(1) SENESCENCE. Some organisms, such as pine trees and corals, are extremely long lived and experience greatly reduced rates of senescence.
- Pine trees reproduce by sending out pollen and fertilizing new seeds in the normal manner. In addition to growing in size, individuals also grow by sending out underground roots that travel a distance and emerge far away and form what appears to be a new tree in every manner, but is in fact just an extension of the original individual.
- Corals reproduce by spawning, sending out clouds of gametes into the water, the bigger the coral the bigger the cloud. Corals can also live thousands of years, growing larger and showing no signs of senescence the entire time.

(a, 3 pts) What shared trait that these two organisms possess causes them to live to be so old (experiencing greatly reduced rates of senescence)?

The shared trait of these organisms is that their reproduction increases with their age and size.

(b, 4 pts) Use technical terms from class to propose a hypothesis based on this trait that explains this phenomena of reduced or absent senescence.

This increase in reproduction with older age results in the decline of reproductive value being lessened or eliminated. This results in stronger selection against alleles that are deleterious at old age, the antagonistically pleiotropic ones that cause senescence.

(2) FUNDAMENTAL PROPERTIES OF EVOLVING POPULATIONS (1 pt each)
What three properties must a population of individuals have or experience in order to be capable of sustained evolution?

<table>
<thead>
<tr>
<th>selection</th>
<th>variation</th>
<th>heredity</th>
</tr>
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<tbody>
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</table>
(3) SNAILS (12 pts total). This question is based on a published study performed by a CSULB undergraduate named Amberle Mckee (McKee, A; Voltzow, J; Pernet, B. 2013. Substrate attributes determine gait in a terrestrial gastropod. Biological Bulletin 224:53-61) that studied the locomotion of snails. In particular when they chose to "lope" (raising their body in waves and leaving a discontinuous trail of mucus) versus using "adhesive crawling" (sliding along the surface with the whole foot always in contact, leaving a solid trail). They tested two hypotheses: (1) the loping preserves mucus lost, which is especially important when on absorbant surfaces (like concrete) and (2) the loping is faster than crawling and may aid in predator escape. They performed three experiments, the first two to test hypothesis 1 and the last to test hypothesis 2.

In the figures below you will draw a pattern of hypothetical data that would support each hypothesis on the left and data that would provide no support on the right.

Experiment 1: They placed snails on glass and concrete surfaces and measured how often they used their loping behavior versus crawling.

Experiment 2: They placed the snails on either a glass or concrete surface and by weighing them before and after they calculated how much mucus was left behind on the surface.

Experiment 3: They measured the speed of some snails that were crawling and some that were loping.

Since the speed increases as the snail gets bigger they plotted the speed against the shell size for a range of snails from small to large (n=7 each).
(4) RELATEDNESS. Depicted to the right is a pedigree (family tree) representing males (squares) and females (circles) that mate to produce offspring (indicated below the line connecting the mated individuals). For example, in the figure below B and C are sisters and both daughters of the male and female depicted at the top.

(a, 10 pts) Compute the degree of relatedness between each of the pairs of labeled individuals in this pedigree and fill out the table below with these values. Assume that the allele of interest is in the individual labeled vertically and the coefficient is for the relatedness to the individual labeled horizontally.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
<tr>
<td>A</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>B</td>
<td>1/4</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1/4</td>
<td>1/2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1/8</td>
<td>1/4</td>
<td>1/2</td>
<td>1</td>
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</table>

(5) KIN SELECTION. Now consider the evolution of a helpful behavior that may arise in a hypothetical mutant within a population. This behavior is such that it benefits only individuals with a specific relationship to the possessor of the mutation. Each time the behavior is manifested it incurs a 3% fitness penalty to the helper (reduced survivorship or something), but provides a 7% fitness benefit to the aided individual.

(a, 5 pts) Using Hamilton's Rule, determine the range of r values for which this mutation would be selected and increase in frequency within the population (i.e., for all r>?).

Using Hamilton's equation the behavior will be advantageous when:  
\[Br - C > 0\]  
\[(0.07) r - 0.03 > 0\]  
\[(0.07) r > 0.03\]  
\[r > 0.03/0.07\]  
\[r > 0.429\]

(b, 5 pts) Would this mutation be advantageous or disadvantageous if it only aided brothers, cousins, half-siblings, parents or uncles? (consider each separately and circle the appropriate abbreviation below).

<table>
<thead>
<tr>
<th>Relation</th>
<th>ADV</th>
<th>DIS</th>
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</thead>
<tbody>
<tr>
<td>Brothers</td>
<td></td>
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<tr>
<td>Cousins</td>
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<tr>
<td>Half-siblings</td>
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<tr>
<td>Parents</td>
<td>ADV</td>
<td>DIS</td>
</tr>
<tr>
<td>Uncles</td>
<td>ADV</td>
<td>DIS</td>
</tr>
</tbody>
</table>
(6). SEMELPARITY AND ITEROPARITY. Cole (and Charnov and Schaffer) modeled the factors that influence the likelihood for an evolutionary switch between different types of reproductive strategies; a similar approach can model other types of adaptations.

Consider a population of wildtype individuals that reproduce over a number of consecutive years and a mutant that causes individuals to produce more offspring, but the offspring are 40% less likely to survive to adulthood (i.e., their survival rate is 60% that of the wildtype). By producing more offspring the adults also have a 10% lower probability of surviving each year however.

(a, 5 pts) How much would this mutant's birth rate \( b_m \) need to be to experience a fitness value equal to the normal wildtype individuals? Express \( b_m \) in terms of \( b_w, P_w \) and \( C_w \) where these terms represent the values in the wildtype individuals.

Show all the steps in your derivation and make your final answer clear.

Wildtype growth rate: \( N' = (b_wC_w + P_w)N \)
Mutant growth rate: \( N' = (b_mC_m + P_m)N \)
They will have equal fitness when: \( (b_mC_m + P_m)N = (b_wC_w + P_w)N \)
Which is: \( b_mC_m + P_m = b_wC_w + P_w \)
From above: \( C_m = 0.6C_w \) and \( P_m = (0.9)P_w \)
This gives: \( b_m(0.6)C_w + (0.9)P_w = b_wC_w + P_w \)
\( b_m(0.6)C_w = b_wC_w + 0.1P_w \)
\( b_m = b_wC_w/0.6C_w + 0.1P_w/0.6C_w \)

\[ b_m = (1.666) b_w + (0.1666) P_w/C_w = 1.666 b_w + 0.1666 P_w/C_w \]

-3 pts for a single major algebra error, otherwise correct

(b, 5 pts) Consider a population in which the normal wildtype adult individuals have a 70% chance of surviving each year and have an average of 4 offspring each year. What juvenile survival rate would be required for this population to experience population growth? (express the answer as a percentage).

When is \( N' = (4C_m + 0.7)N > N \) ?
This is: \( 4C_m + 0.7 > 1 \)
\( 4C_m > 0.3 \)
\( C_m > 0.3 / 4 = 0.075 \)

\[ C_m = 7.5\% \]
(1) Which of the following most accurately matches the scenario described in lecture?
(A) Almost all birds possess the same number of thoracic vertebrae because of functional constraints.
(B) Almost all birds possess the same number of cervical vertebrae because of the antagonistically pleiotropic functions of cancer-causing cell growth and axial patterning in Hox genes.
(C) Almost all birds possess the same number of thoracic vertebrae because of the antagonistically pleiotropic functions of cancer-causing cell growth and axial patterning in Hox genes.
(D) Almost all mammals possess the same number of cervical vertebrae because of the antagonistically pleiotropic functions of cancer-causing cell growth and axial patterning in Hox genes.
(E) Almost all mammals possess the same number of thoracic vertebrae because of the antagonistically pleiotropic functions of cancer-causing cell growth and axial patterning in Hox genes.

(2) Which of the following most accurately matches the scenario described in lecture?
(A) During mammal evolution a double jaw joint evolved which facilitated the reduction in size of the articular and quadrate; allowing them to evolve into the malleus and incus.
(B) During mammal evolution a double jaw joint evolved which facilitated the reduction in size of the articular and quadrate; allowing them to evolve into the stapes and incus.
(C) During mammal evolution a double jaw joint evolved which facilitated the reduction in size of the articular and quadrate; allowing them to evolve into the malleus and stapes.
(D) During mammal evolution a double jaw joint evolved which facilitated the reduction in size of the dentary and squamosal; allowing them to evolve into the malleus and incus.
(E) During mammal evolution a double jaw joint evolved which facilitated the reduction in size of the dentary and squamosal; allowing them to evolve into the stapes and incus.

(3) Why will seals never evolve gills?
(A) Gills are too energetically expensive for seals to possess based on their diet.
(B) Gills are unique to fish and seals are not fish.
(C) Gills make endothermy impossible and seals are warm-blooded.
(D) Gills make parasitic infections too easy in mammals.
(E) The developmental processes of lungs prevent the development of gills.

(4) Which is the correct order of development of (most) vertebrate digits?
(A) 1 - 2 - 3 - 4 - 5
(B) 2 - 3 - 4 - 1 - 5
(C) 3 - 4 - 2 - 1 - 5
(D) 4 - 3 - 2 - 1 - 5
(E) 5 - 4 - 3 - 2 - 1

(5) Which of the following was NOT a species definition described?
(A) Minimalist.
(B) Nominalist.
(C) Phenetic
(D) Phylogenetic.
(E) Typological.

(6) Which of the following was NOT one of the evolutionary constraints described?
(A) Developmental.
(B) Functional.
(C) Pleiotropic.
(D) Selective.
(E) Variational.
Use the following information for the next 3 questions.

Pictured to the right are two pictures of an animal called an Okapi (*Okapia johnstoni*). These mammals live in the jungles of central Africa and although they have stripes like zebras they are actually more closely related to giraffes. These organisms are not toxic nor do they live near zebras. Their color pattern appears to be useful by breaking up their profile and silhouette, making them harder to see from a distance.

(7) Which of the terms below best describes the color pattern okapi possess?
(A) Batesian mimicry with zebras  (D) Aposematic coloration
(B) Mullerian mimicry with zebras  (E) Cryptic coloration
(C) Mullerian mimicry with giraffes

(8) How many neck vertebrae do those okapi have?
(A) 5  (B) 7  (C) 9  (D) 11  (E) Not enough information given

(9) Both male and female okapi possess this color pattern, which of the following does this imply?
(A) The color pattern is used in sexual selection; females choose males based on their stripes.
(B) The color pattern is used in sexual selection; males choose females based on their stripes.
(C) The color pattern is not used in sexual selection in okapis.
(D) Since this pattern differs from giraffes and is similar to zebras, okapi are likely to be able to produce fertile hybrids with zebras.
(D) Since this pattern differs from giraffes and is similar to zebras, okapi are likely to be more closely related to zebras than giraffes are.

(10) Which of the following does not accurately describe a portion of the logical argument for sexual asymmetry leading to differences between males and females?
(A) As energy investment increases, so does the risk of mating with a poor reproductive partner.
(B) Differences in optimal behaviors can lead to differences in morphology.
(C) Females are generally more limited than males in their total number of reproductive events.
(D) Females generally contribute more energy than males to each reproduction event.
(E) Males generally experience higher levels of intersexual competition than females.

(11) Occasionally plants undergo whole genome duplications caused by diploid pollen fertilizing diploid ova, resulting in tetraploid individuals. If both parents are from the same species these are called autopolyploid individuals. If the parents are from different species these are called allopolyploid individuals. If these individuals cease to reproduce with the original population, speciation has occurred. Which model of speciation below most accurately describes this process?
(A) Allopatric.  (C) Parapatric.  (E) Sympatric.
(B) Florapatric.  (D) Peripatric.
(12) Which of the following is NOT accurate?
(A) The evolution of masculinized genitalia in female hyenas is an example of individual level selection being stronger than group level selection.
(B) The lack of highly contagious virulent diseases is likely because group level selection is stronger than individual level selection.
(C) The persistence of the t allele in Mus musculus is due to gene level selection being stronger than individual level selection.
(D) The rarity of altruism in nature is due to group level selection being stronger than individual level selection.
(E) The widespread presence of sexual reproduction showed that group level selection can be stronger than individual level selection.

(13) Consider a situation in which a statistically significant relationship between two traits is seen in a set of taxa. Which of the following would cause this pattern to most strongly support a selective hypothesis linking these two traits?
(A) Many pairs of sister taxa differ in the values of one trait, but not both, in sets across the entire tree.
(B) Many pairs of sister taxa differ in the values of both traits in sets across the entire tree.
(C) Monophyletic groups share similar values of one trait, but not both, across the entire tree.
(D) Monophyletic groups share similar values of both traits across the entire tree.
(E) The traits are almost all the same in all related species, but different in less related taxa.

(14) The males of a number of species of hummingbirds perform courtship dives. They fly to about 20 meters above the female and then fly straight down towards her and only pull up at the last fraction of a second. They repeat these acrobatic dives multiple times. Females seem to use these dives as part of their choice selection. Which of the following modes of females choice is most likely at play?
(A) Direct benefit
(B) Good genes
(C) Handicap principle
(D) Hybridization avoidance
(E) Pre-existing bias

(15) Numerous studies indicate that female humans prefer males taller than themselves. However, studies also show that taller people experience higher rates of breast, skin and ovarian cancer than shorter people. This is likely caused by the alleles that cause faster cell growth predisposing cells to mutations that allow uncontrolled cell growth (i.e., cancer). What is the most appropriate technical term for the phenomenon described?
(A) Antagonistic pleiotropy
(B) Functional
(C) Runaway sexual selection
(D) Sexual dimorphism
(E) Strong inference

(16) This question is based on a report in the New York Times (http://www.nytimes.com/2013/02/21/us/survey-finds-that-fish-are-often-not-what-label-says.html). In 2013 the nonprofit organization Oceana released a report describing their testing of a number of fish from a markets and restaurants (including sushi places). Using genetic testing, they identified widespread mislabeling of the fish species. For example, in 120 samples labeled "red snapper" 28 different species of fish were found (including 17 that were not even closely related to snapper). In some places the fish were the species labeled less than half the time. Assuming that they used DNA barcoding, a technique in which sets of unique genetic sequences are used to define species, what type of species concept would these researchers be using?
(A) Biological.
(B) Nominalist.
(C) Phenetic
(D) Phylogenetic.
(E) Typological.