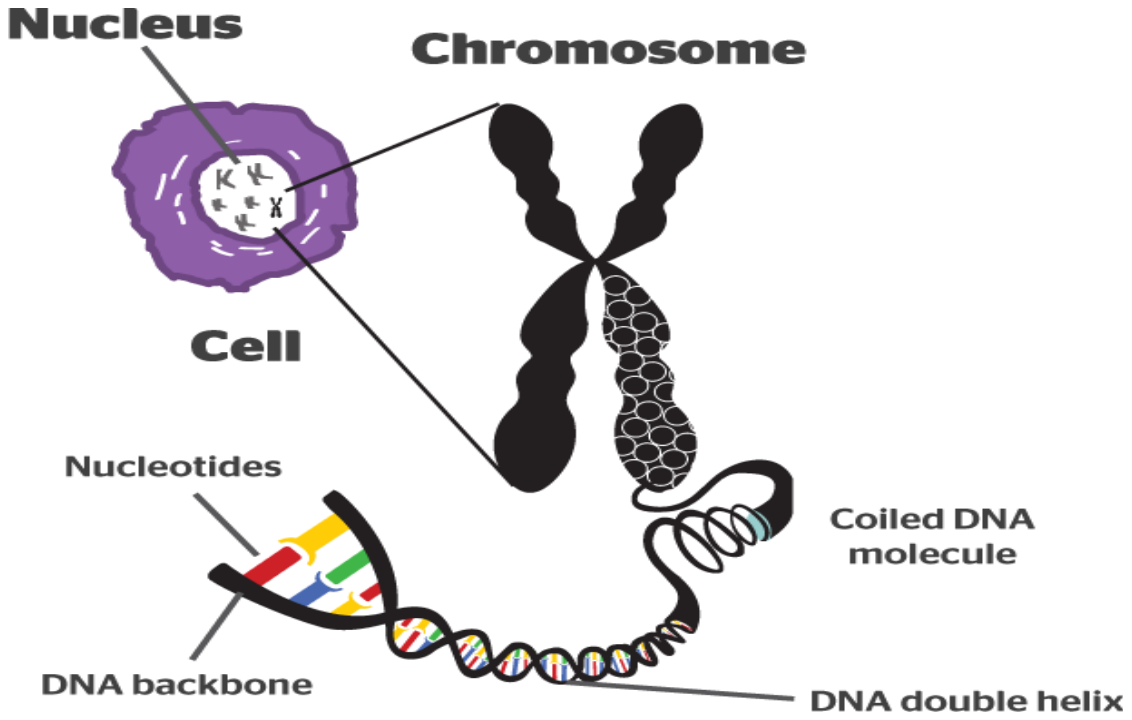
# Chromosome structure, morphology, number and types

# Outline

- Definition and history
- Features of eukaryotic chromosome
- Chromosome size, shape and number
- Chemical composition of chromosome
- Chromosome structure

# Relative position of chromosome in cell



# Chromosome

- Chromosome is a long dense thread containing a coiled and twisted chain of DNA.
- It made up of proteins and a molecule of deoxyribonucleic acid (DNA).
- The term chromosome is derived from a Greek word '**chroma**' which means '**color**' and '**soma**' which means **'body'**.
- The chromosomes are named so because they are cellular structures or cellular bodies and they are strongly stained by some dyes used in research.
- Chromosomes play an important role that ensures DNA is copied and distributed accurately in the process of cell division.
- It is located inside the nucleus.
- They are the vehicle of heredity means they are passed on from parents to offspring.
- Chromosome were first observed by **Hofmeister** in **1848**. However, they were named chromosomes in **1888** by **Waldeyer**

# Chromosomes are of two types

**Autosomes:** that control characters other than sex characters or carry genes for somatic characters.

**Sex chromosomes *(Gonosomes)*** Chromosomes involved in sex determination.

- Humans and most other mammals have two sex chromosomes X & Y, also called **heterosome.**
- Females have two X chromosomes in diploid cells; males have an X and a Y chromosome.
- In birds the female (ZW) is hetero-gametic and male (ZZ) is homo-gametic.

# Chromosome Number

## Diploid and Haploid chromosome number

- Diploid cells (2N where N-chromosome number) have two homologous copies of each chromosome
- The body cells of animals are diploid
- Haploid cells (N) have only one copy of each chromosome
- In plants, gametes (pollen and ovule) are haploid.
- Chromosome number varies from 2n = 4 (n = 2) to 2n = > 1200. (n = gametic or haploid chromosome number  2n = somatic or diploid chromosome number)
- The number of chromosomes varies from species to species
- Normally all individual of a species have the same chromosome number

- ✓ The size of chromosome is normally measured at mitotic metaphase and may be as short as 0.25 µm in fungi and birds, or as long as 30 µm in some plants like Trillium.
- ✓ Each chromosome has two arms -p (the shorter of the two) and q (the longer).
- ✓ Chromosome shape is usually observed at anaphase, when the position of primary constriction (centromere) determines chromosome shape.
- ✓ This constriction or centromere can be terminal, sub-terminal or median in position.

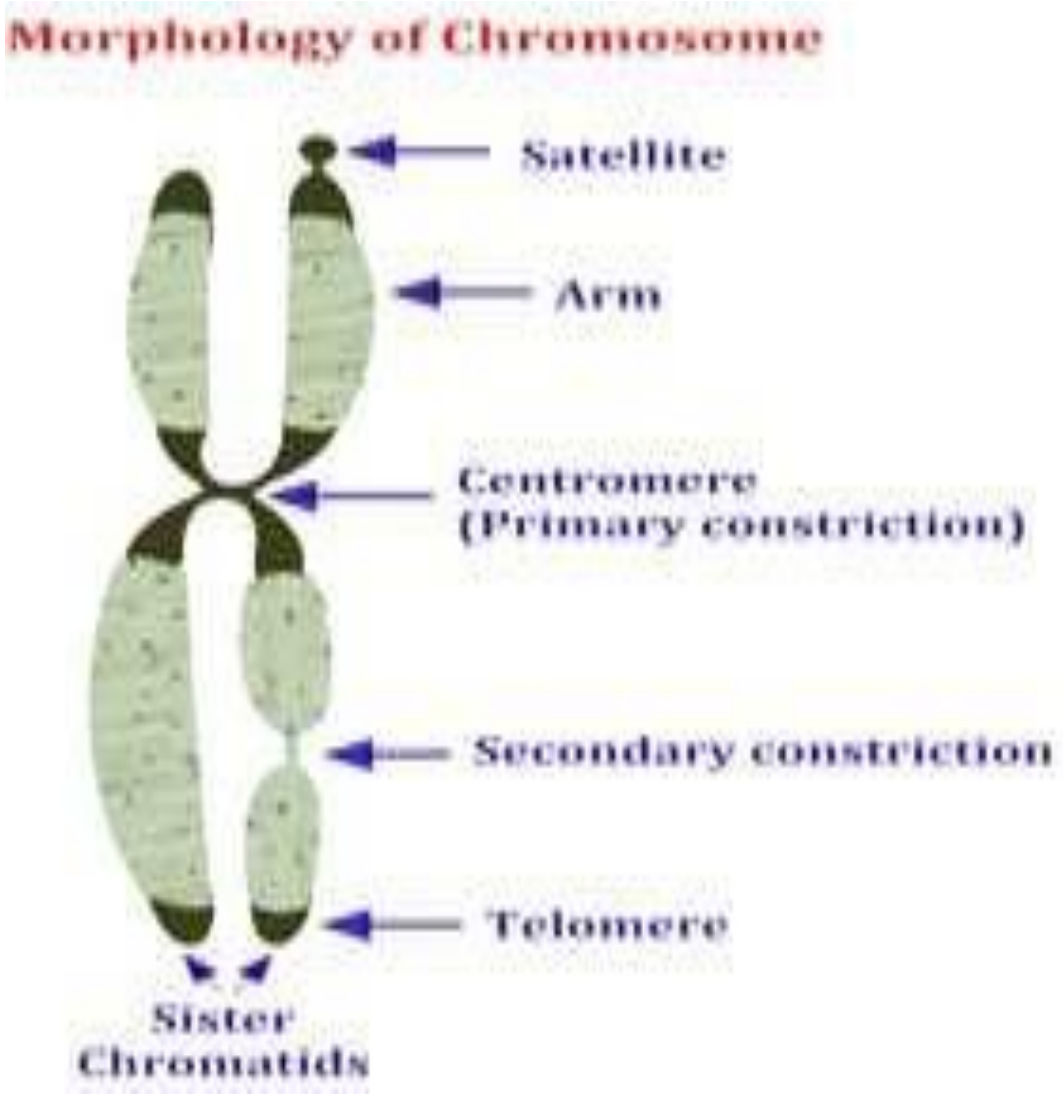
# Homologous Chromosomes

- Diploid organisms have two copies of each chromosome (**except the sex chromosomes**)
- Both the copies are ordinarily identical in morphology, gene content and gene order and hence known as **homologous chromosomes**
- Each pair of chromosomes made up of two homologs
- Homologous chromosome is inherited from separate parents; one homolog comes from the mother and the other comes from the father

| ORGANISM | *SPECIES* | Chromosomal Number | ORGANISM | *SPECIES* | Chromosomal Number |
|---|---|---|---|---|---|
| Alfalfa | *Medicago sativa* | 32 | Oats, white | *Avena sativa* | 42 |
| Avocado | *Persea americana* | 24 | Onion | *Allium cepa* | 16 |
| Barley | *Hordeum vulgare* | 14 | Papaya | *Carica papaya* | 18 |
| Berseem | *Trifolium alexandrinum* | 16 | Peanut | *Arachis hypogaea* | 40 |
| Bermudagrass | *Cynodon dactylon* | 36 | Pearl Millet | *Pennisetum glaucum* | 14 |
| Black mustard | *Brassica nigra* | 8 | Pineapple | *Ananas comosus* | 50 |
| Broad bean | *Vicia faba* | 12 | Potato | *Solanum tuberosum* | 48 |
| cabbage, kale, broccoli, Brussels sprouts, cauliflower, kohlrabi | *Brassica oleracia* | 9 | Rapeseed, rutabaga | *Brassica napus* | 19 |
| Corn (maize) | *Zea mays* | 20 | Rice | *Oryza sativa* | 24 |
| Cotton, American-Egyptian | *Gossypium barbadense* | 52 | Rye | *Secale cereale* | 14 |
| Cotton, desi | *Gossypium arboreum* | 26 | Sorghum | *Sorghum vulgare* | 20 |
| Cotton, upland | *Gossypium hirsutum* | 52 | Soybean | *Glycine max* | 40 |
| Durian | *Durio zibethinus* | 56 | Squash | *Cucurbita pepo* | 40 |
| Ethiopian mustard | *Brassica carinata* | 17 | Sugar beet | *Beta vulgaris* | 18 |
| Flax | *Linum usitatissimum* | 30 | Sugar cane | *Saccharum officinarum* | 80 |
| Garden pea | *Pisum sativum* | 14 | Tamarind | *Tamarindus indica* | 24 |
| Grape | *Vitis vinifera* | 38 | Tobacco | *Nicotiana tabacum* | 48 |
| Guava | *Psidium guajava* | 22 | Tomato | *Lycopersicon esculentum* | 24 |
| Indian Mustard | *Brassica juncea* | 18 | Turnip, Chinese cabbage | *Brassica rapa* | 10 |
| Kidney bean | *Phaseolus vulgaris* | 22 | Wheat, club | *Triticum compactum* | 42 |
| Mango | *Mangifera indica* | 40 | Wheat, common | *Triticum vulgare* | 42 |
| Oats, red | *Avena byzantina* | 42 | Wheat, durum | *Triticum durum* | 28 |

# MORPHOLOGY

- ✓ Mitotic metaphase is the most suitable stage for studies on chromosome morphology.
- ✓ The chromosome morphology changes during cell division.
- ✓ Chromosomes are thin, coiled, elastic, thread-like structures during the interphase.
- ✓ As cells enter mitosis, their chromosomes become highly condensed so that they can be distributed to daughter cells.
- ✓ In mitotic metaphase chromosomes, the following structural features can be seen under
- ✓ The number of chromosomes varies from species to species, But the number remains constant among the members of the species.
- ✓ The lower number of chromosomes is 2 and it occurs in *Ascaris megalocephala* and the maximum number of chromosomes is 1700 and it occur in a *radiolarian* (Protozoa).
- ✓ Generally the chromosomes are arranged in pairs. A pair of similar chromosomes is called **homologous chromosomes.**
- ✓ The size of chromosomes ranges from **0.1 micron to 30 microns.**
- ✓ The diameter varies from **0.2 micron to 2 microns**. In general, plants have larger chromosomes than animals.
- ✓ The length of the human chromosomes varies from **4 microns to 6 microns**



# Chromatid

- Each metaphase chromosome appears to be longitudinally divided into two identical parts each of which is called **chromatid**.
- Both the chromatids of a chromosome appear to be joined together at a point known as **centromere**.
- The two chromatids of chromosome separate from each other during mitotic anaphase (and during anaphase II of meiosis) and move towards opposite poles.
- Since the two chromatids making up a chromosome are produced through replication of a single chromatid during synthesis (S) phase of interphase, they are referred to as **sister chromatids**.
- In contrast, the chromatids of homologous chromosomes are known as **non-sister chromatids**.

## Centromere (Primary constriction)

- ✓ Centromere is the landmark for identification of chromosome.
- ✓ Each chromosome has a constriction point called the **centromere** (Synonym: **Kinetochore**), which divides the chromosome into two sections or arms.
- ✓ The **short arm** of the chromosome is labeled the **"p"** arm. The **long arm** of the chromosome is labeled the **"q"** arm.

## Telomere

- ✓ The two ends of a chromosome are known as telomeres, they play critical roles in chromosome replication and maintenance of chromosomal length.
- ✓ The telomeres are highly stable and telomeres of different chromosomes do not fuse.
- ✓ The telomeric region of chromosome is made up of repetitive sequence of **T** and **G** bases

## Secondary constriction

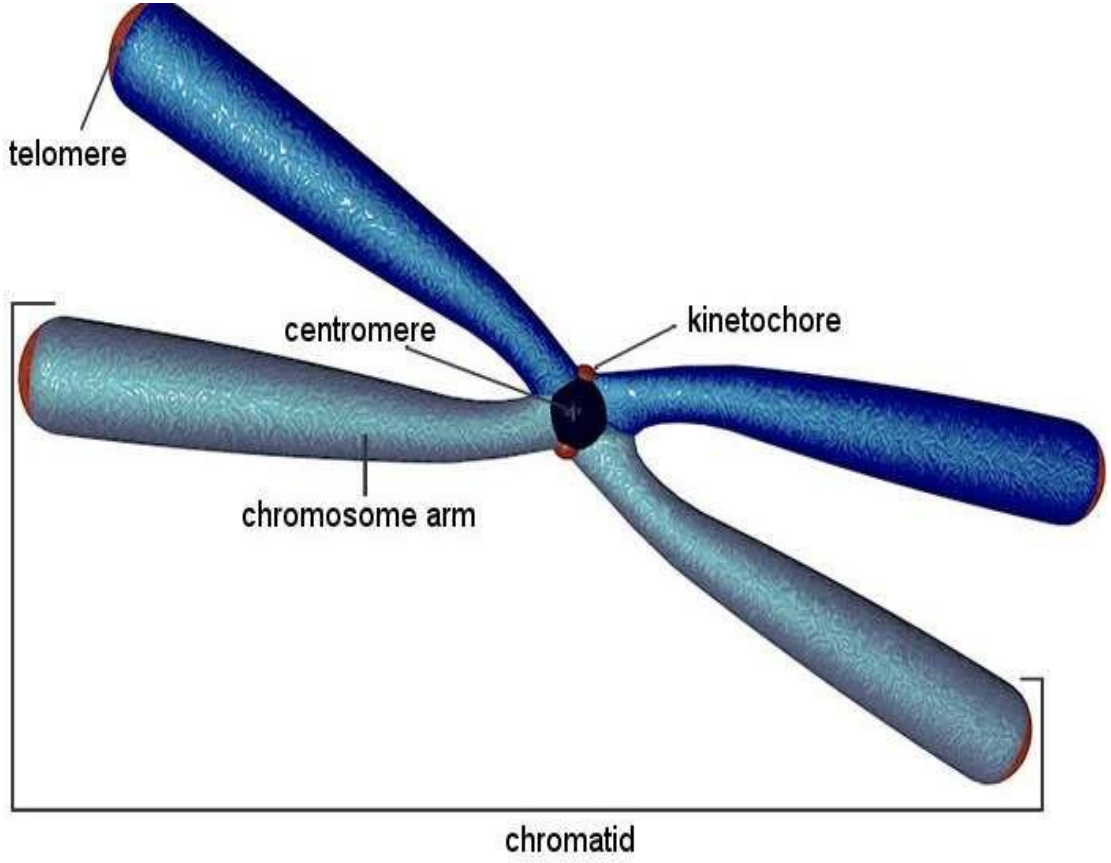
- In some chromosome addition to centromere / primary constriction, one or more constrictions in the chromosome are present termed secondary constrictions.

## Satellite

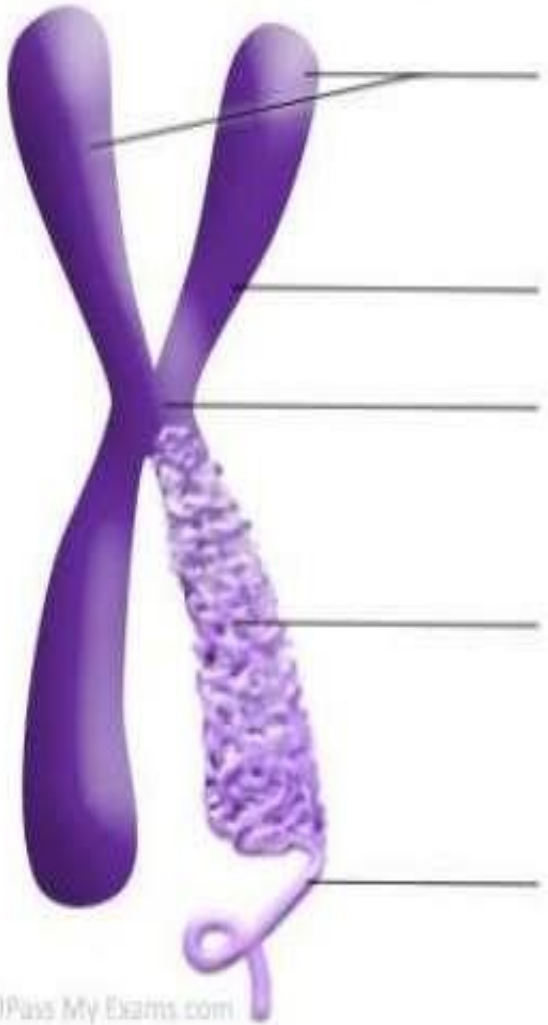
- The chromosomal region between the secondary constriction and nearest telomere is called as satellite and chromosomes that possess this region called as **satellite chromosome** or **sat chromosome**.
- A small chromosomal segment separated from the main body of the chromosome by a secondary constriction is called **Satellite**.

# SHAPE OF CHROMOSOME

- The shape of the chromosomes is changeable from phase to phase in the continuous process of the cell growth and cell division
- Chromosome contain a clear zone, known as **centromere** or **kinetocore**, along their length.
- Centromere divides the Chromosomes into two parts, each part is called **chromosome arm.**
- The position of centromere varies from chromosome to chromosome and it provides different shapes to the chromosomes.



# One Chromosome




**Two Identical Chromatids**
One is an exact copy of the other and each contains one DNA molecule.

**p arm** – short arm structure

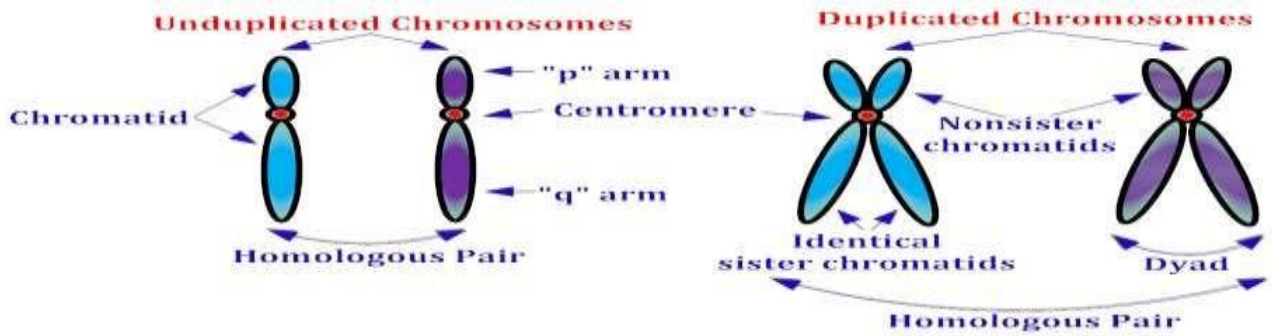
**Centromere** – constricted point of the chromosome

**q arm** – long arm structure

**DNA molecule** – long string like DNA molecule formed into a compact structure by proteins called histones.

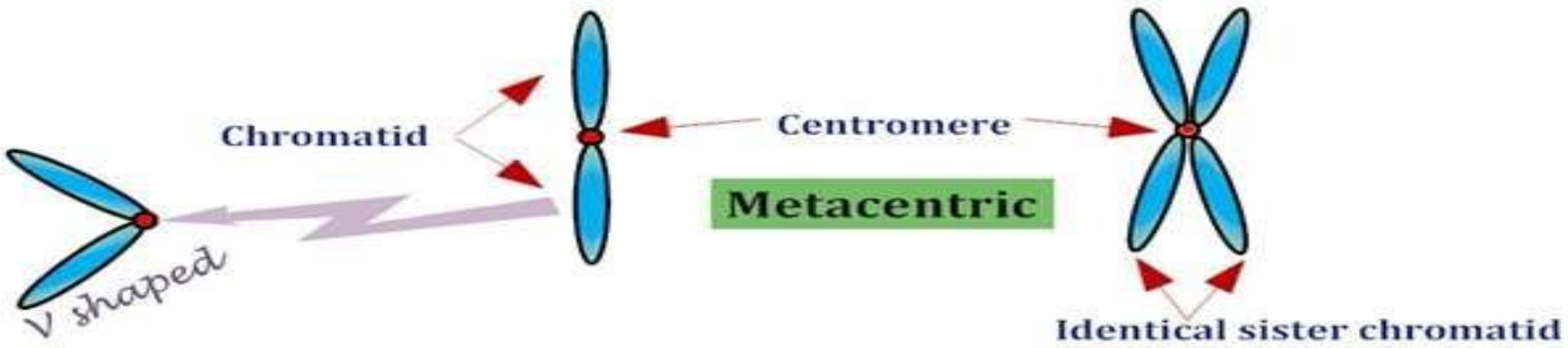
# Chromosomes are classified according to the centromere position :

- At one end: Acrocentric
- Closer to one end: Submetacentric
- Middle: Metacentric
- Each chromosome has two arms, labeled **p (the shorter of the two)** and **q (the longer)**.
- The p arm is named for **"petite"** meaning **"small"**; the q arm is named q simply because it follows p in the alphabet.



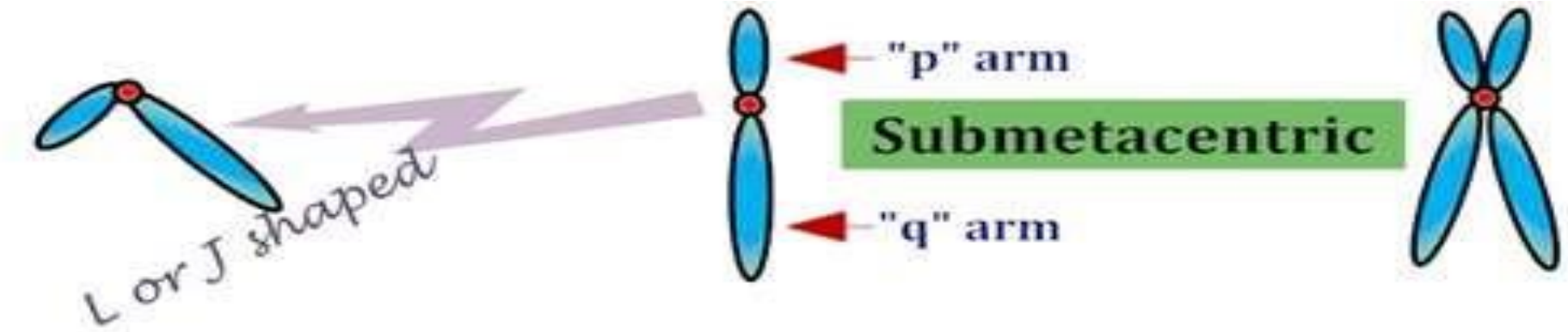
# Metacentric chromosome

- The centromere is located in the center of chromosomes, i.e. the centromere is median. The centromere is localized approximately midway between each end and thereby two arms are roughly equal in length.
- Metacentric chromosome take V shape during anaphase.



# Submetacentric Chromosome

- Centromere is located on one side of the central point of a chromosome. Centromere is submedian giving one longer and one shorter arms.
- Submetacentric chromosome may be J or L shaped during anaphase.



# Acrocentric Chromosome

- The centromere located close to one end of chromosomes. The centromere is more terminally placed and forms very unequal arm length (The "acro-" in acrocentric refers to the Greek word for **"peak"**).
- The **p (short)** arm is so short that is hard to observe, but still present.
- Acrocentric chromosome may be rod shape during anaphase.

# Telocentric Chromosome

- Centromere located at one end of chromosome (at terminal part of chromosome) lies at one end.
- Telocentric chromosome may be rod shape during anaphase.

## According to the number of the centromere the eukaryotic chromosomes may be

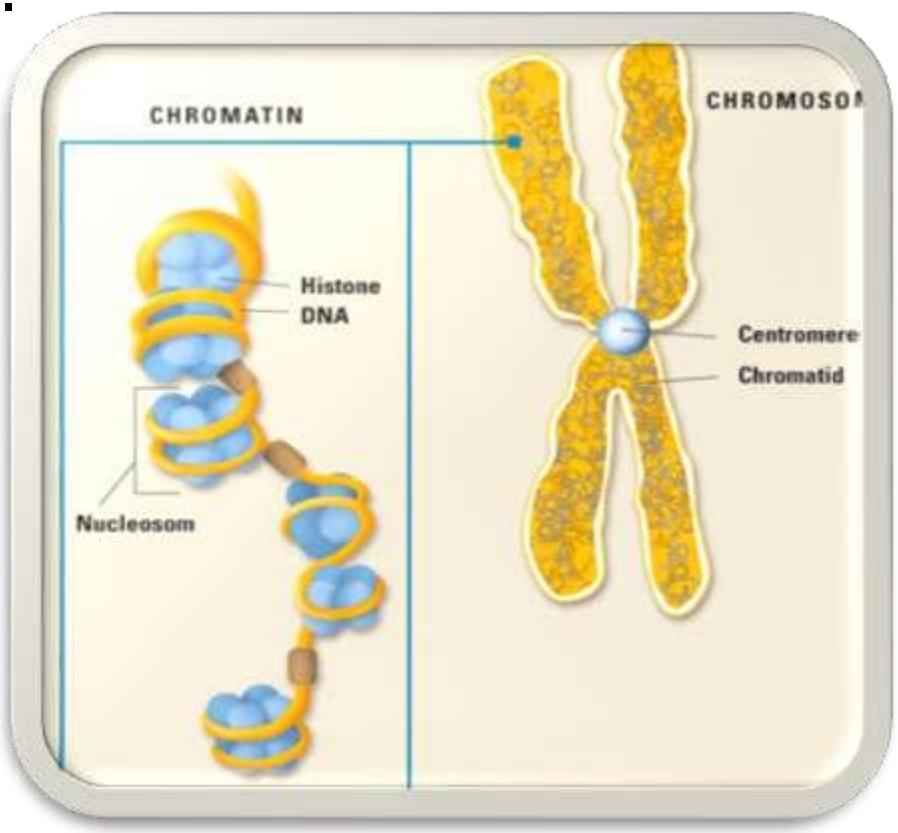
- **Acentric** : without any centromere
- **Mono centric** : with one centromere
- **Dicentric** : with two centromeres
- **Polycentric** : with more than two centromeres

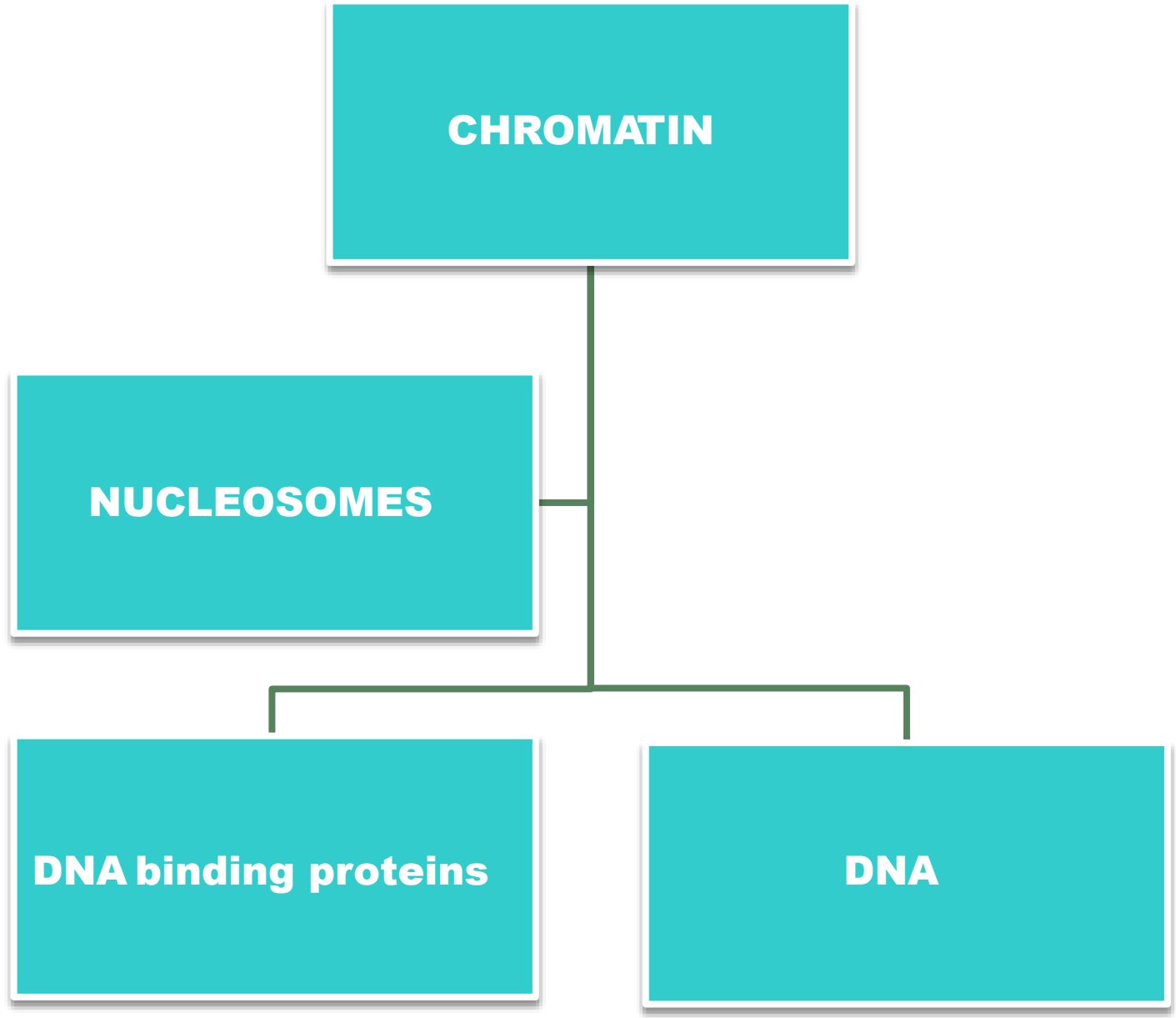
**How large size sequential DNA can fit in to small size chromosome ?**

# The DNA + histone = chromatin

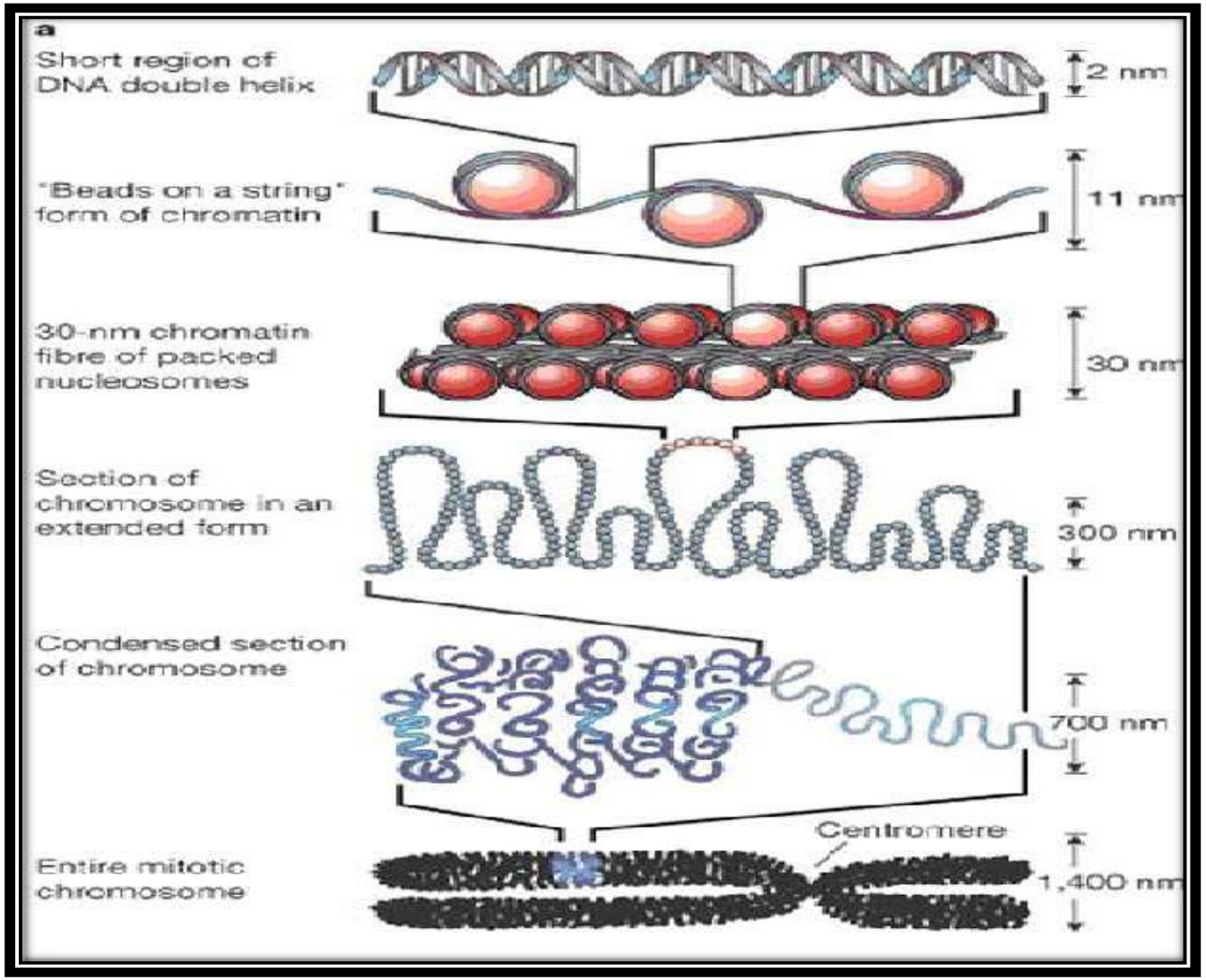
The DNA double helixin the cell nucleus is packaged by special proteins termed histones.

- The formed protein / DNA complex is called chromatin.
- The structural entity of chromatin is the nucleosome.




CHROMATIN
NUCLEOSOMES
DNA binding proteins
DNA

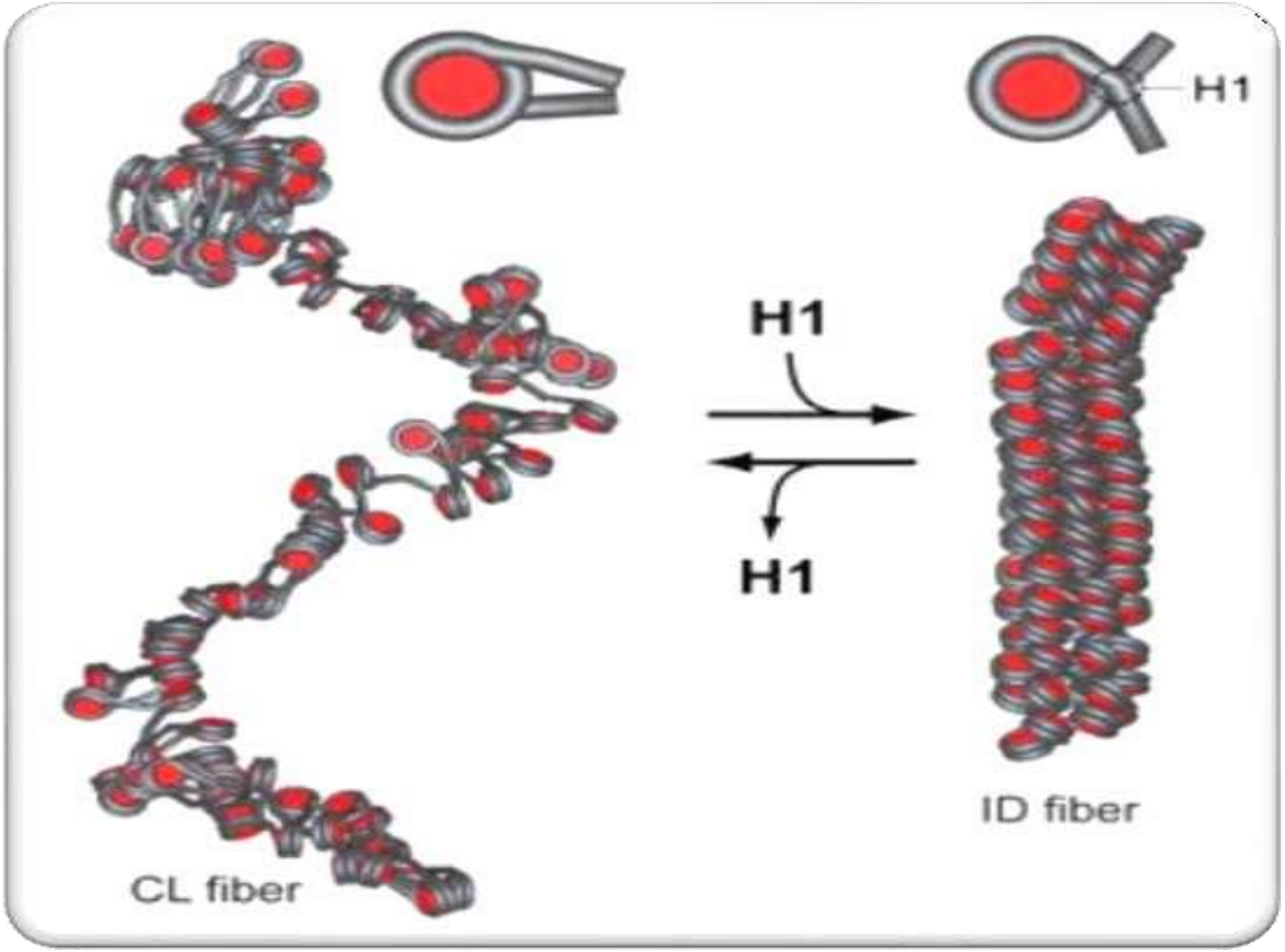
# CHROMOSOME PACKAGING



# Histone

Histone can be grouped into five major classes: H1/H5, H2A, H2B, H3, and H4

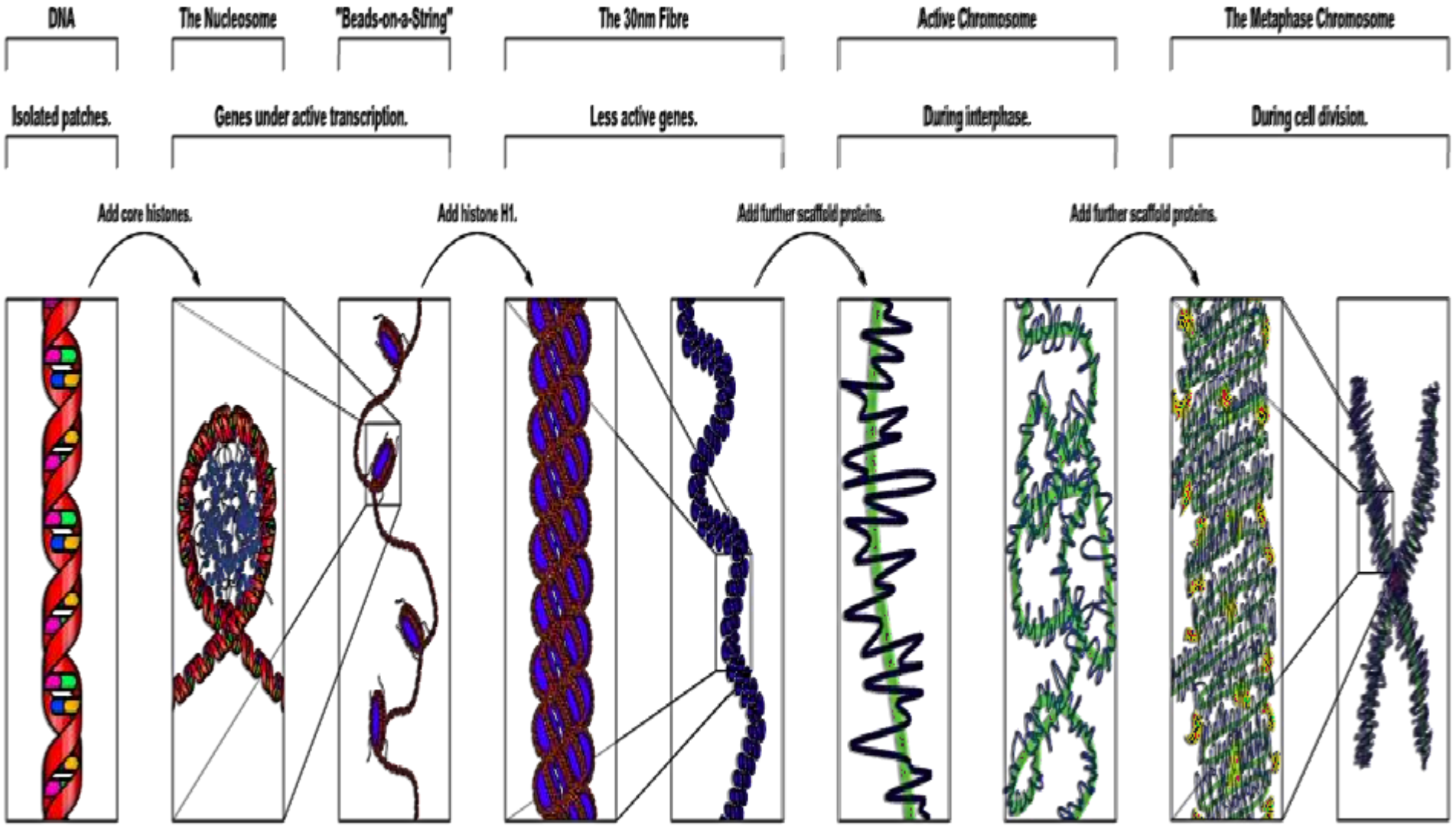
- ✓ These are organized into two super-classes as follows:
  - ✓ **Core histones – H2A, H2B, H3 and H4**
  - ✓ **Linker histones – H1 and H5**




**Linker DNA** is double-stranded DNA in between two nucleosome cores that, in association with histone H1, holds the cores together.

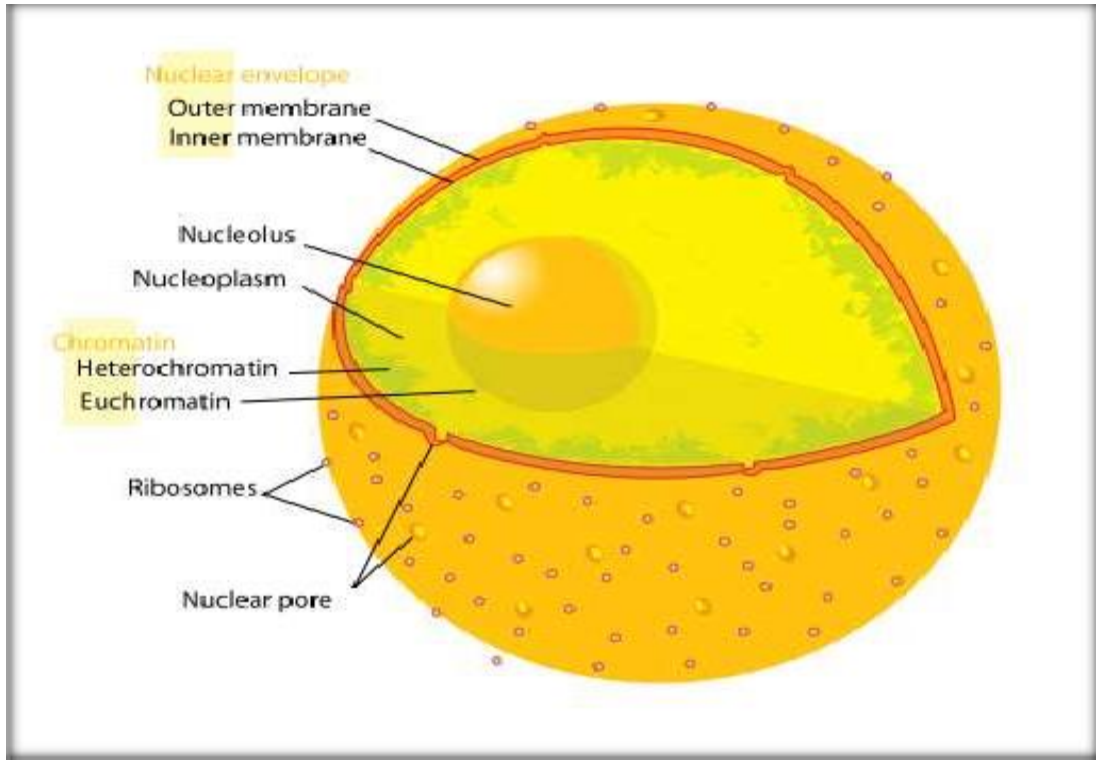
# NUCLEOSOME

- Basic unit of DNA packaging in eukaryotes consists of a segment of DNA wound around histone protein core fundamental repeating units of eukaryotic chromatin.
- The nucleosome core particle consists of approximately 147 base pairs of DNA wrapped in 1.67 left-handed super helical turns around a histone octamer consisting of 2 copies each of the core histones H2A, H2B, H3, and H4.
- The nucleosome cores themselves coil into a solenoid shape which itself coils to further compact the DNA


DNA
The Nucleosome
"Beads-on-a-String"
The 30nm Fibre
Active Chromosome
The Metaphase Chromosome
Isolated patches.
Genes under active transcription.
Less active genes.
During interphase.
During cell division.
Add core histones.
Add histone H1.
Add further scaffold proteins.
Add further scaffold proteins.

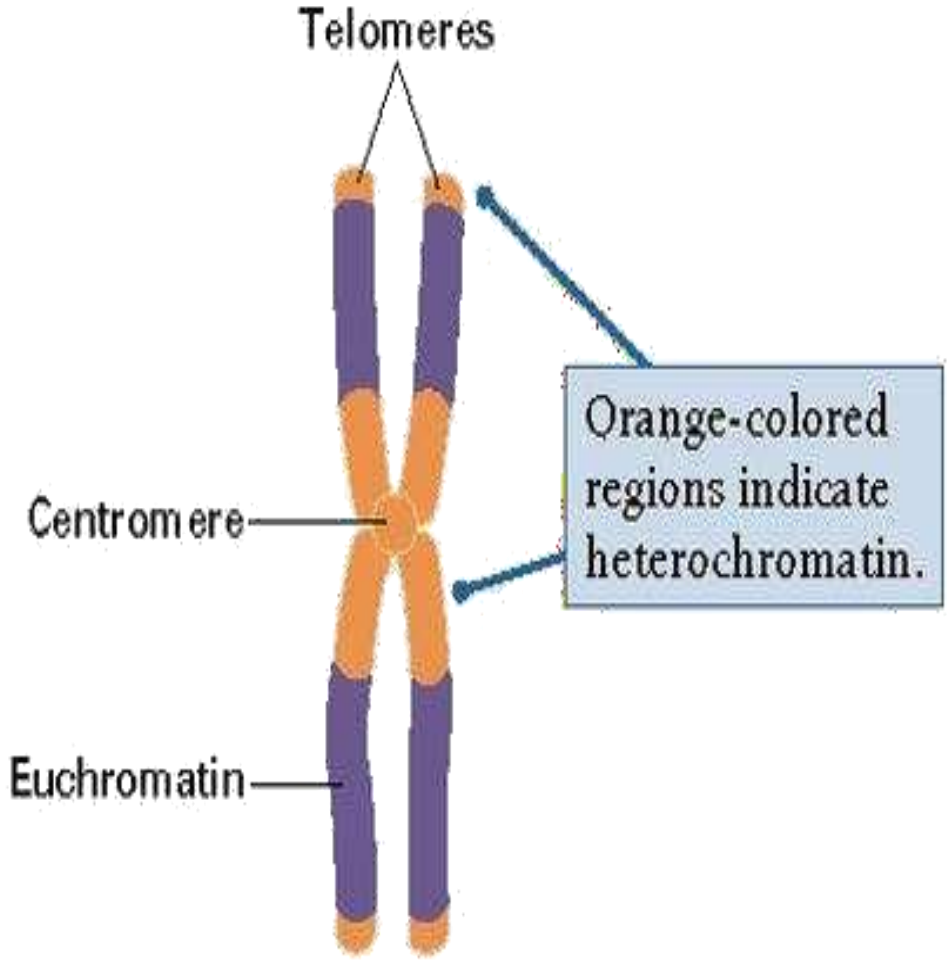
# HETEROCHROMATIN

- Tightly packed chromosome
- Intensely stained
- Consists of genetically inactive satellite sequences
- Both centromeres and telomeres are heterochromatic

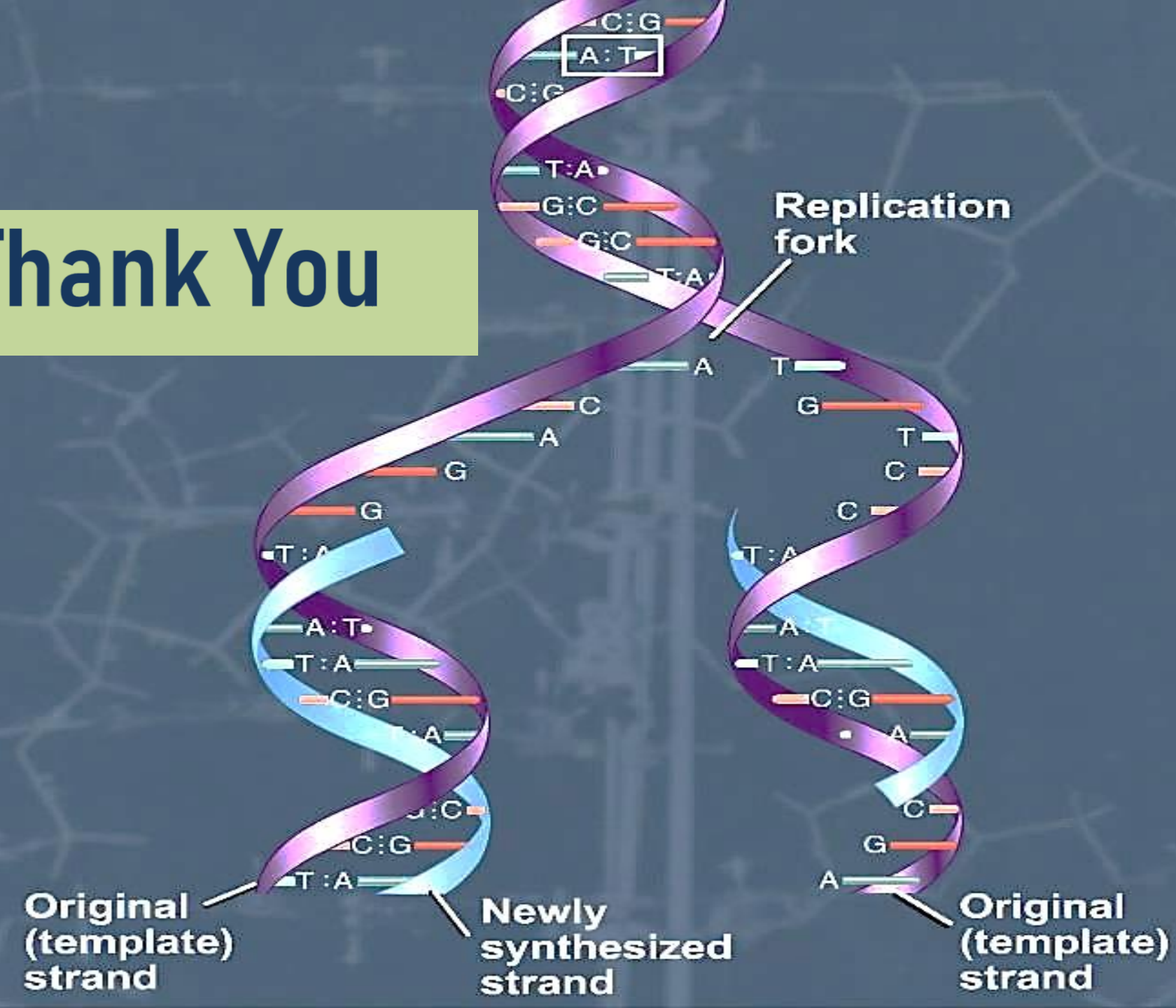


# EUCHROMATIN

lightly packed form of chromatin (DNA, RNA and protein) that is rich in gene concentration often (but not always) under active transcription Unlike heterochromatin, it is found in both cells with nuclei (eukaryotes) and cells without nuclei (prokaryotes) most active portion of the genome within the cell nucleus



# Thank You


Replication fork
Original (template) strand
Newly synthesized strand
Original (template) strand