Study Guide for the 2nd midterm exam

Anth/Biol 5221, 31 October 2011

Mutation, drift, and population size change

1. How are the sizes and shapes of gene genealogies affected when the population size N increases or decreases? (Assume selective neutrality.)

2. How are the relationships of π, S and $2N$ affected when the population size has recently increased or decreased?

Site frequency spectrum and mismatch distribution

3. Be able to calculate them from data (for small, simple data sets), and understand how they relate to the sizes and shapes of gene genealogies.

4. How do they respond to changes of population size (as in #2)?

Neutral theory

5. What is the rate of molecular evolution (ρ)?

6. Why does $\rho = \mu$ at a neutral site (even when selection strongly affects closely linked sites)?

7. What is the central empirical claim of the neutral theory?

8. How is a "molecular clock" calibrated (retrospectively)?

Selection in a large population

Each of the questions in this section could be framed in different ways. For example, we might give you symbols for the three genotypic fitnesses and the two allele frequencies, and ask for an answer in terms of those symbols. Or we might give you numbers and ask for numbers.

9. Assuming fixed, constant fitnesses for the three genotypes at a biallelic diploid locus (W_{11}, W_{12}, W_{22}), what is the *mean fitness* of the population?

10. What are the *marginal fitnesses* of the two alleles?

11. What is next generation's expected allele frequency (p' or q') as a function of these quantities?

12. How can an observed rate of allele-frequency change be used to estimate the relative fitnesses of two alleles (for example, s, if we know the value of h)? This was the subject of some homework problems.

Mutation-selection balance and the genetic load

13. In a large population (i.e., ignoring drift), what is the equilibrium frequency of deleterious recessive alleles ($h = 0$) at a locus where the mutation rate to such alleles is μ per generation and the selective disadvantage of the mutant homozygotes is s?

14. What is the approximate equilibrium frequency of *partially recessive* mutations ($0 < h < 0.5$) under otherwise identical circumstances?

15. What is the *mean fitness* of a large population where a locus is subject to deleterious mutations of effect-size s, dominance h, and these mutations occur at rate μ per gene copy per generation? Why do s and h not appear in the answer?

Interactions of mutation, drift and selection

16. What is the probability of fixation for a newly arisen *neutral* mutation? Probability of loss?

17. What is the *approximate* fixation probability for a newly arisen mutation that is favored by a selection coefficient of s (relative fitness $1 + s$) in the homozygous state, and $s/2$ in the heterozygous state? Does the population size N affect our answer? If so, how?

18. What is the expected rate at which adaptive mutations will fix within a species, given a certain population size (N), selective advantage (s), and genome-wide rate of mutation (U) to alleles with advantages of about that size?

19. Why are most of our deleterious mutations (the ones segregating at appreciable frequencies) at least partly *recessive*?

20. Under what conditions will a deleterious (harmful) mutation have nearly as good a chance of fixing as a neutral mutation?

21. Do we expect more adaptive evolution in large or small populations? Explain.

22. Do we expect to find more or fewer harmful mutations segregating in a selfing plant species (for example, rice) than in a predominantly outbreeding relative? Explain.

Linkage disequilibrium between two loci

23. How do we *describe* the population frequencies of multi-locus genotypes, in the simplest case involving a pair of loci each with two alleles? (For example, suppose one locus has alleles A and a, and the other locus has alleles B and b.)

24. What's the relationship between the allele frequencies at each locus, and the gamete or haplotype frequencies (that is, the frequencies of the haploid pairings AB, Ab, aB and ab)?

25. If we gave you the frequencies of these four gamete types, you should be able to give us the allele frequencies and D (the coefficient of linkage disequilibrium). Or the other way around.

26. Locus B has two alleles: B_1 (with frequency p_1), and B_2 (with frequency $p_2 = 1-p_1$). A new mutation arises at a linked locus, C. What is the probability that this mutant chromosome carries allele B_1?

Please note that almost every one of these questions is very easy to answer if you understand the terminology and a few elementary principles of probability – the ideas we've been stressing from day one of this course. There's very little to memorize. Be confident, you can reason it out!