

## ***Unit 5 -Cell Cycle Mitosis & Meiosis***

- I. *Types of Cell Division* pgs. 2 – 6
- II. *Stages of Mitosis* pgs. 6 – 7
- III. *Types of Reproduction* pgs. 8 – 9
- IV. *Meiosis and Gametogenesis* pgs. 9 – 11
- V. *Glossary* pgs. 11 – 12

### **South Dakota Science Standards**

**9-12.L.1.1 Students are able to relate cellular functions and processes to specialized structures within cells.**

**9-12.N.2.2 Students are able to practice safe and effective laboratory techniques**

<b>Prefix or Suffix</b>	<b>Definition</b>
ana-	upward, back, again
bi-	two
centro-	center
chrom-	color
homo-	same
inter-	between
meta-	after, behind
pro-	before
telo-	end

### **Top Vocabulary Terms**

- 1. Chromosome**
- 2. Chromatin**
- 3. Meiosis**
- 4. Mitosis**
- 5. Interphase**
- 6. Prophase**
- 7. Metaphase**
- 8. Anaphase**
- 9. Telophase**
- 10. Cytokinesis**

# I. Types of Cell Division

## Introduction

You consist of a great many cells, but like all other organisms, you started life as a single cell. How did you develop from a single cell into an organism with trillions of cells? The answer is cell division. After cells grow to their maximum size, they divide into two new cells. These new cells are small at first, but they grow quickly and eventually divide and produce more new cells. This process keeps repeating in a continuous cycle.

Imagine the first stages of a life. In humans, a sperm fertilizes an egg, forming the first cell. From that one cell, an entire baby with trillions of cells will develop. How does a new life go from one cell to so many? The cell divides in half, creating two cells. Then those two cells divide. The new cells continue to divide and divide. One cell becomes two, then four, then eight, and so on. Rapid cell division allows the development of new life, but cell division must be tightly regulated. If the body's close regulation of cell division is disrupted later in life, diseases such as cancer can develop. Cancer involves cells that divide in an uncontrolled manner. Therefore, much research into cell division is underway across the globe in effort to further understand this process and find a cure for cancer.

## Why Cells Divide

Besides the development of a fetus, there are many other reasons that cell division is necessary to life. To grow and develop, you must form new cells. Imagine how often your cells must divide during a growth spurt. Growing just an inch requires countless cell divisions.

Another reason for cell division is to repair damaged cells. Imagine you cut your finger. After the scab forms, it will eventually disappear and new skin cells will grow to repair the wound. Where do these cells come from? Remember that according to the cell theory, all cells must come from preexisting cells. In order to make new skin cells, some of your existing skin cells had to undergo cell division.

Besides suffering physical damage, your cells can simply wear out. Over time you must replace old and worn-out cells. Again, cell division is essential to this process. You can only make new cells by dividing similar preexisting cells.

*What are two reasons that cells need to be able to divide and replicate?*

## Cell Division

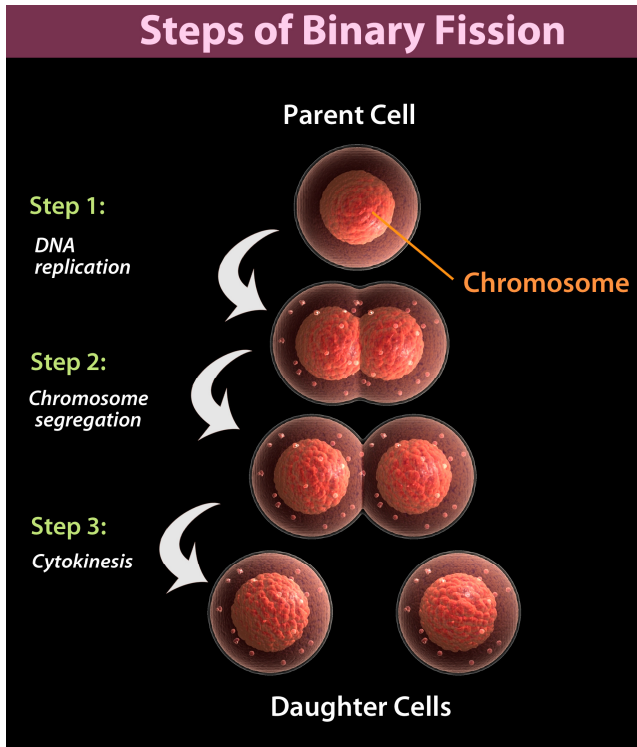
**Cell division** is the process in which one cell, called the **parent cell**, divides to form two new cells, referred to as **daughter cells**. How this happens depends on whether the cell is prokaryotic or eukaryotic.

Cell division is simpler in prokaryotes than eukaryotes because prokaryotic cells themselves are simpler. Prokaryotic cells have a single circular chromosome, no nucleus, and few other organelles. Eukaryotic cells, in contrast, have multiple chromosomes contained within a nucleus and many other organelles. All of these cell parts must be duplicated and then separated when the cell divides.

## Cell Division in Prokaryotes

Most prokaryotic cells divide by the process of **binary fission**. Cell division is relatively simple in prokaryotic cells. Eventually the parent cell will pinch apart to form two identical daughter cells. Binary fission can be broken down into a series of three steps, although it is actually a continuous process. The steps are described below (**Figure 1**); they include DNA replication, chromosome segregation, and cytokinesis.

- **Step 1: DNA Replication.** Just before the cell divides, its DNA is copied in a process called DNA replication. This results in two identical chromosomes instead of just one. This step is necessary so that when the cell divides, each daughter cell will have its own chromosome.
- **Step 2: Chromosome Segregation.** The two chromosomes segregate, or separate, and move to opposite ends (known as *poles*) of the cell.
- **Step 3: Cytokinesis.** A new plasma membrane starts growing into the center of the cell, and the cytoplasm splits apart, forming two daughter cells. This process is called **cytokinesis**. The two daughter cells that result are genetically identical to each other and to the parent cell.



*Figure 1: Steps of Binary Fission. Prokaryotic cells divide by binary fission. This is also how many single-celled organisms reproduce.*

### The Cell Cycle

Cell division is just one of several stages that a cell goes through during its lifetime. The **cell cycle** is a repeating series of events that include growth, DNA synthesis, and cell division. The cell cycle in prokaryotes is quite simple: the cell grows, its DNA replicates, and the cell divides. In eukaryotes, the cell cycle is more complicated.

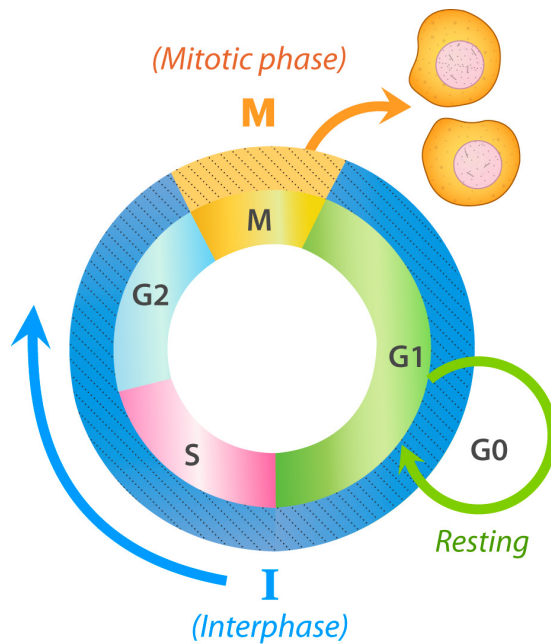
### Cell Division in Eukaryotes

Cell division is more complex in eukaryotes than prokaryotes. Prior to dividing, all the DNA in a eukaryotic cell's multiple chromosomes is replicated. Its organelles are also duplicated. Then, when the cell divides, it occurs in two major steps:

- The first step is **mitosis**, a multi-phase process in which the nucleus of the cell divides. During mitosis, the nuclear membrane breaks down and later reforms. The chromosomes are also sorted and separated to ensure that each daughter cell receives a complete set of chromosomes.
- The second major step is cytokinesis. As in prokaryotic cells, during this step the cytoplasm divides and two daughter cells form.

The diagram in the **Figure 2** represents the cell cycle of a eukaryotic cell. As you can see, the eukaryotic cell cycle has several phases. The mitosis phase (M) actually includes both mitosis and cytokinesis. This is

when the nucleus and then the cytoplasm divide. The other three phases (G1, S, and G2) are generally grouped together as **interphase**. During interphase, the cell grows, performs routine life processes, and prepares to divide. These phases are discussed below.



**Figure 2 - Eukaryotic Cell Cycle.** This diagram represents the cell cycle in eukaryotes. The G1, S, and G2 phases make up interphase (I). The M phase includes mitosis and cytokinesis. After the M phase, two cells result.

*How does cell division in prokaryotes differ from cell division in eukaryotes?*

## Interphase

Interphase of the eukaryotic cell cycle can be subdivided into the following three phases, as shown in the figure above.

- **Growth Phase 1 (G1):** during this phase, the cell grows rapidly, while performing routine metabolic processes. It also makes proteins needed for DNA replication and copies some of its organelles in preparation for cell division. A cell typically spends most of its life in this phase.
- **Synthesis Phase (S):** during this phase, the cell's DNA is copied in the process of DNA replication.
- **Growth Phase 2 (G2):** during this phase, the cell makes final preparations to divide. For example, it makes additional proteins and organelles.

*What are the three phases of interphase?*

## Control of the Cell Cycle

If the cell cycle occurred without regulation, cells might go from one phase to the next before they were ready. What controls the cell cycle? How does the cell know when to grow, synthesize DNA, and divide? The cell cycle is controlled mainly by regulatory proteins. These proteins control the cycle by signaling the cell to either start or delay the next phase of the cycle. They ensure that the cell completes the previous phase before moving on. Regulatory proteins control the cell cycle at three main checkpoints.

1. The G1 checkpoint, just before entry into S phase, makes the key decision of whether the cell should divide.
2. The G2 checkpoint is located at the end of G2 phase. In order for this checkpoint to be passed, the cell has to check a number of factors to ensure the cell is ready for mitosis.
3. The mitotic spindle checkpoint occurs at the point in metaphase where all the chromosomes should have aligned at the mitotic plate.

*How is the cell cycle controlled?*

## Cancer and the Cell Cycle

**Cancer** is a disease that occurs when the cell cycle is no longer regulated. This may happen because a cell's DNA becomes damaged. Damage can occur due to exposure to hazards such as radiation or toxic chemicals. Cancerous cells generally divide much faster than normal cells. They may form a mass of abnormal cells called a **tumor**. The rapidly dividing cells take up nutrients and space that normal cells need. This can damage tissues and organs and eventually lead to death.

*What happens when cells are allowed to grow out of control?*

## Mitosis

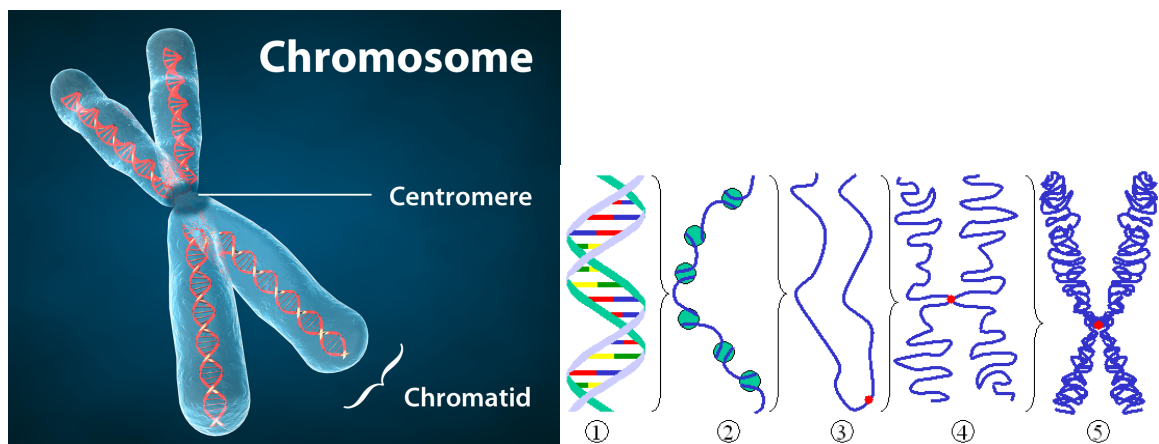
In eukaryotic cells, the nucleus divides before the cell itself divides. The process in which the nucleus divides is called mitosis. Before mitosis occurs, a cell's DNA is replicated. This is necessary so that each daughter cell will have a complete copy of the genetic material from the parent cell.

## Chromosomes

**Chromosomes** are coiled structures made of DNA and proteins. Chromosomes are the form in which the genetic material of a cell goes through cell division. During other phases of the cell cycle, DNA is not coiled into chromosomes. Instead, it exists as a grainy material called **chromatin**.

## Chromatids and the Centromere

DNA condenses and coils into the familiar X-shaped form of a chromosome (**Figure 3**) only after it has replicated. Because DNA has already replicated, each chromosome actually consists of two identical copies. The two copies are called sister **chromatids**. They are attached to one another at a region called the **centromere**.



**Figure 3** – A picture of a chromosome. After DNA replicates, it forms chromosomes like the one shown here.

## Chromosomes and Genes

The DNA of a chromosome is encoded with genetic instructions for making proteins. These instructions are organized into units called **genes**. Most genes contain the instructions for a single protein. There may be hundreds or even thousands of genes on a single chromosome.

## Human Chromosomes

Human cells normally have two sets of chromosomes, one set inherited from each parent. There are 23 chromosomes in each set, for a total of 46 chromosomes per cell. Each chromosome in one set is matched by a chromosome of the same type in the other set, so there are actually 23 pairs of chromosomes per cell. Each pair consists of chromosomes of the same size and shape that also contain the same genes. The chromosomes in a pair are known as **homologous chromosomes**.

*What is the difference between chromosomes and chromatin?*

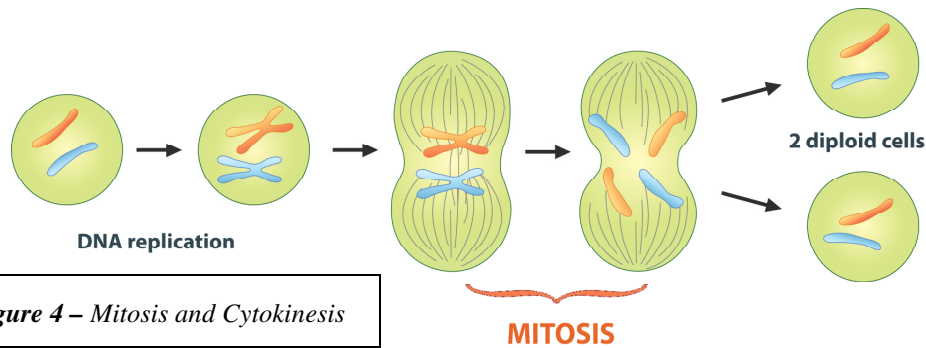
*Where are the genetic instructions for making protein stored?*

*How many chromosomes are found in each human cell?*

## II. Stages of Mitosis

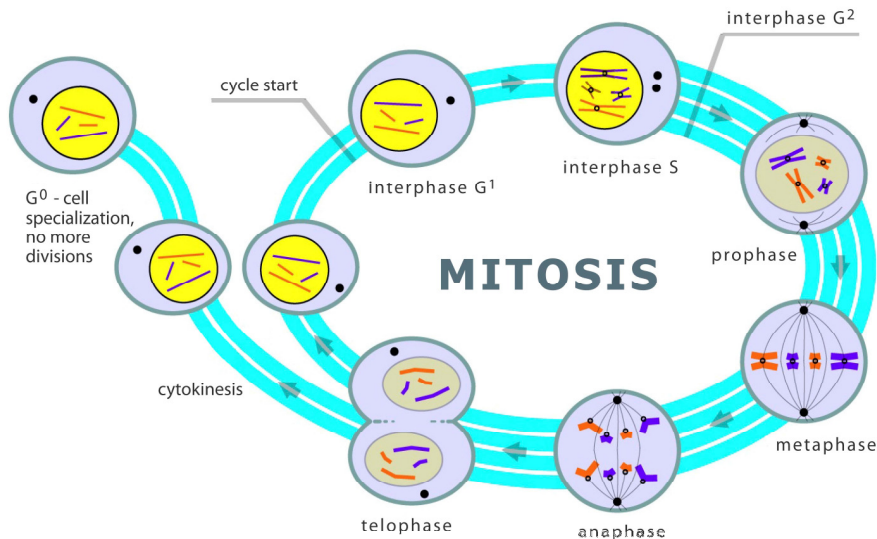
### Mitosis and Cytokinesis

During mitosis, when the nucleus divides, the two chromatids that make up each chromosome separate from each other and move to opposite poles of the cell (**Figure 4**).



*Figure 4 – Mitosis and Cytokinesis*

Mitosis is the phase of the eukaryotic cell cycle that occurs between DNA replication and the formation of two daughter cells. It occurs in four phases called prophase, metaphase, anaphase, and telophase. The stages are shown in **Figure 5** and are described in greater detail in the following sections.



*Figure 5 – The stages of the cell cycle, including interphase, mitosis, and cytokinesis.*

## Prophase

The first and longest phase of mitosis is **prophase**. During prophase, chromatin condenses into chromosomes, and the nuclear envelope, or membrane, breaks down. In animal cells, the centrioles near the nucleus begin to separate and move to opposite poles of the cell. As the centrioles move, a spindle starts to form between them. The spindle consists of fibers made of microtubules.

## Metaphase

During **metaphase**, spindle fibers attach to the centromere of each pair of sister chromatids (see **figure**). The sister chromatids line up at the equator, or center, of the cell. The spindle fibers ensure that sister chromatids will separate and go to different daughter cells when the cell divides.

## Anaphase

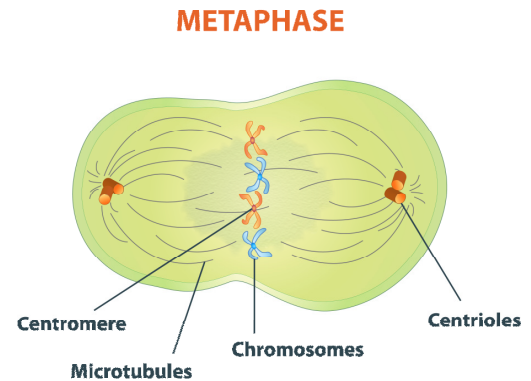
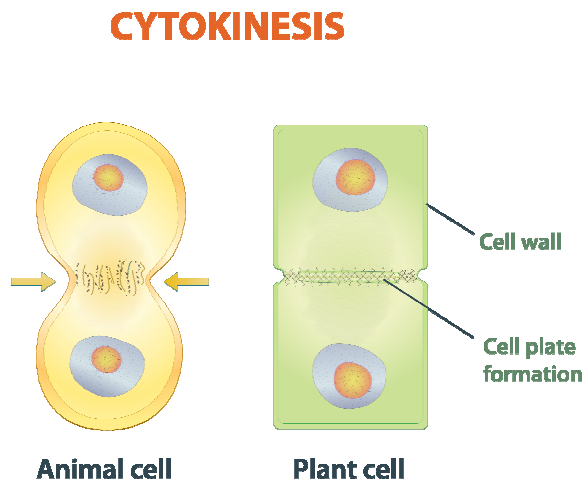
During **anaphase**, sister chromatids separate and the centromeres divide. The sister chromatids are pulled apart by the shortening of the spindle fibers. This is like reeling in a fish by shortening the fishing line. One sister chromatid moves to one pole of the cell, and the other sister chromatid moves to the opposite pole. At the end of anaphase, each pole of the cell has a complete set of chromosomes.

## Telophase

During **telophase**, the chromosomes begin to uncoil and form chromatin. This prepares the genetic material for directing the metabolic activities of the new cells. The spindle also breaks down, and new nuclear membranes form.

## Cytokinesis

Cytokinesis is the final stage of cell division in eukaryotes as well as prokaryotes. During **cytokinesis**, the cytoplasm splits in two and the cell divides. Cytokinesis occurs somewhat differently in plant and animal cells, as shown in the figure below. In animal cells, the plasma membrane of the parent cell pinches inward along the cell's equator until two daughter cells form. In plant cells, a cell plate forms along the equator of the parent cell. Then, a new plasma membrane and cell wall form along each side of the cell plate.



**Figure 6 – Metaphase; sister chromatids are lined up along the equator of the cell.**

**Figure 7 - Cytokinesis is the final stage of eukaryotic cell division. It occurs differently in animal and plant cells.**

What are the four stages of mitosis?

What is the final step of cell division?

How does cytokinesis differ between plant and animal cells?

### III. Types of Reproduction

#### Introduction

Cell division is how organisms grow and repair themselves. It is also how they produce offspring. Many single-celled organisms reproduce by binary fission. The parent cell simply divides to form two daughter cells that are identical to the parent. In many other organisms, two parents are involved, and the offspring are not identical to the parents. In fact, each offspring is unique. Often times, the children of a family tend to resemble their parents, but they are not identical to them. Instead, each has a unique combination of characteristics inherited from both parents. In this lesson, you will learn how this happens.

#### Reproduction: Asexual vs. Sexual

Reproduction is the process by which organisms give rise to offspring. It is one of the defining characteristics of living things. There are two basic types of reproduction: asexual reproduction and sexual reproduction.

#### Asexual Reproduction

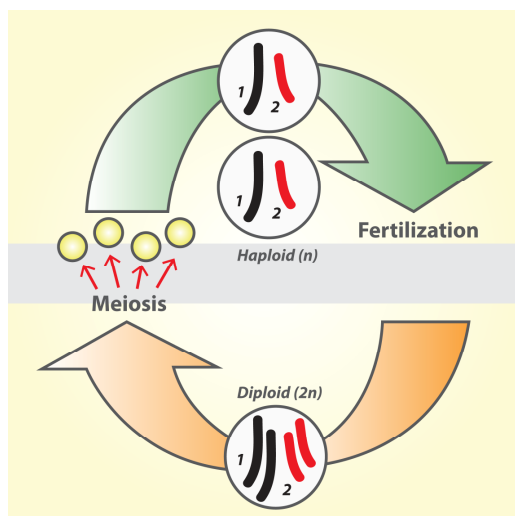
**Asexual reproduction** involves a single parent. It results in offspring that are genetically identical to each other and to the parent. All prokaryotes and some eukaryotes reproduce this way. Asexual reproduction can be very rapid. This is an advantage for many organisms. It allows them to crowd out other organisms that reproduce more slowly. Bacteria, for example, may divide several times per hour. Under ideal conditions, 100 bacteria can divide to produce millions of bacterial cells in just a few hours! However, most bacteria do not live under ideal conditions. If they did, the entire surface of the planet would soon be covered with them. Instead, their reproduction is kept in check by limited resources, predators, and their own wastes. This is true of most other organisms as well.

*What are the two types of reproduction?*

*What are the three types of asexual reproduction and what are the differences between them?*

#### Sexual Reproduction

**Sexual reproduction** involves two parents. As you can see from **Figure 8**, in sexual reproduction, parents produce reproductive cells—called **gametes**—that unite to form an offspring. Gametes are **haploid** cells. This means they contain only half the number of chromosomes found in other cells of the organism. Gametes are produced by a type of cell division called **meiosis**, which is described in detail below. The process in which two gametes unite is called **fertilization**. The fertilized cell that results is referred to as a **zygote**. A zygote is a **diploid** cell, which means that it has twice the number of chromosomes as a gamete.



**Figure 8 - Cycle of Sexual Reproduction.** Sexual reproduction involves the production of haploid gametes by meiosis. This is followed by fertilization and the formation of a diploid zygote. The number of chromosomes in a gamete is represented by the letter *n*.



What is a gamete?

What does it mean to be haploid? Diploid?

What is it called when a sperm and egg unite?

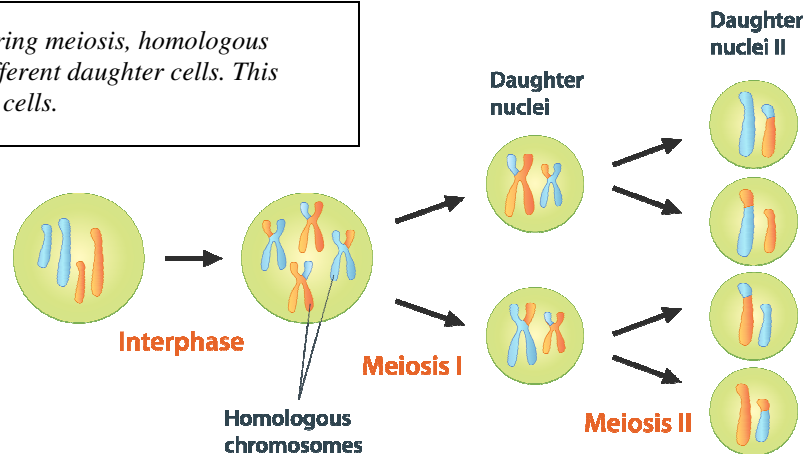
#### IV. Meiosis and Gametogenesis

The process that produces haploid gametes is meiosis. **Meiosis** is a type of cell division in which the number of chromosomes is reduced by half. It occurs only in certain special cells of the organisms. During meiosis, homologous chromosomes separate, and haploid cells form that have only one chromosome from each pair. Two cell divisions occur during meiosis, and a total of four haploid cells are produced. The two cell divisions are called meiosis I and meiosis II. The overall process of meiosis is summarized in **Figure 9**. It is also described in detail below.

**Figure 9** - Overview of Meiosis. During meiosis, homologous chromosomes separate and go to different daughter cells. This diagram shows just the nuclei of the cells.

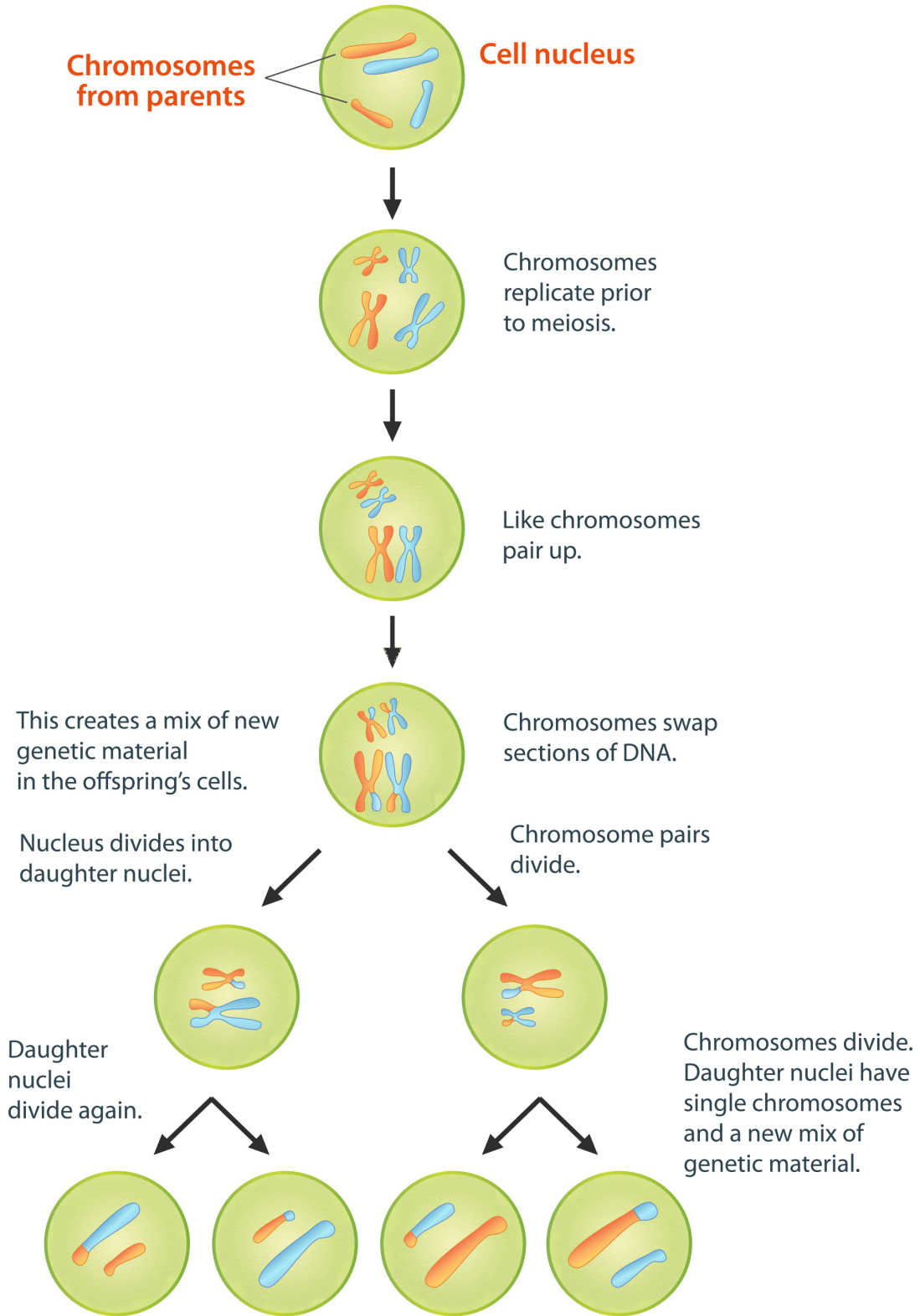
#### Phases of Meiosis

Meiosis I begins after DNA replicates during interphase. In both meiosis I and meiosis II, cells go through the same four phases as mitosis. However, there are important differences between meiosis I and mitosis. The flowchart (**Figure 10**) shows what happens in both meiosis I and II. You can follow the changes in the flowchart as you read about them below.



#### Meiosis I

1. **Prophase I:** The nuclear envelope begins to break down, and the chromosomes condense. Centrioles start moving to opposite poles of the cell, and a starts begins to grow. Importantly, homologous chromosomes pair up, which is unique to prophase I. In prophase of mitosis and meiosis II, homologous chromosomes do not form pairs in this way. When homologous chromosomes pair up, crossing-over can occur. **Crossing-over** is the exchange of genetic material between homologous chromosomes. It results in new combinations of genes on each chromosome.
2. **Metaphase I:** Spindle fibers attach to the paired homologous chromosomes. The paired chromosomes line up along the equator of the cell. This occurs only in metaphase I. In metaphase of mitosis and meiosis II, it is sister chromatids that line up along the equator of the cell.
3. **Anaphase I:** Spindle fibers shorten, and the chromosomes of each homologous pair start to separate from each other. One chromosome of each pair moves toward one pole of the cell, and the other chromosome moves toward the opposite pole.
4. **Telophase I and Cytokinesis:** The spindle breaks down, and new nuclear membranes form. The cytoplasm of the cell divides, and two haploid daughter cells result. The daughter cells each have a random assortment of chromosomes, with one from each homologous pair. Both daughter cells go on to meiosis II.



**Figure 10 – Flowchart of the stages of meiosis I and II.**

## Meiosis II

1. **Prophase II:** The nuclear envelope breaks down and the spindle begins to form in each haploid daughter cell from meiosis I. The centrioles also start to separate.
2. **Metaphase II:** Spindle fibers line up the sister chromatids of each chromosome along the equator of the cell.
3. **Anaphase II:** Sister chromatids separate and move to opposite poles.
4. **Telophase II and Cytokinesis:** The spindle breaks down, and new nuclear membranes form. The cytoplasm of each cell divides, and four haploid cells result. Each cell has a unique combination of chromosomes.

*What is produced at the end of meiosis?*

*In what stage does crossing-over occur?*

## Gametogenesis

At the end of meiosis, four haploid cells have been produced, but the cells are not yet gametes. The cells need to develop before they become mature gametes capable of fertilization. The development of haploid cells into gametes is called **gametogenesis**. Gametogenesis may differ between males and females. Male gametes are called **sperm**. Female gametes are called **eggs**. In human males, for example, the process that produces mature sperm cells is called spermatogenesis. During this process, sperm cells grow a tail and gain the ability to “swim,” like the human sperm cell. In human females, the process that produces mature eggs is called oogenesis. Just one egg is produced from the four haploid cells that result from meiosis. The single egg is a very large cell.

A human sperm is a tiny cell with a tail. A human egg is much larger. Both cells are mature haploid gametes that are capable of fertilization.

*What is gametogenesis?*

*How does this differ between males and females?*

## Vocabulary

**Anaphase:** third phase of mitosis where sister chromatids separate and move to opposite sides of the cell.

**Asexual reproduction:** a form of reproduction in which a new individual is created by only one parent.

**Binary fission:** an asexual form of reproduction where a cell splits into two daughter cells.

**Budding:** occurs when a parent cell forms a bubble-like bud that stays attached to the parent cell while it grows and develops.

**Cancer:** a disease that occurs when the cell cycle is no longer regulated.

**Cell cycle:** sequence of steps in eukaryotic cells that leads to cell division.

**Cell division:** the process in which a parent cell divides to form two new daughter cells.

**Centromere:** a region of DNA typically found near the middle of a chromosome where two identical sister chromatids come in contact.

**Chromatids:** one of two identical copies of DNA making up a replicated chromosome, which are joined at the centromere.

**Chromatin:** complex of DNA and proteins that is visible when a cell is not dividing.

**Chromosomes:** DNA wound around proteins; forms during prophase of mitosis and meiosis.

**Chromosome segregation:** a step in cell reproduction or division, where chromosomes pair off with their similar homologous chromosome.

**Crossing-over:** exchange of DNA segments between homologous chromosomes; occurs during prophase I of meiosis.

**Cytokinesis:** division of the cytoplasm after mitosis or meiosis.

**Daughter cell:** the cell resulting from the replication and division of a single parent cell during cell division.

**Diploid:** when a cell has two sets of chromosomes.

**DNA replication:** DNA is copied; results in two identical chromosomes instead of just one.

**Eggs:** female gametes (sex cells).

**Fertilization:** the process in which two gametes unite.

**Fragmentation:** occurs when a parent organism breaks into fragments, or pieces, and each fragment develops into a new organism.

**Gametes:** cells involved in sexual reproduction; typically egg and sperm cells.

**Gametogenesis:** the development of haploid cells into gametes.

**Genes:** a segment of DNA that is encoded with genetic instructions for making proteins.

**Growth Phase 1 (G1):** stage of interphase where the cell grows and copies some organelles; most of a cell's life is spent in this stage

**Growth Phase 2 (G2):** final stage of interphase where the cell prepares for division.

**Haploid:** when a cell has only one set of chromosomes, typical of a gamete.

**Homologous chromosomes:** chromosomes of the same size and shape that also contain the same genes.

**Interphase:** stage of the cell cycle when DNA is synthesized and the cell grows; composed of the first three phases of the cell cycle.

**Meiosis:** nuclear division that results in haploid gametes.

**Metaphase:** second phase of meiosis where the chromosomes are aligned in the center of the cell.

**Mitosis:** sequence of steps in which a nucleus is divided into two daughter nuclei, each with an identical set of chromosomes.

**Parent cell:** the cell that divides to give rise to two daughter cells during cell division.

**Prophase:** initial phase of mitosis where chromosomes condense, the nuclear envelope dissolves and the spindle begins to form.

**Sexual reproduction:** reproduction where gametes from two parents combine to make an individual with a unique set of genes.

**Sperm:** male gametes (sex cells).

**Synthesis Phase (S):** stage of interphase when a cell's DNA is copied.

**Telophase:** final phase of mitosis where a nuclear envelope forms around each of the two sets of chromosomes.

**Tumor:** a mass of abnormal cells, often a sign of cancer.

**Zygote:** single cell that is formed after the fertilization of an egg; the first cell of a new organism.

## **Works Cited**

<http://www.ck12.org>

[http://commons.wikimedia.org/wiki/Category:Pictures\\_and\\_images](http://commons.wikimedia.org/wiki/Category:Pictures_and_images)