EVOLUTIONARY BIOLOGY BIOS 30305 EXAM #2 FALL 2011

There are 3 parts to this exam. Take your time and be sure to put your name on the top of each page.

Part I. True (T) or False (F) (2 points each).

1) The rate of adaptation to changing environments is limited by the amount of additive genetic variation for the traits under directional selection. T F

2) Observing a higher Fst value for a gene than expected under drift-migration equilibrium provides evidence that the gene may be influenced by selection favoring different alleles in different populations. T F

3) On average, full-siblings should resemble each other more than parents and offspring. T F

4) In Wright’s Shifting Balance Theory, mutation moves a population from a local peak in the fitness landscape, and then selection promotes it to a higher fitness peak in the landscape. T F

The 1st phase of Wright’s Shifting balance relies on drift NOT mutation to move populations from an adaptive peak.

5) According to Fisher’s Fundamental Theorem, mean population fitness evolves at a rate equal to the phenotypic variance in relative fitness. T F

Mean population relative fitness evolves at a rate equal to the additive genetic variation for relative fitness.

6) Sympatric speciation relies on geographic isolation of potentially interbreeding populations. T F

Allopatric speciation relies on geographic isolation.

7) The Red-Queen Hypothesis suggests that negative genetic correlations between fitness traits can maintain genetic variance for fitness in natural populations T F

The Antagonistic-Plieotropy hypothesis suggests that negative genetic correlations between fitness traits can maintain genetic variance for fitness in natural populations

8) Similar ecological conditions can lead to parallel evolution of similar phenotypes. T F

9) The first evidence for metazoan organisms in the fossil record comes from skeletons preserved during the Cambrian Explosion. T F

The first fossil evidence comes from the Ediacaran Fauna prior to the Cambrian Explosion.
10) Character displacement prevents divergence between closely related species when there are unexploited niches available.  

Character displacement would promote divergence into empty niches.

Part II. Multiple Choice (3 points each).

11. Stabilizing selection occurs when…

   A. The individuals with extremely small and large trait values have lower fitness than those with intermediate trait values.
   B. The individuals with intermediate trait values have lower fitness than those with extremely small and large trait values.
   C. The individuals with small trait values have lower fitness than those with larger trait values.
   D. All individuals have equal fitness.

12. When populations are in a rapidly changing environment they can,

   A. Physically move to a more beneficial environment
   B. Adapt to the changing environment and maintain high population fitness.
   C. Adapt at a rate that is slower that the critical rate necessary to track the moving optimum and eventually go extinct.
   D. All of the above.

13. Epistatic interactions are an important component of which of the following…

   A. The build up of postzygotic reproductive isolating mechanisms.
   B. The covariance between half-sibs.
   C. The almost universal observation of inbreeding depression in natural populations following the mating of related individuals
   D. A and C.

14. Which of the following statement best describes the reason for barriers to gene flow when there is postzygotic isolation?

   A) Individuals from different populations meet but do not mate
   B) Copulation occurs, but gametes are not transferred
   C) Gametes are transferred, but eggs are not fertilized
   D) Gametes are transferred, eggs are fertilized, but the zygote dies

15. The observation that two loci are in linkage disequilibrium means…

   A. That they exhibit a non-random association of alleles.
   B. That they are close to one another on a chromosome.
   C. That the loci are functionally related.
   D. That selection is operating on the loci.
16. Which of the following statements about heritability is **TRUE**?

A. Heritability is the additive genetic variance divided by the total genetic variance.
B. Traits that have a genetic basis always have high heritability.
C. Heritability is equal to the selection differential divided by the response to selection.
D. A higher heritability permits a greater evolutionary response to selection.

17. The biological species concept defines species as:

A. Actually or potentially interbreeding populations that are reproductively isolated from other such populations.
B. Populations that form the smallest diagnosable cluster, or group, distinct from other such clusters.
C. Both A and B
D. None of the above

18. Which statement best describes the process of peripatric speciation;

A. The build up of pre-zygotic reproductive isolation in sympatry.
C. Colonization of isolated geographic habitats and divergence through founder effects.
D. Rapid build-up of postzygotic isolation following a host shift.

19. The prevailing view among biologists today is that most speciation occurs according to which model of speciation?

A. Allopatric speciation.
B. Infectious speciation.
C. Instantaneous speciation.
D. Sympatric speciation.

20. Suppose you take two highly inbred lines of organisms (maybe a Boston terrier and a dachshund) and you cross them to produce F₁ progeny. Then you take two of the F₁s and cross them to produce F₂ progeny. Within the F₂ progeny, what level of variation do you expect to see relative to the F₁s?

A. Less variation in F₂s than in F₁s.
B. More variation in F₂s than F₁s.
C. The same amount of variation in F₂s and F₁s.
D. It is completely unpredictable -- anything could happen.
Part III. Short Answer/Problems. Be concise and to the point, short focused answers are better than long rambling ones. **Show your work if you would like partial credit.**

21. It is generally thought that it takes more than a single gene for the evolution of reproductive isolation leading to speciation. (8 points)

A) Why is it difficult to have a single-locus model for speciation?

![Fitness graph showing a fitness valley for AA, Aa, and aa genotypes.]

The single-locus model requires that populations cross a fitness valley created by heterozygote disadvantage. Since selection will always move a population upwards on a fitness landscape this model is unlikely since the initial mutation from A to a (or a to A) in a single population will be deleterious and selection will prevent it from rising to high frequency. In very small populations experiencing strong drift we know that gene frequencies can move in the opposite direction from that favored by selection, so drift is one possible way to “rescue” this single-locus model.

B) How does the Bateson-Muller-Dobzansky 2-locus model of speciation get around this difficulty?

![Diagram of the B-M-D two-locus model showing genotypes AABB, AAbb, aaBB, and AaBB.]

The B-M-D two-locus model of speciation circumvents the problem of the one-locus model by the accumulation of independent mutations that are neutral or beneficial in the genetic background they arise in, but have negative epistatic interactions when put in the same genetic background. These negative epistatic interactions cause a decrease in hybrid fitness that contributes to reproductive isolation.
22. How can we explain Haldane’s observation that when there is an asymmetric deficit in hybrid fitness, it is typically the heterogametic sex that has lower fitness and/or sterility? (8 points)

To explain Haldane’s observation we have to consider gene-gene interactions (epistatic interactions) between genes on autosomes and the sex chromosomes. When these interactions are negative they can lead to a reduction in fitness in hybrid individuals. The Dominance Theory for Haldane’s Rule suggests that the reason the heterogametic sex is more adversely affected by these interaction is because in the homogametic sex there are a full set of positive interactions that can mask these negative effects. In the heterogametic sex, since they have only one sex chromosome all the negative interactions cannot be masked through dominance.

How does Haldane's Rule provide empirical support for the two-locus model of speciation?

The themes of epistasis and multiple genes are illustrated by Haldane’s Rule, and the common observation of the heterogametic sex showing hybrid fitness deficit. The most well supported mechanism for this is dominance relationships among positive and negative epistatic interactions. This observations supports two important features of the evolution of Reproductive Isolating Mechanisms (RIMs). 1) More than one gene is typically involved, and 2) Gene-Gene interactions (i.e., epistasis) are an important part of RIMs.
23. One of the most amazing transitions in the fossil record is the sudden appearance of diverse metazoan organisms in the Cambrian period about 530 MYA. This phenomenon is often referred to as the “Cambrian Explosion”, however, some researchers have questioned whether it was really an “explosion” or more like a “slow burn”. (12 points)

A) Which view do you think is more appropriate? Support your answer with information from class.

You could argue either viewpoint in this answer and receive full credit as long as you support your arguments. While it is certainly true that the diverse array of forms in the Cambrian period appear suddenly in the fossil record around 530 MYA the origin of metazoans certainly precedes this time frame. The somewhat enigmatic Ediacaran fauna dates back as early as 640 MYA. We do not know with any certainty how these forms are connected to the later forms in the Cambrian, however, there are a number of estimates of the origin of modern phyla based on molecular clocks that suggest a divergence time much earlier than the Cambrian. One study by Wray et al. (1996) suggests that the major metazoan groups may have diverged between 1.0-1.2 BYA. Taken together these results suggest that the diversification that lead to the “Cambrian Explosion” began much earlier and that a “slow burn” may be a more appropriate view.

B) The diversification of metazoan groups in the Cambrian period is a classic Adaptive Radiation. What two factors can lead to an Adaptive Radiation? List and explain these two factors and provide examples of these from the Cambrian radiation.

Two factors suggested by the paleontologist G. G. Simpson that play a role in adaptive radiations are:

1) ECOLOGICAL OPPORTUNITY - Can be the result of the invasion of unoccupied territory, or the extinction of a competitor opening up an available niche. The main feature is the availability of unoccupied niches. When there is open niche space for species to diversify into, mechanisms like character displacement can rapidly promote diversification.

An example of ecological opportunity in the Cambrian is the development of trophic levels in the ecological community. For the first time there are predators, prey, etc. changing the number and nature of niches and opening up new unexploited niche space.

2) KEY INNOVATION- The evolution of a novel trait can lead to an adaptive radiation by opening up new niches and exposing organisms to novel selection pressures promoting divergence.

An example of a key innovation contributing to the Cambrian explosion is the evolution of developmental genes such as the Hox genes. The Hox genes are key developmental regulators of body segmentation and would certainly have evolved prior to the diversification in body plans we observe in the Cambrian fauna.
24. For your summer internship you are in charge of managing Lynx in Alaska and you begin to gather quantitative genetic data. When single-parent vs. offspring body size are plotted for Lynx in a population, the data yield a linear regression with a slope of 0.25. The mean mass of all adults in this population is 10 kilograms. In lynx populations there is strong selection on body size and only the largest 25% of these adults breed. If the mean mass of all breeding adults is 12 kilograms, what is the expected mean mass of all adults in the following generation? (10 points)

The slope of a single parent – offspring regression is equal to ½ the heritability.

\[ h^2 = 2(0.25) = 0.5 \]

The selection differential is equal to the difference between the mean of the selected parents and the mean of the base population. In this case, the base population has a mean of 10 kilograms, and the selected parents are the largest 25% of all individuals with a mean of 12 kilograms.

\[ S = 12 - 10 = 2 \text{ kilograms} \]

The response to selection is then,

\[ R = h^2S = (0.5)(2) = 1 \text{ kilogram} \]

In the next generation the mean mass equals the mean in the prior generation plus the response to selection.

\[ 10 + 1 = 11 \text{ kilograms} \]
25. The State of Alaska is considering establishing a small captive population of Lynx as part of their management scheme. Given your expertise in evolutionary genetics you are concerned by this strategy. Captive populations are prone to two (2) genetic issues. What are these issues and why should we be concerned about them? (12 points)

Inbreeding leads to increased homozygosity. When there are deleterious recessive alleles segregating in the population increased homozygosity will lead to greater expression of these deleterious alleles since their effects will no longer be masked in the heterozygous condition. This phenomenon is referred to as inbreeding depression. This potential loss of fitness can have a significant impact on the viability of captive populations.

In addition to the problem of inbreeding leading to increased homozygosity the loss of genetic variation due to random genetic drift is potentially a problem since the response to future selective pressures is dependent on the levels of additive genetic variation for the traits under selection. The loss of this variation can be a problem for maintaining viable captive populations and can impact the opportunity to establish viable wild populations in the future.

List two (2) strategies that conservation managers can utilize to minimize the genetic problems associated with small captive populations?

Lots of possibilities for this one:

Increasing the population size reduces drift and increases the amount of additive genetic variation that can be maintained at equilibrium.

Monitoring the breeding program to ensure equal contributions from all the members of the population increases \( N_e \) and reduces the impact of drift.

Enforcing random mating avoids consanguineous mating and reduces the impact of inbreeding.

Genetic augmentation from outside the populations can also be effective.
Extra Work Space:

Section 1  ____/20
Section 2  ____/30
Section 3  ____/50

Total  ____/100
**Components of Phenotypic Variation:**

\[ V_P = V_G + V_E \], where \( V_P \) is the total phenotypic variance, \( V_G \) is the total genetic variance and \( V_E \) is the environmental variance.

**Components of Genetic Variation:**

\[ V_G = V_A + V_D + V_I \], where \( V_G \) is the total genetic variance, \( V_A \) is the additive genetic variance, \( V_D \) is the dominance genetic variance, and \( V_I \) is the epistatic genetic variance.

**Slope of a regression line of two variables x and y:**

\[ b = \frac{Cov(x, y)}{Var(x)} \]

**Heritability:**

\[ h^2 = \frac{V_A}{V_P} = \frac{V_A}{V_G + V_E} \]

**The Univariate Breeder’s Equation:**

\[ R = h^2 S \], where \( R \) is the response to selection, \( h^2 \) is the heritability, and \( S \) is the selection differential.

**Price’s rule:** \( S = Cov(\text{relative fitness}, \text{phenotype}) \)

\[ \frac{1}{N} \sum [(w_i - \bar{w})(P_i - \bar{P})] \]

**\( V_A \) under drift-mutation equilibrium:**

\[ V_A = 2NV_m \], where \( V_m \) is the genetic variance due to the input by mutation.