Modeling Meiosis

(Adapted with permission from William R. Morgan wmorgan@acs.wooster.edu)

Please bring your textbook to this laboratory session.

A. Objectives

Become familiar with

1. The stages and events of meiosis;
2. Differences between mitosis and meiosis;
3. How genetic variation arises in sexually reproducing organisms

B. Before coming to lab

Reading

1. This exercise
2. Campbell et al. *Biology,* pp. 243-246 (note: there might be a quiz at the beginning of this lab).

C. During lab

Work in a group of two and make sure you have all the materials listed under Part E. Carry out the exercise described under Part F. Answer the 23 italicized questions in your notebook. It is not necessary to copy the questions, just number your answers.

D. After lab

1. Summarize the major differences between mitosis and meiosis in the form of a table in your notebook.
2. Make sure you can now answer all the study guide questions for chapter nine.

E. Materials

- 4 pencils, two different colors (homologous chromosomes 1)
- 4 pens, two different colors (homologous chromosomes 2)
- 4 sharpies, two different colors (homologous chromosomes 3)
- 4 centrioles (erasers or candy)
- 12 centromeres (rubber bands)

F. Background

Meiosis takes place in all organisms that reproduce sexually. In animals, meiosis occurs in special cells of the gonads; in plants, in special cells of the sporangia. Meiosis consists of two nuclear divisions, meiosis I and II, with an atypical interphase between the divisions during which cells do not grow and synthesis of DNA does not take place. This means that meiosis I and II result in four cells from each parent cell, each containing half the number of chromosomes, one from each homologous pair. Recall that cells with only one of each homologous pair of chromosomes are haploid (n) cells. The parent cells, with pairs of homologous chromosomes, are diploid (2n). The haploid cells become sperm (in males), eggs (in females), or spores (in plants). One advantage of meiosis in sexually reproducing organisms is that it prevents the chromosome number from doubling with every generation when fertilization occurs.

(1) What would be the consequences in successive generations of offspring if the chromosome number were not reduced during meiosis?

Lab Study A. Interphase

Working with another student, you will build a model of the nucleus of a cell in interphase before meiosis. Nuclear and chromosome activities are similar to those in mitosis. You and your partner should discuss activities in the nucleus and chromosomes in each stage. Go through the exercise once together and then demonstrate the model to each other to reinforce your understanding. Compare activities in meiosis with those in mitosis as you build your model.

Procedure

1. Build the premeiotic interphase nucleus much as you did the mitotic interphase nucleus.

2. *(2) Which phase is the first phase of interphase?* Represent this phase using your model. (3) *Are the chromosomes condensed or decondensed in this phase?*

   Cell activities in this phase are similar to those activities in interphase before mitosis.

   (4) In G1, are chromosomes replicated or unreplicated?

3. What is the next phase of interphase? Model this phase. Recall that in living cells the centromeres remain single, but in your model you must use two rubber bands. (5) *What color should the sister chromatids be for each pair?*

4. Duplicate the centriole pair.

5. *(6) What is the next phase?* Model this phase.

   (7) What happens in this phase?

Lab Study B. Meiosis I

Meiosis consists of two consecutive nuclear divisions, called meiosis I and meiosis II. As the first division begins, the chromosomes coil and condense as in mitosis. Meiosis I is radically different from mitosis, however, and the differences immediately become apparent. In your modeling, as you detect the differences, make notes in the margin of your lab manual.

Procedure

1. Meiosis I begins with the chromosomes piled in the center of your work area.

As chromosomes begin to coil and condense, prophase I begins. Each chromosome is replicated, made up of two sister chromatids. Two pairs of centrioles are located outside the nucleus.

2. Separate the two centriole pairs and move them to opposite poles of the nucleus.

   The nuclear envelope breaks down and the spindle begins to form as in mitosis.

3. Move each homologous chromosome to pair with its partner. You should have four strands together.

   Early in prophase I, each chromosome finds its homologue and pairs in a tight association called the synaptonemal complex. The process of pairing is called synapsis. Because the chromosomes are replicated, this means that each paired chromosome complex is made of four strands. This complex is called a tetrad.

   (8)How many tetrad complexes do you have in your cell which is 2n = 6?

4. Represent the phenomenon of crossing over by detaching and exchanging identical segments (caps of different color) of any two nonsister chromatids in a tetrad.

   Crossing over takes place between nonsister chromatids in the tetrad. In this process a segment from one chromatid will break and exchange with the exact same segment on a nonsister chromatid in the tetrad. The crossover site forms a chiasma (plural, chiasmata).

Note: If you are having difficulty envisioning the activities of chromosomes in prophase I and understanding their significance, discuss these events with your lab partner and, if needed, ask questions of your lab instructor before proceeding to the next stage of meiosis I.

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5. Move your tetrads to the equator, midway between the two poles.

   Late in prophase I, tetrads move to the equator.

6. To represent metaphase I, leave the tetrads lying at the equator.

   During this phase, tetrads lie on the equatorial plane. Centromeres do not split as they do in mitosis.

7. To represent anaphase I, separate each replicated chromosome from its homologue and move one homologue toward each pole. (In our model, the two magnets in sister chromatids represent one centromere holding together the two sister chromatids of the chromosome.)

(9)How does the structure of chromosomes in anaphase I differ from anaphase in mitosis?

8. To represent telophase I, place the chromosomes at the poles. *Who separates here - sisters or homologues*?

   Two nuclei now form, followed by cytokinesis. *(10) How many chromosomes are in each nucleus?*

   Note: The number of chromosomes is equal to the number of centromeres. In this model, two magnets represent one centromere in replicated chromosomes.

   (11) Would you describe the new nuclei as being diploid (2n) or haploid (n)?

9. To represent meiotic interphase, leave the chromosomes in the two piles formed at the end of meiosis I.

   The interphase between meiosis I and meiosis II is usually short. There is little cell growth and no synthesis of DNA. All the machinery for a second nuclear division is synthesized, however.

10. Duplicate the centriole pairs.

Lab Study C. Meiosis II

The events that take place in meiosis II are similar to the events of mitosis. Meiosis I results in two nuclei with half the number of chromosomes as the parent cell, but the chromosomes are replicated (made of two chromatids), just as they are at the beginning of mitosis. The events in meiosis II must change replicated chromosomes into unreplicated chromosomes. As meiosis II begins, two new spindles begin to form, establishing the axes for the dispersal of chromosomes to each new nucleus.

Procedure

1. *(12) What is the next phase*? Model this phase. Do not forget the centrioles.

   (13) Are there differences between this phase and the same phase in mitosis?

2. Align the chromosomes at the equator of their respective spindles.

   (14) As the chromosomes reach the equator, ___________phase ends and _____phase begins.

3. *(15) Leave the chromosomes on the equator to represent _______phase.*

4. Unwrap the centromere from each replicated chromosome.

(16) As _________phase ______, the centromeres finally split and anaphase II begins.

5. Separate sister chromatids (now chromosomes) and move them to opposite poles.

   (17) In this phase, _______________, unreplicated chromosomes move to the poles.

6. Pile the chromosomes at the poles.

   (18)As ______________ begins, chromosomes arrive at the poles. Spindles break down. Nucleoli reappear. Nuclear envelopes form around each bunch of chromosomes as the chromosomes uncoil. Cytokinesis follows meiosis II.

   - *(19) What is the total number of nuclei and cells now present?*
   - *(20) How many chromosomes are in each?*
   - *(21) How many cells were present when the entire process began?*
   - *(22) How many chromosomes were present per cell when the entire process began?*
   - *(23) How many of the cells formed by the meiotic division just modeled are genetically identical?* (Assume that alternate forms of genes exist on homologues.)