Mitosis

The mitosis is a part of somatic cell division which includes the division of the nucleus (called mitosis or karyokinesis) and the division of the cytoplasm (called cytokinesis). Strasburger (1875), a German botanist, was the first to work out the details of mitosis. Mitosis can be studied best in the root tip and shoot tip of several plants. But the most favourable material is the apices of onion roots.

In mitosis, the metabolic nucleus passes through a complicated system of changes in the form of four different stages, viz., prophase, metaphase, anaphase and telophase. Some important aspects of all these stages are discussed below.

1. Prophase (Gr. pro, before):

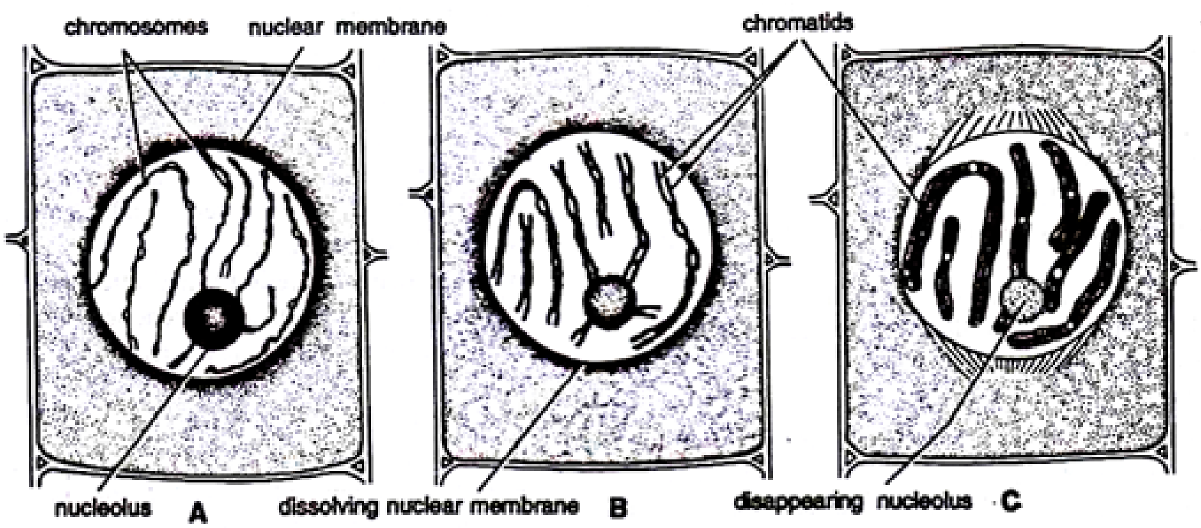

Fig. 305. A-B, Early prophase stages; C, Late prophase stage.

1. It is the first and the longest phase in the mitotic cell division.

2. Chromosomes become visible in the nucleus as short, thick, helically coiled threads (Fig. 305A).

3. Each chromosome splits into two chromatids (Fig. 305B, C) joined at the centromere.

4. Nuclear membrane starts dissolving.

5. Nucleolus also starts dissolving and disappearing.

6. Prophase changes into next stage called metaphase.

4. Chromosomes become shorter and thicker.

5. Chromosomes arrange themselves in the centre or on the equator of spindle.

6. At the end of metaphase, two chromatids of each chromosome also start separating.

ii. Metaphase (Gr. meta, between):

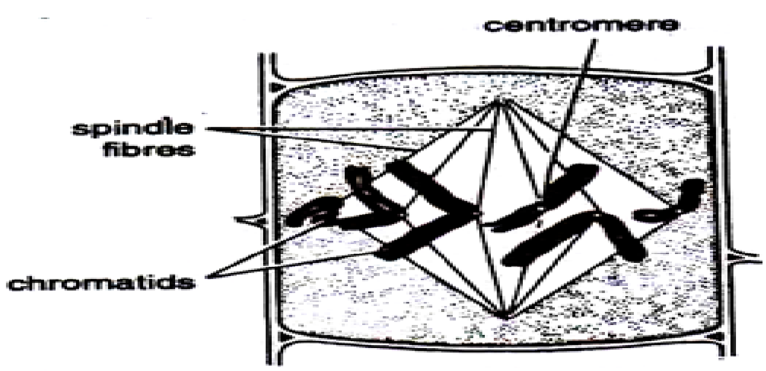

Fig. 306. Metaphase stage.

1. Nuclear membrane disintegrates and disappears completely (Fig. 306).

2. Nucleolus disintegrates and disappears completely.

3. Spindle fibres start appearing and these fibres get attached to chromosomes at centromeres.

4. Chromosomes become shorter and thicker.

5. Chromosomes arrange themselves in the centre or on the equator of spindle

6. At the end of metaphase, two chromatids of each chromosome also start separating.

7. Metaphase changes into the next stage called anaphase.

iii. Anaphase (Gr. ana, back)

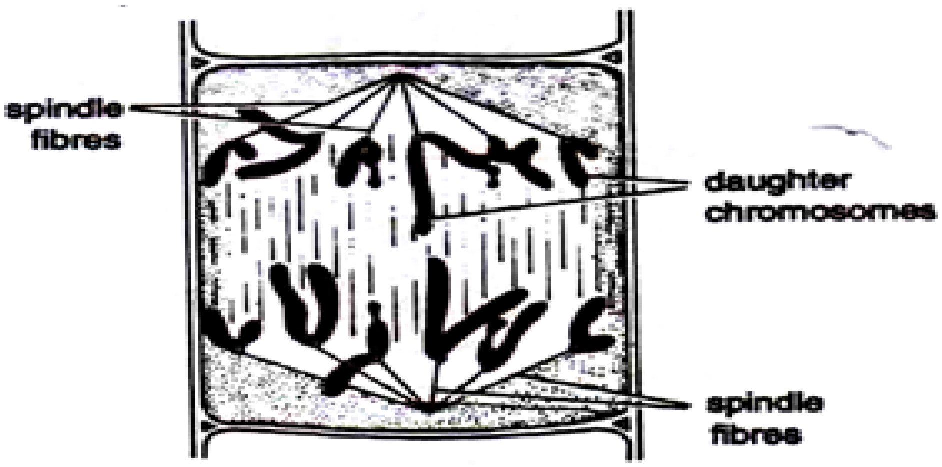

Fig. 307. Anaphase stage.

1. Chromatids separate from each other at centromere and called daughter chromosomes (Fig. 307).

2. Daughter chromosomes move to the opposite poles of the spindle.

3. Daughter chromosomes appear 'V', 'U' or J-shaped during their movement towards poles.

4. Anaphase changes into the next stage called telophase.

iv. Telophase (Gr. telo, end):

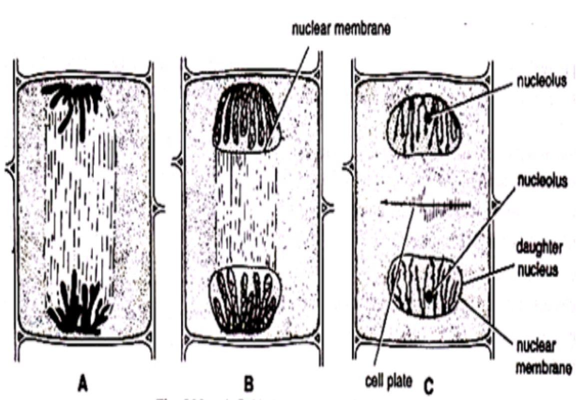

Fig. 308. A-C, Various stages of telophase.

1. Daughter chromosomes are now at the end of the spindle, i.e., present on two opposite poles (Fig. 308A).

2. Nuclear membrane reforms around each group of daughter chromosomes (Fig. 308B).

3. Nucleolus reforms (Fig. 308C).

4. Two nuclei are thus organised, one at each pole of the parent cell.

5. Chromosomes begin to loose their compact structure.

6. Spindle fibres disappear gradually.

7. Thus formed two daughter nuclei are exactly similar to the parent nucleus.

Significance of Mitosis:

1. Mitosis results in the formation of two daughter cells identical with that of the parental cell.

2. By this process, DNA, the main component of chromosomes, is distributed equally among the two newly formed nuclei.

3. Both the daughter cells formed after mitosis are identical and have the same genetic constitution, qualitatively as well as quantitatively, as the parent cell.

4. The number of chromosomes remains the same from one generation to another generation.

5. Resulted daughter cells have the same characters as were present in the parent cell.

6. The characters of the plants grown by vegetative reproduction may be preserved for a long period.

Meiosis

The meiosis is a process of cell division by which the chromosomes are reduced from the diploid to the haploid number. It takes place in all sexually reproducing organisms. Haploid sex cells are produced from the diploid cells in meiosis.

Van Benedin, while working on the horse thread- worm (Parascarisequorum), observed in 1883 that there were twice as many chromosomes visible during mitosis in the fertilized egg as there had been in the sperm and egg nuclei before the mitosis.

By this observation, Van Benedin concluded that the contribution of each of the female and male gametes was half the chromosome number to the zygote Weismann suggested in 1887 that in each generation there must occur reduction division at some stage in which the chromosome number is reduced to half Flemming (1887) and Strasburger (1888) observed that two nuclear divisions take place in rapid succession just prior to the formation of mature eggs and sperms in animals and formation of pollen grains in angiosperms. The entire process of reduction division leading to the formation of gametes was termed as "meiosis" in 1905.

'Meiosis' consists of two successive divisions of the diploid mother nucleus, that are

i) meiosis division I in which the diploid chromosome number (2n) is reduced to haploid chromosome number n, and

(ii) meiosis division II which is a mitotic division.

Meiosis Division I:

In this division the chromosomes are reduced to half, and therefore this is a reduction division.

Meiosis division I is divisible into four major stages (Prophase I, metaphase I, anaphase I and telophase I) which are briefly discussed below:

1. Prophase I:

This is a complicated and prolonged phase of meiosis which can be subdivided further into five sub-stages, i.e., leptotene, zygotene, pachytene, diplotene and diakinesis.

The important features of all these five sub-stages are under-mentioned:

(a) Leptotene:

The diploid nucleus enlarges in volume. The chromosomes appear as long, thin and single threads which soon begin to coil. Several small, bead-like granules (chromomeres) appear in each thread-like chromosome (Fig. 310A).

(b) Zygotene

The homologous chromosomes come together, get themselves arranged side by side, and form pairs or bivalents (Fig. 310B). This pairing is also called synapsis. The pairing chromosomes soon begin to shorten and get thickened, but there is no actual fusion.

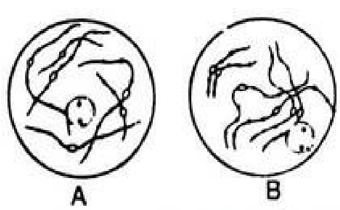

Fig. 310. Leptotene (A) and zygotene (B) stages.

(c) Pachytene:

In this stage the chromosomes become shorter, thicker and get splitted into chromatids linked at the centromeres (Fig. 311). From a pair of each homologous chromosomes are thus produced four chromatids. Identification of the homologous chromosomes can be made in pachytene, which is a long stage of prophase I.

Fig. 311. Pachytene stage.

(d) Diplotene:

Centromeres of paired chromosomes move away from each other (Fig. 312). This movement is because of the development of some repulsive force between the homologous chromosomes. However, the homologous chromosomes remain connected at one or more points called chiasmata.

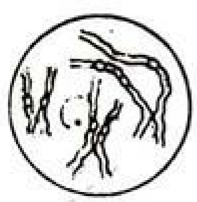

Fig. 312. Diplotene stage.

The physical exchange of genetic material takes place at each chiasma under the process called crossing over. Further coiling and shortening of chromosomes is also seen in late stage of diplotene which soon changes into diakinesis.

e) Diakinesis:

In this last stage of the first meiotic prophase the chromosomes are shortest and thickest. The nuclear membrane starts disintegrating. The nucleolus also disintegrates and disappears (Fig. 313). The chromosomes bivalents move towards the periphery, of the nucleus and remain connected only at the points of chiasmata. The chromosomes are finally released into the cytoplasm.

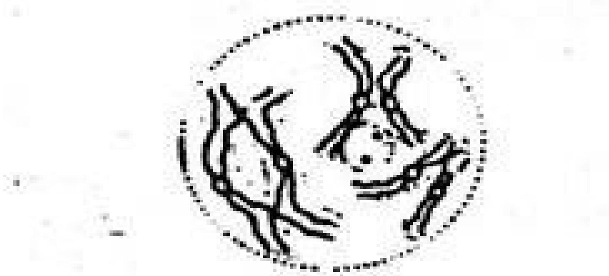

Fig. 313. Diakinesis stage.

2. Metaphase I:

Two major events of metaphase I include complete disintegration of nuclear membrane and the formation of spindle (Fig. 314). All the chromosomes, each along with their two chromatids, move to the equatorial region of the newly formed spindle.

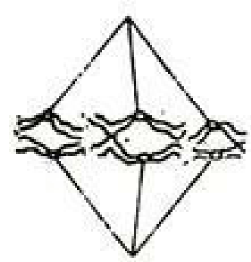

Fig. 314. Metaphase I of meiosis I.

Differing from the metaphase stage of mitosis, the centromeres of chromosome pairs in metaphase stage of meiosis I become attached with the spindle fibres near the equatorial region. The centromeres remain clearly apart from each other and face the opposite poles while the arms of the chromosome pairs lie towards the equator.

3. Anaphase I:

There is first a repulsion and then movement of the two centromeres of the homologous chromosomes towards the opposite poles of the spindle in anaphase I (Fig. 315A). A centromere carries either a paternal or a maternal chromosome to one pole but not both the chromosomes. This actually reduces the chromosome number from diploid (2n) to haploid (n), which is the main feature of meiosis of reduction division.

4. Telophase I:

A nuclear membrane develops around each group of homologous chromosomes present on the two opposite poles in the form of a compact group in telophase I (Fig. 315B). The nucleolus reappears. Both the so formed daughter nuclei contain haploid number (n) of chromosomes, and each chromosome contains a pair of chromatids.

Both the daughter nuclei may or may not be separated by a plasma membrane and soon pass on to the next division, i.e., meiosis division II.

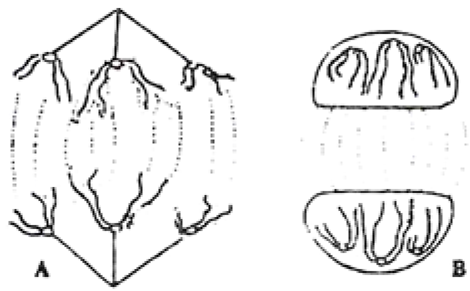

Fig. 315. A, Anaphase I of meiosis I; B, Telophase I of meiosis I.

Meiosis Division II:

This division includes almost all the phases found in mitosis.

Four different phases which constitute meiosis division II are prophase II, metaphase II, anaphase II and telophase II, and main events of all these four phases are discusseappearing

1. Prophase II:

The chromosomes split into chromatids (Fig. 316A) in both the haploid nuclei and cells formed after meiosis division I. The splitted chromatids remain connected only at the centromeres. The chromosomes start coiling and become shorter and thicker. The nuclear membrane and nucleolus start disintegrating and some spindle fibres also start appearing

2. Metaphase II:

The chromosomes get arranged in an equatorial position in the newly-formed spindle (Fig. 316B). Very soon, the chromosome pair separates, of which each contains its own centromere. This is a very short phase of meiosis division II.

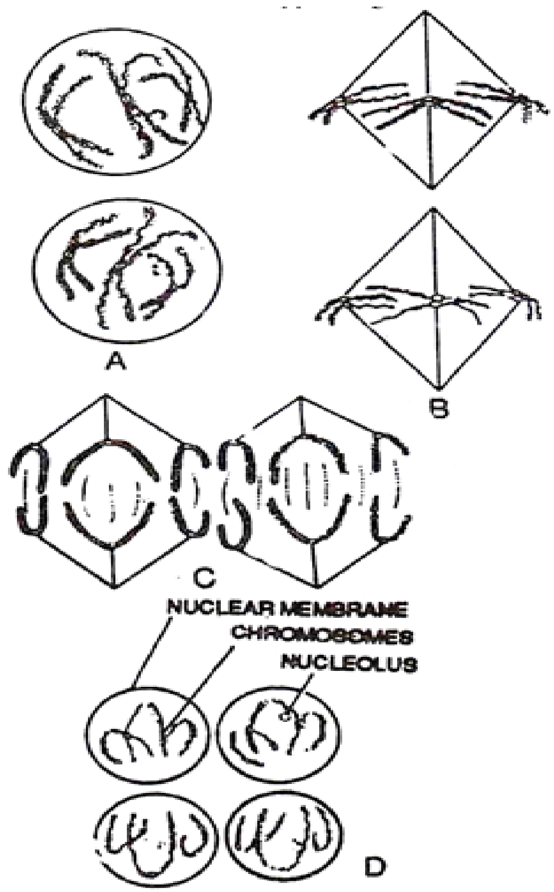

Fig. 316. Stages of meiosis II. A, Prophase II; B, Metaphase II; C, Anaphase II; D, Telophase II.

3. Anaphase II:

In this phase, the two sister chromosomes of each pair start to move towards the opposite poles of the spindle (Fig. 316C). They are being drawn towards the opposite poles by their centromeres.

4. Telophase II:

Each polar group of chromosomes get enveloped by a nuclear membrane, and there is the reappearance of nucleolus. Four cells are formed by cytokinesis, and the nucleus in all these so formed four young cells contain haploid number (n) of chromosomes. In this way, four haploid cells are resulted from a single diploid cell in the process of meiosis.

Significance of Meiosis:

In the process of sexual reproduction the male and female gametes fuse to form a zygote which gives rise to the new off-springs. If the gametes contained the same number of chromosomes as that of their parents, the off-springs would have an ever-increasing chromosomes number in all future generations to come, and this might have resulted always in the formation of new and peculiar types of off-springs, much different from that of their parents. To solve this problem, nature has provided the phenomenon of meiosis to all sexually reproducing plants and animals. Meiosis maintains the haploid nature of gametes.

DNA, the sole hereditary material, is distributed equally among the gametes by the process of meiosis.

Meiosis forms spores (n) from the spore mother cells (2n) and thus maintains the alternation of genera- tions in organisms.