Dropping Your Genes

A Simulation of Meiosis and Fertilization
and
An Introduction to Probability

To fully understand Mendelian genetics (and, eventually, population genetics), you need to understand certain aspects of probability as illustrated by the behavior of chromosomes and genes during meiosis and gametic union. Inheritance of factors (alleles of a gene) controlling a particular trait involves a distinct element of chance. The determinations of which allele of a gene pair gets into a particular egg or sperm and which gametes participate in gametic union are random processes. Understanding the consequences of the meiotic process and subsequent gametic union is vital to understanding genetics. The objectives of this exercise are:

1.) to emphasize the importance of the segregation and independent assortment of alleles of genes that occur during the first division of meiosis
2.) to demonstrate the randomness of gametic union
3.) to introduce (or reinforce) some considerations of probability.
4.) to gain experience performing chi-square goodness of fit analyses.

To simulate chromosome behavior during meiosis, you will be provided with a diploid set of autosomal chromosomes (a genome with 2N = 6). Each unit consists of the two chromosomes that make up an homologous pair that you will cut out, fold and glue together back to back (see Figure 1). One side of each unit, then, is a chromosome. Even though real chromosomes consist of many genes, each of yours will have only one. The genes you will use control the expression of the following traits: the capability to roll the tongue (R or r); the capability of tasting PTC (T or t); and the presence of brown eye pigment (N or n). A capital letter represents a dominant allele and a the lower case letter its recessive allele. These “chromosomes”, then, represent members of homologous pairs that already have synapsed and lined up on the metaphase plate during the first meiotic division. Remember that at this stage all chromosomes have replicated. You will have to imagine that each member of the homologous pair consists of two sister chromatids.

Figure 1. An homologous pair of chromosomes with the alleles of one gene labeled to illustrate a heterozygous genotype.
Anaphase of the first meiotic division is simulated simply by dropping the chromosomes onto the table top from a distance of several feet. Since in most cases the second division of meiosis merely separates genetically identical sister chromatids, dropping the chromosomes also simulates gamete formation. Since only one side of the paper chromosomes will be facing up, the allelic notation on that side represents the member of the homologous pair that ended up in that gamete. Dropping one homologous pair ("chromosome") will illustrate Mendel's principle of segregation. Dropping more than one pair will demonstrate independent assortment. Repeated chromosome drops will show the randomness of segregation and independent assortment.

This assignment will be due as directed by your lab instructor.

**The Monohybrid -- One Gene with Two Alleles**

A monohybrid is an individual with a genotype of the sort "Aa". Monohybrid crosses, then, involve mating individuals that differ in the alleles of only one gene (i.e., they are heterozygous). When monohybrids produce gametes, the homologous chromosomes synapse and continue through meiosis. Because of the genetic consequences of meiosis, equal numbers of the gametes having different alleles should be produced. Knowing the relative proportions of the gametes, you can calculate the probability of obtaining various genotypes among the progeny produced by gametic union.

A simple example can illustrate these ideas. Choose a particular chromosome from your genome. Have a lab partner choose the same chromosome from his or her genome. By "dropping your genes", both of you can form gametes independently. Each partner should keep track of the alleles that face up (the genotype of the gamete) and record the genotype of the zygote formed by uniting your gametes with your lab partner's gametes. Partners should produce 30 gametes each and, by gametic union, 30 zygotes.

Before forming gametes and zygotes, though, predict the expected outcomes by filling in the appropriate columns in the tables below. Then generate gametes and zygotes and include the observed results in the tables. Finally test your gene dropping and uniting data to see if your observed results agree with your predicted outcomes.

**Gametes**

<table>
<thead>
<tr>
<th>Result (genotypes)</th>
<th>Probability</th>
<th>Observed (O) Number</th>
<th>Expected (E) Number</th>
<th>Deviation (O-E)</th>
<th>(O-E)^2</th>
<th>(O-E)^2 / E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totals</td>
<td>1</td>
<td>30</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When calculating the expected number for each zygotic genotype, remember that the formation of your gametes and those of your lab partner are independent events. You, therefore, need to calculate the probability of two independent events occurring simultaneously. This probability is expressed by the **product rule** that states that the **joint probability of two independent events occurring is the product of their individual probabilities**. You have already figured out the probability of obtaining gametes of each genotype, now figure out the combinations possible during gametic union and their probabilities.

Dropping Your Genes
You should have noticed that two of the combinations above are genetically identical. That is, if an individual is heterozygous and one allele is dominant over its homologous allele, only the characteristic controlled by the dominant allele will appear in that individual. To calculate the total probability of producing an individual with either of the two heterozygous combinations you need to use the sum rule that states that the probability of either of two mutually exclusive events occurring is the sum of their individual probabilities.

The Dihybrid -- Two Unlinked Genes, Each With Two Alleles

Now, what happens if the parents differ genetically in two characteristics controlled by the expression of two unlinked genes? Dihybrid individuals have a genotype of the sort “AaBb.” “Unlinked” means that the “A” gene is on one pair of homologous chromosomes and the “B” gene is on a different pair. “Dihybrid” means that these individuals are heterozygous for each gene. By producing gametes from parents that have different genetic contributions for two traits, you can demonstrate Mendel’s principle of independent assortment. To predict the gametic genotypes resulting from meiosis in dihybrid parents, consider only one pair of alleles of one of the genes. Because of the genetic consequences of meiosis, each gamete will have one or the other of the two alleles. The same will hold true for the alleles of the second gene. Therefore, the probability of a gamete containing any two of the alleles on non-homologous chromosomes is the product of their individual probabilities. The alleles on non-homologous chromosomes will appear in the gametes in all possible combinations.

You can simulate meiosis in a dihybrid by choosing two chromosomes from your genome and dropping them simultaneously. Only one allele on each chromosome will be facing up and the two alleles will represent the genotype of a gamete. Again, work with a lab partner who should choose the same two chromosomes from his or her genome. Each of you should produce 40 gametes and, by gametic union, 40 zygotes.

As above, predict the expected outcomes before generating gametes and zygotes. To simplify your predictions for the zygotes, you should take dominance into account and deal only with phenotypic categories and not genotypic ones. For example, AABB will look like AaBb, AABb and AaBB. You can write all of these combinations as “A--B--”. To calculate the probabilities for the phenotypic categories resulting from a dihybrid cross, you will have to use both the product and the sum rule. As you produce gametes and zygotes, keep track of the genotypes. You should compare your results with the expected one by using the Chi-square test.
The Trihybrid -- Three Unlinked Genes, Each With Two Alleles

By adding a third chromosome to the parental genomes, you could simulate a trihybrid cross. At this point, however, the manipulations really become tedious and not even necessary. You should have noticed a pattern when moving from the monohybrid cross to the dihybrid one. Simply by adding a second pair of homologous chromosomes with different alleles, you doubled the number of genetically different gametes produced as a result of the segregation and independent assortment that occur during meiosis. After gametic union (assuming a clear dominance relationship) you also doubled the number of phenotypic categories among the progeny.

Instead of “dropping your genes” to simulate the gametic results of meiosis and the zygotic results of gametic union, simply predict the resulting gametic genotypes and their probabilities of occurring. Then list the possible phenotypic results for the progeny resulting from gametic union and the probability of obtaining individuals in each category. Assume that you and your mate each produce 100 gametes and, by gametic union, 100 zygotes.

### Gametes

<table>
<thead>
<tr>
<th>Result (genotypes)</th>
<th>Probability</th>
<th>Expected (E) Number</th>
</tr>
</thead>
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### Zygotes

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<td>100</td>
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