Chapter 10 cell cycle and cell division

Chapter 10 Cell Cycle and cell division notes discusses the processes of cell cycle regulation and cell division, fundamental to the growth, development, and reproduction of organisms. The chapter highlights the distinct phases of cell division—interphase and mitotic phase—and their respective roles in DNA replication and cell division.

What is a Cell Cycle?

Cell division is a very important mechanism for all living things. The cellular division represents a fundamental biological phenomenon across all living organisms. Throughout the cellular division process, essential events such as DNA replication and cellular enlargement occur concurrently. When a cell divides, it also copies its DNA and grows bigger. All these activities—cell division, DNA copying, and growth—need to happen together in the right order to make sure cells split correctly and make new cells with complete sets of genes. The complete process of a cell copying its DNA, making more cells, and splitting into two new cells is called the "cell cycle."

Phases of Cell Cycle

There are two main phases of the cell cycle- the Interphase and the M Phase.

Interphase

Interphase is the longest phase of the cell cycle, during which the cell grows, replicates its DNA, and prepares for cell division. It's like the "preparation phase" before the actual division happens. Interphase can be divided into three subphases: G1 (Gap 1), S (Synthesis), and G2 (Gap 2).

- The G1 phase occurs after cell division (mitosis) and before DNA replication initiation. During G1, the cell grows and is metabolically active but does not replicate its DNA.
- The S phase, or synthesis phase, is when DNA replication happens, doubling the amount of DNA per cell. Despite DNA doubling, the chromosome number remains the same as in G1. In animal cells during S phase, DNA replication begins in the nucleus, and centrioles duplicate in the cytoplasm.
- The G2 phase involves protein synthesis in preparation for mitosis while cell growth continues. Some adult animal cells, like heart cells, and others divide only as needed to replace lost cells, exiting G1 to enter a non-dividing state called G0. Cells in G0 remain metabolically active but only proliferate when needed by the organism.

M Phase

The M phase, or mitotic phase, is the phase of the cell cycle where actual cell division occurs. It consists of two main processes: Karyokinesis and cytokinesis.

The Karyokinesis stage of cell division involves further four stages, which are:

Prophase: First stage of mitotic cell division, following S and G2 phases of interphase. In S and G2 phases, new DNA molecules are intertwined, but not distinct. Prophase starts with condensation of chromosomal material. Centrosomes, duplicated during S phase, move toward opposite cell poles. Cells in late prophase lack Golgi complexes, endoplasmic reticulum, nucleolus, and nuclear envelope when viewed under a microscope.

The key features of prophase are:

- Chromosomal condensation into compact mitotic chromosomes, each consisting of two chromatids attached at the centromere.
- Centrosomes move to opposite poles, radiating microtubules called asters.

Metaphase: Second stage of mitosis marked by complete disintegration of the nuclear envelope. Chromosomes spread throughout the cell cytoplasm, and by the end of this stage, the condensation is complete, and visible under a microscope.

Key features of Metaphase are:

- Spindle fibers attach to chromosome kinetochores.
- Chromosomes move to the spindle equator and align along metaphase plate via spindle fibers to both poles.

Anaphase: At the start of anaphase, the third phase of karyokinesis: Each chromosome positioned at the metaphase plate divides simultaneously. The resulting daughter chromatids, now known as daughter chromosomes, begin moving toward opposite poles.

Key features of the anaphase are:

- Centromeres split, separating chromatids.
- Chromatids migrate to opposite poles.

Telophase: At the start of telophase, the final phase of karyokinesis:

Chromosomes that have reached the poles become less condensed and lose their distinct structure. Individual chromosomes become indiscernible, and chromatin material tends to gather at each pole.

Key features of telophase are:

- Chromosomes assemble around opposite spindle poles, losing their individual identity.
- A nuclear envelope forms around the chromosome clusters at each pole, resulting in the formation of two daughter nuclei.
- Components like the nucleolus, Golgi complex, and endoplasmic reticulum (ER) reassemble.

Cytokinesis: Cytokinesis is the process of cell division that occurs after the nuclear division phase (karyokinesis) in eukaryotic cells. Cytokinesis is started by the formation of a furrow in the plasma membrane. The furrow deepens and eventually meets at the center, dividing the cytoplasm into two.

What is Meiosis?

Sexual reproduction involves the merging of two gametes, each containing a full haploid set of chromosomes. Gametes originate from specialized diploid cells. The unique type of cell division that halves the chromosome count, leading to the generation of haploid offspring cells, is termed meiosis. Meiotic events are grouped into 2 phases: Meiosis I and Meiosis II

Phases of Meiosis I

The following are the phases of the Meiosis I:

Prophase I: This stage of meiosis stands out for its complexity and duration, contrasting with the relatively simpler prophase of mitosis. This phase comprises five distinct stages: Leptotene, Zygotene, Pachytene, Diplotene, and Diakinesis.

- Leptotene marks the initial stage where chromosomes gradually become visible under the light microscope while continuing to compact.
- In Zygotene, homologous chromosomes start pairing together through a process known as synapsis, forming structures called bivalents or tetrads, helped by the development of a synaptonemal complex.
- Pachytene follows, characterized by the distinct appearance of four chromatids within each bivalent and the initiation of crossing over at specific points known as recombination nodules, facilitated by the enzyme recombinase.
- During Diplotene, the dissolution of the synaptonemal complex occurs, and chiasmata, the visible manifestations of crossover points, become more pronounced.
- Diakinesis marks the final stage of prophase I, characterized by the terminalization of chiasmata, full condensation of chromosomes, and the assembly of the meiotic spindle, signaling the transition to metaphase.

Metaphase I: This is marked by the alignment of bivalent chromosomes along the equatorial plate, with microtubules from opposite spindle poles attaching to kinetochores.

Anaphase I: This is distinguished by the separation of homologous chromosomes, with sister chromatids remaining attached at their centromeres.

Telophase I: This involves the reappearance of the nuclear membrane and nucleolus, followed by cytokinesis, resulting in the formation of two daughter cells, each containing half the chromosome number of the parent cell.

Phases of Meiosis II

The following are the phases in Meiosis II:

Prophase II: This stage in meiosis II starts immediately after cytokinesis, often before chromosomes fully elongate. The nuclear membrane vanishes by the end of prophase II, and chromosomes recompact.

Metaphase II: This stage sees chromosomes aligning at the equator, with microtubules from opposite spindle poles attaching to sister chromatids' kinetochores.

Anaphase II: This stage begins with the simultaneous splitting of each chromosome's centromere, allowing sister chromatids to move toward opposite poles through microtubule shortening.

Telophase II: This stage marks the end of meiosis, during which two sets of chromosomes are once again enclosed by a nuclear envelope.