1. **PHYLOGENTIC TREE.** About two months ago the movie Zootopia was released. This movie featured a number of anthropomorphic characters from different animal species. The picture below shows 14 of them. These come from 12 species in several different orders of mammals.

(a, 3 pts) How many orders of mammals are represented by the cast shown? \# orders = _____

(b, 5 pts) In the box below, draw the phylogeny of the orders represented. Provide the correct technical name for each order.

(c, 2 pts) Also in the box below, list the species above contained in each of the orders in your tree.
2. CHRONOLOGY. (3 pts each). For each of the following 5 sets of events, dates or named geologic times number them from 1 (oldest) to 4 (most recent). An example is given to show the numbering procedure.

Example set

<table>
<thead>
<tr>
<th>Event</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>War of 1776</td>
<td>1</td>
</tr>
<tr>
<td>First DVD player</td>
<td>4</td>
</tr>
<tr>
<td>War of 1812</td>
<td>2</td>
</tr>
<tr>
<td>First car</td>
<td>3</td>
</tr>
</tbody>
</table>

Set 1

<table>
<thead>
<tr>
<th>Event</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of Mesozoic</td>
<td>3</td>
</tr>
<tr>
<td>Start of Cambrian</td>
<td>2</td>
</tr>
<tr>
<td>200 million year ago</td>
<td>1</td>
</tr>
<tr>
<td>First vascular plants</td>
<td>4</td>
</tr>
</tbody>
</table>

Set 2

<table>
<thead>
<tr>
<th>Event</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>First birds</td>
<td>3</td>
</tr>
<tr>
<td>Start of Cambrian</td>
<td>2</td>
</tr>
<tr>
<td>65 million year ago</td>
<td>1</td>
</tr>
<tr>
<td>Start of Jurassic</td>
<td>4</td>
</tr>
</tbody>
</table>

Set 3

<table>
<thead>
<tr>
<th>Event</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Cambrian explosion</td>
<td>3</td>
</tr>
<tr>
<td>Start of Proterozoic</td>
<td>2</td>
</tr>
<tr>
<td>500 million year ago</td>
<td>1</td>
</tr>
<tr>
<td>First eukaryotes</td>
<td>4</td>
</tr>
</tbody>
</table>

Set 4

<table>
<thead>
<tr>
<th>Event</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of Cretaceous</td>
<td>3</td>
</tr>
<tr>
<td>Start of Jurassic</td>
<td>2</td>
</tr>
<tr>
<td>Start of Triassic</td>
<td>1</td>
</tr>
<tr>
<td>First dinosaurs</td>
<td>4</td>
</tr>
</tbody>
</table>

Set 5

<table>
<thead>
<tr>
<th>Event</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>First lands plants</td>
<td>3</td>
</tr>
<tr>
<td>First amphibians</td>
<td>2</td>
</tr>
<tr>
<td>First reptiles</td>
<td>1</td>
</tr>
<tr>
<td>251 million year ago</td>
<td>4</td>
</tr>
</tbody>
</table>

3. HOMOLOGY/ANALOGY: (5 pts). The concepts of homology and analogy were novel when the theory of evolution was proposed by Lamarck and later by Darwin and Wallace. The explanation for homology provided by evolutionary theory was the single most important line of evidence that convinced scientists of the 1800s that evolution has occurred. Describe the logic of the homology/analogy line of evidence for evolution. Don't just define the terms, describe the logic and argument.

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

____________________  ____________________  ____________________
5. RELATEDNESS. Depicted to the right is a pedigree (family tree) just like the one in class, representing males (squares) and females (circles) that mate to produce offspring.

Compute the Probabilities of alleles being shared between two individuals due to the ancestry depicted and write these in the boxes in the table below. (1 pt each)

The probability you will calculate is the probability of an allele in the individual listed in the leftmost column being in the individual listed in the 2nd column.

For the 3rd column (first column of boxes) consider allele on an autosome.

For the 4th column (second column of boxes) consider alleles on the X chromosome.

For the 5th column (second column of boxes) consider alleles on the Y chromosome.

<table>
<thead>
<tr>
<th>allele in indiv.</th>
<th>also in indiv.</th>
<th>if allele on autosome</th>
<th>if allele on X chromosome</th>
<th>if allele on Y chromosome</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>A</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>B</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6. INTERPRETING MODERN RESEARCH. The abstract below is from a paper published in 2014. (González-Santoyo et al. 2014. A Mismatch between the Perceived Fighting Signal and Fighting Ability Reveals Survival and Physiological Costs for Bearers. PLoS ONE 9(1): e84571) Read the abstract carefully to answer the questions (two words has been redacted).

Abstract: Signals of fighting indicate an animal's intention to attack and so they serve to prevent costly aggressive encounters. However, according to theory, a signal that is different in design (i.e. a novel signal) but that fails to inform fighting intentions will result in negative fitness consequences for the bearer. In the present study we used males of the territorial damselfly *Hetaerina americana*, which have a ###### wing spot during territory defense that has evolved as a signal of fighting ability. By producing a novel signal (covering the ###### spot with blue ink) in territory owners, we investigated: a) the behavioral responses by conspecific males; b) survival cost and c) three physiological mediators of impaired survival: muscular fat reserves, muscle mass and immune ability. We predicted that males with the novel signal would be attacked more often by conspecifics as the former would fail to convey fighting ability and intentions adequately. This will result in lower survival and physiological condition for the novel signal bearers. We found that, compared to control males (males whose ###### spot was not changed), experimental males had __________ survival, were less able to hold a territory, and had a __________ muscle mass. It seems that spot modified males were not able to effectively communicate their territory tenancy, which may explain why they lost their defended sites. Our results provide support for theoretical models that a novel signal that fails to informing fighting ability may lead to a fitness cost for bearers.

(a, 2 pts) The color spot these damselflies have is a particular color which has been redacted with ###### symbols above. Based on multiple examples from class, what color do you predict this to be? (write the word on the blank to the right)

(b, 2 pts) On the blank to the right, provide the word of (or a synonym) that fits in the blanks in the abstract (write the word on the blank to the right)

(c, 2 pts) This study is quite similar to one described in the course. On the blank to the right, provide the name of the species (write the name on the blank to the right)

(d, 8 pts) Two experiments were described in that lecture that studied some of the same general processes as in the study above. Describe one of the experiments and in the left box draw one of the bar charts they obtained (you must label the axes and show a pattern that matches their data). In the right box show hypothetical data from the experiment that would not have supported their hypothesis.
POPULATION GENETICS.

7. Hardy-Weinberg equilibrium. Consider a population of 1600 individuals with two segregating alleles "A" and "a" at a locus of interest with the number of individuals of each genotype as shown to the right. Let p represent the frequency of the "A" allele and q represent the frequency of the "a" allele.

(a, 2 pts ea) What are the values of p and q?

p = 

q = 

(b, 5 pts). If we were to compare the observed frequency of the genotypes to that expected if the population was at Hardy-Weinberg equilibrium we would do this with a $\chi^2$ test. What value of $\chi^2$ would we obtain if we did so?

$\chi^2 =$

(c, 1 pt) Based on the table of critical $\chi^2$ values shown to the left, does this population appear to be at Hardy-Weinberg equilibrium or not? (circle one)

YES NO

8. Effective population size. Consider a population with an effective population size of $Ne = 1073$.

(a, 4 pts) If the population has 410 females, how many males does it have? (round your answer to the nearest integer)

# = 

(b, 4 pts) If the population fluctuates (i.e., alternating yearly between two values) and one of those values is 1,500, what is the other value? (round your answer to the nearest integer)

# =

9. Mutation: selection balance. Consider a highly deleterious mutation that cuts the juvenile survival probability in half. The frequency is estimated to be about 1 copy per 3,000 wildtype alleles

(a, 4 pts) In a country like the United States (population size = 300,000,000), what is the expected number of individuals homozygous for the deleterious allele? (NOTE: round your answer to the nearest integer for this question)

# =

(b, 4 pts) If that mutation is recessive, what is the best estimate for the mutation rate from a functional allele to that deleterious one?

$\mu =$

(c, 4 pts) If that mutation is dominant, what is the best estimate for the mutation rate from a functional allele to that deleterious one?

$\mu =$
FOR THE REMAINING QUESTIONS USE YOUR SCANTRON FORM

MULTIPLE CHOICE: (2 pts each).

(1) Convergent evolution tends to lead to ____________ ?
(A) analogy
(B) homology
(C) speciation
(D) symplesiomorphy
(E) synapomorphy

(2) When two taxa share a trait because of inheriting it from a distant ancestor (rather than acquiring it from a very recent common ancestor) we term this trait a _________ ?
(A) Convergence.
(B) Homoplasy.
(C) Phylogeny.
(D) Sympleisiomorphy
(E) Synapomorphy.

(3) Which of the following was NOT a species definition described?
(A) Essentialist.
(B) Nominalist.
(C) Phenetic
(D) Phylogenetic.
(E) Tautological.

(4) If the migration rate between two regions (each of which is polymorphic for two alleles) were to increase considerably, which of the following is the predicted effect?
(A) The overall allele frequency would decline.
(B) The overall allele frequency would trend toward p=0.5
(C) The regional allele frequencies would become similar.
(D) The regional allele frequencies would trend towards p=0.5.
(E) The two alleles would become similar.

(5) Priming a person by discussing infectious disease was shown to increase particular attitudes or prejudice, which of the following describes the feelings or opinions influenced in this way?
(A) Anti-elderly and ageist opinions.
(B) Anti-female and misogynist opinions.
(C) Anti-immigrant and ethnocentric opinions.
(D) Anti-male and misandrist opinions.
(E) Anti-poor and capitalist opinions.

(6) Which of the following is the best description of the "Cinderella Effect"?
(A) Human females provide less parental care to offspring that are biologically not their own.
(B) Human females provide less parental care to offspring that are biologically their own.
(C) Human males provide less parental care to offspring that are biologically not their own.
(D) Human males provide less parental care to offspring that are biologically their own.
(E) Human males and females provide less parental care to the offspring born most recently.

(7) The phenomenon in which individuals develop into one of two distinct adult forms was termed which of the following?
(A) Developmental constraint.
(B) Developmental noise.
(C) Neoteny.
(D) Phenotypic plasticity.
(E) Sexual dimorphism.

(8) The game theory scenario modeling the behavior of individuals, in which they adopted either a submissive or aggressive strategy when interacting with others, was termed which of the following?
(A) Flight or flight.
(B) Hawk/dove.
(C) Prisoner's dilemma.
(D) Smoke detector principle.
(E) Tit for tat.
(9) Consider the fossil skull shown to the right. It is from an organism that lived 6-7 million years ago in central Africa (current day Chad). It is either one of our ancestors or a very close relative of this ancestor. Which species is this?
(A) Ardipithecus ramidus. (D) Pan paniscus.
(B) Australopithecus anamensis. (E) Sahelanthropus tchadensis.
(C) Homo rudolphensis.

(10) Consider the fossil skull shown to the right. It is from an organism that lived 1.8-2.4 million years ago in central Africa (current day Kenya). This is the first species described in class that shows evidence of making and modifying stone tools. It is either one of our ancestors or a very close relative of this ancestor. Which species is this?
(A) Ardipithecus ramidus. (D) Pan paniscus.
(B) Australopithecus anamensis. (E) Sahelanthropus tchadensis.
(C) Homo rudolphensis.

(11) Consider the fossil skeletons shown to the right (they have been scaled to the same height). Which of the sequences below is the correct one that names the species, from left to right?
(A) Chimpanzee ... Gorilla ... Orangutan ... Human
(B) Chimpanzee ... Orangutan ... Gorilla ... Human
(C) Gorilla ... Orangutan ... Chimpanzee ... Human
(D) Orangutan ... Chimpanzee ... Gorilla ... Human
(E) Orangutan ... Gorilla ... Chimpanzee ... Human

(12) Which of the following is the best term for the study of the processes that influence fossil formation?
(A) Paleobiology. (D) Taphonomy.
(B) Paleontology (E) Taxonomy.
(C) Stratigraphy.

(13) A number of traits about primates are used, in combination, to distinguish them from other mammal groups; which of the following is not one of these traits?
(A) Ability to use tools to acquire food.
(B) Forward facing eyes with overlapping fields of vision.
(C) Relatively large brains for the size of the body.
(D) Shift from smell to vision as the primary sense used.
(E) Teeth that are very different from one another in shape and size.

(14) What type of variation must be present for a population to experience evolutionary change?
(A) Advantageous (D) Genetic
(B) Deleterious (E) Morphological
(C) Environmental

(15) The number of ___________ vertebrae is remarkably conserved across mammals.
(A) abdominal (D) sacral
(B) cervical (E) thoracic
(C) lumbar
(16) Which of the following sets of words best fits the blanks. "Changes in a population are caused by _______ in individuals that increase in frequency to become ___________ which then fix, resulting in ____________ that can be used differentiate species from one another."
(A) mutations ... polymorphisms ... substitutions
(B) mutations ... substitutions ... polymorphisms
(C) polymorphisms ... mutations ... substitutions
(D) polymorphisms ... substitutions ... mutations
(E) substitutions ... polymorphisms ... mutations

(17) When describing four distinct ways to study evolution, which of the following was NOT one of the ways listed?
(A) Comparative. (D) Observational.
(B) Empirical. (E) Theoretical.
(C) Experimental.

(18) When describing four distinct model of female choice, which of the following was NOT one of the ones listed?
(A) Direct benefit. (D) Hybridization avoidance.
(B) Good genes. (E) Territories.
(C) Handicap principle.

(19) When describing four distinct types of genetic variation, which of the following was NOT one of the ones listed?
(A) Additive. (D) Recessive.
(B) Dominance. (E) Total.
(C) Epistatic.

(20) 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 (D) Sexual dimorphism
(B) Functional constraint (E) Strong inference
(C) Runaway sexual selection

(21) Imagine we are comparing the wildtype sequences for two taxa and they differ at a single nucleotide. If the difference between having an adenine or a cytosine at that certain nucleotide position equates to having either an asparagine (medium sized polar amino acid coded for by the AAC codon) or histidine (large basic amino acid coded for by the CAC codon), which of the following would we use to describe it?
(A) a nonsynonymous polymorphism for a radical amino acid change.
(B) a nonsynonymous substitution for a conservative amino acid change.
(C) a nonsynonymous substitution for a radical amino acid change.
(D) a synonymous polymorphism for a conservative amino acid change.
(E) a synonymous polymorphism for a radical amino acid change.
(22) Fisher's fundamental theorem is best paraphrased by which of the following?
(A) Populations evolve the fastest when they have the highest immigration rate.
(B) Populations evolve the fastest when they have the highest mutation rate.
(C) Populations evolve the fastest when they have the most environmental variation.
(D) Populations evolve the fastest when they have the most genetic variation.
(E) Populations evolve the fastest when they have the largest population size.

(23) 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 that they arose within, speciation has occurred. Which model of speciation below most accurately describes this process?
(A) Allopatric.
(D) Peripatric.
(B) Florapatric.
(E) Sympatric.
(C) Parapatric.

The following 3 questions are based upon the video you watched in preparation for this exam.

(24) Hank talks about a specific figure from a book, which of the following is the correct description of the figure and book?
(A) The figure is named, "Brave New World" and comes from a 1932 book published by Huxley.
(B) The figure is named, "Early Man" and comes from a 1965 book published by Howell.
(C) The figure is named, "Man's Walk to the Future" and comes from a 1899 book published by Davis.
(D) The figure is named, "Onward and Upward" and comes from a 1946 book published by Rommel.
(E) The figure is named, "Origin of Species" and comes from a 1959 book published by Darwin.

(25) Hank lists a number of flaws about the figure, which of the following was not one of the flaws he talked about?
(A) The figure only shows males, ignoring females entirely.
(B) The figure implies that we evolved from Neanderthals which is incorrect.
(C) The figure includes many species that are not direct ancestors of humans.
(D) The figure includes Cro-Magnon man, which is no longer accepted as a valid species.
(E) The figure shows tools and clothing at inappropriate times during the history depicted.

(26) Hank provided a definition of what makes a species "evolutionarily successful" in his monologue. What was his definition??
(A) It continues to exist and evolve.
(B) It increases in population size over time.
(C) It migrates to new locations other than the starting one.
(D) It produces more species than its competitors.
(E) Its fitness increases over time.