

## MCDB 1041/MCDB 2152 Activity 1: Meiosis

by Jennifer Knight and Michelle Smith, MCD Biology, University of Colorado

Work in groups of 2-4 people. Discuss and agree on answers to the questions posed throughout this exercise. Your LA will check to make sure you are making progress on the questions, but you do not have to turn in your answers.

### Objectives:

- Know the chromosomal makeup of a human cell
- Draw chromosomes before, during and after meiosis
- Describe the difference between a “sister” and “homologous” chromosome
- Discover how variability arises in the generation of offspring

---

### Background

Today you will be working through the process of meiosis using paper chromosomes. It is important that you actually manipulate the chromosomes and draw the results. In thinking about how meiosis works, it is easiest to think about just a few chromosomes in a human cell, rather than all the chromosomes.

So, for today’s exercise, imagine you are exploring the inheritance of two of the most common genetic disorders in the US, hemochromatosis and cystic fibrosis. We have made up which chromosomes contain these genes, but the diseases are in fact caused by defects in the genes described below.

### Hemochromatosis

- Imagine that the gene involved in the disease hemochromatosis is on chromosome 1. The allele “A” shown on chromosome 1 is the normal form of the gene.
- The protein made from the “a” allele is defective. People with two mutant copies of the this gene absorb too much iron from their diet. Hemochromatosis is inherited in a recessive manner: you have to inherit two copies of the recessive “a” allele in order to get the disease.

### Cystic fibrosis

- Imagine that the gene involved in the disease Cystic Fibrosis is on chromosome 3. “F” is the normal form of the gene that codes for the channel protein that allows chloride to pass through a cell, thus enabling normal lung and pancreas functions.
- “f” is the abnormal recessive form of the gene. The channel protein made from the “f” allele is defective. Like hemochromatosis, cystic fibrosis is also inherited in a recessive manner.

### Let’s meet Chris and Emma:

Chris and Emma are each carriers for hemochromatosis and cystic fibrosis. Another way of saying this is that they are heterozygous.

1. Write the genotype of Chris and Emma, with respect to these two genes.
2. What is their phenotype? Do these individuals have symptoms of either disease?

The cells in Chris and Emma’s bodies that will generate their germ cells (sperm or egg) are represented today by two plastic containers, each containing a total of 4 pieces of paper (chromosomes). You also have a little cup with extra chromosomes (you’ll use these for replicating your “chromosomes”). In each plastic container, there should be 2 different lengths of paper, numbered 1 and 3, and 2 different colors of paper (pink and green are for Chris, and yellow and orange are for Emma). The different colors indicate that the two copies of each chromosome are non-identical; these are homologous chromosomes. The two different colors also represent the fact that Chris, for example, inherited one set of chromosomes from each of his parents (a “green parent” and a “pink parent”).

**TO START: Take out the contents of one cell. There should be 4 chromosomes: 2 yellow and 2 orange or 2 green and 2 pink.** Take out the chromosomes labeled 1 and 3 (for example: one pink #1, one green #1, one pink #3, and one green #3). The different chromosomes are indicated both by the number at the bottom, and by the fact that they are different lengths.

The term “homologous chromosome” describes the relationship between the two #1 chromosomes and the two #2 chromosomes.

1. Are the homologous chromosome #1s different from each other?
2. Do the homologous chromosomes have the same set of genes?
3. Do they have the same alleles?

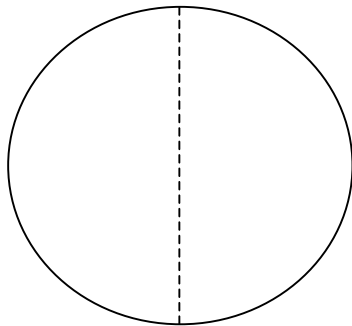
Before a cell enters into either mitosis or meiosis, it makes an identical copy of its DNA. “Replicate” each chromosome by selecting matching color and size paper pieces from the general supply in the paper cup. A replicated chromosome is comprised of two sister chromosomes known as sister chromatids.

4. Are the sister chromatids different from each other?
5. Do the sister chromatids have the same set of genes?
6. Do they have the same alleles?

### **Drawing Meiosis 1 and 2**

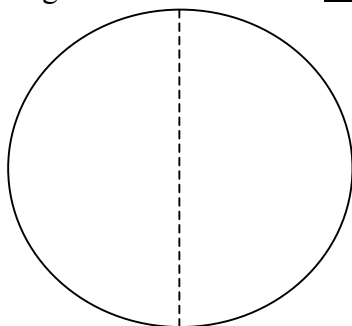
During meiosis the homologous chromosomes align themselves so half of them are on one side of a center line through the cell (illustrated as a dotted line below, and known as the metaphase plate) and half of them are on the other side of the metaphase plate. Take one set of replicated chromosomes (either the Emma’s OR Chris’ and align the chromosomes as if they were in metaphase of meiosis I.

1. Draw what that looks like here (note chromosome # and letters on your drawing):



For this example, there are two different ways to line up the chromosomes on the metaphase plate.

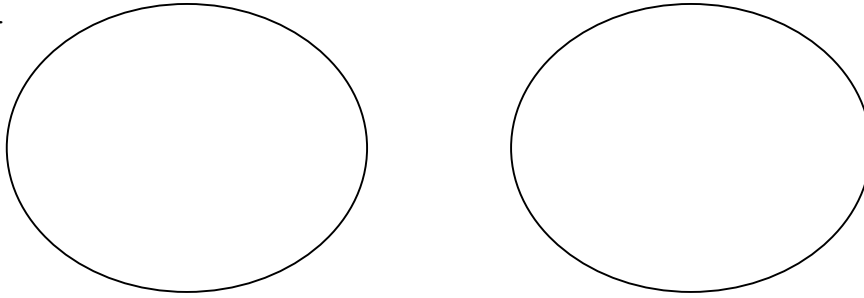
2. Look at your drawing above and draw the other way that the chromosomes could align:



The principle you have just illustrated in the two drawings above is called **Independent Assortment**. Aside from crossing over (recombination), which we will discuss later, it is the main reason why there are so many different possibilities in the genotypes of germ cells.

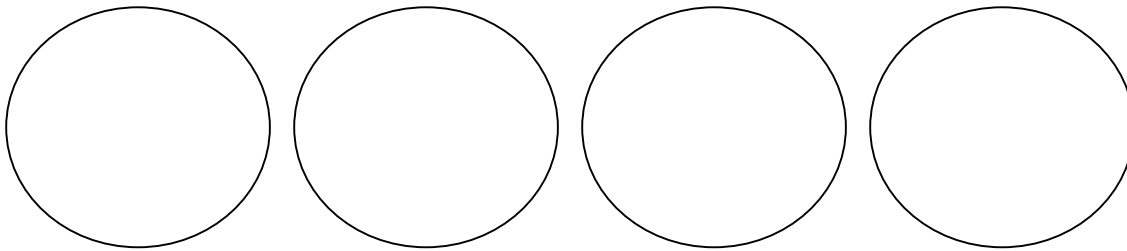
At the end of meiosis I, the cell splits into two new cells.

3. Draw the chromosomes that are in each of these cells below (note chromosome # and letters on your drawing).



At the end of meiosis II, four cells have been generated from the two above. The end products of meiosis are gametes (egg or sperm).

4. Draw these gametes with their chromosomes here (note chromosome # and letters on your drawing):



**Concepts: What can you deduce from your meiosis drawings?**

5. How many chromosomes are in each sperm cell at the end of meiosis for this activity?
6. In real life, how many chromosomes are there in each gamete in humans after meiosis?
7. Is the process of meiosis similar for producing both egg and sperm? Can you think of any differences?

### Part 3: Making the next generation

You have completed the meiosis process for either Chris or Emma. Now, go through meiosis for the other parent. Once both sets of meiosis are complete for both parents, **randomly** pick a germ cell from Chris (pink and green) and a germ cell from Emma (orange and yellow) and put them together: this is **Child 1**.

1. Record its “genotype” (chromosome color and alleles; see example child) and phenotype in the table below.

Chromosome number	Example child	Child 1	Child 2	Child 3
1 (longest)	Pink: A Yellow: A			
3 (shortest)	Green: f Yellow: F			
Phenotype	Normal			

2. Generate 2 more children and record their genotypes and phenotypes in the table.

**Decision time!**

3. When you made each child above, you probably just picked from the gametes you made from one round of meiosis I and II. If you were mimicking real life, is that realistic? Should you return all the pieces of paper to their original containers and begin meiosis over again to produce each new child? Why or why not?

**Concepts: What can you deduce from the mating activity?**

What results do you get if you align the chromosomes differently at metaphase of meiosis I? If meiosis is normal, could Chris and Emma end up with a **child** that has

4. 2 orange and 2 yellow chromosomes? Why or why not?
5. 2 pink and 2 yellow chromosomes? Why or why not?
6. One orange, 1 green, 1 pink and 1 yellow chromosome? Why or why not?
7. All 4 chromosomes of one color? Why or why not?

**Practice connecting meiosis to inheritance probabilities**

1. Say Bob is heterozygous for sickle cell anemia, Ss. Bob's wife Sarah is also Ss. Draw a Punnett Square if you would like.  
What's the chance that Bob and Sarah's offspring will have sickle cell anemia?  
What's the chance than Bob and Sarah's will be normal phenotypically?

2. Say Bob is ALSO heterozygous for cystic fibrosis, so his genotype is SsFf.

What gametes can Bob produce?

What's the chance of producing each gamete?

If Sarah is SsFF, draw out the Punnett Square for their possible children. Circle all who will be normal phenotypically with respect to cystic fibrosis, but will have sickle cell anemia.

Challenge question: What's the probability of this phenotype?