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Carolina BioKits™

Chromosome Simulation

Meiosis Activity

Meiosis involves two sequential divisions, called meiosis I and meiosis II. Each nucleus resulting from meiotic division is haploid, meaning that it contains half the number of chromosomes as the parent. Like mitosis, meiosis is a continual process in which the phases progress smoothly from one to the next, with no distinct point separating them. For the purposes of this discussion and to facilitate modeling, we will designate events in the process of mitosis as separate phases. During this activity, you will manipulate the materials at your lab station in order to visualize the events that occur during each phase. For each step of the Procedure, read the description of the events in the phase, and then follow the directions to model the step using the model materials provided.

Materials

40 red beads
40 yellow beads
4 magnetic centromeres
4 red plastic centrioles
4 3-foot pieces of string
clear adhesive tape (shared)
masking tape (shared)
string (shared)

Procedure

1. Build a nuclear membrane.
   a. Use the saved tape to create a closed circle or hexagon shape on the surface of your desk or on a clear space on the floor, as your teacher directs. If necessary, obtain additional masking tape. The tape ring represents the nuclear membrane of the cell. Your entire workspace represents the area inside the cell.
   b. Allow the two red chromatids to come together at the magnetic centromeres. Repeat with the two yellow chromatids.
   c. Place the red and yellow chromosomes inside the nuclear membrane.
   d. Now you are ready to model events in the cell cycle.
2. **Interphase:** Interphase occurs before mitosis as a preparation for nuclear division. It is the longest stage of the cell cycle. During this time, DNA is replicated and the cell rapidly grows and produces organelles. The nuclear membrane and nucleolus are distinct. The nucleolus is made of nucleic acids and proteins.
   a. Position two plastic centrioles outside the nuclear membrane ring, touching at right angles.
   b. Position the chromosomes in a pile inside the nuclear membrane. If you looked at a cell in interphase under a compound microscope, you would not be able to see individual chromosomes, because they are so long and thin. Only when they are condensed are they visible under the microscope, assuming their characteristic "X" shape.
   c. On the Meiosis Sketches page, make a diagram of the chromosome model at this stage of meiosis.

3. **Prophase I:** The chromosomes condense and the nuclear membrane disappears as it breaks down. Microtubules attach to the chromosomes, pulling homologs together. The homologs can exchange genetic information by way of crossing-over. Crossing-over occurs when sections of DNA are traded between non-sister chromatids of a homologous pair. This allows for greater genetic variation between daughter cells.
   a. Move the two centrioles so that they are on opposite sides of the nucleus, about 8 inches from the outer edge of the nuclear membrane.
   b. Use a piece of transparent tape to secure each centriole to the work surface so that the opening of the bead faces the area that was the nucleus.
   c. Break down the nuclear membrane by pulling pieces of tape from the work surface. If possible, keep the tape in strips on the side of your workspace to reuse later as a new nuclear membrane.
   d. Arrange the chromosomes with arms outstretched to demonstrate that they are condensed. Then, twist the arms of sister chromatids together.
   e. Bring the homologous chromosomes together while the arms of each chromosome are still twisted. The red chromosome (the two red chromatids) will be connected to the yellow chromosome (the two yellow chromatids) at the centromeres.
   f. To simulate crossing-over, detach a few beads from each chromosome at some point of your choosing, and exchange them. The sections must be of equal length.
   g. On the Meiosis Sketches page, make a diagram of the chromosome model at this stage of meiosis.
4. **Metaphase I:** The nuclear membrane has completely disappeared. Microtubules radiating from opposite sides of the cell line up homologous pairs along the equator of the cell. The way that the homologs of a pair line up along the equator is random. The importance of this random assortment is that it generates greater genetic variation between daughter cells. For simplicity, you are modeling only one homologous pair of chromosomes. Chromosome number varies by species.
   a. Using two pieces of string, tie a loop around each pair of magnetic centromeres. When you have finished, each chromosome (consisting of two chromatids) should have a length of string hanging off it from one side.
   b. Thread one loose end of the string through one of the centrioles, and thread the other loose end through the other centriole.
   c. Position the chromosomes near the midpoint between the centrioles and at a right angle to the strings, as shown in Figure 3.
   d. On the Meiosis Sketches page, make a diagram of the chromosome model at this stage of meiosis.

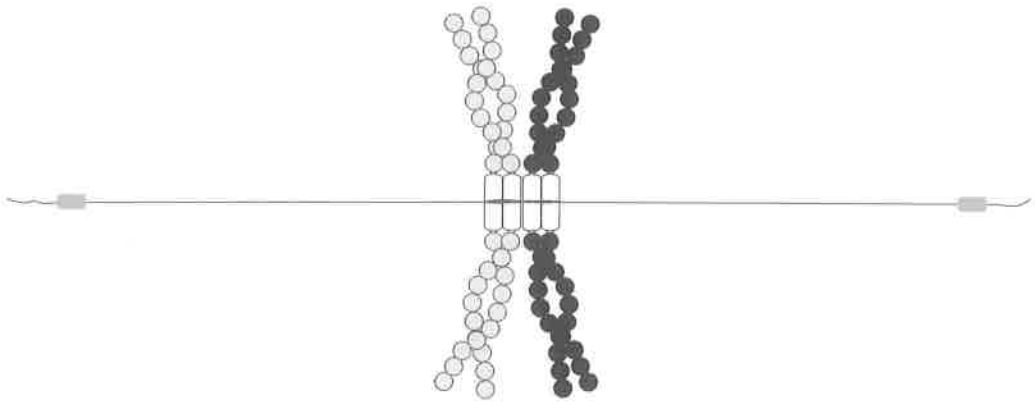


Figure 3. Metaphase of meiosis I

5. **Anaphase I:** Homologous chromosomes are pulled toward opposite sides of the cell by microtubules. Note that sister chromatids are still held together by a centromere, which is not the case in anaphase of mitosis.
   a. Gently pull the ends of the strings through the centrioles so that the homologous chromosomes separate and move toward opposite sides of the cell and adjacent to a centriole.
   b. On the Meiosis Sketches page, make a diagram of the chromosome model at this stage of meiosis.
6. **Telophase I:** A visible nuclear membrane begins to form around each set of chromosomes. The chromosomes decondense, and the microtubules break down. These processes may vary somewhat by species.
   a. Remove the string from each chromosome, and set aside the strings. Save the pieces of string for the next activity.
   b. To represent decondensing, pile the chromosomes beside their closest centriole.
   c. Use the masking tape you set aside, along with additional masking tape, to create a new nuclear membrane around each set of chromosomes. Each new nuclear membrane should be about the same size as the original. This concludes the modeling of meiosis.
   d. On the Meiosis Sketches page, make a diagram of the chromosome model at this stage of meiosis.
   e. **Cytokinesis** will occur at the same time as telophase. Each of the two cells has a haploid set of chromosomes, but these are still sister chromatids.
7. **Prophase II:** Meiosis II begins after a brief interphase. DNA was not replicated, but the centrioles do duplicate before prophase II. The chromosomes of each cell condense, and the nuclear membranes break down. Note that you are now modeling two cells. Model the same event in both cells, side-by-side.
   a. Add two more centrioles. The new centrioles should be placed adjacent and at a right angles to the existing centrioles.
   b. Move each pair of centrioles so that they are on opposite sides of the nucleus, about 8 inches from the outer edge of the nuclear membrane.
   c. Use a piece of transparent tape to secure each centriole to the work surface so that the opening of the bead faces the area that was the nucleus of the cell.
   d. Break down the nuclear membranes by pulling pieces of tape from the work surface. If possible, keep the tape in strips on the side of your workspace to reuse later as a new nuclear membrane.
   e. Arrange the chromosomes with arms outstretched to demonstrate that they are condensed. Then, twist the arms of sister chromatids together.
   f. On the Meiosis Sketches page, make a diagram of the chromosome model at this stage of meiosis.
8. **Metaphase II:** The chromosomes line up along the equator of each cell. Model the same event in both cells, side-by-side.
   a. Using four pieces of string, tie a loop around each magnetic centromere. When you have finished, each chromatid should have a length of string hanging off it from one side.
   b. Thread one of the loose ends of the string through one of the centrioles, and thread the other loose end through the remaining centriole.
   c. Position the chromosome near the midpoint between the centrioles and at a right angle to the strings, as shown in Figure 4.
   d. On the Meiosis Sketches page, make a diagram of the chromosome model at this stage of meiosis.

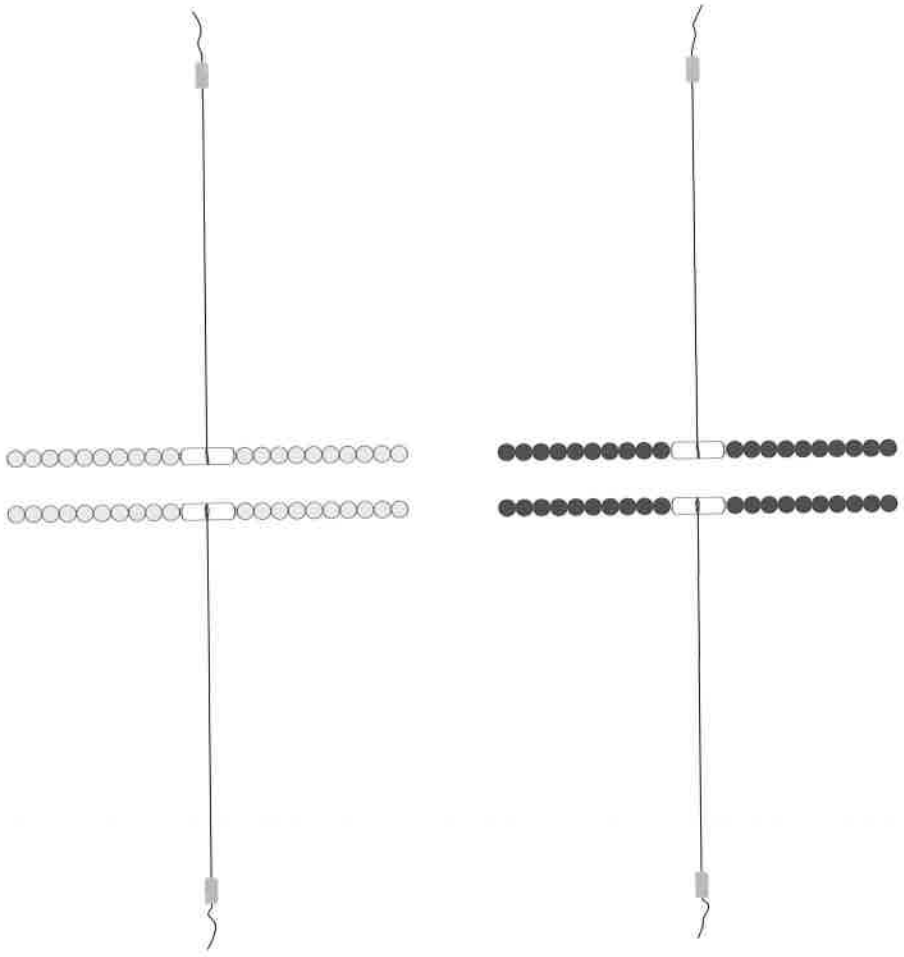
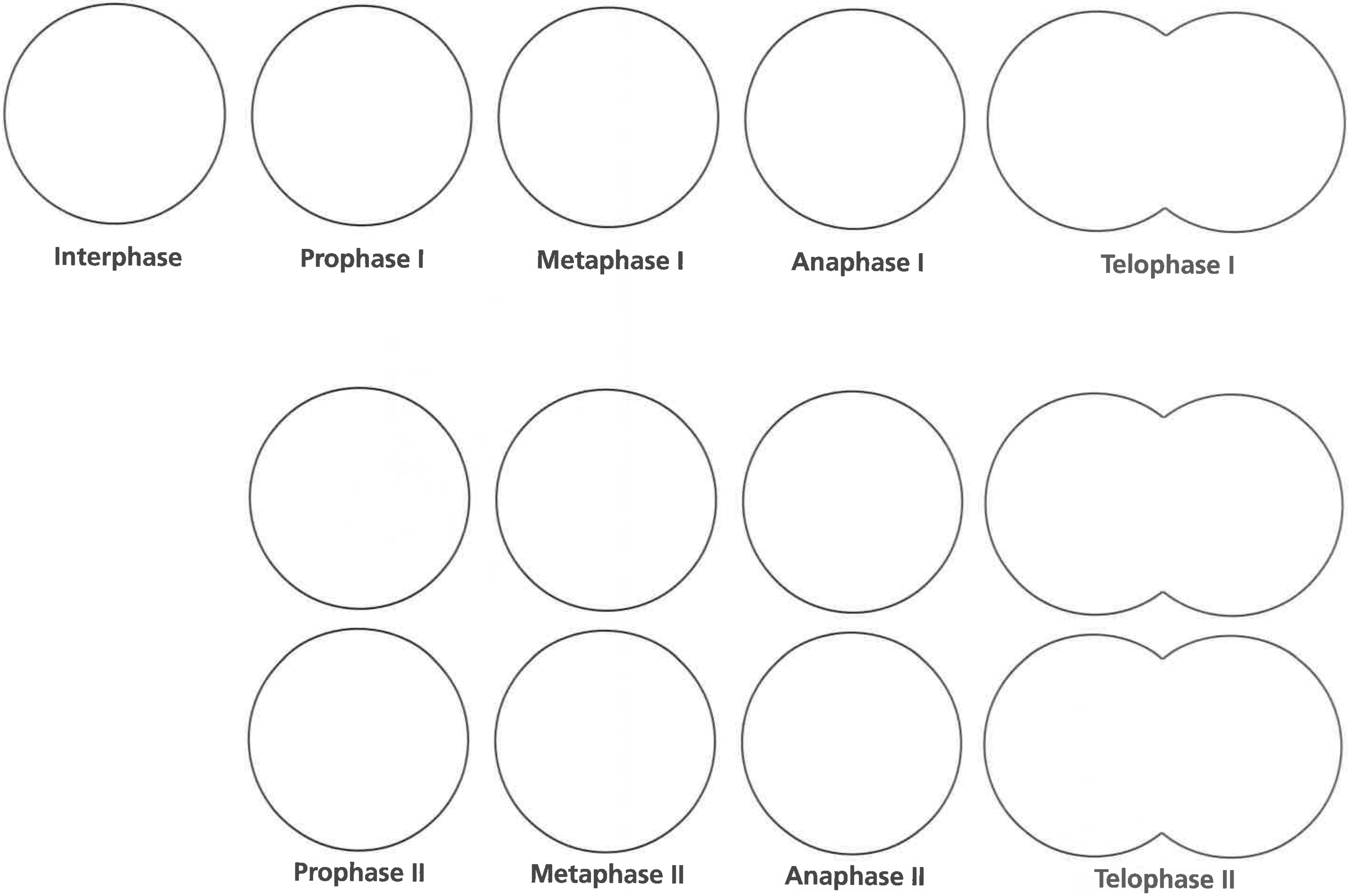
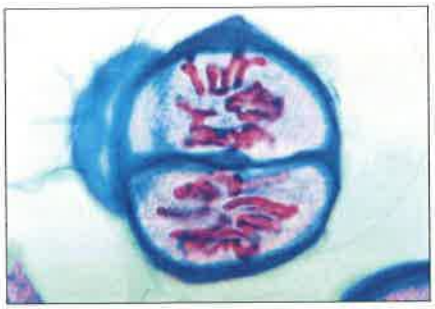


Figure 4. Anaphase II of meiosis

9. **Anaphase II:** Microtubules pull sister chromatids toward opposite sides of the cell. Each chromatid is now properly referred to as a chromosome.
   a. Gently pull the ends of the strings through the centrioles so that the sister chromatids separate and move toward opposite sides of the cell.
   b. Make a simple diagram of the model at this stage on the Meiosis Sketches page.
10. **Telophase II:** A visible nuclear membrane begins to form around each set of chromosomes. The chromosomes decondense, and the microtubules break down.
   a. Remove the string from each chromosome and set it aside.
   b. To represent decondensing, pile the chromosomes beside their closest centriole.
   c. Use the masking tape you set aside, along with additional masking tape, to create a new nuclear membrane around each of the four nuclei. This concludes the modeling of meiosis.
   d. On the Meiosis Sketches page, make a diagram of the chromosome model at this stage of meiosis.
   e. **Cytokinesis** occurs during Telophase II separating the two cells into four haploid cells, but those events are not portrayed in the model.
11. Save your chromosome structures for the next activity. Undo any bead changes that you made to the chromosomes in the crossing-over step. Each structure should be entirely red or entirely yellow.

Meiosis Sketches





Carolina BioKits™
Chromosome Simulation
Teacher's Manual and Student Guide

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CAROLINA®
www.carolina.com

Carolina Biological Supply Company
2700 York Road
Burlington, North Carolina 27215
Phone: 800.334.5551
Fax: 800.222.7112
Technical Support: 800.227.1150
www.carolina.com
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