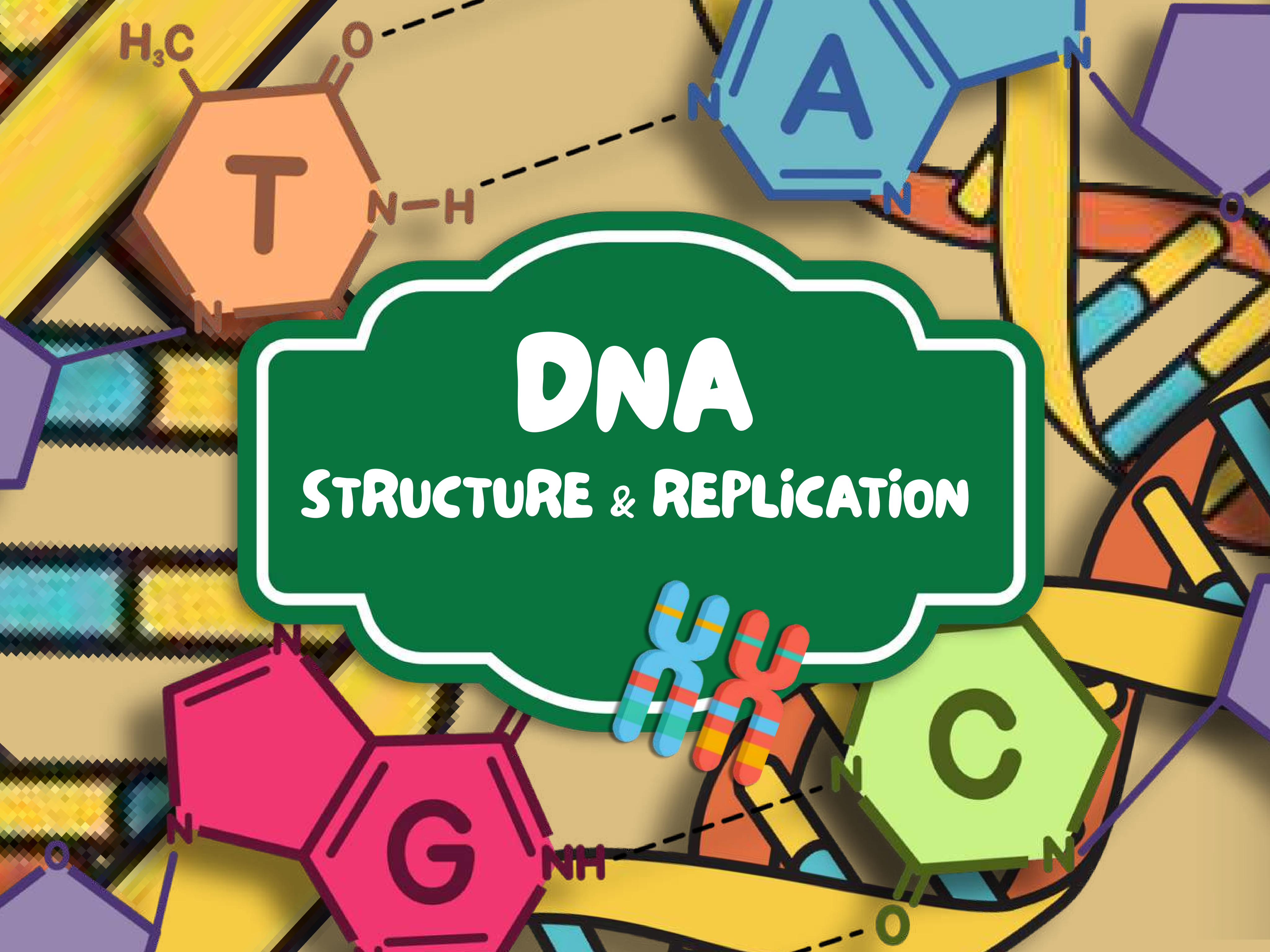
DNA

STRUCTURE & REPLICATION



INTRODUCTION

Did you know there's a secret code inside every living thing—even you? It's not written in numbers or letters like a video game cheat code… it's made of something called DNA! And it's hiding in every single cell of your body, telling it what to do—like what color your eyes are, how tall you might grow, or even whether you can roll your tongue (go ahead, try it!).

In this unit, we're going to crack the code of DNA. You'll learn how the order of tiny parts called nucleotides can create all the instructions your body needs. It's kind of like spelling words—only instead of letters, your cells use molecules called A, T, C, and G. You'll even explore how scientists think DNA came to be in the first place. Spoiler alert: it wasn't made in a lab… but we can study it there!

We'll also jump into the wild world of DNA technology. Ever wanted to copy a piece of DNA (kind of like photocopying a recipe)? Scientists use a tool called PCR to do just that. Want to sort DNA pieces by size? We've got gel electrophoresis—think of it as a tiny DNA race track! And if you thought that was cool, wait until you hear about CRISPR, a real-life "genetic scissors" scientists use to edit genes. Yes, edit—like a Google Doc for your DNA!

But with great power comes great responsibility. We'll also talk about ethics—the big questions about what we should do with this amazing technology. Should we use it to cure diseases? What about changing eye color or building super plants? You'll get to explore your own ideas and discuss how these tools could affect people and the world around us.

So get ready to become a DNA decoder, gene editor, and biotech explorer. This unit will show you how tiny molecules can have HUGE effects—and how science is opening doors we never imagined!

VOCABULARY

Vocabulary Word	Definition
5' (Five Prime)	
3' (Three Prime)	
Adenine	
Base Pairing	
Cytosine	
Deoxyribonucleic Acid (DNA)	
DNA Helicase	

Vocabulary Word	Definition
DNA Ligase	
DNA Polymerase	
Gel Electrophoresis	
Genetic Code	
Genetic Engineering	
Guanine	
Lagging Strand	
Leading Strand	

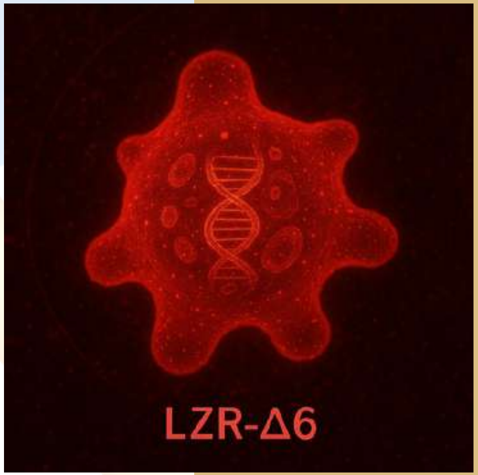
Vocabulary Word	Definition
Nitrogenous Base	
Nucleotide	
Okazaki Fragments	
Phosphate Group	
Polymerase Chain Reaction (PCR)	
Primase	
Purine	
Pyrimidine	

Vocabulary Word	Definition
Replication	
Semiconservative Replication	
Single-Stranded Binding Proteins (SSBs)	
Thymine	
Topoisomerase	
Uracil	

PHENOMENON

The Code That Shouldn't Exist

Mission Log – Sol 83



You didn't come to Mars to become a genetic detective. But here you are. Deep beneath the Martian ice shelf, your team found something unbelievable—a living organism. It was microscopic, jelly-like, and glowing faintly under the microscope. You named it "LZR-Δ6." At first, it seemed harmless. But now, the algae in the HAB's oxygen tank are mutating. The plants are growing strange leaves. Even one of the lab mice is showing unusual traits.

You run a DNA scan on the strange Martian lifeform. The results are shocking.

It has DNA. Just like Earth life. But the nucleotide sequence—the order of those A, T, C, and G bases—is unlike anything you've seen before. Some sections seem familiar... others don't even make sense. But then it hits you: the unfamiliar sections are mimicking your crew's DNA.

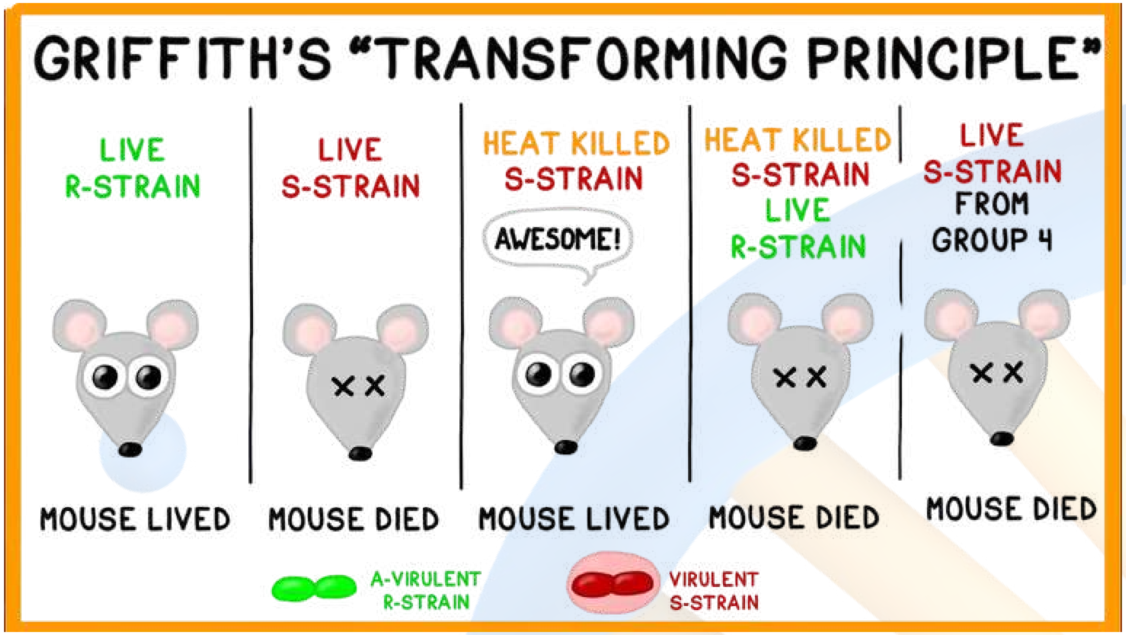
You wonder—is it copying us? Is it learning from our genes?

To find out, you start using PCR to copy the strange DNA segments so you can study them. You run them through gel electrophoresis to sort out the fragments. The patterns look... off. It's as if this lifeform can change its code. One of the scientists suggests testing it with CRISPR-Cas9 to see how it reacts when edited. But others warn: If we edit it... will it edit us back?

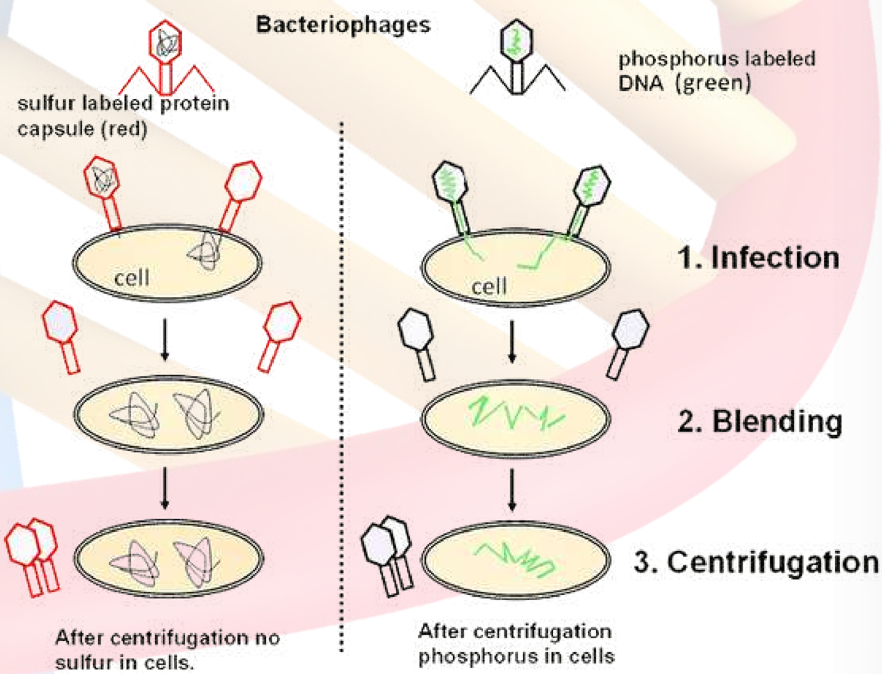
- What evidence from the story shows that the Martian organism might be using or copying Earth DNA?
    - "The DNA scan showed that the organism had sequences that looked like _______________."
    - "This suggests it might be _______________ from the crew's DNA."
- Why did the scientists use PCR, and how does this help them study the strange DNA?
    - "The scientists used PCR to _______________."
    - "This helps them by making it easier to _______________."
- How does gel electrophoresis help scientists analyze DNA from the Martian lifeform?
    - "Gel electrophoresis separates DNA pieces based on _______________."
    - "This allows scientists to _______________ and compare the DNA fragments."
- What is CRISPR, and why are some crew members worried about using it on the alien DNA?
    - "CRISPR is a tool that scientists use to _______________."
    - "Some crew members are worried because changing the DNA might _______________."
- What are some of the ethical questions scientists should think about before editing the Martian DNA?
    - "One ethical question is whether we should _______________."
    - "Scientists need to consider how editing the DNA could _______________."

HISTORY OF DNA

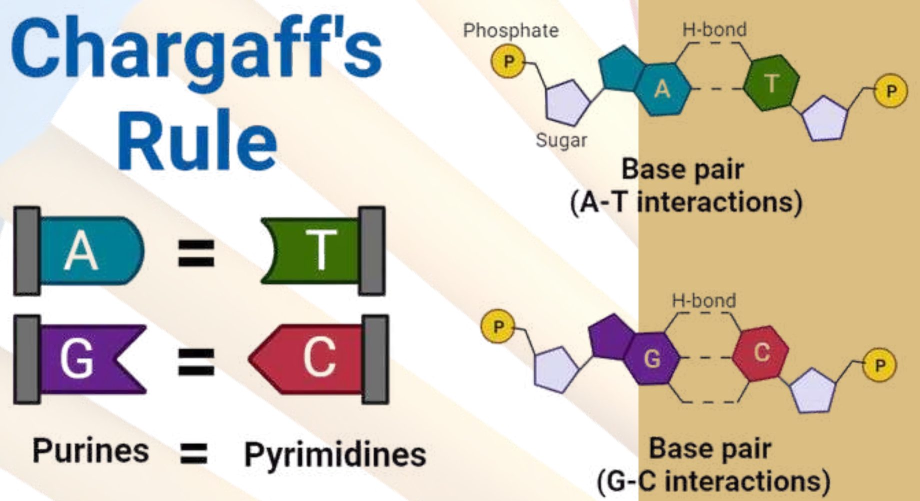
- Early Beliefs
  - Early scientists thought **protein** was the cell's **hereditary** material because it was more complex than DNA (**Deoxyribonucleic Acid**)
  - **Proteins** were composed of 20 different **amino acids** in long **polypeptide** chains
- **Griffith Transformation**
  - Fred Griffith worked with virulent S and non-virulent R strain Pneumococcus bacteria
  - He found that R strain could become **virulent** when it took in DNA from heat-killed S strain
  - Study suggested that **DNA** was **probably** the **genetic material**



- **Hershey & Chase**
  - **Chromosomes** are made of both **DNA** and protein
  - Experiments on **bacteriophage** viruses by Hershey & Chase proved that **DNA** was the cell's **genetic** material



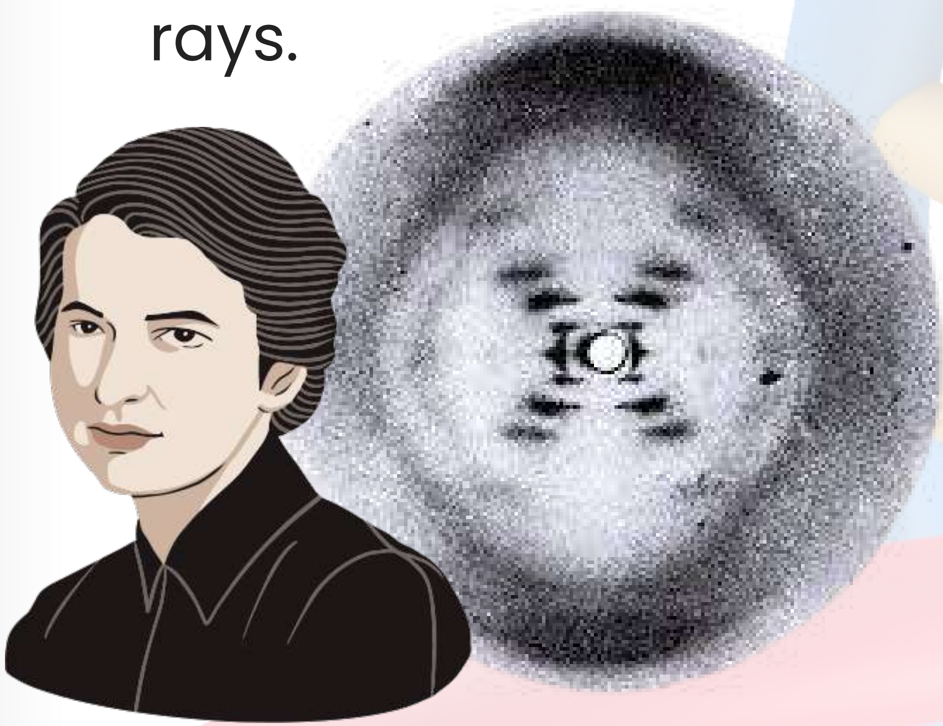
- **Edwin Chargaff and Chargaff's Rule**
  - Erwin Chargaff showed the amounts of the four bases on DNA (Adenine, Thymine, Cytosine, Guanine)
  - In a body or somatic cell:
    - Adenine (A) = 30.3%
    - Thymine (T) = 30.3%
    - Guanine (G) = 19.5%
    - Cytosine (C) = 19.9%



  - **Adenine** must pair with **Thymine**
  - **Guanine** must pair with **Cytosine**
  - The bases are held together by weak hydrogen bonds

DNA STRUCTURE & FUNCTION

- **DNA's First Photograph**
  - **Rosalind Franklin** took **diffraction** x-ray photographs of **DNA** crystals
  - In the 1950's, **Watson & Crick** built the first **model** of **DNA** using Franklin's X-rays.

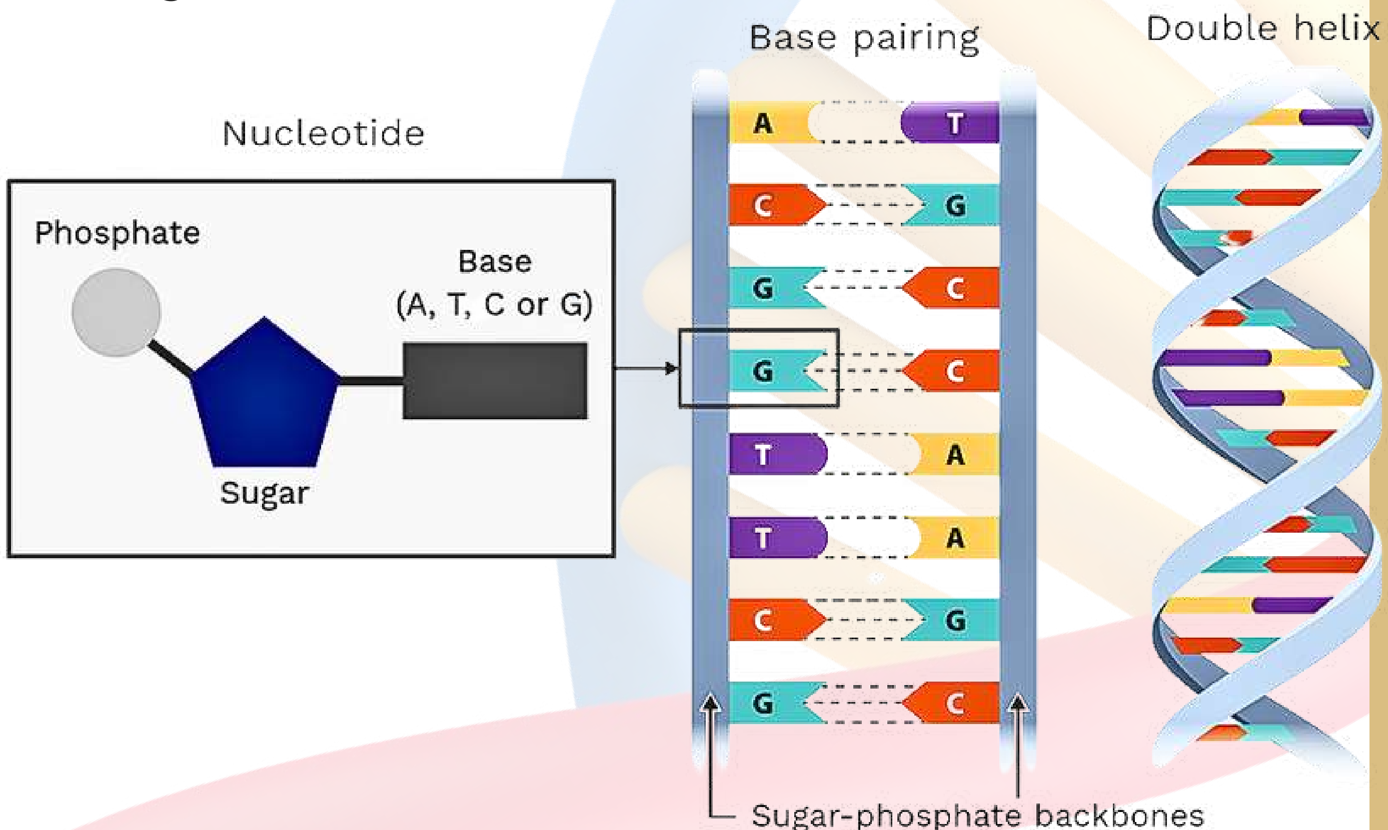


- Why was Frederick Griffith's experiment with mice important for understanding how bacteria change?
- What did Oswald Avery discover about the substance that transforms harmless bacteria into harmful ones?
- How did the Hershey-Chase experiment show that DNA carries genetic information?
- What did Rosalind Franklin's pictures of DNA teach scientists about its shape?
- Why was Watson and Crick's discovery of the double helix shape of DNA so important?

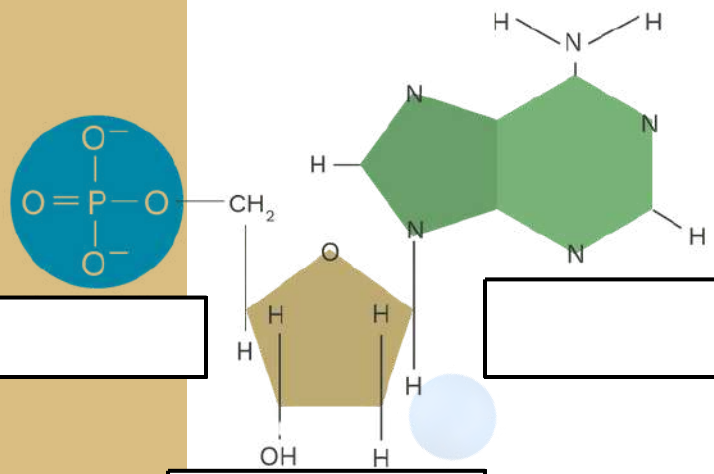
DNA STRUCTURE

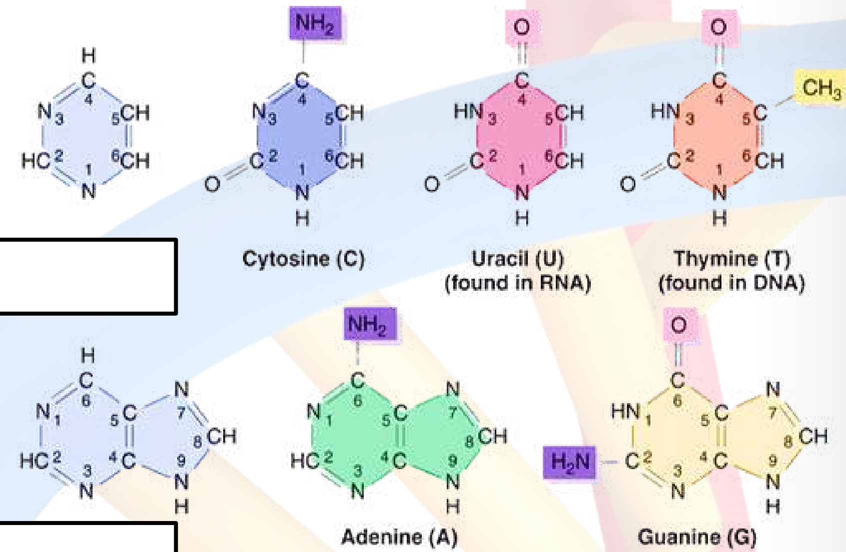
- **Two** strands coiled called a **double helix**
- Sides made of a **pentose** sugar **Deoxyribose** bonded to **phosphate** (PO4) groups by **phosphodiester** bonds
- Center made of **nitrogenous** / molecular **bases** bonded together by weak **hydrogen bonds**

- **Helix**
  - **Most DNA (B-DNA) has a right-hand twist** with 10 base pairs in a complete turn
  - Left twisted DNA is called **Z-DNA** or southpaw DNA
  - **Hot spots** occur where right and left twisted DNA meet producing mutations



- **Nucleotides**
  - DNA stands for **Deoxyribonucleic Acid**
  - Made up of subunits called **nucleotides**
- **Nucleotide**: Basic building block of DNA, consisting of a phosphate group, a 5-carbon sugar, and a nitrogenous base
  - **Phosphate Group**: Part of the nucleotide that forms the backbone of DNA
  - **5-Carbon Sugar:** In DNA, this sugar is deoxyribose
  - **Nitrogenous Base**: Encodes genetic information
- Double ring **Purines**: Adenine (A) and Guanine (G)
- Single ring **Pyrimidines**: Thymine (T) and Cytosine (C)



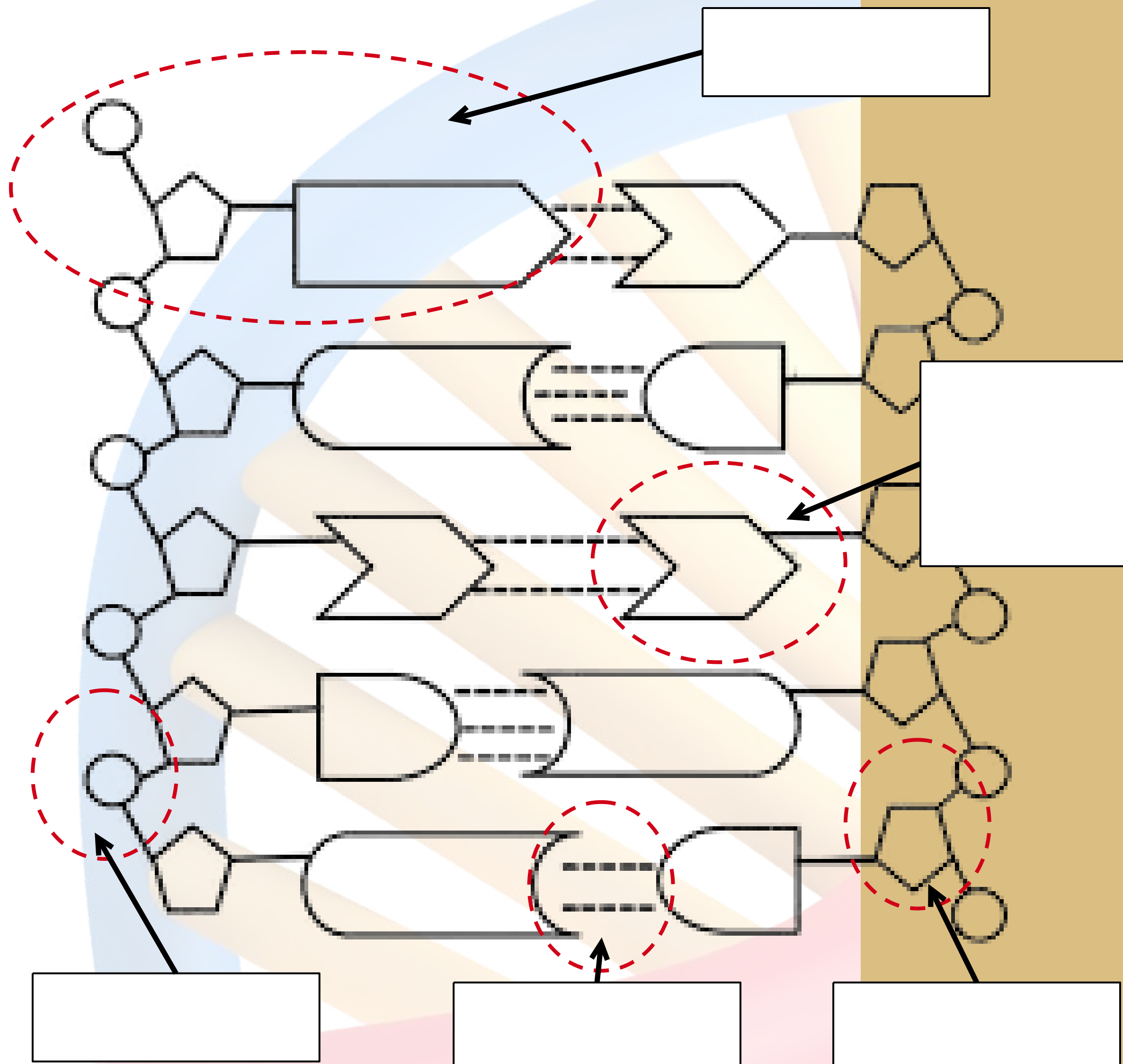


Parent DNA

A T G C C G A A A T A C G T A C G G G T C A

Complimentary DNA

- **Base Pairing**
  - **Purines** only pair with **Pyrimidines**
  - **Three** hydrogen bonds required to bond **Guanine** to **Cytosine**
  - **Two** hydrogen bonds are required to bond **Adenine** to **Thymine**
  - These are what allow for DNA to be copied exactly

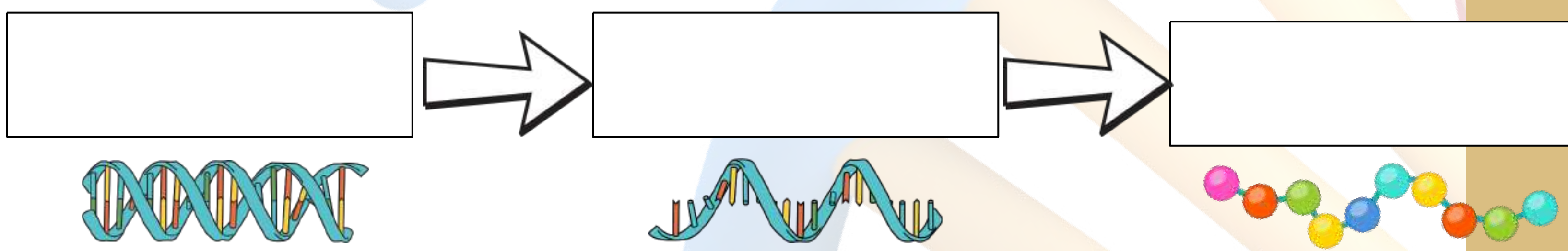


- How does DNA help baby robins grow inside their eggs?
- What is DNA, and why is it important for birds like Ruby?
- How do the nitrogenous bases in DNA pair up, and why is this pairing important?
- What role do chromosomes play in storing DNA in baby robins?
- Why is DNA described as the blueprint of life in Ruby's story?

DNA FUNCTION

- **Genetic Information**
  - **DNA** carries instructions for **traits** like eye color and disease susceptibility.
  - Information is in the **order / sequence** of the bases**:** A, T, C, and G.
- **Protein Synthesis**
  - **DNA** guides making **proteins.**
  - **Genes** copy to **mRNA,** then build **proteins** in cells.

- DNA passes from **parents** to **offspring.**
  - It keeps **genetic** info **safe** and **passes** it on.
- **Regulation** of Cell Functions
  - DNA **controls** how cells **work.**



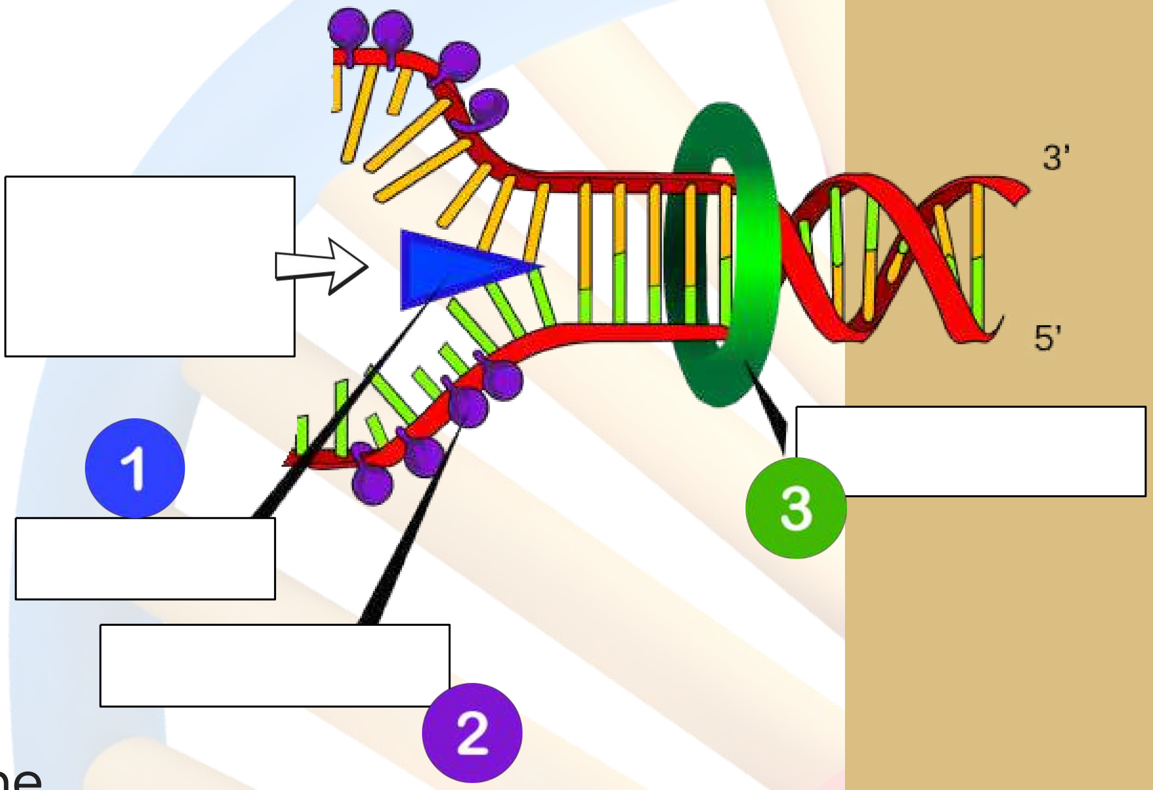
- How did Emily and her father use DNA to improve their horse breeding at Legacy Ranch?
- What is DNA, and how does it pass traits from parent horses to their foals?
- Why is DNA described as a double helix, and what are its parts?
- How did Emily select Thunder and Bella for breeding Ace, and why was this important?
- How did Emily explain DNA's role in shaping Ace's abilities to the townspeople?

DNA REPLICATION

- **Basics**
  - **Replication:** Process by which DNA is copied before a cell **divides**
  - **DNA** is **copied** during the **S or synthesis phase** of interphase
  - New cells will need **identical** DNA strands
  - Occurs in the **nucleus** of **eukaryotes**
- **Replication Fork**
  - Begins at Origins of Replication
  - Two **strands open** forming **Replication Forks: (Y-shaped region)**
  - **New strands** grow at the forks
- **Replication Bubbles**
  - As the 2 DNA strands open at the origin**, Replication Bubbles** form
  - **Eukaryotic** chromosomes have **MANY** bubbles
  - **Prokaryotes (bacteria)** have a **single** bubble

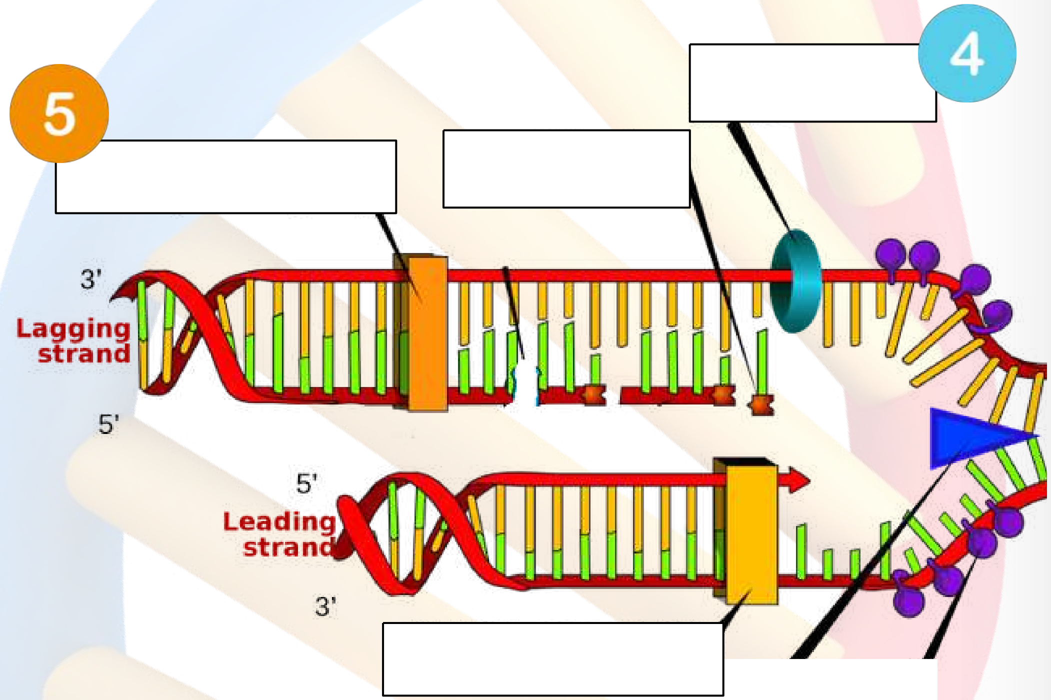
REPLICATION SEQUENCE

1. **DNA Helicase**
   - **Unwinds** and **separates** the 2 DNA strands by breaking the weak hydrogen bonds
2. **Single-Stranded Binding Proteins (SSBs)**
   - Attach and keep the 2 DNA strands separated and untwisted
3. **Topoisomerase**
   - Attaches to the 2 forks of the bubble to **relieve stress** on the DNA molecule as it separates



PRIMASE & POLYMERASE

4. **RNA Primers and Primase**
   - Before new DNA strands can form, there must be **RNA primers** present to **start** the addition of **new nucleotides**
   - **Primase:** The **enzyme** that synthesizes the **RNA Primer**
5. **DNA Polymerase (various) :**
   - **Adds** the **new nucleotides**
   - Can only **add nucleotides** to the **3′ (Three Prime) end** of the **parent DNA**
   - This causes the **NEW strand** to be **built** in a **5′ (Five Prime) to 3′** direction

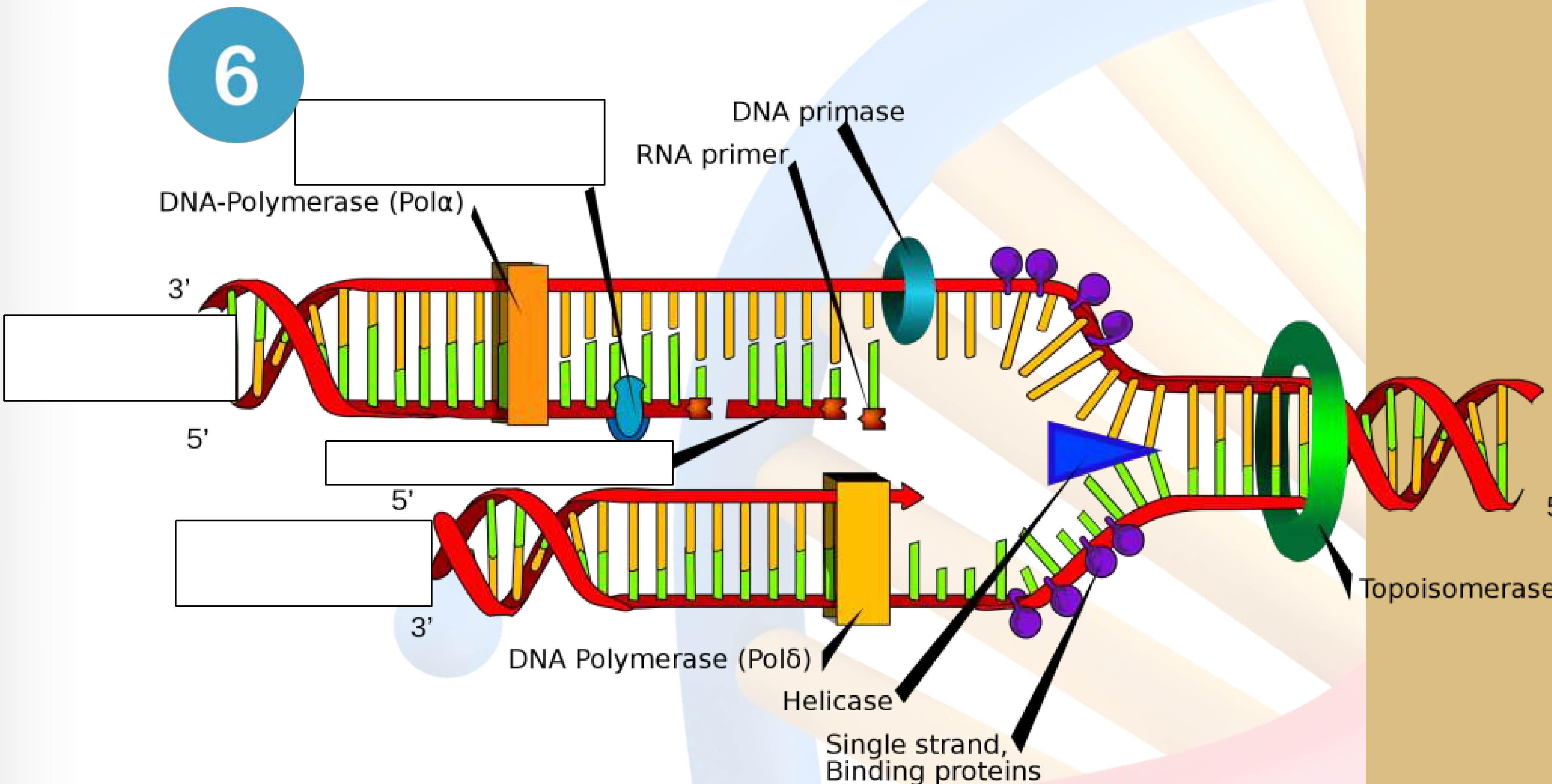


REPLICATION SEQUENCE

6. DNA Ligase

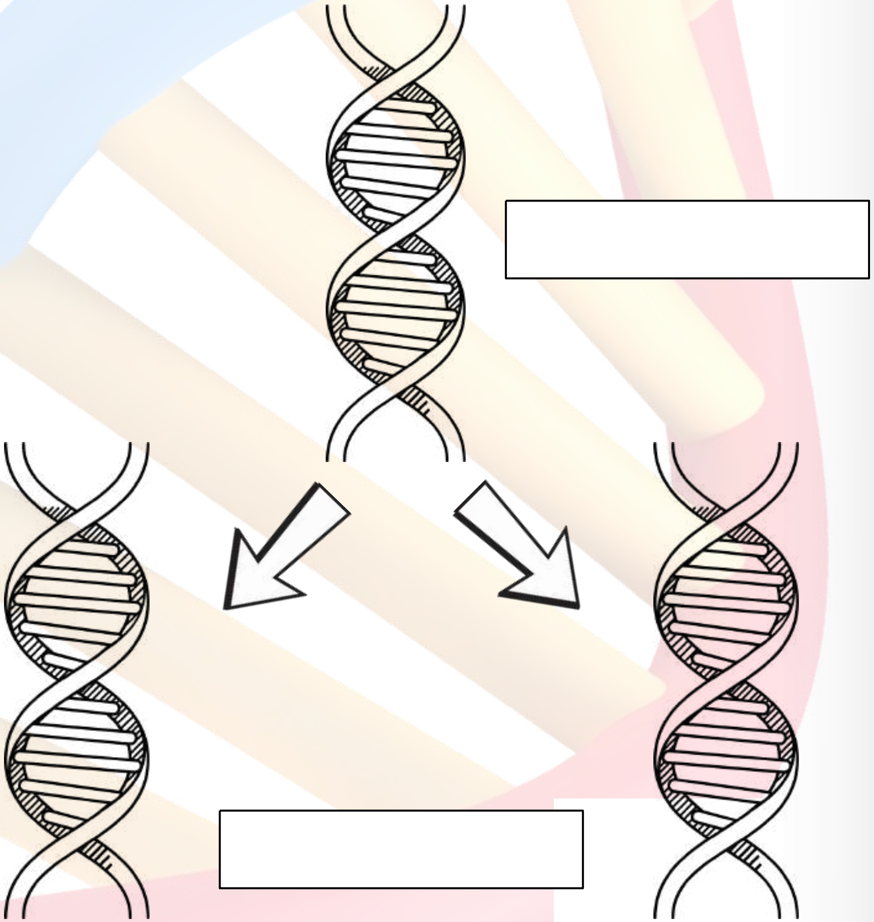
- **Okazaki Fragments**
  - Series of short segments on the **lagging strand**
  - Must be joined together by an enzyme **– DNA Ligase**
- **Leading and Lagging Strands**
  - The **Leading Strand (continuous)**
  - Synthesized as a **single strand from** the point of origin **toward** the opening replication fork - follows **Helicase**
  - The **Lagging Strand (discontinuous)**
  - Synthesized **discontinuously** against overall direction of replication
  - This strand is made in **MANY short segments**
  - It is replicated **from** the **replication fork** toward the **origin**

REPLICATION SEQUENCE



SEMICONSERVATIVE REPLICATION

- **Semiconservative Replication**
  - Idea presented by Watson & Crick
  - The two strands of the **parental molecule** separate, and each acts as a template for a new **complementary strand**
  - **New DNA** consists of **1 PARENTAL (original)** and 1 NEW **COMPLIMENTARY strand** of DNA



- What happened when Lena accidentally cut her finger while slicing an apple?
- How did DNA replication help in the healing process of Lena's cut finger?
- Who were the key enzymes involved in DNA replication, and what were their roles?
- How did Helicase and Topoisomerase prepare the DNA for replication?
- Why was DNA Polymerase important in creating new skin cells to heal Lena's cut?

PROOFREADING

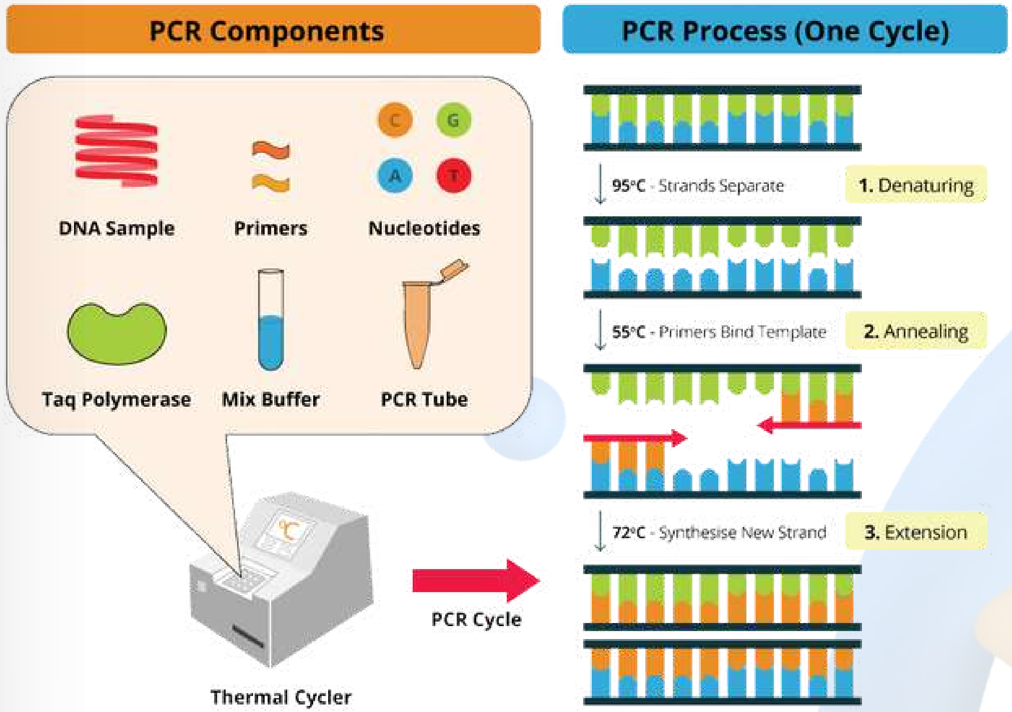
- **Proofreading DNA**
  - **DNA polymerase** initially makes about 1:10,000 base pairing errors
  - Enzymes **proofread** and **correct** these mistakes
  - The new error rate for DNA that has been proofread is 1 in 1 billion base pairing errors

DNA DAMAGE

- **DNA Damage & Repair**
  - **Chemicals** & **ultraviolet radiation** damage the **DNA** in our body cells
  - Cells must **continuously** repair **DAMAGED** DNA
  - **Excision Repair**: Occurs when any of over 50 repair enzymes remove damaged parts of DNA
  - **DNA polymerase** and **DNA ligase** replace and bond the new nucleotides together

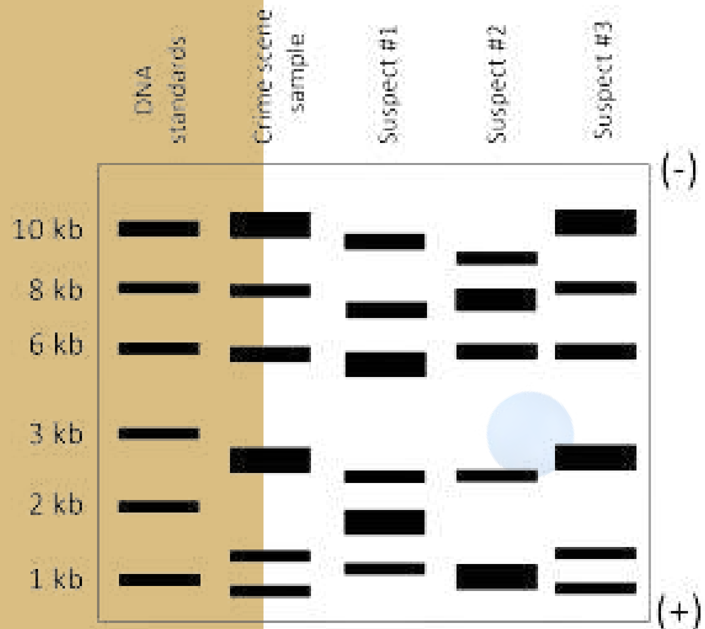
BIOTECHNOLOGY

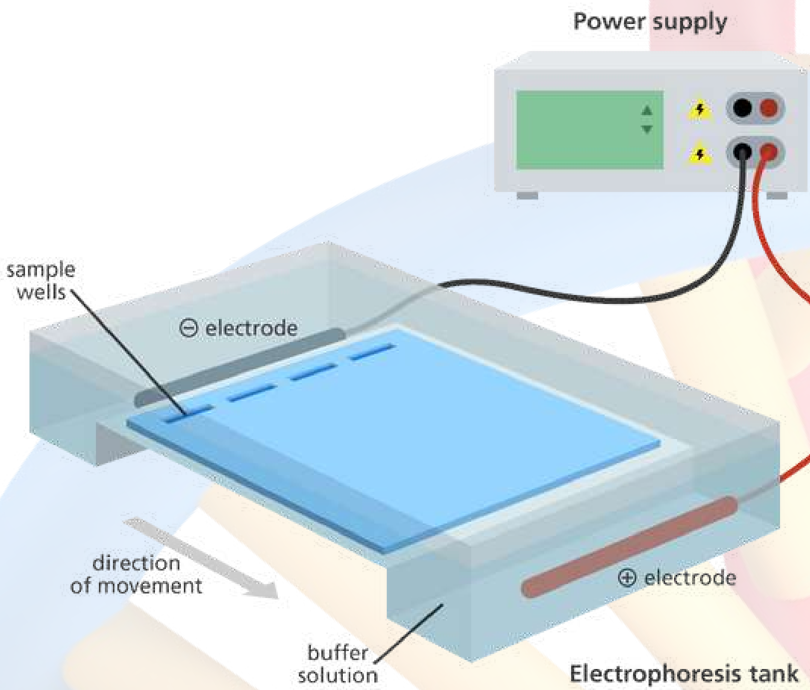
- **Polymerase Chain Reaction** (PCR)
  - **PCR**: **Amplifies** specific DNA **sequences** for research and **analysis**
  - Process:
    - **Denaturation**: DNA strands are heated to separate them
    - **Annealing**: Primers bind to the target DNA sequence
    - **Extension**: DNA polymerase extends the primers to form a new DNA strand
- **Components**: DNA template, primers, DNA polymerase, nucleotides
- **Example**: Identifying genetic **mutations**, **forensic** analysis



GEL ELECTROPHORESIS

- **Gel Electrophoresis:** Technique used for **analysis** and **research** to **separate** DNA **fragments** based on **size**
- **Process:**
  - DNA samples are loaded into a gel
  - An **electric current** is applied, causing the DNA fragments to move
  - **Smaller** fragments move **faster** and **farther** than **larger** ones
- **Components:** Agarose gel, buffer solution, DNA samples, electric current
- **Example: DNA fingerprinting,** analyzing **PCR** products

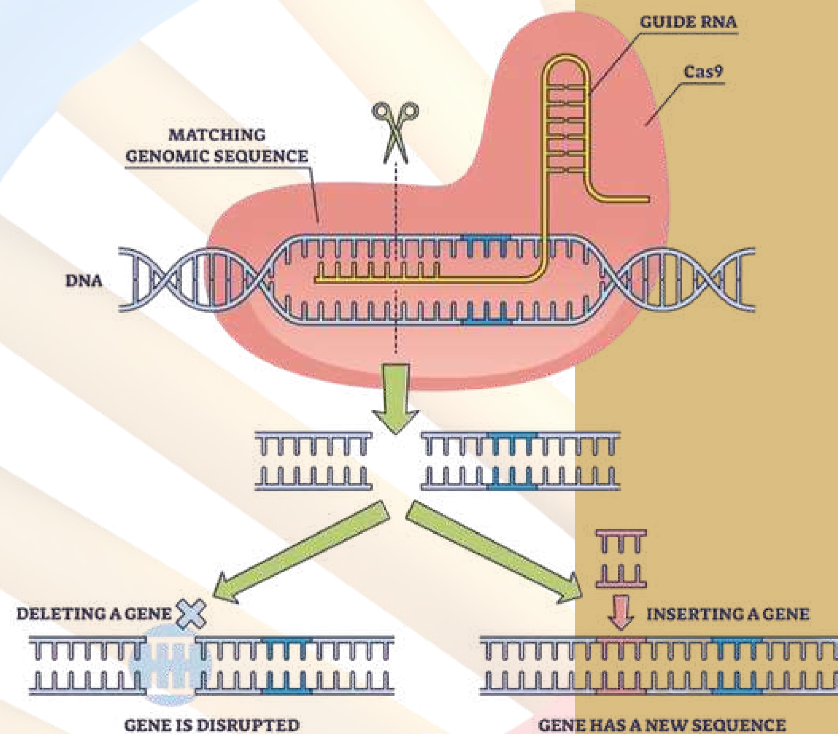




- What happened at Mr. Thompson's bakery that made Detective Elena get involved?
- How did Detective Elena and her team find a clue inside the bakery?
- What did Dr. Sara use PCR for in the lab, and how does PCR work?
- What role do restriction enzymes play in the lab test, and why are they important?
- How does gel electrophoresis help scientists analyze DNA samples?
- How did Dr. Sara identify the robber using DNA evidence?
- How did PCR, restriction enzymes, and gel electrophoresis help solve the robbery case?

GENETIC ENGINEERING

- **Genetic Engineering: Manipulation** of an organism's **genome** using **biotechnological** techniques like **CRISPR-Cas9**
- **Process:**
  - **CRISPR-Cas9:** A guide RNA directs the Cas9 enzyme to a specific DNA sequence, where it makes a cut
  - The cell's natural **repair mechanisms** can **add** or **remove genetic material,** or introduce **new DNA**
- **Components:** Guide RNA, Cas9 enzyme, target DNA sequence
  - **Example:** Creating genetically modified organisms (GMOs), gene therapy



GENETIC ENGINEERING

- **Ethical Considerations**
  - Surrounding the use of genetic engineering and biotechnological practices
- **Debates**:
  - **Safety** and long-term effects of **GMOs**
  - Genetic **privacy** and **discrimination**
  - Ethical implications of **human** genetic **modification**
- **Examples:**
  - **Editing genes** to cure diseases
  - **Enhancing** human abilities
  - Creating **designer babies**
- **Societal Implications**
  - DNA technologies and biotechnological advancements impact medicine, agriculture, and ethics
    - **Medicine**:
      - **Personalized** medicine based on **genetic** information

- **Gene** therapy for treating **genetic** disorders

- **Agriculture**:
  - **Genetically modified crops** with **increased** yield and **resistance** to pests
  - Ethical concerns about GMOs and biodiversity
- **Ethics:**
  - Discussions on genetic **modifications** and their societal **impact**
- Balancing **innovation** with ethical

SUMMARY

1. How did scientists discover that DNA, not protein, is the genetic material?
    - "At first, scientists believed proteins were the genetic material because _______________.'
    - "Experiments by Griffith and Hershey & Chase showed that _______________ is responsible for passing genetic information."
2. What is the structure of DNA, and how does it help DNA do its job?
    - "DNA is shaped like a _______________ and is made of building blocks called _______________."
    - "Its shape and base pairing help it _______________ and _______________ genetic information."
3. What happens during DNA replication, and why is it important?
    - "DNA replication happens before a cell divides so that _______________."
    - "The process is called _______________ because each new DNA strand keeps one old and one new strand."
4. What is PCR, and how is it used in research and analysis?
    - "PCR is a tool scientists use to _______________."
    - "It helps in research by making many copies of _______________ so scientists can study it more easily."
5. How does gel electrophoresis help scientists study DNA?
    - "Gel electrophoresis separates DNA fragments based on _______________."
    - "This lets scientists _______________, such as when they do DNA fingerprinting or test for mutations."
6. What are some ethical and societal concerns about genetic engineering and DNA technology?
    - "One ethical concern about using tools like CRISPR is _______________."
    - "DNA technology can help society by _______________, but it also raises questions about _______________."

RESOURCES

Cognito. (2020, March 8). GCSE Biology – What is DNA? (Structure and Function of DNA) [Video]. YouTube. https://www.youtube.com/watch?v=T6_wKPAbf2k

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MAMMOTH SCIENCE

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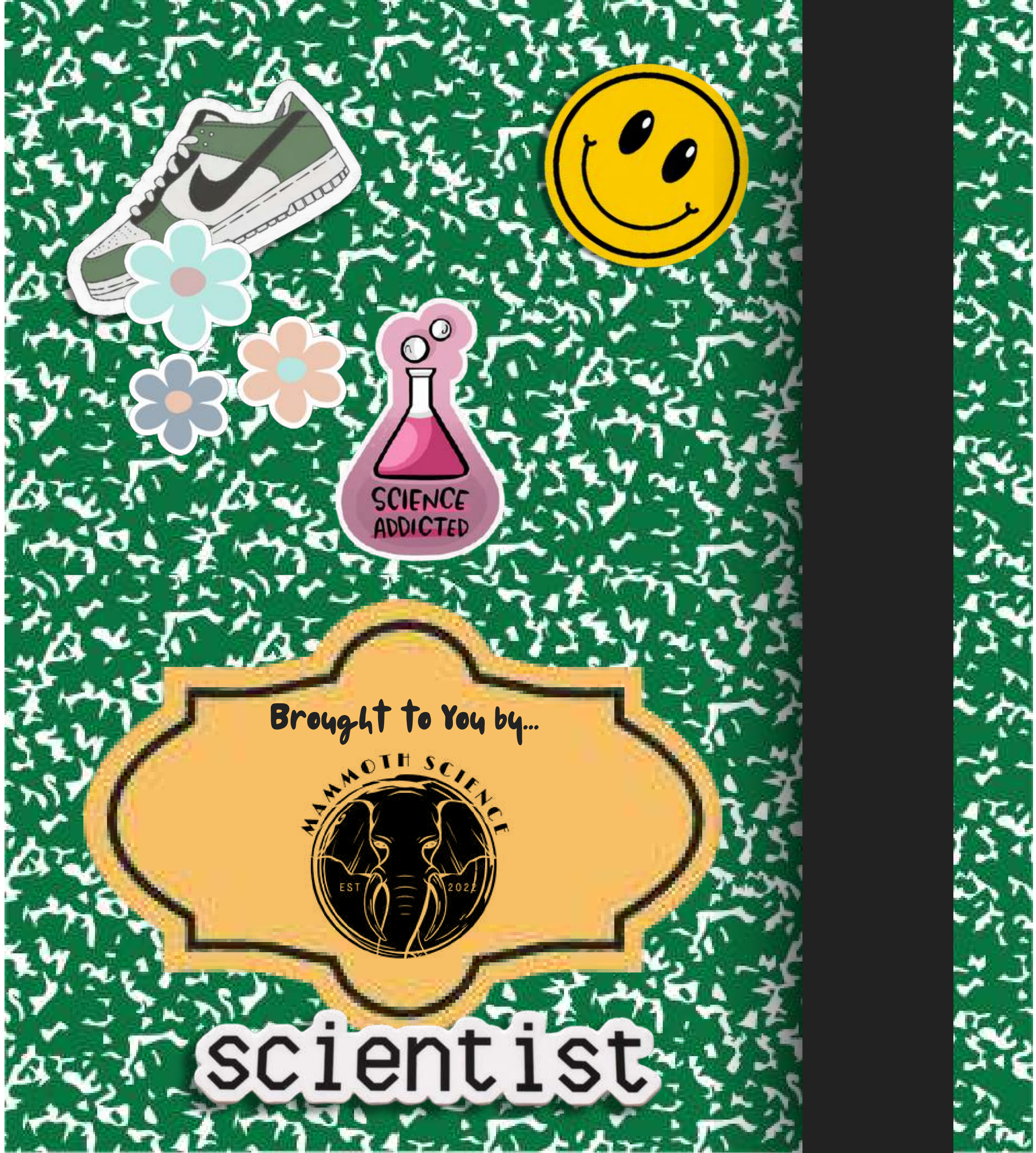
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