

**Department of biology**

**BOTANY (PLANT BIOLOGY)**

**First stage**

**(5)**

**CELL DIVISION**

**By**

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**The cell cycle** Cell division in plants occurs in meristems and involves two parts: **mitosis** in which the chromosomes are replicated and sorted into two nuclei, and **cytokinesis** in which the cell wall, cytoplasm and organelles divide. In dormant meristems, the cells rest in **G0 phase**.

When conditions are correct, the cell begins the processes leading to division. The entire cycle may be considered as four phases, **G1, S, G2** and **M** (*Fig. 1*).



In **G1 phase** the cell doubles in size and new organelles and materials needed for two cells are formed. During this phase, the nucleus migrates to the center of the cell and is surrounded by a sheet of cytoplasmic strands called the **phragmosome** that bisects the center of the cell at the plane across which it will divide. The phase ends with the **G1/S checkpoint**. The process can stop at this point (see the figure), or proceed to **S phase** in which DNA and associated nuclear proteins are replicated. At the end of S phase the cell contains two full copies of its genetic information. It proceeds to **G2 phase** when the chromosomes begin to condense and structures required for division form. A distinct band of microtubules, the **pre-prophase band**, forms around the cytoplasm in a ring where the edge of the phragmosome lay, again predicting the plane of cell division. At the end of G2, the cell has to pass another checkpoint (**G2/M**) at which stage, if conditions are suitable, it enters **M phase** in which the cell divides. Stages G1 to G 2 are known as **interphase**. M phase, when division occurs, can be divided into a series of stages that can be recognized by microscopy.

**Cell cycle control:**

In **meristems,** a population of cells characterized by thin cell walls and the lack of large vacuoles are constantly dividing. The daughter cells may undergo a few further divisions, but then lose the capacity to divide and after a phase of cell enlargement generally develop large vacuoles. **Plant hormones auxin** and **cytokinin** , are known to initiate the cell cycle. Auxin stimulates DNA replication, while cytokinin initiates the events of mitosis. The cell cycle is also controlled by the activity of cell proteins called **cyclins** and **cyclin dependent protein kinases** (CDPKs; **a kinase is an enzyme which will phosphorylate another protein)**. One group of cyclins, the **G1 cyclins**, are manufactured by the cell in G1 and activate CDPKs which stimulate DNA synthesis at the G1/S control point. If sufficient G1 cyclins are not formed, the cell will not progress to S. Having passed this point, the G1 cyclins are degraded and a new family of cyclins, the mitotic or **M cyclins** are produced. These activate a second set of CDPKs which permit the cell to pass the G2/M control point into mitosis . Whereas animal cells which pass G1/S are committed to undergo division, plant cells are not. This means that many plant cells continue to replicate DNA without dividing. This is known as **endoreduplication**, which is shown by more than 80% of all plant cells and particularly cells with a high metabolic activity and requirement for protein synthesis **Mitosis,** or nuclear division, ensures the equal division of the nuclear material between the daughter cells in eukaryotic organisms. During mitosis the chromosomes condense, and move to the center of the cell where they fully contract. They then split longitudinally into two identical halves that appear to be pulled to opposite poles of the cell by a series of microtubules. In these two genetically identical groups, the coiling of the chromosomes relaxes again, and they are reconstituted into the nuclei of the two daughter cells. It is a continuous process that can be divided into five major phases: interphase, prophase, metaphase, anaphase, and telophase.

**Interphase**: The chromatin, if visible at all, can only be seen as small grains or threads. Interphase is generally considered to be a “resting phase.” However, the cell is replicating the genetic material, preparing for mitosis.



**Prophase**: The beginning of mitosis is illustrated by the chromosomes gradually becoming visible. They start out as elongated threads that shorten and thicken. Chromosomes become more condensed and undergo spiral contractions, like a thin wire being turned into a coiled spring. This coiling involves the entire DNA–protein complex. Each chromosome is composed of two longitudinal halves, called chromatids, joined in a narrow area known as the centromere, where the chromatids are not coiled. The centromere, located on each chromosome, divides the chromosomes into two arms of varying lengths. As prophase progresses, the nucleoli grow smaller and finally disappear. Shortly after, in most cell types, the nuclear envelope breaks down, putting the contracted chromosomes into direct contact with the cytoplasm; this marks the end of prophase.



**Metaphase**: The chromosomes, still doubled, become arranged so that each centromere is on the equatorial region of the spindle. Each chromosome is attracted to the spindle fibers by its centromere; often the arms of the chromosome point toward one of the two poles. Some of the spindle fibers pass from one pole to the other and have no chromosome attached.



**Anaphase**: The chromatids separate from one another and become individual chromosomes. First, the centromere divides and the two daughter chromosomes move away from the equator toward opposite poles Their centromeres, which are still attached to the spindle fiber, move first, and the arms drag behind. The two daughter chromosomes pull apart; the tips of the longer arms separate last. The spindle fibers attached to the chromosomes shorten as the chromatids divide and the chromosomes separate. The fibers appear to move, but in fact the microtubules are continuously formed at one end of the spindle fiber and disassembled at the other. In the process, it appears as if the spindle fibers were tugging the chromosomes toward the poles by their centromeres. By the end of anaphase, the two identical sets of chromosomes have separated and moved to opposite poles.



**Telophase**: The separation is made final; the nuclear envelopes are organized around the two identical sets of chromosomes. The spindle apparatus disappears. Nucleoli also reform at this time. The chromosomes become increasingly indistinct, uncoiling to become slender threads again.

**Cytokinesis**: As mitosis ends, cytokinesis begins, resulting in the formation of two daughter cells. The cleaved membrane slowly draws together, forming a narrow bridge, then separates the cell into two daughter cells. The cells now enter interphase.

**Table 1. Events in mitosis**

|  |  |
| --- | --- |
| **Stage** | **Events** |
| **Early prophase** | Chromosomes visible in nucleus |
| **Mid prophase** | Chromosomes shorten and thicken; the two parts (chromatids) making up each chromosome become visible with a join (centromere) |
| **Late prophase** | Kinetochores (specialized structures attached to microtubules) attach at the centromeres. Nuclear envelope breaks down |
| **Metaphase** | Chromosomes align at the center of the cell; chromosomes aligned by microtubules which run from the centromeres to the pole ends of the cell |
| **Anaphase** | Begins with coordinated movement of chromatids, drawn by the kinetochore microtubules. The two sets of chromatids (now called daughter chromosomes) are now separated to opposite ends of the cell |
| **Telophase** | Daughter chromosomes now visible at ends of cell; nuclear envelopes develop around chromosomes and a cell plate forms which will develop into the cell wall |

**Meiosis:**

Meiosis is the form of eukaryotic cell division that produces **haploid** sex cells or gametes (which contain a single copy of each chromosome) from **diploid** cells (which contain two copies of each chromosome). The process takes the form of one DNA replication followed by two successive nuclear and cellular divisions (Meiosis I and Meiosis II). As in mitosis, meiosis is preceded by a process of DNA replication that converts each chromosome into two sister chromatids.

**Meiosis I**

Meiosis I separates the pairs of homologous chromosomes

**Prophase I**

The homologous chromosomes pair and exchange DNA to form recombinant chromosomes. Prophase I is divided into five phases:

1. **Leptotene**: chromosomes start to condense.
2. **Zygotene**: homologous chromosomes become closely associated (synapsis) to form pairs of chromosomes (bivalents) consisting of four chromatids (tetrads).
3. **Pachytene**: crossing over between pairs of homologous chromosomes to form chiasmata (sing. chiasma).
4. **Diplotene**: homologous chromosomes start to separate but remain attached by chiasmata.
5. **Diakinesis**: homologous chromosomes continue to separate, and chiasmata move to the ends of the chromosomes.

**Prometaphase I**

Spindle apparatus formed, and chromosomes attached to spindle fibres by kinetochores.

**Metaphase I**

Homologous pairs of chromosomes (bivalents) arranged as a double row along the metaphase plate. The arrangement of the paired chromosomes with respect to the poles of the spindle apparatus is random along the metaphase plate. (This is a source of genetic variation through random assortment, as the paternal and maternal chromosomes in a homologous pair are similar but not identical. The number of possible arrangements is 2n, where n is the number of chromosomes in a haploid set. Human beings have 23 different chromosomes, so the number of possible combinations is 223, which is over 8 million.)

**Anaphase I**

The homologous chromosomes in each bivalent are separated and move to the opposite poles of the cell.

**Telophase I**

The chromosomes become diffuse and the nuclear membrane reforms.

**Cytokinesis**

The final cellular division to form two new cells, followed by Meiosis II. Meiosis I is a reduction division: the original diploid cell had two copies of each chromosome; the newly formed haploid cells have one copy of each chromosome.

**Meiosis II**

Meiosis II separates each chromosome into two chromatids

The events of Meiosis II are analogous to those of a mitotic division, although the number of chromosomes involved has been halved.

**Meiosis generates genetic diversity through:**

A - The exchange of genetic material between homologous chromosomes during Meiosis I

B - The random alignment of maternal and paternal chromosomes in Meiosis I

C- The random alignment of the sister chromatids at Meiosis II