Chromosomes

Chromosomes are self-reproducing thread-like structures packaged with DNA 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.

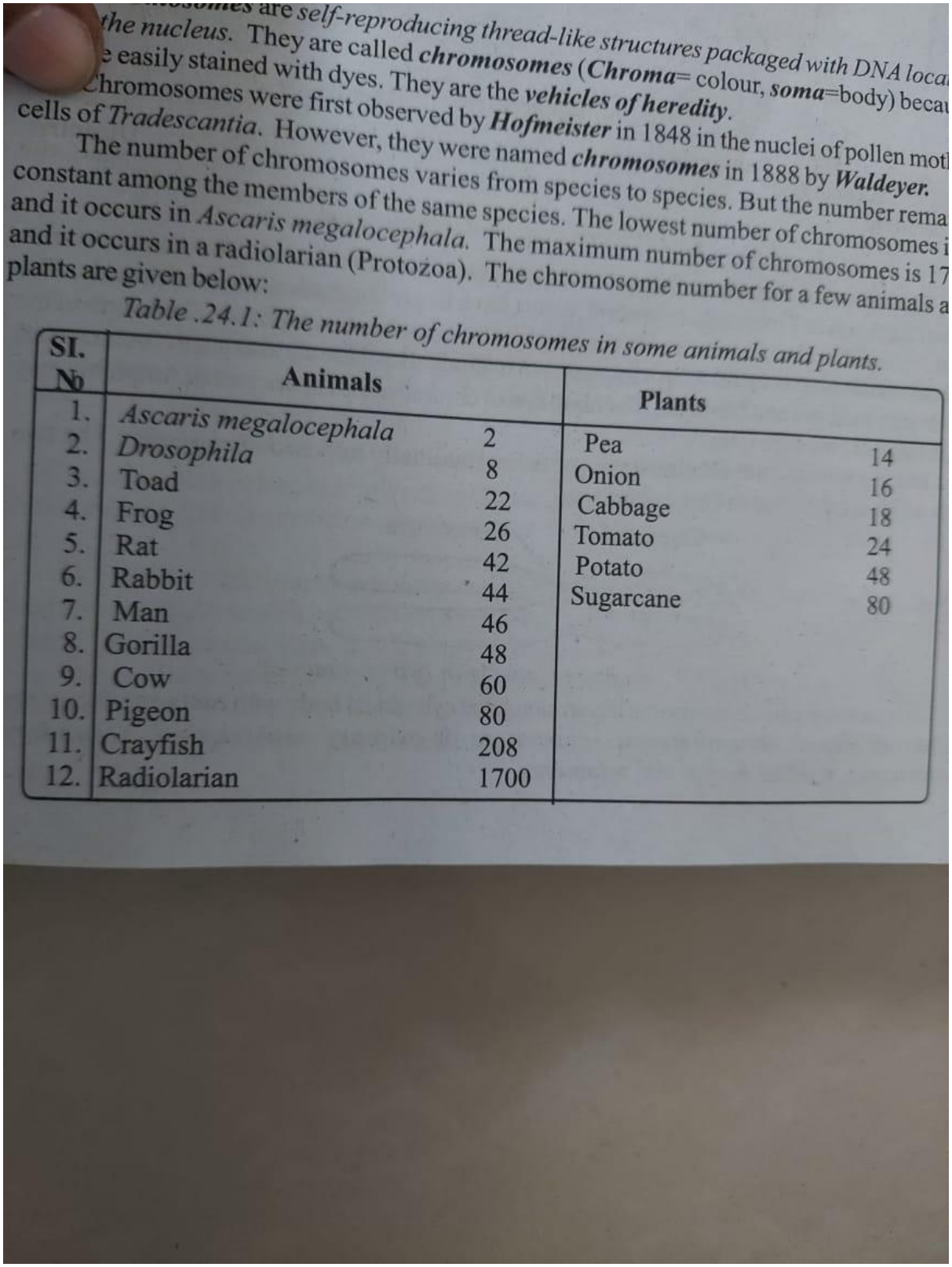
However, they were named chromosomes in 1888 by Waldeyer.

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 in a radiolarian (Protozoa).



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and it occurs in a radiolarian (Protozoa). The chromosome number for a few animals a
plants are given below:

Table .24.1: The number of chromosomes in some animals and plants.

Sl. No	Animals		Plants	
1.	*Ascaris megalocephala*	2	Pea	14
2.	*Drosophila*	8	Onion	16
3.	Toad	22	Cabbage	18
4.	Frog	26	Tomato	24
5.	Rat	42	Potato	48
6.	Rabbit	44	Sugarcane	80
7.	Man	46		
8.	Gorilla	48		
9.	Cow	60		
10.	Pigeon	80		
11.	Crayfish	208		
12.	Radiolarian	1700		

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 is 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 chromosomes is largely determined by the position of its centromere.

On this basis, chromosomes are classified into four types. They are the following:

1. Telocentric: The centromere is located at the end of the chromosome. Such chromosomes are rare. It exits normally in certain species of Protozoa.
2. Acrocentric: These are rod-like chromosomes having a very small arm and a verylong 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.

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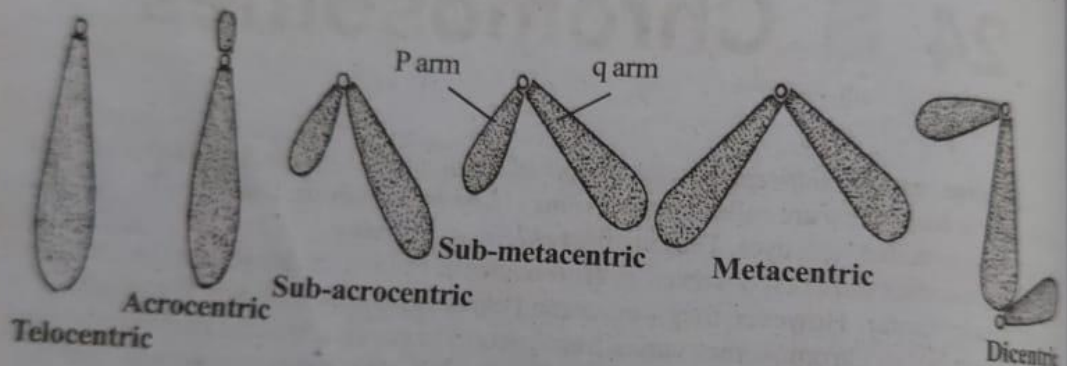

Fig.24.1 : Different shapes of chromosomes.

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 brush*** chromosomes in oocytes of Amphibia may each upto 800 microns long.

During mitosis, the chromosome splits longitudinally into two ***chromatids***. The two chromatids are attached to the centromere.

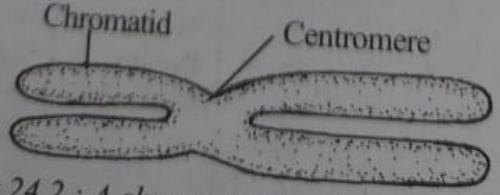

Fig.24.2 : A chromosome with two chromatids.

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

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A typical somatic chromosome has an elongated cylindrical body with two arms.

It consists of chromonema, chromomeres, centromere or primary constriction, secondary constriction, satellite bodies and telomeres.

The chromosome contains two identical, spirally coiled filaments.

They are called chromonemata.

The nature and degree of coiling of chromonemata is variable is 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 meiotic 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.

During cell division, the chromonemata become condensed to form chromatids.

So the chromonemata and chromatids are the two names of the same structure at different stages of the cell.

The DNA wraps around the histones to form a bead-like structure called nucleosome.

Nucleosome is a complex of DNA and histones.

It appears as a string of beads on DNA strand.

The term nucleosome was coined by Oudet in 1975.

The nucleosome consists of a particle and DNA.

The core particle contains 8 histone molecules.

The surface of the core particle is surrounded by a flat super helical strand of DNA that makes 1.75 turns.

The adjacent nucleosomes are connected by a linker DNA.

A single histone molecule binds to the linker DNA.

During interphase certain regions of the chromatin stain darker with Feulgen.

Such regions are called heterochromatins.

The other regions are called euchromatins.

This phenomenon is known as heteropycnosis or differential staining.

Heterochromatin is in close contact with nucleolus.

During mitosis, the heterochromatic regions may stain more strongly (+ve heteropycnosis) or more weakly than euchromatic regions

(-ve heteropycnosis).

There is a lighter staining narrow in the chromosome called centromere or kinetochore.

This narrow region is in the form of a constriction.

Hence it is also called primary constriction.

The part of the chromosome which lie on either side of the centromere are called arms.

The short arm is called p arm and the long arm is called q arm.

The shape of the chromosomes is determined by the location of the centromere.

The centromere has five zones, namely an inner zone, two middle zone 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.

Some 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 referred 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 which satellite are called SAT chromosomes (Sine Acido Thymonucleinico).

The satellites are usually single.

But in some cases there are may be two or more.

The tips of chromosomes are called telomeres.

They determine the polarity of chromosomes.

They prevent the joining of the ends of the adjacent chromosomes.

The telomere is rich in G repeats. The replication of telomere is brought about by telomerase.

The repeated division of chromosome during cell division results in the shortening of telomere.

The aging of man is said to be related to the shortening of telomere.

The life of man can be increased by preventing the shortening of telomeres.

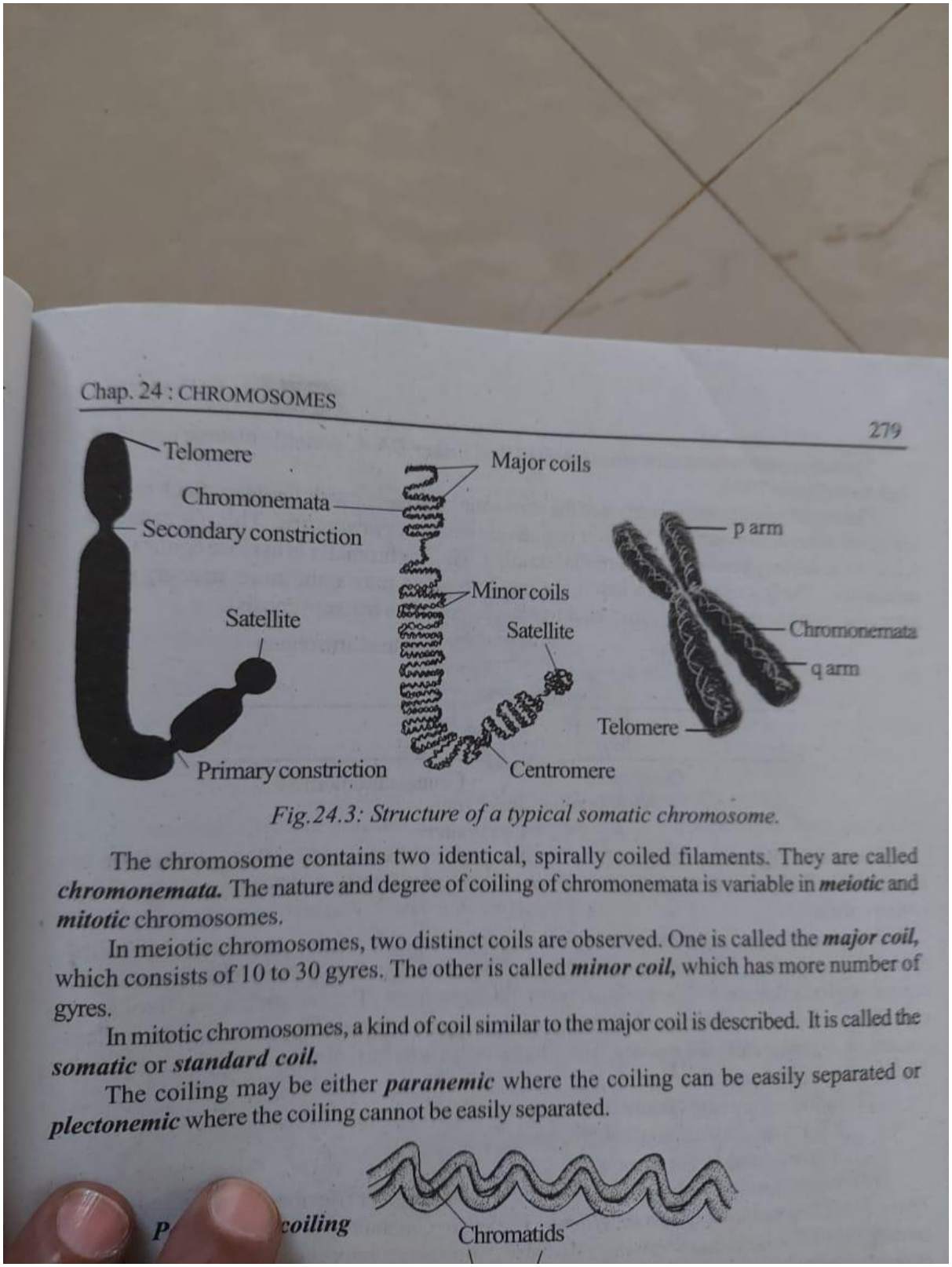

Fig.24.3: Structure of a typical somatic chromosome.

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.***

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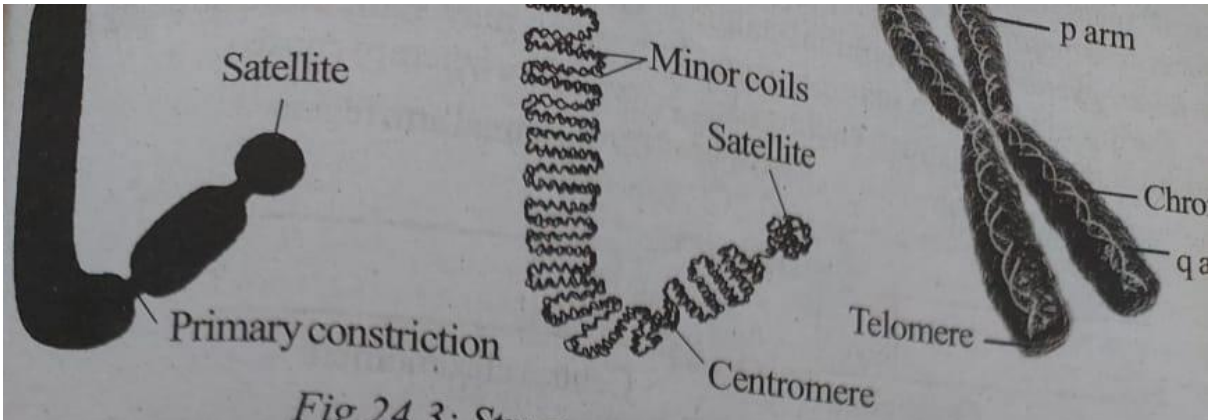

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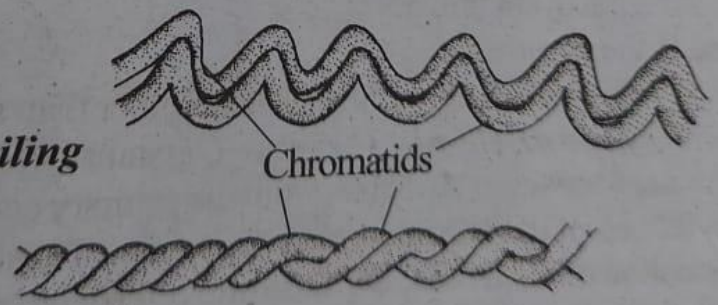

Fig.24.4 : Types of coilings between chromonemal threads.

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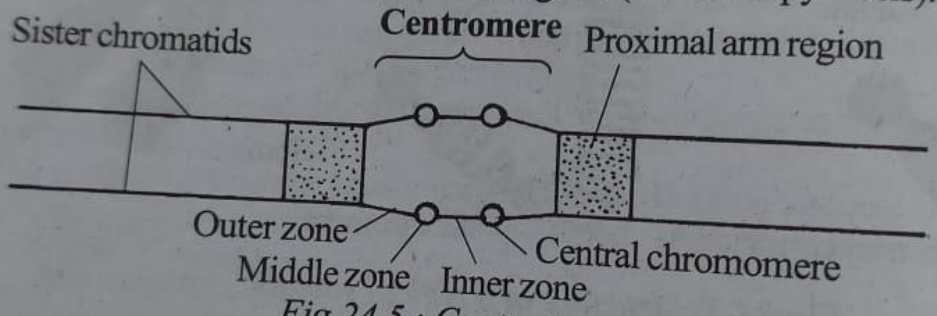

Fig.24.5 : Centromere.

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Chemical composition

Chemically, the chromosomes are formed of nucleic acids and proteins.

About 90% are deoxyribonucleoproteins.

The remaining 10% constitute the residual chromosome.

The DNA proteins are formed of 45% DNA and 55% basic proteins, the histone.

The residual chromosome is the substance of the chromosome remaining after the removal of DNA and histones.

The residual chromosome contains RNA, DNA and residual protein.

The residual protein is acidic in nature, which forms the structural integrity of the chromosome.

If the residual protein is removed , the structural integrity of the chromosome is lost.

Removal of DNA and histone does not affect the structural integrity.

There is another special type of protein called chromosomin formed of high tryptophan.

The linkage between the DNA and protein is the ionic nature and is called salt linkage.

Specific divalent ions, namely Ca^{++}, Mg^{++} and Fe^{++} present in cells form additional linkage in the chromosomes between DNA and protein or between DNA groups.

Functions of Chromosomes

1. They control the heredity. They carry genes from parents to youngones.
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 number and the structure of chromosomes lead to the formation of few species.

Giant Chromosomes

Giant Chromosomes 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.

Polytene Chromosomes

Polytene chromosomes is multistranded chromosome containing 1000 to 16,000 chromonemata (DNA).

- It is giant chromosome.
- It is discovered by Balbiani in 1881.
- They are prominent in the salivary gland cells of Chironomous larva. Hence they are called salivary gland chromosomes.
- They are found in the larvae of dipteran flies such as Drosophila, Chironomous etc.

- They are found in the tissue of salivary gland, gut, fat body and Malpighian tubules.
- The cells containing polytene chromosomes are called polytene cells.
- Polytene chromosome of the salivary gland of Drosophila larva has 1000 Chromonemata and that Chironomous has 16,000 chromonemata.
- The polytene cells are unable to undergo mitosis and are destined to die after metamorphosis.
- The polytene cells are unable to undergo mitosis and are destined to die after metamorphosis.
- The polytene chromosomes are visible in the interphase nucleus.
- The polytene chromosomes are involved in cocoon formation.

- They many stranded condition is formed by endomitosis, chromosomal division without nuclear division.
- In polytene chromosomes, the paternal and maternal chromosomes of a pair remain closely associated with each other. This is called somatic pairing.
- It is 200 micron in length compared to 7.5 micron of somatic chromosome.
- The polytene chromosome has alternating dark and interbands.
- The polytene chromosomes develop enlarged regions here and there. They are called puffs or Balbiani rings.
- The formation of puff is called puffing.
- Puff is the area of gene activity.
- In the puffs the chromonemata uncoil and project out as loops. The loops are the areas of mRNA synthesis.

- The chromosome shows thickenings chromosomes. The chromomeres are tightly coiled areas of mRNA synthesis.
- The diploid cell of Drosophila melanogaster contains 5 pairs of chromosomes. The polytene cell also contains 5 pairs of chromosomes, namely 4 pairs of autosomes and one pair of sex chromosomes.
- All the 5 pairs of chromosomes of a polytene cell become associated with their centromeres in a cluster. The centromeres are fused together to form a disc-like structure called chromocenter.
- The polytene chromosomes of polytene cells appear like a brittle star having a central disc with five arms.
- In the female the two X chromosomes pair together to form a single arm of the brittle star. (I chromosome).

- In the male the single X chromosome remains as a single arm and the Y chromosome is rudimentary. (I chromosome)
- The arms of the 2^{nd} chromosome pair remain as the second and third arms of the brittle star.
- The arms of the 3^{rd} chromosome pair remain as the 4^{th} and 5^{th} arms of the brittle star.
- The fourth chromosomes remain as a bladder.

Lampbrush Chromosomes

The lampbrush chromosome was discovered by Ruckert in 1892. It has the following salient features.

1.It is a giant chromosome.

2. It contains lateral loops and appears like a brush. Hence the name lampbrush chromosome.
3. It is found in the oocytes of Sagitta, Sepia, Echinaster (Echinoderm), insects, sharks, amphibians, reptiles, birds and Acetabularia.
4. They are also found in the spermatocytes.
5. The main axis of each chromosome is formed of 4 chromatids.
6. The length of the lampbrush chromosomes varies from 350 to 1000 milli micron.
7. They have a width of 20 milli micron.

They are meiotic chromosomes

They are seen in prophase I of meiosis.

They are in the bivalent stage.

Paternal and maternal chromosomes are held together by chiasmata.

Each bivalent lampbrush chromosome has four chromatids.

Each chromatid has a chromonema or central axis.

The chromosome has a telomere, a centromere and nucleolar organizer.

The nucleolar organizer produces nucleolus continuously. The nucleoli get separated from the nucleolar organizer and they remain in the nucleoplasm. There may about 1000 nucleoli in a nucleus.

The chromonema has a series of thickenings called chromomeres. In the chromomeres, the DNA is tightly coiled.

Each chromomere produces a loop on one side. The loop is the outward extension of the chromonema of DNA.

The loops are symmetrical, each chromosome having two of them, one for each chromatid.

There may be 10,000 loops per chromosome.

On either side of the base of the loop, the chromosomes produce thick insertions and thin insertions.

The loop consists of a DNA chain and matrix. The DNA is surrounded by matrix. Matrix is made up of RNA and RNP (Ribonucleoproteins).

The lampbrush chromosomes are concerned with synthesis of yolk in the eggs.

Operon concept

Operon theory is the concept of gene regulation proposed by Francois Jacob and Jacques Monod (1961). An operon is a group of structural genes whose expression is coordinated by an operator. The repressor encoded by a regulatory gene binds to the operator and represses the transcription of operon.

Operon, genetic regulatory system found in bacteria and their viruses in which goes coding

for functionally related proteins are clustered along the DNA. This feature allows proteins synthesis to be controlled coordinately in response to the needs of the cell.