Chromosome structure: nucleosomal organization, telomere, centromere, B chromosome, polytene chromosome, lampbrush chromosome

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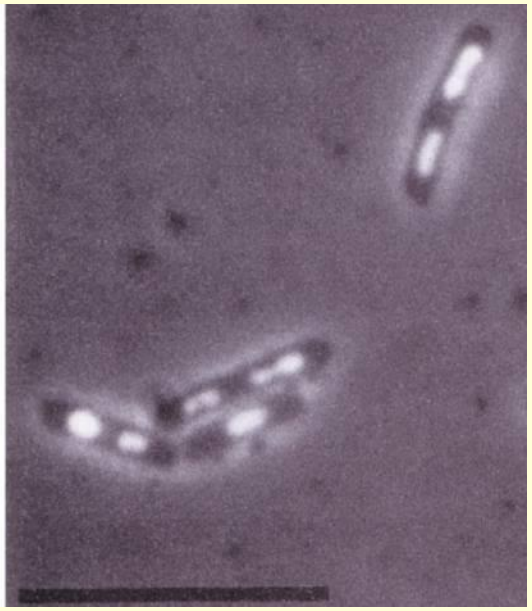
Chromosomes and genome

- Chromosomes
  - complexes of DNA and proteins – chromatin
  - Viral – linear, circular; DNA or RNA
  - Bacteria – single, circular
  - Eukaryotes – multiple, linear
- Genome
  - The genetic material that an organism possesses
  - Nuclear genome
  - Mitochondrial & chloroplasts genome

Bacterial Chromosomes



- In a region called the nucleoid
- DNA in direct contact with cytoplasm

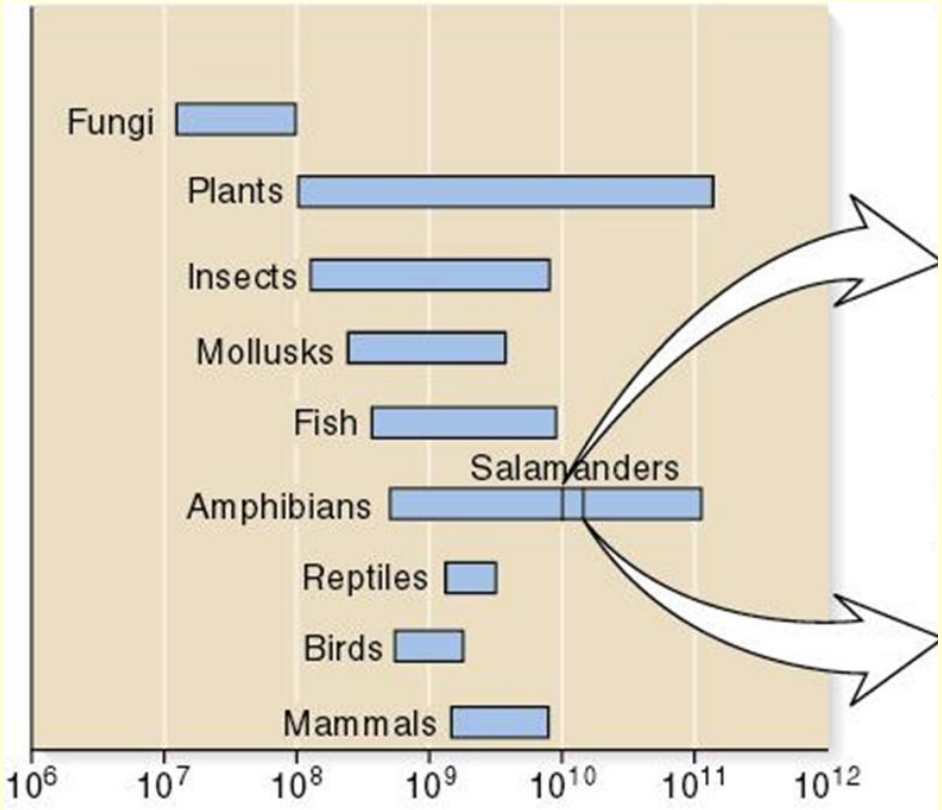
Eukaryotic Chromosomes

- **Eukaryotic species contain one or more sets of chromosomes (ploidy level)**
  - **Each set is composed of several linear chromosomes**
  - **DNA amount in eukaryotic species is greater than that in bacteria**
  - **Chromosomes in eukaryotes are located in the nucleus**
  - **To fit in there, they must be highly compacted**
  - **This is accomplished by the binding of many proteins**
  - **The DNA-protein complex is termed chromatin**

Genomes vary substantially in size

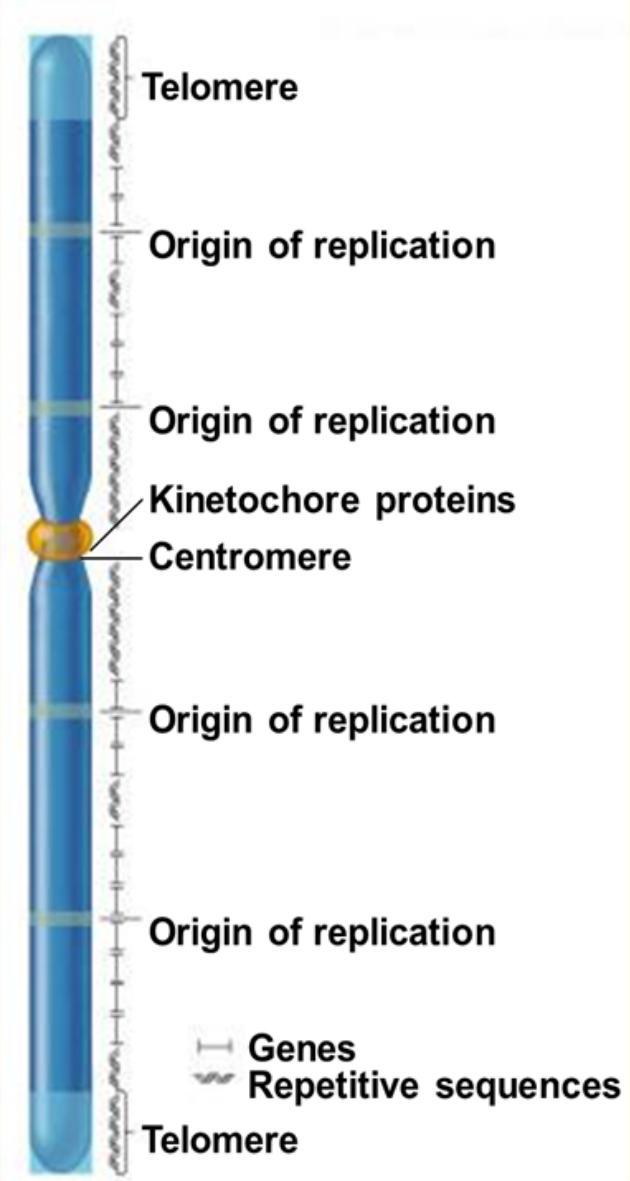
- **variation not related to complexity of the species**
- **Size difference due to accumulation of repetitive DNA sequences**

Variations in DNA content



(a) Genome size (nucleotide base pairs per haploid genome)

EUKARYOTIC CHROMOSOME ORGANIZATION



- Eukaryotic chromosomes are long, linear DNA molecule
- Three types of DNA sequences are required for chromosome replication and segregation
  - Origins of replication (multiple)
  - Centromeres (1)
  - Telomeres (2)

Repetitive Sequences

- Sequence complexity refers to the number of times a particular base sequence appears in the genome

- 2 main types of sequences
  - Moderately repetitive
  - Highly repetitive (low complexity)

Repetitive Sequences

- Unique or non-repetitive sequences
  - Found once or a few times in the genome
  - Includes structural genes as well as intergenic areas
- Moderately repetitive
  - Found a few hundred to a few thousand times
  - Includes
    - Genes for rRNA and histones
    - Origins of replication
    - Transposable elements

Repetitive Sequences

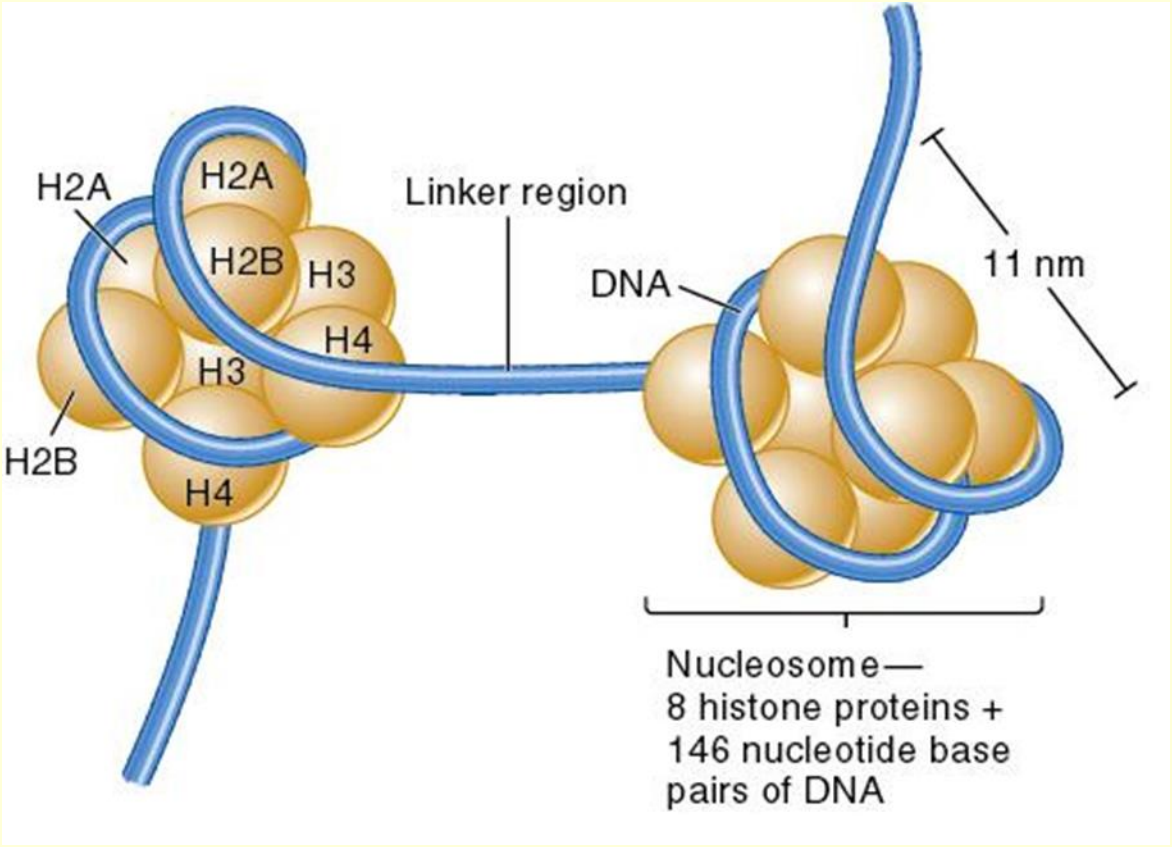
- Highly repetitive
  - Found tens of thousands to millions of times
  - Each copy is relatively short (a few nucleotides to several hundred in length)
  - Some sequences are interspersed throughout the genome
    - Example: *Alu* family in humans
  - Other sequences are clustered together in tandem arrays
    - Example: centromeric satellite & telomeric regions

Eukaryotic Chromatin Compaction

- Stretched end to end, a single set of human chromosomes will be over 1 meter long
  - nucleus is only 2 to 4 μm in diameter

- The compaction of linear DNA in eukaryotic chromosomes involves interactions between DNA and various proteins
  - Proteins bound to DNA are subject to change during the life of the cell
    - These changes affect the degree of chromatin compaction

Nucleosomes

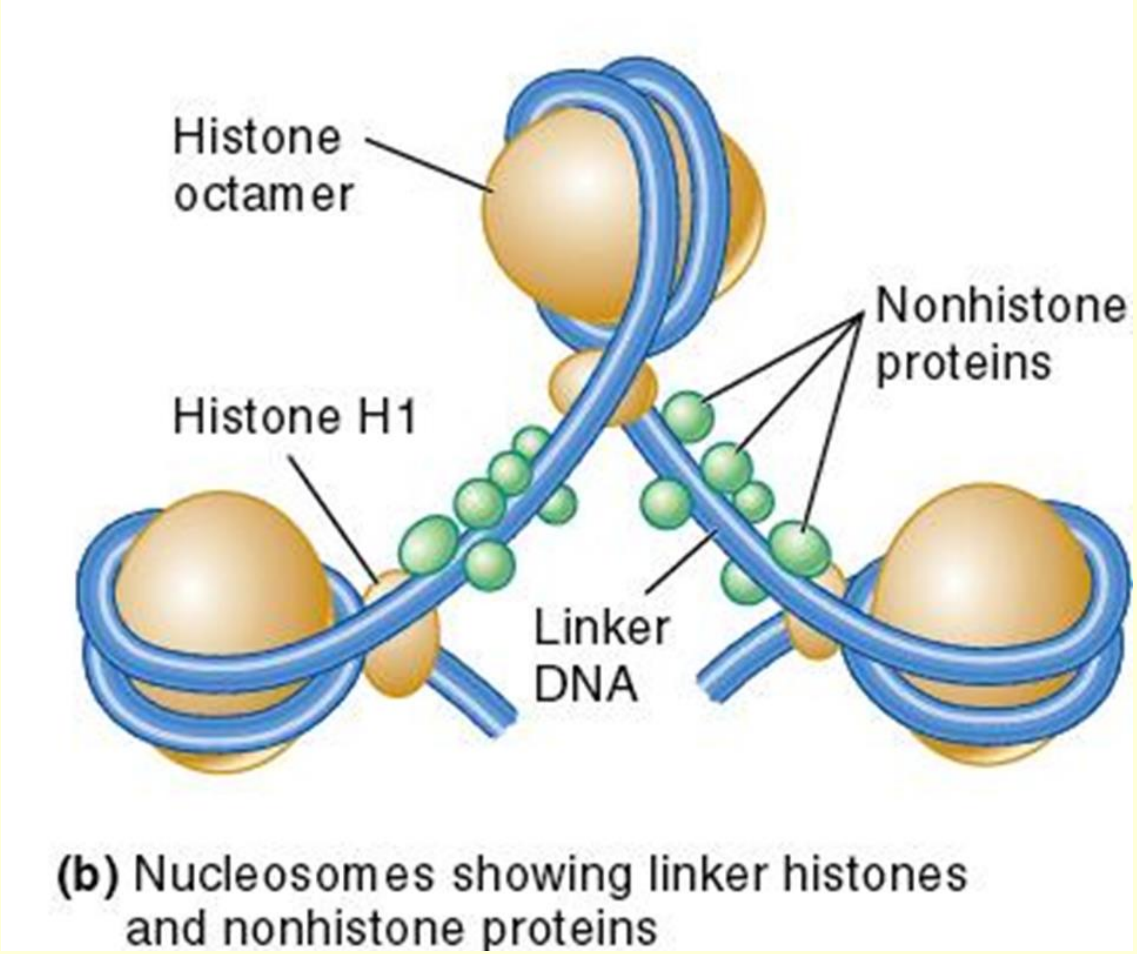


- Histone proteins
  basic (+ charged lysine & arginine) amino acids that bind DNA backbone

- Four core histones in nucleosome
  Two of each of H2A, H2B, H3 & H4

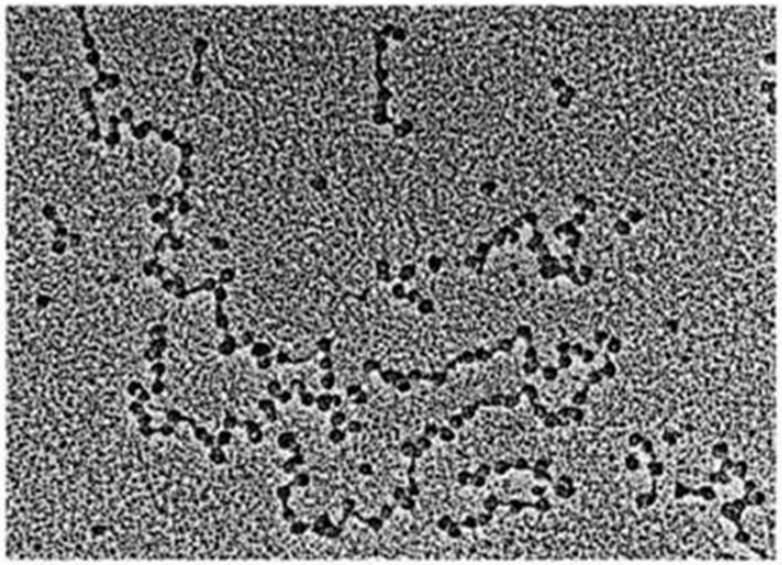
- Fifth histone, H1 is the linker histone

Nucleosomes

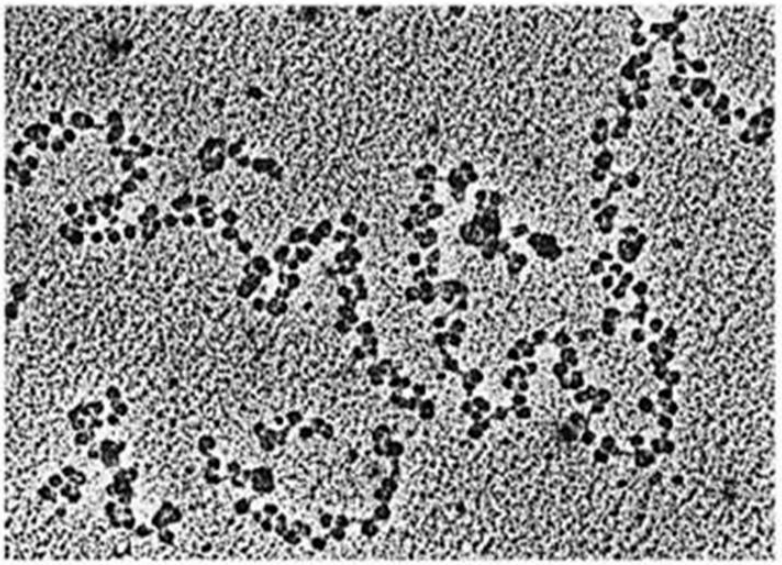


(b) Nucleosomes showing linker histones and nonhistone proteins

Beads on a String

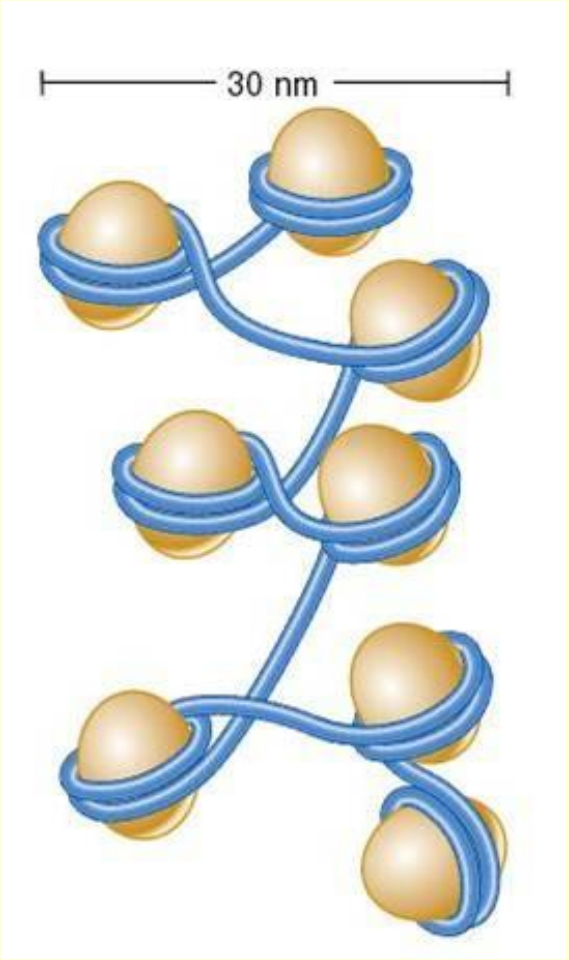


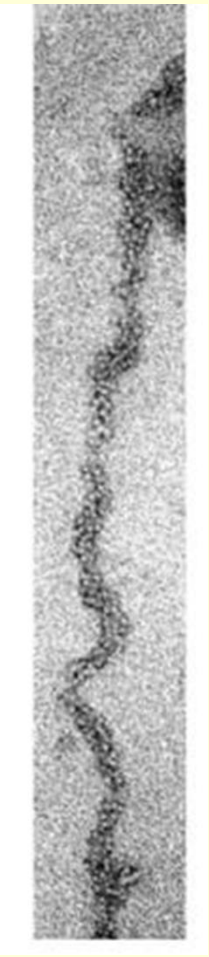
(a) At moderate salt concentration



(b) At low salt concentration

Nucleosomes Join to Form 30 nm Fiber





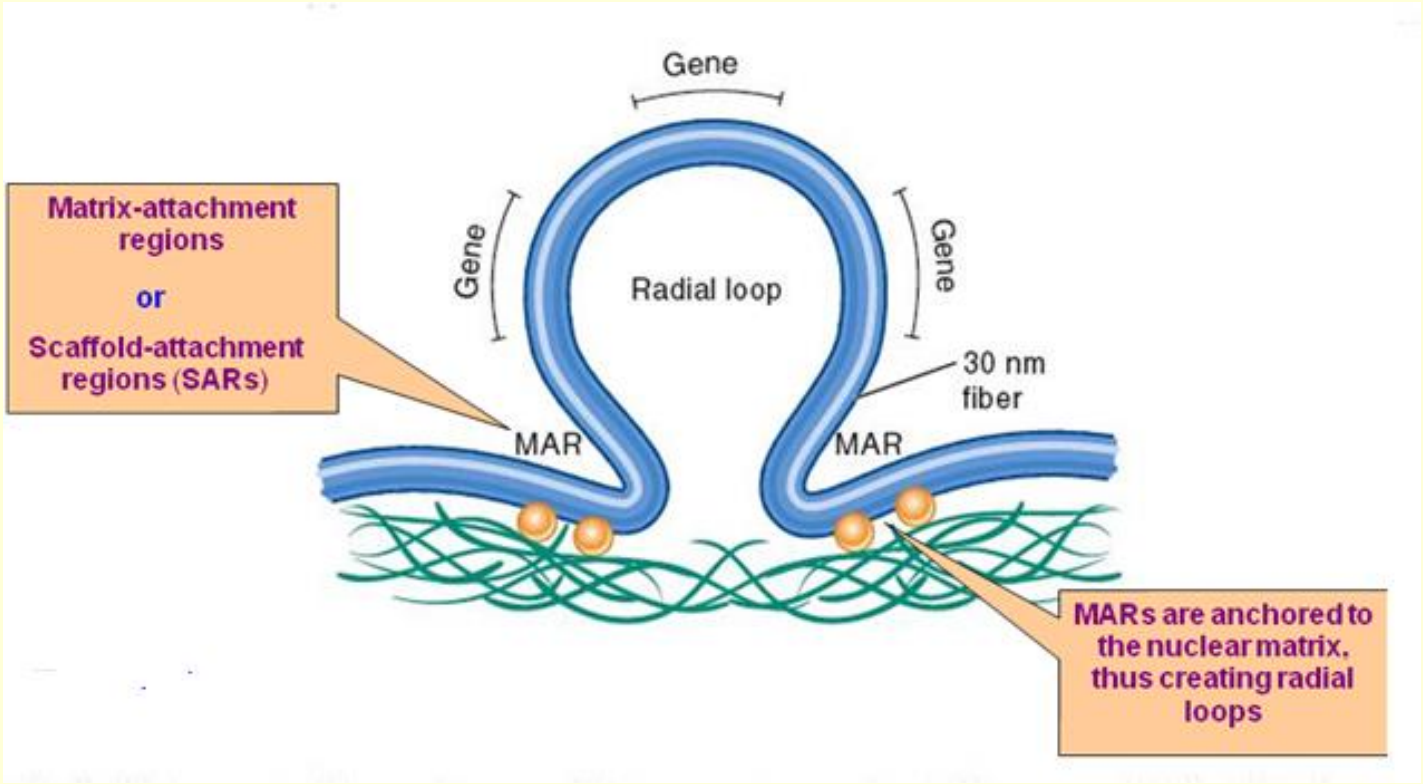
- Nucleosomes associate to form more compact structure - the 30 nm fiber
- Histone H1 plays a role in this compaction

Further Compaction of the Chromosome

- The two events we have discussed so far have shortened the DNA about 50-fold
- A third level of compaction involves interaction between the 30 nm fiber and the nuclear matrix

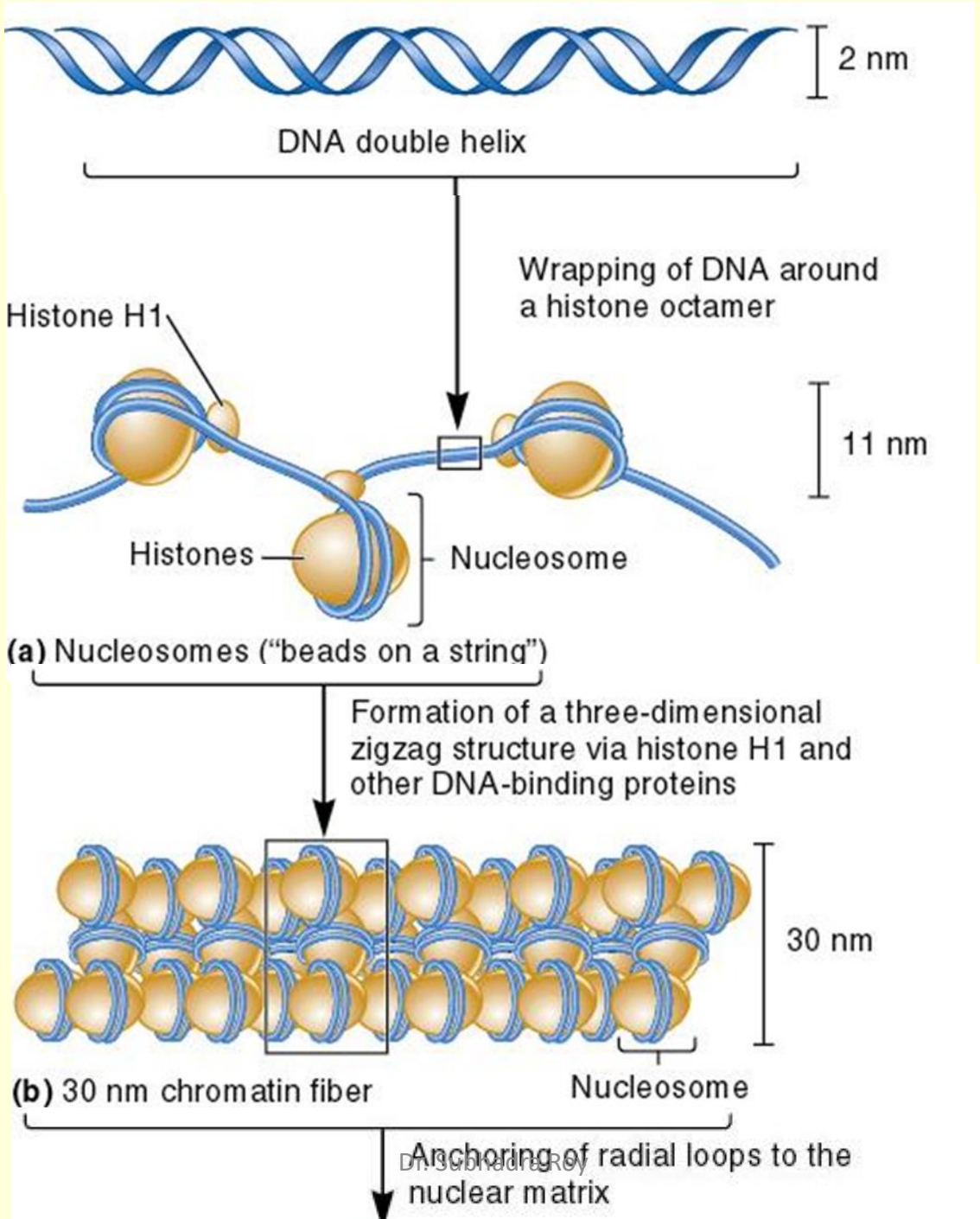
DNA Loops on Nuclear Matrix

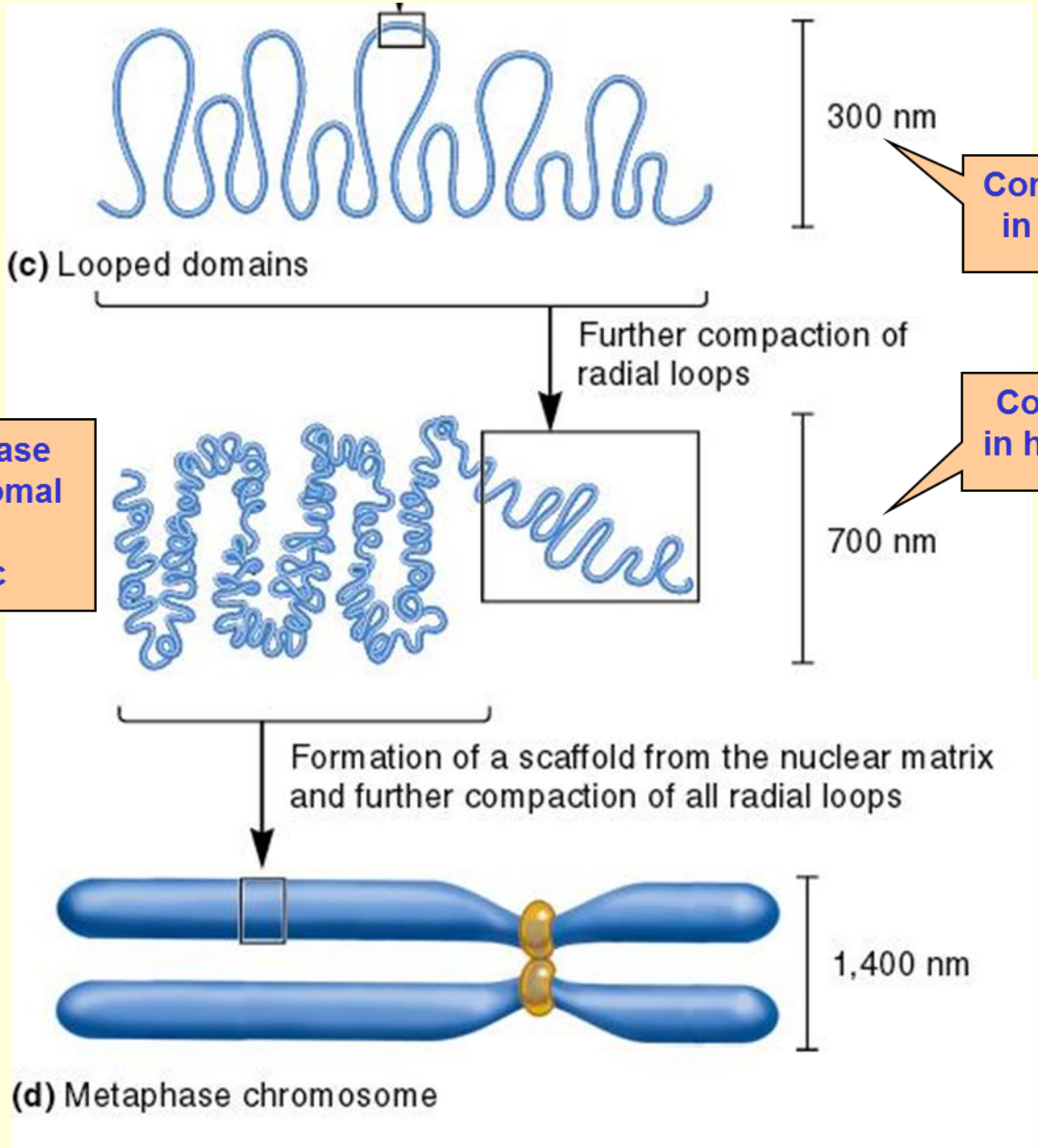
- The third mechanism of DNA compaction involves the formation of radial loop domains



Further Compaction of the Chromosome

- The attachment of radial loops to the nuclear matrix is important in two ways
  - 1. It plays a role in gene regulation
  - 2. It serves to organize the chromosomes within the nucleus
    - Each chromosome in the nucleus is located in a discrete and nonoverlapping chromosome territory





Compaction level in euchromatin

Compaction level in heterochromatin

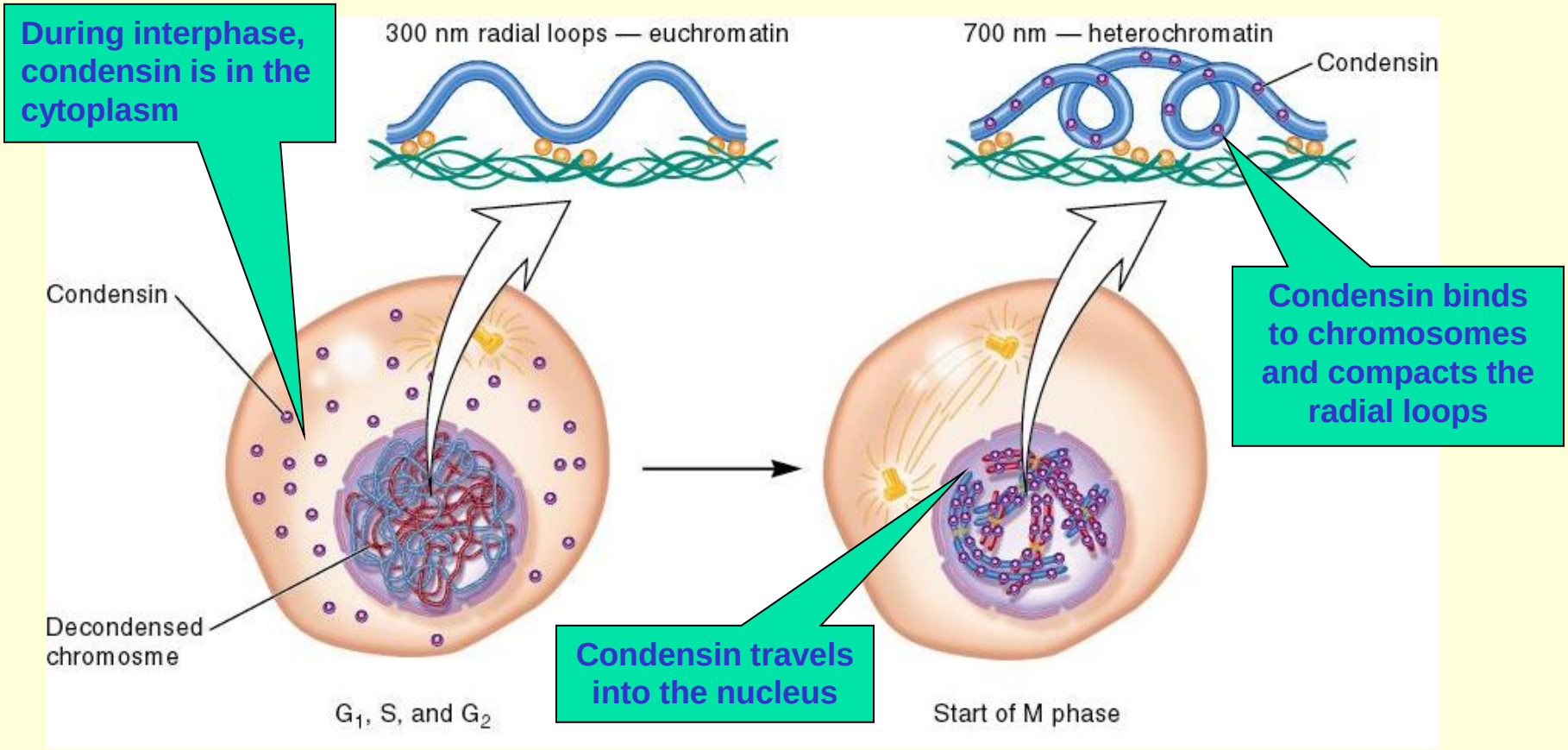
During interphase most chromosomal regions are euchromatic

Metaphase Chromosomes

- Condensed chromosomes are referred to as metaphase chromosomes
- During prophase, the compaction level increases
- By the end of prophase, sister chromatids are entirely heterochromatic
- These highly condensed metaphase chromosomes undergo little gene transcription
- In metaphase chromosomes, the radial loops are compacted and anchored to the nuclear matrix scaffold

Chromosome Condensation

The number of loops has not changed
However, the diameter of each loop is smaller



The condensation of a metaphase chromosome by condensin