CELL AND MOLECULAR BIOLOGY
UNIT III
CHROMOSOMES

DR.S.ARULJOTHISELVI

ASSISTANT PROFESSOR

DEPARTMENT OF ZOOLOGY

PERIYAR GOVERNMENT ARTS COLLEGE

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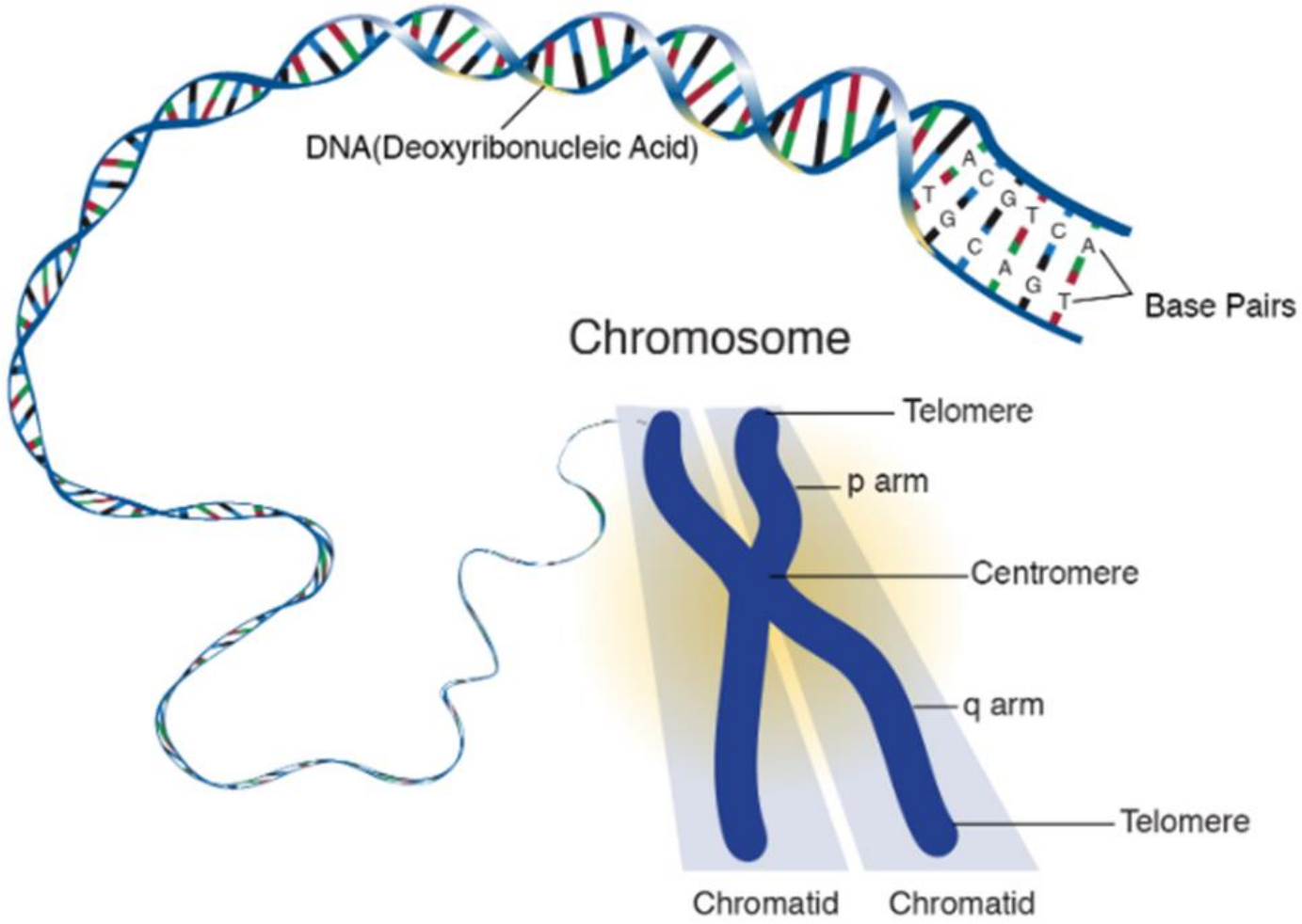


Chromosomes

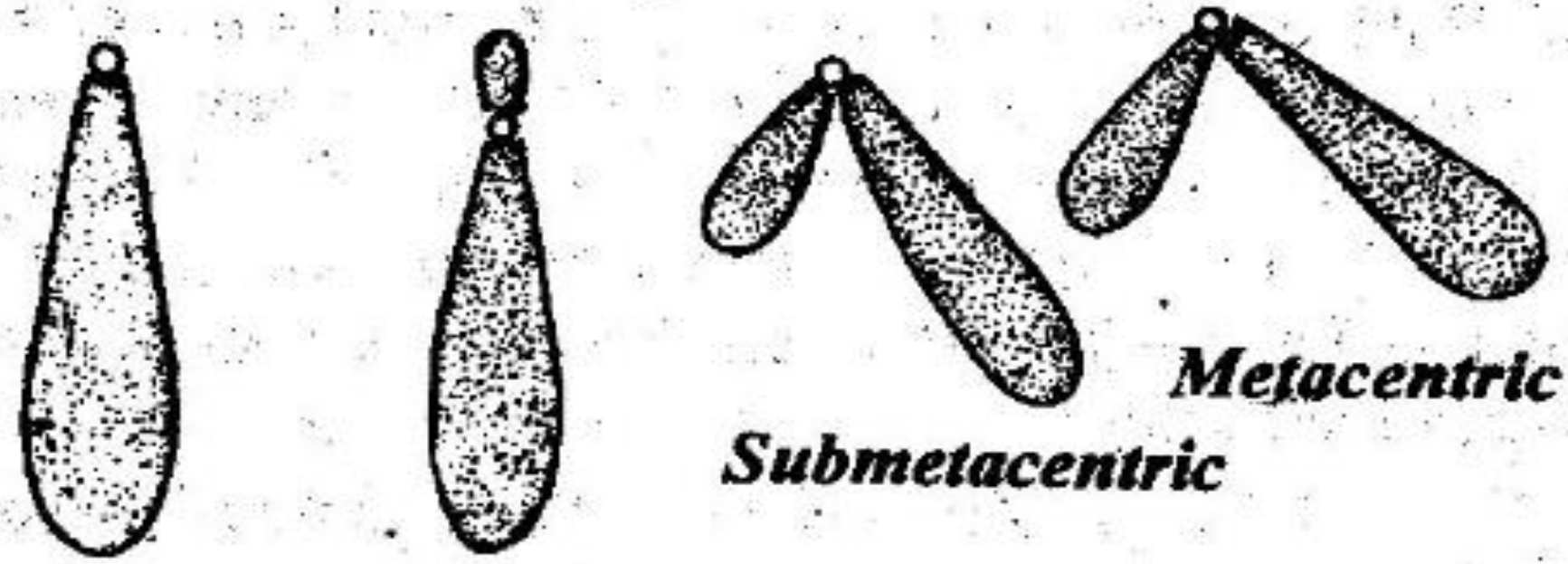
Chromosomes are self-reproducing thread-like structures located inside the nucleus. They are called chromosomes (***Chroma***= colour, ***soma***=body) because they are easily stained with dyes. They are the vehicles of heredity.

Chromosomes were first observed by ***Hofmeister*** in 1848 in the nuclei of pollen mother cells of ***Tradescantia***. However they were named ***chromosomes*** in 1888 by ***Waldeyer.***

The number of chromosomes varies from species to species. But the number remains constant among the members of the same species. The lowest number of chromosomes is 2 and it occurs in ***Ascaris megalocephala.*** The maximum number of chromosomes is 1700 and it occurs ina radiolarian (Protoz--

Generally the chromosomes are arranged in pairs. A Pair of similar chromosomes is called ***homologous chromosomes.*** The somatic cells contain two sets of chromosomes. This number is called *diploid number* which ssjjfuuis represented by ***2n***. The gametes contain only one set of chromosomes. This number is called *haploid number* and it is represented as ***n***. Sometimes a cell may contain more than two sets of chromosomes. This number is called ***polyploid*** (3n, 4n, 5n, etc.).

The shape of a chromosome is largely determined by the position of its centromere. On this basis, chromosomes are classified into four types. They are the following:



Different shapes of chromosomes.

1. Telocentric: The centromere is located at the end of the chromosome. Such chromosomes are rare. It exists normally in certain species of Protozoa.

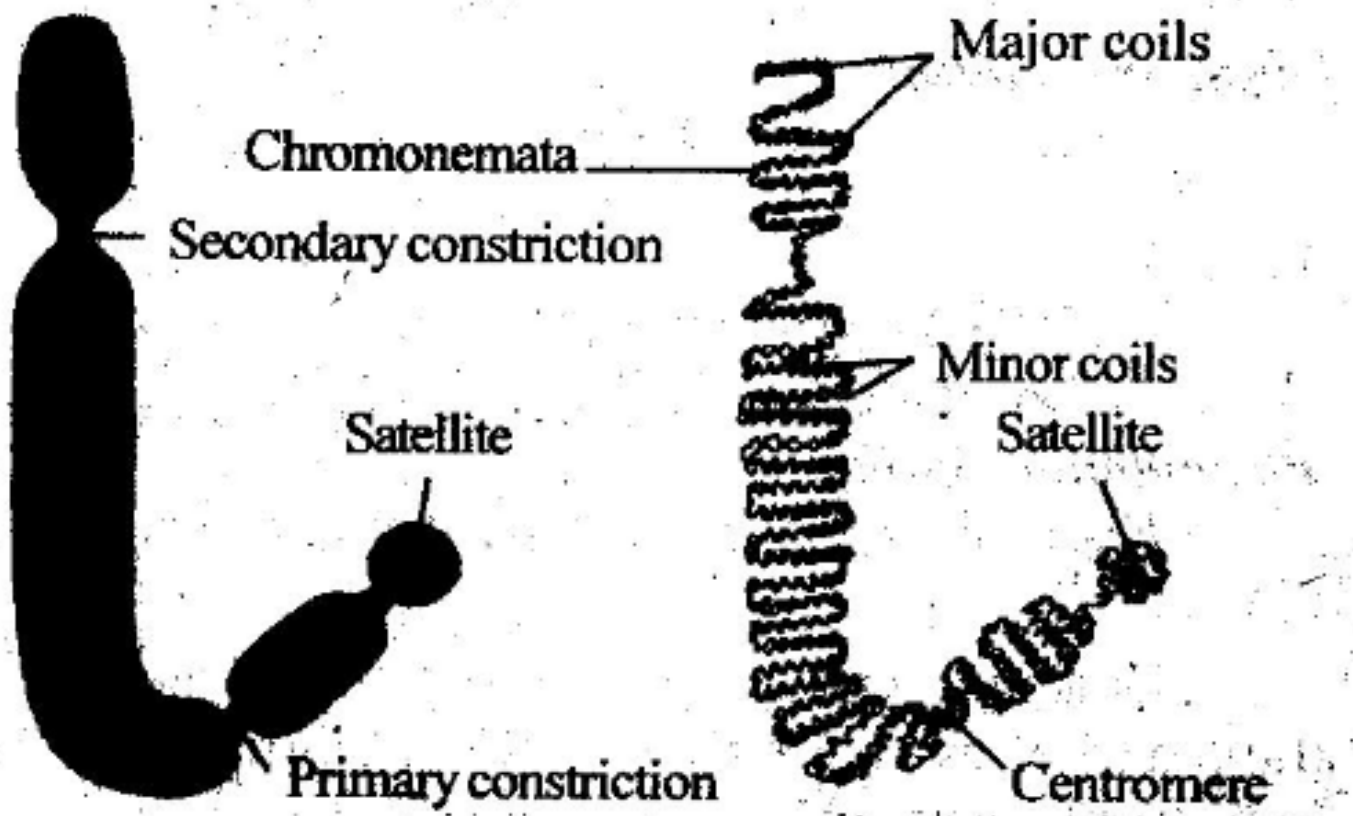
2. Acrocentric: These are rod-like chromosomes having a very small arm and a very long arm. This is characteristic of Locusts.

3. Sub-metacentric: These chromosomes are L-shaped having unequal arms.

4. MetaCentric : These chromosomes are V-shaped. They have arms equal in length. They are characteristic of Amphibia.

The size of the 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 plant ***Trillium*** has chromosomes with the length of 32 microns at metaphase. The length of the human *chromosomes* varies from 4 microns to 6 microns. But there are also giant chromosomes which vary in length and diameter. The ***lamp bursh*** chromosomes in oocytes of Amphibia may reach upto 800 microns long.

A typical somatic chromosome has an elongated cylindrical body with two arms. It consists of a ***pellicle, matrix, chromonema, chromomeres, centromere*** or ***primary constriction, secondary constriction, satellite bodies and telomeres.***

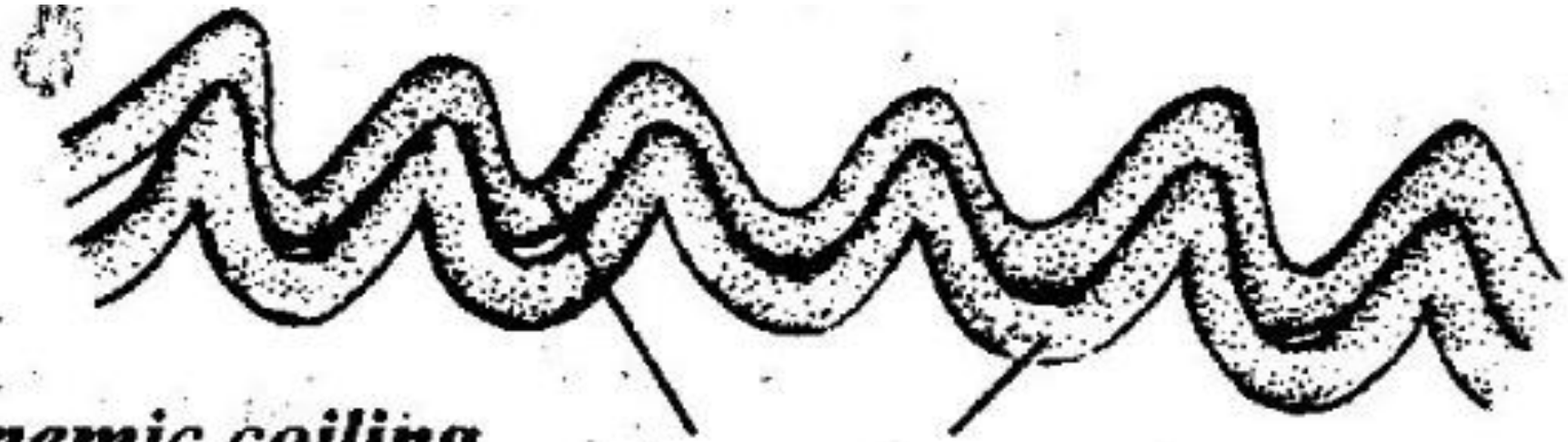


Structure of a typical somatic chromosome.

The outermost covering of the chromosome is the *pellicle*. It is thin and formed of non-genetic material.

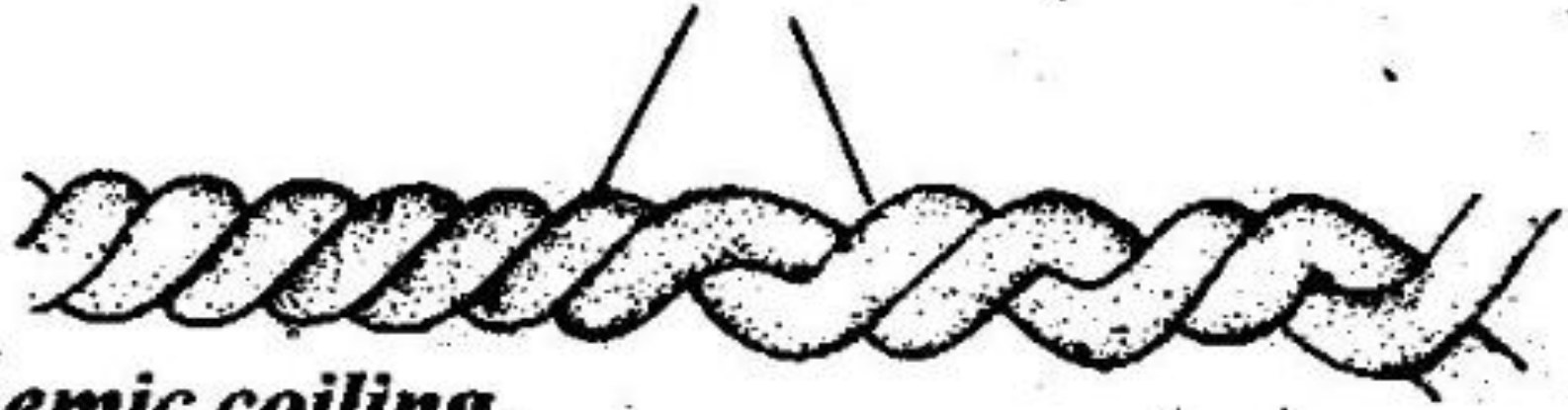
The pellicle encloses a mass of homogenous non-genetic material called the *matrix*. It forms the main bulk of the chromosome. It helps in keeping the chromonemata within the bounds.

Internally, the chromosome contains two identical spirally coiled filaments. They are called ***chromonemata***. The nature and degree of coiling of chromonemata is variable in *meiotic* and mitotic chromosomes. In meiotic chromosomes two distinct coils are observed. One is called the ***major coil***, which consists of 10 to 30 gyres. The other is called ***minor coil***, which has more number of gyres. In mitotic chromosomes, a kind of coil similar to the major coil is described. It is called the ***somatic*** or ***standard coil***. The coiling may be either ***paranemic*** where the coiling can be easily separated or ***plectonemic*** where the coiling cannot be easily separated.



Paranemic coiling

Chromatids



Plectonemic coiling

Types of coilings between chromonema threads.

. During interphase certain regions of the chromati stain darker with Feulgen. Such regions are calle ***heterochromatins.*** The other regions are calle ***euchromatins.*** This phenomenon is known as ***heteropycnosi*** or differential staining. Heterochromatin is in close contac with nucleolus. During mitosis the heterochromatic region

may stain more strongly (+ ve heteropycnosis) or more weakly than euchromatic regions (- ve heteropycnosis).

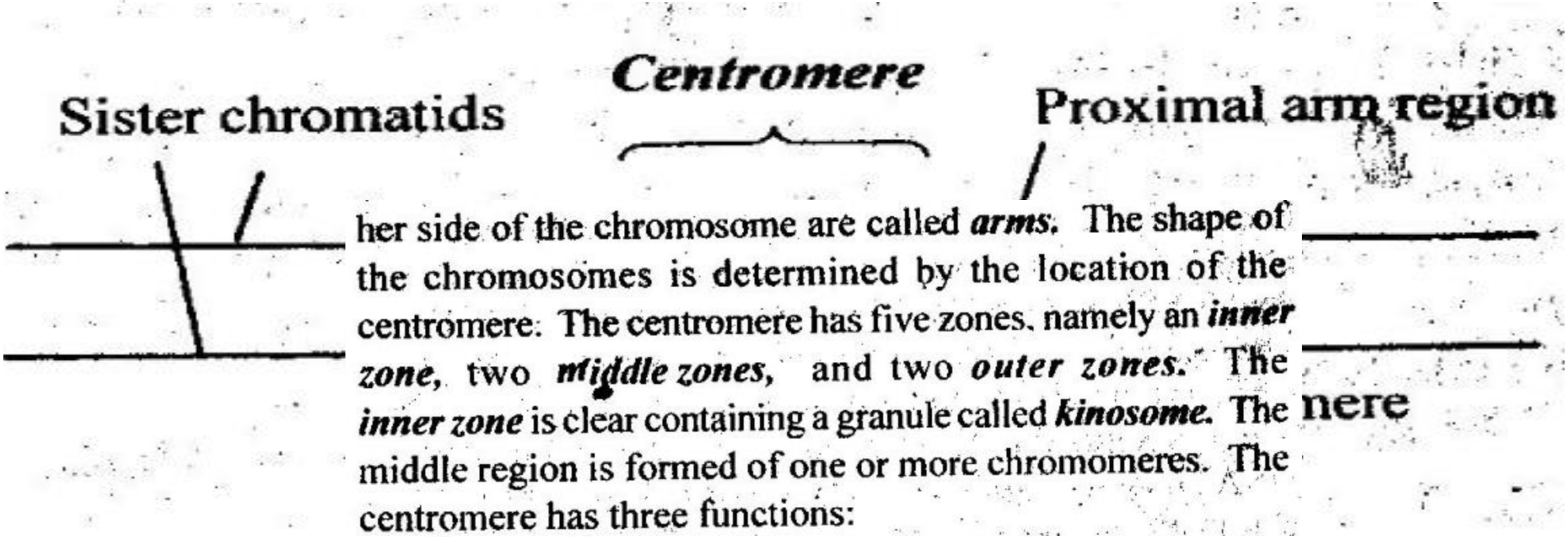
In the meiotic and the mitotic prophase, the chromonema shows alternating thick and thin regions. The thick regions are bead-like structures and are called ***chromomeres.*** The regions in between them are called ***inter-chromomeres.*** It is presumed that genes are located on chromomeres. But some thought that the genes may be located on inter-chromomeres; but it has not been well established.

There is a lighter staining narrow region in the chromosome called ***centromere.*** This narrow region is in the form of a constriction. Hence it is also called ***primary constriction.*** The parts of the chromosome which lie on eit-

her side of the chromosome are called ***arms.*** The shape of the chromosomes is determined by the location of the centromere. The centromere has five zones, namely an ***inner zone,*** two ***middle zones,*** and two ***outer zones.*** The ***inner zone*** is clear containing a granule called ***kinosome.*** The middle region is formed of one or more chromomeres. The centromere has three functions:

1. **Spindle fibres are attached to centromere.**
2. **It helps the formation of spindle fibres.**
3. **It gives shape to the chromosome.**

Centromere.



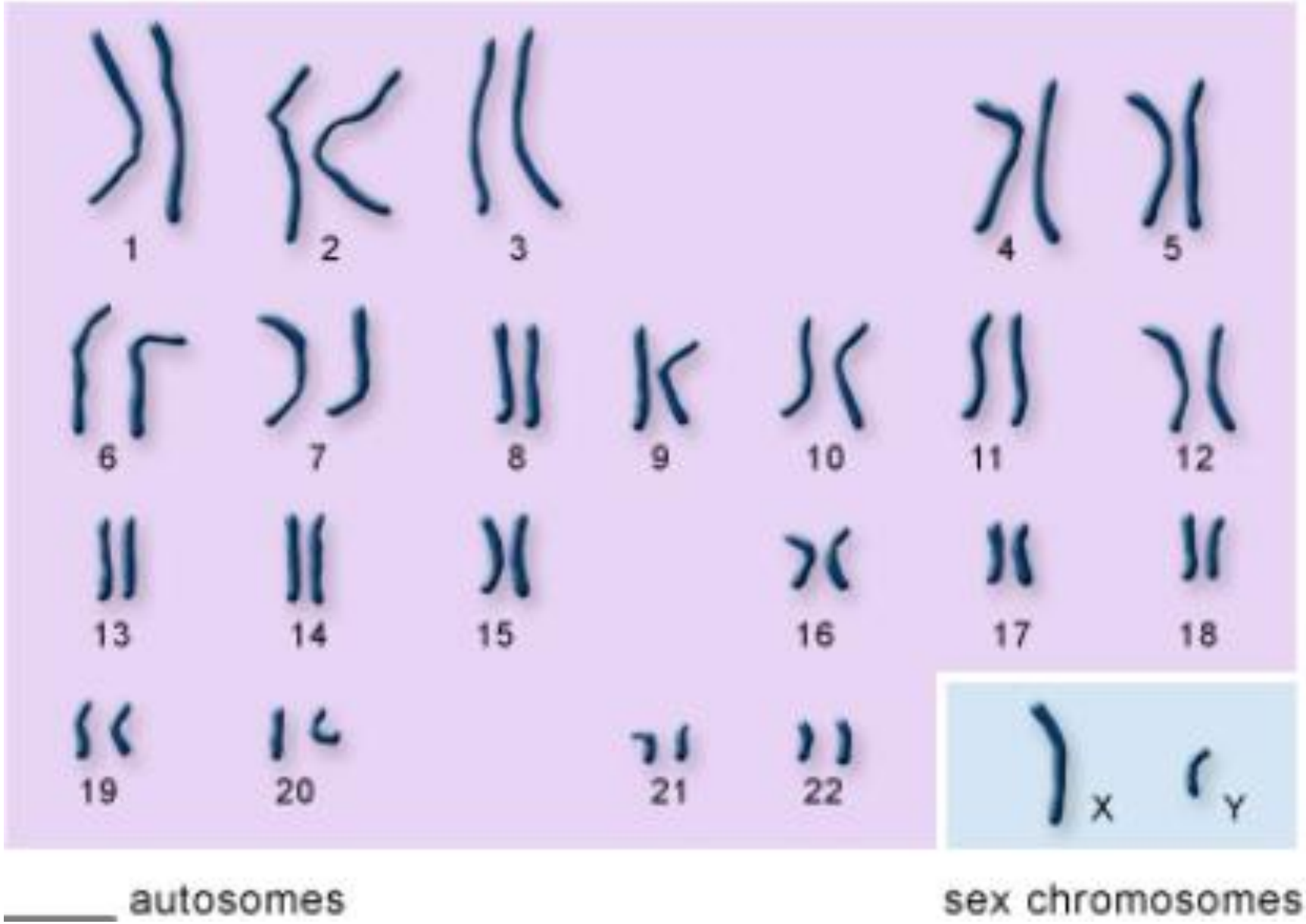
her side of the chromosome are called ***arms.*** The shape of the chromosomes is determined by the location of the centromere. The centromere has five zones, namely an ***inner zone,*** two ***middle zones,*** and two ***outer zones.*** The ***inner zone*** is clear containing a granule called ***kinosome.*** The middle region is formed of one or more chromomeres. The centromere has three functions:

Occasionally, chromosomes contain additional constrictions other than the primary constriction. These are called ***secondary constrictions.*** These are constant in position. The ***secondary constriction*** is sub-terminal in position. It differs from the primary constriction by the absence of marked angular deviations of the chromosomal segments. These constrictions are often associated with the formation of nucleolus. So these are refe.red to as ***nucleolar organizers.*** The chromosomes with these structures are known as the ***nucleolar chromosomes.***

The small piece of chromosome located beyond the secondary constriction is called ***satellite***. It is a round, elongated body and its diameter may be the same as that of the other parts of the chromosome. Chromosomes with satellite are called ***SAT chromosomes*** (Sine Acido Thymonucleinico). The satellites are usually single. But in some cases there may be two or more.

The tips of chromosomes are called ***telomeres (Muller, 1938)***. They determine the polarity of chromosomes. They prevent the joining the ends of the adjacent chromosomes.

The chromonemata are twisted around one another. Each chromonema is formed of about 8 ***microfibrils*** having 60 to 100 A° thickness. Each microfibril is formed of two double helices of DNA. A DNA strand is about 20 A° thick.



Humans have 23 pairs of chromosomes--22 pairs of numbered chromosomes, called autosomes, and one pair of sex chromosomes, X and Y. Each parent contributes one chromosome to each pair so that offspring get half of their chromosomes from their mother and half from their father.

In vertebrates, the chromosomes can be grouped under two groups. They are ***autosomes*** and ***allosomes***. Autosomes are the somatic chromosomes. They are concerned with the vegetative characters of the body. Allosomes are the sex chromosomes. There are concerned with sex characters of the body. They are two types of allosomes, namely ***X*** and ***Y***.

The male of the most species contains XY chromosomes and the female contains XX chromosomes. Generally only one X chromosome is functionally active in an interphase cell. If the cell contains more than one X chromosome, only one X chromosome becomes functional. All the other X chromosomes become inactivated. This inactivated X chromosome is called ***sex-chromatin*** or ***Barr body(Murrar Barr, 1940).***

The diagrammatic representation of the chromosomes or karyotypes showing all the morphological features of the chromosomes of an organism is termed *idiogram.*

Functions of Chromosomes

1. They control the heredity.
2. The chromosomes control the metabolism of an organism.
3. The heterochromatin helps in the formation of nucleolus.
4. Chromosomes control the differentiation of different characteristics of an organism.
5. Changes in the position, number and the structure of chromosomes lead to the formation of new species.

Special Types of Chromosomes

In addition to the normal types of chromosomes, special types of chromosomes with different structure, size, shape and functions have been found in varied groups of animals and plants. These are very useful in cytogenetic studies. The most important are ***giant chromosomes*** and ***supernumerary chromosomes.***

Giant Chromosomes

These are exceptionally larger chromosomes. They are described as unusual chromosomes by ***A.M. Winchester.*** There are two types of giant chromosomes, namely ***polytene chromosomes*** and ***lamp brush chromosomes.***

1. Polytene chromosomes

Polytene chromosomes have the following salient features:

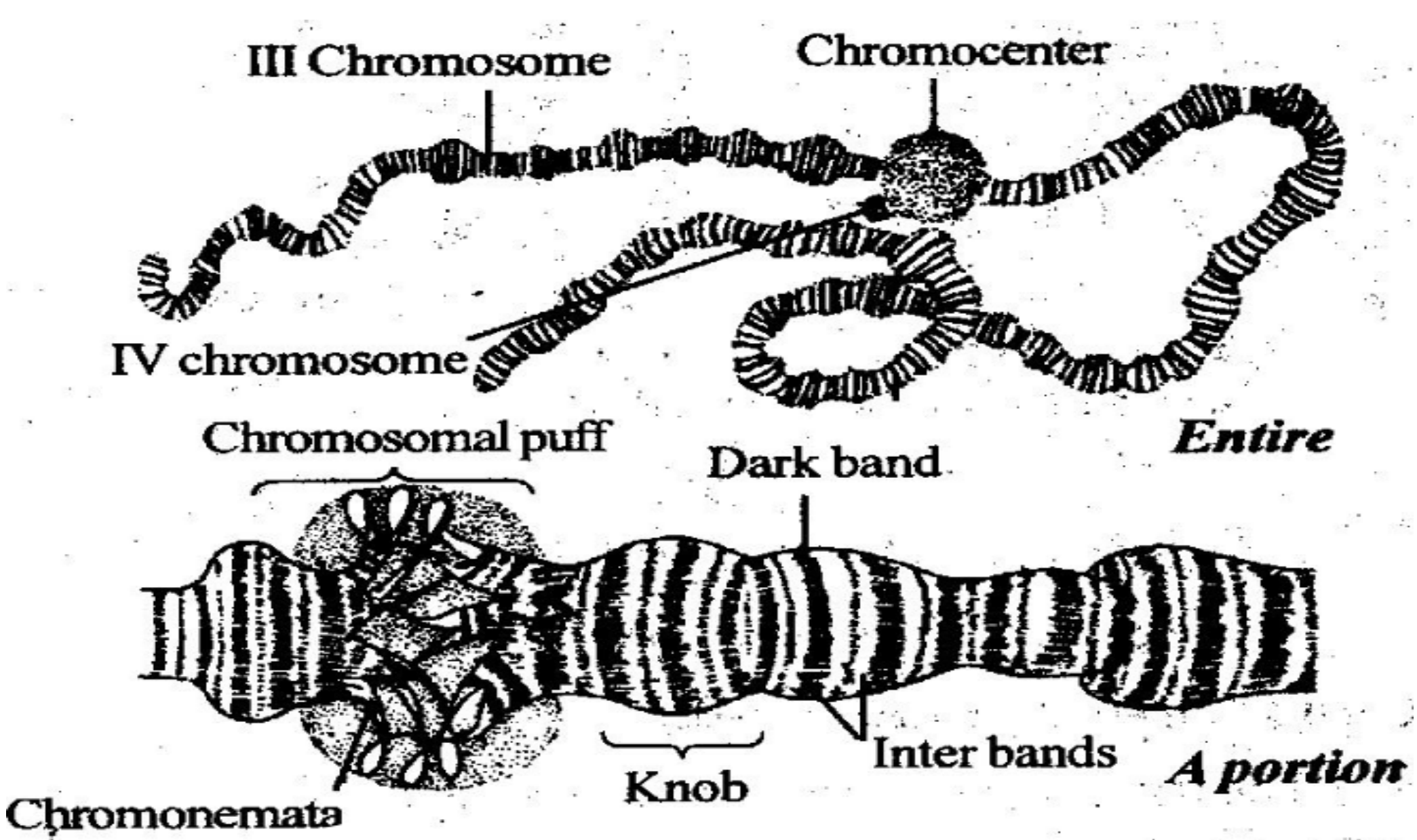
1. It was discovered by ***Balbiani*** in 1881.
2. It is found in the salivary gland cells of ***Chironomus larva.*** Hence it is also called ***salivary gland chromosome.***
3. It is a ***giant chromosome***. It is larger in size. For example, in *Drosophila melanogaster* it is 1000 times larger than somatic chromosomes.

4. The larger size of the chromosome is due to the presence of many longitudinal strands called ***chromonemata***. Hence they are also called ***polytene chromosomes*** (many stranded).

5. The many strands of the giant chromosome are due to repeated division of the chromosome without the cytoplasmic division. This type of division is called ***endomitosis.***

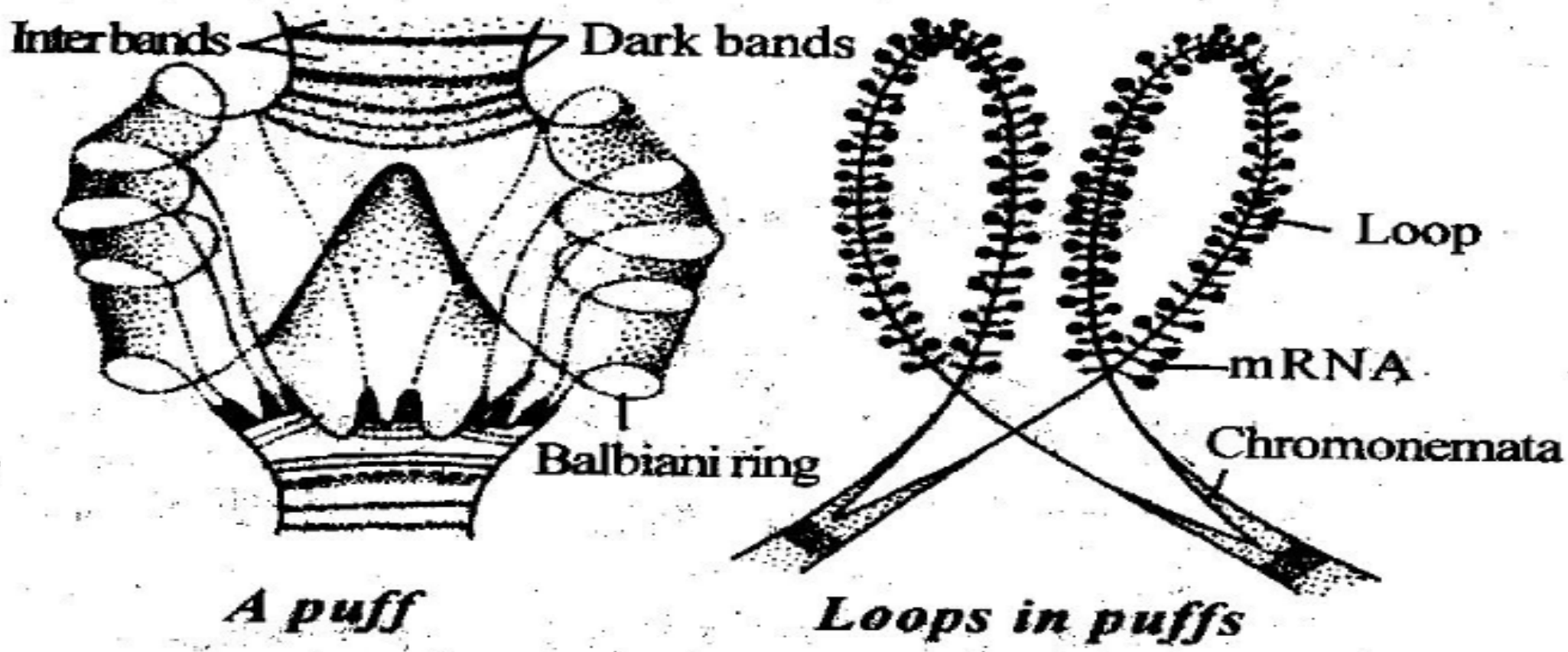
6. The polytene chromosome contains two types of transverse bands, namely ***dark bands*** and ***inter bands.*** The dark bands are darkly stained and the inter bands are lightly stained with nuclear stains. The dark bands contain more DNA and less RNA. The inter bands contain more RNA and less DNA.

7. The bands of polytene chromosomes become enlarged at certain times to form swellings called ***puffs*** or ***Balbiani rings.*** The formation of puffs is called ***puffing.***



Polytene chromosome.

In the regions of puffs the chromonemata uncoil and open out to form many loops. Thus puffing is caused by the uncoiling of individual chromomeres in a band. The puffs indicate the site of active genes when mRNA synthesis takes place.



A puff *Loops in puffs*

Polytene chromosome.

2. Lamp brush chromosomes

The lamp brush chromosome has the following salient features:

1. It was discovered by ***Ruckert*** in 1892.

2. It contains lateral loops and appears like a brush. Hence the name ***lamp brush chromosome.***

3. It is found in the oocytes of *Sagitta, Sepia, Echinaster* (Echinoderm), insects, sharks, amphibians, reptiles, and birds.

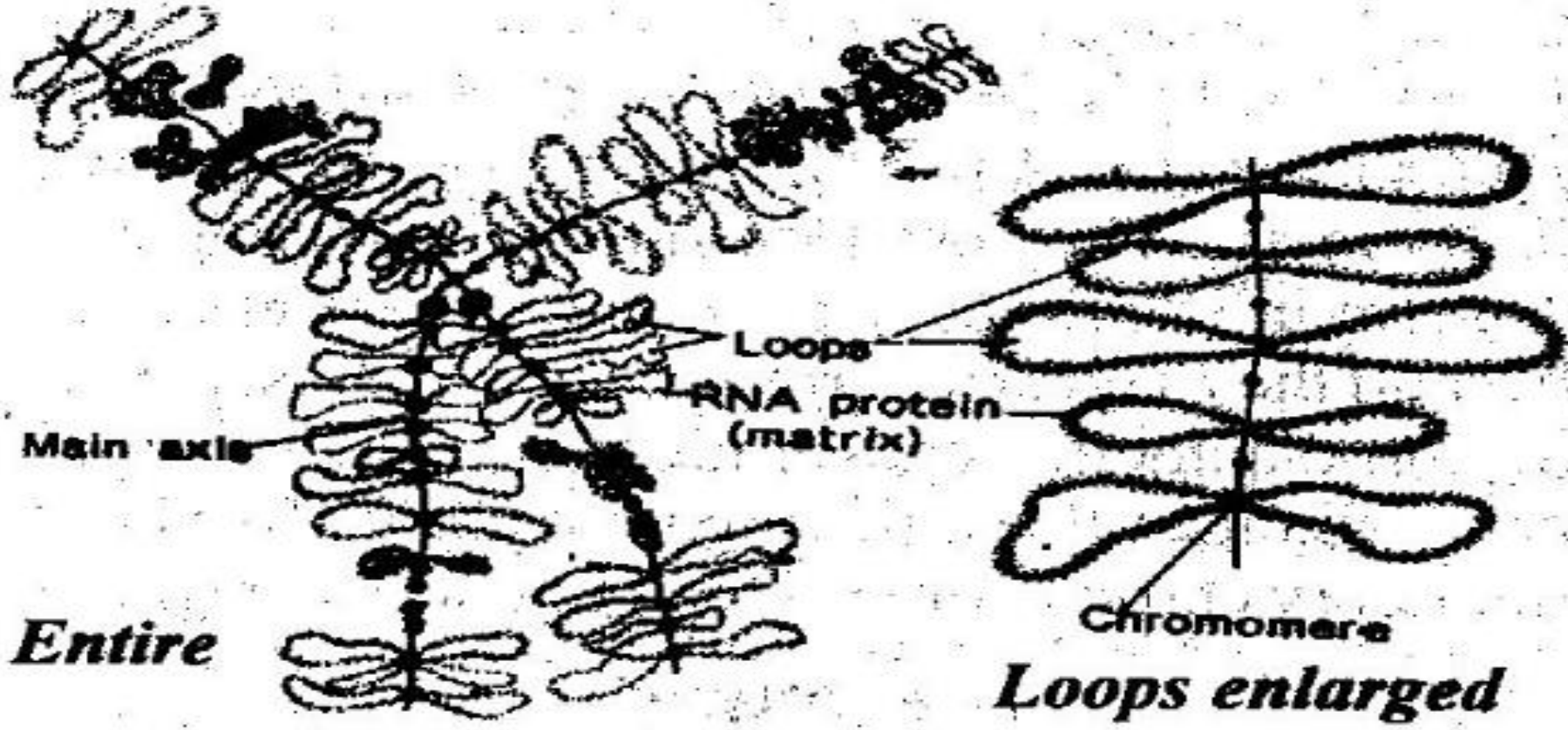
4. It is a ***giant chromosome.*** It is larger in size. Hence it is called a ***giantchromosome.***

5. Each lamp brush chromosome consists of a *main axis* and many *lateral loops.*

6. The main axis of each chromosome is formed of 4 ***chromatids.***

7. The main axis contains a series of thickenings called ***chromomere.***

8. From each chromomere a pair of lateral *loops* one on each side.

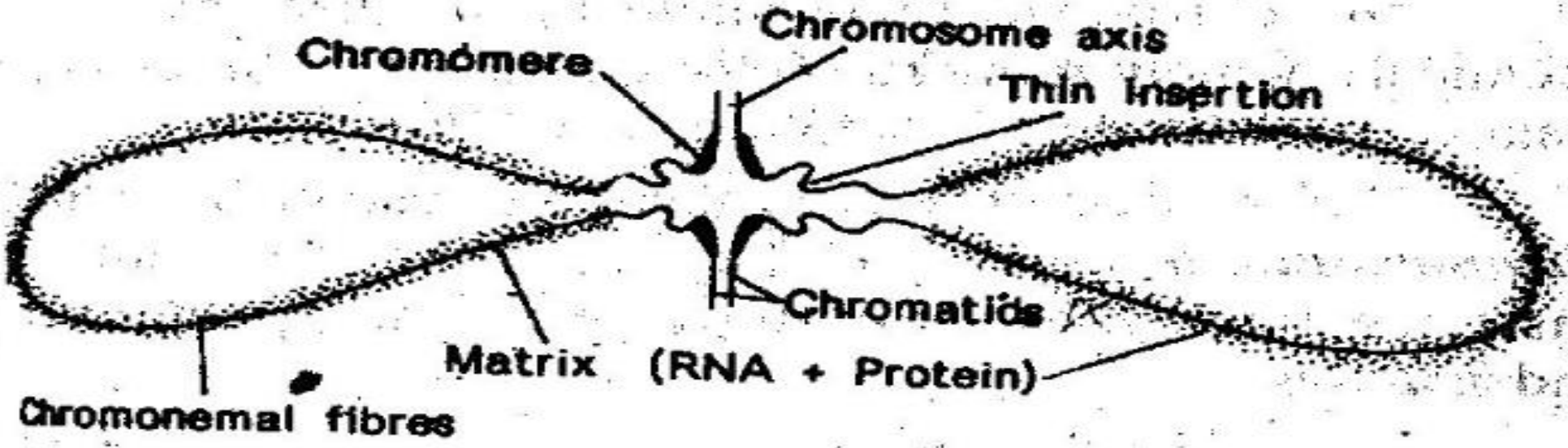


Lamp brush chromosomes.

9. Each loop has an ***axial fibre.*** The axial fibre is the continuation of the chromonema of the main axis. Hence it contains DNA.

10. The axial fibre of the loop is surrounded by a ***matrix.*** The matrix is formed of RNA and proteins. The matrix gives a fuzzy appearance.

11. The synthesis of proteins and yolk takes place in the lateral loops.



lamb brush chromosomes with a pair of loops.

Super numerary Chromosomes

Some plant and animal nuclei, possess one or more extra chromosomes, in addition to normal chromosomes. They are called ***supernumerary chromosomes.*** These are first discovered by ***Wilson*** (1905) in ***Hemipteran*** insect, ***Metapodius terminalis.*** They are smaller in size and genetically inert. They produce little phenotypic effect of the organism in which they are found. These are relatively unstable and they segregate irregularly at meiosis. Undergo somatic non-disjunction and elimination. Their morphology frequently changes through fragmentation. In plants, the supernumerary chromosomes are of unknown origin.

Karyotype

A karyotype refers to the entire set of chromosomes present in a cell.

The 23 pairs of chromosomes of a human cell constitute a karyotype. Similarly the 4 pairs of chromosomes of the cell of a ***Drosophila*** constitute another karyotype.

The karyotype can be studied by photographing the metaphase chromosomes. The photograph showing the chromosomes of a cell is called ***idiogram.***

Heterochromatin

Heterochromatin is the darkly stained condensed regions of chromosomes of the interphase nucleus.

Heterochromatin is associated with tight folding and coiling of the chromosome fibre.

The differential condensation observed in different chromosomes or different regions of chromosomes is called ***heteropycnosis***.

The condensed chromosome is called ***heterochromosome***. The non-condensed chromosome is called ***euchromosome***. The non-condensed chromatin is called ***euchromatin***.

Structure of heterochromatin.

When compared to euchromatin, heterochromatin is ***late replicating***.

Heterochromatin is ***metabolically inert***.