CELL DIVISION

Introduction :

Growth and reproduction are characteristics of cells, indeed of all living organisms. All cells reproduce by dividing into two, with each parental cell giving rise to two daughter cells each time they divide. These newly formed daughter cells can themselves grow and divide, giving rise to a new cell population that is formed by the growth and division of a single parental cell and its progeny. In other words, such cycles of growth and division allow a single cell to form a structure consisting of millions of cells.

Rudolf Virchow proposed the cell lineage theory. Cell lineage theory states **"omnis cellula e cellula"** i.e. new cells arise from pre existing cells. Rudolf Virchow failed to prove the theory.

Starsburger :- New Nuclei arise by division of pre existing nuclei.

Cell division :– 3 main types.

(1) Mitosis (2) Meiosis (3) Amitosis

MITOSIS

Term mitosis was proposed by **Flemming** & its detail study was given by A. Schneider. Mitosis produced genetically identical cells, which are similar to mother cell.

Cause of mitosis :-

(I) **Kern plasm theory : Hertwig** proposed kern plasm theory. According to this theory mitosis occurs due to disturbance in Karyoplasmic Index (KI) of cell.

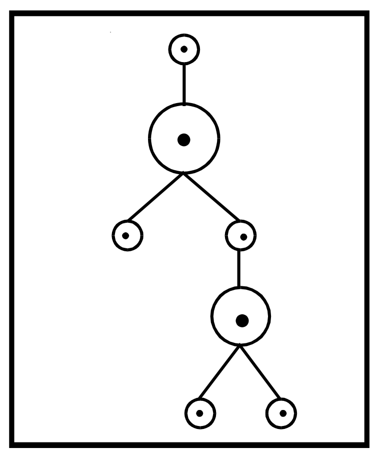
Karyoplasmic Index :

$$KI = \frac{V_n}{V_c - V_n}$$

V_n = Volume of nucleus

V_c = Volume of cell

$V_c - V_n$ = Volume of cytoplasm



Karyoplasmic Index of small cell is high as they have less cytoplasm. Nucleus efficiently controls the acitivity of cytoplasm in small cells.

In a large cell nucleus fail to control the activity of cytoplasm. To attain the control of nucleus on metabolism a large cell divides into two cells.

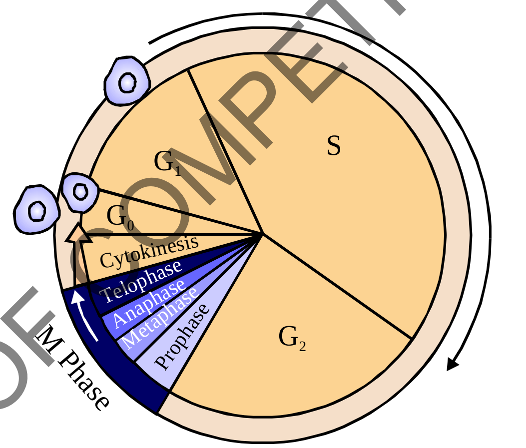
(II) **Surface-volume Ratio :**

- Surface-volume ratio of a cell plays an important role in starting cell division.
- A cell draws all the materials needed for its maintenance & growth from its surface. When a cell grows in size its volumes increases more than its surface. So a stage will reach when the surface area becomes insufficient to draw the material. At such critical stage, division of cell started.

CELL CYCLE

* Cell division is a very important process in all living organisms. During the division of a cell, DNA replication and cell growth also take place.
* All these processes, i.e., cell division, DNA replication, and cell growth, hence, have to take place in a coordinated way to ensure correct division and formation of progeny cells containing intact genomes.
* The sequence of events by which a cell duplicates its genome, synthesises the other constituents of the cell and eventually divides into two daughter cells is termed cell cycle.
* Although cell growth (in terms of cytoplasmic increase) is a continuous process, DNA synthesis occurs only during one specific stage in the cell cycle.
* The replicated chromosomes (DNA) are then distributed to daughter nuclei by a complex series of events during cell division. These events are themselves under genetic control. Complete life cycle of a cell is called as cell cycle.

PHASES OF CELL CYCLE



A diagrammatic view of cell cycle indicating formation of two cells from one cell

- A typical eukaryotic cell cycle is illustrated by human cells in culture. These cells divide once in approximately every 24 hours.
- Yeast can progress through the cell cycle in only about 90 minutes. The time period of cell cycle is varied from organism to organism and also from cell type to cell type.
  Cell cycle involves two stages.
  (1) Interphase
  (2) Division phase/M-phase

1. **Interphase :-** This is phase between two successive M-phase. In interphase cell grows in size and prepares itself for next division. Interphase is **most active phase** of cell cycle.
   The interphase laste more than 95% of the duration of cell cycle.

- In interphase, metabolism of cell increases. A series of metabolic changes occurs during interphase in cell. These changes are not visible under microscope, So some scientist termed interphase as resting phase. But now it's known that it is the most active phase of cell cycle.
- **Howard and Pelc** classified interphase into three sub stages :-

(i) G_1 – phase or Pre DNA synthesis phase (I^{st} Gap phase) (Longest phase of cell cycle)

G_1 phase corresponds to the interval between mitosis and initiation of DNA replication. During G_1 phase the cell is metabolically active and continuously grows

During G_1-most of cell organelles increases in cell and cell rapidly synthesizes different **types of RNA and proteins**. Due to availability of protein, synthesis of new protoplasm takes place in cell and it starts growing in size. Cell grows maximum in G_1 stage.

(ii) S – phase (DNA Synthesis phase :

* Replication of nuclear DNA and synthesis of **histone protein** takes place in s-phase. Replication of cytoplasmic DNA may occur in any stage of cell cycle.
* During this time the amount of DNA per cell doubles. If the initial amount of DNA is denoted as 2C then it increases to 4C. However, there is no increase in the chromosome number; if the cell had diploid or 2n number of chromosomes at G_1, even after S phase the number of chromosomes remains the same, i.e., 2n.

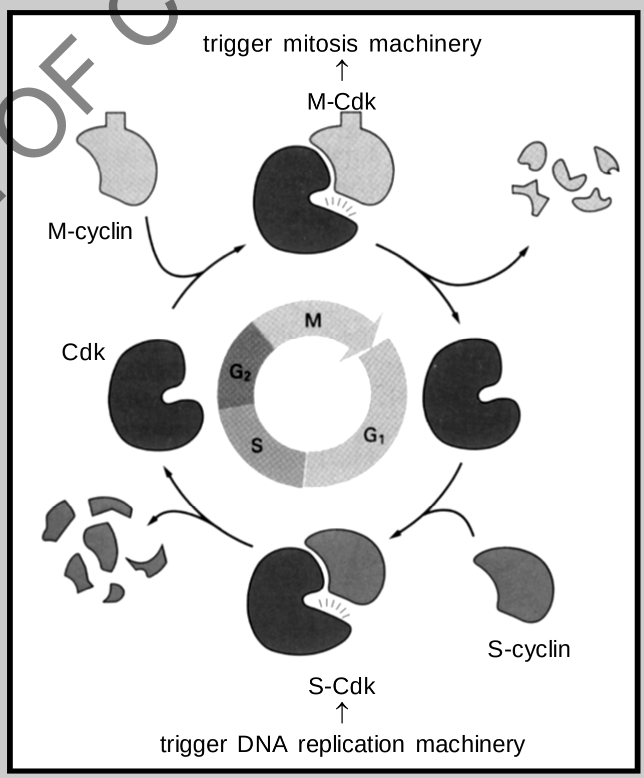
* S-phase marks the phase of DNA replication and chromosome duplication (DNA content in a chromosome become double).
* In animal cells, during the S phase, DNA replication begins in the nucleus, and the centriole duplicates in the cytoplasm. Centriole replicates in late S-phase.
* Some cells in the adult animals do not appear to exhibit division (e.g., heart cells) and many other cells divide only occasionally, as needed to replace cells that have been lost because of injury or cell death. These cells that do not divide further exit G_1 phase to enter an inactive stage called **quiescent stage (G_0)** of the cell cycle.
* Cells in this stage remain metabolically active but no longer proliferate unless called on to do so depending on the requirement of the organism.

(iii) G_2 – phase (2nd Gap phase) or Post DNA synthesis phase (Pre mitosis phase)

* Actual preparation (**Final preparation**) of M-phase occurs during this phase. Special materials required for M-phase are synthesized in G_2 phase. eg. **Tubulin protein**. –(Required for formation of spindle fibres).
* During this phase proteins are synthesised in preparation for mitosis while cell growth continues.
* After G_2 phase cell enters in division or M–phase.

How the cell cycle is controlled

* **Cell cycle is running** by a group of special proteins **"Cyclins and Cdks** (MPF). (Nurse, T.Hunt & Hartwell **2001** studies on saccharomyces (Baker yeast))
* A cell reproduces by performing an orderly set sequences of irreversible events, In which it duplicates it's contents & then divides into two, these events are known as **cell cycle.**
* Molecular biologists, have made remarkable progress in identifying the biomolecules, that control or drive the cell cycle, many biologists, some of whom worked with invertebrate or frog egg's others with yeast cell or cell culture. Scientists concluded that the activity of enzymes, known as **cyclin dependant kinases. (Cdk's)** regulates the cell cycle. Kinase is an enzyme that removes a phosphate group from ATP & add to another protein. The kinases involved in the cell cycle are called **Cdks** because they are activated when they combined with key protein called **cyclin.**



* At some check points $\begin{pmatrix} G_1 \to S \\ G_2 \to M \end{pmatrix}$ a kinase enzyme combines with cyclin & this moves the cell cycle forwardly.

S-kinase is capable of starting the replication of DNA after it combined with **S-cyclin**. After some time S-cyclin is destroyed & **S-kinase** is no longer active. **M-kinase** is capable of turning on mitosis after it has bind with **M-cyclin**. However certain characteristics are universal component of cell cycle control.

2. Division phase :

* **Division phase** or **M–phase** or mitotic phase lasts for only about an hour in the 24 hour duration of cell cycle of a human cell. It is the phase of shortest time in cell cycle.

* The M-phase represents the phase when the actual cell division or mitosis occurs.

* This is the most dramatic period of the cell cycle, involving a major reorganisation of virtually all components of the cell. Since the number of chromosomes in the parent and progeny cells is the same, it is also called as equational division.

* Though for convenience mitosis has been divided into four stages of nuclear division, it is very essential to understand that cell division is a progressive process and very clear-cut lines cannot be drawn between various stages.

* The M-phae start with nuclear division, corresponding to the separation of daughter chromosome (Karyokinesis) and usually ends with division of cytoplasm (cytokinesis).

* Mitosis is divided into the following four stages :-

• **Prophase**

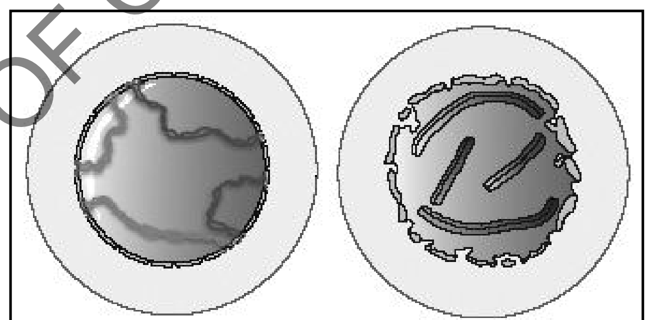
• **Metaphase**

• **Anaphase**

• **Telophase**

Division of nucleus in mitosis and meiosis is **indirect.**

(1) Prophase (Longest stage) :



* Prophase which is the first stage of mitosis follows the S and G2 phases of interphase.

* In the S and G2 phases the new DNA molecules formed are not distinct but interwined.

* Prophase is marked by the initiation of condensation of chromosomal material. The chromosomal material becomes untangled during the process of chromatin condensation. Chromatin threads condenses to form chromosomes.

* Metabolism of cell decreases, cytoplasm becomes **viscous, refractive and pale.**

* The centriole, which had undergone duplication during S phase of interphase, now begins to move towards opposite poles of the cell.

* Astral ray forms due to gelation of proteins around centrioles. Spireme stage of chromosome.

* **Anastral and Amphiastral Mitosis :** In higher plants, centrioles are absent and no asters are formed. Mitosis without asters is known as **anastral mitosis**. In animals, the asters are present and the mitosis is described as **amphiastral**, or **astral mitosis**.

* The completion of prophase can thus be marked by the following characteristic events:

  • Chromosomal material condenses to form compact mitotic chromosomes. Chromosomes are seen to be composed of two chromatids attached together at the centromere.

  • Initiation of the assembly of mitotic spindle, the microtubules, the proteinaceous components of the cell cytoplasm help in the process.

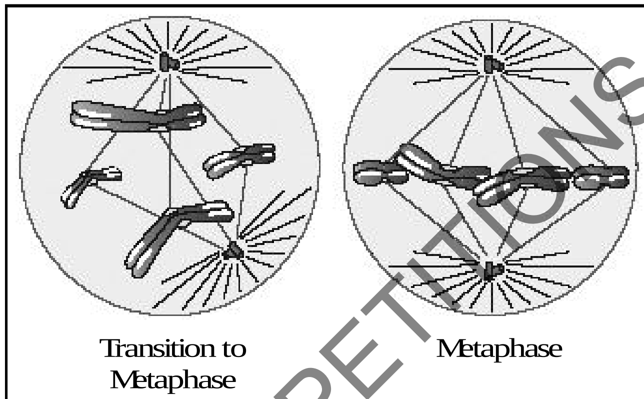
  • Cell at the end of prophase when viewed under the microscope, do not show golgi complexes, endoplasmic reticulum nucleolus and nuclear envolope.

(2) Metaphase :

* The complete disintegration of the nuclear envelope marks the start of the second phase of mitosis, hence the chromosomes are spread through the cytoplasm of the cell.

* By this stage, condensation of chromosomes is completed and they can be observed clearly under the microscope. **This then, is the stage at which morphology of chromosomes is most easily studied.**

* At this stage, metaphase chromosome is made up of two sister chromatids, which are held together by the centromere. Small disc-shaped structures at the surface of the centromeres are called kinetochores. **These structures serve as the sites of attachment of spindle fibres (formed by the microtubules) to the chromosomes that are moved into position at the centre of the cell.**



• Spindle fibres attach to kinetochores of chromosomes.

* Hence, the metaphase is characterised by all the chromosomes coming to lie at the equator with one chromatid of each chromosome connected by its kinetochore to spindle fibres from one pole and its sister chromatid connected by its kinetochore to spindle fibres from the opposite pole. The plane of alignment of the chromosomes at metaphase is referred to as the metaphase plate.
* Chromosomal (discontinous) fibres (which run from pole to centromere) and supporting (continous) fibres (which run from pole to pole) arrange in cell.
* Spindle fibre are composed of 97% tubulin protein and 3% RNA.
* Centromere lies at equator and arms remain directed towards poles.
* Chromosomal fibres have **polarity** i.e. + end at equator and – end at the pole. In metaphase each chromosome splits lengthwise upto the centromere (division of matrix of chromosome).
* Two chromatids of a chromosome repulse each other and the arms of chromosomes are directed towards the opposite poles. Condensation of chromosomes is completed.
* The key features of metaphase are:
    • Chromosomes are moved to spindle equator and get aligned along metaphase plate through spindle fibres to both poles.

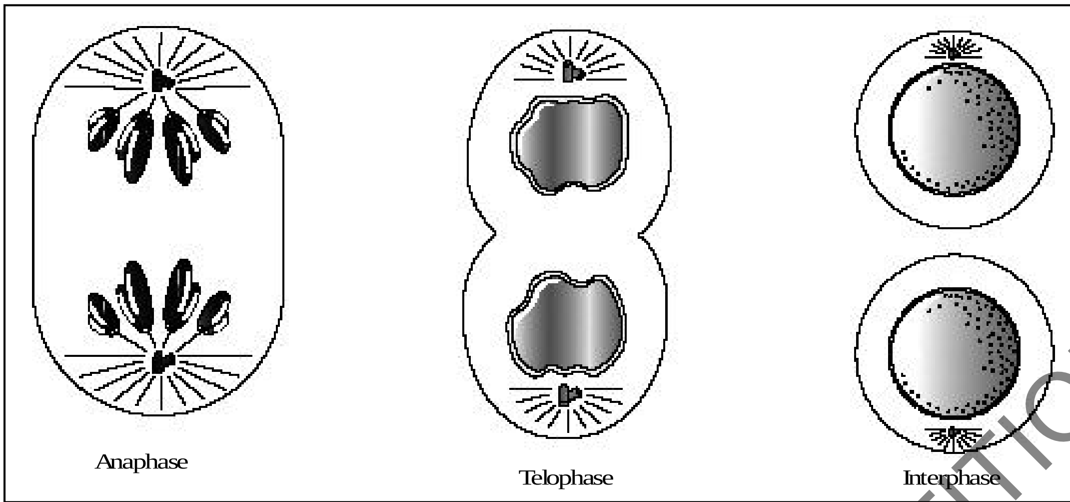
(3) Anaphase :(Shortest stage)

* In early anaphase interzonal fibres (small and contracted) appears at equator of cell.
* Centromere of each chromosome splits lengthwise (**division of centromere**). Sister chromatids separate from each other and new each chromatid reffered to as individual chromosome.
* Number of chromosome becomes double in cell during mitotic anaphase.
* Interzonal fibres expands and they push chromosomes towards the opposite poles. **(Pushing)**
* Chromosomal fibres contract and they pull chromosome towards opposite poles. **(Pulling)**
* By pulling and pushing mechanism chromosomes rapidly move towards the opposite poles.
* As each chromosome moves away from the equatorial plate, the centromere of each chromosome is towards the pole and hence at the leading edge, with the arms of the chromosome trailing behind.
* Approximately 30 ATP are required to carry a chromosome to pole. Chromosomes reach at poles in late anaphase.

Anaphase stage is characterised by the following key events:

• Centromeres split and chromatids separate.

• Chromosome with one chromatids move to opposite poles.



(4) Telophase (Reverse prophase) :

At the beginning of the final stage of mitosis, i.e., telophase, the chromosomes that have reached their respective poles decondense and lose their individuality. The individual chromosomes can no longer be seen and chromatin material tends to collect in a mass in the two poles. This is the stage which shows the following key events:

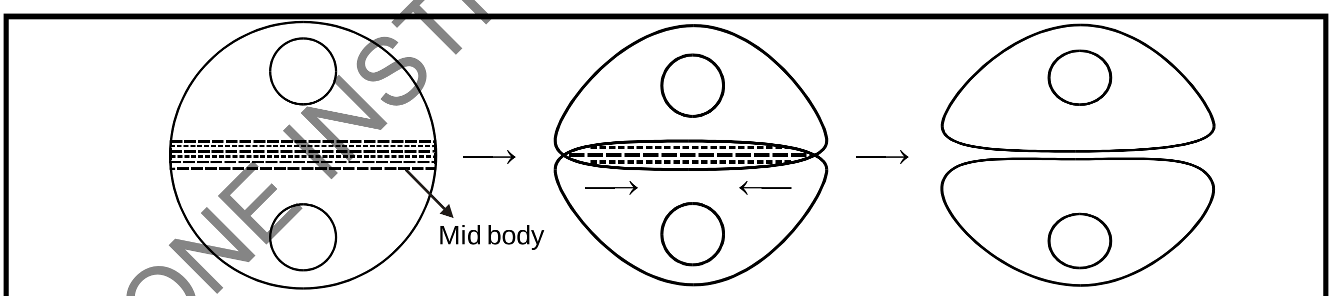
- Chromosomes cluster at opposite spindle poles and their identity is lost as discrete elements.
- Nuclear envelope assembles around the chromosome clusters.
- Nucleolus, golgi complex and ER reform.

CYTOKINESIS

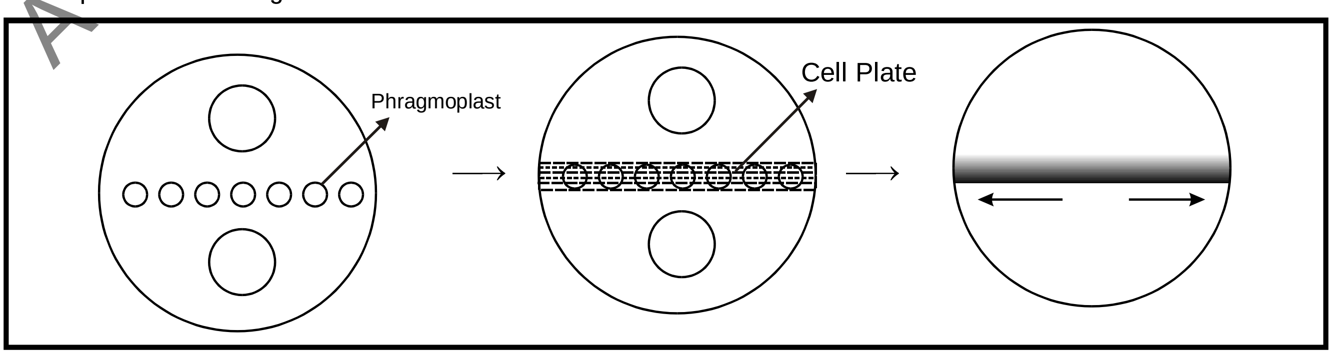
Mitosis accomplishes not only the segregation of duplicated chromosome into daughter nuclei but the cell itself is divided into two daughter cells by a separate process called cytokinesis.

Cytokinesis in animal cell :

Cytokinesis Starts in **late anaphase**. In **animals** center of cytokinesis occurs by **constriction & furrow formation.** Microtubules and microfilaments arrange on equator to form midbody and at the periphary of the equator a contractile ring is formed that is made up of actin and myosin protein. Due to interaction between actin and myosin ring centract thus a furrow forms from the out side to inside in cell. Furrow deepens continuosly and ultimately a cell divides into two daughter cells. In animals cytokinesis occurs in centripetal order.



Cytokinesis in plants – Takes place by **cell plate formation** because constriction is not possible due to presence of the rigid cell wall.



* Many golgi vesicles and spindle microtubules arrange themselves on equator to form **phragmoplast.** Fragementes of ER may also deposit in phragmoplast.
* Membrane of golgi vesicles fuse to form a plate like structure called **cell plate**.
* Golgi vesicles secret calcium and magnesium pectate. Further cell plate is modified into middle lamella.
* In plants, cytokinesis occurs in centrifugal order (cell plate formation is from center to periphery).

SIGNIFICANCE OF MITOSIS

1. **Development of an organism** occurs by mitosis. Every organism starts its life from a single cell i.e. zygote. Repeated mitosis in zygote leads to the formation of the whole body.
2. The growth of multicellular organisms is due to mitosis.
3. Cell growth results in disturbing the ratio between the nucleus and the cytoplasm. It therefore becomes essential for the cell to divide to restore the nucleo-cytoplasmic ratio.
4. A very significant contribution of mitosis is cell repair. The cells of the upper layer of the epidermis, cells of the lining of the gut, and blood cells are being constantly replaced.
5. Mitotic divisions in the meristematic tissues – the apical and the lateral cambium, result in a continuous growth of plants throughout their life.

MODIFICATION OF MITOSIS

1 **Cryptomitosis or Promitosis :** It is a primitive type of mitosis. In this type of division, nuclear membrane does not disappear but remain intact throughout the division. All the changes of karyokinesis occurs inside nucleus even the formation of spindle **(Called as intranuclear spindle)** Such division is found in some protozoans (Amoeba) during binary fission.

2 **Dinomitosis :-** Dinomitoss is founds in dinoflagellates, which are **mesokaryotes.** In mesokaryotic cells histones are absent. Because of this, the chromosomes fail to condense properly and hence are not distinctly visible during cell division. Nuclear membrane persists throughout the cell division and spindle is intranuclear type.

* Normal mitosis is termed as Eumitosis.

3. **Free nuclear division :-** Karyokinesis is not followed by cytokinesis as a result of which multinucleated condition arises. eg. endosperm.

4. **Endomitosis :-** This is duplication of chromosomes without division of nucleus. Endomitosis leads to polyploidy. i.e. Increase in number of genome. Colchicine induces polyploidy in plants. Colchicine is a mitotic poison as it arrests the formation of spindle fibres.

5. **Endoreduplication :** Endoreduplication is a modification of endomitosis. The polytene chromosomes form by process of **endoreduplication.** In endoreduplication, the chromatids replicate but do not get seperated. This process is also known as **polyteny.**

* **Mustard gas and Ribonucleases** are also mitotic poisons.

MEIOSIS

"Term **meiosis**" was proposed by **Farmer** and **Moore.**

The specialised kind of cell division that reduces the chromosome number by half results in the production of haploid daughter cells. This kind of division is called **meiosis.**

Meiosis ensures the production of haploid phase in the life cycle of sexually reproducing organisms whereas fertilisation restores the diploid phase. In meiosis during gametogenesis in plants and animals, leads to the formation of haploid gametes.

Gametes are formed from specialised diploid cells.

The key features of meiosis are as follows:

- Meiosis involves two sequential cycles of nuclear and cell division called **meiosis I** and **meiosis II** but only a single cycle of DNA replication.
- * **Meiosis I :-** Heterotypic division or reduction division. It leads to reduction in chromosome numbers. Division of chromosome does not occurs in meiosis-I and only segregation of homologous chromosomes (Bivatent) takes place.
- Meiosis I is initiated after the parental chromosomes have replicated to produce identical sister chromatids at the S phase.
- Meiosis I involves pairing of homologous chromosomes and recombination between them.
- * **Meiosis II :-** This is a homotypic division or equational division. It does not leads to any change in chromosome number.
- **Meiosis II** is **just like mitosis.** Division of centromere occurs during meiosis II.
- Four haploid cells are formed at the end of meiosis II. All the four dougther cells produced by meiosis are genetically diffrent from each other and also differ from the mother cell.
- * In meiosis, division of nucleus takes place **twice** but division of chromosome occurs only **once.**

Meiotic events can be grouped under the following phases :

Meiosis I	Meiosis II
Prophase I	Prophase II
Metaphase I	Metaphase II
Anaphase I	Anaphase II
Telophase I	Telophase II

Interphase – same as in mitosis

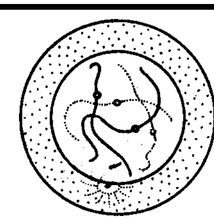
Stages of meiosis I

1. Prophase – I : Typically longer and more complex when compared to prophase of mitosis. Prophase I is classified in five substages :

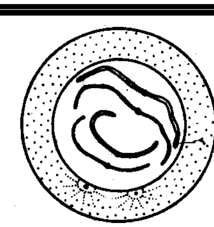
(a) Leptotene r Chromatin threads condense to form chromosomes. Chromosomes are **longest & thinest.** Chromosomes become gradually visible under the light microscope.

* On Chromosomes, bead like structures are present i.e. chromomeres. All the chromosomes in nucleus remain directed towards centrioles, so group of chromosomes in nucleus appears like a bouquet in animal cell. **(Bouquet stage).**

At this stage organism shows a peculiar type of orientation of chromosomes– animals show bouquet type while plants synizesis type.


A. Leptotene

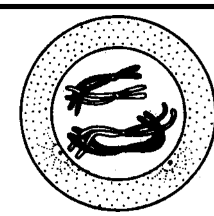
(b) Zygotene or Synaptotene – Zygotene is characterized by pairing of homologous chromosomes **(Synapsis).** Pairs of homologous chromosomes are called **Bivalents.** There develops a structure in between homologous chromosomes, Which is termed as ***synaptonemal complex.*** Synaptonemal complex is composed of three thick lines of ***DNA*** and proteins. According to **Mosses (1956)** synaptonemal complex helps in pairing and chiasmata formation.


B. Zygotene

(c) Pachytene (Thick thread) – Due to increased attraction, homologous chromosomes tightly coil around each other.

* Both chromatids of each chromosome become distinct.

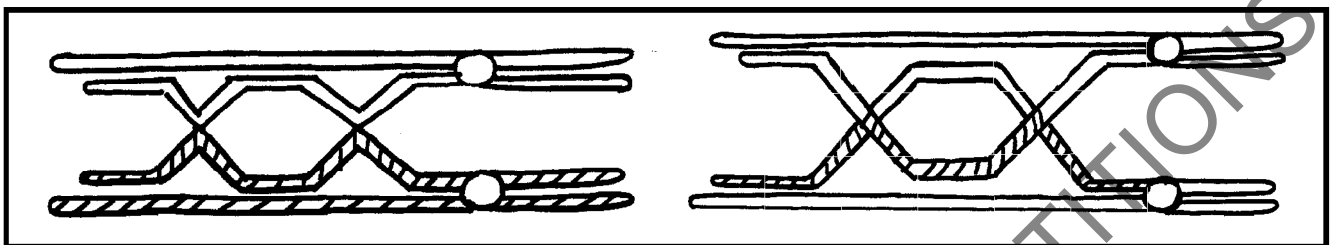
* Each chromosome in a bivalent at pachytene stage distinctly show two chromatids (Total four chromatids), as a result of which bivalent really consists of four chromatids and is called **a tetrad.** Both the chromatids of a chromosome are called **sister chromatids.**


C. Pachytene

* Bivalent is called ***tetrad*** and each chromosome is called **Dyad**.
* ***Recombination nodules*** between nonsister chromatids of homologous pair develop and these non sister chromatid exchange their parts i.e. crossing over. Crossing over was discovered by **Morgan** and **Castle** in ***Drosophila***.

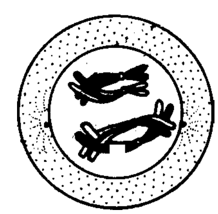
Breakage and reunion theory ⇒ Stern and Hotta

* Breakage and reunion theory is appropriate theory for crossing over which is explained with the help of a most accepted model **(Hybrid DNA model)** of **Holiday** and **Whitehouse**.



* Crossing over is an enzyme mediated process and the enzyme involved is called recombinase (Endonuclease + ligase)
* **Endonuclease** first breaks the nonsister chromatids at the place of recombination nodule.
* Nonsister chromatids reunite after exchanging their parts by Enzyme Ligase As the result of crossing over cross like structures–**chiasmata** (**discovered by Janssen**) form in bivalent.
* Number of chiasmata (singular- chiasma) per bivalent depends on the length of chromosome.

(d) Diplotene – The begining of dipotene is recognised by dissolution of synaptonemal complex (desynapsis). Homologous chromosomes start repulsing each other so x-shape structures appear called **chiasmata** become ***visible***.

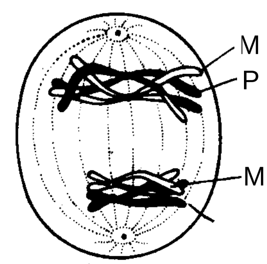


D. Diplotene

* **Diplotene** (Dictyotene) may last long up to month or years (in oocytes of same vertebrates, 12 to 15 years in human Female)
* According to modern scientists chiasmata are not the reason but are only the result of crossing over.

(e) Diakinesis –

* It is final stage of meiotic prophase I.
* Marked by terminalization of chiasmata (Chiasmate open in zip like manner).
* Chromosome are fully condensed and meiotic spindle is assembled to prepare the homologous chromosome for separation.
* Centrioles move towards the opposite poles.
* By the end of diakinesis nuclear membrane and nucleolus disappear.



E. Diakinesis

2. Metaphase I :

* Bivalents arrange on equator (**congression**) of cell to form metaphase plate. The microtubules from the opposite poles of the spindle attach to the pair of homologous chromosome.

Three types of spindle fibres appear in the cell :-

(i) Chromosomal/ Kinetochore Spindle fibres

(ii) Supporting/ Continuous Spindle fibres

(iii) Interzonal Spindle fibres.

3. Anaphase I :

* Due to shortening chromosomal fibre and expansion of interzonal fibre homologous chromosomes segregate from each other and move towards the opposite poles. Sister chromatids remain associated at their centromeres (i.e. chromosomes remain in double chromatid stage)

* Anaphase I is characterised by **segregation** or **disjunction** of chromosomes. **Division of centromere** is absent. Anaphase I is responsible for reduction in chromosome number in daughter cells.

4. Telophase I :

The nuclear membrane and nucleolus reappear. Although in many case the chromosomes do undergo some dispersion, they do not reach the extremely extended state of the interphase nucleus.

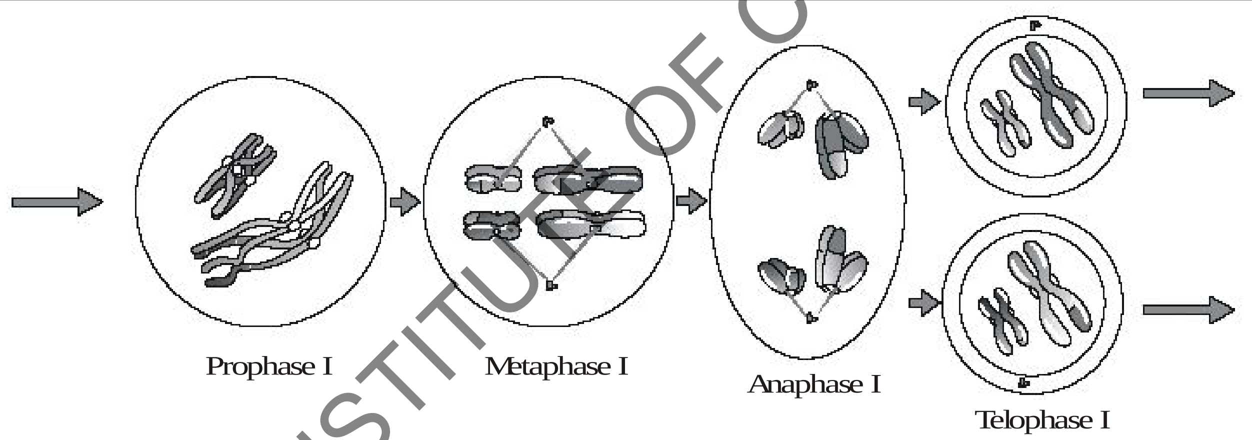
Cytokinesis I :

* Cytokinesis follows telophase-I and a diploid (2n) cell divides into two haploid (n) daugther cells. This is called as diad of cells.

* **In animals** by constriction & furrow formation (successive).

* In most of the plants cytokinesis does not occur after meiosis I.

* Gap between meiosis I and meiosis II is called **Interkinesis**. Preparations of meiosis II occur during interkinesis. It can't be termed as interphase because replication of DNA is absent in interkinesis.



Stages of Meiosis I

* Interkinesis is generally short lived. Interkinesis is followed by prophase-II, a much simpler prophase than prophase-I.

Meiosis – II –

1. Prophase II:

* Meiosis II is initiated immediately after cytokinesis, usually before the chromosomes have fully elongated. In contrast to meiosis I, meiosis II resembles a normal mitosis. The nuclear membrane disappears by the end of prophase II. The chromosomes again become compact.

2. Metaphase II:

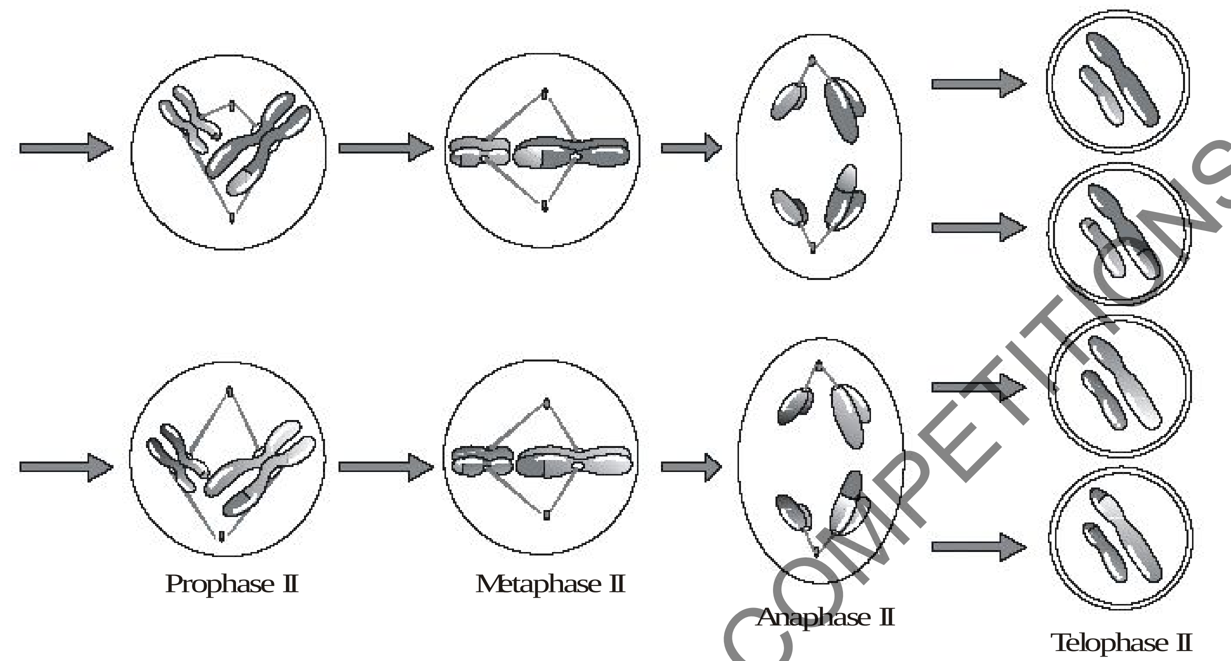
* At this stage the chromosomes align at the equator and the microtubules from opposite poles of the spindle get attached to the kinetochores of sister chromatids.

3. Anaphase II:

* It begins with the simultaneous splitting of the centromere of each chromosome (which was holding the sister chromatids together), allowing them to move toward opposite poles of the cell.

4. **Telophase II:**

* Meiosis ends with telophase II, in which the two groups of chromosomes once again get enclosed by a nuclear envelope; cytokinesis follows resulting in the formation of tetrad of cells i.e., four haploid daughter cells.



Stages of Meiosis II

Types of Meiosis :-

* **Zygotic or Initial meiosis :-** When the meiosis in life cycle of an organism occurs in zygote cell. eg. in algae, fungi.

* **Sporic meiosis or Intermediate Meiosis :-** Meiosis takes place during spore formation. Eg. all the plants except algae.

* **Gametic or Terminal Meiosis :-** Meiosis during the gamete formation. Eg. Animals.

Significance of Meiosis :-

(1) Meiosis is the mechanism by which conservation of specific chromosome number of each species is achieved across generations in sexually reproducing organisms, even though the process (per se paradoxically) results in reduction of chromosome number by half.

(2) It also increases the genetic variability in the population of organisms from one generation to the next. Variations are very important for the process of evolution.

AMITOSIS

* Name 'Amitosis' was given by **Remake** and detail of amitosis is given by **Flemming**. It is most primitive type of cell division. Condensation of chromosomes not occurs in amitosis. Chromosomes are not visible during division. It is a process of division **without recognizable chromosomes.** Amitosis does not involve the formation of spindle. Division of nucleus is **direct**. i.e. without sequential changes (prophase, metaphase, anaphase & telophase). In amitosis, division of cytoplasm and nucleus occur simultaneously by the constriction. In amitosis division may be equal or unequal. Amitosis is **fastest cell division** which may complete in 20–30 minute. Amitosis is cell division of prokaryotes. But exceptionaly also occurs in some eukaryotes.

eg. yeast–budding occurs by amitosis.

* In amoeba multiple fission occurs by amitosis.
* In Paramecium division of meganucleus.
* In mammals–growth of foetal membranes (amnion, chorion, allantois, yolk sac)
* Division of mitochondria and chloroplasts.

Difference between mitosis and meiosis.

S.No.	Mitosis	Meiosis
	1. GENERAL	
1.	The division occurs in somatic cells.	It occurs in reproductive cells.
2.	Both diploid and haploid cells show mitosis.	Meiosis is found only in diploid cells. (or in 4n, 6n, 8n)
3.	It is a single division.	It is a double division.
4.	Mitosis produces two cells	Meiosis produces four cells.
5.	It does not introduce variation.	Meiosis introduces variations due to gene exchange.
6.	Number of chromosome same as mother cells.	Chromosome number reduced (halved).
7.	It is required for growth, repair and healing.	Meiosis involved in only sexual reproduction.
	2. PROPHASE	
8.	It is simpler.	Prophase - I is complicated.
9.	Bouquet stage and synapsis absent.	Bouquet stage (synizesis in plants) and synapsis occurs.
10.	Crossing over and chiasma not seen.	Crossing over and chiasma formation occurs.
	3. METAPHASE	
11.	Chromosome remain as monovalent and has two chromatids	Chromosome as bivalet and four chromatids.
12.	Centromeres are present over the equator or metaphase plate while arms facing towards the poles.	Centromeres projects towards the poles.
	4. ANAPHASE	
13.	Centromere devides during anaphase.	Division of centromere is absent in anaphase - I
14.	Chromosomes are single chromatided.	Chromosome has two chromatids.
15.	The two chromatids of a chromosome separate and become as daughter chromosomes.	Chromatids do not separate in anaphase-I
16.	Chromosomes moving towards the opposite poles are similar	Chromosomes are dissimilar.
	5.TELOPHASE	
17.	It is an essential in which nucleolus and NM reappears	Telophase-I may be absent.

	6. CYTOKINESIS	
18.	Cytokinesis takes place.	Not compulsory (simulteneous after both the divisions in plants)
19.	Daughter cells posses same genetic constitution.	All four daughter cells are differ.

S.No.	Mitosis	Meiosis - II
1.	An interphase occurs prior to mitosis.	Interphase may or may not present prior to meiosis-II if present then called **interkinesis.**
2.	S-phase present.	S-phase absent.
3.	Daughter cells formed after mitosis resemble to mother cell.	Differ from mother cell, quantitatively and qualitatively.
4.	Longer	Shorter.

SPECIAL POINTS

* **Intermediate filaments** has size/diameter in between microfilaments and microtubules. These fillaments form **basket like** structure around the nucleus.
* Cadherins called as cell adhesion molecule.
* **Spectrin :-** (Responsible for structural integrity & biconcave shape of RBC membrane) deficiency or mutation in spectrin makes humans anaemic, leading to abnormality in shape of RBC which become spherical instead of concave.
* **Endosome (receptosome)** is also recently discovered cell organelle which consists of tubules and vesicles and involved in intracellular traffic.
* In certain plants ***(Lilium)*** during leptotene, all chromosomes of a cell are densly clumped to one side and rest of the nucleus has no chromatin material. This event is called **synizesis.** Its significance is subject of future research.
* During the leptotene stage each chromosome is attached to nuclear envelope by **attachment plate** which is made up of by specific proteins. At this time, chromosomes directed to centrosome and appear as **Bouquet.**
* Chiasma formation is the result of crossing over, this is explained by **F. A. Janssen** with chiasma type theory (or one plane theory)
* Genes for **5-s r-RNA** presents separately than NOR.
* In active state of mitochondria, (metabolically busy state) number of cristae is high and matrix is small. (condensed state)
* When mitochondria, metabolically relax, than size of matrix is large and less number of cristae this is called **orthodox state** of mitochondria.
* Metabolically active cell have more dense/developed E.R.
* **Porin** proteins form pores in outer mitochondria and bacterial membranes.
* Erythrocyte membrane in human contain about 40% phospholipids and 52% proteins.
* Generally root tip of onion used for study of mitosis (2n=14)
* Chromosome doubling without division of cell can induce by colchicine. This event is called **C-mitosis.**
* Telomere is concern with ageing of organisms.
* Differential staining of cromatin net is called heteropycnosis. Ex. Barrbody.
* In some organisms karyokinesis is not followed by cytokinesis as a result of which multinucleate condition arises leading to the formatin of syncytium (eg. liquid endosperm in coconut).
* In animals, mitotic cell division is seen only in deploid somatic cells. Against this, the plants can show mitotic division in both haploid and deploid cells.