SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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Student Materials

Learning Sequence Item:

1005

Mitosis and Meiosis

May 1996
Adapted by: William Leonard and Tom Hinojosa

Contents

This micro-unit was adapted by **William Leonard** (Clemson Univ., Clemson, S. C.) and
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Student Sheet

Science as Inquiry/
Science in Personal and Social Perspectives

Oops! There It Grows Again

What do replicating cells look like?

Overview:

What part of a plant is actively growing? Did you think of the roots? In this activity you will observe cells of the tip of an onion root. Your observations will serve as an example of what happens not only in plants, but in many other multicellular organisms, including humans. What needs to happen before a cell duplicates itself? What would a duplicating cell look like?

Procedure:

Work in groups as directed by your teacher. Scan the prepared slide of the onion root tip under appropriate magnification in order to locate a section which appears to be only one cell thick and for which you can see the insides of the cells clearly. Adjust your microscope as necessary to find one cell containing several rod-shaped bodies, the chromosomes. Sketch this cell and the chromosomes in the position they occur. Why are the chromosomes quite difficult to see?

Find another cell which has its chromosomes in a different position than the first cell you observed and sketch it as well. Repeat for as many as several differently-appearing cells. You may need to view more than one slide to find all the different phases of mitosis.

Compare the sketches of the cells you observed to a reference diagram of mitosis. Number each cell you sketched in the order you think represents the chronological sequence of development of these cells. Use a "1" for the first developed cell and so on. Share your numbered sketches with others to verify that you have gotten the order correct. Renumber your sketches if you are convinced by the group to do so. Have your teacher check your results.

Questions:

1. Why would root tip tissue be used for observing mitosis?

2. How does the process of mitosis help an organism grow in size?

3. What is happening overall to the number of chromosomes in the cells during mitosis?

Science as Inquiry

Chromosomes in Motion

How can you model the sequence of mitosis?

Overview:

By now you have observed images of cells in the process of mitosis. But as you know, chromosomes are difficult to actually observe in motion. In this activity you will create a model to more carefully study what's going on during mitosis. Created from evidence drawn from observations, a scientific model is a mental picture or representative physical system of a phenomenon, like mitosis. How closely can you model cellular mitosis? What's different between your model and the real thing?

Procedure:

Work in groups as instructed by your teacher. Use clay to create models of 4 chromosomes as they would appear during Prophase when the cell is beginning mitosis. Basically, you will create 4 chromosomes (2 red; 2 blue), each containing two sister chromatids. Use pipe cleaner pieces as centromeres to join two chromatids of similar color and length. Your chromosomes should look something like Fig. 1.

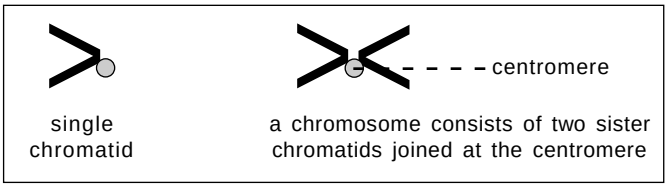

Fig. 1

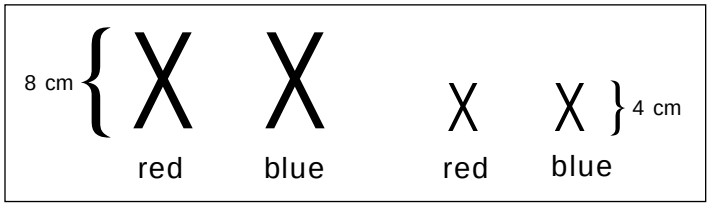

Fig. 2

The pairs of chromosomes which are approximately the same size represent homologous chromosomes. Each homologous chromosome contains genes for the same trait and on the same position of the chromosome. Note that one of each homologous chromosomes, such as the blue chromosomes, came originally from one parent and the other homologue (red) from the other parent. Make a sketch of the chromosomes you made and label it appropriately.

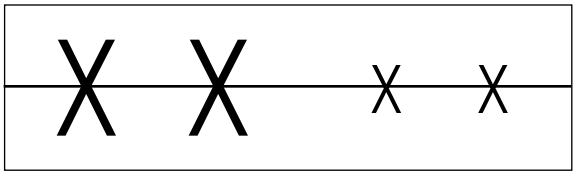

Fig. 3

Use a sheet of paper to represent the nucleus of a cell. Lay the chromosomes randomly on the paper. The chromosomes move and become arranged along the cell's midplane, called the equator, such that one sister chromatid is on the north side of the equator and the other chromatid is on the other side of the equator. Simulate this on the sheet of paper with your chromosome models. Sketch this arrangement and label it appropriately. The arrangement should look something like Fig. 3. This arrangement is called Metaphase.

Anaphase begins with the separation of the centromeres followed by the separation of the chromatids in each pair. The chromatids are pulled away from each other along spindle fibers towards opposite ends,

or poles, of the cell. Simulate these events with your model. Draw on the paper the two poles and spindle fibers using small circles to represent the poles and drawn lines from each chromatid to the respective poles to represent spindle fibers. Move the separated chromatids which are now called chromosomes.

In telophase the spindle fibers disappear and a nuclear membrane forms around each set of chromosomes. How can you simulate this with your model? You may choose to cut the paper in half along the equator to represent the formation of two new cells and/or draw a circle around the chromosomes on each half sheet to represent the newly formed cell membrane. What's the difference between the chromosomes in one of the new cells versus the other new cell?

Questions:

1. What happens next during the subsequent interphase? How could you simulate it with your model? How would you simulate and repeat the entire process to produce more cells?

2. During anaphase, did each homologous pair move to opposite poles—or did one of each of the sister chromatids move to opposite poles?

3. How does the number of chromosomes in the new cells compare to the number of chromosomes in the original cell?

4. What are the two main purposes of mitosis?

5. Name a specific cell type in your body where you would expect mitosis to be occurring right now.

Student Sheet

Science as Inquiry

So That's Mitosis!

What are the important events of mitosis?

Overview:

Can you describe the important events of mitosis yet? How could you help someone else become confident in their understanding of mitosis? This group activity is intended to help clear up your remaining questions or misconceptions about the overall process of mitosis.

Procedure:

Work in groups as instructed by your teacher. Gather and share with others in your group any materials you have including your own work about the process of mitosis. Have someone in the team read aloud the following passage while the others follow it on the diagrams. The team should try to make sense of what is written in the paragraph. Use all you know about mitosis to answer the questions at the end.

Mitosis is only a small portion of the overall cell cycle. Most of the cell's life is spent in interphase. During interphase, the cell carries out its normal functioning, whatever is the job of that cell. Also during interphase, the cell grows in size and manufactures DNA to make more chromosomes.

Cell division consists of mitosis (division of the chromosomes) and cytokinesis (the actual separation of the cell into two new cells). Cell division only takes up about 10% of the life of the cell, with the remaining 90% in interphase. This includes the replication of chromosomes into homologues, each homologue having a pair of sister chromatids.

When mitosis begins, the chromosomes thicken enough so that the paired homologues and their corresponding sister chromatids are visible through a microscope (prophase). The chromosomes then move to and line up on the equator of the cell (metaphase). A spindle fiber fro each pole attaches to each of the sister chromatids of every homologue. One sister chromatid moves to one pole and the other sister chromatid moves to the other pole (anaphase). One of each homologue's sister chromatid clusters at the poles and preparations are made for the cell to separate into two cells (telophase). The cell membrane reforms around each of the two new cells and the two new cells actually separate (cytokinesis). Now there are two, independently functioning cells which will begin the growth process of interphase.

The cell cycle is completed many times, each time producing two cells from one. Because one of each of the sister chromatids of each homologous chromosome is taken into each new cell, the same genes are represented in each cell. Thus, the two daughter cells as well as the mother cell appear and function identically. It is important to recognize that stages such as prophase and metaphase are just names which represent the events at that particular time. Mitosis is a continued and gradual process, just as is adolescence. The names of the stages are simply used as reference points for the study of mitosis.

Discuss the events of the cell cycle among your group until everyone understands the above passage. Write an answer to the following questions about the cell cycle.

Questions:

1. What is the cell cycle?

2. What two important processes occur in the cell during interphase?

3. What happens generally during mitosis?

4. What happens to the chromosomes during prophase?

5. What happens to the chromosomes during metaphase?

6. What happens to the chromosomes during anaphase?

7. What happens to the chromosomes during telophase?

8. What happens to the cell during cytokinesis?

9. How many pairs of each homologous chromosomes are present during prophase?

10. How many chromosomes are present in the cell after cytokinesis?

11. Why do cells need to divide instead of increasing in size?

12. What are other reasons cells need to divide?

Student Sheet

Science as Inquiry/
Science in Personal and Social Perspectives

Caught in the Act

What do cells and chromosomes look like during meiosis?

Overview:

What's going on in meiosis? You know that the cells are moving around and replicating chromosomes, but how does the overall process produce cells that are genetically ready for sexual reproduction? If two cells are to combine in order to create a new individual, how many chromosomes does each sex cell have to contribute and how does this situation come about? In this activity, you will catch some cells in the act of meiosis in order to observe what the chromosomes are doing.

Procedure:

Work in groups as directed by your teacher. Scan the prepared slide of Ascaris (an adult worm) under appropriate magnification in order to locate a section which appears to be only one cell thick and for which you can see the insides of the cells clearly. Adjust your microscope as necessary to find one cell containing several rod-shaped bodies, the chromosomes. Sketch this cell and the chromosomes in the position they occur. Chromosomes become enlarged during meiosis, but still may be a challenge to see.

Find another cell which has its chromosomes in a different position than the first cell you observed and sketch it as well. Repeat for as many as several differently-appearing cells. You may need to view more than one slide to find all the different phases of meiosis.

Compare the sketches of the cells you observed to a reference diagram of meiosis. Number each cell you sketched in the order you think represents the chronological sequence of development of these cells. Use a "1" for the first developed cell and so on. Share your numbered sketches with others to verify that you have gotten the order correct. Renumber your sketches if you are convinced by the group to do so. Have your teacher check your results.

Questions:

1. Why would testicular tissue be used for observing meiosis?

2. How does the process of meiosis help an organism produce sex cells?

3. What is happening overall to the number of chromosomes in the cells during meiosis?

Science as Inquiry

The Significance of Sexual Reproduction

What are the important events of meiosis?

Overview:

Still fuzzy about meiosis? How could you help someone else become confident in their understanding of meiosis? This activity is intended to help clear up your overall understanding of the process and significance of meiosis.

Procedure:

Part 1. Work in groups as directed by your teacher. One member of the group should read aloud the following paragraph, while the others follow it on the diagram your teacher will provide. You may also refer to your own sketches and observations of meiosis in previous activities. The team should try to make sense of what is written in the paragraph and answer the questions which follow it.

Meiosis is divided into two sequences: Meiosis I and Meiosis II. During interphase in meiosis I, the chromosomes are replicated and become large enough to be visible under a classroom microscope. Segments of homologous chromosomes can become exchanged, a process called crossing over. This is a possible source of variation of offspring. In metaphase I, the chromosomes line up at an imaginary equator. Each member of a pair of chromosomes (a homologue) is also made up of two sister chromatids. This gives the appearance of four chromosomes of the same kind. In meiosis I each homologous chromosome of each chromosome pair stays together until anaphase I. During anaphase I, the homologous pairs separate, one of each pair going to one pole and the other going to the opposite pole. Each of these different homologues will eventually end up in a different sperm or egg cell. Anaphase I is one of the two most significant events in meiosis. Why? Because if an individual is heterozygous for a trait that is located on a given pair of homologous chromosomes, different alleles for this trait will appear in the sperm or egg cells. This is one of the evolutionary causes of variation the next generation.

Part 2. A different student should read the following passage while, once again, the team follows along using a diagram of meiosis:

When meiosis II begins, the homologous pairs with their sister chromatids have separated into different cells. The major event in meiosis II occurs during anaphase II. This is when the sister chromatids separate, producing only one sister chromatid from each original chromosome pair in each new egg or sperm. Note that at the end of all of meiosis, each of four resulting cells has only one chromosome and this chromosome is not paired with its homologue. In the human, sperm and egg cells have only 23 chromosomes. All other human cells, including a newly formed fertilized egg, have 23 pairs of chromosomes (46). Another function of meiosis II is to produce lots of sperm or egg cells.

Questions:

Part 1.

1. What is significant about prophase I?

2. What is significant about anaphase I?

3. What is the evolutionary significance of meiosis I?

Part 2.

1. If each human sperm and egg had the same number of chromosomes as all other cells, how many chromosomes would be present in a fertilized egg? What is the problem with this?

2. Why does meiosis II separate the pair of homologous chromosomes into different cells?

3. Why does meiosis II separate the sister chromatids into different cells?

Science as Inquiry

Chromosomes on Parade

How can you model the sequence of meiosis?

Overview:

It is sometimes difficult to visualize in three dimensions the changes in the chromosomes during meiosis. In this activity you will create a model to simulate the process in three dimensions. To simplify the model somewhat, you will work only with two pairs of chromosomes instead of an entire set. (For example, a human has a total of 23 pairs of chromosomes.)

Procedure:

Work in groups as directed by your teacher. Make a long roll about the width of a pencil with each color of clay. Pinch the clay colors into 2 sections 8 cm. in length and 2 sections 4 cm. in length. These will be the chromatids. Use pieces of pipe cleaner as centromeres to join two chromatids of similar color and length. The result will be four bodies (chromosomes) each containing two sister chromatids, such as shown in Fig. 1.

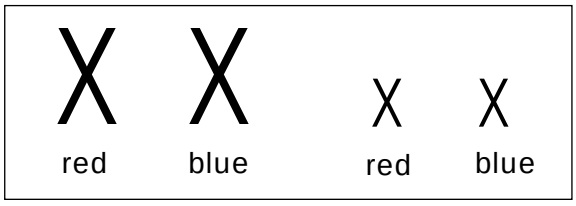

Fig. 1

Lay the chromosomes randomly on the sheet of paper. This sheet will represent the nucleus of a cell which produces eggs or sperm. Place the similar-sized red and blue chromosomes next to each other so that they actually touch. These represent homologous chromosomes each containing genes for the same trait and on the same position of the chromosome. Note that one of each homologous chromosomes, such as the blue chromosomes, came from one parent and the other homologue from the other parent. Record observations of your chromosomes at this point. What phase does this portion represent?

To demonstrate crossing over, pinch off a section of one chromatid form one homologous chromosome (a red one) and replace it with a similar-sized piece from the same part of the other (blue) homologous chromosome. What is the significance of crossing over?

Move the homologous pairs to an imaginary equatorial line on the paper. Orient them horizontally along the equator so that one homologue (with both sister chromatids) is to the north of the equator and one to the south as shown in the illustration which follows. Record observations of your chromosomes at this point. What phase does this portion (shown in Fig. 2) represent?

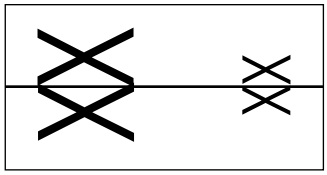

Fig. 2

Make a small circle at the top and bottom centers of the page. This will symbolize the north and south poles respectively. Move the two chromosomes on either side of the equator to their respective poles. Cut the paper in half along the equator. There are now two cells, each containing one homologous chromosome from each chromosome pair. This marks the end of meiosis I. Be sure to record your observations of what has happened so far.

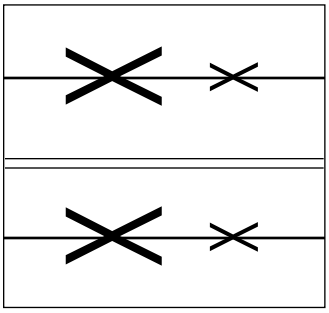

Fig. 3

Place a small circle at the other end of each of the two halves of the paper to symbolize the north and south poles of the new cells beginning meiosis II. Keep the chromosomes on the papers as they were at the end of meiosis I. Draw a line across the center of each of the two new cells to represent their equators. Place the chromosomes horizontally along the equator so that one sister chromatid is in the upper half (north) of the nucleus and the other chromatid is on the south side as shown in the illustration below. Record observations of your chromosomes at this point. What phase does this portion (Fig. 3) represent?

Detach the pipe cleaners from all the sister chromatids. Move the two sister chromatids on the north side of the equator to the north pole and the ones on the south side to the south pole. Cut the two halves of the paper representing the nucleus again in half, representing the nuclei of what is now four cells. Note that each new cell contains two different chromosomes. This represents the formation of eggs or sperm cells at the end of meiosis II. Another name for sperm and egg cells is gamete. Note your observations of the four gametes that were produced in this activity.

Questions:

1. How does the number of chromosomes in the first cell compare to the number of chromosomes in the four final cells? How do the four gametes compare to each other?

2. What determines to which pole a given chromosome will go as the cell divides? In sexual reproduction, what happens to the chromosome number after fertilization?

3. Why do sexually reproducing organisms need to carry out meiosis?