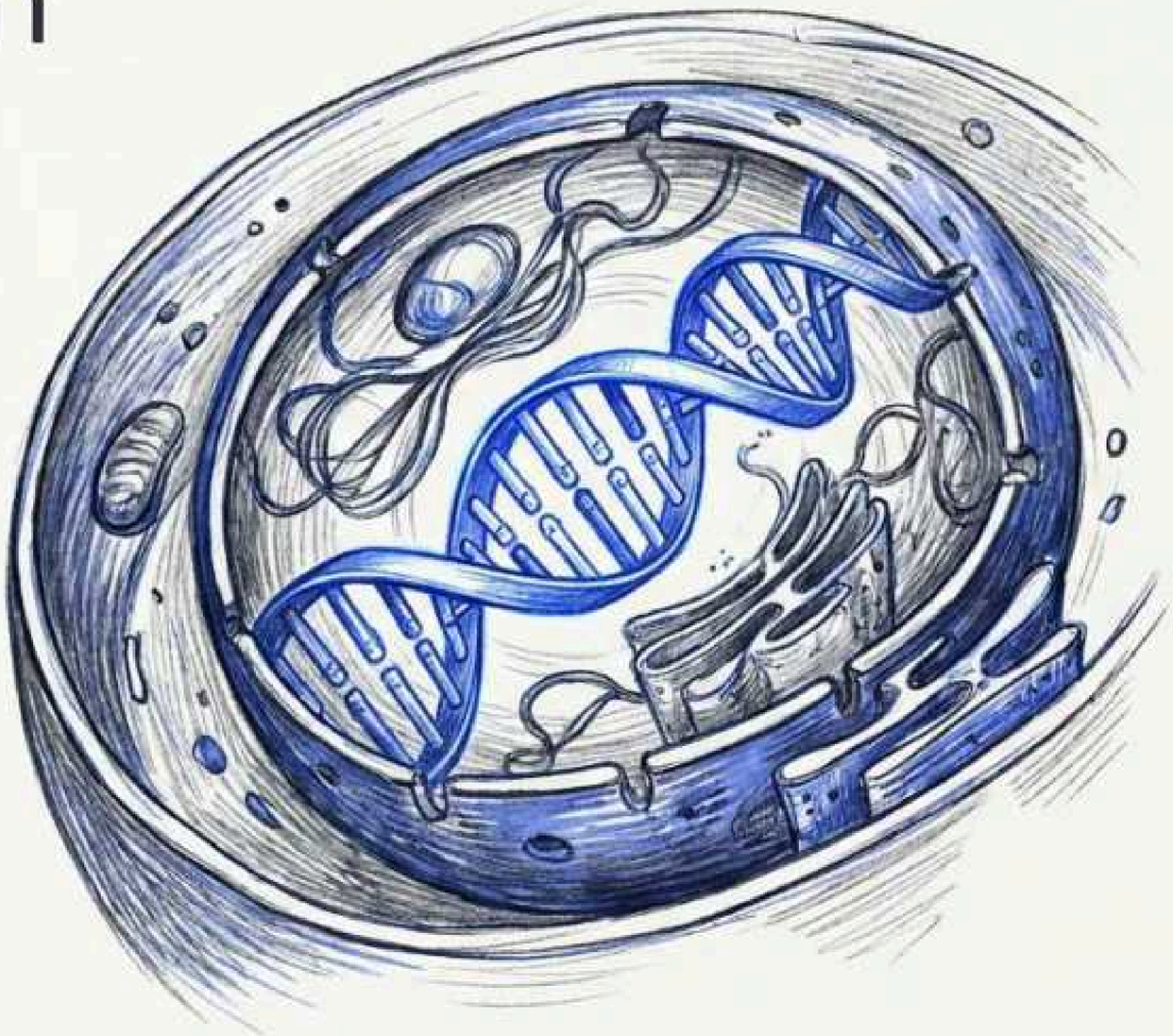
¶ 5.1

Gene Expression and Its Control

Lecture 5



At a Glance
Transcription
RNA processing
The genetic code
Translation
Protein folding
Control of genes

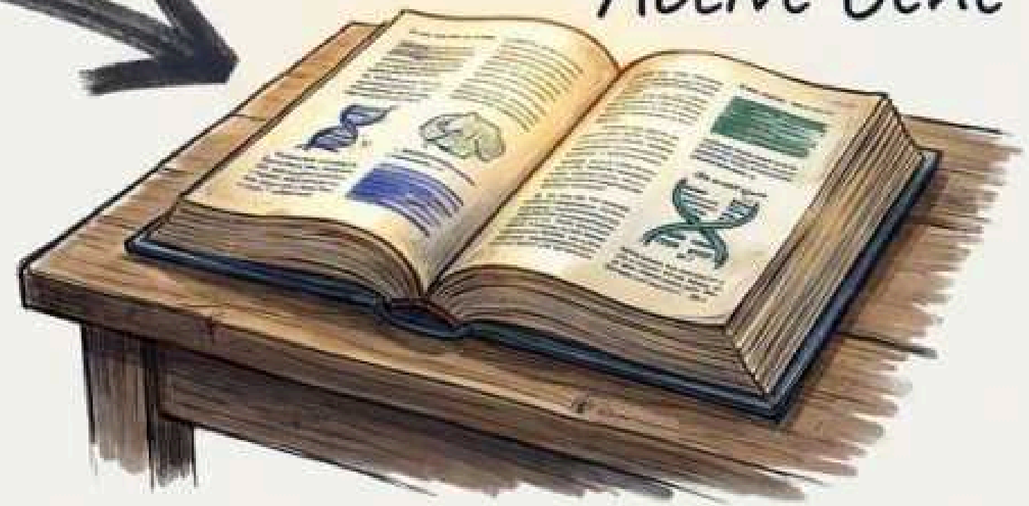
¶ 5.2

A genome is a library; a cell reads only some of its books.



The Genome (Archive)

Active Gene

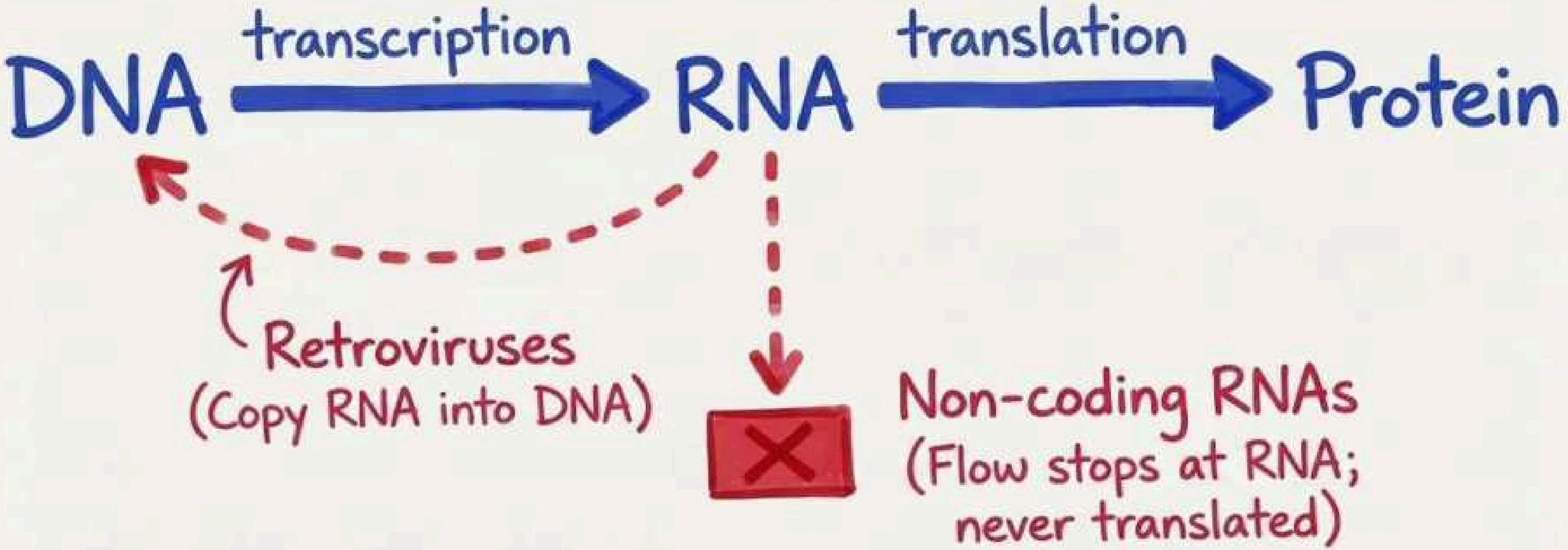


DNA → RNA → Protein → Regulation

(determining when and where to read)

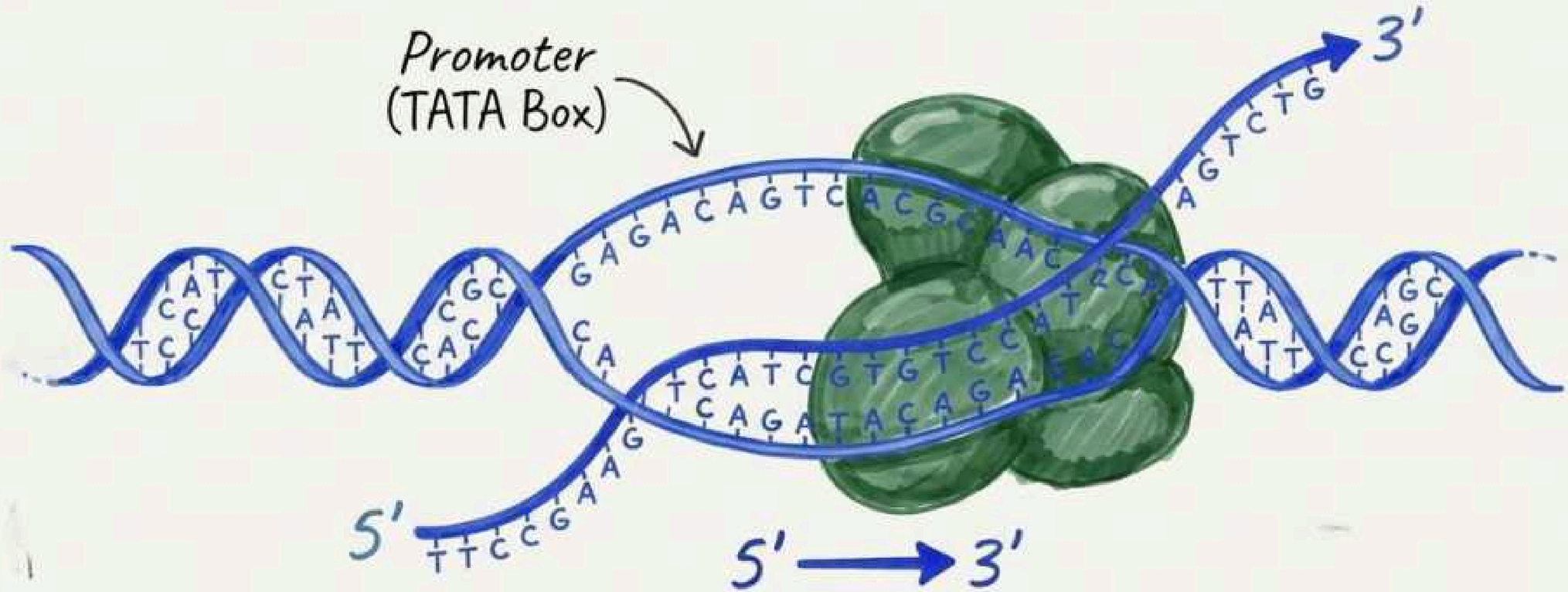
The Central Dogma — Francis Crick, 1958.

¶ 5.3



Initiation of Transcription

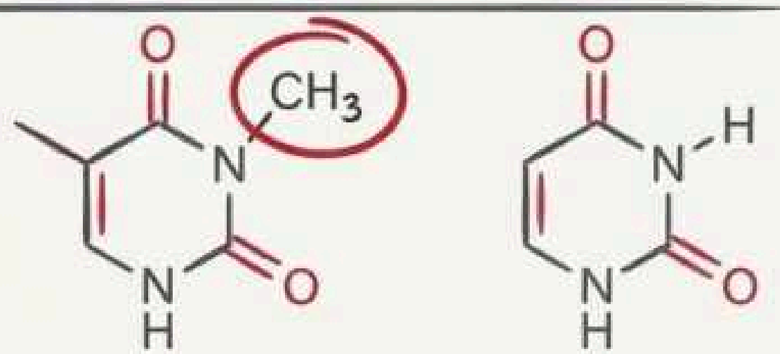
¶ 5.4



Bacteria	Eukaryotes
Polymerase finds and binds the promoter directly.	Requires General Transcription Factors to recognize elements before binding.

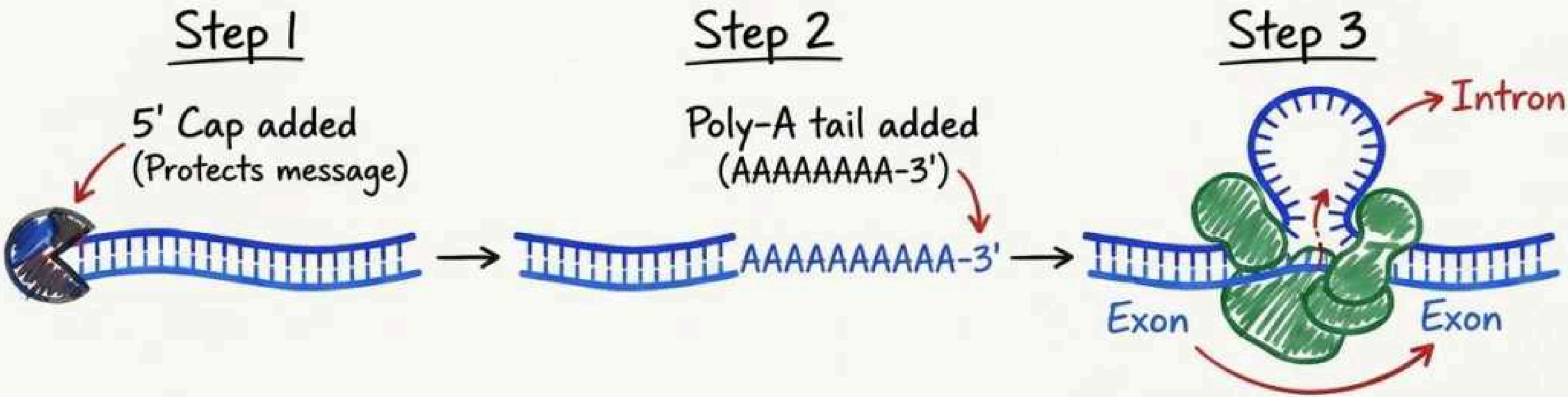
¶ 5.5

Diagnostic Comparison: DNA vs. RNA

	DNA	RNA
Sugar	Deoxyribose	Ribose
Bases	Thymine	
Structure	Usually double-stranded	Usually single-stranded
Fidelity	Transcription accuracy is ≈ *1 error / 10^4* bases (Errors are not inherited)	

¶ 5.6

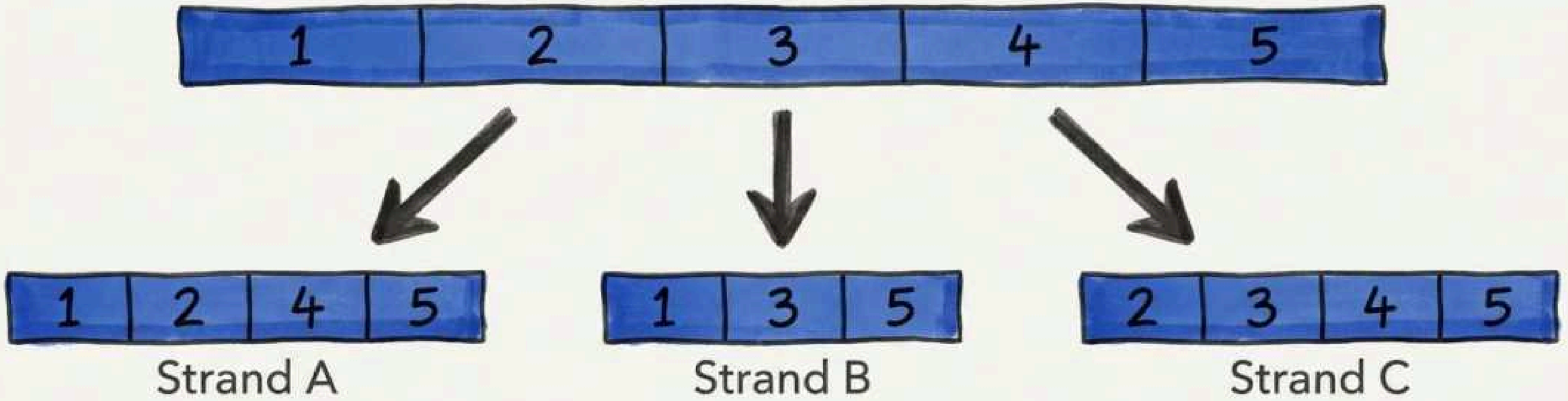
Processing the Eukaryotic Message



Splicing: The spliceosome excises non-coding Introns and joins the functional Exons.

Alternative Splicing: The Combinatorics of Life

¶ 5.7

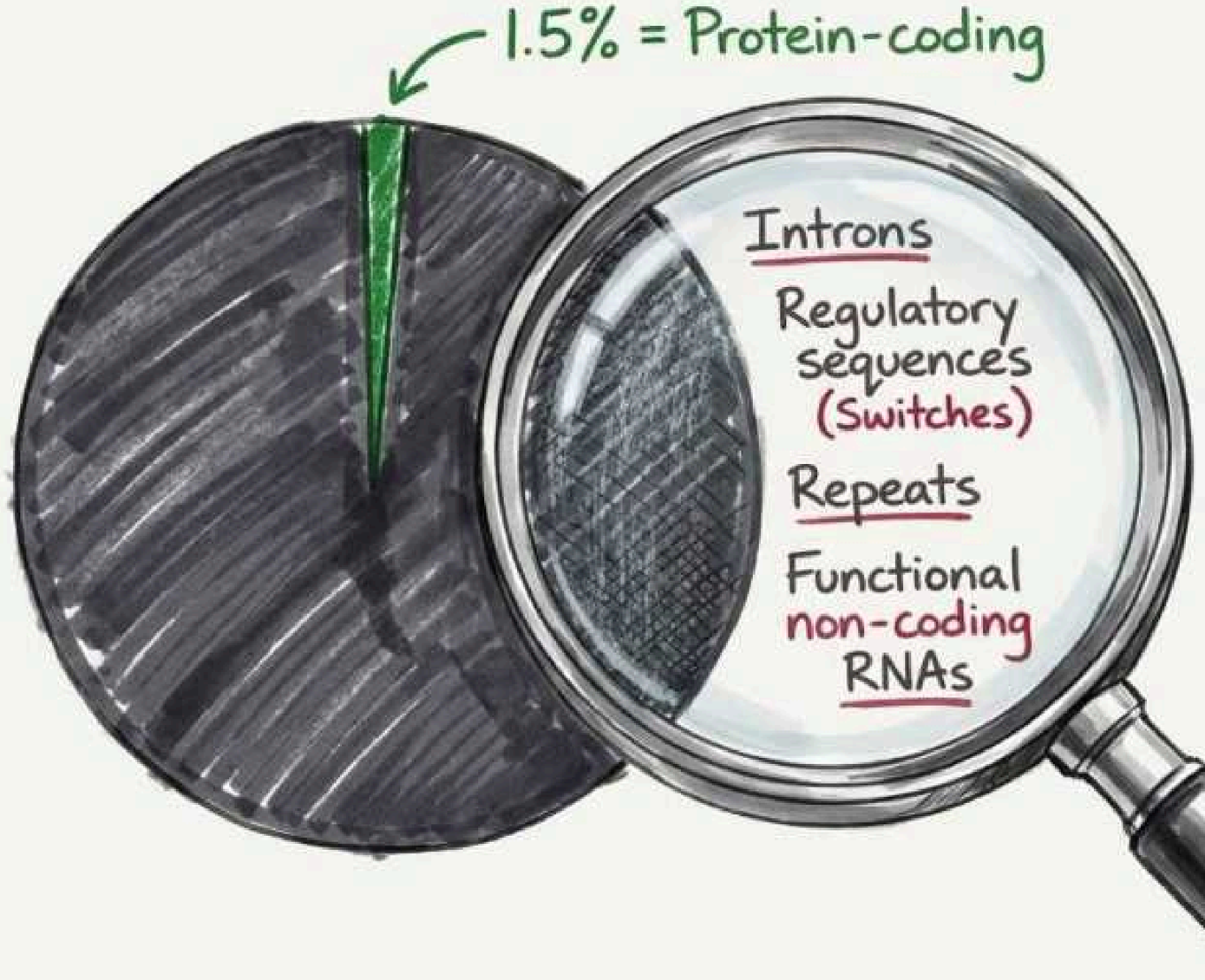


20,000 genes → >100,000 proteins

Fact: ***>90%*** of human multi-exon genes are ***alternatively spliced***, multiplying structural complexity.

The Dark Matter of the Genome

¶5.8



No longer considered 'junk'. This region represents the crucial control circuitry of the cell.

¶ 5.9

The Genetic Code Matrix

4 bases × 4 × 4

= 64 total codons

61 specify amino acids
(Highly redundant code)

3 signal translation to stop

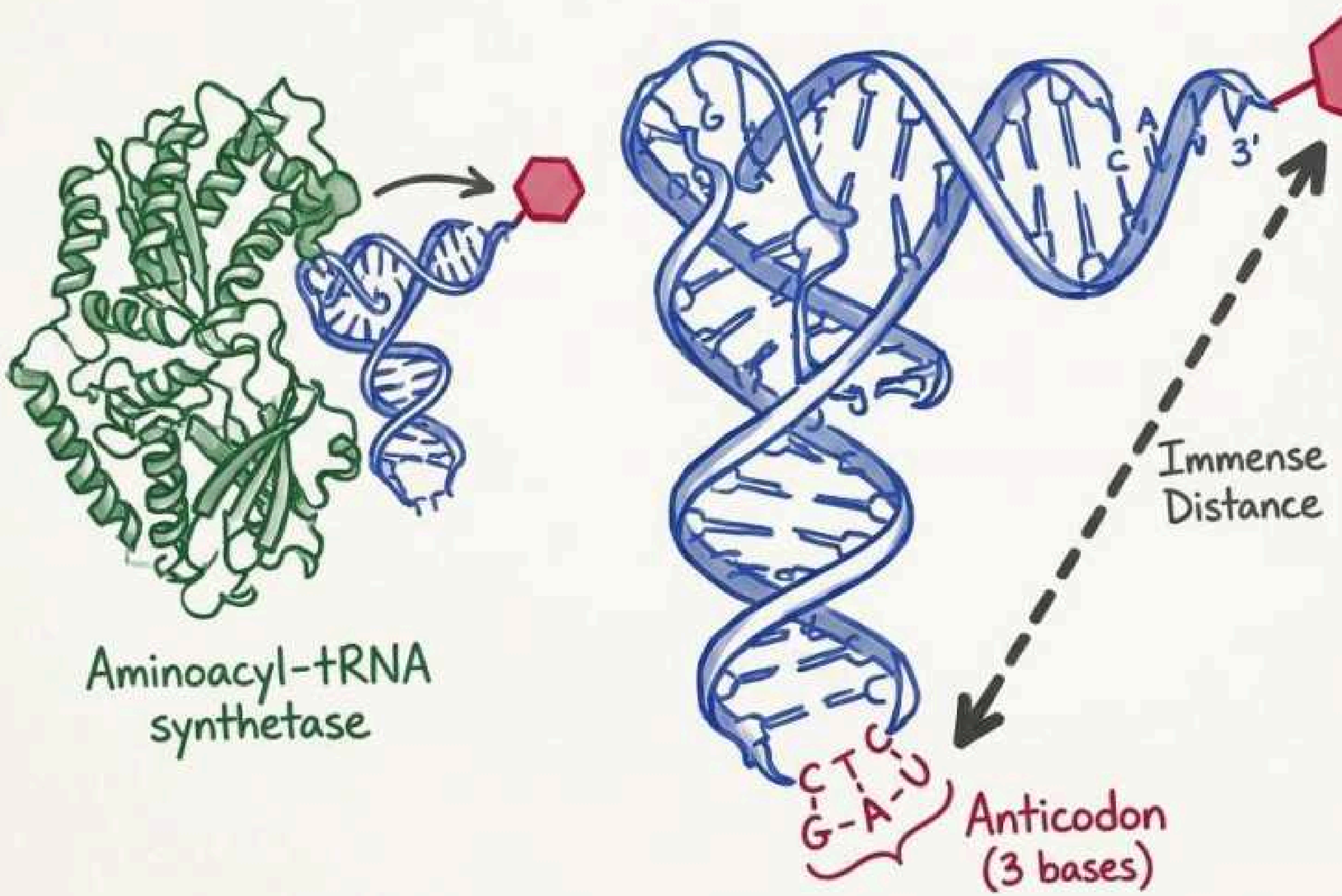
CUU, CUC, CUA, CUG — Gir	UCU, UCC, UCA, UCG — Nin	UAU, UAC — Lyr; **UAA — Stop; UAG — Stip**	UGU, UGC — Yrc; **UGA — Sto; UGG — Stp**
CUU, CUC, CUA, CUG — Leu	CCU, CCC, CCA, CCG — Ern	CAU, CAC — Ard; CAA, CAG — Ard	CGU, CGC, CGA, CGG — Arg
AUU, AUC, AUA — Its; **AUG — Meth**	ACU, ACC, ACA, ACG — Tan	AAU, AAC — Meg; AAA, AAG — Arg	AGU, AGC — Sr; AGA, AGG — Arg
CUU, CUC, CUA, CUG — Leu	CCU, CCC, CCA, CCG — Ale	GAU, GAC — Arg; GAA, GAG — Gla	GGU, GGC, GGA, GGG — Gly

Stop Signals

Start (Methionine)

Wobble: 3rd base changes often yield the same amino acid.

The Adapter: Transfer RNA (tRNA)

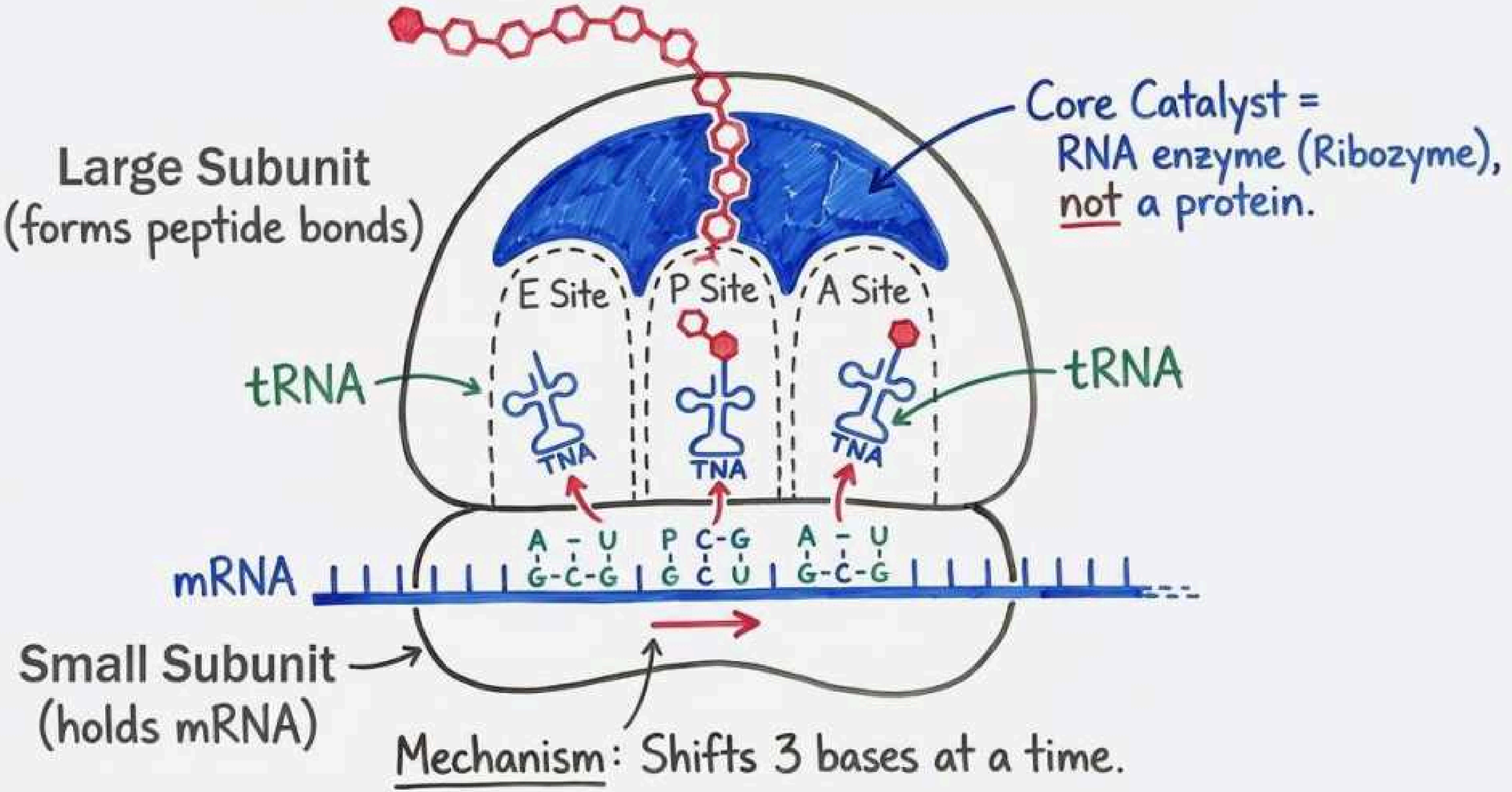


Mechanism: The ribosome physically checks the codon/anticodon pairing at the bottom, **NOT** the attached amino acid at the top.

Therefore, the loading accuracy of the Synthetase enzyme is a **single point of failure**.

Inside the Ribosome Factory

¶ 5.11



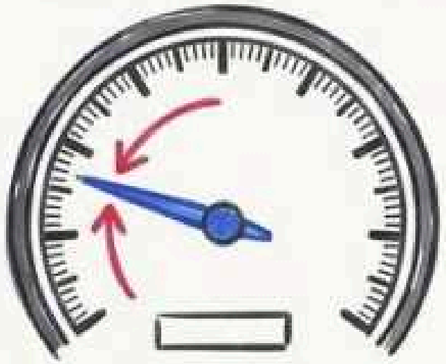
The Speed and Scale of Translation

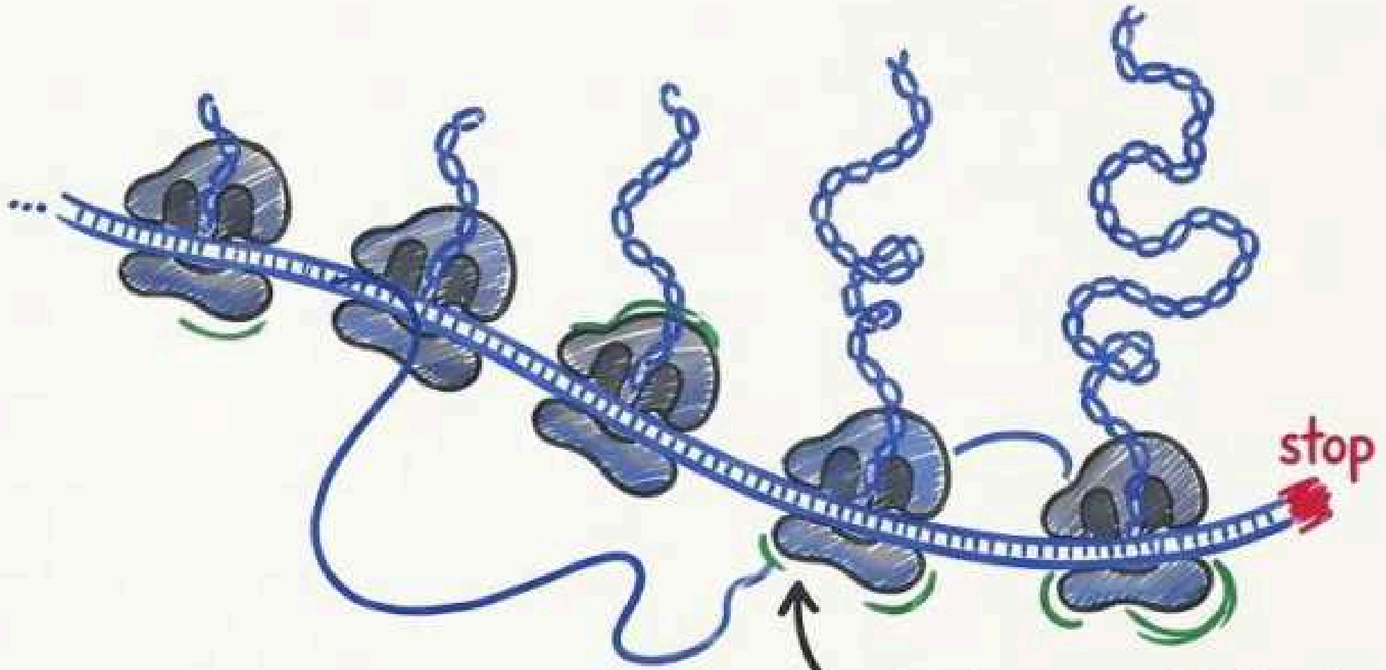
¶ 5.12

Bacteria:
20 aa/s



Eukaryotes:
5 aa/s





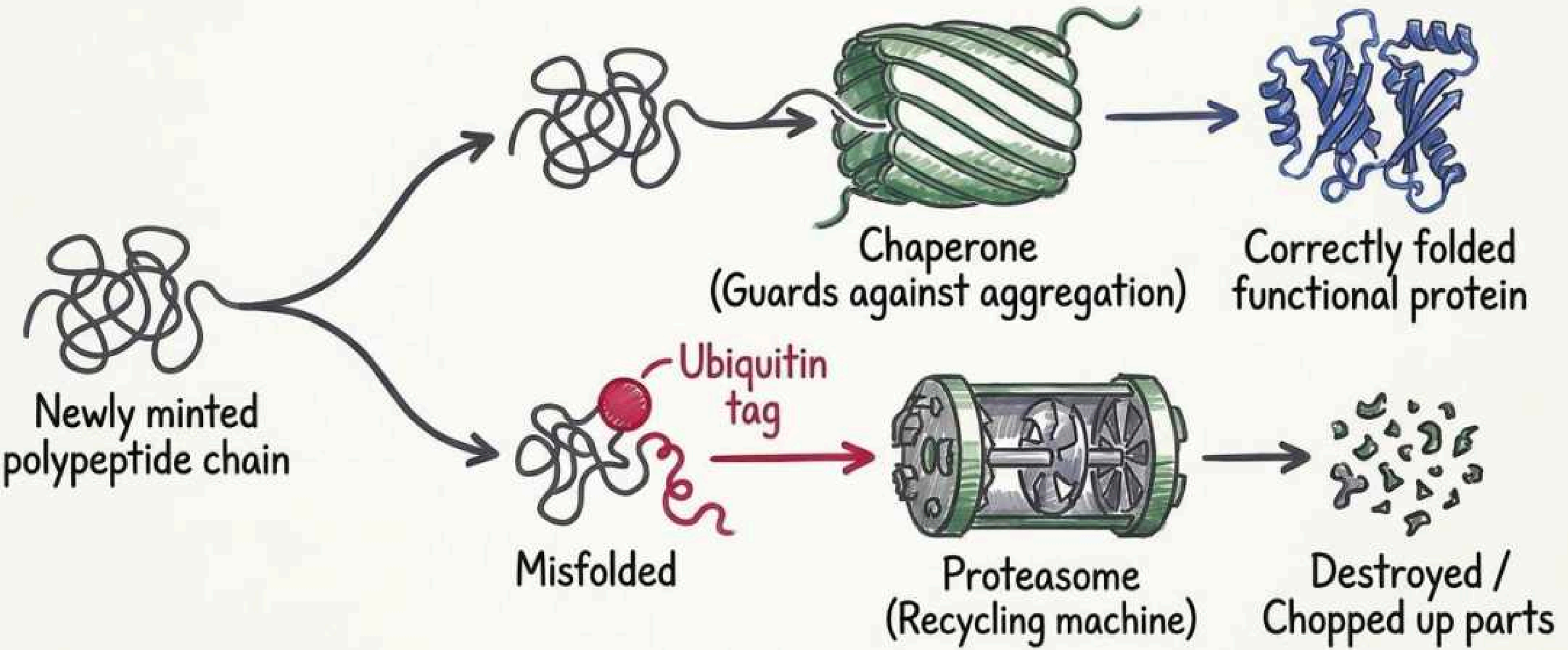
Polysome: Multiple ribosomes reading the same message at once to scale production.

Translation Time (Human Cell): $\frac{400\ \text{aa}}{5\ \text{aa/s}} = 80\ \text{seconds}$

Required Transcript Length: $(400 \times 3) + 3\ (\text{stop}) = 1{,}203\ \text{bases}$

Quality Control: Folding and Destruction

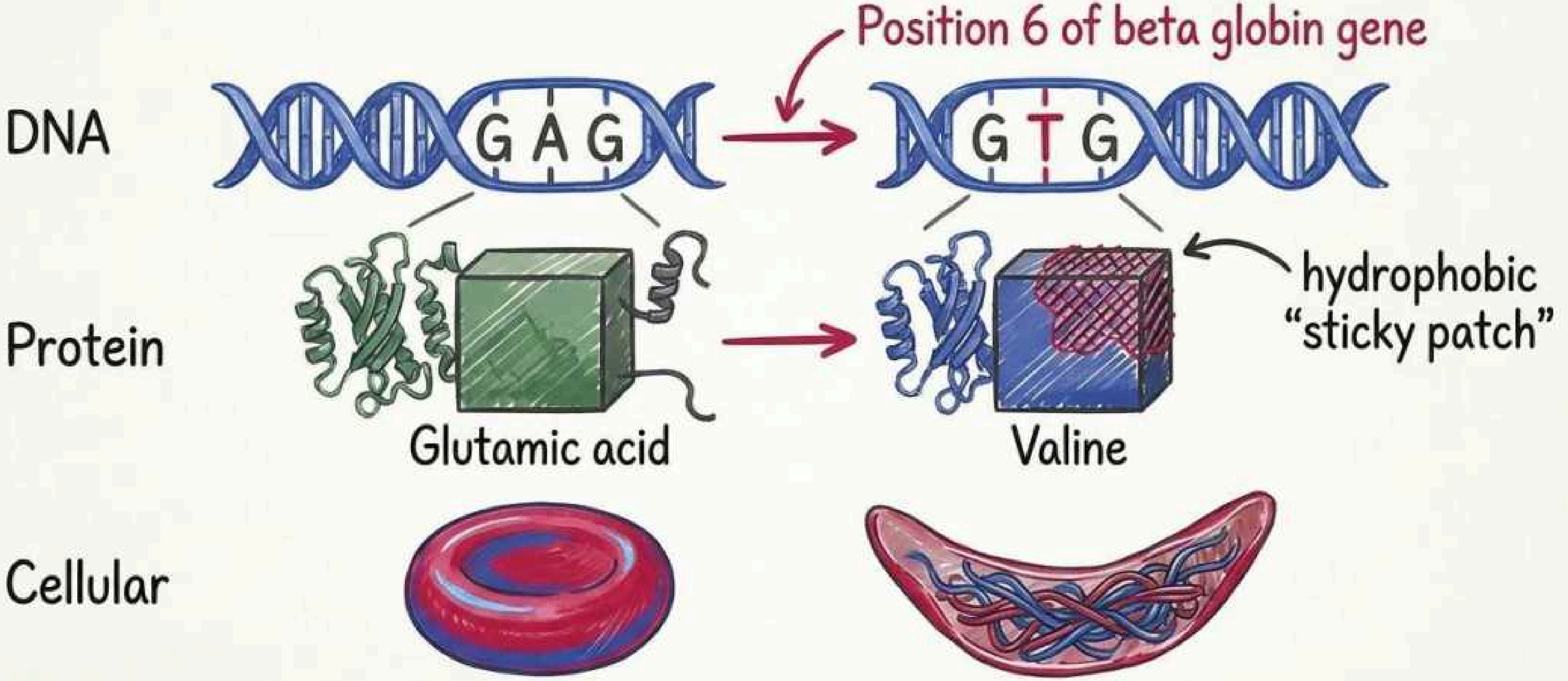
¶ 5.13



A constant cycle of synthesis and destruction maintains cellular control.

When One Base Changes: Sickle Cell Disease

¶ 5.14

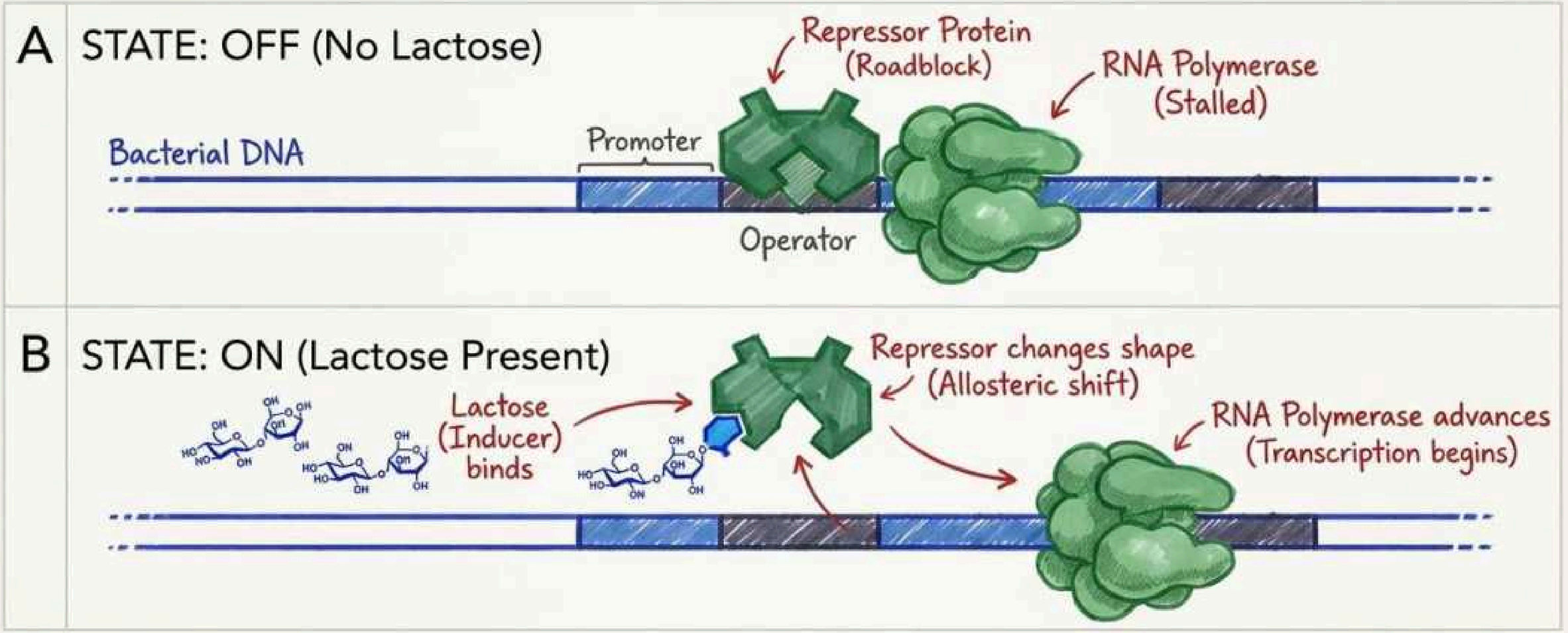


One letter among billions alters one amino acid and changes a life.

Introduction to Regulation: The Lac Operon

¶ 5·15

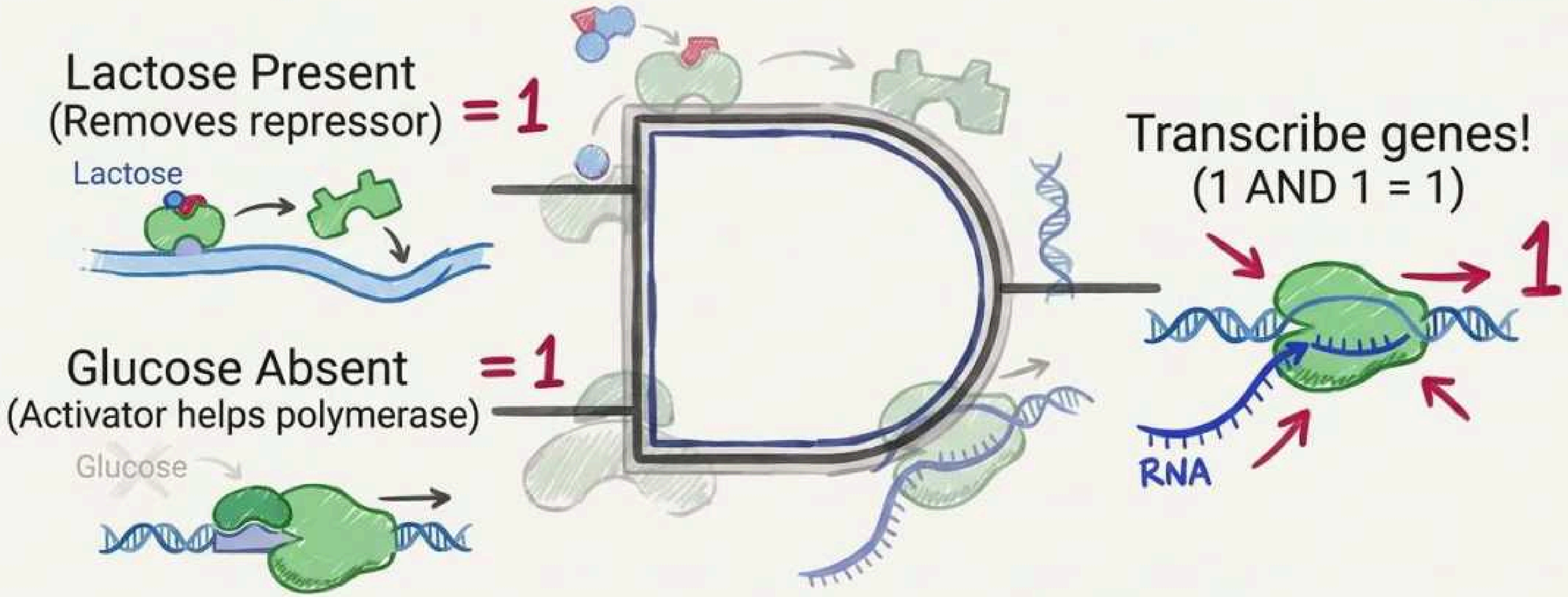
Discovered: François Jacob & Jacques Monod, 1961.



The cell makes enzymes only when they are useful.

Genetic Logic: The Biological AND Gate

¶ 5.16

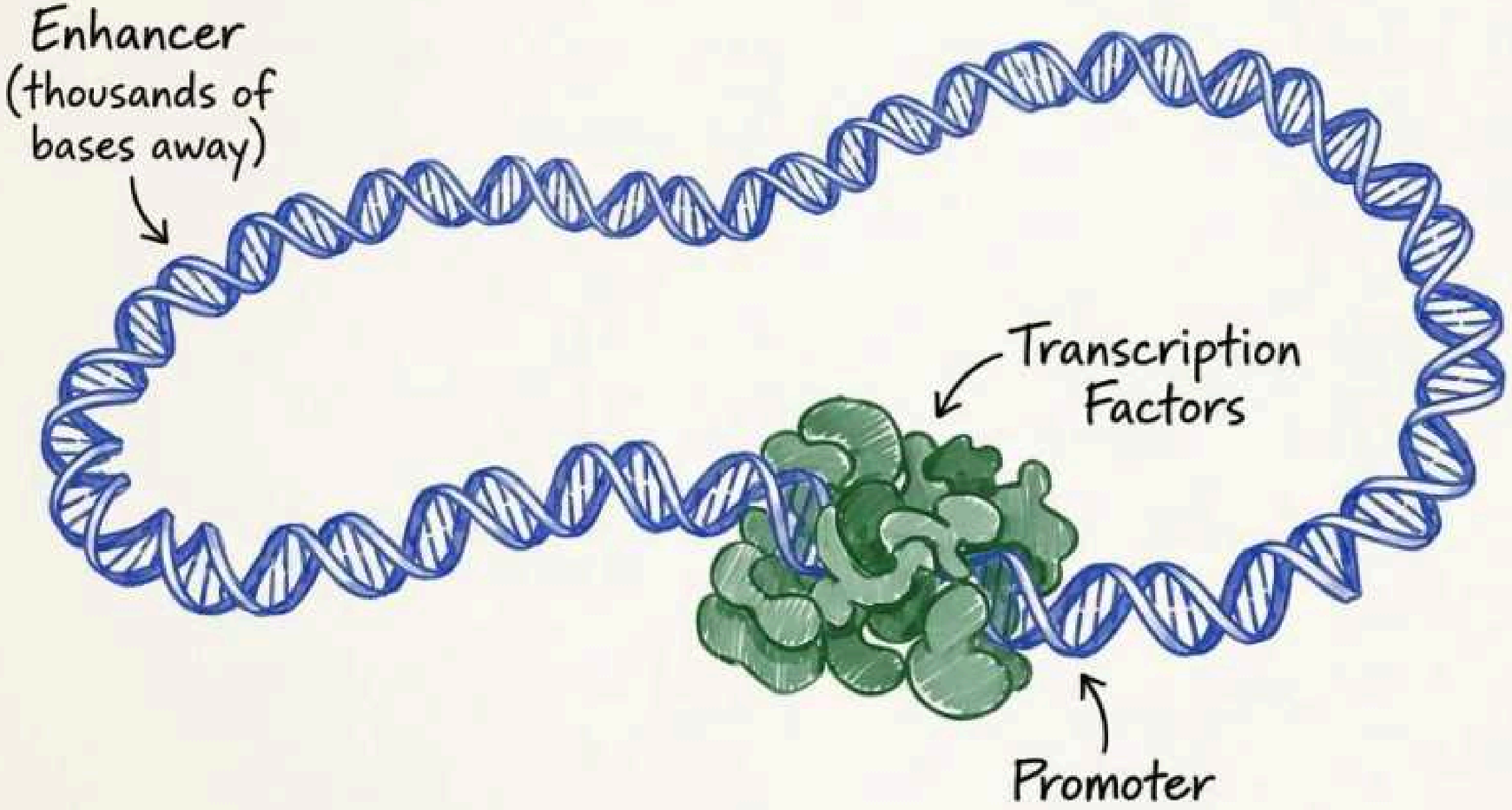


Bacteria are miniature computers, and gene regulation is their logic.

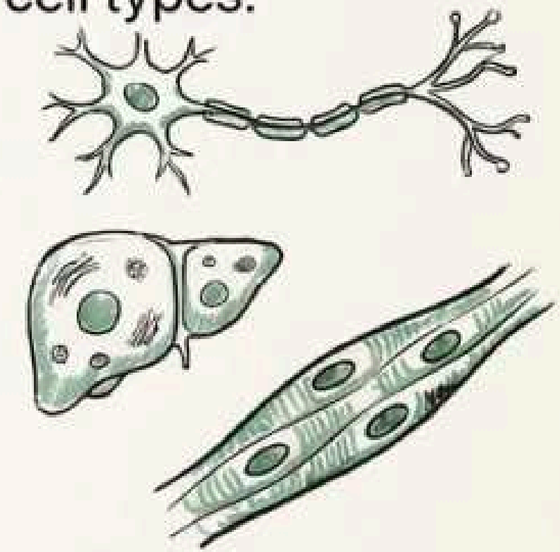
A Master Class Whiteboard

¶ 5.17

Eukaryotic Complexity: The Spatial Loop



Combinatorial Control:
A few dozen factors combine to specify hundreds of distinct cell types.

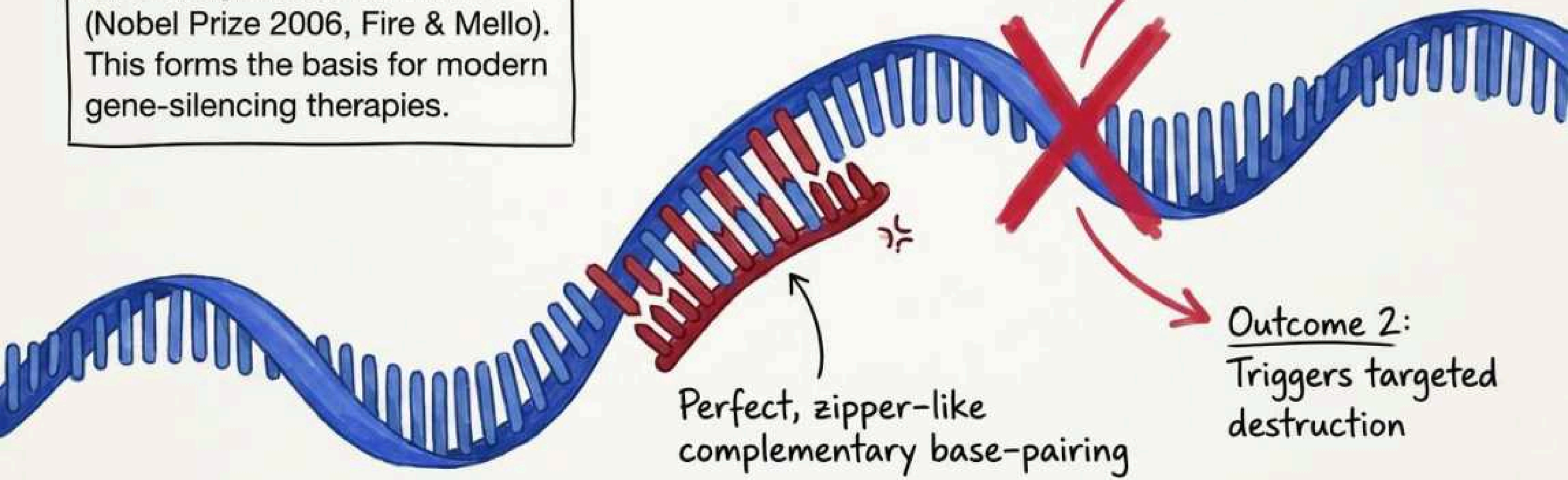


Post-Transcriptional Control: RNA Interference

¶ 5.18

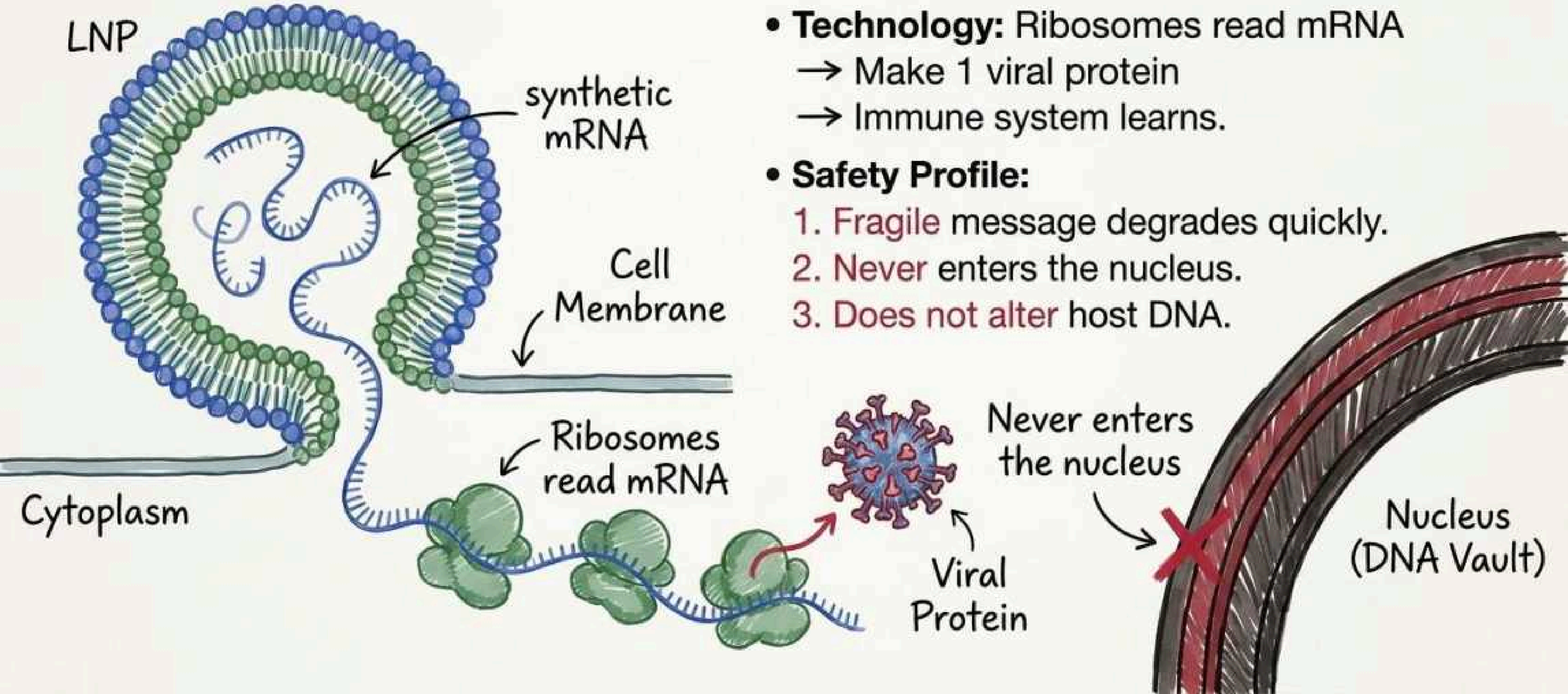
Scale: ≈ 2,000 microRNAs in humans.

Discovery: RNA interference (Nobel Prize 2006, Fire & Mello). This forms the basis for modern gene-silencing therapies.



The Central Dogma as Technology: mRNA Vaccines

¶ 5.19

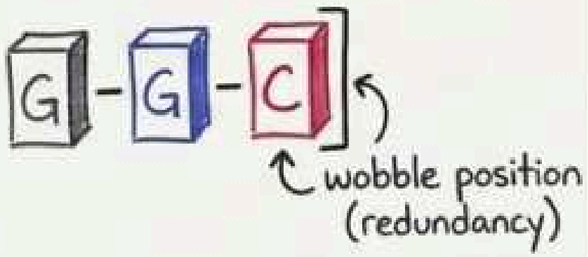


- **Technology:** Ribosomes read mRNA
  → Make 1 viral protein
  → Immune system learns.
- **Safety Profile:**
  1. Fragile message degrades quickly.
  2. Never enters the nucleus.
  3. Does not alter host DNA.

The Takeaway Challenge

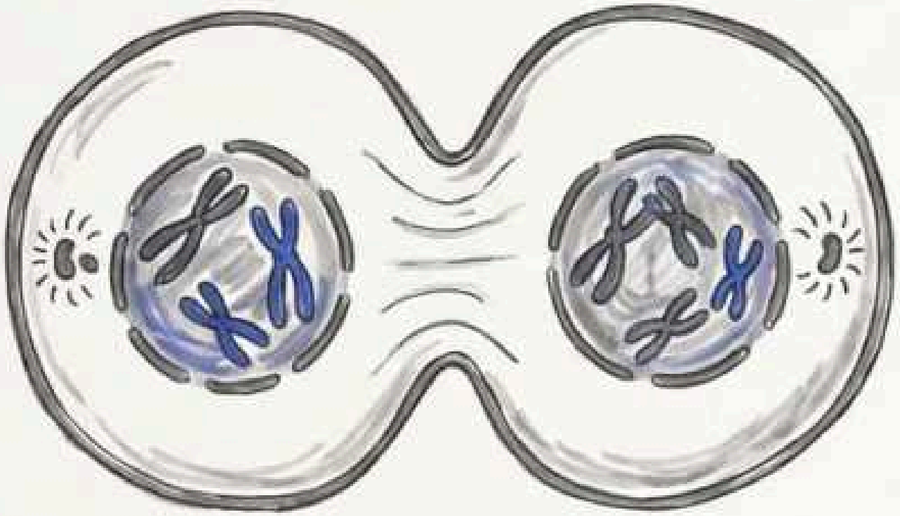
¶ 5.20

A single base mutation occurs in the middle of a gene. What happens?

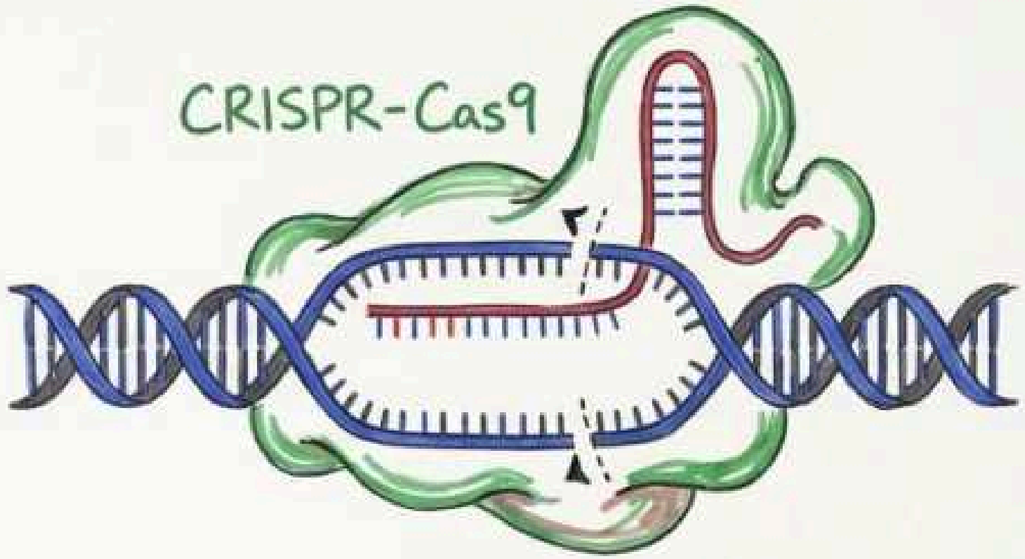
Outcome: None	Outcome: Moderate	Outcome: Severe
		

Looking Ahead to Lecture 6

¶ 5.21



Mitosis



Gene Editing (CRISPR)

Next Session Topics:

- How cells decide to divide.
- How that decision fails in cancer.
- The precise molecular tools that allow us to read and edit genes.