1. Suppose that biased gene conversion can occur at an autosomal locus with two alleles, $A$ and $a$. The probability of an unequal gene conversion event at this locus is $0.8$, and the conditional probability that $a$ converts to $A$ given an unequal conversion event is $0.6$. The frequency of $A$ in an infinite sized, isolated deme is $0.3$

   a). Assume the population is randomly mating, what is the frequency of $A$ in the next generation?
   b). Assume now that there is disassortative mating at this locus with $f = -0.1$. What is the frequency of $A$ in the next generation?
   c). Assume now that there is assortative mating at this locus with $f = 0.3$. What is the frequency of $A$ in the next generation.
   d). Now suppose that after fertilization, the $AA$ homozygote suffers from decreased viability such that the probability of an $AA$ surviving to reproductive maturity is $0.1$ whereas the probability of $Aa$ or $aa$ surviving to reproductive maturity is $0.9$. What is the frequency of the $A$ allele in the population of adult individuals under random mating?

2. A single autosomal locus with two alleles determines which part of an essential resource spectrum is used by the genotypes in a species such that the three different genotypes have no overlap at all in their use of this essential resource. Hence, all competition for this resource is among individuals with the same genotype. The intragenotypic competition reduces the fitness of the genotype in an inverse frequency dependent fashion (i.e., the more common a genotype, the more its fitness declines due to competition). This is reflected in the following model:

<table>
<thead>
<tr>
<th>Genotype:</th>
<th>$AA$</th>
<th>$Aa$</th>
<th>$aa$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotype Frequency:</td>
<td>$G_{AA}$</td>
<td>$G_{Aa}$</td>
<td>$G_{aa}$</td>
</tr>
<tr>
<td>Fitness:</td>
<td>$4/G_{AA}$</td>
<td>$2/G_{Aa}$</td>
<td>$6/G_{aa}$</td>
</tr>
</tbody>
</table>

   a). Draw the adaptive landscape for this situation. What would you predict from Fisher’s Fundamental Theorem of Natural Selection about the course of adaptive evolution from this landscape if the shape of the adaptive landscape was the only information you had about this system?
   b). Given that there is a stable, polymorphic selective equilibrium, what is the allele frequency at the equilibrium point?
   c) How is this equilibrium allele frequency affected by system of mating (measured by $f$)?

3. An autosomal, tandem-multigene family exists with 10 tandem copies per chromosome. Neutral mutations occur within each copy at a rate of $10^{-4}$ per generation. Gene conversion also occurs within the multigene family such that the probability of one copy converting a paralogous copy to its state is $10^{-5}$ per generation. These events are occurring within an ideal population of size 1000.

   a). What is the rate of neutral evolution for a single orthologous copy within the multigene family?
b). What is the rate of neutral evolution for the entire multigene family?

c). What is the expected time to coalescence of all orthologous copies to a common ancestral gene under neutrality for a large sample size?

d). What is the expected time to coalescence of all orthologous and paralogous copies to a common ancestral gene under neutrality for a large sample size?

4. Phenotypes A and a have frequencies F and 1-F (note, these F’s are not inbreeding coefficients, but simply population frequencies of phenotype classes) and fitnesses $3/(1-F)$ and $2/F$, respectively.

a). Use the phenotypic gambit and assume that the two phenotypes are caused directly by haploid alleles A and a. What internal equilibrium exists for this population?

b). Now suppose the organism is actually diploid and phenotype A is caused by dominant allele A at frequency p. What are the equilibrium allele and phenotype frequencies for this population assuming random mating for this locus? Does it match the allele and phenotype frequencies of the diploid population?

c). Now assume that phenotypes result from a continuous strategy, where the common strategy is to adopt the A phenotype with probability F and the a phenotype with probability 1-F. Give the equation for the fitness of a rare mutant with alternative probability f of adopting the A phenotype (fitnesses for phenotypes A and a are still determined by the population frequency of A and a as above). What is the ESS?

d). Explain, in words not equations, how these fitnesses give a stable internal equilibrium. How would this change if the fitnesses were $W_A = 3/F$ and $W_a = 2/(1-F)$?

5. Male lions compete to take over prides of females and sire their young. Suppose a single male lion expects to sire 2 cubs but a pair of males joining together will sire a total of 5. However, in every pair, one of the males is dominant over the other and can determine how much each reproduces.

a). Using Hamilton’s rule, what fraction of the pair’s reproduction $f$ does a subordinate male need to make it pay to join in a pair with an unrelated dominant? (Assume that if the subordinate does not join, neither brother will have a partner).

b). Same question, but now assume the two males are full brothers.

c). The dominant lion benefits from having a subordinate, so suppose the dominant lion has been selected to allow the subordinate just enough reproduction to make it pay for the subordinate to join (i.e. the amounts you found above). This would mean the dominant is harsher to its brother, allowing it less reproduction that a non-relative. How can this be?