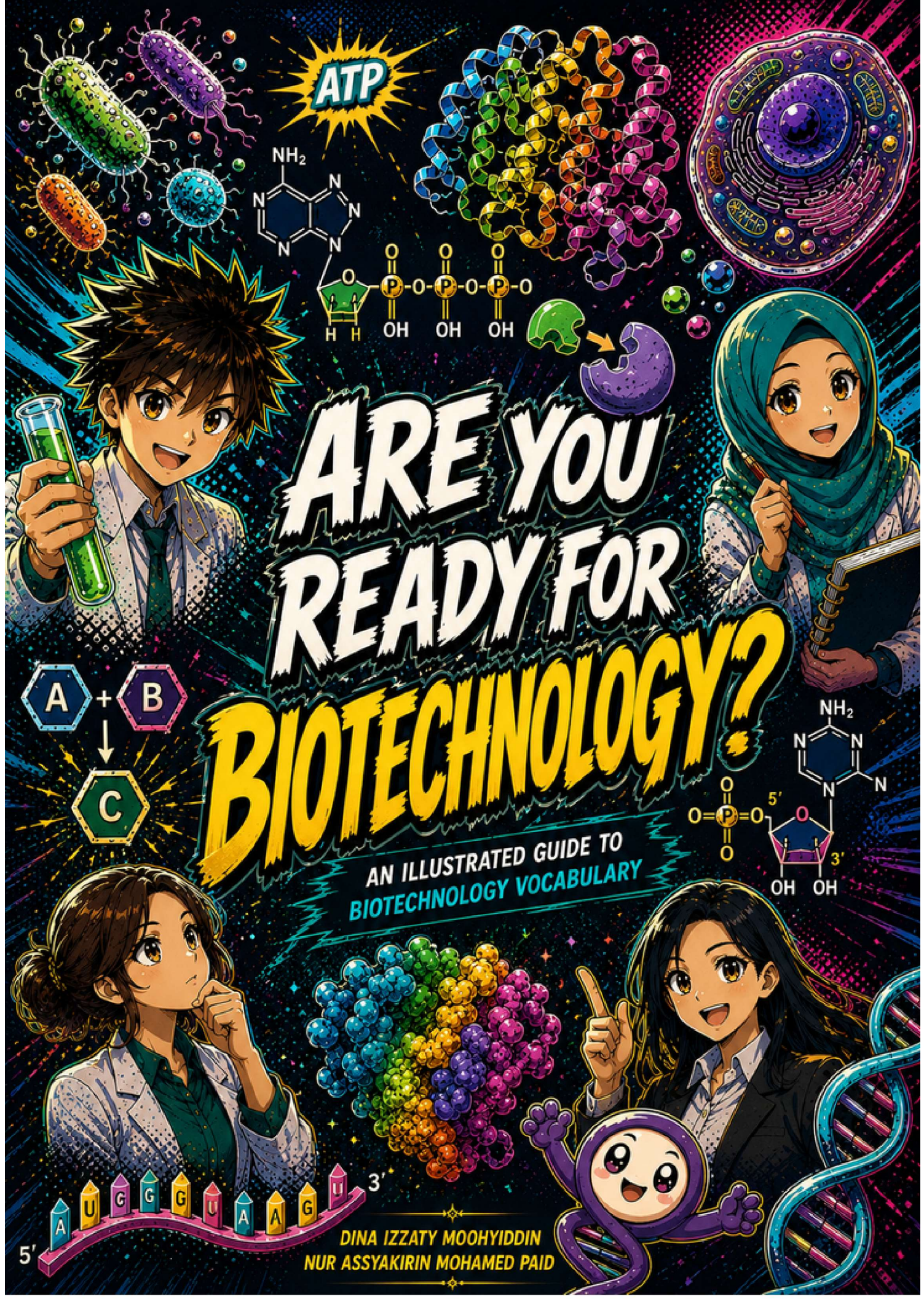
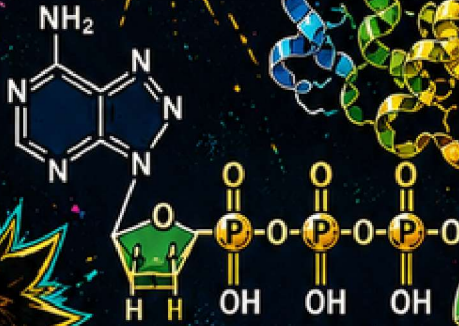


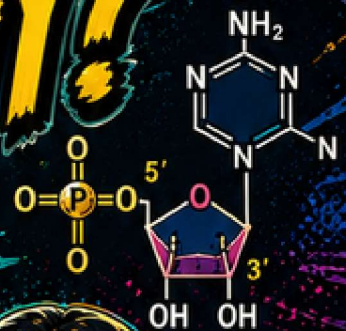
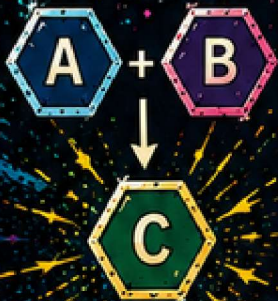


ATP



ARE YOU READY FOR BIOTECHNOLOGY?

AN ILLUSTRATED GUIDE TO
BIOTECHNOLOGY VOCABULARY



DINA IZZATY MOOHYIDDIN
NUR ASSYAKIRIN MOHAMED PAID

ARE YOU READY FOR BIOTECHNOLOGY?

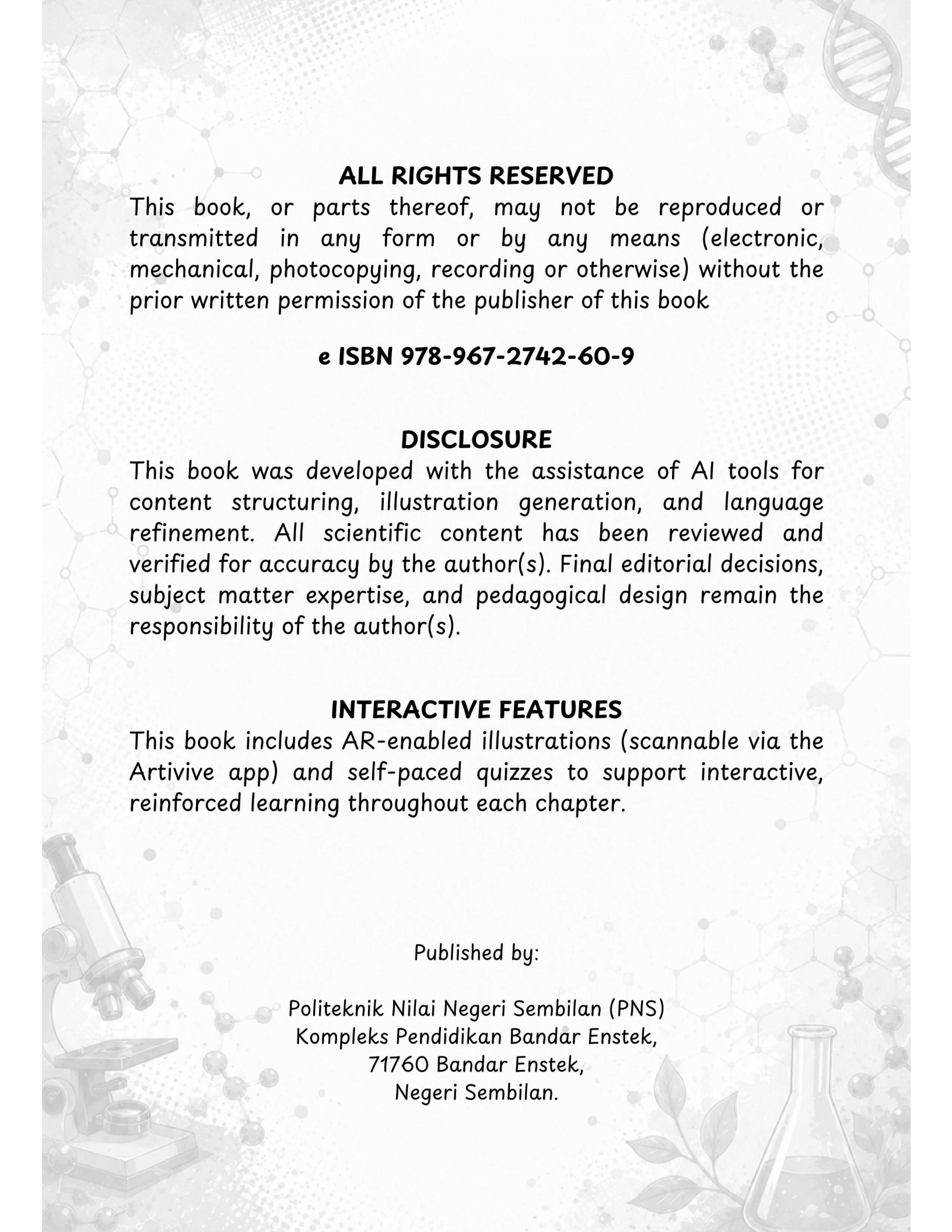
An Illustrated Guide to Biotechnology Vocabulary

by

DINA IZZATY MOOHYIDDIN
NUR ASSYAKIRIN MOHAMED PAID

for





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DISCLOSURE

This book was developed with the assistance of AI tools for content structuring, illustration generation, and language refinement. All scientific content has been reviewed and verified for accuracy by the author(s). Final editorial decisions, subject matter expertise, and pedagogical design remain the responsibility of the author(s).

INTERACTIVE FEATURES

This book includes AR-enabled illustrations (scannable via the Artivive app) and self-paced quizzes to support interactive, reinforced learning throughout each chapter.

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PREFACE

ARE YOU READY FOR BIOTECHNOLOGY?

presents the foundational concepts of molecular biology and biotechnology through a vocabulary-first, visually structured approach. It is intended to support learners in developing a clear and accurate understanding of key terminology before progressing to more complex applications of the subject.

Molecular biology is often introduced through terminology that is used extensively but rarely explained in depth, resulting in students memorising definitions for examination purposes without developing a functional understanding of the underlying concepts. Therefore, this book introduces each key term individually, accompanied by a guiding question, a plain-language explanation, real-world examples, and a corresponding visual illustration.

To further support engagement, selected illustrations are AR-enabled and can be scanned using the Artivive app for additional animated content, while self-paced quizzes are included throughout to help learners review and reinforce key concepts.

This book is intended for students, educators seeking classroom-ready material, and readers with a general interest in biotechnology. It is hoped that this approach will support learners in building both accurate scientific vocabulary and a durable conceptual foundation for further study.

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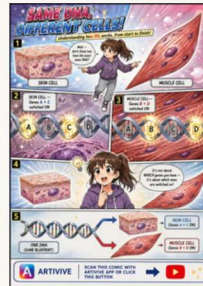
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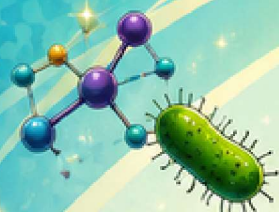
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Test Your Understanding

Chapter 1



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QUIZ



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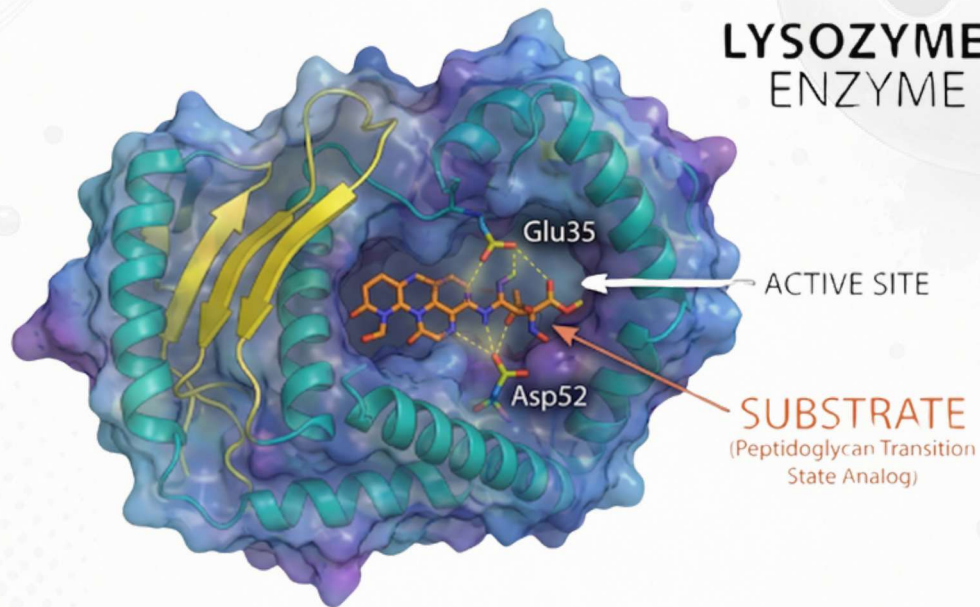
ENZYMES



Look around.
Biotechnology already exists at home.
Dirty clothes can be cleaned using
detergent.
Detergents contain **ENZYMES**.
Enzymes help remove stains.



WHAT IS AN ENZYME?



This is an enzyme.
It helps reactions happen.
The **ACTIVE SITE** is where the reaction happens.
AMINO ACIDS like Glu35 and Asp52 form the
active site.
The **SUBSTRATE** binds to the active site.
Enzymes **INDUCE** reactions.



WHAT DOES INDUCE ACTUALLY MEAN?

THE POWER OF ENZYMES

Nature's Tiny Helpers
Behind Big Clean!



Oh my...
This school
uniform is so dirty!
Stubborn mud won't
even come out...

Sigh
(Sigh)

The teacher
said to use
soap with
enzymes...

Pour
(Pouring)

At the microscopic level,
Enzymes react with the dirt...

Enzyme
(Melekat)

Dirt / Stain

Break
(Pecah)

Fabric

Reaction

Eh?!
The stain is
fading...
like magic!

Scrub
(Scrubbing)

!?

Yes, Amir! The enzyme
catalytically induced the
dirt breakdown reaction
earlier.

Ohh! So it's the
that "started" the
whole chemical
reaction?!

Eureka!
(I get it!)

Correct! It
speeds up the
process!



Enzymes are natural catalysts
that break down dirt and stains,
making cleaning faster and easier!



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WHAT DOES INDUCE MEAN?

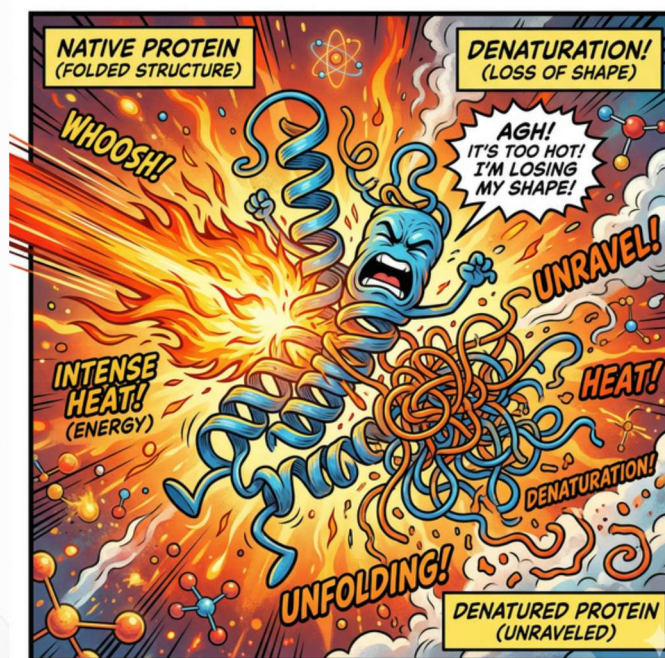
“The enzyme induces a reaction”

simply means:

The enzyme starts the reaction.

The enzyme causes the reaction to happen.

LOOK AT THIS EXAMPLE!



Heat can induce protein denaturation.

simply means:

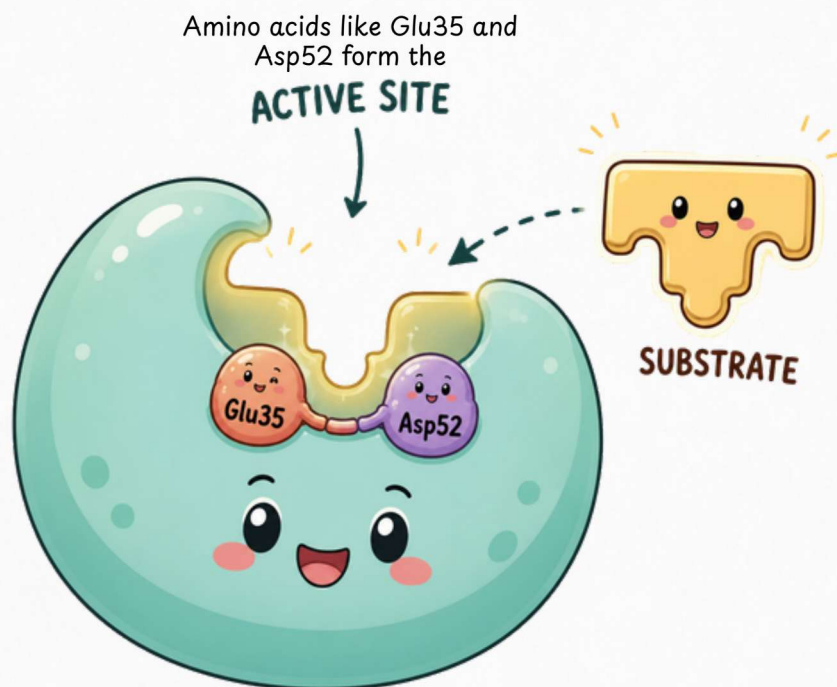
Heat causes proteins to change shape.

WHAT DOES ACTIVE SITE MEAN?

"Express"

simply means:

The active site is a special pocket on the enzyme.
It is shaped to fit only certain substrates.

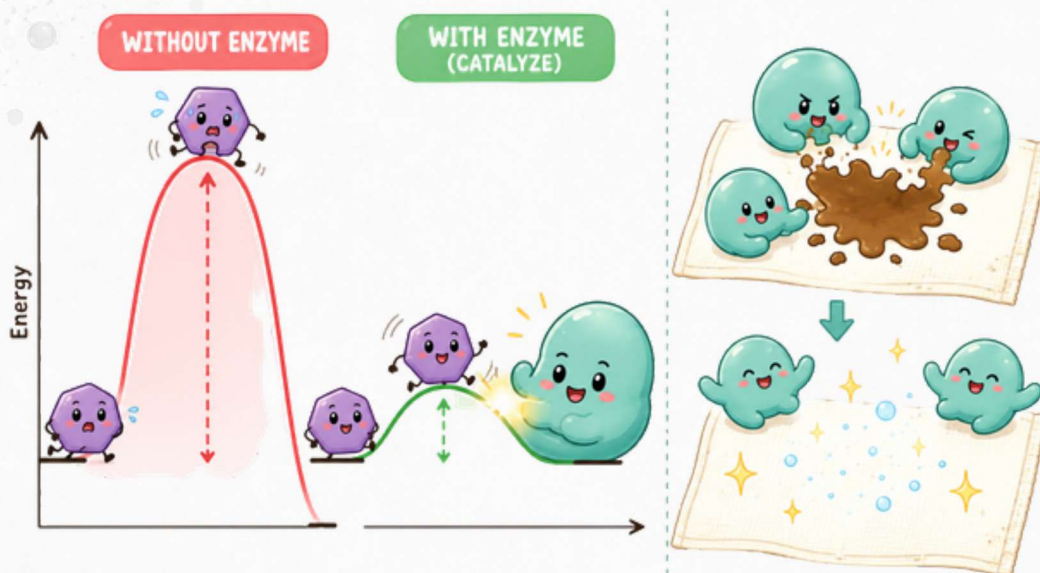


WHAT DOES SUBSTRATE MEAN?

"The substrate binds to the active site"

simply means:

The active site is a special pocket on the enzyme.
It is shaped to fit only certain substrates.



In science, we often use a more specific word:

CATALYZE

Enzymes in detergent catalyze
the breakdown of stains.

Enzymes don't just start reactions.

They speed them up.

Enzymes catalyze reactions by lowering
ACTIVATION ENERGY.



WHAT DOES CATALYZE ACTUALLY MEAN?

WHAT DOES CATALYZE MEAN?

"Enzymes catalyze the breakdown of stains"

simply means:

The enzyme speeds up the reaction.

It doesn't just start the reaction, it makes it go faster.

LOOK AT THIS EXAMPLE!



Saliva can catalyze starch digestion

simply means:

Saliva speeds up the breakdown of starch
into sugar.



ENZYMES: NATURE'S CATALYSTS IN ACTION!



Why is
the stain
still not
coming
off??



It feels like
I'm pushing
something
uphill...



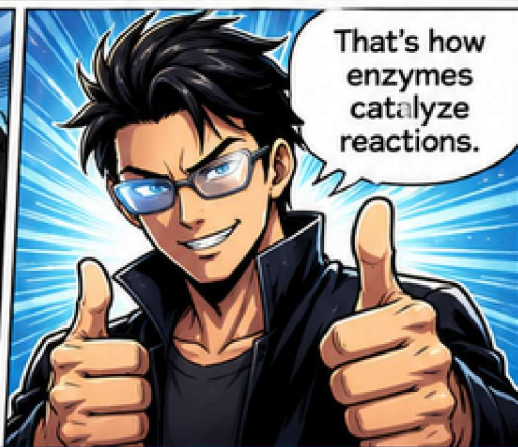
Reactions
need energy
to start...



Enzymes
lower this
barrier.



Now it's
happening
much faster!



That's how
enzymes
catalyze
reactions.

Enzymes are natural catalysts that speed up chemical reactions
by lowering the energy needed to get started.



ARTIVE

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WHAT DOES ACTIVATION ENERGY MEAN?

“Enzymes lower activation energy”

simply means:

Less energy is needed to start the reaction.

The reaction happens faster.

Some enzymes induce reactions.
But some other enzymes can **INHIBIT** them.

WHAT DOES INHIBIT MEAN?

“The enzyme inhibits a reaction”

simply means:

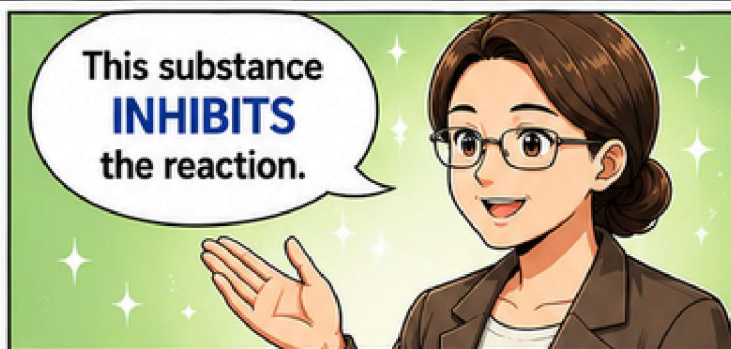
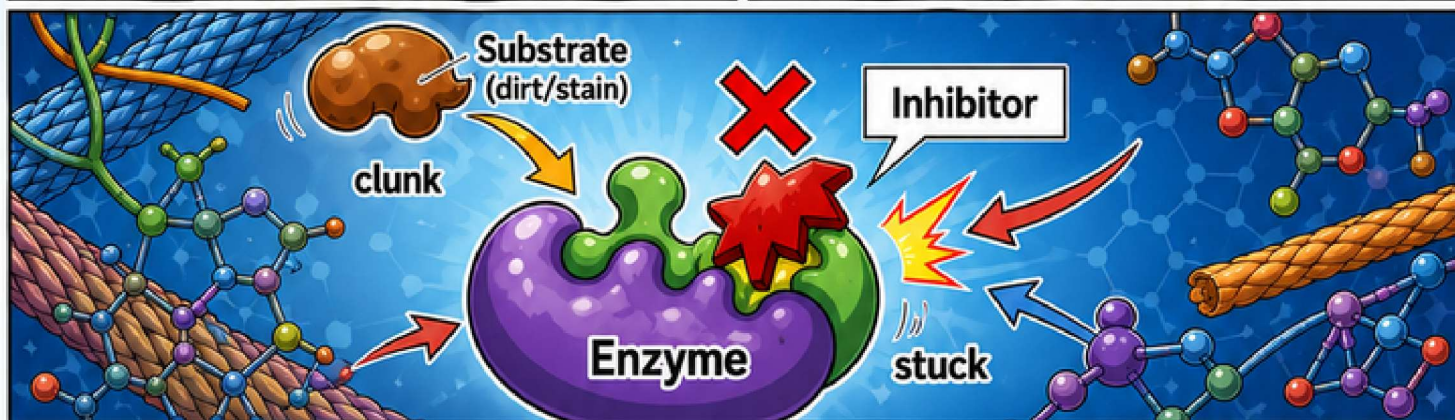
The enzyme stops the reaction.

The enzyme slows down the reaction.

The enzyme prevents the reaction
from happening.

ENZYMES: THE REACTION HEROES!

Small Helpers. Big Impact!



Enzymes are natural catalysts that speed up chemical reactions by lowering the energy needed to get started.



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LET'S LOOK AT THIS EXAMPLE!



A drug inhibits a specific enzyme.

simply means:

The drug blocks the enzyme's action.

LET'S LOOK AT THIS EXAMPLE!



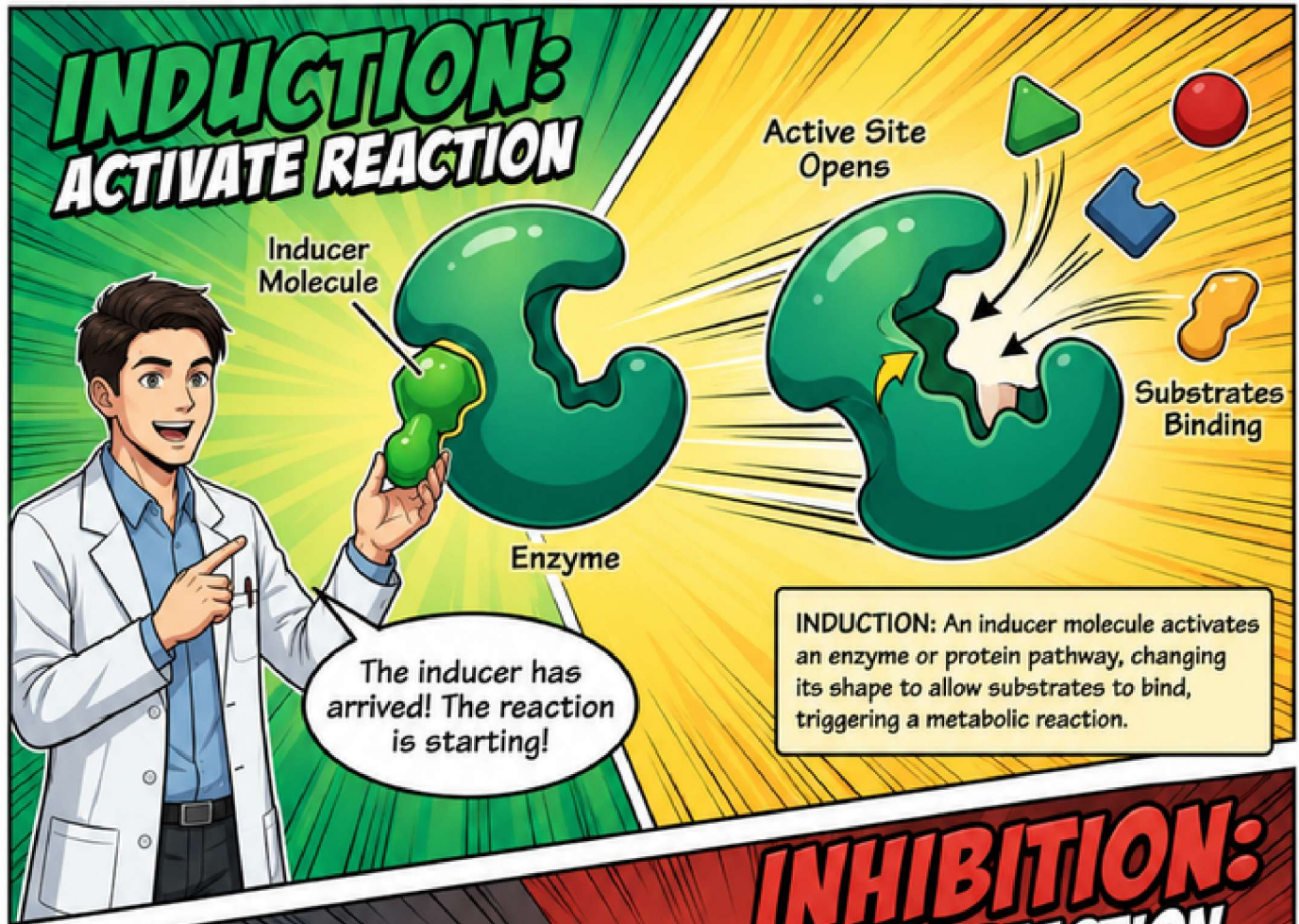
Some chemicals inhibit bacterial growth.

simply means:

Some chemicals stop bacteria from growing.

LET'S COMPARE THE WORDS?

INDUCTION: ACTIVATE REACTION



Inducer Molecule

Enzyme

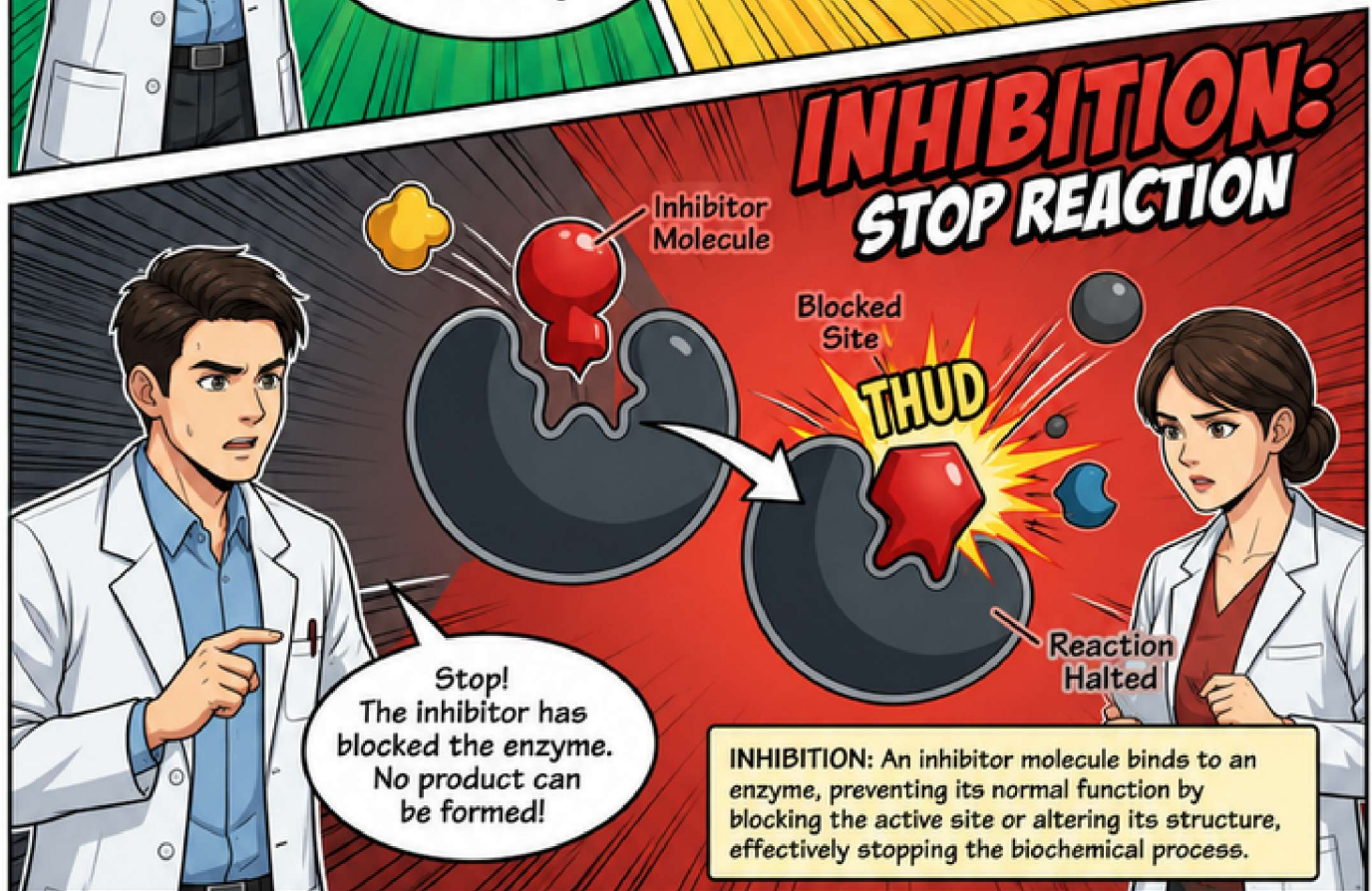
Active Site Opens

Substrates Binding

The inducer has arrived! The reaction is starting!

INDUCTION: An inducer molecule activates an enzyme or protein pathway, changing its shape to allow substrates to bind, triggering a metabolic reaction.

INHIBITION: STOP REACTION



Inhibitor Molecule

Blocked Site

THUD

Reaction Halted

Stop! The inhibitor has blocked the enzyme. No product can be formed!

INHIBITION: An inhibitor molecule binds to an enzyme, preventing its normal function by blocking the active site or altering its structure, effectively stopping the biochemical process.

INDUCTION = ACTIVATE

Helps the enzyme work.

➡ Starts or increases the reaction.

Example: Lactose inducing enzyme production in bacteria.



INHIBITION = STOP

Blocks the enzyme's action.

➡ Stops or decreases the reaction.

Example: Antibiotics inhibiting bacterial enzymes.



Ready for the Challenge?

Test Your Understanding

Chapter 1



Scan the QR code
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Chapter 2

CELLS



This is a single cell.
Cells can increase in number.
One cell can become many cells.
This means cells can **PROLIFERATE**.



WHAT DOES PROLIFERATE ACTUALLY MEAN?

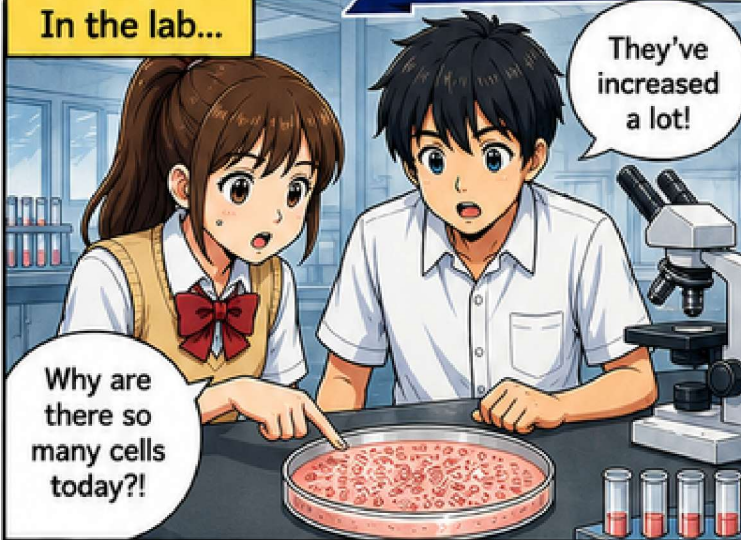


CELLS IN ACTION: GROWING, DIVIDING, THRIVING!



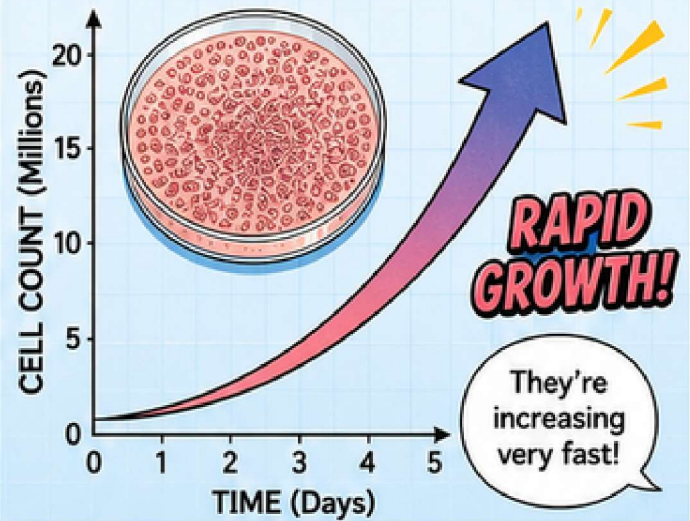
More cells, more life — growth happens every day!

In the lab...

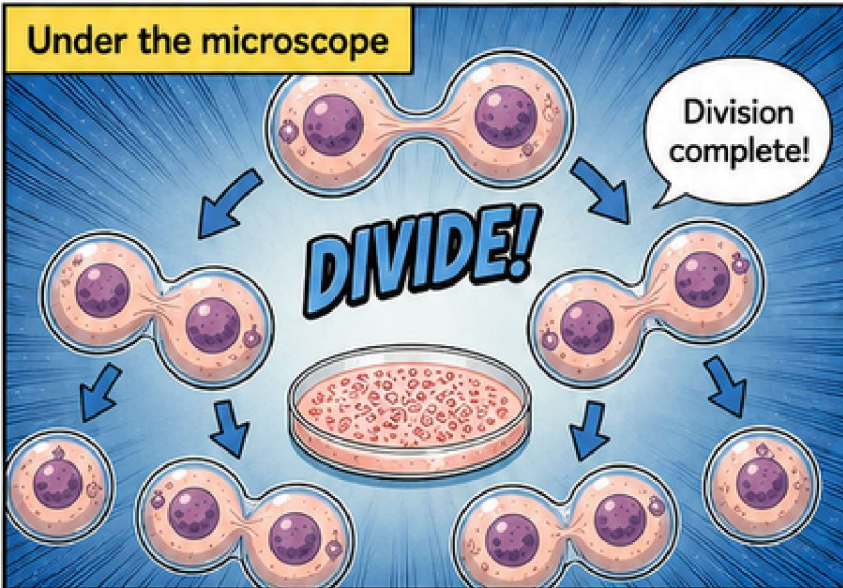


They've increased a lot!

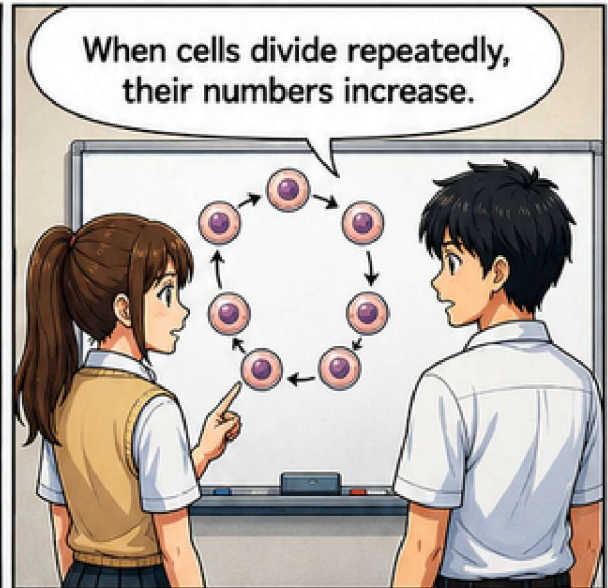
Why are there so many cells today?!



Under the microscope



When cells divide repeatedly, their numbers increase.



What do we call this rapid increase?

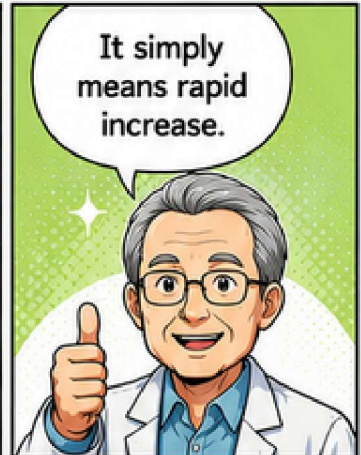


When cells increase quickly in number, number, they **PROLIFERATE**.

PROLIFERATE!



It simply means rapid increase.



Cells **divide** to increase in number. This process is called **proliferation** — the key to growth, healing, and life!



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WHAT DOES PROLIFERATE MEAN?

“Cells proliferate”

simply means:

Cells increase in number.

Cells multiply quickly.

LOOK AT THIS EXAMPLE!



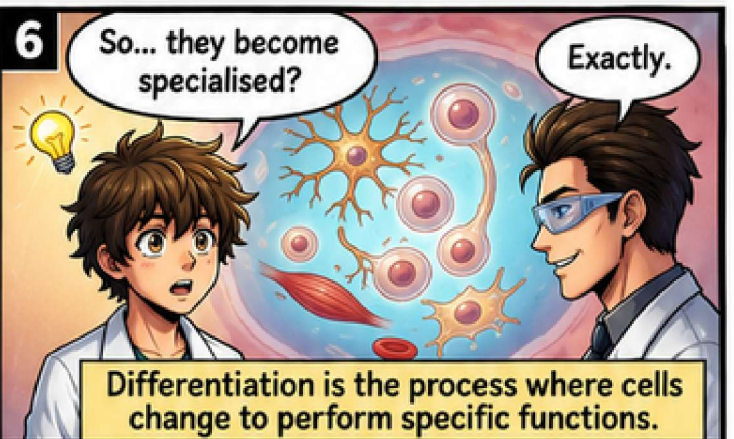
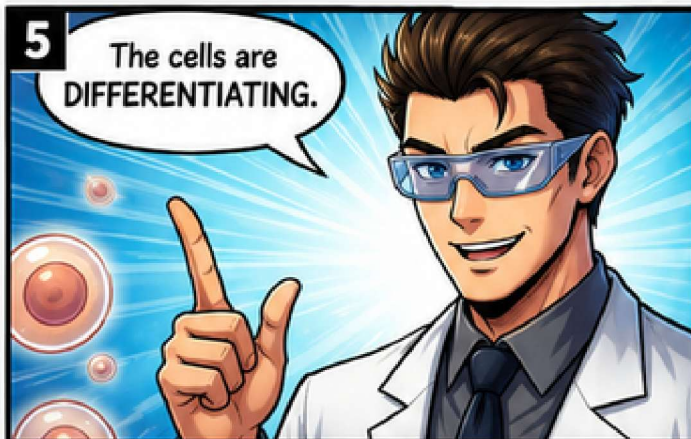
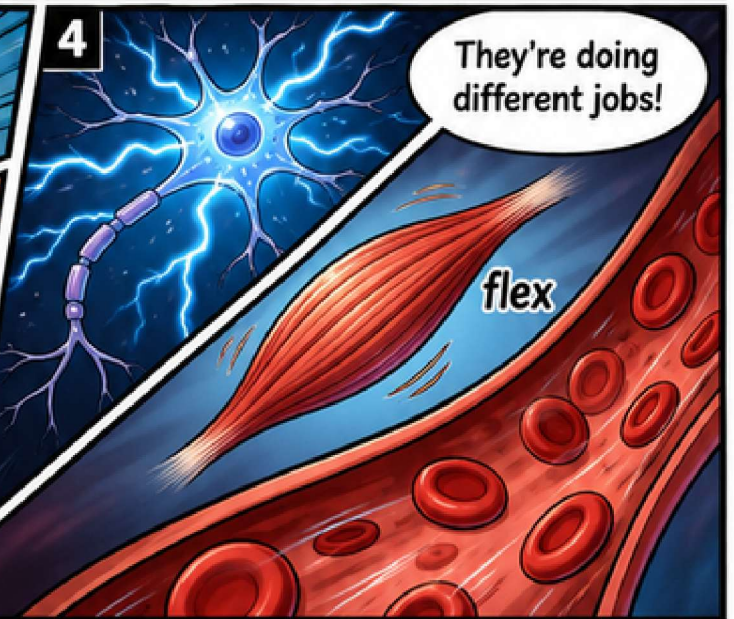
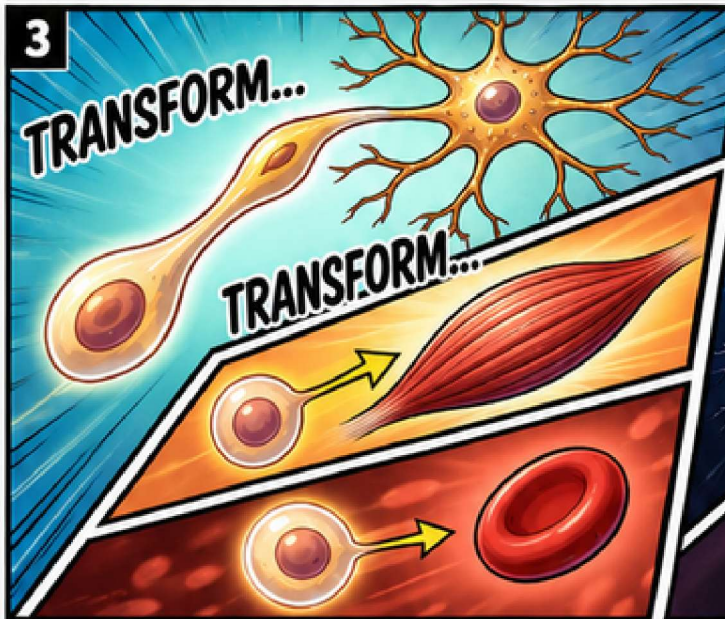
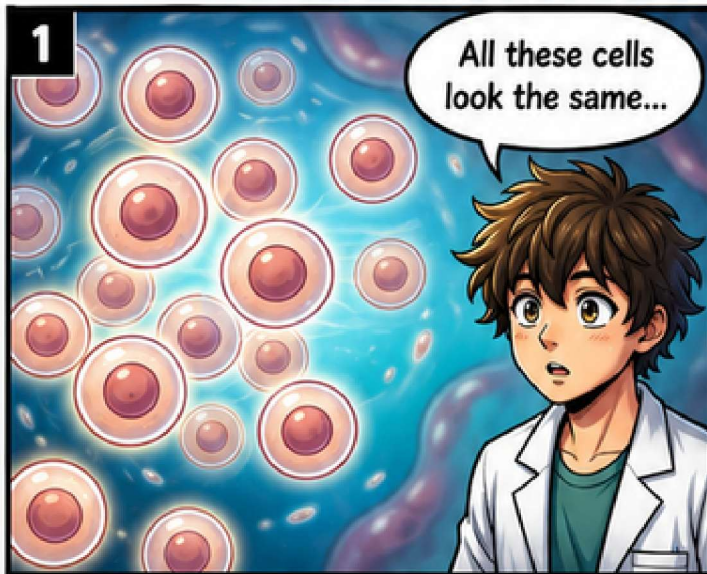
Cancer cells proliferate uncontrollably.

simply means:

Cancer cells multiply rapidly.

THE AMAZING CELL TRANSFORMATION!

Cells can change shape, function, and specialize to do amazing things!



From identical cells to incredible functions — that's the power of differentiation!



ARTIVIVE

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Cells can increase in number.
But cells can also change.
One cell can become different types of cells.
Cells can **DIFFERENTIATE**.



WHAT DOES DIFFERENTIATE MEAN?

“Cells differentiate”
simply means

Cells become different types of cells (e.g. nerve, muscle, blood).
Cells become specialised.

LOOK AT THIS EXAMPLE!

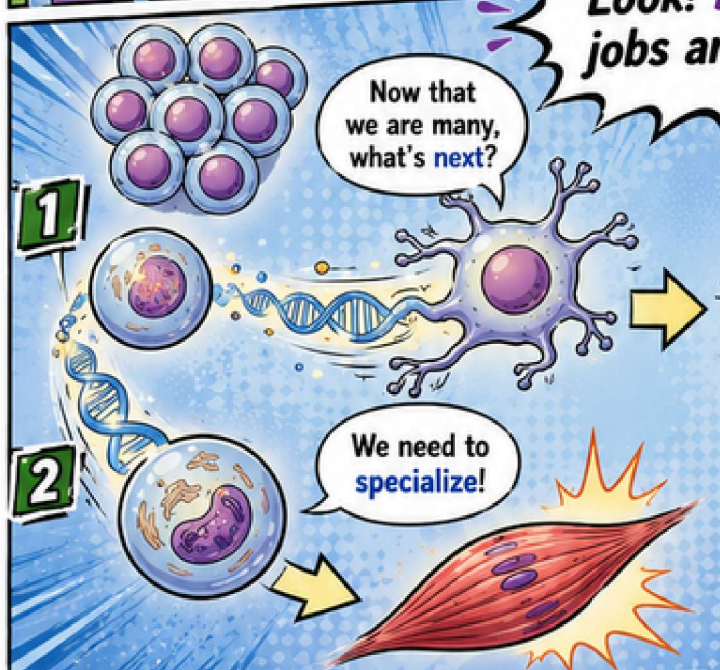
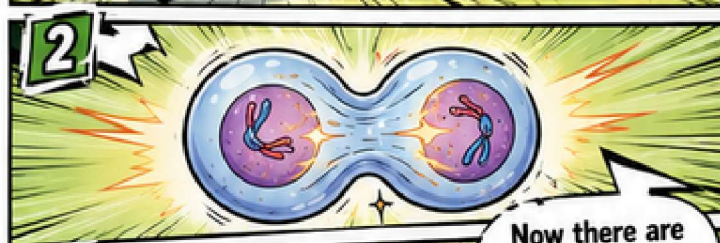


Stem cells differentiate into specialised cells.
simply means:

Stem cells become different types of cells.

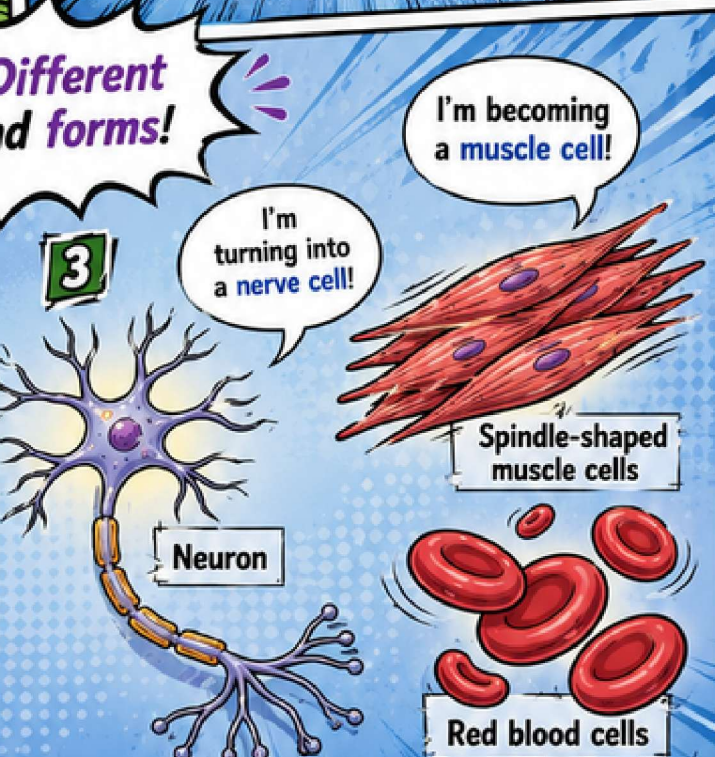
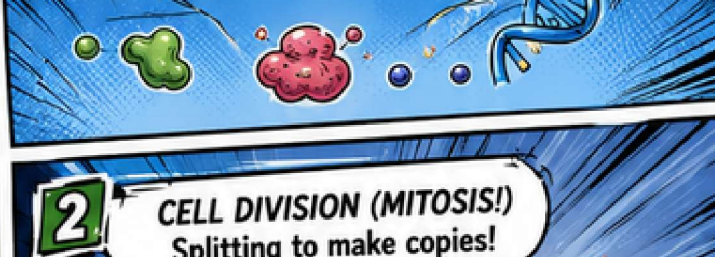
Let's Compare the Words?

PROLIFERATE: Cell Division & Growth

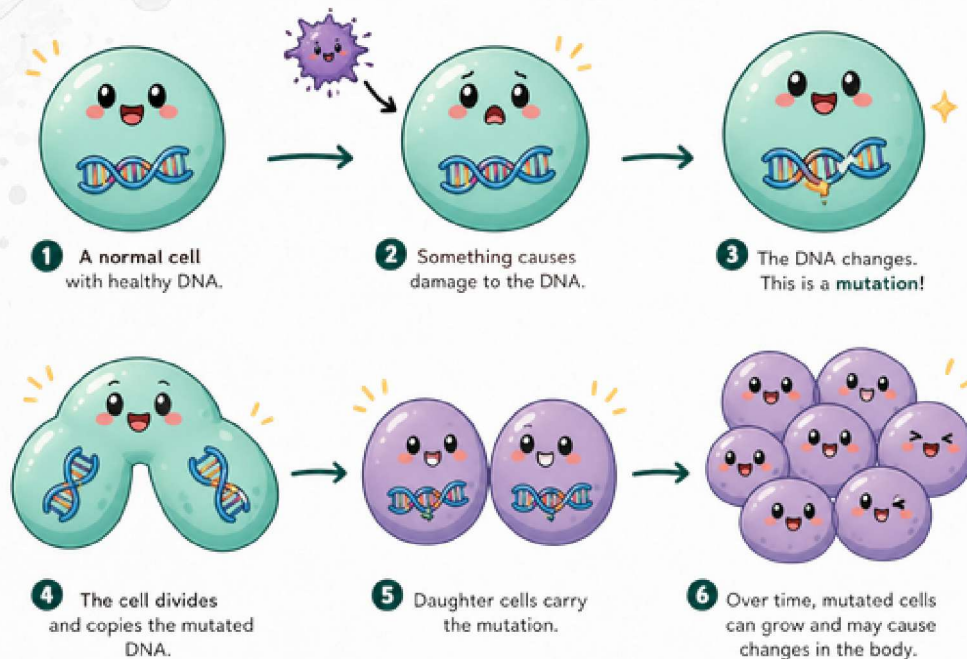


CELL PROLIFERATION: The process by which cells increase in number through cell division. One parent cell creates many identical daughter cells for **growth and tissue repair**.

DIFFERENTIATE: Cell Specialization & Maturation



CELL DIFFERENTIATION: The process where cells change from simple types to **specialized** types with specific functions. Controlled by gene expression, cells acquire **unique features** (e.g., nerve, muscle, blood) for complex functions.



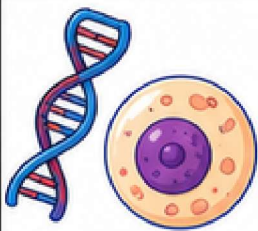
Cells can increase in number.
Cells can become specialised.
But sometimes... something changes inside the cell.

The genetic material can change.

Cells can **MUTATE**.



WHAT DOES MUTATE MEAN?

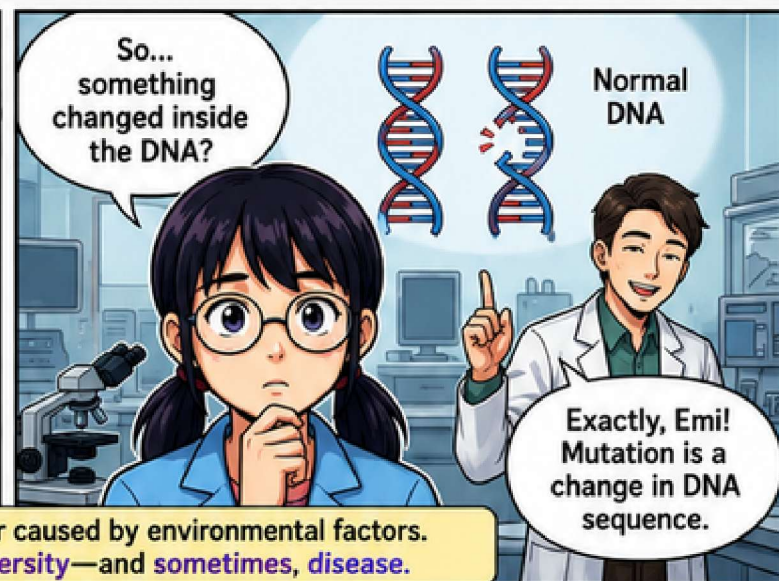
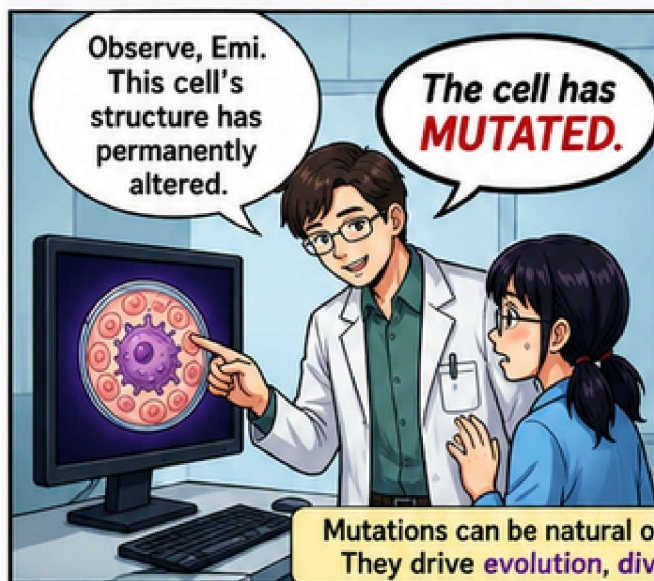
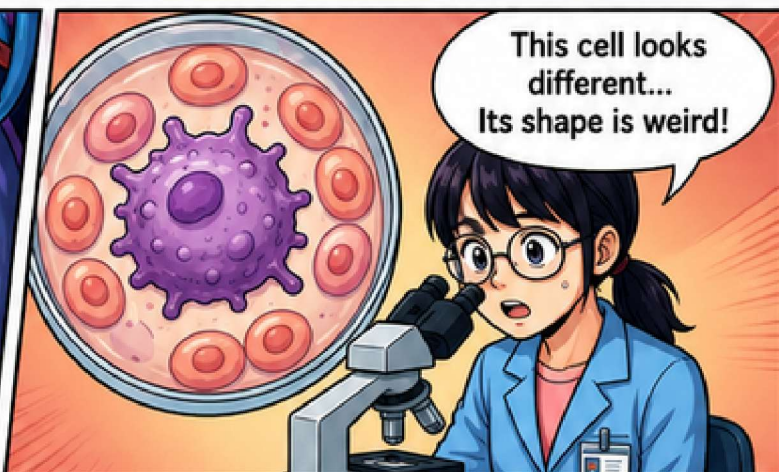
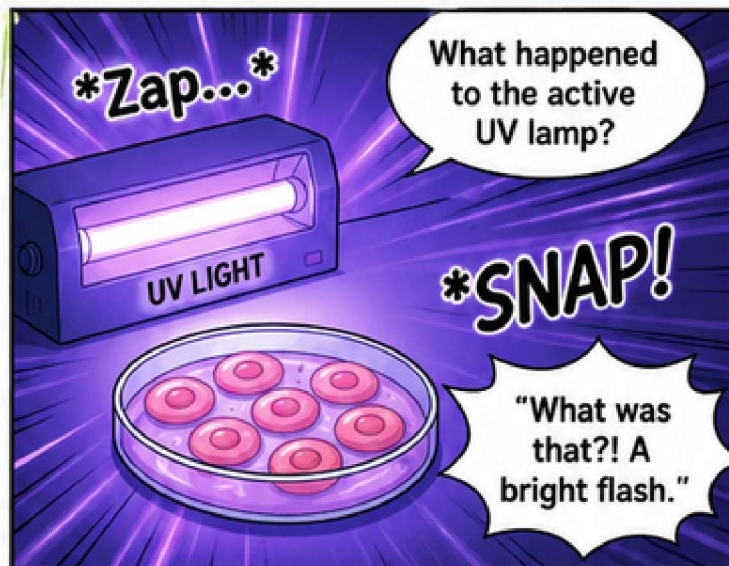
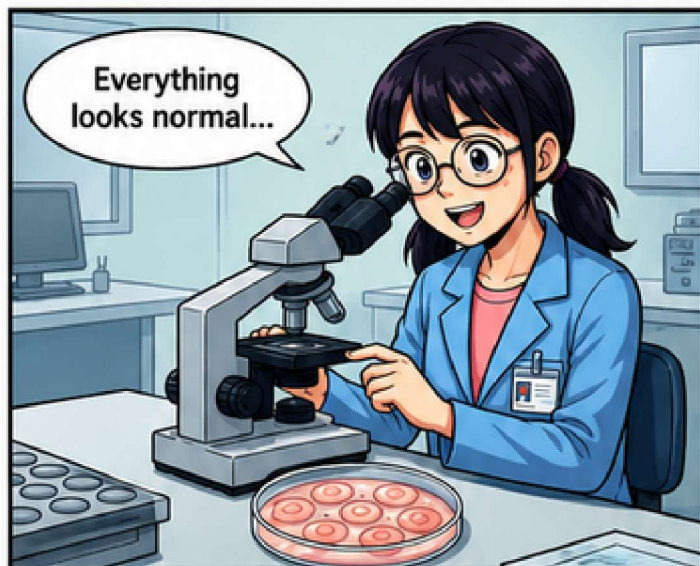


MUTATION:

When Cells Change Forever



Sometimes, a tiny change can make a **big difference**.



Mutations can be natural or caused by environmental factors. They drive **evolution**, **diversity**—and **sometimes, disease**.



WHAT DOES MUTATE MEAN?

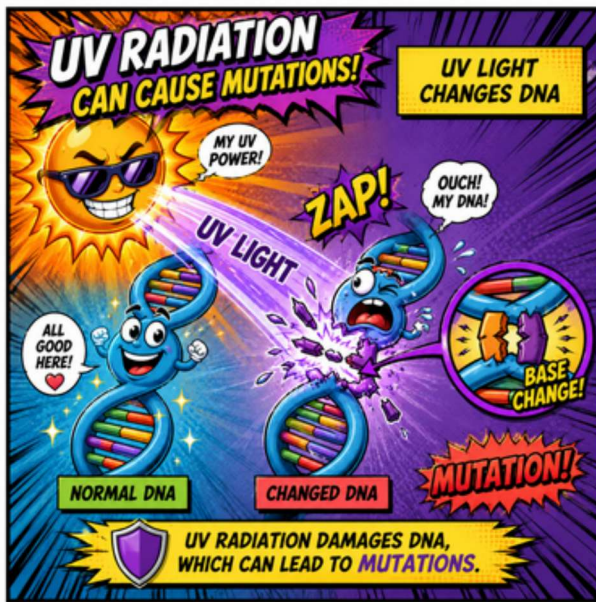
“Cell mutates”

simply means:

The cell's DNA changes.

The genetic material is altered.

LOOK AT THIS EXAMPLE!



UV radiation can cause mutations.

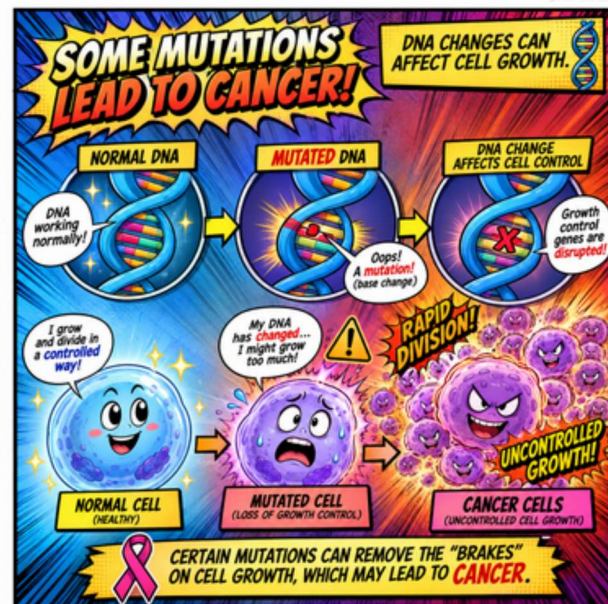
simply means:

UV light changes DNA.

Some mutations lead to cancer.

simply means:

DNA changes can affect cell growth.





Ready for the Challenge?

Test Your Understanding

Chapter 2



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QUIZ



DNA

DNA

DEOXYRIBONUCLEIC ACID

The master blueprint that stores all genetic instructions.

BASE PAIRS

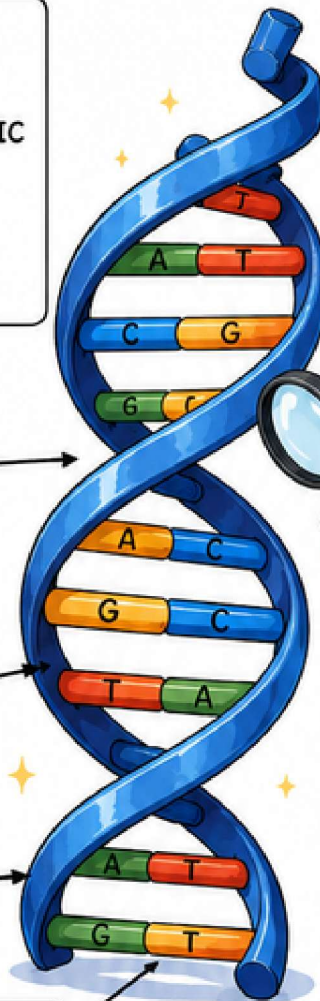
A pairs with T
C pairs with G

SUGAR-PHOSPHATE BACKBONE

DOUBLE HELIX

NUCLEOBASES
A, T, C, G

DNA stores all the important instructions!



This is DNA.

It is double-stranded.

DNA stores genetic instructions.

It contains the bases A, T, C, and G.

The order of these bases carries information.

This means DNA can be **TRANSCRIBED** to produce RNA.

This DNA is called the **template strand**.



WHAT IS DNA MADE OF?

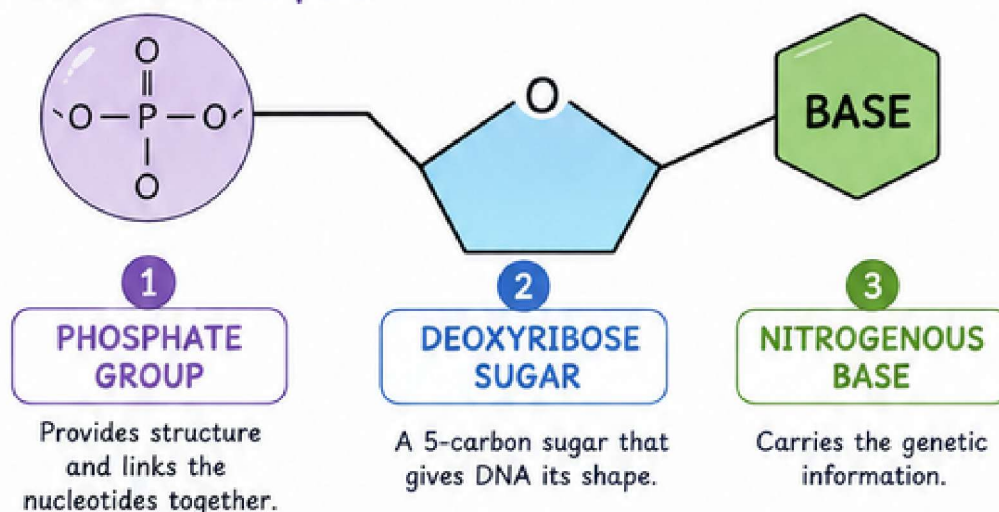
WHAT IS DNA MADE OF?

DNA is made of many small units called **NUCLEOTIDES**.



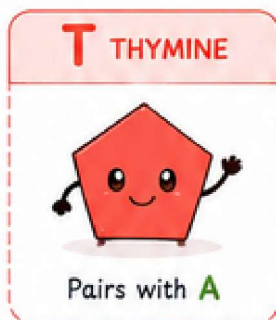
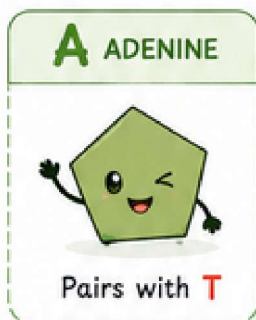
Think of nucleotides as the **building blocks** of DNA!

Each nucleotide has **3 parts**:



THE 4 NITROGENOUS BASES IN DNA

There are four types of bases.
We remember them as:



★ MUST REMEMBER

- DNA is made of nucleotides.
- Each nucleotide has 3 parts: phosphate group, deoxyribose sugar, and a nitrogenous base.
- There are 4 bases in DNA: **A**, **T**, **C**, and **G**.



◆◆◆
WHICH DNA BASES PAIR TOGETHER?

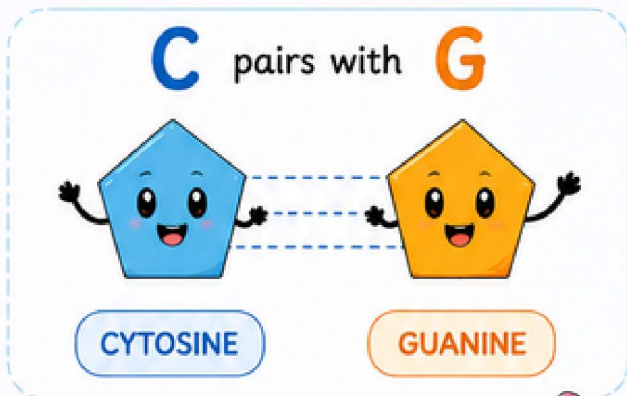
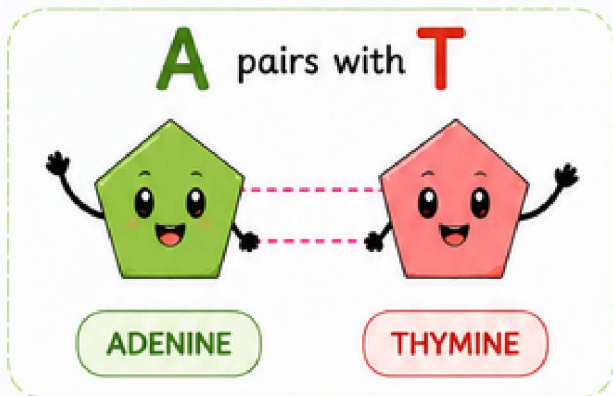
THE BASE-PAIRING RULE

DNA has a special rule.
The bases **always** pair in a specific way.



This rule helps DNA stay strong and makes copying possible!

1. BASES PAIR LIKE THIS:



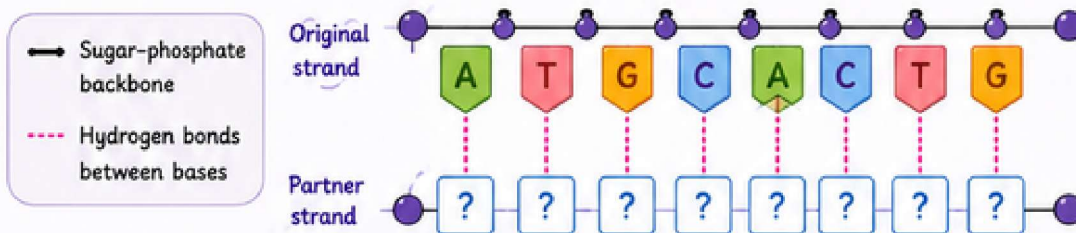
So, the base-pairing rule is:

A ↔ **T** and **C** ↔ **G**

Remember:
Always
A with T,
C with G!

2. COMPLETE THE PARTNER STRAND!

Fill in the missing bases using the base-pairing rule.



Answers

1. **T**
2. **A**
3. **C**
4. **G**
5. **T**
6. **G**
7. **A**
8. **C**

3. WHY IS THIS RULE IMPORTANT?



It keeps DNA stable.

The correct pairing holds the two strands strong together.



It allows DNA to be copied accurately.

Each strand can guide the correct partner bases.



This is how DNA can pass important information to new cells and new organisms!



WHAT SHAPE IS FORMED WHEN
THE TWO DNA STRANDS COME TOGETHER?



THE DNA DOUBLE HELIX

Many nucleotides join together to form long **strands** of DNA.

Two complementary strands twist around each other to form a **double helix**.



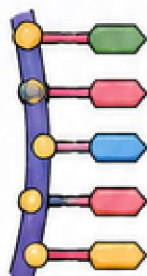
Let's see how the pieces come together to **build DNA!**

1. NUCLEOTIDE



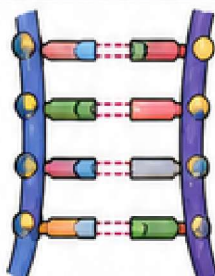
The basic unit of DNA.

2. DNA STRAND



Many nucleotides link together to form a DNA strand.

3. TWO STRANDS



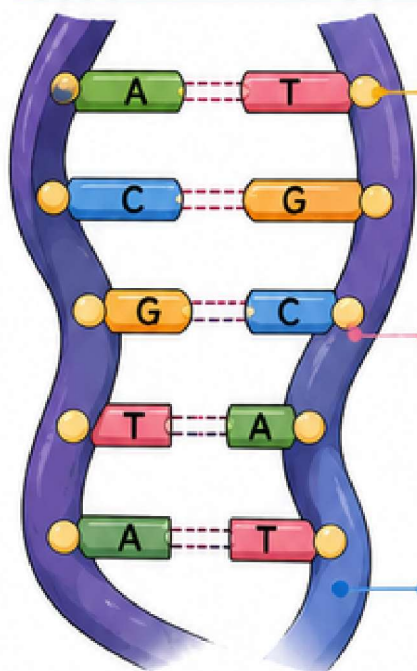
Two complementary strands pair up using base-pairing rules (A-T and C-G).

4. DOUBLE HELIX



The two strands twist around each other to form a **DOUBLE HELIX!**

THE TWISTED LADDER ANALOGY



SIDES OF THE LADDER

Sugar-phosphate backbone

Strong and stable.
Protects the DNA.

STEPS OF THE LADDER

Nitrogenous base pairs
Joined by hydrogen bonds.

A pairs with **T**
C pairs with **G**

THE WHOLE LADDER

Twisted ladder
This twisted shape is called the **DOUBLE HELIX**.



MUST REMEMBER!

2



DNA has two strands.
They are **complementary**.



The strands twist to form a **double helix**.



The sugar-phosphate backbone forms the **outside**.



The base pairs are found **inside**.



FUN FACT!

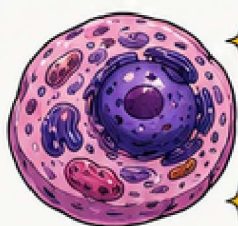
If we stretched all the DNA in one human cell, it would be about **2 meters long!**



THINK AND WONDER!

Where is DNA found **inside the cell?**





DNA THE STORY

DISCOVER THE INCREDIBLE MOLECULE OF **LIFE!**



1

Wow! What's this long, twisted thing inside the nucleus?!

It's DNA!
The molecule that stores all the instructions for life!

2

DNA is made of small units called **NUCLEOTIDES**.

Each nucleotide has 3 parts:

- P** – Phosphate (P)
- S** – Deoxyribose sugar (S)
- N** – Nitrogenous base (A, T, C, G)

There are four bases: **A, T, C and G!**

3

But the bases don't pair randomly! There's a rule!

A pairs with **T**

C pairs with **G**

This special rule is called the **BASE-PAIRING RULE!**

4

These base pairs hold the two strands together like the steps of a ladder.

The outside (backbone) is made of **sugar** and **phosphate!**

When two strands twist together, they form a **DOUBLE HELIX!**

5

DNA is super long (about **2 metres** in one human cell!), but it can fit inside the nucleus!

It is tightly packed and organized so it can be stored safely.

6

DNA is like a master instruction book.

- ✓ It stores instructions.
- ✓ It can be copied accurately.
- ✓ It is stable and protected.

That's why DNA is so important — it keeps life running!



DNA is a long, twisted molecule made of nucleotides. Its base-pairing rule (**A-T** and **C-G**) and double helix structure help **store** and **protect** the instructions for **life**.



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Ready for the Challenge?

Test Your Understanding

Chapter 3



Scan the QR code
to begin!

or

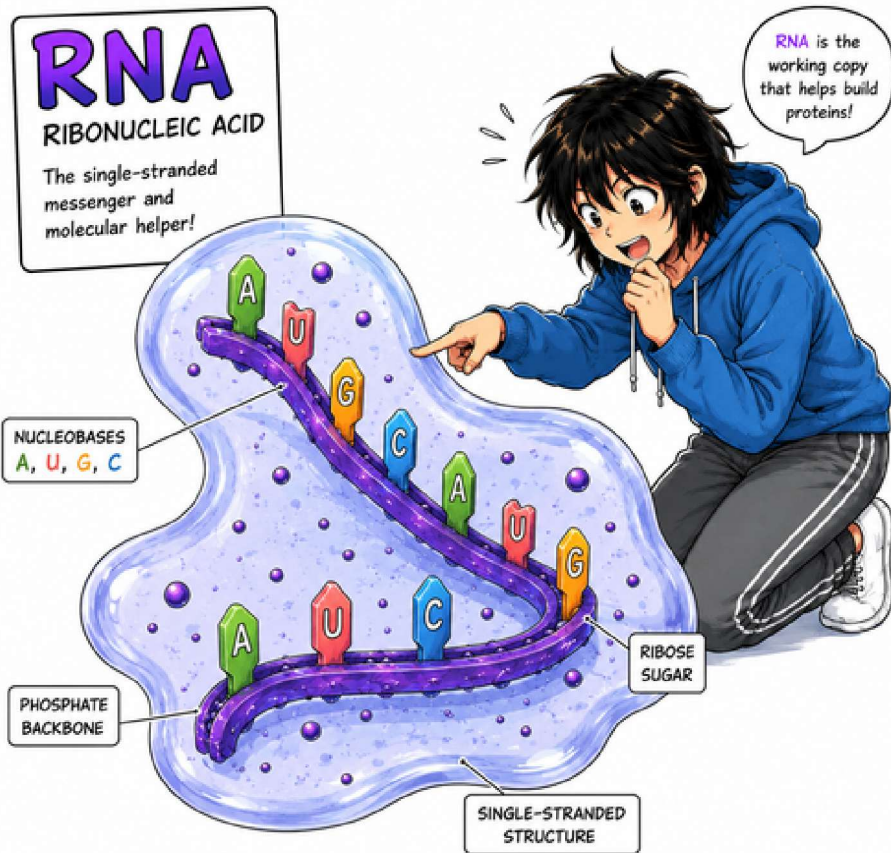
click this button

QUIZ



Chapter 4

RNA



This is RNA.

It is single-stranded.

RNA contains the bases **A**, **U**, **C** and **G**.

RNA helps cells use information from DNA.

It helps cells make **proteins**.

Different types of RNA have different jobs.



WHAT MAKES AN RNA NUCLEOTIDE?

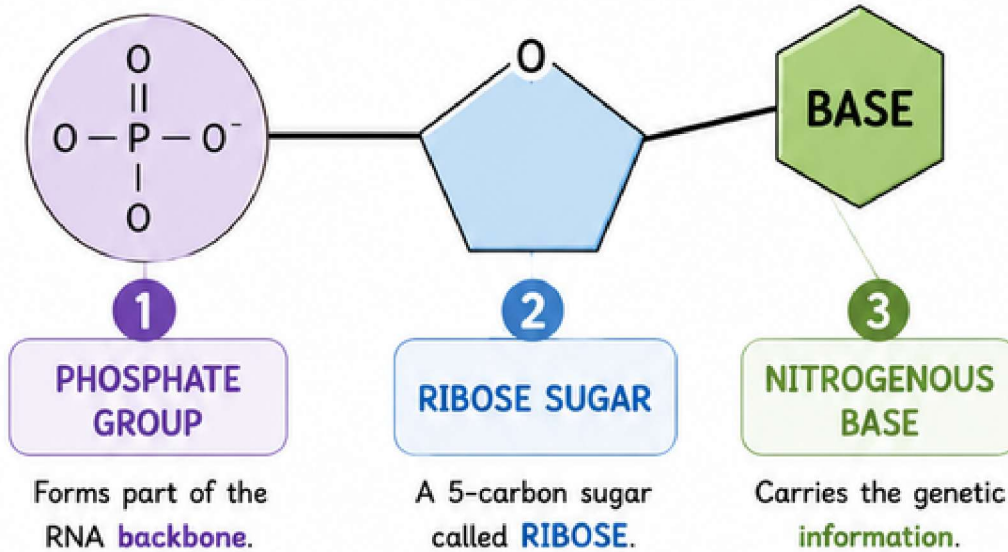
★ WHAT IS RNA MADE OF? ★

RNA is made of many small units called **NUCLEOTIDES**.



Each nucleotide is like a **building block** of RNA!

Each nucleotide has **3 parts**:



THE 4 NITROGENOUS BASES IN RNA

There are four types of bases:

A ADENINE	U URACIL	C CYTOSINE	G GUANINE
			
Pairs with U	Pairs with A	Pairs with G	Pairs with C



MUST REMEMBER!

- **RNA** is made of nucleotides.
- Each nucleotide has 3 parts: phosphate group, ribose sugar and a nitrogenous base.
- The 4 RNA bases are **A**, **U**, **C** and **G**.



◆
HOW IS RNA DIFFERENT FROM DNA?

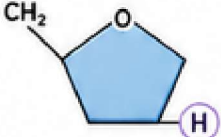
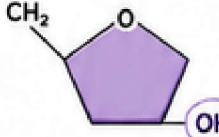


HOW IS RNA DIFFERENT FROM DNA?

Let's compare
RNA and **DNA**
side by side!



RNA and DNA are **similar**,
but there are some **important differences**.

FEATURE	DNA	RNA
 Structure	Double-stranded  (like a ladder)	Single-stranded  (like a single line)
 Sugar	Deoxyribose  (lacks one oxygen)	Ribose  (has one extra oxygen)
 Nitrogenous Bases	A, T, C and G (uses THYMINE)	A, U, C and G (uses URACIL)
 Location	Mainly in the nucleus of the cell. 	In the nucleus and also in the cytoplasm .  ← cytoplasm
 Function	Stores genetic information .	Helps use the information from DNA to make proteins .



MUST REMEMBER!

- **DNA** is double-stranded.
- **RNA** is single-stranded.
- DNA has **deoxyribose** and thymine (**T**).
- RNA has **ribose** and **uracil** (**U**).
- RNA helps make **proteins**.



Remember:

DNA stores the information.
RNA uses the information.



Together, they help
build life!



WHAT ARE THE DIFFERENT TYPES OF RNA
AND WHAT ARE THEIR JOBS?





RNA comes in different types. Each has a special job in the cell!

WHAT ARE THE DIFFERENT TYPES OF RNA?

There are 3 main types of RNA. They work together to make **proteins**!

Remember!

All types of RNA help use the information from **DNA** to make **proteins**.

1 mRNA (messenger RNA)



mRNA is like a "message" copied from DNA.

JOB:

Carries the **genetic** information from **DNA** in the nucleus to the **ribosome** in the cytoplasm.

LOOKS LIKE:



A long, single-stranded molecule.

2 tRNA (transfer RNA)

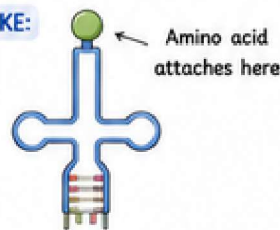


tRNA acts like a "delivery person".

JOB:

Brings the correct **amino acid** to the ribosome based on the message in **mRNA**.

LOOKS LIKE:



A cloverleaf shape.

3 rRNA (ribosomal RNA)



rRNA is a main part of the **ribosome**.

JOB:

Forms the ribosome and helps join amino acids together to build a **protein**.

LOOKS LIKE:



A folded, complex molecule.



EASY WAY TO REMEMBER!

mRNA = **Message**

tRNA = **Transfer** (delivers amino acids)

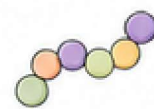
rRNA = **Ribosome** (forms the machine)



DNA is transcribed to **mRNA**.



tRNA brings amino acids to the **ribosome**.



rRNA helps join amino acids to make a **protein**!



KEY POINT

mRNA carries the message, **tRNA** delivers the amino acids, and **rRNA** builds the ribosome. Together, they make **proteins**!



CAN YOU MATCH EACH TYPE OF RNA TO ITS JOB?





Let's follow the journey of making a **protein**!

HOW DO THE 3 TYPES OF RNA WORK TOGETHER?

They all have different jobs, but they work as a **TEAM** to make a **protein**!

Remember!

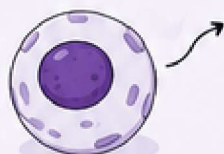
mRNA = message
tRNA = transfer
rRNA = ribosome

1 THE MESSAGE

mRNA carries the message copied from **DNA**.

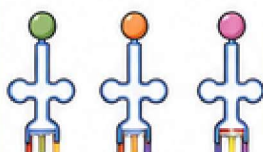


It moves out of the nucleus to the cytoplasm.

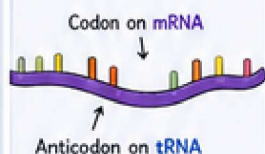


2 THE DELIVERY

tRNA brings the correct **amino acids** to the ribosome.



Each **tRNA** has an **anticodon** that matches the **codon** on **mRNA**.

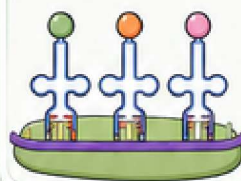


3 THE MACHINE

rRNA forms the **ribosome**, where **proteins** are made.

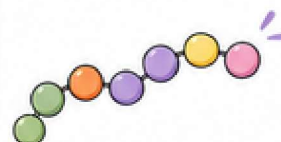


The ribosome holds **mRNA** and **tRNA** together.



4 THE PROTEIN

Amino acids are joined together in the ribosome to make a **protein**.



The protein is released and goes on to do important jobs in the cell!



THE BIG PICTURE

DNA



Information is stored in **DNA** in the nucleus.

mRNA



mRNA is made from DNA and carries the message out.

rRNA



rRNA builds the **ribosome** (the protein-making machine).

tRNA



tRNA brings the right amino acids to the ribosome.

PROTEIN



Amino acids are joined together to make a **protein**!

DID YOU KNOW?

- There are many **mRNAs**, but only 3 main types of **RNAs**!
- rRNA** is the most abundant type of **RNA** in the cell.
- Without these 3, cells cannot make **proteins** and **life cannot exist**!

QUICK SUMMARY

TYPE	NICKNAME	MAIN JOB
mRNA 	The Message	Carries the genetic message from DNA .
tRNA 	The Delivery	Brings amino acids to the ribosome.
rRNA 	The Machine	Forms the ribosome and helps build proteins.



CAN YOU PUT THESE STEPS IN THE CORRECT ORDER?





THE RNA STORY



FOLLOW THE JOURNEY FROM **DNA** TO **PROTEIN**!

1 WHAT IS RNA?



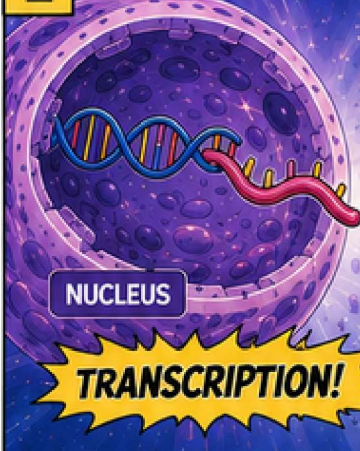
Why do we need RNA?

I'm RNA!
I'm a single-stranded molecule.



My job is to carry the **message** from DNA and help make **proteins**!

2 WHERE AM I MADE?



NUCLEUS

TRANSCRIPTION!

I'm made in the nucleus by a process called...



3 THE 3 MAIN TYPES OF RNA!

mRNA
(messenger RNA)



Carries the message from DNA to the ribosome.



tRNA
(transfer RNA)



Brings the right amino acids to the ribosome.



rRNA
(ribosomal RNA)



Forms the ribosome and helps put everything together.



4 TEAMWORK TIME!

mRNA brings the message. tRNA brings the amino acids. rRNA builds the ribosome.

Here's the message!



mRNA

I've got the amino acids!



tRNA

Let's build that protein!



rRNA

5 FROM MESSAGE TO PROTEIN!

mRNA arrives at the ribosome.



tRNA brings amino acids.



rRNA helps join them together.



A **protein** is formed!



6 THE JOURNEY OF RNA!

DNA holds the instructions.



NUCLEUS

RNA is made by transcription.



IN NUCLEUS

RNA leaves the nucleus.



THROUGH PORE

RNA goes to the cytoplasm.



CYTOPLASM

RNA helps make proteins!



And that's how **RNA** helps build everything in your body — from **muscles** to **enzymes**.



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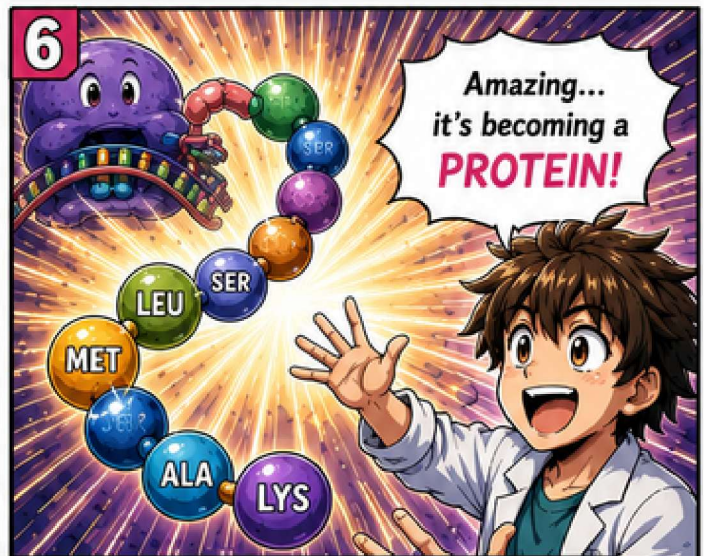
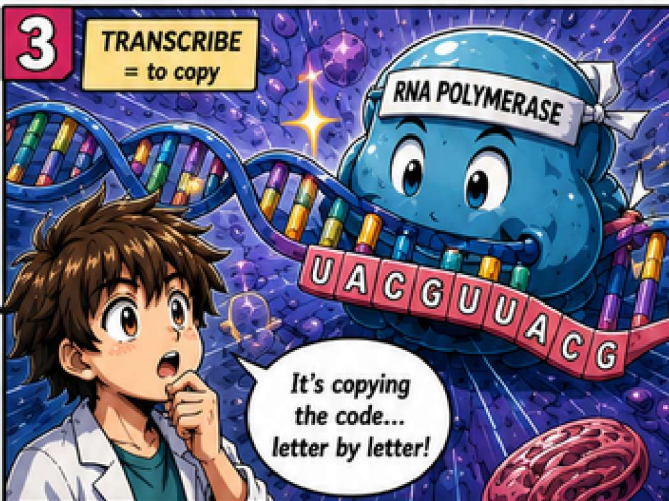




THE RNA STORY



FOLLOW THE JOURNEY FROM **DNA** TO **PROTEIN**!



And that's how **RNA** helps build everything in your body —
from **muscles** to **enzymes**.



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Let's see how
DNA's message
is copied into
RNA!

WHERE DID RNA COME FROM?

RNA is made in a process called
TRANSCRIPTION.

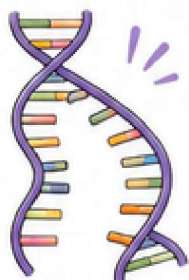
Think of RNA
as a **copy** of the
DNA message!



THE TRANSCRIPTION PROCESS

1 DNA UNWINDS

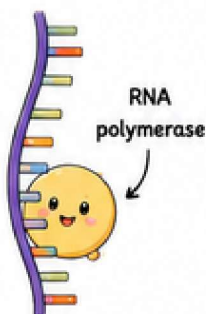
The DNA double helix **unwinds** and opens up.



The enzyme **RNA polymerase** attaches to the DNA.

2 READING THE TEMPLATE

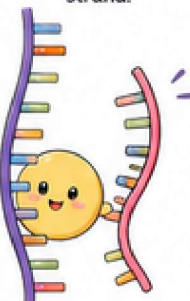
RNA polymerase reads one strand of DNA **template**.



It reads the bases in order, one by one.

3 BUILDING RNA

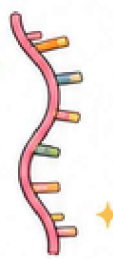
Complementary **RNA** nucleotides are added to build the **RNA** strand.



A - U
T - A
C - G
G - C

4 RNA RELEASED

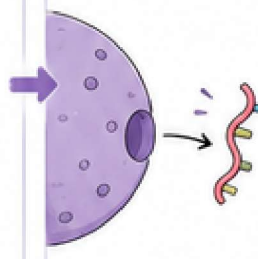
The RNA strand is complete and is **released**.



The new RNA leaves the nucleus through **nuclear pores**.

5 GOES TO THE CYTOPLASM

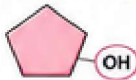
RNA goes to the **cytoplasm** to do its job!



It will join the ribosome to help make **proteins**.



DNA vs RNA

DNA	RNA
Stays in the nucleus. 	Made in the nucleus, works in the cytoplasm. 
Double-stranded. 	Single-stranded. 
Has deoxyribose sugar. 	Has ribose sugar. 
Contains thymine (T) .	Contains uracil (U) .
Stores genetic information. 	Helps make proteins. 



KEY TAKEAWAY!

- ✓ RNA is made from DNA by a process called **TRANSCRIPTION**.
- ✓ RNA is a **copy** of the DNA message.
- ✓ It leaves the nucleus and goes to the **cytoplasm**.
- ✓ Together with tRNA and rRNA, it helps make **proteins**!

Amazing!
From DNA message
to RNA helper,
to **PROTEIN** maker!



POP QUIZ!

Put the steps of transcription in the correct order.

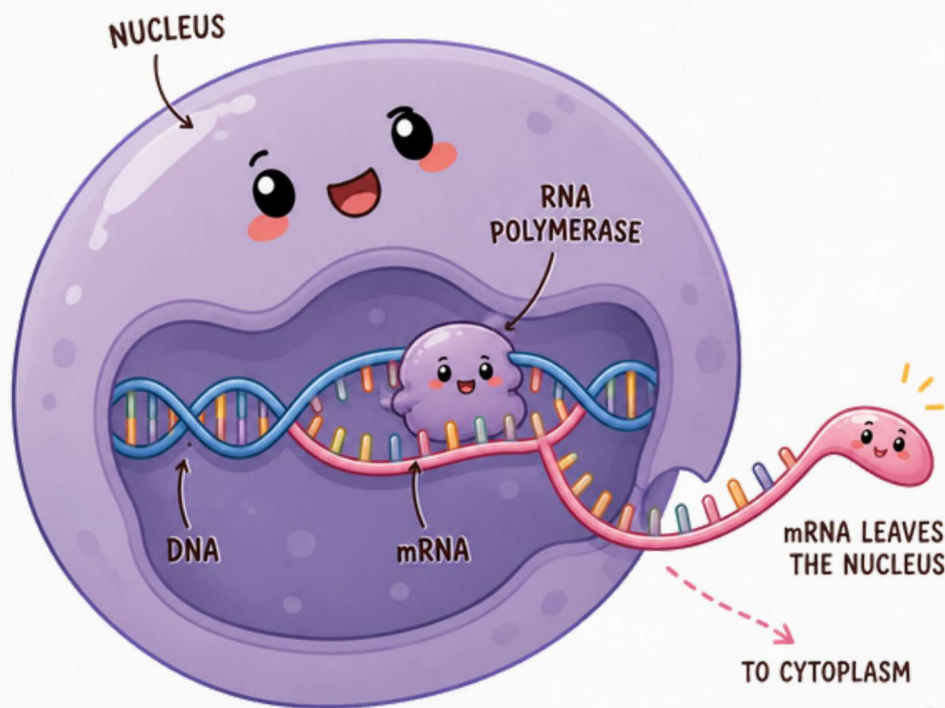
- ☐ RNA is released.
- ☐ RNA goes to the cytoplasm.
- ☐ DNA unwinds.
- ☐ RNA is built.
- ☐ RNA polymerase reads the template.



RNA
Ribonucleic Acid

WHAT DOES TRANSCRIBE MEAN?

“Transcribe”
simply means:
To copy.



mRNA arrives in the cytoplasm.

It meets the ribosome.

The ribosome starts reading the message.

This means mRNA can be **TRANSLATED**.



WHAT DOES TRANSLATE ACTUALLY MEAN?

TRANSCRIBE

Here's the simple idea!

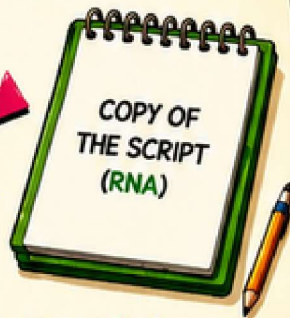
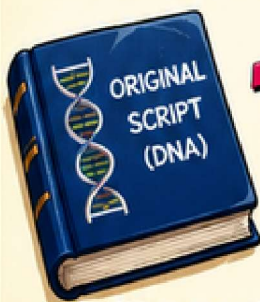
A TERM YOU SHOULD KNOW!

I've heard the word **transcribe***, but what does it mean?

TRANSCRIBE means to make a written or **RNA** copy of genetic information from **DNA**.

THINK OF IT LIKE...

DNA is the **original script** written in the cell.



When something is **transcribed**, it means the information is copied into another form (**RNA**).

IN REAL LIFE...

I listen to my teacher (the original information)...

...then write it down in my own words (the copy).

THAT'S TRANSCRIBE!

THE KEY IDEA

To transcribe is to **convert** information from one form (**DNA**) to another form (**RNA**).



DNA
(original)

TRANSCRIBE



RNA
(copy)

Simple but super important!

IN SHORT...

"TRANSCRIBE
= TO MAKE AN
RNA COPY OF
DNA INFORMATION."

QUICK RECAP

- ✓ It involves copying genetic information.
- ✓ The copy is made in **RNA**.
- ✓ It happens inside cells.



It's how cells get the instructions they need!

One word. Big meaning. Remember: **Transcribe!**



Transcription is the first step in making **proteins** — the building blocks of life!



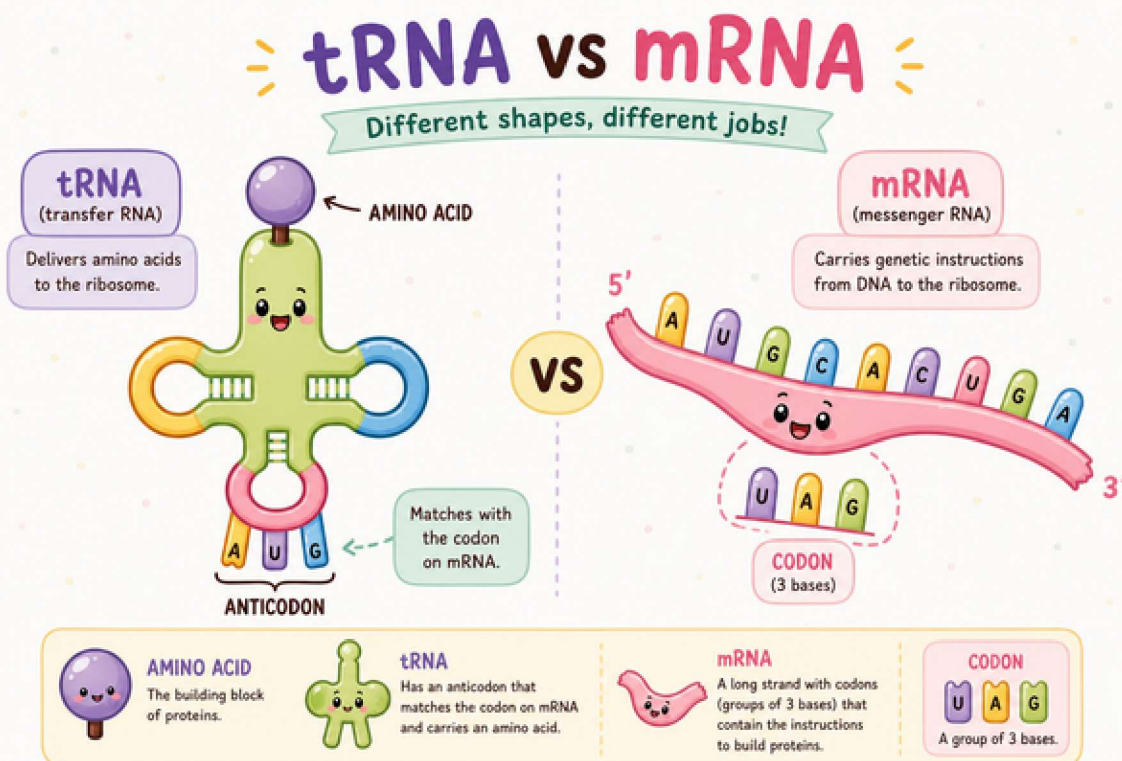
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WHAT DOES TRANSLATE MEAN?

“Translate”
simply means:

To convert into something else.



If mRNA carries the message...
...then another type of RNA, **tRNA**,
carries the amino acids.

tRNA means transfer RNA.
It delivers amino acids to the ribosome.

TRANSLATE!

Let's see how it works!

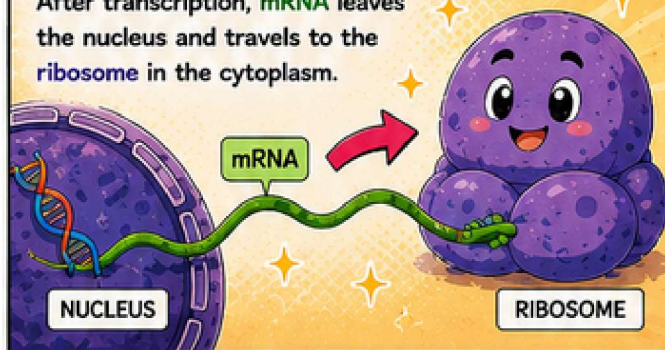
A TERM YOU SHOULD KNOW!

We learned **TRANSCRIBE** (making RNA from DNA). What happens next?

TRANSLATE means the cell uses the **mRNA** code to build a **PROTEIN**!

1. mRNA ARRIVES

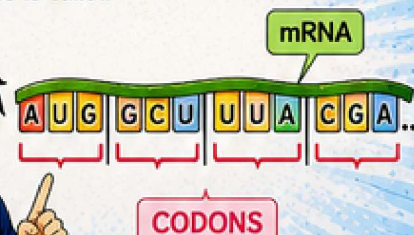
After transcription, **mRNA** leaves the nucleus and travels to the **ribosome** in the cytoplasm.



2. mRNA CODE IS READ

The ribosome reads the **mRNA** three letters at a time. Each three-letter code is called a **CODON**.

Think of codons as words in a sentence!



3. tRNA BRINGS AMINO ACIDS

tRNA molecules bring the right **amino acid** that matches each codon.

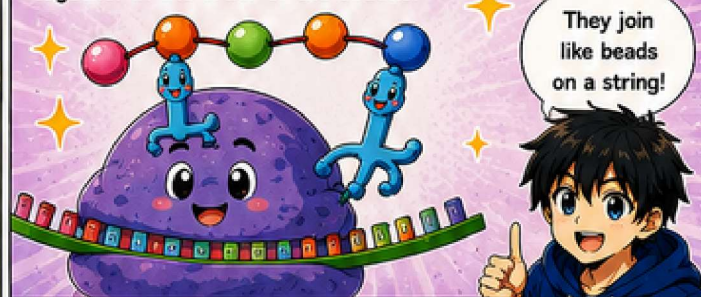
tRNA is like a delivery truck!



4. AMINO ACIDS LINK TOGETHER

The ribosome links the **amino acids** together in the order of the codons.

They join like beads on a string!



5. THE PROTEIN IS MADE!

The chain keeps growing until a **STOP** codon is reached.

When the ribosome sees a stop codon, it releases the new protein!



6. NEW PROTEIN, NEW JOB!

The new protein folds into a shape and goes to work in the cell!



To sum it up...
TRANSLATE =
USE THE **mRNA** CODE
TO BUILD A **PROTEIN**!

QUICK RECAP

- ✓ mRNA brings the code from DNA.
- ✓ The ribosome reads the code (codons).
- ✓ tRNA brings amino acids.
- ✓ Amino acids link together.
- ✓ A new protein is made!

That's how your cells make proteins using the code!



Translation is the next step after transcription — it turns the code into the building blocks that make you **YOU**!

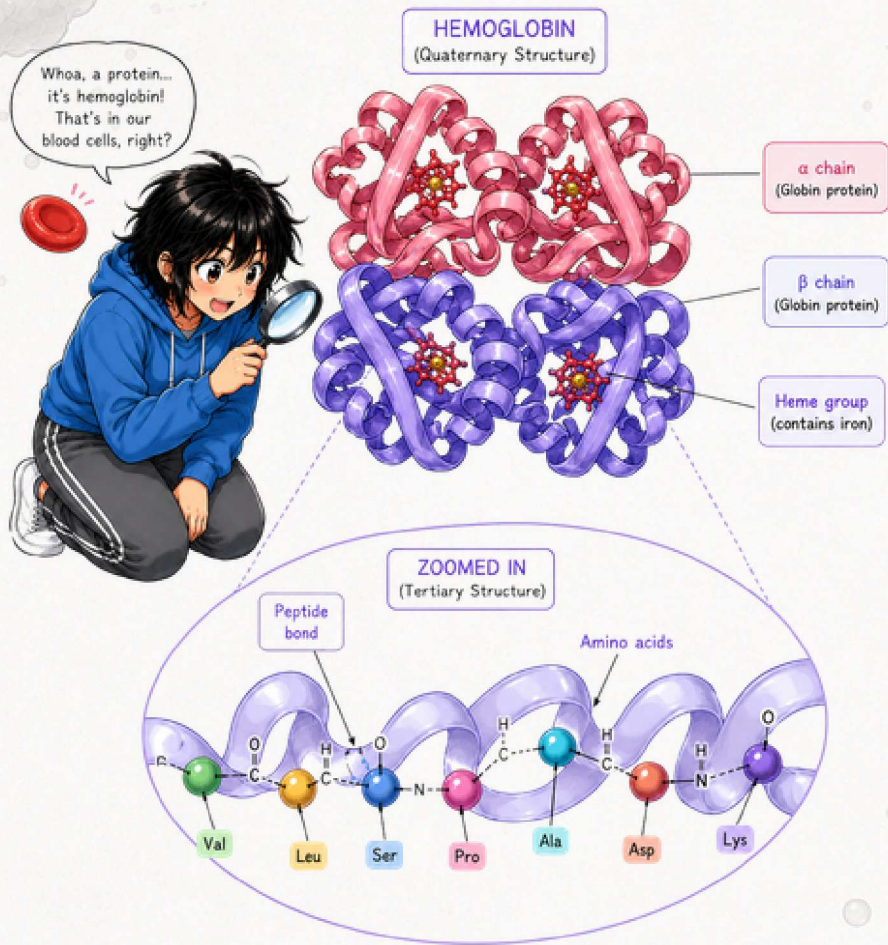


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PROTEINS



This is a protein.
It is made of amino acids.
The amino acids link together in a chain.
Each link is called a peptide bond.
This means amino acids can
POLYMERIZE.



WHAT DOES POLYMERIZE ACTUALLY MEAN?

WHAT DOES POLYMERIZE MEAN?

“Polymerize”

simply means:

To join small units into a long chain.

LOOK AT THIS EXAMPLE!



Amino acids polymerize to form a protein.

simply means:

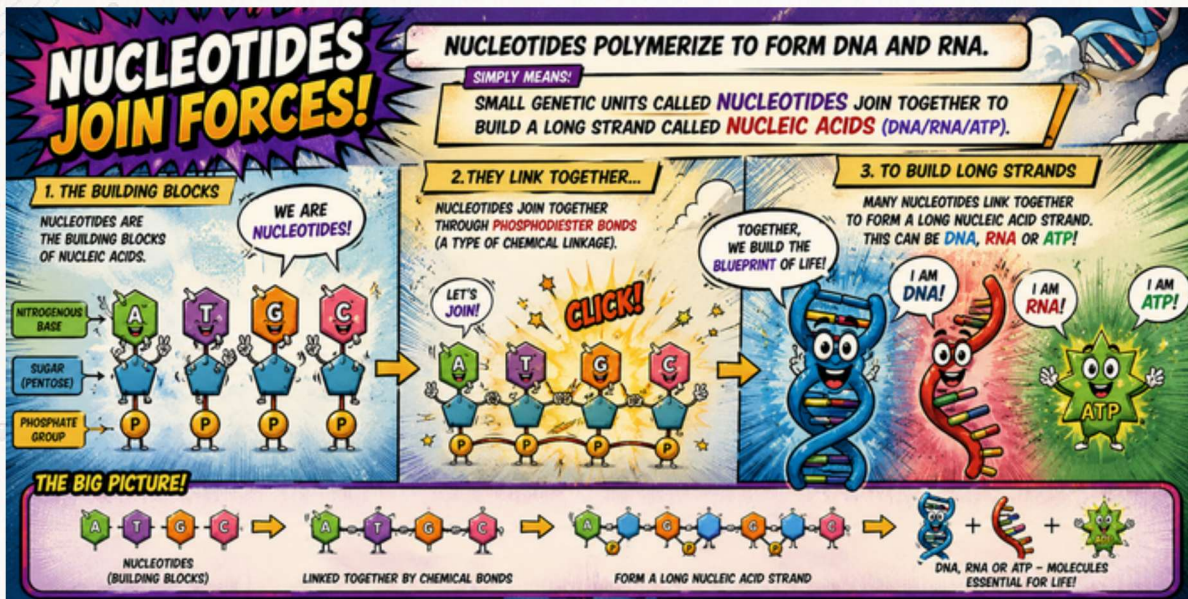
Amino acids link together, one by one, to build a chain.

LET'S LOOK AT OTHER EXAMPLES!

Nucleotides polymerize to form DNA and RNA.

simply means:

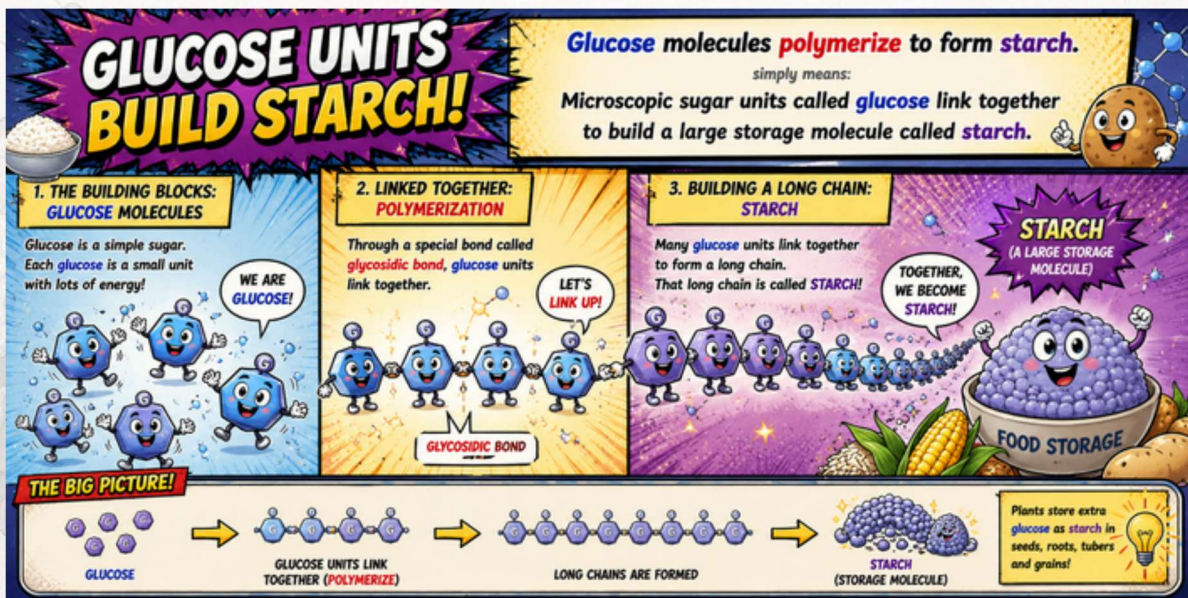
Small genetic units called nucleotides join together to build a long strand called nucleic acids.



Glucose molecules polymerize to form starch.

simply means:

Microscopic sugar units called glucose link together to build a large storage molecule called starch.





BUILDING PROTEINS: AMINO ACIDS POLYMERIZE!

FROM LITTLE MOLECULES TO LIFE'S BIG BUILDERS!

1

What are these little guys doing?

AMINO ACIDS

We're in the CYTOPLASM!

2

Moving closer...

PEPTIDE BOND (forming)

3

SNAP!

ENZYME: PEPTIDE SYNTHASE (in the ribosome)

4

The chain keeps growing!

PEPTIDE BOND (links amino acids together)

5

They're linking together into a **chain**!

Amino acids join, one by one, to build a **protein chain**. This chain will fold and become a **functional protein**!

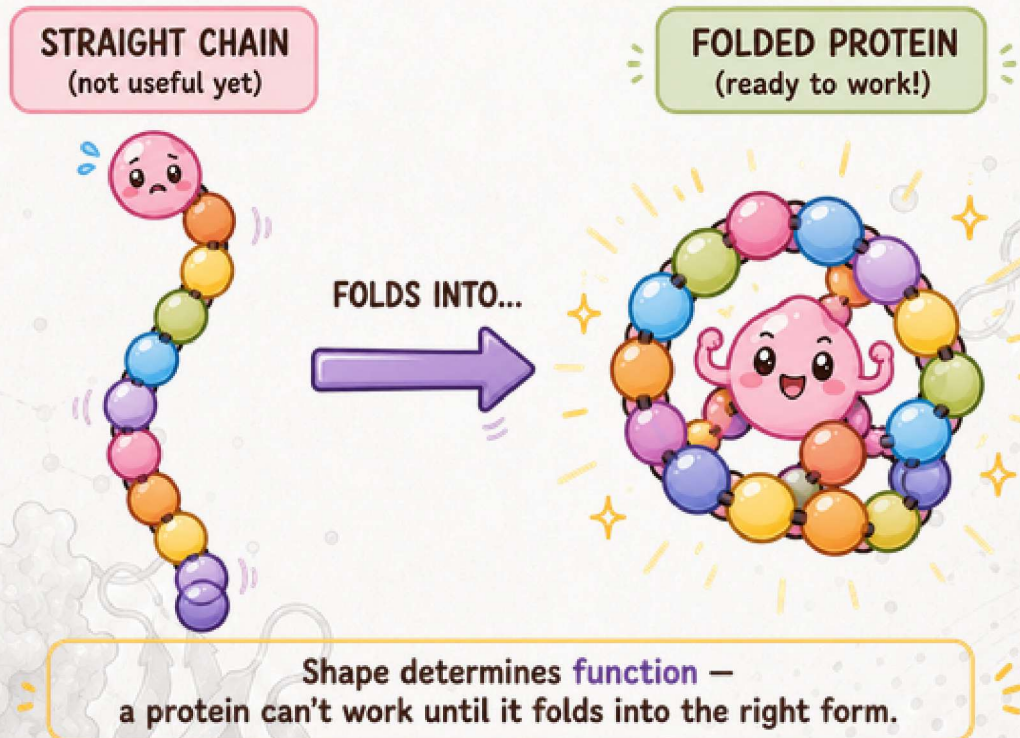
The amino acid chain is formed.
But it's still just a long, floppy string.
It twists and bends into a specific shape.
This means the chain can **FOLD**.

WHAT DOES FOLD ACTUALLY MEAN?

“Fold”

simply means:

To twist and shape into a specific 3D form.



The chain doesn't fold all at once.
It folds in stages, one level at a time.
Each level builds on the one before it.
This means folding has **4 LEVELS**.

WHAT HAPPENS AT EACH LEVEL?

1 PRIMARY STRUCTURE

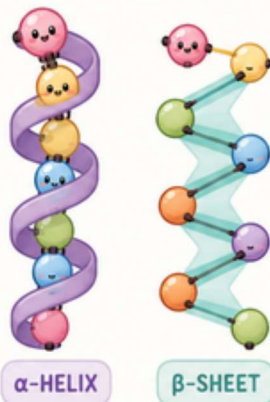
Just the sequence — amino acids in a row



Like letters in a word — order matters!

2 SECONDARY STRUCTURE

Local coiling — spirals (helix) and folds (sheets)



Short local patterns, like curls in hair

3 TERTIARY STRUCTURE

The full 3D shape of one chain



This is usually the 'working shape'

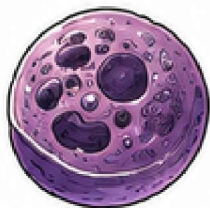
4 QUATERNARY STRUCTURE

Multiple folded chains joining together



Not all proteins need this step — only multi-chain ones (e.g., hemoglobin)

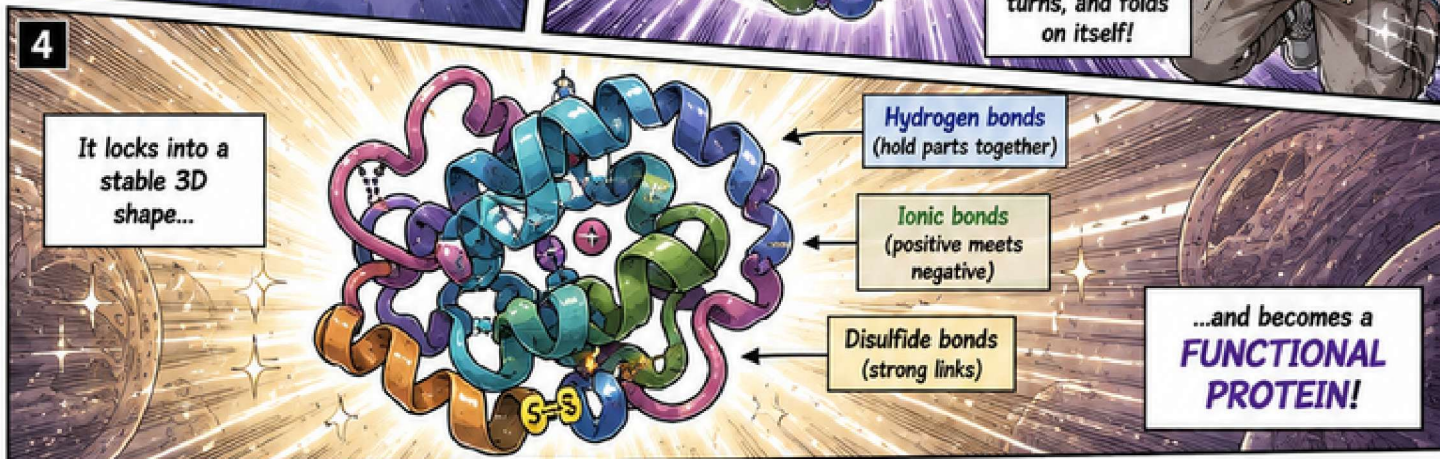
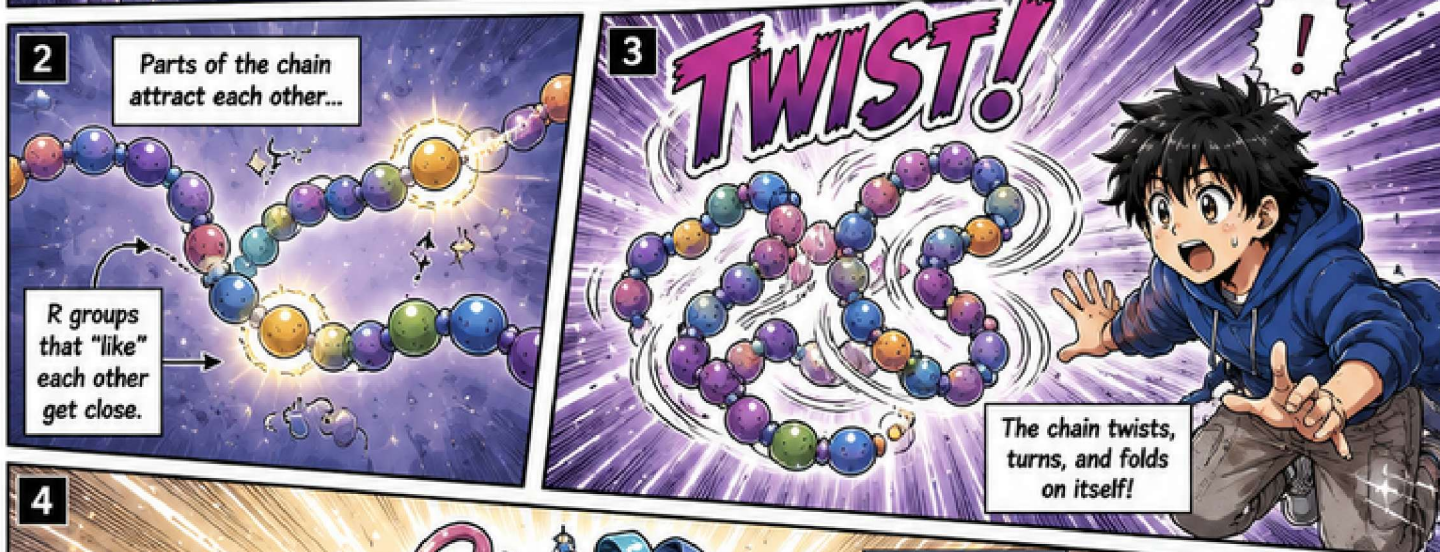
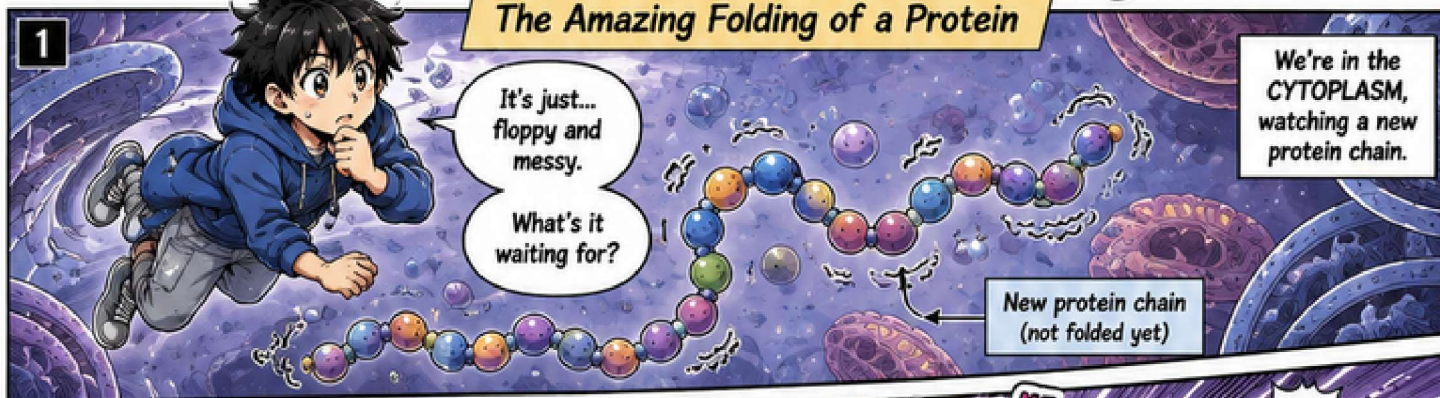
"Primary → Secondary → Tertiary → (sometimes) Quaternary — each level builds the final working shape."



FROM STRAIGHT TO SUPER SHAPE!

A protein's shape is its superpower!

The Amazing Folding of a Protein



A protein can't do its job until it folds into the **right 3D shape**.



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4 LEVELS OF PROTEIN STRUCTURE



FROM A SIMPLE CHAIN TO A POWERFUL TEAM!

1

So... this is the final protein structure?



Not quite. Proteins have more than one level!



We're in the **CYTOPLASM**, exploring how proteins are built!

2

LEVEL 1: PRIMARY STRUCTURE

The amino acid sequence



Amino acids are linked together by peptide bonds in a specific order.

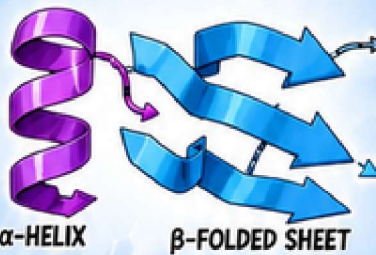


So this is where it all starts!

3

LEVEL 2: SECONDARY STRUCTURE

Local folding into regular patterns



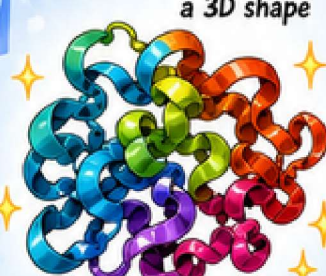
The chain begins to form stable patterns!



4

LEVEL 3: TERTIARY STRUCTURE

One polypeptide folds into a 3D shape



These interactions shape the chain into its unique 3D structure.

Now THAT looks like a protein!

HYDROGEN BONDS

IONIC BONDS

DISULFIDE BONDS



5

LEVEL 4: QUATERNARY STRUCTURE

Two or more polypeptide subunits work together as a team!



So that's it?



Multiple folded polypeptides assemble into a functional protein complex.

Sometimes... there's another level!



Oh... they work as a team.



WHAT WE LEARNED

- 1 Primary - the sequence
- 2 Secondary - local patterns
- 3 Tertiary - 3D shape of one chain
- 4 Quaternary - teamwork of multiple chains

The protein has folded into its shape.
It's ready to do its job.
But then... heat, acid, or other factors arrive.
This means the protein can **DENATURE**.

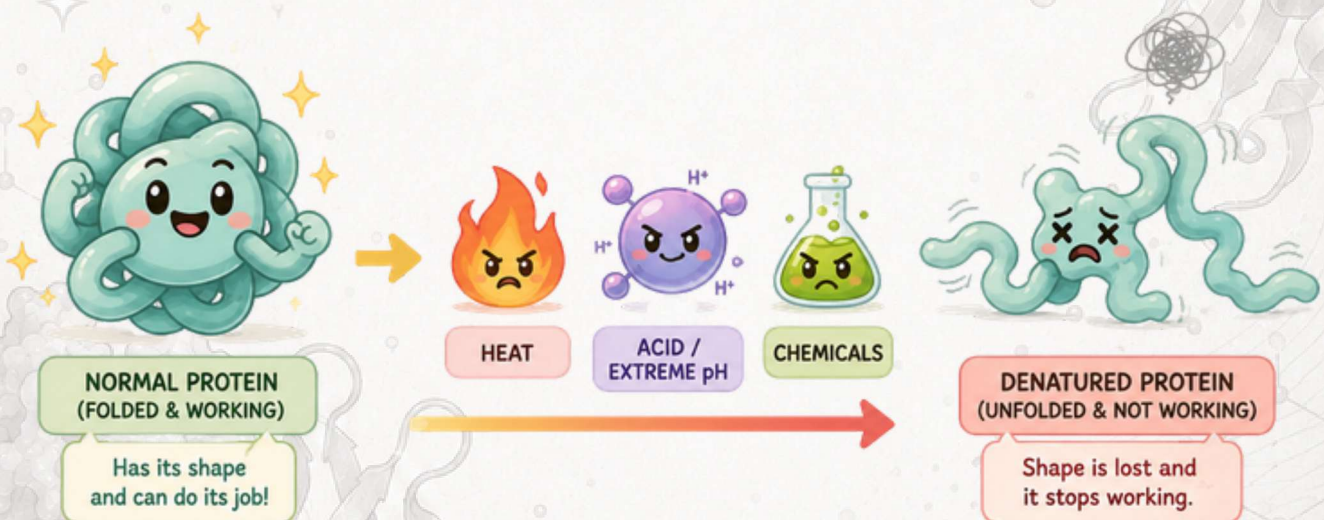
WHAT DOES DENATURE MEAN?

“Fold”

simply means:

To lose shape and stop working.

Heat, extreme pH, or certain chemicals
can cause this. Once the shape is lost,
the protein usually can't fold back.



LOOK AT THIS EXAMPLE!

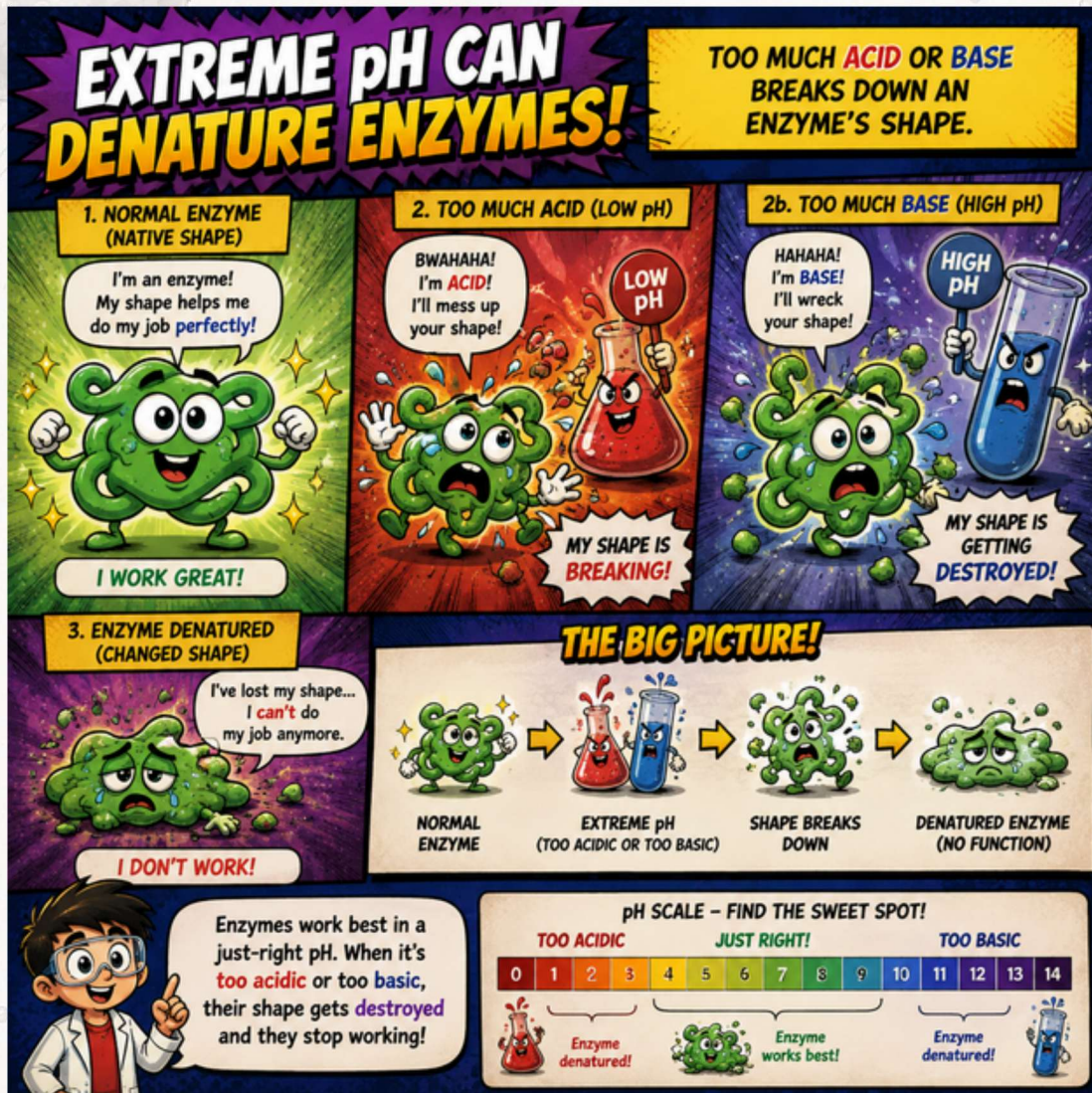


Heat can denature proteins.

simply means:

High temperature causes a protein to lose its shape.

LOOK AT THIS EXAMPLE!



Extreme pH can denature enzymes.

simply means:

Too much acid or base breaks down an enzyme's shape.



WHY COOKING CHANGES PROTEINS FOREVER!



1

Let's see **denaturation** in real life!

Let's see if this actually works...

What are you doing to my egg?



2

RAW
(folded, working shape)



3

SIZZLE!



4

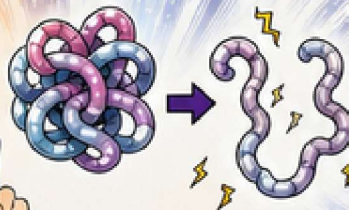
FIRM!

COOKED
(denatured, shape lost forever)

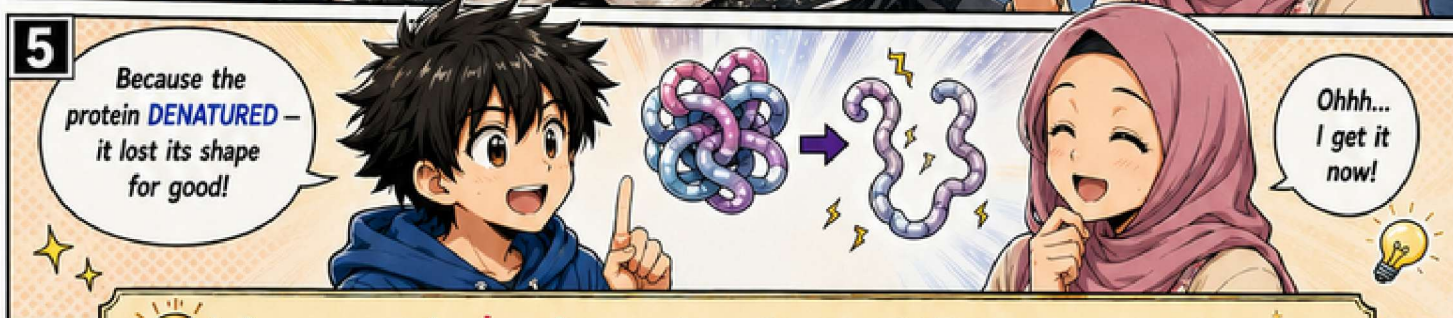


5

Because the protein **DENATURED** – it lost its shape for good!



Ohhh... I get it now!



Once a protein **denatures**, it usually can't refold back to its original shape.

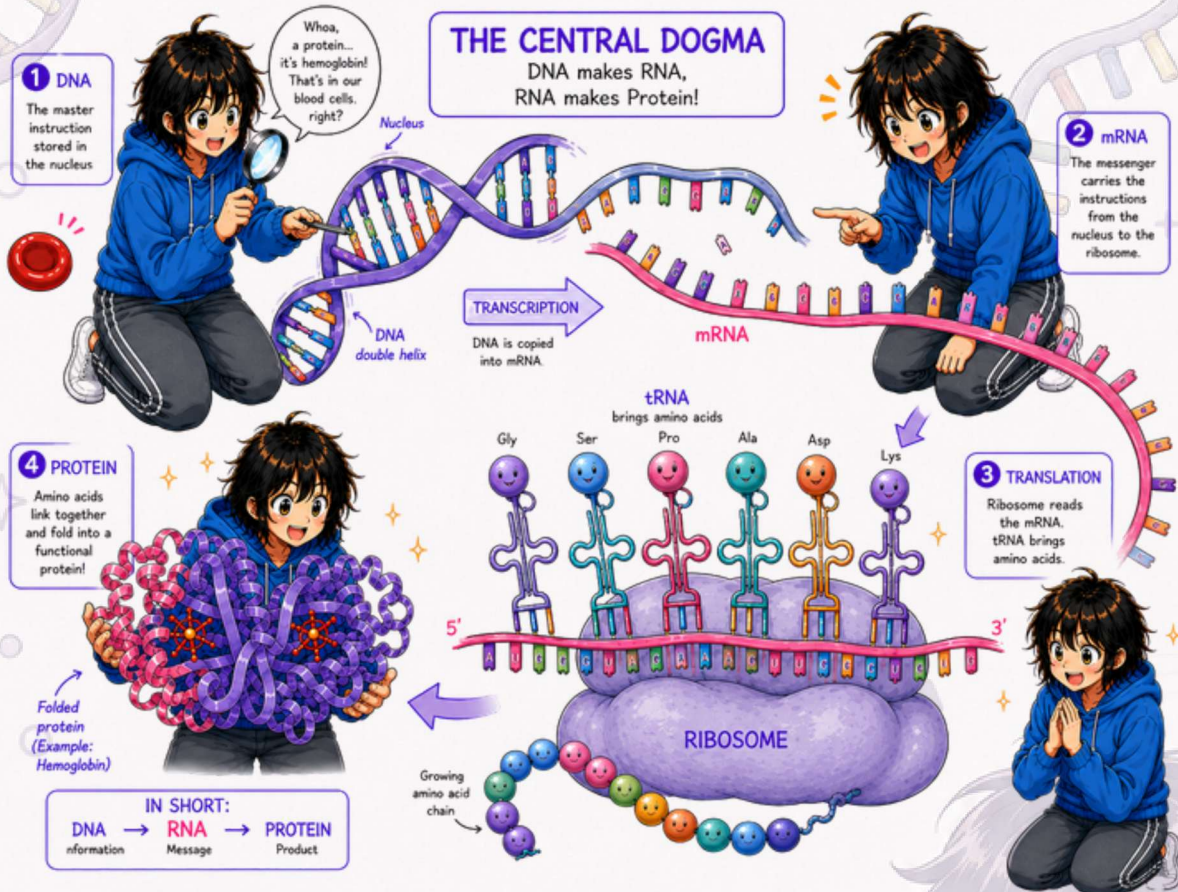


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THIS BUTTON



CENTRAL DOGMA



DNA holds the instructions.
RNA carries the message.
Protein does the work.
Together, this is called
the **CENTRAL DOGMA**.

WHAT DOES "CENTRAL DOGMA" ACTUALLY MEAN?

WHAT DOES CENTRAL DOGMA MEAN?

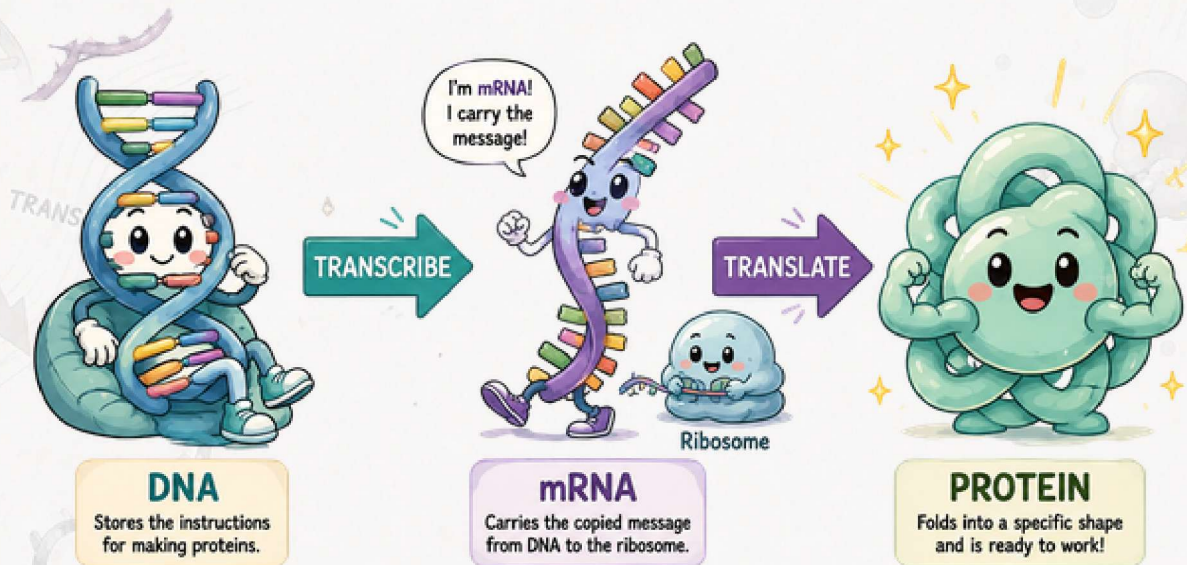
“Central Dogma”

simply means:

The main rule of how genetic information flows.

It flows in one direction:

DNA → RNA → PROTEIN



DNA → RNA → PROTEIN

💡 This is the **Central Dogma** — the master flow of molecular biology.

Every cell in your body follows this rule.
Your hair, your muscles, your enzymes — all made this way.
Even a single typo in DNA can change the protein made.
This means the Central Dogma explains LIFE ITSELF.

PROTEIN
(Polypeptide)

THE CENTRAL DOGMA!

THE MASTER FLOW OF LIFE

1

Understanding how **life** works, from start to finish!

So this is it...
the whole
system.

2

DNA is
TRANSCRIBED
into RNA

3

RNA is
TRANSLATED
into protein

4

The chain
FOLDS
into its
final shape

5

DNA

TRANSCRIPTION

RIBOSOME

TRANSLATION

PROTEIN

DNA to RNA to protein—
one direction, one rule.
And even one small change
can **ripple** all the way
through!



Ready for the

Challenge?

Test Your Understanding

Chapter 4-6



Scan the QR code
to begin!

or
click this button

QUIZ



GENE EXPRESSION

DNA
(Gene)

EVERY CELL HAS THE SAME DNA...
SO WHY ARE CELLS DIFFERENT?

SAME DNA

TRANSCRIPTION

● ON (active)
● OFF (silent)
Genes can be switched ON or OFF.

RED BLOOD CELL



Gene A ● ON
Gene B ● OFF
Gene C ● ON
Gene D ● OFF
Gene E ● OFF

Makes these proteins:



Function:
Carries oxygen
through the body.

NERVE CELL



Gene A ● OFF
Gene B ● ON
Gene C ● ON
Gene D ● OFF
Gene E ● ON

Makes these proteins:



Function:
Sends electrical
signals.

MUSCLE CELL



Gene A ● ON
Gene B ● OFF
Gene C ● OFF
Gene D ● ON
Gene E ● ON

Makes these proteins:



Function:
Contracts and
produces movement.

IMMUNE CELL



Gene A ● OFF
Gene B ● ON
Gene C ● ON
Gene D ● OFF
Gene E ● ON

Makes these proteins:



Function:
Fights germs and
protects the body.



DIFFERENT GENES ARE EXPRESSED

Gene ON → RNA made → Protein made → Cell function

This is called GENE EXPRESSION. ✨



They all have
the same DNA...
but use different
genes!

WHAT DOES "EXPRESSED" MEAN?

A gene is **EXPRESSED** when it is switched **ON**
and its information is used to make RNA
and, ultimately, a protein.

TRANSLATION

Ribosome

Every cell has the same DNA.

But not every gene is being used.

Some genes are active, some are silent.

This means a gene can be **EXPRESSED**.

Polypeptide



WHAT DOES EXPRESSED ACTUALLY MEAN?

Protein

(Functional Product)

WHAT DOES EXPRESSED ACTUALLY MEAN?

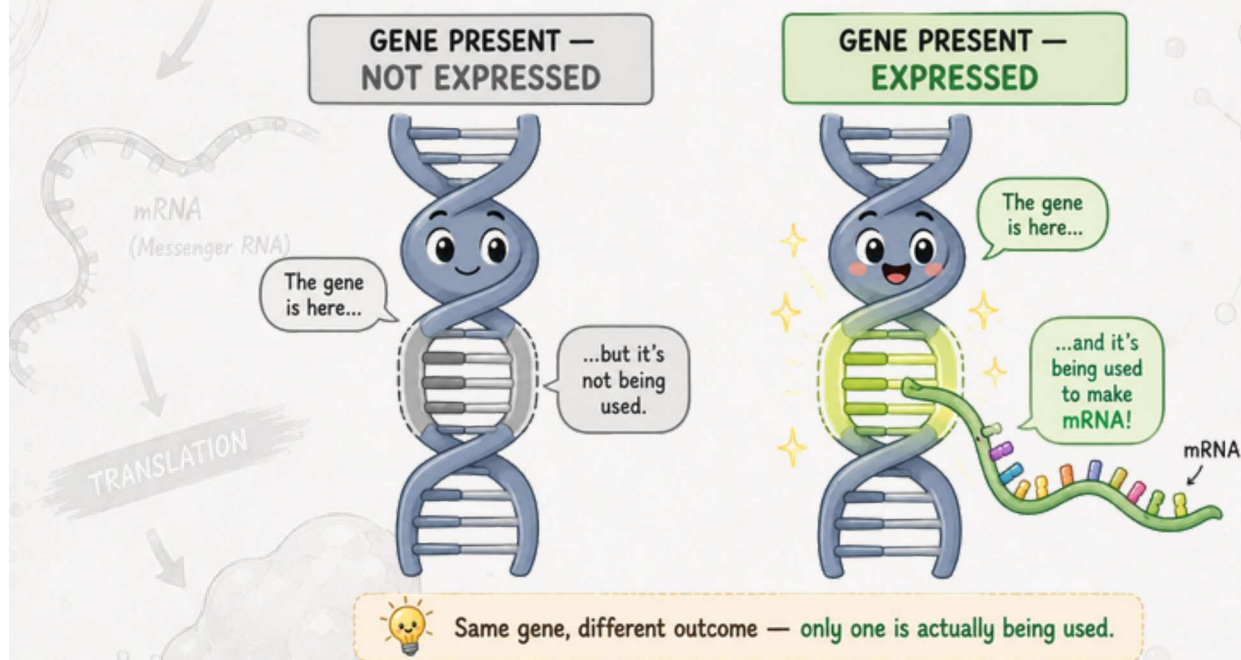
"Express"

simply means:

A gene is actively being used to make its protein.

Having a gene isn't the same as using it.

A gene only matters if it's turned on and read.



A gene isn't always active.
It can be switched on or off.
Something in the cell controls that switch.
This means genes can be **REGULATED**.

WHAT DOES REGULATE ACTUALLY MEAN?

(Functional Product)

WHAT DOES REGULATE ACTUALLY MEAN?

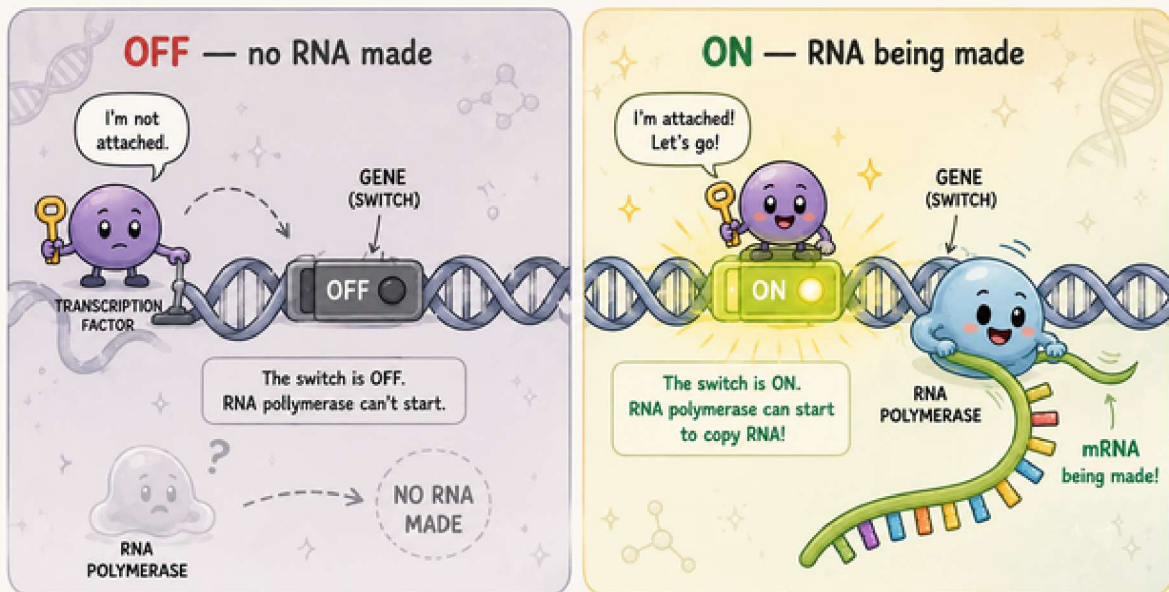
"Regulate"

simply means:

To control whether something happens,
and how much.

TRANSCRIPTION

GENES ARE CONTROLLED LIKE SWITCHES!



Genes aren't always running —
they're turned on and off **exactly when needed.**

Special proteins (called transcription factors)
act like switches.

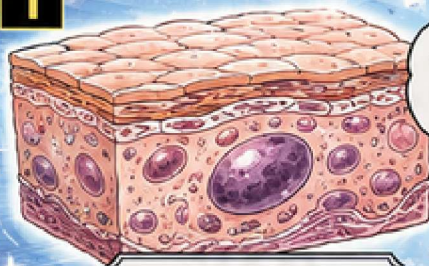
They can turn a gene ON (start making RNA)
or OFF (stop making RNA).

Protein
(Functional Product)

SAME DNA, DIFFERENT CELLS!

Understanding how **life** works, from start to finish!

1



SKIN CELL

Wait —
don't these two
have the exact
same DNA?



MUSCLE CELL

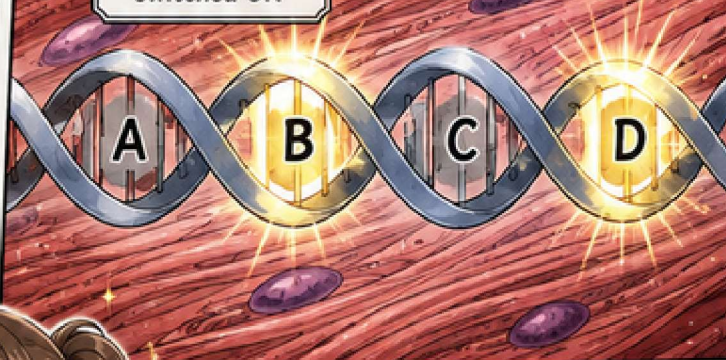
2

SKIN CELL —
Genes **A + C**
switched ON

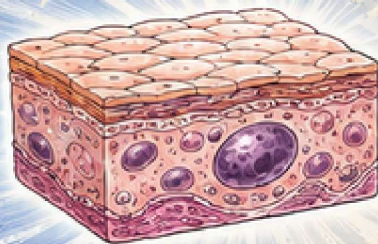


3

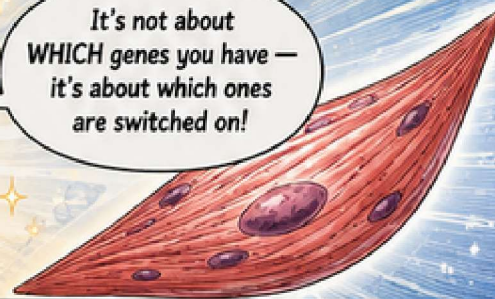
MUSCLE CELL —
Genes **B + D**
switched ON



4



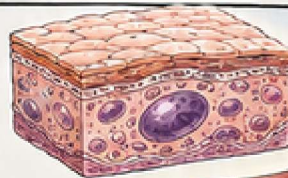
It's not about
WHICH genes you have —
it's about which ones
are switched on!



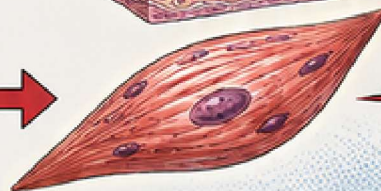
5



ONE DNA
(SAME BLUEPRINT)



SKIN CELL
(Genes **A + C** ON)



MUSCLE CELL
(Genes **B + D** ON)

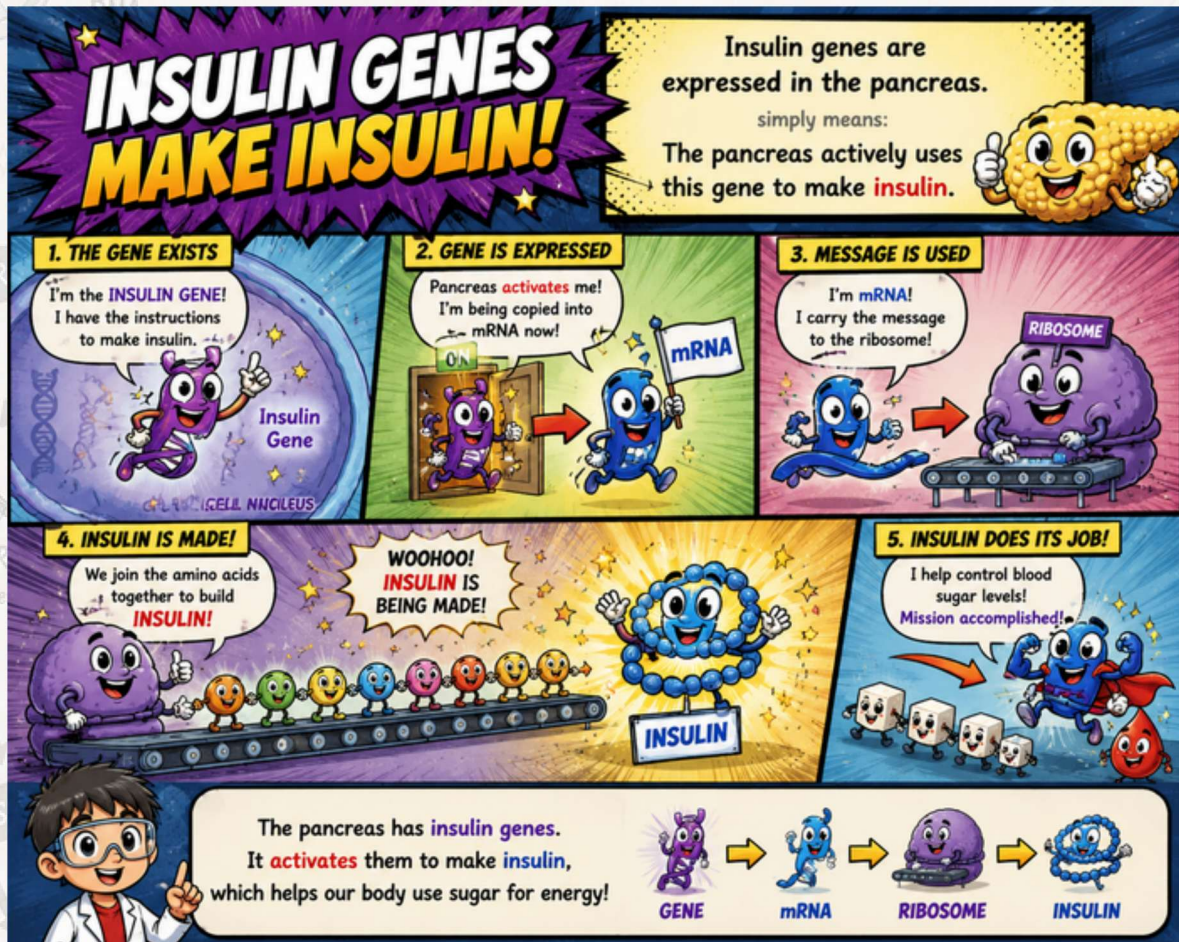


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LET'S LOOK AT THIS EXAMPLE!



Insulin genes are expressed in the pancreas.

simply means:

The pancreas actively uses this gene to make insulin.

Polypeptide

Protein
(Functional Product)

LET'S LOOK AT THIS EXAMPLE!



A gene can sit unused in your DNA until it's expressed.

simply means:

Having a gene isn't the same as using it, just like a recipe in a cookbook isn't a meal until someone actually cooks it.

COOKING UP GENES!

UNDERSTANDING HOW **LIFE** WORKS, FROM START TO FINISH!

1

This recipe's been in the book for years... but we never made it.



2

Creamy Mushroom Pasta

Zzz

Zzz



Ingredients:
Steps:

GENE —
present, but
not expressed



3

SIZZLE!
CHOP!
STIR!



5

Having the recipe isn't the same as making it — a gene only matters once it's expressed!

RECIPE
(DNA)



COOK & USE
(EXPRESSED)



DELICIOUS DISH
(PROTEIN)



A gene sitting in DNA is like a recipe in a book — it only becomes real once it's **actually used**.

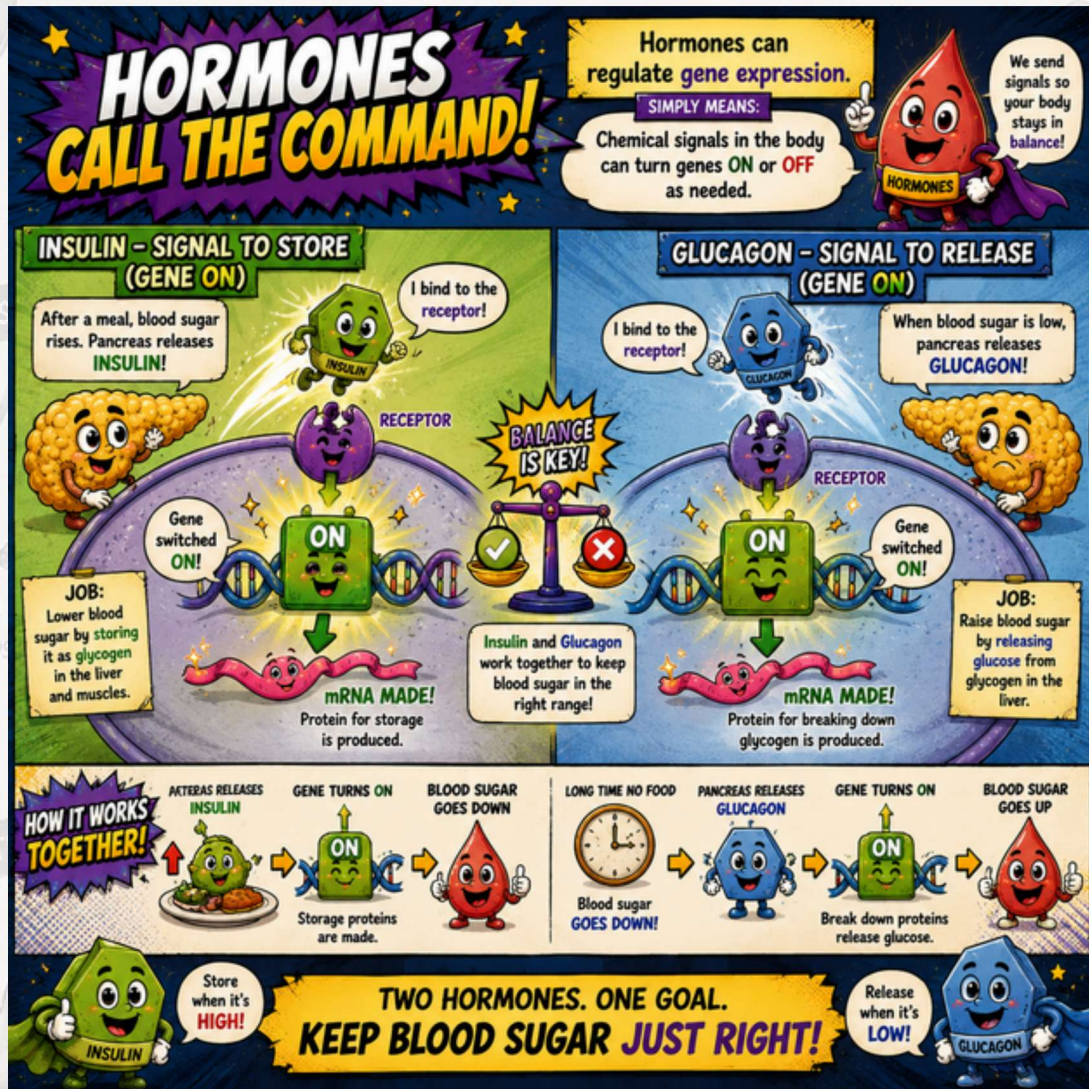


ARTIVIVE

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THIS BUTTON



LET'S LOOK AT THIS EXAMPLE!



Hormones can regulate gene expression.

simply means:

Chemical signals in the body can turn genes on or off as needed.

Protein
(Functional Product)

LET'S LOOK AT THIS EXAMPLE!



The cell regulates exactly how much protein is made.

simply means:

It's not just on/off. The cell can control the amount too, like a dimmer switch instead of a simple light switch.

Protein
(Functional Product)



Ready for the Challenge?

Test Your Understanding

Chapter 7



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QUIZ



GENETIC ENGINEERING

PLASMID
VECTOR

INSERT GENE

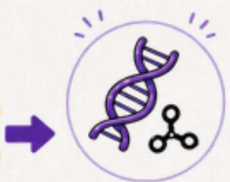


Genetic engineering is **changing** an organism's **DNA** on purpose to give it **useful new traits**.

MAKING PEST-RESISTANT PLANTS



Normal plant
vulnerable to pests.



A **useful gene**
is added or changed
using genetic
engineering.



Pest-resistant plant
Better protected
and healthier!

Scientists can now read the code of life.
But what if they could rewrite it too?
Cutting, adding, or silencing a gene on
purpose.
This is called **GENETIC ENGINEERING**.



HOW DO SCIENTISTS ACTUALLY DO THIS?

GENES DON'T WORK ALONE!

HOW GENE EXPRESSION REALLY WORKS!

1

How does one gene turn into an actual protein?

Genes express their traits in a cell with the help of:

1. **Add a gene** — Insert new instruction into an organism.
2. **Silence a gene** — Turn off instruction that are already there.
3. **Turn off instruction** that are already there.



DNA

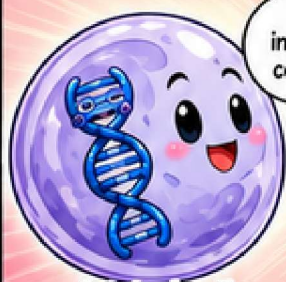


ON/OFF

Let's see how it works!

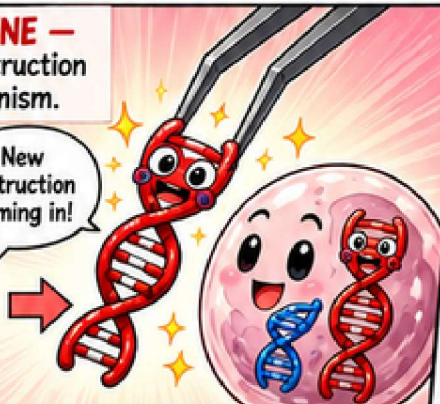
2

1. **ADD A GENE** — Insert new instruction into an organism.



Original cell

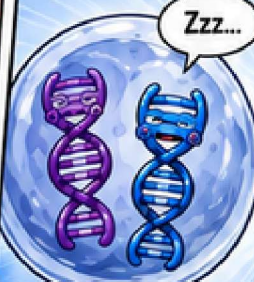
New instruction coming in!



New gene added!

3

2. **SILENCE A GENE** — Turn off instruction that are already there.



Zzz...

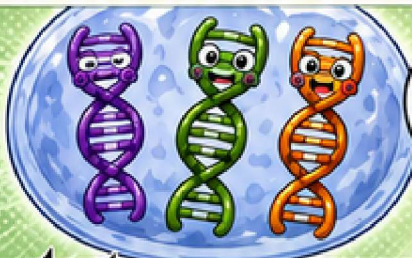


Gene silenced!

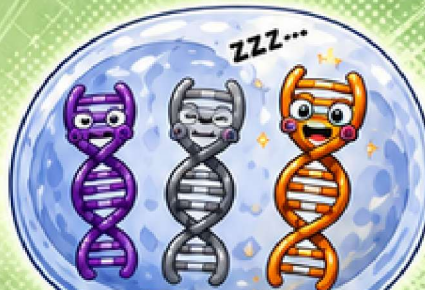


4

3. **TURN OFF INSTRUCTION THAT ARE ALREADY THERE.**



This one needs to be OFF!



Zzz...

Instruction turned off!

5

So, either silencing, or turning off genes changes what gets made in the cell!

DNA (GENE)



mRNA



RIBOSOME



PROTEIN



Exactly! That's how genes turn into functional proteins in our cells!

Genetic engineering works two main ways:

Add a gene — insert new instructions into an organism.

Silence a gene — turn off instructions that are already there.



Genetic engineering works two main ways:

Add a gene —

insert new instructions into an organism.

Silence a gene —

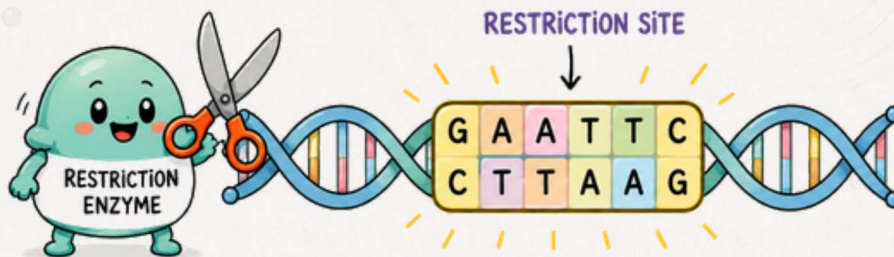
turn off instructions that are already there.

LET'S MEET THE TOOLS, ONE BY ONE.

TOOL 1

RESTRICTiON ENZYME

MOLECULAR SCISSORS THAT CUT DNA!



Meet the first tool: the restriction enzyme.

It acts like molecular scissors.

It cuts DNA at one exact sequence.

This means restriction enzymes

RESTRICT (CUT) DNA.

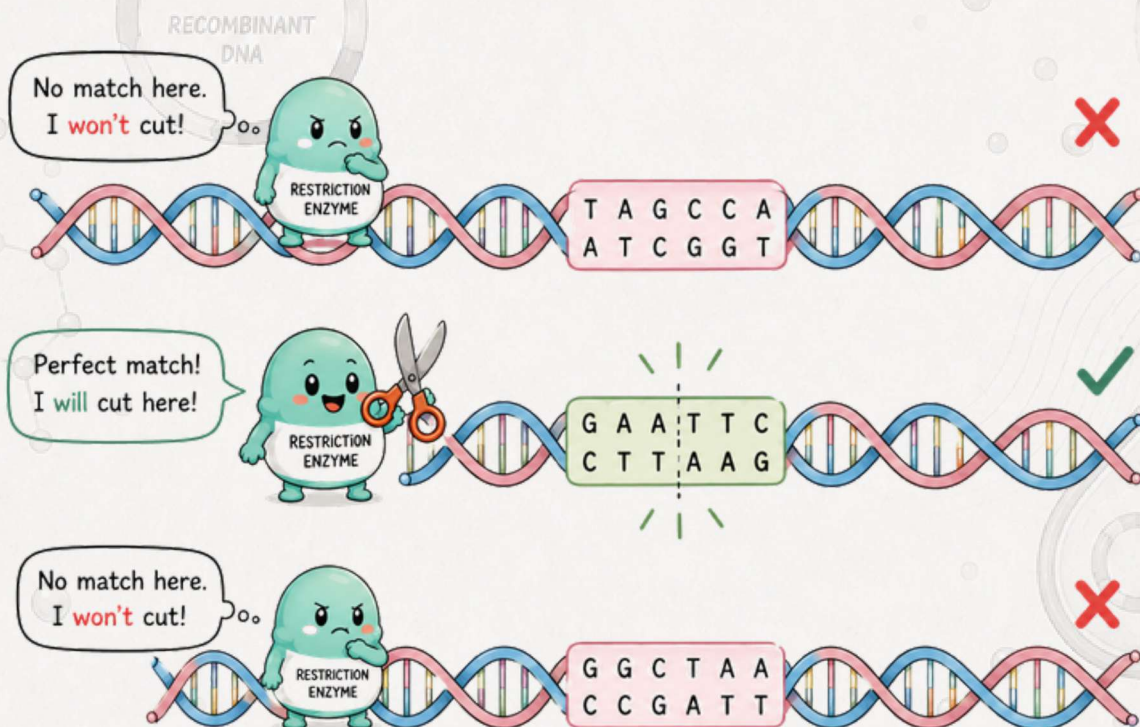
HOW PRECISE IS THIS CUTTING?

"Restrict"

simply means:

To cut DNA at one exact, specific sequence.

Each restriction enzyme only recognizes and cuts
one specific pattern.



LET'S LOOK AT THIS EXAMPLE!

Scientists use restriction enzymes to cut out the
gene they want.

simply means:

Just like scissors following a dotted line,
restriction enzymes cut exactly where needed.

TOOL 2 PLASMID

PLASMID
VECTOR

I am a
plasmid –
a small,
circular DNA
molecule!



INSERT GENE

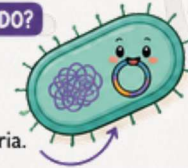
WHAT IS IT?

A small, circular
piece of DNA.



WHAT DOES IT DO?

Carries useful
genes and can
replicate on its
own inside bacteria.



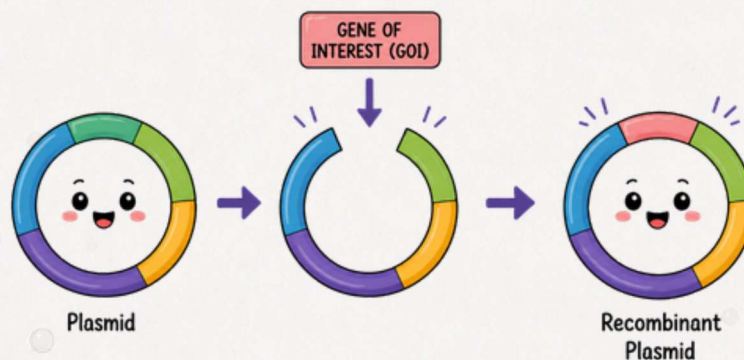
Meet the second tool: the plasmid.

It's a small circular ring of DNA.

It acts as a carrier for the cut gene.

This means the gene can be **INSERTED** into it.

WHERE EXACTLY DOES IT GO?



It goes into a plasmid.

"Insert"

simply means:

To place the cut gene into that vector.

LET'S LOOK AT THIS EXAMPLE!

The insulin gene was inserted into a bacterial plasmid.

simply means:

A human gene can be placed inside a bacterial "carrier," ready to be delivered into the bacteria.

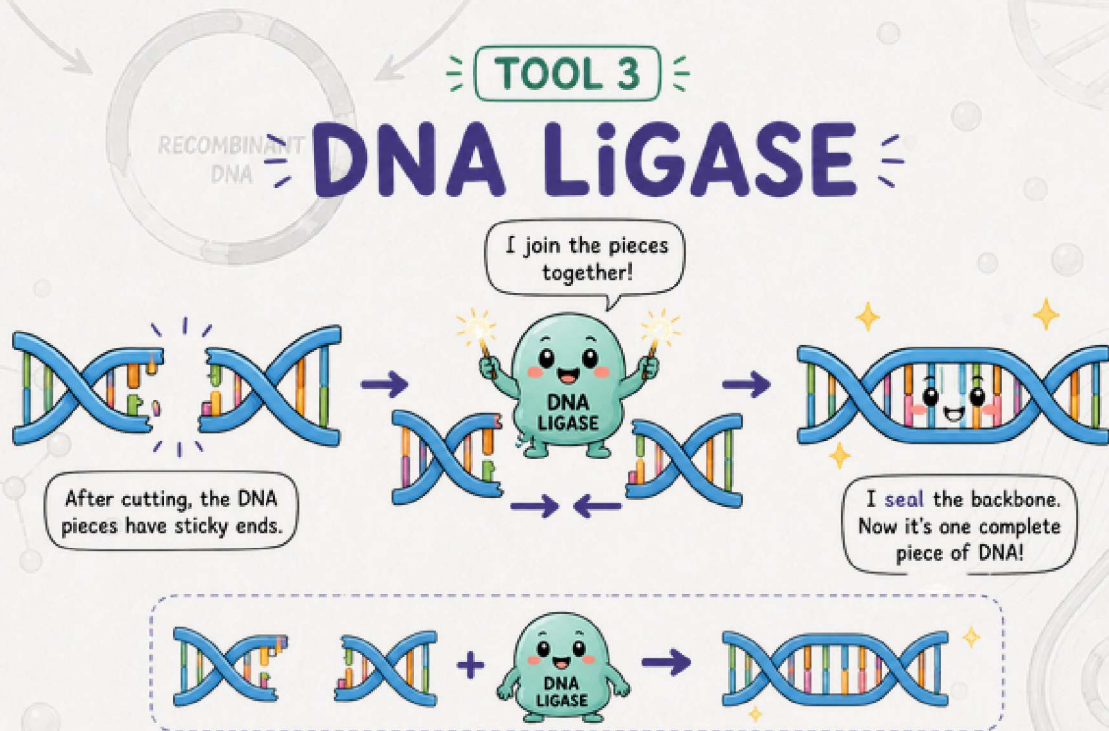


Meet the third tool: DNA ligase.

It acts like molecular glue.

It seals the gene permanently into the plasmid.

This means the gene can be **LIGATED**.



"Ligate"

simply means:

To permanently join two pieces of DNA together.

Without ligation, the gene could simply fall back out.

Ligase locks it in place for good.

LET'S LOOK AT THIS EXAMPLE!

PLASMID
VECTOR

INSERT GENE



DNA ligase ligates the gene permanently into the vector.

simply means:

A special enzyme glues the gene into the plasmid so it stays there.

LET'S LOOK AT THIS EXAMPLE!

PLASMID
VECTOR

INSERT GENE



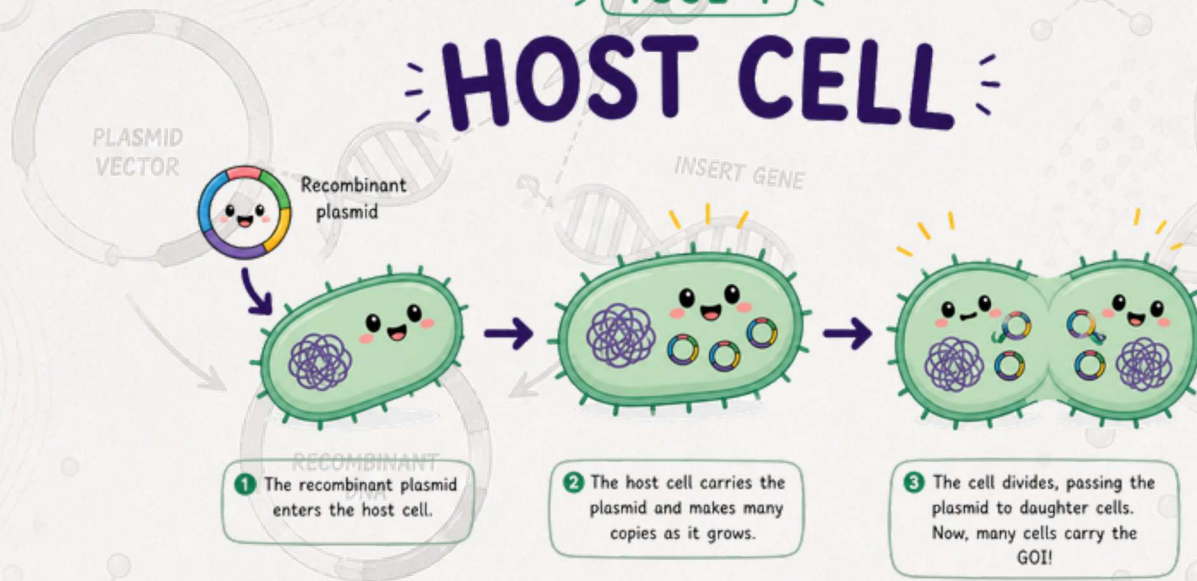
Ligation joins the sticky ends of the DNA together.

simply means:

The matching cut edges are sealed shut, joining the two DNA pieces into one.

TOOL 4

HOST CELL



Meet the fourth tool: the host cell.
Bacteria are often used for this job.
The recombinant plasmid needs to get inside it.
This means the host must be **TRANSFORMED**.

HOW DOES THE PLASMID GET IN?

"Transform"
simply means:

To introduce new DNA into a host organism,
so it takes it up.

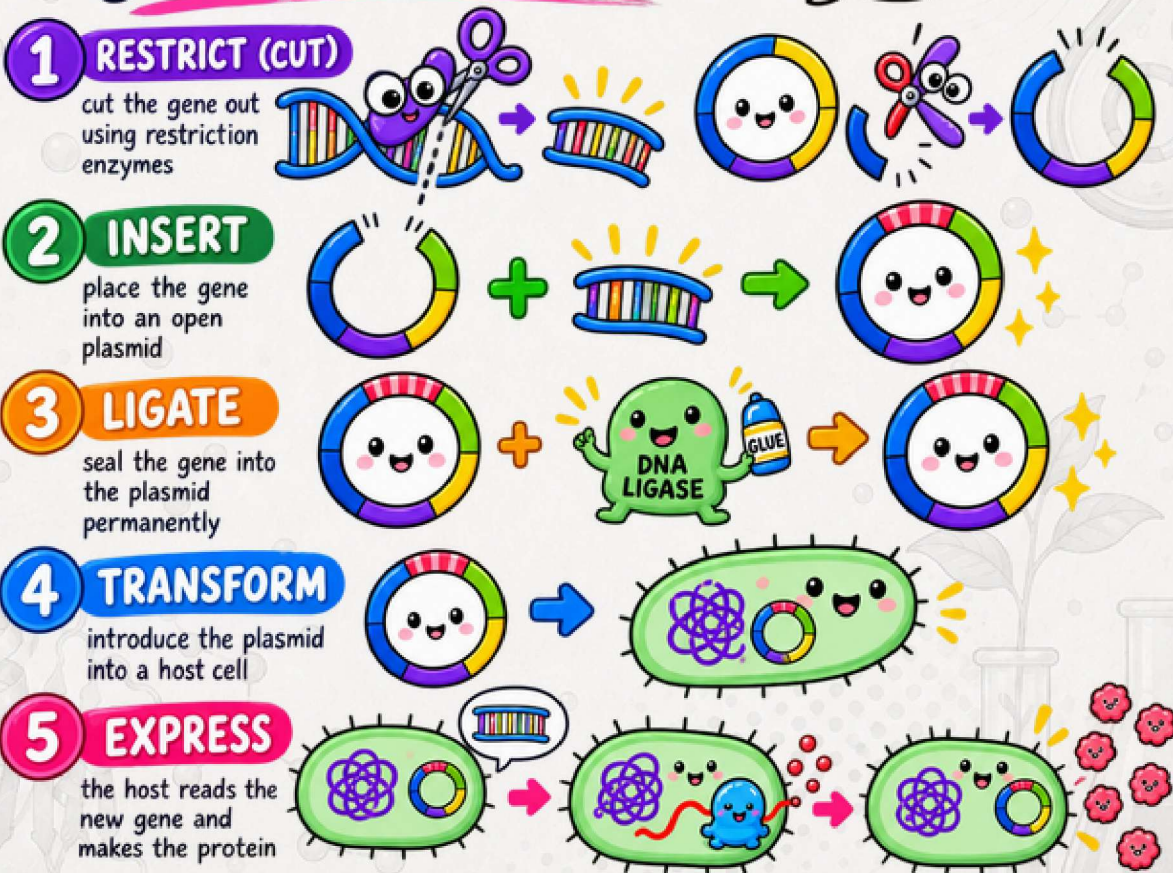
The bacteria now carries a new gene.
Its own machinery transcribes, then translates it.
This means the new gene can finally be
EXPRESSED.

DO YOU STILL REMEMBER WHAT EXPRESS
MEANS?

Once transformed, the bacteria treats the new
gene as its own, transcribing and translating it into
protein

Now that we have **THE TOOLS...**

...here's how
they're actually used,
step by step.



Tiny Tools, BIG IMPACT!

Today, Mia learns that tiny tools make BIG changes!

How do scientists add new genes to living things?

The amazing tools of GENETIC ENGINEERING

1 RESTRICTION ENZYMES — molecular scissors that cut DNA at exact sequences

These scissors find a special DNA sequence...

Recognition sequence
GAATTC

RE CUTTER

SNIP!

2 DNA LIGASE — molecular glue that seals DNA pieces together

I join DNA pieces back together!

Mission:
Build a better bacteria
that produces medicine!

Let's follow
Mia on her
journey to
find out!

3 PLASMID (VECTOR) — a small circular DNA carrier that transports the gene into a host

I'm a tiny
carrier. I'll
deliver the
gene safely!

GENE
ON
BOARD!

PLASMID

4 HOST CELL (e.g., BACTERIA) — the living organism that takes up and uses the new DNA

I take in the
plasmid and use
the new gene!

Plasmid enters
the bacterium

New gene is
used

New protein is
produced!

Wow! Each tool
has a special job,
but **together** they
make genetic
engineering
possible!

THE JOURNEY: Putting it all together!

1



Cut DNA with
restriction enzyme

2



Join the gene
with DNA ligase

3



Insert the gene
into a plasmid

4



Put plasmid into
host cell

5



Host cell uses gene
to make protein!

QUICK
RECAP!

- 1 **Restriction enzymes** — molecular scissors that cut DNA at exact sequences
- 2 **DNA ligase** — molecular glue that seals DNA pieces together
- 3 **Plasmid (vector)** — a small circular DNA carrier that transports the gene into a host
- 4 **Host cell (e.g., bacteria)** — the living organism that takes up and uses the new DNA



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PLASMID
VECTOR

RECOMBINANT
DNA

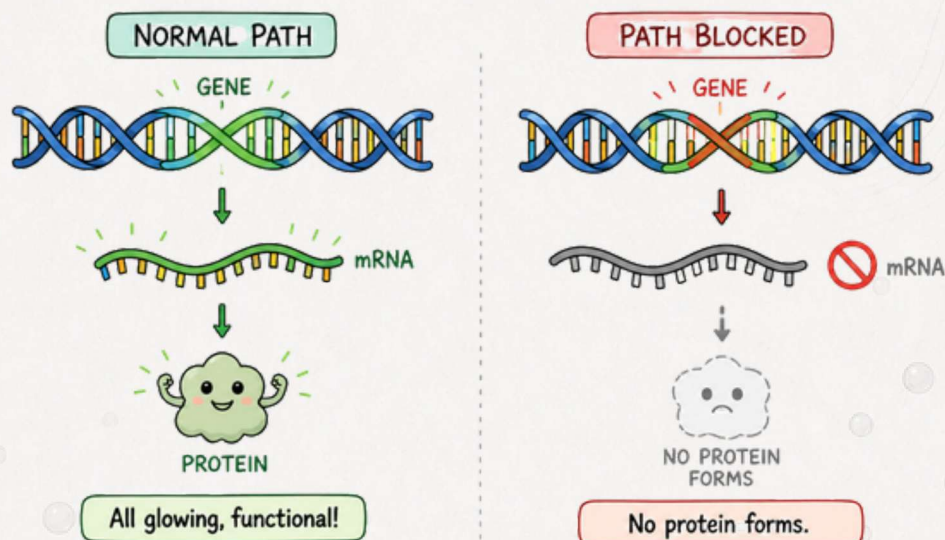
So far, we've added a gene.

But sometimes, a gene causes problems or scientists just want to study it.

They may want to turn that gene off, on purpose.

This means a gene can be **SILENCED**.

HOW DO YOU SWITCH OFF A GENE THAT'S
ALREADY THERE?



The gene is still there —
it's just being stopped from being used.

"Silence" or "Knockout"

simply means:

To stop a gene from being expressed, on purpose.

Remember Central Dogma?

DNA → RNA → Protein.

If you block the RNA step, the protein never gets made, even though the gene is still sitting there in the DNA.

LET'S LOOK AT THIS EXAMPLE!



Scientists knocked out the gene to study its function.

simply means:

The gene was disabled on purpose,
to see what happens without it.

LET'S LOOK AT THIS EXAMPLE!



Silencing a cancer-related gene can help stop tumor growth.

simply means:

Turning off a gene that causes cancer cells to grow can help stop the tumor.

SILENCING A GENE, PROTECTING OUR CROPS!

SMALL SWITCH.
BIG IMPACT.

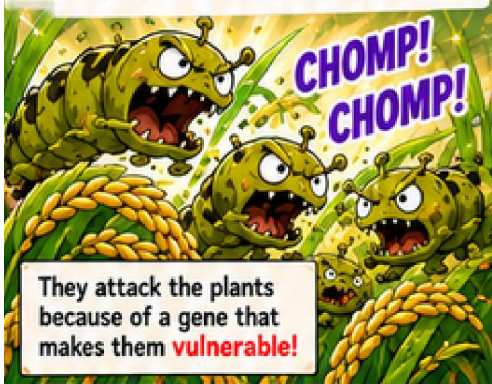
Tiny RNA
to the rescue!

IN A VILLAGE NEAR
THE RICE FIELDS...

Why are
so many plants
getting eaten
by pests?

If this keeps
happening, we'll
lose our entire
harvest...

1 THE PROBLEM: PESTS ARE DESTROYING THE CROPS!



2 THE IDEA: WHAT IF WE CAN SILENCE THAT GENE?

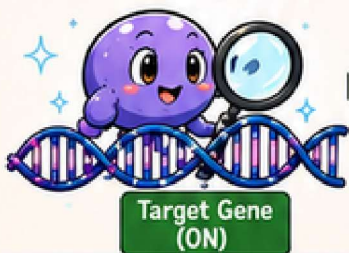


3 THE PLAN: TURN OFF (SILENCE) THE GENE USING NATURE'S TOOL — A SMALL RNA MOLECULE.

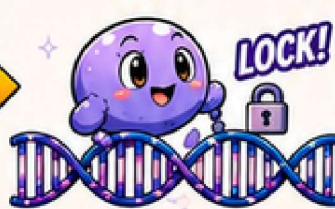


HOW GENE SILENCING WORKS

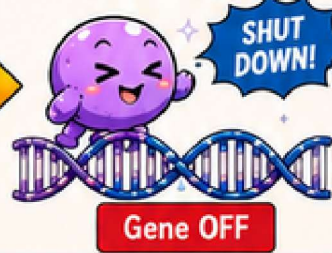
1 The RNA molecule finds the target gene.



2 It attaches and blocks the gene's instructions.



3 The gene is silenced (turned OFF).



4 The plant no longer makes the protein that attracts the pests.



4 THE RESULT: PLANTS ARE PROTECTED FROM PESTS!



5 THE OUTCOME: HEALTHY CROPS, HAPPY FARMERS!



6 THE IMPACT: A SMALL SWITCH FOR A BETTER FUTURE!

Gene silencing helps us grow more food, protect our crops, and build a better tomorrow!

SMALL SCIENCE.
BIG IMPACT. ★

KEY
TAKEAWAY!

Gene silencing **turns off** harmful genes in plants using a **small RNA molecule (RNAi)**. This **protects crops from pests** and helps us grow more food for a healthier and more sustainable future!



SCIENCE
CAN FEED THE
WORLD! ♥

SILENCE OR KNOCKOUT?

YOUR CHOICE. THEIR FUTURE!

A SINGLE GENE CAN CAUSE BIG PROBLEMS...

BUT YOU HAVE A CHOICE!

This gene needs to be dealt with... but how?

?

ERROR!

ERROR!

TROUBLESOME GENE

SILENCE

KNOCKOUT

Do I mute it, or remove it completely?

3 SILENCE — the message is blocked

5 KNOCKOUT — the gene is cut out entirely

BLOCKED — gene still there, just muted.

REMOVED — gene is gone completely.

4 It can be switched back on later

I'm back!

REVERSIBLE — can be switched back on later.

6 This change is permanent

PERMANENT — cannot be undone.

KEY TAKEAWAY!

Same goal — stop the gene — but very different outcomes. ★

Silence is temporary. Knockout is forever.

Choose wisely for a healthier future!



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Chapter 8



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