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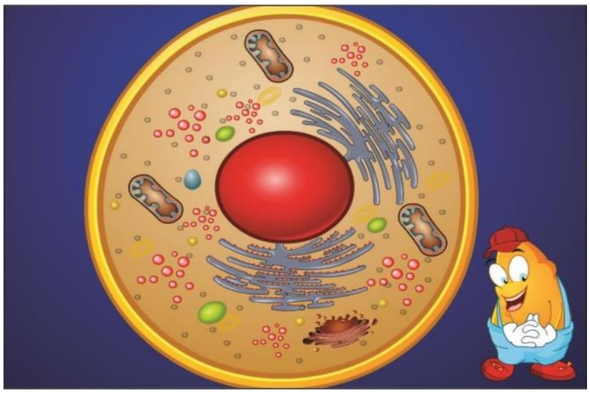
2 Cell Cycle and Cell Division

1- Cell Cycle



Are you aware that all organisms, even the largest, start their life from a single cell? You may wonder how a single cell then goes on to form such large organisms. Growth and reproduction are characteristics of cells, indeed of all living organisms.

All cells reproduce by dividing into two, with each parental cell giving rise to two daughter cells each time they divide. These newly formed daughter cells can themselves grow and divide, giving rise to a new cell population that is formed by the growth and division of a single parental cell and its progeny. In other words, such cycles of growth and division allow a single cell to form a structure consisting of millions of cells.

Cell cycle and regulation of cell cycle

Cell division is a very important process in all living organisms. During the division of a cell, DNA replication and cell growth also take place. All these processes, i.e., cell division, DNA replication, and cell growth, hence, have to take place in a coordinated way to ensure correct division and formation of progeny cells containing intact genomes. The sequence of events by which a cell duplicates its genome, synthesises the other constituents of the cell and eventually divides into two daughter cells is termed **cell cycle.** Although cell growth (in terms of cytoplasmic increase) is a continuous process, DNA synthesis occurs only during one specific stage in the cell cycle. The replicated chromosomes (DNA) are then distributed to daughter nuclei by a complex series

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of events during cell division. These events are themselves under genetic control.

Phases of Cell Cycle

A typical eukaryotic cell cycle is illustrated by human cells in culture. These cells divide once in approximately every 24 hours (Figure 10.1). However, this duration of cell cycle can vary from organism to organism and also from cell type to cell type. Yeast for example, can progress through the cell cycle in only about 90 minutes.

1. **Interphase**, the period preceding mitosis, is the longest phase of the cell cycle and has three distinct sub-stages.

- **G1 Phase (Gap 1)**: This is the phase right after cell division. Cells increase in size, produce RNA and synthesize proteins. Importantly, this phase ensures that everything is in place for DNA synthesis to occur in the next phase.

- **S Phase (Synthesis)**: During this phase, the cell's DNA replicates. At the end of the S phase, each chromosome consists of two chromatids attached at the c

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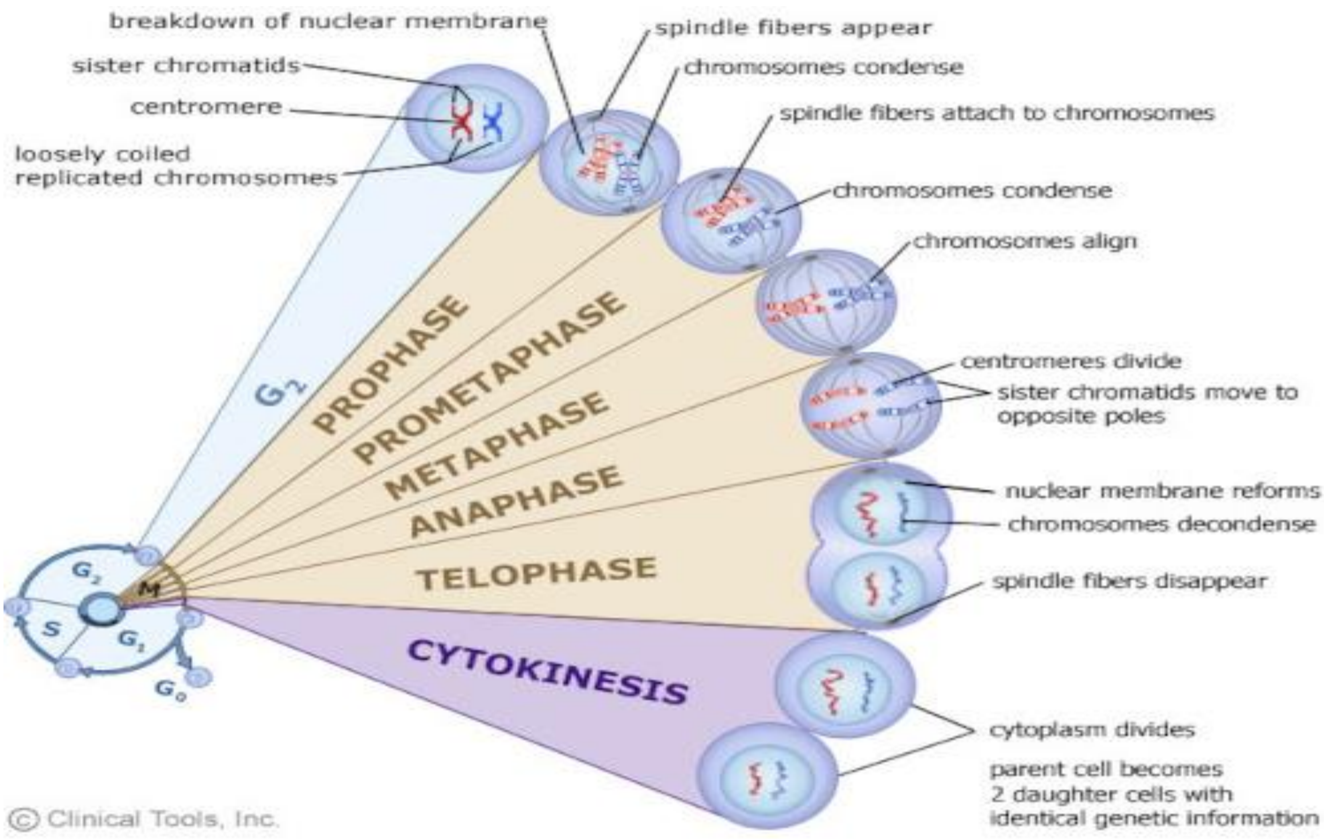

2. **G2 Phase (Gap 2)**: Here, the cell continues growing and prepares for mitosis. It ensures that all the DNA has been replicated without any errors.

M phase A cell divides and forms two new daughter cells during mitosis.

In mitosis or the M phase, one parental cell gives rise to two identical daughter cells. This phase has multiple steps:

- **Prophase**: Chromosomes condense and become visible, the nuclear envelope starts to disintegrate, and the mitotic spindle begins to form.
- **Metaphase**: Chromosomes line up along the cell's equatorial plate, and spindle fibers attach to the centromeres.
- **Anaphase**: Sister chromatids are pulled apart towards opposite poles of the cell.

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- **Telophase**: The chromatids or chromosomes move to opposite ends of the cell and two nuclei form.

Cytokinesis – Division of the Cytoplasm

Following mitosis (or as its final step), the cell undergoes cytokinesis where the cytoplasm divides, creating two daughter cells.

There are two distinct ways the nucleus can be divided, according to the function of the daughter cell:

- **Mitosis:** A single nuclear division that produces genetically identical daughter cells with the same number of chromosomes as the parent cell
- **Meiosis:** A process of two nuclear divisions that produce genetically distinct daughter cells with only half the number of chromosomes as the parent cell

Mitosis

Mitosis is a process of asexual reproduction that results in the production of genetically identical daughter cells (clones)

- It involves a single nuclear division that ultimately results in the production of two daughter cells
    - The single nuclear division separates the sister chromatids into two identical sets of chromosomes
- The chromosome number and genome remains unchanged between the parent cell and daughter cells
- In multicellular organisms, it is used for cell proliferation (generates new body cells for growth and tissue repair)

• Malfunctions in mitosis can lead to the development of cancers (uncontrolled cell division of body cells

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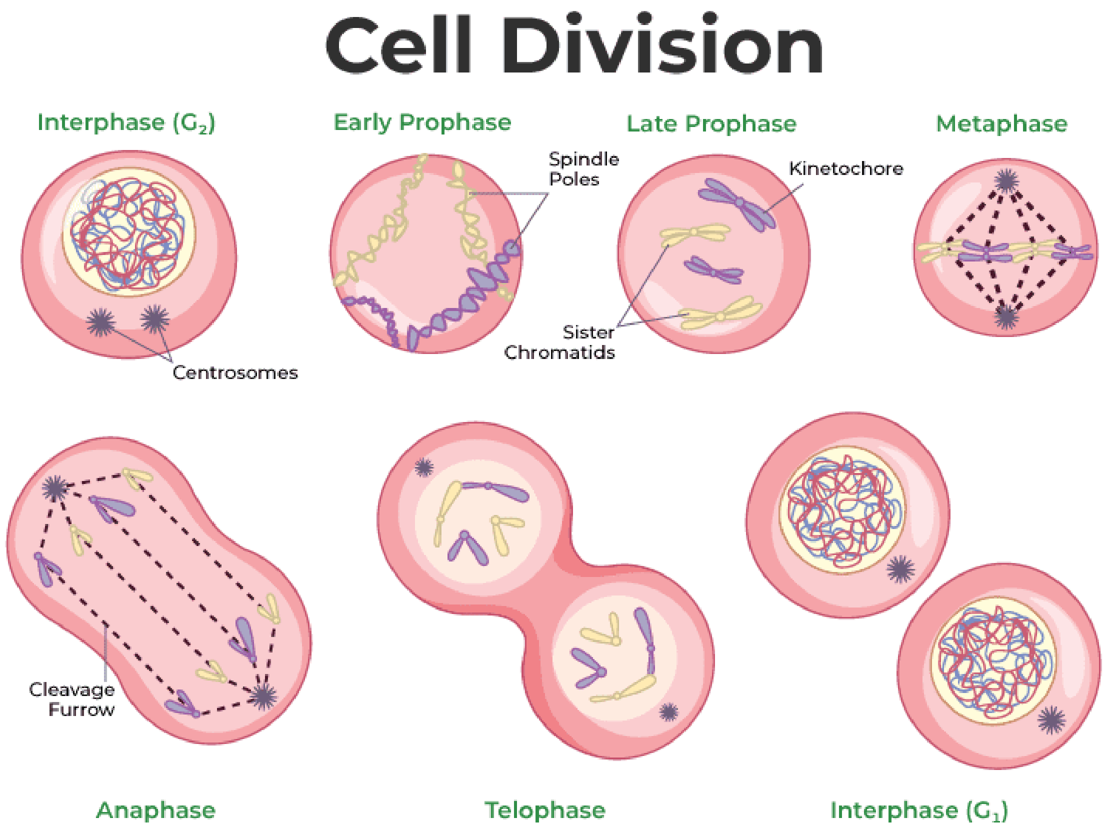

Meiosis

Meiosis is a process of sexual reproduction that results in the production of genetically distinct daughter cells (promotes variation)

- It involves two nuclear divisions that typically result in the production of four daughter cells
  - The first nuclear division divides the total number of chromosomes in two (reduction division)
  - The second nuclear division separates the sister chromatids that were produced by DNA replication
- The chromosome number is halved from parent cell to daughter cell (diploid → haploid)
- In multicellular organisms, it is used to create sex cells

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(gametes) in order to generate offspring that are genetically distinct

- Malfunctions in meiosis can lead to aneuploidy conditions (offspring with an abnormal total number of chromosomes)

Meiosis I

is referred to as "reduction division" because it reduces the chromosome number by half. During this phase, homologous chromosomes are separated, with each daughter cell receiving one chromosome from each pair.

•**prophase I** – chromosomes replicate and condense as the nuclear envelope begins to break down. Crossing over occurs at chiasmata, where homologous chromosomes exchange genetic material, creating new allele combinations and promoting genetic diversity.

- **Prometaphase I** – spindle fibers attach to chromosomes at their centromeres The chromosomes continue to condense.
- **Metaphase I** – homologous chromosomes align along the cell's equator. Independent assortment occurs, where maternal and paternal chromosomes are randomly oriented to either pole, further enhancing genetic diversity.
- **Anaphase I** – homologous chromosomes, each still consisting of two sister chromatids, are pulled toward opposite poles of the cell.
- **Telophase I** – nuclear envelopes reform around each set of chromosomes at the poles.
- **Cytokinesis I** – cytoplasm divides, resulting in two haploid daughter cells, each containing one chromosome from each homologous pair

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Meiosis II

is often referred to as "equational division" because the chromosome number remains unchanged. During this phase, the sister chromatids are separated, resulting in four genetically distinct haploid gametes.

- **Prophase II** – nuclear envelope breaks down, and a new spindle apparatus begins to form in each haploid cell.
- **Prometaphase II** – spindle fibres attach to the centromeres of the chromosomes, preparing them for alignment along the equator.
- **Metaphase II –** chromosomes align in single file along the equator.
- **Anaphase II –** sister chromatids are pulled to opposite poles.
- **Telophase II** – nuclear envelopes reform around each set of separated

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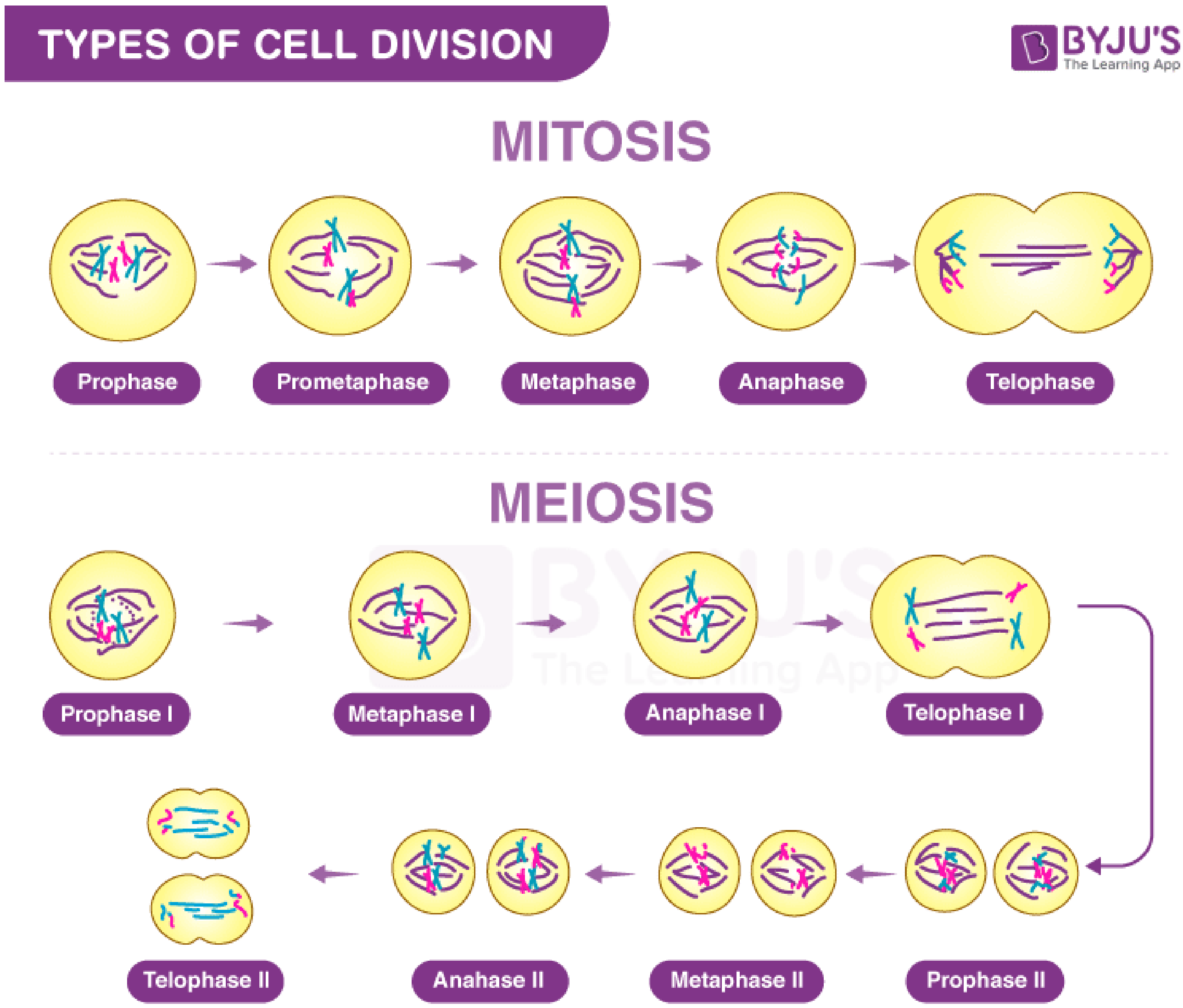

Level meiosis 1&2