Cell Cycle, Mitosis and Meiosis

Grade 7

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Science Methods
December 3, 2007

Lesson Schedule

Objective:

Day 1:

-Notes on Cell Cycle
    *Four stages (S stage, G1, M, G2)
    *Function and process
-Notes on Mitosis
    *Prophase
    *Metaphase
    *Anaphase
    *Telophase

Day 2:

-Finish up Mitosis notes
-Introduce Meiosis
    *Function and process
-Short video
    *Worksheet to go along with video

Day 3:

-Lab activity
    -Replicate Mitosis/meiosis with string and chromosomes (beads)
    -Look at prepared slides under microscope
    -Using an onion root, find and draw the different stages on mitosis
        *Worksheet

Day 4:

-Break kids into groups
-Have each group make a poster board of one of the phases in mitosis or meioses
    *String = Cell Wall
    *Macaroni noodles = Chromosomes
    *Licorice Strings = Spindle Fibers
    *Beads and other objects = Other Organelles

Day 5:

-Play Mitosis/meiosis Jeopardy
    *Prizes awarded to winning team

Grading

Grading will be based on mainly participations. Students will also be graded on the video worksheet, Onion root worksheet, and Mitosis/meiosis poster boards.

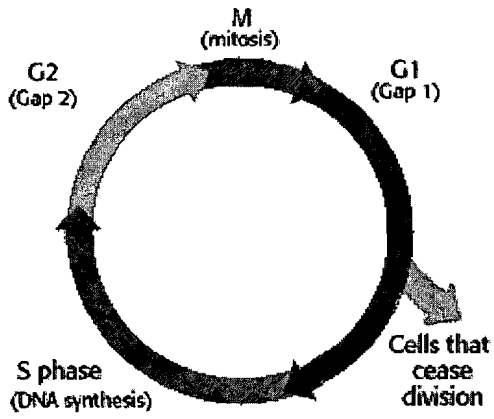
Video Worksheet	_____/5
Onion Root Drawing/Mitosis	_____/5
Poster board 5 pts Creativity 10 pts Mitosis phase representation	_____/15
Participation (2pts per day)	_____/10
Total	_____/35

THE BIOLOGY PROJECT • CELL BIOLOGY

The Cell Cycle & Mitosis Tutorial

The Cell Cycle

Stages of the cell cycle



The cell cycle is an ordered set of events, culminating in cell growth and division into two daughter cells. Non-dividing cells not considered to be in the cell cycle. The stages, pictured to the left, are G1-S-G2-M. The G1 stage stands for "GAP 1". The S stage stands for "Synthesis". This is the stage when DNA replication occurs. The G2 stage stands for "GAP 2". The M stage stands for "mitosis", and is when nuclear (chromosomes separate) and cytoplasmic (cytokinesis) division occur. Mitosis is further divided into 4 phases, which you will read about on the next page.

Regulation of the cell cycle

How cell division (and thus tissue growth) is controlled is very complex. The following terms are some of the features that are important in regulation, and places where errors can lead to cancer. Cancer is a disease where regulation of the cell cycle goes awry and normal cell growth and behavior is lost.

Cdk (cyclin dependent kinase, adds phosphate to a protein), along with cyclins, are major control switches for the cell cycle, causing the cell to move from G1 to S or G2 to M.

MPF (Maturation Promoting Factor) includes the CdK and cyclins that triggers progression through the cell cycle.

p53 is a protein that functions to block the cell cycle if the DNA is damaged. If the damage is severe this protein can cause apoptosis (cell death).

1. p53 levels are increased in damaged cells. This allows time to repair DNA by blocking the cell cycle.
2. A p53 mutation is the most frequent mutation leading to cancer. An extreme case of this is Li Fraumeni syndrome, where a genetic a defect in p53 leads to a high frequency of cancer in affected individuals.

p27 is a protein that binds to cyclin and cdk blocking entry into S phase. Recent research (*Nature Medicine* 3, 152 (1997)) suggests that breast cancer prognosis is determined by p27 levels. Reduced levels of p27 predict a poor outcome for breast cancer patients.

Previous | Next

THE BIOLOGY PROJECT • CELL BIOLOGY

The Cell Cycle & Mitosis Tutorial

Mitosis

What is (and is not) mitosis?

Mitosis is nuclear division plus cytokinesis, and produces two identical daughter cells during prophase, prometaphase, metaphase, anaphase, and telophase. Interphase is often included in discussions of mitosis, but interphase is technically not part of mitosis, but rather encompasses stages G1, S, and G2 of the cell cycle.

Interphase & mitosis

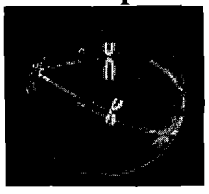
Interphase

The cell is engaged in metabolic activity and performing its prepare for mitosis (the next four phases that lead up to and include nuclear division). Chromosomes are not clearly discerned in the nucleus, although a dark spot called the nucleolus may be visible. The cell may contain a pair of centrioles (or microtubule organizing centers in plants) both of which are organizational sites for microtubules.

Prophase

Chromatin in the nucleus begins to condense and becomes visible in the light microscope as chromosomes. The nucleolus disappears. Centrioles begin moving to opposite ends of the cell and fibers extend from the centromeres. Some fibers cross the cell to form the mitotic spindle.

Prometaphase

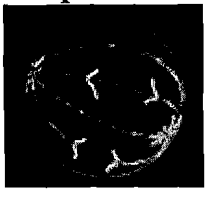


The nuclear membrane dissolves, marking the beginning of prometaphase. Proteins attach to the centromeres creating the kinetochores. Microtubules attach at the kinetochores and the chromosomes begin moving.

Metaphase

Spindle fibers align the chromosomes along the middle of the cell nucleus. This line is referred to as the metaphase plate. This organization helps to ensure that in the next phase, when the chromosomes are separated, each new nucleus will receive one copy of each chromosome.

Anaphase

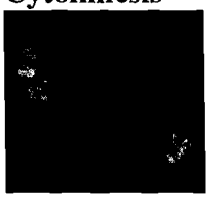


The paired chromosomes separate at the kinetochores and move to opposite sides of the cell. Motion results from a combination of kinetochore movement along the spindle microtubules and through the physical interaction of polar microtubules.

Telophase

Chromatids arrive at opposite poles of cell, and new membranes form around the daughter nuclei. The chromosomes disperse and are no longer visible under the light microscope. The spindle fibers disperse, and cytokinesis or the partitioning of the cell may also begin during this stage.

Cytokinesis



In animal cells, cytokinesis results when a fiber ring composed of a protein called actin around the center of the cell contracts pinching the cell into two daughter cells, each with one nucleus. In plant cells, the rigid wall requires that a cell plate be synthesized between the two daughter cells.

Mitosis animation (480 k)

OR

Mitosis animation

Flash

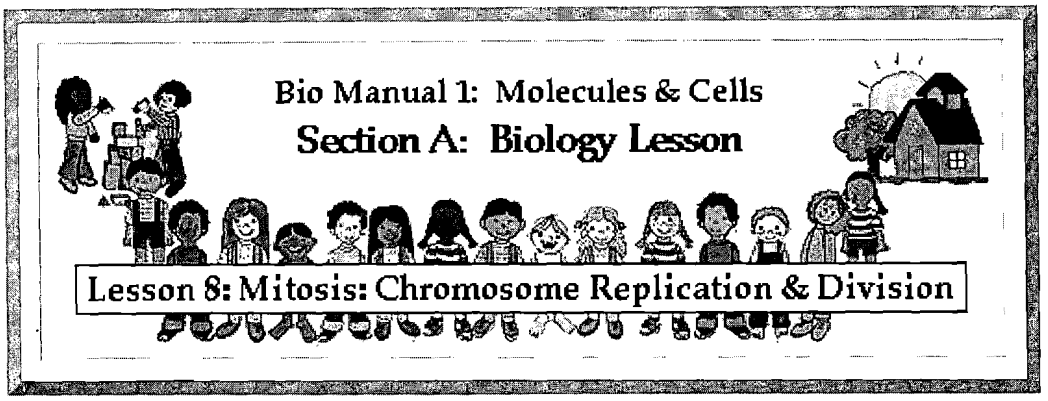
Previous | Next

Vocabulary

The Biology Project > Cell Biology > Intro. to Cell Cycle & Mitosis > Tutorial

The Biology Project
Department of Biochemistry and Molecular Biophysics
University of Arizona
April 1997
Revised: October 2004
Contact the Development Team

http://www.biology.arizona.edu



Mitosis: Chromosome Replication & Division

Grade Level

Prospective and Practicing K-8 Teachers; may be adapted for use in elementary classes.

Time

Exercises 1 & 2 take approximately 2 1/2 hours.

To Ponder

1. How does a human being grow from a single fertilized cell into an individual containing billions of cells?
2. Do all the cells of the body look like one another? Do they perform the same jobs?
3. Do all the cells of the body contain the same genetic information?
4. How is the genetic blueprint that makes you who you are transmitted faithfully from one cell to the next?
5. How long does it take for one parent cell to become two **daughter cells**?
6. Are cells alive?
7. What is a cell, anyway?

Supplies

2 sets of white and 2 sets of red plastic knives, forks and spoons per group for chromosomes
1 large (3 ft) length and two smaller lengths (1.5 ft) of yarn for nuclear membrane
white or brown paper per group
scissors
string for spindle fibers
small rubber bands for centromeres
yarn that is longer and a different color to represent cell membrane

Objectives

Once you have completed these exercises you should be able to:

1. Describe how cells reproduce themselves.

2. Explain how **chromosomes** are copied and distributed to each daughter cell in a precise way.
3. Describe the need for, and the mechanism of, conservation of **hereditary material**.
4. Be able to define and correctly use the following terms: **allele**, **anaphase**, **chromosome replication**, **cytokinesis**, **diploid**, **DNA synthesis**, **gene**, **homologous chromosome**, **interphase**, **life cycle**, **metaphase**, **mitosis**, **prometaphase**, **prophase**, **replicated chromosomes**, **sister chromatids**, **spindle fibers**, **telophase**, **unreplicated chromosomes**.

Background Information

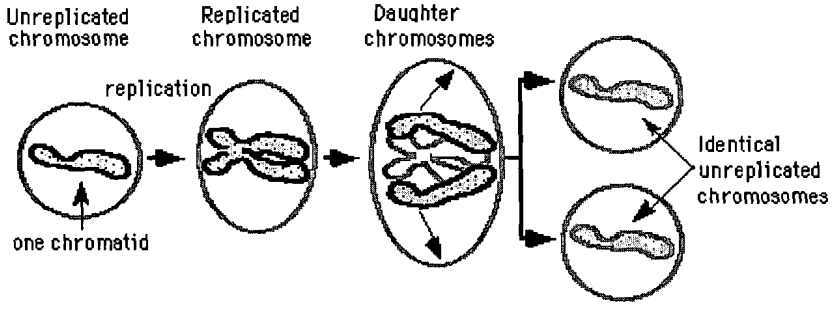
Cell Division

Your body is composed of more than a billion cells. Cells are continually dying, and new cells are continually being formed. An identical copy of your hereditary material is found in the **nucleus** of each and every somatic cell. A **somatic cell** is any cell in the body except for the reproductive cells in the reproductive system.

This genetic blueprint is organized into 46 chapters or parts known as chromosomes. It is estimated that, on average, each chromosome contains between one and two thousand genes. A gene contains the information for making a single **protein** or **RNA product**.

Every time a cell divides, each chromosome must be carefully replicated (copied) and then distributed to assure that each daughter cell gets a complete and accurate set of information. Thus, nuclear division includes successive processes of chromosome replication, separation, and distribution (Figure 1).

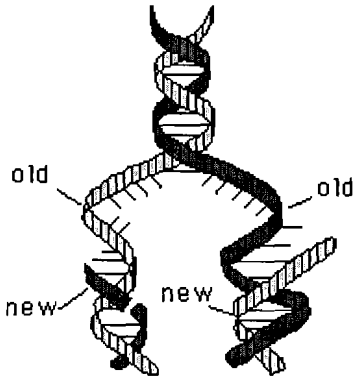
Figure 1: Chromosome Replication & Division



Adapted from Postlethwait, J. H. & Hopson, J. L. (1995). *The Nature of Life*, Third Edition. San Francisco: McGraw-Hill, Inc. Figure 7.8, page 173.

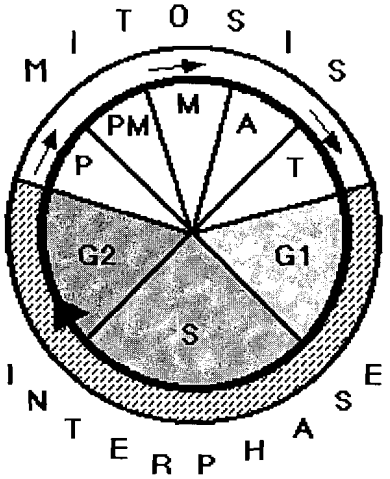
DNA synthesis occurs in the nucleus, producing an exact replica of every chromosome. A chromosome can be thought of as a very long **DNA double helix**. During replication, the double helix opens up and a new complementary strand is synthesized along each **parent strand** (Figure 2). This results in two identical DNA helices, each containing one original parent strand and one newly synthesized strand.

Figure 2: DNA Replicating



DNA synthesis occurs during the S phase of interphase. Each cell goes through a regular **life cycle**, similar to the cycle of life in humans. Where we might call our stages infancy, childhood, adolescence, young adult, adult, and senior, the major cell stages are interphase, mitosis, and cytokinesis. Interphase is subdivided into **G1** (growth 1), **S** (synthesis), and **G2** (growth 2), and mitosis is divided into **P** (prophase), **PM** (prometaphase), **M** (metaphase), **A** (anaphase), and **T** (telophase). This is shown in Figure 3.

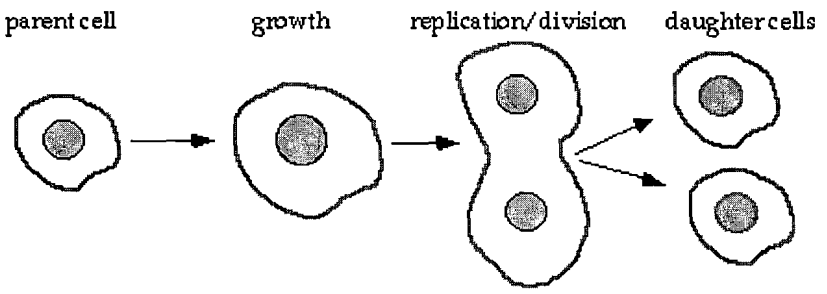
Figure 3: Cell Cycle



Adapted from Postlethwait, J. H. & Hopson, J. L. (1995). *The Nature of Life*, Third Edition. San Francisco: McGraw-Hill, Inc. Figure 7.6, page 171.

Another way to illustrate this cycle is shown in Figure 4.

Figure 4: Cell Division



Adapted from Postlethwait, J. H. & Hopson, J. L. (1995). *The Nature of Life*, Third Edition. San Francisco: McGraw-Hill, Inc. Figure 7.7, page 172.

a. How many rounds of chromosome replication occur in the cell prior to mitosis?
b. How many times does a cell divide in mitosis?

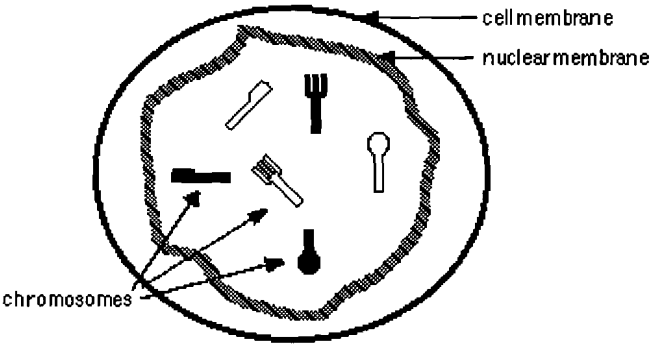
Exercise 1 Exploring the Process of Mitotic Cell Division

1.1 Introduction

To Do

1. You will study mitosis in the Triffle, a mythical creature with six chromosomes that look like knives, forks, and spoons. You will work out each step of the process using paper for **cells**, yarn for **membranes**, string for spindle fibers, and plastic knives, forks and spoons for chromosomes.
2. Go through the entire process (1.1 through 1.8) several times, with each group member taking a turn as the "explainer". Follow along with the procedure below for the first one or two turns, and perform the subsequent repetitions from memory. Answer the questions about **each** stage as you go along, and answer them each time you go through the process. Explain your answers in your own words and your own way -- don't recite them by rote memory.
3. Take one large piece of paper for your cell, and use one color yarn to show the **nuclear membrane** and a different color yarn to show the **cell membrane**.
4. Begin with a cell and nucleus containing six chromosomes represented by two forks (one red & one white), two knives (one red & one white), and two spoons (one red & one white). This represents a diploid cell with three pairs of chromosomes (Figure 5).

Figure 5. Triffle Diploid Chromosome Set



a. What does diploid mean?
b. Are most human cells diploid?
c. How many **pairs** of homologous chromosomes are present in the picture of a Triffle cell above?
d. Draw a circle around each homologous pair of chromosomes in the picture above.
e. Are the homologues, (a short name for **homologous chromosomes**) above paired with one another in the cell, or are they independent from one another?
f. What is the best description of homologous chromosomes?

(choose the best response)

(1) they are the same size and shape
(2) they contain the same types of genes in the same order
(3) they generally contain different versions (alleles) of many of their genes
(4) all of the above

g. Define homologous chromosome.

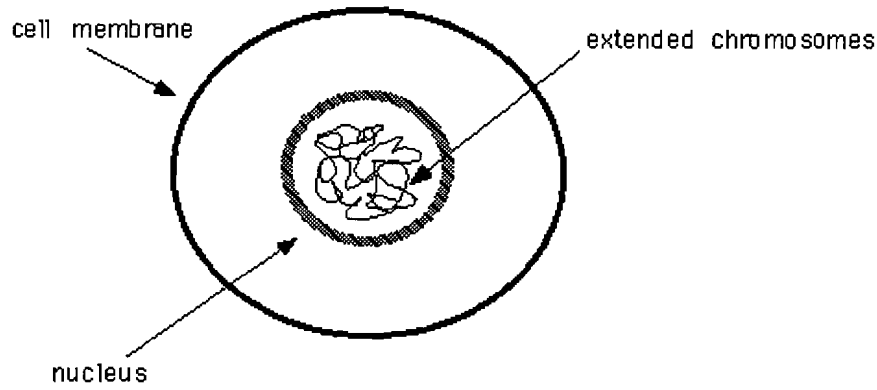
h. Contrast gene and allele.

1.2 Interphase and Chromosome Replication

To Do

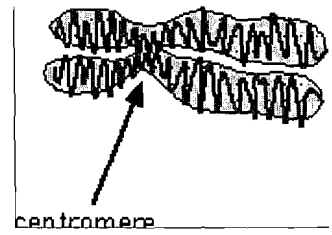
1. Throughout interphase, the chromosomes are **extended** and are not visible in the light microscope (Figure 6). That is, the DNA is uncoiled. We cannot simulate this extended condition with the knives, forks, and spoons, so please imagine it. Replicate each of the chromosomes in your Triffle nucleus, pretending they are extended at the time. Do this by obtaining six more chromosomes that match the set you already have. Attach a red fork to your red fork, a white fork to your white fork, and so on with an elastic band (which will represent the centromere). In this process, each chromosome has essentially made an identical copy of itself.

Figure 6: Interphase



2. Your nucleus initially contained six unreplicated chromosomes, and now it contains six replicated chromosomes. The two identical copies of each chromosome, sister chromatids, remain attached at a point called the centromere (Figure 7).

Figure 7: Chromosome Centromere



Adapted from Postlethwait, J. H. & Hopson, J. L. (1995). *The Nature of Life*, Third Edition. San Francisco: McGraw-Hill, Inc. Figure 7.4C, page 170.

a. What is a chromatid made of (protein, carbohydrate, lipid, and/or DNA)?

b. How do sister chromatids differ from chromosomes?

c. What is the centromere?

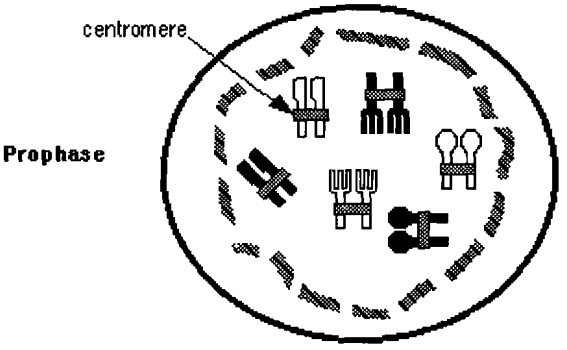
d. Contrast **extended** and **condensed chromosomes**.

1.3. Prophase of Mitosis

To Do

1. In prophase, the replicated chromosomes condense and become visible (Figure 8). This is the first stage of mitosis.

Figure 8. Prophase



a. Are the two sister chromatids that are connected by a centromere identical to one another or do they contain different alleles? Explain.

b. As noted above, these structures are called replicated chromosomes (or, in many books, simply chromosomes). Replicated chromosomes are quite different from the unreplicated chromosomes seen earlier. Compare replicated chromosomes to unreplicated ones (by filling in the blanks below).

(1) the amount of DNA in a replicated chromosome is_____ times the amount of DNA in an unreplicated chomosome
(2) the number of copies of each gene in a replicated chromosome is _____ times the number of copies in an unreplicated chromosome
(3) each replicated chromosome contains _____ (insert number) complete copies of genetic inf
(4) the copies of genetic information in each chromosome are _____ (identical, homologous, or complementary)

c. Do you think that the homologous replicated chromosomes (the two pairs of knives, the two pairs of forks, and the two pairs of spoons) will pair with one another during mitosis? Explain.

d. How many sister chromatids are in your Triffle nucleus in prophase?

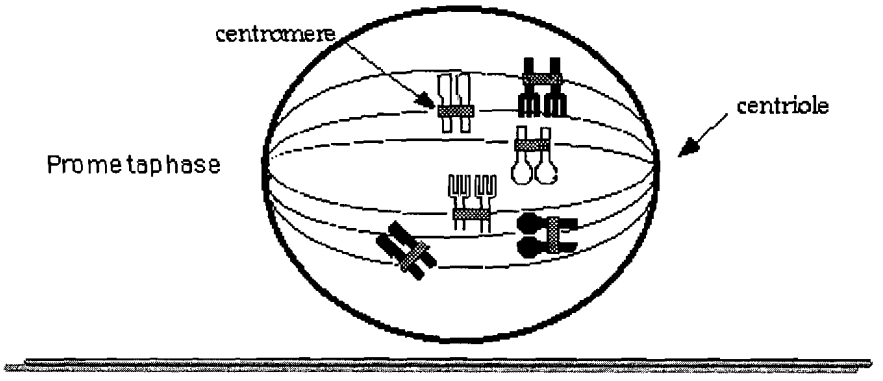
e. A diploid human cell contains 46 unreplicated chromosomes in early interphase. How many sister chromatids will be present in the human cell during prophase of mitosis?

1.4. Prometaphase of Mitosis

To Do

1. In prometaphase, the nuclear membrane literally "disappears", which allows the rest of the mitotic events to occur. Remove the nuclear membrane from around the chromosomes in the nucleus of your cell.
2. Spindle fibers form, emanating from two structures called centrioles that have migrated to opposite poles (ends) of the cell. Spindle fibers are assembled from protein microtubules. Put spindle fibers in your cell using pieces of string and draw the centrioles on the paper at the appropriate points.
3. Some of the spindle fibers attach to the replicated chromosomes at their centromeres (Figure 9).

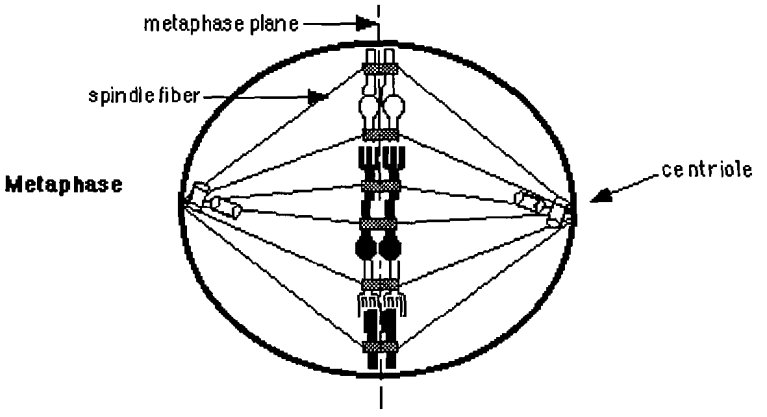
Figure 9: Prometaphase



1.5. Metaphase of Mitosis

1. In metaphase, replicated chromosomes are lined up on the **metaphase plane** (across the center of the cell) by the spindle fibers (Figure 10). Homologous chromosomes are independent of one another. That is, homologous replicated chromosomes such as the two sets of replicated spoons ARE NOT PAIRED.

Figure 10. Metaphase



To Do

2. Arrange your Triffle chromosomes across the center of the cell. The specific order of chromosomes and their orientation (right side up, upside down) is completely random.

a. How many replicated chromosomes are on the metaphase plane in the Triffle?

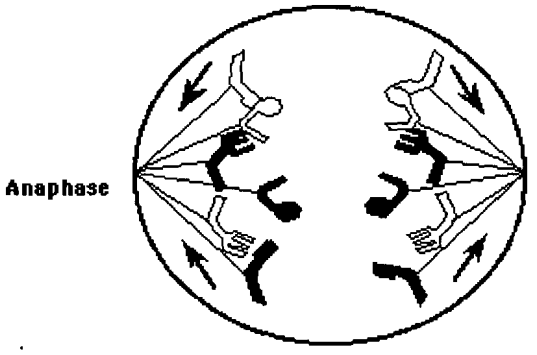
b. How many replicated chromosomes would be on the metaphase plane in a human cell undergoing mitosis?

1.6. Anaphase of Mitosis

To Do

1. In anaphase, sister chromatids separate to become **daughter chromosomes**(Figure 11). Separate your sister chromatids to form daughter chromosomes.

Figure 11. Anaphase



2. Daughter chromosomes are moved toward opposite poles by the spindle fibers. Chromatids are flexible. They do not remain rigid, but rather bend on each side of the centromere as they are dragged through the **cytoplasm**.

a. Are the daughter chromosomes replicated or unreplicated?

b. Are the two sets of daughter chromosomes, the one moving toward the left and the other toward the right, identical or non-identical?

c. Are the two sets of daughter chromosomes identical to those in the parent cell?

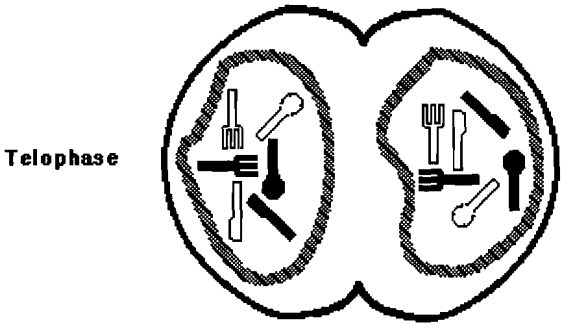
d. What is accomplished by this process?

1.7. Telophase of Mitosis

To Do

1. Daughter chromosomes reach the poles of the cell and become extended (relaxed). The spindle fibers disappear actually, the **microtubulin subunits** are disassembled. You can remove your spindle fibers from your cells and pretend your chromosomes are going into the extended state.
2. Two new nuclear membranes form, one around each set of daughter chromosomes. Use the nuclear membrane yarn to create two new nuclear membranes in your cell (Figure 12). Pinch in the yarn representing the cell membrane.

Figure 12. Telophase

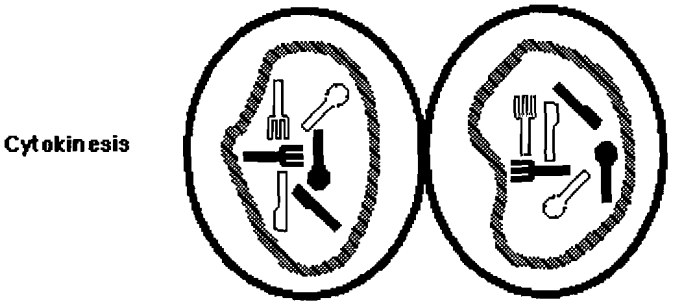


1.8. Cytokinesis

To Do

1. An animal cell pinches in half at the center (Figure 12), from the outside in, until it has produced two separate daughter cells (Figure 13). Divide your cell in half in this manner by replacing the long yarn representing the parent cell membrane with two shorter pieces of yarn representing the membranes of the two daughter cells.

Figure 13. Cytokinesis Completed



2. These daughter cells are now entering the early interphase stage. Pretend that your Triffle chromosomes are becoming extended. The cells will grow to full size and, if continuing to divide, will replicate their chromosomes, and repeat the cycle again.

a. Does the parent cell still exist?

b. How are these daughter cells related to one another?

c. How are these daughter cells related to the parent cell?

d. Overall, what has been accomplished by mitosis?

e. You have used your materials to model mitosis(nuclear division) and cellular division. Explain some ways in which a model differs from the actual things and processes it represents.

1.9. Practice through Repetition

To Do

1. As noted above, you can go through the entire process several times, with each group member taking a turn as the "explainer". Follow along with the procedures outlined above for the first one or two turns, and then perform the subsequent repetitions from memory. You may refer to Table 1 for a rough guide, and your team mates can assist you by asking questions and giving hints.

Table 1. Cell Cycle Summary

Interphase

G1 stage

Growth & development of the cell
Protein synthesis

S-phase

Chromosome replication via
DNA synthesis

G2 stage

Growth & development
Organelle Replication

Mitosis

Prophase

Replicated **chromosomes** condense

Prometaphase

Nuclear membrane dissolves
Spindle fibers form

Metaphase

Replicated **chromosomes** align at center

Anaphase

Sister chromatids separate
Daughter **chromosomes** move to poles

Telophase

New **nuclear membranes** form
Spindle fibers disappear

Cytokinesis

Cell divides into two **daughter cells**

Exercise 2 Chromosomes in Humans

To Do

1. Examine the **chromosome spread** in the top half of Figure 14. How do you think such a picture is obtained?

Figure 14. Human Chromosome Spread and Karyotype

Photograph from Goodenough, U. & Levine, R. P. (1974). Genetics. San Francisco: Holt, Rinehart, & Winston. Figure 2-16, page 57.

2. Then examine the human **karyotype** in the bottom half of Figure 14. How do you think such a picture is obtained?

Describe

3. Relate what you have learned in this lab to:

a. the growth and differentiation of tissues in babies,

b. the use of a somatic cell rather than sperm and egg to create a new organism such as a sheep or frog,

c. another related phenomenon of your own choosing.

Supplementary Resources

Goodenough, U. & Levine, R. P. (1974). *Genetics*. San Francisco: Holt, Rinehart, & Winston. Figure 2-16, page 57.

Klug, W. S. & Cummings, M. R. (1997). *Concepts of Genetics*, Fifth Edition. Upper Saddle River, NJ: Prentice Hall.

Postlethwait, J. H. & Hopson, J. L. (1995). *The Nature of Life*, Third Edition. San Francisco: McGraw-Hill, Inc.

Interactive Mitosis Tutorial (created with Director)

What The Heck is a Gene?

Dictionary of Cell Biology

The Biology Project, University of Arizona

The Cell Cycle Graphic Illustrations

Oklahoma State Univerity

Access Excellence

University of Texas

Related AAAS Benchmarks

Chapter 5: THE LIVING ENVIRONMENT

Section B: Heredity

Grade 6-8 (Benchmark 1 of 3)
In some kinds of organisms, all the genes come from a single parent, whereas in organisms that have sexes, typically half of the genes come from each parent.

Section B: Heredity

Grade 9-12 (Benchmark 1 of 6)
Some new gene combinations make little difference, some can produce organisms with new and perhaps enhanced capabilities, and some can be deleterious.

Section F: Evolution of Life

Grade 9-12 (Benchmark 4 of 9)
Heritable characteristics can be observed at molecular and whole-organism levels--in structure, chemistry, or behavior. These characteristics strongly influence what capabilities an organism will have and how it will react, and therefore influence how likely it is to survive and reproduce.

Section B: Heredity

Grade 9-12 (Benchmark 6 of 6)
The many body cells in an individual can be very different from one another, even though they are all descended from a single cell and thus have essentially identical genetic instructions. Different parts of the instructions are used in different types of cells, influenced by the cell's environment and past history.

Section C: Cells

Grade 3-5 (Benchmark 2 of 2)
Microscopes make it possible to see that living things are made mostly of cells. Some organisms are made of a collection of similar cells that benefit from cooperating. Some organisms' cells vary greatly in appearance and perform very different roles in the organism.

Section C: Cells

Grade 6-8 (Benchmark 1 of 4)
All living things are composed of cells, from just one to many millions, whose details usually are visible only through a microscope. Different body tissues and organs are made up of different kinds of cells. The cells in similar tissues and organs in other animals are similar to those in human beings but differ somewhat from cells found in plants.

Section C: Cells

Grade 9-12 (Benchmark 4 of 8)
The genetic information in DNA molecules provides instructions for assembling protein molecules. The [genetic] code used is virtually the same for all life forms.

Chapter 6: THE HUMAN ORGANISM

Section B: Human Development

Grade 9-12 (Benchmark 1 of 4)
As successive generations of an embryo's cells form by division, small differences in their immediate environments cause them to develop slightly differently, by activating or inactivating different parts of the DNA information.

THE BIOLOGY PROJECT • CELL BIOLOGY

Online Onion Root Tips

Determining time spent in different phases of the cell cycle

The assignment

In this activity, you will be presented with cells from the tip of an onion root. You will classify each cell based on what phase it is in. At the end you will count up the cells found in each phase and use those numbers to predict how much time a dividing cell spends in each phase. You can base your calculation on a total cell cycle of 24 hours.

Copy this table onto a piece of paper. You can enter data in this table as you go along, or at the end of the activity.

	Interphase	Prophase	Metaphase	Anaphase	Telophase	Total
number of cells						36
percent of cells						100%

Previous | Next

Vocabulary

The Biology Project > Cell Biology > Intro to Onion Root Tips Activity > Activity

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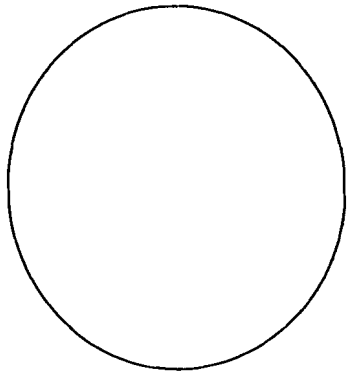
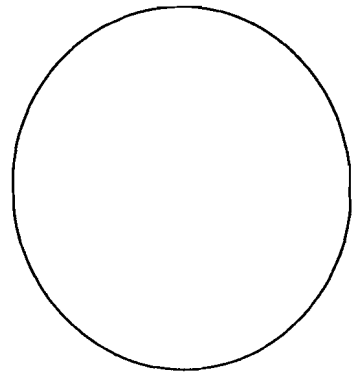
Onion Root Drawings

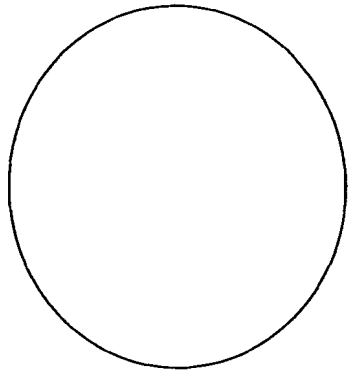
Prophase



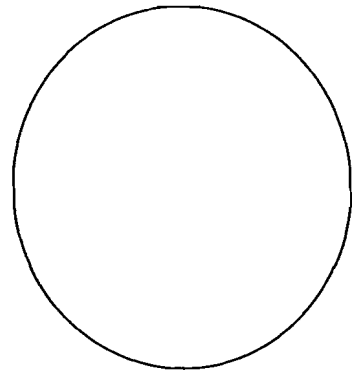
Anaphase



Metaphase



Telophase



Benchmark 5 The Living Environment

5C Cells #2
Cells repeatedly divide to make more cells for growth and repair....

Resources

- Stages of Mitosis
- The Biology Project

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Mitosis

Purpose

To develop an understanding of mitosis.

Context

Students have been taught at an early age that the cell is the building block of life, and have most likely used a simple microscope to view cells in elementary school. They have been introduced to the idea that organisms depend on cell division to pass the genetic information from one cell to the next, but how this is accomplished is still a mystery. They are now ready to understand the concept that one cell is capable of making an exact copy of itself.

This lesson will introduce students to the step-by-step phases of mitosis in an effort to imprint on the young mind the idea that each cell is highly organized. Prior to this lesson, students should have discussed both plant and animal cell structures. If they haven't, focus students solely on animal cells throughout the lesson.

Planning Ahead

In this lesson, students will make physical representations of mitosis. Read the activity ahead of time and choose appropriate materials for your class.

Possible materials:

- Poster board
- Glue
- Scissors
- Yarn (any color)
- Several small beads
- Lifesavers or other round candy
- Construction paper
- Macaroni
- Spools of thread
- Markers, crayons, or colored pencils

Students will also develop and perform a skit about the phases of mitosis. The props needed for this activity will depend on your students' ideas as they create the skit.