Cell Cycle and Mitosis

Cell Cycle is an orderly sequence of events by which a growing cell duplicates its contents and divides into two.

The period required to complete one cell cycle is called generation time, e.g., 20 minutes for bacterial cell, 90 minutes in yeast, 19 hours in beans, 20 hours for onion root tip cells, 22 hours for human cells growing in culture etc.

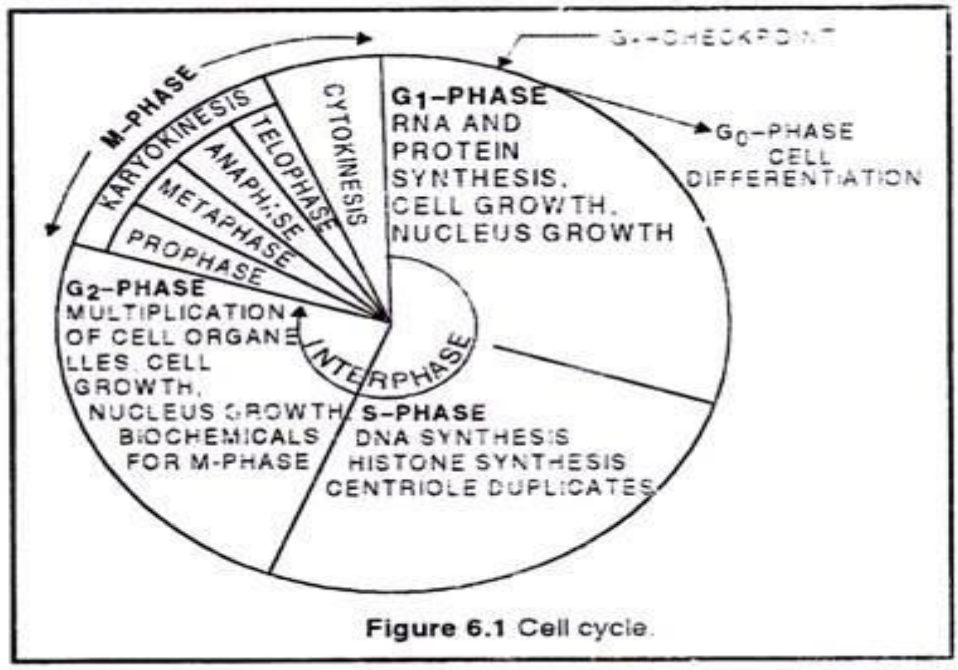

Figure 6.1 Cell cycle.

Howard & Pelc (1953) studied the details of cell cycle. The entire cell cycle may be divided into four phases: G_1 S, G_2 & M. The phases G_1, S and C_2 are together known as interphase (I-phase) which lasts more than 95% of the generation time. Though the interphase is called resting phase, it is actually an active or energy phase which is preparatory to cell division.

i. G_1– phase (= Gap-I or First growth phase or post-mitotic gap phase):
It is the most variable as well as longest phase of cell cycle during which RNA and proteins are synthesized.
It immediately follows the phase of division (mitosis or meiosis). It is also called as the pre-DNA synthesis phase. This phase includes the synthesis of the substrates and enzymes necessary for DNA synthesis. Therefore G_1-phase is marked by the transcription of various types of RNAs and synthesis of different types of proteins.

The regulation of the duration of cell cycle occurs primarily by arresting it at specific point of G_1. The cell in the arrested condition is said to be in the G_0-stage. When conditions change and growth is resumed, the cell re-enters the G_1-phase.
In a specific point of G_1 a cell decides whether to start anew cycle or to withdraw from the cycle. This point is called G_1 checkpoint. The cell that leaves the cell cycle to remain in a resting stage is said to be in Go state or quiscent phase.

ii. S-phase (= synthetic phase):
During this phase DNA synthesis or replication takes place. As a result the DNA content per cell doubles.
It is the phase of DNA synthesis. Histones are also synthesized during this phase, and become associated with the newly replicated DNA. During this phase, the euchromatic regions of the genome replicate earlier than the heterochromatic regions. Moreover, in some cells, the G-C rich regions of the genome replicate earlier than A-T rich ones.

iii. G_2-phase (= Gap II or Second Growth Phase or Pre-mitotic phase).
In this phase, cell growth continues due to synthesis of RNA and proteins. However, DNA synthesis stops.
It is also called as the post-DNA synthesis phase. It is the period between the end of DNA synthesis and the start of cell division. During this phase all the metabolic activities concerning the growth of cytoplasm and its constituent organelles and macromolecules are performed. Also, the factors necessary for chromosome condensation during mitosis are synthesized during this phase. During G_2, a cell contains 2-times the amount of DNA present in the original diploid cell.

iv. M-Phase (= Mitotic phase).
It is the final phase of cell cycle. It starts with nuclear division (Karyokinesis) and ends with division of cytoplasm (cytokinesis or C-phase)

Mitosis

Prophase:

The prophase (Gr., pro=before; phasis=appearance) is the actual first phase of the mitosis.

During the prophase, following events take place in the cell:

1. The cell becomes spheroid, refractive and viscous.
2. The disintegration of nuclear envelope starts.
3. Due to the DNA duplication in the interphase, each chromosome now possesses two chromatids. Each chromatid consists of a single DNA molecule wrapped in the nucleoproteins.
4. Both chromatids remain connected with each other by the centromere and both remain closely associated along their entire lengths.
5. The chromatids become shortened and thickened.
6. The nucleolus starts to disappear.
7. Each centriole separates and migrates towards the opposite poles of the cell. Each centriole duplicates, so that both poles of the cell contain paired centrioles or diplosome.
8. The centrosome forms an elongated body or bridge known as the centrodesmus in between the two centrioles.
9. From the centrodesmus, delicate filaments (microtubules) or asters arise and form the spindle.

Prometaphase:

In, prometaphase (Gr., pro=before; Meta=after; phasis = appearance), following changes usually occur in the cell:

1. The nuclear membrane completely disintegrates.
2. A clear zone known as the equator appears in between the mid-line of the spindle and the nucleus.
3. The chromosomes move towards the equator.

Metaphase:

The metaphase (Gr., Meta=after; phasis=appearance) follows the prometaphase and during this phase following events occur in the cell:

1. Each chromosome reaches to the equator and all arrange themselves radially at the periphery of the spindle.
2. The smaller chromosomes usually remain towards the interior, while the larger chromosomes remain at the periphery.
3. Some of the fibres of microtubules of the spindle attach with the centromere of each chromosome and are known as the chromosomal fibres.
4. Some of the fibres or microtubules of the spindle remain attached from one end to the other end with the centrioles and are known as continuous fibres.
5. Certain fibres occur in between the chromosomes and are known as inter-zonal fibres or inter-chromosomal fibres.

Anaphase:

In the anaphase (Gr., ana=up; phasis=appearance), following changes occur in the cell:

1. The centromere of each chromosome divides into two.
2. The chromatids of each chromosome are separated and form two chromosomes.
3. The chromosomes become shorter and thicker and migrate towards the opposite poles of the cell.
4. Due to shortening of the spindle fibers the two chromatids separate from one another and move towards the opposite poles of the spindle, so that the chromosomes frequently assume a V, I, J or L shape.
5. The migration of the daughter chromosomes towards the opposite poles is achieved by the contraction of chromosomal fibres and the stretching of inter-chromosomal or interzonal fibres. The interzonal fibres push the daughter chromosomes towards the opposite poles.

Telophase:

The telophase is the final stage of mitosis and during this phase following events occur:

1. The chromosomes which reach at the opposite poles of the cells now elongate, the coils of DNA protein fibres loosen and the chromosomes become thread-like.
2. The nucleolus reappears.
3. The endoplasmic reticulum forms the new nuclear envelope around the chromosomes and the nucleolus.
4. The microtubules of the aster and mitotic spindle rearrange and disappear.

Thus, after the telophase, two daughter nuclei are formed due to the karyokinesis. The karyokinesis is followed by the cytokinesis.

Cytokinesis:

In the process of cytokinesis, the cytoplasm splits from the equatorial region and the two daughter halves of the cytoplasm are separated. Soon after a unit membrane of lipoprotein develops in between the two daughter cells.

The cytokinesis of the plant cells the cytokinesis involves the movement of the endoplasmic reticulum and dicytosomes to the equator where they fuse to form the primary cell wall.

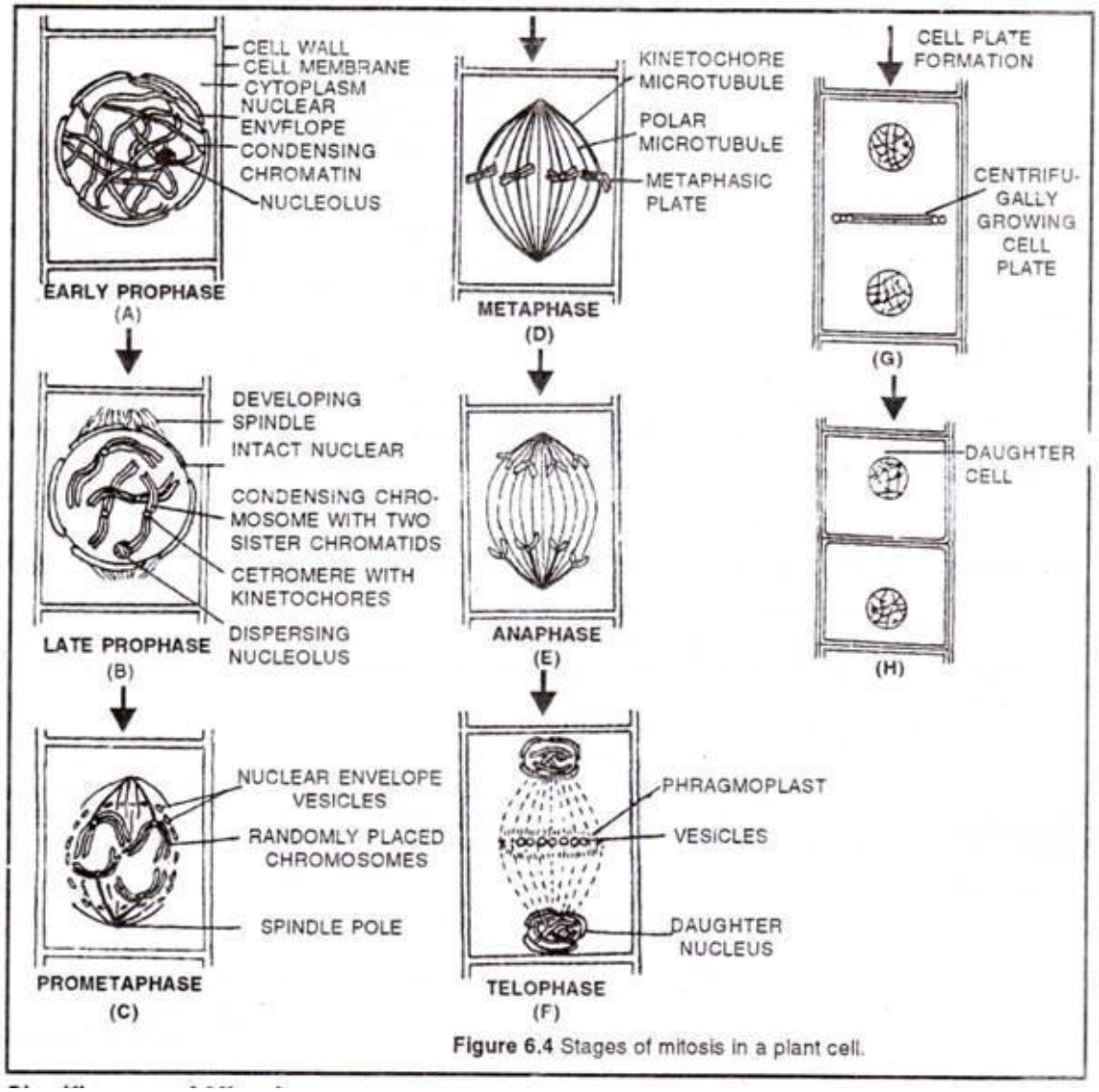

Figure 6.4 Stages of mitosis in a plant cell.

Significance of Mitosis:

1. In mitotic division, the chromosome number in each daughter cell remains the same like the parent cell.
2. The mitosis helps the cell in maintaining its proper size.

3. Through the process of the mitosis, an equilibrium is maintained in the amount of DNA and RNA contents.

4. The mitosis provides the opportunity for the growth and development of the body of the organisms.

5. Due to the mitosis, the old decaying and dead cells are replaced by the new cells.

6. The mitosis helps the organisms in the asexual reproduction.