ANSWER KEY

1. Hardy-Weinberg equilibrium (HWE) provides a quantitative basis for studying genetics in natural populations. Which of the following is NOT a necessary assumption for HWE?
   a. Similar genotypes mate preferentially with one another.
   b. Populations are assumed to be very large.
   c. There is no migration into or out of the population.
   d. There is no mutation at the locus of interest.
   e. The gene is assumed to not be under natural selection.

2. Speciation can occur when different populations accumulate enough genetic differences that they become unable to reproduce with one another. The evolutionary force called ________________ is thought to greatly retard this process.
   a. gene flow
   b. genetic drift
   c. inbreeding
   d. natural selection
   e. mutation

   See lecture notes.

3. A single copy of a new allele appears in a population of orchids when pollen is transferred from a distant population. The allele is neutral with respect to selection. There is a 1% probability of this allele becoming fixed through the action of genetic drift. How many orchids are in the population? (Assume that the size of the population is constant, and that this species of orchid is diploid.)
   a. 10
   b. 20
   c. 50
   d. 100
   e. 500

   Probability of fixation = the frequency in the population. $1\% = 1/(2N)$ so $N = 50$.

4. A salamander larva may or may not metamorphose into an adult at age 2 months. This decision is based on levels of hormones in the body. If the hormone levels are higher than a certain value, metamorphosis will always occur. If they are less than this value, metamorphosis almost never occurs. "Do I metamorphose after 2 months ?" is best characterized as a
   a. continuous trait
   b. meristic trait
   c. threshold trait
   d. Mendelian trait
   e. determinant trait

   See the definitions.

5. Genetic variation can be studied in natural populations using
   a. DNA sequence differences
   b. differences in the electrophoretic mobility of proteins
   c. morphological characters only if they have a genetic basis
   d. A and B only
   e. A, B and C

6. Expected heterozygosity is
   a. the number of heterozygotes seen in a sample from a natural population.
   b. the number of heterozygotes you expect to see in an inbred population.
   c. the probability that an allele is randomly chosen once from a gene pool.
   d. the probability that the same allele is randomly chosen twice from a gene pool.
   e. the probability that two different alleles are randomly chosen from a gene pool.

Question 7 concerns the data set below. The mitochondrial DNA gene *cytochrome oxidase I* was sequenced in 40 water mites (all the same species). Four different alleles were found. Because this is a mtDNA gene, every individual has only one copy. (In other words, the genotype for mtDNA is haploid, not diploid.)

Allele	Sequence	Number of gene copies found
"1"	ATCCA**C**GTCGTCATCACT**G**…	32
"2"	ATCCA**T**GTCGTCATCACT**G**…	6
"3"	ATCCA**C**GTCGTCATCACT**A**…	1
"4"	ATCCA**C**GTCGTCATCACT**T**…	1

7. What is the frequency of allele 1 in the mitochondrial gene pool?
   a. 0.032 b. 0.32 c. 0.64 d. 0.80 e. 32
   =32/40

8. Imagine a simple natural selection model with random mating and only viability selection. All heterozygous *Aa* offspring survive to adulthood, but all homozygous individuals die. If we take a very large sample from this population and test for Hardy Weinberg genotypic proportions, what will we find?
   a. Neither adults nor newborn offspring are in HW proportions.
   b. Both adults and newborn offspring are in HW proportions.
   c. Adults are in HW proportions but not newborn offspring.
   d. Newborn offspring are in HW proportions but not adults.
   e. If you sample this population and determine everyone's genotype, you will not be able to test for HW proportions.
   See the lectures on natural selection models. This is exactly what happens in the models. HW proportions are always found in zygotes if there is random mating.

9. During a wildfire, a large population of butterflies in an isolated canyon in Tierrasanta goes extinct. One month later, a large storm event blows 10 butterflies in from a population to the north that is

fixed for A. During the same storm, 10 butterflies blow in from a different population to the south that is fixed for a.

The 20 butterflies mate randomly in this canyon, and the population grow quickly to a very large size (10,000 butterflies). There is random mating in the canyon every generation. There is no more dispersal.

After the 20 founders arrive, how long until we expect the canyon to reach genotype frequencies p^2, $2pq$ and q^2?

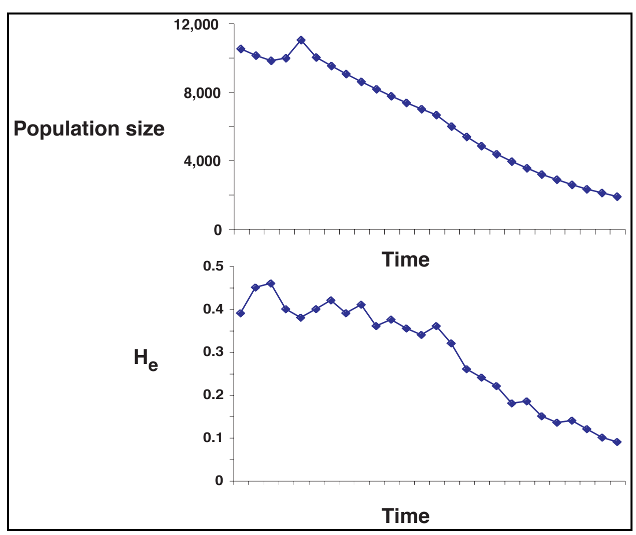
a. 0 generations after colonization (the 20 colonists will be in HW equilibrium when they all arrive)
b. 1 generation after colonization
c. 20 generations after colonization
d. 10,000 generations after colonization
e. never

One generation of random mating is required for HW proportions.

10. In population genetics, fitness is calculated using
    a. the number of offspring that survive and reproduce
    b. the physical strength of the organism
    c. the number of times an organism mates in its lifetime
    d. the overall health of the organism
    e. a jar of M and M's, some dice and a slot machine.

11. If you are outbreeding, then you choose your mates
    a. without considering whether they are related to you.
    b. if they are related to you.
    c. if they are very closely related to you.
    d. if they are unrelated to you.
    e. if they look like you.

12. The picture at the rights shows a long term study where population size was monitored over time, and H_e was calculated for microsatellites. The microsatellites consist of areas of the genome that do not code for anything. (They are selectively neutral.)



These data provide an excellent example of
    a. Hardy Weinberg equilibrium changing gene frequencies over time.
    b. a bottleneck leading to lowered variation.
    c. natural selection (complete dominance) against mutant alleles.
    d. reduction in mutation rates.
    e. a decline in absolute fitness for the population at these loci.

13. A population of swallows is studied. Adult birds are scored at a single locus that has two alleles. Of 120 randomly surveyed birds, 85 are *BB*, 12 are *Bb* and 23 *bb*. Does this locus depart from Hardy-Weinberg frequencies? (For 1 degree of freedom $\chi^2 > 3.84$ is significant.)

a. Yes. $\chi^2 = 1534.4$

b. Yes. $\chi^2 = 101.6$

c. Yes. $\chi^2 = 63.5$

d. No. $\chi^2 = 1.8$

e. No. $\chi^2 = 0.5$

Genotype	#O	freq O	Exp freq genotypes	# Expected genotypes	(O-E)^2	.../E
BB	85	0.70833333	0.57506944	69.0083333	255.733403	3.70583364
Bb	12	0.1	0.36652778	43.9833333	1022.93361	23.2573007
bb	23	0.19166667	0.05840278	7.00833333	255.733403	36.4899029
SUM	120	1	1	120		**63.45304**

freq B and b
0.75833333
0.24166667

14. Which microevolutionary forces could be responsible the data in question 13?

a. inbreeding
b. natural selection
c. mutation
d. A or B only
e. A, B or C

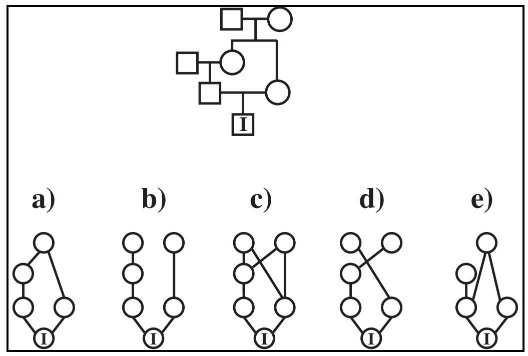
Inbreeding creates a deficiency of heterozygotes.
Mutation operates too slowly to generate a huge deficiency of heterozygotes in one generation.

15. There is a population of wildflowers in a field that is infinitely large. In this field, all flowers produce the same number of offspring. There is a 10% chance of self-pollinating and a 90% chance of mating randomly with any flower. Assume there is no mutation, migration or natural selection. Over time, what will happen to genetic variation at a locus that is polymorphic right now?

a. H_o will decrease to zero, and H_e will decrease to zero.
b. H_o will decrease to zero, and H_e will increase to one.
c. H_o will decrease to zero, and H_e will reach a stable equilibrium between zero and one.
d. H_o will reach a stable equilibrium between zero and one, and H_e will reach the same stable equilibrium.
e. H_o will reach a stable equilibrium between zero and one, and H_e will reach a different stable equilibrium between zero and one.

- In question 15, inbreeding is occurring, and there are no other microevolutionary forces. In an infinitely large population, the probability of selfing will be infinitely small (and therefore zero.) If the population only had 10 individuals, there would be a 10% chance of selfing under random mating.
- Under a system of inbreeding in an infinitely large population, where there are no other microevolutionary forces, p and q do not change over time. Inbreeding in an infinitely large population does not lead to fixation of one allele or the other.
- If the locus is polymorphic now, $H_e = 2pq$ will be greater than zero and less than one. Remember that H_e is always equal to $2pq$ by definition.
- Since p and q are not changing over time, H_e will not change over time.
- H_o will be less than H_e under inbreeding.
- H_o will only be zero at equilibrium when $F = 1$ and organisms mate only by selfing.

16. Sperm from a prize racehorse are often used to sire many offspring, and family lines may be inbred. A prize horse's daughter is bred with her full sister's son. The pedigree is shown here. Which path diagram is correct?



c

17. Purple plumage in parrots is a caused by a homozygous recessive condition at a single locus. The forward rate of mutation from the "green gene" to purple is 0.01. The backward rate of mutation is so small that it can be ignored. The frequency of the purple allele is 0.10. What will frequency of the purple allele be in one generation?

a. 0.110 b. 0.109 c. 0.100 d. 0.901 e. 0.999

See formula sheet.
Frequency of green after on generation is 0.9*(1 - 0.01) = 0.891
So frequency of purple = 1-0.891 = 0.109

18. In a population of petunias, there are only one-third as many heterozygotes as you would expect from random mating. The average petunia has an inbreeding coefficient of _______.

a. 0.167 b. 0.300 c. 0.333 d. 0.340 e. 0.667

=1-(1/3)

Questions 19-20 concern blood types in Los Angeles.

Blood type	Genotype	# people
A	I_A I_A	20
A	I_A I_O	10
B	I_B I_B	30
B	I_B I_O	10
AB	I_A I_B	10
O	I_O I_O	20

19. What is the observed frequency of the AB blood type?
    a. 0.01 b. 0.05 c. 0.10
    d. 0.24 e. 0.90

= 10/100

20. After random mating, what do we expect the frequency of the AB blood type to be?
    a. 0.175 b. 0.24 c. 0.40 d. 0.48 e. 0.96

= 2 * (60/200) * (80/200)

21. Which of the following is true about mutation?
    a. Mutation is a powerful microevolutionary force that can change allele frequencies dramatically in a short time.
    b. Under some models of mutation, heterozygosity decreases to zero unless it is balanced by another force (like natural selection).
    c. Mutation rates are usually around 1% - 10% per gene per generation.
    d. The one way mutation model leads to random increases or decreases in gene frequencies from generation to generation.
    e. In the two-way mutation model, the mutation rates μ and ν decline over time to zero.

    c is wrong by many orders of magnitude. d is wrong because the one way mutation model does not produce random fluctuations: the population moves steadily towards fixation for a.

22. Which of the following is NOT true about the "island model" of migration?
    a. There is no mainland in this model, only islands.
    b. The island model assumes that migration rates are constant over time, and equal in all populations.
    c. The island model ignores any natural selection on the locus being studied.
    d. The island model generally takes longer to reach equilibrium than a mutation model would.
    e. The island model shows that allele frequencies p and q will eventually be the same everywhere, unless there is another force acting (like drift).

    See the model description.

23. What is the link between Darwin's theory of evolution and the population genetic models of natural selection?
    a. Darwin believed that mutations drive adaptation over short time periods, which is shown in the models.
    b. Darwin thought that fitness should increase over time. The models show this mathematically.
    c. Darwin believed that heritable traits do not evolve, which is shown in the natural selection models.
    d. Darwin believed in "survival of the fittest", which means mathematically that the selective coefficient *s* increases as fitness *w* increases.
    e. Darwin believed that the least fit individuals will contribute the most to the next generation. This is how the natural selection models are constructed.

    Average w for the population increases over time.

24. Which model of natural selection maintains polymorphism in most situations?
    a. complete dominance
    b. partial dominance
    c. overdominance
    d. underdominance
    e. all of the above

25. One percent of San Diego residents have excessive nose hair, caused by a recessive condition at a single locus. Assuming that there is random mating in San Diego, how many people are heterozygous carriers of this debilitating condition? (Heterozygous carriers have normal nose hair).
    a. 1% b. 2% c. 4% d. 18% e. 80%

    $q^2 = 0.01$, so $q = 0.1$ and $p = 0.9$. $2pq = 0.18$

26. What is the best way to determine whether a trait is a quantitative trait, a single-locus Mendelian trait, or has no genetic basis at all?
    a. Look at one individual and see what their phenotype is.
    b. Look at <u>many</u> individuals and see what their phenotype is.
    c. Sequence the DNA for one individual for 10 randomly chosen genes, and calculate H_o.
    d. Sequence the DNA for <u>many</u> individuals for 10 randomly chosen genes, and calculate H_o.
    e. Do a standard breeding experiment with individuals of different phenotypes, and examine the phenotypic distributions in the F1 and F2 generations.

See notes from the last lecture.

27. In thrushes (birds), the number of eggs a female can lay is under strong natural selection to increase. It has been under natural selection in this same way for a long time. How much variation do we expect to see now in the genes that control number of eggs? (Mating is random.)
    a. Lots of variation: in every individual, all the genes that affect egg laying are probably heterozygous. Example: AaBbCcDd…
    b. High amounts of variation, but every individual may not be heterozygous at every locus.
    c. No variation: in every individual, all the genes that affect egg laying are probably fixed in the same way. Example: AABBCCDD…
    d. No variation: in every individual, all the genes that affect egg laying are probably homozygous, but in different ways. Example: some individuals are AAbbCCDD…, some aaBBCCdd…, some AABBccdd…, etc.
    e. There is no way to predict this.

Stated during the last lecture.

Answer d) is wrong for 2 reasons. First, there is variation at each locus (i.e., there is more than one allele). If there is random mating and more than one allele, you will find some heterozygotes. Answer d) says there will be no heterozygotes.

Second, the additive model has one "unit" of size for every capital letter. Individual aaBBCCdd will have smaller eggs than individual AAbbCCDD, who will have smaller eggs than AABBCCDD. So at equilibrium, the population will all be fixed in the same way for each gene, and every individual has the same (best) fitness. In answer d), the second and third individuals listed as examples have lower fitness than AAbbCCDD, which is not possible. Only answer c) is possible.

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28. In areas of Africa where malaria is prevalent, normal *AA* individuals have a fitness of 0.85 and heterozygous *AS* individuals (with one sickle cell gene copy) have a fitness of 1.0. All homozygous *SS* individuals have severe anemia and a fitness of 0. What is the equilibrium frequency of the normal *A* allele in these areas?

    a. 0 b. 0.54 c. 0.85 d. 0.87 e. 1.0

$= 1 / (1+0.15)$

29. In other areas of the world where malaria is not common, normal *AA* individuals have the highest absolute fitness, and heterozygous *AS* individuals have lowered survivorship (fitness = 0.95). Homozygous *SS* individuals with severe anemia have a fitness of 0.2. What is the equilibrium frequency of the normal *A* allele in these areas?

    a. 0 b. 0.06 c. 0.44 d. 0.94 e. 1.0

For a partial dominance model, the best allele is fixed at equilibrium. $p = 1.0$

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30. You will find that the frequency of *AA* in zygotes is p^2 when
    a. the population is in Hardy Weinberg equilibrium
    b. there is random mating
    c. there is inbreeding
    d. A and B only
    e. A, B and C are all true

31. Most natural selection models have both stable and unstable equilibria. In a model of full dominance with 2 alleles, a population is sitting exactly on the unstable equilibrium. To move away from this unstable equilibrium would require

a. no other microevolutionary forces. (Natural selection can easily move the population off of the unstable equilibrium.)
b. genetic drift.
c. some inbreeding.
d. some outbreeding.
e. a mutation.

The unstable equilibrium is where there are no "A" alleles, only a. The only way to move it to the stable equilibrium (fixation for A) is to have at least one mutation from a->A.

32. A model with both drift and gene flow …

a. can be used for situations in which Hardy Weinberg equilibrium applies.
b. was first developed by Charles Darwin to explain descent with modification.
c. is used to estimate how much gene flow is actually occurring in natural populations.
d. shows that divergence among populations increases as gene flow increases.
e. explains why tomato soup with less salt costs more than regular tomato soup.

See lecture notes for answer c. Answer d is exactly the opposite: more gene flow means less divergence.