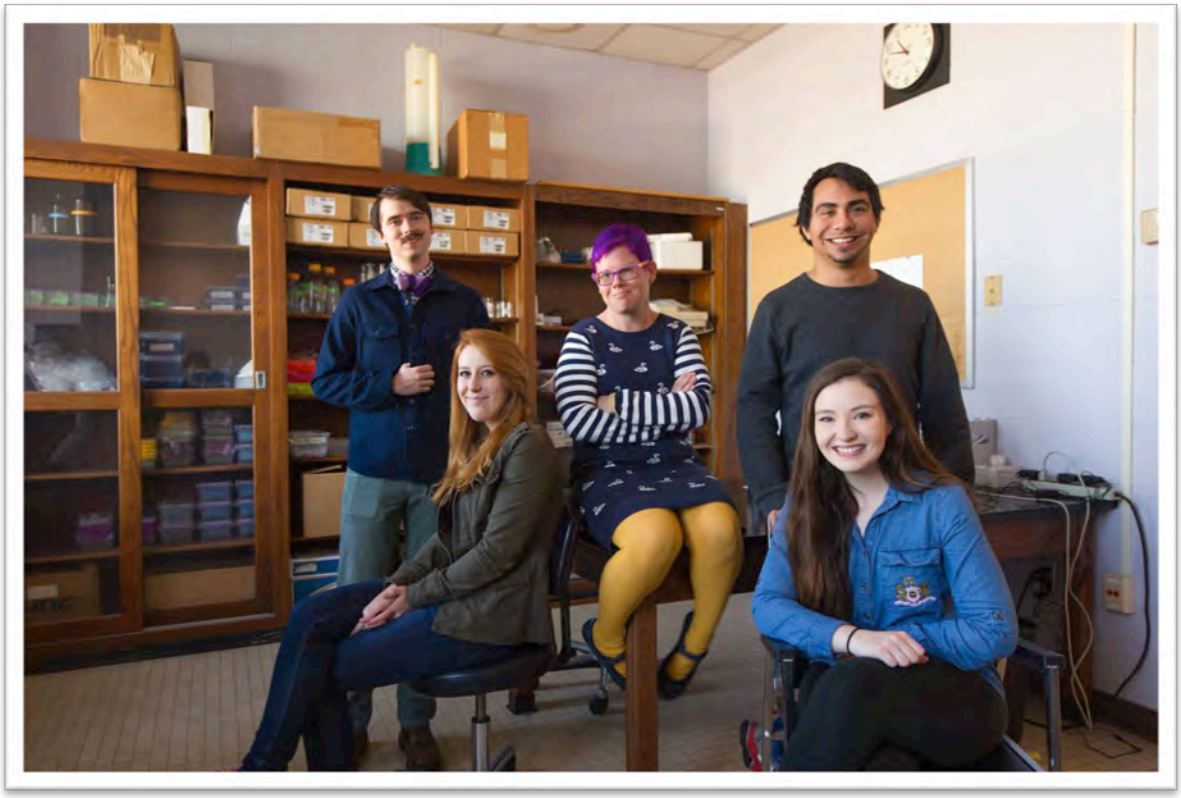
Becky Fox

Associate Professor of Biology



Application for Bingham Award for Excellence in Teaching

Becky Fox – Application for Bingham Award for Excellence in Teaching

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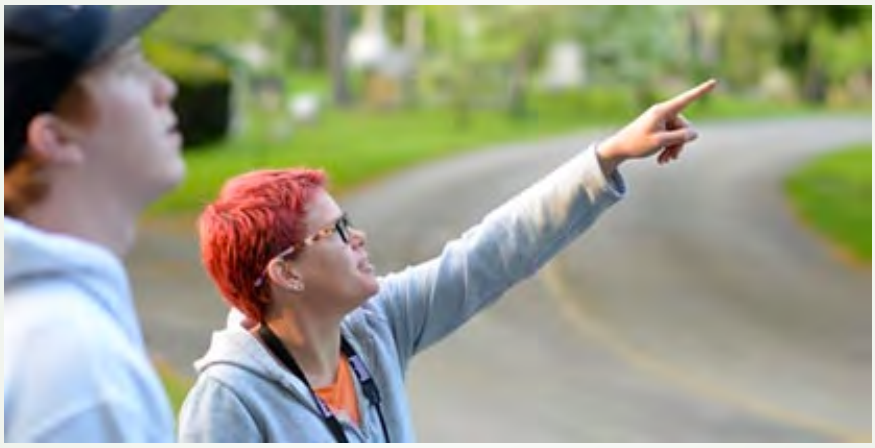

TEACHING RESPONSIBILITIES

As a faculty member in the Biology and Neuroscience programs, I am currently responsible for teaching a total of six courses, with most of my upper level courses on an every other year or every third semester rotation: BIO 1206 Integrating Concepts in Biology: Organisms and Ecosystems , BIO 3016 Comparative Vertebrate Anatomy , BIO 3065 Animal Physiology, BIO 3224 Neurobiology, NEUR 4044 Capstone in Neuroscience (on a rotating basis with the other faculty in the program), and BIO 2164 Ornithology. Prior to our curriculum revision in Biology in 2014, I was also responsible for teaching BIO 2304 Cell and Molecular Biology (phased out in the 2014-2015 academic year) and BIO 4044 Senior Seminar in Biology (phased out after Fall 2015).

BIO 1206 Integrating Concepts in Biology: Organisms and Ecosystems (ICBO). This is one course in the introductory two-semester sequence for Biology majors. Course enrollment tends to be around 12-16, and the clientele is first- and second-year students who are either pre-health or intending to be biology majors. Drs. Wagner, Bray, and I all teach this course, with two of us typically teaching sections in any given semester. Thus, the textbook, lab, and lecture schedule are roughly standardized across sections, though each of us certainly puts our own "twist" on the course and the materials and assignments we give. The course content focuses on concepts related to evolution, information flow, structure and function, homeostasis, and emergent properties at organismal and ecological levels, and the main thrust of the course is on developing and improving students' competencies in data interpretation, quantitative reasoning, critical thinking, and application of the scientific process. The course includes both lecture and laboratory components. The main challenges of this course, particularly in the fall, are related to the fact that the majority of the students are in their first year, and the discussion-based and experimental design-focused nature of the course makes it very different from the courses most of them have taken in high school. Thus, one of my focuses in teaching this course is in getting students comfortable with this new way of thinking and assimilating information (through activities that provide scaffolding) and in helping students to develop effective study strategies and confidence as biologists.

BIO 2304 Cell and Molecular Biology. This course was part of the old core curriculum for the Biology and Biology-emphasis Neuroscience majors. The course was an introduction to cell biology and biochemical processes such as protein folding and enzyme kinetics, and covered most aspects of cell structure and function, with a focus on understanding – at least conceptually - how structure and function arose out of chemical interactions such as hydrogen bonding, and how cellular processes related to larger-scale processes at the organismal level (e.g., the process of digestion, the development of cancer, etc.). The course clientele was primarily pre-health students and majors in biochemistry, biology, and neuroscience. Most students were in their second or third year. The primary challenge associated with

teaching this course were that for many students, cellular processes seem very abstract and hard to visualize. For some students, the chemistry content was also a bit challenging. Thus one of my focuses in teaching the class was on developing activities and demonstrations that helped students picture what was going on in the cell. The course included both lecture and lab components, with the last month of lab focused on a student-driven cell culture project. Enrollment was typically 20-25 students.

BIO 2165 Ornithology. This is a sophomore-level May Term elective in the Biology major. Course content focuses on bird biology, with an emphasis on behavior and ecology, and on basic field methods, particularly bird identification in the field both visually and based on songs and calls. The class is taught in a very hands-on way, including a week of class meetings at my field research site. During "field week," students engage in activities including observation of parental care in house sparrows, surveys of species abundance in various microhabitat types, and a scavenger hunt that calls on their bird-identification skills. Over the course of the term, students work in pairs to design and carry out a small-scale field research project over the course and put together a thematic natural history museum exhibit using some of the bird specimens in Transy's collection. The main challenge in this course is the time constraint imposed by the four-week May term.

BIO 3016 Comparative Vertebrate Anatomy (CVA). CVA is an upper-level elective in the Biology major, and is required by many vet schools. Historically, quite a few pre-health students in addition to the small pre-vet cohort choose to take the course, and it usually fills past capacity (I cap the course at 16 and actual enrollment after I course pass students in is usually around 20). Course content covers vertebrate anatomy from an evolutionary and structure/function perspective, and emphasizes hands-on discovery via dissection and side-by-side comparison of birds, amphibians, mammals, and sharks on a system-by-system basis as well as independent projects in the lab. I am currently revising the course to increase the emphasis on human anatomy in order to make it more relevant to our pre-health students and more helpful to them in the application process. The main challenge in teaching this course are that anatomy is extremely content-heavy (far beyond what can possibly be covered in 14 weeks of 1 hour lectures), so my main focus in class has to be on addressing overarching themes and helping students develop the skills to organize and synthesize the material in their textbook and the papers we read. Additionally, this is the first anatomy class most students have ever taken, so helping students to master dissection skills and develop the study habits that will allow them to succeed on lab practicals is another major focus.

BIO 3065 Animal Physiology. This course is an upper-level elective for the Biology, Biochemistry, and Neuroscience majors. This is a popular course, so enrollment is typically 18-22 (again, usually over capacity as I cap the class at 16 and course pass students in on a case-by-case basis after that). The course is especially popular with pre-health students. Course content focuses on the function of various organ systems in vertebrates and their role in maintaining homeostasis. One of my major

focuses in this class is on helping students link what they have learned in other classes (cell biology, genetics, biochemistry, and ecology) to content in Animal Physiology, with an emphasis on understanding the interrelationship between biochemical and biophysical processes, cell biology and organismal physiology. One of my favorite final exam questions is, "Explain why it is an organism will die if it stops breathing. Address the question on both a physiological and a cellular level." I use a unique model for the lab in this course: at the beginning of the semester I choose a theme or broad question, and then groups of students are responsible for choosing questions related to the theme, reading the primary literature, developing hypotheses, and designing experiments to test them. In the past, we have used convict cichlid fish as our study subjects, but I am currently redesigning the lab to focus on human physiology using the Vernier sensor system. The model I use for the laboratory is the main challenge in this course, both in terms of providing sufficient scaffolding for the students to design rigorous experiments without simply taking over, and in terms of students' discomfort with not having a detailed "roadmap" for the lab. However, my experience is that over the course of the semester, the vast majority of students make major gains in their comfort with the primary literature, their skill designing experiments and interpreting results, and the depth of their understanding of physiological concepts.

BIO 3224 Neurobiology. Neurobiology is a required course in the upper-level core for all emphases in the Neuroscience major and an elective in the Biology major. Enrollment is typically 14-16 students, but has been as high as 25. Most of the students taking the course are juniors and seniors, weighted heavily toward Neuroscience majors. Course content focuses on the cellular basis of nervous system function during the first half of the course, beginning with the molecular basis of resting membrane potential and action potentials and building up to the structure and functions of neural circuits. The second half of the course focuses on larger-scale processes in the nervous system such as control of body movements and coordination and the relationship between the hippocampus, memory, and spatial learning. Because studying cellular neuroscience in an undergraduate laboratory is exceptionally challenging from a technical perspective and the perspective of time constraints (e.g., some protocols for staining proteins in neurons take upwards of 14 hours for a small set of brain sections), I rely heavily on computer-based labs such as MDCUNE's "Swimmy" program, in which students conduct experiments on a simulated neural circuit in order to map it. Students, working in groups, also use a digitized library of stained zebra finch brain sections to address a question of their choice related to sex differences and/or the influence of exposure to estradiol on the development of the bird song system. The biggest challenge in this course is that students enter this course with varying levels of knowledge of cell biology, depending on their major and/or their emphasis within the Neuroscience major. Thus one of my big tasks early on in the semester is to design activities that help to get everyone on the same page without boring students with more knowledge.

BIO 4044: Senior Seminar in Biology. Before we changed the biology curriculum, this was a topical seminar in biology that met three days a week to discuss primary and

secondary literature related to the theme of the course. The three times I taught the course, topics were as follows: developmental plasticity and epigenetics, mating systems and sexual selection, and mechanisms of behavior. For the first few weeks, of the class I typically chose the readings, after which students were responsible for choosing readings and leading discussion. Over the course of the semester, each student also produced a substantial review paper related to some aspect of the course theme. One of my focuses in the course was in structuring assignments and feedback in a way that helped students to produce a high-quality final paper. I typically set a series of deadlines, followed by individual conferences with students after major deadlines (e.g., the deadlines for the annotated outline and the first draft).

NS 4444 Captstone in Neuroscience: As this class has only been in existence for three years, we are still working out as a program exactly what we want to do with this course. I taught the second iteration of the course last fall, and followed the same model as I followed for Senior Seminar in Biology, except with a Neuroscience-oriented topical focus (on neuroecology and the neurobiology of behavior for that iteration of the course).

Rebecca Ann Fox

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Education

Ph.D., Animal Behavior, 2002-2007, University of California, Davis.
Dissertation title: Personality, mate choice, and pair compatibility in cockatiels (*Nymphicus hollandicus)*. Professor James R. Millam, advisor.

M.S., Avian Sciences, 2000-2002, University of California, Davis.
Thesis title: The impact of parental care on behavioral development in orange-winged Amazon (*Amazona amazonica*) chicks. Professor James R. Millam, advisor.

B.S., Biology (*summa cum laude*), 1996-2000, Arizona State University.
Honors thesis title: Comet Hyakutake: Observations of an Oort Cloud comet at closest approach. Professor Susan Wyckoff, Honors thesis director.

Academic Positions

Associate Professor. 2016-present. Department of Biology, Transylvania University, Lexington KY.

Courses taught (in winter '17 after return from sabbatical)
BIO 1042 Integrating Concepts in Biology: Organisms and Ecosystems
BIO 3016 Comparative Vertebrate Anatomy

Assistant Professor. 2010-2016. Department of Biology, Transylvania University, Lexington KY.

Courses taught:
BIO 1044 Biological Interactions
BIO 1042 Integrating Concepts in Biology: Organisms and Ecosystems
BIO 2304 Cell and Molecular Biology
BIO 3016 Comparative Vertebrate Anatomy
BIO 3065 Animal Physiology
BIO 3044 Neurobiology
BIO 3164 Ornithology
BIO 4044 Senior Seminar in Biology
NEUR 4044 Capstone in Neuroscience
IDS 2014 Further Engagements
FEN 1014 First Engagements

Postdoctoral Scholar, 2007-2010, Department of Biology, University of Nevada, Reno.
Project: Impacts of social environment on hippocampal development in mountain chickadees. Professor Vladimir V. Pravosudov, supervisor.

Adjunct Professor. 2007. Department of Biology, California State University, Sacramento.
Courses taught: BIO 166 Ornithology

Associate Instructor. 2006. Department of Animal Science, University of California, Davis.

Courses taught: AVS 123 Management of Captive Birds

Research Experience and Interests

Research Interests

Proximate underpinnings of animal personalities and impact on fitness, with particular interests in the following:

- Relationship among stress hormones, personality traits, and plasticity
- Mechanistic underpinnings of individual differences in variance sensitivity
- Personality, pair compatibility, and reproductive success in monogamous birds

Extramural collaboration

Fall 2016- Kevin McGraw, Arizona State University. Personality, risk-taking, and physiology in house finches as a function of urbanization.

2010-present Dave Westneat, University of Kentucky. Personality, plasticity, and parental care in house sparrows. *Recently completed year three of a four year, $640,000 National Science Foundation grant for field-based and captive work on parental care and variance sensitivity in house sparrows. Approximately $178,000 of the grant funds went to Transy to fund the purchase of new equipment for my lab, to pay for the materials needed for hormone analyses, and to support student research related to the project as well as travel to meetings.*

Manuscripts Currently in Revision

* Indicates undergraduate coauthor

Fox, R.A., Ali, N.* The forest or the trees? Neophobia and the 'environmental sensitivity syndrome' in house sparrows (*Passer domesticus*). *In revision for submission for Journal of Avian Biology.*

Publications

Fox, R.A., Millam, J.R. 2014. Personality traits of pair members predict pair compatibility and reproductive success in a socially monogamous parrot breeding in captivity. Zoo Biology 33:166-172.

Fox, R.A., Roth, T.C. II, LaDage, L.D., Pravosudov. V.V. 2010. No effect of social group composition on hippocampal formation morphology and neurogenesis in mountain chickadees (*Poecile gambeli*). Developmental Neurobiology, 70:538-5487.

Fox, R.A., Millam, J.R. 2010. The use of ratings and direct behavioral observation to measure temperament traits in cockatiels. Ethology, 116: 59-75.

LaDage, L.D., Roth, T.C. II, **Fox, R.A.,** Pravosudov, V.V. 2010. Ecologically-relevant spatial memory use modulates hippocampal neurogenesis. Proceedings of the Royal Society of London Series B: Biological Sciences, published online.

Fox, R.A., LaDage, L.D., Roth T.C. II, Pravosudov, V.V. 2009. Behavioural profile predicts dominance status in mountain chickadees, *Poecile gambeli*. Animal Behaviour 77: 1441-1448.

LaDage, L.D., Roth, T.C. II, **Fox, R.A.**, Pravosudov, V.V. 2009. Effects of captivity and memory-based experiences on the hippocampus in mountain chickadees. Behavioral Neuroscience 123: 284-291.

LaDage, L.D., Roth, T.C. II, **Fox, R.A.**, Pravosudov, V.V. 2009. Flexible cue use in food-caching birds. Animal Cognition 12: 419-426.

Fox, R.A., Millam, J.R. 2006. Novelty and individual differences influence neophobia in orange-winged Amazon parrots (*Amazona amazonica*). Applied Animal Behaviour Science 104: 107-115.

Fox, R.A. Hand-rearing: behavioral impacts and implications for captive parrot welfare. In: *Manual of Parrot Behavior* (ed. A. Luescher). University of Iowa Press, Des Moines, pp. 83-91.

Fox, R.A., Millam, J.R. 2004. The effect of early environment on neophobia in orange-winged Amazon parrots (*Amazona amazonica*). Applied Animal Behaviour Science 89: 117-129.

Presentations and Abstracts

Fox, R.A. Personality and plasticity in the field: measuring neophobia in free-living house sparrows. *Presented at the Animal Behavior Society 2015 Meeting, June 10-14 2015, Anchorage, AK.*

Fox, R.A., Ali, N.* Is 'neophobia' in house sparrows related to the ability to generalize? *Presented at the International Society for Behavioral Ecology Biennial Congress, July 31-August 5 2014, New York City.*

Fox, R.A. Are more neophobic house sparrows more sensitive to environmental variation? *Poster presented at Animal Behavior Society 2013 Annual Meeting, July 28-Aug. 1 2013, Boulder, CO.*

Fox, R.A., Williams, R.N.* How consistent is "consistent"? Personality and stress responsiveness in house sparrows. *Presented at the Animal Behavior Society 2012 meeting, June 10-14 2012, Albuquerque, NM.*

Fox, R.A., Williams, R.N.* Badges of personality? Corticosterone, bib size, and neophobia in house sparrows (*Passer domesticus*). *Presented at the Society For Integrative and Comparative Biology Annual Meeting. Jan. 3-7 2012, Charleston, SC.*

Fox, R.A., LaDage, L.D., Roth, T.C. II, Pravosudov, V.V. 2010. Behavioral profile and aggression in mountain chickadees. Society for Integrative and Comparative Biology Annual Meeting, January 3-7, 2010, Seattle, WA.

Fox, R.A., LaDage, L.D., Roth, T.C. II, Pravosudov, V.V. 2008. Individual behavioral traits predict dominance status in mountain chickadees. 12th International Behavioral Ecology Congress, Ithaca, NY.

Fox, R.A., Roth, T.C. II, LaDage, L.D., Pravosudov V.V. 2008. Effects of social environment on spatial memory in mountain chickadees. Integrative biology of scatter hoarding: ecology, psychology, and neuroscience (workshop at the 12th International Behavioral Ecology Congress, Ithaca, NY).

LaDage, L.., Roth, T. II, **Fox, R.**, Pravosudov, V. 2008. Food-caching mountain chickadees preferentially respond to color over spatial cues in an associative learning test. 12th International Behavioral Ecology Congress, Ithaca, NY.

Pravosudov, V.V., Roth, T.C. II, **Fox, R.A.**, LaDage, L.D. 2008. The relationship between the environment, spatial cognition, and the hippocampus in food-caching birds. Integrative biology of scatter hoarding: ecology, psychology, and neuroscience (workshop at the 12th International Behavioral Ecology Congress, Ithaca, NY).

Roth, T.C., II, LaDage, L.D., **Fox, R.A.**, Pravosudov, V.V. 2008. Hippocampal volume in food-hoarding parids: are North American brains really smaller than Eurasian? Integrative biology of scatter hoarding: ecology, psychology, and neuroscience (workshop at the 12th International Behavioral Ecology Congress, Ithaca, NY).

Fox, R.A., Millam, J.R. 2007. Making a match: personality and pair compatibility in cockatiels, *Nymphicus hollandicus*. Animal Behavior Society 2007 meeting, Burlington, VT (Allee award competition).

Fox, R.A., Millam J.R. 2006b. Personality traits, behavior, and courtship in cockatiels (*Nymphicus hollandicus*). International Society for Comparative Psychology Biennial Conference, Christchurch, New Zealand.

Fox, R.A., Millam, J.R. 2006a. Do cockatiels consider personality when choosing mates? Animal Behavior Society 2006 meeting, Snowbird, UT. [Also reported on the *News @ Nature* website].

Fox, R.A., Millam, J.R. 2005. Measuring parrot personalities, a ratings-based approach. Animal Behavior Society 2005 meeting, Snowbird, UT.

Fox, R. A., Millam, J.R. 2003. Unpredictable environments and neophobia in Orange-winged Amazon Parrots (*Amazona amazonica*). Animal Behavior Society 2003 meeting, Boise, ID. [Also reported in the Aug. 2, 2003 issue of *Science News* as "Maybe What Polly Wants is a New Toy"].

Fox, R. A., Millam, J.R. 2002. Maternal separation influences the development of neophobia in Orange-winged Amazon (*Amazona amazonica*) chicks. Animal Behavior Society 2002 meeting, Bloomington, IN.

Presentations and Abstracts by Students in my Lab

Hamilton, H.P.*, Martin, G.R., Fox, R.A. 2016. House sparrow pair compatibility predicts reproductive success. *Poster presented at the 23rd annual Indiana University Animal Behavior Conference, March 31-April 2 2016, Bloomington IN.*

Rowe, R.D.*, Saldaña, C.*, Fox, R.A. 2016. Are neophobia and habituation related to nesting habitat in house sparrows (*Passer domesticus*)? *Poster presented at the 23rd annual Indiana University Animal Behavior Conference, March 31-April 2 2016, Bloomington IN.*

Ali, N.*, Fox R.A. Do sparrows like toys? Enrichment and indicators of welfare in captive house sparrows (*Passer domesticus*). *Poster presented at the Animal Behavior Society 2015 Meeting, June 10-14 2015, Anchorage, AK.*

Coomes, C.*, Gardner, S.*, Fox, R. Free-living house sparrows (*Passer domesticus*) exhibit personality and plasticity in response to novel objects. *Poster presented at the Animal Behavior Society 2015 Meeting, June 10-14 2015, Anchorage, AK.*

Gardner, S.*, Coomes, C.*, Fox, R. Investment in parental provisioning predicts response to novelty in free-living house sparrows. *Poster presented at the Animal Behavior Society 2015 Meeting, June 10-14 2015, Anchorage, AK.*

Marshall, C.*, Ali, N.*, Fox, R. Do convict cichlids (*Amatitliana nigrofasciata*) have personalities? *Poster presented at the Animal Behavior Society 2015 Meeting, June 10-14 2015, Anchorage, AK.*

Gardner, S.*, Coomes, C.*, Fox, R. Neophobia, corticosterone, and parental behavior in free-living house sparrows (*Passer domesticus*). *Poster presented at the 22nd annual Indiana University Animal Behavior Conference, March 26-28 2015, Bloomington, IN.*

Ali, N.*, Fox R.A. Do sparrows like toys? Enrichment and indicators of welfare in captive house sparrows (*Passer domesticus*). *Poster presented at the Kentucky Academy of Sciences Annual Meeting, November 14-16, 2014, Lexington, KY.*

Coomes, C.*, Gardner, S.*, Fox, R. Badges of stress? Bib size, circulating corticosterone, and corticosterone deposition in feathers in house sparrows (*Passer domesticus*). *Poster presented at the Kentucky Academy of Sciences Annual Meeting, November 14-16, 2014, Lexington, KY.*

Hirn, T.*, Fox, R.A. Stress and immune function in house sparrows (*Passer domesticus*): is there a relationship? *Poster presented at the Kentucky Academy of Sciences Annual Meeting, November 14-16, 2014, Lexington KY.*

Ali, N.*, Fox R.A. Stochastic environmental variation reduces behavioral repeatability in house sparrows (*Passer* domesticus). Poster *presented at the National Conference on Undergraduate Research, April 3-5 2014, Lexington, KY.*

Williams, R.N.*, Fox, R.A. Effects of circadian rhythm and corticosterone levels on activity levels and fearfulness in house sparrows (*Passer domesticus*). *Presented at the Animal Behavior Society 2012 meeting, June 10-14 2012, Albuquerque, NM.*

Service to the University

2015	**Member, Transylvanian Scholarship selection committee**
2014-present	**Member, Library subcommittee of CPC**
2012-2014	**Co-organizer (with Peter Fosl, Jeremy Paden, and Jack Furlong), First-Year Faculty Forum.**
2012-2014	**Member, Committee for Admissions and Academic Standards**
2012	**Collaborator (with Meg Upchurch and Kenny Moorman) on successful proposal for Neuroscience major.**
2011-present	**Academic advising.** Currently advising 24 students, primarily a mix of Biology and Neuroscience majors.

2011-present **Representative to Board of Trustees Student Life Committee**
2011-present **Chair, Institutional Animal Care and Use Committee.**

Other Professional Service

Ad hoc reviewer for *Zoo Biology*, *Behaviour*, *Ethology*, *Animal Behaviour*, *Behavioral Ecology*, *Poultry Science*, *Journal of Comparative Psychology*, *Proceedings of the Royal Society of London B, The Auk*.

2015 **Participant in NSF-funded planning workshops for EREC field station.** University of Kentucky. (2, 1-day workshops)
2014 **Judge for film competition,** Animal Behavior Society Annual Meeting
2013 **Reviewer**, Graduate Student Research Grants, Animal Behavior Society.
2006 **Organizer, "Communicating Research" Seminar Series.** UC Davis
2001-2002 **Avian Sciences Graduate Group Representative** to the UC Davis Graduate Student Association. Spring, 2001 – Spring, 2002

Professional Development

2016 **Evidence-Based Teaching in STEM.** Attended fall semester seminar series at Arizona State University.
2012 **Writing Across the Curriculum Workshop.** Transylvania University
2011 **Vernier Software and Technology Data Collection with LabQuest workshop.** Lexington, KY.
2011 **Sustainability Across the Curriculum Workshop.** Transylvania University.
2005 **Seminar in College Teaching.** 9-week certificate program through the UC Davis Teaching Resources Center.

Grants, Fellowships, and Awards

2013 "Parental care and the integration of personality and plasticity at multiple levels of phenotypic variance" Collaboration with David Westneat (University of Kentucky). National Science Foundation ($177,895 over four years to Transylvania University).
2013 "Birds, Bibs, and Situations: Understanding the Links Among Personality, Plasticity, and Phenotype in House Sparrows (*Passer domesticus*)." Jones Grant ($2,700)
2012 "Personality in House Sparrows: Consistency of Behavioral and Physiological Measures and Influence of Day Length." Jones Grant ($2,940)
2011 "Temperament in House Sparrows (*Passer domesticus*): Relationship Between Behavioral Type, Plumage Characteristics, and Hormone Levels." Jones Grant ($2,040)
2006 University of California Dissertation Year Fellowship
2005 Sigma Xi Grant-in-Aid-of-Research ($1,000)
2004 American Ornithologists' Union Van Tyne Award ($2,000)
2005 Professors for the Future Fellow (UC Davis)
2004 Phi Beta Kappa (Northern California Association) Graduate Fellowship
2001 National Science Foundation Pre-doctoral Fellowship
2000 Phi Kappa Phi Graduate Fellowship

Professional Societies: Animal Behavior Society, Society for Integrative and Comparative Biology.

Honor Societies: Phi Beta Kappa, Phi Kappa Phi, Transylvania University Holleian Society.

Invited Public Outreach and Other Talks

May 2016	EcoLunch seminar, Biology Graduate Program, University of Kentucky
September 2014	EcoLunch seminar, Biology Graduate Program, University of Kentucky
May 3, 2008	Discover the Oasis 2008 seminar, hosted by The Oasis Sanctuary Foundation, Cascabel, AZ.
January 25, 2008	National Parrot Research and Preservation Foundation "Parrot Festival," Houston, TX.
May 6, 2006	Discover the Oasis 2006 seminar, hosted by The Oasis Sanctuary Foundation, Cascabel, AZ.
October, 2004	Bay Area Bird Club, Greenbrae, CA
June, 2004	Fresno Area Bird Club, Fresno, CA
May 21, 2004	West Valley Bird Society, Sherman Oaks, CA
August 11, 2003	West Valley Bird Society, Sherman Oaks, CA
August 13, 2003	East San Gabriel Bird Society, Los Angeles, CA
April 20, 2003	East San Gabriel Bird Society, Los Angeles, CA
April 13, 2003	Bird Care Seminar, Santa Cruz, CA (host: Parrotdise)
March 28, 2003	Bay Area Bird Club, Greenbrae, CA
February 24, 2003	Santa Rosa Bird Society, Santa Rosa, CA
February 21, 2003	West Valley Bird Society, Sherman Oaks, CA
January 18, 2003	Monterey Bird Society, Monterey, CA
June 22, 2002	Pet Bird Seminar, Pleasanton, CA (host: Diane Grindol)

Published Fiction

Rebecca Fox. "Where You're Planted." To be published in *Masques of Darkover (Darkover Anthology 17)*, Ed. Deborah J. Ross. Marion Zimmer Bradley Literary Works Trust. Forthcoming 2017.

Rosemary Edghill and Rebecca Fox. "Stormcrow." 2016. In: *Realms of Darkover (Darkover Anthology 16)*, Ed. Deborah J. Ross. Marion Zimmer Bradley Literary Worsk Trust.

Rosemary Edghill and Rebecca Fox. "Harmless as Serpents." To be published in forthcoming Valdemar X anthology, Ed. Mercedes Lackey and John Helfers. DAW Books. Forthcoming 2017.

Rosemary Edghill and Rebecca Fox. 2015. "Learning to Breathe Snow." In: *Gifts of Darkover (Darkover Anthology 15),* Ed. Deborah J. Ross. Marion Zimmer Bradley Literary Works Trust.

Rosemary Edghill and Rebecca Fox. 2014. "A Brand from the Burning." In: *No True Way: All-New Tales of Valdemar,* Ed. Mercedes Lackey and John Helfers. DAW Books.

Rosemary Edghill and Rebecca Fox. 2014. "Second Contact." In: *Stars of Darkover (Darkover Anthology 14)*, Ed. Deborah J. Ross. Marion Zimmer Bradley Literary Works Trust.

Rosemary Edghill and Rebecca Fox. 2013. "Bone Dance." In: *Elementary (All-New Tales of the Elemental Masters),* Ed. Mercedes Lackey and John Helfers. DAW Books.

TEACHING PHILOSOPHIES AND PEDAGOGIES

TEACHING PHILOSOPHIES AND PEDAGOGIES

The syllabus for my BIO 1206 course opens with two quotes. The first, from anthropologist and sociologist Claude Levi-Strauss (edited slightly to be more inclusive), states, "The scientist is not a person who gives the right answers, [s]he's the one who asks the right questions." The second is a favorite quote from George Bernard Shaw: "Science is always wrong. It never solves one problem without creating ten more." Science is a lively, exhilarating, *collaborative* conversation aimed at answering fundamental questions about how the world works. Those answers, as Shaw so rightly observes, usually wind up leading to even more questions (which, as I regularly tell my students, is really the fun part). Furthermore, the scientific process is a conversation in which students can absolutely take part, even at the very beginning of their undergraduate careers if not sooner!

My role as an instructor is to equip my students with the tools they need to do science, and to invite them to join the conversation. *Thus, nearly everything I do is designed to expose students to biology and neuroscience as they are practiced in the "real world", and to empower them to use their newfound skills to develop and answer questions of their own.* To that end, my teaching 'recipe' consists of six basic ingredients: (a) an open-ended, semi-Socratic approach in the classroom, (b) a classroom culture that promotes inclusion, self-confidence, and collaboration, (c) plenty of collaborative, hands-on activities to build students' confidence in their ability to understand the material, (d) student-driven research projects, (e) regular, prompt, and relevant feedback, and (f) exams that not only assess student progress toward learning outcomes, but also ask students to apply what they know to address novel questions.

A.) Semi-Socratic approach

Beyond the simple fact that educational research has repeatedly shown that the traditional chalk-and-talk lecture is a singularly ineffective method for promoting learning, retention, or transfer (Barr and Tagg 2012), science is at its heart a conversation rather than a transfer of facts. In that conversation, papers are published and discussed, alternative hypotheses are proposed, debated, and tested, new results support or shed doubt on long-held ideas. *My goal as a teacher is to engage my students as scientists and bring them into that conversation.* While inquiry-based instruction has been shown to produce substantial gains in conceptual understanding and scientific thinking (Gormally et al. 2009), asking students to discover everything from first principles can be tremendously inefficient, particularly in content-heavy upper level classes.

My approach in the classroom was partly born out of a desire to avoid the pitfalls (and boredom) of pure lecture while minimizing the inefficiencies and issues related to lack of scaffolding in pure inquiry-based approaches (e.g. Kirschner et al. 2006). Thus, most of my class sessions are structured around a set of questions that ask students to work collaboratively and use some combination of prior knowledge,

data, experimental results, published research, or simple models to construct an understanding of core concepts.

A given class period generally alternates between periods of small-group discussion and/or hands-on investigation (e.g., dissection, mini-experiments, simulations, etc.) and instructor-facilitated work as a whole class in which I use Socratic questioning to help the class use what they have just done to arrive at an understanding of more general principles. This approach requires preparation, flexibility, and sometimes a sense of humor, but over the years I have found that it pays off handsomely in terms of conceptual understanding, facility with the scientific method, and student confidence.

B.) Building a supportive classroom culture

Of course, all the careful planning and Socratic questioning in the world will come to naught if students do not feel comfortable enough to take a few intellectual risks and speak up in class. *Thus, one of the keys to making my approach to instruction work is creating a classroom culture where students feel comfortable enough to regularly toss out ideas and questions of their own.*

In the classroom, I strive to create an informal, egalitarian, inclusive atmosphere, to create activities that promote collaboration and interaction, to avoid letting any one student dominate the class with either questions or answers, and to stress the importance of coming to class prepared to participate. I try as much as possible to get out from behind the desk or podium at the front of the class - instead I walk around or room and sit at the tables with my students during discussions. I also strive to avoid letting my own agenda for the day from keeping me from making space for any relevant questions students might raise. This means we sometimes get a bit off track with the syllabus, but the payoffs in terms of engagement and understanding seem like more than a fair tradeoff.

In the spirit of inclusiveness, I also use an assortment of modalities for both teaching and assessment. For example, small-group and online discussions give my more introverted students a chance to speak up without the stress of talking in front of the whole class, papers and take-home essay exams give students who struggle with test anxiety a chance to show me what they know, and hands-on activites give kinesthetic learners a chance to really engage with the material. The use of multiple modalities also gives me a chance to pinpoint the reasons a student might be having difficulties in class. A student's performance on some hands-on assignments once helped to show me that she was doing poorly on exams not because of a lack of understanding of the material but because she was struggling with the vocabulary – something that was easy enough to clear up with a bit of one-on-one work during office hours and new study strategies. This student is now applying to medical school.

C.) Hands-on activities and games

Hands-on activities are another pillar of my approach to instruction. *Biology and neuroscience are full of abstract-seeming ideas and events that take place on a microscopic scale. Over the last several years, I've designed a number of activities to help students develop an intuitive understanding of these concepts.* For example, the

kinetics of Lego hydrolase activity and the associated **enzyme kinetics lab** for Cell and Molecular Biology paired a simulation of enzyme properties using Legos with an exercise in which students empirically measured the properties of the enzyme acid phosphatase in the lab and analyzed their data. In my BIO 1206 course (Integrating Concepts in Biology: Organisms and Ecosystems; essentially an introductory course in ecology), we play a lot of short illustrative games (like the **natural selection game**) during class, aimed at giving students an understanding of concepts like natural selection and physiological allocation.

D.) Student-driven research

I have spent a lot of time working with undergraduate researchers over the course of my career, from the small army of students who helped me collect data for my dissertation to the 20+ research students I have mentored since coming to Transy in the fall of 2010. I have had the pleasure of mentoring many of these for two plus years, and watching these students grow into scientists in their own right has taught me that *the best way to learn science is by actually doing it.* Thus, I integrate student-driven research with appropriate scaffolding into every course I teach.

This integration ranges from relatively restricted, small-scale projects aimed at teaching students the fundamentals of experimental design, hypothesis testing, and collaborative research in my lower-level classes to open-ended semester long projects that require students to engage heavily with the primary literature in my upper-level classes. The entirety of the lab in my Animal Physiology course has historically been student driven, with my role as the instructor being to provide the theme for the semester's lab and to guide students in developing experiments. One of the experiments from my 2013 Animal Physiology course led to a **poster** presented at the Animal Behavior Society national meeting.

E.) Instructor feedback

Because so much of my instruction is student-centered and student-driven, *regular and prompt feedback to students – particularly in the context of student-led research - has become a key component to my approach to teaching.* Certainly in my life as a researcher I depend on feedback from collaborators and peers to help me refine hypotheses, improve experiments, revise papers, and clarify my thinking. Therefore, I structure my courses to make sure my students have the same opportunity.

I break large projects down into chunks with specific deadlines, both to combat the inevitable student procrastination and to let me give feedback at each stage of a project. I use rubrics to help clarify my expectations for assignments and to make sure everyone gets evaluated fairly. At particularly challenging phases of a project (such as going from outline to first draft in a senior seminar paper, or revising an experimental design), I like to conference with students individually or in their lab groups. I also make sure students have the opportunity to turn in and get feedback on at least a few in-class or homework assignments before each exam, just so that they know whether or not they are on the right track to understanding the material before the stakes get high.

E.) Exams

Exams are the final ingredient in my teaching "recipe". Someone once told me that *students ought to come out of an exam knowing something they did not know going into it,* and that piece of advice stuck. While I certainly ask my share of standard-issue exam questions aimed at making sure students are meeting course learning objectives, I also like to include some questions that require students to synthesize what they know to address a novel question – for example, using what they know about the relationship between kidneys and blood pressure to explain why so many blood pressure drugs target kidney function. My questions about the bumbling Dr. Strangeglove and his adventures on various alien planets have become notorious among my students, and are useful for encouraging students to study in a way that focuses on fitting information into the bigger picture rather than simply memorizing facts.

I chose science as a career because the process of discovery is exhilarating – there's no better feeling than chasing the answers to unanswered questions. I chose it because there's nothing I love more than kicking around new ideas with my scientific peers. I chose it because getting my hands dirty in the lab and the field is fun. This is what science is about – not listening to lectures and memorizing equations and lists of facts. Thus, nearly everything I do in the classroom, from semi-Socratic teaching and hands-on activities to student-driven projects and the way I give feedback, is designed to expose students to biology and neuroscience as they are really done, and to invite them to join the conversation.

Works Cited

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SYLLABI AND COURSE MATERIALS

Syllabi and Course Materials

A.) Syllabi

Beyond using my syllabi to communicate course policies, course goals/learning objectives, grade scales, and assignment due dates, I also use them to set the tone of the class from the first few minutes of the first day of class. While I try to keep my syllabi from becoming overly long, I look at them as a tool to clearly communicate my teaching philosophies and instructional approach, to build community within the class, and to encourage buy-in from my students.

Most of my syllabi contain some variant of the phrase "Science is best learned by doing." I try to make it very explicit to my students that the scientific approach is a way of understanding how the world works, not a seemingly endless list of facts to memorize. In fact, in my ICBO syllabus, I state it even more explicitly: "*While you will certainly learn plenty of facts in this course, the main emphasis of this class is on learning to think like a scientist. Thus, this course is more discussion-oriented than lecture oriented, and we focus more on evaluating data and asking good questions than on memorizing facts."*

I am also quite explicit that, just as working scientists rely on collaboration and discussion, learning in my classes is a community affair. I always include a statement about "respect and classroom climate" in my syllabi. The version in my syllabus for Neurobiology reads, *"Learning in this class is a collaborative effort. You'll work in pairs or in teams in the lab, and classroom discussion is highly encouraged. Therefore, all members of this class are expected to treat one another with consideration, respect, and equality, regardless of race, religion or lack thereof, social class, disability, age, gender, gender presentation, sexual orientation, health status, geographical origin, appearance, political views, etc."* I also remind students to take responsibility for doing their part in the class and the laboratory. In my ICBO syllabus, I remind my students that, "*because this class is largely hands-on and discussion-based, everyone's success depends on all students having read the material, taken notes, and answered the integrating questions PRIOR TO CLASS. Coming to class unprepared hurts everyone (and annoys your instructor) – so don't do it!"* and I also state, *"While part of your lab grade is based on attendance, showing up for lab isn't just about your grade – it's also part of being a good collaborator!"*

One of the other things that I strive to make clear to my students from the outset is that I am their partner and cheerleader in learning and discovery. One tool that I use for this is to apply "we" and "our" language rather than "you" and "your" language as much as possible, in statements like, "*we will focus more on evaluating good data and asking good questions than memorizing facts"* (ICBO), "*In this class, we will explore the links between structure and function, with an emphasis on the relationship between the physiological challenges presented by particular environments or life history strategies and the evolution of the vertebrate body plan*," (CVA) and "*Exactly what we investigate will depend to some extent on the will of the class"* (Animal Physiology).

As another step toward fostering community and collaboration and a sense that the class is meant to be an egalitarian environment, I use my syllabi to communicate my availability and willingness to work with students. I have always provided my students with my cell phone number and told them to feel free (within reason) to text me if they have questions or concerns outside of class and office hours. It's often a much more reliable way to reach me than email, particularly in the spring months when I may very well be in the field doing research when I am not in my office, and students seem to prefer it. In my experience, students do not abuse the opportunity to text me whenever they like, and sometimes they will text me after the course is over with things like bird photographs they've taken, memes relevant to course material, and news of their accomplishments. A recent grad who is now in chiropractic school texted me the other day to let me know she'd had a poster accepted to a big conference. Although I've forgotten to include the statement in a syllabus or two, most of my syllabi contain a statement about my open-door policy *("feel free to stop by whenever my door is open (which is most of the time)"*) and hints about where to find me outside of posted office hours if I'm not in my office (usually my research lab down the hall).

In order to promote student investment in the course and increase the likelihood that students will get what I hope out of class assignments, I strive to be transparent about my reasoning behind decisions about course structure and assignments. For example, when I explained the semester project in Comparative Vertebrate Anatomy, I said, "*The semester project is intended to introduce you to comparative anatomy/morphology as a living discipline and to allow you to apply the anatomical terminology and expertise in dissection that you're acquiring in class to a problem that is of interest to you. You will work in groups of no more than three to develop a hypothesis relating to structural differences within a taxon or between at least two groups of vertebrates, and then empirically test that hypothesis using observation and measurement of specimens (skeletons, whole mounted animals, preserved organisms) that are available to you in the laboratory."* In my Neurobiology course, I give a short weekly quiz to encourage students to retain and review challenging material, a decision I explain by saying, "*Recent research in learning (and my own experience at Transy) strongly suggests that frequent testing promotes higher retention of material. Therefore, each Monday except for the first week, you'll take a short ~10 min quiz on the material."* I have found that it is much easier to convince students to buy in and really invest in assignments when they understand why they're doing the work in the first place.

While my syllabi certainly include many of the usual things about absence policies, grade scales, how to turn in homework (I typically collect it electronically), and whether or not I allow students to use technology in the classroom (I do, though I expect them to do so respectfully), I also view my syllabi as a sort of community charter for my classes. I also use them to set the tone of future interactions between myself and my students and between students and their peers in the class, and to help them understand why they're being asked to do certain assignments. While I have not directly collected any empirical data to measure the effectiveness of my syllabi in accomplishing those things, I do know that I routinely score well over both the national and institutional mean on "instructor/student interaction" and

"instructor commitment to student learning," on my SUMMA evaluations which suggests to me that these measures are effective.

B.) Instructional Materials and Labs

I create and adapt a variety of course materials for each of my classes, in order to promote discussion of and engagement with course content and the development of novel ideas and to help my students gain a more intuitive understanding of difficult or abstract concepts,

As part of my semi-Socratic approach to teaching, most class sessions are structured around a set of questions that ask students to work collaboratively (I generally ask them to work with partners or small groups) and use data, experimental results, or simple models to construct an understanding of core concepts. The **inclusive fitness exercise**, for example, was aimed at helping my ICBO students understand how sterile worker castes might have evolved in social insects, and the **sunfish questions** asked students to grapple with data presented in their textbook to draw conclusions about how differences in predation might relate to the evolution of life history strategies. **Thinking about neurotransmitters** asked students in Neurobiology to consider how serotonin and its various transporters and receptor subtypes related to the function of antidepressants and antiemetic drugs.

We also do a lot of hands-on "playing" in my classes. I use in-class simulation exercises and games to help students develop an intuitive understanding of abstract-seeming concepts and processes that take place on a microscopic scale. The **kinetics of Lego hydrolase activity** and the associated **enzyme kinetics lab** for Cell and Molecular Biology paired a simulation of enzyme properties using Legos with an exercise in which students empirically measured the properties of the enzyme acid phosphatase in the lab and analyzed their data. **The natural selection game** in my ICBO course used a simple foraging simulation to allow students to explore how natural selection works, as well as the importance of trait heritability and differential reproductive success. In Neurobiology, I use the **action potential activity** to help students understand how excitatory and inhibitory input to a neuron can change the neuron's resting potential, and how postsynaptic potentials can combine to allow a neuron to reach threshold and fire an action potential.

Labs take a variety of forms. Some labs, such as the **size lab** in CVA and the **enzyme kinetics lab** in Cell and Molecular Biology use a structured but largely inquiry-based approach to help students learn foundational concepts (in these cases, allometric scaling and Michaelis-Menten kinetics). Others, like the **skull lab** and the **peroxidase lab**, are meant as scaffolding: using a relatively short, topical lab to give students an opportunity to conduct and receive feedback on a small-scale, largely independently designed research project before diving into a multi-week semester project like **protist population dynamics** (ICBO) the **cell culture project** (Cell and Molecular Biology), the **bird song system lab** (Neurobiology), or the CVA **semester project** (for which I have included the question/hypothesis proposal and experimental plan proposal assignments). The semester lab projects, which are conducted in pairs or small groups (and thus also let students build skills

in collaboration), serve four main purposes: (1) to ask students to evaluate the literature and use their own prior knowledge to generate research questions and hypotheses, (2) to encourage students to develop their skills in designing experiments, (3) to develop quantitative reasoning and data analysis skills, and finally (4) to help students develop and hone their scientific communication skills.

C.) Other Assignments

Over the course of the semester, I give a variety of assignments in any given course. **Problem sets** (see examples from **Cell and Molecular Biology, Animal Physiology,** and **Neurobiology**) are probably the most commonly given assignments. Problem sets are intended to encourage students to review crucial concepts and to apply what they have learned to understanding problems in the "real world" (like problem of protein wastage faced by people on strict vegan diets). In Animal Physiology and recently in my May Term Ornithology course, I have asked students to write a couple of **blog posts** during the semester (published on the class blogs on WordPress – http://transyanimalphys.wordpress.com and http://birdieblogblog.wordpress.com). These blog posts are helpful from two perspectives: the help students practice communicating science to the public, which is an increasingly important skill for working scientists, and they also help students understand difficult and/or unfamiliar material – in my experience, there is no better way to really solidify understanding of a concept than to have to explain it to someone else in plain English.

In some courses (notably senior seminar and capstone), I give major, semester-long paper assignments (the papers for senior seminar and capstone are sometimes known as 'library theses'). A project of that scope and length can be difficult for undergraduates to manage, so I like to break the assignment itself into smaller chunks that are due at regular intervals. This "chunking" helps to keep students from procrastinating and also allows me to give feedback to students at each stage of project development. After particularly crucial assignments (e.g., the annotated outline and first draft), I schedule individual conferences with students to give feedback, discuss the overall picture, and help them work out a plan to go forward.

I use **rubrics** to score most major assignments, and generally make the rubrics available to students before the assignment itself is due in order to make my expectations clear to my students. This tends to minimize both my frustration and theirs. Additionally, the use of rubrics helps to keep *me* focused and ensure that I give feedback to the student on each of the key parts of the assignment and score every student in the class according to the same criteria.

D.) Exams

At some point during my first or second year as a faculty member, someone at the Animal Behavior Society conference made the comment that a student ought to leave an exam knowing something he or she did not know going into the exam. The comment stuck, and over the last few years I have come to regard my exams as

not just a tool for assessing students' progress in meeting learning outcomes, but as a pedagogical tool as well.

My **in-class exams** contain a mix of question types, ranging from relatively straightforward factual questions to questions that ask students to use what they know to interpret data and draw conclusions and/or design an experiment, to questions that ask students to apply prior knowledge to an unfamiliar question (such as questions about drug mechanisms). Students say that some of the most memorable questions on my exams are the questions about the **bumbling Dr. Strangeglove** and his adventures wandering the galaxy in his spaceship. Since the questions ask about "alien" species, students cannot simply 'regurgitate' memorized information – they have to actually understand and apply what they have learned in the class. Because so many of the constituents in my classes are pre-health students, I also include at least a handful of multiple choice questions on my exams. Students at liberal arts schools get relatively little experience with multiple choice questions compared to their peers at larger public institutions, so I like to include these questions in order to prepare my pre-health students for the kinds of questions they may face on the MCAT.

In my upper-level classes, I often make the comprehensive portion of the final exam a **take-home exam**, generally handed out 2-4 weeks prior to the final exam and due on the day of the final itself. The take-home exams allow students to choose from a short "menu" of potential questions relevant to course content, and then ask them to do research in the primary and secondary literature to answer the question they have chosen. These exams are quite popular with my students, partly because they allow students who do not test well because of test anxiety or other issues to show me what they know. On my side of the equation, these take-homes are particularly useful for assessing students' ability to analyze and evaluate information in the primary literature (levels 4 and 5 in Bloom's taxonomy), as well as their facility in using that information to develop and support a hypothesis (level 6 in Bloom's taxonomy). Furthermore, these take-home exams reinforce what I spend the entire semester telling them: that it is more important to learn how to analyze, evaluate, and interpret information than it is to memorize a pile of facts!

BIO 1206: Integrating Concepts in Biology – Organisms and Ecosystems
WINTER SEMSTER 2016

Lecture: MWF, 10:30-11:20
Laboratory: T, 9:30-12:15

~ * ~

The scientist is not a person who gives the right answers, (s)he's one who asks the right questions. ~Claude Lévi-Strauss

Science is always wrong. It never solves a problem without creating ten more.
~George Bernard Shaw

~ * ~

Instructor: Becky Fox, Ph.D.
Email: rfox@transy.edu
Phone: 233-8288 (office) or 530-400-7575 (cell – texting is probably the best way to contact me)
Office: BSC 313
Office Hours: MWF 9:00-10:00 and 2:00-3:30; Tues. 1:30-3:30
Other times by appointment, or feel free to stop by whenever my door is open (which is most of the time).

Course website: Class materials - including some lab exercises - will be posted on Moodle

Required Texts:
Campbell, Heyer, and Paradise (2014). *Integrating Concepts in Biology*. Trunity (electronic text)

Papers and articles posted on Moodle

Course Description: This is an introductory course in college biology that focuses on the concepts of evolution, information flow, biological structure and function, homeostasis, and emergent properties of biological systems. This course focuses on questions at the scale of whole organisms to ecosystems.

Course Philosophy:
While you will certainly learn plenty of facts in this course, *the main emphasis of this class is on learning to think like a scientist.* Thus, this course is more discussion-oriented than lecture oriented, and we focus more on evaluating data and asking good questions than on memorizing facts.

Because this is a collaborative, seminar-style course, your attendance and contribution to the discussion is hugely important! As such 10% of your grade is

based on attendance and engagement. Having 3 or more unexcused absences from class will reduce your grade. Additionally, because this class is largely hands-on and discussion-based, everyone's success depends on *all* students having **read the material, taken notes, and answered the integrating questions PRIOR TO CLASS.** Coming to class unprepared hurts everyone (and annoys your instructor) – so don't do it!

Course Learning Objectives
Students who successfully complete BIO 1206 will be able to:

- Clearly articulate core concepts of organismal and evolutionary biology and ecology including homeostasis, speciation, homeostasis, population dynamics, etc. and some of the central questions associated with those concepts

- Interpret data presented in charts, graphs, and tables, and use those data to draw conclusions and evaluate hypotheses.

- Use existing data to develop novel questions and design experiments to address them.

- Effectively present raw data using graphs, and use some basic statistical techniques to analyze those data.

- Effectively use PowerPoint to present a scientific experiment and its results.

Laboratory:
The focus of the lab for BIO 1206 is on developing your skills with regard to formulating hypotheses, designing experiments to test them, and analyzing data. Since students will be working in pairs or small groups, primarily on their own projects after the first few weeks of the semester, LAB ATTENDANCE IS MANDATORY. While part of your lab grade is based on attendance, showing up for lab isn't just about your grade – it's also part of being a good collaborator! ☺

Because you'll be doing multi-week projects with live organisms (and real organisms can't read a class schedule), you'll find that some of your lab work will take place outside of scheduled lab time. Careful planning – and a commitment to working collaboratively with your lab partner – should ensure that this does not become burdensome.

Also, please be aware that putting your name on a collaborative project when you weren't a significant contributor to the final product is a form of academic dishonesty and will be treated accordingly (not to mention the fact that it is disrespectful to your collaborators!). Just as is required by a lot of scientific

journals, you will be required to specify each partner's contribution to each project, either in your lab notebook or on a form you turn in with the project.

Lab grades will be based on attendance, lab notebooks, data analyses, and the final presentation at the end of the term – specifics will be given on a separate assignment sheet.

Exams: Exams are a mixture of matching, multiple choice, short answer, and essay questions. Don't expect to be able to get a grade you're happy with simply by memorizing – a number of the questions will ask you to propose experiments or interpret data, just as we do in class. Knowledge and skills in this class (as in real life) build on previous knowledge and skills, so all exams are cumulative.

Makeup exams are given for medical or emergency situations (proper documentation required). I will also give makeups in cases where you must be absent for school sponsored travel or a religious holiday – but only if you let me know and make arrangements in advance!

Grade breakdown

Source	Number of grades	Points (each)	Total points	Percentage of grade
In-class exams	3	100	300	45
Final exam	1	100	100	15
Class engagement (participation)	13	5	65	10
Lab engagement (incl. attendance)	13	5	65	10
Lab notebook checks	3	15	45	5
Lab presentation	1	20	20	3
Final powerpoint (protists)	1	50	50	7
Biomath and ethics (student's choice)	2	10	20	3
Total			**665**	**100**

Grading:
I am philosophically opposed to curving grades either up or down, primarily because I feel that everyone in the class deserves to have an equal opportunity to earn an A (or not). Thus *your* grade should only be dependent on *your* effort, and not on how the rest of the class performs. I use a modified +/- system as detailed below. I round final grades to the nearest integer

90-97 A 98-100% A+
89 possibly A- (depending on demonstrated effort)
80-82% B- 83-86% B 87-89% B+
70-72% C- 73-76% C 77-79% C+
60-62% D- 63-66% D 67-69% D+ Below 60% F

Course Policies

Submitting Assignments: Assignments that are to be submitted electronically are due **ON MOODLE** by the date and time specified. Assignments to be turned in on paper are due **AT THE BEGINNING OF CLASS** unless otherwise specified**.** Homeworks that are turned in late (i.e. after they have been collected at the beginning of class or after the time cutoff on Moodle) receive an automatic 5% deduction. Every 24 hours that an assignment is late will result in a further 10% deduction from the grade you would have received if the assignment had been turned in on time. That said, it is ALWAYS better to turn in an assignment late than to not turn it in at all!

Academic honesty: Academic dishonesty will not be tolerated. Please refer to the Student Handbook for descriptions of offenses and policies. Any violation of the policy will have serious consequences and may result in an F (0%) for the assignment, exam, or the course. If you have questions regarding what is allowable, please ask. There will be substantial group work in the class and the policy holds for group work as well. If you were not a significant contributor to the group, it would be dishonest to claim the group product as your own. Plagiarism will not be tolerated: all references (even your textbook) **must** be properly cited in the text and the reference listed in a bibliography. If you are unsure about proper citation, or whether something should be cited, please ask.

Absences: If you miss lecture, make sure you get the notes from a classmate. Excessive absences will likely result in a deduction from your grade. *Exams and lab assignments may be made up only in cases of documented personal or family emergencies or illness, religious holidays, or if you are traveling for a school-sponsored event.* If you know you are going to be traveling or missing class for a religious observance, it's your responsibility to let me know in advance and make arrangements to make up the lab and/or exam.

Technology in class: We have an electronic textbook and live in an internet-connected world. You are thus welcome to bring laptops, tablets, phones to class – we'll use them. HOWEVER, you should be aware of a couple of things: (1) research shows that trying to do anything while simultaneously reading facebook/email/texting etc. is the equivalent of doing it with a BAC of 0.1%, and (2) research also suggests that taking handwritten notes is better for getting facts into your long term memory. Furthermore, if you text or surf the web or play games in class and get caught, it will result in a deduction from your engagement grade. I will not necessarily announce that I've caught you. Do so at your own risk.

Disability Accommodations: I'm happy to provide any accommodations (a quiet room for testing, extended time, etc.) to which you're entitled, but it is your responsibility to let me know you are entitled to receive accommodations. Accommodations should be documented with the Disabilities Coordinator, Brenda

Dennis (bdennis@transy.edu), who can also help you with determining what may be reasonable accommodations for your situation.

Respect and Classroom Climate:
Learning in this class is a collaborative effort. You'll work in pairs or in teams in the classroom and in the lab, and classroom discussion is highly encouraged. Therefore, all members of this class are expected to treat one another with consideration, respect, and equality, regardless of race, religion (or lack thereof), social class, disability, age, gender, gender presentation, sexual orientation, health status, geographical origin, appearance, political views, etc.

Week	**Monday**	**Tuesday (Lab)**	**Wednesday**	**Friday**
1 1/11 – 1/15	Intro to class and textbook	Introduction/ Human variation and correlation	Ch 18.1 – up to "Frog choruses attract predators"	18.2 – Foraging (thru q. 27)
2 1/18/1-22 (No class Monday)	MLK DAY – NO CLASS	Optimal foraging lab	18.2: Obtaining resources (cont'd) – thru end. [Ruddy ducks]	18.3: (Thru q. 35) [do worksheet]
3 1/25-1/29	Principles of Darwinian Evolution / Darwin's finches data analysis assignment	Populus lab – genetic drift and selection	19.1: Mate choice in guppies (Thru. q. 7)	Frequency dependent selection – Beards and Guppies [on Moodle]
4 2/1-2/5	19.3: Gene flow and genetic isolation (only to q. 19) / Blue and golden-winged warblers (on Moodle)	**Exam 1 (1st half)**/ Design corn experiment	19.4: Non-adaptive evolution	Phylogeny and tree thinking
5 2/8-2/12	20.1 (Orchids) / Tree exercise with data	Introduction to protist lab / Bring computers to do research and design experiment	20.2: Plant invasion of land	20.3: Human evolution
6 2/15-2/19	Darwin's finches and "instant evolution" (on Moodle)	Set up trial run of protists / tear down corn experiment	21.1; Bee tongues [on Moodle]	21.1: Antagonistic coevolution (snake-newt) Brodie reading & thought Qs
7 2/22-2/26	21.2: Corals, endosymbiosis, and coral bleaching	Analysis of corn data	21.4: Adaptation to disturbance	24.1: Growth in unicellular organisms

8 2/29-3/4	24.2 Soil microbes and nitrogen fixation	**Exam 2 (1st half)/** Present experiment to classmates	24.3 – red tides	Superorganisms and eusocial animals 25.1 (bee example only; q. 11-12)
9 3/7-3/11	25.3: How (and why) might cooperation evolve?: the wasp story	Analyze preliminary data, revise experiment as needed	Demography and population dynamics	26.1: Age structures in populations
10 3/14-3/18 SPRING BREAK	SPRING BREAK	SPRING BREAK	SPRING BREAK	SPRING BREAK
11 3/21-3/25	LAB DAY – SET UP EXPERIMENTS	26.3 – Flock response to predators	27.1: Trophic cascades	27.2: Competition
12 3/28-4/1	27.3: Energy flow and species interactions	End experiment	27.4: Food webs	28.1: Organismal homeostasis
13 4/4-4/8	28.2: Tradeoffs and allocation	**Exam 3,** no official lab (suggest you work on presentations)	29.1: Life history strategies	29.2: Predation and populations
14 4/11-4/15	29.3: Predator/prey cycles	PRESENTATIONS	Ch 30.1: Feedback cycles	Wrap-up and review

FINAL EXAM: WED, 4/20, 12:00-2:00 PM

BIO 2304 CELL AND MOLECULAR BIOLOGY
Winter 2014
SYLLABUS

INSTRUCTOR CONTACT INFORMATION
INSTRUCTOR: Becky Fox, Ph.D.
Office: BSC 313
Phone: 233-8288 (office) 530-400-7575 (cell; texts preferred)
Email: rfox@transy.edu

please note that emails/text messages received after 7 PM may not be answered until the following morning.

Lecture: 12:30-1:20 MWF
Lab: 12:30 – 4:15 T

OFFICE HOURS:
MTWF: 9-11:30 AM
Th: By appointment only
Other times by appointment

TEXTBOOKS
Required: Essential Cell Biology, 4th edition, Alberts et al., Garland Science, 2014
Writing Papers in the Biological Sciences, 5th edition, McMillan, Bedford/St. Martins, 2012.

Recommended: Biology **(**any recent edition), Campbell and Reece, Pearson Benjamin Cummings (same book as used in Biological Interactions)

Course description:
Cell and Molecular Biology is a writing-intensive course aimed at students who have completed Biological Interactions and at least one semester of college chemistry.

Cells are the basic units of life, and this course will serve as an introduction to their structure and function. In particular, we will focus on (1) the molecular constituents of the cell (e.g., proteins) and the chemical processes that underlie cellular function, (2) the relationship between structure and function on multiple levels ranging from molecules to entire cells, (3) how cells adapt to their environments (which they must do continuously). In addition, this course will engage students in independent research experiences and introduce students to the craft of scientific writing.

Course Goals:
Students who succeed in BIO 2304 will demonstrate:

(1) knowledge of the basic processes and molecular constituents of a cell, and an understanding how these processes are studied.

(2) the ability to apply current knowledge to unfamiliar problems (via reading, discussion, active learning, problem solving, and lab investigations).

(3) the ability to formulate and justify testable hypotheses based on the primary literature, design well-controlled experiments to test those hypotheses, and correctly analyze and interpret quantitative data.

(4) the ability to effectively communicate information in standard scientific formats.

(5) effective and productive collaboration with peers

Course Structure:
A Note About Moodle:
We make heavy use of Moodle in this course, so you'll want to make sure you check the class Moodle regularly and make sure you are signed up to receive news forum updates via email.

LECTURE

"Lecture" format

The lecture portion of the class will consist of a mixture of small-group activities, discussions, hands-on investigations, and traditional lectures. **Because we do a lot of active learning and problem solving in class, it is very important that you make a concerted effort to keep up with the readings and come prepared to think about and discuss them!**

Problem sets and Friday group quizzes.

Most weeks you will receive a short problem set on Monday morning. Some problems will come from your textbook, others will not. *Some problems may be based on material in the reading that is not covered in lecture.* Problem sets are due that Friday morning at the beginning of class. ***Each student should do his or her own work on the problems.*** During the first 20-25 minutes of class on most Fridays, groups of 3-4 students will work together to complete a quiz based on that week's problem set. Problem sets will be worth 5% of your grade, and group quizzes will be worth 10% of your grade.

Writing assignments

This is a writing-intensive course, with a focus on learning to effectively communicate scientific findings. Over the course of the quarter, you'll learn to write a scientific manuscript, including standard conventions for formatting and communicating information, constructing clear tables and graphs, and

explaining methodology. Expect to have a short (1-2 page) individual writing assignment most weeks, as well as a few larger, collaborative group assignments during the semester. THESE ASSIGNMENTS ARE DUE ON MOODLE BY MIDNIGHT ON THE DATE NOTED IN THE SYLLABUS. Your writing assignments will be worth 15% of your grade.

Please note you're always welcome to submit a draft of an assignment for preliminary feedback at least 2 days prior to the due date. This does not necessarily guarantee you an 'A' on the assignment.

Exams

Three exams (expect to take about two hours for each exam) will be given during lab (dates as noted on the syllabus). The final exam will be given during finals week as scheduled. The first three exams combined are worth 30% of your grade. The comprehensive final is worth 20% of your grade.

Expect exams to contain a variety of question types: multiple choice, essay, short answer, etc. Essay and short-answer questions will require you to **understand and apply concepts, make hypotheses, clearly articulate your reasoning, and/or solve problems.** You may be asked to generate and justify a hypothesis, analyze and interpret data, or design an experiment. Just reading through the text and memorizing your notes will not be sufficient to earn an A or a B on an exam!

LABORATORY

Expectations for student work:

While we may spend some time at the beginning of lab discussing particularly difficult techniques, students are expected to be relatively independent in this lab. **This means that you are responsible for reading through the lab handouts and making sure you understand the procedures ahead of time,** and that you are expected to take the initiative to ask questions before you begin if you don't understand something.

Lab groups

Lab groups must consist of no less than 3 people and no more than 4. You may choose your own group members, but choose wisely – your best friend may not be your ideal lab partner!

Lab notebooks

Students are expected to keep organized lab notebooks (details on that in a separate handout) in which you record your experimental plans and the data you collect during lab. Lab books will be collected at least twice during the semester (after the Peroxidase lab and just prior to the final exam).

Independent projects
During the second half of the semester, lab groups will work on two independent projects in which you are expected to identify a question of interest based on your knowledge of cell biology and research in the primary literature, develop hypotheses, and design an experiment to test those hypotheses. All group members are expected to work collaboratively and make approximately equal contributions to these projects. The design and execution of each independent project is worth 10% of your lab grade.

Lab Attendance:

ATTENDANCE IS REQUIRED Being late or absent can affect your whole group, so please be responsible to and respectful of your group members and show up on time for lab every Tuesday. Because CMB labs are time-intensive and time-sensitive (and are also group activities), **they can't be made up**. If you must miss lab due to an emergency (documented family or medical emergency, religious observance, or school-sponsored travel), contact me ahead of time to make other arrangements to get credit for the lab. In the case of religious observances and school-sponsored travel (which you should be aware of beforehand), *you must inform me ahead of time or you will not be allowed to do the make-up work.* In order to document attendance, I will initial everyone's lab books once we have started the lab exercise.

Lab preparation/participation grade:

A passing grade (70%) in lab is earned in lab by showing up on time **and prepared** for lab and participating fully in the day's lab activity. *You should have read the lab handouts and outlined your plan for the lab and your expectations and predictions in your lab notebook* ***before coming to lab***. Lab accounts for 20% of your grade.

Lab Safety:

On lab days, all students are expected to follow standard safety rules: wear long pants and close-toed shoes, avoid shirts with baggy sleeves, and do not eat or drink in the lab under any circumstances. Any additional safety precautions required for particular experiments will be introduced prior to performing the lab. Federal regulations require that you have access to safety data (Material Safety Data Sheets, or MSDS) on all materials used in the lab. MSDS will be available in the lab, or can be looked up at www.ilpi.com/msds/index.html.

COURSE POLICIES
Absences:

If you miss lecture, make sure you get the notes from a classmate. *Exams, group quizzes, and labs may be made up only in cases of documented personal or family emergencies or illness, religious holidays, or if you are traveling for a school-sponsored event.* If you know ahead of time that you're going to miss class, it's your responsibility to let me know in advance and make arrangements to make up the exam or assignment.

Disability Accommodations:

I'm happy to provide any accommodations (a quiet room for testing, etc.) to which you're entitled, but it is your responsibility to let me know you are entitled to receive accommodations at the beginning of the term.

Respect and Classroom Climate:

Learning in this class will be a collaborative effort. You'll work in teams in the lab, and classroom discussion is highly encouraged. Therefore, all members of this class are expected to treat one another with consideration and respect.

GRADING

The grade that you earn in this class will be based on the following:

GRADE COMPONENT	POINTS
In-lab exams, (3 x 100 points):	300
Writing/Group Assignments/Presentations:	150
Problem sets	50
Friday Quizzes (8-10 pts each)	100
Lab (Notebooks, experimental design, participation):	200
Final Exam:	200
TOTAL	1000

Lab Grade Breakdown	*200 points*
Preparation/On-time arrival/Participation/Lab quizzes	110
Lab notebooks (at least 2 checks, 5-15 points each)	30
Experimental design/execution for peroxidase project (10 points for proposal, 15 for execution)	25
Experimental design/execution for culture project (10 points for proposal, 15 for execution)	25

Writing assignment breakdown	*150 points*
Parts of a scientific paper	5
Materials and methods	5
Results/Discussion	15
Introduction (group)	15
Project bibliographies (2 x 5 pts)	10
Peroxidase project report (group)	50
Cell culture poster (group)	50

GRADE SCALE

98-100% A+	87-89% B+	77-79% C+	67-69% D+	below 60% F
90-97% A	83-86% B	73-76% C	63-66% D	
	80-82% B-	70-72% C-	60-62% D-	

Week/dates	Topic(s)	Reading	Lab	Assignments due
Week 1 Jan. 6-10	*What is a cell? *Intro to scientific writing *Macromolecules	Alberts Ch. 1/2 (Campbell 2-4) Paper on Moodle	Introduction to spectrophotometry	Friday: Problem Set 1
Week 2 Jan. 13-17	*Macromolecules *Presenting experimental results *Introduction to Enzymes	Alberts Ch. 2/3 (Campbell 5) McMillan p. 71-76	Enzyme kinetics wet lab	Monday: Parts of a scientific paper Thursday: Materials and methods section for lab 1 Friday: Problem set 2
Week 3 Jan 20-24 NOTE: *Monday is Holiday*	*Bioenergetics, enzymes, and biosynthesis *Interpreting experimental data	Alberts Ch. 3 (Campbell 8) McMillan ch. 2-3	Enzyme kinetics data analysis MEET IN COMPUTER LAB!	Tuesday, in lab: spreadsheet for data analysis (notebook) Friday: Problem set 3
Week 4 Jan. 27-31	* What are Peroxidases? *Protein structure and Protein synthesis *Reading and evaluating scientific writing	Alberts Ch. 4 and pp. 246-260 (Campbell 5) Mc.Millan p. 76-85	EXAM 1 (weeks 1-3)	Friday: Results and discussion for enzyme kinetics lab; Problem set 4
Week 5 Feb. 3-7	*Proteins cont'd * Intro to membrane structure	Alberts. Ch 4/11 (Campbell 5) McMillan p. 210-218 and ch. 1	Characterization of peroxidases #1 (Library research and project planning) *Experimental design	Tuesday: Question proposal due in lab (notebook) Friday: Group proposals and article summaries due

Week 6 Feb 10-14	*Membrane Structure & Transport	Alberts Ch. 11/12 (Campbell 7)	Characterization of peroxidases #2	Tuesday: Question proposal due in class Friday: Problem set 5
Week 7 Feb 17-21	*Membrane Transport *Writing effective introductions	Alberts Ch. 12 (Campbell 7) McMillan p. 69-71	Characterization of peroxidases #3	Friday: Intro for peroxidase report [GROUP ASSIGNMENT] Friday: Problem set 6
Week 8 Feb 24-28	*Glycolysis and TCA cycle: cellular energy from food *Citations in scientific papers	Alberts Ch. 13 (Campbell 9) McMillan ch. 6	EXAM 2 Weeks 4-7	Friday: Bibliography for peroxidase report due [GROUP ASSIGNMENT]
Week 9 Mar 3-7	Chemiosmosis: Energy generation in mitochondria and chloroplasts	Alberts Ch. 14 (Campbell 9-10) McMillan p. 61-69, 93-103	Microscopy refresher/use of the hemocytometer/ work time for proposals Dilutions	Wednesday: Peroxidase reports due; Turn in lab notebooks Friday: Problem set 7 & Cell culture project proposals due [GROUP ASSIGNMENT]
Mar 10-14 SPRING BREAK No CLASS				
Week 10 Mar 17-21	Intracellular Transport	Alberts Ch. 15 (Campbell 6)	Intro to sterile technique/ Start Projects!	Friday: Problem set 8
Week 11 Mar 24-28	Cell communication	Alberts Ch. 16 (Campbell 11)	Cell culture	Friday: Problem set 9

Week 12 Mar 31-Apr 4	Cytoskeleton and cell movement	Alberts Ch. 17 (Campbell 6)	EXAM 3 Weeks (8-11)	<u>Wednesday:</u> Annotated bibliography for cell culture project due [GROUP ASSIGNMENT] <u>Friday:</u> Problem set 10
Week 13 Apr 7-11	Apoptosis, Cell Cycle control & Cancer *Review for final on Friday	Alberts Ch. 18/21 McMillan p. 201-210	Cell Culture *Poster session	<u>Friday:</u> Problem set 11
Apr 18 12:00-2:00 PM	FINAL EXAM	20% week 12-13; 80% comprehensive		COMPLETED LAB NOTEBOOKS DUE DAY OF FINAL!!

BIO 3016: COMPARATIVE VERTEBRATE ANATOMY
FALL SEMESTER 2014
Lecture/Laboratory: MWF 12:30-2:20

Life is a copiously branching bush, continually pruned by the grim reaper of extinction, not a ladder of predictable progress. – Stephen Jay Gould

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Office hours: MW 9-10 and 2:30-3:30; T/Th 9-11

Other times by appointment, or feel free to stop by whenever my door is open (i.e., most of the time).

Course website: Class materials - including some lab exercises - will be posted on Moodle.

Required Texts:
Kardong, K.V. (2014) *Vertebrates: Comparative Anatomy, Function, Evolution.7th ed.*
Kardong & Zalisko (2014). *Comparative Vertebrate Anatomy: A Laboratory Dissection Guide,* 7th ed.

Course description: CVA focuses on using principles of physiology and evolutionary biology to understand the both the unity and the diversity of structure among the various vertebrate taxa. In this class, we will explore the links between structure and function, with an emphasis on the relationship between the physiological challenges presented by particular environments or life history strategies and the evolution of the vertebrate body plan.

Course objectives:
Students who successfully complete CVA will be able to:

• Identify anatomical features in vertebrate specimens, both macroscopic and histological.

• Using anatomical characters, identify animals as members of one of the major vertebrate groups

• Discuss – using scientific evidence – vertebrate origins and the vertebrate phylogenetic tree, as well as some of the major controversies surrounding the vertebrate phylogeny.

• Demonstrate an understanding of the links between ecological challenges, structure, and function in vertebrates, and be able to use this knowledge to ask

novel(ish) questions in comparative morphology and design experiments to test them.

Laboratory:
Because so much of this class is hands-on and based on discussion and direct observationof specimens, lab time is integrated with class time. While some days will be entirely lecture/discussion/presentations and others will be entirely devoted to dissection or working with specimens, most classes will consist of a mix of both. Material from labs will be included on the exams, *so it is important that you attend every class* (of if you must miss a class for illness, religious reasons, or a school-sponsored trip, that you get the notes from a classmate).

Because our lab takes place on a regular class day and there are other lectures after oursIT IS EXTREMELY IMPORTANT THAT YOU DO A VERY THOROUGH JOB OF CLEANING UP AFTER YOURSELVES. On dissection days or days that involve us having a lot of specimens out, the last 10 minutes of every class will be devoted to cleanup. Each lab group will be responsible for making sure their instruments are properly cared for, waste is disposed of, and specimens are returned to where they belong. Before you leave class you will be ask to initial a sheet certifying that you've cleaned up as directed in the "Care of Lab Equipment and Specimens" handout. FAILURE TO CLEAN UP PROPERLY WILL RESULT IN A LOSS OF POINTS ON THAT LAB ASSIGNMENT. How many points you lose depends on how big a mess you leave.

Additionally, skeletal specimens and bird skins are fragile, valuable, and difficult to replace. You are expected to handle them with respect and care and return them to wherethey belong at the end of class!

Lab Safety:
While most of our specimens for dissection are stored in relatively nontoxic preservatives, the specimens themselves have been perfused with formaldehyde (which is a sensitizer, an irritant, and a carcinogen). Therefore on dissection days, *you must wear goggles* (you can either use the ones we provide or bring your own), *gloves, long pants, and close-toed shoes.* Students who choose to may bring scrubs or a lab coat for use in dissection. <u>There is absolutely no food or drink permitted in the classroom once we start dissecting.</u>

Lab Practicals:
There will be three lab practicals during the semester (dates given in the syllabus). One of the three practicals will be part of the final exam. Students will be asked to identify organs and structures in the organisms they have dissected, and to answer questions about their structure and function. Keeping good notes in lab is to your advantage!

Exams:
Exams are structured as follows: ~30% multiple choice/matching, ~70% free-response. Exams will be given during class, and are written to take about an hour and a half. Some questions on the exam may require you to look at specimens. Do not expect to be able to get an A or a B on the exam just by memorizing facts! My exam questions generally ask to solve problems or to integrate and synthesize information.

Semester Project:
The semester project is intended to introduce you to comparative anatomy/morphology as a living discipline and to allow you to apply the anatomical terminology and expertise in dissection that you're acquiring in class to a problem that is of interest to you.

You will work in groups of no more than three to develop a hypothesis relating to structural differences within a taxon or between at least two groups of vertebrates, and then empirically test that hypothesis using observation and measurement of specimens (skeletons, whole mounted animals, preserved organisms) that are available to you in the laboratory. The assignments for this project will be broken up into parts (details given on specific handouts) to help keep you on track. *Be aware that this project will likely involve a substantial time investment outside of class (and possibly further dissection)*, particularly mid-semester when you start taking your measurements.

You will produce a writeup of your results in a standard scientific format, and will present your findings to the class in a ~10 minute oral presentation during the last two days of class.

YOU WILL BE REQUIRED TO SIGN OUT THE SPECIMENS AND TOOLS YOU USE OUTSIDE OF CLASS AND RETURN THEM IN GOOD CONDITION AT THE END OF EACH WORK SESSION.

Homeworks:
On weeks that you do not have assignments related to your semester project due, you will usually have some sort of short assignment. These assignments may take a variety of forms. Some may be problem sets; others will ask you to do some research in the literature or to read and critique a paper or two. These assignments are intended to reinforce what you are learning in class and to encourage you to delve deeper into a topic than you might if you were just reviewing lecture notes or reading the text.

Grade Breakdown (1000 points total)

In-class Exams – 2 x 150 points	300 points
Semester Project –	200 points
Hypothesis proposal: 10 points	
Revised hypothesis: 10 points	

Research plan:	20 points
Plan revisions:	10 points
Preliminary data	10 points
Data analysis	20 points
Writeup 1st draft	50 points
Final draft	30 points
Presentation	40 points

Lab Practicals 3 x 50 points	150 points
Lab assignments (total points vary)	100 points
Homeworks –5 x 10 points each	50 points
Final Exam (Cumulative)	200 points

Grade Scale

98-100% – A+	72-77.9% – C
90-98% -- A	70-71.9% – C
88-89.9% – B+	68-69.9% – D+
82-87.9% -- B	62-67.9% – D
80-81.9% -- B-	60-61.9% – D-
78-79.9% – C+	Below 60 – F

Policies:

Submitting Assignments: Semester project assignments are due ON MOODLE by 11:59 PM ON THE DUE DATE LISTED IN THE SYLLABUS. Homework assignments are due FRIDAY AT THE BEGINNING OF CLASS unless otherwise specified. Homeworks that are turned in late (i.e. after they have been collected at the beginning of class) receive an automatic 5% deduction. Every 24 hours that an assignment is late will result in a further 10% deduction from the grade you would have received if the assignment had been turned in on time. That said, it is always better to turn in an assignment late than to not turn it in at all!

Academic honesty:

Academic dishonesty will not be tolerated! Please refer to the Student Handbook for descriptions of offenses and policies. Any violation of the policies will have serious consequences and may result in a grade of F (0%) for the assignment, exam, or the course. If you have any questions about what is allowable, please ask. There will be substantial group work in this class, and the policy holds for group work as well. If you were not a significant contributor to the group, it would be dishonest to claim the group product as your own. Plagiarism will not be tolerated, and all references **must** be properly cited in the text and the reference listed in the bibliography. If you are unsure about proper citation, or unsure if something should be cited, please ask.

Absences:

If you miss lecture, make sure you get the notes from a classmate. Excessive absences will likely result in a deduction from your grade. Exams, lab practicals, and labassignments may be made up only in cases of documented personal or family

emergencies or illness, religious holidays, or if you are traveling for a school-sponsored event. If you know you are going to be traveling or missing class for a religious observance, it's your responsibility to let me know in advance and make arrangements to make up the lab, practical, and/or exam.

Disability Accommodations:
I'm happy to provide any accommodations (a quiet room for testing, etc.) to which you're entitled, but it is your responsibility to let me know you are entitled to receive accommodations. Accommodations should be documented with the Disabilities Coordinator, Brenda Dennis (bdennis@transy.edu), who can also help you with determining what may be reasonable accommodations for your situation.

Respect and Classroom Climate:
Learning in this class is a collaborative effort. You'll work in teams of two in the lab, and classroom discussion is highly encouraged. Therefore, all members of this class are expected to treat one another with consideration and respect.

Week & Dates	Topic	Reading (Kardong)	Lab Topics	Assignment
1 9/2-9/5	Intro: What's a vertebrate? Why study comparative morphology?	Ch. 1 (p. 29-41 not required)	What makes something a vertebrate?; Phylogeny refresher	None, except what's due in lab
2 9/8-9/12	Chordates and Vertebrate origins	Ch. 2-3	The vertebrate family tree/lamprey dissection (Fri.)	Background and hypothesis (Fri.)
3 9/15-9/19	Biological "design"	Ch. 4	Allometry, surface area to volume	Spandrels assignment (due Wed. for discussion)
4 9/22-9/26	Embryology and development	Ch. 5 & 563-589	Comparative embryology, vertebrate reproduction, project time	Background and hypothesis revisions (Fri.)
5 9/29-10/3	Integument, exam 1	Ch. 6	Integument	Integumentary specializations assignment (Fri)
6 10/6-10/10	Exam 1 (Monday) Skull	Ch. 7	Lab practical Wed.) Start the skull lab!	Skull lab proposal (Fri)., Research plan (Fri.)
7 10/15-10/17 (No class Monday)	Skulll cont'd, axial skeleton	Ch. 8	Skull lab, (Mon) Skeleton, project time	Classify this fossil! (Friday)
8 10/20-10/24	Appendicular skeleton	Ch. 9	More skeleton, project time	Research plan revisions (Friday)
9 10/27-10/31	Musculature I	Ch. 10	Musculature, project time	Muscle papers (Friday)
10 11/3-11/7	Locomotion, exam 2 (Wed.)	None except kinematics stuff	Kinematics exercise Lab practical (Friday)	Project progress report (Monday)
11 11/10-11/14	Circulatory and respiratory systems	Ch. 11-12	Ch. 8, projects	Preliminary data (Fri.)
12 11/17-11/21	Digestive and Urogenital	Ch. 13-14	Ch. 9, projects	Feeding specialization

	systems			assignment (Fri)
13 11/24-11/25 (No class Wed-Fri.)	Nervous system and sensory organs	Ch. 16-17	Sheep brain, Sensory worlds, project time	Data analysis (Wed.)
14 12/1-12/5	Conclusions and presentations	Ch. 18	Project time, presentations, Final practical (Friday)	Presentations

BIO 3065 – Animal Physiology
Fall Semester 2015
SYLLABUS

General Information

Instructor: Becky Fox
Office BSC 313 / Phone 233-8288 or Cell 530-400-7575 (prefer text)**
Email: rfox@transy.edu**

**please note that emails and/or texts received after 7 pm may not be answered until the following morning

Office Hours: MWF 1:30-3:30
Tues. 10:00-11:00 or by appointment (my research day)
Thurs. 1:30-4:00

Class meeting time: 11:30-12:20 MWF
Lab time: 9:30-12:15 Thurs.

Please feel free to stop in anytime my door is open! If you don't find me in my office, I'm probably in 303 (across from the ICBM lab).

Required Textbook

Hill et al. 2013. *Animal Physiology.* 3rd. ed. Sinauer and Associates.
Plus an assortment of papers from the primary literature, which will be placed on Moodle.

Course Description

Animal physiology provides an introduction to the physical and chemical processes that govern the lives of animals (primarily vertebrates, though we will touch on some processes in invertebrates). Emphasis will be placed on understanding the relationship between cell biology and physiology, physiological processes as adaptations to environmental challenges, and the relationship among physiology, behavior, and fitness.

The course is thematically organized, and consists of four units (*From cells to organisms, Homeostasis, hormones, and behavior, Powering the metabolic machinery,* and *Nutrient and water balance)*. There will be two in-class exams, one at the conclusion of each pair of units (two in-lab exams + 1 comprehensive final).

Science is best learned by doing! As such, this class will emphasize experimental design and hypothesis testing via a semester long research project examining the effects of endocrine disruption on hormone levels, aggression, and/or reproductive behavior in convict cichlids *Amatitliana nigrofasciata*. Exactly what we investigate

depends to some extent on the will of the class – this is a very broad topic, and the class as a whole will be responsible for designing the study. You will organize yourselves into four lab groups, and each group will be responsible for the background reading, experimental design, and data analysis for one part of the experiment. At the conclusion of the study, we will hold a symposium with the aim of arriving at an understanding of how our data fit together. *This is not just busywork – this past year a couple of members of the 2013 Animal Phys class presented a poster on one of the experiments at the national meeting of the Animal Behavior Society!*

Course Goals:
Students who are successful in Animal Physiology will demonstrate:

- The ability to clearly explain the link between cell biology and physiological processes.
- An understanding of the physiological "problems" animals face, how these problems relate to environmental challenges, and how physiological mechanisms have evolved to address these problems.
- The ability to use previously-learned concepts to solve unfamiliar problems.
- The ability to critically evaluate papers in the primary literature in Animal Physiology, and use those papers to develop testable hypotheses and well-controlled experiments.
- Laboratory skills for collecting physiological data, and the ability to appropriately analyze and interpret these quantitative data.
- The ability to effectively communicate about animal physiology to a nonspecialist audience.

Course Structure

While a certain amount of background knowledge is necessary in order to formulate good hypotheses, design well-controlled experiments, and place your findings in the context of your discipline, science is not a body of knowledge to be learned, but rather a way of finding out about the world. You will find that the way the course and associated assignments are structured and the way exams are written will reflect this. As such, you will be expected to take a fair amount of responsibility for learning "the facts" so that we can more productively engage with the questions, big and small (this is the most interesting part anyway!)

A Quick Note About Moodle: We make fairly heavy use of Moodle in this class. I use the news forum for communicating with the class, and post powerpoints, readings,

and assignments to Moodle. You will use Moodle for turning in assignments, and from time to time we will use the discussion forums as a prelude to or in order to follow up on class discussions. You'll want to make sure to check the class Moodle site regularly, and be sure you're receiving email notifications from the news forum.

Lecture: One day most weeks will be set aside for groups to present the design for their portion of the study, and/or to discuss literature relevant to the part of the project we're working on. As a class, we'll decide whether you'd rather that day be Monday or Friday. These discussion days will also be a chance for you to offer feedback on experiments and ask questions that may help the next group design their part of the study. The other two days will consist of a mixture of traditional lecture, small group activities, and in-class problems aimed at clarifying the material in the text. As we obviously won't be able to get through *everything* in the text, you're responsible for letting me know what you particularly want to be sure we talk about in class – thus it is probably a wise idea to at least skim the reading the week before, so you can decide if there's anything you find confusing.

Lab: This semester, we'll be working on a long-term study of the effect of endocrine disruption on behavior and hormone levels in convict cichlids. You'll be split into four lab teams, and each team will be responsible for designing one segment of the study, providing the protocol for each lab session during that segment of the study, analyzing the data for that segment, and writing up their results. We will work as a class to gather all the data. In many cases experiments will require some work outside of lab. (*ALSO: Please be careful handling the fish as we'll be using them all semester!)*

Class Blog: Because a big part of doing science is communicating with both your colleagues and the public about what you're doing, we will be maintaining a Animal Phys blog this semester (http://transyanimalphys.wordpress.com ; username = transyanimalphys; password = Stripeyfish247!). You will be responsible for making one INDIVIDUAL post about something interesting in the literature that is relevant either to our study or to something we're talking about in class, and one GROUP post that talks about your group's part of the study and why you're doing it. You will sign up for an individual post slot during the first week of class. You will make one group post at some point during the process of running your group's part of the study. *You probably will want to take some time with these posts, because the blog will be linked off the Transy Biology Facebook page, and a number of your BSC colleagues (and other folks) will probably be reading.* Posts will be graded, but you can send them to me for informal scoring according to the rubric and have a chance to revise them before you post them and they are graded "for real."

Grades
The grade you earn in class will be based on the following.

Assignments	
1 individual blog post	50
1 group blog post	25
1 group paper discussion	25
Presentation of experimental design	25
Experimental protocol first draft	75
Experimental protocol as used	25
Writeup of results	50
25 points for data analysis and graphs	
25 points for rest of writeup	
Symposium presentation (group)	25
Problem sets (10 x 10 pts each)	100
"Being a good lab member"	
Group data (4 sets, 10 points each)	40
Participation in paper discussions	45
Commentary on experimental design (3 x 5 pts each)	15
Participation in Moodle discussions (6 x 5 pts each)	30
Exams	
2 in-lab exams (200 pts each)	400
Final exam	200
Class participation	
Contribution to group, notebooks, attendance etc.	50
	1180 points

Week/dates	Topic(s)	Reading	Lab (tentative)	Assignments due
From Cells to Organisms				
Week 1 Sept. 8-10	Molecules and Cells in Physiology	Ch. 2	Intro & brainstorming	
Week 2 Sept. 14-18	Molecules and Cells in Physiology (cont'd)	Ch. 5, Ch. 8 through p. 194	Set up fish, continue developing questions and hypotheses	Friday: Problem set 1
Homeostasis, Hormones, and Behavior				
Week 3 Sept. 21-25	Animals in the context of their environments / Hormones and homeostasis	Ch. 1 & 16	Normal behavior and hormone measurement	Monday: group 1 protocol presentation & draft due Friday: problem set 2
Week 4 Sept. 28-Oct. 2	Biological clocks and reproduction	Chapter 15 & 17	Normal behavior and hormone measurement	Group 1 paper discussion Friday: Problem set 3
Week 5 Oct. 5-9 (no class Friday 10/9)	Metabolism	Ch. 7 and 9	Normal behavior and hormone measurement	Monday: Group 2 protocol presentation & draft due Friday: Problem set 4
Week 6 Oct. 12-16	Metabolism and thermoregulation	Ch. 9 and 10	Hormone manipulation and behavior	Group 2 paper discussion Friday: Problem set 5
Powering the metabolic machinery				
Week 7 Oct. 21-23 (No class Mon. and Tues. 10/19 and 10/20)	Circulation and cardiovascular physiology	Ch. 24	EXAM 1	
Week 8 Oct. 26-29	Circulation and cardiovascular physiology/	Ch. 25	Hormone manipulation and behavior	Monday: Group 3 protocol presentation &

	respiration			draft due Friday: Problem set 6
Week 9 Nov. 2-6	Respiration	Ch. 22	Endocrine disruption and hormone levels	Monday: group 3 paper discussion Friday: Problem set 7
Week 10 Nov. 9-13	More on respiration	Ch. 23	Endocrine disruption and hormone levels	Monday: Group 4 protocol presentation & draft due Friday: Problem set 8
Nutrient and Water Balance				
Week 11 Nov. 16-20	Nutrition and Digestion	Ch. 6	Endocrine disruption and behavior	Group 4 paper discussion Friday: Problem set 9
Week 12 Nov. 23-24 (No class Wed. – Fri. 11/25-11/27)	Water and salt physiology	Ch. 27-28	NO LAB - THANKSGIVING	
Week 13 Nov. 30-Dec. 4	Water and salt physiology	Ch. 28-29	Endocrine disruption and behavior	Monday: data analysis and troubleshooting Friday: problem set 10
Week 14 Dec. 7-11	SYMPOSIUM WEEK		EXAM 2	Monday: Writeup drafts due
FINAL EXAM				By Wed: final draft of writeup due

BIO 3224 NEUROBIOLOGY
Transylvania University
Winter Term 2016

SYLLABUS

INSTRUCTOR: Becky Fox, Ph.D.
Office: BSC 313
Phone: 233-8288 (office) 530-400-7575 (cell; texts preferred – probably the easiest way to get ahold of me)
Email: rfox@transy.edu

CLASS LOCATION AND MEETING TIME:
Lecture: MWF 12:30-1:20 PM, BSC 120 (Strickland Auditorium)
Lab: Thurs. 9:30 – 12:15 PM, BSC 320 OR Thursday afternoons

OFFICE HOURS: (may be subject to change slightly; will notify)
MWF: 9-10:00 AM, 2:00-3:30 PM
Tue: 1:30-3:30 PM
Thur: By appointment only

REQUIRED TEXT:
Purves, D., et al. 2012. *Neuroscience (Fifth ed.)*

Supplemental texts posted on Moodle.

TEXTBOOK WEBSITE:
http://sites.sinauer.com/neuroscience5e/. Please register for an account! There's lots of useful stuff there (flashcards, animations), and we'll use the quiz feature for a lot of our Monday quizzes.

COURSE DESCRIPTION: This is a first class in the cellular and physiological aspects of neurobiology, designed for students who have successfully completed (at minimum) ICBM OR Cell and Molecular Biology OR Biopsychology. Using a mixture of lectures, in-class discussions and activities, labs, and independent projects, we will investigate the structure and function of the neuron, as well as how neurons work together in neural circuits and how those circuits relate to larger-scale processes with a particular focus on the control of movement and neuroplasticity.

LEARNING OBJECTIVES FOR THE COURSE:
By the end of the semester, students who successfully complete the course will:

- Demonstrate an understanding of the principles underlying electrical and chemical signaling within the nervous system, and be able to apply these principles to map neural circuits.

- Be able to make connections between the small-scale molecular processes in individual neurons and larger-scale phenomena such as planned movement.

- Have begun to develop a familiarity with both classic and contemporary primary literature in neurobiology, and be able to use these primary sources to generate hypotheses and design experiments.

- Show familiarity with and be able to use some basic techniques for studying nervous system structure and function.

ASSIGNMENTS

Problem sets. Expect a problem set each week, except on exam weeks. The precise format of the problem set may vary depending on the topic.

Paper critique. To encourage you to become more comfortable reading the neurobiology literature (and to apply your new expertise in neurobiology), you will need to choose a paper from the primary literature (i.e., describing an experiment) relevant to something we've talked about in class and write a short summary and critique of the paper. You can turn this in at any point in the semester *prior to Spring Break* (the drop-dead deadline is March 11th at 11:59 PM).

Lab writeups: Working in groups, you'll do a brief write-up for each lab project. (introduction, materials and methods, results, discussion, and works cited). YOU WILL SWITCH GROUPS FOR EACH LAB PROJECT.

Song system lab: Our big project for the semester will be an investigation of endocrine disruption and plasticity in the zebra finch song system, using a digitized library of brain sections. You'll learn how to use ImageJ (a software tool for quantifying measurements made under a microscope) and will conduct a statistical analysis of your data. Working in groups of 4-5, you will read relevant background literature, conduct the investigation, put together a formal writeup, and do a brief presentation related to the project during the last week of class.

EXAMS & QUIZZES

Quizzes. Recent research in learning (and my own experience at Transy) strongly suggests that frequent testing promotes higher retention of material. Therefore, each Monday except for the first week, you'll take a short ~10 min quiz on the material.

Exams. Two exams (expect to take about an hour and a half to two hours for each exam) will be given during lab (dates as noted on the syllabus). The final exam will be 50% comprehensive and 50% over the last third of the class.

Exams will be primarily problems and short essays. Questions will require you to **understand and apply concepts, make hypotheses, clearly articulate your reasoning, and/or solve problems.** Just reading through the text and memorizing your notes will not be sufficient to earn an A or a B on an exam. The more problems you can do while studying, the better off you'll be!

GRADING

The grade you earn in this course will depend on the following:

GRADE COMPONENT		POINTS
Problem sets (10 x 10 points each)		100
Monday Quizzes (12 x 5 points each)		60
Paper Critique		20
Lab Assignments		240
Reflex/reaction time lab assignment	20 points	
Independent expt. proposal	20 points	
Independent expt. writeup	40 points	
Swimmy quizzes (2 x 10 pts each)	20 points	
Swimmy writeup	40 points	
Song system presentation	40 points	
Song system writeup	60 points	
Exams (2 x 200 points each)		400
Final Exam		250
TOTAL POINTS POSSIBLE FOR THE COURSE		1070

GRADE SCALE

98-100% A+	77-79% C+	60-62% D-
90-97% A	73-76% C	below 60% F
87-89% B+	70-72% C-	
83-86% B	67-69% D+	
80-82% B-	63-66% D	

COURSE POLICIES

Absences:

If you miss lecture, make sure you get the notes from a classmate. *Exams, quizzes, and labs may be made up only in cases of documented personal or family emergencies or illness, religious holidays, or if you are traveling for a school-sponsored event.* If you know ahead of time that you're going to miss any of the above, it's your responsibility to let me know in advance and make arrangements to make up the exam or assignment.

Disability Accomodations:

I'm happy to provide any accomodations (a quiet room for testing, etc.) to which you're entitled, but it is your responsibility to let me know you are entitled to receive accommodations.

Technology in Class. We live in a technology-intensive, internet-connected world. You are thus welcome to bring your laptops, tablets, and phones to class – we'll use them. HOWEVER, you should be aware of a couple of things: (1) research shows that trying to do anything while simultaneously reading facebook/checking email/texting etc. is the equivalent of doing it with a BAC of 0.1%, and (2) research also suggests that taking handwritten notes is better for getting things into your long term memory. Furthermore, if you text or surf the web or play games in class and get caught, it will result in a small deduction from your grade. I will not necessarily announce that I've caught you. Do so at your own risk.

Respect and Classroom Climate:
Learning in this class is a collaborative effort. You'll work in pairs or in teams in the lab, and classroom discussion is highly encouraged. Therefore, all members of this class are expected to treat one another with consideration, respect, and equality, regardless of race, religion or lack thereof, social class, disability, age, gender, gender presentation, sexual orientation, health status, geographical origin, appearance, political views, etc.

	Topic(s)	**Reading**	**Lab**	**Assignments due (Friday unless noted)**
Week 1 Jan. 11-15	Studying the nervous system Membrane potentials	Ch. 1/Ch. 2 thru p. 33	Reflexes & Reaction times	Problem set 1
Week 2 Jan. 18-22 *NOTE: No class Monday*	Action potentials & their molecular basis	Rest of ch. 2 & ch. 3 (Read ch. 4 if you need a review on ion channels)	Planning day for experiment	Problem set 2 Assignment from previous lab. (Fri)
Week 3 Jan 25-29	Synapses	Ch. 5	Reflexes & reaction times independent experiment	Independent expt. Proposal (Mon.) Problem set 3
Week 4 Feb 1-5	Neurotransmitters & neurotransmitter receptors	Ch. 6 (Read ch. 7 if you need a refresher on cell signaling)	Swimmy tutorial (computer lab)	Problem set 4
Week 5 Feb. 8-12	Neural circuits and what they do	Movement case study (Moodle)	EXAM 1	Independent experiment writeup (Fri.)
Week 6 Feb. 15-19	Synaptic plasticity	Ch. 8	Swimmy 1	Swimmy quiz (Thurs.) Problem set 5
Week 7 Feb. 22-26	How neural circuits form & how they're modified by experience	Ch. 23 (521-533 only) & 24	Swimmy 2	Swimmy quiz (Thurs.) Problem set 6

Week 8 Feb 29-Mar. 4	The neural basis of associative learning	Aplysia case study and readings on learning (Moodle)	Intro. to song system lab	Swimmy writeup Problem set 7
Week 9 Mar. 7-11	Neurogenesis and memory	Ch. 25 & 31	EXAM 2	Critiques (Fri.)
Mar 14-18 SPRING BREAK NO CLASS				
Week 10 Mar 21-25	Environmental enrichment and the hippocampus: a case study in neuroplasticity	Memory case study (Moodle)	Song system lab	Problem set 8
Week 11 Mar 28-April 1	Control of movement: LMNs	Ch. 16	Song system lab	Problem set 9
Week 12 April 4-8	Control of movements: UMNs	Ch. 17	Song system lab	Problem set 10
Week 13 April 11-15	Modulation of movement by cerebellum & basal ganglia	Ch. 18 & 19	Presentations	Song system writeup (Fri.)
Fri April 22, 12:00-2:00	SCHEDULED DATE FOR FINAL EXAM BUT YOU CAN TAKE IT ANYTIME FROM READING DAY ON	50% week 9-13; 50% comprehensive		Optional problem set due Tues.

Senior Seminar Winter 2015:
Inside The (Very) Private Lives of Animals: Mating Systems, Life History Strategies, and Sexual Selection
(BIO 4444)

Instructor: Becky Fox
Office BSC 313 / Phone 233-8288 or Cell 530-400-7575 (prefer text)
Email: rfox@transy.edu

Office Hours: MWF 10:30-12:00 and 3:30-4:30
Tues. 1:30-4:00
Thurs. BY APPOINTMENT ONLY

Class meeting time: 9:30-10:20 MWF

Required Texts
Bennet PM & Owens IPF. 1999. *Evolutionary Ecology of Birds: Life Histories, Mating Systems, and Extinction.* Oxford Series in Excology and Evolution, Oxford University Press.

Zuk M. 2002. Sexual Selections: What We Can and Can't Learn About Sex From Animals. University of California Press.

Plus an assortment of papers from the literature.

Theme of the Class
The sex lives of animals are wildly diverse, ranging from the strict genetic and social monogamy practiced by albatrosses and many large parrots to the seemingly indiscriminate promiscuity of spring peepers mating in an ephemeral pond to the caste system of eusocial bees and wasps. With this amazing diversity of mating systems comes a host of questions, some of them well explored, others still perplexing. What makes monogamy advantageous for some species but not others? Why does lek mating persist, given that in such systems reproductive success generally accrues to only a handful of males in the population? What's the link between cooperative breeding and the evolution of eusociality? Given that there's no reproductive payoff, why do we see homosexuality – not just in humans, but in nonhuman species as well? Is breeding a cooperative endeavor, or is it really just a case of males and females exploiting one another? Over the course of this semester, we will explore many of these questions (which ones get the most attention depends to some extent on you), as well as underlying theory about life history strategies and sexual selection that may help us begin to answer them.

Course Structure and Goals

In class we will analyze both primary sources – original research reports -- and secondary sources such as review articles. As we read both types of literature the contrast should help you understand the type of writing you will be expected in this class. The abilities to read and critique new research in biology, and to discuss and debate questions that biologists pose are essential skills for any biologist. In general this class will call upon you to:

a. apply all you have learned so far to new questions and situations
b. synthesize and integrate scientific information and ideas from disparate sources
c. think about science creatively
d. engage in civil scientific discourse based on your knowledge of data, evidence and logical predictions, (not merely your opinions and personal experience)
e. pose scientific problems and reason through new scientific questions and hypotheses
f. articulate how we know what we know about topics discussed in this course
g. reason independently about scientific evidence
h. write in depth about a biological subject distinguishing what is known, what is not known, what is controversial, and what future avenues of research seem open
i. persuade your peers that your ideas have merit

This is NOT a lecture-based class. Discussion should be our main class activity. In order for everyone to get as much as possible out of the class, you'll need to contribute both in writing and in discussion. During the second half of the class, you'll be responsible for choosing scientific papers for the class to read, and you'll present your own research to the class at the end of the term.

The point of this seminar is to build a learning community exemplified by individuals who respect and listen to one another, who expect to both challenge and support one another and who are willing to take risks, being spontaneous about sharing their ideas, critical reasoning and imaginings. In short, we will strive to reflect the best aspects of a community of scientists at work. (Thanks to Dr. Wagner for saying this better than I could!)

GRADES

There is no curve in this class. As you're probably well aware, I'm philosophically opposed to curving grades up or down, since I feel everyone deserves an equal chance to earn an A. Grades are based purely on points earned. This means that theoretically it's possible for everyone to do very well.

GRADE SCALE

98-100% A+	77-79% C+	60-62% D-
90-97% A	73-76% C	below 60% F
87-89% B+	70-72% C-	
83-86% B	67-69% D+	
80-82% B-	63-66% D	

	points	%
Evidence of regular engagement with material	130	26%
Discussion leader	20	4%
Book chapter topic proposals	40	8%
Library Contribution	30	6%
Annotated Outline	50	10%
Initial completed draft submitted	50	10%
Final draft submitted	125	25%
Presentation on your chapter	50	10%
	495	

You must receive at least a C- (70%) in both your engagement/discussion leader grade and your finished draft of your book chapter in order to pass this class. There are no exams for this class.

EVIDENCE OF REGULAR ENGAGEMENT

Since this is a reading and discussion-intensive course, for you to get the most out of the class, you need to read and think about the material *before* class. You're encouraged to make notes and jot down any questions that come to mind and share these in class. You should always bring the text we're discussing to class.

Your "participation" grade is based on your active involvement in the course via taking part in discussion, posing pertinent questions, and offering insightful, stimulating comments. *You can't do this without careful and critical reading before class!*

Your participation grade is based on QUALITY, not QUANTITY of participation.

On a weekly basis, you'll get either a –, √, or **+**, depending on the quality of your participation.

+ = You have provided evidence that you have completed and understood the readings, and you have come to class prepared to ask stimulating questions, provide outstanding critical analysis, and thoughtful, insightful responses to comments made by classmates. You need to consistently earn + marks to get an A in engagement.

√ = You seem to have read and understood the texts, but have not critically reflected on them or shared your analysis. Only √s will earn you a C for engagement.

- = You didn't participate adequately in discussion, or gave no evidence of having read the material

You will also be asked regularly to write short responses to what you have read at the beginning of class as a prelude to class discussion. These responses will count toward your engagement grade and may not be made up if you are absent.

UNEXCUSED ABSENCES WILL RESULT IN A 5 POINT DEDUCTION FROM YOUR TOTAL CLASS POINTS. [Excused absences include graduate/professional school interviews, medical appointments, and family funerals. Absences are not excused unless I am notified in advance; voice mail or text/email messages will suffice.]

DISCUSSION LEADER
Twice during the semester, you will lead class discussion: once for an assigned reading, and once for readings you have chosen for the class (most likely for papers you're using in your chapter). You may open with a short writing prompt, or begin with questions or a presentation in which you give some additional information on the subject or frame some basic themes (if you choose this option, your presentation should be at most 5-8 minutes long). You are expected to involve the rest of the class, not monopolize the discussion.

For the second round, you'll need to do some additional work in terms of choosing a paper and doing some background research, so schedule a time to see Dr. Fox at least a week in advance. Papers you have chosen must be sent to Dr. Fox for posting on Moodle at least a week before your assigned date.

BOOK CHAPTER. This is a written assignment in several parts.

- **A. Library contribution.** We will maintain a community library of article PDFs that you find while conducting research for this project. This will allow class members to access one another's finds, and hopefully make your research work a little bit easier. The libarary will be maintained on a Moodle forum, ideally organized by topic. When posting an article to the Moodle forum, you must also include a short post with a brief summary of the paper and its major findings – it will help me know you've read it, and help your classmates decide if it's useful.
- **B. Annotated outline.** An outline is a powerful tool to help organize your thoughts and see whether your "story" has any holes. You will produce a detailed outline of your chapter, incorporating at least ten references (more is better).
- **C. Initial Finished Draft of Paper.** You will synthesize and critically review the body of original work you have read on the topic of your chapter. While your paper must of course report information, your paper *must be organized to support a central thesis* (in other words, you're making an argument, and using the papers you've found to support it). Depth and thorough analysis is far more important than being comprehensive but shallow. This draft is worth 90% of the grade for your chapter. A revised draft can be submitted, but will increase your grade by at most one letter grade.

D. Presentation of Paper Findings (20 minutes max). You will make a 10-15 minute presentation to the class in which you briefly summarize your findings, highlighting novel information or examples that have not yet been discussed in class. You will choose one of your references for the class to read in preparation for your presentation/discussion. Following your presentation will be an open question and answer period/discussion with your classmates which should incorporate what they've read.

A. Final Paper. While you will have the opportunity to revise your work, as noted above, you can only increase your grade by one letter grade, so it's in your best interest to do as good a job as possible on your finished draft so that no further revisions are necessary.

To accommodate the needs of the class, we may be somewhat flexible on some days with regard to the time spent discussing assigned readings. However, presentations, once assigned, and all other major paper due dates are not flexible.

Academic Integrity. In addition to interfering with your learning, academic dishonesty violates the climate of trust and honesty that we are trying to create within this class and within the broader academic community. In this class, academic integrity means that you:

a. Do your own reading and do not rely on your classmates to brief you on the assignment.
b. Do your own work on your writing assignments, and avoid representing someone else's work as yours (this includes making sure you cite sources as appropriate. If in doubt, cite it).
c. Contribute your fair share when working with a partner on presentations/discussions.
d. Cite only those references in your paper that you have actually read.
e. Give due credit for any ideas that weren't yours originally.

HOWEVER, once everyone has completed the required reading, you are encouraged to discuss the material with your classmates outside of class.

Please feel free to check with me if you're unsure whether an activity violates this policy.

Week	**Monday**	**Wednesday**	**Friday**
1 1/5-1/9 The basics (and some classics)	Intro	Clutton-Brock 1988 B&O: Ch. 7	Trivers 1972 Orians 1969
2 1/12-1/16 Life history: what does it have to do with anything?	B&O ch. 1-3	B & O Ch. 4-5	B&O Ch. 8
3 1/19-1/23 (No class Monday) Sexual selection and some cool questions	MLK DAY NO CLASS	Chapter brainstorming session / Emlen and Oring 1977 B & O Chapter 9	Finish B& O Chapter 9, Zuk ch. 11
4 1/26-1/30 What does it all mean?	**Chapter Proposals Due/Chapter Selection**	Zuk 1-3	Zuk 4-5
 2/2-2/6 What does it all mean (part 2)?	Zuk 6-7	Zuk 8-9	Zuk 10, 12
6 2/9-2/13 Will of the class	Round-up discussion	Free choice 1-2	Free choice 3-4

7 2/16-2/20 Will of the class	Free choice 5-6	Free choice 7-8	Free choice 9-10
2/23-2/27 Here's where things get real	Free choice 11-12	**WORK DAY**	**Annotated outlines due!**
9 3/2-3/6 Editing and therapy as needed	CONFERENCES	CONFERENCES	CONFERENCES
10 3/9-3/13 SPRING BREAK	SPRING BREAK	SPRING BREAK	SPRING BREAK
11 3/16-3/20 Now it's really real	Will of the class	Will of the class	**First full drafts due!** PEER EDITING DAY
12 3/23-3/27 Editing and therapy as needed	CONFERENCES	CONFERENCES	CONFERENCES
13 3/30-4/3 (No class Wed-Fri.)	PRESENTATIONS 1-2	PRESENTATIONS 3-4	PRESENTATIONS 5-6
14 4/6-4/10	PRESENTATIONS 7-8	PRESENTATIONS 9-10	PRESENTATIONS 11-12

Why We Do The Things We Do: Neuroecology, Ecophysiology, and the Evolution of Behavior

NEUR 4444: Capstone in Neuroscience/
BIO 4444: Senior Seminar in Biology
FALL 2015

Instructor: Becky Fox
Office BSC 313 / Phone 233-8288 or Cell 530-400-7575 (prefer text)
Email: rfox@transy.edu

Office Hours: *MWF* 1:30-3:30
Tues. 10:00-11:00; all other times by appointment (my research day)
Thurs. 1:30-4:00

Class meeting time: 9:30-10:20 MWF

Required Texts:
Carew, T.J. 2000. *Behavioral Neurobiology: The Cellular Organization of Natural Behavior.* Sinauer Associates.
(This book has been out forever, so you should be able to get a used copy pretty cheaply. It's also available in paperback).

Assorted papers, posted on Moodle.

Theme of the class:
Ever wondered why the thought of taking a test you're not prepared for makes your mouth go dry and your stomach feel sick? Been curious about how a tiny honeybee is able to remember her way back to a particular patch of flowers? Wondered why the heck it is you just can't stay away from McDonald's fries even though you know *exactly* how terrible they are for you? Pondered why it is that prairie voles are monogamous, while their close cousins the montane voles aren't and neither are most other rodents? (Okay, the answer to this last question is probably 'no', but the answer is fascinating.) This seminar is all about the physiological mechanisms underlying the behavior of both humans and nonhuman animals and the ecological circumstances and other factors that shape their evolution. We will even read a couple of articles about neuro*botany*! Once we've spent some time developing a shared background in neurobiology and ecophysiology, exactly which questions we explore (and there are plenty out there!) will depend on you and your interests.

Course Structure and Goals
In class we will analyze both primary sources – original research reports -- and secondary sources such as review articles. As we read both types of literature the contrast should help you understand the type of writing you will be expected in this class. The abilities to read and critique new research in biology and neuroscience, and to engage in integrative, cross-disciplinary discussion and debate are essential skills for people working in both

fields, as interdisciplinary research has become the norm rather than the exception. *You can expect to have to stretch a little bit outside your comfort zone, but you can also expect that you will always have something unique to contribute to the discussion!*

In general this class will call upon you to:

a. apply all you have learned so far to new questions and situations
b. synthesize and integrate scientific information and ideas from disparate sources
c. think about science creatively
d. engage in civil scientific discourse based on your knowledge of data, evidence and logical predictions (not merely your opinions and personal experience)
e. pose scientific problems and reason through new scientific questions and hypotheses
f. articulate how we know what we know about topics discussed in this course
g. reason independently about scientific evidence
h. write in depth about a subject distinguishing what is known, what is not known, what is controversial, and what future avenues of research seem open
i. persuade your peers that your ideas have merit

This is NOT a lecture-based class. Discussion should be our main class activity. In order for everyone to get as much as possible out of the class, you'll need to contribute both in writing and in discussion. During the second half of the class, you'll be responsible for choosing scientific papers for the class to read, and you'll present your own research to the class at the end of the term.

The point of this seminar is to build a learning community exemplified by individuals who respect and listen to one another, who expect to both challenge and support one another and who are willing to take risks, being spontaneous about sharing their ideas, critical reasoning and imaginings. In short, we will strive to reflect the best aspects of a community of scientists at work. (Thanks to Dr. Wagner for putting this far better than I ever could – I totally appropriated it from his senior sem syllabus!)

Expectations for BIO vs. NEUR

In all respects but one, expectations are identical. The only difference between the two groups is with regard to your choice of topics. NEUR students *must* write their paper on a topic that has a substantial neuroscience-related component (though it can deal with other things too), and *must* present one paper that is specifically about some aspect of the neurobiology of behavior. BIO students *may* write their paper on a neuroscience topic and lead discussions on neuro papers if they're so moved, but are not required to – any topic relating to the physiology and evolution of behavior in humans, plants, animals, or microbes is open to you!

GRADES

There is no curve in this class. As you're probably well aware, I'm philosophically opposed to curving grades up or down, since I feel everyone deserves an equal chance to

earn an A (or not). Grades are based purely on points earned. This means that theoretically it's possible for everyone to do very well.

GRADE SCALE

98-100% A+	77-79% C+	60-62% D-
90-97% A	73-76% C	below 60% F
87-89% B+	70-72% C-	
83-86% B	67-69% D+	
80-82% B-	63-66% D	

	points	%
Evidence of regular engagement with material	130	29%
Discussion leader	20	4%
Book chapter topic proposals	40	9%
Annotated Outline	50	11%
Initial completed draft	50	11%
Final draft submitted	125	27%
Presentation on your chapter	50	11%
	465	

You must receive at least a C- (70%) in both your engagement/discussion leader grade and your finished draft of your book chapter in order to pass this class. There are no exams for this class.

EVIDENCE OF REGULAR ENGAGEMENT

Since this is a reading and discussion-intensive course, for you to get the most out of the class, you need to read and think about the material *before* class. You're encouraged to make notes and jot down any questions that come to mind and share these in class. You should always bring the text we're discussing to class.

Your "participation" grade is based on your active involvement in the course via taking part in discussion, posing pertinent questions, and offering insightful, stimulating comments. *You can't do this without careful and critical reading before class!*

Your participation grade is based on QUALITY, not QUANTITY of participation.

On a weekly basis, you'll get either a –, √, or **+**, depending on the quality of your participation.

+ = You have provided evidence that you have completed and understood the readings, and you have come to class prepared to ask stimulating questions, provide outstanding critical analysis, and thoughtful, insightful responses to comments made by classmates. You need to consistently earn + marks to get an A in engagement.

√ = You seem to have read and understood the texts, but have not critically reflected on them or shared your analysis. Only √s will earn you a C for engagement.

- = You didn't participate adequately in discussion, or gave no evidence of having read the material

You will also be asked periodically to write short responses to what you have read at the beginning of class as a prelude to class discussion. These responses will count toward your engagement grade and may not be made up if you are absent.

UNEXCUSED ABSENCES WILL RESULT IN THE LOSS OF THE PARTICIPATION POINTS FOR THAT DAY.

DISCUSSION LEADER
Once during the semester, you will lead class discussion on readings you have chosen for the class (most likely for papers you're using in your chapter). You may open with a short writing prompt, or begin with questions or a presentation in which you give some additional information on the subject or frame some basic themes (if you choose this option, your presentation should be at most 5-8 minutes long). You are expected to involve the rest of the class, not monopolize the discussion.

As preparing for discussion is a non-trivial amount of work and may involve some background research, schedule a time to see Dr. Fox at least a week in advance of your discussion. Papers you have chosen must be sent to Dr. Fox for posting on Moodle at least a week before your assigned date.

SEMINAR PAPER. This is a written assignment in several parts.

A. **Paper proposals.** You'll produce two one-paragraph proposals for two different papers, using 3-5 sources each. Your proposal should describe your topic, why it's interesting and/or novel from a scientific standpoint, and give us some general idea of what your specific question and hypothesis, as well as the strategy you plan to use to support your hypothesis. With the help of your classmates, you'll pick the stronger and more interesting topic to write on.
B. **Annotated outline.** An outline is a powerful tool to help you organize your thoughts and see whether your "story" has any holes. I still write an outline for any manuscript I'm working on! You will produce a detailed outline of your chapter, incorporating at least ten references (more is better).
C. **Initial Finished Draft of Paper.** You will synthesize and critically review the body of original work you have read on the topic of your chapter. While your paper must of course report information, your paper *must be organized to support a central thesis* (in other words, you're making an argument, and

using the papers you've found to support it). Depth and thorough analysis is far more important than being comprehensive but shallow.

D. **Presentation of Paper Findings** (20 minutes max). You will make a 10-15 minute presentation to the class in which you briefly summarize your findings, highlighting novel information or examples that have not yet been discussed in class. You will choose one of your references for the class to read in preparation for your presentation/discussion. Following your presentation will be an open question and answer period/discussion with your classmates which should incorporate what they've read.
E. **Final Paper**. Using feedback from your professor and classmates, you'll revise your first draft into a strong, polished final product.

To accommodate the needs of the class, we may be somewhat flexible about discussion scheduling. There are also work days and conference days built into our schedule, which can be moved around based on the needs of the class as necessary. However, <u>presentations, once assigned, and all other major paper due dates are not flexible.</u>

Academic Integrity. In addition to interfering with your learning, academic dishonesty violates the climate of trust and honesty that we are trying to create within this class and within the broader academic community. In this class, academic integrity means that you:

a. Do your own reading and do not rely on your classmates to brief you on the assignment.
b. Do your own work on your writing assignments, and avoid representing someone else's work as yours
c. Contribute your fair share when working with a partner on presentations/discussions.
d. Cite only those references in your paper that you have actually read. You don't have to read *every single word*, but you should have, at minimum, read the introduction, results, and discussion and given the results some critical consideration of your own.
e. Give due credit for any ideas that weren't yours originally. If you have any doubt at all, *cite it,* even if it feels a little excessive to you. It's not uncommon for most of the sentences in the introduction to a scientific paper to end with a citation.

HOWEVER, once everyone has completed the required reading, you are encouraged to discuss the material with your classmates outside of class.

Please feel free to check with me if you're unsure whether an activity violates this policy!

Week	**Monday**	**Wednesday**	**Friday**
1 9/8 – 9/10 The link between brains, behavior, and ecology	LABOR DAY – NO CLASS!	Intro day	Neurons as the building blocks of behavior (Carew Chapter 1)
2 9/14-9/18 Neuroecology and sensory worlds	Neuroecology (Sherry 2006)	"Sensory worlds" (von Uexkill 1934)	Echolocation in bats (Carew Chapter 2)
3 9/21-9/25 finish sensory worlds/ The adaptive value of stress	Prey location in barn owls (Carew Chapter 3)	**Paper brainstorming session**	Adapting to environmental challenges – "The emergency life history stage" (Wingfield 1998)
4 9/28-10/2 Neuroecology of memory	**Paper Proposals Due/Peer comments**	Spatial learning and the hippocampus in rats (Carew Ch. 12)	The ecology of good memory: a case study in chickadees (Roth and Pravosudov 2009; Roth et al. 2011
5 10/5-10/8 Birdsong – nature, nurture, or both?	Nature vs. nurture (and the reality) Lehrman (1953) Marler (1997)	Neurobiology of song learning (Carew Ch. 8)	PRESIDENT CAREY'S INAUGURATION – NO CLASS
6 10/12-10/16 Intelligent plants and smart pollinators	"The intelligent plant" (New Yorker Article; Pollan 2013) Action potentials in venus flytraps (Volkov	Associative learning in honeybees (Carew Ch. 9)	Plant signals and cognition in pollinators (Leonard et al. 2011a, b)

	et al. 2009)		
7 10/21-10/23 Tasty food and the gut as a mind-control device?	FALL BREAK – NO CLASS	Microbiome and the gut-brain axis (Cryan and O'Mahoney 2011)	Is tasty food addictive? (Drenowski 1997; Gearhardt et al. 2011)
8 10/26-10/29 Your turn to drive the bus (mostly)!	Neurobiology of pair bonding (Young et al. 2011)	Free choice 1-2	Free choice 3-4
9 11/2-11/6 Your turn to drive the bus!	Free choice 5-6	Free choice 7-8	**Work day: annotated outlines due by 11 PM**
10 11/9-11/13 Editing and therapy as needed	Free choice 9-10	CONFERENCES	CONFERENCES
11 11/16-11/20 You pick	CONFERENCES	Will of the class	Will off the class
12 11/23-11/24 Almost there….	Peer editing day	THANKSGIVING	THANKSGIVING
13 11/30-12/4 Presentations!	**Full drafts due!** Presentations 1-2	Presentations 3-4	Presentations 5-6

14 12/7-12/11 Presentations!	Presentations 7-8	Presentations 9-10	Yay, you're done! Class brunch! **Final drafts due Wed. of finals week!**

Questions about the Sunfish Data

1.) Based on the data, which populations had a "fast" life history? Which had a "slow" life history?

2.) What do the first graph and the table tell you about the relationship between the amount fish invest in body growth and the amount they invest in reproduction?

3.) What does the last graph tell you about the relationship between adult mortality and the amount individuals invest in each reproductive attempt? First it might be useful to explain what the adult: juvenile ratio tells you.

4.) If you were going to guess, which ponds probably have the highest predation rates? Why?

Inclusive Fitness!

Up to this point, we've pretty much talked exclusively about *direct fitness* – the fitness an organism gains by producing its own offspring. However, because individuals also share a lot of genes with their relatives (particularly parents and siblings), there's another way for individuals to potentially gain fitness as well: by helping their relatives' offspring survive. This is called *indirect fitness*.

Q: Why might helping relatives' offspring survive help increase an organism's fitness? (Hint: think about the fact that the end result of natural selection is a change in allele frequencies).

Thus, an organism's total fitness is calculated as follows:

Fitness = direct fitness (own offspring) + indirect fitness (relatives' offspring)

Under this definition of fitness, we're mostly concerned with how many copies of genes that are identical by descent (IBD) are likely to get passed down to the next generation. Two copies of a gene are identical by descent if they're copies of the same ancestral gene (i.e., you and your sister both have green eyes because your mom has green eyes – in that case, you and your sister have a gene that is IBD for eye color. If your brother has brown eyes – because your dad does - that gene is not IBD to you and your sister's gene for eye color).

It's possible to calculate the proportion of the genes between two individuals that is likely to be IBD. (To convert this to a percentage, just multiply by 100). This is called the *coefficient of relatedness or r.* The table below gives values of r for common relationships. Since some of you haven't yet had genetics, you don't have to calculate this for yourself, but the idea that you're more closely related to your sister than to your nephew should make sense intuitively.

Coefficients of Relatedness

Relationship of Self to:	Coeff. of Rel. (r)
Self	1.0
Offspring or Parent	0.5
Full Sibling	0.5
Half Sibling	0.25
Uncle/Aunt or Nephew/Niece	0.25
Grandparent or Grandchild	0.25
First Cousin	0.125

Q: What's the percentage of genes IBD you're likely to have in common with your first cousin? What about your parent? Your brother or sister?

Q: Fitness-wise, would you be better off helping a relative or a nonrelative reproduce, if it meant you could do less reproduction yourself? How about a cousin vs. a sibling? Why?

Once you know r, you can actually calculate the fitness an organism can gain by helping others.

Inclusive fitness = (# of offspring you produce * r to YOUR offspring) + (# of additional offspring you help your relative produce * r to THEIR offspring)

If you're helping a non-relative, that r is 0, so you get no additional fitness from doing that.

Q: Based on the inclusive fitness calculation, would you be better off:

(a) producing 10 offspring yourself, or helping a NONRELATIVE produce 10 offspring?

(b) producing 10 offspring yourself or helping your sibling produce 10 offspring?

(c) producing 10 offspring yourself or helping your sibling produce 20 offspring?

Q: Given that workers don't reproduce, what do your answers to b and c tell you about what might be going on in bee hives in terms of relatedness?

In general, *cooperative breeding* (helping at the nest) and *eusociality* (division of labor) can evolve when **individuals gain more in inclusive fitness by helping than they lose by producing fewer – or no – offspring themselves. This is known as <u>Hamilton's Rule</u>.**

Thinking about neurotransmitters

1.) While the scientific community is still arguing about it, it is thought that depression may be related (at least in part) to a deficiency in serotonin production. (Serotonin is abbreviated 5-HT, short for "5-hydroxytryptamine")

Symptoms of depression include long-lasting changes in behavior like changes in sleep patterns, changes in appetite, and changes in emotional regulation.

A.) Do you think the receptors involved in mediating these processes are ionotropic or metabotropic? Why?

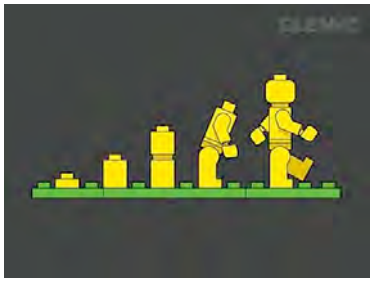
B.) There are also serotonin receptors in other parts of the brain (called 5-HT_3 receptors) that are involved in triggering emesis (vomiting). A lot of antiemetics (drugs that inhibit vomiting) target these receptors. Do you think these receptors are ionotropic or metabotropic? Why? Are the drugs *agonists* or *antagonists* for these receptors?

C.) Some drugs used to treat depression (like Prozac and Zoloft) belong to a class of drugs called SSRIs. SSRI stands for *selective serotonin reuptake inhibitor. Explain, in terms of receptor kinetics (remember our old friend Michaelis-Menten?) how inhibiting serotonin reuptake might be useful in treating a serotonin deficiency.* While no one is positive this is how SSRIs work, this is thought that this is why they're so useful in treating depression.

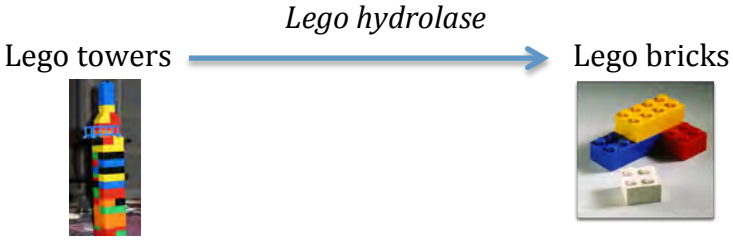
D.) SSRIs only influence reuptake in certain types of neurons (this is why they're called *selective*). Why wouldn't you want your depression treatment to influence reuptake in *all* neurons?

The Kinetics of Lego hydrolase

The enzyme we will be studying is *Lego hydrolase*. It's an enzyme that breaks down Lego towers brick by brick. So the substrate for this enzyme is Lego towers, and the product of this reaction is Lego bricks.



So:



Each one of your groups represents the person running the experiment (who will watch the timer), plus a beaker with however many enzyme molecules there are other people in it (so if there are five people in your group, there is one experimenter and four molecules in your beaker). Each Lego tower is a substrate molecule. The concentration of substrate is the number of Lego towers at your table. So if you have one Lego tower, your concentration is 1. If you have three Lego towers, your concentration is 3.

Part 1:

You're studying the time course of the reaction catalyzed by Lego hydrolase at a substrate concentration of four.

Each person in your group besides the experimenter should take one Lego tower. This is analogous to each of the substrate molecules binding to an enzyme that has an available active site. Start a stopwatch on your phone, or have someone in your group watch the clock. As soon as you start it, the reaction starts. Each person with a tower should take apart their tower one brick at a time in a leisurely fashion. Every 5 seconds, stop and count the TOTAL number of single bricks on your table. This is the amount of product in your beaker at that time point. Once you've counted, do your reaction for another five seconds and count again. Do this six times, even if your substrate is gone before that.

Time (s)	Product concentration (bricks)
0	
5	
10	
15	
20	
25	
30	

Sketch a graph of product concentration vs. time.

A.) What do you observe about the number total number of bricks on your table over time (i.e., what's going on in your graph)?

B.) Explain, in terms of the availability of Lego towers, why this happened.

C.) What part of your experiment from last week does this remind you of? What do you expect to see when you plot your data for that part of the experiment? Why?

D.) You can determine the rate of an enzyme-catalyzed reaction using the following equation:

$$\text{Rate} = \frac{[\text{product at time 2}] - [\text{product at time 1}]}{\text{Time elapsed between time 2 and time 1}}$$

What part of the graph would probably be best to use if you're trying to calculate how quickly an enzyme can turn substrates into products as long as there's enough substrate available? (This quantity is known as v_o, or the initial velocity) What part of the graph *don't* you want to use?

E.) What's the v_o for Lego hydrolase at this substrate concentration?

Part 2:
In this experiment, you still have the same enzyme concentration in your beaker. You're studying the effect of substrate concentration on reaction rate. Run your reaction for however long it took to turn all of your Lego towers into Lego bricks in the first experiment. So if it took 3 rounds of 5 seconds to break down your Lego towers last time, do the reaction for 3 rounds of 5 seconds this time. Try to dismantle your towers at the same rate you did during the first experiment.

Do this experiment six times:

Once with a [Lego towers] of 1
Once with a [Lego towers] of 2
Once with a [Lego towers] of 3
Once with a [Lego towers] of 4

Once with a [Lego towers] of 5
Once with a [Lego towers] of 6

In each case, every enzyme who can should take a Lego tower and dismantle it.

Record your data:

Lego tower concentration	# bricks at end of experiment
1	
2	
3	
4	
5	
6	

Now calculate your v_o for each of these experiments. You can assume that at time 0, you had 0 bricks. So what would your equation for v_o be?

[Lego towers]	v_o
1	
2	
3	
4	
5	
6	

A.) Sketch a plot of v_o vs. [Lego towers].

B.) How many active sites (enzyme molecules) did you have available in your beaker? What did you observe about v_o when you had more substrate molecules than you had available active sites (i.e., all the active sites were saturated with substrate)? Why did this happen?

The value of v_o when all the active sites are saturated is known as $v_{max.}$

K_m is a constant that tells you about the affinity of the enzyme for the substrate. It is the concentration of substrate when v_o is ½ v_{max}.

C.) From your graph, what is v_{max}? What would the units of v_o be?

D.) From your table or your graph, what is [Lego towers] when v_o = ½ v_{max}? This is k_m for this Lego hydrolase reaction.

E.) What part of your experiment from last week does this remind you of? What do you expect to observe when you analyze the data for that part of the experiment?

The Natural Selection Game!

(Modified (kind of extensively) from http://www.stem.neu.edu/programs/re-seed/activities-and-labs/natural-selection-bird-beak/)

Part 1. How does natural selection work?

In this part of the game, you will be who are all competing for food on one of four islands. Each of you has a particular type of beak: dissection probe, flat forceps, fork, or spoon. Each bird will also have a "stomach" (cup). The islands all have different food types.

In each round (generation), your goal is to get as many food items into your "stomach" as you can in 20 seconds.

1.) At the end of the first round round, count your food items. Who gets to reproduce, and how many offspring are produced, is determined as follows (offspring have the same phenotype as their parents):

- The bird with the least food died without reproducing and leaves 0 offspring. This bird will not forage the next round.

- The bird with the most food is "thriving" and leaves two offspring.

- The other bird (or two birds) "survive" and leave one offspring each.

Once you've determined who reproduced and how well they did, record your data in the data sheet.

2.) Put all your food items back on the island. Forage again. The same rules as in the last "generation" apply, except taking into account that there are more birds in this generation than the last one. In this case, each of the offspring from the last generation can leave one or two offspring each (or starve).

- The bird type with the least food in its stomach goes extinct (however many birds there are starve before reproducing).

- All of the birds belonging to the type that got the most food leave two offspring each, so if there were two of these birds at the start of this generation, there will be 2 birds x 2 offspring/bird = 4 offspring to start the next generation.

- All of the birds belonging to type in second place leave 1 offspring each.

Once you've determined who survived and how well they did, fill in your data sheet.

3.) Assuming there are still two types left on your island, put all the food back and forage again. Assume the first place type leaves 2 offspring each and the second place type leaves one offspring each.

4.) At the end of this last generation, fill your data in to the data table on the board.

Q: What did you observe about the relationship between food type on the island and the number of birds with each beak type?

Q: Explain your results in terms of competition, survival, and reproductive success.

Q: What was the selective pressure in your system? What might have happened if there was more than one food type readily available on your island?

Part 2. Does it matter if parental traits are heritable?

1.) In this part, you'll repeat the game for another three generations, assuming that the "best" forager produces two offspring, the middle foragers produce one, and the worst forager dies without reproducing.

2.) Only this time, the type of offspring each forager produces isn't dependent on its own type. To determine which offspring you produce, you'll choose a random number for each offspring. Go to www.random.org, set your min at 1 and your max at 4, and hit "generate".

If you get a 1, the offspring has a fork, if you roll a 2, the offspring has a spoon, if you roll a 3, the offspring has a dissection probe, if you roll a 4, the offspring has big forceps. Record the number of each type of offspring in your data sheet.

3.) If one type vanishes from your island in the next generation, the player with that type of beak shouldn't forage. If it reappears in the next one because of dice rolling, the player with that type of beak can forage again.

4.) After the first generation, your calculation gets a little more complicated because you have to take into account the number of each type on your island.

Let's say the spoon does the best, the forceps do second best, and the dissection probe dies.

Let's also say there were 2 spoons, 2 dissection probes, and 2 forceps in that generation (based on the random numbers).

Each spoon leaves 2 offspring, so you wind up with 2 x 2 = 4 offspring from spoons. Get a random number once for each of the offspring (4 random numbers total) and record the phenotype.

Each forceps leaves one offspring, so you wind up with 2 x 1 = 2 offspring. Get a random number once for each offspring (2 random numbers total) and record the phenotype.

The dissection probes leave 0 offspring, so you don't need to do any dice rolling there.

5.) At the end of the third generation, do your calculations and record your results in the data table on the board.

Q: How do these results differ from the results from the first version of the game (when variation WAS heritable)?

Q: What do these results tell you about a condition that has to exist in order for natural selection to occur?

Part 3. What happens if (almost) everyone does equally well?

Now let's say that there was a change in conditions on your island so that your "prey" now primarily consists of small balls of play-doh (which should be relatively easy to collect – somehow – with all of your beak types).

Q: How would you expect your data compare to your data in part 1(when there was a lot of variation in the fitness of various beak shapes)? HINT: you might think about what happened to allele frequency in yesterday's simulation when everyone had equal fitness and the population was large.

Summing up.

Based on what you've observed in your previous experiments, define natural selection and write a list of "rules" for what needs to happen for natural selection to occur.

Action Potential Activity

An electrical signal that propagates through a nerve cell all the way to the axon terminal is referred to as an *action potential*.

In the lab, we often trigger action potentials by direct electric stimulation. However, in your brain, whether or not an action potential is triggered depends on input from other neurons that *synapse* on that neuron. Sometimes that input is excitatory. Sometimes it is inhibitory. Whether or not a neuron fires an action potential depends on whether or not it gets enough excitatory input to reach the *threshold voltage* that will cause voltage-gated Na+ channels in the axon to open and the axon to become much more permeable to sodium.

In this activity, you'll use a large beaker to represent the *axon hillock* of your neuron. The axon hillock is the region where the cell body connects to the axon. This region often receives input from other neurons. In the case of your "neuron", the axon hillock receives *excitatory* input (the little beakers which contain water) from two other neurons, and *inhibitory* input (the flask) from a third neuron.

The water in your beakers represents positively charged ions that flow into your neuron when it receives excitatory input from another neuron. If you add enough "positively charged ions" to your large beaker, the voltage will reach "threshold" and the action potential will propagate along the axon to the axon terminus (this is represented by your big beaker overflowing into the pan underneath it.)

A.) You'll notice that your "neuron" starts out at a voltage known as the *resting potential.* What determines what the resting potential of a cell is?

B. Your "neuron" receives *inhibitory* input from its neighbor and becomes *hyperpolarized*. Pour the water that's in your "neuron" into the flask.

What happens to the amount of water (positive ions) that you need to add to your "neuron's" axon hillock to reach threshold when your "neuron" is hyperpolarized? Is the voltage you'd measure when the axon hillock is hyperpolarized more positive or more negative than the resting potential?

What do you think happens on a cellular level when inhibitory input is received?

C. Return your "neuron" to resting potential. Now a different one of your neuron's neighbors fires, and it receives excitatory input from that neuron. Pour the water from one of your little flasks into the big beaker.

What happens to the "voltage" across the membrane: does it become more positive or more negative?

Does your neuron fire an action potential? Why or why not?

D. Return your "neuron" to resting potential. Now both of the neighbors that make excitatory connections with your main neuron fire. Pour the water from both of your little flasks in the beaker.

Does your neuron fire an action potential? Why or why not?

E. Return your "neuron" to resting potential. Now all three of your neuron's neighbors (the two excitatory neighbors and the one inhibitory neighbor) fire. Use your "neuron" to fill your flask up to the line, then pour the water from both the little beakers into your "neuron."

Does your “neuron” fire an action potential? Why or why not?

F. What have you figured out about how neurons “decide” when to fire?

The Size Lab! (And Introduction to Allometry)

Changes in size can drive changes in anatomy (for example, cross-sectional area of leg bones, or the complexity of the circulatory system) and physiology (e.g., metabolic rate, heart rate, respiration), both over developmental and evolutionary time. In this lab, you'll investigate why dramatic differences in anatomy and physiology are often associated with differences in size, and you'll learn how to use Excel to examine *allometric* relationships and empirically determine the allometric equation describing a particular relationship. Allometric relationships describe how some feature – finger length, skull diameter, heart rate, etc., etc. - changes with body size.

Part 1: Surface area, volume, and cooling

Equipment:
4 sizes of beaker (on your table)
Ruler or calipers
Water
Ice bucket
Thermometer

1.) Add enough water to your beakers to fill them to about 1 cm below the lip.

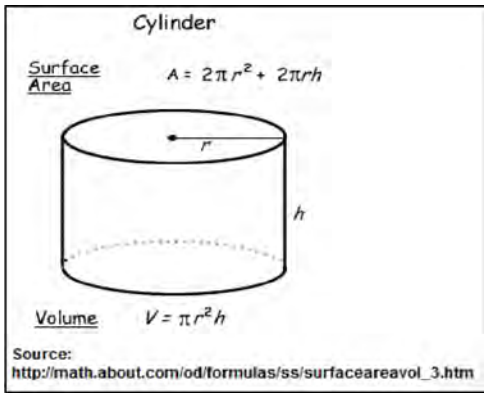
2.) Using the ruler, measure the diameter of your beaker (not including the lip) and the height of the water (it doesn't matter if you measure in cm or mm as long as you use the same units to measure diameter and height).

3.) Measure the temperature of the water in each of the beakers. Make sure to stir with the thermometer so you're sure you're not hitting a warm or a cool spot. This will be your temperature at t0.

4.) Place your beakers in the ice bucket so there is ice surrounding the beaker nearly up to the top.

5.) For the next 20 minutes, measure the temperature in each beaker every 2 minutes. This will allow you to calculate the rate of cooling.

6.) Calculate the surface area and volume of the water in each beaker. Remember the radius (r) is ½ the diameter, and approximate pi as 3.14. Fill the values in to the data table on the next page.



7.) You can use Excel to quickly find the average rate of cooling for each beaker:

- First, make a scatterplot with time (in minutes) on the x axis and temperature (in C) on the y axis. Remember, your temperature at 0 minutes was the temperature you measured at the start of the experiment.

- Fit a trendline to your data, and ask Excel to show the equation for the trendline. The slope of the trendline is your cooling rate in ^{0}C/min.

8.) Fill your cooling rates in on the data table (don't forget your units!).

Table 1. Relationship among surface area, volume, and cooling rate in cylinders

Beaker size	Diameter	Height	Surface area	Volume	Cooling rate

Q: What increases faster as an object increases in height (or diameter): surface area or volume?

Q: What did you observe about the rate of cooling in your beakers?

Q: One of the smallest *endothermic homeotherms* (warm-blooded animals that maintain their body temperature within a narrow range) is the bee hummingbird, which weighs about 2 grams and measures 5-6 cm in length. This isn't the smallest *vertebrate*: there are lizards much smaller, but they're *ectothermic poikilotherms* which don't produce their own body heat metabolically. Explain, given your results in this experiment, why there's probably a size limit on endothermy.

Q: Since heat is transferred via diffusion, use your results to explain why circulatory systems tend to get increasingly complex as organisms get bigger.

Part 1.5: What happens if you change the ratio of surface area to volume?

1.) Take your graduated cylinder, and calculate the surface area and volume when it's filled to 250 ml (about the same volume as you added to your 250 ml beaker).

Q: How does the surface area of your graduated cylinder compare to the surface area of your beaker? What do you predict this will do to the cooling rate?

2.) Add 250 ml to your cylinder, measure the temperature at t0. and put it in the ice bucket for 10 minutes. Measure the temperature again. Compare it to the temperature at 10 minutes for the beaker of the same volume.

Q: How did your prediction pan out? What does this tell you about what animals can do (either behaviorally or via evolutionary adaptations) to increase their rate of heat gain or loss?

Part 2: Introduction to allometry

A general allometric equation is given as $y = ax^n$. Such equations are useful when there's a relationship between x and y, but the relative difference between them isn't constant – as in the case of surface area and volume (or many relationships between body size and anatomical features).

It's actually relatively easy to derive an allometric equation empirically using excel and taking advantage of the properties of logarithms.

Try it using your data on volume and cooling rate:

1.) Take the log of volume and cooling rate (it's usually easiest to just create two new columns in excel). You can calculate logs using the formula =log().

2.) Make a scatterplot with log(volume) on the x axis and log(cooling rate) on the y axis.

3.) Fit a trendline to the data and find the equation. It will be in the form of $y = mx + b$

Because y and x are logarithms, you can take the antilog of the equation, which winds up giving you

$Y = \text{antilog}(b)*x^m$

Antilog(b) just equals 10^b.

Q: What's the allometric equation for the relationship between volume and cooling rate?

Part 2.5: The mystery beaker!

You can use this equation to predict the cooling rate for any beaker of this shape.

1.) Pick one of the beakers up front, fill it with water, calculate the volume of the water as before, and use the equation to calculate what the cooling rate should be.

Q:What do you predict the cooling rate will be in C/min?

2.) Measure the temperature of the beaker at t0, then put it in your ice bucket for 5 minutes, measure the temperature again, and calculate the cooling rate. How does this line up with your prediction?

Part 3: Allometric scaling of volume and mass

Your job now is to use the Play-Doh up front to derive the allometric relationship between the volume of a sphere and its mass. (The volume of a sphere is $(4/3)\pi r^3$)

Q: Explain what you did and give the equation you found.

Q: Assuming animals are roughly spherical (which is admittedly silly, but it's an okay mathematical approximation in some cases), what other major problem – besides issues with heating and cooling - do they face as they get bigger in the linear dimension (i.e., get longer or taller?) What structural adaptations will they need to cope with this problem?

Lab 2: Enzyme Kinetics

Overview
As we'll talk about over the next few weeks, many different chemical reactions happen in cells: molecules get broken down (such as breaking down sugars to make energy), molecules get synthesized (e.g., proteins, polysaccharides, nucleic acids), chemical groups are transferred from one molecule to the other (phosphorylation reactions). In all of these reactions, enzymes are the workhorses. Enzymes are proteins that work to catalyze (speed up) chemical reactions.

Enzymes are typically very specific for their substrates (the molecules they work on), such that most enzymes only carry out one reaction (or in some cases two – the forward reaction and the reverse reaction, depending on the concentrations of reactants and products).

In this lab, your job is to investigate how enzymes behave.

You'll investigate two major questions:

(1) When you give an enzyme a set amount of substrate to work on, how does the amount of product produced by the reaction the enzyme catalyzes change over time?

(2) How does the amount of substrate available to the enzyme affect the rate of the reaction it catalyzes?

The enzyme you're working with today is an enzyme called *acid phosphatase*, which is found in wheat germ. As the name suggests, it catalyzes the removal of phosphate groups from organic molecules. Unlike some enzymes, which only work on a single substrate, it can use a variety of substrates with phosphate groups.

In this lab, we'll use a synthetic substrate called nitrophenol phosphate (NPP).

Acid phosphatase catalyzes the following reaction.

```
        Acid
        phosphatase
NPP ------------------>  Nitrophenol
```

NPP is colorless, but nitrophenol turns yellow in basic solutions, so you can easily use the spectrophotometers to measure the amount of product (nitrophenol) present in your test tube. Any nitrophenol present has been produced by the reaction catalyzed by acid phosphatase.

For more details on enzyme-substrate reactions, read the opening section of the attached handout.

1. Make your standard curve

Before you go any further with your experiment, you want to collect data in order to make a *standard curve*. A standard curve takes advantage of Beer's Law to let you calculate the amount of nitrophenol in your sample based on the absorbance you measure.

Q: Remember Beer's Law from last week? What does Beer's Law say about how absorbance changes with increasing concentration of a (colored) substance? (You can just draw a picture if that's easier.)

To make a standard curve, you'll measure the absorbance of known concentrations of nitrophenol and make a graph of nitrophenol concentration (your independent variable, on the x axis), vs. absorbance (your dependent variable, on the y axis).

Next week you'll use Excel to fit a linear trendline to the data. Then you can use the equation for this trendline to calculate the amount of nitrophenol present in your samples after the enzyme-substrate reaction has taken place.

Q: The equation for your trendline will take the form y = mx + b. M and b are constants. b is the y-intercept, and m is the slope of the trendline.

(1) What does x represent (i.e., substrate concentration or absorbance)?

(2) What does y represent (i.e., substrate concentration or absorbance)?

(3) What does b (the y intercept) represent? Do you expect this number to be much bigger than 0, much smaller than 0, or close to 0? Why?

(4) How would you rearrange this equation so you can use it to solve for nitrophenol concentration in your samples using the absorbance data?

How to make your standard curve:

1. Turn on your Spec20, set the wavelength to 410 nm, and let it warm up for 10-15 minutes. (You can do this when you walk into class).
2. Blank your Spec20 just as you did last week.
   a. Fill a cuvette with 1.5 ml of the 0 nMol nitrophenol
   b. Make sure your Spec20 is set to Transmittance mode
   c. Adjust the dial so it reads 0% transmittance
   d. Insert the cuvette in the spectrophotometer
   e. Set the dial so it reads 100% transmittance
   d. Set the spectrophotometer to absorbance mode, and you're ready to go!

3. Measure the absorbance for each of the nitrophenol standards provided, including the 0 nMol standard. You can make a table in your lab notebook, or record your data here.

Table 1. Nitrophenol standard curve

Nitrophenol concentration (nm)	**Absorbance (A/A_o)**

2. Measuring the progress of an enzyme-substrate reaction over time

In this section of the lab, you'll do two things

(1) Follow the progress of the enzyme-substrate reaction catalyzed by pure acid phosphatase over a 30-minute period by measuring the amount of product present in a test tube at several time points. You'll collect the data to make a plot of nitrophenol concentration (i.e., the amount of product produced by the reaction) on the y axis, vs. time on the x-axis.

(2) Determine whether there is acid phosphatase present in wheat seeds (wheat germ). Next week, if it turns out there is indeed acid phosphatase present in wheat seeds, you'll use your data to calculate how much.

Q. What do you expect to happen to see happen to the concentration of product (nitrophenol, which is yellow) present in your solution of enzyme and substrate over time (will it increase? Will it decrease? Will it stay the same)? Why?

Q. Given that the enzyme only has a set amount of substrate available to work on (the 10 ml of NPP solution you'll add when you start the reaction), what do you expect will happen to the concentration of yellow nitrophenol present in your test tube if you run the reaction for long enough (will it keep increasing forever? Will it decrease? Will it eventually level off?)? Why?

Q. You can use the data you collect in this part of the experiment to measure the *rate* of the enzyme-substrate reaction. Given that

Rxn. rate = (change in amount of product produced) / (amt. of time elapsed)

(1) How would you use your data to calculate reaction rate? You can just write the equation you'd use if you want.

(2) Do you want to use data from early in the reaction or much later in the reaction to do this calculation? Does it matter? Why? HINT: Think about the last question.

Q. How will you decide if there's acid phosphatase present in the extract you make from the wheat germ (wheat seeds)?

How to do this part of the experiment:

Materials
Wheat germ
Extraction buffer containing NP-40
Mortar and pestle
Microfuge tubes
Test tubes
KOH
Pure acid phosphatase (green; in microfuge tube in your ice bucket)

"Phosphatase substrate solution" (nitrophenol phosphate)
Cuvettes

A. Make the wheat germ extract
What you'll do here is grind up wheat seeds with an *extraction buffer* containing a detergent called NP-40 that will disrupt the phospholipid bilayer of the cell membranes and allow you to extract the contents of the cytoplasm including any enzymes present.

Q: Why do detergent molecules disrupt the phospholipid bilayer? Why won't they affect any enzymes you extract from the cell? (You may need to use your book to answer this).

How to do it:
1. Weigh out 0.5 g wheat germ

2. Put it in a mortar and add 5 ml of extraction buffer

3. Grind the tissue and buffer with the buffer until a homogenous suspension is formed (it will look brown and grainy)

4. Put 1 ml or so of this in a microfuge tube (there are volume markers on the side)

5. Centrifuge for 5 min. *Don't forget to balance the centrifuge either by sharing it with another group, or putting a microfuge tube with 1 ml of water in it across from your sample.*

6. When you're done centrifuging, pull off the supernatant (the liquid on top) with a pipettor, put it in a fresh microfuge tube labeled "wheat germ extract," and put the tube in the ice bucket at your lab bench.

B. Do the enzyme assay using both pure acid phosphatase and the wheat germ extract.
Here, you'll measure the progress of the breakdown of NPP into nitrophenol (catalyzed by acid phosphatase) over time, and determine whether there is acid phosphatase in your wheat germ extract.

How to do the experiment:
1. On your lab bench, there should be a test tube rack containing two large (25 ml) test tubes and fourteen small (10 ml) test tubes.

2. Get a sharpie and label one large tube "AP" (for acid phosphatase) and one tube "WGE" (for wheat germ extract)

3. Label 7 small tubes AP1 through AP7. Label 7 small tubes WGE1 through WGE7.

4. Add 1 ml KOH to tubes AP1 through AP7 (put 1 ml in each tube). Add 1 ml KOH to tubes WGE1 through WGE7.

Q. KOH is a strong base. It is used to stop the enzyme-substrate reaction from happening. Given that enzymes are proteins, and proteins are held together with hydrogen bonds, why does putting the enzyme in a basic solution stop the reaction from happening?

4. Add 10 ml of "phosphatase substrate solution" (which is actually NPP) to the large AP tube. Add 10 ml of phosphatase substrate solution/NPP to the large WGE tube.

5. Remove 1 ml of NPP from the AP tube and put it in small tube AP1. Remove 1 ml of NPP from the WGE tube and put it in small tube WGE1. These will give you the amount of nitrophenol present in the solution at the time you started the reaction (t0).

6. Add 0.1 ml (100 µl) of pure acid phosphatase (the green substance in the microfuge tube in your ice bucket) to the large AP tube. Add 0.4 ml (400 µl) of your wheat germ extract to the large WGE tube. Shake both tubes gently to mix. Start a stopwatch. Once you've added the acid phosphatase and the wheat germ extract, the reaction (NPP → nitrophenol) will start, because the enzyme (if it's present) will be able to catalyze it. *Don't panic if you don't see a color change – the nitrophenol won't turn yellow until you add it to the KOH.*

7. After 2.5 min, take 1 ml of solution out of the large AP tube and add it to tube AP2. After 2.5 min, take 1 ml of solution out of the large WGE tube and add it to tube WGE2.

8. After 5 min, take 1 ml of solution out of the large AP tube and add it to tube AP3. After 5 min, take 1 ml of solution out of the large WGE tube and add it to tube WGE3.

9. After 10 min, take 1 ml of solution out of the large AP tube and add it to tube AP4. After 10 min, take 1 ml of solution out of the large WGE tube and add it to tube WGE4.

10. After 15 min, take 1 ml of solution out of the large AP tube and add it to tube AP5. After 15 min, take 1 ml of solution out of the large WGE tube and add it to tube WGE5.

11. After 20 min, take 1 ml of solution out of the large AP tube and add it to tube AP6. After 20 min, take 1 ml of solution out of the large WGE tube and add it to tube WGE6.

12. After 30 min, take 1 ml of solution out of the large AP tube and add it to tube AP7. After 30 min, take 1 ml of solution out of the large WGE tube and add it to tube WGE7.

13. Measure the absorbance of the solutions in tubes AP1-AP7 and WGE1 – WGE7. Since you already blanked the specs when you made your standard curve, you don't need to do it again.

Fill in the tables below, or make a table in your lab book.

Table 2. Nitrophenol produced by reaction of NPP with acid phosphatase

Tube	**Reaction time (min)**	**Absorbance**
AP1	0	
AP2	2.5	
AP3	5	
AP4	10	
AP5	15	
AP6	20	
AP7	30	

Table 3. Nitrophenol produced by reaction of NPP with wheat germ extract

Tube	**Reaction time (min)**	**Absorbance**
WGE1	0	
WGE2	2.5	
WGE3	5	
WGE4	10	
WGE5	15	
WGE6	20	
WGE7	30	

3. How does substrate concentration affect the rate of an enzyme-catalyzed reaction?

In this part of the experiment, we'll examine how giving enzymes more substrate to work on affects the rate of reaction. Since we haven't yet talked in class about

exactly how enzymes work, you'll make your predictions for this part in class next week.

Materials
Pure acid phosphatase (green, in microfuge tube in your ice bucket)
"Phosphatase substrate solution" (NPP)
"Substrate dilution buffer" (Tris-acetate, pH 4.5)
KOH
Test tubes
Cuvettes

How to do the experiment

A. Make a serial dilution of NPP

Serial dilutions are commonly used in biology, so it's useful to understand how these work. The serial dilution we'll use will dilute the concentration of NPP by half each time, and give you 7 different concentrations of NPP to test with your acid phosphatase. You'll start with 1 mM NPP and end up with ~ 15 μM NPP for your smallest dilution.

How to do your serial dilution
1. Get 8 test tubes and label them 1-8 with a sharpie.

2. Place 1 ml of substrate dilution buffer in tubes 1-7. Leave tube 8 empty.

3. Put 2 ml of phosphatase substrate/NPP (1000 μM) into tube 8.

3. Transfer 1 ml from tube 8 into tube 7 and mix. (This will give you a solution that is half NPP and half dilution buffer.)

4. Transfer 1 ml from tube 7 into tube 6 and mix.

5. Transfer 1 ml from tube 6 into tube 5 and mix.

6. Transfer 1 ml from tube 5 into tube 4 and mix.

7. Transfer 1 ml from tube 4 into tube 3 and mix.

8. Transfer 1 ml from tube 3 into tube 2 and mix.

9. Discard 1 ml from tube 1. Don't transfer anything into it.

Q: What is the concentration of NPP in each tube? Fill in the table below.

Table 4. Concentrations of serial dilutions of NPP

Tube	**NPP concentration (µM)**
1	0 (dilution buffer only)
2	
3	
4	
5	
6	
7	500
8	1,000

How to do the enzyme reactions and measure product produced

1. Quickly add 10 µl of the pure acid phosphatase (the green stuff) to tubes 1-8 and mix.

2. Set a timer for 15 min.

3. When the timer goes off, add 1 ml of KOH to each tube to stop the reaction and cause any nitrophenol produced to turn yellow.

4. Add 3 ml of water to each tube. (This is to reduce the intensity of the color so it doesn't max out the spectrophotometers).

5. Read the absorbance from each tube and record it in the table below, or in your lab notebook.

Table 5. Absorbance of nitrophenol produced by reaction between various concentrations of acid phosphatase and NPP after 15 min.

Tube	**NPP concentration (µM)**	**Absorbance (A/A_o)**
1	0 (dilution buffer only)	
2		
3		
4		
5		
6		
7	500	
8	1,000	

WHAT YOU NEED TO DO WITH THESE DATA FOR NEXT WEEK'S LAB

1. Create an excel workbook with 3 worksheets/tabs. Label one tab "standard curve". Label the second tab "NPP over time". Label the third tab "Michaelis-Menten"

2. In the "standard curve" tab, enter your data from Table 1. Don't forget to put column labels in the first row (concentration and absorbance).

3. In the "NPP over time" tab, enter your data from Table 2 and Table 3. You should have three columns: reaction time, AP absorbance, WGE absorbance

4. In the Michaelis-Menten tab, enter your data from Table 5. You should have 2 columns, one labeled "NPP concentration", and one labeled "Absorbance".

5. Email the sheet to yourself, put it on your H drive, or bring it to next Thursday's lab on a flash drive.

The Skull Lab!

We've been talking a fair bit this past week about the relationship between ecological niche, selection pressures, and skull morphology, and you've been introduced to a few studies that have explored this relationship. This is your chance to do some comparative anatomy research of your own.

Before Lab
What you and your lab partner(s) will do before lab is do a little bit of research in the primary (journal articles) and secondary (textbooks and field guides) literature and come up with a question and a hypothesis that you'd like to test using some combination of the skulls listed below.

Both your question and your hypothesis need to be justified based on what you know from class and what you've read in your literature research, though it doesn't have to be a tremendously complicated question.

Once you've decided what you're interested in asking, you'll want to design a small study to address your question using the available skulls (list on page 2). In this study, you'll want to use **quantitative** measures of at least one aspect of skull morphology to address your question. Things you might measure (depending on your question) include the number and type of teeth (you can assign numerical scores to particular tooth types), the length of various parts of the skull, size of braincase, etc.

Since you'll be making cross-species comparisons, you're going to have to think about how you plan to control for the effects of things like differences in body size or number of teeth, etc. that are unrelated to the question you're asking but may bias the data, (A hint here: ratios are your friend, and it's worth looking at how other studies have dealt with these issues).

I'll put some possibly-relevant papers on Moodle in the files section in the Papers For Skull Lab folder, both to get you started and to give you an idea of the kinds of papers you ought to take a look at.

In Lab:
You'll take and record your measurements (I'll provide calipers and rulers and string), then analyze and graph your data – bring your laptops if you've got them.

Good science depends on replication, so you'll want to take measurements on multiple skulls from each species you're considering. You'll then calculate the **mean** and **standard error** (standard deviation / √n , where n is your number of subjects) for each of your measurements. One of the things this will give you an idea of is how much variation there is in a particular trait within the population you're studying. You'll graph these means (or data points, if you're looking at allometry) with error bars representing your standard errors – if you don't know how to do it in Excel, I'll be happy to show you, and you'll use a statistical test – most likely a t-test – to determine whether your data

support your hypothesis. I can help you identify the best statistical test for your data and point you at online tools for doing your statistics.

After Lab:
You and your partner will write a mini paper – no more than three or four pages long, single spaced (not including graphs), with an introduction outlining the rationale behind your question and your hypothesis, a short methods section explaining what you measured and why, your results (graphs and results of your statistical test(s)), a brief discussion that interprets your results and puts them in a larger context, and a bibliography. You should cite at least three journal articles in your paper. This mini-paper will be due by 6 PM next Tuesday.

Available skulls
American alligator (4)
Bowfin (2)
Frog (3)
Cat (15)
Gopher (8)
Rabbit (10)
Ground squirrel (10)
Tree squirrel (2)
Mink (10)
Marten (9)
Skunk (9)
Coyote (3)
Bobcat (2)
Turkey (3)

** minks, martens and skunks are all mustelids and relatively closely related

Checklist
for the Skull Lab

Pre-lab

- Read at least 2 journal articles on a topic relating to skull morphology and ecology/evolution.
  - Searches you might try: Skull morphology + diet, Skull morphology + niche, skull morphology + mammals, skull morphology + carnivores, omnivores, or herbivores, tooth morphology and diet, etc.

- Using these journal articles, develop a research question related to skull morphology (it doesn't have to be a huge question, just a justified one)

- Based on what you know about skulls, and anything you've read, come up with a hypothesis.

- Decide on study species appropriate to the question. The number of study species will depend on your question.
  - You can use a field guide or zoo or natural history museum websites or Wikipedia to find out about the diet, body size, etc. of the animals you might be interested in studying.

- Decide what you're going to measure. These measures should be quantitative: length, width, number, etc. You can also weigh your skulls if your study seems to call for it. Also decide what you're going to do to cope with body size variation between species.

- Now that you know what you're measuring and what species you're using, come up with predictions of what you'll see if your hypothesis is supported. Your predictions should be justified based on your literature research or information from your text.

In Lab

- Take your measurements and record them in an Excel spreadsheet

- Calculate mean and standard error for each of your measurements for each species.

- Graph your results, including error bars, and do any statistical tests (I'm happy to help you with this, including figuring out what tests to use).

- Start thinking about how you're going to interpret your findings.

After Lab

- Talk with your partner and decide what your conclusions are, based on your data.

- Write the mini-paper (length: about 3 pages, single spaced, not including graphs)
  - Introduction: Give a little background justifying your , hypothesis, and predictions (don't forget your parenthetical citations!)
  - Methods: What study species did you use, what measurements did you make, how did you control for body size, what statistical test did you use?
  - Results: Briefly summarize your findings in words, and present your graphs (with descriptive captions)
  - Conclusions: Interpret your data, and put it in the context of the literature (here is where you cite whatever papers you've read, and/or your textbook, and use this information to justify your interpretation.)
  - Bibliography: I'm not picky how you format it as long as you're consistent (APA, Journal of Physiology, etc.)

– Mini-papers are due 1 week from Tuesday by 6 PM.

Peroxidase Project

Cell and Molecular Biology

Lab 1. Research, Hypotheses, and Predictions

In these projects, you'll be studying a family of *isoenzymes* known as peroxidases. Peroxidases are a kind of enzyme that catalyzes the oxidation of various organic compounds using H_2O_2 as an oxidizing agent (what organic compound gets oxidized depends on which specific peroxidase you happen to be talking about). In other words, the SUBSTRATES of the enzyme are H_2O_2 and whatever organic compound the enzyme is oxidizing.

You'll be working with mung bean plants (*Vigna radiata*). Mung beans are easy to sprout, and you can start a lot of them at once, so you potentially can have several *replicates* for whatever treatments you decide to do. Simply put, a replicate is a repetition of your treatment. For example, if you're interested in studying the effects of heat stress on peroxidase production in dandelions, you might want to subject six different dandelion plants to the same high temperature and have six control plants that are grown at a "normal" temperature.

Q. Why do you want to have replicates when you're carrying out an experiment? (HINT: Think about how it's different to get a result once, vs. getting the result six out of six times.)

Q. Why do you need a control group?

What You're Going to Do For This Project

The fun thing about this project is that you – working in groups of 3-4, of course -- get to design your own studies. However, this does not mean just doing whatever you want at random. Your study should have a clear rationale, and **the questions you ask, the hypotheses you generate, and the way you interpret your data should be based on**

what you already know about how enzymes work, and information from peer-reviewed journal articles you've read on the subject.

The WRONG way to ask a question: We're going to compare peroxidase concentration in strawberry leaves, beet leaves, and tomato leaves.

What's wrong with it? No research or knowledge of enzyme mechanisms to justify your question!

The RIGHT way to ask a question: Extreme heat is likely to disrupt enzyme function because it can disrupt hydrogen bonding and denature proteins. Therefore, we are going to compare peroxidase activity between peaches that have been heat-treated, and those kept at room temperature.

This question is justified based on reference to cellular mechanisms.

Or you might ask a question like this:

Previous research shows that peroxidase activity changes with ripening in peaches and other climacteric fruit (here you'd cite whatever paper you read it in). We plan to investigate whether this is also the case in non-climacteric fruit. We will compare peroxidase activity over the course of ripening in peaches (climacteric) and limes (non-climacteric).

This question is justified based on reference to previous research.

Whatever hypotheses you come up with and whatever predictions you make should be based on what you know about enzymes, and/or what you've read.

Some General Information About Plant Peroxidases That May Help You Get Started

Peroxidases form a large family of related enzymes that are ubiquitous in plants. Members of an enzyme family are often referred to as "isoenzymes." These enzymes catalyze the oxidation of phenolic compounds at the expense of hydrogen peroxide (H_2O_2). In other words, they use hydrogen peroxide as an oxidation agent.

The general form of the reaction carried out by all peroxidases is as follows:

$$H_2O_2 + \text{other substrate (phenolic compound)} \xrightarrow{\text{Peroxidase}} H_2O + \text{oxidized substrate} + O_2$$

All peroxidases use H_2O_2 as one of their substrates, but the second substrate varies from peroxidase to peroxidase. Some, like horseradish peroxidase, may actually be able to use a variety of second substrates so long as they're the right general shape and provide some

reducing power (this makes it extremely useful in research). A huge number of peroxidase isoenzymes have been identified and these proteins have 30 to 80% sequence similarity with each other.

Although hundreds of papers have been published on peroxidases, the precise functions of the enzymes are uncertain. In plant systems, peroxidase is likely to play a role in the synthesis of the cell wall. Here the enzyme cross links phenolic residues of cell wall polysaccharides and glycoproteins which serve to strengthen these cell wall components.

Peroxidase can also kill microorganisms and destroy chemicals that are toxic to both plant and animal cells including H_2O_2, phenols, and alcohol. For these reasons, it has been proposed that peroxidase protects cells from microorganisms and toxic chemicals. Thus, peroxidases are likely play roles in plant defense mechanisms, but the precise function of all peroxidase isoenzymes in this process is not known. The picture becomes even more complex since plant peroxidase isoenzymes can be tissue specific and developmentally regulated in the absence of stress stimuli making it likely that at least some of these isoenzymes play roles in normal developmental processes.

So, questions you might think about asking about plant peroxidases could potentially include:

(1) Where is the most peroxidase produced in a plant during a particular stage of development?

(2) How does peroxidase production change in a particular region (stem, root, leaves, etc.) across developmental stages?

(3) How does a particular stressor affect the level of peroxidase?

Your search terms should include “peroxidase”. What other search terms you use depend on the questions/cellular mechanisms that interest you. The general information below may give you some idea of search terms you might want to use.

Things you might try:

Peroxidase and heat

Peroxidase and injury

Peroxidase and development

Peroxidase regulation

Peroxidase distribution

Etc.

<u>By Monday</u>, you'll want to turn in a completed version of the project proposal form at the end of this packet (it's also posted on Moodle). Each group should turn in one form.

Things that you should consider

(1) What, specifically, is your research question? It should be narrow enough that you can answer it using a treatment group and one or two controls. Remember – you only get a couple of weeks in lab. It should also arise from some of the reading you've done.

(2) What is your hypothesis – your hypothesis should be a potential answer to your question. It should be testable. It should also be justified, based on what you've read.

(3) What are your predictions? You should be able to say: If our hypothesis is correct and we do X, we expect to see Y happen.

<u>Between Lab 1 and Lab 2.</u> Get your bean sprouts and going and apply treatments if necessary.

Lab 2. Sample collection, initial peroxidase level testing, and tissue printing.

Questions you'll answer in this lab:

(1) Where are <u>active</u> peroxidases located in our plants?

(2) Tentatively, how much <u>active</u> peroxidase is present in our samples?

In this laboratory, you will localize peroxidase in plants by a technique called tissue printing. This technique can be used to localize specific enzymes, antigens, and nucleic acids in animal and plant tissues. You will section your plant tissue: vegetables, roots, thick leaves or stems with a razor blade and transfer the proteins from the cut tissue sections to a nitrocellulose membrane by application of gentle pressure. An imprint of the tissue proteins will be formed on the nitrocellulose membrane. The enzyme peroxidase will then be detected on the membrane by the reaction:

$$\textbf{Chloronapthol} + H_2O_2 \xrightarrow{\text{peroxidase}} \textbf{Chloronapthol} + H_2O + O_2$$

(**Soluble, colorless substrate)** **(Insoluble Purple Product)**

This reaction is catalyzed by the enzyme peroxidase, so it only occurs at an appreciable rate when the enzyme is present. The nitrocellulose membrane will be incubated with the peroxidase substrates chloronapthol and hydrogen peroxidase as a part of the color development solution. The peroxidase converts the colorless chloronapthol to an insoluble purple product, which is deposited at the site of the enzyme. This reaction can also be used to estimate the absolute amount of peroxidase activity in plant extracts. On the same nitrocellulose sheets, you can deposit drops of standards with known amounts of peroxidase and drops of cell-free extract.

Q. Why do these methods only tell you about active peroxidases? (i.e., enzymes where the active site is functioning?).

Procedures.

Preparation of Cell-Free Extracts

Depending on how you prepare your cell-free extracts (which will depend on what your question is), you can obtain information on the peroxidase levels in the plant as a whole, or peroxidase levels in specific *parts* of the plant. If you want to know about the plant as a whole, grind up the entire plant sample. If you're just interested in roots or leaves, just grind up roots or leaves.

Make sure you make one cell free extract per replicate of the treatment and the control.

Q. Why do you want to make one extract per replicate, rather than just grinding all your plants together?

Preparation of Cell Free Extracts

(Before you begin, be sure you have set aside additional tissue for printing as described below!)

1. Place 2 grams of a selected plant tissue into a mortar and add 2 ml of enzyme extraction buffer. This buffer contains 2 mM $MgCl_2$, 20 mM NaCl, 0.01% NP40, 10 mM Tris, pH 8.0. It

would be advisable to consider what this buffer does and why it contains these items. You may want to chop the tissue into small pieces with scissors.

2. Use the pestle to grind the tissue and buffer into a homogenous suspension. The mechanical action of the pestle and the chemical action of the detergent Nonidet P-40 that is present in the extraction buffer should disrupt the plant cells which in turn will liberate their cytoplasmic proteins.

3. Use spatulas, toothpicks, etc. to load the contents of the mortar into one or more microcentrifuge tubes.

4. Clean your mortar and pestle well with alcohol and distilled water. Repeat steps 1-3 with your other plant tissue samples.

5. Centrifuge the suspensions for 5 minutes and use a glass pipet to transfer the supernatant into clean microfuge tubes. You can combine all the supernatant from the same type of sample at this point if you had filled more than one tube with suspension. Label these tubes with your group symbol, tissue type, and "100% extract".

6. Transfer 10 microliters of each of your extracts into another clean tube. Then add 90 microliters of distilled water and label "10% extract". These will help you in quantifying the amount of peroxidase in your extracts.

The main reason you're making the 10% extract is because peroxidase activity in your sample may be higher than peroxidase activity in your standards. The 10% extract would then give you a "readable" level that you would multiply by 10 to get the actual level of peroxidase activity in your plant tissue. If you can interpret the data from your 100% extracts, you don't need to bother with the 10% extracts.

<u>Preparation of the Tissue Prints</u>

(Be sure to wear gloves during this procedure to avoid transfer of proteins from your hands to the nitrocellulose membrane! Try to touch only the edges.)

1. Use one of the dividing sheets to decide on your exact layout for the standards, the 10% and 100% extracts, and the tissue prints. Use a ruler to help you decide where to put each sample, drawing a picture in your lab notebook. Remember you'll have several tissue prints, extracts and four peroxidase standards.

2. Wet one sheet of nitrocellulose by floating it in a dish with about 20 ml of distilled water.

3. Place a moist paper towel on the lab bench and place the nitrocellulose on the moist towel.

4. Gently blot the nitrocellulose with a kimwipe or dry paper towel to remove excess moisture.

5. Pipet 5 microliters of each of the four peroxidase standards provided onto the nitrocellulose about ½ cm from the side. The standards should be carefully pipetted onto the membranes to form individual spots 1 cm apart from each other. Be sure to use a fresh tip for each spot.

Standards	
#1	0.01 micrograms of HRP per milliliter
#2	0.1
#3	1.0
#4	10.0

6. Pipet 5 microliters of each of your extracts, both the 10% and the 100% solutions, onto the nitrocellulose. Be sure the spots remain separate and not too close to (at least 1 cm apart from) the standards. Allow about 5 minutes for the solutins to be absorbed onto the membranes

7. At this point, put your labeled 100% extracts into the freezer for use next week.

8. Using a razor blade, cut your tissue samples to show a cross section. Gently blot each cut surface onto a paper towel to remove excess liquid.

9. Position the cut surface of the plant onto the nitrocellulose and press down firmly for ten seconds making sure not to move your hand during the process.

10. Remove the plant section and repeat steps 8 and 9 for your other plant samples.

11. You may want to make a drawing of each plant section in your lab notebook.

<u>Detection of Peroxidase</u>

1. Examine the tissue prints to determine if any imprints can be seen on the nitrocellulose before staining.

2. Place about 15 milliliters of freshly prepared color development solution into a dish. Place the nitrocellulose membrane into the dish and observe for the next 5 minutes. The color development solution was made by adding 5 ml of chloronapthol, 0.7 ml of hydrogen peroxide, and 2 ml of 1 M Tris buffer to 150 ml of distilled water.

3. After 5 minutes, discard the color development solution in your waste beaker. Add distilled water to the dish.

4. Record the relative darkness of the standards and extract spots. Are certain regions of the tissue prints darker than others? Can you estimate the concentration of peroxidase in different tissues or in different regions of your tissues? Be sure you have a good diagram or picture of the nitrocellulose membrane results before movng to the next step.

Detection of Total Protein

1. After discarding the water from the dish, add 15 ml of protein blot stain. This solution (Ponceau S) should stain all proteins on the nitrocellulose membrane red.

2. After 5 minutes, discard the stain into your waste beaker and rinse the nitrocellulose with distilled water three times. Note the regions that are red. Are there regions that are red that did not stain blue above?

3. If you would like to keep your nitrocellulose, you can put it into a small plastic bag, then cover the bag with foil and put it in the refrigerator.

4. When analyzing your data you should be able to estimate the amount of peroxidase in a standard amount of your undiluted vegetable extracts and describe the areas or types of tissues that contained the highest concentration of peroxidase.

Q. How would you interpret the data if you had no peroxidase activity in your samples *and* no protein detected?

Q. How would you interpret the data if you had high peroxidase activity in the leaves in your control plants and no peroxidase activity in the leaves your experimental plants (though you had high levels of protein staining in the leaves of your experimental plants)?

<u>Between Lab 2 and Lab 3</u>: Make predictions about the electrophoresis, and decide which cell-free extracts to run in your gel and do spectrophotometry on.

Electrophoresis lets you separate proteins based on charge and size, and ask questions about *which* peroxidases are present.

Q. You'll be using chloronapthol to detect peroxidases in your gels. Will this tell you anything about any inactive peroxidases that are present in your samples? Why or why not?

Q. Based on your results from the first lab, which samples do you expect to detect peroxidases in? Explain.

Q. (a) Based on your reading, internet searches, etc., how many peroxidases do you expect to see in each of your samples? Do you expect them to be positively charged? Negatively charged? Give a citation or two to back up what you're saying.

(b) If you didn't see any peroxidase activity in one of your samples in the first lab, do you expect to see any peroxidases in the gel for that sample? Explain.

If you have a bunch of samples, you may not want to test all of them in the third lab. (Bear in mind you only have eight wells for electrophoresis). You'll want to think about which samples it would be most productive to test. Things you might consider:

(1) If it was hard to tell whether total peroxidase activity was different in your control plants versus your experimental plants just using the spots of cell-free extract, you'll probably want to do spectrophotometry to see if you can detect a difference quantitatively.

Q. Here, you'll want to get an absorbance value on each replicate and perform a t-test to compare your control and experimental plants. Why?

(2) If you're trying to see if there's a correlation between duration of treatment or concentration of acid, etc., and peroxidase levels, you'll want to get quantitative values of peroxidase using spectrophotometry in any region where you think you may have seen an effect.

(3) If you didn't see any peroxidase activity in a particular region when you did tissue printing, it's probably not worth running those samples in the electrophoresis.

Q. Why not?

Lab 3. Spectrophotometry and Protein Electrophoresis

In this lab, you'll use spectrophotometry to get quantitative measures of peroxidase levels in your samples (rather than qualitative, as in the last lab).

You will also further characterize the peroxidase in plant extracts by assessing the peroxidase isoenzyme profiles. Peroxidase isoenzymes have different net charges and thus move differently in an electric field. Some forms of peroxidase are basic proteins and these forms will migrate to the negative (black) electrode during electrophoresis. In contrast, peroxidase isoenzymes which are acidic proteins migrate toward the positive (red) electrode during electrophoresis.

You will electrophorese the plant extracts along with protein standards on agarose gels. The extracts contain hundreds of colorless proteins in addition to peroxidase. In order to identify the peroxidase isoenzymes, you will selectively stain the gels after electrophoresis for peroxidase activity. In order to detect the peroxidase isoenzymes after electrophoresis, the agarose gels will be incubated with chloronapthol and H_2O_2. The highly colored product of the reaction localizes in the electrophoretic zones of the peroxidase activity and the amount of purple color formed is quantitatively related to the level of the peroxidase isoenzymes present.

In order to characterize the peroxidase isoenzymes in the tissue extracts, you will compare their migration to the migration of four protein standards. The isoelectric points of these standards are included in the table below followed by a brief description of their properties and functions.

Protein	**Color**	**Isoelectric Point***	**Net Charge at pH 8.6**
Cytochrome C	Orange	10.2	Positive
Hemoglobin	Red	7.2	Negative
Serum Albumin**	Blue	4.8	Very negative
Horse Radish Peroxidase (HRP) (Basic isoenzymes)	Colorless	9.0	Positive
Horse Radish Peroxidase (HRP) (Mixture)	Colorless	9.0 7.1 6.2	Positive Negative Negative

*** The isoelectric point of a protein is defined as the pH at which a protein does not migrate in an electric field.**

** Bromophenol Blue has been added to the serum albumin sample, which stains this protein blue.

Cytochrome C – Plant and animal tissues contain a class of cell protein pigments called cytochromes. Cytochrome C, which is one of the best characterized of the cytochromes, is an integral part of the electron transport system in mitochondria and is involved in cellular energy production (ATP synthesis). Cytochrome C consists of a single polypeptide chain, which is wound around a central, nonproteinaceous compound called heme. It is the iron containing heme group which is responsible for the orange-brown color of this protein. The protein is basic in nature primarily because it contains a high concentration of lysine residues. The isoelectric point of horse cytochrome C is 10.2 and at pH 8.6 the protein carries a net positive charge. Thus cytochrome C, unlike most proteins, migrates to the negative electrode during electrophoresis at pH 8.6.

Hemoglobin – Hemoglobin contains an iron containing heme group and the iron is involved in oxygen binding. Hemoglobin is involved in the transport of oxygen in blood. The isoelectric point of rabbit hemoglobin is 7.2. Thus, this protein should move toward the positive electrode during the electrophoretic separation. This protein standard will be in the same tube and run in the same electrophoresis lane as the serum albumin.

Serum albumin – Serum albumin is the major protein found in blood plasma. This protein binds and transports a large number of smaller molecules in blood. Unlike the proteins described above, albumin is not naturally colored. However, the tracking dye bromophenol blue has been added to your serum albumin sample, and some of this dye will bind and remain bound to the albumin during the electrophoretic run, turning the albumin band blue. The remainder of the bromophenol blue will migrate faster than albumin, and when this free dye has migrated to the positive electrode end of the gel, the electrophoretic separation is complete. Serum albumin is a relatively acidic protein, and has the lowest isoelectric point of the proteins that will be used in this exercise. Thus, this protein possesses a very negative net charge at pH 8.6 and will migrate faster than the other three proteins described above. This protein standard will be in the same tube and run in the same electrophoresis lane as the hemoglobin.

Horse radish peroxidase (HRP) – Horse radishes are a rich source of peroxidase, and in this laboratory you will use two different preparations as standards. The first preparation (HRP-Basic) contains a single basic peroxidase isoenzyme, which will migrate to the negative electrode during electrophoresis. The second preparation (HRP-Mixture) contains three peroxidase isoenzymes: one basic and two acidic.

Procedures

1. Thaw your extracts from last week and place on ice.

2. To save time 1.2% agarose gels will have been prepared for you. The electrophoresis buffer is at pH 8.6 and contains Tris-glycine. The gels are submerged in this buffer during the electrophoresis. You should always wear gloves when handling a gel or stains.

Electrophoresis

1. Each lab group will have one gel to use, containing 10 lanes. Determine what you will put into each lane, including the four standards listed in the introduction to this lab (cytochrome C, hemoglobin/serum albumin, HRP basic, HRP mixture).

2. Put 15 microliters of each extract into a clean microfuge tube. Add 15 microliters of electrophoresis sample buffer. This buffer contains glycerol, electrophoresis buffer, and

bromophenol blue. The glycerol will make the extract mixture heavy enough to sink into the well and the bromophenol blue will add color so you can see it migrate.

3. Load 12 microliters of each standard and extract/sample buffer mixture into a lane in the gel.

4. Connect the gel to the power source and run at about 120 V. Electrophoresis should be carried out until the bromophenol blue in the extracts has migrated to within 1 cm of the red (positive) end of the gel. This should take about an hour.

5. Remove the gel from the electrophoresis cell, rinse in distilled water, and note the positions of the colored standard proteins in the gel. You may want to record direction of migration and measure those distances from the wells (in mm) with a ruler.

6. Pour about 50 ml of peroxidase substrate solution (2 ml 1 M Tris buffer, 5 ml chloronapthol, 500 microliters H_2O_2 in 130 ml distilled water) over your gel and put the gel into the 37 degree incubator in BSC 304 for 30 minutes.

7. Rinse the gel with distilled water and observe using a light box. What bands can you see? Where are they located compared with the standards? Is there more than one isoenzyme apparent?

8. If you want to save your gel, put it into a small plastic bag with a bit of extra buffer and put it into the refrigerator.

<u>Spectrophotometric Determination of the Amount of Peroxidase</u> (this can be done during the electrophoresis run)

1. Set the spectrophotometer to 575 nm and blank using water.

2. Put 40 microliters of each of the standards provided into a labeled glass tube (not a cuvette!).

Standards

#1	0.08 micrograms of peroxidase per milliliter
#2	0.4
#3	2.0
#4	10

3. Add 5 ml of color development solution to each of the glass tubes containing the standards and mix the contents well. Let the tubes sit for 3 minutes.

4. Pour the contents of the most dilute standard into a cuvette and take an absorbance reading. Then quickly pour the contents back into the glass tube. Pour the contents of the second standard into the same cuvette and get a reading. Repeat for standards 3 and 4.

5. Put 5 microliters of each of your extracts into a labeled glass tube.

6. Add 5 ml of color development solution to each of the glass tubes containing the extracts and mix the contents well. Let the tubes sit for 3 minutes.

7. Pour the contents of the lightest colored tube into a clean cuvette and take an absorbance reading. Then quickly pour the contents back into the glass tube. Pour the next of the next darkest extract tube into the same cuvette and get a reading. Repeat for the remaining tubes.

8. Put 40 microliters of each of your extracts into a labeled glass tube.

9. Add 5 ml of color development solution to each of the glass tubes containing the extracts and mix the contents well. Let the tubes sit for 3 minutes.

10. Pour the contents of the lightest colored tube into a clean cuvette and take an absorbance reading. Then quickly pour the contents back into the glass tube. Pour the next of the next darkest extract tube into the same cuvette and get a reading. Repeat for the remaining tubes.

11. Use the absorbance readings from the standards to make a line graph relating peroxidase concentration and absorbance. Use the equation of that line to estimate the amount of peroxidase in each of your extracts. Did you get consistent results when you used 5 and 40 microliters? Are your results consistent with your peroxidase concentration estimates from last week?

What now?

1.) Determine how many peroxidases are in your sample, and whether they're large, small, or medium. Determine whether they're positive or negative. Go back to the literature on mung beans or http://peroxibase.toulouse.inra.fr/ and see if you can tentatively identify them.

2.) Use your excel-fu to create a standard curve for your spectrophotometry samples, and convert all your absorbances to concentrations.
3.) Analyze your data and plot it, and decide whether your results support your hypothesis, lead you to reject it, or are mixed. If you're not sure what statistical techniques to use (t-tests, correlations, etc.), talk to Dr. Fox.

4.) Once you think you've arrived at a tentative answer, make an appointment with Dr. Fox to discuss your data.

5.) Write up your paper. It should have an abstract, introduction, materials and methods section, results section, discussion, and works cited. Include figures as appropriate.

GROUP RESEARCH PROPOSAL FORM

Names of investigators (group members):

Lab section:

Title of Your Project:

Research question:

Hypothesis & predictions:

Chemicals, drugs, or other equipment (UV lamp, etc.) needed:

Brief (1 paragraph) justification for study. YOU MUST CITE SOURCES; EITHER YOUR TEXTBOOK OR JOURNAL ARTICLES

Brief summary of experimental plan: (What treatments are you doing? What is your control group? What measurements are you taking, and what will they tell you?)

Sources cited:

Protist Population Dynamics

(Developed from Glase and Zimmerman (1991) and https://bcrc.bio.umass.edu/biol197/sites/bcrc.bio.umass.edu.biol197/files/protist_ecology_lab_manual.doc**)**

WEEK 1 HANDOUT

Goals of the Lab:

1.) Introduce the study of population ecology.

2.) Explore the impact of reproduction and death rates, competition, and predation on population growth.

3.) Practice designing and refining experiments, and analyzing and interpreting data.

4.) Learn a little bit about protists.

Lab timeline:

Week 1:

- Refresh your microscopy skills
- Examine prepared slides
- Work with a partner to develop a testable hypothesis about the effect of some aspect of competition or predation, or other factors on population dynamics in protists.

Week 2:

- Present your proposed experiments to your classmates for feedback
- Revise your experiment as needed/desired
- Learn how to count protists
- Set up trial run of experiment
- Collect data throughout the week

Week 3:

- Quick and dirty analysis of trial run data
- Revise experiment as needed
- Set up actual experiment
- Collect data throughout the week

Week 4:

- Data analysis (computer lab)
- Stat working on presentation for your study

Part 1: Microscopy refresher and introduction to the players

A.) Get a microscope from the cabinet, and a "letter e" slide. Have everyone in your group practice focusing on the letter e with each one of the objectives until everyone is comfortable using the microscope. Don't be shy about asking for a hand if you need one!

B.) Get a *Paramecium* slide. Take a look under the microscope. Draw a sketch.

B.) Meet the players!

1. Introduction to the Players. You will have access to four species of protists for your experiment: *Paramecium, Colpidium, Didinium,* and*Euglena*.
2. Do a little research and find out about each species – which ones are big, which ones are small, which ones are predatory, which ones do photosynthesis, etc. This will help you figure out which protists to use to address particular questions.
3. Make a sketch of each species in your lab notebook so you have a "search image" – you'll be actually looking at live individuals next week and it helps to know what you're looking for.

Part 2: Design your experiment

Working in a group of 2, you'll want to
(1) Develop a testable hypothesis about competition and/or predation and population dynamics, and
(2) design an experiment – with appropriate controls – to test this hypothesis.

You may find the information in the second packet ("Potentially Useful Information") helpful in this regard. Your notes on predator-prey population dynamics and chapter 27.1 might also be helpful.

a. For example, you might want to repeat the experiments described below – such as co-culturing the two species and observing the impact of co-culture on population growth. You may want to examine the impact of predation (Chaos) on the population density of Paramecia or study the impact of prey density on the population dynamics of Chaos. Or you may decide to do something completely different!

b. Once you have agreed upon an idea for your experiment, work with your partner to develop the idea into a specific experiment.

c. A few suggestions for your experimental design:
    i. Set up at least 2 cultures for each condition (more is better to obtain meaningful population estimates).
    ii. Start with about 50 individuals per ml of Paramecia (you can go higher or lower than this in some vials if you're manipulating prey density).
    iii. Start with a much smaller number of predators (if you use them), about 2 to 3 individuals per flask (again, you can vary this somewhat if you're manipulating predator density).
    iv. Plan on returning several times over the next 10 days to sample your cultures. For predator prey experiments you should return to

sample at about 24, 48, 72 and 96 hours, and then less frequently. For competition experiments, you should return at 48, 72 and 96 hours, and then less frequently

v. Think about how you want your cultures incubated – in the incubator, on a windowsill, wrapped in foil, in the fridge, etc.

4. Start working on your Powerpoint

Next week you'll present your experiments to your classmates (and your professor) at the beginning of lab for feedback. Therefore, you'll need to put together a short (no more than 8 minutes or so) Powerpoint presentation.

Your presentation should include the following:

- Some background about your idea, including a justification for your hypothesis (you are absolutely allowed to cite your book or the "potentially useful information" handout, or other sources as desired).

- Your hypothesis, and *specific* predictions about what you expect to see.

- Your proposed experimental design, and the reasoning behind it.

Hints for making a good Powerpoint:

a.) DO Have a script – know what you're going to say so you aren't compelled to make text-heavy slides so you can read from them.

b.) DON'T make slides that contain huge paragraphs of text or crowd your slides with tons and tons of bullet points. All they do is distract your audience, who is going to try to read your slides rather than listen to you. A few bullet points (no more than one line if you can help it) to remind your audience what you said are fine, but make your words count and use them sparingly!

b.) It's a terrific idea to use charts, graphs, and diagrams to help convey your point. However, while more visual is almost always better, don't let bells and whistles – like flashy animations - take the place of your content.

d.) Make sure your font is big enough to read, and your colors show up. You're welcome to come test your presentation out on the projector if you want.

3.) Make your experimental plan:

You'll turn this in along with your Powerpoint. Your plan should include:
1.) What cultures you're setting up – how many vials, about how many protists in each vial, what conditions you're going to incubate them under, etc.

2.) How often you're going to sample, who is going to sample each time, and what data you're going to collect.

3.) Contingency plans for what you'll do if something unexpected comes up – if one of your team members is sick, or has to go to a meeting, etc. How will you contact each other? Who will take over?

4.) A spreadsheet you'll all use to keep track of your data. Google drive is great for this!

The Cell Culture Project!

Project Introduction

In the culminating project of this semester, you'll be growing cells in culture, and using these cells to ask a research question and test a hypothesis based on your knowledge of cellular mechanisms. In your research, you can manipulate the external environment: exposing your cells to heat or cold treatments or to ultraviolet radiation, or adding water-soluble vitamins, nutrients, or tiny doses of things that may be toxic, like heavy metals. You can also manipulate cells' social environment by manipulating the density at which you seed plates to look at the importance of cell-cell interactions in promoting or inhibiting growth.

My advice to you is to START with the mechanism or cellular process you might be interested in looking at, whether it's glucose availability, crowding, periods of oxygen deprivation, or enzyme disruption by heat or cold (or whatever else), and then research ways to look at this mechanism in cultured cells. I'm happy to help you find papers on whatever you're interested in.

AS IN THE PEROXIDASE PROJECT, WHATEVER QUESTION YOU ASK AND WHATEVER HYPOTHESES YOU TEST NEED TO BE JUSTIFIED WITH REFERENCE TO THE LITERATURE AND/OR YOUR TEXTBOOK. You should have at least one treatment group and one or more thoughtfully-designed controls.

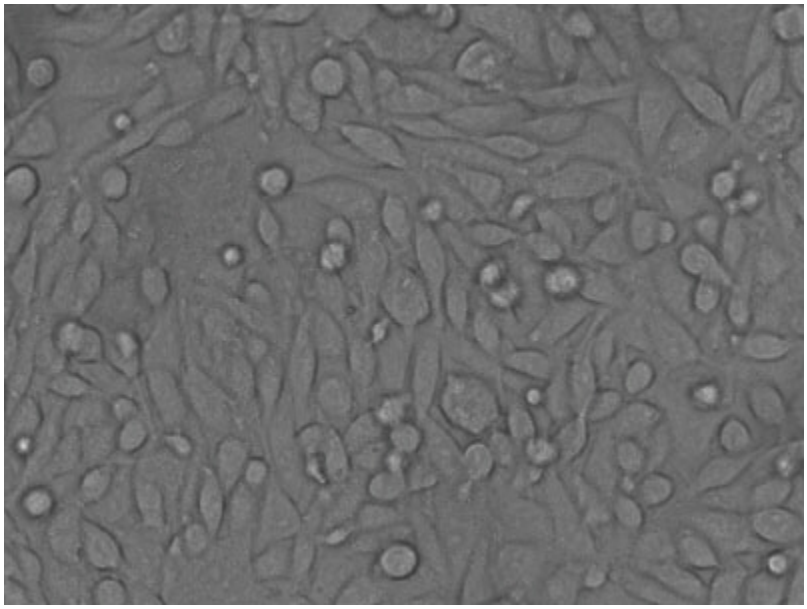
You'll have three weeks in which to complete the project, and access to the lab and equipment outside of class hours. Expect to spend some time outside of class working on your experiments.

HOWEVER, as in the peroxidase lab, everyone will use a common set of techniques, most of which involve counting and staining cells and methods for seeding flasks and plates, all of which I will teach you before you start your experiment. *Therefore, don't worry about having to make up your own techniques.* All you need to worry about is what treatments you want to do, what dosages you should use for whatever treatments you're using (you should be able to find this in the primary literature) and what parameters you want to measure to get a QUANTITATIVE answer to your question.

You'll probably want to do several replicates of your experiment and do some simple statistical tests (t-tests to compare control and treatment groups, for example). I will be available during lab and office hours to help you with those.

Cell culture model system

Your cell culture model system is mouse liver fibroblasts, otherwise known as "L cells" or "L_m cells." They are grown in a nutrient-rich medium called McCoy's medium. L cells represent an established murine cell line obtained from C3H. These cells are fibroblasts established from a methylcholanthrene-induced tumor described originally by Earle 929 fibroblasts (Sanford et al, 1948). These cells do not adhere to one another and do not express cell adhesion molecules (http://www.copewithcytokines.org/cope.cgi?key=L%20cells) . This is a commonly used cell culture line.



L cells in culture, showing typical morphology

Parameters you can measure to test your hypotheses

- Total number of cells present at the end of a certain time period (a couple of days to a week)
- Total number of LIVE cells present at the end of a certain time period (a couple of days to a week)
- Number of dead cells
- Cell viability (# live cells/ total # cells)
- Growth rate (seed several wells with the same density of cells in the same treatment, and count the cells in one well per day for several days) -growth rate = (cells at t1 – cells at t2)/(t1-t2)
- Time to reach confluence
- Cell morphology: you can develop a numerical scoring system for cell morphology in order to follow changes over time.

You'll probably want to replicate each treatment – including the control treatment – several times and measure the average and the standard deviation of whatever variable(s) you're measuring, which will give you an idea of how consistent the effects of your treatments are.

PROPOSALS ARE DUE 11/5 by 6 PM. PROJECTS NEED TO BE FINISHED PRIOR TO THANKSGIVING BREAK.

Bird Song System Lab

In this lab, you'll have access to slides from normal male birds (n = 9), as well as from normal females (n = 6) and females that were treated as chicks with implants containing of 5 (n = 6), 15 (n = 7), or 50 ug (n = 6) of estradiol at hatch. Brains were sectioned so that you can measure the volumes of Area X, HVC, and RA. You may use these data to address any relevant question you can think of, though a couple of obvious ones are (a) whether estradiol has an organizational effect on the song system, and (b) whether the song system responds in a dose-dependent way to early estradiol administration.

Of course, before you decide what question you want to ask, it helps to find out something about your study system.

Working with classmates and/or group members, you should answer the following questions and turn your answers in before spring break:

1.) Draw the avian song system (a schematic/cartoon is fine). Identify the functions of the major parts, *especially* HVC, Area X, and RA.

2.) Find out how the song system typically differs between male and female songbirds. Size-wise, what differences would you expect to see between normal males and normal females (concentrate on HVC, Area X, and RA). Why?

3.) What are the differences between *organizational* and *activational* effects of a hormone?

4.) Is early estradiol (E_2) exposure likely to have an organizational or activational effect? Why?

5.) Identify a research question of interest (that can be answered using the slides in the slide database) and propose a hypothesis that you intend to test. Justify your hypothesis – you may need to do a little reading in the literature; feel free to cite any papers you read as justification.

6.) Explain how you'll use the slides to test your hypothesis.

7.) Download the image database and ImageJ. Using the directions in the lab manual, try your hand at tracing the brain sections on the slides. Make sure you're not having any issues. [you don't have to turn this part in].

ONCE YOU TURN YOUR ANSWERS IN, I'LL ASSIGN YOU SUBJECTS. YOU CAN START COLLECTING DATA AT ANY POINT AFTER THAT. Once you've measured all your slides, let me know, and I'll tell you which subject belongs to which group. Slides should always be scored blind to avoid bias.

CVA: Your Awesome Semester Project! ☺

First assignment: Hypothesis and Justification (first stab)

For your project this semester, you'll be choosing an anatomical question to investigate. It can be anything you happen to be curious about that you can plausibly investigate using the specimens available in lab or in Transy's larger collection (talk to Dr. Day if you're wondering if we have something on campus). Questions can range from the force potentially generated by the hindlimbs of various organisms to forelimb musculature in animals of different groups to modifications of the skull associated with different feeding adaptations. The only caveat is that it *can't* be the question you choose to investigate during the skull lab.

Our dissection specimens are lampreys, sharks, necturus, pigeons and rats. We have cat, rat, frog, necturus, perch, and pigeon skeletons, an armadillo skeleton, and two human skeletons, plus an assortment of mammal and bird skulls. I have ~10 frozen house sparrow carcasses available for measurement; we can talk about how to clean the skeletons if you want them. There may be some other specimens in the Moosnick museum we can use as well.

You will work in pairs to carry out this project.

For this assignment, your objectives are as follows:

0. Pick a partner.

1a. Identify a question that interests you – you may need to do a bit of reading in your book or some google searching first.

1b. Find – and read – at least 5 papers related to your topic. Most should be primary research papers (i.e., the kind that have a methods section), but one or two can be review papers. In fact, I recommend you find a review for one of your sources – it's the best way of getting into a topic quickly.

2. Arrive at a tentative hypothesis that you'd like to test.

3. Write what will wind up being the introduction for your full experimental proposal: give some background on the question and why it's interesting, state your research question specifically, then propose and justify your hypothesis based on the papers you've read. DON'T FORGET TO BE THOROUGH ABOUT CITING YOUR SOURCES!

4. Include a bibliography. Format type is up to you as long as it's either APA or the style of a scientific journal, just make sure it's consistent!

I won't set a minimum or maximum page limit, except to say that unless you are an extremely concise writer, two pages is likely to be too short and for most people five is likely to be too long.

DUE FRIDAY 9/12 BY 11:59 PM.

Experimental Plan Proposal

Now that you have a testable hypothesis, you want to start thinking about exactly how you want to test it. Your experimental plan will essentially be a materials and methods section with some justification. You should write 2-3 pages outlining your plan.

In your experimental plan, you should address:

1.) Your hypothesis, and the specific predictions you plan to test (you've already justified these, so you don't need to write any more on the subject). **What you do need to address – given the measurements you plan to take – is what you expect to see if your hypothesis is supported.**

2.) What specimens you plan to examine, how many specimens you plan to use, and how examination of these specimens in particular will help you to test your hypotheses.

3.) What parts of those specimens you're specifically going to look at, and how you're going to get them. This may be a non-trivial detail, involving locating the appropriate structures, dissecting them out, and (in the case of bones) cleaning and drying them.

4.) How you're going to control for issues like body size and taxonomic differences.

5.) What measurements you're going to take, and how you'll analyze them.

** You are *absolutely* allowed to go to the literature and utilize existing methods – that's what M & M sections are there for. Just cite whatever you use!**

THIS ASSIGNMENT IS DUE TUESDAY, 10/21 BY 11:59 PM.

Cell and Molecular Biology Week 9 Problem Set
Winter 2014

1.) Explain why acetyl Co-A is a central molecule in the metabolism of both fats and sugars.

2.) A deficiency of the vitamin thiamine causes elevated levels of both pytuvate and alpha keto-glutarate in the blood. Suggest a likely role of thiamine in general in metabolism consistent with this finding.

3.) Explain why making membranes permeable to protons would interfere with both respiration and photosynthesis.

4.) To make beer, you essentially combine grain, sugar, yeast, and water in a big glass bottle and cap this tightly so air can't get in. When you cap the bottle, the liquid isn't fizzy. After a week or two, it is (in fact, if you don't have a valve to release the pressure, the top of the bottle might blow off). Explain.

5.) Glycolysis: produces _____ ATP (net) and _____ NADH
The end product of glycolysis is: _____, which has _____ carbons
The oxidation of pyruvate produces _____ ATP and _____ NADH
The end product of the oxidation of pyruvate is _____, which has _____ carbons from the original glucose.
The Krebs Cycle produces _____ ATP, _____ NADH, and _____ $FADH_2$, and its other end product is _____, which is oxidized/reduced (circle one) relative to glucose.

6.) Beyond the obvious – that ethanol is toxic – why do active animals do lactic-acid fermentation rather than ethanol fermentation?

7.) Is the following statement true or false: since plants can do photosynthesis, they don't carry out aerobic respiration. Explain.

Animal Physiology Problem Set 7

1.) A common problem facing folks who decide to go vegetarian – and particularly those who decide to go vegan - without reading up at least a little on nutrition is amino acid wastage, even when they seem to be eating an adequate amount of protein. This problem can be alleviated pretty easily without requiring the vegan individual to start eating animal food or take supplements – all he or she has to do is make some simple changes like eating beans and rice *together*, rather than at separate meals. Explain what's going on here.

2.) Question 8, p. 159

3.) One of the seemingly strange paraxdoxes of the modern Western world is that obesity and malnutrition (deficiencies in vitamins and other nutrients) can coexist in the same patient. Explain, given the "typical" American diet (though admittedly this is a little bit of a stereotype) how this might be possible.

4.) If a person is diagnosed with a gastric ulcer, what type(s) of food might a doctor suggest this person avoid eating? Explain. [HINT: find out what an ulcer is, and then think about what the organ in question does]

5.) It's been suggested that a steady diet of junk food (and/or high soda consumption) can actually increase the likelihood a person will overeat. Is this junk science, or is it actually a reasonable hypothesis from a physiological perspective? Explain.

Problem Set 10

1.) A patient comes into your clinic complaining of tremors, particularly in her hands. (A) What are some of the potential causes of these tremors? (B) What questions will you ask, and what tests will you do, in order to determine what's causing your patient's symptoms? Explain how you'll arrive at your diagnosis (you're welcome to make lists, draw arrows, or make a flowchart).

2.) You're a defense lawyer trying to decide whether to accept a new client. Your client was pulled over for reckless driving and then failed a field sobriety test: in particular, he failed the finger-to-nose touch test and the *horizontal gaze nystagmus* test, which measures the ability of an individual to follow a moving object with his eyes. Your client swears he's just a crappy driver and hadn't had a drop to drink that night, and says he deserves traffic school -- not a DUI! Unfortunately, the lab lost your prospective client's blood alcohol test, so it's his word against the cop's. What medical information might help you decide whether or not to take his case? Explain.

3.) Why do the differences between the symptoms of Parkinson's and (early) Huntington's disease make sense in light of the disinhibitory circuits in the basal ganglia? Drawing a picture might help.

Final Paper Rubric

Topic: Novel, of appropriate scope – not too narrow or too broad (5)

Thesis statement: Clear, takes a position that can be supported with evidence (10)

Introduction: Introduces question, explains why it's significant, gives background leading up to and supporting question and thesis statement (10)

Body of paper: Gives evidence supporting all parts of thesis statement , also addresses potential arguments against the thesis with reference to the literature (15)

Conclusions: Ties together evidence supporting thesis and draws a definite conclusion, gives an overview of unanswered questions/directions for future research (10)

Stylistic considerations: Well-written, well-organized, shows elements of mature style. (5)

References and Citations (5): All ideas not the authors' own have been correctly cited, bibliography has adequate number of sources for this stage of the project

SKULL LAB RUBRIC

(adapted from course1.winona.edu/.../air/No%20Carolina%20assess_**lab_rubric**.doc)

	1 **Beginning or incomplete**	2 **Developing**	3 **Accomplished**	4 **Exemplary**	**Score**
Experimental Design	Design does not allow hypothesis to be tested	Design related to hypothesis but experiment is not controlled, too many variables are tested, and/or too few specimens are measured	Experiment is controlled and addresses hypothesis, with a few minor errors	Experiment is well-controlled, variables measured are appropriate, appropriate number of specimens measured to allow statistical analysis of data.	
Introduction	Very little background information provided or information is incorrect	Some introductory information, but still missing some major points	Introduction is nearly complete, missing some minor points	Introduction complete and well-written; provides all necessary background principles for the experiment	
Materials and Methods	Missing several important experimental details or not written in paragraph format	Written in paragraph format, still missing some important experimental details	Written in paragraph format, important experimental details are covered, some minor details missing	Well-written in paragraph format, all experimental details are covered	
Results: data, figures, graphs, tables, etc.	Figures, graphs, tables contain errors or are poorly constructed, have missing titles, captions or numbers, units missing or incorrect, etc.	Most figures, graphs, tables OK, some still missing some important or required features, or results not summarized in sentence form	All figures, graphs, tables are correctly drawn, but some have minor problems or could still be improved, results may be summarized in sentence form with a few minor errors	All figures, graphs, tables are correctly drawn, are numbered and contain titles/captions, results concisely and completely summarized in sentence form	
Discussion	Very incomplete or incorrect interpretation of trends and comparison of data indicating a lack of understanding of results	Some of the results have been correctly interpreted and discussed; partial but incomplete understanding of results is still evident	Almost all of the results have been correctly interpreted and discussed, only minor improvements are needed	All important trends and data comparisons have been interpreted correctly and discussed, good understanding of results is conveyed	
Statistical Analysis	Comparisons are made, but no statistical analysis	Attempt at statistical analysis, but statistics are used incorrectly or not correctly interpreted	Appropriate statistics chosen, minor errors in analysis (e.g. missing a covariate that should have been included) or in interpretation	Statistics are appropriate, all necessary variables and covariates included, interpretation is correct and complete	
Spelling, grammar, sentence structure	Frequent grammar and/or spelling errors, writing style is rough and immature	Occasional grammar/spelling errors, generally readable with some rough spots in writing style	Less than 3 grammar/spelling errors, mature, readable style	All grammar/spelling correct and very well-written	
Total	+1 for on-time turn in				

Corn Lab Data Analysis Rubric

Statistics (3 pts) – *appropriate to question, all data that should be analyzed was analyzed*

Graphs (3 pts) – *data clearly and appropriately presented.*

Interpretation of statistics (3 pts) *Statistics are interpreted clearly and completely, author understands p values, data interpreted in light of the question*

Overall impression (1 pt) *Data and results presented clearly – graphs are labeled, it's clear what stats refer to, etc.*

ICBO Winter 2016 – Exam 2
Dr. Fox

Name: _____

1.) Two populations of insects that were separated by a very tall mountain range underwent a speciation event (became two different species), even though selection pressures were very similar on both sides of the mountain range. The differences between the populations probably arose due to:

a.) gene flow
b.) high heterozygosity
c.) genetic drift
d.) natural selection
e.) inbreeding depression

2.) All plants have some similarities to green algae, including the presence of chloroplasts as well as certain physiological and genetic characters. Many of the characters that plants and green algae have in common are probably (circle all that apply):

a.) synapomorphies
b.) probably the result of convergent evolution
c.) shared ancestral characters
d.) shared derived (evolved) characters
e.) the result of character displacement

3.) When predators attack the clownfish it hides in the arms of the sea anemone who can then sting and kill the predator. The anemone then eats the predator. The clownfish is immune to the anemone poisons. The clown fish-anemone relationship is an example of:

a.) mutualism
b.) amensalism
c.) Predation
d.) commensalism
e.) endosymbiosis

4.) When you look at white-tailed deer they go from weighing over 240 lbs on average on the US mainland to only 64 lbs in the Florida Keys, presumably as an adaptation to limited space on islands. This is an example of _____ selection.

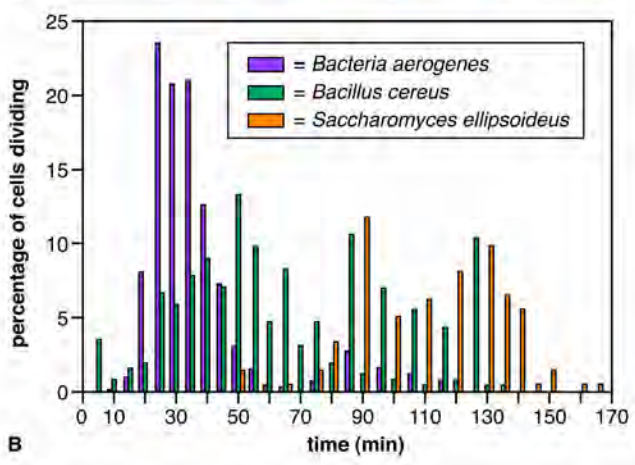
a.) Disruptive
b.) Artificial
c.) Directional
d.) Stabilizing
e.) Sexual

5.) Which of the following can lead to speciation in the absence of natural selection (circle all that apply)?

a.) sexual selection
b.) genetic drift
c.) gene flow
d.) diseases
e.) competition

6.) Given the graph at right, which organism is likely to be the <u>last</u> to reach the carrying capacity of the petri dish in which it's being grown?

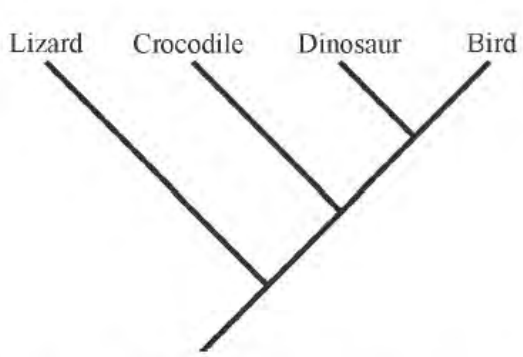
a.) *B. cereus*
b.) *S. ellipsoideus*
c.) *B. aerogenes*
d.) a and c should do so around the same time
e.) There is no way of knowing.



7.) You're studying a population of beetles, and discover that r = -0.10 for this population. From this number alone, you can be most certain that:

a.) the population is growing
b.) the population is shrinking
c.) the beetles will soon be extinct
d.) adult survival is high
e.) juvenile mortality is high

8.) Birds, lizards, and crocodiles all have *amniotic eggs.* Assuming that lizards are the outgroup for this phylogenetic tree, amniotic eggs are an example of:



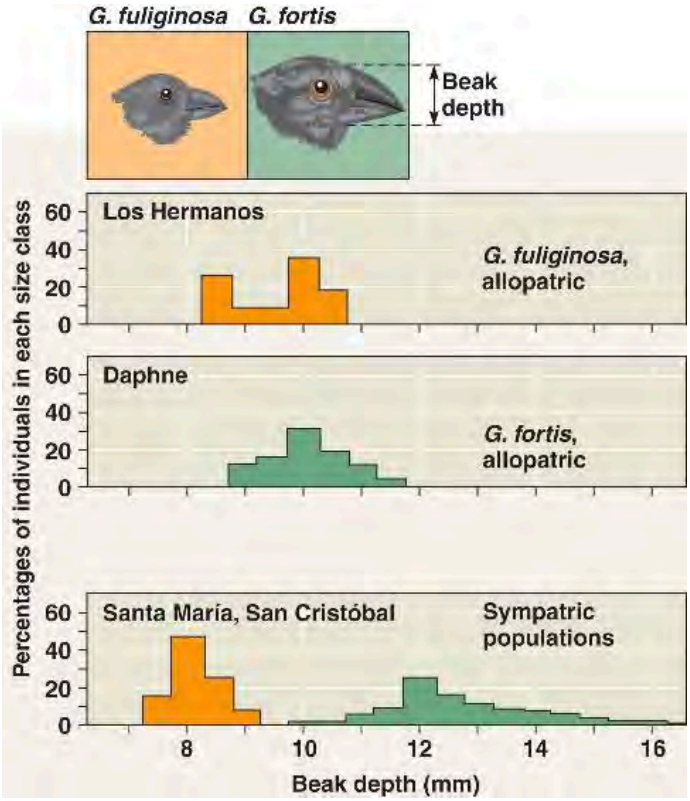
a.) a shared derived character
b.) a shared ancestral character
c.) convergent evolution
d.) natural selection
e.) the founder effect

9.) It is possible to argue that blue-winged and golden-winged warblers are the *same* species based on the:

a.) morphological (or typological) species concept
b.) genetic species concept
c.) subspecies concept
d.) biological species concept
e.) none of the above – there is no way to argue that they belong to the same species.

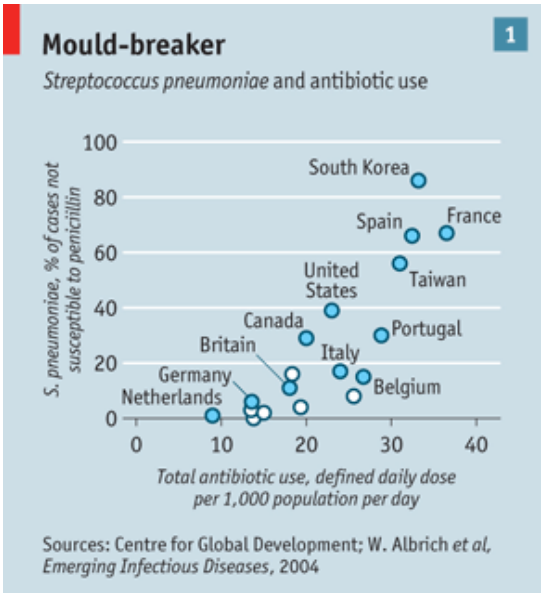
4.) The bottom graph – showing a situation where both finches occur on the same island – provides an example of:

a.) the bottleneck effect
b.) character displacement
c.) the founder effect
d.) diffuse coevolution
e.) sympatric speciation



***Part 2. Short answer and problems* (80 points)**
Answer completely but concisely. Feel free to use drawings if they help.

11.) This graph shows the relationship between penicillin use and the percentage of reported cases of *Streptococcus* that were resistant to penicillin. (a) Describe the relationship you observe, and (b) develop a hypothesis – using what you already know from examples we've discussed in class – to explain why this relationship might exist (8 pts).



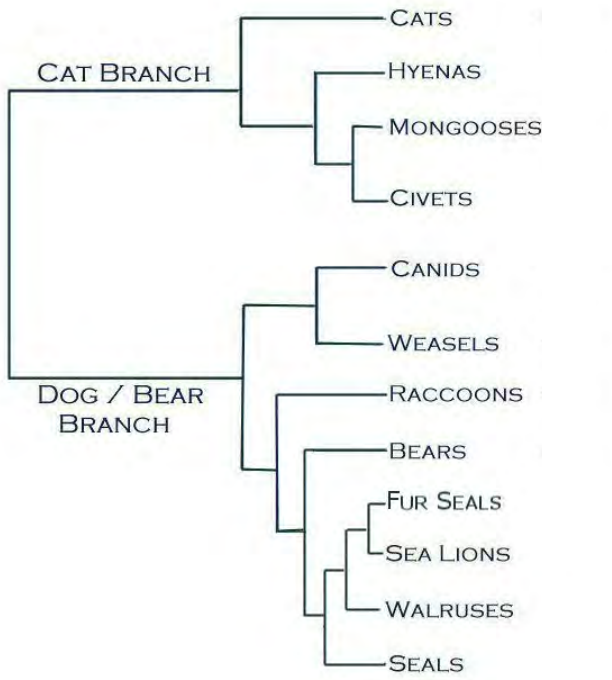
12.) (a) Given the following character matrix, construct a phylogenetic tree. Assume hairy monsters are your outgroup.: (8 pts)

	Long legs	Purple fur	One eye	One horn
Hairy monster	1	0	0	0
One-Horned People Eater	1	1	1	1
Purple People Eater	1	1	0	0
One-eyed People Eater	1	1	1	0

(b) You discover a creature that has purple fur but has short legs, two eyes, and no horns. Does it belong on your phylogenetic tree? If so, where? Explain your reasoning. (2 pts)

13. The figure above depicts a number of different species of birds occupying and foraging in *the same* salt marsh habitat. As you might guess, this salt marsh is pretty full of birds. You should notice two things here: (1) their beaks can have wildly different shapes, and (2) given that they're foraging in different places, each species almost certainly eats a diet that is at least slightly different than the other species it's sharing a habitat with. *Explain these observations: what may have driven the evolution of this diversity of bill sizes and shapes and diets?* (10 pts)

14.) (10 pts) Based on this phylogenetic tree, answer the following questions. (Canids are dogs). Circle the best answer.



A. What is most closely related to Cats?

B. Circle an example of a Sister taxa group?

C**.** Circle which of the following common mammal name is not **monophyletic?**

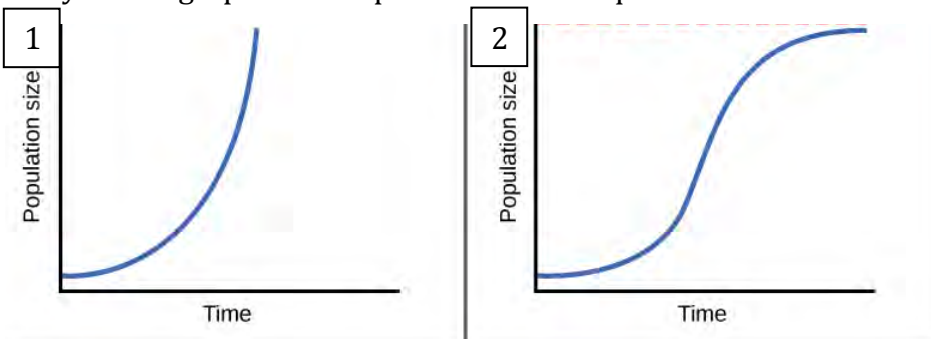
DOGS **BEARS** **SEALS** **WEASELS** **CATS**

E. Based on parsimony, what is the minimum number of times the truly aquatic lifestyle need to evolve?

(label the tree)

F. What is more closely related to Raccoons? Weasels or Canids?

15.) 11. Use the graphs below to answer the following questions. You may write directly on the graphs if it helps to answer the question.



A. In which population is r the only limit to population growth? (2 points)

B. Where is population growth *rate* highest in population 2 (mark on graph)? Why, biologically, is population growth highest at that point? (4 points)

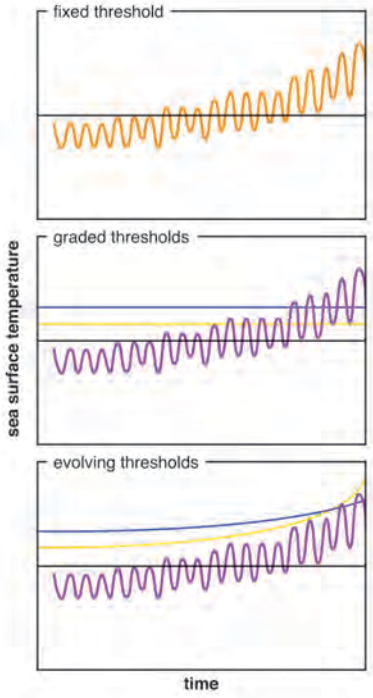
C. Which population is experiencing density-dependent growth? Give at least three examples of how density-dependent effects reduce population growth. (4 points.)

16.) (6 pts) In your protist experiment you set up the vial with 500 paramecium and after 14 days you find there are 3675 paramecium in the vial.
1. Calculate r (partial credit is only possible by showing your work)

2. Given the value of r you calculated, how many days will it take the population to double in size?

17.) (A) Based on the table below, which model of coral bleaching and coral extinction can you definitively rule out? Explain. (4 pts)

temperature (°C)	algal species	relative photosynthestic capacity	differences within a species	differences between species
28.5	1 2	0.540 ± 0.021 0.568 ± 0.029		
31.3	1 2	0.543 ± 0.030 0.619 ± 0.023	*	≠
32.0	1 2	0.469 ± 0.032 0.617 ± 0.024	♦ *	≠



(B) Why is it that knowing something about how particular *algae* perform at different temperatures can let you make predictions about *coral* extinction? (4 pts)

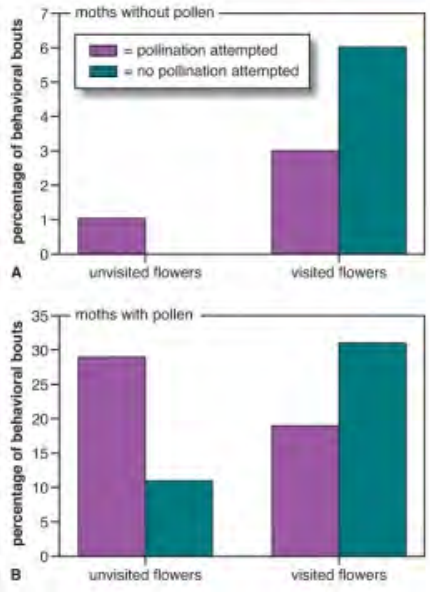
18.) Bats use a form of natural sonar to locate prey (like tiger moths, *Bertholdia trigonia*) in the dark. In 2009, Corcoran et al. (*Science* 325: 325-327) demonstrated that tiger moths produce clicks at exactly the same frequency as bat sonar, and that these clicks reduce bats' success in capturing moths. These findings suggest tiger moths might be jamming bats' sonar.

(A) Explain how ultrasonic clicking in moths might have evolved. (4 pts)

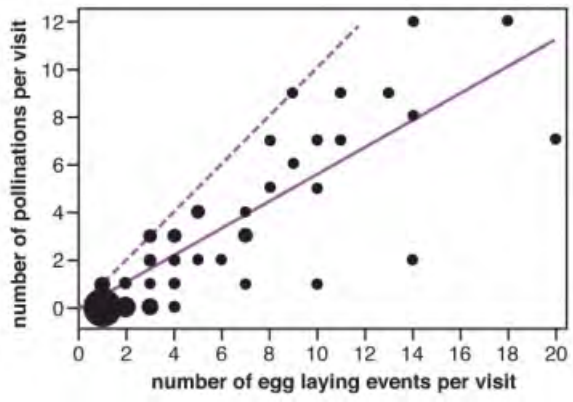
(B) Imagine you find a population of moths that has never been exposed to bats. Would you expect to see these moths emitting large numbers ultrasonic clicks in response to hearing bats hunting? Explain why or why not. (4 pts)

(c) Would you predict that *only* populations of tiger moths that have been exposed to bats are able to emit ultrasonic clicks? Explain. (2 pts)

19.) 14.) (A) (6 pts) The Yucca moth lays eggs and brings pollen to the yucca plant. ①What does this graph tell us about the Yucca moth mutualistic behavior and ②what evidence is there that the moth experiences competition with other moths? [be specific, draw arrows or label parts of the graphs to support your answer]



(B) (4 pts) Using the following graph, explain what evidence there is that the Yucca moth is acting "selfishly" in the pollination mutualistic relationship with the Yucca plant.



NAME _____

BIO 3065 – Animal Physiology
Fall Semester 2015
Examen Numero Uno
Thursday, October 22, 2015

Part 1. Matching (sort of). Fill in the blank with the appropriate word(s) from the list. (0.5 pts each blank/item on a list unless otherwise noted)

Aldosterone	Leptin	Angiotensin
Glucocorticoids	Ghrelin	Insulin
Epnephrine and	Estrogens	Glucagon
norepinephrine	Progesterone	Melatonin
PRL	Androgens	Vasopressin
GH	CRH	Oxytocin
ACTH	TRH	T_3
TSH	GHRH	T_4
FSH	GnRH	
LH	Renin	

1.) If you're hungry all the time, you might have too much _____ and too little _____.

2.) If you're cold all the time and gaining weight, you might be low on _____ (or potentially _____).

3.) Pick one of the axes you know, and list all the hormones in it, in the order they're released. (2 pts)

4.) List three hormones that are likely to affect organisms on a genomic level (and explain why you listed these three).

5.) List three hormones that are likely to increase if you're dehydrated.

6.) Increasing the amounts of PER and CRY in your SCN is most likely to affect the secretion of which hormone? (For an extra point, give another hormone that may be affected and explain why)

Part 2. Long(ish) answer. Answer the following questions as completely and concisely as possible. Your answer can include drawings, flowcharts, tables, and text – whatever helps you answer the question. Feel free to use bullet pointed lists if you prefer (as long as you include the relevant information). Don't feel obligated to fill the entire space provided (though you certainly can if you need to!)

1.) **A disease that isn't cushy.** Cushing's disease (also known as Cushing's syndrome or Itsenko-Cushing disease) is reasonably common in senior horses, but thankfully pretty rare in humans (~20,000 – 200,000 cases in the US per year). Cushing's occurs either when the hypothalamus overproduces CRH (aka CRF) or when a type of tumor called a pituitary adenoma produces abnormally large amounts of ACTH constitutively (i.e., all the time).

(a) List four symptoms you might expect to see in Cushing's patients, and for each one, give a mechanistic reason you'd expect to see it. (10 pts)

(b) Administration of *dexamethasone,* a synthetic glucocorticoid (kind of like prednisone), followed by collection of a blood sample some time later, is often used as a diagnostic test for Cushing's disease. Explain what you'd expect to see in the blood sample (1) if the patient in fact has Cushing's disease, and (2) if the symptoms they're exhibiting are due to something else. (5 pts)

2.) **The Pill is a many-splendored thing.**
Combined oral contraceptive pills (aka birth control or "the Pill") contain both estradiol and progestin (a progesterone).

(a) The Pill is quite effective at preventing conception. From a mechanistic standpoint, why? (5 pts)

(b) If a woman is taking standard birth control, rather than extended-cycle birth control, each one month supply of birth control contains seven "sugar pills" (meaning they don't contain any hormone). Women will menstruate during the week that they take the sugar pills. Women on extended-cycle dosing (who take sugar pills for seven days every three, six, or twelve months depending on the pill regimen) *only* menstruate when they're taking sugar pills. *Explain what's going on here.* (5 pts)

(c) The Pill is also used to treat hormone-related acne in women as well as the masculinizing effects of polycystic ovary syndrome (PCOS) such as hirsutism (excessive hair growth). In most cases of PCOS, LH is elevated and the LH/FSH ratio is higher than normal. **Explain why The Pill is so effective at treating acne and hirsutism related to PCOS.** (5 pts)

3.) **Diet advice.** There's a lot of advice about diet and exercise going around these days. Some of it at least makes good sense from a physiological perspective (even if it hasn't been tested directly), some of it is questionable, and some of it is terrible. Your job is to evaluate each of these claims based on what you know. If there might be a reasonable physiological explanation, say what it is. If the advice may iffy (you can justify it, but the argument isn't as strong), explain your reasoning. If the advice is really terrible, explain why. In each case, be specific!

(a) THE CLAIM: If you really want to burn calories, you should engage in high-intensity interval training, where you exercise at maximum capacity for a few minutes, then at a lower level for a few minutes, then at maximum capacity for a few minutes, etc. for about half an hour a few times a week. Doing steady-state cardio (like running a long distance) isn't as effective. (5 pts)

(b) THE CLAIM: A calorie is a calorie is a calorie, whether it comes from a twinkie or from broccoli. It doesn't really matter what you're eating, as long as you count calories. (5 pts)

(c) THE CLAIM: One reason that people in the Western world are fatter than they were a few decades ago is because many more people central heat and air conditioning (i.e., climate control) in our houses and offices. (5 pts)

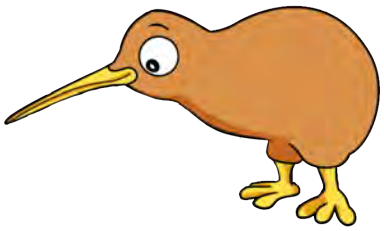
4.) **Life is all about tradeoffs.** Based on what you've learned in class, you can actually make some pretty good predictions about the types of animals (homeotherm/poikilotherm, endotherm/ectotherm, large/medium/small, thick or thin fur/feathers, thick or thin skin/scales, etc.) that you'd expect to predominate in particular environments. *Think about the characteristics of each environment and make your predictions (only consider animals that live there year-round, as migration can change things). Briefly explain your answers.*

(A) Tropical rainforest: consistently hot and wet, abundant and predictable food supply. (5 pts)

(B) Desert: hot during the day, cold at night, very little rainfall/low humidity, food is scarce and food supply isn't predictable. (5 pts)

(C) Tundra: cold and dry. Food is sometimes abundant, but food supply isn't predictable. (5 pts)

5.) **Way down South.** Most birds that breed seasonally in New Zealand (which in the Southern Hemisphere and has a more or less temperate climate that's not that different from parts of the US) start breeding around September and stop around December. This is true of birds native to New Zealand, birds at similar latitudes in the Southern Hemisphere, and non-native birds that have been introduced to New Zealand (Cockrem 1995).



Let's say you capture some birds in New Zealand and bring them back to Lexington. You keep them outdoors in aviaries.

When would you expect to see the birds start breeding in Lexington? Explain your answer. (10 points)

BONUS:
All turned around? You have two groups of homing pigeons, which are known to use the sun to navigate. One group has been housed on short days (10 hours light and 14 hours dark; a lot like winter here in KY) for two years. The lights go on about 6:30 AM. The other group has been housed under constant dim light for two months. Which group is more likely to have trouble with navigation and why? [Worth up to 4 points, depending on how close you get].

NAME: _____

BIO 3224 NEUROBIOLOGY
~~BOSS FIGHT~~ FINAL EXAM
Fall Semester, 2012
Tuesday, December 11, 2012

1.) Thanks to your favorite graduate advisor, Dr. Strangeglove, you're *still* stuck doing fieldwork on Super Mario World (though he promises you'll be home in time for Christmas). This time you've caught yourself a creature the locals call *Birdo.*

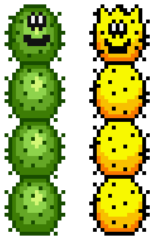
Birdo is a vertebrate, meaning that it has a spinal cord. A couple of days after you catch Birdo, Birdo steps on a sharp rock inside its enclosure with its left foot. It almost instantly lifts its left foot off the ground, but it doesn't fall over – it balances on its right leg.

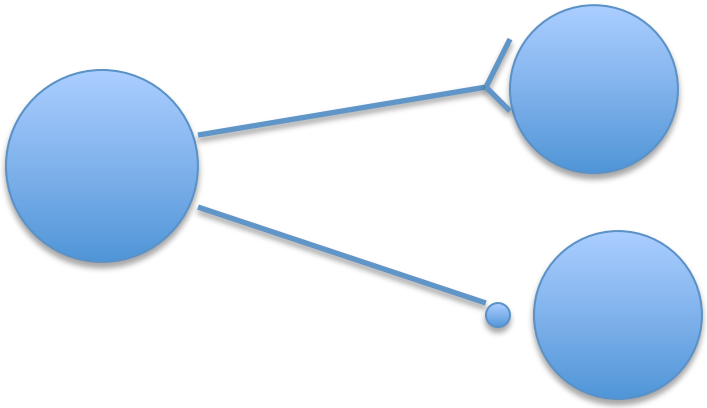
Since you know so much about neurobiology, you're able to make a pretty good guess as to what the neural circuit for this behavior looks like. *Draw a sketch of the circuit for this behavior, and briefly explain your reasoning for drawing it this way (i.e., why did you choose to include or exclude certain parts of the nervous system?).* (10 points)

2.) What have would happened to the behavior described in question 1 if you injected Birdo's left foot with lidocaine (a sodium-channel blocker)? Identify the neuron in the circuit that is probably being affected by the lidocaine and explain what the lidocaine does on a cellular level (you might find it helpful to use the Goldman equation and/or the Nernst equation and the following ion concentrations. Permeabilities are given for a typical neuron at rest. (10 points)

ION	**[Intracellular]**	**[Extracellular]**	**PERMEABILITY**
K^+	140 mM	4 mM	1 mM
Na+	15	145	0.05
Cl-	4	110	0.1
Ca^{2+}	0.0001	5	0

3.) Two weeks before Christmas, Dr. Strangeglove sends you and your labmate off to world 2 to study cactus-like creatures known as *Pokeys*. You're studying a particular neuron in a region of the Pokey brain that you think is analogous to the basal ganglia. This neuron synapses on two other neurons, and you're pretty sure (based on electrophysiological data) that it makes an excitatory synapse with one and an inhibitory synapse with the other:





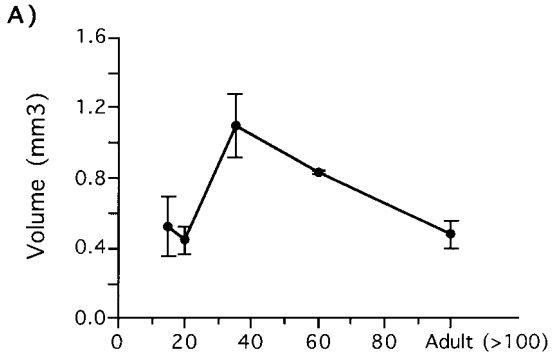
When you mention this at lab meeting, your labmate calls you an idiot, and says there's no way this could be true because it would violate Dale's Law.

(A) Your labmate gets up and draws a slightly different circuit on the board. "There," she says, "this circuit will behave the same way, and there's no way that it can violate Dale's Law." What does her circuit look like? What neurotransmitters are most likely secreted at each of the axon terminals? (6 points)

(B) You insist that you're right, and there's actually a way for *your* circuit to exist without violating Dale's Law at all. What argument do you give? (Hint: think about dopamine). (6 points)

4.) A week before Christmas, Dr. Strangeglove sends you off to the jungle to catch *cheep-cheeps.* Cheep-cheeps are strange amphibious creatures that are like a cross between a fish and a bird. When you examine their brains, you discover they have a song system identical to that of songbirds on Earth. You also know that cheep-cheeps are age-limited learners.

(A) You discover that during the sensorimotor phase of song learning, the volume of the DLM-IMAN terminal field (i.e., where neurons from the thalamus synapse on neurons in IMAN) is actually *larger* than it is in adult cheep-cheeps (see figure below, actually from a real paper -- Nordeen & Nordeen 1997)



(A) Propose a hypothesis that may explain this observation. How might you test this hypothesis? (6 points)

(B) If cheep-cheeps learned new songs every winter, how might the graph above change? Explain. (4 points)

5.) Three days before Christmas, you get into another argument with your labmate. Before you left for Super Mario World you were studying spatial learning in corvids (crows and related birds). Jackdaws (which only rarely store food) scored really badly on your spatial learning task, whereas Clark's nutcrackers (which store thousands of seeds each fall and retrieve them months later) scored very well. Your labmate claims that jackdaws are just stupid.

JACKDAW

(A) Propose an alternate hypothesis to explain the jackdaws' poor performance on the spatial task. Explain your reasoning (5 points)

CLARK'S NUTCRACKER

(B) What experiment might you do to ~~prove~~ strongly support the hypothesis that your labmate is wrong? (5 points)

6.) Two days before Christmas, Dr. Strangeglove finally calls you back to base camp. He tells you that he'll buy your plane ticket home for the holidays, on one condition – that you use your knowledge of neuroscience to design a <u>really effective</u> warning sign to keep people out of the patch of piranha plants near camp. Graduate students have been stumbling in there and getting bitten all field season, and he's tired of having to fill out the paperwork.

Sketch your warning sign, or explain how you'd design it. In your answer, also address what areas of the brain you're targeting, and why (from a neurobiological perspective) your design is particularly effective. (10 points)

AND NOW FOR SOMETHING COMPLETELY DIFFERENT ….
All of these questions refer to parts of the nervous system. (Each blank is worth 1 point).

1.) Severe damage to the _____ is rarely fatal but often results in changes in cognition or personality, while much more minor damage to the _____ is generally fatal.

2.) A patient comes in with normal visual reflexes and the ability to distinguish light from dark, but she can't name any of the objects she sees. Her _____ and _____ are probably fine, but she most likely has damage to her _____.

3.) Problems with regulating circadian rhythms (in the absence of other symptoms) suggest a problem with the _____, while problems with sleep-wake cycles coupled with hormonal abnormalities suggest a problem with the _____.

4.) Damage to either the _____ or the _____ can result in tremor during voluntary movement. <u>Extra point</u>: How do you tell the difference?

p.s. HAVE A GREAT WINTER BREAK (AND HAPPY HOLIDAYS!)

Neurobiology Final Exam Take-Home Portion
(Due by the Wednesday of finals week at 11:59 PM)

Ground rules

1.) *Pick one question.* If you turn in the answers to two, I'll grade the first one I read.

2.) *This portion is open-book, open-notes, open-internet, open-journal-articles.* Just make sure you cite wherever the information came from! Also, while you can use Wikipedia or other websites as a starting point to find other resources, you may not cite them in your answer. Your citations must come from something published or from your class notes.

3.) *You must cite at least one journal article/book chapter from something other than your textbook in your answer.*

4.) *You **may not under any circumstances** discuss your answers with your classmates. This is to be entirely your own work.*

5.) *Your answer should be 2-3 typed, single-spaced pages in length and contain a bibliography.*

1.) We've mentioned **endogenous (also known as intrinsic) bursters** several times in class, though we haven't really dwelt on them at any point. This is your chance to find out more about them. In your answer to this question, you should address the following: (1) What is an endogenous burster, and how does it differ from a tonically active neuron? (2) How is the bursting generated, since by definition it occurs without synaptic input? (3) Where are circuits with endogenous burster neurons important? Pick two, and describe what the endogenous burster(s) are doing in these circuits.

2.) People talk casually about being "addicted to junk food," but is junk food addiction really a thing? This is your chance to find out. In your answer, you should address (1) the similarity or dissimilarity between the behavior of food-addicted individuals and individuals with other addictions (considering animal models might be useful here) and (2) the similarity or dissimilarity of what's going on neurobiologically in food addicts and individuals addicted to other substances – you might consider fMRI data, data on neurotransmitters, etc. Include a short conclusion where you sum up the evidence and make a case for your argument that food addiction either is or isn't a real phenomenon.

3.) Even in the absence of processes like Alzheimer's disease, cognitive function nonetheless changes with age – even as early as your 20s, you see a loss of some

kinds of cognitive flexibility - as anyone who's ever tried to start a second language in their 20s can attest. However, there are almost certainly things we can do to "hang on" to as much cognitive function as possible with age. To answer this question, address: (1) What are the most prominent changes in cognitive function as people age? (2) What is probably going on neurobiologically to explain these changes? (3) Discuss two potential interventions to prevent cognitive decline with aging, and explain what changes these interventions are likely to cause in the brain (for this part of the question, looking at papers on animal models might be helpful).

Take Home Final Questions

Directions. Choose whichever of the questions on the list is most to your liking. Do whatever research you need to do – in your book, in journal articles, in other physiology texts – and answer the question as completely as possible.

Textbooks and other academic texts and journal articles are legitimate sources; Wikipedia, WebMD, drug company and medical center websites, and popular science blogs are not. Don't plagiarize: *make sure you cite your sources and include a bibliography!* Also, while you are welcome to do any independent research you like, you MAY NOT ask outside people (including friends, classmates, and professors) for assistance.

While there are no hard and fast length requirements, a page or less is probably too short, and five pages single-spaced is probably too long. You may include drawings or figures as appropriate.

And now, without further ado: THE LIST!

***

1.) While the popular press will tell you it takes 3,500 excess calories for a person to gain a pound, it turns out that this may not be a hard and fast number. In a 1990 study, Bouchard et al. ("The response to long-term overfeeding in identical twins;" http://www.nejm.org/doi/full/10.1056/NEJM199005243222101) showed that when young were fed 1,000 extra calories per day for 84 days under controlled conditions, weight gain ranged from 4.3 kg to 13.3 kg . Within pairs of identical twins, the amount of weight gained was similar, suggesting a genetic (and thus ultimately physiological) basis for this difference in metabolism.

Propose three potential physiological differences among individuals that might account for this difference in weight gain among individuals eating an identical diet. Be detailed, and explain your reasoning.

2.) A variety of medications are used to treat high blood pressure (see http://www.heart.org/HEARTORG/Conditions/HighBloodPressure/PreventionTreatmentofHighBloodPressure/Types-of-Blood-Pressure-Medications_UCM_303247_Article.jsp#.Vk_W2t-rRo4). What surprises a lot of laypeople is that very few of these medications actually target the blood vessels themselves. Many of them also have side effects that don't seem to be related to their purpose – that is, lowering blood pressure.

Pick three drugs from the list on the website above (each one from a different class), identify its target (does it block a receptor? Interfere with a channel? Alter the activity of an enzyme? Be specific – which one!), and describe in detail the mechanism by which

acting on that target should ultimately help to lower blood pressure. You can draw a flowchart if you find that helpful (or in the case of some drugs, refer to the Poiseulle equation) . Additionally, identify one side effect (ideally one that's not closely related to a drop in blood pressure) and explain the mechanism by which this drug likely causes that side effect.

3.) The term *diabetes* simply refers to the production of copious amounts of urine. There are actually two types of diabetes: *diabetes insipidus* and *diabetes mellitus*. *Diabetes mellitus* can be caused by either an autoimmune condition that attacks the beta cells in the pancreas - Type I diabetes - or by insulin resistance* (as a result of poor diet or obesity) – Type II diabetes. *Diabetes insipidus,* on the other hand can be caused by (among other things) a head injury or a brain tumor (neurogenic D.I.), or a defect in the AVP2-R (a vasopressin receptor) (nephrogenic D.I.).

(A) Explain – based on a urinalysis and your understanding of what causes each condition – how you would distinguish between diabetes insipidus and diabetes mellitus. Be detailed!

(B) How might you use levels of insulin in the bloodstream to distinguish between Type I and Type II diabetes? How would you use measures of AVP in the bloodstream to distinguish between neurogenic and nephrogenic DI? Explain your answers.

(C) Explain how the causes listed for diabetes mellitus and diabetes insipidus can both result in the production of copious urine. A flowchart might help. In the case of 'head injury/brain tumor' speculate on what part of the brain might be injured. Explain your reasoning.

*in a lot of cases of Type II diabetes, you eventually see impaired insulin secretion from the beta cells as well, but early Type II diabetes (and "pre-diabetes") is often primarily characterized by insulin resistance.

Comparative Vertebrate Anatomy
Fall Semester 2014
Take-home portion of final exam
DUE TUESDAY OF FINALS WEEK BY 11:59 PM

Ground Rules

1.) This portion of the exam is open book, open notes, open going to the library/doing research on the internet. You should use at least two sources outside the text and/or your lab book.

2.) Any sources you use should be cited both as parentheticals in the text and listed in a bibliography. Sources should be either primary literature (scientific journals) or *academic* secondary sources (textbooks, reputable books or websites that might be found in our library – *not Wikipedia, popular press books, or guides to keeping certain organisms as pets.*)

3.) YOU MAY NOT TALK TO YOUR CLASSMATES ABOUT THIS PORTION OF THE EXAM. DISCUSSING THE QUESTION WITH YOUR CLASSMATES OR ANYONE ELSE WILL BE CONSIDERED CHEATING.

4.) Your answer should be at least 1 single-spaced, typed page long, and no more than 3 single-spaced typed pages long.

5.) Points will be deducted if you turn it in late (how many depends on how late).

Your Options:

A.) One way to understand how particular environmental conditions might drive the evolution of anatomy and physiology in organisms inhabiting particular environments is by examining the traits of organisms from different taxa that all inhabit the same environment (e.g., desert, ocean, etc.).

(1) Choose a habitat type (rainforest, tundra, desert, ocean, freshwater, high altitude etc., etc.), or a particular lifestyle (flight, burrowing), describe at least two physiological or other challenges that that particular environment/lifestyle poses for organisms, and (2) describe at least three adaptations, preferably in different organ systems, that you'd expect to see in response to those challenges. *Please discuss members of at least two major groups of vertebrates in your answer (e.g., if you're talking about adaptations to desert environments you might pick kangaroo rats and a desert lizard).* Remember, the skeleton and the muscles also count as organ systems.

B.) When a particular group of vertebrates has no close extant relatives and there are no living organisms that might be intermediate forms (for example, egg-laying mammals that suggest a reptilian origin for the group), it can be tough to sort out phylogenetic origins. In fact, arguments frequently arise among comparative anatomists about this sort of issue. While current scientific consensus – due to recent genetic work and the discovery of new fossils – is that birds did in fact arise from the therapod dinosaurs, for decades the origin of birds was hotly debated. Some anatomists felt strongly that birds were probably closely related to the therapods, while others argued for a crocodilian origin. Morphological evidence was strong on both sides of the argument.

(1) In your paper, lay out the morphological evidence (anatomical similarities) for a *therapod* origin of birds, and for a *crocodilian* origin of birds. (2) Once you've done that, point out at least one problem with each of these arguments – these issues are one of the reasons we needed so much additional evidence to settle this argument. (3) Since it's now pretty clear that crocodilians and birds exhibit a certain amount of convergent evolution, speculate on why this might be.

STUDENT EVALUATIONS

STUDENT EVALUATIONS

A.) SUMMA evaluations

Over the last three years, my SUMMA evaluations have been quite positive across the board. In general, I score at – and generally above – the institutional mean on all measures, particularly with regard to the aggregate measures (instructor preparation and organization, instructor commitment to student learning, student/instructor interaction, testing methods and evaluation, course objectives, and course assignments). I frequently score significantly above the national mean at the $p < 0.05$ level (and sometimes at the $p < 0.01$ level) on at least one or two of the aggregate measures – most frequently instructor commitment to student learning and instructor/student interaction.

That instructor commitment to learning is one of my strongest categories seems likely to be related to my instructional approach. Rather than relying on straightforward-to-prepare and predictable lectures, I instead try to give students as many opportunities as possible to engage directly with the material in discussions, simulations/modeling exercises, and games. This approach can necessitate extensive preparation (e.g., the time involved in developing a simulation exercise) and requires me to be flexible since every class is different in how they respond to a particular activity. However, it promotes student engagement, allows students to interact with content through a variety of modalities, and frankly seems to be a great deal more enjoyable for everyone.

I suspect my 'commitment to learning' scores are also bolstered by the fact that I try to be as transparent as possible with my students about *why* I am asking them to do particular assignments and what I hope they will get out of those. As I sometimes joke, "I'm not doing this for my benefit. If I wanted to make my life easy, I wouldn't give you *any* homework." Additionally, I am generally happy to scrap my plans for a particular class period in order to make sure the class understands the material – once, when my animal physiology class was struggling to understand transport in the Loop of Henle, I cooked up an on-the-spot activity in which I had my students act out the loop as a class, using balls of yellow and blue paper to simulate where water and salt were going. It seemed to help: the looks of bafflement disappeared and most of the class later did fairly well on those questions on the exam.

In terms of instructor/student interaction, it seems reasonable to infer that my flexible, egalitarian style in the classroom and my open-door policy are two of the main drivers. I run a fairly 'loose' classroom where I strive to make sure that everyone feels heard, everyone has a chance to engage with and understand the material, and no one is afraid to take an intellectual risk. During group work and pair discussions, I circulate in the room and visit with each group or pair, often trying to sit down with them rather than stand over them. I like to ask leading questions (e.g., "and what did we talk about yesterday that might relate?") rather than putting students on the spot or telling students the answer. I try my best to

remain upbeat, positive, and encouraging, even when I might privately be a little frustrated. I think my open door policy and "text me whenever with questions" approach also help my score in this area. Additionally, I alluded to in the last paragraph, my style is flexible and somewhat democratic. I am willing to devote extra class time to making sure the class understands a difficult concept, and conversely, to move on if we seem to be belaboring something everyone already understands.

Of course this flexibility is also my (relative) downfall in another area: instructor preparation/organization. While I typically score at or above institutional and unit mean in this area, I do not score as well here as I do in the two categories I have just described. While I would need to poll students to know for sure, I suspect my lower scores here are due to the fact that I *am* so loose and democratic in terms of class period structure. Sometimes we get (productively) off track with the lecture when a student brings up an interesting question or observation; other times we end up a little behind the syllabus in order to address an issue a significant fraction of the class is having with the material. While this approach seems to work for most students and we always end up getting through all the course material, I imagine it must also feel a bit unstructured to some.

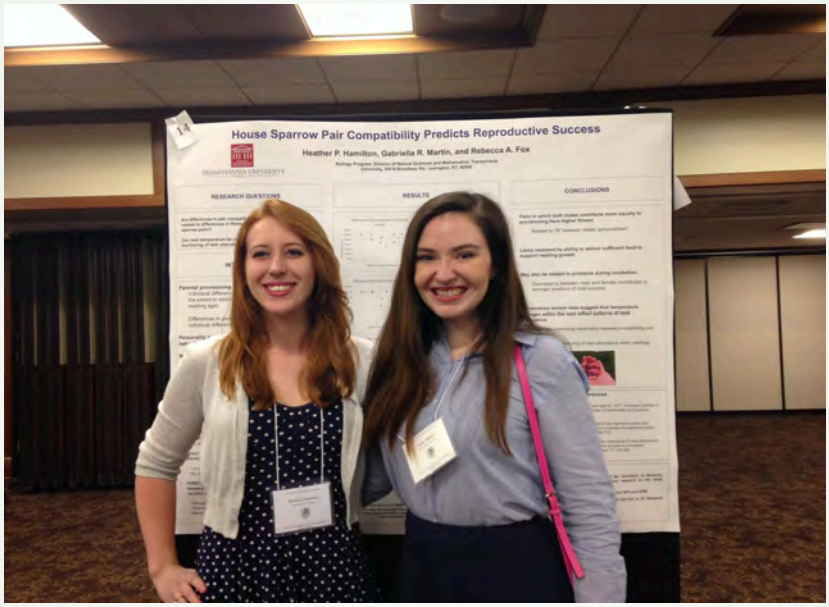
The area I have struggled in the most relative to the others (though again, my scores are generally at or above unit and institutional mean and have improved *dramatically* since my first year at Transy) relates to exams and evaluation of student work. This is unambiguously related to the fact that I am a bit of a slow reader and it slows my grading down. I have done several things to speed up and streamline my grading since my first year at Transy: taking a workshop on providing feedback on student writing and student work more generally, implementing rubric grading, and choosing a few key things on which to focus my feedback on any given assignment. I strive to (and largely succeed at) returning all exams and writing assignments within 7 days of receiving them, and make sure to always return all in-class and homework assignments at least a week prior to the relevant exam. With a few bobbles (usually related to unusual demands on my time during a particular semester) I have steadily improved in this measure over the last six years.

B.) Comments from former students

A few weeks ago, a former student emailed me and said, "I started my first year of medical school and we are taking cell biology and I owe you a huge thank you for preparing me so well for this course! I feel ready to take it on and that's definitely due to your wonderful teaching." Another student, a neuroscience major who is now in chiropractic school, texted me a few months ago: "I just briefly wanted to thank you for everything you've done for me. I'm sitting in my Anatomy and Physiology class and we are discussing the nervous system. I already know all of this information because of you and I'm doing so well in most of my classes. You gave me the knowledge and confidence I needed to succeed here and I am truly grateful." These are far from the only student thank-yous I've received over the last six years: the bulletin board in my office is covered with thank-you cards from former students.

There is obviously a positivity bias here since only happy students are likely to send me a thank you note, but the comments in the thank you notes seem to speak to the strengths identified in my SUMMA scores. For example, another former student, now in medical school, wrote in a thank-you he gave to me at graduation that one of his favorite memories of me was a time I'd stayed after scheduled lab time to let him and his lab partners re-do an experiment after a technical glitch. He wrote, "this was one of the first times I really felt like my professors cared about me as an individual." Students have thanked me for "contagious enthusiasm," for being someone who they feel like they can talk to, and for always being willing to take time with them one-on-one to help them succeed. While I certainly don't do what I do in order to gain student approval, it is always nice to get these notes because they tell me I am succeeding at being the kind of instructor I want to be.

SUPPLEMENTARY EVIDENCE OF TEACHING EFFECTIVENESS



SUPPLEMENTARY EVIDENCE OF TEACHING EFFECTIVENESS

A.) Success of In-Class Activities

I am the kind of instructor who is always tinkering with my courses – trying new activities and assignments, rearranging the order in which existing material is presented, and using information gleaned from assessments like exams and writing assignments as well as conversations with students to identify areas where students might be struggling with concepts and might benefit from a different approach to the material. This approach keeps the course material fresh (especially in courses that I teach every semester or every year) and helps me find approaches that work better for my students.

For example, I have long used the three-week "Swimmy" lab from MDCUNE (https://mdcune.psych.ucla.edu/modules/swimmy), in my Neurobiology course. In the "Swimmy" lab, students manipulate the behavior of a simulated neural circuit in order to map it. I have traditionally scheduled this lab for after we have gone over the material on neural circuits and central pattern generators in class – material that usually takes 3-4 class sections to cover because the material is challenging and typically have a lot of questions. Last winter term after we were a few weeks into the term and I ascertained the class was willing, I decided to try an experiment: I rearranged the lecture and lab schedule a bit so that the students completed the Swimmy lab *before* the class sessions on circuits. It is entirely possible to solve the circuit in Swimmy like a logic puzzle, without needing a great deal of background on the biology of neural circuits, and I wondered if prior hands-on experience mapping a circuit would make the material easier to understand when we covered it. As it turns out, not only did the students have relatively little trouble mapping the circuit, I was also right about its effect on student understanding. When I rearranged the schedule, I allotted four class periods to cover neural circuits and a case study on flight in locusts; we finished the material in two and a half. Central pattern generator mechanisms, once a big stumbling block for students, was now a complete non-issue. Students also did well on those questions on the exam. I will definitely be doing the Swimmy lab first in the future.

Another example of the success of in-class activities comes from my Cell and Molecular biology course. During my first and second year at Transy, enzyme kinetics was a huge source of frustration for my Cell and Molecular Biology students, just as it had been for me as an undergraduate. While we did a quantitative lab on enzyme kinetics as part of the course, I was consistently frustrated with the lab reports (and especially with the fact that students by and large all made the same errors in interpreting the data). The errors that students were making indicated that they were struggling conceptually, so after trying a few tweaks to the material that were at best moderately successful, I spent the summer after my second year thinking about what I might do to help students better understand what k_m and V_{max} really meant and why enzymes behaved the way they did. The answer I came up with was a simulation exercise with graphing that used Legos to simulate substrates, called **the kinetics of Lego hydrolase.** The Lego hydrolase simulation

paralleled and was paired with the **enzyme kinetics lab,** which I revised to include questions that explicitly required students to draw connections between what they were doing in the lab and what they had done in the simulation**.** Pairing these activities not only dramatically improved the quality of the enzyme kinetics lab reports, but also turned exam questions about enzymes from the most-missed questions on the second exam to some of the least-missed questions.

The **action potential activity** was born out of a similar issue – in this case, students in neurobiology were struggling to really "get" the idea of resting membrane potential, as well as the effect of excitatory and inhibitory post-synaptic potentials (IPSPs and EPSPs) on the postsynaptic neuron. After thinking a bit about possible analogies, I came up with a short exercise that used water in a beaker to represent the amount of positive charge under a small section of membrane. Doing this exercise before I introduced the Nernst and Goldman Equations (which are used to calculate membrane potential based on membrane permeability and ion concentrations) meant that students no longer became so hung up on the math that they did not think about what was actually going on in the neuron. In fact, if you ask my students about membrane potential these days (as I did last winter), they'll tell you that they find the concept "pretty easy to understand."

B.) Quality of Student Work

One of the metrics I use to determine whether I am successfully helping students to join the scientific conversation in their own right (and how well I am succeeding at inspiring them to engage with the material and invest in the class) is the quality of the work they turn in, particularly when it comes to major projects and takehome exams. I look not only at factual accuracy, but at students' willingness to tackle challenging topics, the depth of students' thinking, and the originality of their ideas. While quality obviously varies somewhat within a class based on student ability, interest in the subject matter, and preparation, it is rare for me to be disappointed in the work of the class as a whole, and it is rare for students to fail a major assignment (I will note that this is definitely not because I am an "easy" grader – it is rare for more than about 20% of the students in any given class to earn an A either on a given assignment or in the class as a whole).

I have included a few examples of the A-quality work I have received over the last few years: a **senior seminar paper on sexual selection and speciation in cichlid fish** that would not have been out of place in a scientific journal, one student's **response to a take-home final question in CVA on the evolution of flight**, and **a poster a student presented at the national meeting of the Animal Behavior Society in 2015** that was based on part of her group's portion of the lab in Animal Physiology (the theme that semester was the relationship between neophobia, exploratory behavior, and stress hormones in convict cichlid fish). There are certainly many more examples I could include here, but I have chosen these three for the sake of brevity.

C.) Success of research mentees after graduation

As I discuss in the next section, I do not see my scholarly activity – particularly as it relates to mentoring undergraduate researchers – as in any way separate from my vocation as an educator. In fact, one of the things I do with my student researchers who are interested in applying to graduate school is hold periodic informal mentoring sessions to answer their questions, help them identify potential advisors, and assist them with the application process. While my research students have many other professors, advisors, and mentors at Transy and I cannot by any stretch of the imagination take all of the credit for their success, the fact is that many of my former research students have gone on to do quite well.

Kat Sasser, who worked with me in 2013, is now my collaborator Dave Westneat's Ph.D. student and has passed her qualifying exams, and Casey Coomes, who worked with me in 2013-2014 and 2014-2015 is a second-year PhD. Student at Tulane, working with Liz Derryberry on heat stress and behavior in New World sparrows. Casey recently received an honorable mention in the National Science Foundation Graduate Research Fellowship Program. Sarah Gardner, another of my students from 2013-2015 is finishing her M.S. in Integrative Biology at Oklahoma State in the fall, working on behavioral genomics in mice with Polly Campbell and Jennifer Grindstaff, and will remain in their lab to pursue her PhD. Meredith Fox, a student of mine from 2011-2013, who has since left graduate school to pursue a career in public science education and aviculture at Sea World, spent two years studying bioacoustics at the University of Utah, and received the Gaige Award from the American Society for Ichthyologists and Herpetologists for her research. Rachel Williams, my student in 2010-2011, finished her DVM at Purdue last May and is now the head veterinarian at the Muncie Animal Rescue Foundation. Rebecca Oliver, a student of mine from 2012-2014 now has a masters' in bioethics from the University of Pennsylvania, served as a visiting lecturer at Princeton in Asia in Thailand for a year, and is now enrolled in medical school. Nur Ali (2013-2015) is pursuing her MPH at UK, and Courtney Marshall (2014-2015) is finishing a year as a Fulbright Teaching Fellow in Malaysia and plans to pursue a Ph.D. in epidemiology when she returns. I am very proud of all of them, and am grateful to have had the chance to mentor such talented students while also pursuing my own research interests.

10

Validating the speciation engine: the role of selection in the radiation of cichlids in Lake Malawi

[STUDENT NAME REMOVED FOR PRIVACY REASONS]
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Introduction

What is the origin of species? The astounding biodiversity of Earth's ecosystems has led many scientists to question the factors that promote such great biodiversity and why some lineages rapidly diverge while other lineages do not. In *On the Origin of Species*, Darwin set out to explain the processes by which ecological and phenotypic diversity interact by studying the adaptive radiation[1] of Galapagos finches (Darwin, 1859). However, 150 years later, the specific mechanisms driving the speciation events that result in spectacular biodiversity are still not well understood (Gavrilets and Losos, 2009). In the midst of global climate change, maintenance of biodiversity is a significant endeavor and understanding how lineages are able to rapidly adapt and diverge is increasingly relevant.

The Engine of Speciation

Throughout the study of speciation, many models have been proposed in an attempt to describe the processes by which species diverge. Many of these models provide explanation for cladogenesis[2] in specific contexts, such as allopatric versus sympatric speciation, or specific factors that contribute to cladogenesis, such as ecological or sexual selective pressures. Few models, however, have been developed to integrate the specific contexts and factors driving speciation. One such model is the speciation engine. This model, proposed by Danley and Kocher, makes adaptations to an

[1] Adaptive radiation- the diversification of an ancestral group of organisms into a variety of related forms specialized to fit different environments or ways of life, each often further diversifying into more specialized types

[2] Cladogenesis- an evolutionary splitting event where a parent species splits into two distinct species, forming a clade

original divergence with gene flow[3] model developed by Rice and Hostert (Danley and Kocher, 2001; Danley *et* al, 2000; Rice and Hostert, 1993).

In the divergence with gene flow model, disruptive selection acts on naturally occurring genetic variation. In order for this disruptive selection to cause divergence, the selective pressures must first be strong in relation to the strength of the collecting pressures of gene flow. Further, when disruptive selection works through pleiotropy[4] and genetic hitchhiking[5], the assortative mating[6] that results reduces the required strength for selection to over come gene flow (Rice and Hostert, 1993). It is also possible that increasing the number of traits being subjected to selective pressure may also decrease the necessary strength to overcome gene flow (Rice and Hostert, 1993; Nosil, 2012). The pre-zygotic isolation necessary for divergence develops as a result of pleiotropy and as consequence of disruptive selection on a specific character, or set of traits. Thus, the first prediction of this model is that selection must be disruptive, strong in relation to gene flow, and multifarious[7] (Danley and Kocher, 2001; Danley *et* al, 2000).

Second, this model predicts the development of a positive feedback loop, which provides foundation for the naming of the engine of speciation model. Prior to a cladogenic event, disruptive selection pressures on a specific character, fostered by pleiotropy and hitchhiking, increase. When cladogenesis occurs, disruptive selection for the character is reduced, as selection is no longer exerting disruptive effects on the specific character within each of the newly diverged groups. Gene flow within the newly formed species is also reduced as a result of speciation, as alleles are now being shared only within each smaller, newly diverged population. This reduced gene flow primes new species for subsequent divergence as disruptive selection acting on a different character, or set of traits, builds slowly with time. With priming, this model predicts that a positive feedback loop will develop resulting in multiple cladogenic episodes, with each event resulting from selection on a different character (Danley and Kocher, 2001; Danley *et* al, 2000).

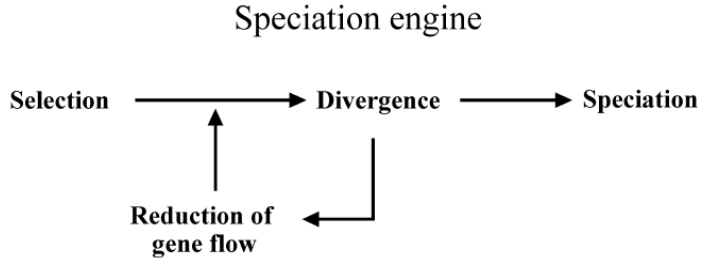

Fig. 1. Summary of the positive feedback loop predicted by the engine of speciation model in which each cladogenic event primes subsequent speciation. Figure adapted from Rice and

[3] Gene flow- is the transfer of alleles from one population to another

[4] Pleiotropy- when one gene influences multiple, seemingly unrelated phenotypic traits

[5] Genetic hitchhiking- the change in the frequency of an allele that is caused by linkage to an allele at another locus

[6] Assortative mating- non-random mating pattern in which individuals with similar genotypes/phenotypes mate with one another more frequently than would be expected under a random mating pattern

[7] Multifarious- when selection acts on multiple traits decreasing the required selection strength for speciaiton

Hostert, 1993, and taken from: Danley, P.; Kocher, T. (2001) Speciation in rapidly diverging systems: lessons from Lake Malawi. *Molecular Ecology*. **10**, 1075-1086.

In addition, the third prediction of this model maintains that gene flow will decrease overall. If gene flow is reduced with each cladogenic event, over multiple events, it is expected that gene flow will be reduced with time and each subsequent cladogenic event. This predicts that gene flow between present species will be reduced in comparison to ancestral species. Likewise, the fourth prediction of the engine of speciation model predicts that selective pressures will also decrease overall. Each cladogenic event reduces the selection on the involved character, and as each additional event reduces selection on a new character, selection overall is reduced. While the strength of selection at past speciation events can be difficult to determine, the strength can be inferred from decreasing complexity in divergent character. Decreasing character complexity holds predictive value because selection must be stronger to overcome gene flow with regard to complex characters involving many alleles, whereas a lesser selective pressure is required to overcome gene flow with regard to genetically less complex characters. Thus, this model predicts that the complexity of divergent characters will decrease over time (Danley and Kocher, 2001; Danley *et* al, 2000; Rice and Hostert, 1993).

Several aspects of this model make the engine of speciation particularly effective for explaining patterns of divergence. As the model predicts that selection during consequent cladogenic events will act on new characters, this model provides the opportunity to integrate the various factors and contexts driving speciation. Ecological factors, for example may play a greater role in selection on more complex characters in an early cladogenic event, whereas sexual selection may play a role in later cladogenic events by selecting for less complex traits like minute differences in pigmentation. Within the model's explanation of these cladogenic events, there is an allowance for non-adaptive evolution to exert effects (Danley and Kocher, 2001; Danley *et* al, 2000). In providing an explanation for the variation in levels of biodiversity among ecosystems and taxa, this model is argues that differential selective pressures will create variance in species richness (Danley *et* al, 2000).

Analysis of the Speciation Engine

Key to the study of species origins is the use of model taxa. Since the ancestry and speciation of all organisms cannot be studied, use of models allows for speciation to be studied in several representative taxa so that conclusions may be inferred about the speciation of many taxa. Darwin's finches, *Anolis* lizards from the Caribbean, Hawaiian silverswords, and East African cichlids have all served as model species in recent study of adaptive radiation. This paper will focus on East African cichlids, which have grown in popularity as a model organism for a variety of reasons. As a model, East African cichlids are particularly well suited for the study of speciation as the present phenotypic diversity represented in current species offers a natural 'mutant screen' that can be assayed for molecular differences. Further, newly diverged, yet morphologically dissimilar, species can be used to artificially generate hybrid crosses, which can be utilized to study the segregation of alleles and related phenotypes. Logistically, the husbandry of cichlids makes them an excellent model organism as wild individuals can

be easily transitioned to the lab and the generation time is relatively short. With regard to experimentation, the high degree of relatedness makes genetic and genomic resources widely applicable and genetic maps, cDNA microarrays, SNPs, and ESTs are currently available (Salzburger, 2009). As they are well suited to speciation study, there has been a great body of speciation work done utilizing the East African cichlid model. Thus, for this paper, we will review the East African cichlid model, specifically the radiation of the mbuna clade in Lake Malawi, to analyze the predictions of the speciation engine.

Alternative Speciation Hypotheses

In contrast to the engine of speciation, other hypotheses have been proposed to address the roots of speciation. To discuss these models, this paper will operate under the biological species concept, but with respect for the recognition and morphological species concepts that are present in cichlid literature (Kornfield and Smith, 2000). The biological species concept maintains that a species is defined as organisms that do not interbreed, and if they do, they do not produce viable hybrid offspring. By extension, the recognition concept clarifies that within species organisms must recognize potential mates, and the morphological species concept specifies that individuals are of the same species if they appear morphological similar (Clement, 2006).

The first pair of speciation hypotheses describes the manner in which gene flow is reduced in the diverging population. In allopatry, a geographic barrier separates the population into two distinct groups between which gene flow is reduced, or completely cut off, by the geographic barrier (Genner, 2005). One extension of allopatric speciation is the founder effect. In the founder effect, a small segment of the existing population becomes the founders of a new population through separation. Allopatric speciation follows as the newly founded population experiences reduced gene flow and diverges from the original population (Barton and Charlesworth, 1984). Allopatric speciation has been proposed as a potential mechanism for speciation in cichlids as drying events in Lake Malawi caused extreme fluctuations in the water level of the lake, allowing for patches of rocky habitat to become segmented and geographically isolated (Genner and Turner, 2005). The timing of fluctuations in lake level has been shown to coincide with bursts of speciation in the East African Great Lakes (Sturmbauer *et al*, 2001). However, it is unlikely that allopatric speciation is the only mechanism contributing to reduced gene flow in cichlid speciation events. Researchers have undermined evidence in support of allopatric speciation alone by demonstrating that gene flow still exists between recently diverged populations and that there is no correlation between dispersal ability, as it relates to gene flow, and species richness (Genner and Turner, 2005).

In sympatric speciation, a divergence with gene flow model, species diverge while still inhabiting the same geographic area and disruptive selection is primarily responsible for the necessary reductions in gene flow driving speciation. This type of speciation has remained controversial since Ernst Mayr deemed it theoretically unlikely in 1963 (Via, 2001). Recent models, however, demonstrate that sympatric speciation is not only a plausible theory, but is likely exerting effects in the speciation of cichlids in Lake Malawi (Danley *et al*, 2000). In brief, a randomly mating population experiences

disruptive selection, often in the form of runaway sexual selection[8] or ecological selection, which drives an evolutionary shift in assortative mating (Bolnick and Fitzpatrick, 2007). Philopatry[9] and genetic linkage[10] further facilitate disruptive selection (Via, 2001). Reinforcement, or heightened mating discrimination among sympatric taxa, combined with pleiotropy and genetic hitchhiking, results in reproductive isolation (Noor, 1999). Currently, cichlid radiations are considered the most probable example of sympatric speciation (Via, 2001). To explain the speciation of East African cichlids, it most likely that periods of allopatric and sympatric speciation among clades have both contributed to reduced gene flow and divergence. This alternation between allopatry and sympatry, known as landscape dynamics, potentially works in tandem with the engine of speciation model and would, in theory, contribute to the rapid nature of speciation in some cichlid species (Aquilee *et al*, 2012).

Within sympatric speciation, ecological and sexual selective factors contribute to reduction in gene flow and divergence. Sexual selection describes the process by which a change in mating preference associated with an alteration in secondary sex characteristics drives assortative mating and results in divergence. Sexual selection is also a factor in speciation by sexual conflict. Sexual conflict describes conflict that arises when males and females employ different, exploitative strategies for maximizing lifetime reproductive output, leading to runaway co-evolution, pre-zygotic, and reproductive isolation. In the development of reproductive isolation, Haldane's rule argues that after two species have diverged, hybrid inviability is more likely to have developed in the heterogametic sex upon sexual contact post divergence. Thus assessment of Haldane's rule for newly diverged species allows for analysis of the role of sexual selection (Panhuis *et al*, 2001). While evolutionary studies and modeling experiments have demonstrated the power of sexual selection and conflict to drive speciation (Gavrilets, 2014), others argue that sexual selective pressures are not strong enough to overcome gene flow without functioning in coordination with ecological selection and adaptive radiation (Scordato *et al*, 2014; Ritchie, 2007). In cichlid species specifically, experiments indicate that adaptive radiation is predictable only when the ecological and sexually selected factors are considered together (Wagner *et al*, 2012).

Ecological factors, such as opportunity, contribute to speciation as species invade and adapt to new ecological niches. As populations of a species become isolated within specific ecological niches, gene flow is reduced between the populations and divergence develops (Losos and Mahler, 2010). Exploitation of ecological niches is often related to "key innovations" that allow species to exploit new resources with in niches. This provides a demonstration of how ecological factors may exert selective pressures on phenoptypic plasticity in morphological traits, like the beaks of Darwin's finches (Genner, 2005). Similarly, new morphologies may arise through hybridization, but are then maintained by ecological selective pressures (Genner, 2005; Seehausen, 2004).

[8] Runaway sexual selection- when females exhibit a strong preference for a male secondary sex characteristic and mate only with male possessing a strong expression of that trait, resulting in a subsequent generation of males with strong expression of the trait and females with a strong preference for it, leading to extreme dimorphism

[9] Philopatry- the tendency of an organism to remain in a specific area

[10] Genetic linkage- the increased likelihood that alleles that are located closer to each other on the chromosome will be inherited together

Though ecological selective pressures have been critical to the adaptive radiation of cichlids in Lake Malawi (Seehausen, 2006), ecological factors are insufficient in explaining the more recent divergences in cichlid lineages, which have occurred in largely homogenous environments and resulted in no detectable changes in functional morphology (Genner, 2005).

If allopatric and sympatric contexts, as well as sexual and ecological factors, cannot sufficiently explain speciation on their own in certain taxa, then there is a need for an integrated model, which encompasses these contexts and factors, that can provide a holistic explanation for speciation phenomena. The speciation of cichlids in Lake Malawi serves to validate the speciation engine model as the nature of the selective pressures involved, reductions in selection and gene flow, and factors under selective pressure in this system support cyclical patterns in selection pressures that drive speciation in the presence of gene flow. Thus, this paper argues, through model validation, that the speciation engine holds great potential as an integrated model to explain speciation in East African cichlids and perhaps other taxa.

Review of Cichlid Phylogeny

Comprising more than 10% of all teleost fish species, the Cichlidae family boasts the most biodiversity of any vertebrate group. Cichlids have come to inhabit lacustrine and riverine ecosystems throughout Central and South America, Africa, Madagascar, and in southern regions of India and Sri Lanka, with some species moving northward into the United States, Jordan, and Iran. Cichlids are thought to have originated between 130-165 million years ago (mya) and African and American lineages are thought to have diverged from 70-90 mya. The East African Great Lakes, including Lakes Victoria, Malawi and Taganyika, represent the greatest cichlid biodiversity with 1,800-2,000 species dispersed among the three lakes. This great biodiversity is a result of rapid speciation, making East African cichlids an extensively studied model taxa in the study of speciation and adaptive radiation (Sturmbauer et al, 2011).

Another effect of rapid speciation is difficulty in reconstructing the phylogenetic relationships of current species, as evidence suggests gene flow is still occurring at some level between recently diverged species, demonstrating the difficulty in making species distinctions (Won *et al*, 2005). Of the three lakes, Lake Malawi maintains the greatest number of cichlid species, with an estimated 500-700 endemic cichlids. This paper will focus specifically on cichlid speciation in Lake Malawi, as the following phylogenetic maps are well accepted and the diversity of the lake lends itself particularly well for studying speciation models.

The basic phylogeny of the major cichlid lineages has been well established through analysis of mitochondrial DNA. As demonstrated in Figure 2, Lake Malawi was originally invaded by a haplochromine ancestor of the Tropheini, a tribe of African cichlids endemic to Lake Taganyika that migrated throughout the rivers and lakes of East Africa. With the invasion of Lake Malawi, this ancestor gave rise to the two populations, one inhabiting sandy substrate and the other, loosely referred to as the mbuna (meaning rockfish), inhabiting the rocky shoreline (see Fig. 2 and 3). The mbuna, a highly philopatric clade, will be the primary focus of this paper. In a subsequent radiation, the

mbuna diversified through development of trophic specialization, followed by a third radiation driven by selection on secondary sex characteristics (Kocher, 2004).

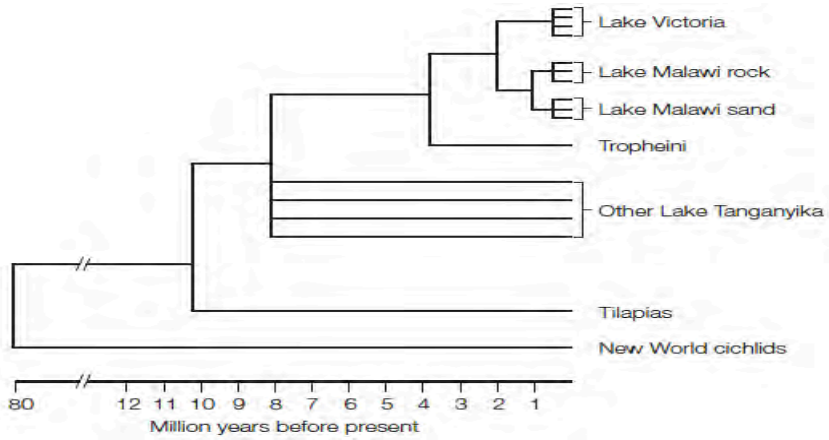

Fig. 2. A reconstruction of the phylogenetic relationships of major cichlid lineages, see text for description. Figure taken from: Kocher, T. (2004) Adaptive evolution and explosive speciation: the cichlid fish model. Nature. **5**, 288-298.

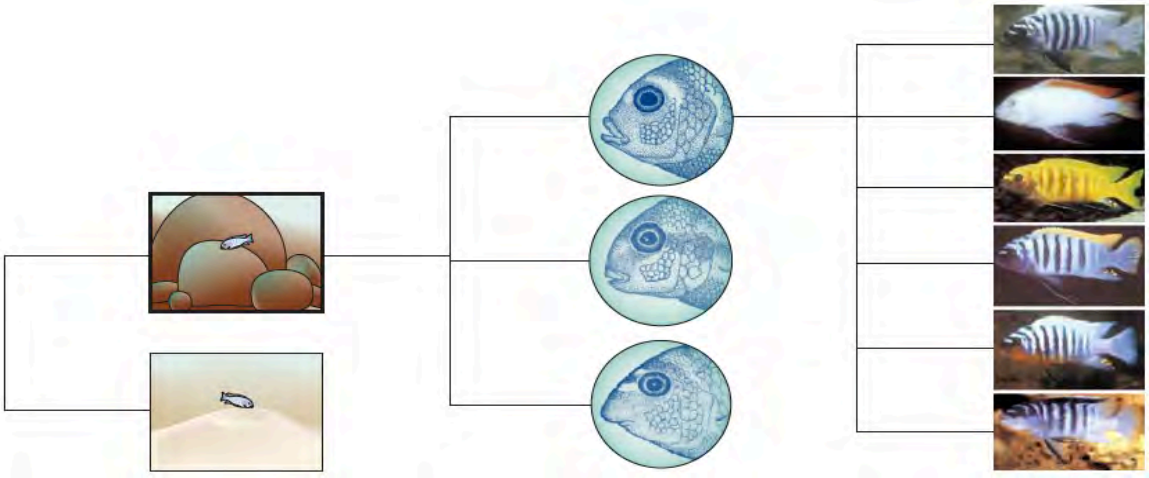

Fig. 3. A basic reconstructed phylogeny of the mbuna. The first radiation represents the divergence into sand and rock dwelling clades also shown in Fig. 1. The second radiation demonstrates specialization in trophic morphology in both habitat groups and demonstrated in the figure through representation of the variety in jaw shape of *Metriaclima* (top), *Tropheops* (middle), and *Labeotropheus* (bottom). The third radiation resulted in a variety of male color pattern, which is evidenced by the variety of pigmentation exhibited within the *Metriaclima*. Figure taken from: Kocher, T. (2004) Adaptive evolution and explosive speciation: the cichlid fish model. Nature. **5**, 288-298.

Ecological Niches

In the primary radiation shown in Fig. 3, the ancestral cichlid group split into two benthic populations, the sand and rock dwellers, resulting in the formation of two macrohabitat clades (Danley and Kocher, 2001; Moran *et al*, 1994). Though this radiation has not been well studied, it is supposed that strong, multifarious selection resulted in

behavioral and morphological variation that allowed for specialization to ecological niches (Danley and Kocher, 2001). Macrohabitat differentiation has occurred as a first radiation event in other taxa, including the Darwin's finches, which prior to experiencing notable trophic specialization, first differentiated into tree and ground dwelling clades. The pattern also emerges in other lacrustine fish as groups differentiate into benthic and pelagic clades (Salzburger, 2008). Further, similar ecological niche specialization has been demonstrated as a first radiation in the differentiation of three spine sticklebacks into benthic and limnetic morphs. The evolution in body shape that characterizes this macrohabitat differentiation in sticklebacks has been shown to be the result of a few genes with widespread effects in conjunction with many genes of smaller effect (Albert *et al*, 2007). Likewise, benthic and limnetic differentiation in whitefish involved selection acting on a number of traits including swimming behavior, growth rate, morphology, and life history in the form of maturity and fecundity (Rogers and Bernatchez, 2007). Assuming that the molecular foundations of ecological niche specialization in the ancestral cichlid group coincide with these parallel differentiations in other taxa, it is likely that differentiation in cichlids resulted from similarly strong, divergent, multifarious selective pressures.

Trophic Specialization

After diverging into ecological niches, cichlid phylogeny argues that the mbuna underwent a second radiation driven by ecologically selected adaptations in trophic morphology (Kocher, 2004). Such adaptations are characterized by morphological changes in craniofacial structure, mandible structure, pharyngeal jaw apparatus, and dentition, resulting in an extreme variety of feeding structures (Albertson *et al*, 2005; Danley and Kocher, 2001; Fraser *et al*, 2013; Salzburger, 2008). Despite the specialization and specificity of these structures, there remains a remarkable degree of plasticity that can be acted upon by ecological factors present later in development (Gunter *et al*, 2013; Young, 2013). Trophic specialization in the mbuna provides an example of how ecological selection and sexual selection may work in coordination as ecological pressures select for specific trophic adaptations while sexual selection via mating preference reinforces trophic adaptations through selection against the production of less viable hybrids.

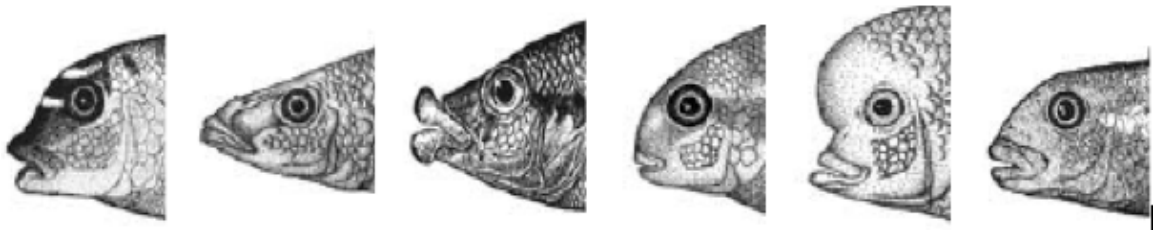

Fig. 4. Demonstration of the variety of trophic morphologies exhibited across species in Lake Malawi. Figure adapted from: Albertson, R.; Kocher, T. (2006) Genetic and developmental basis of cichlid trophic diversity. Heredity. 97, 211-221.

One dichotomy through which mbuna trophic morphology is often described is biting phenotypes, which require a high mechanical advantage, versus sucking phenotypes, which require a low mechanical advantage (Albertson and Kocher, 2006).

Cichlids possess multiple rows of similarly shaped teeth on two sets of jaws and teeth are replaced throughout life (Streelman *et al*, 2003). Biting phenotypes are characterized by a short, powerful jaw and an outer row of short, close, multi-cusped teeth, whereas sucking phenotypes possess large, intermittently spaced teeth, with fewer cusps and an elongated jaw. These differences allow biting species to specialize in shearing algae from the substrate, while sucking species are suited for sucking up plankton or loose plant or algal material from the substrate or water column (Albertson and Kocher, 2006).

Evolution and development studies conducted on mbuna from Lake Malawi have revealed a number of molecular pathways that may potentially be driving morphological differences between biting and sucking phenotypes. The trophic specialization of Darwin's finches has previously been attributed to variations in *bmp4* expression between finches with larger and smaller beaks. Similarly, *bmp4* has been shown to exert control over mandible development in mbuna species, with differential expression resulting in more biting or sucking-like phenotypes (Albertson *et al*, 2005). Expression of *bmp4* and other BMPs has also been shown to drive variation in cichlid dentition by influencing the regeneration of teeth and number of cusps (Fraser *et al*, 2013). The critical role of *bmp4* in mbuna trophic morphology is further supported as the *bmp4* gene exhibits an accelerated protein evolution in East African cichlids in comparison to other taxa, contributing to the potential for variation in mbuna *bmp4* specifically (Salzburger, 2008).

In addition to BMPs, FGFs, and many genes associated with the Hedgehog (Hh), Notch, and Wnt/β-catenin signaling pathways have all been implicated in evolution of trophic variation. For example, BMPs and Hh genes interact in the development and patterning of mbuna dentition. FGFs have been shown to interact with the Notch pathway and BMPs to control the regeneration of teeth, while the Wnt/β-catenin pathway works in tandem with Notch signaling to control cusp formation and proper mineralization of teeth (Fraser *et al*, 2013). Further, microarray technology has revealed a differential expression of *cimp1* and *magp4* between different trophic morphologies in mbuna. Based on expression patterns during development, it is believed that *cimp1* plays a role in the formation of shorter feeding structures, while *magp4*, a glycoprotein responsible for Smith-Magenis Syndrome[11] in humans, is thought to govern the development of wide mouths and large fleshly lips. Finally, other genes, such as *otx2*, *pax9*, *bapx1*, and *edn1* are suspected to play a role in mbuna trophic variation because the phenotypes exhibited with varied expression of these genes in other taxa prove parallel to phenotypes associated with trophic morphology variation in mbuna (Albertson and Kocher, 2006).

Differential gene expression is also associated with trophic plasticity in cichlids. Trophic plasticity has been studied in Lake Victoria through *Astatoreochromis alluaudi*. *A. alluaudi* presents natural variation in wild populations, with populations feeding on hard-shelled snails demonstrating significantly more robust, molariform jaw morphology, whereas populations feeding on softer food demonstrate smaller, papilliform jaws. When this variation is experimentally manipulated through foods provided to *A. alluaudi*, 187 genes where marked by differential expression between molariform and papilliform morphs. However, further study specifically highlighted the differential expression of genes specifically related to osteoblast proliferation and differentiation, including *bmp2*, *runx2b*, and *osx*. Other genes, including *bmp2* and *cx43*, had elevated expression in

[11] Smith-Magenis Syndrome- a developmental disorder in humans characterized in part by a prominent lower jaw, dental abnormalities, and a down-turned mouth with a very full upper lip

response to mechanical bone strain. The role of phenotypic plasticity in speciation is not well understood, but as selection works on phenotype rather than genotype, it is important to consider the molecular foundations of plasticity that may be involved (Gunter *et al*, 2013).

The number of genes involved, or potentially involved, in the trophic specialization of the mbuna demonstrates the genetic complexity of coordinating craniofacial, mandible, pharyngeal, and dental traits. Thus, strong, divergent, multifarious selection acting on several trophic traits would be required to stimulate divergence in the presence of gene flow within this second radiation in the mbuna clade. However, in comparison to the prior radiation driven by ecological niche specialization, several factors indicate that this radiation was primed by prior speciation events. First, differentiation into ecological niches in the previous radiation would have resulted in decreased gene flow within the diverged populations, making it easier for selection to overcome gene flow in association with trophic morphologies. Second, trophic morphology traits, though genetically complex and involving many alleles, would theoretically be easier for selection to overcome than the traits associated with ecological niche specialization. This is because traits associated with trophic morphology and head characteristics have been shown to be genetically linked in cichlids and other taxa (Genner and Turner, 2005), thus demonstrating a decreased complexity of divergent traits in comparison to those selected for in the previous radiation. Third, the potential for sexual selection to also exert selective pressure in this radiation by selecting against less viable hybrids increases the likelihood for divergence in this radiation. Finally, the potential for selection to be acting on trophic plasticity makes for yet another contributing factor for selective pressures in this radiation.

Sexual Selection on Multiple Cues

With the first radiation in the mbuna clade of Lake Malawi stemming from differentiation into ecological niches and the second radiation being driven by trophic specialization, the third radiation in the mbuna clade is characterized by sexual selection acting on male secondary sex characteristics in the form of visual and non-visual cues, while most other morphological features remain unaltered. The reproductive strategies of the mbuna provide ample opportunity for sexual selection to exert disruptive effects. First, the mbuna are mouthbrooders, meaning that parental care responsibilities are placed almost entirely upon the female mbuna who highly invests in large eggs and rears fry in her mouth for several weeks post-fertilization (Danley and Kocher, 2001). In this reproductive system, mistakes come at a high cost to females. Thus, females are expected to be highly selective in their mating preferences. Second, the mbuna utilize a lek-like mating system in which males are in high competition for females and experience varying degrees of mating success (Danley and Kocher, 2001). Within this lek-like system, females will select males based on color pattern, auditory and olfactory signals, mating behaviors, or a combination of these cues. For the purposes of this paper, we will focus specifically on nuptial coloration.

Coloration in the mbuna clade is both diverse and repetitive. In a phylogenetic analysis of the mbuna, it was found that 90% of mbuna species have one of four male nuptial phenotypes, while 80% of species exhibit one of three X-linked color patterns in females. The variation in male nuptial coloration among sympatric species in regions of

Lake Malawi, in conjunction with repetition of similar coloration patterns across the lake, drive questions about the potential evolutionary origins of this distribution of nuptial coloration phenotypes. If nuptial coloration phenotypes had evolved once and then spread throughout lake, one would expect similarly colored species to be more closely related than dissimilarly colored sympatric species (Allender *et al*, 2003) and that a divergence based on nuptial coloration would have occurred earlier in the mbuna phylogeny. However, if sexual selection on nuptial coloration were the root cause of many recent divergences, one would expect dissimilarly colored sympatric species to be more closely related than similarly colored allopatric species. Phylogenetic evidence at the population level demonstrates that dissimilarly colored sympatric species are in fact more closely related, arguing that sexual selection is the root cause of speciation events in the third radiation of the mbuna clade (Allender *et al*, 2003).

Female mate choice is demonstrated within this distribution of nuptial coloring as females exhibit a preference for males with the coloration most closely resembling that of their own species. When provided with a choice, female mbuna consistently prefer males of their own species as opposed others. However, when given the choice between a dissimilarly colored, more closely related sympatric species and a similarly colored, more distantly related allopatric species, females consistently prefer the allopatric species, demonstrating that females are recognizing and choosing mates based on nuptial coloration (Jordan, 2008). It is likely that female mate choice has played a significant role in the rapid speciation of the mbuna as directed mate selection decreases gene flow and facilitates reproductive isolation. To explore the potential linkage of genes controlling nuptial coloration and female mate choice, Ding *et al* hybridized two recently diverged, morphologically dissimilar mbuna species (*M. benetos* and *M. zebra*) and performed quantitative genetic analyses. Results from this study, though they did not specifically reveal a linkage between coloration and mate choice, demonstrated that only a few genes control female mating preference. This suggests that a low number of genes controlling female preference may facilitate speciation in the mbuna clade. Evidence of post-zygotic isolation also manifested in this experiment as only female hybrids were produced from *M. benetos* females bred with *M. zebra* males. This may provide evidence of Haldane's rule with hybrid inviability potentially developing in the heterogametic sex (Ding *et al*, 2014).

Other results from Ding *et al* indicated that many genes of small effect are involved in the coloration of male mbuna, which is inconsistent with other studies. In another hybridization study using *M. zebra*, O'Quin *et al* found that 1 to 4 genes were responsible for male nuptial coloration in the mbuna cichlid pair (Ding *et al*, 2014). Further, Barson *et al* determined that there was a minimum of 4 to 7 loci responsible for body coloration in the blue and yellow nuptial phenotypes of *P. zebra* and *P. 'zebra gold.'* Evidence also suggests that the loci responsible for yellow coloration on the belly, chest, and dorsal fin are genetically linked (Barson *et al*, 2006). Additional studies have examined the role of specific genes in aspects of mbuna pigmentation. Accelerated evolution has been uncovered in the gene, *hag*, which has been shown to control pigmentation phenotypes, and in *csf1ra*, which has been shown to play role in the pigmentation of mbuna egg dummy spots that are known to have a direct correlation with male reproductive success (Salzburger, 2008). The limited number of genes potentially responsible for male nuptial coloration in mbuna provides explanation for the repetition

of phenotypes across the lake as many different divergences may have been acting on the same genes. With a limited number of genes in control of coloration it likely that sexual selection on these genes is resulting in species divergence.

Though Ding *et al* did not uncover a linkage between nuptial coloration and mate choice, linkages have been uncovered between genes controlling coloration and mbuna sex determining genes[12], allowing for speciation through genetic conflict[13]. As proposed by Kocher, a small population causes high competition between brothers for mates, and thus selection favors mothers who produce more female offspring. Such a population is vulnerable to a gene, W, that represses the development of males. Then a new color mutation may develop in linkage with W. Any male that chooses to mate with a female of the new color variant benefits from a selective advantage, creating a runaway selection for male preference and the female trait, leading to the creation of a new sex determining gene (Kocher, 2004). This is proposed model for the evolution of the orange-blotch pigmentation phenotype in female mbuna, as the genetic basis of orange-blotch has been linked to the female heterogametic sex determiner, W, on chromosome 5. Male blue nuptial coloration in mbuna is linked to the ZW and X"Y" loci for sex determination. The evolution of new sex determining genes that are linked to sex specific nuptial traits as resolution to genetic conflict presents the possibility for extremely rapid species divergence (Parnell and Streelman, 2013).

When operating under the visual cue of nuptial coloration to drive mating preference, mating preferences can experience total collapse with alterations in lighting (Danley and Kocher, 2001). Thus, genes involved with color perception in mbuna may be acted upon by natural selection in adaptation to specific photic environments, but potentially also by sexual selection as these genes have to power to alter mating preference (Salzburger, 2008). Vertebrates possess visual pigments made of opsin proteins that can fine tune spectral sensitivities. Mbuna utilize 7 different cone opsin proteins and related genes. Along with differential expression, the amino acid sequence of the opsin protein determines the spectral absorbance of the pigment, allowing for great variation to be achieved within visual systems. Heterochronic changes in opsin are responsible for slight changes in spectral sensitivities across cichlid species in Lake Malawi. No research has been conducting the potential for slight differences in visual sensitivity to affect mating preference, and more research is need to determine whether color perception has been acted on by sexual selection (Carleton *et al*, 2008).

Thus, as changes in lighting can cause a breakdown in mate choice, ecological factors may also play a role in selection on color and color perception in the mbuna. The orange-blotch phenotype, for example, is thought to provide cryptic benefits to females (Parnell and Streelman, 2013). Also, when observing variation in male nuptial coloration, there is some ecological correlation. The male nuptial phenotype exhibiting an orange dorsal fin, for example, is associated with species feeding on plankton, as females in this species often feed while swimming above males defending territory below. Further, the yellow chest phenotype in males is associated with benthic foraging as males and females interact on the same level in the water column (Allender *et al*, 2003).

[12] Sex determining genes- one of multiple genes that can influence sex determination in cichlids

[13] Genetic conflict- competition between sex determining genes within the genome

Strong, divergent, multifarious sexual selection has the opportunity to exert selective pressure on multiple traits, including genes underlying female mate choice, male nuptial coloration, and possibly color perception in mbuna to cause rapid speciation. Sexual selection acting in this radiation allows for the occurrence of non-adaptive evolution in mbuna speciation (Danley and Kocher, 2001). The strength of this sexual selection may be bolstered by ecological selective pressures (Allender *et al*, 2003), further increasing the likelihood that speciation will occur. As there are few genes that are responsible for exerting control over female mate choice, male nuptial coloration, and color perception in mbuna, many parallel episodes of speciation acting on the same genes are able to occur among previously diverged, allopatric clades, resulting in repetition of phenotypes (Allender *et al*, 2003). Further, the reduced number of genes involved in these sexually selected traits demonstrates a reduced character complexity in comparison to the number of genes and genetic pathways involved in the secondary trophic radiation. A limited number of genes and reduced character complexity argues that a lesser selection pressure is necessary to overcome gene flow in this radiation with regard to prior radiations. Gene flow is also reduced from prior radiations as mating behaviors and strong female mating preferences create mechanisms of isolation acting on gene flow already reduced by priming. The combination of multiple sexually selected traits controlled by a limited number of genes, reduced gene flow, and divergent, multifarious sexual selection provides explanation for the prolific nature of speciation in the third radiation of the mbuna clade.

Disruptive, Strong, Multifarious Selection

The first prediction in the speciation engine model states that selection must be disruptive, strong in relation to gene flow, and multifarious (Danley and Kocher, 2001; Danley *et* al, 2000; Rice and Hostert, 1993). We see evidence of disruptive, strong, multifarious selection in each of the three radiations of the mbuna clade. In the first radiation driven by differentiation into ecological niches, we see evidence of selection that is disruptive and strong enough to overcome gene flow by acting multifariously on traits including swimming behavior, growth rate, morphology, and life history in the form of maturity and fecundity (Rogers and Bernatchez, 2007). The second radiation provides further evidence as selection is acting multifariously on trophic traits, such as craniofacial structure, mandible structure, pharyngeal jaw apparatus, and dentition (Albertson *et al*, 2005; Danley and Kocher, 2001; Fraser *et al*, 2013; Salzburger, 2008). Support for genetic linkage in these trophic traits (Genner and Turner, 2005) provides evidence that genetic hitchhiking has reduced the required strength for selection to over come gene flow in this radiation, indicating that selection is indeed strong. Finally, in the third radiation of the mbuna, selection acts multifariously on female mate choice, male nuptial coloration, and color perception (Barson *et al*, 2006; Carleton *et al*, 2008; Ding *et al*, 2014). Genetic hitchhiking arises in this radiation as genes for coloration become linked to sex determiners (Kocher, 2004; Parnell and Streelman, 2013), influencing the distribution of alleles in the population and reducing the required strength for selection. Further, there is some evidence for the development of pre-zygotic isolation in this radiation, presumably through pleiotropy, as we see possible hybrid inviability in the

Ding *et al* results (Ding *et al*, 2014). Consequently, the speciation of mbuna clade in Lake Malawi serves to validate the speciation engine model by upholding the prediction that in order for this disruptive selection to cause divergence, the selective pressures must be disruptive, strong in relation to the strength of the collecting pressures of gene flow, and multifarious.

Multiple Episodes of Speciation

The second prediction of the speciation engine maintains that a positive feedback loop will develop resulting in multiple cladogenic episodes, with each event being primed by prior speciation and resulting from selection on a different character. The phylogenetic history of the mbuna clade provides evidence for the development of this feedback loop (Danley and Kocher, 2001). Each of the radiations in the mbuna clade demonstrates a cladogenic episode, demonstrating that the feedback loop has resulted in multiple episodes. There is evidence for priming as each radiation causes a reduction in gene flow. The first radiation causes a reduction in gene flow as divergent species become isolated within ecological niches. The second reduces gene flow as hybrids with intermediate jaw morphology are selected against, isolating species by trophic specialization. The third radiation causes a reduction in gene flow as strong mating preferences create behavioral isolation between species. Finally, each radiation in the mbuna clade demonstrates selection on three separate characters, one for each radiation. The first acted on aspects of development, behavior, and body morphology, and the second acted on trophic morphology while the third radiation acted on secondary sex characteristics. Thus, the mbuna speciation validates the speciation engine by supporting the prediction of a positive feedback loop.

Levels of Gene Flow Decrease With Time

The third prediction of the speciation engine posits that that gene flow will decrease overall (Danley and Kocher, 2001). Discussion of the previous prediction demonstrated how gene flow is reduced by each radiation within the mbuna clade. Then intuitively it can be argued that if gene flow is reduced by each radiation, then over three radiations, it is expected that gene flow will be reduced with time and each subsequent radiation. More direct support can be inferred from the dispersal ability of present mbuna species in comparison to ancestral species. If gene flow is decreasing overall, then gene flow in ancestral species should be greater than in present species (Danley and Kocher, 2001). Dispersal ability provides an indication of gene flow as species with great dispersal ability are more capable of dispersing their genes among populations whereas the genes of highly philopatric species are confined to the population inhabiting their limited geographic range. The proposed relationship between selection, philopatry, and probability of speciation is diagramed in Fig. 5. The recognized ancestor of the mbuna prior to the first differentiation into ecological niches was a member of the Tropheini tribe. The Tropheini tribe was able to migrate throughout the rivers and lakes of East Africa (Kocher, 2004), providing evidence for the great dispersal ability of the ancestral

tribe and by extension the specific ancestor that gave rise to the mbuna clade. By contrast, current mbuna species are characterized by extreme philopatry (Danley and Kocher, 2001; Genner and Turner, 2005). Increased philopatry in present mbuna species argues for decreased gene flow overall. Therefore, the mbuna speciation validates the speciation engine by supporting the prediction that gene flow will decrease overall.

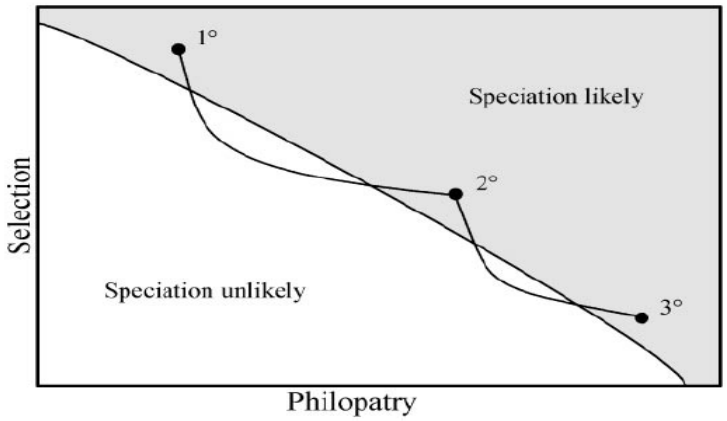

Fig. 5. Diagram of the relationship between selection, philopatry, and probability for speciation. As the degree of philopatry increases gene flow is reduced, consequently reducing the strength of selection required to overcome gene flow (Danley and Kocher, 2001). Figure taken from: Danley, P.; Kocher, T. (2001) Speciation in rapidly diverging systems: lessons from Lake Malawi. Molecular Ecology. 10, 1075-1086.

Decreasing Selection Pressure

Finally, the fourth prediction of the engine of speciation model predicts that selective pressures will also decrease overall. As the strength of selection at past speciation events can be difficult to determine, decreasing character complexity is used to argue a decrease in selective pressures (Danley and Kocher, 2001; Danley *et* al, 2000; Rice and Hostert, 1993). Decreasing character complexity is evidenced by the genetic architecture of involved traits over the course of the three radiations in the mbuna clade. In the first radiation, differentiation into ecological niches was characterized by the involvement of several seemingly unrelated traits, with body shape only resulting from a few genes with widespread effects alongside many genes of smaller effect (Albert *et al*, 2007). The involvement of many genes that likely possess limited linkage argues for a high degree of character complexity. In the second radiation, trophic specialization involved fewer related traits that showed evidence of linkage (Genner and Turner, 2005). In this radiation, genes from several pathways have been implicated as potential sources for trophic variation in mbuna (Albertson *et al*, 2005; Albertson and Kocher, 2006; Fraser *et al*, 2013; Gunter *et al*, 2013). Potential linkage between these genes, however, and the critical effects of *bmp4* specifically, argue a decrease in character complexity with regard to the first radiation. In the third radiation driven by sexual selection, the primary traits involved were female mating preferences and the male nuptial phenotypes from which females select (Danley and Kocher, 2001). A few genes have been shown to control female mating preference (Ding *et al*, 2014), male nuptial coloration (Barson *et al*, 2006),

and color perception (Carleton *et al*, 2008), and there is strong evidence for genetic hitchhiking when male and female coloration become linked to sex determining genes (Parnell and Streelman, 2013). The limited number and effect of these genes in conjunction with the potential for strong linkage demonstrate a decrease in character complexity with regard to trophic morphology. With a decrease in character complexity moving from each radiation, the speciation of the mbuna validates the speciation engine by supporting the prediction supporting the prediction that selection will decrease over time by providing evidence of decreasing character complexity.

Conclusions

What is the origin of species? Though the process of speciation may never be fully understood, the speciation engine model has contributed much to our theoretical understanding of how gene flow and selection interact to generate rapid speciation and pockets of extreme biodiversity. Unlike other hypotheses that provide incomplete explanations of speciation, the speciation engine provides a holistic description that integrates the many contexts and factors that, through an additive effect on selection strength or a reductive effect on gene flow, contribute to speciation. This model is particularly effective in its inclusion of non-adaptive evolution and support for sympatric speciation. By emphasizing patterns of gene flow and selection in its predictions, this model does not discriminate among factors that might contribute to speciation. Selection for a trait need not be adaptive to drive speciation, so long as some factor, like sensory exploitation or other sympatric phenomena, results in selection that is strong enough to overcome gene flow, which may be simultaneously reduced by an additional unrelated factor. Within this, the speciation engine demonstrates how sexual selection is able to generate extreme biodiversity by overcoming gene flow and fostering mating behaviors that create further isolation.

This model also gives resolution to why some lineages rapidly diverge while others do not by advocating variance in selection pressures. In contrast to the prolific speciation of East African cichlids, there are about 20 other families of fishes inhabiting the East African Great Lakes that have not diversified in rapid and diverse manner of the Cichlidae (Salzburger, 2008). This is likely because a unique combination of ecological factors and internal factors like life history or genetic architecture have created variance in selective pressures and required selection strength to overcome gene flow between cichlids and other families of fishes.

In sum, the speciation of cichlids in Lake Malawi, specifically the mbuna clade, serves to validate the speciation engine model as the nature of the selective pressures involved, reductions in selection and gene flow, and factors under selective pressure in this system coincide with the model's predictions. The cichlid model is an easy system through which to validate the predictions of the speciation engine because it is a well-studied taxa and speciation in the East African Great Lakes has been rapid and recent. However, other model taxa including Darwin's finches, exhibit some patterns of speciation that also serve to validate the predictions of this model. Future research should work to explore the predictions of speciation engine in other rapidly diverging model taxa.

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[STUDENT NAME REMOVED FOR PRIVACY REASONS]
Take Home CVA Final

The lifestyle of flight and its contingent challenges/ adaptations are often thought of as bird exclusive. However, flight is not species specific to just that group; mammals, specifically bats, also use flight as a means of locomotion, with their own set of adaptations. Adaptations that increase the feasibility of flight occur to the skeletal system, musculature system, integument system, and in tandem, the circulatory and respiratory systems. While adaptations occur in both species they are not identical and share only to a certain extent similarities within these adaptations. Speaking phylogentically, this makes sense as aves and mammals do not share a common ancestor (Kardong, 2014). While a common ancestor does not exist, common challenges emerge for both bats and birds as they attempt flight. The first is obviously gravity. In order to overcome this force, several adaptations must be made. Once the organism has become airborne, the next challenge involves reducing the amount of drag, so distances can be travelled. Overcoming both of these challenges is an incredibly energetically expensive activity, but through the muscular, skeletal, integument, and respiratory and circulatory adaptations in each organism these challenges are tackled allowing for an aerial means of locomotion.

All of the adaptations of varying organ systems in birds and bats are intertwined to make the organism highly adapted for flight; therefore there will be convergence between adaptations of differing organisms, and convergence within organisms, as an adaptation for one challenge may also be useful in overcoming another. Modifications to all of these systems work together to produce an organism adapted as best as possible to the demands of flight.

Birds utilize many adaptations to their skeletal, muscular, integument and respiratory and circulatory systems to allow for flight. Initially they must overcome the force that keeps all other terrestrial animal land locked: gravity. To overcome gravity birds must generate lift. Different parts of the previously mentioned systems have been adapted to ease the expense of generating lift. To generate lift the lower part of the wing deflects the air it meets down, which imparts upward momentum on the wing. The upward tilted wing also creates an area of negative pressure, pulling the wing up. This area of pressure can be controlled by the angle of attack of the wing at any given moment. The utilization of the angle of attack is a characteristic of an airfoil, in this case the cambered wing of the bird (Kardong, 2014). To generate lift the skeleton, muscular, and integument systems must be highly adapted to work in tandem, while the circulatory and respiratory system must be ready to supply oxygen to this energetically expensive activity.

The first system adapted is that of the skeleton. Before even considering how these bones are moved to generate lift, it is important to look at their construction. Birds' possess pneumatic bones, which aid their respiratory system, but also makes them lighter, because they are hollow. Birds' bones are also fused throughout the body. These fusions allow for fewer bones, making the birds generally lighter. This decrease in mass allows for less energy to be expended when attempting to

generate lift to overcome the force of gravity (Kardong, 2014). These bones lay down a structure on which muscles can be attached.

The muscles of the bird have been adapted so that the pectoral muscles are extremely developed, making up between 10%-25% of the birds body mass. The back muscles have been reduced, as they are not as essential to flying, and have the potential to weigh the bird down. The large pectoral muscle creates a downward thrust strong enough to over come the force of gravity (Bauchinger et al., 2011). To increase efficiency the bulk of the muscles in the wing are located proximally to the body. These shoulder muscles are used to generate force during the down stroke and the upstroke, combining with the power of the pectoral muscle to overcome gravity. The distal forelimb muscles also play a part in take off, a period of unsteadiness in flight. They are needed to modify the shape of the wing so that the leading edge of the wing is elevated above the body (Dial, 1992).

The muscles combine with the skeleton to create a beat cycle divided into four phases. The first is the upstroke-down stroke transition, the second is the down stroke, the third is the down stroke-upstroke transition, and the upstroke. During the upstroke-down stroke phase the wing is fully extended and is then forcefully brought down and forward. During the down stroke-upstroke phase, the motion reverses, lifting the wing up and back. The upstroke does not necessarily generate significant lift, but it does reposition the wing for successful lift generation by the down stroke (Kardong, 2014). The integument of birds is also important to the beat cycle. Primary feathers help to generate the forward thrust that occurs in the upstroke-down stroke phase. Secondary feathers help to provide general lift like those of an airplane wing (Kardong, 2014). The bones and the muscles of the chest, shoulder, and forearm work together with the feathers covering the wings to generate lift, allowing the bird to overcome the force of gravity.

Adaptations of the circulatory and respiratory system that work against the challenges of gravity and drag can be talked about together. In order to overcome both forces birds expend a great deal of energy. To make up for this expenditure, birds have adapted to become extremely efficient at extracting oxygen and moving it through their body, utilizing the respiratory and circulatory systems. Birds bring air in through aspiration, and distribute the oxygen using crosscurrent gas exchange. Crosscurrent exchange is considered the most efficient form of gas exchange, as a gradient between oxygenated and deoxygenated blood always exists. The airflow is also kept unidirectional and never mixes with any deoxygenated air, which would subsequently lower the oxygen concentration. Transitioning more towards the cardiovascular system the ventricular muscles of the birds' four chambered hearts are the strongest of all vertebrates, allowing even more efficient circulation of blood (Kardong, 2014). This rapid and efficient transfer of oxygen rich blood allows birds to readily keep up with the great energy expenditures generated from adaptations supporting flight.

Once birds have become airborne the goal is to travel forward against the force of drag. The goal of adaptations to this challenge is to make the bird as drag resistant as possible. Any organism that takes flight is susceptible to two categories of drag. The first, parasitic, is the organism's resistance to pass through a medium. This can be caused by profile drag due to the animal's shape, friction drag caused by

stress at the boundary layer, and pressure drag caused by the backflow in the wake. The second type of drag is induced, associated with lift (Kardong, 2014). Although lift must be generated for flight, it also increases overall drag.

As previously noted, the skeletal and muscular systems seem to work together to create adaptions for challenges faced by birds. The reduction of drag is no different. The cambered shape created by the bones of an airfoil, capable of changing its angle of attack, is essential to the reduction drag. Research conducted on the angle of attack showed a 25% increase of induced drag when the angle of attack was changed from zero degrees to fifteen degrees (Tucker, 1993). This shows the necessity of having bones in this formation and specialized muscles in the wings that can control this angle at a moments notice.

The integument plays a big role in the reduction of drag for birds. Contour feathers covering the body give it a streamlined shape that creates a laminar airflow reducing friction drag. The primary feathers located on the manus do more than help generate forward thrust. These feathers are also essential to the reduction of drag. These feathers are separated horizontally and vertically to form slotted tips, which can work to reduce induced drag. In an experiment a wing with a feathered tip reduced total drag by 12% compared to a hypothetical wing with feathers that were stationary against airflow. These slots allow smaller birds to mimic the higher span factors soaring birds such as gulls experience (Tucker, 1993).

It is apparent that birds are highly specialized for flight. However they are not the only organisms capable of this means of locomotion. Bats also use flight as their primary means of locomotion. They too have developed specific adaptations to their skeletal, muscular, integument, and respiratory and circulatory systems to overcome the challenges of flight. Although these adaptations have occurred in bats, they are by no means as specialized as those in birds.

In terms of circulatory and respiratory systems bats resemble other endothermic mammals. They have a four-chambered heart, which pumps blood using an efficient two pump system, however like other mammals they use the less efficient concurrent gas exchange system (Kardong, 2014). The major challenges of flight, overcoming gravity and reducing drag, obviously still exert a great energy expenditure on bats. However, bats do not seem to have become as adaptively specialized to deal with these challenges. That is not to say that this system does not work at all, bats have strong four chambered hearts they utilize a two-pump system to maintain blood velocity. While the circulatory and respiratory systems in bats does not seem to have adapted as well as in birds, adaptations have been rather successful in other systems. Adaptations to the skeletal, musculature, and integument systems seem to serve bats well as they too face the challenges of overcoming gravity and reducing drag.

Adaptations that overcome the challenges of gravity and drag are very closely related in bats. Therefore it is easier to talk about adaptations that overcome these challenges together. The adaptation of the skeletal system of the bat is actually the opposite of the adaptation found in birds. Rather than fuse bones to decrease the number and the subsequent weight, bats keep all digits traditionally found in the manus of a mammal and elongate them (Kardong, 2014). This elongation combined with flexibility of the joints in the wing most likely allows for increased control over

the wing. Birds' wings have a relatively fixed shape, while bats have much more control over the manipulation of their wings. This increase in manipulation means that bats can more easily change their angle of attack, which can aid in lift and decrease drag once the bat is airborne. The flexibility also allows the bat to move its wings to a position that decreases some of its parasitic drag. However, the muscles and bones that make up the skull, particularly the nose and ears increase drag incurred by the bat, while birds who have a more streamlined body do not have this same parasitic drag problem (Muijres, Johansson, Bowlin, Winter, & Hedenström, 2012).

Another difference between bat and bird adaptation can be seen in the muscles used to for take off; the initial moment when the force of gravity is overcome. Instead of having a strong pectoral and shoulder musculature, bats use the springy tendons connected to the triceps and bicep muscle to power lift off. This creates a strong down beat that propels them into the air. Once the bat is airborne it uses a similar four phase beat cycle, but the muscle used to generate the beat cycle are different from birds. Birds use just their large pectoralis major for the down stroke, while bats have adapted to use the pectoralis, deltoid, subscapularis, and serratus anterior (Leen & Novick, 1969). The integument covering these bones and muscles is also different. In terms of integument bats cover the spaces between their elongated digits with thin membranous skin. Unlike feathers this skin does not provide for slotting, which likely increases drag rather than decreasing it (Muijres, et al., 2012).

Overcoming gravity and decreasing drag are more complicated for bats as they do not appear to have developed as specialized adaptations for flight. While flight is obviously not reserved for only aves, they do appear to be the best adapted to the challenges of this form of locomotion (Muijres, et al., 2012). Both overcoming gravity and reducing drag are energetically expensive undertakings, without the aid of the skeletal, muscular, integument, and circulatory and respiratory system adaptations, birds would not have been able to become so specialized at flight. Another organism the bat, while also using flight as a primary method of locomotion, has not developed the same specialized adaptations. Although these two organisms do not share a direct common ancestor, the common lifestyle pressures associated with flight would seem to indicate similar adaptions would develop (Kardong, 2014). However this is not the case. It would appear that birds have successfully become the most specialized for flight. This probably speaks to why there are so many more airborne birds than airborne organisms of any other vertebrae group.

Resources

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Do convict cichlids (*Amatitlania nigrofasciata*) have personalities?

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INTRODUCTION

- **Personality: Individual differences in behavioral traits that are repeatable across time and sometimes across contexts [1]**
- **Commonly-studied trait is neophobia**
  - Unwillingness to approach novel objects
- **Neophobia may also be related to hormonal responsiveness to stress.**

Research Questions:

1. Do convict cichlids change their behavior in response to novelty (plasticity)?
2. Do convict cichlids exhibit repeatable individual differences in response to novelty (personality)?
3. How does response to novel objects relate to behavior in a novel environment?

MATERIALS AND METHODS

Housing/Care:
- Housed two fish to a 10 gallon tank, separated by a divider
- Fed on alternate days except during personality testing

Personality Testing:
- Open field test: Placed in novel tank
  Measure: hiding, exploration, inspection

Novel Object: Microcentrifuge tube with colored rocks inside

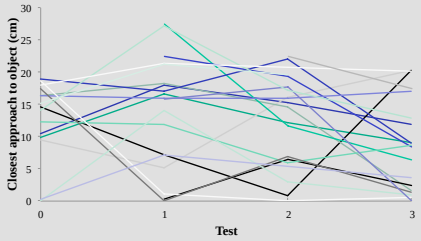
- Novel object tests-
  - Presentation of 3 novel objects with food in floating ring
  - Measure: feeding latency, approach distance, furthest distance

- **Data analysis**
  - Behavioral reaction norm approach using linear mixed models (LMM)
  - Principal components analysis (PCA) to examine relationship between novel object and open field behavio

Amatitlania nigrofasciata

RESULTS

Novel object tests



Graph 1: Behavioral reaction norms for closest approach to a novel object. Test 0 = no object; measured closest approach to a point on the feeding ring within 5 min.

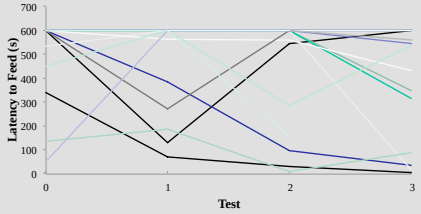
Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	18.657	95.865	.000
ObjectID	2	52.043	.760	.473
Obj#	2	52.165	2.600	.084
ObjectID * Obj#	4	63.639	.531	.713

Significant random effect of individual (personality):
-2dLL = 6.2, $p < 0.01$

Table 1: Test of fixed effects (plasticity)
Dependent variable-closest distance (cm)

*



Graph 2: Behavioral reaction norms for latency to feed when novel object presented in feeding ring. Test 0 = no object present. Test time = 600s.

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	22.756	309.590	.000
ObjectID	2	61.575	2.957	.054
Obj#	2	61.282	.083	.921
ObjectID * Obj#	4	72.965	2.512	.050

Significant random effect of individual (personality):
-2dLL = 10.8, $p < 0.01$

Table 2: Test of fixed effects (plasticity)
Dependent variable- latency to feed (s)

Relationship between response to novel objects and open field behavior

Structure Matrix

	Component 1	Component 2
furthest (cm)	-.078	.770
closest (cm)	-.082	-.793
Hiding (s)	-.989	.017
Inspecting (s)	.936	.052
Exploration (s)	.974	-.027

Extraction Method: Principal Component Analysis.
Rotation Method: Promax with Kaiser Normalization.

Table 1: Results of principal components analysis of novel object and open field data

Factor 1- related to behavior in open field test

Factor 2- related to behavior in novel object test

CONCLUSIONS

Yes, convict cichlids have personalities!

- Significant random effects of individual on:
  - Latency to feed
  - Closest approach to the novel object

Convict cichlids also change their behavior in response to novel objects

- Respond to object presence/absence
- Respond to object color
- Some evidence for differences in habituation

Response to novel objects ≠ exploratory behavior

Future Directions
- Is there a correlation between personality differences and hormonal stress response?
  - Evidence from other species suggests there should be!

Predator exposure test:

Collect water from beaker

Extract steroids with C16 cartridge

EIA for cortisol

ACKNOWLEDGEMENTS

We thank the biology program at Transylvania University for their constructive feedback on this project and poster. We also thank the members of the Fall 2013 BIO-3065 class for data collection and help with project design, especially Roshni Desai, Shanelle Grose, Melissa White, Alexis Carey, Casey Coomes, and Sarah Gardner. This work was supported through funding provided by the Transylvania University Biology Department. Poster printing, travel, and conference registration were provided by NSF-1257787 to D.F. Westneat and R. Fox.

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SCHOLARLY ACTIVITY IN SUPPORT OF TEACHING EXCELLENCE

SCHOLARLY ACTIVITY IN SUPPORT OF TEACHING EXCELLENCE

A.) Philosophy of Scholarship and Relationship to Pedagogy

One of my greatest frustrations as a postdoc at a large research university was the majority view of scholarship as privileged and teaching as secondary (and if possible, the domain of graduate students and specialized "teaching faculty" who were often treated as second-class citizens). This seemed somewhat backward to me, since most scientists will tell you that science is not a collection of facts to be memorized, but a way of thinking and learning about the world. As such, science scholarship and science pedagogy are inextricably intertwined. When I mentor students working on research projects (who are not only participating in the process of generating new knowledge, but are also learning biology via an apprenticeship model), the connection between science teaching and science scholarship is obvious. However, this connection does not end at the door of my lab!

Beyond giving me the ability to bring new discoveries and cutting-edge thinking into my classes, my scholarship informs a great deal of my approach to teaching, from the way in which I write homework and exam problems to the way in which I structure my lesson plans. The major impetus behind breaking up lecture with frequent breakout sessions for students to discuss thought questions in small groups was an attempt to replicate the give-and-take I have observed among my research students (and among my collaborator's graduate students) during discussions of journal articles in lab meetings.

I like to think that no matter whether I am in the classroom, doing research in the field, or interacting with students informally outside the classroom (and even when I'm on sabbatical), I am always teaching. My research and my pedagogy are almost inseparable, and I am constantly looking for new ways to bring my students into scientific conversation, from the very first moment of their very first biology class until the last day of senior seminar (and sometimes even after that, as some of my former students who are now in graduate school still come to me for advice and support). I can't imagine myself doing anything else, and I cannot think of a more rewarding vocation.

B.) Conference Attendance

With the exception of this past academic year, when the dates of my 'usual' national/international conferences (national meeting of the Animal Behavior Society, International Society for Behavioral Ecology biennial conference) coincided with the end of my field season in Kentucky and the beginning of my sabbatical in Arizona, I try to attend at least one national or international conference in my field per year. I also endeavor to take my current research students to (at minimum) a regional meeting like the IU Animal Behavior Conference in order to present their research. Often, at least some of my research students accompany me to and present at national meetings of the Animal Behavior Society at well.

From a pedagogical standpoint, regular attendance at scientific meetings has proven invaluable in terms of learning new approaches and techniques that I can use in my teaching. A few years ago at the Animal Behavior Society meeting, I attended a talk on a noninvasive method for measuring circulating steroid hormones like testosterone, estradiol, and cortisol in fish. This method sounded ideal for my Animal Physiology lab, and in fact it was - noninvasive measurement and manipulation of hormone levels in convict cichlid fish was one of the cornerstones of the student-driven labs for the last two iterations of the course. Similarly, these meetings provide an opportunity for conversations with colleagues teaching similar subjects. A conversation with a colleague over drinks about the best way to get students thinking about the relationship between evolution and anatomy led to my decision to conduct dissections in CVA organ system by organ system rather than taxon by taxon.

Conference attendance has also allowed me to receive mentorship from established teacher-scholars: Mike Noonan, a longtime professor at Canisius College and one of my recommenders, has been a mentor of mine since graduate school, and his advice and encouragement has been invaluable.

Student attendance at conferences is also quite useful for not just my research mentees, but for students in the biology major as a whole. For my mentees, conference presentations give them a goal to work toward with their research and provide them with avenues to showcase their work and network with peers as well as potential REU (research experiences for undergraduates) and/or graduate mentors. More than that, many of my students have said they find attending conferences to be perspective-altering: they have the opportunity to see the scientific process at work in the 'real world', they are exposed to new ideas and cutting-edge research that then inform their own research projects, and they feel empowered as scientists. A conversation at the IU Animal Behavior Conference in 2015 led my students Casey Coomes and Sarah Gardner to reanalyze their field data in a novel way, and what they found was interesting enough that they presented it as a poster at the national meeting of the Animal Behavior Society. Beyond direct benefits to my mentees, student attendance at meetings has beneficial effects in the classroom as well: students who have attended conferences often "pollinate" classes with their experience, whether it is relating interesting research they heard about, championing the benefits of really learning statistics, or helping their peers produce more professional poster or oral presentations.

C.) Research Focus, Collaborations and Related Student Work

On a more personal level, I find scholarly activity – from pursuing my own research to attending conferences to establishing new collaborations – to be deeply satisfying. My own research focuses on the behavioral and physiological ecology of "animal personalities." Over the last two decades, there has been an explosion of interest among ecologists, physiologists, and behavioral biologists in stable individual differences in behavioral characteristics in nonhuman animals, often referred to as "animal personalities." In the context of nonhuman animals, personality is typically defined as consistent individual differences in behavior that persist over time and in some cases across situations. The existence of personalities

has now been documented in over 100 species, ranging from primates and parrots to dumpling squid and a number of arthropods. In some cases, these personality traits have also been linked to hormonal or other physiological differences among individuals, suggesting that personality differences may be driven by underlying physiological or neurobiological mechanisms. Personality differences have also been linked to individual differences in survival and reproductive success (i.e., fitness) in many species. However, the patterns of linkage are complex and suggest that which personality type is most fit in a population may depend on the prevailing environmental conditions at the time. The fact that natural selection seems to maintain personality differences among individuals within populations poses a bit of a challenge for traditional optimality-based models of behavior, but it also may hold the key to answering questions such as why some individuals in a population are more likely to disperse (leave their natal habitat to breed elsewhere) than others, why some populations are better able than others to adapt to human-caused disruption of the environment, and why pairs consisting of two supposedly 'high quality' individuals sometimes have poor reproductive success.

I have been pursuing various aspects of the behavioral and physiological ecology of personality in birds, as well as the implications of personality for welfare in captive birds, since graduate school. At present, the central focus of my research is on individual differences in sensitivity to environmental variation, which I study using both captive and free-living House sparrows (*Passer domesticus*) and house finches (*Haemorhous mexicanus*) as a model species. Coping with both predictable and unpredictable variation in the environment (such as changes in weather, food availability, and the distributions of potential mates and predators) is one of the central challenges faced by any organism. Behavioral change in response to environmental perturbation, generally referred to as behavioral plasticity, is frequently mediated by glucocorticoid hormones (colloquially called stress hormones). Thus, individual differences in sensitivity to environmental change seem likely to be tied to individual differences in hormonal responsiveness to stressors and may also be related to individuals' ability to adapt to urban areas.

My research to date has primarily addressed four central issues *(1) Do house sparrows exhibit individual differences in sensitivity to environmental variation? (2) How are differences in sensitivity related to differences in hormonal responsiveness to novelty?, (3) Are these differences in sensitivity related to differences in responsiveness to offspring demand in free-living birds, and (4) what mechanisms underlie personality and physiological differences between urban and rural birds?* I also have a long-standing interest in the relationship among personality traits, pair behavioral compatibility, and reproductive success in monogamous birds, on which I published **a research article in 2014**, and which is currently the focus of a two-year field project on house sparrows by two students the in my lab, Gabby Martin and Heather Hamilton (currently seniors at Transy).

I have attacked my central research questions using a combination of lab and field studies. Working in collaboration with recent graduate Nur Ali, who is a co-author on the article currently in revision for submission to the Journal of Avian Biology, I found that house sparrows do indeed exhibit what we have termed an "environmental sensitivity syndrome," at least in captivity. Highly sensitive birds

exhibit high levels of neophobia (avoidance of novel stimuli), slow learning of a feeding task involving an initially unfamiliar object, high sensitivity to small changes in a previously-learned task, and high corticosterone responsiveness to novelty. On the other end of the continuum, birds exhibit low neophobia, rapid learning of the feeding task, low responsiveness to changes in the task, and low corticosterone responsiveness to novelty. These results suggest that House sparrows do in fact differ in sensitivity to changes in their environment, and that differences in hormonal responsiveness to stress may underlie this personality difference.

In collaboration with Dave Westneat at the University of Kentucky, I am also working on a series of experiments aimed at measuring differences in environmental sensitivity in free-living birds and relating these differences to individual differences in responsiveness to changes in offspring demand (measured using short-term manipulations of brood size). In August 2013, Dave and I were awarded a four-year **National Science Foundation grant (NSF-1257787)** to study the physiological underpinnings and fitness implications of individual differences in parental care in house sparrows. The grant was originally submitted and recommended for funding with Dave Westneat and myself as co-Principal Investigators. However, due to administrative issues relating to Transy's lack of an established Office of Sponsored Programs at the time, the grant was finally funded as an award to Dave with a $177,895 subcontract to Transy.

Dave and I and our respective students recently completed our third funded field season at UK's North Farm and are in the process of analyzing the behavioral and hormonal data from the brood size manipulation experiments conducted in 2014 with the intent of submitting a paper in the next year. Preliminary results of the fieldwork on the sensitivity syndrome, which I presented at the Animal Behavior Society meeting in Anchorage, Alaska this past June, suggest that free-living sparrows exhibit repeatable individual differences in neophobia. Over the last two field seasons, I have also collected behavioral and hormonal data that should enable us to determine whether free-living birds exhibit the rest of the sensitivity syndrome. These data were collected in collaboration with recent graduates Casey Coomes, Sarah Gardner, and Courtney Marshall, all of whom presented posters at the national meeting of the Animal Behavior Society in June 2015.

My current crop of undergraduate researchers (Heather Hamilton, Gabby Martin, Devin Rowe, and Lorin Martin) are continuing this work and have added a focus on the influence of parental behavior on offspring development to the mix. Heather, Gabby, and Devin all presented **posters** at the IU Animal Behavior meeting this past spring, and I am planning to have all of my students present their finished projects at the 2017 meeting of the Animal Behavior Society in Toronto.

D.) Benefits to Students

One of the most positive aspects this particular set of research projects, the location of our field site , and the fact that I am able to maintain a colony of sparrows on campus is that my research program is highly amenable to involving undergraduates. My students have had a very good track record in terms of Kenan grants: Casey Coomes ('15) received a Kenan in 2013 to develop a method for extracting and measuring stress hormones deposited in feathers, and Thomas Hirn

('16) received one in 2014 for work on the relationship among personality, stress, and immune function in captive House sparrows. This past summer Lorin Martin ('17) received a Kenan to look at the relationship between growth and immune function in House Sparrow nestlings. Rebecca Oliver ('14) also received a Kenan in 2013 to work with me on personality and the effects of stress on hippocampal size in House sparrows, but ended up turning it down because she was accepted to the Yale bioethics program for the same summer.

Additionally, my NSF funding with Dave Westneat has enabled me to fund 3-4 students each summer to do field research (Casey Coomes, Sarah Gardner, Courtney Marshall, and Clay Huffman during summer 2014; Gabby Martin, Heather Hamilton, Devin Rowe, and Chris Saldana during summer 2015, and Gabby Martin, Devin Rowe, and Heather Hamilton during summer 2016). Through this field research, Transy students have had the opportunity to interact with students and faculty from UK and other institutions, as well as to become involved in the sort of large-scale, long term field project that most students only read about in textbooks. In one summer alone "Team Sparrow" as a whole collected 700 blood samples for parentage analysis and hormones, banded more than 700 nestlings, and took 2000+ hours of video to monitor parental behavior, and Dave and his students have been collecting this sort of data at our site for the last 25 years! The benefits to students of participating in a project like this are huge, and not just in terms of bolstering their scientific resumes: they learn about scientific collaboration and the practical aspects of working as part of a big research group. They learn about the real-world importance of good communication and good recordkeeping, and about problem solving when things inevitably go wrong in the field.

E.) Sabbatical Research Focus and Pedagogical Goals

I am currently using the fall term of my sabbatical to do research in the lab of my colleague Kevin McGraw at Arizona State University. My project is focused on comparing risk-taking behavior in urban and rural house finches and testing several hypotheses about the mechanisms underlying the phenotypic differences between the two populations. I hope to establish a long-term collaboration with Kevin to look at geographic differences among house finch populations in the US and to do some comparative work between house finches and house sparrows to test hypotheses about behavioral adaptations to urbanization and invasion success.

Part of my purpose in taking this sabbatical is also pedagogical: Kevin is the long-time chair of SOLUR (School of Life Sciences Undergraduate Research) at ASU and has a truly outstanding track record of mentoring undergraduate researchers in his own laboratory. This sabbatical presents an opportunity for me to engage in conversations about best practices for supporting undergraduate research, to observe Kevin's strategies in action, and to develop ideas and action plans for my own lab. Additionally, I am able to attend a School of Life Sciences seminar series on Evidence-Based Teaching in STEM (which will hopefully allow me to add some new methods to my toolbox) and to be involved with the interdisciplinary Central Arizona Project Long Term Ecological Research (CAP-LTER) center, with the aim of developing modules in urban ecology for my current courses and eventually developing an entire Urban Ecology course.

RESEARCH ARTICLE

Personality Traits of Pair Members Predict Pair Compatibility and Reproductive Success in a Socially Monogamous Parrot Breeding in Captivity

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While pair behavioral compatibility seems to be a determinant of reproductive success in at least some species of monogamous birds, the specific factors underlying among-pair variation in behavioral compatibility remain poorly understood. However, recent research on the relationship between personality traits and reproductive success in several species of socially monogamous birds suggests that the fit between mates' personality traits might play a role in determining behavioral compatibility. To test this hypothesis, we used ten pairs formed by free choice from a captive population of cockatiels (*Nymphicus hollandicus*) to investigate whether personality ratings could be used to predict pair compatibility and reproductive success in pairs breeding for the first time. We found that pairs that ultimately hatched eggs paired disassortatively for agreeableness (an aggregate measure of social style which measures birds' tendency to be aggressive vs. gentle, submissive, and tolerant of others' behavior), and, as predicted, showed lower intrapair aggression and better coordination during incubation. Conversely, unsuccessful pairs paired assortatively for agreeableness, showed higher levels of intrapair aggression, and showed poorer coordination during incubation. Our results suggest that personality measurements may provide a useful adjunct to other information currently used in selecting mates for birds breeding in captivity. Zoo Biol. XX:XX–XX, 2014.

Keywords: personality; pair compatibility; reproductive success; parrot; Nymphicus hollandicus

INTRODUCTION

Captive propagation of relatively long-lived, socially monogamous birds (e.g., many psittacine species) can prove challenging for a variety of reasons [Yamamoto et al., 1989; Snyder et al., 1996]. Some causes of poor reproductive success in captive birds—such as infertility, inbreeding depression, and/or genetic incompatibility between mates [Lewis, 1990; Snyder et al., 1996; Neff and Pitcher, 2005; Pryke and Griffith, 2008] can be difficult to predict or control. In other cases reproductive difficulties may be alleviated by changing captive management practices [Millam et al., 1988; Myers et al., 1988]. However, not all cases of reproductive failure in birds breeding in captivity can be attributed to either explicitly genetic or physiological causes (e.g., infertility), or to management issues.

Several studies suggest that some of these unexplained cases of reproductive failure may be due to behavioral incompatibility between mates. Baltz [1998] demonstrated that reproductive success of force-paired Micronesian kingfishers (*Halcyon cinnamomina cinnamomina*) could be predicted based on 90 min of behavioral observation following the introduction of new pairs to an aviary. Furthermore, those pairs that exhibited a combination of low aggression and high nest activity were more likely to produce surviving offspring [Baltz, 1998]. Similar effects have also been seen in force-paired California condors in captivity (*Gymnogyps californianus*), in which pairs classified as incompatible based on behavioral observations were

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less able to coordinate parental care [Harvey et al., 2003]. Additionally pairs of cockatiels (*Nymphicus hollandicus*; a small, socially-monogamous Australian parrot) that exhibited higher levels of behavioral compatibility prior to breeding were also better able to synchronize incubation behavior and hatched a greater proportion of fertile eggs than less compatible pairs when breeding in captivity [Spoon et al., 2006].

Unfortunately, while variation in pair behavioral compatibility seems to account for some instances of differential reproductive success among pairs of captive birds—and likely wild birds as well—the factors that might underlie this variation remain poorly studied. However, the results of the handful of studies that have investigated the relationship between behavioral similarity between mates and reproductive success suggest that the mix of behavioral traits within a pair might influence pair behavioral compatibility [e.g., Both et al., 2005; Schuett et al., 2010; Gabriel and Black, 2012]. At least in some years, pairs of wild Steller's jays (*Cyanocitta stelleri*) in which partners were more similar in risk-taking behavior and willingness to explore initiated nests sooner and were more likely to fledge offspring than less-similar pairs [Gabriel and Black, 2012]. Assortative pairing for behavioral characteristics has also been shown to positively influence offspring condition in wild great tits (*Parus major*) [Both et al., 2005]. Similarly, captive pairs of zebra finches (*Taenopygia guttata*) in which mates were more closely matched with regard to exploratory behavior reared chicks that scored higher on measures of body condition [Schuett et al., 2011] than the offspring of less closely matched pairs.

Both risk-taking and exploratory behavior have been shown to be repeatable in a variety of avian and non-avian species, as have a number of other behavioral traits [c.f. Bell et al., 2009]. In nonhuman animals, behavioral traits that vary among individuals and are repeatable over time and across at least some situations within individuals are often referred to as "personality" or "temperament" [e.g., Gosling, 1999], and have been shown to affect welfare in captivity [e.g., Weiss et al., 2006] as well as fitness in the wild [c.f. Smith and Blumstein, 2008]. Accordingly, the assessment of personality traits has been proposed as a captive management tool in zoos [e.g., Gold and Maple, 1994; Wielebnowski, 1999; Freeman et al., 2004; see commentary by Watters and Powell, 2012]. Of greater relevance to the present study, personality traits (which are by definition stable over time) seem more likely than more labile behavioral characteristics to influence behavioral compatibility within pairs in a consistent manner. We propose that the mix of personality traits within a pair may predict behavioral compatibility between mates and reproductive success.

A variety of techniques are used to measure personality in nonhuman animals. Behavioral ecologists tend to favor direct measurement of one or a few stable behavioral indicators of personality type, such as exploration a novel environment, latency to investigate novel objects, or aggression toward conspecifics [e.g., Colleter and Brown, 2011; Miranda et al., 2013; Verbeek et al., 1994]. Such measures have been shown predict individual variation in ecologically-relevant behaviors such as dispersal and antipredator behavior, as well as variation in fitness [Dingemanse et al., 2003; Quinn and Cresswell, 2005; c.f. Smith and Blumstein, 2008]. On the other hand, researchers interested in the behavior of domestic animals, captive primates, or animals in zoological settings often use questionnaire-based instruments in which keepers and others familiar with the animals whose personality traits are to be measured rate the animals on a variety of behavioral descriptors (such as "curious" and "confident") using a Likert scale [e.g., Horse Personality Questionnaire, Lloyd et al., 2007; Gorilla Behavior Index, Gold and Maple, 1994; Dog Mentality Assessment, Svartberg and Forkman, 2002; Cockatiel Personality Index (CPI), Fox and Millam, 2010]. Such instruments have the advantage of capturing a broad range of behaviors without requiring hours of direct focal observation, can be completed by animal-care personnel, and at least in the case of the CPI, personality scores show significant correlations with direct, quantitative measurements of behavior [Fox and Millam, 2010].

The goal of the present study was to determine whether personality measurement using a questionnaire-based instrument (the CPI) could be used to predict behavioral compatibility and reproductive success in captive pairs of cockatiels. Cockatiels (*N. hollandicus*) were chosen as our model species for several reasons. First, we had already developed and tested an instrument—the CPI—for measuring personality in this species [Fox and Millam, 2010]. Second, cockatiels breeding in captivity have been shown to exhibit among-pair variation in behavioral compatibility, even when pairs are formed under free-choice conditions [Spoon et al., 2004], and this variation in behavioral compatibility has been shown to predict reproductive success [Spoon et al., 2006]. Finally, in terms of reproductive behaviors—long-term pairing, shared incubation, and biparental care of offspring [Spoon et al., 2004; 2006]—cockatiels are hardly unique among either parrots in particular or socially monogamous birds in general, so it may be possible to apply the results of the present study to other species, at least qualitatively if not quantitatively.

METHODS

Subjects

Subjects were 10 pairs of cockatiels originally formed by free mate choice in small groups of 8 males and 8 females in a 4 m × 2 m × 1 m indoor aviary. One male and one female that failed to pair in the first free-choice group were used in the second group, so a total of 15 pairs could possibly have formed. These 10 pairs were the only pairs that formed during free-choice pairing; the remaining five males and five females remained unpaired according to our criteria. Pairs were

initially identified based on the extent of proximity maintenance between males and females [i.e., paired birds spent more time within 0.5 m of one another than either pair member spent with any other opposite-sex conspecifics; after Spoon et al., 2004] and were considered stable once both pair members began directing pair-maintenance behaviors—allopreening, proximity maintenance, copulation, and copulation solicitations—primarily, and generally exclusively, toward one another. We considered the pair formation period to have ended once all identified pairs in the aviary had been stable for at least 2 weeks and no new pairs appeared to be forming. The end of pair formation took from 3 to 5 months. This appears to be typical for captive cockatiels in a free-choice situation [Spoon et al., 2004].

All birds were sexually mature (age $\sim$ 1–3 years) and reproductively naïve at the beginning of the study in order to prevent the potential effects of personality on mate choice from being confounded with the effects of prior experience. Prior to introduction into the aviary for mate choice, all birds had also been rated by at least two (and generally three) experienced observers using the cockatiel personality instrument described below [see also Fox and Millam, 2010]. During the rating period, birds were housed in small social groups of 2–3 individuals.

Cockatiel Personality Instrument

The Cockatiel Personality Instrument (CPI) used in this study was the instrument described in Fox and Millam [2010]. In constructing the scale, three independent observers observed 62 young cockatiels for 135 min each (9 sessions of 15 min focal observation), after which each observer rated each bird on 44 adjectives which scored on a seven-point Likert scale [see Fox and Millam, 2010 for the full list of adjectives]. Observers also had the option to mark "not enough information to rate," which was scored as 0 on the assumption that the observers lacked information because they had never observed the animal engaging in the relevant behaviors. The decision of which of the 44 adjectives to retain for the final instrument was based on inter-observer agreement and inter-observer reliability: adjectives retained had to demonstrate both significant inter-rater agreement and moderate or better ($\rho^* \geq 0.37$) inter-rater reliability [Fox and Millam, 2010]. Agreement and reliability values for each of the items considered for inclusion in the CPI is published in Fox and Millam [2010]. The final CPI consisted of eleven adjectives that were scored on the same seven-point Likert scale. Each adjective on the CPI was followed by a brief explanation of the meaning of the adjective [Fox and Millam, 2010; see Table 1].

Scores for each adjective were averaged across observers and then summarized using Fox and Millam's [2010] factor loadings (see Table 1). Average adjective scores within a factor were converted to *Z*-scores based on the entire population of cockatiels that had been rated to date (68 birds), and added to give a total factor score. Adjective scores that loaded negatively on a factor were reverse-coded before scores were calculated. These factor scores were used in all subsequent analyses. Each bird was thus scored on three separate personality factors: agreeableness, boldness, and affiliativeness.

Personality trait structure did not differ between the subsample of 20 birds used for this study and the full population of rated birds (68). Within our sample, Cronbach's α—a measure of internal consistency—for the agreeableness, boldness, and affiliativeness scales was 0.94, 0.89, and 0.92, respectively (as compared to 0.91, 0.90, and 0.89 in the full population).

Raters

Raters consisted of one of the authors (R.A.F.) as well as several undergraduate students who had each spent a total of 135 min spread over 9 days conducting focal behavioral observations of each individual to be rated prior to completing the CPI. As raters had spent a substantial amount of time observing the birds, they were assumed to have sufficient familiarity with individuals to rate them. Each bird

TABLE 1. Cockatiel personality inventory

AGREEABLE
(−) **Aggressive**—Causes harm or potential harm, high frequency of aggressive behaviors.
(+) **Gentle**—Responds to others in an easy-going, kind, considerate manner. Is not rough or threatening.
(+) **Submissive**—Appeasing or acquiescing to others. Gives in readily to conspecifics
(+) **Tolerant**—Permits other animals to make contact or interact in close proximity.
BOLD
(+) **Daring**—Is not restrained or tentative. Not timid, shy, or coy.
(+) **Confident**—Behaves in a positive, assured manner.
(+) **Curious**—Readily explores new situations, seeks out or investigates novel situations.
(−) **Fearful**—Retreats readily from others or from outside disturbances or novel objects, shows fearful behaviors.
(−) **Insecure**—Hesitates to act alone. Seeks reassurance from others.
AFFILIATIVE
(+) **Sociable**—Appears to like the company of others.
(+) **Warm**—Seeks or elicits bodily closeness, touching, grooming.

Scales for the three personality factors (Agreeableness, Boldness, Affiliativeness) are given, along with the definitions of each scale item. Factor loadings (positive or negative) are given in parentheses. Factor loadings and their sign are taken from Fox and Millam [2010].

was rated by at least two independent observers, and generally by three.

Measurement of Pair Behavioral Compatibility

As Spoon et al. [2006] showed that cockatiel pairs that were more behaviorally compatible had lower rates of intrapair aggression, intrapair conflict was used as a proxy for behavioral incompatibility. Prior to removal from the aviary, each pair was observed seven times for 20 min per session over a period of 2 weeks (a total of 140 min. observation per pair). For each pair, we recorded the number of bill-thrusts, bites, chases, intra-pair fights, and flying attacks that pair members directed at one another during the observation period [see Fox and Millam, 2010 for ethogram]. The sum of all instances of intrapair aggression across the 140 min of observation (hereafter referred to as "total intrapair aggression") was used for statistical analyses. All observational data were collected using The Observer 5.0 (Noldus Information Technology, Wageningen, The Netherlands).

Breeding Trials

Following pair identification and behavioral observation, each pair was removed from the aviary and housed separately in a 0.5 m × 0.5 m × 0.3 m battery-style cage with access to a stainless-steel nestbox lined with wood shavings. Pairs were maintained on long-day photoperiod (15L:9D) to stimulate breeding behavior and provided with ad lib access to a diet formulated for breeding parrots (Roudybush breeder diet, Roudybush, Inc., Woodland, CA) and water, as well as with several enrichment objects that were rotated periodically. Nestboxes were checked daily for new eggs and hatchlings. When there were hatchlings were present in the nestbox, the shavings were changed several times weekly.

Because all pairs were inexperienced, pairs that failed to successfully hatch eggs during a first breeding attempt (i.e., none of their eggs hatched after 28 days) were allowed to lay and incubate least one more clutch before being classified as unsuccessful.

Measurement of Incubation Behavior

We observed incubation behavior in each of the 10 pairs by videotaping the interior of each pair's nestbox for 8 hr once at the approximate midpoint of the incubation period of each clutch (incubation in cockatiels lasts ~18–21 day). We scored nest attendance for both the male and the female via continuous observation of both individuals during this 8 hr period. We recorded the total time each individual spent inside and outside the nestbox. Because coloration is sexually dimorphic in wild-type cockatiels (males have yellow heads and females have gray heads), males and females were easy to distinguish. We scored video from either the last clutch incubated (in unsuccessful pairs) or the first successful clutch (in the case of pairs that successfully hatched eggs).

We were interested in coordination of incubation activities, therefore pairs were observed during the light hours only as nest attendance does not change at night [the female alone incubates at night; Spoon et al., 2006]. Miniature cameras equipped with infrared LEDs were used to videotape birds on the nest (NightOwl Night Vision Cameras, Windy City Parrot, Chicago, IL). We excluded from the analysis one pair that laid, but failed to incubate, two partial clutches of eggs.

Statistical Analyses

Pairs that successfully hatched at least one egg during the breeding trials were considered reproductively successful, and pairs that failed to hatch any eggs were considered unsuccessful. Egg breakout at the end of the incubation period suggested that reproductive failure in unsuccessful pairs was not due to infertility [Fox and Millam, unpublished data].

We compared total intrapair aggression [an indicator of pair incompatibility; e.g., Baltz, 1998; Spoon et al., 2004] and the amount of time that either both members or neither member of the pair were incubating. Pair overlap in the nestbox and nestbox vacancy were considered to be indicators of poor coordination of incubation behavior between mates [e.g., Spoon et al., 2007]. We analyzed the data using Mann–Whitney *U*-tests.

To examine whether the relationship between mates' personality traits (as measured by the CPI) differed between successful and unsuccessful pairs, we calculated the correlation coefficient (r) between females' factor scores and their mates' scores on the same factor separately for successful and unsuccessful pairs. We then used the Fisher r-to-Z transformation to determine whether any difference in correlation coefficients for mates' scores on a particular factor was statistically significant.

Ethical note: All experiments were carried out under Animal Care Protocol #11386, approved by the University of California, Davis Institutional Animal Care and Use Committee, and conformed to ABS and ASAB guidelines for the ethical treatment of animals.

RESULTS

Intrapair Aggression Prior to Breeding

While birds were still housed in the large aviary prior to breeding trials, we observed significantly lower levels of total intrapair aggression in pairs that were ultimately successful ($n = 6$) than in unsuccessful pairs ($n = 4$) (two-tailed Mann–Whitney U-test, $n_1 = 6$, $n_2 = 4$, $U = 22.5$, $P = 0.02$; Fig. 1).

Coordination of Incubation Behavior

While unsuccessful pairs did not differ significantly from successful pairs with regard to the total duration of pair

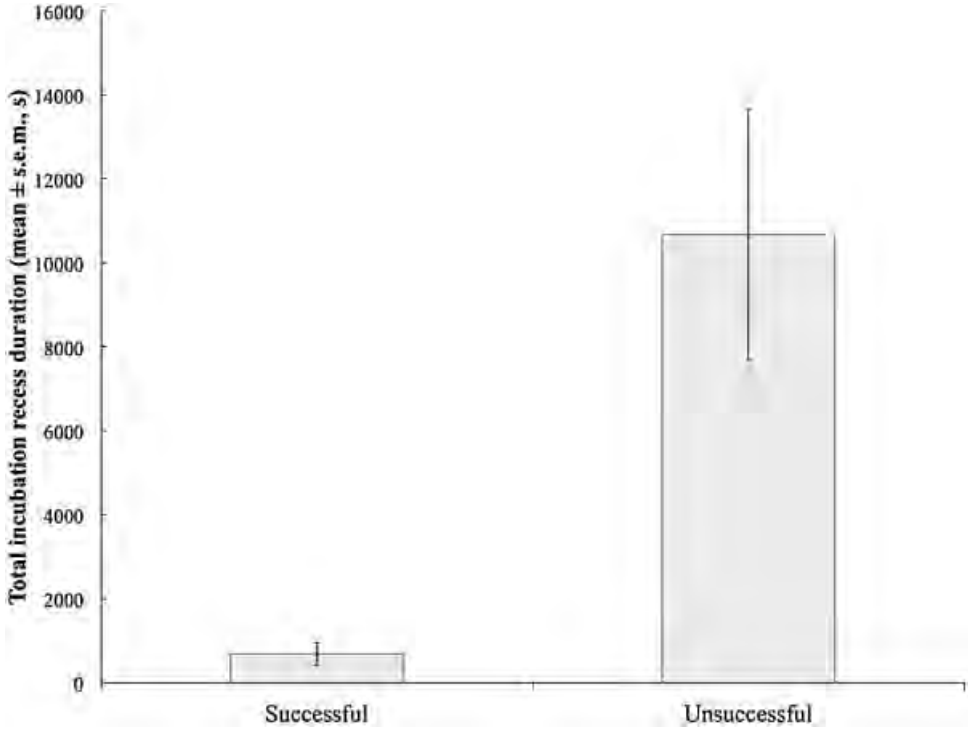

Fig. 1. During 140 min of focal observation prior to breeding, pairs that ultimately successfully hatched eggs exhibited, on average, significantly fewer instances of intrapair aggression than did pairs that failed to successfully hatch eggs, suggesting that successful pairs were more behaviorally compatible.

overlap in the nestbox (two-tailed Mann–Whitney U-test, $n_1 = 6$, $n_2 = 3$, $U = 11.0$, $P = 0.71$), unsuccessful pairs left their eggs uncovered for significantly longer than successful pairs (two-tailed Mann–Whitney U-test, $n_1 = 6$, $n_2 = 3$, $U = 18.0$, $P = 0.02$; Fig. 2).

Relationship Between Mates' Personality Scores

Neither successful nor unsuccessful pairs exhibited a significant correlation between mates' scores on either boldness (successful: $r = 0.37$, $t_4 = 0.81$, $P = 0.47$; unsuccessful: $r = 0.40$, $t_2 = 0.62$, $P = 0.60$) or affiliativeness (successful: $r = -0.37$, $t_4 = -0.79$, $P = 0.47$; unsuccessful: $r = 0.18$, $t_2 = 0.26$, $P = 0.82$). The difference between the correlation coefficients for mate agreeableness in successful and unsuccessful pairs was also not significantly different (Fisher's r-to-Z transformation, $Z = -0.49$, $P = 0.64$). However, mates' agreeableness scores were strongly negatively correlated in pairs that were ultimately successful ($r = -0.84$, $t_4 = -3.06$, $P = 0.04$) and strongly positively correlated pairs that were ultimately unsuccessful ($r = 0.97$, $t_3 = 5.66$, $P = 0.03$) (see Fig. 3). The difference between these correlation coefficients was significant (Fisher's r-to-Z transformation, $Z = -2.87$, $P < 0.01$). The strength of the correlation between mates' agreeableness scores in unsuccessful pairs persisted when the pair of highly-agreeable birds that failed to incubate their eggs was removed from the data ($r = 0.81$, $t_2 = 1.38$, $P = 0.40$), although the correlation was no longer significant owing to small sample size.

DISCUSSION

Consistent with the results of Spoon et al. [2007], we found that pairs of cockatiels that successfully hatched offspring exhibited lower levels of intrapair aggression prior to breeding and were better able to coordinate incubation behavior during breeding trials. Our results support the notion that pair behavioral compatibility is associated with improved reproductive success in captivity [Baltz, 1998; Harvey et al., 2003; Spoon et al., 2006].

We also found that the relationship between mates' personality traits differed significantly between successful and unsuccessful pairs. Birds that ultimately bred successfully paired disassortatively for agreeableness score (i.e., more agreeable females paired with less agreeable males and vice-versa), while birds that failed to breed successfully paired assortatively for agreeableness score. Additionally, it is possible that similarity in affiliativeness score might also have influenced pair compatibility. Correlations between mates' affiliativeness scores were moderate and in opposite directions in successful and unsuccessful pairs. Furthermore, because there is a moderate and statistically significant correlation between affiliativeness and agreeableness in the larger sample of birds used to develop the CPI ($r = 0.38$,

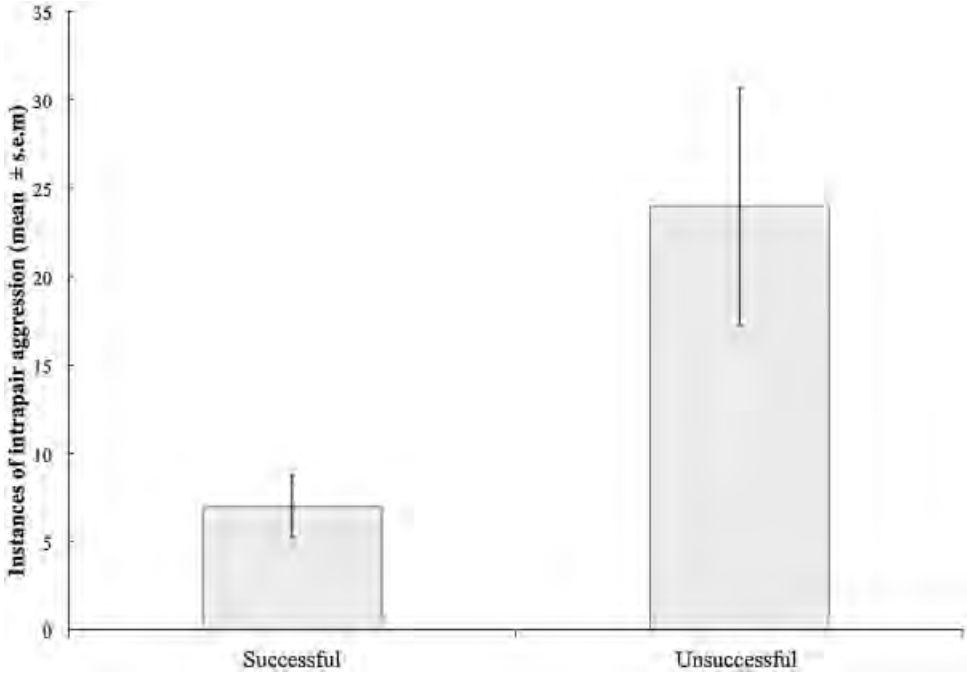

Fig. 2. At the approximate midpoint of the incubation period, successful pairs had significantly shorter total incubation recess durations (i.e., the total amount of time when neither member of the pair was incubating) than did unsuccessful pairs. Pairs were videotaped for 8 hr during the light hours of the photoperiod.

$t_{66} = 3.35$, $P < 0.01$; Fox and Millam, unpublished data), these variables may also be partially confounded. Thus, the hypothesis that disassortative pairing for affiliativeness could also increase pair behavioral compatibility should be tested in a larger sample of birds.

However, while it is possible that boldness played a role in mate choice, is unlikely to have influenced compatibility since the correlation between mates' boldness scores is approximately the same size and in the same direction in both successful and unsuccessful pairs. It also seems clear that the positive relationship between mates' agreeableness scores in unsuccessful pairs was not driven by the presence of a pair of highly agreeable individuals in that sample, as it persists when these individuals are removed from the analysis. Additionally, as birds were rated before they were introduced into the aviary to choose mates, these correlations cannot be attributed to convergence (or lack thereof) between mates' personality scores after pairing.

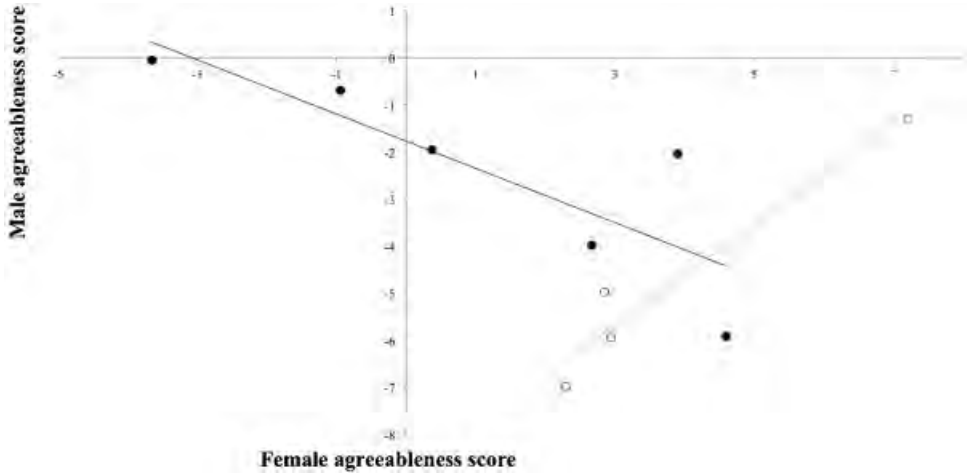

Fig. 3. Birds that ultimately hatched eggs successfully (closed circles) paired disassortatively for agreeableness, while those that failed to hatch eggs (open circles) paired assortatively. Agreeableness is a measure of social "style," and birds were rated for agreeableness prior to pairing using the Cockatiel Personality Instrument [Fox and Millam, 2010].

In several studies using exploratory behavior as the index of individual personality, similarity between partners may be associated with increased behavioral synchrony or hormonal compatibility [Steller's jays: Gabriel and Black, 2012; Zebra finches: Royle et al., 2010; Schuett et al., 2011] However, in the case of agreeableness, it seems reasonable to suggest that disassortative pairing for agreeableness scores may limit intrapair aggression and promote compatibility. Certainly, in agreement with Spoon et al. [2006], unsuccessful pairs—which paired assortatively for agreeableness—showed significantly higher levels of intrapair aggression than successful pairs. Additionally, birds with higher agreeableness scores exhibit significantly fewer aggressive behaviors towards flockmates than individuals scoring lower on agreeableness [Fox and Millam, 2010]. Thus, it seems easy to see how the highest levels of intrapair aggression might be seen in pairs of birds which both score low on agreeableness. It seems more difficult to understand why a pair containing two individuals with high agreeableness scores might not be reproductively successful. However, assortative pairing between two highly agreeable birds may be associated with other difficulties with reproductive behavior or parental care. While the unsuccessful pair containing the two highly agreeable individuals had low levels of total intrapair aggression, this pair also completely failed to incubate their eggs.

CONCLUSIONS

1. Consistent with the results of several other correlational studies [Both et al., 2005; Schuett et al., 2011; Gabriel and Black, 2012], our findings suggest that the combination of personality traits within a pair can predict reproductive outcomes in pairs of socially monogamous birds, possibly mediated by effects on pair behavioral compatibility.
2. Dissimilarity in agreeableness (a measure of social "style") between mates predicts pair compatibility and reproductive success in cockatiels, possibly because this personality trait mismatch limits intrapair conflict. However, a force-pairing study would be necessary to establish a causal relationship between personality dissimilarity and pair compatibility.
3. Furthermore, this study suggests that personality ratings using a questionnaire-based instrument like the CPI may provide a useful adjunct to other information currently used in selecting potential mates for birds in captive-breeding situations and for understanding cases of reproductive failure that are unrelated to infertility or genetic incompatibility.

ACKNOWLEDGMENTS

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Collaborative Research: Parental care and the integration of personality and plasticity at multiple levels of phenotypic variance

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I. Background

Many phenotypes vary and this variance has a hierarchical structure, with differences occurring between taxa, between individuals within species, and for some phenotypes, between instances within individuals (50). This structure has been vitally important; the most successful hypothesis explaining differences between species, Darwin's evolution by natural selection, requires between-individual variance to operate (39); variation at one level is thus integral to a process producing variation at another level. Other examples of this occur. Within-individual variation can occur in response to variation in an environmental factor and it constitutes phenotypic plasticity (16, 48, 106B, 123). Plasticity also affects variance at other levels. For example, plasticity may contribute to between-individual variation if differences in the environment experienced during development produce different phenotypes despite similar reaction norms (34). In addition, the within-individual effect of environment (plasticity) can differ between individuals (or genotypes) (e.g., I x E or G x E; 48, 102). Again, these levels are linked: individual variation in plasticity is necessary for differences in plasticity between populations to evolve. Each of these levels (between species, between individuals, and within-individuals) is thus integrated by fundamentally important biological processes, and nearly all current work on phenotypic variation occurs at one or more of these levels. Our main objective here is to describe some additional and mostly uninvestigated elements of the hierarchical structure of phenotypic variance and to propose tests of alternative hypotheses about their biology.

We focus on variation within a species and present a simple equation (9) to illustrate our approach. Phenotype (*Y*), measured in individual *j* and instance *i* fits the following equation:

$$Y_{ij} = (\beta_0 + ind_{0j}) + (\beta_1 + ind_{1j})X_{ij} + e_{0ij} \quad (1)$$

whereby β_0 is the overall mean phenotype in the population and ind_{0j} represents the deviation of each individual from β_0. The term β_1 describes how the phenotype changes, averaged over all individuals, with changes in an environmental factor (X), and ind_{1j} describes individual deviance in slope from β_1. The final term, e_{0ij}, contains residual variance.

Behavior is an example of a phenotypic attribute that fits this equation particularly well. It varies in two ways that provide unique opportunities to enhance understanding of hierarchical patterns of phenotypic variance and their complexities. First, many behavioral traits vary from instance to instance within the same individual. If such variation is predictable with differences in environment, then it is plasticity (16, 102, 106B, 123). Thus β_1 describes the average plasticity in a population. At some level, all behavior shows population plasticity. The term β_1 can evolve if there is between-individual variation in the extent of plasticity (i.e., significant ind_{1j}), yet despite the importance of individual variation in plasticity to understanding the evolution of behavior, remarkably few studies of behavior in free-living subjects have measured variation in plasticity or investigated the underlying mechanisms that produce it.

Behavior also shows repeatability (12, 33), which means that individuals differ (e.g., there is significant ind_{0j}, 34, 102, 148). When the differences between individuals are relatively stable, they are called personality (28, 113, 130B). Considerable effort has been devoted to understanding the functional consequences and developmental causes

of personality in animals (e.g., 113). These studies have elaborated some aspects of equation 1, but some important elements have been ignored.

One that is of critical importance is that the terms ind_{0j} and ind_{1j} may covary (e.g., 34, 89, 148) as is illustrated in Figure 1 & 2A. This covariance means that personality and plasticity are integrated phenomena (148). It also raises questions about the underlying biology producing the covariance. We explore this in more detail below using parental care as the focal behavior.

Second, most researchers ignore the residual variance term (e_{0ij}) in equation 1 (but see 29, 136). We argue here that e_{0ij} contains important biology with links to other levels of phenotypic variance. Residual variance might differ from one individual to the next (Fig. 1), in which case we might call this a personality axis, with some individuals being "variance-prone" and others "variance-averse" (112). The residual term might also vary systematically with the environment (Fig. 1), in which case residual variance (variance proneness) may exhibit plasticity (e.g., 23, 24, 25, 63), a phenomenon predicted by Stephens' (137) shortfall-avoidance hypothesis. Finally, there could be complex covariances within and between levels (as in Fig. 1 in which individual residual variance, $ind_{\sigma j}$, covaries negatively with individual intercept, ind_{0j}). These patterns of variances and covariances may reflect trade-offs, constraints, or adaptive complexes of related traits. A few studies have investigated residual variance in behavior (96, 136, 153) but none have examined individual differences or the links between the patterns of residual variance and other levels in the hierarchy of variance.

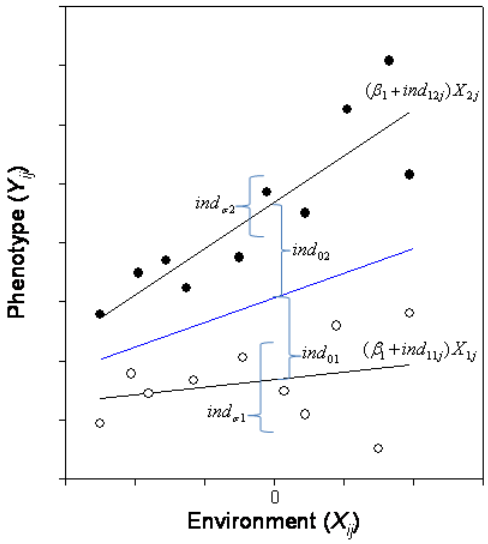


Figure 1. Graphical depiction of equation (1) applied to hypothetical data from two individuals. The solid blue line represents an average reaction norm with β_0 the intercept (at the mean environment, X_{ij} = 0) and β_1 the mean slope over environmental factor X_{ij}. The two individuals deviate from the population intercept (ind_{01} and ind_{02}) and they differ in slopes (black lines, ind_{11} and ind_{12}). Also, the individual with the larger intercept has a steeper slope, hinting at a positive covariance between intercept and slope. The two individuals also differ in mean residual variance indicated by brackets labelled $ind_{\sigma 1}$ and $ind_{\sigma 2}$. Finally, the residual variance changes with X_{ij} and does so more in individual 1 which also has a larger mean residual variance. Moreover, individual 2 has a larger intercept and a smaller residual variance, indicating a negative covariance across these levels.

Parental behavior as a model trait

Parental behavior is a labile trait that is predicted to be shaped by trade-offs either concurrently or through residual reproductive value (30, 61, 74, 154, 157). Theory about parental care is well supported at several levels of phenotypic variance. Differences between species in parental care correlate with differences in the value of care to offspring and the potential impact of care on the parent's ability to reproduce again (13, 30). Experiments within species confirm that parents exhibit plasticity in response to

changes in the number of offspring (35, 101, 163), the work load of a partner (59, 164), or the effort or risk required to provide care (e.g., 38, 41).

There are two important gaps in our understanding of parental care. First, there has been little integration of between-individual and within-individual variance in parenting. Studies of repeatability of parental behavior (44, 49, 99, 127) have not explicitly included plasticity in their analysis. Similarly, plasticity evolves when it varies among individuals, but despite the importance of plasticity in parental care theory, only two studies to date have tested for and found individual variation in plasticity (72, 148). Westneat et al. (148) analyzed provisioning rate in house sparrows and found that individual differences in feeds/hr positively covaried with within-individual plasticity (change in feeds/hr) in response to increasing nestling age (Figure 2A). This covariance must have a biological basis and its existence profoundly shapes our thinking about the integration of personality and plasticity. For example, one explanation for this covariance is that it stems from individual differences in the maximum provisioning achievable (quality or state, 89); i.e., differences in an individually-stable attribute (i.e., personality) limit plasticity (Figure 2B). Alternatively, the covariance could arise from individual differences in the ability to assess changes in nestling condition or aspects of the environment. Individuals who are slow to assess such changes will show shallower reaction norms and, by mathematical necessity, smaller intercepts. In other words, individual differences in plasticity could drive personality. Which one is correct has implications for understanding how between- and within-individual variance evolves. In this proposal we describe a test of these alternative hypotheses.

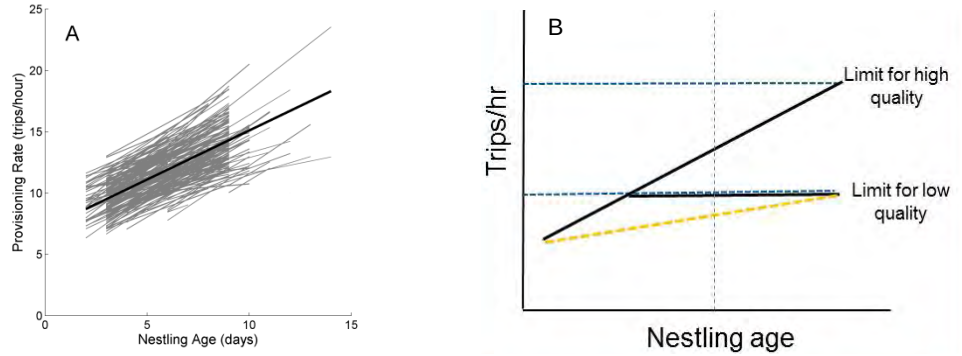


Figure 2. Effect of nestling age on provisioning reaction norms. A) Reaction norms of individual house sparrows with respect to nestling age (from ref. 148). Lines were extracted from multiple observations of known individuals across broods and time within broods. B) Graphical illustration of the quality hypothesis; that is, how differences in parent's maximum ability ("quality") could impact reaction norm shape with respect to nestling age, producing the spreading out of reaction norms seen in (A). An assumption is that nestling demand increases with age (165). The bolded lines are the change in provisioning with nestling age, and the yellow dashed line is the inferred reaction norm resulting from linear mixed model analysis of data collected from a low quality individual. A mix of high and low quality individuals would produce the "fanning-out" of reaction norms (with slope and intercept covarying positively).

Second, many studies of parental behavior only explain a small fraction of the total variance (72, 86, 148, 158, 167, 170). Stochasticity in resources is a likely cause (103). Optimal foraging theory in stochastic environments predicts that when mean intake rates fall below subsistence, individuals should switch to foraging in more variable

habitats (91, 92, 137). This same logic can be applied to parental behavior (170, 171) and there is some support for doing so. Two studies manipulated offspring demand and found that parents altered where they collected food (96, 153). This affected both the mean delivery of food to the nest as well as its variance. However, changes in variance could be either a byproduct of a decision based on mean delivery, or one based directly on differences in variance. Studies of the possibility that foragers do assess variance *per se* have produced conflicting results, although this depends in part on which aspects of foraging are variable (66). Nearly all of these have been done in highly artificial settings, but in an experiment with free-living subjects performing a controlled but natural foraging task, Ratikainen et al. (112) found strong evidence of variance sensitivity. Whether parents foraging for offspring are similarly sensitive to variance is not known, yet the mechanisms affecting reward are likely to be different than for solitary foragers, and such sensitivity to variance would have implications for theory regarding parental care. We propose a test of the variance sensitivity hypothesis and its major alternative, the byproduct hypothesis, for parents provisioning offspring.

[…]

Hormones and parental care reaction norms

The idea that between-individual differences and within-individual flexibility are integrated also has implications for understanding the mechanistic basis for variation in parental care. There is abundant evidence that parental care is affected by the actions of hormones (2, 20, 67, 155), yet the empirical details are confusing. Here we focus on the hormones corticosterone (C) and prolactin (PRL). Corticosterone has a wide array of effects on physiology and behavior (e.g., 76, 122). Because C increases in response to stressful events, it is a central feature of the stress response. Evidence has accumulated that C may mediate trade-offs between current reproduction and survival. Often, stress-induced increases in C lead to reduced care or nest desertion (3, 60, 78, 131, 156). However, support also exists for the idea that changes in C are a normal part of behavioral shifts during reproduction. Across many taxa, baseline levels of C increase during reproduction (118); in some birds C is highest during the nestling provisioning stage of breeding (55), individuals with higher C during the nestling period produce better quality offspring (15, 105), and experimental increases in exogenous C increase behavioral elements of parental care such as foraging activity (e.g., 32, 122). These results are not universal, however, as some studies manipulating C have found no effects on parental behavior (e.g., 106).

Prolactin is also known to affect parental care (2, 20, 67), but again the evidence is mixed on its precise role. PRL levels increase in response to nestling cues (130), positively covary with level of care (e.g., 3, 36), and experimental increases in PRL increase provisioning (21). Prolactin may interact with corticosterone in affecting behavior (e.g., 32, 93) and the hormones may be inter-regulated at least in response to chronic stressors (31, 71). There is thus abundant evidence for some influence of these hormones in regulating parental care, yet for neither do the details fit any particular mechanistic model.

The conflicting nature of these results may be resolved in several ways. C (and perhaps PRL) may follow the allostatic model (76, 90), in which different physiological and behavioral states are reached by different amounts of hormone or interactions with different types of receptors. Birds have three types of receptors with differing affinities for C (19, 76) and multiple receptors for PRL may also exist (107). These could produce

different relationships between exogenous hormone and behavior depending on the context. Context-dependence means that precisely defining the type of stressor, the situation, and the specific behavioral effects may be necessary to better understand the role of hormones in modulating parental behavior.

In addition, we suggest several new approaches, linked with the reaction norm perspective outlined above, that may be fruitful in clarifying the role of C and PRL in parental behavior. First, changes in nestling demand are well known to affect parenting behavior (e.g., 35, 56, 101, 153, 160, 166) yet concurrent studies of hormones have failed to provide a consistent story. Most such studies have altered demand early in the nestling period and measured hormone levels many days after the change in demand (e.g., 56, 78, 106). If the allostatic model is correct, this delay could have allowed time for a resetting of baselines through changes in receptors (19, 115), binding proteins (82), or baseline exogenous hormone (76). To our knowledge, no study has directly connected the change in demand with the response by measuring hormone levels immediately after a change in demand.

Second, it is conceivable that C interacts with other hormones, such as PRL, to affect parental behavior. The evidence for this is mixed (2), but few studies have defined specific elements of parental behavior and assessed how different hormones might affect them. Consider, for example, the known effects of C in increasing locomotor activity (76, 122) and the effects of PRL in increasing affiliation with the nest (54, 145). Increased activity is a necessary part of increasing provisioning, especially of insects, to offspring since new food sources must be found. However, activity alone is not sufficient—the food must also be left uneaten and carried back to the nest, a highly unusual behavior except by parents. Our working hypothesis is that C and PRL affect these different parts of an integrated sequence of behaviors. We suggest that an assessment of the separate behavioral components of parental care and the effects of hormones on each will provide new insights.

Third, C is clearly a mechanism for plasticity, and yet neither it nor its behavioral effects have been explicitly analyzed using a reaction norm approach. In particular, it is not known how between-individual differences in hormone might interact with within-individual changes in that hormone to influence behavior although evidence suggests that those interactions exist (e.g., 78). No study of the hormonal basis of parental care has combined an explicit partitioning of variance as outlined in equation 1 with experimental manipulations of hormones. This could lead to new and perhaps surprising findings; between-individual differences in baseline C might covary more strongly with between-individual differences in the slope of parental care reaction norms than with intercepts. We will assess hormonal correlates of parental care reaction norms. We will also test the hypothesis that complexities in phenotypic variance have a hormonal basis.

Finally, C and/or PRL could be associated with either individual differences or within-individual changes in stochastic variance. A hormonal basis to heterogeneous residual variance would stimulate a number of new questions about the mechanisms of assessing variance and making decisions about where to forage and for what types of food items.

[…]

IV. METHODS

A. General Methods

Training of personnel and the development of young researchers: The proposed research will require multiple personnel, and so offers a superb opportunity to train

students at multiple levels, from high school through post-doctoral. We will improve activities that have proven successful in the past. First, the postdoc and senior graduate students will be involved in the mentoring of other students (see also Mentoring Plan). Undergraduate students are not merely field assistants — they will gain skills in the full process of doing research, from reading literature and writing a research plan, carrying out data collection and ensuring it is reliable, analyzing data in a variety of ways (graphs, tables, statistics), and presenting findings orally or written. Students will choose among several partially defined projects and then matched with more experienced personnel. They will read original literature, observe techniques, practice taking data with oversight, and write a short proposal that refines their project. They will be integrated fully into the project and will be trained across multiple venues of research, including working in the field on free-living birds, doing experiments in aviaries, and analyzing samples in the lab (using PCR, ELISA). They will enter their data and learn to analyze them graphically and statistically. The results will be written up and presented as a paper or a poster. We have had considerable success in recent years with independent study students and summer interns from a variety of programs (REU, KBRIN, and Kentucky Young Scientists) and we will expand that to three new programs (see below). Several summer interns have gone on to graduate school, and a high school student working in the lab recently won the district science fair and received third place in her division at the national science fair held in California. An achievable goal is for experienced personnel to gain mentorship skills while the less experienced gain a variety of research skills.

[…]

Hormone measurements: Plasma will be collected from blood samples and frozen at -70 C until analysis in the lab of Dr. Rebecca Fox. C levels will be measured using methods that have been previously validated for house sparrows (84) and which use the Enzo Life Sciences (formerly Assay Designs) corticosterone EIA kit. This particular kit is widely used by avian biologists (e.g., 84, 117, 146, 173). This EIA is a competitive binding assay. Briefly, 20µl of plasma is incubated for 10 minutes with steroid displacement buffer at 1% of raw plasma volume. Treated plasma is then assayed in triplicate, at a total dilution of 1:40 (previously determined as the optimal dilution for accurate measurement of C in adult HOSP; 84), with a standard curve run on each plate. Samples will be completely randomized across plates to ensure that inter-plate variance will not bias results in any particular direction.

This protocol is already in use in Dr. Fox's lab (Williams and Fox, in prep). Preliminary data also suggests that individual males show a significant correlation between stress C levels measured first in September and then in March of the following year ($r = 0.58$, $F_{1,11} = 5.59$, $p = 0.04$). As the September and March samples were run on separate plates about six months apart, this suggests that not only is there within-individual consistency in C levels, our measurement methods are accurate. We are currently able to achieve intra-assay variation of ~10% based on average %CV of samples assayed in duplicate. Refinements in technique and improvements in equipment will improve intra-assay variation.

Circulating prolactin (PRL) levels will also be measured in Dr. Fox's lab using a heterologous radioimmunoassay available from the National Hormone and Pituitary Program (NHPP; Harbor-UCLA Medical Center, Torrance, California). This assay is a double-antibody competitive-binding assay that uses anti-chicken-prolactin serum made in rabbit (AFP-151) and an iodinated ($Na^{125}I$), highly-purified preparation of chicken prolactin (AFP-4444B). Briefly, raw plasma (25µl for duplicate assays) is incubated with prolactin antiserum (1:500,000 dilution) and labeled prolactin and then sheep anti-rabbit

gamma globulin is used to precipitate the bound labeled prolactin complexes (see ref 27 for a detailed description of the procedure). A standard curve using chicken prolactin will be measured for each assay and used to calculate prolactin concentrations in the samples and as a standard to determine inter-assay variation.

This assay has been successfully used to quantify circulating PRL in a range of bird species (e.g., 27, 26, 57, 73, 124). As the chicken PRL RIA has not previously been used in house sparrows, before using the assay to measure PRL in our blood samples, we will validate the assay using stripped HOSP plasma spiked with known concentrations of prolactin standard (a standard method for validating hormone assays; e.g. 84) as well as by confirming that a serial dilution of pooled house sparrow plasma parallels the chicken prolactin standard curve (after 27). We will also determine the optimal dilution factor for PRL quantification in HOSP plasma using pooled plasma (i.e., where most samples should fall within the detection limits of the assay and within the linear part of the standard curve).

[…]

1. Hormonal basis of parental reaction norms: We will assess the hormonal basis for personality, plasticity, the covariance between the two, and the patterns of residual variance. These will be conducted on both free-living and captive birds.

Field studies: We will capture adults (target N = 40 males and 40 females) and collect blood samples on Day 8 for every nesting attempt (N >2 for each adult). For experimental broods, this will occur immediately following the completion of the experimental manipulations in Section IV.B.1 and IV.B.2 above. Blood samples for measuring corticosterone will be collected within 2 min of capture; trial runs of this indicate this can be successful in >75% of cases, with the remaining cases occurring within 2.5 min. and likely to have minimal effect on assayed levels of C. Blood samples for prolactin will be collected immediately afterwards and will be complete within 5 min after capture. These data will allow us to measure among-individual and within-individual response to the experimental manipulation for both parental care and hormone levels. Thus we can test for the hormone correlates of between-individual differences in provisioning reaction norms, including intercept levels of provisioning, the change in provisioning with respect to changes in nestling demand, and between-individual differences in residual variance.

Aviary studies (Summer 2014-2016): To better understand the mechanistic underpinnings to variation in reaction norm parameters, we need a more precise understanding of how changes in conditions influence hormone profiles, and how those profiles in turn affect behavioral components of parental care. We thus propose two aviary studies.

The first study (Summer 2014) will assay hormone levels in the subjects involved in the aviary experiment on variance sensitivity. Individuals will be sampled every other day starting in late incubation and immediately following the manipulation of offspring demand and the trials involving feeder choice. The final dataset will thus consist of approximately 18 samples for each bird (9 for each of two broods), with 2 samples following a manipulation that either enhanced or reduced offspring demand. We will take behavioral data on activity, whether the individual is foraging for offspring (at insect feeders) or for itself (at separate seed feeders), and how quickly upon finding an item it returns to the nest. As described above, we also will have data on choice of feeder. These data will provide a more detailed assessment of the effect of manipulating offspring demand on both hormones and behavior.

The second study (Summer 2015 & 2016) will test the effects of C and PRL and their possible interactions on separate components of care. We will set up 24 breeding pairs and on nestling day 6 will inject subjects with either C (dose) or PRL (dose) in a 2x2 design. The subjects will be housed with the feeders as described in the aviary test of variance sensitivity plus additional feeders containing seed for adults. We will test for effects of each hormone and their interaction on the subject's time budget, the pattern of foraging behavior, and choice of feeders differing in mean and variance of food available.

If the number of breeding attempts is sufficient, we will combine the hormone treatments with a brood demand manipulation later on the same day. However, because this splits the sample in half (1/2 for demand increased, 1/2 for demand decreased), we do not anticipate completing this experiment within the grant period.

[…]

Budget Justification

A. Salaries and Wages – Senior Personnel. The Co-Principal Investigator, Dr. Fox, will work full-time (100% effort) for two months every summer of the four-year project period. Her compensation is calculated based on 2/9 of her base academic salary of $55,500 ($12,321 per year for four years for a total of $49,284). She will be responsible for directing portions of the project relating to hormonal analyses and manipulations, for assuring successful project completion (including submission of progress reports as required). Dr. Fox will supervise the undergraduate students at Transylvania University, be responsible for blood collection, hormone analysis, and hormone manipulations, and will prepare manuscripts for publication and present results at national meetings.

B. Salaries and Wages – Other Personnel. A total of $25,700 ($4700 during year 1 and $7,000 per year during years 2,3, and 4) is requested to fund two undergraduate research assistants for 10 hours per week each (20 hours per week total) during the academic year for years 1-4, as well as one research assistant for 20 hours per week during the summers during years 2-4. These juniors and seniors will assist with bird care, collecting behavioral data, assorted laboratory duties such as making solutions and cleaning glassware, and assisting in conducting assays. Students will be offered the opportunities to present their work at meetings, pursuant to successful completion of the research. Efforts will be made to recruit first-generation college students and students with diverse backgrounds.

C. Fringe Benefits. Fringe benefits are calculated for faculty at 30% during summer, and 7.65% for students. The total fringe for the project is $16,752.

D. Permanent Equipment. A Multiskan FC microplate reader ($5,191) with an integrated Dell or similar laptop computer ($1,500) running Skanit research software ($2,332) are requested. This equipment is essential to the completion of the corticosterone analyses, and is intended to replace equipment at Transylvania University that is more than ten years old. The total requested for permanent equipment is $9,023.

E. Travel

1. Domestic Travel. Out of state travel costs are based on the average round trip airfare on domestic carriers and the per diem rate for hotel, meals, and expenses estimated by the General Services Administration. In each year of the project we are requesting funds to cover the cost of the co-PI and one student to attend and present at two conferences annually at approximately $1,000 per person per trip for a total of $16,000 over four years (2 individuals x 2 conferences x $1,000 x 4 years = $16,000).

2. Foreign Travel. Not applicable.

F. Participant Support Costs. Not applicable.

1. Stipends. Not applicable.
2. Travel. Not applicable.
3. Subsistence. Not applicable.
4. Other. Not applicable.

G. Other Direct Costs

1. Materials and Supplies. A total of $60,026 is requested for materials and supplies, including 60 Enzo Life Sciences corticosterone assay kits (15 per year, at a cost of $3,375 per year or $13,500 for the duration of the project) and 24 chicken prolactin radioimmunoassay kits from the National Hormone and Pituitary Program (NHPP) (8 per year, at a cost of $8,000 per year or $32,000 for the duration of the project). The number of kits is estimated assuming 400 blood samples per year, assayed in triplicate, plus an additional kit for validation purposes. We request $8860 for other consumable supplies, including pipette tips and other plasticware, glassware including scintillation vials and other reagents and materials necessary for the project. Finally, we request a set of VWR electronic micropipettors ($1,640), which will help to increase assay precision, a VWR incubating microplate shaker ($1,874) which will enable us to limit assay variability due to temperature variations in the lab, and a microcentrifuge ($2150) to replace the lab's existing microcentrifuge, which is 15+ years old.

2. Publication Costs/Documentation/Dissemination. A total of $1,000 is requested for printing, copying, and dissemination.

3. Consultant Services. Not applicable.

4. Computer Services. Not applicable.

5. Subawards. Not applicable.

6. Other. Not applicable.

H. Total Direct Costs. $170,773 over the four years of the project.

I. Indirect Costs. (48.5% of all but equipment) $78,449

J. Total Direct and Indirect Costs. $249,222

K. Residual costs. None.

L. Amount of this Request. $249,222

M. Cost Sharing Proposed Level. Not required.

Are neophobia and habituation related to nesting habitat in house sparrows (*Passer domesticus*)?

R. Devin Rowe, Christopher Saldaña, and Rebecca A. Fox

Biology Program, Division of Natural Sciences and Mathematics, Transylvania University, 300 N Broadway Rd., Lexington, KY, 40508

RESEARCH QUESTION

- **Do house sparrows that nest in high-disturbance communal areas behave differently than HOSP that live in low-disturbance isolated areas?**
- **Does location influence habituation to novel objects?**

INTRODUCTION

Neophobia: Avoidance of novelty. [3]

Likely adaptive – allows organisms to avoid traps, potential poisons, etc. ("Dangerous niche hypothesis") [3]

At least in some species, neophobia varies with habitat/ degree of urbanization. [1,4]

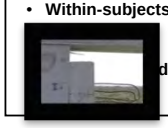
Wild and captive HOSP show repeatable individual differences in neophobia (personality). [2,5]

Nest across a wide variety of habitats.

Predict that nest site choice correlates with neophobia.

MATERIALS and METHODS

- **N= 4 bluebird boxes(BB Box) nests (isolated, low density)**
  N = 3 nests at barns (high human disturbance, high density) at UK Maine Chance Equine facility
- **Tested 2x during chick rearing (nestlings 3-6 days old)**
- **Observed provisioning behavior**
  1 hr control trial (no object)
  1 hr with object (patterned paper square)
- **Within-subjects design, mixed model ANOVA**
  fixed effects in model: sex, day, [illegible]
  dom effect of pair



Left: first hour(control)

Right: second hour (novel object)

RESULTS

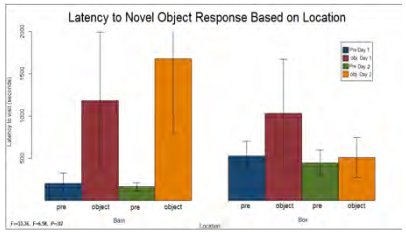


Figure 1. Overall, birds had longer latencies to first visit when an object was present.

Object presence: $F_{1,33.35} = 16.72$, $p < 0.01$

HOSP nesting at barns had longer latencies to approach the box when an object was present.

Location x object presence: $F_{1,33.35} = 6.58$, $p = 0.02$

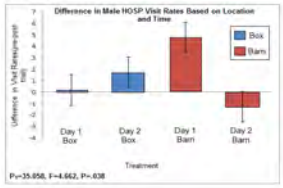
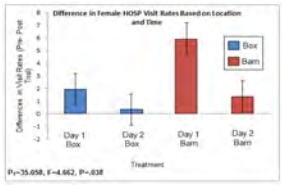


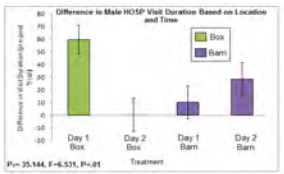
Figure 2. In general, birds of both sexes tended to make more feeding visits when there was no object present.

Object presence: $F_{1,35.06} = 3.48$, $p = 0.07$

The extent of habituation across days varied with sex and nest location.

Sex x object presence x nest location x day: $F_{1,35.06} = 4.66$, $p = 0.04$





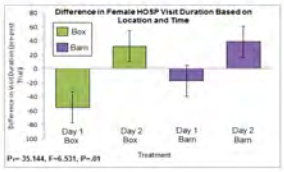


Figure 3. Duration of box visits differed by sex and day.

Sex: $F_{1,35.19} = 6.47$, $p = 0.02$
Day: $F_{1,35.19} = 5.87$, $p = 0.02$

On day 1, females tended to spend longer at the box when the object was present.

Box males, but not barn males, appear to habituate to the object.

Females' behavior in response to the novel ohject at both sites changed across days.

CONCLUSIONS

HOSP change provisioning behavior in response to potentially-risky unfamiliar objects.

Barn birds (high human disturbance) were more neophobic than box birds (low human disturbance)

Barn birds also seemed to be slower to habituate to an unfamiliar object.

HOSP also show sex differences in habituation and in response to object.

Females seem to respond by defending the nest (especially when nestlings are young), while males avoid the box

Causal relationship between neophobia and nest site choice uncl

References

1.) **Bokony V., Kulcsar A., Toth Z. Likar A. 2012. Personality traits and behavioral syndromes in differently urbanized populations of house sparrows (*Passer domesticus*).**

2.) **Coomes C., Gardner S.*, Fox R. Free-living house sparrows (*Passer domesticus*) exhibit personality and plasticity in response to novel objects. *Poster presented at the Animal Behavior Society 2015 Meeting, June 10-14 2015, Anchorage, AK.***

3.) **Greenberg, R. 2003. The role of neophobia and neophilia in the development of innovative behaviors in birds. In: Reader SM, Laland KN *(eds.). Animal Innovation.* Oxford: OUP, pp. 175-197.**

4.) **Sol D., Lapiedra O, Gonzalez-Lagos C. 2013. Behavioural adjustments for a life in the city. Animal Behaviour 85: 1101-1112.**

5.) **Fox, R.A., Ali, N. The forest or the trees? Neophobia and the 'environmental sensitivity syndrome' in house sparrows (*Passer domesticus*). *In revision.***

Acknowledgments

We would like to thank David Westneat and the University of Kentucky Biology Department for allowing us to conduct research on his study population at UK's Maine Chance facility.

Transylvania University provided summer housing for RDR and CS.

Funding: National Science Foundation Award (IOS-1257787) to DF Westneat and RAF.

RDR would like to thank Elias Hanna for all of his emotional support.

House Sparrow Pair Compatibility Predicts Reproductive Success

Heather P. Hamilton, Gabriella R. Martin, and Rebecca A. Fox

Biology Program, Division of Natural Sciences and Mathematics, Transylvania University, 300 N Broadway Rd., Lexington, KY, 40508

RESEARCH QUESTIONS

Are differences in pair compatibility/parental contribution related to differences in fitness in free-living house sparrow pairs?

Can nest temperature be used as a proxy for long-term monitoring of nest attendance?

INTRODUCTION

Parental provisioning in HOSP:

Individual differences in *behavioral plasticity* (e.g., the extent to which provisioning changes with nestling age)

Differences in *personality* (consistent between-individual differences in behavior) **[1]**

Personality match between mates a predictor of behavioral compatibility in other monogamous birds [2]

More compatible pairs have higher fitness [3]

Likely mediated by differences in ability to coordinate parental behaviors like incubation and provisioning

Prediction: Pairs in which males and females make more equal contributions to chick rearing will have higher fitness

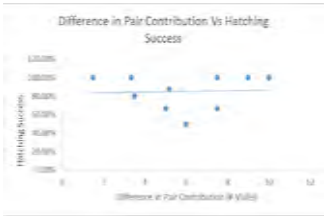
METHODS

- **10 pairs of free-living HOSP**
  UK Maine Chance Farm
- **Direct observation of provisioning behavior**

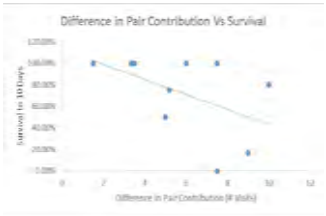
  1 hr every other day, nestling day 2 – day 10
- **HOBO U23 Pro v2 temperature sensor to monitor incubation**

  Simultaneous direct observation of nest attendance

RESULTS

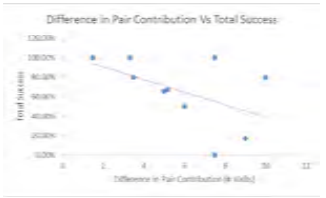


Average discrepancy between female and male provisioning was not correlated with hatching success (proportion of eggs that hatched successfully)



Average discrepancy between female and male provisioning was negatively correlated with nestling survival (proportion of nestlings that survived until banding at 10 d).

r = 0.50, p = 0.14

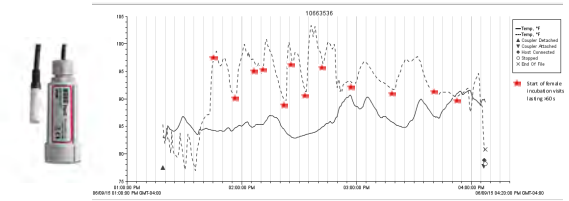


Average discrepancy between female and male provisioning was negatively correlated with total success (proportion of the original clutch that hatched successfully and survived until banding at 10d)

r = 0.54, p = 0.10

REMOTE MONITORING OF INCUBATION

Comparison between temperature sensor readings and observed entry and exit of female during time of incubation



Temperature trace from a HOBO U23 Pro v2 temperature and relative humidity logger in a pair's nest, directly under either the eggs for a one hour period, while simultaneously conducting direct observation of the behavior of both pair members. The dashed line is the nest temperature; the solid line is the exterior temperature

CONCLUSIONS

Pairs in which both mates contribute more equally to provisioning have higher fitness

Related to "fit" between mates' personalities?

Likely mediated by ability to deliver sufficient food to support nestling growth.

May also be related to problems during incubation.

Discrepancy between male and female contribution a stronger predictor of *total* success

Temperature sensor data suggest that temperature changes within the nest reflect patterns of nest attendance

Useful for examining relationship between compatibility and incubation

May enable monitoring of nest attendance when nestlings are young

References

1.) Westneat DF, Hatch MI, Wetzel DP, Ensminger AL. 2011. Individual variation in parental care reaction norms: integration of personality and plasticity. American Naturalist 178: 652-667.

2.) Fox RA, Millam JR 2014. Personality traits of pair members predict pair compatibility and reproductive success in a socially monogamous parrot breeding in captivity. Zoo Biology 33:166-172.

3.) Spoon TR, Millam JR, Owings DH. 2006. The importance of mate behavioural compatibility in parenting and reproductive success by cockatiels (*Nymphicus hollandicus*). Animal Behaviour 71: 315-326.

Acknowledgments

We would like to thank David Westneat and the University of Kentucky Biology Department for allowing us to conduct research on his study population at UK's Maine Chance facility.

Transylvania University provided summer housing for HPH and GRM.

Funding: National Science Foundation Award (IOS-1257787) to DF Westneat and RAF.

BIO 1164: BIOLOGY AND HUMAN CONCERNS

WINTER TERM 2017
"The Dinosaurs in Your Backyard"

INSTRUCTOR: Dr. Becky Fox
Office: BSC 313
Research lab: BSC 303
Email: rfox@transy.edu
Cell phone: 530-400-7575 (texts preferred; please be considerate about time of day)
Office phone: 859-233-8288 (worst bet for reaching me quickly)
Course website: Materials will be posted on the class Moodle page.
Office hours:
MWF 1:30 – 3:30 PM
T 9:15-11:15 AM
And by appt. as needed

I haven an open door policy – feel free to stop by anytime my research lab or office door is open. I'm somewhere on the Biology hall most of the time. ☺

CLASS MEETING TIME: 11:30-12:20 MWF

MEETING LOCATION: BSC 310

REQUIRED TEXTS:

Pickrell, J. 2014. *Flying Dinosaurs: How Fearsome Reptiles Became Birds.* Columbia University Press.

Lister-Kaye, J. 2016. *Gods of the Morning: A Birds-Eye View of a Changing World.* Pegasus Books.

Assorted other readings will be posted on Moodle.

COURSE SUMMARY: This is, as the course title implies, a class about prehistoric dinosaurs and their relationship to modern-day dinosaurs – a.k.a. birds - but that's really only part of the story. This semester we will also use the discovery of the dinosaur/bird relationship as a case study that will let us talk about one of the major ideas in biology (evolution by means of natural selection), how the scientific approach is used to understand the natural world, how scientists change their minds based on new evidence, and about how scientific findings get communicated

the public (or not). In the second half of the course, we'll also do a little urban ecology and use population trends in modern birds to discuss how anthropogenic (human-caused) changes in the environment are changing our world. Successfully communicating scientific findings to non-scientific audiences will be one of the major foci of this class.

STUDENT LEARNING OUTCOMES

In this course, students will:

1.) Articulate and apply the basic principles underlying evolution by natural selection.

2.) Understand how the scientific method of generating knowledge works, and be able to articulate what is meant by terms like "hypothesis" and "theory" which are often misused colloquially.

3.) Generate and interpret charts and graphs, and use them to convey their own findings.

4.) Explore various means of communicating scientific findings and ideas to non-scientists, discuss what seems to work and what doesn't, and develop their own recommendations for best practices for scientific communication.

5.) Examine the links between science and society, with an emphasis on extinctions, climate change, and urban ecology.

Course Components:

Exams:
We will have three exams and a final. Semester exams will be given during lab time to allow you plenty of time to think and write. My exams are typically a mix of multiple-choice/matching, short answer, and brief essay questions. Expect to have to consider evidence, develop arguments, and support your ideas, just as you would in any other non-science class. Don't expect to get an A or B on the exam just by memorizing your notes!

Weekly(ish) Assignments: Learning ought to be an active endeavor! In support of this goal, you'll have an assortment of short assignments, on a more or less weekly basis – I'll typically assign them on Monday with a due date of Friday by the beginning of class. Some assignments will be brief essays, others may ask you to do some research on a topic and report out to the class, and still others may ask you to

survey your friends and compile the results. None of them are meant to be busywork, and I hope you'll find them enjoyable and/or enlightening.

Participation/Engagement: I don't believe in the "sage on a stage" model of instruction, particularly since research has shown it time and again to be thoroughly ineffective. Learning in this class is therefore a collaborative endeavor. For this to work out, we all need to contribute! I know some people are more introverted than others, so 'contributing' doesn't only mean "raising your hand in class." Active involvement in group activities and small group discussions totally counts, as does writing a thoughtful start-of-class reflection, or contributing a good question for class discussion.

This is why I believe in active learning ☺

Semester Project: Since communicating about science to a general audience is a focus of this class, your project will give you the opportunity to do just that. You will choose a topic that is somehow related to things we've discussed in class, and you will have your choice of formats – blog, in-depth magazine article, podcast, TED talk style video, teaching exercise, etc. You will also write a short 2-3 page paper explaining why you made the choices you did in developing the final product, and how those choices relate to what you've learned about effectively communicating science to a non-scientific audience. During the last week of class, you'll make a presentation about your project to the class. More specific information and requirements will be given in a formal assignment sheet.

Lab: At its heart, biology is a hands-on discipline, and best learned by doing. Therefore, we have lab once a week. Because you put in a lot of work in lab, lab is worth 1/5 of your grade, and the specific breakdown of lab grades is detailed in the lab syllabus.

Grading:

Grade Scale	
98-100% – A+	72-77.9% – C
90-98% -- A	70-71.9% – C
88-89.9% – B+	68-69.9% – D+
82-87.9% -- B	62-67.9% – D
80-81.9% -- B-	60-61.9% – D-
78-79.9% – C+	Below 60 – F

Please note that I don't believe in curving grades. This class is a collaborative community, not a competitive one. Everyone should have an equal chance to earn an A (or not)!

Grade Breakdown

(1000 points total – includes points from lab)

In-class Exams – 3 x 100 points		300 points
Semester Project –		200 points
Proposal	25 points	
Final product	100 points	
Meta narrative	50 points	
Class presentation	25 points	
Lab (points breakdown in lab syllabus)		200 points
Participation (13 weeks x 5 pts)		65 points
Weekly assignments (individual points vary)		135 points
Final Exam (Cumulative)		100 points

COURSE POLICIES

Submitting assignments:
Assignments to be turned in on Moodle are due by 11:59 PM on the due date. If you're having trouble uploading to Moodle or aren't sure if you submitted the assignment successfully, email me a copy. "Moodle wasn't working" is not a valid excuse for failing to turn something in on time. Assignments to be submitted in class are due at the beginning of class. Assignments that are turned in late receive an automatic 5% deduction. Every 24 hours that an assignment is late will result in a further 10% deduction from the grade you would have received if the assignment had been turned in on time, down to a grade of 50%. *However, it is always better to turn in an assignment late than to not turn it in at all – 50% is better than 0%!*

Grade disputes: Except in cases where points have been totaled wrong or I obviously missed reading part of your answer to a question, if you wish to dispute a grade, you must wait 24 hours and then submit your dispute *in writing* to me. Grades must be disputed within 7 days of receiving them, or the grade you received on the exam or assignment will be final.

Academic honesty: Academic dishonesty will not be tolerated. Please refer to the Student Handbook for descriptions of offenses and policies. Any violation of the policy will have serious consequences and may result in an F (0%) for the assignment, exam, or the course. If you have questions regarding what is allowable, please ask. There will be substantial group work in the class and the policy holds for group work as well. If you were not a significant contributor to the group, it would be dishonest to claim the group product as your own. Plagiarism will not be tolerated, all references **must** be properly cited in the text and the reference listed

in the bibliography. If you are unsure about proper citation, or whether something should be cited, please ask.

Absences: If you miss lecture, make sure you get the notes from a classmate. Excessive absences will result in a deduction from your participation grade. *Exams, lab practicals, and lab assignments may be made up only in cases of documented personal or family emergencies or illness, religious holidays, or if you are traveling for a school-sponsored event.* If you know you are going to be traveling or missing class for a religious observance, it's your responsibility to let me know in advance and make arrangements to make up the lab, practical, and/or exam.

Respect and Classroom Climate: Learning in this class is a collaborative effort. You'll work in teams in the lab, and classroom discussion is highly encouraged. Therefore, all members of this class are expected to treat one another with consideration and respect – that includes giving members of our classroom community your full attention and not being distracted by your phone, laptop, side conversations, etc.

I support Transy's commitment to diversity, and welcome individuals of all ages, backgrounds, citizenships, disabilities, sex, education, ethnicities, family statuses, genders, gender identities, geographical locations, languages, military experience, political views, races, religions, sexual orientations, socioeconomic statuses, and work experiences. If you feel you feel threatened or discriminated against, I encourage you to speak with me and/or make a Hate/Bias Incident Report available on inside.transy.edu:
https://publicdocs.maxient.com/reportingform.php?TransylvaniaUniv&layout_id=11
Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories such as race, national origin, etc. If you or someone you know has been harassed or assaulted, you can find the appropriate resources here ...

- DPS (233-8118) or 911
- Bluegrass Rape Crisis Center: http://bluegrassrapecrisis.org/
- Title IX coordinator: Ashley Hinton-Monser (ahinton@transy.edu, 859-233-8854)
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AMERICANS WITH DISABILITIES ACT
If you have a documented disability seeking academic adjustments or accommodations please contact Amber Morgan (233-8502, OM 211) with Disability Support Services to develop an official plan for accommodations. Contact me during

the first two weeks of class to discuss your plan. All discussions will remain as confidential as possible.

Course Schedule

May be subject to minor changes; exam dates are firm

Week & Dates	Topic	Reading	Assignment
1 **1/9-1/13**	History of Earth and fundamentals of the game	HHMI "deep history" (link on Moodle), "Just a theory" Scientific American article (Moodle) FD introduction	Dinosaur survey
2 **1/16-1/20 (no class Monday – MLK Day)**	Natural selection and evolution	*Origin of Species* ch. 4 (Moodle)	Misconceptions about evolution assignment
3 **1/23-1/27**	Darwin and the dinosaurs	FD Ch. 1-3	"Cast of characters"
4 **1/30-2/3**	Dinosaurs had *what?!* And were related to *who?!* The actual science vs. science reporting: the case of the dinosaur's voice **EXAM 1 (Thur.)**	FD Ch. 4-5 Articles on Moodle	None (exam week)
5 **2/6-2/10**	Feathers!	FD Ch. 6 and 9 Feather chapter from *Manual of Ornithology* (Moodle) Dinosaur tail article (Moodle)	Project proposals due
6 **2/13-2/17**	Getting off the ground: the evolution and physics of flight	FD Ch. 7	Science communication assignment

7 **2/20-2/24**	"Good mother lizards" – then and now	FD. Ch. 8 Reproduction chapter from *Brief Ornithology* (Moodle)	"Dinosaur biography" presentations in lab
8 **2/27-3/3**	What happened to the dinosaurs? **Exam 2 (Thur.)**	FD. Ch. 9-10 "De-extinction" TED talk (Moodle)	Prep for debate, otherwise none
9 **3/6-3/10**	What is a naturalist? Living in the anthropocene	GOM ch. 1-6 Blue and golden-winged warblers article (Moodle)	Types and purposes of science writing
10 **3/13-3/17**	**SPRING BREAK**		
11 **3/20-3/24**	Urban Ecology	GOM ch. 7-12 *Avian Urban Ecology* chapter (Moodle)	Presenting science to nonscientists (collaborative assignment)
12 **3/27-3/31**	Climate Change	GOM ch. 13-19 Climate change articles (Moodle)	Article "taste test" assignment
13 **4/3-4/7**	Conserving the Dinosaurs in your Backyard **Exam 3 (Thur.)**	Bird conservation articles (Moodle)	None (exam week)
14 **4/10-4/14**	Wrap-up, review, and presentations		Projects due

FINAL EXAM: Tuesday, April 18, 12:00-2:00 PM

BIO 1164: BIOLOGY AND HUMAN CONCERNS

WINTER TERM 2017
"The Dinosaurs in Your Backyard"

LAB SYLLABUS

INSTRUCTOR: Dr. Becky Fox
Office: BSC 313
Research lab: BSC 303
Email: rfox@transy.edu
Cell phone: 530-400-7575 (texts preferred; please be considerate about time of day)
Office phone: 859-233-8288 (worst bet for reaching me quickly)
Course website: Materials will be posted on the class Moodle page.
Office hours:
MWF 1:30 – 3:30 PM
T 9:15-11:15 AM
And by appt. as needed

I haven an open door policy – feel free to stop by anytime my research lab or office door is open. I'm somewhere on the Biology hall most of the time. ☺

LAB MEETING TIME AND LOCATION: Th., 1:30-4:15, BSC 304

REQUIRED MATERIALS: Lab handouts will be posted on Moodle.
You will need binoculars for the week 11 and 12 labs. For weeks 11 and 12 we will be outdoors, so you will also want appropriate clothes and potentially a rain jacket.

STUDENT LEARNING OUTCOMES

Students will:

* Be able to identify the characteristics of modern birds, and explain how they relate to the characteristics of their dinosaur ancestors in the context of evolution by natural selection.

* Address popular misconceptions about prehistoric dinosaurs.

* Develop and practice some basic lab skills in vertebrate biology: basic microscopy, simple dissection (of feathers), identification of specimens using a key, etc.

* Develop hypotheses and test predictions about the impact of human activities on bird diversity in Lexington.

Lab Safety
Please read the handout on Moodle on lab safety. You will be asked to sign a contract agreeing to abide by its provisions.

IMPORTANT: Students MUST wear long pants and closed-toed shoes AT ALL TIMES in BSC 304 – even if you're just coming into the lab for a moment. If you show up for lab inappropriately dressed, you'll be sent home to change.

NO FOOD OR DRINK IS PERMITTED IN THE LAB **AT ANY TIME,** even in your backpack. Leave water bottles, snacks, etc. on the cart outside the door.

DO NOT CHEW GUM OR APPLY MAKEUP OR LIP BALM IN THE LAB - EVER.

Specific notes:
We will be working in a lab where preserved specimens are handled and dissected, and will be handling some preserved bird skins. Specimens and skins may be treated with formaldehyde (a toxic carcinogen and irritant) and/or arsenic (a poison). It's important to wear gloves when handling any specimen and to treat all surfaces in the lab as potentially contaminated. WASH YOUR HANDS prior to exiting the lab.

Lab Cleanup
We share this lab space with other classes. *Please* be conscientious about cleaning up after yourselves! Failure to clean up adequately will result in a deduction from your participation grade.

Attendance
LAB ATTENDANCE IS MANDATORY. Lab is a crucial part of this class, and you will be tested over lab material. Additionally, since you'll be doing much of your work in pairs or small groups, showing up for lab isn't just part of your grade – it's part of being a good collaborator! Also, please be aware that putting your name on collaborative work when you weren't a significant contributor to the final product is a form of academic dishonesty and will be treated accordingly.

Lab Components:		**200 points total**
In-lab assignments (individual points vary):		125 points
Lab engagement:		75 points
Attendance (9 non-exam labs x 5 pts)	45 points	
Lab group contribution/collaboration	35 points	

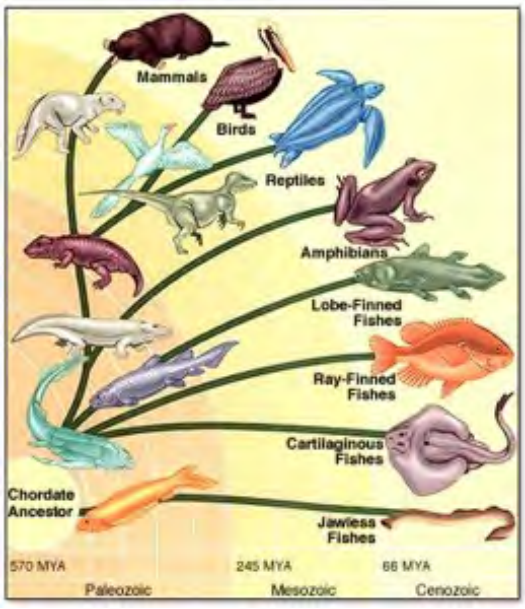
Lab Schedule

*May be subject to change; Exam dates are firm

Date	Topic/Exercise
1.12	*Jurassic World* viewing
1.19	Evolution lab
1.26	Owl pellets
2.2	EXAM 1
2.9	Feather dissection
2.16	Bird characteristics
2.23	"Dinosaur Biographies" / revisiting *Jurassic World*
3.2	EXAM 2
3.9	Habitat fragmentation
3.16	SPRING BREAK
3.23	Birding – campus and downtown Lex
3.30	Birding – London-Ferrill garden
4.6	EXAM 2
4.13	No lab – use the time to put the finishing touches on your projects

BIO 3016: Comparative Vertebrate Anatomy
Winter Term 2017
Lecture/Discussion Syllabus

Life is a copiously branching bush, continually pruned by the grim reaper of extinction, not a ladder of predictable progress. ~Stephen Jay Gould



Instructor: Becky Fox, Ph.D.
Email: rfox@transy.edu
Phone: 233-8288 (office) or 530-400-7575 (cell; prefer texts. Please be courteous about time of day!)
Office: BSC 313
Research space: BSC 303
Office Hours:
MWF 1:30-3:30 PM
Tues. 9-11:15 AM
Other times by appointment, or feel free to stop by whenever my door is open (which is most of the time).

Course meeting time: 9:30-10:20 MWF

Location: BSC 310

Course website: Class materials outside of the textbook will be posted on Moodle

Required Texts:
Kardong, K.V. (2014) *Vertebrates: Comparative Anatomy, Function, Evolution.*7th ed.

Netter's Human Anatomy Coloring Book

Course description: CVA explores both the unity and the diversity of structure among the various vertebrate taxa. In this class, we will study the links between structure and function, with an emphasis on the relationship between the physiological challenges presented by particular environments or life history strategies and the evolution of the vertebrate body plan. We will also spend some time considering human anatomy specifically, with an emphasis on healthcare applications.

Student Learning Outcomes

In this course, students will:

- Discuss – using scientific evidence – vertebrate origins and the vertebrate phylogenetic tree, as well as some of the major controversies and exciting new developments surrounding the vertebrate phylogeny.
- Develop and demonstrate an understanding of the links between ecological challenges, structure, and function in vertebrates, and
- Engage with the primary literature and be able to use their knowledge of anatomy as a living discipline to ask novel(ish) questions in comparative morphology and design experiments to test them.
- Apply their understanding of the vertebrate anatomy to the human body plan, both in terms of its commonalities with the anatomy of other vertebrates and its uniqueness.
- Learn and be able to correctly use the vocabulary of anatomy and comparative morphology.

Course Components

Exams:
Exams are structured as follows: ~30% multiple choice/matching, ~70% free-response. Some questions on the exam may require you to look at specimens. Do not expect to be able to get an A or a B on the exam just by memorizing facts! My exam questions generally ask to solve problems or to integrate and synthesize information.

Homeworks:
On most weeks, you will have some sort of short assignment. These assignments may take a variety of forms. Some will be problem sets and draw on your *Anatomy Coloring Book*; others will ask you to do some research in the literature or to read and critique a paper or two. These assignments are intended to reinforce what you are learning in class and to encourage you to delve deeper into a topic than you might if you were just reviewing lecture notes or reading the text.

Science Writing Assignments:
Being able to communicate science to non-scientists is an increasingly important skill for a number of reasons (including the ability to influence important policy decisions at the local, state, and national level). Additionally, there is no better way to learn material than to have to explain it to a non-expert. For these two reasons, you'll have three opportunities to practice your scientific communication skills, by (1) writing a short news blurb, (2) writing a longer magazine article-style piece, and (3) creating an infographic

about some topic related to vertebrate anatomy.

Grade Breakdown (1100 points total – includes points from lab)

In-class Exams – 2 x 150 points		300 points
Semester Project		130 points
Hypothesis proposal:	20 points	
Research plan:	30 points	
Writeup 1st draft	50 points	
Final draft	30 points	
Lab Practicals 2 x 50 points		100 points
Lab participation and assignments		200 points
Homeworks –7 x 10 points each		70 points
Science writing assignments		100 points
News blurb:	20 points	
Infographic:	30 points	
Magazine article:	50 points	
Final Exam (Cumulative)		200 points

Grade Scale

98-100% – A+	72-77.9% – C
90-98% -- A	70-71.9% – C
88-89.9% – B+	68-69.9% – D+
82-87.9% -- B	62-67.9% – D
80-81.9% -- B-	60-61.9% – D-
78-79.9% – C+	Below 60 – F

Policies:

Submitting Assignments:

Semester project and writing assignments are due **ON MOODLE** by **11:59 PM ON THE DUE DATE LISTED IN THE SYLLABUS**. Homework assignments are due **FRIDAY AT THE BEGINNING OF CLASS** unless otherwise specified**.** Assignments that are turned in late receive an automatic 5% deduction. Every 24 hours that an assignment is late will result in a further 10% deduction from the grade you would have received if the assignment had been turned in on time, down to a grade of 50%. *However, it is always better to turn in an assignment late than to not turn it in at all – 50% is better than 0%!*

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develop an official plan for accommodations. Contact me during the first two weeks of class to discuss your plan. All discussions will remain as confidential as possible.

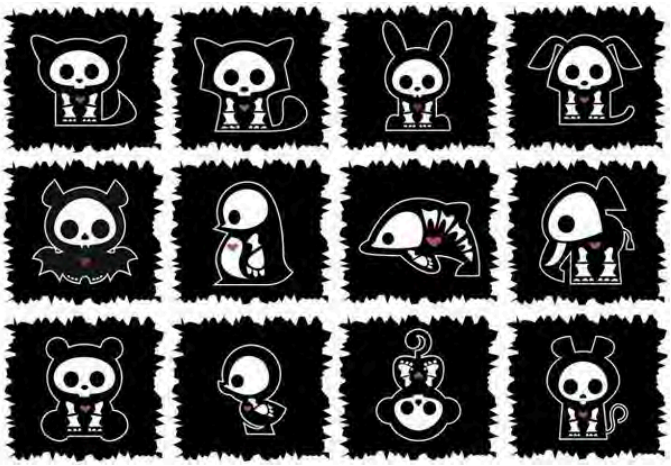
Week & Dates	Topic	Reading (Kardong)	Assignment
1 **1/9-1/13**	Intro: What's a vertebrate? Anatomical terminology	Ch. 1 (p. 29-41 not required)	Netter, 1-1 through 1-3 and questions
2 **1/16-1/20 (no class Monday – MLK Day)**	Chordates and Vertebrate origins	Ch. 2-3	Problem set
3 **1/23-1/27**	Biological "design" and embryology	Ch. 4-5 and 563-589	Background and hypothesis (Fri.)
4 **1/30-2/3**	Integument	Ch. 6	Skull lab proposal (Mon) Netter 1-5, 1-6, 1-12 and questions (Fri.)
5 **2/6-2/10**	Skull	Ch. 7	News blurb
6 **2/13-2/17**	Skeleton	Ch. 8	Skull lab writeup
7 **2/20-2/24**	Skeleton cont'd **Exam 1**	Ch. 9	Research plan (Fri)
8 **2/27-3/3**	Musculature	Ch. 10	"Pokemon" assignment
9 **3/6-3/10**	Musculature and locomotion,	Ch. 10	Netter 2 and 3 and questions
10 **3/13-3/17**	**SPRING BREAK**		ENJOY YOUR BREAK!
11 **3/20-3/24**	Circulatory System	Ch. 11	Infographic / Netter 5-1 through 5-7 and questions
12 **3/27-3/31**	Respiratory System	Ch. 12	Netter 7 and questions
13 **4/3-4/7**	Digestive and urogenital system	Ch. 13-14	Magazine article (Mon.)
14 **4/10-4/14**	Nervous system and sense organs **Exam 2**	Ch. 16-17	First drafts due (Mon.)

FINAL EXAM: Thursday 4/20, 12:00-2:00 PM

*Schedule subject to minor changes. Exam dates are firm.

BIO 3016: Comparative Vertebrate Anatomy
Winter Term 2017
Laboratory Syllabus

Instructor: Becky Fox, Ph.D.
Email: rfox@transy.edu
Phone: 233-8288 (office) or 530-400-7575 (cell; prefer texts)
Office: BSC 313
Office Hours: MWF 1:30 – 3:30 PM
T 9:15-11:15 AM
And by appt. as needed



Otherwise, feel free to stop by any time my office or research lab (BSC 303) door is open, which is most of the time.

Course meeting time: 9:30-12:15 Thursday

Location: BSC 304

Course website: Some lab exercises will be posted on the class Moodle site.

Required Text:
Kardong & Zalisko (2014). *Comparative Vertebrate Anatomy: A Laboratory Dissection Guide, 7th ed.*

STUDENT LEARNING OBJECTIVES
In this laboratory, students will:

- Identify anatomical features in vertebrate specimens, both macroscopic and histological.
- Using anatomical characters, identify animals as members of one of the major vertebrate groups
- Learn dissection skills, including proper use of scalpel and scissors, how to skin specimens, etc.
- Develop and test hypotheses about anatomical differences among vertebrate groups.
- Learn how to derive allometric relationships and statistically control for allometric effects.

Laboratory Description:
The best way to learn anatomy is through hands-on observation, drawing, and description. Therefore, you will spend this semester doing just that. You will examine histological specimens and skeletal preparations, and will also dissect representative vertebrates. Material from labs will be included on the exams.

Lab Safety:
Please read the handout on Moodle on lab safety. You will be asked to sign a contract agreeing to abide by its provisions.

IMPORTANT: Students MUST wear long pants and closed-toed shoes AT ALL TIMES in BSC 304 – even if you're just coming into the lab for a moment. If you show up for lab inappropriately dressed, you'll be sent home to change.

NO FOOD OR DRINK IS PERMITTED IN THE LAB **AT ANY TIME,** even in your backpack. Leave water bottles, snacks, etc. on the cart outside the door.

DO NOT CHEW GUM OR APPLY MAKEUP OR LIP BALM IN THE LAB - EVER.

Specific notes:
We will be working with and dissecting preserved specimens and will be handling some preserved vertebrate skins. Specimens and skins may be treated with formaldehyde (a toxic carcinogen and irritant) and/or arsenic (a poison). It's important to wear gloves when handling any specimen and to treat all surfaces in the lab as potentially contaminated.

PRESERVED SPECIMENS OFTEN CONTAIN LIQUID AND CAN "SQUIRT". YOU MUST WEAR **GOGGLES OR SAFETY GLASSES** AT ALL TIMES DURING DISSECTION. Also, do not lean over specimens with your mouth open.

WASH YOUR HANDS prior to exiting the lab.

Cleanup
We share our lab space with other classes. Therefore, *IT IS EXTREMELY IMPORTANT THAT YOU DO A **VERY THOROUGH JOB** OF CLEANING UP AFTER YOURSELVES.* On dissection days or days that involve us having a lot of specimens out, the last 10 minutes of every class will be devoted to clean-up. Each lab group will be responsible for making sure their instruments are properly cared for, waste is disposed of, and specimens are returned to where they belong. *Before you leave class you will be ask to initial a sheet certifying that you've cleaned up as directed in the "Care of Lab Equipment and Specimens" handout.*

FAILURE TO CLEAN UP PROPERLY WILL RESULT IN A LOSS OF POINTS ON THAT LAB ASSIGNMENT. How many points you lose depends on how big a mess you leave. Your life – and mine – will be much easier if you just don't leave a mess! ☺

Additional notes:
Many of the specimens we will work with – particularly skeletal preparations – are both fragile and quite expensive, as well as difficult to replace. Please handle them with the appropriate care and respect! Unnecessarily rough or irresponsible handling may result in a deduction from your grade, particularly if it results in loss or breakage of a specimen.

Lab Practicals:
You will take three lab practicals this semester, intended to assess your ability to identify anatomical structures in actual organisms – and to encourage you to learn to do so (dates given in the syllabus)! One of the three practicals will be part of the final exam. You will be asked to identify organs and structures in the organisms they have dissected, and to answer questions about their structure and function. While I do not collect lab notebooks in this class, keeping good notes in lab is decidedly to your advantage!

Semester Project:
The semester project is intended to introduce you to comparative anatomy/morphology as a living discipline and to allow you to apply the anatomical terminology and expertise in dissection that you're acquiring in class to a problem that is of interest to you. You will work in groups of 2-3 to develop a hypothesis relating to structural differences within a taxon or between at least two groups of vertebrates, and then empirically test that hypothesis using observation and measurement of specimens (skeletons, whole mounted animals, preserved organisms) that are available to you in the laboratory. The assignments for this project will be broken up into parts (details given on specific handouts) to help keep you on track. *Be aware that this project will likely involve a substantial time investment outside of class.*

Also, please be aware that putting your name on collaborative work when you weren't a significant contributor to the final product is a form of academic dishonesty and will be treated accordingly.

Lab grade breakdown

Lab total	**430 points**
Semester Project	130 points
Hypothesis proposal: 20 points	
Research plan: 30 points	
Writeup 1st draft 50 points	
Final draft 30 points	
Lab Practicals 2 x 50 points	100 points
In-lab assignments (individual points vary)	60 points
Skull lab proposal	20 points
Skull lab writeup	60 points
Participation (attendance, group contribution)	60 points

Lab Schedule

Potentially subject to minor changes. Exam dates are firm.

Date	Topic/Exercise
1.12	Phylogeny refresher and the vertebrate family tree
1.19	Size lab
1.26	Integument
2.2	Skull lab 1
2.9	Skull lab 2
2.16	Skeleton
2.23	Exam 1/Lab practical 1, project time
3.2	Kinematics of movement, project time
3.9	Shark, project time
3.16	SPRING BREAK
3.23	Mudpuppy, project time
3.30	Rat
4.6	Pigeon
4.13	Exam 2/Lab practical 2

January 6, 2017

To Whom It May Concern:

It is my distinct pleasure to recommend Professor Rebecca Fox for a Bingham Award for Teaching Excellence. Early on in her career, I participated in two pre-tenure visitations, so I am familiar with Professor Fox's struggles to move from a satisfying graduate career to one in which teaching excellence is primary. Subsequently, I have invited her into my course on animal ethics, Animal Minds/Human Values, and in a first year research course I'd taught entitled The Posthuman: From Chimp to Cyborg, to discuss avian cognition -- and most recently, cetacean intelligence as well. The later invitation came as a result of ongoing conversations we had enjoyed about her teaching strategies. It is on these experiences that I base my enthusiasm for Professor Fox's teaching craft.

If you talk about Professor Fox's teaching trajectory at Transylvania, the standard account goes something like this: in her first few years, Professor Fox had difficulty moving from doing research, with teaching as a side constraint to an environment wherein teaching excellence was expected. Over several years, with encouragement from her division and faculty across the campus, she made a truly impressive turn-around, using her formidable skills as a researcher to enliven and discipline her teaching. From early visitations to her class, I can add an important element that often goes missing in this standard narrative: even early-on, Professor Fox clearly enjoyed the connection with her students, no matter her initial problems with focus and organization. What makes Professor Fox a remarkable teacher at present is precisely what was abundantly obvious even in those first years; namely, her joy in getting students involved in studying the variety and ingenuity of animal lives.

In addition to talking about her current approaches over the last two years -- from a new introductory course developed by the biology program to her ongoing attempts to connect her fieldwork to her upper-level courses -- Professor Fox would often share new findings about avian cognition with me. Eventually, I invited her to my classes. In the last several years, she has addressed my classes three times, all of them aiming to make a case for the intelligence of birds, and most recently, cetaceans as well. In each appearance, Professor Fox sent materials ahead of time -- current scientific articles, which challenged many of my non-science-major students to read slowly and observantly, and enticing popular articles from credible and even literary sources (e.g., an article from the *New Yorker* puzzling over whether or not it is ethical to eat cetaceans, given what we now know about their impressive cognitive abilities). By dint of such offerings, she signaled that her two days with my students would not only be about praising avian and cetacean competencies but about ethical duties we might have towards them as a result of these scientific discoveries.

In the classes, Professor Fox complemented the formality and formidability of the readings by her friendly, informal demeanor. An introduction featuring why she chose ornithology and her subsequent experiences with scrub jay feeding strategies took a few minutes to set up,and t the

rest of the class became an intense-yet-amicable investigation of avian intelligence, wherein she did not use her fascinating videos and slides until a question relevant to them was raised. This very effective tactic showed how thoroughly knowledgeable Professor Fox was about her subject-matter but also how she would wait for student interest to move deeper. One student raised the question of whether there were any linguistic building blocks in avian lives, and Professor Fox showed an absolutely stunning video of baby chicks being fed, where the mother seemed to tell them apart by differential chirping sounds.

The whole class appeared seamless as if the places students were driving the discussion were quite the most logical places to go, with Professor Fox merely providing color commentary and dead-on short videos -- while in fact she was clearly prepared to take any number of pathways depending on student interest.

In the second class on cetaceans, Professor Fox took a quite different tack. She began with a fairly old video of an octopus escaping a Mason jar by unscrewing the top. “Ok, this should surprise you,” she began, “but let’s think about this. *What* is so jolting about this behavior?” We eventually explored Octopus ethology largely by gently discounting multiple student hypotheses about what it would take for a body in a cetacean habitat and an evolved life in the sea to “figure out” such an escape. She, of course, ended with a conversation about the aforementioned *New Yorker* article.

In the first class, Professor Fox used her own area of expertise to the best advantage, surrounding my students with vivid supporting clips of behaviors and deepening the discussion as she went. In the second, she pushed student expertise, Socratically, with little further elaboration on octopus cognition beyond encouraging students to apply what the readings had stated. In two classes, she demonstrated impressive pedagogical flexibility and a canny knowledge of students’ interests. Scrub jay intelligence is a hard sell, so she sold it hard; octopus behavior is all over the internet and inherently interesting, so she pushed students to think harder than they thought they could about cetacean ethology.

I have very much enjoyed working with Professor Fox in my classes, where that original joy in enticing students to learn and think that she demonstrated in my initial visitations to her class still shines, but also she now has at her command an array of teaching strategies that she maps onto the demand of the materials and the structure of the classes. I strongly recommend her for the Bingham Award.

Sincerely,

Jack Furlong
Professor, Philosophy

Recommendation for Becky Fox

Quite honestly, Dr. Becky Fox was initially a disappointment. Although her job talk was impressive, soon into her first semester at Transylvania search committee members were scratching their heads and regretting their choice. By all accounts—including her own—Becky's was something of a train wreck in the classroom. Nevertheless, with a lot of hard work on her part, and good support from several colleagues, Becky has become a great teacher and research mentor to our students, and I gladly recommend her for a Bingham Award for Teaching Excellence.

Despite her very rough start, Becky became a teacher who is valued by students and faculty alike. I was Becky's division chair for five of her six years at the assistant professor stage, and was appointed to conduct her first evaluation even before I was division chair. I readily attest to the *steady* and *marked* improvement I observed during all six formal evaluations. Furthermore, I interviewed each faculty member face to face for both the mid-probationary review and the tenure decision. The transformation in Becky that I witnessed first-hand, and through the eyes of her biology colleagues, was wonderful to behold.

There are many factors behind this transformation, but chief among them is that Becky found her own voice and developed the confidence to use it. After trying (and failing) to be who she perceived a Transylvania faculty member to be, she started being her own unique self, allowing herself the freedom to teach as she thought best, research as she thought best, and even dress as she thought best. (I realize discussing anyone's attire—and especially a woman's—in a professional letter such as this can be problematic, so I asked Becky for permission and explained the context. I also asked whether to refer to her as Dr. Fox or Becky, and she chose first name.) It seems that the intensity of Becky's wardrobe—much like the plumage of the birds she studies—is highly correlated with her well-being, so when she broke out the vibrant cardigans and neon hair, we knew she had finally found not only her voice but her academic home.

Although hired by the biology program, Becky was pivotal in creating the interdisciplinary Neuroscience major, which quickly attracted students. Thus, Becky serves as an integral component of two of the college's most popular majors. The biology faculty also appreciate that Dr. Fox frequently enlists "marginalized" students who (like Becky) are somewhat outside of the social norm; students who, quite frankly, most of the biology faculty seem unable or unwilling to reach. Becky greatly enhances the biology program by giving these students an academic identity, by teaching them how to be scientists, and by directing them toward graduate programs where they thrive.

Becky quite naturally blends her professional work with teaching. By many standards, her research program is the best in the division: she is co-PI on a quarter-million dollar National Science Foundation grant that directly benefits Transylvania students (including $25,000 in student salary, $9,000 in laboratory equipment, and $8,000 in student travel). Through this grant, Becky was enabled to take several students to a national conference in Alaska where they presented their own research. At least four of Becky's research students are already in graduate school in PhD programs, and a fifth won a Fullbright!

It seems appropriate to mention how Becky influences teaching beyond her own classroom. Several untenured faculty (including some outside of the division) have commented to me upon the significance of Becky's mentorship. Because she had such a difficult transition into teaching, she is particularly interested in helping our new faculty make this adjustment. In this way, Becky flipped the negative experience of her difficult first year into a source for a very positive leadership experience, which impacts teaching in many other classrooms around campus.

Six years ago, I could not have envisioned writing this letter. Even three years ago, I would have politely declined if asked to write in support of Becky's application. Today, however, I write with much confidence that the committee will find Dr. Becky Fox to be an outstanding teacher and an asset to the entire Transylvania community. Please grant her this prestigious award which she so clearly deserves.

Sincerely,

Jamie Day
Professor of Physics

Canisius
COLLEGE
Where leaders are made

Animal Behavior, Ecology, and Conservation
phone 716-888-2770 | fax 716-888-3157| email abec@canisius.edu

December 10, 2016

Bingham Trust
Transylvania University

Re: Rebecca Fox

To the Award Committee:

It is my pleasure to provide an external recommendation for Dr Rebecca Fox's candidacy for the Bingham Teaching Award. I write to you as a Professor of Biology at Canisius College in Buffalo (New York) where I was also the founding chair of the Animal Behavior, Ecology, and Conservation program. Dr Fox's professional record is impressive, and I am happy to report a very favorable report from a peer institution.

I have known Dr Fox for many years through her membership in the Animal Behavior Society (ABS). It has been my pleasure over the years to have numerous discussions of pedagogical strategies with Dr Fox, both informally and in organized events. In this way, I have learned a great deal about the creative ways that Dr Fox engages students. I have also had numerous occasions to see her interact with students at ABS meetings.

Dr Fox is thoroughly devoted to her students and to the profession of teaching. I enthusiastically endorse her for the Bingham Teaching Award.

Sincerely,

Michael Noonan, PhD
Professor, Biology
Animal Behavior, Ecology, and Conservation

MN/if

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TRANSYLVANIA UNIV/WINTER 2016

INSTRUCTOR'S NAME		
Fox, Rebecca		
COURSE TITLE		
INSTRUCTOR SUMMARY OF UNIT CLASSES		
COURSE NUMBER	UNIT	INSTITUTIONAL CODE
	NSM	TRA2098.S
REGISTERED STUDENTS	FORMS RETURNED	PERCENT PARTICIPATION
38	37	97.3%

This report summarizes results from the Survey of Student Opinion of Instruction. The first page contains identification items, percent of student participation, and responses from the Instructor's Questionnaire.

The second and third pages summarize the distribution of student responses to each questionnaire item using a scale from five to one where five means "Strongly Agree" and one means "Strongly Disagree." In each line, the distribution of responses is a **percent** distribution based upon the total number of responses to each item. Means are based upon the appropriate **total responses** for each identified category.

FACTOR MEANS **~~INSTRUCTOR RESPONSES~~ (AND STANDARD DEVIATIONS) FOR INSTRUCTOR, UNIT, INSTITUTION AND NATIONAL SAMPLE.

THIS PAGE OF THE INSTRUCTOR SUMMARY CONTAINS MEANS AND STANDARD DEVIATIONS FOR EACH OF SIX FACTORS IDENTIFIED BY FACTOR ANALYSIS OF THE FIRST 21 QUESTIONS. THE QUESTIONS COMPRISING EACH FACTOR ARE INDICATED IN ORDER OF FACTOR LOADING. MEANS ARE BASED UPON THE TOTAL RESPONSES WITHIN EACH OF THE INDICATED SUMMARY LEVELS. THE NATIONAL SAMPLE IS COMPRISED OF MORE THAN ONE MILLION (SURVEY OF STUDENT OPINION OF INSTRUCTION TM) QUESTIONNAIRES ADMINISTERED OVER THE PREVIOUS FIVE YEARS.

		INSTRUCTOR MEAN (SD)	UNIT MEAN (SD)	INSTITUTION MEAN (SD)	NATIONAL MEAN (SD)
FACTOR 1 INSTRUCTOR COMMITMENT TO STUDENT LEARNING QUESTIONS: 10 , 7 , 20 , 17 , 16 , 8 , 1 , 21	***	4.81 (0.444)	4.56 (0.806)	4.56 (0.522)	4.42 (0.913)
FACTOR 2 INSTRUCTOR PREPARATION AND ORGANIZATION QUESTIONS: 9 , 11 , 3	*	4.66 (0.561)	4.55 (0.799)	4.56 (0.798)	4.44 (0.886)
FACTOR 3 INSTRUCTOR/STUDENT INTERACTION QUESTIONS: 4 , 13 , 18 , 14	***	4.66 (0.578)	4.19 (1.117)	4.29 (0.555)	4.17 (1.076)
FACTOR 4 TESTING QUESTIONS: 6 , 5	***	4.72 (0.533)	4.46 (0.899)	4.47 (0.894)	4.35 (0.936)
FACTOR 5 COURSE OBJECTIVES QUESTIONS: 15 , 12	***	4.76 (0.486)	4.49 (0.846)	4.52 (0.814)	4.42 (0.868)
FACTOR 6 COURSE ASSIGNMENTS QUESTIONS: 2 , 19	***	4.65 (0.628)	4.44 (0.893)	4.45 (0.856)	4.25 (0.981)

SIGNIFICANTLY DIFFERENT FROM THE NATIONAL MEAN ..... * = AT .05 LEVEL / ** = AT .01 LEVEL / *** = AT .001 LEVEL

Foxy Rebecca

SUMMARY OF UNIT CLASSES

STUDENT RESPONSES	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	ITEM MEAN	UNIT MEAN	INSTITUTIONAL MEAN
1. The clarity and audibility of the instructor's speech are excellent.	37	81.0	18.9	0.0	0.0	0.0	4.81	4.71	4.70
2. The contents of the assignments contribute to my understanding of the subject.	37	75.6	16.2	8.1	0.0	0.0	4.67	4.54	4.55
3. The requirements of the course (projects, papers, exams, etc.) were explained adequately.	37	64.8	29.7	5.4	0.0	0.0	4.59	4.49	4.49
4. The instructor's presentation often causes me to think in depth about this subject.	37	75.6	18.9	5.4	0.0	0.0	4.70	4.33	4.42
5. The instructor has adequate means for evaluating my learning.	37	75.6	21.6	2.7	0.0	0.0	4.72	4.48	4.48
6. The methods being used for evaluating my work (such as tests, projects, etc.) are reasonable.	36	77.7	16.6	5.5	0.0	0.0	4.72	4.43	4.45
7. Adequate opportunities are provided by the instructor for me to ask questions.	37	91.8	8.1	0.0	0.0	0.0	4.91	4.70	4.70
8. The instructor is teaching the course material or skills clearly.	37	75.6	18.9	5.4	0.0	0.0	4.70	4.43	4.49
9. The instructor seems to be well prepared.	37	75.6	21.6	2.7	0.0	0.0	4.72	4.62	4.62
10. The instructor seems to care about my learning.	36	91.6	8.3	0.0	0.0	0.0	4.91	4.63	4.64
11. The course appears to have been carefully planned.	37	72.9	21.6	5.4	0.0	0.0	4.67	4.55	4.56
12. Course objectives are being achieved.	37	81.0	16.2	2.7	0.0	0.0	4.78	4.50	4.54
13. During the term, I looked forward to attending this class.	37	67.5	24.3	8.1	0.0	0.0	4.59	3.89	4.06
14. Compared with other courses on this level carrying an equal amount of credit, the effort I put into this course is as much as in other courses.	36	66.6	27.7	5.5	0.0	0.0	4.61	4.20	4.23
15. Course objectives have been expressed clearly.	36	77.7	19.4	2.7	0.0	0.0	4.75	4.49	4.50
16. The instructor demonstrates a personal commitment to high standards of professional competence.	36	91.6	8.3	0.0	0.0	0.0	4.91	4.63	4.64
17. The instructor provides useful feedback on student progress (identifying strengths and weaknesses).	36	75.0	19.4	5.5	0.0	0.0	4.69	4.34	4.38
18. In this course, I am learning much.	36	77.7	19.4	2.7	0.0	0.0	4.75	4.37	4.43
19. The out-of-class assignments are challenging.	36	72.2	19.4	8.3	0.0	0.0	4.63	4.35	4.35
20. The instructor supervises and helps in new experiences without taking over.	36	80.5	13.8	5.5	0.0	0.0	4.75	4.52	4.45
21. The instructor relates underlying theory to practice.	36	86.1	11.1	2.7	0.0	0.0	4.83	4.53	4.51
22. Overall, I rate this instructor a good teacher.	36	86.1	13.8	0.0	0.0	0.0	4.86	4.53	4.55

Fox, Rebecca

SUMMARY OF UNIT CLASSES

STUDENT RESPONSES	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	ITEM MEAN	UNIT MEAN	INSTITUTIONAL MEAN
23. Examinations cover material or skills emphasized in the course.	32	87.5	12.5	0.0	0.0	0.0	4.87	4.56	4.56
24. The time allowed to complete exams is adequate.	32	90.6	9.3	0.0	0.0	0.0	4.90	4.33	4.48
25. Examination questions are phrased clearly.	32	56.2	31.2	12.5	0.0	0.0	4.43	4.25	4.36
26. The textbooks contribute to my understanding of the subject.	32	37.5	15.6	34.3	12.5	0.0	3.78	4.14	4.36
27. The course is practical and useful to those students for whom it was specifically planned.	32	78.1	15.6	3.1	3.1	0.0	4.68	4.49	4.53
28. The clinical experiences, or laboratory, meet my learning needs for this course.	31	64.5	19.3	9.6	3.2	3.2	4.38	4.31	4.35
29. The instructor explains or illustrates laboratory or clinical techniques clearly.	31	67.7	29.0	3.2	0.0	0.0	4.64	4.43	4.42
30. Pre-laboratory assignments (assigned readings and exercises) contribute to my understanding of laboratory experiments.	28	60.7	28.5	10.7	0.0	0.0	4.50	4.26	4.31
31. The laboratory contributes to my understanding of the subject.	30	63.3	20.0	16.6	0.0	0.0	4.46	4.28	4.31
32. The laboratory manual adequately explains the procedures to be followed in the laboratory.	26	65.3	19.2	15.3	0.0	0.0	4.50	4.27	4.35
33. Equipment and materials needed to perform the laboratory experiments are organized and readily available for use during the laboratory.	29	68.9	24.1	6.8	0.0	0.0	4.62	4.55	4.52

34. My perception of the teaching method used in this course is

Total Responses	Lecture	Discussion	Demonstration	Combination of these	Other
30	40.0	3.3	0.0	56.6	0.0

35. This course is

Total Responses	In my major	General requirement	An elective	Required cognate	Other
30	93.3	0.0	0.0	0.0	6.6

36. My class is

Total Responses	Freshman	Sophomore	Junior	Senior	Graduate
29	37.9	0.0	24.1	37.9	0.0

37. My grade point average to date is (round off)

Responses	4.0 – 3.5	3.4 – 3.0	2.9 – 2.5	2.4 – 2.0	Under 2.0
28	28.5	60.7	10.7	0.0	0.0

The grade I presently have in this class is

Responses	A	B	C	D	F
28	35.7	60.7	0.0	3.5	0.0

	Yes	No	Not needed
If I needed help outside of class, the instructor has given help to me.	100.0	0.0	0.0

40.		5	4	3	2	1
41.		5	4	3	2	1
42.		5	4	3	2	1
43.		5	4	3	2	1
44.		5	4	3	2	1
45.		5	4	3	2	1
46.		5	4	3	2	1
47.		5	4	3	2	1
48.		5	4	3	2	1
49.		5	4	3	2	1
50.		5	4	3	2	1

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This report summarizes results from the Survey of Student Opinion of Instruction. The first page ontains identification items, percent of student participation, and responses from the Instructor's uestionnaire.

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INSTRUCTOR'S NAME		
Fox, Rebecca		
COURSE TITLE		
INSTRUCTOR SUMMARY OF UNIT CLASSES		
COURSE NUMBER	UNIT	INSTITUTIONAL CODE
	SS	TRA2087.S
REGISTERED STUDENTS	FORMS RETURNED	PERCENT PARTICIPATION
7	5	71.4%

FACTOR MEANS ~~**INSTRUCTOR RESPONSES~~ (AND STANDARD DEVIATIONS) FOR INSTRUCTOR, UNIT, INSTITUTION AND NATIONAL SAMPLE.

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	INSTRUCTOR MEAN (SD)	UNIT MEAN (SD)	INSTITUTION MEAN (SD)	NATIONAL MEAN (SD)
FACTOR 1 INSTRUCTOR COMMITMENT TO STUDENT LEARNING QUESTIONS: 10 , 7 , 20 , 17 , 16 , 8 , 1 , 21	4.70 (0.464)	4.54 (0.804)	4.52 (0.579)	4.42 (0.913)
FACTOR 2 INSTRUCTOR PREPARATION AND ORGANIZATION QUESTIONS: 9 , 11 , 3	4.00 (0.845)	4.53 (0.792)	4.51 (0.817)	4.44 (0.886)
FACTOR 3 INSTRUCTOR/STUDENT INTERACTION QUESTIONS: 4 , 13 , 18 , 14	4.35 (0.670)	4.31 (0.964)	4.24 (0.617)	4.17 (1.076)
FACTOR 4 TESTING QUESTIONS: 6 , 5	4.30 (0.823)	4.42 (0.881)	4.44 (0.885)	4.35 (0.936)
FACTOR 5 COURSE OBJECTIVES QUESTIONS: 15 , 12	4.40 (0.699)	4.49 (0.786)	4.46 (0.825)	4.42 (0.868)
FACTOR 6 COURSE ASSIGNMENTS QUESTIONS: 2 , 19	4.40 (0.699)	4.40 (0.815)	4.41 (0.851)	4.25 (0.981)

QUESTIONS: 2 , 19

15.

Fox, Rebecca

SUMMARY OF UNIT CLASSES

STUDENT RESPONSES	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	ITEM MEAN	UNIT MEAN	INSTITUTIONAL MEAN
1. The clarity and audibility of the instructor's speech are excellent.	5	100.0	0.0	0.0	0.0	0.0	5.00	4.71	4.66
2. The contents of the assignments contribute to my understanding of the subject.	5	40.0	60.0	0.0	0.0	0.0	4.40	4.54	4.53
3. The requirements of the course (projects, papers, exams, etc.) were explained adequately.	5	40.0	40.0	20.0	0.0	0.0	4.20	4.44	4.45
4. The instructor's presentation often causes me to think in depth about this subject.	5	60.0	20.0	20.0	0.0	0.0	4.40	4.41	4.34
5. The instructor has adequate means for evaluating my learning.	5	60.0	20.0	20.0	0.0	0.0	4.40	4.44	4.45
6. The methods being used for evaluating my work (such as tests, projects, etc.) are reasonable.	5	40.0	40.0	20.0	0.0	0.0	4.20	4.40	4.42
7. Adequate opportunities are provided by the instructor for me to ask questions.	5	100.0	0.0	0.0	0.0	0.0	5.00	4.70	4.67
8. The instructor is teaching the course material or skills clearly.	5	20.0	80.0	0.0	0.0	0.0	4.20	4.50	4.45
9. The instructor seems to be well prepared.	5	40.0	20.0	40.0	0.0	0.0	4.00	4.60	4.58
10. The instructor seems to care about my learning.	5	80.0	20.0	0.0	0.0	0.0	4.80	4.64	4.64
11. The course appears to have been carefully planned.	5	20.0	40.0	40.0	0.0	0.0	3.80	4.55	4.51
12. Course objectives are being achieved.	5	40.0	40.0	20.0	0.0	0.0	4.20	4.53	4.49
13. During the term, I looked forward to attending this class.	5	20.0	60.0	20.0	0.0	0.0	4.00	4.12	4.00
14. Compared with other courses on this level carrying an equal amount of credit, the effort I put into this course is as much as in other courses.	5	20.0	80.0	0.0	0.0	0.0	4.20	4.24	4.22
Course objectives have been expressed clearly.	5	60.0	40.0	0.0	0.0	0.0	4.60	4.45	4.43
The instructor demonstrates a personal commitment to high standards of professional competence.	5	40.0	60.0	0.0	0.0	0.0	4.40	4.64	4.62
The instructor provides useful feedback on student progress (identifying strengths and weaknesses).	5	60.0	40.0	0.0	0.0	0.0	4.60	4.23	4.32
In this course, I am learning much.	5	80.0	20.0	0.0	0.0	0.0	4.80	4.48	4.39
The out-of-class assignments are challenging.	5	60.0	20.0	20.0	0.0	0.0	4.40	4.27	4.30
The instructor supervises and helps in new experiences without taking over.	5	80.0	20.0	0.0	0.0	0.0	4.80	4.39	4.39
The instructor relates underlying theory to practice.	5	80.0	20.0	0.0	0.0	0.0	4.80	4.50	4.45
Overall, I rate this instructor a good teacher.	5	80.0	20.0	0.0	0.0	0.0	4.80	4.57	4.54

Total Responses	Freshman	Sophomore	Junior	Senior	Graduate
3	0.0	0.0	0.0	100.0	0.0

37. My grade point average to date is (round off)

4.0 – 3.5	3.4 – 3.0	2.9 – 2.5	2.4 – 2.0	Under 2.0
33.3	66.6	0.0	0.0	0.0

Fox, Rebecca SUMMARY OF UNIT CLASSES STUDENT RESPONSES

	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	ITEM MEAN	UNIT MEAN	INSTITUTIONAL MEAN
23. Examinations cover material or skills emphasized in the course.									
24. The time allowed to complete exams is adequate.									
25. Examination questions are phrased clearly.									
26. The textbooks contribute to my understanding of the subject.	3	33.3	33.3	33.3	0.0	0.0	4.00	4.41	4.33
27. The course is practical and useful to those students for whom it was specifically planned.	3	66.6	33.3	0.0	0.0	0.0	4.66	4.61	4.54
28. The clinical experiences, or laboratory, meet my learning needs for this course.									
29. The instructor explains or illustrates laboratory or clinical techniques clearly.									
30. Pre-laboratory assignments (assigned readings and exercises) contribute to my understanding of laboratory experiments.									
31. The laboratory contributes to my understanding of the subject.									
32. The laboratory manual adequately explains the procedures to be followed in the laboratory.									
33. Equipment and materials needed to perform the laboratory experiments are organized and readily available for use during the laboratory.									

34. My perception of the teaching method used in this course is

Total Responses	Lecture	Discussion	Demonstration	Combination of these	Other
3	0.0	66.6	0.0	33.3	0.0

35. This course is

Total Responses	In my major	General requirement	An elective	Required cognate	Other
3	100.0	0.0	0.0	0.0	0.0

36. My class is

Total Responses	Freshman	Sophomore	Junior	Senior	Graduate
3	0.0	0.0	0.0	100.0	0.0

37. My grade point average to date is (round off)

Total Responses	4.0 – 3.5	3.4 – 3.0	2.9 – 2.5	2.4 – 2.0	Under 2.0
3	33.3	66.6	0.0	0.0	0.0

38. The grade I presently have in this class is

Total Responses	A	B	C	D	F
3	33.3	66.6	0.0	0.0	0.0

39. If I needed help outside of class, the instructor has given help to me.

Yes	No	Not needed
100.0	0.0	0.0

		5	4	3	2	1			
40.		5	4	3	2	1			
41.		5	4	3	2	1			
42.		5	4	3	2	1			
43.		5	4	3	2	1			
44.		5	4	3	2	1			
45.		5	4	3	2	1			
46.		5	4	3	2	1			
47.		5	4	3	2	1			
48.		5	4	3	2	1			
49.		5	4	3	2	1			
50.		5	4	3	2	1			

4.16 (1.124) 4.55 (0.745) 4.46 (0.825) 4.42 (0.868)

QUESTIONS: 15 , 12

13.

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This report summarizes results from the Survey of Student Opinion of Instruction. The first page ontains identification items, percent of student participation, and responses from the Instructor's uestionnaire.

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INSTRUCTOR'S NAME		
Fox, Rebecca		
COURSE TITLE		
INSTRUCTOR SUMMARY OF UNIT CLASSES		
COURSE NUMBER	UNIT	INSTITUTIONAL CODE
	NSM	TRA2087.S
REGISTERED STUDENTS	FORMS RETURNED	PERCENT PARTICIPATION
22	21	95.4%

FACTOR MEANS **~~INSTRUCTOR RESPONSES~~ (AND STANDARD DEVIATIONS) FOR INSTRUCTOR, UNIT, INSTITUTION AND NATIONAL SAMPLE.

THIS PAGE OF THE INSTRUCTOR SUMMARY CONTAINS MEANS AND STANDARD DEVIATIONS FOR EACH OF SIX FACTORS IDENTIFIED BY FACTOR ANALYSIS OF THE FIRST 21 QUESTIONS. THE QUESTIONS COMPRISING EACH FACTOR ARE INDICATED IN ORDER OF FACTOR LOADING. MEANS ARE BASED UPON THE TOTAL RESPONSES WITHIN EACH OF THE INDICATED SUMMARY LEVELS. THE NATIONAL SAMPLE IS COMPRISED OF MORE THAN ONE MILLION (SURVEY OF STUDENT OPINION OF INSTRUCTION TM) QUESTIONNAIRES ADMINISTERED OVER THE PREVIOUS FIVE YEARS.

	INSTRUCTOR MEAN (SD)	UNIT MEAN (SD)	INSTITUTION MEAN (SD)	NATIONAL MEAN (SD)
FACTOR 1 INSTRUCTOR COMMITMENT TO STUDENT LEARNING QUESTIONS: 10 , 7 , 20 , 17 , 16 , 8 , 1 , 21	4.14 (1.161)	4.54 (0.800)	4.52 (0.579)	4.42 (0.913)
FACTOR 2 INSTRUCTOR PREPARATION AND ORGANIZATION QUESTIONS: 9 , 11 , 3	4.00 (1.191)	4.58 (0.759)	4.51 (0.817)	4.44 (0.886)
FACTOR 3 INSTRUCTOR/STUDENT INTERACTION QUESTIONS: 4 , 13 , 18 , 14	3.94 (1.235)	4.23 (1.059)	4.24 (0.617)	4.17 (1.076)
FACTOR 4 TESTING QUESTIONS: 6 , 5	* 3.76 (1.375)	4.48 (0.858)	4.44 (0.885)	4.35 (0.936)
FACTOR 5 COURSE OBJECTIVES QUESTIONS: 15 , 12	4.16 (1.124)	4.55 (0.745)	4.46 (0.825)	4.42 (0.868)
FACTOR 6 COURSE ASSIGNMENTS QUESTIONS: 2 , 19	4.11 (1.108)	4.49 (0.837)	4.41 (0.851)	4.25 (0.981)

SIGNIFICANTLY DIFFERENT FROM THE NATIONAL MEAN ..... * = AT .05 LEVEL / ** = AT .01 LEVEL / *** = AT .001 LEVEL

Fox, Rebecca

SUMMARY OF UNIT CLASSES

STUDENT RESPONSES	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	ITEM MEAN	UNIT MEAN	INSTITUTIONAL MEAN
1. The clarity and audibility of the instructor's speech are excellent.	21	57.1	33.3	4.7	0.0	4.7	4.38	4.68	4.66
2. The contents of the assignments contribute to my understanding of the subject.	21	42.8	33.3	19.0	0.0	4.7	4.09	4.61	4.53
3. The requirements of the course (projects, papers, exams, etc.) were explained adequately.	21	42.8	38.0	9.5	4.7	4.7	4.09	4.53	4.45
4. The instructor's presentation often causes me to think in depth about this subject.	21	47.6	23.8	19.0	0.0	9.5	4.00	4.33	4.34
5. The instructor has adequate means for evaluating my learning.	21	52.3	19.0	19.0	0.0	9.5	4.04	4.52	4.45
6. The methods being used for evaluating my work (such as tests, projects, etc.) are reasonable.	21	33.3	19.0	23.8	9.5	14.2	3.47	4.44	4.42
7. Adequate opportunities are provided by the instructor for me to ask questions.	21	61.9	28.5	0.0	0.0	9.5	4.33	4.70	4.67
8. The instructor is teaching the course material or skills clearly.	21	47.6	33.3	9.5	4.7	4.7	4.14	4.42	4.45
9. The instructor seems to be well prepared.	21	42.8	19.0	28.5	0.0	9.5	3.85	4.65	4.58
10. The instructor seems to care about my learning.	21	66.6	23.8	0.0	0.0	9.5	4.38	4.63	4.64
11. The course appears to have been carefully planned.	21	47.6	28.5	14.2	0.0	9.5	4.04	4.57	4.51
12. Course objectives are being achieved.	21	47.6	33.3	9.5	4.7	4.7	4.14	4.57	4.49
13. During the term, I looked forward to attending this class.	21	28.5	23.8	38.0	0.0	9.5	3.61	3.92	4.00
14. Compared with other courses on this level carrying an equal amount of credit, the effort I put into this course is as much as in other courses.	21	42.8	33.3	4.7	4.7	14.2	3.85	4.23	4.22
15. Course objectives have been expressed clearly.	21	57.1	19.0	14.2	4.7	4.7	4.19	4.53	4.43
16. The instructor demonstrates a personal commitment to high standards of professional competence.	21	42.8	38.0	9.5	0.0	9.5	4.04	4.66	4.62
17. The instructor provides useful feedback on student progress (identifying strengths and weaknesses).	21	23.8	38.0	23.8	4.7	9.5	3.61	4.29	4.32
18. In this course, I am learning much.	21	52.3	33.3	9.5	0.0	4.7	4.28	4.43	4.39
19. The out-of-class assignments are challenging.	21	47.6	38.0	4.7	0.0	9.5	4.14	4.37	4.30
20. The instructor supervises and helps in new experiences without taking over.	21	38.0	52.3	0.0	0.0	9.5	4.09	4.49	4.39
21. The instructor relates underlying theory to practice.	21	57.1	23.8	9.5	0.0	9.5	4.19	4.50	4.45
22. Overall, I rate this instructor a good teacher.	21	38.0	42.8	4.7	4.7	9.5	3.95	4.57	4.54

Fox, Rebecca — SUMMARY OF UNIT CLASSES — STUDENT RESPONSES

	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	ITEM MEAN	UNIT MEAN	INSTITUTIONAL MEAN
23. Examinations cover material or skills emphasized in the course.	16	50.0	18.7	12.5	6.2	12.5	3.87	4.57	4.56
24. The time allowed to complete exams is adequate.	16	81.2	18.7	0.0	0.0	0.0	4.81	4.41	4.47
25. Examination questions are phrased clearly.	16	31.2	31.2	12.5	12.5	12.5	3.56	4.35	4.38
26. The textbooks contribute to my understanding of the subject.	18	33.3	33.3	22.2	11.1	0.0	3.88	4.22	4.33
27. The course is practical and useful to those students for whom it was specifically planned.	18	66.6	22.2	0.0	11.1	0.0	4.44	4.56	4.54
28. The clinical experiences, or laboratory, meet my learning needs for this course.	16	50.0	25.0	6.2	0.0	18.7	3.87	4.31	4.31
29. The instructor explains or illustrates laboratory or clinical techniques clearly.	16	43.7	37.5	0.0	12.5	6.2	4.00	4.35	4.33
30. Pre-laboratory assignments (assigned readings and exercises) contribute to my understanding of laboratory experiments.	9	33.3	44.4	11.1	0.0	11.1	3.88	4.18	4.22
31. The laboratory contributes to my understanding of the subject.	16	37.5	37.5	0.0	12.5	12.5	3.75	4.24	4.25
32. The laboratory manual adequately explains the procedures to be followed in the laboratory.	7	42.8	14.2	14.2	0.0	28.5	3.42	4.25	4.24
33. Equipment and materials needed to perform the laboratory experiments are organized and readily available for use during the laboratory.	16	43.7	18.7	18.7	6.2	12.5	3.75	4.53	4.43

My perception of the teaching method used in this course is

Responses	Lecture	Discussion	Demonstration	Combination of these	Other
18	44.4	16.6	0.0	38.8	0.0

This course is

Responses	In my major	General requirement	An elective	Required cognate	Other
18	88.8	0.0	11.1	0.0	0.0

My class is

Responses	Freshman	Sophomore	Junior	Senior	Graduate
17	0.0	0.0	23.5	76.4	0.0

My grade point average to date is (round off)

Responses	4.0 – 3.5	3.4 – 3.0	2.9 – 2.5	2.4 – 2.0	Under 2.0
15	40.0	46.6	13.3	0.0	0.0

The grade I presently have in this class is

Responses	A	B	C	D	F
15	33.3	66.6	0.0	0.0	0.0

40.		5	4	3	2	1	
41.		5	4	3	2	1	
42.		5	4	3	2	1	
43.		5	4	3	2	1	
44.		5	4	3	2	1	
45.		5	4	3	2	1	
46.		5	4	3	2	1	
47.		5	4	3	2	1	
48.		5	4	3	2	1	
49.		5	4	3	2	1	

SUMMA
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TRANSYLVANIA UNIV/WINTER 2015

This report summarizes results from the Survey of Student Opinion of Instruction. The first page contains identification items, percent of student participation, and responses from the Instructor's Questionnaire.

The second and third pages summarize the distribution of student responses to each questionnaire item using a scale from five to one where five means "Strongly Agree" and one means "Strongly Disagree." In each line, the distribution of responses is a **percent** distribution based upon the total number of responses to each item. Means are based upon the appropriate **total responses** for each identified category.

INSTRUCTOR'S NAME		
Fox, Rebecca		
COURSE TITLE		
INSTRUCTOR SUMMARY OF UNIT CLASSES		
COURSE NUMBER	UNIT	INSTITUTIONAL CODE
[redacted]	NSM	TRA2064.S
REGISTERED STUDENTS	FORMS RETURNED	PERCENT PARTICIPATION
27	23	85.1%

FACTOR MEANS **~~INSTRUCTOR RESPONSES~~ (AND STANDARD DEVIATIONS) FOR INSTRUCTOR, UNIT, INSTITUTION AND NATIONAL SAMPLE.

THIS PAGE OF THE INSTRUCTOR SUMMARY CONTAINS MEANS AND STANDARD DEVIATIONS FOR EACH OF SIX FACTORS IDENTIFIED BY FACTOR ANALYSIS OF THE FIRST 21 QUESTIONS. THE QUESTIONS COMPRISING EACH FACTOR ARE INDICATED IN ORDER OF FACTOR LOADING. MEANS ARE BASED UPON THE TOTAL RESPONSES WITHIN EACH OF THE INDICATED SUMMARY LEVELS. THE NATIONAL SAMPLE IS COMPRISED OF MORE THAN ONE MILLION (SURVEY OF STUDENT OPINION OF INSTRUCTION TM) QUESTIONNAIRES ADMINISTERED OVER THE PREVIOUS FIVE YEARS.

3.	INSTRUCTOR MEAN (SD)	UNIT MEAN (SD)	INSTITUTION MEAN (SD)	NATIONAL MEAN (SD)
4. FACTOR 1 INSTRUCTOR COMMITMENT TO STUDENT LEARNING QUESTIONS: 10 , 7 , 20 , 17 , 16 , 8 , 1 , 21	* 4.68 (0.628)	4.44 (0.886)	4.49 (0.550)	4.41 (0.915)
5.				
6. FACTOR 2 INSTRUCTOR PREPARATION AND ORGANIZATION QUESTIONS: 9 , 11 , 3	4.50 (0.815)	4.46 (0.860)	4.48 (0.832)	4.44 (0.886)
7.				
8. FACTOR 3 INSTRUCTOR/STUDENT INTERACTION QUESTIONS: 4 , 13 , 18 , 14	4.43 (1.013)	4.07 (1.172)	4.18 (0.575)	4.17 (1.077)
9.				
10. FACTOR 4 TESTING QUESTIONS: 6 , 5	4.19 (1.147)	4.34 (0.948)	4.39 (0.911)	4.35 (0.937)
11.				
12. FACTOR 5 COURSE OBJECTIVES QUESTIONS: 15 , 12	4.63 (0.609)	4.41 (0.858)	4.45 (0.827)	4.41 (0.869)
13.				
14. FACTOR 6 COURSE ASSIGNMENTS QUESTIONS: 2 , 19	4.46 (0.756)	4.38 (0.913)	4.38 (0.877)	4.26 (0.977)

15. SIGNIFICANTLY DIFFERENT FROM THE NATIONAL MEAN ..... * = AT .05 LEVEL / ** = AT .01 LEVEL / *** = AT .001 LEVEL

Fox, Rebecca

SUMMARY OF UNIT CLASSES

	STUDENT RESPONSES	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	MEAN	MEDIAN	STANDARD DEVIATION
1.	The clarity and audibility of the instructor's speech are excellent.	23	82.6	8.6	8.6	0.0	0.0	4.73	4.64	4.66
2.	The contents of the assignments contribute to my understanding of the subject.	23	60.8	17.3	21.7	0.0	0.0	4.39	4.47	4.50
3.	The requirements of the course (projects, papers, exams, etc.) were explained adequately.	23	52.1	26.0	13.0	8.6	0.0	4.21	4.37	4.41
4.	The instructor's presentation often causes me to think in depth about this subject.	22	77.2	13.6	4.5	0.0	4.5	4.59	4.19	4.31
5.	The instructor has adequate means for evaluating my learning.	23	56.5	21.7	8.6	8.6	4.3	4.17	4.36	4.38
6.	The methods being used for evaluating my work (such as tests, projects, etc.) are reasonable.	23	56.5	21.7	13.0	4.3	4.3	4.21	4.32	4.40
7.	Adequate opportunities are provided by the instructor for me to ask questions.	23	82.6	17.3	0.0	0.0	0.0	4.82	4.64	4.66
8.	The instructor is teaching the course material or skills clearly.	23	73.9	26.0	0.0	0.0	0.0	4.73	4.28	4.42
9.	The instructor seems to be well prepared.	23	73.9	21.7	4.3	0.0	0.0	4.69	4.52	4.5
10.	The instructor seems to care about my learning.	23	86.9	13.0	0.0	0.0	0.0	4.86	4.50	4.5
11.	The course appears to have been carefully planned.	23	73.9	17.3	4.3	4.3	0.0	4.60	4.49	4.
12.	Course objectives are being achieved.	23	69.5	26.0	4.3	0.0	0.0	4.65	4.44	4
13.	During the term, I looked forward to attending this class.	23	69.5	13.0	8.6	0.0	8.6	4.34	3.71	
14.	Compared with other courses on this level carrying an equal amount of credit, the effort I put into this course is as much as in other courses.	23	52.1	34.7	8.6	0.0	4.3	4.30	4.08	
15.	Course objectives have been expressed clearly.	23	69.5	21.7	8.6	0.0	0.0	4.60	4.39	
16.	The instructor demonstrates a personal commitment to high standards of professional competence.	22	77.2	18.1	4.5	0.0	0.0	4.72	4.59	
17.	The instructor provides useful feedback on student progress (identifying strengths and weaknesses).	23	60.8	30.4	0.0	4.3	4.3	4.39	4.1	
18.	In this course, I am learning much.	23	73.9	8.6	13.0	4.3	0.0	4.52	4.	
19.	The out-of-class assignments are challenging.	22	63.6	27.2	9.0	0.0	0.0	4.54	4	
20.	The instructor supervises and helps in new experiences without taking over.	22	68.1	27.2	4.5	0.0	0.0	4.63		
21.	The instructor relates underlying theory to practice.	22	68.1	18.1	13.6	0.0	0.0	4.54		
22.	Overall, I rate this instructor a good teacher.	23	69.5	17.3	4.3	8.6	0.0	4.47		

Fox, Rebecca — SUMMARY OF UNIT CLASSES — STUDENT RESPONSES

	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	ITEM MEAN	UNIT MEAN	INSTITUTIONAL MEAN
23. Examinations cover material or skills emphasized in the course.	13	38.4	46.1	15.3	0.0	0.0	4.23	4.44	4.48
24. The time allowed to complete exams is adequate.	13	53.8	38.4	7.6	0.0	0.0	4.46	4.22	4.40
25. Examination questions are phrased clearly.	12	41.6	41.6	16.6	0.0	0.0	4.25	4.19	4.34
26. The textbooks contribute to my understanding of the subject.	18	55.5	27.7	11.1	5.5	0.0	4.33	3.98	4.28
27. The course is practical and useful to those students for whom it was specifically planned.	17	64.7	23.5	0.0	5.8	5.8	4.35	4.38	4.49
28. The clinical experiences, or laboratory, meet my learning needs for this course.	9	33.3	44.4	22.2	0.0	0.0	4.11	4.29	4.31
29. The instructor explains or illustrates laboratory or clinical techniques clearly.	10	60.0	30.0	10.0	0.0	0.0	4.50	4.33	4.32
30. Pre-laboratory assignments (assigned readings and exercises) contribute to my understanding of laboratory experiments.	9	44.4	44.4	11.1	0.0	0.0	4.33	4.08	4.16
31. The laboratory contributes to my understanding of the subject.	9	44.4	33.3	22.2	0.0	0.0	4.22	4.17	4.22
32. The laboratory manual adequately explains the procedures to be followed in the laboratory.	6	66.6	16.6	16.6	0.0	0.0	4.50	4.16	4.22
33. Equipment and materials needed to perform the laboratory experiments are organized and readily available for use during the laboratory.	8	62.5	25.0	12.5	0.0	0.0	4.50	4.43	4.40

34. My perception of the teaching method used in this course is

Total Responses	Lecture	Discussion	Demonstration	Combination of these	Other
17	11.7	59.8	0.0	29.4	0.0

35. This course is

Total Responses	In my major	General requirement	An elective	Required cognate	Other
18	94.4	0.0	5.5	0.0	0.0

36. My class is

Total Responses	Freshman	Sophomore	Junior	Senior	Graduate
17	41.1	5.8	0.0	52.9	0.0

37. My grade point average to date is (round off)

Total Responses	4.0 – 3.5	3.4 – 3.0	2.9 – 2.5	2.4 – 2.0	Under 2.0
17	35.2	35.2	29.4	0.0	0.0

38. The grade I presently have in this class is

Total Responses	A	B	C	D	F
17	17.6	64.7	17.6	0.0	0.0

	Yes	No	Not needed
39. If I needed help outside of class, the instructor has given help to me.	94.1	0.0	5.8

40.		5	4	3	2	1				
41.		5	4	3	2	1				
42.		5	4	3	2	1				
43.		5	4	3	2	1				
44.		5	4	3	2	1				
45.		5	4	3	2	1				
46.		5	4	3	2	1				
47.		5	4	3	2	1				
48.		5	4	3	2	1				
49.		5	4	3	2	1				
50.		5	4	3	2	1				

SUMMA
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TRANSYLVANIA UNIVERSITY/FL '14

This report summarizes results from the Survey of Student Opinion of Instruction. The first page contains identification items, percent of student participation, and responses from the Instructor's Questionnaire.

The second and third pages summarize the distribution of student responses to each questionnaire item using a scale from five to one where five means "Strongly Agree" and one means "Strongly Disagree." In each line, the distribution of responses is a **percent** distribution based upon the total number of responses to each item. Means are based upon the appropriate **total responses** for each identified category.

INSTRUCTOR'S NAME		
Fox, Rebecca		
COURSE TITLE		
INSTRUCTOR SUMMARY OF UNIT CLASSES		
COURSE NUMBER	UNIT	INSTITUTIONAL CODE
	NSM	TRA2034.S
REGISTERED STUDENTS	FORMS RETURNED	PERCENT PARTICIPATION
32	32	100.0%

FACTOR MEANS **~~INSTRUCTOR RESPONSES~~ (AND STANDARD DEVIATIONS) FOR INSTRUCTOR, UNIT, INSTITUTION AND NATIONAL SAMPLE.

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	INSTRUCTOR MEAN (SD)	UNIT MEAN (SD)	INSTITUTION MEAN (SD)	NATIONAL MEAN (SD)
FACTOR 1 INSTRUCTOR COMMITMENT TO STUDENT LEARNING QUESTIONS: 10 , 7 , 20 , 17 , 16 , 8 , 1 , 21	4.48 (0.889)	4.36 (0.915)	4.45 (0.587)	4.41 (0.915)
FACTOR 2 INSTRUCTOR PREPARATION AND ORGANIZATION QUESTIONS: 9 , 11 , 3	4.32 (0.989)	4.37 (0.892)	4.43 (0.858)	4.44 (0.886)
FACTOR 3 INSTRUCTOR/STUDENT INTERACTION QUESTIONS: 4 , 13 , 18 , 14	* 4.49 (0.869)	4.00 (1.158)	4.12 (0.620)	4.17 (1.077)
FACTOR 4 TESTING QUESTIONS: 6 , 5	4.09 (1.191)	4.26 (0.970)	4.34 (0.926)	4.35 (0.937)
FACTOR 5 COURSE OBJECTIVES QUESTIONS: 15 , 12	4.46 (0.776)	4.32 (0.875)	4.38 (0.855)	4.41 (0.869)
FACTOR 6 COURSE ASSIGNMENTS QUESTIONS: 2 , 19	4.33 (0.967)	4.32 (0.907)	4.31 (0.904)	4.26 (0.977)

SIGNIFICANTLY DIFFERENT FROM THE NATIONAL MEAN ..... * = AT .05 LEVEL / ** = AT .01 LEVEL / *** = AT .001 LEVEL

24. The time allowed to complete exams is adequate.

Fox, Rebecca

SUMMARY OF UNIT CLASSES

	STUDENT RESPONSES	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	ITEM MEAN	UNIT MEAN	INSTITUTIONAL MEAN
1. The clarity and audibility of the instructor's speech are excellent.	32	65.6	31.2	0.0	0.0	3.1	4.56	4.55	4.61
2. The contents of the assignments contribute to my understanding of the subject.	31	64.5	19.3	12.9	0.0	3.2	4.41	4.39	4.44
3. The requirements of the course (projects, papers, exams, etc.) were explained adequately.	32	53.1	25.0	12.5	6.2	3.1	4.18	4.28	4.35
4. The instructor's presentation often causes me to think in depth about this subject.	32	68.7	9.3	18.7	0.0	3.1	4.40	4.12	4.25
5. The instructor has adequate means for evaluating my learning.	32	53.1	18.7	12.5	12.5	3.1	4.06	4.29	4.34
6. The methods being used for evaluating my work (such as tests, projects, etc.) are reasonable.	32	53.1	21.8	15.6	3.1	6.2	4.12	4.23	4.33
7. Adequate opportunities are provided by the instructor for me to ask questions.	32	81.2	12.5	3.1	3.1	0.0	4.71	4.60	4.64
8. The instructor is teaching the course material or skills clearly.	32	59.3	25.0	12.5	3.1	0.0	4.40	4.19	4.38
9. The instructor seems to be well prepared.	32	62.5	18.7	12.5	3.1	3.1	4.34	4.44	4.50
10. The instructor seems to care about my learning.	32	78.1	9.3	6.2	3.1	3.1	4.56	4.46	4.57
11. The course appears to have been carefully planned.	32	62.5	21.8	12.5	3.1	0.0	4.43	4.38	4.44
12. Course objectives are being achieved.	32	62.5	28.1	9.3	0.0	0.0	4.53	4.35	4.43
13. During the term, I looked forward to attending this class.	32	53.1	31.2	6.2	6.2	3.1	4.25	3.65	3.86
14. Compared with other courses on this level carrying an equal amount of credit, the effort I put into this course is as much as in other courses.	32	75.0	12.5	12.5	0.0	0.0	4.62	3.96	4.07
15. Course objectives have been expressed clearly.	32	59.3	28.1	6.2	6.2	0.0	4.40	4.30	4.33
16. The instructor demonstrates a personal commitment to high standards of professional competence.	32	68.7	18.7	6.2	3.1	3.1	4.46	4.49	4.55
17. The instructor provides useful feedback on student progress (identifying strengths and weaknesses).	32	53.1	18.7	15.6	12.5	0.0	4.12	4.05	4.21
18. In this course, I am learning much.	32	75.0	18.7	6.2	0.0	0.0	4.68	4.25	4.29
19. The out-of-class assignments are challenging.	32	50.0	34.3	9.3	3.1	3.1	4.25	4.25	4.19
20. The instructor supervises and helps in new experiences without taking over.	32	75.0	12.5	9.3	3.1	0.0	4.59	4.27	4.27
21. The instructor relates underlying theory to practice.	32	65.6	18.7	12.5	3.1	0.0	4.46	4.30	4.36
22. Overall, I rate this instructor a good teacher.	32	68.7	15.6	12.5	3.1	0.0	4.50	4.37	4.46

Fox, Rebecca

23. Examinations

Becky

Fox, Rebecca — SUMMARY OF UNIT CLASSES — STUDENT RESPONSES

	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	ITEM MEAN	UNIT MEAN	INSTITUTIONAL MEAN
23. Examinations cover material or skills emphasized in the course.	29	68.9	17.2	13.7	0.0	0.0	4.55	4.39	4.48
24. The time allowed to complete exams is adequate.	29	79.3	17.2	3.4	0.0	0.0	4.75	4.25	4.37
25. Examination questions are phrased clearly.	29	62.0	6.8	24.1	6.8	0.0	4.24	4.16	4.29
26. The textbooks contribute to my understanding of the subject.	29	27.5	20.6	20.6	17.2	13.7	3.31	3.84	4.18
27. The course is practical and useful to those students for whom it was specifically planned.	29	68.9	13.7	13.7	3.4	0.0	4.48	4.35	4.45
28. The clinical experiences, or laboratory, meet my learning needs for this course.	29	62.0	20.6	10.3	3.4	3.4	4.34	4.26	4.24
29. The instructor explains or illustrates laboratory or clinical techniques clearly.	27	48.1	22.2	25.9	3.7	0.0	4.14	4.25	4.25
30. Pre-laboratory assignments (assigned readings and exercises) contribute to my understanding of laboratory experiments.	23	52.1	34.7	13.0	0.0	0.0	4.39	4.04	4.11
31. The laboratory contributes to my understanding of the subject.	28	67.8	17.8	10.7	0.0	3.5	4.46	4.16	4.18
32. The laboratory manual adequately explains the procedures to be followed in the laboratory.	27	59.2	18.5	14.8	3.7	3.7	4.25	4.13	4.12
33. Equipment and materials needed to perform the laboratory experiments are organized and readily available for use during the laboratory.	28	82.1	10.7	3.5	3.5	0.0	4.71	4.47	4.35

34. My perception of the teaching method used in this course is

Total Responses	Lecture	Discussion	Demonstration	Combination of these	Other
29	13.7	0.0	3.4	82.7	0.0

35. This course is

Total Responses	In my major	General requirement	An elective	Required cognate	Other
29	75.8	3.4	13.7	0.0	6.8

36. My class is

Total Responses	Freshman	Sophomore	Junior	Senior	Graduate
28	28.5	7.1	39.2	25.0	0.0

37. My grade point average to date is (round off)

Total Responses	4.0 – 3.5	3.4 – 3.0	2.9 – 2.5	2.4 – 2.0	Under 2.0
25	40.0	36.0	24.0	0.0	0.0

38. The grade I presently have in this class is

Total Responses	A	B	C	D	F
28	14.2	78.5	7.1	0.0	0.0

	Yes	No	Not needed
39. If I needed help outside of class, the instructor has given help to me.	96.4	0.0	3.5

40.		5	4	3	2	1			
41.		5	4	3	2	1			
42.		5	4	3	2	1			
43.		5	4	3	2	1			
44.		5	4	3	2	1			
45.		5	4	3	2	1			
46.		5	4	3	2	1			
47.		5	4	3	2	1			
48.		5	4	3	2	1			
49.		5	4	3	2	1			
50.		5	4	3	2	1			

SUMMA
INFORMATION SYSTEMS INC

TRANSYLVANIA UNIV/WINTER 2014

INSTRUCTOR'S NAME		
Fox, Rebecca		
COURSE TITLE		
INSTRUCTOR SUMMARY OF UNIT CLASSES		
COURSE NUMBER	UNIT	INSTITUTIONAL CODE
	NSM	TRA3941.S
REGISTERED STUDENTS	FORMS RETURNED	PERCENT PARTICIPATION
30	29	96.6%

This report summarizes results from the Survey of Student Opinion of Instruction. The first page contains identification items, percent of student participation, and responses from the Instructor's Questionnaire.

The second and third pages summarize the distribution of student responses to each questionnaire item using a scale from five to one where five means "Strongly Agree" and one means "Strongly Disagree." In each line, the distribution of responses is a **percent** distribution based upon the total number of responses to each item. Means are based upon the appropriate **total responses** for each identified category.

FACTOR MEANS **INSTRUCTOR RESPONSES (AND STANDARD DEVIATIONS) FOR INSTRUCTOR, UNIT, INSTITUTION AND NATIONAL SAMPLE.

THIS PAGE OF THE INSTRUCTOR SUMMARY CONTAINS MEANS AND STANDARD DEVIATIONS FOR EACH OF SIX FACTORS IDENTIFIED BY FACTOR ANALYSIS OF THE FIRST 21 QUESTIONS. THE QUESTIONS COMPRISING EACH FACTOR ARE INDICATED IN ORDER OF FACTOR LOADING. MEANS ARE BASED UPON THE TOTAL RESPONSES WITHIN EACH OF THE INDICATED SUMMARY LEVELS. THE NATIONAL SAMPLE IS COMPRISED OF MORE THAN ONE MILLION (SURVEY OF STUDENT OPINION OF INSTRUCTION TM) QUESTIONNAIRES ADMINISTERED OVER THE PREVIOUS FIVE YEARS.

	INSTRUCTOR MEAN (SD)	UNIT MEAN (SD)	INSTITUTION MEAN (SD)	NATIONAL MEAN (SD)
FACTOR 1 INSTRUCTOR COMMITMENT TO STUDENT LEARNING QUESTIONS: 10 , 7 , 20 , 17 , 16 , 8 , 1 , 21	* 4.68 (0.602)	4.44 (0.842)	4.52 (0.489)	4.40 (0.918)
FACTOR 2 INSTRUCTOR PREPARATION AND ORGANIZATION QUESTIONS: 9 , 11 , 3	4.64 (0.628)	4.47 (0.825)	4.50 (0.813)	4.43 (0.890)
FACTOR 3 INSTRUCTOR/STUDENT INTERACTION QUESTIONS: 4 , 13 , 18 , 14	4.37 (0.931)	4.03 (1.129)	4.21 (0.500)	4.15 (1.079)
FACTOR 4 TESTING QUESTIONS: 6 , 5	4.58 (0.773)	4.34 (0.915)	4.42 (0.884)	4.33 (0.940)
FACTOR 5 COURSE OBJECTIVES QUESTIONS: 15 , 12	4.60 (0.590)	4.41 (0.814)	4.46 (0.817)	4.40 (0.871)
FACTOR 6 COURSE ASSIGNMENTS QUESTIONS: 2 , 19	* 4.56 (0.751)	4.37 (0.884)	4.40 (0.850)	4.25 (0.974)

SIGNIFICANTLY DIFFERENT FROM THE NATIONAL MEAN ..... * = AT .05 LEVEL / ** = AT .01 LEVEL / *** = AT .001 LEVEL

ntly have in this clas

B	C	D	Yes	No	Not needed	50.
	17.6	0.0	94.1	0.0	5.8	

Fox, Rebecca

SUMMARY OF UNIT CLASSES STUDENT RESPONSES

	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	ITEM MEAN	UNIT MEAN	INSTITUTIONAL MEAN
1. The clarity and audibility of the instructor's speech are excellent.	29	82.7	17.2	0.0	0.0	0.0	4.82	4.59	4.65
2. The contents of the assignments contribute to my understanding of the subject.	29	68.9	20.6	6.8	3.4	0.0	4.55	4.46	4.50
3. The requirements of the course (projects, papers, exams, etc.) were explained adequately.	29	51.7	41.3	6.8	0.0	0.0	4.44	4.40	4.42
4. The instructor's presentation often causes me to think in depth about this subject.	29	55.1	31.0	10.3	3.4	0.0	4.37	4.10	4.32
5. The instructor has adequate means for evaluating my learning.	29	68.9	24.1	6.8	0.0	0.0	4.62	4.36	4.41
6. The methods being used for evaluating my work (such as tests, projects, etc.) are reasonable.	29	72.4	17.2	6.8	0.0	3.4	4.55	4.32	4.42
7. Adequate opportunities are provided by the instructor for me to ask questions.	29	86.2	10.3	3.4	0.0	0.0	4.82	4.63	4.67
8. The instructor is teaching the course material or skills clearly.	29	62.0	24.1	10.3	3.4	0.0	4.44	4.27	4.45
9. The instructor seems to be well prepared.	29	79.3	10.3	10.3	0.0	0.0	4.68	4.54	4.58
10. The instructor seems to care about my learning.	29	86.2	13.7	0.0	0.0	0.0	4.86	4.57	4.64
11. The course appears to have been carefully planned.	29	86.2	6.8	6.8	0.0	0.0	4.79	4.47	4.50
12. Course objectives are being achieved.	29	65.5	31.0	3.4	0.0	0.0	4.62	4.41	4.48
13. During the term, I looked forward to attending this class.	28	46.4	35.7	10.7	3.5	3.5	4.17	3.72	3.97
14. Compared with other courses on this level carrying an equal amount of credit, the effort I put into this course is as much as in other courses.	29	62.0	24.1	6.8	6.8	0.0	4.41	4.06	4.16
15. Course objectives have been expressed clearly.	29	65.5	27.5	6.8	0.0	0.0	4.58	4.41	4.43
16. The instructor demonstrates a personal commitment to high standards of professional competence.	29	75.8	20.6	3.4	0.0	0.0	4.72	4.58	4.64
17. The instructor provides useful feedback on student progress (identifying strengths and weaknesses).	28	53.5	35.7	7.1	3.5	0.0	4.39	4.14	4.29
18. In this course, I am learning much.	29	72.4	17.2	3.4	3.4	3.4	4.51	4.25	4.39
19. The out-of-class assignments are challenging.	29	68.9	24.1	3.4	3.4	0.0	4.58	4.28	4.30
20. The instructor supervises and helps in new experiences without taking over.	29	79.3	17.2	3.4	0.0	0.0	4.75	4.37	4.37
21. The instructor relates underlying theory to practice.	29	75.8	13.7	10.3	0.0	0.0	4.65	4.40	4.44
22. Overall, I rate this instructor a good teacher.	29	72.4	17.2	10.3	0.0	0.0	4.62	4.41	4.56

Fox, Rebecca

SUMMARY OF UNIT CLASSES

STUDENT RESPONSES	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	ITEM MEAN	UNIT MEAN	INSTITUTIONAL MEAN
23. Examinations cover material or skills emphasized in the course.	24	58.3	33.3	4.1	4.1	0.0	4.45	4.45	4.51
24. The time allowed to complete exams is adequate.	24	87.5	8.3	4.1	0.0	0.0	4.83	4.30	4.41
25. Examination questions are phrased clearly.	24	37.5	37.5	16.6	8.3	0.0	4.04	4.22	4.34
26. The textbooks contribute to my understanding of the subject.	24	41.6	33.3	12.5	4.1	8.3	3.95	3.95	4.27
27. The course is practical and useful to those students for whom it was specifically planned.	23	78.2	13.0	4.3	4.3	0.0	4.65	4.34	4.47
28. The clinical experiences, or laboratory, meet my learning needs for this course.	24	50.0	37.5	8.3	4.1	0.0	4.33	4.20	4.24
29. The instructor explains or illustrates laboratory or clinical techniques clearly.	24	45.8	41.6	12.5	0.0	0.0	4.33	4.18	4.21
30. Pre-laboratory assignments (assigned readings and exercises) contribute to my understanding of laboratory experiments.	23	34.7	47.8	17.3	0.0	0.0	4.17	3.97	4.11
31. The laboratory contributes to my understanding of the subject.	24	45.8	20.8	25.0	8.3	0.0	4.04	4.08	4.15
32. The laboratory manual adequately explains the procedures to be followed in the laboratory.	23	47.8	26.0	13.0	13.0	0.0	4.08	4.12	4.19
33. Equipment and materials needed to perform the laboratory experiments are organized and readily available for use during the laboratory.	23	60.8	26.0	4.3	4.3	4.3	4.34	4.30	4.30

34. My perception of the teaching method used in this course is

Total Responses	Lecture	Discussion	Demonstration	Combination of these	Other
23	56.5	0.0	0.0	43.4	0.0

35. This course is

Total Responses	In my major	General requirement	An elective	Required cognate	Other
24	91.6	0.0	4.1	4.1	0.0

36. My class is

Total Responses	Freshman	Sophomore	Junior	Senior	Graduate
23	8.6	56.5	26.0	8.6	0.0

37. My grade point average to date is (round off)

Total Responses	4.0 – 3.5	3.4 – 3.0	2.9 – 2.5	2.4 – 2.0	Under 2.0
22	36.3	40.9	18.1	4.5	0.0

38. The grade I presently have in this class is

Total Responses	A	B	C	D	F
22	31.8	50.0	18.1	0.0	0.0

39. If I needed help outside of class, the instructor has given help to me.

Yes	No	Not needed
95.4	0.0	4.5

40.		5	4	3	2	1
41.		5	4	3	2	1
42.		5	4	3	2	1
43.		5	4	3	2	1
44.		5	4	3	2	1
45.		5	4	3	2	1
46.		5	4	3	2	1
47.		5	4	3	2	1
48.		5	4	3	2	1
49.		5	4	3	2	1
50.		5	4	3	2	1

SUMMA INFORMATION SYSTEMS INC

This report summarizes results from the Survey of Student Opinion of Instruction. The first page tains identification items, percent of student participation, and responses from the Instructor's estionnaire.
The second and third pages summarize the distribution of student responses to each questionnaire item g a scale from five to one where five means "Strongly Agree" and one means "Strongly Disagree." In h line, the distribution of responses is a **percent** distribution based upon the total number of onses to each item. Means are based upon the appropriate **total responses** for each identified gory.

INSTRUCTOR'S NAME		
Fox, Rebecca		
COURSE TITLE		
INSTRUCTOR SUMMARY OF UNIT CLASSES		
COURSE NUMBER	UNIT	INSTITUTIONAL CODE
	NSM	TRA3911.S
REGISTERED STUDENTS	FORMS RETURNED	PERCENT PARTICIPATION
28	26	92.8%

FACTOR MEANS ~~**INSTRUCTOR RESPONSES**~~ (AND STANDARD DEVIATIONS) FOR INSTRUCTOR, UNIT, INSTITUTION AND NATIONAL SAMPLE.

IS PAGE OF THE INSTRUCTOR SUMMARY CONTAINS MEANS AND STANDARD DEVIATIONS FOR EACH OF SIX FACTORS IDENTIFIED BY FACTOR ALYSIS OF THE FIRST 21 QUESTIONS. THE QUESTIONS COMPRISING EACH FACTOR ARE INDICATED IN ORDER OF FACTOR LOADING. MEANS ARE SED UPON THE TOTAL RESPONSES WITHIN EACH OF THE INDICATED SUMMARY LEVELS. THE NATIONAL SAMPLE IS COMPRISED OF MORE THAN MILLION (SURVEY OF STUDENT OPINION OF INSTRUCTION TM) QUESTIONNAIRES ADMINISTERED OVER THE PREVIOUS FIVE YEARS.

	INSTRUCTOR MEAN (SD)	UNIT MEAN (SD)	INSTITUTION MEAN (SD)	NATIONAL MEAN (SD)
ACTOR 1 INSTRUCTOR COMMITMENT TO STUDENT LEARNING UESTIONS: 10 , 7 , 20 , 17 , 16 , 8 , 1 , 21	* 4.67 (0.535)	4.46 (0.832)	4.45 (0.195)	4.40 (0.918)
ACTOR 2 INSTRUCTOR PREPARATION AND ORGANIZATION UESTIONS: 9 , 11 , 3	4.33 (0.800)	4.48 (0.822)	4.43 (0.869)	4.43 (0.890)
CTOR 3 INSTRUCTOR/STUDENT INTERACTION ESTIONS: 4 , 13 , 18 , 14	4.20 (0.938)	4.09 (1.088)	4.12 (0.653)	4.15 (1.079)
CTOR 4 TESTING ESTIONS: 6 , 5	* 4.01 (0.804)	4.36 (0.880)	4.33 (0.934)	4.33 (0.940)
TOR 5 COURSE OBJECTIVES STIONS: 15 , 12	4.35 (0.743)	4.45 (0.786)	4.38 (0.869)	4.40 (0.871)
TOR 6 COURSE ASSIGNMENTS STIONS: 2 , 19	4.44 (0.725)	4.34 (0.915)	4.28 (0.920)	4.25 (0.974)

SIGNIFICANTLY DIFFERENT FROM THE NATIONAL MEAN ..... * = AT .05 LEVEL / ** = AT .01 LEVEL / *** = AT .001 LEVEL

Fox, Rebecca — SUMMARY OF UNIT CLASSES

STUDENT RESPONSES	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	ITEM MEAN	UNIT MEAN	INSTITUTIONAL MEAN
1. The clarity and audibility of the instructor's speech are excellent.	26	76.9	19.2	3.8	0.0	0.0	4.73	4.61	4.60
2. The contents of the assignments contribute to my understanding of the subject.	26	50.0	38.4	11.5	0.0	0.0	4.38	4.47	4.44
3. The requirements of the course (projects, papers, exams, etc.) were explained adequately.	26	42.3	34.6	23.0	0.0	0.0	4.19	4.45	4.35
4. The instructor's presentation often causes me to think in depth about this subject.	26	42.3	38.4	15.3	0.0	3.8	4.15	4.14	4.23
5. The instructor has adequate means for evaluating my learning.	26	38.4	38.4	19.2	3.8	0.0	4.11	4.38	4.32
6. The methods being used for evaluating my work (such as tests, projects, etc.) are reasonable.	26	23.0	46.1	30.7	0.0	0.0	3.92	4.34	4.33
7. Adequate opportunities are provided by the instructor for me to ask questions.	26	84.6	15.3	0.0	0.0	0.0	4.84	4.67	4.64
8. The instructor is teaching the course material or skills clearly.	26	50.0	46.1	3.8	0.0	0.0	4.46	4.28	4.36
9. The instructor seems to be well prepared.	26	69.2	23.0	7.6	0.0	0.0	4.61	4.55	4.52
10. The instructor seems to care about my learning.	26	96.1	3.8	0.0	0.0	0.0	4.96	4.64	4.60
11. The course appears to have been carefully planned.	26	42.3	42.3	7.6	7.6	0.0	4.19	4.44	4.43
12. Course objectives are being achieved.	26	46.1	46.1	7.6	0.0	0.0	4.38	4.45	4.42
13. During the term, I looked forward to attending this class.	26	34.6	38.4	19.2	7.6	0.0	4.00	3.80	3.90
14. Compared with other courses on this level carrying an equal amount of credit, the effort I put into this course is as much as in other courses.	26	53.8	26.9	7.6	7.6	3.8	4.19	4.11	4.07
15. Course objectives have been expressed clearly.	25	52.0	32.0	12.0	4.0	0.0	4.32	4.44	4.3
16. The instructor demonstrates a personal commitment to high standards of professional competence.	26	84.6	15.3	0.0	0.0	0.0	4.84	4.58	4.5
17. The instructor provides useful feedback on student progress (identifying strengths and weaknesses).	26	50.0	42.3	3.8	3.8	0.0	4.38	4.14	4.1
18. In this course, I am learning much.	26	53.8	38.4	7.6	0.0	0.0	4.46	4.31	4.
19. The out-of-class assignments are challenging.	26	65.3	19.2	15.3	0.0	0.0	4.50	4.20	4.
20. The instructor supervises and helps in new experiences without taking over.	26	73.0	23.0	3.8	0.0	0.0	4.69	4.35	4
21. The instructor relates underlying theory to practice.									

Fox, Rebecca

SUMMARY OF UNIT CLASSES

STUDENT RESPONSES	TOTAL RESPONSES	STRONGLY AGREE 5	4	3	2	STRONGLY DISAGREE 1	ITEM MEAN	UNIT MEAN	INSTITUTIONAL MEAN
23. Examinations cover material or skills emphasized in the course.	26	42.3	38.4	15.3	3.8	0.0	4.19	4.47	4.44
24. The time allowed to complete exams is adequate.	26	80.7	19.2	0.0	0.0	0.0	4.80	4.31	4.32
25. Examination questions are phrased clearly.	26	26.9	19.2	30.7	15.3	7.6	3.42	4.16	4.23
26. The textbooks contribute to my understanding of the subject.	26	19.2	46.1	11.5	23.0	0.0	3.61	4.00	4.16
27. The course is practical and useful to those students for whom it was specifically planned.	26	42.3	50.0	3.8	3.8	0.0	4.30	4.44	4.41
28. The clinical experiences, or laboratory, meet my learning needs for this course.	26	42.3	30.7	15.3	11.5	0.0	4.03	4.17	4.09
29. The instructor explains or illustrates laboratory or clinical techniques clearly.	26	42.3	23.0	23.0	11.5	0.0	3.96	4.17	4.12
30. Pre-laboratory assignments (assigned readings and exercises) contribute to my understanding of laboratory experiments.	26	34.6	38.4	19.2	7.6	0.0	4.00	3.99	4.01
31. The laboratory contributes to my understanding of the subject.	26	46.1	19.2	23.0	11.5	0.0	4.00	4.07	4.07
32. The laboratory manual adequately explains the procedures to be followed in the laboratory.	23	43.4	17.3	17.3	8.6	13.0	3.69	4.08	4.0
33. Equipment and materials needed to perform the laboratory experiments are organized and readily available for use during the laboratory.	26	50.0	23.0	19.2	7.6	0.0	4.15	4.39	4.2

34. My perception of the teaching method used in this course is

Total Responses	Lecture	Discussion	Demonstration	Combination of these	Other
25	20.0	8.0	0.0	68.0	4.0

35. This course is

Total Responses	In my major	General requirement	An elective	Required cognate	Other
26	84.6	0.0	11.5	3.8	0.0

36. My class is

Total Responses	Freshman	Sophomore	Junior	Senior	Graduate
25	4.0	16.0	52.0	28.0	0.0

37. My grade point average to date is (round off)

Total Responses	4.0 – 3.5	3.4 – 3.0	2.9 – 2.5	2.4 – 2.0	Under 2.0
25	52.0	32.0	16.0	0.0	0.0

38. The grade I presently have in this class is

Total Responses	A	B	C	D	F
25	16.0	72.0	12.0	0.0	0.0

39. If I needed help outside of class, the instructor has given help to me.

Yes	No	Not needed
100.0	0.0	0.0

40.		5	4	3	2	1			
41.		5	4	3	2	1			
42.		5	4	3	2	1			
43.		5	4	3	2	1			
44.		5	4	3	2	1			
45.		5	4	3	2	1			
46.		5	4	3	2	1			
47.		5	4	3	2	1			
48.		5	4	3	2	1			
49.		5	4	3	2	1			
50.		5	4	3	2	1			