Gene Organization

Lecture Objectives:

- What are DNA, Gene, Chromosome and Genome?
- What is the difference between eukaryotic and prokaryotic gene structure?
- What DNA Packaging?

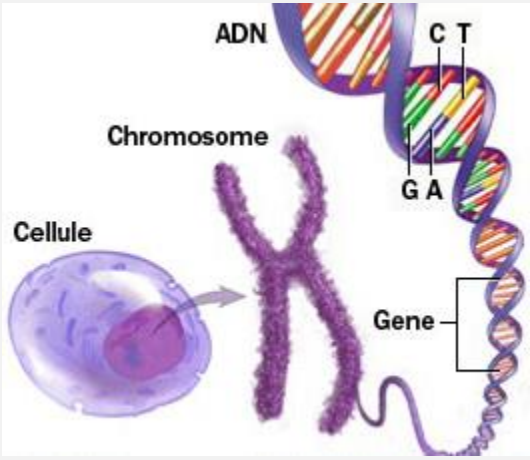
- Genetic information is stored in DNA.
- Segments of DNA that encode proteins or other functional products are called **genes**.
- Gene sequences are transcribed into messenger RNA intermediates (mRNA).
- mRNA intermediates are translated into proteins that perform most life functions.

DNA …Gene …Chromosome …Genome

DNA (deoxyribonucleic acid) is the genetic material of living organisms. DNA is a long string of paired chemical units (nucleotides) that come in four different types, and it carries information organized into units called genes.

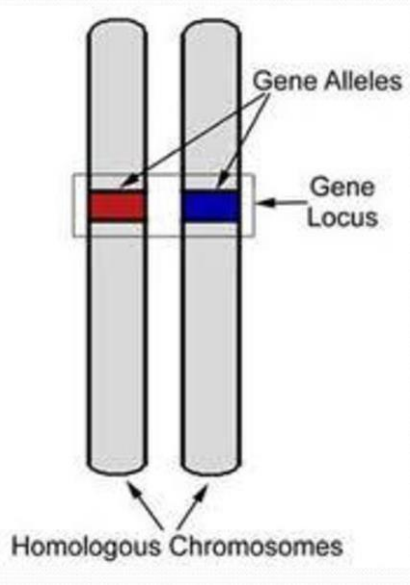
Genes typically provide instructions for making proteins, which give cells and organisms their functional characteristics.

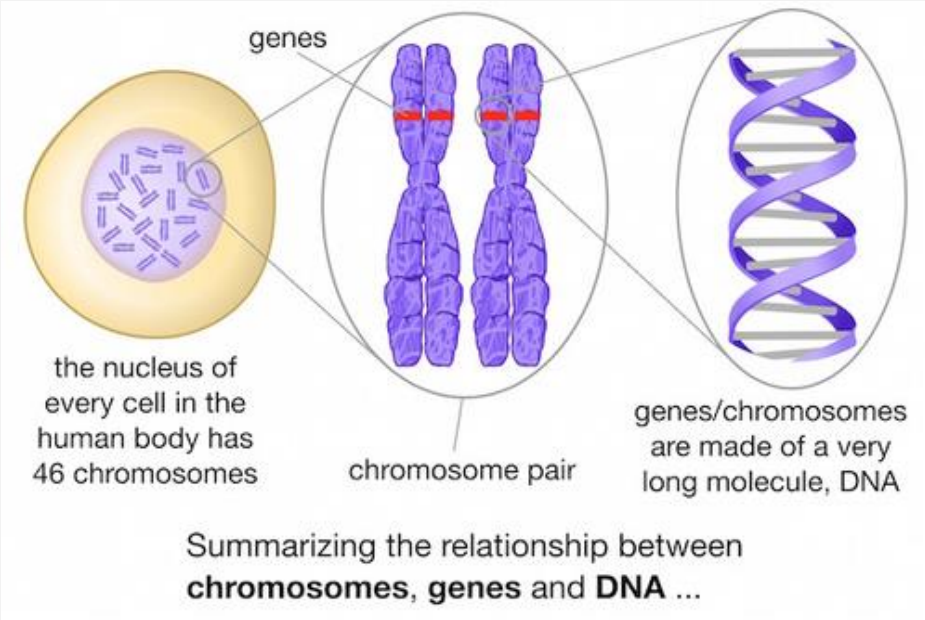
Chromosomes structures within cells that contain a person's genes, it is a super condensed form of DNA where it is wrapped around histone proteins. Each species has its own characteristic number of chromosomes. Humans, for instance, have 46 chromosomes in a typical body cell.



DNA …Gene …Chromosome …Genome

- The genes on each chromosome are arranged in a particular sequence, and each gene has a particular location on the chromosome (called its locus), each gene may exist in alternative forms called alleles.



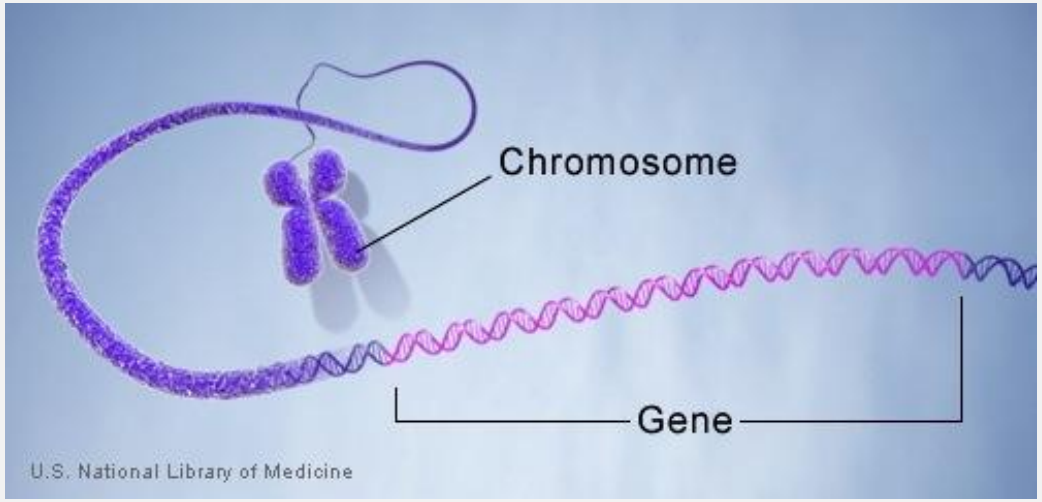


Genome

- The word “genome,” coined by German botanist **Hans Winkler** in 1920, was derived simply by combining **gene** and the final syllable of **chromosome.**
- A genome is the genetic material of an organism. It consists of DNA (or RNA in RNA viruses).
- The genetic content of the organelles (**chloroplasts and mitochondria**) in the cell, **is not** considered part of the nuclear genome.
- The genome is the ultimate source of information about an organism.

Concept of Gene

Genes are the basic physical and functional units of heredity. Each gene is located on a particular region of a chromosome and has a specific ordered sequence of nucleotides (the building blocks of DNA).



Gene Structure

A structural gene involves a number of different components:

Promoters:

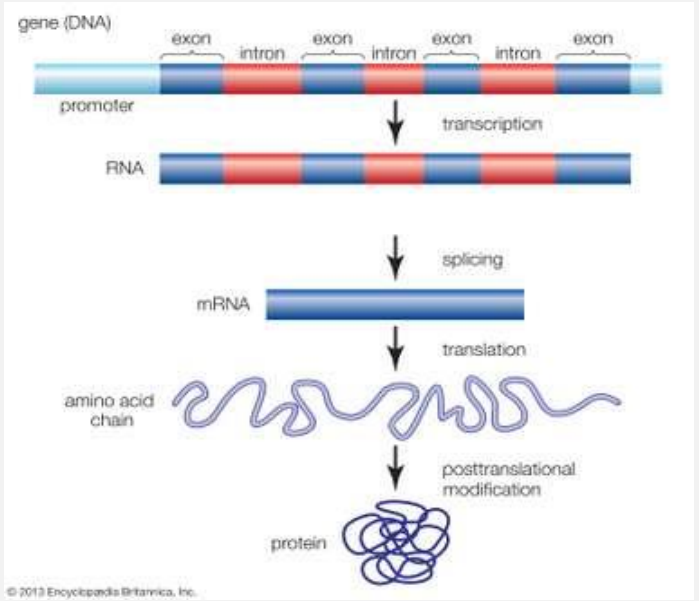
Promoters are about 100 to 1000 base pairs long and found upstream of their target genes. The sequence of the promoter region controls the binding of the RNA polymerase and transcription factors, therefore promoters play a large role in determining where and when your gene of interest will be expressed.

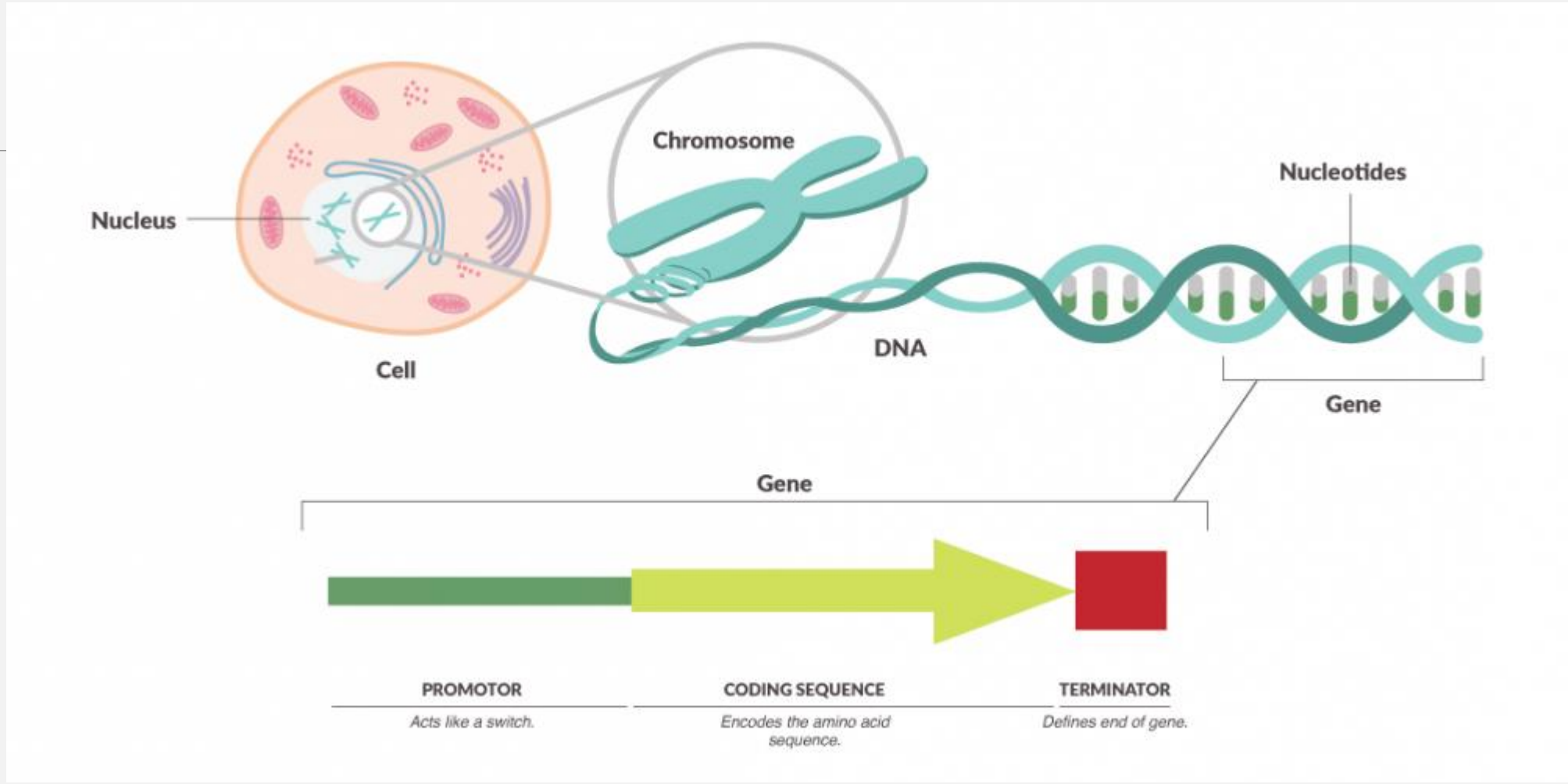
Intron:

Introns are nucleotide sequences in DNA and RNA that do not directly code for proteins, and are removed during the precursor messenger RNA (pre-mRNA) stage of maturation of mRNA by RNA splicing.

Exons:

Exons are nucleotide sequences in DNA and RNA that are conserved in the creation of mature RNA.




Nucleus
Cell
Chromosome
DNA
Nucleotides
Gene
Gene
PROMOTOR
Acts like a switch.
CODING SEQUENCE
Encodes the amino acid sequence.
TERMINATOR
Defines end of gene.

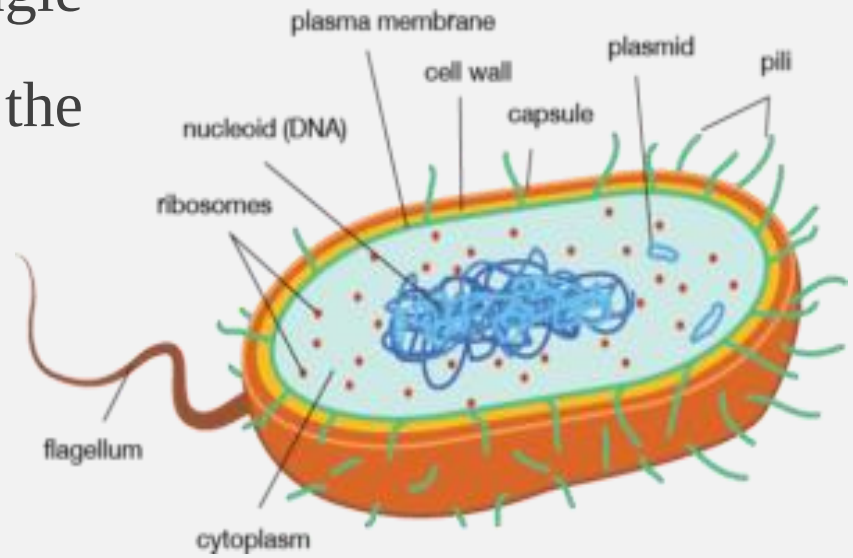
Gene Number and size

Genome size refers to the amount of DNA contained in a haploid genome expressed either in terms of the number of base pairs, kilobases (1 kb = 1000 bp), or megabases (1 Mb = 1 000 000 bp), or as the mass of DNA in picograms (1 pg = 10−12 g)

Comparison of Prokaryotic and Eukaryotic

Genome of all living organisms represents their hereditary material and is formed of DNA.

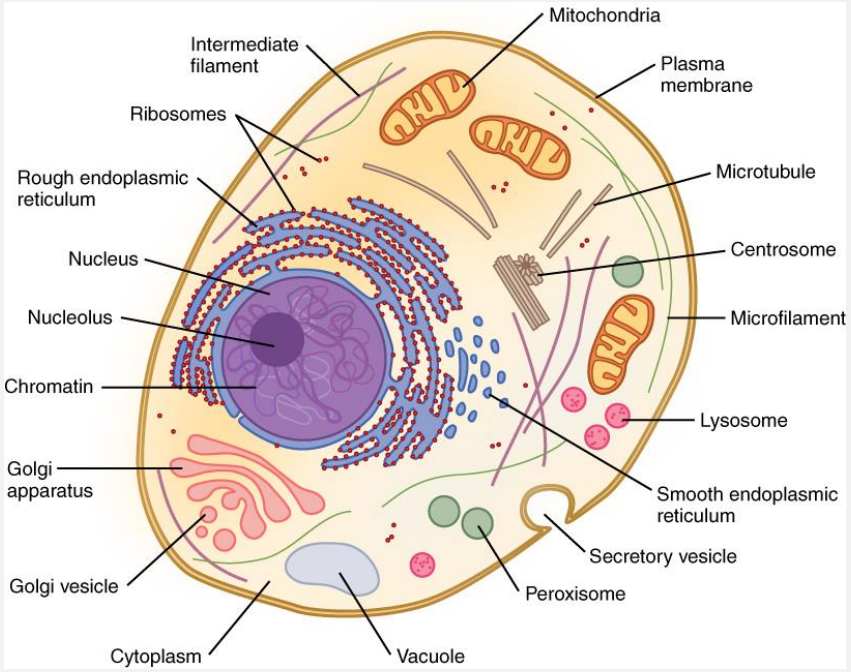
❖**In Prokaryotic cells-** Genomic DNA forms a single circular chromosome, without basic proteins, lies in the cell cytoplasm in nucleoid region.



Comparison of Prokaryotic and Eukaryotic

❖**In Eukaryotic cells-** DNA is associated with basic proteins(histones), form long chromatin fibers.

❖ **Chromatin fibers** form a network, enclosed in a double layered nuclear envelop, condenses into chromosomes during cell division



Prokaryotic gene structure

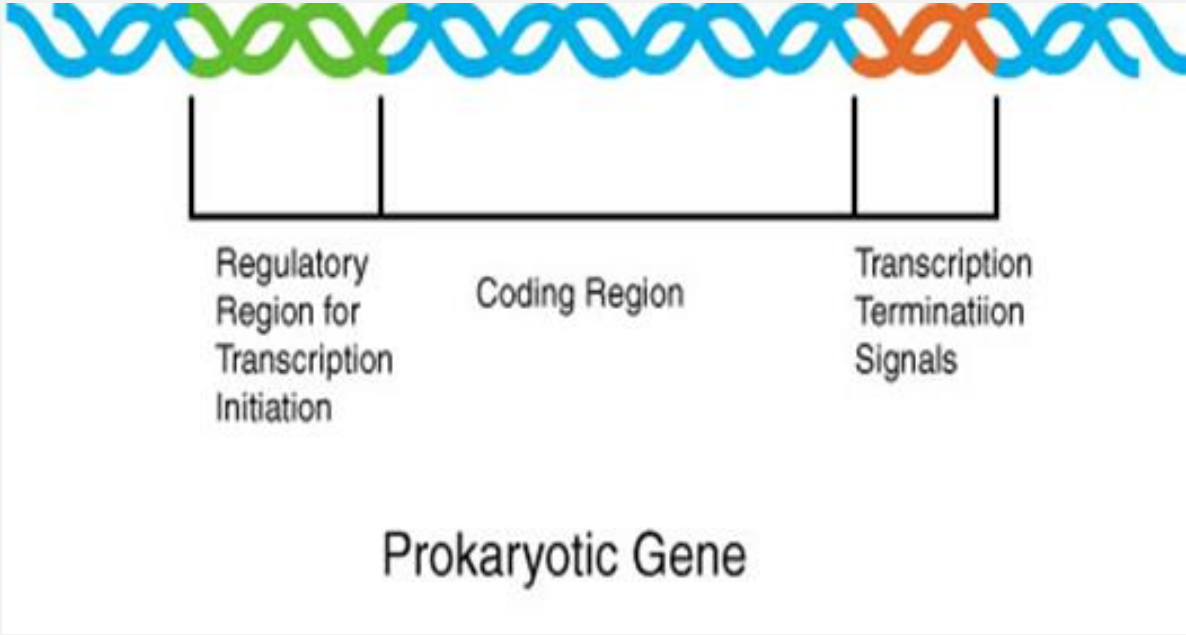
Prokaryotic Gene is composed of three regions:

1.Promoter region

2.RNA coding sequence

3.Terminator region

Prokaryotic gene is continues and uninterested where there is no introns present. The region 5’ of the promoter sequence is called upstream sequence and the region 3’ of the terminator sequence is called downstream sequence.

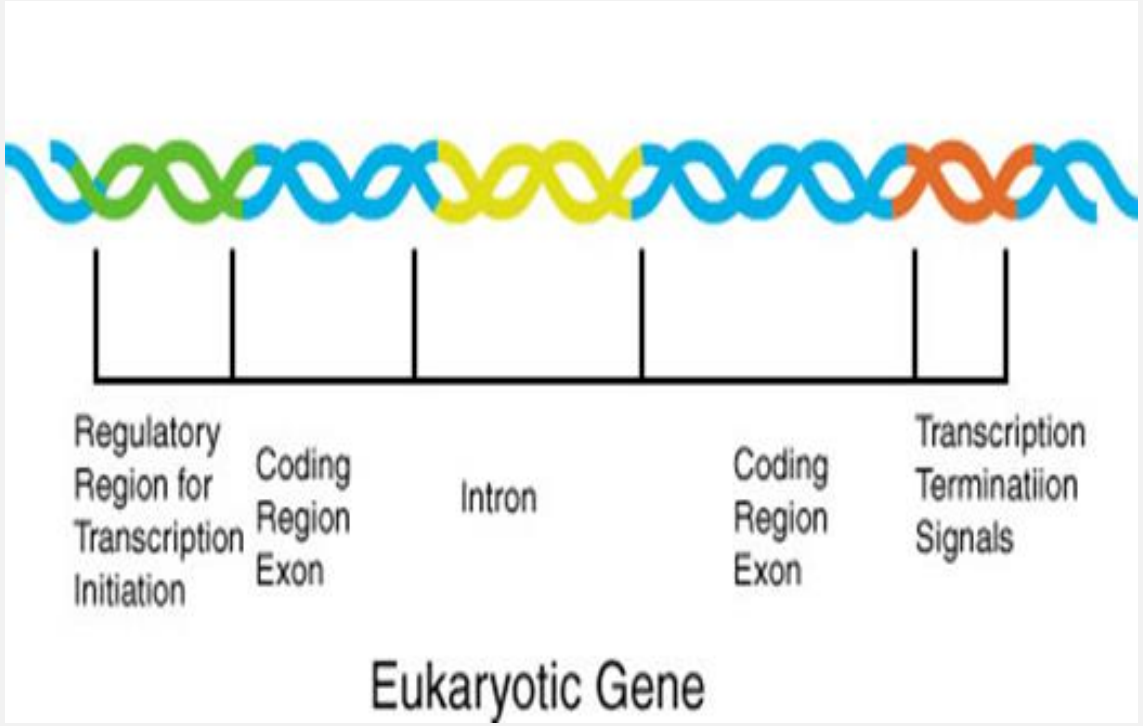


Eukaryotic gene structure

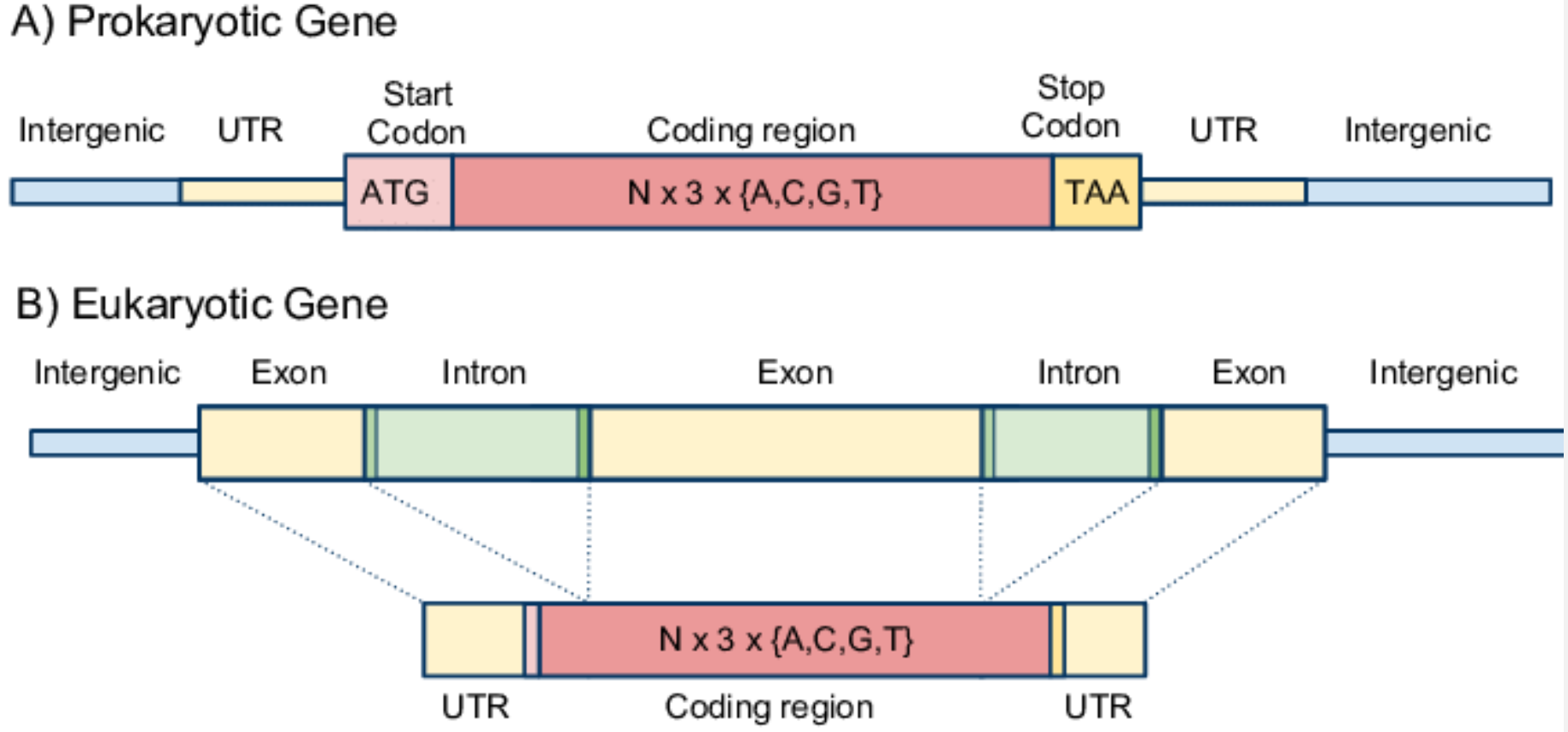
Eukaryotic gene are complex structures compared that prokaryotic gene. They are composed of following regions

- Exons
- Introns
- Promoter sequences
- Terminator sequences
- Upstream sequences
- Downstream sequences
- Enhancers and silencers

(upstream or downstream) Signals (Upstream sequence signal for addition of cap. Downstream sequences signal for addition of poly A tail.



Comparison of Prokaryotic and Eukaryotic

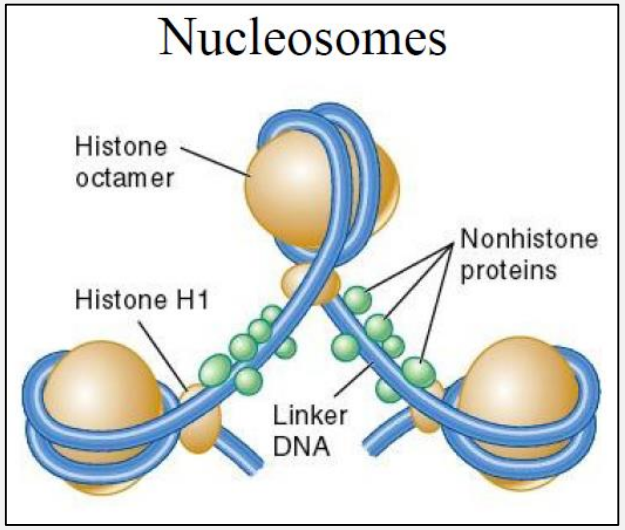


DNA Packaging

Gene expression in eukaryotes may also be regulated through by alterations in the packing of DNA, which modulates the access of the cell's transcription enzymes (e.g., RNA polymerase) to DNA. The DNA helix is wrapped around special proteins called histones, and this are wrapped into tight helical fibers. These fibers are then looped and folded into increasingly compact structures, which, when fully coiled and condensed, give the chromosomes their characteristic appearance .

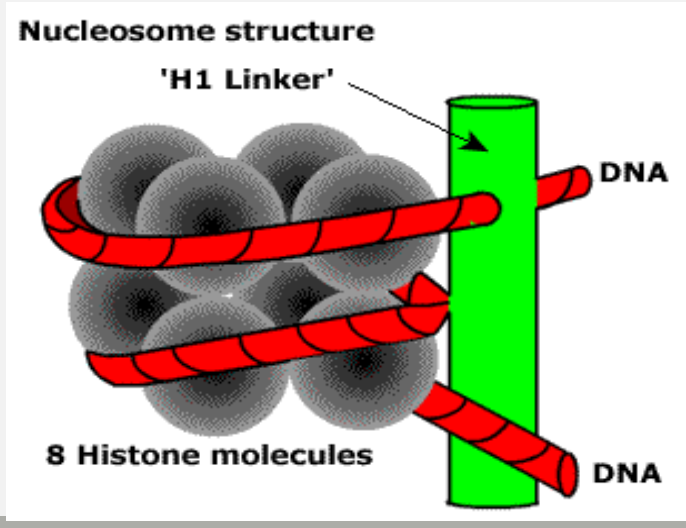
DNA Packaging

Eukaryotes have large genomes compared to prokaryotes. In order to fit their genomes into a cell, eukaryotes must pack their DNA tightly inside the nucleus. To do so, DNA is wound around proteins called histones to form nucleosomes, the main unit of DNA packaging.



DNA Packaging

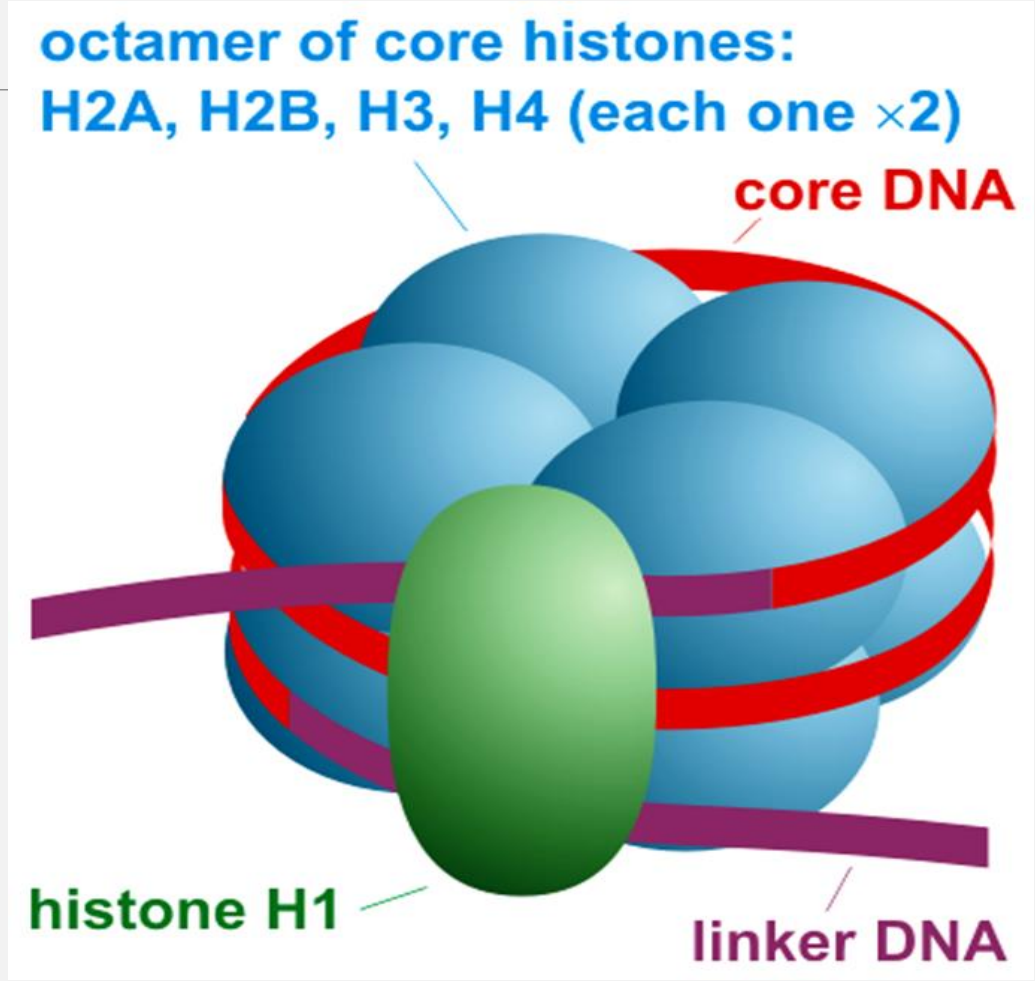
So, nucleosomes are composed of double-stranded of negatively charged DNA that wrapped around a core of eight positively charged histone proteins. Each core is composed of four different types of (H_2A, H_2B, H_3 and H_4) that are each present in two copies. Another type of histone (H_1) binds to both the nucleosome and the linker DNA, stabilizing the structure.



Histones are divided into two groups:

1-Core histones

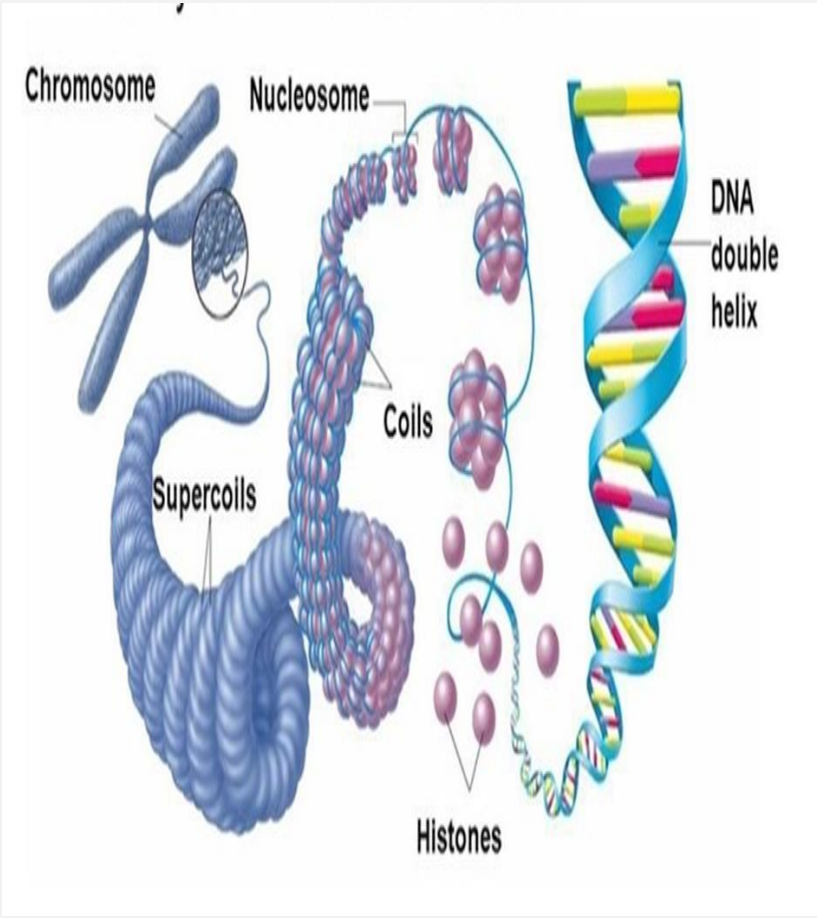
2-Linker histones



Summary

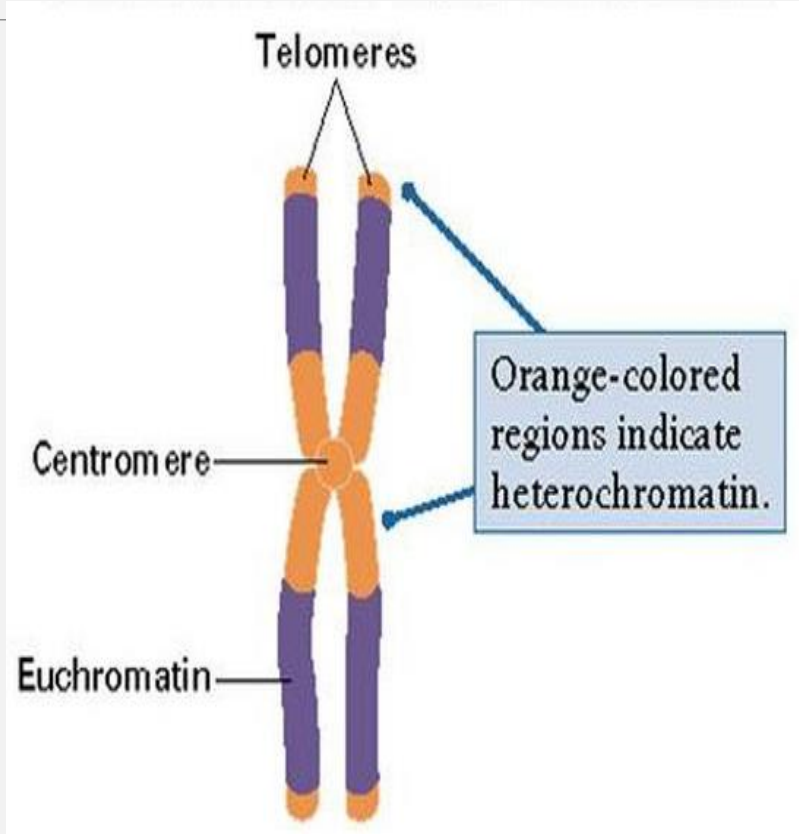
The first level of packing in Chromatin involves the binding of DNA to histones into fundamental packing unit particles called **nucleosomes.**

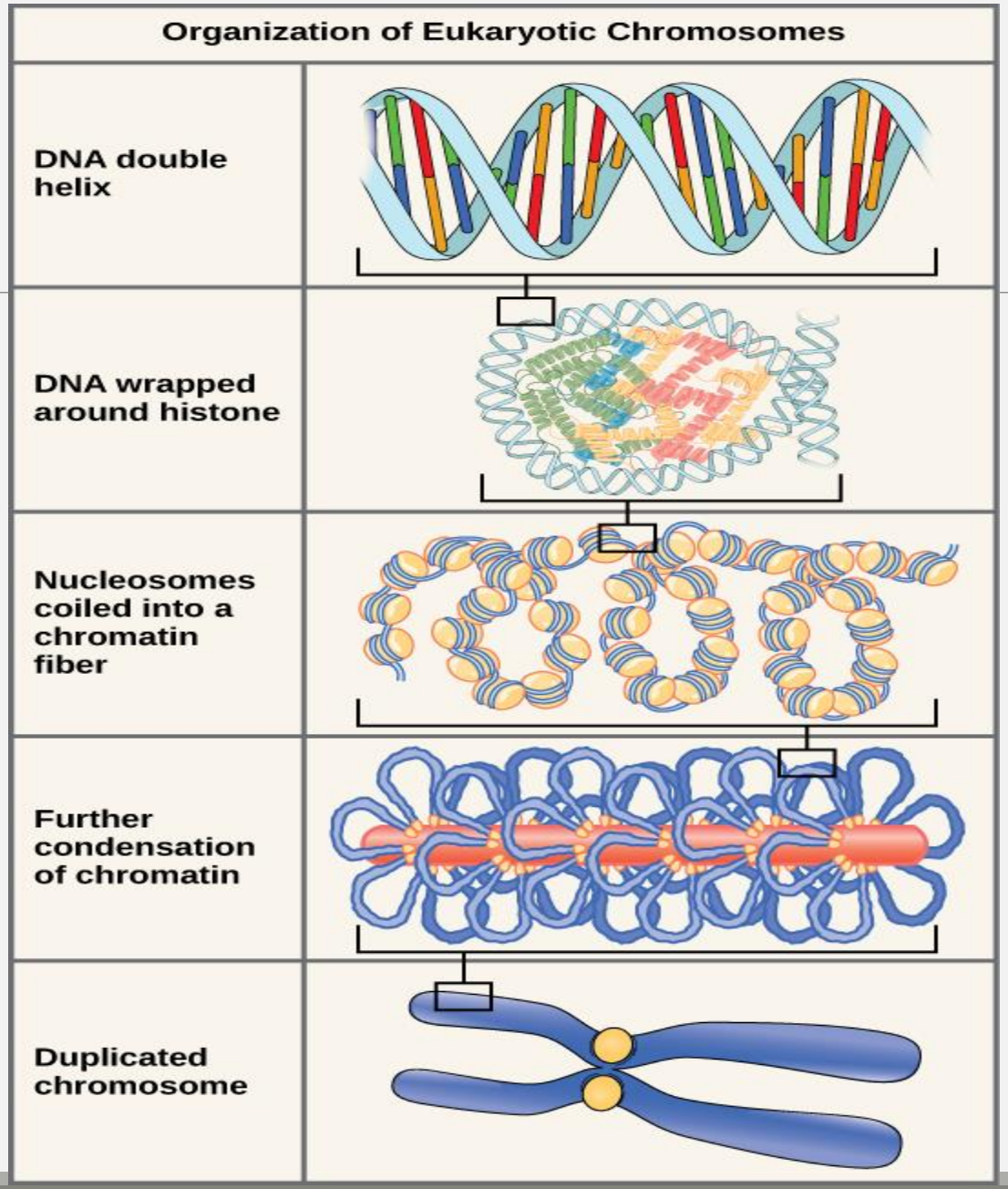
The second level of packing involves packing of nucleosomes into 30 nm thick **chromatin fibre**.

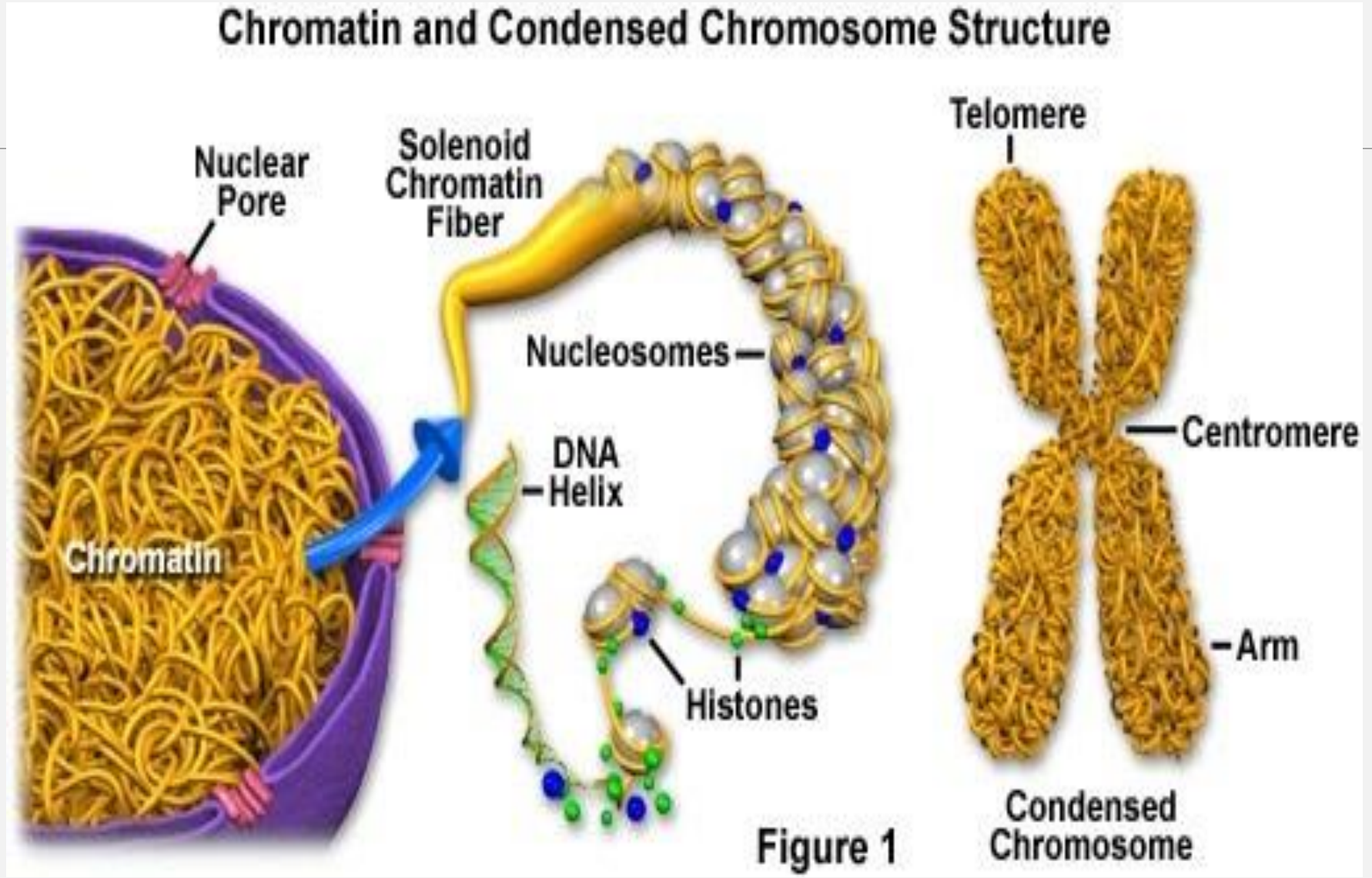


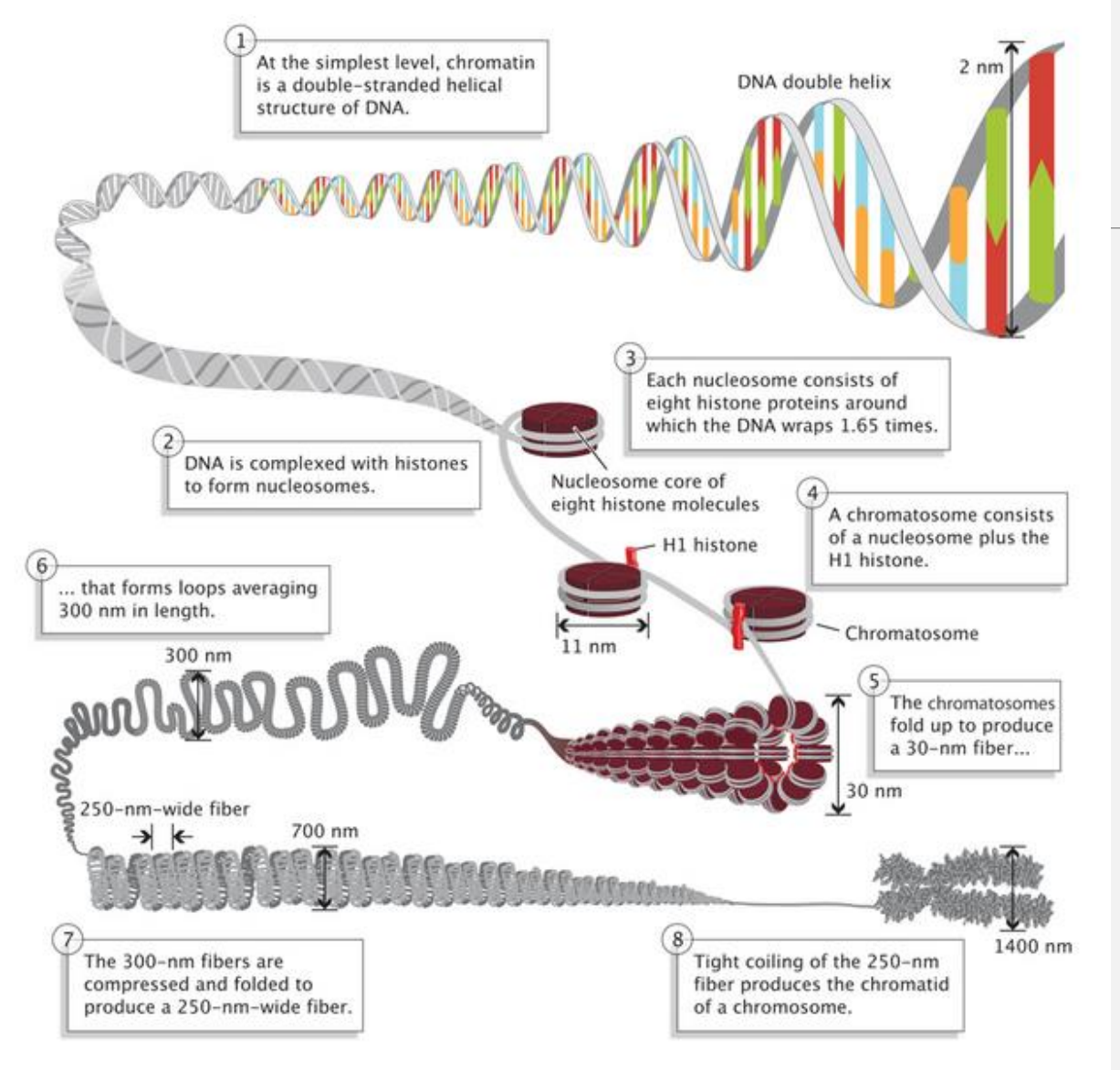
The highest level of packing of chromatin in the chromosome is found at **the metaphase stage** of cell division.

There are two distinct types of chromatin- **euchromatin** and **heterochromatin** which differ on their staining properties.




Organization of Eukaryotic Chromosomes
DNA double helix
DNA wrapped around histone
Nucleosomes coiled into a chromatin fiber
Further condensation of chromatin
Duplicated chromosome


Chromatin and Condensed Chromosome Structure
Nuclear Pore
Solenoid Chromatin Fiber
Telomere
Nucleosomes
Centromere
DNA Helix
Chromatin
Histones
Arm
Figure 1
Condensed Chromosome


1
At the simplest level, chromatin is a double-stranded helical structure of DNA.
DNA double helix
2 nm
3
Each nucleosome consists of eight histone proteins around which the DNA wraps 1.65 times.
2
DNA is complexed with histones to form nucleosomes.
Nucleosome core of eight histone molecules
4
A chromatosome consists of a nucleosome plus the H1 histone.
H1 histone
6
... that forms loops averaging 300 nm in length.
11 nm
Chromatosome
300 nm
5
The chromatosomes fold up to produce a 30-nm fiber...
30 nm
250-nm-wide fiber
700 nm
1400 nm
7
The 300-nm fibers are compressed and folded to produce a 250-nm-wide fiber.
8
Tight coiling of the 250-nm fiber produces the chromatid of a chromosome.

Prokaryotes and Eukaryotes genome

Prokaryotes	Eukaryotes
Single cell	Single or multi cell
No nucleus	Nucleus
One piece of circular DNA	Chromosomes
No mRNA post transcriptional modification	Exons/Introns splicing

comparative genome sizes of organisms

organism	Size (bp)	gene number	average gene density	chromosome number
Homo sapiens (human)	3.2 billion	~25,000	1 gene /100,000 bases	46
Mus musculus (mouse)	2.6 billion	~25,000	1 gene /100,000 bases	40
Drosophila melanogaster (fruit fly)	137 million	13,000	1 gene / 9,000 bases	8
Arabidopsis thaliana (plant)	100 million	25,000	1 gene / 4000 bases	10
Caenorhabditis elegans (roundworm)	97 million	19,000	1 gene / 5000 bases	12
Saccharomyces cerevisiae (yeast)	12.1 million	6000	1 gene / 2000 bases	32
Escherichia coli (bacteria)	4.6 million	3200	1 gene / 1400 bases	1
H. influenzae (bacteria)	1.8 million	1700	1 gene /1000 bases	1

Human Genome: General Information

- Genetic material in humans is stored in two organelles: nucleus (about 3200 Mbp) and mitochondria (16.6 kb).
- Human chromosomes are not of equal sizes; the smallest, chromosome 21, and the largest, chromosome 1.
- Only a very small amount of human DNA is responsible for the differences among humans, indeed among all organisms.