

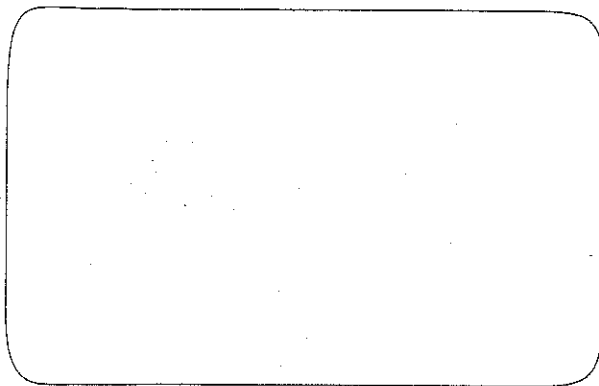
Mitosis and Meiosis Manipulative Models — Student Guide

INTRODUCTION

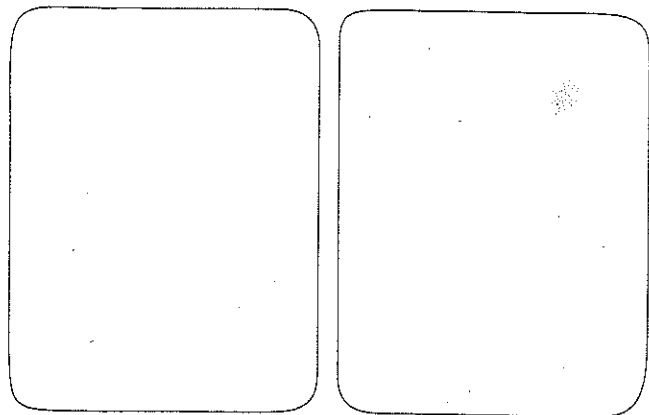
New cells are produced by the process of cell division. An existing cell that divides is called the parent cell, while the new cells that are formed are called the daughter cells. In the type of cell division known as mitosis, two daughter cells which are genetically identical to each other and in turn identical to the original parent cell are produced. In the type of cell division known as meiosis, four daughter cells are produced; however, the number of chromosomes in each of the daughter cells is half that of the parent cell. The cells produced during meiosis are the gametes, or sex cells. During reproduction, each parent contributes one gamete; when fertilization occurs, these specialized cells fuse to form the new offspring's first cell.

Using the parts in this kit, you will create models of each step that occurs during both mitotic and meiotic cell division. This kit includes the pieces shown below.

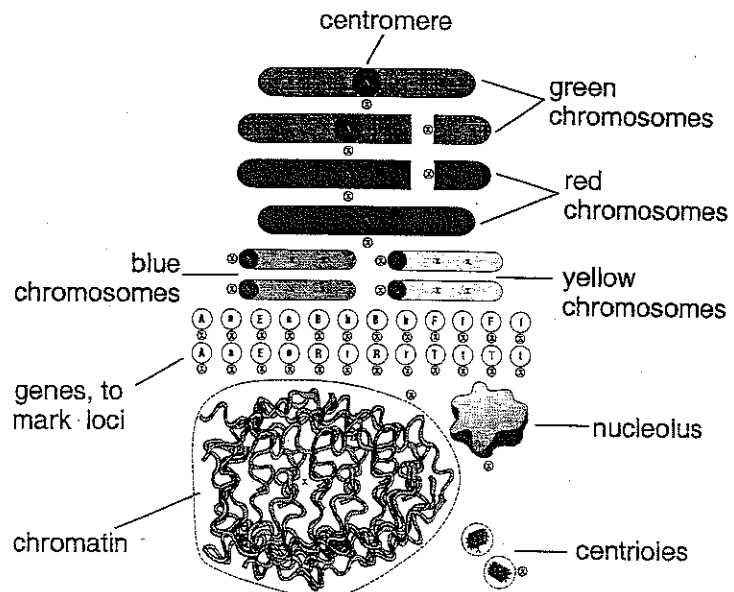
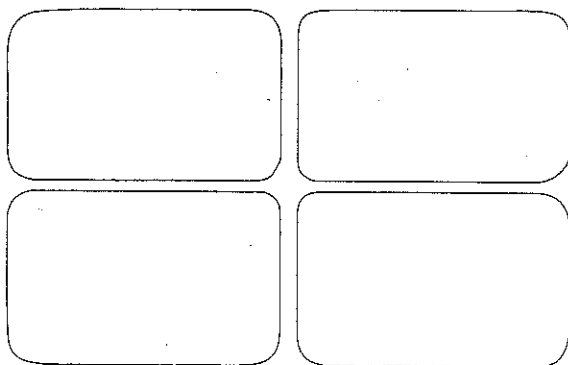
Cell base #1 — parent cell



Cell base #2 — daughter cells,
for mitosis and meiosis



Cell base #3 — gametes, for meiosis



OBJECTIVES: MITOSIS

1. Demonstrate and identify the stages in the cell cycle.
2. Describe the structure of a chromosome and the function of a gene.
3. Distinguish between haploid and diploid and define homologous chromosomes.
4. Identify and/or demonstrate the formation/function of genes, alleles, locus, chromosomes, chromatids, centromeres, centrioles and spindles.
5. Demonstrate and describe the events occurring in each stage of mitosis with emphasis on the behavior of chromosomes.

USING THE MANIPULATIVES TO DEMONSTRATE THE STAGES OF MITOSIS

Following is a description of each phase of mitosis. Use your manipulative as described to illustrate the changes that occur during each of these phases.

INTERPHASE

Most of the life of a cell is spent in INTERPHASE, actively synthesizing materials needed for its growth and maintenance. Use your manipulative to show interphase by accurately placing the cell chromatin, nucleolus, and centriole pair on black line cell base #1, representing a complete parent cell.

At this point, the model illustrates that the DNA is replicated, even though the individual chromosomes are not visible. Instead, the chromosomal DNA exists as part of the intertwined chains of chromatin contained in the nucleus.

DNA synthesis occurs during interphase. During late interphase, the two centrioles in the microtubule organizing center separate and a new centriole develops near the base of each, resulting in two pairs of centrioles.

PROPHASE

The first stage of mitosis, PROPHASE, starts when the chromatin threads begin to condense and appear as chromosomes. In fact, the transformation of chromatin into several short, distinct rods is one of the first observable signs that prophase has begun. At this point, the chromosomes have not yet separated from their duplicates and are referred to as CHROMATIDS. Twin chromatids remain attached to one another at their centromeres. (The number of chromosomes in a cell is determined by counting the number of visibly separate centromeres. If two sister chromatids are joined in a chromosome, the entire structure is considered to be a single chromosome. A chromatid becomes a chromosome when it has its own centromere.)

Early in prophase, the microtubule organizing center splits, each daughter center containing one pair of centrioles, and migrates toward opposite poles of the cell. Spindles form between the centrioles, which have reached the poles of the cell. The fibers of the spindles appear to guide the movements of the chromosomes during mitosis. During prophase, the nuclear envelope breaks down, allowing the chromosomes to mingle with the cytoplasm. The nucleolus disappears.

Using the materials in this kit, you should be able to show and verbally describe all of the activities and steps of prophase.

To do this, use the same black line "parent" cell base (#1) that you used for interphase, with the chromatin and nucleolus in place. Now, remove the nucleolus and chromatin from the cell base. Next, show the normal diploid number of chromosomes with alleles of genes attached. (Different alleles of the same gene are at the same locus on a chromosome but have different nucleotide sequences.) Then replicate the chromosomes by pressing the centromeres of the two red chromosomes together, the two yellow chromosomes together, the two blue chromosomes together, and the two green chromosomes together. Next, place centrioles one atop the other joined by a spindle fiber thread, near the center of the cell where the chromatin used to be. Separate the centrioles to illustrate their migration toward the poles and the formation of the spindles.

At this point you should be able to use the chromosomes to identify the following structures and/or define the following terms: centromeres, homologous chromosomes, identical chromosomes, chromatids, genes, alleles, locus, diploid, and haploid.

METAPHASE

METAPHASE is the short period during which the paired chromatids are lined up along the equatorial plane of the cell at right angles to the spindle fibers. In this phase, spindle fibers attach to the centromeres of the chromosomes. By being pulled toward the more distant pole or being pushed away from the closer pole, or both, each chromosome ends up aligned along the cell's equator, midway between the spindle poles. During metaphase, the chromatids are thick and often are coiled around each other.

Using the manipulatives, show the chromosomes lined up in a single file along the cell equator, perpendicular to the long axis of the spindle apparatus and equidistant from each pole of the cell.

ANAPHASE

ANAPHASE begins with the splitting apart of the centromeres of sister chromatids. Each chromatid is now an independent chromosome. The separated chromosomes now begin to move toward opposite poles. The chromosomes move toward the poles, with the centromeres which are attached to the spindle fibers leading the way and the arms of the chromosomes trailing behind. Anaphase ends when a complete set of chromosomes has arrived at opposite ends of the cell. While cytokinesis (that is, the division of the cytoplasm) may begin towards the end of anaphase, it will not be complete until the cytoplasm has completely divided, at the end of telophase.

Using the manipulatives, show the separation of the sister chromatids at the centromeres. (You should also hear it, by way of the sound that occurs when the two sides of the Velcro split apart from one another.) Next show how the separated chromosomes move towards opposite poles along either side of the spindle, with an equal number of chromosomes moving to each pole of the cell.

TELOPHASE

The final stage of mitosis, TELOPHASE, is characterized by a return to interphase conditions. The chromosomes begin to elongate. A new nuclear membrane forms around each set of chromosomes, nucleoli reappear, and spindle fibers disappear. The final divisions of the cytoplasm (cytokinesis), yielding two daughter cells with newly formed nuclei and approximately half of the organelles from the parent cell, is completed during telophase. The division of an animal cell is accomplished by a cleavage furrow. In plant cells, cytoplasmic division occurs by the formation of a cell plate. The animal cells have centrioles and asters (made of microtubules that radiate out from the centrioles); the plant cells do not have centrioles or asters.

Demonstrate telophase by bringing back the chromatin, nucleolus and nuclear membrane on cell base #1, plus a new one of each, which you will draw or create. Show the cell splitting to form two cells half the size of the original parent cell (black line cell base #2.) The two new daughter cells should look exactly like the original parent cell did at the beginning of this exercise, during interphase.

QUESTIONS

Write your answers to the following questions on a separate sheet of paper.

1. What is the difference and relationship between a gene and an allele?
2. What is the difference and relationship between a chromosome and a homologous chromosome?
3. How many chromosomes are in the parent cell in the manipulative? How many chromosomes are in each of the daughter cells produced in the manipulative?
4. How do the daughter cells produced in the manipulative compare to the parent cell in respect to chromosomes present?
5. Why did the chromosomes line up, single file, during metaphase?
6. Would the daughter cells be any different if you had lined up the chromosomes, single file, in a different order during metaphase?
7. What are the differences between plant and animal mitosis?
8. Keeping the above answers in mind, describe how mitosis maintains a constant chromosome number and why daughter nuclei are always genetically identical to the parent cell.

9. What role does cell division play in the growth of an organism?
10. What is the function of the centromere region of a chromosome?
11. What is the function of a centriole?
12. What is the function of spindle fibers?

OBJECTIVES: MEIOSIS

1. Contrast the events of mitosis and meiosis.
2. Explain synapses, linkage, and crossing-over as related to meiosis.
3. Explain the separating of the homologous chromosomes.
4. List and explain the principal events of the stages of meiosis.
5. Explain the difference between the first and second meiotic divisions.
6. Cite the similarities and differences between spermatogenesis and oogenesis.

MEIOSIS VS. MITOSIS

As you know from the previous activity, mitosis ensures that each daughter cell will receive exactly the same number and kind of chromosomes that the parent cell had. In contrast, meiosis, a special type of cell division reserved for the production of gametes, reduces the number of chromosomes so that each new cell is haploid. The process of meiosis assures that the chromosome number of a species remains the same from generation to generation. Thus, in effect, meiosis separates the members of each homologous pair of chromosomes.

While several events are the same for meiosis and mitosis, there are several important differences.

1. In meiosis there are two successive nuclear and cell divisions. In mitosis there is only one nuclear division and cytokinesis.
2. In meiosis, a total of four cells are produced. In mitosis, a total of two cells are produced.
3. Each of the four cells created by meiosis contain the haploid number of chromosomes. In mitosis each daughter cell contains the diploid number of chromosomes.
4. Cells created by meiosis contain only one of each homologous pair of chromosomes. Cells created by mitosis contain complete pairs of homologous chromosomes.
5. During meiosis, the homologous chromosomes containing genetic information from each parent are thoroughly shuffled, and one of each pair is randomly distributed to each new cell. As a result of mitosis the daughter cells contain an identical complement of chromosomes, and this chromosome complement is identical to that of the parent cell.
6. In meiosis there is crossing over during Prophase I. In mitosis there is no crossing over during prophase.

USING THE MANIPULATIVES TO DEMONSTRATE THE STAGES OF MEIOSIS

Meiosis consists of two successive cell divisions. Each division includes stages comparable to the four stages of mitosis, namely prophase, metaphase, anaphase and telophase.

INTERPHASE

As in mitosis, the chromosomes duplicate themselves during the synthesis stage of the cell cycle before meiosis actually begins. When a chromosome duplicates, it consists of two chromatids joined by their centromeres. To be considered a complete chromosome, the structure must possess an unshared centromere. Place the chromatin, nucleolus, and centriole pair into cell base #1 to illustrate the cell during interphase before meiosis begins.

You can study the process of meiosis using the chromosome manipulatives that were used for mitosis. The green and red chromosomes are homologous and the yellow and blue are homologous to each other. Remove the chromatin and nucleolus and place a single red, green, yellow and blue chromosome on black line cell base #1. DNA synthesis occurs during interphase, so replicate each of the chromosomes. Join each of the original chromosomes, at the centromere, with another of the same color. These chromosomes, originally composed of one strand, are now made up of two strands, or chromatids, joined together at the centromere region. A chromosome composed of two chromatids is called a DYAD. By the end of the interphase, the centriole pair has also been replicated. Add another pair of centrioles to cell base #1.

PROPHASE I

During prophase of the first meiotic division, the chromatin shortens and thickens. Each chromosome is visible as two chromatids joined by a centromere. The nuclear membrane and nucleolus break apart and a spindle forms between opposite poles of the cell. While the chromatids are still elongated and thin, the homologous chromosomes eventually lie close together, side by side along their entire length in a process called SYNAPSIS. Each chromosome in this homologous pair contains the same genetic information in the same order. All the genes located on a particular chromosome are LINKED together and will tend to be inherited together. The tendency for linked genes to stay together is not absolute.

Since the diploid number for your manipulative is four, there are two homologous pairs. Since each chromosome has already been doubled at this time and actually consists of two chromatids, synapsis results in the coming together of four chromatids, forming a TETRAD.

During SYNAPSIS tetrad chromatids often become wrapped around one another. Large enzyme complexes assemble, snip parts of the chromosomes, and graft broken ends together (almost always a maternal "stump" with a paternal "stem" or vice versa), so that genetic material may be exchanged between both sister and nonsister chromatids. This breaking of the maternal and paternal chromatids and rejoining the broken segments is known as CROSSING-OVER. Due to crossing-over, the sister chromatids of a chromosome are no longer identical. The nuclear membrane and nucleolus disintegrate.

Using the red and green dyads, form a tetrad and show crossing-over taking place during prophase. Also move the centrioles toward the poles and show the formation of the spindles.

METAPHASE I

Chromosomes have untwined by metaphase I and can now be seen as dyad chromosomes. The chromosomes line up along the equator of the cell, at right angles to the spindle fibers, with the homologous chromosomes paired. Show this on your manipulative by pairing the red and green dyads and the yellow and blue dyads, and placing them along the equator of the cell. Attach one end of each spindle fiber to the centromere of each dyad; attach the other end of each spindle fiber to the centriole at the pole that is on the same side of the equator as the dyad.

ANAPHASE I

During anaphase of the first meiotic division, the homologous chromosomes of each pair, but not the daughter chromatids, separate and randomly move toward opposite poles. **The chromatids are still united by their centromeres. This differs from mitotic anaphase, in which the centromeres separate and the daughter chromosomes pass to opposite poles.**

Show this on the manipulative by pulling the elastic string representing the spindles so that the chromosomes are pulled to opposite sides of the cell. Using the manipulatives, you should be able to see how this step represents a second significant difference between the events of mitosis and meiosis.

TELOPHASE I

During telophase, the cytoplasm divides, forming two cells with two separate nuclear membranes. Each cell contains one member of each pair of homologous chromosomes, so that there are two double chromosomes at each pole — that is, two chromatids joined by a centromere in each cell. The chromosome number has been reduced to haploid, one half the diploid number.

At this point, you should be using cell base #2 of your manipulative to show the two cells formed during the first meiotic division.

INTERPHASE II

During interphase II, the chromosomes do not completely elongate. The amount of time spent "at rest" following telophase I depends on the type of organism. Because interphase II does not resemble interphase I, interphase II is often called INTERKINESIS. DNA replication does not occur during interkinesis. This represents a third major difference between mitosis and meiosis.

The following phases of the second cell division of meiosis usually occur quickly and in both of the cells formed by the first cell division.

PROPHASE II

During prophase II, the second cell division of meiosis begins. If the chromosomes relaxed after telophase I, they recondense. The centrioles replicate. The nuclear membrane and nucleolus break apart, centrioles move toward the poles and the chromosomes shorten and become visible. Each chromosome is made of chromatids joined by a centromere. As in mitotic prophase, there is no pairing of homologous chromosomes and there is no genetic recombination as in prophase I. On the manipulative, add a pair of centrioles to each cell and move them to opposite poles.

METAPHASE II

During metaphase II, the chromatids, still attached by centromeres, again line up in a single file along the equator. The chromosomes are attached by spindles from centrioles from both poles. The metaphases of the first and second division can be distinguished from one another because, in the first, the chromatids are arranged in bundles of four (tetrads) and, in the second, the chromatids are arranged in groups of two (dyads). On your manipulative, line up the chromatids in a single file along the equator. Attach an elastic string (to represent spindles) from each sister chromatid to the centriole at each pole.

ANAPHASE II

During anaphase II, the centromeres split and the daughter chromatids, now complete chromosomes, separate and move to opposite poles. By using your manipulative to illustrate this step, you should be able to see and hear the centromeres split during anaphase II. Now that each chromatid has its own visibly separate centromere region, it can be called a chromosome.

TELOPHASE II

In telophase II, the cytoplasm divides, forming two cells, each with the haploid number of chromosomes. A nuclear membrane forms around the chromosomes in each daughter cell and the chromosomes gradually elongate, forming chromatin threads. Once cytokinesis takes place, four cells have been formed as the product. These are indicated by the four cell membranes shown on cell base #3 of your manipulative. Move the chromosomes and centriole at each pole on cell base #2 into a separate cell to illustrate the haploid number of chromosomes in each gamete.

QUESTIONS

Write your answers to the following questions on a separate sheet of paper.

1. Did homologous chromosomes pair during prophase of mitosis?
2. What happens during prophase I that is different from prophase in mitosis?
3. What happens during anaphase I that is different from anaphase in mitosis?
4. How is metaphase I during meiosis different from metaphase in mitosis?
5. Compare the amount and arrangement of genetic material in each cell following telophase I of meiosis and telophase of mitosis.

6. What is the difference between prophase I and prophase II of meiosis?
7. What is the difference between metaphase II of meiosis and metaphase I of meiosis?
8. How many cells formed during meiosis and mitosis?
9. Describe the cells for meiosis and mitosis, noting whether they are haploid or diploid.
10. Name four major differences between meiosis and mitosis.
11. If the red and yellow chromosomes represent paternal chromosomes and the blue and green chromosomes represent maternal chromosomes, what are the specific genetic traits of the mother and father, as represented by the genes on their chromosomes?

PATTERNS OF INHERITANCE

Using your meiosis manipulative, you should be able to produce models of an egg cell and sperm cell. When these two cells are joined, the resulting zygote has a diploid number of chromosomes. The genetic instructions for that individual are complete and the fertilized egg begins to divide.

After demonstrating the production of the offspring by combining a male gamete (sperm) and a female gamete (egg) using the meiosis manipulative, you should be able to:

1. Describe the genotype and phenotype of the offspring.
2. Explain terms relating to genetic inheritance such as gene, dominance, recessiveness, co-dominance, chromosome, allele, locus, homologous, homozygous, heterozygous, genotype and phenotype.
3. Relate the inheritance of genetic traits to the behavior of chromosomes in meiosis.
4. Summarize the concepts of homologous chromosomes and allelic genes.
5. Distinguish between homozygous and heterozygous genotypes. Relate genotype to phenotype in terms of dominance. To do this, use the key below.

GENETIC TRAIT DECODER KEY

AA = brown hair	RR = no red hair
Aa = brown hair	Rr = no red hair
aa = blond hair	rr = red hair (overrides brown and blond hair)
BB = brown eyes	FF = rounded nose
Bb = brown eyes	Ff = rounded nose
bb = blue eyes	ff = pointed nose
TT = thick lips	EE = big ears
Tt = thick lips	Ee = medium ears
t = thin lips	ee = small ears
XX = female	XY = male

NOTE: While the genes representing the traits above may appear on one chromosome for demonstration purposes, in reality these genes are mapped on several different chromosomes.

While using the manipulatives to show patterns of inheritance, keep the following items in mind:

GENES are segments of DNA that encode the information needed to produce a particular trait.