Mathematical Modeling of Allele Frequency Changes over Time

Evolution occurs in populations of organisms as a result of the differential reproductive success among individuals that is a product of natural variation. One way to study evolution is to study how the frequency of alleles in a population changes from generation to generation. We know that alleles are inherited from two parent organisms, but how are alleles inherited if we consider an entire population? We can then follow how allele frequencies change in a population and then use the observation to predict what will happen to a population in the future.

Mathematical models and computer simulations are tools used to explore the complexity of biological systems that might otherwise be difficult or impossible to study. In this activity, we'll use a spreadsheet to model how a hypothetical gene pool changes from one generation to the next. The model will let us investigate variables that affect allele frequencies, such as selection, mutation, and migration.

Because the real world is quite complicated, we need to make some reasonable assumptions about the a system that will simplify it for us. This means the model will never truly represent the real case, but it can provide a good approximation.

Here is our driving question: "*How do allele frequencies change in a population from one generation to the next?*"

Let's try to simplify the question with some basic assumptions. We will assume that all the organisms in our population are diploid for a gene locus that has two alleles - *A* and *B*. We will use A and B to represent the alleles (rather than A and a) because it will make using the spreadsheet easier. The population reproduces sexually.

1. What assumptions do we have to make about the inheritance of the alleles in our model?

2. Describe how gametes would be produced by our sample organism and how alleles would be assorted into those gametes.

3. In order for the spreadsheet to predict the genotypes of individuals, what assumptions will we have to make about the population?

Spreadsheets are powerful tools because they allow us to ask "What if?" questions. They can repeatedly make a calculation based on the results of another calculation. They can also model the randomness of everyday events.

4. How can a spreadsheet be used to help us answer our driving question?

Take some time to explore the spreadsheet so that you are familiar with the way it works.

5. How can the spreadsheet model be tested to make sure it behaves as we would expect?

6. Use the spreadsheet to investigate the effect of different starting allele frequencies.

7. Explain what it means for a population to be in Hardy-Weinberg equilibrium.

8. Under what conditions, if any, could the frequency of any allele ever reach zero?

9. a) How can we use the spreadsheet to model the effect of genetic drift?
b) What risk does genetic drift pose for endangered or threatened species?

10. a) What would the Hardy-Weinberg theorem predict about the allele frequencies as the population size increases?
b) Did the model demonstrate the prediction?

11. Perform a chi-squared analysis for each of the populations to determine if the allele frequency is as you would expect after 10 generations.

12. How could we change the model to account for variables such as immigration, emigration, and death?

13. Suggest one additional question that could be investigated using this model.