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Catalog No. FB1992
Publication No.11013

Magnetic Meiosis Models

Biology Demonstration Kit

Introduction

All new cells are formed from previously existing cells. New cells are formed through cell division. Teach the mechanisms of meiosis with this simple and informative magnetic demonstration.

Concepts

- Meiosis
- Homologous chromosomes
- Crossing over

Background

Meiosis is the process of nuclear cell division that reduces the number of chromosomes in daughter cells by half. In order for two individuals to produce offspring with the same number and types of chromosomes as themselves, they must evenly reduce the number of their chromosomes. The resulting cells containing half the original number of chromosomes are known as *haploid cells*. The haploid cells of one individual combine with the haploid cells of a second individual to produce a new individual with the same number and types of chromosomes as the parents. Sexual reproduction allows for greater diversity in a population. When two individuals sexually reproduce, they bring forth a new individual with a unique mixture of genes. This variety of genes in a population allows for more diversity in characteristics and a stronger overall population. This strength is shown in a population's ability to adapt to changes in the environment and also to evolve.

Two processes must take place when cells, called *gametes,* are created for reproduction. First, the amount of genetic information must be cut in half so that chromosome numbers do not double in the next generation. Second, genetic variation must be added to the next generation of organisms. Events that occur during meiosis accomplish both of these requirements.

Meiosis occurs in reproductive tissues. In contrast to mitosis, in which only one division occurs, meiosis involves two cellular divisions, *meiosis I* and *meiosis II*. In meiosis, cells reduce their normal *diploid* (*di* = two in Greek) chromosome number by half to create four *haploid* (*hap* = one in Greek) cells.

Interphase occurs just before meiosis I begins. In this stage, the chromosomes are in the *chromatin* or thread-like form. This loose form is needed so that the DNA can replicate itself in preparation for cell division. In humans, this means that two versions of the gene, one form from the mother and one form from the father, are both replicated, creating two identical copies of each version. The result is four copies of each gene.

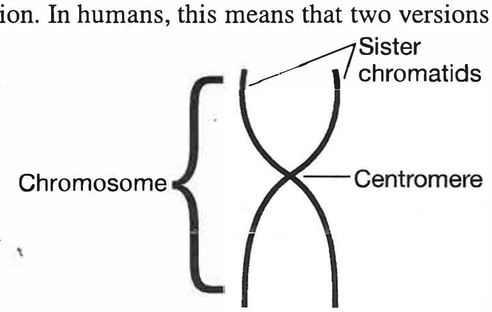

Figure 1.

Meiosis I

Meiosis I begins with *prophase I* where the duplicated threads of chromatin condense to form two identical sister chromatids. These sister chromatids attach to each other at a special point called the *centromere*. This whole structure is called a *chromosome* (see Figure 1). Also refer to Figures 2–5 as necessary.

There are two sets of each chromosome, one with two copies of the mother's genes and one with two copies of the father's genes. Also during prophase, the centrioles are copied. *Centrioles* control the migration of chromosomes to opposite ends of the cell during cell division. Two homologous chromosomes—that is, chromosomes that contain the same genes—move adjacent to each other to form a structure called a *tetrad* (*tetra* = four in Greek) (see Figure 2). While these two homologous chromosomes or homologs are aligned as a tetrad, they may exchange sections of similar genetic code with each other. This process is called *crossing over* because the homologs appear to "cross" each other as DNA strands are exchanged (see Figure 3). The exact location where the cross occurs is called the *chiasmata*. It is this

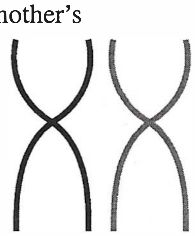

Figure 2.

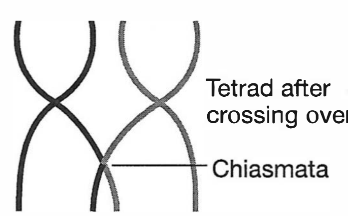

Figure 3.

exchange of genetic information that creates new genetic variation in living organisms. Crossing over does not occur between sister chromatids because they are identical and no genetic change would occur if identical pieces of DNA switched places. Also during prometaphase I, the spindle fibers attach to the centromeres and the nuclear membrane breaks apart.

In *metaphase I,* the nuclear membrane completely disappears and the genetically altered and attached chromosomes align in the middle of the cell. The orientation is random, with the homolog from either parent on a side. This means there is a 50–50 chance for the daughter cells to receive their mother or father's genetically altered chromosome.

During *anaphase I,* the altered homologous chromosomes separate and migrate to opposite ends of the cell. The chromosomes migrate when they are pulled towards opposite centrioles by spindle fibers that are attached between the centrioles and the centromere on each homolog.

Telophase I occurs when the chromosomes reach the centrioles on the opposite sides of the cell. Cytokenesis occurs at the same time. In animal cells, the cell membrane pinches inward to divide the cytoplasm and organelles into two cells. In plant cells, new cell walls form along the center of the cell creating two cells.

Meiosis II

Meiosis II begins with prophase II. During *prophase II,* the chromatin condenses (if it unraveled during interphase II), the centrioles are duplicated, and spindle fibers begin to reform.

In *prometaphase II,* the nuclear membrane begins to break apart and the new spindle fibers attach to the centromeres of the chromosomes. One spindle fiber from each centriole attaches to the centromere on each chromosome. Recall that there is just one copy of each chromosome in each cell but that each chromosome is composed of two sister chromatids.

Metaphase II is characterized by the alignment of the chromosomes along the center of the cell in preparation for the separation of the sister chromatids. Keep in mind, *the sister chromatids are no longer identical* because of the crossover events that occurred in prometaphase I.

In *anaphase II,* the centromere is split in half as the sister chromatids separate and move to opposite sides of the cell.

In *telophase II,* each sister chromatid moves toward a centriole located on the opposite side of the cell. At the same time cytokinesis occurs, splitting the cell in half again. A total of four new haploid cells have been produced from the original cell. Each haploid cell contains one sister chromatid, which includes a single complete set of genes.

Materials (for each demonstration)

Centromere magnets, 8*

Chalk or dry erase marker

Magnetic board

Magnets, round, blue, 32*

Magnets, round, red, 32*

**Materials included in kit.*

Safety Precautions

This demonstration is considered nonhazardous. Please follow all classroom safety guidelines.

Procedure

Draw a cell on the board using chalk or a dry erase marker. This cell should include centrosomes and a nuclear envelope. It should be modified throughout the demonstration to reflect the changes in each stage of meiosis. Refer to the *Background* section frequently for explanation of each step.

Meiosis I

Prophase I

1. Arrange the magnets to represent four chromosomes as shown in Figure 4 for Prophase I.
2. Draw the centrosomes separating to form spindle fibers.
3. Erase portions of the nuclear envelope to display its degradation.

Metaphase I

4. Line up the chromosomes in homologous pairs on the metaphase plate (see Figure 4, Metaphase I).
5. Sketch the centrosomes at opposite poles and the microtubules in between.

Anaphase I

6. Separate the homologous chromosomes towards opposite poles (see Figure 4, Anaphase I).

Telophase I & Cytokinesis

7. Alter the drawing of the surrounding cell to reflect the cleavage furrow beginning to form two separate cells (see Figure 4, Telophase I & Cytokinesis.

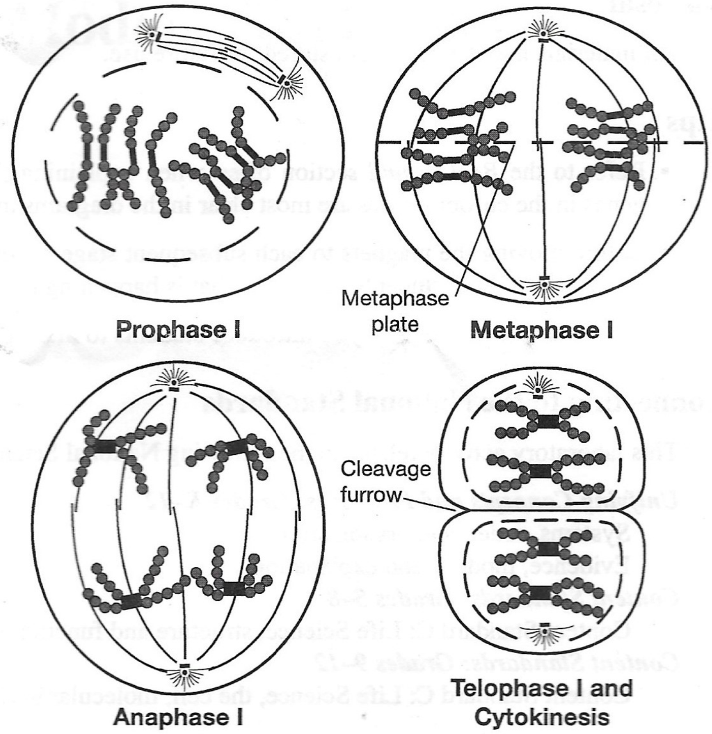

Figure 4. Meiosis I

Meiosis II

Prophase II

8. Separate into two cells. Draw spindle fiber formation in each cell (see Figure 5, Prophase II).

Metaphase II

9. Align chromosomes along the metaphase plate of each cell (see Figure 5/Metaphase II).
10. Using chalk, include centrosomes, microtubules, and kinetochore microtubules.

Anaphase II

11. The centromeres of sister chromatids separate and the chromatids move towards opposite poles (see Figure 5, Anaphase II).

Telophase II and Cytokinesis

12. Using chalk, begin to separate cells by drawing a cleavage furrow (see Figure 5, Telophase II & Cytokinesis).
13. Once the two cells officially separate, haploid daughter cells are formed.

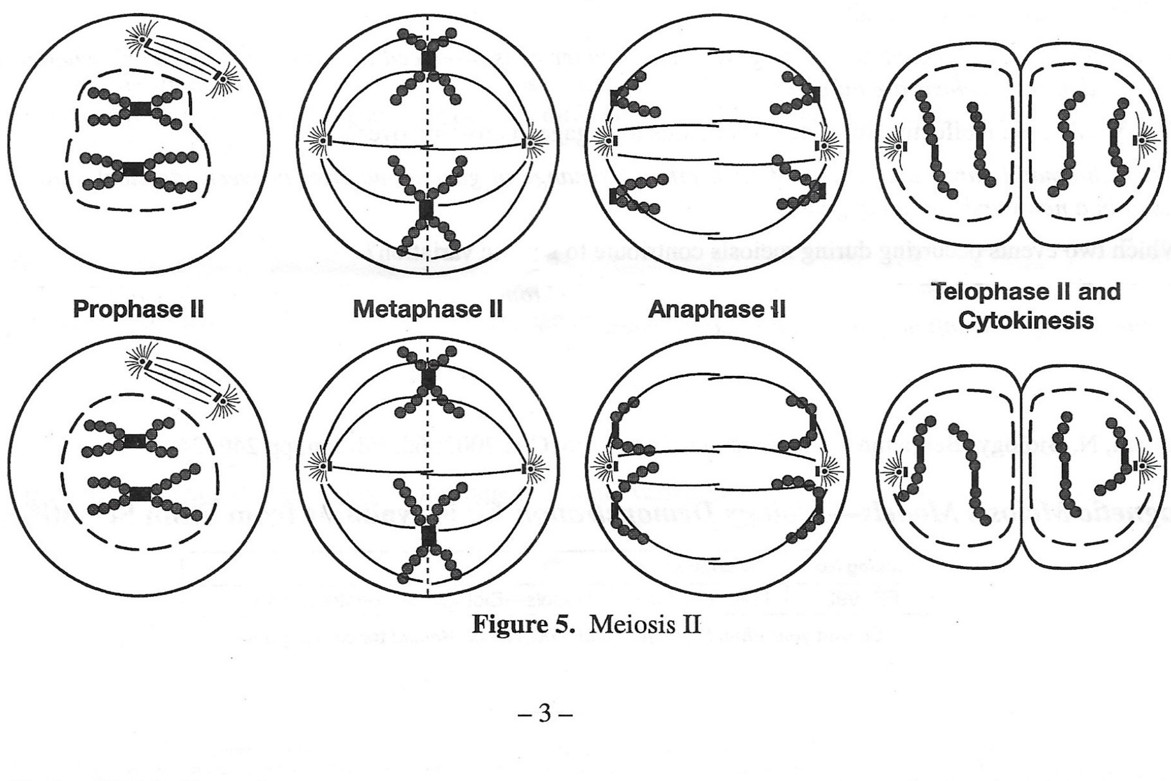

Figure 5. Meiosis II

Disposal

All materials may be saved and stored for future use.

Tips

- Refer to the *Background* section often when explaining this demonstration to the class. The exact moves of individual genes in the chromosomes are most clear in the diagrams in the *Procedure* section.
- Before moving the magnets to each subsequent stage of mitosis, trace the originals with colored chalk or dry erase markers. This will help students visualize what is happening throughout the overall process.
- This is an excellent activity to introduce students to meiosis as well as a review before an exam.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Content Standards: Grades 5–8
Content Standard C: Life Science, structure and function in living systems, reproduction and heredity
Content Standards: Grades 9–12
Content Standard C: Life Science, the cell, molecular basis of heredity, organization in living systems

Answers to Worksheet Questions

1. What is the purpose of meiosis?

   Meiosis is necessary for sexual reproduction. The process halves the chromosome number of gametes which compensates for the doubling that occurs during fertilization. Human sperm and ova each have a haploid set of 23 different chromosomes, one from each homologous pair.

2. In what respect is meiosis II similar to mitosis?

   In both meiosis II and mitosis sister chromatids separate during anaphase.

3. Critical-thinking question: Compare and contrast mitosis/meiosis. Prophase I of meiosis is different in one key respect from the events of prophase during mitosis. Explain this difference and how the daughter cells obtained during mitosis vs. meiosis are different as a result.

   No tetrads in mitosis equal no crossing over so daughter cells produced by mitosis are identical, whereas daughter cells produced during meiosis are different.

4. Why would it be ineffective for sister chromatids to engage in crossing over?

   Sister chromatids are exact copies of each other. Exchange of genetic material between identical chromatids would not result in a new combination of genes.

5. Which two events occurring during meiosis contribute to genetic variation?

   During Prophase I, crossing over between homologous chromosomes contributes to genetic variation. During metaphase I, independent orientation of tetrads also contributes.

References

Campbell, N. Biology; Benjamin Cummings: San Francisco, CA; 2002; 6th Edition. pp 240–241.

The *Magnetic Meiosis Models—Biology Demonstration Kit* is available from Flinn Scientific, Inc.

Catalog No.	Description
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Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.