Name: _____
Bio AP

Lab: Cell Division B: Mitosis & Meiosis
(Modified from AP Biology Investigative Labs)

BACKGROUND:

One of the characteristics of living things is the ability to replicate and pass on genetic information to the next generation. All new cells come from previously existing cells. New cells are formed by the process of cell division which involves both replication of the cells nucleus (karyokinesis) and the division of the cytoplasm (cytokinesis) to form two genetically identical daughter cells.

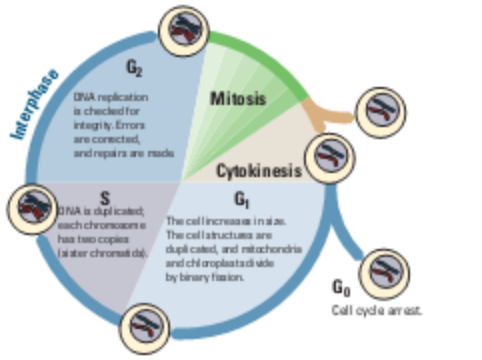
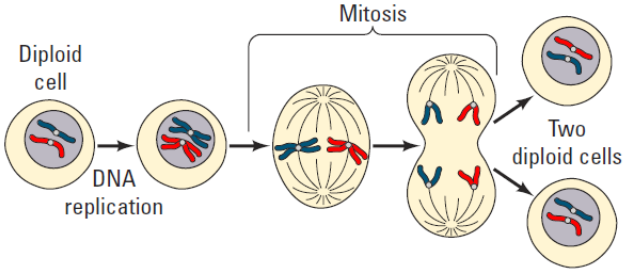


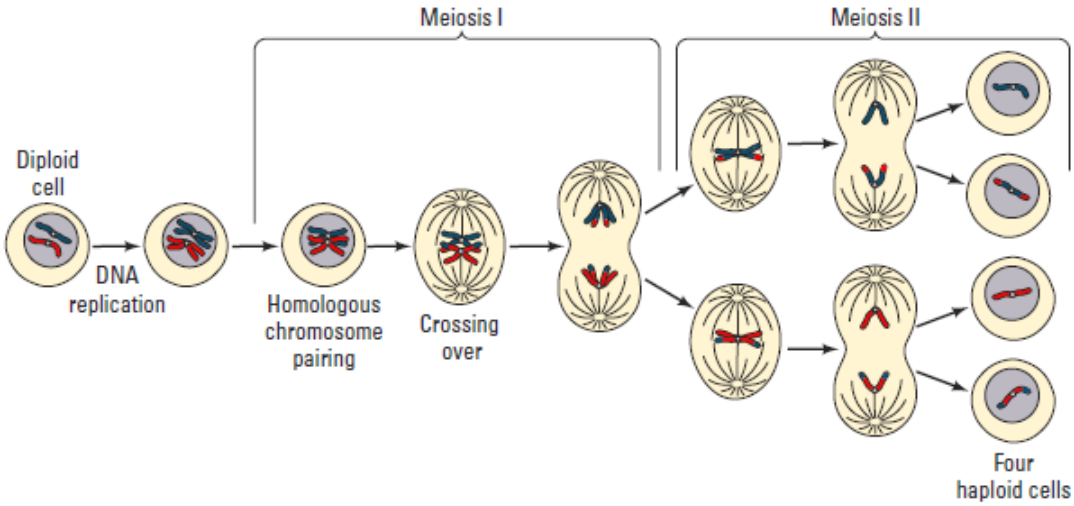
Figure 1. The Cell Cycle Showing Interphase, Mitosis, and Cytokinesis

Cell division in eukaryotes requires the cell to manage a complicated process of duplicating the nucleus, other organelles and multiple chromosomes. This process, called the cell cycle, is divided into three parts: interphase, mitosis, and cytokinesis (figure 1). In the first growth phase (G_1), the cell grows and prepares to duplicate its DNA. In the synthesis phase (S), the chromosomes are replicated. In the second growth (G_2), the cell prepares to divide.

There are two types of nuclear division: mitosis and meiosis. Mitosis typically results in new somatic (body) cells. Formation of an adult organism from a fertilized egg, asexual reproduction, regeneration, and maintenance or repair of body parts is accomplished through mitotic cell divisions. In mitosis, the duplicated chromosomes are separated into two nuclei. In most cases, mitosis is followed by cytokinesis, when the cytoplasm divides and organelles separate into daughter cells. Again, this type of cell division is asexual and is important for growth, renewal, and repair of multicellular organisms.



Meiosis resembles mitosis but serves a very different purpose. Meiosis is a cell division resulting in the halving, or reduction, of chromosome number in each cell. A diploid organism has two sets of chromosomes (2n), while a haploid organism has one set of chromosomes (n). Meiosis produces gametes (ova and sperm) in animals and spores in fungi, plants and protists. Meiosis consists of two successive nuclear divisions that produce four haploid cells. The first division (meiosis I) is the reduction division; the second division (meiosis II) separates the sister chromatids.



Three other important characteristics of meiosis are the exchange of genetic material (“crossing over”) between homologous chromosomes, the independent assortment of the chromosomes, and the separation of

alleles of the same gene. These characteristics along with random fertilization increase the genetic variability in the offspring. These mechanisms are essential to our understanding of genetics and evolution in sexually reproducing organisms.
The hallmark of sexual reproduction is the great diversity seen in the gametes and in the resulting offspring produced by fertilization. Meiosis is integral to this process because this type of cell division produces the sex cells, gametes.

LEARNING OBJECTIVES:

- To explain how DNA is transmitted to the next generation via mitosis
- To manipulate chromosome models to demonstrate the events of mitosis
- To manipulate chromosome pop beads to depict replication or duplication of a chromosome to form sister chromatids.
- To explain how DNA is transmitted to the next generation via meiosis followed by fertilization
- To manipulate chromosome models to demonstrate the events of meiosis I and II.
- To manipulate chromosome pop beads to understand the concept of homologous chromosomes
- To manipulate chromosome pop beads to understand tetrad formation, synapsis, and crossing over

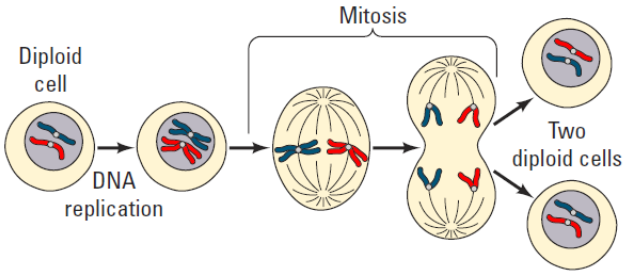
GENERAL SAFETY:
Follow your teacher's directions. Do not work in the laboratory without your teacher's supervision.

THE INVESTIGATION:
In Part 1 you will review the stages of the cell cycle and the replication of chromosomes during the S stage of Interphase. You will then simulate the M stage of the cell cycle (mitosis) using pop beads. In Part II of the investigation you will use the pop beads to simulate the stages of meiosis. You will study crossing over and recombination that occurs during meiosis, and how these processes lead to increased variation.

MATERIALS:
Pop bead meiosis simulation kit (60 beads of two different colors, 8 magnetic centromeres)

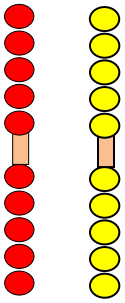
Part I: Mitosis Simulation

The diagram at the right illustrates how chromosomes move during mitosis. It is important that you understand how chromosomes duplicate, align, separate and move to new cells or daughter cells.



Procedures:
Make two strands of five red pop beads and attach each strand to a centromere.

Repeat with two strands of five yellow pop beads and attach each strand to a centromere. These represent a *homologous pair* of chromosomes.



Next, make a homologous pair of chromosomes like above, but with eight beads. You now have two pairs of homologous chromosomes, differentiated by their size.

NOTE: ALL DIAGRAMS MUST BE DONE ON ONE ENTIRE PAGE OF YOUR LAB JOURNAL. USE ONE PAGE FOR MITOSIS AND ONE PAGE FOR MEIOSIS.

- Interphase:
  Interphase, the longest stage of the cell cycle, is the preparation phase for the next mitosis and cytokinesis. During this phase, DNA exists as chromatin, with a spaghetti-like granular appearance, not as distinct chromosomes.
  The G_1 phase begins.
  What happens during this time? _____

  Before the S phase, a chromosome can be simulated by one strand of plastic beads, which is made of one double-stranded DNA molecule. If you attach two strands of the same color beads at their centromeres, you have a duplicated chromosome. This is how chromosomes appear after DNA replication during the S phase of the Cell Cycle. Each half of the duplicated chromosome is called a *sister chromatid.* It is duplicated chromosomes that enter mitosis.

  Replicate each of your chromosomes. **Draw** a diagram of a cell in the S stage of Interphase showing the replication of each chromosome. Place a circle around ONE of the replicated chromosomes. Label the sister chromatids and the centromere. (Remember –in reality chromosomes are in the form of chromatin (uncondensed) and would not be visible as distinct units).

  What is the diploid number of this cell the cell? _____
  What is the haploid number of this cell? _____

  The G_2 phase begins. What happens during this time? _____

Mitosis

- Prophase:
  During prophase the nuclear membrane will dissolve, spindle fibers will form and chromosomes will condense , centrioles migrate to opposite sides of the cell and spindle fibers begin to appear (use your imagination).
  Arrange the four chromosomes randomly in an imaginary cell on your workspace. Place the centrioles in the correct positions. **Draw** a diagram. Label the centrioles and spindle fibers, circle the replicated chromosomes.

- Metaphase:
  During metaphase chromosomes line up along the metaphase plate. The centromere of each sister chromatid are attached by spindle fibers to the centrioles at opposite poles of the cell.
  Arrange your four chromosomes along the metaphase plate, with the centrioles in the correct position **. Draw** a diagram. Label the centrioles and spindle fibers. Circle the replicated chromosomes.

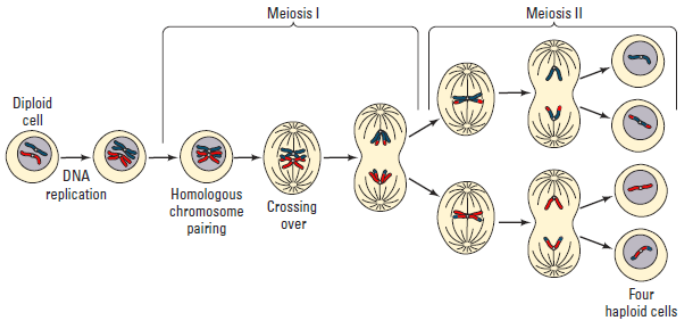
- Anaphase:
  During anaphase the chromatids of each chromosome separate at the centromere and move to opposite sides of the cell. Each chromatid is now called a chromosome. Separate the chromatids of each chromosome and move them into the correct position.
  Draw a diagram. Circle the chromosomes.

- Telophase:
  During telophase the spindle apparatus disappears, and the nuclear membrane reappears and forms two separate nuclei, one for each daughter cell. The chromosomes uncoil and become chromatin.
  What happens during Cytokinesis? _____

How do the two new cells compare to the original cell with which you began? _____
Draw a diagram showing the daughter cells. Be sure to draw the chromosomes as chromatin.

You have just simulated the process of the cell cycle, especially Mitosis and Cytokinesis, in an animal cell.

Part II: Meiosis Simulation



Two critical events occur in the life history of all sexually reproducing organisms: *meiosis* and *fertilization*. During the interphase preceding meiosis, the chromosomal material (DNA) is replicated. Then, during meiosis, the nucleus undergoes two divisions, one of which is a reduction division. By a precise mechanism, meiosis produces four daughter nuclei, each with one-half the number of chromosomes, and thus one-half as much DNA, as the parent nucleus. Whereas the parent nucleus is *diploid* (2n), each of the daughter nuclei is *haploid* (n). In diploid cells, the chromosomes are present in matched pairs called *homologous chromosomes*. Each parent contributes one member of each pair during sexual reproduction. In the reduction division of meiosis, the pairs of homologous chromosomes are separated. Haploid cells, therefore, contain only one member of each homologous pair of chromosomes.

Now, you will simulate the steps in the process using the pop-beads. The Meiosis simulation will use the two pairs of homologous chromosomes you made for the mitosis simulation.

Where and why does meiosis occur? _____

- Interphase:
  A cell entering meiosis has prepared almost exactly as a cell does before mitosis. There is an Interphase with G_1, S, and G_2 stages.
  Simulate DNA replication as you did for the mitosis simulation

Meiosis I:

- Prophase I:
  Homologous chromosomes come together and synapse along their entire length. This pairing or synapsis of homologous chromosomes represents the first big difference between mitosis and meiosis. A tetrad, consisting of four chromatids, is formed. Line up the homologous chromosomes to represent synapsis. With the chromosomes in the tetrad formation, entwine the chromosomes of the pairs and simulate the process of crossover. Crossing over can be simulated by popping the beads apart on one chromatid and doing the same with the other chromatid. Reconnect the beads to those of the other color. **Draw** a diagram. Place a box around each tetrad. Within each tetrad circle the replicated chromosomes. Label each chromatid.
  NOTE how crossing over results in recombination of genetic information.

- Metaphase I:
  The crossed-over tetrads line up along the equatorial plate. This represents a second major difference between meiosis I and mitosis. **Draw** a diagram. Place a box around each tetrad. Within each tetrad circle the replicated chromosomes. Label each chromatid.

- Anaphase I:
  The homologous chromosomes separate and are "pulled" to opposite sides of the cell. This represents a third difference between meiosis I and mitosis. **Draw** a diagram. Circle the homologous chromosomes.

- Telophase I:
  Centriole duplication takes place at the end of telophase in preparation for the next division. Formation of a nuclear envelope and division of the cytoplasm (cytokinesis) often occur at this time to produce two cells. Each of the chromosomes within the two daughter cells still consist of two sister chromatids. **Draw** a diagram. Circle the replicated chromosomes. Label each chromatid.
  Is each daughter cell diploid or haploid? _____
  Are the chromosomes single of replicated? _____
  Are the daughter cells genetically identical or genetically different? _____. Defend your answer._____

Between Meiosis I and Meiosis II, the cell undergoes INTERKINESIS or Interphase II. During this phase there is NO S stage. Why? _____

Meiosis II:
A second meiotic division is necessary to separate the chromatids of the chromosomes in the two daughter cells formed by the first division. This is what occurs in meiosis II. Meiosis II is similar to mitosis **except** that only ONE homolog from each homologous of chromosomes is present in each daughter cell undergoing meiosis II.

- Prophase II:
  During prophase the nuclear membrane will dissolve, spindle fibers will form and chromosomes will condense , centrioles migrate to opposite sides of the cell and spindle fibers begin to appear (use your imagination).
  Arrange the chromosomes randomly in the imaginary haploid daughter cells produced by the first meiotic division. Place the centrioles in the correct positions. **Draw** a diagram. Label the centrioles and spindle fibers, circle the replicated chromosomes.

- Metaphase II:
  During metaphase chromosomes line up along the metaphase plate. The centromere of each sister chromatid are attached by spindle fibers to the centrioles at opposite poles of the cell.
  Arrange your chromosomes along the metaphase plate, with the centrioles in the correct position**. Draw** a diagram. Circle the replicated chromosomes. Label the chromatids.

- Anaphase II:
  During anaphase the chromatids of each chromosome separate at the centromere and move to opposite sides of the cell. Each chromatid is now called a chromosome. Separate the chromatids of each chromosome and move them into the correct position.
  Draw a diagram. Circle the chromosomes.

- Telophase II:
  During telophase the spindle apparatus disappears, and the nuclear membrane reappears and cytokinesis takes place. The chromosomes uncoil and become chromatin.
  Draw a diagram.
  Is each daughter cell diploid or haploid? _____
  Are the chromosomes single of replicated? _____
  Are the daughter cells genetically identical if genetically different? _____. Defend your answer._____

ANALYSIS OF RESULTS:

1. Compare mitosis and meiosis with respect to the following:

	Mitosis	Meiosis
Chromosome number of parent cell (Diploid or Haploid)		
Number of DNA replications		
Number of divisions		
Number of daughter cells produced		
Chromosome number of daughter cells (Diploid or Haploid)		
Purpose		

2. It is important for you to understand not only the process of meiosis but also the vocabulary used in describing the chromosomes and the changes they undergo. Compare the following terms using both words and labeled diagrams.
    a) Chromatin and heterochromatin
    b) Chromosome and replicated (duplicated) chromosome
    c) Replicated chromosome and sister chromatids
    d) Homologous chromosomes
    e) Synapsis and tetrad formation
    f) Crossing over and independent assortment

3. How do meiosis and fertilization increase genetic diversity AND evolution? Be sure to include the concept of crossing over, independent assortment and fertilization in your answer.