

ANSC 446 / IB 416
Population Genetics
Exam 2, October 17, 2008

Name _____

(5 pages) Please underline or indicate your answer. If rounding, use 3 significant digits. Show your work or describe your logic to earn partial credit for incomplete answers.

- (8) 1. At a diploid biallelic locus, calculate the expected heterozygosity for the first four generations, given $H_0 = 0.4$, for the following:

- (4) a. lineages where there is complete selfing

Initially 0.4, subsequent generations 0.2, 0.1, 0.05, 0.025

- (4) b. lineages where there is continuous full-sib mating

Initially 0.4, subsequent generations 0.4, 0.3, 0.25, 0.2
(Also acceptable: initially 0.4, then 0.3, 0.25, 0.2, 0.1625).

- (8) 2. A population of 400 cattle is surveyed at a locus with two codominant alleles. The genotype A_1A_1 is found to be present in 80 cattle, A_1A_2 is present in 40 cattle, and A_2A_2 is present in 280 cattle.

- (4) a. What are the allele frequencies?

$\Pr(A_1) = p = (80 + 40/2) / 400 = 0.25$ $\Pr(A_2) = q = (280 + 40/2) / 400 = 0.75$

- (4) b. Estimate the level of inbreeding (inbreeding coefficient) in the population.

$F = 1 - H/2pq = 1 - ((40/400)/(2 \times 0.25 \times 0.75)) = 1 - (0.1/0.375) = 0.733$

Hint: verify using $f = 0.733$ on unit square

- (4) 3. Assume that the initial and final allele frequencies before and after selection are 0.2 and 0.1. How many generations does it take for this amount of change when there is a recessive lethal?

Answer: $t = 1/0.1 - 1/0.2 = 10 - 5 = 5$ generations

- (18) 4. The relative fitnesses found for alleles at a locus in the major histocompatibility complex are 0.5, 1, and 0.75 for alleles A_1A_1 , A_1A_2 , and A_2A_2 , respectively.

- (2) a. What are the values of the selection coefficients s_1 and s_2 ?

$$s_1 = 0.5 \quad s_2 = 0.25$$

- (2) b. What is the name given to this type of fitness array?

Heterozygote advantage, or overdominance

- (4) c. What is the equilibrium frequency for A_2 ?

$$q_e = s_1 / (s_1 + s_2) = 0.5 / (0.5 + 0.25) = \mathbf{0.667}$$

- (2) d. Would the equilibrium frequency be stable? Why or why not?

Yes, overdominant systems are stable because fitness is at a maximum in the equilibrium state. Thus deviations away from the equilibrium frequency lead to selection effects on allele frequency that move them back to the equilibrium frequency.

- (4) e. What is the genetic load at the equilibrium frequency?

Genetic load is the reduction in fitness from the maximum possible, which would occur if all individuals were heterozygous (which is not possible).

Mean fitness at the equilibrium state is: $1 - [s_1 s_2 / (s_1 + s_2)]$

Thus genetic load is $[s_1 s_2 / (s_1 + s_2)] = (0.5)(0.25) / (0.5 + 0.25) = \mathbf{0.167}$

- (4) f. Four isolated populations have initial allele frequencies for A_2 of 0.0, 0.45, 0.55 and 1.0. At what frequency will allele A_2 stabilize in each of these four populations?

Initial $\Pr(A_2)$ of $q = 0.0$ will remain at 0.0

Initial $\Pr(A_2)$ of $q = 0.45$ will go to 0.667

Initial $\Pr(A_2)$ of $q = 0.55$ will go to 0.667

Initial $\Pr(A_2)$ of $q = 1.0$ will remain at 1.0

- (14) 5. Give the best definition for the following terms:

(2) a. Philopatry: tendency of progeny to remain near their natal (or parental) territory

(2) b. Coefficient of inbreeding, f , is the probability that 2 homologous alleles are identical by descent (IBD)

(2) c. Fisher's fundamental theorem of natural selection: the rate of increase in fitness of any species at any time is equal to its genetic variance in fitness at that time.

(2) d. Inclusive fitness: fitness of an individual plus his/her effect on the relatives of the individual weighted by their coefficient of relationship

(2) e. Antagonistic pleiotropy: negative correlation of two components of fitness; ie, a single locus affects multiple selection components in opposite directions.

(2) f. Meiotic drive: segregation distortion among gametes, in which heterozygous individuals do not produce equal proportions of their two different alleles in gametes as predicted by Mendelian segregation. An example is the *t* locus in the house mouse.

(2) g. Indel: an insertion-deletion variant between two DNA sequences. When the two sequences are aligned, one is missing a region found in the other.

(10) 6. Determine the frequencies at generation $t+1$ for the following:

(5) a. At a biallelic autosomal locus, a deleterious allele with a dominance level of 0.4 and selection coefficient of 0.4 is found at a frequency of 0.2. Assuming random mating, what will be the frequency of the allele in the next generation?

$$\begin{aligned}\Delta q &= - \frac{spq[h - (2h - 1)q]}{1 - 2hspq - sq^2} = \\ &= \frac{-(0.4 \times 0.8 \times 0.2)(0.4 - ((2 \times 0.4) - 1) \times 0.2)}{1 - (2 \times 0.4 \times 0.4 \times 0.8 \times 0.2) - (0.4 \times 0.2^2)} \\ &= -(0.064)(0.44) / (1 - 0.0512 - 0.016) = -0.02816 / 0.9382 = -0.0300\end{aligned}$$

$$q_1 = q_0 + \Delta q = 0.2 - 0.0300 = 0.17$$

(5) b. For the situation described in (a), and assuming the Basic Selection Model, what was the frequency of the three genotypes among only those progeny that were inviable?

Since $p = 0.8$ and $q = 0.2$, the frequency of the three genotypes among progeny were:

$$\begin{aligned}\Pr(A_1A_1) &= P = 0.8^2 = 0.64 \\ \Pr(A_1A_2) &= H = 2pq = 0.32 \\ \Pr(A_2A_2) &= Q = 0.2^2 = 0.04\end{aligned}$$

The selection coefficient is 0.4, which means that 40% of the homozygotes (A_2A_2) for the deleterious allele were inviable:

$$0.4 \times 0.04 = 0.016$$

The dominance level is 0.4, which means the proportion of inviable heterozygotes is 0.4 times the selection coefficient of 0.4. Among all progeny, the proportion of heterozygote (A_1A_2) and inviable is therefore:

$$0.32 \times 0.4 \times 0.4 = 0.0512$$

For dominant homozygotes, there is no inviability: $0.64 \times 0 = 0$

Thus the frequency of genotypes among inviable individuals was:

$$A_1A_1: 0$$

$$A_1A_2: 0.0512 / (0.0512 + 0.016) = 0.762$$

$$A_2A_2: 0.016 / (0.0512 + 0.016) = 0.238$$

- (3) 7. Give an example of positive assortative mating.

Example: Sexual imprinting in the common buzzard (or hawk) in Europe leads to positive assortative mating of progeny to mates with plumage coloration similar to the maternal plumage coloration.

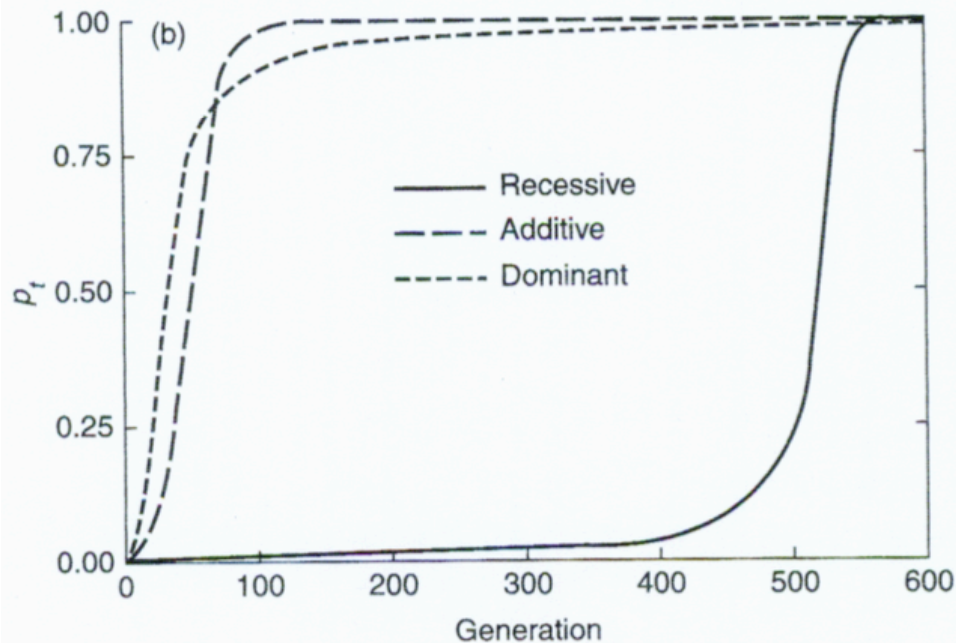
Many other examples are possible; these do not have to involve sexual imprinting nor preference for the maternal phenotype.

- (6) 8. For a diploid lineage with no history of inbreeding,

(3) a. What is the coefficient of relationship between parent and offspring? **0.5**

(3) b. What is the kinship coefficient between parent and an offspring? **0.25**

- (4) 9. The following Figure from Hedrick's text shows the rise in frequency for an allele at an initially low frequency ($p_0 = 0.01$) undergoing positive Darwinian selection ($s = 0.1$), in cases where the allele is recessive, dominant, or additive:



Given that the fitness value for an additive allele is exactly half way between the fitness of a dominant allele and the fitness of a recessive allele, why doesn't the curve showing increase in an additive allele fall exactly intermediate between the curve for a dominant and the curve for a recessive allele?

At low frequencies an allele is found almost entirely in heterozygous genotypes. Selection does not affect the heterozygous state if the allele is recessive, but the heterozygotes are subject to selection if the allele is additive. Hence at low frequencies an additive (like a dominant) allele increases quickly in frequency due to positive selection acting on the heterozygotes, while a recessive allele does not.

(4) 10. Four alleles (A_1 , A_2 , A_3 , A_4) at a single locus (A) have been identified on a plant that prevents self-fertilization by self-incompatibility. If the A locus is at equilibrium, what is the expected allele frequency of allele A_3 ?

Answer: $q_{eA3} = 1/(n \text{ alleles}) = 1/4 = .25$

(8) 11. Assume that the fitnesses are 0.9, 1.0 and 0.6 for alleles A_1A_1 , A_1A_2 , and A_2A_2 , respectively.

(4) a. Calculate the mean fitness when $q = 0.4$.

$$\begin{aligned} w\text{-bar} &= p^2w_{11} + 2pqw_{12} + q^2w_{22} \\ &= (0.9 \times 0.6^2) + (2 \times 0.6 \times 0.4 \times 1) + (0.6 \times 0.4^2) \\ &= (0.324 + 0.48 + 0.096) = 0.9 \end{aligned}$$

(4) b. Is the mean fitness higher for any other allele frequency? Why or why not?

Yes. The highest level of fitness for an overdominant system will be at equilibrium, when $q_e = s_1/(s_1 + s_2) = 0.1 / (0.1 + 0.4) = 0.2$

(4) 12. What is the difference between purifying and Darwinian selection?

Purifying selection reduces the frequency of deleterious alleles in a population with fitness **disadvantage** of s . Adaptive or positive Darwinian selection increases the frequency of alleles that are advantageous in the present environment with fitness **advantage** of s . The difference is that the former is due to fitness disadvantage while the latter is due to fitness advantage

(9) 13. In the pedigree on the right, CA1 and CA2 are outbred.

(3) a. What is the inbreeding coefficient for individual U?

$$f = 0$$

(3) b. What is the inbreeding coefficient for individual Z?

$$f = (0.5)^6 + (0.5)^6 = 1/64 + 1/64 = 2/64 = 0.03125$$

(3) c. Genotypes are shown for the A locus for individuals included in the pedigree. What are the possible genotypes for individual Z to have at the A locus? Which of these would be identical by descent, and which have identity in state?

Three possible genotypes for Z:

A_1A_1 identity in state

A_2A_2 identity in state

A_1A_2 neither

