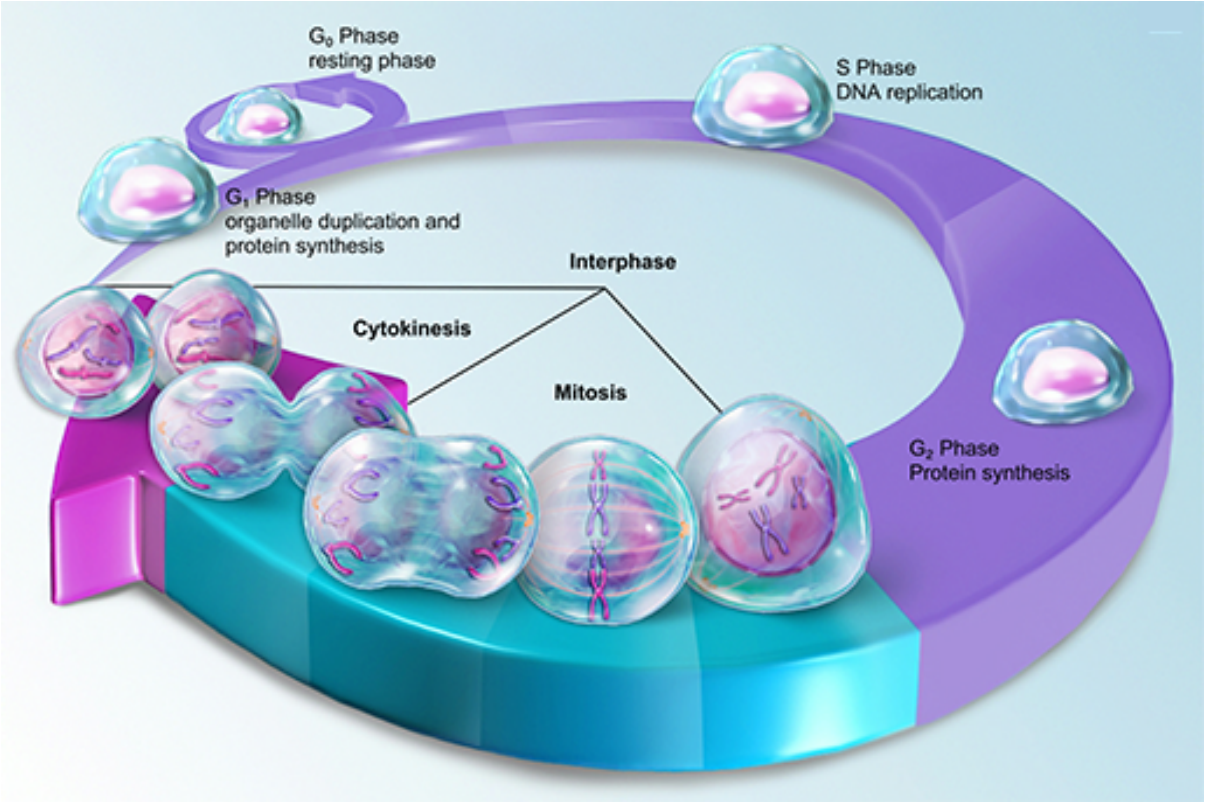
# The Cell Cycle and Mitosis

**The biological processes by which cells grow, replicate their DNA, and multiply, ultimately contributing to the growth and repair of an organism**

**Written by Amirali Banani | January 6, 2024**




3D diagram of the cell cycle | Credit: Visible Body

## Key Terminology

**Chromosome:** a threadlike structure in the cell nucleus that carries **genes**. The structure of a chromosome includes **two sister chromatids** and a **centromere**, its center, that connects the two sister chromatids. Chromosomes are composed of **chromatin**, a biological substance located in the cell nucleus that consists of DNA and protein.

The **nucleus** controls the functions of a living cell. It contains the master set of instructions that determines what each cell will become, how it will function, when it will grow and divide, and when it will die.

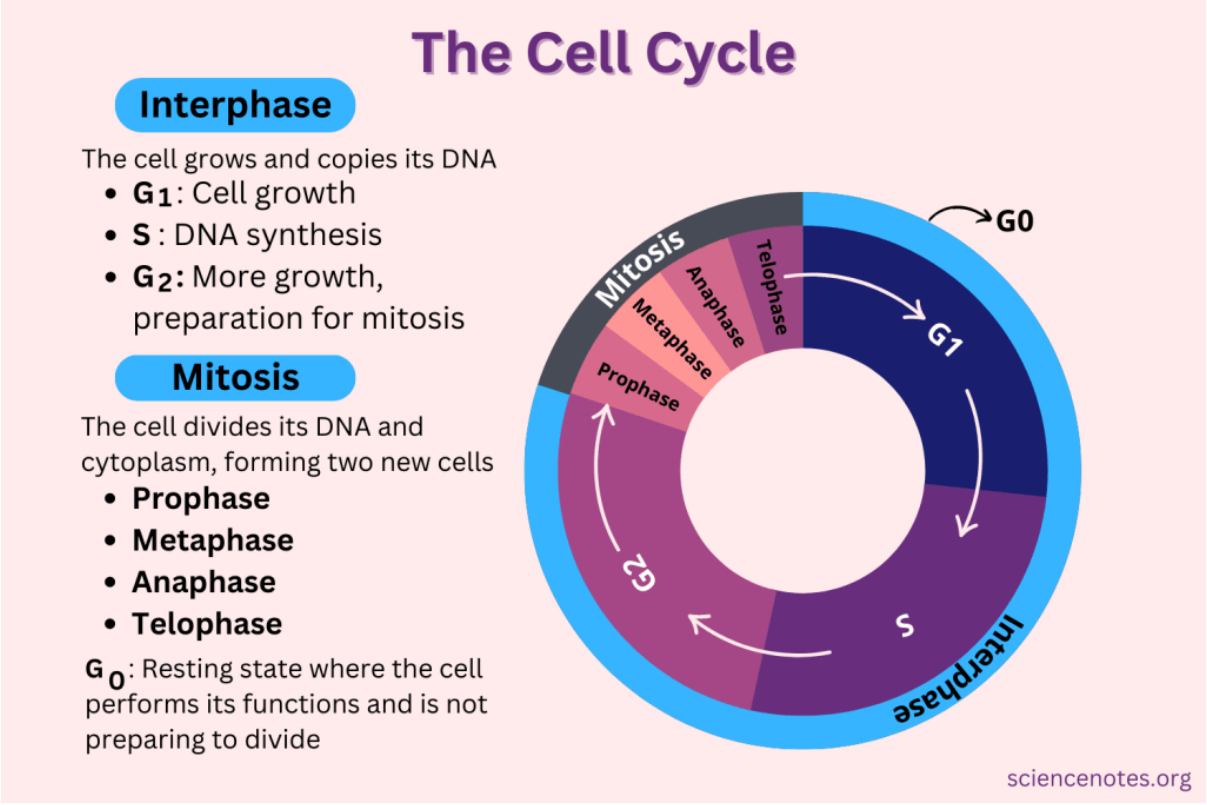
The **nucleolus** is the most prominent domain in the nuclei of eukaryotic cells, whose main function is the synthesis of **ribosomal RNA (rRNA)** and **ribosome biogenesis**.

**Biogenesis:** the production of new living organisms or the synthesis of biological substances by living organisms. Conceptually, biogenesis encompasses the hypothesis that complex living things have arisen only from other living things through **reproduction**.

**DNA Replication:** The process during which the cell nucleus copies and replicates the 3 billion base pairs of genetic information in DNA and, as a result, produces two identical DNA molecules that have the same sequence of nitrogenous bases as the original DNA molecule. The four main **enzymes** that are involved in controlling this process are **DNA helicase**, **RNA primase**, **DNA polymerase**, and **DNA ligase**.

**Spindle Fibers:** Tiny tube-like structures made of protein that attach to chromosomes during mitosis and separate them into **sister chromatids**.

## The Cell Cycle




A diagram of the cell cycle, showing the different proportions of interphase and mitosis with their stages. | Credit: sciencenotes.org

## The 3 Stages of the Cell Cycle

**1. Interphase**

**2. Mitosis**

**3. Cytokinesis**

## Interphase

Constitutes most of the life of a cell. During this stage, the cell grows and carries out the functions necessary for its survival. During **DNA replication**, the cell nucleus replicates its genetic material. Then, the cell continues to grow and prepare for **mitosis and cytokinesis**, duplicating its contents and producing the nutrients necessary for cell division.

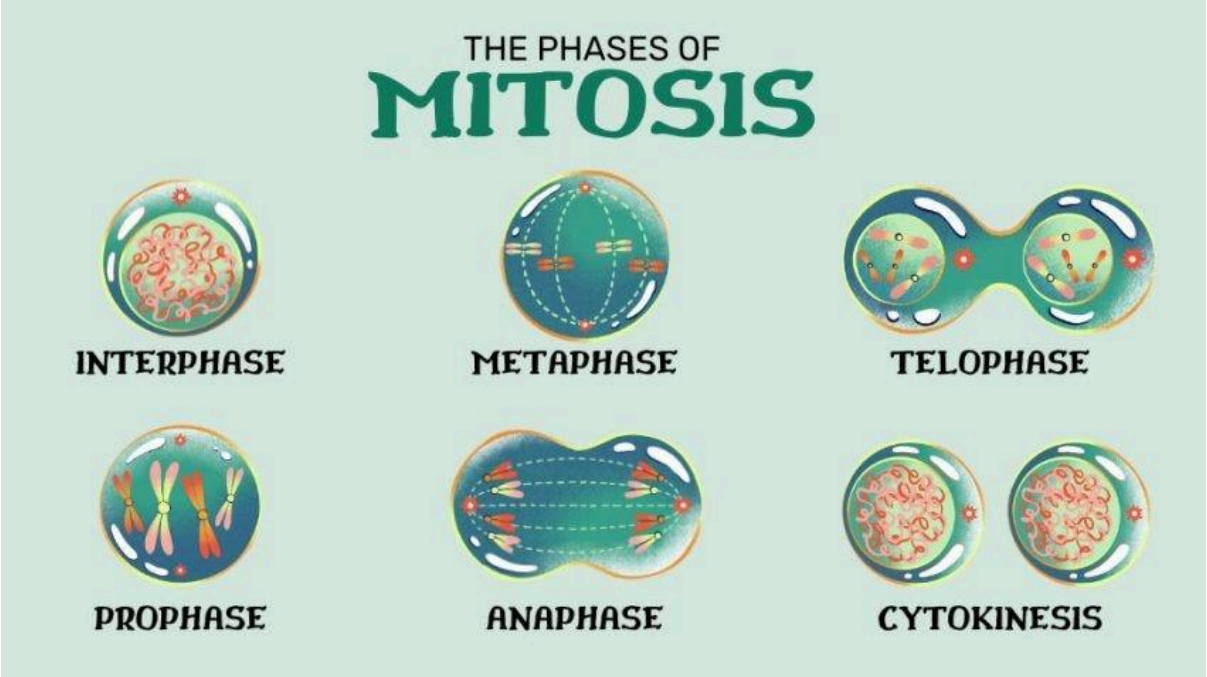
**Events of Interphase**

**Growth and Preparation (G1):** The cell increases in size and produces the proteins and molecules necessary for it to function.

**DNA Replication:** The DNA molecule unwinds, and the nitrogenous bases split apart. Each side of the DNA molecule becomes a template on which a new side forms. The new bases bond with the bases on the "template sides" of the DNA molecule, and this process of replication results in **two identical DNA molecules**.

**Continued Growth and Preparation (G2)/Preparation for Mitosis:** After the DNA has been replicated, the cell continues to grow and is active, producing essential biological materials for the two new cells that will be produced after mitosis and cytokinesis. As the chromatin is in its loosely coiled form, the DNA instructions for making a specific protein can be **transcribed into RNA** and then **translated by the ribosomes** so that essential proteins can be manufactured in preparation for mitosis and cytokinesis. The important energy-generating organelles, such as the mitochondria and the chloroplasts (in the case of plants), are duplicated.

## Mitosis/Cytokinesis

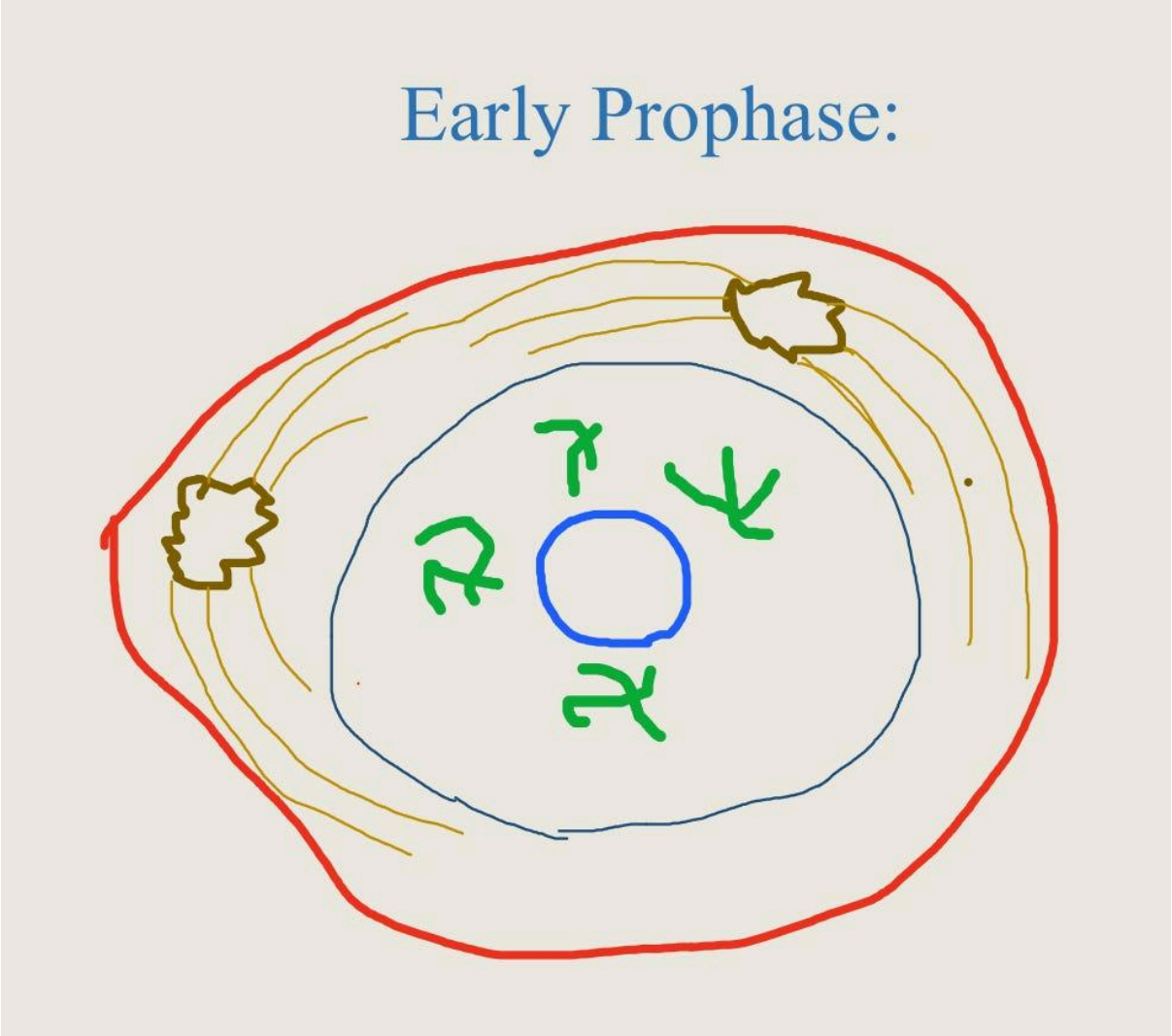



It is the process by which a cell divides into two diploid daughter cells, each with **identical genetic information** as the parent cell. Mitosis consists of 5 stages: prophase, metaphase, anaphase, telophase, and finally, cytokinesis, which is the final stage where the cell divides. In animal cells, this happens through the constriction of the cellular membrane; in plant cells, a plate forms at the center of the cell to divide it into two equal parts.

## Phases of Mitosis

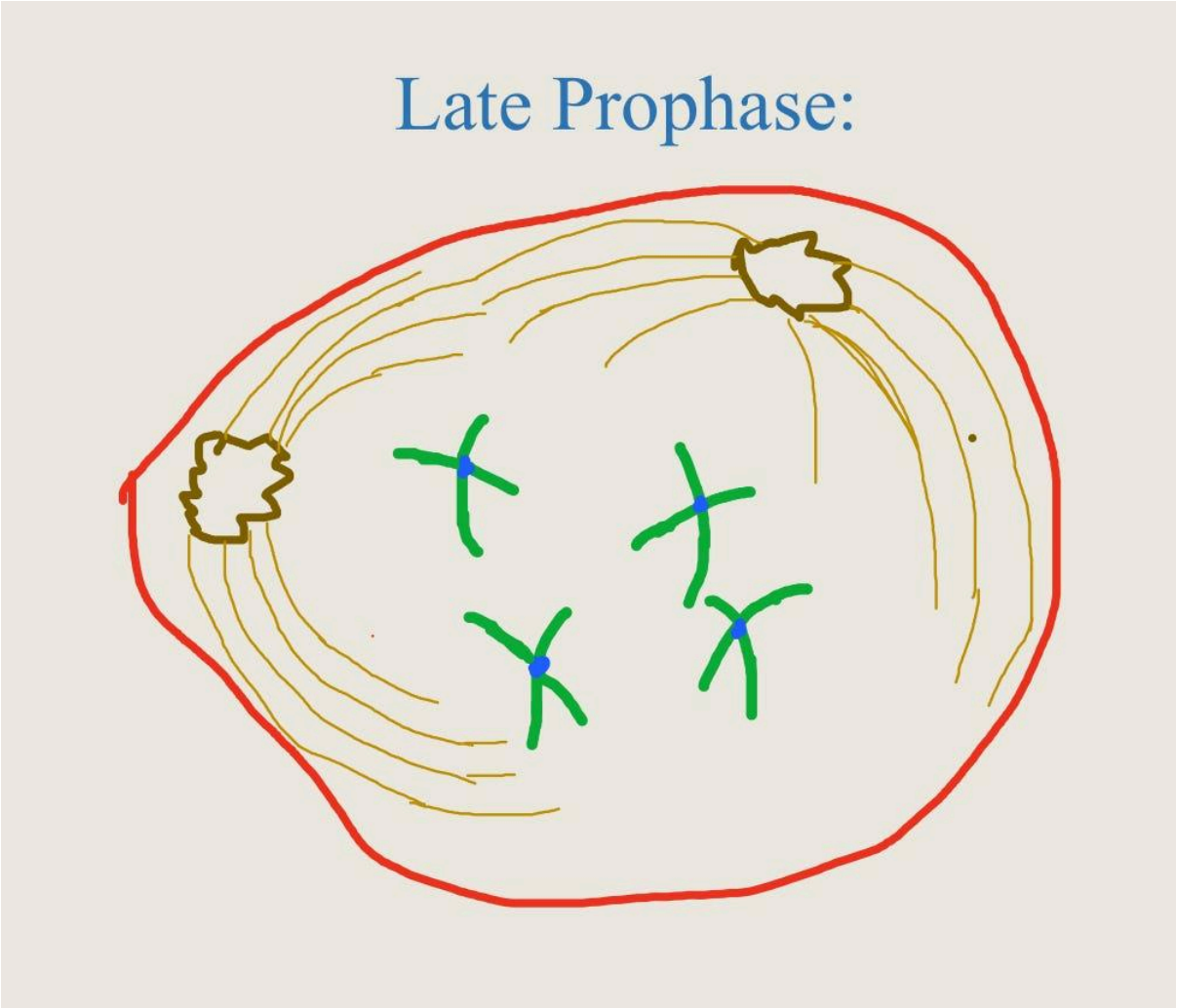
### Early Prophase

The nuclear membrane and nucleolus start to break down, the chromatin, which consists of the DNA, begins to condense into chromosomes, and spindle fibers begin to form.



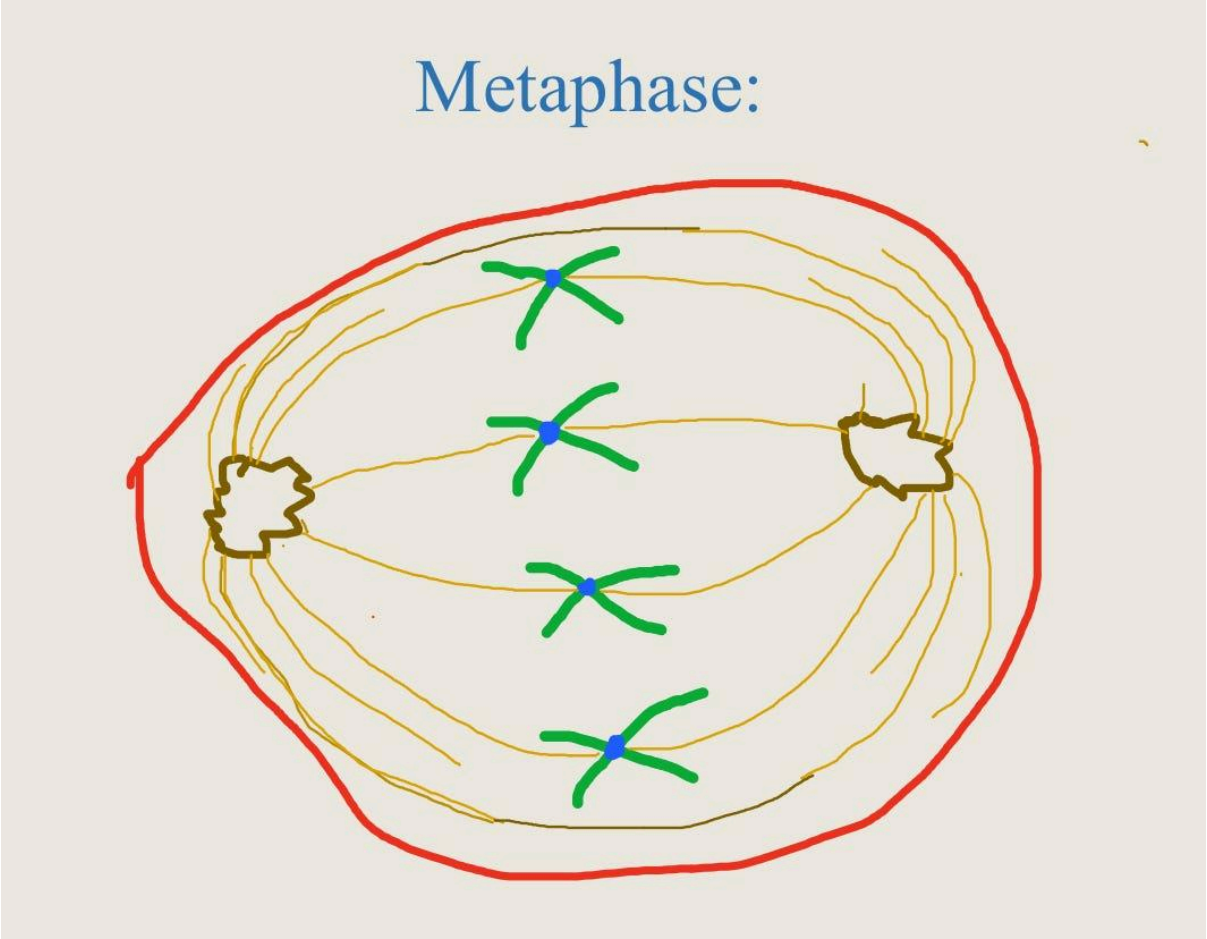
## Late Prophase

The nuclear membrane and nucleolus have completely disappeared, the chromatin has fully condensed into X-shaped chromosomes, and the spindle fibers have completed development.



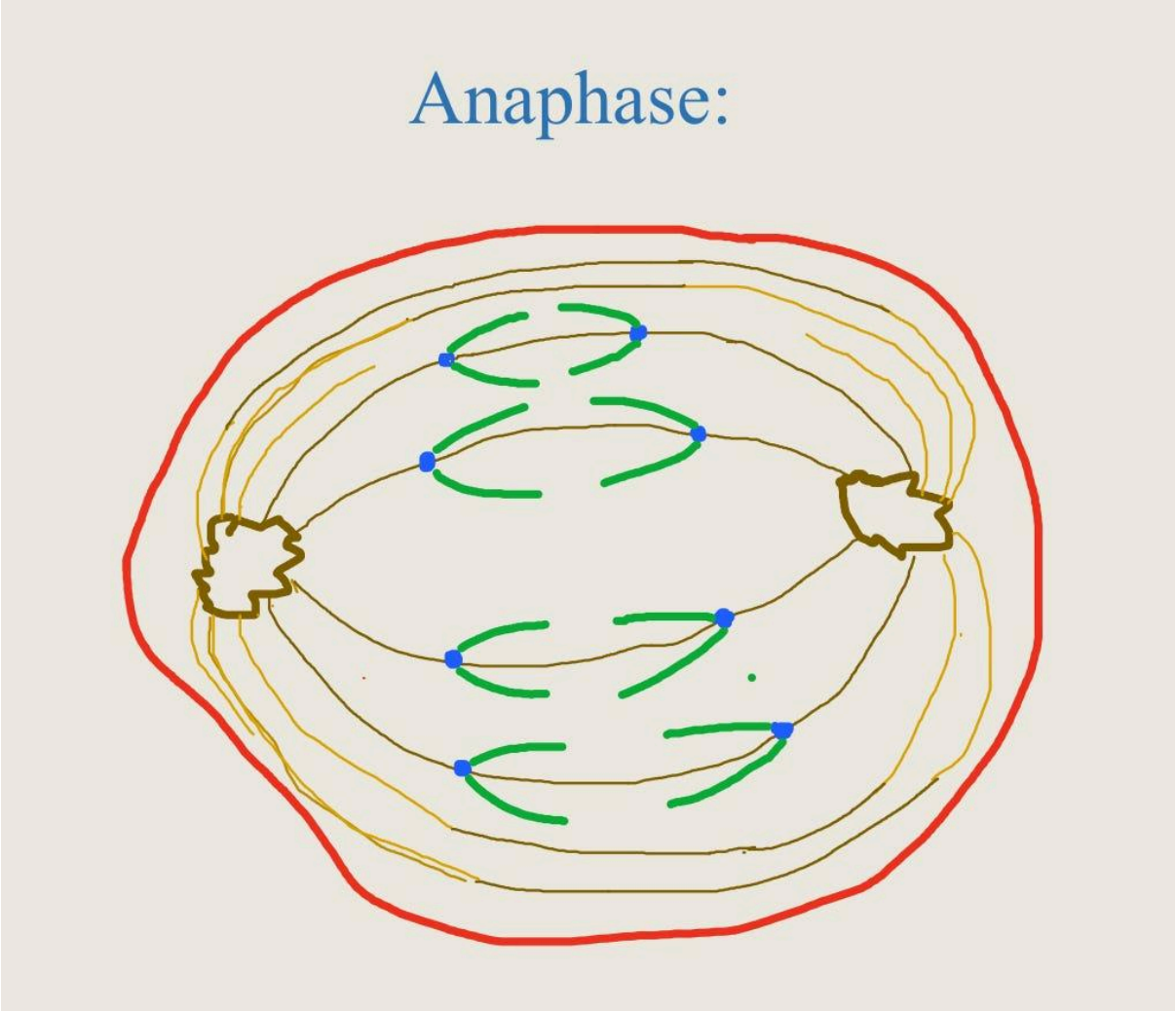
## Metaphase

The chromosomes line up along the equator of the cell with the guided movement of the spindle fibers, while the centrioles move to the opposite poles of the cell. The two sister chromatids of each chromosome are ready to be separated.



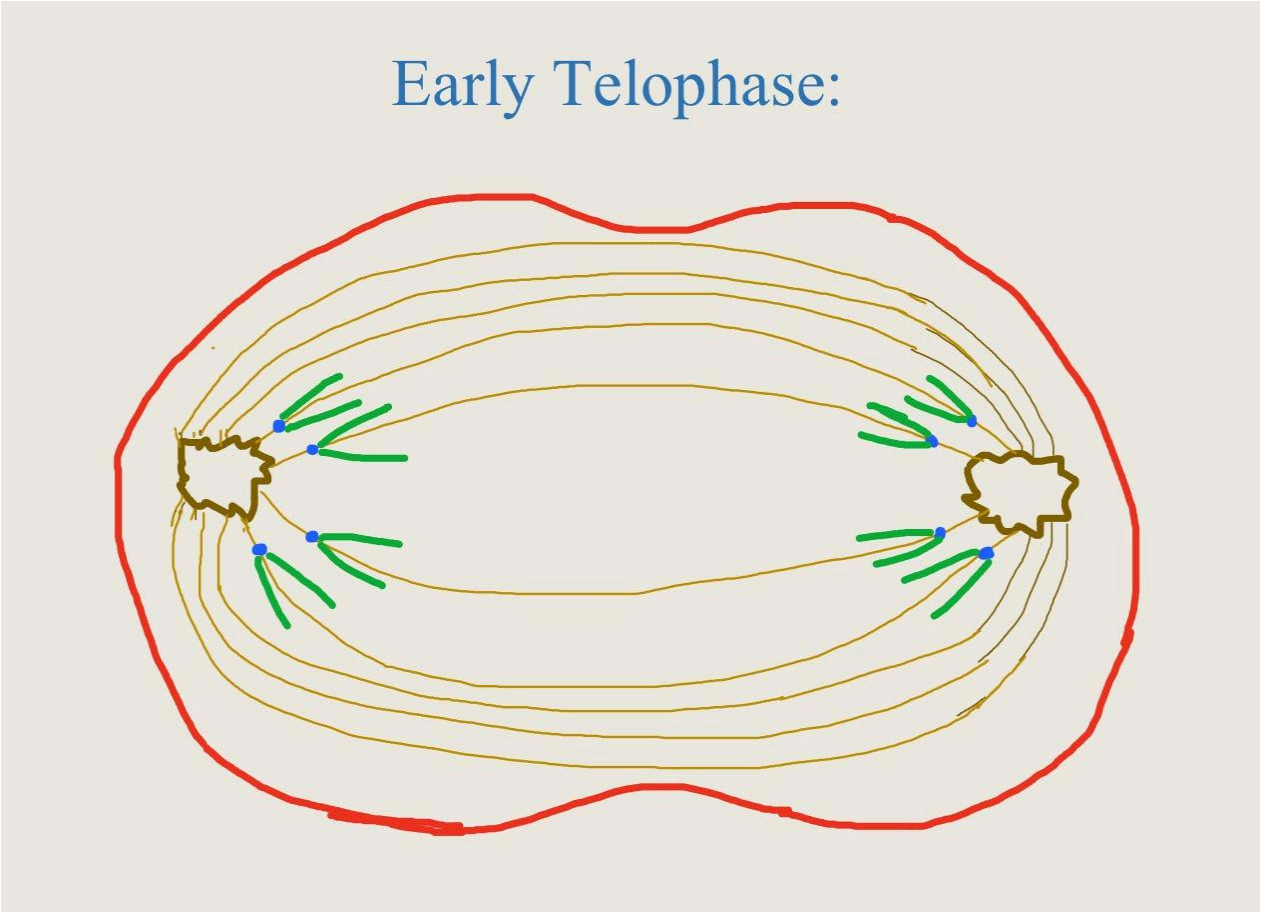
## Anaphase

The spindle fibers contract and pull on the centromeres of the chromosomes, separating the sister chromatids of each chromosome. In this stage, half of the chromosomes are pulled to one pole of the cell, and the other half are pulled to the opposite pole.



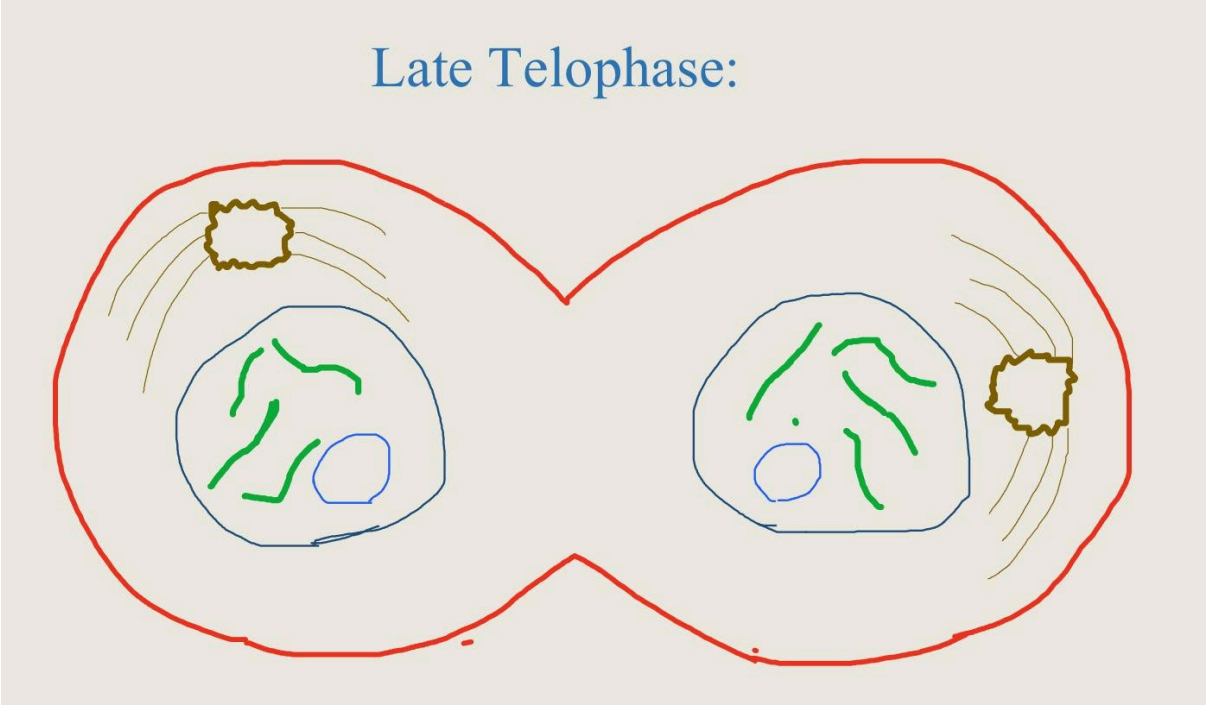
**Early Telophase**

The chromosomes have almost reached their respective poles, and the cellular membrane begins to constrict at the center.



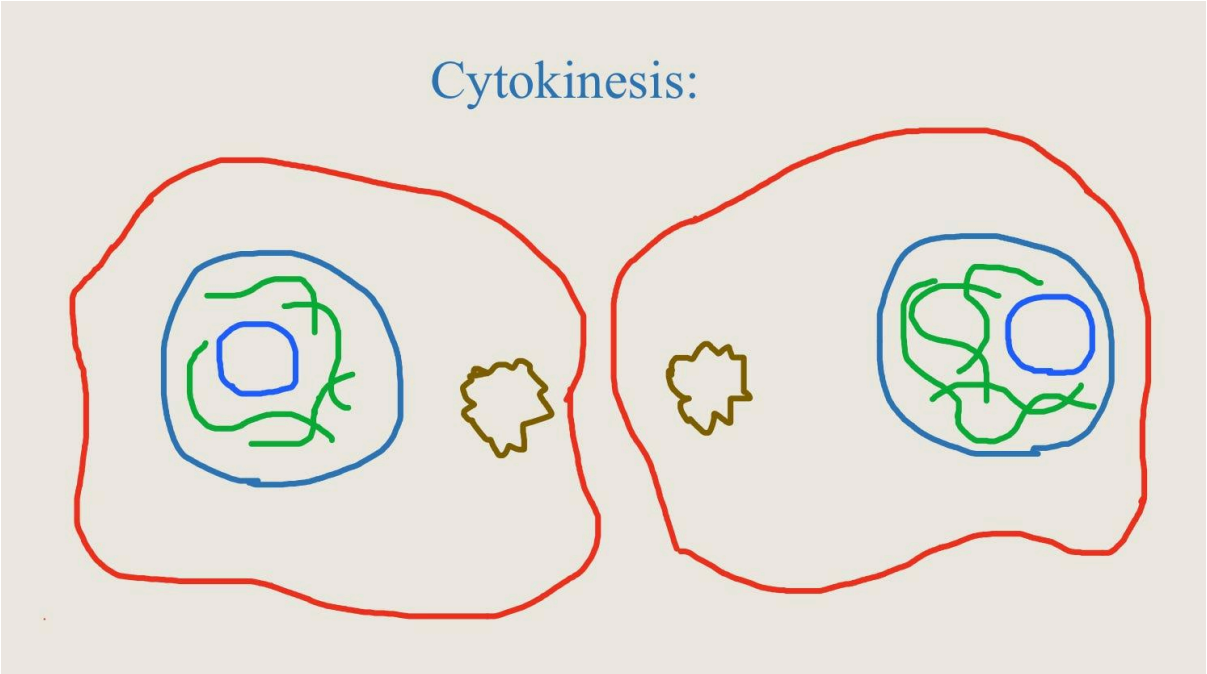
## Late Telophase

The chromosomes have arrived at their respective poles, and the cell membrane continues to constrict at the center. A nuclear membrane begins to develop around each set of chromosomes in each pole of the cell, and a nucleolus begins to form within the nuclear membrane. The cell prepares for cytokinesis.




## Cytokinesis

The chromosomes uncoil for interphase; a nuclear membrane has fully developed around each set of chromosomes, forming two nuclei, and the nucleoli have completed their formation inside the nuclei. The spindle fibers have completely disappeared, and the cellular membrane has completed its constriction, resulting in two genetically identical, diploid daughter cells.




**How cancer occurs:** In the cell cycle, there are **checkpoint proteins** that instruct the cell nucleus whether to continue the procedure of mitosis and cytokinesis or to terminate the process. The checkpoint proteins monitor the different stages of the cell cycle, including interphase, DNA replication, and the phases of mitosis. If anything goes wrong in these stages—for example, if the DNA doesn't replicate correctly or if the chromosomes don't separate properly during mitosis—the checkpoint proteins send chemical signals to the cell nucleus, instructing it to end the process.

However, if the checkpoint proteins don't function properly and thus don't send the vital signals to the nucleus to instruct it to end the cell growth and division process due to a problem that has occurred, this will cause the cell to divide uncontrollably. Consequently, a tumor can result, which can lead to cancer.

## Summary of the Main Ideas

### The 3 Stages of the Cell Cycle

**1) Interphase:** the stage in which cells carry out the functions necessary for their survival and prepare for division.

- **Growth and Preparation I (GP I)**
- **DNA Replication**
- **Growth and Preparation II (GP II)**

**2) Mitosis:** the division of the duplicated contents of the cell's nucleus into two equal parts.

**3) Cytokinesis:** Separates the two nuclei and duplicated contents of the cell into two genetically identical daughter cells.

## Stages of Mitosis

**Early Prophase:**

- Replicated strands of chromatin condense into X-shape chromosomes.
- The nucleolus disappears, and the nuclear membrane breaks down.
- Spindle fibers begin to form and stretch across the cell from centrioles that have moved to opposite poles of the cell.

**Late Prophase:**

- Spindle fibers complete their formation.
- The spindle fibers attach to chromosomes at their centromeres.
- The nuclear membrane disappears completely.

**Metaphase:**

- The chromosomes line up across the equator of the cell (spindle fibers guide this movement).

**Anaphase:**

- Spindle fibers contract and pull on the centromeres of the chromosomes, splitting them apart into sister chromatids.
- The spindle fibers pull the sister chromatids to opposite poles of the cell.
- Once they separate, each sister chromatid is considered a chromosome.

**Telophase:**

- One complete set of chromosomes is now at each pole of the cell.
- Spindle fibers disappear.
- A nuclear membrane forms around each set of chromosomes.
- A nucleolus reappears within each nucleus.
- The cell is ready for cytokinesis.

**Cytokinesis:** the process by which the cell divides into 2 identical daughter cells. In animal cells, this happens through the constriction of the cellular membrane;

in plant cells, a plate forms at the center of the cell to divide it into two equal parts.

**Summary of DNA Replication**:

- It occurs between the two phases of cellular growth and preparation (GP I and GP II).
- The cell replicates the 3 billion base pairs of genetic information in the nucleus of the cell and produces two identical DNA molecules.
- **Enzymes control this process.**