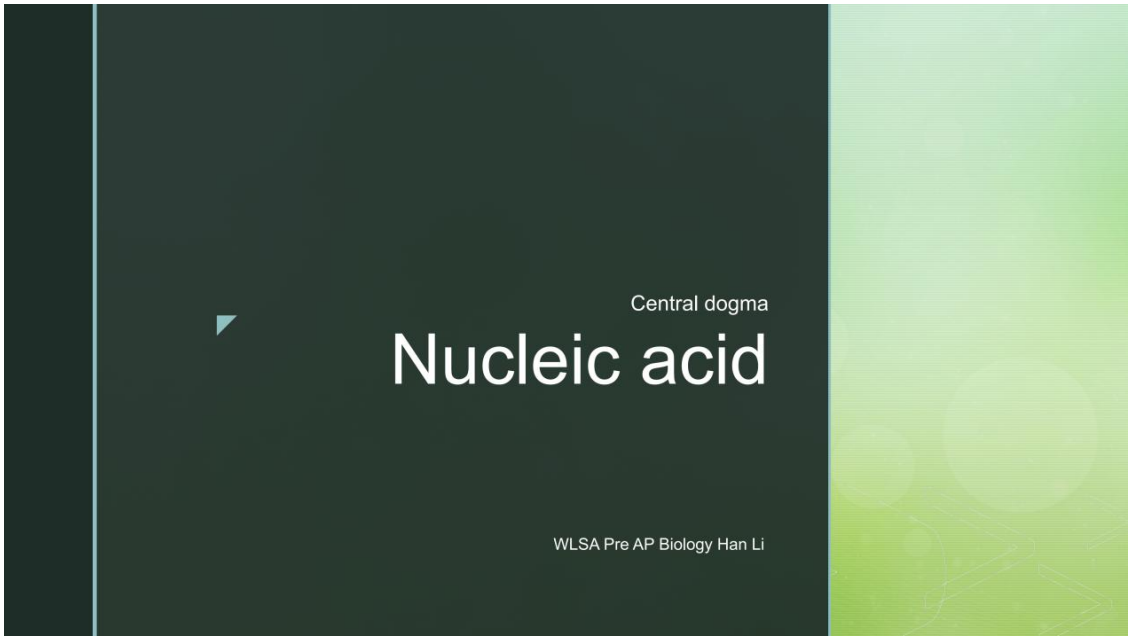
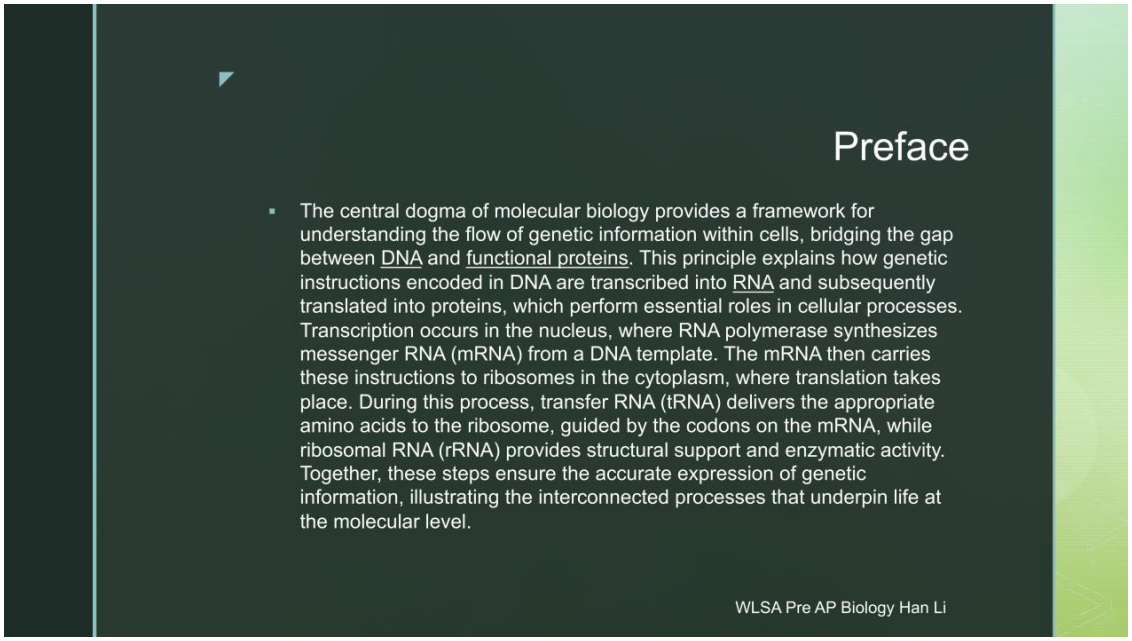

Central dogma
Nucleic acid
WLSA Pre AP Biology Han Li

Molecular Biology — Page 2



Page 2 Annotation

Title: Preface

Clear Explanation:

The Central Dogma is the basic framework that explains how genetic information moves from DNA to functional proteins inside cells.

DNA stores the instructions.

Transcription turns a section of DNA into messenger RNA (mRNA).

Translation reads the mRNA and assembles amino acids into proteins.

Proteins then perform almost all the important jobs in the cell (structure, enzymes, transport, signaling, etc.).

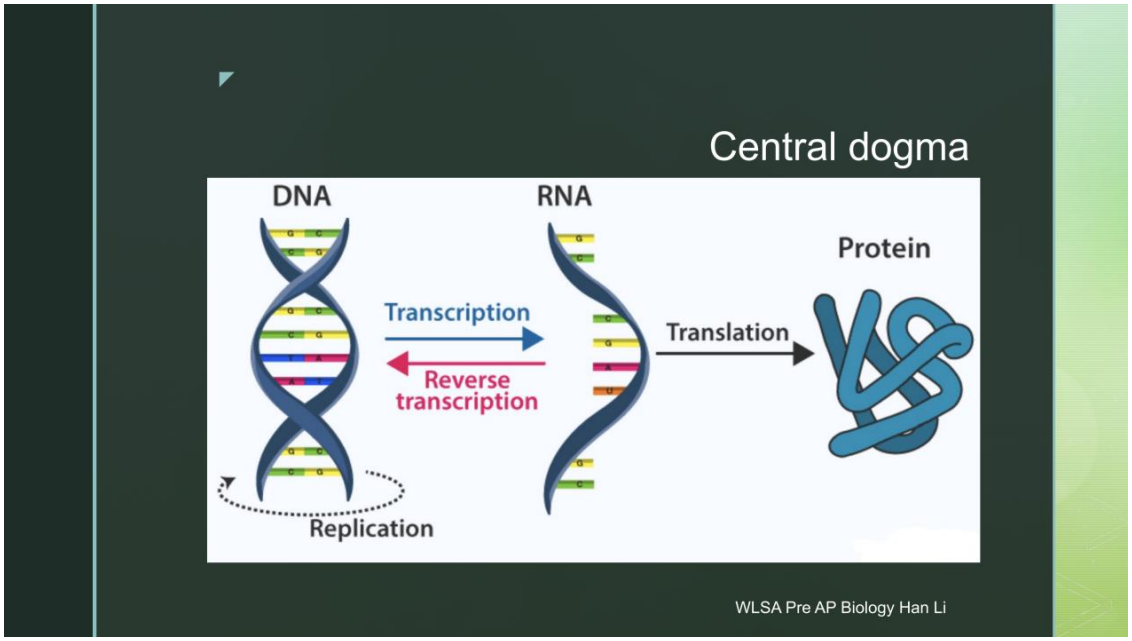
Key Points:

- DNA → RNA (Transcription)
- RNA → Protein (Translation)
- Transcription happens in the nucleus
- Translation happens in the cytoplasm at ribosomes
- tRNA brings amino acids
- rRNA helps form the ribosome structure

Why It Matters:

This is the core “information flow” rule of molecular biology. Almost every topic in genetics and biotechnology connects back to these steps.

Molecular Biology — Page 3



Page 3 Annotation

Title: Central Dogma (Diagram)

Clear Explanation:

This diagram shows the complete Central Dogma flow:

- **DNA** can make copies of itself (**Replication**)
- DNA is transcribed into **RNA** (Transcription)
- RNA can also be reverse-transcribed back into DNA (Reverse Transcription – important in viruses like HIV)
- RNA is translated into **Protein** (Translation)

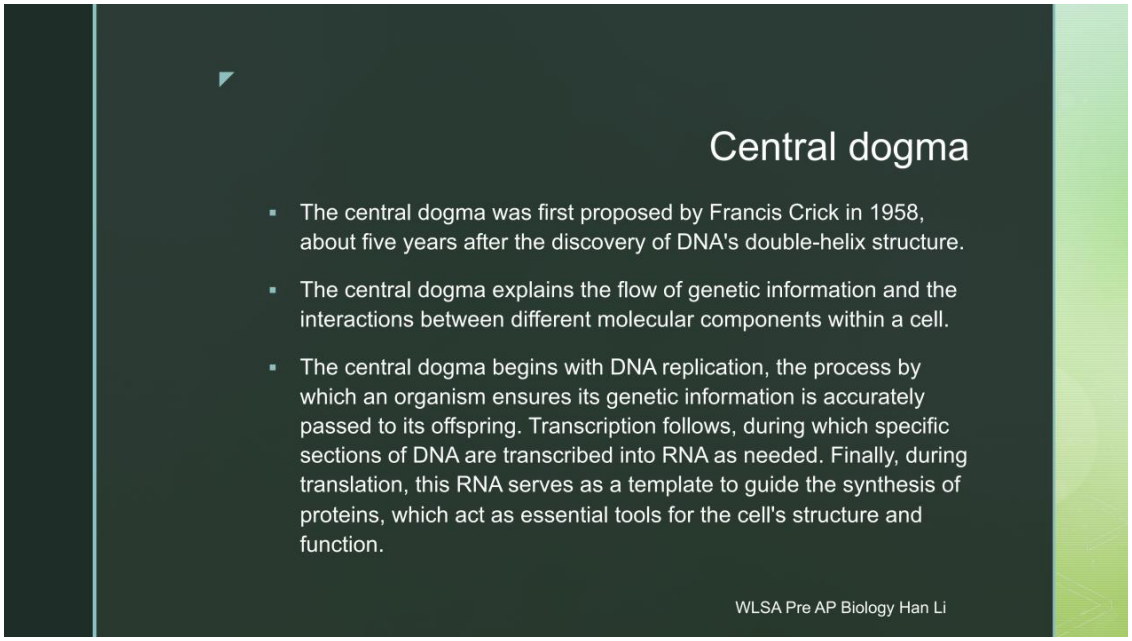
Key Points:

- Arrows show the direction of information flow
- Replication = DNA → DNA
- Transcription = DNA → RNA
- Translation = RNA → Protein

Why It Matters:

The diagram gives you a visual “roadmap” of how genetic information is used. Most questions in this unit will ask you to identify or explain one of these arrows.

Molecular Biology — Page 4



Page 4 Annotation

Title: Central Dogma (Detailed Explanation)

Clear Explanation:

The Central Dogma was first proposed by Francis Crick in 1958. It describes the normal flow of genetic information in cells:

1. **Replication**: DNA makes an exact copy of itself so it can be passed to daughter cells.
2. **Transcription**: Specific genes are copied from DNA into mRNA when the cell needs that protein.
3. **Translation**: The mRNA is read by ribosomes and used to build proteins.

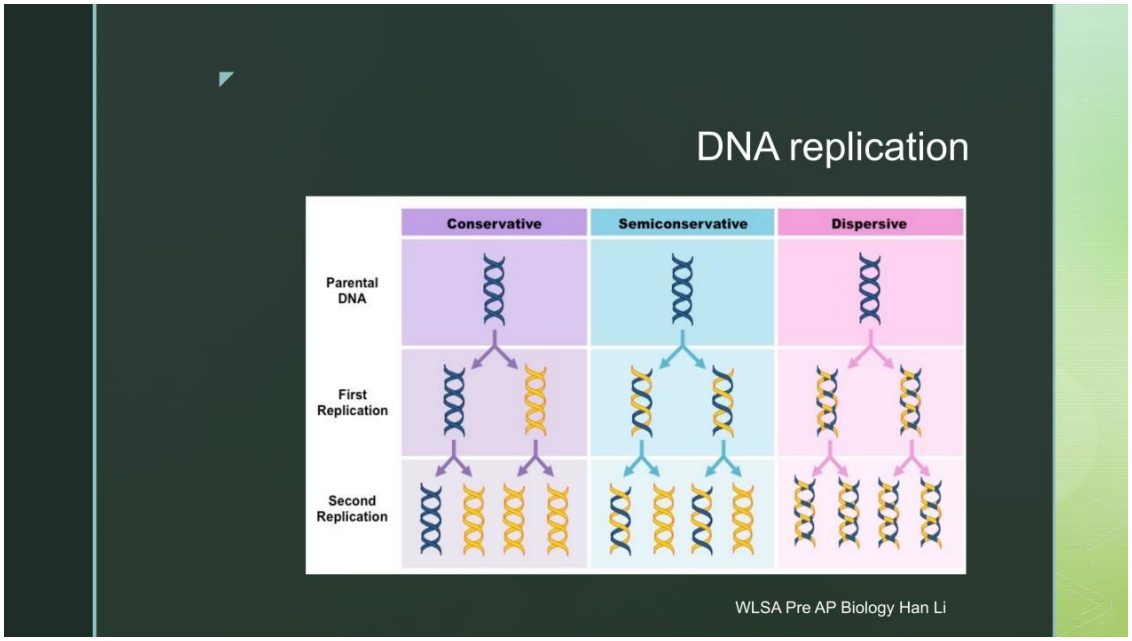
Key Points:

- Proposed by Francis Crick (1958)
- DNA replication ensures genetic information is passed to offspring
- Transcription and translation allow cells to make the proteins they need

Why It Matters:

This principle connects genes (DNA) to actual cell function (proteins). It is the foundation of modern molecular biology and biotechnology.

Molecular Biology — Page 5



Page 5 Annotation

Title: DNA Replication (Three Models)

Clear Explanation:

Scientists once debated how DNA replicates. There were three main theories:

- **Conservative**: The original double helix stays together and a completely new copy is made.
- **Semiconservative**: Each new DNA molecule has one old strand and one new strand.
- **Dispersive**: The DNA is broken into pieces and new pieces are mixed in randomly.

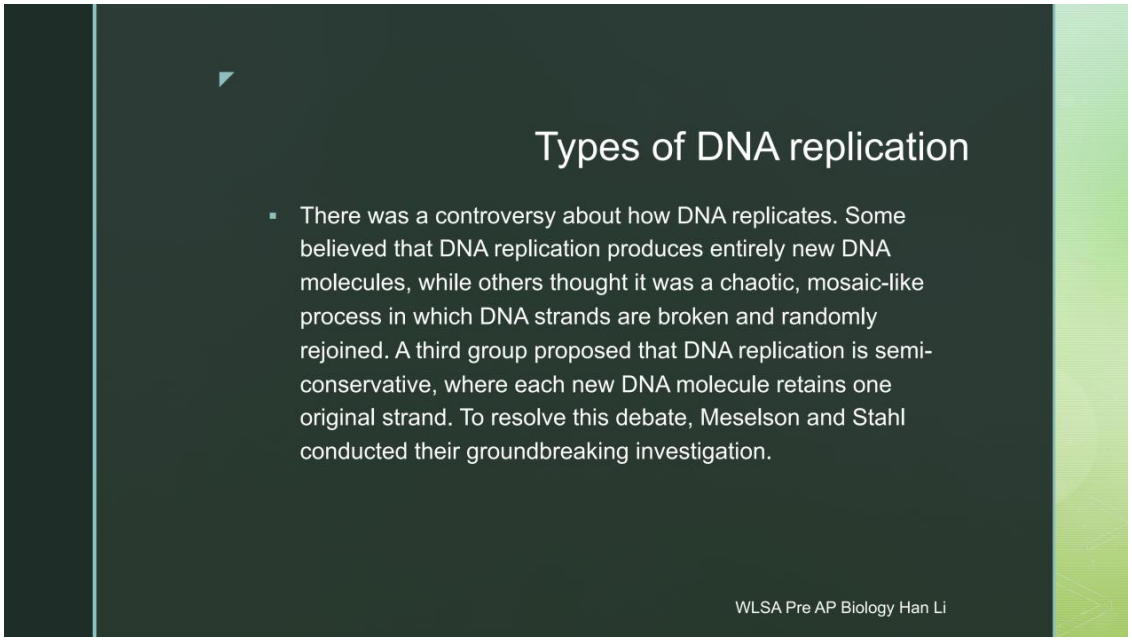
The diagram shows what each model would look like after one and two rounds of replication.

Key Points:

- Conservative: Parental strands stay together
- Semiconservative: Each daughter DNA has 1 parental + 1 new strand
- Dispersive: Strands are mixed old and new pieces

Why It Matters:

The correct model (semiconservative) was proven by the Meselson-Stahl experiment. This is one of the most famous experiments in biology.



Page 6 Annotation

Title: Types of DNA Replication

Clear Explanation:

Early scientists had different ideas about DNA replication. Some thought it made entirely new DNA, others thought it was messy and random, and a third group proposed the **semiconservative** model (each new DNA keeps one original strand).

To settle the debate, Meselson and Stahl designed a famous experiment using heavy and light nitrogen isotopes to track old and new DNA strands.

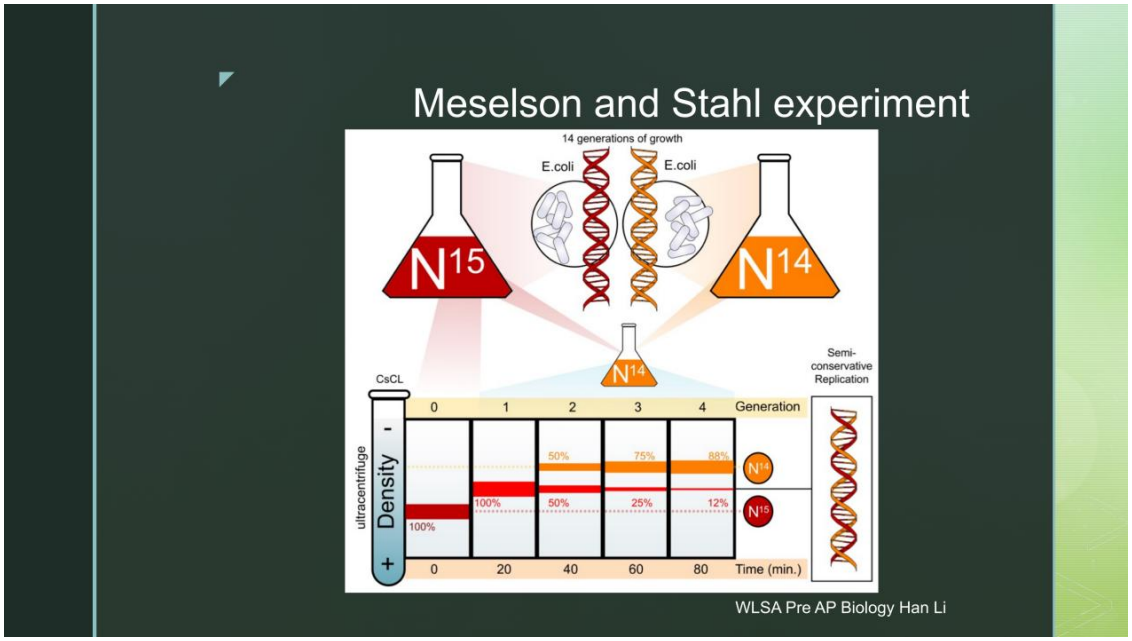
Key Points:

- There was a scientific controversy in the 1950s
- Meselson and Stahl's experiment (1958) proved the semiconservative model is correct

Why It Matters:

This example shows how science works: hypotheses are tested with experiments. The semiconservative model is now accepted as the universal mechanism of DNA replication in living cells.

Molecular Biology — Page 7



Page 7 Annotation

Title: Meselson and Stahl Experiment

Clear Explanation:

This diagram shows the famous Meselson and Stahl experiment (1958) that proved DNA replication is **semiconservative**.

Bacteria were first grown in heavy nitrogen (^{15}N) so all DNA was heavy. Then they were switched to light nitrogen (^{14}N). After each generation, scientists used centrifugation to see how heavy or light the DNA was.

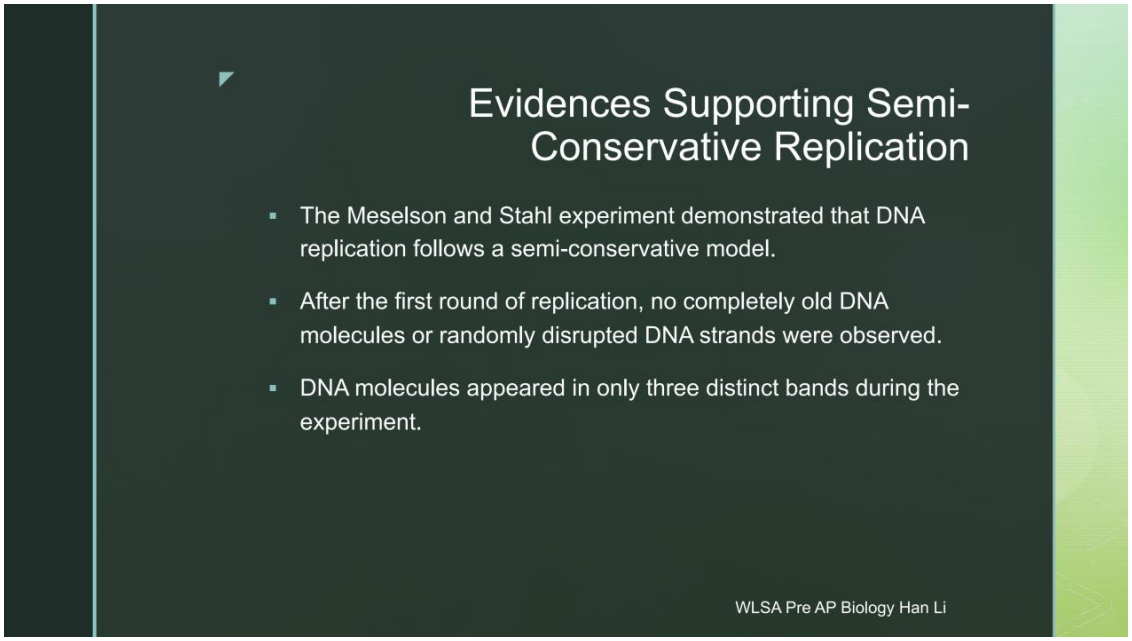
The results showed that after one generation, all DNA was “hybrid” (one heavy strand + one light strand). After two generations, half was hybrid and half was completely light.

Key Points:

- Used heavy (^{15}N) and light (^{14}N) nitrogen to label DNA
- After 1 generation → only hybrid DNA
- After 2 generations → hybrid + light DNA
- This matches the semiconservative model

Why It Matters:

This experiment ended the debate and confirmed that each new DNA molecule keeps one original (parental) strand — the foundation of modern genetics.



Page 8 Annotation

Title: Evidences Supporting Semi-Conservative Replication

Clear Explanation:

The Meselson and Stahl experiment provided strong evidence that DNA replication follows the **semiconservative model**.

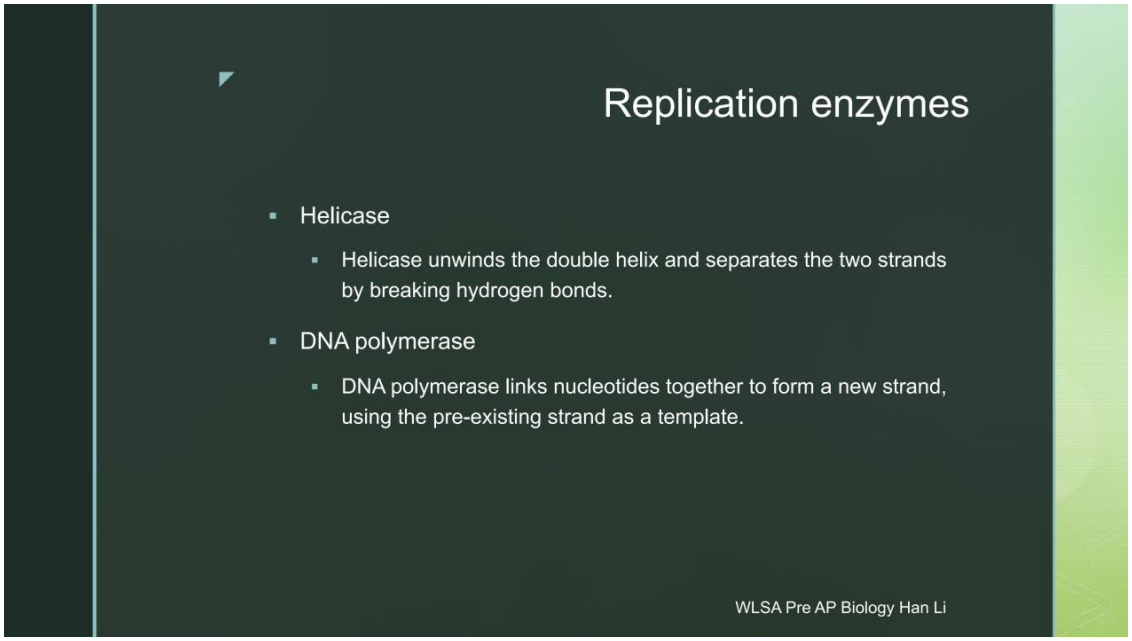
After the first round of replication, scientists did not see any completely old DNA or randomly mixed DNA. Instead, they saw only three clear bands in the centrifuge, which perfectly matched the prediction of the semiconservative model.

Key Points:

- No fully old DNA after first replication
- No randomly broken and rejoined strands
- Only three distinct density bands appeared

Why It Matters:

This is a classic example of how a well-designed experiment can definitively prove one scientific hypothesis over others.



Page 9 Annotation

Title: Replication Enzymes

Clear Explanation:

Two key enzymes are essential for DNA replication:

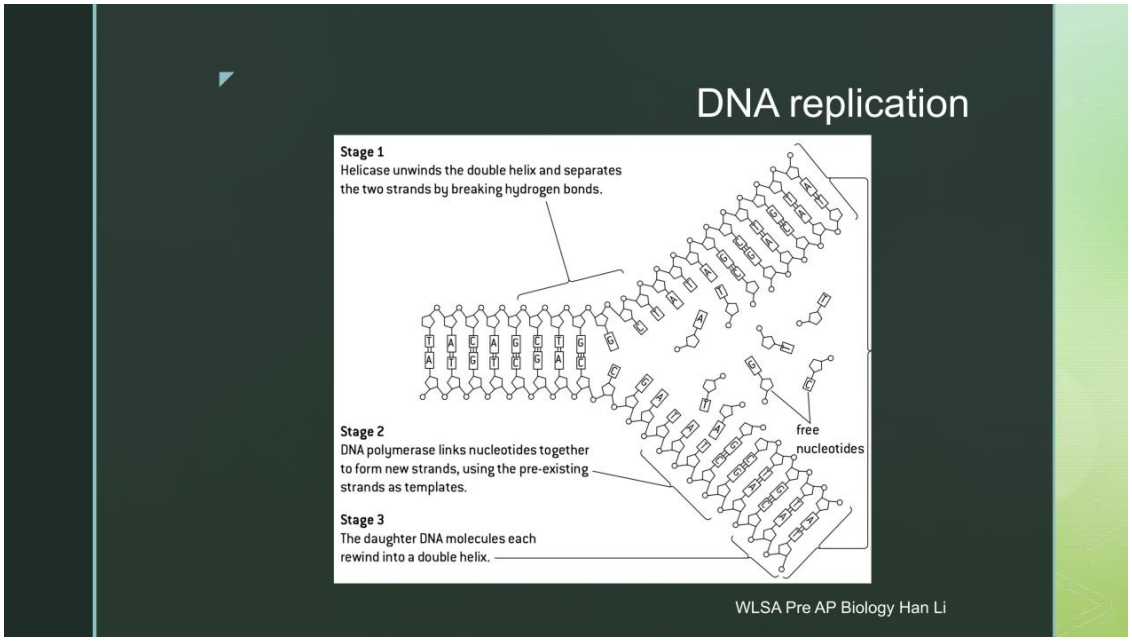
- **Helicase**: Unwinds the double helix by breaking the hydrogen bonds between base pairs, separating the two DNA strands.
- **DNA Polymerase**: Reads the template strand and adds complementary nucleotides to build the new strand.

Key Points:

- Helicase = “unzipper” of DNA
- DNA polymerase = “builder” of new strand
- Both work together during replication

Why It Matters:

These enzymes make the complicated process of copying 3 billion base pairs fast and accurate.



Page 10 Annotation

Title: DNA Replication (Stages)

Clear Explanation:

This diagram illustrates the three main stages of DNA replication:

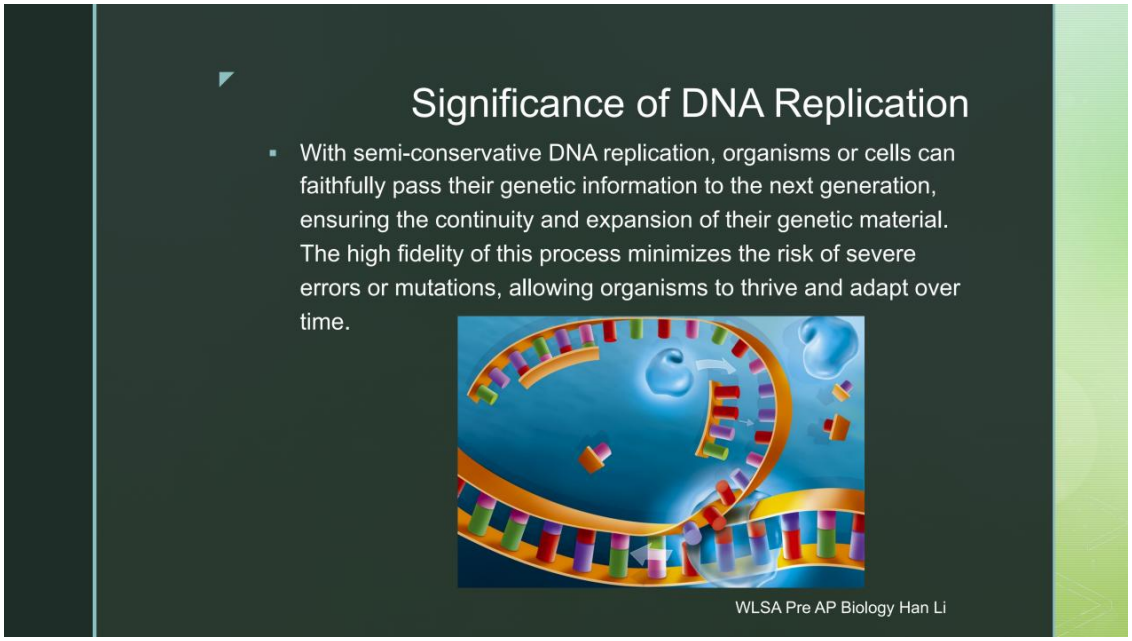
- **Stage 1**: Helicase unwinds the double helix and separates the two strands.
- **Stage 2**: DNA polymerase adds free nucleotides to form new complementary strands.
- **Stage 3**: The two new double helices rewind and separate into two daughter molecules.

Key Points:

- Helicase opens the helix
- DNA polymerase synthesizes new strands
- Each daughter DNA has one old and one new strand

Why It Matters:

This shows the actual molecular mechanism behind semiconservative replication.



Page 11 Annotation

Title: Significance of DNA Replication

Clear Explanation:

Because DNA replication is semiconservative and extremely accurate, organisms can reliably pass their genetic information to the next generation.

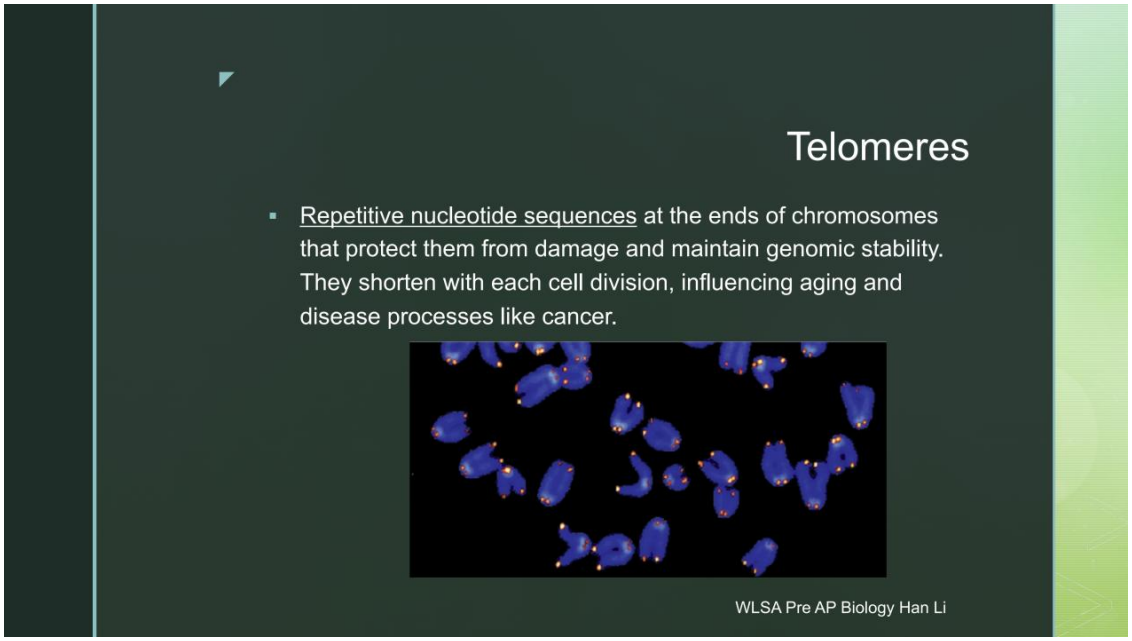
The high fidelity (accuracy) of this process greatly reduces dangerous mutations, allowing life to continue and evolve over billions of years.

Key Points:

- Faithful copying of genetic information
- Minimizes harmful mutations
- Essential for growth, reproduction, and evolution

Why It Matters:

Without accurate DNA replication, life as we know it could not exist.



Page 12 Annotation

Title: Telomeres

Clear Explanation:

Telomeres are repetitive DNA sequences (like TTAGGG repeated many times) located at the very ends of chromosomes. They act like protective “caps” that prevent chromosomes from breaking or sticking together.

With each cell division, telomeres naturally get a little shorter.

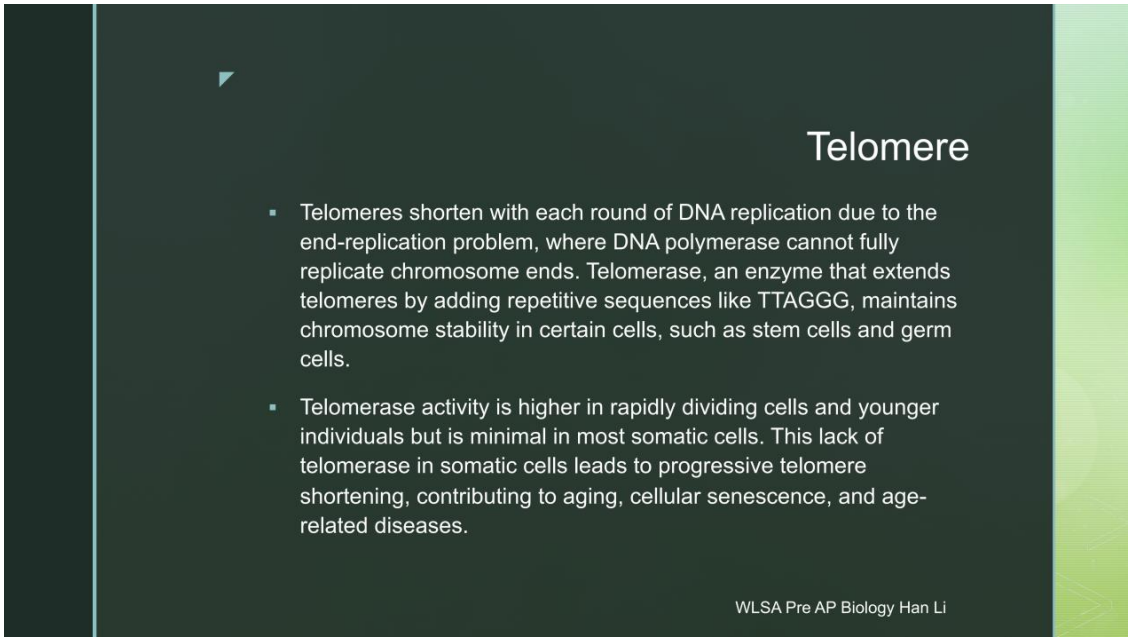
Key Points:

- Protective caps at chromosome ends
- Shorten with every cell division
- Related to aging and cancer

Why It Matters:

Telomere shortening is one of the reasons cells eventually stop dividing (senescence), which is linked to aging and some diseases.

Molecular Biology — Page 13



Page 13 Annotation

Title: Telomere (Continued)

Clear Explanation:

Telomeres shorten because DNA polymerase cannot fully copy the very end of the linear chromosome (the “end-replication problem”).

The enzyme **telomerase** can add extra TTAGGG repeats to the ends, but it is only active in stem cells, germ cells, and cancer cells. In normal body (somatic) cells, telomerase is turned off, so telomeres keep shortening.

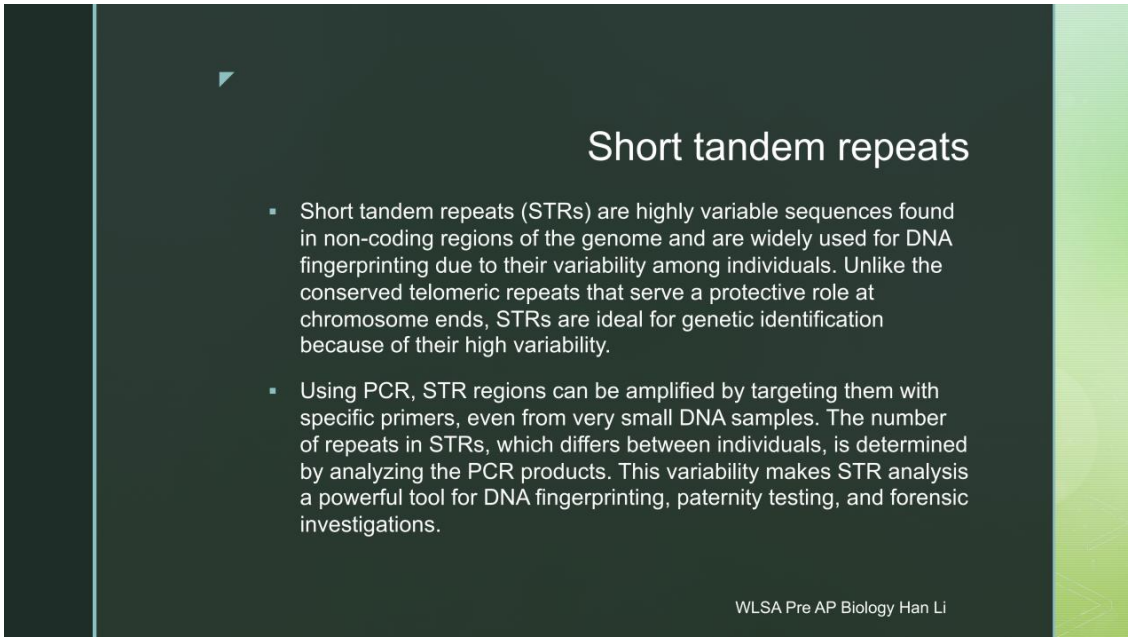
Key Points:

- End-replication problem → telomeres shorten
- Telomerase adds repeats (active in certain cells)
- Short telomeres → aging and disease

Why It Matters:

Understanding telomeres helps explain why we age and why cancer cells can divide forever.

Molecular Biology — Page 14



Page 14 Annotation

Title: Short Tandem Repeats (STRs)

Clear Explanation:

Short tandem repeats (STRs) are short DNA sequences that repeat many times in non-coding regions of the genome. The number of repeats varies greatly between individuals.

Because they are so variable, STRs are the main tool used in **DNA fingerprinting** for forensics, paternity tests, and crime scene investigations.

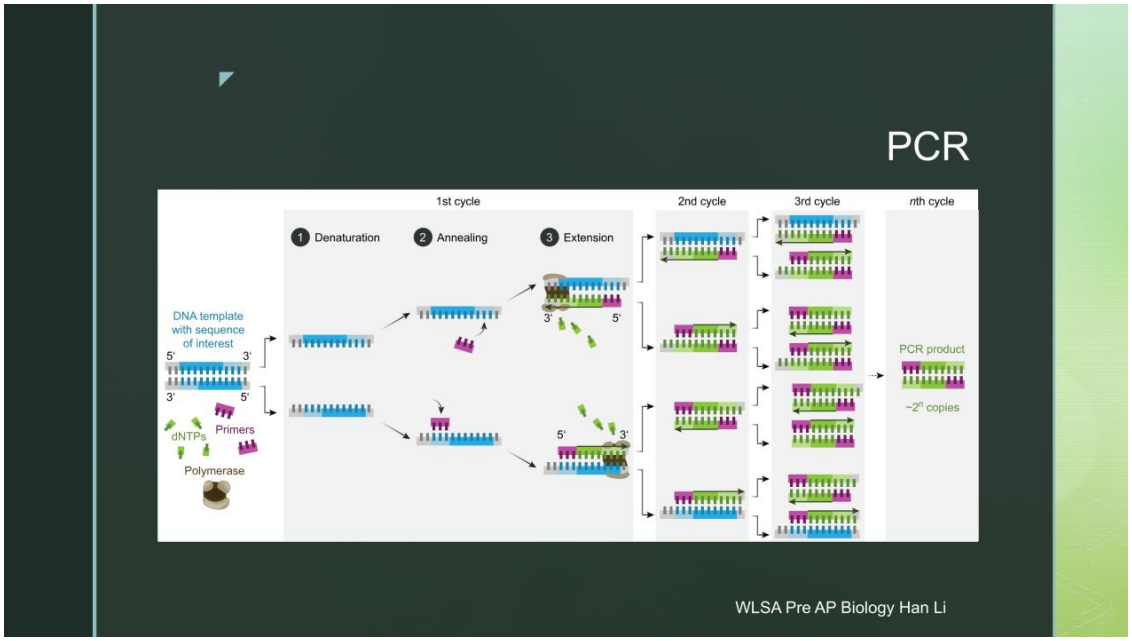
Key Points:

- Highly variable between people
- Used in DNA fingerprinting
- Amplified using PCR

Why It Matters:

STR analysis allows scientists to identify individuals with extremely high accuracy from tiny amounts of DNA.

Molecular Biology — Page 15



Page 15 Annotation

Title: PCR (Polymerase Chain Reaction) – Diagram

Clear Explanation:

This diagram shows how PCR works to make millions of copies of a specific DNA segment.

It repeats three steps in a cycle:

4. **Denaturation** — heat separates the DNA strands
5. **Annealing** — primers bind to the target sequence
6. **Extension** — Taq polymerase builds new DNA strands

After many cycles, you get billions of copies of the target DNA.

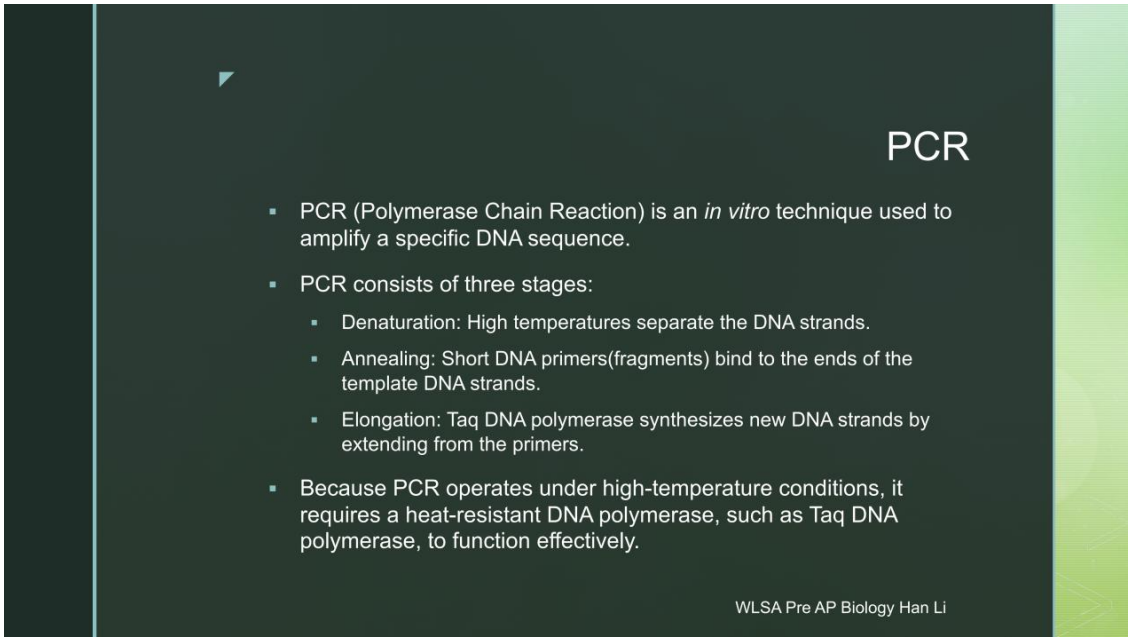
Key Points:

- In vitro (test-tube) DNA amplification
- Three steps per cycle: Denature → Anneal → Extend
- Uses heat-stable Taq polymerase

Why It Matters:

PCR is one of the most important techniques in modern biology and medicine.

Molecular Biology — Page 16



Page 16 Annotation

Title: PCR (Summary)

Clear Explanation:

PCR (Polymerase Chain Reaction) is a laboratory technique used to make millions or billions of copies of a specific piece of DNA. It has three repeated steps and requires a special heat-resistant enzyme called Taq DNA polymerase.

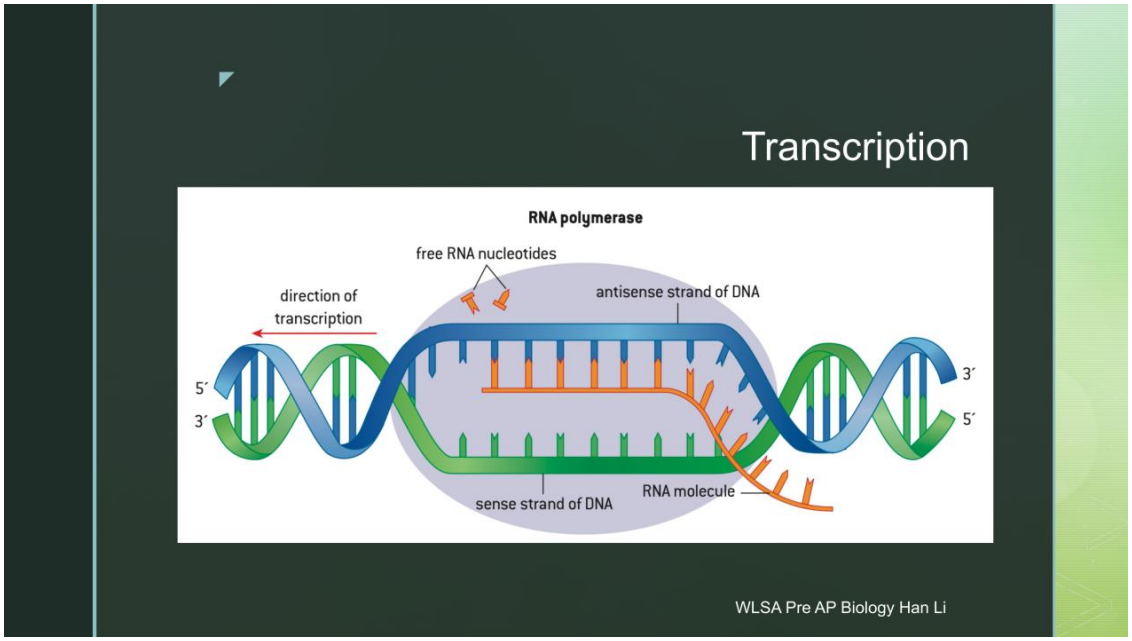
Key Points:

- Denaturation (high temperature)
- Annealing (primers bind)
- Elongation (polymerase builds new strands)

Why It Matters:

PCR allows scientists to study tiny amounts of DNA — essential for forensics, disease diagnosis, and genetic research.

Molecular Biology — Page 17



Page 17 Annotation

Title: Transcription (Diagram)

Clear Explanation:

Transcription is the process of copying a gene from DNA into messenger RNA (mRNA).

RNA polymerase moves along the DNA template strand, reading it and building a complementary RNA molecule. Only one DNA strand (the template or antisense strand) is transcribed.

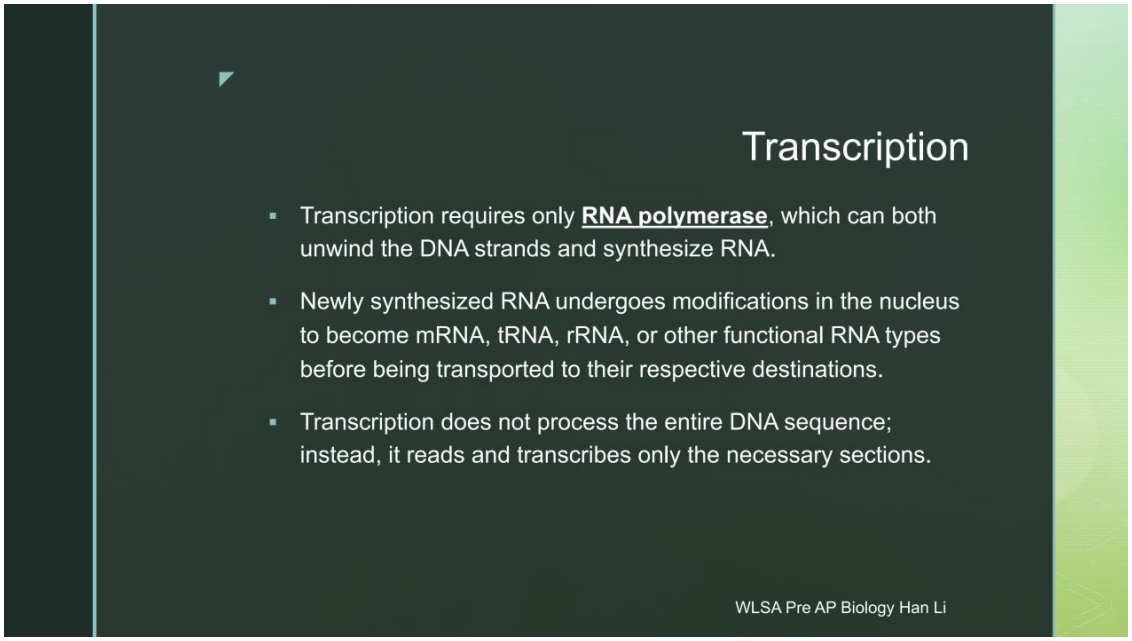
Key Points:

- RNA polymerase does both unwinding and synthesis
- Direction of transcription is 5' → 3' on RNA
- Only specific genes are transcribed when needed

Why It Matters:

Transcription turns the genetic code in DNA into a usable message (mRNA) that can leave the nucleus.

Molecular Biology — Page 18



Page 18 Annotation

Title: Transcription (Summary)

Clear Explanation:

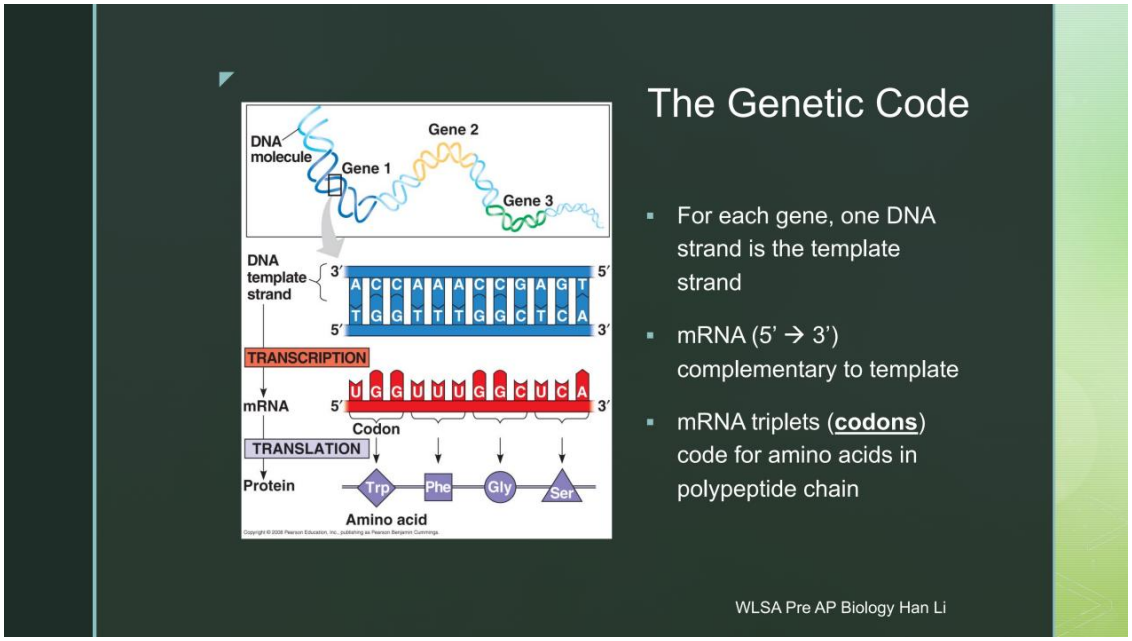
Transcription uses only RNA polymerase. It does not copy the entire DNA — only the sections (genes) that the cell currently needs. The newly made RNA is then processed and modified in the nucleus before becoming mature mRNA, tRNA, or rRNA.

Key Points:

- RNA polymerase unwinds DNA and builds RNA
- Newly made RNA is modified in the nucleus
- Only necessary genes are transcribed

Why It Matters:

This allows cells to control which proteins are made at any given time.



Page 19 Annotation

Title: The Genetic Code

Clear Explanation:

The genetic code is the set of rules by which information in mRNA is translated into proteins.

- Each gene has a **template strand** of DNA
- mRNA is complementary to the template (but uses U instead of T)
- mRNA is read in groups of three nucleotides called **codons**
- There are 64 possible codons (4^3) that code for 20 amino acids + 3 stop signals

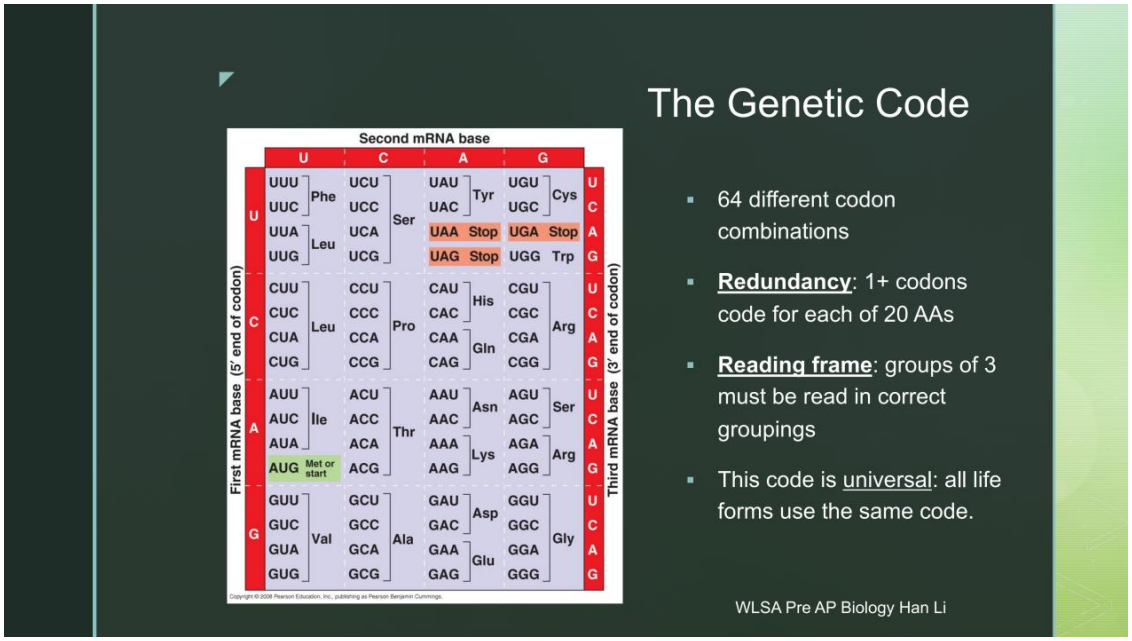
Key Points:

- 64 codons total
- Redundancy: most amino acids have more than one codon
- Reading frame must be correct
- The code is **universal** — almost all living things use the same code

Why It Matters:

The genetic code is the "language" that connects genes to proteins.

Molecular Biology — Page 20



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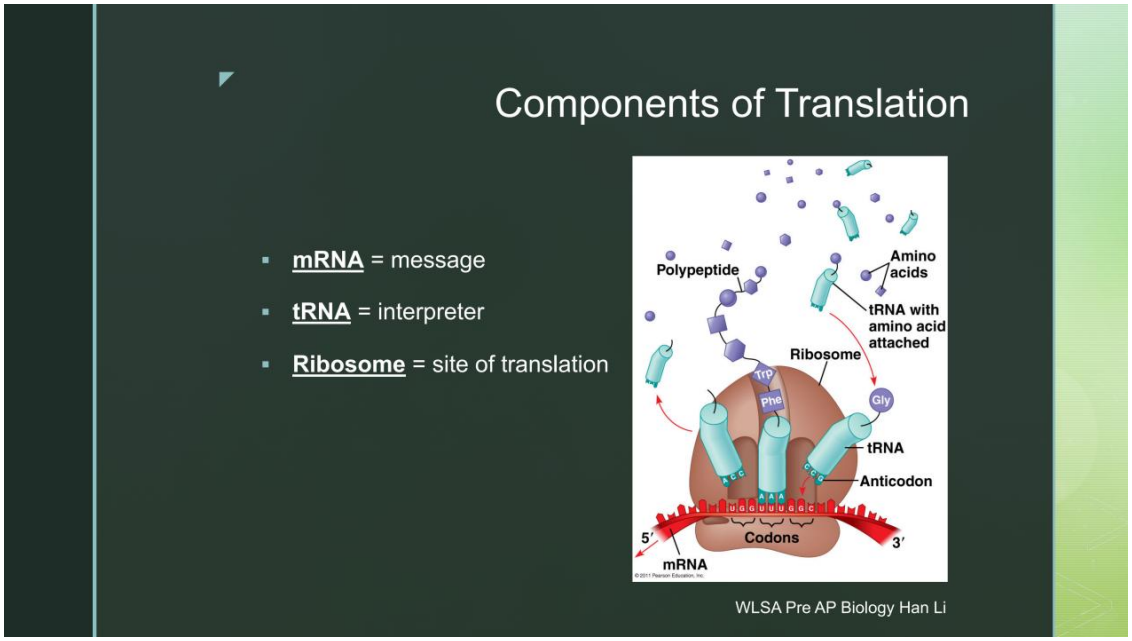


Page 21 Annotation

Title: Components of Translation

Clear Explanation:

Translation is the process of building a protein using mRNA as the instructions.

Three main components:

- **mRNA** = the message (carries the code)
- **tRNA** = the interpreter (brings the correct amino acid)
- **Ribosome** = the factory where translation happens

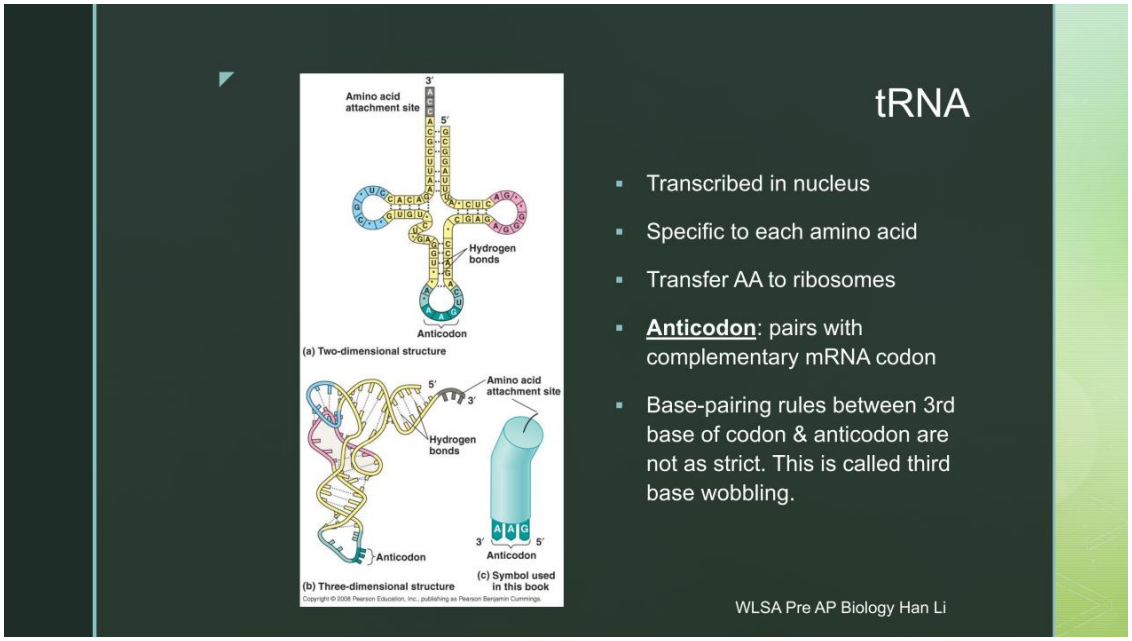
Key Points:

- mRNA = message
- tRNA = brings amino acids
- Ribosome = site of protein synthesis

Why It Matters:

These three work together like a factory assembly line to turn the genetic code into real proteins.

Molecular Biology — Page 22



Page 22 Annotation

Title: tRNA

Clear Explanation:

Transfer RNA (tRNA) is a small RNA molecule that acts like a translator. Each tRNA carries one specific amino acid and has an **anticodon** that matches a codon on the mRNA.

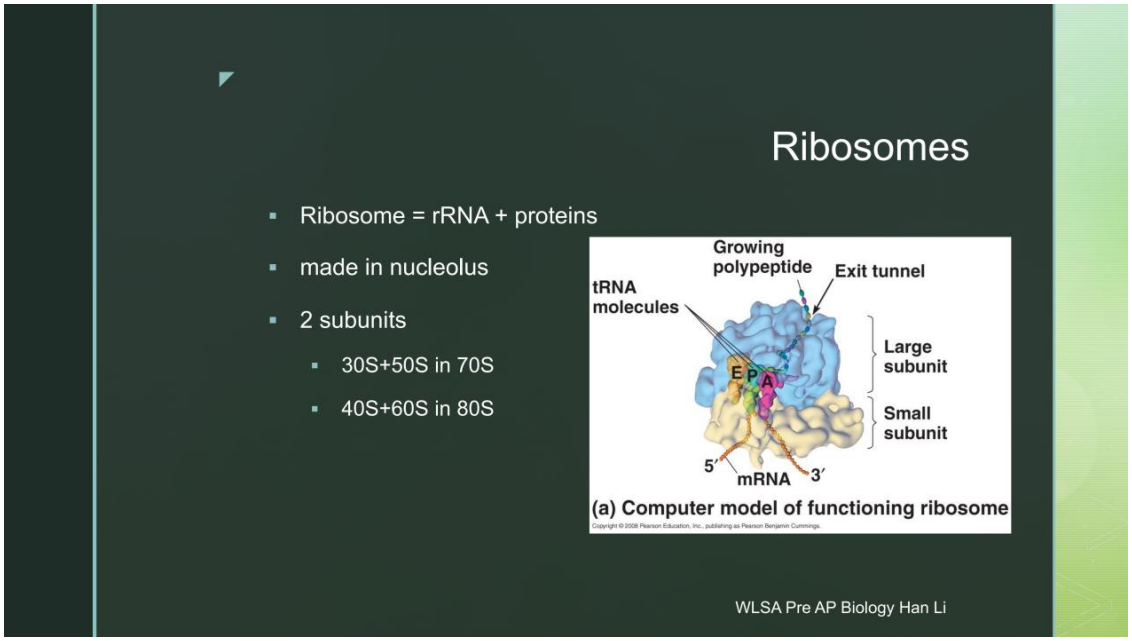
The third base of the codon and anticodon can “wobble” (not follow strict base-pairing rules), allowing fewer tRNAs to cover all 61 codons.

Key Points:

- Specific to one amino acid
- Has anticodon that pairs with mRNA codon
- Third-base wobble

Why It Matters:

tRNA is the bridge between the nucleic acid language (codons) and the protein language (amino acids).



Page 23 Annotation

Title: Ribosomes

Clear Explanation:

Ribosomes are the cellular machines that build proteins. They are made of ribosomal RNA (rRNA) and proteins.
A ribosome has two subunits (small and large) and three important sites:

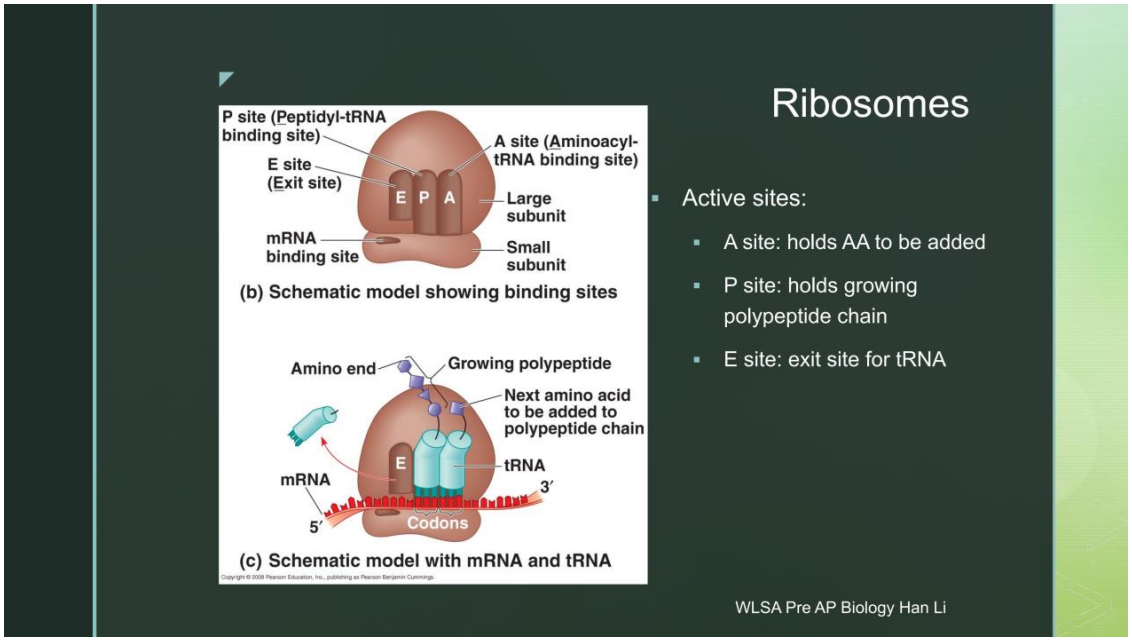
- **A site**: holds the incoming tRNA with the next amino acid
- **P site**: holds the tRNA with the growing polypeptide chain
- **E site**: exit site for empty tRNA

Key Points:

- Made in the nucleolus
- Two subunits (prokaryotes 70S, eukaryotes 80S)
- Three binding sites: A, P, E

Why It Matters:

The ribosome is where translation actually happens — turning mRNA instructions into a chain of amino acids.



Page 24 Annotation

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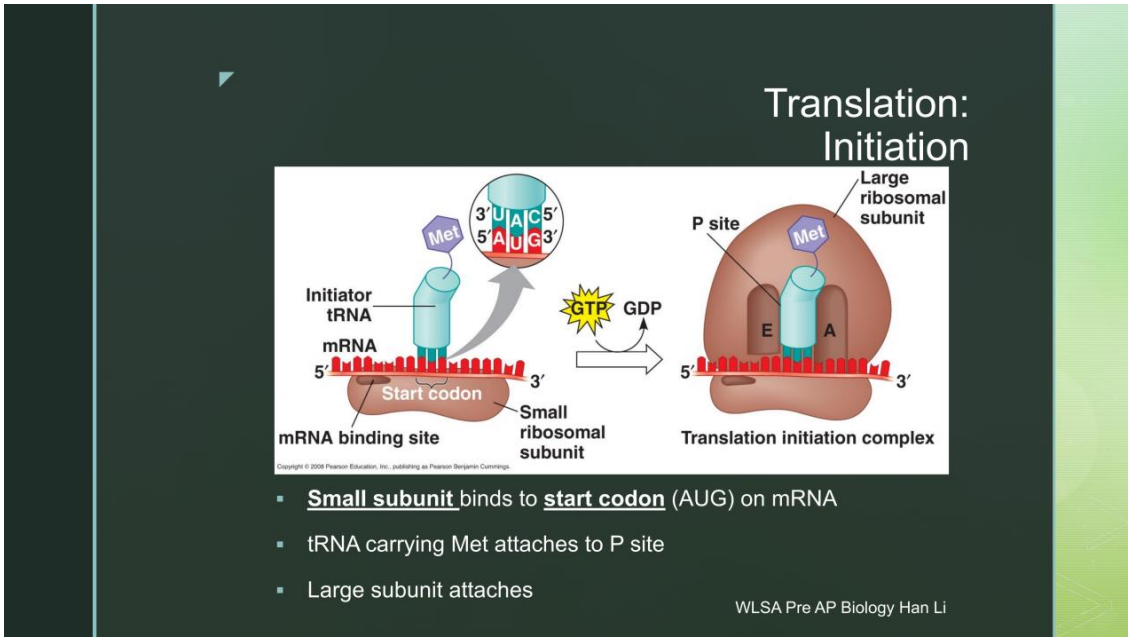


Page 25 Annotation

Title: Translation: Initiation

Clear Explanation:

Translation begins (initiation) when:

7. The small ribosomal subunit binds to the start codon (AUG) on mRNA.
8. The initiator tRNA carrying methionine (Met) attaches to the P site.
9. The large subunit joins to form the complete ribosome.

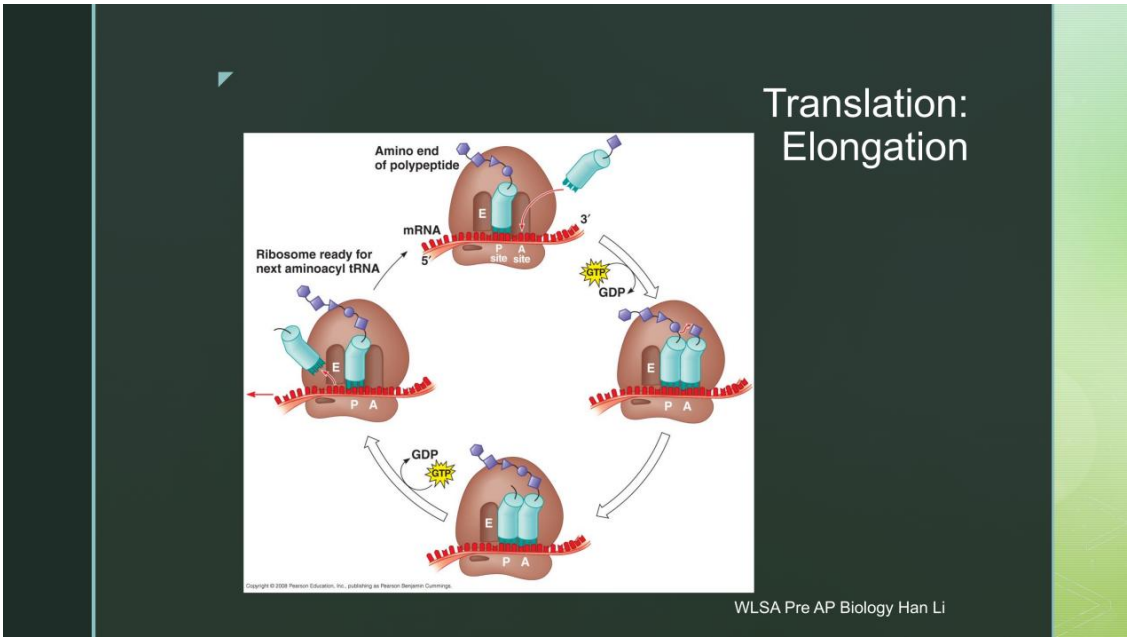
Key Points:

- Starts at AUG (methionine)
- Forms the translation initiation complex

Why It Matters:

Correct initiation ensures the protein starts at the right place and in the right reading frame.

Molecular Biology — Page 26



Page 26 Annotation

Title: Translation: Elongation

Clear Explanation:

During elongation, the ribosome moves along the mRNA one codon at a time.

- A new tRNA with the next amino acid enters the A site
- A peptide bond forms between the growing chain and the new amino acid
- The ribosome shifts (translocates), moving the empty tRNA to the E site and the growing chain to the P site

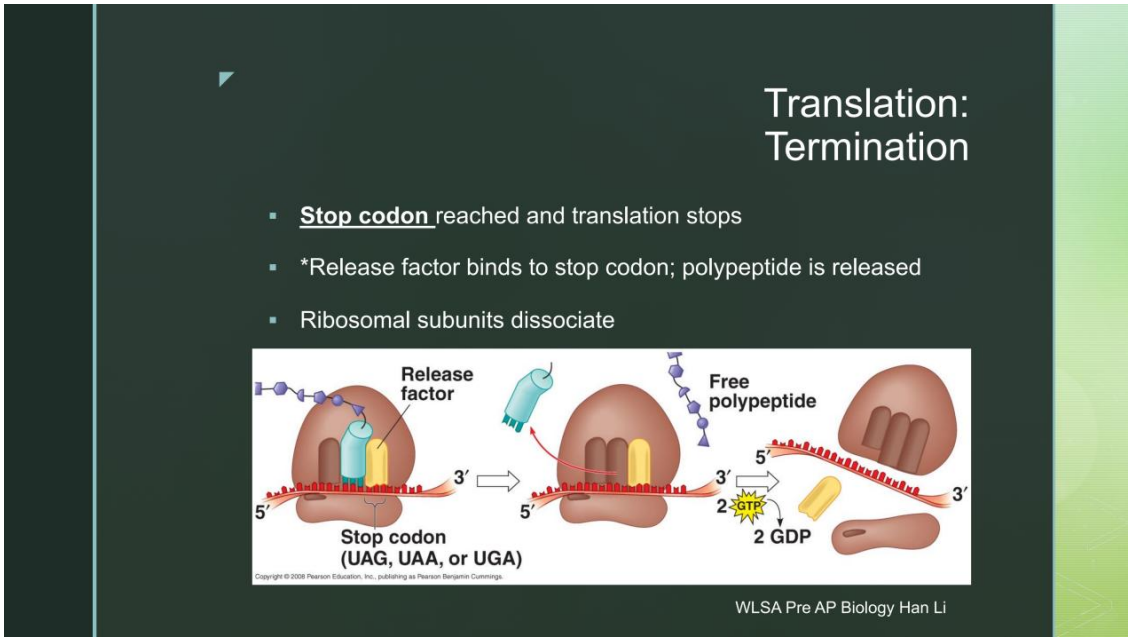
This cycle repeats, making the polypeptide longer.

Key Points:

- Incoming amino acid enters A site
- Peptide bond formation
- Ribosome translocates

Why It Matters:

Elongation is the main phase where the protein chain is actually built.



Page 27 Annotation

Title: Translation: Termination

Clear Explanation:

Translation stops when the ribosome reaches a **stop codon** (UAA, UAG, or UGA) on the mRNA. These codons do not code for any amino acid.

Instead of a tRNA, a special protein called **release factor** binds to the stop codon. This causes the ribosome to release the completed polypeptide chain. Finally, the two ribosomal subunits separate and can be reused for another round of translation.

Key Points:

- Stop codons: UAA, UAG, UGA
- Release factor binds to stop codon
- Polypeptide (protein) is released
- Ribosomal subunits dissociate

Why It Matters:

Termination ensures the protein is finished at exactly the right length. Without proper termination, the cell could make incorrect or incomplete proteins.

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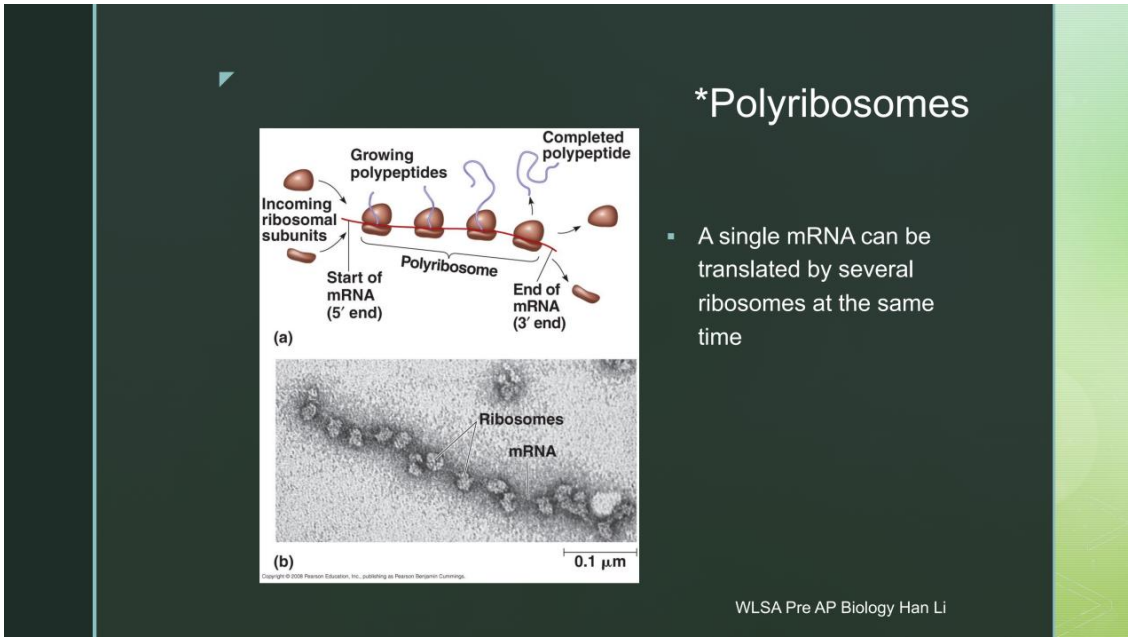

Page 28 Annotation

Title: Polyribosomes (Polysomes)

Clear Explanation:

A single mRNA molecule can be translated by **many ribosomes at the same time**. This structure is called a **polyribosome** (or polysome).

While one ribosome is moving along the mRNA making a protein, another ribosome can start right behind it. This allows the cell to produce many copies of the same protein very quickly from just one mRNA.

Key Points:

- One mRNA → multiple ribosomes
- Called polyribosome or polysome
- Increases efficiency of protein synthesis
- Visible in electron microscope images

Why It Matters:

Polyribosomes are an important way cells make large amounts of protein quickly (for example, when making antibodies or enzymes).

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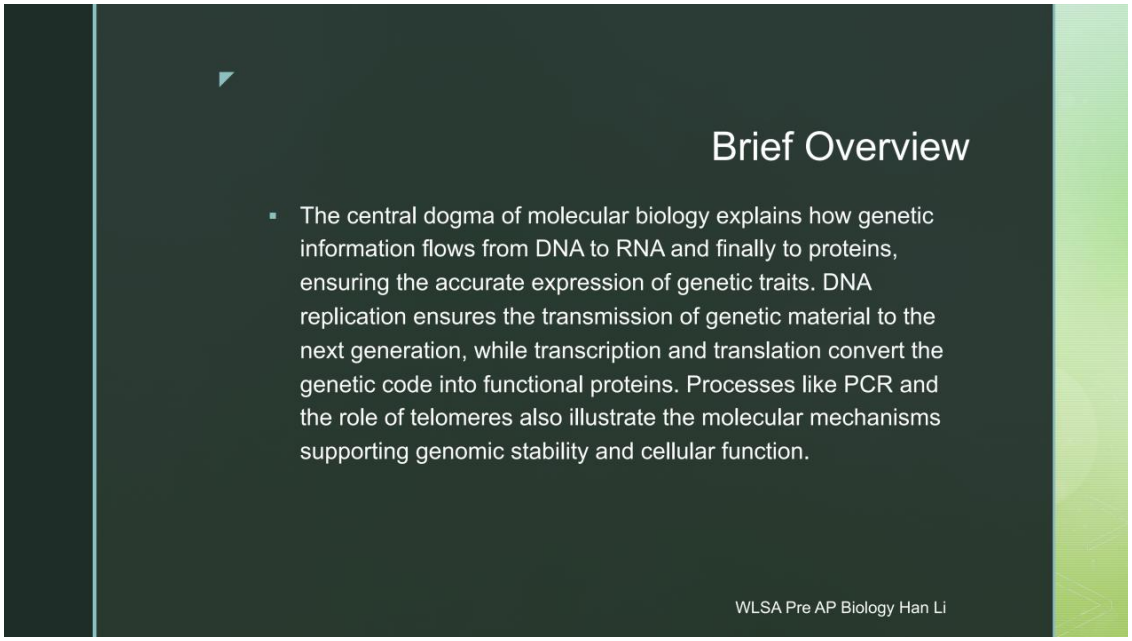

Page 29 Annotation

Title: Brief Overview

Clear Explanation:

This slide gives a quick summary of the entire unit.

The **Central Dogma** explains how genetic information flows:

DNA → RNA (transcription) → Protein (translation).

DNA replication ensures genetic material is passed accurately to the next generation.

Other important topics include telomeres (which protect chromosome ends) and PCR (a technique to copy DNA in the lab).

Key Points:

- Central Dogma = DNA → RNA → Protein
- DNA replication = semiconservative
- Transcription + Translation = protein synthesis
- Telomeres and PCR are practical applications

Why It Matters:

This overview connects all the pieces you learned in the unit and shows how they work together in real biology.

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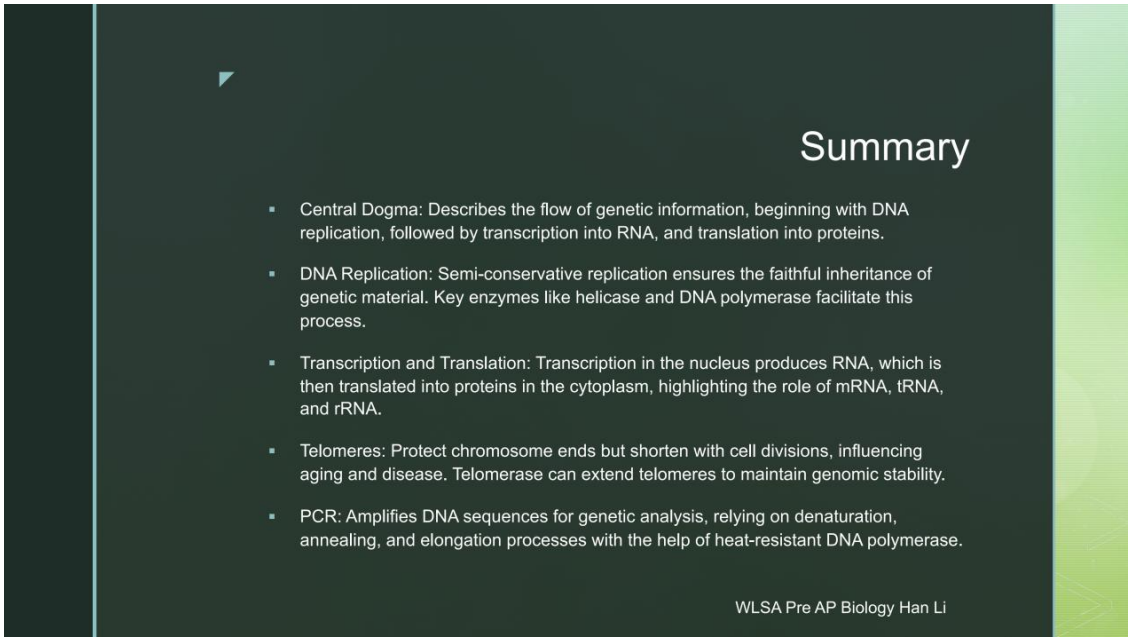

Page 30 Annotation

Title: Summary

Clear Explanation:

This is the final summary slide of the unit. It reviews the most important ideas:

- The **Central Dogma** describes the flow of genetic information (DNA replication → transcription → translation).
- DNA replication is **semiconservative** and uses enzymes like helicase and DNA polymerase.
- Transcription makes mRNA in the nucleus; translation makes proteins in the cytoplasm using mRNA, tRNA, and ribosomes.
- Telomeres protect chromosome ends but shorten with each cell division (related to aging).
- PCR is a lab technique that rapidly copies specific DNA segments using heat-resistant polymerase.

Key Points:

- Central Dogma flow
- Semiconservative replication
- Role of mRNA, tRNA, rRNA
- Telomeres and aging
- PCR technique

Why It Matters:

You should now understand the complete “information highway” of the cell — from DNA to functional proteins. This knowledge is the foundation for all future topics in genetics, biotechnology, and medicine.