Population Genetics Practice Exercise #1

I'm sure you all remember the classic example of industrial melanism in *Biston betularia*.[1] The *typica* form is the light-colored form, while the *carbonaria* form is the dark-colored form. Here are some release-recapture data from two different places:[2]

	Number released	Number recaptured
Central Birmingham (city)		
typica	144	18
carbonaria	486	140
Dorset wood (forest)		
typica	163	67
carbonaria	142	32

To keep things simple, let's assume that any any individual that was not recaptured died.

1. What are the viabilities of *typica* and *carbonaria* in each habitat?

	Number released	Number recaptured	Viability
Central Birmingham (city)			
typica	144	18	$18/144 \approx 0.13$
carbonaria	486	140	$140/486 \approx 0.29$
Dorset wood (forest)			
typica	163	67	$67/163 \approx 0.41$
carbonaria	142	32	$32/142 \approx 0.23$

2. What is the viability of *carbonaria* relative to *typica* in each habitat?

[1] If you don't, pick up any good textbook on evolution, and look in the index. You're almost certain to find it there. You might also be interested in a fairly recent review by Cook and Saccheri (*Heredity* 110:207-212; 2013).

[2] I will reveal the source of the data on Sunday when I post my answers to these exercises. The source I'm referrring to includes calculations that will give you the answers, and the whole point of this exercise is to give you a chance to try this on your own.

	Viability	Relative viabioity
Central Birmingham (city)		
typica	0.13	
carbonaria	0.29	$0.29/0.13 \approx 2.3$
Dorset wood (forest)		
typica	0.41	
carbonaria	0.0.23	$0.23/0.41 \approx 0.55$

3. The color forms are determined by alternative alleles at a single locus. Assume that genotypes are in Hardy-Weinberg proportions in the individuals that were released and that there is no mutation or migration of individuals into these habitats. What will the frequency of the *typica* and *carbonaria* forms be in the next generation before selection?

   I just realized that I didn't give you quite enough information to answer this question. I needed to tell you that *carbonaria* is dominant to *typica*. Now that you know that, let p be the frequency of the *typica* allele. In Central Birmingham

$$\begin{aligned} p^2 &= 144/(144+486) \approx 0.23 \\ p &= \sqrt{0.23} \approx 0.48 \end{aligned}$$

   In Dorset Wood

$$\begin{aligned} p^2 &= 163/(163+142) \approx 0.53 \\ p &= \sqrt{0.53} \approx 0.73 \end{aligned}$$

   To get the frequency of the *typica* allele in the next generation, we simply plug the viabilities (or relative viabilities) from above into the equation for allele frequency change with viability selection

$$p' = \frac{p^2 w_{11} + pq w_{12}}{p^2 w_{11} + 2pq w_{12} + q^2 w_{22}}$$

   In Central Birmingham

$$\begin{aligned} p' &\approx \frac{p^2(0.13) + pq(0.29)}{p^2(0.13) + 2pq(0.29) + q^2(0.29)} \\ &\approx 0.40 \\ \text{Frequency of } \textit{typica} &= p'^2 \approx 0.16 \\ \text{Frequency of } \textit{carbonaria} &= 1 - p'^2 \approx 0.84 \end{aligned}$$

In Dorset Wood

$$\begin{aligned} p' &\approx \frac{p^2(0.41) + pq(0.23)}{p^2(0.41) + 2pq(0.23) + q^2(0.23)} \\ &\approx 0.81 \\ \text{Frequency of } \textit{typica} &= p'^2 \approx 0.66 \\ \text{Frequency of } \textit{carbonaria} &= 1 - p'^2 \approx 0.34 \end{aligned}$$

So just as you would expect from what you've learned about industrial melanism, the frequency of the *typica* allele decreases ($0.48 \rightarrow 0.40$) in a polluted, urban area (Central Birmingham) and increases ($0.75 \rightarrow 0.81$) in an unpolluted, forest area (Dorset Wood).

Here are some more conceptual questions to test your understanding.

5. The lecture notes identify several different components of fitness, i.e., different types of natural selection that may be occurring. Natural selection at one locus always leads to a change in allele frequecies. For each type of natural selection identified below, identify the life history stage at which this change in allele frequency would be detected.

   (a) Segregation distortion

   Difference in allele frequency in heterozygotes (1/2) and in functional gametes

   (b) Gamete (or gametophytic) competition

   Difference in allele frequency between functional gametes (or gametophytes) and gametes that participate in fertilization.[3]

   (c) Fertility selection

   Difference in allele frequency between mated pairs and allele frequency in newly-formed zygotes (assuming that there isn't segregation distortion of gamete competition).

   (d) Viability selection

   Difference in allele frequency between zygotes and adults.

   (e) Sexual selection

   Difference in allele frequency between adults and allele frequency in mated pairs (in one or both sexes).

[3]For botanists, think about the difference between allele frequencies in pollen deposited on the stigma and allele frequencies in the pollen tubes that reach ovules.

6. I asserted in the last question that "Natural seelction at one locus always leads to a change in allele frequencies." In the notes I assert that if the relative fitness of heterozygotes is greater than that of either homozygote (stabilizing selection or heterozygote advantage), then the population will evolve to a stable polymorphic equilibrium where the allele frequency doesn't change and both alleles are present. Explain why these statements aren't contradictory.

   There are two keys to answering this question.

   (a) I lied (a little) in saying that "natural selection at one locus always leads to a change in allele frequencies. That's *almost* true, but it's not quite right. What I should have said is that "natural selection at one locus always leads to a change in allele *or genotype* frequencies."

   (b) The change in genotype frequencies as a result of viabiity selection happens within a generation, between zygote and adult. The result is a change in genotype frequencies, but not a change in allele frequencies (at equilibrium). The allele frequency in zygotes of the next generation matches the frequency in adults of the preceding generation.