Lab 8. The Modeling and Microscopic Observation of Mitosis and Meiosis in Plant and Animal Cells

Prelab Assignment

Before coming to lab, read carefully the introduction and the procedures for each part of the experiment, and then answer the prelab questions at the end of this lab handout. Hand in the prelab assignment just *before* the start of your scheduled lab period. Bring your textbook to class when you do this lab.

Goals of this Lab

After completing this lab exercise you should be able to...

- Identify and describe the stages of the cell cycle, mitosis, and meiosis, recognizing the events that occur during each stage.
- Distinguish between mitosis and cytokinesis as they take place in animal and plant cells.
- Identify the structures involved in mitosis and meiosis and describe the role each plays.
- Describe the significance of crossing over, independent assortment, and segregation in meiosis.
- Indicate the differences and similarities between mitosis and meiosis.
- Describe the importance of mitosis and meiosis in the life cycle of an organism.

Introduction

"All cells arise from preexisting cells" is one tenet of the cell theory. It is easy to understand this concept when thinking about unicellular organisms such as *Amoeba* and bacteria. Each cell divides to give rise to two entirely new individuals. But it is quite fascinating that each of us began life as *one* single cell and developed into an astonishingly complex animal. This one cell has *all* the hereditary information we'll ever need.

In ***somatic cells*** (body cells) of multicellular critters and in single-celled eukaryotic organisms, the nucleus divides by mitosis into two daughter nuclei, which have the same number of chromosomes and the same genes as the parent cell. Multicellular organisms prepare for sexual reproduction by producing ***gametes*** (egg or sperm cells) by another type of nuclear division, ***meiosis***. In meiosis, nuclei of certain cells in ovaries or testes (sporangia in plants) divide twice, but the chromosomes are duplicated only once. Meiosis results in the formation of four daughter nuclei each with half the number of chromosomes with differing ***alleles*** (alternate forms of a gene) as the parent cell. Eggs and sperm (spores in plants) eventually form from the cells produced by meiosis.

In sexually reproducing higher plants and animals, ***fertilization***, the fusion of egg and sperm nuclei, produces a single-celled ***zygote***. The zygote divides by mitosis into two cells, these two into four, and so on to produce a multicellular organism. During cell division each new cell receives a complete set of hereditary information and organelles.

The hereditary material of both eukaryotes and prokaryotes is ***DNA*** (deoxyribonucleic acid). In prokaryotes, the DNA is organized into a single ***chromosome***. Prior to cell division, the chromosome duplicates. Then the cell undergoes ***prokaryotic fission***, the spitting of the cell into two, with each new cell receiving a full complement of the genetic material. This exercise, however, will consider cell division in eukaryotic organisms only.

In eukaryotes, the process of cell division is more complex, primarily because of the more complex nature of the chromosomes. Chromosomes in eukaryotes consist of a complex of DNA and structural proteins. These proteins are involved with the folding and condensation of the DNA within the chromosomes. The nuclei in eukaryotic cells contain chromosomes with clusters of ***genes***, discrete units of hereditary information consisting of DNA that codes for a particular trait. Cell division is preceded by duplication of the chromosomes and usually involves two processes: ***mitosis*** (division of the nucleus) and ***cytokinesis*** (division of the cytoplasm). Whereas mitosis results in the production of two nuclei, both containing identical chromosomes, cytokinesis ensures that each new cell contains all the metabolic machinery (enzymes, organelles, nutrients, etc.) necessary to sustain life.

Dividing cells pass through a regular sequence of events called the ***cell cycle*** (fig.1). Notice that the majority of time is spent in interphase and that actual nuclear division, mitosis, is but a brief portion of the cycle. ***Interphase*** is divided into three parts: the ***G_1 period***, during which cytoplasmic growth occurs; the ***S period***, when DNA is duplicated; and the ***G_2 period***, when the structures involved with mitosis are synthesized.

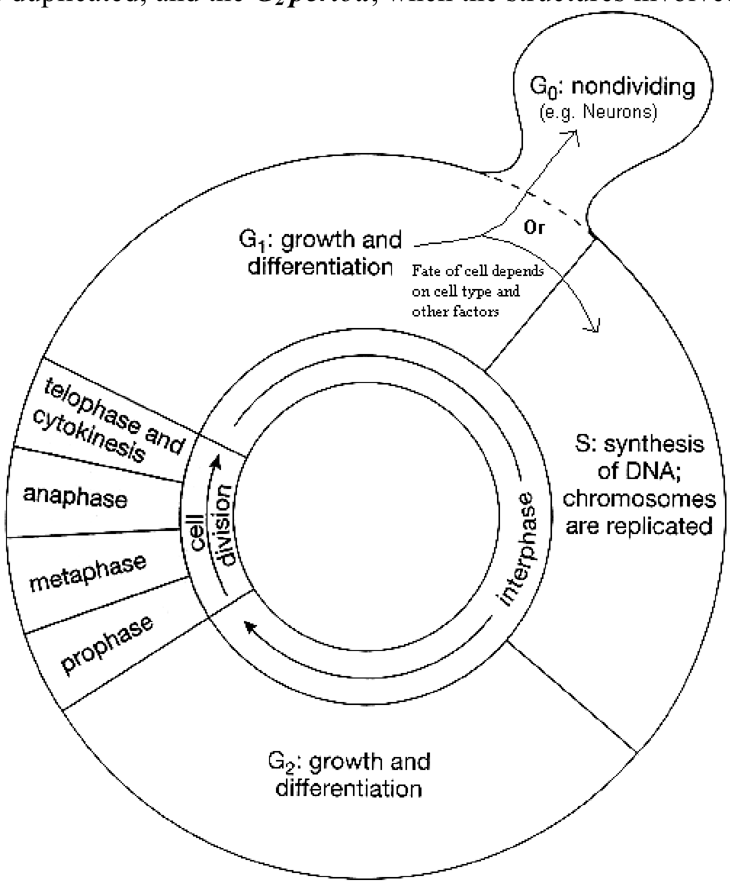


Figure 1. The cell cycle of eukaryotic cells.

Interphase is a metabolically active part of the cell cycle: new DNA is synthesized (S-phase), proteins are assembled from amino acids, carbohydrates are actively synthesized, while others are broken down to provide energy for the various cellular processes (G_1 and G_2). Meanwhile all of the normal day-to-day activities of the cell are taking place. In short interphase is a very busy time in the life of a cell.

In this lab activity you will....

- Use pop bead models of chromosomes to model the cell cycle, mitosis, and meiosis.
- Observe prepared slides of onion cells and whitefish blastula with a compound microscope to study mitosis and cytokinesis in plant and animal cells.

Part 1. Modeling the Cell Cycle and Mitosis

Important Note!! To get an overview of this laboratory activity and to use your lab time efficiently read the following procedure *before* attending lab. If you and your group members are not familiar with the procedure before coming to lab you will have great difficulty completing this exercise during the lab period.

Introduction

Within the nucleus of an organism each chromosome contains ***genes***, which are units of inheritance. Genes may exist in two or more alternate forms called ***alleles***. Chromosomes come in look-alike pairs called ***homologous chromosomes***. Homologous pairs have the same length, staining pattern, and possess the genes for the same characteristics at the same ***loci*** (location on the chromosome). *One homologue is inherited from the organism's mother, the other from the father.* Thus each homologue contains genes for the same traits. However, the homologues may or may not have the same alleles. Therefore, ***homologous chromosome are genetically different*** since although they contain the same genes, they may have different varieties (alleles) of those genes. An example will help.

Suppose the trait in question is flower color and that a flower has only two possible colors, red or white. The gene contains the information for flower color. Now there are two homologues in the nucleus (one from each parent plant), so each bears the gene for flower color. But, on one homologue, the allele might code for red flowers, while the allele on the other homologue might code for white flowers. There are two other possibilities. The alleles on both homologues might code for red flowers, or they both might be coding for white flowers. These three possibilities are mutually exclusive since *each homologue can contain only one allele of a particular gene*.

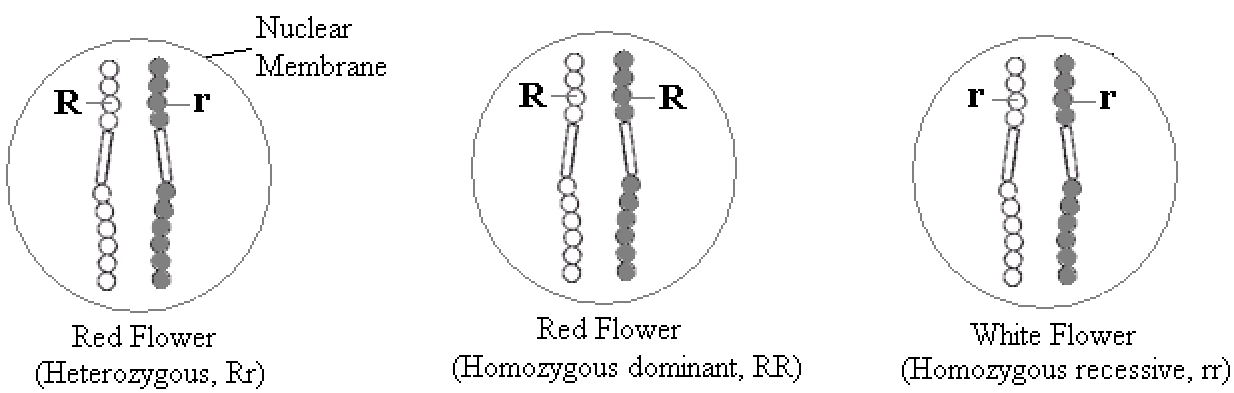


Figure 2. Nuclei with one pair of homologous chromosomes (unduplicated). The alleles are **R**, for Red flower color, and **r**, for white flower color. Since red flower color is dominant over White, the heterozygous condition, Rr, yields a red flower.

Materials

60 - Pop beads of one color
60 - Pop beads of another color
4 - Magnetic centromeres

Procedure (Work in groups of 2)

1. Use pop beads to construct ***two pairs*** of homologous chromosomes in the ***unduplicated state***: a long pair and a shorter pair. (Note: There should be a total of four chromosomes!)
   - Use about 10 beads per homologue for the first pair, and a smaller number of beads for the second homologous pair.
   - Make each member of a homologous pair a different color, but all beads within a chain should be the same color—see figure 3, below
   - Place the centromere at any position in the chromosome, but as in figure 3, below, it must be in the same position for each homologue within a homologous pair.
   - You should have enough beads and centromeres left over to duplicate each chromosome during the S-phase of interphase.

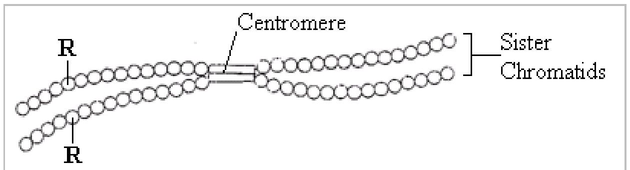
Figure 3. Models of a *homologous pair* of chromosomes (unduplicated) made from pop beads and magnets. Each bead represents a gene and each magnet a centromere.

Modeling of Interphase of the Cell Cycle

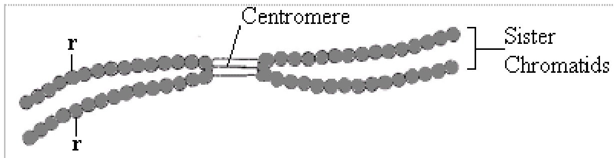
During interphase the chromosomes are in an uncoiled or uncondensed state. The DNA in the uncoiled state is very thin and tangled up like cooked spaghetti. While in the uncoiled state, the DNA and its associated protein is called ***chromatin.***

2. **Modeling G1 (Gap 1).** Pile the chromosomes on the table to represent the uncoiled mass of chromatin in G_1. Much metabolic activity occurs during G_1:
   - The mass of cytoplasm increases and continues to do so throughout interphase, proteins are synthesized, and new organelles are produced.
   - Visible in the nucleus throughout interphase are one or more ***Nucleoli*** (Singular, nucleolus: the site of ribosomal subunit synthesis)
   - Two centrioles located just outside the nucleus in animal cells and absent in most plants, duplicate during late G_1 or early S-phase. Centrioles are too small to be seen with a compound microscope.

3. **Modeling S (Synthesis) Phase.** Use the extra pop beads and centromeres to duplicate your chromosomes. DNA duplication in cells is called ***replication***.
   - Make a second strand that is *identical* to the first strand of each chromosome.
   - Use the magnets to connect the duplicated strands. A centromere in the real world is a single unit until it splits during late metaphase of mitosis. Consider your pair of magnets as a single centromere that is connecting two identical duplicated chromosomes called ***sister chromatids***. See figure 4 on the following page.



A model of a duplicated chromosome consisting of two genetically identical sister chromatids.



A model of a duplicated chromosome consisting of two genetically identical sister chromatids.

Figure 4. Models of a *homologous pair of duplicated chromosomes* for a heterozygous genotype, **Rr**. Since the two homologues are genetically *different* from each other they are represented in different colors.

4. *Modeling G2 (Gap 2).* This is pretty easy to do... Don't do anything to the chromosomes! During G_2, besides carrying out the normal cell activities, the cell is busy preparing for mitosis:
   - ***Microtubules*** (proteins responsible for separating the chromosomes during anaphase of mitosis) and various enzymes are synthesized. In prophase of mitosis microtubules begin assembling into spindle fibers. Spindle fibers are responsible for the separation of the chromatids during anaphase of mitosis.
   - As a sign that G_2 is ending and mitosis is about to start, pairs of ***centrioles*** start to move towards opposite sides of the nucleus.

Modeling Mitosis and Cytokinesis. Division of the nucleus is called mitosis, and is normally followed by cytokinesis, division of the cytoplasm. Mitosis is divided into stages: prophase, metaphase, anaphase, and telophase.

5. *Modeling Prophase.* Leave the chromosomes piled on the table to represent prophase. The chromatin is a tangled mass in this stage of mitosis. The major events/signs of prophase...
   - The ***chromatin*** condenses (i.e. shorten due to coiling around structural protein), making the duplicated chromosomes visible under a compound microscope.
   - Microtubules outside the nucleus begin to assemble into ***spindle fibers*** (not yet visible under the microscope).
   - Prophase is nearing an end as the ***nucleoli*** (inside the nucleus) and the ***nuclear envelope*** disappears.

6. <u>*Modeling Metaphase.*</u> Line up the duplicated chromosomes at the equator of your imaginary cell. The spindle fibers are responsible for pulling the highly condensed duplicated chromosomes to the middle of the cell. The major events/signs of metaphase...
   - The ***nuclear envelope*** is no longer distinctly visible under the microscope.
   - ***Duplicated chromosomes***, each consisting of two sister chromatids, line up along the equator of the cell. Individual chromatids are only visible with an electron microscope.
   - ***Spindle fibers*** extend from pole to pole and are often clearly visible with the compound microscope.
   - Microtubules are attached to the chromosomes at the ***kinetochores***, groups of proteins that form the outer faces of the centromeres. (Not seen with a compound microscope.)
   - Metaphase ends as the ***centromeres*** split.

7. <u>*Modeling Anaphase.*</u> Represent anaphase by separating the magnetic centromeres then move the chromosomes (i.e. the separated sister chromatids) toward opposite poles of your imaginary cell. Once separated, each chromatid is called a chromosome.
   - During anaphase the sister chromatids of each duplicated chromosome separate with each chromosome moving toward an opposite pole of the cell.
   - Shortening of the microtubule spindle fibers is responsible for pulling the chromosomes to the poles.
   - Anaphase ends as the chromosomes reach the poles of the cells.

8. <u>*Modeling Telophase.*</u> Represent telophase by piling the chromosomes at the poles of your imaginary cell. The cell is in telophase when the chromosomes (formerly sister chromatids) arrive at opposite poles. Major events occurring during telophase....
   - Spindle fibers disassemble and disappear from view.
   - Chromosomes uncoil and as a result become thinner and barely visible with compound microscope.
   - One or more nucleoli reappear toward the end of telophase
   - Telophase comes to an end as a nuclear envelope re-forms around each newly formed daughter nucleus.

9. <u>*Modeling Cytokinesis.*</u> Leave the two piles of chromosomes at the poles to represent cytokinesis. The end of telophase signals the end of mitosis, division of the nucleus. Mitosis is usually followed by cytokinesis, division of the cytoplasm. Cytokinesis results in the formation of two separate cells and begins during telophase.
   - Cytokinesis in Plants: Golgi body derived vesicles migrate to the equator and fuse to form a ***cell plate*** that eventually grow into a cell wall that separates the parent cell into two daughter cells, each about half the size of the original cell. No pinching is seen as in animal cells.
   - Cytokinesis in Animals: ***A cleavage furrow*** forms at the equator leading to the pinching of the parent cell into two daughter cells each about half the size of the original cell.

Part 2. Observation of the Cell Cycle in Onion Cells

Introduction

Mitosis and cytokinesis in plants occur primarily in specialized regions call *meristems*. Meristems are regions of active growth. A meristem contains cells that have the capability to divide repeatedly. Each division results in two cells. One of these, the derivative, eventually *differentiates* (becomes specialized for a particular function), and usually loses its ability to divide again. The other cell, however, remains meristematic and eventually divides again. This process summarized in figure 5, accounts for the unlimited and prolonged growth of many plant tissues.

Plants have two types of meristems:

- ***Apical meristems***, found at the tips of plant shoots and roots, are responsible for their increase in length.
- ***Lateral meristems***, located beneath the bark of woody plants, are responsible for the increase in girth.

You will observe a prepared slide of *allium* (onion) root tips and observe cells at the various stages of the cell cycle.

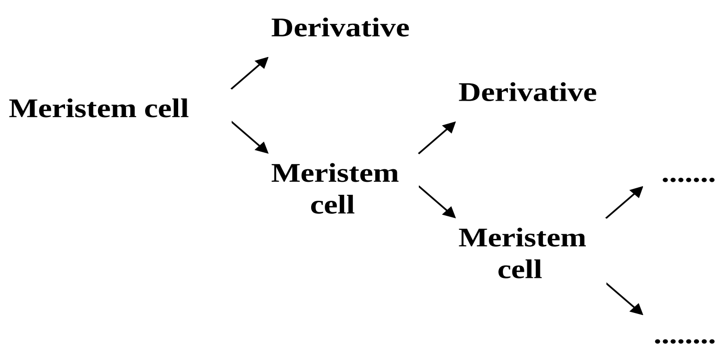


Figure 5. Cell division in plant meristems.

Materials

Prepared slide of onion (*Allium*) root tip mitosis
Compound microscope

Procedure

1. Work individually, but share the task of locating the cells to sketch in step 5.
2. Obtain a prepared of a longitudinal section of an *Allium* (onion) root tip. This slide was prepared from the terminal part of an actively growing root. It was "fixed" by chemicals to preserve the cellular structure and stained with dyes with high affinity for the structures involved with mitosis.

3. To get an overall impression of root morphology, observe with the low-power objective (10x). Note the root cap, and zones of cell division and differentiation. The root cap protects the delicate root tip as it is pushed through the soil as the cells divide in the zone of cell division.
   - The cells produced by cell division then enter the G1 phase of the life cycle and elongate and differentiate into different types of cells: Epidermal cells with root hairs absorb water and minerals from the soil; Cells involved with the transport water and minerals (Xylem tissue); Cells involved with the transport sugars (Phloem tissue).
4. Focus on the zone of cell division, apical meristem, and the region just behind the root cap. Now observe with the high power objective, 40x.
5. Survey the zone of cell division at high power and locate the following stages of the cell cycle: Interphase, prophase, metaphase, and telophase/cytokinesis. In the appropriate spaces on the report sheet use a sharp pencil to make a sketch of a representative cell in each phase.
   - **Label clearly**: Cell wall, cytoplasm, nucleus, nuclear envelope, nucleolus, chromatin, chromosomes, sister chromatids, spindle fibers (collectively called mitotic spindle), and cell plate.

> !!! **Use the descriptions of interphase and mitosis in Part 1 and illustrations of mitosis in your textbook to assist you with step 5!**

Part 3. Observation of the Cell Cycle in Whitefish Blastula

Introduction

Blastulas are a convenient source of animal cells that are actively undergoing cell division. A ***blastula*** is a very young embryo and consists of solid ball of cells produced from the many divisions of a zygote. Blastula cells are clearly visible, have a short interphase, and divide frequently. You will observe a prepared slide containing cross sections of several whitefish blastulas. By scanning these blastulas you should be able to locate cells at the various stages of mitosis and cytokinesis.

Whereas plants have meristems where cell division occurs continuously, animals do not have such regions to which mitosis and cytokinesis are limited. Cell division occurs continually throughout many tissues of an animal's body, replacing worn-out or damaged cells.

Materials

Prepared slide of whitefish blastula mitosis
Compound microscope

Procedure

1. Work individually, but share the task of locating the cells to observe and sketch in steps 3 and 4.
2. Examine a slide of whitefish blastula with the low-power objective. The slide has several blastulas. Select one to observe, focus, and then switch to high power for detailed observation.

> !!! **Use the descriptions of interphase and mitosis in Part 1 and illustrations of mitosis in your textbook to assist you with step 3!**

3. Survey one or more blastula at high power to locate cells at the following stages of the cell cycle: Interphase, prophase, metaphase, and telophase/cytokinesis.
4. In the appropriate spaces on the report sheet use a sharp pencil to make a sketch of a representative whitefish blastula cell in ***metaphase***, and another in ***telophase/cytokinesis.***
    - **Label clearly:** Plasma membrane, cytoplasm, daughter nuclei, nuclear envelope, chromatin, chromosomes, mitotic spindle, ***asters*** (an array of microtubules that surround each centriole pair at the poles of the spindle), ***Centrioles*** (small dots, sometimes too small to be seen, at the poles around which the microtubules of the spindle and the asters appear to radiate), and cleavage furrow.

Part 4. Modeling Meiosis

Introduction

Like mitosis, meiosis is a process of nuclear division. During *mitosis*, the number of chromosomes within the daughter nuclei remains the same as was present in the parental nucleus. In *meiosis*, however, the number of chromosomes of the daughter cells is one-half that of the parental nucleus. Moreover, while mitosis is completed after a singe nuclear division to produce ***somatic cells*** (body cells), meiosis involves two divisions (called ***meiosis I*** and ***meiosis II***) to produce ***gametes*** (reproductive cells: sperm and eggs, and spores in plants).

Recall from part I that in the somatic cells of most eukaryotes chromosomes exist in pairs called homologues. ***Homologous chromosomes*** are two chromosomes, one inherited from each parent, that are physically similar to each other and contain genetic information for the same traits. A cell is ***diploid (2n)*** when *both* homologues of each homologous pair are present in the *same* nucleus. A cell is ***monoploid (n)*** (a.k.a. ***haploid***) when only *one* homologue of each homologous pair is present. If the parental nucleus contains the diploid number of chromosomes before meiosis, all four daughter nuclei will contain the monoploid (haploid) number at the completion of meiosis. In humans, for example, each somatic cell contains 23 homologous *pairs* of chromosomes (i.e. 46 chromosomes); hence the diploid or 2n number of chromosomes for humans is 46. On the other hand, human gametes contain only 23 chromosomes; thus the monoploid or n number of chromosomes in humans is 23.

The reduction in the number of chromosomes is the basis of sexual reproduction. Figure 6 illustrates the life cycle of a higher animal. Note that meiosis produces monoploid (n) gametes, egg and sperm, and that fertilization restores the diploid chromosome number as the two monoploid gamete nuclei fuse to form a zygote. The diploid number of chromosomes is conserved as the zygote divides repeatedly by mitosis to eventually form the new organism

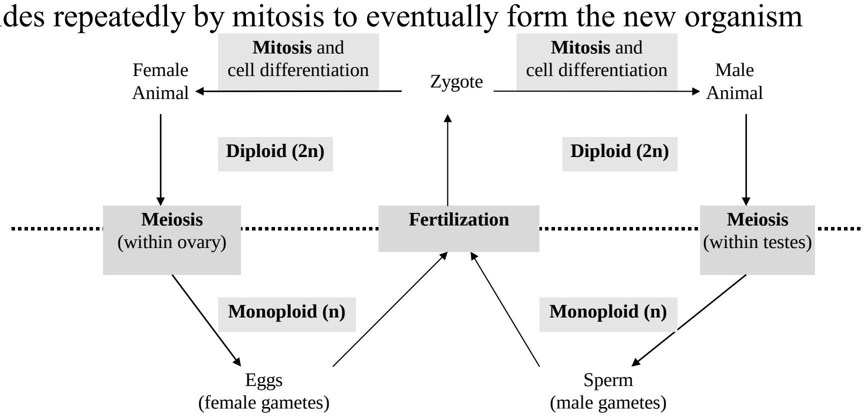


Figure 6. The life cycle of a sexually reproducing animal.

Materials

60 - Pop beads of one color
60 - Pop beads of another color
8 - Magnetic centromeres
White tape

Procedure (Work in groups of 2)

1. As in step 1 of modeling mitosis, use pop beads to make ***two pairs*** of homologous chromosomes: a long pair and a shorter pair.
   - Use about 10 beads per homologue for the first pair, and a smaller number of beads for the second homologous pair.
   - Make each chain of a pair a different color, but all beads within a chain should be the same color.
   - Place the centromere at any position in the chromosome, but it must be in the same position for each homologue within a homologous pair.

!!!	**Complete the table under part 4 of the report sheet as you perform the following procedure.**

2. *Modeling G1 (Gap 1).* Pile the chromosomes on the table to represent the uncoiled mass of chromatin in G_1. Cell activities are similar to those in G_1 prior to mitosis. See part 1 for details.
3. *Modeling S (Synthesis) Phase.* Use the extra pop beads and centromeres to duplicate your chromosomes. The S-phase prior to the commencement of meiosis is similar to that prior to the start of mitosis.
4. *Modeling G2 (Gap 2).* Leave the models piled up on the table. Events are similar to those in G_2 prior to mitosis.

Modeling Meiosis I.

5. *Prophase I.* The chromatin is a tangled mass in this stage of mitosis. The events of prophase I are similar to those in prophase of mitosis, but with one very important exception, the formation of tetrads and the resulting process of crossing over:
   - In early ***prophase I*** homologous chromosomes pair up their partners in a process known as ***synapsis.*** This complex of two homologous chromosomes is called a ***tetrad*** (since there is a total of four chromatids, two from each homologue). In a process known as ***crossing over*** non-sister chromatids within each tetrad exchanges genetic information. In crossover, a segment form one chromatid will break and exchange with the exact same segment of on a *nonsister* chromatid in the tetrad. Crossing over results in new combinations of alleles along a chromatid, thus leading to great genetic variation in the offspring. Crossover does not create new genes, only new combinations of genes--sort of like shuffling a deck of cards. The site where crossover occurs is called a ***chiasma*** (plural, ***chiasmata***).

6. *Modeling Prophase I.* Leave the chromosomes piled on the table to represent prophase, then label the chromatids of one of the tetrads and model crossing over as outlined below.
   a. **Labeling the alleles for tongue rolling.** Let the letters"R" and "r" represent alleles or alternate forms of the gene that controls the ability of humans to roll their tongue.
      - Using small pieces of white tape label one bead on each chromatid of one chromosome "R" for tongue roller (Recall that each bead represents a gene). See figure 4.
      - Label the beads in the same position of the two chromatids of the other member of the homologous pair "r" for non-tongue roller.

   b. **Labeling the alleles for skin pigmentation.** Let's assume that the genes for tongue rolling and skin pigmentation are *linked* (i.e. they are located on the same chromosome).
      - On each chromatid with the "R" allele, label another bead "N" for normal skin color.
      - On the other member of the homologous pair of chromosomes at the same gene locus (i.e. location), label the gene "n" for albino.
      - The result should be one duplicated chromosome with a genotype (genetic make up) of "RN" and the other duplicated homologue, "rn", as shown in figure 7 below.

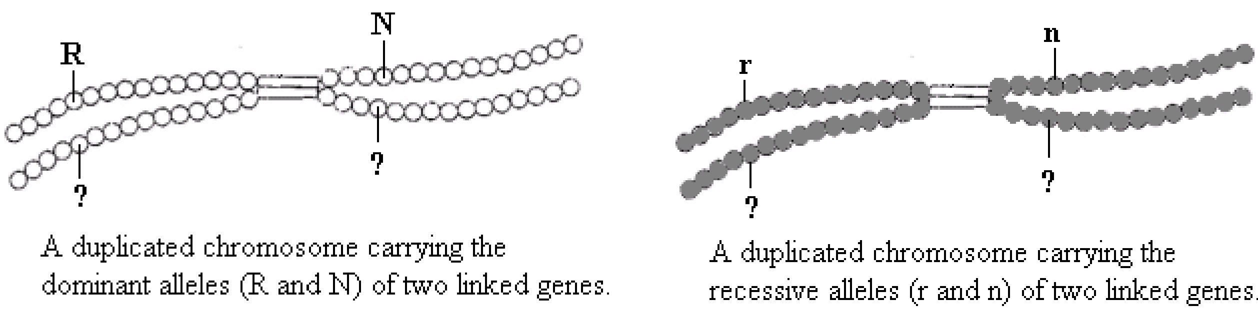


Figure 7. Models of a *homologous pair of duplicated chromosomes* for a heterozygous genotype, RrNn, where the genes R and N are linked (i.e. found on the *same* chromosome). *What are the allele symbols for the unlabeled chromatids*?

c. **Modeling Crossing over.** Slide the two labeled homologues together and twist the chromatids about each other to simulate ***synapsis*** as illustrated in figure 8, below. Simulate crossing over by exchanging identical segments between non-sister chromatids of the tetrad. Have crossover take place somewhere between the loci for tongue rolling and skin pigmentation. Remember that crossover only occurs between *non-sister* chromatids.
   - What are the combinations of alleles present on chromatids formed as the result of a crossover between homologues "RN" and "rn" during prophase I? Record your response in the appropriate space on the report sheet (i.e. Answer question 10.).
   - Confirm your results with other groups and/or your instructor.

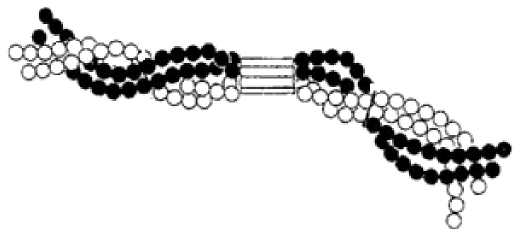


Figure 8. A model of a homologous pair of chromosomes (a "Tetrad") undergoing a very warm embrace (***synapsis***!) during prophase I.

!!!	**Having difficulties visualizing and understanding the significance of prophase I? Consult other groups and/or your instructor for help.**

6. *Modeling Metaphase I.* Move the two tetrads to the equator of your imaginary cell. The tetrads begin moving to the equator in late prophase I.
   - During metaphase I the homologous pairs remain paired as tetrads midway between the poles. In contrast, during metaphase of *mitosis*, the duplicated chromosomes line up single file at the equator.
7. *Modeling Anaphase I.* Represent anaphase by separating each duplicated chromosome from its homologue, and move the homologues to opposite poles your imaginary cell.
   - During anaphase I, the *homologous pairs move to opposite poles*. Sister chromatids of each duplicated chromosome remain connected. Centromeres do not split until anaphase of meiosis II.
   - In the real world, duplicated chromosomes are held together by one centromere. In our model of duplicated chromosomes, the two magnets represent *one* centromere holding together two sister chromatids

Having difficulties counting the number of chromosomes at each stage?
Number of chromosomes = Number of centromeres
In our model, the two magnets in a *duplicated* chromosome represent one centromere.

8. *Modeling Telophase I and Cytokinesis.* Represent telophase I by placing the chromosomes at the poles of your imaginary cell. There should be one long and one short chromosome at each pole. Telophase is followed by cytokinesis resulting in the formation of two cells. How many chromosomes are present in each cell? Are the resulting cells diploid or haploid? Record your responses in the table of the report sheet.

9. ***Meiotic Interphase.*** After meiosis I is complete, the daughter cells enter interphase, however, there's no S-phase, hence chromosomes remain as they were at the end of meiosis I and no new DNA synthesis occurs.

Modeling Meiosis II.

Meiosis II is very similar to mitosis:

- During Prophase II the chromosomes condense and appear as a tangled mass in the cell. By late prophase the nuclear membrane and nucleoli disappear in each cell. Synapsis and crossover cannot occur since there is only one homologue of each pair present... Recall that the homologues separated during anaphase I.
- During metaphase II the still *duplicated chromosomes line up at the equator* just as they do in metaphase of mitosis.
- In anaphase II the *sister chromatids separate* just as they do in anaphase of mitosis.
- Nuclear membranes reform during telophase II and a total of four cells are the result after cytokinesis is finished.

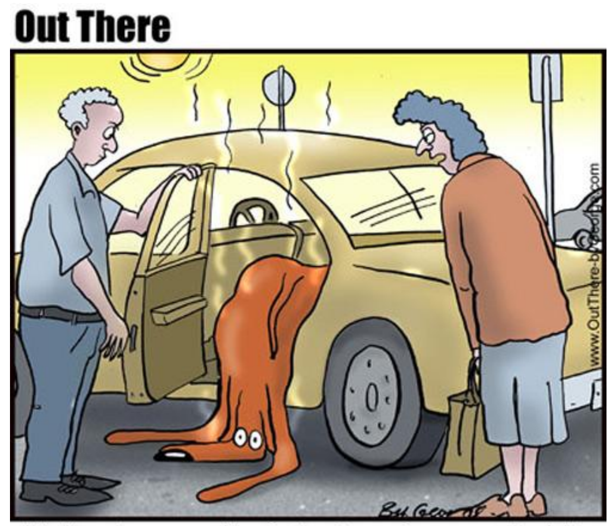
10. ***Modeling Prophase II.*** Leave the chromosomes piled on the table to represent prophase. The chromatin is a tangled mass in this stage of mitosis.

11. ***Modeling Metaphase II.*** Line up the *duplicated chromosomes at the equator* of your imaginary cell.

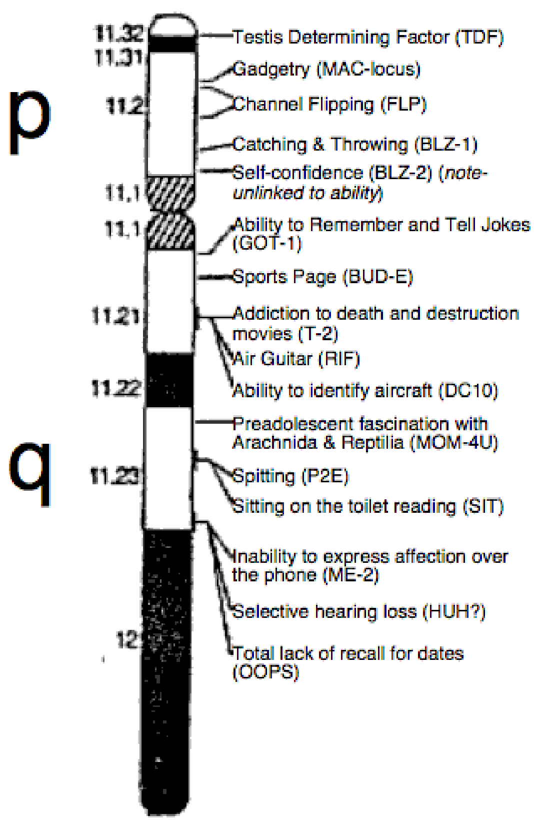
12. ***Modeling Anaphase II.*** Represent anaphase by separating the magnetic centromeres then move the chromosomes (i.e. the *separated sister chromatids*) toward opposite poles of your imaginary cell.

13. ***Modeling Telophase II and Cytokinesis II.***
    - Represent telophase by piling the chromosomes at the poles of your imaginary cell. Telophase comes to an end as a nuclear envelope re-forms around each newly formed daughter nucleus.
    - Cytokinesis II begins during telophase and results in the formation of four separate cells from the two cells that entered meiosis II. Leave the two piles of chromosomes at the poles to represent cytokinesis.

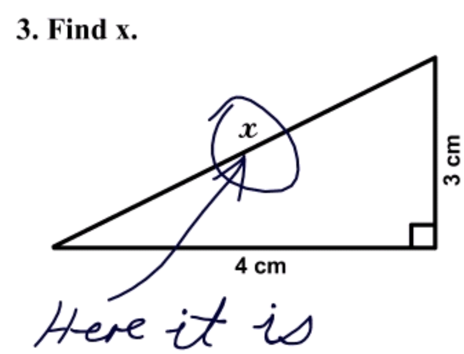
"Curse me all you want Barry… but I told you ten minutes ago we were getting close to the edge of the map."



"Well knock me over with a feather Doug…for once you're right, twenty minutes in the hot car was enough to melt the dog!"



A partial genetic map of chromosome number 11



A student's response to a math test involving the Pythagorean theorem.

Lab 8 Report Sheet
Mitosis and Meiosis
Biol 211

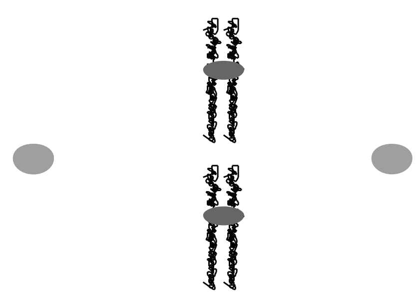
Name ______________________________________
Group Number _______ **Date** ________________

Part 1. Modeling the Cell Cycle and Mitosis in Animal Cells

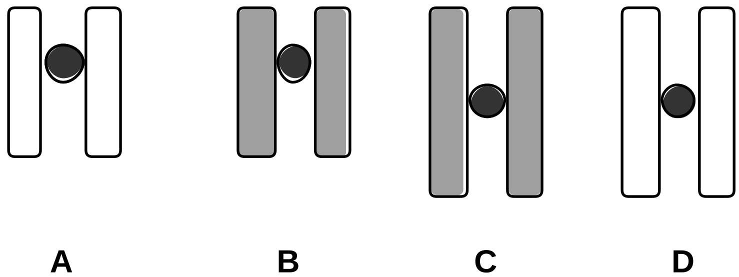
1. Complete the table below as you model the cell cycle with the pop bead models.

Phase of Cell Cycle	Number of Homologous Pairs per Cell	Number of Chromosomes per Cell	No. of Chromatids per Chromosome
G_1			one
G_2			
Prophase			
Metaphase			
Anaphase			
Telophase			
At End of Cytokinesis			

2. Below is a diagram of an animal cell at metaphase of mitosis. Draw the mitotic spindle and centrioles, and then Label each of the following in the figure: Chromosome*, sister chromatids, spindle fibers, aster, centrioles, and centromere.*



Questions 3 -7 pertain to the following sketches of duplicated chromosomes.



3. Which chromosomes above represent homologous pairs? ____________________

4. How do the chromatids in chromosome A compare genetically? (*circle your choice*)

   a.) genetically the same b.) genetically different

5. How do the chromatids of chromosomes "A" and "B" compare genetically? (*circle your choice*)

   a.) genetically the same b.) genetically different

6. How do the chromatids of chromosomes "A" and "D" compare genetically? (*circle your choice*)

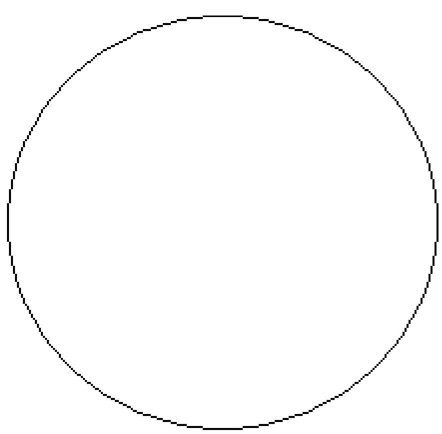
   a.) genetically the same b.) genetically different

7. If no other chromosomes exist in a cell but the ones above, what is the........

   a. diploid number (2n) of the cell? ___________

   b. monoploid number (n) of the cell? ___________

Part 2. Observation of the Cell Cycle in Onion Cells



Interphase: *Allium* as viewed at ________x

Prophase: *Allium* as viewed at ________x

Metaphase: *Allium* as viewed at ________x

Anaphase: *Allium* as viewed at ________x

Telophase and Cytokinesis:
***Allium* as viewed at ________x**

Part 3. Observation of the Cell Cycle in Whitefish Blastula

Metaphase: Whitefish Blastula
as viewed at ________x

Telophase and Cytokinesis:
Whitefish Blastula as viewed at ________x

8. List some of the major differences that you observed between plants and animal mitosis.

	Plant Mitosis	Animal Mitosis
Cytokinesis		
Centrioles		
Asters		

Part 4 Modeling Meiosis

9. Complete the table below as you model meiosis with pop bead models of ***two pair*** of homologous chromosomes.

Phase of the Cell Cycle	Number of Chromosomes per Cell	Number of Chromatids per Chromosome	Number of Homologous Pairs per Cell	Diploid, 2n, or Haploid, n ?
G_1		**one**		
G_2				
Prophase I				
Metaphase I				
Anaphase I				
Telophase I (after nuclear envelopes reform)				
At End of Cytokinesis I				
Prophase II				
Metaphase II				
Anaphase II				
Telophase II (after nuclear envelopes reform)				
At End of Cytokinesis II				

10. What are the combinations of alleles present on chromatids formed as the result of a crossover between homologues “RN” and “rn” during prophase I?

    Genotypes of the gametes due to crossover: ____________________________________

Application Questions

11. Use your knowledge of mitosis and a bit of common sense/logic to explain how each of the following help to facilitate the process of mitosis:
    a. Condensation of the chromatin:

    b. Disappearance of the nucleoli and nuclear envelope:

    c. Attachment of the spindle fibers to the centromeres:

12. Crossover occurs between *nonsister* chromatids of homologous pairs. But suppose crossover occurred between sister chromatids. Would the occurrence of crossover between the sister chromatids of a duplicated chromosome during prophase I of meiosis result in increased genetic variation? ***Yes*** or ***No*** Circle your and <u>*explain why or why not*</u>.

13. Earthworms, *Lumbricus terrestis*, have 18 pairs of chromosomes in each somatic cell.

    a. What is the 2n (diploid) number for earthworms? ___________

    b. What is the n (monoploid) number for this species? ___________

14. If one sister chromatid of a chromosome has the allele *D*, what allele will the other sister chromatid have? _____________

15. a. If two alleles on one sister homologous chromosome are *A* and *B*, and the alleles on the other homologue are *a* and *b*, how many different genetic types of gametes would be produced *without* the occurrence of crossover? ________________

    b. List the genotypes for all possible gametes if crossover does *not* occur. ________________

    c. If crossover were to occur, how many different genetic types of gametes could be produced? _________ List them: ____

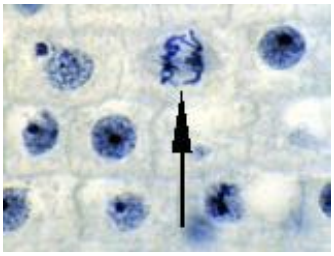
16. ***Colchicine*** is an alkaloid from the autumn crocus that prevents microtubule proteins from assembling into spindle fibers. If colchicine were added to a culture of rapidly dividing cells and then viewed with a microscope several hours later, what phase(s) of mitosis would you expect the cells to be in? *Explain*.

17. ***Taxol***, an anti-cancer drug from the bark of the Pacific yew tree, has the opposite action of colchicine. Taxol stabilizes microtubules and thus prevents the breakdown of spindle fibers. Explain how taxol acts to kill rapidly dividing cells such as cancerous tissue.

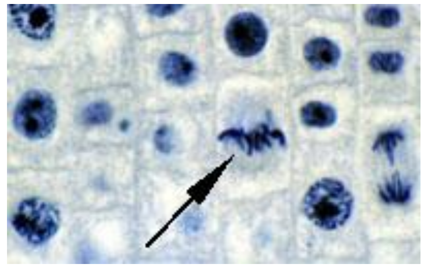
18. Compare the major differences between processes of mitosis and meiosis by completing the table below.

	Mitosis	**Meiosis**
Prophase Does synapsis and X-over occur? (circle your choice)	Yes *or* No ?	Prophase 1: Yes *or* No ? Prophase 2: Yes *or* No ?
Metaphase How do the chromosomes align in the middle of the cell?		Metaphase 1: Metaphase 2:
Anaphase What separates from each other and is pulled to the poles of the cell?		Anaphase 1: Anaphase 2:
Phase when sister chromatids separate		
Number of divisions		
Number of daughter cells		
How do the number of chromosomes in the daughter cells compare to their diploid parent cell?	The same (diploid 2n) ***or*** Different (haploid, n) ?	End of meiosis 1: Diploid, 2n *or* haploid, n? End of meiosis 1: Diploid, 2n *or* haploid, n?
Genetic similarity of daughter cells	The same ***or*** Different?	The same ***or*** Different?

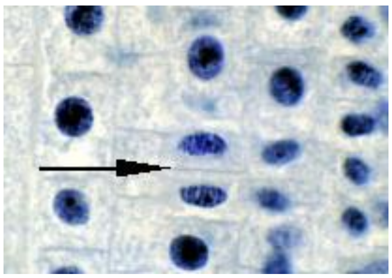
19. Identify each stage in the high-power photomicrographs of onion root tip mitosis.



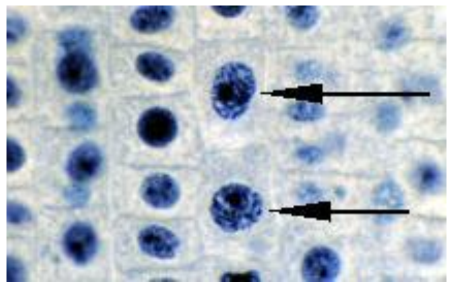
a. ______________________________



b. ______________________________

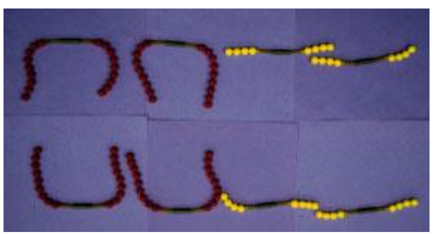


c. ______________________________



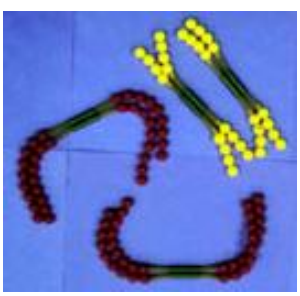
d. ______________________________

20. Identify each stage of mitosis that is modeled by beads in the images below.

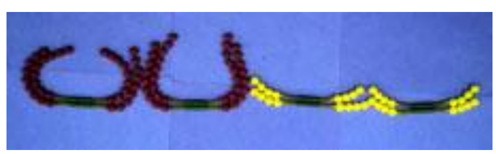


a. ______________________________

b. ______________________________



c. ______________________________



d. ______________________________

Lab 8. Prelab Questions
Mitosis and Meiosis
Biol 211

Name ______________________________________
Group Number ________ **Date** _____________

Note: Do the prelab reading at the beginning of this lab handout *before* attempting to answer the questions that follow! Hand in this assignment just *before* the start of your scheduled lab period.

1. Use your knowledge of the cell cycle and mitosis to determine during which phase or of the cell cycle each of the following events take place. Select your responses form the following: ***G_1 phase***, ***S phase***, ***G_2 phase***, ***interphase***, ***prophase***, ***metaphase***, ***anaphase***, ***telophase and cytokinesis***.
   a. Chromosomes replicate:
   b. Chromosomes uncoil and become less visible under a compound microscope:
   c. Microtubules are synthesized:
   d. Cells grow:
   e. Cells carryout their ordinary day to day activities:
   f. Cytoplasm divides into two cells:
   g. Sister Chromatids separate:
   h. Duplicated chromosomes line up in the middle of the cell:
   i. Chromatin condenses:
   j. Nuclear membrane disappears:
   k. Nucleoli disappear:
   l. Spindle fibers first become visible under a compound microscope:
   m. Chromosomes begin to be visible under a compound microscope:
   n. Centromeres split:
   o. Microtubules (spindle fibers) attach to centromeres:
   p. Microtubules assemble into spindle fibers:
   q. Spindle disorganizes as chromosomes reach the poles of the cell:
   r. Nuclear envelope re-forms:
   s. Sister chromatids are produced:

2. Suppose you are trying to help a fellow budding biologist find with a microscope representative cells going through the various stages of the life cycle of a cell. What should they look for when trying to find cells going through the following phases?

   Interphase:

   Prophase:

   Metaphase:

   Anaphase:

   Telophase:

   Cytokinesis in plants:

   Cytokinesis in animals:

3. Is it possible to differentiate under a *compound light microscope* cells passing through the following stages of interphase: G1, S, and G_2? *Explain.*

4. Why is ***interphase*** not considered one of the stages of mitosis?

5. What would be the consequence(s) in future generations if ***mitosis*** produced the gametes instead of ***meiosis***?

6. If both homologous chromosomes of each pair are present in the nucleus of the cell, the nucleus is ____ (compete the sentence)

7. The somatic cells of chimpanzees have 48 chromosomes.

	Answers
a. The "2n" number of chromosomes in chimps is	a. __________
b. The monoploid number of chromosomes in chimps is	b. __________
c. The haploid number of chromosomes in chimps is	c. __________
d. The "n" number of chromosomes in chimps is	d. __________
e. The diploid number of chromosomes in chimps is	e. __________