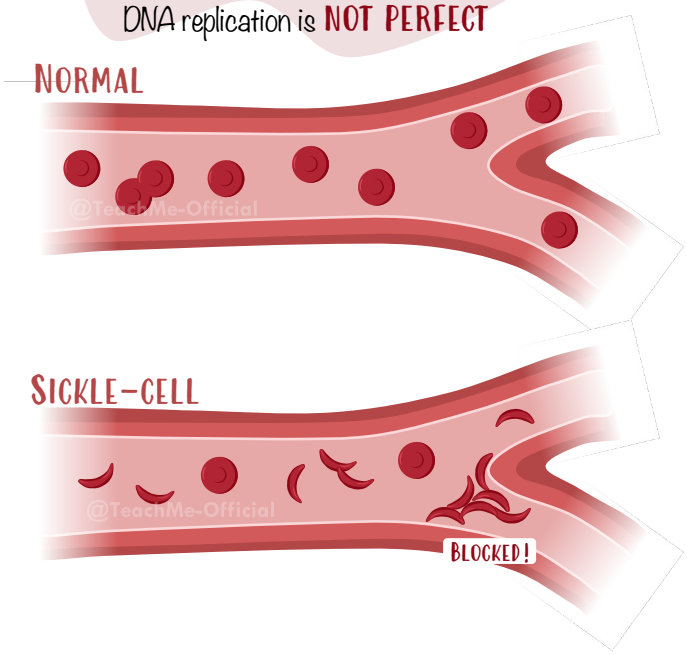
REMEMBER: Each cell contains all your DNA, but will only **EXPRESS** genes for proteins that it needs (so not all genes are expressed in all cells). For example; the gene which codes for hemoglobin (used to carry oxygen) will only be expressed in red blood cells.

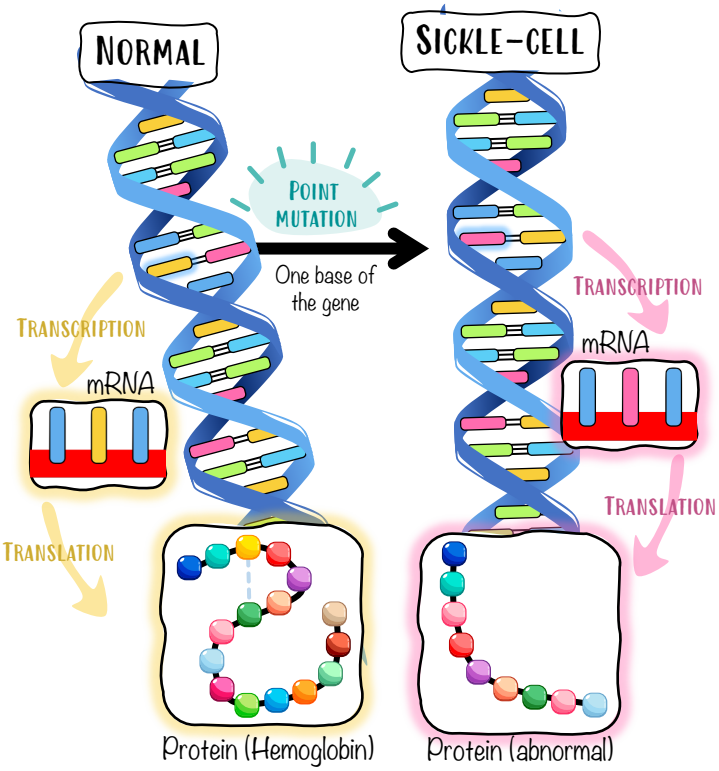
Gene Expression: the process by which the information encoded in a gene is used to direct the synthesis of a protein molecule.

A **DNA MUTATION** can cause alterations in the mRNA sequence, therefore affecting the **AMINO ACID SEQUENCE** of a protein.

Mutations occur when **PERMANENT** changes to DNA is made.

DNA replication is **NOT PERFECT**





Using the example of **SICKLE CELL DISEASE**, a DNA mutation causes a different amino acid to be present in the **HEMOGLOBIN PROTEIN** (resposnible for carrying oxygen), causing red blood cells to become sickle-shape instead of the normal biconcave structure – this abnormal shape causes the RBCs to be likely to block small vessels and are worst at carrying oxygen.

More detail about mutations and sickle-cell disease seen in section **D1.3**

notes