Histone, Chromatin & DNA Packaging

Prokaryotic and Eukaryotic Chromosomes Organization

- DNA molecules are organized within cells into the structures we observe
- as **chromosomes**.
- Because the total length of cellular DNA in cells is up to a hundred thousand times the cell's length, the packing of DNA into chromosomes is crucial to cell architecture.
- Cells package their DNA not only to protect it, but also to regulate which genes are accessed and when. DNA packaging helps conserve space in cells.
- Packaging is the reason why the approximately two meters of human
- DNA can fit into a cell that is only a few micrometers wide

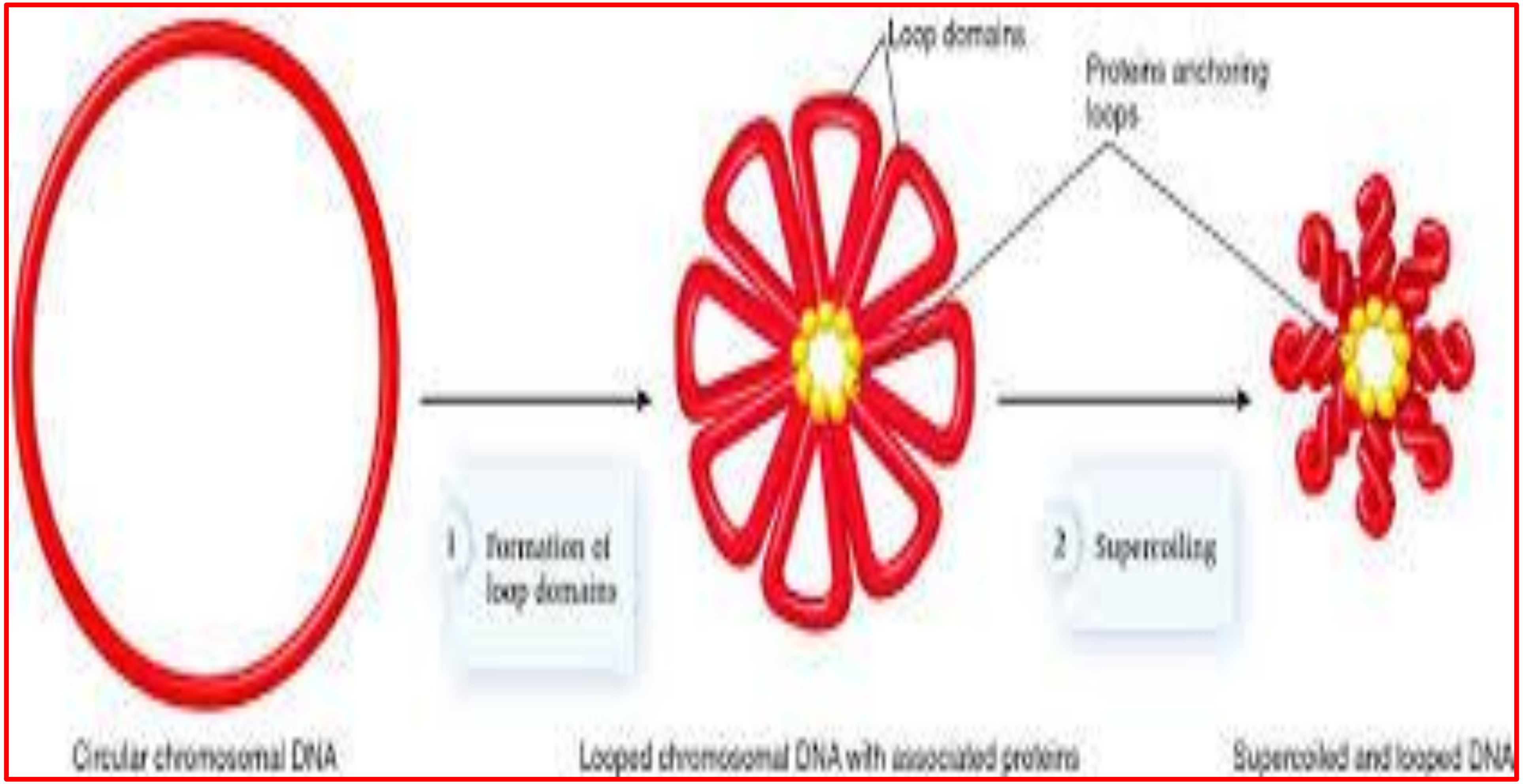
- The term chromosome comes from the Greek words for color (chroma) and body (soma). Scientists gave this name to chromosomes because they are cell structures, or bodies, that are strongly stained by some colorful dyes used in research because the length of a chromosomal DNA molecule is much greater than the length of a chromosome, there must be an efficient packaging system.

- Thus, What are the mechanisms that pack DNA into chromosomes?

- Chromosomes are thread-like or supercoiled structures located inside the cell (in cytoplasm of prokaryotes or nucleus of the eukaryotes).
- Each chromosome is made of proteins and a single molecule of deoxyribonucleic
- acid (DNA).
- Most prokaryotes contain a single, circular chromosome that is found in an area in the cytoplasm called the nucleoid.
- The nucleoid :(meaning nucleus-like) is an irregularly-shaped region within the cell of a prokaryote that contains all or most of the genetic material. In contrast to the nucleus of a eukaryotic cell, it is not surrounded by a nuclear membrane.
- The genome of prokaryotic organisms generally is a super coiled circular, double-stranded piece of DNA.
- The length of a genome widely varies, but generally is at least a few million base pairs It is commonly referred to as a prokaryotic chromosome.
- The chromosome for this bacterium is circular and this is a common
- arrangement, but there are a number of species with linear chromosomes.

Structure of bacterial chromosome

- A model of the overall structure of the bacterial chromosome:
- (A) The unfolded, circular chromosome of *E. coli* depicted as a single line for
- simplicity, though of course it is a double-stranded helix.
- (B) The DNA folded into chromosomal domains by protein-DNA associations.
- The proteins are depicted as the yellow circles, interacBng with both the DNA and with each other 6- 8 domains are shown in these figure A and B , but the actual number for E. coli is about 50.
- (C) Supercoiling and other interacBons cause the chromosome to compact greatly

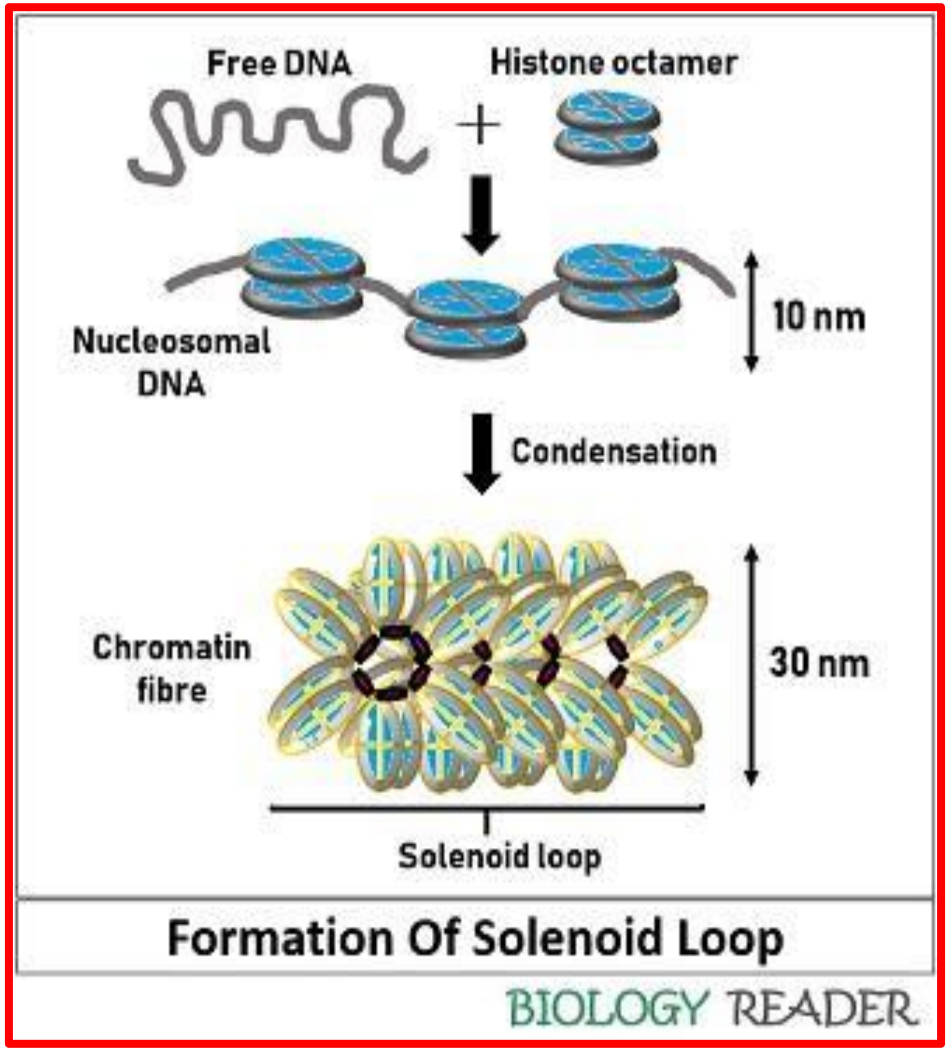

Loop domains
Proteins anchoring loops
1 Formation of loop domains
2 Supercoiling
Circular chromosomal DNA
Looped chromosomal DNA with associated proteins
Supercoiled and looped DNA

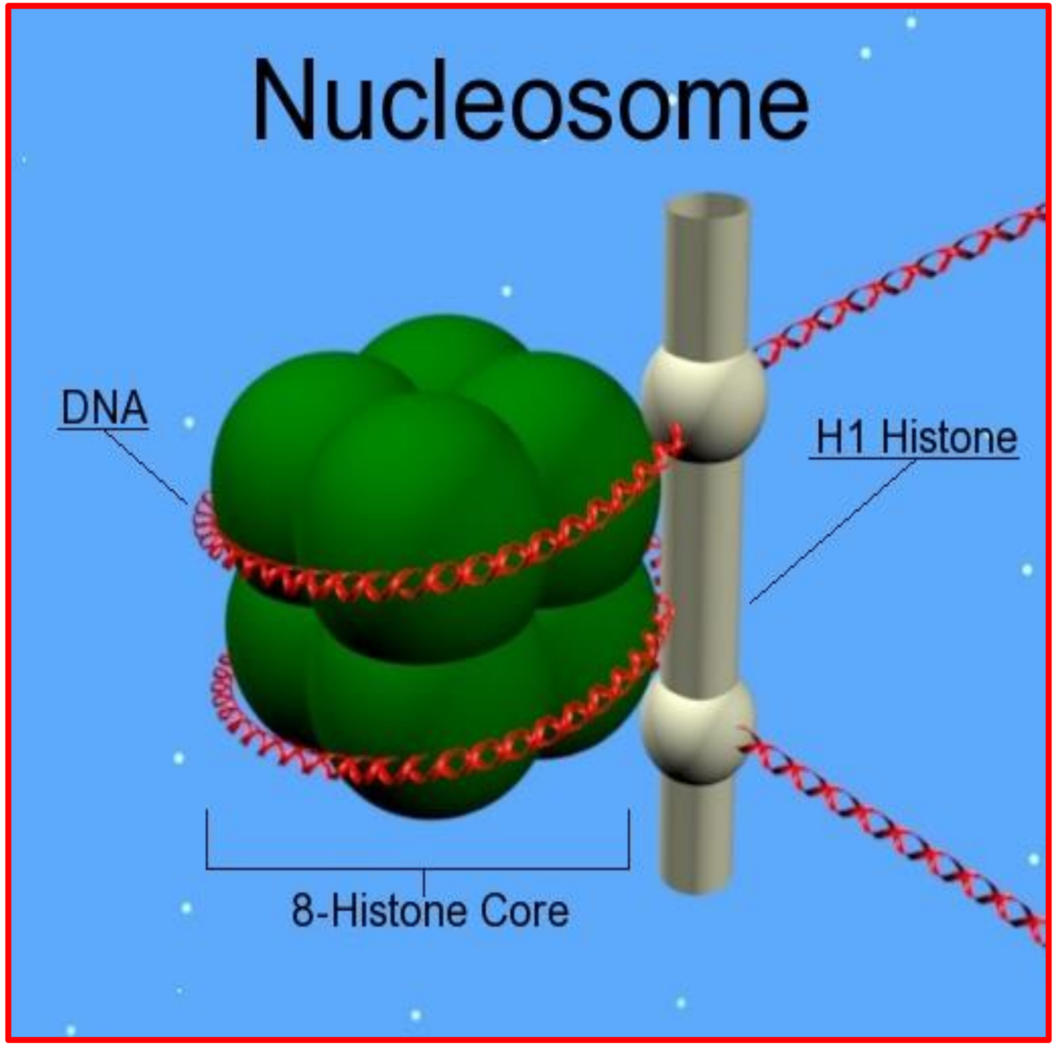
Chromatin organization and chromosome structure of eukaryotes

- Each species of plants and animals has a set number of chromosomes.
- for example, Humans have 46 chromosomes while a rice plant has 12
- and a dog 39.
- in fact, the packing is at the level of the nucleus, where the 2 m of DNA in
- a human cell is packed into 46 chromosomes, all in a nucleus 0.006 mm
- in diameter, because the length of a chromosomal DNA molecule is much
- greater than the length of a chromosome, there must be an efficient
- packaging system.
- The subunit designation of the chromosome is chromatin. The fundamental unit of chromatin is the **nucleosome**

Levels of DNA packaging

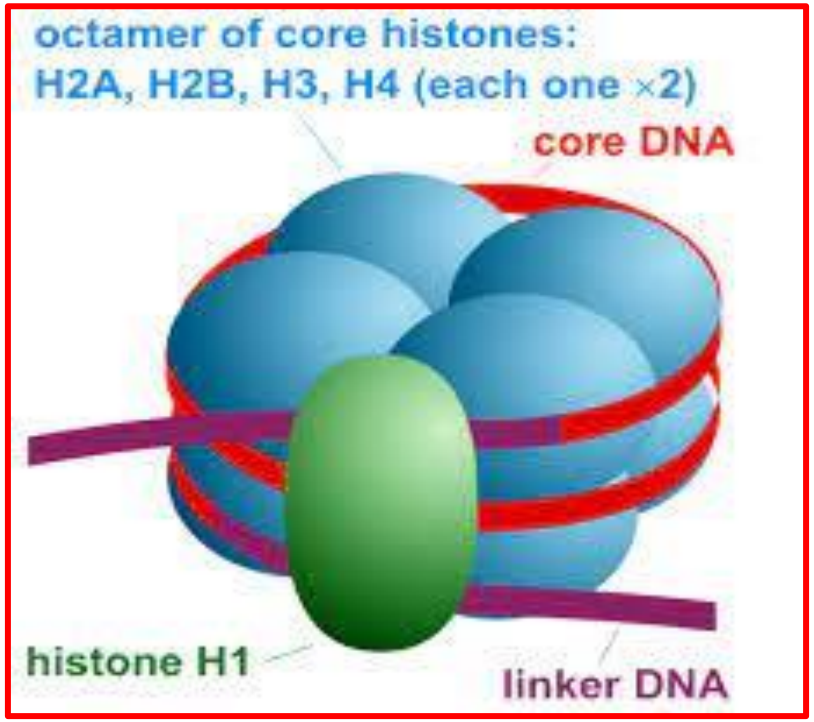
- First level twisting or super coiling of DNA molecules .
- Second level warping of DNA around histones.
- Formation of folds or zig zag by HI histone and the linker (other benefits of linker create elasticity and flexibility to chromatin beside binding two adjacent nucleosome)
- Formation of (30 nm) fibers and solenoid model by collecting each 6 nucleosome together


Free DNA
Histone octamer
Nucleosomal DNA
10 nm
Condensation
Chromatin fibre
30 nm
Solenoid loop
Formation Of Solenoid Loop
BIOLOGY READER


Nucleosome
DNA
H1 Histone
8-Histone Core

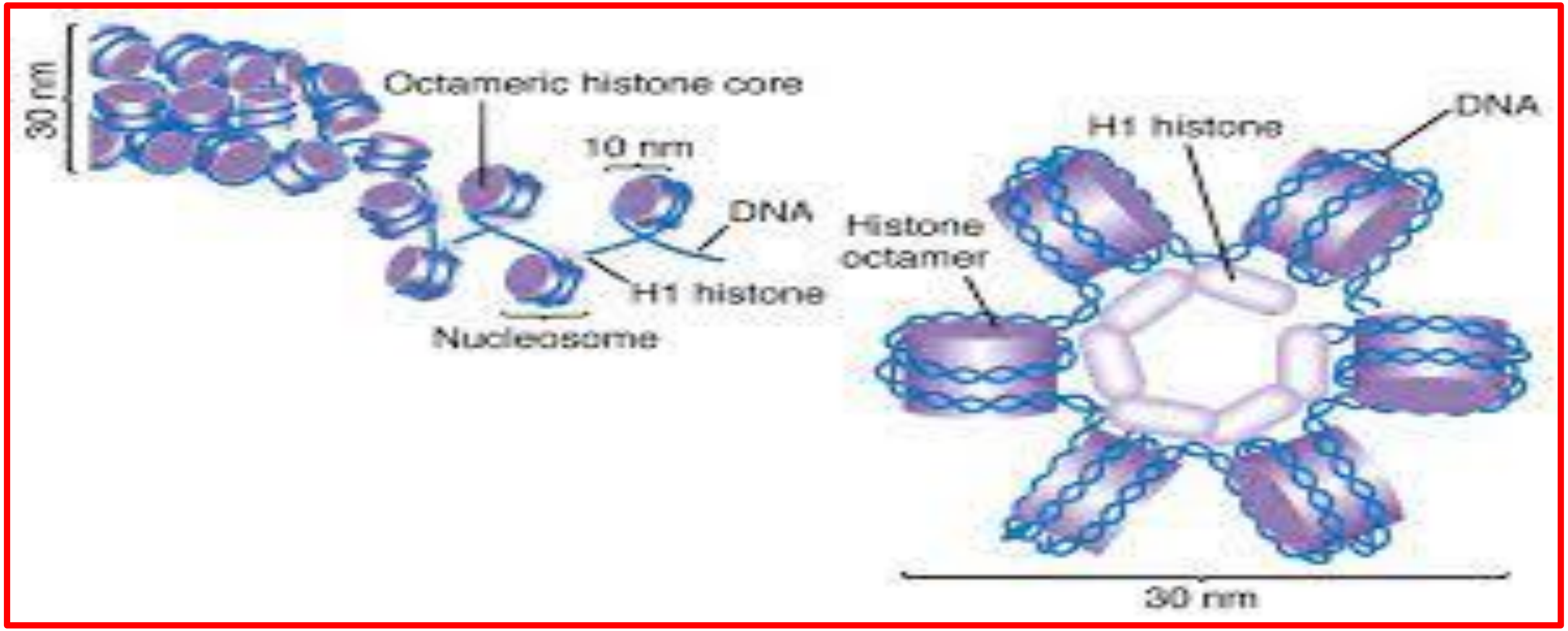
Hstones

- are a family of basic proteins that associate with DNA in the nucleus.
- Each histone octamer is composed of two copies each of the histone
- proteins H2A, H2B, H3, and H4.
- These are known as the **core histones**.
- The fifth histone H1 usually exist out
- side the core (in the binding region
- between nucleosome and another).
- each nucleosome attached with
- followed one by linker DNA (20-60 bp).

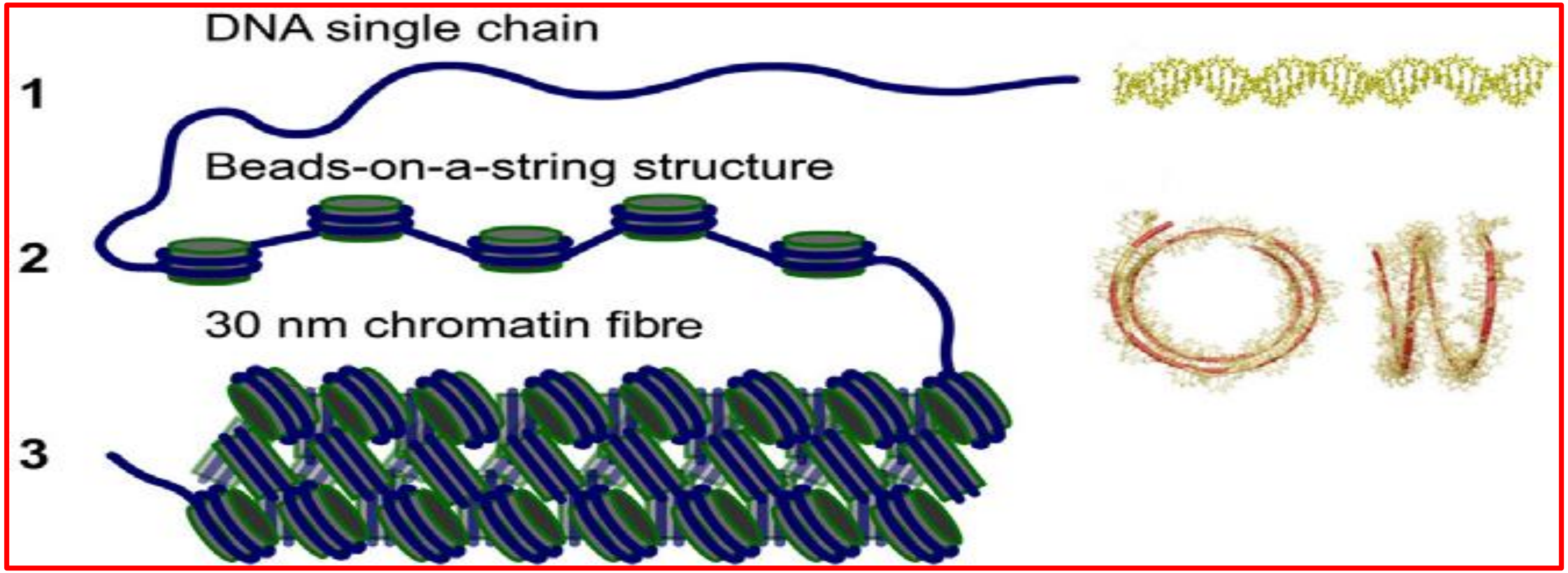


- All four of the core histones amino acid sequences contain between 20
- and 25% of lysine and arginine.
- They relatively small (molecular size for the core protein 11.4 KD-15.4KD) and highly positively charged proteins allowing them to closely associate with negatively charged DNA, for H1 Histone it is relatively larger (MW: 21KD) and percentage of basic amino acid is 30.5%.
- Five major families of histones exist exist: H1/H5, H2A, H2B, H3
- and H4. Histones H2A, H2B, H3 and H4 are known as the core histones,
- while histones H1 and H5 are known as the linker histones

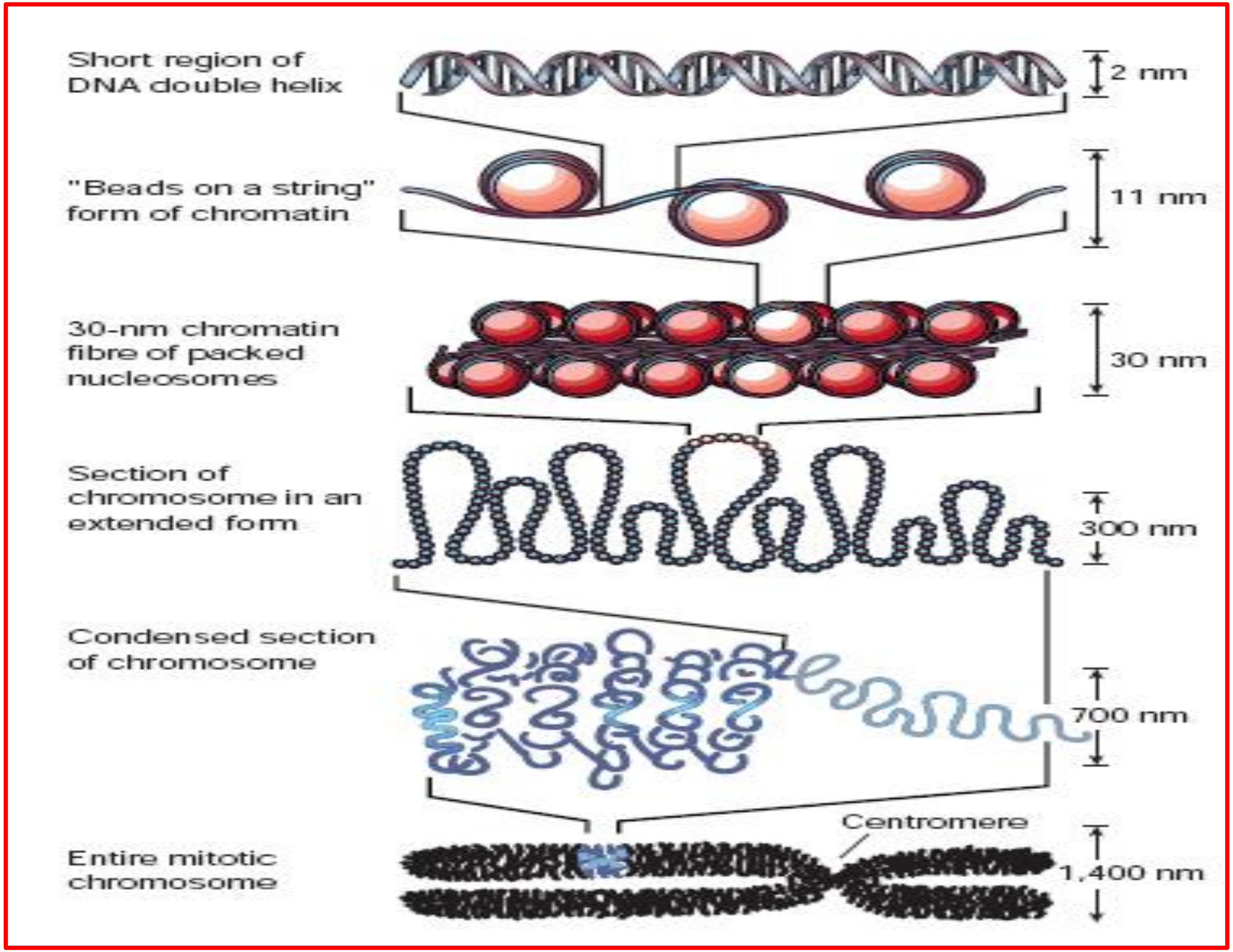
- The second level of packing is the coiling of beads in a helical structure called the 30 nm chromatin fiber this appears to be a solenoid
- structure with about 6 nucleosomes per turn.
- where additional H1 histone proteins are associated with each nucleosome to maintain the chromosome structure.



- The final packaging occurs when the fiber is organized in loops, Chromatin
- is further condensed by folding into loops.
- The final result of chromatin packaging is the supercoiled, compact DNA that makes up chromosomes.
- Chromatin :it is the major component of the nucleus, the genetic material consist from 50% DNA and protein for each and during interphase this chromatin appeared as uncondensed diffused material look like beads- in string but during metaphase it will arrange to thread-like structure.

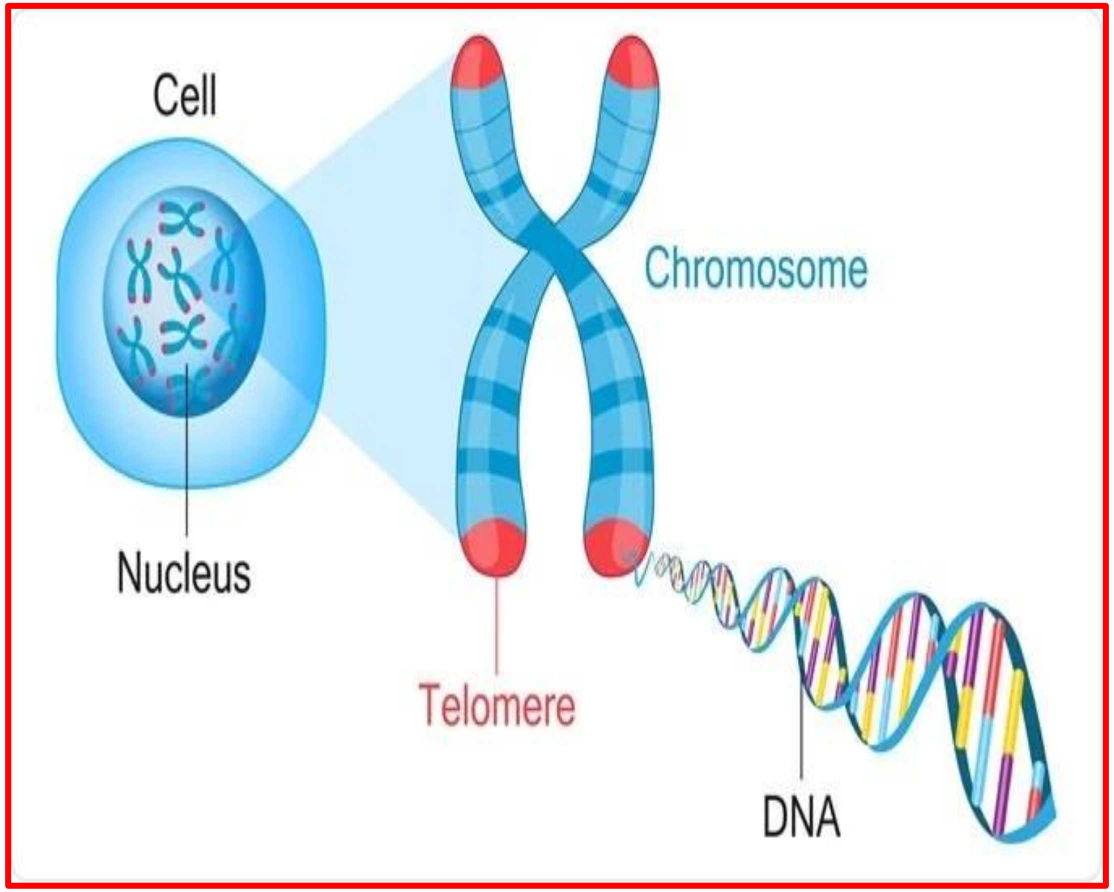


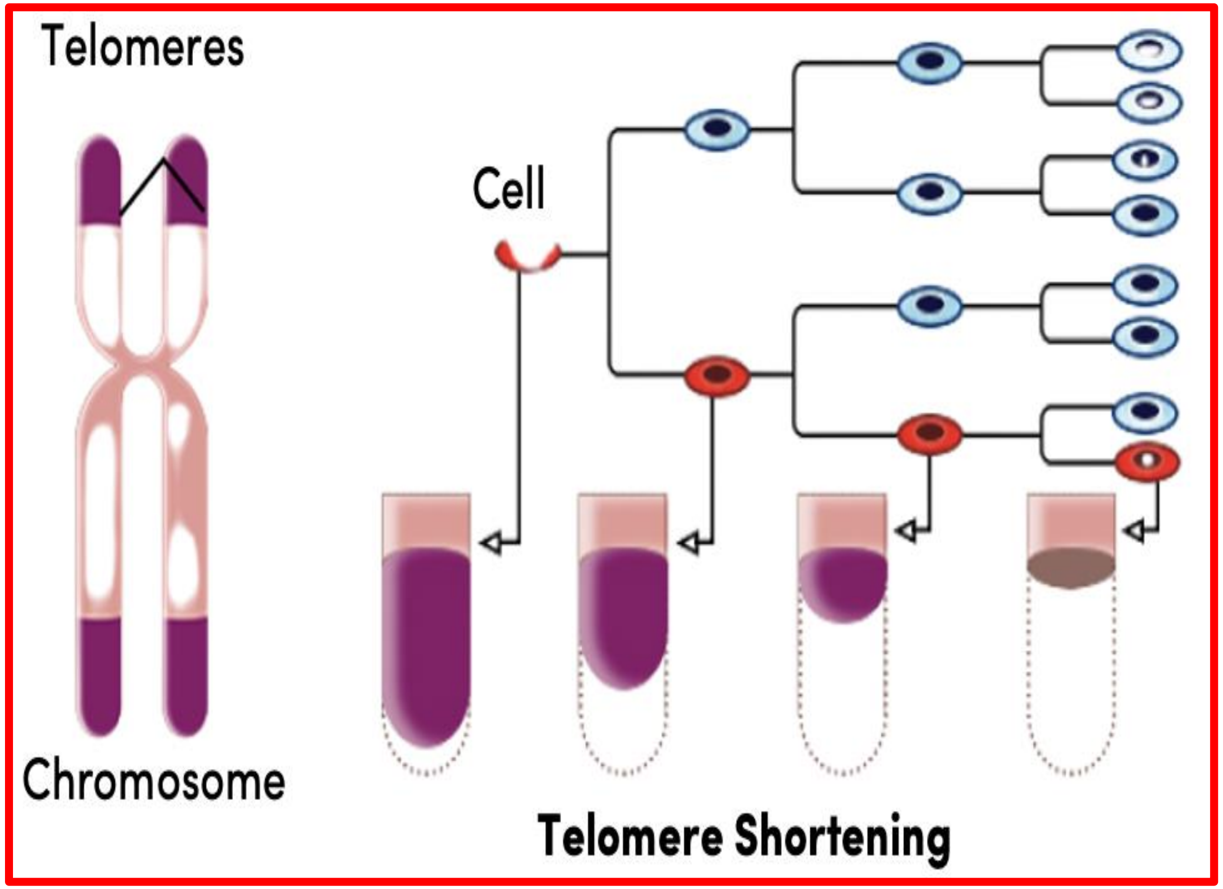
- Chromosomes are composed of DNA tightly-wound around histones.
- Chromosomal DNA is packaged inside microscopic nuclei with the help of histones.
- These are positively-charged proteins that strongly adhere to negatively-charged DNA and form complexes called nucleosomes.
- Each nucleosome is composed of DNA wound 1.65 times around eight histone proteins. Nucleosomes fold up to form a 30-nanometer chromatin fiber, which forms loops averaging 300 nanometers in length.
- The 300 nm fibers are compressed and folded to produce a 250 nm-wide fiber, which is tightly coiled into the chromatid of a chromosome


Short region of DNA double helix
2 nm
"Beads on a string" form of chromatin
11 nm
30-nm chromatin fibre of packed nucleosomes
30 nm
Section of chromosome in an extended form
300 nm
Condensed section of chromosome
700 nm
Entire mitotic chromosome
Centromere
1,400 nm

Telomeres

- v Telomeres are repetitive stretches of DNA located at the ends of linear chromosomes. They protect the ends of chromosomes.
- **In many types of cells**, telomeres lose a bit of their DNA every time a cell divides. Eventually, when all of the telomere DNA is gone, the cell cannot replicate and dies.
- White blood cells and other cell types with the capacity to divide very frequently have a special enzyme that prevents their chromosomes from losing their telomeres.
- Because they retain their telomeres, such cells generally live longer than other cells.
- Telomeres also play a role in **cancer**.
- The chromosomes of malignant cells usually do not lose their telomeres, helping to fuel the uncontrolled growth that makes cancer so devastating


Cell
Chromosome
Nucleus
Telomere
DNA


Telomeres
Cell
Chromosome
Telomere Shortening