SCIENCE 10
ROCKRIDGE

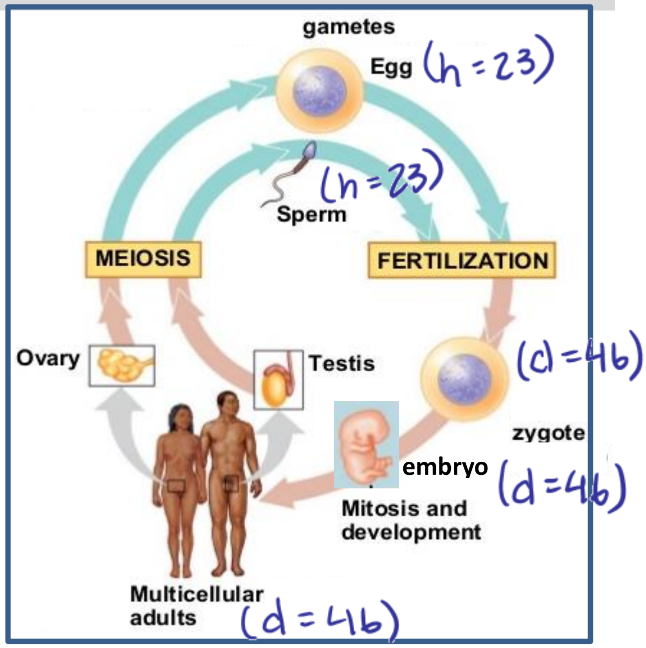
NAME: KEY.
BLOCK: _____ DATE: ____________

# Genetics, Meiosis & Fertilization – Understanding How Genes Are Inherited[1]

## GAMETES & FERTILIZATION

Almost all the cells in your body were produced by mitosis. The only exceptions are the **gametes (sex cells)** – sperm or eggs – which are produced by a different type of cell division called **meiosis**.

When organisms undergo sexual reproduction, the sperm and egg cells unite in a process called **fertilization** to form a single cell called the **zygote.** The zygote contains all the chromosomes from both the sperm and the egg. The zygote then divides into two cells by mitosis, then these cells each divide by mitosis, and mitosis is repeated many times to produce the cells in an embryo which then develops into a new organism.




1. Each cell in a normal human **embryo** has 23 pairs of homologous chromosomes, for a total of 46 chromosomes per cell. How many chromosomes are in a normal human **zygote**? Explain your reasoning.

   46 → each gamete contributes 23 during fertilization

2. How many chromosomes would human sperm and egg cells have if they were produced by mitosis? 46

3. If sperm and egg cells were produced by mitosis, how many chromosomes would a human embryo have? 92

**A human embryo with that many chromosomes in each cell would be abnormal and would die before it could develop into a fetus. This explains why gametes can *not* be made by mitosis.**

Fill in the blanks in each sentence below using the following terms: ***sperm cell, egg cell, 23, 46***

4. Each human sperm and egg should have 23 chromosomes, so fertilization will produce a zygote with 46 chromosomes; this zygote will develop into a healthy embryo with 46 chromosomes in each cell.

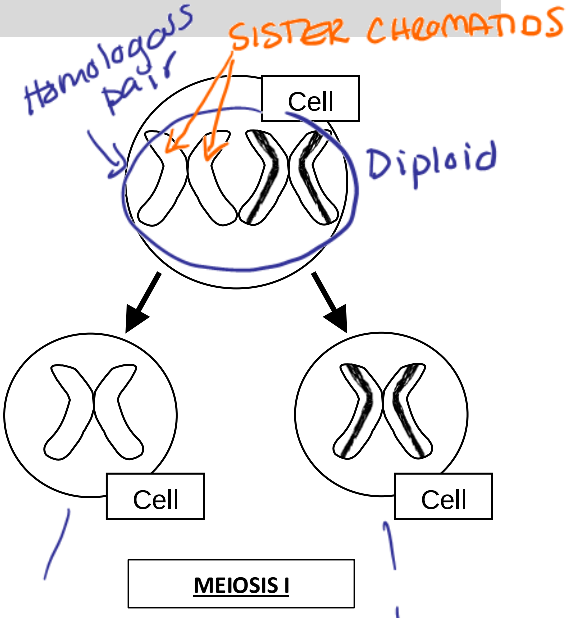
5. Each sperm and each egg produced by meiosis has only one chromosome from each pair of homologous chromosomes. When a sperm and egg unite during fertilization, the resulting zygote has 23 pairs of homologous chromosomes. For each pair of homologous chromosomes in a zygote, one chromosome came from the sperm cell and the other chromosome came from the egg cell

A cell that has pairs of homologous chromosomes is **diploid**.
A cell that has only one chromosome from each pair of homologous chromosomes is **haploid**.

6. Next to each type of cell/organism in the above diagram, write:
   - ☑ The number of chromosomes in that type of cell(s)
   - ☑ a **d** for diploid cell(s) or an **h** for haploid cell(s).

[1] Adapted from a document by Drs. Ingrid Waldron, Jennifer Doherty, R. Scott Poethig, and Lori Spindler, Department of Biology, University of Pennsylvania, © 2015; Teachers are encouraged to copy this Student Handout for classroom use. Word files for this Student Handout and for a shorter Student Handout, together with Teacher Preparation Notes with background information and instructional suggestions are available at http://serendip.brynmawr.edu/exchange/waldron/meiosis.

## Meiosis – Cell Divisions to Produce Haploid Gametes




Before meiosis, the cell makes a copy of the DNA in each chromosome. Then, during meiosis there are <u>two cell divisions</u>, **Meiosis I** and **Meiosis II**. These two cell divisions <u>produce four haploid daughter cells</u>.

<u>Meiosis I</u> is different from mitosis because each pair of homologous chromosome lines up next to each other and then the two homologous chromosomes separate. (The figure shows Meiosis I for a cell with a single pair of homologous chromosomes; the stripes on the chromatids of one of the chromosomes indicates that this chromosome has different alleles than the other homologous chromosome.)

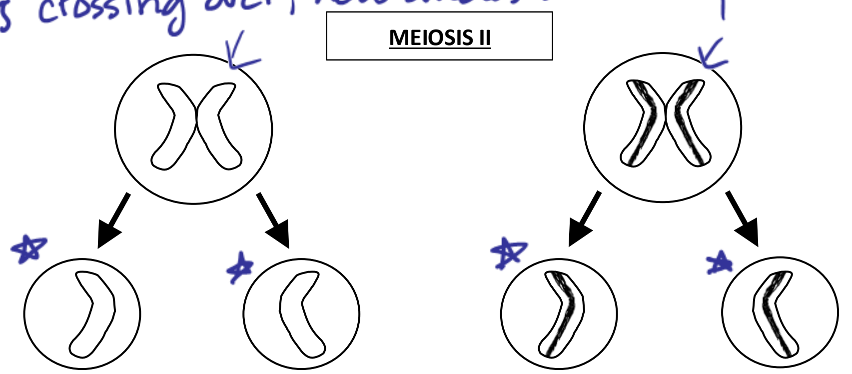
Meiosis I produces daughter cells with half as many chromosomes as the parent cell, so the **daughter cells are haploid**. Each daughter cell has a different chromosome from the original pair of homologous chromosomes.

**7.** In the figure for Meiosis I, label:
- [x] the diploid cell
- [x] the pair of homologous chromosomes in the diploid cell
- [x] the two sister chromatids in one of these chromosomes.

**8.** Do the chromosomes in the two daughter cells produced by Meiosis I have the same alleles for each gene? Explain your reasoning.

NO CROSSING OVER → yes. They are a product of DNA replication, so each chromatid is identical

CROSSING OVER → no. During crossing over, new alleles are transferred.




<u>Meiosis II</u> is like mitosis since the sister chromatids of each chromosome are separated. As a result, each daughter cell gets one copy of one chromosome from the pair of homologous chromosomes that was in the original cell. These haploid daughter cells are the gametes.

**9.** Put a star (*) beside the cells in the diagram OF Meiosis II that represent sperm produced by meiosis.

## Modeling Meiosis

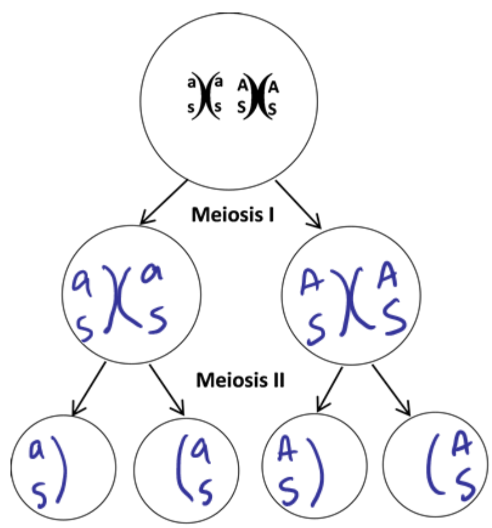
To model meiosis, you will use the same pairs of model homologous chromosomes that you used to model mitosis, as well as one additional chromosome pair – chromosomes with the gene for alcohol metabolism. Human chromosome 11 has the genes that can result in albinism and sickle cell anemia (as well as more than 1000 additional genes). Human chromosome 12 has different genes, including a gene that can result in alcohol sensitivity. The table below shows the effects of the L and l alleles of this gene.

**10.** The genotype for a person with the chromosomes for this activity is **AaSsLl**. What phenotypic characteristics would a person with this genotype have? Circle the appropriate phenotypic characteristics in this table.

| Genotype | → | Protein | → | **Phenotype** (characteristics) – circle below. |
|---|---|---|---|---|
| **AA** or **Aa** | → | Enough normal enzyme to make melanin in skin and hair | → | Normal skin and hair color |
| **aa** | → | Defective enzyme for melanin production | → | Very pale skin and hair color; albino |
| | | | | |
| **SS** or **Ss** | → | Enough normal hemoglobin to prevent sickle cell anemia | → | Normal blood; no sickle cell anemia |
| **ss** | → | Sickle cell hemoglobin, which can cause red blood cells to become sickle shaped | → | Sickle shaped red blood cells can block blood flow in the smallest blood vessels, causing pain, etc.; sickle cell anemia |
| | | | | |
| **LL or L l** | → | Defective enzyme (defective protein inactivates any normal enzyme) | → | Alcohol sensitive (skin flush and discomfort after drinking alcohol) |
| **l l** | → | Normal enzyme for alcohol metabolism | → | Not alcohol sensitive |

You will begin modeling meiosis with only one pair of the model chromosomes. Use this pair of model chromosomes to model each step of meiosis. Use string to model the cell membranes at each stage.

**11.** Show the results of your modeling in this figure. Sketch and label the chromosomes in each cell that is produced by Meiosis I and by Meiosis II.

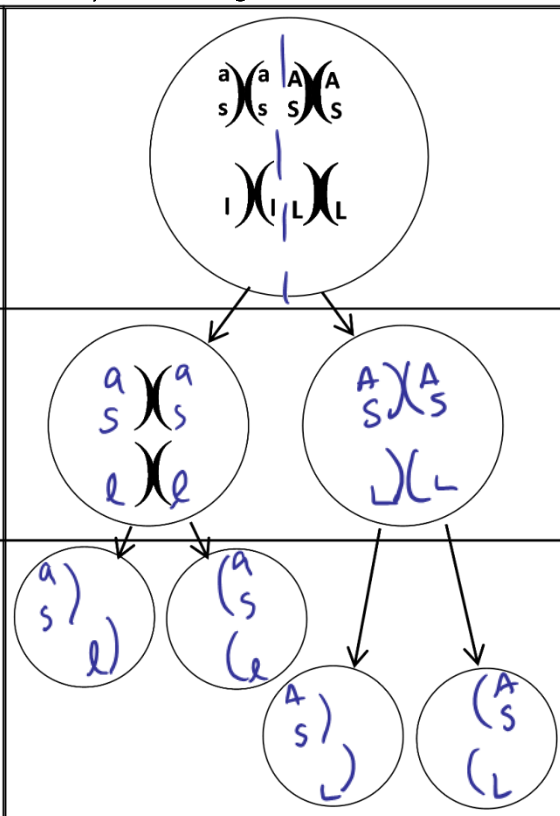
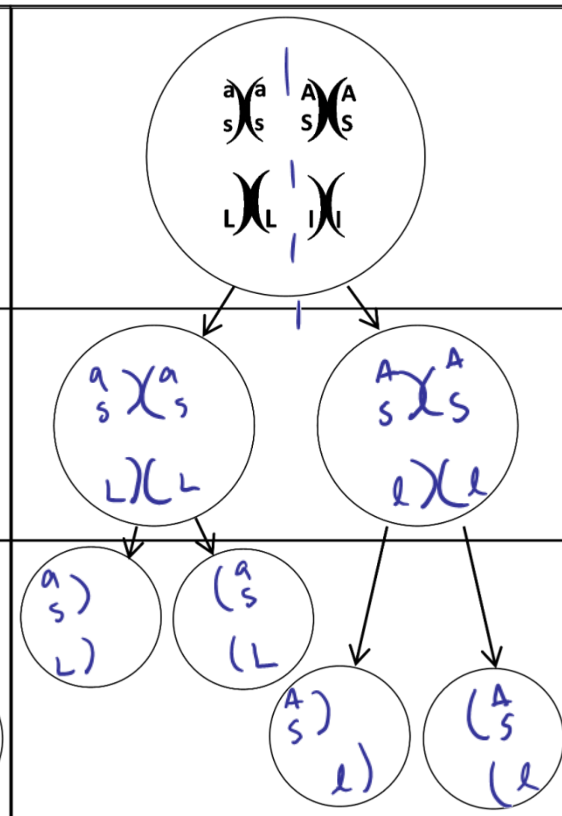



**12.** You have modeled meiosis, beginning with a diploid cell that has the alleles **AaSs.** The haploid gametes produced by meiosis have the alleles: __ **AS** or **as** __ **AASS** or **aass** __ **AaSs**

Next, you will model meiosis using both pairs of model chromosomes. At the beginning of Meiosis I each pair of homologous chromosomes lines up independently of how the other pairs of homologous chromosomes have lined up. This is called **independent assortment**. As a result of independent assortment, at the beginning of Meiosis I the **as** chromosome can be lined up on the same side as either the **l** chromosome or the **L** chromosome (see figure).

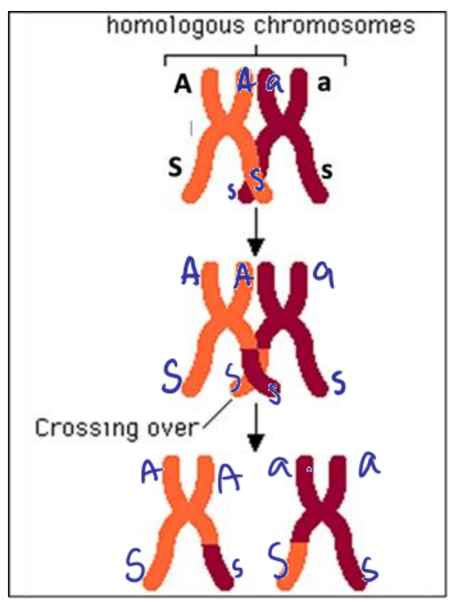
- Use your four model chromosomes to model Meiosis I and Meiosis II for both of the possible ways of lining up the model chromosomes at the beginning of Meiosis I.

**13.** Record the results of your modeling in this chart.

| | | |
|---|---|---|
| **Chromosomes at the beginning of Meiosis I** |  |  |
| **Chromosomes at the end of Meiosis I** | | |
| **Chromosomes at the end of Meiosis II** | | |
| **Alleles in the gametes** | asl or ASL | asL or ASl |

When a pair of homologous chromosomes is lined up next to each other during Meiosis I, the two homologous chromosomes can exchange parts of a chromatid. This is called **crossing over**.

*14.* **A)** *On each chromatid of the chromosomes in the bottom row of the figure to the right, label the alleles for the genes for albinism and sickle cell anemia.*




When these chromosomes and chromatids separate during Meiosis I and II, this produces gametes with four different combinations of alleles for the genes for albinism and sickle cell anemia.

**b)** *The combinations of alleles in the different gametes are:*

AS As aS as

**14a.** Explain why different gametes produced by the same person can have different combinations of alleles for genes that are located on two different chromosomes.

Independent Assortment

**14b.** Explain why different gametes produced by the same person can have different combinations of alleles for two genes that are located far apart on the same chromosome

Crossing over.