Lab 10: Mitosis and Meiosis

- ✓ **Assigned pages**: **Inquiry into Life** (lab manual) - **pp. 59-78**.
- ✓ **NOT CLASS week of 19 November**……happy holiday!
- ➢ **Mini quiz week of 26 November** on GOALS for **Lab 10**.
- ➢ More information and a color copy is available at the BioLab website: **http://cortland.edu/biolab/110.html**

GOALS:

Objectives - by the end of this lab you should be able to:

- Be able to name the stages of the cell cycle and identify what is happening in each.
- Given a diagram or slide depicting mitosis or meiosis, be able to name the stage and state what is happening.
- Be able to state differences between oogenesis and spermatogenesis in mammals.
- Given a parent cell with any chromosome number, be able to trace the chromosomes step by step through mitosis or meiosis.

Key terms - by the end of this lab you should be able to define/describe:

mitosis (know the stages)
meiosis (know the stages)
cytokinesis
nucleus vs. nucleolus
chromosome
• sister chromatids
• centromere
• homologous chromosomes
spindle fibers
centriole
chromosome number
• diploid
• haploid
cleavage furrow
cell plate vs. cell wall (in plants)
spermatogenesis
• seminiferous tubules
oogenesis
• polar bodies
crossing-over

Lab Activities:

I. Introduction to the Cell Cycle

a. **pp. 59-60: Read** thoroughly. Be able to **explain** what happens at each stage of the cell cycle and **define** key terms.

II. Animal cell *mitosis*

a. **pp. 61-63**: **Read** thoroughly. **Know the stages** and be able to **define** the key terms.
b. **p. 64**: Follow the directions to **view models and slides** of the whitefish blastula.
c. **p. 65**: Understand how **cytokinesis** works in animals (cleavage furrow).
d. **powerpoint slides**: on the computer, review the **MITOSIS** slides for the **whitefish** blastula

III. Plant cell *mitosis*

a. **p. 64**: **Read** thoroughly. **Know the stages** (compare to pp. 62-63) and be able to **define** the key terms.
b. **p. 66**: Understand how **cytokinesis** works in plants (cell plate).
c. **powerpoint slides**: on the computer review the **MITOSIS** slides for the **onion cell**

IV. Summary - Mitosis

a. **p. 66**: **Answer** questions 1 &2; **Fill in** Table 5.2

V. Meiosis

a. **pp.67-69**: Read thoroughly and follow the procedures for simulating meiosis with chromosome bead sets. Use the

schematic diagram in figure 5.7 (pp. 70-71) and the **summary information at the end of this handout** as a guide.
b. **pp. 68-69**: Answer the questions for meiosis I and meiosis II as well as the summary questions (p. 69).
c. **powerpoint slides**: on the computer review the slides for **MEIOSIS**.

VI. Mitosis versus meiosis
a. **p. 72**: **Examine** Figure 5.8 and **fill in** Table 5.3 with general differences between mitosis and meiosis.
b. **p.73**: **Examine** Fig. 5.8 and **fill in** Tables 5.4 and 5.5 with specific differences as indicated. You may want to compare to Fig. 5.3 (Mitosis) and Fig. 5.7 (Meiosis)).

VII. Gametogenesis (formation of gametes by meiosis) in animals
a. **pp. 74-76**: Read thoroughly and answer questions 1-4 (p. 74).

VIII. Review – Chapter 5

SUMMARY INFORMATION

The Cell Cycle

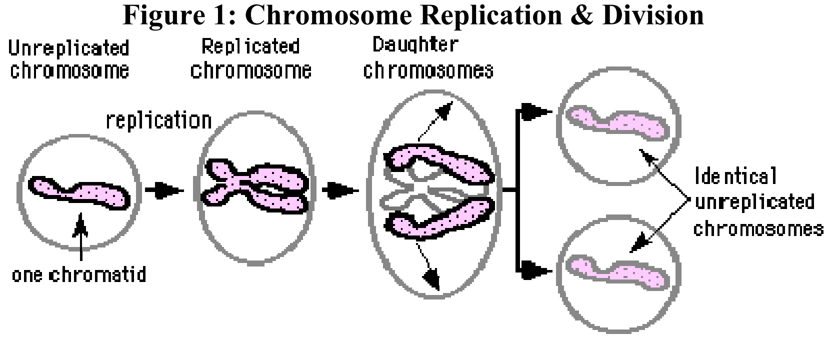
The following is from: http://www.biologylessons.sdsu.edu/classes/lab8/lab8.html

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).

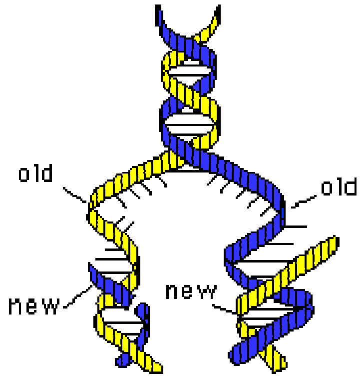
Figure 1: Chromosome Replication & Division



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.

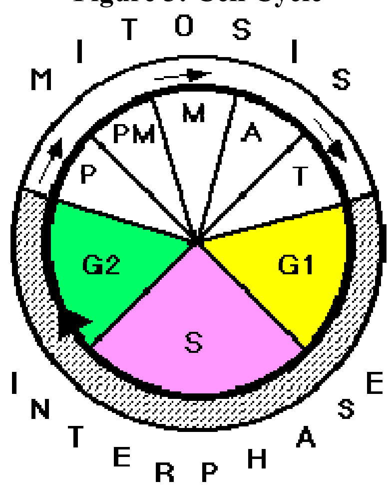
DNA synthesis occurs in the nucleus, producing an exact replica of every chromosome. A chromosome can be thought of as a very long **DNA double helix**. During replication, the double helix opens up and a new complementary strand is synthesized along each **parent strand** (Figure 2). This results in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

INTERPHASE

This is the non-dividing phase.
During interphase, the nucleus is visible and the chromosomes are uncoiled and invisible.

Interphase includes G1, S and G2.
G1
Each chromosome has one chromatid.
The cell grows in size.
Synthesis of organelles occurs.
S
This is when DNA synthesis (DNA replication) occurs.
G2
After DNA replication is complete, each chromosome has TWO chromatids.
The synthesis of enzymes and other proteins in preparation for mitosis occurs during this period.

Mitosis

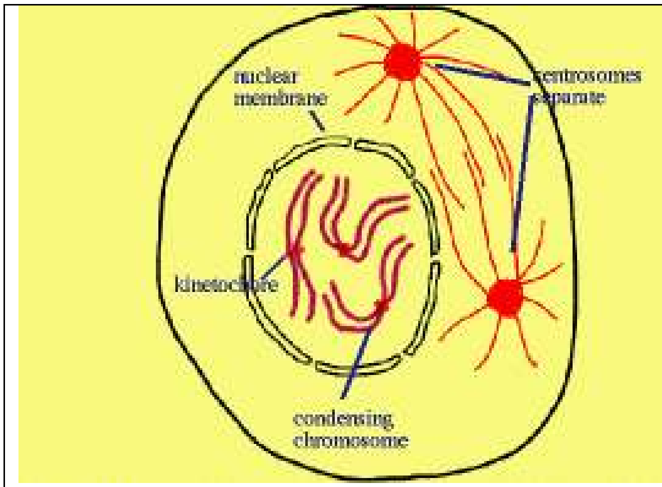
The following information for mitosis is adapted from: http://128.121.138.33/VRML/mitosisb4.html and http://faculty.clintoncc.suny.edu/faculty/michael.gregory/files/Bio%20101/Bio%20101%20Lectures/Mitosis/mitosis.htm. Additional descriptive information comes from: J. D. Watson, et al. 1987. Molecular Biology of the Gene. 4th edition. The Benjamin/Cummings Publishing Company, Inc: Menlo Park, CA. 1163 pp and you lab manual.

<u>Mitosis</u> produces two daughter cells that are identical to the parent cell. If the parent cell is haploid (N), then the daughter cells will be haploid. If the parent cell is diploid, the daughter cells will also be diploid.

N → N OR 2N → 2N

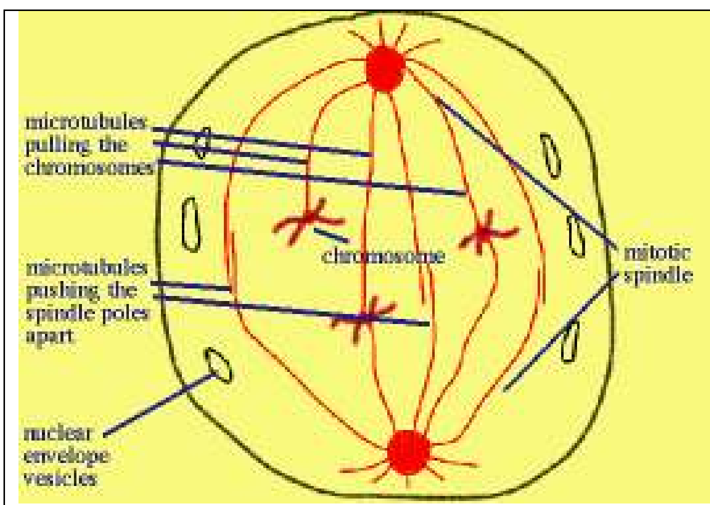
This type of cell division allows multicellular organisms to grow and repair damaged tissue.

PROPHASE



The DNA has already duplicated during interphase. In all cells, DNA occurs as a coil 'wound around' proteins. This DNA-protein complex is called chromatin.
Chromatin winds in upon itself and the coils condense into **chromosomes**. Each chromosome is composed of TWO **chromatids** ("sister chromatids") held together by a constriction (**centromere)**. **<u>HINT</u>**: *count the number of centromeres to get the number of chromosomes!* (At left you see 3.)
The nucleolus has disappeared and the nuclear membrane begins to disintegrate.
Centro*somes* have already duplicated and now separate. A mitotic spindle which arises from two centrosomes begins to form. **In animals**, the centrosome contains two **centrioles** and an aster (fibers produced by and radiating from the centriole). **In plants**, there is spindle pole which lacks centrioles and aster.

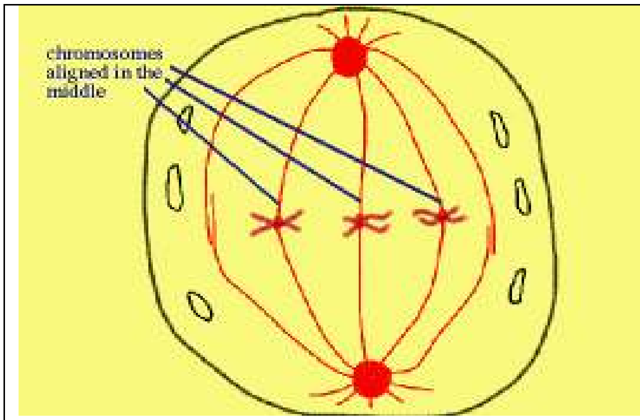
PROMETAPHASE



The nuclear envelope totally disintegrates, but its vesicles remain visible.
Kinetochores form on each **sister chromatid** and anchor each chromatid to the spindle microtubule ("**kinetochore spindle fiber**") pulling the chromosomes to the center of the cell.
Polar spindle microtubles ("**polar spindle fibers**") connect and push the spindle poles apart.

Mitosis - continued:

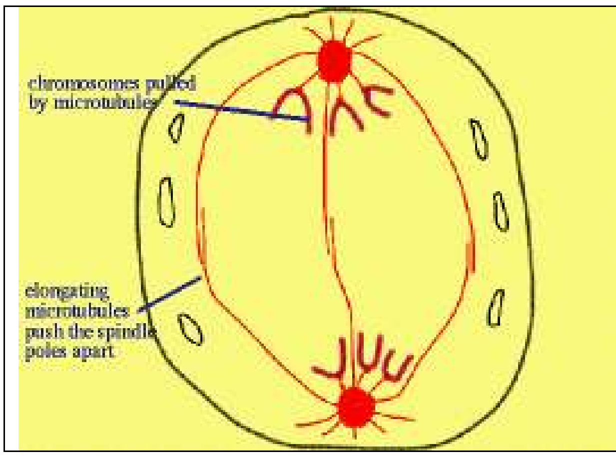
METAPHASE



Each chromosome (a pair of chromatids), anchored by their kinetochores to the spindle fiber, is aligned in the middle of the cell along the metaphase plate (center of the fully formed kinetochore spindle fibers). (**<u>Remember</u>**: there are <u>TWO</u> kinetochores per chromosome (one for each chromatid) in the constricted centromere region of each chromosome.)

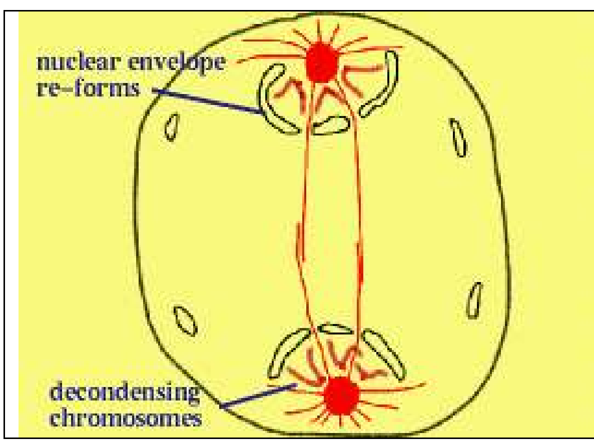
In the diagram to the left, you see:
3 chromosomes;
2 chromatids per chromosome (= 6 chromatids);
3 centromeres (*1 centromere per chromosome*); and
6 kinetochores (1 kinetochore per chromatid = 2 kinetochores per chromosome).

ANAPHASE



The pairs of chromatids are pulled apart; one chromatid anchored by its kinetochore to a kinetochore microtubule (kinetochore spindle fiber) is pulled toward one centrosome and the other chromatid, anchored by its kinetochore is pulled toward the opposite centrosome.
* ***These separated, individual chromatids are now called chromosomes***.
By separating to opposite sides of the cell, each new "daughter cell" cell (formed in telophase) will receive the same number of chromosomes (same DNA) as the parent cell.
Cytokinesis (division of the cytoplasm) begins in anaphase.

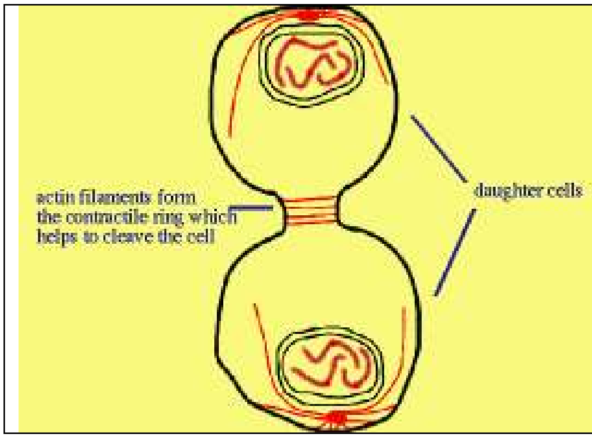
TELOPHASE



Chromosomes uncoil ("decondense") and revert back to loosely coiled chromatin.
The nuclear membrane ("nuclear envelope") starts to reform.
The spindle apparatus breaks down.
Cytokinesis continues.

Mitosis - continued:

LATE TELOPHASE



The actin filaments in the middle of the cell form a contractile (constricting) ring that helps to divide the cell into TWO cells. Cytokinesis is now complete.

The nuclear membranes are completely reformed, *forming a new nucleus in each daughter cell.*

Many of the events in telophase are the reverse of prophase. The chromosomes uncoil, the nuclear membranes around daughter nuclei appear, the spindle apparatus breaks down, and the nucleolus reappears. The nucleolus is a structure within the nucleus where the ribosomal subunits are produced. Cytokinesis is completed as telophase ends.

In Plants: Instead of a cleavage furrow (animal cells), plants form vesicles derived from the Golgi apparatus fuse at the equator of the cell to form a **cell plate** (see figure 5.3, bottom right, p. 63, lab manual). These vesicles contain materials necessary to construct a **cell wall** between the cells.

Additional Notes/Questions:

Meiosis

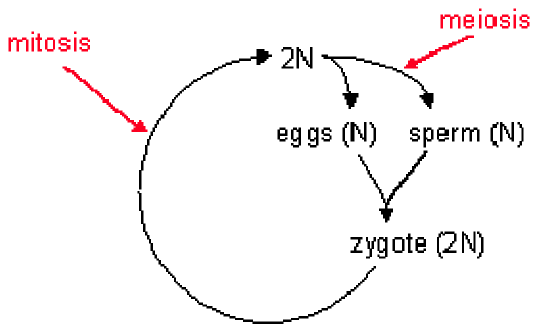
The following information for mitosis is adapted from: http://128.121.138.33/VRML/mitosisb4.html and http://faculty.clintoncc.suny.edu/faculty/michael.gregory/files/Bio%20101/Bio%20101%20Lectures/Mitosis/mitosis.htm. Additional descriptive information comes from: J. D. Watson, et al. 1987. Molecular Biology of the Gene. 4th edition. The Benjamin/Cummings Publishing Company, Inc: Menlo Park, CA. 1163 pp and you lab manual.

Meiosis produces daughter cells that have one half the number of chromosomes as the parent cell.

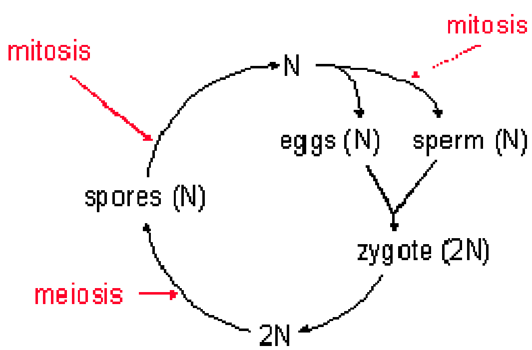
2N (diploid) → N (haploid)

Meiosis enables organisms to reproduce ***sexually***. The gametes (sperm and eggs) produced are haploid.
Meiosis is necessary in sexually-reproducing organisms because the fusion of two gametes (fertilization) doubles the number of chromosomes. Meiosis involves TWO divisions producing a total of four daughter cells.

In animals, meiosis occurs only when gametes (sperm, eggs) are formed.



In plants, gametes are not produced directly. Instead meiosis produces spores and then **mitosis produces gametes**. Although plants have an additional step, meiosis eventually results in the production of haploid gametes.



There are TWO divisions in meiosis; the first division is meiosis 1 and the second is meiosis 2. The phases have the same names as those of mitosis. A number indicates the division number (1st or 2nd):

meiosis 1: prophase 1, metaphase 1, anaphase 1, and telophase 1

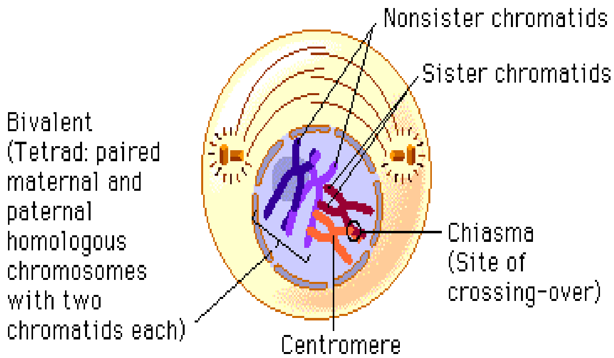
meiosis 2: prophase 2, metaphase 2, anaphase 2, and telophase 2

In the first meiotic division, the number of cells is doubled but the number of chromosomes is not. This results in 1/2 as many chromosomes per cell.

The second meiotic division is like mitosis; the number of chromosomes does not get reduced.

Meiosis – continued: Meiosis I

Prophase I



In this cell (above) 2N = 4

There are **<u>8</u>** chromatids (4 pairs of 2 "sister chromatids"), in this cell (see you lab manual, p. 67 for additional clarification).

Image from: http://www.phschool.com/science/biology_place/biocoach/meiosis/proi.html

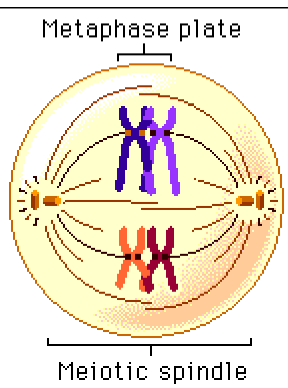
The events that occur during prophase of mitosis also occur during prophase I of meiosis. The DNA has been replicated, chromosomes coil up, the nuclear membrane begins to disintegrate, and the centrosomes begin moving apart.

<u>Synapsis</u> (joining) of homologous chromosomes produces tetrads (also called bivalents).
The two chromosomes may exchange fragments by a process called **crossing over**.

When the chromosomes partially separate in late prophase, the areas where crossing over occurred remain attached and are referred to as chiasmata (sing. chiasma). They hold the chromosomes together until they separate during anaphase. Crossing over between **homologous chromosomes** is likely to occur at several different points, resulting in chromosomes that are mixtures of the original two chromosomes.
One <u>kinetochore</u> forms on each chromosome (=one kinetochore per pair of chromatids) instead of on each chromatid as in mitosis**.**

The **spindle fibers** attach to the chromosomes and begin to move them to the center of the cell as they do in mitosis.

Metaphase I



In this cell (above) 2N = 4
Image from: http://www.phschool.com/science/biology_place/biocoach/meiosis/metai.html

Homologous pairs of chromosomes (bivalents or tetrads) become aligned independently in the center of the cell and are anchored to spindle fibers.

In the diagram at left you see:
8 chromatids arranged in 4 pairs of 2 sister chromatids which is the same as
4 chromosomes arranged into
2 tetrads (= 2 pairs of homologous chromosomes)

Remember: there is only **one kinetochore per pair** of chomatids (= one kinetochore per chromosome)

Meiosis I – continued:

Anaphase I

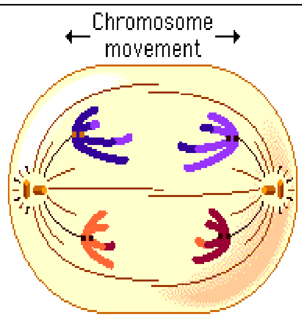


Image from: http://www.phschool.com/science/biology_place/biocoach/meiosis/anai.html

Anaphase I begins when **homologous chromosomes separate**. The two chromosomes of each bivalent (tetrad) separate and start moving toward opposite poles of the cell as a result of the 'pulling back' action of the kinetochore spindle fibers.

In anaphase I the two sister chromatids remain attached at their centromeres and **move together** toward the centro*some* ("pole"). A key difference between mitosis and meiosis is that **sister chromatids remain joined <u>after</u> metaphase in meiosis I**, whereas in mitosis they separate

Telophase I

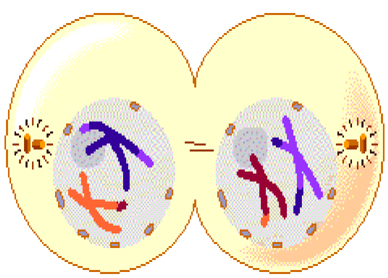


Image from: http://www.phschool.com/science/biology_place/biocoach/meiosis/teloi.html

The **homologous chromosome pairs complete their migration** to the two centro*somes* (poles). As a result, a haploid set of chromosomes is at each pole; each chromosome still has <u>two</u> chromatids.

A **nuclear envelope reforms** around each chromosome set, the **spindle disappears**, and **cytokinesis follows**.
In animal cells, cytokinesis involves the formation of a cleavage furrow, resulting in the pinching of the cell into two cells. After cytokinesis, each of the two progeny/daughter cells has a nucleus with a **haploid** (1N) set of chromosomes. We started with 4 chromosomes per cell and end up with 2 chromosomes per cell, at the end of meiosis I.

Many cells that undergo rapid meiosis do not uncoil (decondense) the chromosomes at the end of telophase I. Other cells do exhibit chromosome decondensation at this time and the chromosomes recondense in prophase II.

Interkinesis

Interkinesis is similar to <u>interphase</u> except DNA synthesis does **<u>not</u>** occur.

The **homologous chromosome pairs reach the poles of the cell**;
new nuclear envelopes form around them; and
cytokinesis follows to produce <u>two</u> cells.

<u>Remember</u>: The two daughter cells produced from **<u>meiosis I</u>** are haploid (1N).

Meiosis II
- is similar to mitosis but, in this case, **TWO** haploid (1N) cells **yield FOUR** haploid cells. Meiosis II is summarized in your lab manual on p. 69 with a graphic on p. 70.

Prophase II

• The centrioles duplicate. The two pairs of centrioles separate into two centrosomes.

• The nuclear envelope breaks down, and the spindle apparatus forms.

Anaphase II

• The centromeres separate

• The two chromatids of each chromosome move to opposite poles on the spindle.

The separated chromatids are now called chromosomes in their own right. So, in our example, the FOUR separated chromatids in each daughter cell are now FOUR chromosomes.

Telophase II

• A nuclear envelope forms around each of the sets of chromosomes. So, in our example, we will have FOUR new nuclei.

• Cytokinesis takes place in LATE TELOPHASE, producing two new daughter cells (gametes, in animals) from each cell produced at the end of meiosis I. Each cell produced from **meiosis II** has a haploid set of chromosomes. So, in our example FOUR new HAPLOID cells are produced, two from each cell produced at the end of meiosis I.

• Because of crossing-over, some chromosomes are seen to have recombined segments of the original parental chromosomes.

Additional Notes/Questions:

The following information on gametogenesis is from:
http://faculty.clintoncc.suny.edu/faculty/michael.gregory/files/Bio%20101/Bio%20101%20Lectures/Meiosis/meiosis.htm

Gametogenesis

Gametogenesis is the formation of gametes. The formation of eggs is ***oogenesis*** and the formation of sperm is ***spermatogenesis***.

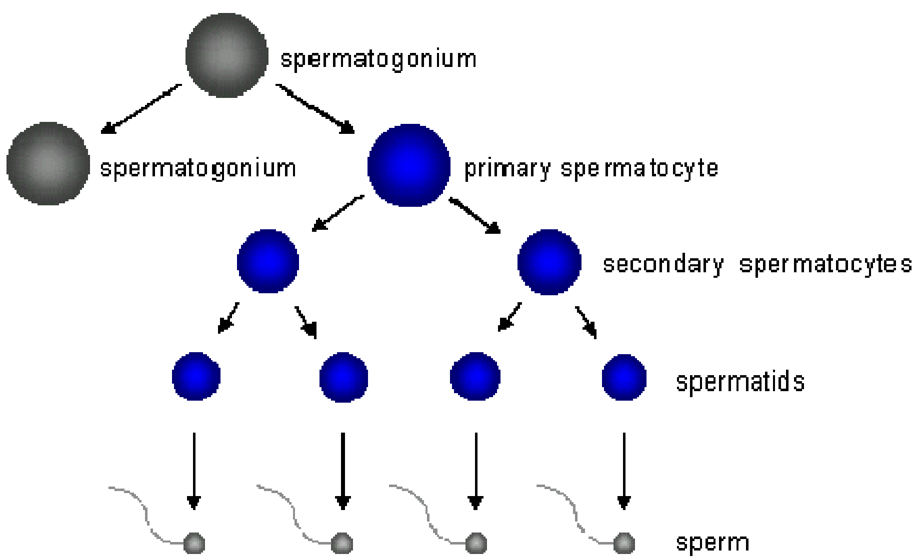
In animals, gametes are formed by meiosis.

Spermatogenesis

Spermatogenesis occurs in **seminiferous tubules** in testes.

The cell that undergoes meiosis is a ***primary*** **spermatocyte (2n)**. The first meiotic division produces two ***secondary*** **spermatocytes (1n)** and the second division produces **spermatids (1n)**, which mature to form sperm.

Meiosis I, Meiosis II, and the maturation process each take approximately 16 days (48 days total).



Males do not run out of sperm because mitosis precedes each meiosis. The diagram above shows that a spermatogonium divides by mitosis to produce a primary spermatocytes and a spermatogonium.

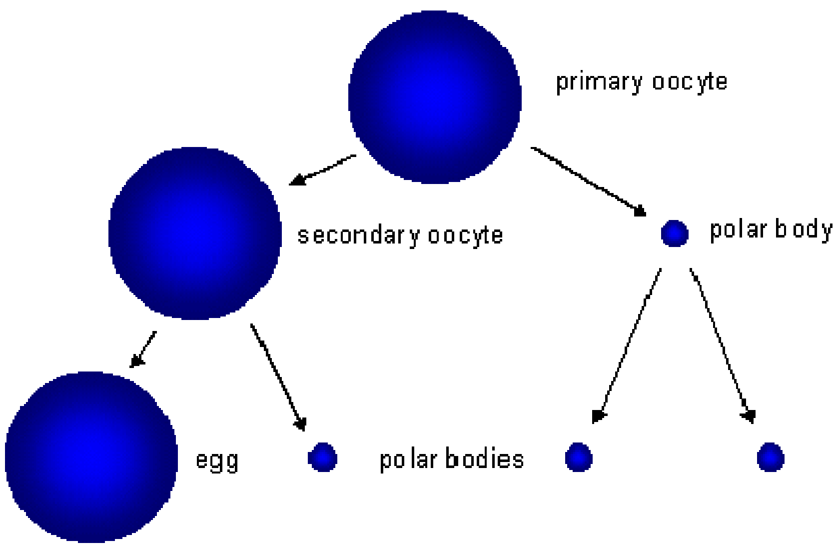
Gametogenesis – continued:

Oogenesis

Oogenesis occurs in the ovary. It produces one viable egg and two to three polar bodies.

Each of the **meiotic** divisions in humans is unequal. During the first meiotic division, a large ***secondary*** **oocyte** and a small **polar body** are produced. The secondary oocyte will divide to produce an egg and a polar body. The first polar body may divide to produce two more polar bodies.

Although the polar bodies are very small and nonfunctional, they contain a full set of chromosomes.

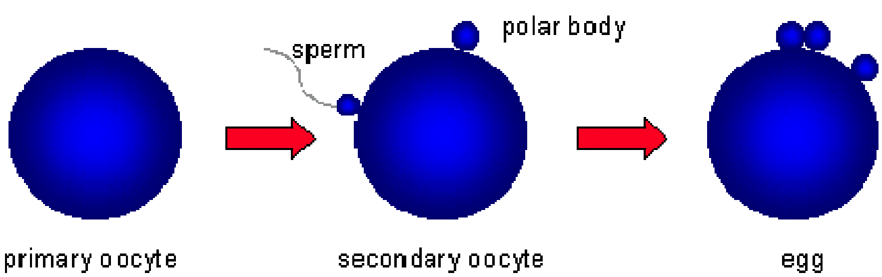


The ***primary*** **oocyte** is contained within a structure called a follicle. As the follicle enlarges, it produces hormones. During ovulation, the follicle ruptures and, in humans, releases the secondary oocyte.

Meiosis in human females begins before person is born but stops in prophase I and does not resume until after puberty. Each month, approximately 1000 primary oocytes will to mature but most will die.

Ovulation occurs approximately once every 28 days. Females ovulate approximately 400 times during their lifetime. Secondary oocytes are released at ovulation. The second meiotic division resumes after penetration by sperm.

In humans, secondary oocytes are fertilized. Eggs are produced only after fertilization of a secondary oocyte.



In the diagram above, the first polar body produced after the first meiotic division did not divide again. Women are born with all of the primary oocytes that they will ever have (2 million). At puberty, there are approximately 400,000 left.