For B.Sc. Part I (Subs) Students

STRUCTURE OF CHROMOSOME

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Lecture No.10

- A chromosome is a thread-like self-replicating genetic structure containing organized DNA molecule package found in the nucleus of the cell.
- **E. Strasburger** in 1875 first discovered thread-like structures which appeared during cell division.
- **Waldeyer** (1888) gave the **term chromosome** (chroma- colour + some-body) because they get stained with baisc dyes.
- In all eukaryotes nucleus contain definite number of chromosomes having definite size and shape.
- The number of chromosomes in a given species is generally constant.
- Somatic chromosome is the chromosomes found in somatic cells of a species and is represented by 2n (diploid).
- Generally somatic cells contain 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

- Gametic chromosome number is exactly half of somatic chromosome number and is represented by n (haploid)
- It denotes the number of chromosomes found in gametes of a species

Chromosomes are of two types

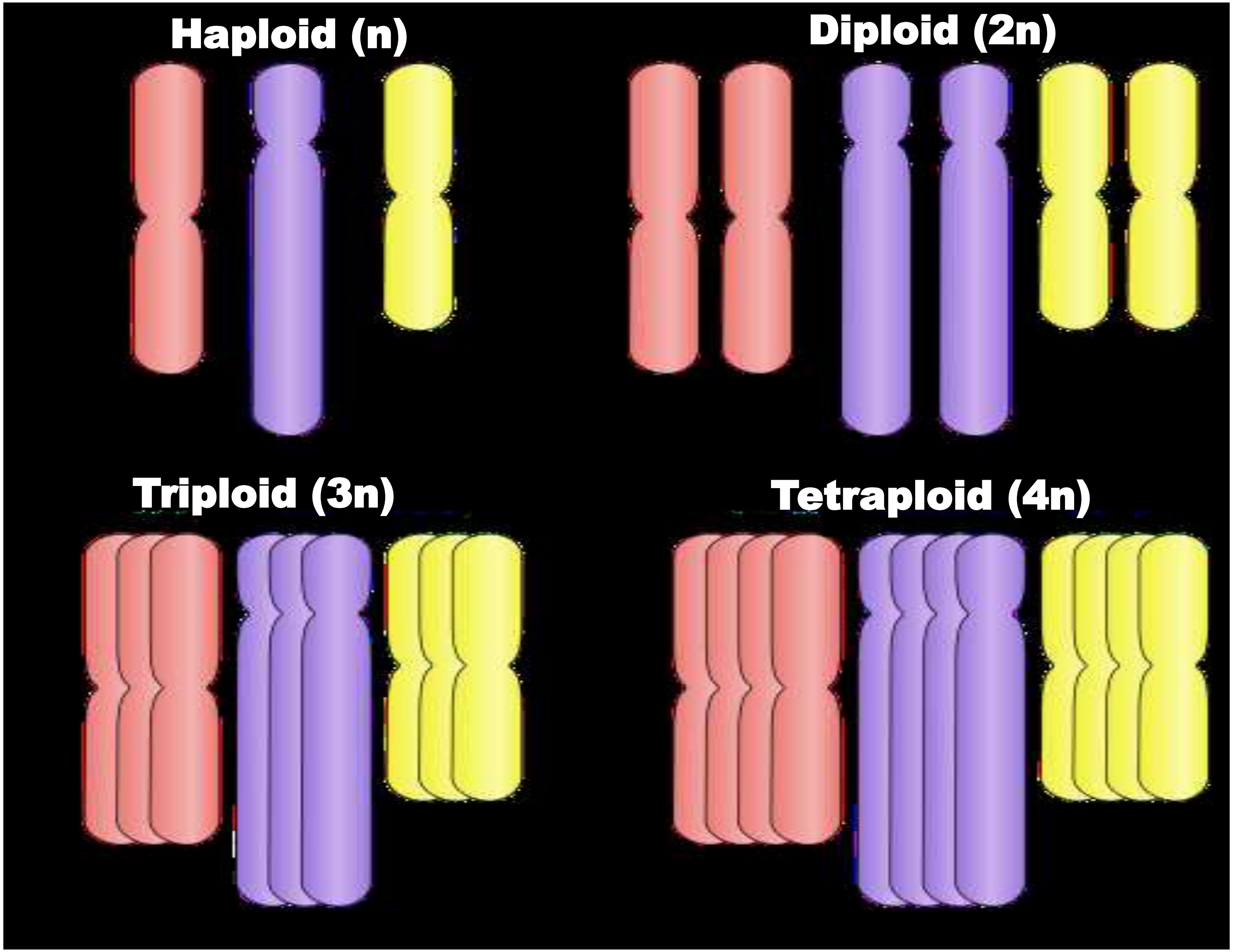
Autosomes

- Chromosome that control characters other than sex characters or carry genes for somatic characters

Sex chromosomes

- 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



Size of Chromosome

- Depending upon the cell division the size of the chromosome shows a remarkable variation
- The size of chromosome is normally measured at mitotic metaphase
- Longest and thinnest chromosome during interphase and hence not visible under light Microscope.
- Smallest and thickest chromosome during mitotic metaphase.
- Size of chromosome is not proportional to the number of genes present on the chromosome.

Morphology of Chromosome

- In mitotic metaphase chromosomes, the following structural features can be seen under the light microscope

1. Chromatid
2. Centromere
3. Matrix
4. Secondary constriction
5. Chromomere
6. Chronomena
7. Telomere

- Morphology of chromosome changes during cell division and mitotic metaphase is the most suitable stage for studies the chromosome morphology.

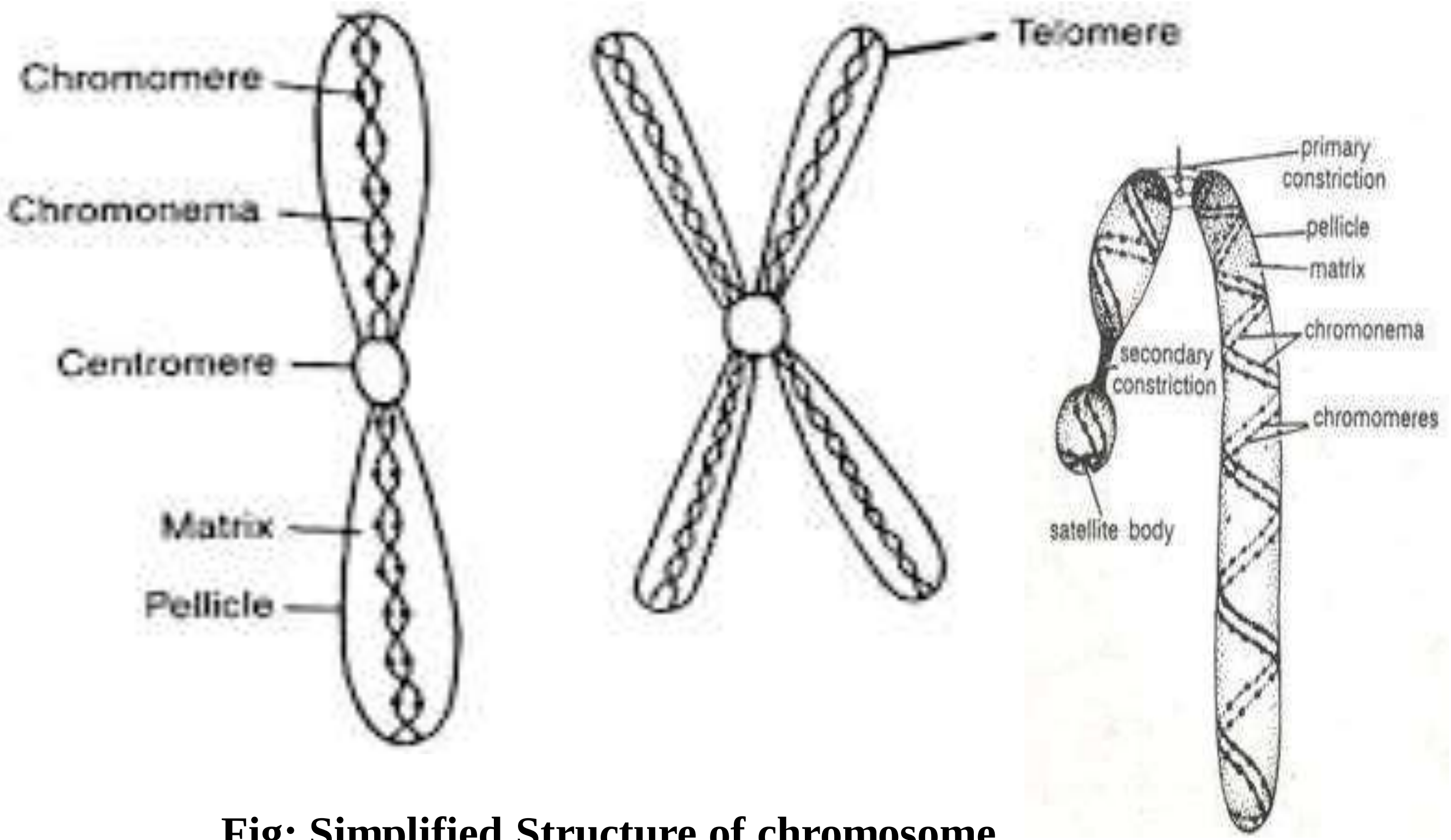
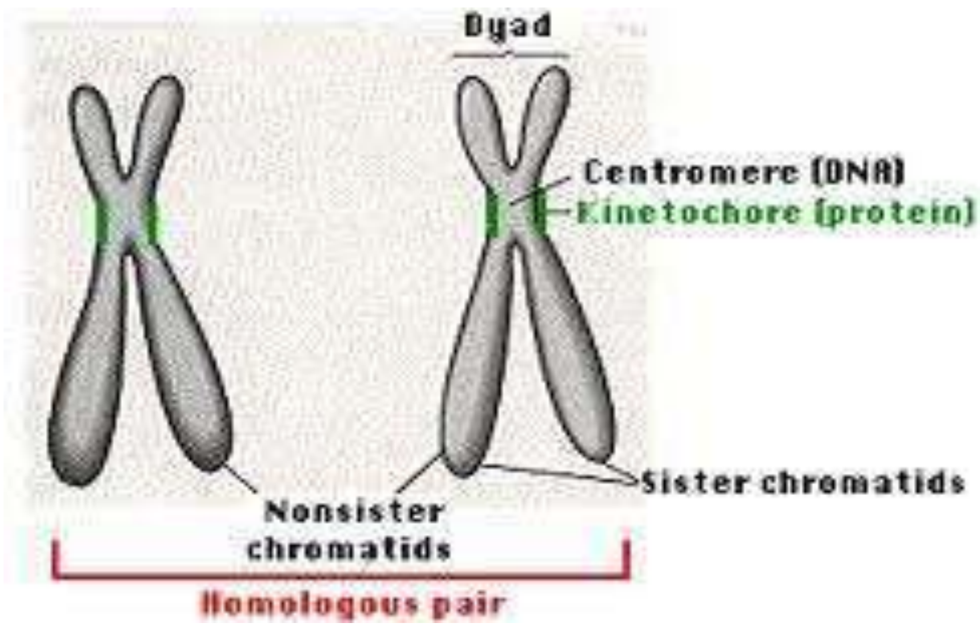


Fig: Simplified Structure of chromosome

1. Chromatid

- Each metaphase chromosome appears to be longitudinally divided into two identical parts each of which is called chromatid.
- Chromatids of a chromosome appear to be joined together at a point known as centromere.
- Two chromatids making up a chromosome are referred to as sister chromatids.
- The chromatids of homologous chromosomes are known as nonsister chromatids



2. Centromere

- ➢ Centromere is the region where two sister chromatids appear to be joined during mitotic metaphase
- ➢ It generally appears as constriction and hence called primary constriction and helps in the movement of the chromosomes to opposite poles during anaphase of cell division.
- ➢The centromere consists of two disk shaped bodies called kinetochores

❖Depending on position of the centromeres, chromosomes are classified into following categories

✓ Metacentric

➢ Centromere is located exactly at the centre of chromosome, Such chromosomes assume 'V' shape at anaphase

✓ Submetacentric

➢ The centromere is located on one side of the centre point such that one arm is longer than the other. These chromosomes become 'J' or 'L' shaped at anaphase

✓ Acrocentric

➢ Centromere is located close to one end of the chromosome and thus giving a very short arm and a very long arm. These chromosomes acquire ‘ J’ shape or rod shape during anaphase.

✓ Telocentric

➢ Centromere is located at one end of the chromosome so that the chromosome has only one arm. These chromosomes are ‘I’’ shaped or rod shaped.

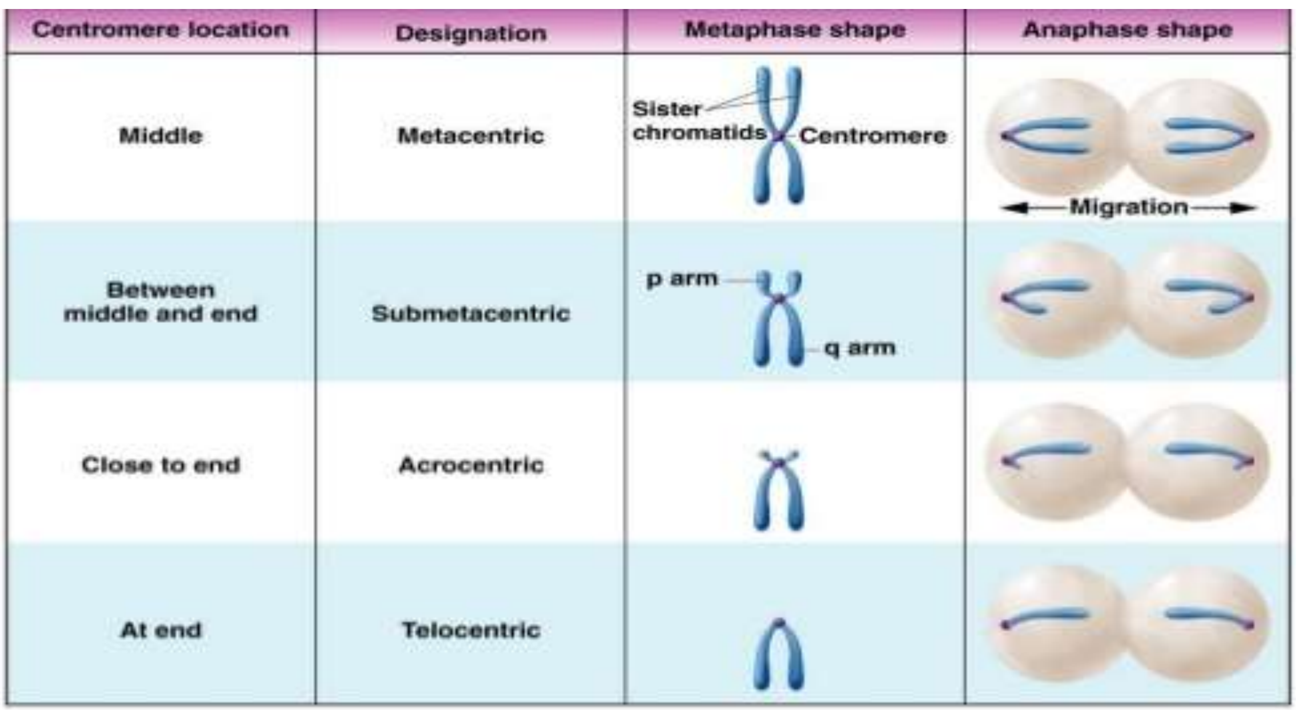


Diagram adopted from Concepts of Genetics, Klug.W.S., 10th ED

3. Matrix

- It is the ground substance of chromosome which contains the chromonemata.
- Both matrix and pellicle are non genetic materials and appear only at metaphase, when the nucleolus disappears

4. Secondary constriction

- The constricted or narrow region other than that of centromere is called secondary Constriction
- Production of nucleolus is associated with secondary constriction and therefore it is also called nucleolus organizer region
- The chromosomes having secondary constriction are known as satellite chromosomes or sat chromosomes
- Chromosome may possess secondary constriction in one or both arms of it.

5. Chromomere

- In some species like maize, rye etc. chromosomes in pachytene stage of meiosis show small bead like structures called chromomeres.
- The distribution of chromomeres in chromosomes is highly characteristic and constant
- They are clearly visible as dark staining bands in the giant salivary gland chromosomes

6. Chromonema

- A chromosome consists of two chromatids and each chromatid consists of thread like coiled structures called chromonema (plural chromonemata).
- The chromonemata form the gene bearing portion of chromosomes

7. Matrix

- The mass of acromatic material which surrounds the chromonemata is called matrix
- The matrix is enclosed in a sheath which is known as pellicle
- Both matrix and pellicle are non genetic materials and appear only at metaphase, when the nucleolus disappears

Composition of chromosomes

- The material of which chromosomes are composed is called chromatin
- N. Fleming introduced the term chromatin in 1879.
- Chromatin was classified into two groups by cytologists on the basis of its affinity to basic dyes like acetocarmine or feulgen (basic fuchsin) reagent at prophase
- The darkly stained regions were called heterochromatin, while lightly stained regions were called euchromatin

Heterochromatin

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

- This differential staining capacity of different parts of a chromosomes is known as 'heteropycnosis

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

Karyotype and Ideogram

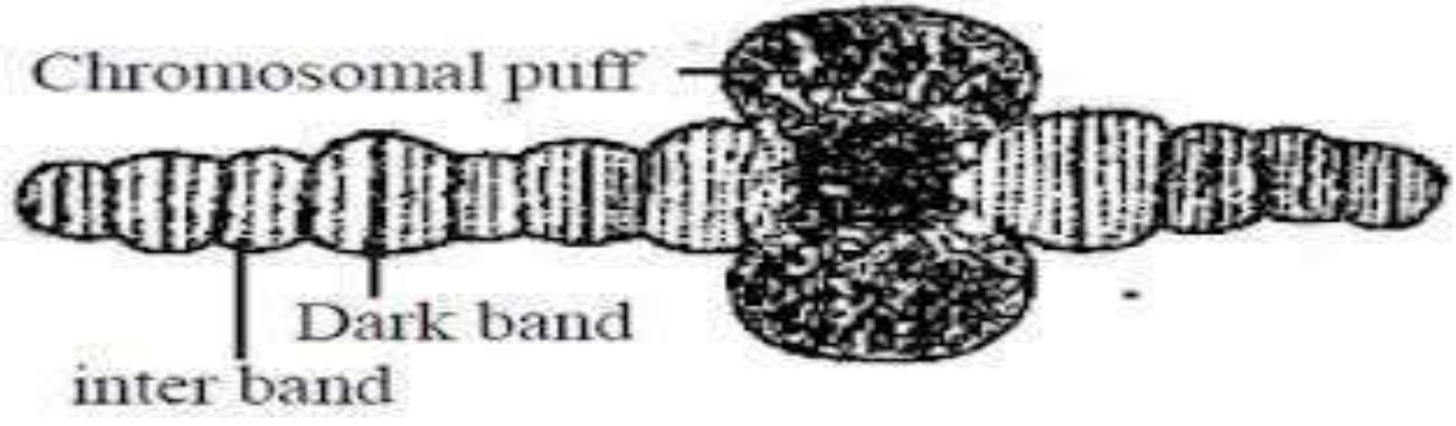
- Generally, karyotype is represented by arranging the chromosomes in descending order of size, keeping their centromeres in the same line
- The karyotype of a species can be represented diagrammatically showing all the morphological features of chromosomes known as Idiogram.

SPECIAL TYPES OF CHROMOSOMES

- Some tissues of certain organisms contain chromosomes which differ significantly from normal chromosomes in terms of either morphology or function. Such chromosomes are referred as special chromosomes.

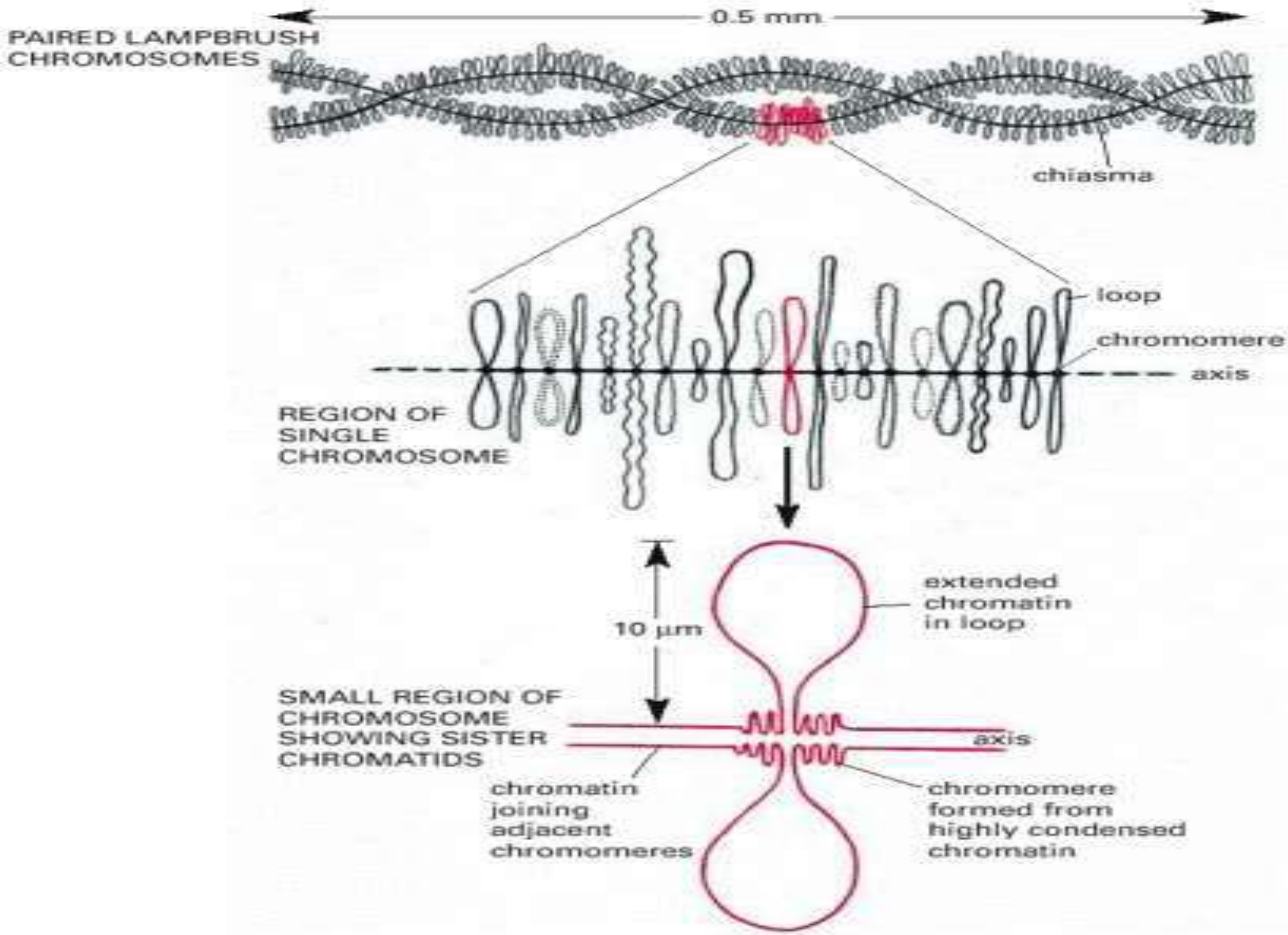
Polytene chromosomes or Gaint Chromosome

- Polytene chromosomes were first discovered by E. G. Balbiani in 1882 in *Dipteran* salivary glands and hence commonly called salivary gland chromosomes.
- These chromosomes replicate repeatedly but the daughter chromatids do not separate from one another and the cell also does not divide. This phenomenon is known as endomitosis or endoreduplication.
- It results in the formation of many stranded giant chromosomes known as polytene chromosomes and the condition is known as polyteny.
- Their size is 200 times or more than the normal somatic chromosomes (autosomes) and very thick. Hence they are known as giant chromosomes.



Lamp brush chromosomes

- These were first observed by W. Flemming in 1882 and were described in detail in oocytes of sharks by Rukert in 1892.
- They occur at diplotene stage of meiotic prophase in oocytes of all animal species.
- Since they are found in meiotic prophase, they are present in the form of bivalents in which the maternal and paternal chromosomes are held together by chiasmata at those sites where crossing over has previously occurred.
- Each bivalent has four chromatids, two in each homologue.
- The axis of each homologue consists of a row of granules or chromomeres, each of which have two loop like lateral extensions, one for each chromatid.
- Thus each loop represents one chromatid of a chromosome and is composed of one DNA double helix.
- One end of each loop is thinner than other which is known as thickend.
- There is extensive RNA synthesis at thin ends of the loop while there is little or no RNA synthesis at the thick ends.


0.5 mm
PAIRED LAMPBRUSH CHROMOSOMES
chiasma
loop
chromomere
axis
REGION OF SINGLE CHROMOSOME
10 µm
extended chromatin in loop
SMALL REGION OF CHROMOSOME SHOWING SISTER CHROMATIDS
axis
chromatin joining adjacent chromomeres
chromomere formed from highly condensed chromatin

DNA Packaging in the Chromosome

- In the nucleus of a normal human cells there are 46 chromosomes each containing 48-240 million bases of DNA.
- Watson and crick model of DNA predicts each chromosome have a contour length of 1.6-2.8 cm.
- While the total length of DNA would be about 3 m.
- While, the average diameter of nucleus is about 5 mm.

How it is Possible???

- A high degree of organization is needed to fit this amount of DNA into the nucleus.

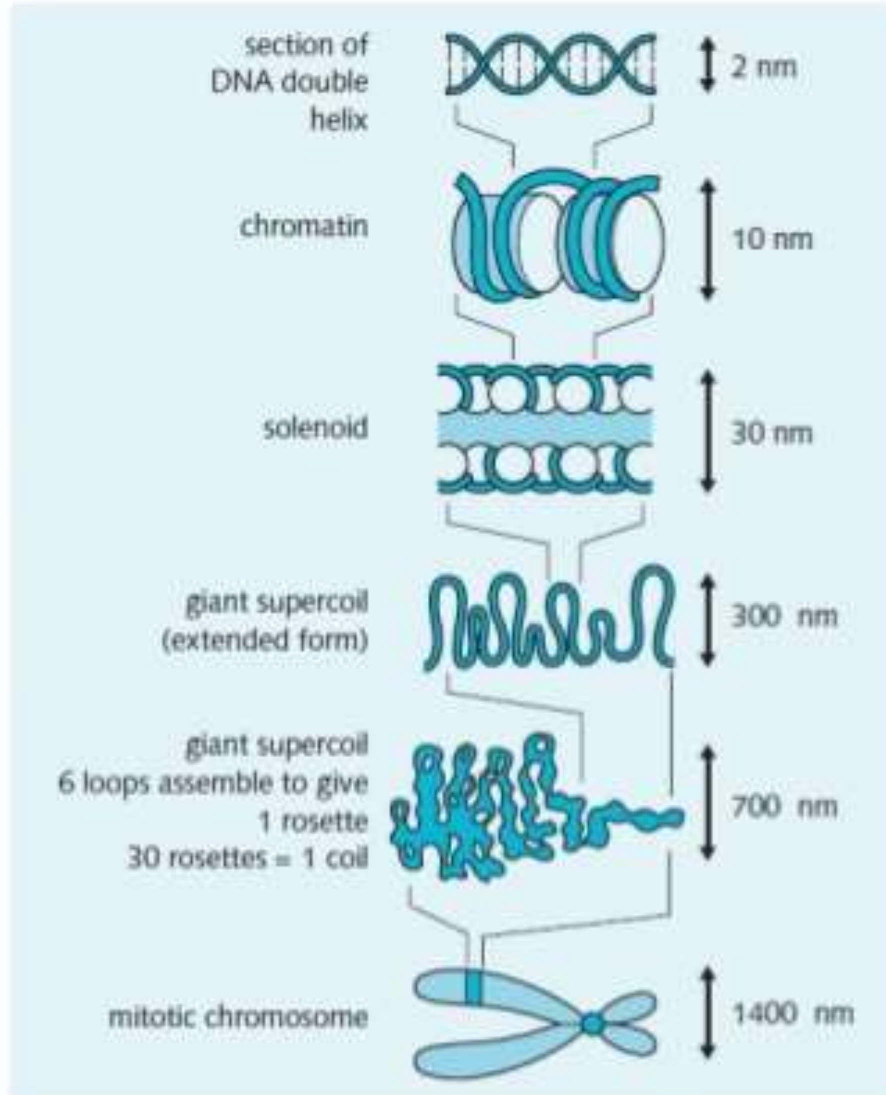
Three higher order of chromatin structure

DNA winds onto nucleosome spools

The nucleosome chain coils into a solenoid

The solenoid forms loops, which attach to a central scaffold

The scaffold plus loops arrange into a giant supercoil



he different levels of DNA condensation, rom DNA double helix to mitotic hromosome

Diagram adopted from
Crash course: Cell Biology and Genetics, 4th ED

DNA + Histone = Chromatin

- The DNA double helix in 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

Histone

- Histone can be grouped into five major classes

✓ H1, H2A, H2B, H3, and H4

✓ These are organised into two super-classes as follows:

Core histones – H2A, H2B, H3 and H4

Linker histones – H1

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

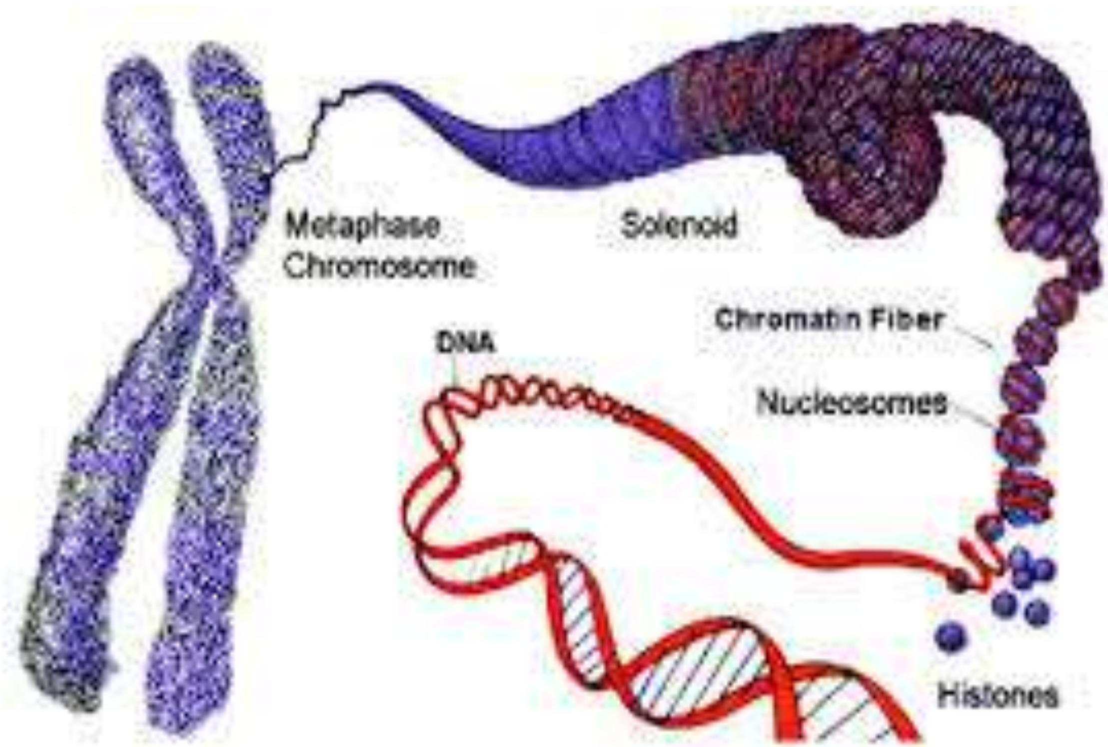
Nucleosome

- The nucleosome core particle consists of 146 base pairs of DNA wrapped in 1.67 left-handed superhelical turns around a histone octamer consisting of 2 copies each of the core histones H2A, H2B, H3, and H4

- Nucleosome is basic unit of DNA packaging in eukaryotes
- Consists of a segment of DNA wound around histone protein core
- Nucleosome is fundamental repeating units of eukaryotic chromatin
- The nucleosome cores themselves coil into a solenoid shape which itself coils to further compact the DNA

- Core particles are connected by stretches of "linker DNA", which can be up to about 80 bp long.
- Technically, a nucleosome is defined as the core particle plus one of these linker regions; however the word is often synonymous with the core particle
- Linker histones such as H1 and its isoforms are involved in chromatin compaction and sit at the base of the nucleosome near the DNA entry and exit binding to the linker region of the DNA
- Non-condensed nucleosomes without the linker histone resemble "beads on a string of DNA" under an electron microscope

- The protein-DNA structure of chromatin is stabilized by attachment to a non-histone protein scaffold called the nuclear matrix.
- In contrast to most eukaryotic cells, mature sperm cells largely use protamines to package their genomic DNA, most likely to achieve an even higher packaging ratio
- Histone equivalents and a simplified chromatin structure have also been found in Archea, proving that eukaryotes are not the only organisms that use nucleosomes


Metaphase
Chromosome
Solenoid
Chromatin Fiber
DNA
Nucleosomes
Histones

Thank You !!