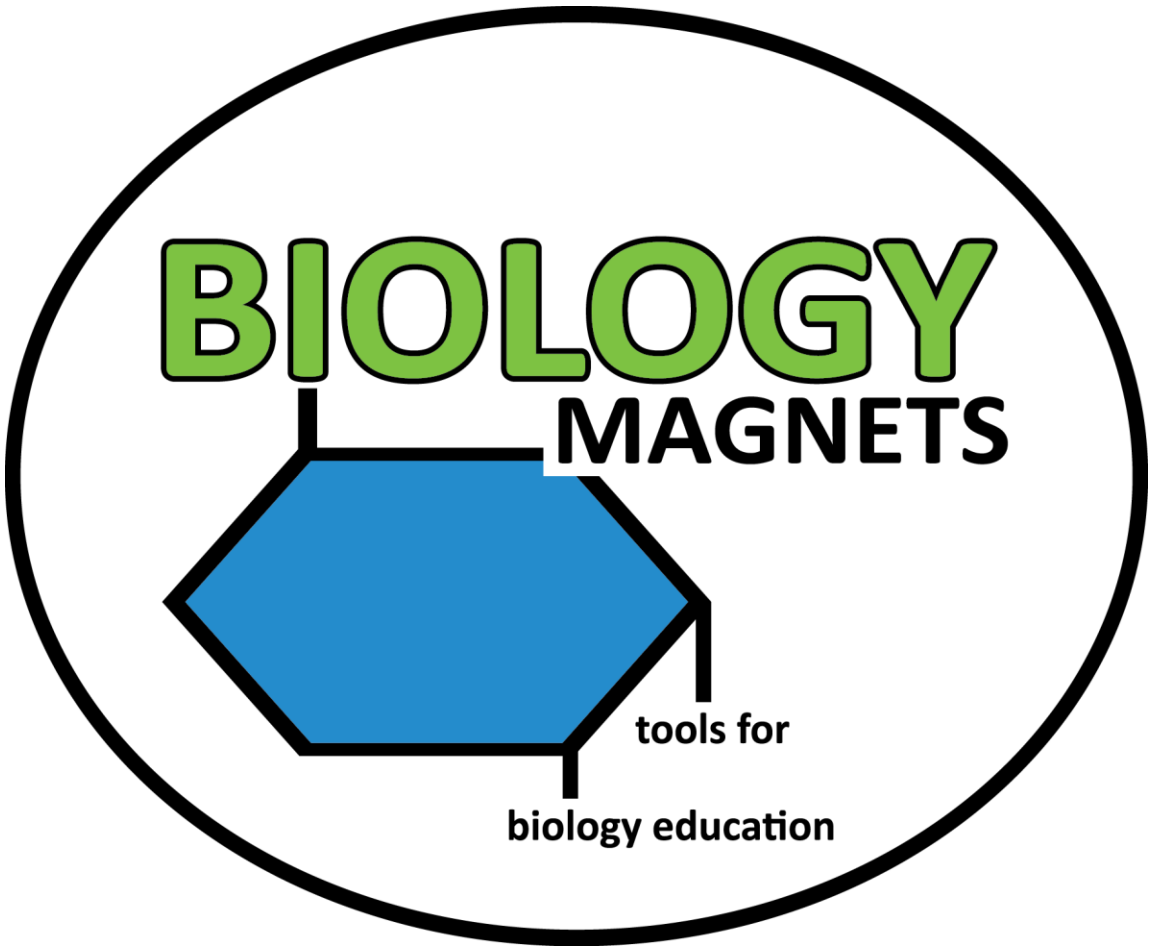
Biology Magnets Module 4: Chromosomes - Teacher and Student Guides



Teacher Information

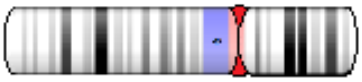
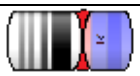
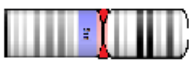
This module uses magnets designed for teacher and student interaction to guide learning the various classes of organic molecules. Contained in this guide are four different lesson ideas that can last from 10 minutes each to an entire class period, depending upon teacher preference. Each lesson has both teacher-centered and student-centered activities. The student-centered activities are most effective if students are in small groups. It may be necessary to have multiple magnet sets for large classes. A student handout is provided which can be printed out and given to each student group to help guide their progress as they work with the magnets. If budget or white board space is limited, groups can alternate between using a set of magnets and doing other activities. Teachers can refer to the videos posted at the Biology Magnet web site at Biology Magnets.com for guided teaching instructions.

Magnet Care and Maintenance

Biology magnets are made to last for years. Periodically magnets will fall off or are knocked off the plastic. A piece of magnetic tape is included with each module, which should be able to replace around 10-12 magnets if necessary. Simply cut a new magnet and peel off the back to replace. Magnetic tape can be purchased from a hobby store to replace magnets lost over time. Laminate may peel off, especially on small pieces. Transparent tape can be used as a replacement or to re-attach laminate that comes loose by curling the tape over the back of the magnet. The machines used to cut Biology Magnets are not always perfectly accurate. Sometimes a bit of white or black outline on the edges occurs or a cut might be slightly off center. Use scissors to remove extra outline that is unnecessary if desired. Store magnets in the clasp envelopes in which they arrived for easy organization.

Copyright Information – Module 4 - Chromosomes

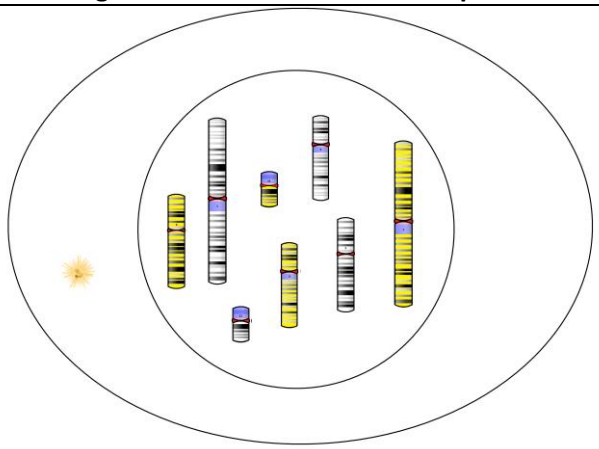
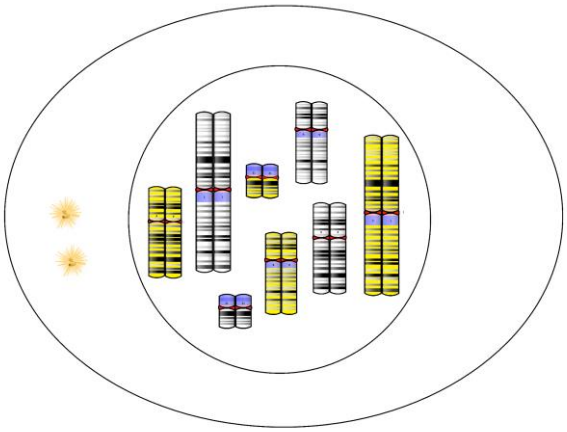
Biology Magnets Module 4 Materials List

Magnet Name	Quantity	Picture
Chromosome 1 White	2	
Chromosome 9 White	2	
Chromosome 21 White	2	
X Chromosome White	2	
Y Chromosome White	2	
Chromosome 1 Yellow	2	
Chromosome 9 Yellow	2	
Chromosome 21 Yellow	2	
X Chromosome Yellow	2	
Y Chromosome Yellow	2	
Chromosome 1M White Long Piece	1	
Chromosome 1M White Short Piece	1	
Chromosome 9M White Long Piece	1	
Chromosome 9M White Short Piece	1	

Chromosome 1M Yellow Long Piece	1	
Chromosome 1M Yellow Short Piece	1	
Chromosome 9M Yellow Long Piece	1	
Chromosome 9M Yellow Short Piece	1	
Centrosome	4	
3” Magnetic Tape Strip	1	
Total Quantity	**33**	

Lesson 4A – The Cell Cycle and Mitosis (15-70 minutes)

Teacher Centered Activity (15-30 minutes): This lesson utilizes the Biology Magnets to show the process of the cell cycle and mitosis. Start by making a large oval with a marker on the board that will represent the cell membrane, and a smaller oval in the center of the larger oval to represent the nuclear membrane. Place the white and yellow chromosome magnets into the nuclear membrane, and a centrosome in the cytoplasm. This represents the cell during G1 of interphase. These cells are diploid, with two sets of chromosomes (one yellow set and one white) (**Figure 4.A.1**). Introduce the second copies of the chromosomes to show the duplication that happens during S phase of interphase. Remind students that the chromosomes are actually uncoiled chromatin at this time, but the chromatin cannot be accurately represented with the magnets. Also, place another copy of the centrosome in the cytoplasm (**Figure 4.A.2**).

Figure 4.A.1 – Cell in G1 of Interphase	Figure 4.A.2 – Cell in S phase of Interphase
	

Mitosis: To start prophase, move one of the centrosomes to the opposite side of the cell and draw some spindle fibers protruding from the centrosome toward the chromosomes. Erase the nuclear membrane. Move some of the chromosomes so they attach to spindle fibers. It will be too messy to draw all of the chromosomes attaching to spindle fibers (**Figure 4.A.3**). Move the chromosomes to the center of the cell at the metaphase plate to represent metaphase (**Figure 4.A.4**). Break the sister chromatids apart at the centromere to show anaphase and move the daughter chromosomes toward opposite sides of the cell (**Figure 4.A.5**). For telophase, erase the spindle fibers and move the chromosomes to opposite ends of the cell. Draw a new nuclear membrane around the chromosomes. Draw a cleavage furrow and a division representing cytokinesis separating the cell membrane to make two new diploid cells (**Figure 4.6**).

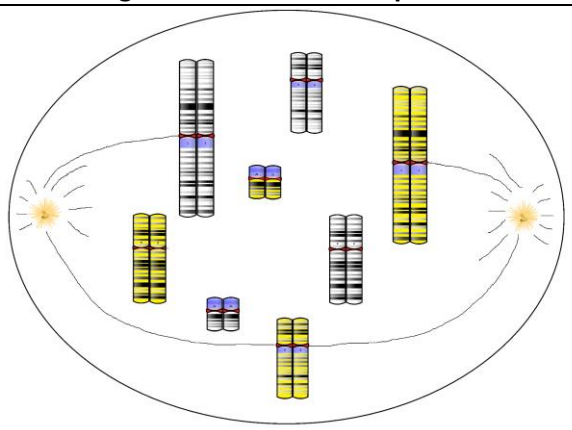
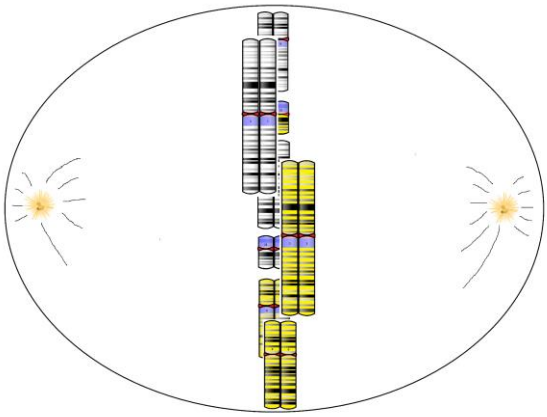
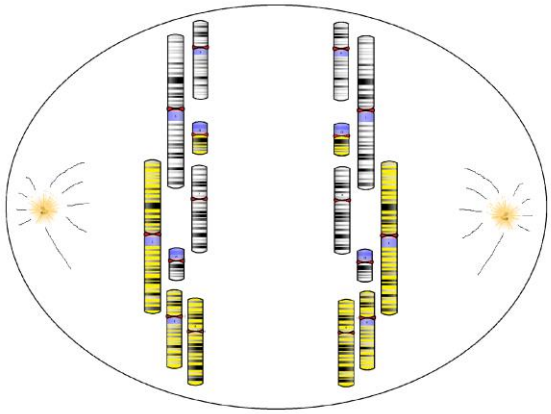
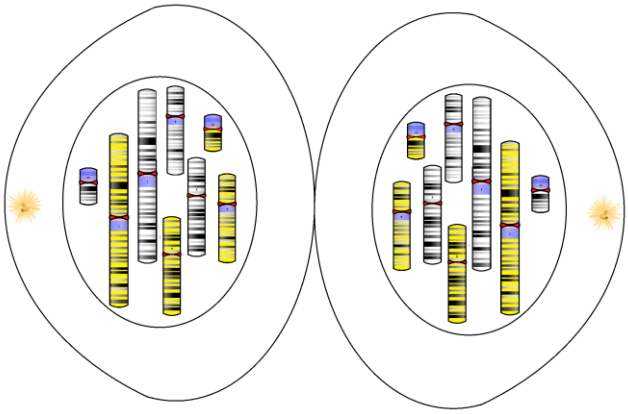
Figure 4.A.3 – Cell in Prophase	Figure 4.A.4 – Cell in Metaphase
	

Figure 4.A.5 – Cell in Anaphase	Figure 4.A.6 – Cell in Telophase and Cytokinesis
	

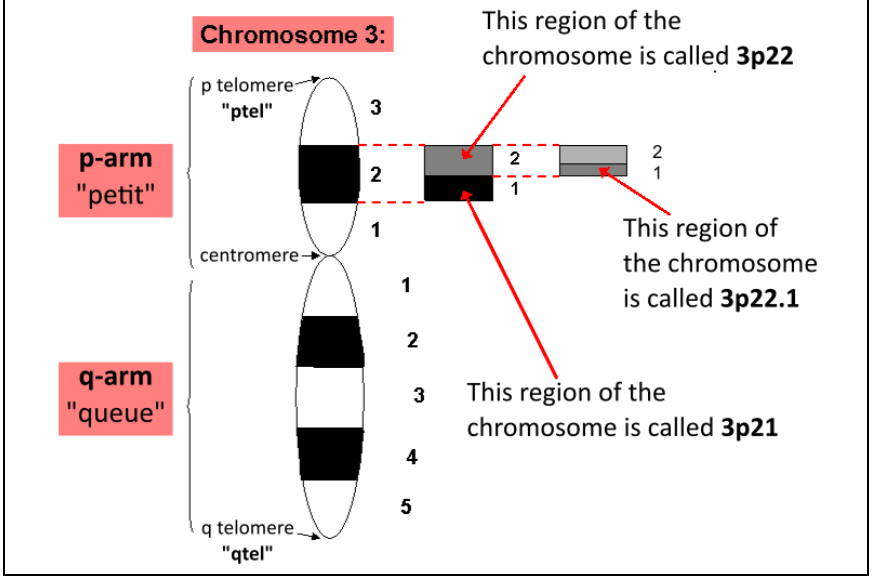
Student Centered Activity (15-40 minutes): After teaching the cell cycle, put students into small groups. A copy of the student guide for the lesson may be given to each group if necessary. Have the students take turns moving the chromosomes to accurately model the different phases of the cell cycle. Allow the students to correct and help one another. Continue to practice until each student can model the cell cycle accurately without looking at the guide.

Extra exercises:

Sex Chromosomes: Use the Y chromosome in place of one of the X chromosomes to show the difference between the male (XY) and female (XX) chromosomal configurations. Have students represent both male and female cells going through mitosis.

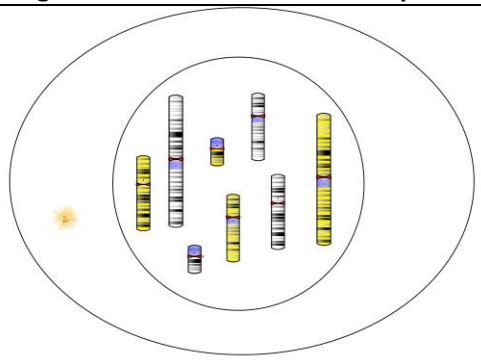
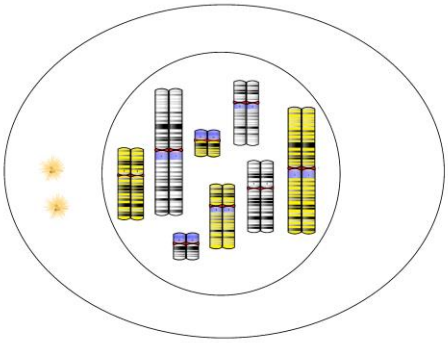
Banding Nomenclature: The Biology Magnets depict chromosomes banded with Giemsa stain (G-banding). To signify a location of a gene on the chromosome, scientists use the cytogenetic banding nomenclature (**Figure 4.A.7**). Go over this system with the students. Then, using a dry erase marker, mark a spot (or several spots) on a chromosome magnet for each student and have the students use the banding nomenclature to accurately represent the location of the spot. The chromosomes have already been labeled 1, 9, 21, X, or Y based on what human chromosome they represent. The blue portions of the chromosomes are highly variable regions between humans. The red portions are the centromeres.

Figure 4.A.7 – Cytogenetic Banding Nomenclature



Lesson 4B – Meiosis (20-80 minutes)

Teacher Centered Activity (20-30 minutes): This lesson utilizes the Biology Magnets to show the process of meiosis. Start by making a large oval with a marker on the board that will represent the cell membrane, and a smaller oval in the center of the larger oval to represent the nuclear membrane. Place the white and yellow chromosome magnets into the nuclear membrane, and a centrosome in the cytoplasm. This represents the cell during G1 of interphase (**Figure 4.B.1**). Introduce the second copies of the chromosomes to show the duplication that happens during S phase of interphase. For this lesson, use the chromosomes labeled 1M and 9M to represent the copies of chromosomes 1 and 9. Remind students that the chromosomes are actually uncoiled chromatin at this time, but the chromatin cannot be accurately represented with the magnets. Also, place another copy of the centrosome in the cytoplasm (**Figure 4.B.2**).

Figure 4.B.1 – Cell in G1 of Interphase	Figure 4.B.2 – Cell in S phase of Interphase
	

Meiosis I: Meiosis I begins with prophase I. Move one of the centrosomes to the opposite side of the cell. Erase the nuclear membrane and draw spindle fibers protruding from the centrosomes. Inform the students that the spindle fibers will attach to the red kinetochores on the chromosome and pull the chromosomes to the center of the cell. Match up the chromosomes with their homologous pairs (e.g. white chromosome 1 with yellow chromosome 1). Exchange the pieces between the white and yellow 1M and 9M chromosomes to demonstrate crossing over (**Figure 4.B.3**). Move the homologous pairs (a.k.a tetrads) to the metaphase plate in the middle of the cell to represent metaphase I. Explain independent assortment, the idea that how the chromosomes align at the metaphase plate is random for each pair (**Figure 4.B.4**). Separate the homologous pairs and move them to opposite sides to represent Anaphase I (**Figure 4.B.5**). Then draw a new nuclear membrane around the chromosomes and erase the spindle fibers to represent Telophase I. Draw a cleavage furrow to separate the cells to demonstrate cytokinesis (**Figure 4.B.6**).

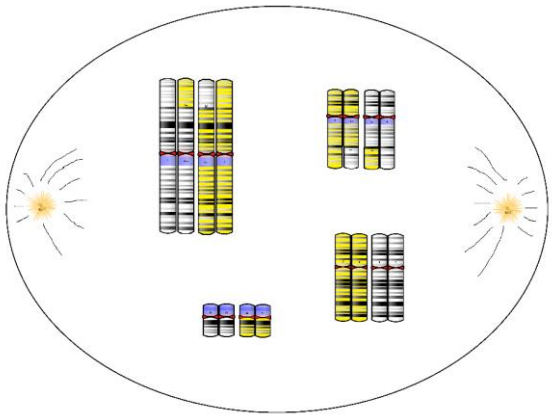
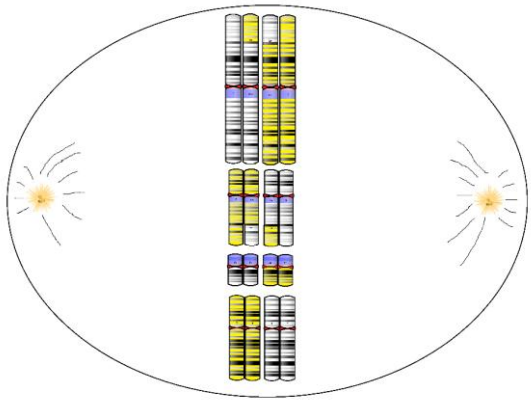
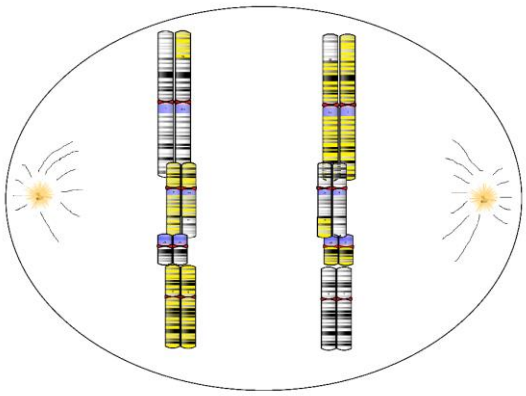
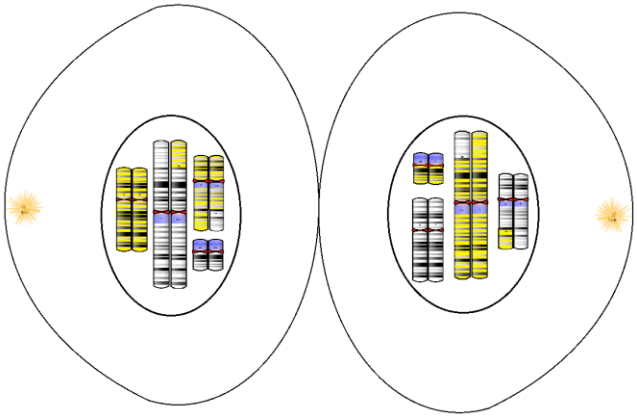
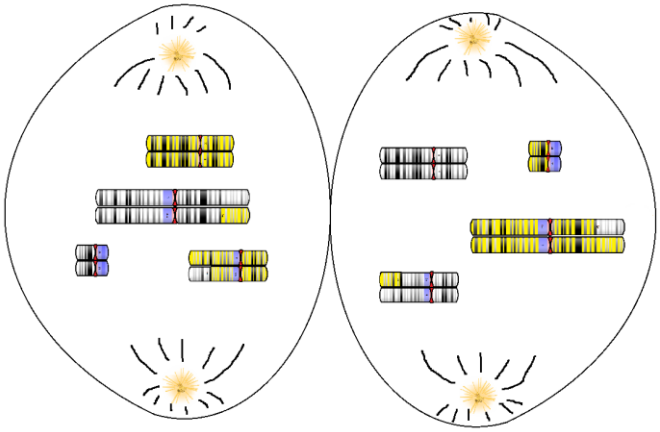
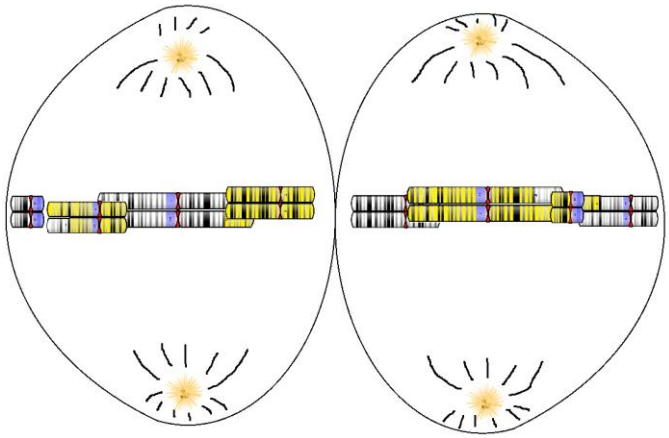
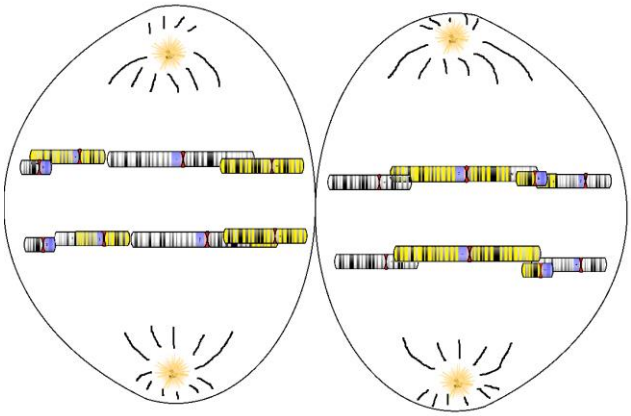
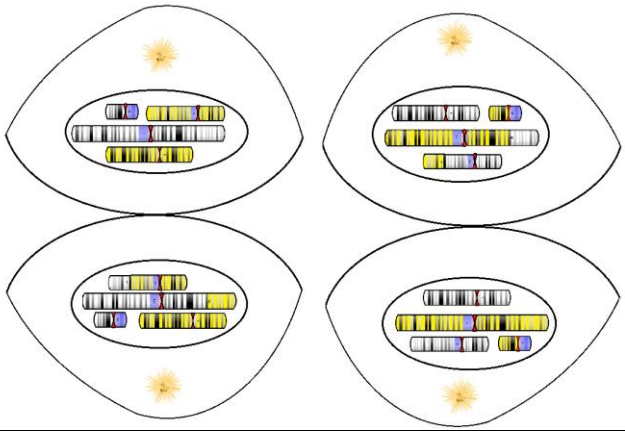
Figure 4.B.3 – Prophase I of Meiosis	Figure 4.B.4 – Metaphase I of Meiosis
	

Figure 4.B.5 – Anaphase I of Meiosis	Figure 4.B.6 – Telophase I of Meiosis and Cytokinesis
	

Meiosis II: The events in meiosis II are very similar to mitosis, except it happens in both cells at the same time. The chromosome Biology Magnets will move up/down for the second division rather than left/right. During interkinesis, the centrosomes are copied again. Place the other two centrosome magnets in the cytoplasm of each cell. For prophase II, erase the nuclear membranes (which dissolve) and move the centrosomes to opposite sides of the cell. Use a marker to draw spindle fibers coming from the centrosomes as in meiosis I (**Figure 4.B.7**). For metaphase II, move the chromosomes to the middle of the cell (**Figure 4.B.8**). In anaphase II, separate the chromosomes at the centromere and move them to opposite sides of the cell (**Flgure 4.B.9**). In telophase II, erase the spindle fibers and draw new nuclear membranes around the chromosomes. Draw a division between the cells to represent cytokinesis as in meiosis I. (**Figure 4.B.10**) Now there are four haploid cells, each with a different combination of genes.

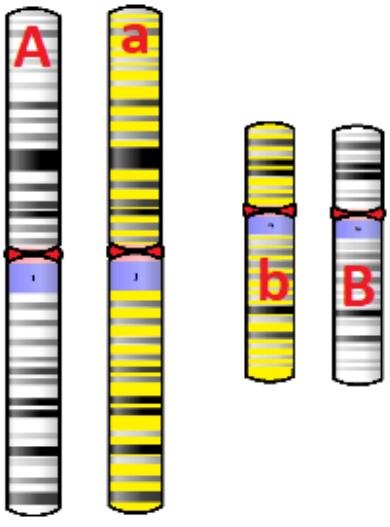
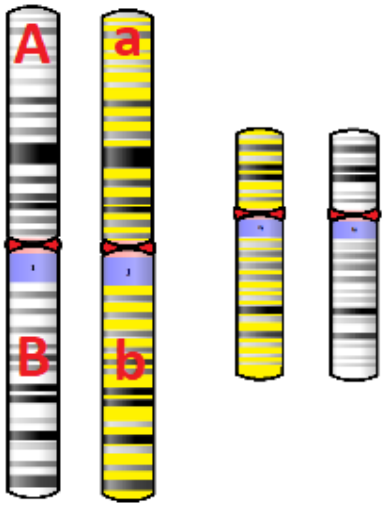
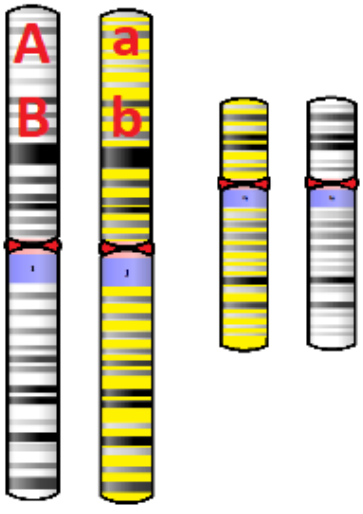
Figure 4.B.7– Prophase II of Meiosis	Figure 4.B.8 – Metaphase II of Meiosis
	
Flgure 4.B.9 – Anaphase II of Meiosis	**Figure 4.B.10 – Telophase II of Meiosis**
	

Student Centered Activity (20-50 minutes): After teaching the meiosis, put the students into small groups. A copy of the student guide for the lesson may be given to each group if necessary. Have the students take turns moving the chromosomes to accurately model the different phases of meiosis including crossing over and independent assortment. Allow the students to correct and help one another. Continue to practice until each student can model meiosis accurately without looking at the student guide.

Extra exercises:

Independent Assortment of Unlinked Alleles to Gametes – Use a dry erase marker to write alleles onto the chromosomes and show how alleles are distributed independently to gametes in meiosis. For example, start with an individual being genotype AaBb by writing "A" on the initial white chromosome I and "a" at the same locus on the yellow chromosome I. Write "B" on white chromosome 9 and "b" on yellow chromosome 9 (**Figure 4.B.11**). Move through the steps of meiosis and show how each gamete will get only one of the four alleles because the alleles are located on different chromosomes.

Linked Genes – Use a dry erase marker to write alleles onto the chromosomes and show how can be linked which can lead to unequal distribution in meiosis. For example, start with an individual being genotype AaBb by writing "A" on the initial white chromosome 1 at the top end of the short arm and "a" at the same locus on the yellow chromosome I. Write "B" on white chromosome 1 in a location farther down the chromosome and "b" on yellow chromosome 1 at the same locus. Go through the steps of meiosis, showing how crossing over is likely to separate the alleles if the alleles are far apart (**Figure 4.B.12**) but is less likely to separate the alleles if the alleles are close together. During the crossing over phase both genes will be switched if they are written on the top of chromosome 1 as shown (**Figure 4.B.13**).

Figure 4.B.11 – Chromosomes in G1 with alleles A and B (in red) on different chromosomes (unlinked)	**Figure 4.B.12 – Chromosomes in G1 with alleles A and B (in red) on the same chromosome (linked) far apart**	**Figure 4.B.13 – Chromosomes in G1 with alleles A and B (in red) on the same chromosome (linked) close together**
		

Lesson 4C – Chromosomal Mutations and Karyotyping (20-90 minutes)

Chromosomal Mutations Teacher Centered Activity (10-20 minutes): Use the sets of chromosomes labeled 1M and 9M to show several different types of chromosomal mutations. (**Figures 4.C.1-4.C.4**).

Student Centered Activity (10-20 minutes): After teaching the chromosomal mutations, put the students into small groups. A copy of the student guide for the lesson may be given to each group if necessary. Have the students use the chromosomes labeled 1M and 9M to show the different types of chromosomal mutations. Allow the students to correct and help one another. Students should practice until they can name all of the mutations without looking at the guide.

Extra exercise: Online Research: Research the chromosomal mutations and report to the class about what mutations cause what disorders. For example, Jacobsen syndrome, caused by a deletion on chromosome 11, can cause heart defects. Have the students try to represent the mutations with the Biology Magnets.

Figure 4.C.1 – Deletion Mutation – A chromosome segment is lost

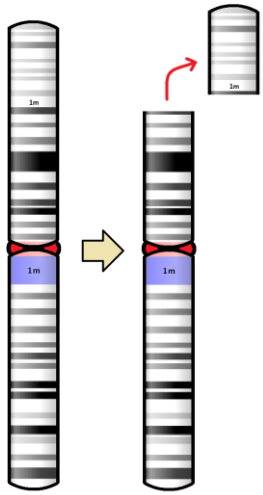


Figure 4.C.2– Translocation – A segment of chromosome is transferred to another

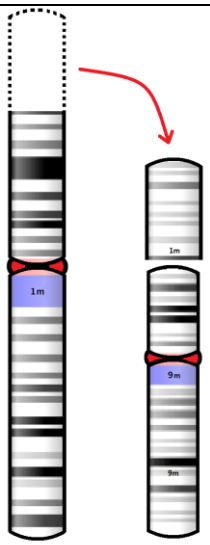


Figure 4.C.3 – Duplication – A segment from one chromosome is transferred to its homologous chromosome

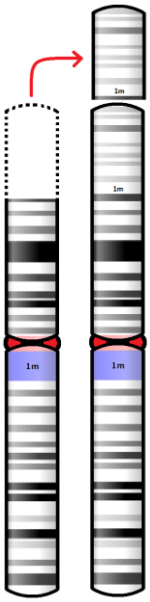
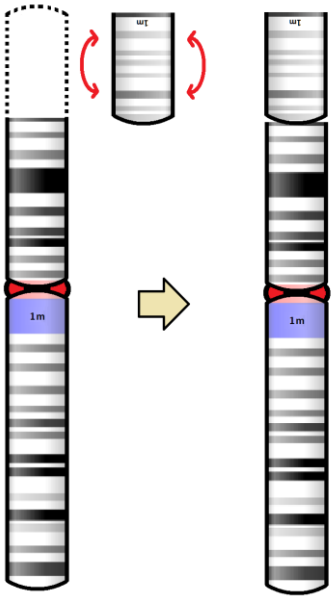


Figure 4.C.4 – Inversion – A segment of a chromosome is inverted



Karyotyping Teacher Centered Activity (10-20 minutes): A karyotype is a picture of a cell in metaphase with the chromosome pairs ordered from largest to smallest with the sex chromosomes last. Remind students that human cells have 46 chromosomes instead of 4. Have the students model mitosis but stop the process in metaphase and then remove and pair the chromosomes in order from largest to smallest. Karyotypes differ for males and females (**Figures 4.C.5-4.C.6**). Have the students demonstrate a karyotype of XXY disorder (Klinefelter syndrome) (**Figure 4.C.7**).

Student Centered Activity (10-30 minutes): Have the students use the Biology Magnets to model mitosis but stop at metaphase. Have them remove the chromosomes from the cell and make a karyotype. Have them identify if the cell is male or female. Have the students demonstrate the XXY disorder known as Klinefelter syndrome with the Biology Magnets.

Extra exercise: Online Research: Have students research and report findings to the class on the chromosomal mutations that can be detected with a karyotype. For example, Down syndrome, caused by an extra chromosome 21, causes mental retardation among other problems. Have the students try to represent the mutations with Biology Magnets.

Figure 4.C.5 – Biology Magnet karyotype of a female (XX)

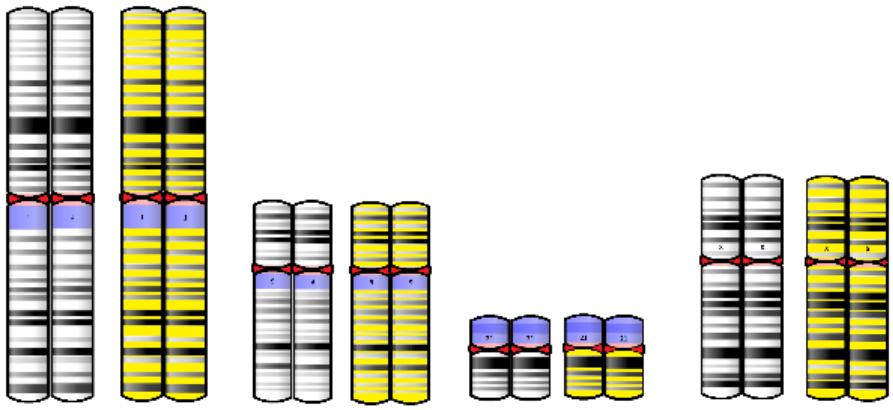


Figure 4.C.6 – Biology Magnet karyotype of a male (XX)

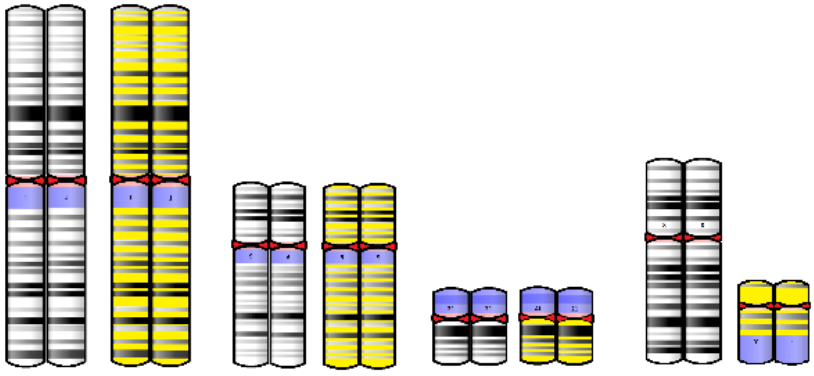
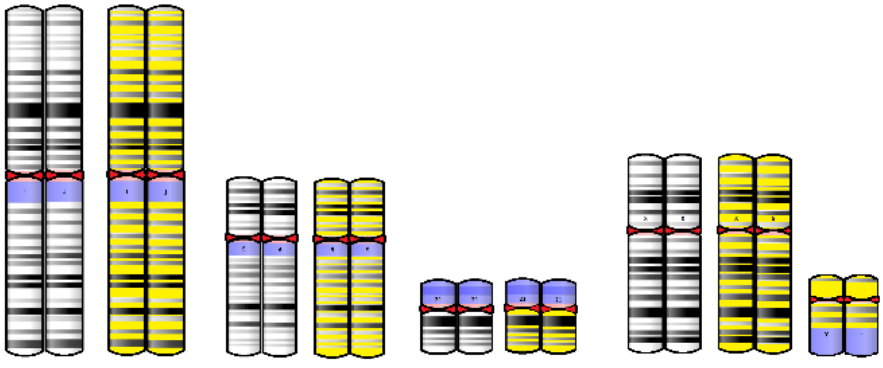
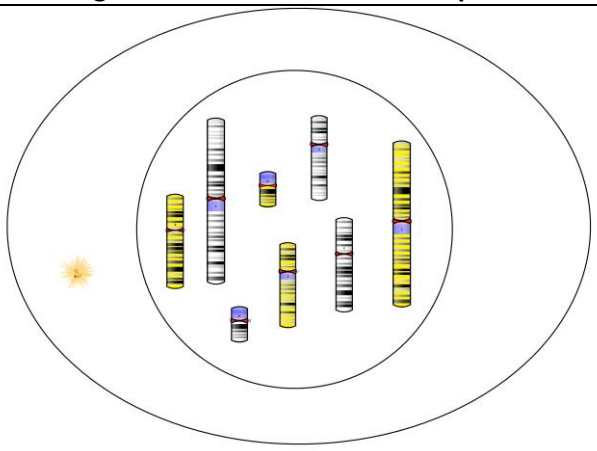
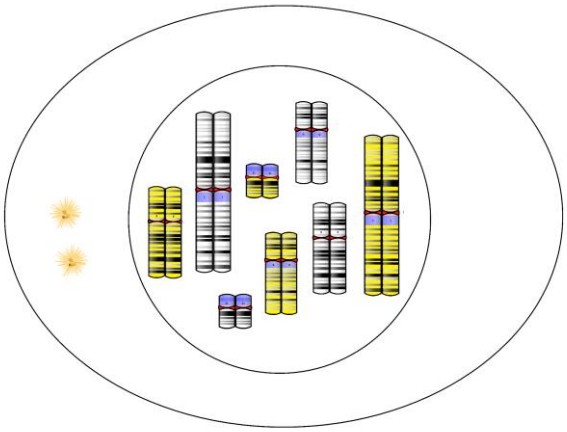


Figure 4.C.7 – Biology Magnet karyotype of a male with Klinefelter Syndrome (XXY)



Lesson 4A – The Cell Cycle and Mitosis – Student Guide

Student Centered Activity: After learning about the cell cycle, put the chromosome Biology Magnets on the board. Start by making a large oval with a marker on the board that will represent the cell membrane. Make a smaller oval in the center of the larger oval to represent the nuclear membrane. Place one of each of the white and yellow chromosome magnets into the nuclear membrane. Do not use the magnets that are labeled Y, 1M, or 9M, these are for a later lesson. Also place a centrosome in the cytoplasm. This represents the cell during G1 of interphase. The chromosomes are actually uncoiled chromatin at this time, but the chromatin cannot be accurately represented with the magnets (**Figure 4.A.1**). Next, place the second copies of the chromosomes into the membrane to show the copying of chromosomes that happens during S phase of interphase. Also, place another copy of the centrosome in the cytoplasm (**Figure 4.A.2**).

Figure 4.A.1 – Cell in G1 of Interphase	Figure 4.A.2 – Cell in S phase of Interphase
	

Mitosis: To start mitosis in prophase, move one of the centrosomes to the opposite side of the cell and draw some spindle fibers protruding from the centrosome toward the chromosomes. Erase the nuclear membrane. Move some of the chromosomes so they attach to spindle fibers. It will be too messy to draw all of the chromosomes attaching to spindle fibers (**Figure 4.A.3**). Move the chromosomes to the center of the cell at the metaphase plate to represent metaphase (**Figure 4.A.4**). Break the sister chromatids apart at the centromere to represent anaphase and move the daughter chromosomes toward opposite poles (**Figure 4.A.5**). For telophase, erase the spindle fibers and move the chromosomes to opposite ends of the cell. Draw a new nuclear membrane around the chromosomes. Draw a cleavage furrow and a division representing cytokinesis separating the cell membrane to make two new cells (**Figure 4.A.6**).

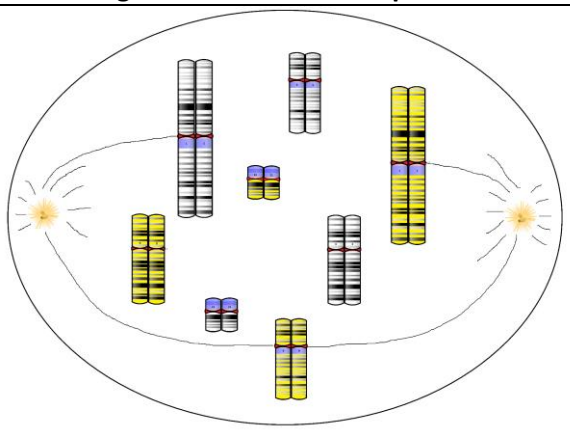
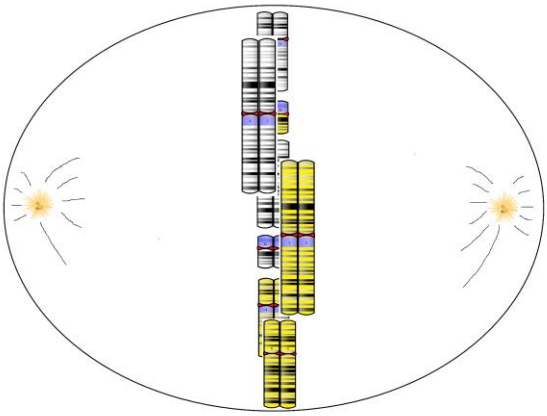
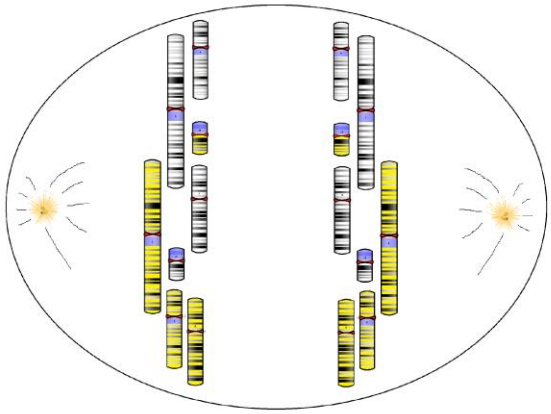
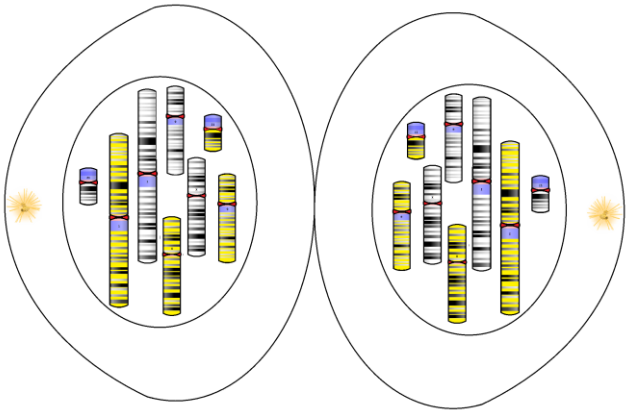
Figure 4.A.3 – Cell in Prophase	Figure 4.A.4 – Cell in Metaphase
	

Figure 4.A.5 – Cell in Anaphase	Figure 4.A.6 – Cell in Telophase and Cytokinesis
	

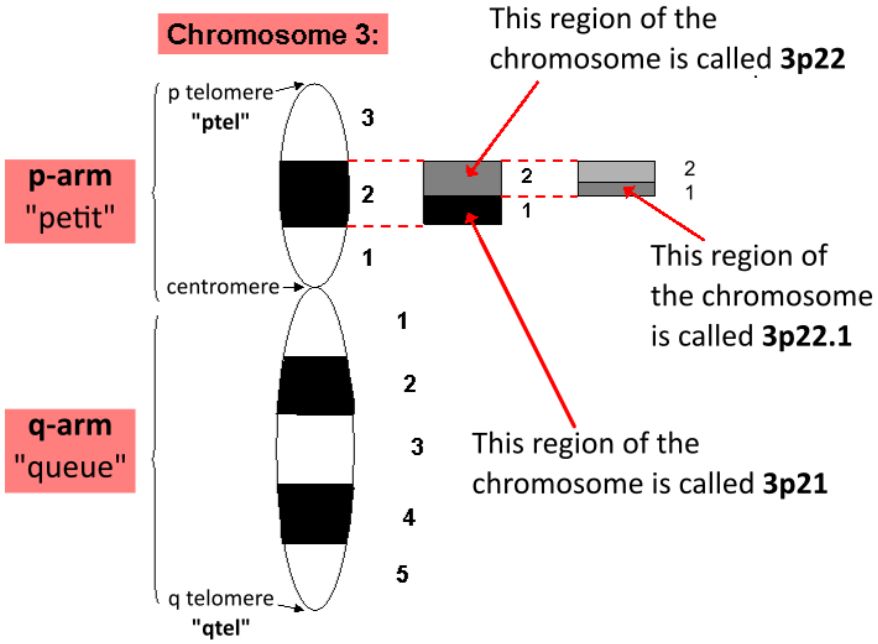
Take turns moving the chromosomes to accurately model the different phases of the cell cycle. Continue to practice until each student can model the cell cycle without looking at the guide. After finishing, show your teacher.

Extra exercises:

Sex Chromosomes: Use the Y chromosome in place of one of the X chromosomes to show the difference between the male (XY) and female (XX) chromosomal configurations. Use the Biology Magnets to show both male and female cells going through mitosis.

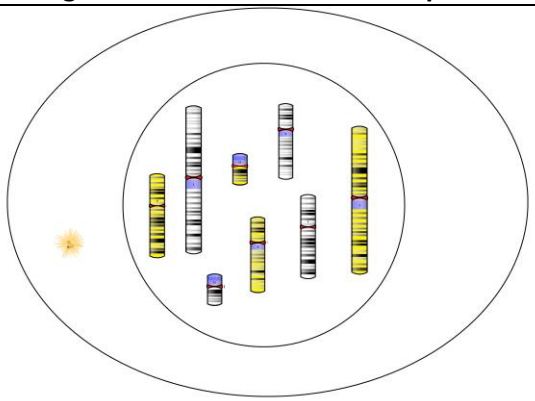
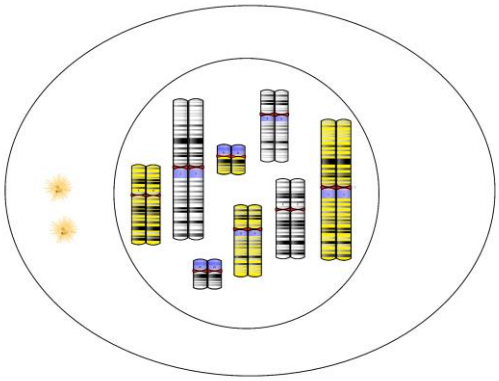
Banding Nomenclature: The Biology Magnets depict chromosomes banded with Giemsa stain (G-banding). To signify a location of a gene on the chromosome, scientists use the cytogenetic banding nomenclature (**Figure 4.A.7**). Have your teacher or a student from another group mark a spot on one of the chromosomes, and use the diagram to figure out how to name the spot. Tell your teacher when you finish.

Figure 4.A.7 – Cytogenetic Banding Nomenclature



Lesson 4B – Meiosis – Student Guide

Student Centered Activity: Start by making a large oval with a marker on the board that will represent the cell membrane, and a smaller oval in the center of the larger oval to represent the nuclear membrane. Place the white and yellow chromosome magnets into the nuclear membrane, and a centrosome in the cytoplasm. This represents the cell during G1 of interphase (**Figure 4.B.1**). Introduce the second copies of the chromosomes to show the duplication that happens during S phase of interphase. For this lesson, use the chromosomes labeled 1M and 9M to represent the copies of chromosomes 1 and 9. Also, place another copy of the centrosome in the cytoplasm (**Figure 4.B.2**).

Figure 4.B.1 – Cell in G1 of Interphase	Figure 4.B.2 – Cell in S phase of Interphase
	

Meiosis I: Meiosis I begins with prophase I. Move one of the centrosomes to the opposite side of the cell. Erase the nuclear membrane and draw spindle fibers protruding from the centrosomes. Match up the chromosomes with their homologous pairs (e.g. white chromosome 1 with yellow chromosome 1). Exchange the pieces between the white and yellow 1M and 9M chromosomes to demonstrate crossing over (**Figure 4.B.3**). Move the homologous pairs (a.k.a tetrads) to the metaphase plate in the middle of the cell to represent metaphase I. Demonstrate independent assortment, the idea that how the chromosomes align at the metaphase plate is random for each pair (**Figure 4.B.4**). Separate the homologous pairs and move them to opposite sides to represent Anaphase I (**Figure 4.B.5**). Draw a new nuclear membrane around the chromosomes and erase the spindle fibers to represent Telophase I. Draw a cleavage furrow to separate the cells to demonstrate cytokinesis (**Figure 4.B.6**).

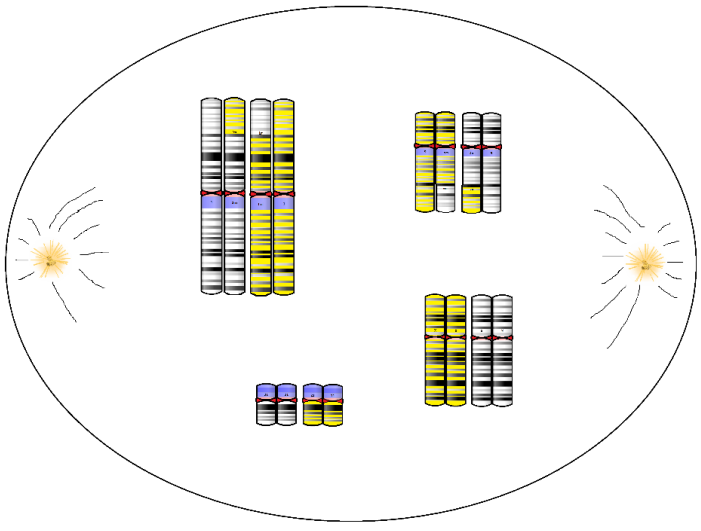
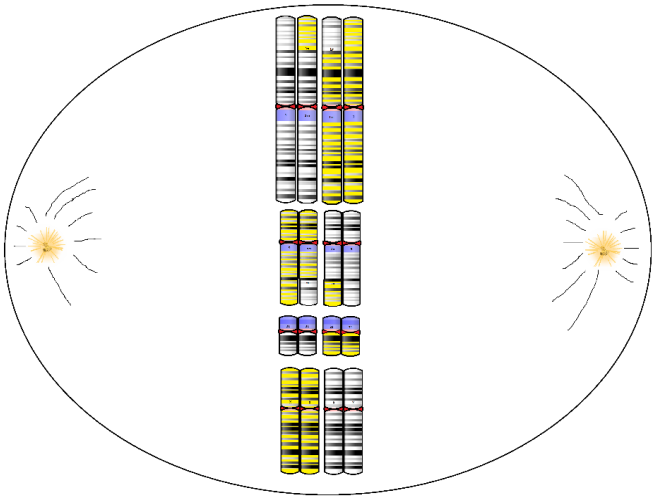
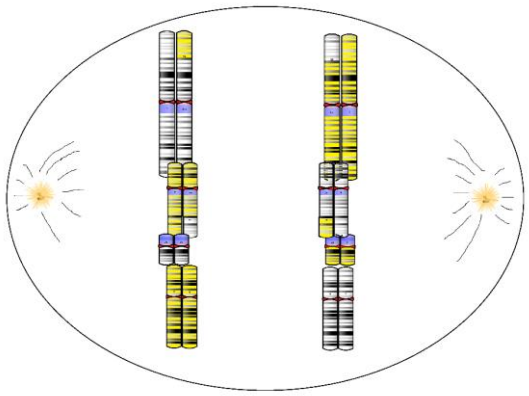
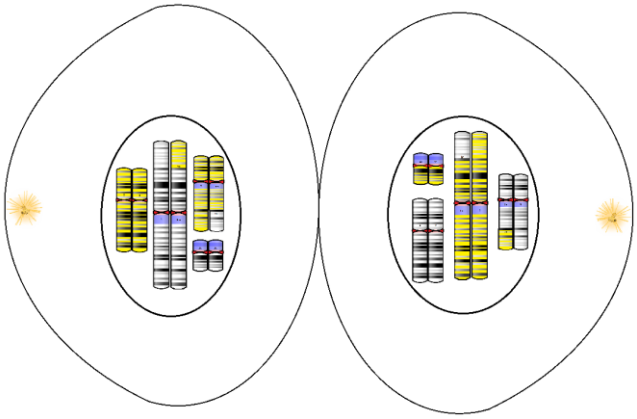
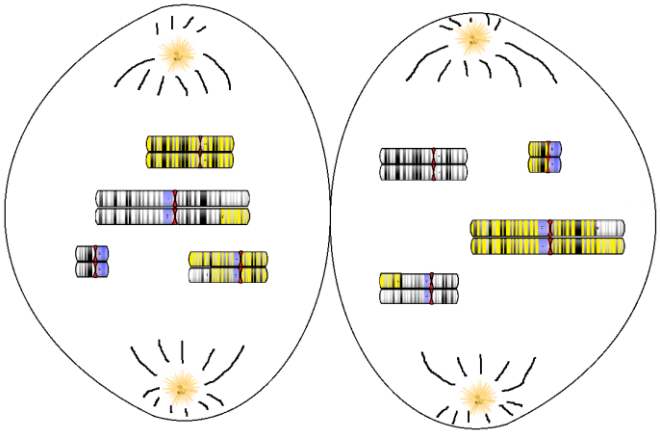
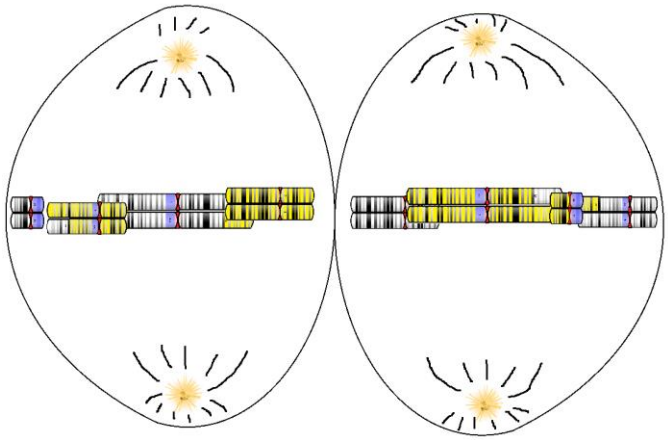
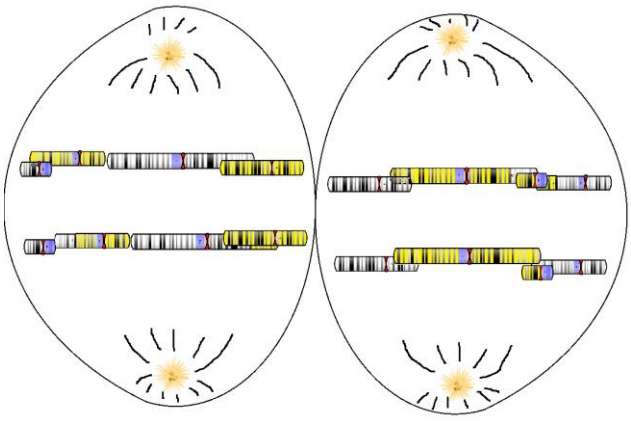
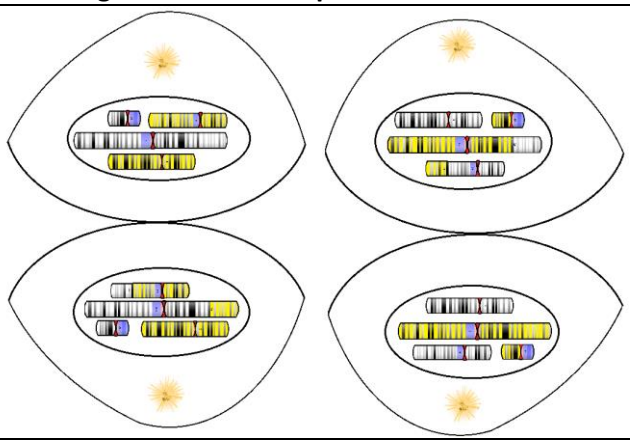
Figure 4.B.3 – Prophase I of Meiosis	Figure 4.B.4 – Metaphase I of Meiosis
	

Figure 4.B.5 – Anaphase I of Meiosis	Figure 4.B.6 – Telophase I of Meiosis and Cytokinesis
	

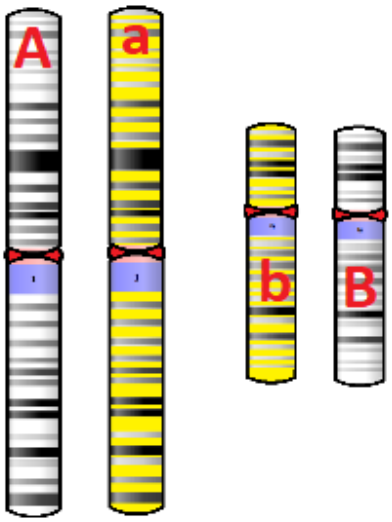
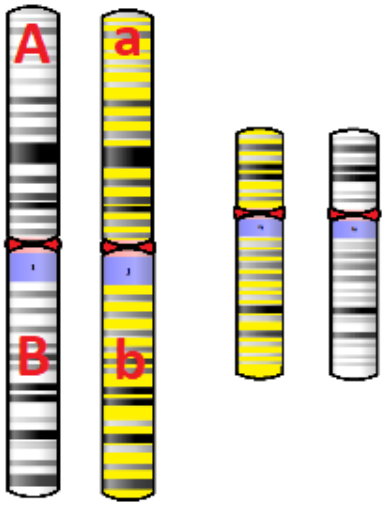
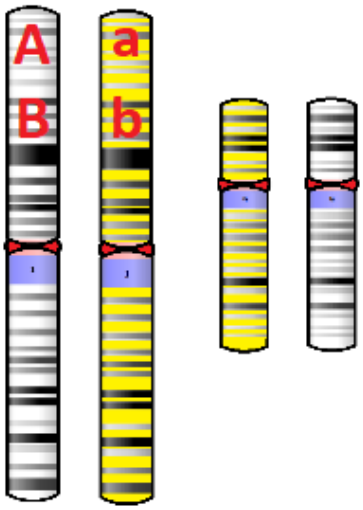
Meiosis II: The events in meiosis II happen in both cells at the same time. During interkinesis, the centrosomes are copied again. Place the other two centrosome magnets in the cytoplasm of each cell. For prophase II, erase the nuclear membranes (which dissolve) and move the centrosomes to opposite sides of the cell. Use a marker to draw spindle fibers coming from the centrosomes as in meiosis I (**Figure 4.B.7**). For metaphase II, move the chromosomes to the middle of the cell (**Figure 4.B.8**). For anaphase II, separate the chromosomes at the centromere and move them to opposite sides of the cell (**Flgure 4.B.9**). For telophase II, erase the spindle fibers and draw new nuclear membranes around the chromosomes. Draw a division between the cells to represent cytokinesis. (**Figure 4.B.10)** Now there are four haploid cells, each with a different combination of genes. Continue to practice the process until each student can model meiosis accurately without looking at the guide.

Figure 4.B.7 – Prophase II of Meiosis	Figure 4.B.8 – Metaphase II of Meiosis
	
Flgure 4.B.9 – Anaphase II of Meiosis	**Figure 4.B.10 – Telophase II of Meiosis**
	

Extra exercises:

Independent Assortment of Unlinked Alleles to Gametes – Use a dry erase marker to write alleles onto the chromosomes and show how alleles are distributed independently to gametes in meiosis. For example, start with an individual being genotype AaBb by writing "A" on the initial white chromosome I and "a" at the same locus on the yellow chromosome I. Write "B" on white chromosome 9 and "b" on yellow chromosome 9 (**Figure 4.B.11**). Move through the steps of meiosis and show how each gamete will get only one of the four alleles because the alleles are located on different chromosomes.

Linked Genes – Use a dry erase marker to write alleles onto the chromosomes and show how alleles can be linked which can lead to unequal distribution in meiosis. For example, start with an individual being genotype AaBb by writing "A" on the initial white chromosome 1 at the top end of the short arm and "a" at the same locus on the yellow chromosome I. Write "B" on white chromosome 1 in a location farther down the chromosome and "b" on yellow chromosome 1 at the same locus. Go through the steps of meiosis, showing how crossing over is likely to separate the alleles if the alleles are far apart (**Figure 4.B.12**) but is less likely to separate the alleles if the alleles are close together. During the crossing over phase both genes will be switched if they are written on the top of chromosome 1 as shown (**Figure 4.B.13**).

Figure 4.B.11 – Chromosomes in G1 with alleles A and B (in red) on different chromosomes (unlinked)	**Figure 4.B.12 – Chromosomes in G1 with alleles A and B (in red) on the same chromosome (linked) far apart**	**Figure 4.B.13 – Chromosomes in G1 with alleles A and B (in red) on the same chromosome (linked) close together**
		

Lesson 4C – Chromosomal Mutations and Karyotyping – Student Guide

Chromosomal Mutations Student Centered Activity: Use the chromosomes labeled 1M and 9M to show the different types of chromosomal mutations (**Figures 4.C.1-4.C.4**). Practice until everyone in the group can name all of the mutations without looking at the guide.

Extra exercise: Online Research: Research the chromosomal mutations and report to the class about what mutations cause what disorders. For example, Jacobsen syndrome, caused by a deletion on chromosome 11, can cause heart defects.

Figure 4.C.1 – Deletion Mutation – A chromosome segment is lost

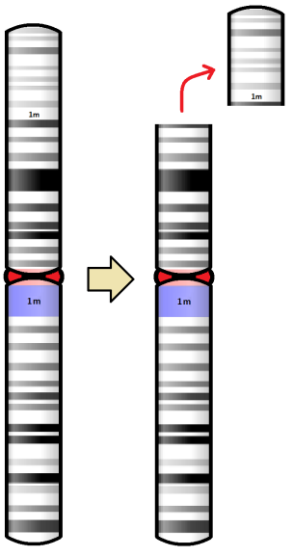


Figure 4.C.2– Translocation – A segment of chromosome is transferred to another

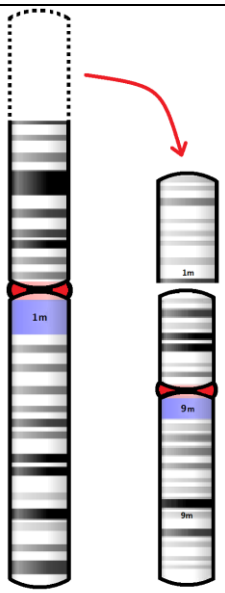


Figure 4.C.3 – Duplication – A segment from one chromosome is transferred to its homologous chromosome

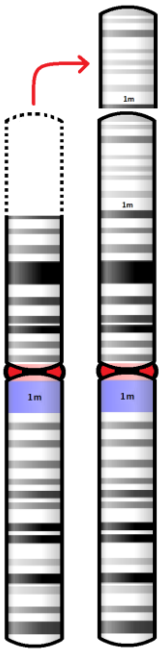
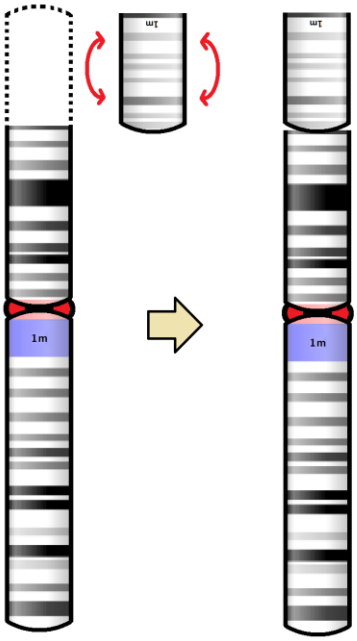


Figure 4.C.4 – Inversion – A segment of a chromosome is inverted



Karyotyping Student Centered Activity: Use the Biology Magnets to model mitosis but stop at metaphase. Remove the chromosomes from the cell and make a karyotype. A karyotype is a picture of the chromosomes taken during metaphase and then order the chromosome pairs from largest to smallest with the sex chromosomes coming last. Identify if the cell is male or female (**Figures 4.C.5, 4.C.6**). Demonstrate a Karyotype of the XXY disorder known as Klinefelter syndrome with the Biology Magnets (**Figure 4.C.7**) .

Extra exercise: Online Research: Research the chromosomal mutations that can be detected with a karyotype. For example, Down syndrome, caused by an extra chromosome 21, causes mental retardation among other problems. Have the students report their findings to the rest of the class.

Figure 4.C.5 – Biology Magnet karyotype of a female (XX)

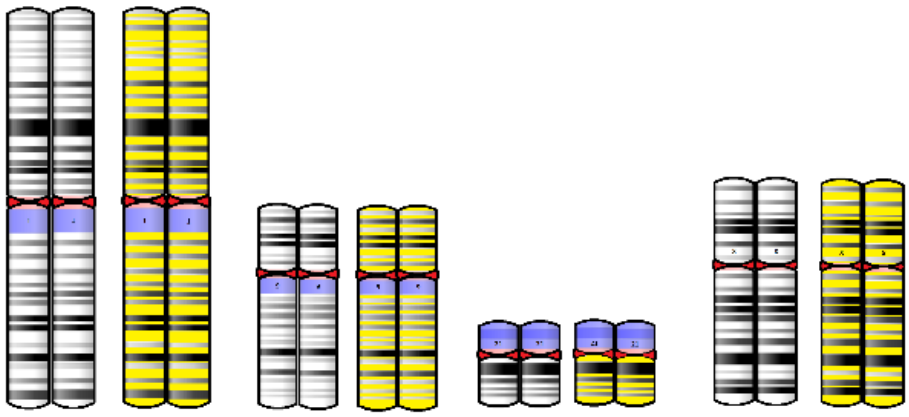


Figure 4.C.6 – Biology Magnet karyotype of a male (XX)

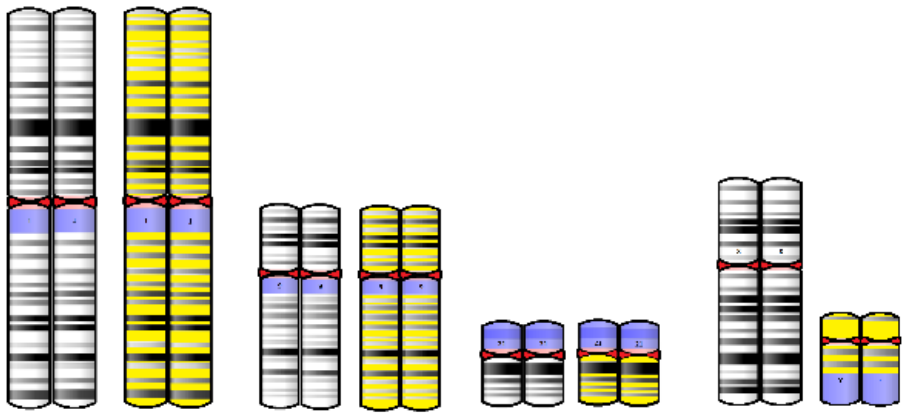


Figure 4.C.7 – Biology Magnet karyotype of a male with Klinefelter Syndrome (XXY)