Genetic Organization of Eukaryotes and Prokaryotes

Introduction

- **Genetic organization** refers to how DNA is arranged, packaged, and regulated inside a cell.
- The **basic unit of genetic material is DNA**, but its organization differs **greatly** between prokaryotes (bacteria, archaea) and eukaryotes (plants, animals, fungi, protozoa).
- These differences influence **gene expression, replication, mutation, and evolution**.

Genetic Organization in Prokaryotes

1. Genome Structure

- Prokaryotes are **haploid organisms** (contain a single copy of each gene).
- DNA is usually arranged as a **single, circular, double-stranded chromosome** located in the **nucleoid region** (not enclosed by a membrane).
- Genome size: **0.5–10 million base pairs (Mbp)**.
- Example:
    - *E. coli* genome ≈ 4.6 Mbp, ~4,000 genes.

2. Nucleoid Organization

- DNA is **supercoiled** with the help of enzymes (DNA gyrase, topoisomerases).
- **Nucleoid-associated proteins (NAPs)** (e.g., HU, H-NS, IHF) help in compacting DNA.
- No **histone proteins** (except in some archaea).

3. Plasmids

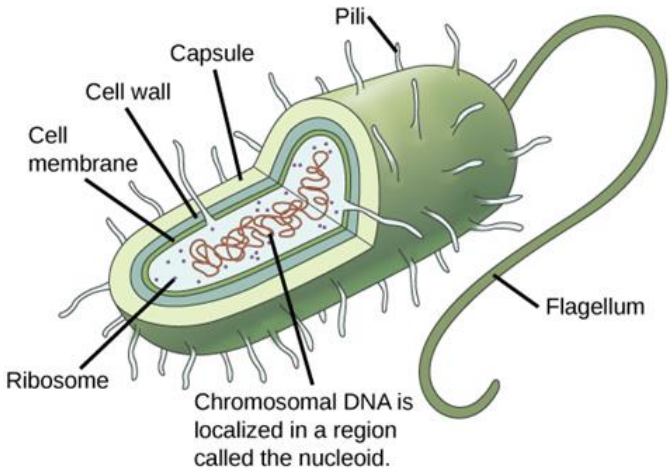
- Small, circular, extrachromosomal DNA molecules.
- Carry **non-essential but advantageous genes**:
    - Antibiotic resistance (R plasmids).
    - Virulence factors.
    - Metabolic pathways.
- Replicate independently of the main chromosome.

4. Genes and Operons

- Genes are **continuous**, without introns (in most bacteria).
- Organized into **operons** (e.g., lac operon, trp operon).
- Operon = cluster of genes under control of a single promoter → allows **coordinated gene regulation**.
- mRNA is **polycistronic** (one mRNA codes for multiple proteins).

5. Genetic Elements

- **Chromosomal DNA** – essential genes.
- **Plasmids** – accessory genes.
- **Transposons (jumping genes)** – mobile DNA segments.
- **Bacteriophages** – viruses that may integrate into bacterial DNA.



Genetic Organization in Eukaryotes

1. Genome Structure

- Eukaryotes are **diploid (2n)** in most cases (two copies of each gene).
- DNA is **linear** and divided into **multiple chromosomes** inside the nucleus.
- Genome size: much larger than prokaryotes.
    - Humans: ~3.2 billion base pairs, ~20,000–25,000 protein-coding genes.

2. Chromatin Organization

- DNA is associated with **histone proteins** to form **nucleosomes**.
- Each nucleosome: ~147 bp of DNA wrapped around histone octamer (H2A, H2B, H3, H4).
- Further compacted into:
    - **Euchromatin** → lightly packed, transcriptionally active.
    - **Heterochromatin** → densely packed, transcriptionally inactive.

3. Chromosomes

- Eukaryotic DNA is packaged into **linear chromosomes** with:
    - **Centromere** (attachment site for spindle fibers).
    - **Telomeres** (protect chromosome ends).
    - **Replication origins**.
- Exist in **homologous pairs** (one from each parent).

4. Genes

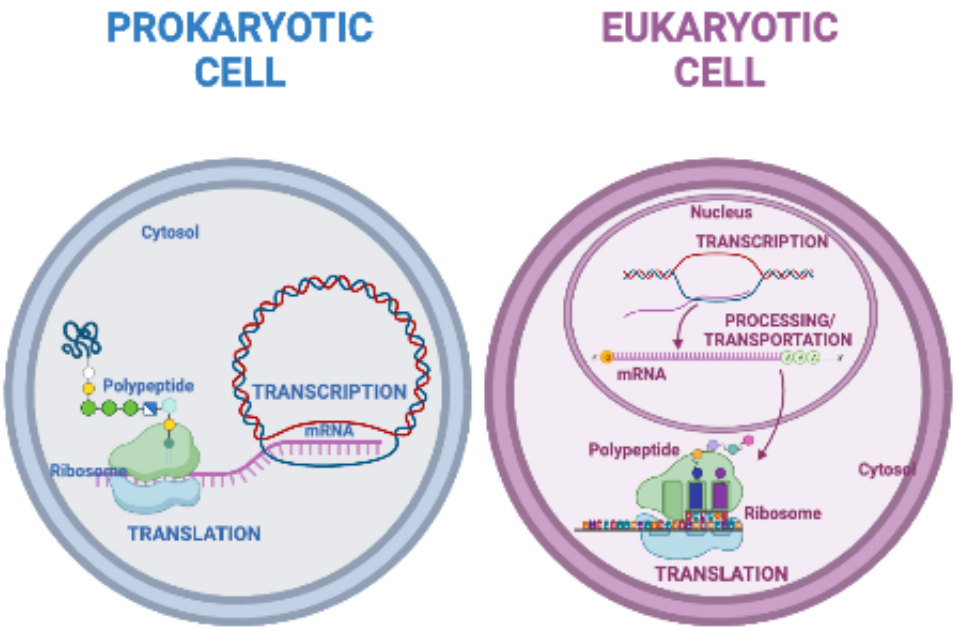
- Eukaryotic genes are complex:
  - Contain **exons (coding sequences)** and **introns (non-coding sequences)**.
  - Require **RNA splicing** after transcription.
- Promoters, enhancers, and silencers regulate expression.
- mRNA is **monocistronic** (one gene → one mRNA → one protein).

5. Extra-Nuclear DNA

- **Mitochondria** and **chloroplasts** have their own DNA (circular, prokaryote-like).
- Codes for some of their own proteins but depends on nuclear DNA.

6. Repetitive DNA and Non-Coding Regions

- A large portion of eukaryotic DNA is **non-coding** (~98% in humans).
- Includes:
  - Satellite DNA.
  - Microsatellites.
  - Transposons and retrotransposons.



Comparison: Prokaryotic vs. Eukaryotic Genetic Organization

Feature	Prokaryotes	Eukaryotes
DNA form	Single, circular chromosome	Multiple, linear chromosomes
Genome size	Small (0.5–10 Mb)	Large (10 Mb – billions of bp)
Location	Nucleoid (no membrane)	Nucleus (membrane-bound)
Histones	Absent (except archaea)	Present (DNA wrapped around histones)

Plasmids	Common	Rare (except in yeast)
Gene structure	No introns, continuous	Introns + exons
Transcription	Polycistronic mRNA (operons)	Monocistronic mRNA
Extra DNA	Plasmids, transposons, phages	Mitochondrial & chloroplast DNA
Genome content	Mostly coding DNA	A large fraction of non-coding DNA

Significance of Genetic Organization

- Determines **gene expression patterns**.
- Explains why eukaryotes have complex regulation and specialization.
- Prokaryotic organization allows **rapid adaptation** to environmental changes.
- Eukaryotic organization supports **multicellularity and complex development**.

Conclusion

- The **genetic organization of prokaryotes is simple**, with small, circular DNA, plasmids, and operons for coordinated expression.
- In contrast, **eukaryotic genetic organization is complex**, involving histone packaging, introns, linear chromosomes, and regulatory sequences.
- These differences reflect evolutionary adaptations:
    - Prokaryotes → efficiency and survival in rapidly changing environments.
    - Eukaryotes → complexity, regulation, and development of multicellular organisms.