

Introduction to Gene Expression

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Key concepts, stages, and regulatory mechanisms

1. What Is Gene Expression?

Term	Definition
Gene	A DNA segment that contains the instructions for making a functional product (usually a protein or functional RNA).
Gene expression	The process by which information encoded in a gene is converted into a functional product.
Central Dogma	DNA → RNA → Protein (with some exceptions, e.g., functional RNAs).

Why it matters: Gene expression determines cell identity, response to stimuli, development, and disease states.

2. Major Steps of Gene Expression

1. **Transcription** – synthesis of RNA from a DNA template.
2. **RNA processing** – (eukaryotes) capping, splicing, poly(A tail addition).
3. **Translation** – synthesis of protein from messenger RNA (mRNA).
4. **Post-translational modifications** – folding, cleavage, phosphorylation, etc.

Note: In prokaryotes, transcription and translation can be coupled (occur simultaneously).

3. Transcription Details

Component	Role
RNA polymerase (RNAP)	Catalyzes phosphodiester bond formation; different forms for bacteria (RNAP core) and eukaryotes (RNA Pol I, II, III).

Introduction to Gene Expression

Component	Role
Promoter	DNA sequence upstream of the gene where RNAP binds; includes -35 and -10 elements (bacteria) or TATA box (eukaryotes).
Enhancers / Silencers	Distant regulatory DNA elements that increase or repress transcription when bound by specific transcription factors.
Transcription factors (TFs)	Proteins that recognize DNA motifs, recruit RNAP, and modulate its activity.
Termination signals	Sequences that cause RNAP to stop transcription (e.g., rho? dependent/independent in bacteria; poly?A signal in eukaryotes).

3.1 Initiation (Eukaryotes)

1. **Pre?initiation complex (PIC) formation:** TBP (TATA?binding protein) + TFI proteins recruit RNA Pol?II.
 2. **Chromatin remodeling:** SWI/SNF complexes slide or evict nucleosomes to expose DNA.
 3. **Phosphorylation of Pol?II CTD** (C?terminal domain) triggers promoter clearance and transition to elongation.
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4. RNA Processing (Eukaryotic mRNA)

1. **5? Capping** – addition of 7?methylguanosine cap; protects RNA, aids ribosome binding.
2. **Splicing** – removal of introns by the spliceosome; alternative splicing creates multiple isoforms.
3. **3? Poly?A tail** – ~200 adenines added; stabilizes mRNA, assists nuclear export.

Result: A mature mRNA ready for export to the cytoplasm.

5. Translation Overview

Step	Key Players	Main Events
Initiation	40S ribosomal subunit, eIFs, Met? tRNA, mRNA cap	Assembly of the 80S ribosome at the start codon (AUG).
Elongation	60S subunit, eEFs, aminoacyl?tRNAs	Peptide bond formation; ribosome moves codon?by?codon.

Introduction to Gene Expression

Step

Key Players

Main Events

Termination Release factors (eRF1