Name_______________

Hardy-Weinberg and Evolution

The Hardy-Weinberg equation is used to determine whether there is any change in the distribution of given alleles over time. You will work through several examples of Hardy-Weinberg equilibrium calculations and determine the significance of your calculations regarding the evolution of the population in question.

Objectives:

1. Here are some terms we will be using. For today's exercise, I have bolded some terms you should look up if you don't know them:
   a. population genetics
   b. gene flow
   c. reproductive isolation
   d. allopatric speciation
   e. sympatric speciation
   f. parapatric speciation
   g. niche
   h. allelic frequency
   i. sexual selection
   j. founder effect
   k. Hardy-Weinberg equilibrium and the assumptions that it underlie it
2. Become comfortable with H-W calculations and determine if a population is at equilibrium.
3. Determine or hypothesize about factors influencing allelic frequency

Background (covered yesterday in class)

Review screencast as needed. The equation is straightforward and can be derived from a Punnett Square. If two heterozygous animals mate, the probability of getting gamete A' is ½ (0.5) from the first parent as is probability of getting gamete 'a.' The same is true for the other parent. Thus, for all the gametes produced by the either parent, ½ of them will be 'a' and ½ 'A.'

So, the probability of getting AA in the offspring is ½*½ or ¼. The probability of aa is also ¼, and the probability of Aa is 2x1/4, since, there are two ways to get Aa (two boxes in the square that are Aa). The total distribution of offspring will be:

$$\left(\tfrac{1}{2}\right)^2 + 2\left(\tfrac{1}{2}\right)^2 + \left(\tfrac{1}{2}\right)^2 = 1$$

for the frequency of AA, Aa, and aa respectively (the total must equal 1, if there are only two alleles being considered).

If you consider all the gametes in a *population*, perhaps one allele is present at a higher frequency than ½. Suppose there are only two alleles in the population at a particular locus and the 'a' allele is present at .75 of the total, the 'A' is present at 0.25. Then we can give the probability of the 'A' allele being donated by any **random** parent as "p=0.25" and that of a random parent donating 'a' as q=0.75. The frequency of AA, Aa and aa will still equal 1, provided there are only two alleles and the distribution will be

$$0.25^2 + 2(0.25 \times 0.75) + 0.75^2 = 1$$

or, more generically: $p^2 + 2pq + q^2 = 1$

This equation also derives from the observation that the sum of all probabilities must equal 1. Thus, p+q=1. Squaring both sides gives you $p^2 + 2pq + q^2 = 1$. Each is just a different way of stating of the Hardy-Weinberg equation.

Assuming simple dominance as the relationship between two alleles, you can only identify the homozygous recessive, since, again, assuming simple dominance, Aa and AA look the same.

So, let's suppose that blue eyes is a simple recessive to brown eyes and 15% of the people in some population have blue eyes. The frequency of the 'b' allele (q) is $\sqrt{0.15} = 0.39$. If there are **only two alleles,** the frequency of the B allele ('p') must be 1-0.39 or 0.61. You can now calculate what the frequency of the BB (p^2) and Bb (2pq) individuals in the population.

Assumptions:

I bolded a couple of things above. I assumed that mating in the population was random. What if people just don't like blue eyes? What if brown-eyed people are prone to a disease that kills them before they have offspring? Then there could be some *net* selective pressure on the trait, favoring brown or blue eyes due to either a survival advantage or sexual selection. I think I was a little loose with this in class…what the H-W equilibrium requires is that the **sum** of selective pressures be zero.

If there is net selection, I can still calculate the values of "p" and "q," but they will change over time. In that case, the allelic frequency **will not be in equilibrium.** It's possible that the sexual selection against blue eyes could eventually come back into balance with the survival advantage in favor of blue eyes and there would be no *net* selective pressure (like the tails of birds we discussed). They population would reach a new equilibrium.

Also, what if there is an influx of people from Norway who just cannot stand the cold anymore? Suddenly there will be a disturbance in the allelic frequency. The same would happen if there was an exodus of people with brown eyes, for example.

However, if there is no **net** pressure favoring one or the other allele AND there is no influx of new people with a different distribution, the allelic frequency will stay constant. The trait will stay in equilibrium.

To determine whether a trait is in equilibrium and thus whether there is any pressure on the trait, you have to determine the values of p and q at a few times, and see if it is changing. Well, assuming only two alleles, you really only have to determine "q."

Geisel's Songbirds

There is a population of songbirds in the outskirts of San Diego known as Geisel's Songbirds (no there isn't…I made it up. But, there is a cute joke here if you spot it). Among that population, researchers find variation in tail-type due to different alleles at the GMF locus. The dominant L allele has two long tail feathers while the 'l' allele has only one small tail feather when homozygous.

San Diego Population			
Year	**2 feather**	**1 feather**	**Total observed**
1960	427	98	525
1980	666	151	817
1990	625	143	768
2000	524	119	643
2010	538	167	705

Is the population in equilibrium between 1960 and 2000? What can you conclude about the relative selective advantage of 2 versus 1 feather through that time period? We will consider the case of 2010 later.

Winds of Change

In 1968 there were persistent very strong winds from the west. A small population of Geisel's Songbirds were blown over the ridge to the Palm Desert. The birds were surveyed every two years between 1970 and 2010 in their new population.

Palm Desert Population			
Year	**2 feather**	**1 feather**	**Total**
1970	3	15	18
1980	20	130	150
1990	20	185	205
2000	50	450	500
2010	49	470	519

What explains the fact that the allelic frequency is so different in 1970 in the palm desert population than it was in the initial San Diego population (you can speculate on a specific…but I'm really looking for the general term—it's a bolded term in the terms list)?

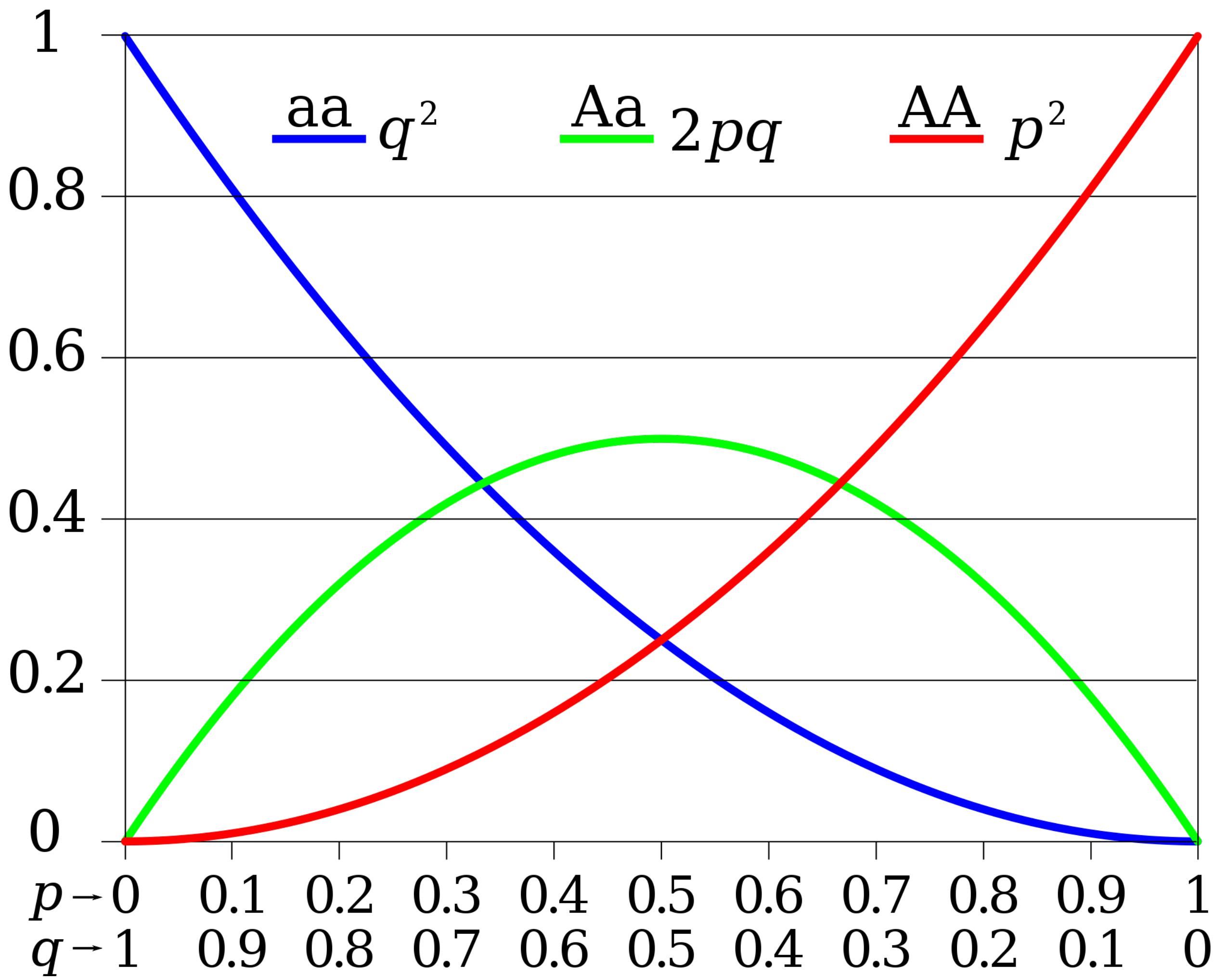
Is this population in equilibrium initially? What are the values for 'p' and 'q' in 1970 and 2010? What is the first year that we can see equilibrium being reached?

Suppose the Palm Desert population and the San Diego population no longer interbreed, or only rarely so, because of the mountains. Could this lead to speciation? How would you define speciation (among the types listed at the top of this document and represented on the last page).

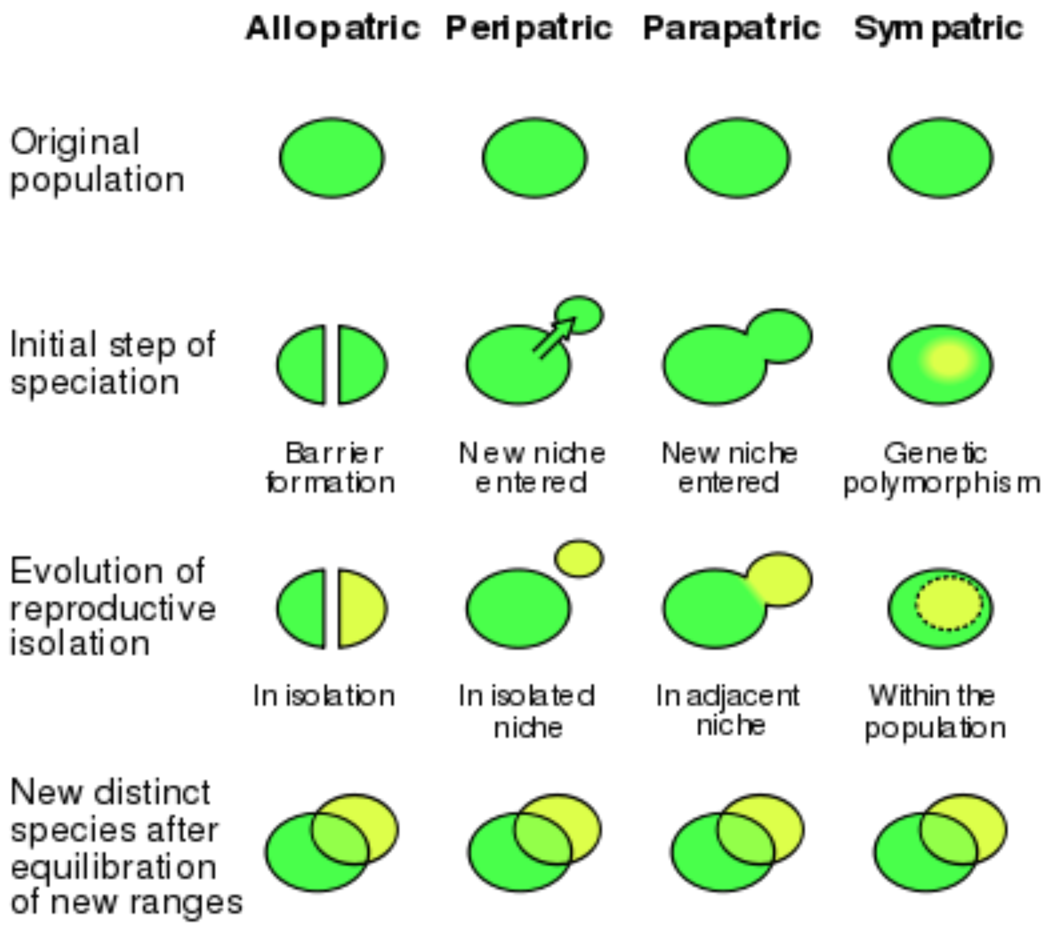
Consider the San Diego population between 2000 and 2010. Hypothesize what could cause the deviation from equilibrium.

We will discuss this in a bit.

Also, Below is a plot of H-W distributions



1
0.8
0.6
0.4
0.2
0
aa q^2
Aa $2pq$
AA p^2
$p \rightarrow$ 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
$q \rightarrow$ 1 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0


Allopatric
Peripatric
Parapatric
Sympatric
Original population
Initial step of speciation
Barrier formation
New niche entered
New niche entered
Genetic polymorphism
Evolution of reproductive isolation
In isolation
In isolated niche
In adjacent niche
Within the population
New distinct species after equilibration of new ranges