

### **FINAL EXAM Study Guide**

This study guide condenses the set of questions I distributed on the midterm exam study guides. Although the prior study guides are more thorough, this one might help to focus your studying given the short time before the final exam.

You should know the following formulas, be explain to explain what their components mean, and be able to use them:

$$\Delta N/\Delta t = rN$$

$$\Delta N/\Delta t = r_{\max} N (1-(N/K))$$

$$R = S \times h^2$$

$$R_o = \sum l_x \cdot m_x$$

$$\chi^2 = \sum (O-E)^2/E$$

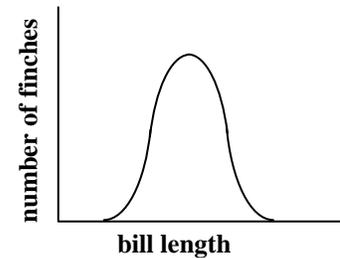
#### **Unit 1. Biodiversity and conservation biology**

- 1) Be able to define the following words and phrases: biodiversity, genetic diversity, species diversity, endemic, fragmentation, invasive species, keystone species
- 2) Relate generally how the current extinction rate compares to historical (background) extinction rates, to historical mass extinction rates, and to current speciation rates.
- 3) In what ways does habitat fragmentation specifically pose a threat to biodiversity?
- 4) In what ways do introduced species specifically pose a threat to biodiversity?
- 5) Describe two distinct risks of small population size and why these risks are less likely to threaten large populations.
- 6) Imagine different ways of designing an ecological reserve in terms of how a given amount of reserved land can be divided among fragments. Explain the advantages and disadvantages of these types of reserve design.

#### **Unit 2. Population and conservation genetics**

- 1) Be able to use and distinguish the following words and phrases: population, evolution, quantitative trait, polygenic, phenotypic variation, genetic variation, heritability, natural selection, strength of selection, response to selection, fitness, allele frequencies, genotype frequencies, Hardy-Weinberg equilibrium, mutation, migration, gene flow, genetic drift, sampling error, fixation, founder effect, bottleneck, random mating, assortative mating, inbreeding, inbreeding depression, heterozygosity.
- 2) Explain what it means to say that a trait *must have a genetic basis* in order to evolve in response to natural selection. Provide an example.
- 3) Is natural selection possible without evolution? Is evolution possible without natural selection? Explain your answers.
- 4) Evaluate the following statement: the evolutionary response to natural selection is always smaller than the strength of selection.
- 5) What does it mean for a population to be in Hardy-Weinberg equilibrium? Explain the five conditions that must be met for HWE.

- 6) Carry out the following steps to determining whether a population is in HWE: (1) calculate allele frequencies from observed genotype frequencies, (2) predict HW genotype frequencies based on those allele frequencies, and (3) determine whether the difference between observed and predicted genotype frequencies demonstrate that the population is in HWE.



- 7) Determine whether a set of genotype frequencies is possible for a given set of allele frequencies.
- 8) The figure to the right shows the distribution of bill length in a population of finches. Graph the expected distribution of bill length in this population after several generations of selection for larger bill size. Assume that bill length has zero heritability.
- 9) Be able to explain how, why and in which direction genetic drift and gene flow are expected to influence genetic diversity within and between populations. Given the increasing threat of habitat fragmentation, why is the combination of gene flow and genetic drift especially important to consider together?
- 10) Of the five population genetic processes, which can lead to a population being better adapted to its current environmental conditions?
- 11) Conservation managers often try to purchase corridors of undeveloped habitat so that larger preserves are linked into networks. Why? What genetic goals are they aiming for? Describe two effects on population genetic structure. Use the populations of prairie chickens described in the article by Westemeier et al. as an example.
- 12) How do genetic drift, gene flow and inbreeding affect threatened species? Discuss how efforts to conserve biodiversity can address each of these processes.

### Unit 3. Population ecology

- 1) Be able to use the following words and phrases: population dynamics, birth, death, immigration, emigration, exponential growth, per capita rate of increase, carrying capacity, density independent, density dependent, logistic growth, fecundity, life table, allocation, trade-off, dispersal, metapopulation, rescue effect, population viability analysis
- 2) What four basic individual processes can contribute to changes in population size?
- 3) Explain the biological conditions under which populations could experience exponential growth. Use an example.
- 4) Explain the range of biological conditions that can limit exponential growth.
- 5) Explain how to incorporate the parameter  $K$  to change the exponential growth equation to the logistic growth equation.
- 6) List at least three density-dependent processes that can regulate population sizes.
- 7) Which population growth model is more appropriate for: a population of bacteria that have just colonized your nasal passages? A population of elephants? The human population? A newly invasive plant species? The population of fruit flies in a jar in the lab?
- 8) Explain why a genotype that has the highest fecundity may not have the highest fitness.

### Sample problems

- 1) Suppose you showed that there is a great deal of variation in swimming speed within a population of Atlantic salmon. Describe an experiment that you could use to test the degree to which variation in swimming speed in this population of fish is heritable. Draw a graph representing the results you would expect if heritability of swimming speed is high, and a second graph representing the results you would expect if this trait is not heritable.
- 2) Imagine that you're interested in the evolution of distastefulness in sponges. For your study, you measure the distastefulness of sponges before and after exposing the population to predation by parrotfish. You find that the mean distastefulness before natural selection is 5.0 BTU (bad-taste units), while the mean distastefulness after predation is 6.0 BTU. You continue to follow this population and find that the mean distastefulness in the next (offspring) generation is 5.6 BTU. Calculate (a) the strength of selection on caterpillar distastefulness and (b) the heritability,  $h^2$ , of distastefulness.
- 3) A single gene is thought to determine whether your earlobes are attached or free-hanging, with the recessive allele coding for attached earlobes. In a population of 485 people, 100 are homozygous dominant, 240 are heterozygous, and 145 are homozygous recessive (and therefore have attached earlobes). What is the frequency of the dominant allele in this population? Is the population in Hardy-Weinberg equilibrium? Show your work.
- 4) The frequency of the sickle-cell allele, HbS, in the African-American population is 0.04. What is the frequency of the normal allele, HbA (assume these are the only two alleles in the population)? If the population is in Hardy-Weinberg equilibrium, what percentage of the population is predicted to be carriers (heterozygotes) of sickle-cell disease?
- 5) A population of *Streptococcus* bacteria has a per capita rate of increase of 0.5. What can you deduce about birth vs. death rates for this population? How many generations of exponential growth would be required for this population to quadruple in size?

#### Unit 4. Species interactions

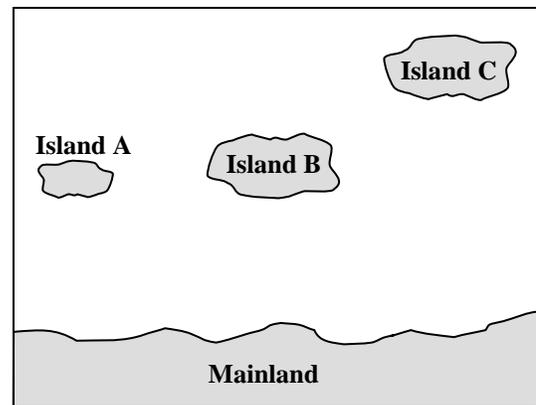
- 1) Be able to use and distinguish among the following terms: intraspecific competition, interspecific competition, competitive exclusion, fundamental niche, realized niche, niche partitioning, competitive release, predation, carnivore, herbivore, parasite, host, cryptic coloration, aposematic coloration, mimicry, mutualism, commensalism, symbiosis
- 2) Distinguish two possible outcomes of competition. Be able to explain conditions that would lead to each type of outcome.
- 3) Compare and contrast the concepts of fundamental and realized niches. Explain how biotic and abiotic factors define differences between the two types of niches.
- 4) Design an experiment to determine the fundamental and realized niche of a plant species that is found growing on north-facing but not south-facing slopes of a valley. Graphically represent two different possible outcomes of such an experiment, and verbally describe what each outcome would tell you about the fundamental and realized niche of the species.
- 5) Define each of the following types of interactions, and explain what kind of outcome is expected at the individual level and population level for each interactor: herbivores, predators, parasites, parasitoids, pathogens.
- 6) Describe and distinguish three types of adaptations involving coloration that can help prey to avoid predators.

#### Unit 5. Community ecology

- 1) Be able to use and distinguish the following terms: community, intermediate disturbance hypothesis, indirect effect, species diversity, keystone species, succession, primary succession,

secondary succession, pioneer community, climax community, biogeography, island biogeography,

- 2) Explain four factors that can promote the stable coexistence, rather than exclusion, of competing species.
- 3) Be able to diagram both direct and indirect effects among a set of species interactions, for example, interactions among beavers, cottonwoods, leaf-eating beetles, and beetle predators.
- 4) Be able to predict the effects on community structure if a top predator prefers to eat species that are competitively inferior, and the effects if it prefers to eat a species that is competitively superior.
- 5) According to the intermediate disturbance hypothesis, both low and high levels of disturbance can reduce species diversity. Explain the different mechanisms responsible for a reduction in species diversity at either extreme. Your answer should involve trade-offs between competitive and dispersal abilities and how particular qualities are promoted in each situation.
- 6) Imagine that a new volcanic island has been formed. Predict how biodiversity on the island is likely to change over time. Graph and explain your prediction.
- 7) Suppose you are planning to study the bird communities on the islands shown in this figure. Islands A and B lie equal distances from the mainland but differ in area, while islands B and C are identical in area but lie at different distances from the mainland. (a) According to the equilibrium model of island biogeography, which of the islands should experience higher rates of immigration? Explain your prediction. (b) What does the equilibrium model of island biogeography predict concerning relative rates of extinction on these three islands? Explain your prediction. (c) Where would you expect the equilibrium number of species to be highest? Be able to show your prediction graphically.
- 8) Make an argument for how the theory of island biogeography can be useful for conservation biology.



## Unit 6. Ecosystems and Human Impacts

- 1) Be able to use and distinguish the following terms: ecosystem, food web, trophic level, biomass, primary production, secondary production, consumer, decomposer, detritivore, climate, biome, ecological footprint
- 2) Why is the biomass of producers within an ecosystem greater than the biomass of consumers within the same ecosystem? More generally, explain what accounts for the reduction of productivity at each successively higher trophic level.
- 3) Compare and contrast how energy and nutrients are moved through ecosystems. Discuss at least one similarity and one difference.
- 4) Explain why the tilt of the earth results in different seasons. List the major factors that lead to the creation of distinct climates. Give an example of how differences in these factors can lead to distinct biomes. Be able to name some biomes and describe their basic characteristics.
- 5) Do a simple sketch of the global carbon cycle, including the major reservoirs for carbon and the major pathways by which carbon is moved among these reservoirs. Describe two ways in which humans are altering the movement of carbon among reservoirs.
- 6) What information would you need to know to calculate your own ecological footprint?

### **Unit 7a. Speciation and macroevolution**

- 1) Be able to use the following words and phrases: speciation, species, reproductive isolation, vicariance, allopatric, sympatric, adaptive radiation
- 2) Discuss the relative merits and limitations of the biological, morphological, and phylogenetic species concepts.
- 3) What three steps are involved in the process of speciation? How does genetic isolation of populations occur during allopatric speciation? What is different about how it occurs during sympatric speciation? During stasipatric speciation?
- 4) How can each of the following---mutation, migration, genetic drift, natural selection, sexual selection, non-random mating--contribute to genetic divergence during the process of speciation?

### **Unit 7b. Phylogenies and the tree of life**

- 5) Be able to use the following words and phrases: taxonomy, phylogeny, phylogenetic hypothesis, parsimony, common ancestor, most recent common ancestor, sister group, branch, node, monophyletic, paraphyletic, polyphyletic, character, character state, character state transition, outgroup, ancestral, derived, informative character, shared derived character, extant, homology, homoplasy
- 6) Why are “shared, derived traits” used to identify monophyletic groups? What other kinds of traits are there, and why are they not useful for identifying monophyletic groups?
- 7) Be able to use a set of character states to determine the most parsimonious phylogeny for a small group of related organisms.
- 8) Given a phylogeny for a group covered in the class (e.g., Archaea-Eukarya, Plantae, or Fungi), be able to locate the position of evolutionary changes in major traits that define clades within these groups.
- 9) Using a given phylogeny, be able to identify sister groups and degrees of evolutionary relatedness between groups.
- 10) Be able to discern how many phylogenetic hypotheses and how many topologies are represented among a group of choices.
- 11) Understand the meaning of parsimony as well as how it is applied to choosing a best phylogenetic hypothesis.
- 12) Compare and contrast homology and homoplasy. Which is more valuable for inferring phylogenies? Why?
- 13) “Birds should be regarded as a separate class from reptiles.” Provide one argument in favor of this statement and one argument against. More generally, address whether or not there should remain 5 taxonomic classes of vertebrates based on a phylogenetic approach.
- 14) How is it that eukaryotes can be considered to be more closely related to some prokaryotes (the Archaea) than to other prokaryotes (the Bacteria)? That is, why doesn't “prokaryote” describe a useful feature to understand evolutionary relatedness among these three groups?
  - Your textbook states that human populations within Africa are more genetically diverse than all human populations outside of Africa. How can this be? How does this statement relate to the Y-chromosome phylogeny developed by Ke et al.?
  - How are patterns of past isolation and gene flow revealed by a phylogeny? Use the study described by Ke et al. as an example.

### **Unit 8a. Bacteria and Archaea**

- 1) Be able to use the following words and phrases: prokaryote, eukaryote, extremophile, halophile, thermophile, nitrogen fixation, autotroph, heterotroph, photosynthesis, chemosynthesis
- 2) Be able to discuss the phylogenetic position, phylogenetic status (i.e., is it monophyletic, paraphyletic, polyphyletic), and some of the defining characteristics of the following groups: Bacteria, Archaea, Eukarya.
- 3) Would you predict that pathogenic bacteria obtain energy from light, organic molecules, or inorganic molecules? Explain.
- 4) If you were to map photosynthesis onto a phylogeny of the prokaryotes, what sort of pattern would emerge? Same question for eukaryotes. Discuss two processes that are important for explaining these patterns.
- 5) Discuss the profound significance of cyanobacteria for the evolution of biodiversity. Include two critical roles that cyanobacteria have played in the subsequent diversification of life, especially in the radiation of animals.

### **Unit 8b. Protists and the origin of eukaryotes**

- 6) Be able to use the following words and phrases: ingestion, absorption, cilia, flagella, endomembrane system, primary producers, plankton, phytoplankton, endosymbiosis, secondary endosymbiosis, multicellularity, chlorophyll, algae, meiosis, alternation of generations
- 7) Be able to discuss the phylogenetic position, phylogenetic status, and defining characteristics of the following groups: land plants, choanoflagellates, fungi, animals.
- 8) Discuss the evolutionary origin of the following traits: nuclear envelope, mitochondria, chloroplasts, cell wall, external shell, multicellularity. Which are thought to have evolved once and which more than once?
- 9) Outline the steps in the endosymbiosis theory for the origin of mitochondria. What did each partner provide the other, and what did each receive in return? Answer the same questions for the origin of chloroplasts.
- 10) Describe the major sources of evidence in support of the endosymbiotic hypothesis.

### **Unit 9a. Plants**

- 1) Be able to use the following words and phrases: gamete, embryo, embryophyte, moss, pores, stomata, vascular tissue, lignin, fern, ovary, ovules, pollination, seed, gametophyte, sporophyte, spore, zygote.
- 2) Be able to discuss the phylogenetic position, phylogenetic status, and defining characteristics of the following groups: green algae, non-vascular plants, seedless vascular plants, gymnosperms, angiosperms.
- 3) Draw a simplified and map the origin of the following traits:.
- 4) For plants, what challenges are associated with life on land? Discuss the evolutionary innovations within plants that are important for living and reproducing on land. Be able to draw a simplified phylogeny of major groups of land plants and map these traits (seeds, tracheids, vessels, cuticle, stomata, pollen, flowers, fruits) onto the phylogeny.
- 5) Draw a generalized life cycle that includes an alternation of generations and label the following events or structures: sporophyte, gametophyte, meiosis, zygote, fertilization, spores, gametes. Explain how the two parts of the life cycle are emphasized in different groups of plants.

### **Unit 9b. Fungi**

- 6) Be able to use the following words and phrases: mycorrhizae, saprophyte, yeast, hyphae, mycelium, heterokaryotic, chitin, endophyte, extracellular digestion, spore, plasmogamy, karyogamy, opisthokont.

- 7) Be able to discuss the ecological roles and importance to humans of the following groups: ectomycorrhizal fungi, arbuscular mycorrhizal fungi, lichens, yeasts, chytrids.
- 8) Describe two distinct ways that fungi increase the productivity of terrestrial ecosystems.
- 9) Explain the general life cycle of fungi, including how sexual recombination is achieved.

### **Unit 10. Animals**

- 1) Be able to use the following words and phrases: diploblast, triploblast, tissue, epithelium, ectoderm, endoderm, mesoderm, asymmetry, radial symmetry, bilateral symmetry, cephalization, pentaradial symmetry, coelom, pseudocoelom, hydrostatic skeleton, protostome, deuterostome, gastrulation, exoskeleton, endoskeleton, internal fertilization, external fertilization, metamorphosis, water vascular system, pharyngeal gill slits, notochord, dorsal hollow nerve cord.
- 2) Be able to discuss the defining characteristics and phylogenetic status (mono-, para, or polyphyletic) of the following groups: Porifera, Cnidaria, protostomes, deuterostomes, pseudocoelomates, Annelida, Arthropoda, Platyhelminthes, Mollusca, Echinodermata, Chordata, vertebrates, invertebrates, fishes, amphibians, reptiles, birds, mammals.
- 3) Draw a simplified phylogeny of animals, including the following phyla: Porifera, Cnidaria, Platyhelminthes, Annelida, Mollusca, Arthropoda, Echinodermata, Chordata. (To make the task simpler, start at the top of the tree by putting phyla in major clades together, then join these clades, then fill in the basal groups). On this phylogeny, be able to map the origin of the following traits: 1<sup>st</sup> body axes, 2<sup>nd</sup> body axis, radial symmetry, bilateral symmetry, diploblasty, triploblasty, coelom, pseudocoelom, segmentation, protostome development, deuterostome development, notochord, pharyngeal gill slits.
- 4) Draw a phylogeny for the three major groups of eukaryotes that are multicellular. What is the evidence that multicellularity has evolved multiple times independently?
- 5) Draw a simplified phylogeny of deuterostomes, including the following groups: echinoderms, amphibians, lampreys, lungfish, ray-finned fishes, sharks, reptiles, mammals. Be able to map the origin of the following traits: cranium, cartilaginous skeleton, radial symmetry, pharyngeal slits, bony skeleton, vertebrae, jaw, lungs, limbs, amnion, endothermy, notochord.
- 6) What challenges for animals are associated with life on land? Discuss the evolutionary innovations within the vertebrates that are important for living and reproducing on land. Compare these changes to those seen in the colonization of land by plants.
- 7) Compare and contrast the major adaptations involved in the diversification of the three most species-rich animal lineages: arthropods, molluscs, and vertebrates.
- 8) Given a well-supported phylogeny, use the principle of parsimony and information about extant taxa to deduce the most likely states for various ancestral species in the phylogeny.