GENE REGULATION

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Molecular Biology

Semester I

Week 5

11-04-2025

Outline

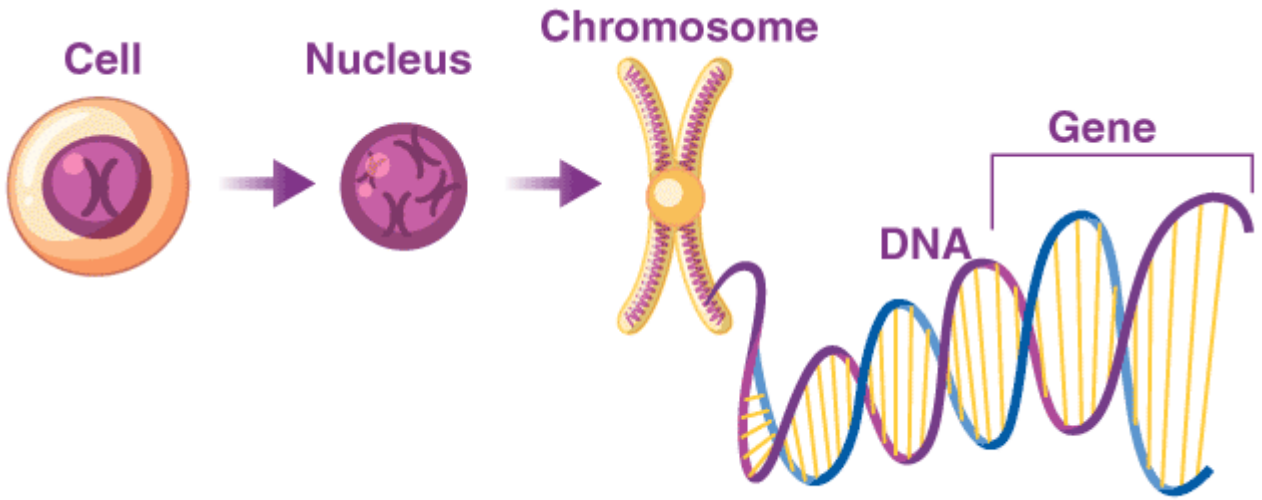
- Introduction to Gene Regulation
- Why Gene Regulation Matters
- Levels of Gene Regulation in Eukaryotes
- Differences Between Prokaryotic and Eukaryotic Gene Expression
- Purpose of Gene Expression Regulation
- Structure of a Eukaryotic Gene

Objectives

- Define gene regulation and explain why it is essential for cellular function.
- Describe how gene regulation enables adaptation, development, and tissue specificity.
- Identify the major structural components of a eukaryotic gene
- Explain the role of regulatory DNA elements such as enhancers, silencers, and promoters.

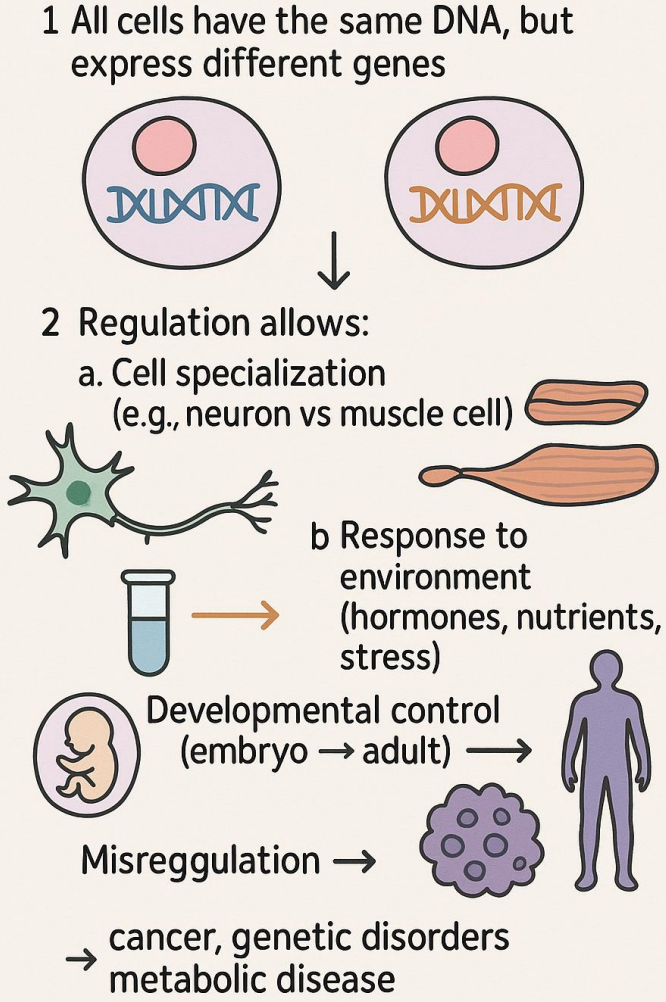
Gene Regulation

- **Gene:** A gene is a part of DNA that codes for a particular protein. DNA is the information database of the cell and exists within the cell nucleus. It carries all the important genetic instructions that produce proteins required by our cells.
- Each gene carries a particular set of instructions, which is usually in a coded format, used for an accurate function or for a distinct protein.



Gene Regulation

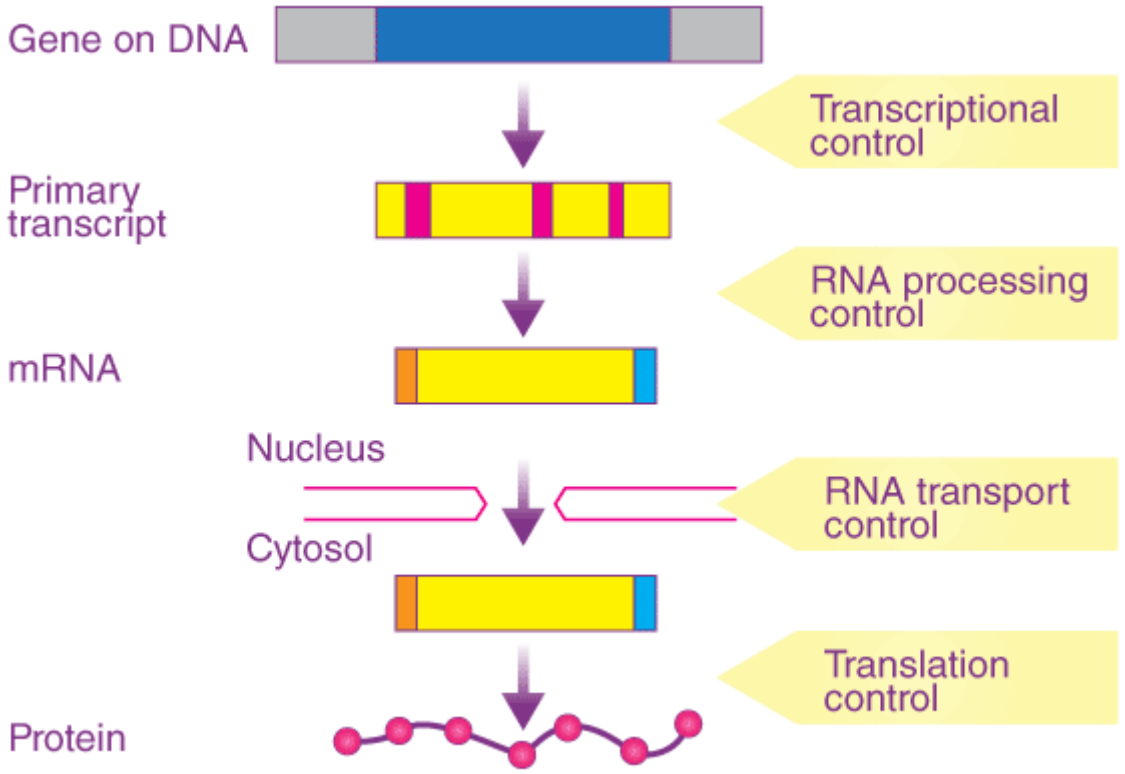
- **Gene regulation** is the process of controlling which genes in a cell's DNA are expressed, or "turned on," to produce proteins or RNA.
- **Why Gene Regulation Matters:**
  - All cells have the same DNA, but express different genes
  - Regulation allows:
    - Cell specialization (e.g., neuron vs muscle cell)
    - Response to environment (hormones, nutrients, stress)
    - Developmental control (embryo → adult)
  - Misregulation → cancer, genetic disorders, metabolic disease



Regulation of Gene Expression in Eukaryotes

Levels of Gene Regulation

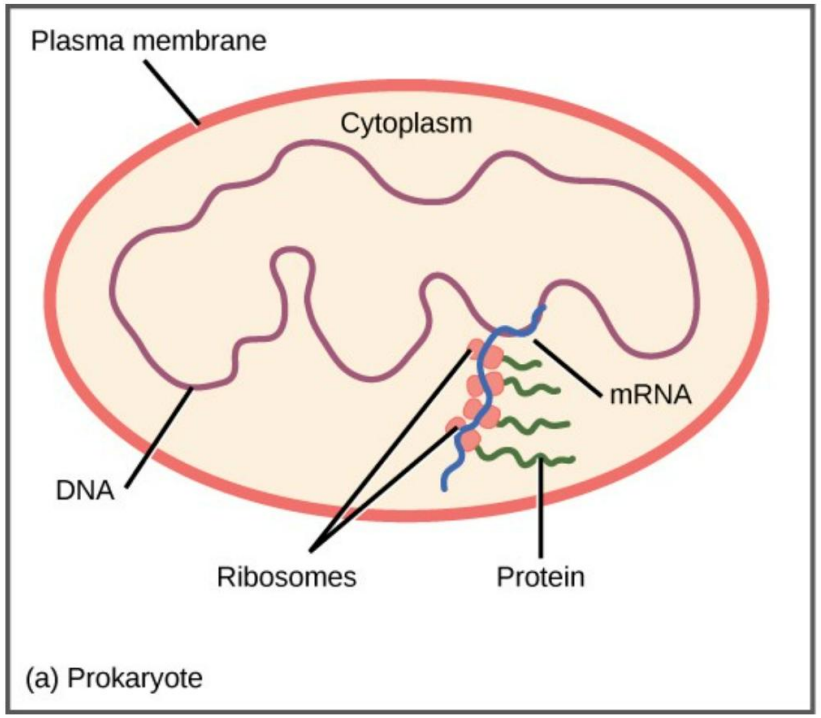
Level	Example
Transcriptional	Promoters, enhancers, transcription factors
Post-transcriptional	RNA splicing, miRNA
Translational	Ribosome binding control
Post-translational	Protein modification, degradation

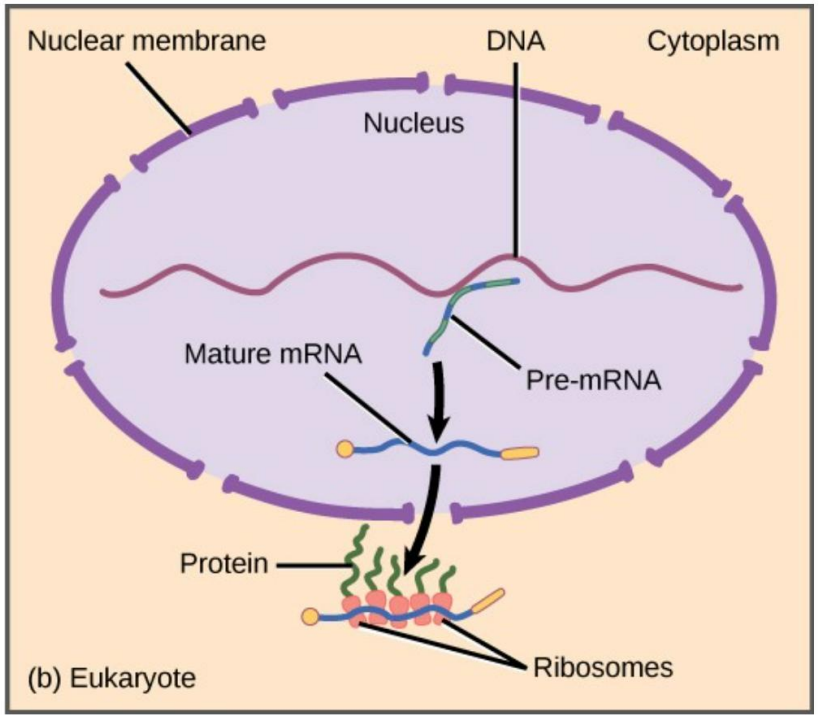


Differences in prokaryotic and eukaryotic gene regulation

Prokaryotic organisms	Eukaryotic organisms
Lack nucleus	Contain nucleus
DNA is found in the cytoplasm	DNA is in the nucleus
Transcription and translation occur almost simultaneously	Transcription occurs in the nucleus prior to translation, which occurs in the cytoplasm.
Gene expression is regulated primarily at the transcrip-tional level	Gene expression is regulated at many levels: epigenetic, transcriptional, nuclear shuttling, post-transcriptional, translational, and post-translational

Prokaryotic versus Eukaryotic Gene Expression





Prokaryotic transcription and translation occur simultaneously in the cytoplasm, and regulation occurs at the level of transcription. In eukaryotes, transcription and translation are physically separated, and gene expression is regulated at many different levels.

Purpose of regulation of gene expression:

Regulated expression of genes is required for:

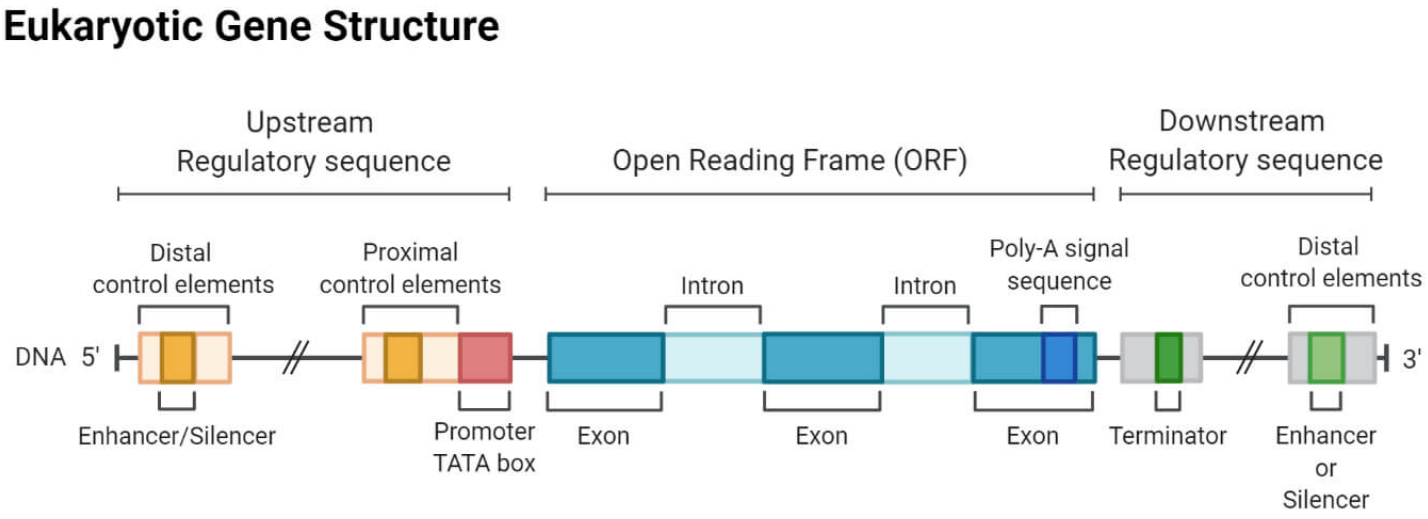
1) Adaptation – Cells of multicellular organisms respond to varying conditions. Such cells exposed to hormones and growth factors change substantially in – shape, growth rate and other characteristics.

2) Tissue specific differentiation and development

- The genetic information present in each somatic cell of an organism is practically identical.
- Cells from muscle and nerve tissue show strikingly different morphologies and other properties, yet they contain exactly the same DNA.
- These diverse properties are the result of differences in gene expression.

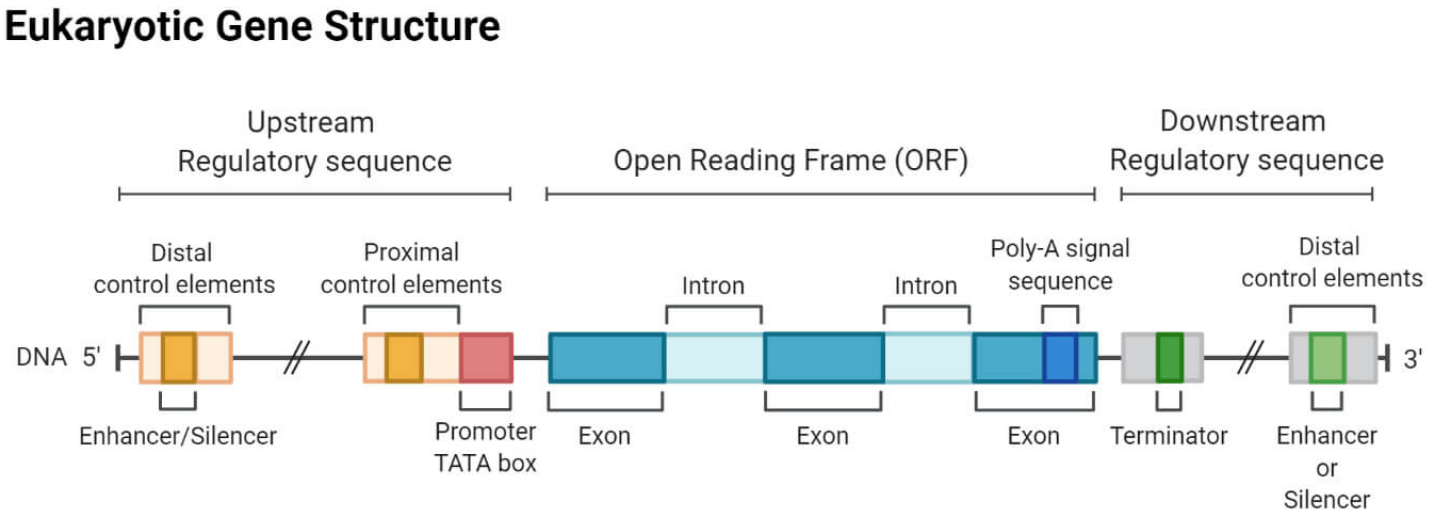
Structure of a Eukaryotic Gene

- A eukaryotic gene contains a **promoter** (regulates transcription), a **5’ UTR**, **exons** (coding regions), **introns** (non-coding regions removed by splicing), a **3’ UTR**, and a **poly-A signal** at the end. Exons contain the start codon (AUG) and stop codon (UAA/UAG/UGA) that define the protein-coding sequence.



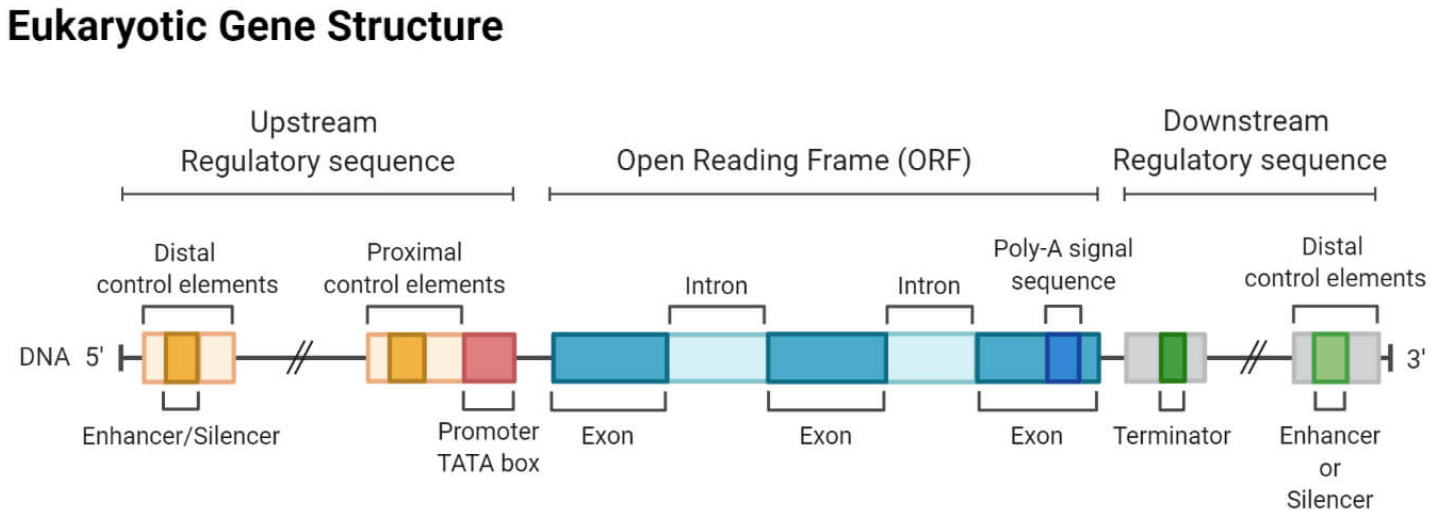
Structure of a Eukaryotic Gene

- **Upstream Regulatory Sequence**
- **Distal control elements (Enhancers/Silencers)**
  DNA regions far from the gene that increase or decrease transcription.
- **Proximal control elements**
  Regulatory sequences located close to the promoter that assist in transcription activation.



Structure of a Eukaryotic Gene

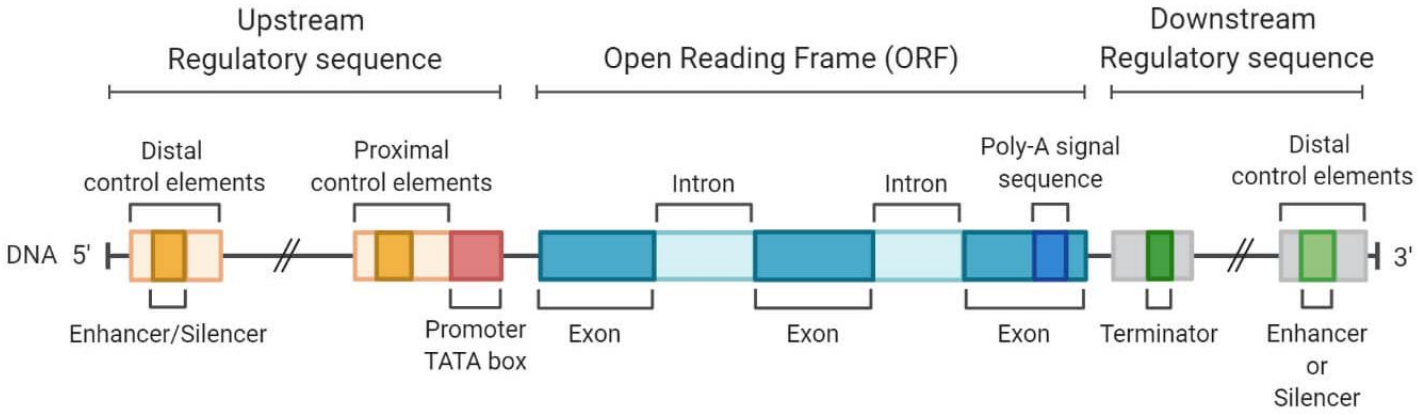
- **Promoter (with TATA box)**
  - The site where **RNA polymerase and transcription factors bind** to start transcription.
  - The **TATA box** is a common core promoter element in eukaryotes.



Structure of a Eukaryotic Gene

- **Open Reading Frame (ORF)**
  - The coding region of the gene that will be transcribed and translated into protein.
  - Consists of **Exons** (kept in mRNA, translated) and **Introns** (removed during RNA splicing).

Component	Function
Exons	Protein-coding sequences that remain in mature mRNA.
Introns	Non-coding sequences removed during splicing.

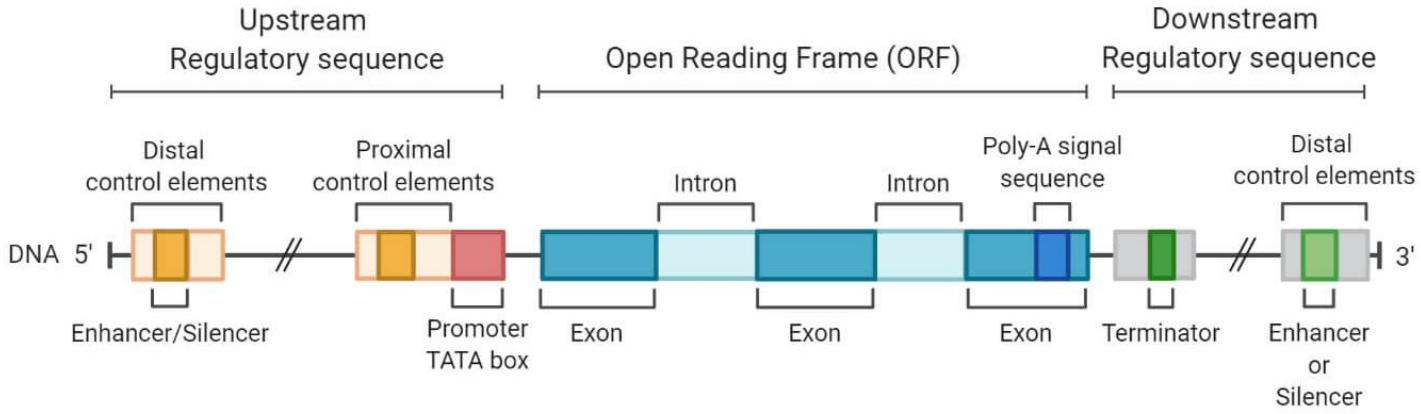


Structure of a Eukaryotic Gene

- **Poly-A Signal Sequence**
  - Signals where **polyadenylation** occurs (addition of poly-A tail to mRNA for stability & export).

- **Terminator**
  - DNA sequence that signals the end of transcription.

- **Downstream Regulatory Sequence**
  - Distal enhancers or silencers located after the gene, also regulate transcription efficiency.



Reference

- Alberts, B., Johnson, A., Lewis, J., Morgan, D., Raff, M., Roberts, K., & Walter, P. (2022). *Molecular biology of the cell* (7th ed.). W. W. Norton & Company.
- Berg, J. M., Tymoczko, J. L., Gatto, G. J., & Stryer, L. (2019). *Biochemistry* (9th ed.). W. H. Freeman and Company.
- Lodish, H., Berk, A., Kaiser, C. A., Krieger, M., Bretscher, A., Ploegh, H., & Amon, A. (2021). *Molecular cell biology* (9th ed.). W. H. Freeman and Company.
- Watson, J. D., Baker, T. A., Bell, S. P., Gann, A., Levine, M., & Losick, R. (2014). *Molecular biology of the gene* (7th ed.). Pearson Education.