

Introduction to Molecular Genetics

Introduction to Molecular Genetics – Study Notes

1. What Is Molecular Genetics?

- **Definition:** The branch of biology that examines how genetic information is encoded, replicated, expressed, and regulated at the molecular level (DNA, RNA, proteins).
 - **Goal:** Connect the physical chemistry of nucleic acids with the phenotypic traits of organisms.
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2. Central Dogma of Molecular Biology

Process	Molecule(s) Involved	Main Enzyme(s)	Outcome
Replication	DNA → DNA	DNA polymerases, helicase, primase, ligase	Accurate copying of the genome
Transcription	DNA → RNA	RNA polymerase, transcription factors	Synthesis of messenger (mRNA), ribosomal (rRNA), transfer (tRNA), and non-coding RNAs
Translation	mRNA → Protein	Ribosome, tRNAs, aminoacyl-tRNA synthetases, initiation/elongation/termination factors	Polypeptide chain assembly

Note: Reverse transcription (RNA → DNA) and RNA editing are important exceptions.

3. DNA Structure & Organization

Feature	Description	Functional Significance
Double helix	Two antiparallel strands, 10.5bp per turn	Provides stable storage of genetic information
Base pairing	A–T (2 H-bonds), G–C (3 H-bonds)	Ensures fidelity during replication & transcription

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Feature	Description	Functional Significance
Chromatin	DNA wrapped around histone octamers ? nucleosomes ? 30?nm fiber	Compacts DNA and regulates access
Higher?order structure	Loops, topologically associating domains (TADs), chromosome territories	Coordinates gene regulation and replication timing

4. Genes and Regulatory Elements

Element	Location	Role
Promoter	Upstream of transcription start site (TSS)	Binds RNA polymerase & basal transcription factors
Enhancer	Can be distal (kb–Mb away)	Increases transcription via looping & transcription factor binding
Silencer	Similar to enhancers but represses transcription	Recruits repressors or chromatin remodelers
Operator (prokaryotes)	Within/near promoter	Binds repressor proteins to block transcription
5? UTR / 3? UTR	Untranslated regions of mRNA	Influence translation efficiency, stability, localization
Introns / Exons	Eukaryotic genes	Introns removed by splicing; exons encode protein sequence
Poly?A signal	3? end of pre?mRNA	Directs cleavage and polyadenylation, stabilizing mRNA

5. DNA Replication Essentials

- Origin of Replication (Ori)** – Specific DNA sequences where replication initiates.
- Bidirectional Forks** – Two replication forks move outward from each Ori.
- Key Enzymes & Functions**
 - **Helicase** – Unwinds DNA duplex.
 - **Primase** – Synthesizes short RNA primers.
 - **DNA Polymerase III (prokaryotes) / DNA Pol?? & ? (eukaryotes)** – Extends primers (5??3?).
 - **DNA Ligase** – Joins Okazaki fragments on the lagging strand.

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- **Topoisomerase** – Relieves supercoiling ahead of the fork.

4. **