AP BIOLOGY
HEREDITY
ACTIVITY #1

NAME______________________

DATE___________HOUR_____

MEIOSIS LAB

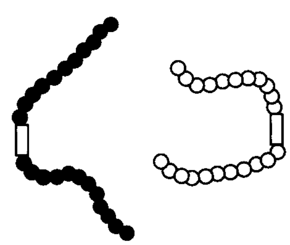
INTRODUCTION

Meiosis involves two successive nuclear divisions that produce four haploid cells. **Meiosis I** is the reduction division. It is this first division that reduces the chromosome number from diploid to haploid and separates the homologous pairs. **Meiosis II,** the second division, separates the sister chromatids. The result is four haploid gametes.

Mitotic cell division produces new cells genetically identical to the parent cell. Meiosis increases genetic variation in the population. Each diploid cell undergoing meiosis can produce 2^n different chromosomal combinations, where n is the haploid number. In humans the number is 2^{23}, which is more than eight million different combinations. Actually, the potential variation is even greater because, during meiosis I, each pair of chromosomes (homologous chromosomes) comes together in a process known as **synapsis.** Chromatids of homologous chromosomes may exchange parts in a process called **crossing over.** The relative distance between two genes on a given chromosome can be estimated by calculating the percentage of crossing over that takes place between them.

PART I: SIMULATION OF MEIOSIS

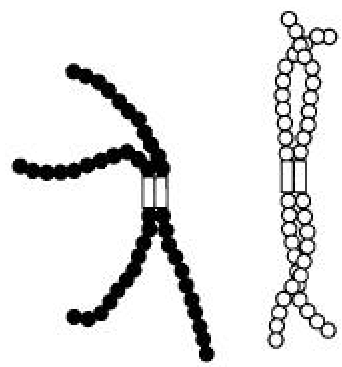
In this exercise you will study the process of meiosis using chromosome simulation kits. Your kit should contain two strands of beads of one color and two strands of another color. A homologous pair of chromosomes is represented by **one** strand of each color, with one of each pair coming from each parent. The second strands of each color are to be used as chromatids for each of these chromosomes.



Interphase:

Place one strand of each color near the center of your work area. (Recall that chromosomes at this stage would exist as diffuse chromatin and not as visible structures.) DNA synthesis occurs during interphase and each chromosome, originally composed of one strand, is now made up of two strands, or chromatids, joined together at the centromere region. Simulate DNA replication by bringing the magnetic centromere region of one strand in contact with the centromere region of the other of the same color. Do the same with its homolog.

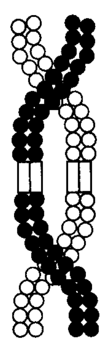
Summary: DNA Replication



Prophase I:

Homologous chromosomes come together and synapse along their entire length. **This pairing or synapsis of homologous chromosomes represents the first big difference between mitosis and meiosis.** A **tetrad,** consisting of four chromatids, is formed. Entwine the two chromosomes to simulate synapsis and the process of crossing over. Crossing over can be simulated by popping the beads apart on one chromatid, at the fifth bead or "gene," and doing the same with the other chromatid. Reconnect the beads to those of the other color. Proceed through prophase I of meiosis and note how crossing over results in recombination of genetic information.

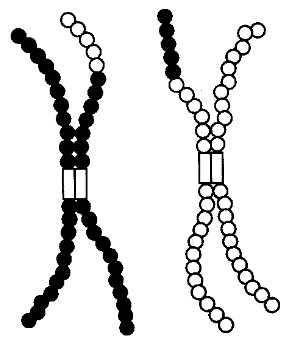
Summary: Synapsis and Crossing Over



Metaphase I:

The crossed-over tetrads line up in the center of the cell. Position the chromosomes near the middle of the cell.

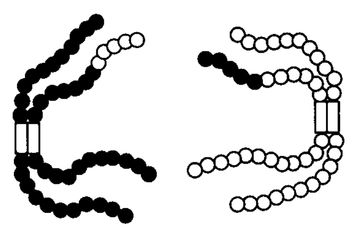
Summary: Tetrads align on equator



Anaphase I:

During anaphase I, the homologous chromosomes separate and are "pulled" to opposite sides of the cell. This represents a second significant difference between the events of mitosis and meiosis.

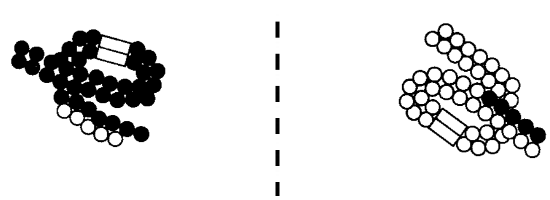
Summary: Tetrads separate
Chromosome number reduced



Telophase I:

Place each chromosome at opposite sides of the cell. Centriole duplication is completed in telophase in preparation for the next division. Formation of a nuclear envelope and division of the cytoplasm (cytokinesis) often occur at this time to produce two cells, but this is not always the case. Notice that each chromosome within the two daughter cells still consist of two chromatids.

Summary: 2 Haploid cells formed
Each chromosome composed of 2 chromatids



Meiosis II:

A second meiotic division is necessary to separate the chromatids of the chromosomes in the two daughter cells formed by this first division. This will reduce the amount of DNA to one strand per chromosome. This second division is called meiosis II. It resembles mitosis except that only one homolog from each homologous pair of chromosomes is present in each daughter cell undergoing meiosis II.

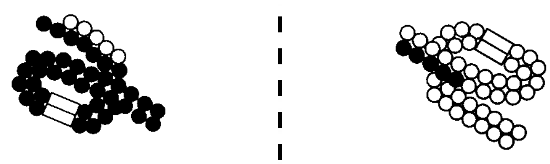
The following simulation procedures apply to haploid nuclei produced by meiosis 1.

Interphase II (Interkinesis):

The amount of time spent "at rest" following telophase I depends on the type of organism, the formation of new nuclear envelopes, and the degree of chromosomal uncoiling. Because interphase II does not necessarily resemble interphase I, it is often given a different name - interkinesis. DNA replication does not occur during interkinesis. This represents a third difference between mitosis and meiosis.

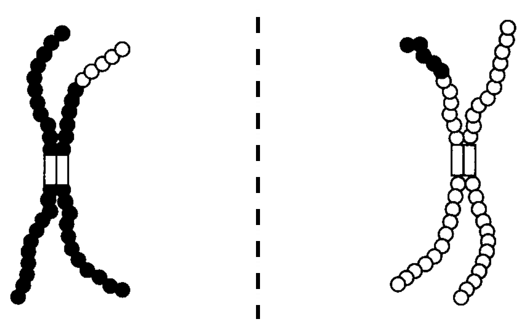
Prophase II:

No DNA replication occurs. Replicated centrioles (not shown) separate and move to opposite sides of the chromosome groups.



Metaphase II:

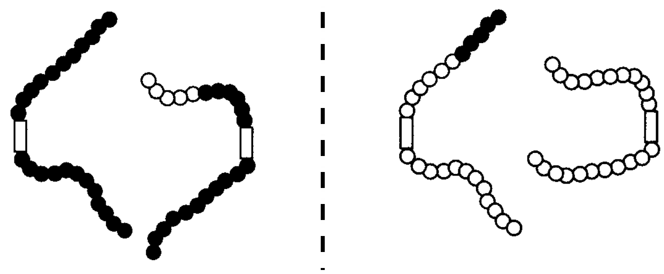
Orient the chromosomes so they are centered in the middle of each daughter cell.



Anaphase II:

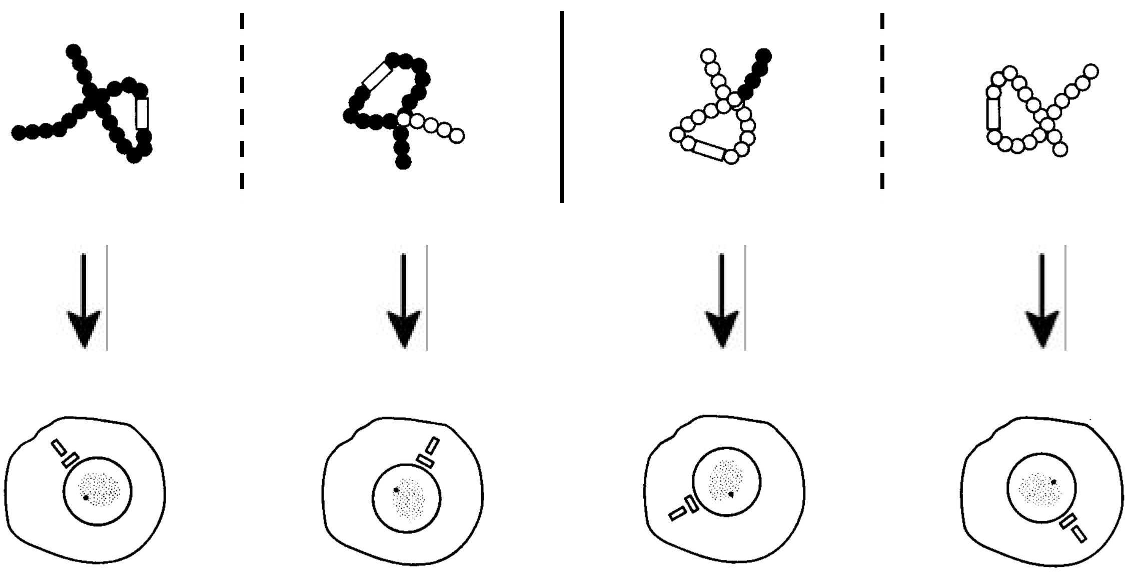
The centromere regions of the chromatids now appear to be separate. Separate the chromatids of the chromosomes and pull the daughter chromosomes toward the opposite sides of each daughter cell. Now that each chromatid has its own visibly separate centromere region, it can be called a chromosome.

Summary: Chromatids separate



Telophase II:

Place the chromosomes at opposite sides of the dividing cell. At this time a nuclear envelope forms and, in our simulation, the cytoplasm divides.



Analysis and Investigation:

1. Complete the following chart comparing mitosis and meiosis.

	Mitosis	Meiosis
Chromosome number in parent cells (2n or n)		
Number of DNA replications		
Number of divisions		
Number of daughter cells produced		
Chromosome number of daughter cells (2n or n)		
Purpose		

2. How are Meiosis I and Meiosis II different?

Meiosis I	Meiosis II

3. How do oogenesis and spermatogenesis differ?

Meiosis I	Meiosis II

4. Why is meiosis important for sexual reproduction?

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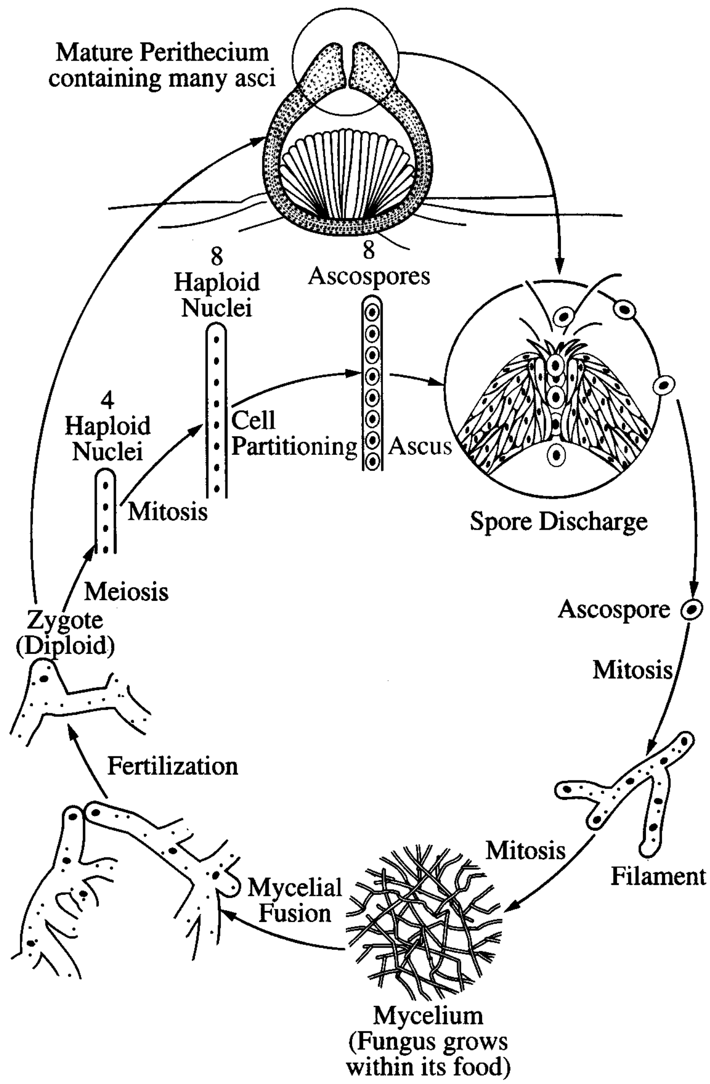
PART II: CROSSING OVER DURING MEIOSIS IN *SORDARIA*

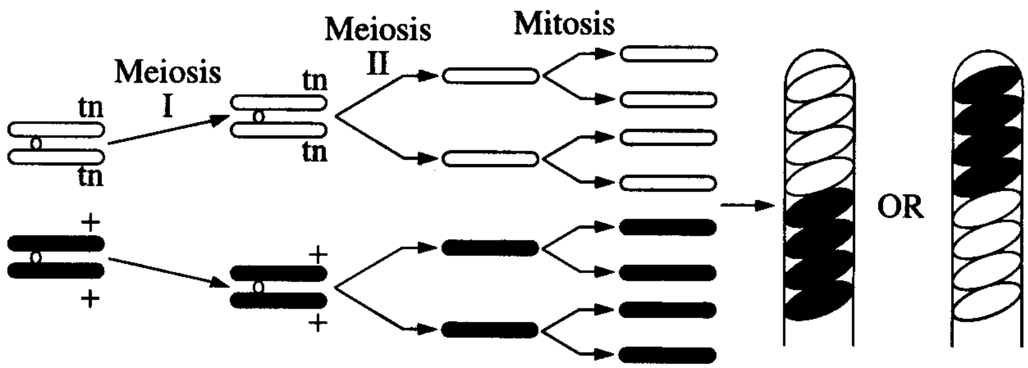
Sordaria fimicola is an ascomycete fungus that can be used to demonstrate the results of crossing over during meiosis. *Sordaria* is a **haploid** organism for most of its life cycle. It becomes **diploid** only when the fusion of the mycelia (filamentlike groups of cells) of two different strains results in the fusion of the two different types of haploid nuclei to form a diploid nucleus. The diploid nucleus must then undergo meiosis to resume its haploid state.

Meiosis, followed by mitosis, in *Sordaria* results in the formation of eight **haploid ascospores** contained within a sac called an **ascus** (plural, **asci**). Many asci are contained within a fruiting body called a **perithecium.** When ascospores are mature the ascus ruptures, releasing the ascospores. Each ascospore can develop into a new haploid fungus. The life cycle *of Sordaria fimicola* is shown at the right.



To observe crossing over in *Sordaria,* one must make hybrids between wild-type and mutant strains of *Sordaria. Wild-type Sordaria* have black ascospores (+). One mutant strain has tan spores (tn). When mycelia of these two different strains come together and undergo meiosis, the asci that develop will contain four black ascospores and four tan ascospores. The arrangement of the spores directly reflects whether or not crossing over has occurred. In the diagram below, no crossing over has occurred.

FORMATION OF NONCROSSOVER ASCI



Two homologous chromosomes line up at metaphase I of meiosis. The two chromatids of one chromosome each carry the gene for tan spore color (tn) and the two chromatids of the other chromosome carry the gene for wild-type spore color (+).

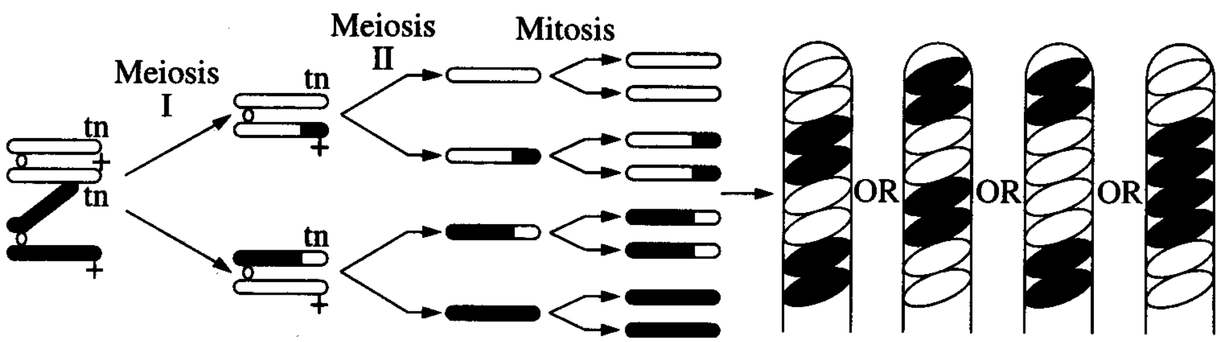
The first meiotic division (Meiosis I) results in two cells each containing just one type of spore color gene (either tan or wild-type). Therefore, segregation of these genes has occurred at the first meiotic division (Meiosis I).

The second meiotic division (Meiosis II) results in four cells, each with the haploid number of chromosomes (1n).

A **mitotic** division simply duplicates these cells, resulting in 8 spores. They are arranged in the 4:4 pattern.

The diagram below shows the results of crossing over between the centromere of the chromosome and the gene for ascospore color.

MEIOSIS WITH CROSSING OVER



In this example, crossing over has occurred in the region between the gene for spore color and the centromere. The homologous chromosomes separate during meiosis I.

This time, the Meiosis I results in two cells, each containing both genes (1 tan, 1 wild-type); therefore, the genes for spore color have not yet segregated.

Meiosis II results in segregation of the two types of genes for spore color. A **mitotic** division results in 8 spores arranged in the 2:2:2:2 or 2:4:2 pattern. Any one of these spore arrangements would indicate that crossing over has occurred between the gene for spore coat color and the centromere.

5. Examine each of the *Sordaria* pictures. For each picture, count the number of asci that do not show crossing over and the number showing crossing over.

Number of asci not showing crossing over ●●●●○○○○ ○○○○●●●●	Number of asci showing crossing over ○○●●○○●● ●●○○●●○○ ○○●●●●○○ ●●○○○○●●	**Total Asci**

The frequency of crossing over appears to be governed largely by the distance between genes, or in this case, between the gene for spore coat color and the centromere. The probability of a crossover occurring between two particular genes on the same chromosome (linked genes) increases as the distance between those genes becomes larger. The frequency of crossover, therefore, appears to be directly proportional to the distance between genes.

A **map unit** is an arbitrary unit of measure used to describe relative distances between linked genes. The number of map units between two genes or between a gene and the centromere is equal to the percentage of recombinants. Customary units cannot be used because we cannot directly visualize genes with the light microscope. However, due to the relationship between distance and crossover frequency, we may use the map unit.

6. Using the data you collected in #1, determine the distance between the gene for spore color and the centromere. Calculate the percent of crossovers by dividing the number of crossover asci (2:2:2:2 or 2:4:2) by the total number of asci x 100%.

   % of Crossovers = ____

7. To calculate the map distance, divide the percentage of crossover asci by 2. The percentage of crossover asci is divided by 2 because only half of the spores in each ascus are the result of a crossover event.

   Map Distance = ____

8. Draw a pair of chromosomes in Meiosis I and Meiosis II, and show how you would get a 2:4:2 arrangement of ascospores by crossing over. Use the diagram on page 9 for help.

Part III: Questions

Note: Use pages 226 – 237 to complete these questions.

9. Match the term with the correct definition or description.

______ Transmission of traits to offspring; Continuity of biological traits from one generation to the next	A. Variation
______ Inherited differences among individuals within a species	B. Heredity
______ Study of heredity and variation	C. Genetics

10. Describe the relationship among the following terms: **genes, DNA, chromosomes.**

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11. Determine if each of the following is true of **AS**exual or **S**exual reproduction.

______ 1 parent

______ 2 parents

______ offspring gets all its genes from one parent

______ offspring gets ½ of its from each parent

______ offspring is a clone of the parent

______ results in greater genetic variation

______ offspring vary genetically from siblings and parent

12. Match the term with the correct definition.

A. Autosome
B. Diploid
C. Fertilization
D. Gamete
E. Haploid
F. Homologous chromosomes
G. Karyotype
H. Meiosis
I. Sex chromosome
J. Somatic cell
K. Zygote

______ Body cells; cells other than sex cells

______ Display or photomicrograph of an individual's somatic-cell metaphase chromosomes arranged in standard sequence

______ Pair of chromosomes that have the same size, centromere position and staining pattern

______ A chromosome that is not a sex chromosome

______ Dissimilar chromosomes that determine an individuals sex; X and Y

______ Two sets of chromosomes; 2n

______ One set of chromosomes; 1n

______ Haploid reproductive cell; egg or sperm

______ Cell division that produces haploid cells

______ Fusion of egg and sperm; restores the diploid chromosome number

______ Fertilized egg; diploid cell produced by the fusion of 2 haploid gametes

13. Classify each of the following characteristics as true of the **A**nimal, **F**ungi, or **P**lant sexual life cycle.

______ gametes produced by meiosis

______ gametes produced by mitosis

______ gametes are the only haploid stage

______ multicellular organism is diploid

______ zygote is the only diploid stage

______ multicellular organism is haploid

______ alternation of generations

______ multicellular haploid stage is called the gametophyte

______ multicellular diploid stage is called the sporophyte

______ spores produced by meiosis

14. Match the characteristics with the correct phase.

A. Interphase I
B. Prophase I
C. Metaphase I
D. Anaphase I
E. Metaphase II
F. Anaphase II

______ Centromeres split, sister chromatids separate; single stranded chromosomes pulled to opposite poles

______ Chromosomes replicate

______ Homologous chromosomes line up at the equator (metaphase plate)

______ Chromosomes, consisting of two sister chromatids, line up singly at the metaphase plate

______ Synapsis of homologous chromosomes; crossing over at chiasmata; spindle forms

______ Homologous chromosomes separate and are pulled to opposite poles

15. Identify the phase of meiosis represented by each of the following diagrams.

			

		

16. Classify each of the following characteristics as true of **MI**tosis or **ME**iosis.

______ 1 division

______ 2 divisions

______ produces 2 daughter cells

______ produces 4 daughter cells

______ process used to produce gametes in animals

______ maintains chromosome number

______ cuts chromosome number in half

______ produces cells that are clones of the mother cell

______ creates genetic variation

17. Explain how each of the following is a source of genetic variation in a sexually reproducing population.

Independent Assortment	
Crossing Over	
Random Fertilization	