B.Sc. Botany– 2ND SEM

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Cell Division & Cell Cycle

Cell division is the process in which one cell, called the parent cell, divides to form two new cells, referred to as daughter cells.

The **cell cycle** is a repeating series of events that include growth, DNA synthesis, and cell division

The cell cycle was discovered by **Prevost and Dumas** (1824) while studying the cleavage of zygote of Frog. It is a series of stages a cell passes through, to divide and produce new cells.

Thus, the entire process where with the help of one single parent cell a new cell population grows and develops is known as the cell cycle.

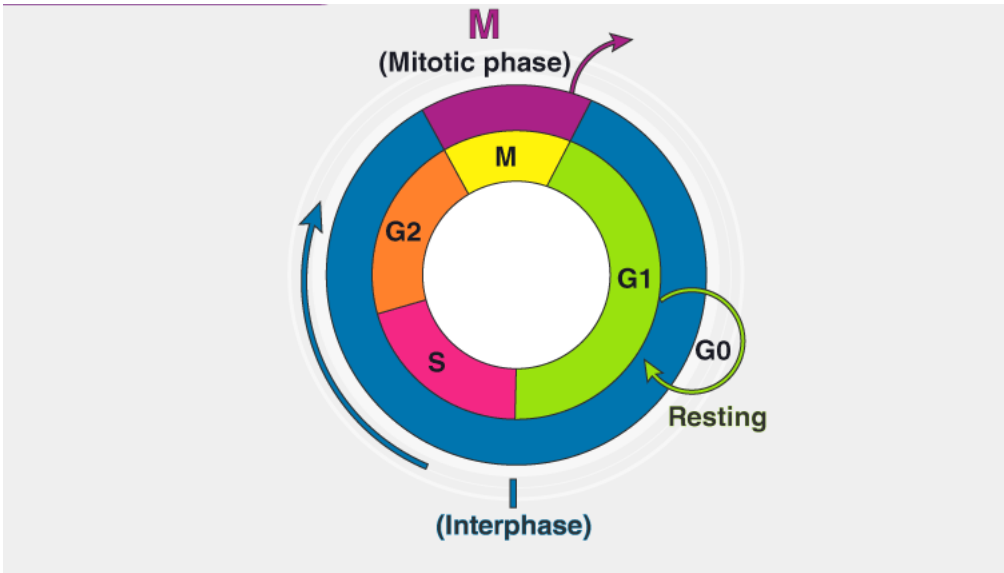
Phases of Cell Cycle

Cell cycle or cell division refers to the series of events that take place in a cell leading to its maturity and subsequent division. These events include duplication of its genome and synthesis of the cell organelles followed by division of the cytoplasm.

A typical eukaryotic cell cycle is divided into two main phases:-

A. Interphase

B. Mitotic Phase (M Phase)



A. **Interphase**

Also known as the resting phase of the cell cycle; interphase is the time during which the cell prepares for division by undergoing both cell growth and DNA replication. It occupies around **95% time of the overall cycle**. The interphase is divided into three phases:-

- **G1 phase (Gap 1)** – G1 phase is the phase of the cell between mitosis and initiation of replication of the genetic material of the cell. During this phase, the cell is metabolically active and continues to grow without replicating its DNA.

- **S phase (Synthesis)** – DNA replication takes place during this phase. If the initial quantity of DNA in the cell is denoted as *2N*, then after replication it becomes *4N*. However the number of chromosomes does not vary, viz., if the number of chromosomes during G1 phase was *2n*, it will remain *2n* at the end of S phase. The centriole also divides into two centriole pairs in the cells which contain centriole.

- **G2 phase (Gap 2)** –During this phase, the RNA, proteins, other macromolecules required for multiplication of cell organelles, spindle formation, and cell growth are produced as the cell prepares to go into the mitotic phase.

Some cells like cardiac cells in the adult animals do not exhibit division and some others only divide to replace those cells which have been either damaged or lost due to cell death. Such cells which do not divide further attain an inactive **G0 phase** also known as **quiescent phase** after they exit the G1 phase. These cells remain metabolically active but do not divide unless called upon to do so.

B. Mitotic Phase (M Phase)

This is the phase of the equational division as the cell undergoes a complete reorganization to give birth to a progeny that has the same number of chromosomes as the parent cell.

The other organelles are also divided equally by the process of cytokinesis which is preceded by mitotic nuclear division.

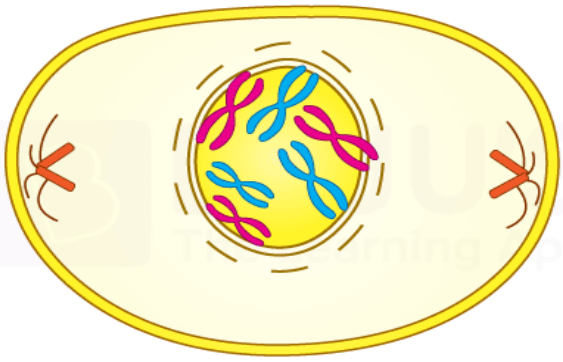
In this process a eukaryotic cell separates the nuclear DNA and chromosomes and divides into two different but similar sets of nuclei. The chromosomes are pulled apart by a mitotic spindle, which is a specialized structure consisting of microtubules.

The mitotic phase is divided into four stages:-

1. Prophase
2. Metaphase
3. Anaphase and
4. Telophase

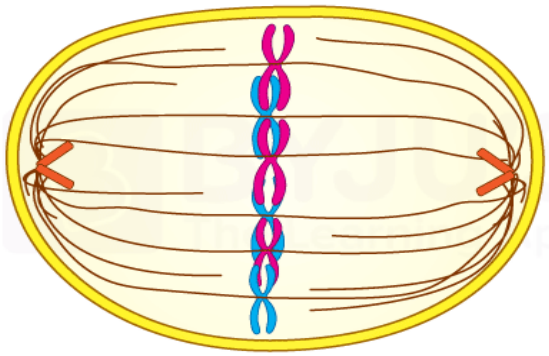
1. Prophase

- Prophase which is the first stage of karyokinesis of mitosis
- It is marked by the initiation of condensation of chromosomal material. Chromosomal material condenses to form compact mitotic chromosomes. Chromosomes are seen to be composed of two chromatids attached together at the centromere.
- Centrosome which had undergone duplication during interphase, begins to move towards opposite poles of the cell. Each centrosome radiates out microtubules called asters. The two asters together with spindle fibres forms mitotic apparatus.



2. Metaphase

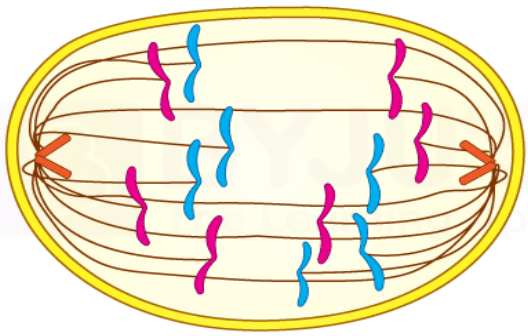
- Complete disintegration of the nuclear envelope, hence the chromosomes are spread throughout the cytoplasm of the cell.
- This is the stage at which morphology of chromosomes is most easily studied.
- At this stage, metaphase chromosome is made up of two sister chromatids, which are held together by the centromere
- Spindle fibres attach to kinetochores of chromosomes
- Chromosomes are moved to spindle equator and get aligned along metaphase plate through spindle fibres to both poles.



3. Anaphase

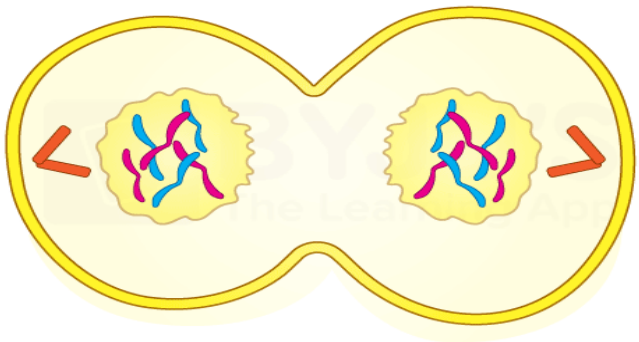
The anaphase stage is characterised by the following key events:

- Centromeres split and chromatids separate
- Chromatids move to opposite poles



4. Telophase

- In this phase, the chromosomes that have reached their respective poles decondense and lose their individuality
- Nuclear envelope develops around the chromosome clusters at each pole forming two daughter nuclei.
- Nucleolus, Golgi complex and ER reform.



Cytokinesis

Cytokinesis starts just after telophase, which denotes the division of the cytoplasm to form two daughter cells. Thus, it marks the completion of cell division.

Significance of Mitosis

1. Mitosis is responsible for the development of the zygote into an adult.
2. Equal distribution of chromosomes to each daughter cell.
3. It is responsible for the growth and development of an individual.
4. It maintains the constant number of chromosomes in all body cells of an organism.
5. Mitosis is required for asexual reproduction, vegetative propagation in plants and is also responsible for the repair and regeneration of damaged tissues.
6. Mitosis helps in maintaining the purity of the genome as no recombination or crossing over takes place.
7. It is responsible for the repair and regeneration of old and damaged cells in animals e.g. gut epithelium, blood cells, etc.

Meiosis

Sexual reproduction in organisms takes place through the fusion of male and female gametes, the sperm and the egg respectively. Gametes are haploid in nature, i.e., they contain only half the number of chromosomes. This genetic content makes them different from other body cells. Meiosis leads to the formation of haploid cells.

Mitotic cell division is equational in nature while meiosis is a reduction division. The salient features of meiotic division that make it different from mitosis are as follows:-

1. It occurs in two stages of the nuclear and cellular division as Meiosis I and Meiosis II. DNA replication occurs, however, only once.
2. It involves the pairing of homologous chromosomes and recombination between them.
3. Four haploid daughter cells are produced at the end, unlike two diploid daughter cells in mitosis.

Meiosis I

Meiosis 1 separates the pair of homologous chromosomes and reduces the diploid cell to haploid. It is divided into several stages that include, prophase, metaphase, anaphase and telophase.

Meiosis 1 Stages

The different stages of meiosis 1 can be explained by the following phases:

- Prophase 1
- Metaphase 1
- Anaphase 1
- Telophase

Prophase 1

Prophase I is longer than the mitotic prophase and is further subdivided into 5 substages,

  - leptotene
  - zygotene
  - pachytene
  - diplotene
  - diakinesis

- The chromosomes begin to condense and attain a compact structure during leptotene.

- In zygotene, the pairing of homologous chromosomes starts a process known as chromosomal synapsis, accompanied by the formation of a complex structure called synaptonemal complex. A pair of synapsed homologous chromosome forms a complex known as bivalent or tetrad.

- At pachytene stage, crossing over of non-sister chromatids of homologous chromosomes occurs at the recombination nodules. The chromosomes remain linked at the sites of crossing over.
- Diplotene marks the dissolution of the synaptonemal complex and separation of the homologous chromosomes of the bivalents except at the sites of cross-over. The X-shaped structures formed during separation are known as chiasmata.
- Diakinesis is marked by the termination of chiasmata and assembly of the meiotic spindle to separate the homologous chromosomes. The nucleolus disappears and the nuclear envelope breaks down.

Metaphase 1

The bivalents align at the equatorial plate and microtubules from the opposite poles attach to the pairs of homologous chromosomes.

Anaphase 1

The two chromosomes of each bivalent separate and move to the opposite ends of the cells. The sister chromatids are attached to each other.

Telophase 1

The nuclear membrane reappears and is followed by cytokinesis. This gives rise to a dyad of cells.

Significance of Meiosis I

a) Reduces chromosome number to half for sexual reproduction.
b) Crossing over leads to variations.
c) Random distribution of paternal and maternal chromosomes (independent assortment) leads to variations.
d) Disturbance in disjunction causes genomatic mutations.
e) Formation of spores/gametes is induced.

Meiosis II

Meiosis-II is just like the mitotic division, but not Mitosis because:

(i) It always occurs in haploid cells

(ii) It is not preceded by interphase.

(iii) The two chromatids of a chromosome are often dissimilar.

(iv) The daughter cells formed after meiosis II are neither similar to each other nor similar to the parent cell.

Meiosis II Stages

Meiosis II also comprises the four stages and are relatively simple as compared to Meiosis I. The four stages of meiosis II are as follows:-

- **Prophase II** – It immediately sets off after the cytokinesis when the daughter cells are formed. The chromosomes begin to condense accompanied by the dissolution of the nuclear membrane and the disappearance of the Golgi apparatus and ER complex.

- **Metaphase II** – The chromosomes are connected to the centriole poles at the kinetochores of sister chromatids through the microtubules. They also get aligned at the equator to form the metaphase plate.

- **Anaphase II** – In this phase of meiosis II, there is a simultaneous splitting of the centromere of each chromosome and the sister chromatids are pulled away towards the opposite poles. As the chromatids move towards the poles, the kinetochore is at the leading edge with the chromosomal arms trailing.

- **Telophase II** – The chromosomes dissolve again into an undifferentiated lump and a nuclear envelope develops around it.

  Telophase is followed by cytokinesis that marks the end of meiosis. Four haploid daughter cells are formed as a result.

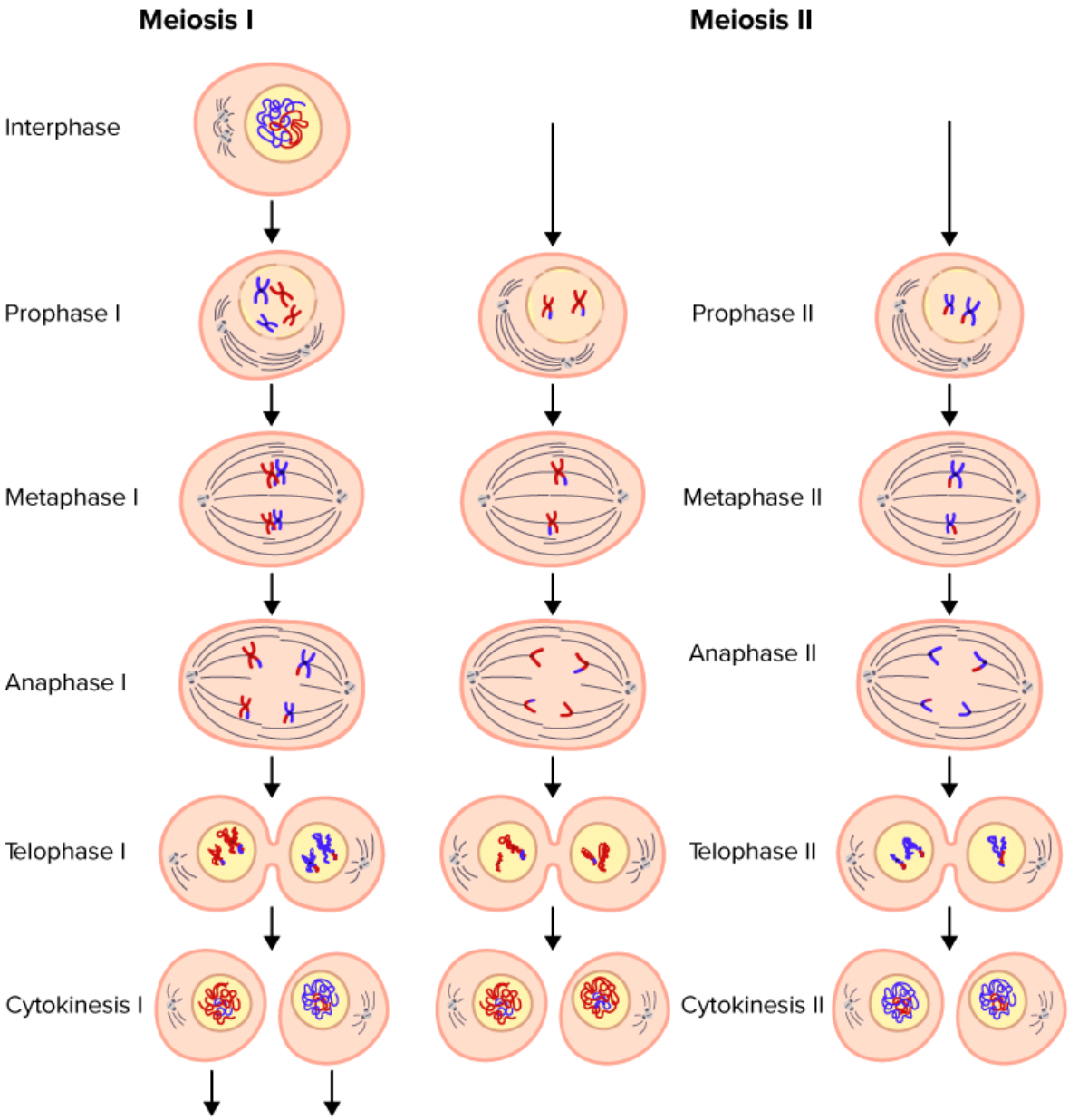


Fig. Different stages of Meiosis I and Meiosis II

Significance of Meiosis

1. Meiosis is responsible for the formation of sex cells or gametes that are responsible for sexual reproduction.
2. It activates the genetic information for the development of sex cells and deactivates the sporophytic information.
3. It maintains the constant number of chromosomes by halving the same. This is important because the chromosome number doubles after fertilization.

4. In this process independent assortment of maternal and paternal chromosomes takes place. Thus the chromosomes and the traits controlled by them are reshuffled.
5. The genetic mutation occurs due to irregularities in cell division by meiosis. The mutations that are beneficial are carried on by natural selection.
6. Crossing over produces a new combination of traits and variations.

Difference between Mitosis and Meiosis	
Mitosis	**Meiosis**
Interphase	
Each chromosome replicates during the S phase of the interphase. The result is two genetically identical sister chromatids (However, do note that interphase is technically not a part of mitosis because it takes place between one mitotic phase and the next).	Chromosomes not yet visible but DNA has been duplicated or replicated.
Prophase	
Prophase –Each of the duplicated chromosomes appears as two identical or equal sister chromatids. The mitotic spindle begins to form. Chromosomes condense and thicken.	Prophase I – crossing-over and recombination – Homologous chromosomes (each consists of two sister chromatids) appear together as pairs. Tetrad or bivalent is the structure that is formed. Segments of chromosomes are exchanged between non-sister chromatids at crossover points known as chiasmata (crossing-over).
Metaphase	
Metaphase -The chromosomes assemble at the equator at the metaphase plate.	Metaphase I – Chromosomes adjust on the metaphase plate. Chromosomes are still intact and arranged as pairs of homologues (bivalent).
Anaphase	
Anaphase – The spindle fibres begin to contract. This starts to pull the sister chromatids apart. At the end of anaphase, a complete set of daughter chromosomes is found on each pole.	Anaphase I – Sister chromatids stay intact. However, homologous chromosomes drift to the opposite or reverse poles.

Mode of Reproduction	
Asexual Reproduction	Sexual Reproduction
Occurrence	
All the cells	Reproductive cells
Function	
General growth and repair, Cell reproduction	Genetic diversity through sexual reproduction
Cytokinesis	
Occurs in Telophase	Occurs in Telophase I and in Telophase II
Discovered by	
Walther Flemming	Oscar Hertwig