CHAPTER - 08
CELL CYCLE AND CELL DIVISION

All cells reproduce by dividing into two the cell which undergo division is called parental cell and new cells formed are called daughter cells. The newly formed cells are again filled with protoplasm and hereditary materials. The karyocytoplasmic index or karyoplasmic index or nucleocytoplasmic ratio changes. So the cell again divided and thereby Nucleocytoplasmic ratio decreases. Cell division was first observed by Prevost and Dumas in animals (Zygote of frog) and Nagali in plants.

During cell division DNA replication and cell growth occurs. All the events that takesplace in between two successive cell division is called cell cycle that is the sequence of events by which a cell duplicate its genome. Synthesis of cell constituents and finally the cell divide into daughter cells is termed as cell cycle. It is first described by **Howard and Pelc**. Cell growth is a continuous process while DNA synthesis occurs only during one specific stage of cell cycle. It is under genetic control. The duration between two cell cycles is called generation time. It varies from cell to cell.

Human cell (typical) - 24 hrs.

Yeast cells - 90 minutes

E.coli - 20 minutes

Cell cycle is divided into two main phases.

1. Interphase or I phase or Intermitosis

2. M phase

Interphase - It is also called resting phase, but it is the most active phase which prepare material and energy for the next division. It last for 95% time duration of cell cycle. There is 24 hrs. cell cycle time of human cell 23 hrs. for interphase and 1 hrs. for division. This is a period with intense biosynthetic activity takes place. So it is known as preparatory phase. Interphase is further divided into three stages. They are :

A) G1 or first gap phase - between M phase and S phase, duration 10 - 12 hrs, spent 41% of total time of cell cycle. Largest phase, cell is metabolically active and grow. There synthesis :

1. Proteins for DNA duplication (enzyme)

2. Raw material for DNA duplication (Nucleotide, sugar and phosphoric acid) ATP and all type of RNA, cell organelle also synthesis there.

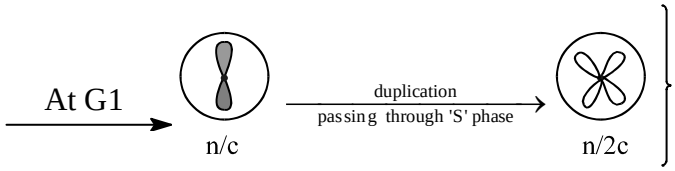
B) S-phase or Synthetic phase / or Synthesis phase duration: 6 to 8 hours spent 33% time between G1 and G2 where

1) duplication or replication of DNA takes place

2) Formation of Histone protein takes place

3) Division of centrosome or centriole duplicate when 'S' phase complete the amount of DNA in a cell becomes double in

i) Haploid cell (Cell with one chromosome for a character)

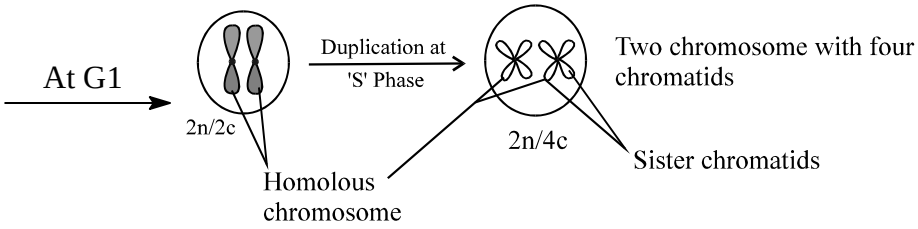


one chromosome with two chromatids
the chromosome number canot change
because chromatids attached centromere

'n' number of chromosome

'c' number of chromatid or DNA content

ii) In diploid cell - Cells with two chromosome for a character one from father (paternal) and one from mother (maternal). Both control similar characters so called homologous chromosome.



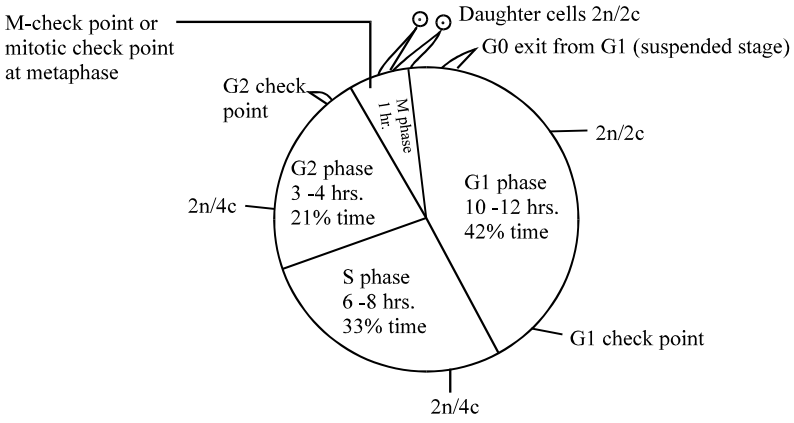
C) G2 phase, Gap phase - 2, Growth phase - 2 duration 3 to 4 hours spent 21 percent time

In this the cell continues to grow and prepare for division. DNA duplication stop synthesis of RNA, proteins and ATP continues. Tubulin protein that is used for the synthesis of spindle fibres is synthesised linear among cell organella mitochondria and plastids are formed in this stage. G2 phase take up 21% time of cell cycle.

D) G0 or quiescent stage or phase

In some case cells divided only occasionally these cells that donot divided further it exit from G1 phase and enter into a suspended inactive stage called G0 or quiescent stage. These cells are metabolically active but can't proliferate or differentiate till it reenter in to the cell cycle depending on the requirement of organism.

M-phase or Dividing phase : The actual phase of cell division. When a cell enter into dividing **phase there is no change in the rate of metabolism** that is the metabolic rate remain same.



A cell go for G0 phase due to the absence of Mitogen or ATP.

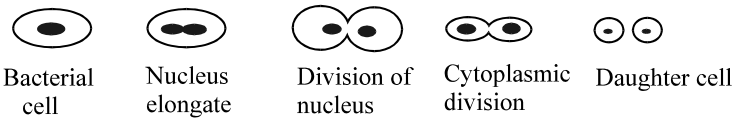
Mitogens are chemical which trigger cell division. eg. Cytokinin, Auxin (in plant), Lymphokinase and epidermal growth factor in Animals.

M-phase is dividing phase. There are three type of cell division.

1) Amitosis 2) Mitosis 3) Meiosis

1. Amitosis : It is primitive type of cell division. First reported by Robert Remak and described by W. Flemming.

It takes place in prokaryotes like bacteria, cyanobacteria and eukaryotes like Dinoflagellates, yeast, diseased cell and in old cells. In this the nucleus elongates and divided into two. In between the nuclei cytoplasm also divide and form two unequal daughter cells without spindle formation and disappearance of nuclear membrane. So this division is also called **Direct division** and endonuclear division. There is no spindle formation.



Mitosis

Cell division occurs in vegetative and reproductive cells.

In plants it takes place in haploid (n) diploid (2n) and polyploid cells. But in animals mitotic division takes place in Diploid cells except some social insects like honey bees. It is an equational division in which chromosome number of parental cell and daughter remain same.

Mitosis produce two daughter cells. Mitosis was first described by Strasburger in plants and then Flemming in animals. The term was coined by W. Flemming. Best material to study mitosis is **Root tip cells**. Mitosis takesplace in two stages.

1. Karyokinesis - Nuclear division

2. Cytokinesis - Cytoplasmic division

1. Karyokinesis

Division of nucleus, it is further divided into four stages. They are

(i) Prophase

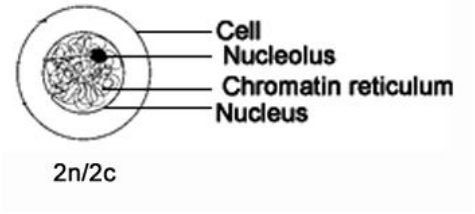
(ii) Metaphase

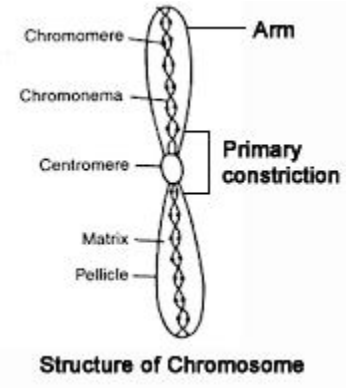
(iii) Anaphase

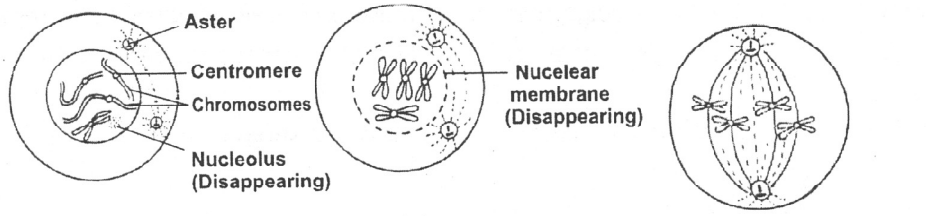
(iv) Telophase

(i) Prophase

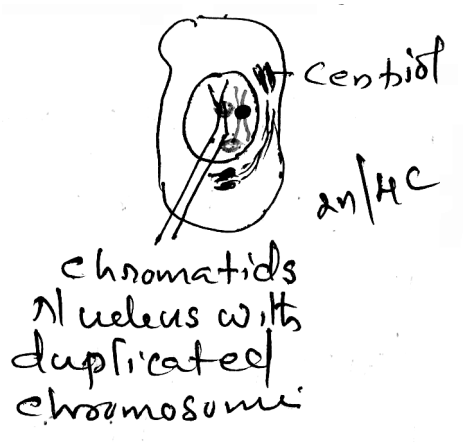
First stage of karyokinesis and longest phase. Marked by the initiation of condensation of chromosomal material in the parental cell before division starts. Chromosomal material celled chromatin (formed of DNA and Histon protein) exist as thread called thromatin thread. It form a ball like mass of wool called spireme stage. In the early prophase condensation and spiralisation leads to the formation of **chromonemata**. During condensation the area of genes condense first and appear like beaded. The bead like portions are called **chromomeres** the chromonemata surrounded by matrix and pellicle form chromosome.







At middle prophase each chromosome split longitudinally except centromere and each half is known as chromatids. Along with this the centriole move to the two poles of the cells (opposite poles of the nucleus)



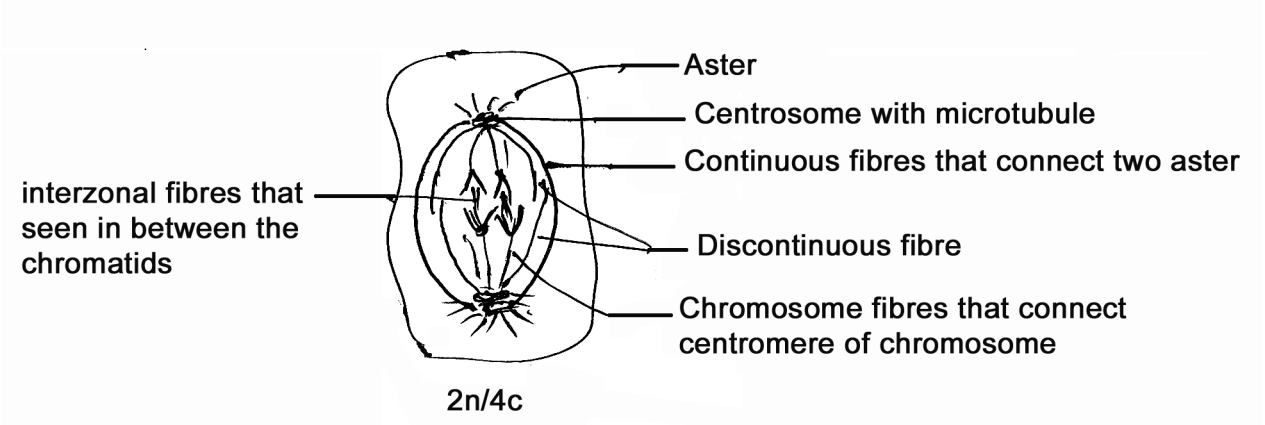
At late prophase nucleolus, nuclear membrane and cell organella disappear chromosomes are more condensed and spindle fibres are arising from spindle apparatus when centriole reach the two pole it produce protein fibres centriole and protein fibre constitute Aster. It is seen in animal cells so in animal cells mitosis is **asteral** and it takes place in between two aster so called **centric** but in plants spindle fibres are formed from MTOC (Micro Tubular Organization Center) There is no aster so mitosis is **Anastral** and **Acentric**. Aster produce four type of spindle fibres formed of a protein known as **tubulin**. The four type of spindle fibres are

1) Continuous fibre

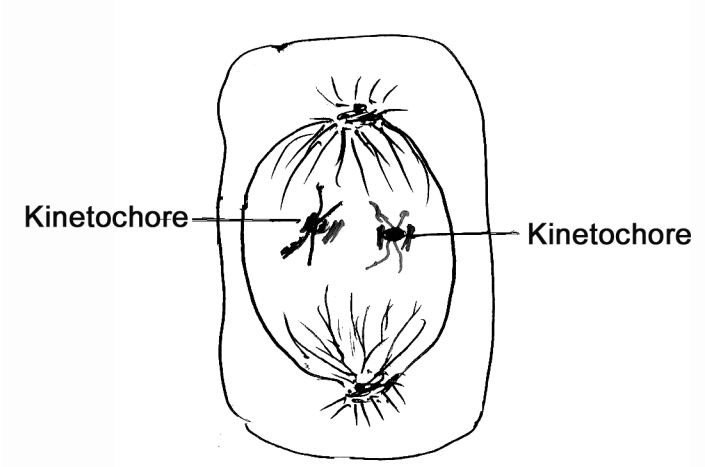
2) Chromosome fibre

3) Discontinuous fibre

4) Intersonal fibre



The two asters together with spindle fibres form mitotic apparatus. The middle broad part of spindle apparatus is called equator.



Chromosome scattered in the cytoplasm. Spindle fibres extended towards the centre kinetochore develops on either side of the centromere.

(ii) Metaphase

This is marked by the complete disappearance of the nuclear envelope. Chromosome are thick, short and distinct there for structure or morphology of chromosome is studied in Metaphase. Spindle fibres are connected to the kinetochore. The centromeres of the chromosome arranged in a linear sequence at the equator and arms of the chromosome lie in different direction. This is known as metaphase plate.

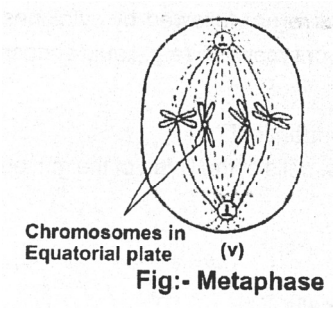
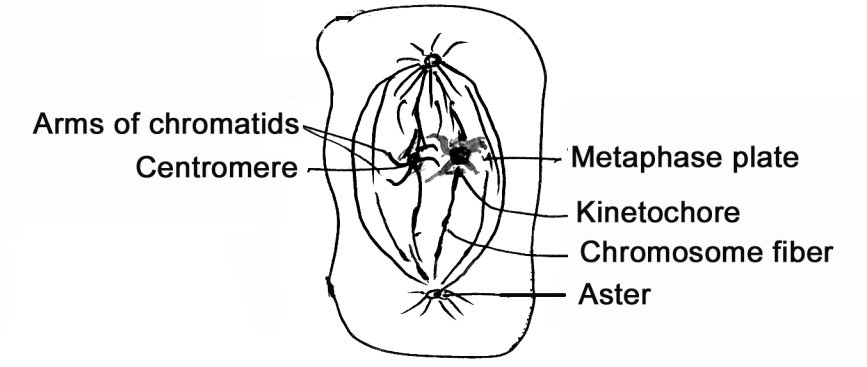
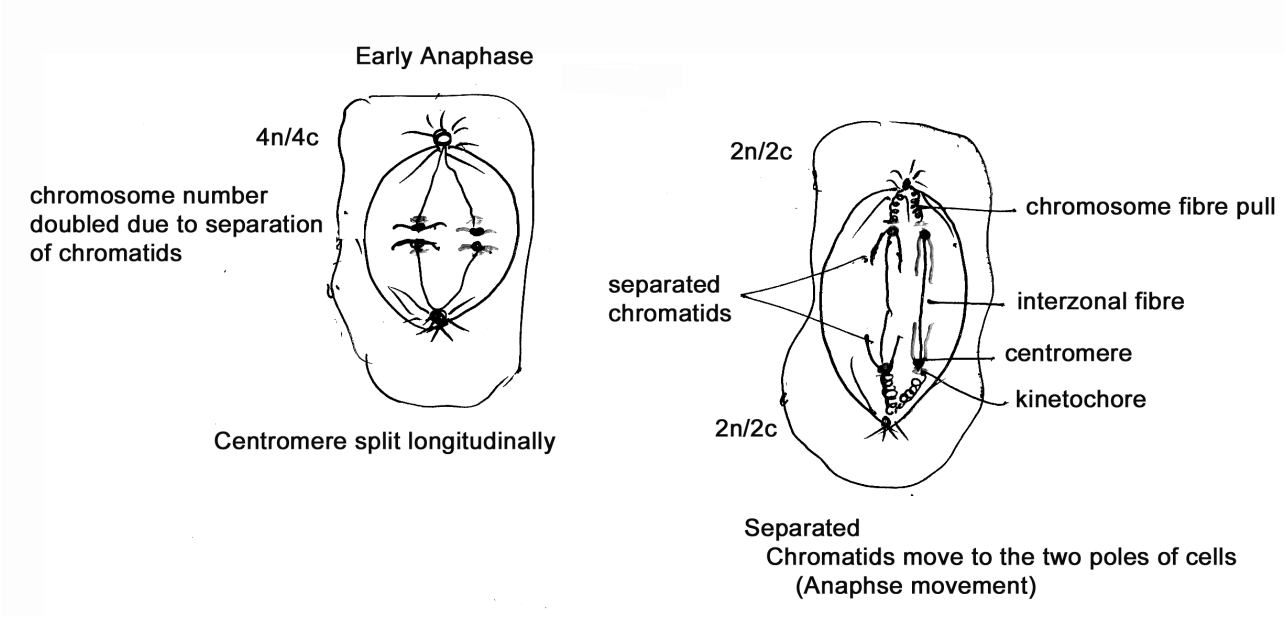


Fig:- Metaphase



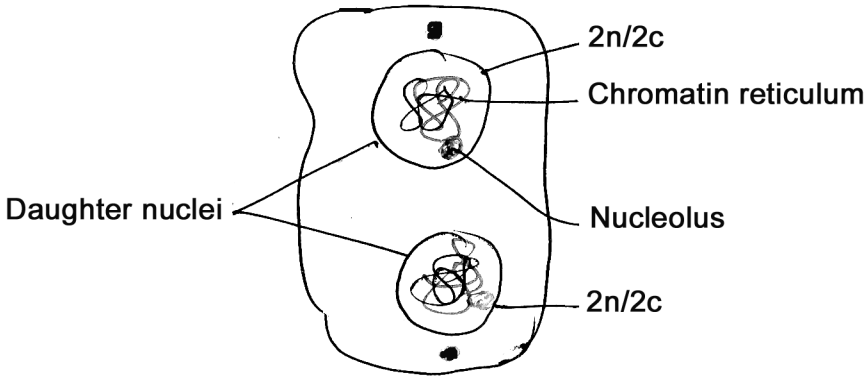
Anaphase

Anaphase promoting complex (APC) activated is a ubiquitin ligase complex that initiates the process of separation of sister chromatids due to the activity of this centromere split longitudinally and chromatids separated as a result number of chromosome become doubled. After that the chromatids move to the two poles of the cells. In this movement centromere move first and arms behind it. The movement is due to the pull created by the chromosome fibre and pull created by the interzonal fibre during this movement chromosome attain definite shape. Metacentric chromosome 'V' shape, Submetacentric 'L' shape, Acrocentric 'J' shape and Telocentric 'i' shape. Metacentric '  ', Submetacentric '  ', Acrocentric '', Telocentric '' shape of chromosome is studied in this stage.



Telophase

It is opposite to the prophase in this chromatids reach the two poles of the cell they again uncoiled cell organalle nuclear membrane and nucleolus reappear thus two daughter nuclei are formed in the cell. The daughter nuclei contain chromosome number equal to the parental nuclei. So mitotic division is called equational division.



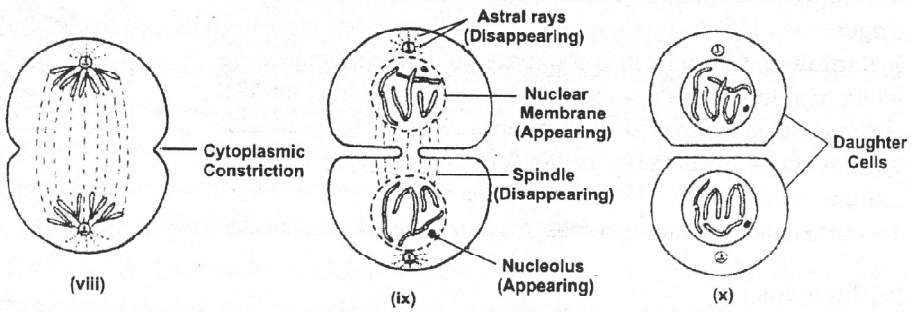
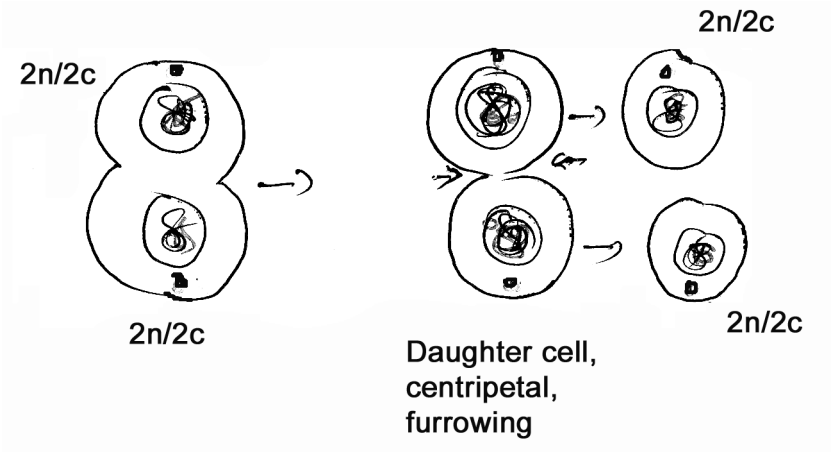


Fig:- Early Telophase

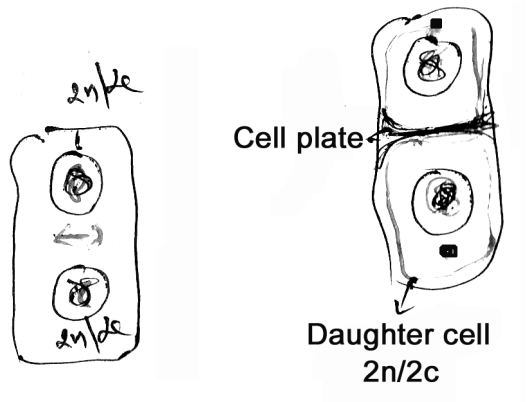
Fig:- Late Telophase

Cytokinesis

In animal cell a furrowing is formed in between the nuclei from periphery to centre so division is centripetal and divide the cell into two daughter cells.



But in plant cell a cell plate is formed in between the two nuclei called phragmoplast (it is the vesicle of golgi complex). It extended towards the periphery and divided the cell into two. The phragmoplate later forms the **middle lamella** the cell plate formation is centrifugal (from centre to peripheral part of cell). In some organism karyokinesis is not followed by cytokinesis that leads to multinucleate condition leads to the formation of syncytium. (liquid endosperm of coconut).



Significance of mitosis

1. Restore nucleocytoplasmic ratio
2. Leads to growth
3. Involved in cell repair, regeneration and differentiation
4. Leads to asexual reproduction and multicellularity

Meiosis

First described by Hertwig, then by Beneden Terms was coined by Farmer and Moore. The best material to study meiosis is **immature anther**. Meiosis takes place in two phases, Meiosis I and Meiosis II.

Meiosis I is further divided into

Prophase I It is the longest phase, it is further subdivided into 5 stages namely Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.

Metaphase I

Anaphase I

Telophase I

Cytokinesis I

Meiosis II It is further divided into prophase II, Metaphase II, Anaphase II, Telophase II, Cytokinesis II. In between Meiosis I and Meiosis II there is a resting phase called Interkinase. In this cell itself is prepared for second division. Meiosis also have interphase it consist of G_1, S and G_2 . Of this G_2 is short or some case it is absent and in this centrosome and centriole duplicate. Meiosis takesplace only in diploid cells. It takes place in diploid and haploid organisms.

Types of Meiosis

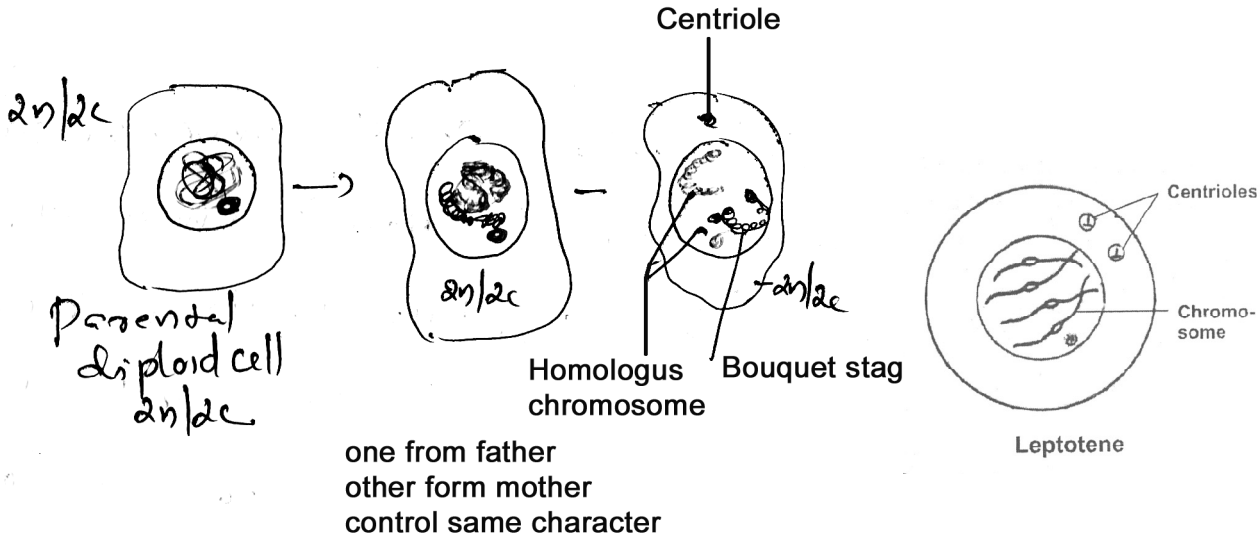
1. Zygotic Meiosis or initial meiosis takesplace in haploid organism like chlamydomonas. In this two gamete formed through mitosis fuse and form zygote. Zygote undergo meiosis so called zygotic meiosis. It leads to the formation of haploid organism so called **initial meiosis**.

2. Sporic meiosis : takes place in plants for the formation of spore from spore mother cell (diploid). It takesplace at the middle of the life cycle of plant like pteridophyte and prophyte so called **intermediate meiosis.**

3. Gametic Meiosis or Terminal meiosis for the formation of gamete from germinal cell so called terminal meiosis takes place in **animals.**

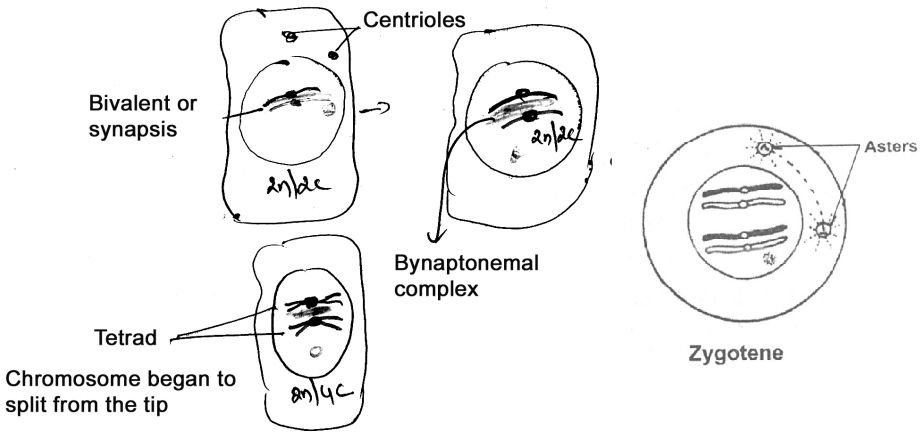
I. Meiosis I - Prophase I

Leptotene stage



Chromatin condensed to form chromosome during condensation it appears like bouque so this stage is called bouquet stage. Centromere not clear.

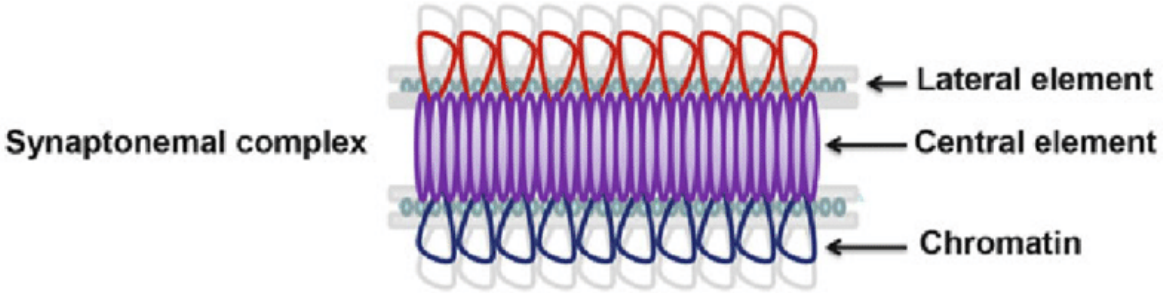
Zygotene



In this chromosome are more thick and short and homologs. Chromosome pair their entire length due to the help of synaptonemal complex. (It is a trilaminal protein complex formed of ubiquiten) and form bivalent or synapsis.

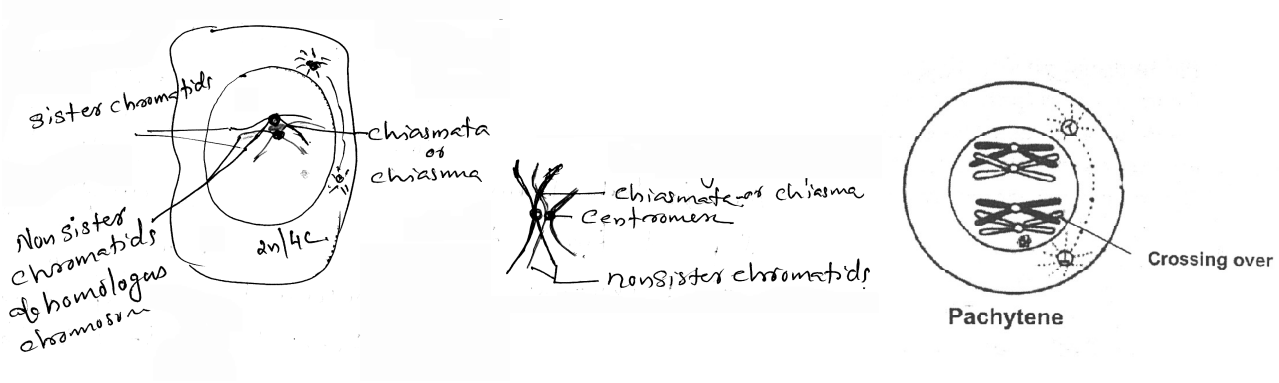
The bivalent chromosome began to split from the tip and form tetrad but it is visible only at **pachytene stage.**

by mosses synaptonemal complex first observed



Pachytene

It is the longest stage in which non sister chromatids of homologus chromosome exchange their genetic material called crossing over. The region at which crossing over takes place is known as chiasmata or chiasma. But is it visible only at the diplotene stage. Crossing over is an enzyme mediated process. The enzymes are located in the recombinant nodule and the enzyme is collectively called recombinase it contain endonuclease for cutting DNA and Ligase for rejoining fragmented DNA.

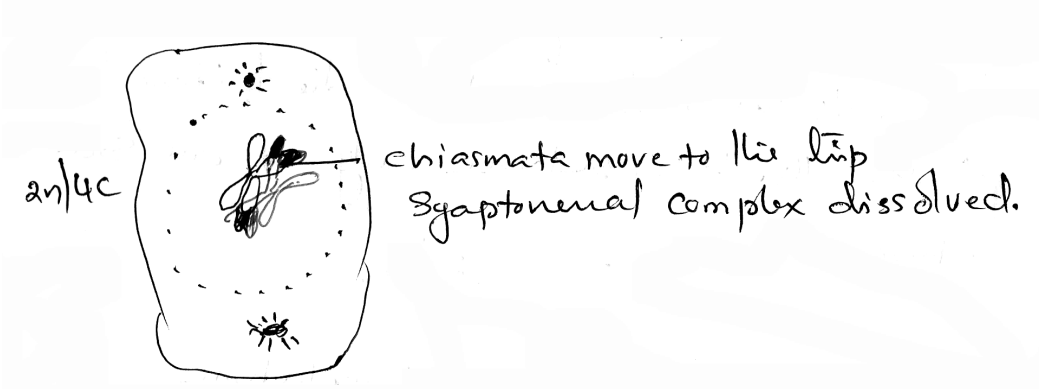


Crossing over takesplace near the centromere. The synaptonemal complex start to dissolving when crossing over proceeded.

Crossing over : it is first observed by **Morgan**.

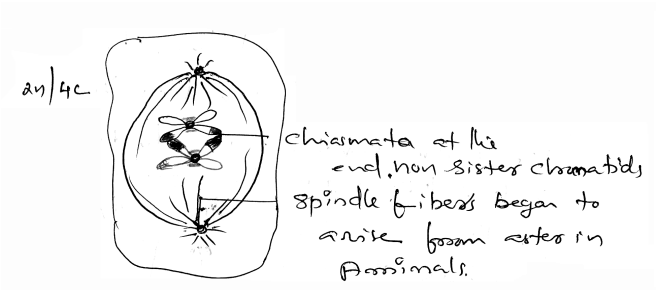
Diplotene

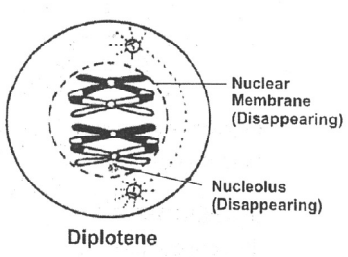
This is a shortest stage marked by the complete dissolution of synaptonemal complex and chiasma is clearly visible. Now the chiasmata began to move from centromere region to the tip. In the oocytes of some vertebrates diplotene last for months or years. There the chromosome enlarged in size and are called Lamp brush chromosome. Nuclear membrane and nucleolus start disintegrating.

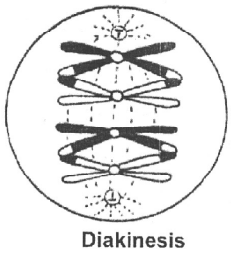


Diakinesis

It is the last short substage of prophase I. Separation of Homologus chromosome proceeded towards the terminal part known as terminalisation. It is by the shifting of chiasmata towards the end of chromosome. Centrioles are reached on opposite poles. From aster spindle fibres began to produce nuclear membrane and cell organalle disintegrate and duplicated homologus chromosome lies in the cytoplasm.

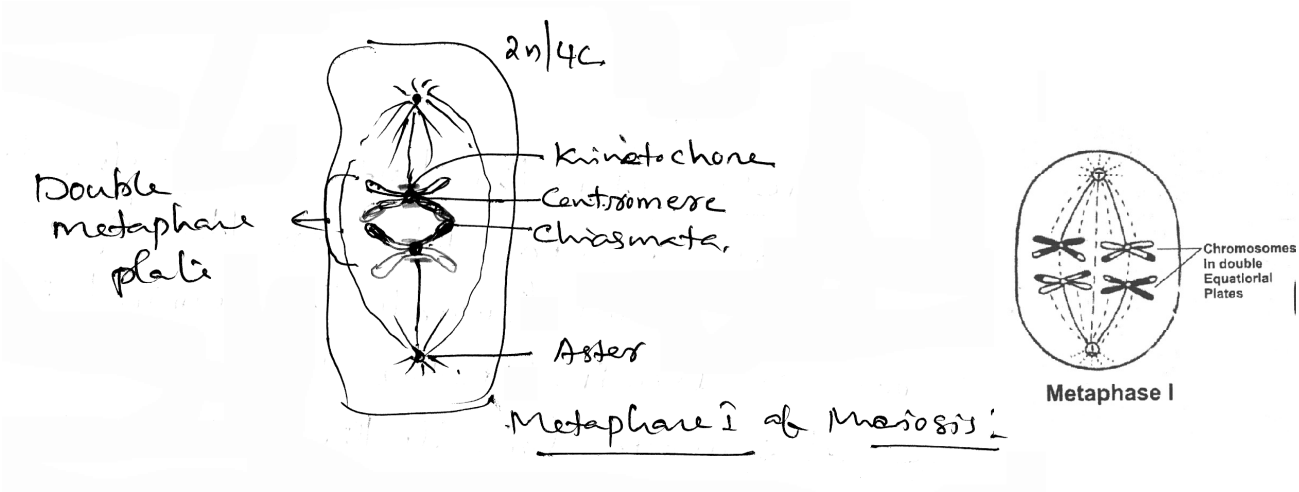






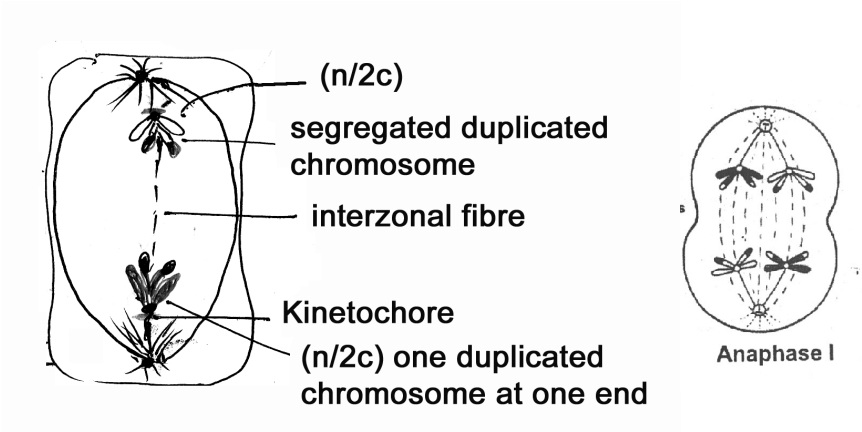
Metaphase I

Bivalent chromosomes that of which chiasmata are connected align on the equatorial in two row and form double metaphase plate. In this the arms of homologus chromosomes lies parallel to the equator and centromere projected towards the poles and spindle fibres are connected towards the kinetochore only at one side of the chromosome.



Anaphase I

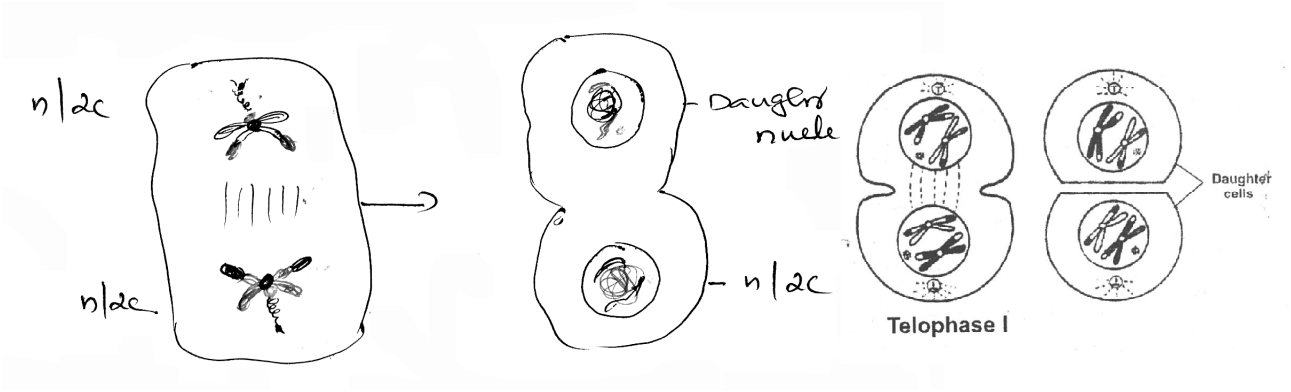
In this homologus chromosome separate by the separation of chiasmata while the chromatids remain attached at the centromere that is the centromere is not dividing. And thereby duplicated chromosomes move to the two poles of the cells and thereby the chromosome number of the nucleus because half while the DNA content is double (n/2c). This leads to the segregation of **Mendelian factor.**



At the end of anaphase chromosome reach the two poles of the cell. This process is called **Disjunction.**

Telophase I

In this stage chromosome reach the two poles they gain uncoil become thin and elongated nucleolus and nuclear membrane reappear and thus two haploid nucleus are formed with double the amount of DNA (n/2c). Cytokinesis may or may not be takesplace.



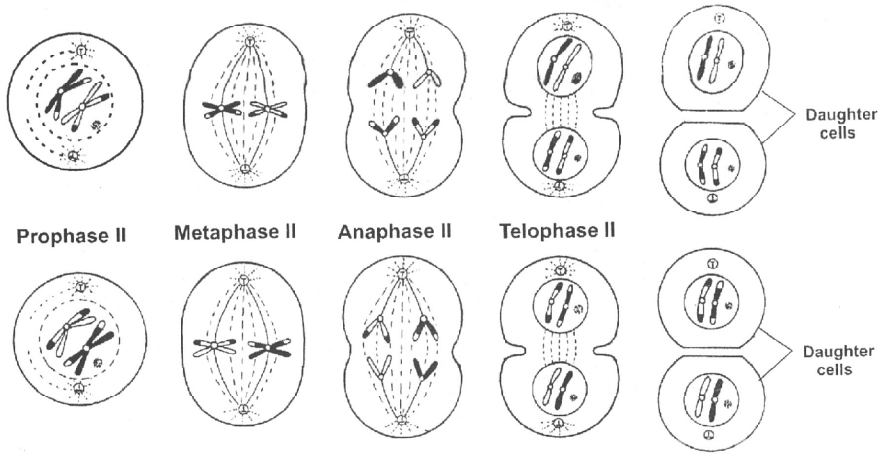
This leads to the formation of two daughter cells. With half the number of chromosome of parental cell (parental cell 2n/2c, Daughter cell n/2c) Therefore meiosis I is called **heterotypic division. Reduction division of chromosome** takesplace in Meiosis I.

Meiosis II

It is initiated immediately after cytokinesis usually before the chromosome have fully elongated. It takesplace in two daughter cells simultaneously and almost resemble a normal mitosis.

Prophase II

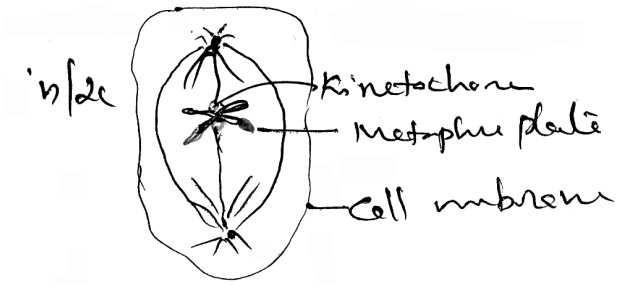
In both the cells chromosome again become compact and nuclear membrane disappears.

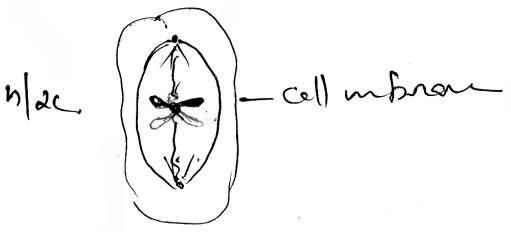


Spindle fibres arise from the pole opposite to the centromere or at rightangle to the first division.

Metaphase II

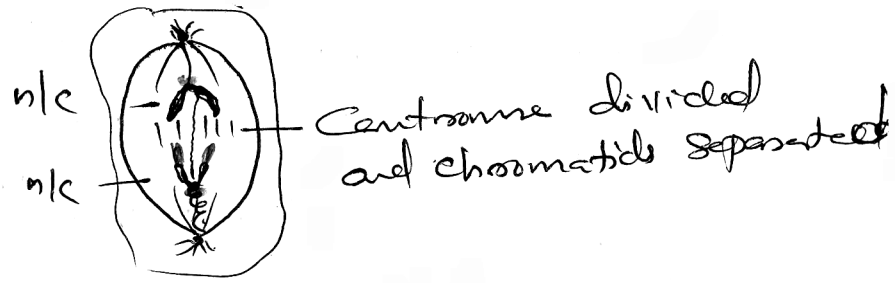
In this in both the cells chromosomes align at the equator and microtubules from opposite pole form spindle fibres connected to the kinetochore of sister chromatids on both side and form metaphase plate.





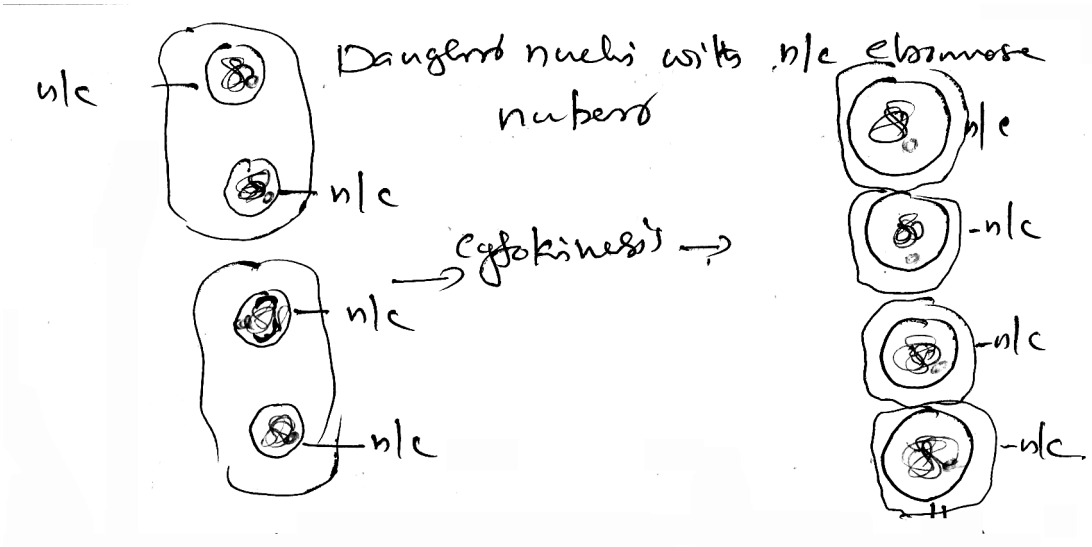
Anaphase II

In this the centromere split longitudinally and chromatids separated and move to the two pole of each cells by the shortening of microtubules or chromosome fibre.



Telophase II

In this in both the cells chromatids reach the two poles they again uncoil nuclear membrane and nucleolus reappear and thus form four daughter nuclei with haploid number of chromosome.



Cytokinin II

In both the cells in between the two daughter nuclei cytoplasm divide and form a tetrad of four cells. In this four cells the chromosome number is equal to the number of chromosome from where Meiosis II start. So this division is called Homotypic division among the four cells two have parental character only but the other two are recombinant formed because of crossing over.

Significance of meiosis

1. Produce genetic variability through crossing over

2. Produce haploid gamete it creates constancy of chromosome number of a species generation after generation.

3. Have greater significance in the evolution of organism.

Difference between Mitosis and Meiosis

	Mitosis	Meiosis
1	Takes places in haploid and diploid cells. Only in diploid cell in animal	Only in diploid cells
2	Two daughter cells are formed	Four daughter cells are formed
3	Chromosome number is similar to parental cell	Chromosome number is half of the parental cell
4	Occur in haploid and diploid organism	Occur in diploid and haploid organism (in the zygote of haploid organism)
5	Prophase long but not complex	Prophase long and complex. It is further subdivide into five substages
6	Takesplace in one phase	In two phase ; Meiosis I and Meiosis II
7	No synapsis or crossing over	Synapsis and crosing over occur
8	Helps in growth and repair	Helps in the formation of gametes
9	One cell division and one chromosome division	One chromosome division and two cell division(cytoplasmic division)
10	No significance in evalution	More significance in evolution due to the presence of crossing over
11	Found in both sexually and asexually reproducing organism	Found only in sexually reproducing organism