PRELIMINARY COMPREHENSIVE EXAMINATION

CONTENT: The Preliminary Comprehensive Examination is an oral examination primarily designed to ensure that the student has a broad knowledge of organismic and evolutionary biology. The student will be examined in the following subjects: general biology, evolution, ecology, and statistics. In addition students are expected to demonstrate familiarity with the principal questions, the working literature (e.g., journals) and the leading scientists central to their research, as well as show in-depth comprehension of the material covered in courses the student has already taken. Students whose main research interests lie outside of biology may petition the Graduate Program Director to substitute other general subjects for the exam. For example, students with a focus in Geosciences may request to substitute earth sciences for general biology. Successful completion of this exam qualifies a student to become a Ph.D. candidate.

Students seeking a joint degree must confer with the Graduate Program Directors of both programs during the exam planning process to assure that the requirements of both programs are being met.

A student is expected to have familiarity with areas central to his or her research, even if the relevant coursework is not yet completed. All students are expected to be familiar with the fundamentals of statistics, the working literature (e.g., journals) and leading scientists relevant to the discipline.

TIMING: Students normally take this exam by the end of the fourth semester in residence. Upon written request to the OEB GPD, students without previous graduate training in organismic and evolutionary biology (e.g., no M.S.) will be given one extra year to schedule the Preliminary Comprehensive Examination.

EXAMINATION COMMITTEE: The OEB GPD, after consultation with the Major Advisor and student, formally approves the Examination Committee by way of a memo to the student and the committee. The committee will consist of four members who are OEB Faculty. The other committee members may or may not be part of the student’s Guidance Committee. In order to reflect the breadth of training that OEB promotes, the committee will consist of at least one member outside the Major Advisor’s department. The OEB GPD will assign a moderator for the examination. The role of the moderator is to ensure that the exam is fair for the program and for the student. However, the moderator will not vote.

As part of the exam scheduling process, the student will submit to the OEB GPD a list of all relevant courses taken, including the dates and where completed. This information, as well as the general division of topics and the faculty member
responsible for each topic, will be specified in the memo sent by the OEB GPD approving the exam.

**SCHEDULING OF EXAM:** Once the Examination Committee is approved, the OEB GPD, in consultation with the student, schedules Preliminary Comprehensive Examination. It is the student’s responsibility to select a date for the examination at least four weeks in advance and to ensure that all members of the Examination Committee and the Moderator will be present. Do not plan to schedule prelims during final exam weeks or during intersession (including the period between the end of fall semester and the beginning of intersession), summer, or on a state holiday.

**EXAM AND RESULTS:** If a member of the examining committee cannot be present on the day of the exam, then the student may elect either to accept a substitute or to reschedule the exam. The usual structure of the exam is that it consists of an oral exam only, in which two rounds of questions are asked, with each committee member having 20 minutes for questions in each round. The committee may decide on an alternate structure, but it must contain a substantial oral component, and the student must be informed of the structure at least two weeks in advance.

Only the Examination Committee (not the moderator) will vote. Each member of the Examination Committee will vote on the student’s performance only on questions dealing with their own area(s) of expertise. The student passes with a unanimous positive vote or fails with two or more negative votes. In the event of one negative vote, the Graduate School will be informed that the student has passed, but no defense can be scheduled until any recommendations made by the Examination Committee have been completed. The Examination Committee may require additional coursework to strengthen the background of the student. Again, no defense can be scheduled until any recommendations have been completed. If the student fails, the Examination Committee may either: 1) terminate the student from the Ph.D. program, or 2) provide the student an opportunity to retake the entire exam or portions of the exam within six months.

Once the student passes the Preliminary Comprehensive Exam, the Moderator submits a memo to the OEB GPD indicating the results. The OEB GPD then submits a memo to the Graduate School with the exam results. It is student’s responsibility to verify that both memos are sent. The Dissertation Committee can be appointed once the student advances to candidacy.
OEB PRELIMINARY COMPREHENSIVE EXAMINATION GUIDELINES

Content

The Preliminary Comprehensive Examination is an oral examination primarily designed to ensure that the student has a broad knowledge of organismic and evolutionary biology. The student will be examined in the following subjects: Ecology Evolution General Biology Statistics

In addition, students are expected to demonstrate familiarity with the principal questions, the working literature (e.g., journals) and the leading scientists central to their research, as well as show in-depth comprehension of the material covered in courses the student has already taken. Students whose main research interests lie outside of biology may petition the Graduate Program Director to substitute other general subjects for the exam. This will be determined when scheduling the exam.

Examination Committee

The Examination Committee consists of four members, including at least one from outside the department of the student's major advisor. As part of the exam scheduling process, the student will submit to the OEB GPD a list of all relevant courses. This information, as well as the division of topics and the faculty member responsible for each topic, is specified in the memo sent by the OEB GPD approving the exam.

Moderator

The GPD will appoint a moderator for Preliminary Comprehensive Examination once the exam is scheduled. The role of the moderator is to ensure that the exam is fair for the program and for the student. The moderator will not vote.

Exam Structure

The usual structure of the exam is that it consists of an oral exam only, in which two rounds of questions are asked, with each committee member having 20 minutes for questions in each round. Committee members will ask questions on their assigned topic. The committee may decide on an alternate structure, but it must contain a substantial oral component, and the student must be informed of the structure at least two weeks in advance. If a member of the examining committee cannot be present on the day of the exam, then the student may elect either to accept a substitute or reschedule the exam.

Results

Only the Examination Committee will vote. Each member will vote on the student’s performance only on questions dealing with their own area(s) of expertise.

Vote

1) The student passes with all four members of the Examination Committee voting "pass".
2) The students fails with two or more negative votes. If the student fails, the Committee may either:
   • provide the student an opportunity to retake the all or portions of the exam within 6 months
   • terminate the student from the Ph.D. program
3) In the event of one negative vote, the graduate school will be informed that the student has passed, but no defense can be scheduled until any recommendations made by the committee have been met. The Examination Committee may require additional coursework to strengthen the background of the student. Progress on these recommendations will be checked at Graduate Reviews.

Once the student passes the Preliminary Comprehensive Exam, the Moderator submits the results via memo to the OEB GPD indicating the outcome. The OEB GPD then submits a memo to the Graduate School with the exam results.
DATE: ____________________________
FROM: ____________________________
(MODERATOR)
TO: OEB Graduate Program Director
SUBJECT: Results of Preliminary Comprehensive Exam

STUDENT: ____________________________
DATE OF EXAM: ____________________________
EXAMINATION COMMITTEE

__________________________________________
__________________________________________
__________________________________________
__________________________________________
MODERATOR ____________________________
RESULTS: _______PASS _______FAIL
RECOMMENDATIONS:

__________________________________________
__________________________________________
__________________________________________
__________________________________________

__________________________
Moderator's Signature
ANNOUNCEMENTS The research of Ethan Temeles, OEB faculty member from Amherst College, was featured on a recent Science cover.

Several OEB students have had good news recently. Three students received NSF DDIG’s (Eben Goodale, Elijah Goodwin, and Andrea Ward). Two students were awarded Current Student Graduate School Fellowships (Manny Azizi and Joanna Grand). Elijah Goodwin received a Graduate School Mentoring Grant. Congratulations to all.

The call for proposals for a NSF Center for Synthesis in Biological Evolution (CSBE) has gone out. Preproposals are due September 17, with full proposals due February 1, 2004. Beth Brainerd and Peg Riley are heading the team working on the preproposal.

ORAL EXAMS The ad hoc prelim committee (M. Coombs, B. Dumont, B. Jakob) prepared and distributed a questionnaire to OEB faculty, postdocs and students in early May. On May 16, a productive all-OEB meeting on oral exams was held to discuss the responses. The results indicate that there is no clear consensus for changing the current exam format. Brainerd suggested that rather than instituting a change in policy, that we instead create tools designed to help both students and faculty prepare for the exam. One problem that has been observed is that students are not beginning their preparation when they start their graduate training but rather when they start their fourth semester. Several suggestions that do not require Steering Committee approval will be acted upon now, specifically: 1) compile a list of questions asked at each exam and 2) generate a reading list to guide students in their preparation. A discussion followed on whether to change the GENERAL BIOLOGY category to ORGANISIMAL BIOLOGY, and to make this flexible by mutual consensus. No decision was made, but the prelim committee was asked to create a list of areas to be included under this category and bring it to the next Steering Committee meeting for further consideration. There were also asked to begin development of the two tools listed above.

OEB ASSOCIATE DIRECTOR AND COMMITTEE ELECTIONS Steve McCormick was nominated and elected unanimously to a three-year term as Associate Director/Graduate Program Director. He will replace Todd Fuller who served as interim director for the spring semester. Steve is a physiologist at the Conte Fish Lab in Turners Falls, and has held adjunct status in both the Biology and Natural Resources Conservation departments for 12 years. He has served on the OEB Steering Committee, has chaired both the Seminar Committee and the most recent Darwin Fellow Search Committee, and has trained graduate students in OEB, Biology and NRC.

Francis Juanes was appointed head of the Seminar Committee to begin in the fall. He replaces Peter Alpert who has ably chaired the committee for five years. Thanks to Peter for a terrific job.

A Steering Committee election will be conducted by email before the end of May.
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<td>Byers</td>
<td>Richmond</td>
<td>McGangal</td>
<td>Jakob</td>
<td>✓</td>
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<tr>
<td>Jin Wu*</td>
<td>9/25/08</td>
<td>Adler</td>
<td>Normark</td>
<td>Porter</td>
<td>Sievert</td>
<td>Coombs</td>
<td>✓</td>
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<td>Tom Eiting</td>
<td>11/15/08</td>
<td>Adler</td>
<td>Byers</td>
<td>Ours</td>
<td>Coombs</td>
<td>Irshick</td>
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<tr>
<td>Holly Hernandez*</td>
<td>12/10/08</td>
<td>Adler</td>
<td>Byers</td>
<td>Podos</td>
<td>Sievert</td>
<td>Katz</td>
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<tr>
<td>David Hof</td>
<td>12/10/08</td>
<td>Irshick</td>
<td>Byers</td>
<td>Podos</td>
<td>Sievert</td>
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<td>Rachel Elder</td>
<td>1/9/09</td>
<td>Adler</td>
<td>Podos</td>
<td>Byers</td>
<td>Sievert</td>
<td>Lesher</td>
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* Joint degree student
Statistics (Brainerd)
- What is the difference between standard deviation and standard error? What do each tell you about the data?
- Describe a data set from your own research. How do you measure variance between species or individuals?
- How do you determine if values measured for your data are different across species?
- If you do an ANOVA and the result is significant how do you determine which groups are significantly different?
- What kind of test is this?
- Why is p=0.05 the standard level for determining significance of a data set?
- How do you determine power in a statistical test?
- What is the difference between Type I and Type II error?

Evolution (Normark)
- What is the origin of birds?
- What characteristics do they have in common with their closest fossil and living ancestor?
- When Darwin came up with his theory of sexual selection, how did he explain the elaboration of male traits (e.g., did he think that traits were honest signals)?
- How did Fisher explain the elaboration of traits in males?
- When/how did additional theories of sexual selection arise?
- What do you think is the predominant mechanism underlying sexual selection: honest signals or chase/run away? (Brainerd)
- How would you define a species?
- Why/how is that definition problematic in Darwin's finches?
- What levels of genetic diversity would you expect on islands versus mainlands? Compare this to previous discussions of song and morphological diversity?

Ecology (Jakob)
- What kind of information is presented in a life table?
- Draw a curve that determines population growth. What equation explains that curve?
- How does/can behavioral data related to models of logistic growth?
- How might behavior affect ecological processes on a large scale?
- For what are the following people know (choose 4 of the 5 for each group):

  Group A
  **Superstars**
  E. O. Wilson
  W. D. Hamilton
  John Maynard Smith
  Wynne-Edwards
  ???

  Group B
  **Behavioral Ecologists**
  John Krebs
  Ellen Ketterson
  Charles Wolcott
  Stephen Emlen
  Anders Moller

  Group C
  **Random Scientists**
  Steve Lima
  ? Schoener
  ? McClintock
  Parker (any Parker)
  ???
General Biology (Podos - advisor)

- The title of your research interests is "Morphological Constraints on Avian Signal Evolution." What do you mean by this? Start by defining what signals are and how they are used.
- (Jeff brought a tuning fork and "thwacked" it to make a sound) Explain to me what is happening when I strike this tuning fork. How is sound being produced?
- How is sound, a physical wave, transferred into "meaning" for an organism?
- What are the major properties of acoustic signals that are measured and quantified by researchers? How are they calculated?
- Based on the three graphs you drew to answer the above question, draw the signal produced by this tuning fork.
- (Jeff played two bird songs: Song Sparrow and Swamp Sparrow) I am going to asked you the same question from two different perspectives about these two songs. How did the birds learn this song?
- First from the proximate perspective. Describe the process of song learning in a bird.
- If we knew everything about the neural substrate of a bird brain, could we predict the song that it would learn? Explain.
- Now from the ultimate perspective. How did these two birds (which are sister species) learn such different songs (i.e., how do songs evolve)?
(These are most of the questions I was asked, I think! They're grouped by subject, and only sometimes in any sort of order)

Committee: Stats (Bruce Byers), Ecology (Ben Normark), Evolution (Jeff Podos), General Bio. (Beth Jakob).

Stats:
1. How would you design an experiment to test the relationship between plumage brightness and mate choice in, say, Chestnut-sided Warblers?
2. What statistical test would you use to analyze these data?
3. What is the difference between regression and ANOVA?
4. What is meant by the terms statistically and biologically significant?
5. What is the statistical interpretation of a P-value?
6. How do you calculate statistical power?
7. What is pseudo-replication? How do you avoid it? How do you determine how many samples you need?

Ecology:
8. What is a niche?
9. Describe the niche of your study organism (habitat, food sources, feeding methods...).
10. What are your organism’s main competitors?
11. How important is competition in maintaining the spacing patterns of your organism within suitable habitat?
12. What is competitive exclusion? Do you see evidence of it in your warblers? What would evidence look like? (this lead to adaptive radiation questions in evolution section)
13. How would you describe human population growth through time? (discuss exponential and logistic growth)
14. How would you determine how many species live in the Amazon Basin? (discuss species-area curves)

Evolution:
15. What is an adaptive radiation?
16. What are the features of an adaptive radiation? (discuss features and evidence)
17. Define communication.
18. What are the different ways that organisms communicate?
19. Is it still communication if only the sender and not the receiver benefit?
20. Are birds dinosaurs?
21. How do we know (that birds are dinos)? (discuss evidence and chronology)
General Bio:
22. Why does your heartbeat sound like “flub-dub”? 
23. Which animals have 4-chambered hearts? What do others have? 
24. Building on what you said, why have four chambers, separation of oxygenated blood, ect.? 
25. Do inverts have hearts, describe insect circulatory systems…respiratory systems… 
26. Why do you “see” starts when you bang your head? 
27. Describe a neuron, how it works, action potential…which ion rushes out? 
28. Why are many people afraid of snakes even though very few people are actually hurt by them? (everybody jumped in on this one) Are people evolving? What about in underdeveloped parts of world? 
29. How would you describe yourself/your field as a scientist/in science? 
30. Name four other field of science that border your field (behavioral ecology)and are affected by it, could learn something from it? How? Give examples of each.

Preparation Advice: 
If you’re reading this, then I bet you’re preparing for your prelims…a few books I thought anybody might find helpful-

Song of the Dodo (David Quammen) is a fun place to start and has lots of good historical ecology and evolution info. as well as cool interviews with mini biographies of some important and/or interesting folks.

The Ant and the Peacock (Helena Cronin) has well-written accounts of Darwin and Wallace and modern explanations of sexual selection and altruism (more important for people interested in these topics, but useful for anyone).

Foundations of Ecology (Leslie Real and James Brown) is a big collection of historically important papers w/commentary placing them in context- read the commentaries and the papers of interest...

Primer of Ecology (Nick Gottelli) Super-clear treatment of population models, and it’s short!

Other stuff I found helpful- I made a time-line of people, dates and ideas (not that anyone asked me about them, but they may ask you!) And Campbell’s “Biology” text really is good, as well as Futuyma’s detailed “Evolutionary Biology”. Good Luck!
Here are some of the topics covered during my comprehensive examination.

**Ecology:** (Ben Letcher)
Population models beginning with simple (exponential growth) to complex (individual based models)
Other models covered: logistic growth, predator-prey, interspecific competition, Leslie matrices

**General Biology:** (Francis Juanes)
Bioenergetics, Animal communication mechanisms, Osmoregulation

**Statistics:** (Kevin McGarigal)
Experimental design, Power analyses, Manipulative vs. Mensurative experiments,
Basic definitions: Parameter, Statistic, Standard Error, Inferential Statistics
Types of Anova designs and their assumptions

**Evolution:** (Willy Bemis)
Drawing cladograms, Life history strategies, Evolutionary significance of exotic species introduction and experimental design to answer pertinent questions
Prelim Exam Questions for Michelle Monette

Statistics (Steve McCormick):

• Draw two sampling distributions (say of heights) one with high variability and one with low variability.
• What are some measures of variance that we use in statistics?
• What is heteroscedasticity?
• What exactly are we measuring when we do a t-test or an ANOVA?
• What are Type I and Type II errors?
• What is pseudoreplication? Give an ecological example.
• What type of statistical test would you use when you are looking for the effects of temperature, time, and size on plasma cortisol levels of angled rainbow trout?
• What do you do when you have two variables, say time and size that are related? Have you violated an assumption of your statistical test?
• What is the significance of \( \alpha = .05 \)? When you use this significance level in a statistical test what is your chance of committing a Type I error? (Tom Zoeller)

Evolution (Jeff Podos):

• What is the distinction between microevolution and macroevolution?
• What is Evo/Devo and does it fall under micro or macroevolution?
• What do we use to measure evolution?
• Based on what defining characteristic do we group taxa?
• What is a synapomorphy?
• Give an example of an evolutionary relationship that was clarified after the implementation of cladistics.
• What is phenetics and how does it differ from cladistics? When did the discipline of cladistics come about? What are some of the problems with phenetics?
• What was Darwin famous for?
• What was the Neo-Darwinian synthesis?
• What is population genetics? Is population genetics the same as quantitative genetics?
• Give an example of natural selection. What is the controversy of industrial melanism?
• How would you defend the theory of evolution against the theory of creationism? How would you convince a supporter of creationism that natural selection exists?
• How has the complexity of the vertebrate eye evolved through natural selection?

General Biology (Tom Zoeller):

• How do you test the seawater tolerance in the lab? What parameters do you measure?
• How does an osmometer work? What are its units?
• What is the difference in osmolality between fish plasma and full strength seawater?
• Are there respiratory effects of acid/Al exposure? Or only osmoregulatory? If so, how are they occurring, what are the mechanisms?
• What is actually killing a fish when they die of osmoregulatory failure?
• Does plasma pH decrease during acid/Al exposure? And if so, is there a Bohr effect? What is a Bohr effect, draw it on the board?
• What role do binding proteins play in controlling hormone dynamics?
• What is cortisol? What type of hormone is it and what are its actions? What is the name of its binding protein?
• How does a steroid hormone get into a cell and exert its action?
• Is an unliganded steroid hormone receptor active, if so, is it causing the activation or repression of transcription?
• How many and what kind of cortisol receptors do fish have?
• What happens to a hormone after it is used by its target tissue? Is it broken down into waste products?
• Do fish have mineralocorticoids like mammals? If not, do they have a hormone that acts as a mineralocorticoid?
• What are the effects of thyroid hormone on metabolic rate? If someone has higher levels of circulating TH are they necessarily hyperthyroid?

Ecology (Martha Mather):

• What is ecology? How is the discipline of ecology important to your research?
• What other disciplines interact with ecology?
• What are some of the abiotic and biotic factors that influence the distribution of salmon in streams?
• If you were in a restaurant and you were given the choice of ordering wild salmon or farm-raised salmon which one would you choose and why? What are the consequences of choosing either?
• Discuss the problems with counting wild and hatchery-reared salmon as the same and discuss why you think the scientific evidence contradicting this decision was overlooked.
• Why do anadromous fish migrate? If anadromy is such a good life history strategy then why don’t all fish have it?
• In the past 10 years, what have been the major issues highlighted in the journals Science and Nature concerning salmon?
• What role does evolution play in ecology?
• What would you do if you were given all the money and time in the world to solve the Pacific Northwest salmon problem? What would your approach be to this task?

Things I did to study:

- Books Read:
  - Schmidt-Nielson’s Animal Physiology
  - Douglas Futuyma’s Evolutionary Biology
  - Gotelli, Primer of Ecology
  - Kachigan, Multivariate Statistical Analysis
  - Dolph Schluter, The ecology of Adaptive Radiation

- Met with or discussed the exam with my committee members
- Had a practice exam with my advisor and his post-doc
- Made a timeline of the development of evolutionary theory
- Practiced drawing the evolution of vertebrates
- Practiced answering questions with another OEB student and myself
- Tried to anticipate questions and tried to think about the big picture when studying concepts
Normark asked for a description of Taft’s dissertation research.

Round 1:

Podos:
- Define evolution.
- What is the evidence for evolution?
- What are the criteria for homology?
- What is ontogeny?
  - Does ontogeny always involve learning?
- How does a single cell develop into a complex organism; particularly in the early stages (Jeff was looking for a discussion of gene expression here)
- What is the relationship between evolution and development?
  - How is developmental biology important to an evolutionary biologist?

Alpert:
- Would it matter if tree swallows disappear?
- Would change in the community of cavity-nesting birds have ecosystem effects?
- What are the ecological consequences of high and low ecosystem diversity?
- How does ecological diversity affect productivity?
- If productivity increases, what happens to diversity?
- How do *Tachycineta* swallows differ in different habitats?
- How do plants and animals differ in their habitat requirements?
  - How do they differ in their nutrient requirements?

Normark:
- How is homology assessed?
- What are micro- and macroevolution?
- Is speciation a different process from gene frequency change; i.e. is it micro or macroevolution?
- Are there different levels of selection (gene, individual, group)?
  - Which levels are important?

Elkinton:
- Scenario: You want to examine the relationship between mosquito abundance and tree swallow nesting rate. You set out four different colors of insect trap, and want to compare how effective they are at catching skeeters.
If the following table is a summary of your data, what can you say about the traps?

<table>
<thead>
<tr>
<th>Color</th>
<th>Count</th>
<th>+/-</th>
<th>Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow</td>
<td>55</td>
<td>+/- 15</td>
<td>a</td>
</tr>
<tr>
<td>White</td>
<td>37</td>
<td>+/- 10</td>
<td>ab</td>
</tr>
<tr>
<td>Blue</td>
<td>27</td>
<td>+/- 5</td>
<td>b</td>
</tr>
<tr>
<td>Red</td>
<td>7</td>
<td>+/- 2</td>
<td>c</td>
</tr>
</tbody>
</table>

What is the difference between a standard error and a confidence limit?
What does an ANOVA tell you?
What is the appropriate way to test if the different colors have different effects at different sites?
Draw a graph of the relationship you would expect between mosquito abundance and tree swallow nest occupation rate.

Round 2:

Podos:
How do moths avoid being eaten by aerial insectivores?
Describe echolocation.
How do moths hear?
Describe the physical and cellular events in hearing.
What are the inter- and intracellular events in sensory transduction?
Describe how neurons transmit signals.
What is sound?
Describe the graphical and mathematical representations of sound used by behavioral biologists.

Alpert:
Is ozone good?
How do animals protect against ozone?
What is the effect of solar radiation on organisms?
How do greenhouse gases work?
What kinds of ecological interactions can be demonstrated/studied in birds, and what kinds cannot?

Normark:
How do living things deal with (or counteract the negative effects of) mutation?
How does DNA damage differ from mutation?
Does sexual reproduction affect mutation?
How many mutations are present in germ cells in an individual human?
How many are neutral?
How many correspond to coding regions?
Are mutation rates optimal or minimal?
Give a brief description of the evolution of birds.

Elkinton:
Describe the bootstrap?
What is the value of the bootstrap in regression and in phylogenetic systematics?
Preliminary exam questions for Erika Parker:

Exam date: March 4, 2005

Committee: Ben Letcher Statistics
Boyd Kynard Ecology
Beth Brainerd General Biology
Willy Bemis Evolution
Jeff Podos Moderator

Statistics:
(1) What is a probability distribution? Name five. What are probability distributions used for in statistics?
   Draw the standard normal distribution and label the axes. What are the parameters of this distribution? What happens to the curve when you change these parameters?
   Why are so many statistical tests based on the normal distribution?
   Draw two normal distributions that you would like to compare. What does a t-test do?
   What does alpha = 0.05 mean? What is a p-value? Draw the two curves we are comparing so that p = 0.06 and so that p = 0.04.
   Draw a Poisson distribution. What is it used for?
(2) What are some statistical methods used for phylogenetic analyses?
   What is parsimony? (Bemis)
   What are Monte Carlo methods? (Bemis)
   What is the difference between a bootstrap and a jackknife?
   What are multivariate statistics? What are they used for? Do they test hypotheses?
   What is a cumulative distribution function? Draw one. Using calculus, how do you go from a probability density function to a cumulative distribution function? How do you go from a CDF to a PDF?
   How do we determine the abundance of a population of animals?

Ecology:
(1) What is ecology?
   What is behavioral ecology?
   Tell me about the history of ecology. How did it get started?
   Who were some of the pioneers of the study of ecology?
   What topics were most important to early ecologists?
   What topics are most important to ecologists today?
   Who are some of the big names in ecology today?
(2) What are some principals of ecology demonstrated by studies of sticklebacks?
   (We had a discussion of migration – I can’t remember the exact questions.)
   (Ditto for water temperature and habitat selection of fishes.)
   What are pheromones? How do they relate to ecology? Would you expect pheromones to be large or small molecules? Why? (Kynard)
   What commercially important, non-mammalian pheromone was recently discovered? (Letcher)
   What are the advantages and disadvantages of field and laboratory studies of habitat selection?
General Biology:

(1) Define osmoregulation.
If you take a marine fish that can’t osmoregulate in fresh water – a stenohaline marine fish – and put it into fresh water, it dies. What happens? What actually kills the fish (on a cellular level)? What about a freshwater fish in sea water?
In fishes that can osmoregulate in both fresh and salt water, what physiological changes occur when the fish moves between the two habitats?
How do the kidneys of freshwater fish and marine fish differ?
We’ve discussed the kidney’s role in osmoregulation. What else do kidneys do?
What chemical compounds do animals use to excrete metabolic wastes? Which is more toxic, ammonia or urea? Which one do fishes use? How do they excrete it?
Where in the body are these nitrogenous waste compounds formed?
How does QTL mapping work?
When you narrow down a trait to a particular region of a chromosome, then what can you do to try to assign a specific gene or genes to that trait?

(2) What is lift and what causes it? What are some properties of an airfoil that affect how much lift it can produce?
How do fishes generate lift? How do fishes use lift? How is it advantageous to have a tail that generates lift?
What is drag and what causes it? What adaptations do fishes have for reducing drag?
How does having a roughened surface reduce drag?

Evolution:

(1) Draw a cladogram that includes hagfishes, lampreys, Chondrichthyes, Actinopterygii, and Sarcopterygii.
About half of all vertebrate species are in the first four groups; the rest are Sarcopterygians. Roughly how many vertebrate species are there? How many species are in Chondrichthyes?
Now draw the cladogram again and expand the group Actinopterygii to show several basal clades and Teleosts.
(Hands me a hammerhead shark tail skeletal preparation) What can you tell me about this tail? What order of fishes is it?
Put heterocercal tails on your expanded cladogram. Are the heterocercal tails of sturgeons and paddlefishes plesiomorphic or apomorphic?
That tail clearly shows two synapomorphies of Chondrichthyes. What are they?
(Hands me a tarpon tail skeletal preparation) Orient this tail dorsoventrally as it would be in the living animal. What can you tell me about this tail? What species is it and how do you know?
Returning to the cladogram…Draw some small trees with the possible groupings of gars, bowfins, and teleosts. All of these are considered correct by some biologists and there is support for all of them. How do you decide which tree is more correct? Can you ever know what all the intermediate taxa looked like?

(2) What is the difference between microevolution and macroevolution?
Who are some recent big names in macroevolution?
What do you know about evo-devo? Why do you think it is such a big deal right now?
Who said “ontogeny recapitulates phylogeny” and when?
This idea fell out of favor fairly soon after it was introduced, but periodically someone revives it and defends it vigorously. Why do you think this happens? Who was a recent and vocal proponent of this idea?

What do you think of fads in science? Why do they happen? Do they encourage or impede progress?

What I did to prepare:
- Met with committee members to discuss what I should know and what I should read
- Talked to other students who had completed their exams
- Discussed topics like osmoregulation and biomechanics of swimming with others who know a lot more about these topics than I do – this really helps
- Practiced answering questions with other OEB students

Materials I used to prepare:
- Biometry, Sokal & Rohlf
- Animal Physiology, Eckert et al. (Schmidt-Nielsen’s Animal Physiology is good too)
- Developmental Biology, Gilbert
- Life in Moving Fluids: The Physical Biology of Flow, Vogel
- Quantitative Genetics, Falconer & Mackay
- Vertebrate Life, Pough, Heiser, & McFarland
- Functional Anatomy of the Vertebrates, Liem, Bemis, Walker, & Grande
- An Illustrated Guide to Theoretical Ecology, Case (Gotelli’s A Primer of Ecology is another good reference for the use of mathematical models in ecology)
- Ecology, Ricklefs
- Ecology of Teleost Fishes, Wootton
- Behaviour of Teleost Fishes, Pitcher
- Behavioural Ecology: An Evolutionary Approach, Krebs & Davies
- Evolution, Futuyma
- Principles of Conservation Biology, Meffe & Carroll
- My class notes from Ichthyology, Ecological Genetics, Multivariate Statistics, and BioEpi 640
- Rennie, J. 2002. 15 answers to creationist nonsense. Scientific American. July 2002, pp. 78-85. (The title is a bit harsh, but I recommend the article. It’s just one of many good publications about ways to defend evolution to a creationist.)
Ben Taft - Prelim Exam

description of thesis project
how individual variation affects fitness

1. Bird song has substantial variation
tree swallows not examined for song, though much is known about their ecology
high rates of phylogeny

2. Evidence that they learn local song

Widely ranging species
Studies on song in sympathy vs allopatry

Tree & green swallows exist in same sites

---

Jeff

Define Evolution
What is the evidence for Evolution
What are the criteria for homology
What is ontogeny
VCs ontogeny always involve learning
How does a single cell develop into a complex organism; particularly the early stages (1-4 cell
relationship between evolution, ontogeny & development, [van Brees]

Peter would it matter if tree swallows disappear
Would change in nest cavity bird species composition
has ecosystem effects

Ecological consequences of more or less diversity?

Diversity affects productivity.
2:40  Is ozone good?
How do animals protect against ozone?
What is the effect of solar radiation on organisms?
What kinds of animal/plant interactions can be demonstrated by birds, and what can't?

How do greenhouses work?

Bir 05:20:50

What do living things deal with mutation?
How does DNA damage differ from mutation?
Does sexual reproduction affect mutation?
How many mutations are present in germ cells in each generation?

How many are neutral?
Correspond to coding regions?
Are mutations role minimal or optimal?
Evolutionary history of birds

3:05  What is the value of bootstrapping?
- in regression analysis
Exam for Annie Paradis
19 Oct 2005
Committee: Joe Elkinton (ecology)
           Ben Normark (evolution)
           Paul Sievert (stats)
           Adam Porter (general bio & entomology)

Ecology

What pattern of dispersion do you see in adelgid within trees and hemlock stands?

What are some commonly used indices of dispersion, and how do you test them statistically?

What is Taylor’s power law?

What is sequential sampling and how does it work?

Are adelgid populations regulated? What is meant by ‘regulate’?

Is there evidence of density dependence with respect to overwintering mortality in adelgid? How can you test this? What is a key factor?

What are Allee effects?

Why do populations cycle? Give examples. How do you test whether or not cycles exist?

What is a random walk?

Evolution

(I was given a tree topology with adelgidae labeled) Label the rest of the branches. What are the closest relatives of adelgid?

What do you know about coalescent theory?

What is lineage sorting?

What is the typical fate of asexual lineages? What are the costs of sex? How is sex maintained?

What is the Hardy-Weinberg equilibrium and why is it important? Does it apply to asexual species?
Do gene trees always agree with species trees? Why or why not?

Discuss two significant events/ideas in the field of evolutionary biology in the 20th century. How did they change the way we think about evolution?

What was Fisher’s contribution to the modern synthesis?

What is the most commonly used definition of a species? Can you use the biological species concept for adelgid? Which concept would you use?

What is sympatric speciation? Why is it controversial?

**General biology & entomology**

What are the differences between predators, parasites, and parasitoids? Give an insect example of each. What Order and Family are the examples you just gave members of?

Tell me about the mating system of Cimicidae (bed bugs).

Why don’t insects get cancer?

How long do insects live? What insect has the longest life span?

How do insects deal with the problem of water loss? What adaptations do desert insects have for dealing with dry climates?

What molecular tools would you use in a population level (intraspecific) study?

How are microsatellites developed? Where are microsatellites found? How are AFLPs developed? Can you detect heterozygosity with AFLPs? With microsatellites?

How many genes should you use to build a phylogeny?

What maintains the ‘shape’ of cells?

What happens to cells when they freeze and how do insects deal with the potential for this problem in cold temperatures?

**Statistics**

What is a statistical population?

Describe the scientific method. What is a null hypothesis? Is null hypothesis testing ‘going out of fashion’?
What is the central limit theorem and why is it important?

When would you use regression vs. ANOVA?

What are the assumptions of multiple regression? Which is most important? How do you determine whether your data meet these assumptions?

If your data do not meet the assumptions of a statistical test such as ANOVA, what are your alternatives?

What are outliers and how do you deal with them?

(Given an example) What is the appropriate design for this experiment? What is the difference between repeated measures and randomized complete block designs?

When you are finished with your studies on adelgid in Connecticut and Massachusetts, will you be able to infer anything about adelgid populations in Maine?
Mike Jones  
12/11/06

Committee:  
Paul Sievert, Major advisor – Statistics  
Bruce Byers – Evolution  
Al Richmond – Bio  
Todd Fuller – Ecology

Paul/Statistics

1.) What is the Central Limit Theorem?  
2.) What do 95% confidence intervals tell you? Why are the 95% confidence intervals of a regression line concave?  
3.) Discuss frequentist statistics, R. A. Fisher, p-values, hypothesis testing.  
4.) How do you interpret a p-value of 0.051?  
5.) What are the assumptions of linear regression?  
6.) What are the assumptions of ANOVA?  
7.) How is multiple regression abused?  
8.) How do you test for multicollinearity? What can you do if your predictors have multicollinearity problems?  
9.) What is tolerance and how is it calculated?  
10.) When would you use multiple regression?  
11.) Discuss structure, applications, and limitations of Bayesian analysis.  
12.) Compare: Randomized complete block, completely randomized ANOVA  
13.) Compare: Randomized complete block and repeated measures ANOVA  
14.) What are the assumptions of RCB and RM ANOVA?  
15.) What is an F-ratio? How is it calculated for ANOVA & regression?  
16.) Define: statistical population

Al/General Biology

1.) Describe the 4-step process through which cells divide.  
2.) What are the five kingdoms?  
3.) What are the 3 domains?  
4.) What is the difference between hibernation and brumation?  
5.) Physiologically, what happens when a turtle hibernates?  
6.) How does a turtle mitigate lactic acid build-up during hibernation?  
7.) What are proctists?  
8.) Trace a drop of blood from the inferior vena cava to the aorta.  
9.) How does protein synthesis work?  
10.) Why are we warmblooded? By what mechanisms? For what evolutionary purpose? What causes homeothermy?  
11.) Are the zygapophyses of a tuna homologous to our zygapophyses?  
12.) What is this? (Eggshell of Aepyornis, very large egg).
13.) What are the differences between the prokaryotes and eukaryotes? Describe the inside of a prokaryotic cell.
14.) What is neural crest? What structures are derived from neural crest?

Bruce/Evolution
1.) Draw a phylogenetic tree, indicating the evolutionary origin of turtles.
2.) How are phylogenies built?
3.) What are synapomorphies?
4.) What are shared ancestral characters called?
5.) How would you identify whether a trait is ancestral or derived?
6.) What is homology? How can you tell if structures are homologous?
7.) What synapomorphies are shared between turtles and their sister group?
8.) What is an adaptation? How can you tell if a trait is adaptive? How can you test whether a trait is adaptive?
9.) How do molecular clocks work? How are molecular clocks calibrated? Where in the genome would you look to estimate the divergence time of two related species?
10.) What molecular techniques are available to determine the distances between a.) species b.) populations c.) individuals

Todd/Ecology
1.) Are there maladaptive traits? (following up Bruce’s question)
2.) How do turtles:
   a. Disperse?
   b. Migrate?
   c. Find each other
   d. Socialize
   e. Reproduce
   f. Orient? Do they have map or compass sense?
3.) Describe some ways that many ecological studies set up incorrectly? What is one way that studies are analyzed incorrectly?
4.) Why do turtles have shells?
5.) Who wrote the landmark paper on pseudoreplication?
6.) How could you “mark” hatchling turtles at the nest to find out where they disperse?
7.) Why do some turtles a.) live a long time; b.) lay a lot of eggs?
8.) Can turtles smell?
9.) What is a good r-squared value? While are low r-squared commonly reported in ecology?
10.) What ecological factors vary with the size of the organism? How do trophic dynamics affect the abundance of large organisms?
Kate Jenks
OEB Comprehensive Exam
19 January 2007

Committee:
Todd Fuller (Major advisor; Biology)
Bruce Byers (Evolution)
Curt Griffin (Ecology)
Paul Sievert (Statistics)

General Biology:
1. Name and describe different types/strategies of reproduction
2. Describe the entire process of digestion
3. What adaptations do animals have for feeding?
4. Digestive tract differences between herbivores and carnivores
5. What is nutrition? What are the major components of food?
6. How does nutrition affect population parameters?
7. How does nutrition affect egg growth and stages of reproduction?
8. Name prominent evolutionary biologists/ecologists.

Evolution:
1. Why are deleterious alleles present and maintained in populations? Example?
2. List important symbiotic mutualisms. Describe each symbiotic relationship and what makes it ecologically significant.
3. Describe the roles of prokaryotes in cycling of carbon and nitrogen.
4. How does nutrient cycling differ in terrestrial versus aquatic ecosystems?
5. How does nutrient cycling differ in temperate and tropical systems?
6. Definition of a species and the conservation implications of using different definitions.
7. Why are there many studies on whales and bird vocalizations, but very few on canids?
8. What is adaptive radiation?
9. Sympatric versus allopatric speciation
10. Describe the conditions you would expect to occur for a speciation event
11. Draw a graph of the frequency of a deleterious allele in a population; explain

Ecology:
1. What are the four provisions of the U.S. Endangered Species Act?
2. What are habitat conservation plans (HCPs) and how would you design one?
3. How are thresholds of population size for an endangered species determined?
4. What are the pluses/minuses of HCPs?
5. Describe Population Viability Analysis
6. Genetics of small populations; and examples of populations with low genetic diversity
7. What influences effective population size?
8. What is the 50/500 rule?
9. How do you incorporate demographic and environmental stochasticity into a stage-based population model?

10. Metapopulation definition and models

11. Discuss Minimum Convex Polygons and Kernel Estimators for home range analysis

Statistics:
1. What is a null hypothesis?
2. What is an ANOVA?
3. What is an F-ratio? How does it come into play with ANOVA?
4. What is the difference between a Type I and Type II Model?
5. What is the difference between a Type I and Type II error?
6. What is the Central Limit Theorem?
7. What is a linear regression most often used for?
8. How do you choose between regression models?
9. Is there anything wrong with step-wise regression?
10. What is an r² value?
11. Discuss Frequentist statistics, p-values, why is it going “out of fashion”?
12. Basic assumptions of Frequentist statistics
13. What makes a good sample design?
14. Difference between simple random sampling, stratified sampling, adaptive sampling
15. In Frequentist statistics, what is a 95% confidence interval?
16. Discuss the limitations of Bayesian analysis
17. How are priors incorporated into Bayesian analysis?
18. What parameters do you need to know to do a power analysis?
STATISTICS
What is the statistical population?
How does a researcher choose the population of a study? What are you able to make inference about?
What is the current debate about hypothesis testing? Where do you fall?
Discuss the differences between Frequentist and Bayesian statistics. Why is Frequentist more popular? Which is older?
When do people use power analysis? Is the equation for power the same for all tests?
What is effect size? How does a researcher calculate it?
When would you use an ANOVA versus Regression? Which test allows you to make stronger inference?
If you had many possible predictor variables for a linear regression, how would you choose the variables for the final model?
What are potential problems with forward, backward, stepwise methods?
Why can't you compare different models with the r^2? What does the adjusted r^2 account for?
If you had a student that had done multiple testing and had a few significant results and many non-significant results, what would your comments/concerns be?
When do you use Logistic regression? What does logistic regression predict?
What is a parameter? What is the difference between a parameter and a test statistic?
Why would you use a repeated measures design?
What are the assumptions of parametric statistics? Which are the most important? What would you do if you did not meet the assumptions?
What is a non-parametric test you might try?
What is the central limit theorem? Why is it important?

EVOLUTION
What is an adaptation?
How do you define fitness? How do you measure fitness?
How do you test to see if something is an adaptation?
How do you make sure that your experiment is testing for the effects of the trait of interest?
What is homology?
What is the difference between a derived and an ancestral trait? Draw a tree and explain how why derived traits are used for phylogenies.
Define sexual selection? Why might sexual selection be stronger in a population with large variance in reproductive success?
Is there sexual selection in plants? Give an example.
Why are deleterious alleles are maintained in populations?
Outline the evolution of land plants. Include time periods if you want. What are key adaptations? What did they allow for?
Why might wind pollination have re-evolved in flowering plants?

ECOLOGY
Define physiological ecology, population ecology, community ecology, and ecosystem ecology. What are questions you might ask, and things you might measure for each? How does your research address each?
Draw and explain the nitrogen cycle.
What is the basis behind hypothesis that non-native plants that are un-like the native community are more likely to become established?
Does that mean a hemlock stand is vulnerable to invasion?
What is complementary resource use?
Why does nutrient availability increase following a disturbance?
What is the enemy release hypothesis?
Would you expect competition stronger between a native and an introduced species, or two natives?
What is a potential explanation for why we usually do not see more intense competition between native and introduced species?

GENERAL BIOLOGY
How do plants grow towards light? Why is that adaptive?
If I bore a hole into a certain type of tree (I can’t remember the species) water that is under pressure will shoot out of the hole. Why?
What is genomics?
How do people identify the coding region of DNA for specific traits?
What is the difference between breeding and genetic engineering? Some people are against genetic engineering. Why? What is your opinion?
What should every undergraduate know about biology to graduate?
What should students know about cell structure?
How old is life? What was the first life?
Does all life need water? What is water needed for?
Do plants have pheromones?
What is a pheromone?
What are the differences between plants and animals?
Prelims Questions:
Student: Zhiyi Sun
Date: June 1 2007
Exam committee:
Jeffrey Blanchard General Biology
Adam Porter Evolution
Curtice Griffin Ecology
Stephen McCormick Statistics

General Biology:
1. Draw the tree of life on the board as you see it. If you have a mitochondria genome sequence, where would it most likely be in the tree? What about chloroplast?
   Is it a rooted or unrooted tree? If I want to know the root, how can I do? Why tRNA genes were used to infer the root of the tree?

2. What is the Gene Ontology? How is Gene Ontology used in biological research? How would a computer scientist define an ontology? Compare the Gene Ontology to traditional organismal taxonomy. Compare the Gene Ontology to traditional phylogenetic (evolutionary-based) taxonomy. Is there or might there be theoretical basis for determining changes in relationships in Molecular process in the Gene Ontology?

3. You sequence the genomes of three organisms and determine the genome sizes to be 4, 3 and 2 megabases. Starting with the unannotated DNA genomic sequences how would you determine the functional differences between these three organisms?
   How would you determine why the genomes are different sizes?

4. Phages that infect Prochlorococcus have genes encoding key components of photosynthesis. What is the function of these genes? Why do phage have these genes? Is these beneficial to Prochlorococcus?

Ecology:
1. What are species? Alternative definitions of species. What is your understanding of species of bacteria? How to diagnose species? Why molecular character is a better way for defining species than morphology (under certain conditions)?
2. What is species diversity? How to measure it?
3. How do you understand stochasticity in ecology? Why is it important especially in conservation biology?
4. What is PVA? Discuss the 4 factors considered in PVA? What factors are deterministic and what are random in the PVA models?
5. What is the basic problem in conservation biology with respect to small population?
   What's the consequence of small population?
6. What is the effective population size? What is an ideal population? What's the relationship between effective population size and consensus population size?
   What factor define/affect the effective population size?
7. What is metapopulation? What is island biogeography theory? How was island biogeography theory applied in metapopulation?
8. What is succession? 2 types of ecological succession. Discuss wetlands succession. What factors do contribute to hydroperiod of wetlands?
9. what methods are often used to prevent species from extinction or for maintaining biodiversity in conservation biology?

Evolution
1. How does evolution happen? What do you think of sexual selection? Does sex always result in reproduction? Give some examples in bacteria. Does bacteria have sex? Does viruses have sex? How do viruses exchange genes?
2. What’s the origin of life?
3. How could you know that 2 organisms have the same ancestor? Do you know any method for that? How does parsimony method work? What’s the difference between parsimony and maximum likelihood? How do you choose the model or parameter for your phylogenetic analysis? Model-dependence is either an advantage for Maximum likelihood method but it could also be problematic, so is there any way to fix or improve this problem?
4. Do you know about the idea of independent comparison in phylogenetic analysis? Can you think about its application in horizontal gene transfer study?
5. Do you know character displacement? What is niche? Can 2 species coexist in one niche?
6. Besides the chlorophyll based photosynthesis, are there any other types of photosynthesis? How did photosynthesis evolve? What’s your evidence?
7. Do different Prochlorococcus ecotypes show adaptation to their environment?
8. Why genomes become bigger? What mechanisms have been proposed for explaining genome reduction?

Statistics
1. (drew a curve on the board) What’s the name of this distribution? Discuss distribution parameters. Compare population (true) mean and sample (observed) mean. Compare two distributions and discuss different sampling methods based on its distribution. How do you decide sampling size? (type I, type II error, and power )
2. Discuss one-factor experiment design for hormone effect experiment. (including completely random design, ANOVA procedure, F-test, input parameters )
3. Besides ANOVA, what are alternative analyses you can try? (nonparametric analysis)
4. In the previous example, if hormone levels are different among all the fishes, what kind of analysis would you choose? (regression)
5. If your true sample is not normally distributed (skewed), what would you do before carry out any statistical analysis? (normalization) What kind of normalization would you try?
6. Do you know about Baysian theory and Baysian method? Talk about its application in your research area?
7. (some general biology questions) How do you measure metabolic rate of bacteria? If you and your bacteria were both locked in the cold room, what would you do? What change would you expect happen to your metabolic rate and to bacteria?
Round 1
Adam: Evolution:
What is fitness? – got into discussion of kin selection eventually
What is heritability: narrow sense vs. broad?
What is quantitative genetics? How do we partition the variance of a quantitative trait?
What is relatedness?
If you have ten clones on an island who are genetically identical what is the relatedness between them?

Paul Sievert: Stats
What are some basic areas of statistics?
Discuss when/where you would use each method.
What is your opinion about the current debate over parametric statistics?
Power analysis: What is beta?
What do you think of the various uses of power analysis (a priori, a posteriori)?

Lynn: General Bio
What is the difference between an animal and a plant?
What is the most common enzyme on earth?
Photosynthesis: What is it? Describe the two parts.
What is problem with PHS in hot/dry environments?
Differentiate C3 from C4 Photosynthesis
Describe and compare meiosis and mitosis.

Joe: Ecology
How do you think bees are distributed in space? How would you measure this?
How do you test for aggregation in a population?
How would your quadrat size affect your sampling?
Draw a correlogram.
What regulates bumblebee populations? How would you test for population regulation in bee populations?

Adam: Entomology:
(Shows a bunch of pictures) What is this? It was an aggregate of Meloidae beetle larvae, which are nest parasites of bees, and have a bizarre life cycle.
Draw a phylogeny of the insects (at the detail of orders)?
We had discussion of food webs and biological control – specificity of biological control agents and all that.
Round 2:

Adam: Evolution:
Something about phylogenetics, how we build trees, and such.

Paul: Stats:
What are the assumptions of ANOVA?
How do you test for these assumptions?
What can you do if you violate these assumptions?
What are the similarities between randomized complete block design and repeated measures ANOVA?
Why would you do an ANCOVA?
What is a Mean Square?
What are random vs. fixed variables?
What additional assumption is part of multiple regression? How would you test if this assumption was violated?

Lynn: General Bio:
How do you tell the difference between male and female? (getting at gamete size)
Why are there only two sexes? (Lynn put this question out for fun, because it is the question she couldn’t answer on her orals)

Joe: Ecology:
Are diverse or simple communities more stable? Why?
Tell me about the modeling you are doing for your thesis.

Adam: Entomology:
Draw a generalized insect gut.
Discuss the functions of the various parts.
How would this differ in say a mosquito?
How do insects fly?
How and why is flight different in small vs. large insects?

How I prepared:

Books: Futuyma’s evolution textbook, Sokal and Rohlf, Gotelli’s primer of Ecology, the GRE biology prep book for general bio, as well as Cambell’s general bio textbook.

I also spent a lot of nights studying with other graduate students. This was the best possible preparation, because we all got to practice verbalizing our understanding of the various concepts.
Prelim questions Laura Wegener Parfrey

Stats (Paul Sievert)
1. What are the different model selection methods? What are the drawbacks of forward and backward selection?
2. What would you do/write if you got a P value of .51? .49?
3. What is the central limit theorem?
4. Explain and graph the difference between type 1 and 2 errors.
5. What statistics are used in your work? Why?
6. Paul read an excerpt from a new paper that used a new stats method and asked me to explain if and how I could use it in my work.
7. What is probability?

Evolution (Ben Normark)
1. Ben showed me a nucleotide alignment and asked several questions about it; which codon sites are informative for species relationships vs deep?
2. If there are two copies of a gene in a genome do you expect them to become divergent? (convergent evolution)
3. When was the molecular clock theory proposed?
4. Do sequences follow a molecular clock
5. What is the neutral theory of evolution and who proposed it?

Gen Bio (Laura Katz)
1. Draw the tree of life
2. Draw the life cycle of plants, fungi, animals, and ciliates and label which parts are haploid vs diploid
3. Does germline develop from soma or vise versa?
4. Laura Katz showed me a picture of the antennapedia mutation in Drosophila and asked what it was.
5. What gene family is responsible for this mutation?
6. How many hox clusters are in animals
7. Do all eukaryotes have hox clusters? Are they conserved? What would this conservation look like in Ben’s alignment?
8. What is the central dogma of molecular biology?

Ecology (Joe Elkinton)
1. Draw density dependence on a graph
2. Why are density dependence mechanisms expected to be involved in regulation of populations
3. Where else might you see density dependence?
4. What is Taylor’s power law
5. What are degree days
6. Come up with and Explain an ecological experiment using Bayesian statistics
7. What measures would you use to test this experiment
Statistics (Paul)
What are the three major approaches to perform statistics? How do they differ? When would you use each?
What are the tendencies of current statistics?
What is power analysis? What factors affect your power? How does the variance affect power?
What is alpha?
What is a fully crossed design? What is a block design?
When would you use a block design?
What is repeated measures design?
What’s the difference between confidence intervals and credibility intervals?
What can you test using the frequentist approach?
What’s a statistic?
What are the major assumptions of multiple regression? How can you test for collinearity?
If you have a student who collected 30 variables and 6 samples of each, and wants to conduct a multiple regression, what problems do you foresee? What would be the solution?
What’s the desirable ratio of samples per variable?
How do you test for homogeneity of variance?
What was Ronald Fisher famous for? How about Pearson?
How do you calculate an F-ratio?

Ecology (Duncan) – these were some of his questions embedded in the discussion
What’s an adaptive radiation?
Why has community ecology taken more emphasis in the present?
What are trophic cascades? Can you cite examples?
Why is “the world so green”?
What’s character displacement? What needs to happen for character displacement to occur?
What’s the role of competition?
Describe an experiment where you could test competition on the resource distribution (levels of the tree) on *Anolis* lizards.
What are the factors that determine bat distribution, abundance and diversity?
Describe an experiment where you could test competition on food competition in bats.
Why are there so many species in some places than others?
What factors affect bat diversity, abundance and distribution?
What’s a null model?
Can you cite an example of adaptive radiation? How that might have occurred?

**Evolution (Bruce)**
How have birds speciated in the Galapagos? Is allopatric speciation possible in birds? (a follow-up on Duncan’s questions)
Draw a phylogeny of mammals. What characters relate bats to its sister groups?
Why is this phylogeny better than previous ones?
How did flight evolve in bats? Are there any new hypothesis besides Darwin’s?
What’s a homology? How can you distinguish homologies?
How would you use outgroups to determine if a character is an homology?
How do you call a shared primitive trait?
What’s the neutral theory of evolution? Does it account for population sizes?
Are deleterious mutations considered in the model?

**General Biology (Betsy)**
What are the orders in the Afrotheria?
Are marsupials a monophyletic group?
What are “insectivorans”?
Draw a eukaryotic (animal) and a prokaryotic cell and describe the differences.
Are ribosomes organelles? (Laura Katz)
Are there cells without ribosomes? (Laura Katz)
Draw a plant cell and compare to the animal cell.
What are genes? How does protein production occurs?
What are the main types plants perform photosynthesis? What are CAM plants?
What are independent contrasts? What are its assumptions?
Would you use independent contrasts for your Thesis?
How does the diversification of angiosperms played a role in bat diversification? When did this occur? When did bats diversify?

**Note**: Questions are not in any particular order, and I’m surely forgetting some.
Committee members sometimes intervened in each other’s sections during discussions (just so you know).

**Literature I read to prepare, as recommended by my committee:**

**General Bio**

**Evolution**
“Classic” evolution papers (e.g., Fisher, Dobzhanki, Felsenstein, Mayr, Kimura, Wright, Grant, Gould, etc.).

**Ecology**


Statistics


BIOLOGY
The title of your dissertation is Signal Function and Sexual Selection in the song of the Swamp Sparrow. Tell me what this means. (led to discussion of what is a signal.)
What is song? Do animals other than birds have song?
Why is the study of communication important, especially for people who do not study animals?
Is communication restricted to the animal kingdom?
(Also led to a discussion of the forebrain of birds.)
What is a neuron?
How does information pass between neurons and from one part of the body to the other?
Describe action potentials and ion channels. How does the brain of a bird cause it to sing?
Tell me about transcription and translation.
Why doesn’t protein synthesis occur straight from DNA to proteins (why all this m and t RNA steps?)?
Define Sexual Selection?
What do antlers or songs tell females...why should they choose to mate with these males?
When can signals be reliable?
Elaborate on the handicap principle.
How would you demonstrate/measure that the handicap principle is working to keep signals reliable?
How else could signals be reliable?

EVOLUTION
Describe the costs involved in the handicap principle.
Define a signal.
Question about the acoustic properties of song, complexity, learned vs unlearned.
How did signals evolve?
Tell me about ritualization.
What do females stand to gain by mating with a high quality male?
Are there costs to female choice?
How might animals speciate under sexual selection?
What is reinforcement?
What is a good example of adaptation through natural selection?
How do you test for adaptation in the field? ...the lab?
What is the difference between artificial selection and experiment evolution in the lab?
What is the Evolution history of birds?
What is their closest relative? How about extinct relative?
What are the arguments involved of the theropod origin of birds?
What synapomorphies lead to this conclusion.
Can behavioral synapomorphies be used as evidence?
ECOLOGY
Round 1
There are many perspectives in ecology. Step by step, Robin went through the below perspectives and asked me to define each and reference each to my research.

Physiological Ecology
Population Ecology
Community Ecology (other than predator and prey interactions, what other types of interactions occur under community ecology).
Ecosystem Ecology
(We didn’t have time to talk about Landscape Ecology, she didn’t ask, but I think she would have given time.)

These topics lead to discussion of niche theory, dynamics in pop. ecol., What is r and k selection?), what are some trade-offs (eg generation time, age at sexual maturity)?, pred-prey oscillations, mutualisms, define a habitat.

Round 2
What is the enemy release hypothesis concerning invasive species?
What evolutionary changes are involved?
What trade-offs are involved?
What is a common garden experiment?

STATISTICS
Describe your study design.
What does an ANOVA tell you?
What can you make inference on using statistics?
What is a statistical population?
What kind of sampling do you do?
What are you assuming about this type of sampling to use parametric statistics?
What is stratified sampling and how does it differ from systematic sampling?
When would you use each?
Contrast Randomization tests with a Frequentist approach?
When would you use randomization and why?
When would you use a repeated measures ANOVA?
What types of variables are used in the two types of regression? In ANOVA?
Can you ever use continuous variable in ANOVA and can you use categorical variables in regression? How?
If you can use each in each, why use one test rather than the other?
Tell me about the paper “Abuse of Power”
What kind of power analysis do the authors disagree with?
Is a post-hoc power analysis ever ok?
Why do you use the proportional sign in your equation on the board?
What are the assumptions of parametric statistics?
What are the assumptions of a MANOVA?
How do you test for (multi)collinarity?
Can a regression be non-linear?
What do mathematicians mean by linear?
Podos – General Biology

- Can you tell me about transcription and translation
  - What is RNA
  - Evolutionarily, which came first?
- Do all cells in an organism have the same DNA?
  - How can this lead to specialization
  - How do cytoplasmic contents affect cell fate?
- How many species are there?
  - What is a species?
  - Describe different species concepts.
- Is there a trend over evolutionary time toward diversification?
- What does the title of your dissertation mean?
- What is a signal?
- What is sexual selection; how does it differ from natural selection?
  - Under which condition would this be expected?
  - How does this relate to mating systems?
  - Who related degree of parental investment to sexual selection? (Trivers)
- Dawkins and Krebs said that most signaling systems should be dishonest. What prevents this dishonesty?

Byers – Evolution

- Bruce had a magazine (New Scientist), which had an article about evolution myths and misconceptions. He asked me to debunk four of these:
  - Natural selection is the only means of evolution
  - Evolution cannot be disproven and thus is not a valid scientific theory
  - Evolution produces organisms perfectly adapted to their environment
  - Evolution cannot make predictions
- Describe the last common ancestor of all living organisms.
- Describe some evidence of horizontal gene transfer
- Describe the paradox of the lek (why is there variation in traits under strong selection)
- Define heritability
  - How would you measure it in natural settings? With manipulations?
- What is frequency dependent selection?
- What are evolutionary trade-offs?
These are all the direct questions I was asked. The rest of the questions involved different scenarios on these topics

Stats:
1) What is the difference between an Anova and a regression? When do you use each and what are the assumptions of each?
2) What is multiple regression?
3) What is the purpose of multivariate statistics?
4) How do you interpret a p value?
5) Talk about pseudo-replication.
6) What is a Type I error? Type II?
7) If your data do not meet the assumptions of regression or ANOVA what are alternative tests you can use. What are the benefits/ drawbacks?

General Biology:
1) What is an acclimation? Acclimatization? (I used the example of high altitude hypoxia and the short and long term responses as you go up in temperature).
2) What are some acclimations that happen when an organism moves from a cool environment to a warm environment?
3) “I begin walking towards a frog and it jumps away. Describe what has just happened”.
   - I had to talk about, sensory response, nerve conduction to the CNS to the PNS to the muscle. How a nerve impulse travels so fast over long distances and what organism have a lot of nerve impulse studies been done on?
   - Also had to explain how a nerve impulse gets transmitted to a muscle and then how a muscle contracts.
   - Finally, fast twitch versus slow twitch muscles.

Evolution
1) What is adaptive radiation?
2) Over what time scale does adaptive radiation occur
   For anoles in the Caribbean, what was it that Losos found? (principle of ecomorhs)
3) How do you tell if a population is evolving?
4) What is an adaptation? Exaptation?
5) How do you test if a trait is adaptive?
6) How can a lethal allele be maintained in a population.
JIN WU’s PRELIM QUESTIONS September 25, 2008

**Lynn Adler (Ecology)**
what is ecology?
what ecologists study below population level? above landscape level?
why we don't see population growth as theoretically model predicts?
what is MacArthur Wilson model? explain in detail

**Ben Normark (Evolution)**
what difference between cladistics and phylogenetics?
what is homology? what is orthologue? paralogue?
Ben ask me to graph the rate of beneficial genes / deleterious genes get fixed as population size increase
Ben asked me a lot of names related to evolutionary synthesis, what theory them contributed to
what is sexual selection? what consequence of sexual selection? Ben also asked me questions like why, for example, colorful feather increase the chance of being found by predators, but male birds still use colorful colors to attract female

**Paul Sievert (Statistics)**
What is power analysis? effective population size? large population size increase power or decrease power?
what is P-value? what p=.7 means?
some questions about colinearity.
what the meaning and purpose of randomization?
some questions about experiment design, like completely randomized design
give examples of goodness to fit test, when you use it
what is F-ratio
(surprise, Paul didn't ask me about types of error)

**Adam Porter (General Biology/Entomology)**
Adam gave me a box of insects, asked me about the order and family, which two are most phylogenetically unrelated
what are the differences of digestive system among grasshopper, mosquito, aphids? why?
how insect fly?
what is SNP
what is microsatellite
what is RNAi?
how you find trait is heritable?
how you find the gene correspond to the trait?
what defense mechanism plant have? what secondary chemicals do you know?
how insects trigger plant defense?
how plants could trigger thousands of defense genes at the same moment?

I may lost some questions, people like to interrupt and ask something indetail.
Good comminucation is as important as knowledge.

Many thanks
Jin
Evolution - Ben Normark

How is genetic drift related to population size?
How are genetic drift and population size related to selection?
How does coalescence relate to population size and drift?
Discussion about the neutral theory.
How do the roles of genetic drift/selection/pop. size differ in sexual and asexual species?
What are the contributions of Fisher, Wright, Haldane, Dobzhansky, Mayr to the modern synthesis?
How did the views of Fisher and Wright differ regarding selection and drift?
Describe some species concepts besides the biological species concept.
What kinds of sexual selection are there where female mate choice is involved? Which kinds are advantageous/neutral/disadvantageous to the fitness of the female?
Question about the role of parasites in sexual selection.
If you sequenced 10 different loci from each of 10 different organisms, under what conditions would you expect all 10 loci to give the same phylogeny? Conflicting phylogenies?
What if 5 gave the same phylogeny and the other 5 all gave different phylogenies?
What does the phrase "RNA world" mean?

Statistics - Paul Sievert

What is the purpose of statistics?
What different kinds of statistical approaches are there?
What are different ways to measure the center of a distribution?
What is type I/ type II error?
What is power? How is power related to effect size? To type II error?
What is R squared?
What is/what is the purpose of non-linear regression? Problems with non-linear regression compared to using linear regression for the same data?
Why would you plot residuals?
What are the differences between a factorial and a nested ANOVA?
What is a mixed model?
What is/what is the purpose of generalized linear models?
What is a link function? What is a generalized additive model?

Ecology - Lynn Adler

What are the different levels at which ecology is studied? (Organismal, Population, Community, Ecosystem, Landscape)
What kinds of things are measured at each level? How do you measure community diversity?
How do we describe the differences between food webs? What is connectivity? Linkage density?
What are the ways a population of one species can affect a population of another species in the community?
What is "apparent competition"?
What are the problems that arise when modeling a mutualistic interaction?

General bio - Duncan Irschick (focus on genetics)

What is DNA/RNA/alleles/chromosomes? What is a gene?
How does transcription/translation/the genetic code work?
What two principles of genetics did Mendel discover?
What is Hardy-Weinberg equilibrium? Write the equation. What are the assumptions of Hardy-Weinberg?
Are most alleles selectively neutral?
Bruce Byers (Evolution)

How are phylogenies inferred from molecular data?
How do you know if a character is derived?
How can you estimate the time of a divergence?
Why might an estimate from a molecular clock be different from the actual time of divergence?
What is the benefit of using multiple genes to infer a phylogeny?
Why might inferences based on different genes yield different phylogenies?
How is a gene tree different from a species tree?
Explain/give an example of how different genes can have different evolutionary histories.
Why would you choose 1 method (eg. Parsimony, likelihood, Bayesian) over another?
When inferring the deepest branch splits on the tree of life, why do some genes place Archea in Bacteria and vice versa while other genes do not?
What are some ways in which horizontal gene transfer can occur?
When the same or similar gene that already exists in a population is transferred horizontally, why do we often detect the presence of only 1 of the genes?
What genes are used to infer deep branch splits on the tree of life? Why?
When would you use a gene that is subject to genetic drift?
Why would a bird signal its level of aggression instead of just attacking?
Why do receivers respond to signals?
If cheating/bluffing (dishonest signaling) is advantageous, why doesn’t it spread through a population? (led to a discussion of the handicap mechanism)
Some signals seem cheap to produce (e.g. melanin patches in birds). How is the reliability of these types of signals maintained?
What are receiver-dependent costs?
Do all signals have costs? (Paul)
Give an example of a signal that doesn’t have costs? (Paul)
Do deceptive/dishonest signals exist? Give some examples.
Why do receivers still respond to them?
Is the maintenance of deceptive signals frequency-dependent?

Jeff Podos (General Biology)

What is the central dogma?
Describe the process it is referring to (transcription and translation).

Did Darwin know about the Central Dogma?

What was known about genetics when Darwin wrote “The Origin of Species”?

How did Darwin think heredity worked?

How did Darwin deal with this issue in “The Origin of Species”?

During the modern synthesis, was the Central Dogma predicted?

(Jeff was also getting at chromosome theory, meiosis, and how it relates to Mendelian Genetics).

What is an adaptation?

How can you test if a trait is an adaptation?

How do owls detect and locate their prey?

What is sound?

How is sound translated into location of prey in an owl’s brain?

What are the properties of sound waves?

If you want to measure these properties of a bird’s song, what would you do?

When recording a bird, how is sound translated into information in the recorder?

How does the microphone do this?

Can sound be transmitted through other media besides air? (Paul)

What are the different ways animals produce sound (with some reference to the physics of sound production)?

How do we know that bird song functions in territorial defense? What is the evidence?

In the temperate zone, why do males of most songbirds sing while females do not? (led to a discussion of parental investment and sexual selection)

In the tropics, why do females of many songbird species also sing, and why does duetting occur?

If a mutant female in a duetting species arose that did not sing, and singing is costly for females, wouldn’t this spread through the population?

**Duncan Irschick (Ecology)**

Duncan asked me to read “The Ecology of Adaptive Radiation” by Dolph Schluter.

Why did you like Schluter’s book?

Tell me about the ecological theory of adaptive radiation.

Can there be a non-adaptive radiation? What are some possible examples?

How can you distinguish between an adaptive radiation and a non-adaptive radiation?

How can you detect rapid speciation?

What is the role of sexual selection in adaptive radiation?

Describe recent work on the role of sexual selection in ecological speciation in African Cichlids.

How can a single ancestral species of *Anolis* lizards diversify into several species on a single relatively small island (e.g. Jamaica)?

What degree of geographical isolation is necessary for speciation?

Why doesn’t gene flow obliterate differentiation?

Have you looked at any recent issues of *Ecology*?

What current trends do you notice in relation to 30 years ago?
Why do plant studies dominate the current literature?
Are manipulative experiments better than observational? Why?
Give some examples of how phylogenies are used in community ecology?
Who was Ricklefs’ advisor? (Paul)

**Paul Sievert (Statistics)**

What is a statistic?
What is a P-Value?
What are some measures of variation?
What is a sum of squares?
What are degrees of freedom?
Are degrees of freedom always (n-1)?
Why are degrees of freedom (n-1) and not (n-2) or something else? (Ben Letcher)
What does the first column in an ANOVA design matrix represent? (Ben Letcher)
What is a fully crossed ANOVA design?
Why would you use a fully crossed design?
What are some reasons for plotting your data?
How do you deal with outliers?
What is the relationship between power and decision errors?
What is Type II error?
What factors affect power?
What is a statistical population?
How do you define your statistical population?
What are some methods of parameter estimation?
Can you use randomization for parameter estimation?
Can you use continuous variables in an ANOVA? Why would you do so?
Can you use categorical variables in regression? Why would you do so?
When would you use ANCOVA vs. multiple regression with dummy variables?
In multiple regression, how would you choose among different models?
Why wouldn’t you use $r^2$?
Why is a model with fewer predictor variables better?
Defend the principal of parsimony.
An Orals Survival Kit

Too often, no one explains to graduate students what to expect of their comprehensive exams

By ERIC HALLSTEIN, MICHAEL KIPARSKY, and ANNE SHORT

It is like standing in front of a firing squad. Your executioners are four professors who are experts in their fields. You write before them as they take turns posing questions almost beyond your grasp. The threat hangs constantly over your head: Fail to satisfy them, and your graduate career will end.

That's how many graduate students imagine their oral exam. But the reality doesn't have to be that bad.

While it's true that a Ph.D. oral exam can be the most terrifying hurdle in graduate school, it can also be a positive and rewarding experience. Truly. For many students, the stress associated with preparing for orals is largely because they will experience the exam format for the first, and last, time. Too often, no one explains what to expect or how to prepare.

We know because we've been there. We're all doctoral students in the sciences and social sciences who have successfully passed our oral exams. And we are about to let you in on the real secret of orals: The outcome can be determined, in large part, in advance of the actual test. Your performance is the end product of a much longer process of collaborative learning and demonstration of knowledge that starts when you first meet the members of your exam committee.

The scope, structure, and timing of oral exams vary among institutions and departments. Some exams test your subject-area knowledge, some focus on your proposed research, and many cover a combination of the two. The nature of the exam may not be clearly spelled out to students, or it may be difficult to understand before you have been through the experience.

Your first task is to clarify what your exam will be about. As far in advance as possible, talk with students, faculty members, and advisers to answer some basic questions: What will be the structure of your exam? How much material will it cover? Will the exam focus on knowledge of your chosen fields, your proposed research, or both? Note that there may not be one-size-fits-all answers even within a single department.

As you proceed through your preparation, make a conscious decision about what the oral exam means to you. Frame it as an opportunity, rather than an obstacle, as you solidify your expertise, refine your research plan, and strengthen your relationships with members of your exam committee (some of whom may serve
on your dissertation committee). This process will not only help you develop more effective studying and organizational habits, but also help you become proficient at discussing your research.

**Prepare your exam committee.** As soon as you know the members of your committee, meet individually with each of them. Every interaction you have with your committee will make the exam itself more predictable and your preparation more focused.

It's helpful to view those conversations as informal, friendly negotiations. In many cases, you can steer your committee members toward your objectives, although you should not expect to perfectly predict what will be on the exam.

If you have the freedom to construct your own committee, select people you like, people who like you, and people whom you think will like one another. If your department assigns faculty members to your committee, learn as much as you can about them and their research.

Ask committee members about their exam style and about the scope of the exam. It's fair to ask: "I know the exam will mostly be an extemporaneous conversation, but are there particular topics you want me to demonstrate knowledge of?" (Note: This question is one step away from "What are you going to ask me?")

You need to establish expectations clearly with your committee to avoid nasty surprises and help make your studying efficient. Overcommunicate.

Try to meet with each committee member once or twice a month. That may not be normal practice in all departments, but push for it if you can. In each meeting, choose a topic, a book, or a paper to discuss, so as to gradually demonstrate your knowledge and expose areas that deserve more attention.

**Develop reading lists.** Many students are responsible for identifying their exam "fields" and developing reading lists that will define the content of the exam.

Define your fields carefully. Write a brief statement that delineates each field and how it relates to your research. That statement will help you create a focused reading list and may give your committee a better sense of the boundaries of your preparation.

Keep your readings lists as short as possible, but remember that expectations range widely. Natural-science students in our program may have 10 seminal journal articles on their reading lists, while social-science students often have dozens of books. In many departments, your reading list is a proxy for a wider body of knowledge you are expected to know that includes the context, theory, and significance of the articles. Even a short list can be quite comprehensive. To really understand a key paper, you may have to trace it backward and forward in time, reading papers it cites and those that cite it later.

Discuss your reading list with your committee members as early as possible. Start small, as professors are more likely to add to a draft reading list than to subtract.

**Organize and study.** The oral exam is probably unlike any test you have ever taken. You will need a good system of taking notes and synthesizing information. You will also want to practice communicating your knowledge and thinking on your feet during the exam. Given the magnitude of the studying involved here, burnout is common. Our suggestions:

- Project management is critical since you will work toward a test date many months in advance. Before
you pick an exam date, create a study syllabus that realistically charts out a schedule for mastering your readings and for accomplishing other key milestones. Leave plenty of time to synthesize information and allow some elbow room for the inevitable slowdowns. Make sure your schedule includes a couple of long weekends off. Once you’ve mapped out a time line, stick to it.

- Create a support group to work through concepts with others, and practice expressing your ideas orally.

- Don't forget what is *not* on the list — you are being evaluated on your general expertise, so give yourself latitude to think broadly during your studying. Make a point to know the major historic breakthroughs and shifts in your fields. In addition to each text, understand the main ideas, themes, actors, and conflicts of your fields.

- Many people find it effective to build the overall picture of their field as they study, rather than waiting until the end. Pace yourself. You want to know what authors said (or did) and how each one relates to the others.

- For each reading, ask: How does this reading affect or influence my research? The reading could influence the study design or framing, exemplify a theoretical argument, or highlight a gap. The exam is about your ability to engage with the material, not to memorize it.

- Write, write, and write some more. Orals are unlike class exams where you have to remember the material for only a few days. You need to become fluent in your discipline. Whether it is on notecards or multipage appendices, it is helpful for most people to systematically take notes on each source as soon as they finish reading it. You may want to record a two-sentence summary and list methods, key findings, and the source's relevance to your research. Those summaries will be a helpful reference for your studying.

- Get some rest. Connections happen best when one is rested. Fresh ideas often emerge spontaneously in off hours.

**The final push.** In the final few weeks leading up to the exam, shift your focus toward synthesis of your readings, clear articulation of your ideas, and understanding the broader context of your chosen fields. The broad relevance of your subject matter is fair game in many departments. Think about how your topic fits into the "real world." Read the newspaper, attend relevant seminars, skim relevant journals.

About three weeks before your exam, recruit a few senior students to create a mock version. Follow that with a second mock exam a week later. Take those sessions seriously. Many students find practicing for orals to be their most important study aid. Even if you know the material, you need to practice communicating what you know under pressure.

About two weeks before the exam, start scaling back on your studying. Your mind needs time to rest and prepare. Shift from learning new material to synthesizing. Just before the exam, take a day or two off completely. Do something fun to help you relax. Get plenty of sleep.

**Exam day.** You are ready. Your hard work is about to pay off. Focus on the immense amount you have learned, not on the details that may have slipped through the cracks. The people on your committee want you to succeed — even if they might make you sweat in the process.
If you give a presentation, use it to show your committee members that you are ready for whatever they throw at you, and as a way to try to steer the conversation. Consider bringing a couple extra copies of your materials you have prepared, such as your research proposal or syntheses of your fields. Take notes as you are questioned and briefly outline your responses.

Try as much as possible to make the oral exam a conversation, rather than a question-and-answer session. Think of yourself as a teacher, rather than as someone being examined. You just may know more about the questions being asked than anyone else in the room.

If you are unclear about what a faculty member is asking, request clarification. If you are stuck and unable to proceed, ask for a slight push in the right direction. It can sometimes help to work things through from first principles. State your assumptions clearly before launching into quantitative derivations or theoretical discussions. That way, faculty members can more easily understand what you are doing and redirect you, if necessary.

Remember to breathe.

The central goal of the oral exam is to find the limits of your knowledge. You will be pushed into discussing things you do not know well. At some point, "I don't know" is a correct answer. However, "I don't know, but here is how I would go about answering that question ..." is always a better one.

After the exam. Celebrate. Invite your friends out and take a well-deserved hiatus so that you are ready to return to your work.

Strong relationships you have built, the intellectual foundation you have established, and the approaches to learning you have developed will all help you to write your dissertation. In the end, the oral exam can be a satisfying entry point into the next phase of your research.

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