



Chapter 13 Project

Genetic Shuffle

Project Goal + Timeline

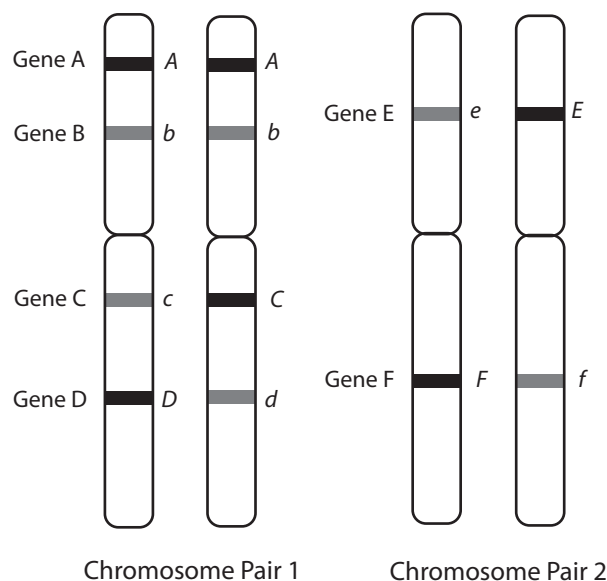
In this project, you will simulate genetic assortment during meiosis and fertilization to examine sources of genetic diversity. You'll apply what you've learned about meiosis, crossing over, and independent assortment in an interactive way that is rooted in the modern, molecular understanding of these phenomena. This project will help demonstrate the mechanisms behind the huge amount of genetic diversity possible in eukaryotes. This project should take about two hours to complete and is best completed with a partner or larger group.

Directions

Eukaryotes with a sexual life cycle, existing as diploid cells but reproducing through the fusion of haploid cells, have a tremendous amount of genetic diversity. This diversity comes about through a variety of means, and you will simulate some of these processes here.

Although we have many thousands of genes, arrayed across 22 pairs of homologous chromosomes and one pair of sex chromosomes, your simulation will employ a simpler model. We will consider 6 genes across 2 pairs of homologous chromosomes. You can represent the chromosomes and genes in a variety of ways, such as by using cards or Play Doh, or just by recording alleles for the genes. We'll identify the genes as genes A through F. We'll assume each gene has two alleles (for example, *A* and *a*) with the uppercase allele (e.g., *A*) dominant to the lowercase allele (e.g., *a*). We'll also assume each gene is associated with a single trait. For example, allele *A* results in trait A.

Let's suppose genes A through D are located on chromosome pair 1, while genes E and F are located on chromosome pair 2. The figure shows the arrangement of the genes on the chromosomes, along with a hypothetical pair of alleles for each gene.



You will create a diploid genotype for an individual, and your partner will do the same. If you would like a random genotype, you should roll a die for the alleles for each gene. To do so, first roll a die for each gene on one homologous chromosome of chromosome pair 1 and chromosome pair 2. If you roll a 1 through 4, it should be the dominant allele, and if you roll a 5 or 6 it should be the recessive allele. Then, repeat this process for each of the genes on the other homologous chromosome of both pairs.

You can represent the genotype on the following table.

TABLE 1: Diploid Genotype for Six Genes

Gene and Position	Allele on Paternal Homolog	Allele on Maternal Homolog
A, chromosome 1 position 1		
B, chromosome 1 position 2		
C, chromosome 1 position 3		
D, chromosome 1 position 4		
E, chromosome 2 position 1		
F, chromosome 2 position 2		

If you are using cards or another material to represent these traits, you should do so in a clear manner and have them set up and ready for meiosis. Based on this first step, answer the following questions:

1. What is the genotype of your individual? Please make a note of the order of the alleles on each homologous chromosome for both chromosomes.
2. Does the individual express the dominant or recessive phenotype associated with each gene?

Now, let's simulate meiosis. You will produce 4 gametes for each cell undergoing this process. First, however, we need to replicate each chromosome and pair these homologous pairs up through synapsis of prophase I. During this step, crossing over can occur. If this happens, you should swap the alleles at a particular point but only between two sets of nonsister chromatids. Before simulating crossing over, you will need to rewrite the genotypes you recorded in Table 1 in duplicate to represent the sister chromatids. You can do this in the first part of Table 2 (the "Before Crossing Over" section).

Now, you will simulate crossing over. Roll a die. If you roll a 2, you have crossing over occurring between the positions of genes A and B. To reflect this, the alleles of genes B, C, and D should be switched between two nonsister chromatids (between a sister chromatid of a paternal homolog and a sister chromatid of a maternal homolog). Rolling a 3 is a crossover event between the positions of genes B and C, so you should switch the alleles of genes C and D between two nonsister chromatids. Rolling a 4 is a crossover event between the position of genes C and D, so you should switch the alleles of gene D between two nonsister chromatids. Rolling a 5 is a crossover event between genes E and F, so you should switch the alleles of gene F between two nonsister chromatids. Rolling a 1 represents no crossover, while rolling a 6 represents a double crossover event; first between genes A and B and then again between genes B and C, so you only switch the alleles of B between the two nonsister chromatids.

TABLE 2: Results of Crossing Over

Gene	Before Crossing Over				After Crossing Over			
	Paternal Homolog		Maternal Homolog		Paternal Homolog		Maternal Homolog	
	Sister Chromatid	Sister Chromatid	Sister Chromatid	Sister Chromatid	Sister Chromatid	Sister Chromatid	Sister Chromatid	Sister Chromatid
A								
B								
C								
D								
E								
F								

Compare your results for each of the previous genes with a partner. Finally, you will simulate independent assortment to create 4 gametes from meiosis. To determine the genotype of each gamete, roll a die. If you roll an even number, don't take any action. The chromosomes will assort as you have written in Table 2, so you can copy the "After Crossing Over" results into Table 3 to represent the genotypes of your four gametes. However, if you roll an odd number, you'll switch the paternal homolog alleles for genes E and F with the maternal homolog alleles for genes E and F before entering the results in Table 3. This will simulate the chromosomes sorting independently of one another to form daughter cells. Now, you can write the final four columns again to specify the four possible gametes you have created in Table 3.

Now, you and your partner will each have four gametes after crossing over and independent assortment. Both of you will need to select one gamete to combine in fertilization. (You can do this separately.) Roll the die once; rolling between a 1 and a 4 will select which gamete you produced that is used in the fertilization event. If you roll a 5 or 6, try again. Your partner will do the same, creating (most likely) a different fertilization event.

TABLE 3: Independent Assortment and Fertilization

	Before Fertilization				After Fertilization	
Gene	Gamete 1	Gamete 2	Gamete 3	Gamete 4		
A						
B						
C						
D						
E						
F						

You and your partner have now created two new diploid organisms from the same set of four gametes. Based on your results, please answer the following questions:

- Based on what you did in this simulation, what is the relationship between the two offspring or fertilization events? How are they related?
- What are the similarities between the two offspring you produced? Write their genotype and their phenotype.
- Consider the original chromosome pairs you designed in Table 1. How many possibilities were there for the genotypes of the gametes, assuming crossing over did not occur? Based on this value, how many total possibilities were there for the genotypes of the offspring produced by fertilization, also assuming crossing over did not occur?
- How did crossing over affect the number of possible genetically distinct gametes that could be produced? How does this mechanism affect the possible genotypes of the offspring?
- In the simulation, how did the distance between linked genes affect the chance that the alleles for the genes would become unlinked by a crossing over event? How did this aspect of the simulation relate to the actual effect of genetic distance on the frequency with which linked genes become unlinked?

You should summarize your results by drawing a depiction of the cells involved, drawing the different homologous chromosomes as they progress through meiosis I, meiosis II, and fertilization.

Project Materials

- Project worksheet and a pen, or a computer with a word processor
- At least one 6-sided die
- A partner
- Optional: index cards, Play Doh, or some other object to represent the different alleles

 Student Checklist

- ☐ Complete Table 1
- ☐ Complete Table 1 Questions
- ☐ Complete Table 2
- ☐ Complete Table 3
- ☐ Complete Final Questions
- ☐ Draw a representation of the events that transpired in the simulation