1. The long necks of giraffes have the same basic bone structure, including exactly seven vertebrae (the major bone components) in their necks as humans do. This means that individual giraffe vertebrae can be more than 30 cm long. This surprising similarity in structure is due to:

    A. convergent evolution
    B. co-evolution
    C. acclimation
    D. **homology**
    E. homoplasy

2. Cheetahs have highly specialized lean musculo-skeletal structure. If cheetahs were leaner, they would have health problems; if they had a heavier build they would not be fast enough to chase down antelopes. This is an example of:

    A. directional selection
    B. **stabilizing selection**
    C. disruptive selection
    D. balancing selection

3. As ocean temperatures warm, many species of coral are struggling to survive in their current locations because they can't tolerate hot spells well anymore. Assuming coral are not very mobile, this situation would create conditions for

    A. **directional selection**
    B. stabilizing selection
    C. disruptive selection
    D. balancing selection

4. Which pair of statements is logically equivalent?

    A. All swans are blue; all blue things are swans
    B. All swans are blue; no non-swans are blue
    C. **No swans are blue; no blue things are swans**
    D. No swans are blue; all non-swans are blue

5. For the purposes of this question, assume that all swans are blue. Which of the following is then logically correct?

    A. **If Drake is a swan, then Drake is blue**
    B. If Drake is blue, then Drake is a swan
   C. Both A and B
    D. Neither A nor B

6. Sharks and dolphins are distantly related, but have similar body shapes and swimming styles. Fossils show that their ancestors were less similar to each other. These observations support the theory of _____ because they provide evidence that _____.

    A. Evolution by natural selection; all species are related to each other.
    B. Evolution (only); all species are related to each other.
    C. **Evolution by natural selection; species change adaptively over time.**
    D. Evolution (only); species change adaptively over time.

7. Which of the following is the best example of a vestigial trait?

    A. Male fig wasps typically live their whole life inside a single fig, mating with other wasps that they find there and dying after the females leave
    B. **Many insects develop wings that they don't use**
    C. In flatfish, one eye migrates to the other side of the head, so that the fish can use both eyes while lying down on the ocean floor
    D. The bone structure in the front flipper of a turtle is very similar to that of a human arm and hand

Use this figure for the following two questions.
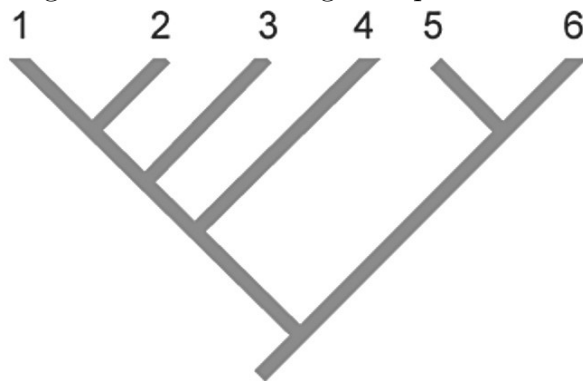
8. In the phylogenetic model pictured, species 3 _____ closer to species 2 than species 1, and _____ closer to species 4 than species 5.

    A. is; is
    B. is; is not
    C. **is not; is**
    D. is not; is not

9. In this model, the sister taxon to species 4 is species:

    A. **1, 2 and 3**
    B. 3
    C. 5 and 6
    D. 1, 2, 3, 5 and 6

10. In a famous 17th-century experiment, researchers put eight similar pieces of meat into eight identical jars. Four of the jars were sealed, and four were left open to the air. Maggots grew on the meat in open jars, but not in the sealed jars. Which of the following hypotheses are consistent with this experimental result? You should answer this question *without* taking into account knowledge you may have from other experiments.

    A. Maggots are spontaneously generated by rotten meat, and can grow with or without air.
    B. Maggots are spontaneously generated by rotten meat, but cannot grow without air.
    C. Maggots result from microscopic fly eggs; flies must have access to the meat for maggots to grow.
    D. A and C are both consistent with this experiment.
    E. **B and C are both consistent with this experiment.**

11. In the experiment above, why did the researchers use four jars of each type?

    A. To make sure there was enough meat to attract flies.
    B. As a control, to make sure that the two treatments differed as little as possible.
    C. **To reduce the likelihood of accidental results.**
    D. To make efficient use of laboratory equipment.

12. A population of Staphylococcus bacteria is exposed to a drug treatment. Some of the bacteria have a "persistence" allele that allows them to halt metabolic processes when drug concentrations are high, and resume normal life when concentrations drop. Bacteria without the allele die when drug concentrations are high. If the population is exposed to treatment for a long time, we expect that natural selection on the persistence allele:

    A. **will occur, because all of the logical conditions are met**
    B. will not occur, because there is no variation in traits
    C. will not occur, because variation in traits is not heritable
    D. will not occur, because there is no variation in reproductive success
    E. will not occur, variation in reproductive success is not related to heritable traits

13. I want to train my pet squirrel to find my keys in the morning, and to hide under the couch when I play the piano. My best bet is to train it by:

   A. Rewarding it with food when it succeeds
   B. Punishing it when it fails
   C. **Rewarding it for finding keys and punishing it for failing to hide**
   D. Rewarding it for failing to hide and punishing it for finding keys
   E. Asking it to complete pre-tutorial quizzes

14. Small ponds often contain small communities of closely related fish. These fish have small populations, and often arrive in the ponds by random events. Fish in different ponds often show large, and seemingly random, variation in size, shape or color. This is likely due to

   A. gene flow
   B. genetic drift
   C. bottleneck effects
   D. A and C
   E. **B and C**

15. Which of the following is true about *both* stabilizing selection and genetic drift?

   A. They increase the average fitness of a population
   B. They are random processes
   C. They have strong effects on large populations
   D. **They tend to decrease variation**

16. Canada jays in Algonquin park are decreasing in number, probably because food that they cache in the fall has less chance to maintain quality until winter because of climate change. This population is most likely to experience increases in:

   A. Directional selection and gene flow
   B. **Directional selection and genetic drift**
   C. Stabilizing selection and gene flow
   D. Stabilizing selection and genetic drift

17. Two closely related populations of chipmunks are living in allopatry. In order to diverge into separate species, they must overcome the barrier of:

   A. **gene flow**
   B. competition
   C. both gene flow and competition are likely to be barriers
   D. neither gene flow nor competition is likely to be a barrier

18. Which of the following is an advantage of the phenetic approach over the cladistic approach to estimating phylogenetic trees?

    A. allows the use of genetic information
    B. allows the use of phylogenetic information
    C. **requires less information to implement**
    D. allows trait evolution to be mapped to the tree
    E. is a more accurate model of how evolution took place

19. Two species of bumblebee live in old clearings that used to be used for agriculture. They mate frequently, but the hybrid offspring rarely succeed in mating. We expect these species to be under selective pressure to evolve:

    A. **a prezygotic isolating mechanism**
    B. a postzygotic isolating mechanism
   C. sexual competition
    D. mechanisms for gene flow

20. Male cardinals are bright red and easily spotted by predators. Female cardinals are brown and deep red and stand out less. This difference is likely a result of

    A. directional selection
    B. stabilizing selection
    C. disruptive selection
    D. **sexual selection**

21. Compared to closely related birds with less sexual dimorphism, it is likely that the cardinal's adaptation arose because cardinal males have relatively _____ sexual reproduction

    A. more total
    B. **more variance in**
    C. less total
    D. less variance in

22. The figure below shows a phylogenetic tree of the tetrapods, and outlines the traditional group reptilia. Consider the *extant* (living) reptiles: Chelonia, Lepidosaura and Crocodylia. To make this group into a clade (the modern reptile clade) the *minimum* that needs to be added is:
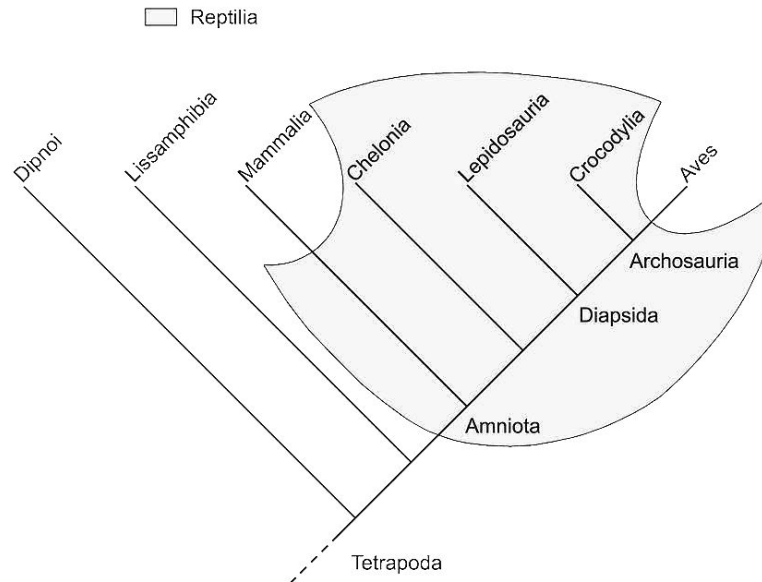
    A. nothing; the living reptiles are already a clade
    B. mammals (Mammalia)
    C. **birds (Aves)**
    D. both mammals and birds

23. Researchers observe an allele where heterozygous individuals have higher fitness than homozygotes. At the population level, we would expect this locus to show _____ heterozygotes than expected from Hardy-Weinberg assumptions, especially if the fitness difference was due to increased _____ in the heterozygotes.

    A. **more; survival**
    B. more; breeding success
    C. less; survival
    D. less; breeding success

24. If the heterozygotes in the previous question are denoted Aa, we would say that:

 A. Allele A is dominant
 B. Allele a is dominant
 C. **Alleles A and a are incompletely dominant**
 D. Genotype Aa is dominant
 E. Genotype Aa is co-dominant

25. A researcher wants to figure out whether oak trees are more closely related to rose bushes or to pine trees. Oak trees share a tree-like form with pines (but not roses), and share flower structure with roses (but not pines). The researcher has evidence that the common ancestor of the three species did not have a tree-like form or flowers. Based on *this information alone*, the researcher has ⎯⎯⎯⎯⎯ evidence that oaks are closer to roses, and ⎯⎯⎯⎯⎯ evidence that oaks are closer to pines.

 A. no; no
 B. no; some
 C. some; no
 D. **some; some**

26. An island has two dominant species of seed plant, and two species of finches: one with bigger beaks that eat bigger seeds from the bigger plant, and one that does the opposite. The ancestral bird on the mainland lived in an area with more plants and had a more flexible beak. The island situation likely resulted from ⎯⎯⎯⎯⎯ selection followed by ⎯⎯⎯⎯⎯ selection.

 A. disruptive; balancing
 B. **disruptive; stabilizing**
 C. directional; balancing
 D. directional; stabilizing

27. Which is *not* a disadvantage of the morphological species concept compared to other species concepts?

 A. It can be subjective
 B. **It is hard to apply to extinct species**
 C. It is problematic for sexually dimorphic species
 D. It is hard to relate to evolutionary units

28. A population of butterflies lives in a region with decreasing rainfall. Eventually, rainfall become so low that the butterfly host plants only survive on mountaintops. If the butterflies rarely fly far enough to go from one mountaintop to another, we would say that the different butterfly populations . . .

    A. have been isolated by dispersal.
    B. **have been isolated by vicariance.**
    C. have undergone speciation in allopatry.
    D. have undergone speciation in sympatry.

29. Sexual selection _____ a form of natural selection, _____ to make organisms better adapted to the environment

    A. is; because it works
    B. is not; because it works
    C. **is; even though it does not always work**
    D. is not; because it does not always work

30. Which of the following is an example of acclimation?

    A. Some species of animals have hemoglobin with very high affinity for oxygen.
    B. Some bacteria can use the energy from sunlight to make sugars.
    C. **Fungi grown at cold temperatures are more likely to survive freezing than those grown at warm temperatures**
    D. Plants that have evolved in low-nitrogen environments allocate more energy to roots and less to leaves.
    E. Hybrid sunflowers can grow in drier environments than either of the parent species

31. (6 marks in total) An eye-color locus is studied in a population of owls. Two alleles are found: L is associated with lighter-coloured eyes, and D is associated with darker-coloured eyes. The study finds that 30% of individuals sampled have genotype LL, 20% have genotype LD, and 50% have genotype DD.

a) What is the frequency of each of the alleles? (2 marks)

    The alleles are L and D. $F(L) = 0.3 + 0.2/2 = 0.4$. $F(D) = 0.5 + 0.2/2 = 0.6$.

b) Based on the allele frequencies calculated above, what genotype frequencies would be expected under the Hardy-Weinberg assumptions? (2 marks)

    The genotypes are LL, LD and DD. There are two ways to make LD (since it's the same as DL). The expected frequencies if everything is random are $F(LL) = F(L)^2 = 0.16$; $F(LD) = 2F(L)F(D) = 0.48$; $F(DD) = F(D)^2 = 0.36$; We check that these add to 1.

c) How do the observed frequencies differ from the expected frequencies you calculated? (1 mark)

The observed frequencies show more homozygotes and less heterozygotes in each of the three genotypes (we expect the three genotypes to agree on what there is more and less of).

d) Assuming this difference is not due to random chance, what is a likely explanation of the difference? (1 mark)

Either non-random mating, or disruptive selection.

32. (5 marks in total) You are studying a new clade of insects. You believe that the common ancestor could fly, had no stinger and could not digest raspberry leaves. Species A and B can both fly, species B and C can both digest raspberry leaves, and all three species have stingers.

a) For each characteristic, *explain* whether it provides at least some information that would inform a cladistic tree. (3 marks)

Flying provides no information, because only one species has the derived trait (of not being able to fly). Digesting does provide information, because it is a derived trait shared between B and C. Stingers provide no information because all three species are the same.
One point for each trait. Half point for correct yes/no answer without a reasonable explanation.

b) Which of these characteristics would you interpret differently in a phenetic framework and why? (1 mark)

In a phenetic framework, the fact that two of the species can fly would be considered a similarity, so we would think that flight provided information. This is how we would think if we weren't sure that the relevant common ancestor could fly.
Half a point for picking the trait, and half a point for a reasonable explanation

c) Based on all the data above, and assuming you are confident about the characteristics of the ancestor, draw a tree showing the phylogenetic relationship you would infer between A, B and C. (1 mark)

If we are confident about the ancestor, we should use the cladistic approach. Thus, we would group B and C based on the fact they can digest raspberry leaves.

33. (4 marks) List two possible results when related populations that have been separated reunite. Explain in one or two short sentences why this might happen and how you might determine how many species the new population or populations represent. Do not give more than two results, and do not write more than two short sentences.

Fusion: if differences are small, or gene flow is strong, the populations might come back together into a single population. This would represent one species. *Reinforcement*: if hybrids have low fitness, natural selection may lead to barriers to reproduction. This would represent two species. *Hybrid zones*: the populations may remain separate but have

an area where they mix, leading to gene flow. Most people would consider this a single species, but not everyone and not all the time; it could be two. *Exclusion*: one population may out-compete the other one, leaving only one species at the end. *New species*: hybrids may develop reinforcement and form their own species which may or may not out-compete one or both of the "parents". This could lead to one, two or three species at the end.