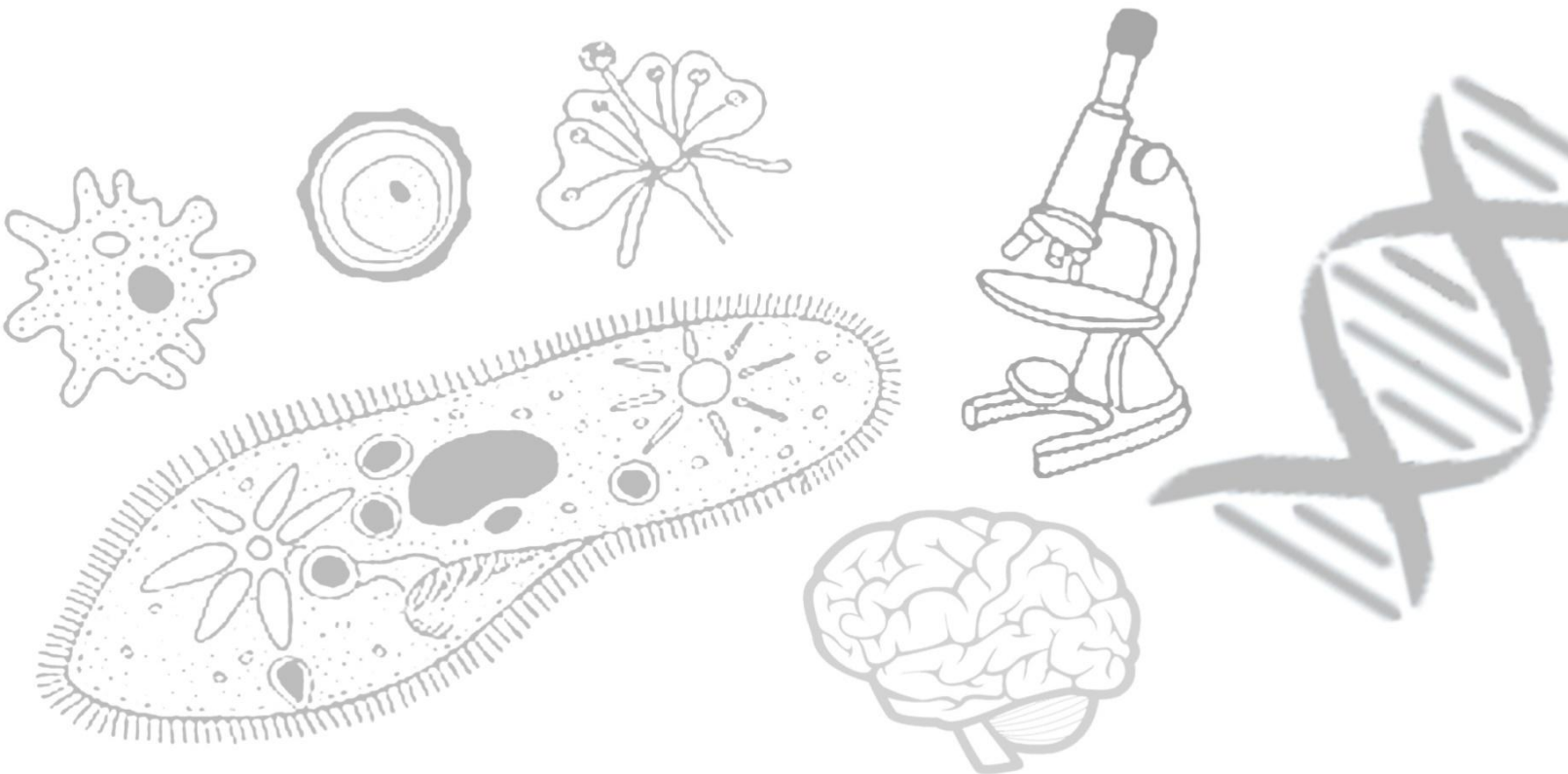
BIOLOGY



Meiosis

- Meiosis is reductional division which occurs only in diploid cells for the formation of haploid cells in which the number of chromosomes and the nuclear DNA content are reduced to half and there is recombination of hereditary material.
- Meiosis takes place only in certain types of cells and occurs only at a particular time.
- Sexually reproducing organisms undergo meiosis and some special cells in multicellular organisms undergo meiosis instead of mitosis at a specific time in the life cycle.
- Meiosis produces gametes in animals, some lower plants and various protists and fungi. It forms asexual reproductive bodies called spores in higher plants which give rise to gamete-producing structures which produce gametes by mitosis.

DID YOU KNOW ?

'Meiosis' was coined by Farmer and Moore (1905) for the process of two consecutive cell divisions in the diploid progenitors of sex cells.

- Meiosis takes several days to complete.
- The cells in which meiosis takes place are called meiocytes. These are of three types—oocytes, spermatocytes and sporocytes.

Essential Features of Meiosis

Meiosis involves two sequential cycles of nuclear and cell division called meiosis I and meiosis II but only a single cycle of DNA replication.

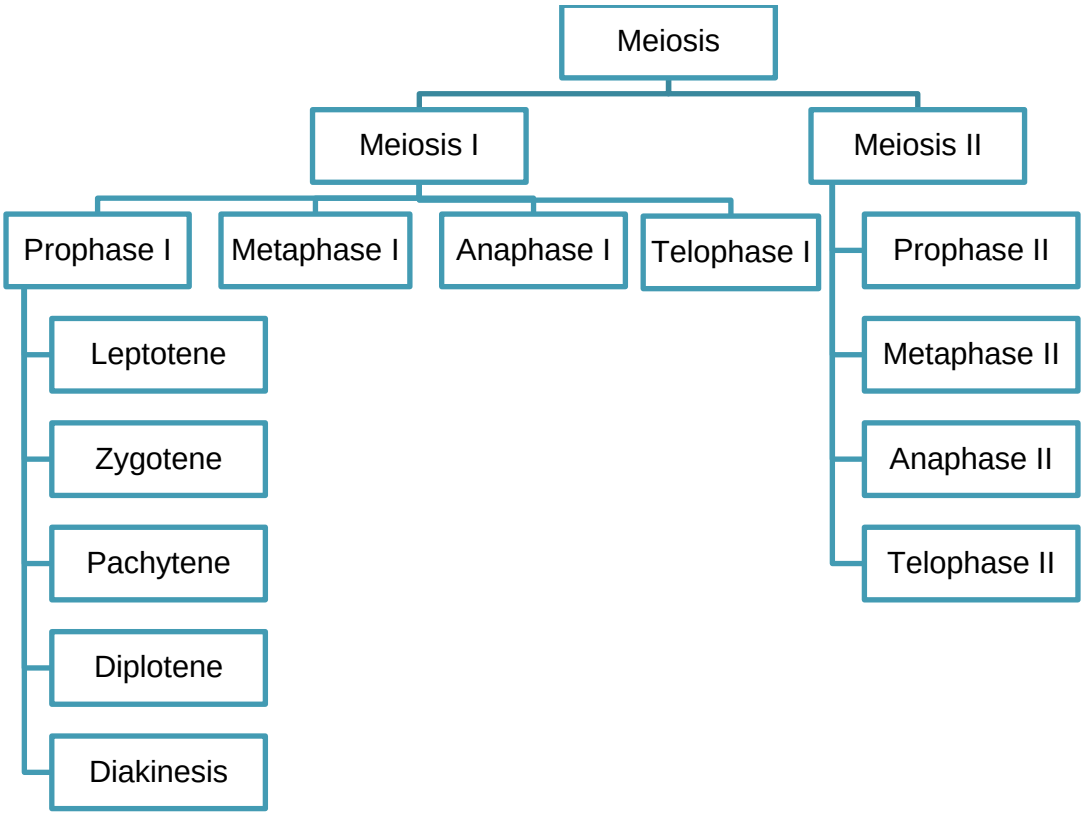
Meiosis I is initiated after the parental chromosomes have replicated to produce identical sister chromatids at the S phase.

Meiosis involves pairing of homologous chromosomes and recombination between them.

Four haploid cells are formed at the end of meiosis II.

Mechanism of Meiosis

- Meiosis consists of two successive divisions which take place rapidly, with the chromosomes replicating only once.
- A parent cell produces four daughter cells, each with half the number of chromosomes present in the parent cell.
- The two divisions of meiosis are called the first and second meiotic divisions or meiosis-I and meiosis-II.
- The division of the events of meiosis is as follows:

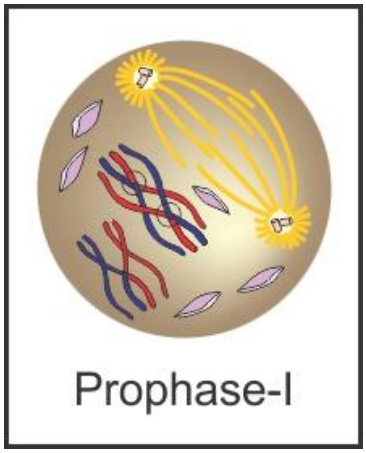


Meiosis I or Heterotypic Division

- Meiosis I begins after the interphase of the cell cycle where DNA duplication occurs in the S phase.
- It reduces the number of chromosomes to half of that of the parent cell.
- Meiosis I consists of four stages—prophase-I, metaphase-I, anaphase-I and telophase-I.

Prophase-I

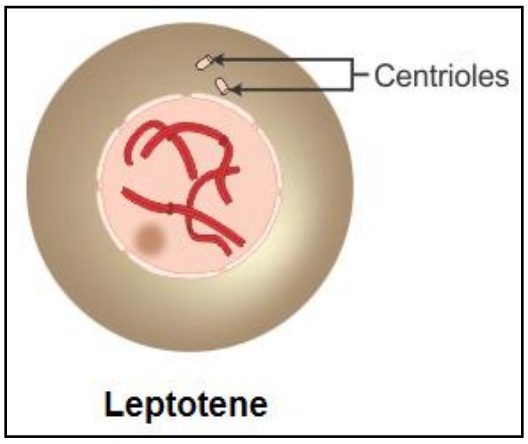
- Prophase-I is very complex and of comparatively longer duration.



- On the basis of chromosome behaviour, prophase-I is divided into five substages—leptotene, zygotene, pachytene, diplotene and diakinesis.

Leptotene/Leptonema

- During the leptotene stage, the duplicated centrioles start moving apart and aster formation takes place.
- The chromatin fibres undergo progressive condensation, coiling, shortening and thickening. They appear in the form of long, thin condensed filamentous chromosomes.



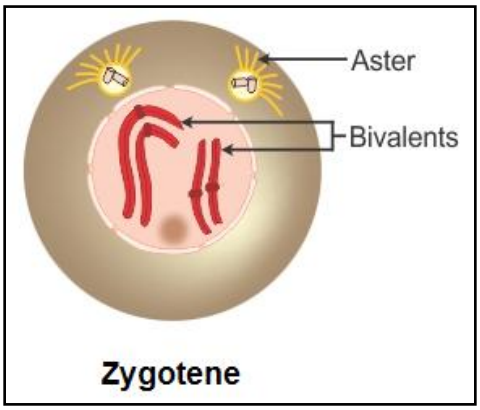
- They possess darkly stained bead-like structures called chromomeres along their entire length.
- Although the chromosomes have replicated, the chromatids are not clearly visible because of the presence of a nuclear protein between them.
- The chromosomes form loops whose ends are attached to the nuclear membrane at the attachment plate. This specific arrangement of chromosomes is called the bouquet stage.

DID YOU KNOW ?

There are no centrioles in plant cells and no asters are formed.

Zygotene/Zygonema

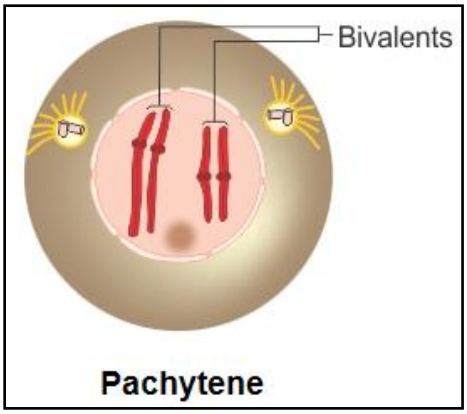
- During zygotene, the homologous chromosomes come to lie in pairs.
- In each pair, one chromosome comes from the mother through the ova and is called the maternal chromosome. The other chromosome comes from the father through the sperm and is called the paternal chromosome.



- The pairing of homologous chromosomes is called synapsis. The paired chromosomes are called bivalents.
- The number of bivalents in a cell is equal to the number of haploid chromosomes.
- Homologous chromosomes of a pair are of the same length and carry the same genes in the same sequence.
- Electron micrographs of the zygotene stage reveal that chromosome synapsis is accompanied by the formation of a complex, tripartite, proteinaceous structure called the synaptonemal complex.
- The chromatids are not visible even during the zygotene stage.

Pachytene/Pachynema

- The bivalent chromosomes become more thickened, shortened and condensed.
- The two visible chromatids of a chromosome are referred to as a dyad.
- A group of four homologous chromatids is called a tetrad.
- The two chromatids of the same chromosome are called sister chromatids and those of two homologous chromosomes are called non-sister chromatids.

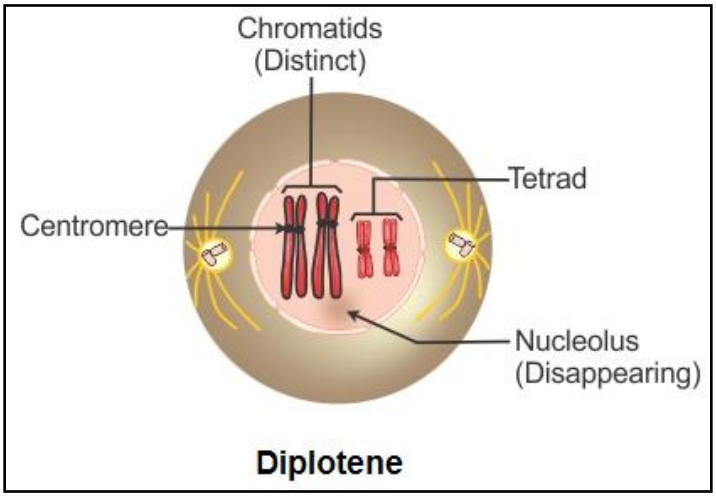


- The tetrad stage is characterised by the appearance of recombination nodules, the site at which crossing over occurs between the non-sister chromatids of the homologous chromosomes.
- Crossing over is the exchange of genetic material between two homologous chromosomes. It is catalysed by an enzyme called recombinase.

The best theory to explain crossing over is the Darlington's theory of breakage and union. The enzyme endonuclease helps in the development of nicks in the chromosome. Gaps are formed in the nicks by exonuclease. Chromatid segments in these gaps are separated by U-protein or unwindase. Reannealing is carried out by R-protein or reannealing protein.

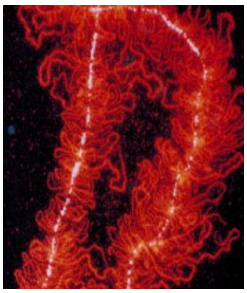
Diplotene/Diplonema

- Diplotene is the longest phase of prophase-I.
- There is dissolution of synaptonemal complex and the recombinant homologous chromosomes begin to separate. This phenomenon is called desynapsis.



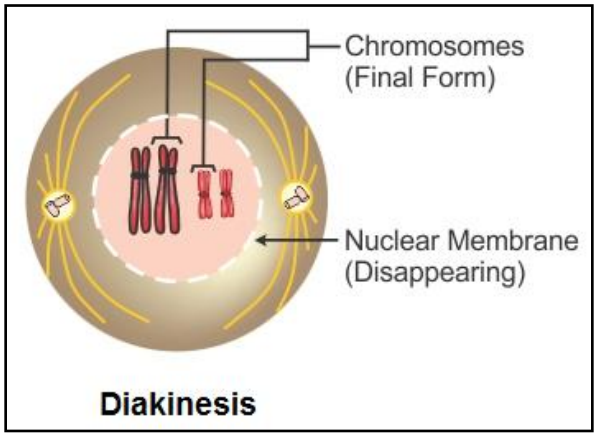
- The separation of homologous chromosomes is not complete. The chromosomes remain attached to one or more points where crossing over has occurred. These points of attachment are called chiasmata.
- The diplotene stage can last for months or years in the oocytes of some vertebrates.
- The suspended diplotene stage is called the dictyotene stage.
- At this stage, the chromosomes decondense and are engaged in rapid synthesis of RNA.
- Terminalisation of chiasmata occurs during the dictyotene stage.

In the diplotene stage, the chromosomes may unfold to the normal form and begin the transcription of mRNA and rRNA to build up food reserves in the cytoplasm. In some species, the chromosomes enlarge greatly, assuming a lampbrush form.



Diakinesis

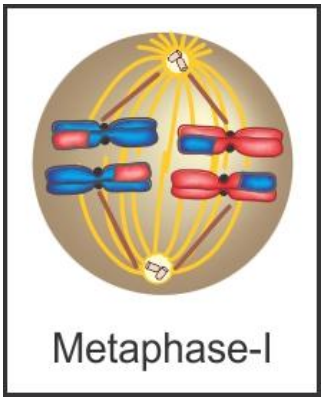
- Complete terminalisation of chiasmata occurs during diakinesis.
- The nucleoli and the nuclear membrane disintegrate and disappear.
- The spindle fibres extend from one pole of paired centrioles to the other pole of paired centrioles.



- Astral rays and asters become fully developed.
- Centrioles are absent in plant cells, and so, no asters are formed.
- The end of diakinesis marks the end of prophase-I and transition to metaphase-I.

Metaphase-I

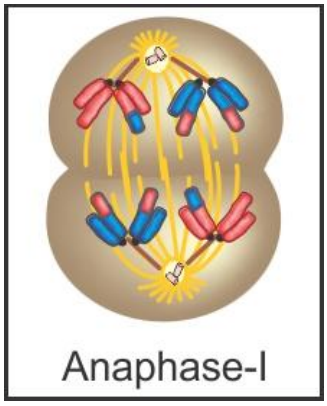
- During metaphase-I, the bivalents align themselves on the equator of the bipolar spindle.
- The centromeres of all bivalents produce a double equatorial or metaphasic plate because of the presence of two centromeres in each bivalent.



- Each metaphasic plate will have half the number of diploid chromosomes.
- The microtubules from the opposite poles of the spindle attach to the pair of homologous chromosomes.

Anaphase-I

- During anaphase-I, one chromosome from each homologous pair moves to the opposite poles with recombined characters of both paternal and maternal chromosomes.



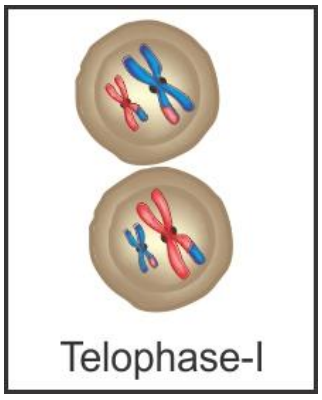
- The movement of chromosomes occurs along the path of their tractile or chromosomal fibres.
- Each chromosome consists of two chromatid threads joined by a centromere.
- There is no division of the centromere.
- At the end of anaphase-I, half of the chromosomes reach one pole and the other half reach the opposite pole.
- Reduction in the number of chromosomes takes place during anaphase-I.

DID YOU KNOW ?

The paternal and maternal chromosomes of each homologous pair segregate independently of the other chromosomes during anaphase-I. Independent assortment of homologous chromosomes introduces genetic variability.

Telophase-I

- The haploid number of chromosomes which have reached each of the poles undergo elongation, coiling and decondensation to form a chromatin network.
- Although the chromosomes undergo some kind of dispersion, they do not reach the extremely extended state of the interphase nucleus.



- The nuclear envelope develops from the elements of the endoplasmic reticulum around the chromatin fibres.
- Formation of new nucleolus occurs during telophase-I.
- The astral rays and spindle fibres disintegrate and disappear.
- The two daughter nuclei are formed, each with a haploid number of chromosomes.
- The end of telophase-I marks the end of karyokinesis of meiosis-I.

Cytokinesis

- Cytokinesis follows karyokinesis of meiosis-I.
- The animal cell cytoplasm divides by a cleavage furrow, while a plant cell cytoplasm divides through cell plate formation.
- By the end of cytokinesis, each diploid parental cell divides into two daughter cells each with a haploid number of chromosomes but double the content of DNA.

FACT !

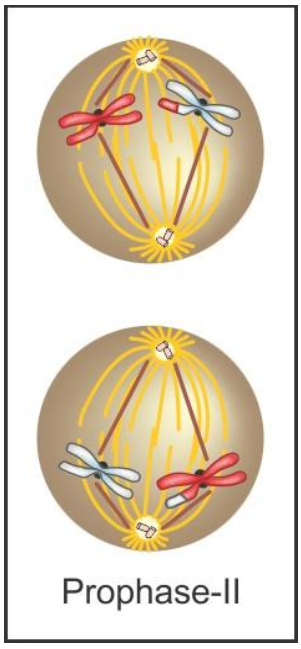
Each daughter cell formed after meiosis-I sometimes undergoes a brief interphase called interkinesis or intermeiotic interphase. There is no replication of chromosomes and no duplication of genes during this phase.

Meiosis II or Homotypic Division

- Meiosis-II resembles mitotic division.
- In this division, the two chromatids of each chromosome separate from each other and go to separate daughter cells.
- The number of chromosomes remains the same as produced by meiosis-I.
- Meiosis-II consists of four stages—prophase-II, metaphase-II, anaphase-II and telophase-II.

Prophase-II

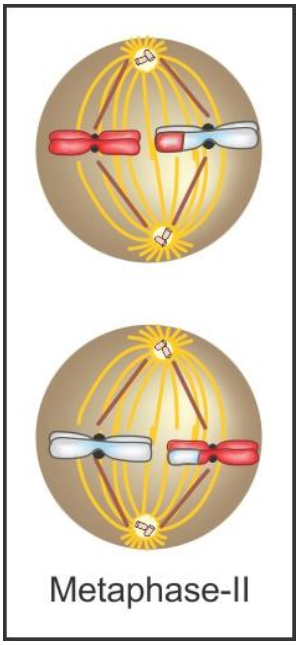
- During prophase-II, the already duplicated centrioles move in pairs to the opposite poles.
- Each pair of centrioles develops astral rays round it to form an aster.



- A spindle is laid down between the two pairs of centrioles.
- The nuclear membrane and the nucleolus disintegrate and disappear.
- The chromatin fibres undergo compaction and appear in the form of distinct chromosomes.
- Each chromosome consists of two chromatid threads joined by a centromere.

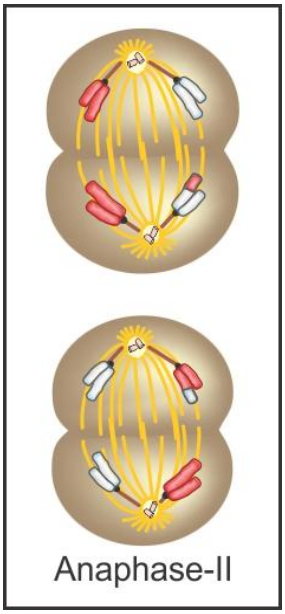
Metaphase-II

- During metaphase-II, the chromosomes come to lie on the equator of the cell and form a single equatorial or metaphasic plate.
- The spindle fibres become attached to both kinetochores of the centromere of each chromosome.



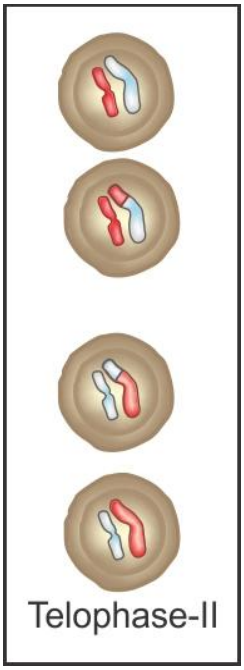
Anaphase-II

- During anaphase-II, the two chromatids of each chromosome start moving away from each other.
- They reach the poles of the spindle where they are called chromosomes.
- Each pole has a haploid number of chromosomes and haploid amount of DNA.



Telophase-II

- During telophase-II, the daughter chromosomes on the opposite poles decondense to form chromatin fibres.



- The nuclear envelope develops from the endoplasmic reticulum and the new nucleolus reorganises.
- The spindle fibres and astral rays disintegrate and disappear.
- This marks the end of telophase-II and karyokinesis of meiosis-II.

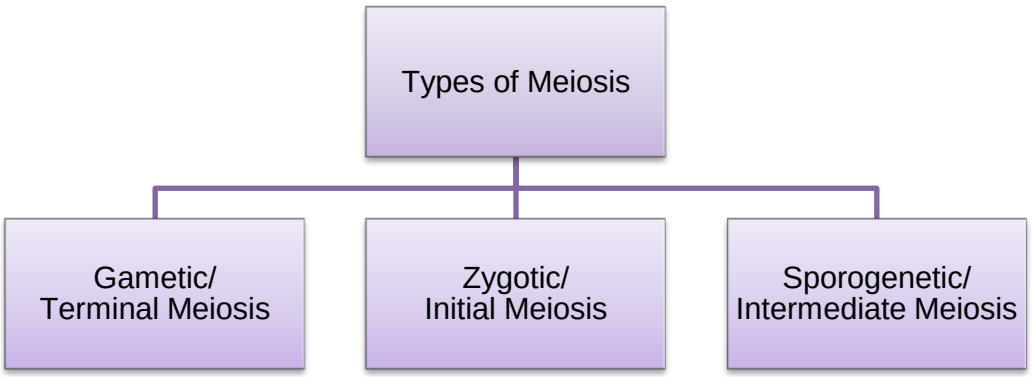
Cytokinesis-II

- Cytokinesis follows karyokinesis of meiosis-II.
- The cytoplasm divides in the middle by furrowing in an animal cell and by cell plate formation in a plant cell.
- At the end of cytokinesis, two daughter cells are formed, each with half the number of chromosomes and half the amount of nuclear DNA of the parent cell.
- Cytokinesis may occur successively after each nuclear division.
- The diploid parent cell divides first by heterotypic division into two haploid cells, which then produce four haploid cells by homotypic division.
- The four daughter cells may form a linear or isobilateral tetrad.

DID YOU KNOW ?

In some cases, cytokinesis is delayed until both the nuclear divisions are completed so that four cells are simultaneously formed, each with a haploid nucleus. This kind of cytoplasmic division is called simultaneous division.

Types of Meiosis



Significance of Meiosis

Formation of Gametes	•Meiosis produces gametes for sexual reproduction in plants and animals.
Formation of Spores	•Meiosis produces spores for asexual reproduction in plants.
Maintenance of Chromosome Number	•The chromosome number in the gametes reduces to half through meiosis so that fertilisation may restore the original diploid chromosome number in the zygote.
Introduction of Variation	•Meiosis brings about new combination of chromosomes which results in variation. •Variations help animal and plant breeders to improve the races of useful animals and plants.
Occurrence of Mutation	•Abnormal meiotic divisions may result in chromosomal mutations, some of which may be advantageous for the organism.
Evidence of Basic Relationship of Organisms	•As meiosis occurs in all sexually reproducing organisms, it offers evidence of the basic relationship of all living organisms.

Differences between Mitosis and Meiosis

Point of Difference	Mitosis	Meiosis
Occurrence	1. Mitosis occurs in all kinds of cells and may continue throughout life.	1. Meiosis occurs only in a special type of cells and at specific times.
Karyokinesis	2. Karyokinesis occurs once.	2. Karyokinesis occurs twice.
Number of Divisions	3. Mitosis involves a single division resulting in two daughter cells.	3. Meiosis involves two successive divisions resulting in four daughter cells.
Type of Division	4. All mitotic divisions are equational divisions.	4. First meiotic division is reductional and second division is equational.
Prophase	5. Prophase is short and without substages.	5. Prophase-I is long with five different substages.
	6. There is no pairing of homologous chromosomes and hence no chance of crossing over and chiasmata formation.	6. There is pairing of homologous chromosomes using the synaptonemal complex during the zygotene stage of prophase-I and often undergo crossing over, hence forming chiasmata.
	7. The chromosomes appear double from the beginning of mitosis.	7. The chromosomes appear as single threads in the initial stages of meiosis.
Metaphase	8. All chromosomes form a single plate in metaphase.	8. Chromosomes form two parallel plates in metaphase-I and one plate in meiosis-II.
	9. On the equatorial plate, chromosomes appear two threaded.	9. On the equatorial plate, chromosomes appear four threaded in metaphase-I, while metaphase-II is similar to the metaphase of mitosis.
Anaphase	10. Splitting of centromere of chromosomes and separation of two chromatids of each chromosome occurs.	10. There is no splitting of centromeres. Separation of homologous chromosomes occurs in anaphase-I. In anaphase-II, splitting of centromeres and separation of chromatids occur.
Telophase	11. Telophase occurs always.	11. Sometimes, telophase-I is eliminated.
	12. Daughter cells possess the same number of chromosomes as that of the parent cell.	12. The chromosome number is reduced to half at the end of telophase-I.
Cytokinesis	13. Cytokinesis occurs after karyokinesis.	13. Sometimes, cytokinesis may not occur after telophase-I of meiosis-I, but it always occurs after telophase-II of meiosis-II, thereby forming four cells.
Significance	14. Mitosis results in growth, repair and healing.	14. Meiosis maintains a constant chromosome number from generation to generation, forms gametes or spores and produces variations because of crossing over.