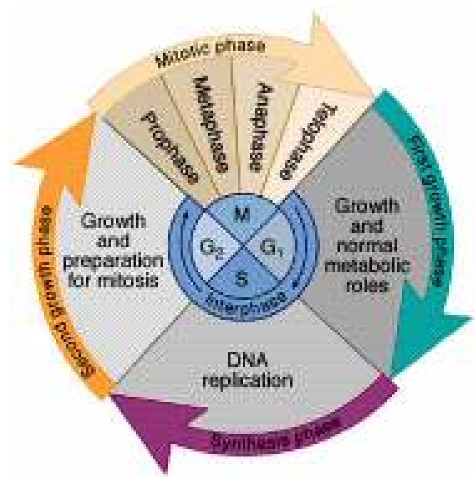
Mitosis and Meiosis

Why do cells divide? There are many reasons for this. Cells absorb and release nutrients threw their membrane. The larger the cell, the harder it is to get rid of all the waste that is produced. So, if there are many small cells (more surface area) rather than one large cell, the waste can be disposed of more readily. The other 3 reasons are critical to the survival of all organisms: Growth, repair and reproduction.

- **Growth**: This is a result of mitosis. The more cells in an organism, the larger that organism is. Humans start off as one single cell, and by the time they are adults, they have over 10 trillion cells!!! This increase in the number of cells also allows for some of those cells to be specialized for various functions. This is important to the survival of many organisms.
- **Repair**: This is a result of mitosis. If tissue is damaged, repair is extremely important. With some organism, they are even able to regenerate lost limbs (such as arms or tails). For us, this is important because it can repair skin, blood vessels and bones, for example. This also replaces cells that have died. You have a "new" skin every 28 days! That means that the old cells died and the new ones took their place.
- **Reproduction**: This is a result of mitosis or meiosis, depending on the type of reproduction. There are two types of reproduction. The first type is **asexual reproduction**, and this is when there is only one parent. This results from normal cell division. This occurs in bacteria, protests, fungi, some plants and some animals. The offspring are genetically identical to that of the parent. The other type of reproduction is **sexual reproduction**. This is when the offspring have a combination of both parents DNA.

Cell cycle

How do cells know when to divide? There are hormones in an organism's body that sends signals to the cells to prepare for division when it is needed. This is all part of the cell cycle, which is made up of various phases, beginning at the start of one cell division and ending at the start of another. There are two main parts to this division: **Interphase**, which is for growth and preparation, and **cell division**, which includes mitosis and cytokinesis.



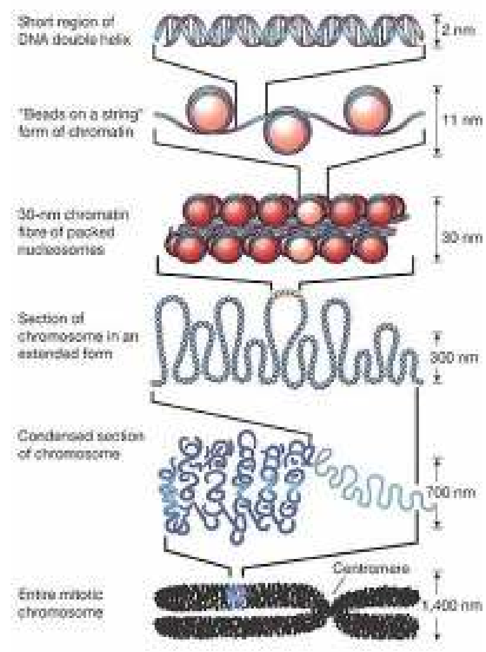
Interphase occurs between divisions, and is the congest phase in the cell cycle. This usually makes up about 90% of the time spent in the cell cycle. This is not a "resting" period, but time for preparation. This is when the cell grows and prepares for division.

There are three stages in **interphase**. **G1** (or gap 1), **S** (or synthesis) and **G2** (or gap 2).

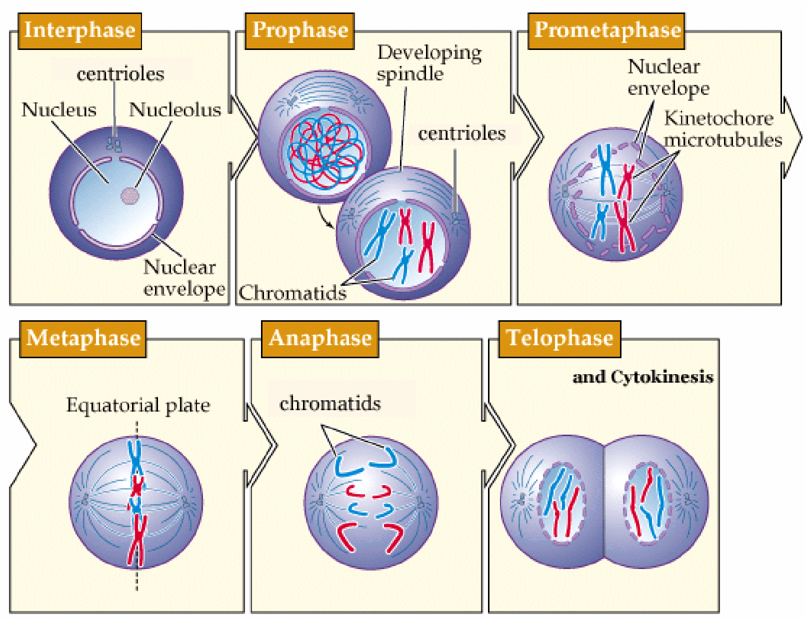
- **G1** – this is the period where the cell grows and develops. Since some cells divide more actively than others, the time spent in the G1 phase will vary. There is no division that takes place in this phase. Just growth and development. What do you think some of those in humans are?
- **S** – This is where the cell is committed to cell division. Inside the nucleus, the chromosomes (including the DNA) begin to replicate, the material makes a copy of itself (more on chromosomes in a minute). This results in two identical copies of chromosomes, called **sister chromatids**. The two sister chromatids are attached to each other at a point celled the centromere. This replication is important, because it allows there to be two full sets of DNA in each of the new cells, at the end of the division.
- **G2** – Organelles and other material required for cell division are replicated or formed. For example, the centrioles in animal cells replicate themselves, to form 2 pairs.

Cell division includes mitosis and cytokenesis. **Mitosis** is the portion of the cell cycle when the cells nucleus is replicated and divided into two identical nuclei containing genetically identical material. This type of cell division is for growth, repair and asexual reproduction. Mitosis forms **somatic cells**, which are also referred to as the cells of the body (having a 2*n* or diploid number of chromosomes). This is the type of cell division all of the cells in the body do except for those responsible for "sex cell" production. **There are 4 main phases in mitosis.**

1) **Prophase** – this is the first stage of mitosis. In this stage the sister chromatids also condense to a visible form. You can see how the DNA is arranged and condensed into chromosomes in the picture. →
   The nuclear envelope also breaks up, exposing the chromosomes. The **spindle fibers** begin to form, extending from the **centrioles**. These are made up of microtubules and attach to the centromere of the sister chromatids. The centrioles slowly migrate to opposite sides of the cell.



2) **Metaphase** – this is when the chromosomes are lined up along the **metaphase or equatorial plate**, an imaginary line in the center of the cell. The chromosomes are moved here with the help of the spindle fibers and the centrioles.
3) **Anaphase** – The centromere of each chromosome are pulled apart by the spindle fibers, causing the sister chromatids to separate, creating two daughter chromosomes. One of the daughter chromosomes is pulled to one side of the cell, while the other is pulled to the opposite pole. This process is critical, because it ensures that the soon to be daughter cells will each have full, identical sets of chromosomes, also being identical to the parent cell.



4) **Telophase** – The new neclei begin to form around the new sets of chromosomes, at each end of the cell. The chromosomes also begin to unravel, back into their loose form. By the end of this phase, the spindle fibers are also dissasembled. At the same time, cytokensis begins, and the cell is "pinched" into tow new cells.

As mitosis comes to an end, the two new nuclei must end up in two new cells; this is where cytokenesis comes in. **Cytokinesis** is when the cell's cytoplasm divides into two, making two new cells called daughter cells. Each of these new cells receives one of the new nuclei, making the daughter cells genetically identical to the parent cell. Animal cells and plant cells complete mitosis and cytokinesis differently. The picture to the right is the while process of mitosis and the beginning of cytokinesis as far as an animal cell is concerned. The cytoplasm "pinches" the cell into two daughter cells, right down the center of the parent cell, until there are two separate daughter cells. However, in plants, a cell plate begins to form along the center of the cell (see page 112 of your zebra book for a picture). This then fuses with the cell membrane and cell wall, cutting the cell into two.

Most reproduction occurs through sexual reproduction. **Sexual reproduction** is NOT HAVING SEX, it is the recombination or mixture of genes. This results in the offspring having a combination of DNA from both parents. This will help add to the variation within a population or a species and this also creates unique individuals, which are not identical to the parents. For this to be possible, there has to be a special type of cell division. If there was a union of two somatic cells, then the offspring would have twice the number of chromosomes as the parents, and that would continue to increase. This is not the case however, so there is a cell division that reduced the number of chromosomes in half. This is important because when we add the two parent cells together (fertilization) the offspring will end up with the same number of chromosomes as the parents, but with a combination of features.

Each species has a different number of chromosomes. For example, humans have 46 chromosomes (23 pairs) in every body cell. All cells contain two complete sets of chromosomes (in humans each set has 23 making a total of 46) called the **diploid (2*n*)** number of chromosomes. The exception to this is with sex cells, such as egg and sperm. Since these will later combine they each only have one set of chromosomes, called **haploid (*n*)** cells, and in humans this means they have 23 chromosomes total. Haploid cells, or reproductive cells, are called **gametes** or sex cells. The process which produces diploid cells was that mentioned above, mitosis. This occurs in all somatic, or body cells. To obtain the reduced number of chromosomes for haploid cells, they undergo what is called meiosis.

Meiosis is the formation of gametes, performed by reproductive cells only. This will result in a reduction of the chromosome number, forming haploid cells (n). So, unlike mitosis, which produces two daughter cells with identical chromosomes, meiosis produces 4 daughter cells, each with half the number of chromosomes, that are not identical to each other (you will learn why in the next unit). This is again important because it keeps the chromosome number constant over generations, in the adult organism. When the egg (n) and the sperm (n) combine ($n + n$) in fertilization, the offspring is a diploid cell ($2n$).

Different organisms have different numbers of chromosomes. Here is a table showing the variation in diploid number of chromosomes for different species.

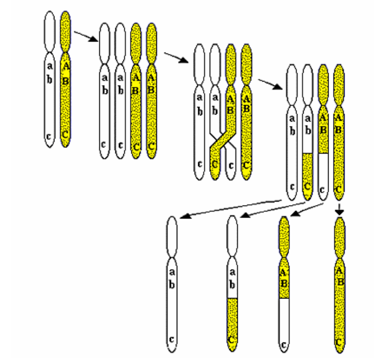
Organism	Diploid Number
Alligator	32
Ameba	50
Bullfrog	26
Carrot	18
Corn	20
Dog	78
Earthworm	36
Fruit fly	8
Horse	64
Hydra	32
Lettuce	18
Redwood	22
Sea urchin	40
Yucca	60

Try figuring out their haploid numbers!

When chromosomes pair, in preparation for meiosis, they arrange with their homologous pair, other wise known as **homologs**. This means that like chromosomes pair with each other. Remember humans have 46 chromosomes, but 23 pairs, each of the chromosomes in the pair are exactly alike in size, gene location and location of the centromere. There is one exception, the sex chromosomes. Females have a pair called XX, both of them are alike, but males are XY. You will learn more about this in the coming weeks when we talk about genetics.

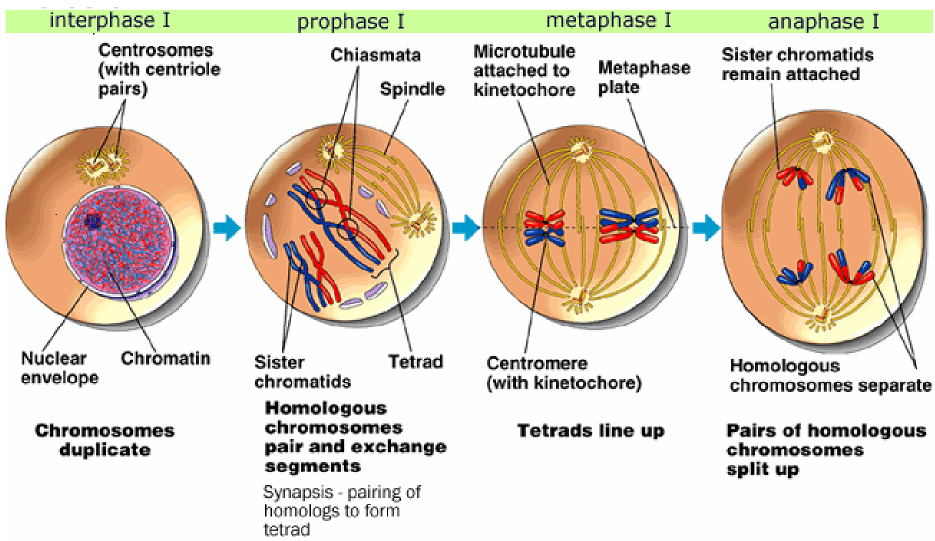
How is it that cells change from a diploid cell to a haploid cell? In a process called meiosis, as mentioned above, the homologous pairs of chromosomes are separated and end up in 4 daughter cells. This happens in two main states, meiosis I and meiosis II. The pairs separate during meiosis I, and meiosis II is when the sister chromatids separate, much like in mitosis.

Meiosis I is a 4 step process. The start of this is much like mitosis, the cells have gone through the G1, S and G2 phases, thus the DNA has been replicated and are in the form of sister chromatids, connected at the centromere. The main difference here is that the homologous pairs of chromosomes pair up and then proceed as follows.



Crossing-over and recombination during meiosis

1) **Prophase I** the chromosomes thicken and are visible under a microscope. The homologous pairs of chromosomes are tangled together and being to move towards the equatorial plate. This means that instead of two sister chromatids like in mitosis, there are now 4 sister chromatids that move together, this is called a **tetrad**. This is also where the nuclear envelope disappears and the spinal fibers begin to form. This is also the phase where **crossing-over** can occur. Due to the way the homologous pairs of chromosomes are tangled together, many times, they "swap" parts of their chromosomes. This is a major source to the addition to the variation between individuals. It is this variation that allows evolution to act on favorable traits, having those that are more favorable survive and the others die off.
2) **Metaphase I** is where the homologous pairs are lined up next to each other, along the equatorial plate (see the diagram below).
3) **Anaphase I** the homologous pairs are now separated, due to the spindle fibers pulling them apart, from the centromere. Each chromosome still has two sister chromatids.
4) **Telophase I** the nuclear membrane may or may not reform, depending on the species, but in any case, cytokinesis does occur, resulting in two new cells, each with the **haploid number of chromosomes**, which are still in the form of sister chromatids.



Meiosis II is what follows after telophase I and cytokinesis. The daughter cells from meiosis I are what go into this phase. They divide again, but this time occurring much the same as mitosis. The only difference is that there are *n* number of chromosomes rather than 2*n*, and we end up with a total of 4 daughter cells rather than 2. Again, since there were two daughter cells produced in meiosis I, and each of them divide again, the result of meiosis is 4 daughter cells, each with *n* number of chromosomes, which are not identical to the original parent cell or each other. This is done through 4 more steps: prophase II, metaphase II, anaphase II and telophase II, followed by the final cytokinesis.