Biology 4415/5415
Evolution

PRACTICE PROBLEMS IN POPULATION GENETICS

1. In a study of the Hopi, a Native American tribe of central Arizona, Woolf and Dukepoo[1] found 26 albino individuals in a total population of 6000. This form of albinism is controlled by a single gene with two alleles: albinism is recessive to normal skin coloration.

a) Why can't you calculate the allele frequencies from this information alone?

b) Calculate the expected allele frequencies and genotype frequencies if the population were in Hardy-Weinberg equilibrium. How many of the Hopi are estimated to be carriers of the recessive albino allele?

2. A wildflower native to California, the dwarf lupin (*Lupinus nanus*) normally bears blue flowers. Occasionally, plants with pink flowers are observed in wild populations. Flower color is controlled at a single locus, with the pink allele completely recessive to the blue allele. Harding[2] censused several lupin populations in the California Coast Ranges. In one population of lupins at Spanish Flat, California, he found 25 pink flowers and 3291 blue flowers, for a total of 3316 flowers.

a) Calculate the expected allele frequencies and genotype frequencies if the population were in Hardy-Weinberg equilibrium.

b) Harding studied the fertility of lupins by counting number of seed pods produced per plant in a subsample of the Spanish Flat population. He found the following:

	mean # pods	number of plants examined
blue	19.33	39
pink	13.08	24

Assume that heterozygotes are as fit as homozygous blue lupins, and that seeds from both pink and blue lupins all suffer about the same mortality rate after germinating. Calculate the relative fitness of each genotype.

[1] Woolf, C. M. and Dukepoo, F. C. 1959. Hopi Indians, interbreeding and albinoism. Science 164: 30-37.
[2] Harding, J. 1970. Genetics of Lupinus. II. The selective disadvantage of the pink flower color mutant in *Lupinus nanus*. Evolution 24: 120-127.

3. Cooke and Ryder[3] studied the nestlings of Ross's goose, a small Arctic nesting goose. Goslings (baby geese) exist in two color morphs, grey or yellow. Cooke and Ryder reported that a population of geese at Karrack Lake, Canada included 263 yellow goslings and 413 grey goslings (676 total). They assumed that color is controlled by two alleles at a single locus.

a) Calculate the frequencies of all three possible genotypes, assuming that grey is dominant and that the population is in Hardy-Weinberg equilibrium. Then repeat, assuming that yellow is dominant.

b) Assume that grey is dominant. (In real life, Cooke and Ryder were unable to determine which allele was dominant.) There is no difference between yellow and grey goslings once they have matured. However, yellow goslings are at an increased risk of predation by a predatory bird, the Arctic skua. If 303 grey goslings survive to adulthood, but only 150 yellow ones do, calculate the fitness of the yellow phenotype relative to the grey one.

c) Now calculate the mean fitness ("w-bar").

d) Use that to predict the effect of selection on the next generation.

4. A 1970 study[4] of 93 house mice (*Mus musculus*) in a single barn in Texas focused on a single locus (the gene for a certain enzyme) with two alleles, A and A'. The genotype frequencies found were:

AA	0.226
AA'	0.400
A'A'	0.374

a) Calculate the allele frequencies.

b) How does this population differ from the predictions of Hardy-Weinberg equilibrium? Show your work.

c) In this specific case, what factor or factors are most likely to be causing deviations from Hardy-Weinberg equilibrium? How can you tell?

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[3] Cooke, F. and Ryder, J. P. 1971. The genetics of polymorphism in the Ross' goose (*Anser rossii*). Evolution 25: 483-496.

[4] I don't remember where I got this problem. . .

5. The geneticist P. M. Sheppard[5] carried out a selection experiment on a laboratory population of the fruit fly *Drosophila melanogaster*. The stubble allele, which affects bristle shape of the fly, is dominant to the wild-type allele.Flies that are homozygous for stubble always die during embryonic development.

a) Sheppard started out with 86% normal flies and 14% stubble flies. Calculate the allele frequencies.

b) Assuming for now that wild-type and stubble flies do not differ in fitness, use the allele frequencies to calculate the mean fitness. Then predict the percentages of normal and stubble flies in the next generation. Show all work.

c) Sheppard introduced an additional source of selection: he removed 60% of the wild-type flies before they could breed in each generation. Repeat part b taking this into account.

6. The Old German Baptist Brethren, informally known as the "Dunkers", is a religious denomination founded in Germany in 1708. Beginning in 1719, a number of Dunkers emigrated from Germany to Pennsylvania. As of 1950, there were about 3500 Dunkers in the United States. Dunkers are not as strict about their lifestyle as other similar religious groups, such as the Amish. However, Dunkers usually marry within their community. Dunkers who marry non-Dunkers often leave the community, and converts to the Dunker denomination are relatively rare.

In 1950, geneticist Bentley Glass studied a population of over 200 Dunkers in southern Pennsylvania.[6] Glass used the MN blood group, a blood type controlled by a single gene with two loci. Individuals may be type M (homozygous for the M allele), N (homozygous for the N allele), or MN (heterozygous). The MN blood type has little clinical significance, and as far as is known there is no survival advantage in having one MN blood type over the other.

a) Glass found 102 Dunkers with type M blood, 96 with type MN, and 31 with type N. Calculate the allele frequencies.

b) Calculate the expected numbers of people who would have each blood type if the population were in Hardy-Weinberg equilibrium. If the expected figures don't match what is observed, suggest why this might be the case.

c) In Germany today, about 30% of the population has type M blood, 50% has type MN, and 20% has type N. In the eastern United States, the figures are almost identical (29% M, 50% MN, 21% N.) Discuss why both of these sets of allele frequencies might differ from the frequencies in the Dunkers. (There could be many reasons, but restrict yourself to the most likely.)

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[5] Sheppard, P. M. 1959. *Natural Selection and Heredity*. Philosophical Library, New York.

[6] Glass, B., Sacks, M. S., Jahn, E. F., and Hess, C. 1952. Genetic drift in a religious isolate: An analysis of the causes of variation in blood group and other gene frequencies in a small population. *American Naturalist* 86: 145-159.

7. P. D. N. Hebert[7] studied the frequencies of alleles for the gene that codes for the enzyme malate dehydrogenase (*Mdh*) in the "water flea," *Daphnia magna*, living in ponds near Cambridge, England. There are three alleles of the *Mdh* gene, abbreviated S, M and F. Hebert found the following genotypes:

genotype	observed number
SS	3
SM	8
SF	19
MM	15
MF	37
FF	32
total	114

a) Calculate the allele frequencies.

b) Is the population in Hardy-Weinberg equilibrium?

8. *Avena fatua* is a species of wild oat (a type of grass). Jain and Marshall studied wild oat population genetics in California.[8] One of the traits they examined was the pubescence (hairiness) of the leaf sheath, which is controlled by a single locus with two alleles, written **L** and **l**. They found that the frequencies of genotypes in one population were:

LL	57.1%
Ll	7.1%
ll	35.8%

a) Calculate the allele frequencies

b) Predict what the genotype frequencies should be under Hardy-Weinberg equilibrium. If there is a difference between actual and predicted frequencies, explain briefly why the differences might exist.

c) Calculate **F**.

9. The biologist B. Battaglia raised the marine copepod *Tisbe reticulata* (a small free-swimming marine crustacean) under crowded conditions. *T. reticulata* has one gene with two alleles, V^v and V^m, showing incomplete dominance. In one of his tanks, Battaglia counted 1751 copepods: 353 V^vV^v, 1069 V^vV^m, and 329 V^mV^m.

a) Show that the population is not in Hardy-Weinberg equilibrium.

b) Discuss why it might not be in Hardy-Weinberg equilibrium.

[7] Hebert, P. D. N. 1974. Enzyme variability in natural populations of *Daphnia magna*. III. Genotypic frequencies in intermittent populations. *Genetics* 77: 335-341.
[8] Jain, S. K. and Marshall, D. R. 1967. Variation in natural populations of *Avena fatua* and *A. barbata*. *American Naturalist* 101: 233-249.

10. True story: In 1912, the geneticist W. H. Goddard suggested that feeble-mindedness was caused by Mendelian inheritance at a single locus with two alleles. Persons homozygous for the recessive, feeble-minded allele (call it **f**) were dopes, dummies, and dimwits—"incapable of managing their affairs with ordinary prudence", as Goddard said. Heterozygotes (**Ff**) and homozygous dominants (**FF**) were of normal intelligence. *This is not actually true*—but pretend that it is, for the purposes of working this problem. (25 pts. total)

a) According to the 1910 census, the population of the United Stetes was 91,972,266. Goddard estimated that 1% of the population was feeble-minded. Assume that the population of the US was in Hardy-Weinberg equilibrium. Calculate the allele frequencies, and then calculate the percentages of the population that would be heterozygous and homozygous dominant. (5 pts.)

b) At one time or another, thirty states had laws mandating the compulsory surgical sterilization of the feebleminded. (As of 1996, Arkansas and nine other states still *did* have such a law on the books.)[9] There were organizations in the early 20th century that lobbied for their enactment nationwide.

Imagine that, in some alternate-reality USA, a mandatory, nationwide law really was put into effect that forced the sterilization of all feebleminded individuals before they could reproduce. Assume that the authorities were so efficient that they were able to track down and sterilize 90% of the feebleminded—and that they never, ever sterilized anyone who wasn't feebleminded. What would be the frequencies of genotypes, and of alleles, after one generation?

11. J. A. Frelinger[10] studied the protein *transferrin* in pigeons. Transferrin is produced by a single gene with two alleles, written as Tf^A and Tf^B. Frelinger measured the genotypes of females in a population of pigeons, and compared the females' genotypes with the numbers of eggs that they laid and sucessfully hatched. The data is given below:

	Female genotype		
	Tf^ATf^A	Tf^ATf^b	Tf^BTf^B
No. of eggs laid	128	267	144
No. of eggs hatched	59	180	75

a) Calculate the relative fitness for each genotype.

b) Suppose we have a population of 500 pigeons. 72 are Tf^ATf^A, 192 are Tf^BTf^B, and the rest are Tf^ATf^b. Calculate the genotype frequencies and allele frequencies, and then predict what these frequencies will be after one round of selection.

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[9] Adler, R. R. 1996. *Estate v. C.W.*: A pragmatic approach to the involuntary sterilization of the mentally disabled. *Nova Law Review* 20:1323-1368.

[10] Frelinger, J. A. 1972. The maintenance of transferrin polymorphism in pigeons. *Proceedings of the National Acedemy of Sciences of the USA* 69: 326-329.

12. Smith[11] studied an African butterfly called *Danaus chrysippus*, in the country of Tanzania. Color and pattern in these butterflies are largely governed by one gene with two alleles showing incomplete dominance. *CC* individuals are lightly colored (called the dorippus phenotype); *cc* individuals are black and brown (the aegypticus phenotype); and *Cc* individuals are intermediate in color (the transiens phenotype).

In April through August 1974, which is the rainy season in Tanzania, Smith counted male butterflies in a population, and noted their mating success. Here's his raw data:

	dorippus	transiens	aegypticus	Total
mated	3	85	23	111
unmated	149	307	155	611
total	152	392	178	722

a) Calculate the allele frequencies in the total population.

b) Estimate normalized fitness values for the population.

c) The above data actually summarize several generations (these butterflies breed continuously and complete 13-14 generations in a year). However, for the purposes of this question, pretend that the total numbers of individuals given in the bottom row of the above table, represent one generation. Predict what the allele frequencies would be after the next round of selection.

Smith continued his observations in the dry season of September 1974-March 1975, and observed the following:

	dorippus	transiens	aegypticus	Total
mated	59	76	2	137
unmated	209	196	47	452
total	268	272	49	589

d) Calculate the allele frequencies in the total population.

e) Estimate fitness values for the population.

g) Come up with two hypotheses for why selection appears to be acting differently on the same population at different times of the year.

[11] Smith, D. A. S. Sexual selection in a wild population of the butterfly *Danaus chrysippus* L. *Science* 187: 664-665.