MID-TERM BIOL 434/509: October 2018

1. (20 *points: 5 each*) The probability of surviving to adulthood varies between the three diploid genotypes at one locus, and no other form of selection is acting on this locus. The survivorship of the three genotypes GG, Gg, and gg are 0.65, 0.8, and 0.6, respectively.

a. If the frequency of the G allele is 0.4 in a large randomly mating population without migration or mutation, what is the frequency of G in the next generation?

$$p' = 0.4(\frac{0.4(0.65) + 0.1(0.8)}{(0.4)^2(0.65) + 2(0.4)(0.6)(0.8) + (0.6)^2(0.6)} = 0.42$$

b. What is the stable equilibrium allele frequency in this population?

1-s : 1 : 1-t → $\frac{0.65}{0.8}$: 1 : $\frac{0.6}{0.8}$ → s=0.01875; t = 0.25

$$\hat{p} = \frac{t}{s+t} = \frac{0.25}{0.1875 + 0.25} = 0.571$$

c. What is the heterozygosity expected at birth when this population is at equilibrium?

$$2\hat{p}\hat{q} = 2(0.571)(1 - 0.571) = 0.4898$$

d. What is the segregation load at equilibrium from this locus?

$$L = 1 - \bar{w}$$

$$= 1 - [(0.571)^2(1-s) + 2(0.571)(0.429)(1) + (0.429)^2(1-t)] \qquad = 0.107$$

2. (15 *points*) A population has a census size of 10000 and an effective population size of 1000. Assume that the mutation rate is 10^{-8} per nucleotide per generation.

a. How many substitutions would we expect to see after 20,000 generations of evolution in a genomic region of 100 neutral nucleotides?

probability of substitution per generation = mutation rate

100 nucleotides x 20,000 generations x 10^{-6} = 0.02

b. At equilibrium between drift and mutation, what do we expect the average heterozygosity to be for each of these base pairs?

$$\frac{4N_e\mu}{4N_e\mu + 1} = \frac{4(1000)10^{-8}}{4(1000)10^{-8} + 1} = 0.00004$$

c. At another locus in this genome, imagine that a new mutation appears that has a selective advantage as a heterozygote of 3%, and a selective advantage of 4% as a homozygote. What is the probability that this new mutation will fix in the population?

$$2s\frac{N_e}{N} = \frac{2(0.03)1000}{100000} = 0.006$$

Note that the *s* in this equation is the heterozygous effect.

3. (12 *points: 6 each*) In an ideal diploid population with 4 individuals, the allele frequency at a neutral locus is 0.25.

a. After one generation, what is the probability that the allele frequency is greater than 0.15?

The allele frequency is *less than* 0.15 if there are 0 or 1 alleles out of 8. The probability of the next generation having 0 or 1 of these alleles is

$$\Pr[0] + \Pr[1] = \binom{8}{0} 0.25^0 0.75^8 + \binom{8}{1} 0.25^1 0.75^7 = 0.100 + 0.267 = 0.367$$

So the probability of having an allele frequency greater than 0.15 = 1 – 0.367 = 0.633

b. After one generation, what is the probability that the heterozygosity is less than 0.25?

Heterozygosity is less than 0.25 if there are 0, 1, 7, or 8 copies of this allele.

Pr[7]=0.000367; Pr[8] = 0.000015, so Pr[0] + Pr[1] + Pr[7] +Pr[8] = ~ 0.367

4. (6 *points*) Define an ideal population. What assumptions are made in its definition?

An ideal population is one in which each offspring has an equal and independent chance of descending from each individual in the previous generation. This implies random mating and no selection.

5. (6 *points*) Describe the assumptions of the infinite allele model.

The infinite allele model assumes that every new mutation is unique and has never appeared in the population before.

6. (18 *points: 6 each*) What is equilibrium mutation load for a locus for which the mutation rate to the deleterious allele is 10^{-6} and the fitness of the three genotype are 1 : 0.999 : 0.94? What is the dominance coefficient for this locus? What is equilibrium allele frequency of the less fit allele?

Load: $L = 2\mu = 2 \times 10^{-6}$

Dominance coefficient: $hs = 0.001;\ s = -0.06; h = \frac{hs}{s} = 0.016666$

Equilibrium frequency : $\hat{q} = \frac{\mu}{hs} = \frac{10^{-6}}{0.001} = 0.001$

7. (10 *points*) A haploid population with 1000 individuals initially has an allele frequency of 0.1 for one allele (with only two alleles at this neutral locus). The variance in the number of adult offspring per individual is 4 in this population. What is the expected genetic variance (E(*pq*)) at this locus after 10 generations?

V_{G0} = 0.1(0.9) = 0.09

N_e = N/(Variance in reproductive success) = 1000/4 = 250

$V_{G10} = \left(1 - \frac{1}{N_e}\right)^{10} V_{G0} = 0.086$

8. (12 *points*) Discuss the processes that we have covered so far in class that can increase or decrease the amount of genetic variation in a population.

Drift can temporarily increase genetic variance, but on average over the long term drift decreases genetic variance in a population.

Selection can either increase or decrease genetic variance. Forms of selection which drive the allele frequency to fixation—such as directional selection or underdominance—decrease genetic variance. Forms of selection which increase the frequency of rare alleles—such as overdominance or negative frequency dependent selection—tend to increase or maintain genetic variance. Directional selection can also reduce the genetic variance of genetically-linked loci through the genetic hitchhiking effects of selective sweeps.

Mutation introduces new alleles into the population. Mutation increases genetic variance.