CHROMOSOMES

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Etymology

- Originated from the **Greek** word **(*chroma*, colour)** and **(*soma*, body)**.

DEFINITION

"A **chromosome** is an organized structure of DNA and protein found in cells. It is a single piece of coiled DNA containing many genes, regulatory and other nucleotide sequences. Chromosomes also contain DNA-bound proteins, which serve to package the DNA and control its functions".

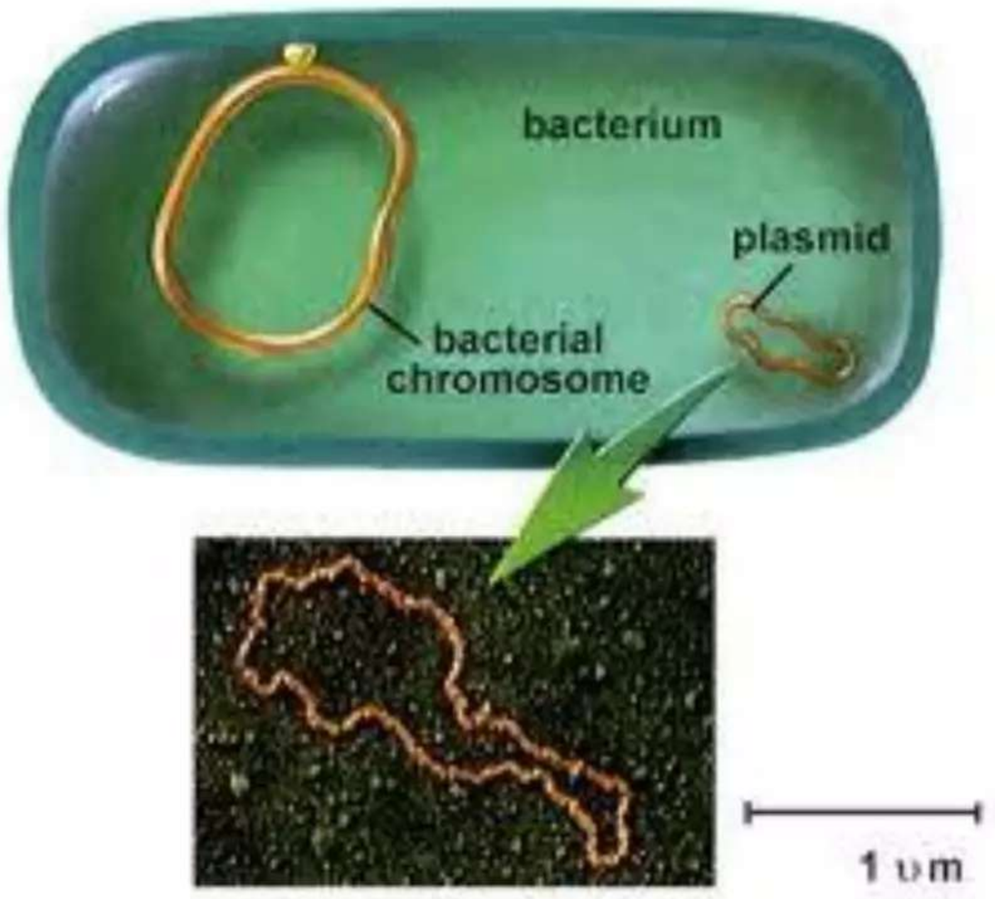
Discovery

- First described by **Strausberger** in **1875**.
- The term **"Chromosome"**, however was first used by **Waldeyer** in **1888**.

Prokaryotic & Eukaryotic Chromosomes

Prokaryotic Chromosomes

- Genomes are simple and the organization of DNA is also different.
- Genomes are contained in single chromosomes, which are usually circular DNA molecules.
- DNA is associated with proteins but no histones present.
- DNA packaging is different from and is not well understood.
- Variation in genome length bearing genes.
- **RNA viruses** having smallest genome.



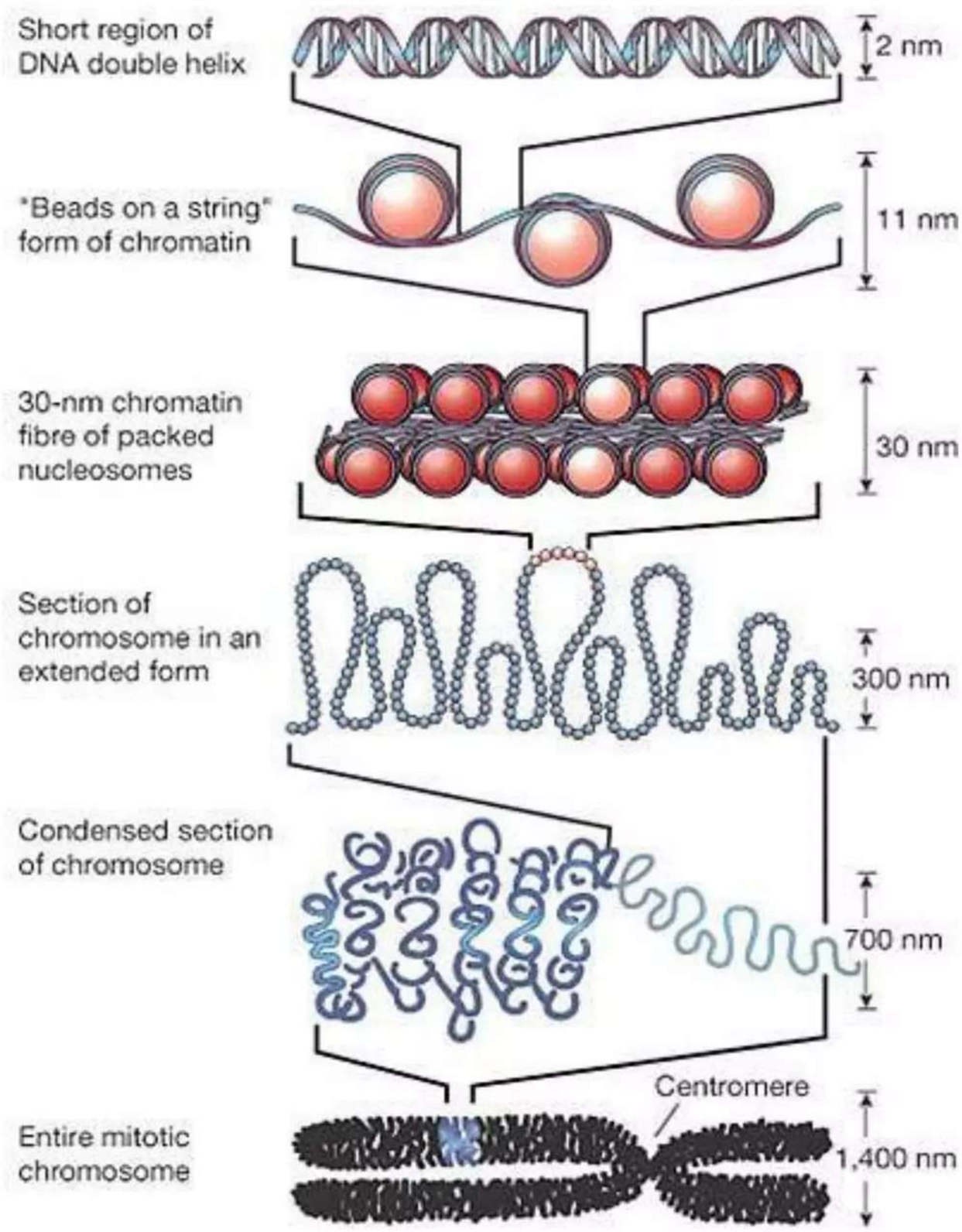
Eukaryotic Chromosomes

- Genomes are composed of multiple chromosomes, each containing a linear molecule of DNA.
- **Histones** are unique feature of eukaryotic cells.
- The packaging of DNA is due to histones.

Chemical Composition

- Composed of thin chromatin threads called **Chromatin Fibers**.
- Interphase chromatin consists of about **30 - 40%** DNA, **50 - 65%** protein and **1-10%** RNA.
- Metaphase chromosomes contain **15 - 20%** DNA, **10 - 15%** RNA and **65 - 75 %** protein.
- DNA consists of nucleotides while the primary protein component is histones.

- Histones strongly attracted to the negatively charged phosphate groups of the DNA.
- There are 5 major types of Histones.
- Thousand of other types of proteins involved in DNA replication and gene expression.
- The degree to which DNA is condensed is expressed as its packing ratio.
- **Packing ratio** - the length of DNA divided by the length into which it is packaged.
- To achieve the overall packing ratio, DNA is not packaged directly into final structure of chromatin.
- Chromatin is composed of repeating 200 base pair unit, which were called **nucleosome**.
- **Nucleosome** was described by **Roger Kornberg** in **1974**.
- **146** base pairs of DNA wrapped **1.75** times around a histone core.
- One molecule **H1** is bound to the DNA as it enters and exits each nucleosome core particle.
- This forms a chromatin subunit known as **Chromatosome**; consist of **166** base pairs of DNA.
- The histones cores act as magnetic forms for the coiling of DNA.
- Nucleosomes wraps up into higher order coils called super coils.



Structure of Chromosome

- Typically a chromosome is made of two chromatids, a centromere and a secondary constriction.
- **Sister chromatids** are two identical copies of the chromosome connected by a centromere.
- The two chromatids of one homologous chromosome with respect to those of the other homologue are called **Nonsister chromatids.**

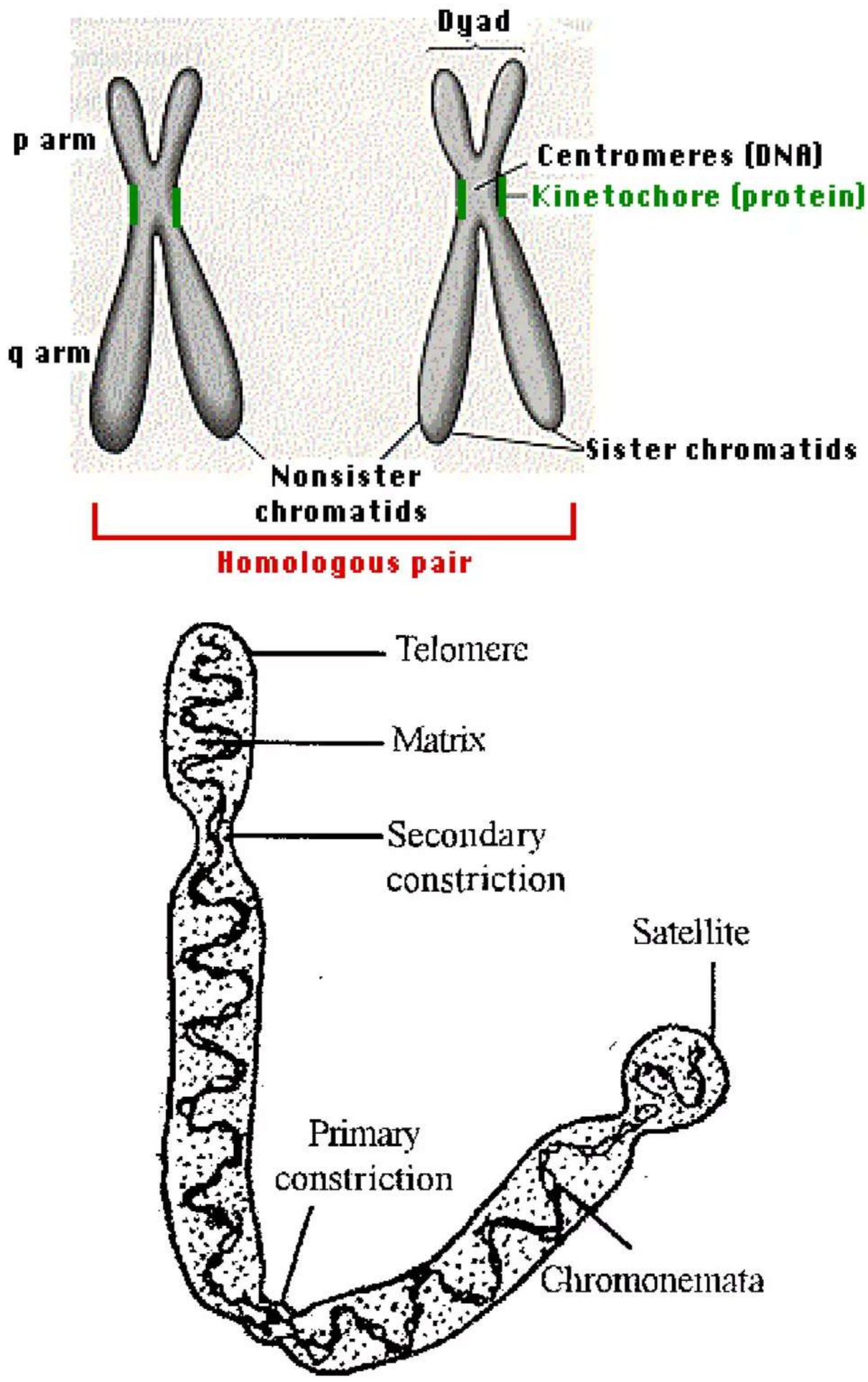


Fig. 3.1 Structure of chromosome

Centromere

- The region where two sister chromatids of a chromosome appear to be joined during cell division is called **Centromere**.
- Also termed as **Primary constriction**.
- **Darkly-stained** region.
- In humans, the centromere contains 1–10 million base pairs of DNA.

- First part of chromosomes to be seen moving towards the opposite poles during anaphase.

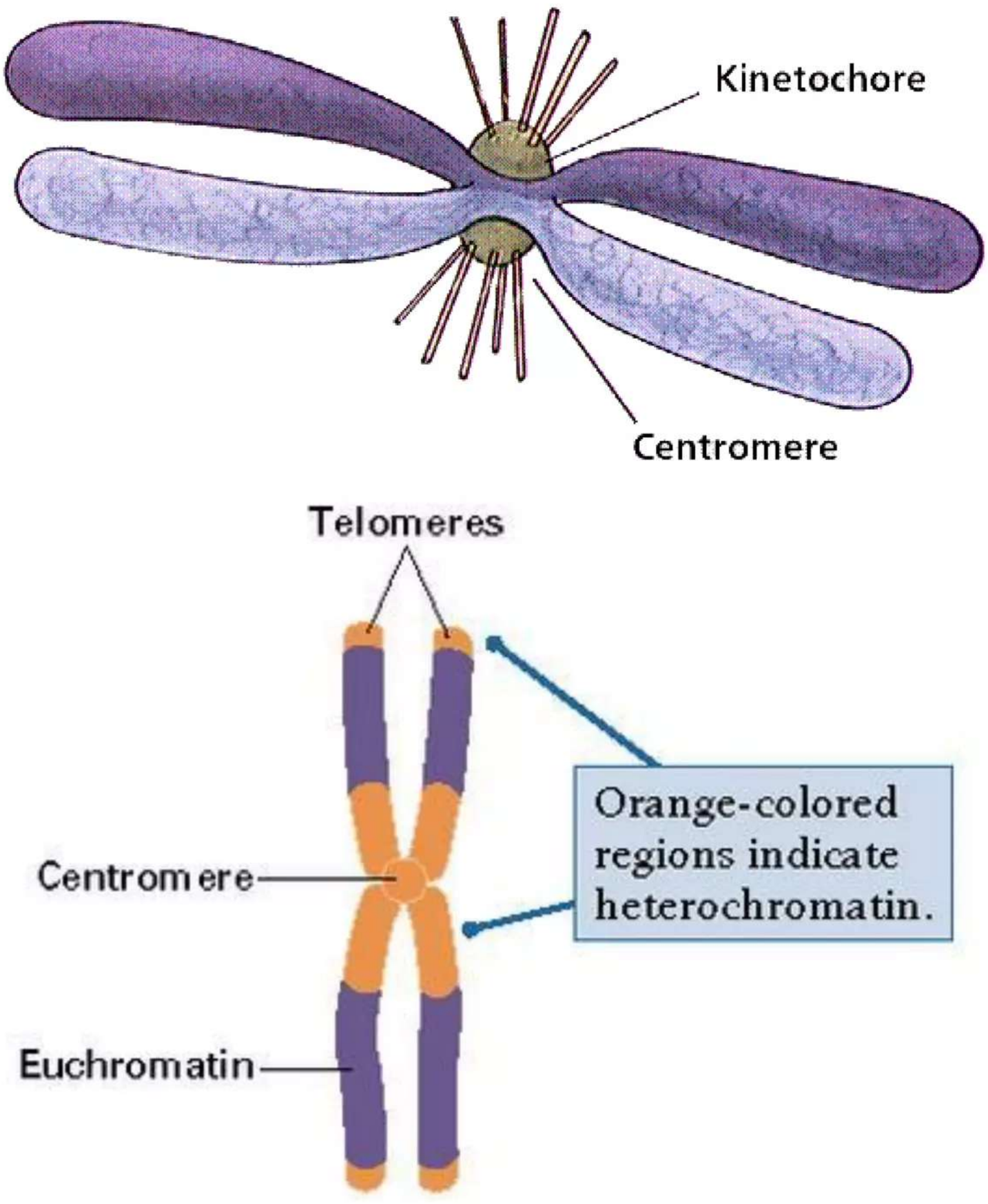
Kinetochore

- The **kinetochore** is the protein structure on chromosomes where the spindle fibers attach during cell division to pull the chromosomes apart.
- DNA sequence within these regions is called ***CEN*** **DNA** of about **120** bp.
- Sub-domains, **CDE-I**, **CDE-II** and **CDE-III**.
- A complex of three proteins called **Cbf-III** binds to normal CDE-III regions but can not bind to a CDE-III region with a point mutation.

Telomere

- Derived from the Greek nouns **telos** "end" and **meros** "part"
- A **telomere** is a region of repetitive DNA sequence at the end of a chromosome, which protects the end of the chromosome from deterioration or from fusion with neighbouring chromosomes.
- Required for the replication and stability of the chromosome.
- **McClintock** noticed that if two chromosomes were broken in a cell, the end of one could attach to the other and vice versa.

Species	Repeated Sequence
Arabidosis	TTTAGGG
Human	TTAGGG
Slime Mold	TAGGG



Regions of Chromosomes

- Several different chemical techniques are used to identify certain chromosomal regions by staining them so that they form **chromosomal bands**.
- There are 2 types of regions in chromosomes.

Euchromatin

- Light staining regions.

- Lightly packed form of chromatin and is often under active transcription.
- Found in both cells with nuclei and cells without nuclei.

Heterochromatin

- Darkly staining and tightly coiled throughout the cell cycle and that is, for the most part, genetically inactive.

Constitutive Heterochromatin

- It is fixed and irreversible in form and function.
- It does not reverse to the euchromatic stage.
- Chromosomes 1, 9, 16 and the Y chromosome contain regions of constitutive heterochromatin.

Facultative Heterochromatin

- It has the faculty to return to the normal euchromatic state.
- Consists of euchromatin that takes on the staining and compactness characteristics of heterochromatin during some phase of development.
- The inactive X chromosome is made up of facultative heterochromatin.

Types of Chromosomes

Autosomes & Allosomes

Autosomes

- Chromosomes that are not directly concerned with reproduction and sex determination are called autosomes.
- These are identical in both the two sexes in man.

- They have loci occupied by autosomal genes.
- The term **"autosome"** was coined by **T.H. Montogomery** in **1904**.

Allosomes/Heterosome

- These chromosomes are directly associated with reproduction and differ from autosomes in size, form and behaviour.
- Usually there is a single pair of allosomes in mammals termed as 'X" and "Y" chromosomes.
- In bugs of Heteroptera like locusts, the female has two X chromosomes while the male has one X. The Y chromosome is absent in these species.

Types of Chromosomes Based on the position of Centromere

1. Metacentric Chromosomes

- The two arms are equal in length.
- Appears in **'V'** shape.

2. Submetacentric Chromosomes

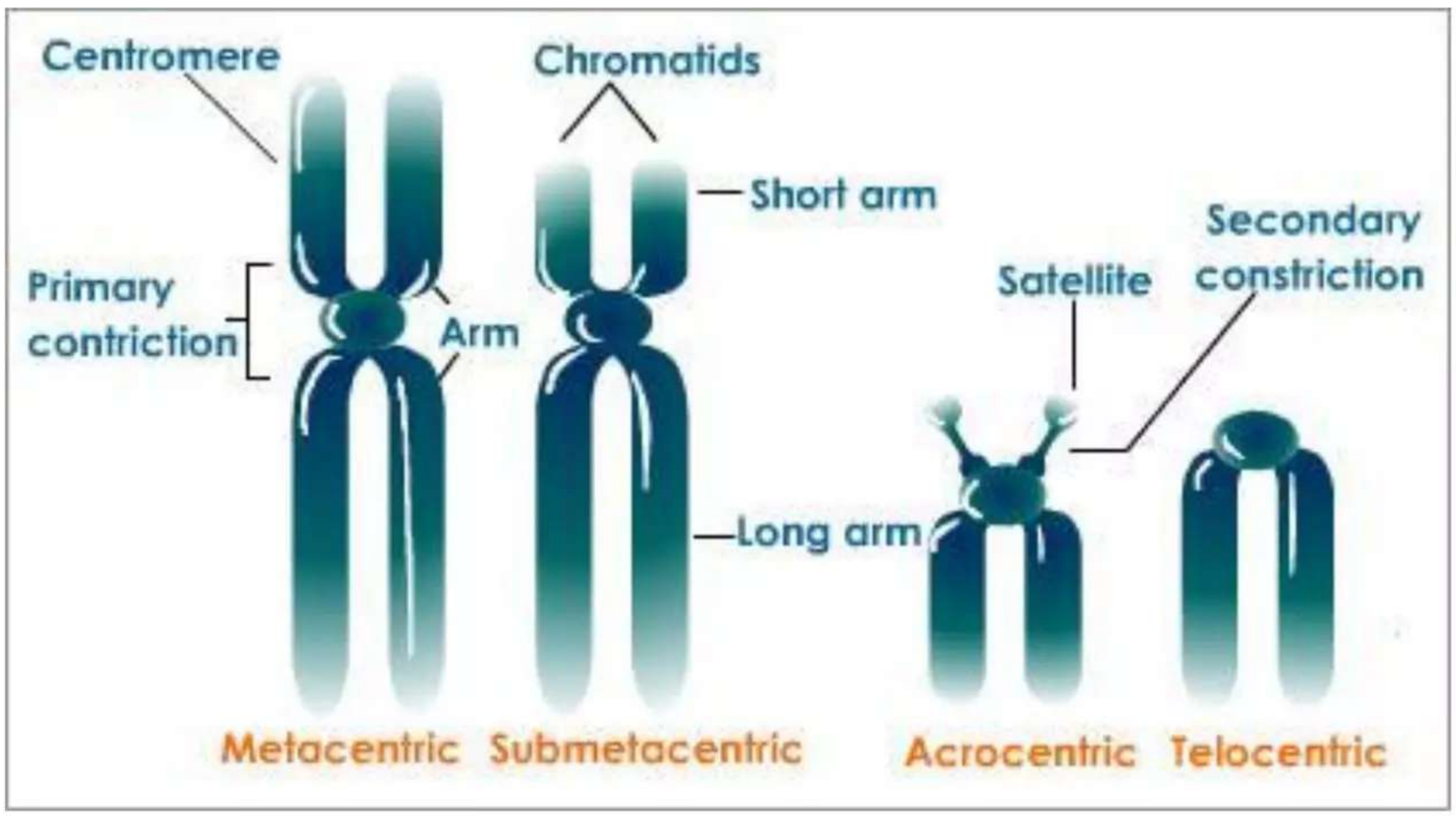
- Also called as **Heterobrachal**.
- Chromatids of one side are slightly longer than the other side.
- Resemble the letter **'L'**.

3. Acrocentric Chromosomes

- Centromere is located closer to one end of chromatid.
- The small round structure is termed as **satellite**.
- Resemble the lettar **'j'**.

4. *Telocentric Chromosomes*

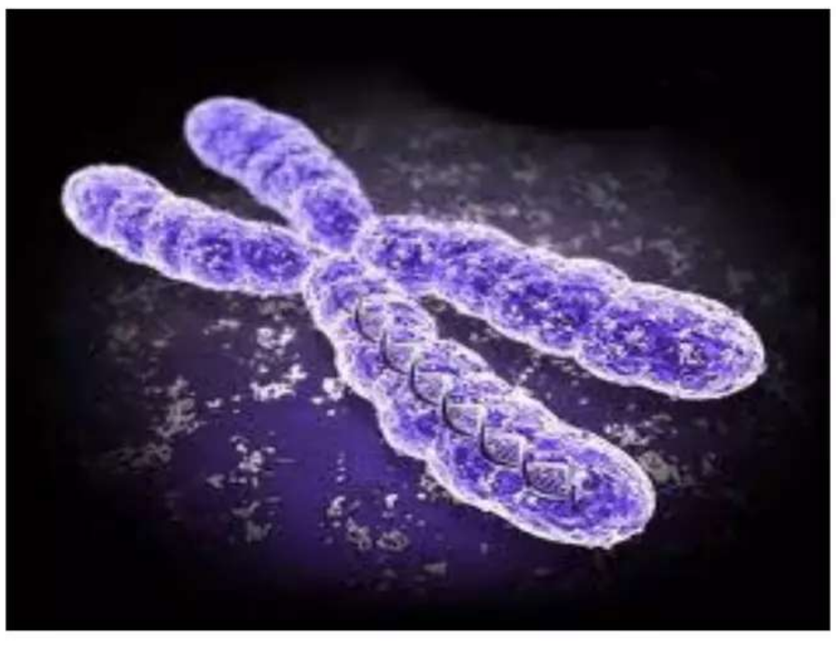
- Also called as **monarchial** type.
- Centromere at the end of chromosomes.
- Not seen in human cells.
- Resemble the lettar **'i'**.



Types of Chromosomes Based on the number of Centromere

Based on the number of Centromere, chromosomes are grouped into five types.

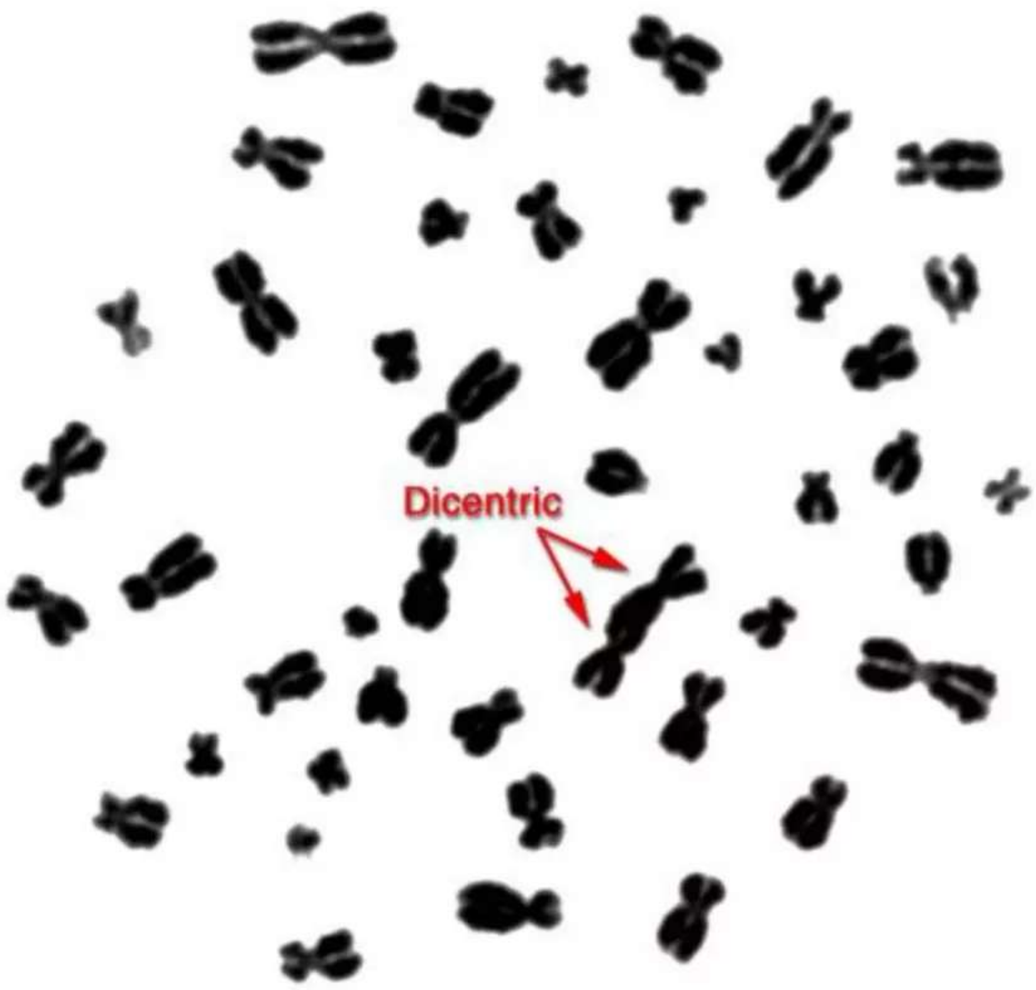
- Chromosomes without centromere are called **Acentric Chromosomes.**

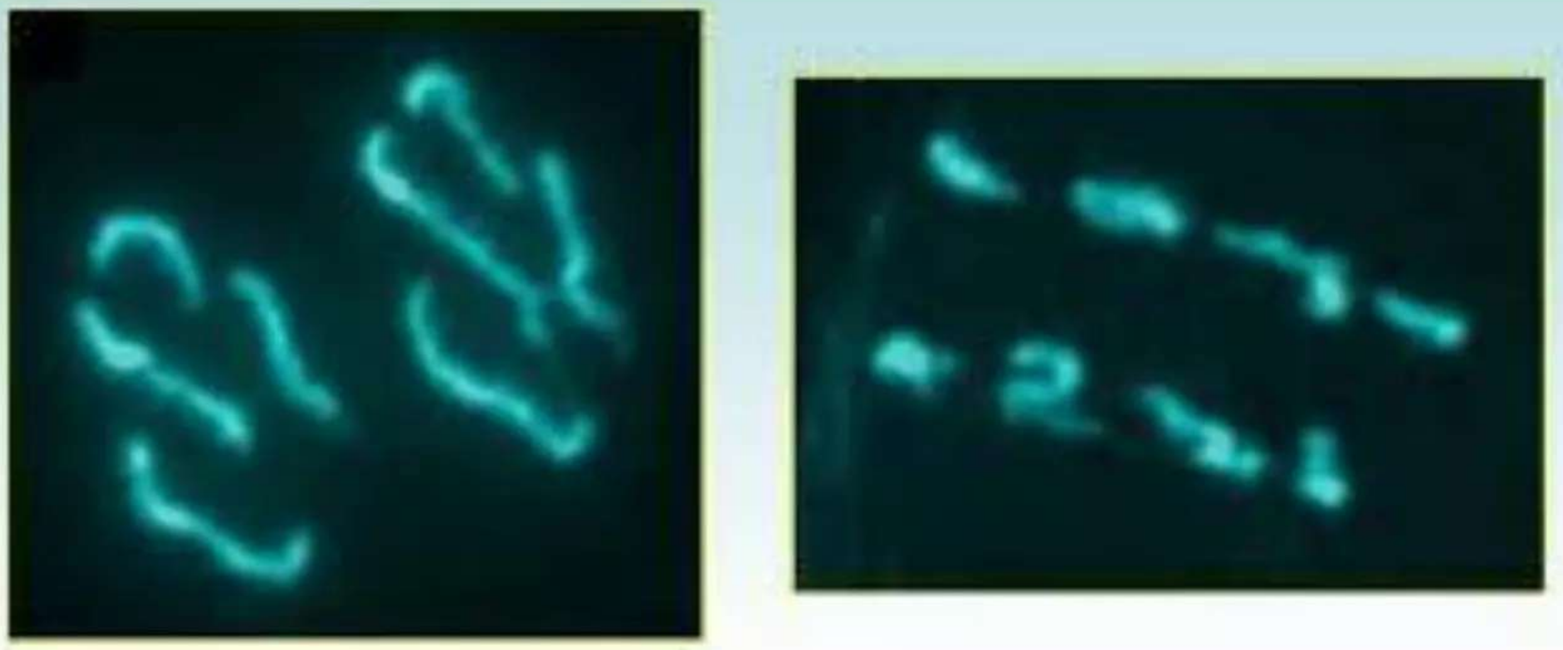


- Chromosomes with one centromere and called **Monocentric Chromosomes.**
- Chromosomes having two centromeres are called **Dicentric Chromosomes.**
- Chromosomes having more than two centromeres are called **Polycentric Chromosomes.**

Chromosomes Diffuse

- Also known as **Holocentric Chromosomes**.
- The entire length of the chromosome acts as the centromere.



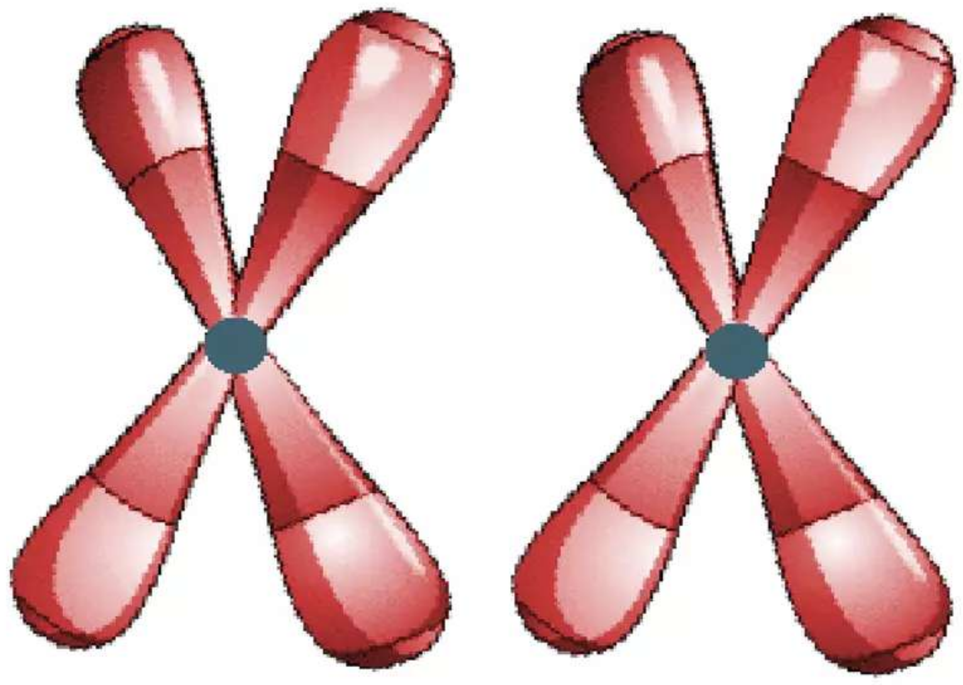


Anaphase in *Rhynchosgora tenuis* (2n = 4) The chromatids move to the poles parallel to one another

Homologous and Non Homologous Chromosomes

Homologous chromosomes

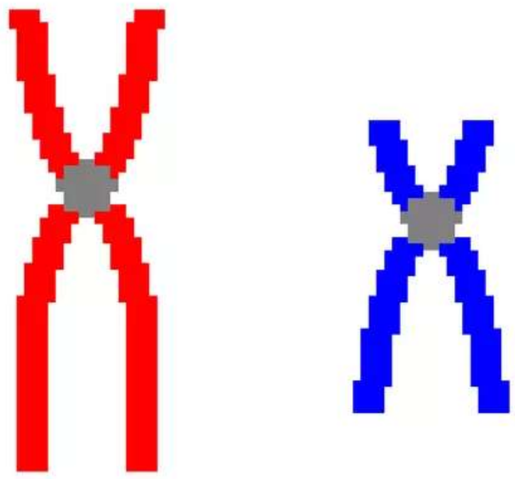
- Chromosome pairs of the same length, centromere position, and staining pattern, with genes for the same characteristics at corresponding loci.
- The pair (synapse) during meiosis.
- Each pair contains genes for the same biological features, such as eye color, at the same locations (loci) on the chromosome.



homologous pair

Non Homologous chromosomes

- Chromosomes that are not members of the same pair.
- Each chromosome of the pair is obtained from the each parent in diploids and contains all the gene pool of that organism.

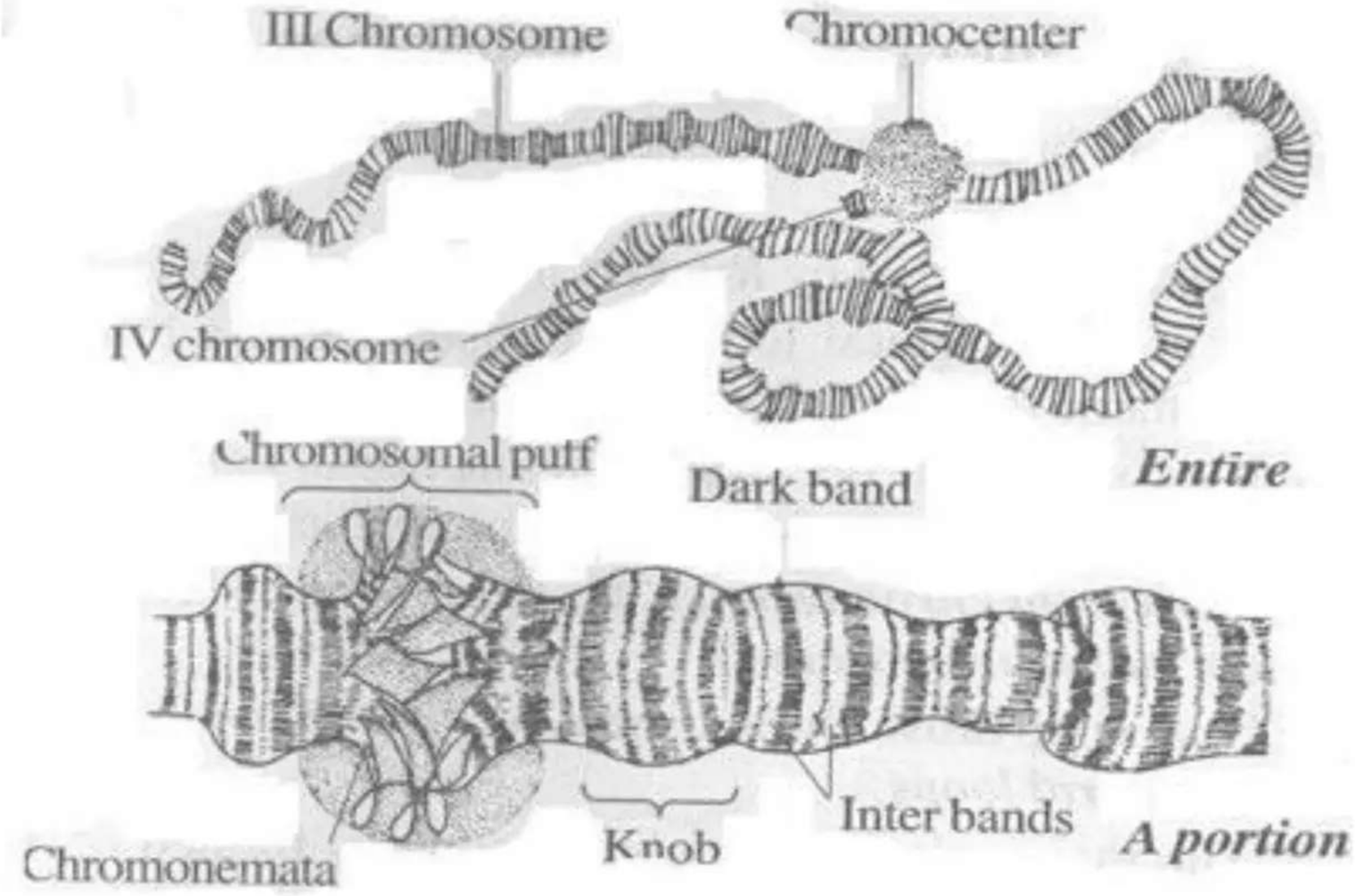


Special Types of Chromosomes

Polytene chromosomes

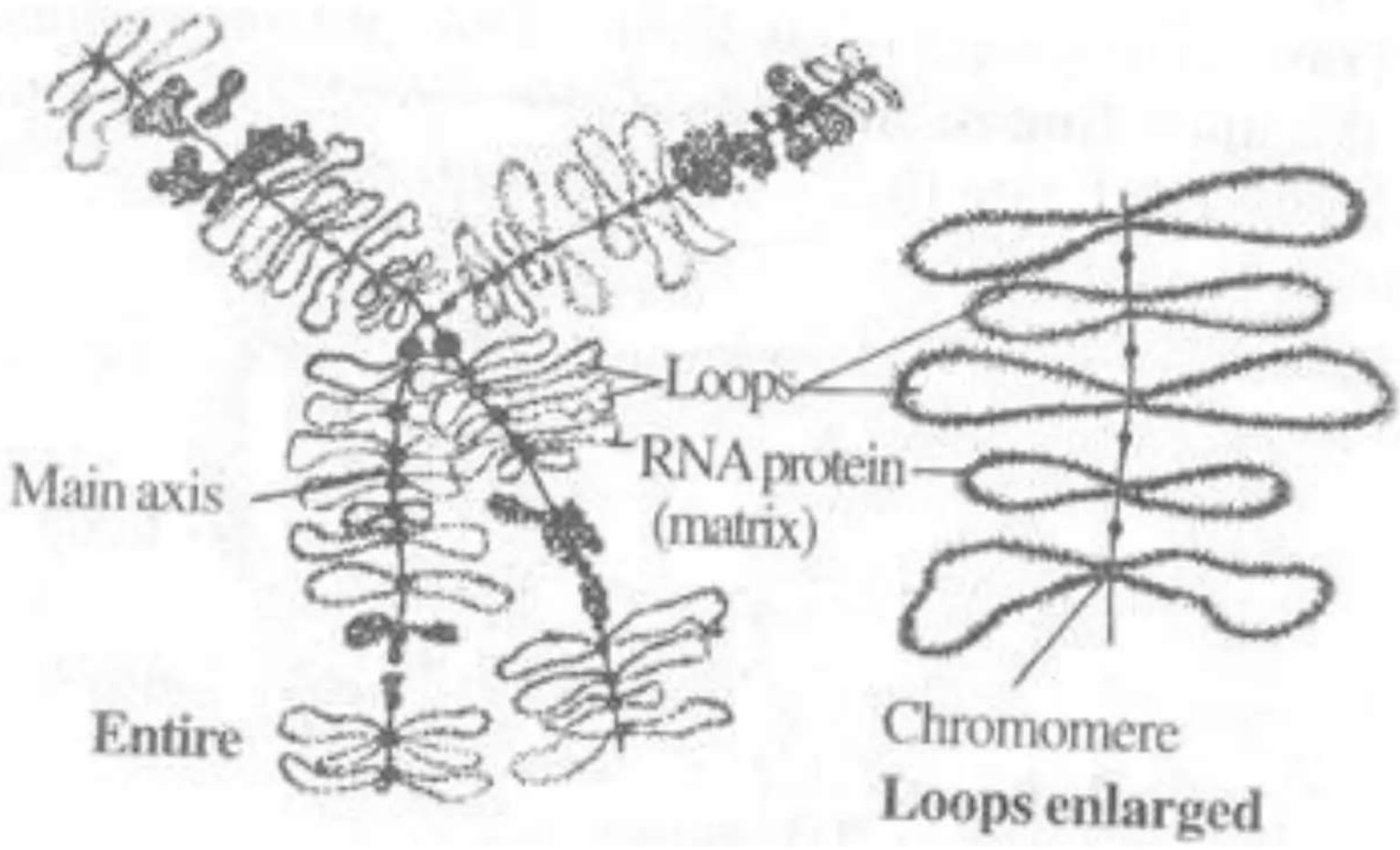
- The nuclei of the salivary gland cells of the larvae of dipterans like Drosophila have unusually long and wide chromosomes, 100 or 200 times in size of the chromosomes in meiosis and mitosis of the same species.
- Salivary gland cells do not divide after the glands are formed, yet their chromosomes replicate several times (a process called **endomitosis**) and become exceptionally giant-sized.
- They are discovered by **Balbiani (l881)** and named by **Koller**.
- The endomitosis process result in the production of 2X chromosomes, where X gives the number of multiplication cycle.

- They have alternating dark and light bands. The dark bands are disc-shaped structures occupying the whole diameter of chromosome. They contain euchromatin
- The light bands are fibrillar and composed of heterochromatin.



Lampbrush Chromosome

- Discovered by **Ruckert** in **1892**.
- Formed during the diplotene stage in the nuclei of oocytes during the active synthesis of mRNA molecules for the future use.
- It contains a main axis whose chromonemal fibres (DNA molecule) gives out lateral loops throughout its length.

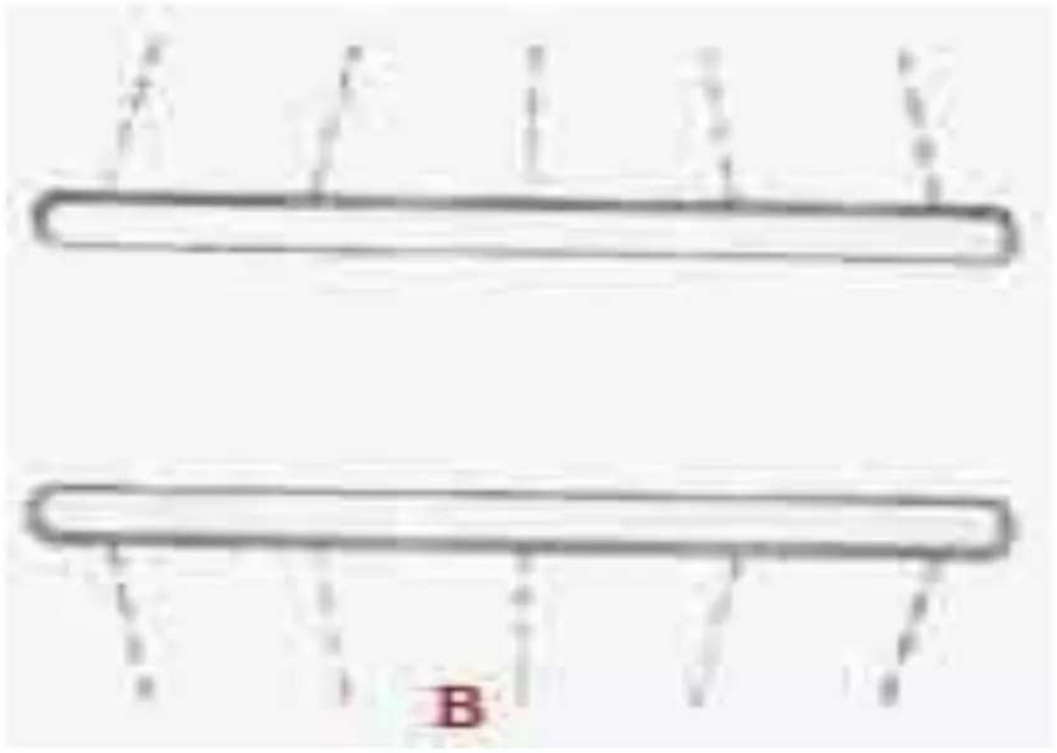


B Chromosomes

- Many organisms have a special chromosome in addition to the autosomes which are called B chromosomes.
- Also termed as **supernumery** or **accessory chromosomes** or **accessory fragments**.
- Smaller than autosomes and the number varies from 0 to 30 /cell.
- In some animals they may be derivatives of sex chromosomes.
- May have negative affects on the cell.

Holokinetic Chromosome

- In insects of the order Hemiptera and in some monocotyledonous plants the kinetic activity is distributed over the entire chromosome.
- The term **diffuse centromere** bas been used as an alternative.
- In **1966 Flach** observed this type of centromere in some primitive Dicotyledons along with pseudoscorpion and *Ascaris*.



Number of Chromosomes

- Normally all the indiviuals of a species have the same number of chromosomes.
- Closely related species usually have similar chromosome number.
- Presence of a whole set of chromosomes is called **Euploidy**.
- It includes haploids, diploids, triploids, tetraploids etc.
- The condition in which the chromosomes sets are present in multiples of **"n"** is **Polyploidy.**

Chromosome Size

- The size of chromosomes shows a remarkable variation depending upon the stages of the cell division.

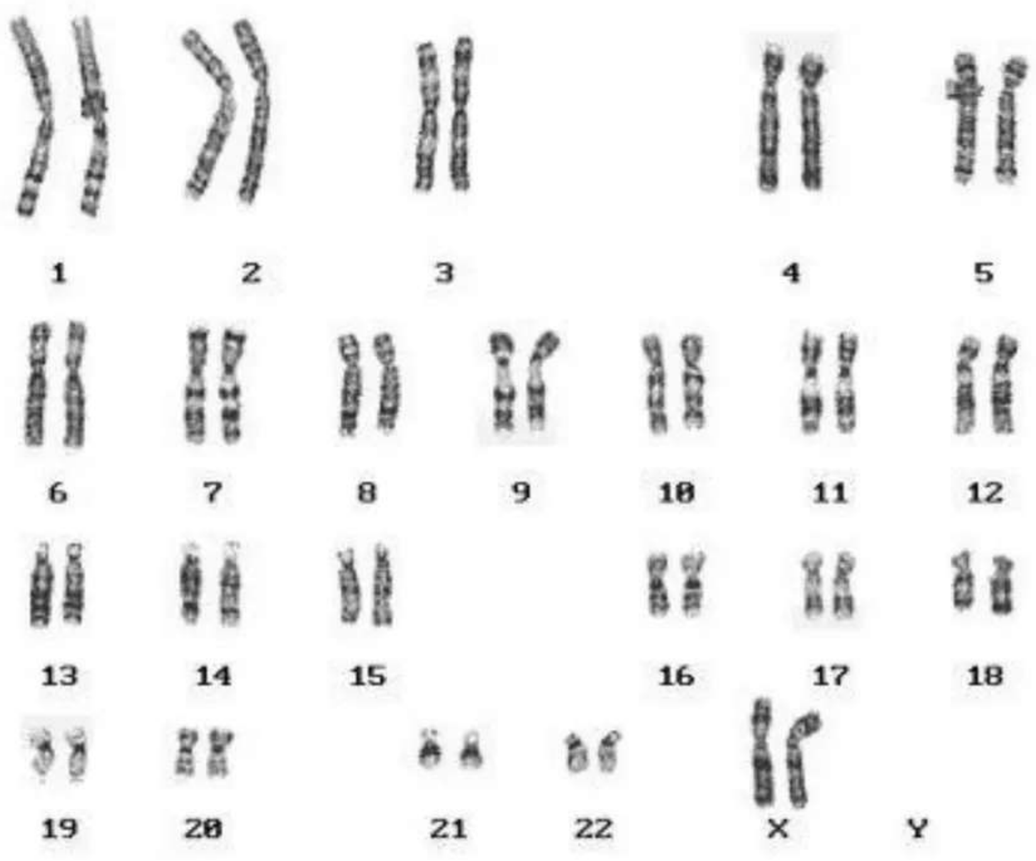
- Longest and thinnest in Interphase.
- Progressive decrease in their length with an increase in thickness in **prophase**.
- Most easily observed during **metaphase** when they are very thick, quite short and well spread in the cell.

- Chromosomes are smallest in **anaphase**.

Therefore, chromosomes measurements are generally taken during mitotic metaphase.

Karyotype

- A **karyotype** is the number and appearance of chromosomes in the nucleus of a eukaryotic cell.
- It describes the number of chromosomes, and what they look like under a light microscope.
- Attention is paid to their length, the position of the centromeres, banding pattern, any differences between the sex chromosomes, and any other physical characteristics.
- The study of whole sets of chromosomes is sometimes known as ***karyology.***
- Karyotypes can be used for various purposes; such as, to study chromosomal aberrations, cellular functions, taxonomic relationships, and to gather information about past evolutionary events.



Karyotype of Human Female

Functions of Chromosomes

- In charge of all the processes.
- **"Packaging material"** that binds DNA and protein together.
- Protein synthesis steps are the responsibility of genes.
- Very important roles in the development of an individual.
- They are the **'vehicles of heredity'.**
- DNA provides the genetic information for various cellular functions essential for survival, growth, development etc.
- Chromosomes protect the genetic material (DNA) from being damaged during cell division.
- Essential for the process of cell division and are responsible for the replication, division and creation of daughter cells.
- Centromeres perform an important function in chromosome movement during cell division.