

638-2500 (60-245) Modeling Mitosis and Meiosis

A Hands on Exploration of Cell Replication

Parts List:

Note: this kit provides enough materials for 2 groups of students to complete all activities

6 Pairs of Autosomes

6 Pairs of Female (X) sex Chromosomes

2 pairs of Male (Y) sex chromosomes

4 Chromosome Fragments: 2 red and 2 pink

16 Square Genes: 8 red and 8 pink alleles

16 Triangular Genes: 8 red and 8 pink alleles

16 Circular Genes: 8 red and 8 pink alleles

Required but not included: colored yarn

24-60245 instructions



Mitosis

Introduction:

Key words:

Interphase: the part of the cell cycle not directly responsible for replication.

Chromosomes: a bit of DNA carrying genes.

Centromere: a structure joining two chromosomes together.

Chromatid: a pair of chromosomes.

Prophase: the first step of mitosis. Chromosomes begin to line up.

Metaphase: chromosomes are lined up, waiting to be separated.

Anaphase: chromosomes are pulled apart.

Telophase: one cell becomes two.

Cytokinesis: the cell membrane ‘pinches’ shut and separates the daughter cells.

A living creature is essentially a collection of information. This information is written down in a complex chemical language. The body is able to read the information contained to carry out many functions. Recently, humans have learned to read this language to better understand and care for the human body. This information is written in a DNA (deoxyribonucleic acid) strand.

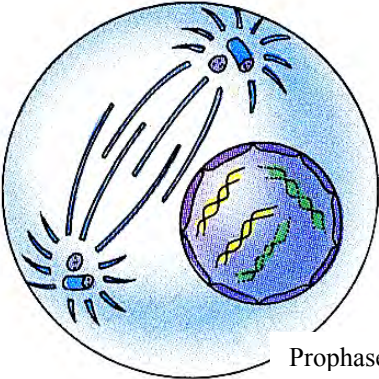
DNA is a complex molecule that contains all the information about a creature. All living things are based on this molecule. While every code is unique, there are many similarities between them. For example, humans and chimpanzees share all but one tenth of one percent of their DNA. The tiny fraction not shared accounts for the differences between us. Humans and bacteria can share up to 90% of our DNA; obviously there are vast differences between the two.

DNA is responsible for carrying all of the information in a cell, which is passed down to the next generation. It is also responsible for replicating proteins and governing the goings on inside a cell. A cell is driven largely by proteins and RNA (ribonucleic acid), which acts as an intermediary between DNA

and a protein. RNA is like the foreman of a cell: it does not create instructions but is responsible for carrying them out.

A cell will spend most of its time between divisions, called *interphase*. During this time period, the cell is concerned with fulfilling its primary function in the body and preparing itself for replication.

During mitosis, a DNA strand will duplicate itself, eventually creating two cells with an identical genetic makeup. During most of a cell's life, *chromosomes*, or bits of DNA, are dispersed throughout the cell performing various functions. However, when the cell is ready to replicate they will form tightly coiled structures, and join up in pairs. The junction of two chromosomes is called a *centromere*. Each side of these chromatids is identical.

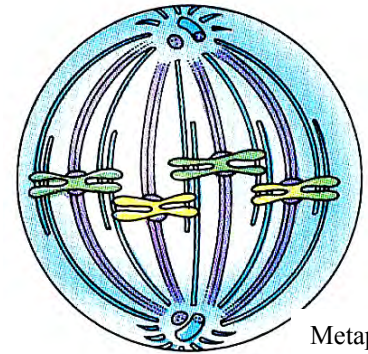


Prophase

The replication process is usually viewed as having 4 stages: prophase, metaphase, anaphase, and telophase.

The stage of cell division known as **prophase** is the initial step. During this time, chromatids will form tightly coiled pairs that join at a centromere. A structure called a mitotic spindle forms outside the nucleus of the cell, which is made of long strands of proteins called microtubules. These are responsible for separating newly replicated chromatids from the original ones. The nuclear membrane of the cell will begin to break down, allowing the microtubules to attach to chromosomes.

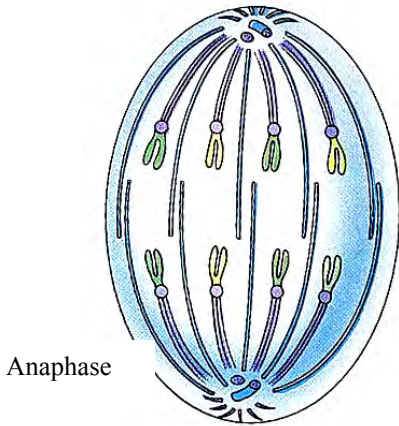
Metaphase occurs when chromatids line up in the center of the cell. Each side of the chromatids is attached to a microtubule. This will allow each side to be pulled to opposite sides of the cell.



Metaphase

During **Anaphase**, the microtubules begin to pull the chromosomes apart. This splits the chromatids in two and moves them to opposite ends of the cell. These new fragments are called *daughter chromosomes*.

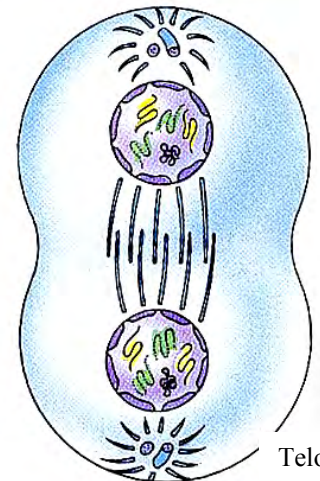
The final stage of mitosis is **Telophase**. The cell elongates, and a nuclear membrane begins to form around each set of daughter chromosomes. The chromosomes become less tightly coiled and begin to disperse. By this time, the genetic material of each cell has been successfully replicated, forming two identical nuclei. While this is the



Anaphase

end of mitosis, it is not the end of the cell cycle. A final step called **Cytokinesis** must occur. During this phase, the cell membrane 'pinches' inward, separating the cell into two smaller cells. Each newly split set of chromosomes now has its own cell to inhabit. The cell will enter interphase again, and the cycle will repeat.

Mitosis is a highly specialized and complex process, with many biochemical reactions occurring. This model shows a more simplified version of the process that is easier for students to absorb, particularly in introductory classes. Mitosis is also not always a perfect

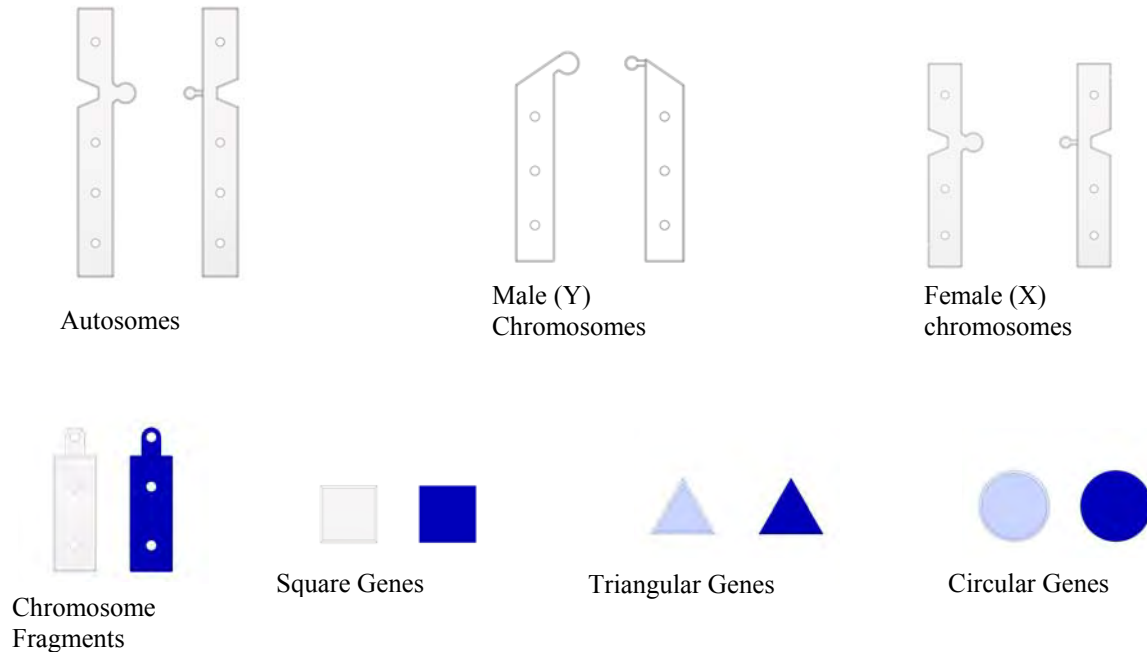


Telophase

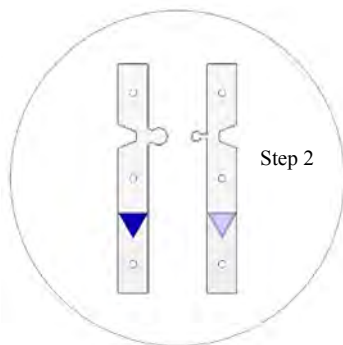
process: errors can and do occur. Often these errors simply result in the cell's death, either through damage or from the body killing the cell. Unchecked errors in replication can lead to mutations and even cancer.

The next section will detail the different parts of your kit, and how to use them to simulate mitotic functions.

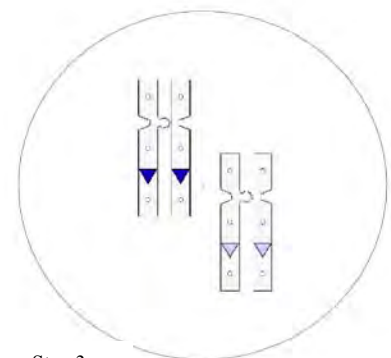
Parts Key:



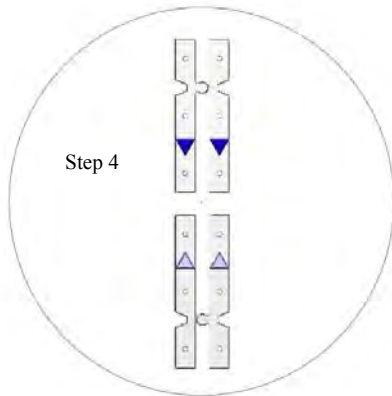
Modeling Mitosis



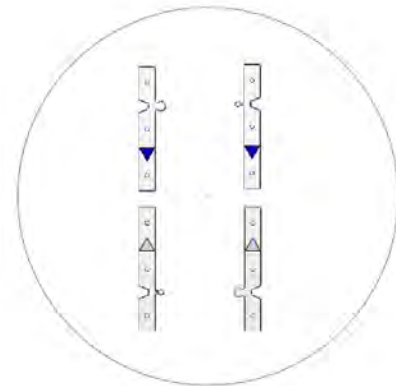
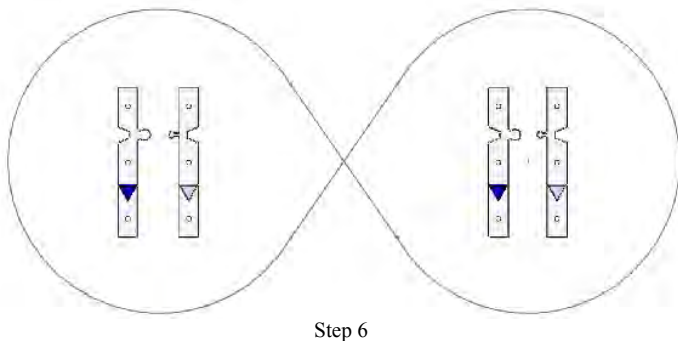
- From your parts set, take two autosomes and about 3-4 feet of string. Ties the free ends of your yarn together to make a circle. This circle represents a cell membrane.
- Place both chromosomes inside your 'cell'. Give them each a gene or two. These genes can be different colors, but they should be the same shape. This represents a chromosome pair. Do not hook the two chromosomes together.
- When a cell is ready to replicate itself, it must first duplicate its entire DNA. This takes place just before mitosis occurs. To model this, make a replica of each chromosome. Genes should have the same shape and color. Attach the new chromosome to the original one using the center hook. You should now have two sets of identical chromosomes joined by a centromere.



4. As we noted above, during metaphase the chromatids line up in the center of the cell. Microtubules attach to each side of a chromatid, ready to pull it apart. You can model these microtubules with string, or use your imagination.



5. For the anaphase portion of the mitosis cycle, we noted that the microtubules pull one half of the chromatid to opposite ends of the cell. Disconnect each chromatid at the center and move each piece to opposite ends of the cell. You can also simulate telophase by elongating the cell and placing the chromosomes at the extreme ends during this step.
6. To complete telophase, enter cytokinesis and complete the cycle, loop your 'membrane' over to create a figure 8 shape. Each loop should have a pair of chromosomes identical to the original cell you constructed.



Congratulations! You have successfully modeled the process of mitosis! Starting with one cell, you replicated DNA, prepared the cell for separation, split the chromosomes, and formed two identical cells. This process is going on inside your body as you read this. Obviously, more genes are involved than the one shown here. To model every gene in a cell would require a great deal of parts and table space, due to the enormous number of them. For the purposes of this kit, one will suffice.

Now that you have mastered replication of cells, it's time to move on to meiosis. You will learn how one cell produces 4 cells with half the usual number of chromosomes.

Meiosis

Keywords:

Haploid: meiosis daughter cells.

Diploid: two haploids joined together.

Tetrad: two pairs of chromatids.

Crossing over: exchange of genetic material between chromatids.

Prophase: the first step of mitosis. Chromosomes begin to line up.

Metaphase: chromosomes are lined up, waiting to be separated.

Anaphase: chromosomes are pulled apart.

Telophase: one cell becomes two.

Cytokinesis: the cell membrane ‘pinches’ shut and separates the daughter cells.

Gamete: a cell produced by meiosis that is used for sexual reproduction.

Meiosis and mitosis do share some similar steps, and a lot of the names are the same. This can be confusing for many students. It is important to keep in mind that meiosis has a drastically different purpose than mitosis. Mitosis takes one cell and turns it into two identical copies; this is useful for healing a wound or growth. However, meiosis takes a parent cell and makes two cells, each with half of the original chromosomes. Each of these cells is called a *haploid* cell.

Why would such a thing be desirable? Obviously a cell with only half its chromosomes cannot function properly. Meiosis is used by sexually reproducing organisms. Each partner will use meiosis to create haploid cells. Two of these will then combine to form a single cell with a complete set of chromosomes. This cell will be fully functional, but it contains genetic material from two donors, giving it much greater genetic variety. Complete cells formed by the combination of two haploid cells are called *diploid* cells.

In order to form the haploid cells, two cell divisions are necessary, which are aptly called meiosis I and meiosis II. Meiosis I has five stages, each with the same names as mitosis: prophase, metaphase, anaphase, telophase, and cytokinesis. Cytokinesis is considered a stage of meiosis because the cells must divide fully before the second stage can occur.

First Meiosis Stage:

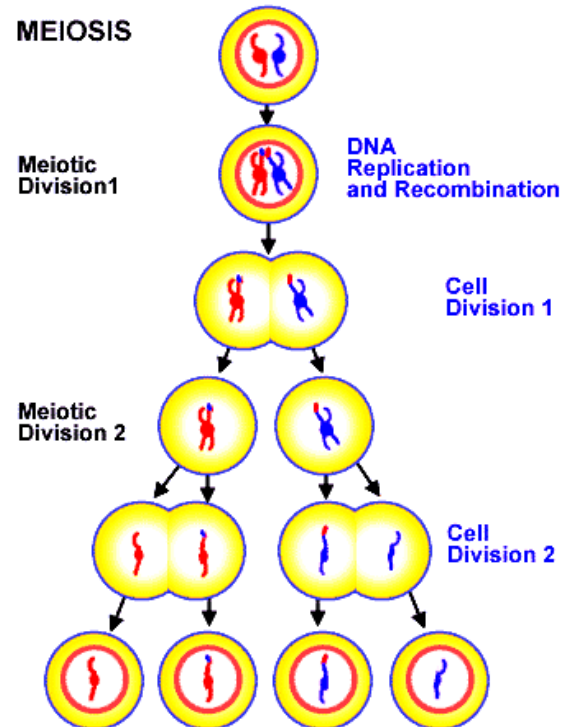
During prophase, two identical chromatids formed during interphase come together, forming a structure called a *tetrad*. While linked this way, the chromatids undergo an important change: *crossing over*. Genetic material is swapped from one chromosome to another, mixing up the genes. This is an important difference between meiosis and mitosis. It ensures that all the daughter cells are genetically unique. During this phase, a spindle of microtubules forms, just like in mitosis.

During metaphase, the tetrads will line up in the center of the cell, similar to mitosis. The microtubules will attach to the tetrads, ready to pull them apart. However, unlike mitosis, a pair of chromosomes is pulled to opposite ends of the cell. This is because splitting a tetrad into two parts requires each part to have two chromosomes.

In anaphase, the microtubules pull the tetrads apart, and move each piece to opposite ends of the cell. Telophase and cytokinesis then occur, creating two daughter cells. This marks the end of the first stage of meiosis.

Second Meiosis Stage:

There is no interphase period between the two stages of meiosis, because there is no need to replicate more genetic material.

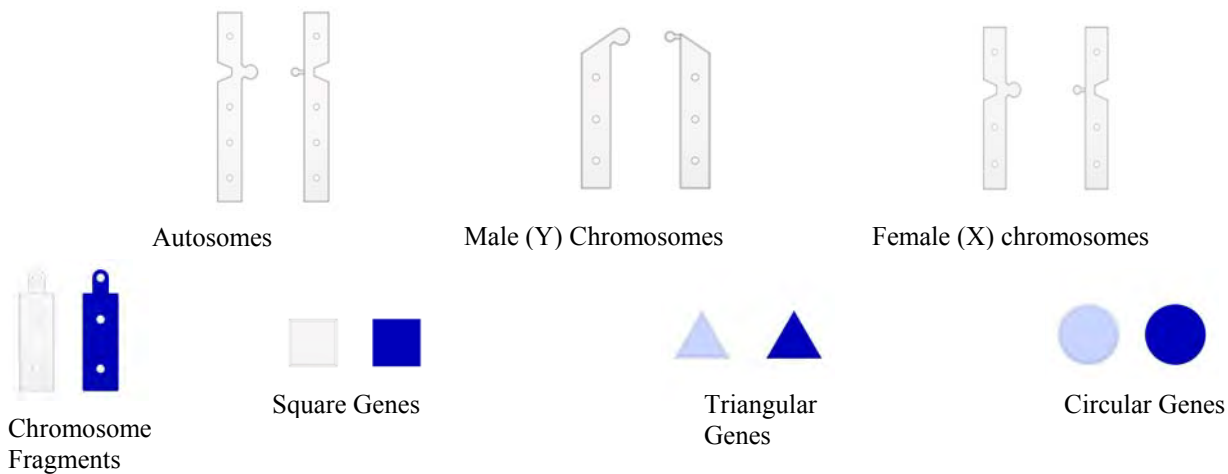


Prophase and metaphase are much like they're analogs in mitosis: a spindle of microtubules form and the chromatids move to the center of the cell. The microtubules prepare to pull the chromatids apart.

During the second stage of anaphase, the microtubules pull the chromatids apart, separating them at the centromere. The pieces move to opposite ends of the cell. Telophase and cytokinesis occur as normal, resulting in a total of four daughter cells.

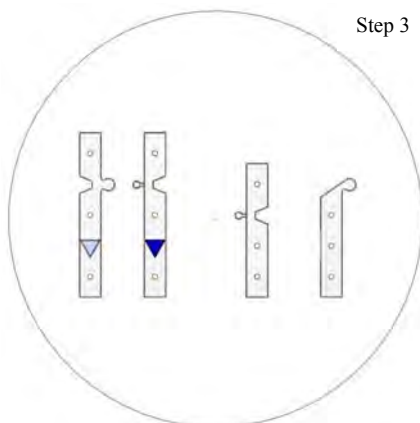
Each daughter cell created in this fashion has only one copy of each chromosome from the parent cell. This means that each daughter cell has only half of the genetic material of a complete cell. In addition, some of this genetic material has crossed over. This makes each daughter cell genetically unique.

Parts Key:



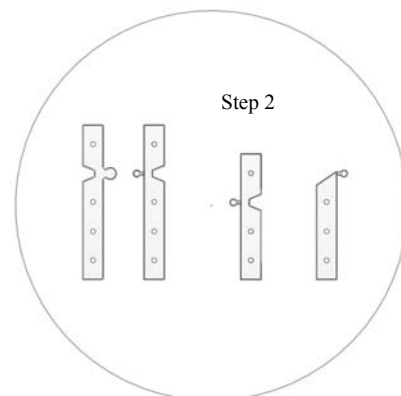
Modeling Meiosis

- To start, you will need two autosomes, a female chromosome, and a male chromosome. You will also need 2 pieces of colored yarn 3-4 feet long.
- Make a loop out of the yarn to represent a cell membrane.



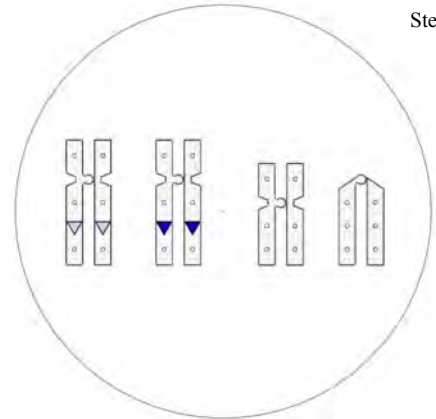
Place the chromosomes inside your 'cell'.

- Choose a gene and place it on the autosome. It should be the same shape but does not need to be the same color.

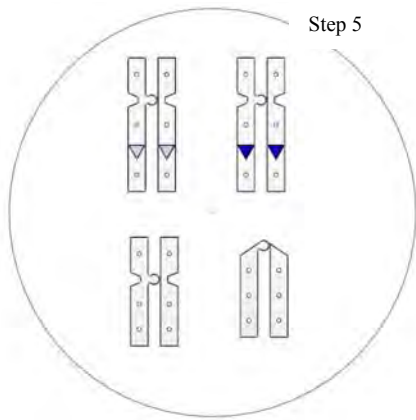


4. Replicate your chromosomes. Create an identical copy of each, making sure they possess the same genes. Connect the two copies at the centromere. This represents the gene replication that occurs during interphase.
5. Have your chromosomes line up in the center of the cell, like what occurs during metaphase. Place your two sets of autosomes next to each other to form a tetrad. Do the same for your sex chromosomes.
6. Form a second loop of yarn and place it next to your cell. Taking care to keep them connected, remove one half of each tetrad and place it in the second loop. This represents the first stage of cell division. You should now have two identical daughter cells.
Note: crossing over will occur during the first division. This process will be explored in greater detail in the next section.

Step 4

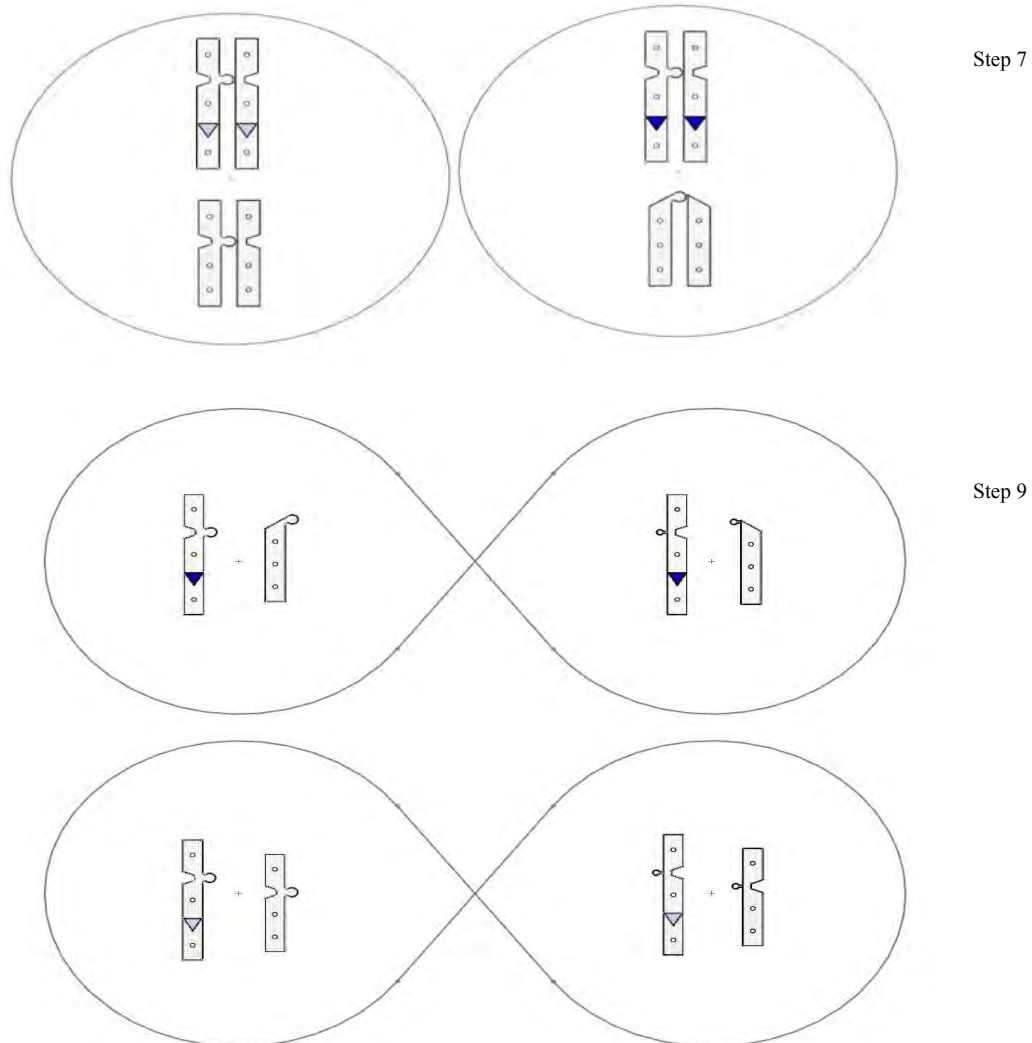


Step 5



7. When the cell begins the second stage of meiosis, the chromosomes do not replicate again. Instead, they move to the center of the cell, preparing to divide. Align the two chromatids in each cell vertically with the centromeres aligned.
8. Separate each chromatid at the centromere. Move the separated pieces to each side of the cell. This represents the second stage of anaphase. This splitting process is carried out by the microtubules, as before.
9. Take your 'membrane' and loop it into a figure 8 shape. Do the same thing for the other 'membrane'. This represents the final division of cells. You should now

have four haploid cells, each with one autosome and one sex chromosome. These cells are also called *gametes*. They will be stored until reproduction occurs, when they will combine with another gamete from the other partner. This results in a complete cell, with equal amounts of genetic material from each parent.

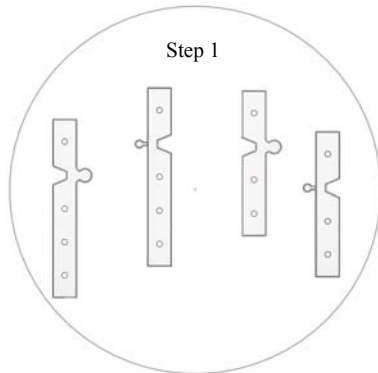


Congratulations! You have successfully modeled meiosis and created four haploid cells, or gametes. Your organism would exchange these cells during mating, eventually creating a complete cell with half of its genes from each parent. This allows for much greater genetic diversity.

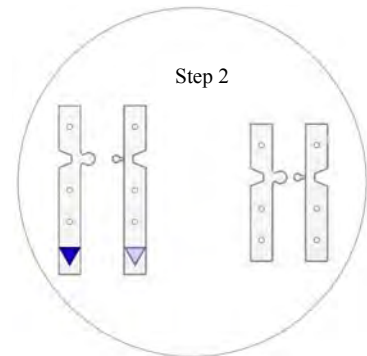
Meiosis is important for diversity, but a process called *crossing over* is crucial. During this process, genes swap from one chromosome to another, allowing for an essentially infinite degree of genetic variation. We will explore and model this process in the next section.

Modeling Crossing Over

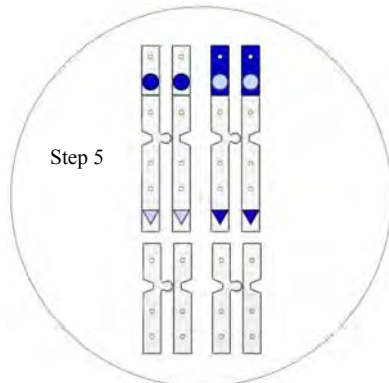
Crossing over is a very important part of meiosis. It allows genes to swap from one chromosome to the next, resulting in a well sorted genetic pattern. It can be likened to ‘shuffling the cards’ to spread genes out as much as possible. This is important because it makes sure that a cell doesn’t get an overabundance of bad genes, which could lead to an ineffective offspring.



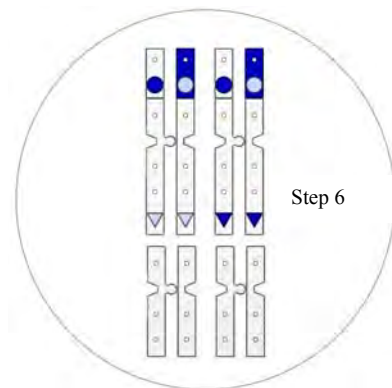
1. You will need two pieces of yarn 3-4 feet long. As before, you will loop these to create your ‘cell membrane’. With the model kit, withdraw two autosomes and two sex chromosomes. These should be X chromosomes. Place them in your cell.



2. Give your autosomes a gene or two. Give each autosome the same shape but different color gene. Pair up your autosomes and sex chromosomes, but don’t connect them.
3. Going to your model kit, find a red and pink chromosome fragment. Place these on top of your autosomes. Give each fragment a different color gene, but of the same type (shape).
4. Using your parts, replicate each autosome and sex chromosome. Take care to ensure each replicated part has the same genes as the original. Don’t forget to replicate your chromosome fragments as well. Connect the two pieces at the centromere. This step represents the gene replication that occurs during interphase.



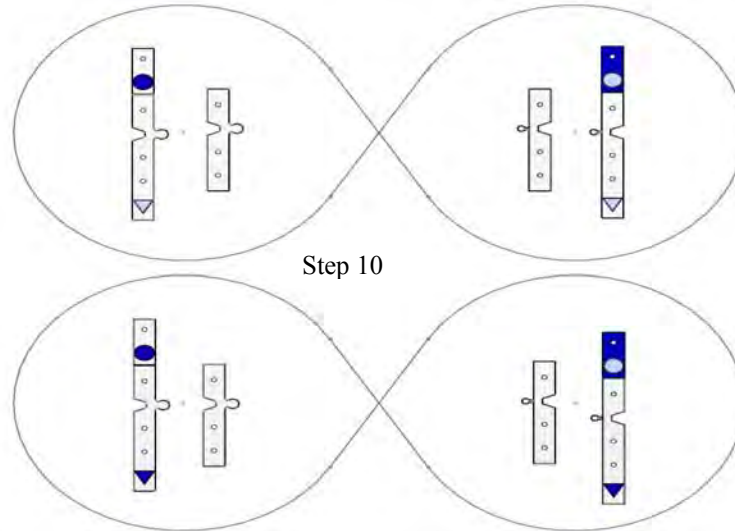
5. For the metaphase portion, line up the chromosomes in the center of the cell. They should be placed side by side to form tetrads.
6. The first stage of prophase during meiosis is when crossing over occurs. In



each tetrad, chromatids become close enough to overlap and exchange similar pieces of information. To model this, exchange the genes on the chromosome fragments. Be sure to switch between non-sister chromatids; that is, ones not joined by a centromere.

7. Make a second loop of yarn. This will represent another cell. Place it next to the first cell and move one pair of chromosomes from each tetrad into it. This models the first cellular division of meiosis. Each daughter cell should now have one pair of autosomes (complete with fragments) and one pair of sex chromosomes.
8. When the cell begins the second stage of meiosis, the chromosomes do not replicate again. Instead, they move to the center of the cell, preparing to divide. Align the two chromatids in each cell vertically with the centromeres aligned.

9. Separate each chromatid at the centromere. Move the separated pieces to each side of the cell. This represents the second stage of anaphase. This splitting process is carried out by the microtubules, as before.
10. Take your 'membrane' and loop it into a figure 8 shape. Do the same thing for the other 'membrane'. This represents the final division of cells. You should now have four haploid cells, each with one autosome and one sex chromosome. These cells are also called *gametes*. They will be stored until reproduction occurs, when they will combine with another gamete from the other partner. This results in a complete cell, with equal amounts of genetic material from each parent. This results in a complete cell, with equal amounts of genetic material from each parent.
11. Notice that each of the four gametes has mixed up chromosome fragments. Crossing over has spread the genes of one cell more evenly over the four haploid cells. This helps to ensure genetic variability amongst offspring, which strengthens the species as a whole.



Cell division is a crucial part of all eukaryotic life. Prokaryotes and archaea have different methods of reproducing, but those are not covered in this kit. The activities outlined in this kit explain how all plant and animal cells reproduce. Why do cells reproduce at all? Cells divide when they are old, when an organism is growing, or when damage needs to be repaired. They also can divide uncontrollably and for no beneficial purpose; this is known as cancer. Some organisms reproduce entirely by mitosis; most animals use meiosis to create sex cells. These sex cells combine with the sex cells of another organism to create genetically unique offspring. This evolutionary trait is a huge advantage; it strengthens the genetic code of a species and makes it more likely useful mutations and combinations will occur.

Cells divide every day; a human body goes through about 30 billion of them in a 24 hour period. Cells are also routinely killed off by the body if they become too old or a too damaged to repair. This phenomenon is called *apoptosis*, or programmed cell death. It is the body's way of ensuring that old or potentially contagious cells do not clutter up the body and cause trouble. In a way, it can be viewed as a form of recycling.

Review Questions:

1. What is the purpose of mitosis, and how does it differ from meiosis?

2. What are the four stages of mitosis?

3. What important part of cell replication is not considered a part of mitosis?

4. What are the cells produced by meiosis called?

5. What are the phases of meiosis during the first stage?

6. What is the purpose of meiosis?

7. Crossing over is the exchange of genetic material from one chromatid to another. What are some benefits of this?

8. There is a part of the cell cycle where the cell is not concerned with replication. Can you name it?

9. True or false: meiosis produces two identical daughter cells:

10. Small threadlike structures are responsible for pulling chromatids apart. Can you name them?

11. True or false: All cells die as a result of disease or injury:

Warranty and Parts:

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.