

Mitosis and Meiosis

1. Students should be able to state why cells divide.
2. Students will draw and identify each phase of mitosis and meiosis and describe the main characteristics of each.
3. Students should know the difference between mitosis and meiosis.

Background information on mitosis and meiosis

Most students know that cells are capable of “dividing” by two different processes – **mitosis** and **meiosis**. As you will see below, some of the terminology that is used in describing mitosis and meiosis is incorrect. For example, the first sentence in this paragraph has two such errors: cells do not divide in the mathematical sense (you do not get two half-cells or quarter-cells); and mitosis and meiosis refer to events that happen to the nucleus and its DNA – not to the entire cell. Unfortunately (because it is confusing), most textbooks (and most biologists) use this inexact terminology (i.e., “cells dividing by mitosis”). In this exercise, quotation marks will be used around such words that may be misinterpreted.

A clear way to understand differences between mitosis and meiosis is to keep track of how many times the contents of the nucleus are “divided up”. Prior to mitosis and meiosis, the DNA in the nucleus replicates (resulting in twice as many chromosomes as before). In mitosis, this double amount of DNA is separated (“divided”) once – half ends up in one cell and half in the other. Thus, each of the two new cells has the same amount of DNA as the original cell. In meiosis, the double amount of DNA is separated twice – once into two portions, and then each of the two portions is divided in half (resulting in four portions). The original cell “divides” into 4 cells – each with one half of the DNA as the original cell.

Important note: The functions of mitosis and meiosis are very different. **Mitosis** is the process by which animals and plants produce more somatic (body) cells. **Meiosis** occurs only in the reproductive cells in a plant or animal. Meiosis is the process by which animals and plants produce eggs or sperm.

Interphase: Cell growth and chromosome duplication

1. Interphase: **G1**

The first gap phase within the Interphase stage of the cell cycle; G1 occurs before DNA synthesis (S phase) begins. “G1” means “gap # 1” in the cell cycle. It was named this because the nuclei of cells that had just been produced by mitosis and cytokinesis appeared to be inactive (a “gap” in their activity). Because there is a second gap, the first one was named “G1”.

2. Interphase: **S phase (Synthesis phase)**

It is a phase during which DNA and other chromosomal constituents are synthesized within the nucleus. Chromosomes duplicate in the “Synthesis phase”

of Interphase, before the cell divides.

3. Interphase: **G2**

The second gap phase within the interphase stage of the cell cycle; G2 occurs after DNA synthesis (S phase) and before mitosis. For many cells, the G2 phase is short relative to the G1 and S phase.

Mitosis: Results in new body cells, for growth and repair

Mitosis - produces two cells genetically identical to the parent cell.
 - consists of four phases: Prophase, Metaphase, Anaphase, and Telophase.
 (Cytokinesis usually overlaps the telophase stage.)

In many textbooks the descriptions of cells, chromosomes and chromatids in mitosis (and meiosis) is confused by incorrect terminology. The words “daughter”, “sister”, and, sometimes, “mother” are used as adjectives to show how structures are related to each other. There are two problems with this terminology. First, the use of these female adjectives (e.g., “sister” chromatids) in no way means that the chromatids are female! The same is true for “daughter” cells. Similarly, in mitosis, sister chromatids (and daughter cells) are genetically identical, so “sister” and “daughter” are still not the correct adjectives. Finally, the “mother” in “mother cell” does not indicate that the cell is female, and it certainly does not give birth to two cells. Rather, the “mother” cell becomes two cells.

1. Mitosis: **Prophase**

Prophase is the first stage of mitosis. During Prophase the chromosomes become visible as distinct structures, the nuclear envelope breaks down, nucleolus disappears. Spindle forms between centrioles, which have moved to the poles of the cell. Kinetochores begin attaching to microtubules.

2. Mitosis: **Metaphase**

During metaphase spindle fibers attach to the kinetochores of the chromosomes, which line up along the cell’s midplane. In mitosis, all chromosomes line up on the midplane independently.

3. Mitosis: **Anaphase**

In this stage, chromatids separate at centromeres, and one group of chromosomes moves toward each pole.

4. Mitosis: **Telophase**

Chromosomes have arrived at poles, and become de-condensed. A nuclear envelope forms around each group chromosomes. Cytokinesis produces two “daughter” cells.

Meiosis: Results in formation of reproductive cells only

Interphase: G1 → S → G2

Chromosomes duplicate in Interphase S phase, the same as before mitosis.

Meiosis produces haploid cells with unique gene combinations. It is a process in which one $2n$ (diploid) cell undergoes two successive nuclear divisions (meiosis I and meiosis II), potentially producing four n (haploid) nuclei; leads to the formation of gametes in animals and spores in plants.

1. Meiosis I: **Prophase I**

Homologous chromosomes synapse, forming tetrads.

Nuclear envelope breaks down.

2. Meiosis I: **Metaphase I**

Tetrads line up on cell's midplane.

Tetrads held together at chiasmata (sites of prior crossing-over).

3. Meiosis I: **Anaphase I**

Homologous chromosomes separate and move to opposite poles.

Note that sister chromatids remain attached at their centromeres.

4. Meiosis I: **Telophase I**

One of each pair of homologous chromosomes is at each pole.

Cytokinesis occurs.

5. Meiosis II: **Prophase II**

Chromosomes condense again following a brief period of interkinesis.

DNA does *not* replicate again.

6. Meiosis II: **Metaphase II**

Chromosomes line up along cell's midplane.

7. Meiosis II: **Anaphase II**

Sister chromatids separate, and chromosomes move to opposite poles.

8. Meiosis II: **Telophase II**

Nuclei formed at opposite poles of each cell. Cytokinesis occurs.

Four gametes (animal) or four spores (plant) are produced.

Table 1. Reviewing the differences between Mitosis and Meiosis

	Mitosis	Meiosis
Where does it take place?	Entire body (all <i>somatic</i> cells)	Only in gametes—eggs in the ovaries, sperm in the testes
How many cell are produced?	Two	Four
What is “divided”?	DNA	DNA
What is the <i>ploidy</i> of the new cells?	Usually* diploid: $2n$ (somatic cells all have two copies of each chromosome) *The ploidy of the daughter cells will always be the same as in the parent cell-remember this for the Questions exercises.	Haploid, or n (one copy—half—because the gametes have to join for a newly fertilized zygote to have both copies of its chromosomes)

Create a pie graph

Examine the amount of time that onion cells spend in each stage of mitotic division as listed below. Do your best to estimate the relative sizes of the “pie slices.” Label your graph with phase names and times.

One entire cycle of mitotic division = 90 minutes

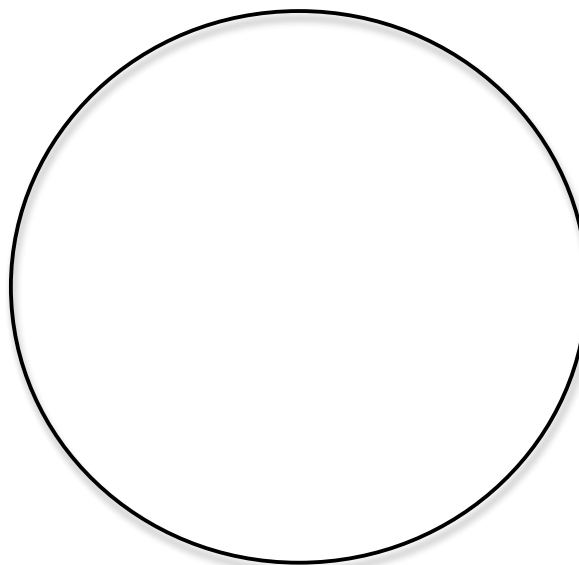
Interphase = 81.0 minutes

Prophase = 3.0 minutes

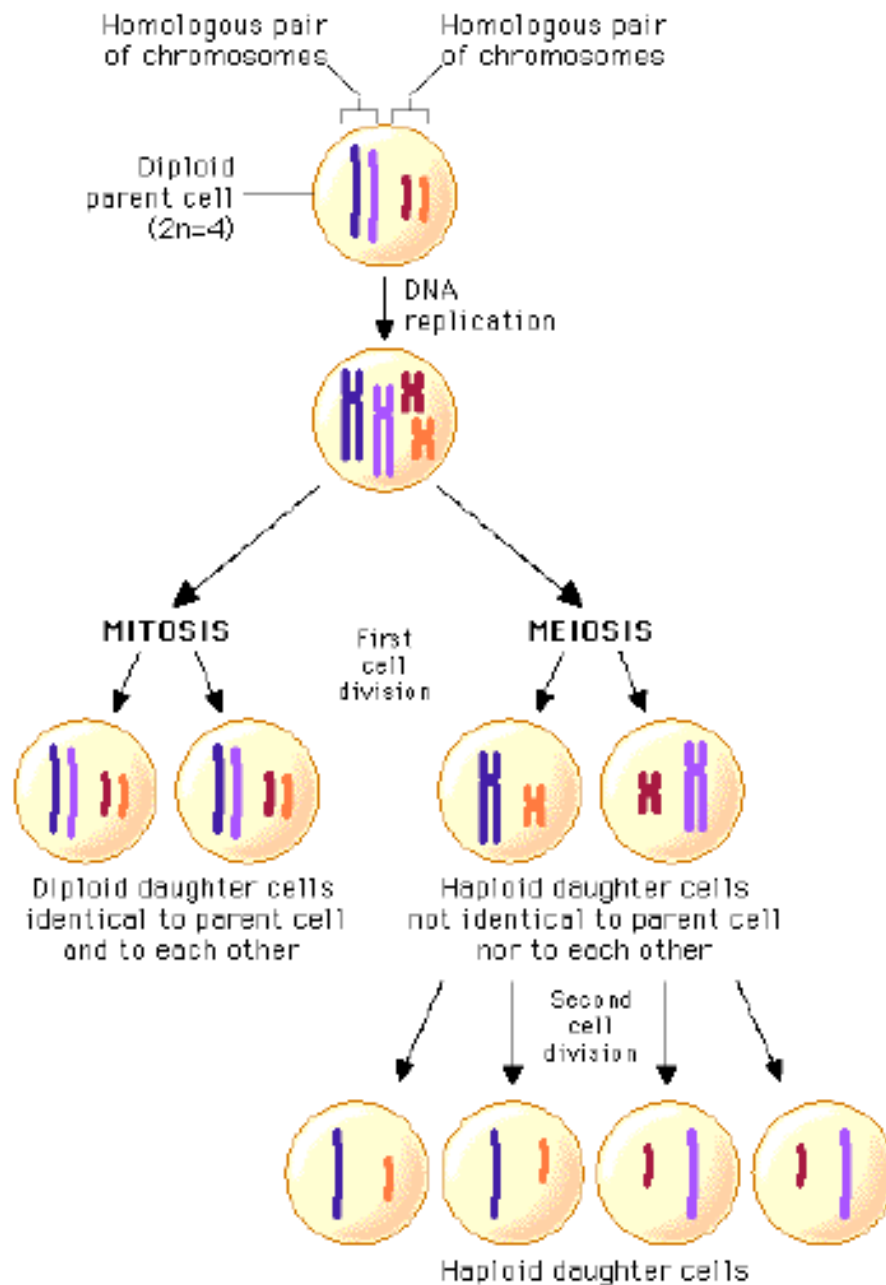
Metaphase = 1.5 minutes

Anaphase = 2.7 minutes

Telophase = 1.8 minutes



The following diagram is from your textbook. It is included here to help you review mitosis and meiosis.



Procedure for today's lab

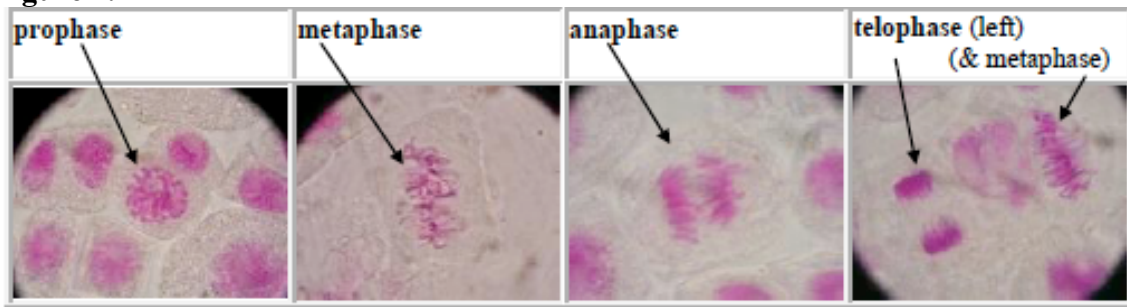
Students may work in pairs today.

You must draw out (in the following circles) the stages of mitosis and meiosis in a cell containing six (6) chromosomes. You must label your drawings with the phase, and briefly describe what is happening to the cell's chromosomes.

Your TA will have demo microscopes set up at the front of the lab so that you can view prepared slides of onion root cells dividing.

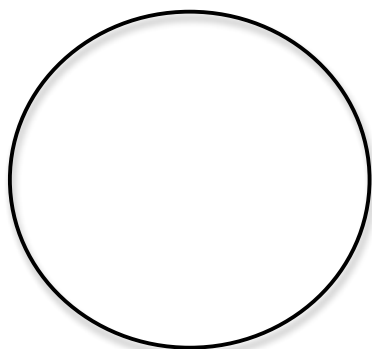
Picture to help with today's lab: Figure 1 is a series of pictures of onion root tip cells in the four classic stages of mitosis. Do not copy these pictures; they are just to give you an idea of what the chromosomes look like in real dividing cells.

Figure 1.



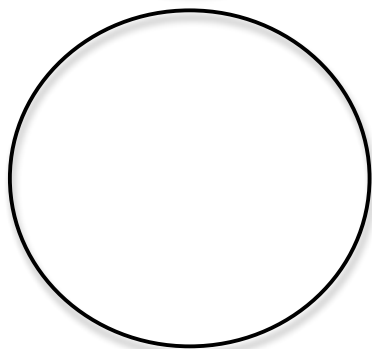
Area to draw out cell divisions

Mitosis (draw cell with 6 chromosomes in mitosis)



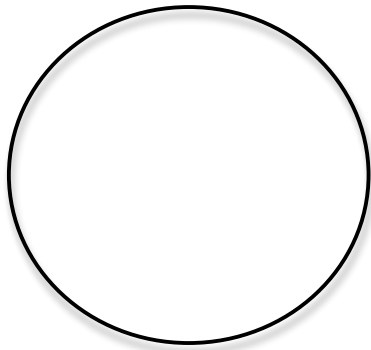
Phase:

Description:



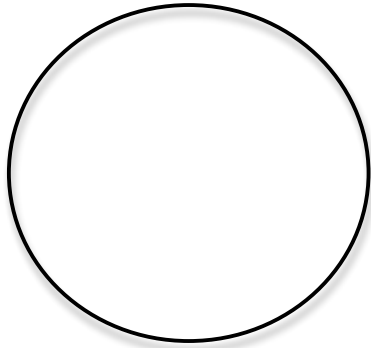
Phase:

Description:



Phase:

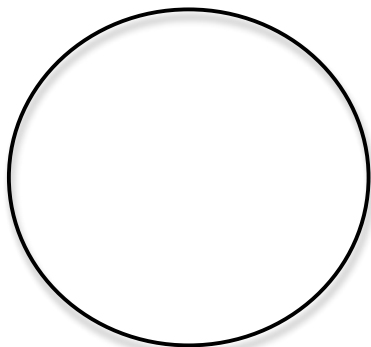
Description:



Phase:

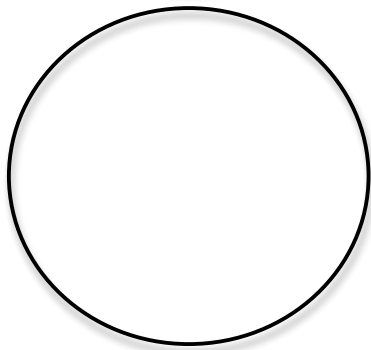
Description:

Meiosis (draw cell with 6 chromosomes in Prophase I – Telophase I only)



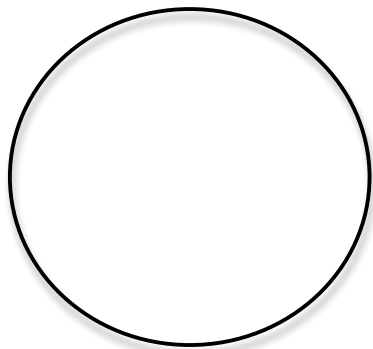
Phase:

Description:



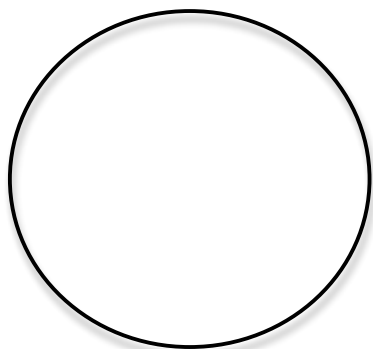
Phase:

Description:



Phase:

Description:



Phase:

Description:

Questions

After today’s lab, you should be able to complete the following chart (one row has been completed for you). *Ploidy* means the number of chromosome sets in a nucleus or cell. If a cell or nucleus contains two sets of chromosomes, it is said to have a *diploid* chromosome number. If it has only a single set of chromosomes, it has the *haploid* number.

Ploidy and number of chromosomes in original cell	Process	Number of cells formed	Number of chromosomes per nucleus	Are resulting cells haploid or diploid?
Diploid, 46	Mitosis	2	46	diploid
Diploid, 46	Meiosis			
Diploid, 10	Mitosis			
Diploid, 10	Meiosis			
Haploid, 5	Mitosis			
Haploid, 10	Mitosis			

ANSWER THE FOLLOWING QUESTIONS:

1. How many *pairs* of chromosomes are in each human body (somatic) cell? _____

2. How many *pairs* of chromosomes are in each egg or sperm? (Be careful.) _____

ANSWER **mitosis** AND/OR **meiosis** FOR THE FOLLOWING QUESTIONS...

3. Forms 2 new cells from each original cell _____

4. Forms 4 new cells from each original cell _____

5. Replication of chromosomes occurs _____

6. Doubled chromosomes pair to form tetrads _____

7. Cells with a reduced chromosome number are formed _____

8. Cells with the same chromosome numbers as original are formed _____

9. Results in forming egg or sperm cells _____

10. Results in forming somatic cells _____

11. Each original cell divides only once _____

12. Each original cell divides twice _____

13. Tetrads are not formed _____

14. Chromosomes move to the cell's center _____

15. Produces cells with new genetic makeup _____

16. Allows for genetic mixing in crossing-over _____