**Cell Cycle and Mitotic Cell Division**

Are you aware that right now, without conscious thought, millions of cell divisions are occurring throughout your entire body? In fact, even the largest organisms start their life from a single cell division. Cells in the body replace themselves throughout an organism’s lifetime. But what triggers cell division, and how does it know when to divide? All cells reproduce by dividing to form daughter cells that can grow and divide themselves. This gives rise to an entire new population of cells from a single parental cell. In other words, cycles of growth and division allow a single parent cell to give rise to a structure consisting of millions of cells.

**The Cell Cycle**

Cell division is an important process to all living organisms, but just one of several stages that a cell goes through in its lifetime. Cell division, DNA replication, and cell growth all have to take place in a proper way to ensure correct division and orientation. The **cell cycle** is the sequence of phases by which a cell duplicates its genome and eventually divides into two daughter cells.

The **cell cycle** can be divided into two basic phases, each with their own sub-phases: **Interphase** and **M Phase**, or **Mitosis**. In every 24-hour duration of the cell life, cell division only lasts about an hour while interphase lasts more than 95% of the duration of the cell cycle. You may be wondering why mitotic division is such a small portion in the cell cycle. To over simplify, the remaining phases of the cell cycle are primarily dedicated to oversee copying the DNA and managing growth. The M Phase begins with the separation of daughter chromosomes and ends with the division of the cytoplasm. The interphase portion is a phase of rest where the cell spends much time preparing for division by undergoing DNA replication and cell growth.

**Interphase can be further divided into three phases:**

-The **G1 phase (Gap 1)** is the interval phase between mitosis and DNA replication initiation. During this phase the cell maintains its normal metabolic processes while growing rapidly. It assembles proteins essential to DNA replication and begins to copy some of its organelles to prepare for cell division. The cell spends most of its life in the G1 phase.

-The **S phase**, or synthesis phase, is the beginning of DNA replication. During this phase the cell’s DNA is copied in the process of DNA replication resulting in double the amount of DNA. It is important to understand the number of chromosomes never increase.

-During the **G2 phase,** cellular proteins are synthesized in preparation for mitosis while the cell continues to grow. Most of this phase is spent “double checking” that the previous processes have been performed correctly in final preparation for cell division.

**Chromosomes**

Before getting to the phases of mitosis, it is important to have a basic understanding of chromosomes. **Chromosomes** are coiled structures of DNA and proteins that make up the form of genetic material in the cell cycle. In several stages of the cell cycle, DNA is not coiled into chromosomes, but instead exists as a grainy material known as **chromatin.** DNA is only present in its characteristic X shape after it has been replicated. After replication, each chromosome actually exists in two identical copies known as sister **chromatids.** These sister chromatids are attached at a region knows as the **centromere.** Only after these sister chromatids are attached is the chromosome seen in its characteristic “X” shape.

**Mitosis**

Arguably the most important period of the cell cycle in which major components of the cell are reorganized is known as **Mitosis.** During the division of the nucleus in mitosis, the two chromatids that make up each chromosome detach from each other and move toward opposite poles in the cell. Mitosis is a very complex stage of the cell cycle and therefore no phases of mitosis are clearly distinguishable. However, for our simplification, mitosis is divided into the following:

**Prophase** follows the S and G2 phases of interphase. DNA molecules formed in the S and G2 are present in the form of chromatin. The chromatin become untangled during the process of chromatin condensation. Now, the duplicated centrioles, small cylindrical organelles, begin to move toward opposite poles in the cell. The completion of prophase signifies 1) the chromosomes are recognized as being composed of a pair of chromatids attached at the centromere and 2) the initiation of the assembly of mitotic spindle, a protein structure necessary for equal division of the chromosome.

**Metaphase** marks the complete breakdown of the nuclear envelope. During this phase the chromosome is made up of two sister chromatids attached at the centromere. Kinetochores are small structures at the surface of the centromere which serve as an attachment site for spindle fibers. They work to move the chromosome into formation at the metaphase plate, the plane through the center of the cell. One chromatid of each chromosome is connected by its kinetochores to spindle fibers from opposite poles in the cell. The completion of metaphase is characterized by 1) each chromosome attaching to the spindle fibers at its centromere and 2) the chromosomes aligning at the metaphase plate.

**Anaphase** splits each chromosome arranged at metaphase. The two sister chromatids are now known as chromosomes of the future daughter nuclei. The chromatids begin migrating toward two opposite poles and away from the metaphase plate with the centromere of each chromosome toward the pole and the arms trailing behind. The completion of anaphase is characterized by 1) the chromatids splitting at the centromere and 2) the chromatids moving to opposite poles of the cell.

**Telophase** marks the final phase of mitosis where the chromosomes have reached the poles and begin to break down. The chromosomes can no longer be seen and chromatin mass begins to collect at the two poles and two nuclei begin to form. At the end of this phase, you will no longer see the chromosomes, only the nuclei at each end of the cell. The final stage of mitosis can be marked by 1) the formation of chromosome clusters at opposite poles and 2) a nuclear envelope beginning to form.

**Cytokinesis** is the process by which the cell itself divides into two daughter cells. This phase marks the end completion of cell division. Animal and plant cells have different mechanisms of cytokinesis to achieve the same goal. In animal cells, a furrow in the cell membrane deepens until it eventually joins in the center, dividing the cell into two. In plants cells, cytokinesis works from the inside out. Wall formation begins in the center and grows outward until it meets the existing outside walls.

**Cell Cycle Checkpoints**

What if the cell division occurred without any regulation? You might expect cells to go from one phase of the cycle to the next without completing the previous phase. Certain checkpoints occur during interphase in which proteins are responsible for making sure the cycle does not go on until the problem is fixed. These “checkpoints” consist of regulatory proteins that signal to either begin or delay the next phase.

-The **G1 checkpoint** occurs just before the beginning of the S phase. It is responsible for ensuring that the cell has made the correct proteins to ensure proper division. If the cell is not ready, it enters into a period of rest until the proper proteins are made.

-As expected the **S checkpoint** occurs during the S phase. It determines whether or not the DNA has been replicated correctly. If so, the cell continues into mitosis.

-The **mitosis checkpoint** occurs at metaphase in mitosis to ensure that all the chromosomes have aligned at the metaphase plate, ensuring the completion of mitosis. If mitosis is complete, the cell cycle repeats.

 Malfunctions in these checkpoints are often where issues such as cancer can occur. Cancer is a disease in which the cell cycle can no longer be regulated and often occurs when a cell’s DNA becomes damaged.

**What is the Importance of Cell Division?**

It is important to note that while every organism requires the production of identical daughter cells by mitosis, not all cell divisions produce identical daughter cells. Multicellular organisms facilitate two different types of divisions. Multicellular organisms’ sex cells divide by a process known as **meiosis** in which a single cell divides into four genetically different daughter cells. As discussed in this chapter, **mitosis** is the dividing of a single cell into two genetically identical daughter cells. Single celled organisms reproduce by mitosis, while multicellular organisms have several different uses for mitosis. All organisms use mitosis for:

1. **Growth**- multicellular organisms can use mitosis to grow by either increasing the size of their cells or increasing the number of cells
2. **Repair-** multicellular organisms can replace damaged cells with new cells that have identical functions
3. **Replacement**- since cells cannot last forever, multicellular organisms replace old cells with new cells capable of preforming the identical function

**Summary**

To ensure proper cell division, cells must complete several important tasks in specific phases. The cell cycle can be divided into two main phases, interphase and mitosis. During interphase, the cell grows and makes a copy of its DNA. During mitosis, the cell separates its DNA into two sets and divides to form two daughter cells. These daughter cells then repeat the same process. Cell division is responsible for cell growth, repair, and replacement for all processes of life.

**References**

Alberts B, Johnson A, Lewis J, et al. Molecular Biology of the Cell. 4th edition. New York: Garland Science; 2002. Mitosis. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK26934/>

Cooper GM. The Cell: A Molecular Approach. 2nd edition. Sunderland (MA): Sinauer Associates; 2000. The Eukaryotic Cell Cycle. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK9876/>

OpenStax, Anatomy & Physiology. OpenStax CNX. Mar 1, 2018 http://cnx.org/contents/14fb4ad7-39a1-4eee-ab6e-3ef2482e3e22@8.119.