Simulating Genetic Drift - Lesson Plan

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Overview:
Students learn the effect of genetic drift on the evolution of traits controlled by more than one locus. Students develop their own hypotheses about the parameters that affect the strength of genetic drift on a trait in a population, specifically the number of individuals in a population and the number of loci that affect the trait. Students test their hypotheses by simulating their own populations using an online simulator.

Necessary Student Background (pre-teaching):
- Traits, genotype, phenotype
- Heritability, inheritance, alleles

Lesson Concepts:
- Evolution is the change of allele frequencies over generations.
- Genetic drift is evolution caused by random sampling error. Sampling error in this case means that the parents for the next generation are not an exact representation of the population.
- Genetic drift can cause one allele to fixate in a population and other alleles at the same locus to be lost from the population.
- Genetic drift occurs in all populations, regardless of size, all the time.
- Genetic drift has the greatest effect in small populations.
- Genetic drift will have the greatest effect for a trait that is determined by 1 locus.
- Environmental factors that affect a trait will hide the effects of evolutionary mechanisms.
- Genetic drift results in less genetic variance within one population.
- Genetic drift results in greater variance among different populations.

Grade Span: Middle school, high school, college lower-division evolutionary biology class, including genetics and evolution

Materials:
- Each student will need access to a computer with Internet connection and access to Google Forms (may require creating a free Google account).
- The teacher should have a computer connected to a projector.

Advance Preparation:
Read Teacher Background (below)
Teacher should view the student online lecture beforehand
Follow instructions in Teacher Packet [Word] [PDF]
- Create a Google Form
- Analyze data in the Google spreadsheet automatically created as responses to the Google Form
- Create a syllabus for a student report

Time: One class period (discussion section or lecture period)

Grouping: Pairs or groups for discussion, but most work done individually

Teacher Background:

Evolution is the change of heritable traits in populations over generations. Evolution can be caused by one or more of the following mechanisms: natural selection, sexual selection, genetic drift, mutations, migration, and horizontal gene transfer. Because it is 1 of the 6 mechanisms of evolution, genetic drift *by itself* can cause evolution in a trait. In many populations, two or more mechanisms can act simultaneously to facilitate evolution.

Genetic drift is evolution in a trait caused by random sampling error. In this case, sampling error is simply the fact that in a population, the parents that create the next generation are not an exact representation of the population. This is true in any finite population as long as not every individual breeds and produces the same number of offspring. A simple example of sampling error is when flipping a coin 10 times, you do not always get 5 heads and 5 tails, which is the expected probability.

In the case of genetic drift, sampling error leads to differences between allele frequencies from one generation to the next. That is, if for a particular gene there were two alleles, a1 and a2, and the population in one generation started with 50% a1 and 50% a2, in the next generation the allele frequencies might shift to 40% a1 and 60% a2. The shift in allele frequencies could occur because *just by chance*, more individuals carrying the a2 allele might have successfully reproduced than those carrying a1. In genetic drift, the change in allele frequency is due to *chance*, not the differences in fitness between a1 and a2.

Genetic drift can cause fixation of an allele at a locus, which means that only one allele is left in the entire population—reversibly, all other alleles are lost completely. The only way for a new allele to enter the population is through mutations or migration.

There is always less sampling error in bigger populations and more error in smaller populations. This means that the effect of genetic drift is strongest in small populations. However, it's important to remember that genetic drift happens in every population, no matter the size. The only difference is the effect of drift on the trait mean in the population. Similarly, genetic drift occurs most strongly for traits that are controlled by few loci (strongest for 1 locus traits). Sampling error is more pronounced with small sample sizes. In the coin example, if you flip a coin 100 times, you are more likely to get 50% heads and 50% tails than if you only flip a coin 10 times

The result of genetic drift is less genetic variance within one population and greater variance among different populations.

Lenski's experimental evolution studies of bacteria are a good introduction to the idea of genetic drift. You can read more about them here:
https://en.wikipedia.org/wiki/E._coli_long-term_evolution_experiment

Vocabulary: genetic drift, evolution, population, trait, sampling error, locus, allele, fixation, variation

Procedure:

- Homework for students before class: Carefully go through the PowerPoint lesson and answer questions throughout the lesson using Google Forms. Follow instructions to conduct simulations and gather data in the same Google Form. Note: this assignment should be due at least one day before class so the teacher has time to analyze the submitted data.
    - Online lecture: http://idea.ucr.edu/documents/flash/simulating_genetic_drift/story.htm
    - Simulation link: https://hilayla.shinyapps.io/drift/
- Teacher analyzes data gathered by students before class, following instructions in the Teacher Packet.

1. Teacher asks students to share in pairs or groups the hypotheses they made on their homework assignments regarding the parameters that affect the strength of genetic drift.
2. Ask: What happens when population size is increased? What happens when the number of loci affecting the trait are decreased? Have students think about the question, then tell their partner/group, and then answer to the class (think-pair-share).
3. Show appropriate analyses/graphs to address each prediction.
4. Make sure to go over reading and interpreting graphs. What are on the x and y axes?
5. Ask: How does genetic drift affect variance within a population? How does genetic drift affect variance among different populations? (think-pair-share)
6. Ask: How do environmental factors obscure (hide) the effect of evolutionary mechanisms on a trait?
7. Ask: How would natural selection and genetic drift interact? Imagine if one allele was favored by selection—would it more quickly reach fixation or loss in the population?