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Lab 6
Cell Division, Mitosis, and Meiosis

Introduction: Connecting Your Learning

All cells, including those in the human body, have a cell cycle. This cycle involves preparing for cell division and eventually dividing. Coupled with cell division is nuclear division. Nuclear division, either mitosis or meiosis, is the process by which the nucleus of a cell divides. **Mitosis** results in two identical daughter cells; each containing the same number of chromosomes as the parent cell. (In humans, this is 46.) In comparison, **meiosis** results in four daughter cells, each containing half the number of chromosomes as the parent cell (23 in humans). Meiosis is essential to sexual reproduction and the inheritance of genes. This lab examines cell division and nuclear division.

Resources and Assignments	
Multimedia Resources	Virtual Microscope
Required Assignments	Lesson 7 Lab 6
Laboratory Materials	None

Focusing Your Learning

Lesson Objectives

By the end of this lesson, you should be able to:

1. Describe the molecular structure of DNA.
2. Identify and describe the stages of mitosis, meiosis, and cell division.
3. Distinguish between cell division and mitosis.
4. Identify the stages of mitosis in onion root tip cells, observed under a microscope.
5. Explain the process of crossing over.

Background Information

Deoxyribonucleic acid (DNA) is an important component that determines who an individual is and what he or she looks like. But DNA is much more complex than simply defining the external features of an individual. DNA is responsible for controlling the complex processes involved in living organisms.

DNA is composed of a coiled double helical strand of ***nucleotides*** that are bonded together in a specific pattern. The backbone of the double helix is composed of linked deoxyribose sugars and phosphorus atoms, and cross-links form between two *nitrogenous bases*. The four nitrogenous bases consist of ***Adenine*** (A), ***Guanine*** (G), ***Cytosine*** (C), and ***Thymine*** (T). An image of a DNA molecule is seen below. Note that the sugar-phosphate backbones are the blue ribbons, and the nitrogenous bases are the cross-links seen in shades of green and orange.

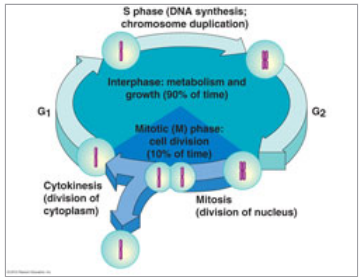
Click on image to enlarge.

Three adjacent bases compose what is known as a ***codon***, which codes for a particular amino acid. The sequence of bases thus determines the sequence of amino acids for different proteins. These proteins eventually are demonstrated as traits in the organism.

It is important to note that DNA does not reside by itself in the nucleus. Instead, it is associated with proteins. When a cell is not dividing, the DNA and associated proteins are uncondensed in the nucleus into a structure called **chromatin**. When the chromatin condenses and coils on itself, the structure is called a ***chromosome***.

All human cells that are not sex cells contain two sets of 23 chromosomes (for a total of 46 chromosomes per cell in human cells), and are called ***diploid*** cells. When cells divide, if the daughter cells are to be functional, they must possess all genetic material found in the parent cell. Therefore, the DNA of the parent cell must be duplicated prior to cell division. For all body cells except sex cells (e.g., sperm or eggs in humans), the process by which cells reproduce is called ***mitosis***. Mitosis plays an important role in cell growth, tissue repair, and asexual reproduction.

Compared with body cells, sex cells only contain one set of chromosomes (23 chromosomes in humans), and are called ***haploid*** cells. Haploid cells are formed through a process called meiosis. In the process of meiosis, which is explained in additional detail below, chromosome numbers from parent cells are halved, yielding one pair of chromosomes (for a total of 23 chromosomes per cell).



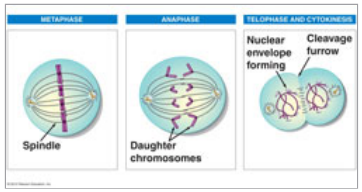
Click on image to enlarge.

Organismal cells undergo a cycle of events, beginning at the point when the cell first forms from a parent cell, through the time when it divides into two daughter cells. This cycle is called the cell cycle. Most of a cell's life is spent in interphase, which is the longest phase of the cell cycle. This is the stage where the cell is metabolically active and performs its normal functions. Several stages of interphase are seen above, which include the following:

G1 – The cell grows and is metabolically active. Organelles are duplicated in preparation for the S stage. In this stage, the DNA is present in the form of chromatin.

S – The DNA and chromosomes are replicated but are not distinguishable because they are still in the form of chromatin fibers.

G2 – The cell continues to grow and is prepared for cell division.



Click on image to enlarge.

Once a cell is ready to divide, the process of mitosis begins. Mitosis consists of four stages: prophase, metaphase, anaphase, and telophase. A visual representation of the events that occur during each stage is seen above.

During ***prophase***, the chromatin fibers coil and condense forming chromosomes that are now visible with a compound light microscope. The chromosomes are held together at the ***centromere***, a pinched region of the chromosome. While connected, each individual chromosome is referred to as a ***sister chromatid***. During prophase, the mitotic spindle forms as outgrowths from the centrosomes, the nuclear envelope begins to disappear, and the centrosomes move to the poles.

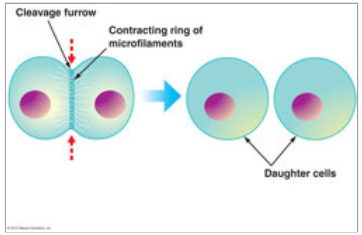
In the next stage of mitosis, ***metaphase***, the sister chromatids line up at the center (equator) of the cell. This area is called the ***metaphase plate***. In addition, the mitotic spindle is completely formed. These fibers extend from the perpendicular to the plane of the centrioles and attach to the centromeres of the sister chromatids. Chromosomes move along these fibers during the subsequent stage of mitosis.

In ***anaphase***, the centromeres split, and one copy of each chromosome (chromatid) is pulled to each centriole due to the contraction of the spindle fibers. Once the chromatids are separated, they are called chromosomes again.

In ***telophase***, separated chromosomes have migrated to opposite ends of the cell, the nuclear envelopes form, chromosomes uncoil, and the mitotic spindle disappears. In this stage, the division of the nuclear material has been completed, along with division of the cytoplasm. ***Cytokinesis*** is the name for the process by which the cytoplasm is divided. This process occurs during telophase, along with the process of nuclear division. It is important to understand the difference between cytokinesis (division of cytoplasm) and mitosis (nuclear division). Nuclear division results in the separation of the information within the nucleus, specifically the replicated chromosomes containing the DNA. In

comparison, cell division (***cytokinesis***) refers to the formation of two cells from one, or the splitting of the cell and cytoplasm. While the two are related, they are separate processes that occur simultaneously.

In animal cells, ***cleavage furrows*** start to appear during telophase. The original cell pinches off into two daughter cells, starting with an indentation at the cell equator called the cleavage furrow. The furrow deepens as microfilaments in the cytoplasm contract, pinching the parent cell into two cells. This process does not occur in plant cells. Rather, in plant cells, a ***cell plate*** forms from cell wall material that collects in the middle of the cell. The cell plate grows outward until its membrane fuses with the parental cell wall, resulting in the formation of two daughter cells. The comparison of these two processes can be seen in the images below. Animal cytokinesis is seen in the image on the left, and plant cytokinesis is seen in the image on the right.



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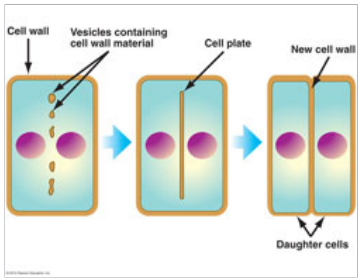
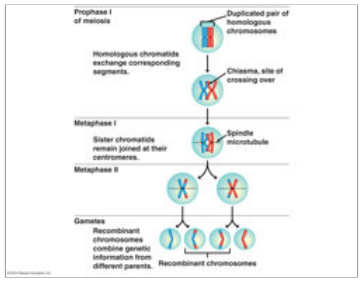


Click on image to enlarge.

Meiosis

As discussed previously, cells involved in the process of sexual reproduction also must divide; however they do so through a process called meiosis. The steps of cellular division of meiosis resemble the steps of mitosis but there are two distinguishing characteristics of meiosis. The first difference between mitosis and meiosis relates to the number of cell divisions and resultant chromosome number found in cells. Sex cells undergo two cell divisions instead of the single division that occurs in mitosis. This results in haploid daughter cells that contain half the number of chromosomes as the diploid, parent cell. The process starts with a single diploid (2n) cell and ends with four haploid (n) cells. Remember that the process of mitosis results in diploid daughter cells each containing the same number of chromosomes as the parent cell.

The second distinction between mitosis and meiosis is that genetic material is exchanged between chromosomes in cells undergoing meiosis. This process where chromosomes exchange material is called crossing over. The process of crossing over, as seen in the image below, leads to an increase in genetic diversity.



Click on image to enlarge.

In this laboratory, the concepts of mitosis and gamete frequency will be investigated. In the first part of the lab, a visual model will be developed, detailing each stage of the cell cycle for a typical cell undergoing mitosis. This virtual exercise will be a drag and drop activity.

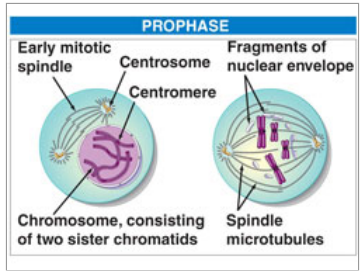
In the second step of the laboratory, microscope slides of an onion root tip and blastula cells are analyzed to count the number of cells observed in each stage of the cell cycle. Then, the percentage of time that cells spend in each stage will be calculated.

Cell Mitosis Examples

Procedures

PART I: Building models of the cell cycle stages

1. Review the stages of the cell cycle to review the major events that occur during each stage. Also, the student should reference the image below which shows some of the visual differences between the stages of mitosis.



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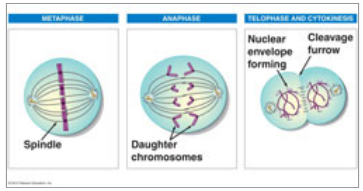


Click on image to enlarge.

2. Using the model cells located above, the pool of chromosomes, spindle fibers, and centrosomes, build a visual model of each stage of the cell cycle. Drag the components into the cells below for each stage until all components are in their correct positions. Finally, provide each stage with the correct name from the pool of cell cycle stages.

You need javascript enabled in order to see this flash file.

PART II: Identifying and counting cells

For this section of the lab, you will view a micrograph of an onion root tip that shows cells in the different stages of the cell cycle. Before beginning the steps below, view the following micrograph of an onion root tip to become familiar with the different stages of the cell cycle, as seen in a micrograph of a cell. Once the micrograph is opened, use the mouse to scroll over a cell. Once the cursor is placed over a cell that should be identified, click on the cell and then identify the stage of mitosis for the cell. Immediate feedback will be provided. Repeat this procedure for all of the cells that are identified on the micrograph. Completing this practice exercise will allow the student to become proficient in correctly identifying cells with their respective stage of mitosis.

I. Using the Virtual Microscope, view an image of an onion root tip and count the number of cells that are in each stage of the cell cycle. As a reminder, the cell cycle consists of the following stages: interphase, prophase, metaphase, anaphase, and telophase/cytokinesis. It may be helpful to record the data in a table similar to the one below to assist in compiling results.

	Interphase	Prophase	Metaphase	Anaphase	Telophase	Total
Number of cells in slide 1	1	2	3	4	5	6
Number of cells - slide 2	7	8	9	10	11	12
Number of cells - slide 3	13	14	15	16	17	18
Number of cells - slide 4	19	20	21	22	23	24
Average number of cells/slide	25	26	27	28	29	30
Percent of cells	31	32	33	34	35	36

II. Repeat Step 1 three more times, each time selecting a different slide from the virtual microscope. Count the cells observed in each stage of the cell cycle for each slide and record the information.

III. After the counts have been completed for all four slides, total the number of cells in each stage and find the average. To find the average, add up the number of cells observed in each stage and divide this number by four. Using the table above as a reference, to calculate the average number of cells in interphase, add the numbers found in locations 1, 7, 13, and 19 and then divide this number by four. Enter that result into location 25 above. Repeat this process for each column (stage in the cell cycle).

IV. Finally, calculate the percent of time that cells are actually in each stage of the cell cycle. To determine the percentage of time cells are in each stage, divide the average number of cells in each stage by the total average number of cells in each field of view. Using the table above as a reference, first determine the total average number of cells by adding across the row entitled Average Number of Cells/Slide. Add up locations 25, 26, 27, 28 and 29. Enter the total obtained into location 30 above. To calculate the percentage of time cells were in telophase, divide the number in location 29 by the number in location 30, then multiply this number by 100 to obtain the percentage. The equation for calculating this percent is shown below.

$$\text{Percent of time spent in Interphase} = \frac{\text{Average number of cells in Interphase}}{\text{Total Average number of cells}} \times 100 =$$

Assessing Your Learning

Warning: You are expected to submit your own, individual work. Using work completed by anyone other than yourself is plagiarism. This includes resources found on internet sites. Posting assessments on an unauthorized web site, soliciting assessment answers or the acquisition of assessments, assessment

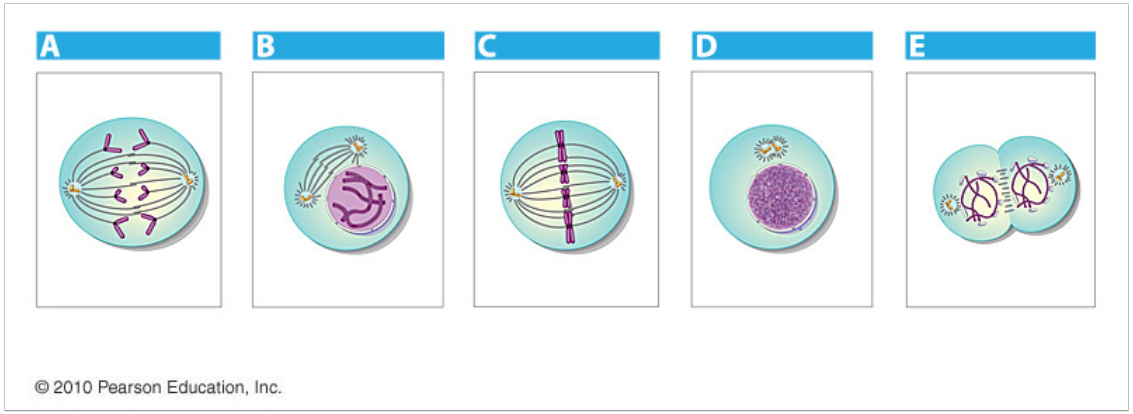
answers, and other academic material is cheating. Cheating and/or plagiarism will result in a failing grade for the course.

Compose answers to the questions below in Microsoft Word and save the file as a backup copy in the event that a technical problem is encountered while attempting to submit the assignment. Make sure to run a spell check. Copy the answer for the first question from Microsoft Word by simultaneously holding down the Ctrl and A keys to select the text, and then simultaneously holding down the Ctrl and C keys to copy it. Then, click the link on the Lab Preview Page to open up the online submit form for the laboratory. Paste the answer for the first question into the online dialog box by inserting the cursor in the box and simultaneously holding down the Ctrl and V keys. The answer should now appear in the box. Repeat this process for each question. Review all work to make sure that all questions have been completely answered and then click on the Submit button at the bottom of the page.

LAB 6

1. Why are spindle fibers important for mitosis? (5 points)
2. State the four bases that make up DNA. (4 points)
    a.
    b.
    c.
    d.
3. What are the two base pairs? (2 points)
    a.
    b.
4. Answer the following questions:
    a. Define the term crossing over. (5 points)
    b. Explain why crossing over is important in meiosis. (5 points)
5. What are the two main differences between mitosis and meiosis? (4 points)
    a.
    b.
6. Answer the following questions:
    a. Explain the difference between mitosis and cytokinesis. (3 points)
    b. When does mitosis occur during the cell cycle? (1 point)
    c. When does cytokinesis occur during the cell cycle? (1 point)
7. Explain the differences that occur during cytokinesis of plant and animal cells. (5 points)

8. Refer to the images below, labeled A through E. Each image details a stage of the cell cycle for a cell undergoing mitosis. Place the images in correct order by placing the letters in the correct sequence, according to the stages of mitosis. (5 points)



a. Interphase

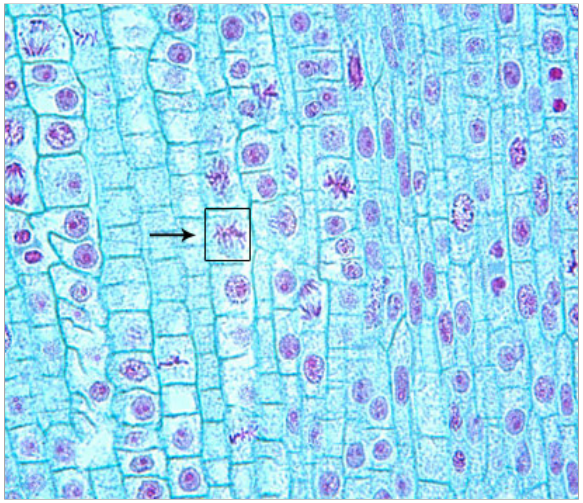
b. Prophase

c. Metaphase

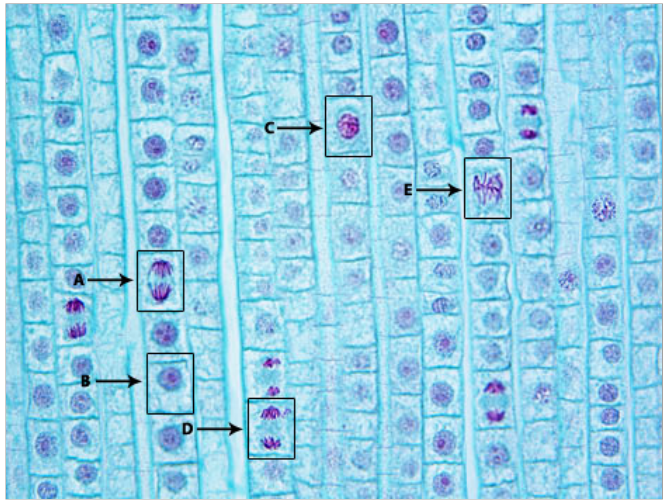
d. Anaphase

e. Telophase/cytokinesis

9. Refer to the image below. What stage of mitosis is the cell below undergoing? (1 point)



10. Refer to the images below. Place the cells identified with the letters A through E in correct order for a cell undergoing mitosis. (5 points)



a. Interphase

b. Prophase

c. Metaphase

d. Anaphase

e. Telophase/cytokinesis

11. Which type of cell division is involved with healing a cut on the skin? Please explain why. (6 points)

12. What three components make up the structure of DNA? (3 points)

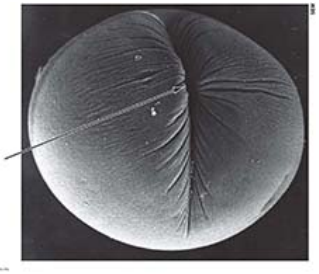
a.

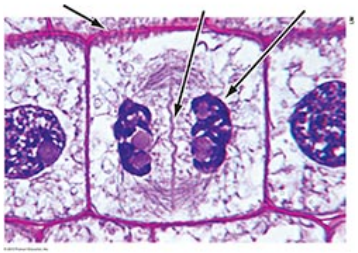
b.

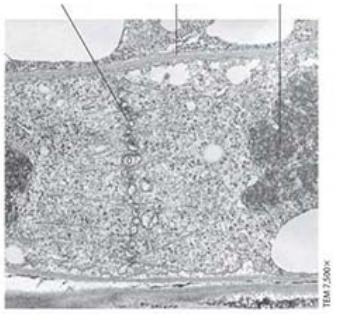
c.

13. Distinguish the differences between chromatin, chromosomes and sister chromatids? (6 points)

14. Refer to the images to identify cytokinesis either by the process of a cleavage furrow or cell plate. (3 points)

a. 

b. 

c. 

15. Describe the cell cycle, and explain the approximate percentage of time the cell is in each stage. (6 points)
16. Are haploid cells formed during mitosis or meiosis? Explain your answer. (4 points)
17. Why is it important that haploid gametes be produced in animals? (4 points)
18. During which stage of meiosis do sister chromatids separate? (2 points)
19. **(Application)** How might the information gained from this lab pertaining to mitosis and meiosis be useful to you in your everyday life or to a healthcare professional? (20 points)

    Key components of critical thinking and application include the following:

    1. Demonstrates application and comprehension of the scientific principles.
    2. Displays competence in applying scientific knowledge to your personal or professional life.
    3. Relevant content is supported by facts, data, and detailed examples.
    4. The application paragraph is organized and structured.

Critical Thinking and Application of Information	0%	1-49%	50-99%	100%
Is your application a detailed description of how the lab content is relevant to your life?	Application did not adequately demonstrate application or comprehension of the scientific principles. Did not include detailed examples, facts or data. Or the application was not included.	A few areas of the application demonstrated some application and comprehension of the scientific principles by applying the knowledge to the student's personal or professional life, but lacked detailed examples to support the content provided. Application demonstrated some organization and structure within the paragraph.	Most areas of the application demonstrated evidence of critical thinking and comprehension of the scientific principles. Displayed good competence and the relevant content was supported with good use of examples that apply the concepts and describe how the information will be relevant and useful to the student's personal or professional life. The application paragraph is primarily presented in an organized and structured manner.	Application included a complete and detailed description of how the concepts are relevant and useful or applicable to the student's personal or professional life. The application includes detailed examples and reveals insight into the scientific principles. The application paragraph maintains a strong sense of purpose and organization throughout.

Have You Met The Objectives For This Lesson?