



1. A DNA substitution that changes the resulting amino acid is referred to as a:
  - A) synonymous substitution
  - B) replacement substitution
  - C) recombined substitution
  - D) reversal substitution
  
2. Some copy errors during DNA replication happen when there is a *low benefit* of perfect replication and a *high cost* of correcting errors. If you increased the benefit of perfect replication, what would happen to the mutation rate (i.e., copy error rate)?
  - A) no selection; no change to mutation rate
  - B) selection for higher mutation rate
  - C) no selection; mutation rate would be lower
  - D) selection for lower mutation rate
  
3. How does effective population size ( $N_e$ ) relate to actual population size ( $N_m + N_f$ )?
  - A)  $N_e \leq (N_m + N_f)$
  - B)  $N_e > (N_m + N_f)$
  - C)  $N_e < 4N_mN_f/(N_m + N_f)$
  - D)  $N_e \geq (N_m + N_f)$
  
4. Which mode of selection is consistent with the Neutral Theory?
  - A) directional selection
  - B) stabilizing selection
  - C) disruptive selection
  - D) none of the above
  
5. (worth 2 points) Four decades after an old growth forest in Oregon was clearcut, an isolated, inbred population of spotted owls in this region was surveyed for allelic diversity. At one loci with two alleles ( $A_1$  and  $A_2$ ), let  $p$  equal the frequency of  $A_1$  and  $q$  equal the frequency of  $A_2$ , and let  $p = 0.75$ . Average pairwise relatedness was 0.5. What is the expected heterozygosity in the inbred population?
  - A) 0.28
  - B) 0.14
  - C) 0.19
  - D) 0.09

6. Consider two alleles ( $B_1$  and  $B_2$ ) in a hypothetical population of mice. Let  $p$  equal the frequency of  $B_1$  and  $q$  equal the frequency of  $B_2$ . Let the observed frequency of heterozygotes be 0.05 and  $p = 0.85$ . What could explain the difference in observed heterozygosity and expected heterozygosity under Hardy-Weinberg equilibrium?

- A) selfing
- B) genetic drift
- C) inbreeding
- D) migration

7. The coefficient of inbreeding for matings between half-siblings is:

- A) 0.5
- B) 0.062
- C) 0.125
- D) 0.25

8. Which type of error has evolutionary consequences?

- A) transcription error
- B) replication error in germ cell line
- C) replication error in somatic cell line
- D) translation error

9. Under what conditions would an allele with a deleterious effect persist in a population?

- A) heterozygote advantage
- B) the mutation is recurring
- C) at low frequency, it will be hidden from selection in heterozygotes
- D) all of the above

10. In phylogenetics, the more recently evolved condition is referred to as:

- A) derived
- B) parsimonious
- C) ancestral
- D) synapomorphic

11. In reconstructing phylogenies, analyses of certain characters can provide contradictory results. This has been an issue in attempts to resolve the evolutionary relationships among gorillas, chimpanzees, and humans. Highly polymorphic loci can be particularly troublesome if lineages have gone through a population bottleneck because many alleles can be lost.

Which of these processes best describes the loss of alleles that results from a population bottleneck?

- A) genetic drift
- B) migration
- C) ecological speciation
- D) natural selection

12. What is parsimony?

- A) the marriage of science and philosophy
- B) the ability to draw conclusions from partial data
- C) some kind of political system
- D) the simplest explanation is more likely to be true

13. The following table will be used for questions 13-16.

The accompanying table shows the character states (A, C, G, or T) in a 16 base pair portion of the sequence of 18S rDNA from 6 insect groups. How many informative loci (i.e., base pair positions) are there?

<u>Taxa</u>	<u>Character state</u>															
	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585
Silverfishes	A	A	T	A	A	G	G	A	T	C	C	A	T	T	G	A
Mantids	A	A	C	G	A	G	T	A	T	C	C	A	T	T	G	G
Flies	A	A	C	A	A	G	G	A	A	C	A	A	T	T	G	G
Beetles	A	A	C	G	A	G	G	A	T	C	A	A	T	T	G	G
Cockroaches	A	A	C	G	A	G	T	A	T	C	C	A	T	T	G	G
Butterflies	G	A	C	G	A	G	G	A	A	C	A	A	T	T	G	G

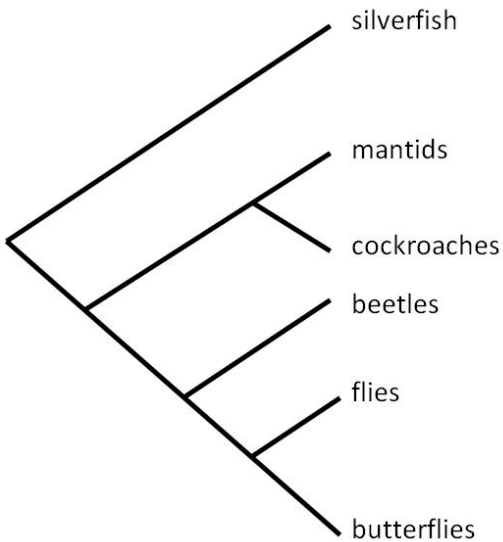
- A) 7
- B) 16
- C) 9
- D) 12

14. Assume silverfishes are the outgroup and have the ancestral state. In the following table, fill in the table with the code for each character state (ancestral = 0; derived =1). How many character states did you code as derived?

Taxa	Character state															
	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585
Silverfishes	A	A	T	A	A	G	G	A	T	C	T	A	T	T	G	A
Mantids																
Flies																
Beetles																
Cockroaches																
Butterflies																

- A) 22
- B) 20
- C) 19
- D) 21

15. (worth 2 points) Consider the following phylogeny and the coded character states you derived in the previous question. Under the principle of maximum parsimony, what is the minimum number of character state changes (assume 0 = ancestral)?



- A) 9
- B) 10
- C) 7
- D) 8

16. In the phylogeny of insects shown in the previous question, how many phylogenetically independent contrasts can be estimated?

- A) 11
- B) 12
- C) 5
- D) 6

17. Hawai'ian honeycreepers (a type of bird) have adapted to different types of habitats and prey types on different islands in the Hawai'ian archipelago and have evolved into a morphologically diverse group of species. Which term best describes this form of ecological speciation?

- A) clinal divergence
- B) habitat divergence
- C) natural selection
- D) adaptive radiation

18. This question has two parts: during what time period (1) and era (2) did the Ediacaran fauna dominate?

- A) ~550 mya; Paleozoic
- B) ~500 mya; Proterozoic
- C) ~550 mya; Proterozoic
- D) ~500 mya; Paleozoic

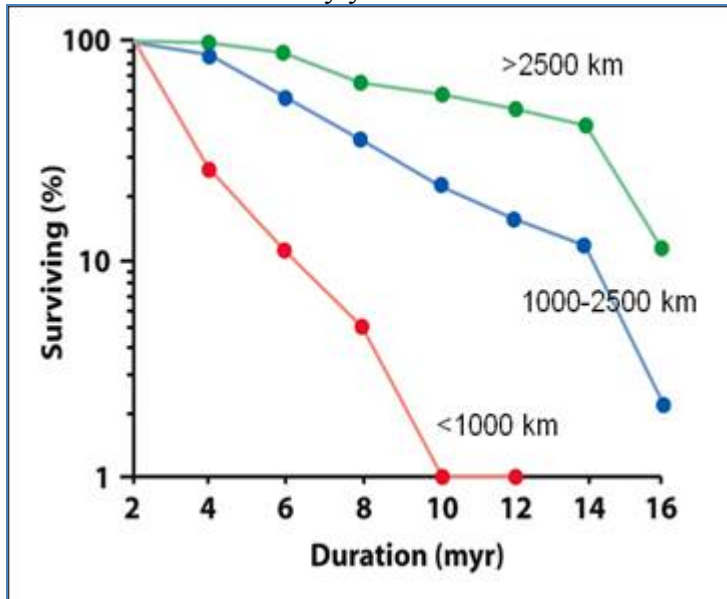
19. What is the correct temporal ordering of periods, from oldest to youngest?

- A) Silurian, Devonian, Ordovician, Carboniferous
- B) Devonian, Ordovician, Carboniferous, Silurian
- C) Ordovician, Silurian, Devonian, Carboniferous
- D) Devonian, Silurian, Ordovician, Carboniferous

20. The following figure shows the percent of bivalve and gastropod species (i.e., clams and snails) still present in the fossil record at time intervals following their original discovery.

- The top line represents species with large geographical ranges (>2500 km)
- The middle line represents species with intermediate geographical ranges (1000-2500 km)
- The lower line represents species with small geographical ranges (<1000 km)

Based on these data, a species of gastropod with a geographical range of 500 km should be extinct after how many years?



- A) 1 myr
- B) <10 myr
- C) 10-15 myr
- D) 15-20 myr

21. What would be the best method to age bones from *Ardipithecus*? Note the following:

- The half-life of  $^{14}\text{C}$  = 5730 years
- The half life of  $^{238}\text{U}$  = 4.5 billion years
- The half life of  $^{40}\text{K}$  = 1.3 billion years

- A) Carbon-14 method
- B) Potassium-argon method
- C) Uranium-lead method
- D) none of the above

22. In the Carbon-14 method of radiometric dating, the half-life of  $^{14}\text{C}$  is 5,730 years. This method would provide the greatest dating resolution for what material?

- A) wooden spear used by *Homo sapiens*
- B) *Ardipithecus* bone
- C) Oldowan stone tool
- D) stone tool used by *Homo sapiens*

23. Imagine that you accept a contract to survey life history traits in a species of fish from 10 geographically isolated lakes. Given that you observe few morphological differences among populations, what should you conclude?

- A) populations lack the raw material for evolution
- B) insufficient time has passed for local adaptation
- C) populations had locally adapted in parallel
- D) any of the above are possible

24. Based largely on fossil evidence of feathered dinosaurs, all birds are thought to have descended from archosaurs (a group of dinosaurs). Moreover, the closest living relatives of birds are the crocodylians (including the alligator, crocodile, and gharial and caiman families). The crocodylians are the only other surviving descendants of the archosaurs.

Given these facts, the group including birds, crocodylians, and archosaurs can be considered as a:

- A) polyphyletic group
- B) paraphyletic group
- C) synapomorphic group
- D) monophyletic group

25. Based on current fossil evidence, what traits best distinguish recent *Homo* lineages (*Homo sapiens*, *H. neanderthalensis*, *H. heidelbergensis*, *H. erectus*, *H. ergaster*) from other *Homo* species and other hominids?

- A) large brain, small teeth, bipedal
- B) small brain, small teeth, bipedal
- C) large brain, large teeth, bipedal
- D) small brain, large teeth, bipedal

26. Humans are most closely related to which of the following organisms?

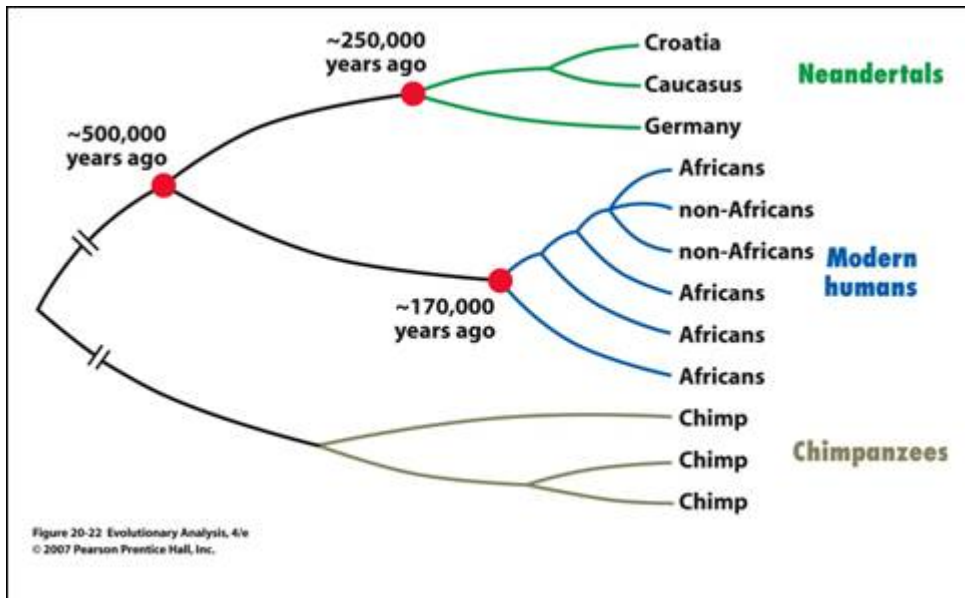
- A) gibbons
- B) gorillas
- C) chimpanzees
- D) orangutans

27. Based on molecular clock data, approximately how many million years ago did the African Great Apes have a common ancestor?

- A) 15
- B) 25
- C) 5
- D) 0.2

28. This figure shows a phylogeny of Neanderthals and modern humans based on mitochondrial DNA sequences. Which hypothesis for modern human origins does this phylogeny support?

- A) African replacement
- B) Candelabra
- C) Multiregional evolution
- D) Hybridization and assimilation



29. The assumption that processes identical to those at work today are responsible for events that occurred in the past is referred to as:

- A) uniformitarianism
- B) macroevolution
- C) gradualism
- D) stasis

30. Who invented the concept of essentialism to explain biodiversity?

- A) Lamarck
- B) Linnaeus
- C) Aristotle
- D) Plato

31. Which sentence best describes natural selection?

- A) populations develop adaptations over time
- B) individuals need to evolve in order to survive
- C) populations need to evolve in order to survive
- D) populations evolve adaptations over time

32. In relation to the discovery of evolution by natural selection, which of the following ideas or facts had the least influence?

- A) laws of inheritance
- B) limits on human population growth
- C) geological uniformitarianism
- D) geographical variation in species

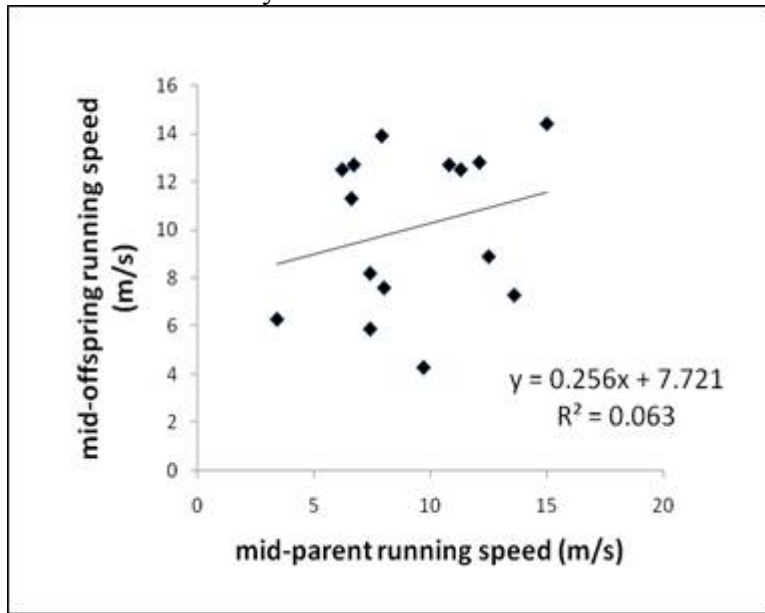
33. Phenotypic variance is comprised of which variance components?

- A) additive genetic variance and dominance genetic variance
- B) environmental variance only
- C) additive genetic variance and environmental variance
- D) genetic variance and environmental variance

34. The slope of the relationship between relative fitness and the trait value is called the

- A) broad sense heritability
- B) selection coefficient
- C) selection differential
- D) selection gradient

35. The following figure shows the relationship between mid-offspring running speed (m/s) and mid-parent running speed (m/s) for 15 greyhound dogs. What is the value of narrow-sense heritability?



- A) 7.721
- B) 0.256
- C) 0.065
- D) 0.063

36. As a follow up from the previous question, the mean running speed for greyhound dogs (the 15 parents) is equal to 10.1 m/s. If only the five fastest dogs (i.e., those with running speeds of 14.4, 13.9, 12.8, 12.7, and 12.7 m/s) are selectively bred, what is the expected response to selection in a single generation?

- A) 1.23 m/s
- B) 0.20 m/s
- C) 0.82 m/s
- D) 0.21 m/s

37. QTLs for flower characteristics were mapped in monkey flowers (*Mimulus cardinalis* and *M. lewisii*) to determine the genetic basis for the transition between bee pollinated flowers and hummingbird pollinated flowers. For QTLs that were physically linked to a marker locus, F2 plants that were homozygous for the *cardinalis* marker allele tended towards which phenotype?

- A) *lewisii* phenotype
- B) *cardinalis* phenotype
- C) neither phenotype
- D) intermediate between *lewisii* and *cardinalis* phenotypes

38. The evolution of a quantitative trait requires mutation to provide the raw material. True or false?

- A) False
- B) True

39. Which type of trait is expected to show the greatest degree of phenotypic plasticity?

- A) genetic
- B) morphological
- C) behavioural
- D) life history

40. Which of these traits is the best example of positive allometry?

- A) number of digits (e.g., fingers or toes)
- B) life history trait
- C) sexually selected trait
- D) brain size

41. Which type of trait will provide the most accurate phylogenetic reconstruction?

- A) genetic
- B) life history
- C) behavioural
- D) morphological

42. In *Fuchsia excorticata*, flowers change from green (receptive to pollen) to red (unreceptive to pollen). The retention of unreceptive flowers is thought to be the result of the time required to form a pollen tube between the stigma and ovary and the time required to form an abscission zone between the ovary and flower. This is an example of what type of evolutionary constraint?

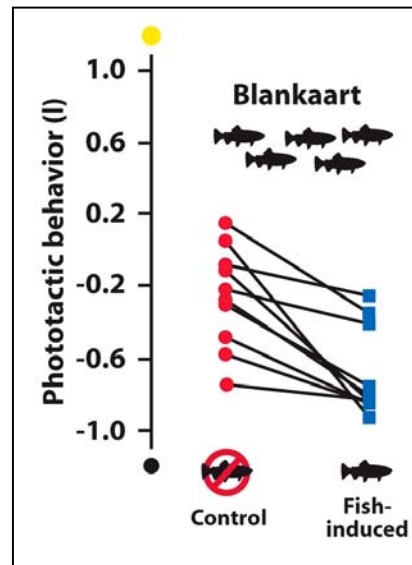
- A) lack of genetic variation
- B) temporal constraint
- C) physiological constraint
- D) phylogenetic constraint

43. Which field of evolutionary biology focuses on understanding the genetic basis of continuous traits?

- A) evolutionary ecology
- B) population genetics
- C) quantitative genetics
- D) behavioural ecology

44. This figure shows reaction norms for 10 *Daphnia* clones measured in two environments. What do non-parallel reaction norms indicate?

- A) effect of genotype; no effect of environment
- B) genotype-by-environment interaction
- C) phenotypic plasticity
- D) effect of environment; no effect of genotype



45. To test whether a trait is an adaptation using phylogenetically independent contrasts, what would be the best trait to estimate the phylogeny?

- A) mtDNA
- B) the trait under study
- C) allozymes
- D) all of the above

46. Different experimental approaches are used to test for natural selection, adaptation, and local adaptation. In lecture we considered the use of phylogenetically independent contrasts to test hypotheses about testes size among species of bats. Was this a test for natural selection, adaptation, or local adaptation?

- A) natural selection
- B) local adaptation
- C) adaptation
- D) all of the above

47. Rusty crayfish is an invasive species in the Great Lakes. How would you test whether they have locally adapted to different sites within the lakes? The following list gives different experiments that could be done as part of testing for adaptation. Rank these from those providing the *most* to *least* valuable information about adaptation.

- i) introduce rusty crayfish to a new site (beyond their current range) and monitor their evolutionary response
- ii) calculate the selection gradient
- iii) reciprocal common garden experiment done in the lab
- iv) test for heritability

- A) i, iii, ii, iv
- B) i, iii, iv, ii
- C) iii, i, ii, iv
- D) ii, iv, i, iii

48. Alpine skypilots are flowers that live in alpine and subalpine regions, and the evolutionary ecology of flower size has been extensively studied by Candace Galen. What experimental method would give a lower estimate of narrow-sense heritability of flower size in alpine skypilots?

- A) if heritability was measured between populations, not within populations
- B) if mothers and daughters were found in different environments, not similar environments
- C) if flowers were hand pollinated, not bee pollinated
- D) if heritability was measured in the lab, not in the wild

49. What symptom would most likely be associated with high virulence?

- A) acute respiratory distress of host causing a high probability of host death
- B) excessive sneezing leading to a high infection rate of new hosts
- C) high reproductive rate of pathogen
- D) long persistence of pathogen in host

50. The strain causing the 1968 human influenza pandemic likely obtained genes for high virulence from an influenza strain infecting which type of host?

- A) dog
- B) swine
- C) horse
- D) bird

51. Vectorborne pathogens generally have higher virulence than directly-transmitted pathogens. True or false?

- A) False
- B) True

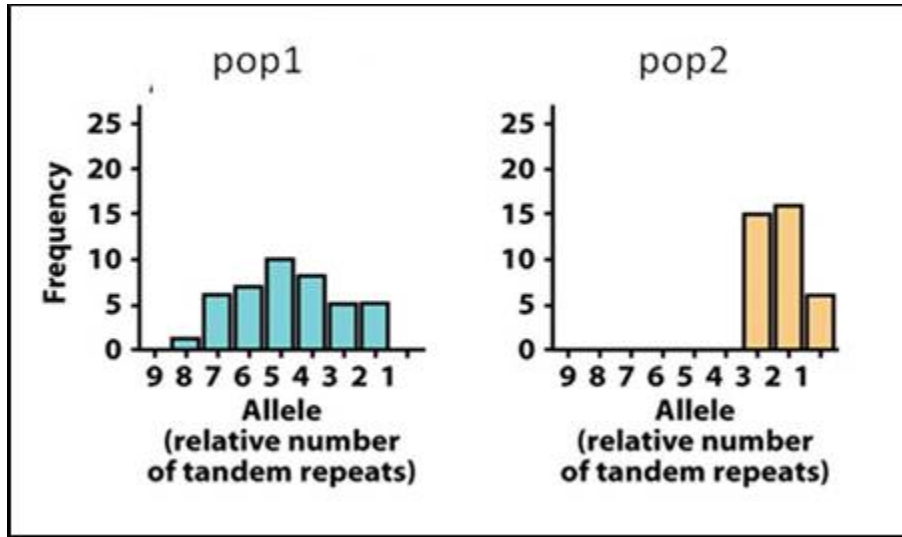
52. Compared to influenza strains that survive, those that go extinct should have more amino acid replacements in the antigenic sites of hemagglutinin. True or false?

- A) True
- B) False

53. In a human population with excellent sanitation (e.g., plumbing, sewers, sewage treatment), virulence should be highest with what kind of vector under the trade-off hypothesis?

- A) water
- B) mosquito
- C) air
- D) person-to-person contact

54. The following figure shows genetic diversity at a tandem repeat locus within two populations (pop1 and pop2) of cells. These cells were sampled from tumours within a patient with colorectal adenocarcinoma. This question has two parts: 1) which population of cells shows greater genetic diversity and 2) which population of cells is more likely to be derived from the other?



- A) pop1; pop1
- B) pop2; pop2
- C) pop1; pop2
- D) pop2; pop1

55. Weak sexual selection on females favours which traits in females?

- A) showy displays
- B) competitive ability
- C) mate preferences
- D) parental care

56. Hangingfly males provide nuptial gifts to females. This is most consistent with which hypothesis for the evolution of mate choice?

- A) sexy son hypothesis
- B) sensory exploitation hypothesis
- C) good genes hypothesis
- D) direct benefits hypothesis

57. Consider an insect-pollinated plant that is dioecious (male and female flowers on different individual plants). If pollination success is limited by access to female flowers more so than seed set is limited by the receipt of pollen, what traits might be sexually selected?

- A) number of male plants per meter squared
- B) number of flowers per plant in male plants
- C) sex ratio of plants in the population
- D) number of ovules per flower

58. In a hypothetical species of fish, females who choose mates with brighter red skin patches on their gill covering produce sons with brighter red patches on their gill coverings and daughters with a preference for this trait. This is most consistent with which hypothesis for the evolution of mate choice?

- A) direct benefits hypothesis
- B) sensory exploitation hypothesis
- C) good genes hypothesis
- D) sexy son hypothesis

59. Under what conditions would you expect stronger sexual selection on females?

- A) females provide more parental care than males
- B) males are smaller than females
- C) males provide more parental care than females
- D) higher cost of mating in males

60. (worth 2 points) The accompanying table refers to male iguanas who successfully copulated vs. those who attempted to copulate on two different islands. On which island was sexual selection on body size stronger, and what is the selection gradient for body size on this island? Note that variance is equal to standard deviation squared.

Island	N	Mean body size (mm)	Standard deviation
<i>Santa Fé</i>			
Successful	253	401	13
Attempted	343	390	26
<i>Genovesa</i>			
Successful	25	243	26
Attempted	147	227	21

- A) Genovesa; 0.04
- B) Genovesa; 0.76
- C) Santa Fé; 0.02
- D) Santa Fé; 0.42

61. In the following figure of survival vs. size in marine iguanas, in which island population and sex would you predict stronger selection against large size?

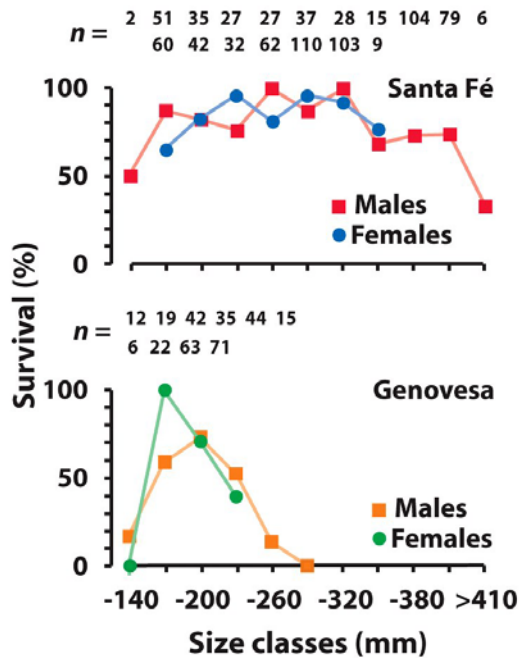


Figure 11-9b Evolutionary Analysis, 4/e  
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- A) Santa Fé females
- B) Genovesa males
- C) Santa Fé males
- D) Genovesa females

62. (worth 2 points) In a hypothetical species of plant with showy flowers, pollen tubes require 3 days to form. If pollen tubes from multiple males compete to reach the ovary, what should happen?

- A) sexual selection should favour showier flowers
- B) the plant should evolve defense mechanisms to prevent multiple fertilizations
- C) no evolution because this is an evolutionary constraint
- D) selection should favour faster pollen tube formation

63. In rough-skinned newts, sexual selection is stronger on males than females. What statistic should be higher in males compared to females?

- A) the average number of mates
- B) mean size of all traits
- C) the slope of the relationship between fitness and number of mates
- D) mean fitness

64. In game theory, a strategy that cannot be invaded by an alternative strategy is called:

- A) an evolutionarily stable strategy
- B) a frequency dependent strategy
- C) an evolutionarily fixed strategy
- D) a density dependent strategy

65. Who showed the conditions favouring selection for an allele that causes altruistic behaviour?

- A) Trivers
- B) Maynard Smith
- C) Fisher
- D) Hamilton

66. What is indirect fitness? Let LRS = lifetime reproductive success.

- A) LRS of relatives
- B) personal LRS
- C) increase in LRS of relatives due to helping action
- D) personal LRS and LRS of relatives due to helping action

67. Under what condition would you expect helping behaviour to evolve because of the benefits of reciprocal altruism?

- A) large, dynamic groups
- B) high levels of predation
- C) small, stable groups
- D) high coefficient of relatedness

68. Relatedness between half-siblings is:

- A) 0.062
- B) 0.125
- C) 0.25
- D) 0.5

69. The following figure shows the benefit to cost ratio of parental care with increasing duration of parent care.

- On the figure, let  $P = 10$  days and  $O = 12$  days.
- Assume that the coefficient of relatedness between offspring and future offspring is 0.5.

This question has two parts. 1) At what age should parents cease parental care and 2) what is the duration of conflict over parental care?

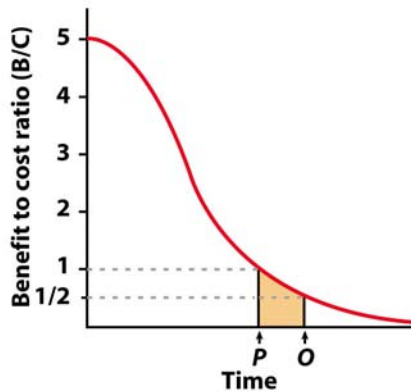


Figure 12-18a Evolutionary Analysis, 4/e  
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- A) 12 days; 2 days
- B) 8 days; 4 days
- C) 10 days; 4 days
- D) 10 days; 2 days

70. (worth 2 points) Consider the two-player contest over a resource (R) called the Hawk-Dove game. If Hawk meets Hawk, they share R equally. If Hawk meets Dove, Hawk kills Dove. If Dove meets Dove, they share R equally. If Player A assumes an equal chance that his/her opponent will play Hawk vs. Dove, what should Player A do? Assume  $R = 10$  fitness units.

Table showing payoff to A

Player A's move	Opponent plays Hawk	Opponent plays Dove
Hawk	0.5R	R
Dove	0	0.5R

- A) play Dove if  $R < 10$
- B) play Dove
- C) play Hawk
- D) play Hawk if  $R > 10$

71. (worth 2 points) Payoffs to Player A in the Prisoner's Dilemma are shown in the following table. If Player A assumes that his/her opponent is equally likely to cooperate vs. defect, what would be the expected payoff to Player A for choosing the best move?

Player A's move	Opponent cooperates	Opponent defects
Cooperate	3	1
Defect	5	2

- A) 4
- B) 1.5
- C) 2
- D) 3.5

72. In fully social (eusocial) insects (e.g., bees), sterile workers cooperatively care for the next generation of young (assume these are their full sisters). Using the following definitions, what would favour such altruistic behaviour?

- i.  $r$  between sisters
- ii.  $r$  between a worker and its offspring (if she could mate and have her own offspring)
- iii.  $r$  between a worker and her parent (the queen)

- A)  $i = 0.5$
- B)  $i > iii$
- C)  $i > ii$
- D)  $i < iii$

73. Alternative mating strategies are often maintained by frequency dependent selection (i.e., rare strategies have higher fitness). In coho salmon, small males use the "sneaking" tactic and dart into nests during spawning in an attempt to fertilize eggs. Large males use the "fighting" tactic whereby they use aggression and threat displays to maintain a position of dominance near the spawning female. As the frequency (i.e., proportion) of "sneakers" increases in the population, how should the fitness of "sneakers" and "fighters" change?

- A) fitness decreases for sneakers; fitness increases for fighters
- B) fitness of sneakers and fighters remains the same
- C) fitness increases for sneakers; fitness decreases for fighters
- D) fitness decreases for sneakers; fitness of fighters remains the same

74. How should an increase in inbreeding affect the strength of selection on altruistic behaviour?

- A) no change
- B) depends on the level of inbreeding depression
- C) decrease
- D) increase

Bonus (worth 1 mark). Individuals develop; populations evolve. True or false?

- A) False
- B) True