1. Assortative mating—
   a. affects genotype frequencies expected under the Hardy–Weinberg equilibrium
   b. affects allele frequencies expected under the Hardy–Weinberg equilibrium
   c. has no effect on the genotypic frequencies expected under the Hardy–Weinberg equilibrium because it does not affect the relative proportion of alleles in a population
   d. increases the frequency of heterozygous individuals above the Hardy–Weinberg expectations

The correct answer is a— affects genotype frequencies expected under the Hardy–Weinberg equilibrium

A. Answer a is correct. When individuals mate preferentially with other individuals that are phenotypically similar, that leads to an overabundance of homozygous individuals occurs since similar phenotypes are likely to share similar genotypes. When matings of similar phenotypes occur more frequently than by random chance, the likelihood of offspring receiving two copies of an identical allele increases, disrupting the Hardy–Weinberg expectations.

B. Answer b is incorrect. Because individual allele frequencies do not change (no alleles are gained or lost from the population), just the proportion of the various genotypic combinations of those alleles

C. Answer c is incorrect. Genotypic frequencies can change even when allele frequencies do not. Assortative mating, by itself, does not change the frequency with which individual alleles are transmitted to the next generation, just the probabilities that a particular allele will be associated with other alleles.

D. Answer d is incorrect. Because when genetically similar individuals mate, it is more likely that offspring will receive two copies of the same allele, leading to an increase in homozygosity.

2. In a population of red (dominant allele) or white flowers in Hardy–Weinberg equilibrium, the frequency of red flowers is 91%. What is the frequency of the red allele?
   a. 9%
   b. 30%
   c. 91%
   d. 70%

The correct answer is d—

A. Answer a is incorrect. Nine percent is the frequency of white flowers in the population, not the frequency of the red allele.

The correct answer is d—

B. Answer b is incorrect. Thirty percent is the frequency of the white allele in the population, not the frequency of the red allele.
The correct answer is d—
C. Answer c is incorrect. Ninety percent is the frequency of red flowers in the population, but this is not the same as the frequency of the red allele.

The correct answer is d— 70%
D. The Hardy–Weinberg equilibrium can be calculated with the equation:

\[(p + q)^2 = p^2 + 2pq + q^2\] such that \(p + q = 1\)

In this case: \(q^2\) (the frequency of white flowers) = 9% or 0.09, and so \(q = 0.3\), because \(p + q = 1\) then \(1 - 0.3 = 0.7\), so \(p\) (the frequency of the red allele) = 0.7, or 70%.

Hint: According to the Hardy–Weinberg equilibrium the letter \(p\) designates the frequency of one allele and the letter \(q\) the frequency of the alternate allele. Because there are only two alleles, \(p\) plus \(q\) must always equal 1. The Hardy–Weinberg equation can be expressed in the form of what is known as a binomial expansion:

\[(p + q)^2 = p^2 + 2pq + q^2\]

If \(q^2 = 0.16\), then \(q = 0.4\). Therefore, \(p\), the frequency of allele \(B\), would be 0.6 (1.0 - 0.4 = 0.6). We can now easily calculate the genotype frequencies: \(p^2 = (0.6)^2 = 0.36\), or 36% \(BB\) individuals. The heterozygous would have a frequency of \(2pq\), or \((2 \times 0.6 \times 0.4) = 0.48\), or 48%.

3. Genetic drift and natural selection can both lead to rapid rates of evolution.
   However—
   a. genetic drift works fastest in large populations
   b. only drift leads to adaptation
   c. natural selection requires genetic drift to produce new variation in populations
   d. both processes of evolution can be slowed by gene flow

The correct answer is d—
A. Answer a is incorrect. Drift occurs most quickly in very small populations.

The correct answer is d—
B. Answer b is incorrect. Only natural selection leads to adaptation.

The correct answer is d—
C. Answer c is incorrect. Genetic drift does not produce new genetic variation; it reduces it through the loss of alleles.

The correct answer is d—both processes of evolution can be slowed by gene flow
D. Answer d is correct. In general, both drift and natural selection cause evolutionary change by reducing genetic variation. An influx of alleles due to immigration can reduce the rate of loss. Note that natural selection does not always lead to a loss of genetic variation.

4. When the environment changes from year to year and different phenotypes have different fitness in different environments—
   a. natural selection will operate in a frequency-dependent manner
b. the effect of natural selection may oscillate form year to year, favoring alternative phenotypes in different years

c. genetic variation is not required to get evolutionary change by natural selection

d. none of the above

The correct answer is b—

A. Answer a is incorrect. Frequency-dependent selection refers to fitness differences that change according to the relative abundance of alternative phenotypes. Environmental variation does not necessarily change the relative fitness of phenotypes in a population.

The correct answer is b— the effect of natural selection may oscillate form year to year, favoring alternative phenotypes in different years

B. Answer b is correct. It describes one way in which natural selection can actually maintain variation within a population. If environmental conditions in one year favor a certain phenotype, evolutionary changes can be reversed (as long as there is still genetic variation) in subsequent years if environmental conditions change and favor the previously inferior phenotype.

The correct answer is b—

C. Answer c is incorrect. Without genetic variation, traits cannot be passed on to offspring.

The correct answer is b—

D. Answer d is incorrect. One answer, b, is correct.

5. The frequency of the sickle cell allele (S) is about 0.12 in African locales exposed to malaria, but has dropped over about 15 generations to about 0.003 in places where malaria has been eradicated (USA). Given the mechanism for heterozygote advantage, how long must malaria be suppressed in Africa before we would expect S to be purged?

a. It will never be lost
b. Less than 15 generations
c. More than 15 generations
d. Not enough information to predict

The correct answer is c—

A. Answer a is incorrect. If individuals who are homozygous never reproduce, and if heterozygotes have no advantage without exposure to malaria, an allele that reduces with reproductive success to zero will eventually be purged.

The correct answer is c—

B. Answer b is incorrect. It should take at least as long as it did to reduce the frequency of the S allele to low levels in the United States.

The correct answer is c—More than 15 generations
C. Answer c is correct. Even at very low frequencies, the allele can increase in frequency if a selective advantage (some pockets of malaria return) arises. Therefore, it would probably take longer than the time it took to reduce it from 0.12 to 0.003 in the United States.

The correct answer is c—

D. Answer d is incorrect. The rate of reduction in the S allele frequency in the United States provides a real-world scenario for a minimum (fast-pace) estimate.

6. What would happen to average birth weight if, over the next several years, advances in medical technology reduced infant mortality rates of large babies to equal that for intermediate-sized babies (see the following figure, red line). Assume that differences in birth weight have a genetic basis.
   a. Over time, average birth weight would only increase
   b. Over time, average birth weight would only decrease
   c. Both a and b
   d. None of the above

The correct answer is a—Over time, average birth weight would only increase

A. Answer a is correct. Decreasing mortality of larger babies to rates equal to intermediate-sized babies would produce directional selection for increased birth weight.

The correct answer is a—

B. Answer b is incorrect. Mortality rates of small babies remain unchanged, meaning that small babies would still be selected against.

The correct answer is a—

C. Answer c is incorrect. Only intermediate and large babies enjoy low mortality. Small babies are still subject to elimination by natural selection.

The correct answer is a—

D. Answer d is incorrect. Directional selection for larger babies would result from reduced mortality of intermediate and large babies compared with small babies.

7. Many factors can limit the ability of natural selection to cause evolutionary change, including—
   a. a conflict between reproduction and survival as seen in Trinidadian guppies
   b. lack of genetic variation
   c. pleiotropy
   d. all of the above

The correct answer is d—
A. Answer a is incorrect. It does represent a limitation. Specifically, in the guppy system, large colorful fish cannot persist where predation is high, but this is not the only correct answer.

The correct answer is d—
B. Answer b is incorrect. It does represent a limitation. Lack of genetic variation means that there is no way to pass on phenotypic variation to offspring, but this is not the only answer.

The correct answer is d—
C. Answer c is incorrect. It does represent a limitation. When a gene affects two traits that may influence survival and reproduction in equal but conflicting ways, natural selection will eventually be unable to produce evolutionary changes in one trait because of the negative consequences in the second trait, but this is not the only answer.

The correct answer is d—all of the above
D. Answer d is correct because a, b, and c are correct.

8. Stabilizing selection differs from directional selection because—
   a. in the former, phenotypic variation is reduced but the average phenotype stays the same, whereas in the latter both the variation and the mean phenotype change
   b. the former requires genetic variation, but the latter does not
   c. intermediate phenotypes are favored in directional selection
   d. none of the above

The correct answer is a—in the former, phenotypic variation is reduced but the average phenotype stays the same, whereas in the latter both the variation and the mean phenotype change
A. Answer a is correct. Stabilizing selection works by elimination of the “extreme” phenotypes, thus reducing the variation while maintaining the mean. In directional selection the distribution is pushed along the phenotype axis in one direction or the other. This has the major effect of changing the mean phenotype.

The correct answer is a—
B. Answer b is incorrect. All natural selection requires genetic variation, irrespective of the mode.

The correct answer is a—
C. Answer c is incorrect. Directional selection favors phenotypes at one extreme of the distribution.

The correct answer is a—
D. Answer d is incorrect. One of the options, a, is the correct answer.

9. Founder effects and bottlenecks—
   a. are expected only in large populations
b. are mechanisms that increase genetic variation in a population

c. are two different modes of natural selection

d. are forms of genetic drift

The correct answer is d—

A. Answer a is incorrect. Founder effects and bottlenecks are events especially associated with small populations.

The correct answer is d—

B. Answer b is incorrect. Both founder effects and drift are mechanisms that lead to loss of genetic variation.

The correct answer is d—

C. Answer c is incorrect. Neither of these events are mechanisms of selection.

The correct answer is d—two forms of genetic drift

D. Answer d is correct. Both of these events are specific forms of genetic drift. Genetic drift can be generally thought of as changes in allele frequencies and even loss of alleles entirely due to sampling of alleles by random processes, and is exacerbated by small population size. Founder effects are essentially the same process, but occur when new populations are found by just a small number of individuals from an originally large population.

Challenge Questions

1. In Trinidadian guppies a combination of elegant laboratory and field experiments builds a very compelling case for predator-induced evolutionary changes in color and life history traits. It is still possible, though not likely, that there are other differences between the sites above and below the falls aside from whether predators are present. What additional studies could strengthen the interpretation of the results?

   Answer—The results depend on coloration of guppies increasing their conspicuousness to predators such that an individual’s probability of survival is lower than if it was a drab morph. In the laboratory it may be possible to conduct trials in simulated environments; we would predict, based on the hypothesis of predation, that the predator would capture more of the colorful morph than the drab morph when given access to both. Design of the simulated environment would obviously be critical, but results from such an experiment, if successful, would be a powerful addition to the work already accomplished.

2. Based on a consideration of how strong artificial selection has helped eliminate genetic variation for speed in thoroughbred horses, we are left with the question of why, for many traits like speed (continuous traits), there is usually abundant genetic variation. This is true even for traits we know are under strong selection. Where does genetic variation ultimately come from, and how does the rate of production compare with the strength of natural selection? What other mechanisms can maintain and increase genetic variation in natural populations?
Answer—Ultimately, genetic variation is produced by the process of mutation. However, compared with the speed at which natural selection can reduce variation in traits that are closely related to fitness, mutation alone cannot account for the persistence of genetic variation in traits that are under strong selection. Other processes can account for the observation that genetic variation can persist under strong selection. They include gene flow. Populations are often distributed along environmental gradients of some type. To the extent that different environments favor slightly different variants of phenotypes that have a genetic basis, gene flow among areas in the habitat gradient can introduce new genetic variation or help maintain existing variation. Similarly, just as populations frequently encounter different selective environments across their range (think of the guppies living above and below the waterfalls in Trinidad), a single population also encounters variation in selective environments across time (oscillating selection). Traits favored this year may not be the same as those favored next year, leading to a switching of natural selection and the maintenance of genetic variation.