Fishy Frequencies: A Hardy-Weinberg Population Genetics Simulation

Introduction:
Understanding natural selection can be confusing and difficult. People often think that animals consciously adapt to their environments - that the peppered moth can change its color, the giraffe can permanently stretch its neck, and the polar bear can turn itself white - all so that they can better survive in their environments.
In this lab you will use green and red m&m's to help further your understanding of natural selection and the role of genetics and gene frequencies in evolution.

Background: Facts about the "Fish"
- These little fish are the natural prey of the terrible fish-eating sharks - YOU!
- Fish come with two phenotypes – green and red:
  - green: this is a recessive trait (ff)
  - red: this is a dominant trait (F_)
- **In the first simulation**, you, the terrible fish-eating sharks, will randomly eat whatever color fish you first come in contact with. (There will be no selection.)
- **In the second simulation**, you will prefer to eat the green fish (these fish taste yummy and are easy to catch) you will eat ONLY green fish unless none are available in which case you resort to eating red fish in order to stay alive (the red fish taste salty, are sneaky and hard to catch).
- New fish are born every "year"; the birth rate equals the death rate. You simulate births by reaching into the pool of "spare fish" and selecting randomly.
- Since the green trait is recessive, the green fish are homozygous recessive (ff). Because the red trait is dominant, the red fish are either homozygous or heterozygous dominant (FF or Ff).

Hardy-Weinberg:
G. H. Hardy, an English mathematician, and W.R. Weinberg, a German physician, independently worked out the effects of random mating in successive generations on the frequencies of alleles in a population. This is important for biologists because it is the basis of hypothetical stability from which real change can be measured. This also allows you to figure out the frequency of genotypes from phenotypes.
You assume that in the total population of m&m's, you have the following genotypes, FF, Ff, and ff. You also assume that mating is random so that ff could mate with ff, Ff, or FF; or Ff could mate with ff, Ff, or FF, etc. In addition, you assume that for the green and red traits there are only two alleles in the population - F and f. If you counted all the alleles for these traits, the fraction of "f" alleles plus the fraction of "F" alleles would add up to 1.

The Hardy-Weinberg equation states that: $p^2 + 2pq + q^2 = 1$

This means that the fraction of pp (or FF) individuals plus the fraction of pq (or Ff) individuals plus the fraction of qq (ff) individuals equals 1. The pq is multiplied by 2 because there are two ways to get that combination.
You can get "F" from the male and "f" from the female OR "f" from the male and "F" from female.

If you know that you have 16% recessive fish (ff), then your qq or q 2 value is .16 and q = the square root of .16 or .4; thus the frequency of your f allele is .4 and since the sum of the f and F alleles must be 1, the frequency of your F allele must be .6 Using Hardy Weinberg, you can assume that in your population you have .36 FF (.6 x .6) and .48 Ff (2 x .4 x .6) as well as the original .16 ff that you counted.

Procedure 1: Without Selection
1. Get a random population of 10 fish from the "ocean."
2. Count green and red fish and record in your chart; you can calculate frequencies later.
3. Eat 3 fish, chosen randomly, without looking at the plate of fish
4. Add 3 fish from the "ocean." (One fish for each one that died). Be random. Do NOT use artificial selection.
5. Record the number of green and red fish.
6. Again eat 3 fish, randomly chosen.
7. Add 3 randomly selected fish, one for each death.
8. Count and record.
9. Repeat steps 6, 7, and 8 two more times.
10. Provide your results for the class. Fill in the class results on your chart.

Procedure 2: With Selection
1. Get a random population of 10 fish from the "ocean."
2. Count green and red fish and record in your chart; you can calculate frequencies later.
3. Eat 3 green fish; if you do not have 3 green fish, fill in the missing number by eating red fish.
4. Add 3 fish from the "ocean." (One fish for each one that died). Be random. Do NOT use artificial selection.
5. Record the number of green and red fish.
6. Again eat 3 fish, all green if possible.
7. Add 3 randomly selected fish, one for each death.
8. Count and record.
9. Repeat steps 6, 7, and 8 two more times.
10. Provide your results for the class. Fill in the class results on your chart.

FINALLY:
1. Fill in your data charts and calculate
2. Prepare a graph showing the frequency of the alleles in each generation
3. Answer the analysis questions.

Analysis:

1. Prepare one graph using both sets of class data (without selection AND with selection). On the "x" axis put generations 1-5 and on the "y" axis put frequency (0-1). Plot both the q and p for both sets of class data. Label lines clearly (without selection AND with selection).
2. In either simulation, did your allele frequencies stay approximately the same over time? If yes, which situation? What conditions would have to exist for the frequencies to stay the same over time?
3. Was your data different from the class data? How? Why is it important to collect class data?
4. With selection, what happens to the allele frequencies from generation 1 to generation 5?
5. What process is occurring when there is a change in allele frequencies over a long period of time?
6. What would happen if it were more advantageous to be heterozygous (Ff)? Would there still be homozygous fish? Explain.
7. In simulation 2, what happens to the recessive alleles over successive generations and why? Why don't the recessive alleles disappear from the population?
8. Explain what would happen if selective pressure changed and the recessive allele was selected FOR?
9. What happens if the sharks only eat very large fish that have already reproduced? What happens if they eat small green fish, before they have a chance to reproduce?
10. In what ways did these simulations represent real life? How were the simulations different from real life situations?

Remember to complete Discussion, Conclusion, and Reflection
Lab Grading Guidelines are at   http://www.jdenuno.com/PDFfiles/LabGuide1.PDF

Table 1: Without Selection…Individual Results

Generation	Green	Red	q^2	q	p	P^2	2pq
1							
2							
3							
4							
5							

Table 3: With Selection…Individual Results

Generation	Green	Red	q^2	q	p	P^2	2pq
1							
2							
3							
4							
5							

Table 2: Without Selection…Class Results

Generation	Green	Red	q^2	q	p	P^2	2pq
1							
2							
3							
4							
5							

Table 4: With Selection…Class Results

Generation	Green	Red	q^2	q	p	P^2	2pq
1							
2							
3							
4							
5							

Remember: Determine proportions of Green and Red fish BEFORE you calculate p and q values

Hardy-Weinberg Population Genetics Lab