

Session-5

The term meiosis was coined by J.B. Farmer in 1905. This type of division is found in organisms in which there is sexual reproduction. The term has been derived from Greek word; Meioum = diminish or reduce. The cells that undergo meiosis are called meiocytes. Three important processes that occur during meiosis are:

1. Pairing of homologous chromosomes (synapsis) at Zygotene of Prophase-I
2. Formation of chiasmata and crossing over at Pachytene of Prophase-I
3. Segregation of homologous chromosomes (or separation of alleles) at Anapahse-I

Both crossing over and segregation contribute to genetic recombination (that is, new gene combination). The first division of meiosis results in reduction of chromosome number to half and is called reduction division. The first meiotic division is also called heterotypic division. Two haploid cells are produced at the end of first meiotic division and in the second meiotic division, the haploid cells divide mitotically and results in the production of four daughter cells (tetrad), each with haploid number of chromosomes. In a tetrad, two daughter cells will be of parental types and the remaining two will be recombinant types. The second meiotic division is also known as homotypic division. Both the meiotic divisions occur continuously and each includes the usual stages viz., prophase, metaphase, anaphase and telophase. Meiotic cell cycle involves the following stages: Interphase: Meiosis starts after an interphase which is not very different from that of an intermitotic interphase. During the premeiotic interphase DNA duplication occurs during the S phase I.

Meiosis-I:

(1) **Prophase-I:** It is of a very long duration and is also very complex. It has been divided into the following sub-stages:

a) **Leptotene or Leptonema:** Chromosomes at this stage appear as thin thread like structures that are loosely interwoven like a loose ball of wool. In some species, on these chromosomes, bead-like structures called chromomeres are found all along the length of the chromosomes.

b) **Zygotene or Zygonema:** It is characterized by pairing of homologous chromosomes (synapsis), which form bivalents. Pairing of homologous chromosomes takes place at one region only but not throughout their length and this pairing occurs in a zipper-like fashion. The paired homologous chromosomes are joined by a protein containing frame work known as synaptonemal complex.

c) **Pachytene or Pachynema:** The chromosomes appear as bivalents. Each bivalent consists of four chromatids and is called a tetrad. At this stage, exchange of segments between non-sister chromatids of homologous chromosomes known as crossing over occurs. During crossing over,

only one chromatid from each of the two homologous chromosomes takes part. The nucleolus still persists.

d) **Diplotene or Diplonema:** At this stage further thickening and shortening of chromosomes takes place. Homologous chromosomes start separating from one another. Separation starts at the centromere and travels towards the ends (terminalization). Homologous chromosomes are held together only at certain points along the length. Such points of contact are known as chiasmata and are the resultant of crossing over. The process of terminalization is completed at this stage.

e) **Diakinesis:** Chromosomes continue to undergo further contraction or condensation. Due to further contraction, the bivalents appear as round darkly stained bodies (with acetocarmine) and they are evenly distributed throughout the cell. The nuclear membrane and nucleolus disappear.

2) **Metaphase-I:** The spindle apparatus gradually organizes. The bivalent are attached to the spindle fibres through the centromeres. The centromeres of the bivalents are arranged on either side of the equator and this type of orientation is called co-orientation.

3) **Anaphase-I:** From each bivalent, one chromosome (having two sister chromatids) move to opposite poles (disjunction). The centromere is the first to move to the pole. Since the two sister chromatids in a bivalent move to same pole, meiosis is called reductional division. Each pole now has a haploid number of chromosomes. Hence separation of homologous chromosomes (separation of alleles) occurs in this phase.

4) **Telophase-I:** Nuclear membranes are formed around the groups of chromosomes at the two poles. The nucleus and nucleolus are re-organized. First meiotic division is followed by second meiotic division (Meiosis-II is essentially mitosis) with or without an intervening interphase. Hence each meiotic division involves two karyokinesis and one cytokinesis.

II. Meiosis-II: The second meiotic division is similar to the mitotic division and it includes the following four stages:

1) **Prophase-II:** The chromosomes having two sister chromatids condense again. The nucleolus and nuclear membrane disappear.

2) **Metaphase-II:** Spindle fibres appear and the chromosomes get arranged on the equatorial plane (auto-orientation). This plane is at right angle to the equatorial plane of the first meiotic division.

3) **Anaphase-II:** Each centromere divides longitudinally and the two sister chromatids or daughter chromosomes moves towards the opposite poles.

4) **Telophase-II:** The chromatids move to the opposite poles The nuclear envelope and the nucleolus reappears. Thus at each pole, there is re-organization of haploid nucleus. Cytokinesis: The division of cytoplasm takes place by cell plate method in plants and by furrow method in

animals. The cytokinesis may take place after meiosis I and meiosis II separately or sometimes may take place at the end of meiosis II only.

Significance of Meiosis: Meiosis plays a very important role in the biological populations in various ways as given below:

1. Meiosis results in production of gametes with haploid (half) chromosome number. Union of male and female gametes leads to formation of zygote which receives half chromosome number from male gamete and half from the female gamete and thus the original somatic chromosome number (diploid condition) is restored. Thus meiosis helps in maintaining constant chromosome number from one generation to another in a given species.

2. Meiosis facilitates segregation and independent assortment of chromosomes and genes.

3. It provides an opportunity for the exchange of genes through the process of crossing over. Recombination of genes results in generation of variability in a biological population which is important from evolution points of view.

4. In sexually reproducing species, meiosis is essential for alternation of generation. Because meiosis results in the formation of male and female gametes that are haploid and union of such haploid gametes leads to the development of diploid zygote and thereby new individual. This haploid phase is followed by diploid phase and is also called as.

Differences between Mitosis and Meiosis

Mitosis	Meiosis
1. Consists of one nuclear division and one cytokinesis	1. Consists of two nuclear divisions and one cytokinesis.
2. One cell cycle results in production of two daughter cells that are identical with parent cell in structure and chromosome composition	2. One cell cycle results in production of four daughter cells. Daughter cells are different from parent mother cell in chromosome number and composition
3. The chromosome number of daughter cells is the same as that of Parent cell (2n)	3. Daughter cells contain half the chromosome number of parent cell (n)
5. It occurs in somatic cells	5. It occurs in reproductive cells
6. Total DNA of nucleus replicates during S phase	6. About 0.3% of the DNA is not replicated during S phase and it occurs during the zygotene stage.

7. The prophase is not divided into sub stages	7. The prophase I is divided into five sub stages
8. There is no pairing between homologous chromosomes	8. Homologous chromosomes pair during pachytene (Synapsis)
9. Segregation and recombination do not occur	9. Crossing over takes place during pachytene
10. Chromosomes are in the form of dyad at metaphase	10. Chromosomes are in the form of tetrad at metaphase-I
11. The centromeres of all the chromosomes lie on the equatorial plate (auto orientation) during metaphase	11. The centromeres of all the chromosomes lie on either side of the equatorial plate (co-orientation) during metaphase I
12. At metaphase, centromere of each chromosome divides longitudinally	12. The centromere does not divide at metaphase I
13. Sister chromatids of each chromosome separate and move to opposite pole during anaphase	13. Sister chromatids of each chromosome do not separate and go to the same pole during the anaphase I
14. Maintains genetic purity due to lack of segregation and recombination as observed in asexual method of reproduction.	14. Generates variability due to segregation and recombination as seen in sexual method of reproduction.
15. Helps in multiplication of cells	15. Helps in alternation of generation

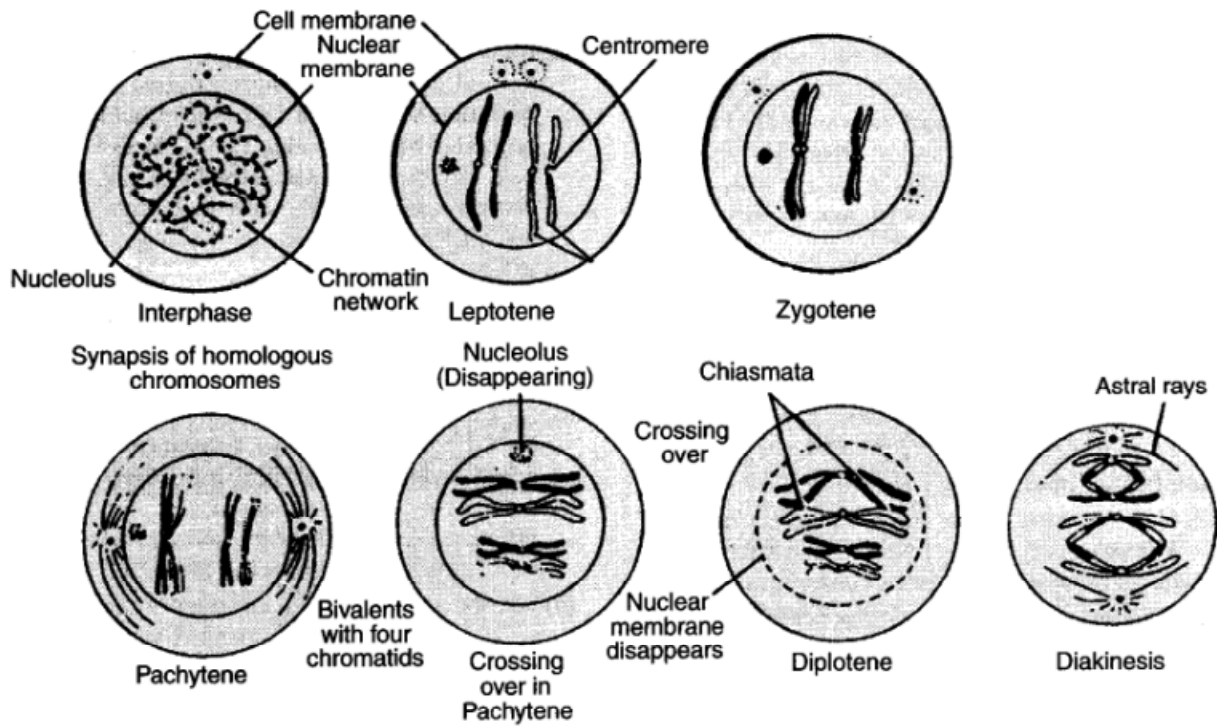
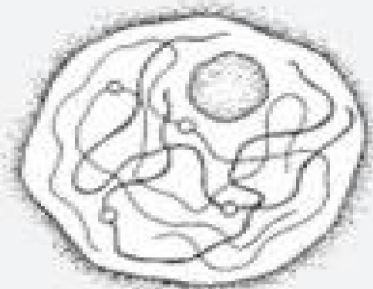


Fig. : Prophase I of meiosis I

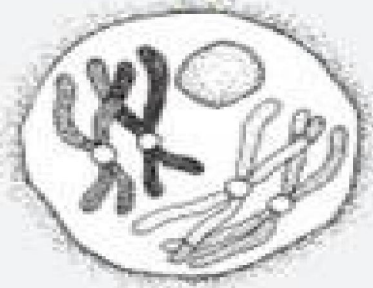
Meiosis: Selected Phases



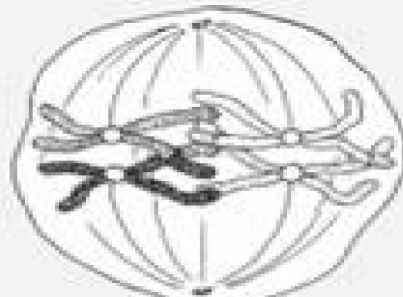
(1) Early prophase I



(2) Prophase I



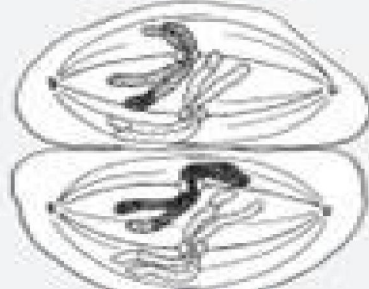
(3) Late prophase I



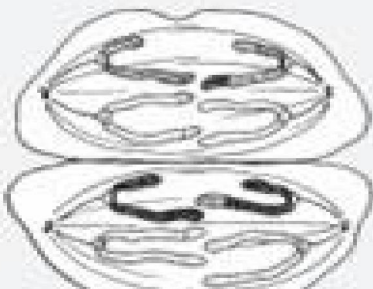
(4) Metaphase I



(5) Anaphase I



(6) Metaphase II



(7) Anaphase II



(8) Late telophase II