**Cellular Reproduction**

**Introduction**

The bodies of living creatures, on the whole, are massive collections of intricate and unique cells that work harmoniously - allowing living creatures to function on a daily basis. Whether it is a massive sperm whale weighing greater than 40 tons or a tiny hog-nosed bat that grows to barely an inch long, all creatures must undergo cellular reproduction on a constant basis in order to grow, survive, compete for resources, and reproduce. In nature, there is an amazing diversity between living animals. While an amazing range of appearances and sizes might be present, all living creatures use cellular reproduction. Many of these creatures have specialized cells. Mammals, for example, have eukaryotic cells that are cells with membrane bound internal units, called organelles. Bacteria, on the other hand, have prokaryotic cells and plant cells contain chlorophyll to help them perform cellular activities that help capture energy from the sun and convert is as fuel.

The study of cells was spurned on by Anton Van Leeuwenhoek’s discovery of the Cork Cell using a compound microscope. Leeuwenhoek was a renowned scientist even though he lacked despite lacking a formal education. He made advancements and upgrades to the microscope and was the first scientist to study red blood cells using a microscope. It was Leeuwenhoek’s idea to use glass lenses to enhance images and focus in on microscopic images that the naked eye could not detect. Without his contributions, modern microbiology and the study of cellular reproduction would be impossible and implausible.[[1]](#endnote-1) In lieu of Leeuwenhoek’s many scientific contributions to the field of microbiology he is acknowledged as the “Father of Microbiology.”

Cellular reproduction is a subset of the field of microbiology. Humans begin their existence as one cell, and after the process of fertilization cellular reproduction begins. One cell becomes two cells, then two cells become four, four cells become eight, and so on and so fourth. The cells in the human body are constantly dying and being regenerated for the entirety of the human lifespan. Thanks to the groundbreaking discoveries of Anton Van Leeuwenhoek and many others, microscopes are available that can capture the imagery of cellular reproduction. In this chapter, the science of cellular reproduction will be explained.

**The breakdown of the Process: Replication**

Before cells can successfully divide and form progeny cells, they must first duplicate the information contained in their DNA. This process must occur to allow for future cells to be able to operate and sustain life. This cellular function is difficult because of the extreme complexity of the double helices of DNA. For instance, a single strand of DNA is composed of subunits called nucleotides and each strand of DNA can be comprised of over one hundred million nucleotide subunits. Nucleotides are the basic structural units of DNA. In order for DNA to be replicated, it must first be split from its double helix formation into two strands. An enzyme known as helicase accomplishes the splitting of the DNA molecule. DNA polymerase travels to DNA and sits atop the double helix. This enzyme then starts to make its way down the molecule slowly, moving from nucleotide to nucleotide on the two strands of DNA. As the DNA polymerase enzyme makes its way down the DNA strands it reads all nucleotides on both strands of DNA. The DNA polymerase uses one strand of DNA like blueprints in order to make a new strand of DNA. The newly synthesizes strand of DNA that is being synthesized is referred to as the lagging strand. The lagging strand is then reassembled by ligase forming a new double helix of DNA that contains one parent strand and one newly assembled strand of DNA..

When DNA is being prepared for replication, the two individual strands of DNA must first be unwound out of their double helix formation into two separate strands. In order to keep the two strands of DNA unwound, an enzyme known as helicase will not only break the bonds holding the two strands of DNA together, but, helicase will also add place holder proteins to the split DNA strands to ensure that the strands do not reassemble with one another. Working harmoniously with helicase, another enzyme, known as DNA topoisomerase, removes the twists and kinks from DNA by breaking the bonds of the DNA and then resealing the break.[[2]](#endnote-2)

Prokaryotes have a unique pattern of replicating genetic information. Prokaryotic cells begin replication at a site known as the origin of replication. Since prokaryotic DNA is circular in nature, replication begins at the origin of replication then begins replication in both directions circumventing the circle of DNA until the two processes reconvene back where they began their replication. It is important to note that prokaryotic replication occurs at rates much faster than those in eukaryotic cells. In fact, prokaryotic cells can replicate their genetic material at rates up to 100,000 nucleotides per minute. Eukaryotes on the other hand are only capable of achieving replication rates around 5,000 nucleotides per second.

One of the pivotal aspects of replicating genetic material is ensuring that progeny cells receive accurately copied sets of the parent cell genetic information. Cells ensure replication accuracy by a proofreading activity that is achieved by the DNA Polymerase enzyme. While it is the job of DNA polymerase to produce new copies of genetic information from template DNA strands of a parent cell, this same enzyme is responsible for double-checking its work by proofreading. DNA polymerase is also capable of revising its own errors by deleting or adding nucleotides as needed. For example, if a cell were exposed to an environmental pathogen that caused DNA damage, then DNA Polymerase could correct this mistake to prevent the genetic problem from being passed onto more cells through cell replication and division. In extreme cases, DNA polymerase can cleave problematic portions of DNA, produce a new strand of DNA, and fit it into the spot that was previously removed.

**Mitosis**

It is important to note that cells divide and replicate their DNA at separate times, not simultaneously. In order for a cell to divide, it must first condense its DNA into short H-shaped DNA molecules known as chromosomes. The chromosomes then split into two long rods known as chromatids. Then each pair of chromatids is divided and distributed into two daughter cells through a process known as mitosis. Mitosis is accomplished by attaching chromosomes to a bundle of microtubules, which are also known as the mitotic spindle. The process of mitosis is comprised of five separate phases. The first, Prophase, is the phase in which mitotic spindle is formed and the chromosomes condense. Next, during Prometaphase, the nuclear envelope of the cell is degraded so that the chromosomes can attach to the mitotic spindle. The spindle attaches to the chromatids of each chromosome at a specialized locale of the chromatid, known as the kinetochore. Following Prometaphase is the Metaphase. During the Metaphase, chromosomes line up across the equatorial plane of the mitotic spindle. Anaphase comes next, during which the now separated chromatids move towards the opposite ends of the line of spindle. The final phase is Telophase. During Telophase the nuclear envelope redevelops around each pair of the unraveling chromatids and the chromosomes begin to spread out. Divisions occur and the result is two new cells.

The most important step in Mitosis is the attachment of the chromatids to the opposing poles of the spindle. This process is crucial because it ensures that daughter cells will receive complete sets of chromosomes. As previously stated, the mitotic spindle is composed of microtubules. These microtubules extend from one pole to the opposite pole. These microtubules are responsible for contracting during anaphase resulting in chromatids being pulled apart and unraveling to help form future genetic information. Centrosomes are found at the ends of the poles of the mitotic spindle. These microscopic structures are responsible for helping sort mitotic spindle. A pair or cylindrical centrioles can be found in the centrosome. The centrioles are also made up of microtubules.

After Mitosis reaches completion, the cell undergoes a process known as cytokinesis. During cytokinesis, the cytoplasm of the cell divides in two. Cytokinesis in eukaryotes (such as humans), occurs by the constriction of the cell about a circle of actin and myosin, the microfilaments of muscles. The parent cell splits into two daughter cells, each of which contains the same number of chromosomes as the parent cell. Each cell should have 23 chromosomes at the completion of cytokinesis.

**Meiosis**

The other cellular reproductive process that occurs in cells is known as meiosis. Meiosis is the process in which DNA is replicated from one cell and distributed into another cell after being mixed with the DNA from another parent cell. These two cells then divide again to create four daughter cells. These daughter cells are known more specifically as gametes. Gametes are reproductive cells of sexually reproducing organisms. Examples of gametes include sperm cells, ova (eggs), and pollen. DNA is present in the form of chromosomes, which are located in the nucleus of the gamete cell. This chromosomal DNA contains two copies of the genetic information of the organism in which the gamete is found. Each chromosome replicating into two new chromosomes characterizes meiosis.

Meiosis is a process that takes place in cells that are also capable of performing mitosis. Eukaryotic organisms have to undergo an intermediate step before their cells can transition from a diploid to a haploid state. Diploid cells are characterized by their two sets of chromosomes, whereas haploid cells have a single set of unpaired chromosomes. Eukaryotic cells start out as diploid, meaning they start out as a reproductive cell known as the zygote. In humans, a dynamic type of cell known as the primordial cell undergoes meiosis. The result of the primordial cell undergoing meiosis is the formation of the haploid cell known as the gamete. The gamete cell in males is the sperm, in the female the gamete cells are the egg cells. When sperm meets egg and the egg is fertilized the new cellular structure formed is known as the zygote. The zygote will then undergo several cycles of mitotic reproduction before it develops into the embryo, the earliest form of human life.[[3]](#endnote-3)

The actual process of meiosis is divided into two cycles: Meiosis I and Meiosis II. Meiosis I is the phase during which chromosomes are separated. Meiosis II, on the other hand, is responsible for subdividing the sister chromatids. After the completion of Meiosis II there will be 4 haploid cells produced. Meiosis differs from Mitosis in that Meiosis is not cyclic. While the Interphase steps that prepare the cell for Meiosis are identical, the rest of the process occurs to produce a non-recyclable product.

 Interphase, the preparatory phase of Meiosis I, is divided into three separate phases. The first step of interphase is the G1 phase. G1 phase is characterized by cellular growth. Next come the S phase. S phase is responsible for replicating genetic material. During G2 phase, the cell continues its growth. G2 is immediately followed by the initiation of Meiosis I. During Meiosis I, the first phase that occurs is prophase I. During prophase I, cellular DNA condenses into structures that resemble thread. Along this line of thread are small beads of genetic information in the form of chromatin. Throughout this phase the chromatin becomes more and more visible. As the Chromatin develops, homologous chromosomes form a line and bind to one another. At the end of Prophase I, a bivalent develops. This bivalent is made up of two chromosomes and four chromatids. One chromosome is donated from each parent.[[4]](#endnote-4)

 The next phase of Meiosis I that occurs is Prometaphase I. During this phase, the nuclear envelope of the cell dissolves, kinetochores form and chromosomes attach to spindle fibers and begin to move. Metaphase I occurs following Prometaphase I. Metaphase I is characterized by the alignment of the two chromosomes. Next is Anaphase I, and during Anaphase I the chromatids of the two chromosomes move to separate poles. During Telophase I, genetic information from parents has been shuffled and is subsequently distributed into two daughter cells. At this point, Meiosis I has reached completion. Meiosis II is almost identical to the steps of Mitosis, the only differences being that Meiosis II lacks an S phase and the chromosomes differ in appearance because they have undergone a shuffling of their components. Meiosis I also produces two haploid daughter cells that each contain 23 chromosomes. Meiosis II begins with Prophase II and this phase is characterized by the redevelopment of the nuclear envelope. Centrosomes inside the enveloped cells arrange spindle fibers in preparation for another division of meiosis. Next comes Metaphase II, during which centromeres develop two kinetochores that are bound to the spindle fibers of the centrosome. Anaphase II follows metaphase II. Anaphase II is emboldened by the release of sister chromatids from centromeres and these sister chromosomes move in the direction of the two opposite poles. The final phase of Meiosis II is Telophase II. During telophase II, chromosomes and spindle spread throughout the nucleus. Nuclear envelopes redevelop around each set of chromosomes, cytokinesis takes place, and, finally, four daughter cells are created – each of which contains a haploid set of chromosomes. At this point Meiosis has reached completion.

As for the differences in cell division cycles, cellular reproduction occurs through different mechanisms in different types of organisms. Prokaryotic cells, which are cells lacking a membrane bound nucleus, can perform the synthesis of DNA in between cell divisions without interruptions. Another interesting fact regarding prokaryotic cell division is the fact that two cycles of prokaryotic DNA synthesis can happen simultaneously. In other words, one cycle of DNA synthesis may begin before a previous cycle reaches completion. Eukaryotes, on the other hand, duplicate their DNA and undergo cellular division only one time between separate increments of time. Eukaryotic cell division can be broken into four separate phases. Those four phases include “G1” which is named for the first gap, “S” or synthetic, G2, and finally “M” which is named for mitosis. This cycle can range from 10 to 20 hours in duration in adult cells, but it can occur at much arrested integrals in neuronal cells of the brain.

Cellular reproduction, whether it be meiosis or mitosis, is a vital process to creating and sustaining life. While these processes are complex, they also have many common components that allow for the production of new daughter cells. Without these processes life would not be possible, and it is for this reason that this science is of the utmost importance.

1. **References**

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